Reconstruction of Σ^0 hyperons at the MPD Experiment

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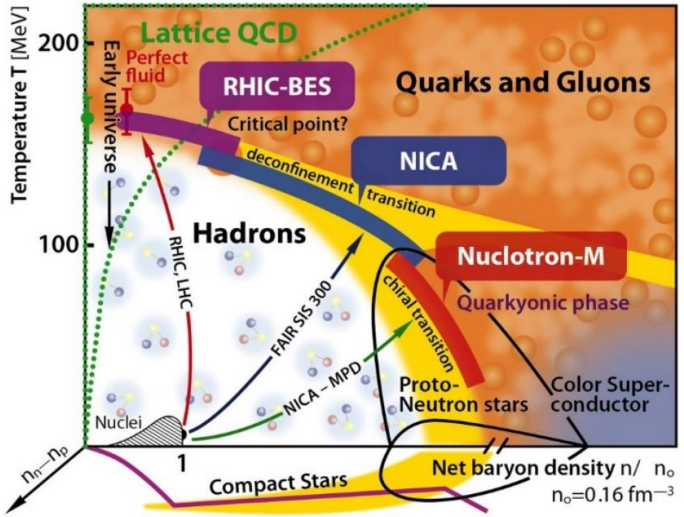
MPD Collaboration

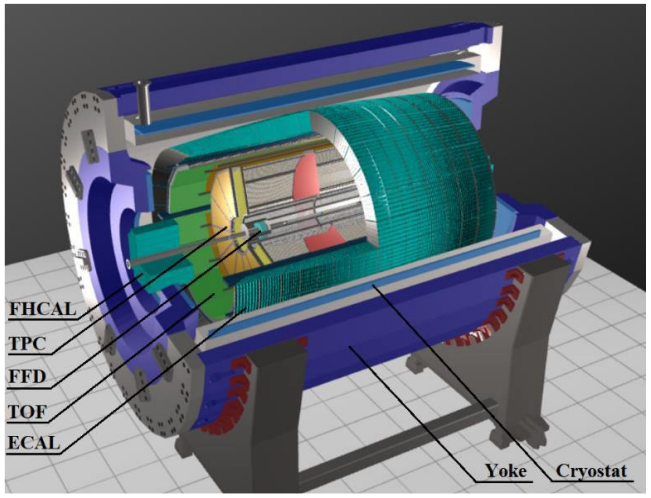
Outline

- **Motivation**
- **Dataset**
- **Photon Reconstruction**
- **Λ Reconstruction**
- **Σ^0 Reconstruction**
- **Summary**

Motivation



Phase diagram



MPD detector

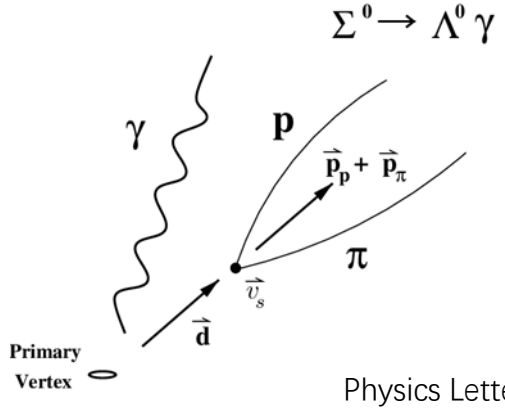
The main purpose of the MPD experiment is to search for the first order phase transition and the critical end-point

Hyperons production in heavy-ion collisions is important for addressing many open questions

$\Sigma^0 \rightarrow \Lambda + \gamma$ ($BR \approx 100\%$):

$$M_{\Sigma^0} = 1192.642 \pm 0.024 \text{ MeV}$$
$$\tau_{\Sigma^0} = 7.4 \pm 0.7 \times 10^{-20} s$$

- Study of strangeness production mechanisms
- Feed-down contribution to Λ and photon spectrum
- As a reference to tune the event generators and models



Physics Letters B 479 (2000)

Dataset

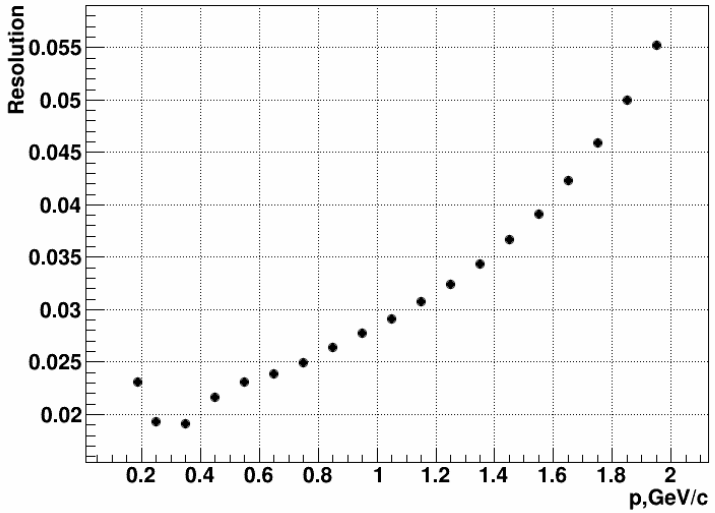
- Collision system: Bi+Bi@9.2 GeV
- Event generator: UrQMD
- Production: 50M events https://mpdforum.jinr.ru/t/request-25-general-purpose-50m-urqmd-bibi-9-2-second-collaboration-paper/455 + 15M events https://mpdforum.jinr.ru/t/request-34-general-purpose-15m-urqmd-bibi-9-2-dielectron-enhanced/618
- Analysis Train (Wagon - pairGLambda):https://mpdforum.jinr.ru/t/request-12-input-request-25-request-34/682
- Event cut: Primary vertex of event reconstructed and vertex_z cut < 100 cm

Photon Reconstruction

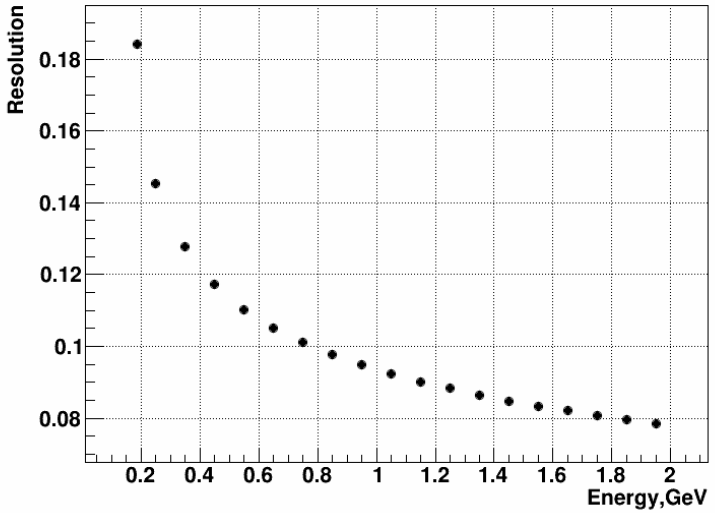
The photon from the Σ^0 is very soft (low energy) due to the small mass difference between Σ^0 and Λ ($m_{\Sigma^0} - m_{\Lambda} \approx 77$ MeV).

Energy resolution of the TPC is better than that of ECal at low energy.

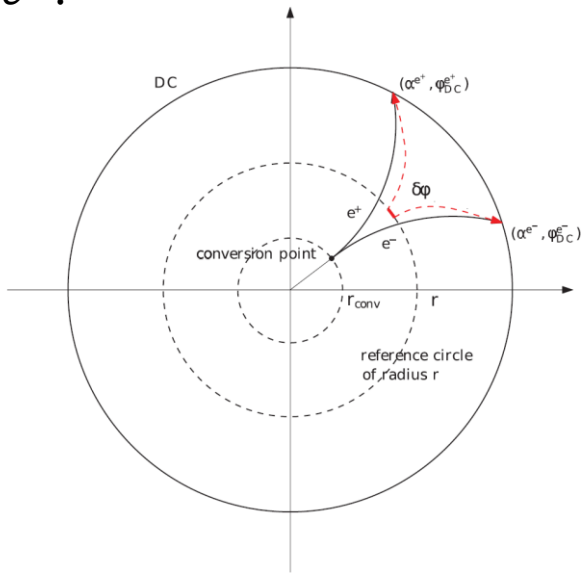
The best way would be to reconstruct photons from photon conversion: $\gamma^* \rightarrow e^+e^-$.



Momentum resolution



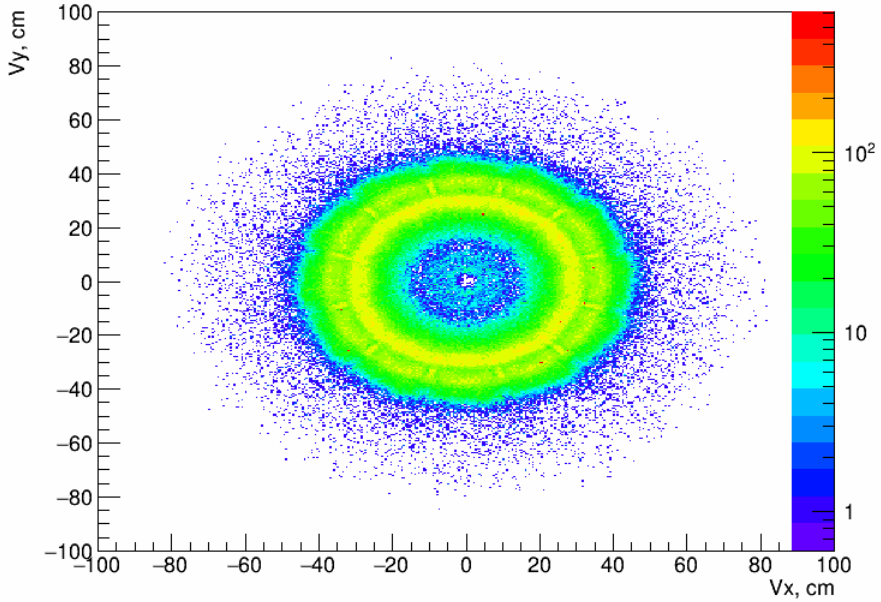
Energy resolution



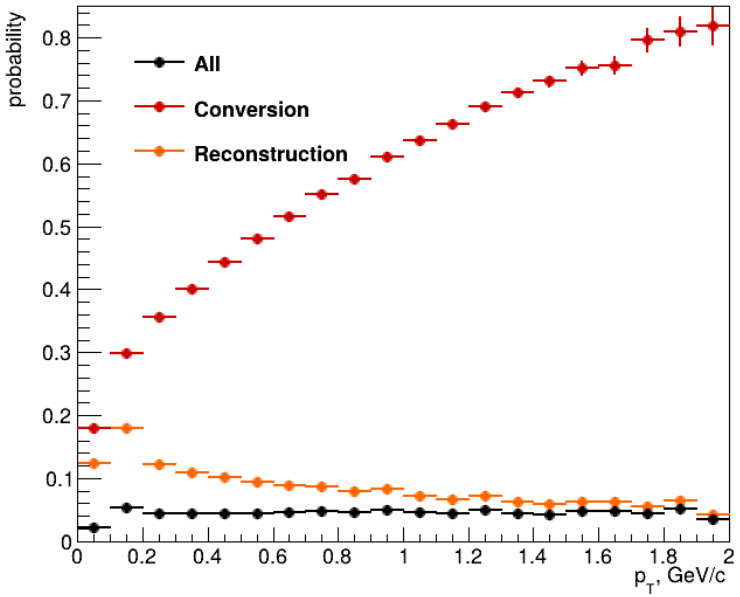
Photon conversion arXiv:1907.08893

Photon Conversion

Photon will convert into a positron-electron pair when it interacts with the materials in the detectors, the probability of photon conversion strongly depends on the material budget



