Cavern Background Simulations in the ATLAS Muon Spectrometer

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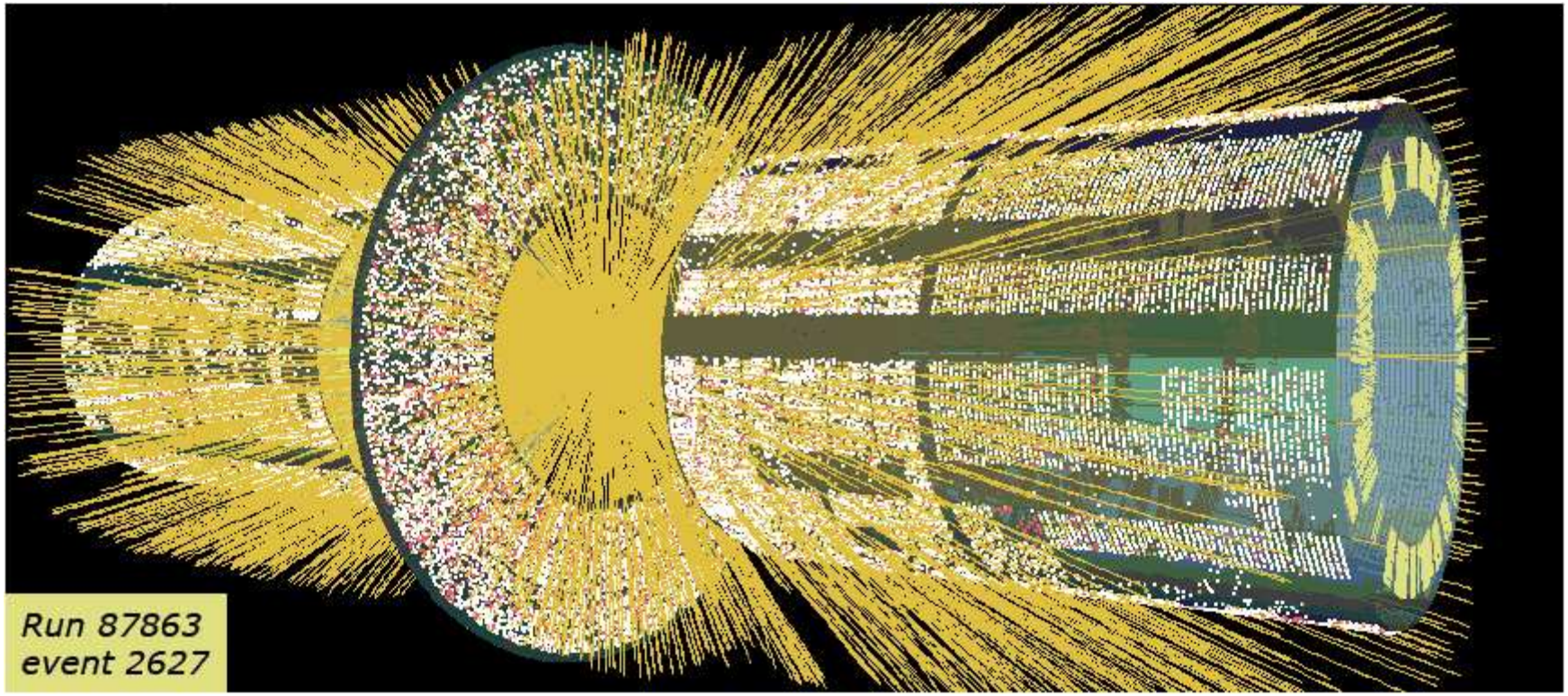
SA-CERN Science Day, 25 November 2008

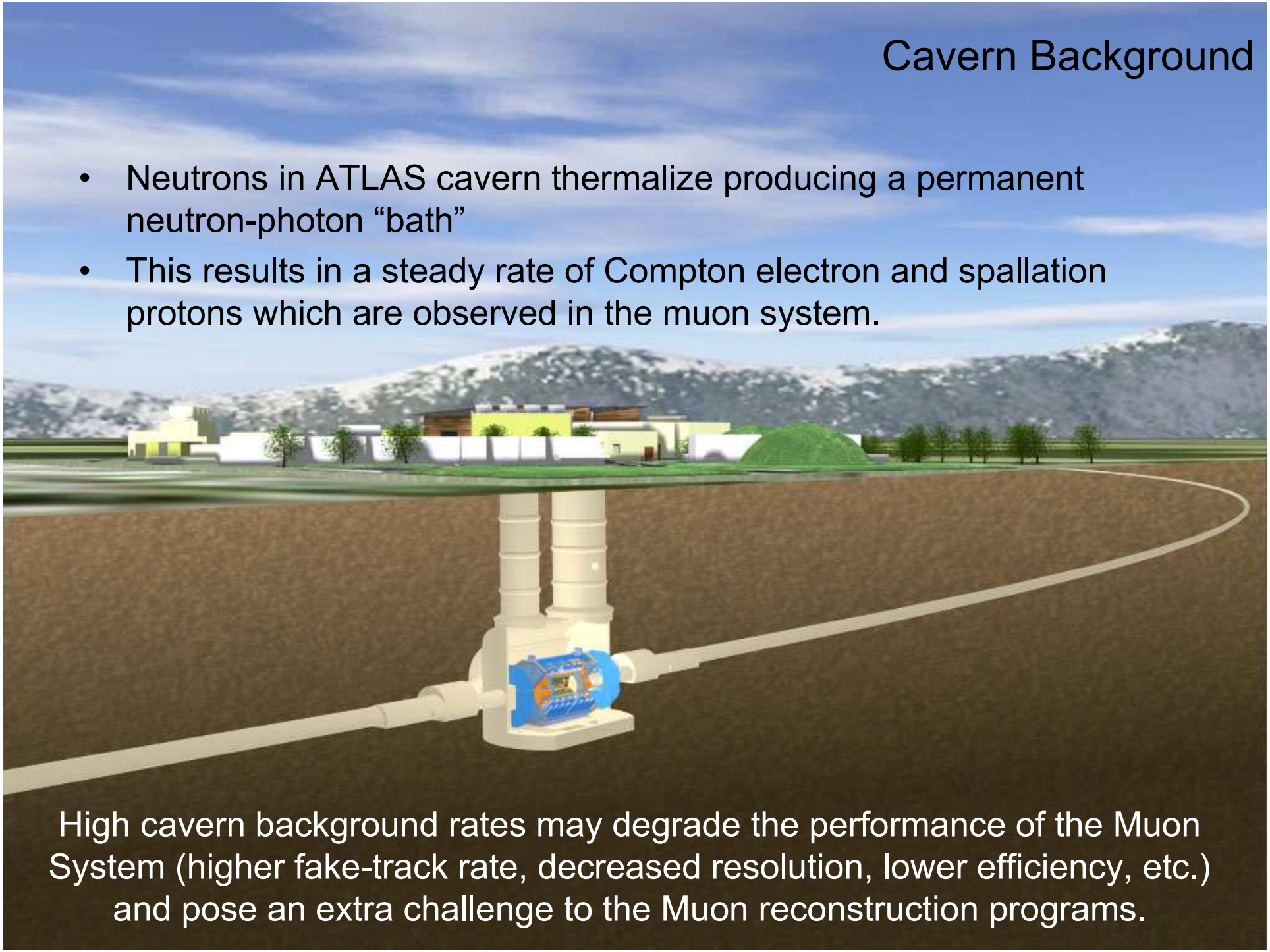
Minimum Bias

- Cross section for inelastic, non-diffractive pp interactions ~ 67 mb
- At 10^{34} $cm^{-2}s^{-1}$ on average expect 23 minimum bias events per bunch crossing
- Therefore readout is of single trigger event superimposed with a number of other uninteresting pp collisions.



Cavern Background

- Neutrons in ATLAS cavern thermalize producing a permanent neutron-photon “bath”
- This results in a steady rate of Compton electron and spallation protons which are observed in the muon system.



High cavern background rates may degrade the performance of the Muon System (higher fake-track rate, decreased resolution, lower efficiency, etc.) and pose an extra challenge to the Muon reconstruction programs.

Cavern Background Simulations

- **Current cavern events were obtained from the G3/Gcalor simulation by the Radiation Task force**
  - Zebra banks converted to ascii, then to POOL.Total available statistics ~ 30 k events
    - 30 k events at Safety Factor (SF)=1
    - 10 k event at SF=2
    - 6 k event at SF=5
    - 3 k events at SF=10

- **The Safety Factor is just the expression of the uncertainty in the total cavern event rate normalization:**
  - SF=5 means take 5 cavern events for 1 pp collision instead of 1 cavern event for 1 pp collision

- **Known issues**
  - No scoring volumes in G4: multiple tracking of neutrals leading to an artificial boost in the cavern hits: fixed by taking only first ones
  - The available statistics is limited: fixed using phi-symmetry of MS
  - Prompt muons. They should already be in the minimum bias simulation; their duplication in the cavern event list is not desirable: fixed, they are removed
  - Available data for 25ns beam structure: need to do something for 75ns
  - The primary cavern events were generated with Pythia5.7 and an improved neutron transport simulation. We are now using Pythia6.X for event generation. The event rate may be too low (~ a factor of 2 too low)
  - A simplified muon spectrometer geometry was used. The muon layout has evolved a lot since.
  - The primary pp interactions were simulated at 14 TeV. Still using that for the 10 TeV production.

Simulation Data

Small private production to check things since the official production is not yet available. SF=5, BC=25ns – available on the grid.

1) Cavern hits only. No pileup effects. No luminosity scaling. Total statistics: 400K events at SF=5

   user08.KeteviAAssamagan.005008.CavernInputSF05.RDO.pool.v4
   user08.KeteviAAssamagan.005008.CavernInputSF05.ESD.pool.v2

2) $H \rightarrow 4\mu$ events. No pileup. 10k events

   user08.KeteviAAssamagan.005300.PythiaH130zz4l.RDO.pool.v2
   user08.KeteviAAssamagan.005300.PythiaH130zz4l.ESD.pool.v9

3) $H \rightarrow 4\mu$ events with cavern background at SF=5. No minimum bias. Luminosity = 2 $x10^{33}$ $cm^{-2}s^{-1}$. 10k events.

   user08.KeteviAAssamagan.005008.005300PythiaH130zz4lSF05.RDO.pool.v2
   user08.KeteviAAssamagan.005008.005300PythiaH130zz4lSF05.ESD.pool.v2

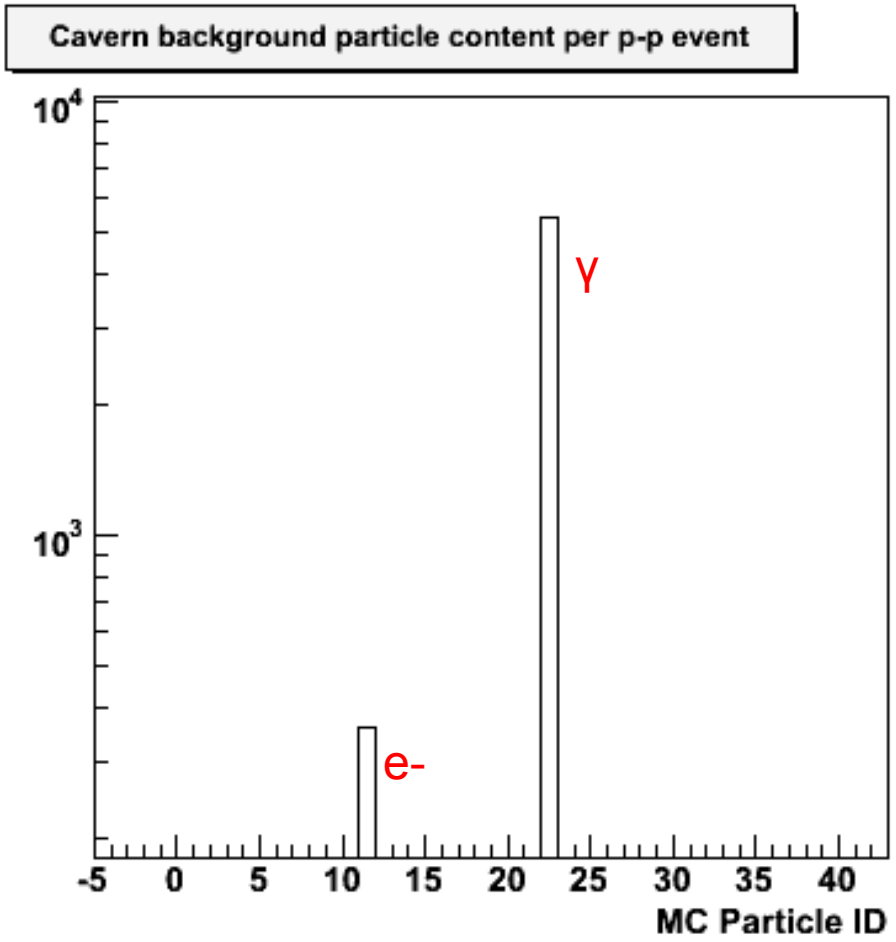
4) $H \rightarrow 4\mu$ events with cavern background at SF=5. With minimum bias too. Luminosity = 2 $x10^{33}$ $cm^{-2}s^{-1}$. 10k events

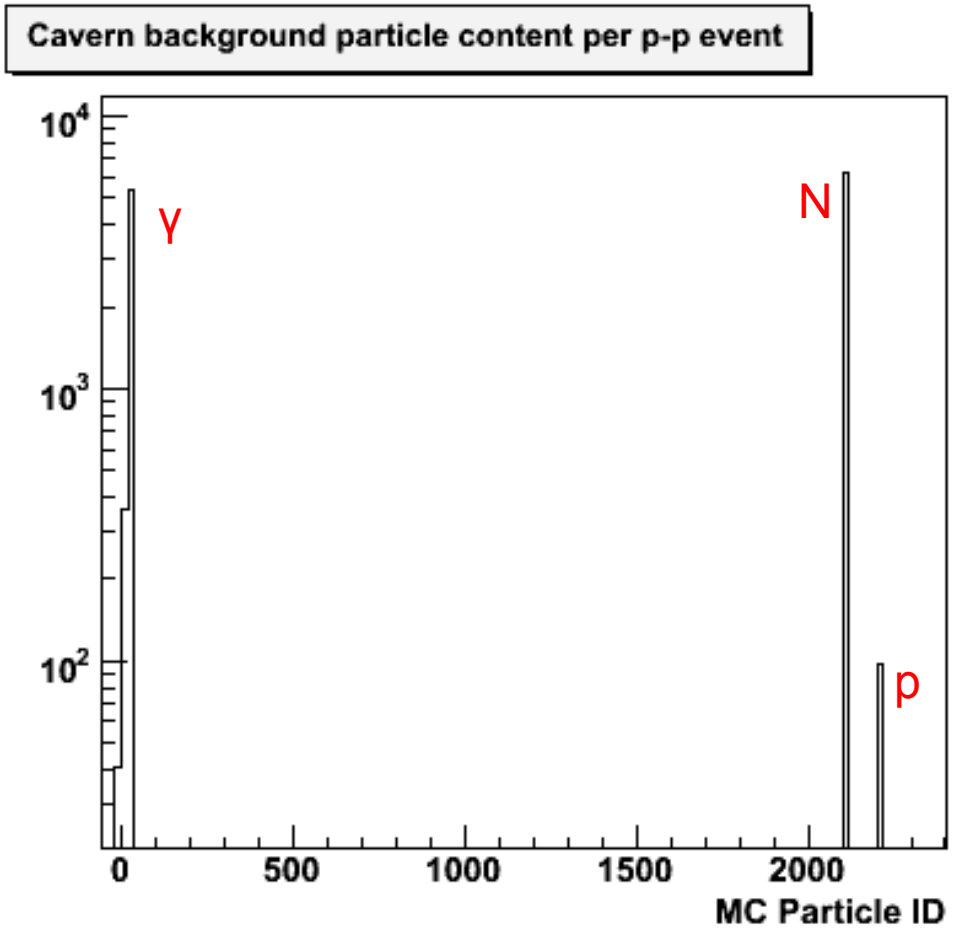
   user08.KeteviAAssamagan.005008.0053005100PythiaH130zz4lSF05.RDO.pool.v1
   user08.KeteviAAssamagan.005008.0053005100PythiaH130zz4lSF05.ESD.pool.v2

Particle Content

(cavern only)

