Muon Identification: Cosmics to Collisions

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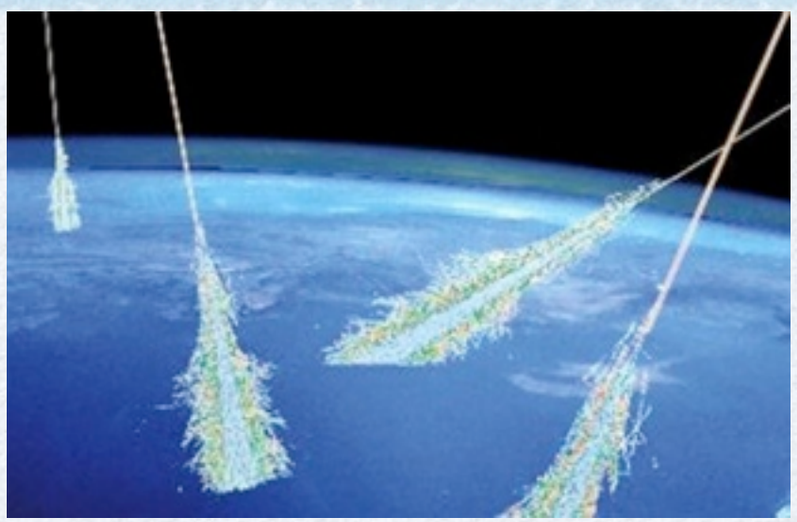
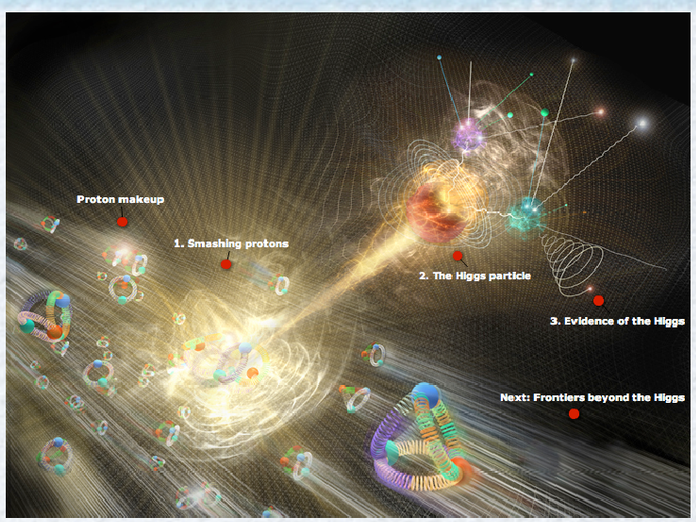
Harvard University



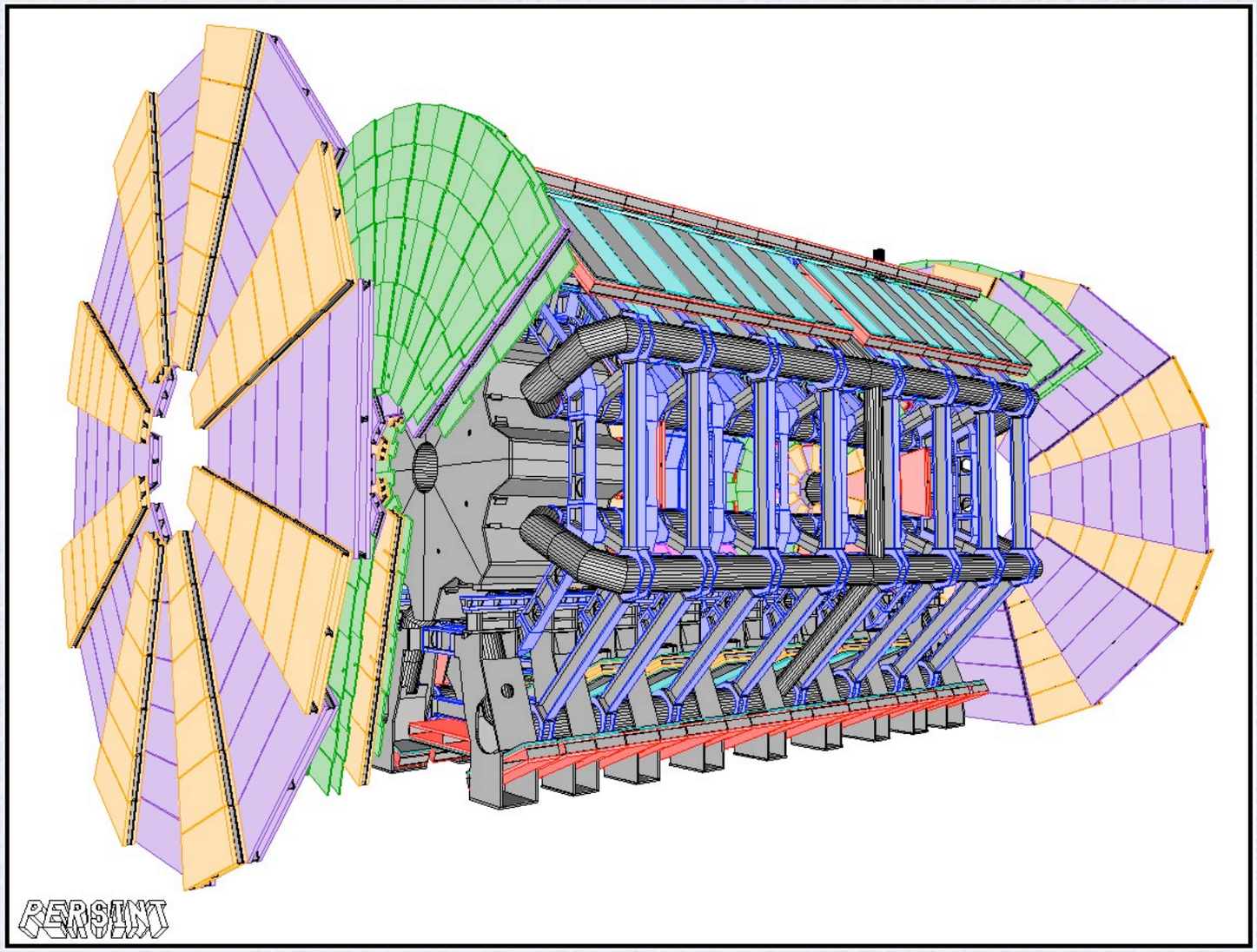


MUON SPECTROMETER

Trigger

-Barrel Resistive Plate Chambers (RPC)

-End Cap Thin Gap Chambers (TGC)



Precision Chambers

-Monitored Drift Tube (MDT)

