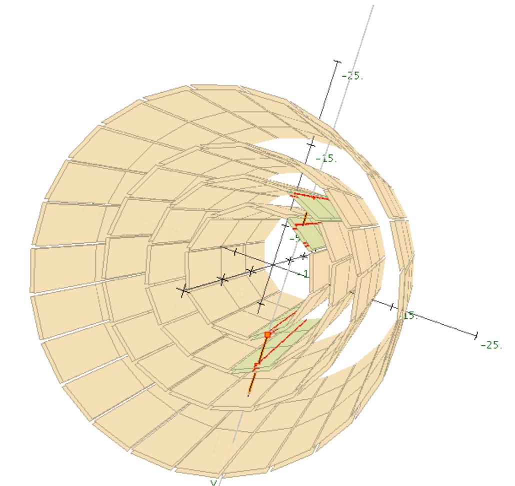
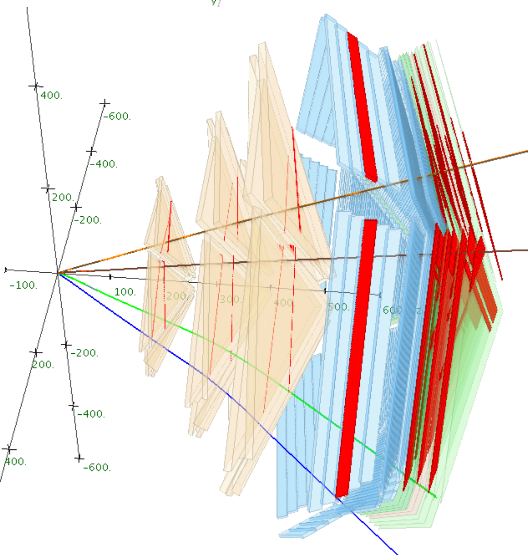
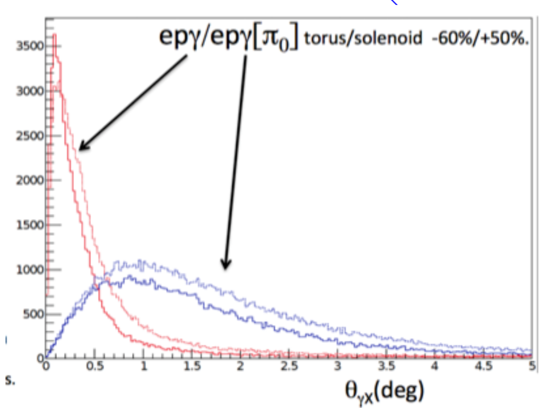






CLAS12 Reconstruction Status and Plans

Veronique Ziegler
Jefferson Laboratory

First CLAS12 Experiment Workshop
October 20, 2015

OUTLINE

- For each system:
  - Tracking detectors (SVT, DC, MM)
  - TOFs (CTOF, FTOF)
  - Cerenkovs (HTCC, LTCC)
  - Calorimeters (EC/PCAL)
  - Forward Tagger (FT-Cal, FT-Hodo, FT-Trk)
  - CND
  - Brief overview of algorithms
  - Validations and/or Version 2.0 fixes
  - Remaining tasks and priorities
  - Current developments and manpower
- Summary and task priorities

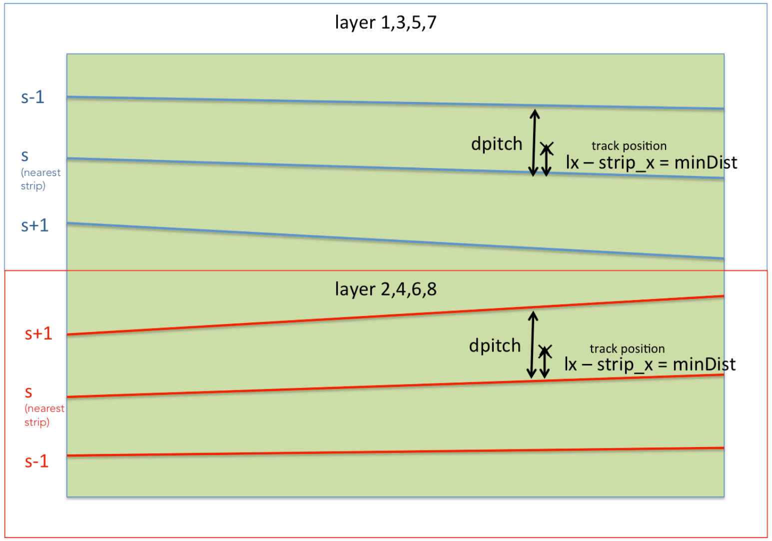
GENERAL COMMENTS

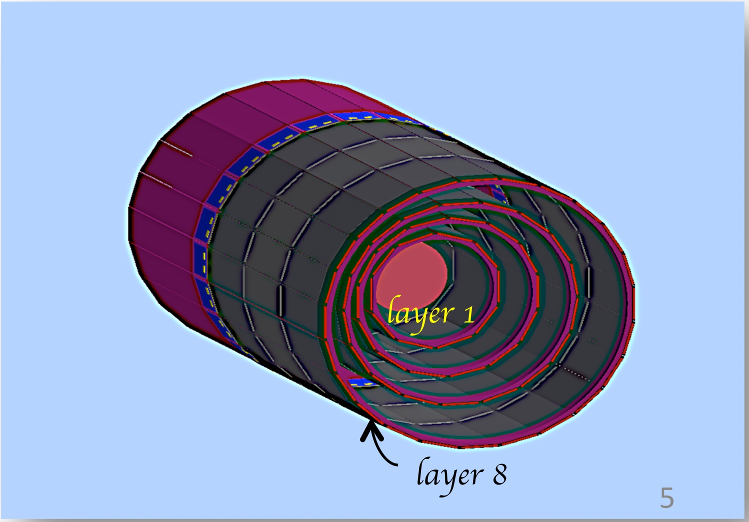
- All reconstruction packages written within coat-java framework
- Service chain SVT, CTOF, DC (Hit-Based & Time-Based), FTOF, EC/PCAL, FT-Cal, FT-Hodo (& FT-Link) tested running ClaRA in multithreaded mode
- Although the services are running and there is no major issue with threading, reconstruction speed & efficiency, some parts of the reconstruction chain are still incomplete, and/or need improvements…

SVT

Algorithms Overview
SVT Tracking

- Input: Crate, Slot, Channel → sector, layer, strip, ADC (ADC→ DAQ Landau charge distribution)
- Clustering algorithm in place → adaptable to MM
- Determination of space points for fitting
- Pattern recognition allowing for 3 out of 4 intersections → adapt to BMT for up to 6 intersections
- Track Fitting Method in place

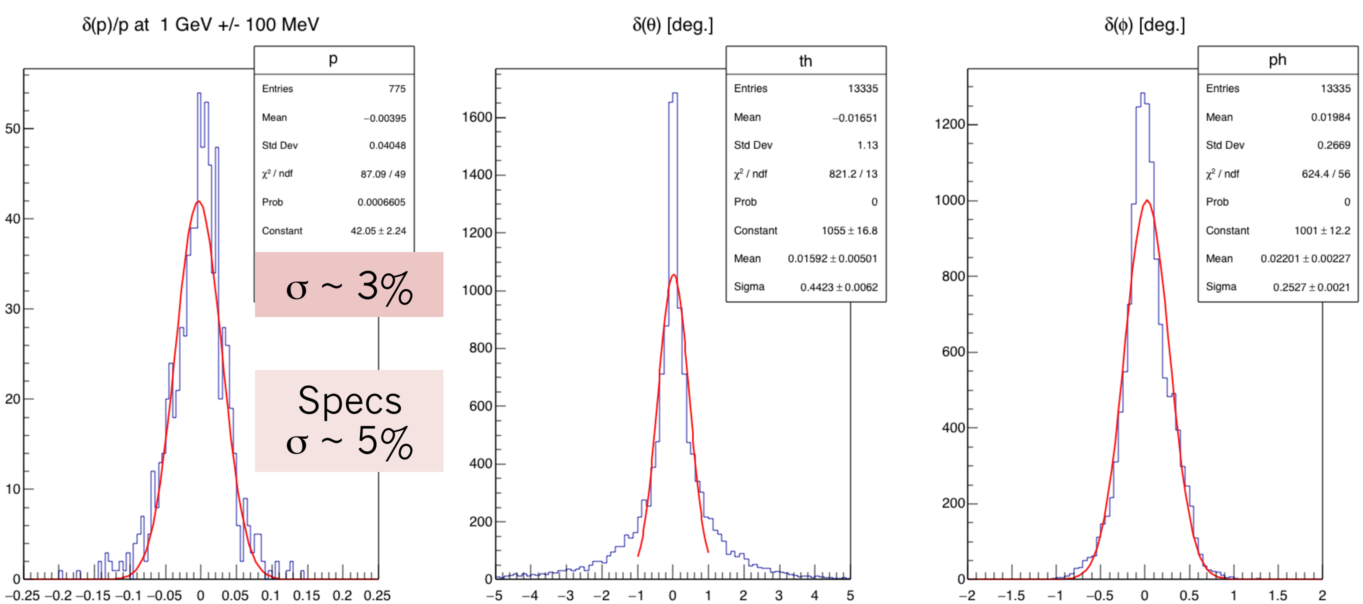




Central Tracking Fitting Method

- Fitting Method: Global Regression Fitters
  - * Karimaki algorithm (Nucl. Inst. and Meth. in Physics Research A305 (1991) 187-191)

Algorithm returns Gaussian parameters ρ(curvature), DOCA and φ (at doca).
Allows for non-iterative solution and returns covariance matrix of fitted parameter.



