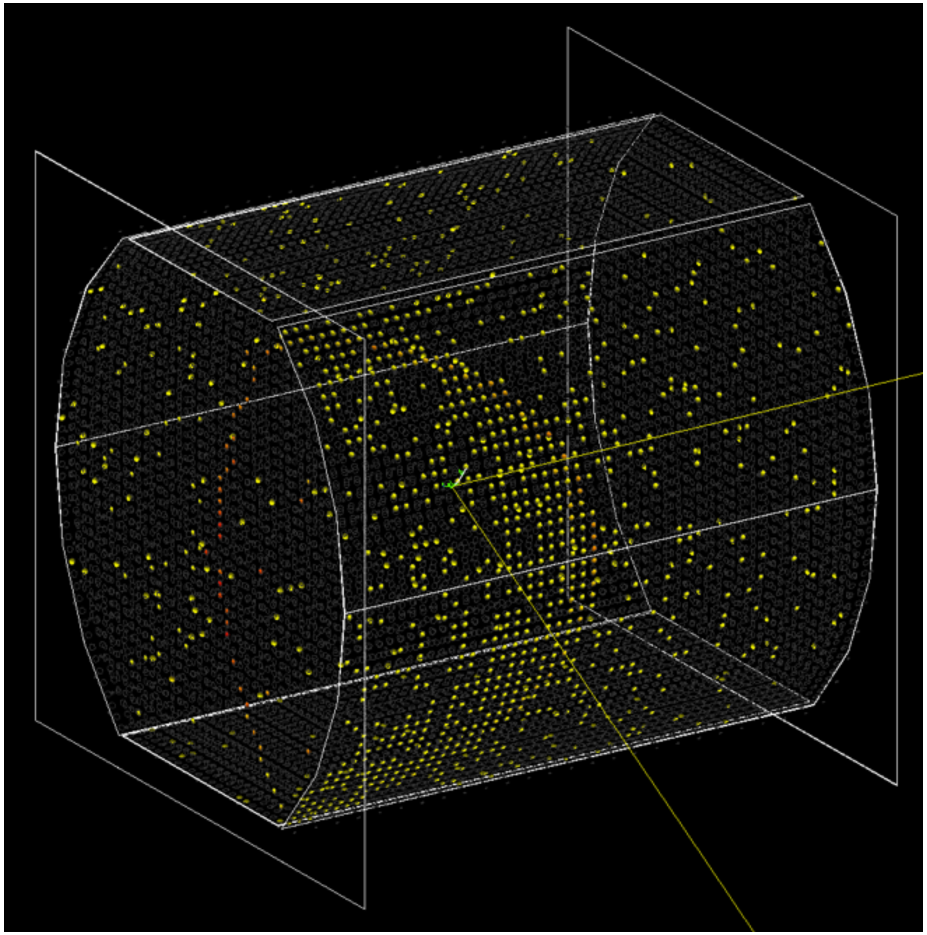
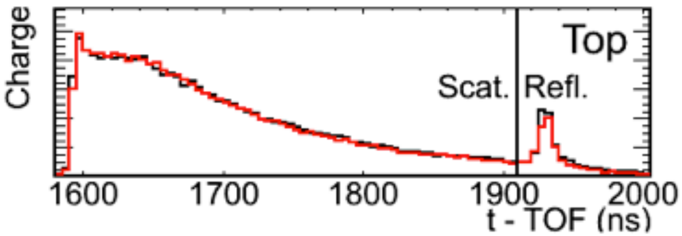
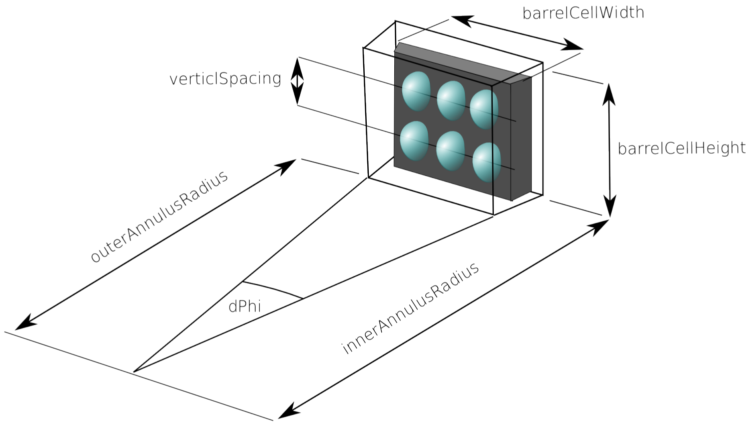
WCSim Status

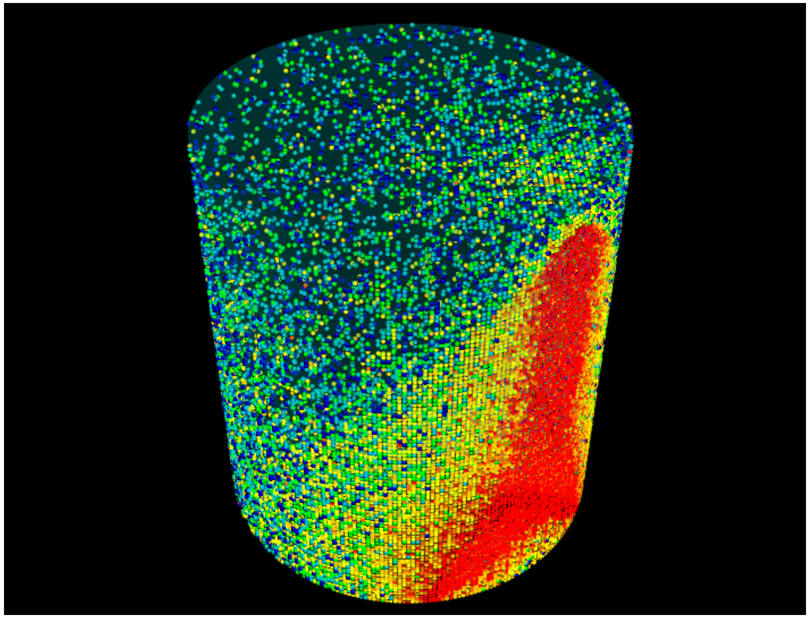






Chris Walter for Software Group
Duke University
3rd Hyper-K Open meeting
Kashiwa Kavli IPMU
6/21/2013

The WCSim simulation package



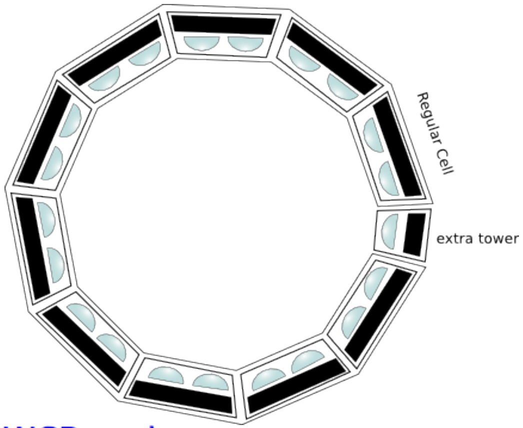
WCSim is a Geant4 based WC Monte Carlo

We built a flexible system in Geant4 and used it to simulate several geometries including the the SK tank so we can tune the simulation with real data and existing MC.

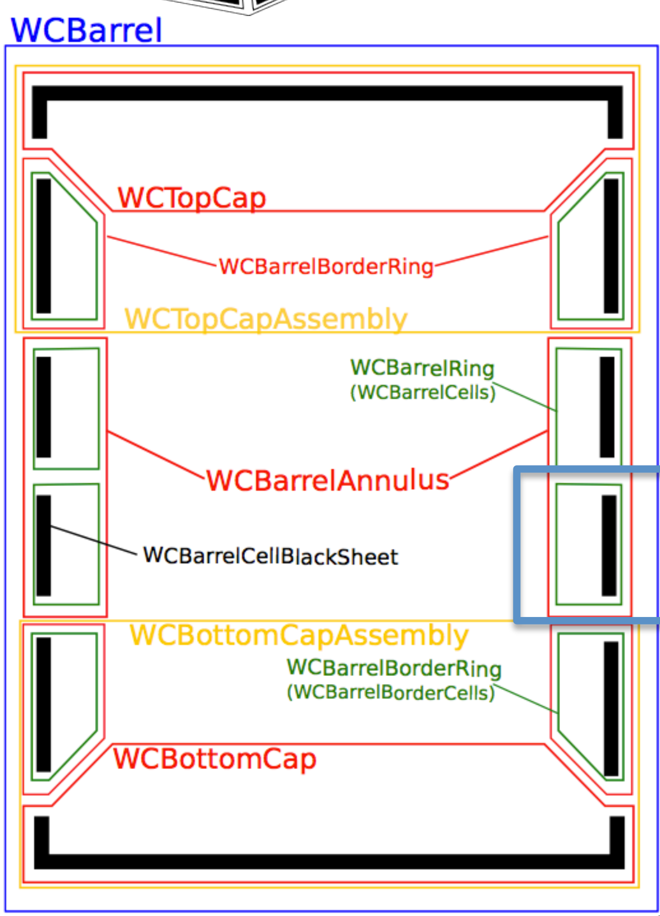
➔ We are now using this for Hyper-K

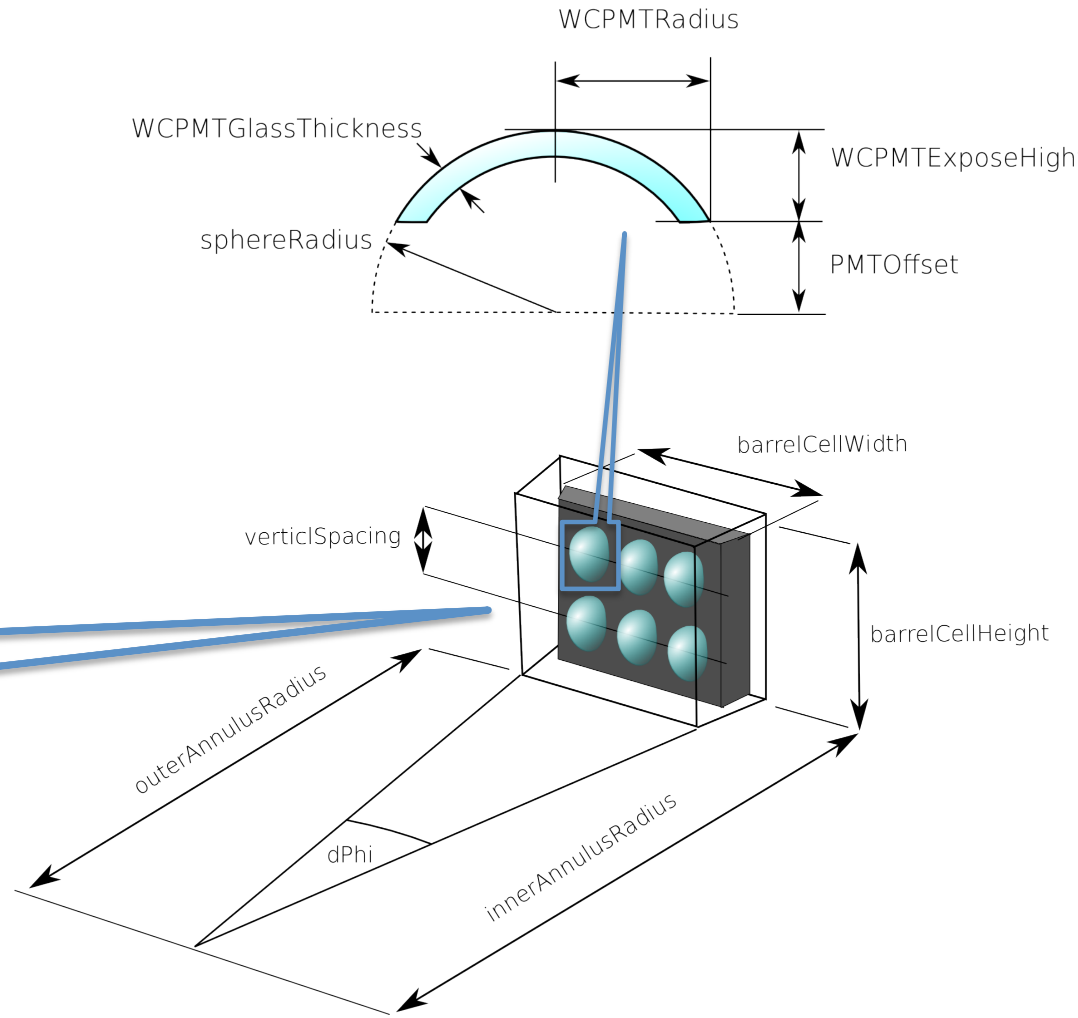
Use shared physics properties -> with many geometry configurations
(cavern size / shape / number or tubes / Tube characteristics/hadronic models all adjustable)

Hyper-K software group members from Duke, ICRR, TIT, UBC, TRIUMF, Manitoba and UCI are working on various aspects for Hyper-K.