Conversion pairs



Conversion probability

Beam pipe: $r = 4\ cm$
TPC inner structures : $r = 27\ cm$

Only about 2% photon conversion can be detected

Photon Reconstruction

Photon reconstruction by photon conversion:

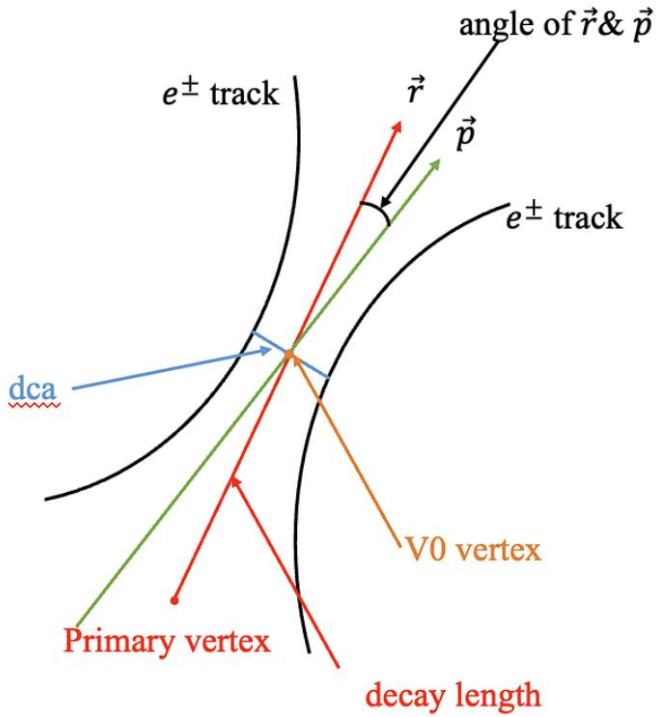
$$\gamma^* \rightarrow e^+e^-$$

Electron identification by TPC and TOF:

- $n_{hits} > 10$
- $p_T > 0.05$ GeV/c
- $n\sigma_{el}^{tpc} < 3.0$
- $n\sigma_{el}^{tof} < 3.0$(if TOF Match)

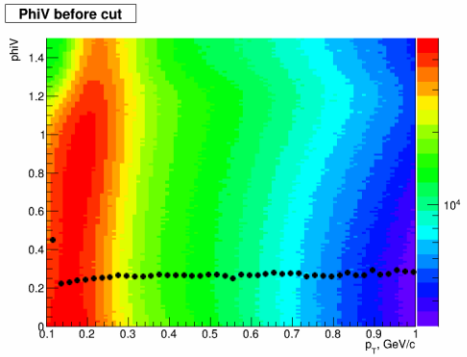
Pair's variables:

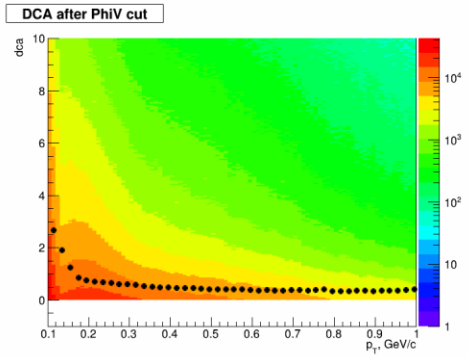
- dca: distance of closest approach for e^+e^- tracks
- Chi2: quality of the secondary vertex reconstruction
- angle: between $\vec{r}$ & $\vec{p}$
- decay length: the distance from primary vertex to V0 vertex
- mass: the mass of mother particle of e^+e^- pair

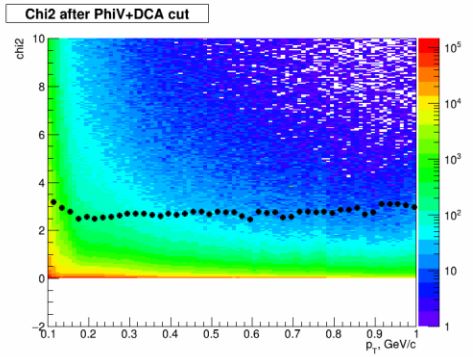


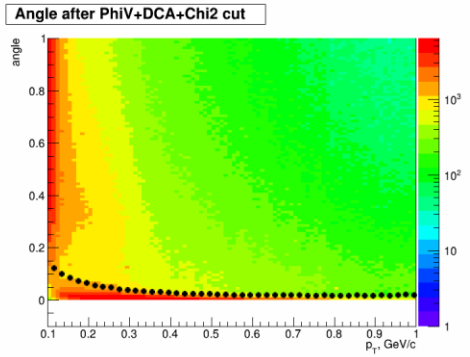
Topological structure of photon conversion

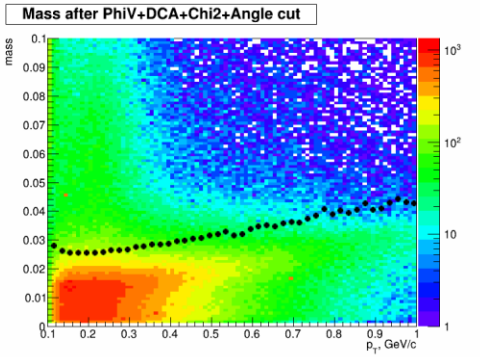
Photon Reconstruction



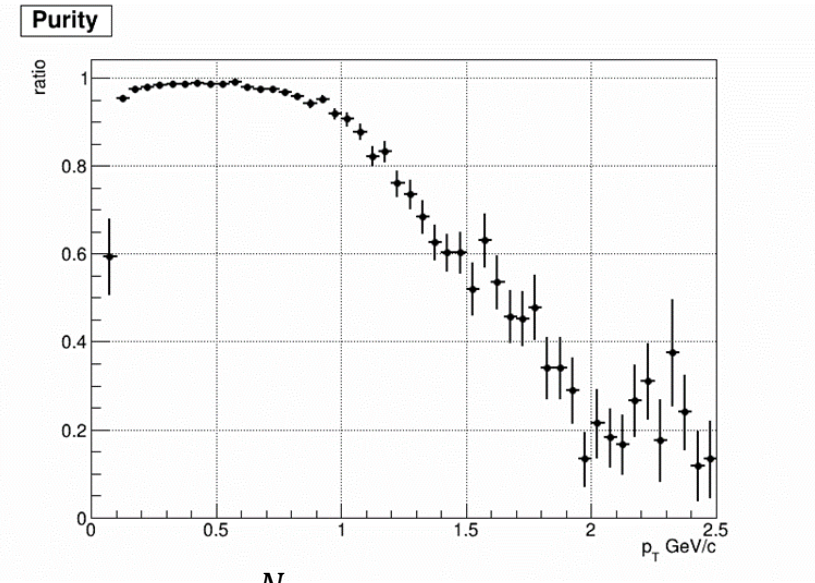


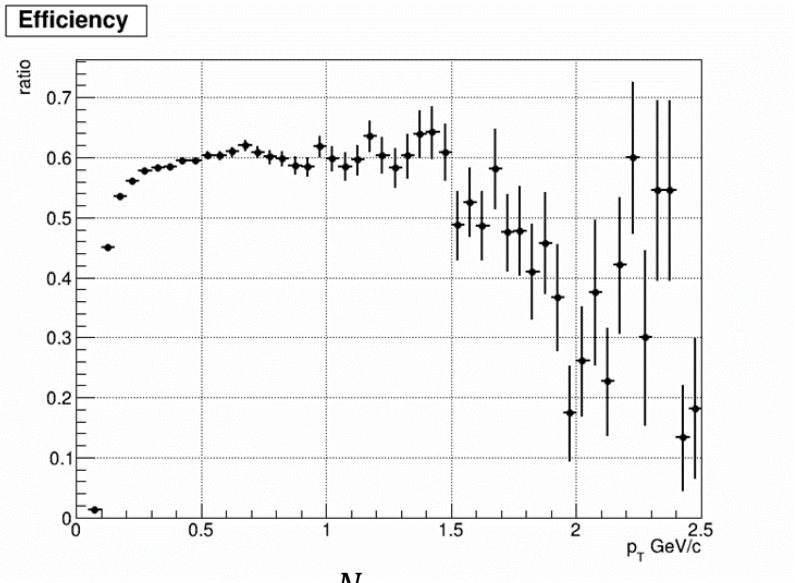






The black dotted curves as selection, which a range accounts for 90% of photon in the total signal.





The purity of photons was large than 90% at $0.1 < p_T < 1.0$ GeV/c

$$\text{Purity} = \frac{N_{True\ pairs\ after\ cut}}{N_{All\ pairs\ after\ cut}}$$

$$\text{Efficiency} = \frac{N_{True\ pairs\ after\ cut}}{N_{Ture\ pairs\ before\ cut}}$$

Λ Reconstruction

Λ reconstruction by the decay channel with BR ≈ 64.1%:

$$\boldsymbol{\Lambda \rightarrow p + \pi^-}$$

p and π^- are selected by the TPC and TOF.

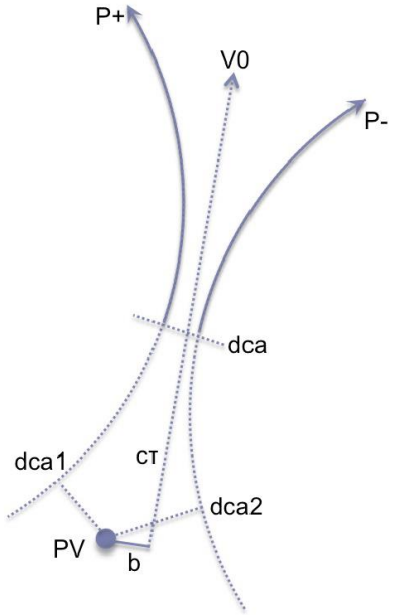
- $n_{hits} > 24$
- $p_T > 0.1$ GeV/c

proton:

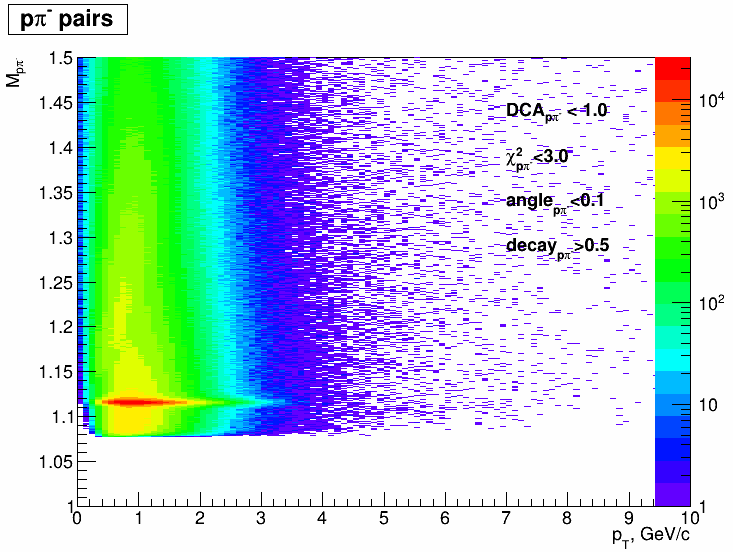
- $n\sigma_p^{tpc} < 3.0$
- $n\sigma_p^{tof} < 3.0$(if TOF Match)
- $\chi_p^2 > 3.0$

