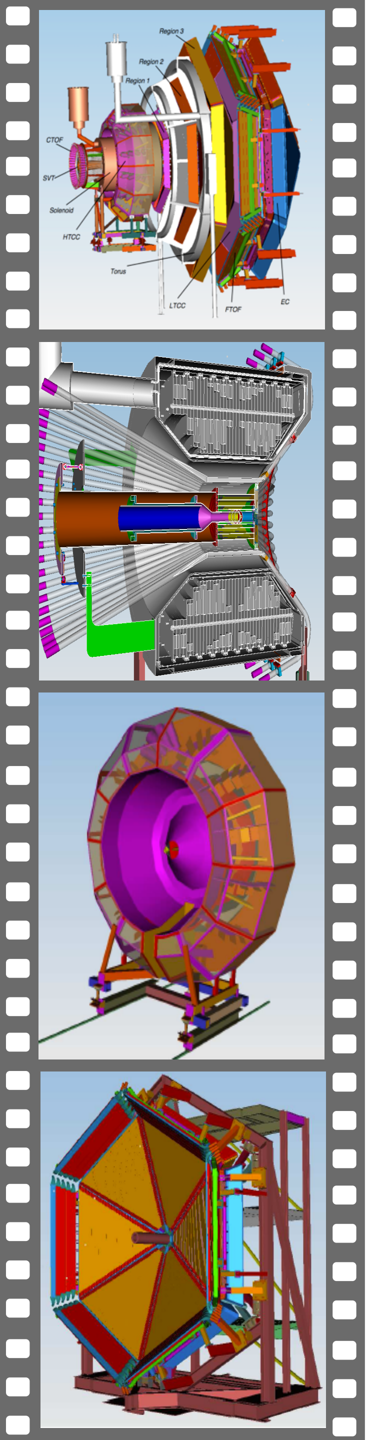


CLAS12
Analysis Readiness

R. De Vita
for the CLAS Collaboration

Jefferson Lab Software Review
November 10, 2016

Outline

- Reconstruction & Calibration validation using pseudo-data
  - GEMC: Realistic detector simulations
  - Reconstruction validation and usage
  - Calibration development and testing
- Data analysis workflow & preparation:
  - Analysis workflow
  - Event generators and background simulations
  - Physics analysis example
  - Analysis organization
- Timeline

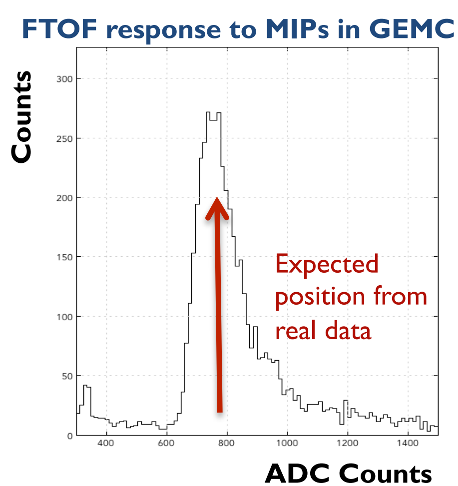
Realistic detector simulations

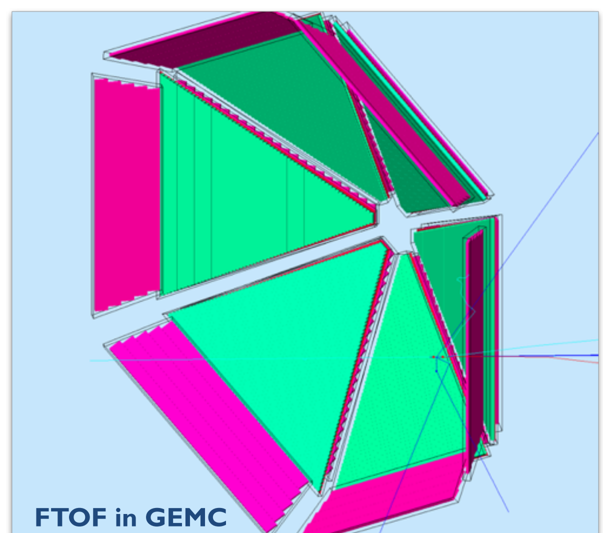
Digitization Routines ⟵ CCDB ⟶ Geometry

- Scintillators attenuation lengths
- Drift Chamber cell inefficiencies, Residuals
- Resolution parameters
- Same constants as real data: actual calibration constants

- Realistic geometry description
- Active and passive materials
- CAD drawing conversion for most complicated elements
- Same geometry for reconstruction

CCDB	To be put in CCDB
FTOF	BST
CTOF	MVT
EC	HTCC
PCAL	LTCC
DC	FT
	CND





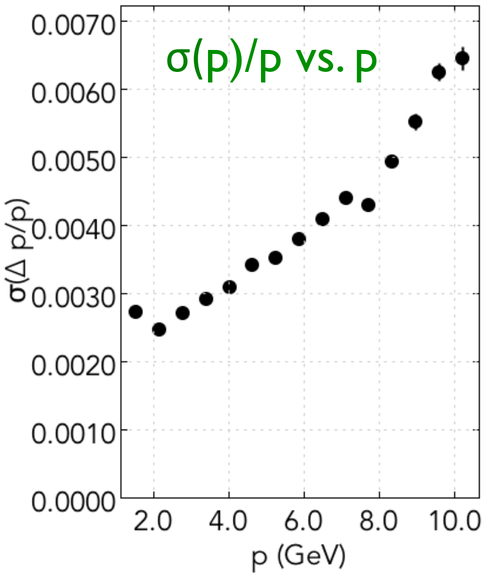
Event Reconstruction

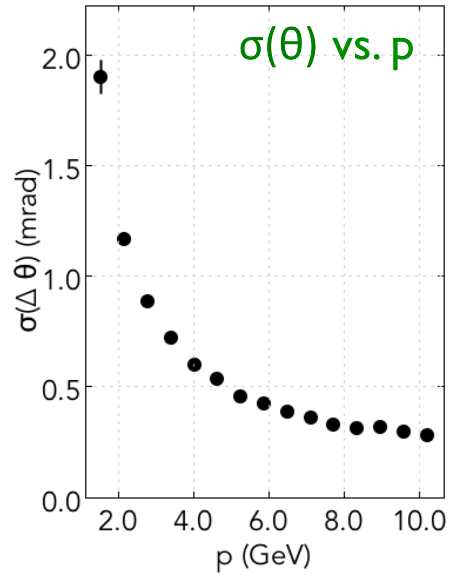
Single track resolution and multi-track event reconstruction

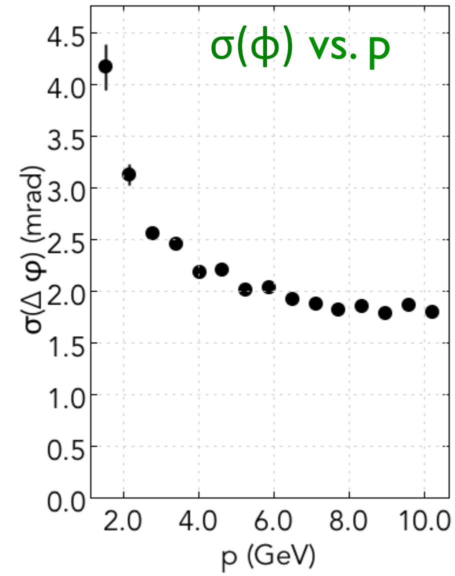
Electron momentum and angular resolution

***TDR**:*

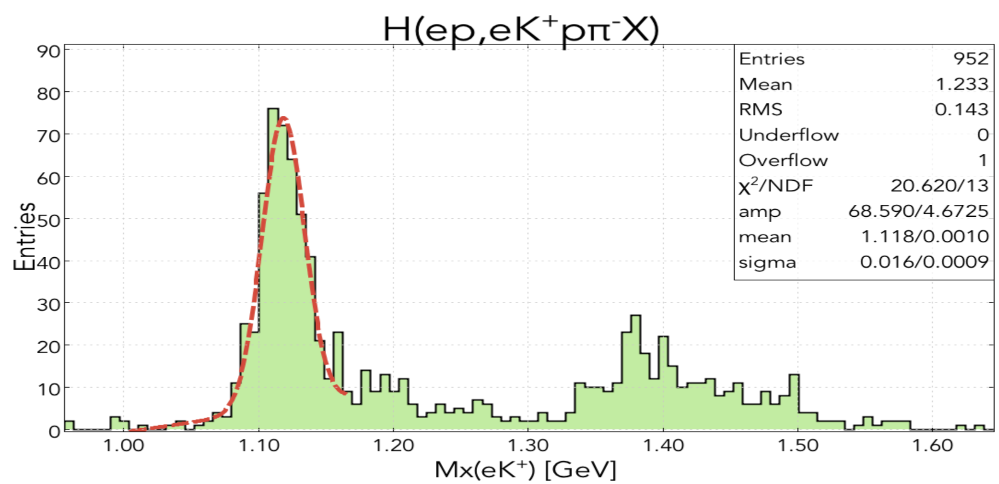
$\sigma(p)/p < 1\%$
$\sigma(\theta) < 1$ mrad
$\sigma(\phi) < 3$ mrad