The program is extremely flexible. By specifying a set of parameters we can define and simulate any cylindrical geometry and tube combination.





Geometry and physics configurations can be chosen without compilation through macro files.

Current Goals and Roadmap

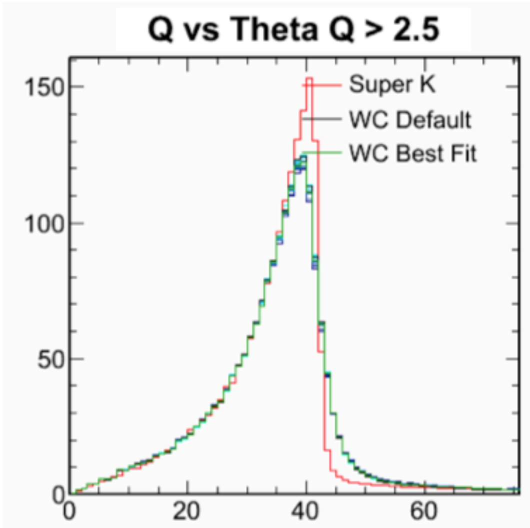
- Create a realistic “one-chamber” Hyper-K geometry. This will allow us to study the performance as a function of chamber size and length.
- Study basic distributions in the new detector.
- Study the performance of new reconstruction.

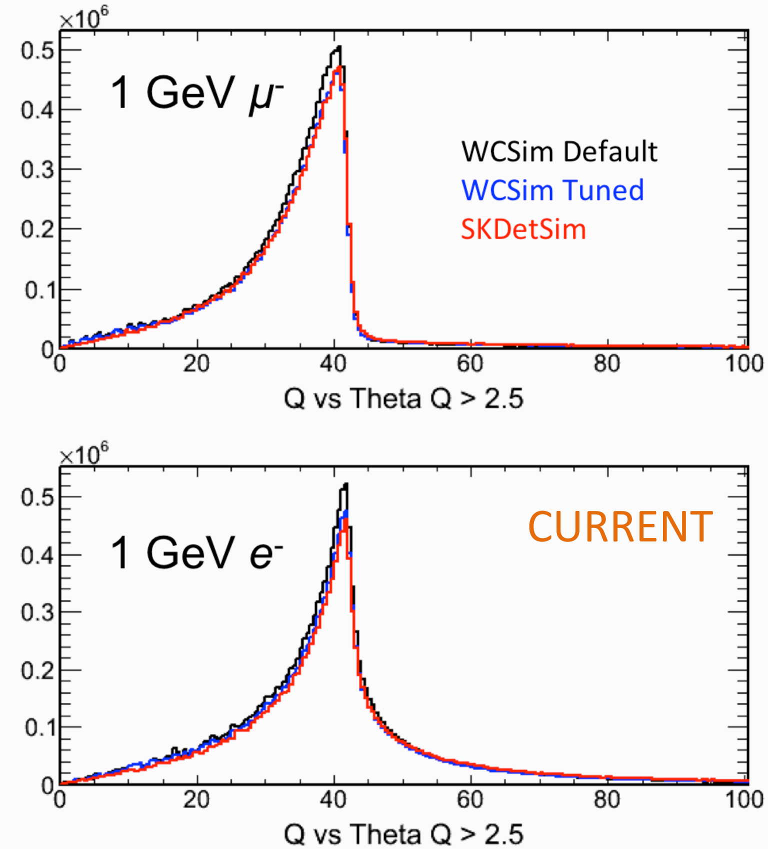
→ See Okajima and Patrick’s talk

Updates from last meeting

Another example: Q vs. Angle

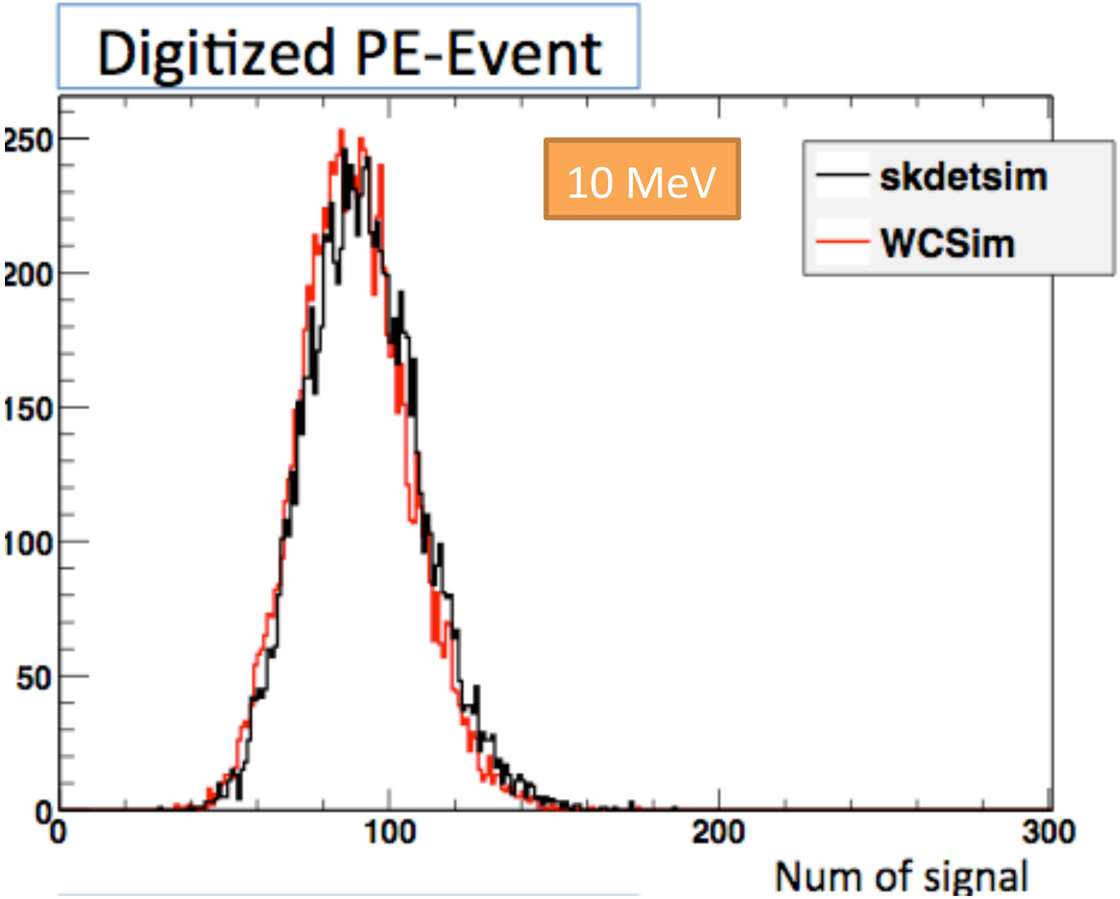
- WCSim rings appear not to cut off as sharply at 42°
  - μ^- shown at right
- Again, this difference is insensitive to the tuning parameters





We reported on a shape discrepancy at the last meeting. This was due to a plotting bug. The actual physics response is fine.

Good low energy agreement with skdetsim



After applying all tuning factors properly and fixing some issues introduced with a recent consolidation of the tube geometry we see good agreement with skdetsim even at low energy (when using digitized charge) in Super-K mode.

Implementing the “egg”

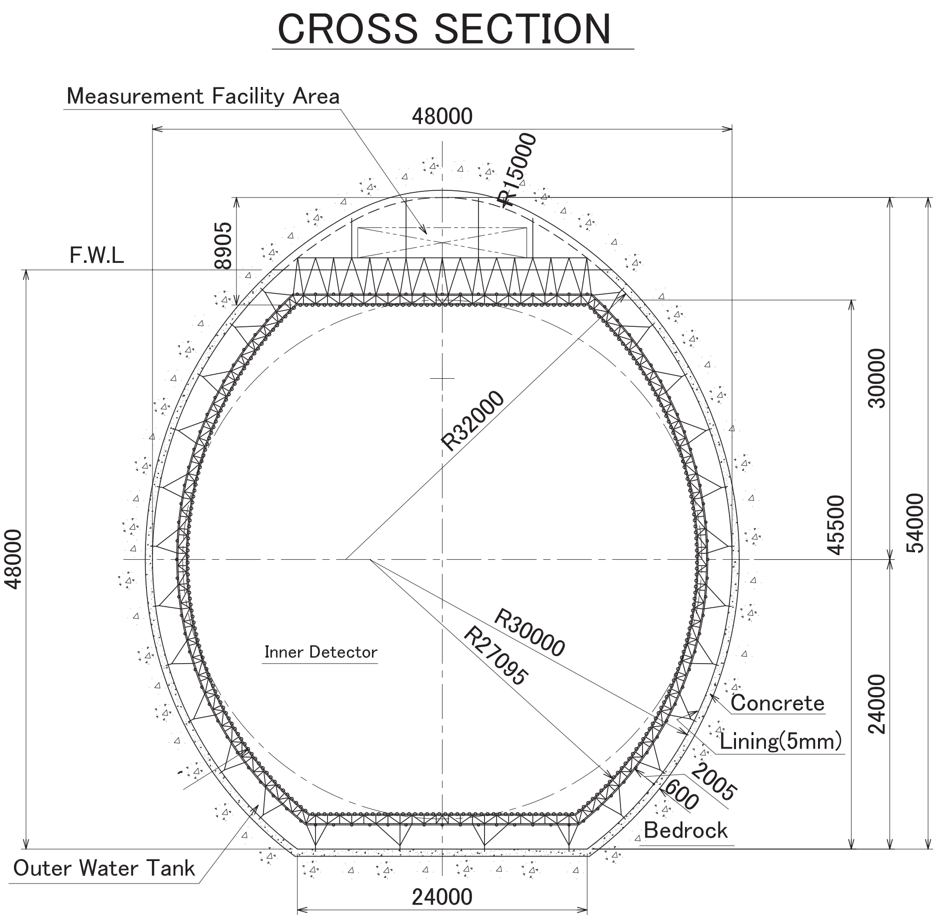
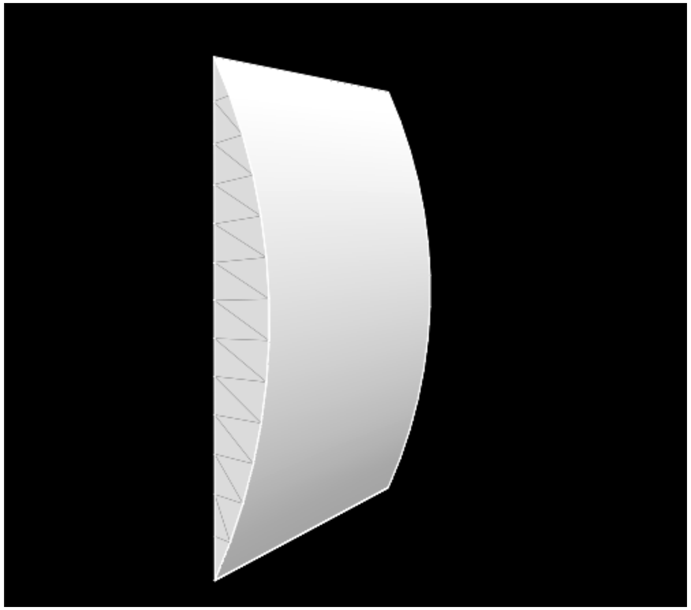


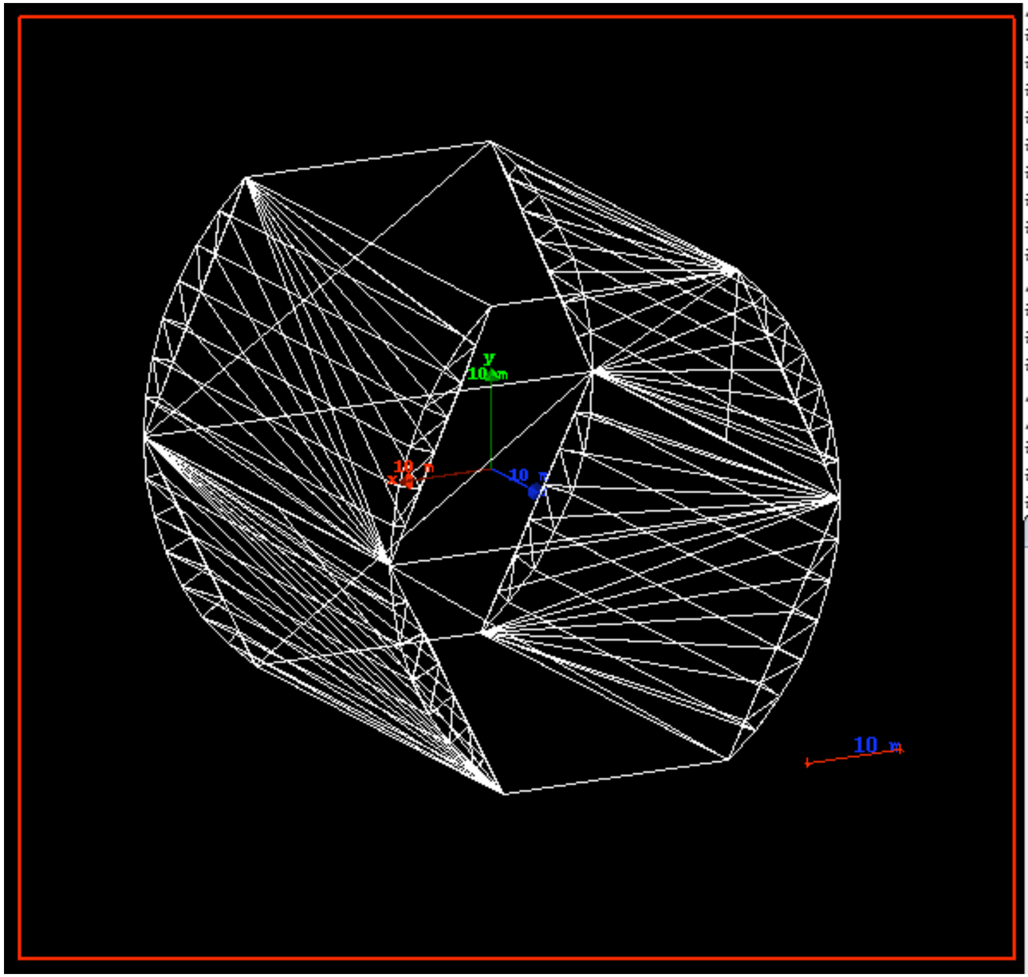
FIG. 6. Cross section view of the Hyper-Kamiokande detector.

