Monte Carlo study for DVCS at Electron-Nucleon Collider (ENC) / Panda

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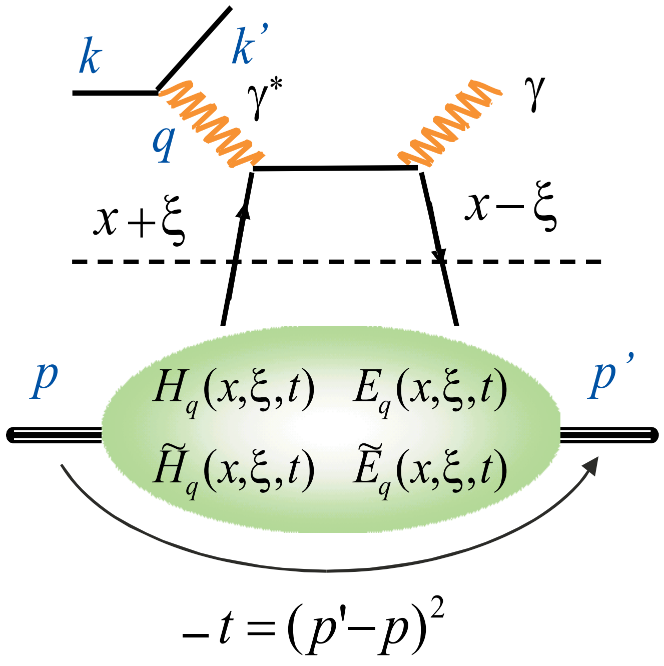
- Introduction of DVCS
- Event generation for DVCS
- Panda detector simulation
- Summary and Outlook

ENC/EIC workshop, GSI, 28-30. May 2009

Generalized parton distribution (GPDs) can be accessed via Deeply Virtual Compton Scattering (DVCS)



DVCS (in QCD): $ep \rightarrow ep\gamma$

DVCS final state is indistinguishable from the Bethe-Heitler QED process

Interference between QCD and QED gives access to the amplitude of DVCS via ϕ_γ asymmetry

Non perturbative region can be described by GPDs using pQCD factorization theorem where is valid in the Bjorken regime :

$$Q^2 >> M^2, \; |t| << Q^2$$

Generator of $ep \to ep\gamma$: GenDVCS1.0

DVCS, Bethe Heitler, Interference by Frankfurt, Freund and Strikman model (hep-ph/9710356) based on two gluon exchange at HERA

$d\sigma_{DVCS}$ is parameterized in terms of DIS differential cross section, for t distribution slope $b = 5.0\ \mathrm{GeV}^{-2}$ and $\eta = 0.4243$

Beam energy @ ENCollider

$E_p = 15$ GeV, $E_e = 3$ GeV

$$s = 2(E_e E_p + |\vec{p}_e||\vec{p}_p|) + m_e^2 + m_p^2$$

$$\approx 180\,(\mathrm{GeV/c^2})^2$$

$$\frac{d\sigma^{\mathrm{DVCS}}}{dxdydtd\phi_r} \sim \frac{1}{Q^6} e^{-b|t|} F_2^2(x, Q^2)\left(1+\eta^2\right)$$

$$\eta = \frac{\mathrm{Re}(A(\gamma^* p \to \gamma p))}{\mathrm{Im}(A(\gamma^* p \to \gamma p))}$$

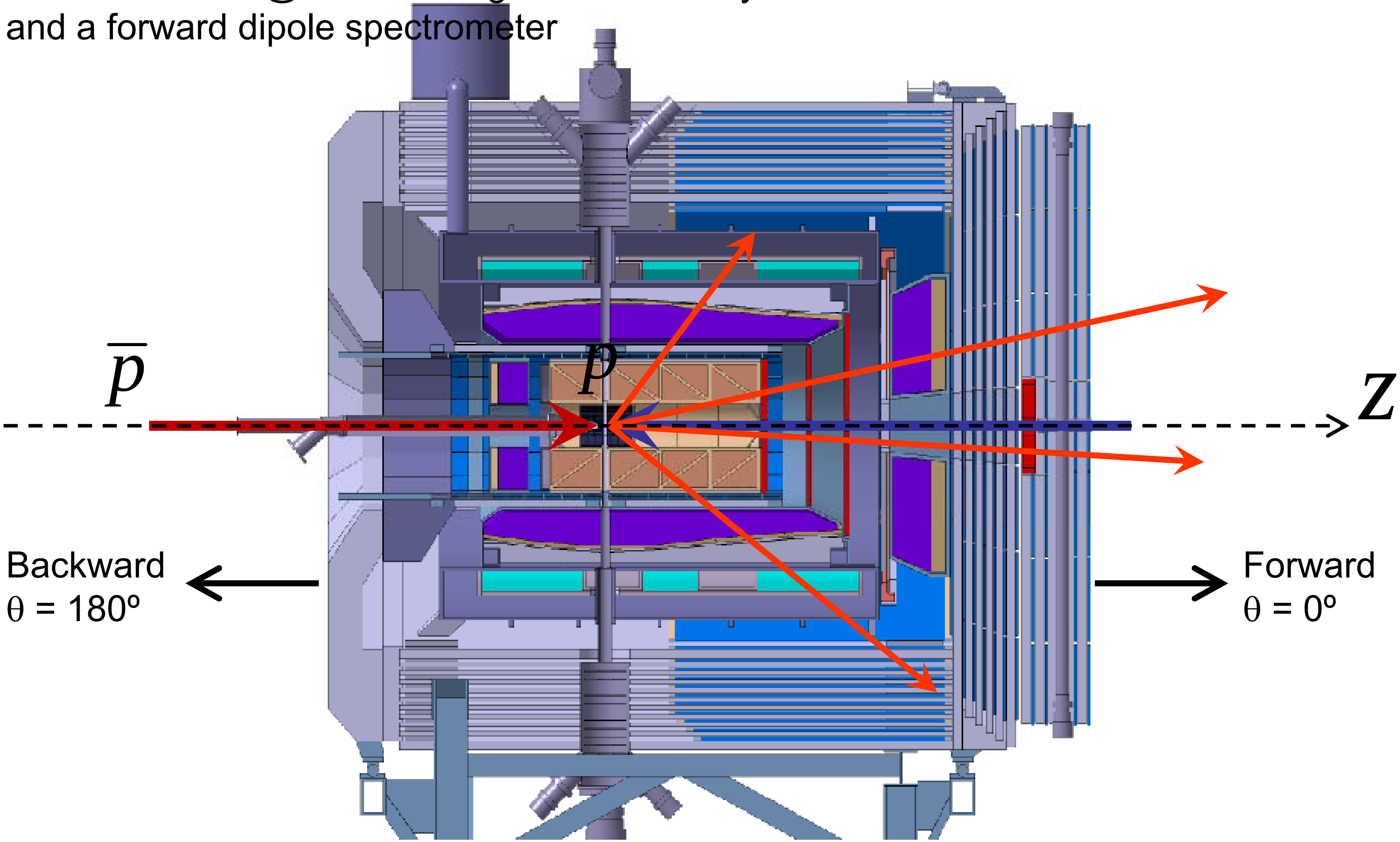
$$\frac{d\sigma^{\mathrm{BH}}}{dxdydtd\phi_r} \sim \frac{1}{Q^4}\frac{1}{|t|}$$

$$\frac{d\sigma^{\mathrm{INT}}}{dxdydtd\phi_r} \sim \pm\frac{1}{Q^5}\eta\frac{e^{-b|t|/2}}{\sqrt{|t|}}\cos\phi_r$$

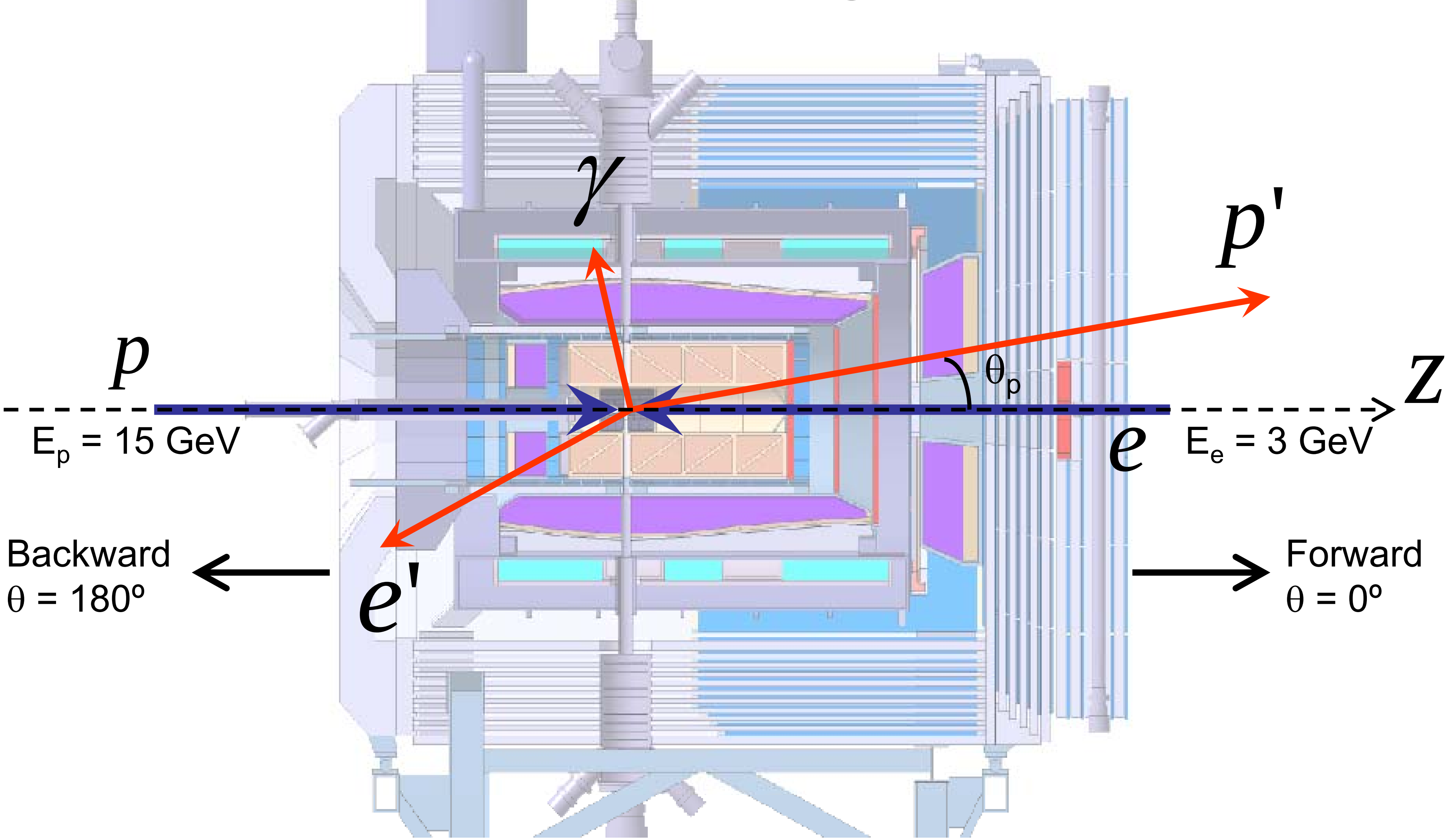
$$\phi_r = \phi_e' - \phi_p$$

Panda spectrometer

Panda detector @ GSI is being built with an aymmetrical solenoid and detectors and a forward dipole spectrometer