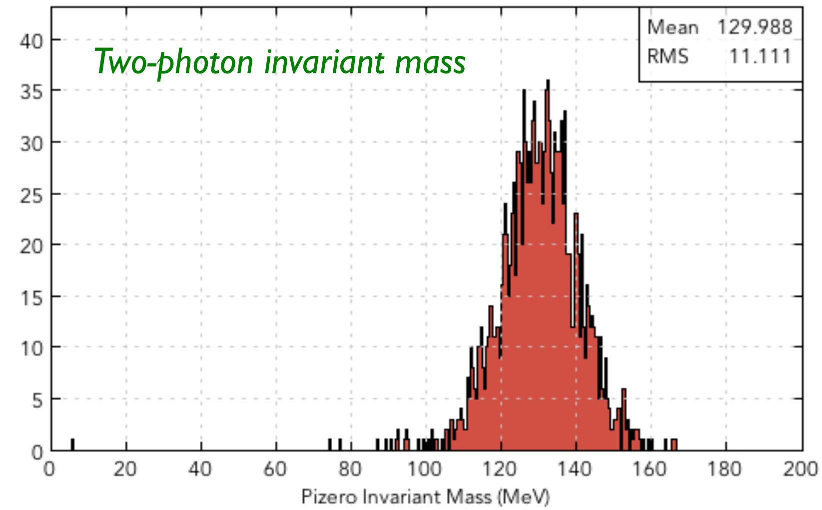


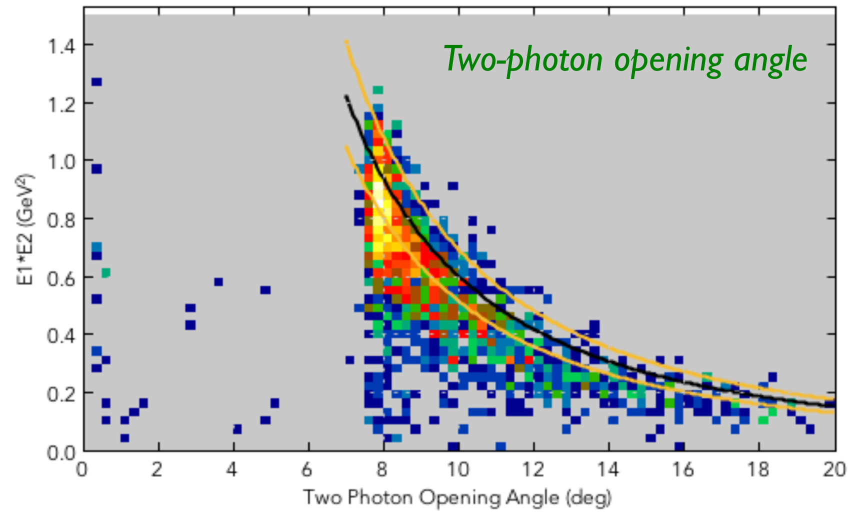
Missing mass from exclusive final states