Global method works well for ~homogenous field

* Results shown for single track events with 0.1 % χ^2 probability cut

Validations & Fixes

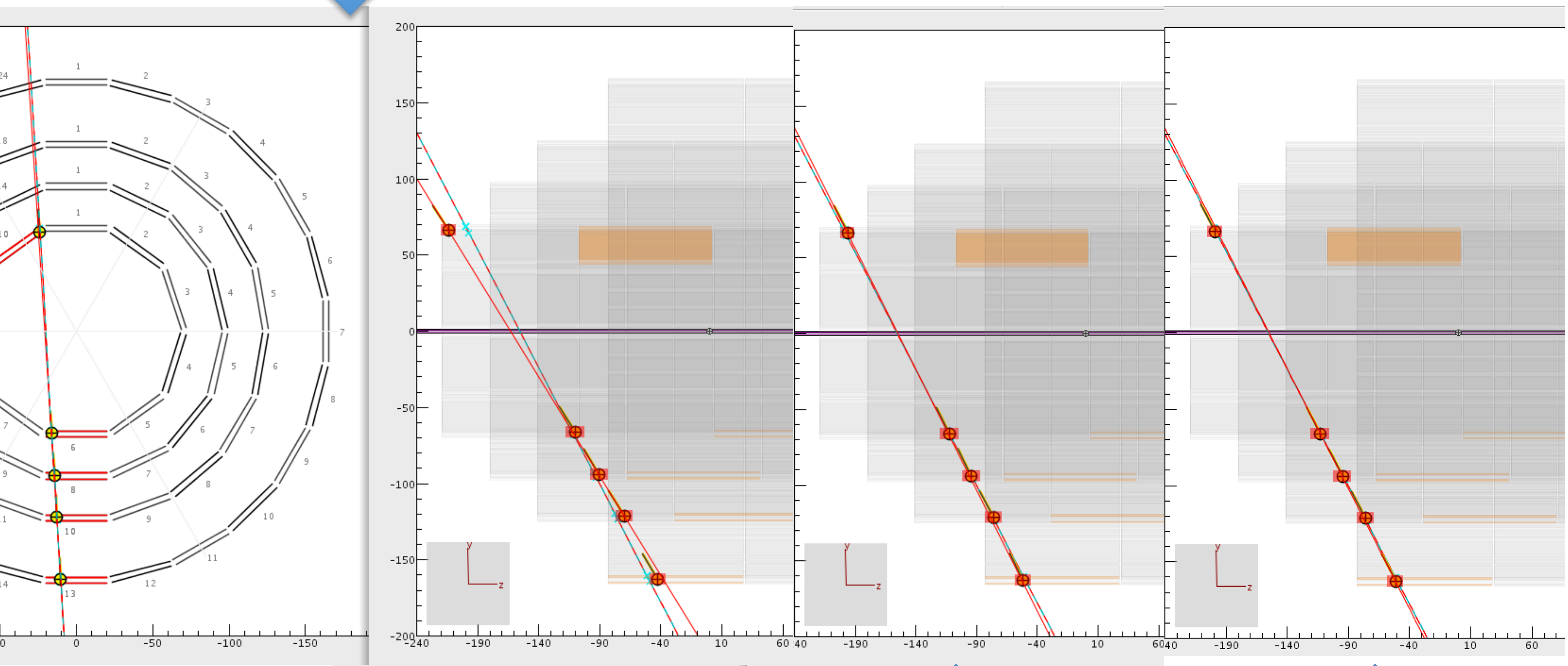
SVT Tracking with Cosmics

- Use SVT cosmics data to test the reconstruction software & algorithms and to identify hardware issues (e.g. dead strips)
- Useful to find bugs, fine-tune the code, tune the MC

Reconstruction Algorithms Refinements

issues with corner clippers resulting in poor z resolution

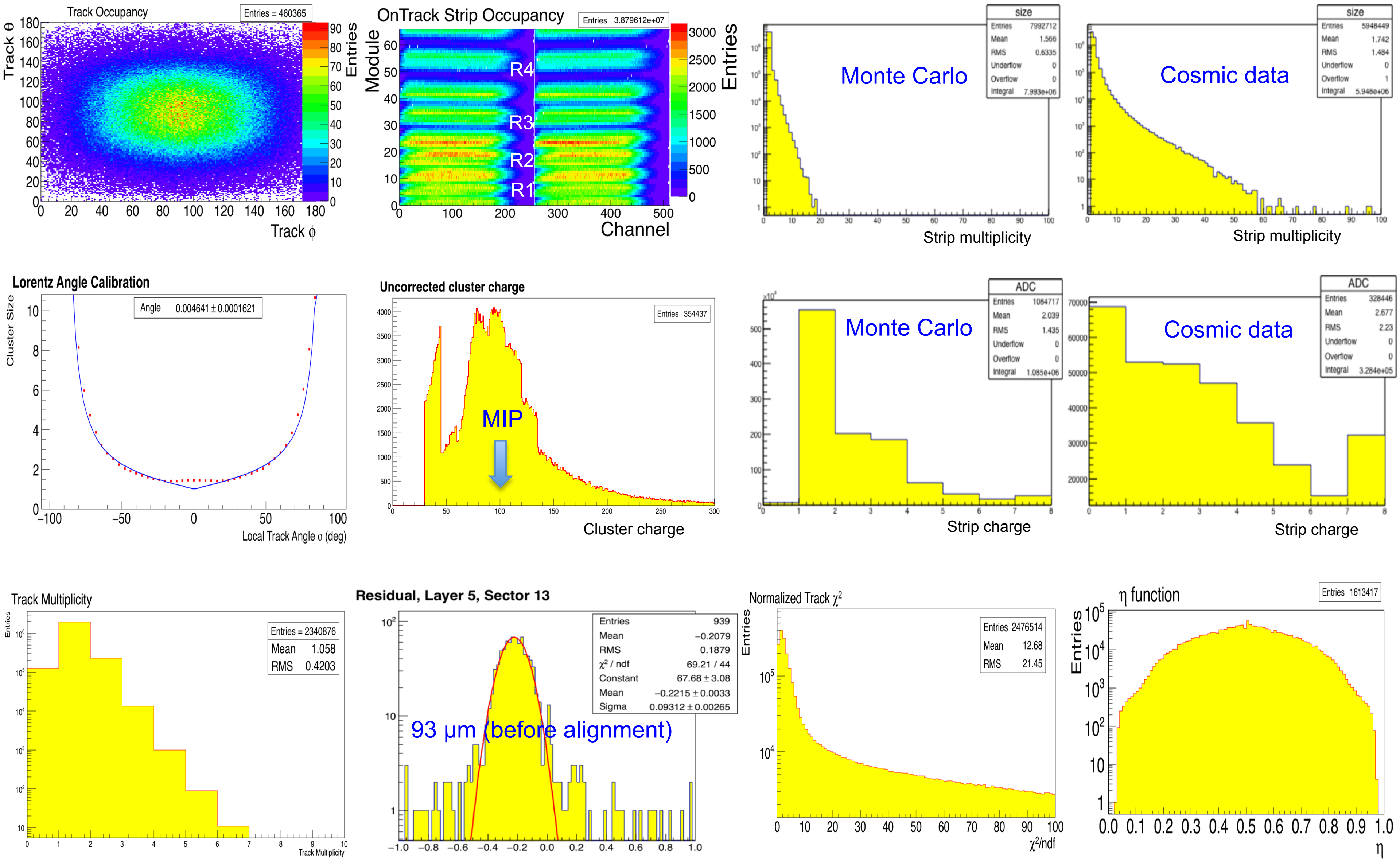
Ongoing code validation, debugging, algorithm improvements using cosmic data simulations



remove corner clipper from global fit

Include in fit to strip indexes using a KF

SVT Data Validation Suite: Sample Plots (Yuri Gotra)



Remaining Tasks
SVT Reconstruction

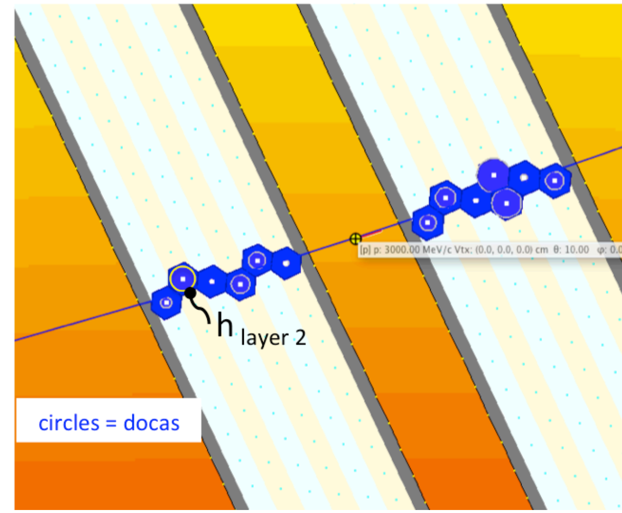
	Task	Manpower	Timescale
1)	Continued validations & fixes	Yuri & Veronique	Ongoing
2)	Geometry code employing survey numbers 1) ccdb tables 2) modifications to algorithms to get core geometry params	Gagik to adapt geometry package, Harut to create the tables, Veronique to modify reconstruction to use geometry package info, Veronique & Jerry to run tests	Before end of year 2015
3)	MC fine-tuning	Yuri & Mauri	Ongoing, aim for completion by end of next year
4)	Energy Loss Package development 1) Material budget from DB table 2) Development of code that can be used for all systems	MK to start development by end of year	One year
5)	Kalman Filter validation [lower priority]	Veronique to check formalism and test on simulated data	March 2016