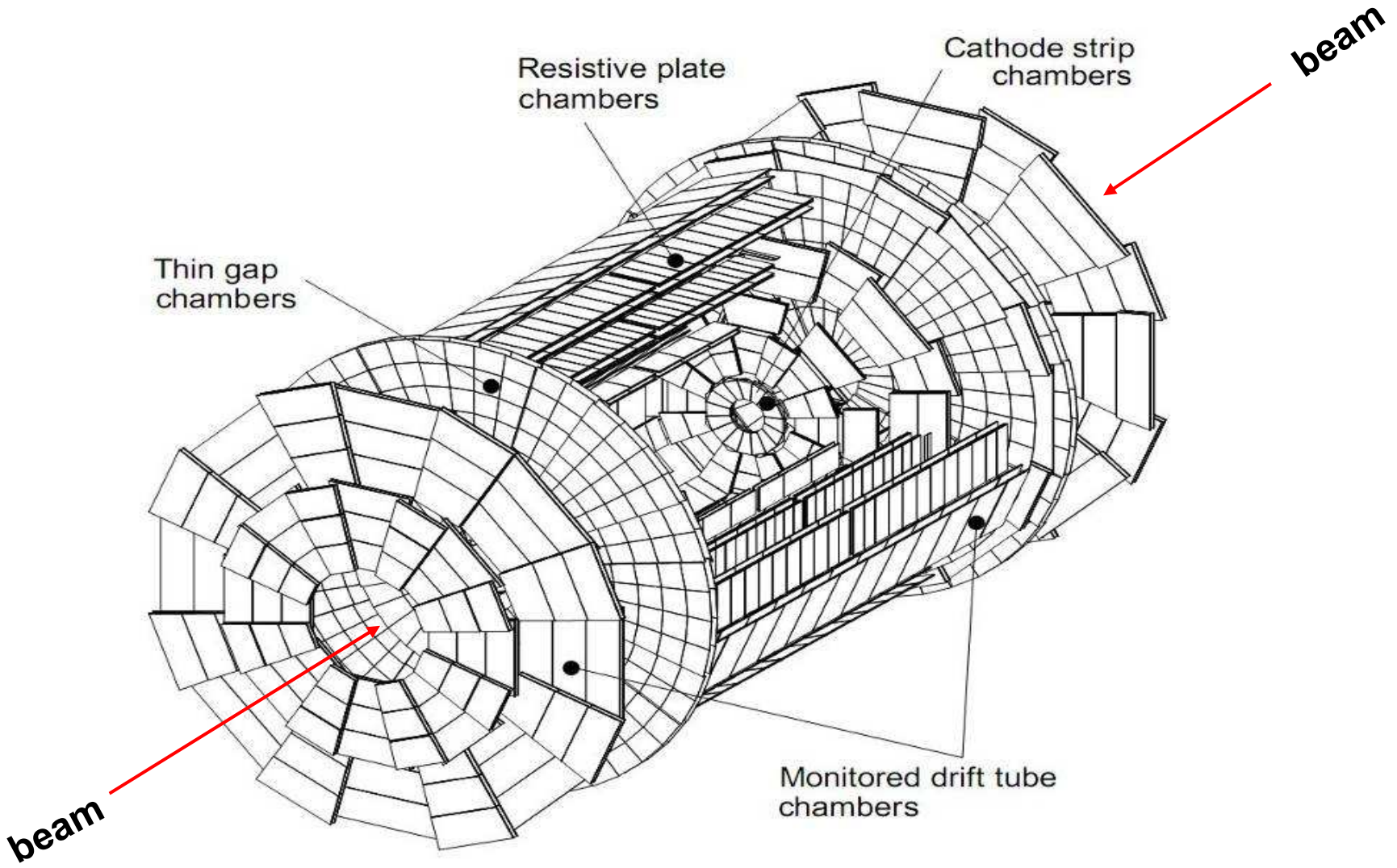
N	1.06×10^{08}	e+	698320
γ	9.16×10^{07}	antiN	273067
e-	6.13×10^{06}	π	11423
p	1.67×10^{06}	K	212



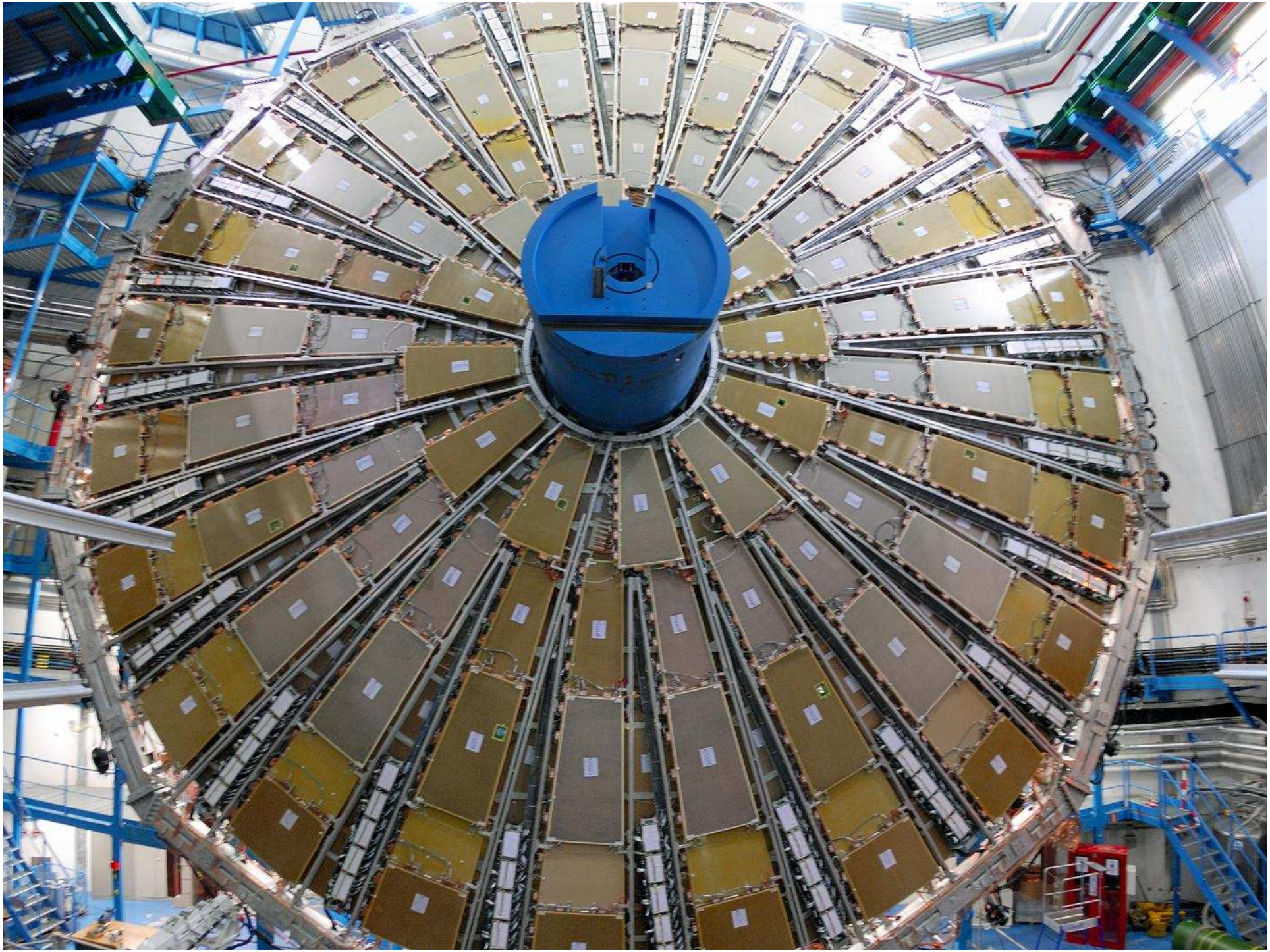


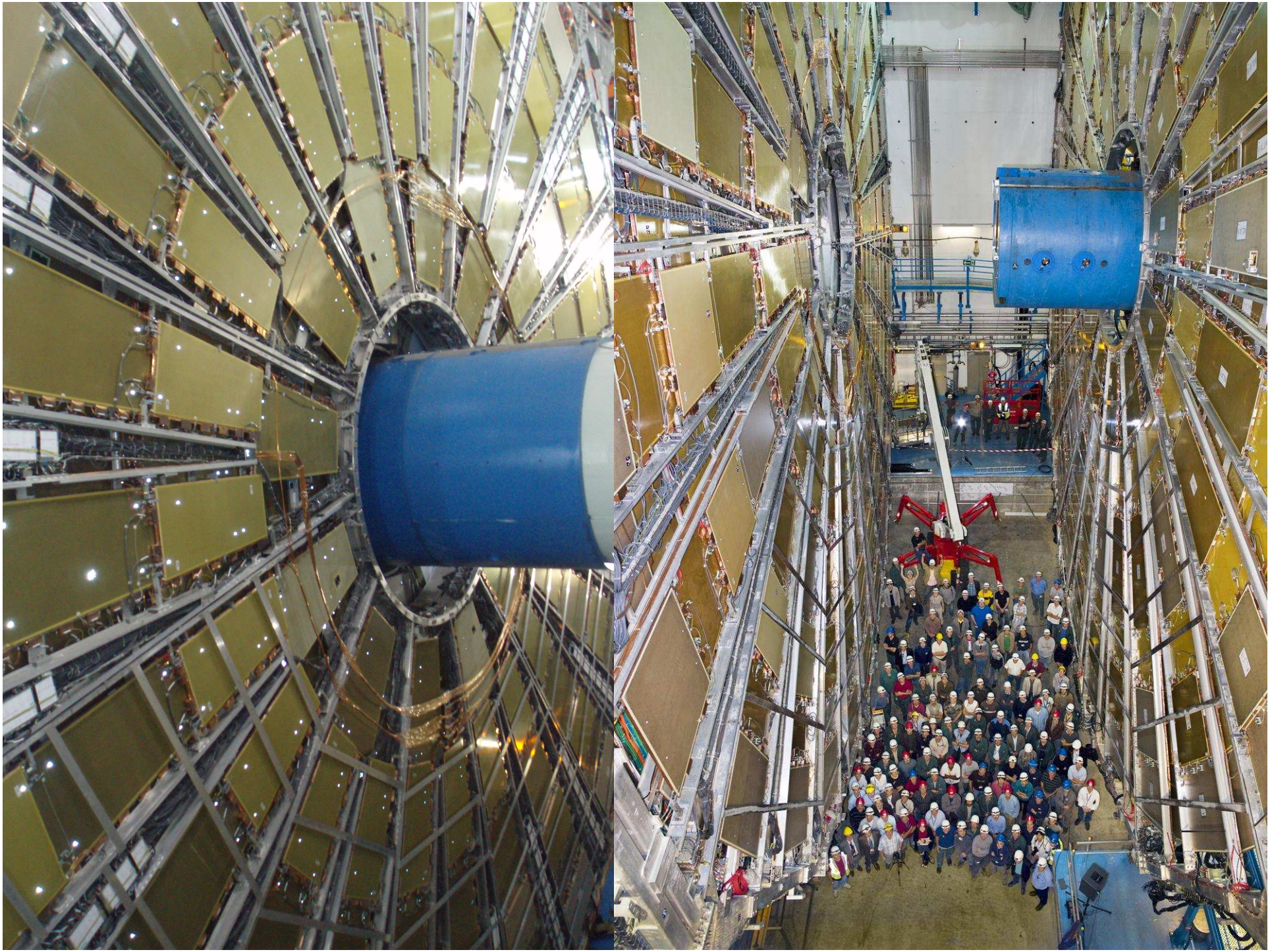
Cavern particle content per p-p event at lumi 10^{34} cm^{-2} s^{-1} and SF=5.