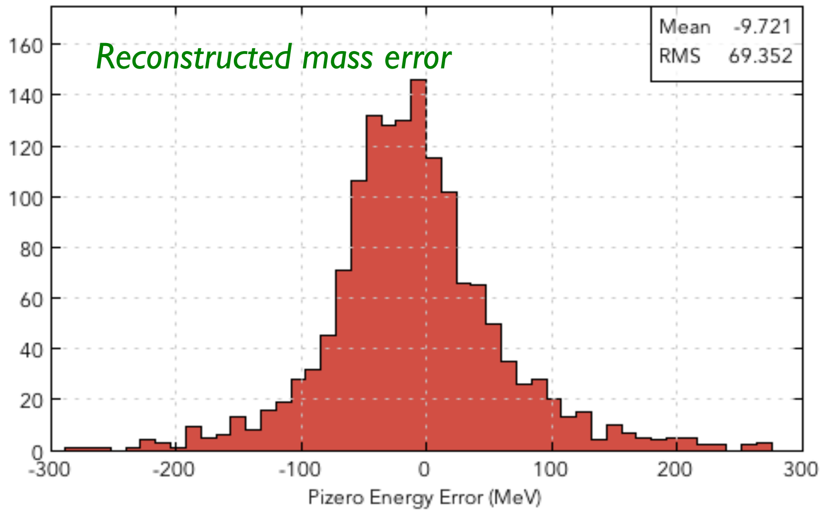


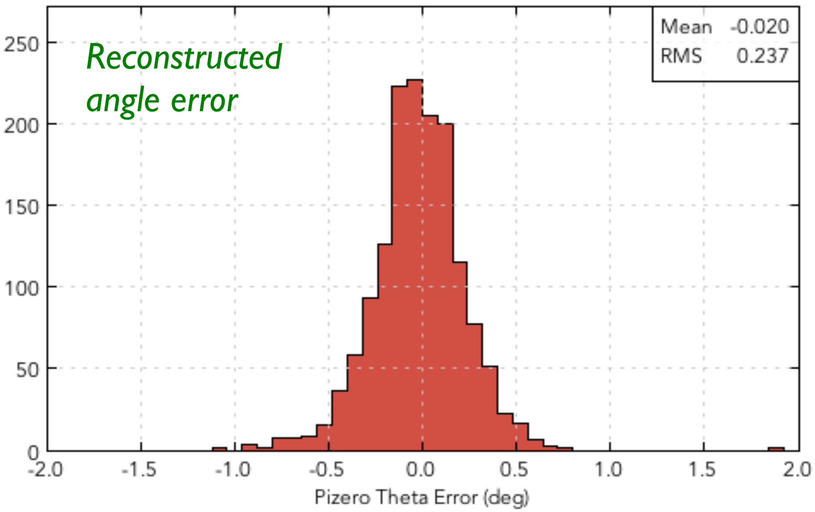
Event Reconstruction

π^0 reconstruction from forward EM calorimeters





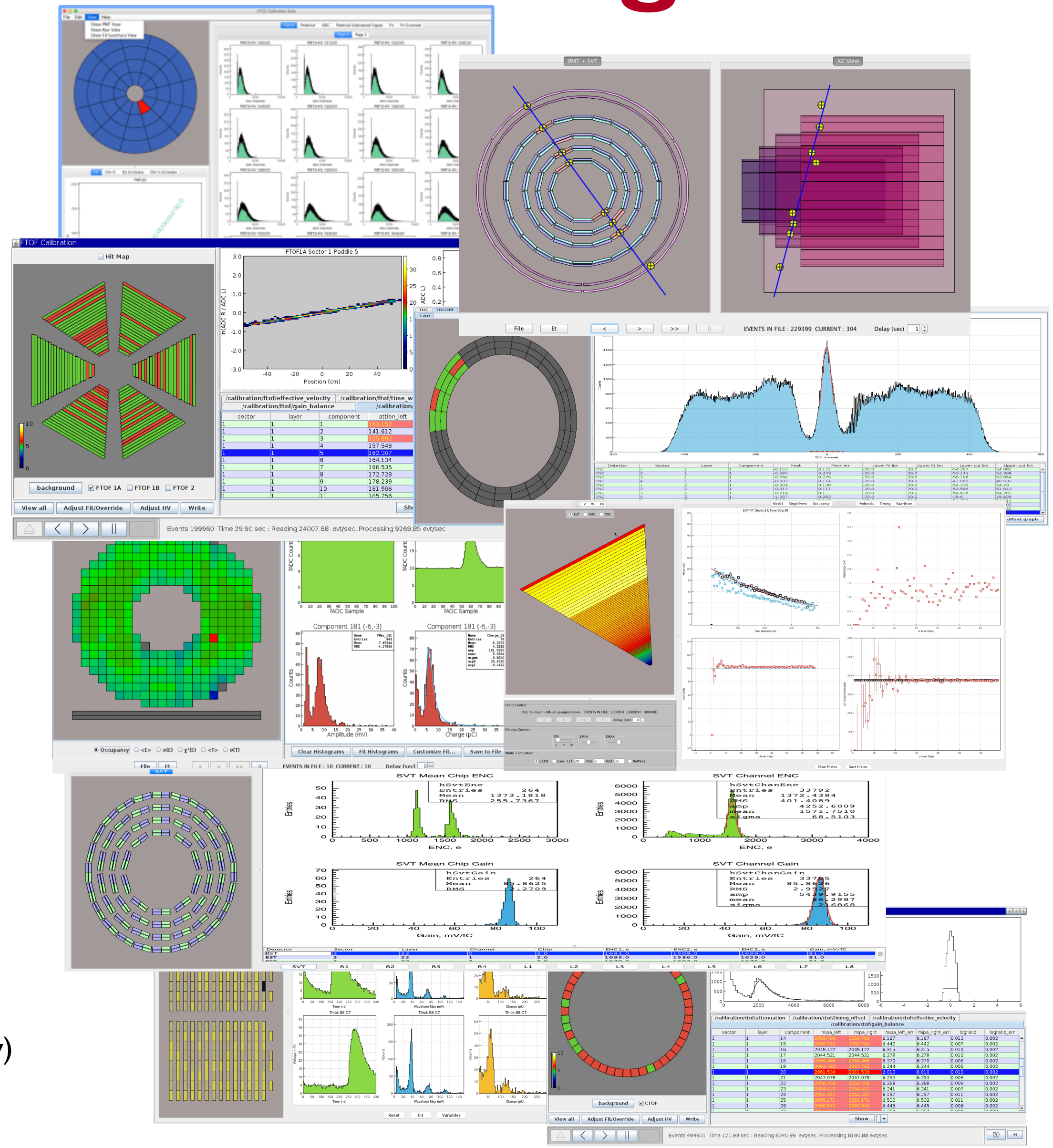




Calibration & Monitoring

Development of calibration and monitoring applications in an advanced stage for both baseline and ancillary CLAS12 subsystems:

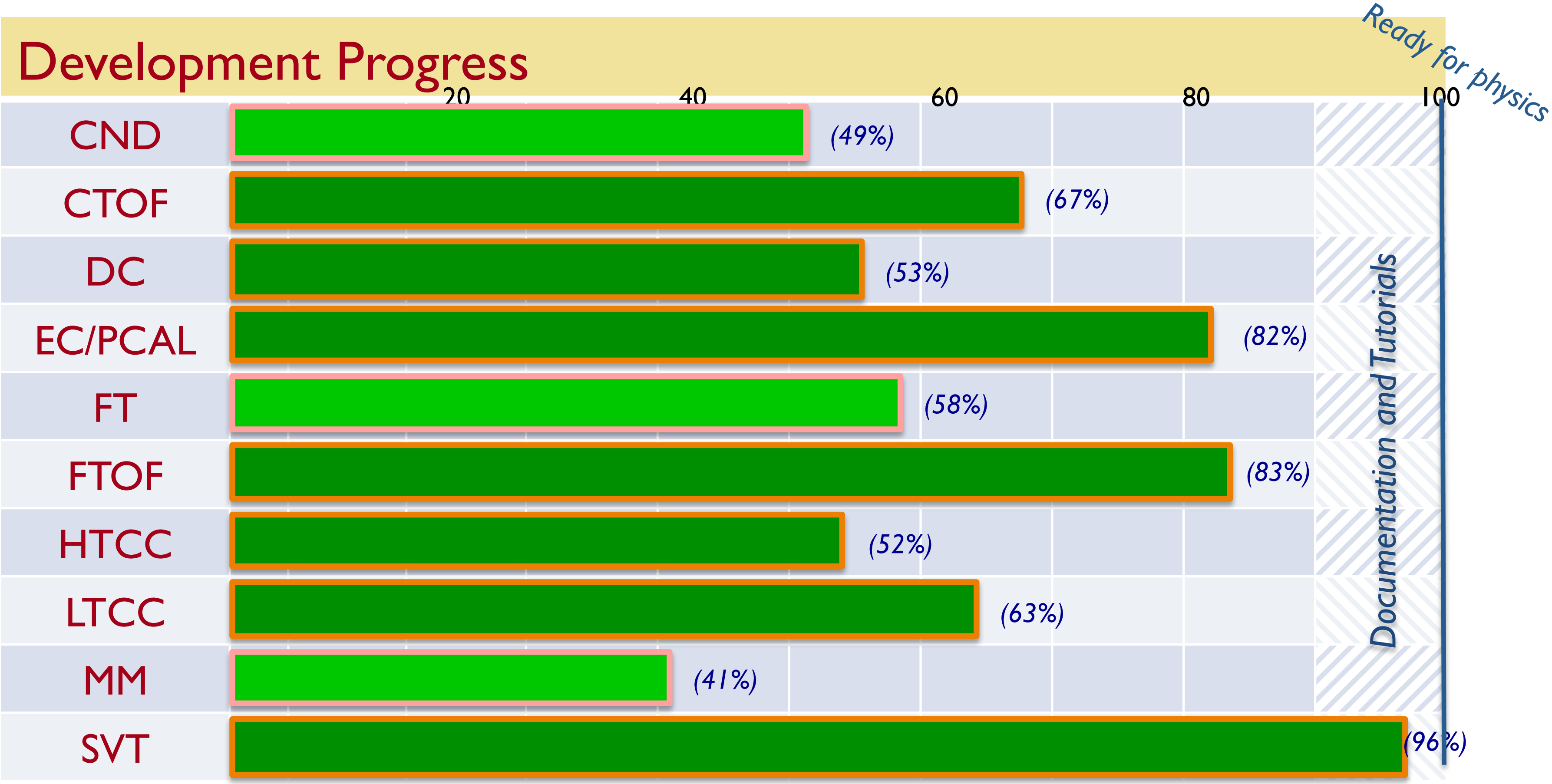
- Calibration and monitoring software is based on COATJAVA
- Algorithm development supervised by the CLAS12 calibration & commissioning group (CALCOM)
- Implementation supervised by the software group
- Tests on both cosmic ray and simulated data
- Preparations for first Calibration Challenge (Dec. 2016) in progress



EC-Pcal (UVA/Jlab)
FTOF (Glasgow, Iowa, Jlab)
LTCC (Temple, Jlab)
DC (Mississippi,JLAB)
HTCC (FIU, Uconn, Jlab)

MM (Saclay)
SVT (Jlab)
CTOF (Glasgow, Jlab)
CND (Orsay, Glasgow)
FT (INFN, Edinburgh)

Calibration Tools



Status: ***Now ready for Feb. 17 KPP***

Timeline: *I) December 12-16, 2016: Calibration challenge*
II) Beginning 2017: Document and tutorials
III) June 2017: ready for physics (First experiment in Fall 2017)

EC/PCAL calibration

Validation of MIP Calibration Algorithm

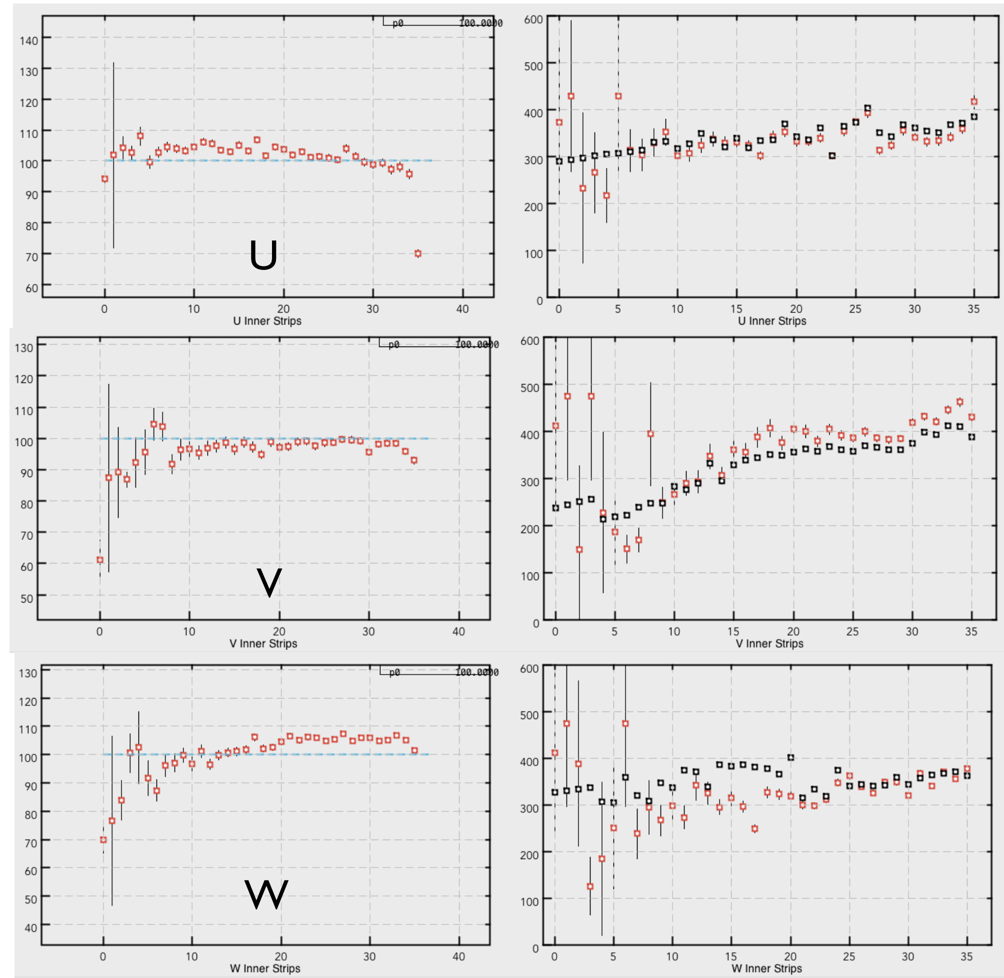
- Fits to simulated data used to evaluate cuts and thresholds.
- Estimate time needed to accumulate sufficient statistics.
- Estimate accuracy of gain and attenuation extraction.

