APCTP-TRP

Yonsei University, Seoul, October 27, 2007

e-HEP and Heavy Flavor Physics

Kihyeon Cho

KISTI

(Korea Institute of Science and Technology Information)

Korea Institute of Science and Technology Information

Outline

- KISTI?
- e-HEP (High Energy Physics)
- Standard Model
- Heavy Flavor Physics @ CDF
- Summary

KISTI "bird's eye view"

Yes KiSTi
www.yeskisti.net

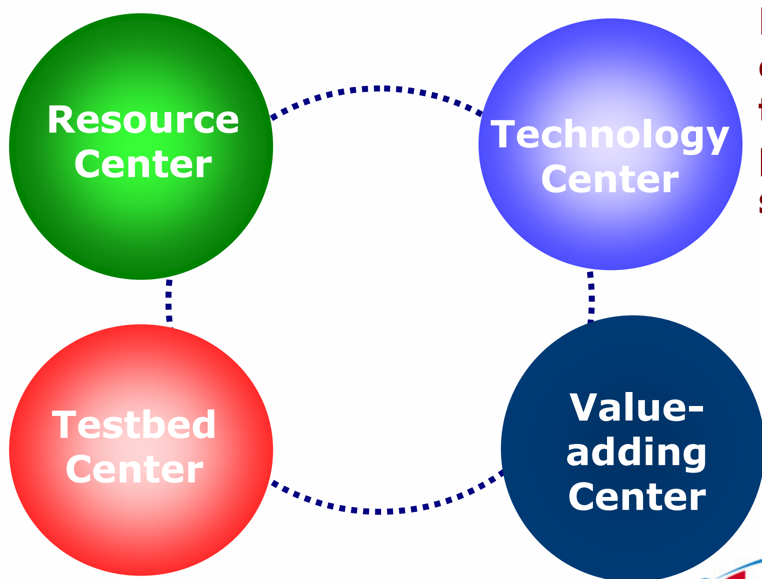
What is KISTI Role?

National headquarters of

1. Supercomputing resources,
2. e-Science,
3. Grid,
4. High performance research networks

Keep securing/providing world-class supercomputing systems

Help Korea research communities to be equipped with proper knowledge of supercomputing



Validate newly emerging concepts, ideas, tools, and systems

Make the best use of what the center has, to create the new values

New Supercomputer (4th)

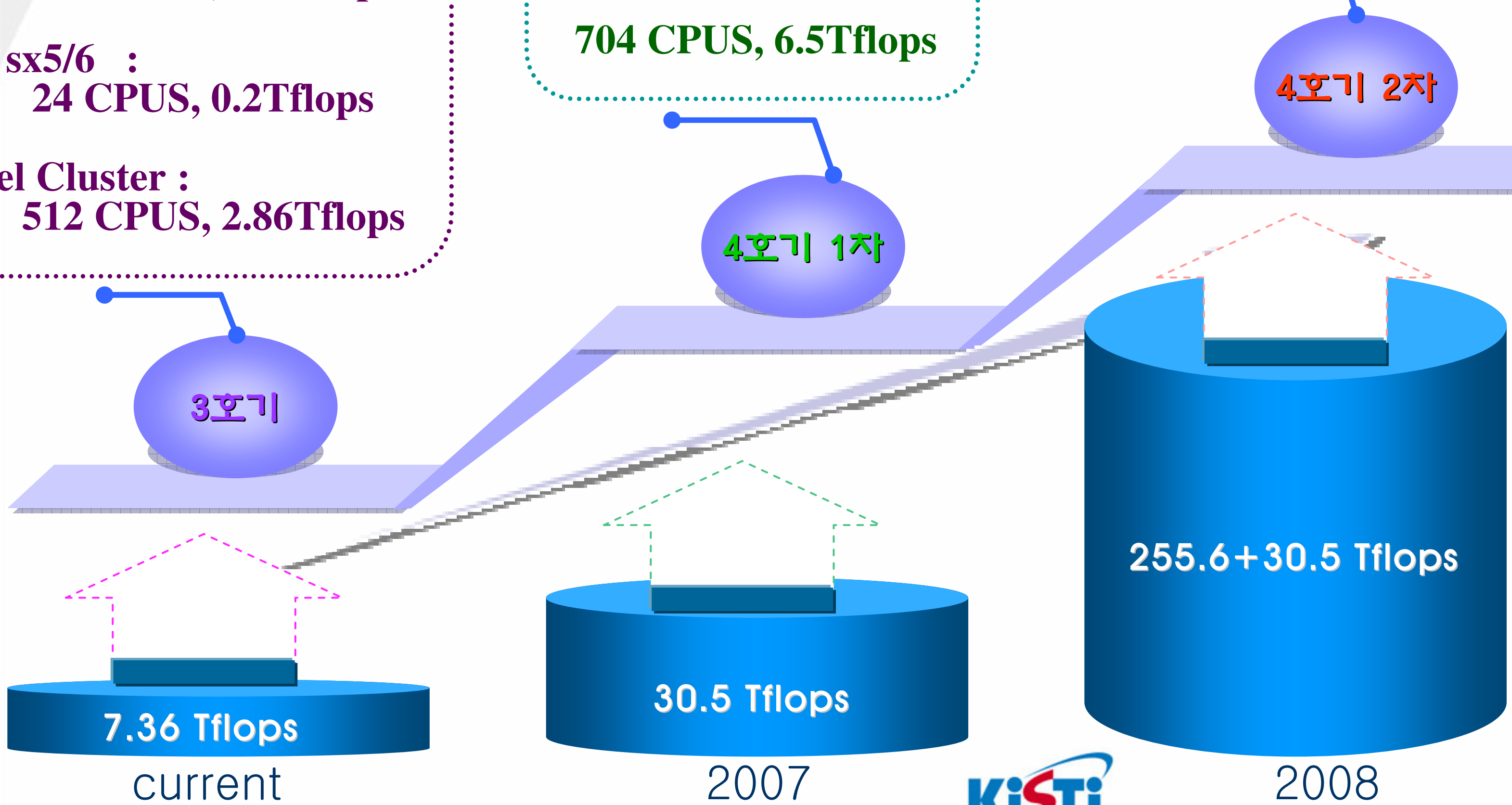
IBM P690/+ :
672 CPUS, 4.3Tflops

NEC sx5/6 :
24 CPUS, 0.2Tflops

Hamel Cluster :
512 CPUS, 2.86Tflops

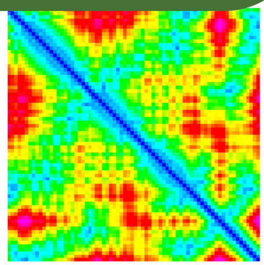
MPP (SUN):
3,008 CPUS, 24Tflops
SMP (IBM):
704 CPUS, 6.5Tflops

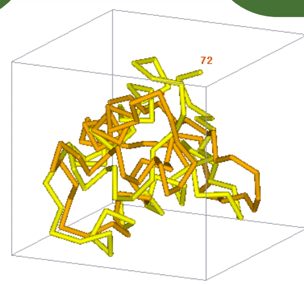
MPP (SUN):
28,256 CPUS,226Tflpos
SMP (IBM):
1,472 CPUS, 29.4Tflops



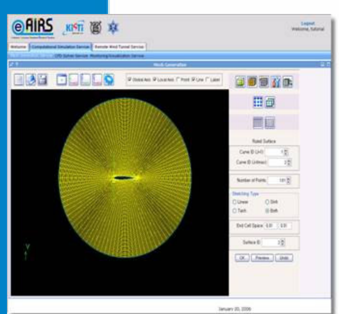
Research areas @ KISTI

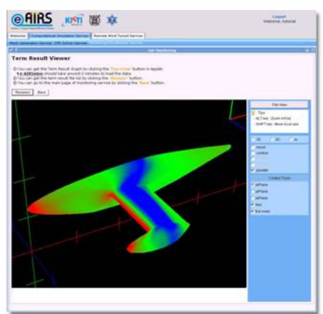
BT/NT
(2001~)



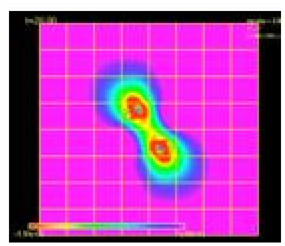


Fluid Dynamics
(2005~)

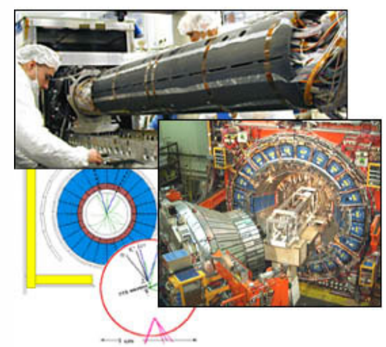




Numerical Relativity
(2005~)

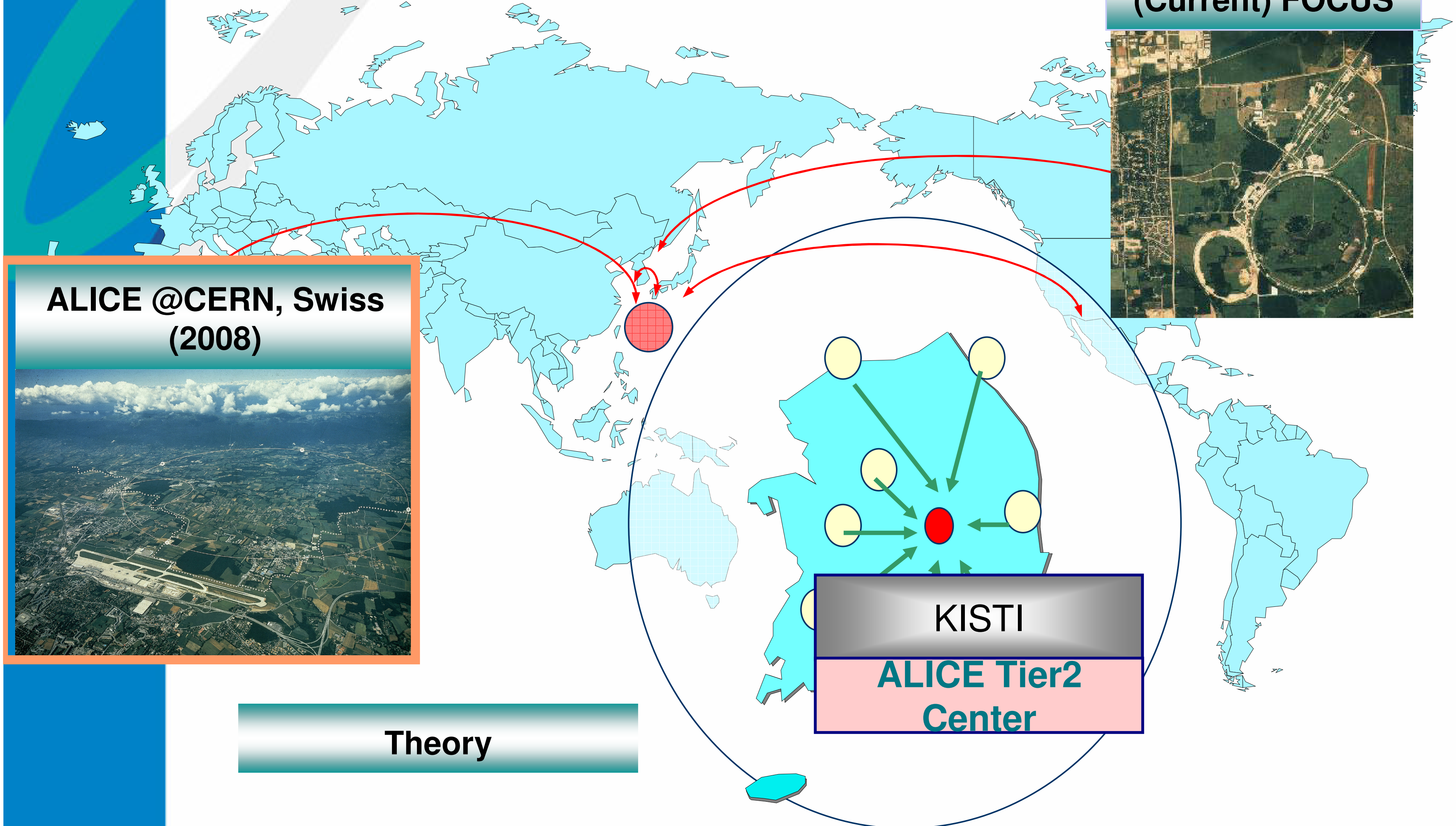


High Energy Physics
(2007~)



=> e-HEP

High Energy Physics @KISTI



ALICE Tier2 MoU (2007.10.23)

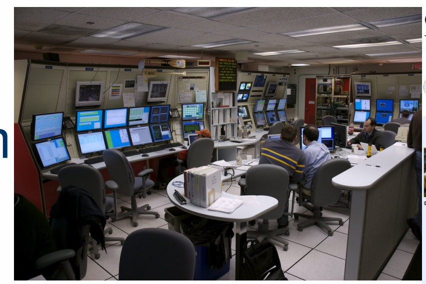
Man Power @ KISTI

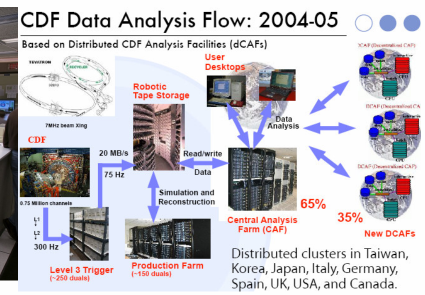
- High Energy Physics Group (8 FTE)
  - Theory: Dr. Sangdong Lee
  - ALICE: Dr. Soonwook Hwang + Dr. Jincheol Kim + 3 Computer Scientists
  - CDF: Dr. Kihyeon Cho and Dr. Hyunwoo Kim

The ultimate goal of e-HEP

- To study high energy physics any time and anywhere even if we are not on-site.

1. Data Production
    - Remote Control Room
2. Data Processing
    - Data Center, Grid Farm
3. Data Publication
    - Using collaborative environment - VRVS, EVO (Enabling Virtual Organization)

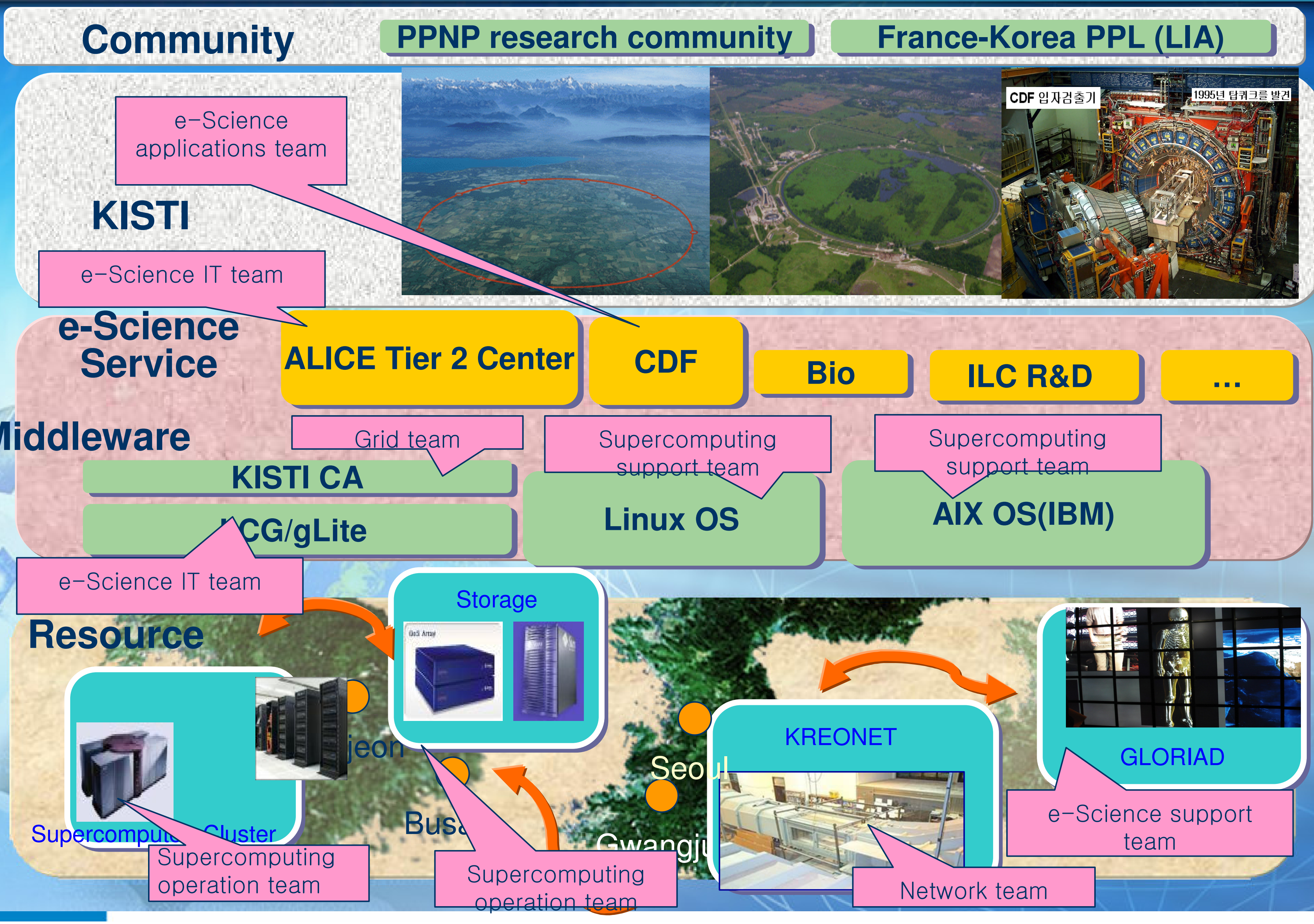




The components of e-HEP

Component	ALICE	CDF
Data Publication	EVO (Enabling Virtual Organization)	
Data Processing	ALICE Tier2 Center	Pacific CAF (CDF Analysis Farm)
	LCG farm	
Data Production	N/A	Remote Control Room

e-HEP Data Processing



e-HEP @KISTI

High Energy Physics Applications

Outline

❖ Goal
- To study High Energy Physics any time, anywhere

❖ Contents
- Data Production: Remote control Room
- Date Processing
  - ALICE Tier2 Center
  - Pacific CAF (CDF Analysis Farm)
- Data Publications: EVO

Products

❖ KISTI participates in CDF (March 2007)

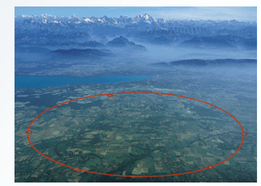
❖ KISTI (Korea)–CNRS (France) MoU (April 2007)

❖ ALICE Tier2 MoU (October 2007)

❖ France–Korea Particle physics Laboratory (Processing)

Research Area

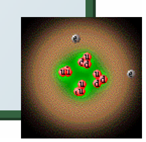
❖ ALICE Tier2 Center

❖Pacific CAF(CDF Analysis Farm) Construction using LCG farm

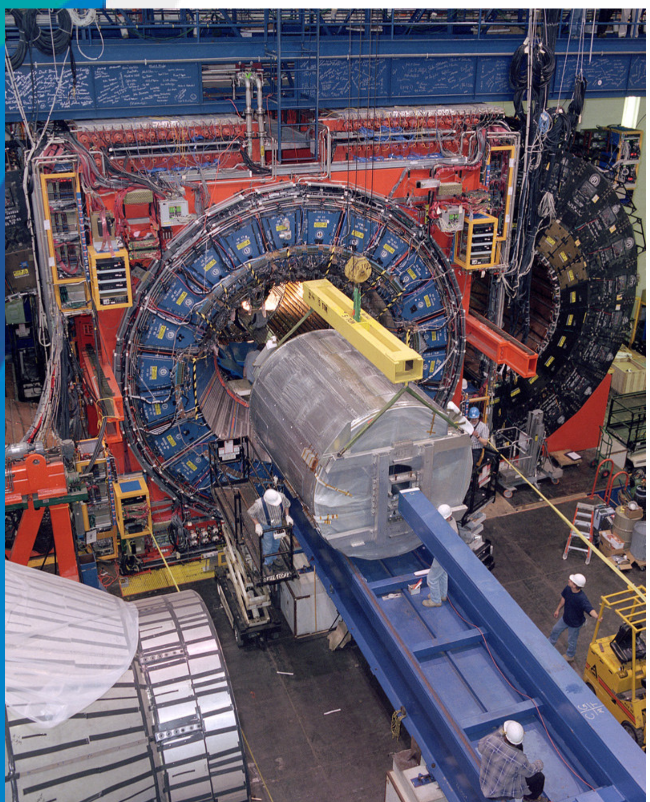
❖ France–Korea Particle Physics Laboratory (LIA) – CDF


❖Leading Particle Physics and nuclear Physics community



CDF Collaboration

CDF Detector



CDF Collaboration

North America

Europe

Asia

Center for High Energy Physics:
Kyungpook National University
Seoul National University
SungKyunKwan University
KISTI
Chonnam National University

Total

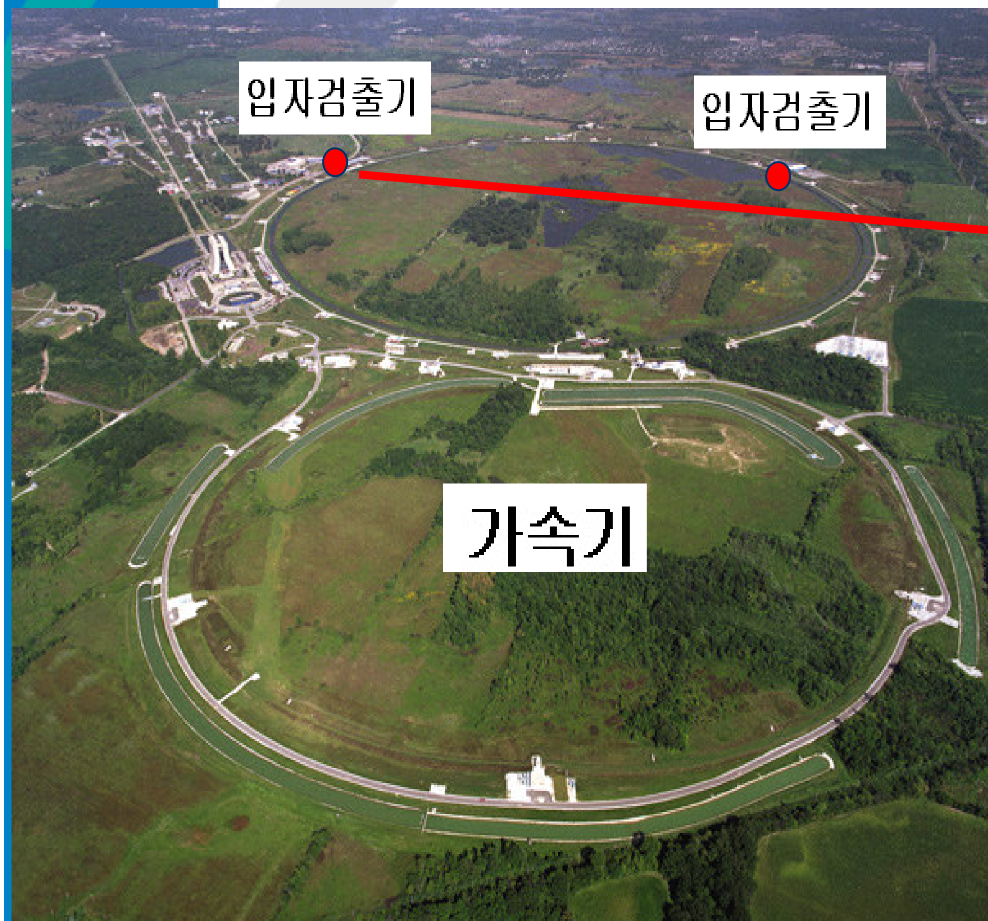
13 Countries

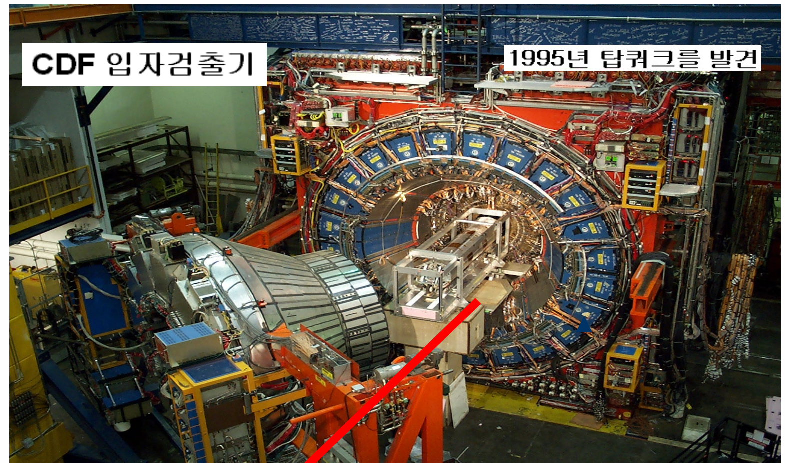
62 Institutes

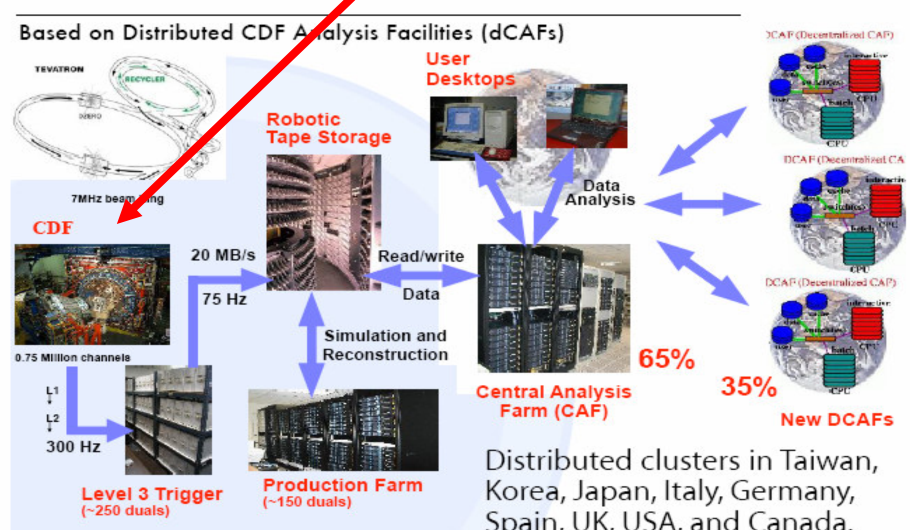
~620 Physicists

World's Most Powerful Accelerator: Fermilab's "Tevatron"

