Reconstruction of eta meson at CBM-RICH detector using conversion method *

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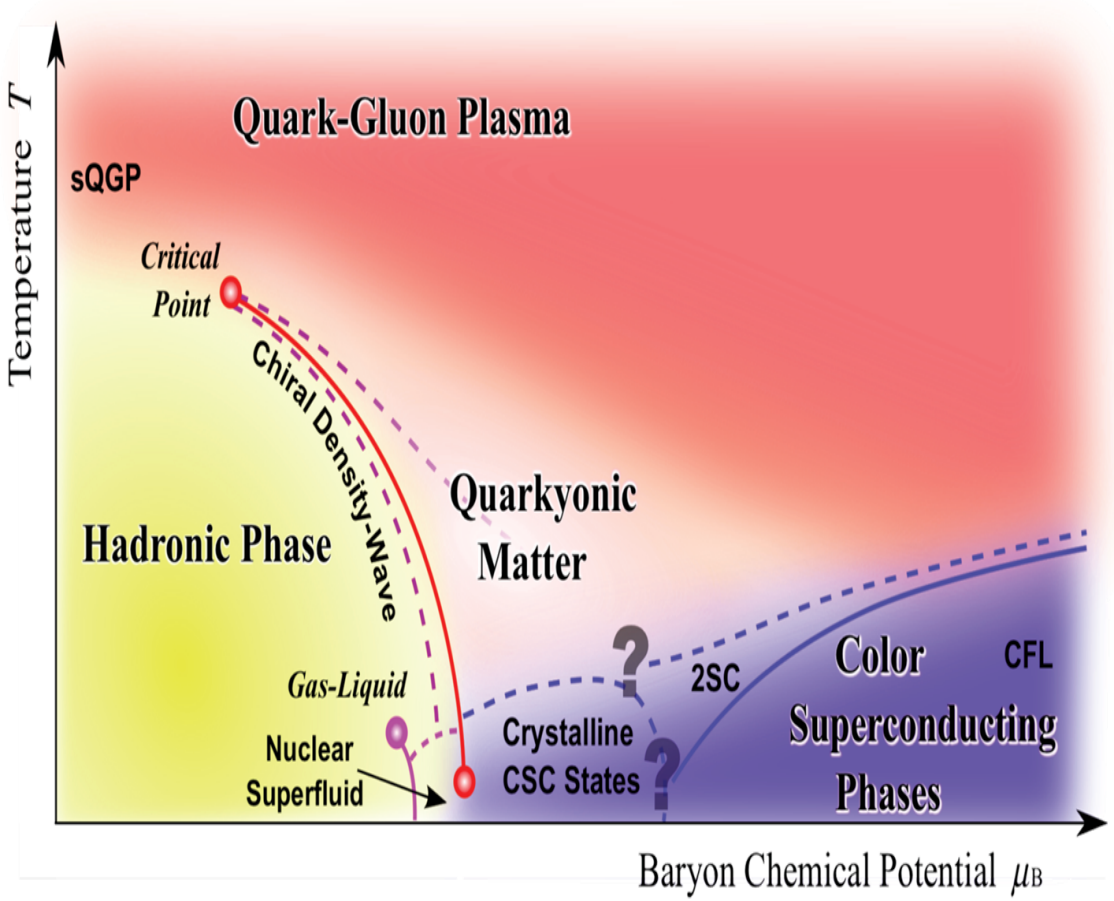
Compressed Baryonic Matter (CBM) experiment at FAIR



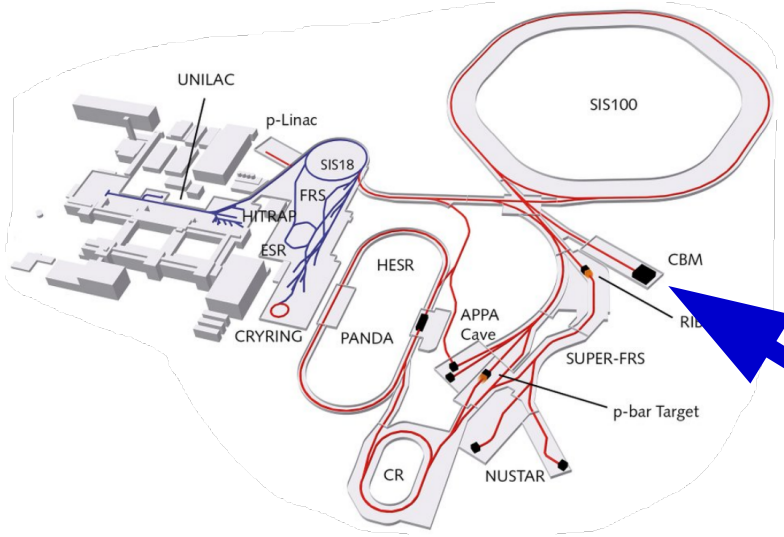
CBM conditions:

- High net-baryon densities
- Moderate temperatures

Possible features of the QCD phase diagram:

- The predicted first order phase transition between hadronic and partonic matter;
- A rich structure such as a critical point;
- New phases like quarkyonic matter.

The CBM detector

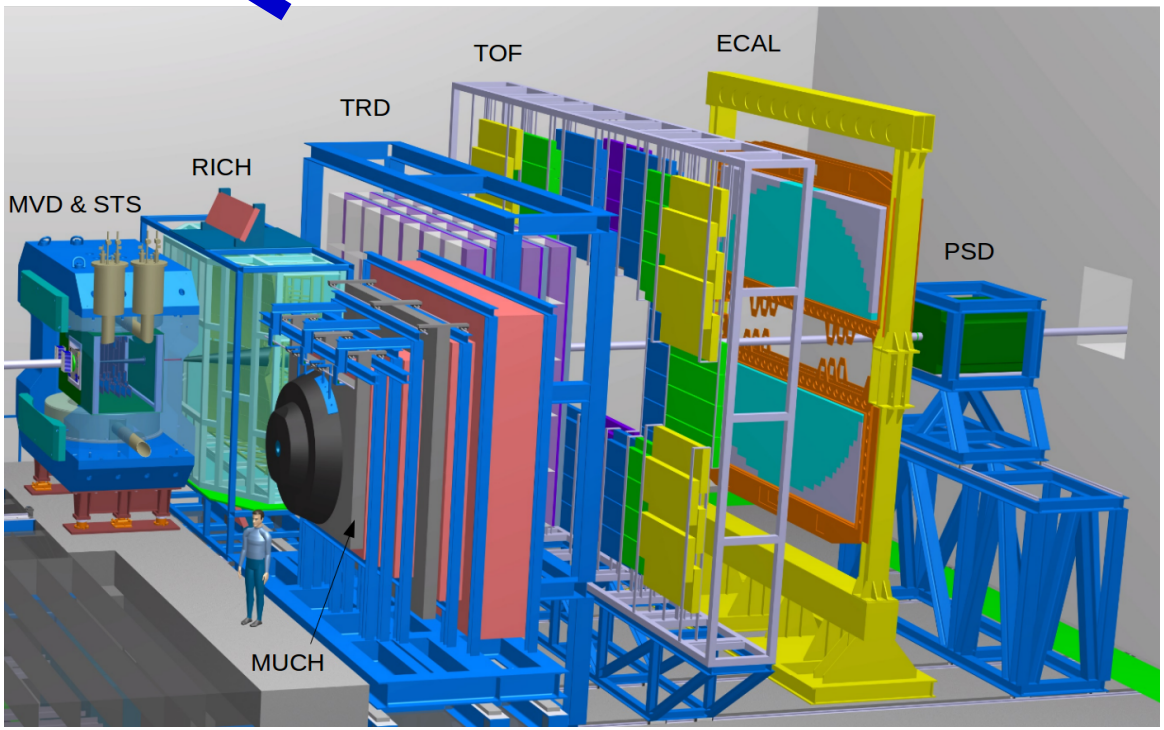


The CBM experiment

- gold-ion beam, 2 – 12 AGeV (SIS100)
- Fixed target (gold)
- Interaction rate: up to 10 MHz

Detector setup:

- Micro Vertex Detector (MVD)
- Silicon Tracking System (STS)
- Ring Imaging Cherenkov detector (RICH)
- Muon Chambers (MUCH)
- Transition Radiation Detector (TRD)
- Time Of Flight detector (TOF)
- Electromagnetic Calorimeter (ECAL)
- Projectile Spectator Detector (PSD)



