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한국과학기술정보연구원
Korea Institute of Science and Technology Information
www.kisti.re.kr

e-Science paradigm for Flavor Physics in the LHC era

Kihyeon Cho
High Energy Physics Team
KISTI (Korea Institute of Science and Technology Information)

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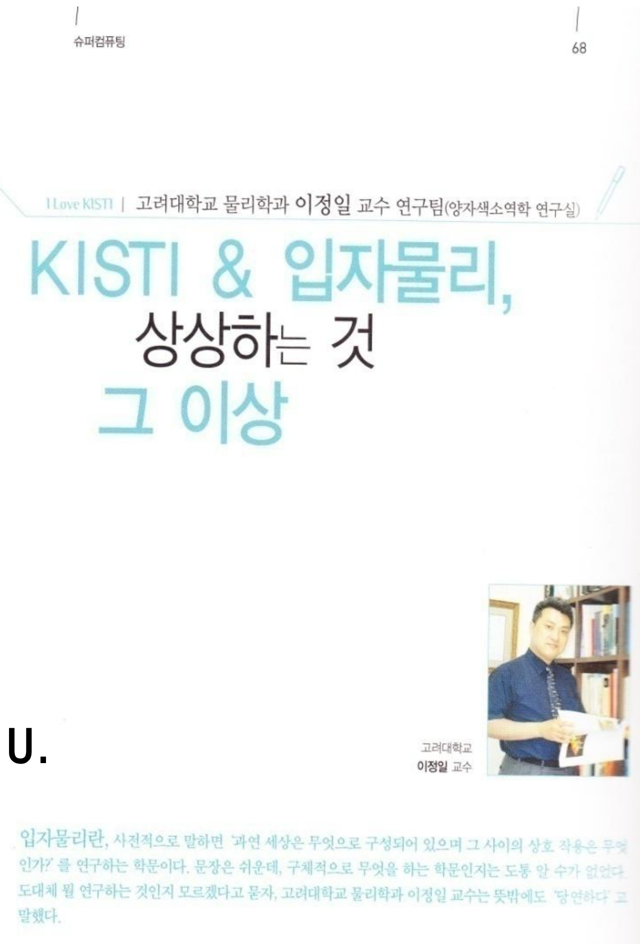
High Energy Physics Team @ KISTI

- High Energy Physics Team (Physicists)
  - Kihyeon Cho – P.I.
  - Soo-hyeon Nam – Senior Researcher
  - Junghyun Kim – Senior Researcher
  - YoungJin Kim – Postdoc
  - Taegil Bae – Postdoc
  - Jihye Moon – Researcher

- Former members
  - Yongseok Oh – Prof. of Physics @ KNU
  - Daejung Kong – Contract Prof. @ KNU
  - Ilsung Cho – Contract Prof. @ KyungHee U.
  - Minho Jeung – Company
  - Hyunwoo Kim – IBM Korea



슈퍼컴퓨팅 68

I Love KISTI | 고려대학교 물리학과 이정일 교수 연구팀(양자색소역학 연구실)

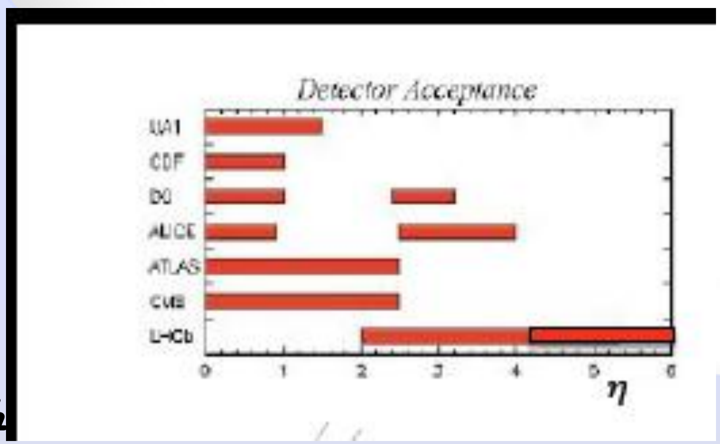
KISTI & 입자물리,
상상하는 것
그 이상

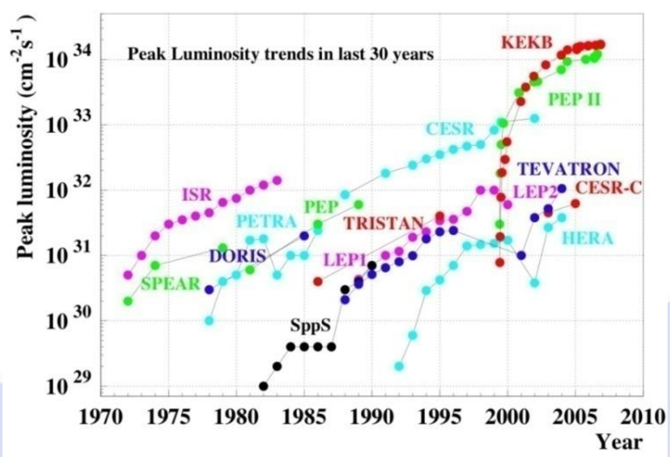
고려대학교
이정일 교수

입자물리란, 사전적으로 말하면 '과연 세상은 무엇으로 구성되어 있으며 그 사이의 상호 작용은 무엇인가?' 를 연구하는 학문이다. 문장은 쉬운데, 구체적으로 무엇을 하는 학문인지는 도통 알 수가 없었다. 도대체 뭘 연구하는 것인지 모르겠다고 묻자, 고려대학교 물리학과 이정일 교수는 뜻밖에도 '당연하다' 고 말했다.

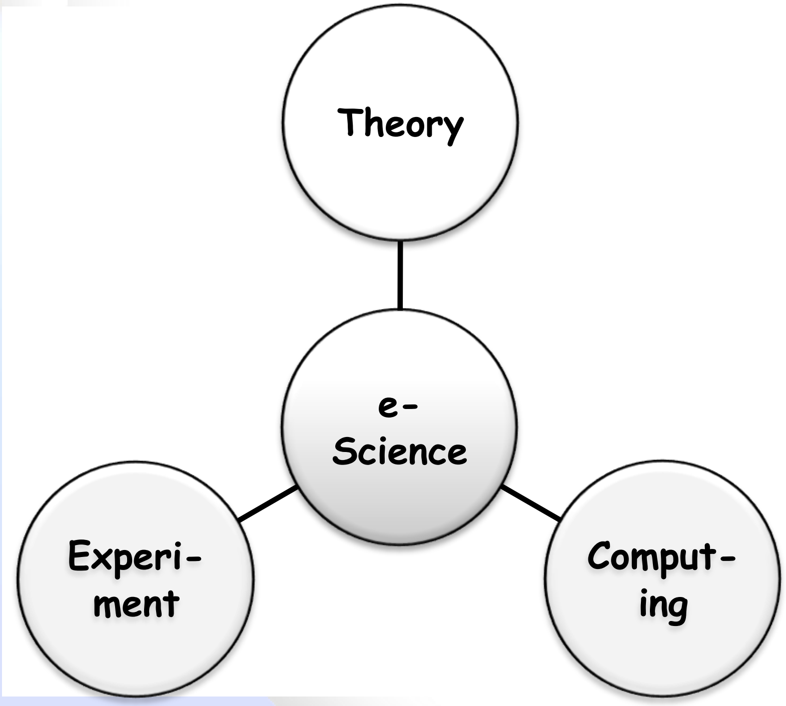
Flavor Experiments @KISTI (2011.8)

	Belle/Belle II	CDF	LHCb (Reference)
Year	1998–2010 (Belle) 2014 – (Belle II)	2001–	2009–
Place	KEK, Japan	Fermilab, USA	CERN, Europe
Collaboration	13/47/~300(Belle II) (Nat./Ins./member)	15/63/620	15/54/730
σ	1 nb (10GeV)	150 μb (2TeV)	300~500 μb (7~14TeV)
Current Luminosity	1 ab^{-1}	10fb^{-1}	350 pb^{-1}





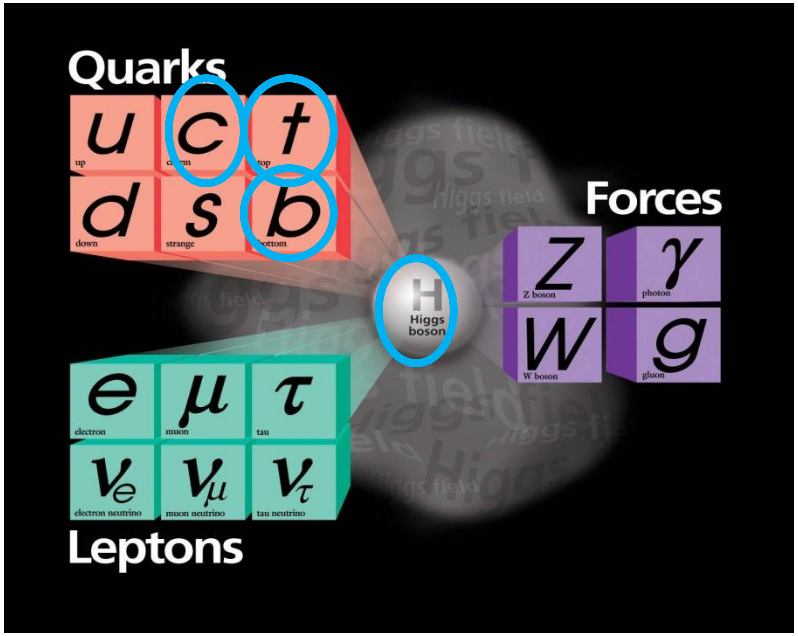
e-Science paradigm of experiment-computing-theory



CDF
Belle/Belle II

cf. LHCb

To probe the Standard Model and search for New Physics



K.Cho and H.W.Kim, JKPS (2009)

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Collider physics based on e-Science paradigm of experiment–computing–theory

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ABSTRACT

Researches in the 21st century are characterized by e-Science paradigm, which is the data centric analysis as a unified concept of experiment–computing–theory. In this paper the e-Science paradigm has been realized in collider physics by constructing the unified research environment of experiment–theory and theory–computing as well as that of computing–experiment performed at KISTI (Korea Institute of Science and Technology Information). In other words, the fusion concept of collider physics of experiment, computing and theory has been applied. The goal of this approach is to study collider physics anytime, anywhere for more efficient research process. The construction of e-Science paradigm of experiment, computing and theory in collider physics provides us with new research methodology in computational physics.

1. Introduction

Until now e-Science for collider physics refers to the large-scale science [1]. However, using the 21st century concept of e-Science paradigm, we combine experiment, theory and computing of collider physics for more efficient research process.

Thousands of years ago, science has put emphasis on experiments to describe natural phenomena. For the last few hundreds of years, science has become theoretical, such as Newton's laws and Maxwell's equations. For the last few decades, science has become computational, focusing on simulation of phenomenological complexities. Today, science can be described by e-Science which is data-centric in nature to unify experiment, theory and computing [2]. However, this concept has not been realized yet. We have realized this e-Science paradigm by constructing the unified research of experiment–theory–computing as shown in Fig. 1.

This is not a collection of each result of experiment computing and theory, but the fusion research of combinations for more efficient research process. We apply this concept to collider physics. The collider physics experiments in this paper are CDF (Collider Detector at Fermilab) experiment at Tevatron collider, Belle/Belle II experiment at KEKB collider and PHENIX (A Physics Experiment at RHIC) experiment at RHIC (Relativistic Heavy-Ion Collider) as

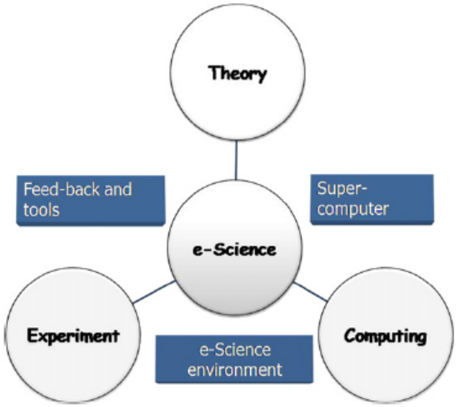


Fig. 1. The paradigm of e-Science which is fusion research of experiment–computing–theory.

2. Methods

The new point as a scientific research in this paper is that we apply the e-Science paradigm to collider physics for the first time.

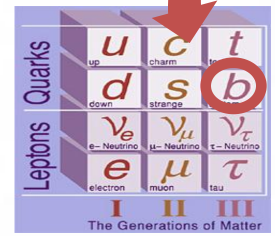
Kihyeon Ch

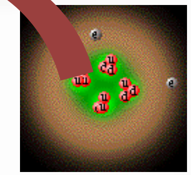
Contents

To study Flavor physics both in experiments (Belle & CDF) and theories

Goal

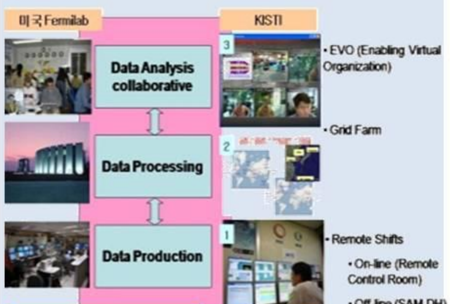
To probe the Standard Model and search for New Physics
⇒ New Discovery





The Standard Model

e-HEP Environment	B Physics Study	New Discovery
2007~2009	2010~2011	2012~2013



e-HEP Environment

New Discovery

B Physics Study using e-HEP

Belle

Belle II DH Working Group Leader

CDF

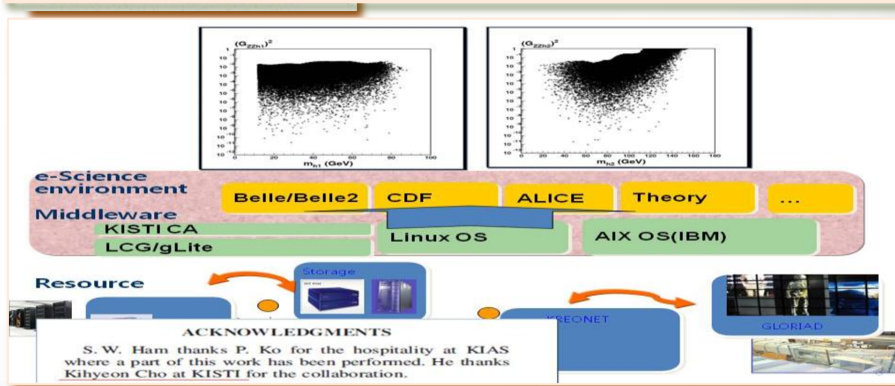
Belle II

Fermilab(U.S.A) KEK(Japan) IN2P3(France)

e-HEP (High Energy Physics)

To study high energy physics anytime anywhere even if we are not on-site (accelerator laboratory)

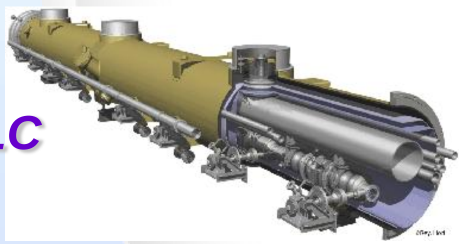
1. Data production
   - CDF Remote Control Room @KISTI
2. Data processing
   - Pacific CAF(CDF Analysis Farm) ⇒ North America CAF @KISTI
3. Data Analysis Collaboration
   - EVO servers @KISTI
4. Belle II Data Handling System
   - Working Group Chair (K. Cho)



Ex) A study of Higgs model using cyberinfrastructure @KISTI

Flavor Physics in the LHC era

ILC



Energy frontier experiments
LHC, ILC, …

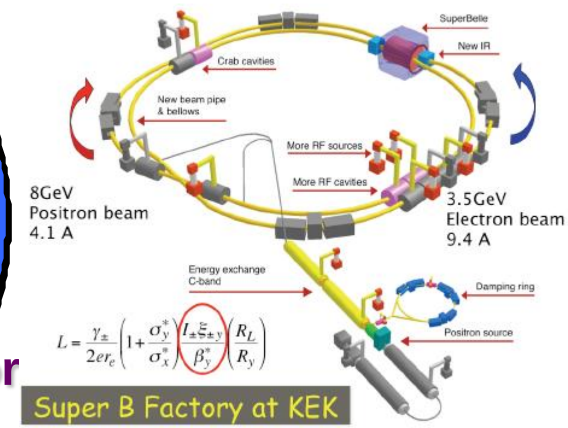
Higgs, SUSY, Dark matter,
New understanding of space-time…

New particles
and new interactions

Three approaches
to
New Physics

Lepton
physics

Quark flavor
physics



ν exp., μ LFV, τ LFV,
g_μ-2, …

Neutrino mixing/masses,
Lepton number non-conservation…

Super-B Factory,
K exp., *etc.*

CP asymmetry, Baryogenesis,
Left-right symmetry, New sources

M. Yamakuchi, Belle II meeting (2008)

Flavor physics in the LHC era

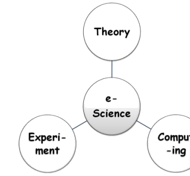
LHC (High P_T)

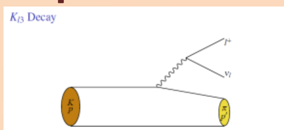
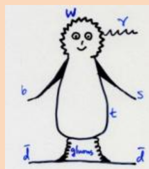
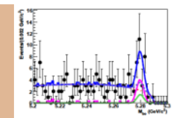
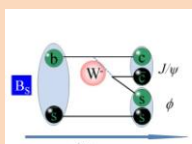
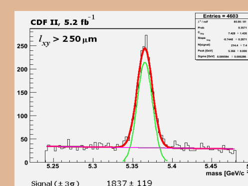
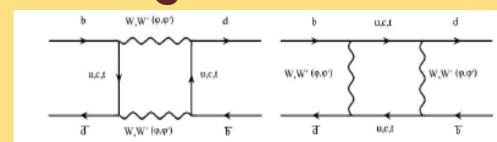
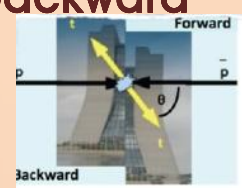
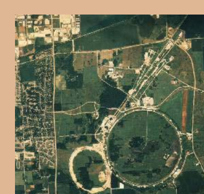
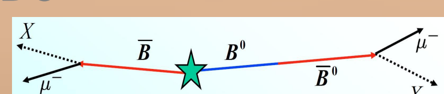
➲ A unique effort toward the high-energy frontier to determine the energy scale of NP.

Flavor physics

➲ A Collective effort toward the high-intensity frontier to determine the flavor structure of NP

Flavor physics topics @ KISTI



Physics	Experiments	Theories
Kaon Semi-leptonic Form factor 	Belle	LGT using Staggered Fermion T. Bae, Work in progress
Rare B^0 decays 	Belle  J.H.Kim, et. al. Belle (2011)	Left-Right models S.-h Nam, Work in progress
Mixing and CPV on Bs → $J/\psi\,\phi$  	CDF  Y.J.Kim, K.Cho et.al. CDF (2011)	Left-Right models  S.-h Nam. et.al, PRD 66, 055008 (2002) √
Top Forward-backward asymmetry 	CDF 	Model independent Analysis S.-h Nam. et.al, PLB 691, 238 (2010)
CP violating dimuon charge asymmetry due to B mixing	D0 	Left-Right models S.-h Nam, Work in progress √

⇒ Feed-back between experiments (Belle & CDF) and theories inside KISTI

Standard Model or not?

- Today’ s talk focus on hardon collider
  - Mixing and CP violation on Bs -> J/$\psi \Phi$
  - Dimuon Asymmetry in D0
  - FCNC b->s mu mu
  - Bs -> mu mu

Probing New Physics

Plenary talk
A.Buras, Beauty 2011:

Maximal Enhancements of $S_{\psi\varphi}$, $Br(B_s \to \mu^+\mu^-)$ and $K^+ \to \pi^+\nu\bar{\nu}$

(without taking correlation between them)

Model	Upper Bound on ($S_{\psi\varphi}$)	Enhancement of $Br(B_s \to \mu^+\mu^-)$	Enhancement of $Br(K^+ \to \pi^+\nu\bar{\nu})$
CMFV	0.04	20%	20%
MFV	0.04	1000%	30%
LHT	0.30	30%	150%
RS	0.75	10%	60%
4G	0.80	400%	300%
AC	0.75	1000%	2%
RVV	0.50	1000%	10%

Large
RH Currents

RS = RS with custodial protections
AC = Agashe, Carone $U(1)_F$
RVV = Ross, Velasco-Sevilla, Vives (04) $SU(3)_F$

Table I. Some interesting observables. In the "present status" column, upper bounds are 90% CL. The expected experimental sensitivities are current estimates and may change in the future. In several processes the most interesting information will come from more detailed measurements that cannot be captured simply by a single number.

Observable	Approximate SM prediction	Present status	Uncertainty / number of events Super-B ($50\,\mathrm{ab}^{-1}$)	LHCb ($10\,\mathrm{fb}^{-1}$)
$S_{\psi K}$	input	0.671 ± 0.024	0.005	0.01
$S_{\phi K}$	$S_{\psi K}$	0.44 ± 0.18	0.03	0.1
$S_{\eta' K}$	$S_{\psi K}$	0.59 ± 0.07	0.02	not studied
$\alpha(\pi\pi, \rho\rho, \rho\pi)$	α	$(89 \pm 4)^\circ$	2°	4°
$\gamma(DK)$	γ	$(70^{+27}_{-30})^\circ$	2°	3°
$S_{K^*\gamma}$	few $\times$ 0.01	-0.16 ± 0.22	0.03	—
$S_{B_s \to \phi\gamma}$	few $\times$ 0.01	—	—	0.05
$\beta_s(B_s \to \psi\phi)$	1°	$(22^{+10}_{-8})^\circ$	—	0.3°
$\beta_s(B_s \to \phi\phi)$	1°	—	—	1.5°
A^d_{SL}	-5×10^{-4}	$-(5.8 \pm 3.4) \times 10^{-3}$	10^{-3}	10^{-3}
A^s_{SL}	2×10^{-5}	$(1.6 \pm 8.5) \times 10^{-3}$	$\Upsilon(5S)$ run?	10^{-3}
$A_{CP}(b \to s\gamma)$	< 0.01	-0.012 ± 0.028	0.005	—
$\lvert V_{cb}\rvert$	input	$(41.2 \pm 1.1) \times 10^{-3}$	1%	—
$\lvert V_{ub}\rvert$	input	$(3.93 \pm 0.36) \times 10^{-3}$	4%	—
$B \to X_s\gamma$	3.2×10^{-4}	$(3.52 \pm 0.25) \times 10^{-4}$	4%	—
$B \to \tau\nu$	1×10^{-4}	$(1.73 \pm 0.35) \times 10^{-4}$	5%	—
$B \to X_s\nu\bar\nu$	3×10^{-5}	$< 6.4 \times 10^{-4}$	only $K\nu\bar\nu$?	—
$B \to X_s\ell^+\ell^-$	6×10^{-6}	$(4.5 \pm 1.0) \times 10^{-6}$	6%	not studied
$B_s \to \tau^+\tau^-$	1×10^{-6}	$<$ few %	$\Upsilon(5S)$ run?	—
$B \to X_s\tau^+\tau^-$	5×10^{-7}	$<$ few %	not studied	—
$B \to \mu\nu$	4×10^{-7}	$< 1.3 \times 10^{-6}$	6%	—
$B \to \tau^+\tau^-$	5×10^{-8}	$< 4.1 \times 10^{-3}$	$\mathcal{O}(10^{-4})$	—
$B_s \to \mu^+\mu^-$	3×10^{-9}	$< 5 \times 10^{-8}$	—	$> 5\sigma$ in SM
$B \to \mu^+\mu^-$	1×10^{-10}	$< 1.5 \times 10^{-8}$	$< 7 \times 10^{-9}$	not studied
$B \to K^*\ell^+\ell^-$	1×10^{-6}	$(1 \pm 0.1) \times 10^{-6}$	15k	36k
$B \to K\nu\bar\nu$	4×10^{-6}	$< 1.4 \times 10^{-5}$	20%	—

Not so near future!!

Grossman, Ligeti, Nir (May 2009)

LHC Era Phase 1: CERN vs. FNAL scenarios 2010–2011

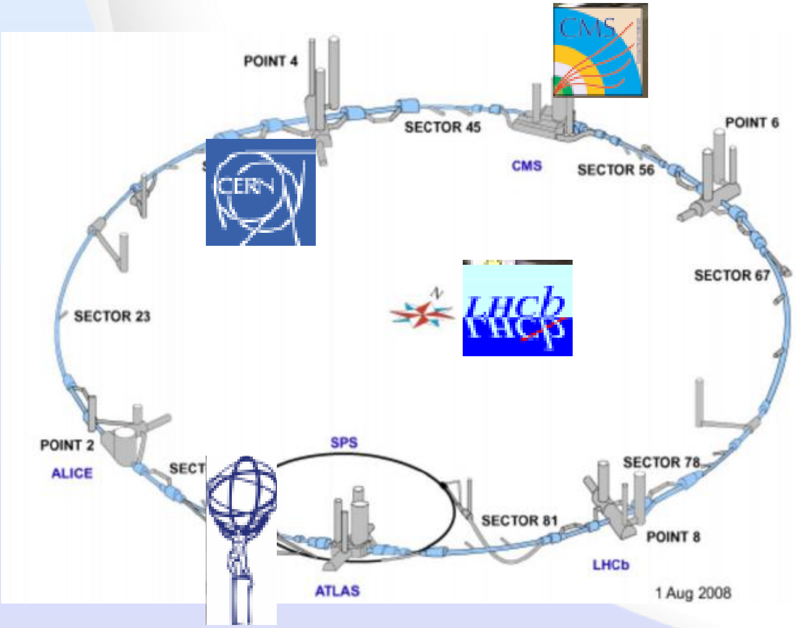
➲ **LHC 2010–2011,**

➲ **currently foreseen schedule:**

pp up to 7 TeV cm non stop with :

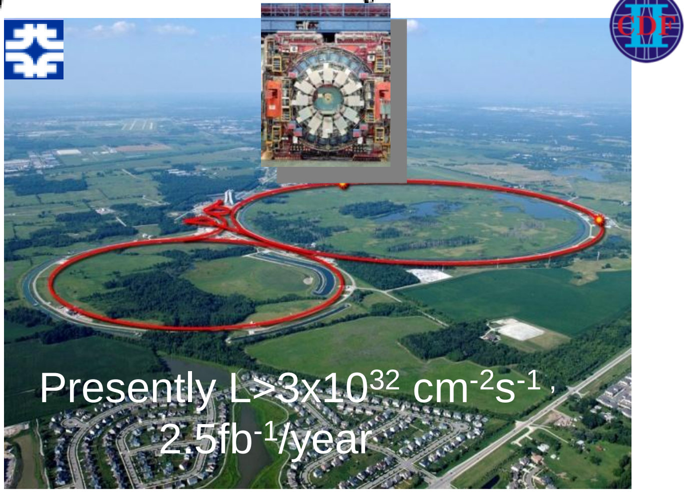
L=1 fb^{-1} (2011)

LHC is starting up again since 2009

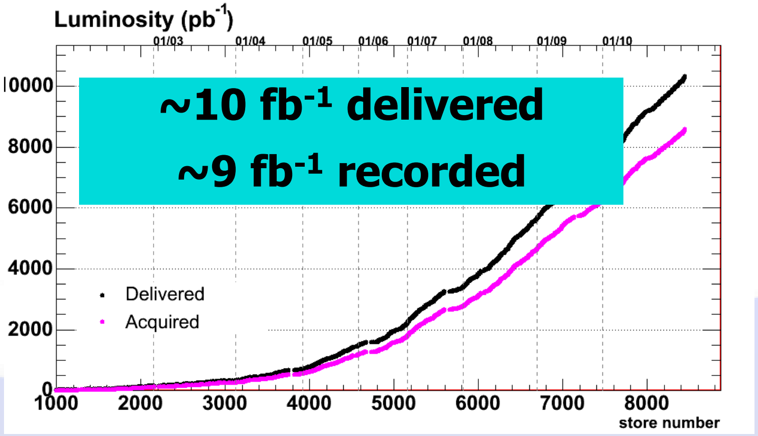


➲ **Tevatron 2010–2011**

$p\bar{p}$ collisions at $\sqrt{s}$ = 1.96 TeV



Expecting to run until end 2011 => 12 fb^{-1}



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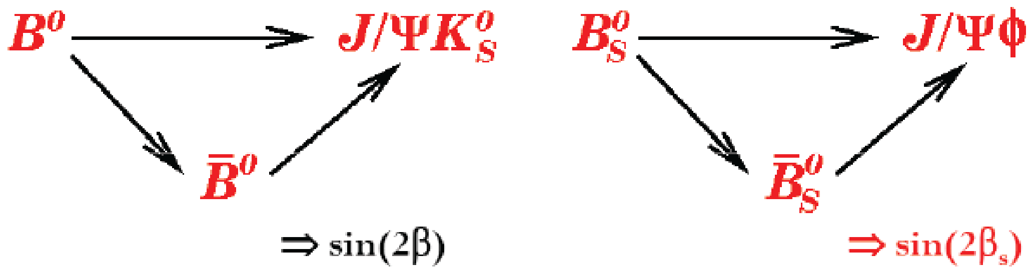
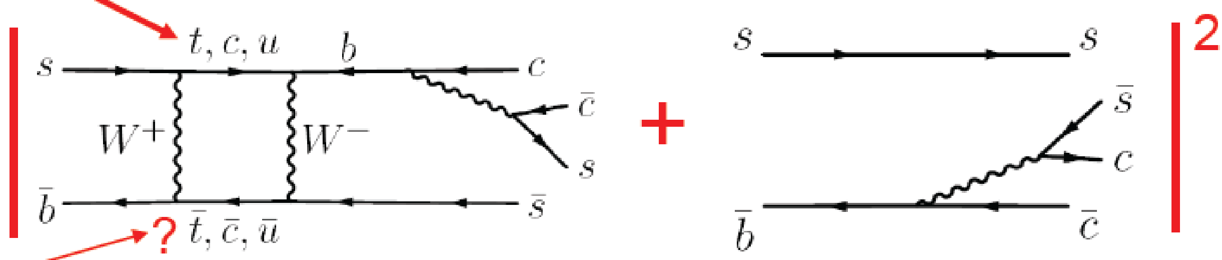
CP violation on Bs –> J/ψ Φ

Analogous to the neutral *B⁰* system, *CP* violation in B_s system is accessible through interference of decays with and without mixing:



dominant contribution from top quark

Decay rate ~



New Physics?

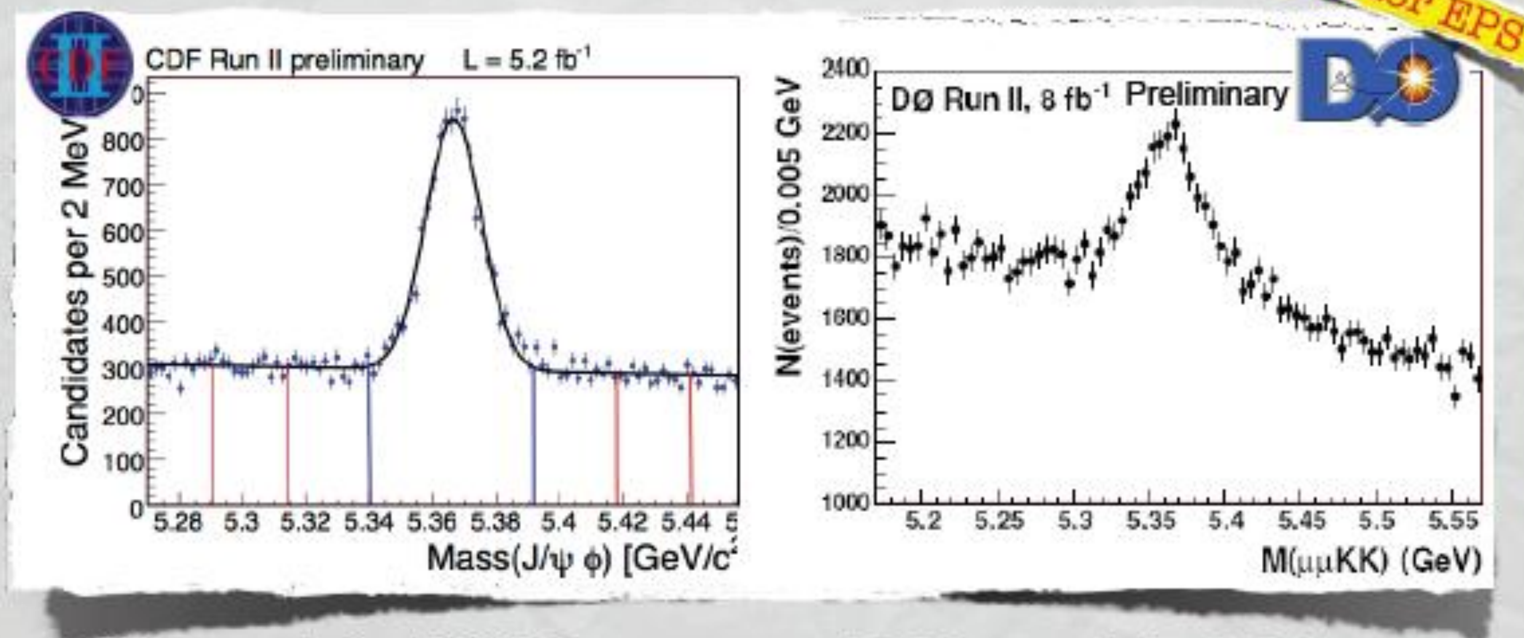
$$\beta_s^{SM} = \arg(-V_{ts}V_{tb}^*/V_{cs}V_{cb}^*) \approx 0.02$$

$$\begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & \boxed{V_{cs}} & \boxed{V_{cb}} \\ V_{td} & \boxed{V_{ts}} & \boxed{V_{tb}} \end{pmatrix}$$

- *CP* violation phase β_s in SM is predicted to be very small, $O(\sin^2\theta_c)$
- New physics particles running in the mixing diagram may enhance β_s

$B_s \to J/\psi\phi$ signals

new for EPS



6500 events in 5.2 fb^{-1}

Identify production flavor using whole event information

5000 events in 8 fb^{-1}

Production flavor using only "other B" in the event

Both include non-ϕ KK component in the angular analysis

DO has issued new results with a complete analysis on 8 fb−1
CDF: nothing since last result almost 2 years old!