CDF 실험





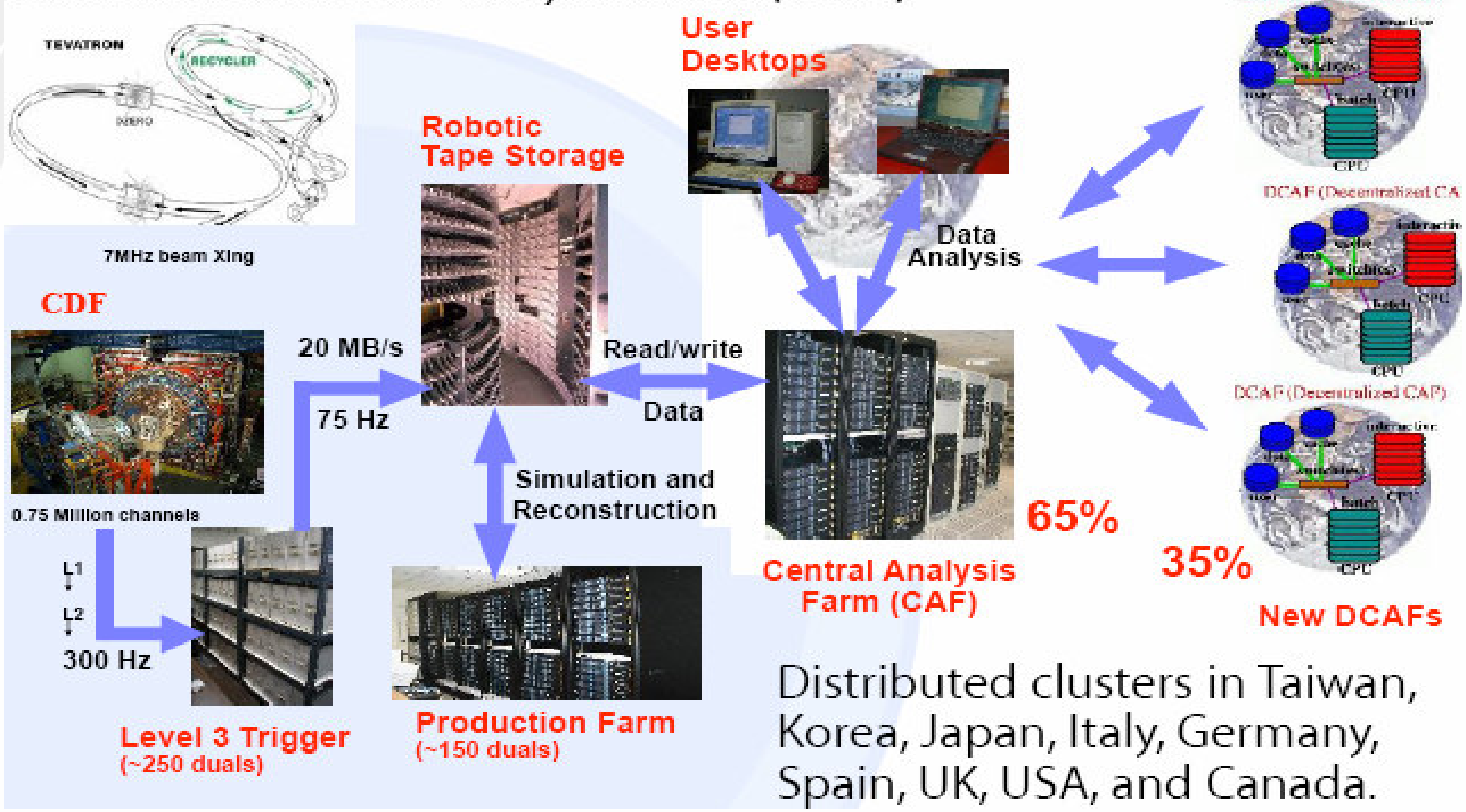


미국 페르미연구소

November 7, 2007

CDF Data Analysis Flow: 2004-05

Based on Distributed CDF Analysis Facilities (dCAFs)

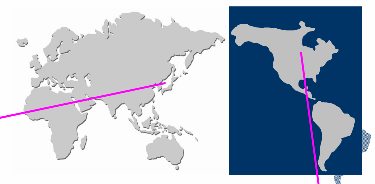


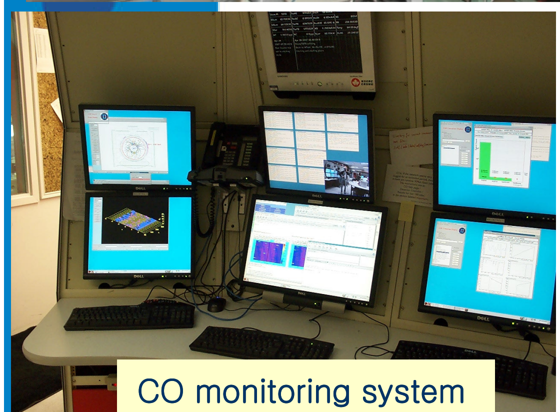
Distributed clusters in Taiwan, Korea, Japan, Italy, Germany, Spain, UK, USA, and Canada.

e-HEP Achievements

1. Data Production
2. Data Processing
   - Pacific CAF (CDF Analysis Farm)
3. Data Publication
4. Leading community
   - France Korea Particle Physics Lab.
   - PPNP Research Community

1. Data Production
Remote CO shift room





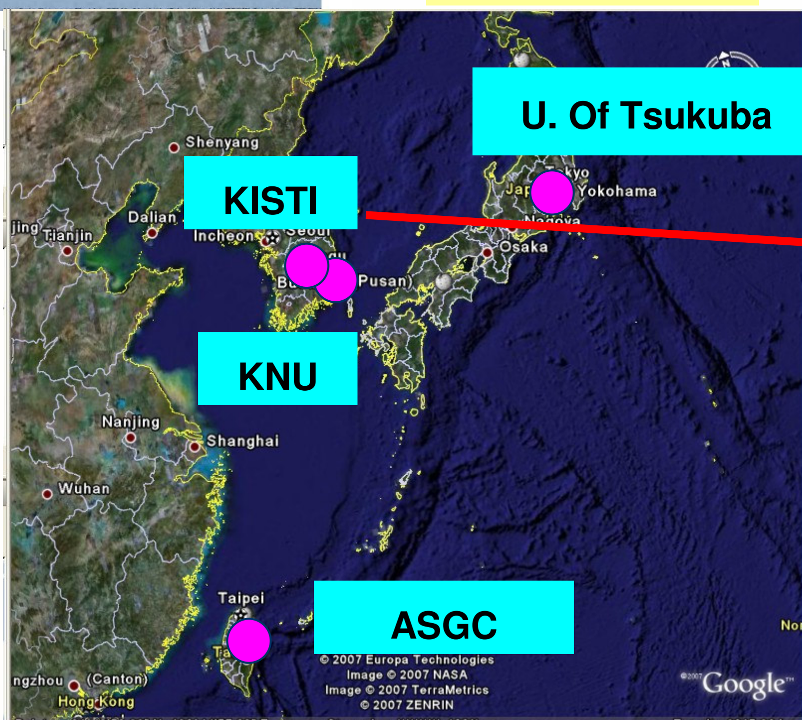
- Pisa, 쯔꾸바대 Remote CO (Consumer Operator) shift room 구축 운영 중
- KISTI도 remote CO shift room 구축 중
- KISTI ordered 10 LCD monitors, 3 servers and webcam, etc.

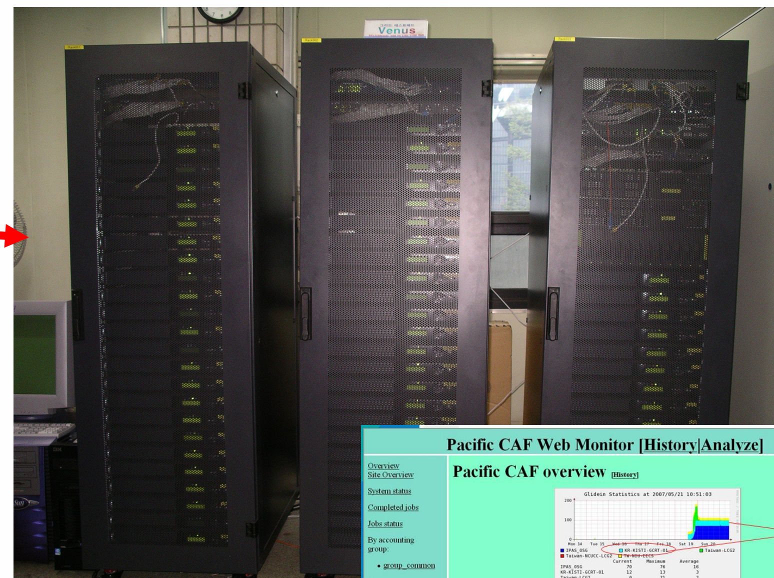
CDF Control Room at Fermilab

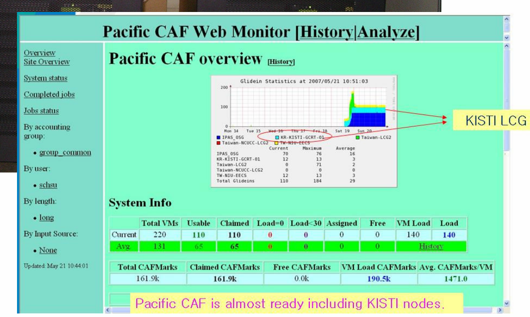
2. Data Processing
– Pacific CAF (CDF Analysis Farm)

- 800 CDF users around world use it.

Pacific CAF







CDF Grid – Outline

CAF
step1(2001~)

Central Analysis Farm :
A large central computing resource based on Linux cluster farms with a simple job management scheme at Fermilab.

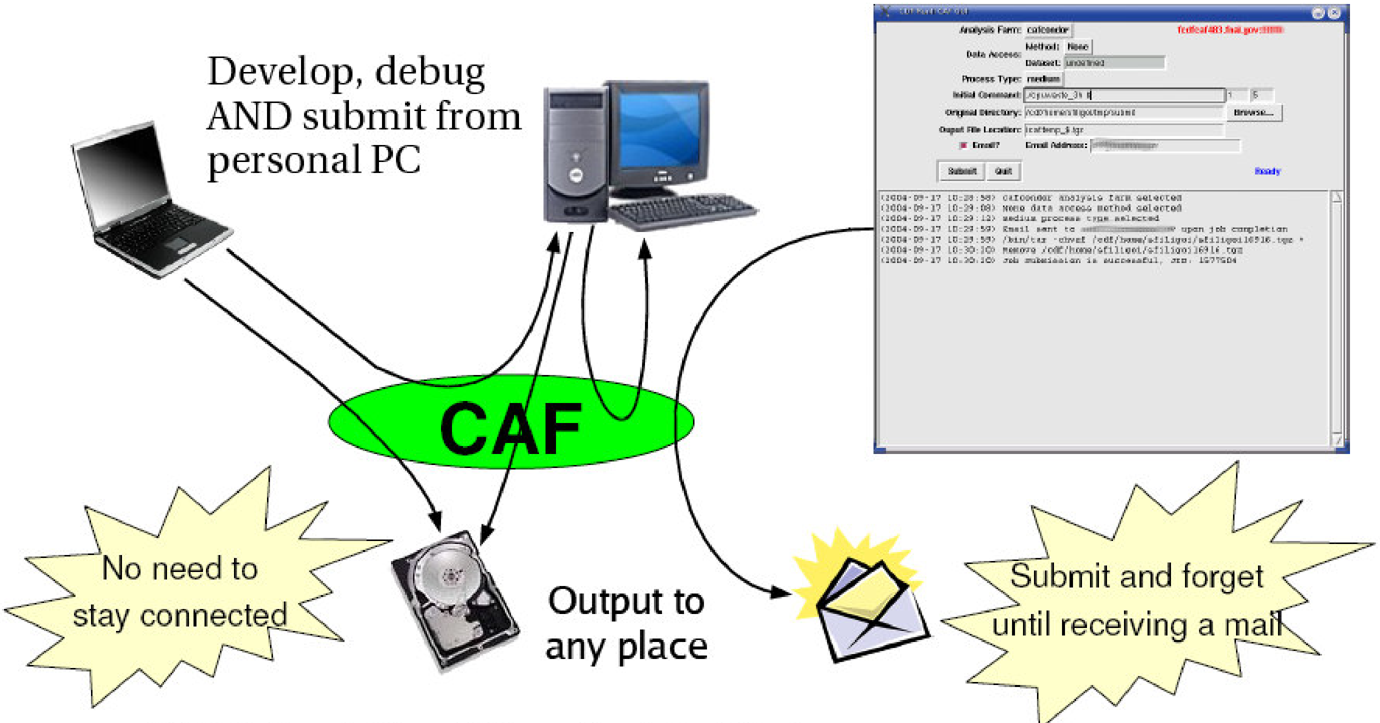
DCAF
step2(2003~)

Decentralized CDF Analysis Farm :
We extended the above model, including its command line interface and GUI, to manage and work with remote resources

Grid
step3(2006~)

We are now in the process of adapting and converting out work flow to the Grid

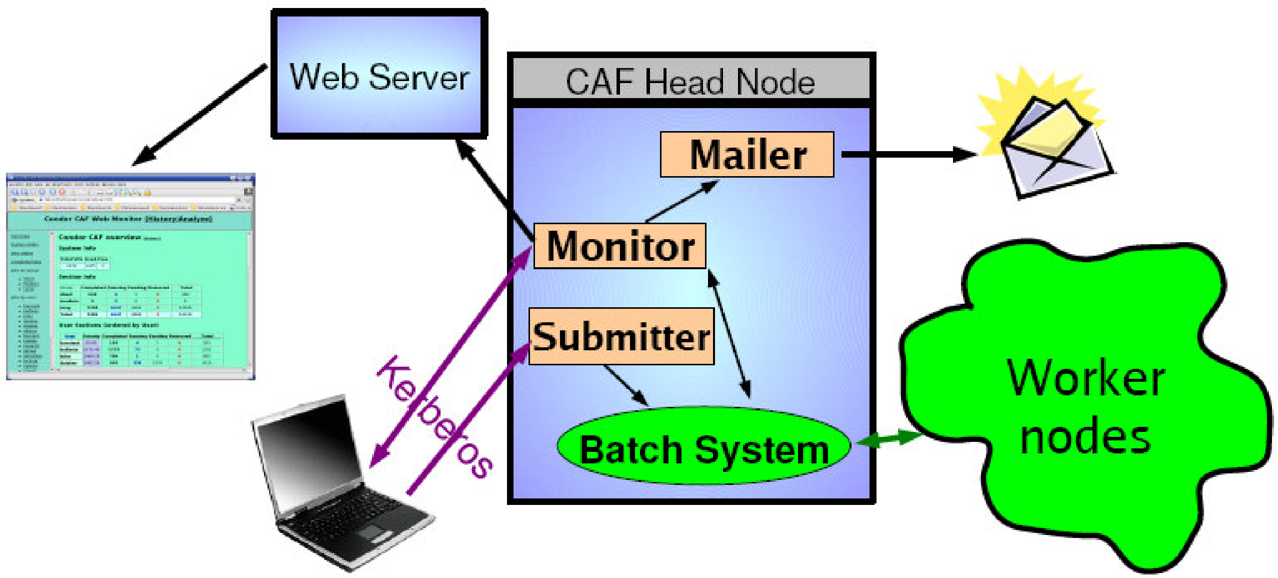
CDF Analysis Farm (CAF)



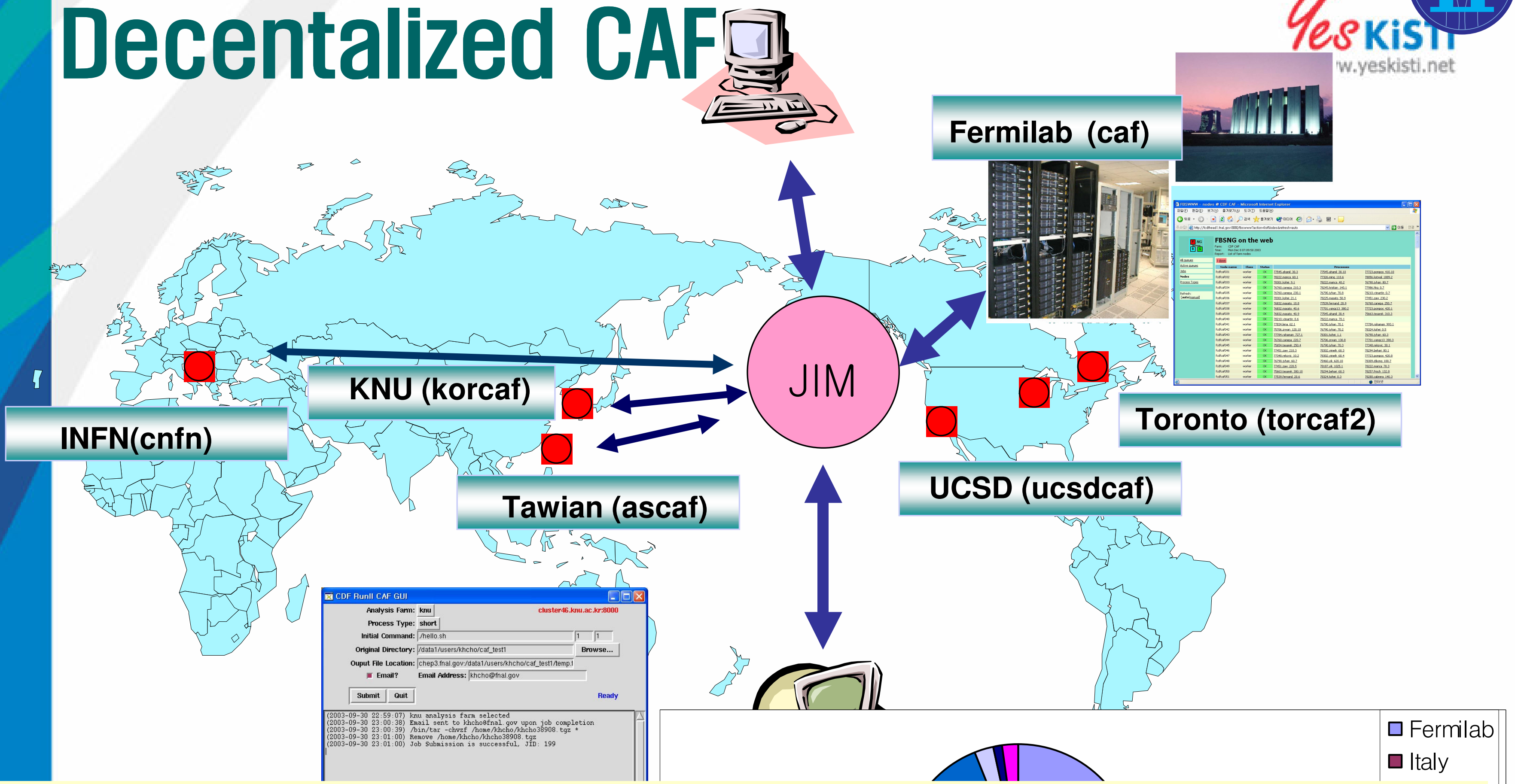
CCP 2006 - Gyeongju, Korea - CDF computing - by Igor Sfiligoi 4

The CAF head node

Just a portal



Decentalized CAF



K. Cho at et al., 9th Int. Conference on Accelerator and Large Experiment Control System Gyeongju, Korea, 374 (2003)

K.Cho et al., Proceedings of Network Research Workshop, The 18th APAN Meetings, Cairns, Australia, vol.1, 233 (2004)

K.Cho, 2nd ICFA workshop on HEP networking, Grids and Digital Divide for Global e-Science (Daegu, 2005) …

Advance to Grid

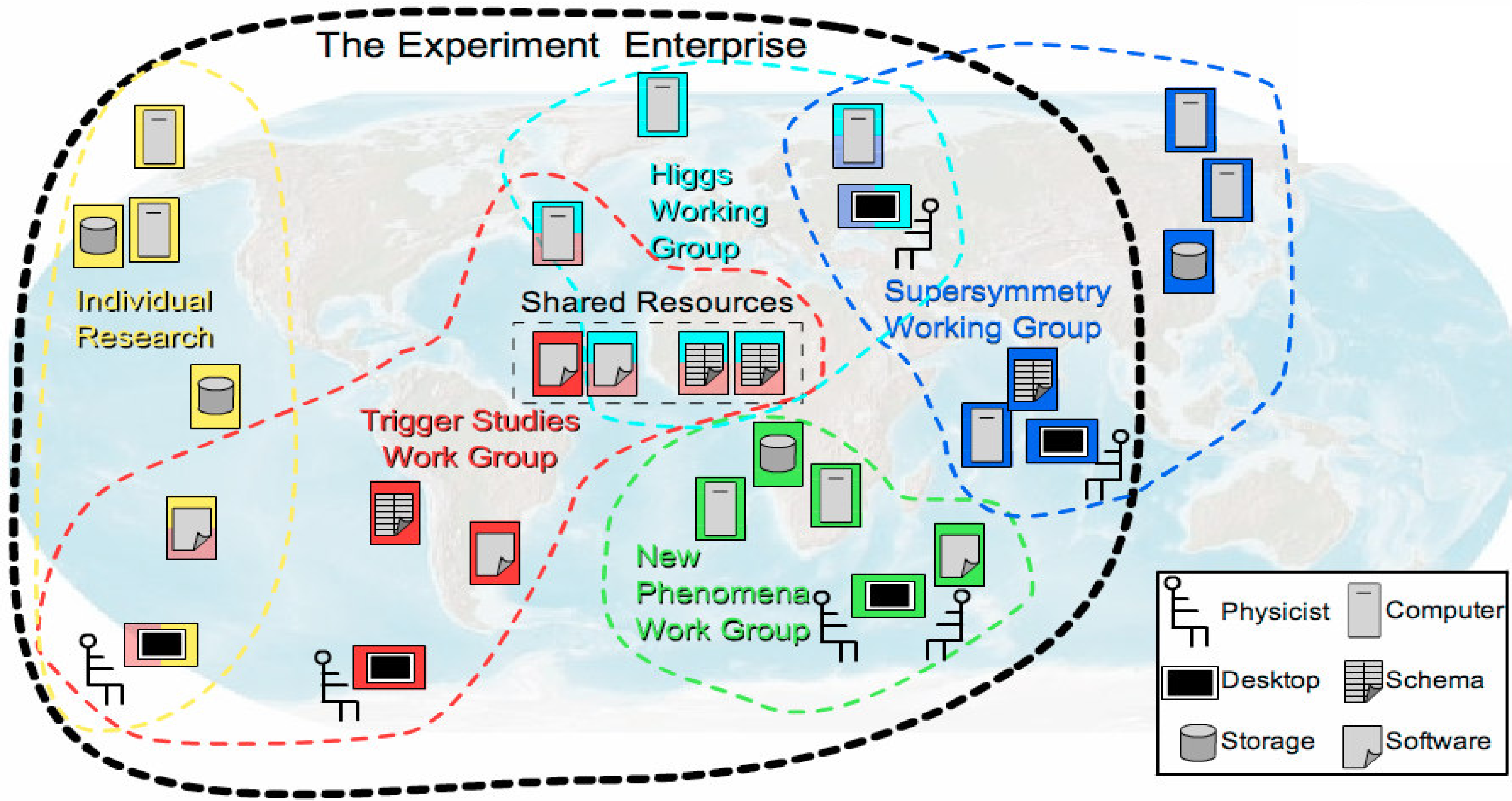
- It is the world wide trend for HEP experiment.
- Need to take advantage of global innovations and resources.
- CDF still has a lot of data to be analyzed.

Cannot continue to expand dedicate resource

USE **Grid**

What is Grid?