- Hyper-K has an “egg-like” geometry for geo-technical reasons. So the top is not the same as the bottom.
- This geometry has now been implemented in WCSim by Peter and Alex.

Water Tank (from Peter)



Slice == G4SubtractionSolid(G4Tub - G4Box)



Construct Half (top or bottom):

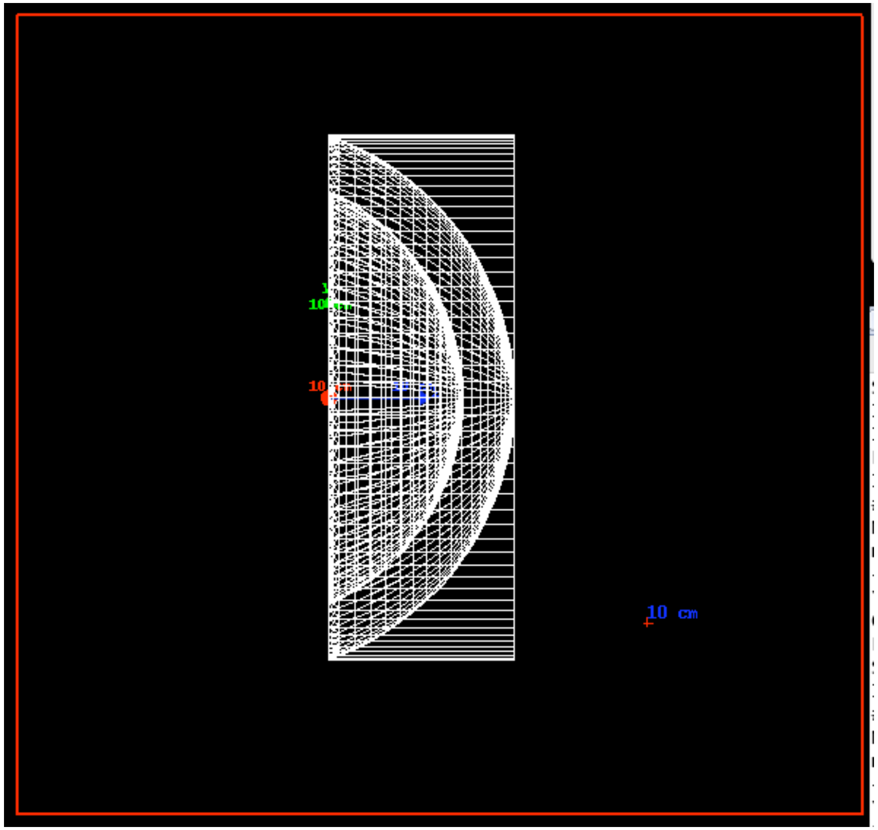
Centre == G4Trap

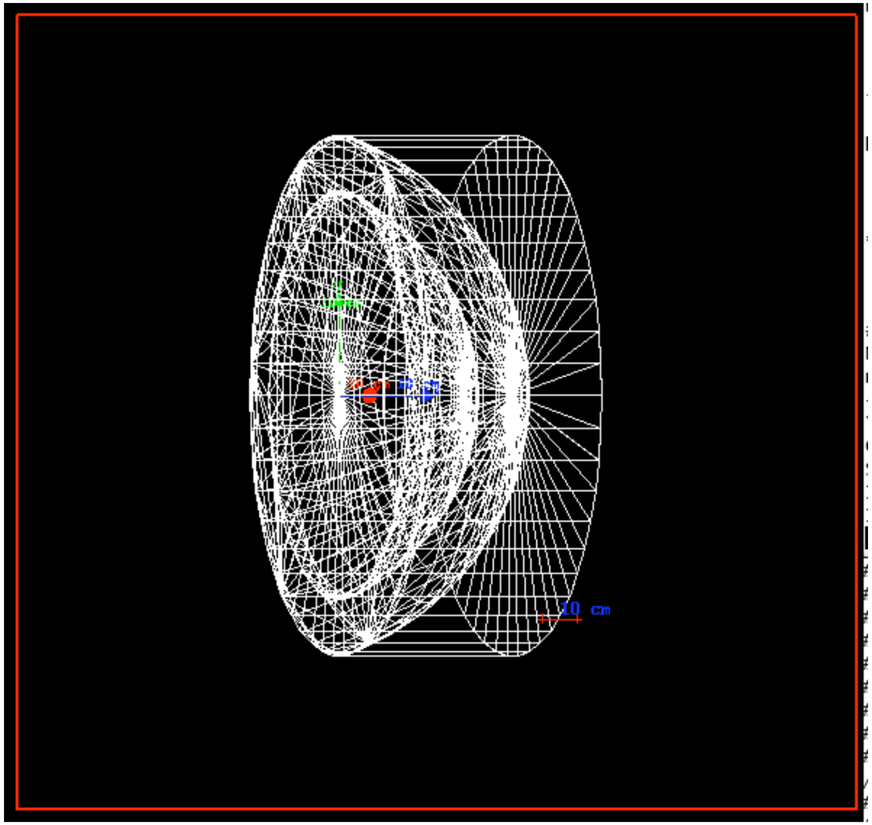
Union1 == G4UnionSolid(G4Trap + Slice(pos1))

Union2 == G4UnionSolid(Union1 + Slice(pos2))

WaterTank == G4UnionSolid(Top+Bottom)

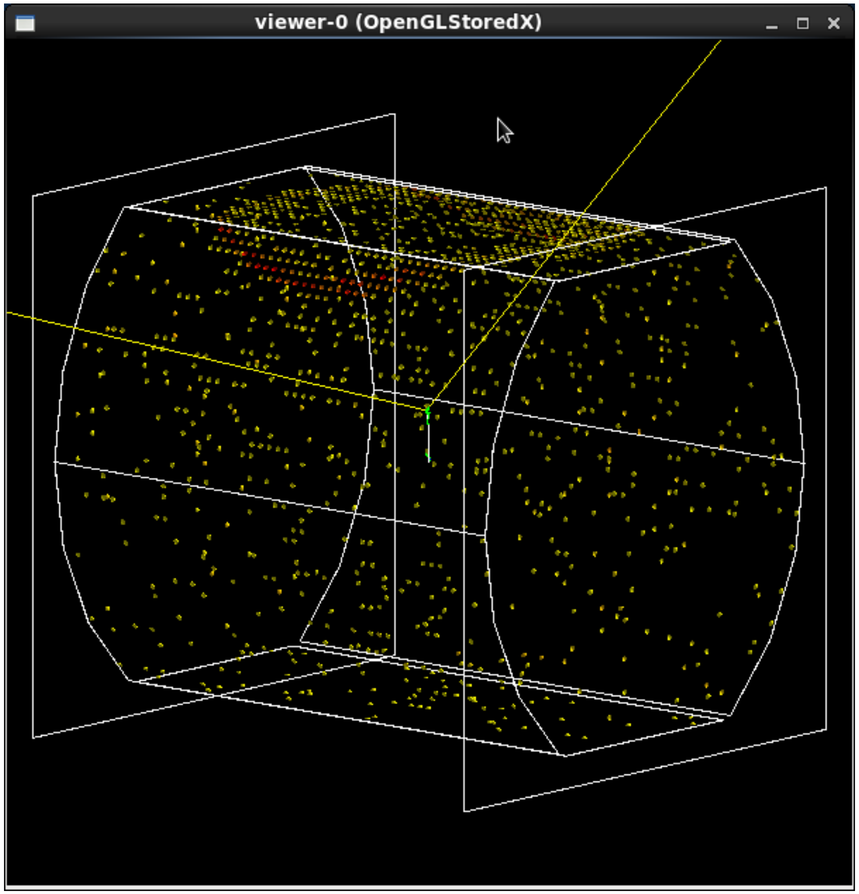
PMT Geometry





Gap is exaggerated for display purposes.

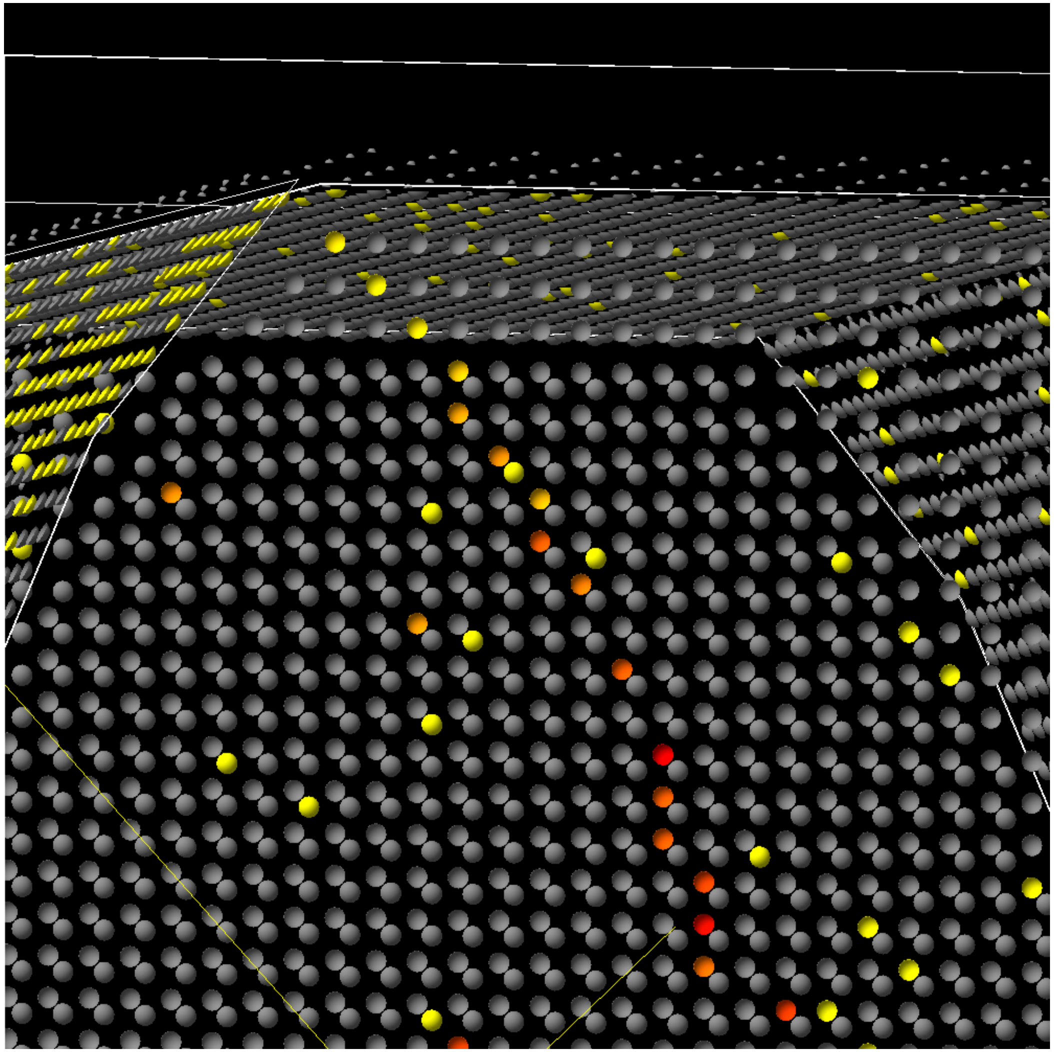
WCSim in Hyper-K mode



Alex took Peter's geometry description and merged it in with the WCSim code base.