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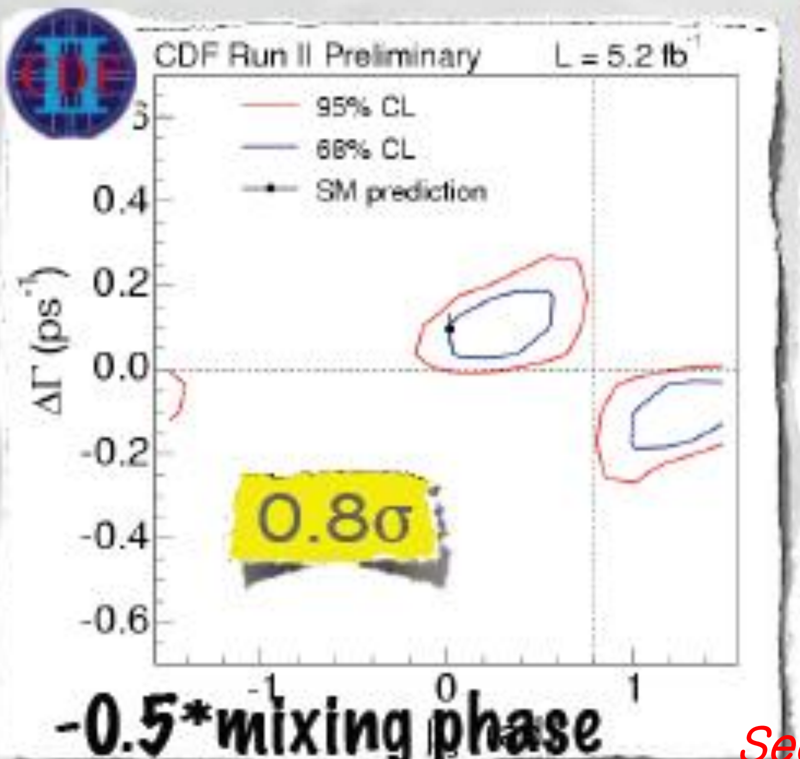
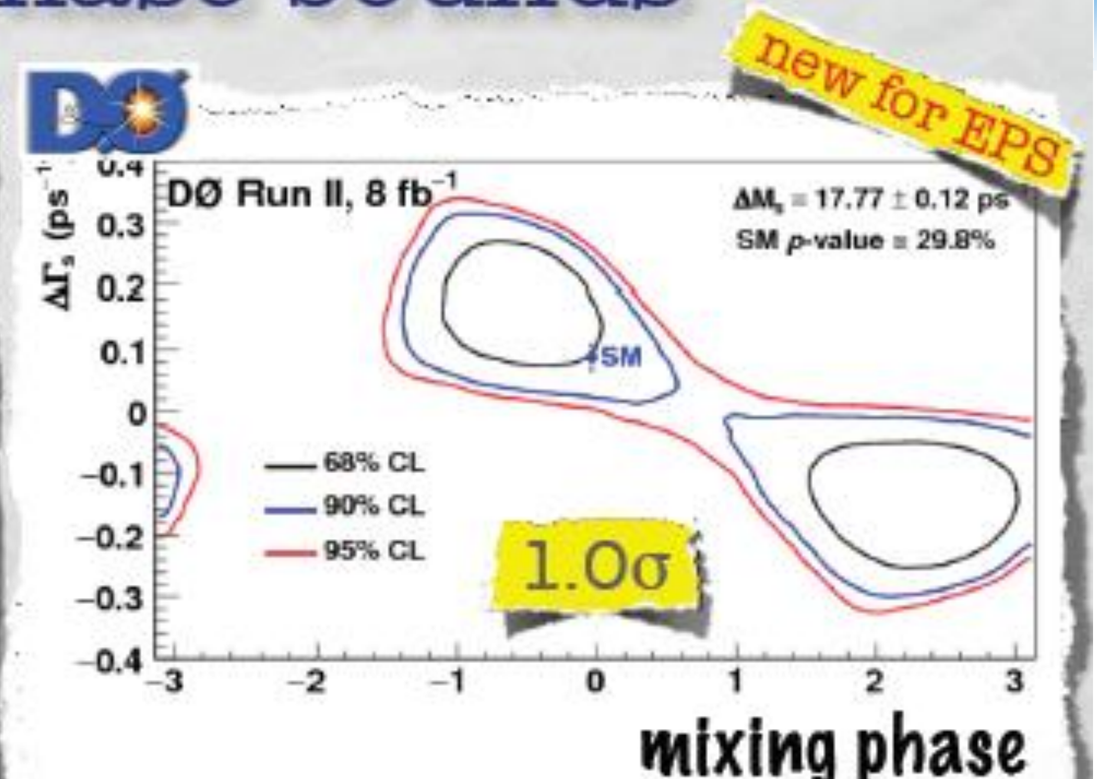
Mixing phase bounds





See EPS D0 presentation on Bs−J/Psiphi new result

CDF Note 10206

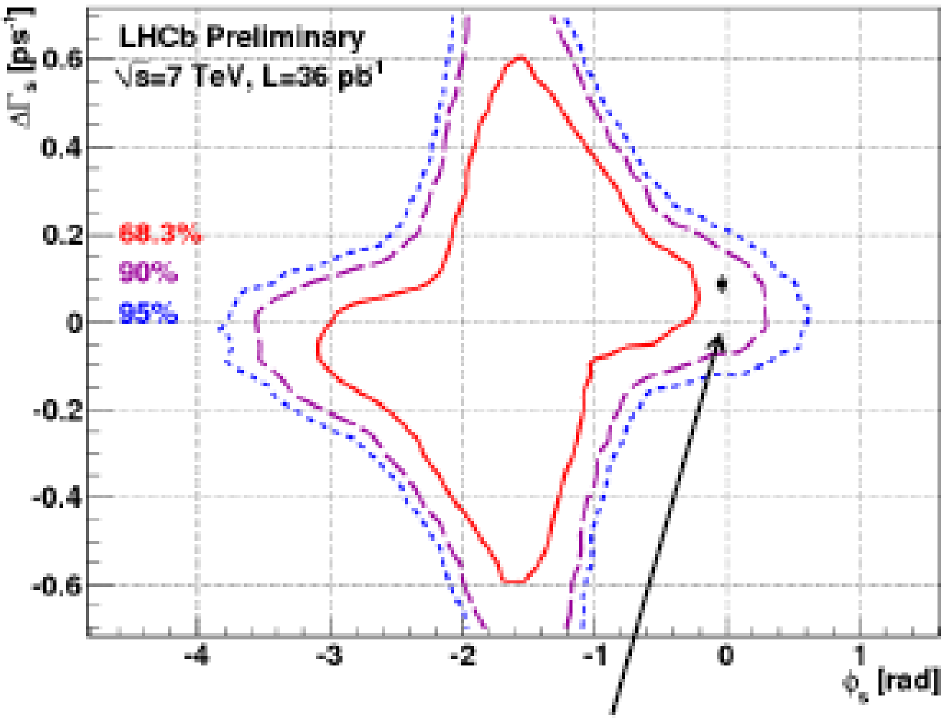
S. Burdin, Thu 15:15

CDF confidence region shrunk. DO region didn't. Both more consistent with SM. Both fluctuate on the same direction.

Tevatron combination in plan. CDF will double statistics.

Who is in CDF???

CP analysis of $B_s \rightarrow J/\Psi\ \Phi$



Standard Model p-value 22% (1.2σ)

757 ± 28 events

Point-estimate not meaningful with current statistics

Feldman-Cousins method to get confidence level contours in $\Delta\Gamma_s - \phi_s$ plane

Here: only statistical error

(systematics effects have been studied and are small compared to statistical uncertainty)

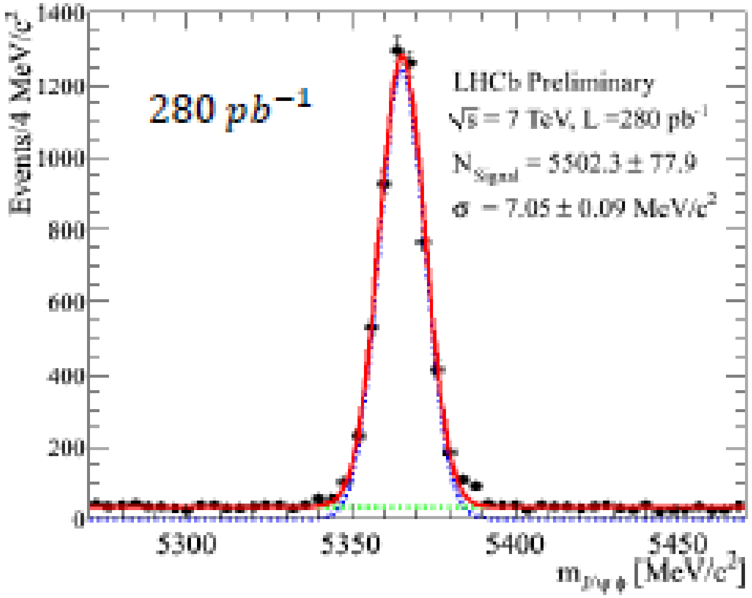
$$\boxed{\phi_s \in [-2.7, -0.5]\ rad\ @\ 68\%\ CL}$$

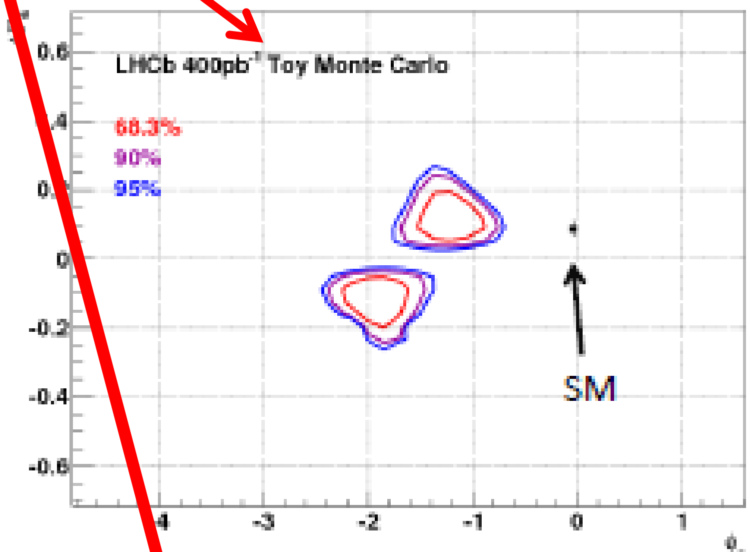
LHCb-Conf-2011-06

Prospects for $B_s \rightarrow J/\Psi\ \Phi$

Results for 10x more statistics ($350 - 400\ pb^{-1}$) very soon

→ expect world best measurement of ϕ_s





Central values from 2010 analysis as input

Assuming identical performance as 2010

Effect of 10x more statistics

LHCb will present its new results for the Lepton Photon Conf .in Mumbai

What is next?

- Does the world is waiting for LHCb result in Mumbai L.P . conf?
- Many voices are advocating that Tevatron should at lea st say its “final word” on Bs-CPV
- D0 did its work (8fb-1 result on Bs->J/Psi Phi analysis + update of the Asl dimuons asymmetry)
- D0 is waiting for CDF
- And also FNAL and the theoreticians (e.g. Nierste’s resu lt)
- CDF will push extremely hard to issue soon a result

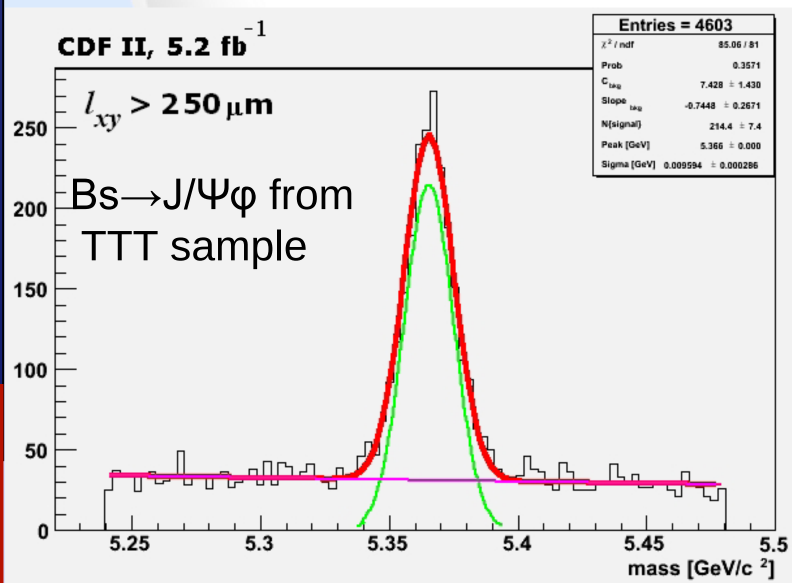
=> CDF is awaiting for the Italian team to issue the resul ts on the dimuon analysis

=> CDF is awaiting for TTT analysis with KISTI and Pari s group.

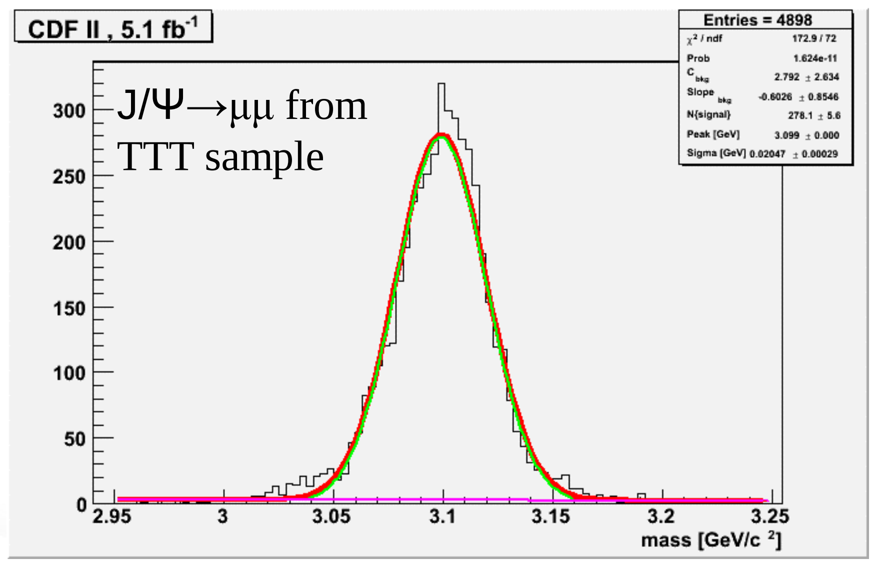
=> The deadline: MUMBAI Lepton Photon Conference

Ongoing analysis @KISTI

- Working with Paris Group
- Including new trigger (TTT) => adds 25% more data
- New analysis => cross-check
- Optimized data selection => more data than just from m ultiplying with the increase in luminosity.
- Untagged analysis in progress with TTT and comparing with Dimuons



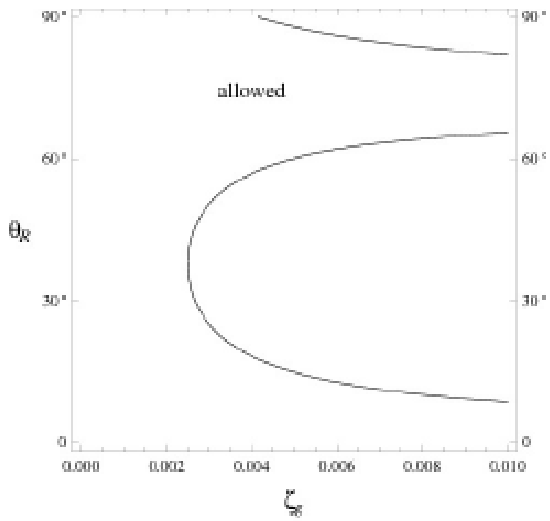
Signal (± 3σ) 1837 ± 119
Background (± 3σ) 636



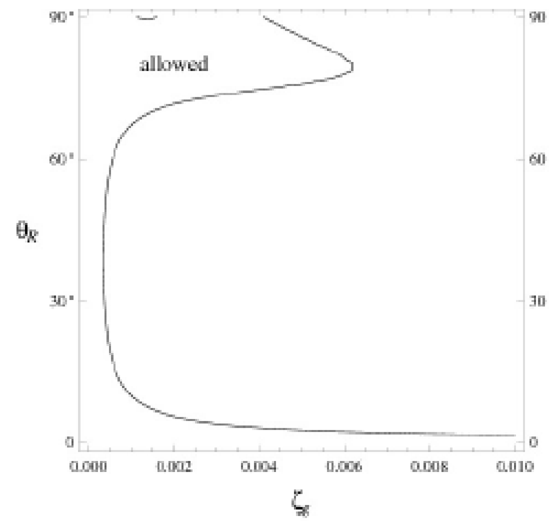
6500 events from dimuon sample now

$B\overline{B}$ Mixing @ KISTI

- Contour plot corresponding to $0.7 < |1 + r_{LR}| < 1.3$ for $\zeta_g = 2\xi_g$ and $\alpha_{2,3,4} = 120°$:



$B_s\bar{B}_s\ (V_I^R)$



$B_d\bar{B}_d\ (V_{II}^R)$

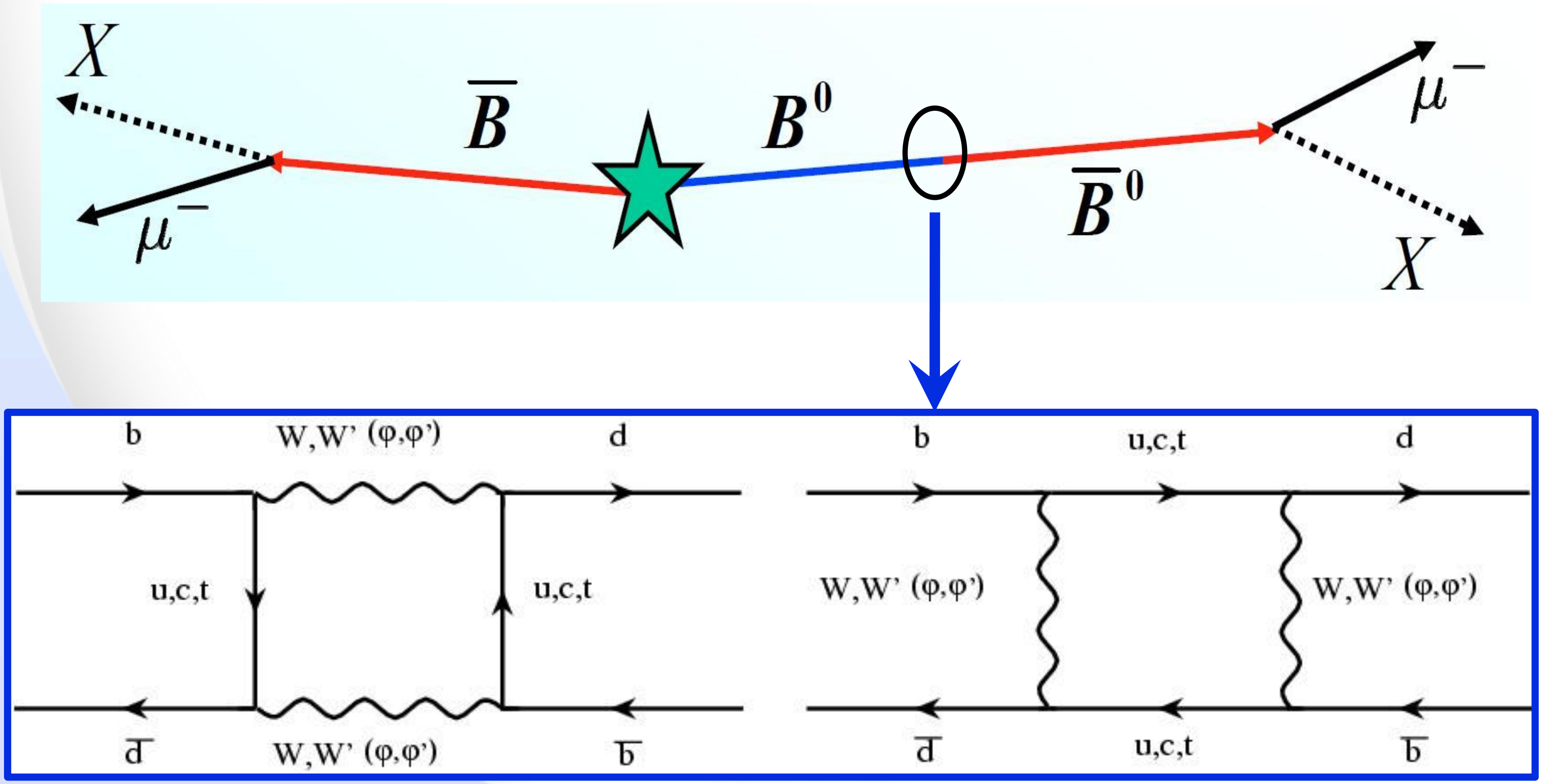
- Right-handed currents cannot significantly contribute to ΔM_{B_d} and ΔM_{B_s} simultaneously.

$\Rightarrow$Currently working on Bs mixing

=> Dr. Soo-hyeon Nam work in progress

Same sign dileptonic asymmetry

- Another way to probe B0– B0bar mixing
- D0 experiment



Same sign dileptonic asymmetry (D0)

- Same sign di-lepton asymmetry very small in SM ~*O(10^-4)* → sensitive NP probe

$$A^b_{\mathrm{sl}} \equiv \frac{N_b^{++} - N_b^{--}}{N_b^{++} + N_b^{--}} = C_d a^d_{\mathrm{sl}} + C_s a^s_{\mathrm{sl}}$$

$$a^q_{\mathrm{sl}} = \frac{\Gamma(\bar{B}^0_q(t) \to \mu^+ X) - \Gamma(B^0_q(t) \to \mu^- X)}{\Gamma(\bar{B}^0_q(t) \to \mu^+ X) + \Gamma(B^0_q(t) \to \mu^- X)} = \frac{\Delta\Gamma_q}{\Delta M_q} \tan\phi_q \qquad \phi = \arg\left(-\frac{M_{12}}{\Gamma_{12}}\right)$$

$$a^d_{\mathrm{sl}}(\mathrm{SM}) = (-4.8^{+1.0}_{-1.2}) \times 10^{-4}$$
$$a^s_{\mathrm{sl}}(\mathrm{SM}) = (2.1 \pm 0.6) \times 10^{-5}$$

$$C_d = 0.594 \pm 0.022,$$
$$C_s = 0.406 \pm 0.022.$$

HFAG, arXiv 1010.1589 [hep-ex] (2010)

- SM prediction $A^b_{\mathrm{s}} = (-0.028^{+0.005}_{-0.006})\%$

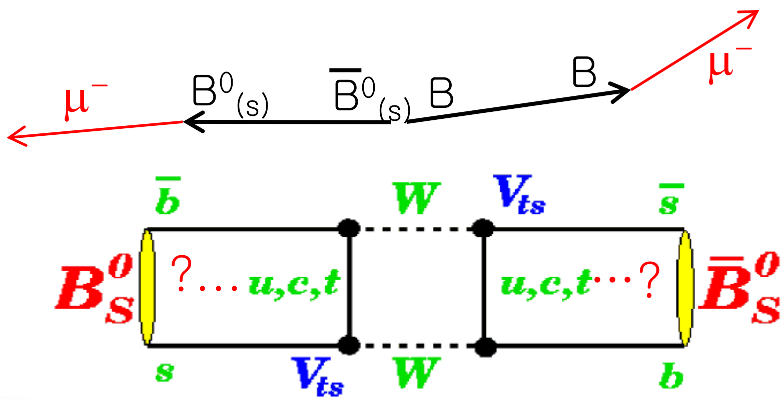
Lentz, Nierste, JHEP 0760, 072 (2007)

- Initial D0 measurement with 6 fb^{-1}

Abazov,PRD 82, 032001(2010), Abazov, PRL 105, 081801 (2010

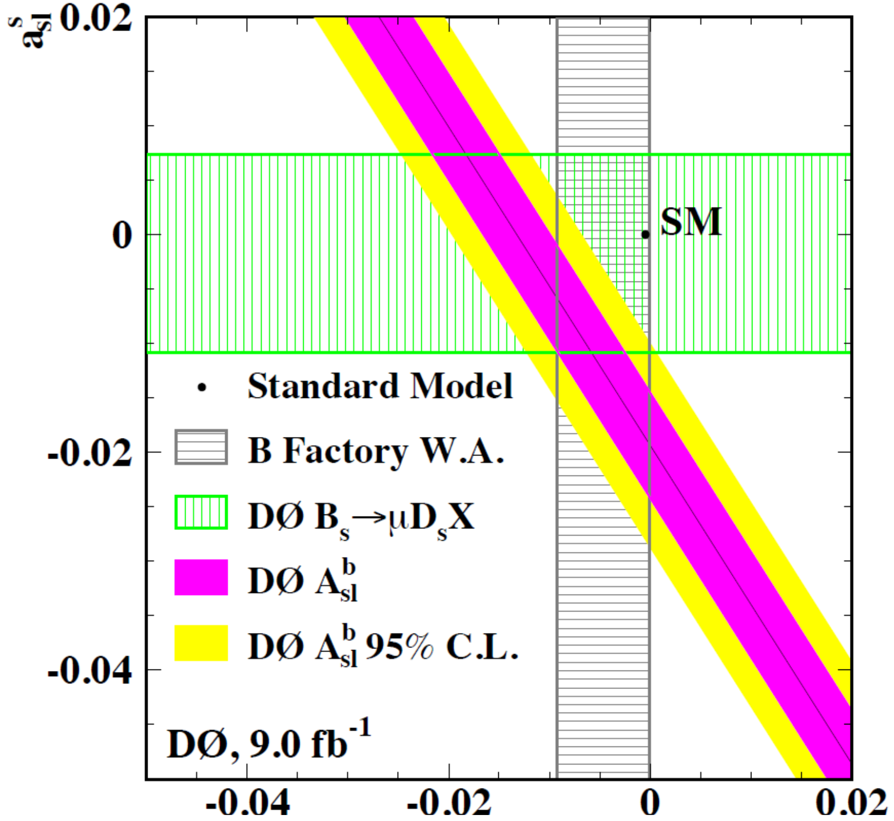
$$A^b_{\mathrm{sl}} = -0.00957 \pm 0.00251\,(\mathrm{stat}) \pm 0.00146\,(\mathrm{sys})$$

was 3.2σ away from SM expectation



- Updated measurement released by D0 at EPS 2011

Same sign dileptonic asymmetry

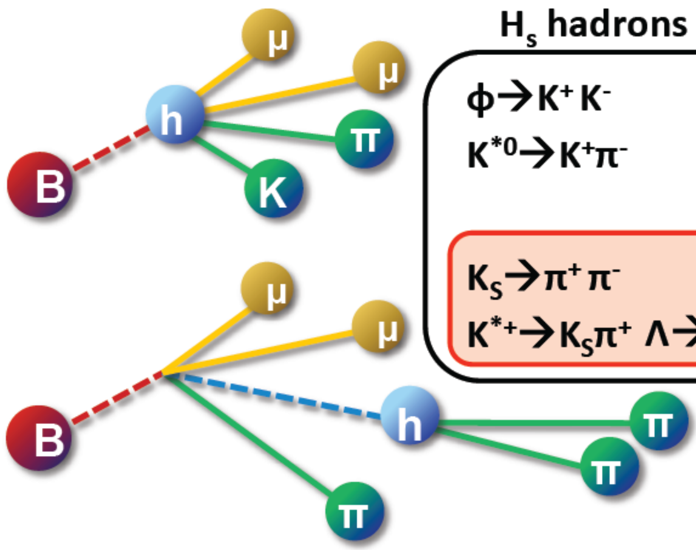


- This measurement (2011) with 9.0 fb^{-1}:
  $A^b_{sl} = (-0.787 \pm 0.172\ (\text{stat}) \pm 0.093\ (\text{syst}))\ \%$, 3.9σ from SM.

Using Left–Right model

To be submitted to "CP violating dimuon charge asymmetry in the LR model" by S.–h. Nam

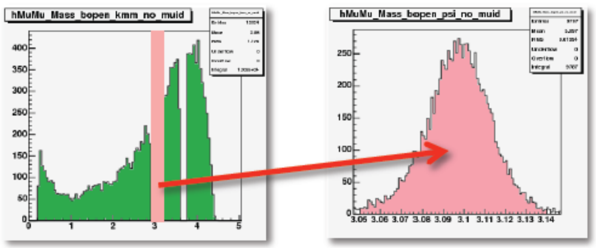
b − > s mu mu



H_s hadrons

- $\phi \to K^+ K^-$
- $K^{*0} \to K^+ \pi^-$
- $K_S \to \pi^+ \pi^-$
- $K^{*+} \to K_S \pi^+$ $\Lambda \to p\pi^-$

signal	control
$B^0 \to K^{*0}\mu\mu$	$B^0 \to J/\psi K^{*0}$
$B^+ \to K^+\mu\mu$	$B^+ \to J/\psi K^+$
$B_s \to \phi\mu\mu$	$B_s \to J/\psi\phi$
$B^+ \to K^{*+}\mu\mu$	$B^+ \to J/\psi K^{*+}$
$B^0 \to K_S\mu\mu$	$B^0 \to J/\psi K_S$
$\Lambda_b \to \Lambda\mu\mu$	$\Lambda_b \to J/\psi\Lambda$



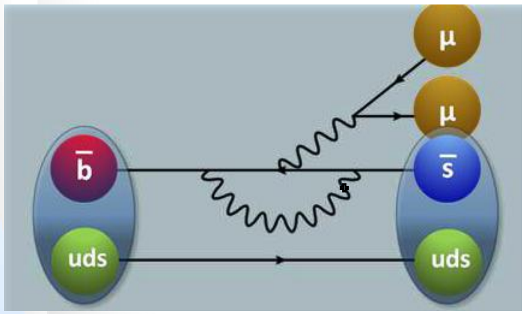
Dimuon mass

12 channel analysis!

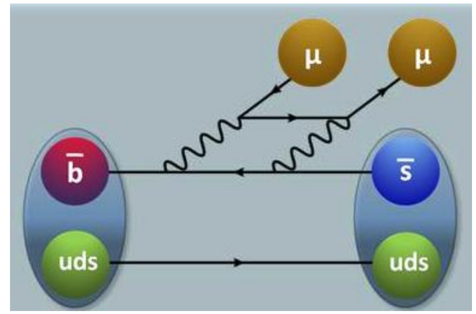
- Start from dimuon trigger
  - Reconstruct $H_b \to H_s\mu\mu$
  - Optimize event selection by NN
- **BR measurement**
- **Angular analysis**

Kihyeon Cho

- Rare decays with BR ~O(10^{-6}) in SM; good probes of NP



+



+NP?

- Various channels:

  $B^0 \to K^{*0}\mu\mu$
  $B^+ \to K^+\mu\mu$
  $B^+ \to K^{*+}\mu\mu$
  $B^0 \to K^0{}_s\mu\mu$,

  first observed by *CDF*:

  $B_s \to \Phi\mu\mu$ (PRL106,161801 (2011))
  $\Lambda_b \to \Lambda\mu\mu$ (arXiv:1107.3753)

Mode	Relative $\mathcal{B}(10^{-3})$	Absolute $\mathcal{B}(10^{-6})$
$\Lambda_b^0 \to \Lambda\mu^+\mu^-$	$2.45 \pm 0.59 \pm 0.29$	$1.73 \pm 0.42 \pm 0.55$
$B_s^0 \to \phi\mu^+\mu^-$	$1.13 \pm 0.19 \pm 0.07$	$1.47 \pm 0.24 \pm 0.46$
$B^+ \to K^+\mu^+\mu^-$	$0.46 \pm 0.04 \pm 0.02$	$0.46 \pm 0.04 \pm 0.02$
$B^0 \to K^{*0}\mu^+\mu^-$	$0.77 \pm 0.08 \pm 0.03$	$1.02 \pm 0.10 \pm 0.06$
$B^0 \to K^0\mu^+\mu^-$	$0.37 \pm 0.12 \pm 0.02$	$0.32 \pm 0.10 \pm 0.02$
$B^+ \to K^{*+}\mu^+\mu^-$	$0.67 \pm 0.22 \pm 0.04$	$0.95 \pm 0.32 \pm 0.08$

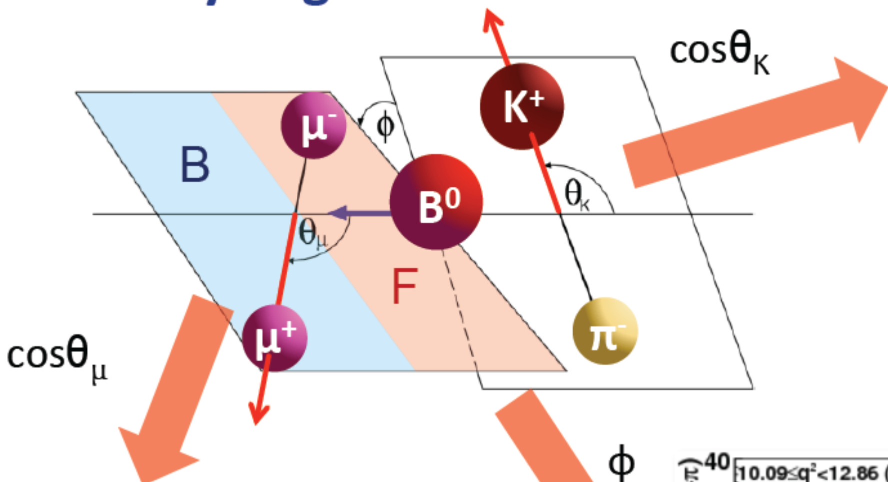
– Most precise BR measurements

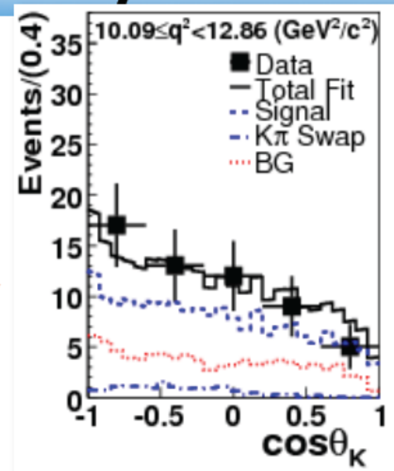
- BR theoretical calculations of $\Lambda_b \to \Lambda\mu\mu$

$(4.0\pm1.2)*10^{-6}$	Phys.Rev.D81,056006 (2010)
$4.4*10^{-6}$	Phys.Rev.D78,114032 (2008)
$2.08*10^{-6}$	Phys.Rev.D64,074001 (2001)

Angular analysis

- **One can extract information from the decay angular distribution**





K* polarization

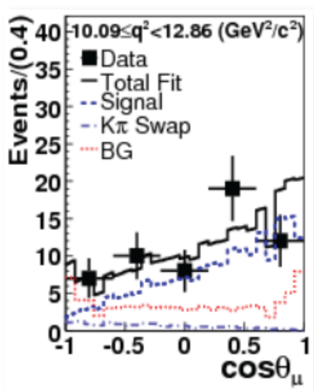
F_L

$$\frac{3}{2}F_L\cos^2\theta_K + \frac{3}{4}(1-F_L)(1-\cos^2\theta_K)$$

NEW

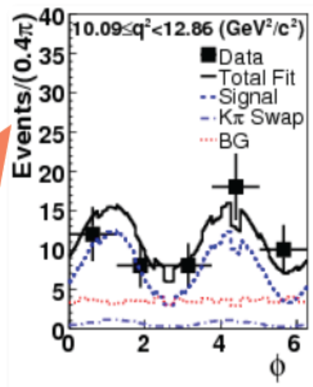
$A_T^{(2)}$ Transverse polarization asymmetry

A_{im} Triple product asymmetry



FB Asymmetry

A_{FB}



$$\frac{1}{2\pi}\left[1 + \frac{1}{2}(1-F_L)A_T^{(2)}\cos 2\phi + A_{im}\sin 2\phi\right]$$