Expected MIP

Simulated **Attenuation**

Fit to GEMC simulation

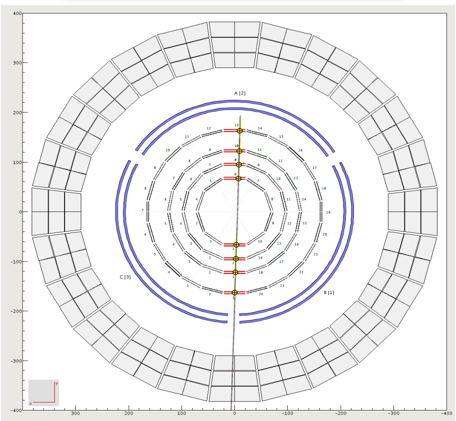
Gain **Attenuation (cm)**



ECAL Inner

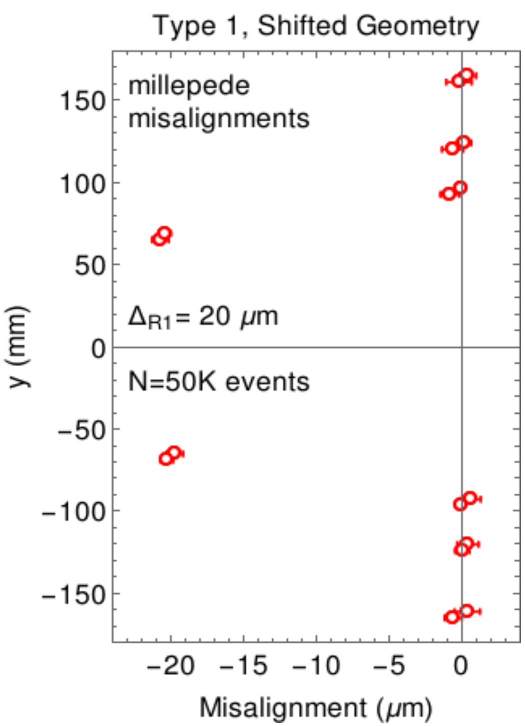
Alignment of the SVT using Millepede

Type 1 track

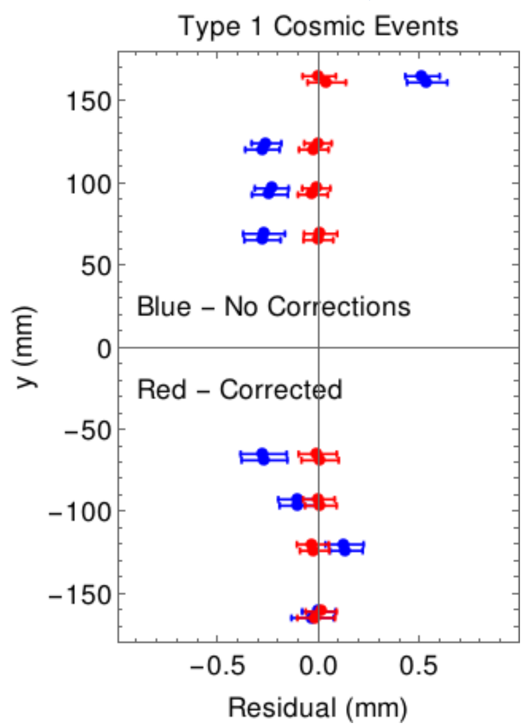


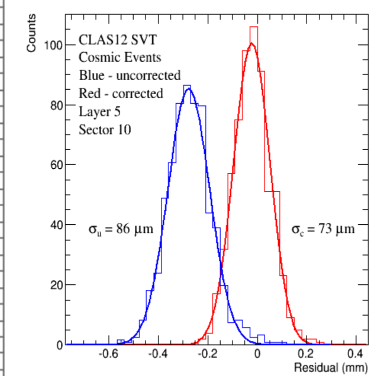
shift barrel R1 by 20 microns

Misalignment results obtained from Millepede tested on MC



Reconstruction of cosmic events with millepede misalignments incorporated

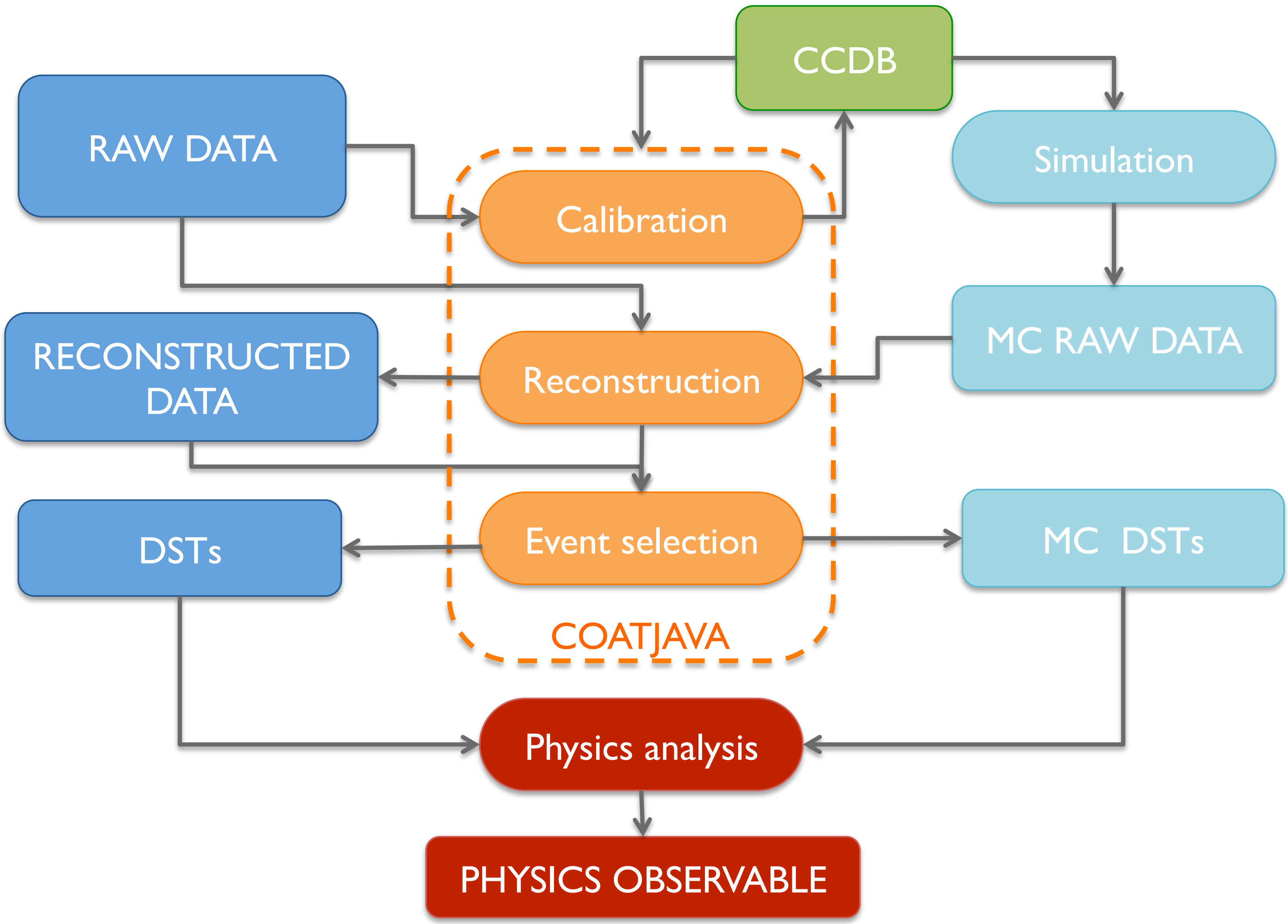




MC validations

Real Data validations

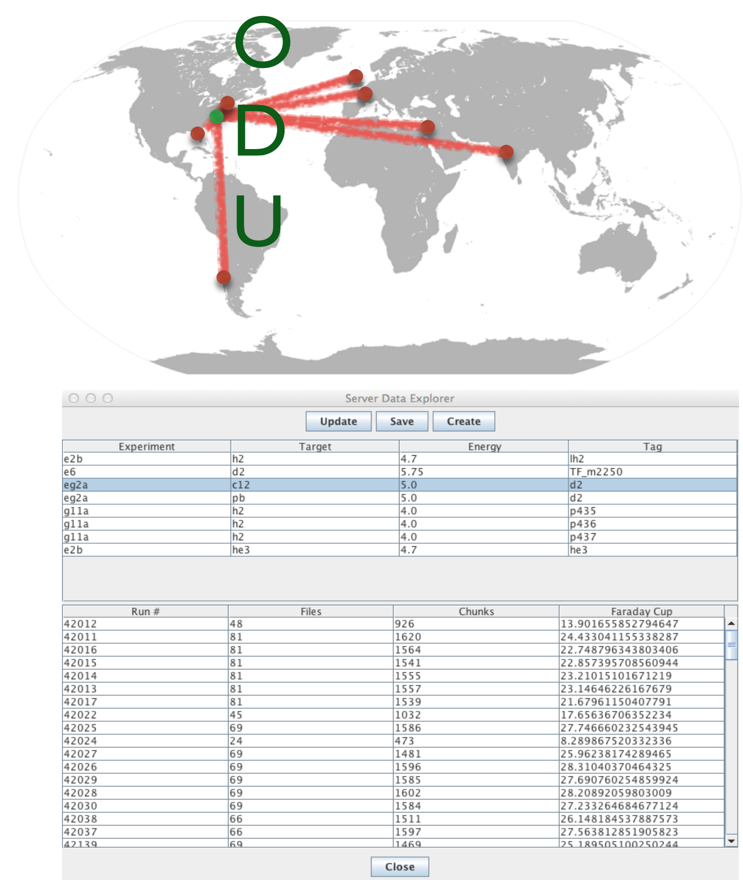
Data Analysis Scheme



Event selection tool

Collection of algorithms and procedures to select events from reconstruction output and build DSTs for specific final states:

- Select golden runs and files
- Select events for specific final state
- Apply:
  - kinematic corrections
  - fiducial cuts
  - …
- Output DST files with:
  - fully corrected 4-vectors for physics analysis
  - detector related info for refinement of PID and signal selection
  - luminosity and helicity related info
- Implement file tagging for easy data handling and distribution inspired by the CLAS data mining project



Experiment	Target	Energy	Tag
e2b	h2	4.7	lh2
e6	d2	5.75	TF_m2250
eg2a	c12	5.0	d2
eg2a	pb	5.0	d2
g11a	h2	4.0	p435
g11a	h2	4.0	p436