We can now run MC particles through the Hyper-K configuration.

Includes both ID and OD tubes

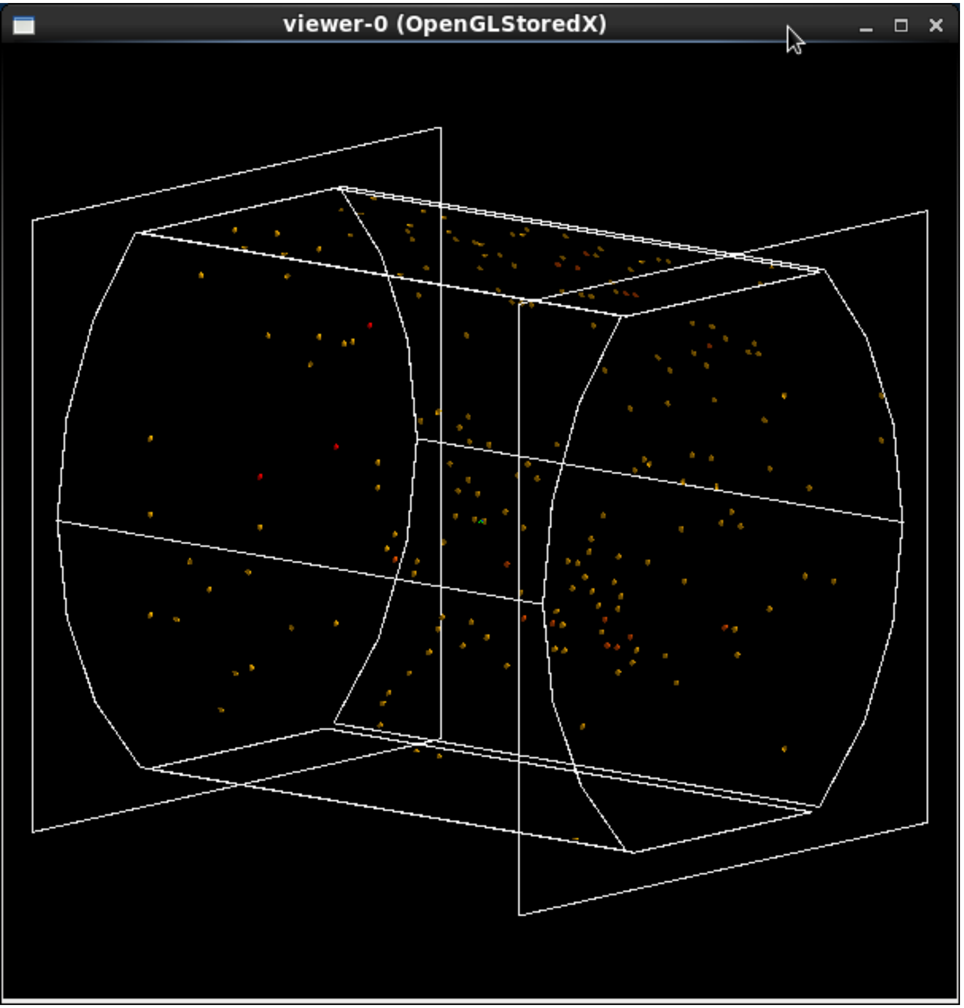


The tube creation function can now have more than one tube type existing simultaneously.

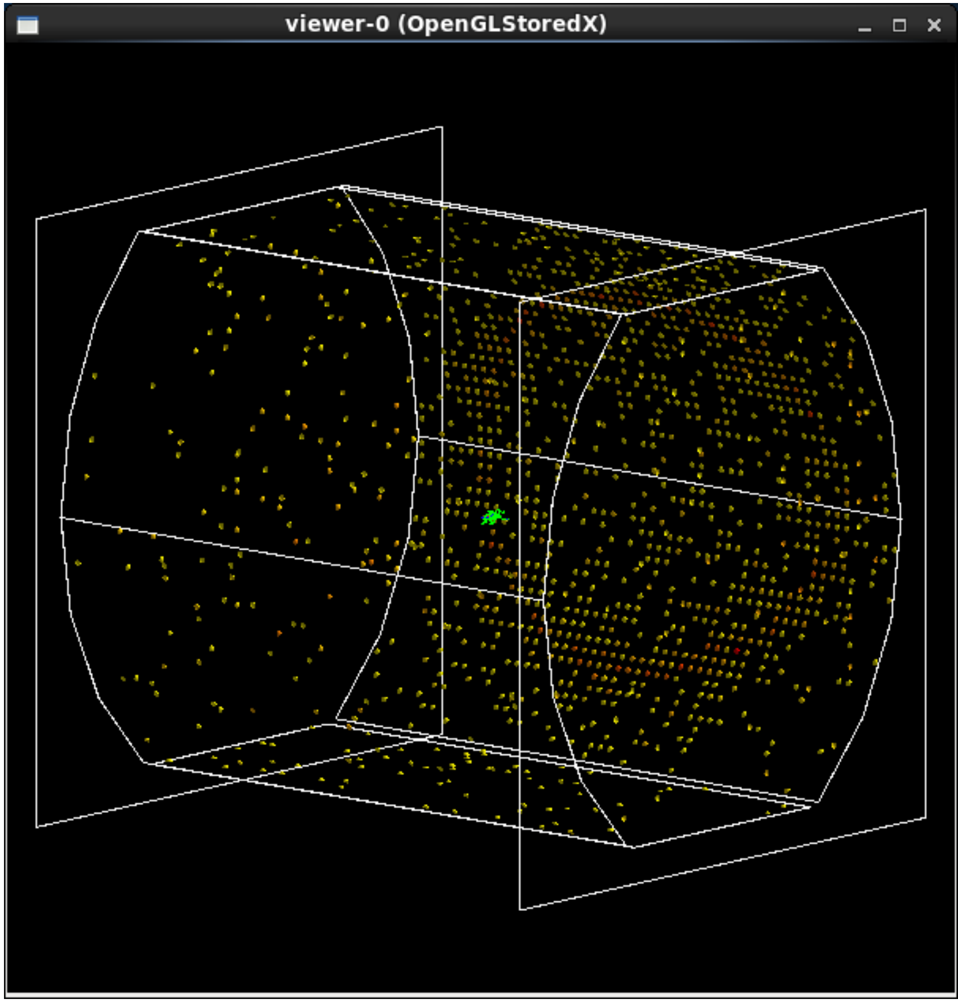
Shown in this view are the OD tube looking up.

The OD is not yet functional for returning hits.