DC

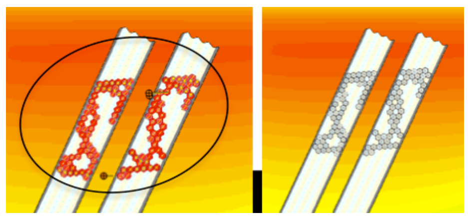
Algorithms Overview

DC Tracking

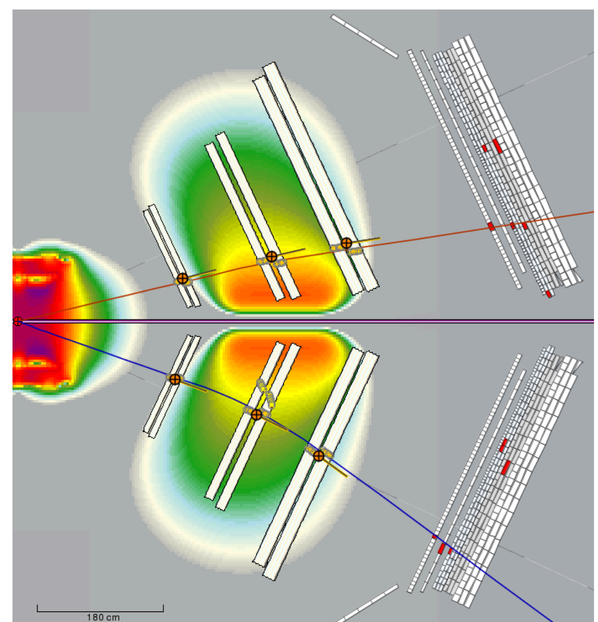
- Input: Crate, Slot, Channel → superlayer, layer, wire, TDC (TDC→ doca function linear in MC)



- Noise rejection algorithm in place



- Clustering & segment finding algorithm in place
- Determination of space points for pattern recognition



- Track state vector at middle plane in region 3 → input to Kalman filter
- Track Fitting KF Method working but no smoothing in place yet (re-eval. past sites)

Forward Tracking Fitting Method

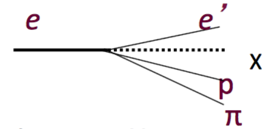
- Kalman Filter (does fits to wires docas)

- For tracks generated in fiducial region between 0.5 and 7 GeV/c, ~0.6% average momentum resolution, ~0.2^o ϕ, ~0.1^o θ resolution

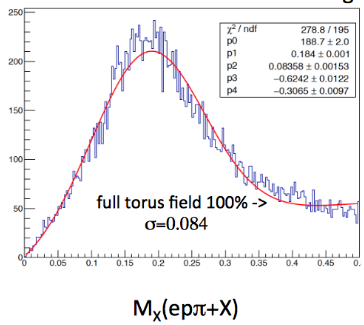
- Validation on MC analysis samples → proposals

Validations (Harut, Raffaella, Andrey)

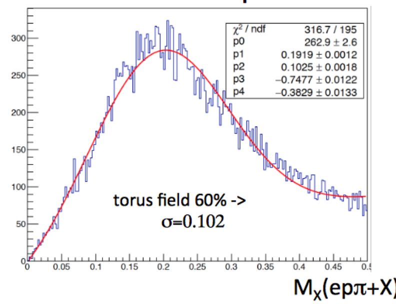
CLAS12 reconstruction: physics impact



The same set of exclusive events were reconstructed for 2 torus field settings.

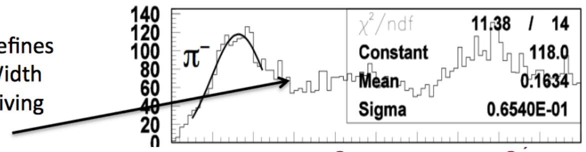


exclusive epπ+X

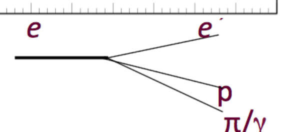


semi-inclusive epπ+X

Resolution in the missing mass defines the signal to background ratio. Width increases by 20%(60% field) or giving ~15% increase in time

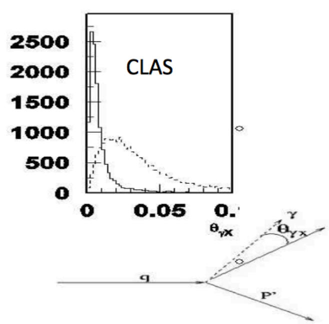


CLAS12 reconstruction: physics impact

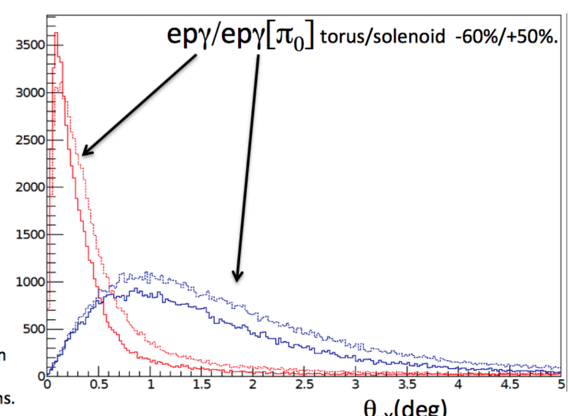


The same set of exclusive events were reconstructed for 2 configurations
torus/solenoid -100%/+100% (solid)
torus/solenoid -60%/+50%. (dashed)

exclusive epγ/epπ$_0$



Background rejection in DVC analysis relies on the cut on the angle between measured and calculated (from electron and proton) photons.



Lower field option may be even better for DVCS studies.

Able to start doing analysis on simulated data with existing code

- Ongoing validations → V. 2.0
- Further down the line:
  - studies at higher lumi (adapt noise finding, reco. algorithms for higher bkgr.)
  - develop algorithm to use only 2 DC regions

Validations & Fixes

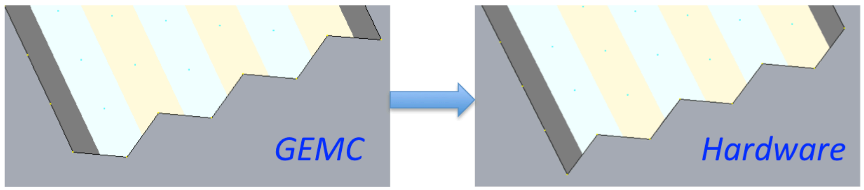
DC Tracking with Cosmics

- Use DC cosmics data to test the reconstruction software & algorithms and to identify hardware issues (e.g. cable swaps)
- Useful to find bugs, fine-tune the code, get Time-To-Distance function → adding special calibration and validation banks

Fixes & To Do List

– Insured proper geometry called for data ✓

DC Geometry fix: *brick-wall pattern*

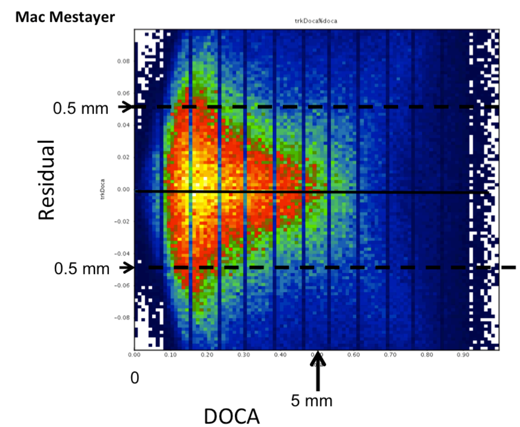


☛ also change in GEMC

– Layer efficiency bank output ✓

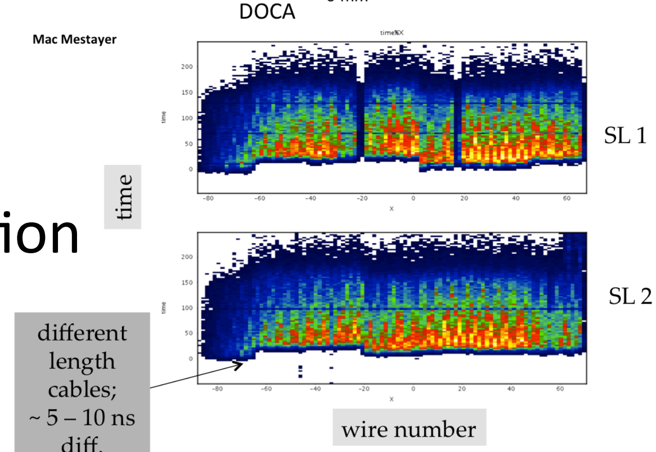
– TBLA banks for time-to-distance analysis

- time residuals ✓
- track doca (TB)
- …



Residuals from un-calibrated data; using same T → X curve as GEMC !