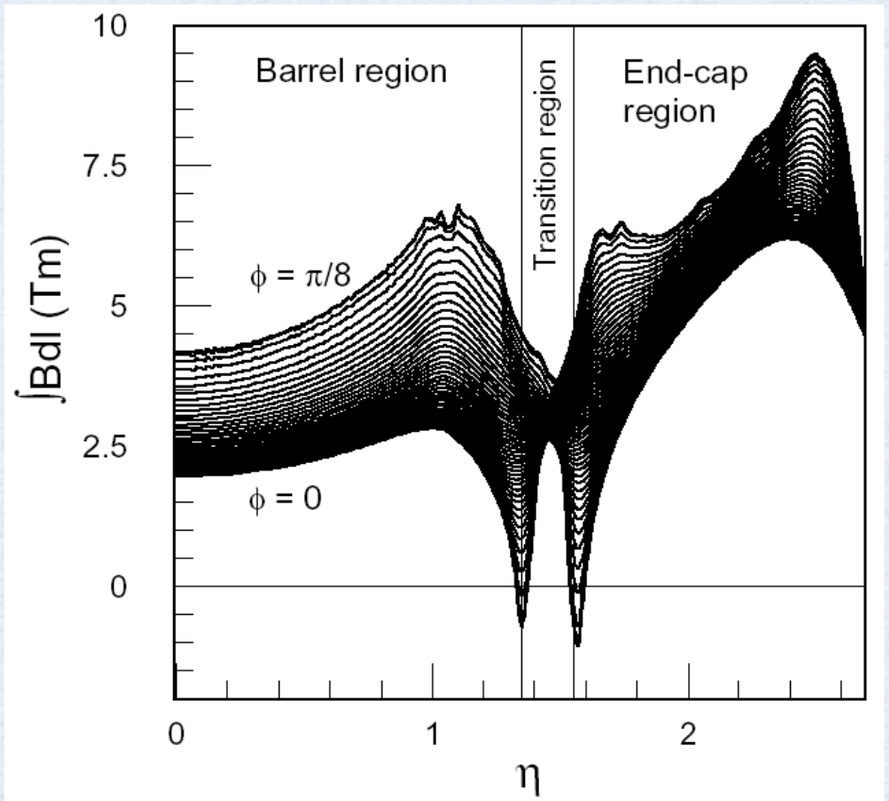
- Cathode Strip Chamber

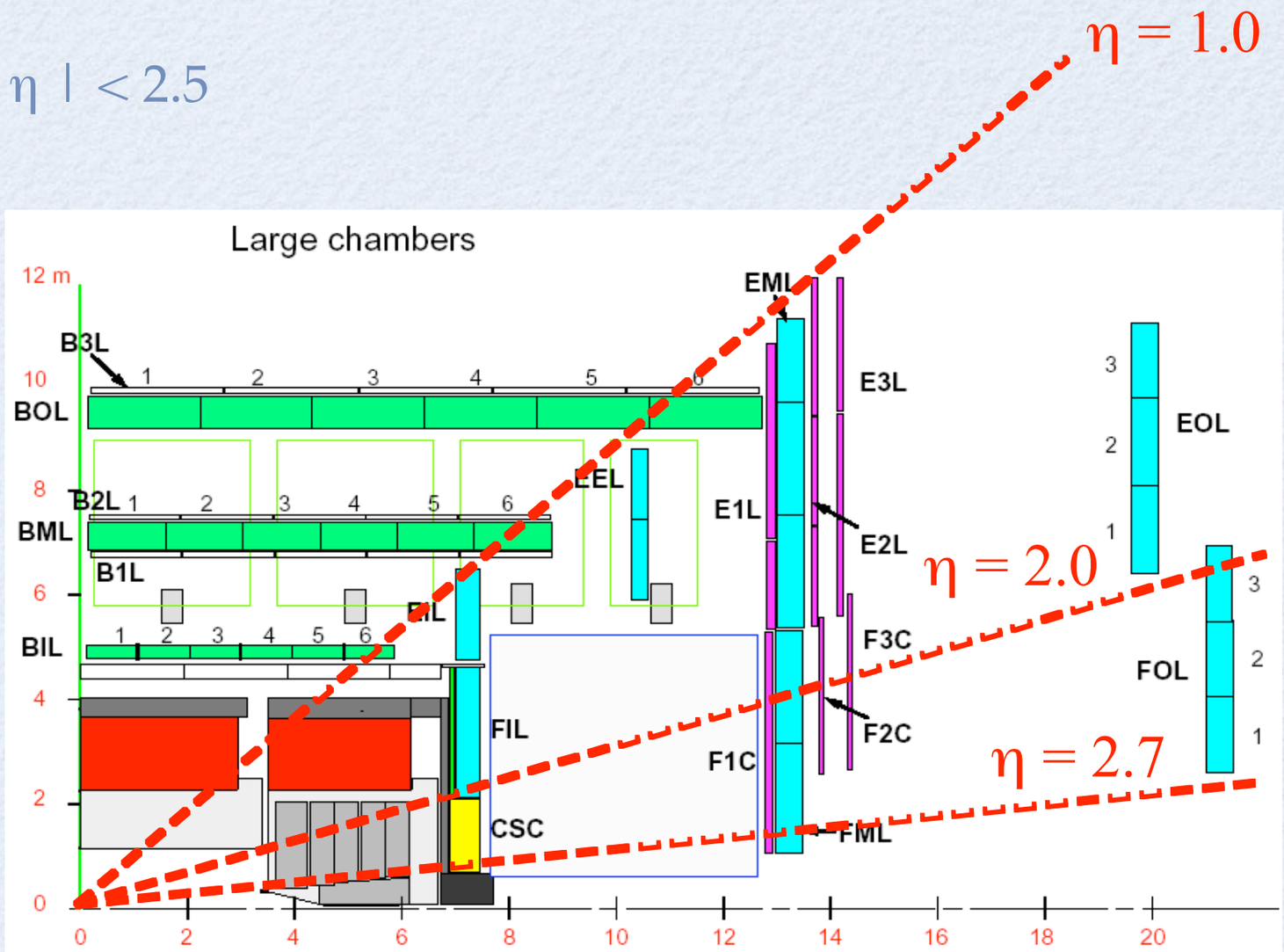
Magnet System

-Barrel and 2 Endcap Toroids

COVERAGE

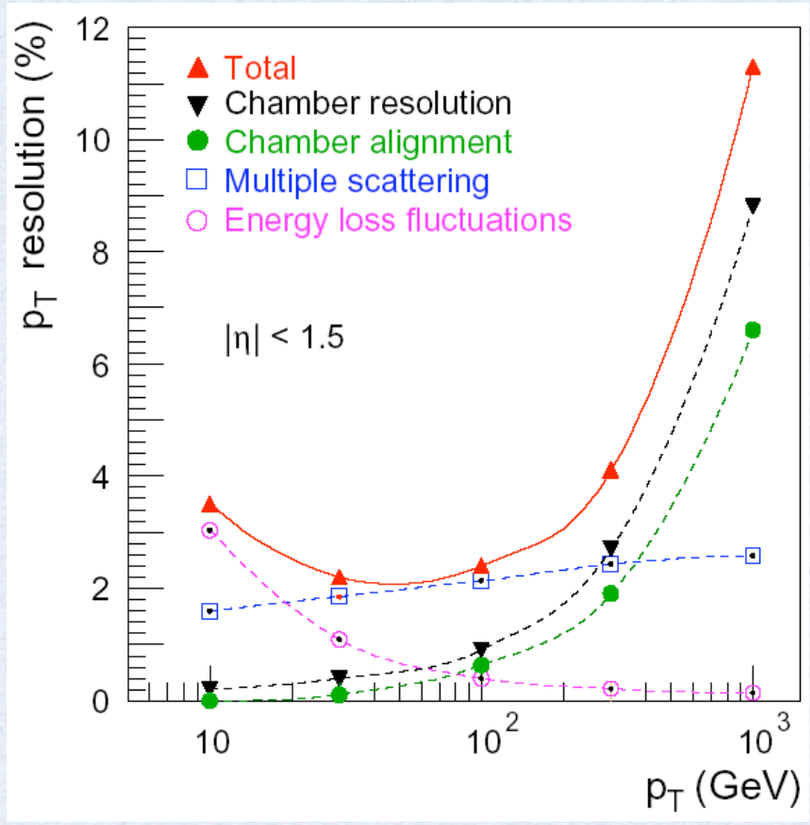
- Trigger to $|\eta| < 2.4$
- Reconstruct to $|\eta| < 2.7$
- Reconstruct with ID track $|\eta| < 2.5$

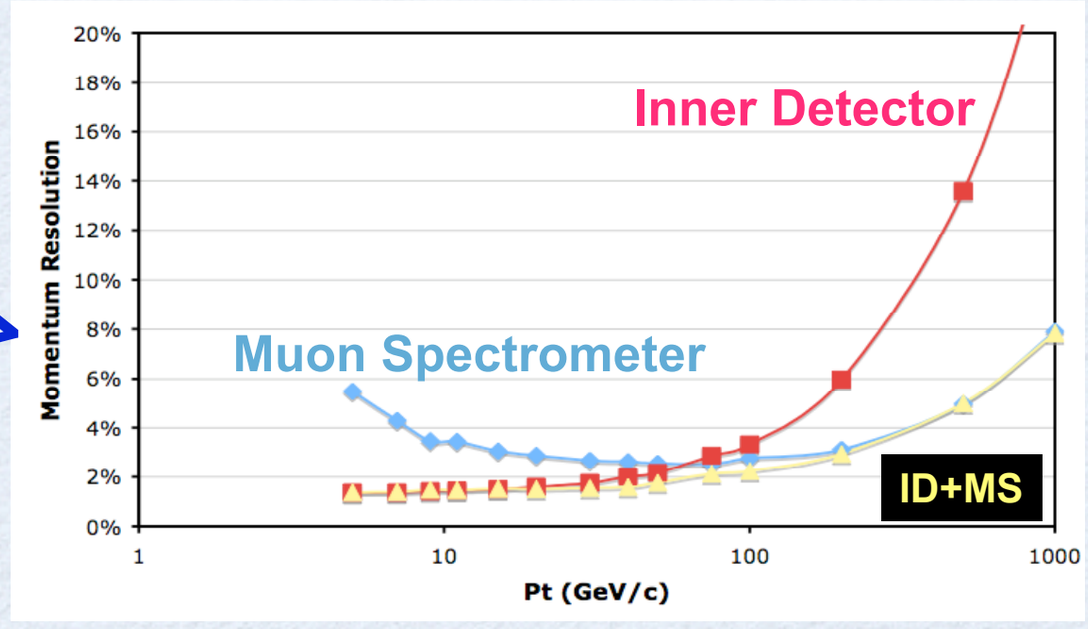




DESIGN SPECIFICATIONS

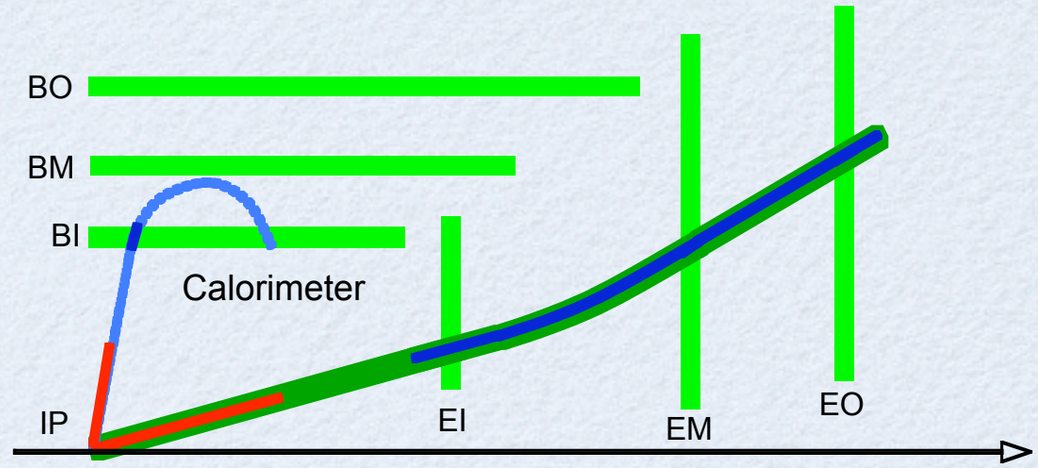
- High Precision Standalone Tracking - measure 1 TeV muon to no worse then 10%
- High Efficiency within geometric acceptance > 95%
- Low fake rate
  - mostly non-prompt muons (heavy flavor, pion decay)
  - Some punch/sail through

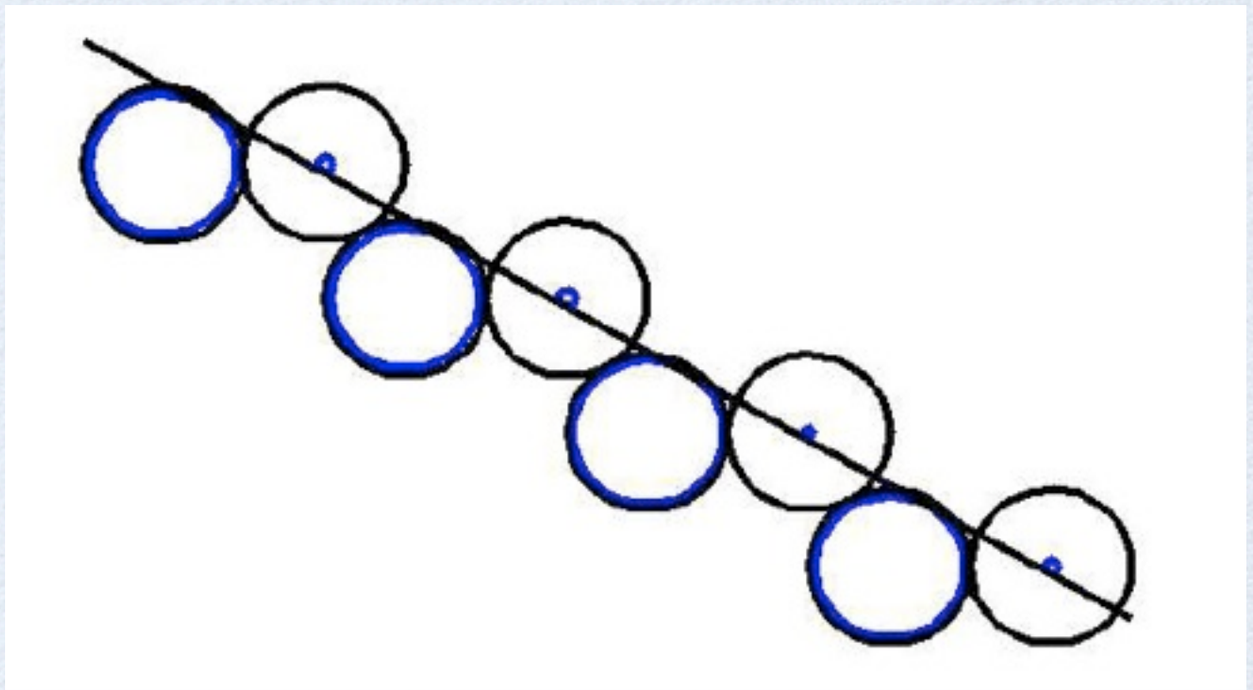




SA- ALGORITHMS

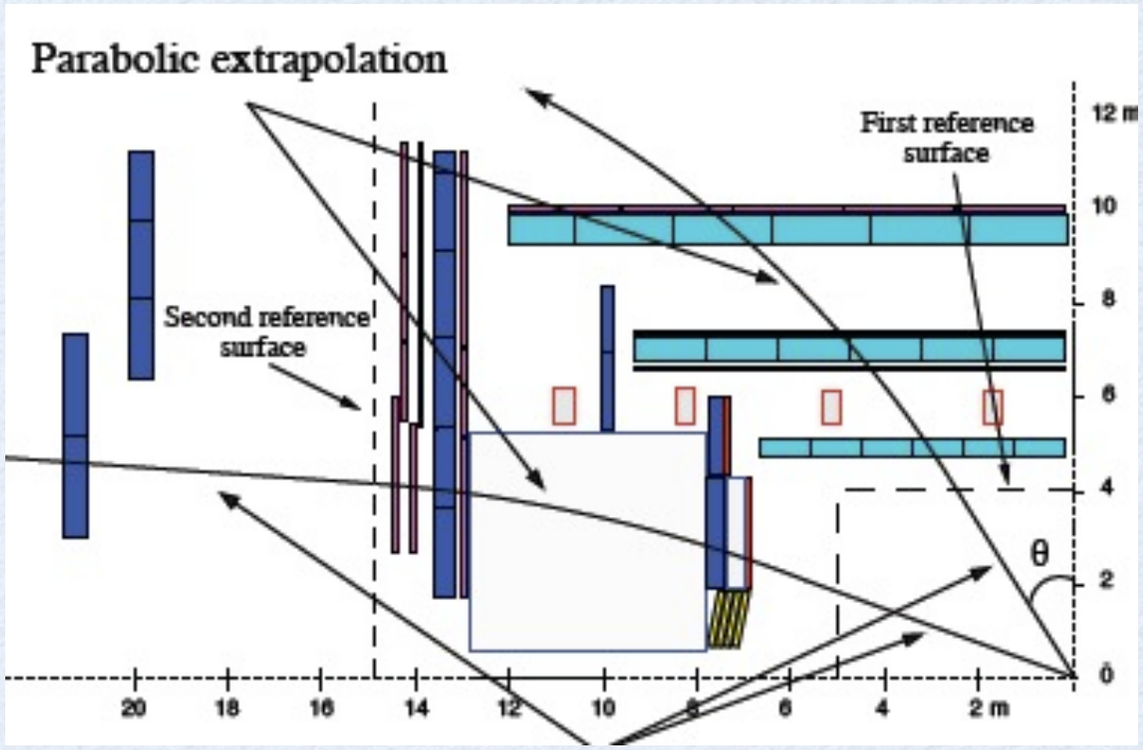
- Muonboy / Moore
- Basic Algorithm
  - Chamber local segment reconstruction
  - Combined Segments
  - Fit Tracks

