TOPAS and 4D simulation

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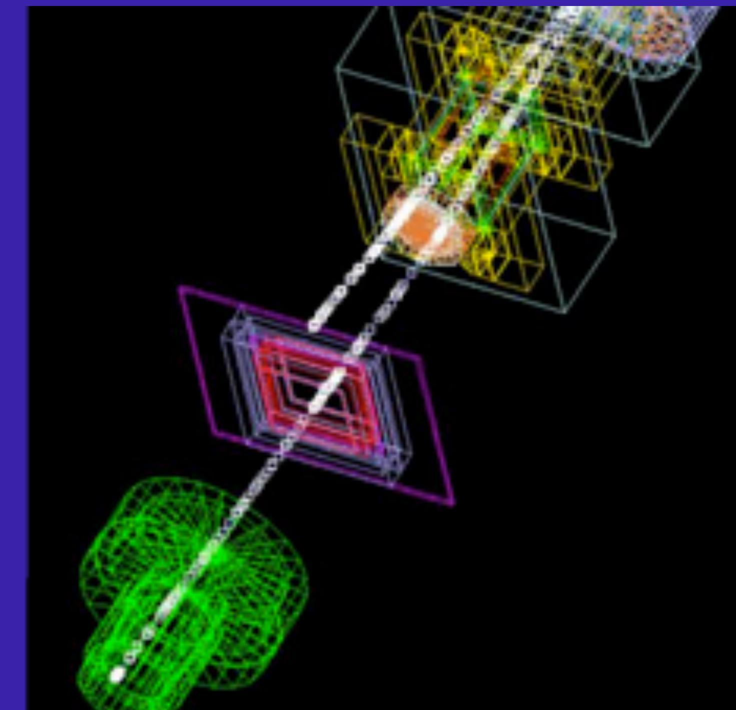
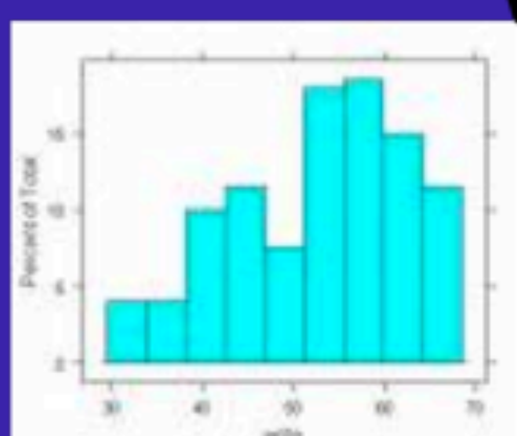
TOPAS

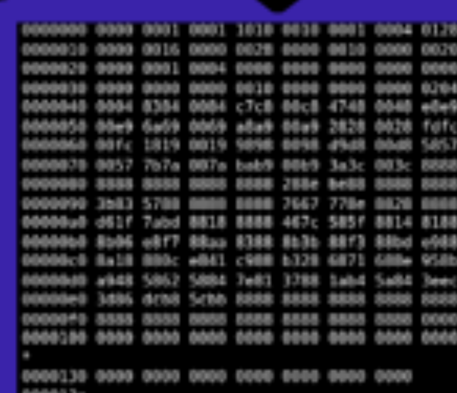
TOPAS - TOol for PArticle Simulation
to make Monte Carlo simulation more easily available to both clinical and research physicists, paying particular attention to reliability, repeatability and ease of use.

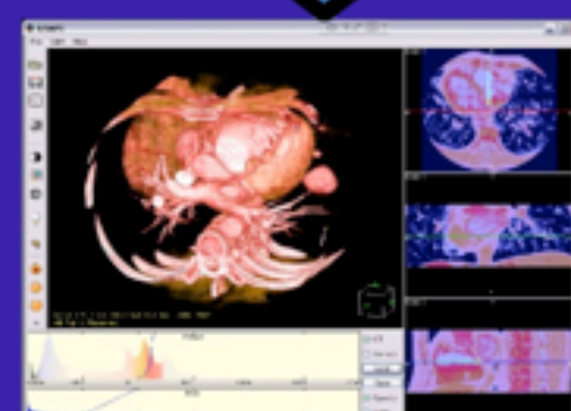


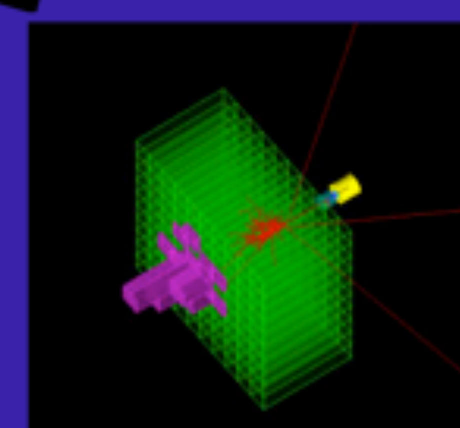
Model nozzle
Import patient CT
Transport in an all particle code
Score dose, fluence, etc.
Save/Replay Phase space
Advanced graphics

Fully 4D:
moving parts of nozzle,
beam current modulation,
time-varying fields for
beam scanning, etc,
patient motion









Execution of TOPAS

....

- TOPAS is not a toolkit but **an application** layered on top of Geant4.

  ➫ `$ topas     hello_simulation.txt`

  topas : name of the execution file.

  hello_simulation.txt : TOPAS parameter file.

- TOPAS doesn't require users to learn C++ programming language.

  ➫ We provide the TOPAS syntax, i.e. TOPAS parameters.

Our challenge was to make time-dependent simulations possible through TOPAS parameter system.

Criteria and Decision

- The syntax for time-dependent parameter should be straightforward and generic enough to apply any time-varying quantities*.

  ex) movements, rotation, time-varying fields, beam current, energy, and etc.
- It should be designed to take into account interplay effects.