ATLAS Muon Spectrometer

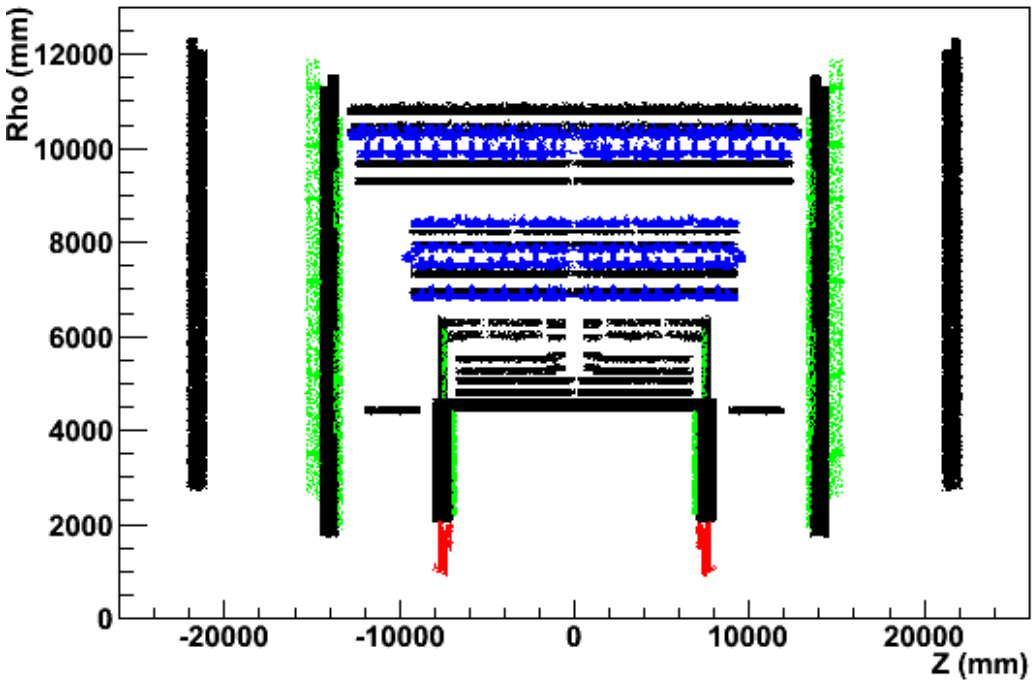



2 x 140 t





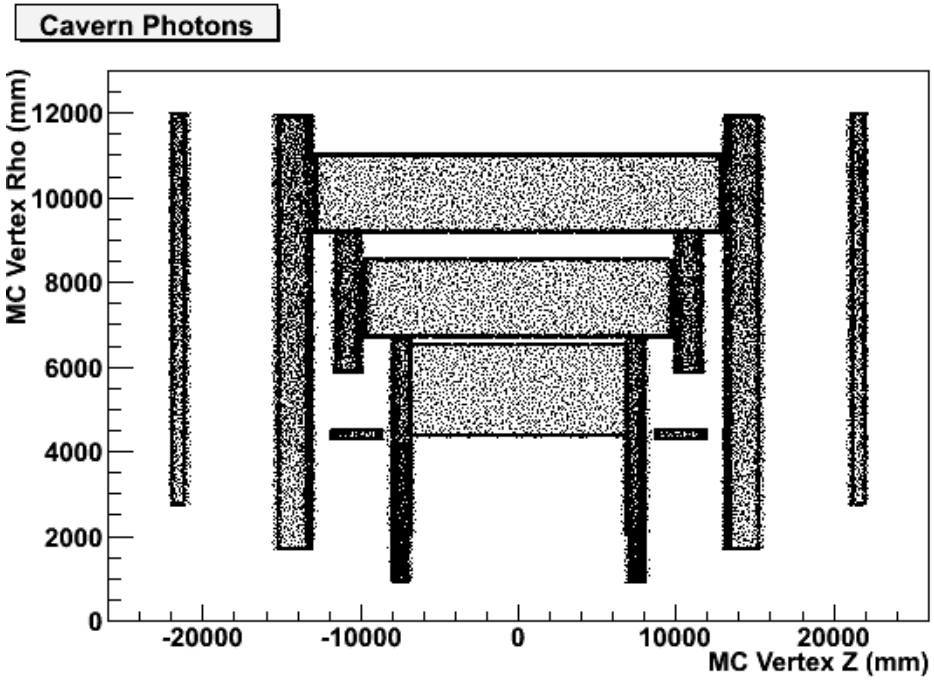
Cavern Background

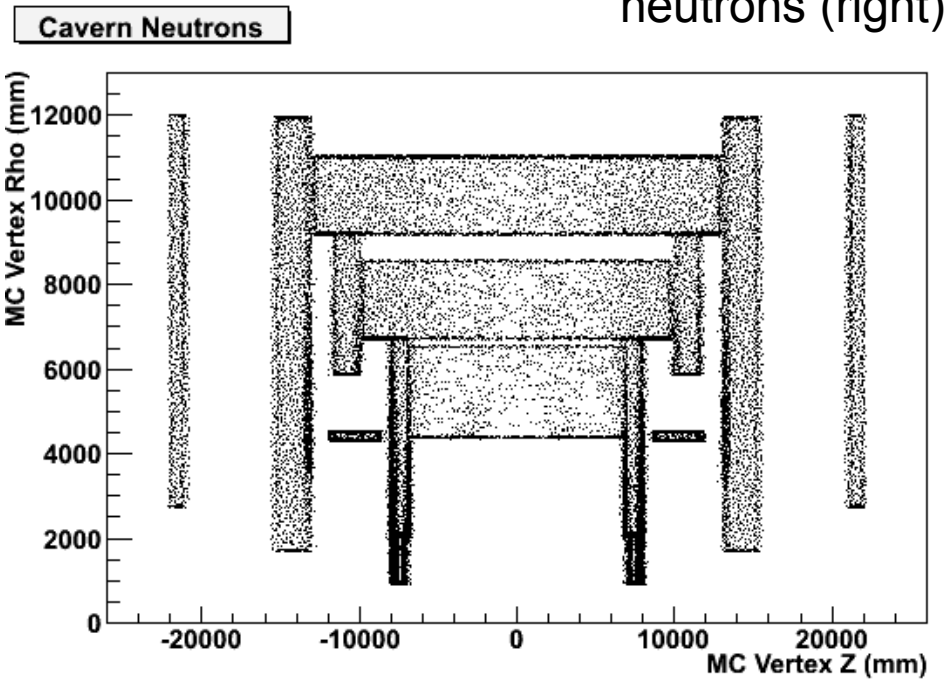


Rho vs Z of cavern PrepRawData

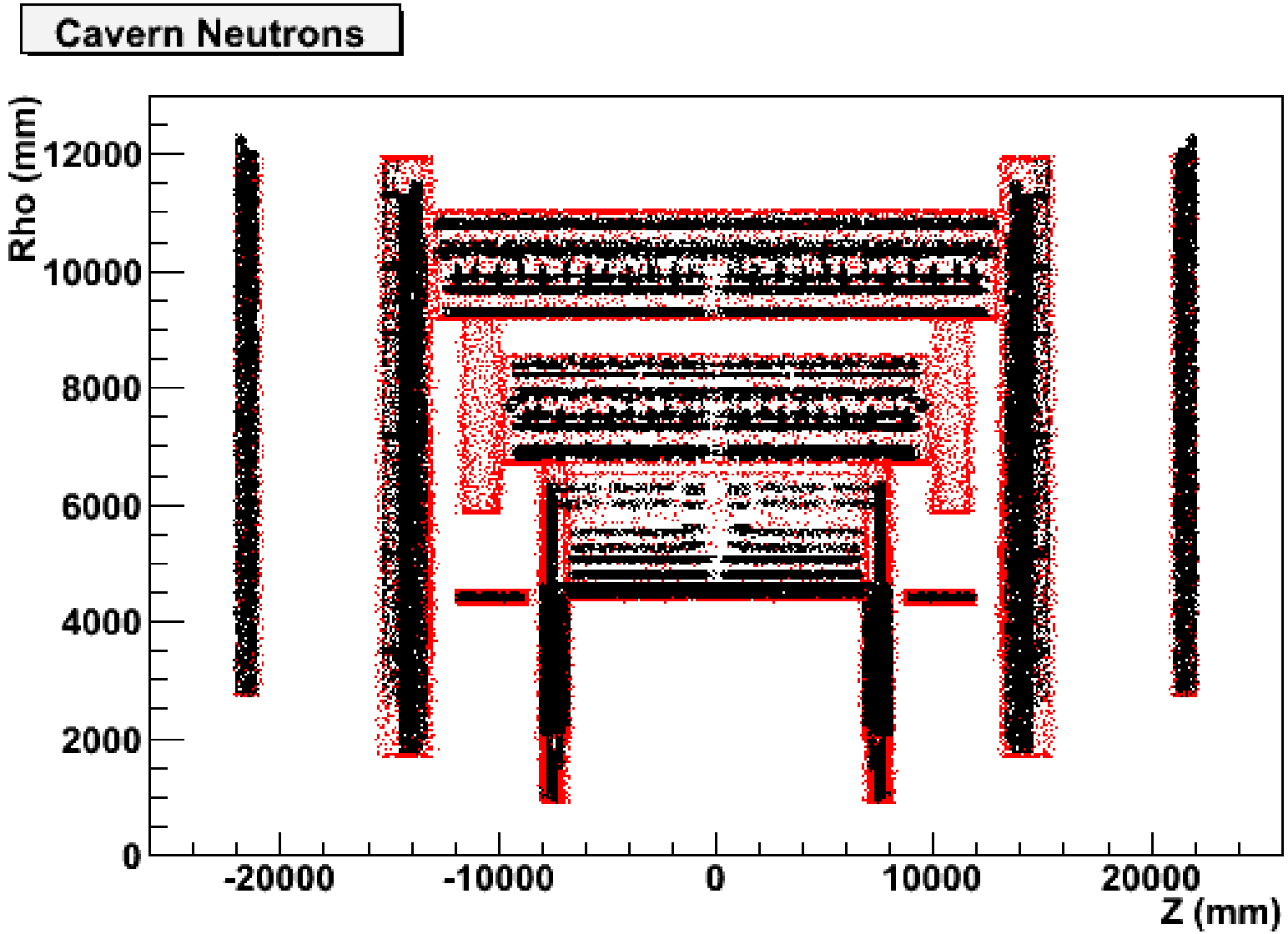
MDT
CSC
RPC
TGC

Rho vs Z of cavern photons (left) and neutrons (right)

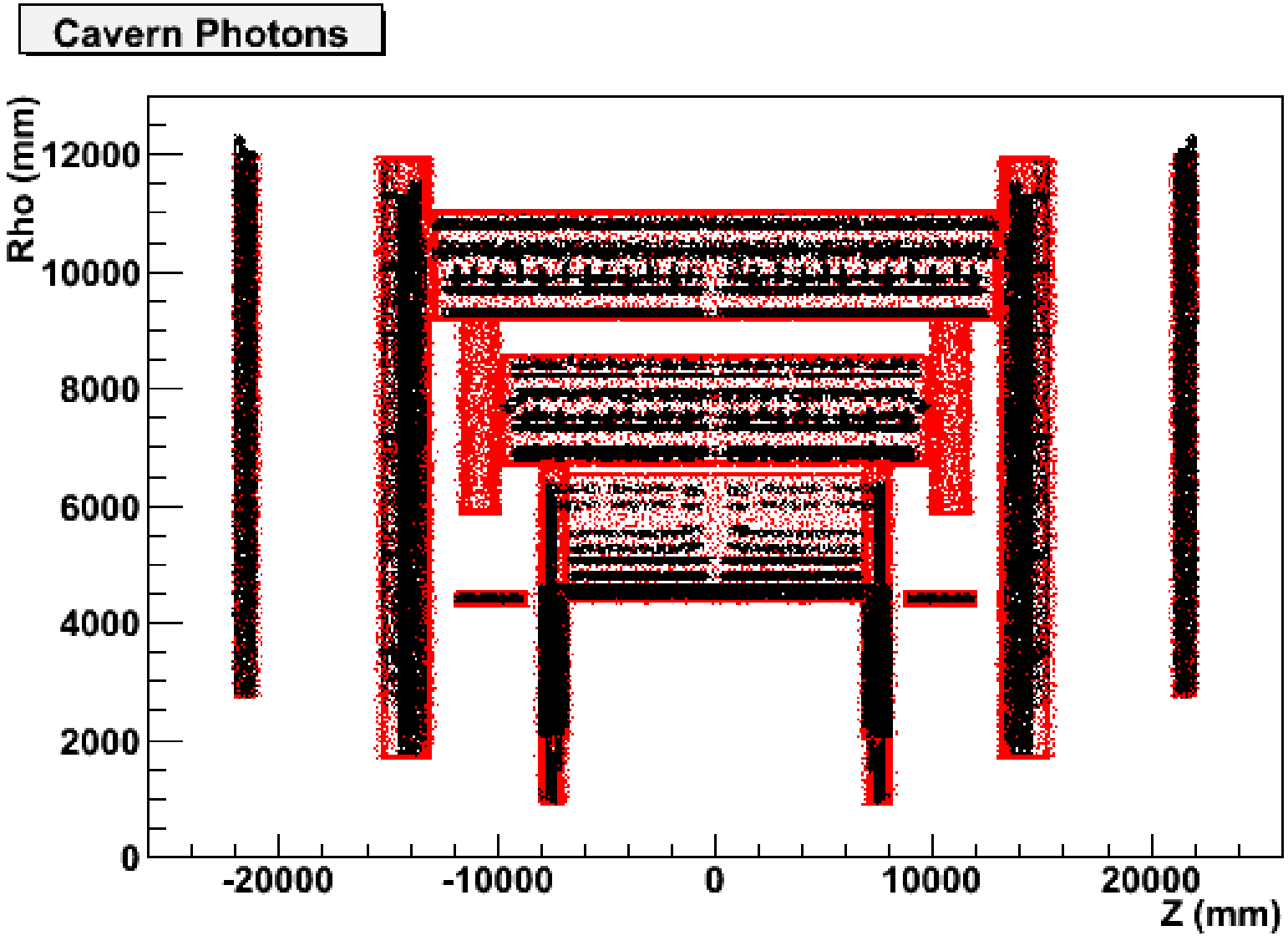




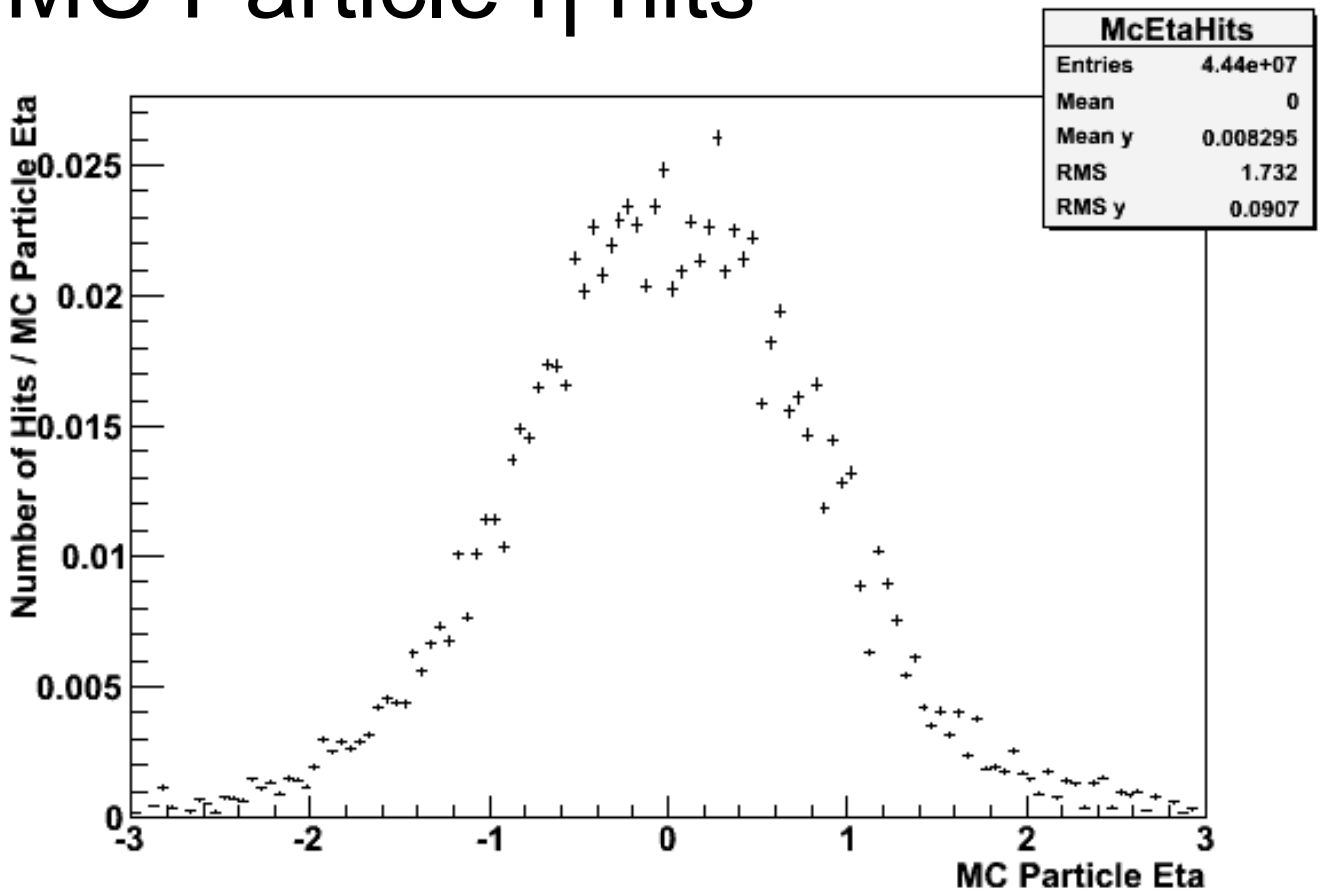
Comparison of neutron hits from MCEventCollection (red) and PrepRawData (black)

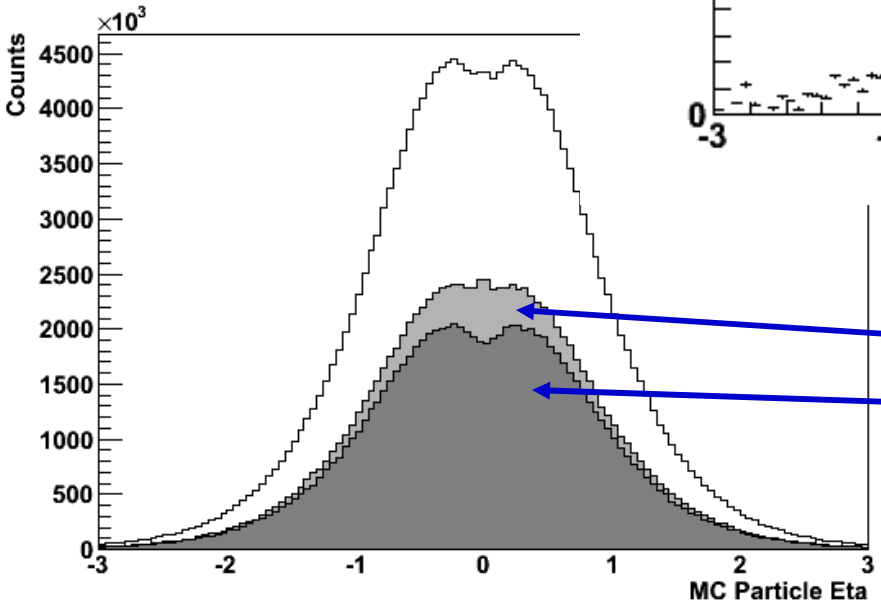


Comparison of photon hits from MCEventCollection (red) and PrepRawData (black)