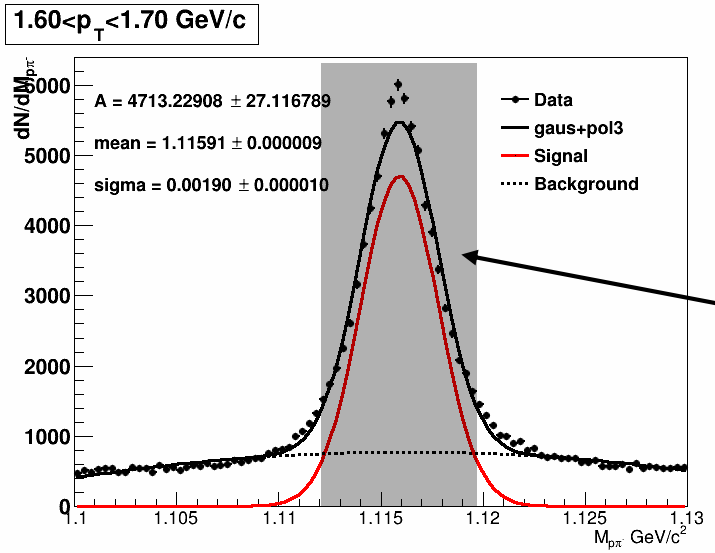
π^-:

- $n\sigma_{\pi^-}^{tpc} < 3.0$
- $n\sigma_{\pi^-}^{tof} < 3.0$(if TOF Match)
- $\chi_{\pi^-}^2 > 7.0$



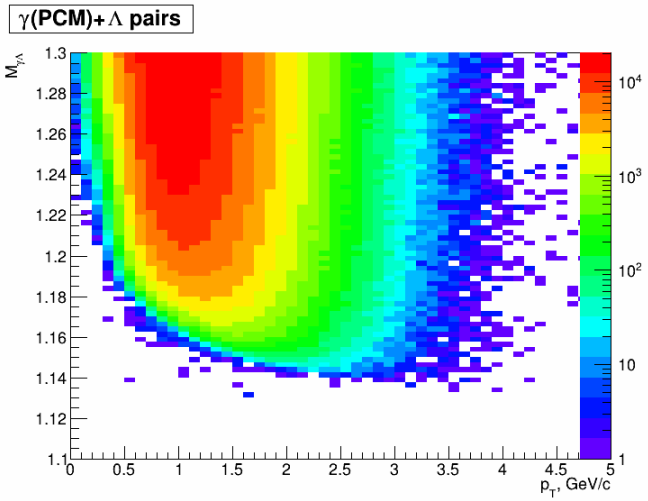
Topological structure of Λ decay

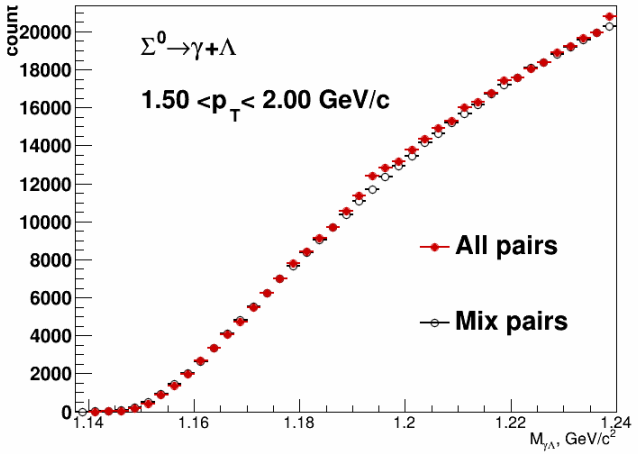


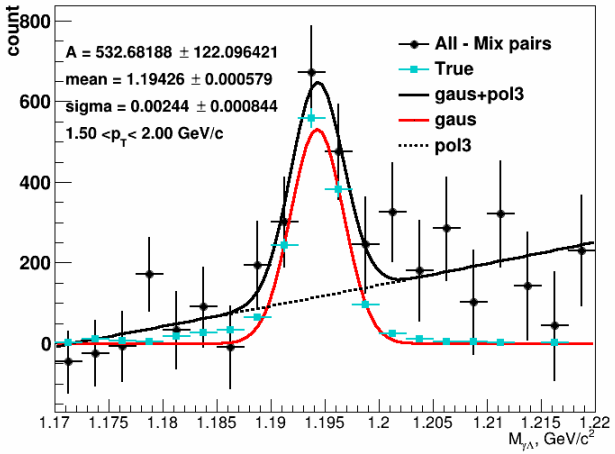


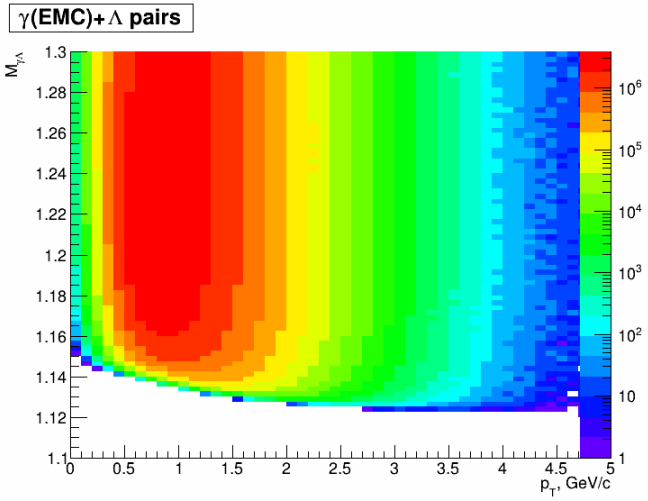
$| M_{p\pi^-} - M_{\mathrm{pdg}_\Lambda} | < 2 * \sigma_\Lambda$ as Λ for reconstruction of Σ^0

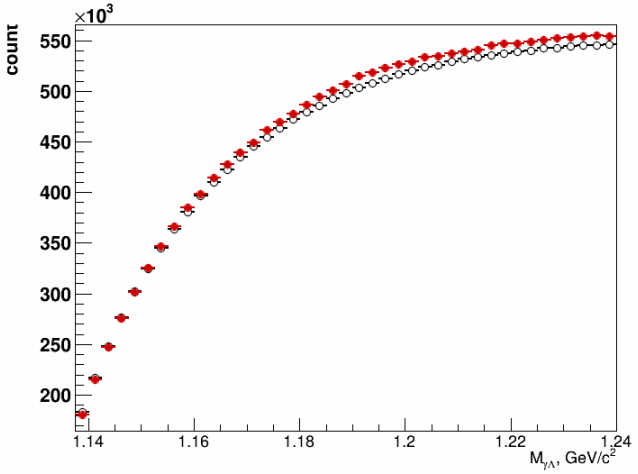
Σ^0 Reconstruction

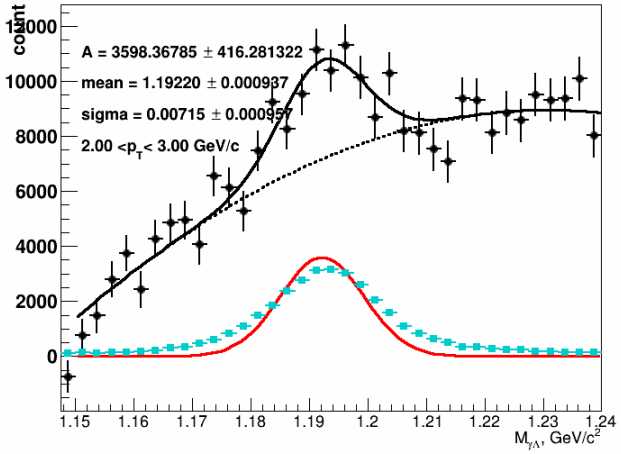








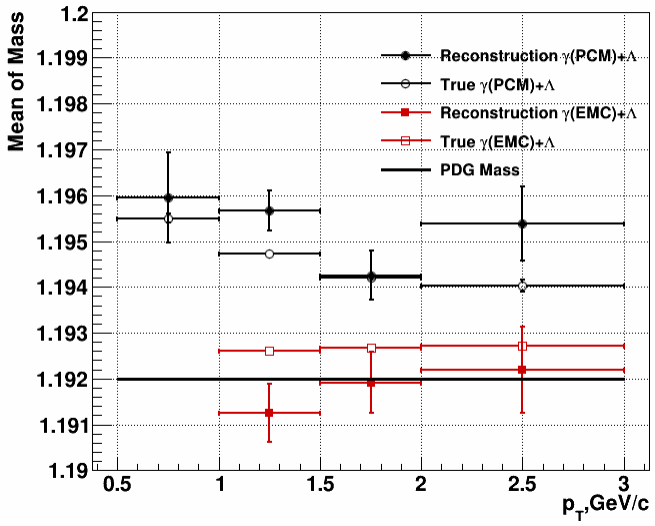




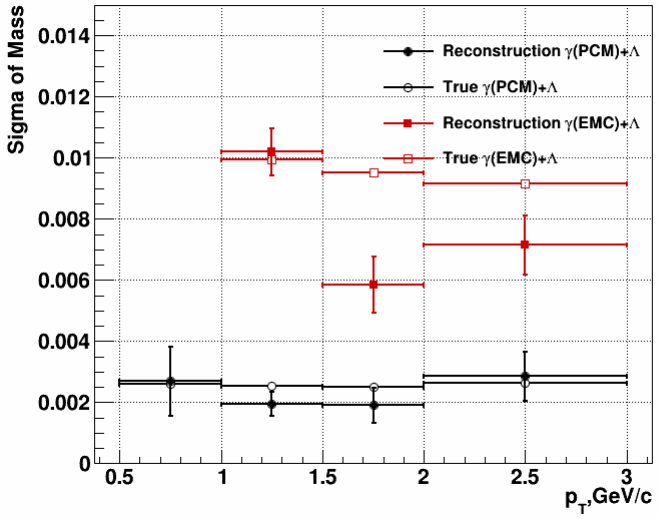
The width of Σ^0 reconstruction by EMC method was large than PCM method

The EMC method had many backgrounds that cannot be extracted by mix events

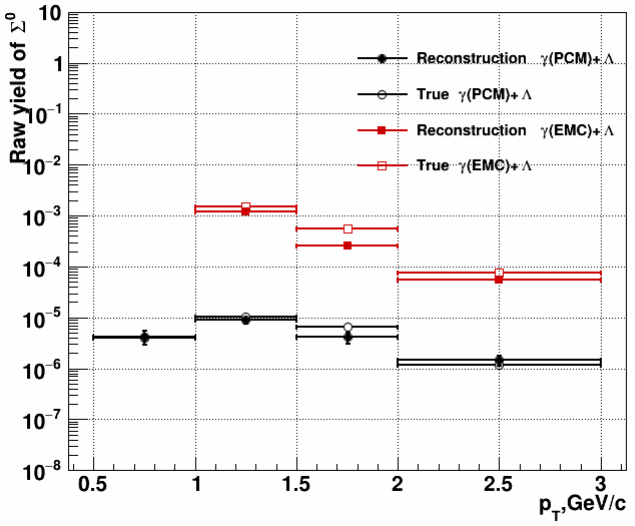
Σ^0 Reconstruction



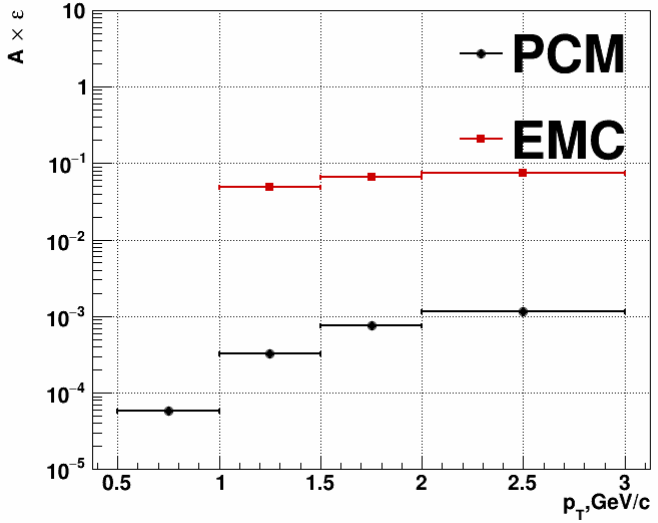
Invariant mass



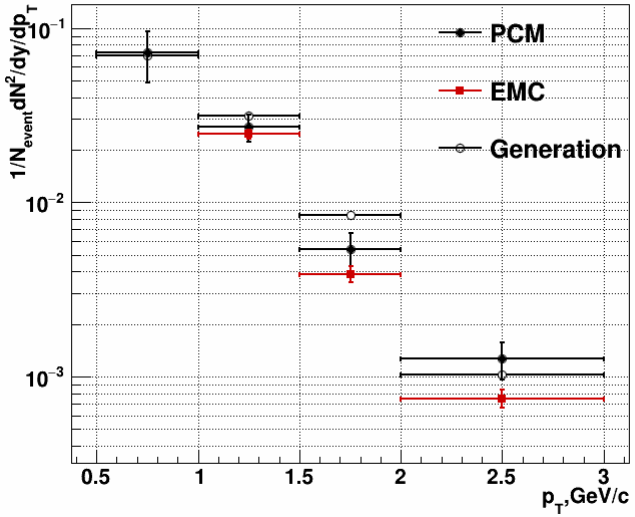
Width



Raw Yield



Efficiency



Yield

Measurements for Σ^0 are possible starting from p_T ~ 500 MeV/c in rapidity range |y|<0.5