Motivation

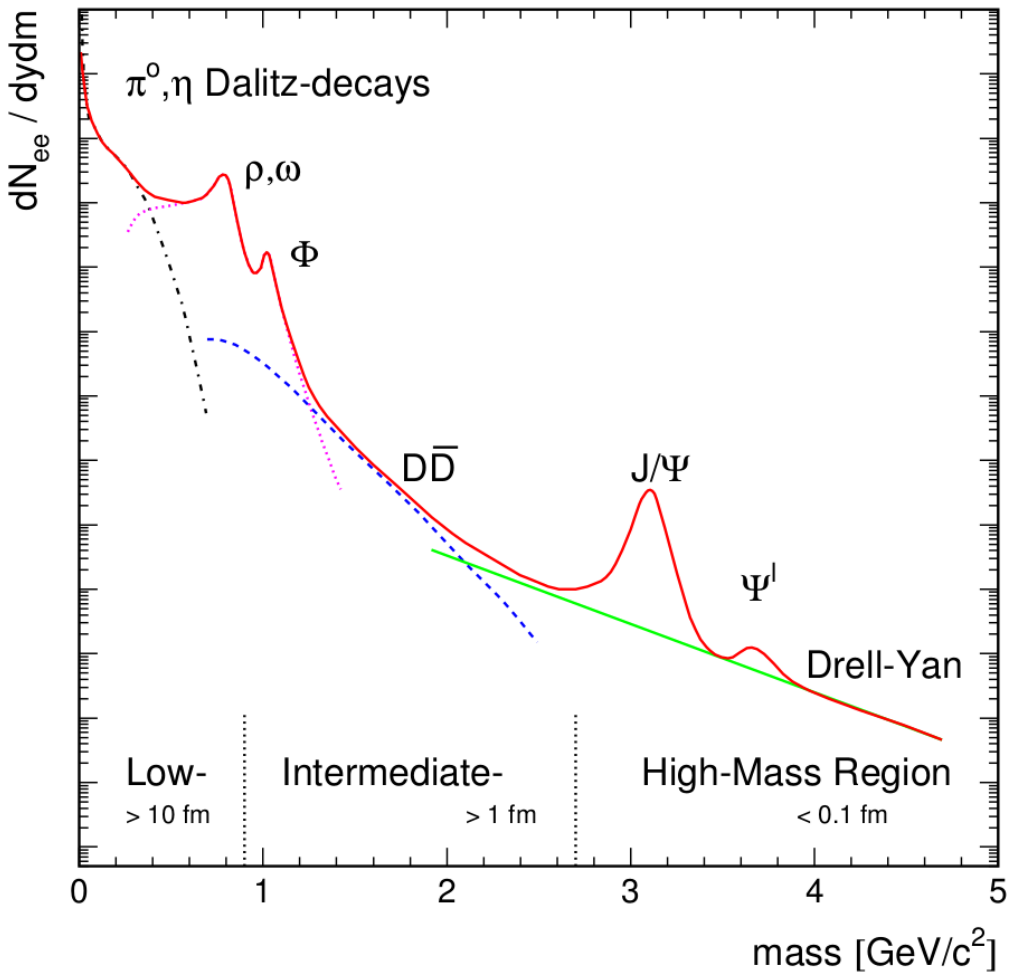
CBM is designed for precise measurements of many observables including particles with very small branching ratio and low production cross section, like:

$\rho \rightarrow e^+ + e^-$ $(4.72*10^{-5}\ \%)$
$\omega \rightarrow e^+ + e^-$ $(7.28*10^{-5}\ \%)$
$\varphi \rightarrow e^+ + e^-$ $(2.95*10^{-4}\ \%)$

As leptons are not affected by final-state interactions, the di-leptonic decay offers the possibility to look into the fireball.

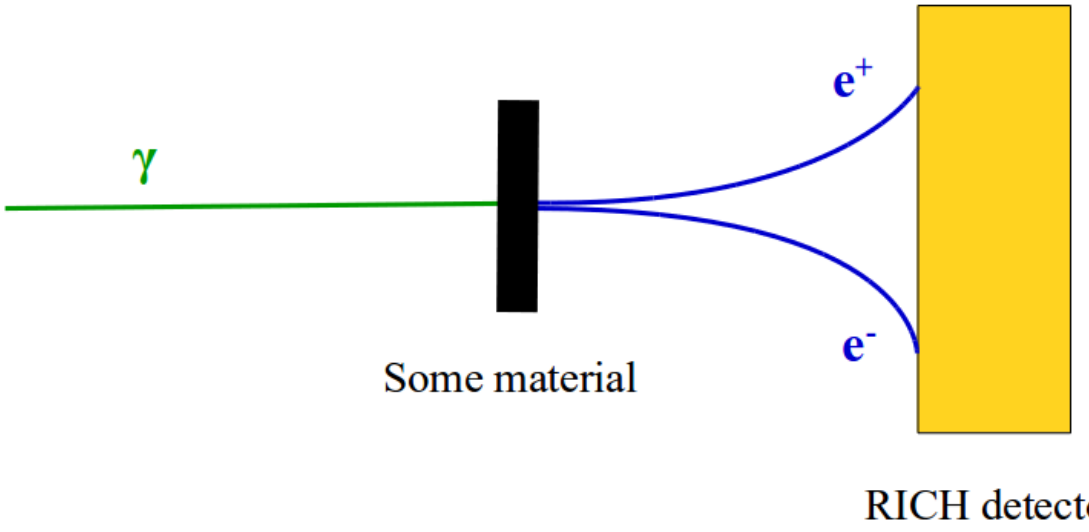
The main background contribution comes from π^0 and η decays:

$\pi^0/\eta \rightarrow \gamma\gamma \rightarrow (e^+ + e^-) + (e^+ + e^-)$
$\pi^0/\eta \rightarrow \gamma + e^+ + e^-$



How accurate one can reconstruct η-meson using conversion method?

Conversion method for η



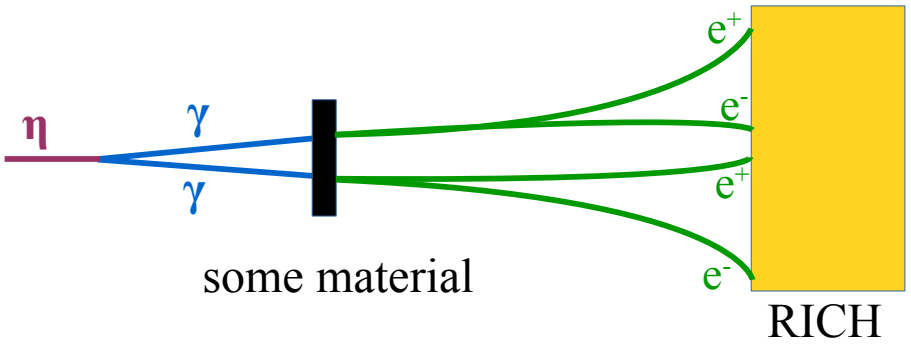
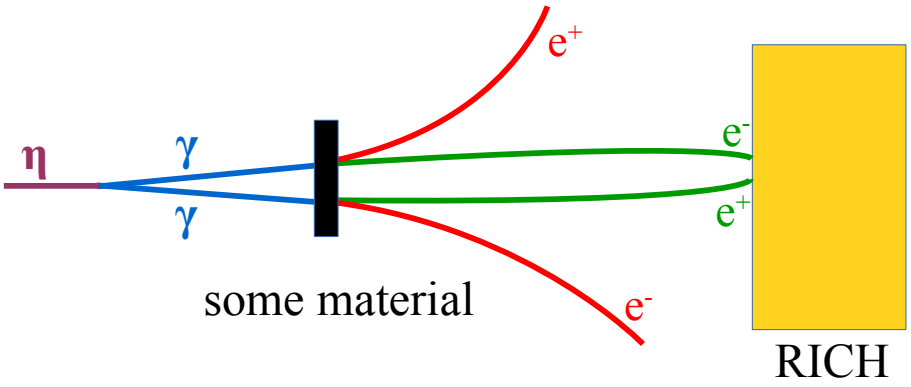
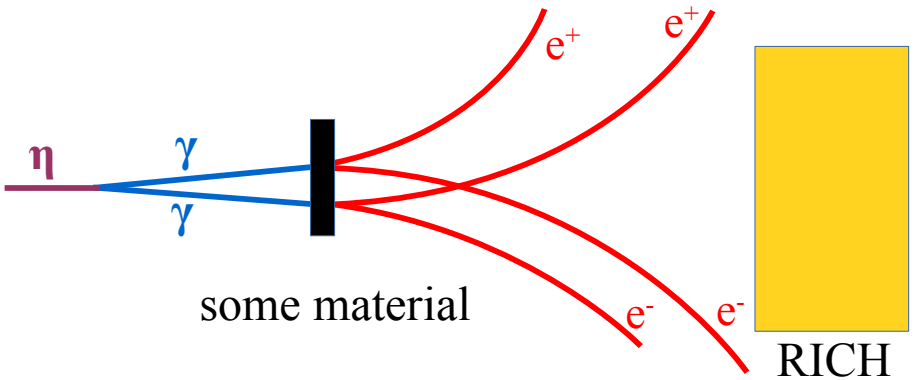
✔	$\eta \rightarrow \gamma + \gamma$	38.8 %
✔	$\eta \rightarrow e^+ + e^- + \gamma$	0.5 %
✗	$\eta \rightarrow \pi^0 + \pi^0 + \pi^0$	31.9 %
✗	$\eta \rightarrow \pi^+ + \pi^- + \pi^0$	23.6 %
✗	$\eta \rightarrow \pi^+ + \pi^- + \gamma$	4.8 %