– Include cable delays (& all calibration constants) in reconstruction



Remaining Tasks
DC Reconstruction

	Task	Manpower	Timescale
1)	Continued validations & fixes	Mac, Krishna, (Olga) & Veronique	Ongoing
2)	Missing TBLA banks	Veronique	End of next week
3)	Time-to-distance function	Mac, Krishna & Veronique (reco. code implementation)	Started, aim for completion mid 1st quarter 2016
4)	Read and incorporate calibrations constants in DC reconstruction * need tables in place	Mac, Krishna, Harut (ccdb tables)	Not started
5)	Kalman Filter improvements * smoothing (swim backwards & exclude sites) * include energy loss correction in fit [lower priority]	Veronique to work with Dave Heddle to adapt swimmer package	End summer 2016

MM

What is in the reconstruction code ?

- FMT
  - hardcoded geometry (probably incorrect) extracted from GEMC perl script
  - Simple cluster, 3-D point reco. & linking to DC track
- BMT
  - missing

Remaining Tasks

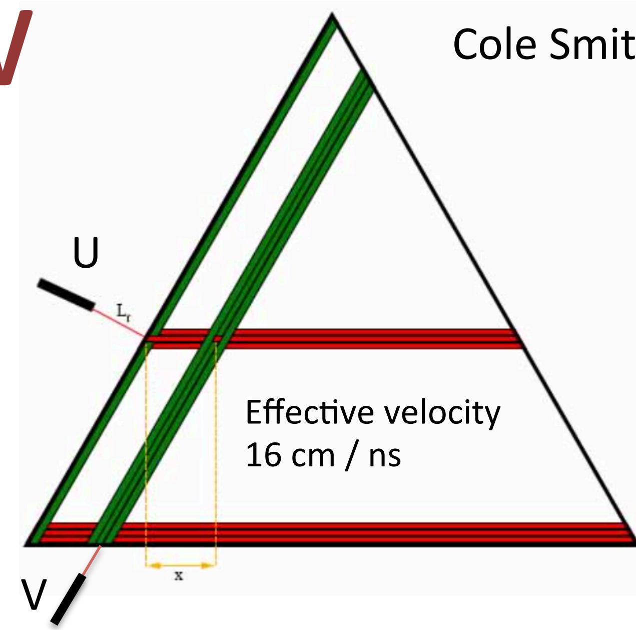
Task		Manpower	Timescale
1)	Geometry	doc: Frank, geometry package: Gagik & student?	After geometry doc
2)	BMT clustering algorithm (Lorentz angle correction)	Veronique	mid-December 2015
3)	BMT to SVT linking	Veronique	mid-December 2015
2)	Extend BST fitting to include BMT data	Veronique	mid-December 2015
3)	Improve FMT rec	Veronique	aim for completion mid 2nd quarter 2016

EC/PCAL

Overview

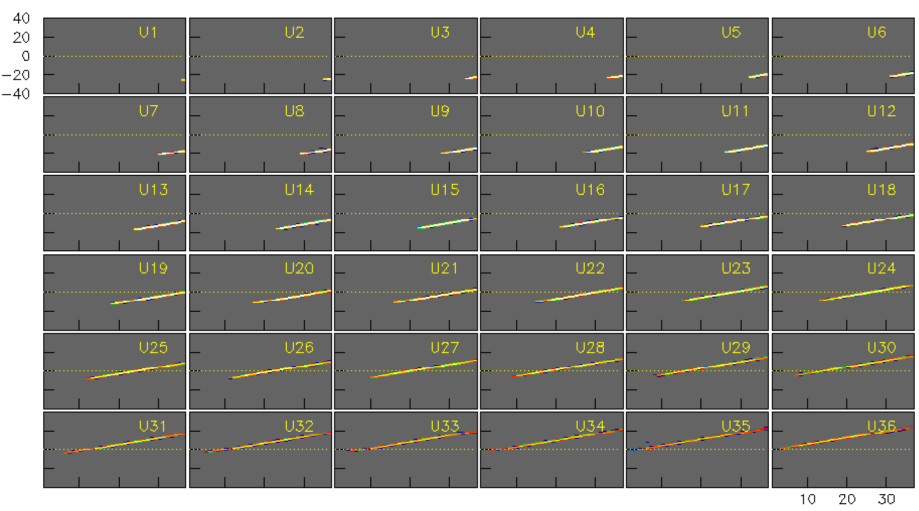
Cole Smith

- DGTZ banks: Raw counts x 24 ps/count to simulate both V1190 / V1290 TDCs
- Simulation checked against data using time differences between cosmic muon hits in different U,V,W layers (below)
- Forward Carriage data show effect of different cable and light guide lengths and provide estimate of time resolution for simulation

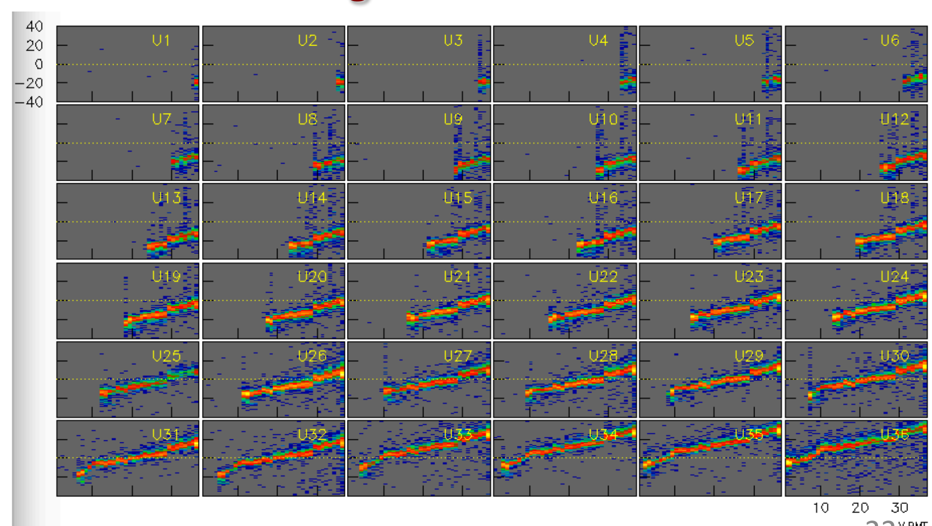


Δt (U-V) vs. V PMT

GEMC



Forward Carriage ECAL Sector 1



Reconstruction Status

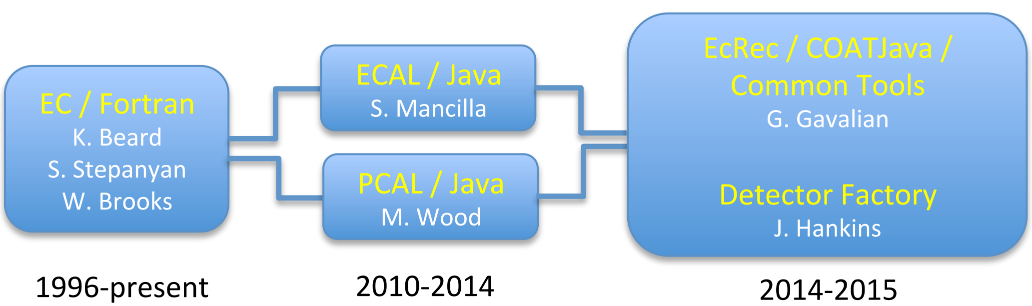
- ❑ EC reconstruction package currently being evaluated by C. Smith in collaboration with Gagik
- ❑ Under COATJava EC is a unified detector with 3 superlayers: 0=PCAL 1=ECAL inner 2=ECAL outer
- ❑ Output bank consists of lists of hits, peaks and clusters for each superlayer →
- ❑ ECReconstruction class does not attempt cluster matching between superlayers

```
package org.jlab.rec.ec;

public class ECReconstruction extends DetectorReconstruction

 public void processEvent(EvioDataEvent event) {
     try {
         ECStore store = new ECStore();
         store.initECHits(event, this.getGeometry("EC"), CCDB);
         store.showHits();
         store.initECPeaks();
         store.showPeaks();
         store.initECPeakClusters();
         store.showClusters();
         this.writeOutput(event, store);
     } catch (Exception e) {
```

The history of EC reconstruction:



Remaining Tasks & Timeline

Cole Smith

- Some missing elements need to be re-implemented:
  1. Introduction of calibration constants from CCDB (in work).
  2. Re-entry points in code for attenuation correction and iteration of reconstruction (in work).
  3. Indexing to allow identification of hit members in clusters, peaks (for iteration, calibration).
  4. Configuration parameters (thresholds, peak/cluster/iteration options, etc.)
  5. Methods for handling two-cluster identification with shared energy in peaks (for pi-zeros).