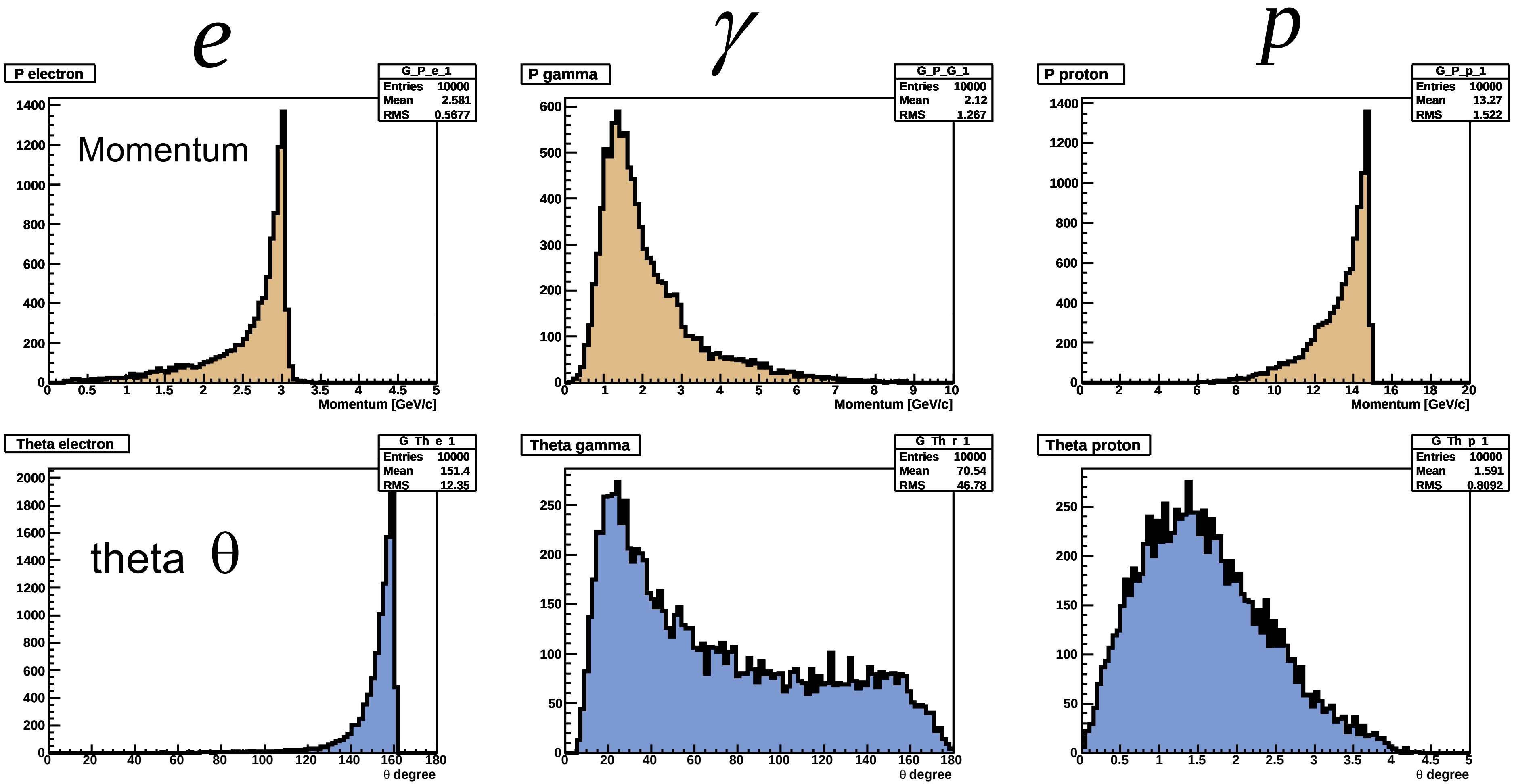


Panda detector @ ENC

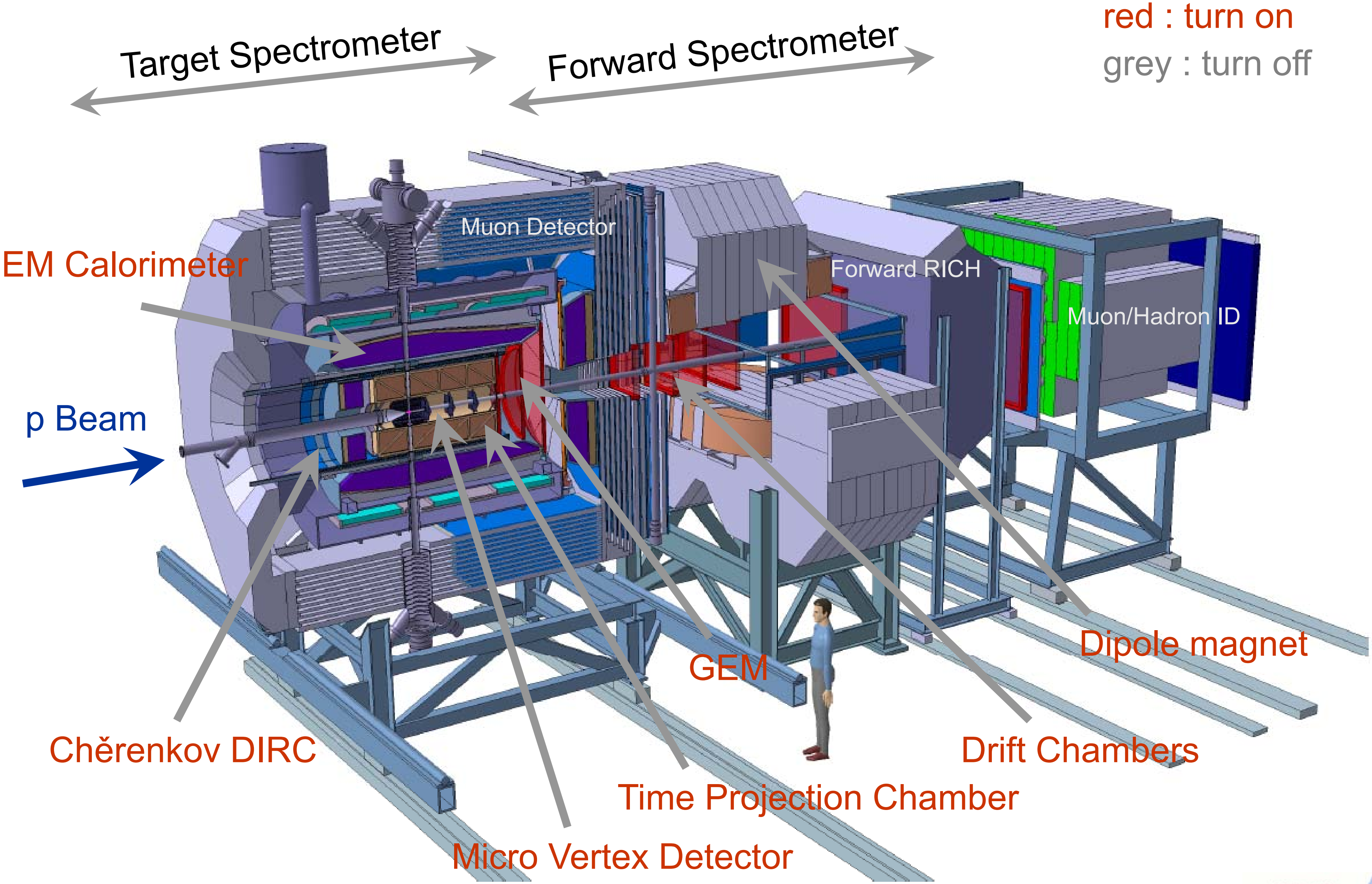


MC true information

Statistics : 10k events @ $Q^2 > 1\ (\mathrm{GeV/c^2})^2$, $0.01 < x_{\mathrm{Bj}} < 0.99$, $0.0 < |t| < 1.0\ (\mathrm{GeV/c^2})^2$



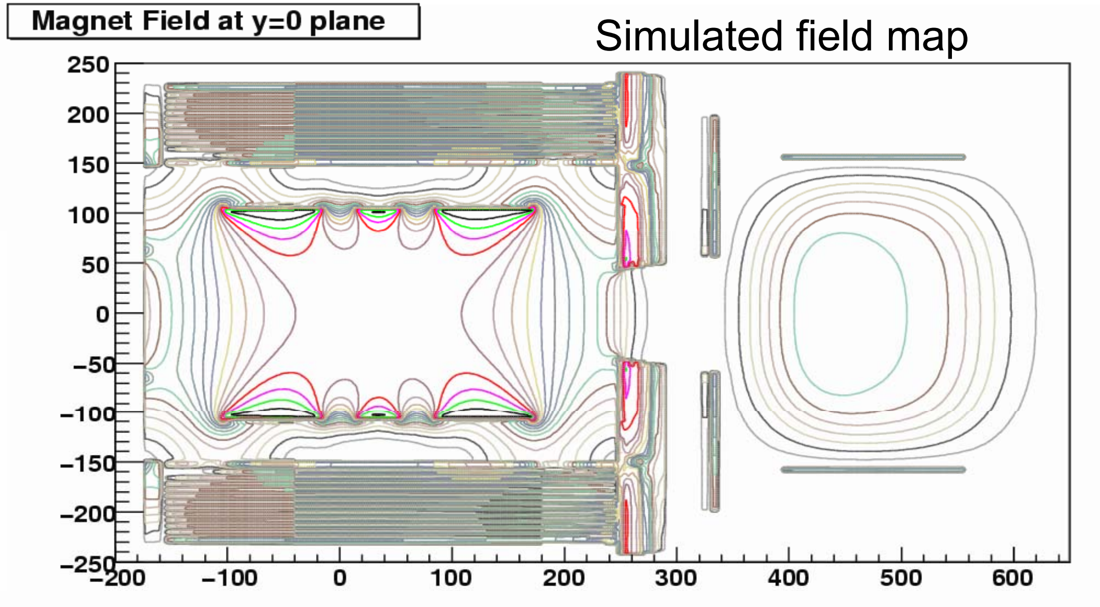
Panda simulation



Simulation of geometrical acceptance

Magnet fields :

Max. 2T Solenoid Magnet
Max. 1T Dipole Magent



Detector setup (present study)