Conversion probability for **single γ** before RICH detector **~ 5%**

Place of γ conversions:

- 28 % in the target
- 72 % in the detector material (MVD & STS)

Lepton identification approaches

Approach	Example	Case	amount of converted photons
Full ID		$\eta \rightarrow (e^+ + e^-) + (e^+ + e^-)$	10 %
Partial ID		$\eta \rightarrow (e^+ + e^-) + (e^+ + e^-)$ $\eta \rightarrow (e^+ + e^-) + (e^+ + e^-)$ $\eta \rightarrow (e^+ + e^-) + (e^+ + e^-)$	55 %
Without ID		$\eta \rightarrow (e^+ + e^-) + (e^+ + e^-)$ $\eta \rightarrow (e^+ + e^-) + (e^+ + e^-)$ $\eta \rightarrow (e^+ + e^-) + (e^+ + e^-)$ $\eta \rightarrow (e^+ + e^-) + (e^+ + e^-)$ $\eta \rightarrow (e^+ + e^-) + (e^+ + e^-)$ $\eta \rightarrow (e^+ + e^-) + (e^+ + e^-)$	100 %

Cuts values for γ reconstruction

Analysis steps:

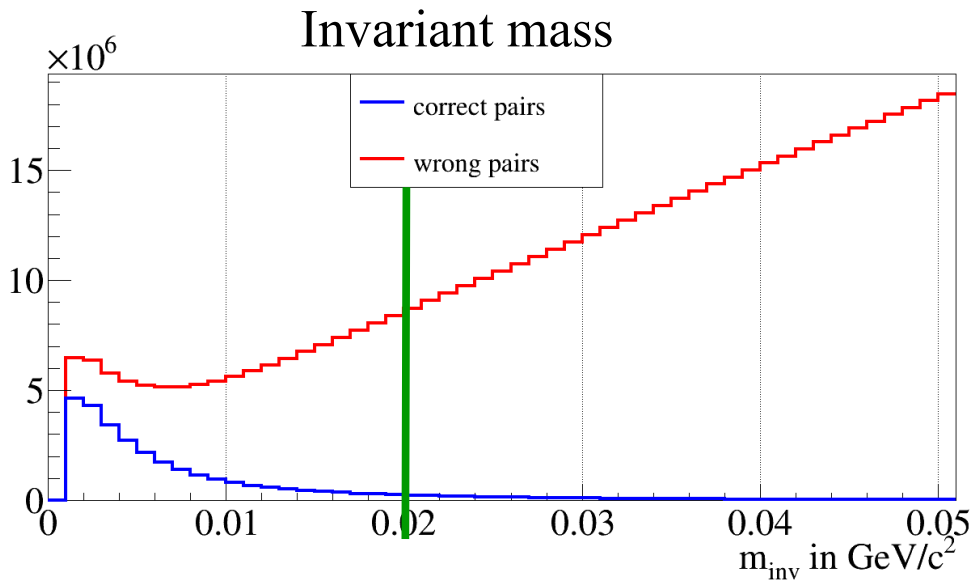
1) Check the track quality:
   - cut on χ^2 from track fit
2) Check identification of leptons inside the RICH:
   - cut on ring *B* and *A* parameters
3) Search for $e^+e^- \rightarrow \gamma$ candidates:
   - cut on opening angle and invariant mass, opposite charge
4) If ≥ 2 γ candidates found:
   - form all possible $\gamma\gamma \rightarrow \eta$ combinations

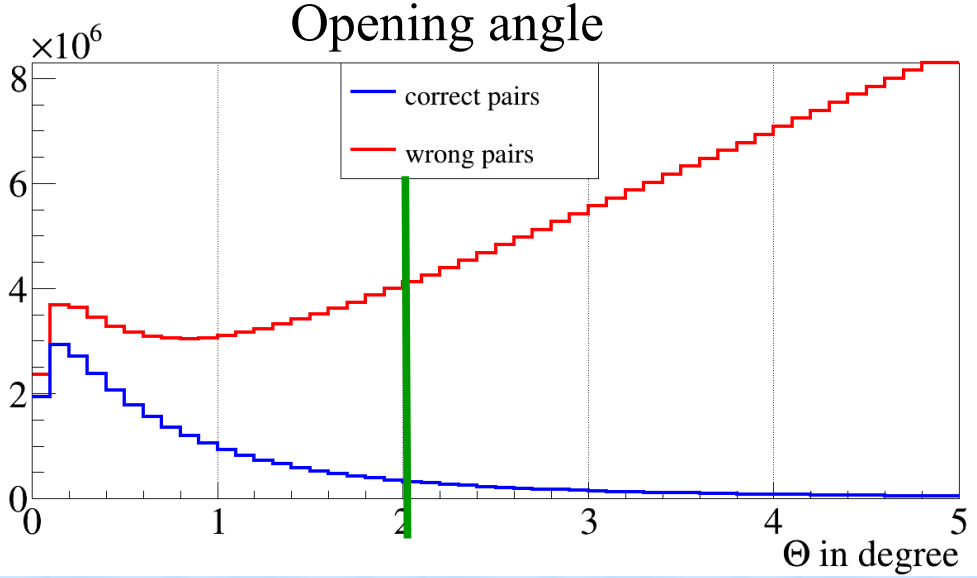
Optimal cuts:

m_{inv} $(e^+e^-) < 20$ MeV/c^2

θ $(e^+e^-) < 2°$

~ 10 photons per event after cuts



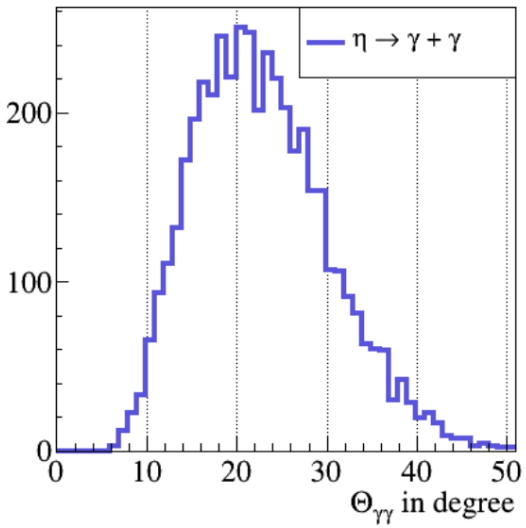


Cut for η reconstruction

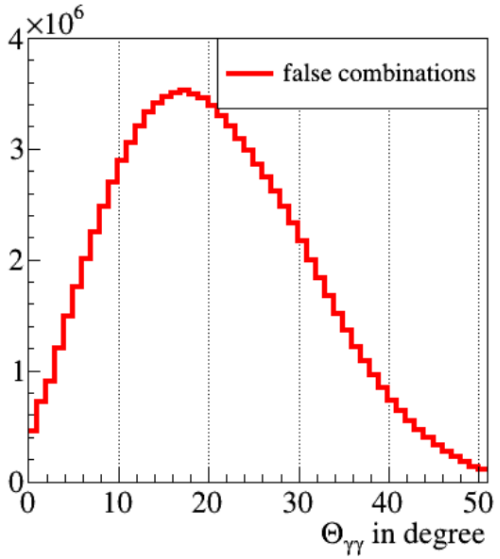
Reconstruction steps:

1) Check the track quality:
   - cut on χ^2 from track fit
2) Check identification of leptons inside RICH:
   - cut on ring *B* and *A* parameters
3) Search for $e^+e^- \rightarrow \gamma$ candidates:
   - cut on opening angle and invariant mass, opposite charge
4) If ≥ 2 γ candidates found:
   - form all possible $\gamma\gamma \rightarrow \eta$ combinations
   - **cut on γγ opening angle for η**