Event displays: electrons

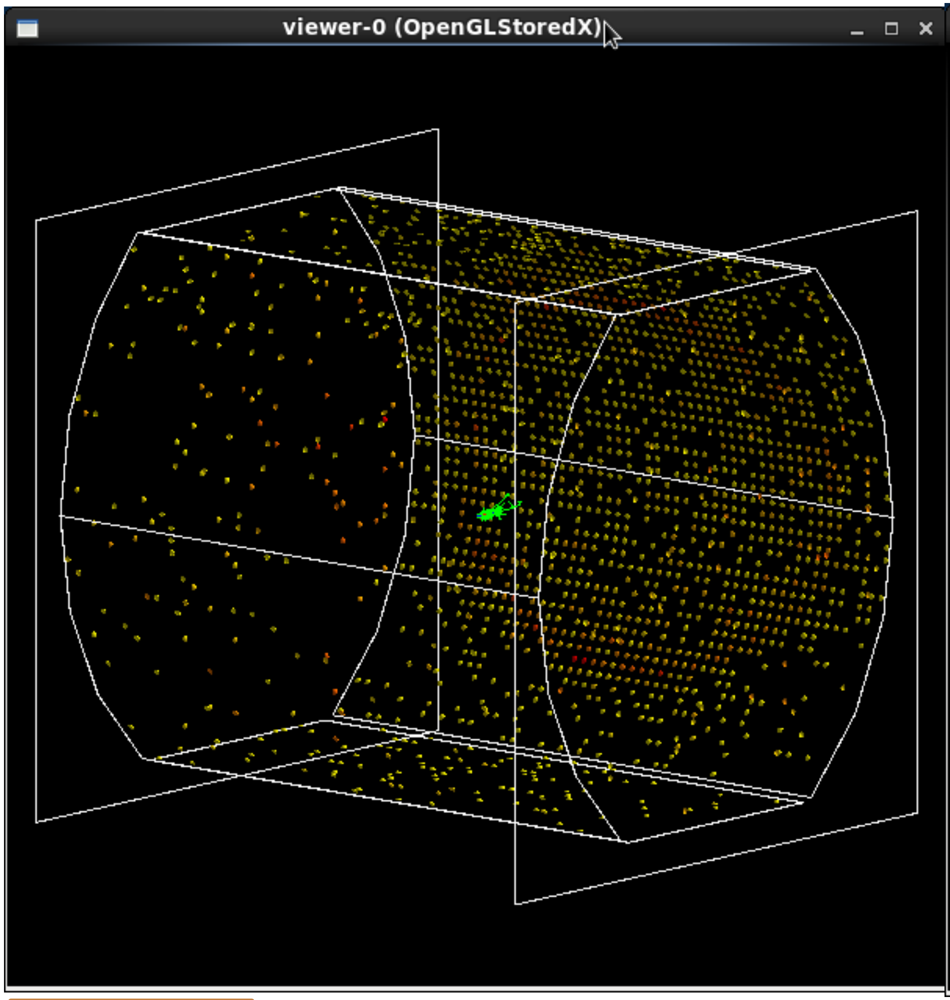


50 MeV

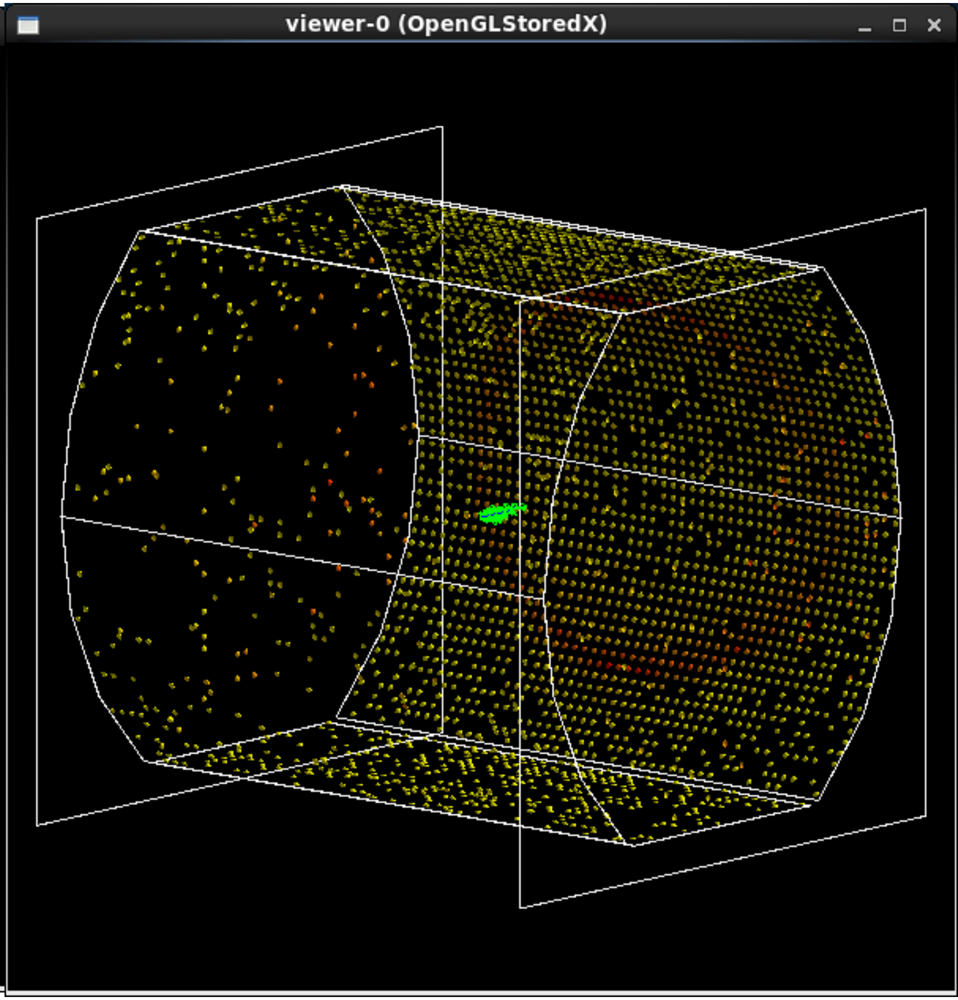


600 MeV

Event displays: electrons

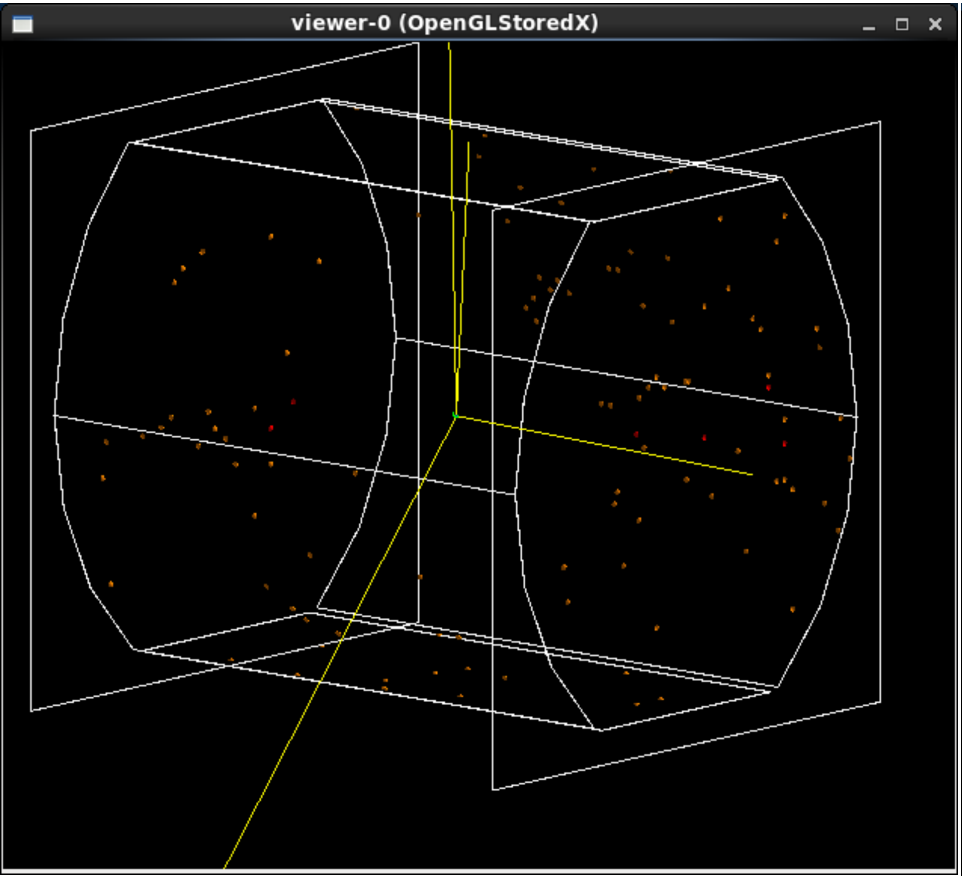


1000 MeV

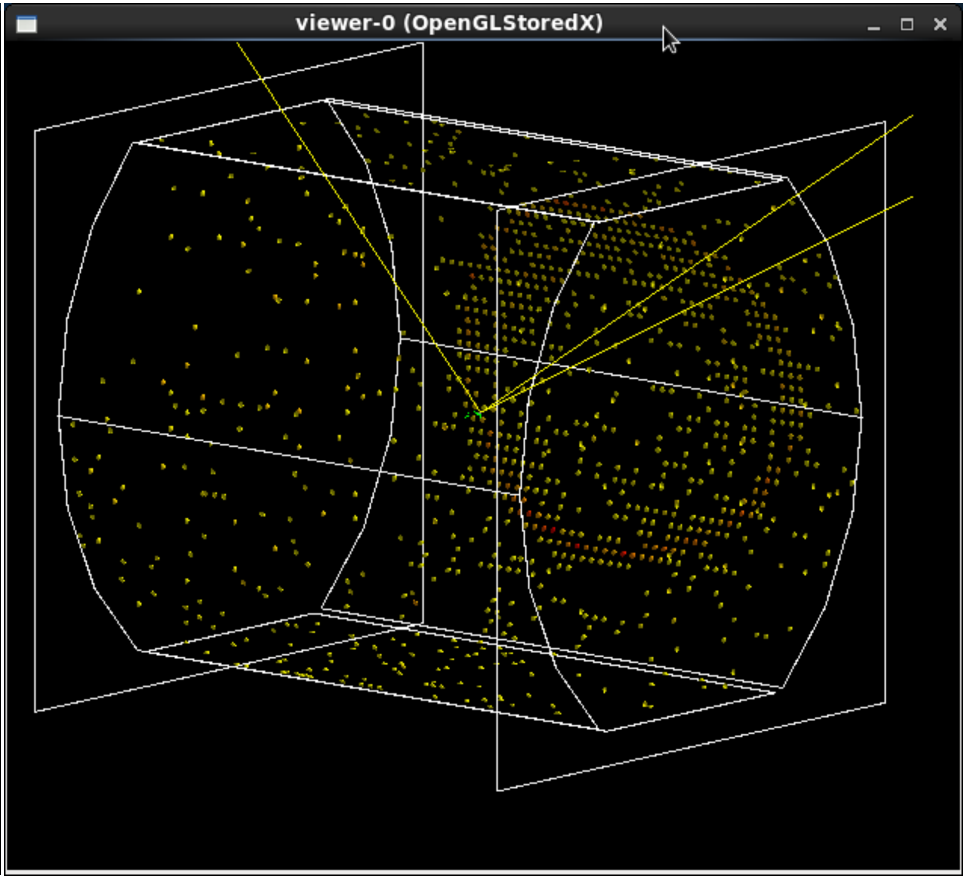


5000 MeV

Event displays: muons

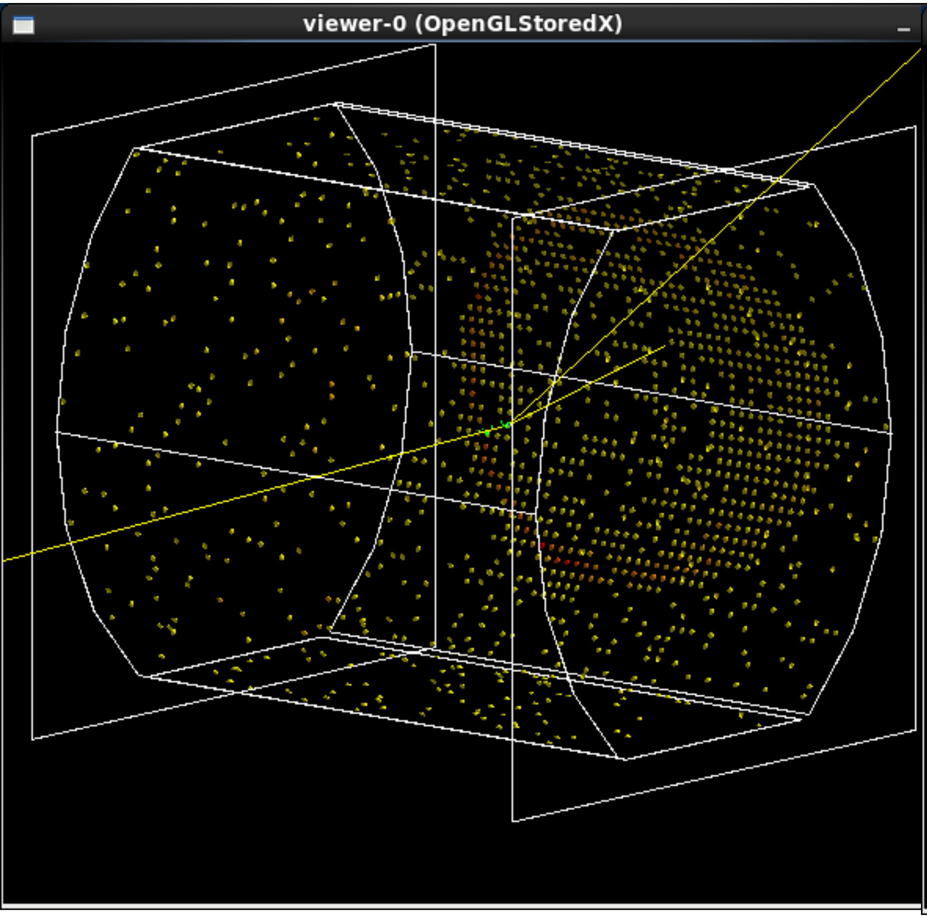


50 MeV

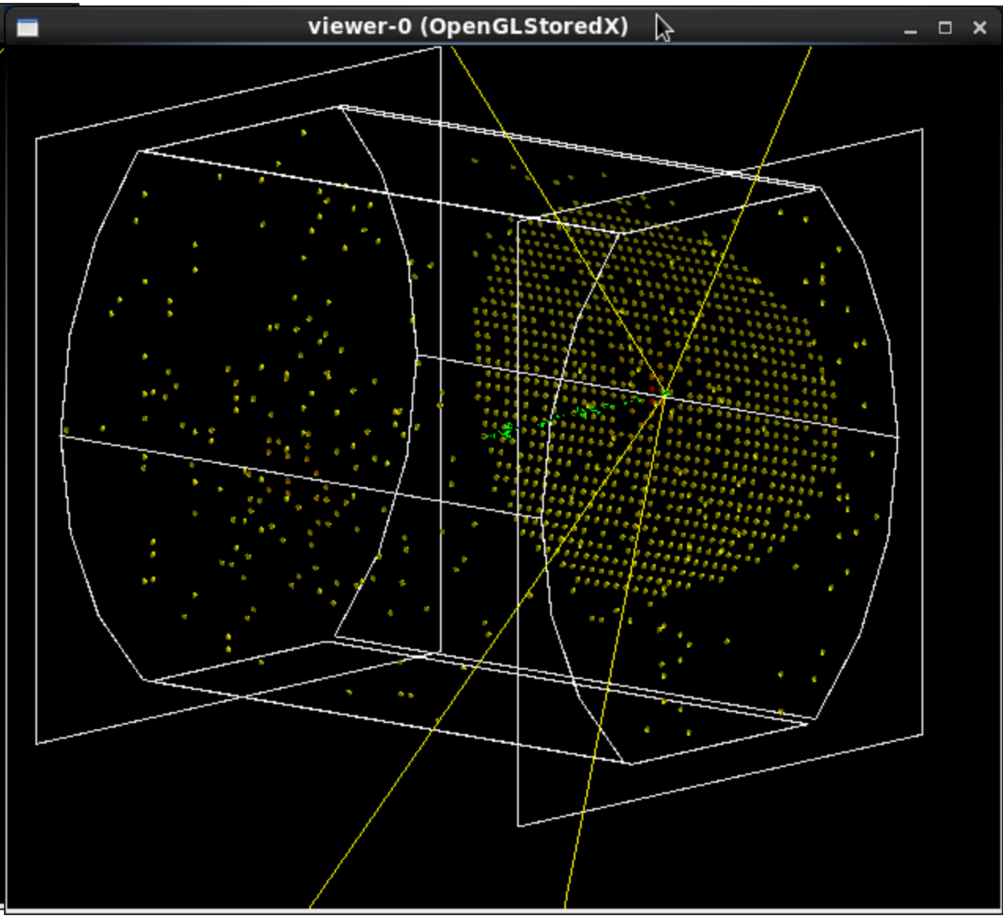


600 MeV

Event displays: muons

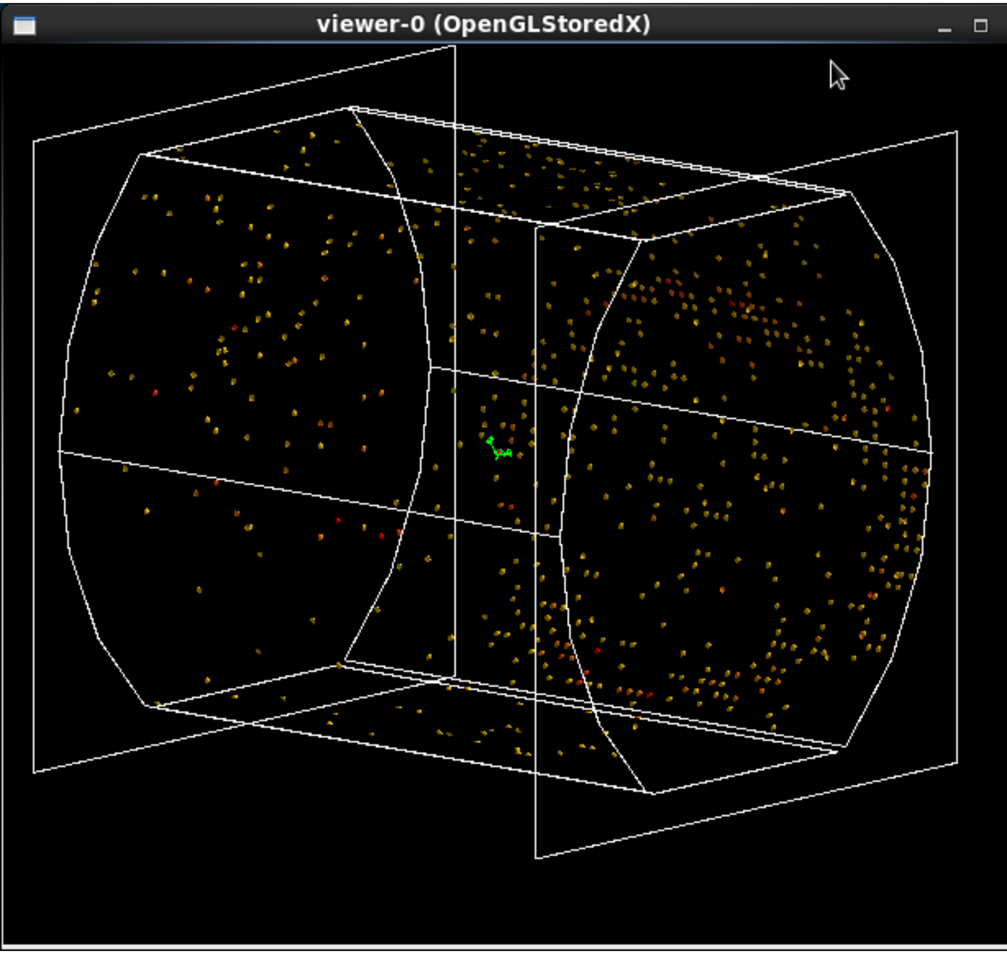


1000 MeV

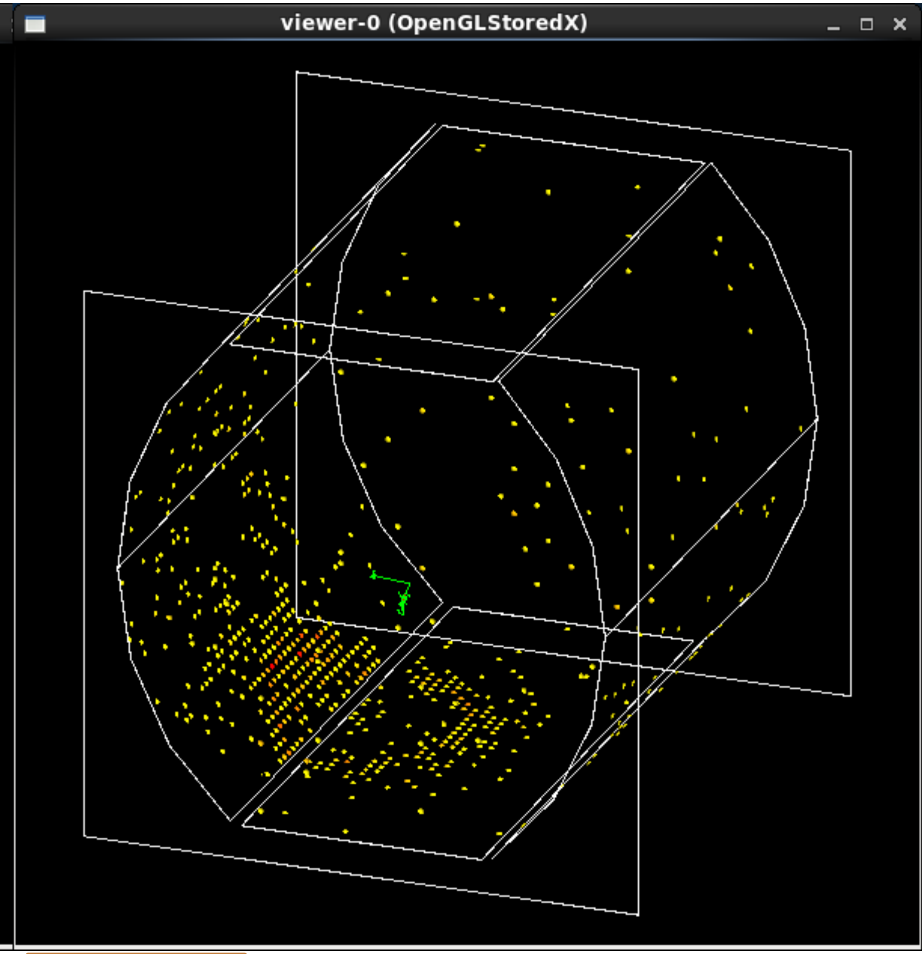


5000 MeV

Event displays: pizero

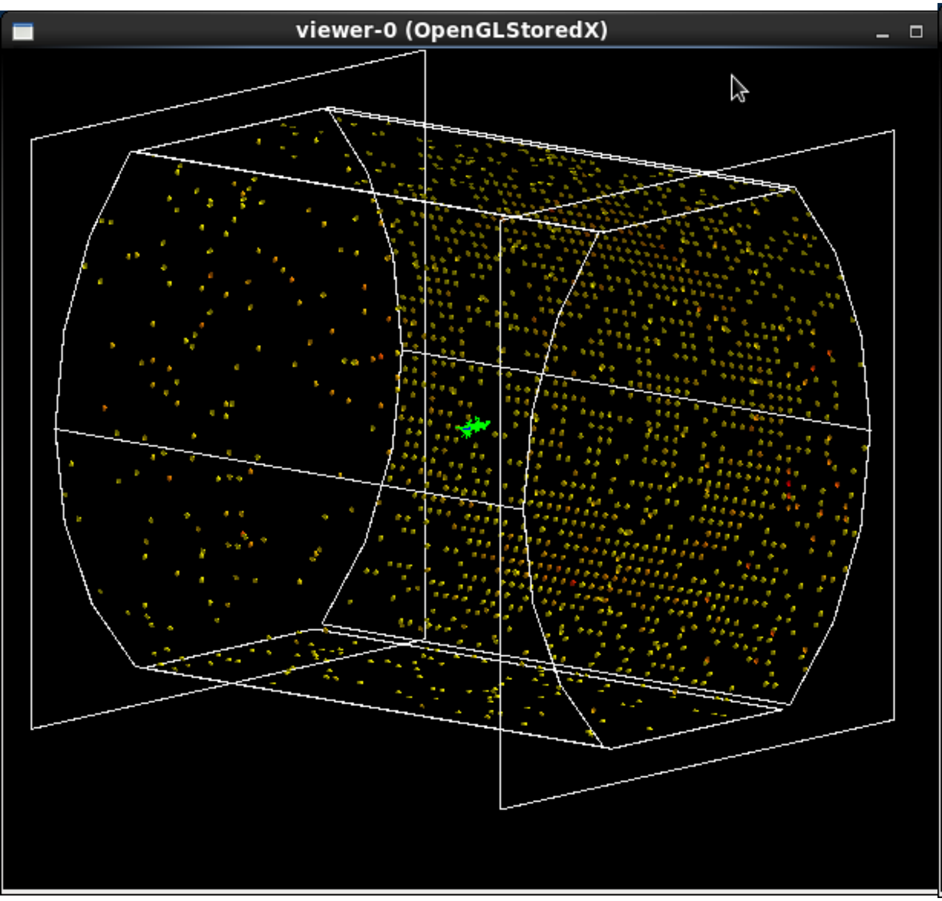


50 MeV

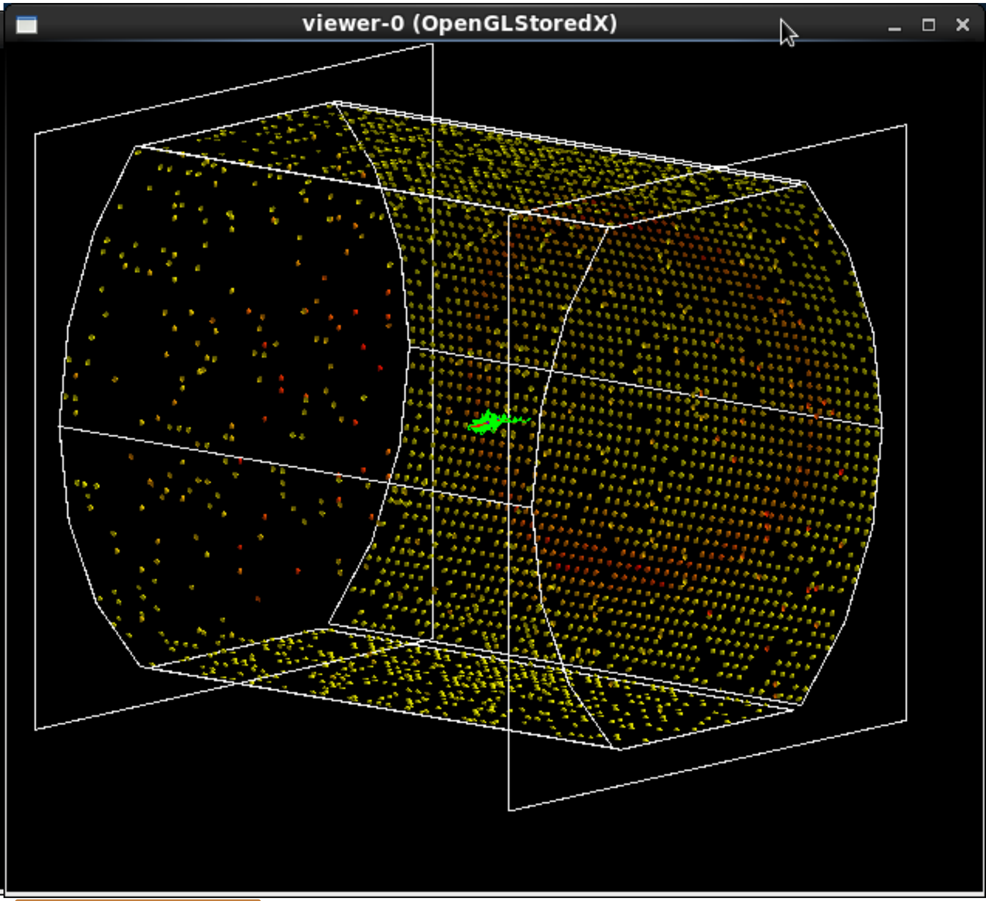


150 MeV

Event displays: pizero



600 MeV



5000 MeV

Dark Noise

We now have added the ability to include dark noise in the simulation. This work was done by M. Askins from the WATCHMAN collaboration and Y. Okajima.