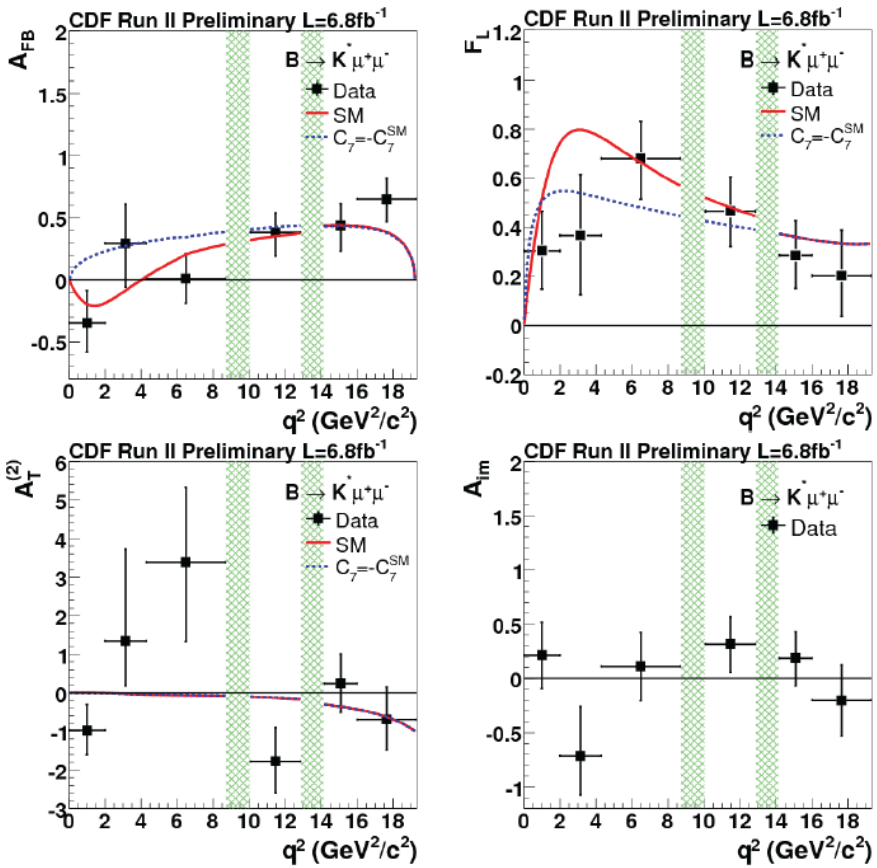
$$\frac{3}{4}F_L(1-\cos^2\theta_\mu) + \frac{3}{8}(1-F_L)(1+\cos^2\theta_\mu) + A_{FB}\cos\theta_\mu$$

Angular fit results

Simultaneous fit with K^{*0} and K^{*+}

A_{FB}

F_L



$A_T^{(2)}$

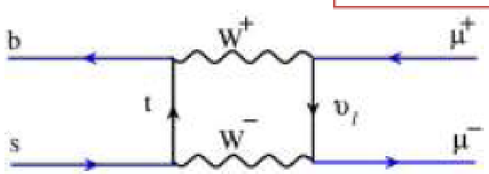
A_{im}

- Among the most precise A_{FB}/F_L measurements
  - comparable resolution with Belle
- No significant deviation from SM so far

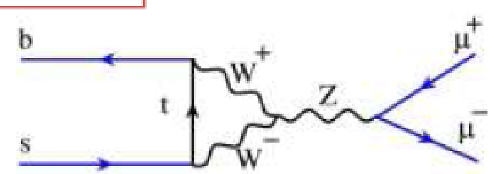
Bs -> mu+ mu−

Rare decay $B_s^0 \to \mu^+\mu^-$: FCNCs, forbidden at tree level

SM Diagrams



Box Diagram



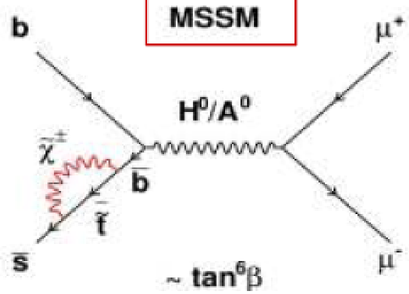
Penguin Diagram

SM Expectation

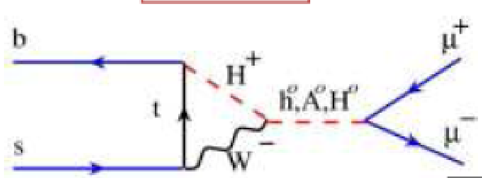
$Br: (3.2 \pm 0.2) \times 10^{-9}$

JHEP 1009 (2010)106

MSSM



2HDM



Penguin Diagram

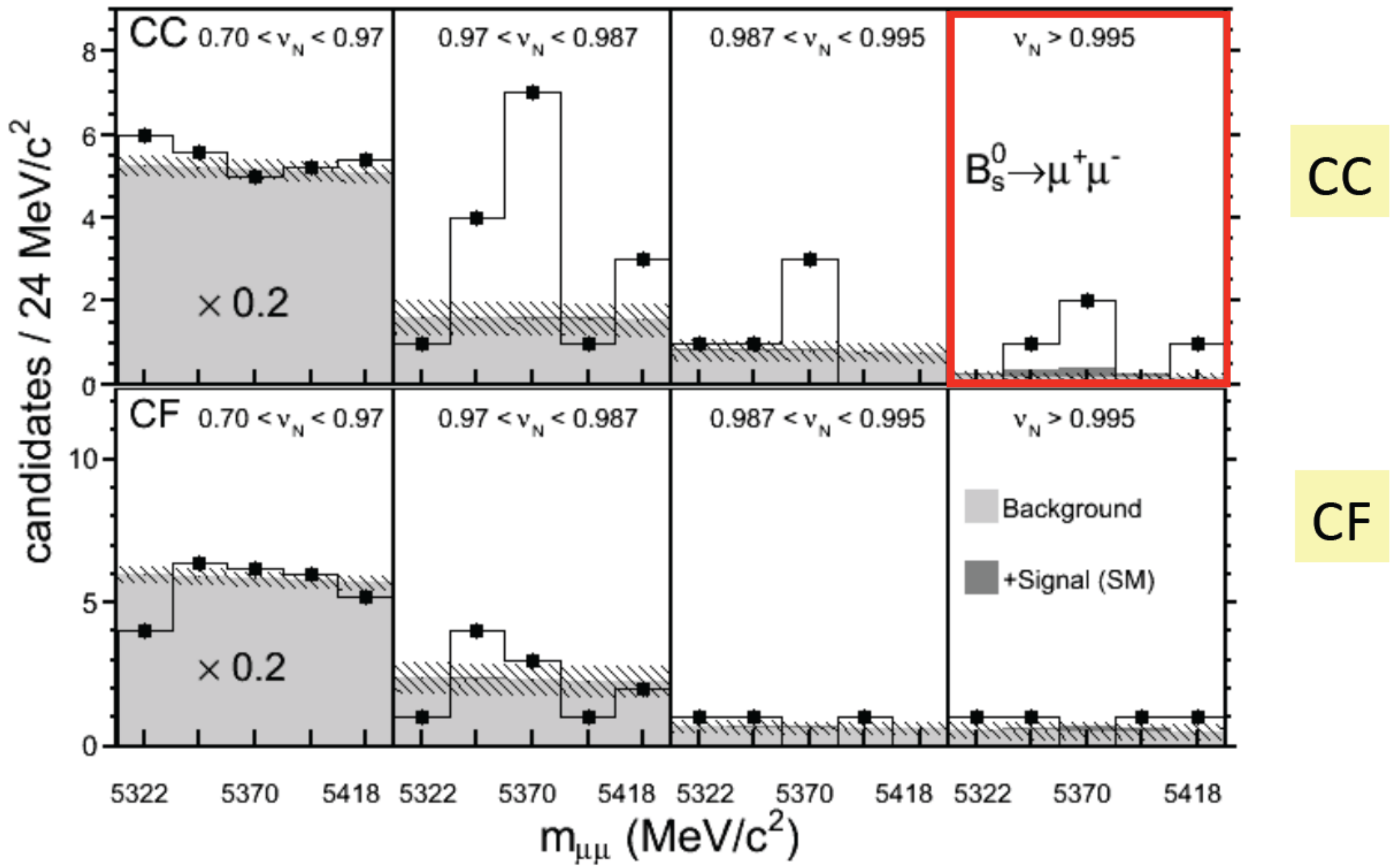
NP Expectation

Br enhancement

Powerful Probe to New Physics

Kihyeon Cho

$B_s \rightarrow \mu^+\mu^-$ Signal Window



Fit to the data in the B_s search window

Using the log-likelihood fit described before, we set the first two-sided limit for the $B_s \rightarrow \mu^+\mu^-$ branching fraction:

$$4.6 \times 10^{-9} < \mathcal{B}(B_s^0 \rightarrow \mu^+\mu^-) < 3.9 \times 10^{-8} \;\; (90\% \, CL)$$

Our central value is

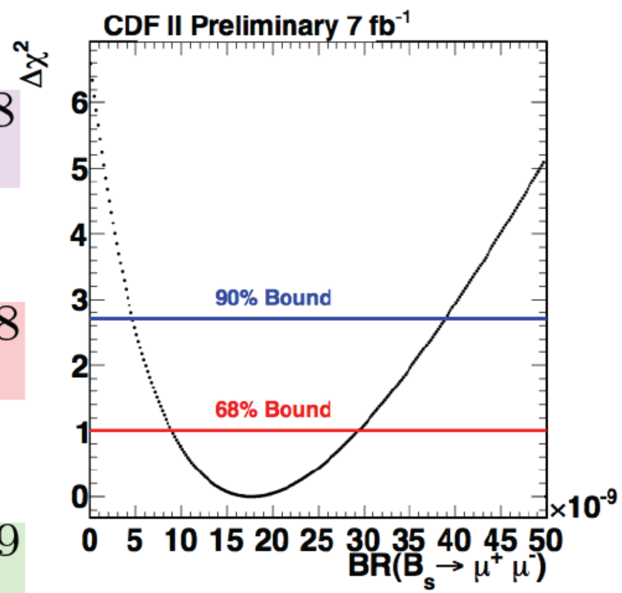
$$\mathcal{B}(B_s^0 \rightarrow \mu^+\mu^-) = 1.8^{+1.1}_{-0.9} \times 10^{-8}$$

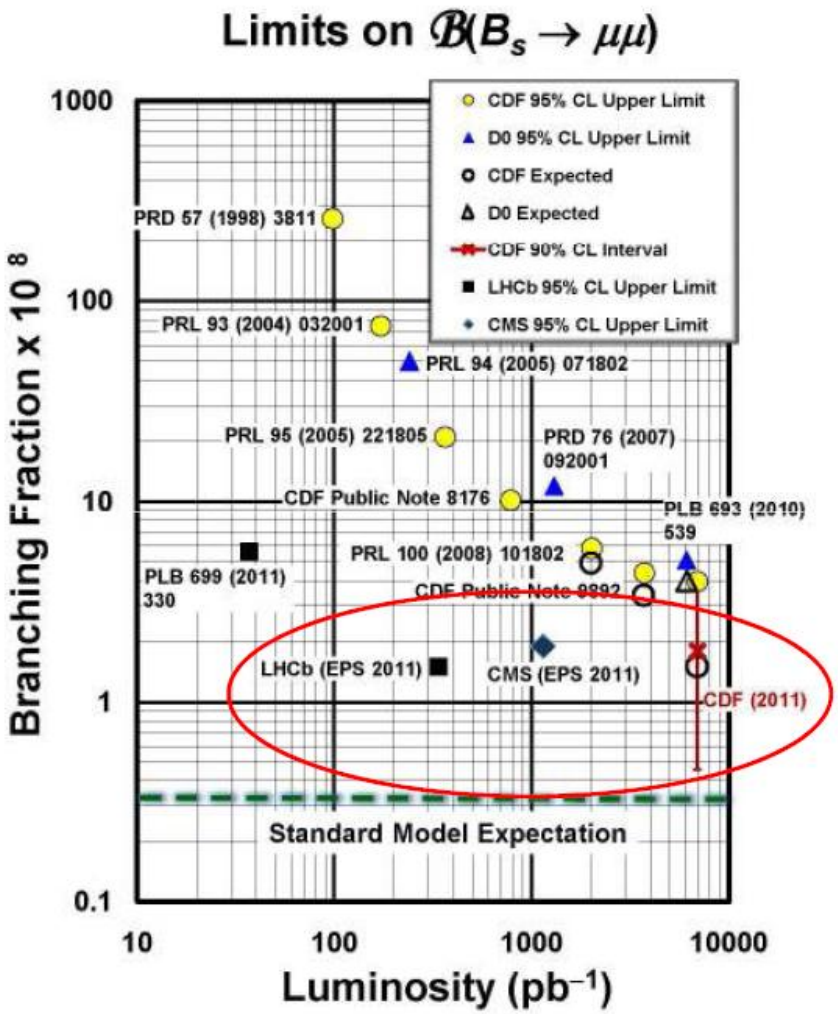
Using just 2 highest NN bins

$$\mathcal{B}(B_s^0 \rightarrow \mu^+\mu^-) = 1.4^{+1.0}_{-0.8} \times 10^{-8}$$

Compare to SM expectation of:

$$\mathcal{B}(B_s^0 \rightarrow \mu^+\mu^-) = (3.2 \pm 0.2) \times 10^{-9}$$





- ➲ What we will see beyond our horizon
- ➲ Results opened at EPS 2011

Summary

Output

Flavor physics using the concepts of e-Science

Theory

e-Science

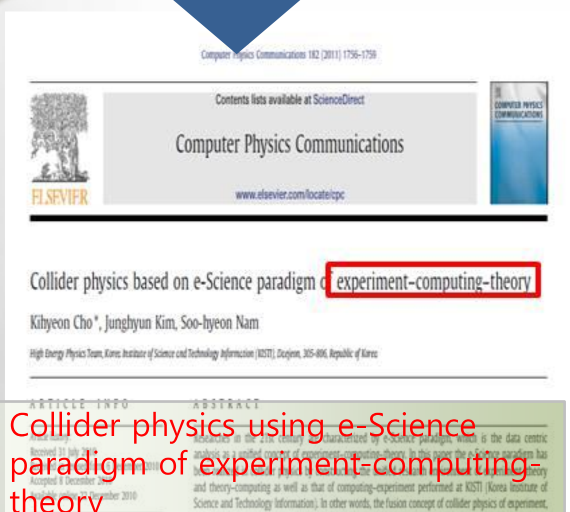
Experi-ment

Comput-ing

- To study high energy physics anytime and anywhere
- Fusion research of experiment-computing–theory

⇒ We are applying both concepts to high energy physics. It is a great success!

Publication


Computer Physics Communications 182 (2011) 1756–1759

Contents lists available at ScienceDirect

Computer Physics Communications

www.elsevier.com/locate/cpc

Collider physics based on e-Science paradigm of experiment-computing-theory

Kihyeon Cho*, Junghyun Kim, Soo-hyeon Nam

Collider physics using e-Science paradigm of experiment-computing-theory

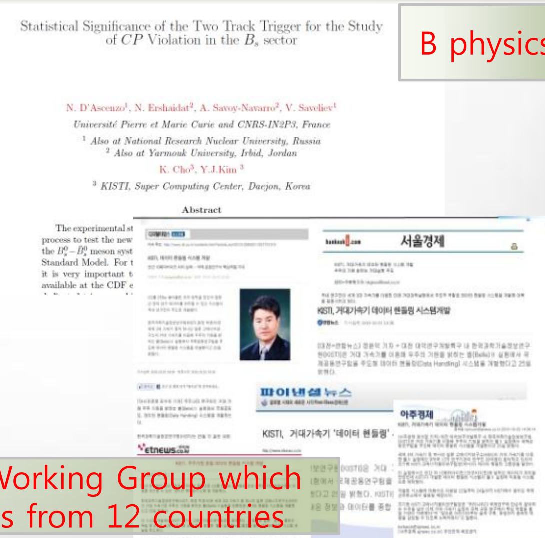

Contents lists available at ScienceDirect

Computer Physics Communications

www.elsevier.com/locate/cpc

The advanced data searching system with AMGA at the Belle II experiment

Leading Belle II Data Handling Working Group which consists of more than 30 persons from 12 countries


Statistical Significance of the Two Track Trigger for the Study of CP Violation in the B_s sector

B physics

Summary (continued)

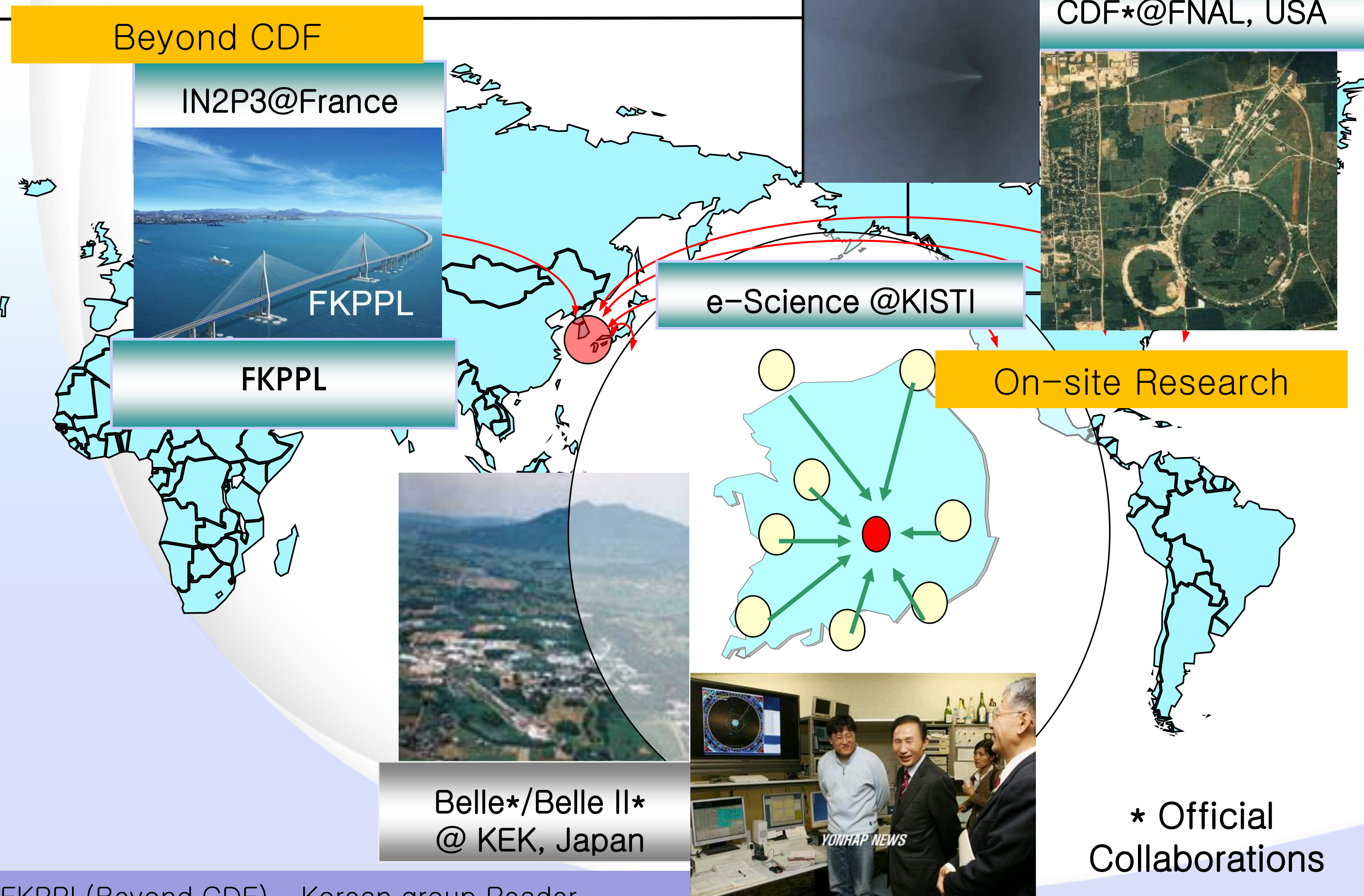
- There are also a few interesting results from the flavor physics experiments indicating hints of something unknown…
  - CP Violation and mixing
  - Dimuon Asymmetry
  - FCNC at b->s mu mu and Bs->mu mu modes
- Standard Model or not, we do not have clear understanding, yet.
- Therefore we continue working on heavy flavor physics in the LHC era.

Acknowledge

- Aurore Savoy-Navarrow

Back-up

HEP @ KISTI

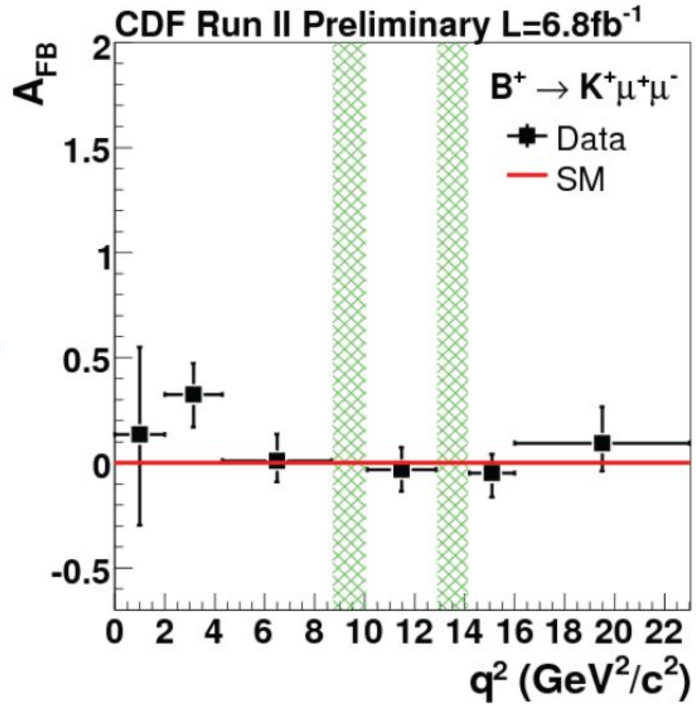


* Official Collaborations

- FKPPL(Beyond CDF) – Korean group Reader
- Belle II Data Handling Working Group Chair

A_{FB} in $B^+ \rightarrow K^+ \mu\mu$

A_{FB}



- Close to zero as expected

Why Flavor Physics?

- The first flavor of new phenomena often comes from flavor physics
  - Weak decays of light hadrons => existence of charm quark
  - CP violation => 3rd quark family
  - B0 oscillation => heavy top quark

- B mesons are especially suitable for beyond SM searches
  - Large mass of b quark – stronger coupling to new particles
  - Abundant production
  - Well developed technique of experimental selection

G. Borissov

B Physics: Two golden cases

- B_s – CPV
- B → 2 leptons especially:

And still many more…

The VIP's of B_s Physics: $B_{s,d} \to \mu^+\mu^-$ and $S_{\psi\phi}$

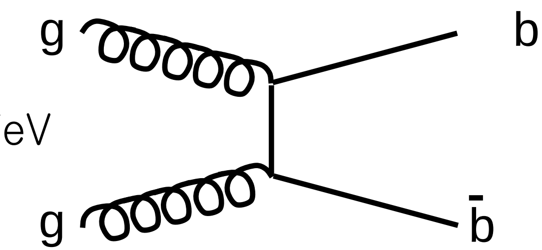
	AC	RVV2	AKM	δLL	FBMSSM	LHT	RS
$D^0-\bar{D}^0$	★★★	★	★	★	★	★★★	?
ε_K	★	★★★	★★★	★	★	★★	★★★
$S_{\psi\phi}$	★★★	★★★	★★★	★	★	★★★	★★★
$S_{\phi K_S}$	★★★	★★	★	★★★	★★★	★	?
$A_{\rm CP}(B \to X_s\gamma)$	★	★	★	★★★	★★★	★	?
$A_{7,8}(B \to K^*\mu^+\mu^-)$	★	★	★	★★★	★★★	★★	?
$A_9(B \to K^*\mu^+\mu^-)$	★	★	★	★	★	★	?
$B \to K^{(*)}\nu\bar{\nu}$	★	★	★	★	★	★	★
$B_s \to \mu^+\mu^-$	★★★	★★★	★★★	★★★	★★★	★	★
$K^+ \to \pi^+\nu\bar{\nu}$	★	★	★	★	★	★★★	★★★
$K_L \to \pi^0\nu\bar{\nu}$	★	★	★	★	★	★★★	★★★
$\mu \to e\gamma$	★★★	★★★	★★★	★★★	★★★	★★★	★★★
d_n	★★★	★★★	★★★	★★	★★★	★	★★★
d_e	★★★	★★★	★★	★	★★★	★	★★★
$(g-2)_\mu$	★★★	★★★	★★	★★★	★★★	★	★★

Table 2: "DNA" of flavour physics effects [55] for the most interesting observables in a selection of SUSY and non-SUSY models. ★★★ signals large effects, ★★ visible but small effects and ★ implies that the given model does not predict sizable effects in that observable.

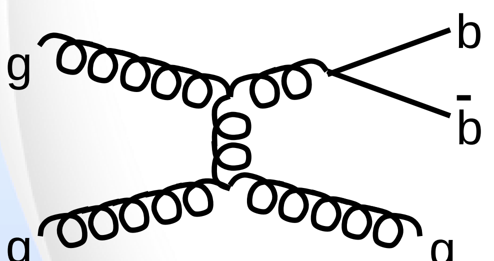
From A. Buras

B physics at Tevatron

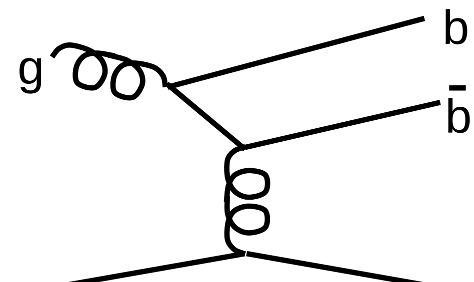
– Mechanisms for b production in $p\bar{p}$ collisions at 1.96 TeV



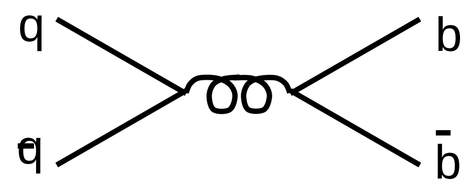
Flavor Creation (gluon fusion)



Gluon Splitting



Flavor Excitation



Flavor Creation (annihilation)

– At Tevatron, b production cross section is much larger compared to B-factories
→ Tevatron experiments CDF and DØ enjoy rich B Physics program

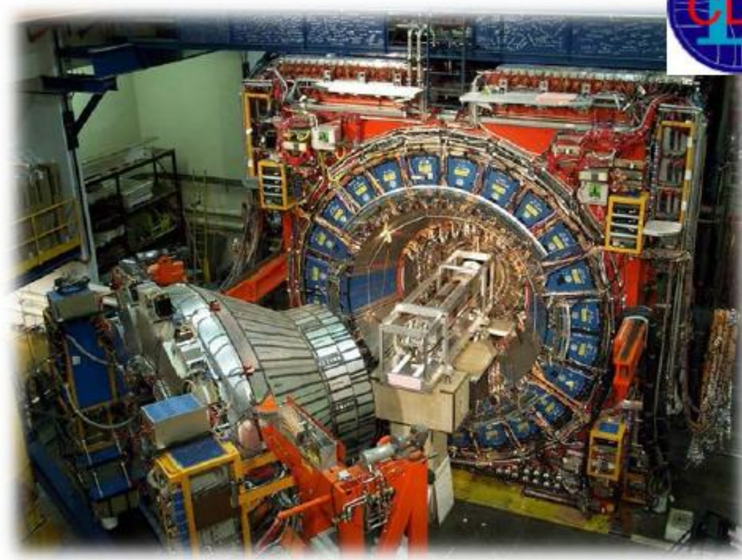
– Plethora of states accessible only at Tevatron: B_s, B_c, Λ_b, Ξ_b, Σ_b…
→ complement the B factories physics program

– Total inelastic cross section at Tevatron is ~1000 larger than b cross section
→ large backgrounds suppressed by triggers that target specific decays

Kihyeon Cho

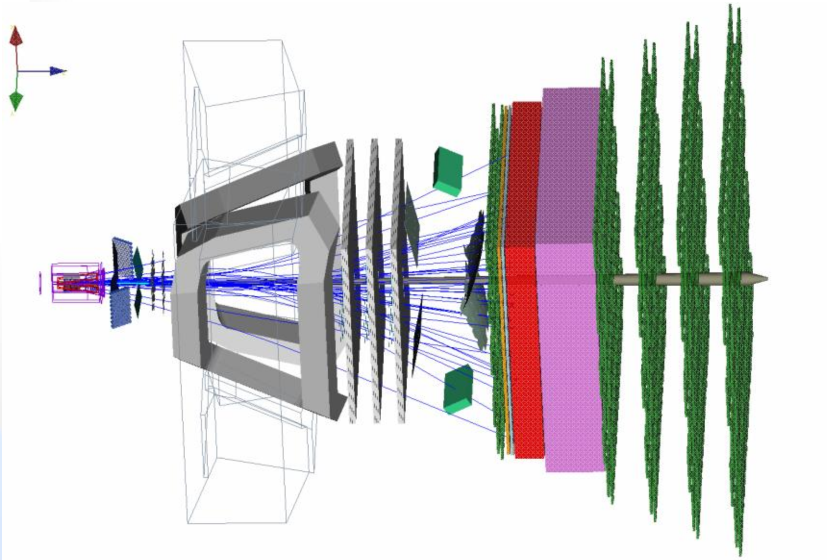
The Detectors

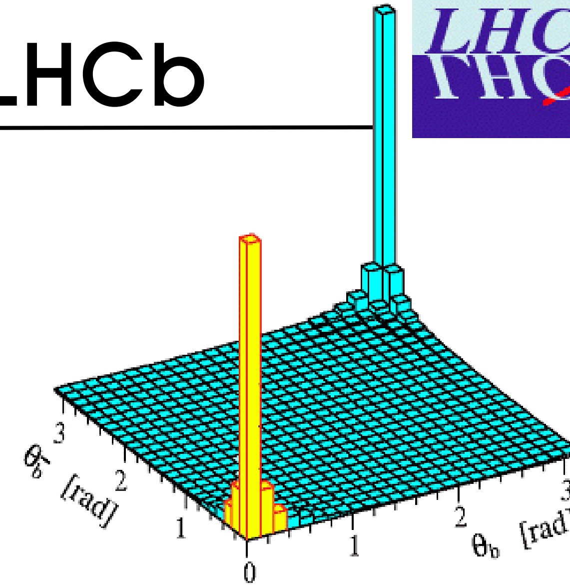
Silicon Tracking, $|\eta|<3$
Scintillating Fiber Tracker
1.9 T B Field, $|\eta|<2$
LAr/U Calorimeter, $|\eta|<2.5$
Jet Energy Scale 1-2%
μ Drift/Scintillator Counters, $|\eta|<2$

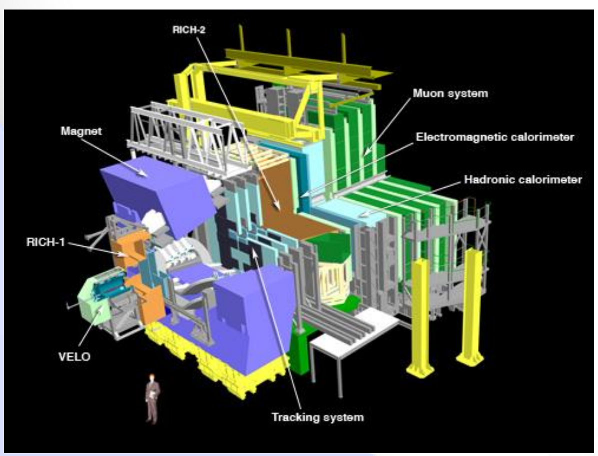


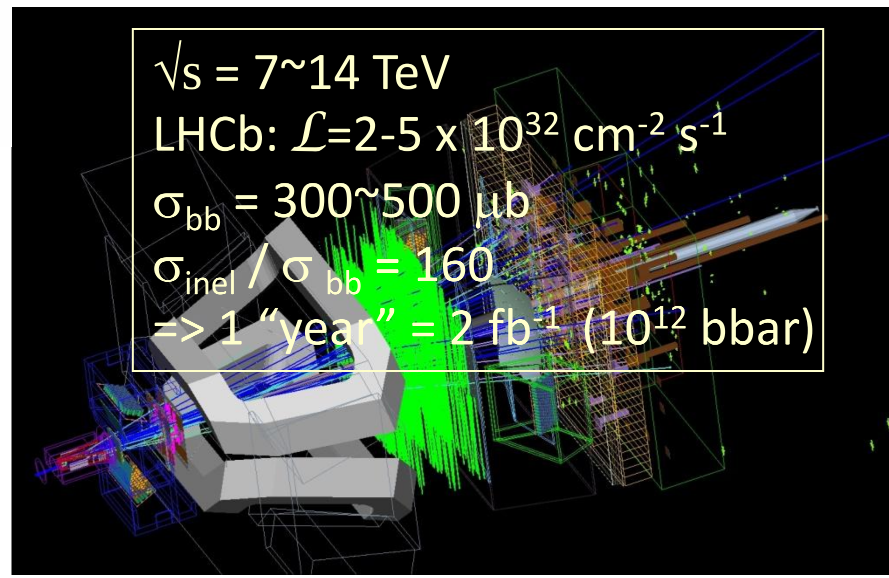
Silicon Tracking, $|\eta|<2.5$
Open Drift Cell Tracker
1.4 T B Field, $|\eta|<1.1$
Pb/Cu/Scint Calorimeter, $|\eta|<3.2$
Jet Energy Scale 2-3%
μ Drift/Scintillator Counters, $|\eta|<1.4$

Heavy Flavor Physics by LHCb





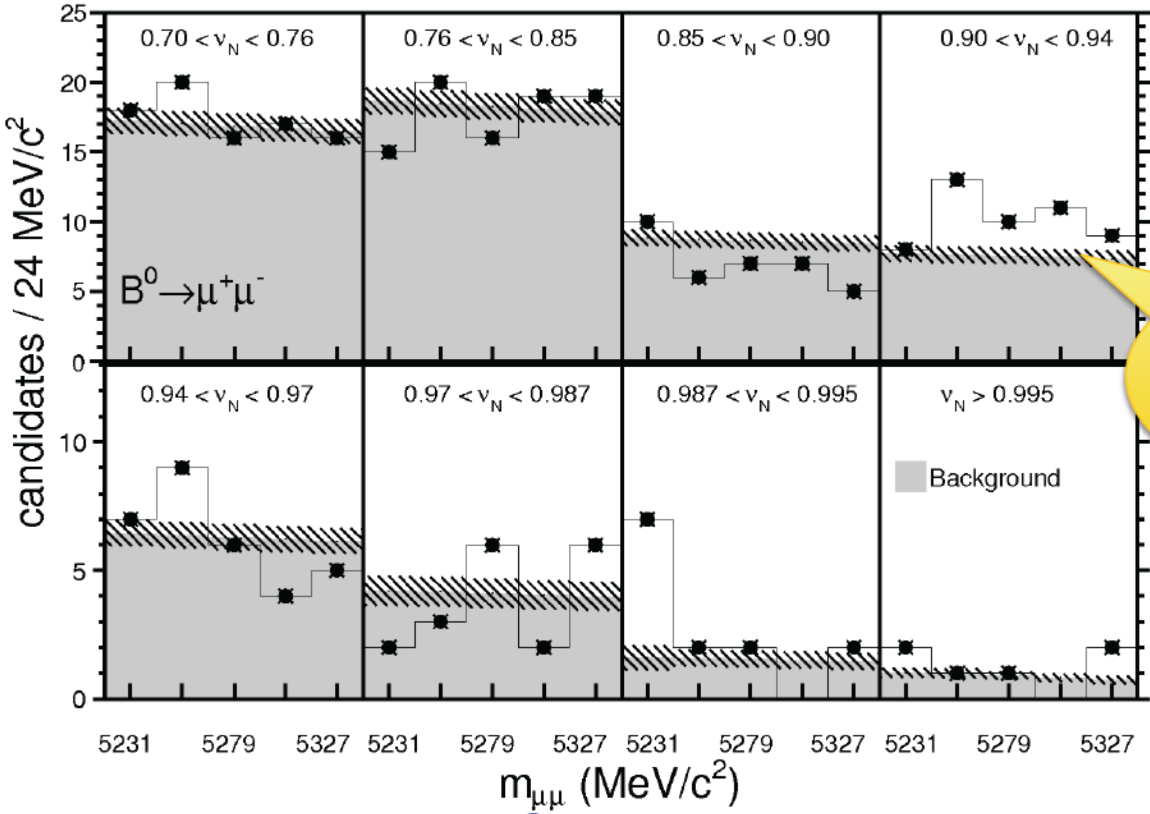




LHCb is a heavy flavour precision experiment searching for New Physics in **CP Violation** and **Rare Decays.**

http://www.cern.ch

$B^0 \rightarrow \mu^+\mu^-$ Signal Window



CC, CF combined

Uncertainty on mean background

$$\text{expected} \quad \mathcal{B}(B^0 \rightarrow \mu^+\mu^-) < 4.6 \times 10^{-9} \; 95\%\, CL$$

$$\text{observed} \quad \mathcal{B}(B^0 \rightarrow \mu^+\mu^-) < 6.0 \times 10^{-9} \; 95\%\, CL$$

Thank you.

cho@kisti.re.kr

Are we done???