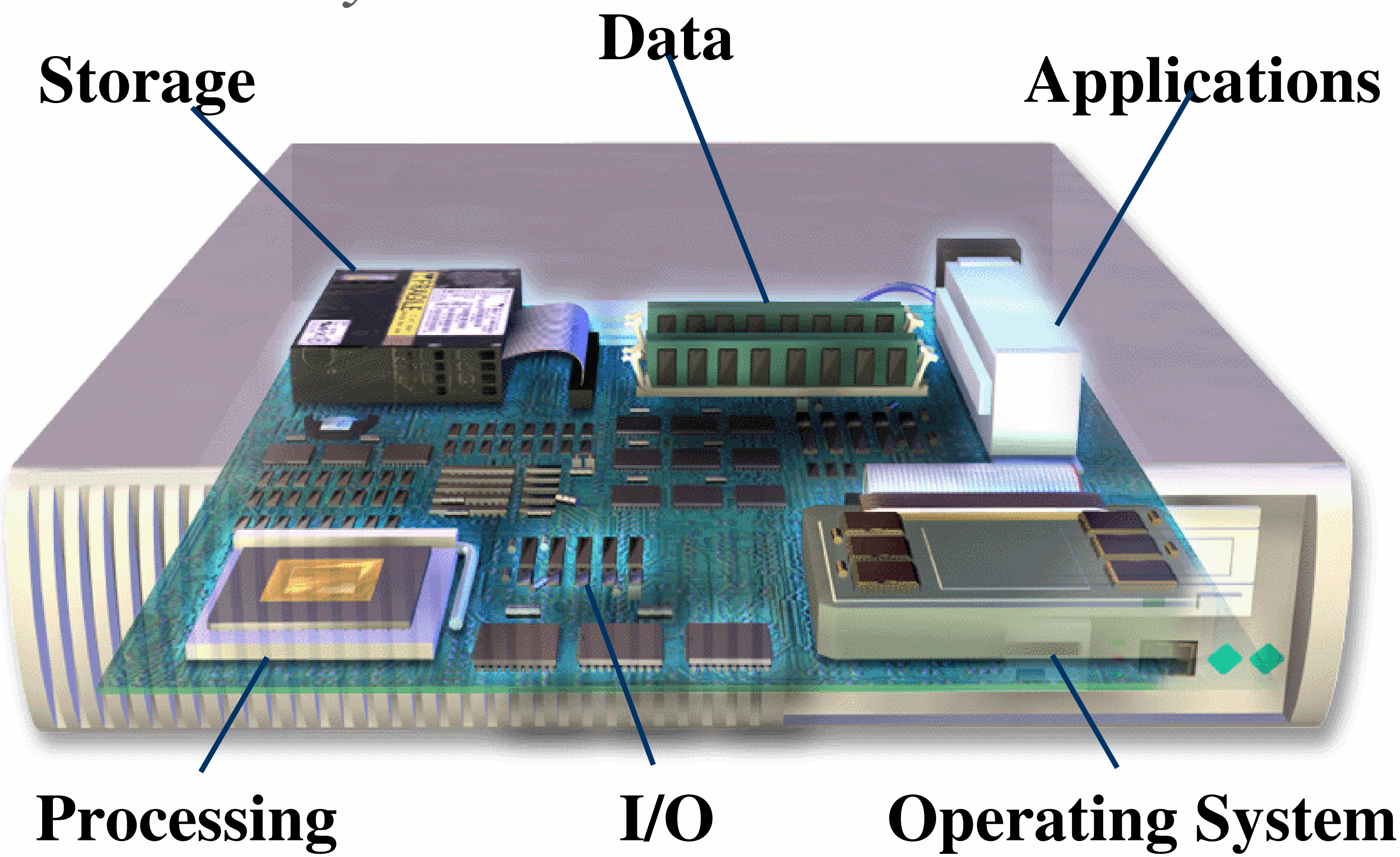
Technologies and infrastructure that support sharing and coordinated use of diverse resources in dynamic, distributed virtual organizations (VO's) – Ian Foster



Ref. Paul Avery

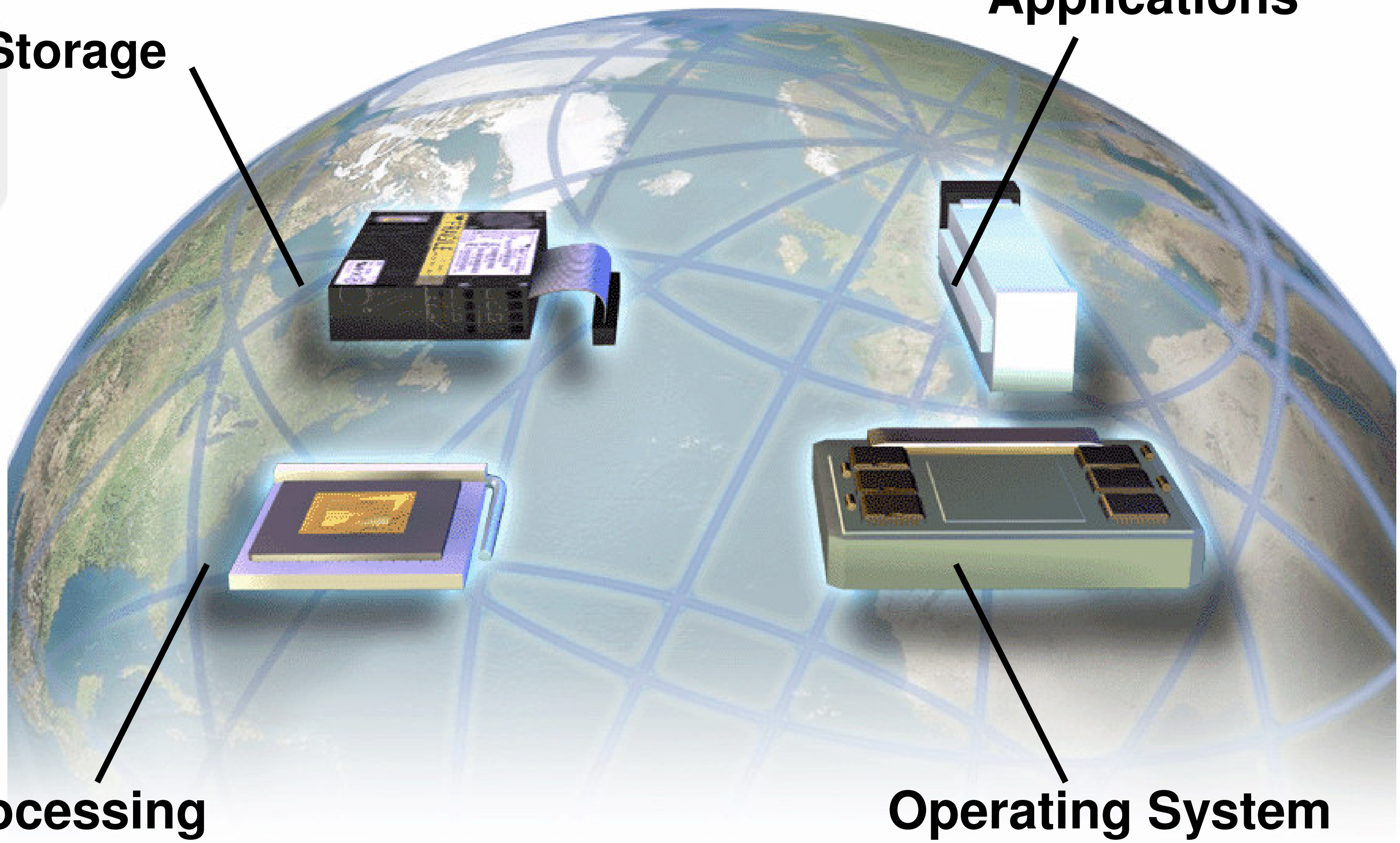
Pre-Internet System

Pre-Internet "System"



Ref. IBM

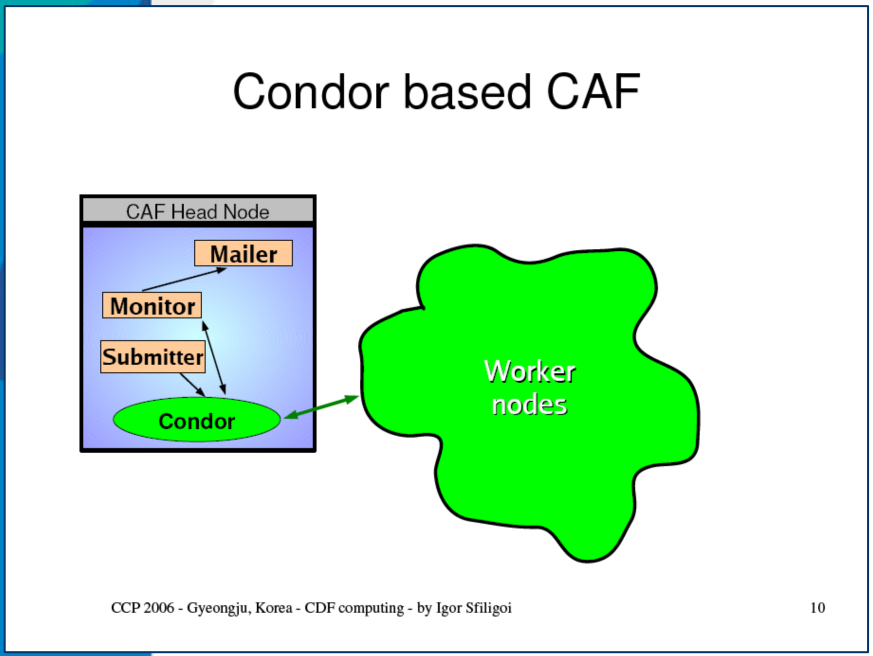
GRID System

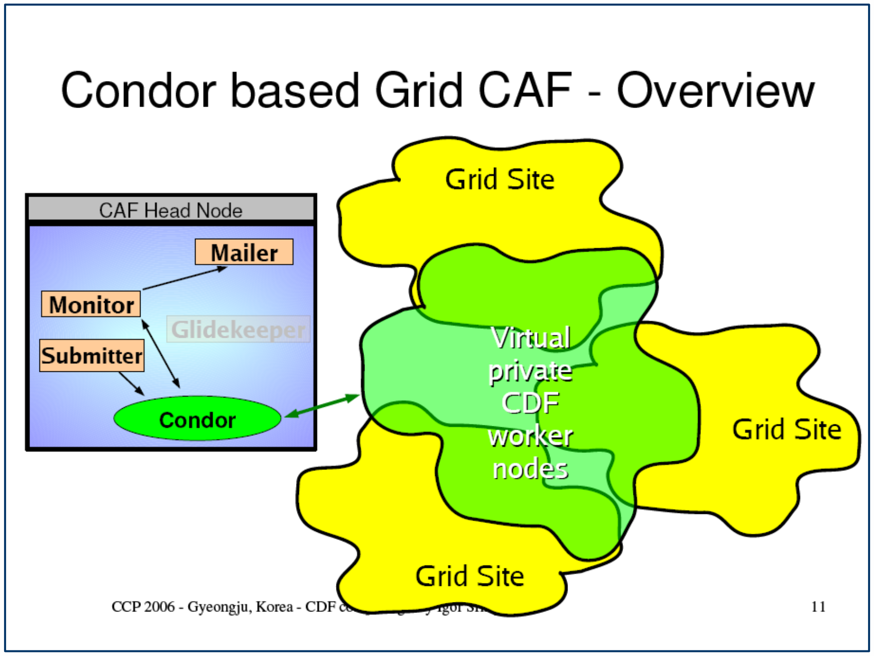


One virtual computing platform, 'limitless' global resources

Ref. IBM

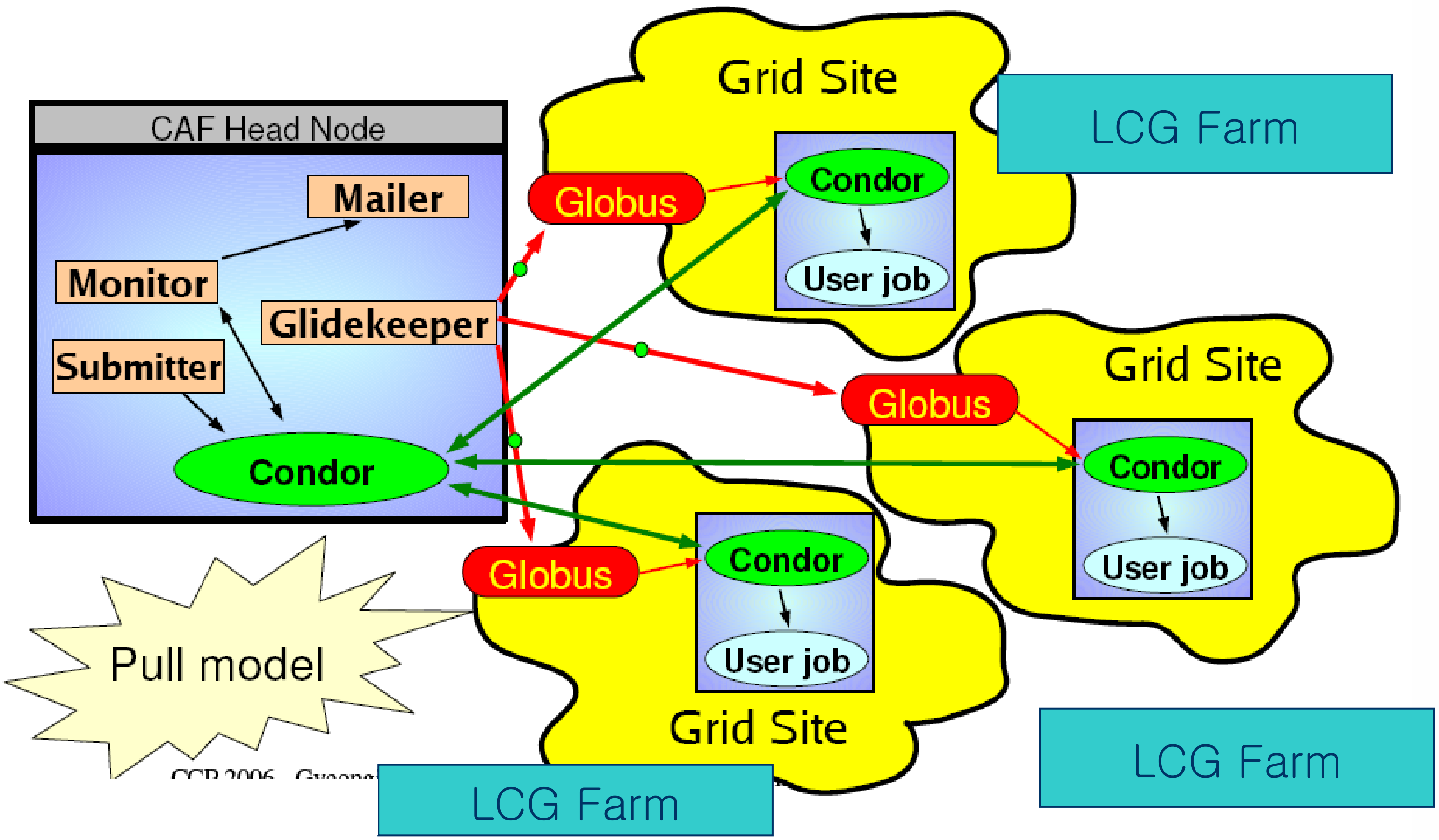
From DCAF
To Condor-based Grid CAF





November 7, 2007

Condor based Grid CAF - Details



CAF (2001~)


CAF
Canada
United States
Mexico
Cuba
Venezuela
Colombia
Brasil
Peru
Bolivia
Chile
Argentina
Greenland
Iceland
Arctic Ocean
North Atlantic Ocean
South Atlantic Ocean
Indian Ocean
Suomi Finland
Sverige
Norge
United Kingdom
Polska
Deutschland
Ukraine
France
Italia
España
Türkiye
Россия
Kazakhstan
Mongolia
China
Iraq
Iran
Afghanistan
Pakistan
India
Myanmar
Thailand
Indonesia
Algeria
Libya
Egypt
Saudi Arabia
Mauritania
Mali
Niger
Chad
Sudan
Nigeria
Ethiopia
DR Congo
Kenya
Tanzania
Angola
Zambia
Namibia
Botswana
Madagascar
South Africa
Aust
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Decentralized CAF [2003~]

Grid CAF [2006~]

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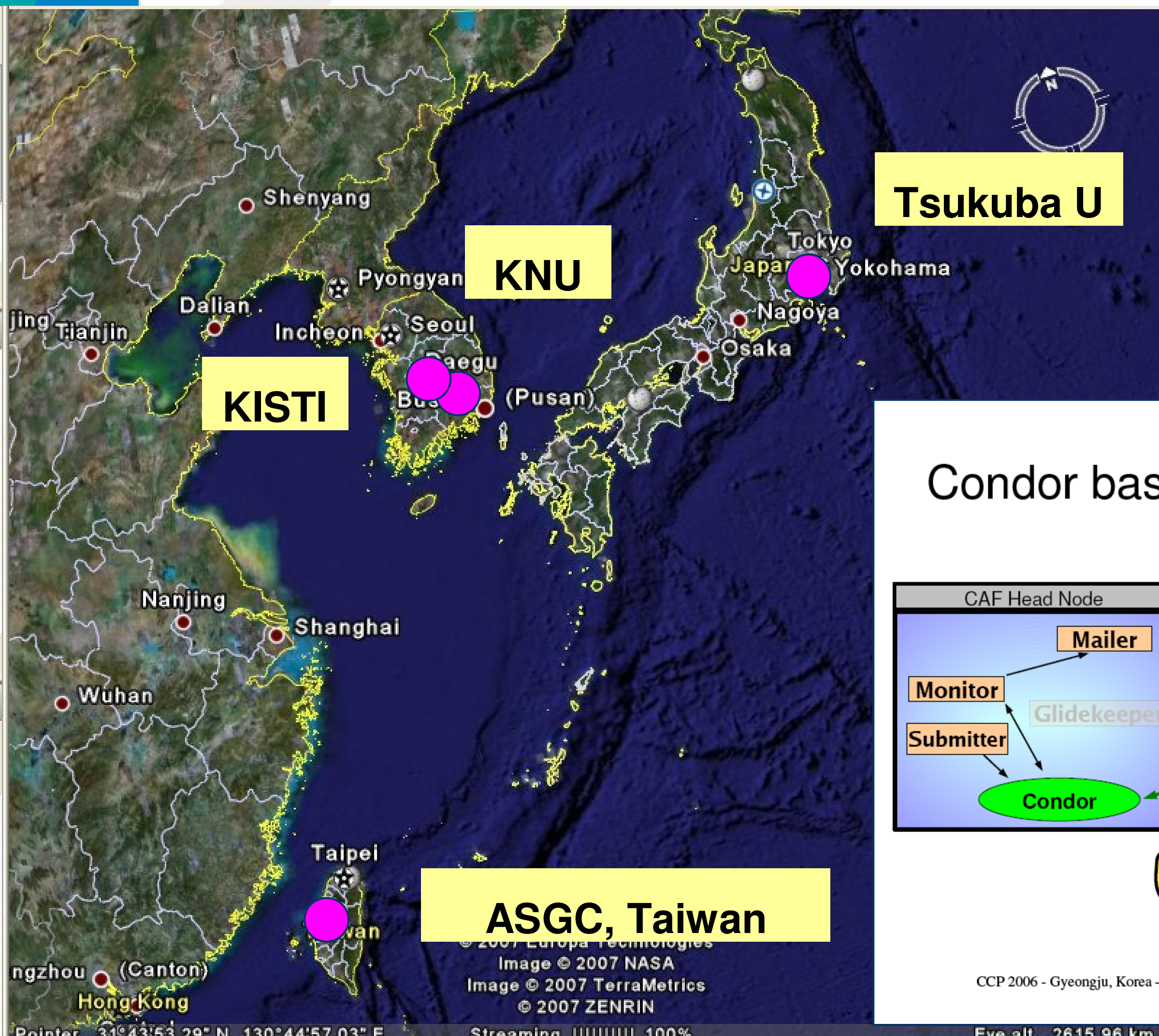
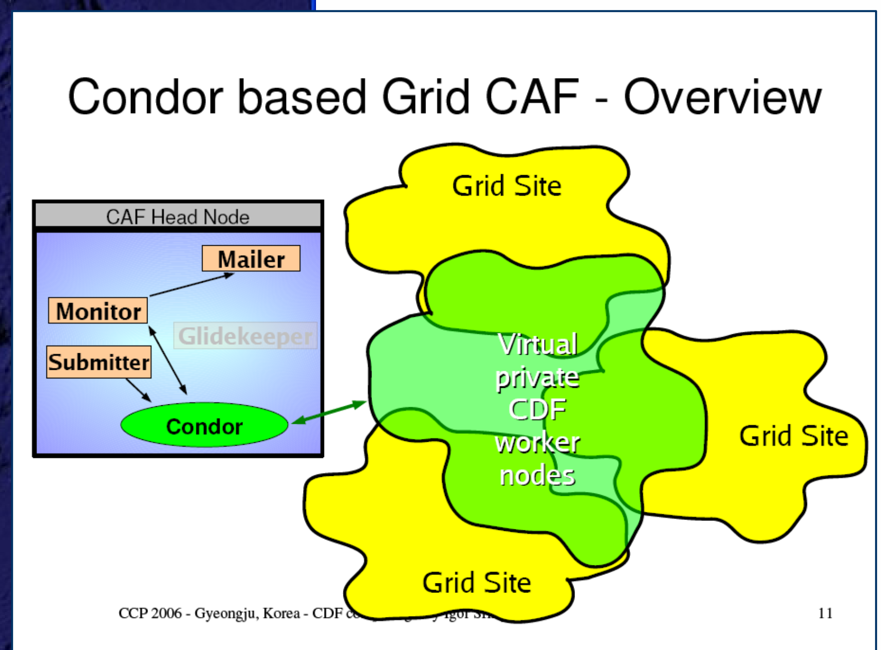
Pacific CAF

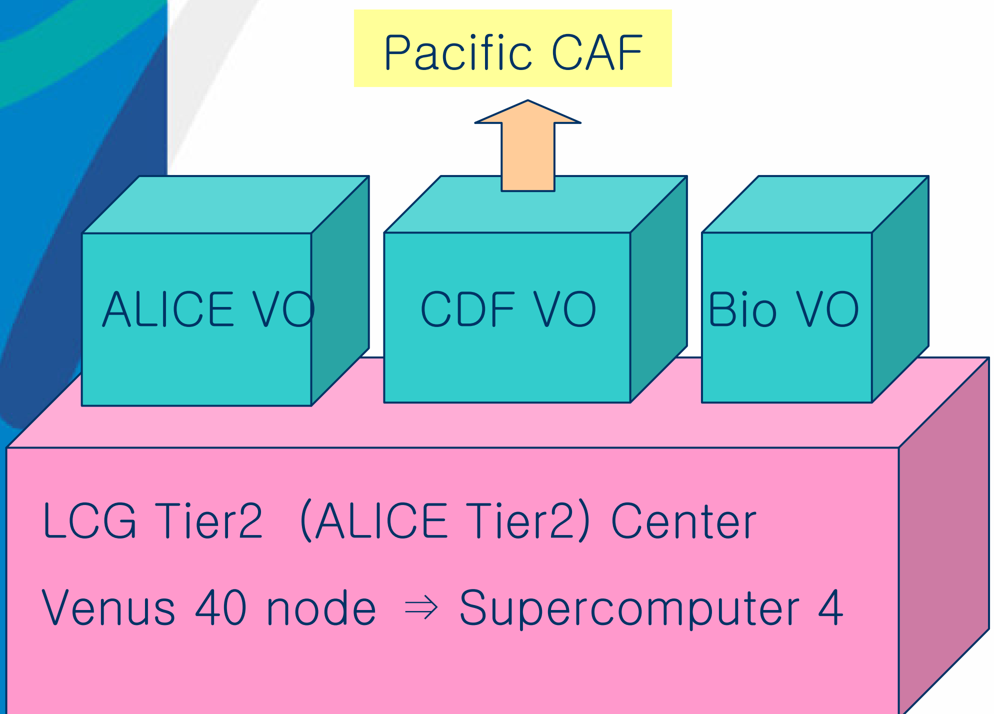


Tsukuba U
KNU
KISTI
ASGC, Taiwan
Shenyang
Pyongyang
Dalian
Tianjin
Incheon
Seoul
Daegu
(Pusan)
Tokyo
Yokohama
Nagoya
Osaka
Nanjing
Shanghai
Wuhan
Taipei
(Canton)
Hong Kong
Image © 2007 NASA
Image © 2007 TerraMetrics
© 2007 ZENRIN
Pointer 31°43'53.29" N 130°44'57.03" E
Streaming ||||||||| 100%
Eye alt 2615.96 km



Condor based Grid CAF - Overview
CAF Head Node
Mailer
Monitor
Glidekeeper
Submitter
Condor
Grid Site
Grid Site
Grid Site
Virtual private CDF worker nodes
11