Detector	Location	Polar angle
Target Spectrometer		
Calorimeter (EM)	Barrel	$22° < \theta < 142°$
Calorimeter (EM)	Forward	$5° < \theta < 22°$
Calorimeter (EM)	Backward	$149° < \theta < 172°$
Micro Vertex	For., Barrel, Back.	$10° < \theta < 170°$
Time Projection Chamber	For., Barrel, Back.	$7.8° < \theta < 160°$
Cherenkov (DIRC)	Barrel	$22° < \theta < 140°$
Cherenkov (DIRC)	Forward	$5° < \theta < 22°$
Time of Flight	Barrel	$22° < \theta < 140°$

Detector	Location	Polar angle
Forward spectrometer		
Drift Chamber	Forward	$0.5° < \theta_x < 10°$ $0.5° < \theta_y < 5°$
GEM	Forward	$0.5° < \theta < 22°$

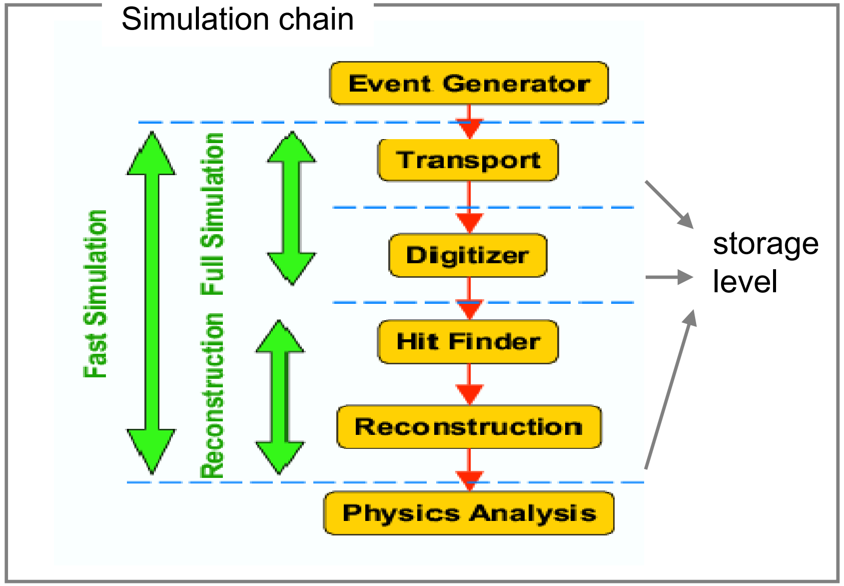
Tracking for electron candidate

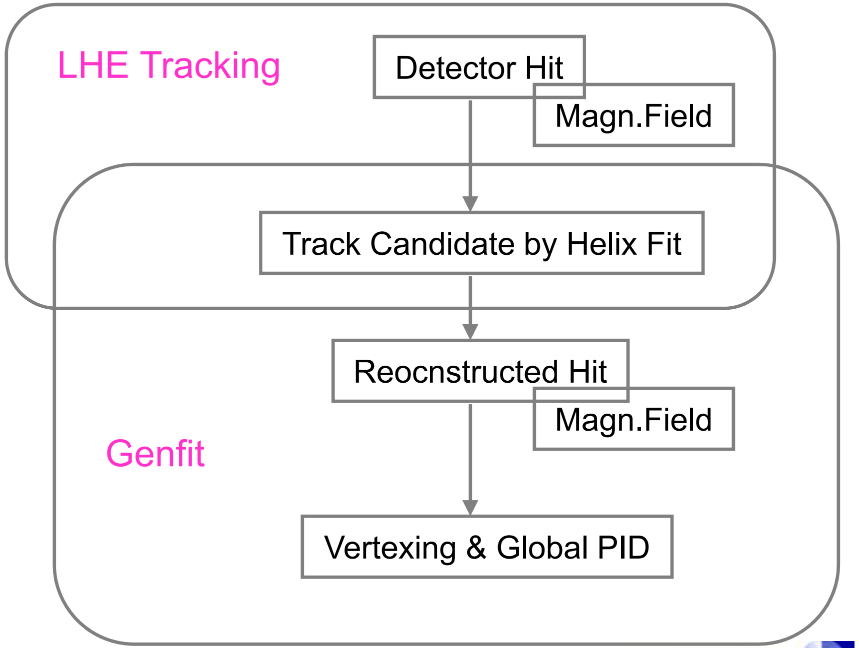
Global Tracking and PID are not completely prepared.

LHE tracking package provides a reconstructed track for electron candidate, mainly as a central tracking.

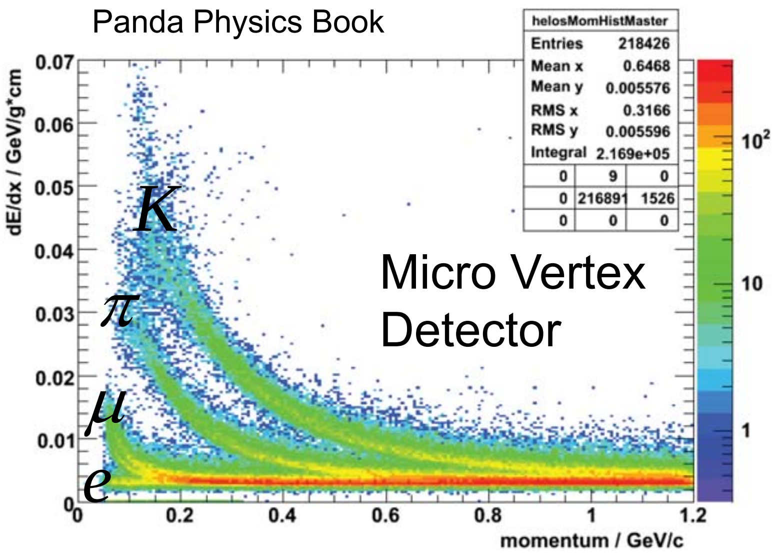
LHE tracking use detector components of
- Time Projection Chamber (TPC)
- Micro Vertex Detector (MvD)
- Time of Fight (ToF)
- Chrenkov DIRC
- Electromagnetic Calorimeter (EMC)

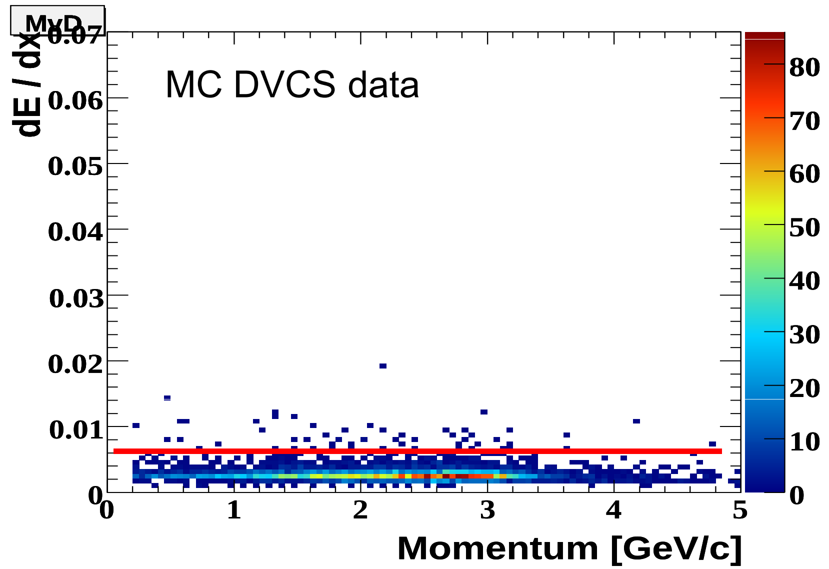
Selection for electron candidate
- $P_e > 0.2$ GeV/c
- $\theta_e > 80^o$
- $Q_{ch} < 0$