- ~~Does the world is waiting for LHCb result in Mumbai L.P. conf?~~
- Many voices are advocating that Tevatron should at least say its “final word” on Bs-CPV
- D0 did its work (8fb-1 result on Bs->J/Psi Phi analysis + update of the Asl dimuons asymmetry)
- D0 is waiting for CDF
- And also FNAL and the theoreticians (see Nierste’s last result)
- CDF will push extremely hard to issue soon a result

=> CDF is awaiting for the Italian team to issue the results on the dimuon analysis

=> CDF would be delighted we finally present a result also,

see discussion of Aurore with Giovanni last Friday.

A may be desperate but in any case last chance ***task force is being undertaken by CDF for getting a result on the Bs->Jpsi Phi*** in order also to update the combination with D0. This is mandatory.

The deadline: MUMBAI Lepton Photon Conference

It means:

=> by August 9 we should present a preliminary result.

=> We have to talk with our Italian colleagues in CDF to collaborate and eventually combine results (provided we have results to combine). This before combining with D0.

LAST CHANCE to BE PART of the GAME!

Kihyeon Cho

Worldwide current status on $B_s \to J/\Psi\phi$ analysis

Latest from Tevatron and LHC

July 31st, 2011

Aurore

한국과학기술정보연구원
Korea Institute of Science and Technology Information
KiSTi
www.kisti.re.kr

EPS’ 2011 from Diego’ s summary talk

see also the presentations in parallel sessions

The B_s mixing phase

BSM physics in mixing

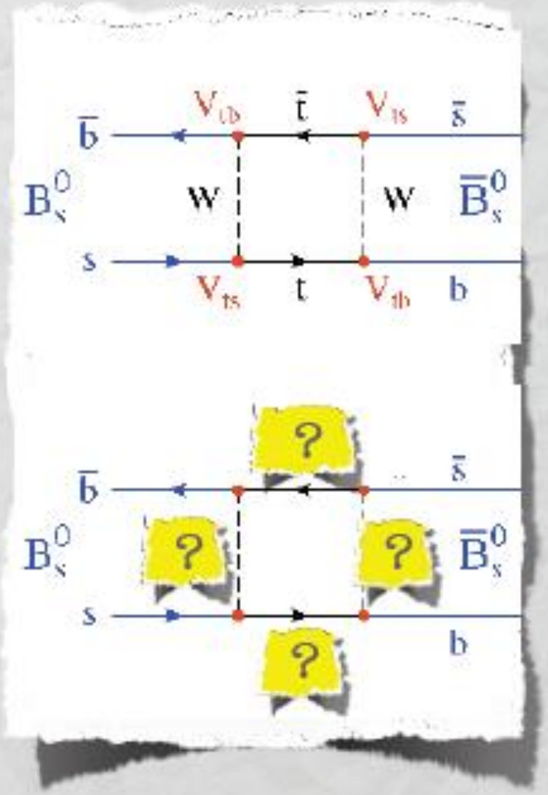
BSM physics can alter mixing phenomenology from SM expectations.

2006: magnitude of mixing consistent with SM (within lattice uncertainties)

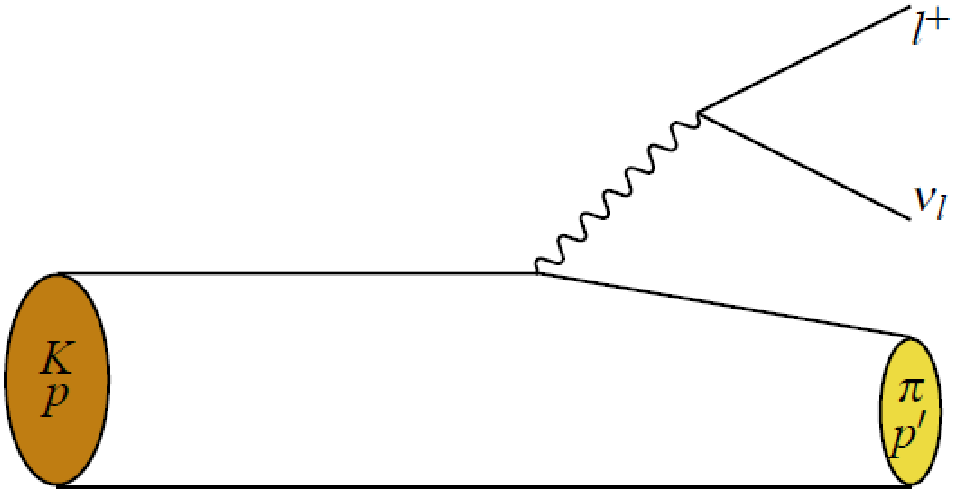
Mixing phase unconstrained - large NP effects still possible.

New physics accessible through interference between $B_s \to J/\psi\phi$ decay w/ and w/o flavor oscillations.

First measurements (2008) showed intriguing 2.2σ discrepancy



K_{l3} Decay



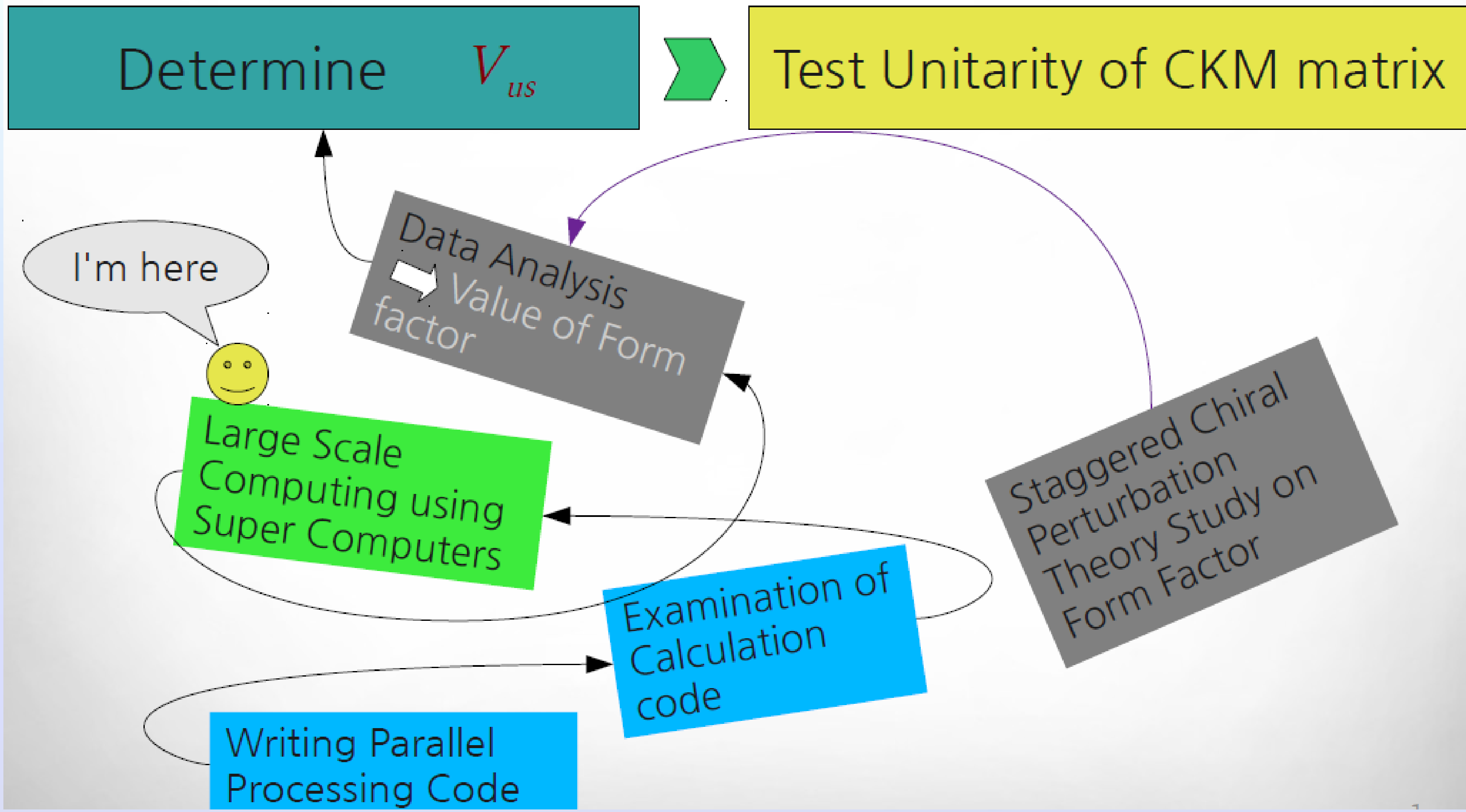
The decay rate is expressed by

$$\Gamma(K_{l3}) = \frac{G_F^2}{192\pi^3} M_K^5 C^2 I |V_{us}|^2 |f_+(0)|^2 S_{\rm ew}(1 + 2\Delta_{\rm SU(2)} + 2\Delta_{\rm em}). \quad (3)$$

$f_+(0)$ Vector form factor at zero momentum transfer,
$q^2 = (p' - p)^2 = 0$

e-HEP Study using Super Computer

→ **Calculation of Kaon Semi-leptonic Decay Form Factor**



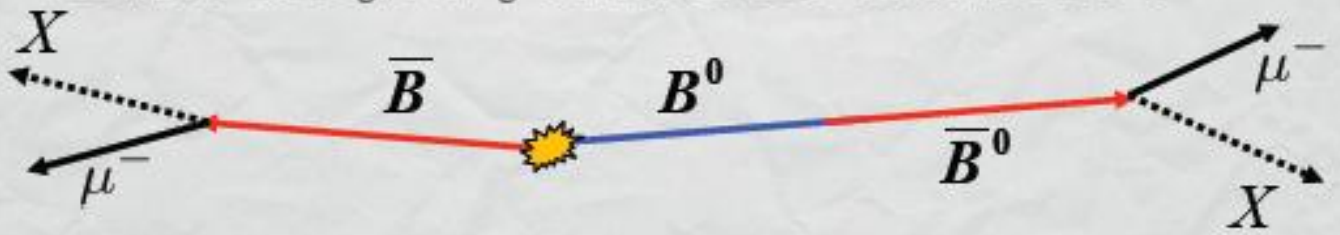
What is coming next?

- At Belle, b → s gamma, leptonic decay provide test of SM and BSM constraints.
  - Belle data sample has not yet been analyzed yet.
  - Even more interesting results at Belle II with two order of magnitude.
- At LHCb, new sensitivity regime at Bs → mu mu and Bs → J/psi phi with 100 pb^{-1} and new discovery with 1fb^{-1}.
- At CDF, still rich production in heavy flavor physics
  - Complimentary to e+e− and LHCb

Another way to look at it

Semileptonic asymmetry

In flavor-symmetric $\bar{p}p \rightarrow \bar{b}b$, like-sign leptons arise from HF decays only if flavor oscillations occur.



Inputs

- From EPS 2011
- FNAL CDF and D0 W&C presentations of r esults for Summer Conferences
- Nierste’ s theory Seminar at FNAL July 29.
- Discussion with Giovanni Punzi

Experimental Status

6.1 fb^{-1}:

BR($B_s \rightarrow \mu^+\mu^-$)<5.1 x$10^{-8}$

PLB 693 539 (2010)

3.7 fb^{-1}:

BR($B_s \rightarrow \mu^+\mu^-$) <4.3 x$10^{-8}$

BR($B^0 \rightarrow \mu^+\mu^-$) <7.6 x$10^{-9}$

public note 9892

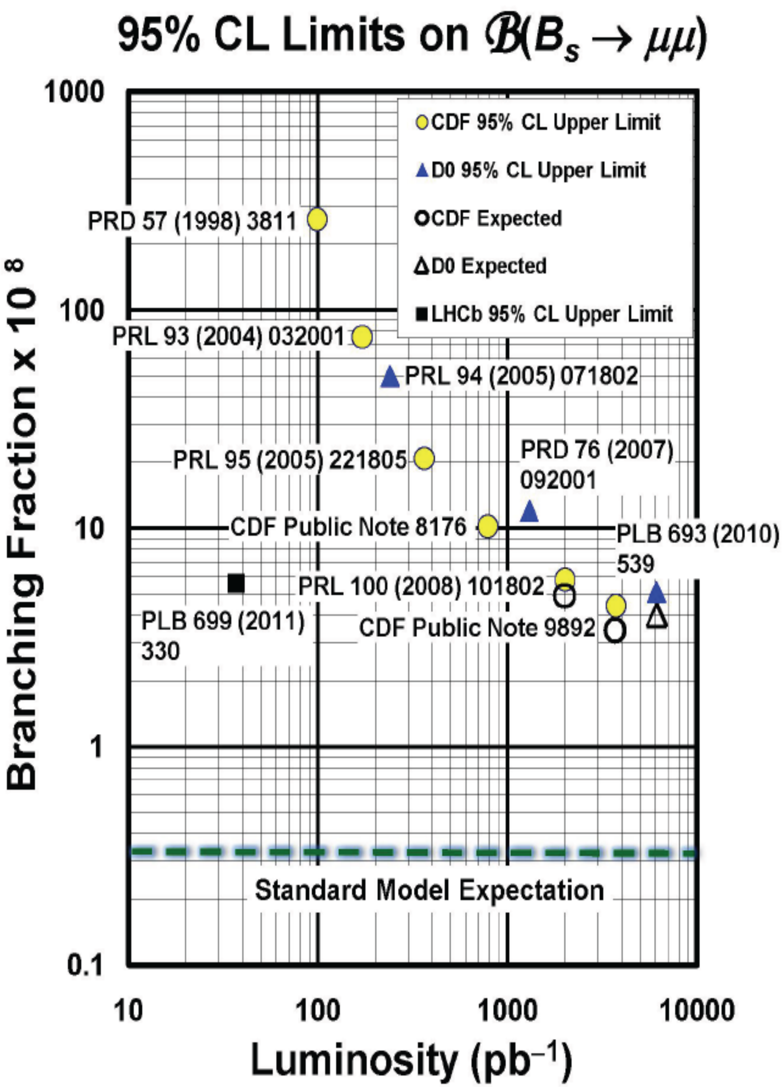
37pb^{-1}:

BR($B_s \rightarrow \mu^+\mu^-$) < 5.6 x 10^{-8}

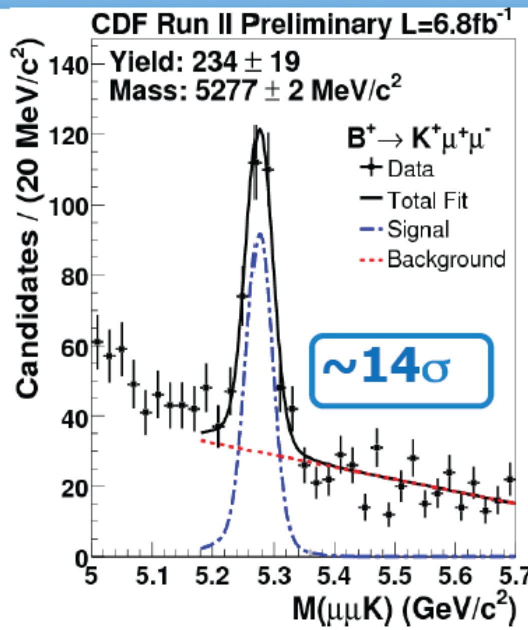
BR($B^0 \rightarrow \mu^+\mu^-$) < 15 x 10^{-9}

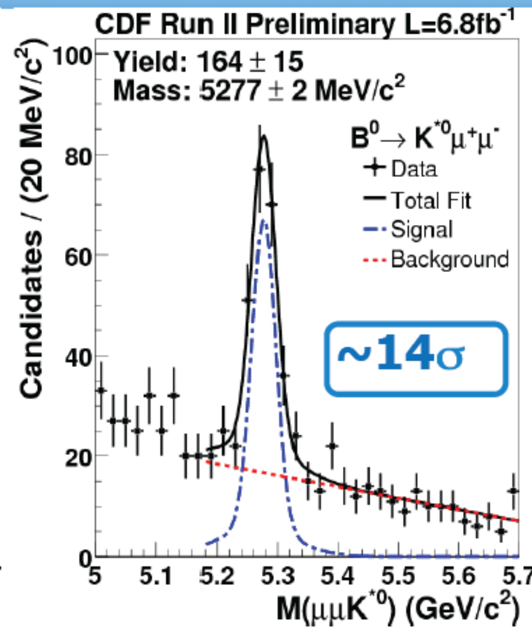
PLB 699, 330 (2011)

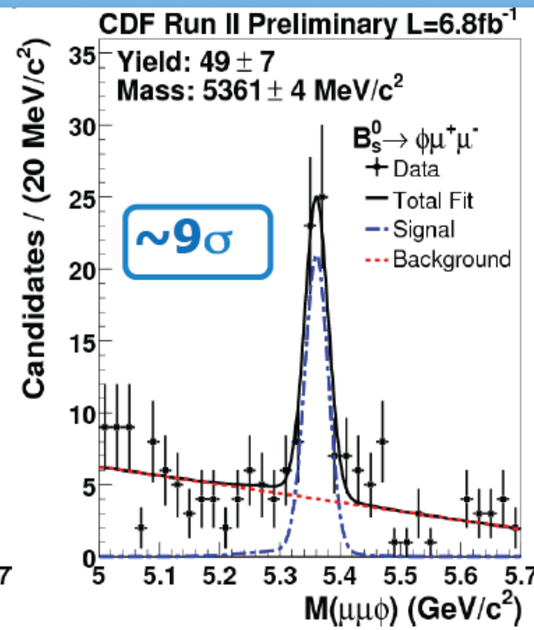
All limits quoted @95% C.L.

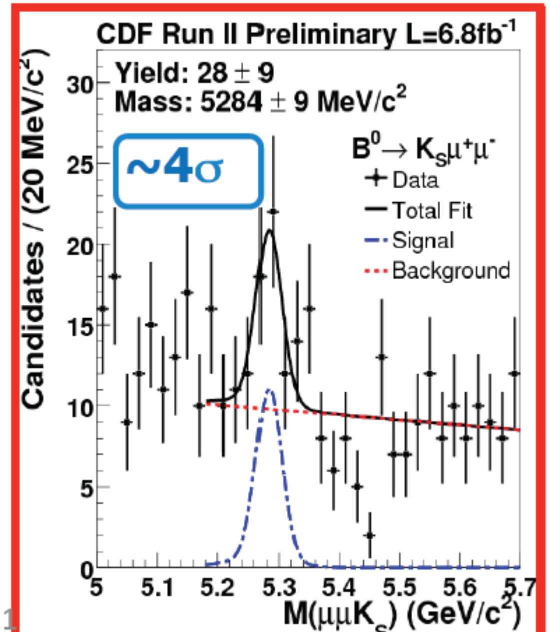


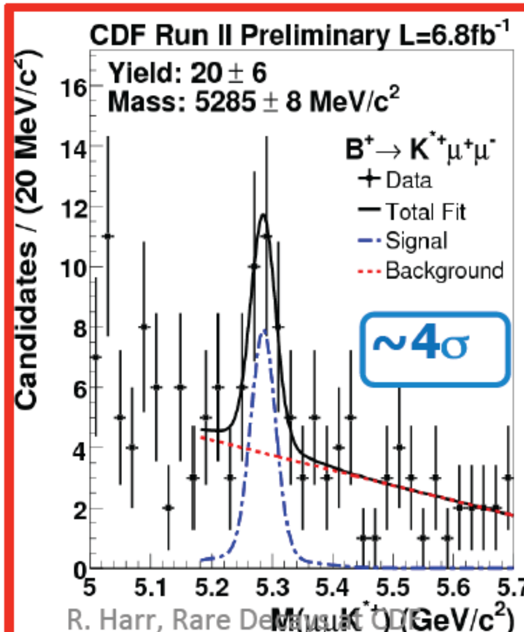
Rare B Yields with 6.8 fb^{-1}











First observations at a hadron collider

Outline

- All of the results shown today are new.
- Annihilation decays [see talk of Austin Napier]
  - Evidence for $B_s \rightarrow \pi\pi$ and 2-sided limit for $B_d \rightarrow KK$
- $b \rightarrow s\mu\mu$ decays
  - Observation of $\Lambda_b \rightarrow \Lambda\mu\mu$
  - $\mathcal{B}$ and $d\mathcal{B}$ for $B \rightarrow K^{(*)}\mu\mu$, $B_s \rightarrow \phi\mu\mu$
  - Angular asymmetries for $B \rightarrow K^{*}\mu\mu$
- $B \rightarrow \mu\mu$ decays
- Summary

Updated Like-Sign Di-Lepton Asymmetry (D0 9 fb^{-1})

– Analysis updated with 9 fb^{-1} from previous 6 fb^{-1}

– Improved muon selection:

– 13% increase in statistics due to looser muon longitudinal momentum selection

– 20% reduction in K and π decay in flight backgrounds

– Muon impact parameter studies support hypothesis that muons are indeed from B decays

$$A^b_{sl} = (-0.787 \pm 0.172 \ (\text{stat}) \pm 0.093 \ (\text{syst}))\%$$

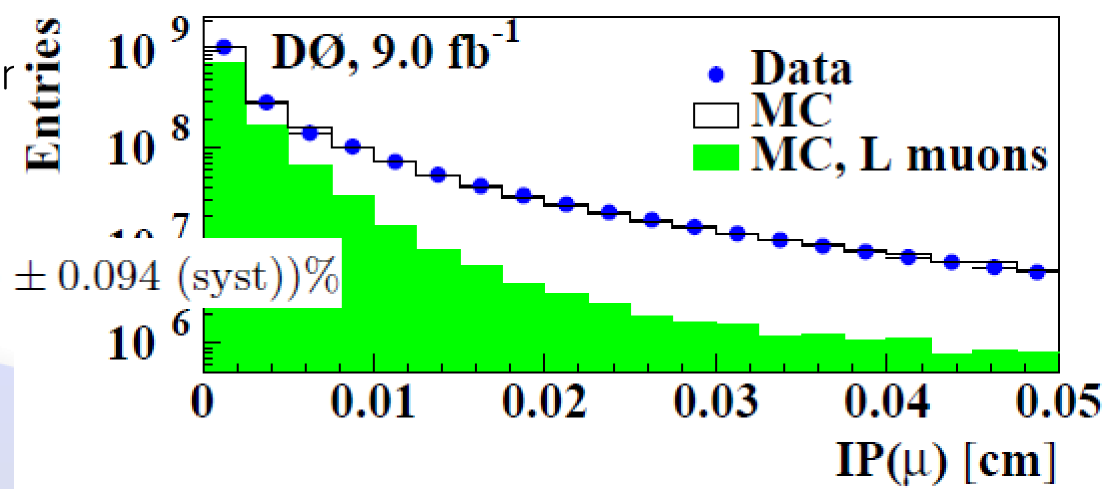
– New result is 3.9σ away from the SM expectation.

– Good agreement between muon impact parameter distributions in data and MC

– Muons from hadron decays and pur

– With an impact parameter cut at 120μm obtain consistent asymmetry

$$A^b_{sl}(IP_{>120}) = (-0.579 \pm 0.210 \ (\text{stat}) \pm 0.094 \ (\text{syst}))\%$$



Measurement of the anomalous like-sign dimuon charge asymmetry with 9 fb^{-1} of $p\bar{p}$ collisions

Bruce Hoeneisen
Universidad San Francisco de Quito
representing the
DØ Collaboration

Fermilab, 30 June 2011

We measure the like-sign dimuon charge asymmetry of direct semileptonic B decays in $p\bar{p}$ collisions:

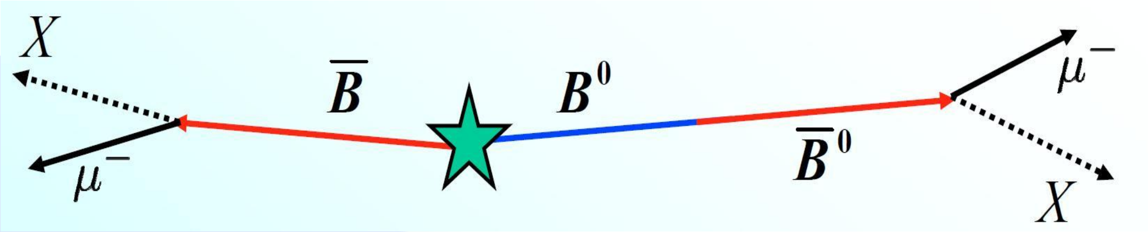
$$A^b_{\mathrm{sl}} \equiv \frac{N^{++}_{b\bar{b}} - N^{--}_{b\bar{b}}}{N^{++}_{b\bar{b}} + N^{--}_{b\bar{b}}},$$

$$A^b_{\mathrm{sl}} = C_d a^d_{\mathrm{sl}} + C_s a^s_{\mathrm{sl}},$$

$$a^q_{\mathrm{sl}} = \frac{\Delta\Gamma_q}{\Delta M_q} \tan\phi_q, \text{ with } q = d, s.$$

A^b_{sl} is obtained from the "raw" charge asymmetries

$$a \equiv \frac{n^+ - n^-}{n^+ + n^-}, \text{ and } A \equiv \frac{N^{++} - N^{--}}{N^{++} + N^{--}}.$$



Why measure $A^b_{\rm sl}$?

- In the Standard Model $A^b_{\rm sl} = (-0.028^{+0.005}_{-0.006})\% \approx 0$.

- New particles beyond the Standard Model can contribute to the box Feynman diagrams of $(B^0_q, \bar{B}^0_q)$ mixing even if these particles are not directly accessible at the Tevatron.

- Any significant deviation of the dimuon charge asymmetry $A^b_{\rm sl}$ from zero is unambiguous evidence of New Physics.

- At the Tevatron, the dimuon charge asymmetry is the most sensitive probe of some extensions of the Standard Model.

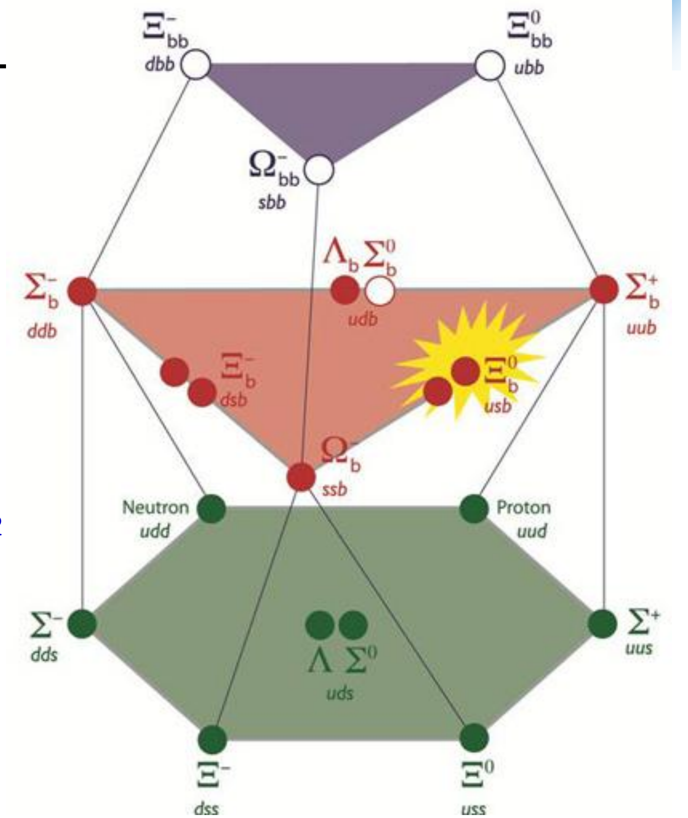
Ξ_b (CDF 4.2 fb^{-1})

- b-baryons states previously observed at Tevatron:
  Ξ^-_b(dsb), Σ_b (uud, ddb), Ω_b(ssb)

- Last missing b-baryon, Ξ^0_b (usb), recently observed by

- Important to keep checking quark model and measure masses of states to compare to theory
(E. Jenkins, P.R. D77 (2008) 034012, R. Lewis and R.M. Woloshyn, P.R. D79 (2009) 014502
D. Ebert et al., P.R. D72 (2005) 034026, M. Karliner et al., Ann. Phys. (NY) 324 (2009) 2,
A. Valcarce et al., Eur. Phys. J. A37 (2008) 217)

- Decay modes observed for the first time



$$\Xi^0_b \to \Xi^+_c\, \pi^-$$

$$\Xi^+_c \to \Xi^-\, \pi^+ \pi^+,\ \Xi^- \to \Lambda\, \pi^-,\ \text{and}\ \Lambda \to p\, \pi^-$$

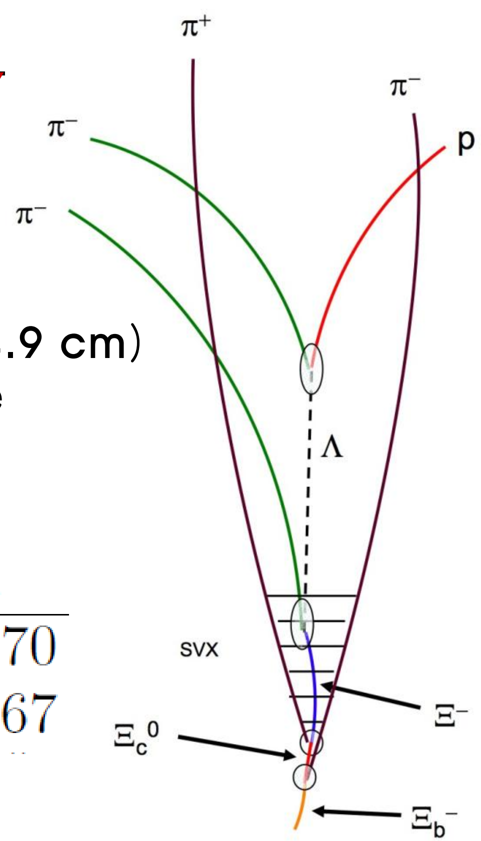
$$\Xi^-_b \to \Xi^0_c\, \pi^-$$ (Ξ^-_b observed before, but not in this decay mode; use as cross check

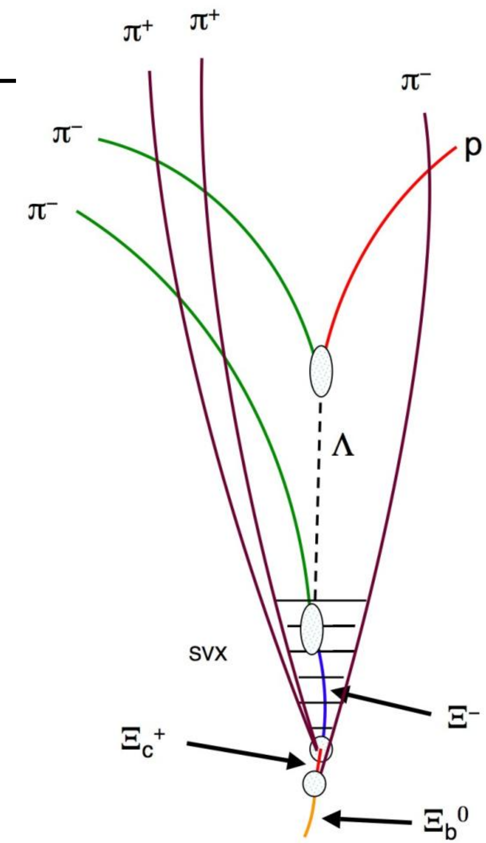
$$\Xi^0_c \to \Xi^-\, \pi^+,\ \Xi^- \to \Lambda\, \pi^-,\ \text{and}\ \Lambda \to p\, \pi^-$$

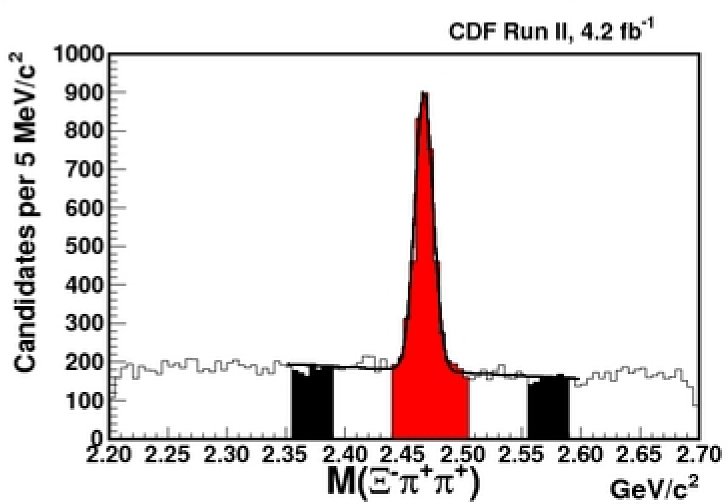
Event Topology

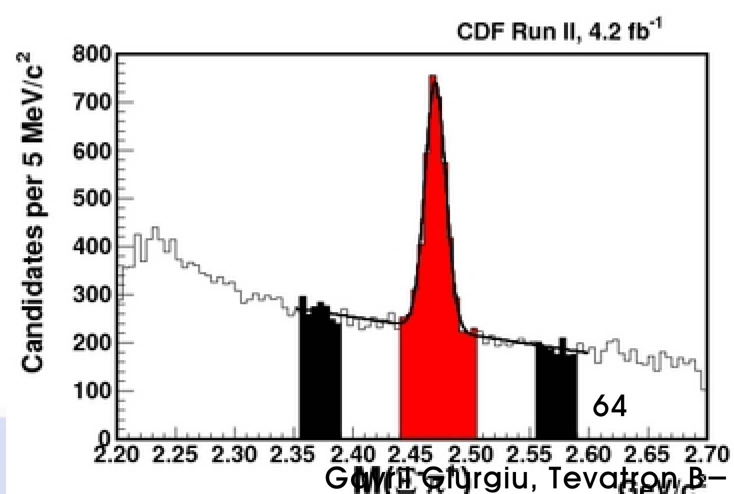
– Long lived Ξ^- ($c\tau$ = **4.9 cm**) tracked through the silicon detector