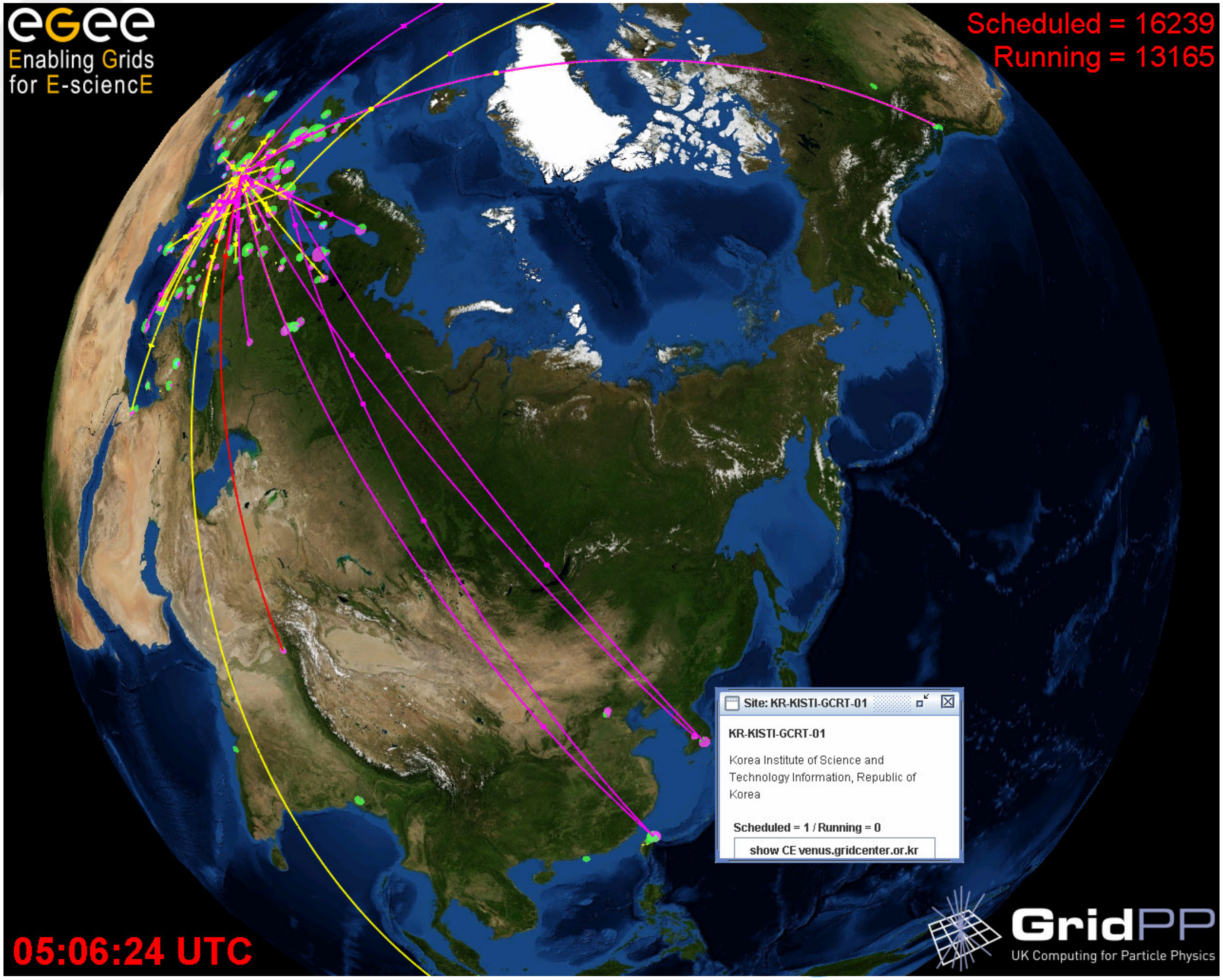
LCG Farm at KISTI: Current



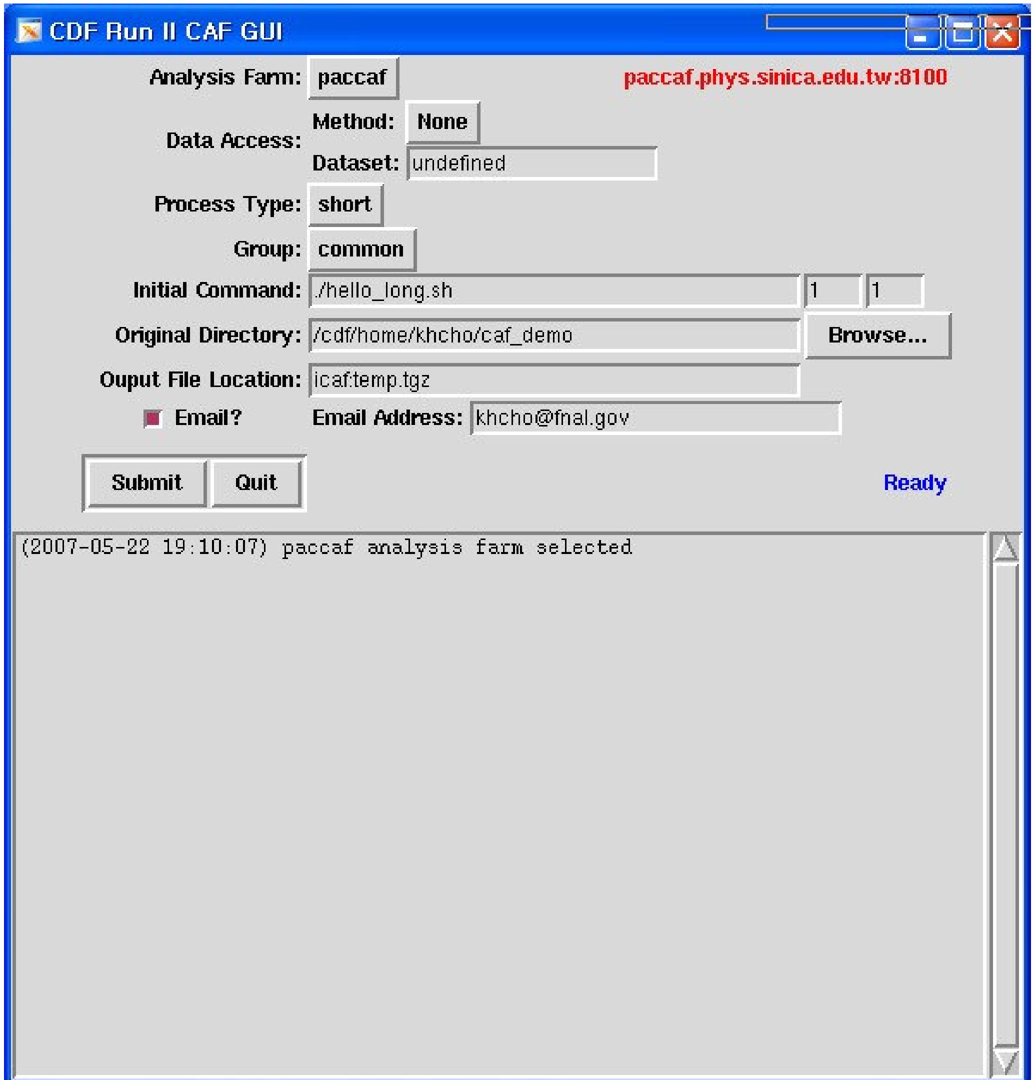
KISTI Testbed Specification

- OS: Scientific Linux 3.0.4
- CPU: Intel® Pentium-IV 2.0GHz
- Memory: 2Gbytge Upgraded
  - Swap Memory: 4GB per all nodes
- Disk: 40GB per all nodes
  - 500GB external storage are shared by CE and all WN as user home directory
- Network: 1Gbit Ethernet

KISTI Farm in LCG Monitoring



Pacific CAF : Submission GUI



Pacific CAF : Monitoring

Yes KISTi www.yeskisti.net

Pacific CAF Web Monitor [History|Analyze]

- Overview
- Site Overview
- System status
- Completed jobs
- Jobs status

By accounting group:

- group_common

By user:

- schsu

By length:

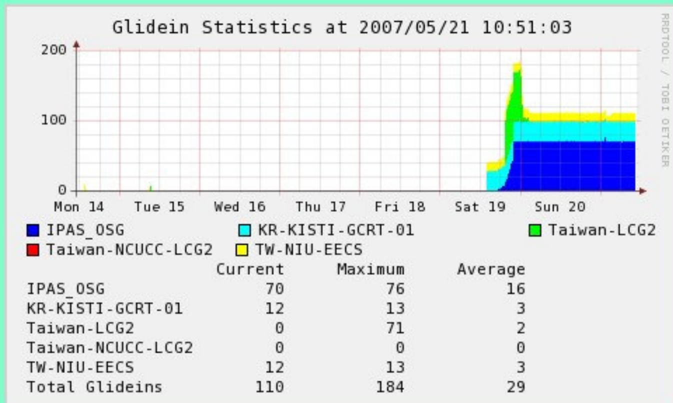
- long

By Input Source:

- None

Updated: May 21 10:44:01

Pacific CAF overview [History]



System Info

	Total VMs	Usable	Claimed	Load=0	Load<30	Assigned	Free	VM Load	Load
Current	220	110	110	0	0	0	0	140	140
Avg.	131	65	65	0	0	0	0	History	

Total CAFMarks	Claimed CAFMarks	Free CAFMarks	VM Load CAFMarks	Avg. CAFMarks/VM
161.9k	161.9k	0.0k	190.5k	1471.0

/hour	Started sections	Finished sections	Submitted jobs	Terminated jobs

‘그리드’ 아시아포털로 육성

과학 한국의 미래
‘영 사이언티스트’

경북대 조 기 현 교수

“그리드(Grid) 기술은 디지털산업 분야에서 일대 혁명을 가져올 뿐 아니라 우주만물을 구성하는 기본 입자의 비밀을 밝혀내는 데 훌륭한 도구가 될 것입니다.”

경북대 고에너지물리연구소의 조기현 교수. 그는 ‘그리드 기술’이 가져올 변화를 이렇게 얘기한다. 그리드는 90년대 중반 시카고대의 이언 포스터 교수가 정립한 개념으로, 남아도는 데이터베이스, 중앙처리장치와 각종 소프트웨어 등을 함께 나눠쓰자는 생각에서 출발했다.

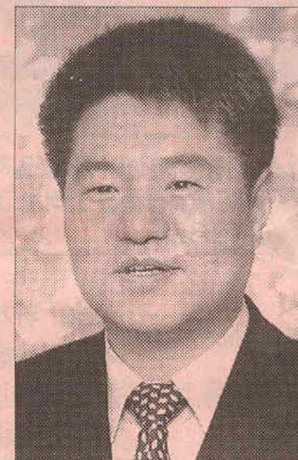
그 원리는 대규모 데이터를 잘게 쪼개 수백, 수천대의 PC에 분산시켜 계산한 뒤 그 결과를 종합하는 것. 즉, 전세계 컴퓨터들을 연결해 강력한 슈퍼컴퓨터의 역할을 할 수 있게 하는 핵심 기술이다.

조 교수가 현재 연구 중인 ‘IT 기반에서의 강입자 충돌 실험’은 이 그리드 기술을 핵심 기반으로 한다.

“강입자 충돌 같은 고에너지물리 실험은 순수 학문에 속하지만 실험결과를 처리하고 분석할 수 있게 해 주는 데이터 그리드 기술은 산업적 측면에서도 파급효과가 엄청날 것입니다.”

국가차원 컴퓨팅·장비 대규모 투자 시급

그리드 기술은 국제적 협력과 공동연구를 필수로 한다. 때문에 그의 연구팀은 26개 미국 대학과 연구소가 미 정부 지원하에 수행 중인 ‘그리드 2003’ 프로젝트와 함께 2007년 유럽입자가속기에서 생산되는 데이터를 분산 처리하는 연구에 참여하고 있다.



“우리의 그리드 개발 기술은 일본 대만 등 경쟁국에 비해 월등합니다. 하지만 대용량 데이터를 처리하는 클러스터 기술에서도 우위를 점하려면 컴퓨팅 시설과 장비에 대한 정부의 대규모 투자가 필요합니다.”

경북대를 글로벌 그리드 체계의 아시아 지역 관문으로 만들겠다는 포부를 갖고 있는 조 교수로선 아직 정부와 기업들의 관심이 부족한 우리 현실이 안타깝기만 하다. 하지만 포스트 인터넷 시대 그리드가 우리 삶을 완전히 바꿔놓을 것이라는 그의 확신에는 변함이 없다. **안현태 기자**/popo@heraldm.com

과기부·과학문화재단 공동기획

3. Data Publication
EVO (Enabling Virtual Organization) system

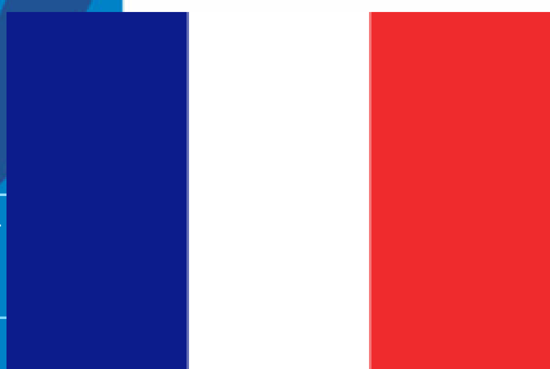
- Have constructed EVO system

⇒ To provide e-Science collaborative research environment

4. Leading community
- France Korea Particle Physics Lab. (LIA)

Contents

- CNRS-KISTI MoU (2007.4.)
- To construct LIA (Laboratory International Associate)
- Particle Physics, bio informatics, Grid Computing



Sharing Techniques

France IN2P3

Grid, e-Science

Korea KISTI

France-Korea e-Science Cooperation

4. Leading Community
– France Korea Particle Physics Lab. (Cont'd)

To collaborate with CNRS/IN2P3 including CDF

	Leading Group	
	France (IN2P3)	Korea (KISTI)
Co-Directors	Vincent Breton, LPC-Clermont Ferrand	Ok-Hwan Byeon, KISTI
ALICE	Pascal Dupieux, LPC-Clemento Ferrand,	Do-Won Kim, Kangnung N. Univ.
ILC Detector R&D	Jean-Claude Brient, LLR-Ecole Polytechnique,	Jongman Yang, Ewha Univ.
BioInformatics	Vincent Breton, LPC-Clermont Ferrand	Doman Kim, Chonnam Univ.
CDF	Aurore Savoy Navarro, LPNHE/IN2P3-CNRS	Kihyeon Cho, KISTI
Grid Computing	Dominique Boutigny, CC-IN2P3	Soonwook Hwang, KISTI

4. Leading Community
– Leading PPNP Community

- Have installed CERN Library etc. on supercomputer
- Have supported KISTI CA
- To allocate network and supercomputer for PPNP community
- Have hosted PPNP (Particle Physics and Nuclear Physics) workshops
  - 11/21/06, 2/26/07, 9/12/07

Summary of e-HEP

CDF 실험의 e-HEP 구축 성과

- 사용자 지원의 우수성
  - CDF실험 연구자 지원 (800 여명, 국내 30여명)

- 국제 협력의 우수성
  - KISTI, 미국 페르미연구소 CDF 실험 국제공동연구 참여 (2007.3)
  - 한(KISTI)-불(CNRS) MoU
  - 프랑스 IN2P3와 CDF 그리드 관련 공동연구
  - 대만, 일본과 Pacific CAF 관련 공동연구

- 기술개발의 우수성
  - CDF Pacific CAF 기술 개발 구축
  - EVO 시스템 국내 최초 유치 서비스 제공

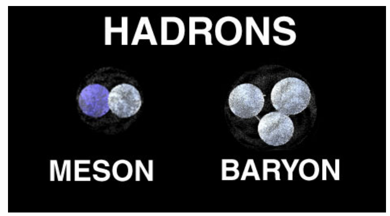
⇒ Heavy Flavor Physics

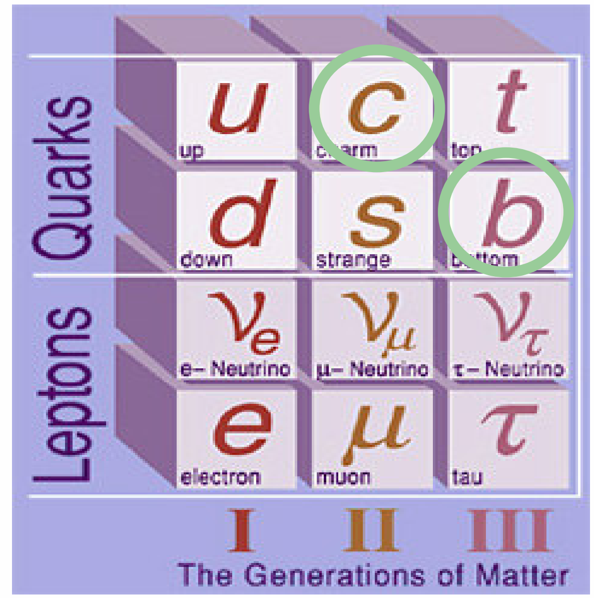
Heavy Flavor Physics

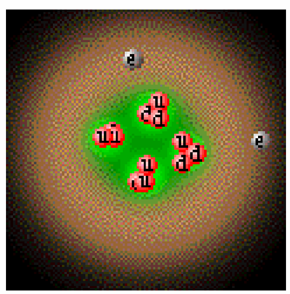
- Standard Model
- My interest in Standard Model
- Heavy Flavor Physics @CDF
  - CP Violation in Bs, Bs mixing, Lifetime difference
  - CP violation D^0, charm mixing
  - $B \rightarrow s l^+ l^-$, $\mu^+ \mu^-$
  - Observation of Ξ_b, Bc, Bs $\rightarrow \psi(2S)\Phi$

Standard Model

- What does world made of?
  - 6 quarks
    - u, d, c, s, t, b
    - Meson (q qbar)
    - Baryon (qqq)
  - 6 leptons
    - e, muon, tau
    - ν_e, ν_μ, ν_τ



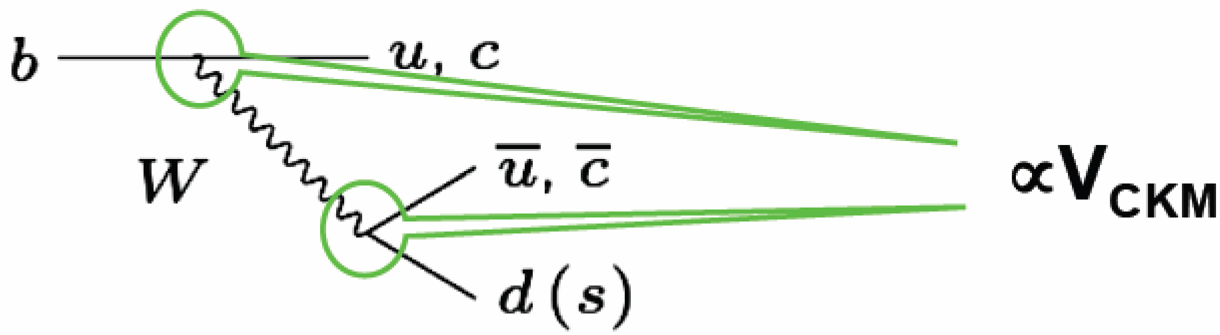




$$\begin{pmatrix} d' \\ s' \\ b' \end{pmatrix} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix} \begin{pmatrix} d \\ s \\ b \end{pmatrix}$$

The CKM matrix

- 3 known generations of quark doublets
  - (u,d),(c,s),(t,b), EM charge (2/3, -1/3)
  - Origin of families unknown in SM
- Only the charged-current EW interaction can change flavor in the SM.
- EW eigenstates are not mass eigenstates.
  - Only SM connection between generations!



The CKM matrix

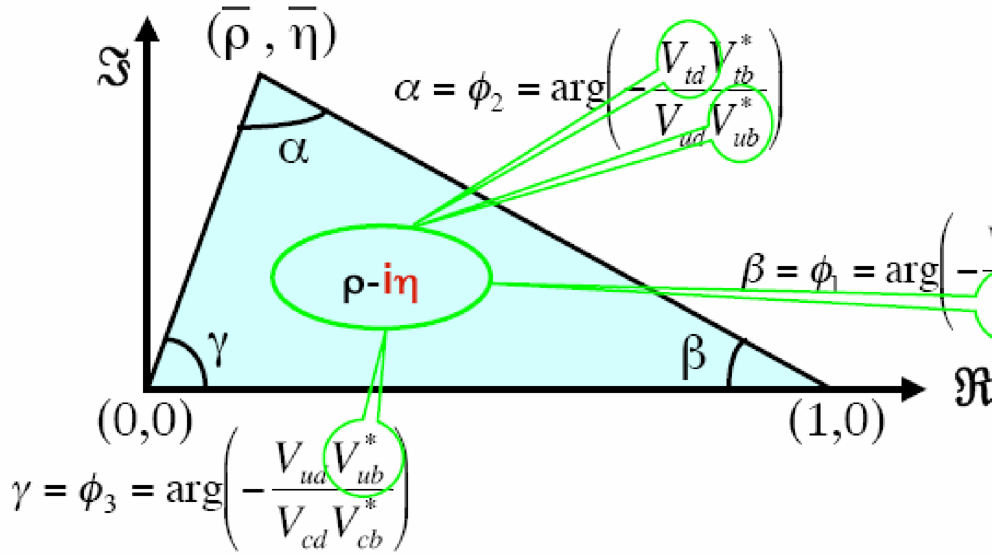
- Relates EW flavor and quark mass eigenstates
  - No prediction of values within SM
- 3 generations, Unitary ⇒ 3 rotations, 1 Phase
  - Non-zero phase implies CPV in flavor transitions
- New Physics (NP) with non-SM flavor couplings would make the CKM description incomplete
  - Eg: 4th generation, SUSY, …

Wolfenstein parameterization

$$V_{CKM} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix} = \begin{pmatrix} 1-\lambda^2 & \lambda & A\lambda^3(\rho-i\eta) \\ -\lambda & 1-\lambda^2/2 & A\lambda^2 \\ A\lambda^3(1-\rho-i\eta) & -A\lambda^2 & 1 \end{pmatrix} + O(\lambda^4)$$

The Unitary Triangles

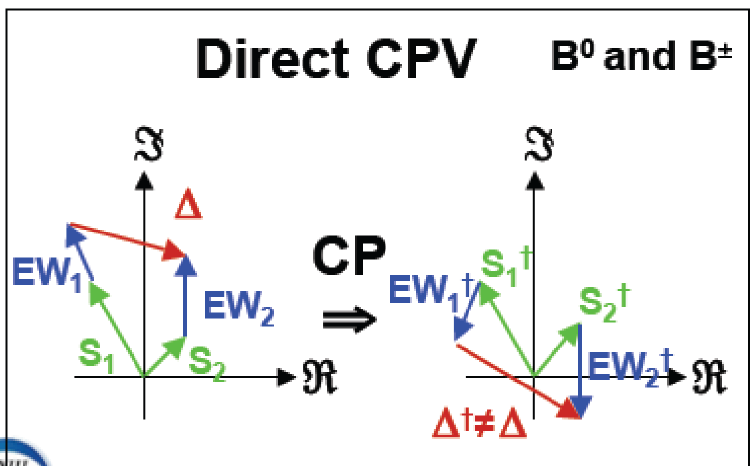
- Graphical expression of unitary condition(s)
  - 1 triagnle has roughly equal-length sides
- CKM unitarity violation would imply New Physics
  - Test SM + CKM by over-constraining angles and sides

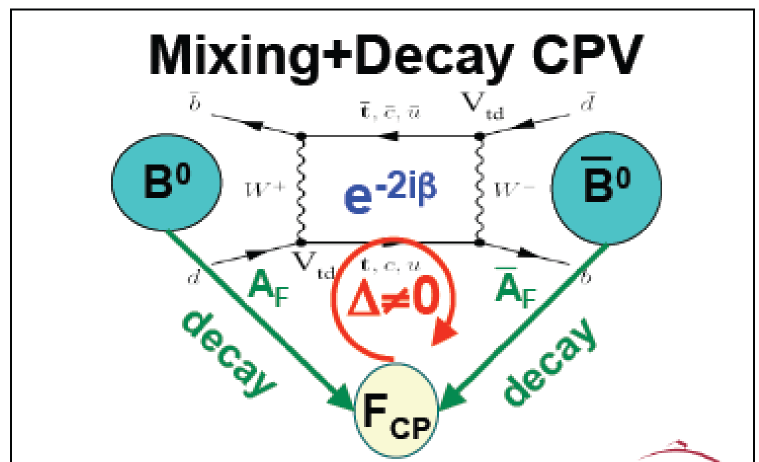


$$\bar\rho + i\bar\eta \equiv -\frac{V_{ud}V_{ub}^*}{V_{cd}V_{cb}^*} = \rho + i\eta + O(\lambda^2)$$

Consequences of CP Violation

- CPV can occur when multiple B→ F amplitudes interfere
  - CPV in decay (direct CPV)
  - CPV in mixing (original CPV seen in Ks, KL)
    - Very small for B system (exp. limit < 10^{-2}, predicted ~10^{3} in SM)
  - CPV in mixing + decay (indirect CPV)
- B system uniquely situated for CPV studies
  - Mixing, long lifetime, large prediction X-section, rich decay set, heavy quarks ⇒ theoretically accessible, …





6 D. Brown, CKM phase and CP Violation in B Decays

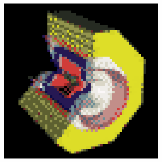
My Interest in Standard Model

- CP Violation on Charm meson
  - 표준모형
    - Cabibbo Suppressed modes : 10^{-3}
    - Cabibbo Favored modes : 0

  ⇒ Percent level at New Physics beyond standard model
- Rare decay modes에 관한 연구 (Charm, B Meson)

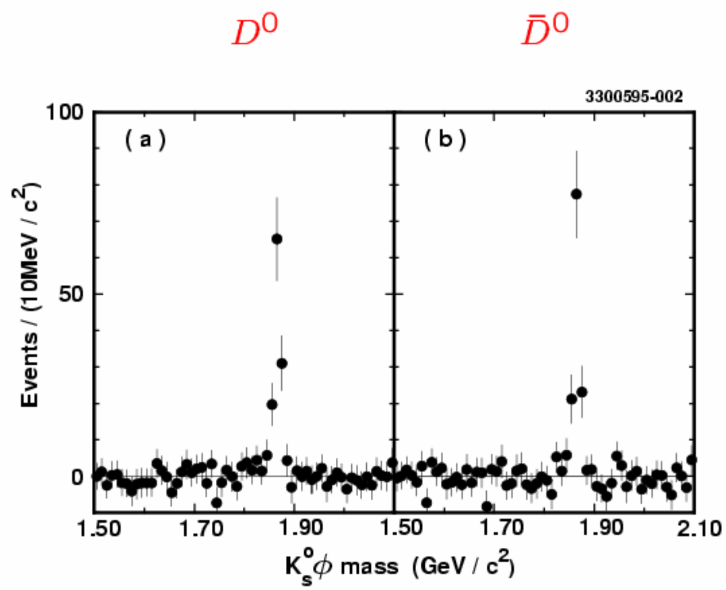
  ⇒ 상호작용의 Mechanism을 이해

by

- e^+e^- 실험 ⇒ CLEO (91-96) 
- Fixed target 실험 ⇒ E687, FOCUS (96-현재)
- Hadron Collider 실험 ⇒ CDF (2001-현재)

Search for CP violation in D^0

[2] $D^0(\bar{D}^0) \rightarrow K_S^0\phi$

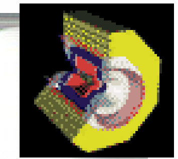


$$A = \frac{\Gamma(D^0) - \Gamma(\bar{D}^0)}{\Gamma(D^0) + \Gamma(\bar{D}^0)},$$

Channel	CP Asymmetry	90% Confidence Range
K^+K^-	0.080 ± 0.061	$-0.020 < A_{KK} < 0.180$
$K_S^0\phi$	-0.028 ± 0.094	$-0.182 < A_{K_S^0\phi} < 0.126$
$K_S^0\pi^0$	-0.018 ± 0.030	$-0.067 < A_{K_S^0\pi^0} < 0.031$

$\Rightarrow$ World's first upper limit

K.Cho et al. Physics Review D52, 4860 (1995)



$K^+\overline{K}^0\pi^+\pi^-$		$(4.0 \pm 0.7) \times 10^{-3}$		678
$K^0K^-\pi^+\pi^+$		$(5.5 \pm 0.8) \times 10^{-3}$		678
$K^*(892)^+\overline{K}^*(892)^0$ $\times$ B$^2(K^*(892)^+ \to K^0\pi^+)$		(1.2 ± 0.5) %		280
$K^0K^-\pi^+\pi^+$(non-$K^{*+}\overline{K}^{*0}$)		$< 7.9 \times 10^{-3}$	CL=90%	678
$K^+K^-\pi^+\pi^+\pi^-$		$(2.5 \pm 1.3) \times 10^{-4}$		600

Fractions of the following modes with resonances have already appeared above as submodes of particular charged-particle modes.