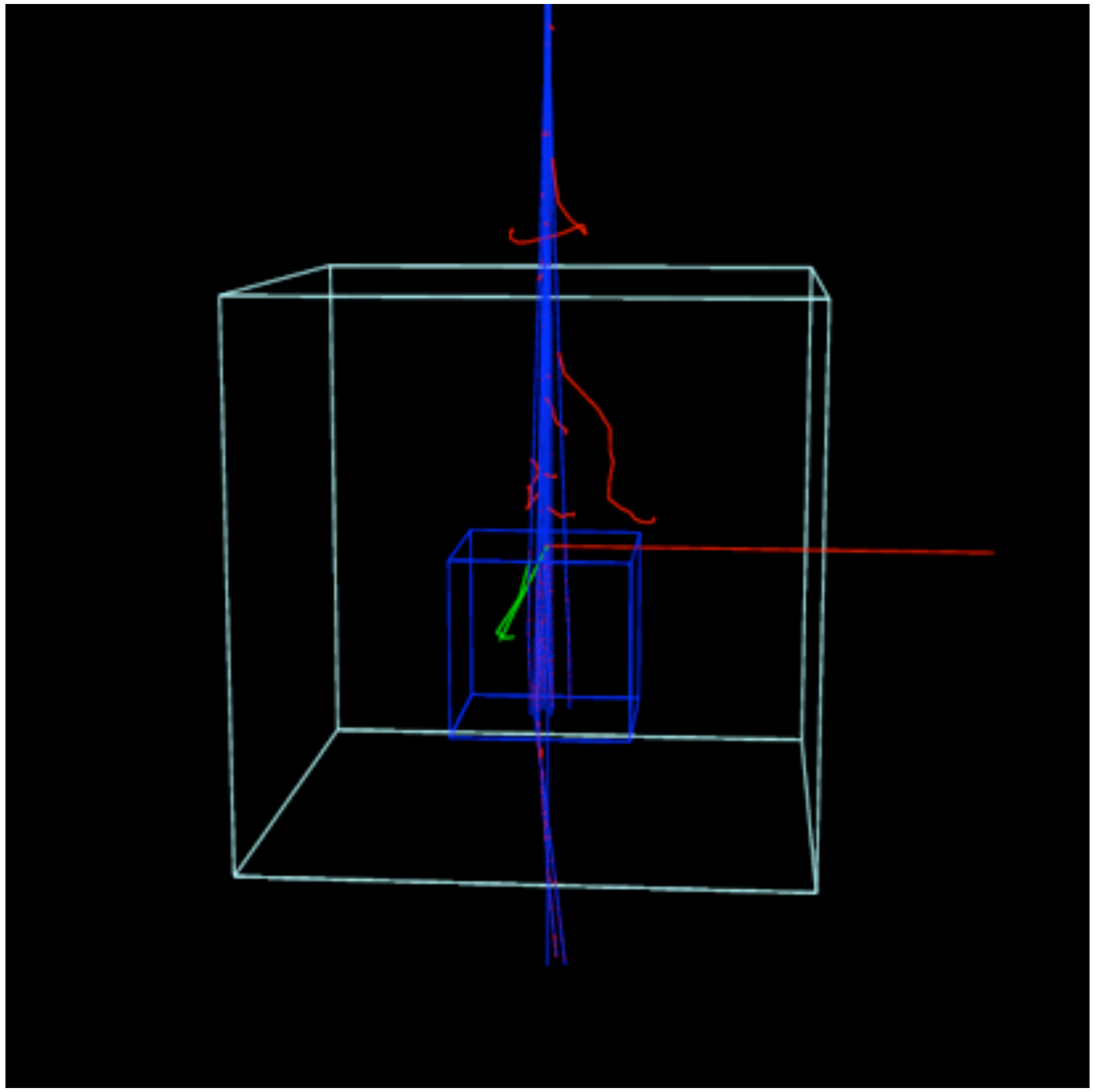
⇨

1. We devised an intermediated parameter, so called "TimeFeature".
2. We separated time-generation from time-dependent quantities, "Sequencing".

* we don't take particle's flying-time into account.

Parameter & TimeFeature

How motion of the BOX can be described through TOPAS TimeFeature?



- TOPAS Parameter.

SmallBox_PositionX = 0.0 cm
...

- TimeDependent TOPAS parameter.

SmallBox_PositionX = **F(t)**
...
=> **F(t)** = v*t + P ,where t in [from, to)

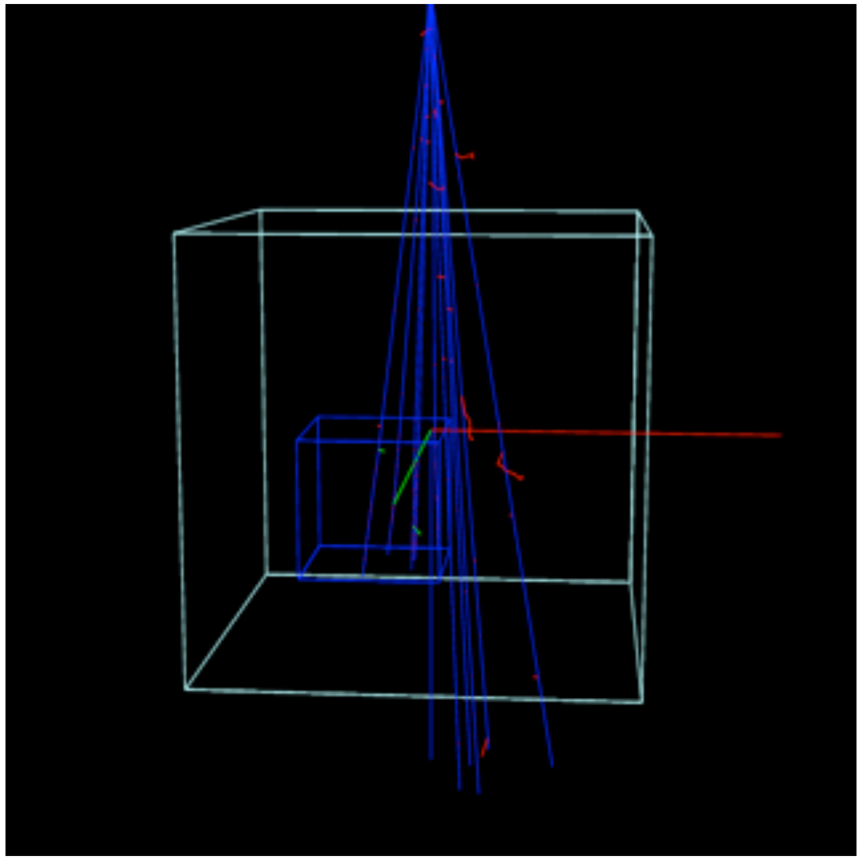
- F(t) is called TimeFeature.
- TimeFeatures are written by TOPAS parameters.