MC Particle η hits

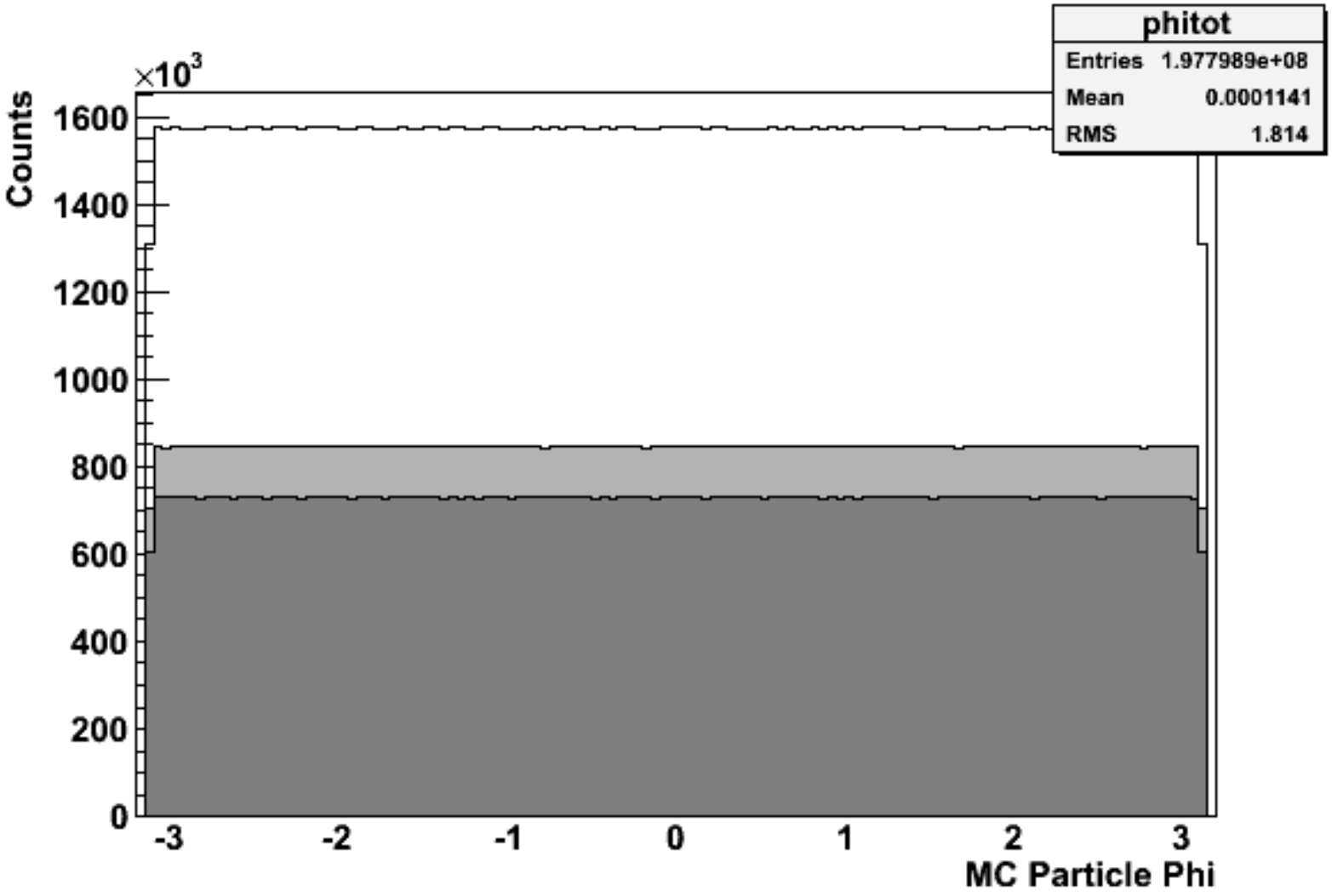




Neutrons

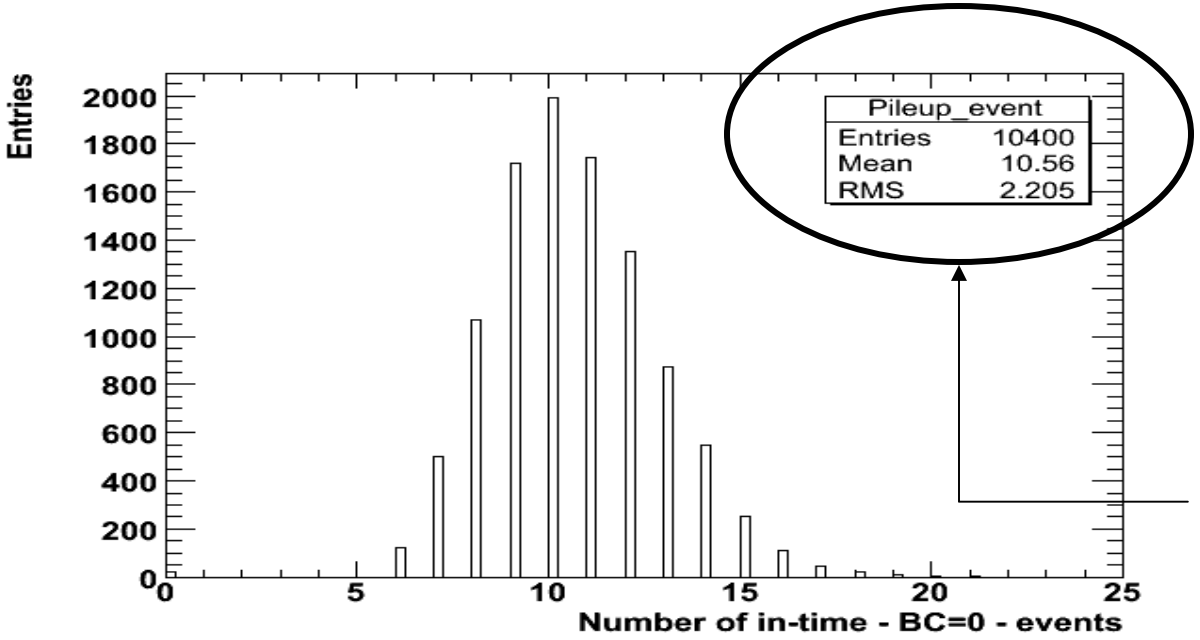
Photons

MC Particle Phi



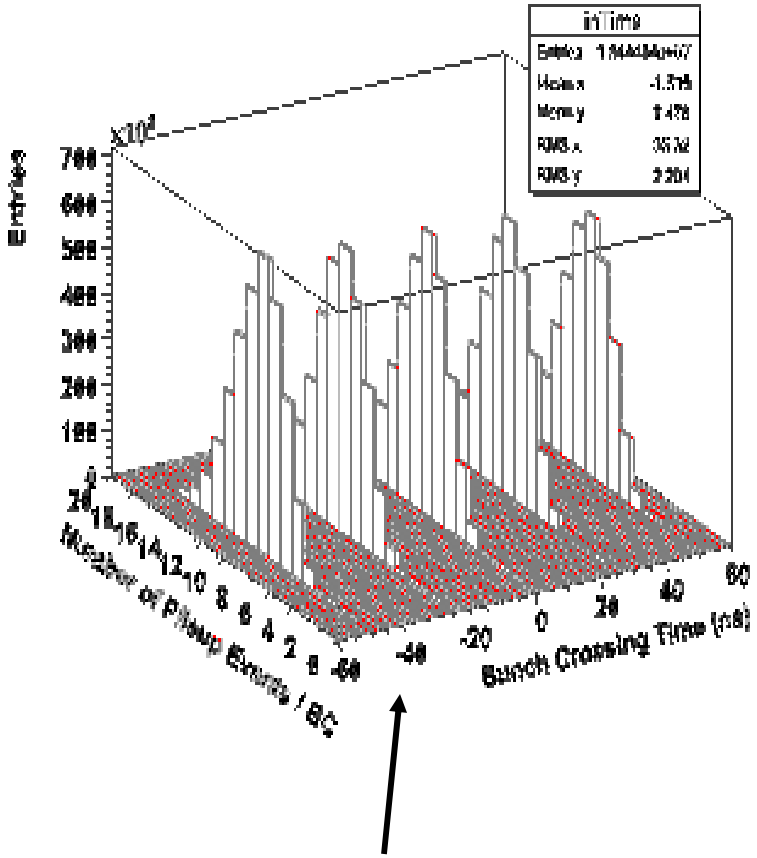
Pileup

- Signal event from 1 pp interaction, in time, at BC=0
- Additional pp interactions: 4.6 minimum bias interactions at 2 10^{33} $cm^{-2}s^{-1}$; Poisson distributed
- Cavern event normalized to one pp interaction
  - At safety factor of N, then take N cavern events for 1 pp interaction. N=5 in my case
  - Luminosity scaling: 4.6 cavern event at SF=N for 2 10^{33} $cm^{-2}s^{-1}$ - a delta function
- Additional contributions from beam halo and beam gas
- Detector and electronics effects



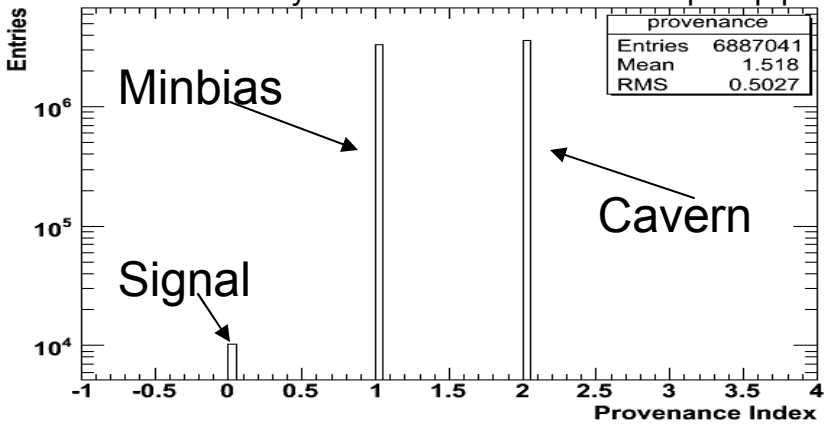
10.56 ~ 4.6+5+1

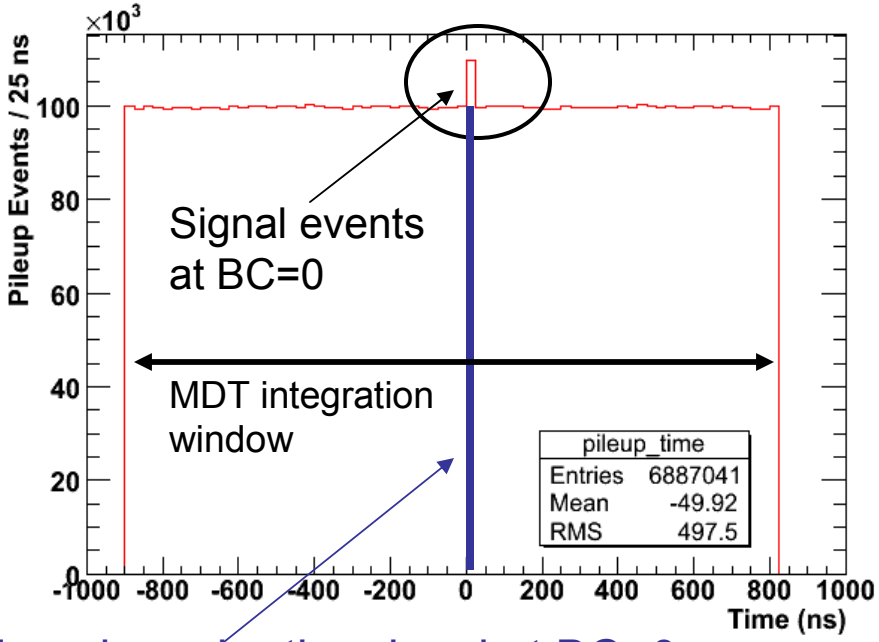
Pileup - detector effect



Pileup events / BC. The signal would be at BC=0 bringing the mean from 9.5 to ~10.5 at BC=0

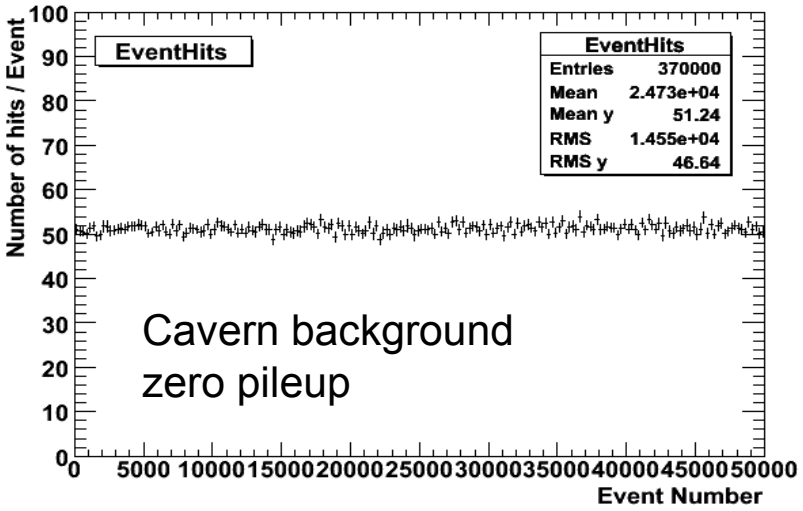
The Provenance index tells you the sources of the truth pileup particles

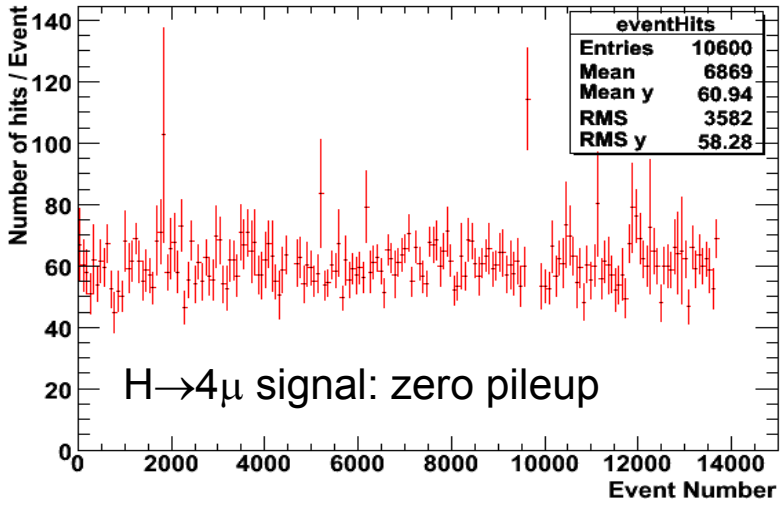




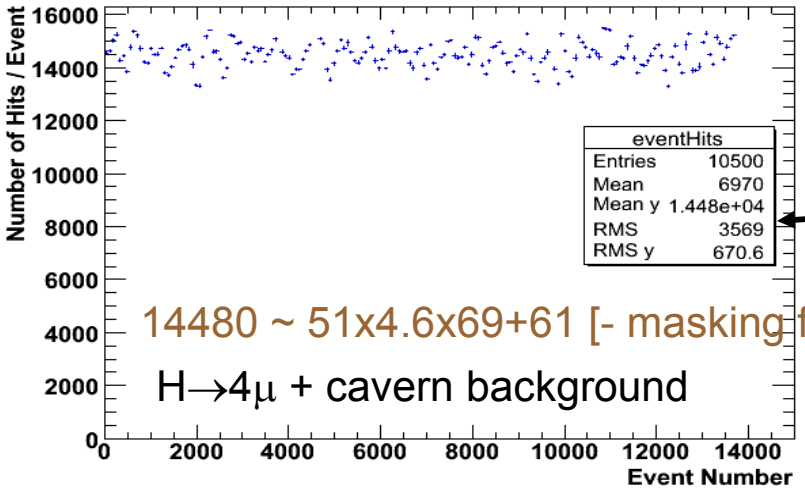
The in-time pileup is under the signal at BC=0

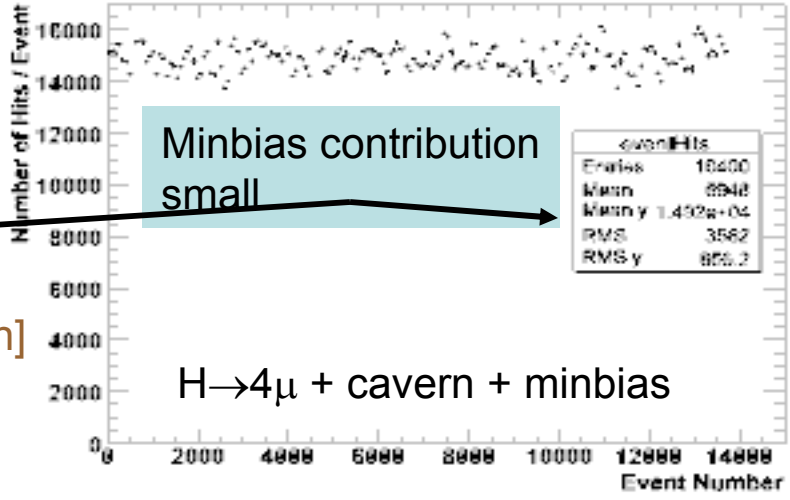
Pileup - event hits



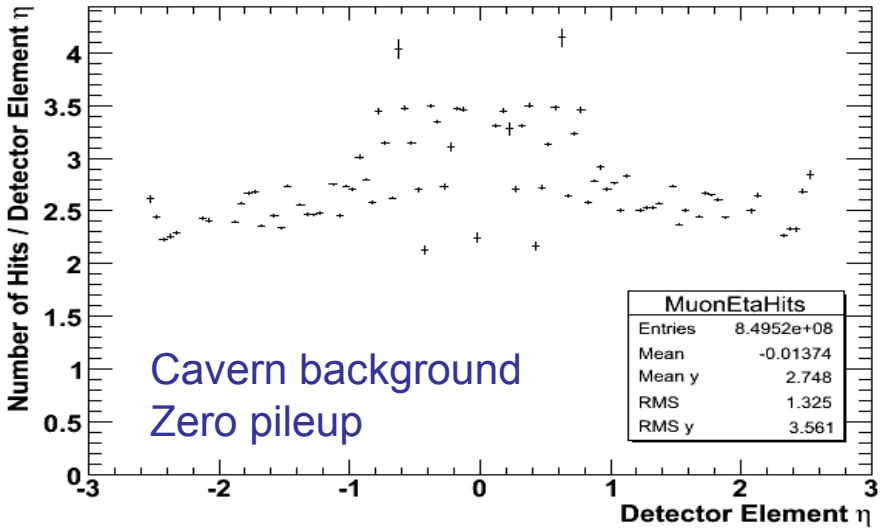


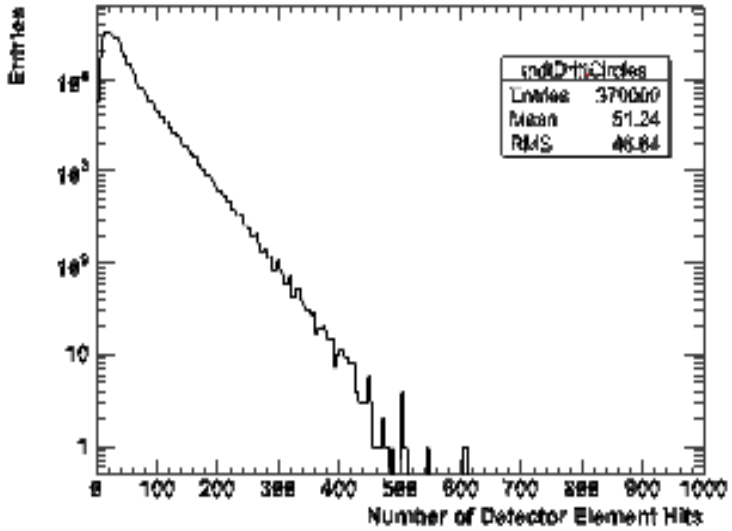
No variation from file to file and no significant variation from event to event