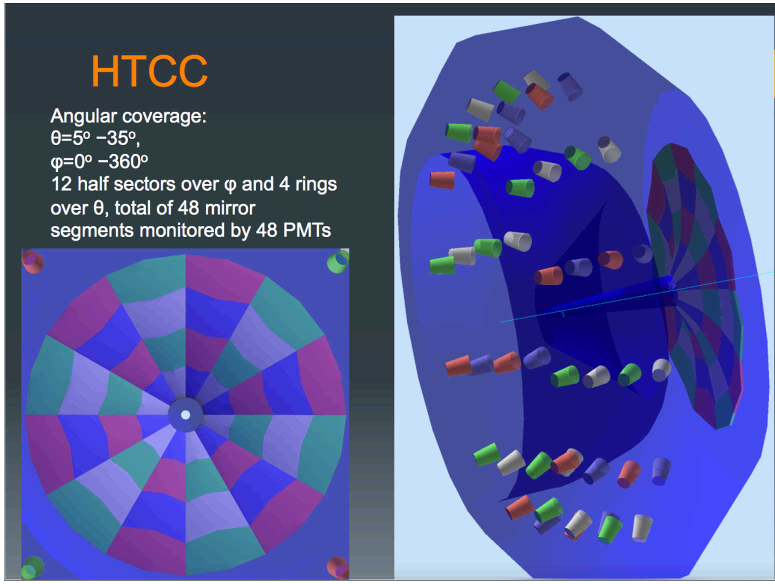
Priorities and Schedule

- Get elements 1-4 working for cosmic CTP trigger studies (Jan 2016)
- Implement two-cluster algorithm and test with GEMC studies (Spring 2016)
- Sector-based trigger: Geometry-based cluster matching in CTP or SSP? Needed for energy sum

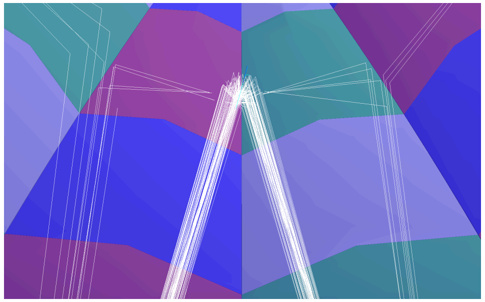
HTCC

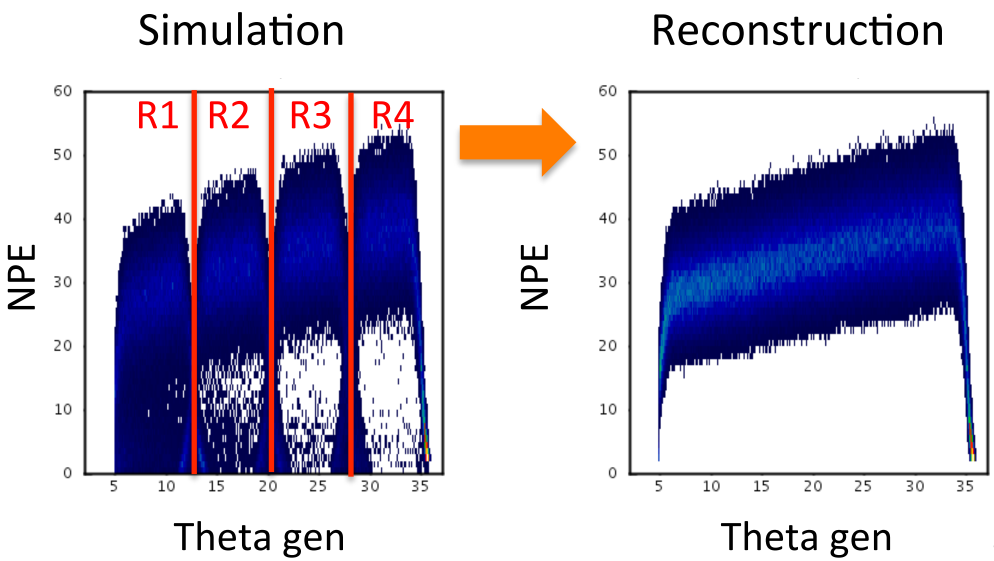
Overview

- Exiting code (original author: A. Puckett, Java: J.Hankins) ported into COAT-Java by Nick Markov
- Simulation and reconstruction incorporated in CLAS12 software framework (Nick)
- Clustering algorithms in place and being validated (Nick)



Clusters are reconstructed for events with hits in several mirrors





Remaining Tasks

1) Complete timing algorithm

2) Low and high θ regions around the border of the mirror show lower number of npe – possibility of fiducial cuts using information from other detectors to be investigated

by Spring 2016…

TOFs

Overview & Status

- GEMC now properly simulates gain matching algorithm for FTOF
- FTOF reconstruction package trimmed down version of A. Colvill's code and ported into COAT-Java framework by Gagik (idem CTOF)
- Current algorithm does independent clustering but no linking between panel 1A and 1B
- No calibrations constants incorporated into the code at this stage (idem CTOF)

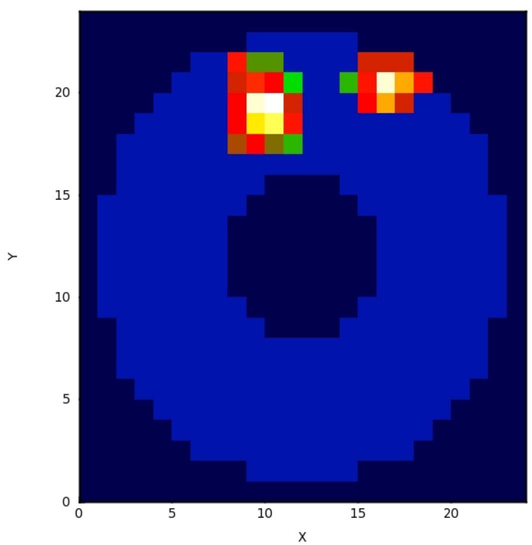
- E. Golovach to complete linking algorithms and use tracking information to improve matching …

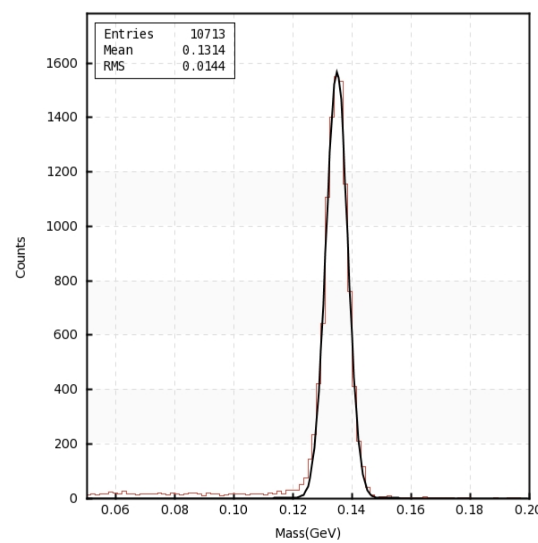
FT

Overview & Status

- ❑ Geometry and digitization of all three FT subsystems implemented in GEMC
- ❑ Reconstruction code developed within COAT-Java framework at Genoa
  - Algorithms developed for all three subsystems
    - ◆ Clustering, Linking algorithms in place and validated for CAL & HODO
  - Calorimeter and hodoscope reconstruction available (in release 1.0)
  - Tracker reconstruction implementation in progress
    - ◆ Tracking was developed by G. Charles in ROOT and being ported into the framework by Raffaella

FT π^0 reconstruction from simulated $ep \rightarrow ep\pi^0$



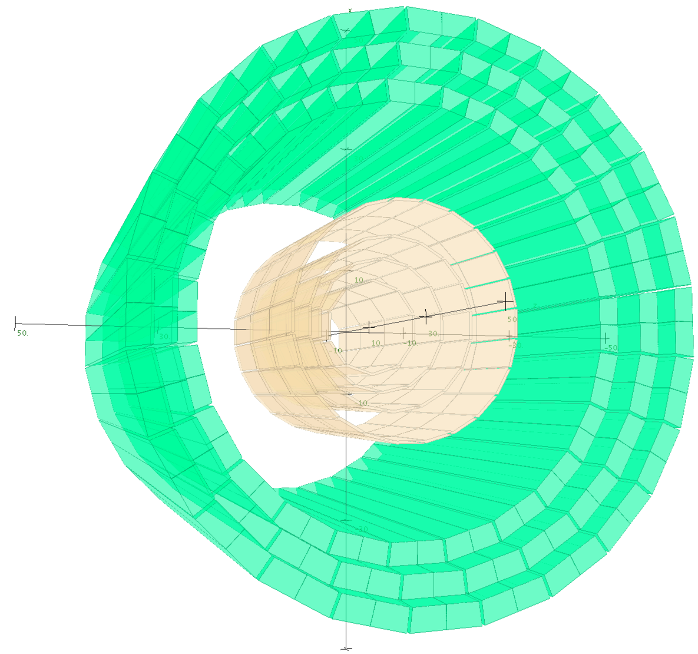


R. deVita

CND

Overview

Daria Sokhan, Gavin Murdoch (Glasgow)



- ❑ Geometry and digitization implemented in GEMC
- ❑ Implemented in ced (D. Heddle)

- ❑ Reconstruction code developed within COAT-Java framework at Glasgow
  - Algorithms developed originally in ROOT an ported into CLAS12 framework

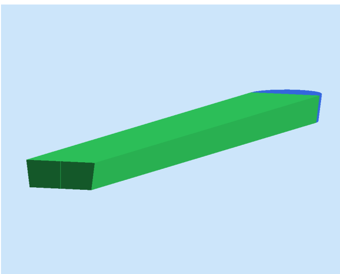
- ADC to energy algorithm in place
- Time and hit position in paddle reconstruction algorithm in place

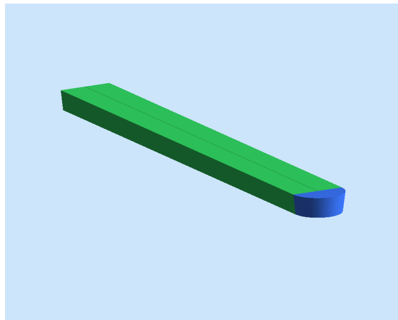
by Spring 2016…

CND geometry in GEMC

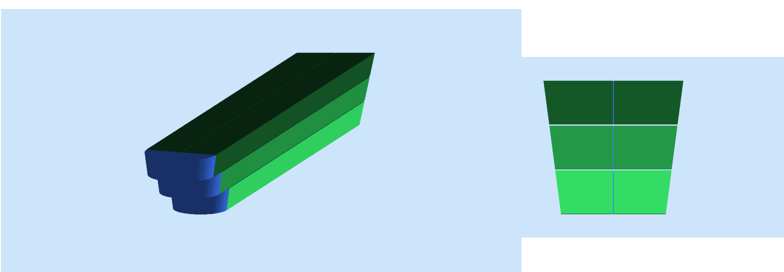
Daria Sokhan, Gavin Murdoch (Glasgow)

Trapezoid scintillator paddles (green) assembled in pairs and coupled with u-turn light guide (blue) at downstream end.