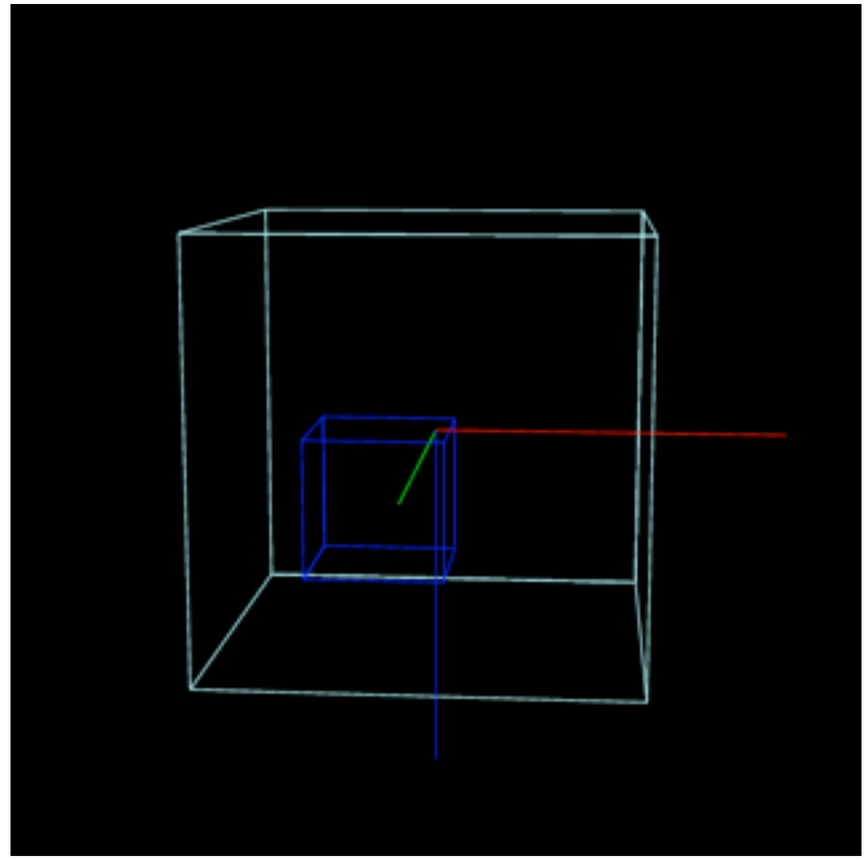
Types

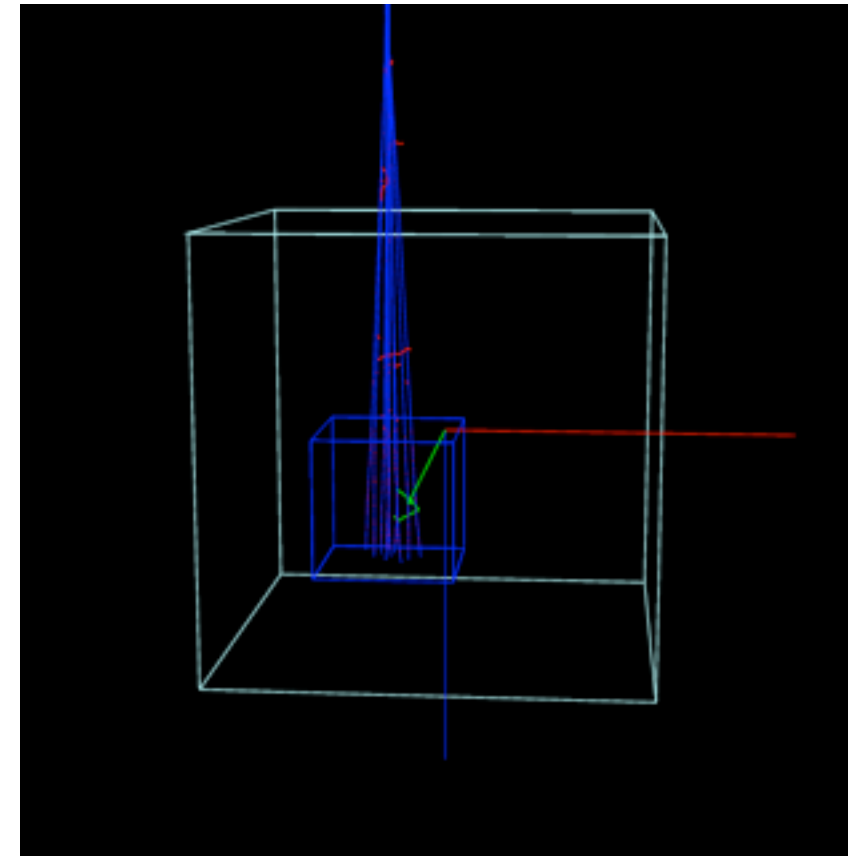
TimeFeature

- Numeric
  - *Equations*
    - ex) Sine, Cosine, Sqrt, Constant, Linear, ...
  - $\prod \mathit{TimeFeature}(t)$
  - $\sum \mathit{TimeFeature}(t)$
  - *ConsecutiveTF*
- Boolean
- String

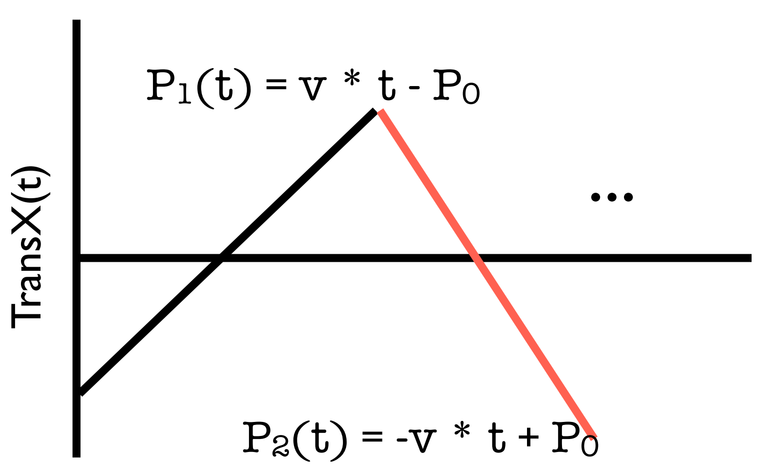
Manipulations



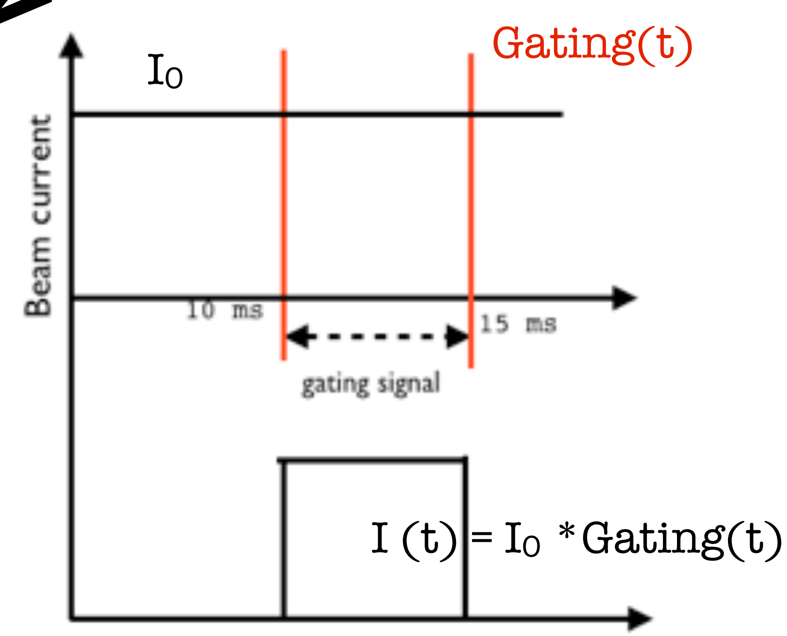




SmallBox_PositionX = TransX(t)

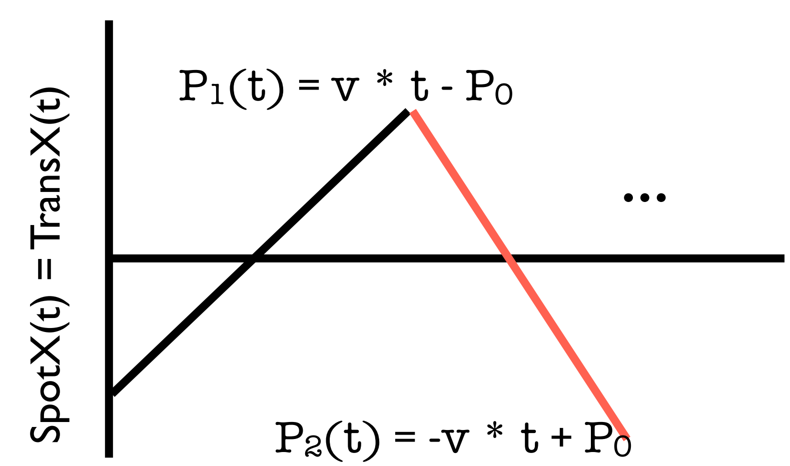


NumOfParticles = Current(t)



SmallBox_PositionX = TransX(t)

Beam_SpotX = TransX(t)



DOI; Duration of Interest

- TOPAS' three execution modes.
  - ➪ Manual : simplest ,nothing to do with time-varying quantities.
  - ➪ Sequential : time is set sequentially, DOI is equally divided.
  - ➪ Random : time is set randomly.

- For both Sequential and Random, time range must be specified.
  ex) TimeRange = 0 100 ms ; [0.0 100)

- For Sequential, time-interval (dT) and # of particles/dT are required.
  ex) Interval = 1 ms, NumParticlesPerdT = 10 -> a total of 1000 particles.

- For Random, Total number of particles needs to be set.
  ex) TotalNumOfParticles = 1000

Random and Sequential Mode

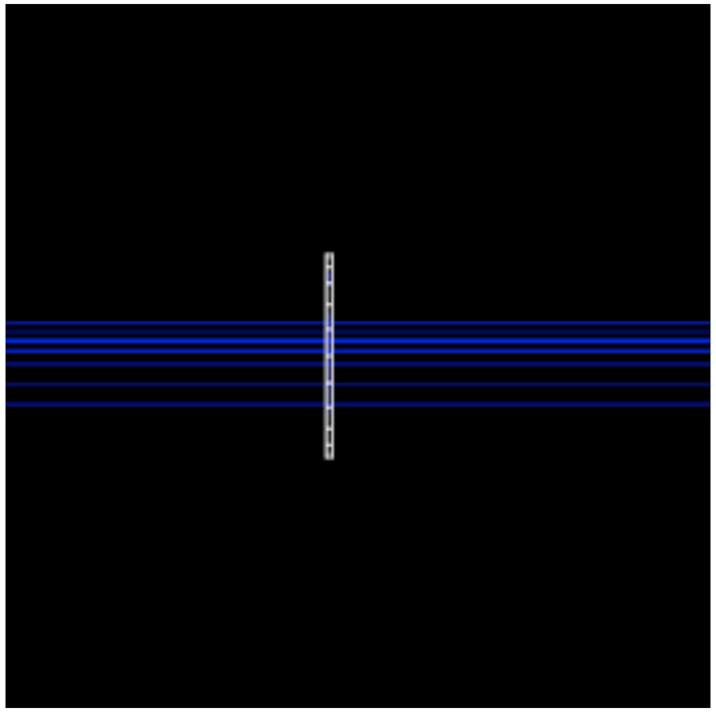
If, everything (TimeFeature, DOI, total # particles) is identical except **execution mode**.