Resonance	Yield
Ξ_c^0	2110 ± 70
Ξ_c^+	3048 ± 67



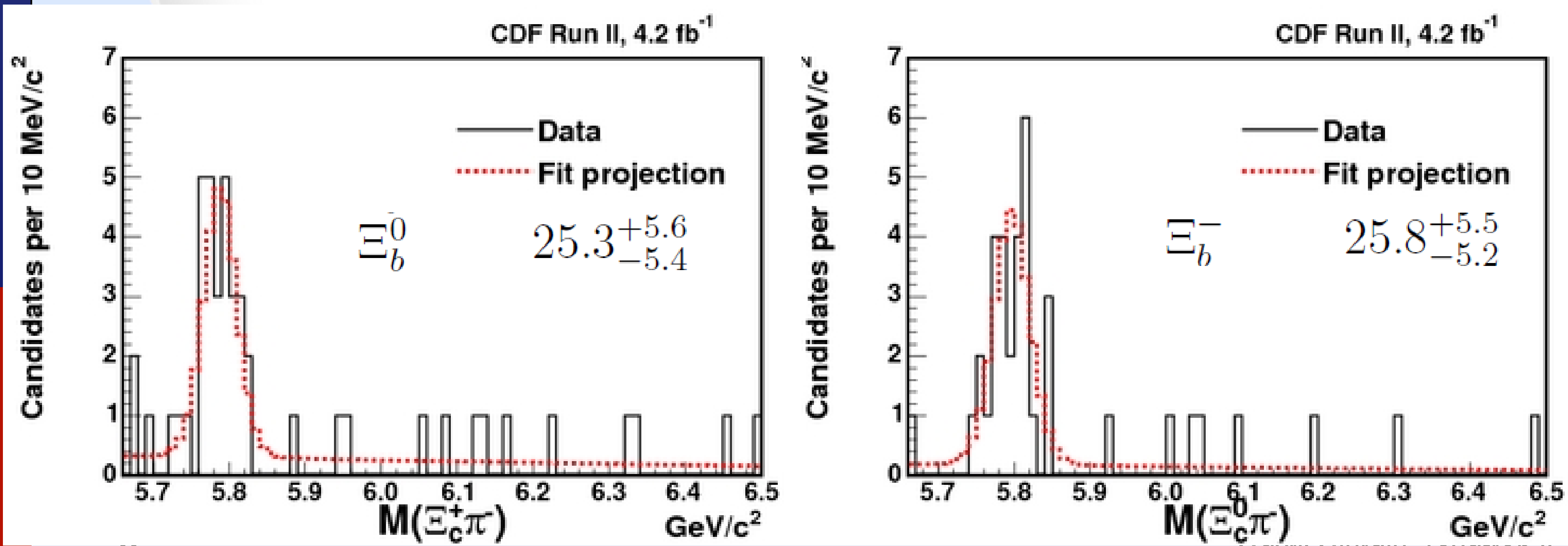




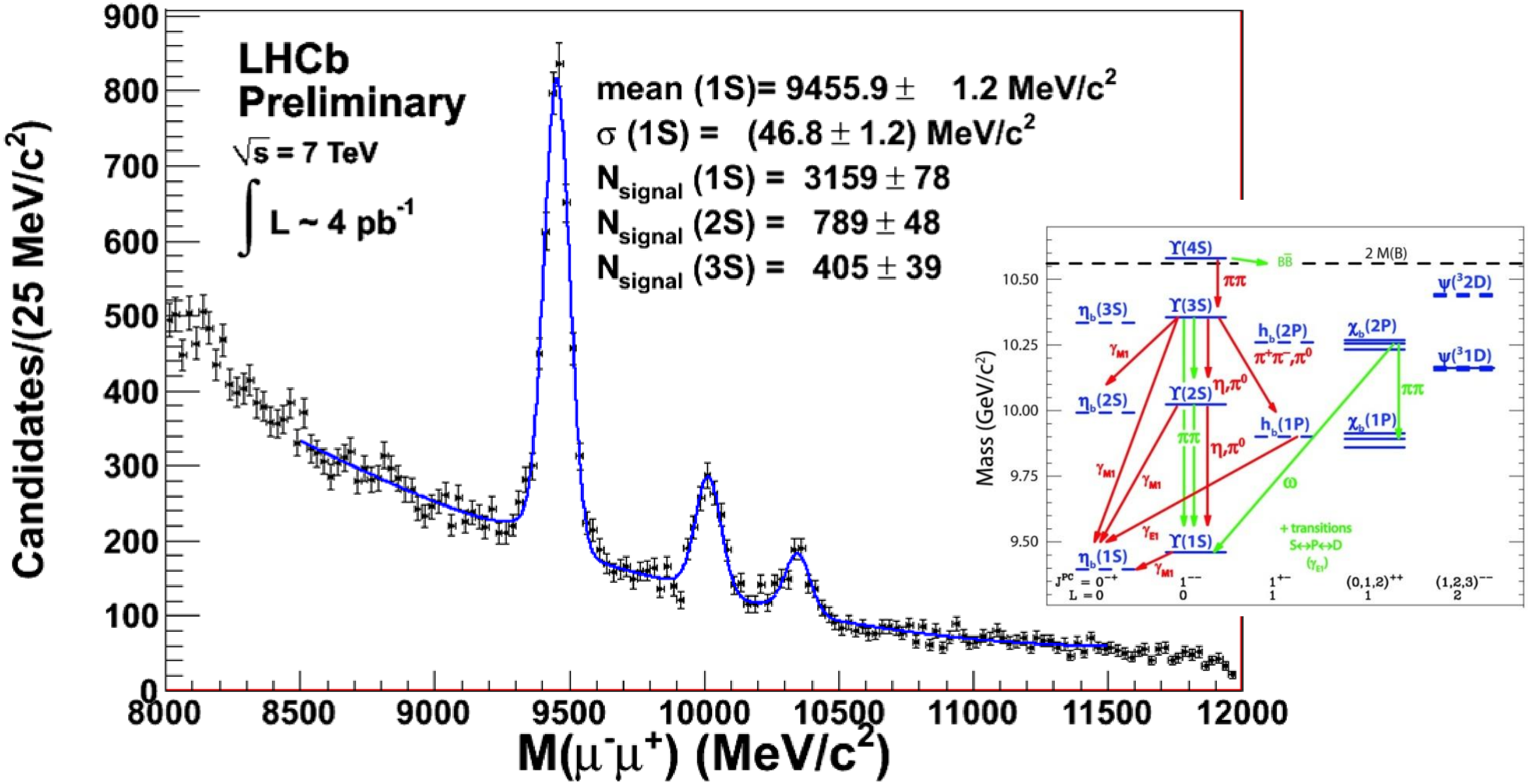


Observation of Ξ_b (CDF 4.2 fb^{-1})

- Measured Ξ^-_b mass $5796.7 \pm 5.1(\mathrm{stat}) \pm 1.4(\mathrm{syst})\ \mathrm{MeV}/c^2$ in good agreement wi earlier best measurement in $J/\psi\,\Xi^-$ final state $5790.9 \pm 2.6(\mathrm{stat}) \pm 0.8(\mathrm{syst})\ \mathrm{MeV}/c^2$
- First measurement of Ξ^0_b mass $5787.8 \pm 5.0(\mathrm{stat}) \pm 1.3(\mathrm{syst})\ \mathrm{MeV}/c^2$
- Largest systematics from mass resolution (1 MeV) and momentum scale (0.5 MeV)
- Significance of each peaks > 6.8σ equivalent statistical significance
- Mass difference $M(\Xi_b^-) - M(\Xi_b^0) = 3.1 \pm 5.6(\mathrm{stat}) \pm 1.3(\mathrm{syst})\ \mathrm{MeV}/c^2$



B physics @ LHCb



Kihyeon Cho

http://www.cern.ch

CDF II Detector

DØ Detector

– Central tracking: – silicon vertex detector
– drift chamber

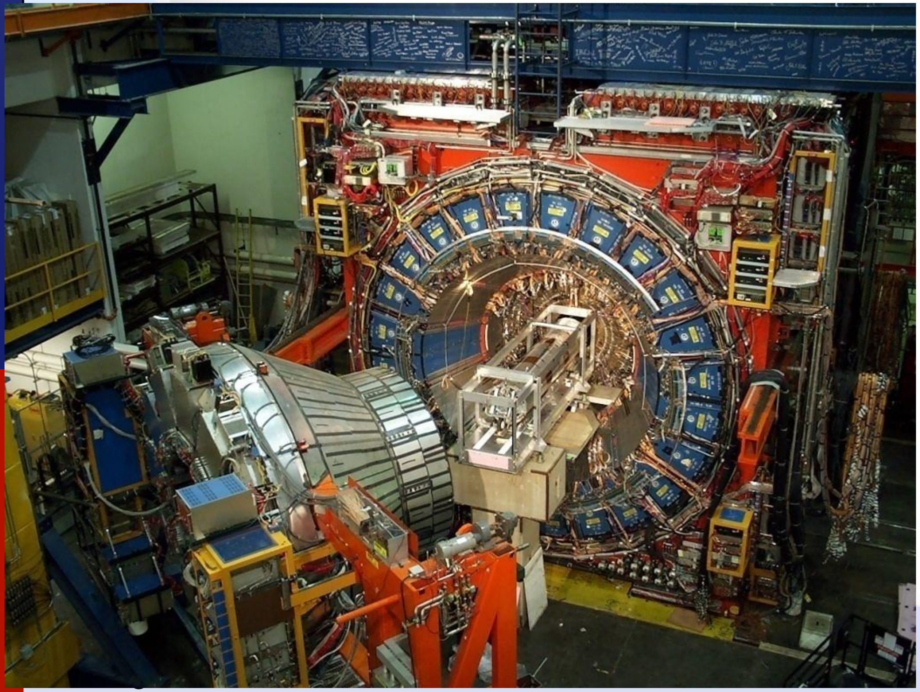
$\delta p_T/p_T = 0.0015\ p_T$

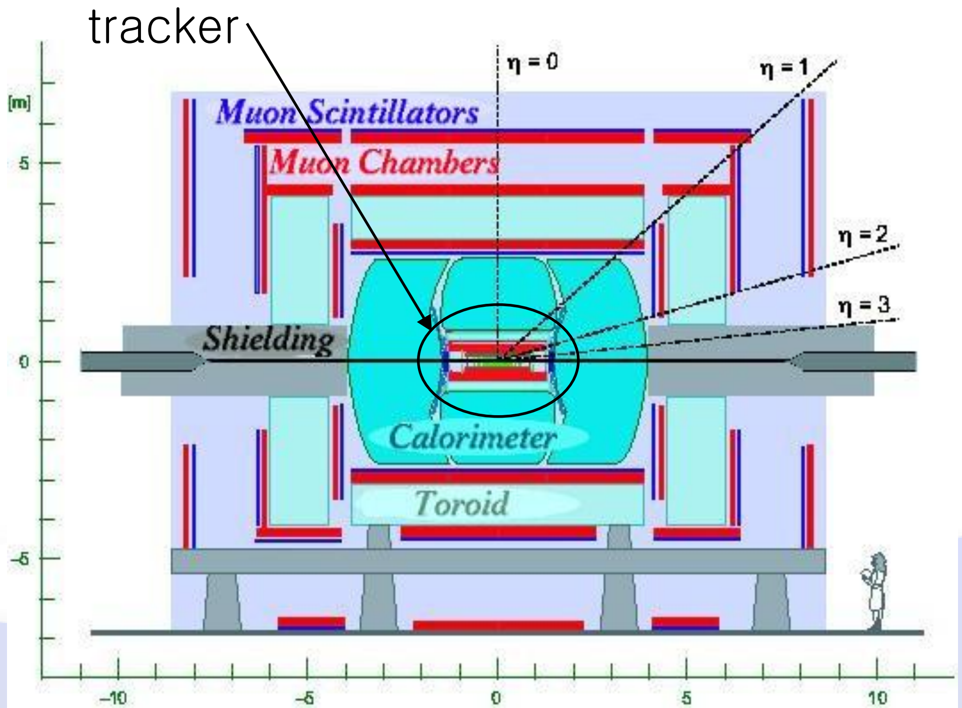
→ excellent mass resolution

– Particle identification: dE/dX and TOF

– Good electron and muon ID by calorimeters and muon chambers

- Excellent tracking and muon coverage
- Excellent calorimetry and electron ID
- 2 Tesla solenoid, polarity reversed weekly
  → good control of charge asymmetry systematic effects
- Silicon layer 0 installed in 2006 improves track parameter resolution





Introduction

- Heavy Flavor Physics probes New Phenomena by either:
  - searching for small deviations from SM in high statistics, precision measurements (mostly B factories) or
  - hunting for quantities highly suppressed in SM with the hope that small NP effects would enhance the observed quantities:
    - BR of rare decays, small CP phases and asymmetries

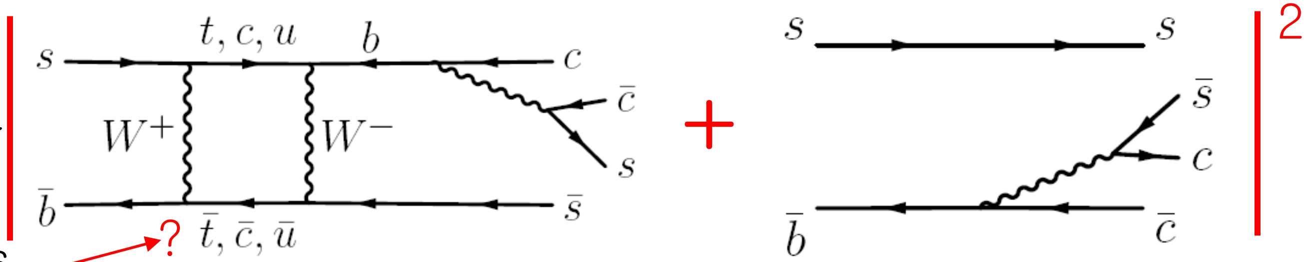
- Recent Heavy Flavor Physics results from CDF and D0 with up to 8 fb^{-1}

  - Rare decays:
    - $B_s \to \mu\mu$ (CDF, D0)
    - $B_s \to s\mu\mu$ (CDF)
  - CPV phase in:
    - in $B_s \to J/\Psi\ \Phi$, BR and lifetime in $B_s \to J/\Psi\ f_0$ (CDF, D0)
    - BR, polarization and CPV in $B_s \to \Phi\Phi$ (CDF)
  - CP asymmetry:
    - in di-lepton asymmetry (D0)
    - hadronic B decays (CDF)
  - New particles and decay modes
    - Ξ_b (CDF)

CP Violation in $B_s \rightarrow J/\Psi\Phi$ (D0 6.1 fb^{-1}, CDF 5.2 fb^{-1})

– *CP* violation in B_s system accessible through interference of decays with and without mixin

Decay rate ~



New Physics particles ?

$$\beta_s^{\mathrm{SM}} = \arg(-V_{ts}V_{tb}^*/V_{cs}V_{cb}^*) \approx 0.02$$

$$\begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & \boxed{V_{cs}} & \boxed{V_{cb}} \\ V_{td} & \boxed{V_{ts}} & \boxed{V_{tb}} \end{pmatrix}$$

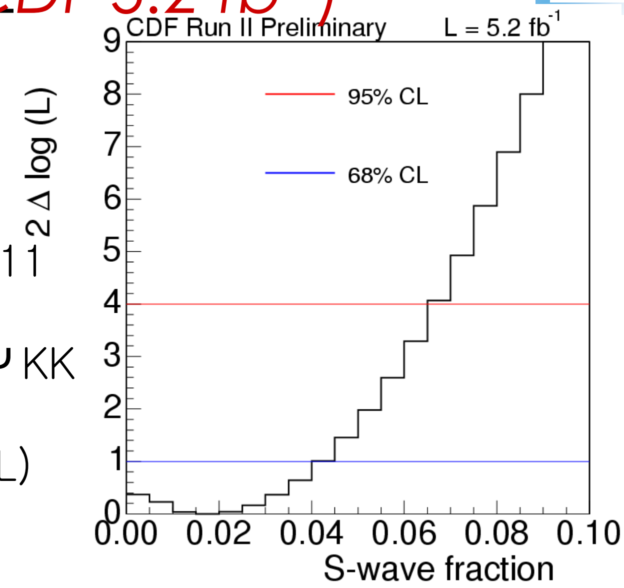
– *CP* violation phase β_s in SM is predicted to be very small in SM
– New physics particles running in the mixing diagram may enhance β_s

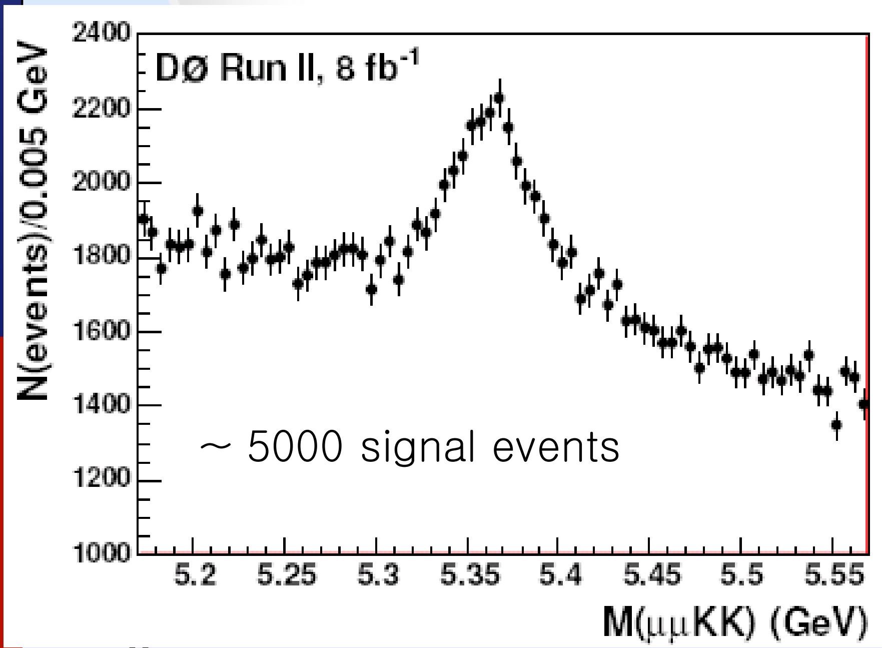
– Note: certain SUSY models with large tan(β) predict enhanced *BR($B_s \rightarrow \mu\mu$)* for large CP violating mixing phase in $B_s \rightarrow J/\Psi\Phi$ *Altmannshofer, Buras, Gori, Paradisi, Straub, Nucl.Phys.B830:17-94,2010*

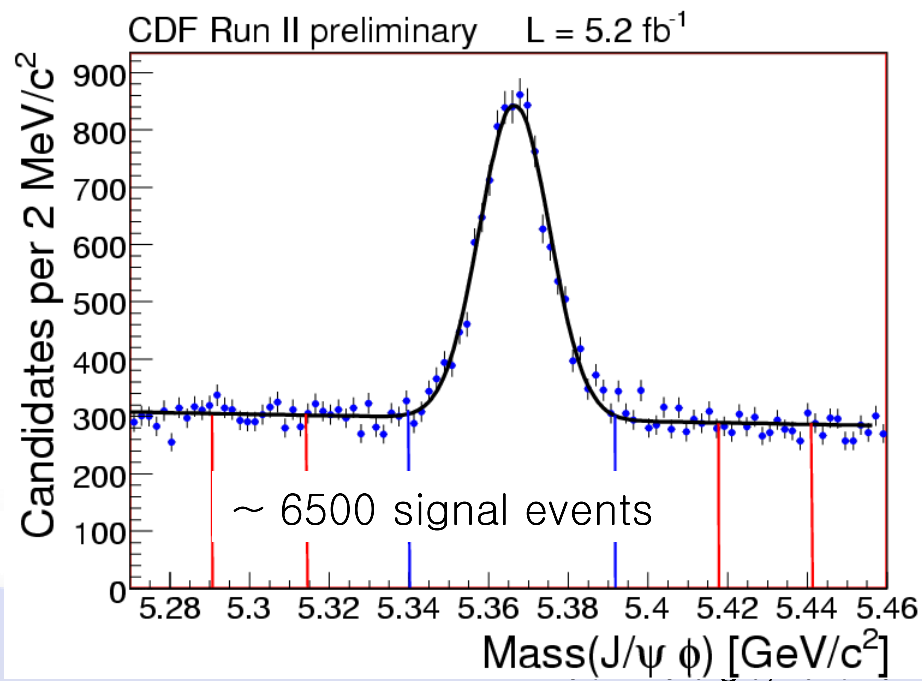
– Multidimensional likelihood function involves B_s decay time and mass, decay angles of daughter muons/kaons and flavor tagging

CP Violation in $B_s \to J/\Psi\Phi$ (D0 8 fb^{-1}, CDF 5.2 fb^{-1})

- Both CDF and D0 early results showed slight deviations from SM (~2σ combined CDF+D0)
- Most recent update from D0 with 8 fb^{-1} shown at EPS 2011
- Both experiments include S–wave contributions $B_s \to J/\Psi KK$ but find different results
  - CDF finds s–wave fraction of ~2% (<6.5% @ 95%CL)
  - D0 measures s–wave fraction of 15–17% ± 3.5%







CP Violation in $B_s \rightarrow J/\Psi\Phi$ (D0 8 fb^{-1}, CDF 5.2 fb^{-1})

– Updated results show better agreement with SM (1σ level each)

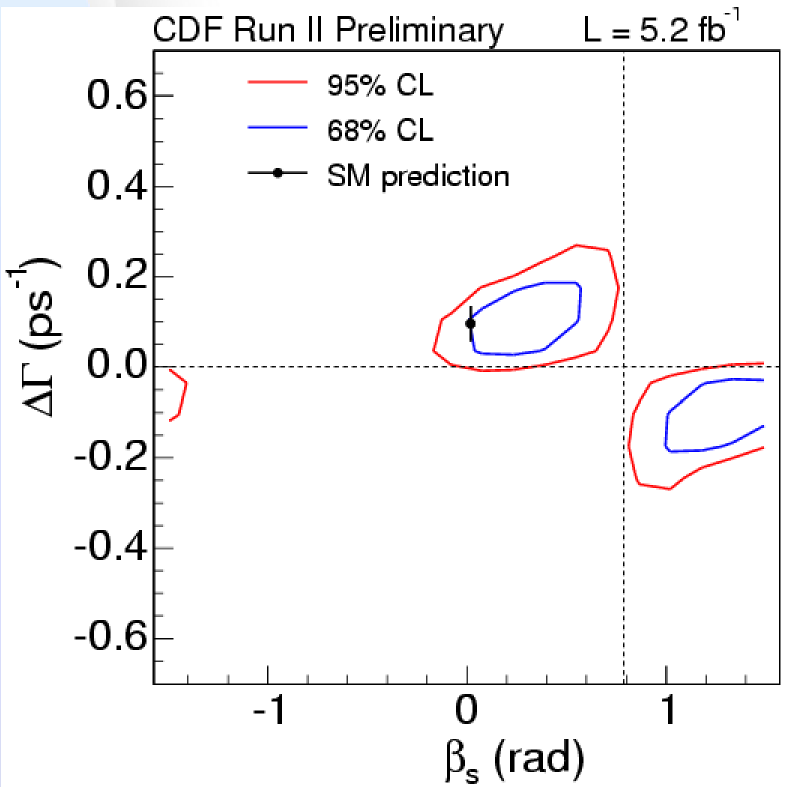
– New Physics may still be present but require better sensitivity than Tevatron experiments

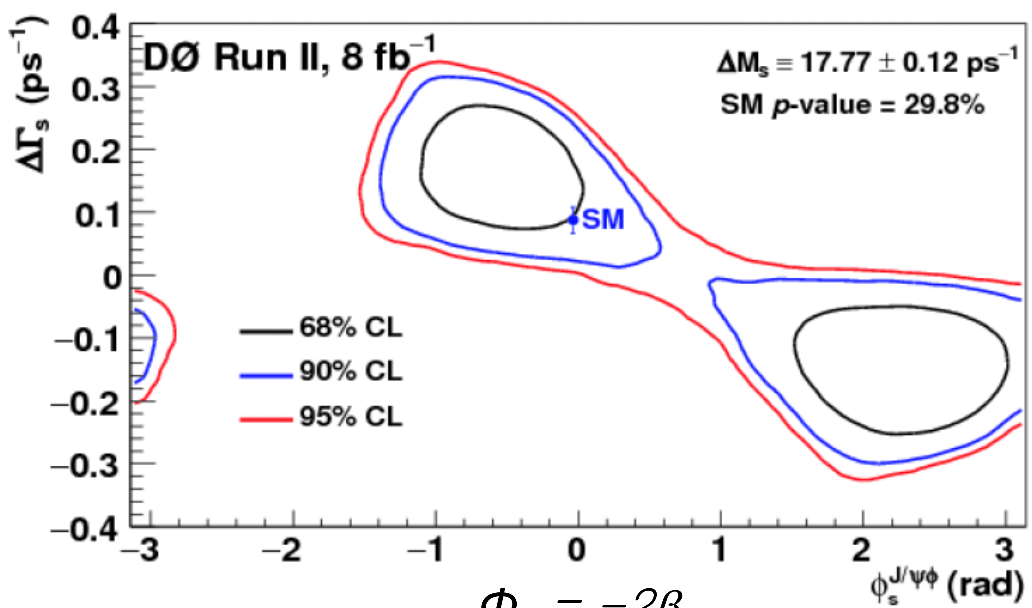
– Tevatron analyses will be updated with full datasets

β_s in [−0.02,0.52] U [1.08,1.55] at 68% CL

$\Phi_s = -0.55^{+0.38}_{-0.36}$ (rad)

$\beta_s = 0.28^{+0.19}_{-0.18}$ (rad)





$\Phi_s = -2\beta_s$

B_s Lifetime, Decay Width Difference and Polarizations

– $B_s \to J/\Psi\Phi$ decays provide most precise measurements of B_s lifetime τ_s and decay width difference $\Delta\Gamma_s$

CDF

$\tau_s = 1.52 \pm 0.03\ (stat) \pm 0.01\ (syst)\ ps$

$\Delta\Gamma_s = 0.075 \pm 0.035\ (stat) \pm 0.01\ (syst)\ ps^{-1}$

$|A_{//}(0)|^2 = 0.231 \pm 0.014\ (stat) \pm 0.015\ (syst)$

$|A_0(0)|^2 = 0.524 \pm 0.013\ (stat) \pm 0.015\ (syst)$

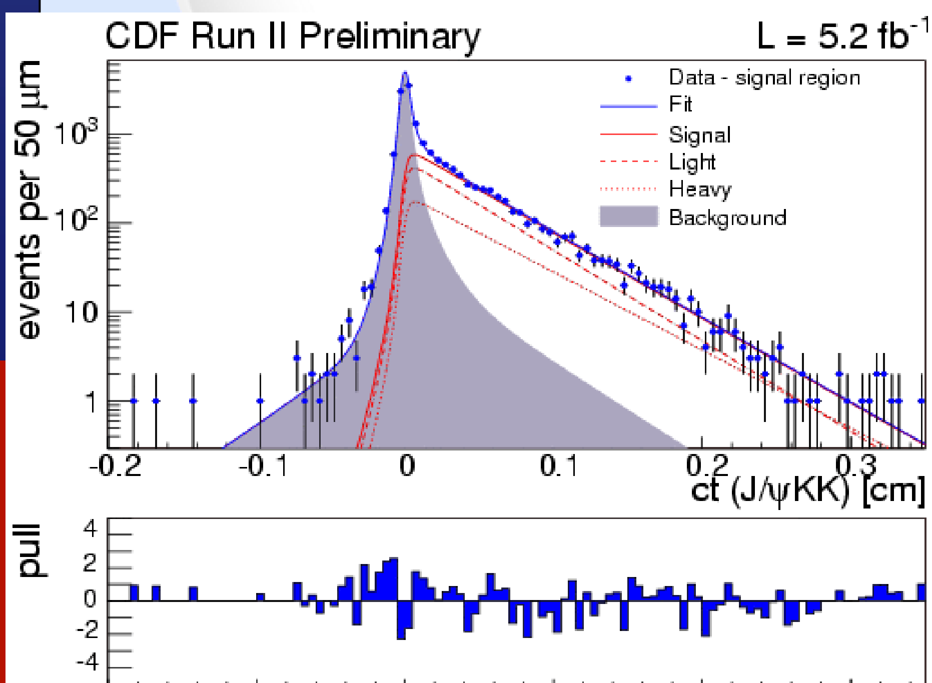
DØ

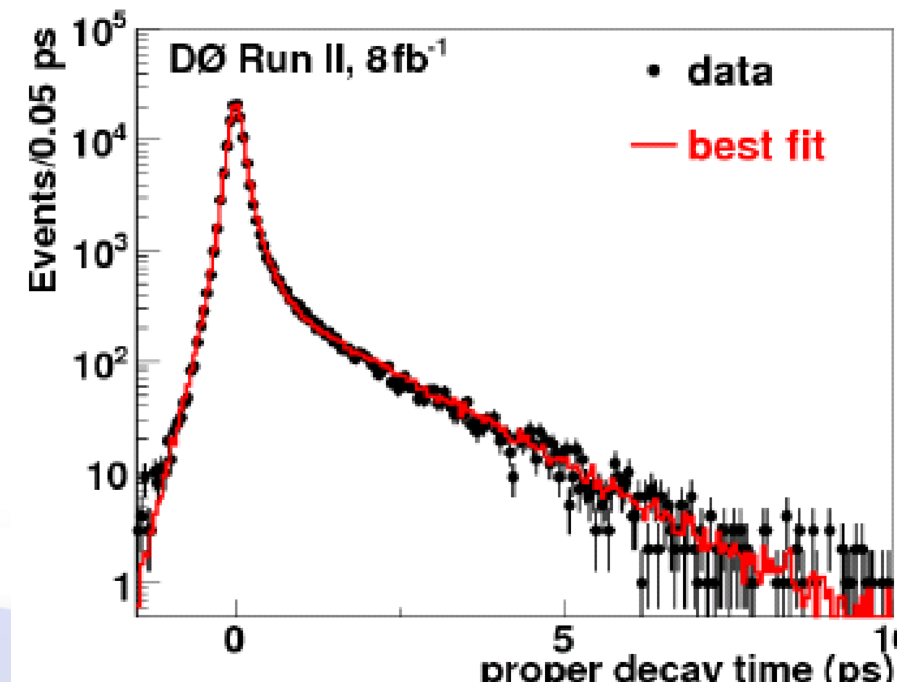
$\tau_s = 1.443^{+0.038}_{-0.035}\ (stat + syst)\ ps$

$\Delta\Gamma_s = 0.163^{+0.065}_{-0.064}\ (stat + syst)\ ps^{-1}$

$|A_{//}(0)|^2 = 0.231^{+0.024}_{-0.030}\ (stat + syst)$

$|A_0(0)|^2 = 0.558^{+0.017}_{-0.019}\ (stat + syst)$





$B_s \to J/\Psi f_0(980),\ f_0 \to \pi\pi$

- Final state in $B_s \to J/\Psi f_0$ is CP odd → a sufficiently large sample would allow determination of CPV parameter β_s without angular analysis

- Related mode $B_s \to J/\Psi f_0(980),\ f_0 \to KK$ may be useful to solve the β_s ambiguity

- Measure ratio $R_{f_0/\phi} = \dfrac{\mathcal{B}(B_s^0 \to J/\psi f_0)}{\mathcal{B}(B_s^0 \to J/\psi \phi)} \dfrac{\mathcal{B}(f_0 \to \pi^+\pi^-)}{\mathcal{B}(\phi \to K^+K^-)}$

- First experimental limit on $B_s \to J/\Psi f_0$ from Belle:

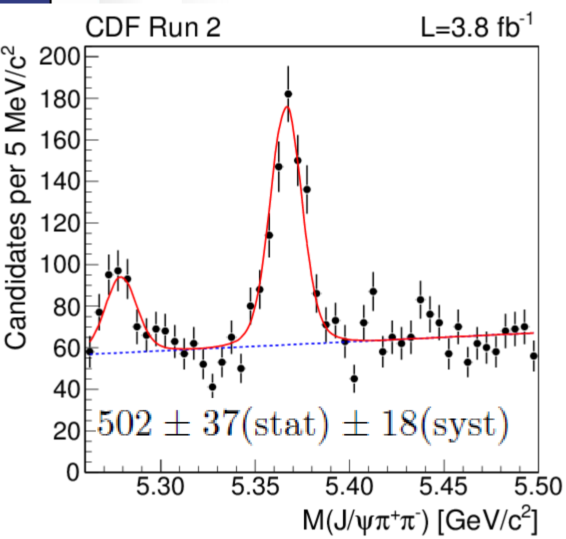
$$\mathcal{B}(B_s^0 \to J/\psi f_0)\mathcal{B}(f_0 \to \pi^+\pi^-) < 1.63 \times 10^{-4} \text{ at } 90\% \text{ C.L.}$$

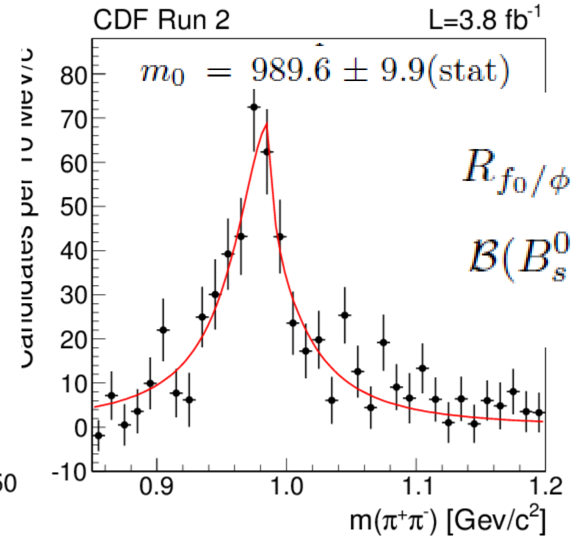
- First observation from LHC $R_{f_0/\phi} = 0.252^{+0.046}_{-0.032}(\text{stat})\ ^{+0.027}_{-0.033}(\text{syst})$

- Followed by Belle $\mathcal{B}(B_s^0 \to J/\psi f_0)\mathcal{B}(f_0 \to \pi^+\pi^-) = (1.16^{+0.31}_{-0.19}\ ^{+0.15}_{-0.17}\ ^{+0.26}_{-0.18}) \times 10^{-4}$

$$R_{f_0/\phi} = 0.206^{+0.055}_{-0.034}(\text{stat}) \pm 0.052(\text{syst})$$

$B_s \to J/\Psi f_0(980),\ f_0 \to \pi\pi$, BR Results (CDF 3.8 fb^{-1}, D0 8 fb^{-1})