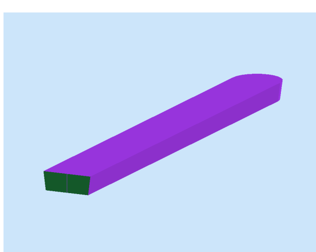




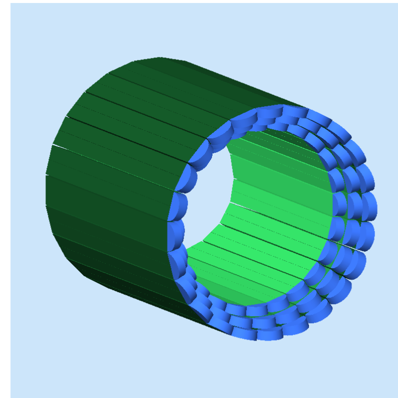
Three layers of pairs form a segment (block):

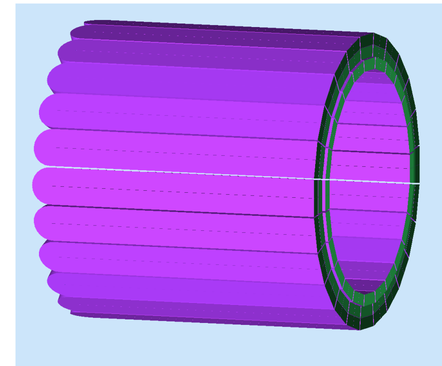


The paddles are additionally wrapped in Al (magenta):

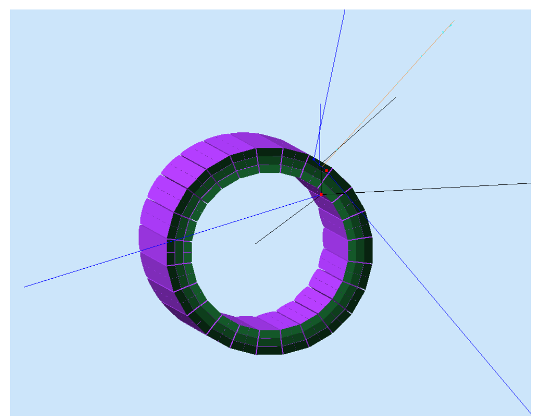


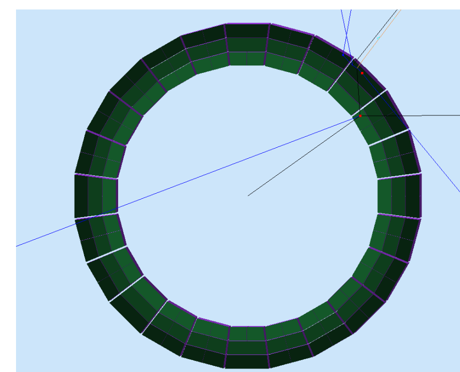
28 blocks assemble to form the full CND barrel:





Full CND geometry has been implemented in GEMC since v. 2.2





Hit digitisation currently being ported into Java.

CND reconstruction

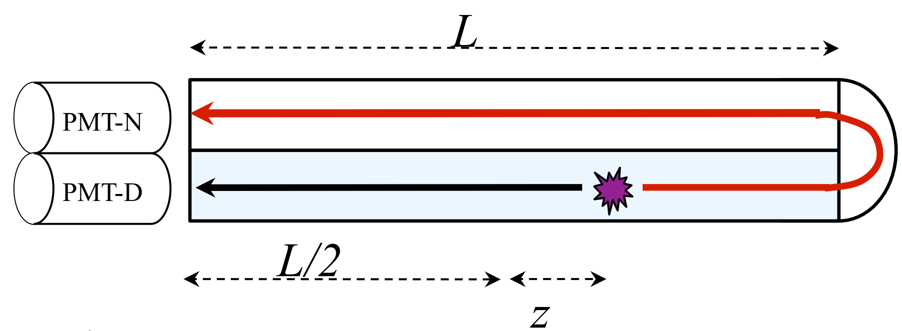
Daria Sokhan, Gavin Murdoch (Glasgow)

★ Convert TDC and ADC counts into time and energy:

$$t_{D,N} = \frac{TDC_{D,N}}{C_{TDC}} - t_{offset}$$

$$E_{D,N} = \frac{ADC_{D,N} - P}{C_{ADC} Y G Q q}$$

C_{TDC}: Conversion from TDC channels to time
t_{offset}: electronic time offsets between the paddles
P: ADC pedestal
C_{ADC}: Conversion from ADC channels charge
q: charge of an electron
G: gain of the PMT
Q: quantum efficiency of the PMT
Y: light yield in scintillator (optical photons per deposited energy)



★ Identify direct / neighbour signal on basis of timing, reconstruct time and position of hit within the paddle:

$$t = \frac{1}{2}(t_D - T_D + t_N - T_N - t_u) - \frac{L}{2}\left(\frac{1}{v_{effD}} + \frac{1}{v_{effN}}\right)$$

$$z = \frac{v_{effD}}{2}(t_D - T_D - t_N + T_N + t_u) - \frac{L}{2}\frac{v_{effD}}{v_{effN}}$$

L: length of paddle
t_u: time for light signal to travel round the u-turn
$T_{D,N}$: time for light signal to travel through long lightguides
$v_{effD,N}$: effective velocity of light in the scintillator

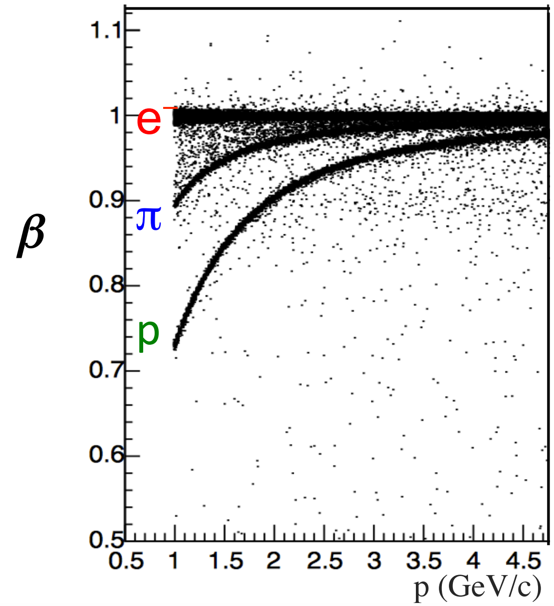
Reconstruction code is functional in ROOT, being translated into Java

EB

Event Reconstruction

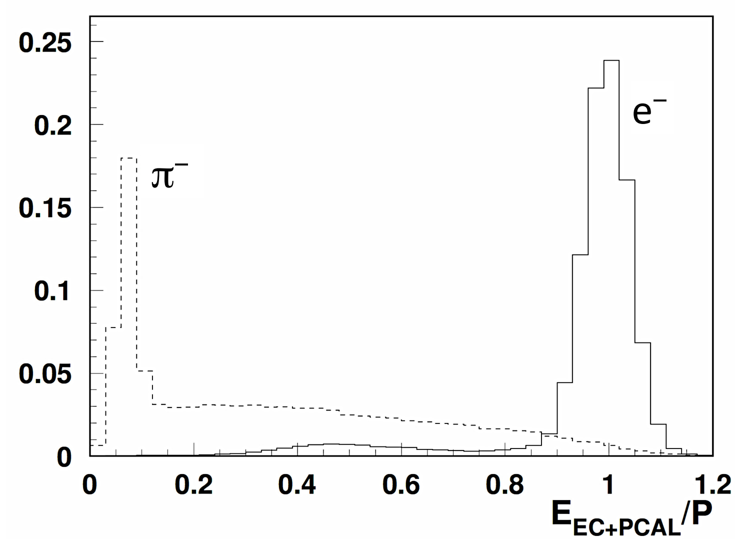
TOF hit matching

- uses geometry package to match DC track to TOF paddle
- Yields β value (i.e. start time and path length)