The fit mean of mass are large than the pdg mass of Σ^0 reconstruction by PCM method

The yields obtained for Σ^0 are not completely consistent with the truly

Summary

- **First observation of Σ^0 for the MPD:**
  - **Photons reconstruction by photon conversion method has high purity**
  - **Lambdas selection was rough and need to improve selections**
- **Signals for Σ^0 are observed in 0.5< p_T <3.0 GeV/c**
- **The first-look results of yields for reconstructed of Σ^0 are not completely consistent with the generated spectra, work in progress**

Next to do:

- **Fine tuning of fits is still required**
- **Improve Lambdas and Photons selections to provide better significance and coverage**

Summary

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Next to do:

Thanks!

- **Fine tuning of fits is still required**
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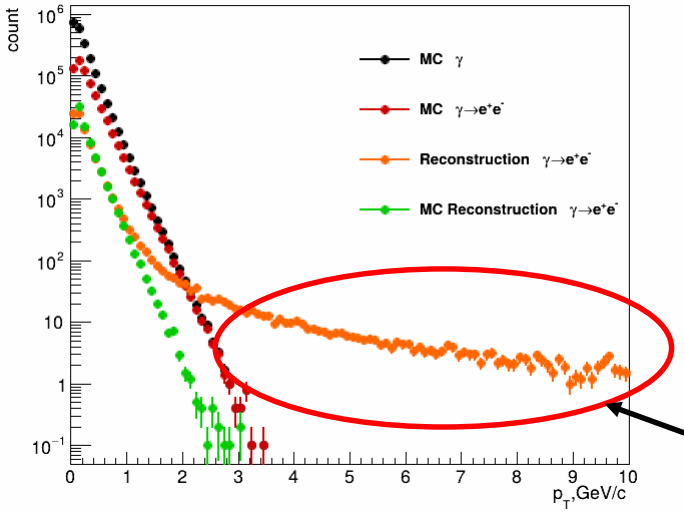
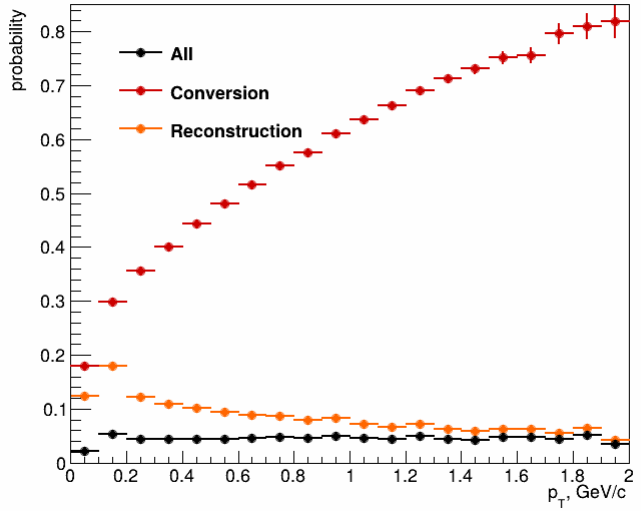
Backup

Photon



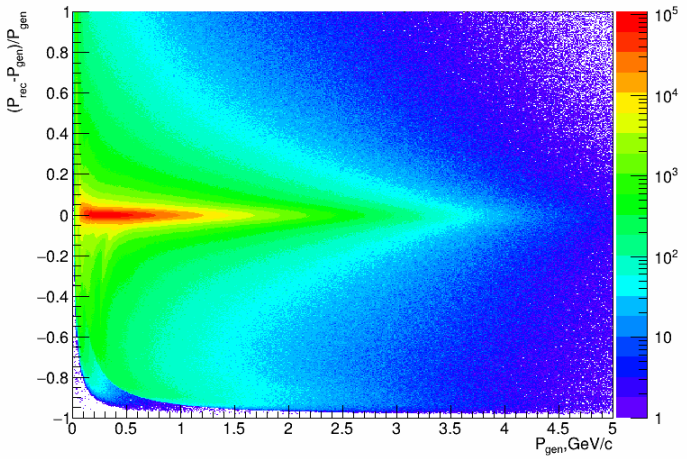


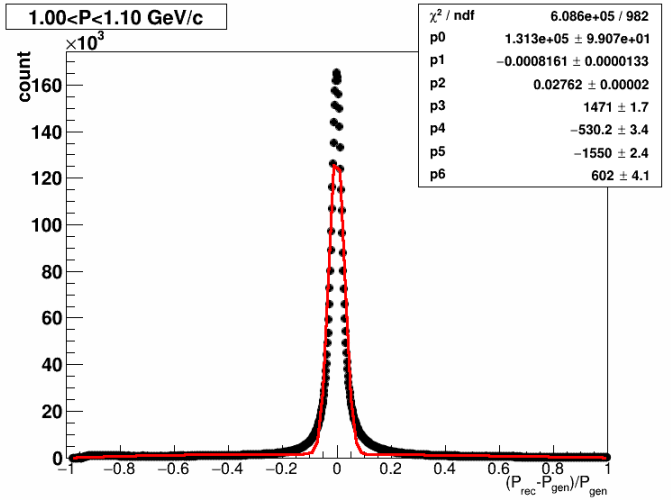
- MC_{γ}: γ from MCStack
- $MC_{\gamma\to e^+e^-}$: $\gamma \to e^+e^-$ from MCStack
- $Reconstruction_{\gamma\to e^+e^-}$: $\gamma \to e^+e^-$ from MpdTpcKalmanTrack
- $MC\ Reconstruction_{\gamma\to e^+e^-}$: $\gamma \to e^+e^-$ from MpdTpcKalmanTrack, p_T from MCStack

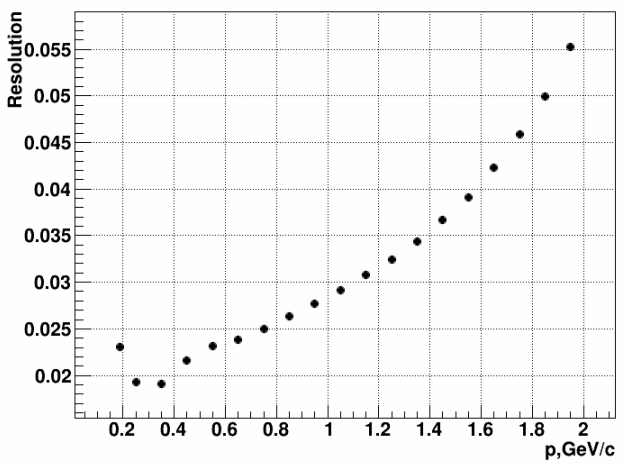
The track used in reconstruction was primary track, so the momentum of e^+e^- pairs was not right

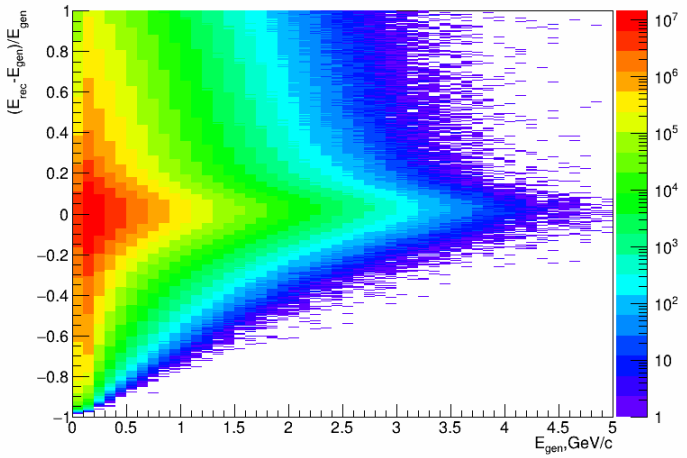
- All: $P = \frac{N_{MC\ Reconstruciton\ (\gamma\to e^+e^-)}}{N_{MC\ (\gamma\to e^+e^-)}}$
- Conversion: $P = \frac{N_{MC\ (\gamma\to e^+e^-)}}{N_{MC\ \gamma}}$
- Reconstruction: $P = \frac{N_{MC\ Reconstrution\ (\gamma\to e^+e^-)}}{N_{MC\ (\gamma\to e^+e^-)}}$