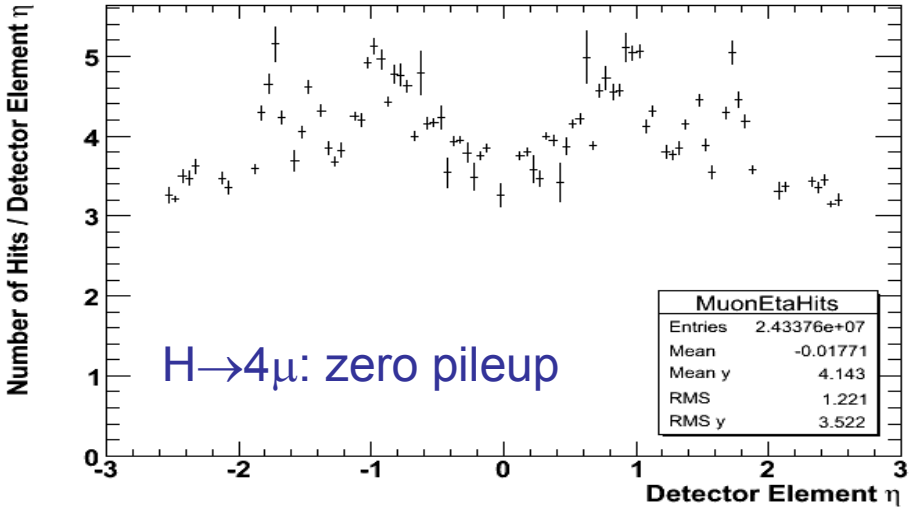


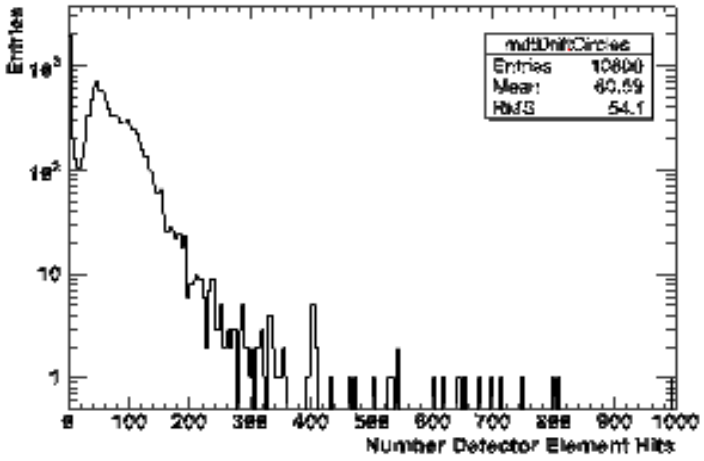


Detector element hits – no pileup

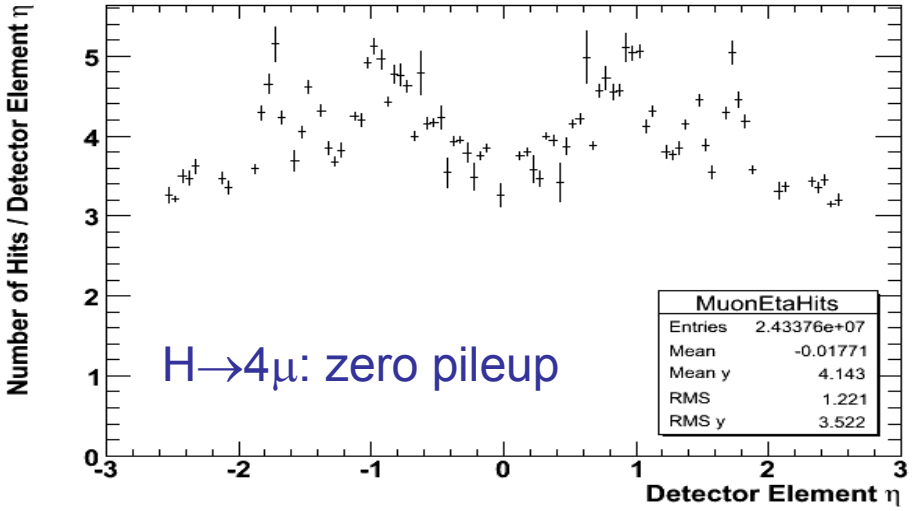


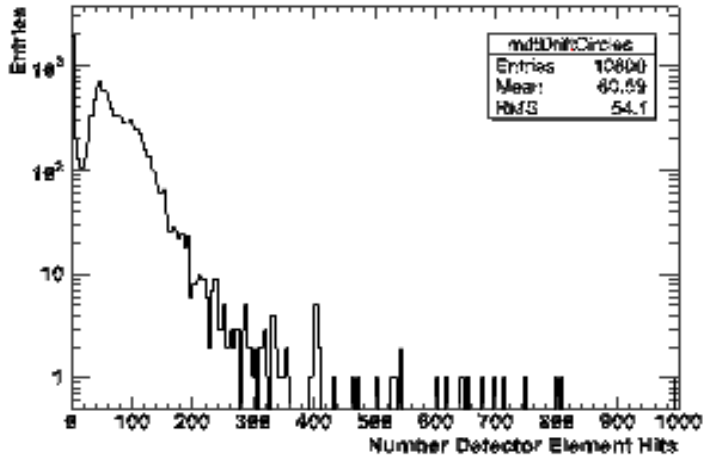




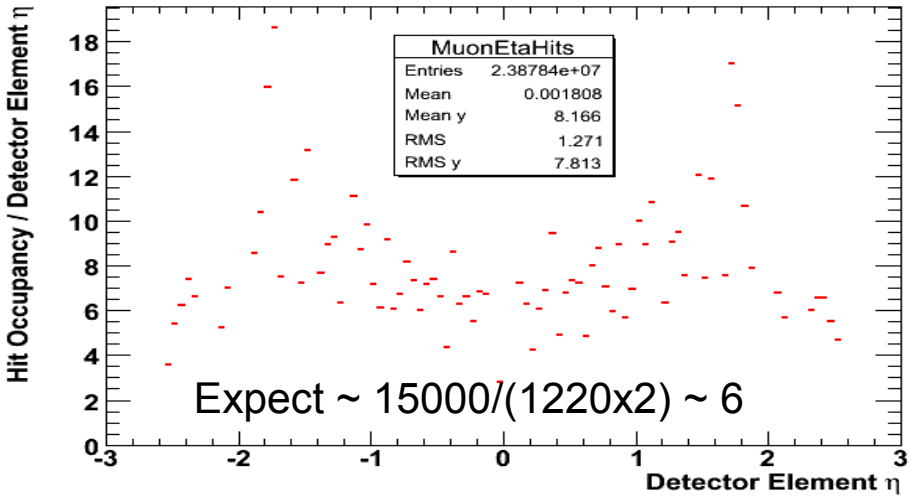


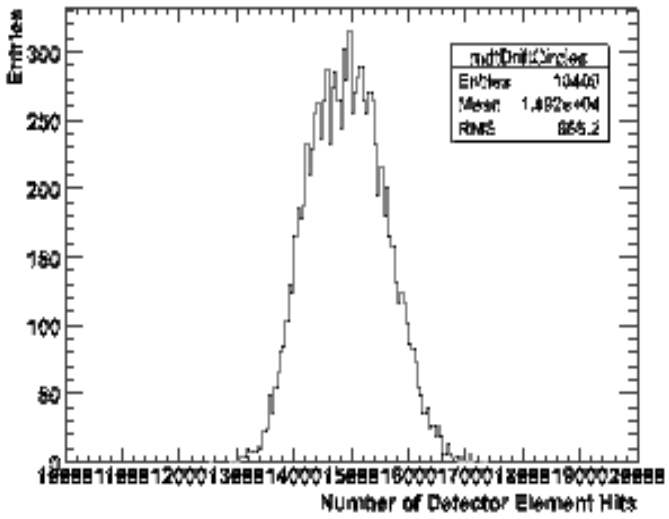
Detector element hits - pileup





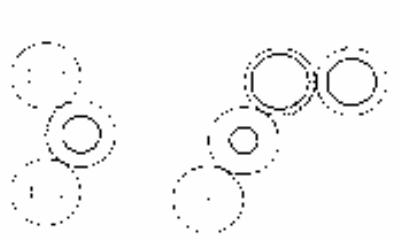
10 Hz/cm^2 @ 2 10^{33} SF=5 :: 10 Hz cm^{-2} 3cm 400 cm 0.8 10^{-6} s = 1% / tube



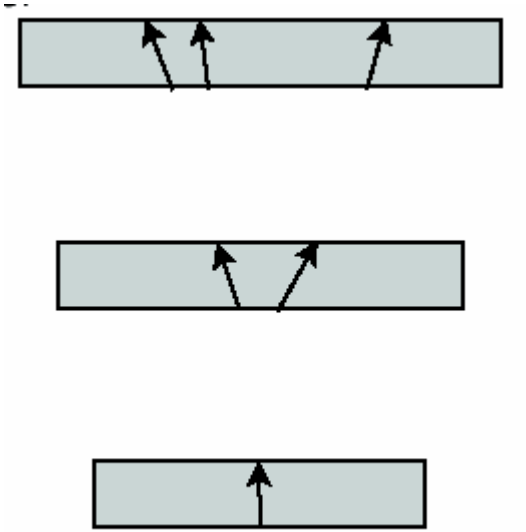


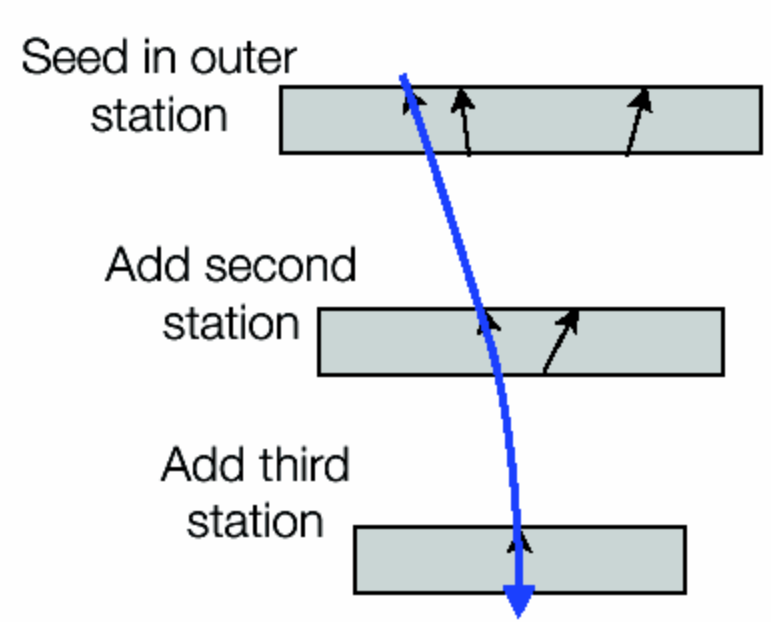
Muon Track Reconstruction Algorithms (Muonboy/MOORE)

Track Reconstruction Procedure:



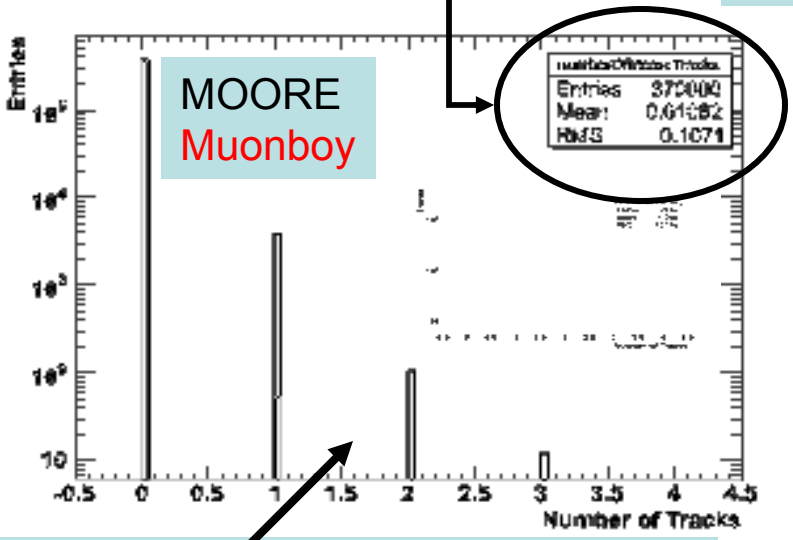
1. Identify regions of interest
2. Combine hits in ROI into local segments via pattern recognition algorithm
3. Combine segments of different stations into track candidates
4. Global track fit of candidate