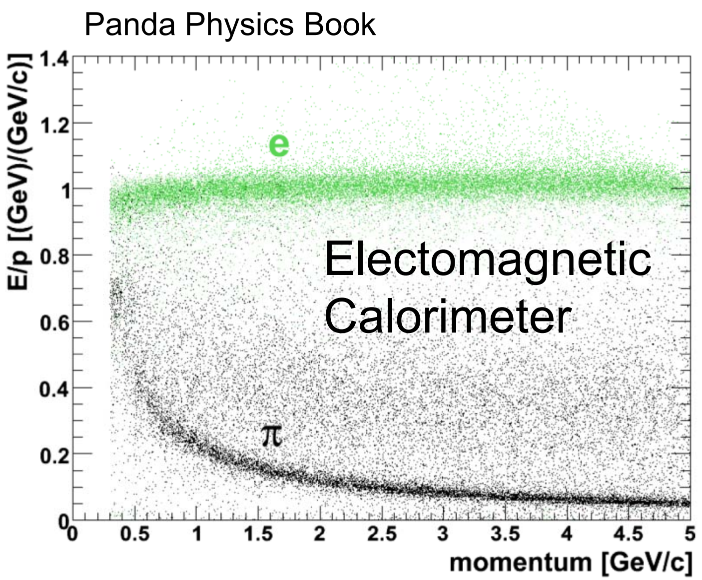


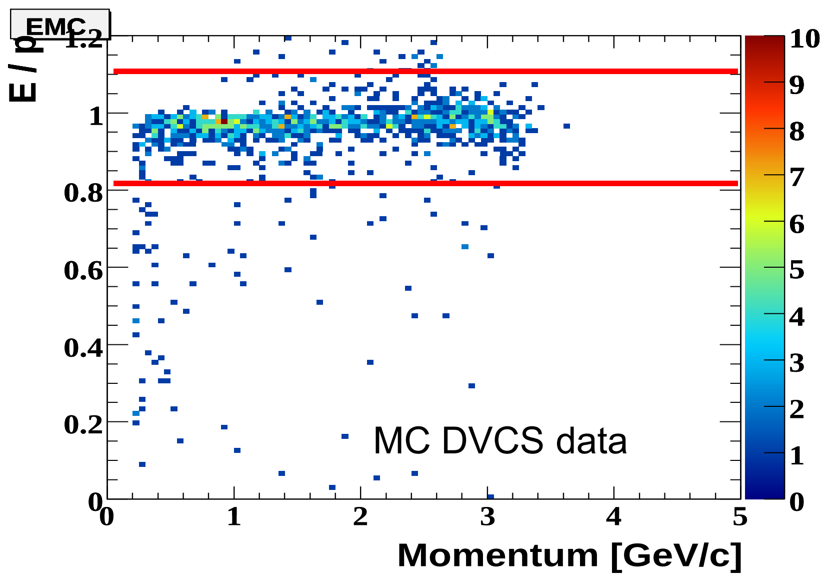


Tracking for electron candidate









Identification of electorn are similar in other detectors

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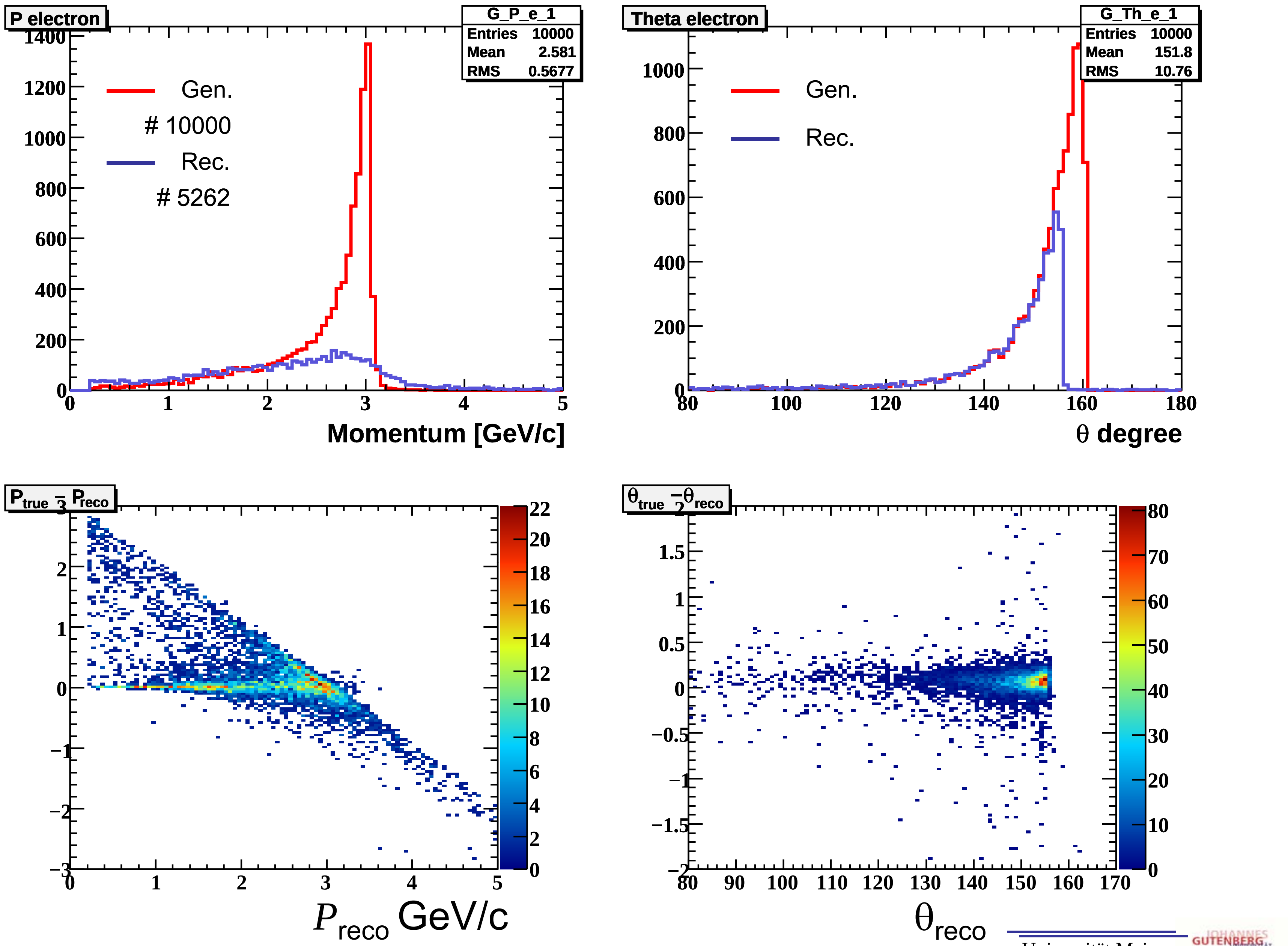
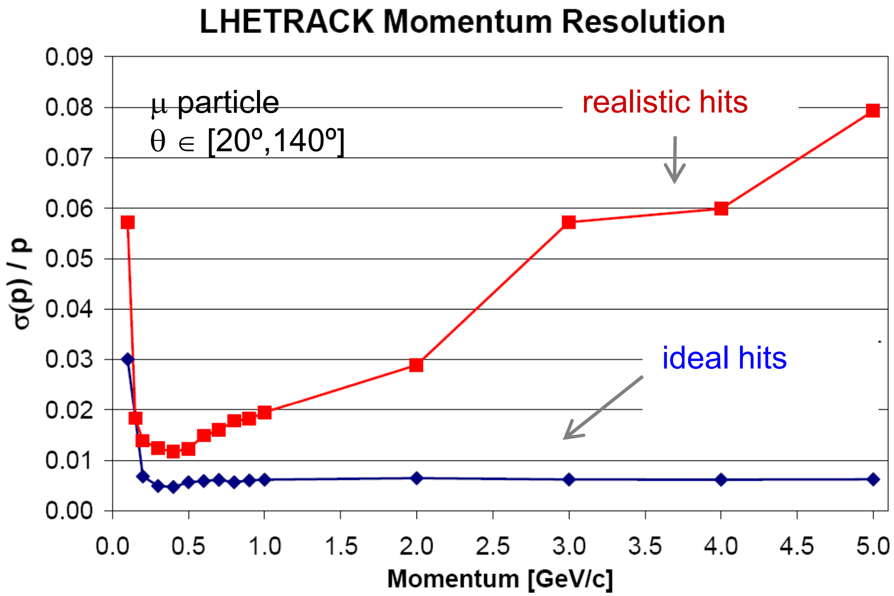
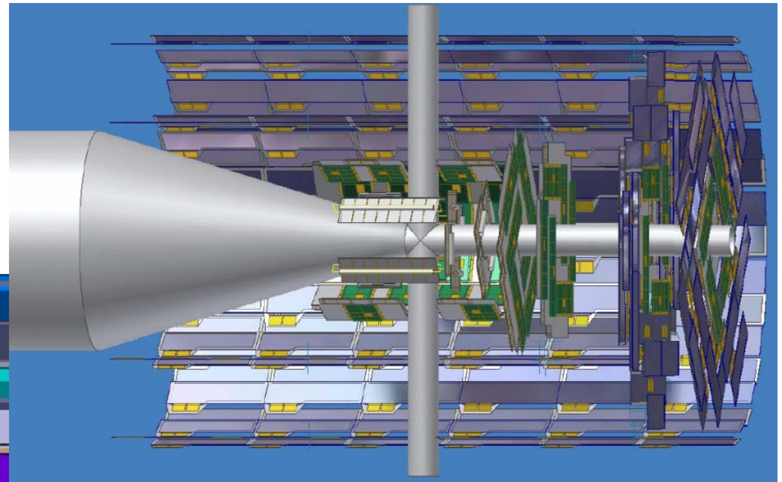
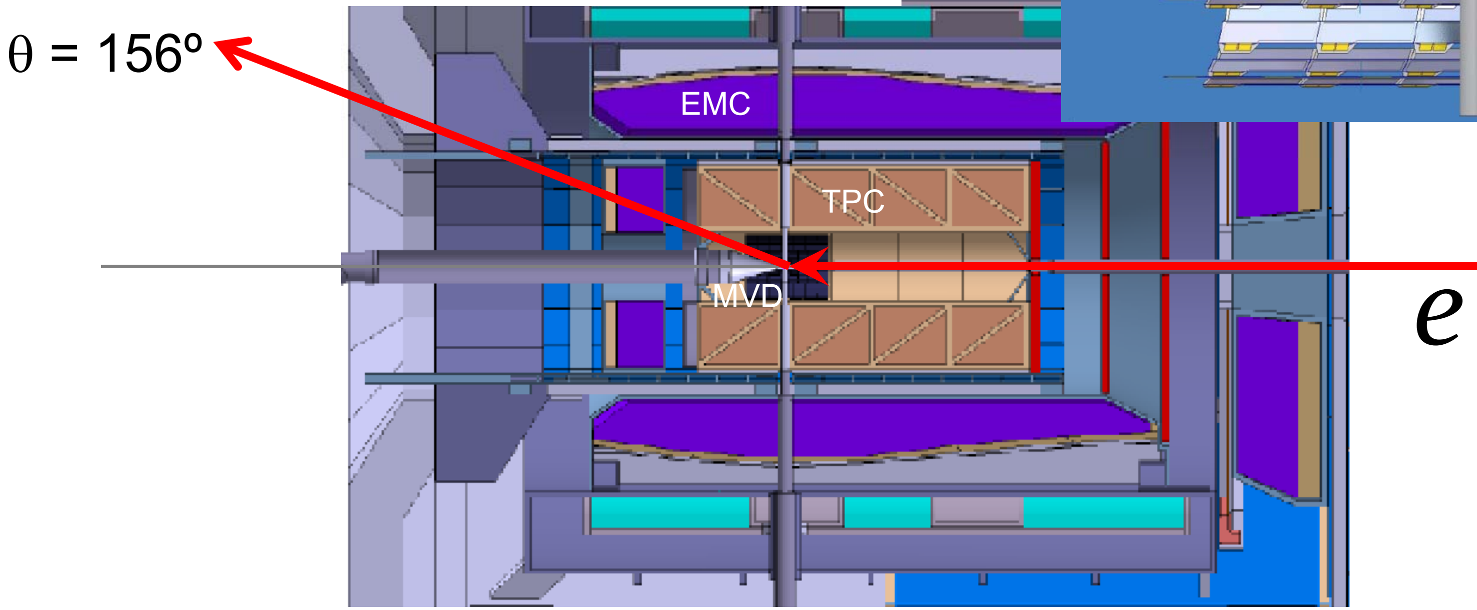
Tracking for electron candidate



Tracking for electron candidate

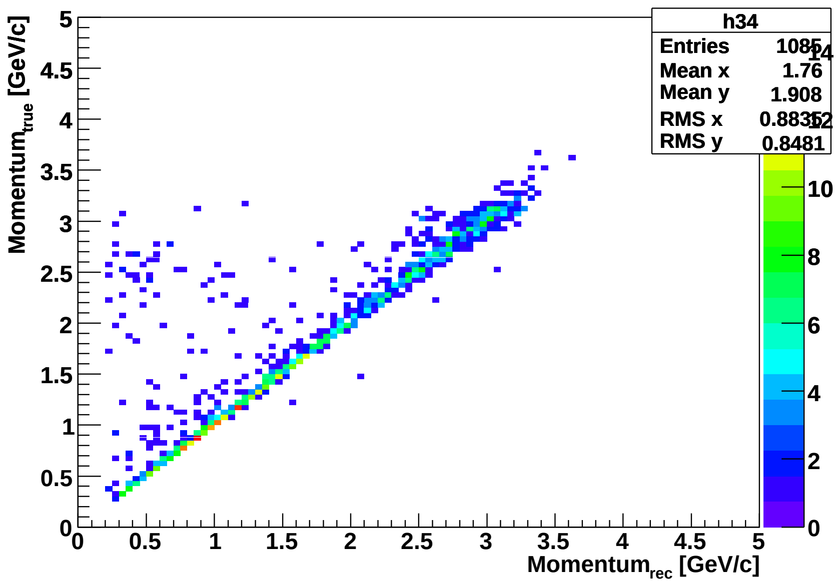




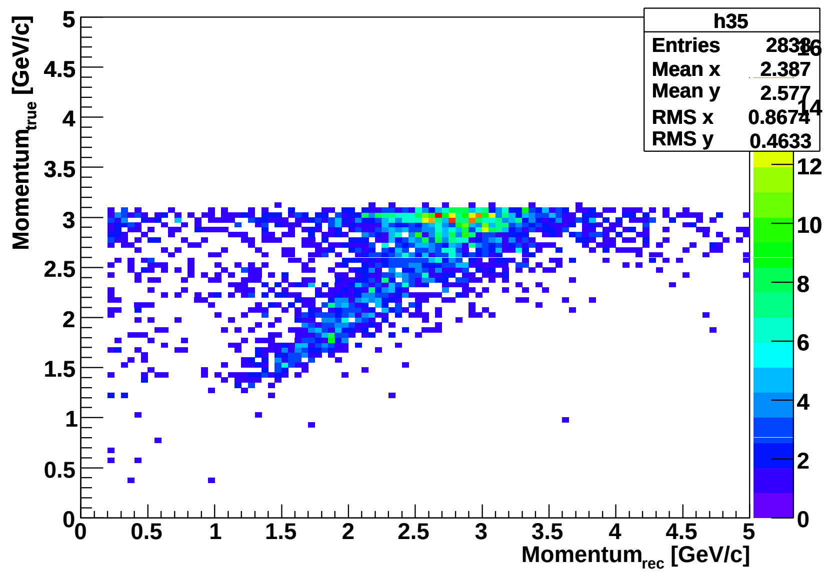


Possible to restore electron?