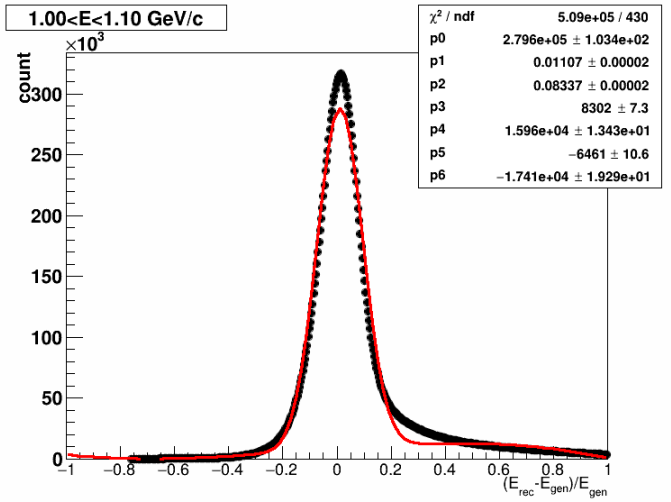
Resolution

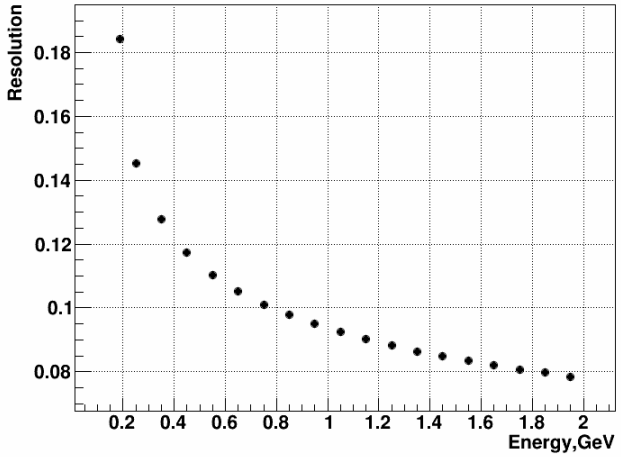








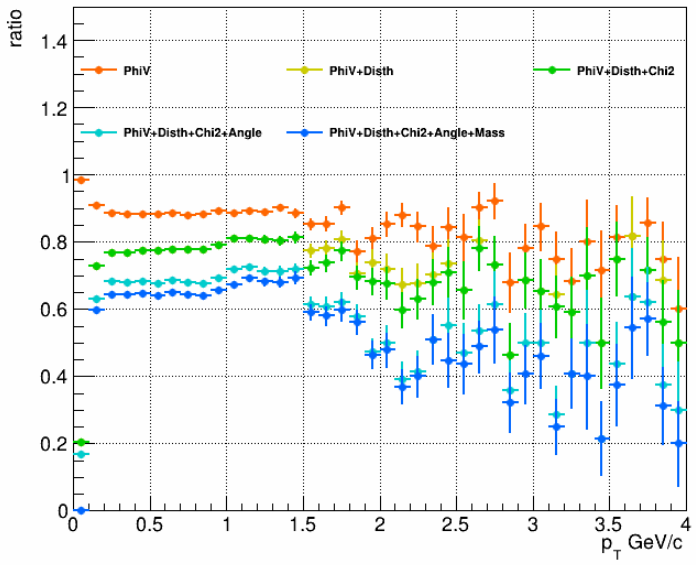




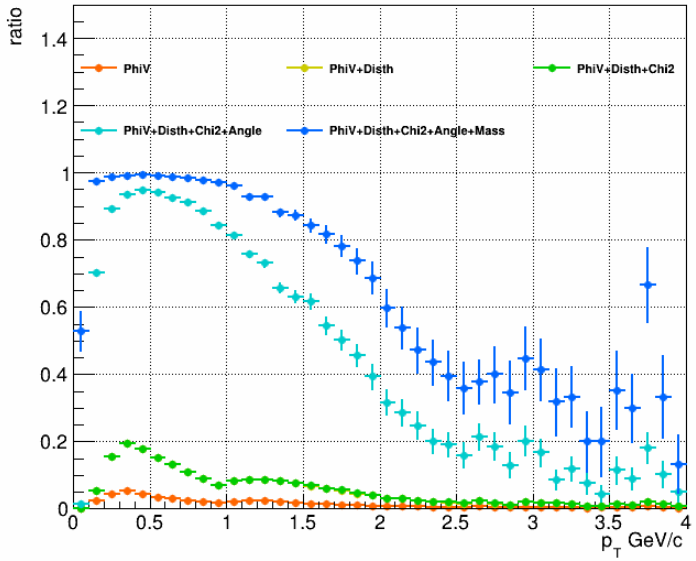
Fit different $\mathrm{P(E)}$ bins $(\mathrm{P}_{rec}-\mathrm{P}_{gen})/\mathrm{P}_{rec}$ $((\mathrm{E}_{rec}-E_{gen})/\mathrm{E}_{rec})$ distribution by a Gaussian function, the Gaussian fitted sigma as a resolution.

Efficiency and purity

Efficiency

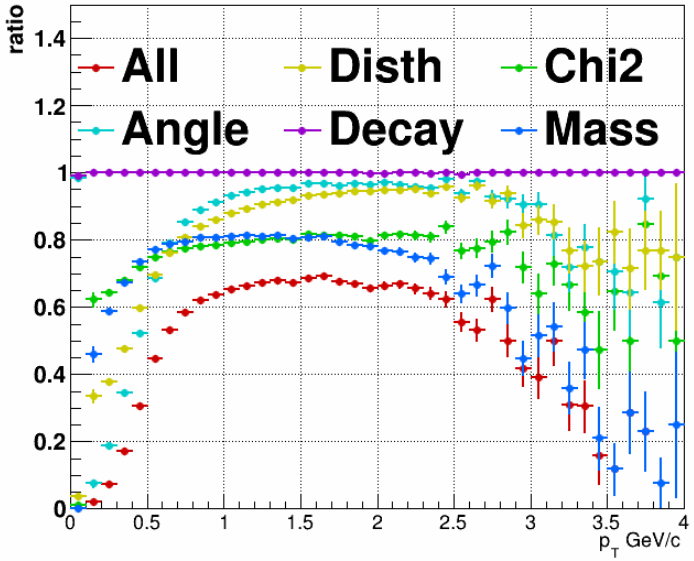


Purity

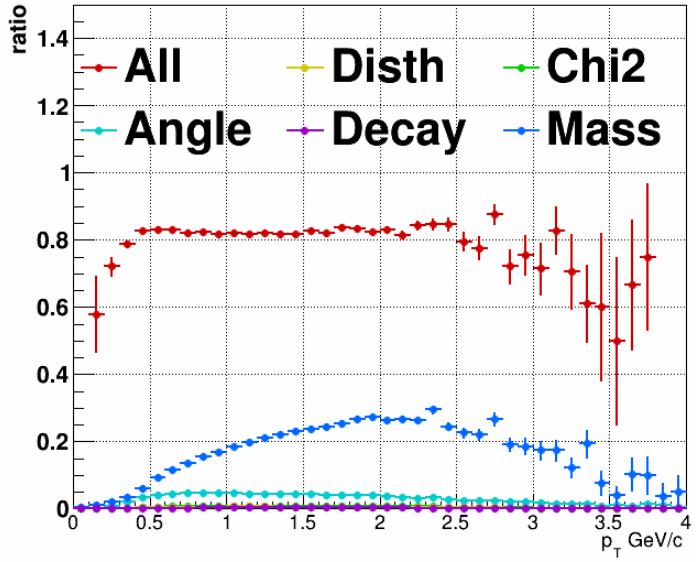


- $PhiV < 1.0\sigma_{PhiV}$
- $Disth < 1.0\sigma_{disth}$
- $\chi^2 < 1.0\sigma_{\chi^2}$ &&$p_T > 1.5$
- $angle < 1.0\sigma_{angle}$
- $Mass < 1.0\sigma_{Mass}$

Efficiency of Λ reconstruction



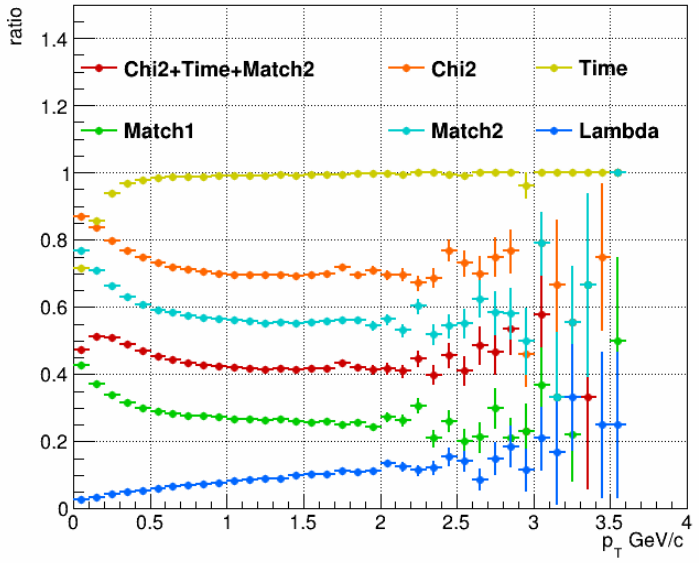
Purity of Λ reconstruction



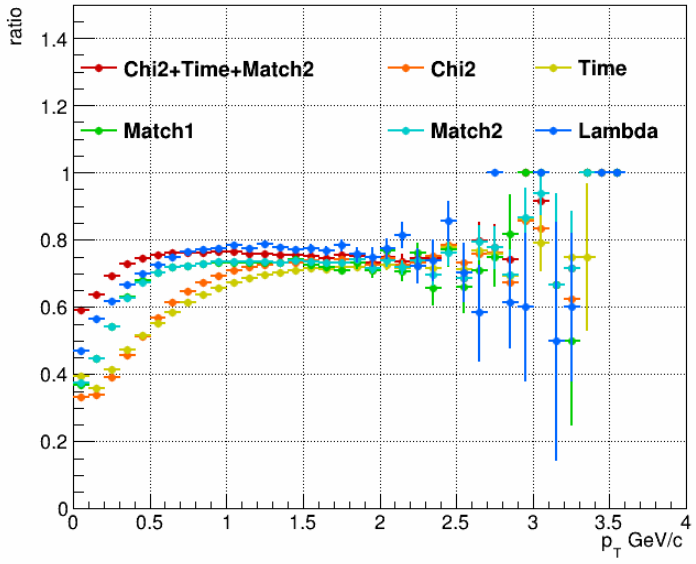
- Dist: $dist < 1.0$
- Chi2: $\chi^2_\Lambda < 3.0$
- Angle : $angle < 0.1$
- Decay: $decay > 0.5$
- Mass: $| M_{p\pi^-} - M_\Lambda | < 0.004$

EMC Photon

Efficiency



Purity



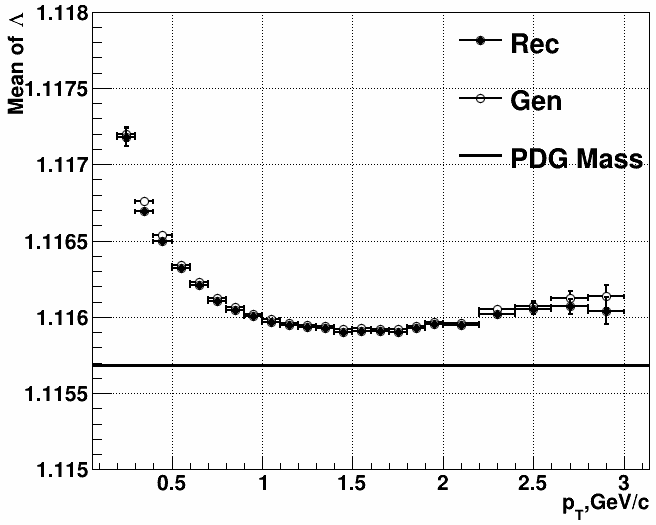
- Chi2: $\chi^2 < 4$
- Time: $T_{cl} < 2$
- Match1:$dphi < 10$ && $dz < 10$
- Match2:

$$\frac{dz^2}{7.5^2} + \frac{dphi^2}{7.5^2} > 4$$

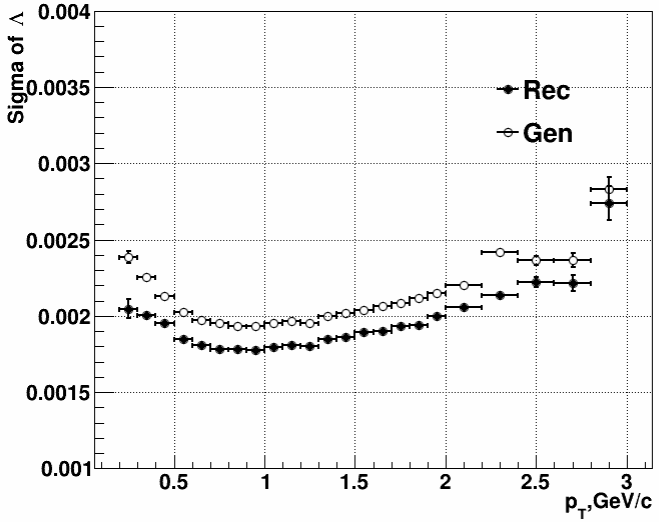
- Lambda:

$$\left(\frac{\lambda_{short} - 1.4}{0.9}\right)^2 + \left(\frac{\lambda_{long} - 2.5}{1}\right)^2 < 1$$