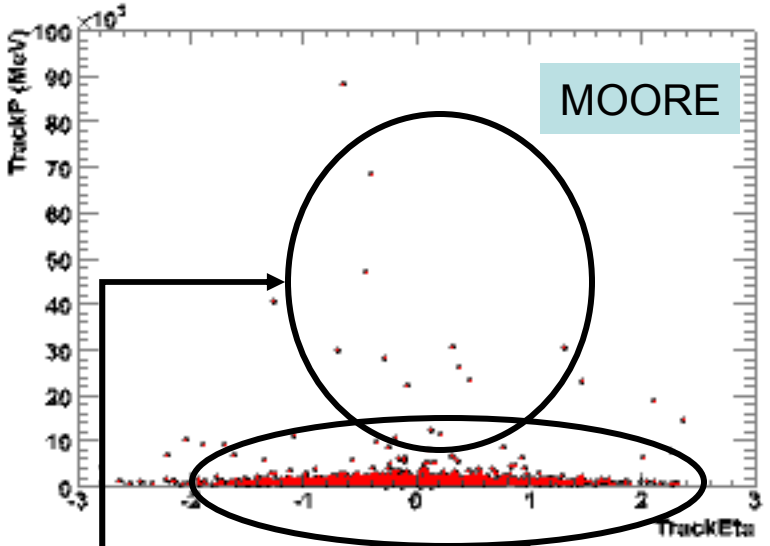


Tracks from the cavern

Note the statistics at SF=5

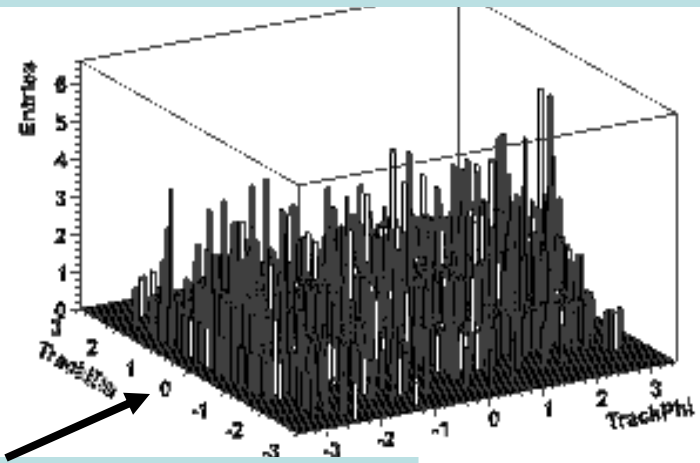


Multiple fake tracks / cavern event

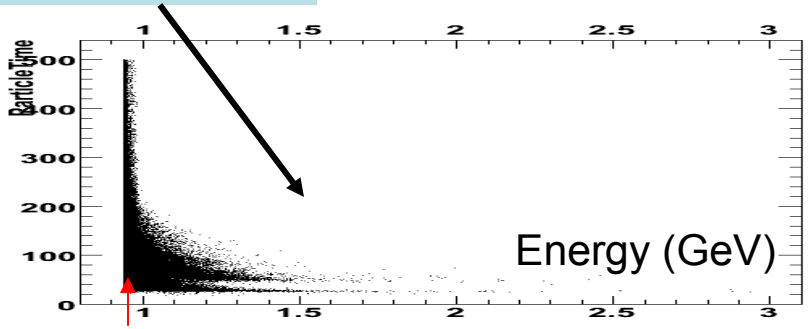


There are no such energetic tracks from the cavern

Low momentum tracks

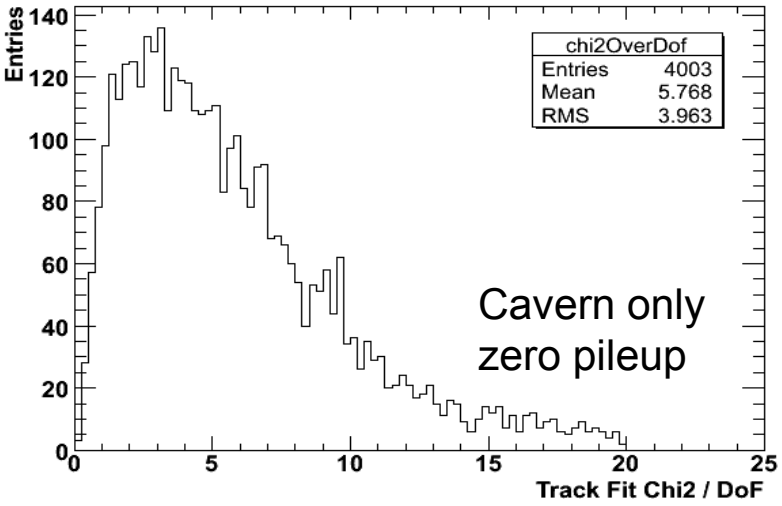


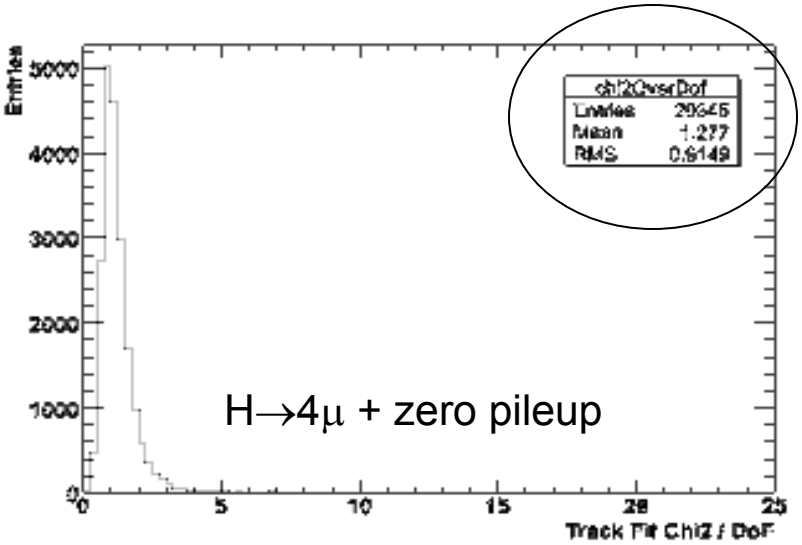
No duplicated tracks

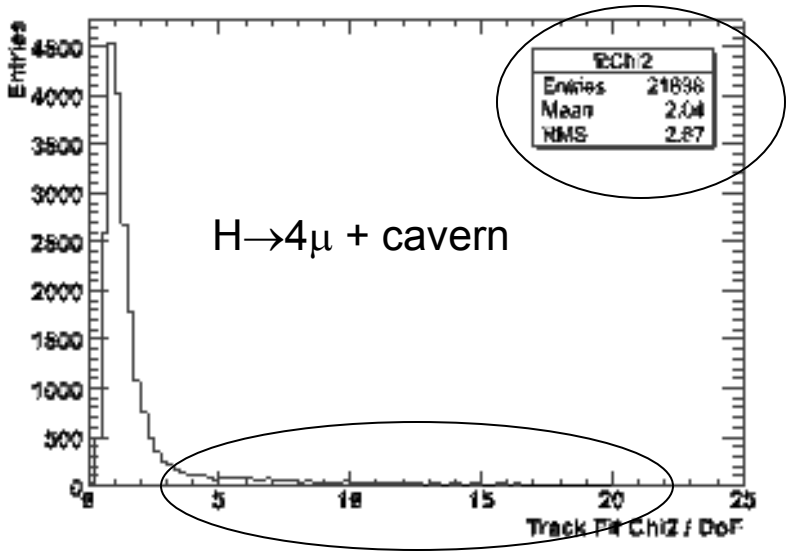


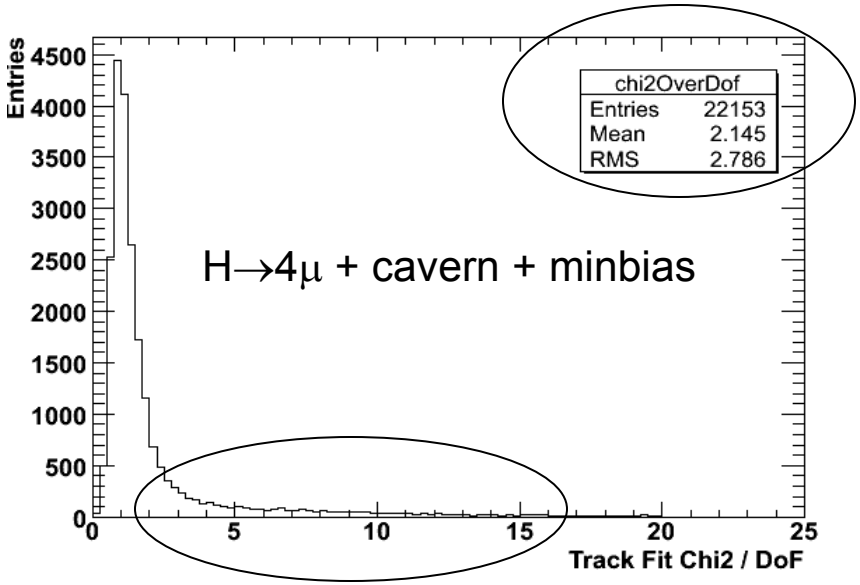
Neutron Mass

Muon Spectrometer Track Fit: MOORE

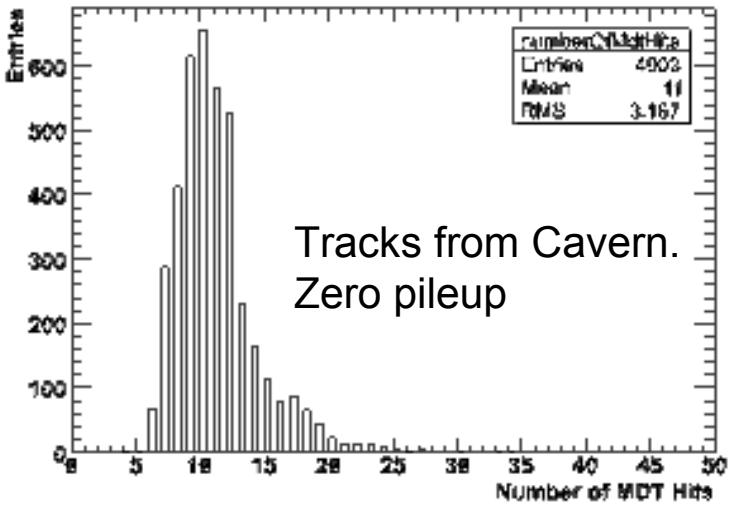


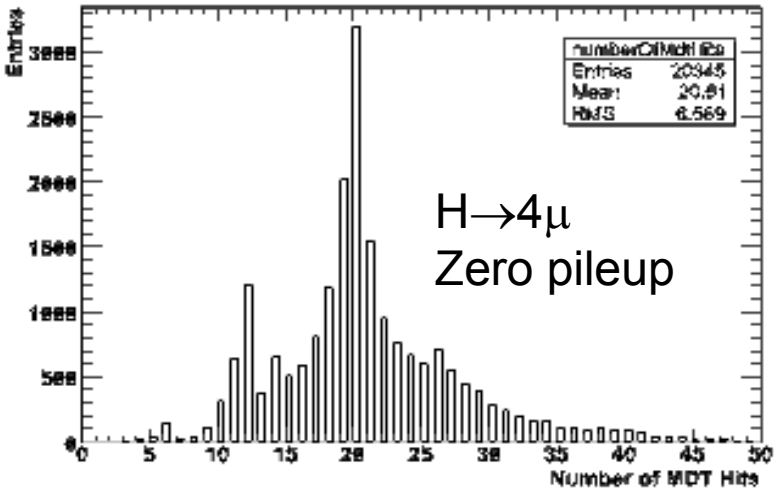


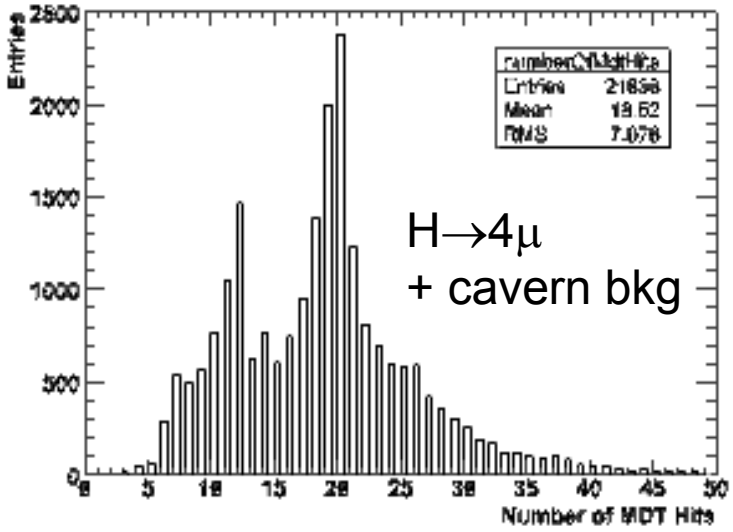


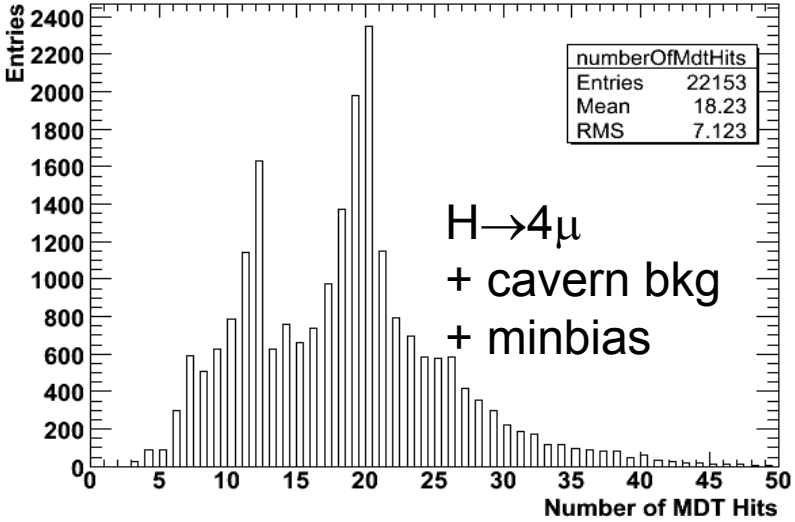


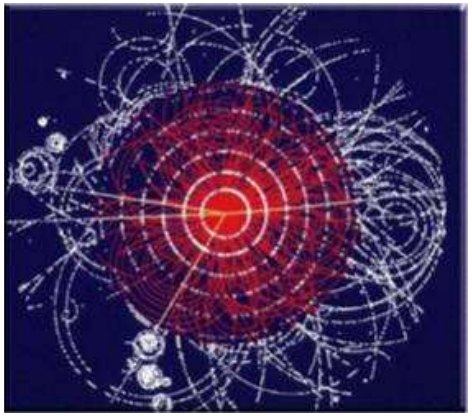
Hits on Tracks











Tracking: to do list

- PhysicsAnalysis/AnalysisCommon/AnalysisExamples/HoleOnTrackExample creates tracks from hits in Muon detectors
- Run on cavern ESD
- Combine with ID track reconstruction (MuID, MuGirl, etc)
- Any tracks made = FAKE tracks

then…

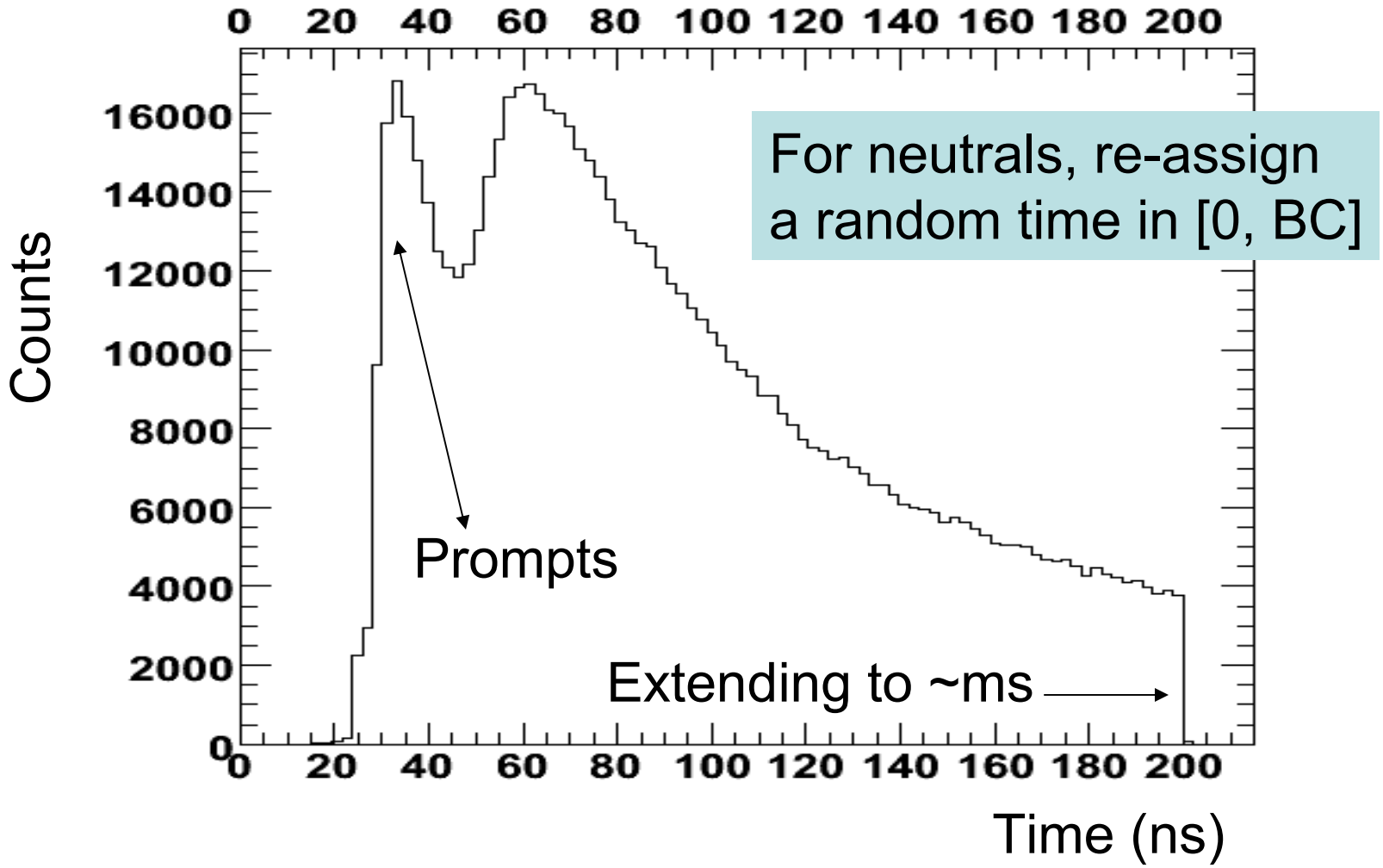
- Use Z→μμ generated signal & fold in with cavern events
- Check tracks for how background affects the resolution and efficiency
- Finally, use real data background with Z→μμ

Conclusions

- The following fixes have been implemented for the cavern background events:
  - To increase statistics, use the phi-rotation of the Muon Spectrometer: for example, at SF=5, we used to have only 6000 events. Now, we can have an arbitrary number of events, in this private production, 400k events have been produced
  - Remove multiple tracking by removing multiple occurrence of same particles in the original cavern events during conversion to POOL
  - Option to generate cavern events for 25 or 75 ns
- Further validation should be carried out when the official pileup production becomes available
- Future work: Tracking reconstruction
  - Identify fake tracks in cavern simulation
  - Resolution & efficiency of reconstruction when combined with signal
- The regeneration of cavern events from first principles is outside the scope of this work. It is a big job. It will require time and a decided team of experts. We should decide whether that is worth doing.

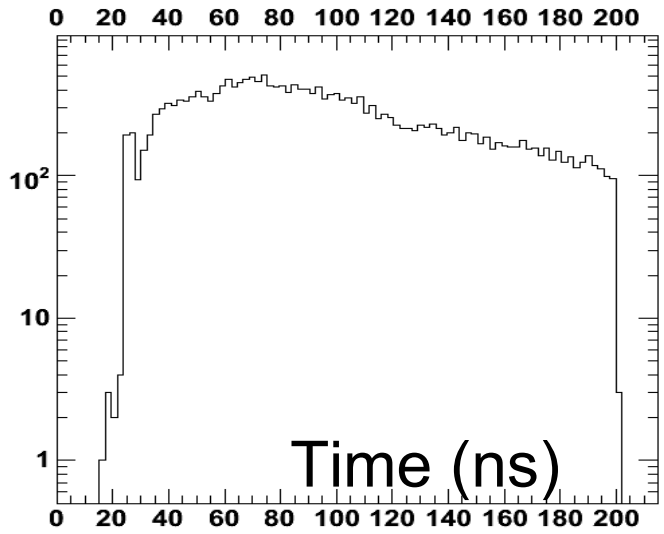
Backup slides

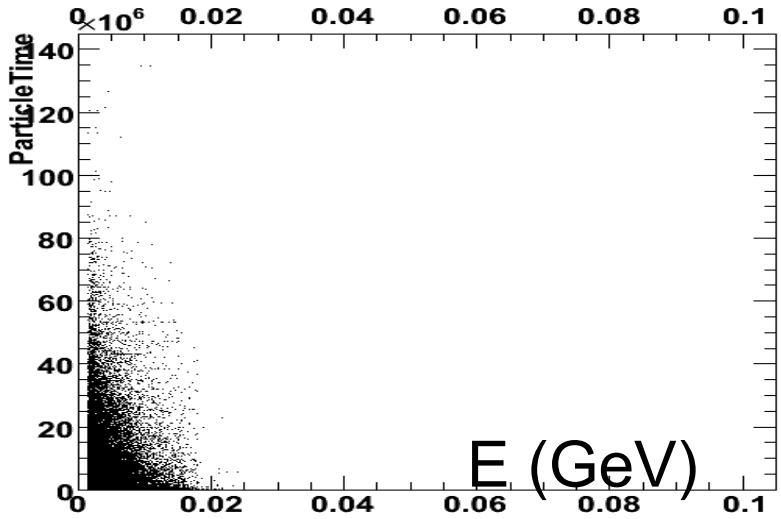
Particle Time

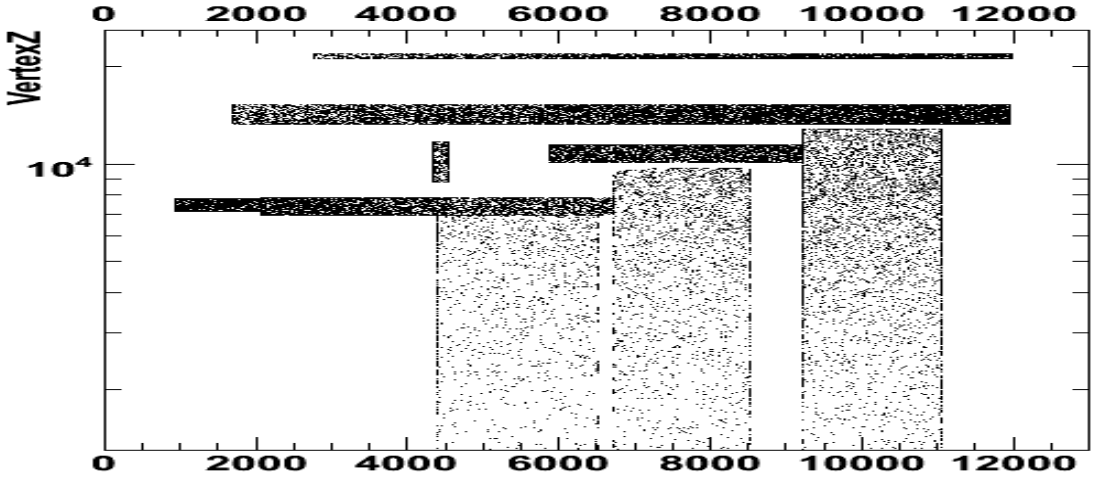


For neutrals, re-assign a random time in [0, BC]