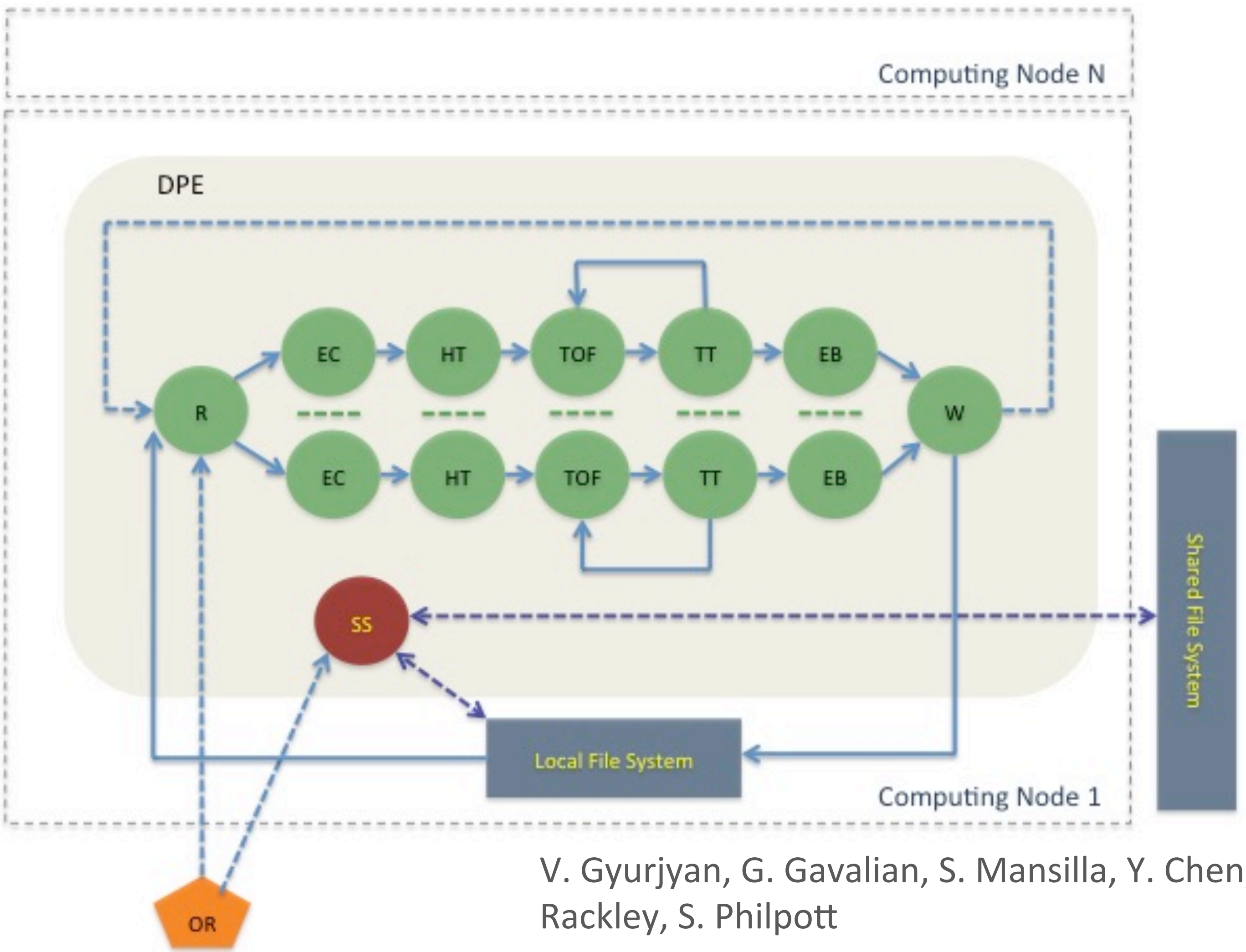


EC/PCAL Responses

$$P(A_i|E) = \frac{P(A_i) \cdot P(E|A_i)}{\sum_{k=1}^{n} P(A_k) \cdot P(E|A_k)}$$

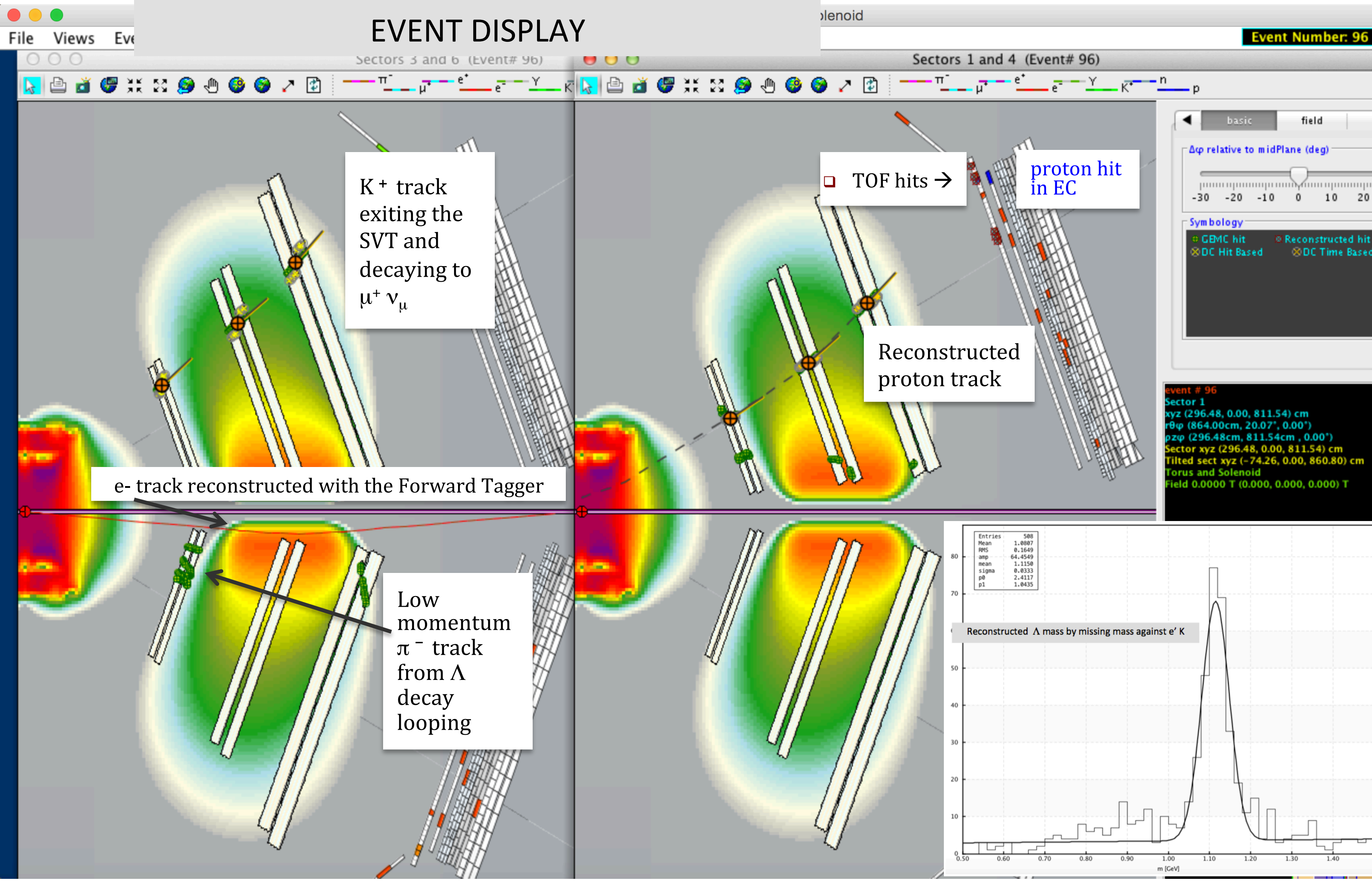


Data Processing



V. Gyurjyan, G. Gavalian, S. Mansilla, Y. Chen, D. Rackley, S. Philpott

EVENT DISPLAY



The e- and proton tracks from the reaction $e^- p \rightarrow e^{-\prime}\ K^+ \Lambda,\ \ \Lambda \rightarrow p\ \pi^-$ reconstructed in the Forward Detectors

- The filled orange circles correspond to reconstructed 3-D points obtained from pattern recognition; the tangent to the reconstructed track at the 3-D point is represented by the line segment connected to the filled circle.
- The dashed line corresponds to tracks swam to z = 0 with the parameters extracted from the reconstruction algorithm

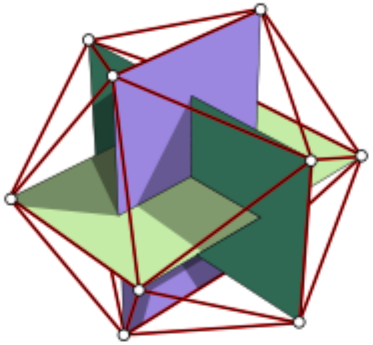
Summary of Priorities

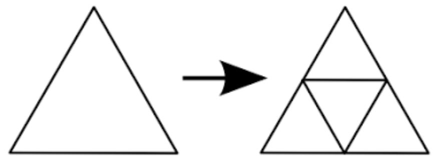
- Event reconstruction
  1) Incorporate calibrations constants into the reconstruction→ started for 1 system, but need a standardized way of doing this for all detectors
  2) Realistic Time to Distance function for DC Tracking→ started using cosmics data
  3) Complete Central Track fitting including Micromegas Tracker→ no geometry yet, but will have to get reco done by mid-December for MMT commissioning
  4) Improve clustering and linking in TOF systems→check & validate Evgeny's work
  5) Improve PID using realistic calorimeters responses
  6) Develop plug-ins for missing detector components (LTCC, MicroMegas, non-baseline components…)
  7) Incorporate Energy Loss Correction in Tracking (DB access for material budget)→MK to develop Eloss package
  8) Improve Forward Kalman Filter by implementing smoothing
- Kinematic Fitter & Vertexer
  1) Develop vertex reconstruction code→may get help from Franz on this, work done by Tony on vertex resolution studies
  2) Develop a kinematic fitter
- Alignment
  - Develop global & local alignment software →Jerry started work on SVT alignment
- Analysis
  - Develop a set of standard analysis cuts →Andrey developing package
  - Develop standard validation suite (event generators, validation & analysis plots) →started