TimeFeature for Water column* thickness

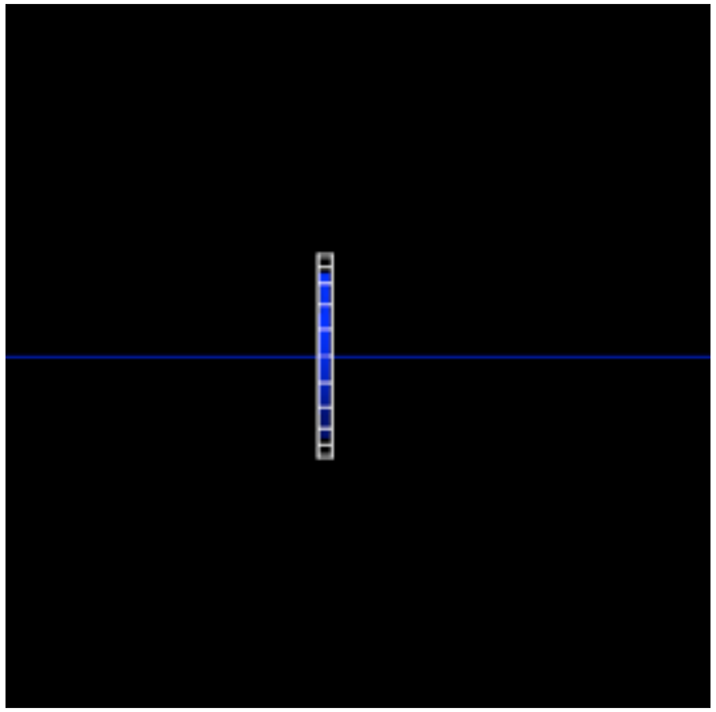
# Assign TimeFeature to actual water phantom
WaterColumn_thickness = **WCThickness**(t)

#Range of Simulation time.
Range = 0.0 100 ms

Mode = Sequential
Interval = 1 ms
NumParticlesPerdT = 20



Mode = Random
TotalNumOfParticles = 2000



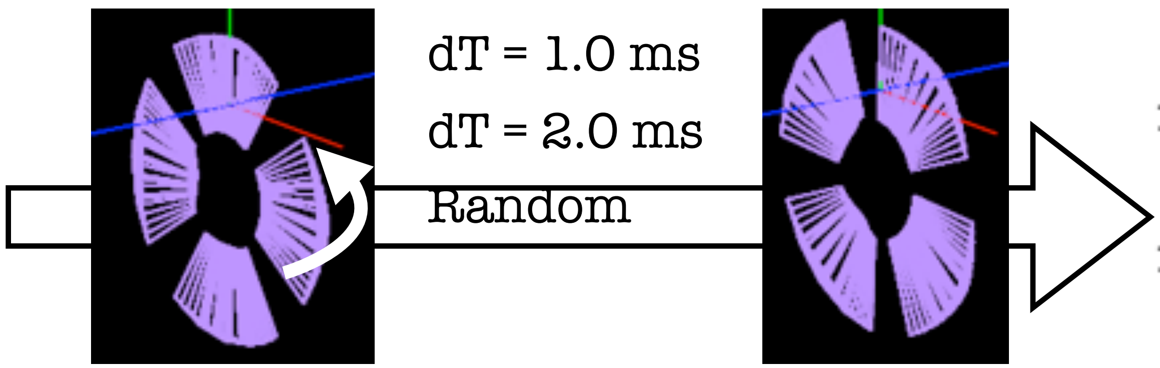
* "Water Column" from UCSF eye-treatment beamline.