g11a	h2	4.0	p437
e2b	he3	4.7	he3

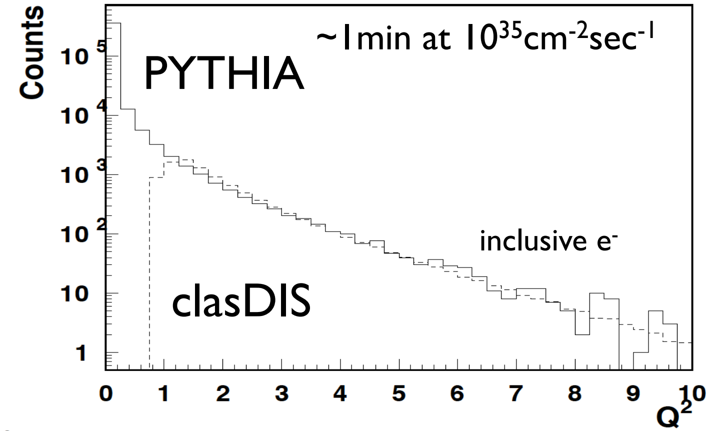
Run #	Files	Chunks	Faraday Cup
42012	48	926	13.901655852794647
42011	81	1620	24.433041155338287
42016	81	1564	22.748796343803406
42015	81	1541	22.857395708560944
42014	81	1555	23.21015101671219
42013	81	1557	23.14646226167679
42017	81	1539	21.67961150407791
42022	45	1032	17.65636706352234
42025	69	1586	27.746660232543945
42024	24	473	8.289867520332336
42027	69	1481	25.96238174289465
42026	69	1596	28.31040370464325
42029	69	1585	27.690760254859924
42028	69	1602	28.20892059803009
42030	69	1584	27.233264684677124
42038	66	1511	26.148184537887573
42037	66	1597	27.563812851905823
42139	69	1469	25.189505100250244

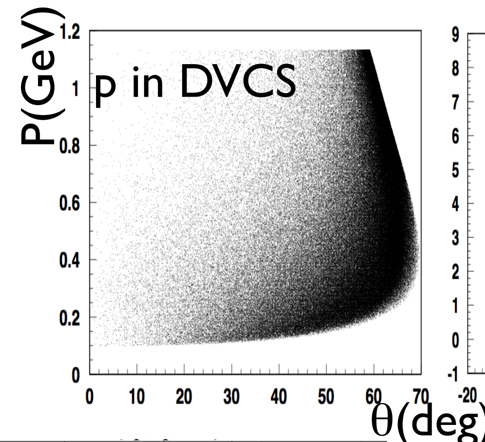
CLAS Data Mining

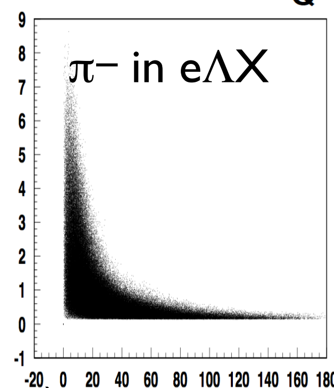
Physics Event Generators

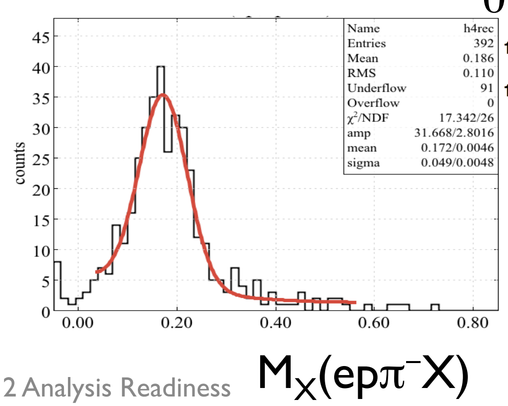
Generated events available for calibration and reconstruction tests, and physics studies:

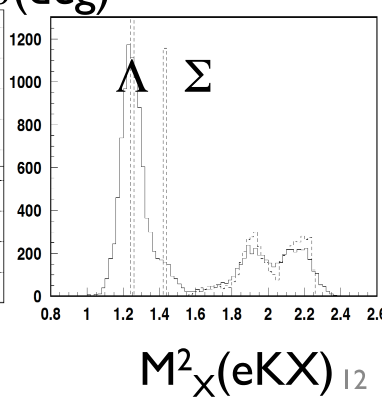
- INCLUSIVE ep → e'X generator
- SIDIS LUND MC (PYTHIA and PEPSI)
  - Generating (claspyth) low Q2 events for hadronic background and PID studies using modified PYTHIA
  - Generate (clasDIS) single and double-spin dependent processes using the modified PEPSI (LEPTO)
- Exclusive events
  - exclusive γ (DVCS), π/η using GPD models
  - exclusive eKΛ, epππ,..