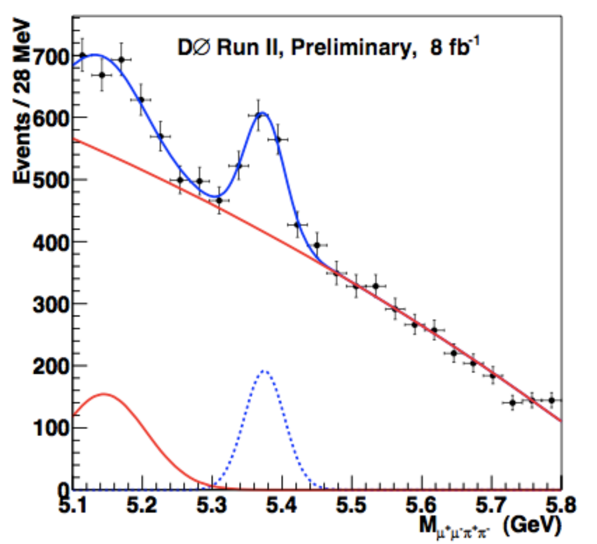


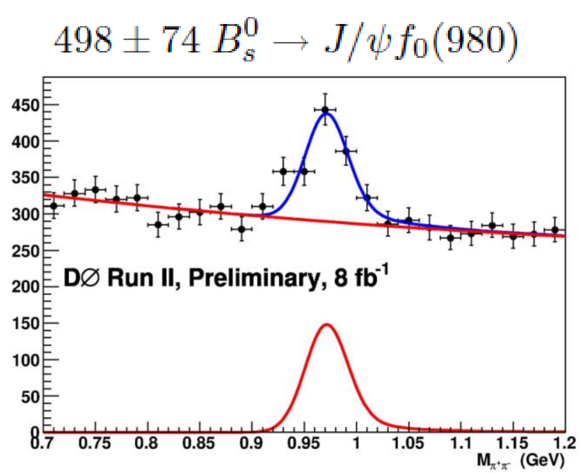
CDF:

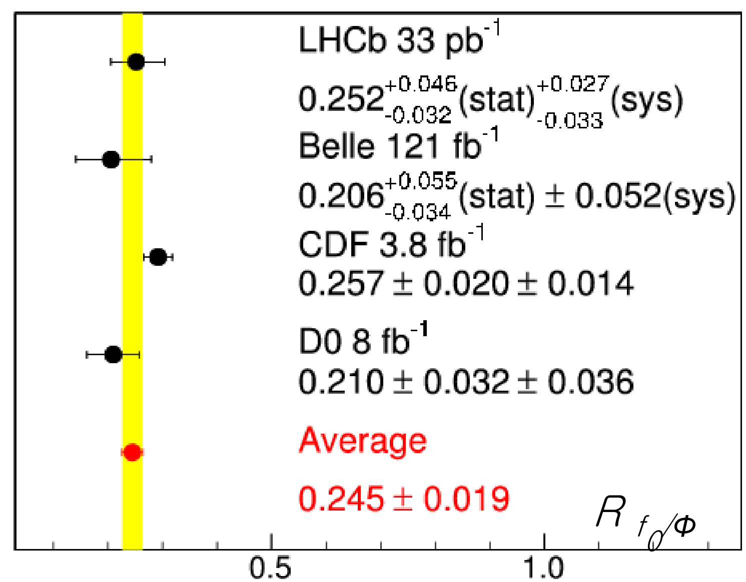
$$R_{f_0/\phi} = 0.257 \pm 0.020(\mathrm{stat}) \pm 0.014(\mathrm{syst})$$

$$\mathcal{B}(B_s^0 \to J/\psi f_0(980))\mathcal{B}(f_0(980) \to \pi^+\pi^-) = (1.63 \pm 0.12 \pm 0.09 \pm 0.50) \times 10^{-4}$$

D0: $R_{f_0/\phi} = 0.210 \pm 0.032(\mathrm{stat}) \pm 0.036(\mathrm{syst})$







B_s Lifetime in $B_s \to J/\Psi f_0(980)$, $f_0 \to \pi\pi$ Decays (CDF 3.8 fb^{-1})

- Using: – theoretical predicti $\Delta\Gamma_s^{SM} = (0.087 \pm 0.021)$

A. Lenz and U. Nierste, J. High Energy Phys. 06, 072 (2007).
U. Nierste and A. Lenz, arXiv:hep-ph/1102.4274.

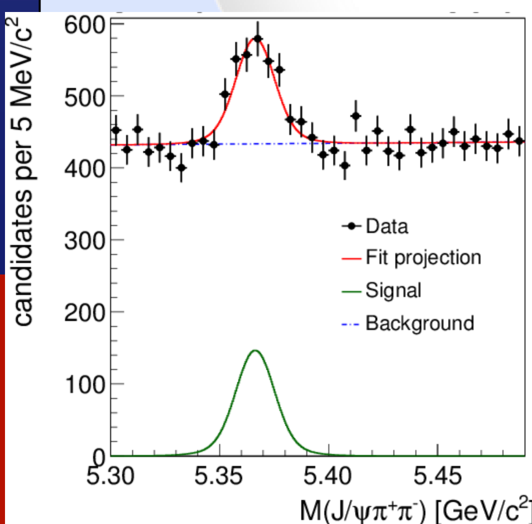
  – world average B^0 lifetime (PDG 201 $\tau_d = (1.525 \pm 0.009)$ ps

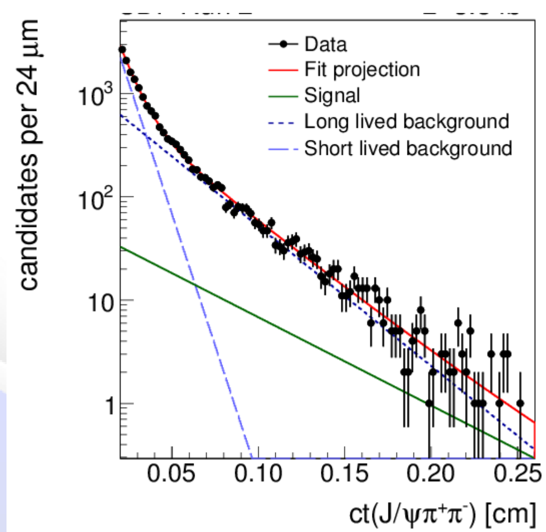
- Determine $\tau_s^H = (1.630 \pm 0.030)$ ps $\quad \tau_s^L = (1.427 \pm 0.023)$ ps.
- Odd final state implies and small CPV → measure lifetime heavy mass eigenstate

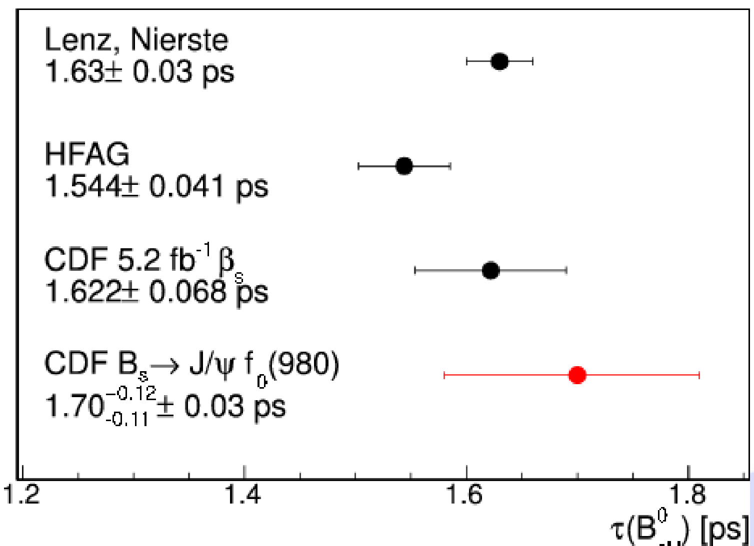
$$\tau(B_s^0 \to J/\psi f_0) = 1.70^{+0.12}_{-0.11}(\text{stat}) \pm 0.03(\text{syst})\ \text{ps}$$

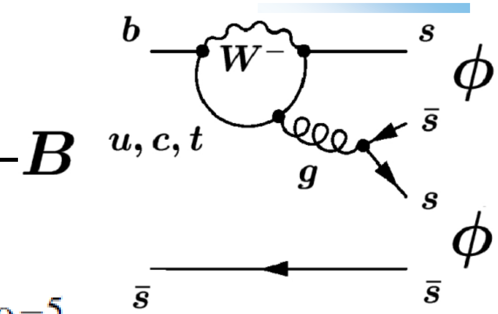
arXiv:11

- Good agreement with theoretical expectations and similar measurements in $B_s \to J/\Psi\Phi$ deca







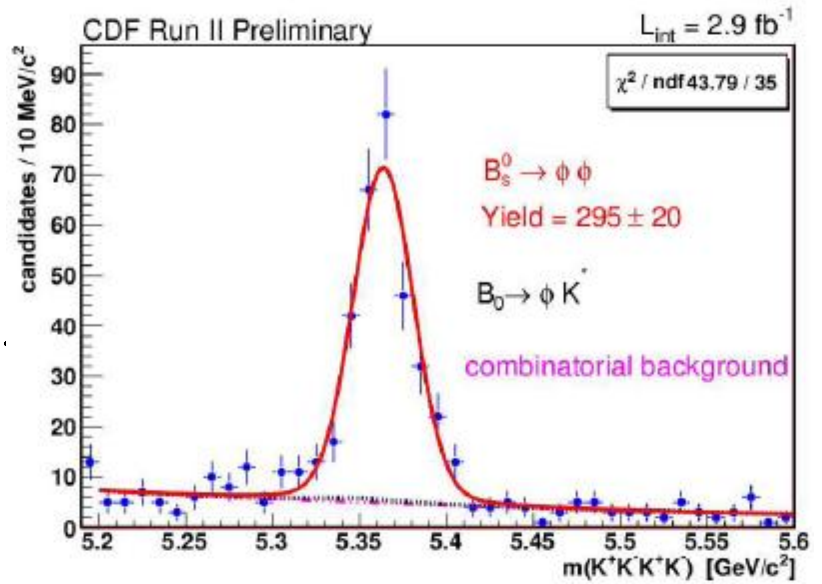


$B_s \rightarrow \Phi\Phi$, BR, Polarization (CDF 2.9 fb^{-1})

– Branching fraction:

$$\mathcal{B}(B_s \to \phi\phi) = [2.40 \pm 0.21(stat.) \pm 0.27(syst.) \pm 0.82(BR)] \times 10^{-5}$$

– Polarization fractions:
  – zero helicity:
    f_T = 0.652±0.041 (stat) ± 0.021 (syst)
  – lin. comb. of ±1 helicity:
    f_L = 0.348±0.041 (stat) ± 0.021 (syst)



– Inconsistent with SM expectation $f_T / f_L \sim M_V / M_B$

– Consistent with "polarization puzzle" in other $b \rightarrow$ penguin transitions from Belle and Babar, like
  $B \rightarrow \Phi K*$, $\rho K* \cdots$ where $f_L \approx f_T$

– NP and SM explanations could be distinguished using Triple Products $TP = q \cdot (\varepsilon_1 \times \varepsilon_2)$

A.Datta and D.London, International Journal of Modern Physics A, 19:2505, 2004, A.Datta, M.Duraisamy, D.London , arXiv:1103.2442, 2011

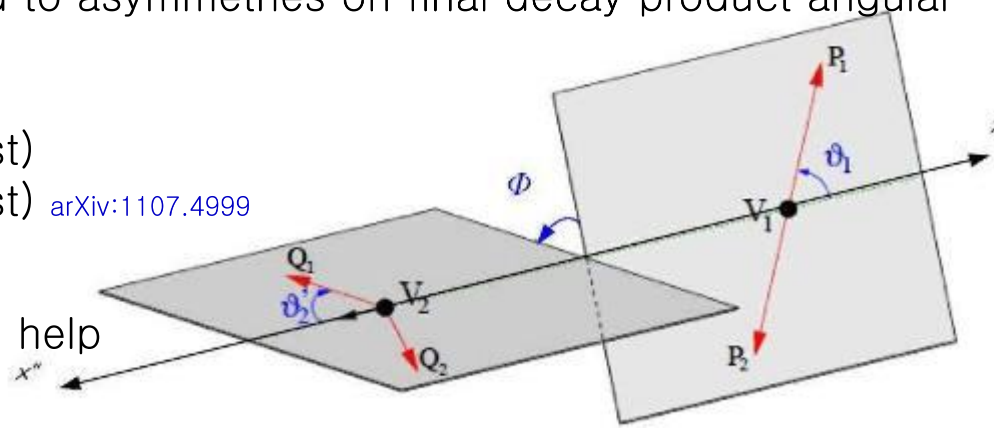
($q = p(\Phi_1) - p(\Phi_2)$ is momentum difference and ε_i is Φ_i polarization)

– In $B \rightarrow \Phi K*$ TP measurements favor SM explanations. What about $B_s \rightarrow \Phi\Phi$?

$B_s \to \Phi\Phi$, Search for CPV (CDF 2.9 fb^{-1})

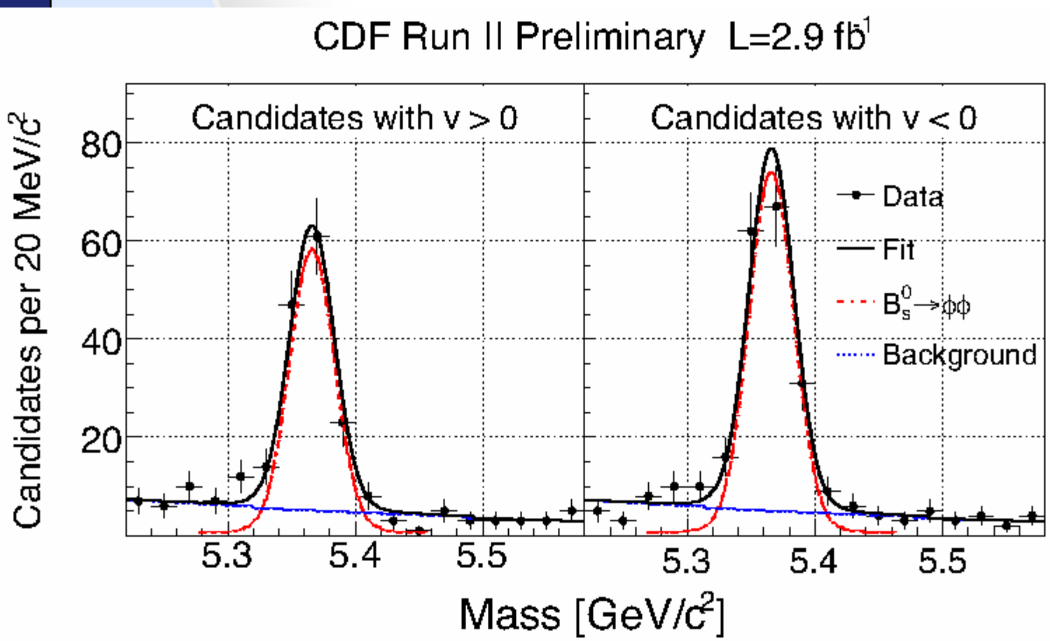
– TP asymmetry A_{TP} are expected to be very small in SM

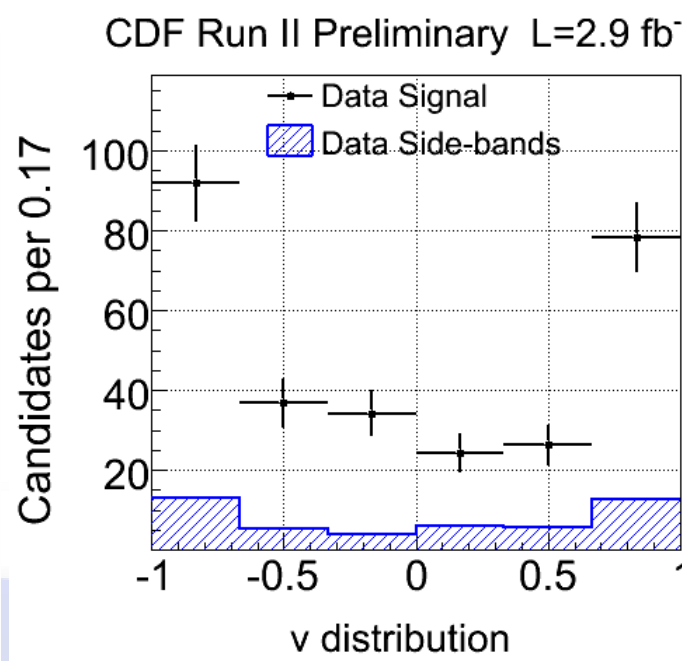
– In $B_s \to \boldsymbol{\Phi\Phi}$: TP asymmetries are related to asymmetries on final decay product angular quantities (e.g. $A_{TP1} \sim A(\cos\varphi\sin\varphi)$)



$A_{TP1} = -0.007 \pm 0.064\ (\text{stat}) \pm 0.018\ (\text{syst})$
$A_{TP2} = -0.120 \pm 0.064\ (\text{stat}) \pm 0.016\ (\text{syst})$ arXiv:1107.4999

– First TP constraints in $B_s \to \boldsymbol{\Phi\Phi}$ decays
– A_{TP2} ~1.8σ from zero; more data would help distinguish between SM and NP



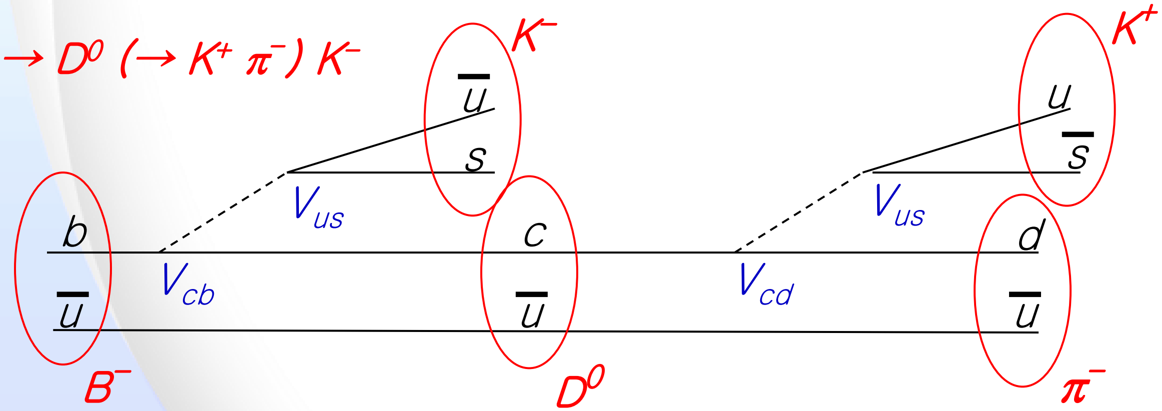


CP Violation in $B \rightarrow DK$ Decays

– Measurements of BR and CP asymmetries in $B^- \rightarrow D^0 K^-$ would determine CMK angle γ using
"ADS" method D. Atwood, I. Dunietz, A. Soni, Phys. Rev. Lett. 78, 3257, (1997), D. Atwood, I. Dunietz, A. Soni, Phys. Rev. D 63, 036005,
Note: CDF provided results for GLW method in 1/fb, *PRD81, 031105(2010)*

– Interference of two decay amplitudes of comparable sizes is sensitive to angle γ

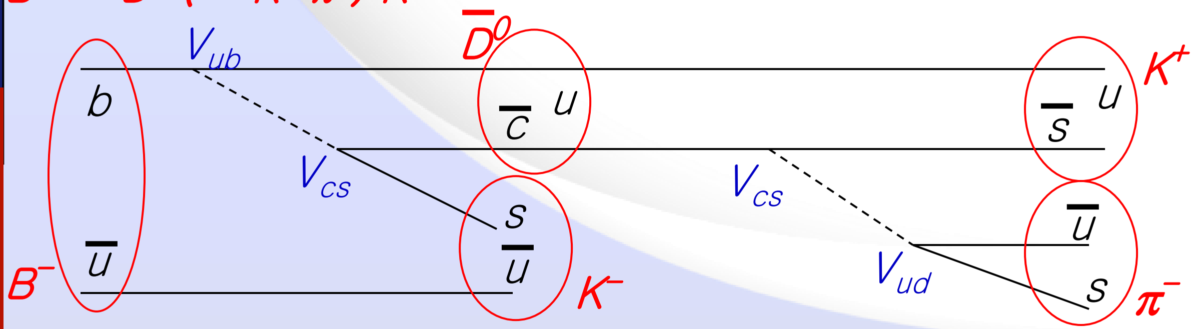
$B^- \rightarrow D^0 (\rightarrow K^+ \pi^-) K^-$



$B^- \rightarrow D^0 K^-$
color allowed
$V_{cb}V^*_{us} \sim \lambda^3$

$D^0 \rightarrow K^+\pi^-$
doubly Cabibbo suppressed
$V_{cd}V^*_{us} \sim \lambda^2$

$B^- \rightarrow \overline{D}^0 (\rightarrow K^+ \pi^-) K^-$



$B^- \rightarrow \overline{D}^0 K^-$
color suppressed
$V_{cb}V^*_{us} \sim \lambda^3 e^{i\gamma}$

$\overline{D}^0 \rightarrow K^+\pi^-$
Cabibbo favored
$V_{cd}V^*_{us} \sim 1$

CP Violation in $B \to DK$ Decays (CDF 5 fb^{-1})

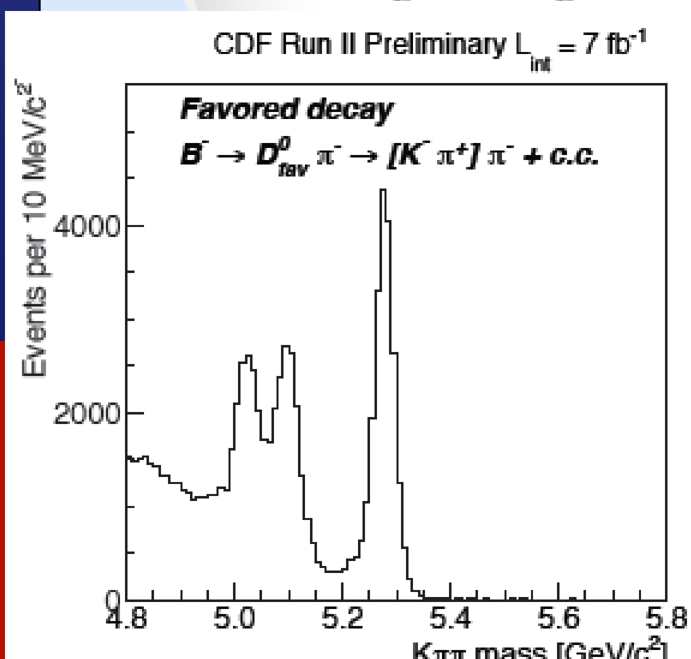
– Observables: $R_{ADS} = \dfrac{\mathcal{BR}(B^- \to [K^+\pi^-]_{D^0}K^-) + \mathcal{BR}(B^+ \to [K^-\pi^+]_{D^0}K^+)}{\mathcal{BR}(B^- \to [K^-\pi^+]_{D^0}K^-) + \mathcal{BR}(B^+ \to [K^+\pi^-]_{D^0}K^+)}$

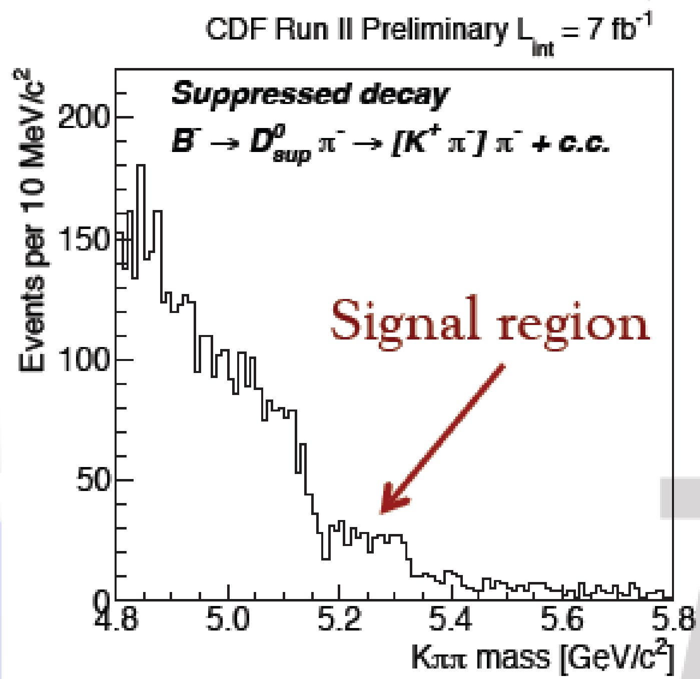
$$A_{ADS} = \frac{\mathcal{BR}(B^- \to [K^+\pi^-]_{D^0}K^-) - \mathcal{BR}(B^+ \to [K^-\pi^+]_{D^0}K^+)}{\mathcal{BR}(B^- \to [K^+\pi^-]_{D^0}K^-) + \mathcal{BR}(B^+ \to [K^-\pi^+]_{D^0}K^+)}$$

are related to angle γ throug $R_{ADS} = r_D^2 + r_B^2 + 2r_D r_B \cos\gamma \cos(\delta_B + \delta_D)$

$$A_{ADS} = 2r_B r_D \sin\gamma \sin(\delta_B + \delta_D)/R_{ADS}$$

where $r_B = |A(b \to u)/A(b \to c)|,\ \delta_B = arg[A(b \to u)/A(b \to c)]$
and similar fo r_D and δ_D





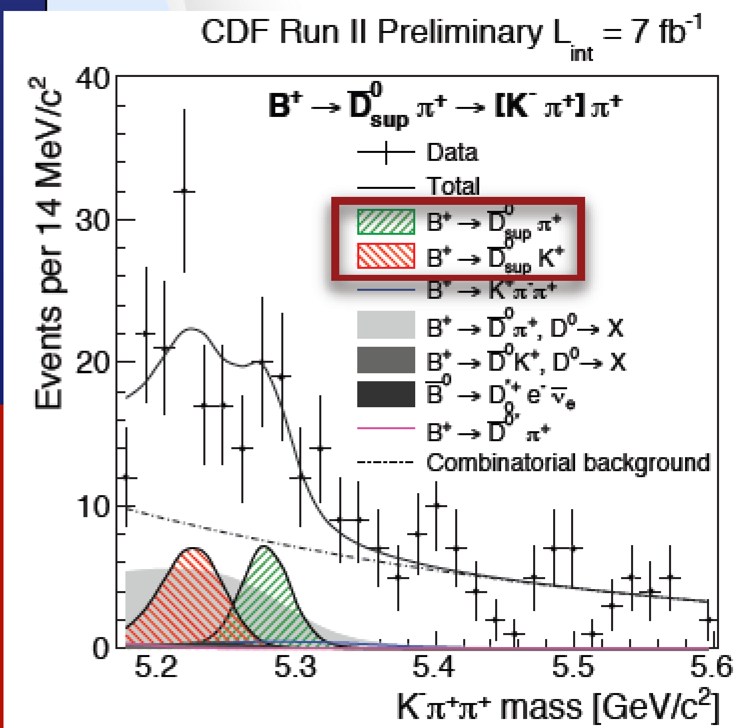
use kinematics and PID to determine sample composition

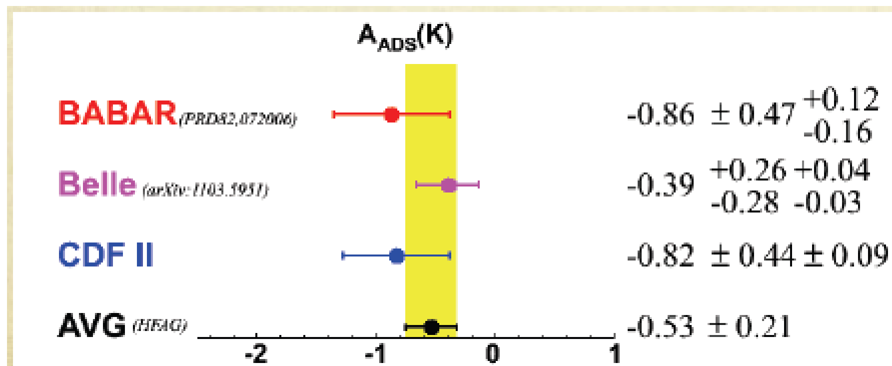
CP Violation in $B \to DK$ Decays (CDF 5 fb^{-1})

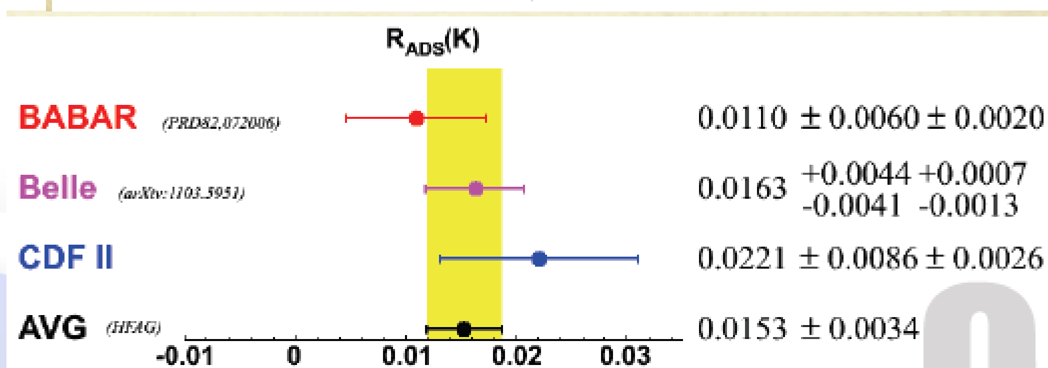
- First evidence of $B^- \to D^0_{suppressed} (\to K^+\pi^-) K^-$ at 3.2σ level

$$R_{ADS}(\pi) = [2.8 \pm 0.7(stat) \pm 0.4(syst)] \cdot 10^{-3}$$
$$A_{ADS}(\pi) = 0.13 \pm 0.25(stat) \pm 0.02(syst)$$
$$R_{ADS}(K) = [22.0 \pm 8.6(stat) \pm 2.6(syst)] \cdot 10^{-3}$$
$$A_{ADS}(K) = -0.82 \pm 0.44(stat) \pm 0.09(syst)$$

- CDF measurements compatible and competitive with B factories







Two Body Charmless B Decays (B → hh)

–Important to improve knowledge of strong interactions dynamics

– Significant contribution from higher-order (penguin) transitions provides sensitivity to NP

– Sensitive to CKM angle γ

– Channels previously investigated at CDF:

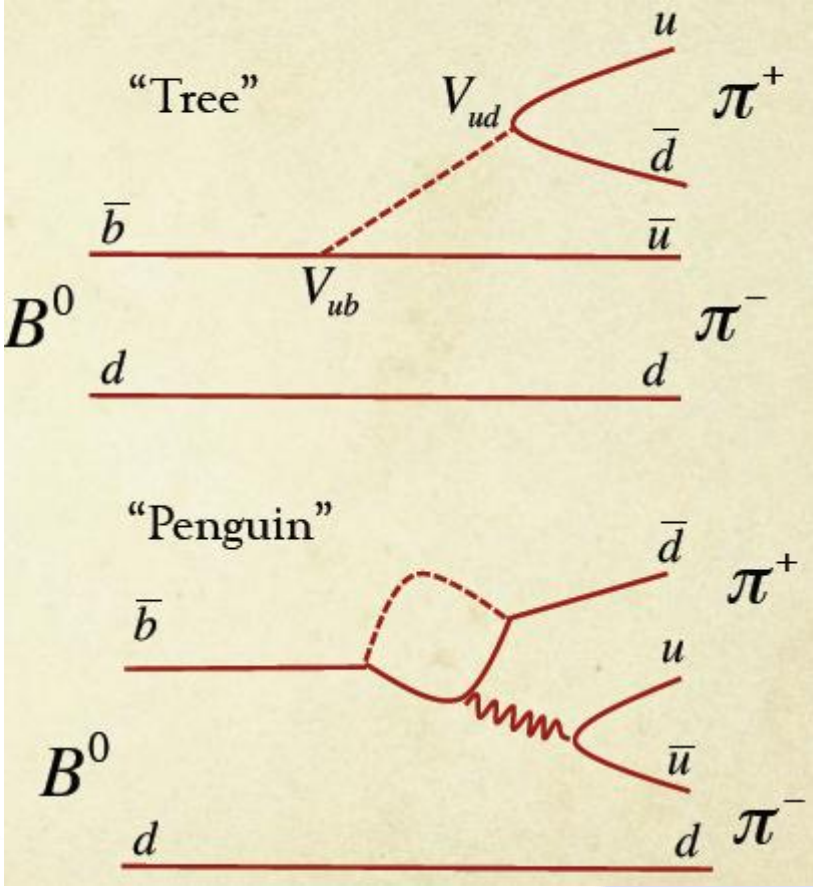
$B^0_s \to K^+K^-$, PRL 97, 211802 (2006)

$B^0_s \to K^-\pi^+$, $\Lambda^0_b \to p\pi^-$, $\Lambda^0_b \to pK^+$, PRL 103, 031801 (2009)

$A_{CP}(B^0_s \to K^-\pi^+)$, $A_{CP}(\Lambda^0_b \to p\pi^-)$, $A_{CP}(\Lambda^0_b \to pK^+)$
PRL 106, 181802 (2011)

– Most recent results from CDF:

First evidence for $B^0_s \to \pi^+\pi^-$ and
bounds on $B^0 \to K^+K^-$



Kihyeon Cho

Gavril Giurgiu, Tevatron B-

First Evidence of $B^0_s \to \pi^+\pi^-$ Decays (CDF 6.1 fb^{-1})

– Events selected by trigger requiring two oppositely charged tracks displaced w.r.t. PV

– Both tracks are assigned pion mass

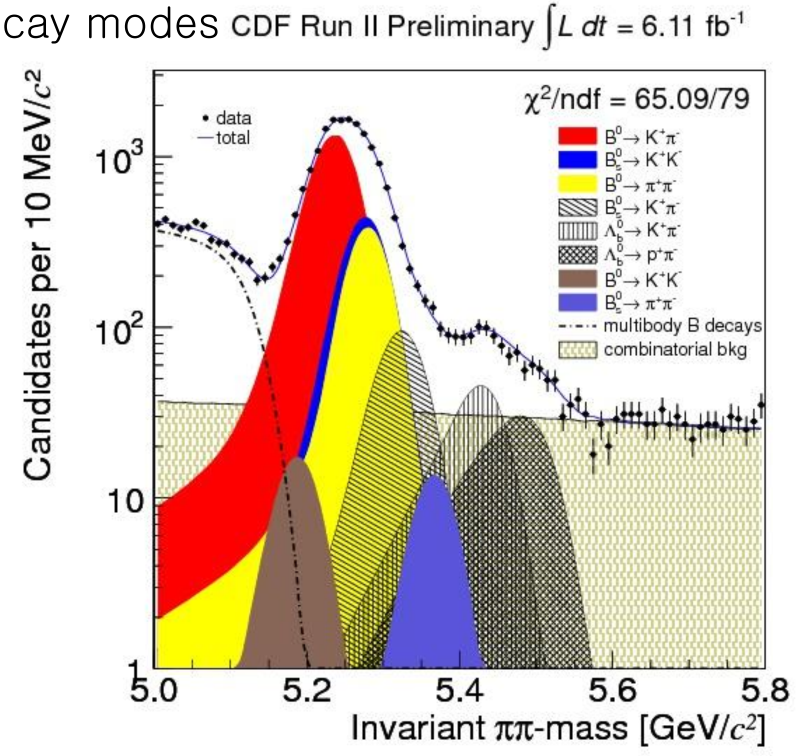
– Both kinematic and PID info used to separate decay modes

– $\pi^+\pi^-$ invariant mass distribution dominated by $B^0 \to K\pi$, $B^0 \to \pi\pi$

– Observe $B_s \to \pi\pi$ mode with 3.7σ significance

– No firm evidence for the $B^0 \to K^+K^-$ is found but measured rate excludes zero at the 90% C.L.