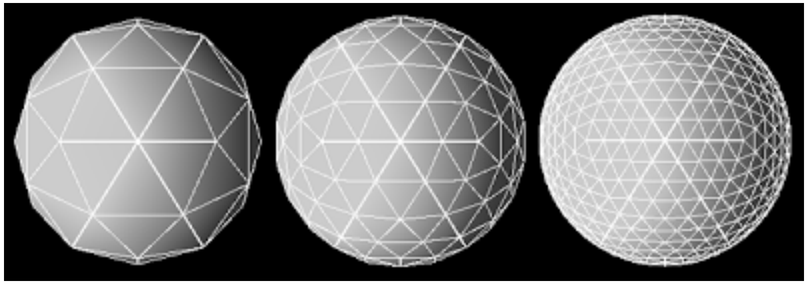
BACK-UPS

Programming of the spherical mirror is underway:

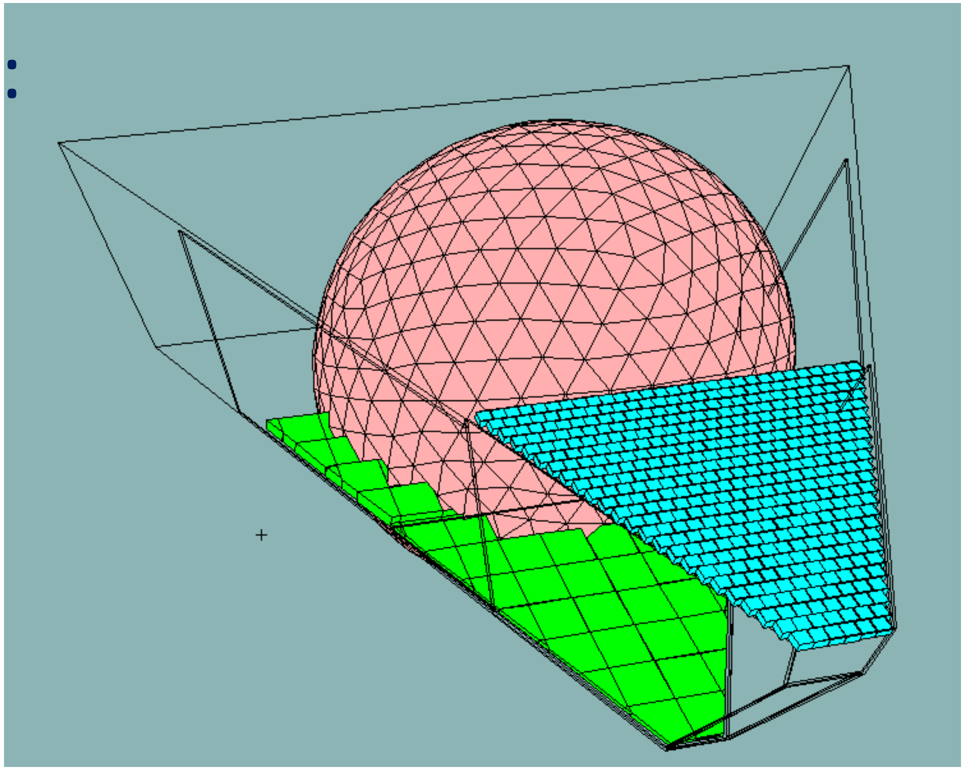
Idea:







Results:

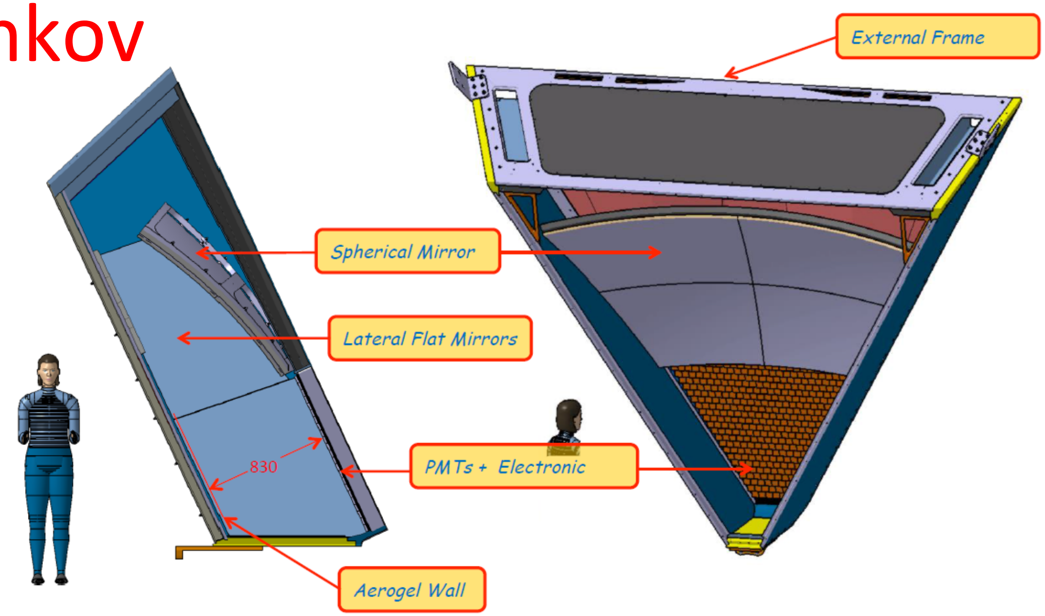


Succeeded to add the Sphere class to CLAS12 geometry, we can make it big or small, move it around, but didn’t succeed to cut it yet.

Work done by F. Benmokhtar
and Duquesne’s students

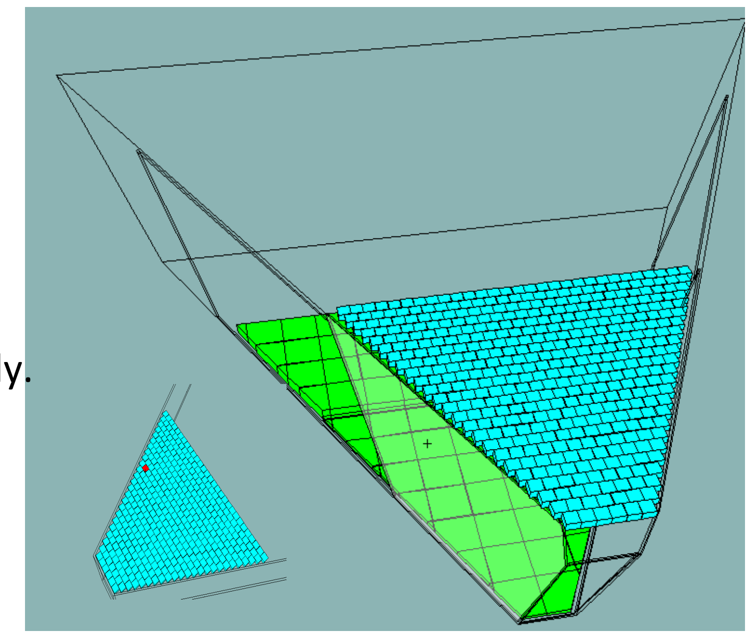
The Ring Imaging CHerenkov (RICH)

Addition of the RICH to CLAS12 Geometry



- clas-geometry
  - Source Packages
    - org.jlab.geom
    - org.jlab.geom.abs
    - org.jlab.geom.base
    - org.jlab.geom.component
    - org.jlab.geom.detector.bst
    - org.jlab.geom.detector.cnd
    - org.jlab.geom.detector.dc
    - org.jlab.geom.detector.ec
    - org.jlab.geom.detector.ft
    - org.jlab.geom.detector.ftof
    - org.jlab.geom.detector.rich
      - RICHAero1.java
      - RICHAero4.java
      - RICHDetector.java
      - RICHElectronics.java
      - RICHFactory.java
      - RICHLMirror.java
      - RICHLayer.java
      - RICHMapmts.java
      - RICHRMirror.java
      - RICHSector.java
      - RICHSphericalMirror.java
      - RICHSuperlayer.java
      - RICHTrapezoid.java
      - RichGeometryApp.java
    - org.jlab.geom.gui
    - org.jlab.geom.prim

- MAPMTs
- Aerogel tiles
- planar mirrors
- Lateral Mirrors
- Electronic panel
- Spherical Mirror: underway
- Ready for material budget study.



Rotatable, zoomable, translatable and option to choose an mapmt

Work done by F. Benmokhtar and Duquesne's students