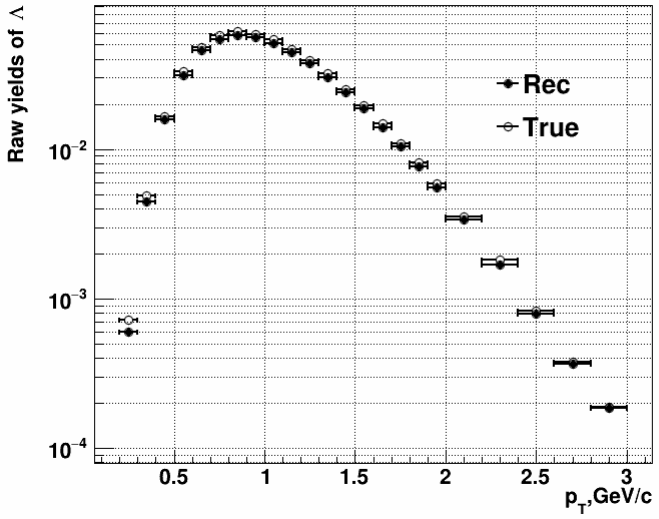
Lambda



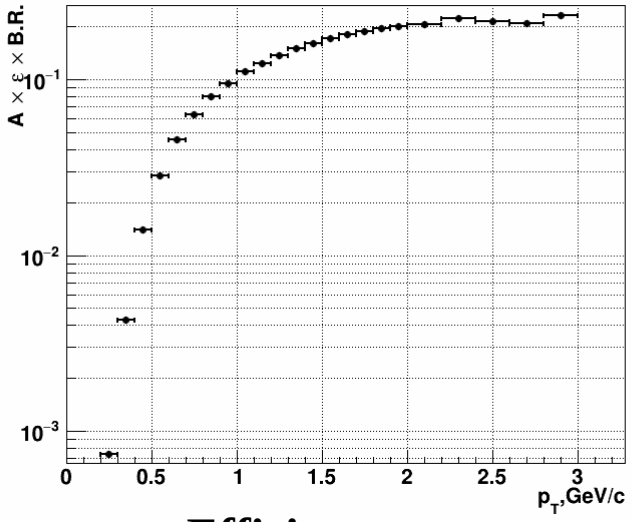
Invariant mass



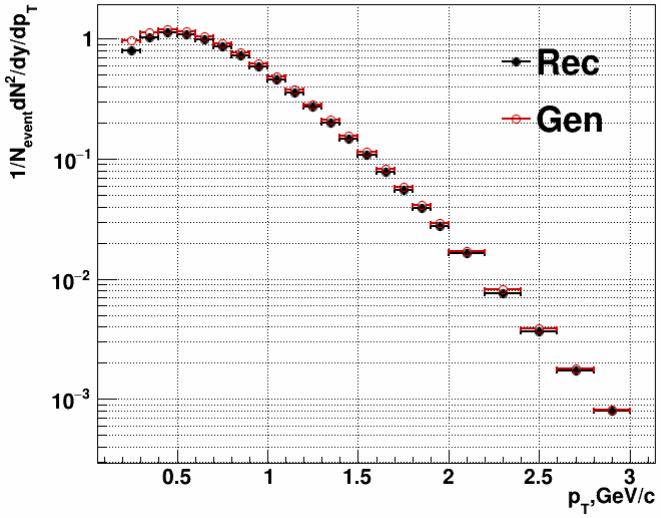
Width



Raw yield



Efficiency



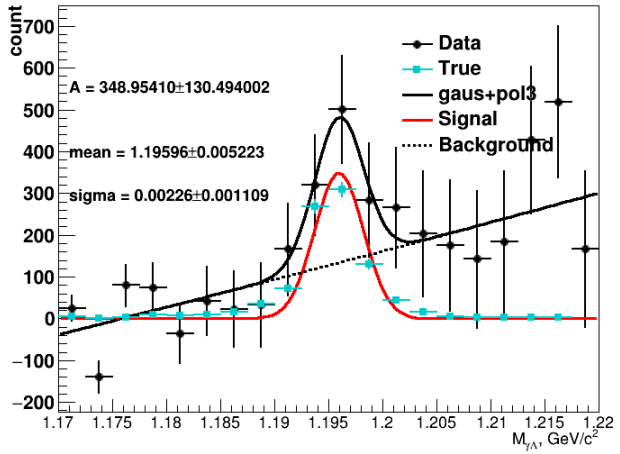
Yield

$$Yield = \int_{mean-3\sigma}^{mean+3\sigma} fit(x)\,dx$$

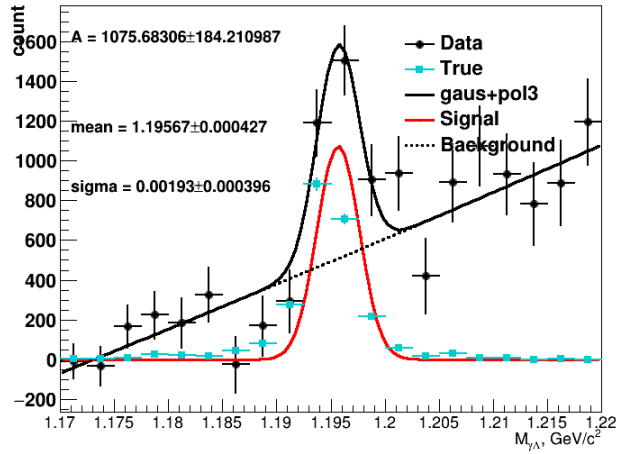
$$Efficiency = \frac{N_{True\ reconstruction}}{N_{MC}}$$