Mode	N_s	Significance
$B^0 \to K^+K^-$	$120 \pm 49 \pm 42$	2.0σ
$B^0_s \to \pi^+\pi^-$	$94 \pm 28 \pm 11$	3.7σ



CDF Note 10498

Mode	Relative $\mathcal{B}$	Absolute $\mathcal{B}$ (10^{-6})	Limit (10^{-6})
$B^0 \to K^+K^-$	$\frac{\mathcal{B}(B^0 \to K^-K^+)}{\mathcal{B}(B^0 \to K^+\pi^-)} = 0.012 \pm 0.005 \pm 0.005$	$0.23 \pm 0.10 \pm 0.10$	$[0.05, 0.46]$ at 90% C.L.
$B^0_s \to \pi^+\pi^-$	$\frac{f_s}{f_d}\frac{\mathcal{B}(B^0_s \to \pi^-\pi^+)}{\mathcal{B}(B^0 \to K^+\pi^-)} = 0.008 \pm 0.002 \pm 0.001$	$0.57 \pm 0.15 \pm 0.10$	–

Conclusions

– D0 and CDF continuing to produce a rich and exciting program in heavy flavor physics
  - interesting effects in same-sign di-lepton asymmetry and $B_s \rightarrow \mu\mu$
  - best measurements of mixing Bs phase β_s/Φ_s

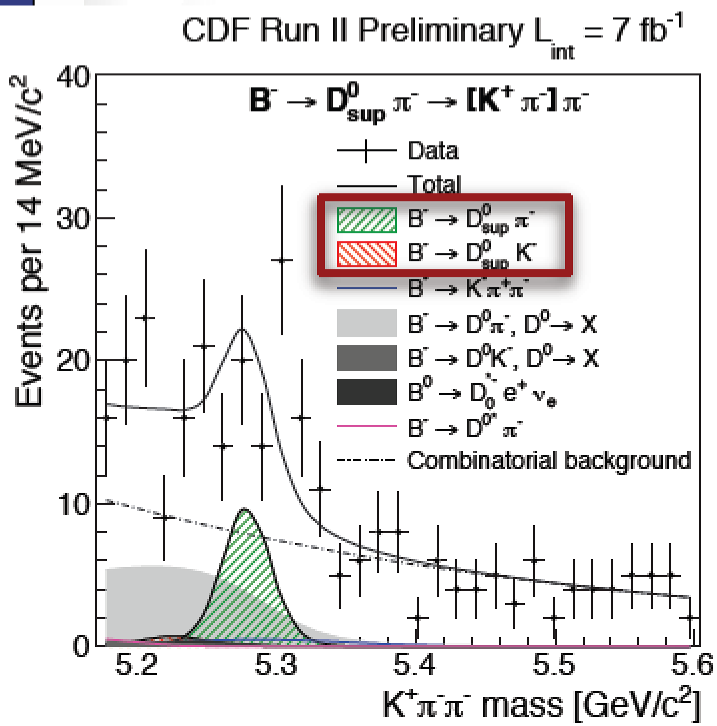
– Exciting competition with LHCb and complementary to e+e– machines

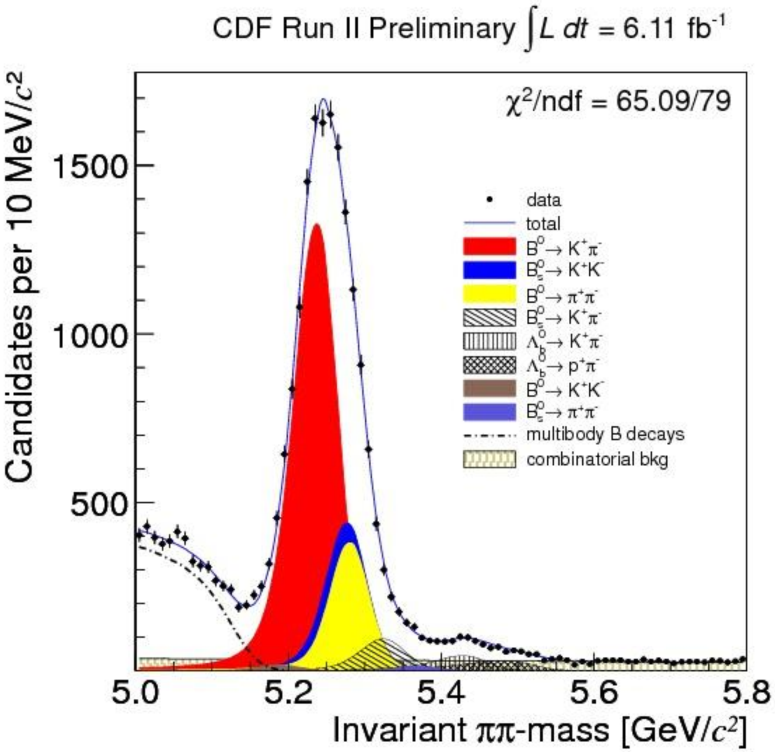
– Many interesting results will benefit from more data.
  - anticipate ~10/fb for analysis by the end of this year.

– Results will continue beyond the end of the Run

– Topics not covered:

  - Measurement of the production fraction times branching fraction $f(b \rightarrow \Lambda_b)$*$BR(\Lambda_b \rightarrow J/\Psi \Lambda)$ (D0, arXiv:1105.0690)
  - Measurement of the time-integrated mixing probability of B mesons (CDF note 10335)
  - Measurement of time-integrated CP violation in $D^0 \rightarrow h^+h^-$ decays (CDF note 10296)
  - Observation of Y(4140) in the $J/\Psi\Phi$ Mass Spectrum in $B^+ \rightarrow J/\psi\ \Phi\ K^+$ (CDF note 10244)
  - Measurement of the resonance properties of $\Sigma_b^{(*)}$ baryons (CDF note 10286)
  - Measurement of the resonance properties of charm baryons (CDF note ???)
  - Observation of the $B_s \rightarrow J/\psi K_s$ and $B_s \rightarrow J/\psi K^*$ decays (CDF, Phys. Rev. D83, 052012 (2011))


CDF Run II Preliminary L_{int} = 7 fb^{-1}
$B^- \to D^0_{sup} \pi^- \to [K^+ \pi^-] \pi^-$
Data
Total
$B^- \to D^0_{sup} \pi^-$
$B^- \to D^0_{sup} K^-$
$B^- \to K^- \pi^+ \pi^-$
$B^- \to D^0 \pi^-, D^0 \to X$
$B^- \to D^0 K^-, D^0 \to X$
$B^0 \to D_0^{*-} e^+ \nu_e$
$B^- \to D^{0*} \pi^-$
Combinatorial background
Events per 14 MeV/c^2
$K^+\pi^-\pi^-$ mass [GeV/c^2]


CDF Run II Preliminary $\int L\, dt$ = 6.11 fb^{-1}
χ^2/ndf = 65.09/79
data
total
$B^0 \to K^+\pi^-$
$B^0_s \to K^+K^-$
$B^0 \to \pi^+\pi^-$
$B^0_s \to K^-\pi^+$
$\Lambda^0_b \to K^-\pi^-$
$\Lambda^0_b \to p^+\pi^-$
$B^0 \to K^+K^-$
$B^0_s \to \pi^+\pi^-$
multibody B decays
combinatorial bkg
Candidates per 10 MeV/c^2
Invariant $\pi\pi$-mass [GeV/c^2]

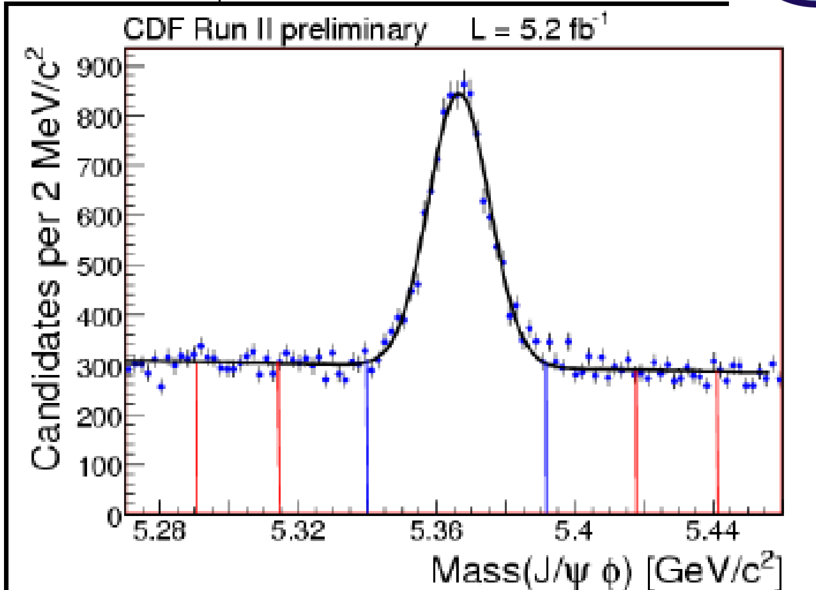
$B_s \to J/\psi\ \varphi$ (CDF)

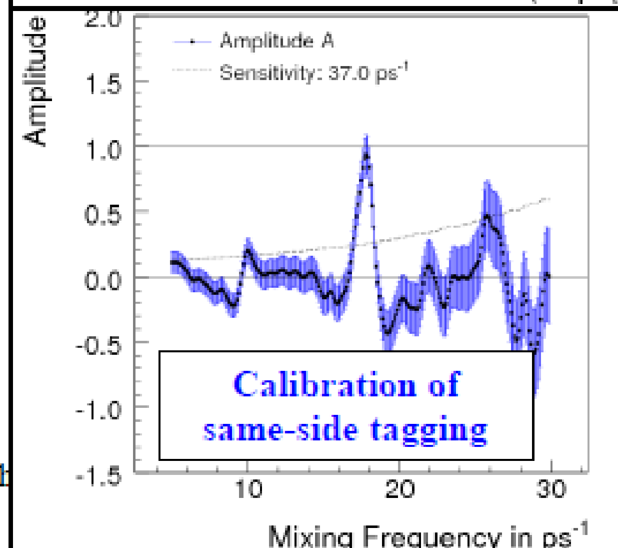
G. Giurgiu, ICHEP-201
CDF Public note 1020

- 5.2 fb^{-1} of data analyzed
- ~6500 signal events
- Same side flavour tagging calibrated in data
- Strong phases are free
- S wave included in the fit
  < 6.5% at 95% CL

$$\tau_s = 1.529 \pm 0.025\ \text{(stat)}\ \pm 0.012\ \text{(syst)}\ \ \text{ps}$$
$$\Delta\Gamma_s = 0.075 \pm 0.035\ \text{(stat)}\ \pm 0.01\ \text{(syst)}\ \ \text{ps}^{-1}$$

Most precise measurements of $\tau(B_s)$ and $\Delta\Gamma_s$





G. Borissov

B_s (B^0) $\rightarrow \mu\mu$ (CDF 7 fb^{-1}, D0 6.1 fb^{-1})

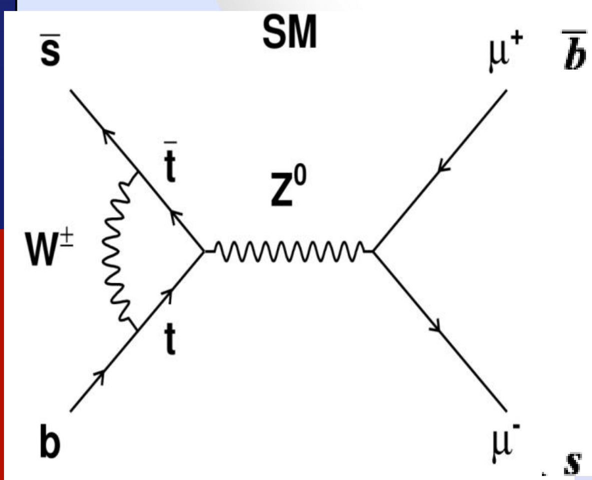
see talk by Kevin Pitts, Updated Search for B → μμ Decays at CDF

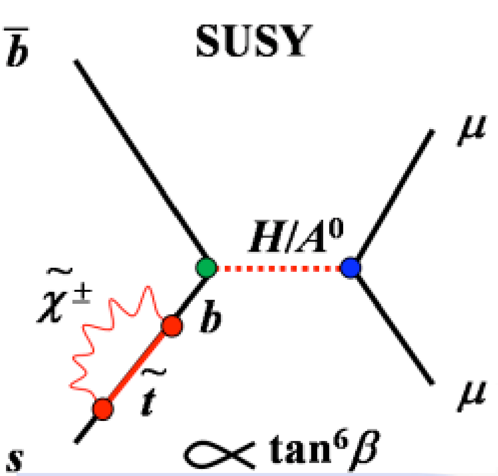
- In SM both Cabibbo and helicity suppressed; rate predicted with ~10% accuracy:
  - BR ($B_s \rightarrow \mu^+\mu^-$) = (3.2 ± 0.2) × 10^{-9}
  - BR ($B^0 \rightarrow \mu^+\mu^-$) = (1.0 ± 0.1) × 10^{-}

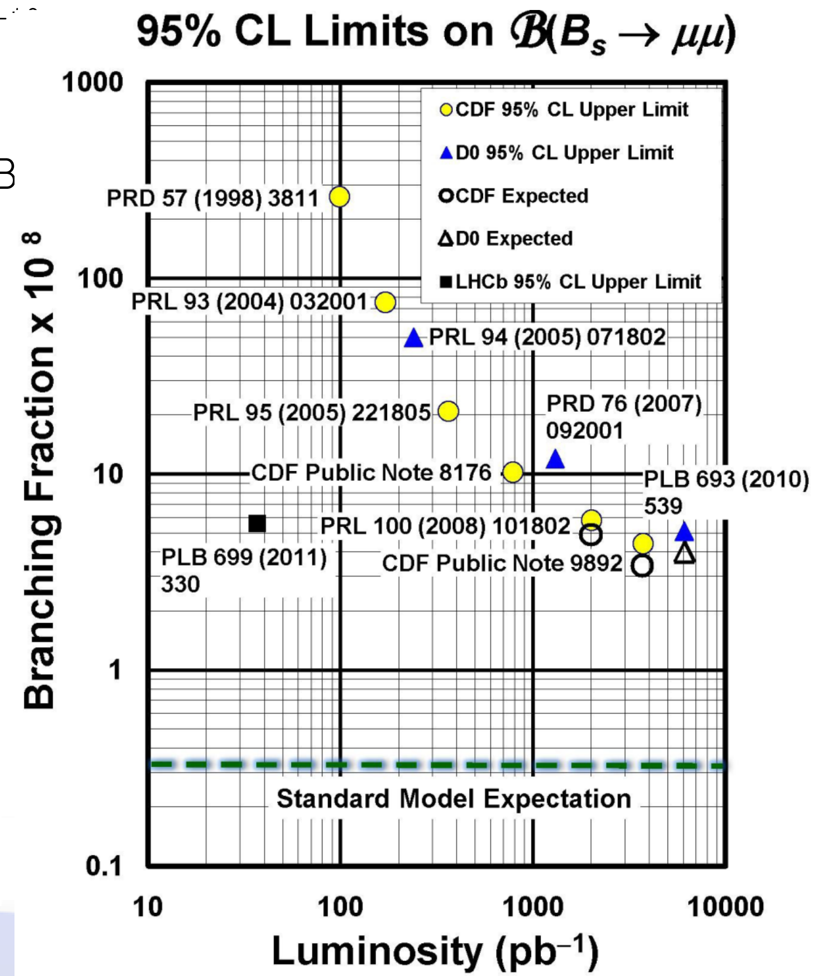
Buras et al., JHEP 1010:009,2010

- Various New Physics models predict enhanced B
  MSSM, mSUGRA, RPV-SUSY, FV, RS, SM4

e.g. Choudhury, Gaur, PRB 451, 86 (1999); Babu, Kolda, PRL 84, 228 (2000), Dedes, Dreiner, Nierste, PRL87:251804 (2001)







B_s (B^0) → μ μ (CDF 7 fb^{-1}, D0 6.1 fb^{-1})

see talk by Kevin Pitts, Updated Search for B → μμ Decays at CDF

– D0 results with 6.1 fb^{-1}

$BR(B_s \to \mu\mu) < 5.1 \times 10^{-8}$

PLB 693 539 (2010)

– New CDF limits (7 fb^{-1}):

$BR(B^0 \to \mu\mu) < 6.0 \times 10^{-9}$

– expected *4.6×10^{-8}*

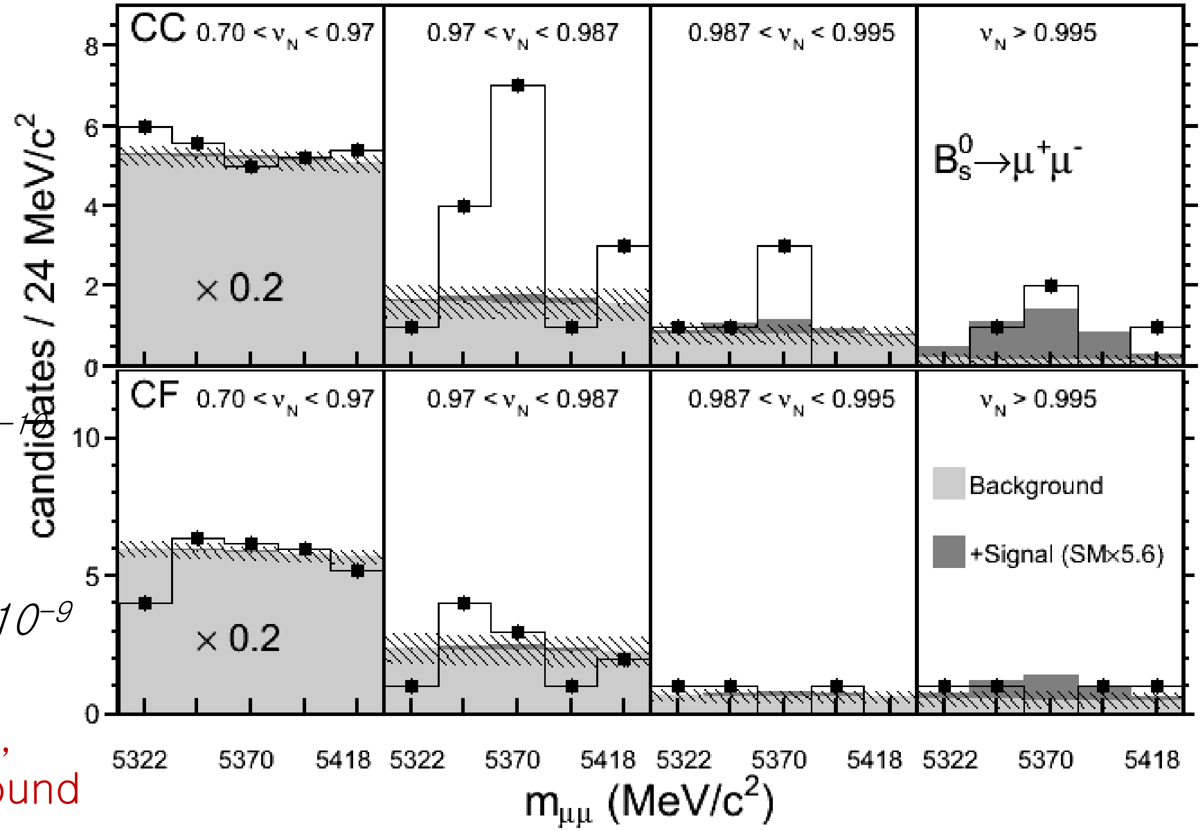
– predicted *$(1.0 \pm 0.1) \times 10^{-10}$*

$BR(B_s \to \mu\mu) < 4.6 \times 10^{-8}$

– expected *1.5×10^{-8}*

– predicted = *$(3.2 \pm 0.2) \times 10^{-9}$*

Buras et al., JHEP 1010:009,2010



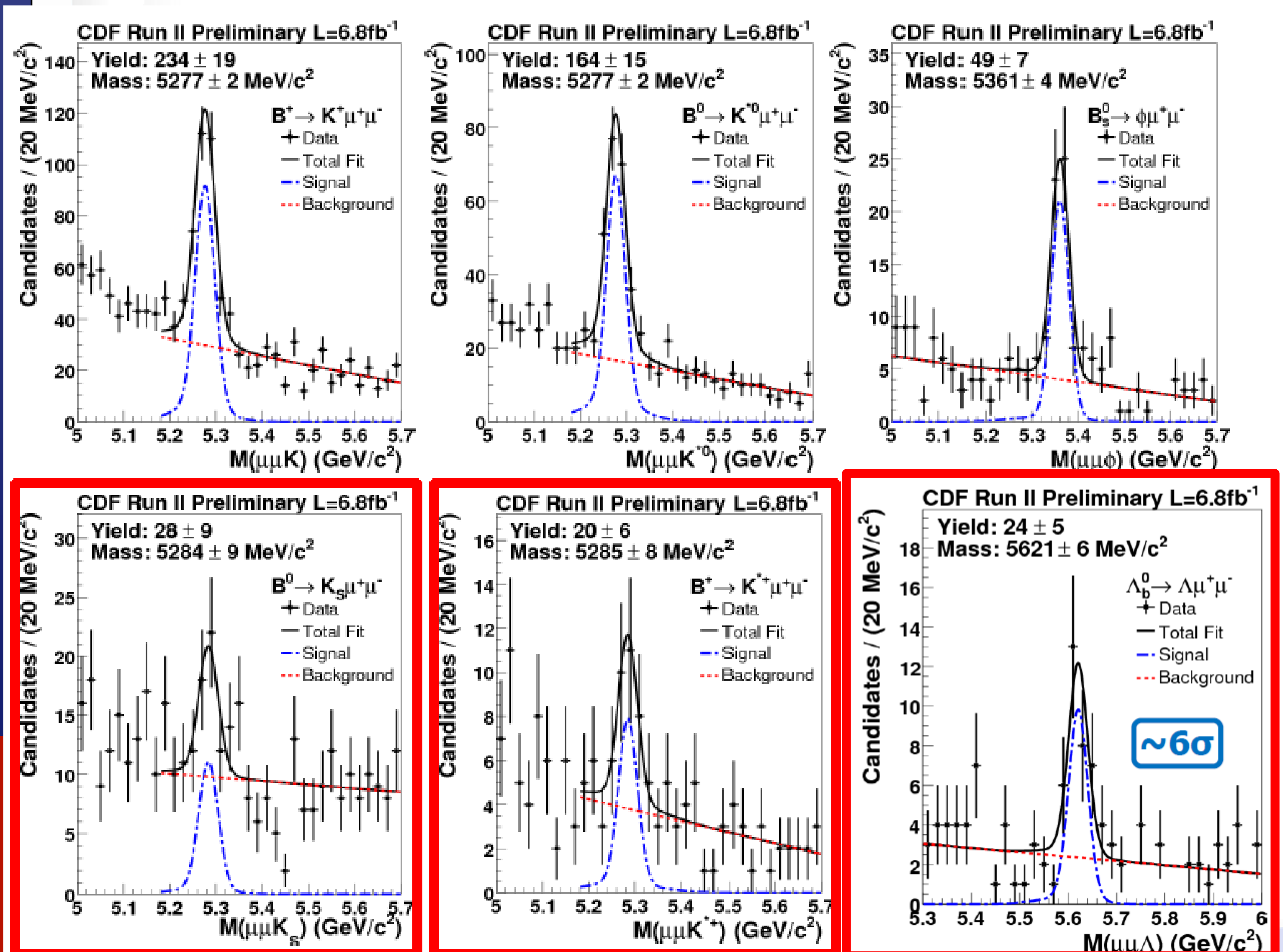
– B_s limit 2.8 sigma discrepant, p–value = 0.27%, with background only hypothesis

– p–value = 2.1% in SM hypothesis

– First two sided limit: *$4.6 \times 10^{-9} < BR(B_s \to \mu\mu) < 3.9 \times 10^{-8}$* at 90% CL

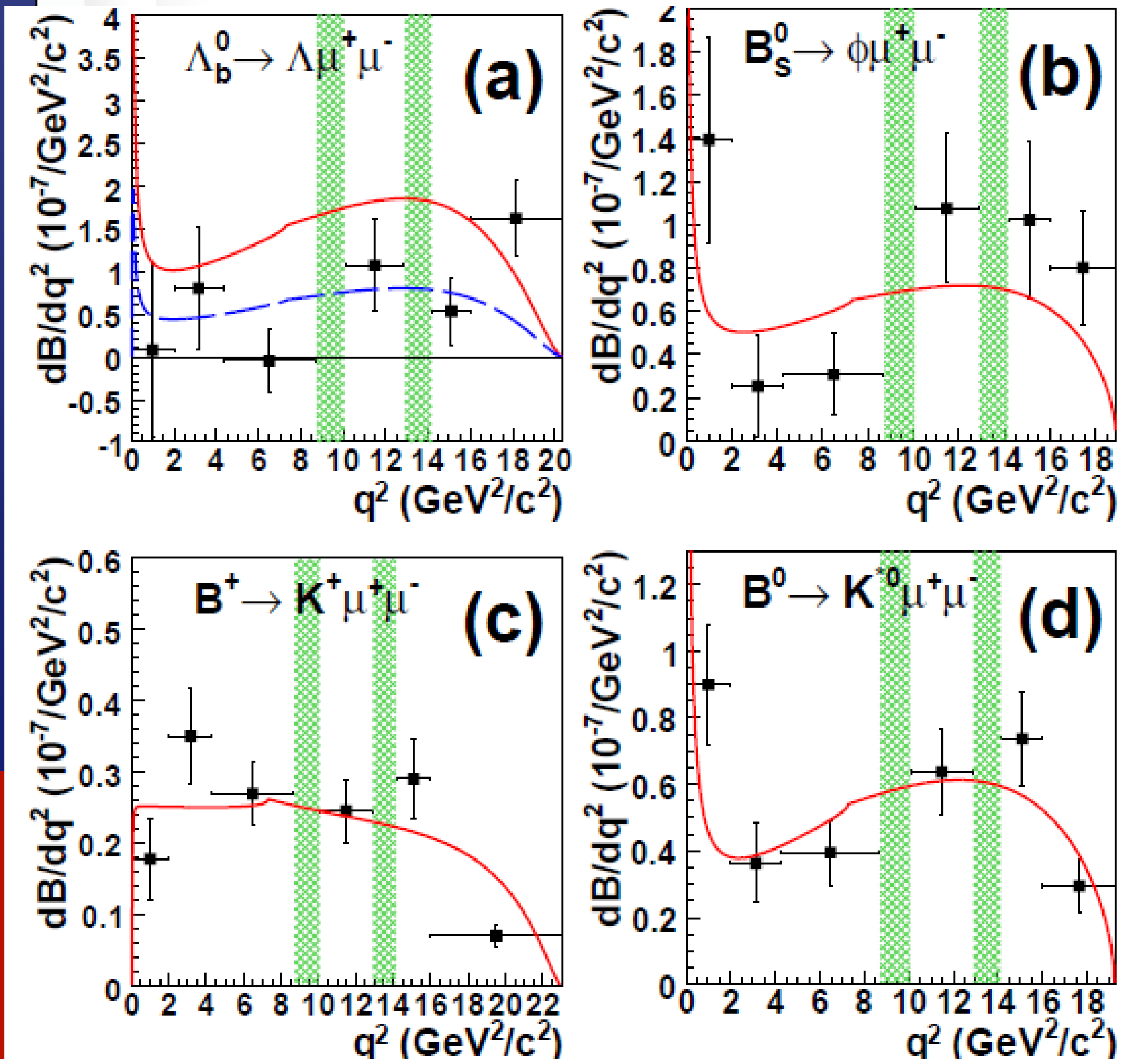
– Central value: *$BR(B_s \to \mu\mu) = 1.8^{+1.1}_{-0.8} \times 10^{-8}$, 5.6 times larges than SM expectation !*

$b \to s\mu\mu$ signals (CDF 6.8 fb^{-1})



$b \rightarrow s\mu\mu$ differential BR (CDF 6.8 fb^{-1})

– BR as function of $\mu\mu$ squared invariant mass (q^2) in good agreement with theory



Phys. Rev. D **61**, 074024 (2000).
Phys. Rev. D **81**,056006 (2010).
Phys. Rev. D **71**, 014015 (2005);
Phys. Rev. D **71**, 014029 (2005).

Review of Heavy Flavor Physics at the Tevatron

Gavril Giurgiu, Johns Hopkins University
for the CDF and DØ collaborations

DPF–APS Meeting, August 12, 2011
Brown University, Providence, Rhode Island

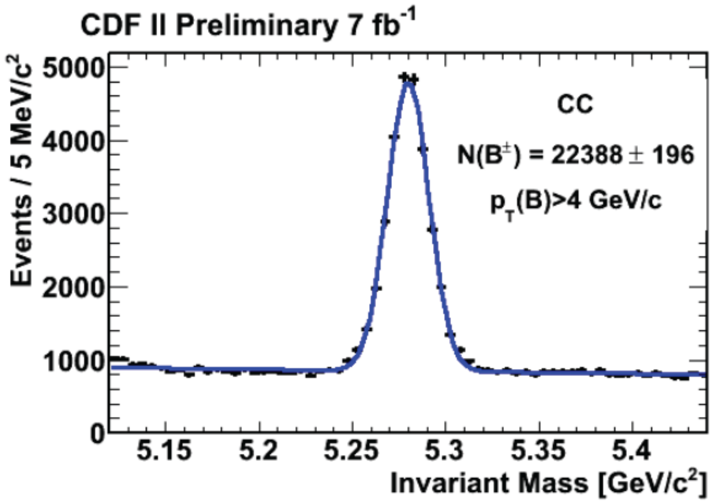
$B \rightarrow \mu\mu$ Analysis Outline

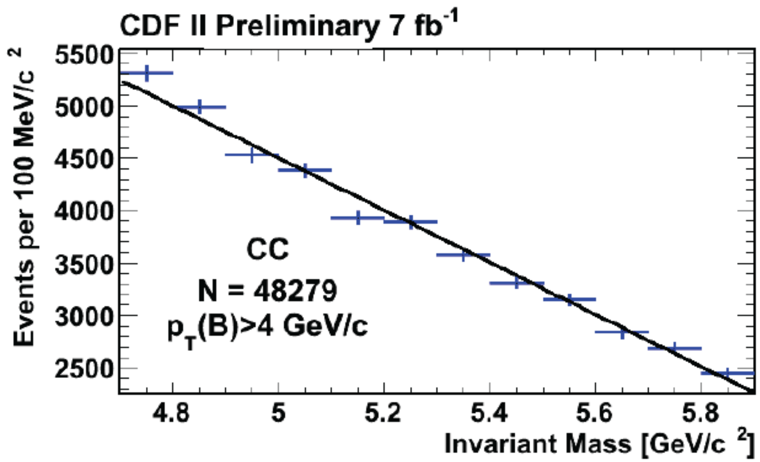
- Unbiased (blinded) analysis
- Dimuon triggered data
- Normalize to $B^+ \rightarrow J/\psi\ [\mu\mu]\ K^+$ with

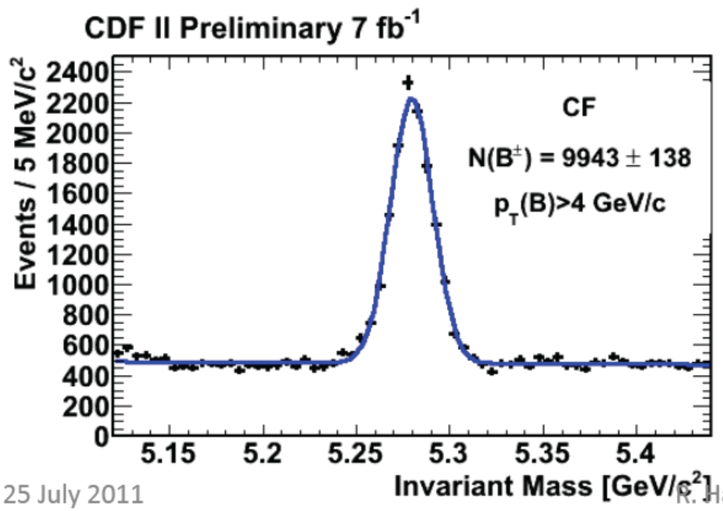
$$BR(B^0_{s(d)} \to \mu^+\mu^-) = \frac{N_{B_{s(d)}}}{N_{B^+}} \cdot \frac{\alpha_{B^+}}{\alpha_{B_{s(d)}}} \cdot \frac{\varepsilon^{total}_{B^+}}{\varepsilon^{total}_{B_{s(d)}}} \cdot \frac{1}{\varepsilon^{NN}_{B_{s(d)}}} \cdot \frac{f_u}{f_s} \cdot BR(B^+ \to J/\Psi K^+ \to \mu^+\mu^- K^+)$$

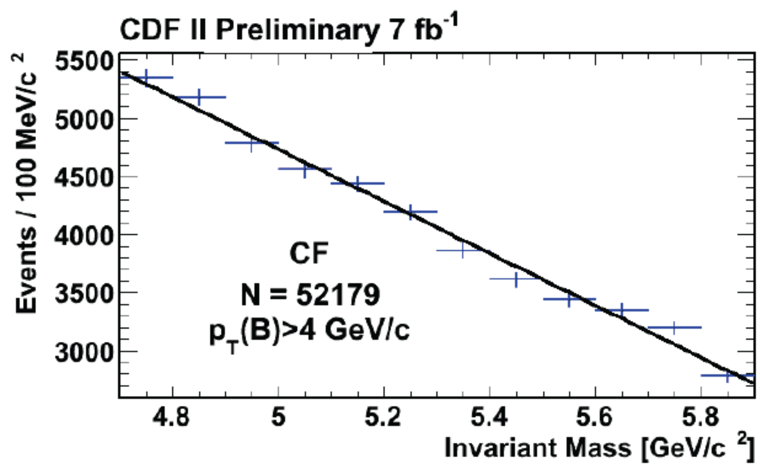
- Baseline event selection (acc. and eff.)
- Neural Net to optimize expected limit
- Evaluation of backgrounds
- Unblind signal region and evaluate

Baseline Selection (Norm. and Sig.)