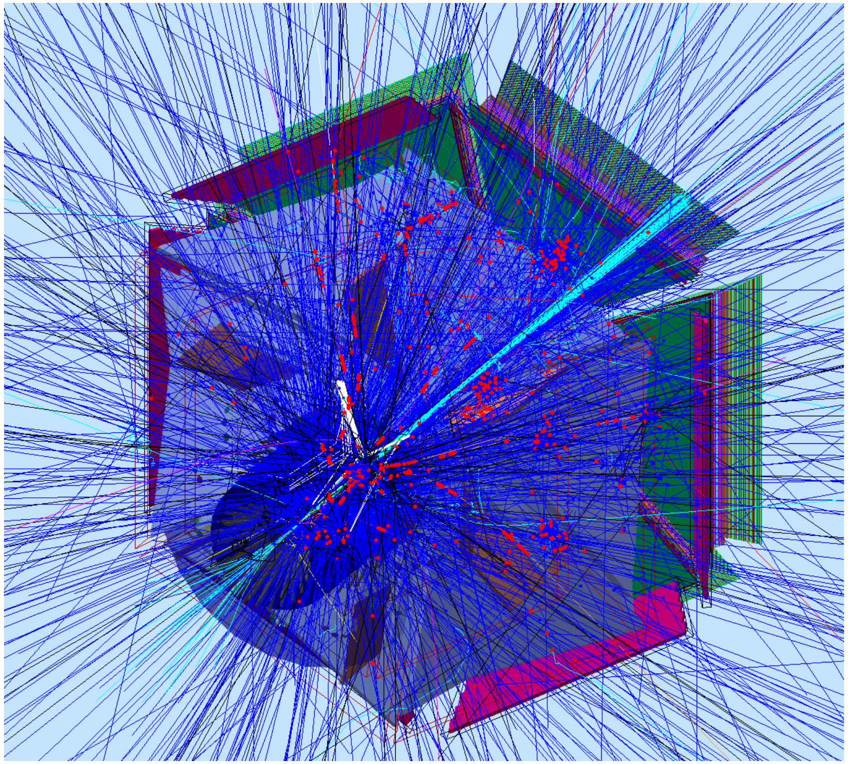
Simulating EM background

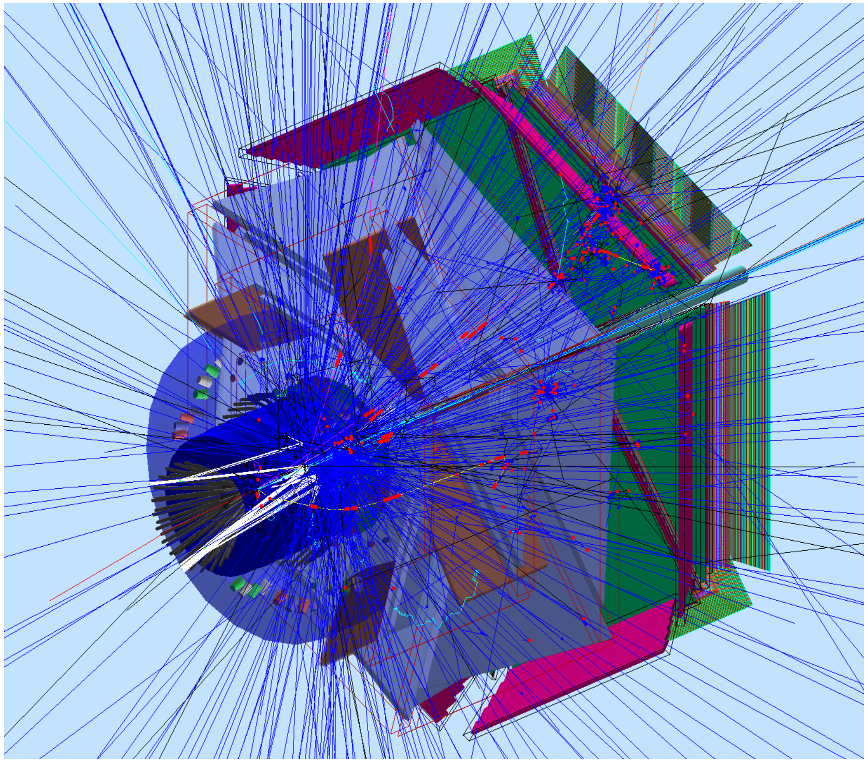
Can be set with gcards:

```
<option name="LUMI_EVENT"      value="124000, 250*ns, 4*ns" />
<option name="LUMI_P"          value="e-, 11*GeV, 0*deg, 0*deg" />
<option name="LUMI_V"          value="(0.,0.,-4.5)cm" />
<option name="LUMI_SPREAD_V"   value="(0.01, 0.01)cm" />
```