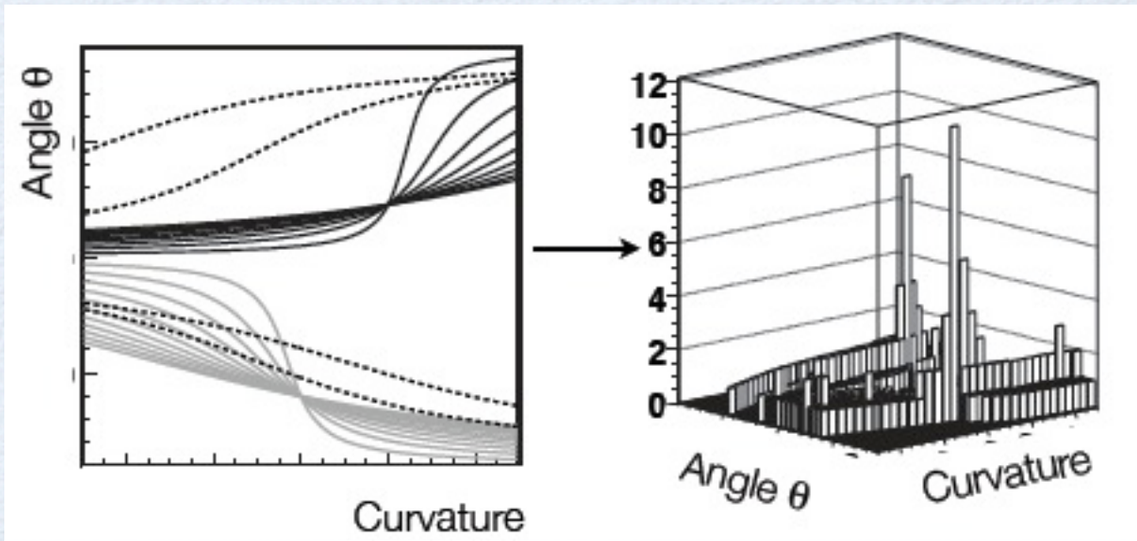




ROAD FINDING

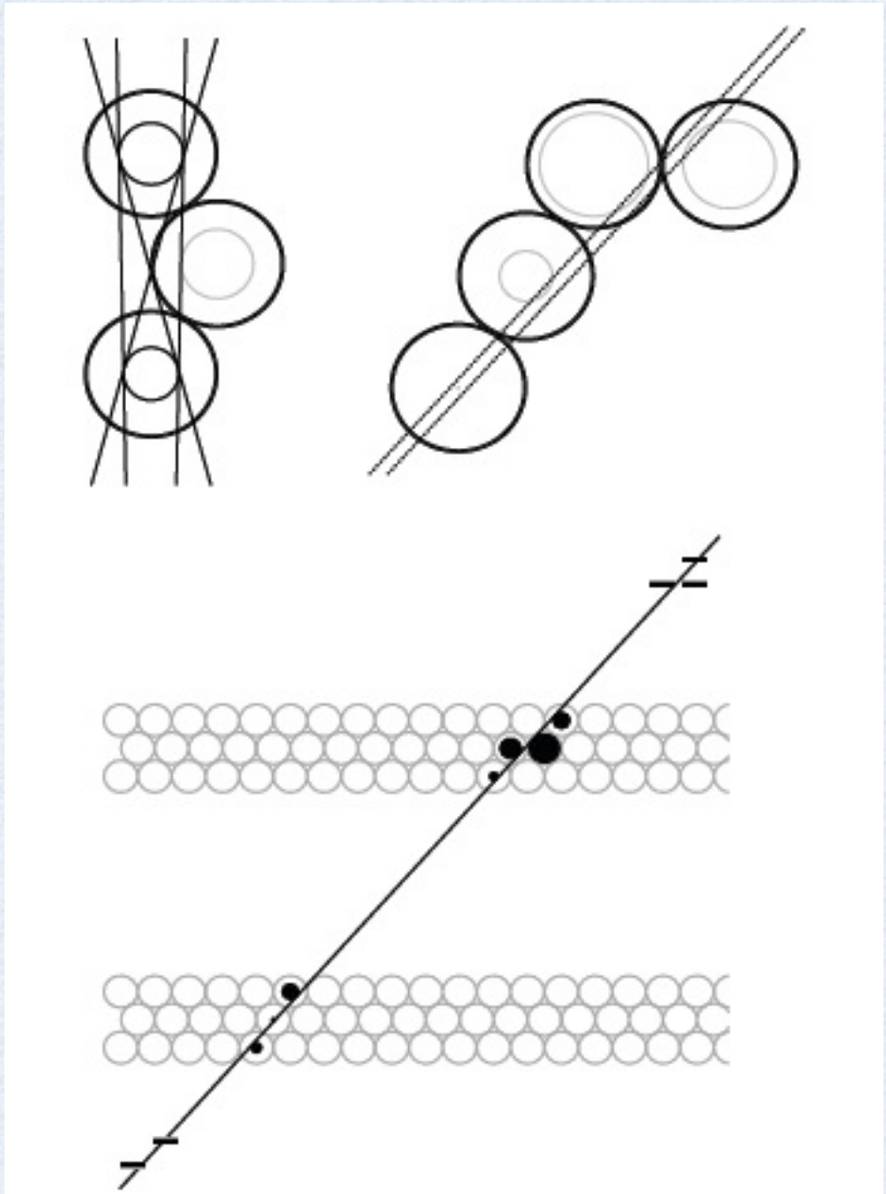
- Use Hough Transform technique to find global patterns
- Provides 2nd coordinate along drift tube for segment finding





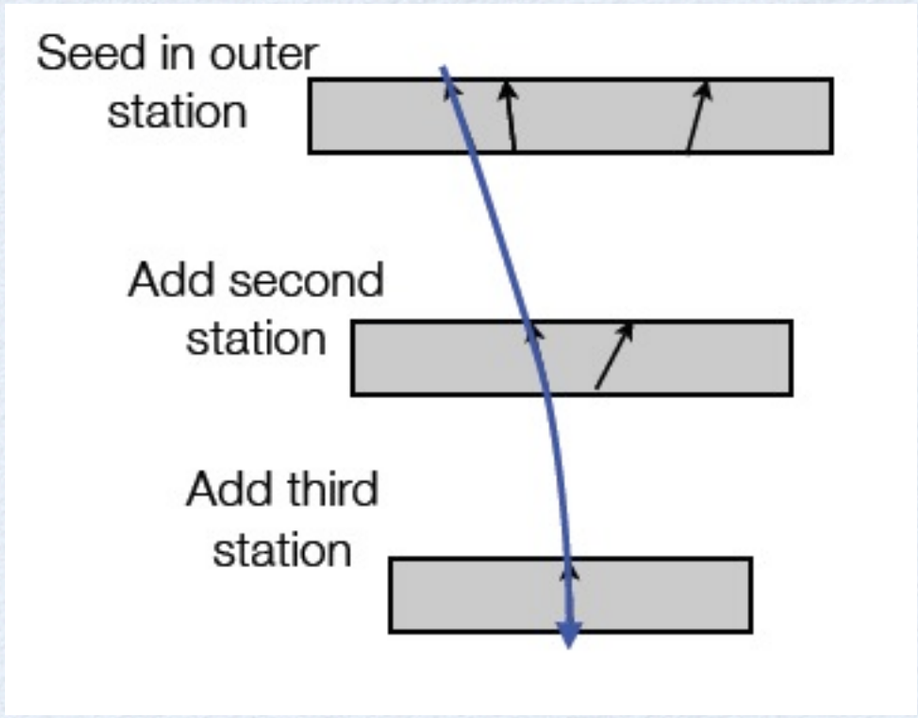
SEGMENT FINDING

- Draw Tangent Lines to circle from outermost dirft circle
- Iterate inward adding hits to line segment
- Fit with MDTs - add nearby trigger hits



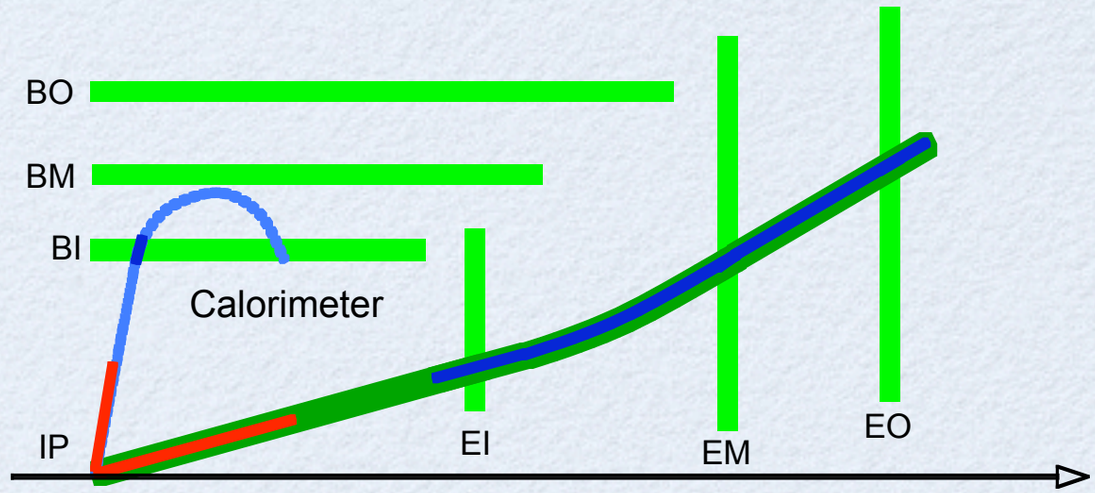
TRACK FINDING

- Combine Segments in global road
- Check consistency of pointing
- Global Track Fit



COMBINED TRACKS

- Extrapolate MS track back through calorimeter
- Match to ID track
- Fit (Muid) or combine tracks according to track parameters/cov



Muid

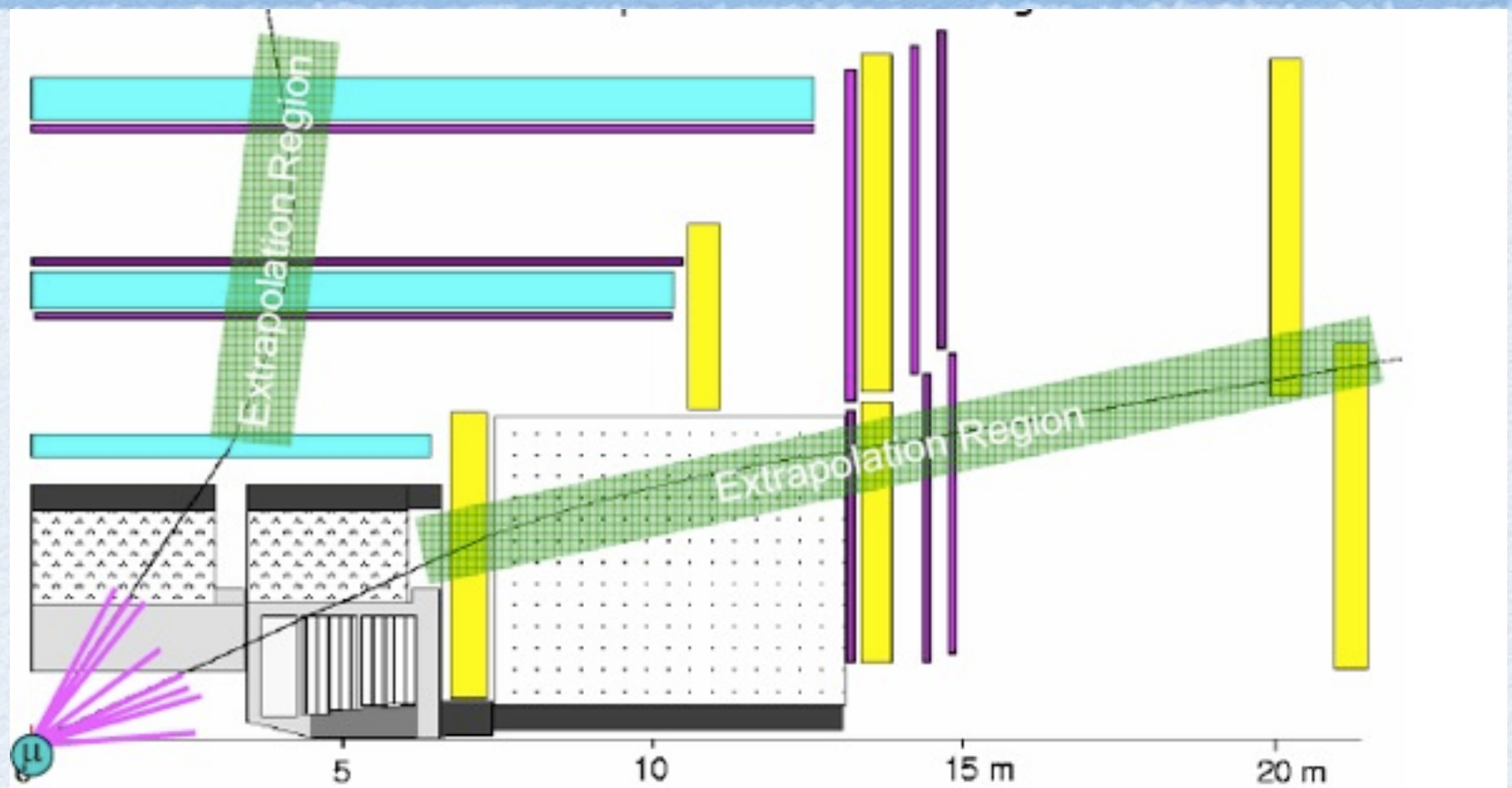
-Muid takes ID track and extrapolates to MS, match with MS track and refit