PCM

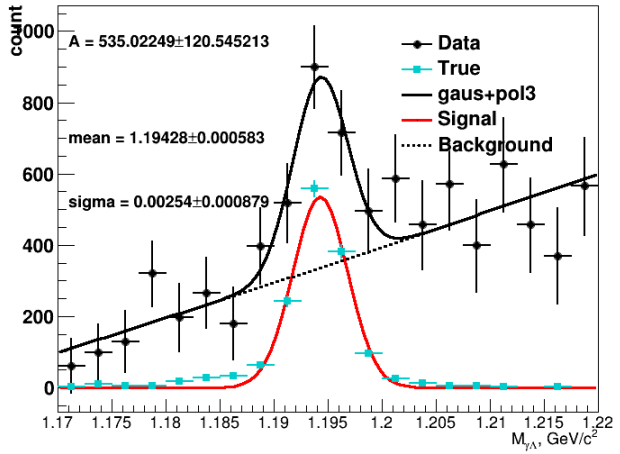
0.50<p_T<1.00 GeV/c



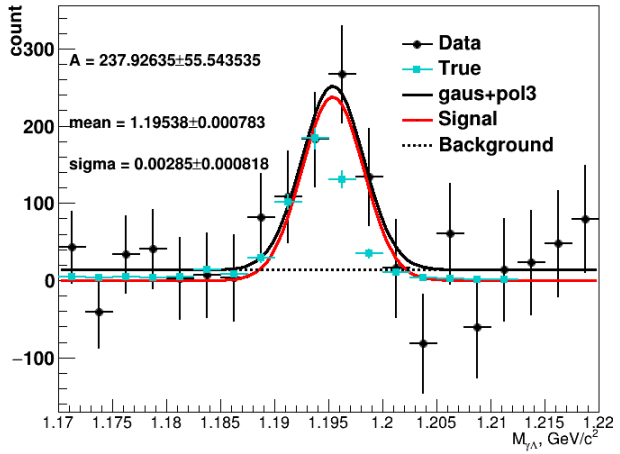
1.00<p_T<1.50 GeV/c



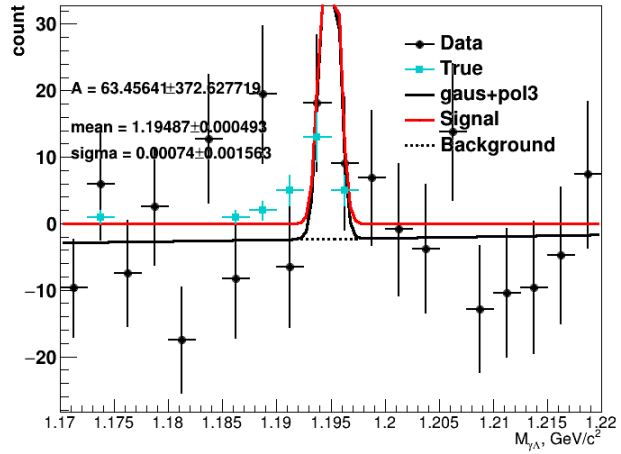
1.50<p_T<2.00 GeV/c



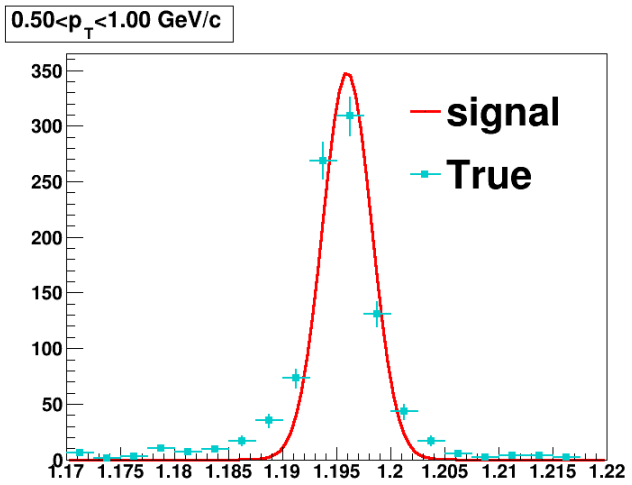
2.00<p_T<3.00 GeV/c

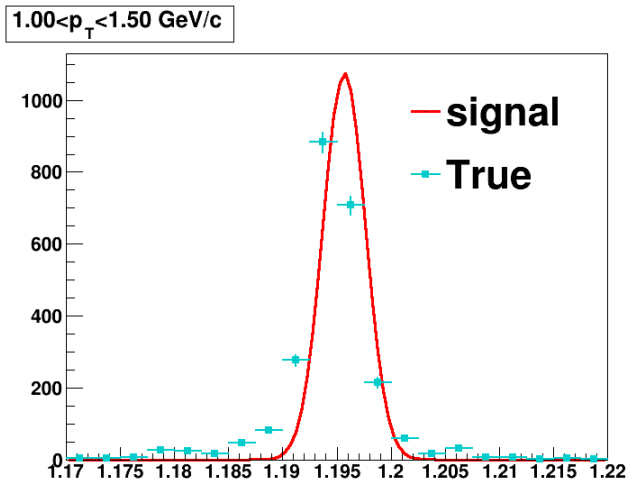


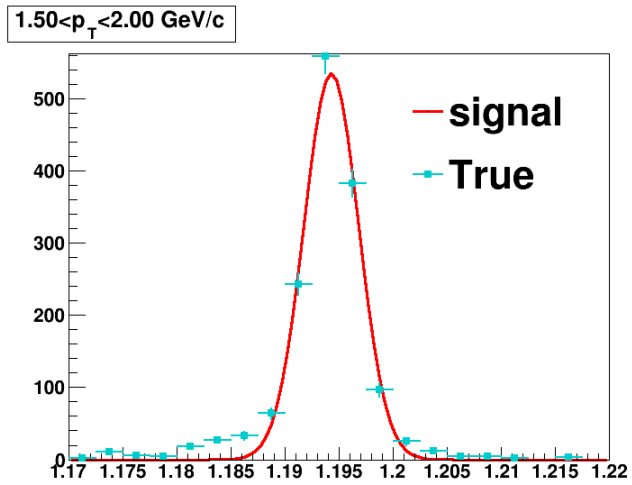
3.00<p_T<4.00 GeV/c

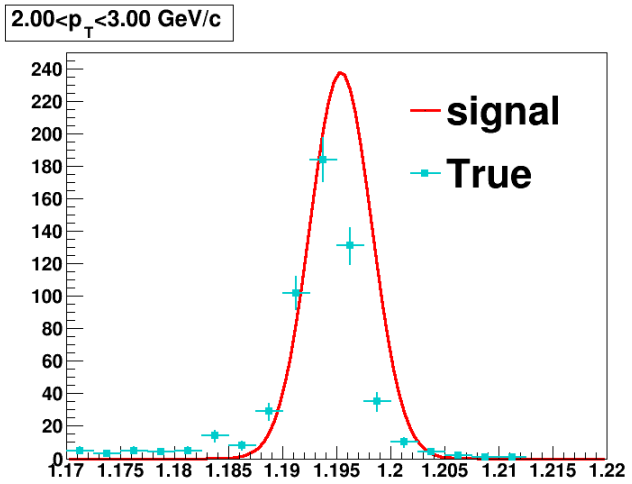


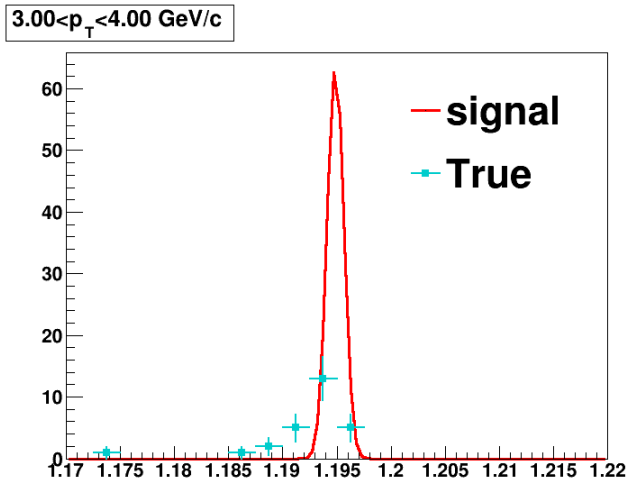
PCM True


0.50<p_T<1.00 GeV/c
signal
True

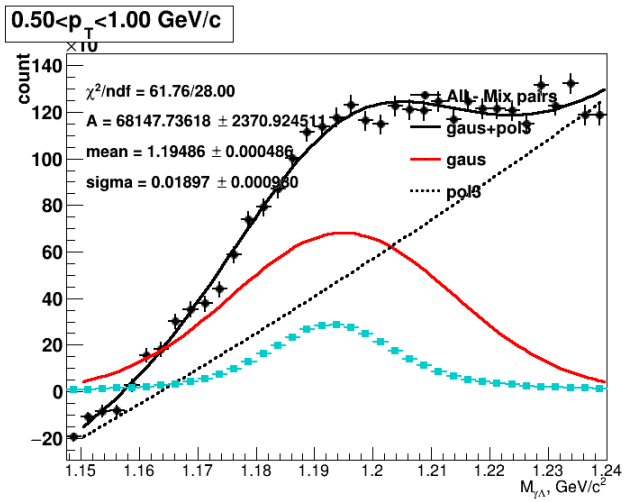

1.00<p_T<1.50 GeV/c
signal
True

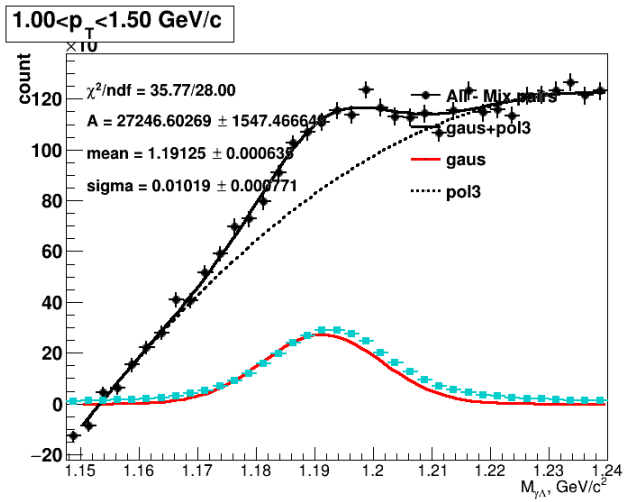

1.50<p_T<2.00 GeV/c
signal
True

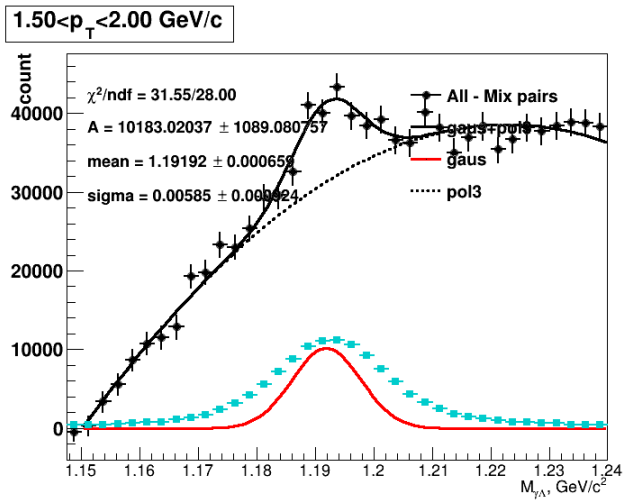

2.00<p_T<3.00 GeV/c
signal
True

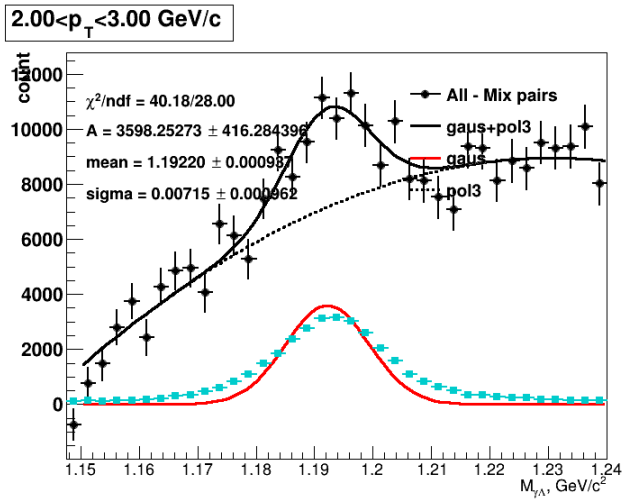

3.00<p_T<4.00 GeV/c
signal
True

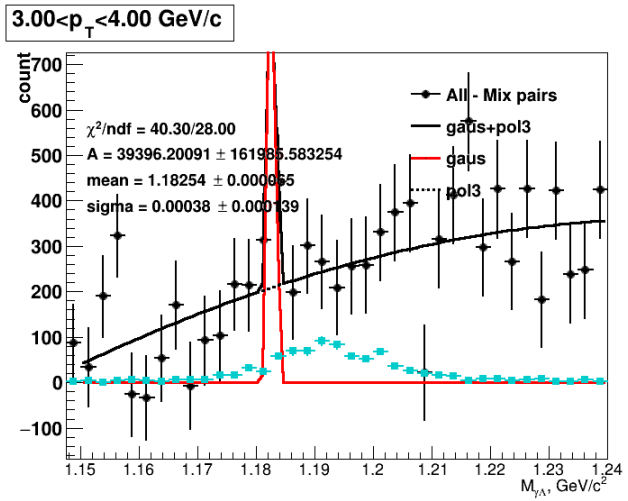
EMC


0.50<p_T<1.00 GeV/c
count
×10
χ²/ndf = 61.76/28.00
A = 68147.73618 ± 2370.924511
mean = 1.19486 ± 0.000486
sigma = 0.01897 ± 0.000950
All - Mix pairs
gaus+pol3
gaus
pol3
M_γΛ, GeV/c²

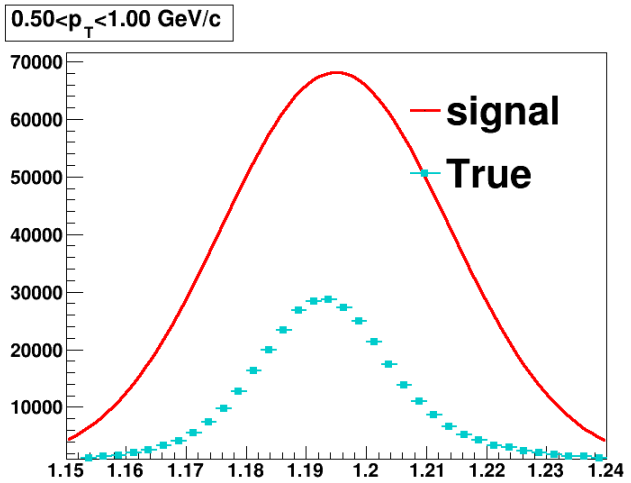

1.00<p_T<1.50 GeV/c
count
×10
χ²/ndf = 35.77/28.00
A = 27246.60269 ± 1547.466644
mean = 1.19125 ± 0.000636
sigma = 0.01019 ± 0.000771
All - Mix pairs
gaus+pol3
gaus
pol3
M_γΛ, GeV/c²

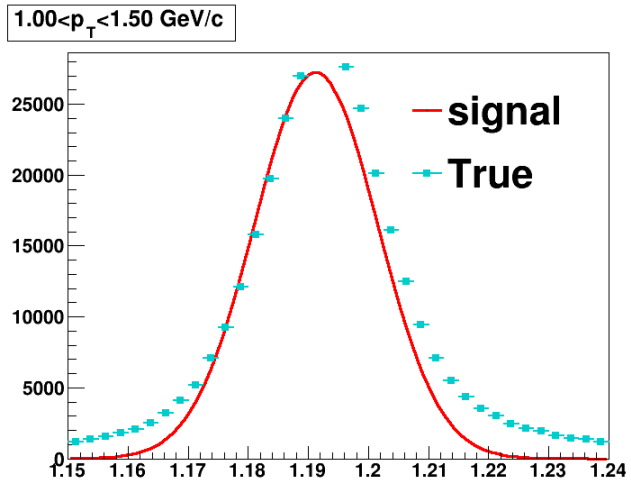

1.50<p_T<2.00 GeV/c
count
χ²/ndf = 31.55/28.00
A = 10183.02037 ± 1089.080757
mean = 1.19192 ± 0.000658
sigma = 0.00585 ± 0.000924
All - Mix pairs
gaus+pol3
gaus
pol3
M_γΛ, GeV/c²

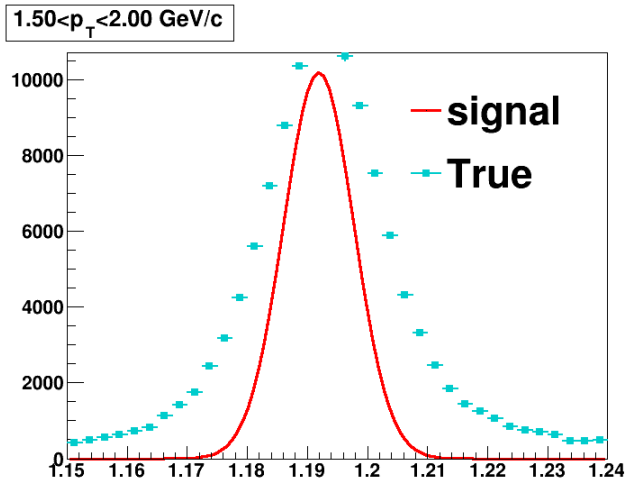

2.00<p_T<3.00 GeV/c
count
χ²/ndf = 40.18/28.00
A = 3598.25273 ± 416.284396
mean = 1.19220 ± 0.000987
sigma = 0.00715 ± 0.000962
All - Mix pairs
gaus+pol3
gaus
pol3
M_γΛ, GeV/c²

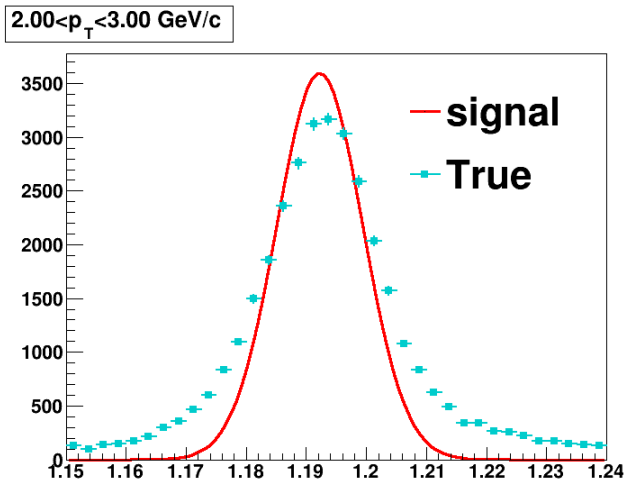

3.00<p_T<4.00 GeV/c
count
χ²/ndf = 40.30/28.00
A = 39396.20091 ± 161935.583254
mean = 1.18254 ± 0.000655
sigma = 0.00038 ± 0.000139
All - Mix pairs
gaus+pol3
gaus
pol3
M_γΛ, GeV/c²