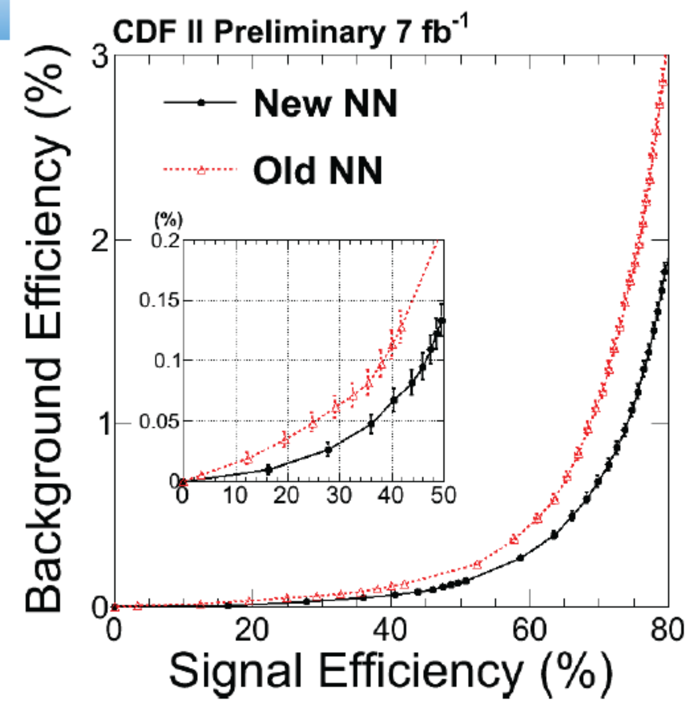


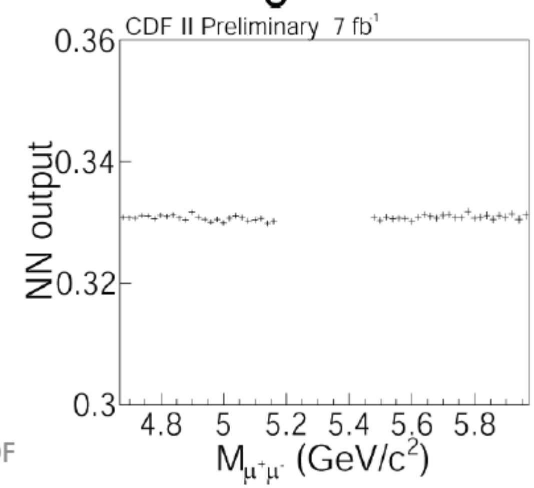




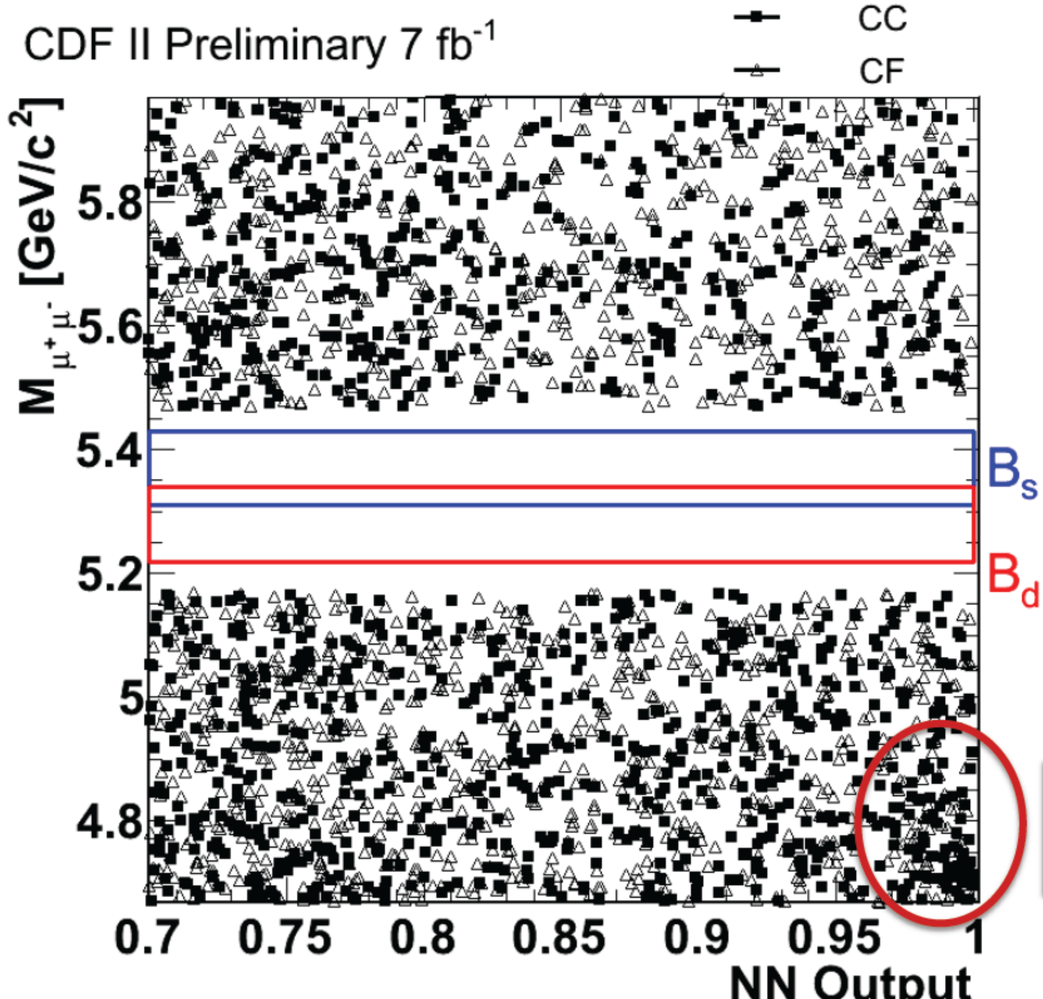
Neural Net Selection

- Improved with respect to previous analysis
- Optimize for $B_s \rightarrow \mu\mu$ expected limit
- Carefully check for bias
  - mass dependence
  - overtraining check with S.B.



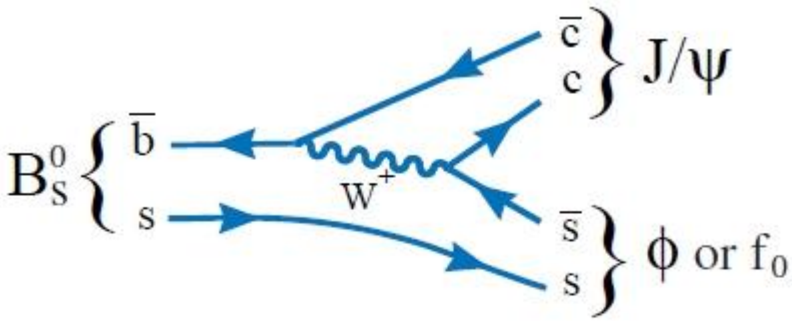


NN vs. Mass, Still Blinded



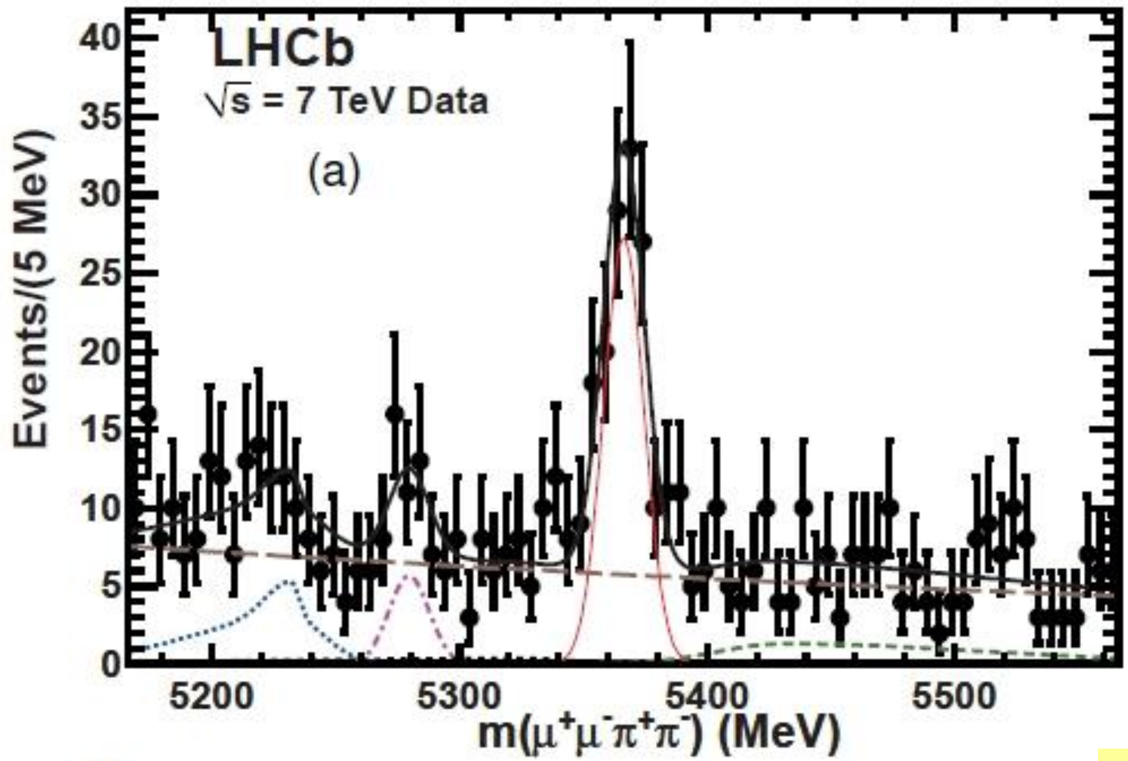
$B \rightarrow X\mu\mu$ Decays

Bs->J/psi f0(980)



Bs -> J/psi f_0(980)

f_0(980) ->π+π−



Kihyeon Cho

http://www.cern.ch

CPV in $B_s \to J/\psi\phi$

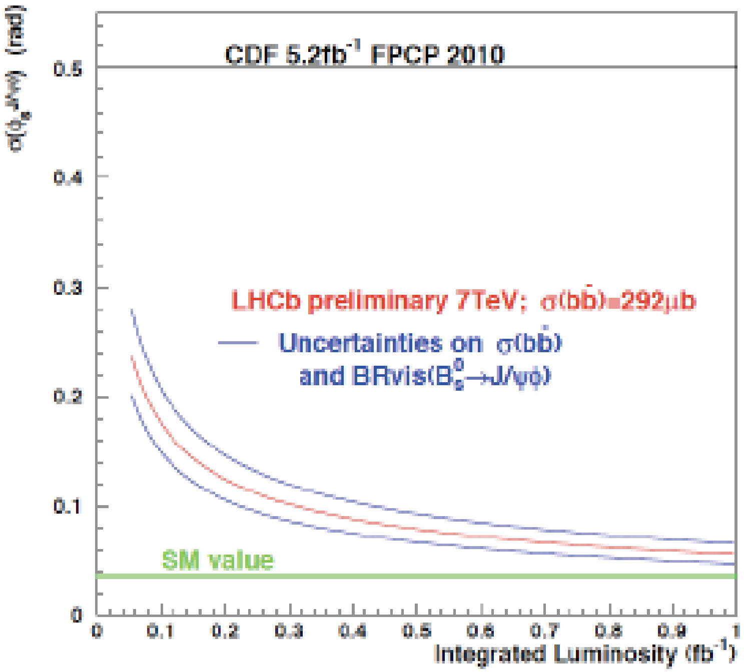
Expected sensitivity:

MC performance:

- 50k events / fb^{-1} consistent with number of $B_s \to J/\psi\phi$ candidates seen in data

- $\langle\sigma_t\rangle = 0.038$ ps. Present resolution in data is ~ 1.6 worse but sufficient for $\Delta m_s \sim 17.7/ps$ (adds 30% dilution to the sensitivity)

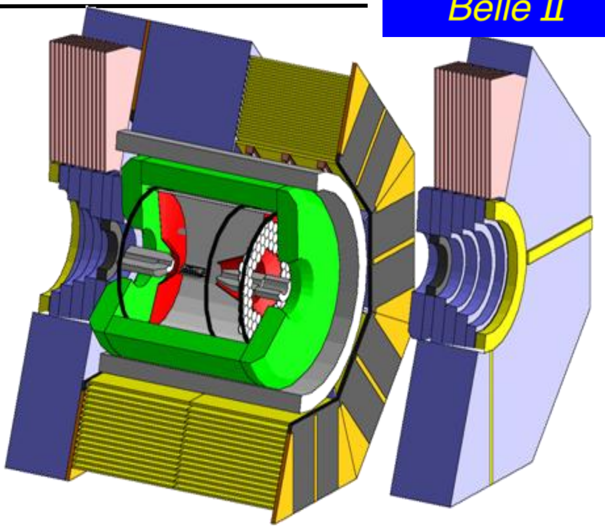
- Tagging performance $\varepsilon D^2 = 6.2\%$ will be tested with more data



A. Golutvin

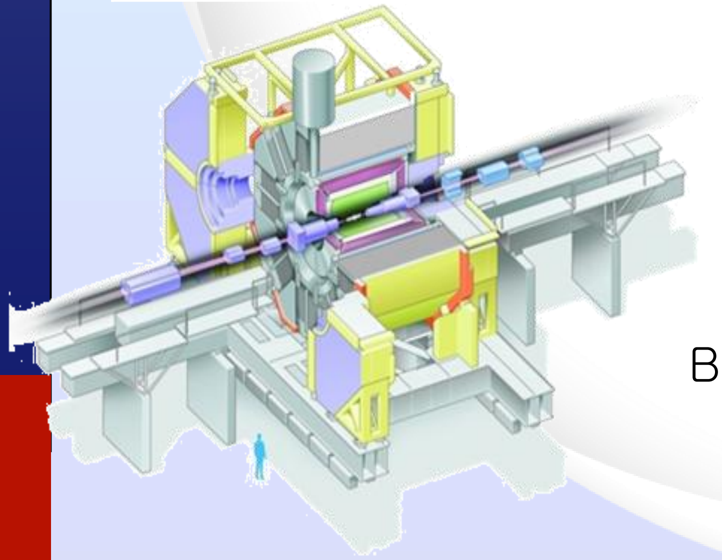
Belle vs. Belle II

Belle	Content	Belle II
1998~2010	Time Schedule	2014~
1 ab^{-1}	Luminosity	50 ab^{-1}
1 Billion	BBbar events	50 Billion
CP measurement	Goal	New Physics



Belle II

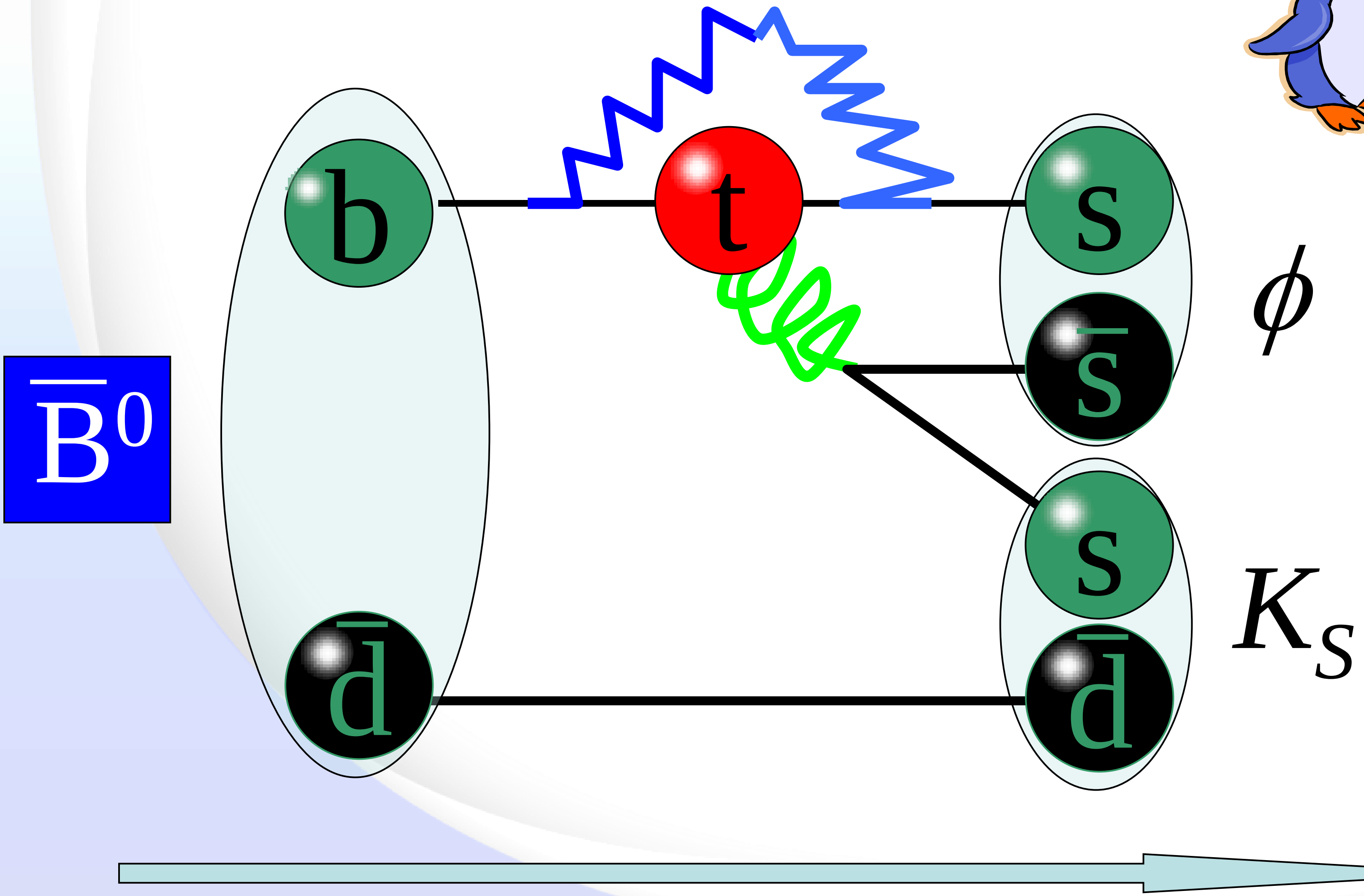
=> Prof. Byeonggu Cheon's talk



Belle

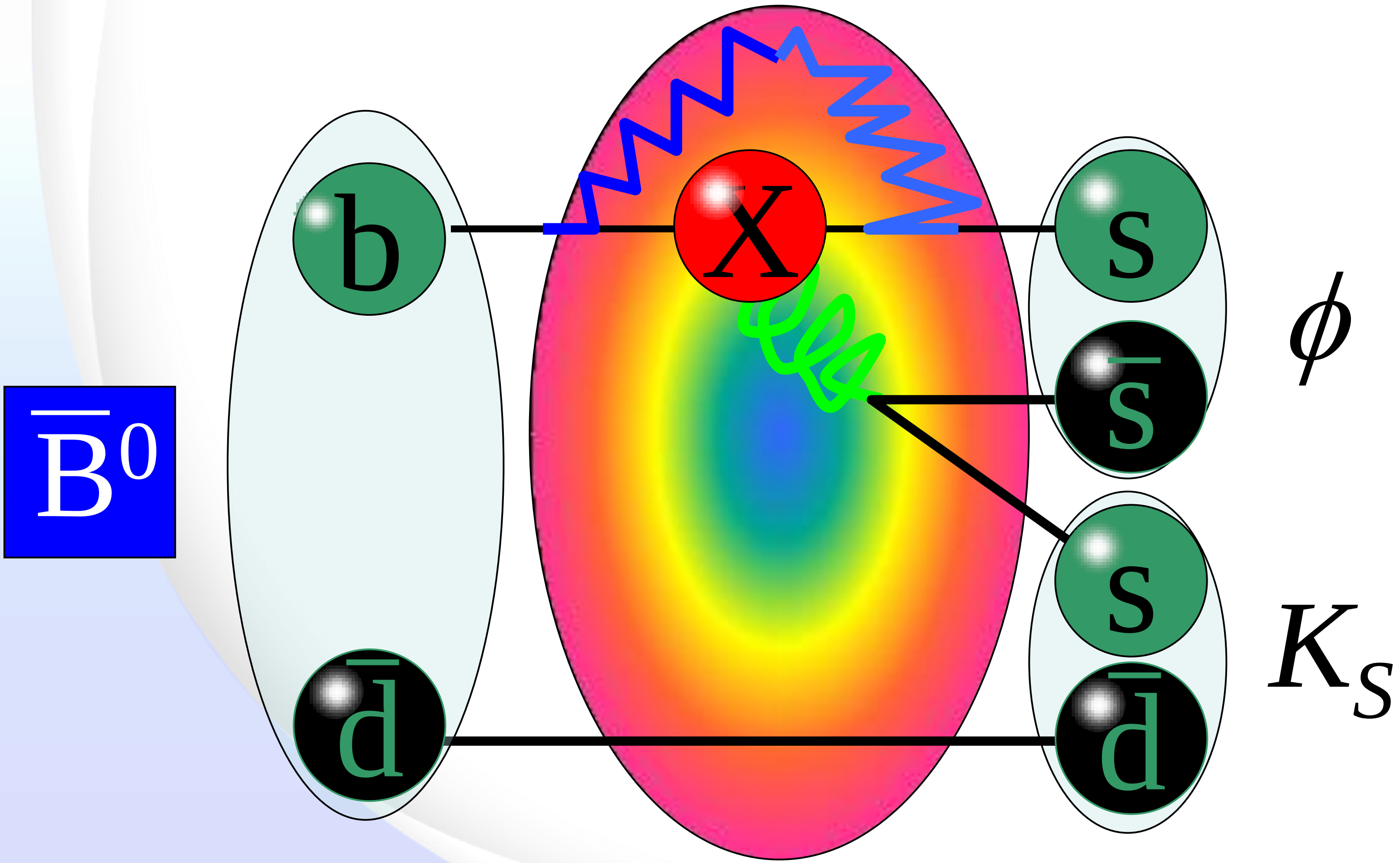
To handle 50 times more data and grid farms
=> New Data Handling System

Penguin diagram



time

If a new particle X exists…

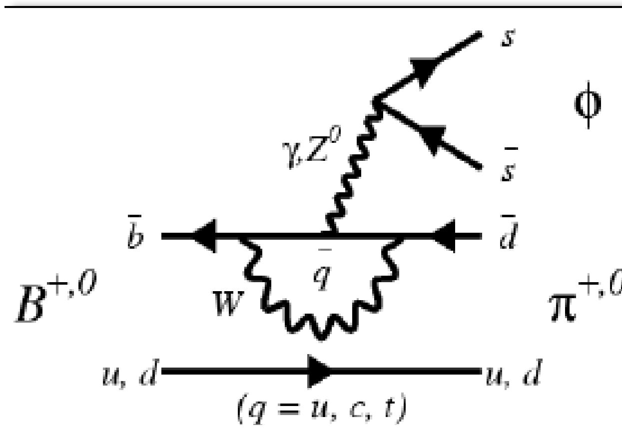


This measurement is sensitive to new physics such as SUSY.

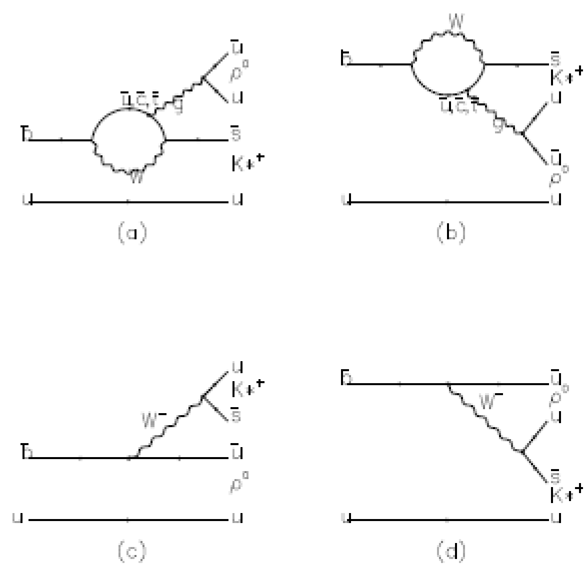
M. Yamakuchi

More penguin modes @ KISTI

- $B \to \Phi\ \pi$
  - Pure EW penguin mode
  - SM Br ~$O(10^{-8})$
  - Babar with 232M BB:
    - UL($\Phi\ \pi^+$) < 2.4*10^{-7} @90%CL
    - UL($\Phi\ \pi^0$) < 2.8*10^{-7} @90%CL
  - Draft is almost ready.

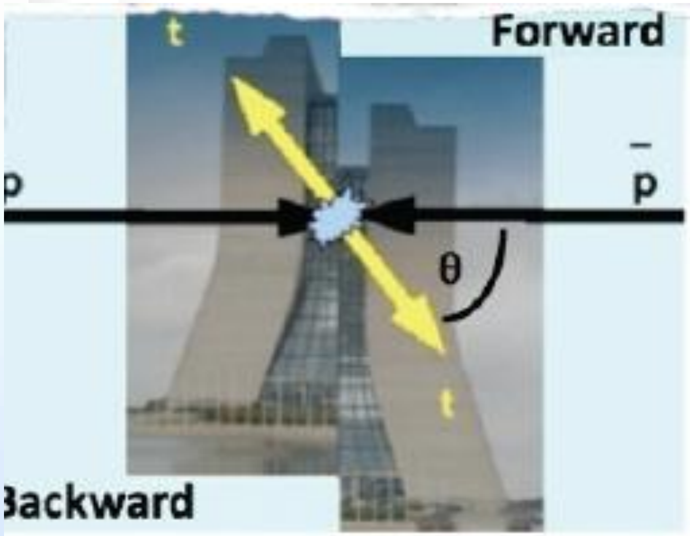


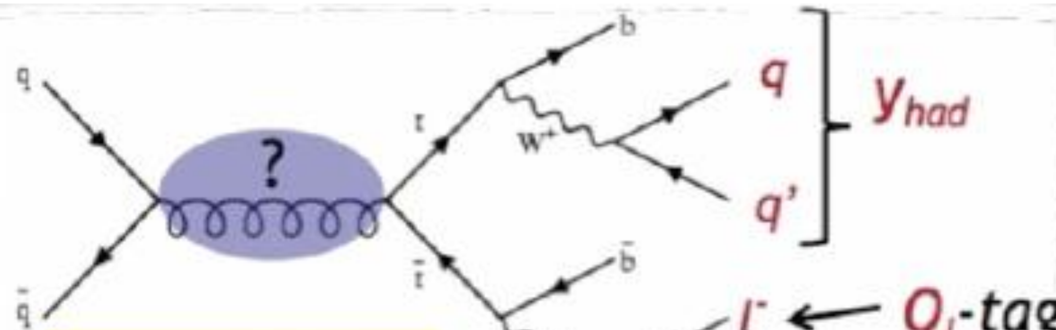
- $B^+ \to \rho^0 K^{*+}$
  - Penguin dominant status
  - Work on progress



Time-Integrated Mixing Probability of B Mesons

$t\bar{t}$ FB Asymmetry at Tevatron





$$A_{fb} = \frac{F - B}{F + B}$$

$t\bar{t}$

NLO QCD: A_{fb}= 0.05 ± 0.015%

CDF (3.2 fb^{-1}):

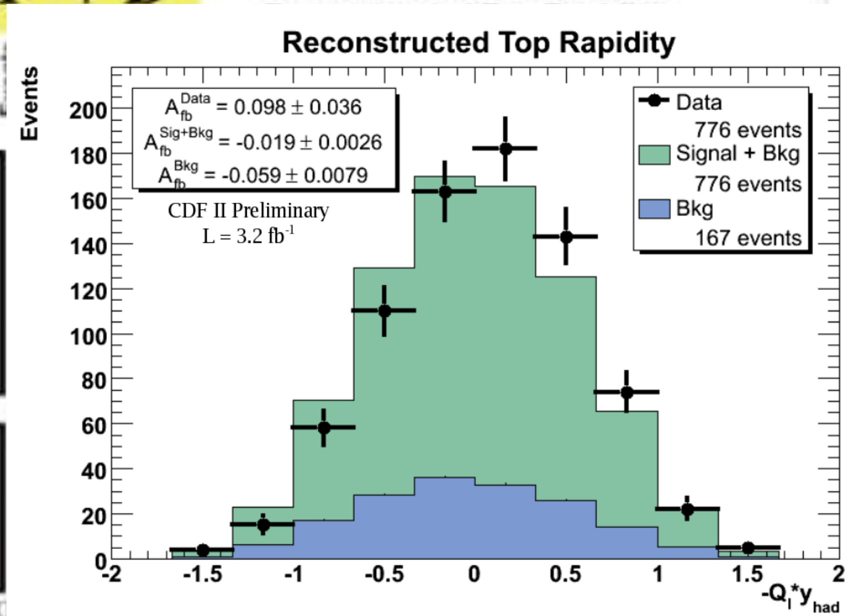
A_{fb} = 0.19 ± 0.07(stat) ± 0.02(syst)

PRL 101, 202001 (2008) previous result (1.9 fb^{-1})

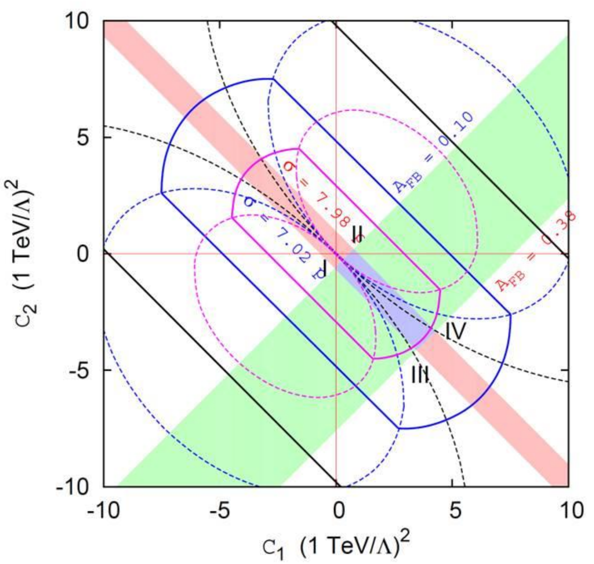
D0 (1.0 fb^{-1}): PRL 100, 142002 (2008)

A_{fb}^{det} = 0.12 ± 0.08(stat) ± 0.01(syst)

November 17, 2009 K. Tollefson, HCP 20



Model independent analysis



The region in (C1,C2) plane that is consistent with the Tevatron data at the one sigma level.

- We used dimension−6 four quark operators with all the possible Dirac and color structures.
- We considered the s−, t− and u− channel exchanges of spin−0 and spin−1 particles whose color quantum number is either singlet, octet, triplet or sextet.
- Our results encode the necessary conditions for the underlying new physics in a compact and an effective way when those new particles are too heavy to be produced at the Tevatron.

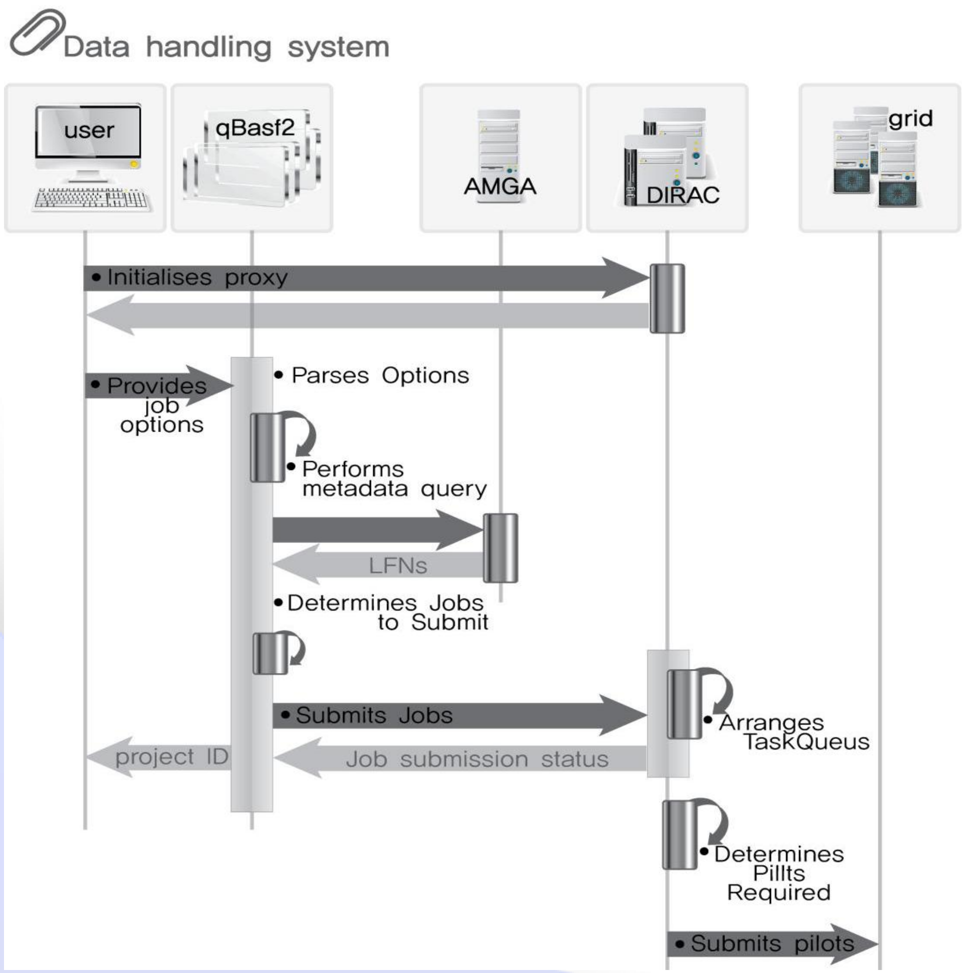
S.−h Nam. et.al, PLB 691, 238 (2010)

Physics topics at KISTI

	Experiment	Theory
Top Forward-backward Asymmetry	CDF	Model independent Analysis
Mixing and CPV on Bs->J/psi phi	**CDF**	Right-handed model
Penguin diagram	**Belle**	Right-handed model

Data Handling Scenario

- To improve the scalability and performance
- We apply AMGA which is middleware for g-Lite



Kihyeon Cho

=> Dr. JungHyun Kim's talk

Newspaper (2010.04.07)

Belle II

English | 日本語 | 中國語

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대덕넷에서 보내드리는 뉴스레터입니다

2010-04

KOREA, 우주 기원 밝히는 '국제 거대실험' 주도

한국과학자, 세계 3대 가속기 이용 실험 '그룹장 역할 톡톡'
조기현 KISTI 박사, 'Belle-II' 데이터 핸들링 그룹장 수행

HelloDD NEWS

세계 4번째 '핵연료 집합체 안전성 시험' 성공

원자력연, 국내 최초 500시간 연속 달성… 2011년 상용화 계획

1년 할 일 하루만에… 초고속 질량분석기 '15T FT-ICR MS'

[KBS]분석과학시리즈⑮]세계적 연구성과 만드는 분석기 개발

적어도 이번 Belle II 프로젝트의 경우 그동안 국제공동연구에 수동적으로 참여해 왔던 한국 과학기술계의 이미지와는 다른 세상 이야기다.

사실 조 박사가 Belle II 프로젝트의 데이터 핸들링 그룹장을 맡은 지 1년이 넘었다. 2009년 3월부터 그룹장을 맡았다. 중책을 맡고 연구가 시작된 이후 그동안 언론이나 외부에 공개된 적이 없다. 그룹장 선임 자체가 뉴스거리였지만, 조 박사는 "아무것도 해놓은 것이 없어 굳이 알리지 않았다"며 겸연쩍어 했다.

◆ KISTI 개발 소프트웨어 'AMGA', Belle II 데이터 핸들링 시스템에 적용

▲일본 쯔꾸바시에 있는 KEK 가속기 내부 Belle 실험의 제어실 앞에서 '찰칵'.
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<대덕넷 김요셉 기자> joesmy@hellodd.com
2010년 04월 06일

2.4 주요 사업 내용

➲ 차세대 가속기 일본 KEK 실험데이터(50 PB, 2014) 활용 프레임워크 구축 중

- Belle II Data Handling 시스템 개발 (워킹 그룹장)
  - ✓ 매월 첫째, 셋째 목요일 오후 5시 (KEK 시각)
  - ✓ To improve scalability and performance
- 세부과제간 공동연구로 추진(e-HEP, 그리드 기술개발, GSDC)