Staco

use covariance matrix to combined

Muon Tagging

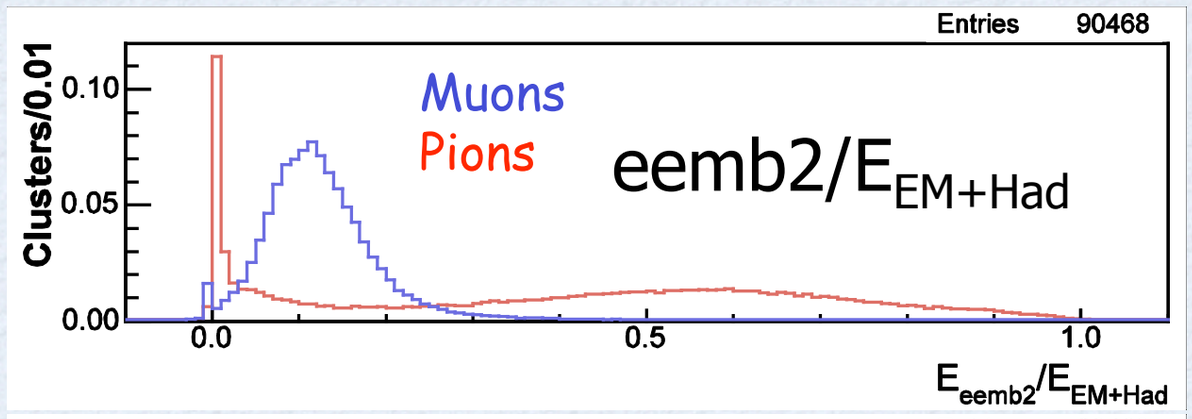
- Start with ID track
  - Extrapolate to MS
- Match to MS Segments
- Optionally refit

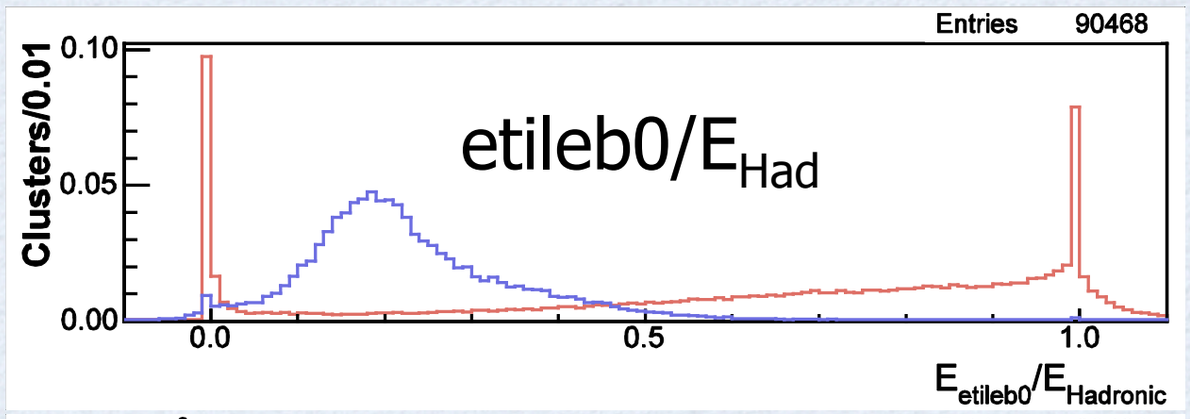


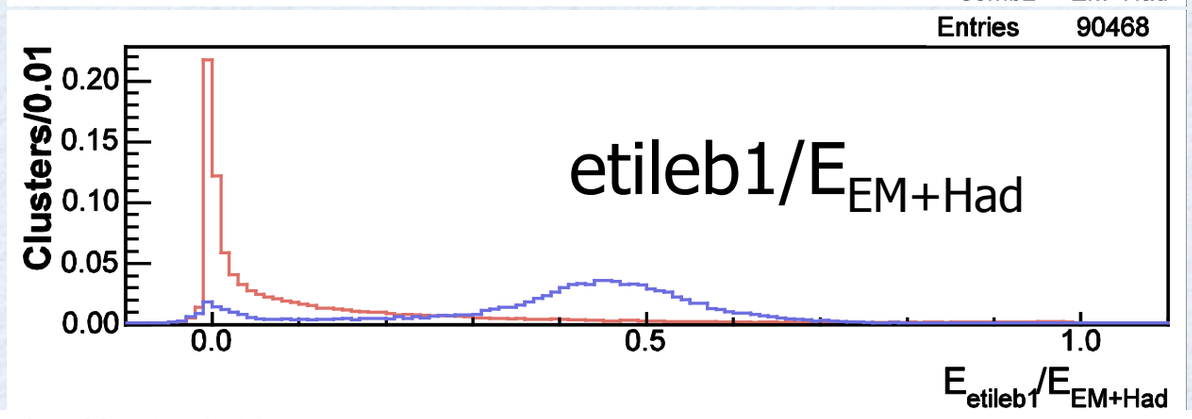
MuGirl
-Use NN to associate Segments, refit track
MuTag/MuTagIMO
-find segments and tag using ID tracks

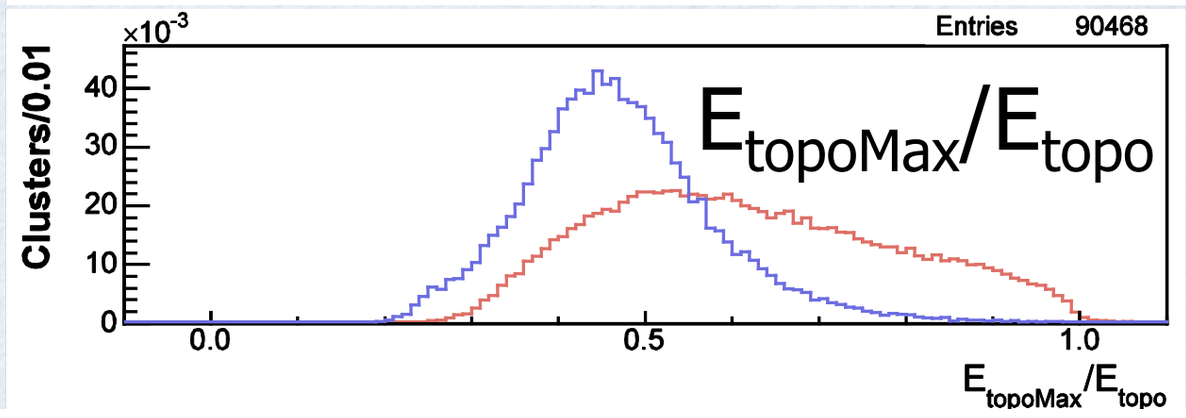
Calorimeter ID

- Extrapolate ID Track to Calorimeter
- Look at energy deposition - separate from isolated single pions

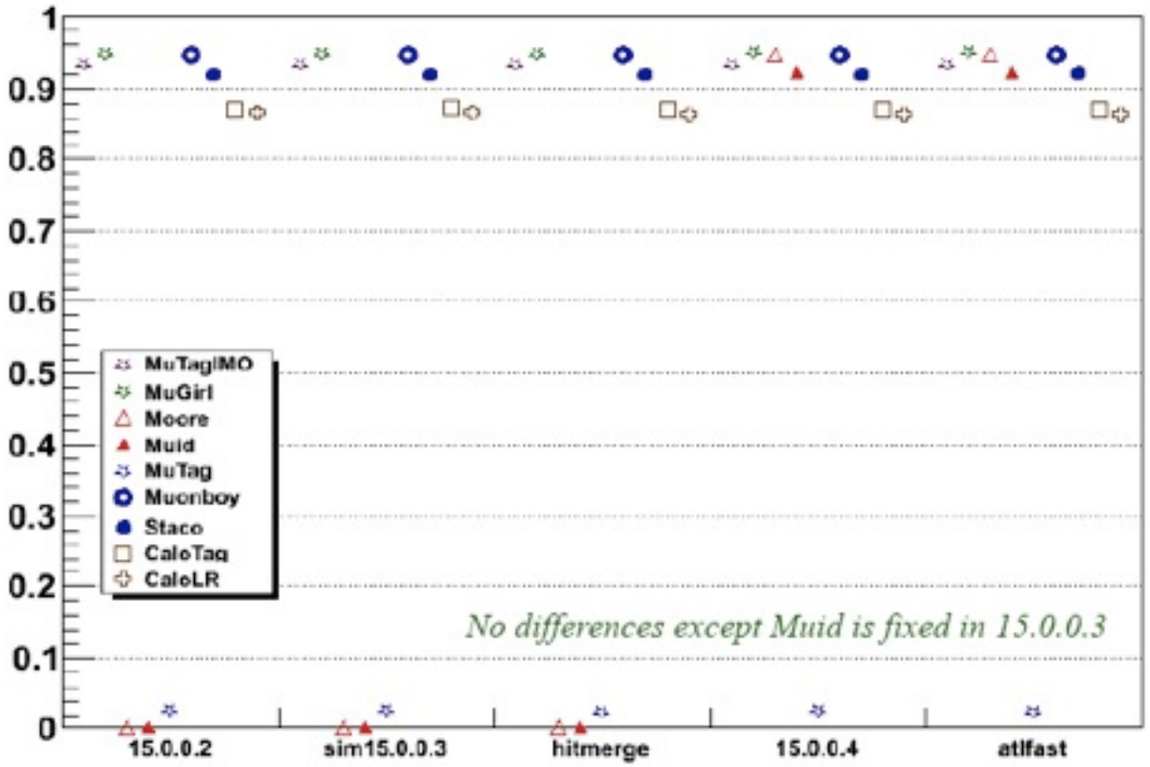


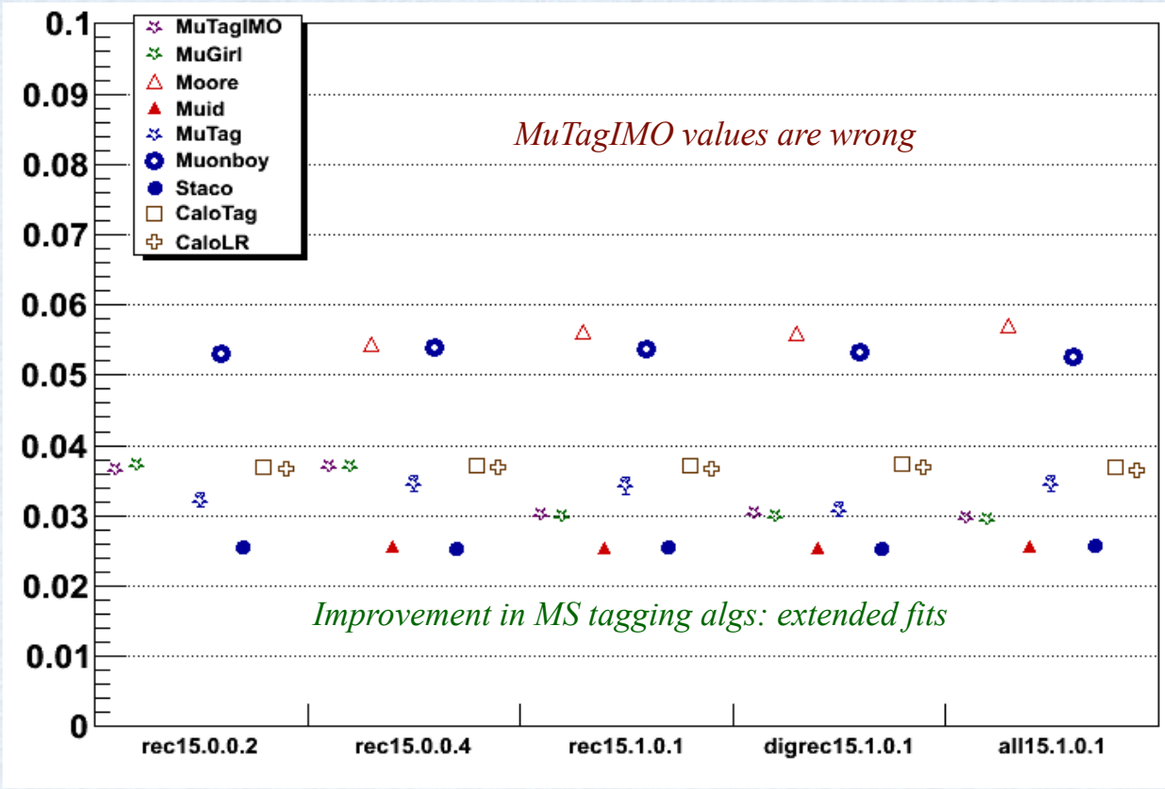






EXPECTED PERFORMANCE





prompt muons from top

Moore/Muonboy: Similar Performance - differences at percent level

AOD/ESD CONTENT

- Muon (AOD/ESD)
  - 4-vector, track link, hit info, isolation info
- TrackParticle (AOD/ESD)
  - Track Object (no detailed hit info)
- Tracks
  - track, full track info