$\phi\pi^+$		$(6.2 \pm 0.6) \times 10^{-3}$		647
$\phi\pi^+\pi^0$		(2.3 ± 1.0) %		619
$\phi\rho^+$		< 1.5 %	CL=90%	258
$K^+\overline{K}^*(892)^0$		$(4.3 \pm 0.6) \times 10^{-3}$		613
$K^*(892)^+\overline{K}^0$		(3.1 ± 1.4) %		611
$K^*(892)^+\overline{K}^*(892)^0$		(2.6 ± 1.1) %		280

Doubly Cabibbo suppressed (*DC*) modes,
$\Delta C = 1$ weak neutral current (*C1*) modes, or
Lepton Family number (*LF*) or Lepton number (*L*) violating modes

$K^+\pi^+\pi^-$	*DC*		$(7.0 \pm 1.5) \times 10^{-4}$		845
$K^+\rho^0$	*DC*		$(2.6 \pm 1.2) \times 10^{-4}$		678
$K^*(892)^0\pi^+$	*DC*	[vv]	$(3.7 \pm 1.7) \times 10^{-4}$		
$K^+\pi^+\pi^-$ nonresonant	*DC*		$(2.5 \pm 1.2) \times 10^{-4}$		
$K^+K^+K^-$	*DC*		$(8.7 \pm 2.1) \times 10^{-5}$		
ϕK^+	*DC*	[vv]	$< 1.3 \times 10^{-4}$	CL=90%	527
$\pi^+e^+e^-$	*C1*		$< 5.2 \times 10^{-5}$	CL=90%	929
$\pi^+\mu^+\mu^-$	*C1*		$< 8.8 \times 10^{-6}$	CL=90%	917
$\rho^+\mu^+\mu^-$	*C1*		$< 5.6 \times 10^{-4}$	CL=90%	757
$K^+e^+e^-$		[ww]	$< 2.0 \times 10^{-4}$	CL=90%	870
$K^+\mu^+\mu^-$		[ww]	$< 9.2 \times 10^{-6}$	CL=90%	856
$\pi^+e^\pm\mu^\mp$	*LF*	[gg]	$< 3.4 \times 10^{-5}$	CL=90%	926
$K^+e^\pm\mu^\mp$	*LF*	[gg]	$< 6.8 \times 10^{-5}$	CL=90%	866
$\pi^-e^+e^+$	*L*		$< 9.6 \times 10^{-5}$	CL=90%	929
$\pi^-\mu^+\mu^+$	*L*		$< 4.8 \times 10^{-6}$	CL=90%	917
$\pi^-e^+\mu^+$	*L*		$< 5.0 \times 10^{-5}$	CL=90%	926
$\rho^-\mu^+\mu^+$	*L*		$< 5.6 \times 10^{-4}$	CL=90%	757
$K^-e^+e^+$	*L*		$< 1.2 \times 10^{-4}$	CL=90%	870
$K^-\mu^+\mu^+$	*L*		$< 1.3 \times 10^{-5}$	CL=90%	856
$K^-e^+\mu^+$	*L*		$< 1.3 \times 10^{-4}$	CL=90%	866
$K^*(892)^-\mu^+\mu^+$	*L*		$< 8.5 \times 10^{-4}$	CL=90%	703

D^0 $\qquad I(J^P) = \frac{1}{2}(0^-)$

Mass $m = 1864.6 \pm 0.5$ MeV (S = 1.1)
$m_{D^\pm} - m_{D^0} = 4.78 \pm 0.10$ MeV (S = 1.1)
Mean life $\tau = (410.3 \pm 1.5) \times 10^{-15}$ s
$c\tau = 123.0\ \mu$m
$|m_{D^0_1} - m_{D^0_2}| < 7 \times 10^{10}\ \hbar\ \mathrm{s}^{-1}$, CL = 95% [xx]
$(\Gamma_{D^0_1} - \Gamma_{D^0_2})/\Gamma = 2y = 0.016 \pm 0.010$
$\Gamma(K^+\ell^-\overline{\nu}_\ell$ (via $\overline{D}^0))/\Gamma(K^-\ell^+\nu_\ell) < 0.005$, CL = 90%
$\Gamma(K^+\pi^-$ (via $\overline{D}^0))/\Gamma(K^-\pi^+) < 4.1 \times 10^{-4}$, CL = 95%

***CP*-violation decay-rate asymmetries**

$A_{CP}(K^+K^-) = 0.005 \pm 0.016$
$A_{CP}(K^0_S K^0_S) = -0.23 \pm 0.19$
$A_{CP}(\pi^+\pi^-) = 0.021 \pm 0.026$
$A_{CP}(\pi^0\pi^0) = 0.00 \pm 0.05$
$A_{CP}(K^0_S\phi) = -0.03 \pm 0.09$
$A_{CP}(K^0_S\pi^0) = 0.001 \pm 0.013$
$A_{CP}(K^\pm\pi^\mp) = 0.08 \pm 0.09$

⇒ 연구결과가 아직 PDG에 게재되어 있음

***CPT*-violation decay-rate asymmetry**

$A_{CPT}(K^\mp\pi^\pm) = 0.008 \pm 0.008$

$\overline{D}^0$ modes are charge conjugates of the modes below.

D^0 DECAY MODES		Fraction (Γ_i/Γ)	Scale factor/ Confidence level	p (MeV/c)
Inclusive modes				
e^+ anything	[yy]	(6.87 ± 0.28) %		–
μ^+ anything		(6.5 ± 0.8) %		–
K^- anything		(53 ± 4) %	S=1.3	–
$\overline{K}^0$ anything + K^0 anything		(42 ± 5) %		–
K^+ anything		$(3.4 ^{+0.6}_{-0.4})$ %		–
η anything	[pp]	< 13 %	CL=90%	–
ϕ anything		(1.7 ± 0.8) %		–
Semileptonic modes				
$K^-\ell^+\nu_\ell$	[qq]	(3.43 ± 0.14) %	S=1.2	867
$K^-e^+\nu_e$		(3.58 ± 0.18) %	S=1.1	867
$K^-\mu^+\nu_\mu$		(3.19 ± 0.17) %		864
$K^-\pi^0e^+\nu_e$		$(1.1 ^{+0.8}_{-0.6})$ %	S=1.6	861

⇒ Particle Physics Booklet (2006)

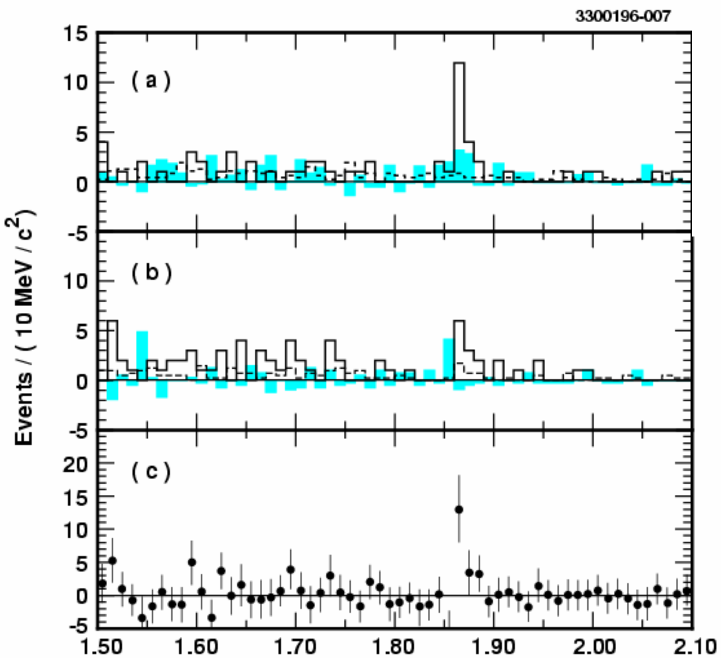
$D^0 \to K \bar{K} X$

- $K_S^0 K_S^0$ part
- Both $D^{*\pm}$ and D^{*0} tags used

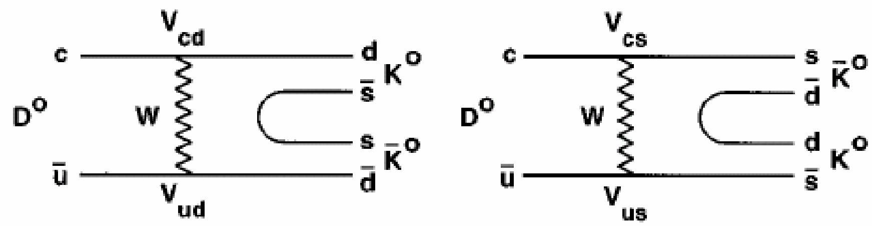
$D^{*\pm}$

D^{*0}

Both



M(KsKs)



Channel	Theory(%)	B(%)	World Average(%)
K^+K^-	0.14∼0.6	0.454±0.028±0.035	0.454±0.029
$K^0\bar{K}^0$	0∼0.3	0.054±0.012±0.010	0.11±0.04
$K_S^0K_S^0K_S^0$		0.074±0.010±0.015	0.086±0.025
$K_S^0K_S^0\pi^0$		<0.059 @90% CL	
$K^+K^-\pi^0$		0.14±0.04	

⇒ World's first upper limit and measurement

- Branching fraction

$$B(K^0\bar{K}^0) = 0.054 \pm 0.012 \pm 0.010\%$$

K.Cho et al., Physics Review D54, 4221 (1996)

⇒ 연구결과가 아직 PDG에 게재되어 있음

$K^0_S K^0_S \pi^0$		$< 5.9 \times 10^{-4}$		740
$K^+K^-\pi^+\pi^-$	[zz]	$(2.49 \pm 0.23) \times 10^{-3}$		677
$\phi\pi^+\pi^- \times B(\phi \to K^+K^-)$		$(5.3 \pm 1.4) \times 10^{-4}$		614
$K^*(892)^0 K^-\pi^+ + c.c.$	[aaa]	$< 5 \times 10$		531
$\times B(K^{*0} \to K^+\pi^-)$				
$K^*(892)^0 \overline{K}^*(892)^0$		$(6 \pm 2) \times 10^{-4}$		272
$\times B^2(K^{*0} \to K^+\pi^-)$				
$K^+K^-\pi^+\pi^-$ nonresonant		$< 8 \times 10^{-4}$	CL=90%	677
$K^0\overline{K}^0\pi^+\pi^-$		$(7.5 \pm 2.9) \times 10^{-3}$		673
$K^+K^-\pi^+\pi^-\pi^0$		$(3.1 \pm 2.0) \times 10^{-3}$		600

Fractions of most of the following modes with resonances have already appeared above as submodes of particular charged-particle modes.

$\overline{K}^*(892)^0 K^0$		$< 1.7 \times 10^{-3}$	CL=90%	608
$K^*(892)^+ K^-$		$(3.8 \pm 0.8) \times 10^{-3}$		610
$K^*(892)^0 \overline{K}^0$		$< 9 \times 10^{-4}$	CL=90%	608
$K^*(892)^- K^+$		$(2.0 \pm 1.1) \times 10^{-3}$		610
$\phi\pi^0$		$(7.5 \pm 0.5) \times 10^{-4}$		645
$\phi\eta$		$(1.4 \pm 0.5) \times 10^{-4}$		489
$\phi\omega$		$< 2.1 \times 10^{-3}$	CL=90%	238
$\phi\pi^+\pi^-$		$(1.06 \pm 0.28) \times 10^{-3}$		614
$\phi\rho^0$		$(5.7 \pm 3.0) \times 10^{-4}$		250
$\phi\pi^+\pi^-$ 3-body		$(7 \pm 5) \times 10^{-4}$		614
$K^*(892)^0 K^-\pi^+ + c.c.$	[aaa]	$< 7 \times 10^{-4}$	CL=90%	531
$K^*(892)^0 \overline{K}^*(892)^0$		$(1.4 \pm 0.5) \times 10^{-3}$		272

Radiative modes

$\rho^0\gamma$	$< 2.4 \times 10^{-4}$	CL=90%	771
$\omega\gamma$	$< 2.4 \times 10^{-4}$	CL=90%	768
$\phi\gamma$	$(2.5 {}^{+0.7}_{-0.6}) \times 10^{-5}$		654
$\overline{K}^*(892)^0\gamma$	$< 7.6 \times 10^{-4}$	CL=90%	719

Doubly Cabibbo suppressed (*DC*) modes, $\Delta C = 2$ forbidden via mixing (*C2M*) modes, $\Delta C = 1$ weak neutral current (*C1*) modes, Lepton Family number (*LF*) violating modes, or Lepton number (*L*) violating modes

$K^+\ell^-\overline{\nu}_\ell$ (via $\overline{D}^0$)	C2M		$< 1.7 \times 10^{-4}$	CL=90%	–
$K^+\pi^-$	DC		$(1.38 \pm 0.11) \times 10^{-4}$		861
$K^+\pi^-$ (via $\overline{D}^0$)	C2M		$< 1.6 \times 10^{-5}$	CL=95%	861
$K^*(892)^+\pi^-$			$(3.0 {}^{+3.8}_{-1.3}) \times 10^{-4}$		711
$K^+\pi^-\pi^0$			$(5.6 \pm 1.7) \times 10^{-4}$		844
$K^+\pi^-\pi^+\pi^-$	DC		$(3.1 \pm 1.0) \times 10^{-4}$		
$K^+\pi^-\pi^+\pi^-$ (via $\overline{D}^0$)	C2M		$< 4 \times 10^{-4}$	CL=90%	

$K^+\pi^-$ or $K^+\pi^-\pi^+\pi^-$ (via $\overline{D}^0$)			$< 1.0 \times 10^{-3}$	CL=90%	–
μ^- anything (via $\overline{D}^0$)	C2M		$< 4 \times 10^{-4}$	CL=90%	–
	C1		$< 2.8 \times 10^{-5}$	CL=90%	932
	C1		$< 6.2 \times 10^{-6}$	CL=90%	932
$\mu^+\mu^-$	C1		$< 4.1 \times 10^{-6}$	CL=90%	926
$\pi^0 e^+e^-$	C1		$< 4.5 \times 10^{-5}$	CL=90%	927
$\pi^0\mu^+\mu^-$	C1		$< 1.8 \times 10^{-4}$	CL=90%	915
ηe^+e^-	C1		$< 1.1 \times 10^{-4}$	CL=90%	852
$\eta\mu^+\mu^-$	C1		$< 5.3 \times 10^{-4}$	CL=90%	838
$\pi^+\pi^- e^+e^-$	C1		$< 3.73 \times 10^{-4}$	CL=90%	922
$\rho^0 e^+e^-$	C1		$< 1.0 \times 10^{-4}$	CL=90%	771
$\pi^+\pi^-\mu^+\mu^-$	C1		$< 3.0 \times 10^{-5}$	CL=90%	894
$\rho^0\mu^+\mu^-$	C1		$< 2.2 \times 10^{-5}$	CL=90%	754
ωe^+e^-	C1		$< 1.8 \times 10^{-4}$	CL=90%	768
$\omega\mu^+\mu^-$	C1		$< 8.3 \times 10^{-4}$	CL=90%	751
$K^-K^+e^+e^-$	C1		$< 3.15 \times 10^{-4}$	CL=90%	791
ϕe^+e^-	C1		$< 5.2 \times 10^{-5}$	CL=90%	654
$K^-K^+\mu^+\mu^-$	C1		$< 3.3 \times 10^{-5}$	CL=90%	710
$\phi\mu^+\mu^-$	C1		$< 3.1 \times 10^{-5}$	CL=90%	631
$\overline{K}^0 e^+e^-$		[ww]	$< 1.1 \times 10^{-4}$	CL=90%	866
$\overline{K}^0\mu^+\mu^-$		[ww]	$< 2.6 \times 10^{-4}$	CL=90%	852
$K^-\pi^+e^+e^-$	C1		$< 3.85 \times 10^{-4}$	CL=90%	861
$\overline{K}^*(892)^0 e^+e^-$		[ww]	$< 4.7 \times 10^{-5}$	CL=90%	719
$K^-\pi^+\mu^+\mu^-$	C1		$< 3.59 \times 10^{-4}$	CL=90%	829
$\overline{K}^*(892)^0\mu^+\mu^-$		[ww]	$< 2.4 \times 10^{-5}$	CL=90%	700
$\pi^+\pi^-\pi^0\mu^+\mu^-$	C1		$< 8.1 \times 10^{-4}$	CL=90%	863
$\mu^\pm e^\mp$	LF	[gg]	$< 8.1 \times 10^{-6}$	CL=90%	929
$\pi^0 e^\pm\mu^\mp$	LF	[gg]	$< 8.6 \times 10^{-5}$	CL=90%	924
$\eta e^\pm\mu^\mp$	LF	[gg]	$< 1.0 \times 10^{-4}$	CL=90%	848
$\pi^+\pi^- e^\pm\mu^\mp$	LF	[gg]	$< 1.5 \times 10^{-5}$	CL=90%	911
$\rho^0 e^\pm\mu^\mp$	LF	[gg]	$< 4.9 \times 10^{-5}$	CL=90%	767
$\omega e^\pm\mu^\mp$	LF	[gg]	$< 1.2 \times 10^{-4}$	CL=90%	764
$K^-K^+e^\pm\mu^\mp$	LF	[gg]	$< 1.8 \times 10^{-4}$	CL=90%	754
$\phi e^\pm\mu^\mp$	LF	[gg]	$< 3.4 \times 10^{-5}$	CL=90%	648
$\overline{K}^0 e^\pm\mu^\mp$	LF	[gg]	$< 1.0 \times 10^{-4}$	CL=90%	862
$K^-\pi^+e^\pm\mu^\mp$	LF	[gg]	$< 5.53 \times 10^{-4}$	CL=90%	848
$\overline{K}^*(892)^0 e^\pm\mu^\mp$	LF	[gg]	$< 8.3 \times 10^{-5}$	CL=90%	714
$\pi^-\pi^- e^+e^+ + c.c.$	L		$< 1.12 \times 10^{-4}$	CL=90%	922
$\pi^-\pi^-\mu^+\mu^+ + c.c.$	L		$< 2.9 \times 10^{-5}$	CL=90%	894
$K^-\pi^- e^+e^+ + c.c.$	L		$< 2.06 \times 10^{-4}$	CL=90%	861
$K^-\pi^-\mu^+\mu^+ + c.c.$	L		$< 3.9 \times 10^{-4}$	CL=90%	829
$K^-K^- e^+e^+ + c.c.$	L		$< 1.52 \times 10^{-4}$	CL=90%	791
$K^-K^-\mu^+\mu^+ + c.c.$	L		$< 9.4 \times 10^{-5}$	CL=90%	710

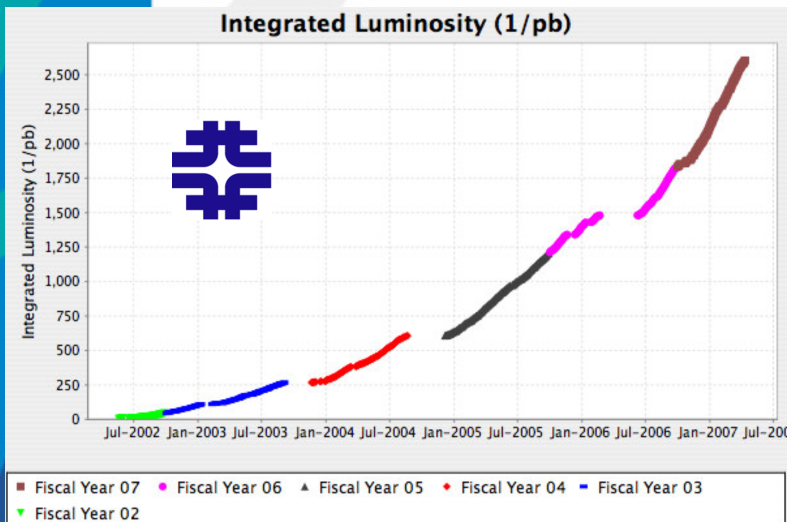
⇒ Particle Physics Booklet (2006)

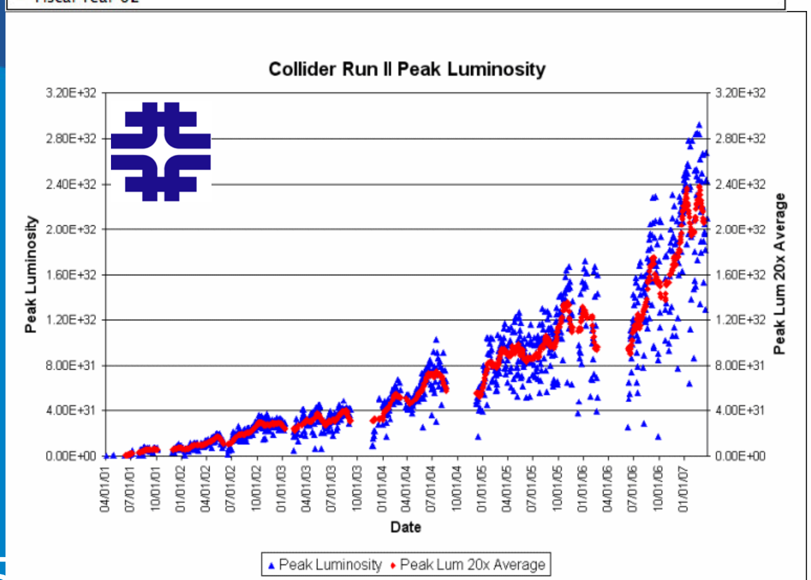
CDF Experiment @KISTI

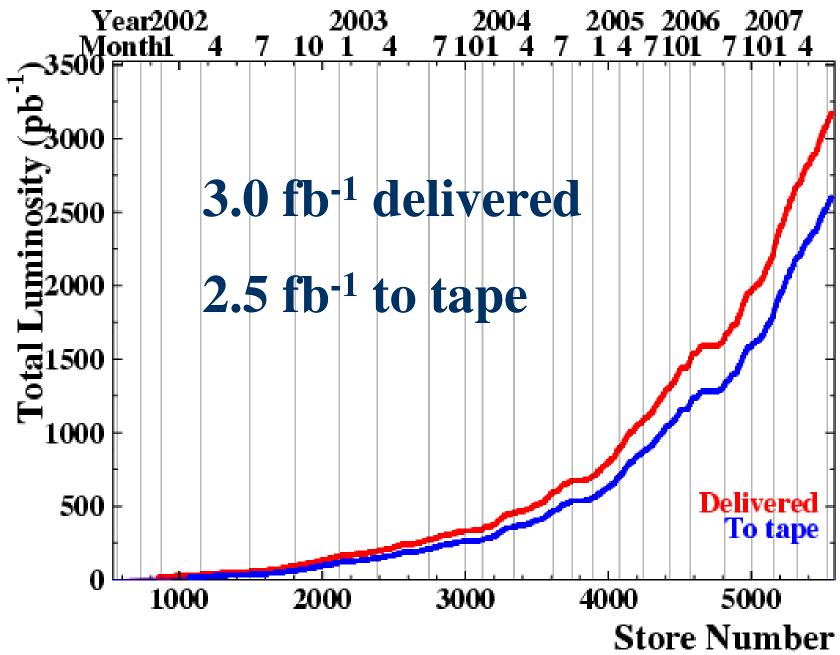
- KISTI-CDF MoU (March 2007)
- Service Job
  - Pacific CAF (CDF Analysis Farm)
  - SAM Data Handling System
  - Remote Control Room
- Physics
  - Heavy Flavor Physics (Bs)
- Authorship since August 2007
- KISTI is working with Yuchul Yang and Dr. Daejung Kong @KNU.

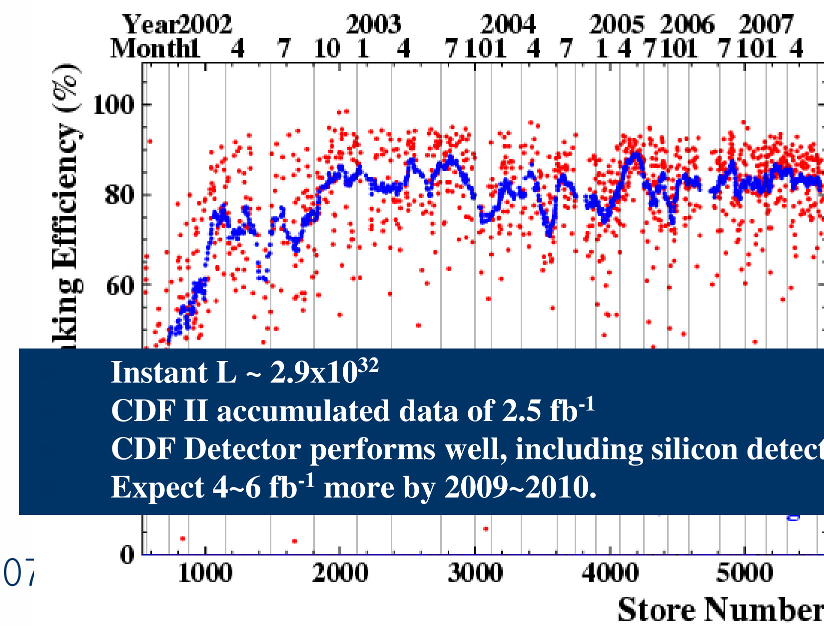
Accelerator & CDF performance

- Accelerator delivers…



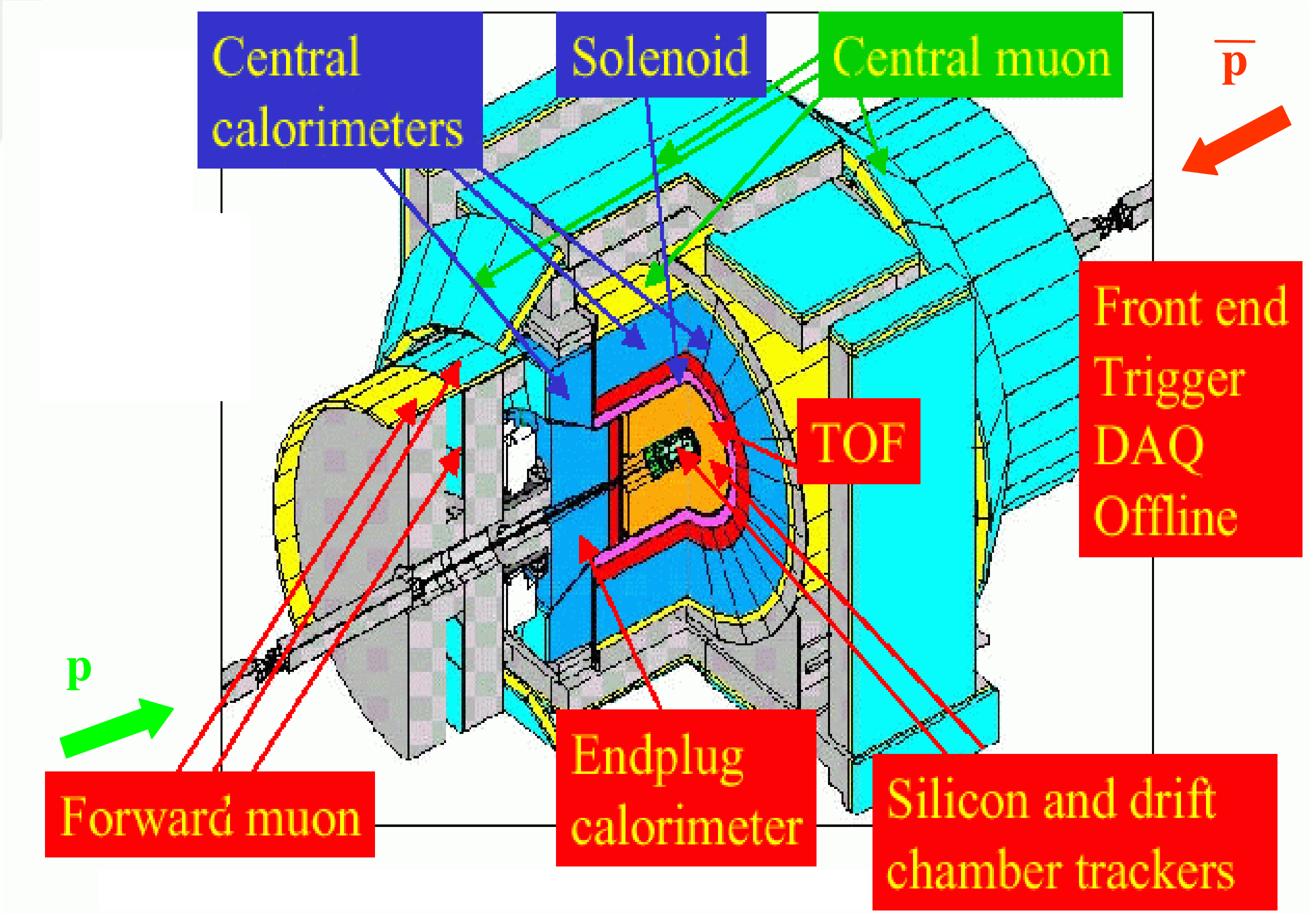






Instant L ~ 2.9×10^{32}
CDF II accumulated data of 2.5 fb^{-1}
CDF Detector performs well, including silicon detectors
Expect 4~6 fb^{-1} more by 2009~2010.