124K e-/event = 10^{35} $s^{-1}cm^{-2}$ on 5cm LH target

Start beam before the target, 100 micron wide

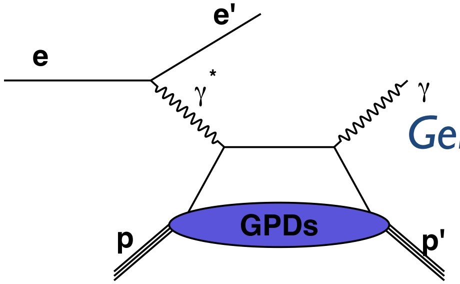




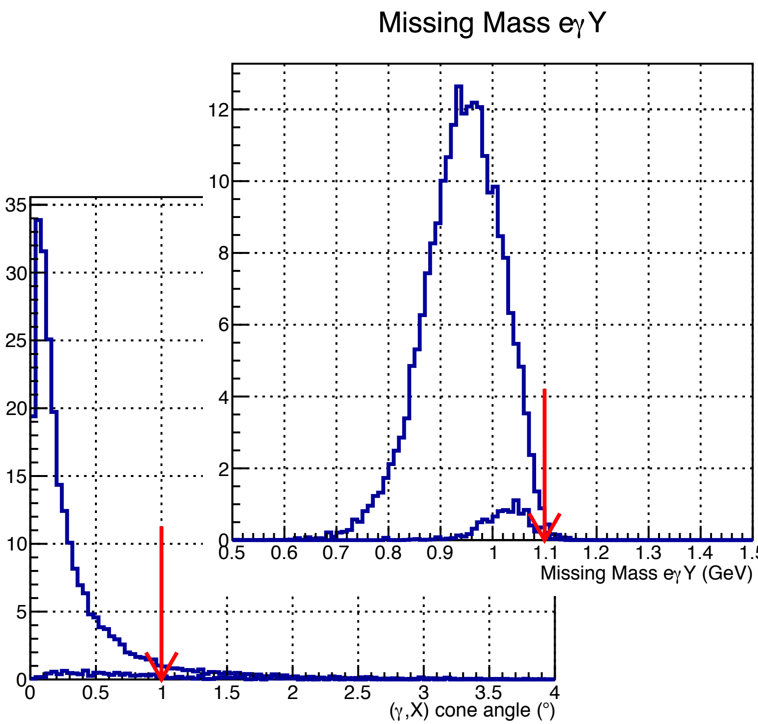
2 dis events at full luminosity

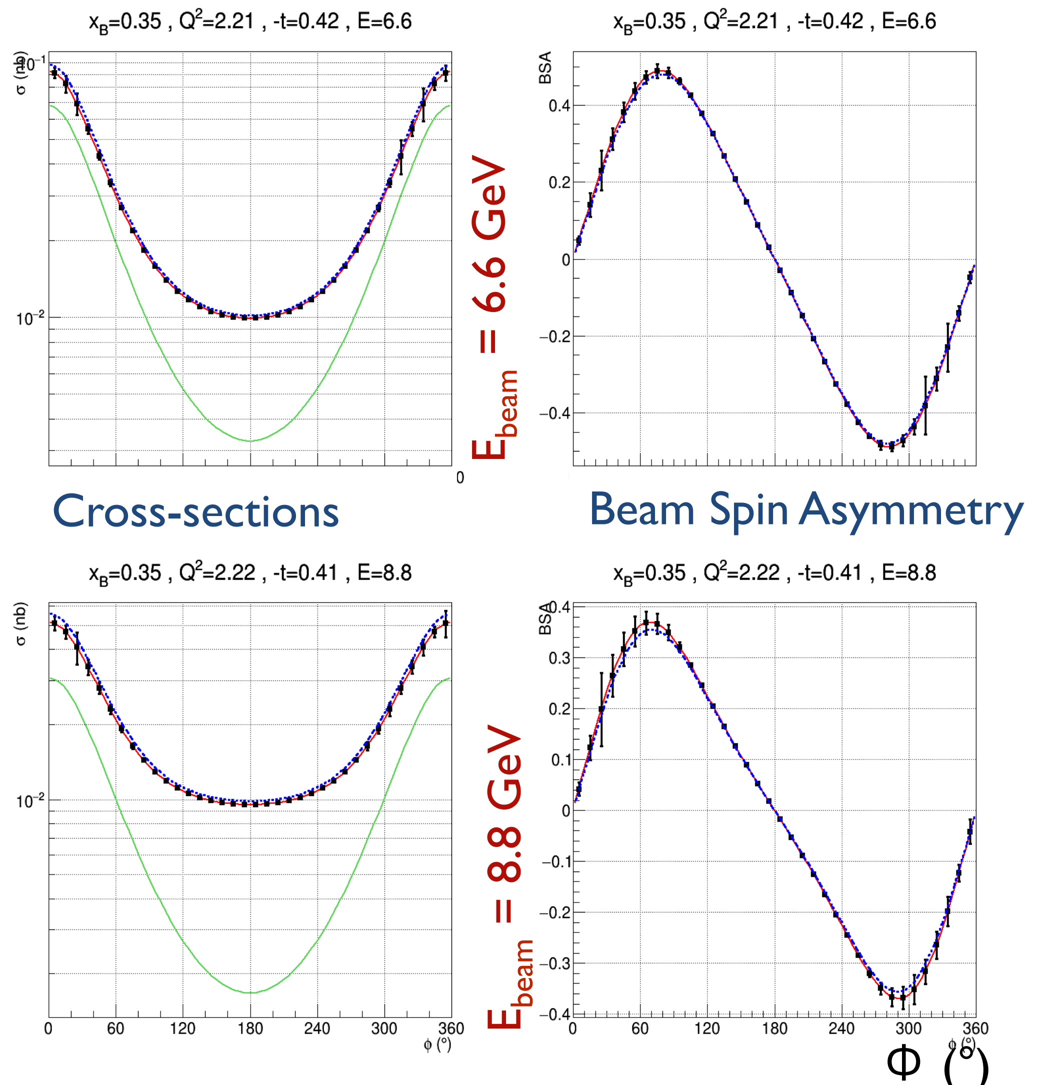
Physics analysis example

Deeply Virtual Compton Scattering

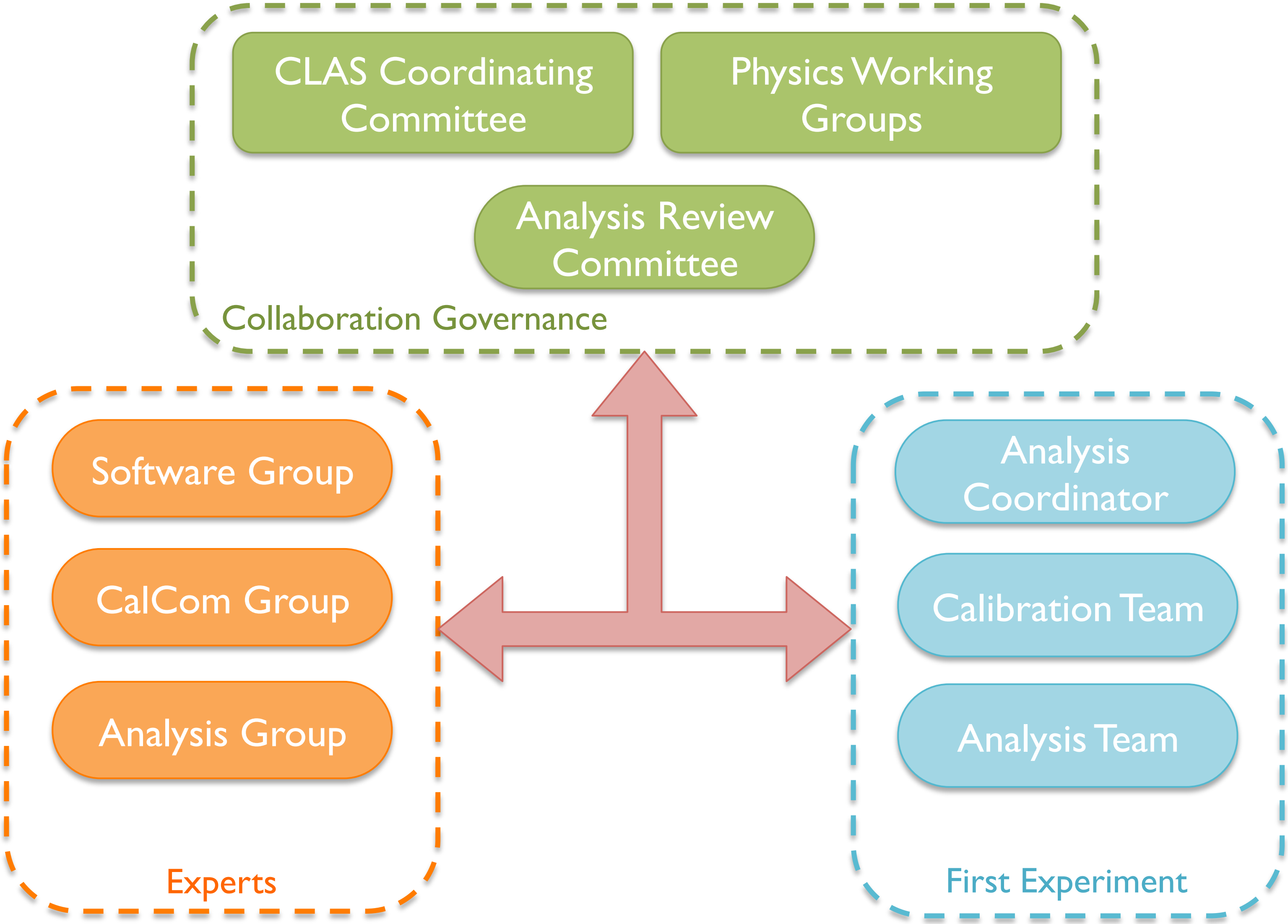


Accessing Generalized Parton Distributions amplitudes

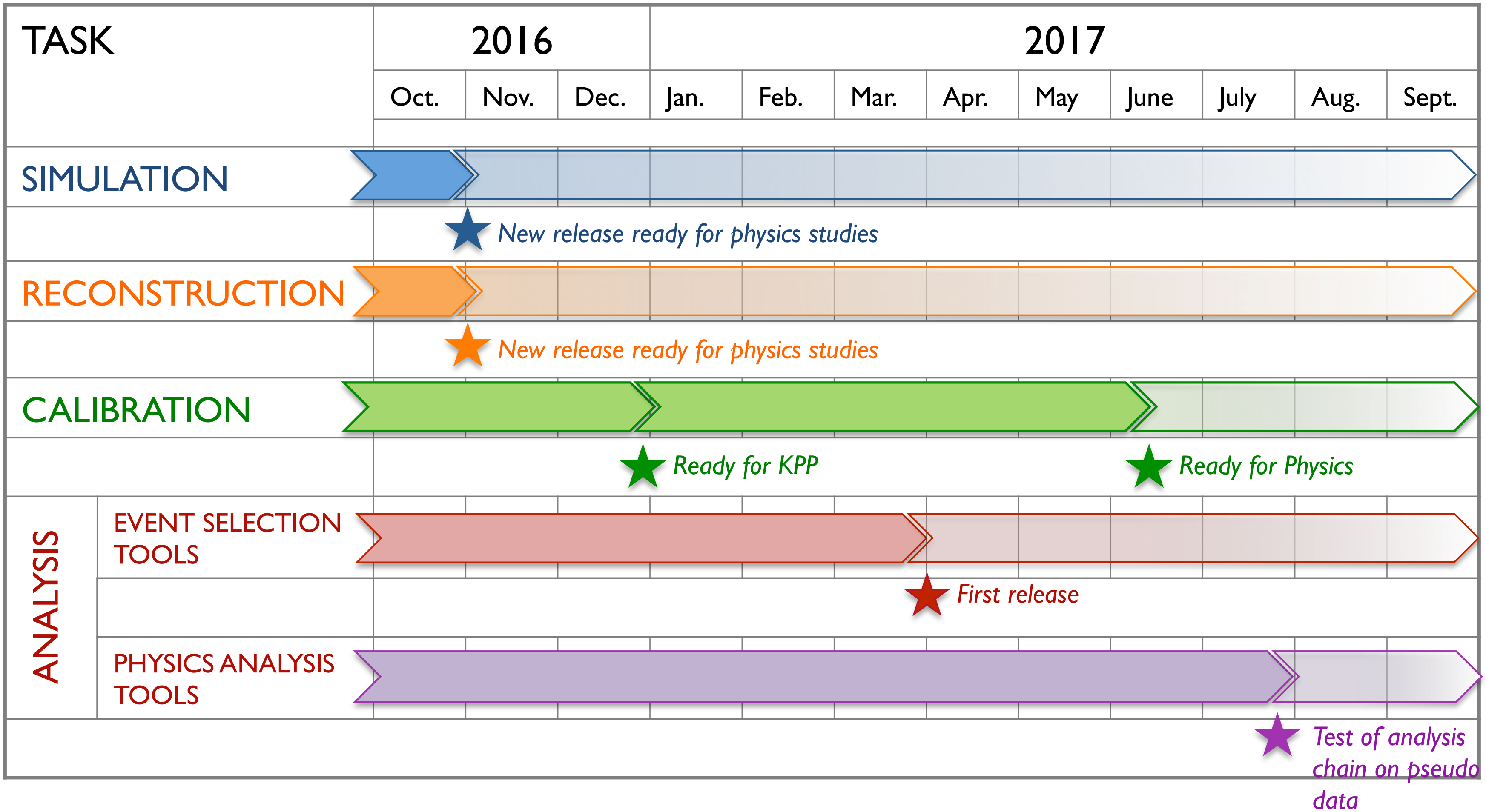




Analysis Organization



Timeline


TASK
2016
2017
Oct.
Nov.
Dec.
Jan.
Feb.
Mar.
Apr.
May
June
July
Aug.
Sept.
SIMULATION
New release ready for physics studies
RECONSTRUCTION
New release ready for physics studies
CALIBRATION
Ready for KPP
Ready for Physics
ANALYSIS
EVENT SELECTION TOOLS
First release
PHYSICS ANALYSIS TOOLS
Test of analysis chain on pseudo data

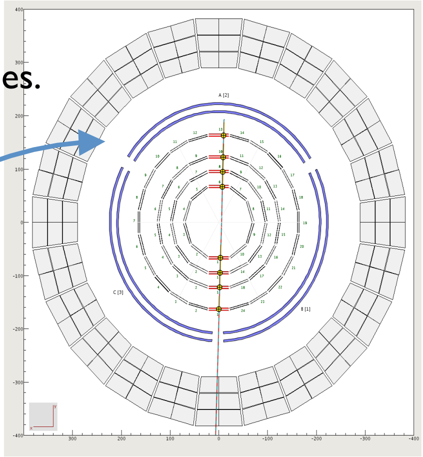
Summary

- Simulations ready to generate realistic pseudo data
- Reconstruction released for user to study physics reactions
- Calibration tools developed with real and pseudo data
- Analysis tools under development:
  - Event generators
  - Event selection and data handling tools
  - Full analysis of physics reactions tested
- Analysis organization and management defined
- Ready for physics in Fall 2017

Backup

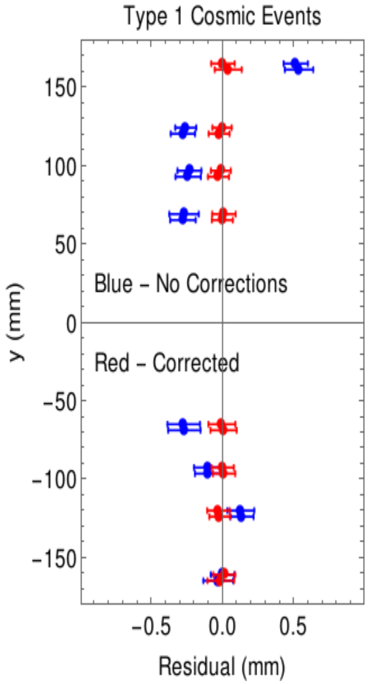
Alignment of the SVT

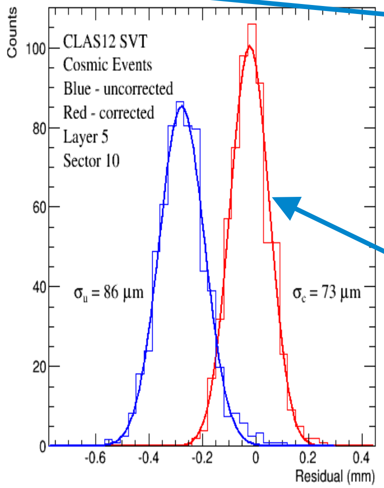
- Track-based alignment of SVT requires fitting many parameters: $N_{sectors} \times N_{layers} \times N_{trans} \times N_{rot} = 66 \times 2 \times 3 \times 2 = 792$
- Program **millepede** does linear least squares with many parameters.
  - Uses matrix form of least squares method and divide the elements into two classes.