With EMC & hits in any detector



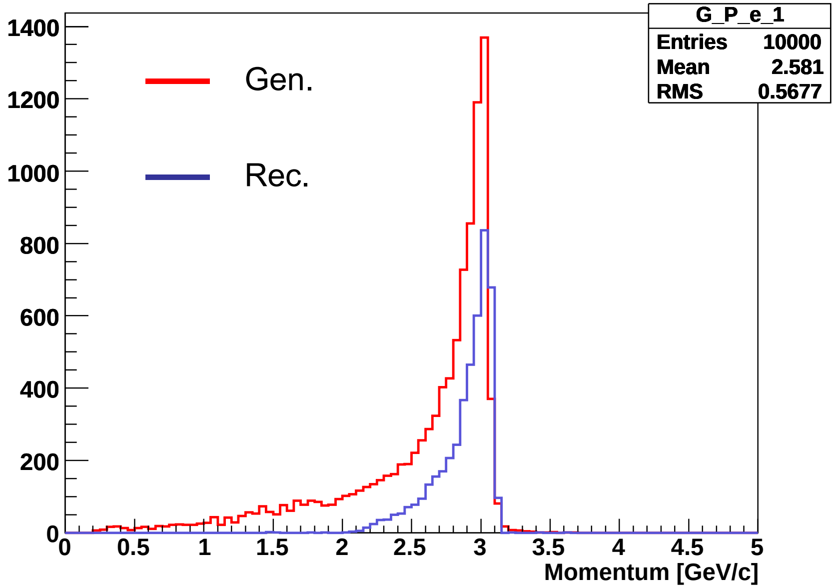
Without EMC & hits in MVD

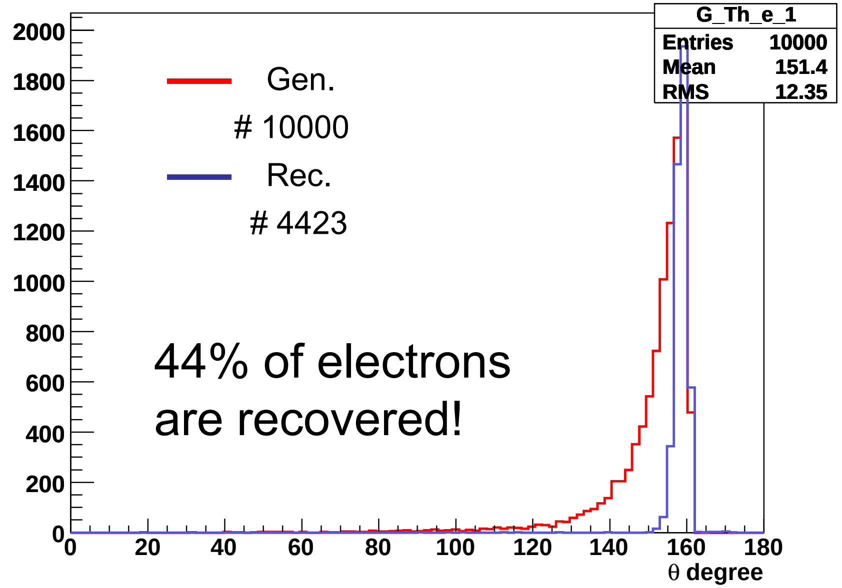


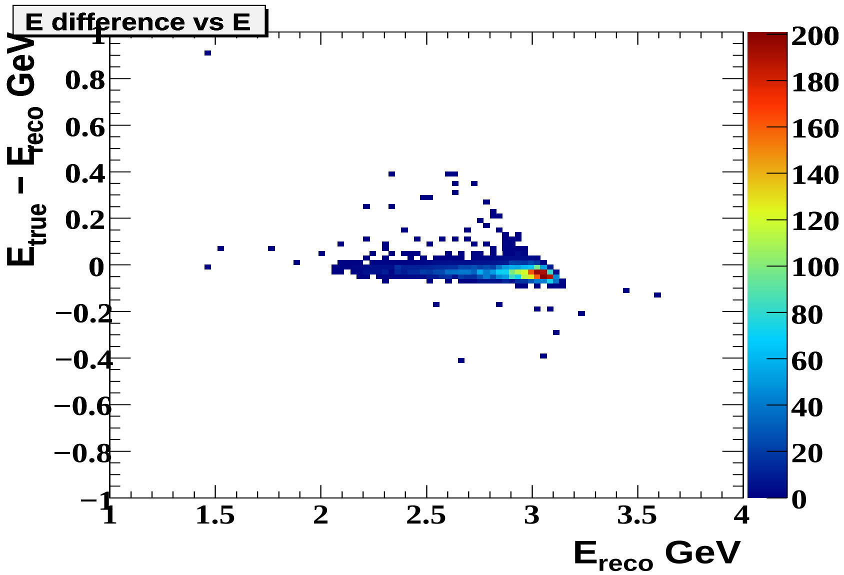
- Only 10% of electron candidates are associated with EMC in LHE tracking
- Recovering of electron in the range of $156^\circ < \theta < 162^\circ$ & $P > 3$ GeV/c can be made with pure EMC information.

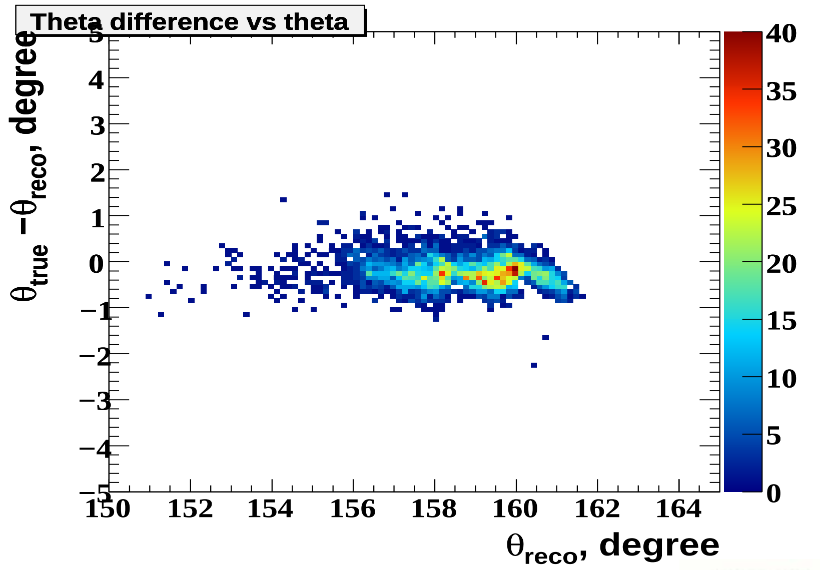
How do we can restore electron?

No association with LHE tracking & using the energy loss of EMC cluster









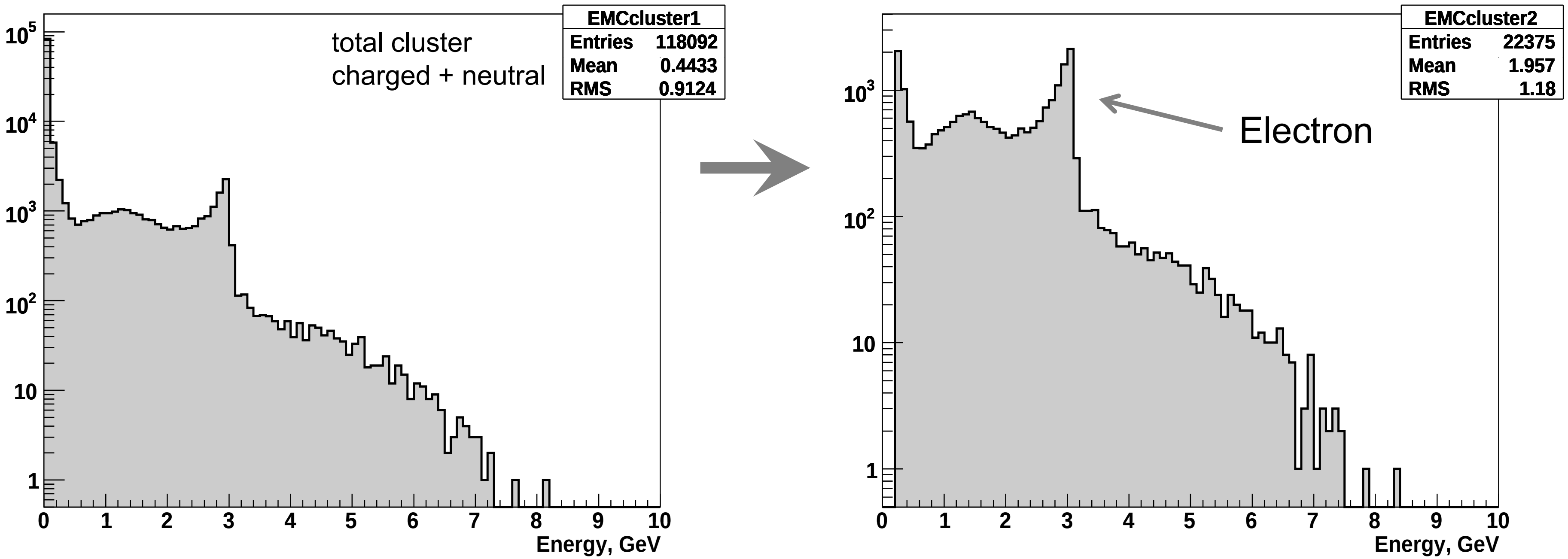
Selection of γ candidate

Using purely EMC information :

— if a cluster is associated with charged track, which is already defined by LHE tracking with EMC, those clusters are excluded.