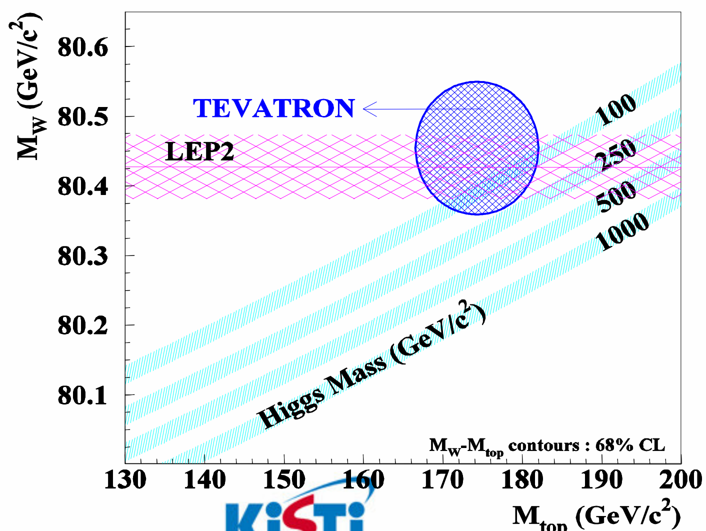
The CDF Detector and Triggers



- $\sigma(b\bar{b}) << \sigma(p\bar{p})$ ⇒ B events are selected with specialised triggers

Hot Physics Programs

- QCD
  - b-bbar dijet production cross section
  - Z+jets cross section measurement
  - Z→ b-bbar
  - Dijet production cross section measurement
- B Physics
  - Spectroscopy
  - Lifetime measurements:
    - B+, B0, Bs and Λ_B
  - Rare decay searches:
    - $B^+ \to \mu^+\mu^- K+$, $B^0 \to \mu^+\mu^- K^*$, $B_s \to \mu^+\mu^- \phi$
    - B→hh
- New Phenomena
  - Search for New Particles Coupling to Z+jets (b'->Z+b)
  - SUSY trilepton combined limit
  - High-mass dielectron (Z' search)
- Top
  - Top mass in all-jets channel
  - Production cross section
  - Search for W' using the single top sample
  - Top Production Mechanism (gg vs qq)
  - Top Charge
- EWK
  - Observation of WZ production
  - Evidence for ZZ production
  - W mass, width
- Higgs
  - H→ττ SUSY Higgs
  - H→WW ME-based analysis
  - ZH→llbb 2D-NN and MET fitter analysis



B physics – The Tevatron is a Full Service of B Factory

Lightest B Mesons

$\bar{b}u$ $\bar{b}d$

B^+ B^0

Antimesons:

$b\bar{u}$ $b\bar{d}$

B^- $\bar{B}^0$

Upsilon:

$b\bar{b}$

Heavier B Mesons

$\bar{b}s$ $\bar{b}c$

B_s B_c

$b\bar{s}$ $b\bar{c}$

$\bar{B}_s$ $\bar{B}_c$

Baryons:

bud

Antibaryons:

$\bar{b}\,\bar{u}\,\bar{d}$

BaBar and Belle energy is too low to make these modes!

B Physics & B Triggers

CDF: $p\bar{p}$ @ $\sqrt{s} = 1.96\,TeV$

b Production cross section: $\sigma(p\bar{p} \to \bar{b}X) = (29.4 \pm 0.6_{(stat)} \pm 6.2_{(sys)})\,\mu b$, |y| < 1
PRD71, 032001 (2005)

Large Cross section !

$\sigma(p\bar{p} \to b\bar{b}) \approx 150\,\mu b$ at 2 TeV (~ 15 kHz!)

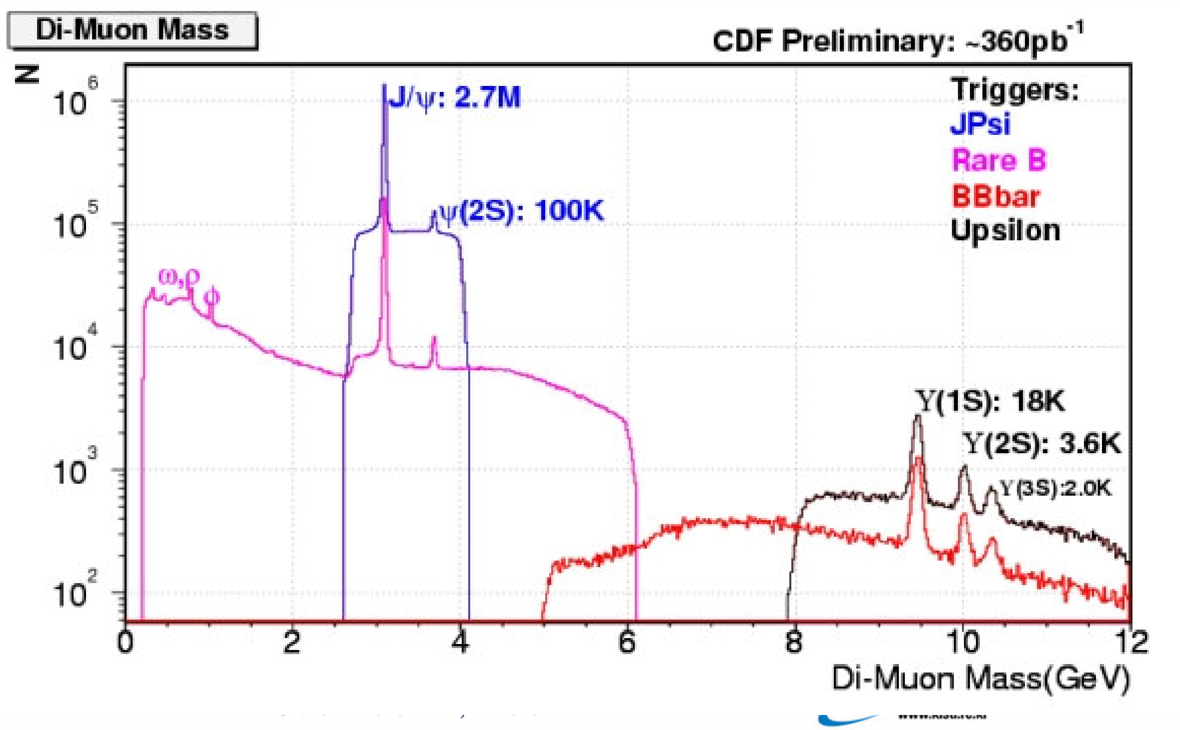
$\sigma(e\bar{e} \to b\bar{b}) \approx 7\,nb$ at Z^0

$\sigma(e\bar{e} \to B\bar{B}) \approx 1\,nb$ at $\Upsilon(4S)$

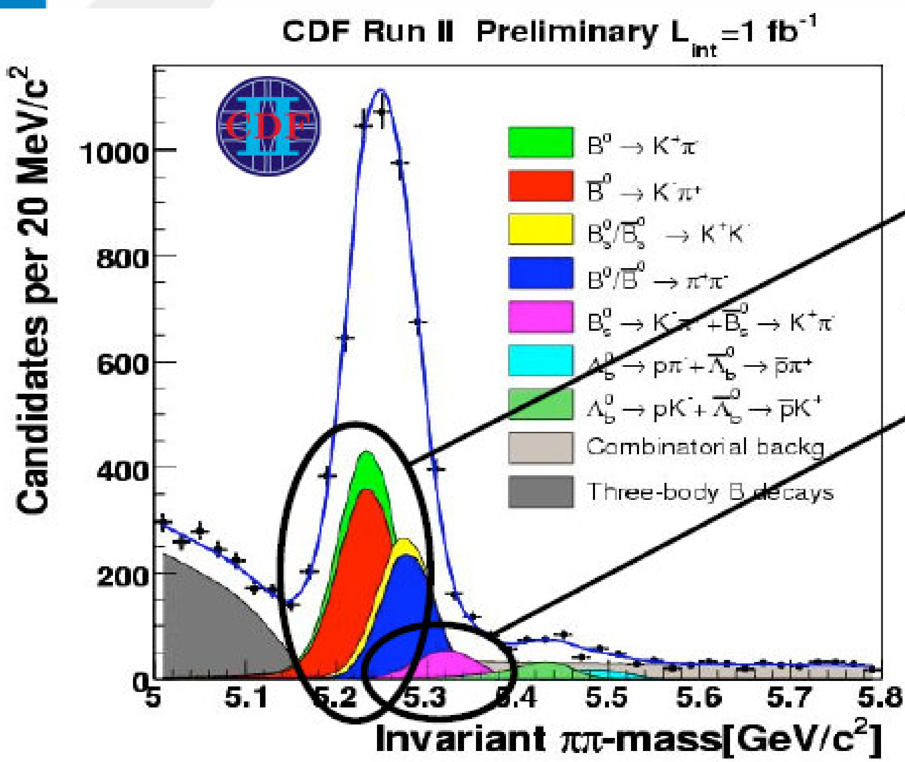
- **Heavy states produced**
  - **B^0, B^+, B_s, B_c, Λ_b, Σ_b, Ξ_b**
- **Di-muon trigger (lifetime, mass, branching ratios, $\Delta\Gamma/\Gamma$)**
  - **$p_T(\mu) > 1.5$ GeV/c, within J/ψ mass window**
- **Two displaced-tracks trigger (branching ratios, mixing)**
  - **$p_T > 2$ GeV/c, 120 μm ≤ d_0 ≤ 1 mm, $L_{xy} > 200$ μm, $\Sigma\, p_T > 5.5$ GeV/c**
- **Lepton + displaced-track trigger (lifetime, f_{baryon} , mixing)**
  - **$p_T(\mu,e) > 4$ GeV/c, 120 μm ≤ d_0 ≤ 1 mm, $p_T > 2$ GeV/c**

Heavy Flavor Physics @ Tevatron

- Tevatron Cross Sections:
  - central (|y|<1) b's at 15kHz
  - central charm at 500 kHz
  - ~$9X10^{10}$ b's already in Run II
  - ~$6X10^{12}$ charm hardons



Direct CP violation in Bs



$A_{K\pi}(B_d)$=-0.086 ± 0.023 ± 0.009

3.5σ significance

$A_{K\pi}(B_s)$=0.39 ± 0.15 ± 0.08

2.3σ significance

Comparing $A_{K\pi}(B_d, B_s)$

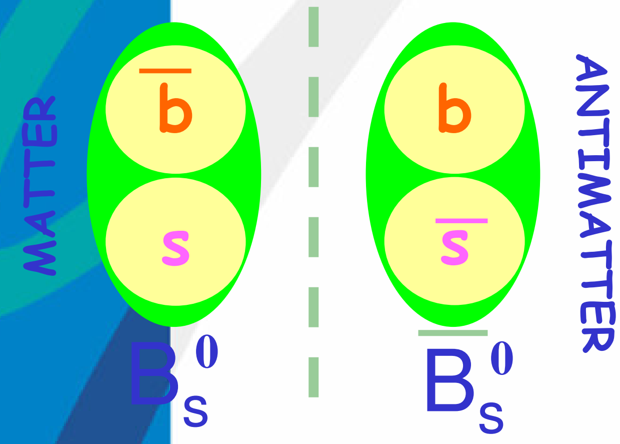
$$\frac{|A(\overline{B}^0 \to K^-\pi^+)|^2 - |A(B^0 \to K^+\pi^-)|^2}{|A(B_s^0 \to K^-\pi^+)|^2 - |A(\overline{B}_s^0 \to K^+\pi^-)|^2} = 0.84 \pm 0.42\ (stat.) \pm 0.15 (sys.)$$

Consistent with SM prediction ≈1.0

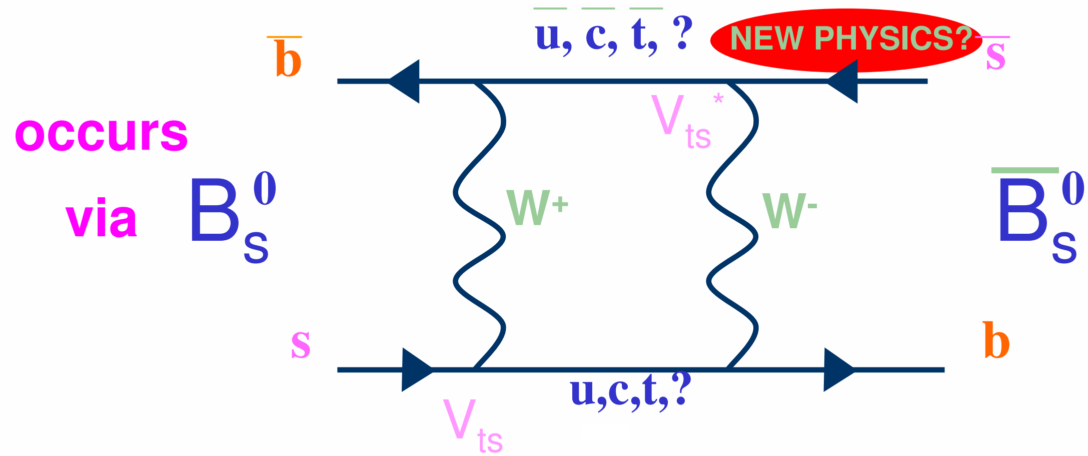
H.J.Lipkin, Phys. Lett. B 621, 126 (2005)

Bs Mixing measurement at CDF

Bound states:



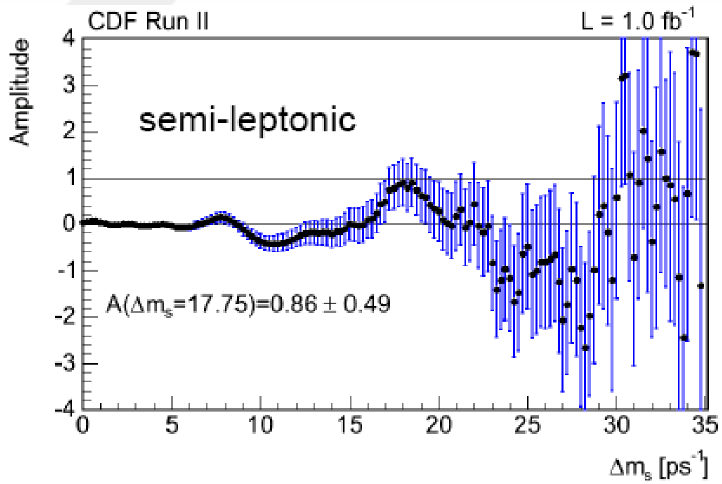
Matter↔antimatter:

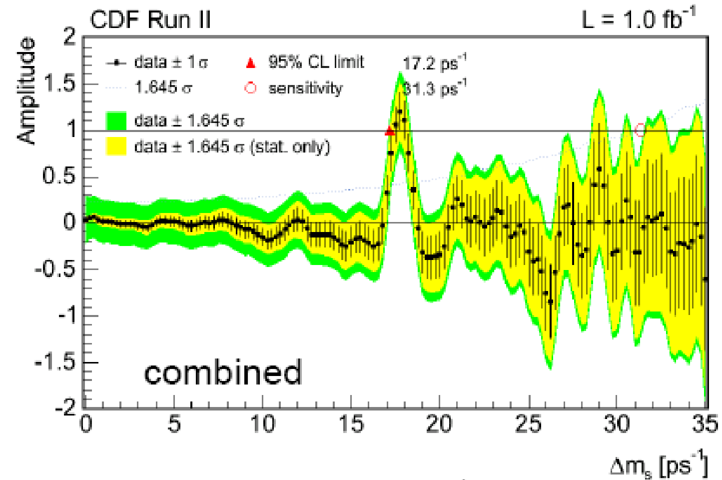


- The mass eigenstates (H and L) are superpositions of B_s^0 and $\bar{B}_s^0$
- System characterised by 4 parameters:
  masses: m_H, m_L lifetimes: Γ_H, Γ_L ($\Gamma = 1/\tau$)
- Δm_s has been measured very precisely
- $\Delta\Gamma$ so far measured imprecisely
- Extra test of Standard Model – new physics can still enter through a phase which can modify $\Delta\Gamma$, test relation between parameters:

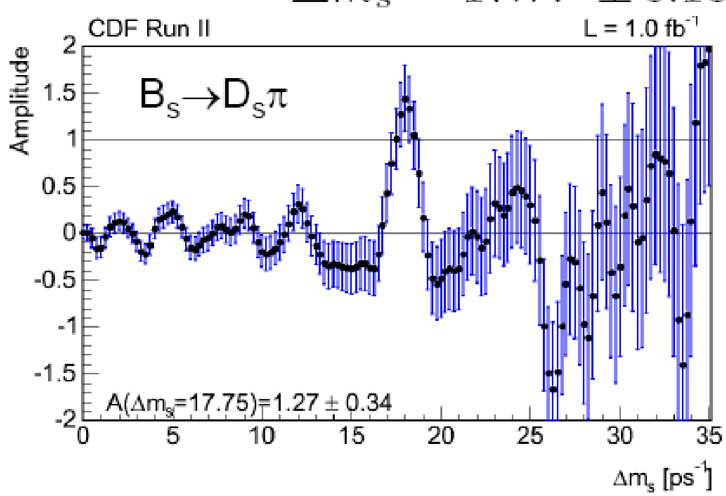
$$\Delta m = \Delta\Gamma \frac{2}{3\pi} \frac{m_t^2}{m_b^2} \left(1 - \frac{8}{3} \frac{m_c^2}{m_b^2}\right)^{-1} h\left(\frac{m_t^2}{M_W^2}\right)$$

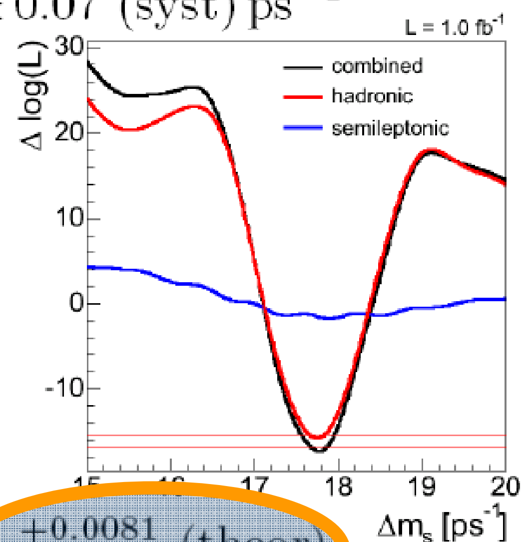
Bs Mixing Results at CDF





$$\Delta m_s = 17.77 \ \pm 0.10 \ (\mathrm{stat}) \ \pm 0.07 \ (\mathrm{syst}) \ \mathrm{ps}^{-1}$$





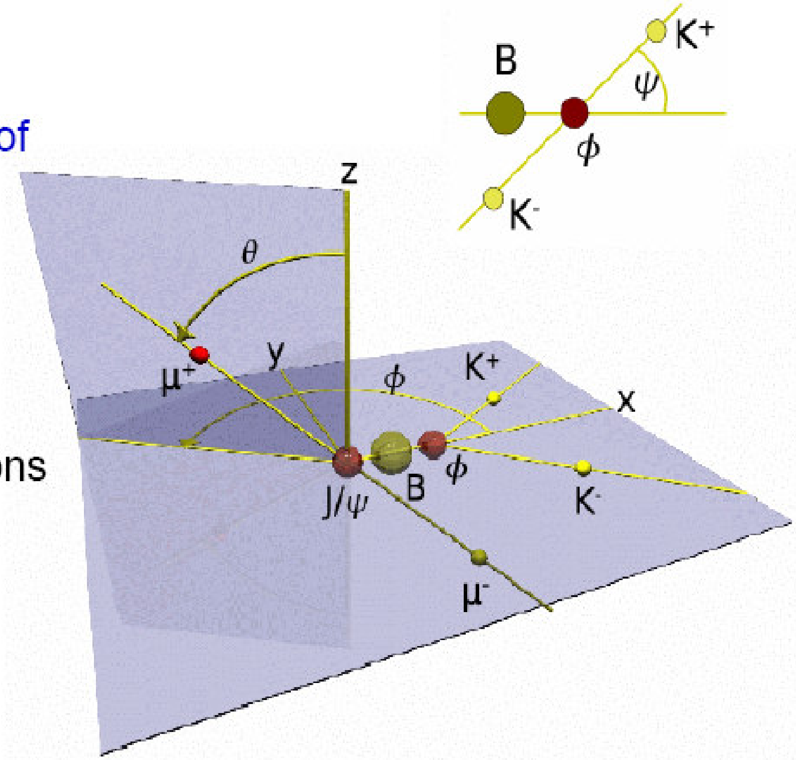
$$|V_{td}/V_{ts}| = 0.2060 \ \pm 0.0007 \ (\mathrm{exp}) \ {}^{+0.0081}_{-0.0060} \ (\mathrm{theor})$$

Theoretical uncertainty ~ 10 x Experimental uncertainty

Lifetime Difference [$\Delta\Gamma_s / \Gamma_s$]

Strategy:

- Choose decay with definite *CP* states: $B_s \rightarrow J/\psi\phi$, $J/\psi \rightarrow \mu^+\mu^-$, $\phi \rightarrow K^+K^-$
  - Vector mesons in final state are CP-odd (L=1) or CP-even (L=0,2)
  - rate depends on relative orientation of meson polarization
    - time-dependent angular distributions allow separation of B_{sL} and B_{sH} components
    - Simultaneous fit to lifetimes, angle space
    - un-tagged measurement
  - modifications of angular distributions due to acceptance effects taken from MC models



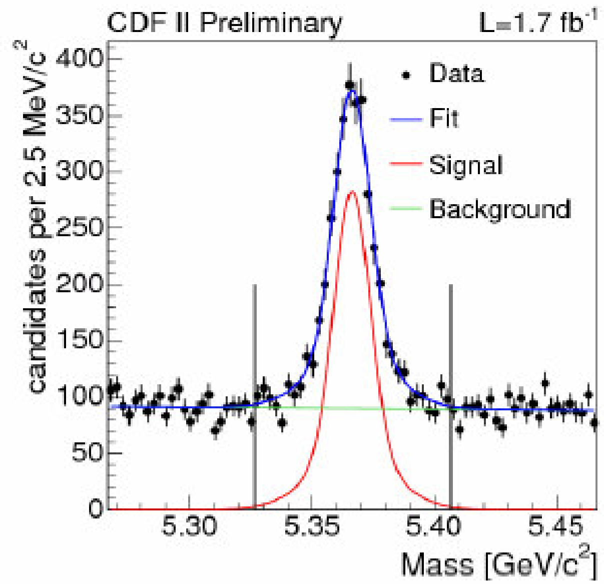
1.7 fb^{-1}

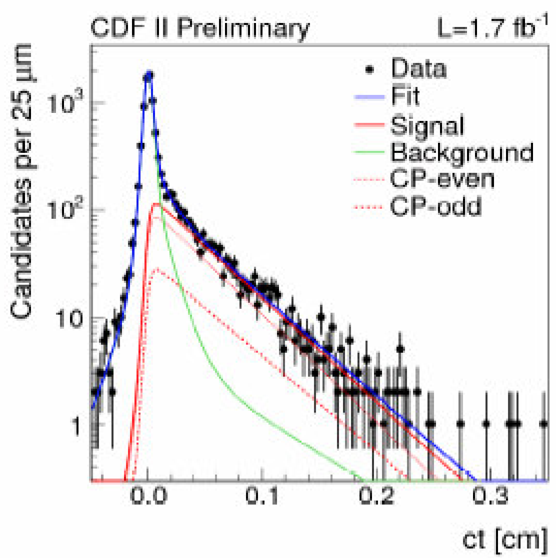
Lifetime Difference (cont'd)

- Standard Model predicts:
  $\Delta\Gamma_s$ ~0.1ps^{-1}, ϕ_s ~0
- Large ϕ_s would indicate new physics