    - Global parameters – the geometry misalignments. Same in all events.
    - Local – individual track fit parameters. Change event-to-event.
  - Calculate first partial derivatives of the fit residuals with respect to the local (i.e. fit) parameters and global parameters (geometry misalignments).
  - Manipulate the linear least squares matrix to isolate the global parameters (geometry) and invert the results to obtain the solution.



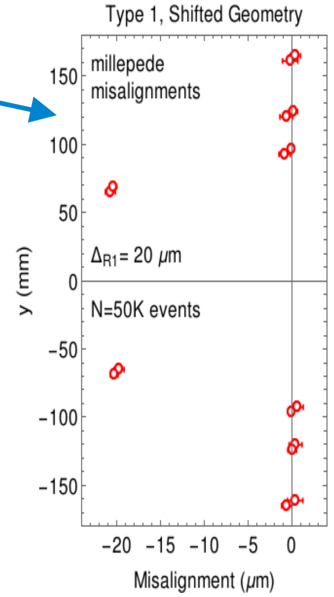
Type I tracks – Horizontal sensors.

- Apply to a 'simple' example – Type I tracks.
  - Simulated cosmics for validation.
  - Shift layers 1-2 (Region 1) by 20 microns in *x*.
  - millepede reproduces shifts in the range 2-500 μm.



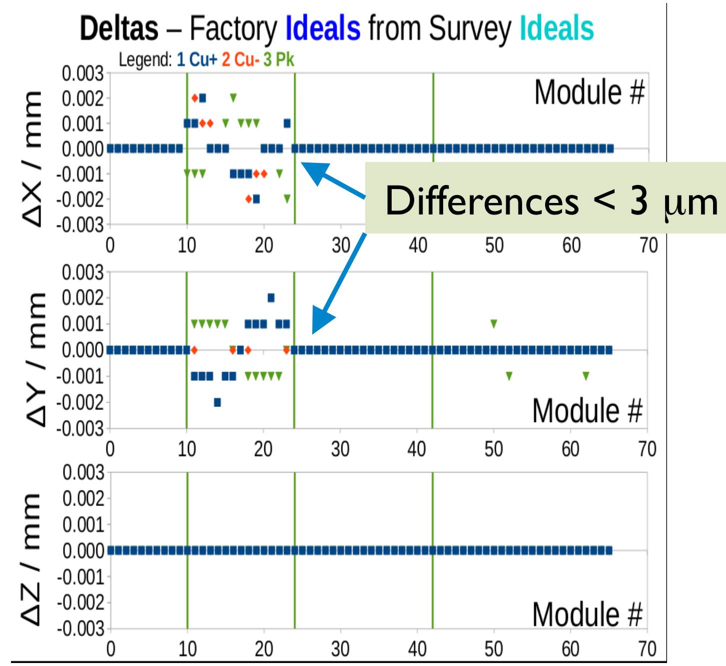


- Apply to Type-1 cosmic ray sample from SVT.
  - 5.9M events; fixed layer 4 to SVT residual.
  - Millepede misalignments added to reconstruction, residuals ~25 μm.
  - Resolution in sectors 70-80 μm.
- Code for more complex events now being tested.

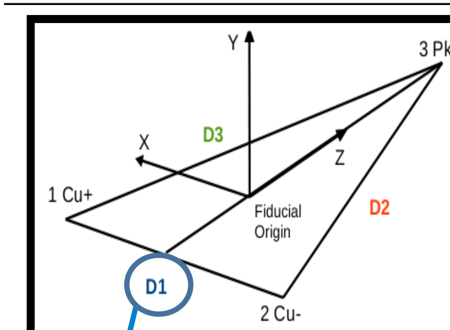


Alignment of the SVT

- Ideal Geometry Validation and Testing
  - Calculate ideal fiducial location on each module.
  - Observed significant difference with engineering drawings - up to 100 µm.
  - Worked with engineers to correct differences.
  - Ideal geometry now well defined with parameters from engineering drawings.



- Geometry package
  - Common Java utility to access geometry for gemc simulation and reconstruction.
  - Generate shifts from ideal geometry to measured fiducial results.
  - Processing fiducial survey data in alignment shifts – validating with simulated tracks.
  - Putting full inventory of material in SVT gemc simulation.



Fiducials form triangle on sensor.