Container Class	Location	Data Access Key
MuonContainer	ESD & AOD	"MuidMuonCollection" , "StacoMuonCollection"

- Muon
- TrackParticle
- MuonSpShower
- DepositInCalo

TileMuContainer	ESD	"TileMuObj"

- TileMu

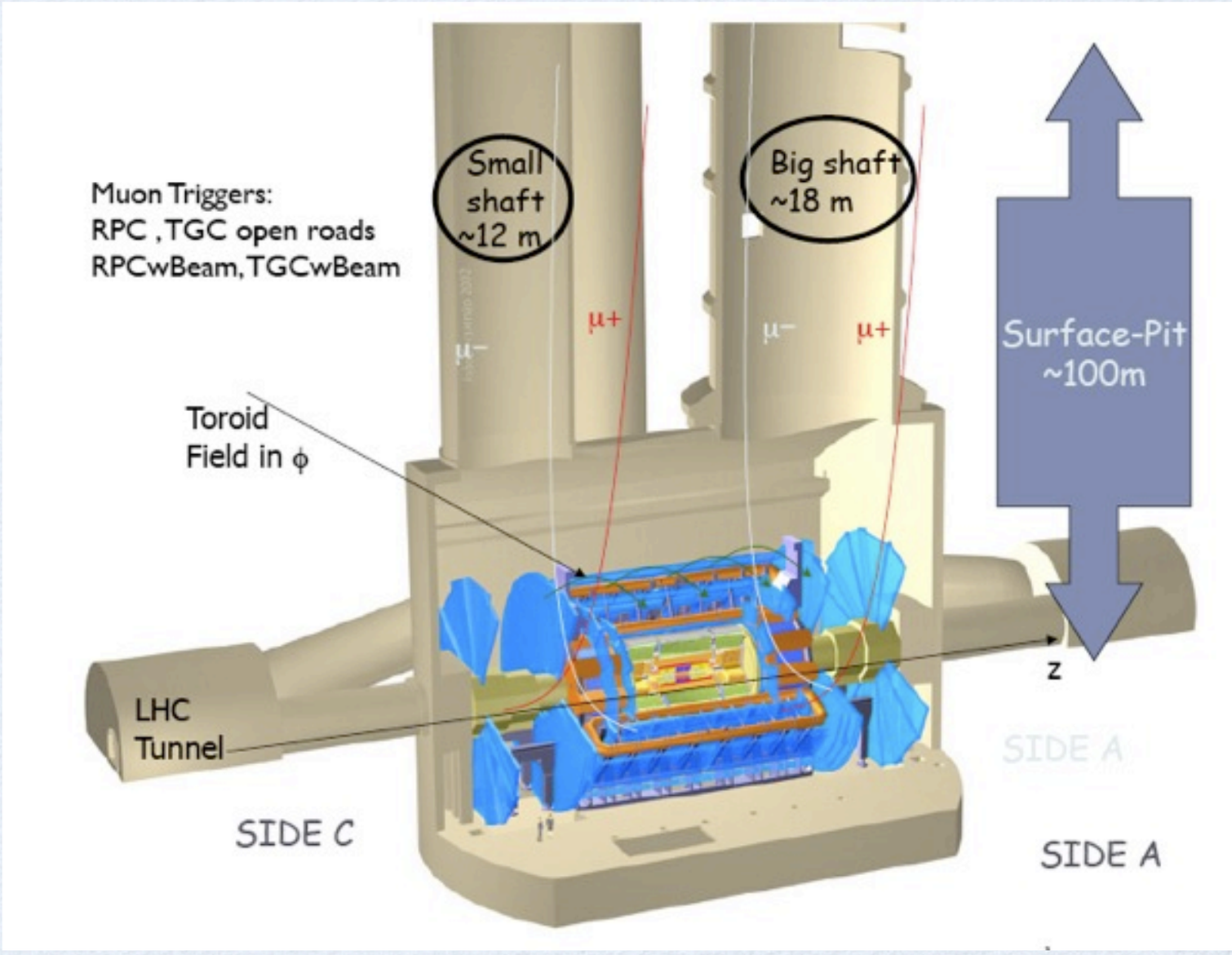
Container Class	Location	Data Access Key
TrackParticleContainer	AOD & ESD	"MuidCombTrackParticles", "MuidExtrTrackParticles", "MuidCombTrackParticlesLowPt" ,"MuTagTrackParticles", "MuonboyMuonSpectroOnlyTrackParticles", "MuonboyTrackParticles", "StacoTrackParticles", "TrackParticleCandidate", "MooreTrackParticles"

Container Class	Location	Data Access Key
TrackCollection	ESD	"ConvertedMooreTracks", "ConvertedMuIdCBTracks", "ConvertedMuIdExtrTracks", "ConvertedMBoyMuonSpectroOnlyTracks", "ConvertedMBoyTracks", "ConvertedMuTagTracks", "ConvertedStacoTracks", "ConvertedIPatTracks", "ConvertedXKalmanTracks", "Tracks"

- TrkTrack
- FitQuality
- Perigee
- MeasurementBase
- Parameters
- TrackStateOnSurface

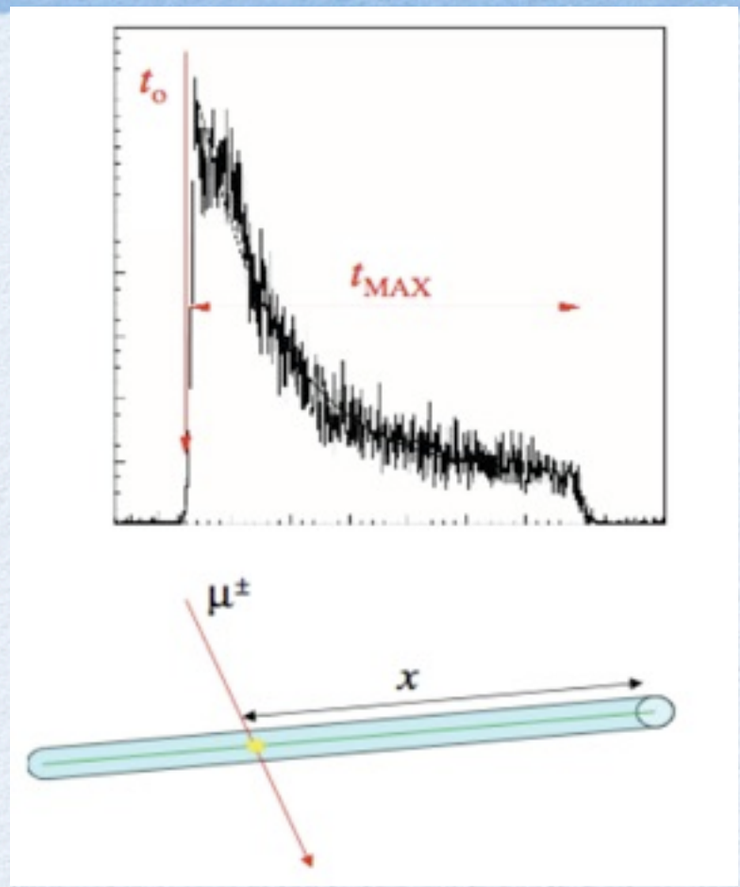
COSMICS OVERVIEW

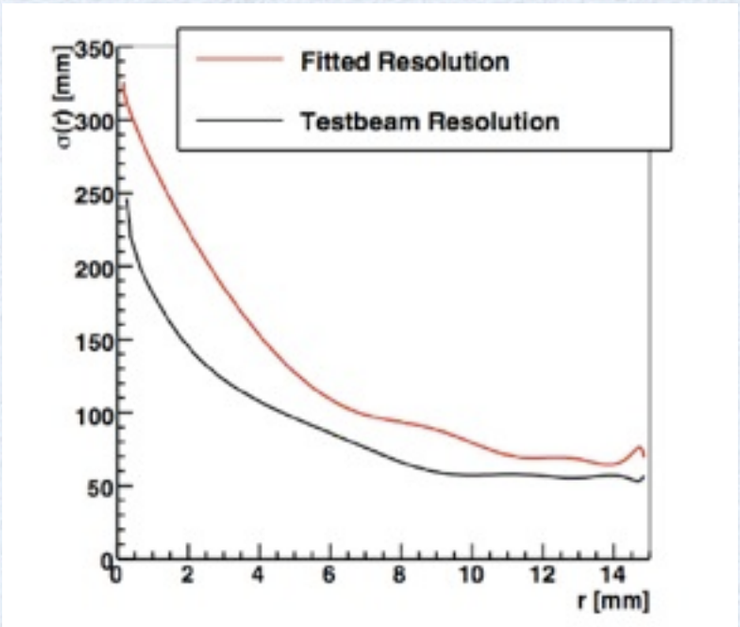
- No collider data, yet..
- 300 million+ cosmic events taken
- ‘out of time’, ‘non-pointing’



COSMICS CALIBRATION

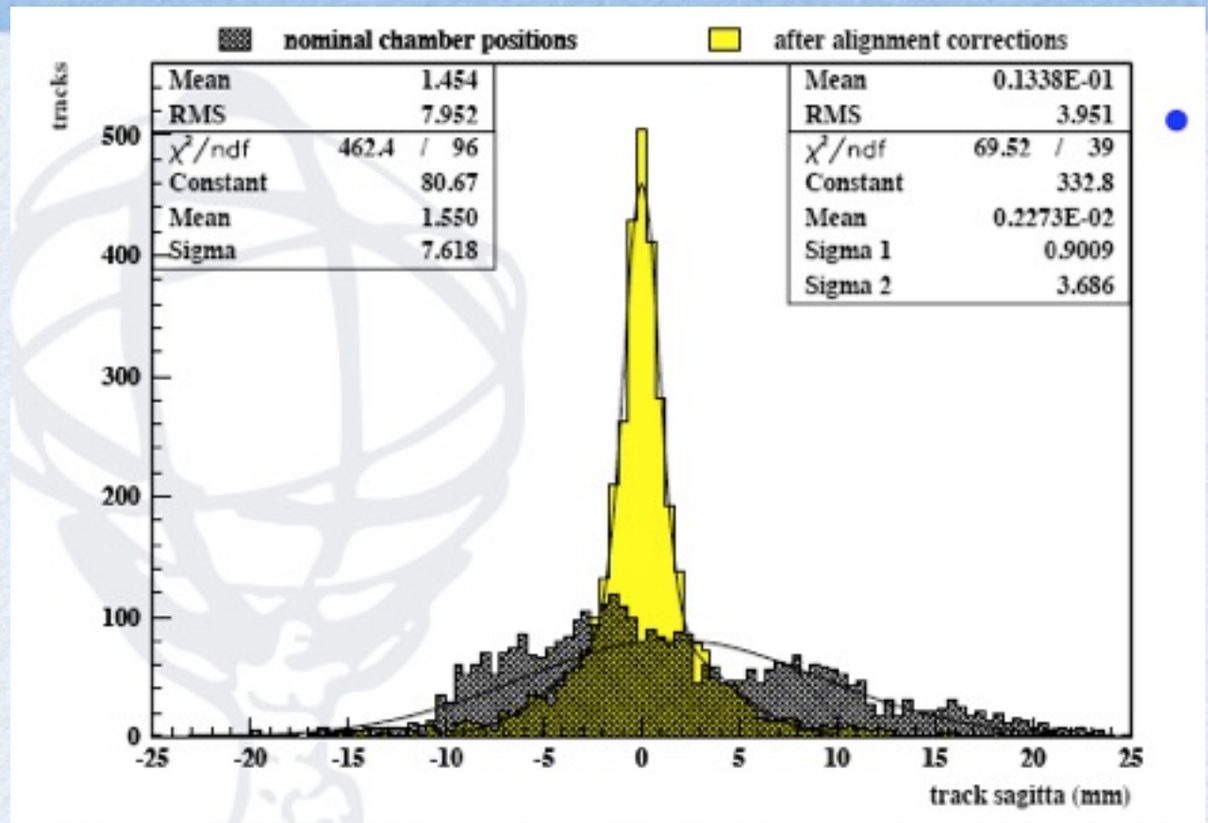
- Drift tube's need
  - r(t) - measure time need to estimate radius, and uncertainty
  - t0 - where is zero!
- Difficult to do during commissioning ..