Signal



Background



Optimal cut:
$10° < \theta\ (\gamma\gamma) < 40°$

$m_{inv}\ (\eta) = 547.85$ MeV

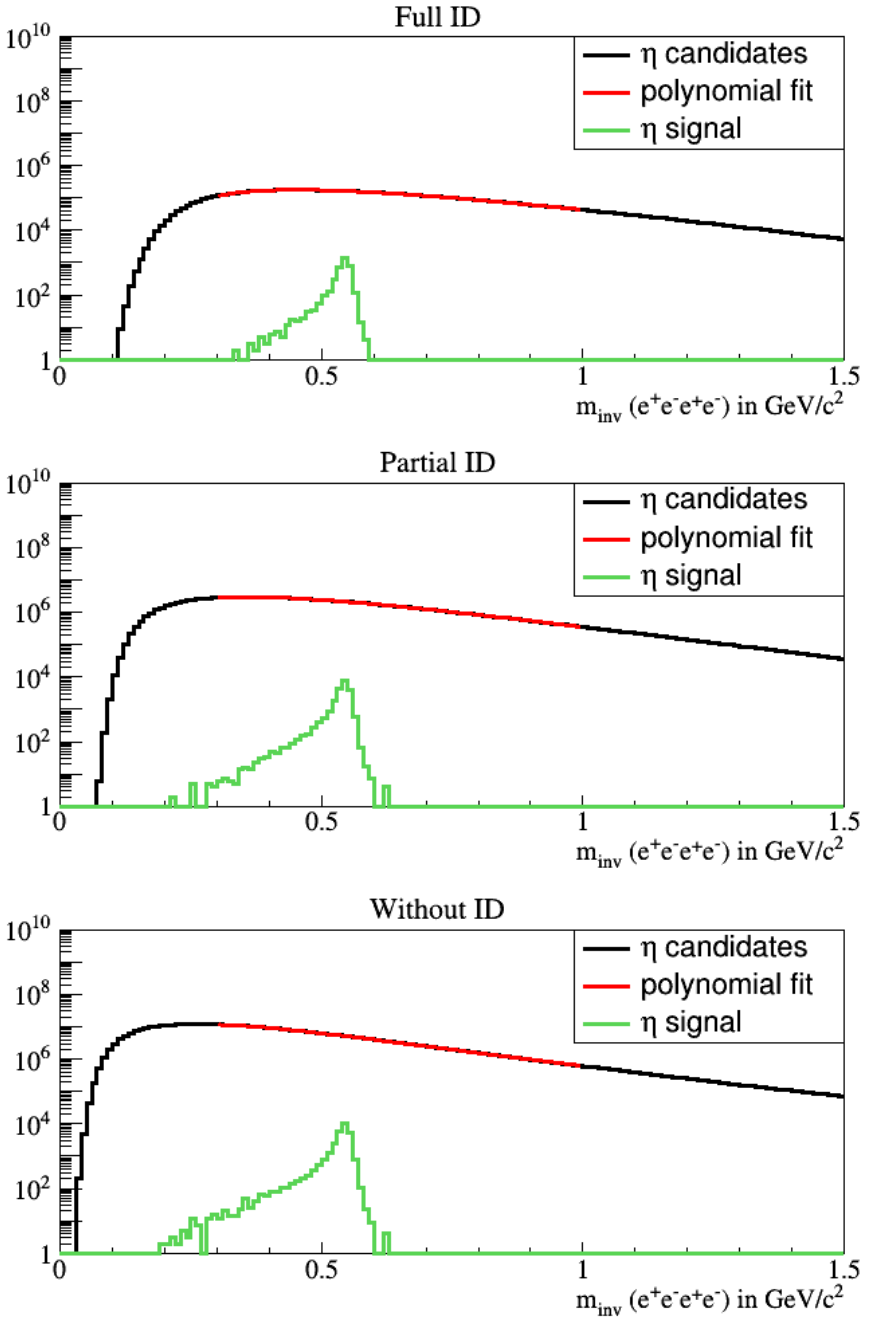
η candidates

The estimation and analysis is based on a simulated sample of 100×10^6 UrQMD events of central Au+Au collisions with a beam energy of 8 AGeV.

Combinatorial background is fit using 7th degree polynomial in the region between 0.3 - 1.0 GeV/c^2 excluding signal regions

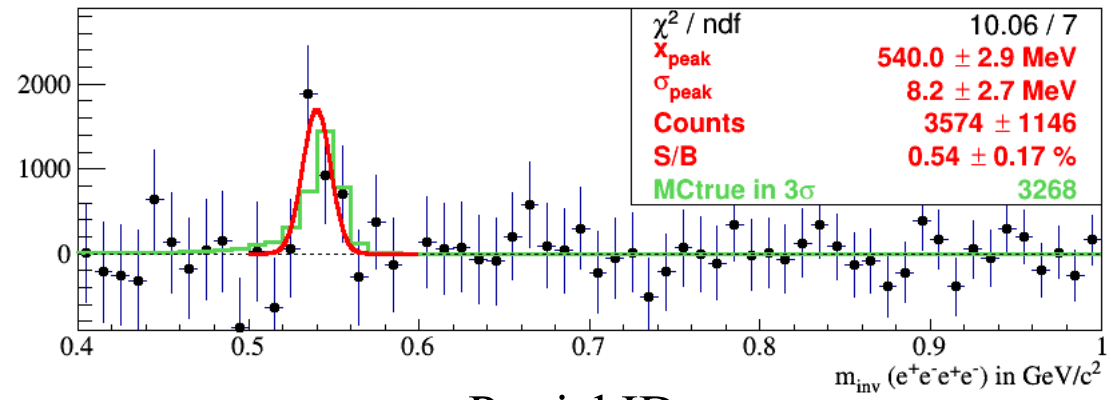
Expected signal to background ratio:

- S/B < 1 %



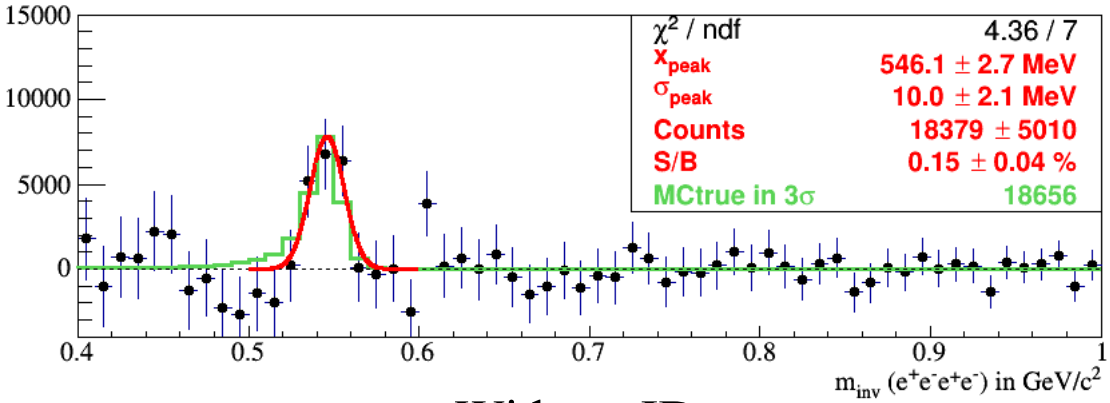
η background-subtracted spectrum

Full ID



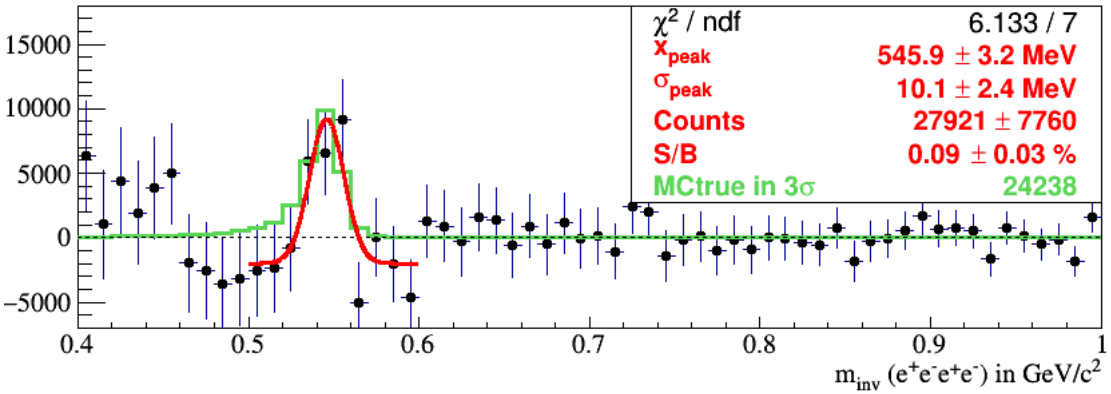
m_{inv} (η)	**reference**
σ (η)	**reference**
η	**reference**
S/B	**reference**