- Separation of B_{sL}(CP even) and B_{sH}(CP odd) states by angular analysis of $B_s \rightarrow J/\psi\ \phi$

- Perform simultaneous mass, lifetime, angular fit

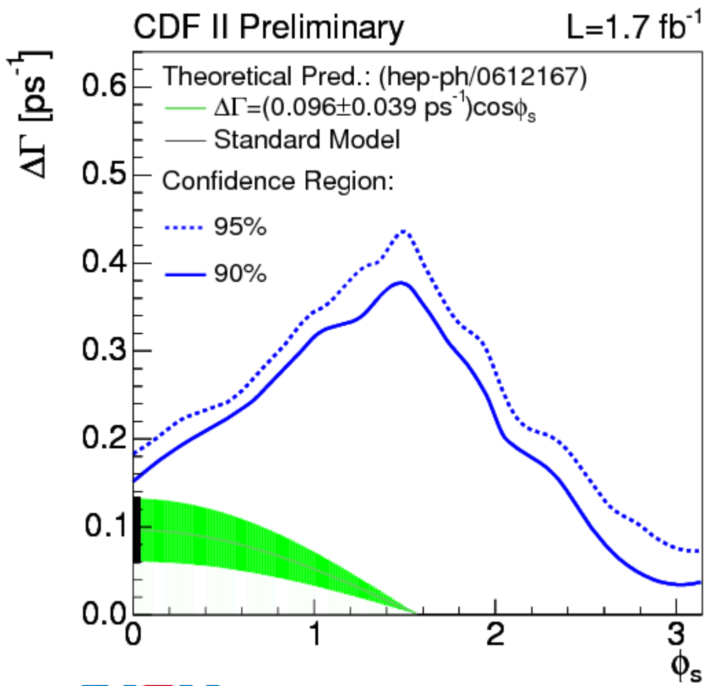




Lifetime Difference (cont'd)

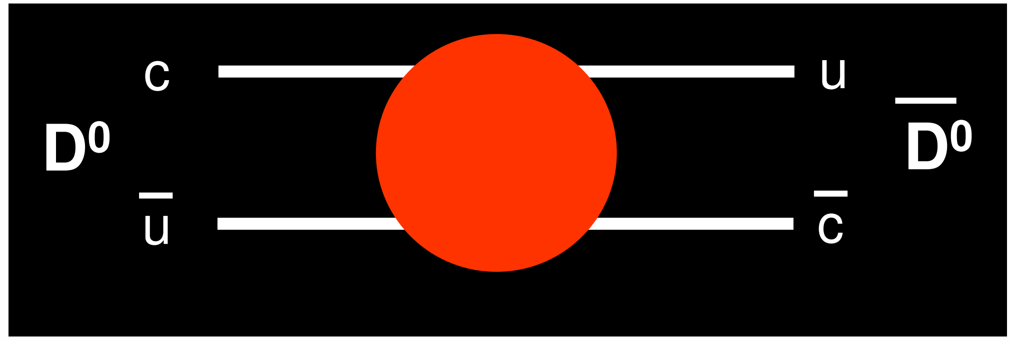
- Assuming no CP violation:
  - $\Delta\Gamma_s = 0.076\ _{-0.063}^{+0.059}$ (stat) ± 0.006 (syst) ps^{-1}
  - $c\tau_s$ = 456 ± 13 (stat) ± 7 (syst) μm
  - $|A_0|^2$ = 0.530 ± 0.021(stat) ± 0.007 (syst)
  - $|A_{||}|^2$ = 0.230 ± 0.027(stat) ± 0.009 (syst)

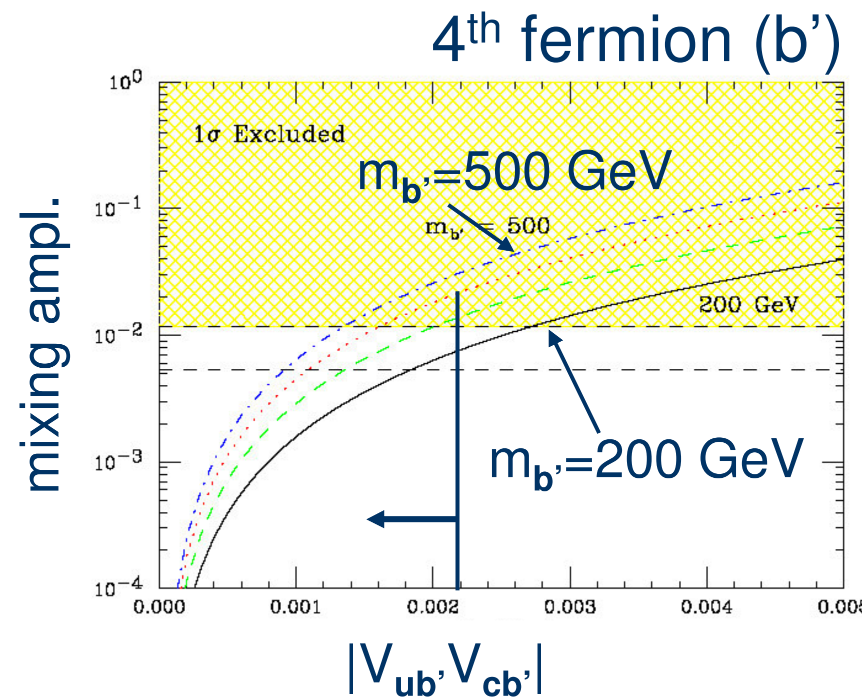
- The $\Delta\Gamma_s$ agrees with predicted value of $0.096 ps^{-1}$.
- We quote p-value and confidence region.
- This is a problem inherent to the fitter with low statistics.



Charm Mixing

- complete the picture of quark mixing
  - K: 1956
  - B_d: 1987
  - B_s: 2006
- new information about processes with down-type quarks in the mixing loop.
- significant step toward observation of CP violation in charm sector.
- could indicate new physics.





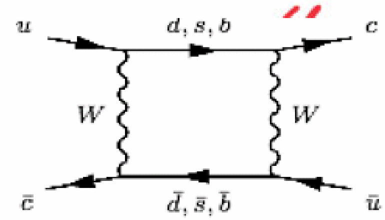
Presentations by Lockman, Golob, Tollefeson

Charm Mixing (cont'd)

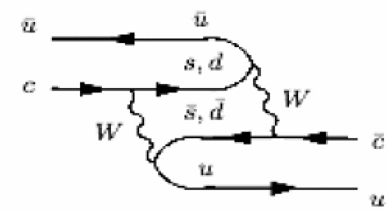
- B factories have presented evidence of charm mixing $D^0 \to K\pi/KK/\pi\pi$

- Large charm samples in CDF data
  - $D^* \to \pi_{soft} D^0$, $D^0 \to K\pi$
  - CDF's time resolution capability allows time dependent measurement
  - π_{soft} charge tags D flavour at production

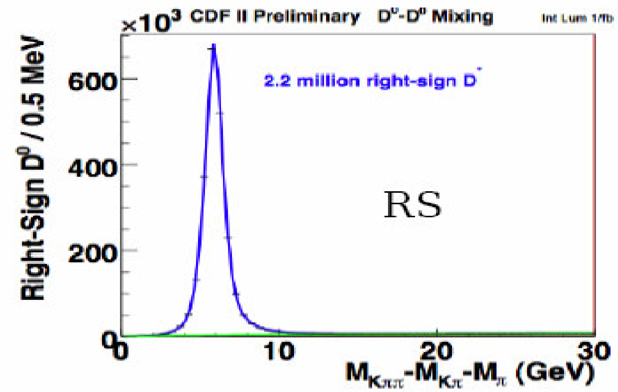
  - RS: $D^{*-} \to \pi_{soft}\ D^0$
  - WS: D^0 mixed or Doubly Cabibbo suppressed decay

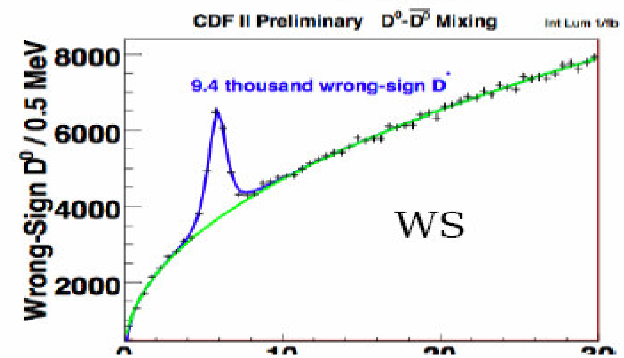


Mixing box diagram



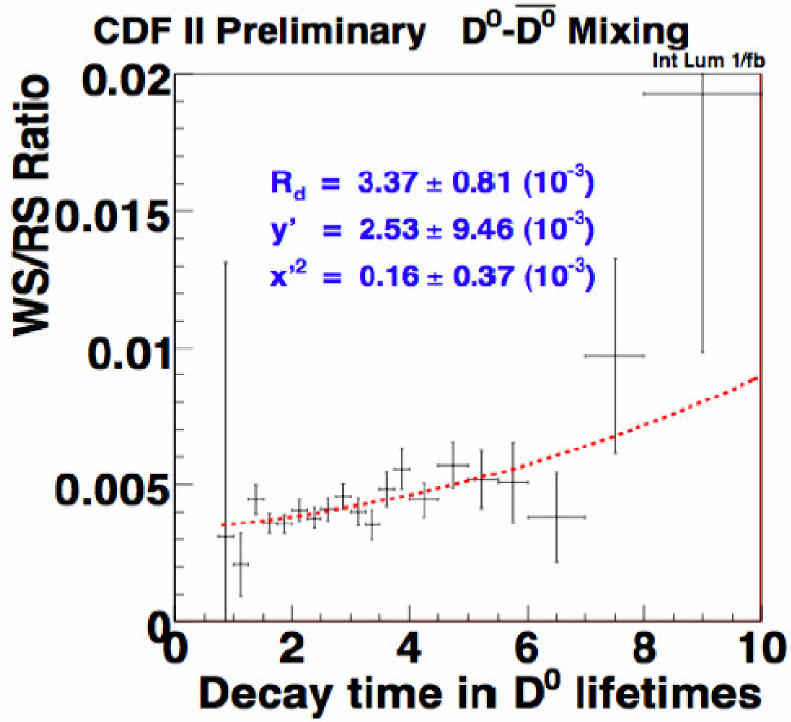
Mixing long distance diagram





1 fb^{-1}

Charm Mixing (cont'd)

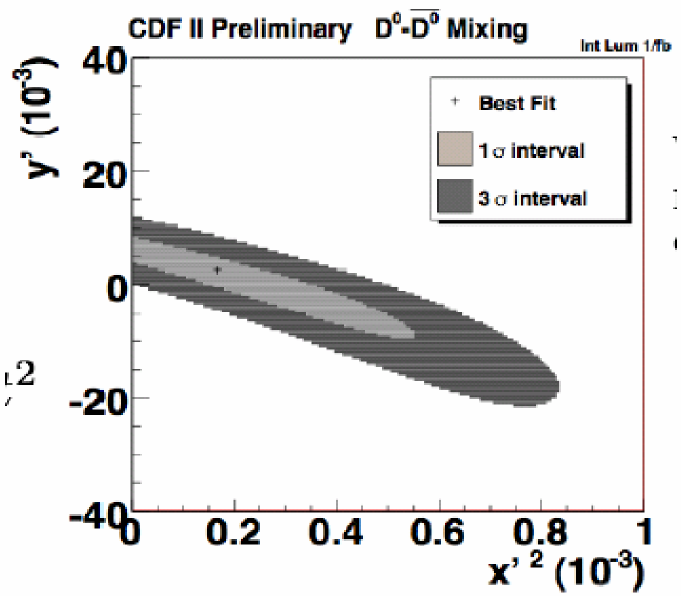


- Perform binned fits to ratio of WS to RS as function of time of D^0 decay
- Probability of no mixing is 0.13%
- Equivalent to 3.2σ significance

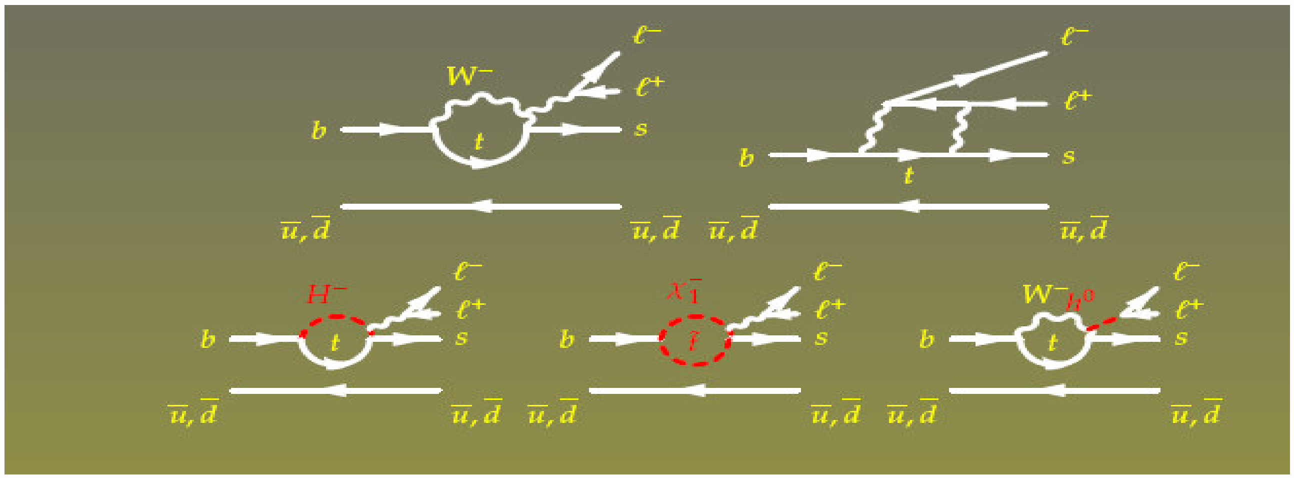
WS/RS ratio:

$$R(t) = R_D + y'\sqrt{R_D}\,t + \frac{x'^2 + y'^2}{4}t^2$$

Allowed regions of charm mixing parameter phase space:



b → sl+l−



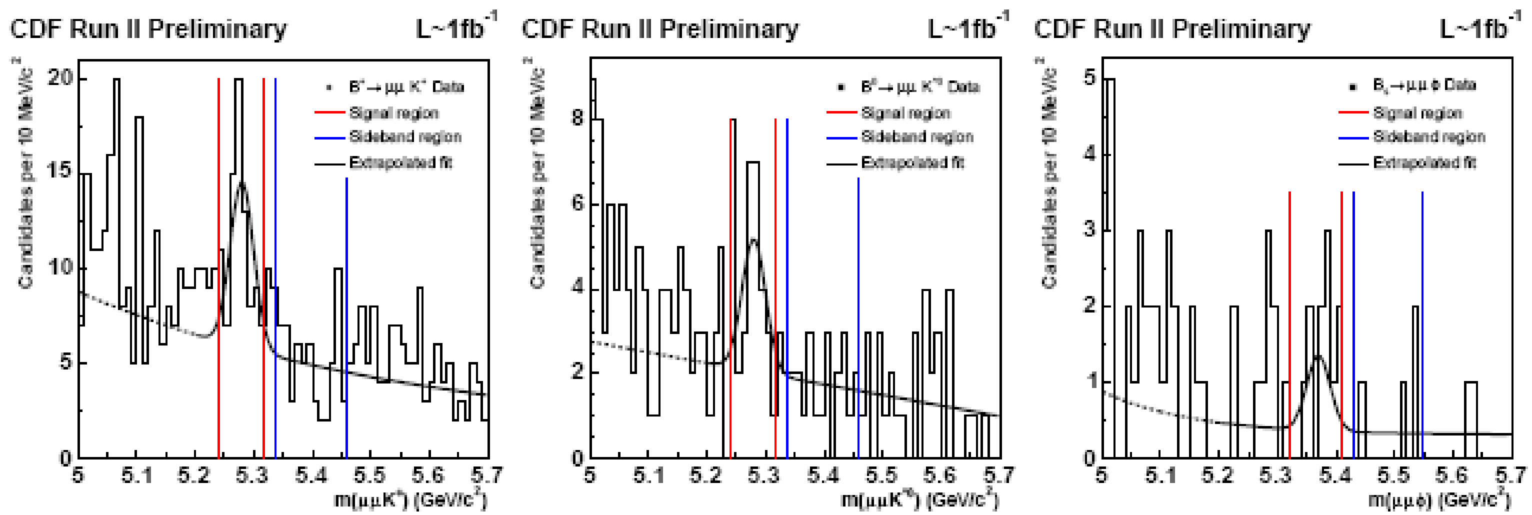
- Many place where NP contribute
- Many observables, ideal to study NP properties
  (sensitive to Wilson coefficients, hence variety of NP)

$B \rightarrow K^* \mu^+\mu^-$ from CDF

- CDF is now competitive in exclusive $b \rightarrow s\ell^+\ell^-$
  (muon only, charged track only mode)
- BF Normalized to $B \rightarrow J/\psi K^{(*)}$ or $B_s \rightarrow J/\psi\phi$

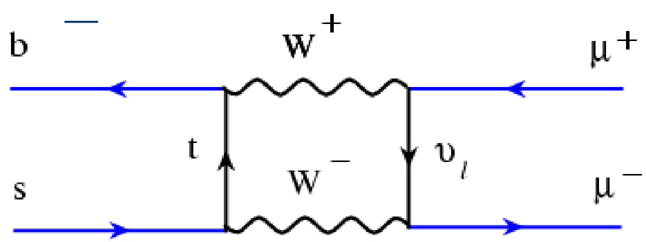
$\mathcal{B}(B^+ \rightarrow K^+\mu^+\mu^-)$	$(0.60 \pm 0.15 \pm 0.04) \times 10^{-6}$	(4.5σ)
$\mathcal{B}(B^0 \rightarrow K^{*0}\mu^+\mu^-)$	$(0.82 \pm 0.31 \pm 0.10) \times 10^{-6}$	(2.9σ)
$\mathcal{B}(B_s \rightarrow \phi\mu^+\mu^-)/\mathcal{B}(B_s \rightarrow J/\psi\phi)$	$<(2.61) \times 10^{-3}$	2.4σ

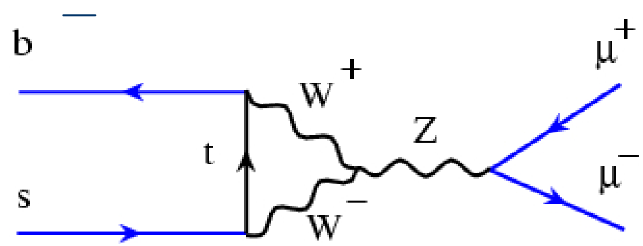
PRELIMINARY



B → μ+μ−

- In Standard Model FCNC decay B → μμ heavily suppressed





- Standard Model predicts $BR(B_s \to \mu^+\mu^-) = (3.4 \pm 0.5) \times 10^{-9}$

A. Buras Phys. Lett. B 566,115

- $B_d \to \mu\mu$ further suppressed by CKM coupling $(V_{td}/V_{ts})^2$

$$BR(B_d \to \mu^+\mu^-) = (1.00 \pm 0.14) \times 10^{-10}$$

- Below sensitivity of Tevatron experiments
- SUSY scenarios (MSSM,RPV,mSUGRA) boost the BR by up to 100x

Observe no events ⇒ set limits on new physics
Observe events ⇒ clear evidence for new physics

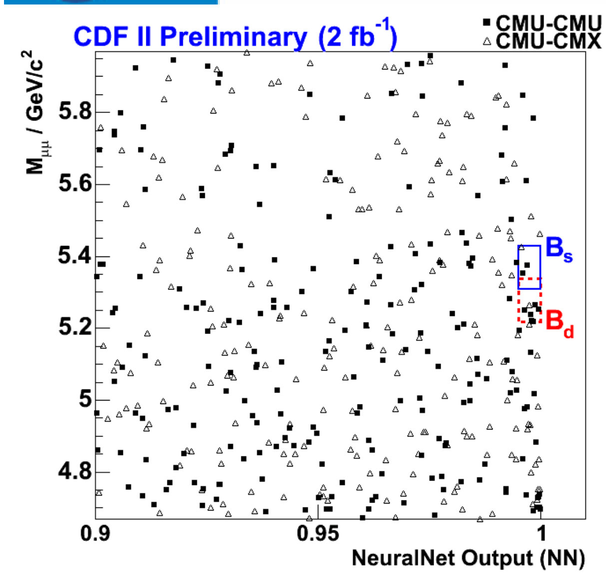
B → μ+μ− (cont'd)

2 fb^{-1}

- **Aim to measure BR or set limit:**

$$BR(B_s \to \mu^+\mu^-) = \frac{N_{Bs}}{N_{B+}} \frac{\alpha_{B+} \cdot \varepsilon_{B+}^{total}}{\alpha_{Bs} \cdot \varepsilon_{Bs}^{total}} \frac{f_u}{f_s} BR(B^+ \to J/\psi K^+) BR(J/\psi \to \mu^+\mu^-)$$

- **Use $B^+ \to J/\psi\ K^+$ as a control mode**
- **Neural network selection**
- **Use particle ID to suppress B→ hh, fake muon backgrounds**
- **Measure remaining background**
- **Measure acceptance and efficiency ratios**



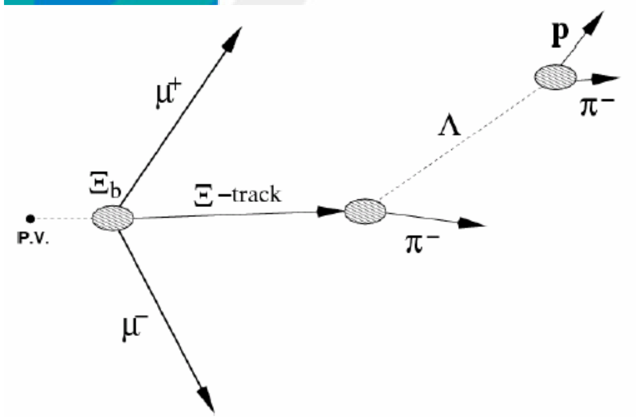
$BR(B_s \to \mu\mu) < 5.8\times10^{-8}$ @ 95% CL
$< 4.7\times10^{-8}$ @ 90% CL

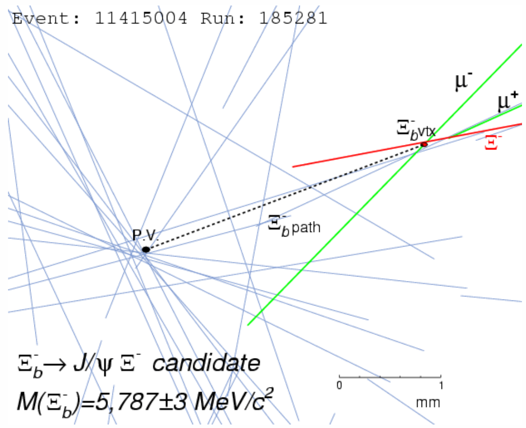
$BR(B_d \to \mu\mu) < 1.8\times10^{-8}$ @ 95% CL
$< 1.5\times10^{-8}$ @ 90% CL

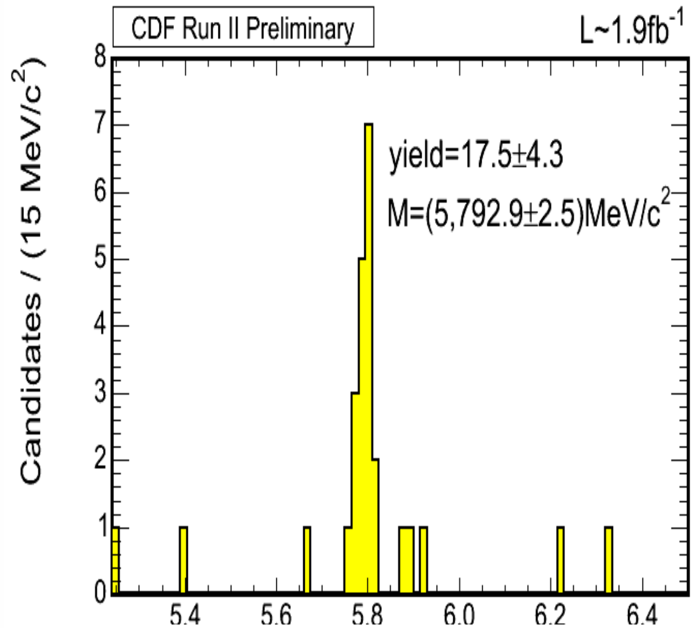
Observation of Ξ_b

1.9 fb^{-1}

- Latest of several b baryon observations in Run II
  $\Xi \to J/\psi \Xi$; $J/\psi \to \mu\mu$; $\Xi \to \Lambda\pi$; $\Lambda \to p\pi$

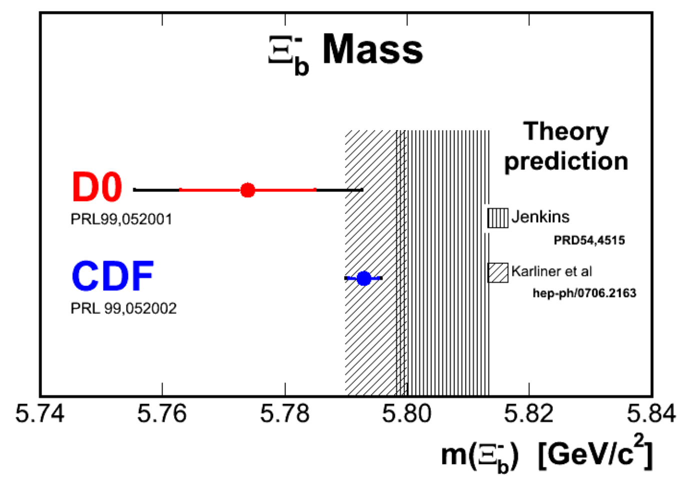






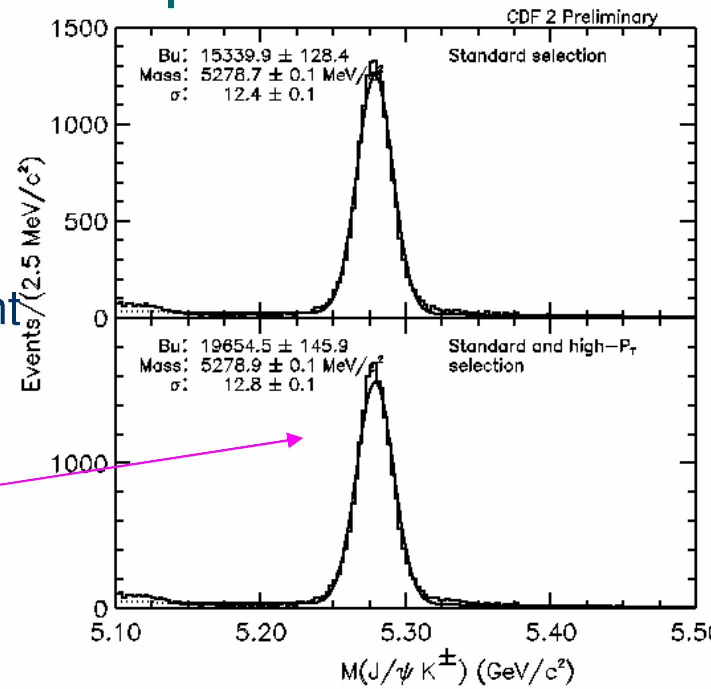
- Use novel tracking approach: form a silicon track for the Ξ
  (first time in hadron collider experiment)