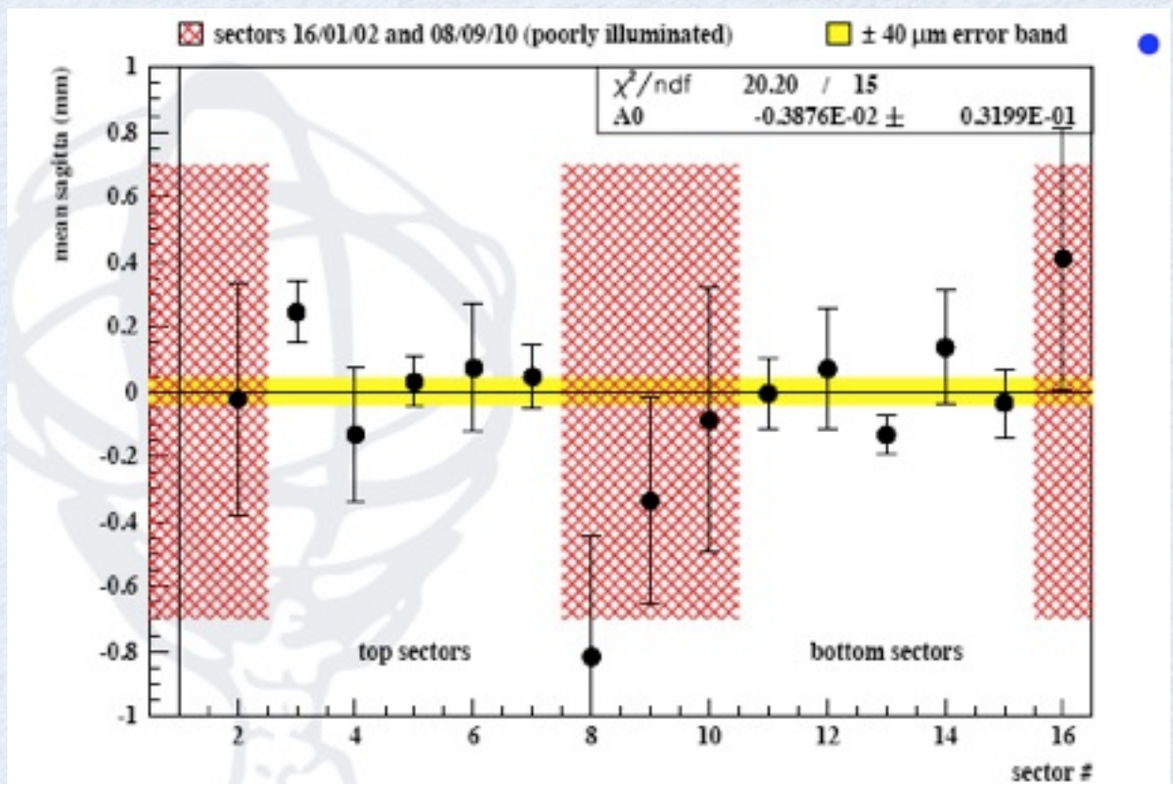




COSMICS ALIGNMENT

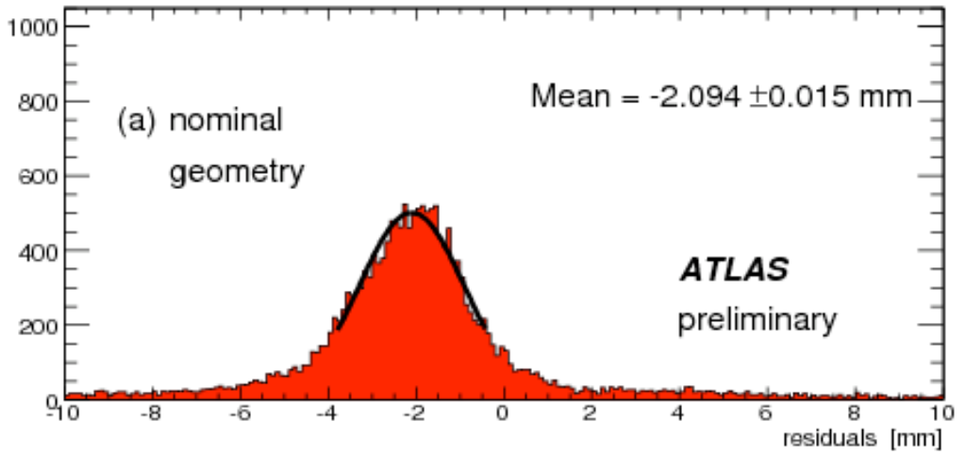
- End cap optical 99% operational
- Barrel - 5/16 sectors
- Look at sagitta for straight B=0 before and after optical constants...

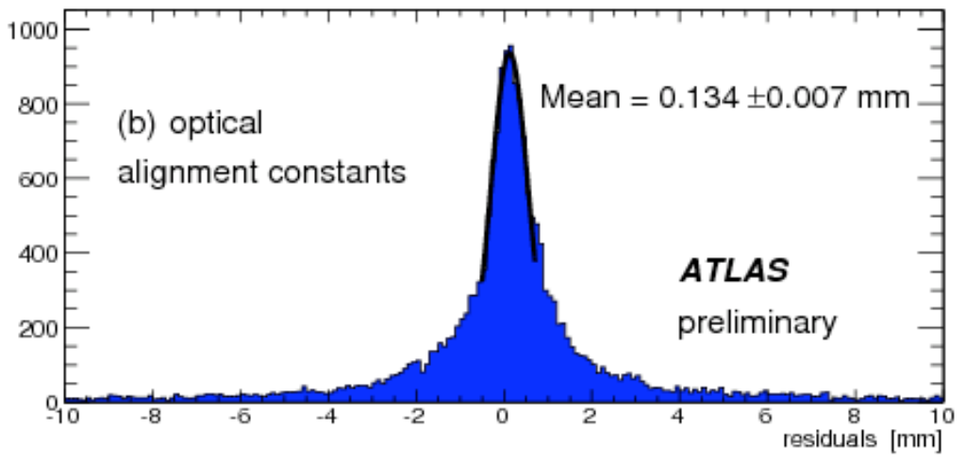


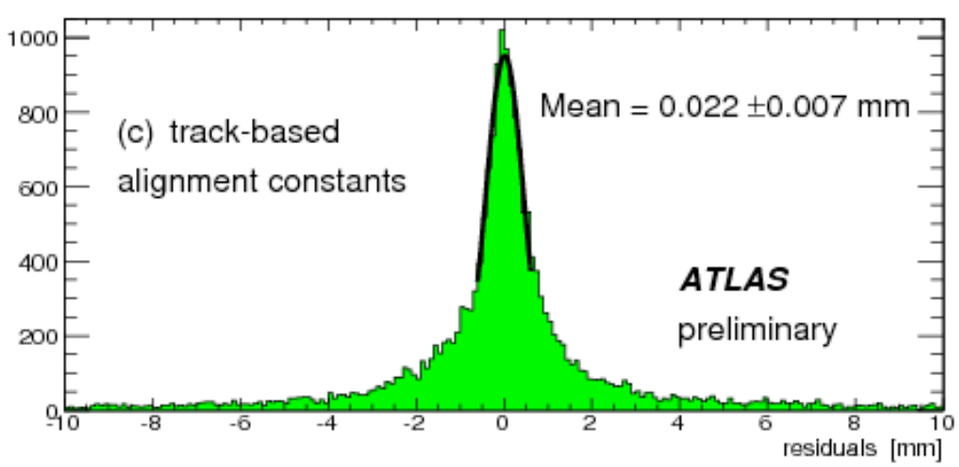


AND IN THE BARREL

- Alignment corrections
  - from optical system
  - from tracks
- barrel system 9 sectors optical system is operational