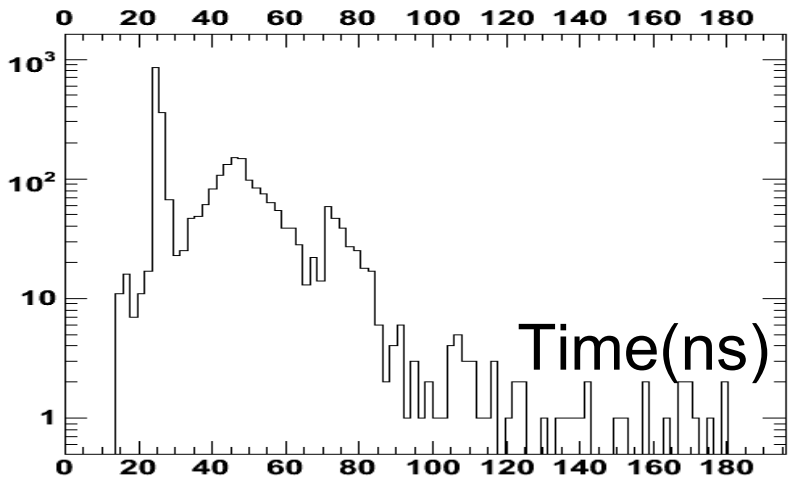
Electron

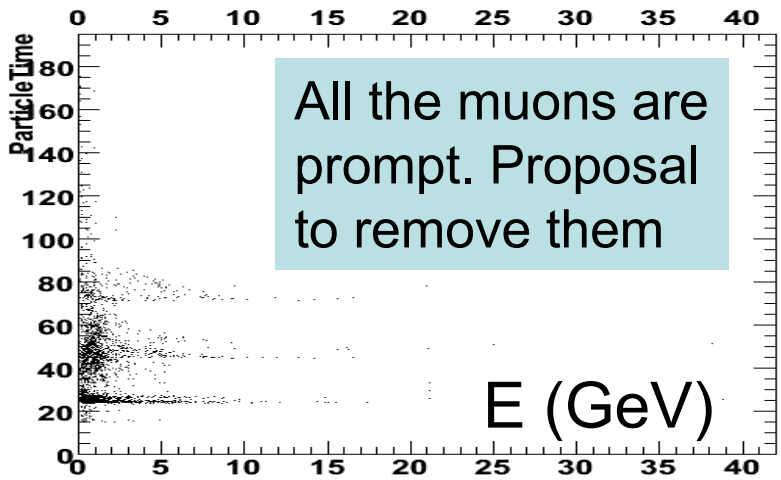


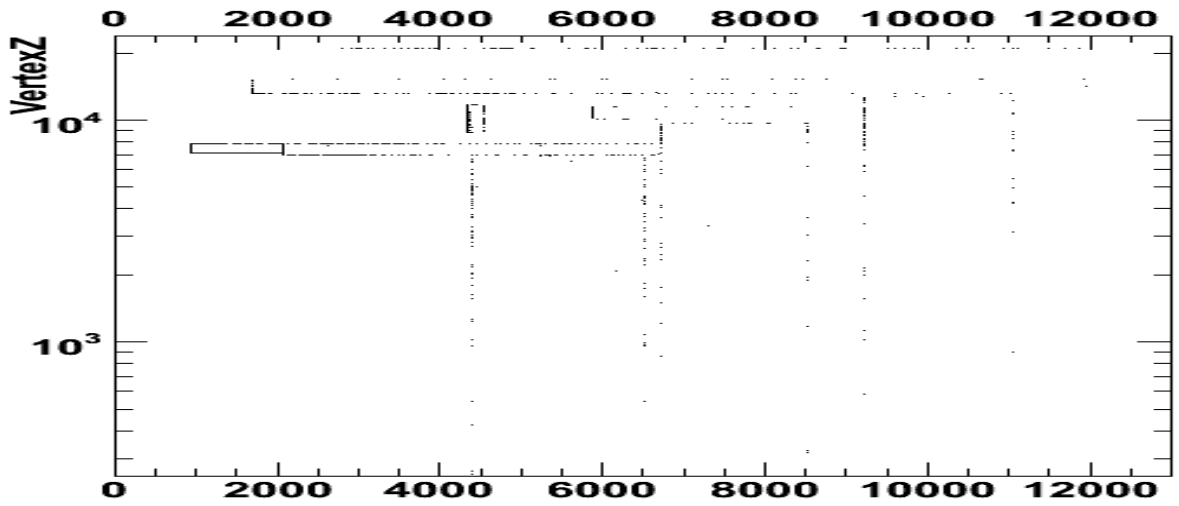




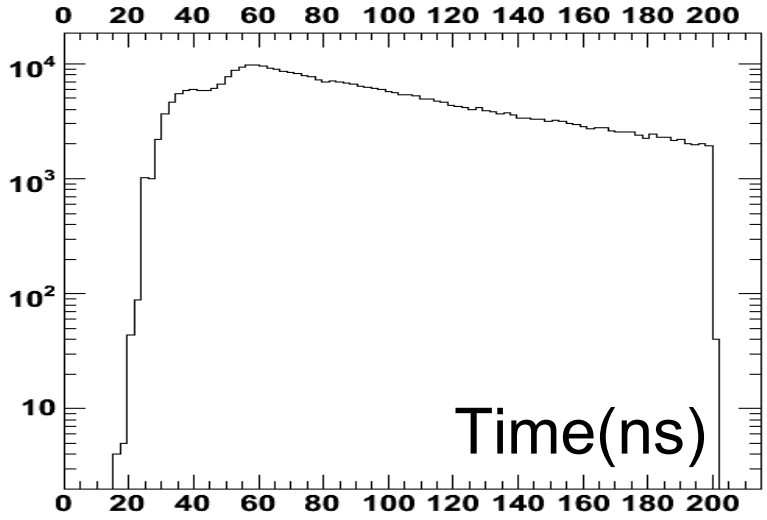
Muon

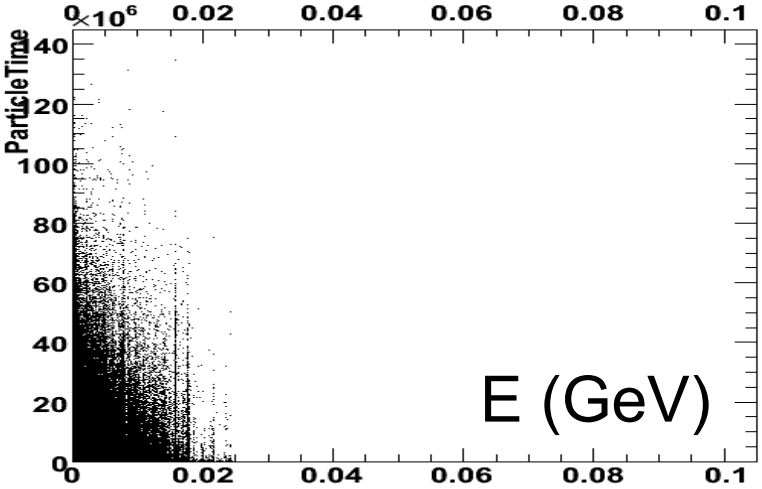

Time(ns)

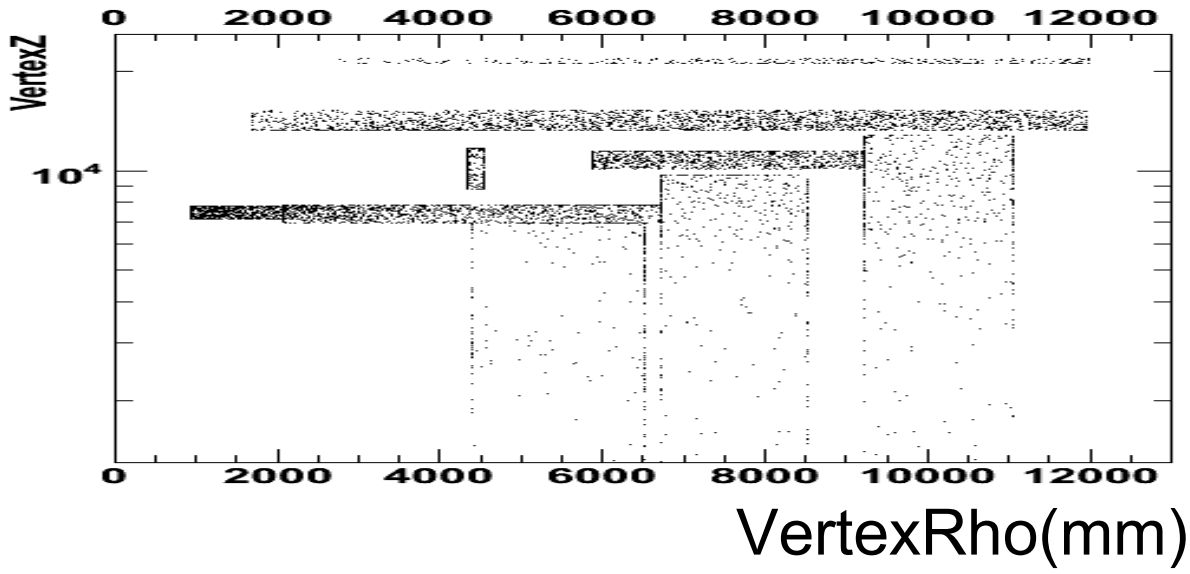

ParticleTime
All the muons are prompt. Proposal to remove them
E (GeV)


VertexZ
VertexRho(mm)

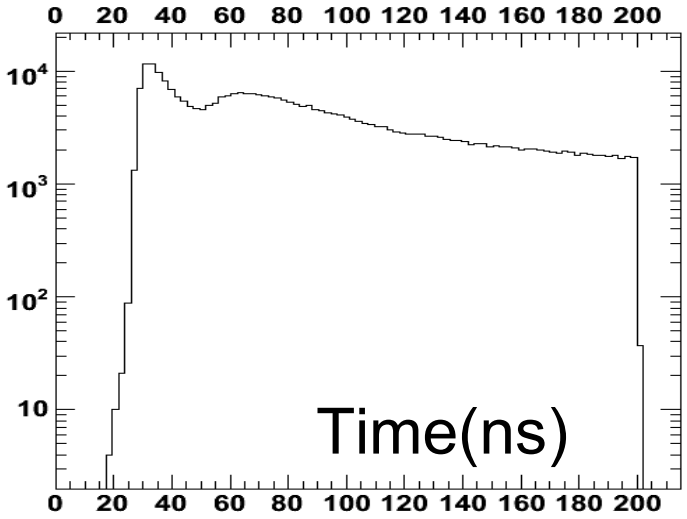
Photon

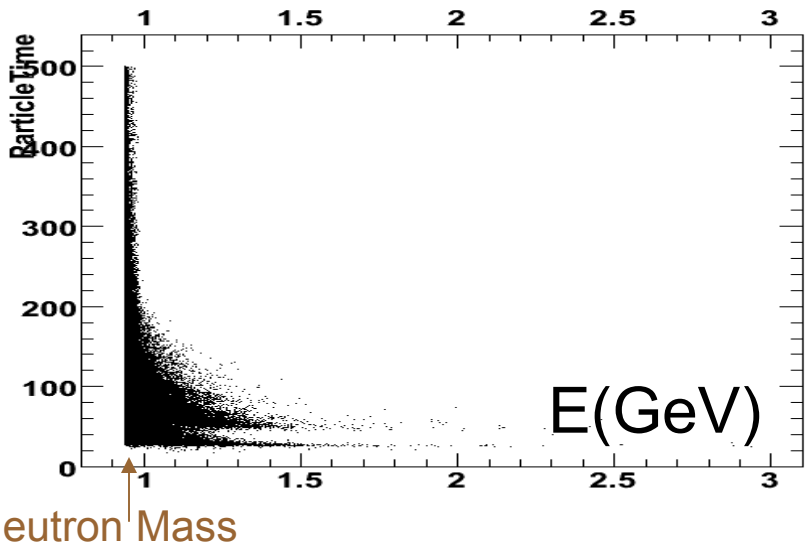


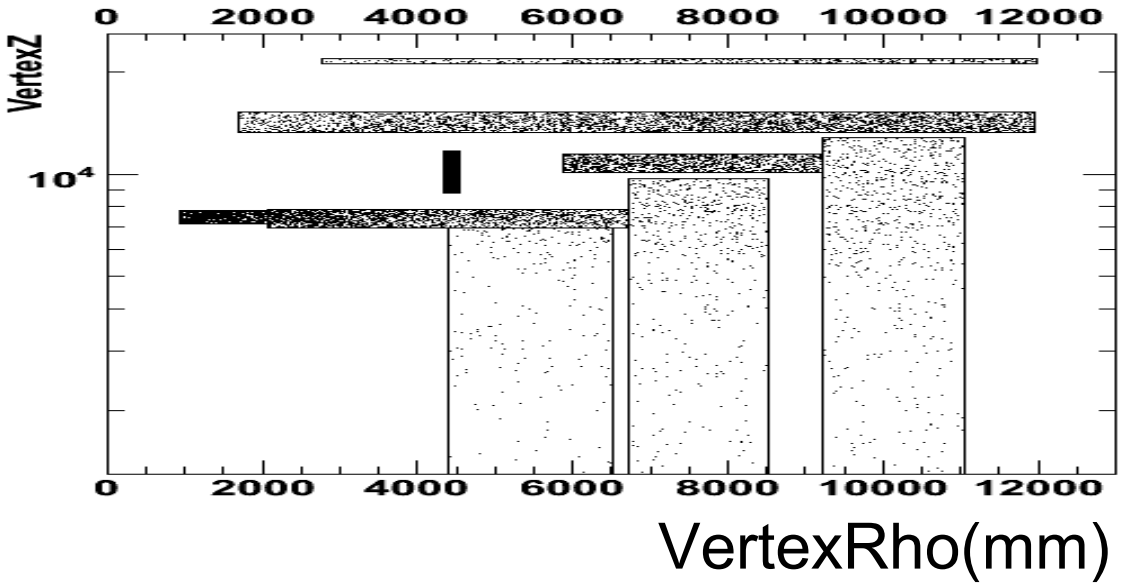




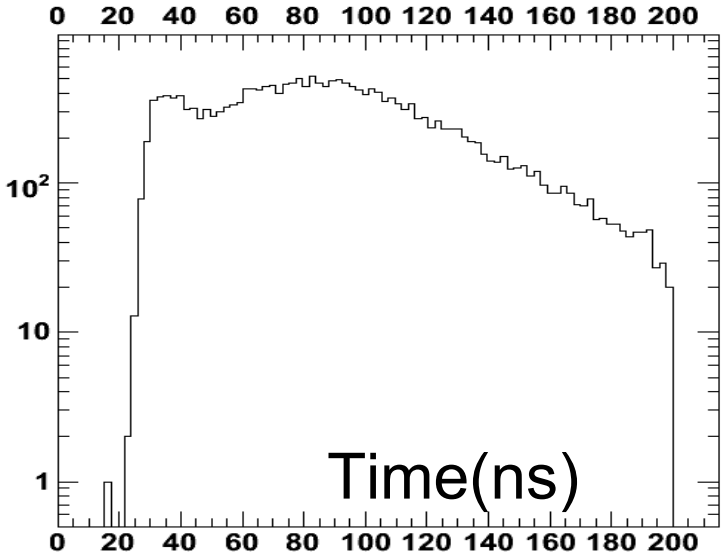
Neutron

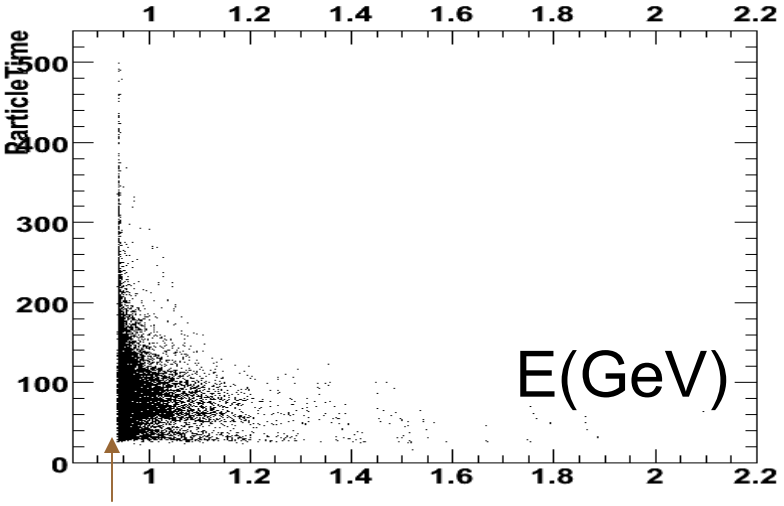

Time(ns)