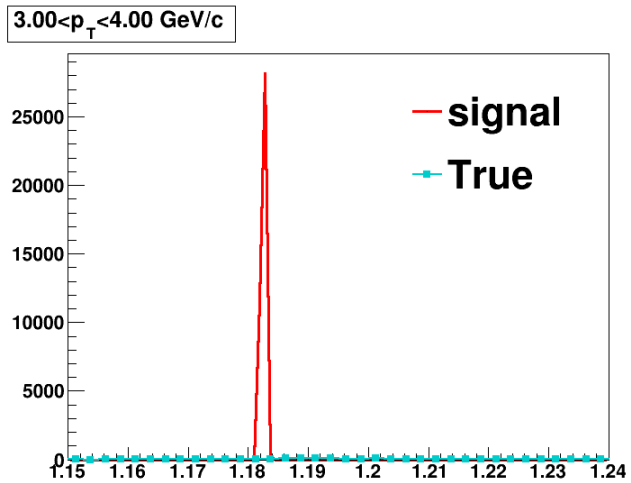
EMC True


0.50<p_T<1.00 GeV/c
signal
True

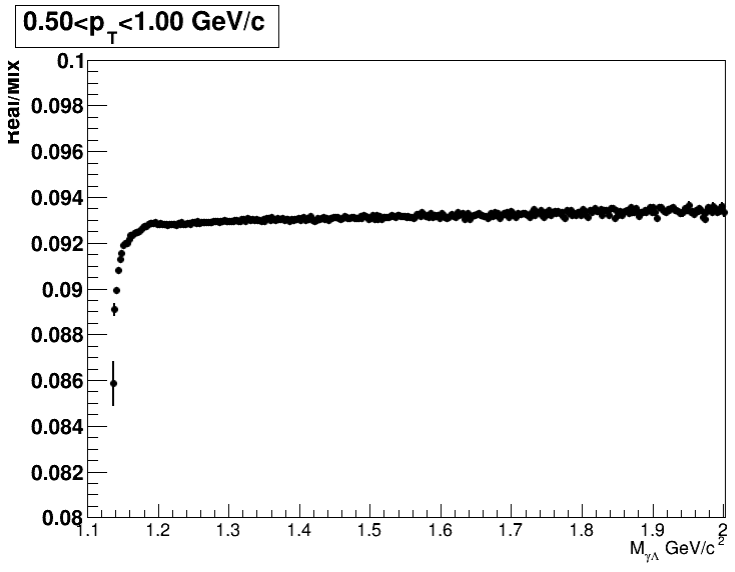

1.00<p_T<1.50 GeV/c
signal
True

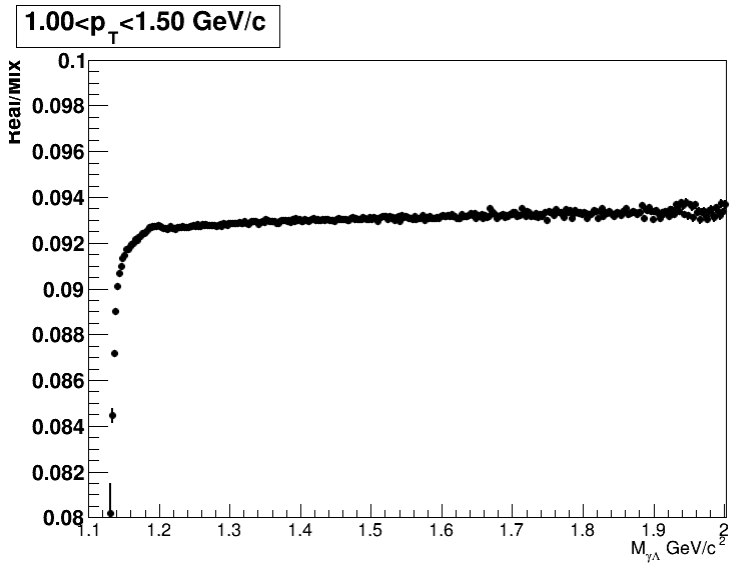

1.50<p_T<2.00 GeV/c
signal
True

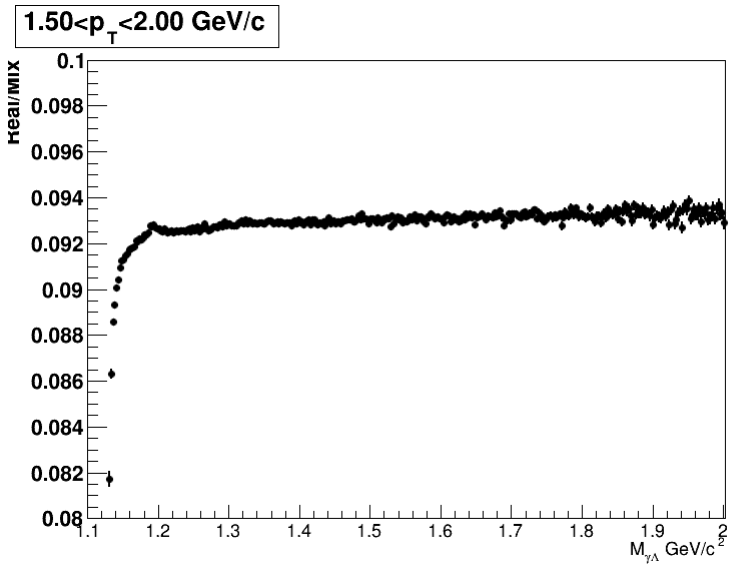

2.00<p_T<3.00 GeV/c
signal
True

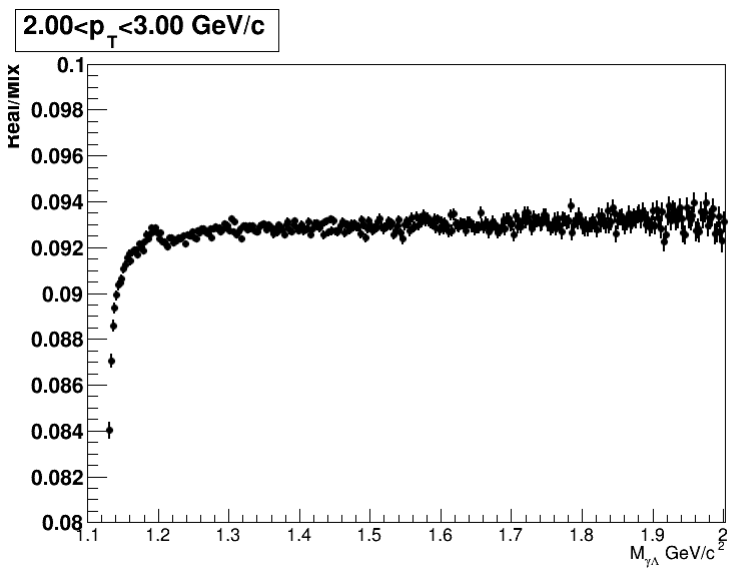

3.00<p_T<4.00 GeV/c
signal
True

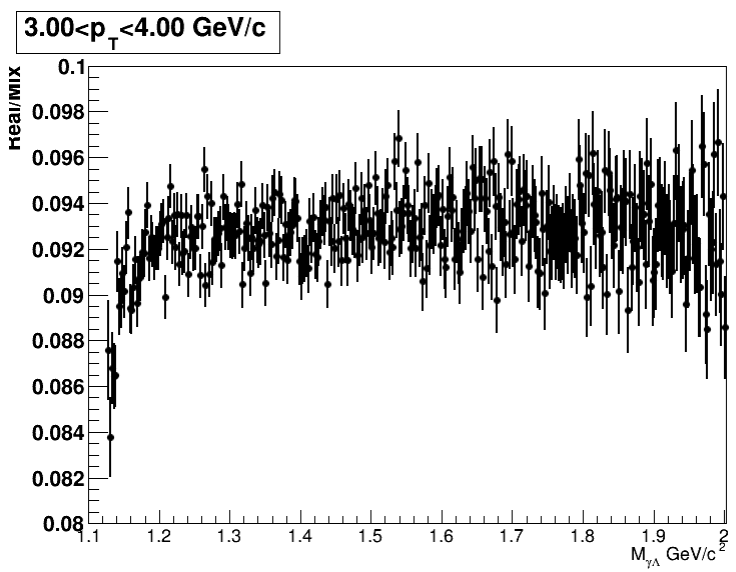
EMC ratio

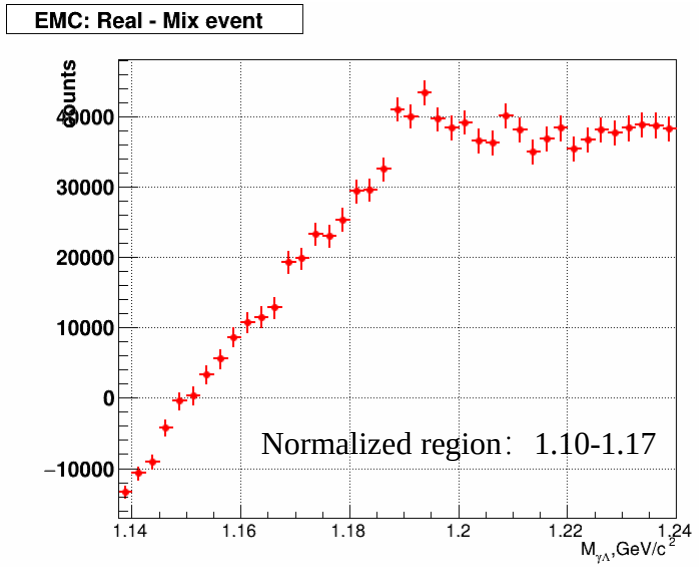
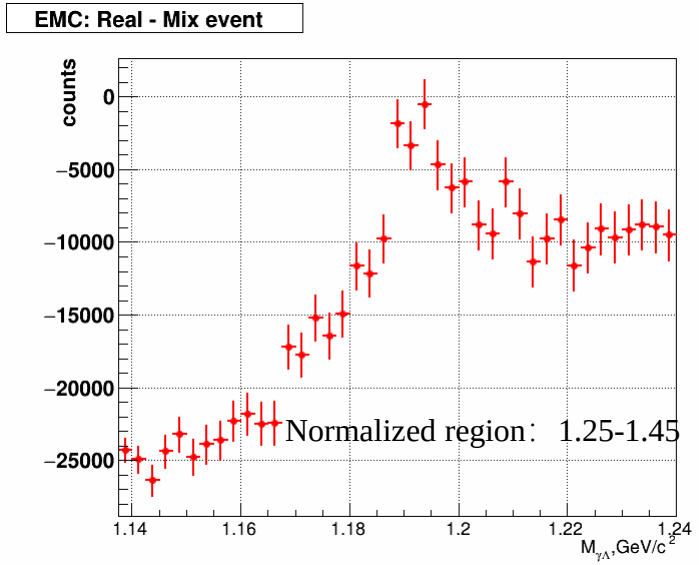

0.50<p_T<1.00 GeV/c
Real/Mix
M_γΛ GeV/c²


1.00<p_T<1.50 GeV/c
Real/Mix
M_γΛ GeV/c²


1.50<p_T<2.00 GeV/c
Real/Mix
M_γΛ GeV/c²


2.00<p_T<3.00 GeV/c
Real/Mix
M_γΛ GeV/c²


3.00<p_T<4.00 GeV/c
Real/Mix
M_γΛ GeV/c²

Normalized region

Mix event: 10(Vz)*10(Cen)*1 (EP)