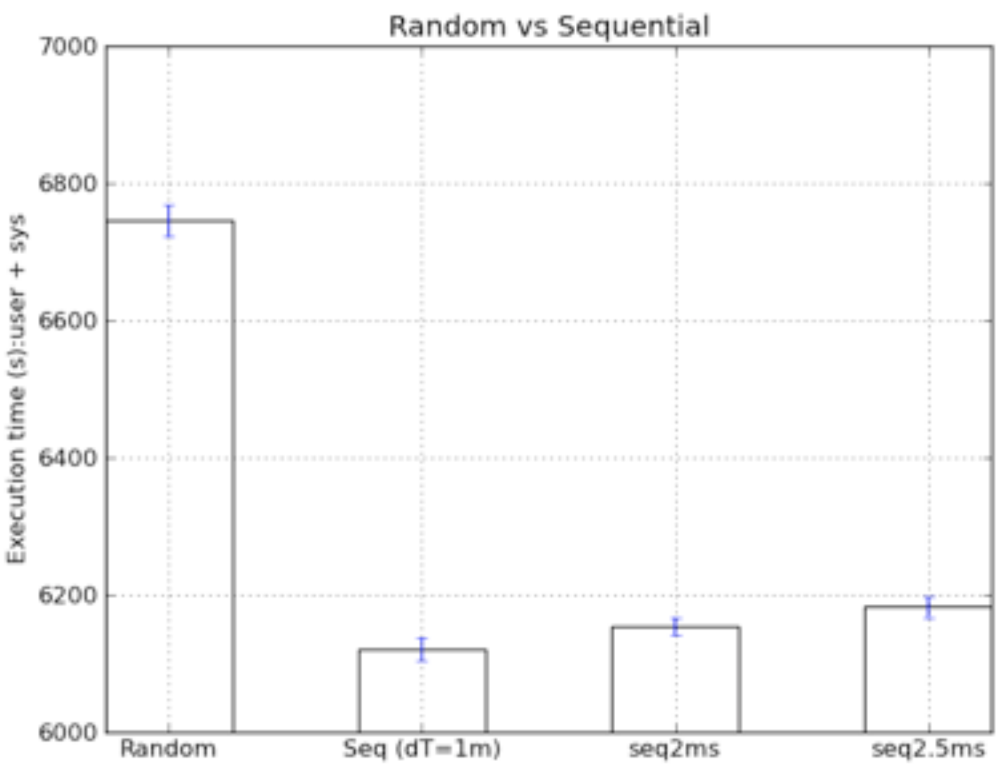
Under-sampling

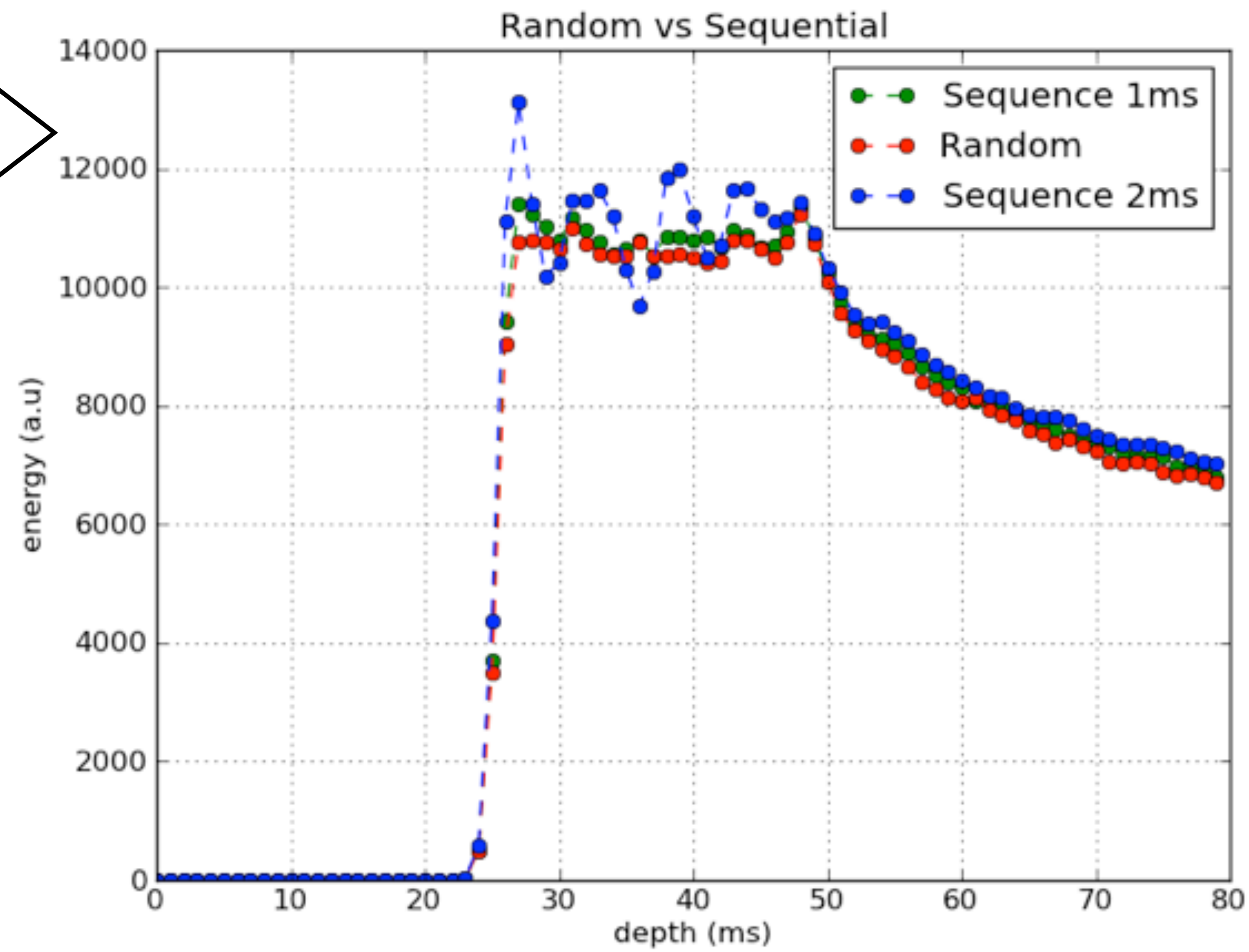
- Sequential mode can reduce simulation time but...

- Time-interval should be carefully set to prevent under-sampling.

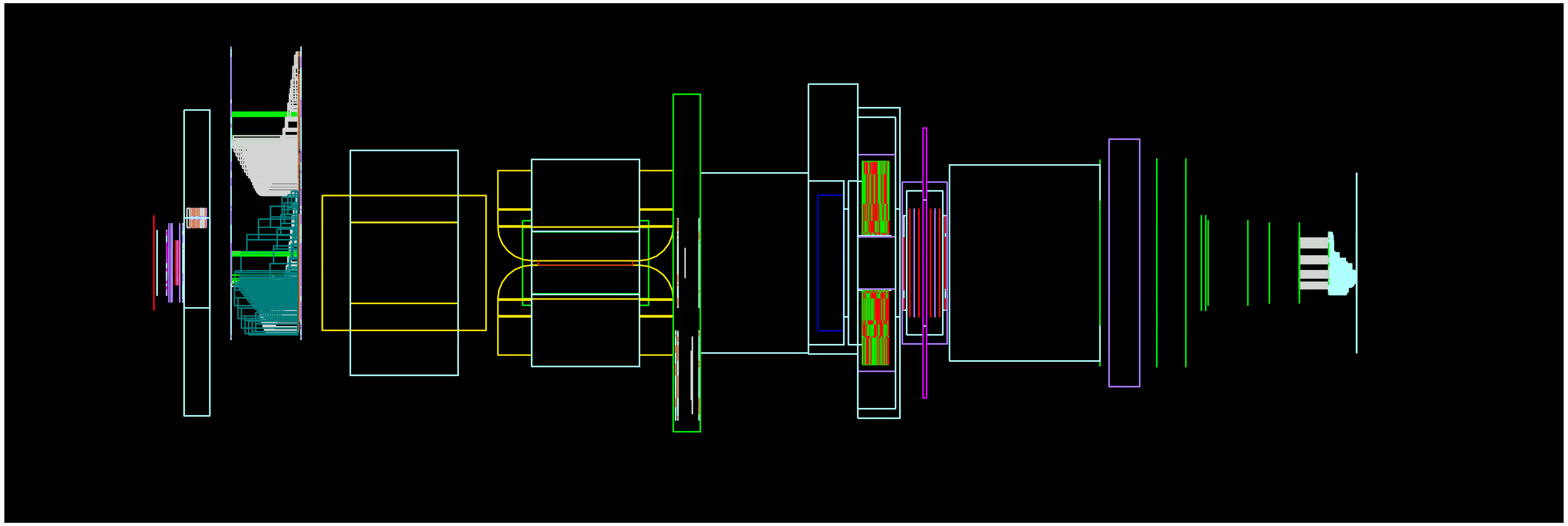
* SOBP production by rotating a propeller of UCSF eye-treatment beamline.