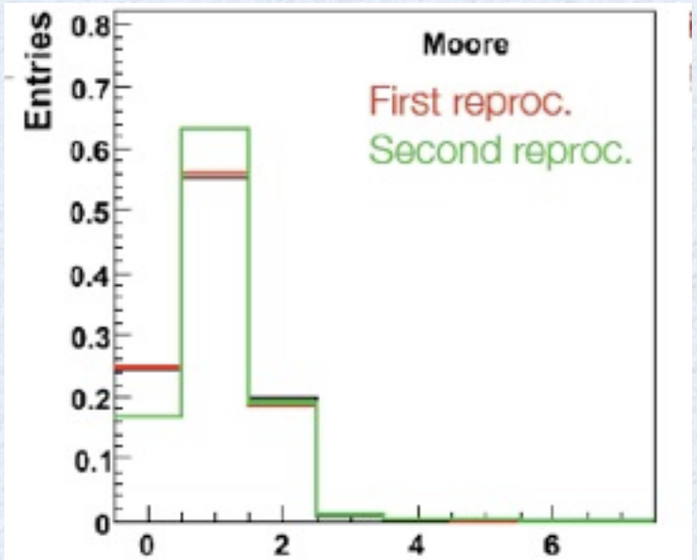


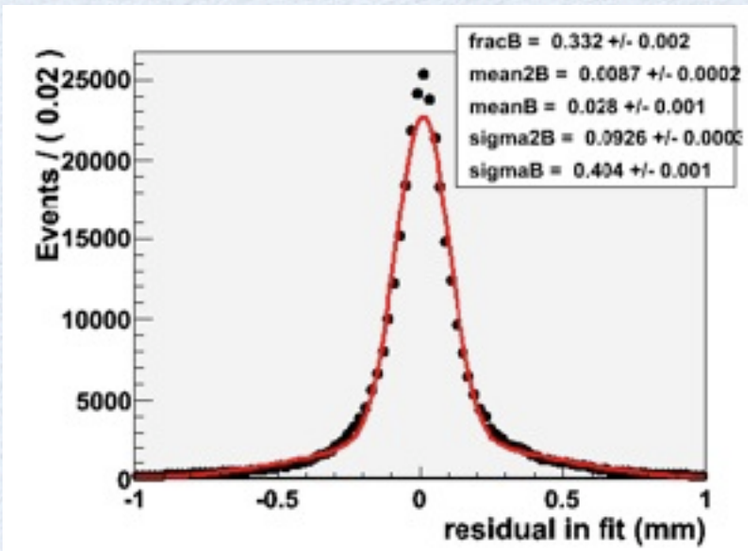


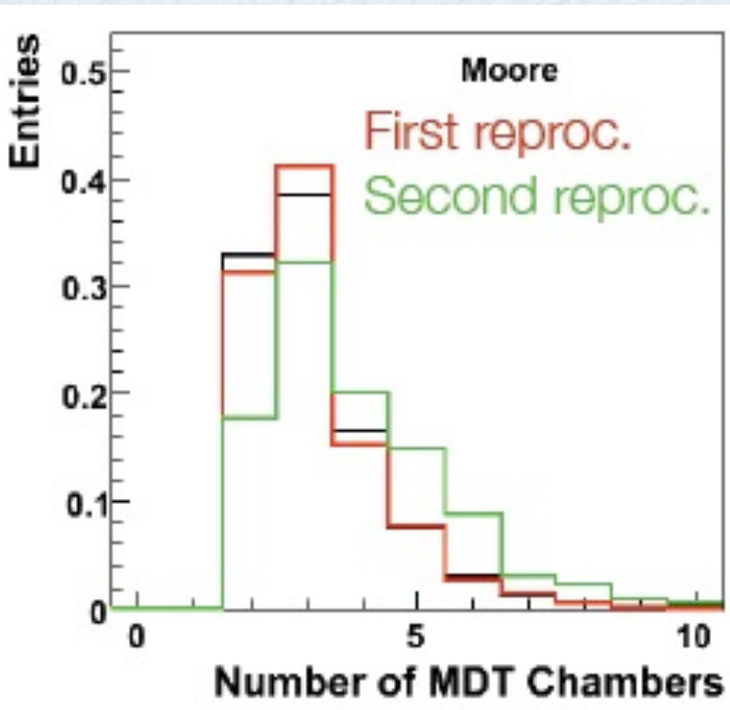


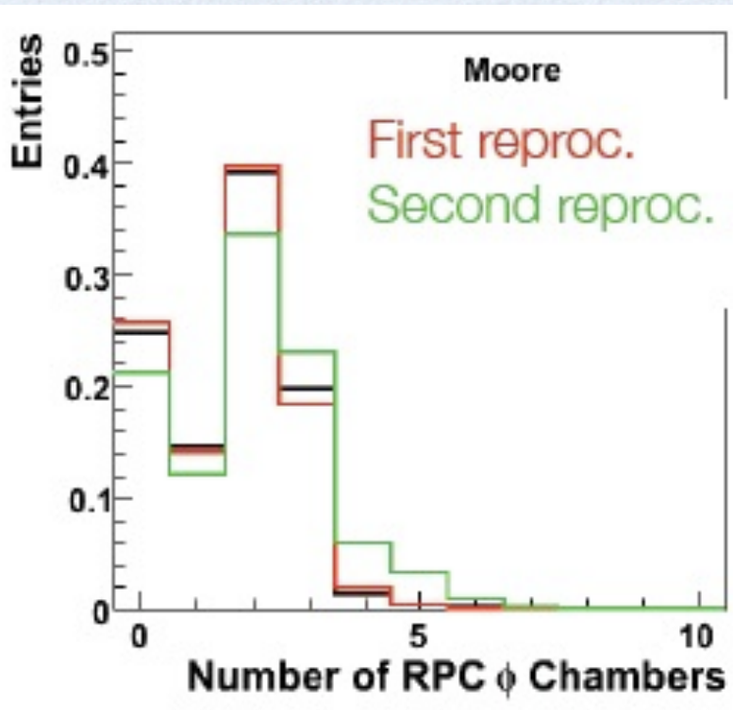
COSMIC TRACKING

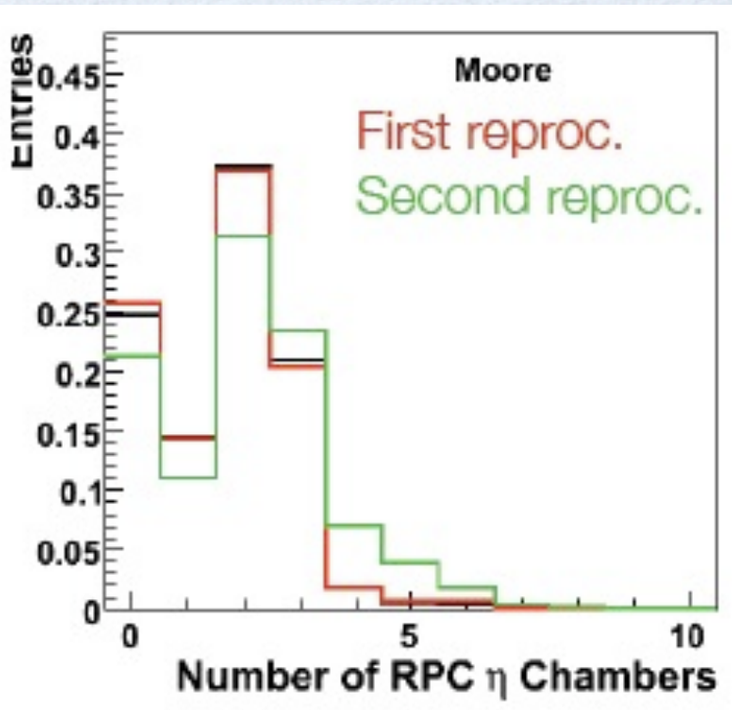
- allow ‘t0’ to float in segment fit
- relax pointing cuts
- enlarge hit uncertainties...
- ~90-120 micron on segment residuals, ~500 micron on track