Partial ID



m_{inv} (η)	**same**
σ (η)	**same**
η	**↑ in 5.1 times**
S/B	**↓ in 3.6 times**

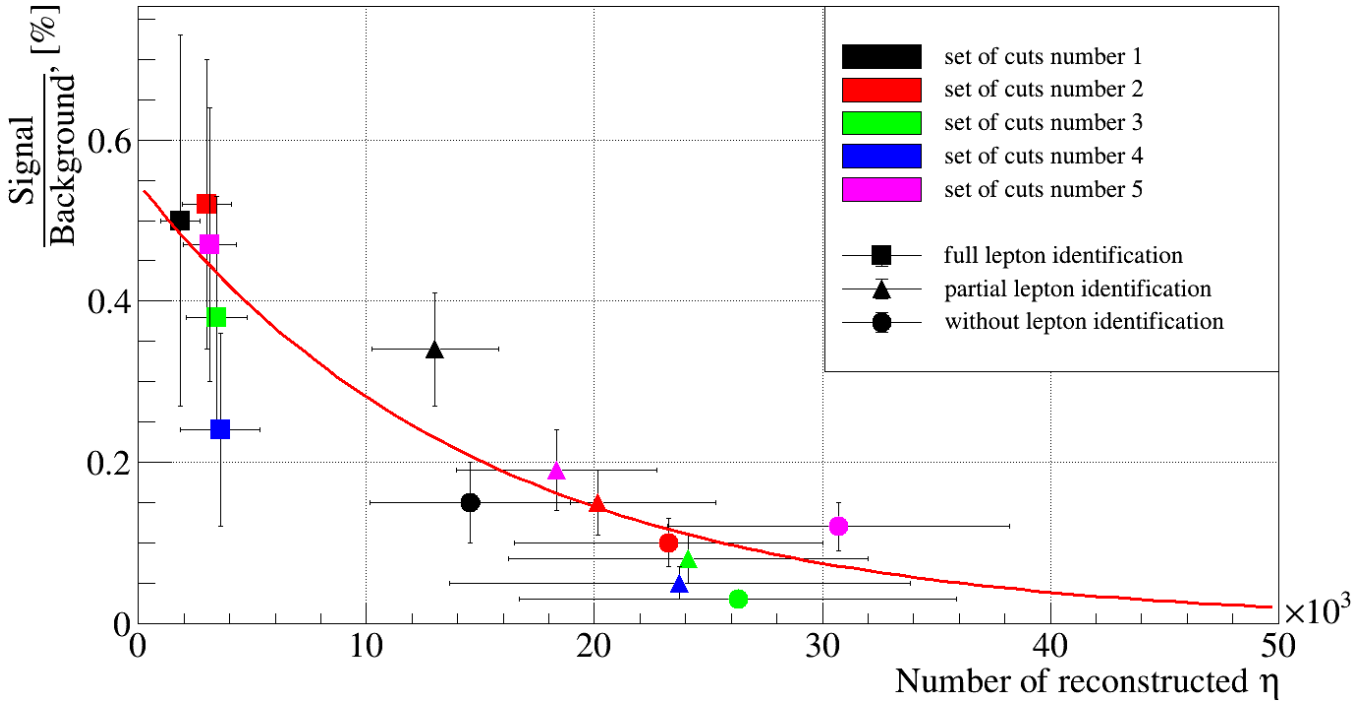
Without ID



m_{inv} (η)	**same**
σ (η)	**same**
η	**↑ in 7.8 times**
S/B	**↓ in 6.0 times**

Summary for η analysis

Fully reconstructed η out of 100×10^6 UrQMD events, central Au+Au@8 AGeV



- 100 million events in CBM: ~ 28 hours of data taking at interaction rate of 100 kHz
- Such sample allows to count number of reconstructed η with an accuracy of ~ 30 %

List of cuts

Set 1:

$m_{inv}(e^+e^-) < 10$ MeV
$\theta\ (e^+e^-) < 1°$
$10° < \theta\ (\gamma\gamma) < 40°$

Set 2:

$m_{inv}(e^+e^-) < 20$ MeV
$\theta\ (e^+e^-) < 2°$
$10° < \theta\ (\gamma\gamma) < 40°$

Set 3:

$m_{inv}(e^+e^-) < 30$ MeV
$\theta\ (e^+e^-) < 3°$
$10° < \theta\ (\gamma\gamma) < 40°$

Set 4:

$m_{inv}(e^+e^-) < 40$ MeV
$\theta\ (e^+e^-) < 4°$
$10° < \theta\ (\gamma\gamma) < 40°$

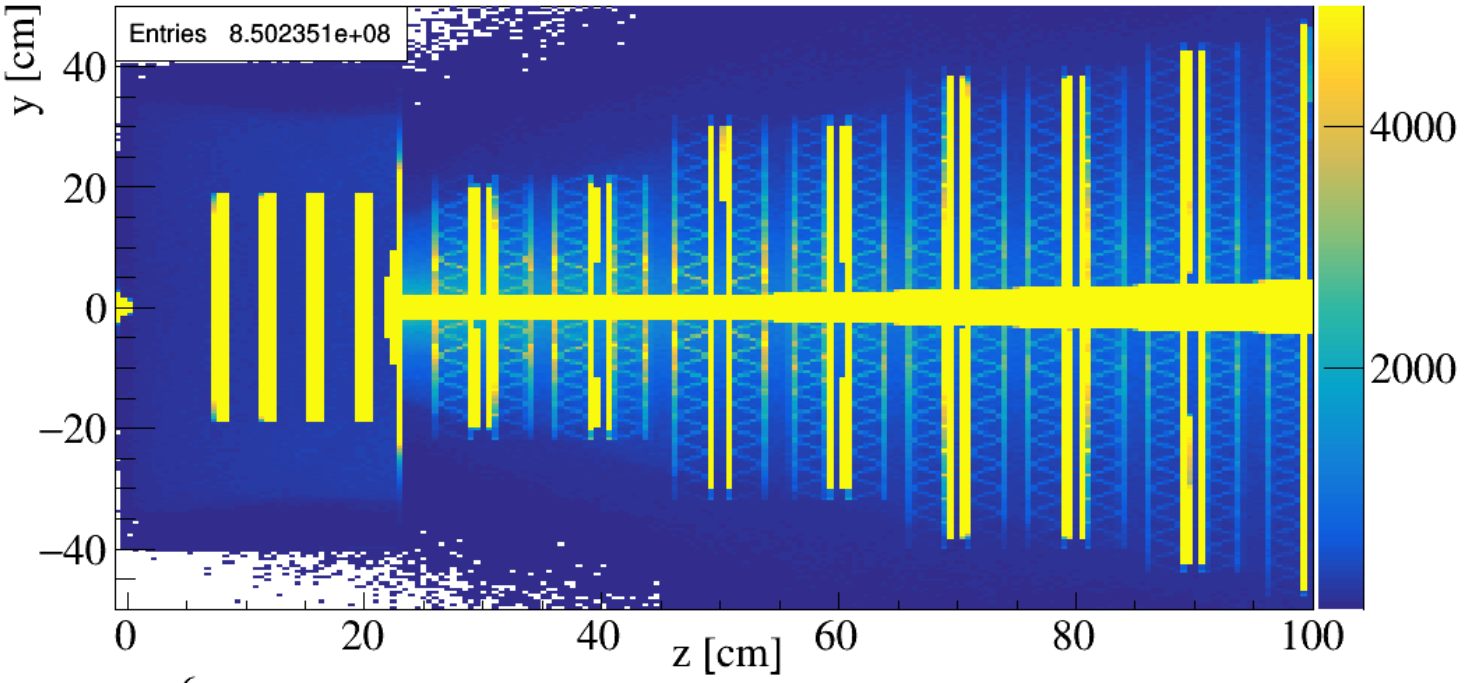
Set 5:

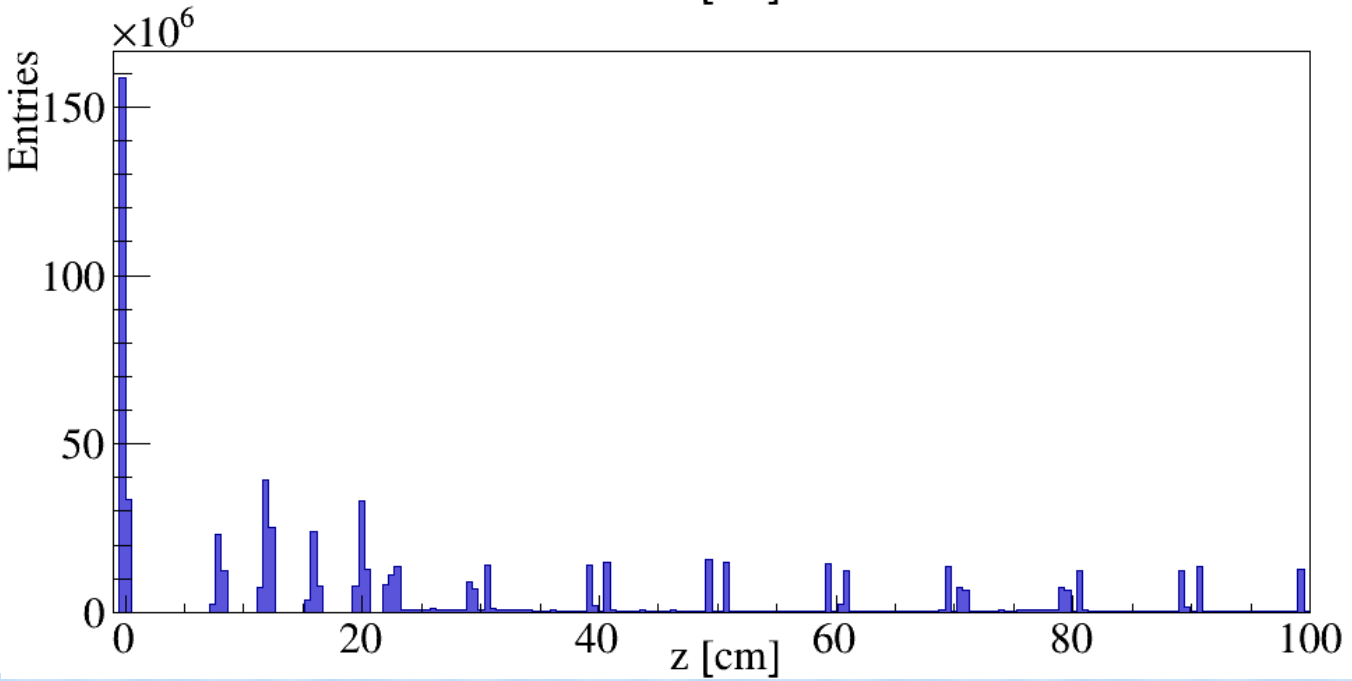
ANN > 0.9
$10° < \theta\ (\gamma\gamma) < 40°$

Thank you for your attention !

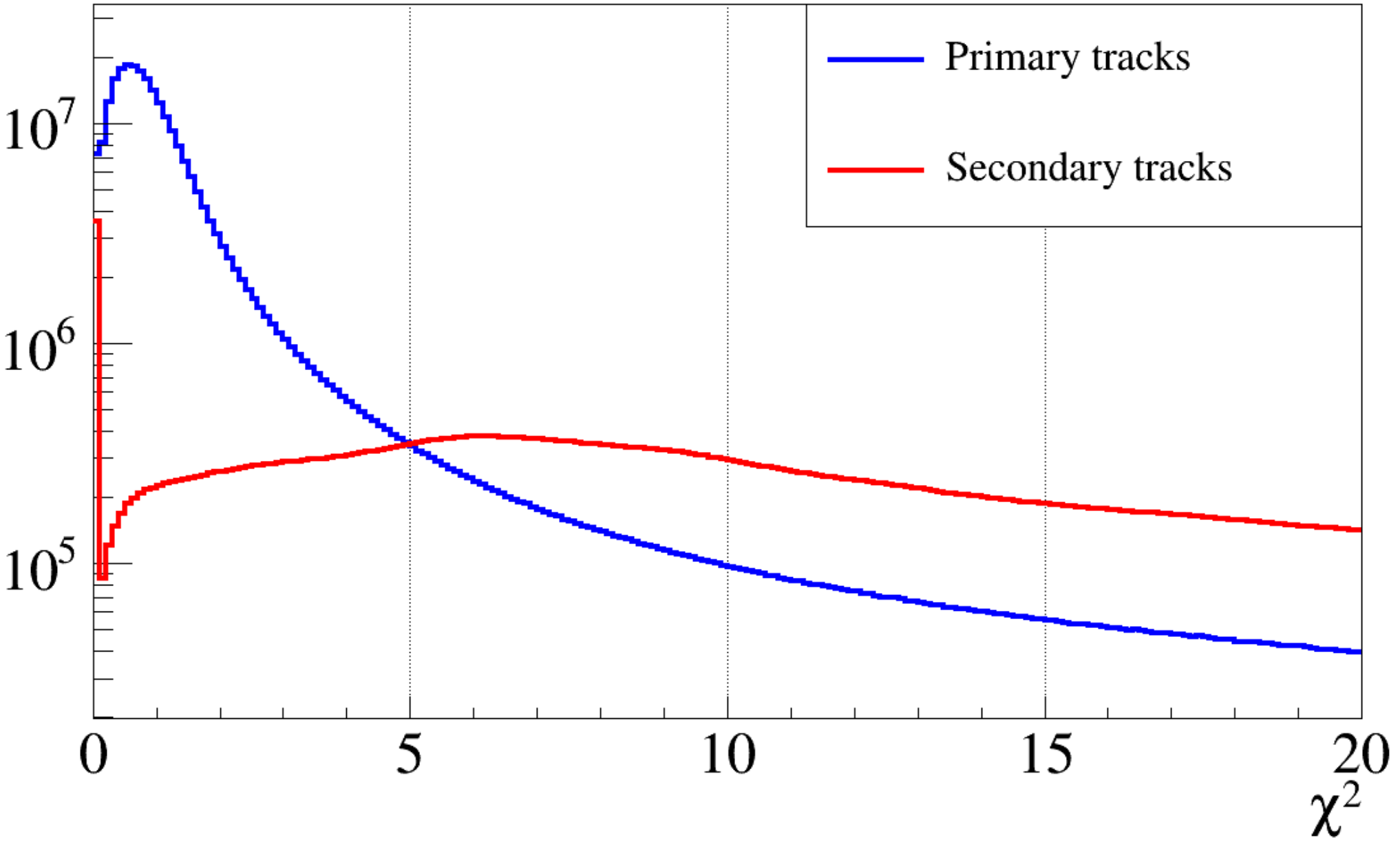
Backup

Conversion points





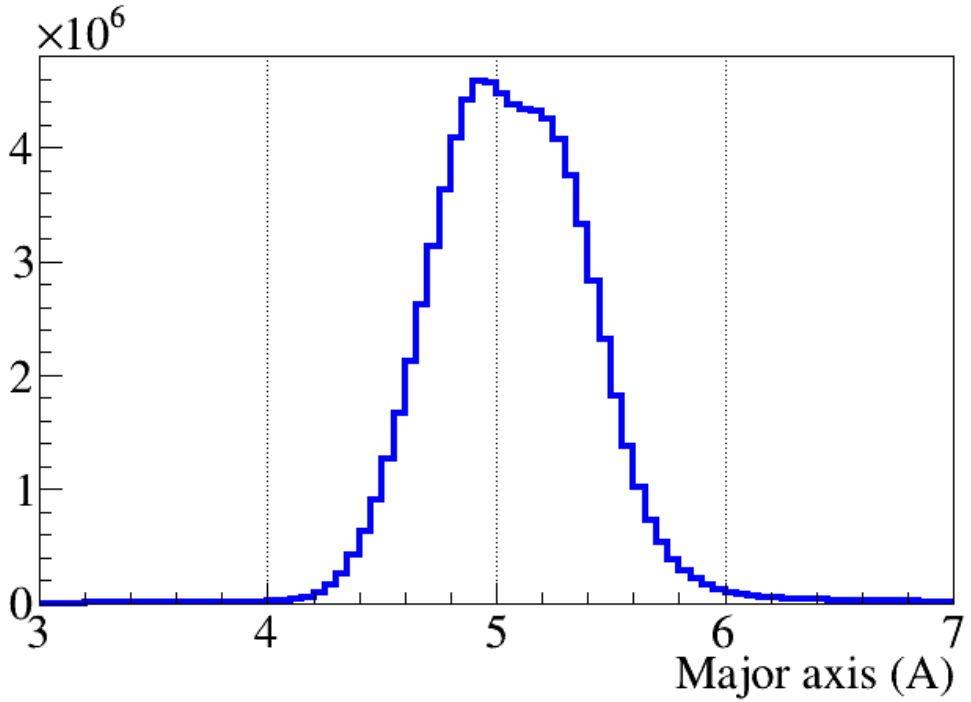
Determination of primary and secondary tracks (<5)