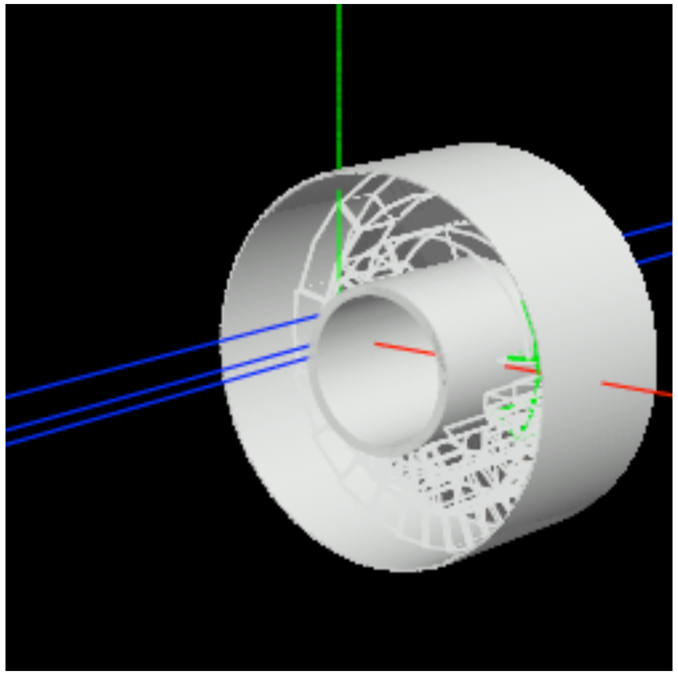




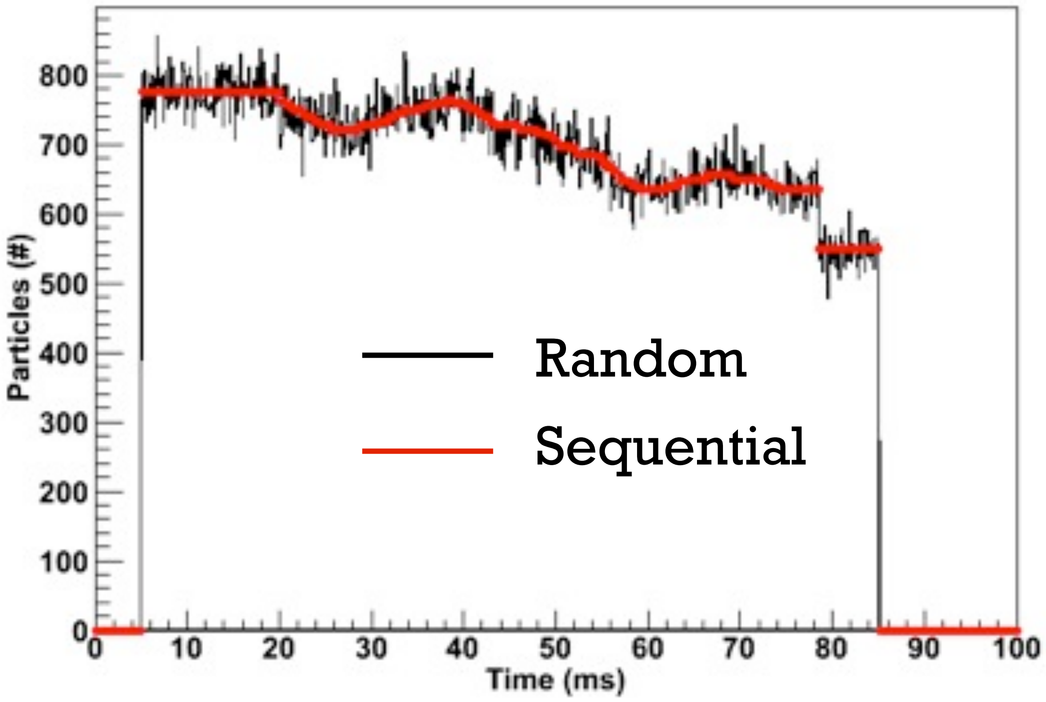
Double scattering@MGH



- Rotation of Range modulator

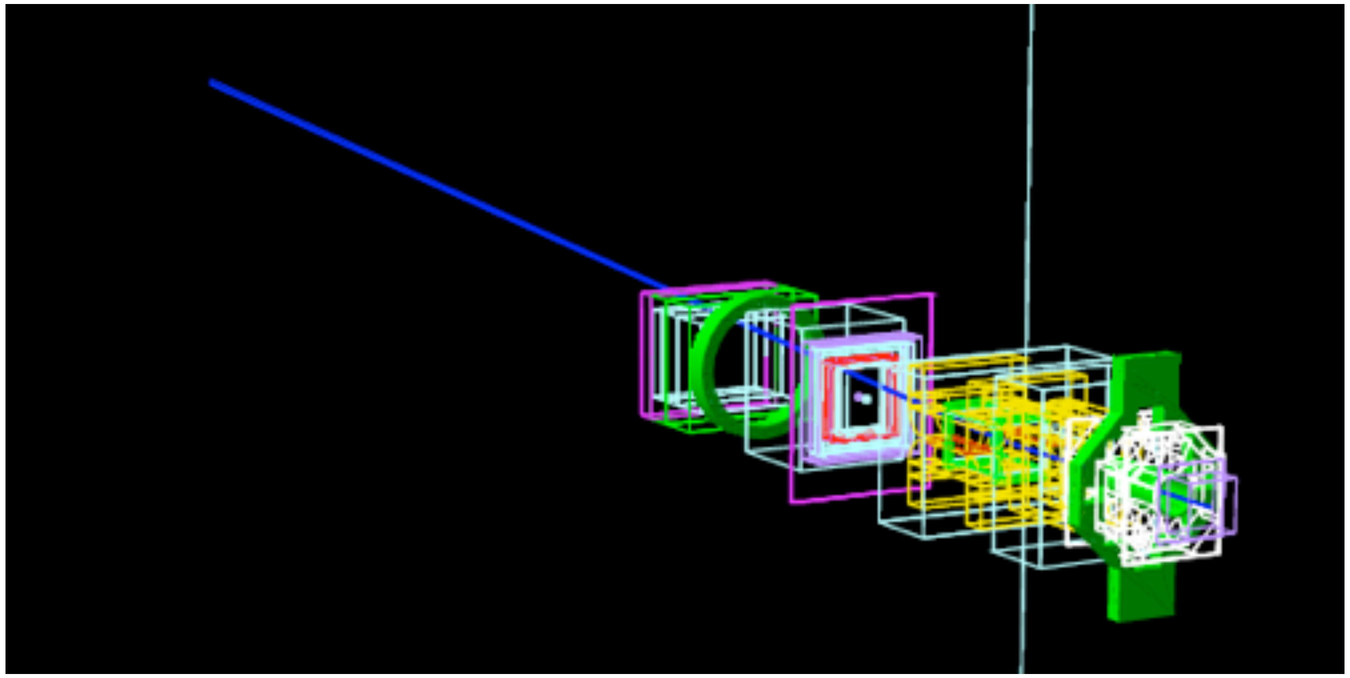


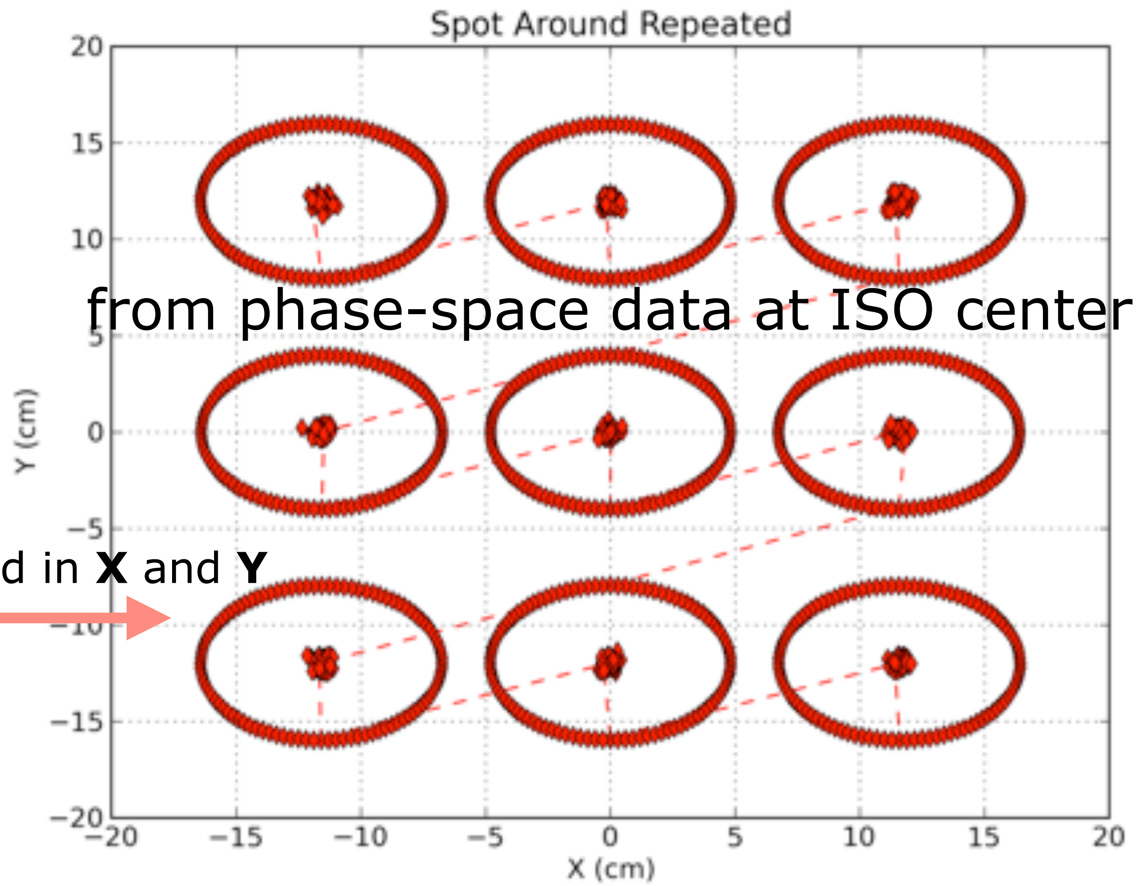
- Beam current modulation



% **For more details about dose calculation, see Jan Schuman's poster.**

Scanned beam@MGH

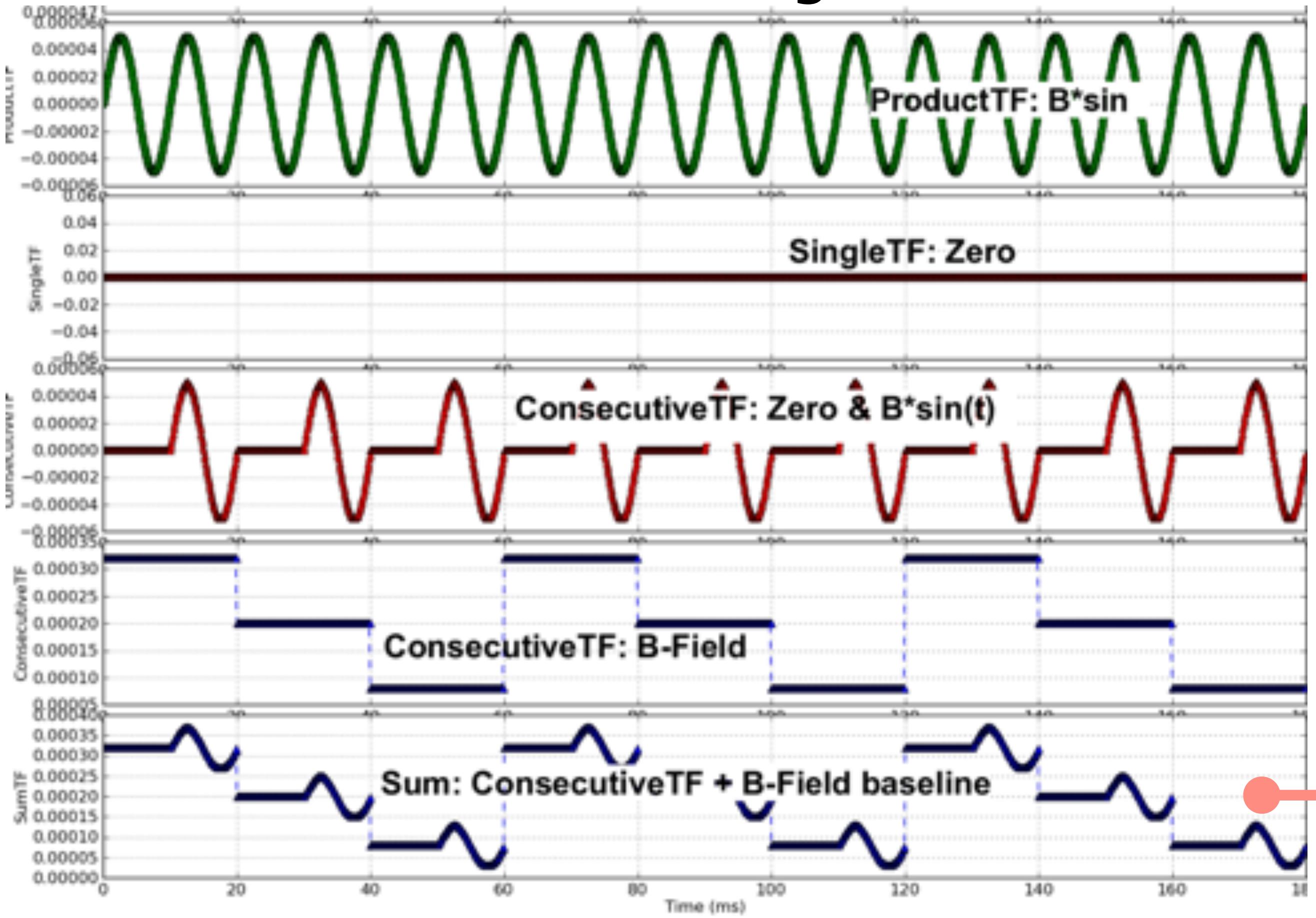


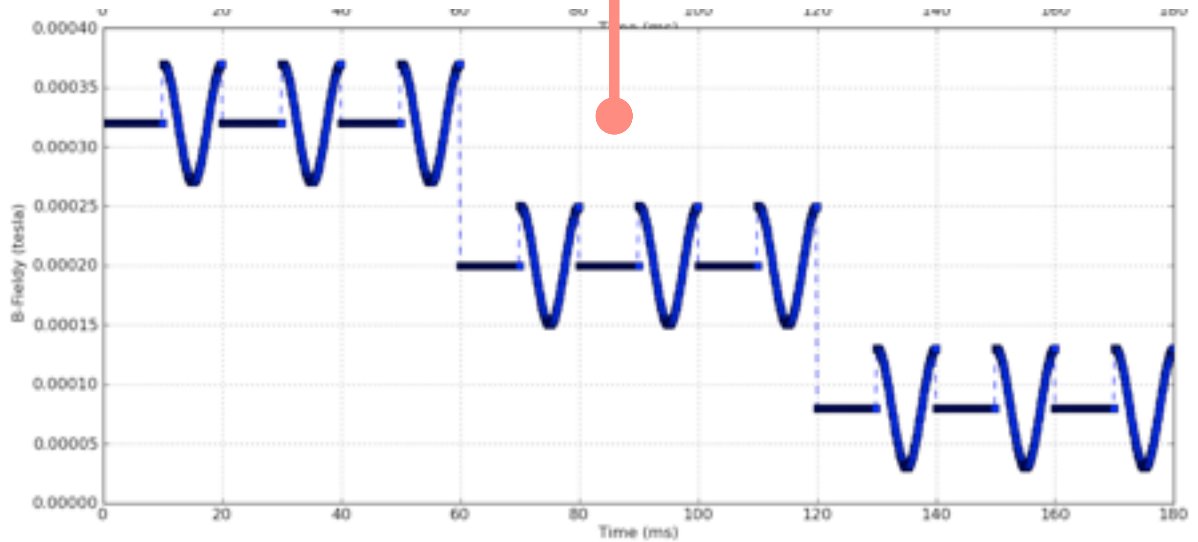