— energy loss of each cluster > 0.2 GeV and $\theta\gamma$ > 5°

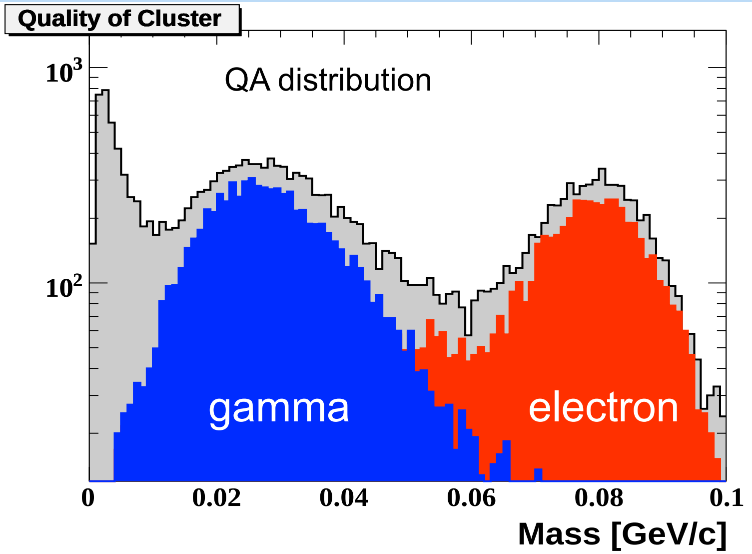
— energy loss correction due to leakage and thresholds for single crystal - 3 MeV, it is roughly 3%, and depends on energy and θ.

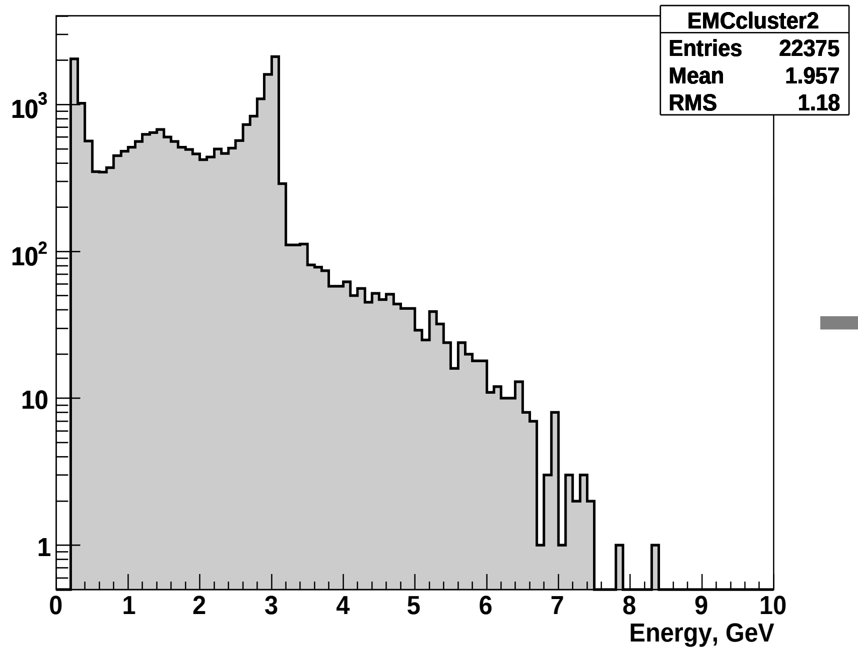


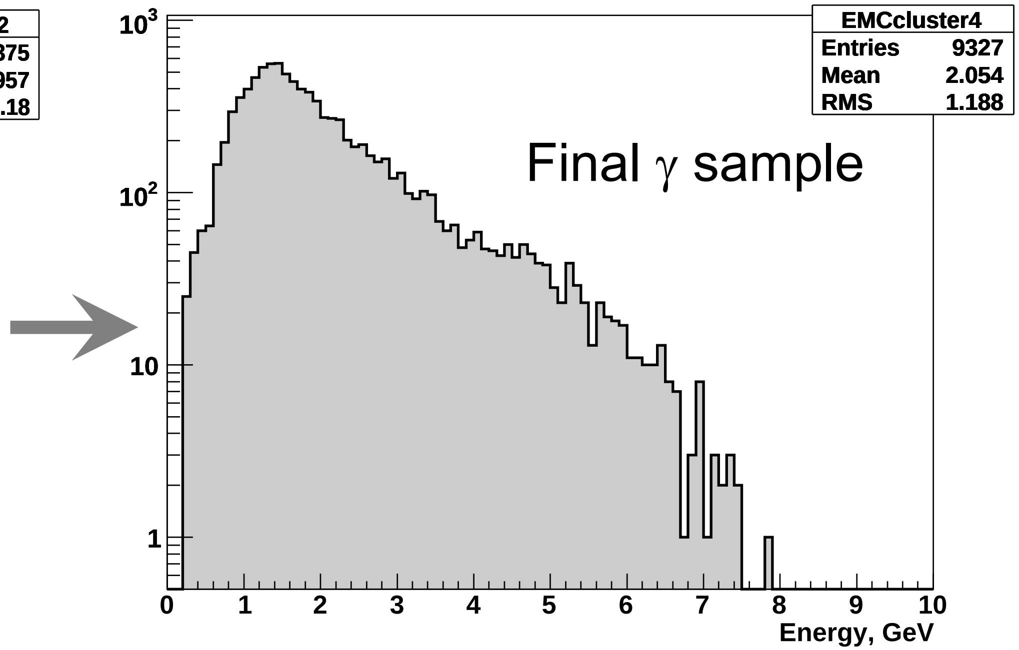
Selection of γ candidate

— Using event shape : θ & ϕ of electron candidates, defined by LHE tracking $|\theta_e - \theta_\gamma| > 5^o$ & $|\phi_e - \phi_\gamma| > 5^o$