```
# command to set dark noise frequency 13/06/09
# default dark noise frequency is 0 kHz
#/DarkRate/SetDarkRate 4 kHz
```

Controlled by .mac file. Currently on global rate.

Tube Type / QE

Not currently being used but we have the ability to easily modify the QE:

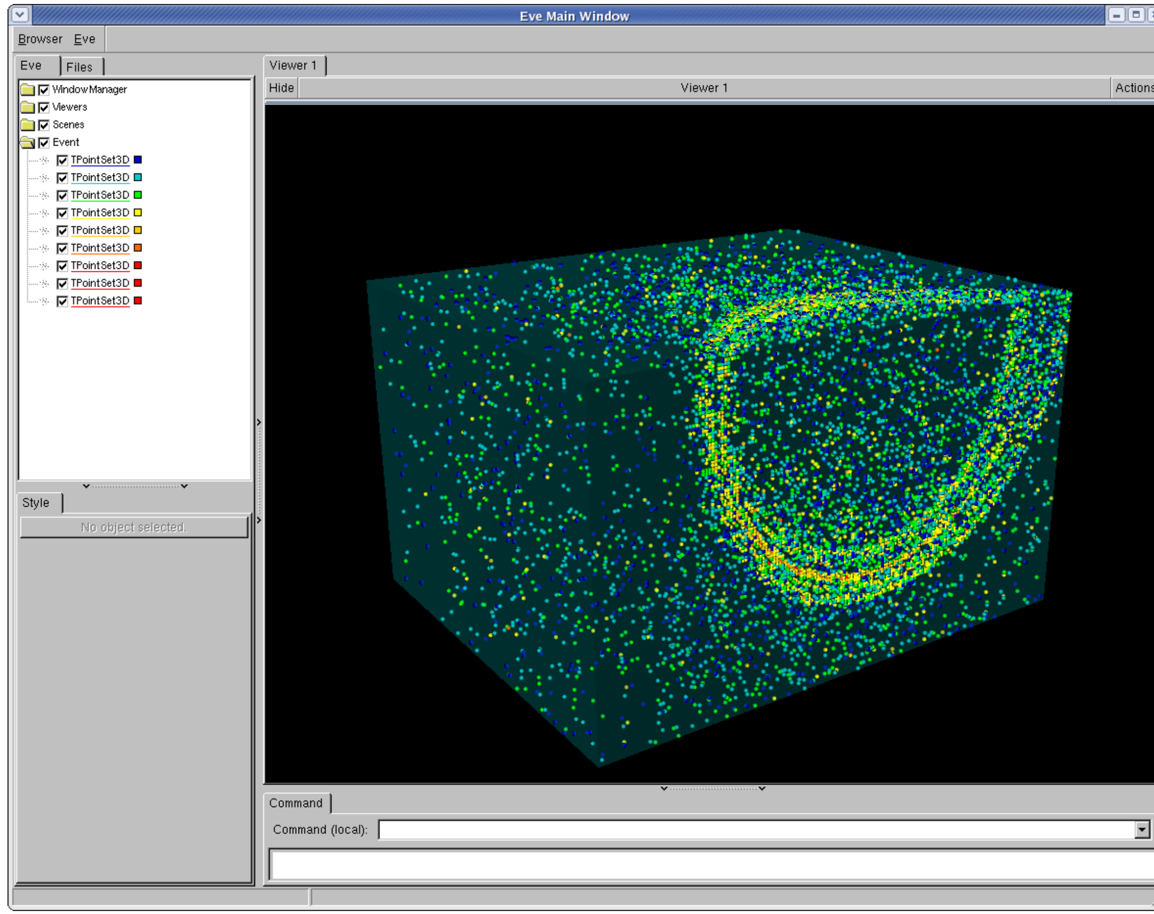
```
 WCPMTName                  ="20inch";

//define the wavelength and QE for different detectors
const G4float wavelength[20] =
  { 280., 300., 320., 340., 360., 380., 400., 420., 440., 460.,
    480., 500., 520., 540., 560., 580., 600., 620., 640., 660.};

// (JF) This is the QE for the SuperK 20" tubes.
const G4float SKQE[20] =
  { 0.00, .0139, .0854, .169, .203, .206, .211, .202, .188, .167,
    .140,  .116, .0806, .0432, .0265, .0146, .00756, .00508, .00158, 0.00};
const G4float SK_maxQE = 0.211;
```