ParticleTime
E(GeV)
Neutron Mass

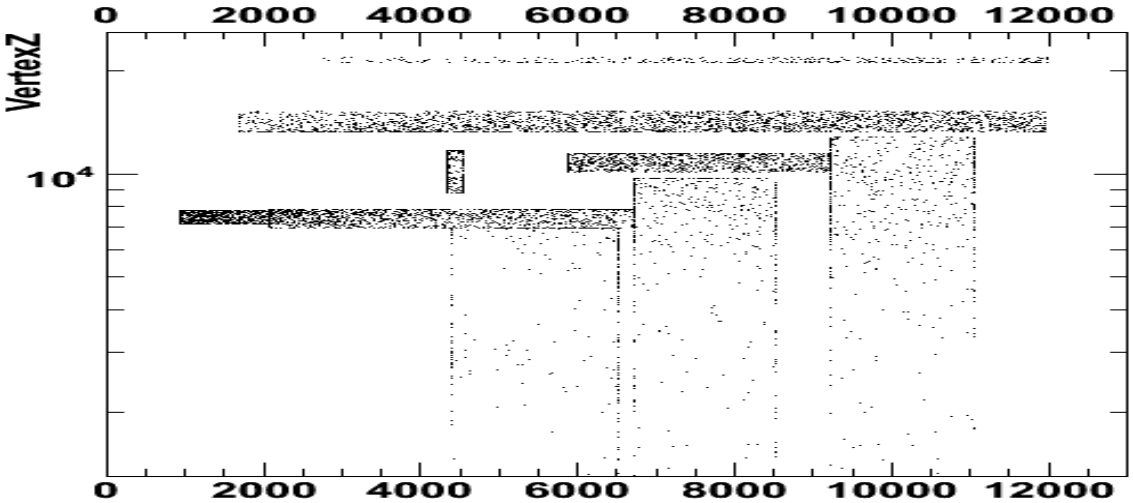

VertexZ
VertexRho(mm)

Proton





Proton Mass



Removal of Duplicates

- 271369461 Jan 29 23:04 CavernBackground_dup.aan.root
- 220061145 Jan 29 14:21 CavernBackground.aan.root

- ievnt,ITYPE,TOF,VECT: 1 1 0.731827E-02 -481.4628 -328.4060 693.5007 -0.6580 -0.1839 0.7303 0.494453E-03
- ievnt,ITYPE,TOF,VECT: 1 1 0.731827E-02 -571.6237 -353.5999 793.5703 -0.6580 -0.1839 0.7303 0.494453E-03
- ievnt,ITYPE,TOF,VECT: 1 1 0.731828E-02 -768.4255 -408.5927 1012.0007 -0.6580 -0.1839 0.7303 0.494453E-03
- ievnt,ITYPE,TOF,VECT: 1 1 0.731828E-02 -819.0891 -422.7497 1068.2323 -0.6580 -0.1839 0.7303 0.494453E-03
- ievnt,ITYPE,TOF,VECT: 1 1 0.731830E-02 -1050.4331 -487.3947 1325.0010 -0.6580 -0.1839 0.7303 0.494453E-03

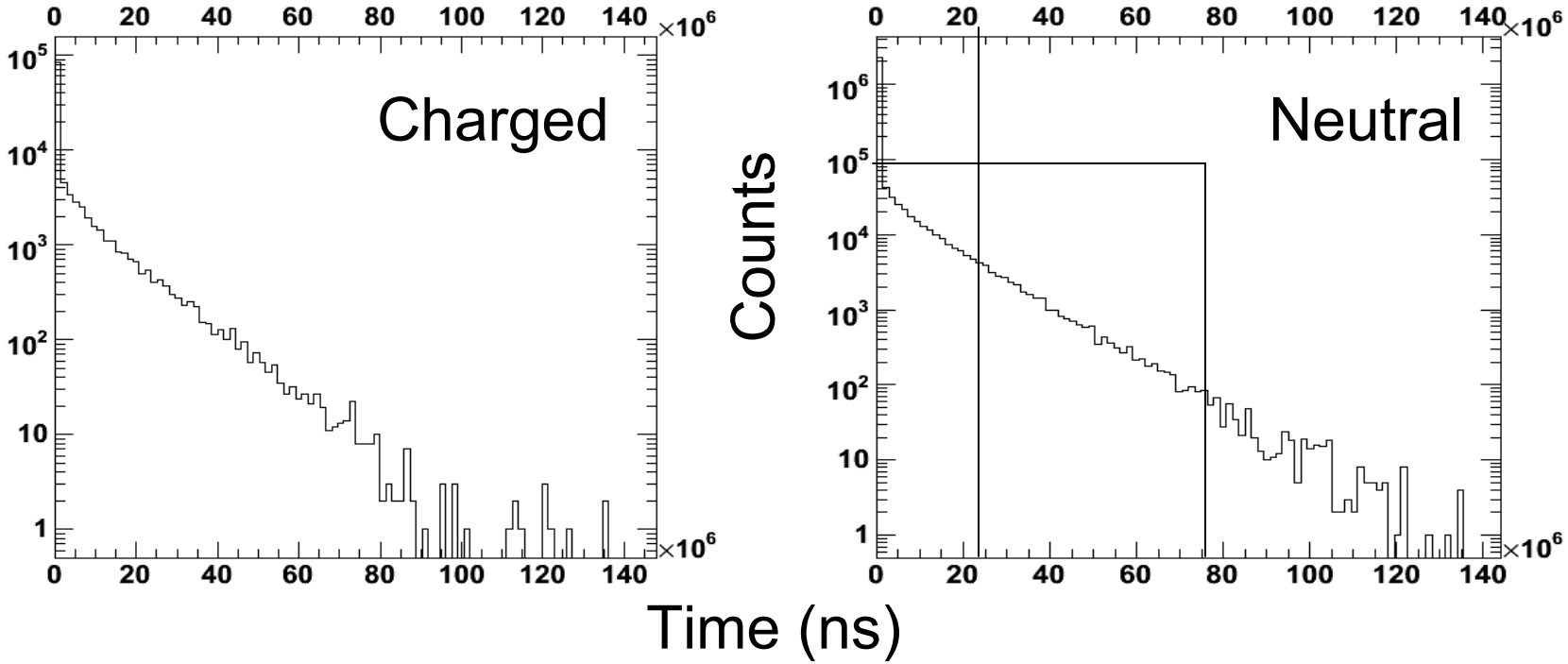
Only the first occurrence in the list is taken

Increasing the Statistics

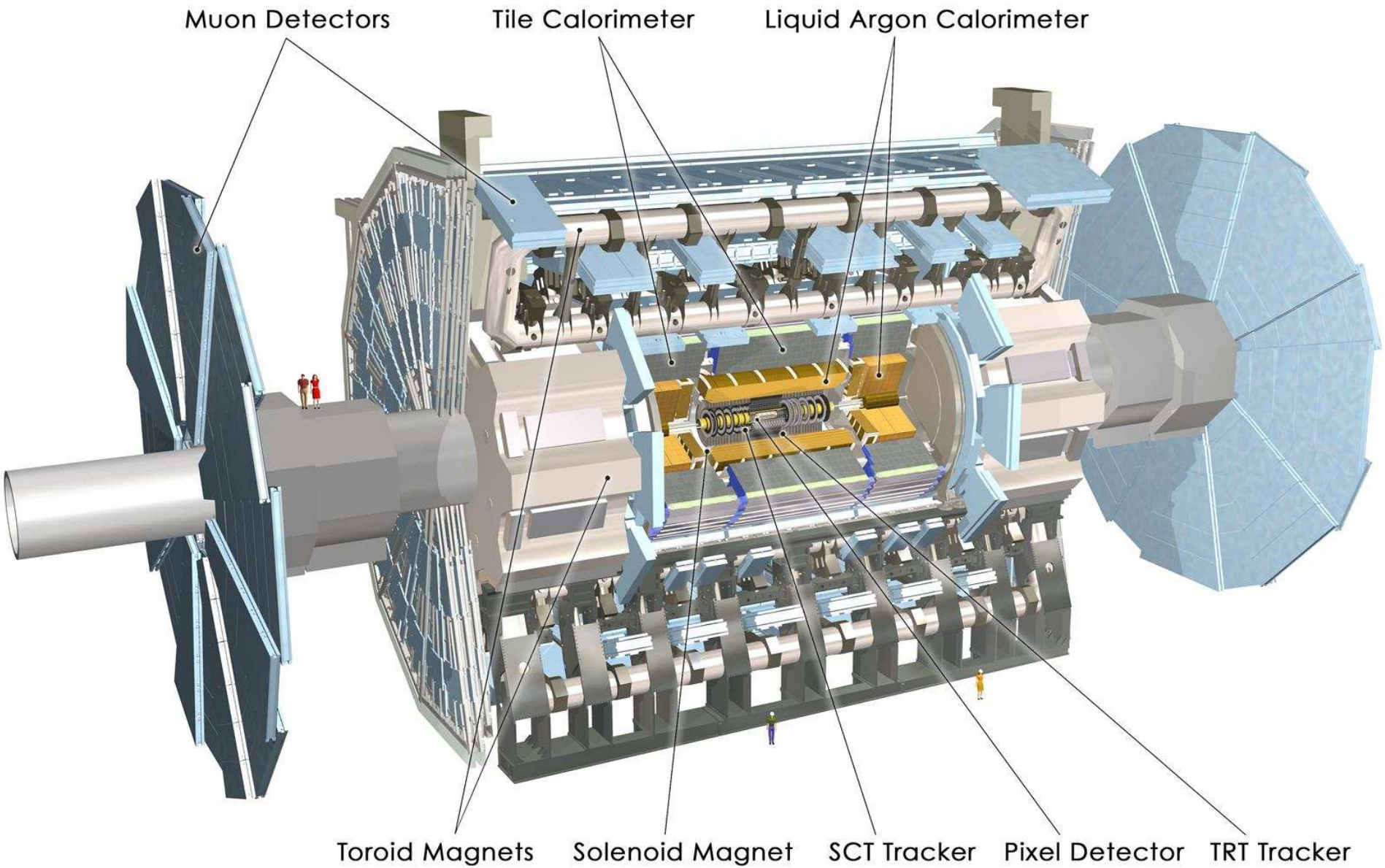
- Original
  - Total available statistics ~ 30 k events
    - 30 k events at SF=1
    - 10 k event at SF=2
    - 6 k event at SF=5
    - 3 k events at SF=10
- Rotate the primary statistics using the 8-hold phi-symmetry of the muon spectrometer
  - The above statistics increases by a factor of 8
  - The number of Athena Event Loop remains unchanged
  - The Safety Factor normalization remains unchanged
  - But there is a factor of 8 more cavern background McEvents in the output
  - For (sector=1; sector<8; ++sector)
    - newPhi = oldPhi + (sector-1) * twopi/8

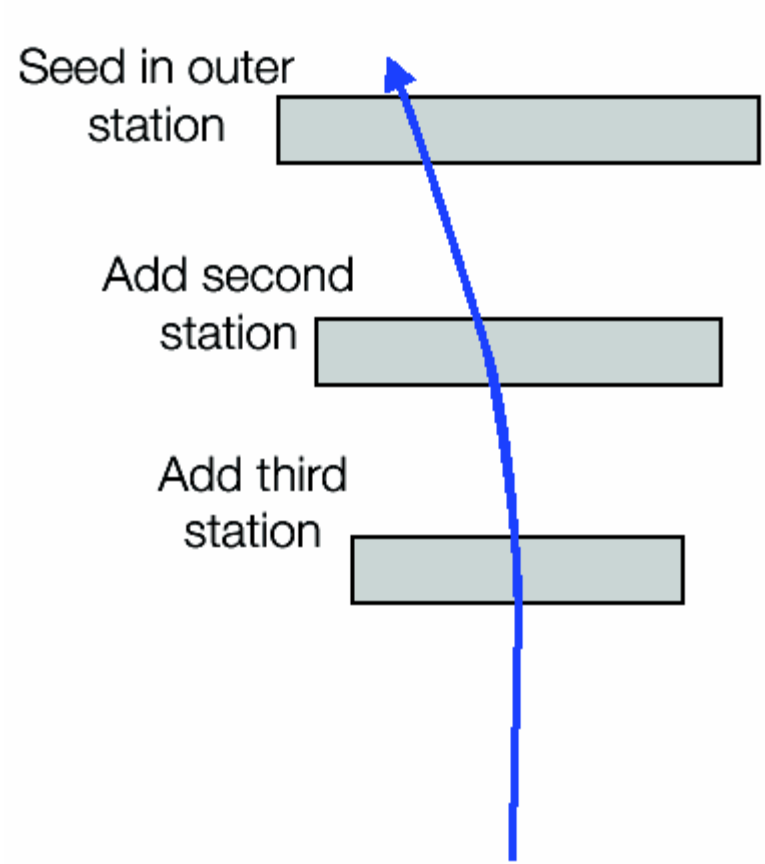
1 ketevi zp 60459280 Jan 30 22:17 mc13.007901.cavernbg_sf01_25ns.evgen._0001.pool.root
File:mc13.007901.cavernbg_sf01_25ns.evgen._0001.pool.root
Size: 60459.280 kb
Nbr Events: 3000
But the McEventCollection itself would have 24000 McEvents,
8 times more, that is 8 McEvents for each Athena Event Loop, before we only have ONE McEvent

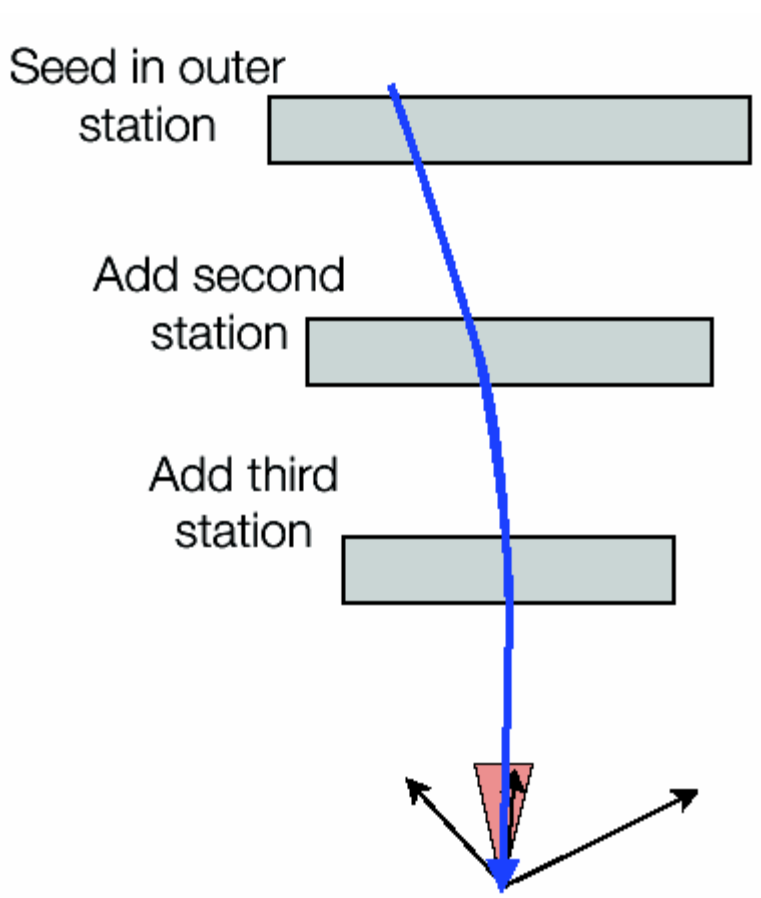
Time at the Scoring Volumes



- The times of the neutrals re-generated as
  - Flat distribution in [0,25 ns]
  - Flat distribution in [0,75ns]


Muon Detectors
Tile Calorimeter
Liquid Argon Calorimeter
Toroid Magnets
Solenoid Magnet
SCT Tracker
Pixel Detector
TRT Tracker


Seed in outer station
Add second station
Add third station


Seed in outer station
Add second station
Add third station