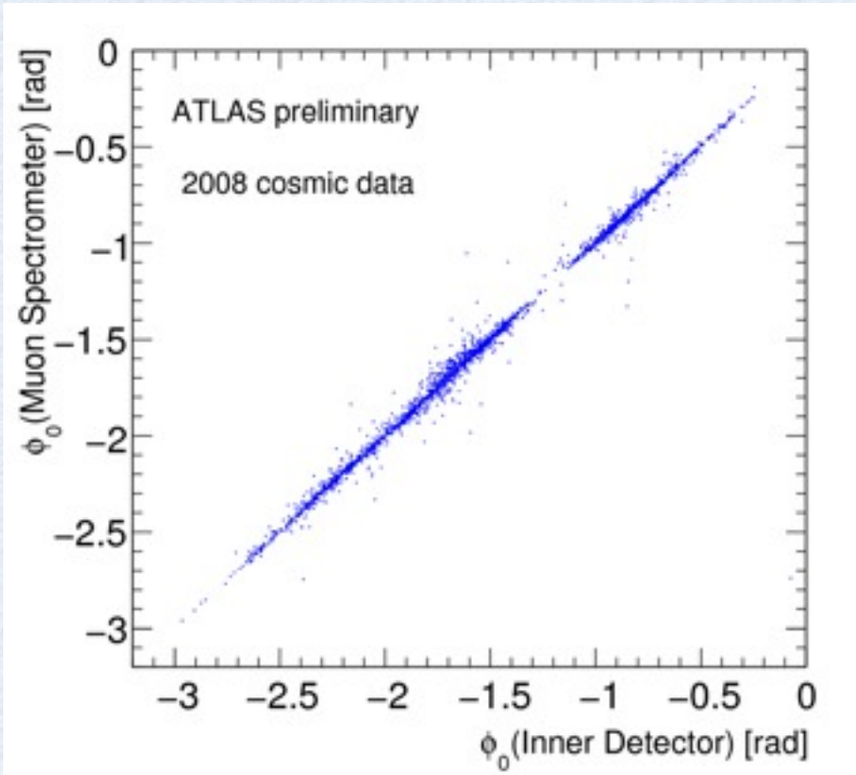


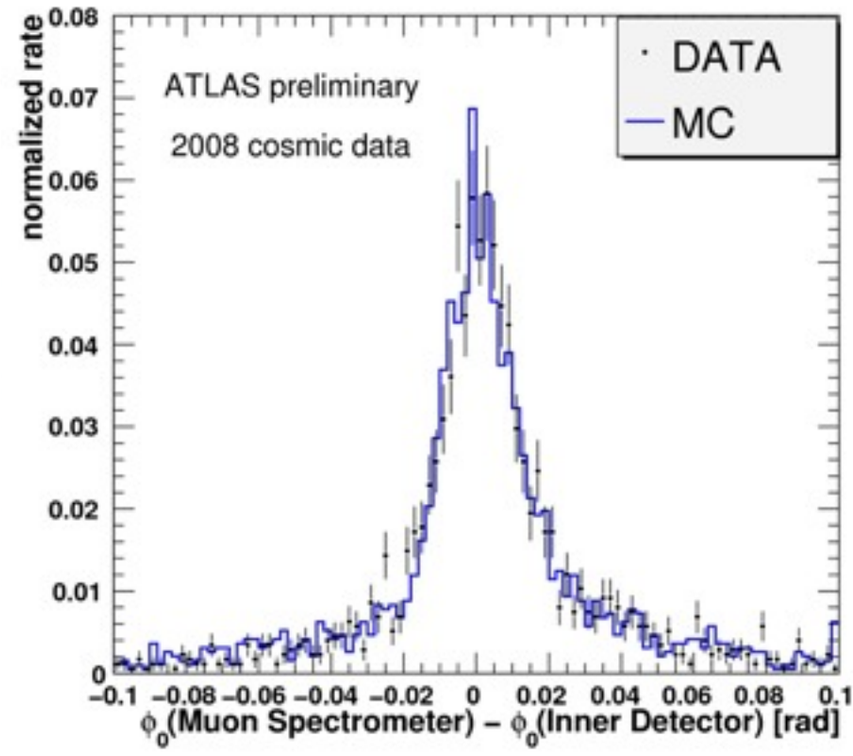


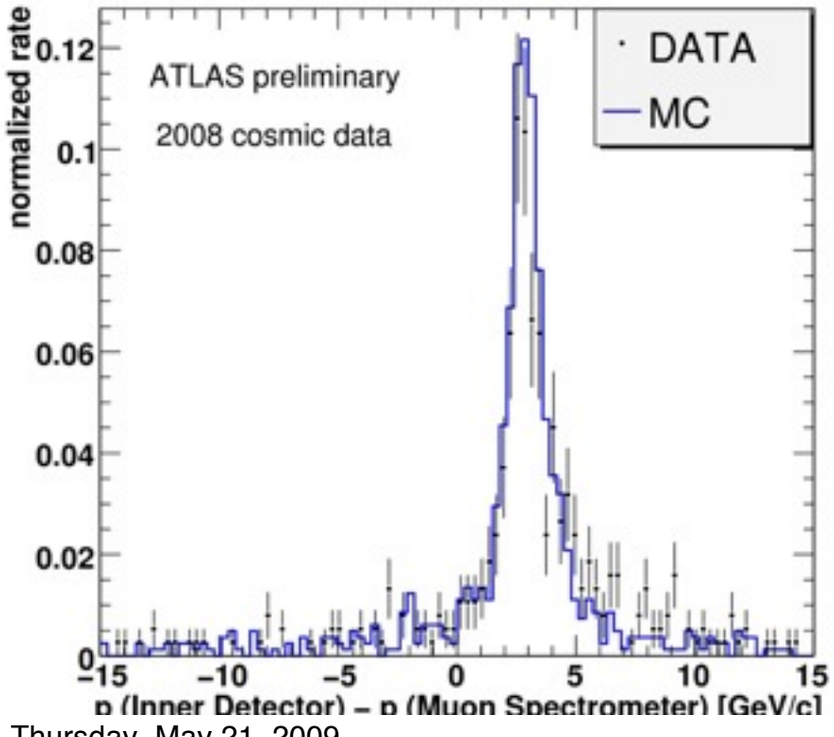


COMBINED TRACKING

Excellent Correlations between ID and MS Track



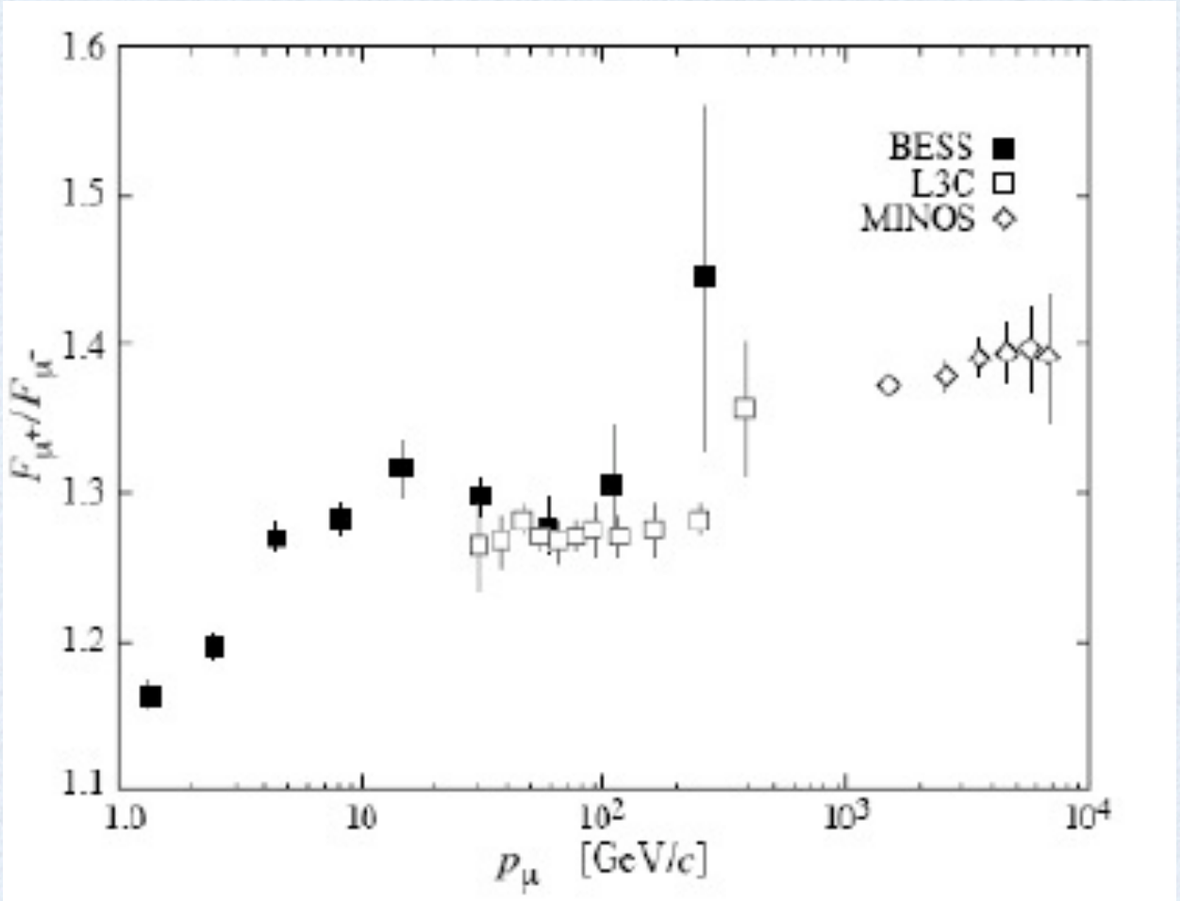


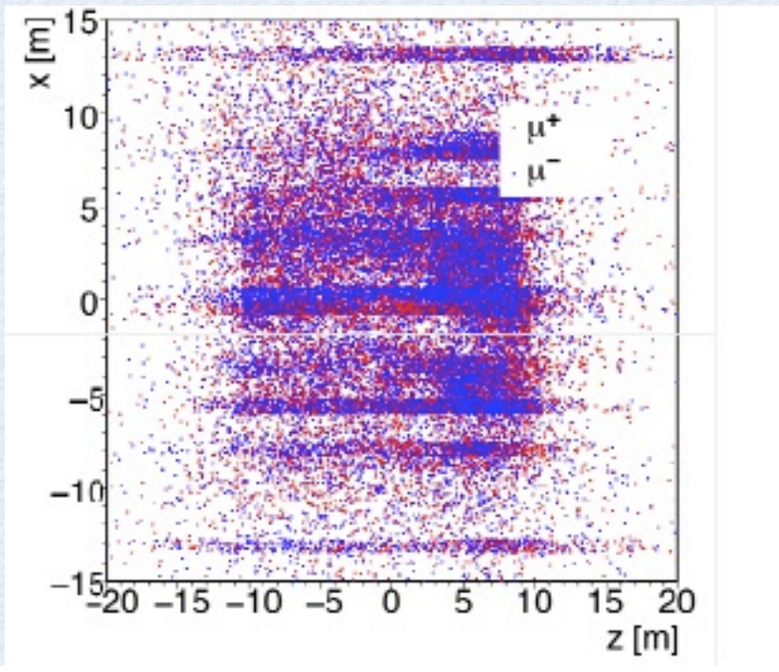


Energy Loss
Consistent with Calorimeter

CHARGE ASYMMETRY

- Expect excess of positive charge muons over negative

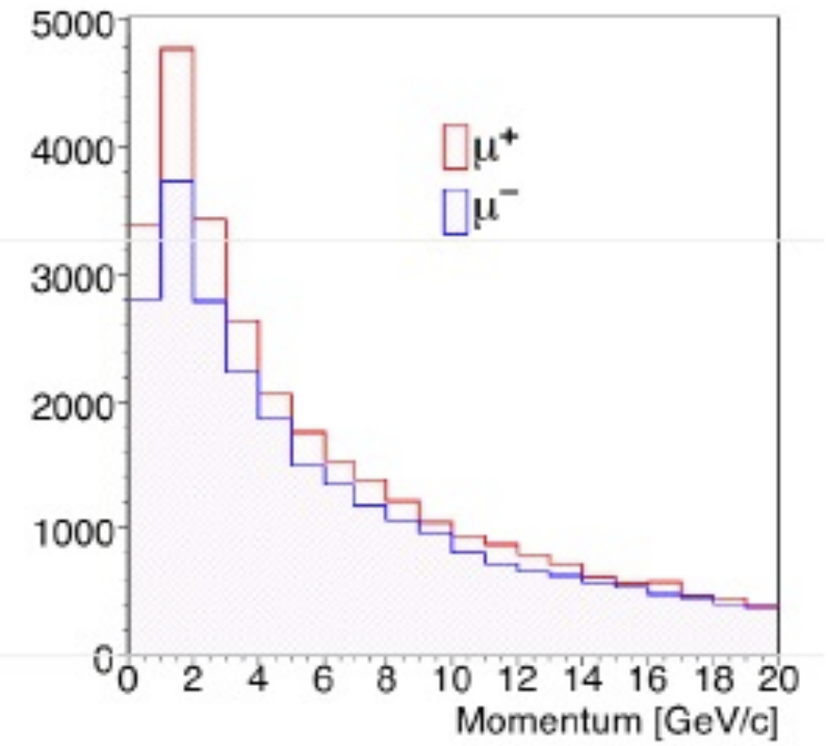




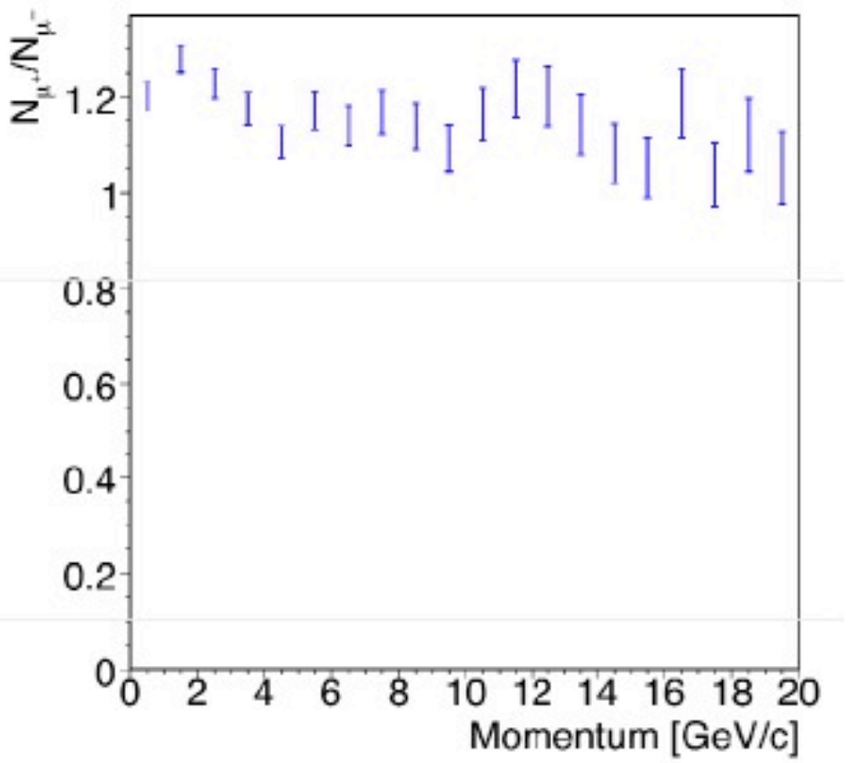
Primary source: cosmic protons

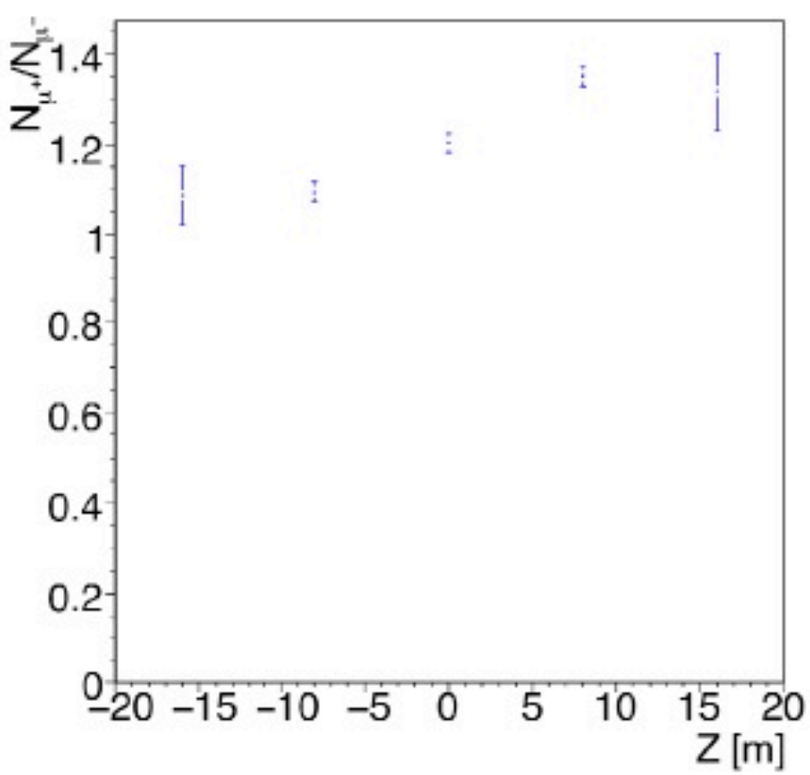
Excess of π^+ / K^+ over π^- K^- in shower development

CHARGE ASYMMETRY



Recall that field bends one sign in to acceptance one out





COSMIC DATA

- ~300 million cosmics recorded in 2008
- more coming now
- Current Formats:
  - ESD, Calibration Ntuple produced at AtlasTier0
- Full MC08 data processed in march (combined reconstruction now available)

COSMIC ANALYSIS

- user09.KevinMatthewBlack.RPCreco91890.BField_[1,6].root
- Triggered with RPC, Toroid Field On, Privately Reprocessed for Muon Data Task Force (14.5.2)
- Calibration Ntuple, CBNT, ESD produced - will give examples how to use Calibration Nuple and ESD
- Note- only MS information in these ESDs
- Few ESDs with all data available also copied to ANL

CALIBRATION NTUPLE

- Easiest complete format to work with for commissioning
- RAW hits, trigger info (logic info), segments, tracks
- Detailed documentation available
- https://twiki.cern.ch/twiki/bin/view/Atlas/MuonCalibNtuple
- Drawback - only muon info

Segments	seg_nSegments	number of segments in the event
	seg_patIndex	index telling the segment to which pattern it belongs
	seg_author	segment author
	seg_chi2	chi squared of the segment fit to the hits on the segment
	seg_quality	quality of segment given as : 100*#Holes + 10*#Out−of−time hits + 1*Delta hits
	seg_fittedT0	fitted T0
	seg_gPosX	X coordinate of the position of the segment (in global coordinates)
	seg_gPosY	Y coordinate of the position of the segment (in global coordinates)
	seg_gPosZ	Z coordinate of the position of the segment (in global coordinates)
	seg_gDirX	X coordinate of the direction of the segment (in global coordinates)
	seg_gDirY	Y coordinate of the direction of the segment (in global coordinates)
	seg_gDirZ	Z coordinate of the direction of the segment (in global coordinates)
	seg_posX	X coordinate of the position of the segment (in local coordinates)
	seg_posY	Y coordinate of the position of the segment (in local coordinates)

ESD ANALYSIS

- sample package at ~kblack/cosmics
- some examples of how to access data, tracks segments
- compute unbiased residuals on segments and tracks
- look at TGC/MDT correlations

ESD ANALYSIS

```
 TrackCollection::const_iterator tIter  = trackCollection->begin();
TrackCollection::const_iterator tIterE = trackCollection->end();
for(;tIter!=tIterE;++tIter){
 if( !*tIter ) continue;

 if (!(*tIter)->fitQuality() ||
      (*tIter)->fitQuality()->chiSquared()/
      (*tIter)->fitQuality()->numberDoF() > m_chi2Cut)
   continue;
```

Select track based on quality

Loop through track collection

```
const StatesCollection *states =  (*tIter)->trackStateOnSurfaces();
if( !states ) break;

StatesCollection::const_iterator sIter  = states->begin();
StatesCollection::const_iterator sIterE = states->end();
for(;sIter!=sIterE;++sIter){
  const Trk::MeasurementBase* measurement =
     (*sIter)->measurementOnTrack();
  const Trk::TrackParameters* parameters =
     (*sIter)->trackParameters();

  if( parameters && measurement) {
     Identifier identifier = m_helperTool->getIdentifier(*measurement);
```

Get Hits and track parameters at surface of hits

CURRENT EFFORTS

- Performance Group
  - moving towards ‘standard’ selections (a bit complicated by the number of algorithms)
  - developing standard methods for measuring performance in-situ (tag-probe,matrix method,etc)
  -

CONCLUSIONS

- Number of Algorithms exist
  - Standalone Tracking, Combined Tracking, Muon Tagging, Calorimeter Muons
    - Current Effort is in Developing Methods to measure performance
- Currently being exercised , debugged, optimized on cosmics