from phase-space data at ISO center

B-Field in **X** and **Y**

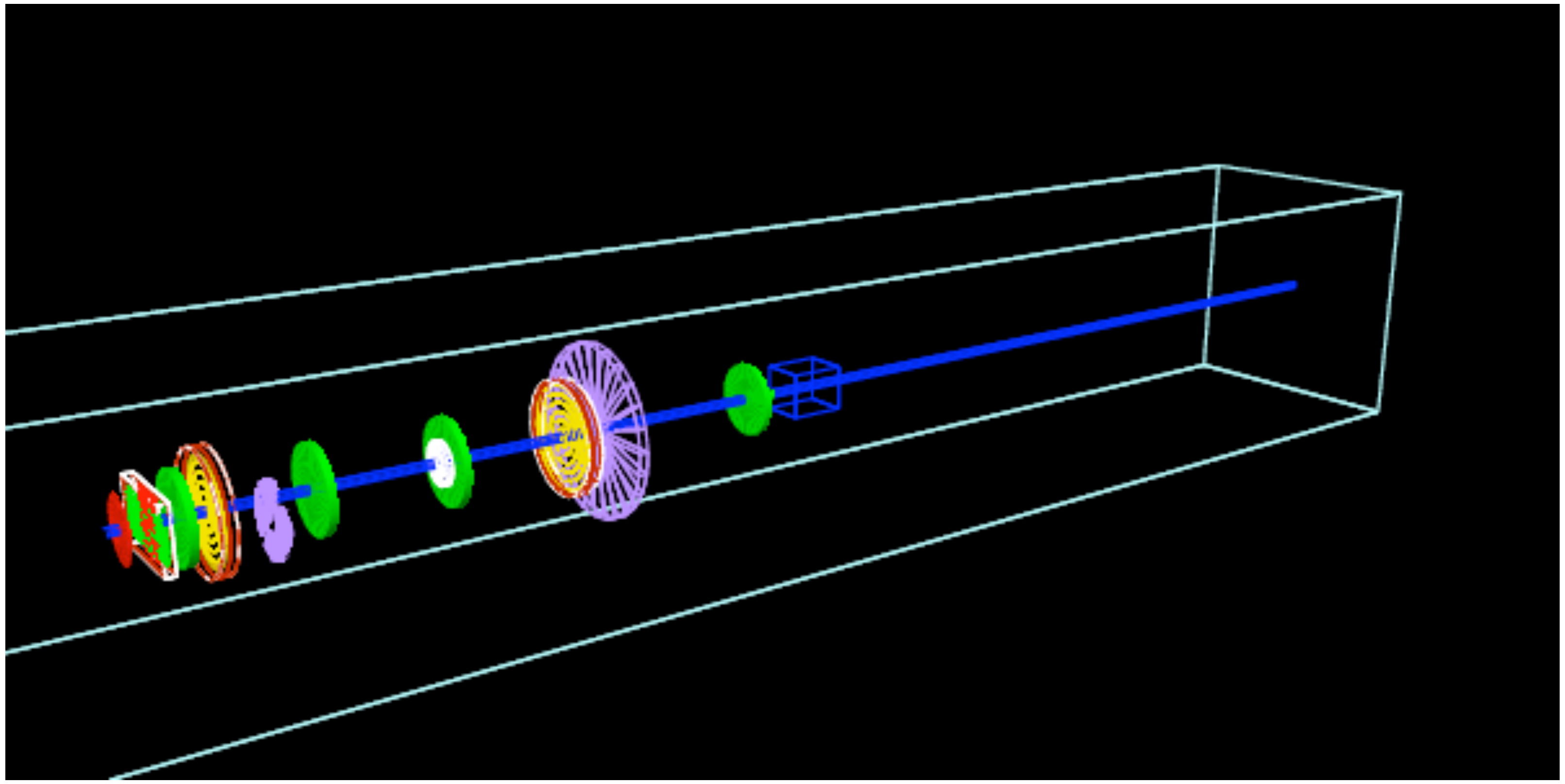
- a TimeFeature for magnetic field

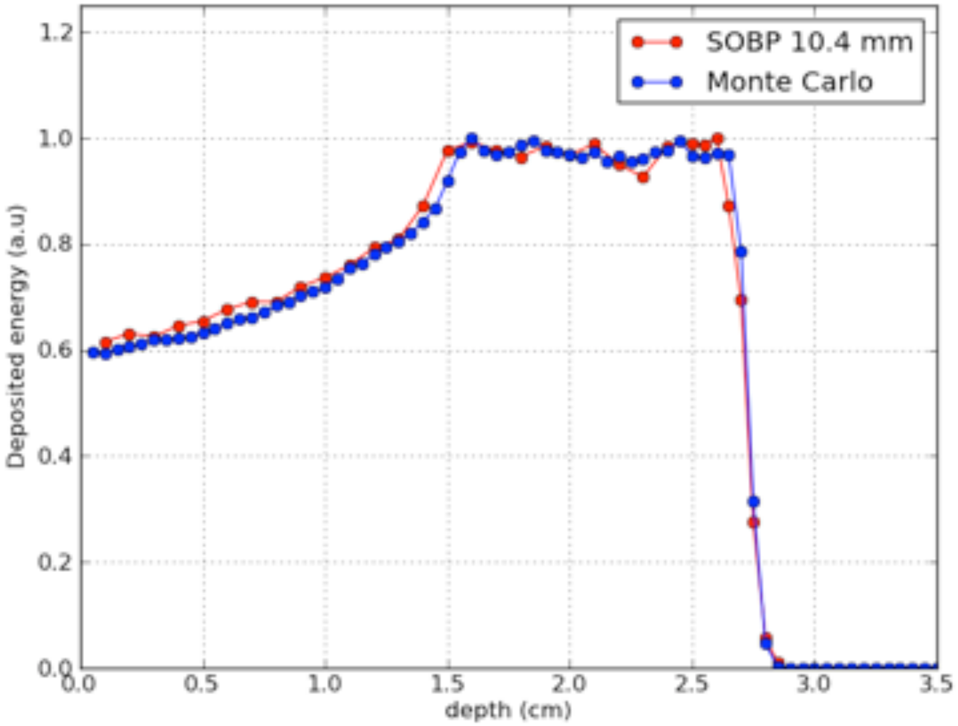


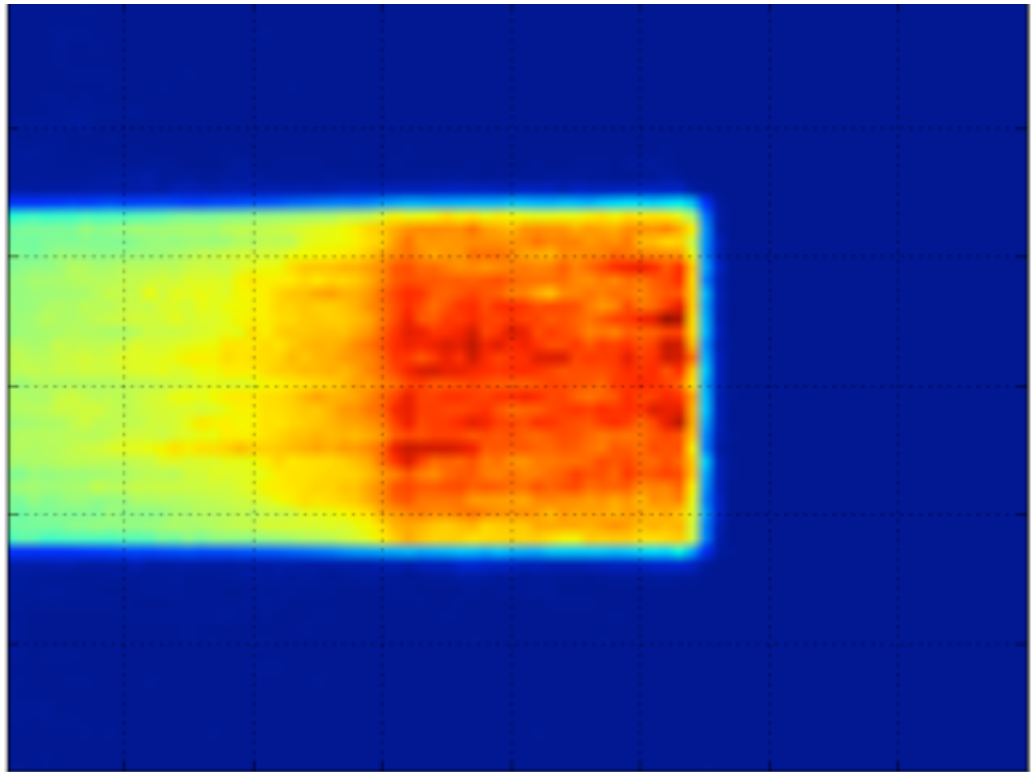


Eye treatment@UCSF/UCD

- Rotation of Propeller







Conclusions

- General method for time-dependent simulation was implemented by taking advantages of TOPAS parameter system.
- The methodology was successfully applied to IBA@MGH facility and UCSF/UCD Eye-treatment system.
- Our approach is relevant to interplay effects, because all time-dependent quantities in TOPAS is independent to each others.
- Random mode is recommended to simulate continuous motions.
- Sequential execution may helpful to shorten simulation time, however the interval should be carefully set to prevent under-sampling.
- Geant4 is a perfect platform to apply TimeFeature.