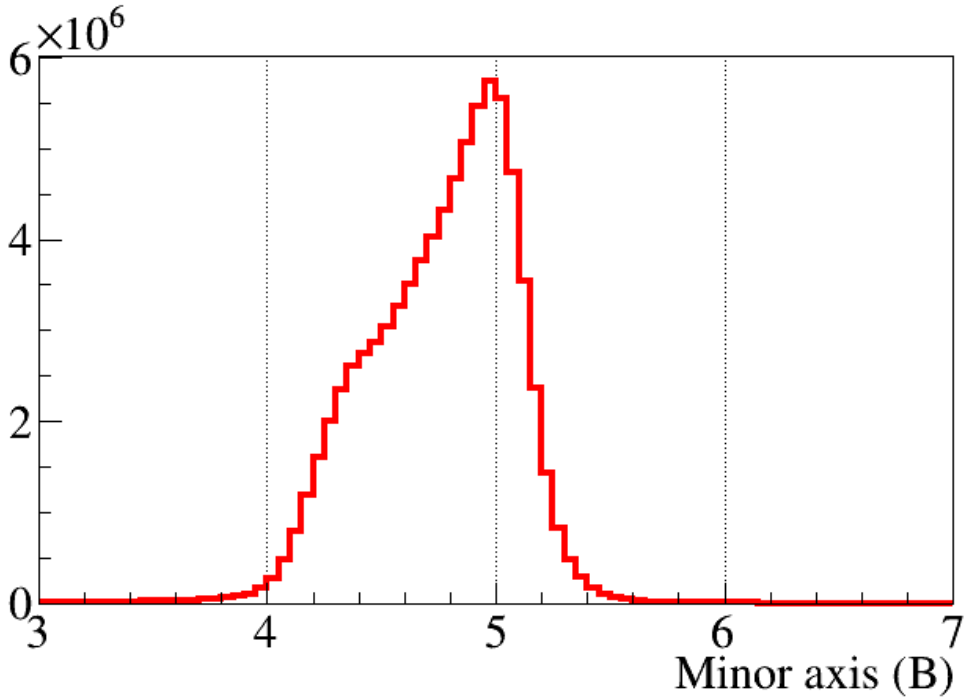


B and A distributions

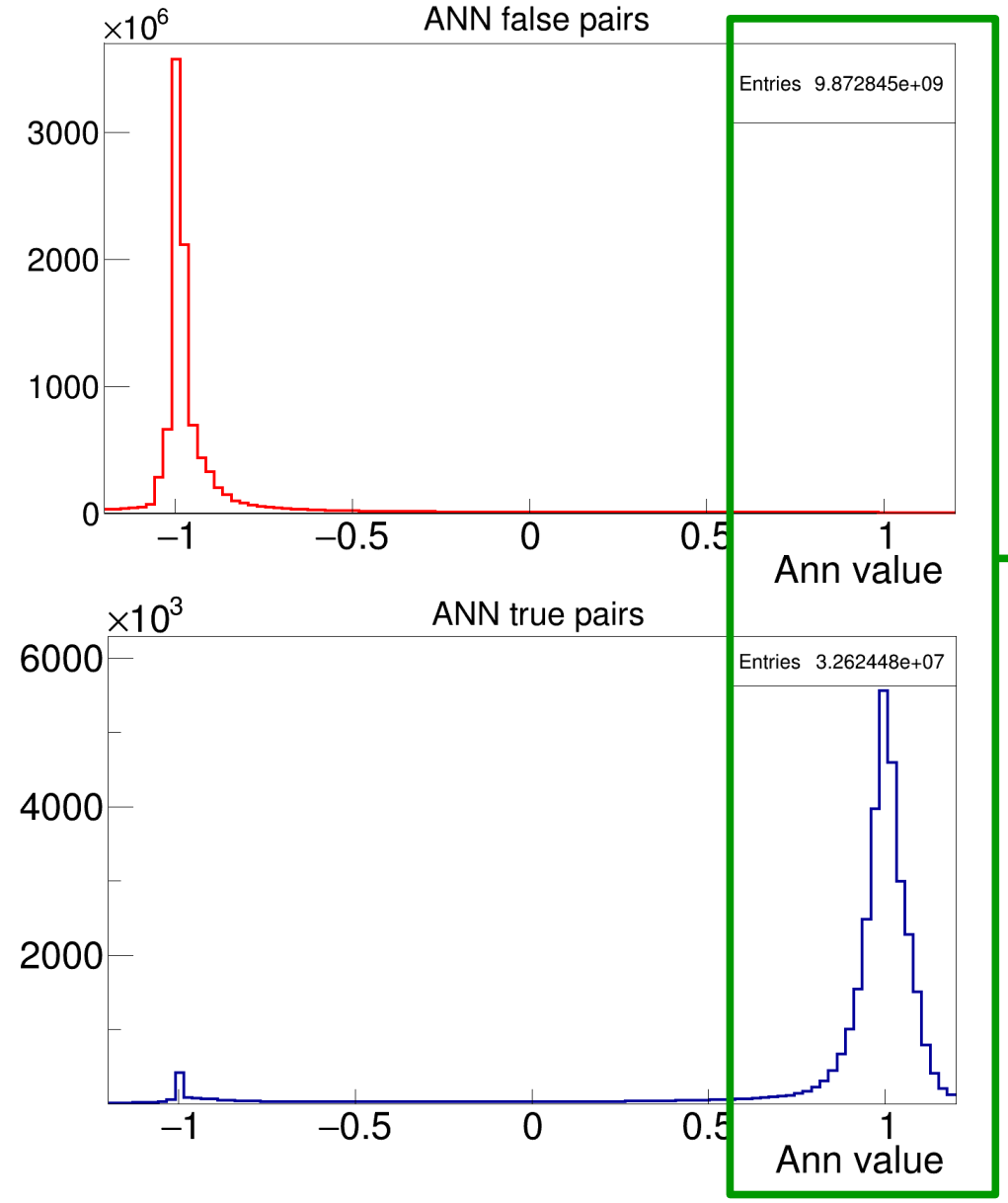
Cuts:

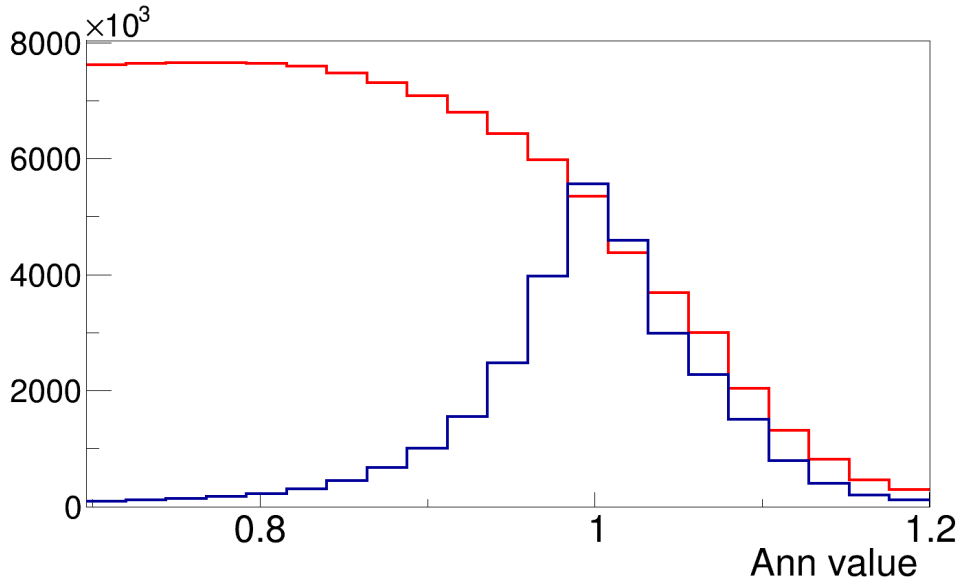
$4 < A < 6$ $4 < B < 6$



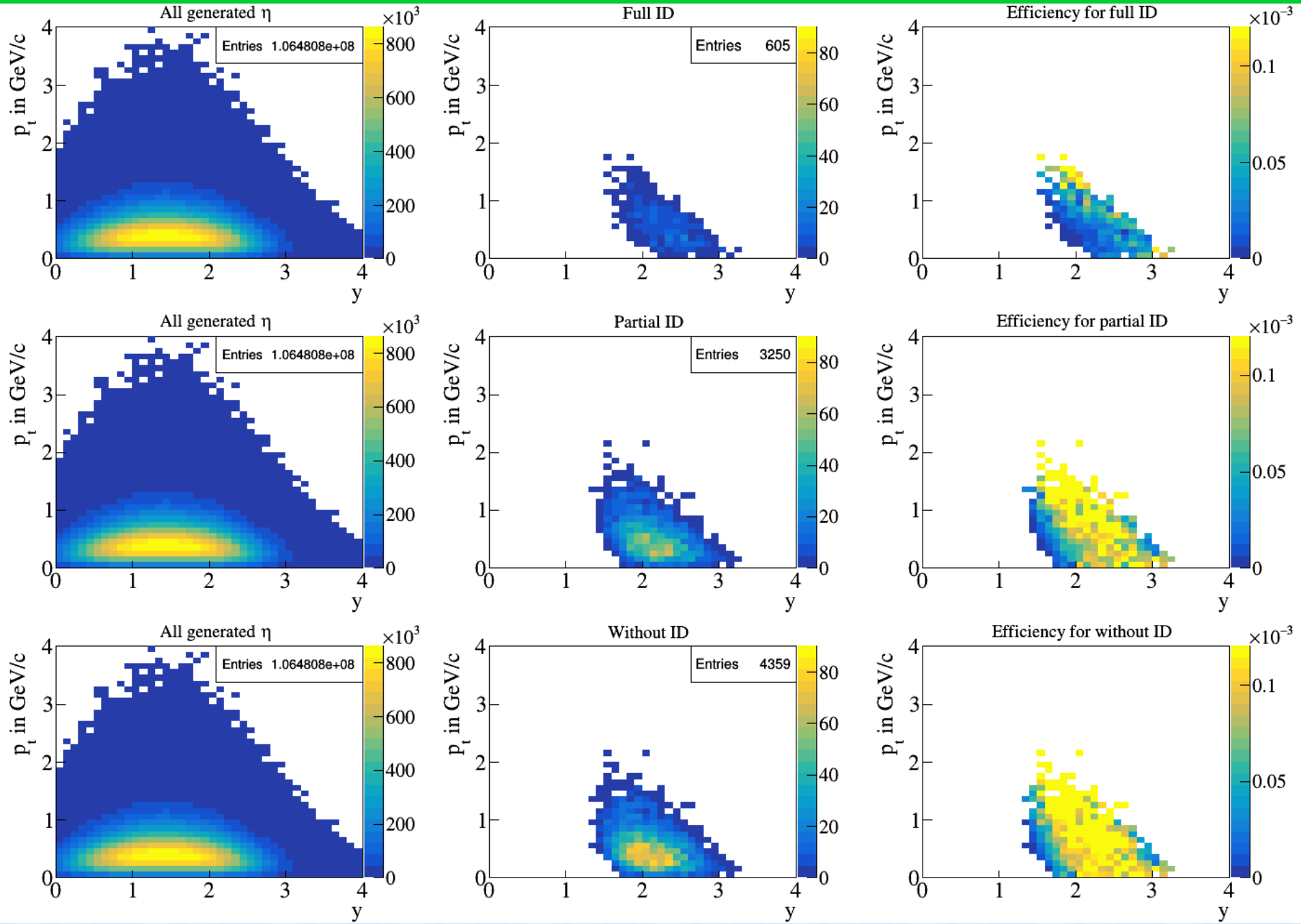


ANN cut


ANN false pairs
×10^6
Entries 9.872845e+09
3000
2000
1000
0
−1
−0.5
0
0.5
1
Ann value
ANN true pairs
×10^3
Entries 3.262448e+07
6000
4000
2000
−1
−0.5
0
0.5
1
Ann value

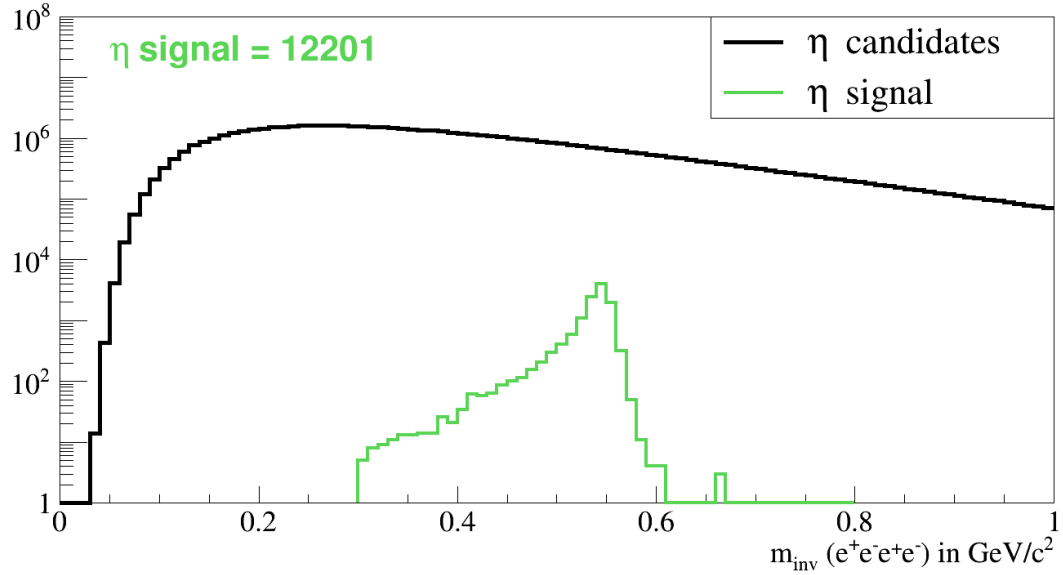

×10^3
8000
6000
4000
2000
0
0.8
1
1.2
Ann value

η acceptance and reconstruction efficiency



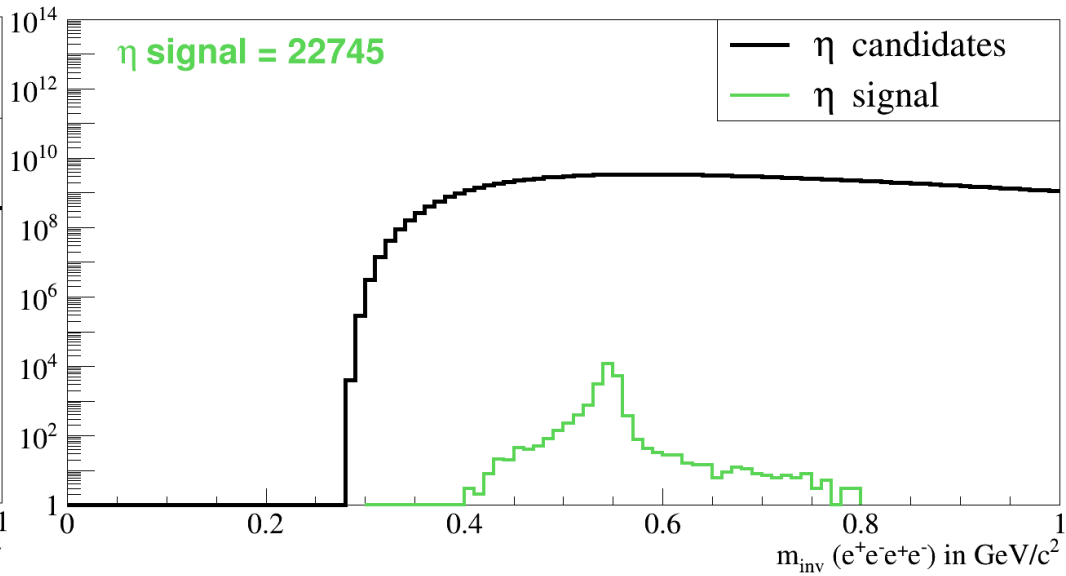
Estimation for η reconstruction

$\eta \rightarrow \gamma\gamma$



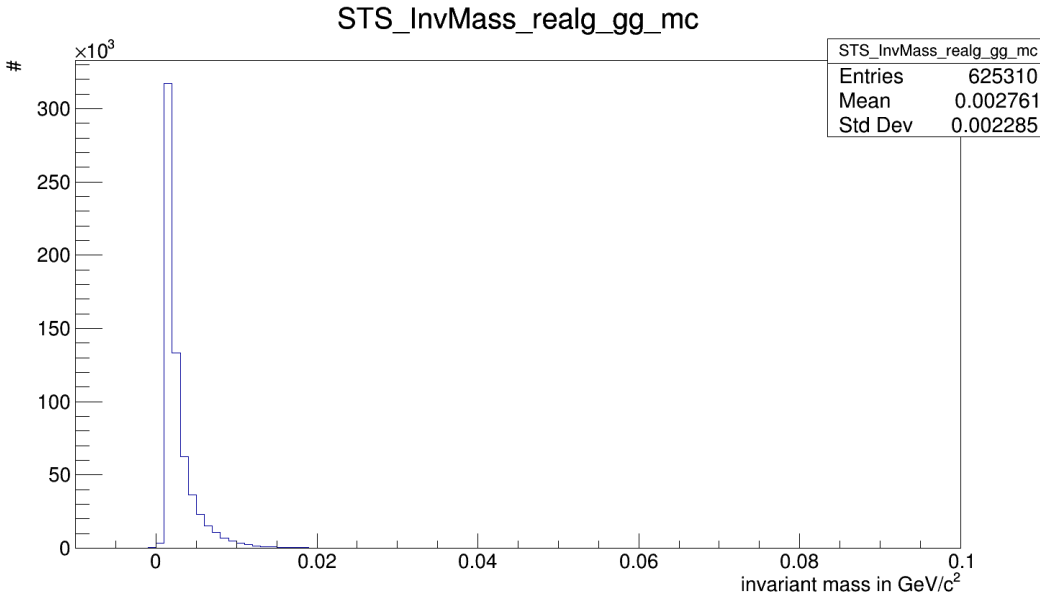
S/B ~ 10^{-2}

$\eta \rightarrow \pi^- + \pi^+ + \gamma$



S/B ~ 10^{-6}

Momentum transfer



Momentum transfer + reconstruction uncertainties