The photons can have the efficiency applied at generation, at the tube, or a hybrid which is useful for WLS.

We have a root based event display used in T2K 2KM and LBNE in the past. We need to modify it for Hyper-K use.

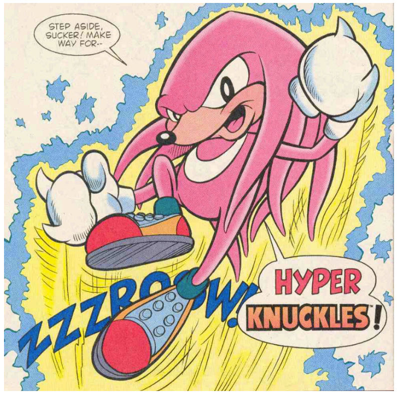
The program produces self descriptive geometry and output files.

You describe the geometry you want and the program generates it and simulates the events. It then writes out all of the tube information and other self descriptive information needed for reconstruction and display by external programs further down the analysis chain.



Example: 150 kton Mailbox design with 30% PMT coverage displayed in root based display.

Conclusions / Plan



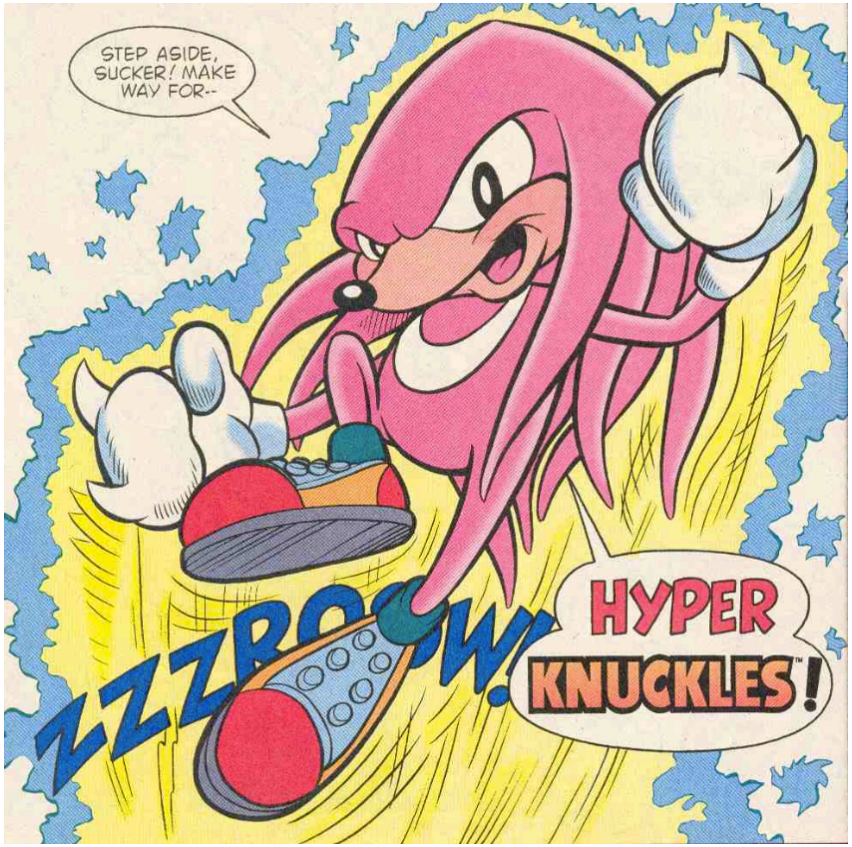
Conclusions

- Good agreement is found in SK mode for digitized charge even at low energy.
- We have implemented and started to use the Hyper-K geometry.
- We need to add some analysis tools (like event display).

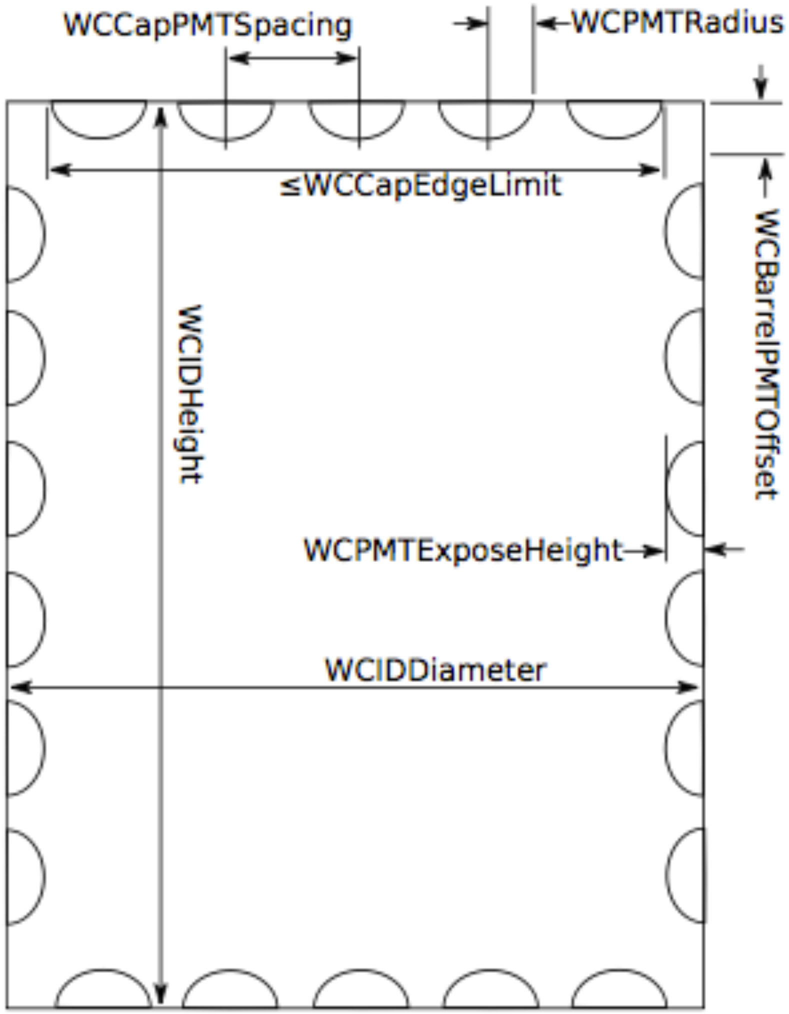
Plan

- We now will study detector and reconstruction performance as a function of detector size etc.
- After basic validation checks we can make MC samples for the physics groups.

Backups



The idea is to describe any detector parametrically.



Write one function for each setup (Super-K, 100kton, etc)

```
void WCSimDetectorConstruction::SetSuperKGeometry()
{
  WCPMTName                  ="20inch";
  WCPMTRadius                =.254*m;
  WCPMTExposeHeight          =.18*m;
  WCIDDiameter               = 33.6815*m;//16.900*2*
                                        //cos(2*pi*rad/75)*m;
  WCIDHeight                 = 36.200*m;
  WCBarrelPMTOffset          = 0.0715*m; //offset from vertical
  WCBarrelNumPMTHorizontal   = 150;
  WCBarrelNRings             = 17.;
  WCPMTperCellHorizontal= 4;
  WCPMTperCellVertical   = 3;
  WCCapPMTSpacing            = 0.707*m; // distance between centers
                                       // of top and bottom pmts
  WCCapEdgeLimit             = 16.9*m;
  WCPMTGlassThickness        = .4*cm;
  WCBlackSheetThickness = 2.0*cm;
  WCAddGd                    = false;
}
```

Can also be done for Hyper-K type geometry

These parameters describe a cylindrical geometry

➔ See Alex's talk

WCSim Tuning

SK Monte Carlo (Geant3)

- **Goal:** Tune WCSim's optical properties to skdetsim
  - SKDETSIM has been well-tuned to a running water Cherenkov detector

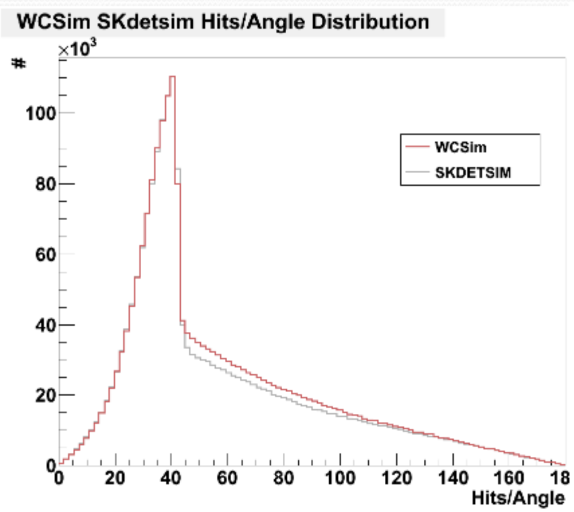
- Parameters being tuned:
  - Black Sheet Reflectivity (higher = more reflection)
  - Glass/Cathode Reflectivity (higher = more reflection)
  - Absorption Length (higher = less absorption)
  - Rayleigh Scattering (higher = less scattering)

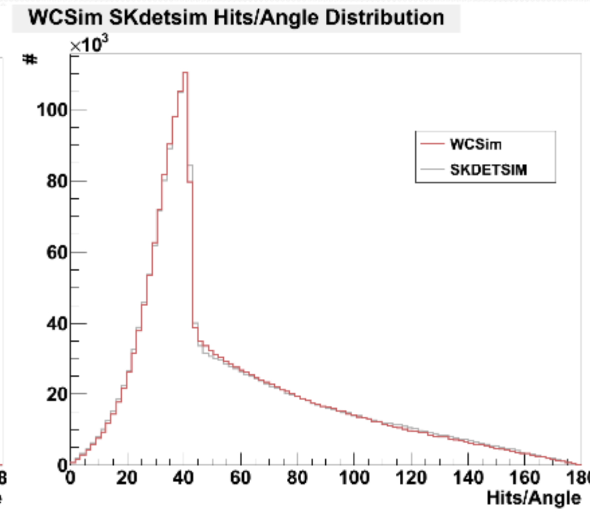
- Tuning against three samples:

– 1 GeV μ- – 1 GeV e-	Particles (produce photons) [Uniform / Isotropic]
– 337 nm calibration laser	Photons (SK laser system)

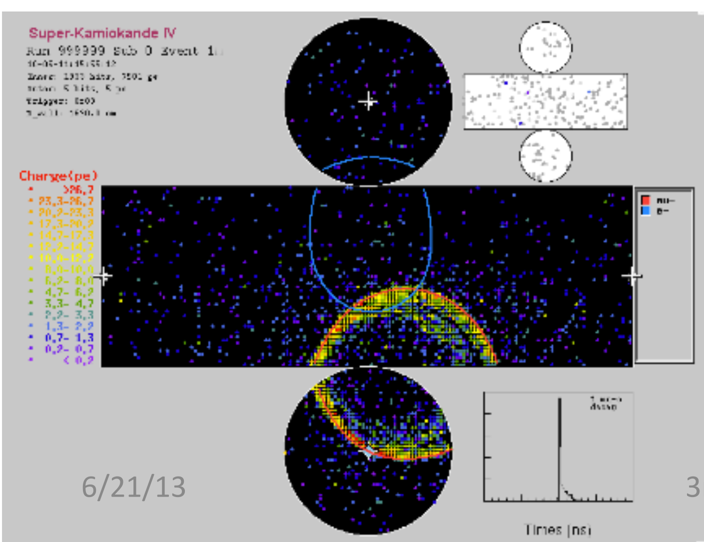
SK validation/reconstruction work

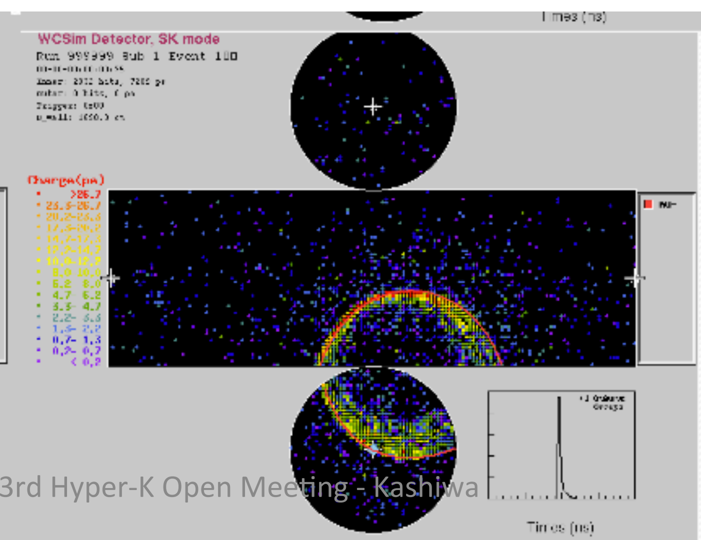
Our most powerful handle: Tuning and validation against the SK MC.