— $0.01 < QA_{cluster} < 0.06$ GeV/c^2 for γ

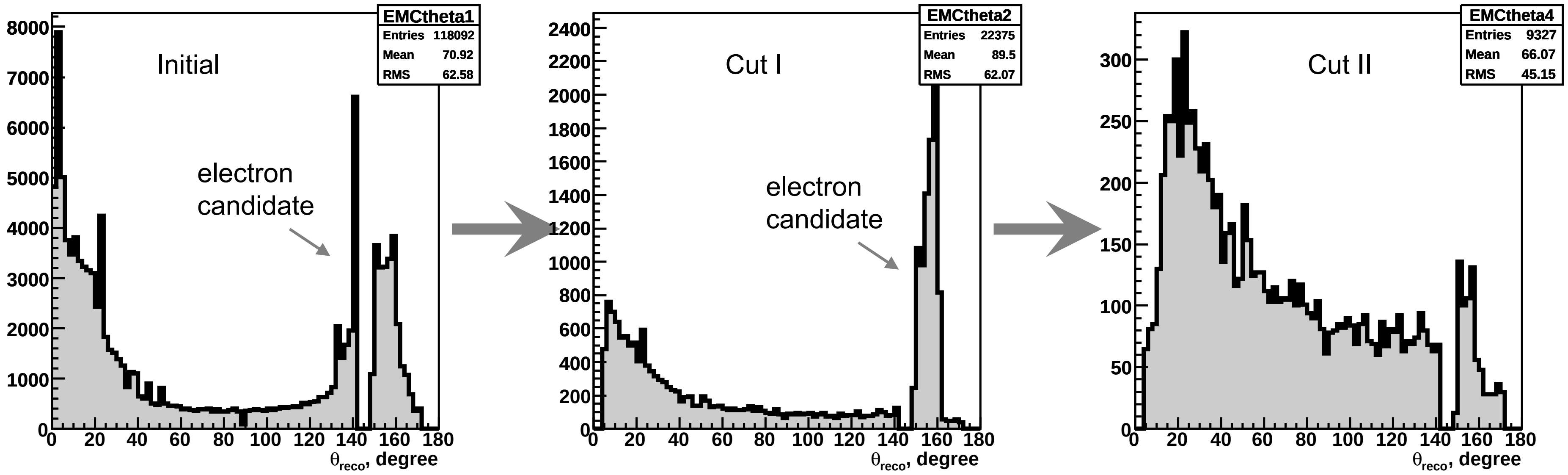






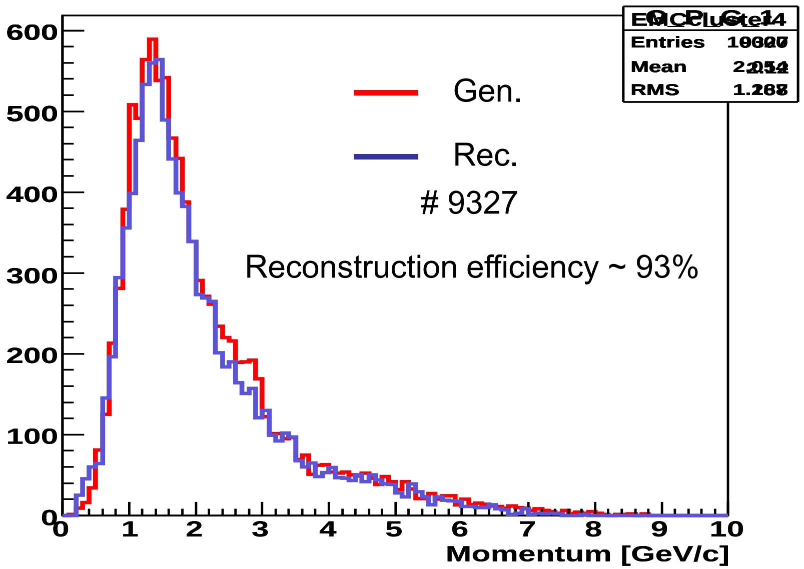
Selection of γ candidate

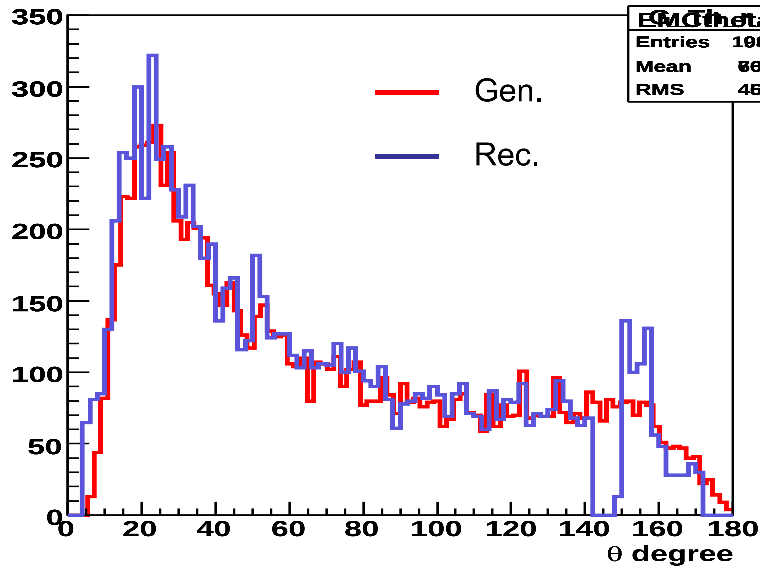
θ distribution for EMC cluster

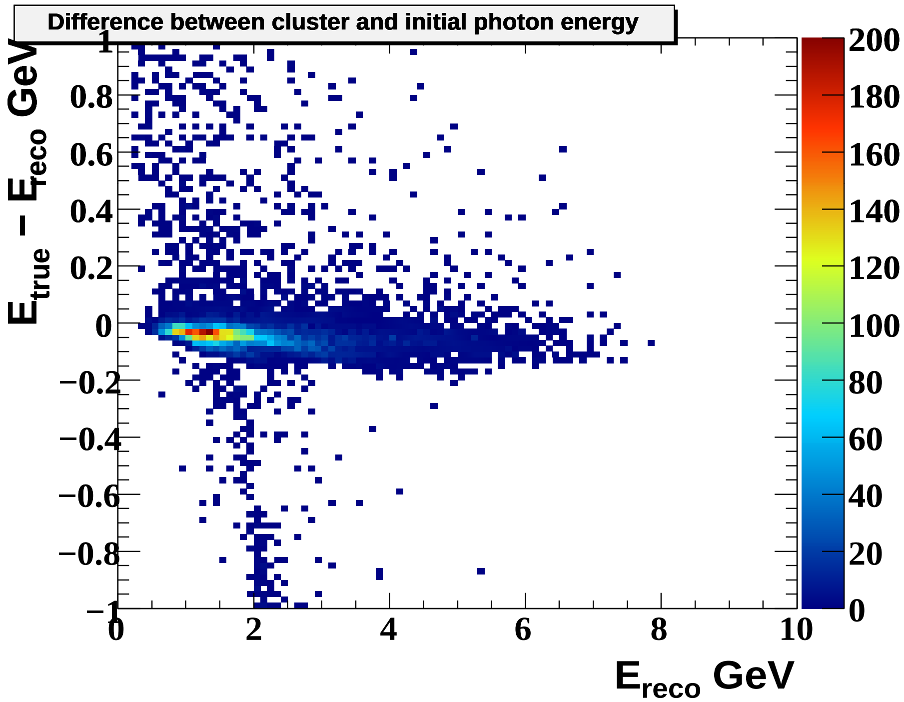


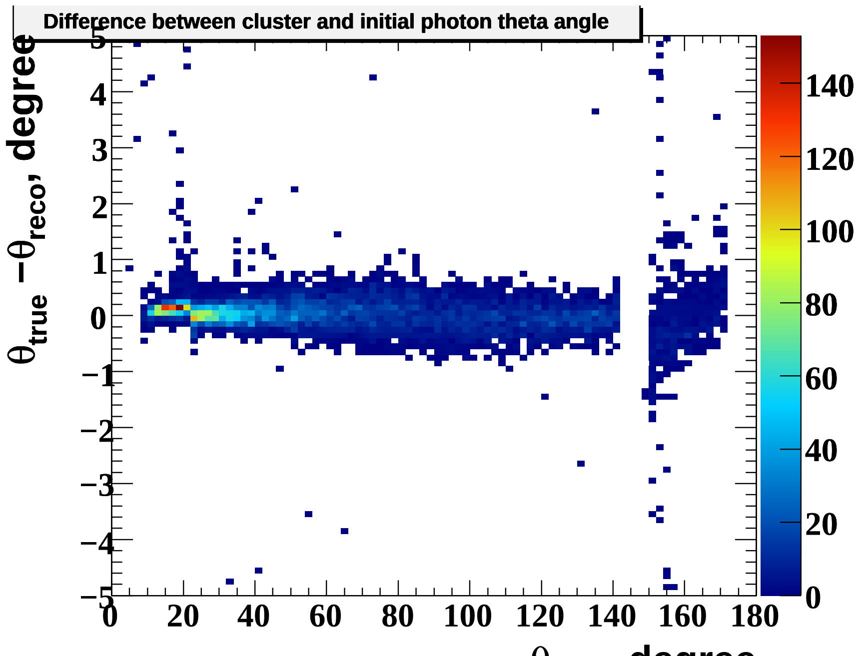
- The gap between barrel and backward EMC at 142º < θ < 149º due to old geometry
- Simplest algorithm finds more than 90% photon candidates
- More sophistcate PID will be performed by neural network using energy deposit in the 3×3 module and 5×5 module.

Selection of γ candidate

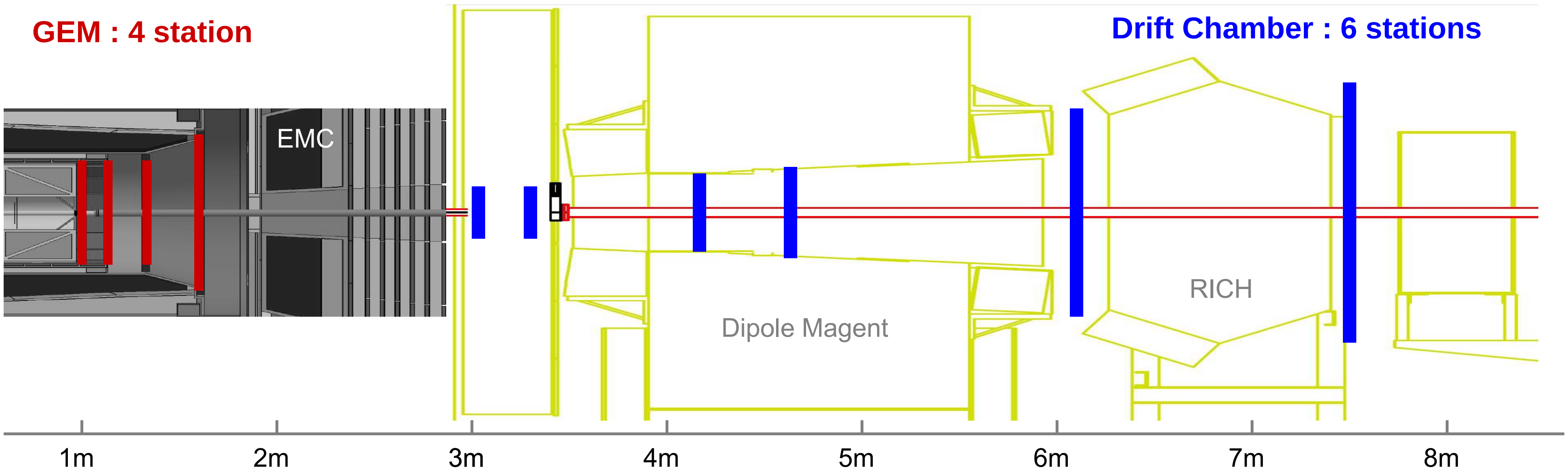








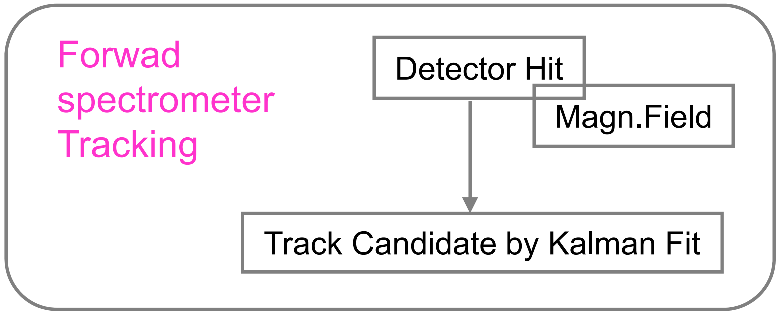
Tracking for proton candidate



Forward spectrometer tracking package
is not completely combined with all devices

To reconstruct proton in FS, an available
detector component is used :

Drift Chamber(DCH)



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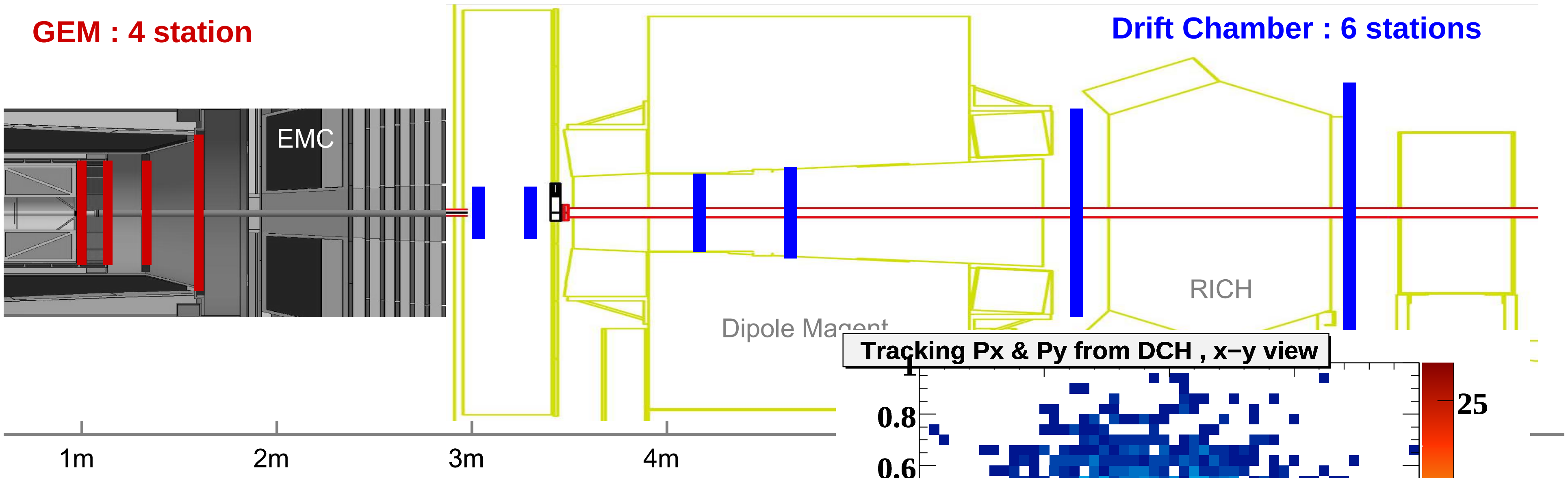