- Statistical significance of Ξ_b signal > 7σ

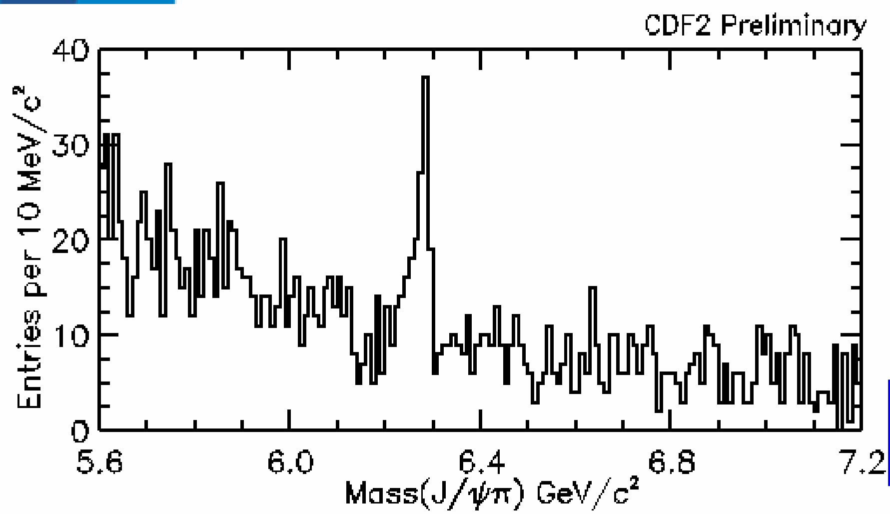


Observation of $B_c \to J/\psi\ \pi$

2.2 fb^{-1}



- B_c is not produced at B factories.
- Precision test of lattice QCD
- Full reconstruction and CDF tracking give precise mass measurement
- New analysis
  - Tune selection on the data: $B^+ \to J/\psi\ K$ control mode
  - Measure mass of the B_c



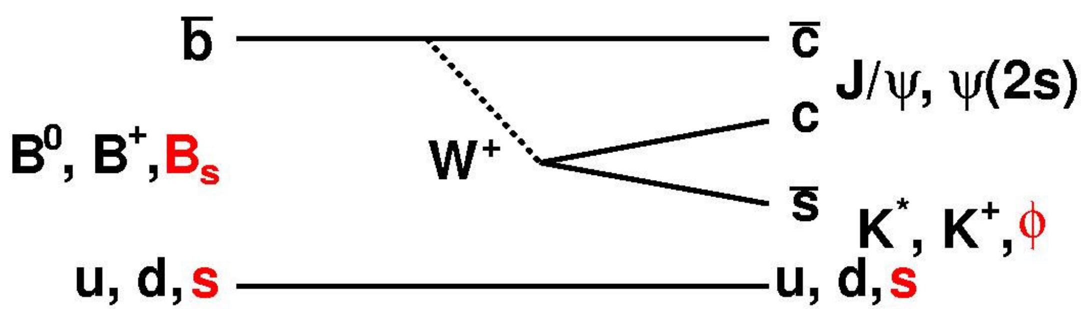
- Poisson probability of background fluctuation to the observed excess is 1.1 x 10^{-19}
- Corresponds to 9σ

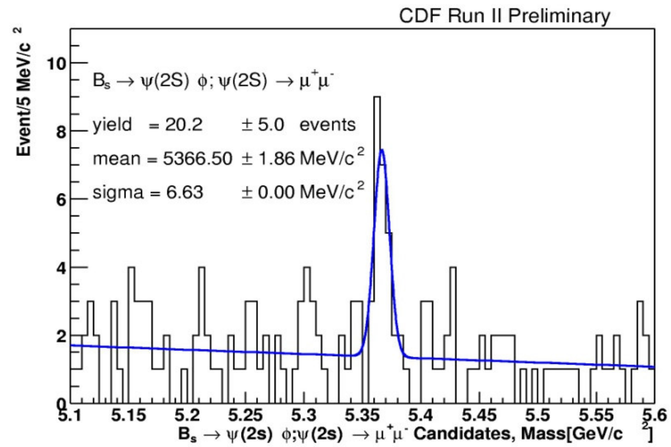
$M(B_c) = 6274.1 \pm 3.2 \pm 2.6\ MeV/c^2$

$M(B_c)_{Lattice} = 6304 \pm 12^{+18}_{-0}\ MeV/c^2$

Observation of Bs → ψ(2S) φ

0.35 fb^{-1}





- In Standard Model, Feynman diagrams are same.
  - $Br(B^0 \to \psi(2S)K^{*0})/Br(B^0 \to J/\psi K^{*0}) = 0.61 \pm 0.10$
  - $Br(B^+ \to \psi(2S)K^+) / Br(B^+ \to J/\psi K^+) = 0.64 \pm 0.06 \pm 0.07$
  - $Br(B_S \to \psi(2S)\,\phi) / Br(B_S \to J/\psi\,\phi) =$???

20.2 ± 5.0 events
$Br(B_S \to \psi(2S)\,\phi) / Br(B_S \to J/\psi\,\phi)$
$= 0.52 \pm 0.13 \pm 0.06(br) \pm 0.04(sys)$

Fermilab *Today*

Thursday, January 26, 2006

Calendar

Thursday, January 26
2:30 p.m. Theoretical Physics Seminar - Curia II
Speaker: E. Lunghi, Fermilab
Title: Analysis of Large Tan beta Effects in the MSSM from the GUT Scale
3:30 p.m. Director's Coffee Break - 2nd Flr X-Over
4:00 p.m. Accelerator Physics and Technology Seminar - 1 West
Speaker: L. Prost, Fermilab
Title: Progress of Electron Cooling at the

$\Gamma(\psi(2S)\phi)/\Gamma_{total}$ Γ_9/Γ

VALUE (units 10^{-4})	EVTS	DOCUMENT ID		TECN	COMMENT
4.8±1.4±1.7		[55] ABULENCIA	06N	CDF	$p\bar{p}$ at 1.96 TeV
• • • We do not use the following data for averages, fits, limits, etc. • • •					
seen	1	BUSKULIC	93G	ALEP	$e^+e^- \rightarrow Z$

[55] ABULENCIA 06N reports $[B(B_s^0 \rightarrow \psi(2S)\phi) / B(B_s^0 \rightarrow J/\psi(1S)\phi)] = 0.52 \pm 0.13 \pm 0.07$. We multiply by our best value $B(B_s^0 \rightarrow J/\psi(1S)\phi) = (9.3 \pm 3.3) \times 10^{-4}$. Our first error is their experiment's error and our second error is the systematic error from using our best value.

Weather

Sunny **40°/31°**

Extended Forecast

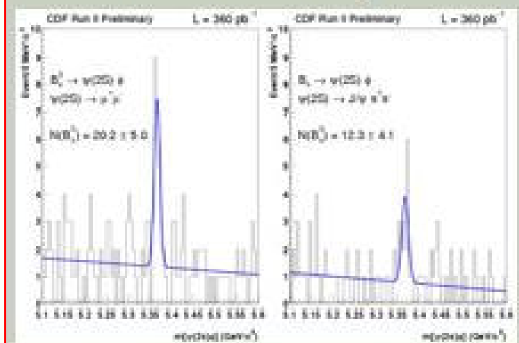
Weather at Fermilab

Visitors investigated physics concepts at last year's open house. (Click on image for larger version.)

This year's Education Office Family Open House will take place on Sunday, Feb. 19. The event offers free family-style

Fermilab Result of the Week

Strange Beautiful Meson Has a New Charming Mode



Mass distributions of Psi(2S) phi observed by CDF, where the Psi(2S) decays into two muons (left) and Psi(2S) decays into J/psi pi+pi- (right). The signal peak contains 20.2+5.0 (left) and 12.3+-4.1 (right) events for the two decay channels, respectively. (Click on images for larger version.)

The $B_s/B_d/B_u$ mesons consist of a bottom quark and a strange/down/up anti-quark. They can decay to final states involving charmonium, a charm quark and anti-quark bound together by the strong force, in a bound state similar to the hydrogen atom. Just like the hydrogen atom, charmonium has a ground state and several excited states, such as Psi(2S) and J/Psi (or Psi(1S)), the latter being the first (or lowest energy) excited state of the charm anti-

Data Analysis Procedure

Decay Channels

$J/\psi \rightarrow \mu^+\mu^-$

$\psi(2S) \rightarrow \mu^+\mu^-$ $\quad \psi(2S) \rightarrow J/\psi\pi^+\pi^-$

$B^{\pm} \rightarrow J/\psi K^{\pm}$ $\quad B_s \rightarrow J/\psi\phi$

$J/\psi \rightarrow \mu^+\mu^-$ $\quad J/\psi \rightarrow \mu^+\mu^-$

$B^{\pm} \rightarrow \psi(2S)K^{\pm}$ $\quad B_s \rightarrow \psi(2S)\phi$

$\psi(2S) \rightarrow \mu^+\mu^-$ $\quad \psi(2S) \rightarrow \mu^+\mu^-$

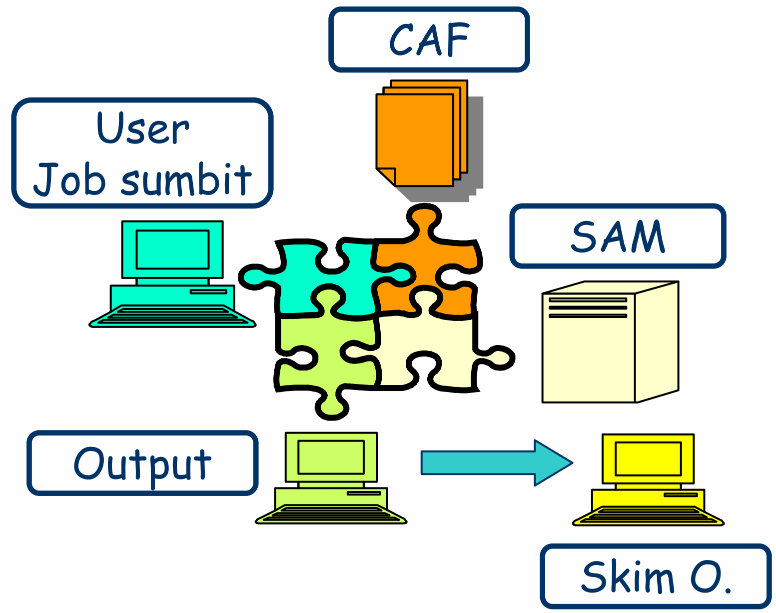
$\psi(2S) \rightarrow J/\psi\pi^+\pi^-$ $\quad \psi(2S) \rightarrow J/\psi\pi^+\pi^-$

$B^{\pm} \rightarrow J/\psi\pi^+\pi^-K^{\pm}$ $\quad B_s \rightarrow J/\psi\pi^+\pi^-\phi$

CAF : CDF Analysis Farm
- batch systems

SAM : Sequential Access via Metadata
- data handling system

Data Analysis Procedure



Total File Size ~ 4.08 TB
Total Liminosity ~ 1.6 fb-1

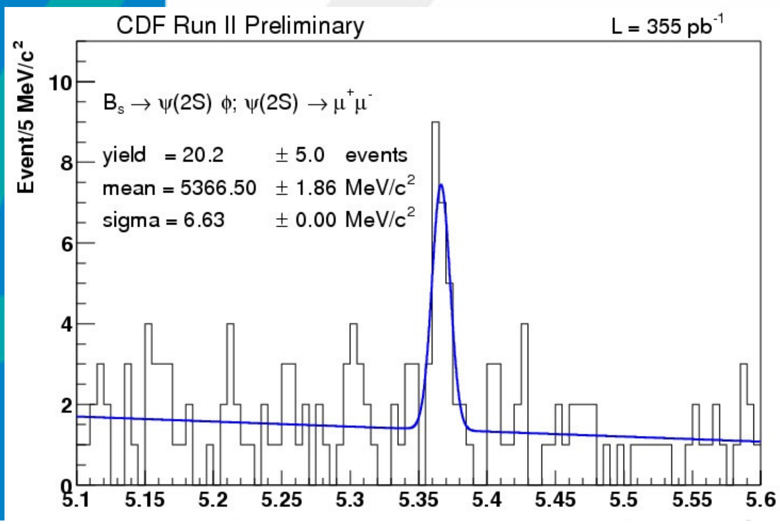
Real time : 29,200 hours
CPU time : 23,877 hours

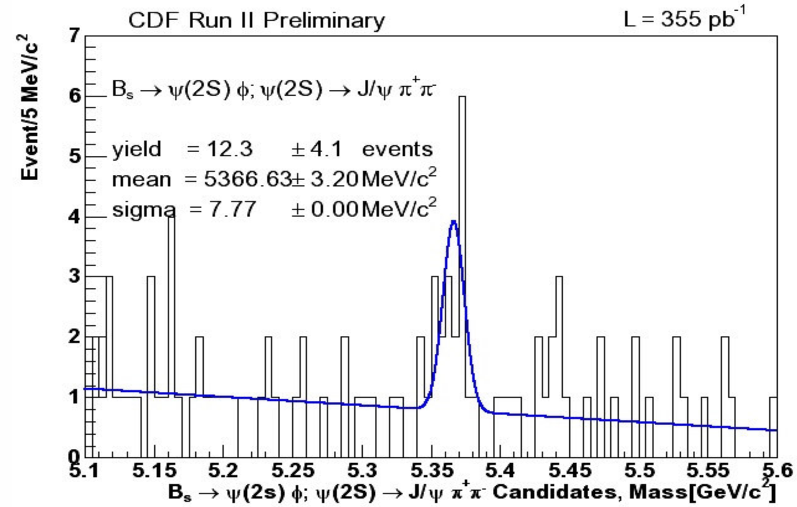
Output ntuple size = 226 GB

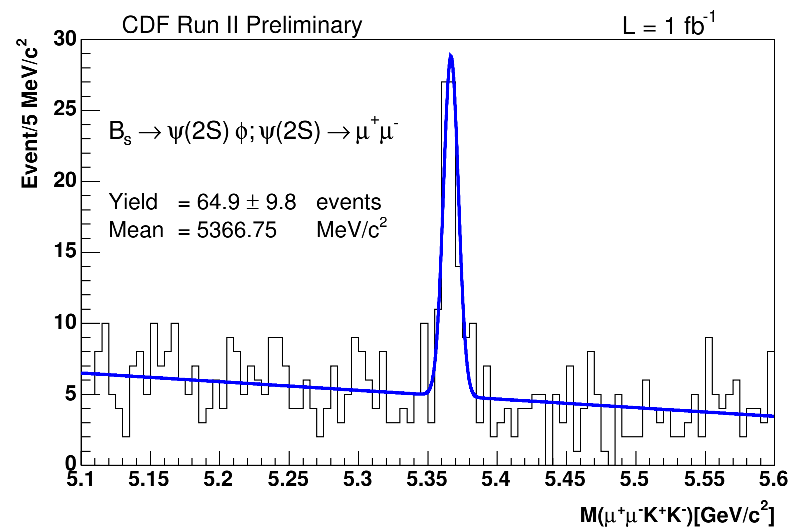
Skimmed output = 88 GB

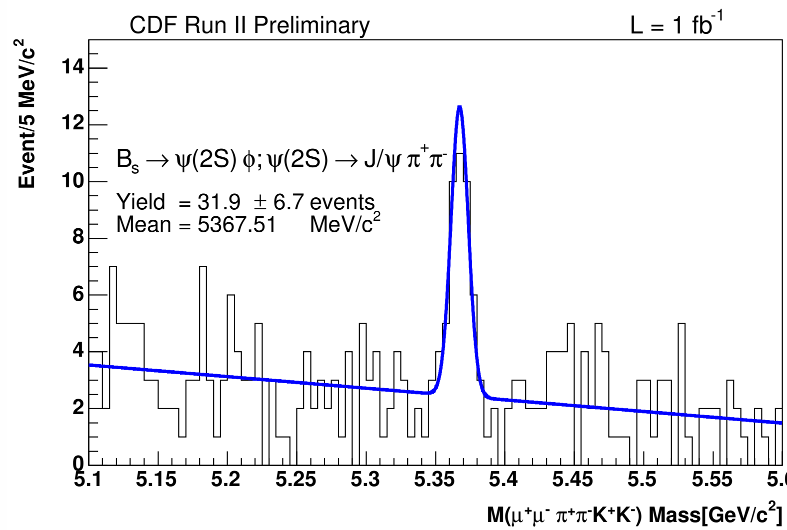
Reconstruction of Bs

1,0 fb^{-1}









~ 3 times yield increased

B Physics Plan @ KISTI & KNU

		$B=B^+$, $K=K^+$	$B=B^0$, $K=K^{*0}$	$B=B_S$, $K=\phi$
$B \rightarrow J/\psi\ K\ P$	P= none	$(1.008 \pm 0.035)*10^{-3}$	$(1.33 \pm 0.06)*10^{-3}$	$(9.2 \pm 3.3)*10^{-4}$
	$P= \pi^+\pi^-$	$(1.07 \pm 0.19)*10^{-3}$	$(6.6 \pm 2.2)*10^{-4}$	
$B \rightarrow \psi(2s)K\ P$	P= none	$(6.48 \pm 0.35)*10^{-4}$	$(7.2 \pm 0.8)*10^{-4}$	$(4.8 \pm 1.4 \pm 1.7)*10^{-4}$
	$P= \pi^+\pi^-$	$(1.9 \pm 1.2)*10^{-3}$		

$B+ \rightarrow J/\psi\ \pi^+\pi^- K^+$ has larger BR than
$B+ \rightarrow J/\psi K^+$ (?)

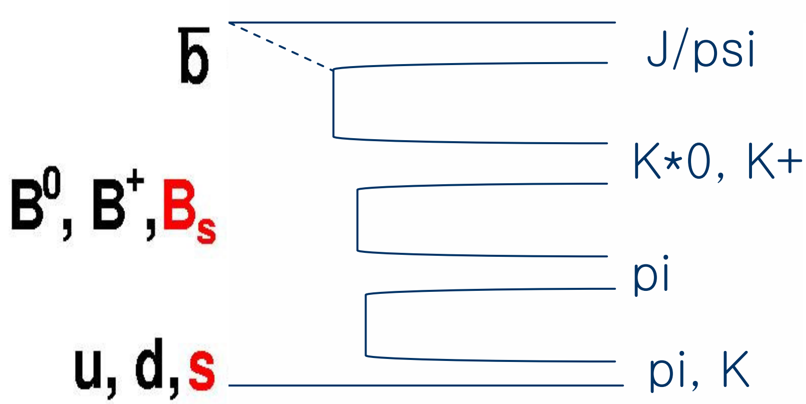
$Bs \rightarrow J/\psi\, \pi^+ \pi^- \phi$

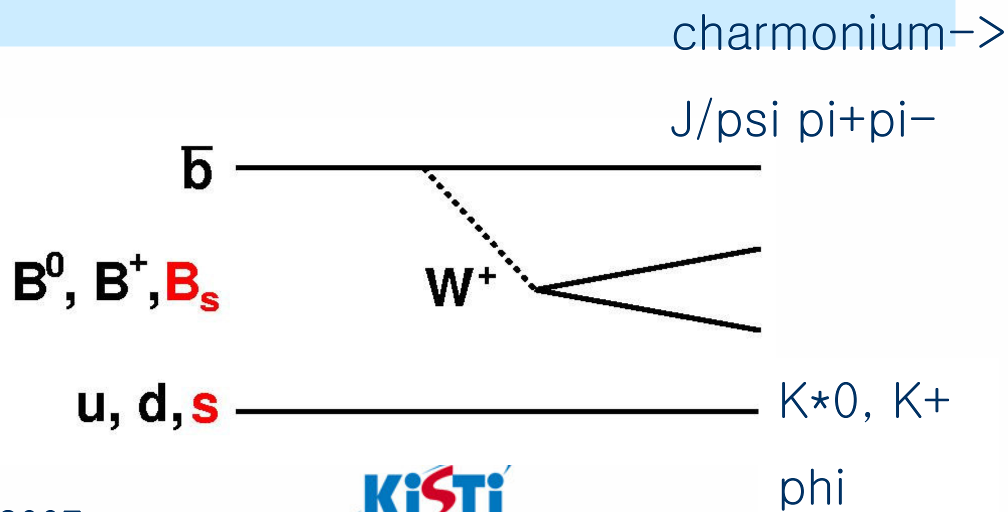
- Could be a good method to separate production mechanism?
  - Internal pop up v.s. Higher resonance state ?
  - X(3872) or $\psi(2s) \rightarrow J/\Psi\, \pi^+\pi^-$?

$Br(B^0 \rightarrow J/\psi\, \pi^+ \pi^- K^{*0})$ / $Br(B^0 \rightarrow \psi(2s)(\rightarrow J/\psi\, \pi^+ \pi^-)\, K^{*0})$

$Br(B^+ \rightarrow J/\psi\, \pi^+ \pi^- K^+)$ / $Br(B^+ \rightarrow \psi(2s)(\rightarrow J/\psi\, \pi^+ \pi^-)\, K^+)$

$Br(B_S \rightarrow J/\psi\, \pi^+ \pi^- \phi)$ / $Br(B_S \rightarrow \psi(2s)(\rightarrow J/\psi\, \pi^+ \pi^-)\, \phi)$





Conclusions

- Since there is no accelerator in Korea, it is important to make e-HEP (High Energy Physics) to study high energy physics anytime and anywhere.

  ⇒ Therefore, the support of KISTI for HEP is important.

- The component of e-HEP (High Energy Physics) are data production, data processing and data publications.
  - Data Production will be done by remote control room.
  - Data Processing is working by Pacific CAF.
  - Data Publication is done by supporting EVO system.

- Using e-HEP, KISTI starts to work on Heavy Flavor Physics at CDF experiments.

Conclusions

- Heavy Flavor Physics
  - Standard Model CKM CPV is well established.
  - Unitary angle precision continues to improve.
  - CP violation provides a unique window on SM.

- Heavy Flavor Physics @ CDF
  - Incredibly rich menu of B physics offer mature experiments at Tevatron.
  - Sophisticated techniques emerging to extract the most information available from the data.
  - Largely complementary in focus, scope
  - Data accruing very fast, expect another 4-6 fb^{-1} by 2009-2010
  - Only 20% was analyzed

- Heavy Flavor Physics at LHC era

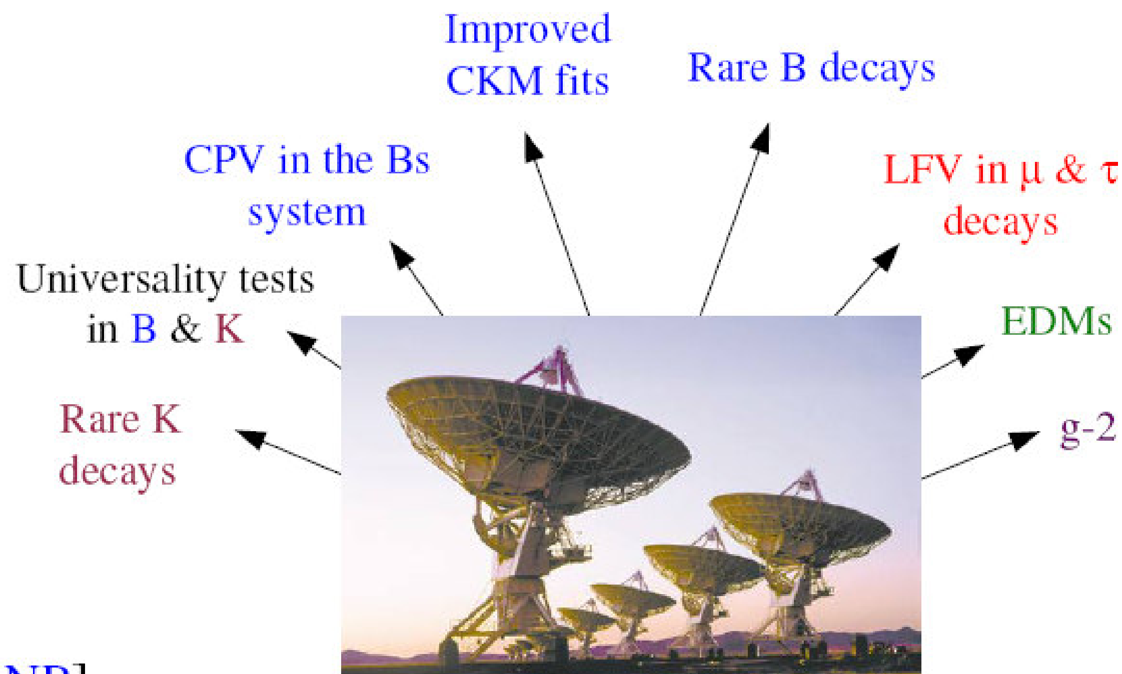
Flavour physics in the LHC era

LHC [high p_T]

A *unique* effort toward the high-energy frontier

[to determine the energy scale of NP]

Flavour physics



A *collective* effort toward the high-intensity frontier
[to determine the flavour structure of NP]

Thank you.

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