The SK MC is tuned to the 1% level. WCSim includes a SK Mode We can use to tune the MC to the validated SK MC. After tuning only geometry and tube configuration is changed.

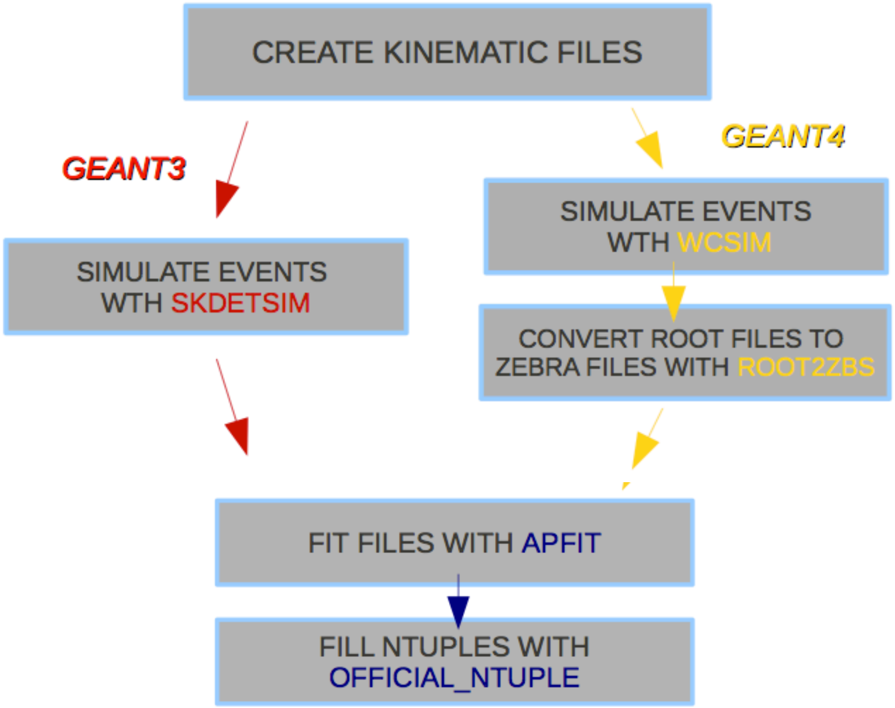




This work allowed us both to tune the Monte Carlo and improve the underlying Geant4 optical model.

Technique for HE validation

➔ See Tarek's talk



Tools Developed:

WCSim Geant4 based calibration sources (laser).

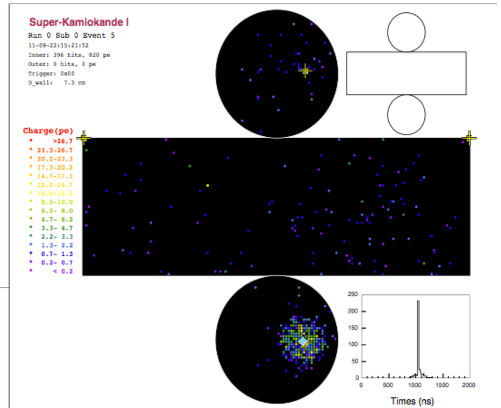
Specialized versions of SK library

Specialized version of **Superscan** event display.

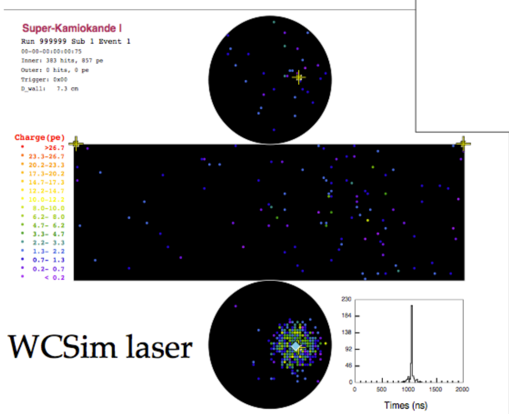
Note: Physics models are sometimes different between Geant3 and Geant4 so that parameters we are tuning don't always mean the same thing.

Simulation of Laser System

Laser from Top position 400 nm

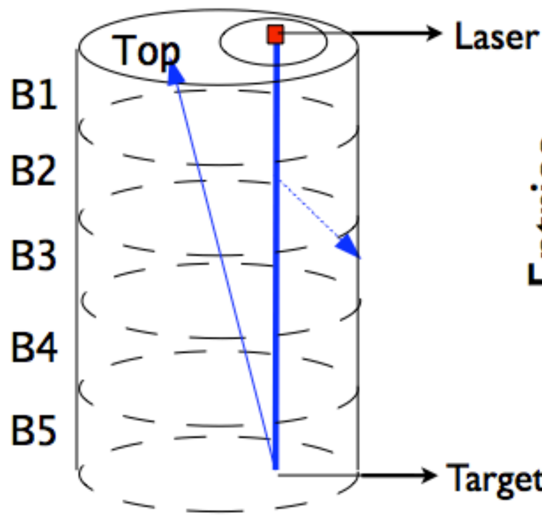


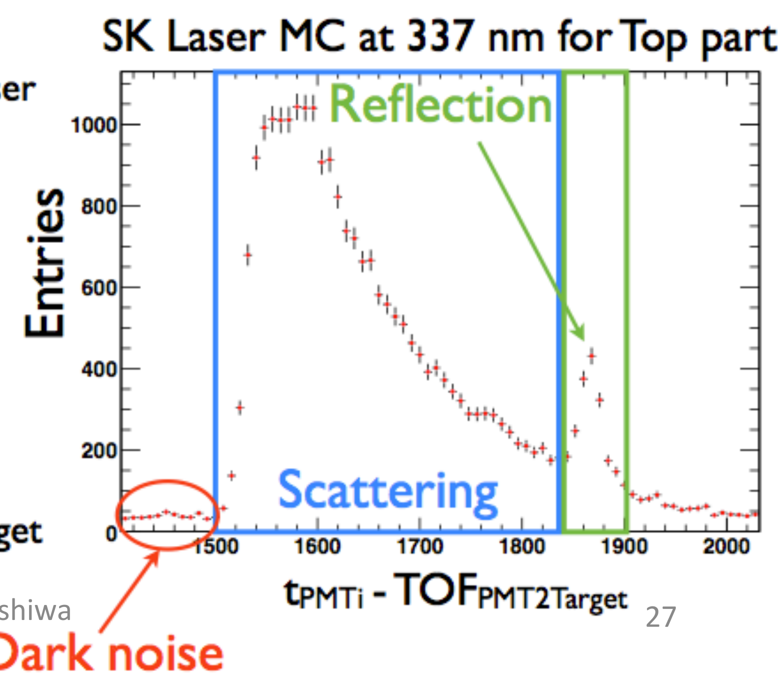
SK laser, without dark noise



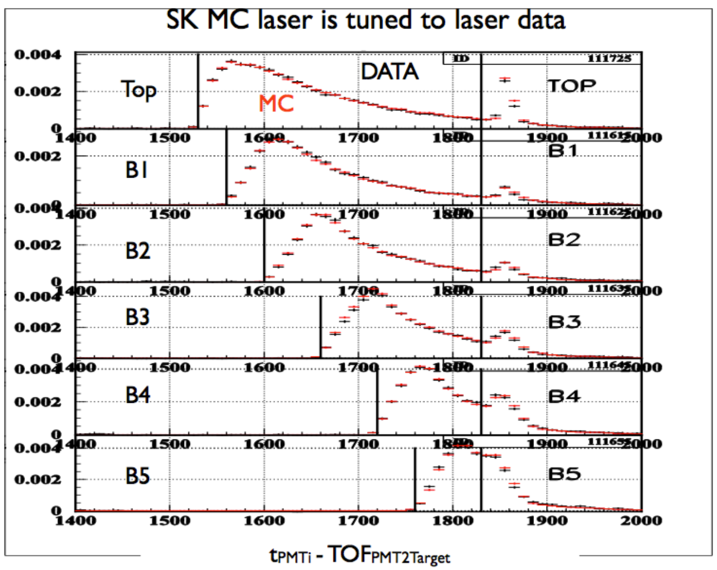
WCSim laser

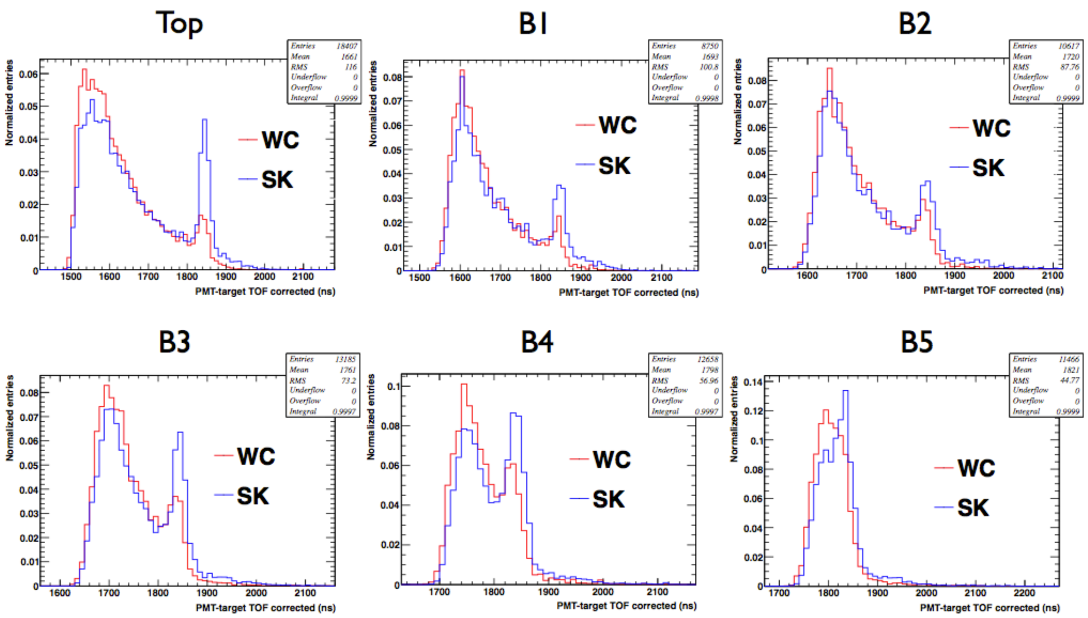
The SK laser calibration allows us to measure the optical scattering and reflection parameters seperately at the same time. We also **implemented the laser system in WCSim**.





Data and MC





Super-K **Data** vs **MC**.

(tuned)

WCSim **MC** vs Super-K **MC**.

(not-tuned)

Untested/Uncompleted items

- The "standard" physics lists are now available.
- We merged in some outstanding work into trunk.
- However, other code exists in development branches that could be useful from various LBNE collaborators (but require work to use)
  - Validation/testing code
  - Rough ideas for holding PMT info in text files
  - Rough ideas for swappable digitizers
  - More complicated PMT efficiency functions
  - Light collector and WLS plate work