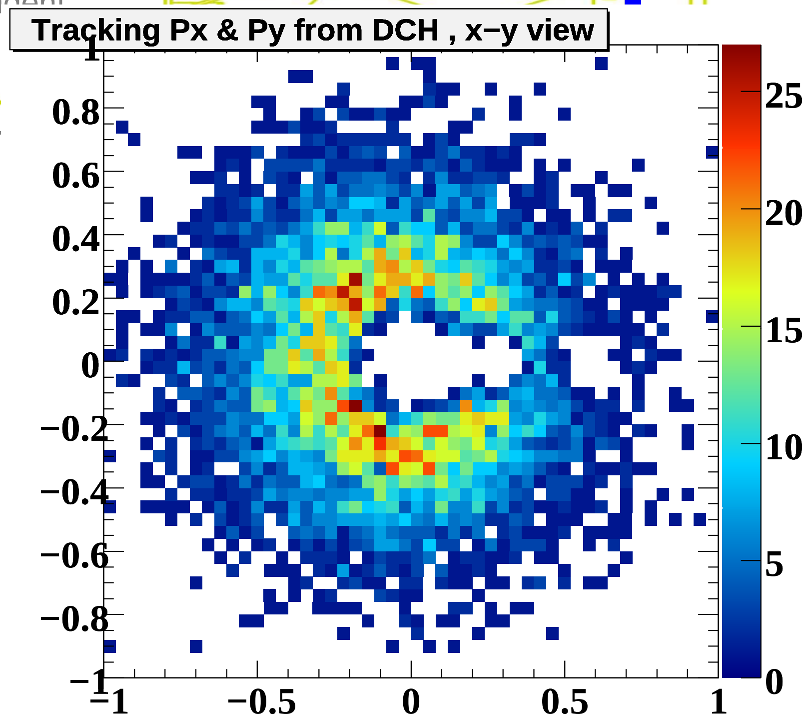

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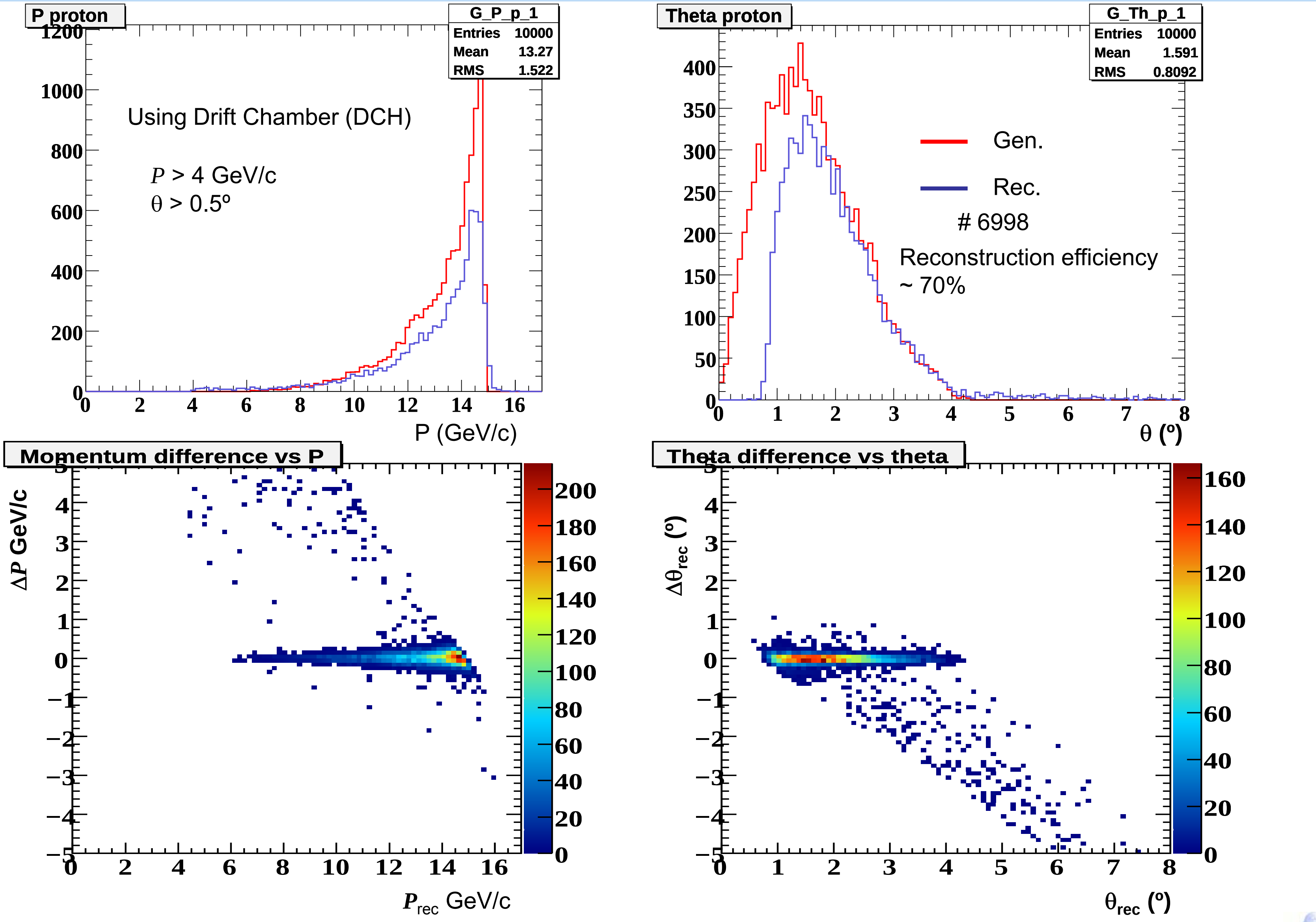
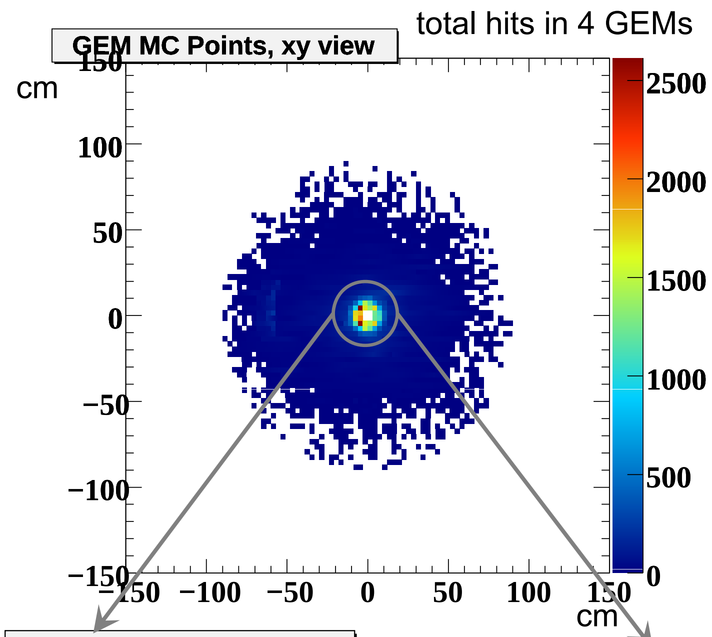
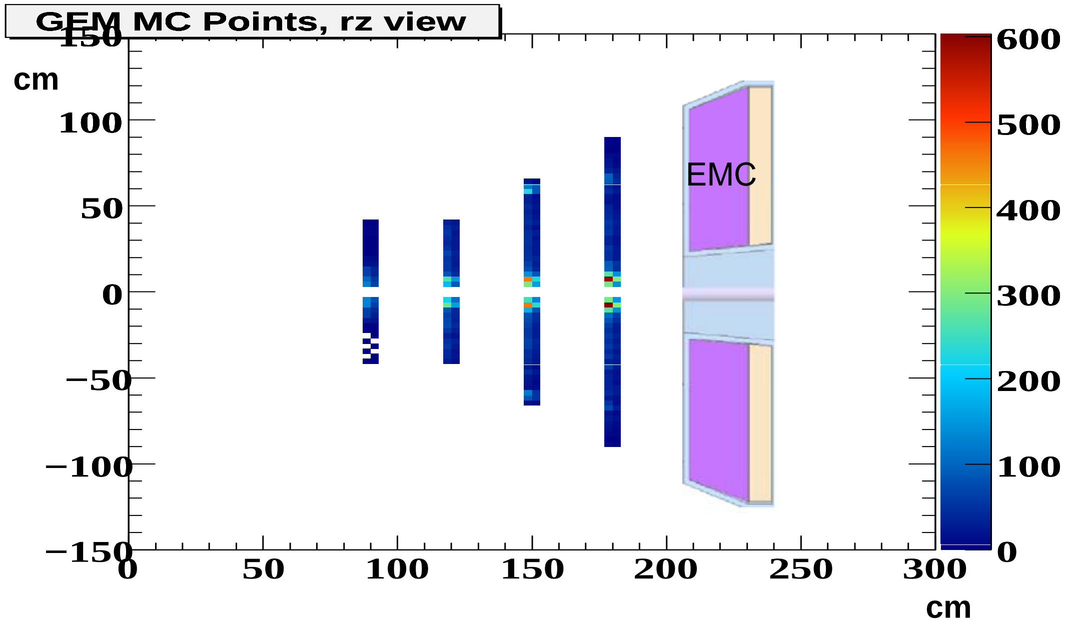
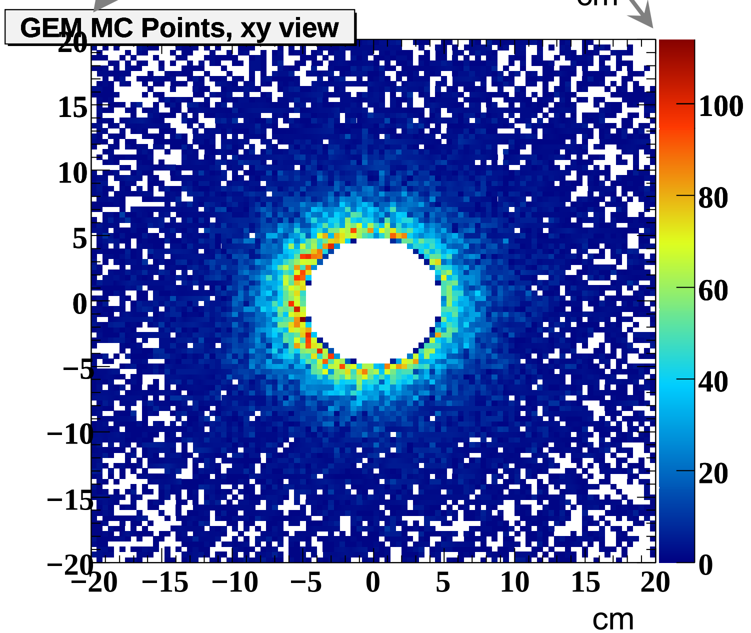


Improvement of proton reconstruction







Reconstruction efficiency for proton can be improved by adding GEM & MvD detector

GEM, DCH & MvD combined tracking package will be prepared soon
Expected reconstruction efficiency ~ 80%

Summary

Full chain MC of DVCS including magnetic field has been simulated with panda detector

- For electron : ~ 90% reconstruction efficiency with LHE tracking & EMC
  need further improvement of tracking

- For photon : ~ 90% reconstruction efficiency with EMC
  seems to be OK

- For proton : ~ 70% reconstruction efficiency with only Drift Chamber
  need global tracking including GEM & MvD

The panda detector see DVCS event & reconstructed well
but small θ detections are crucial!

Outlook

Detector simulation

- Estimation of resolution, efficiency, and acceptance
- Calculation of kinematics after combining the full tracking
- Realistic beam profile & interaction point

MC Generator

- Use different model of MC generators for DVCS
  - What is more suited for intermediated x_{Bj}?
  - FFS model (small x_{Bj}) & VGG model (large x_{Bj})
- Including Bethe-Heitler background & diffractive dissociation