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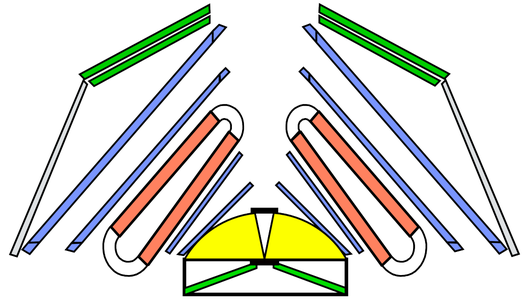
# Reconstruction of neutral mesons via photon conversion method in Ag-Ag collisions at 1.58A GeV with HADES

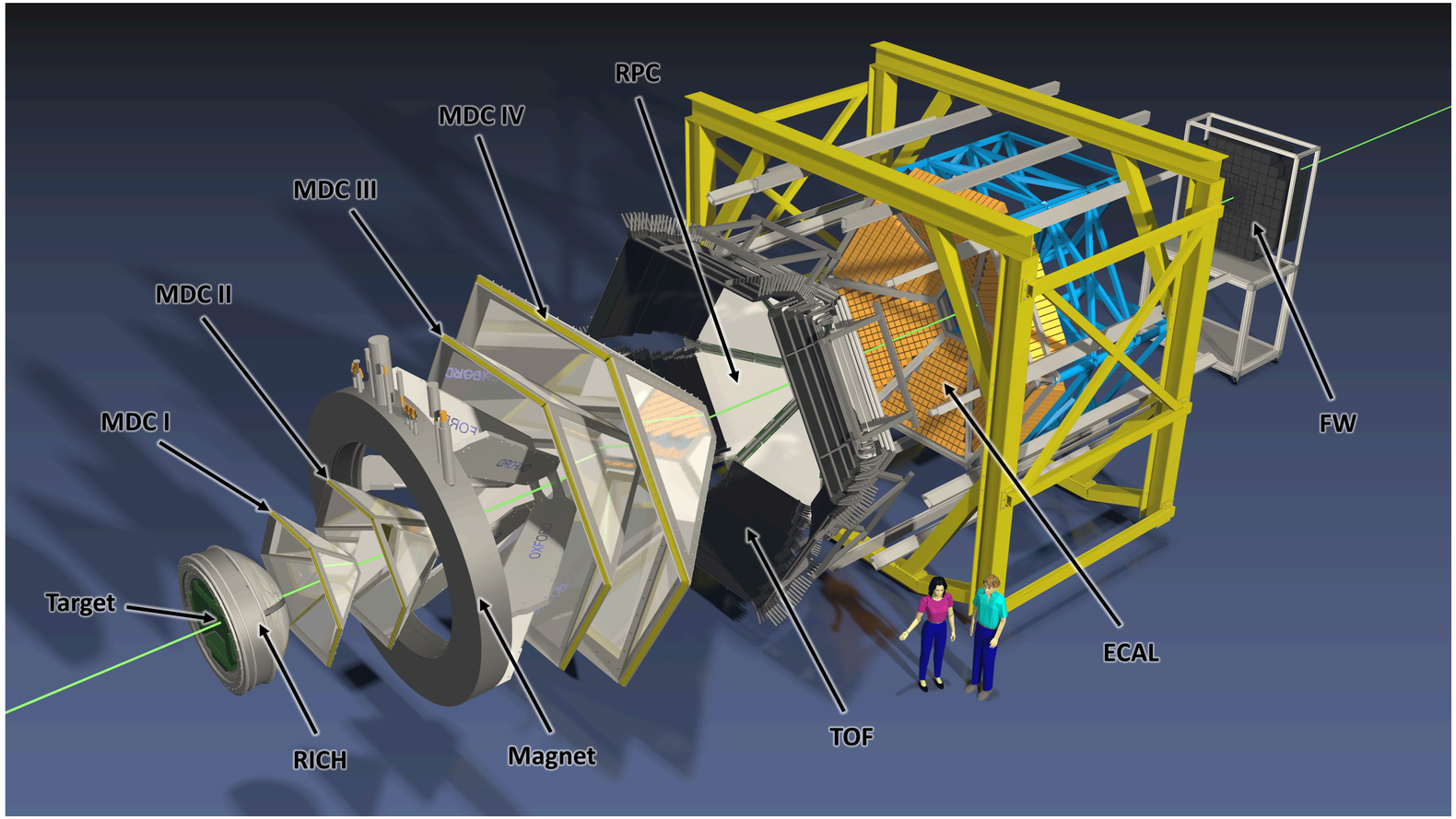
**Tetiana Povar**
**University of Wuppertal**



HADES

Zimányi School Winter Workshop 2022, 06.12.2022,Budapest

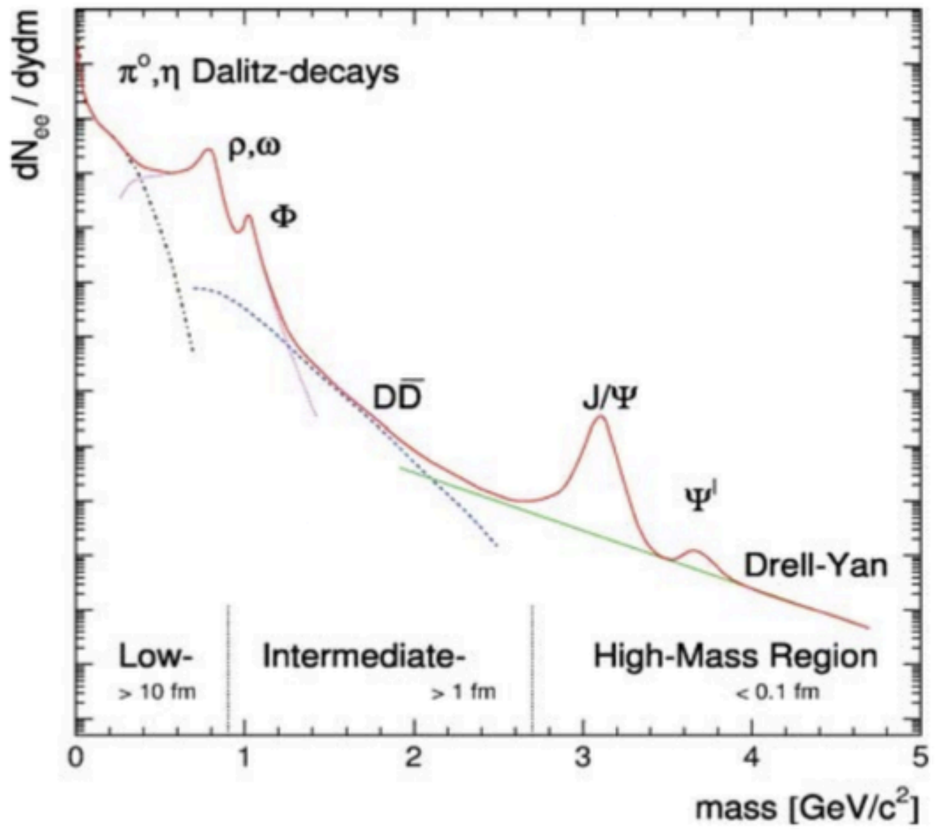
# HADES detector




- Installed at GSI SIS 18, in operation since 2001
- Studying baryonic matter in light and heavy systems
- Part of FAIR – phase 0 program.

- Used Ag+Ag collision data with kinetic beam energy 1.58A GeV produced in March 2019 .

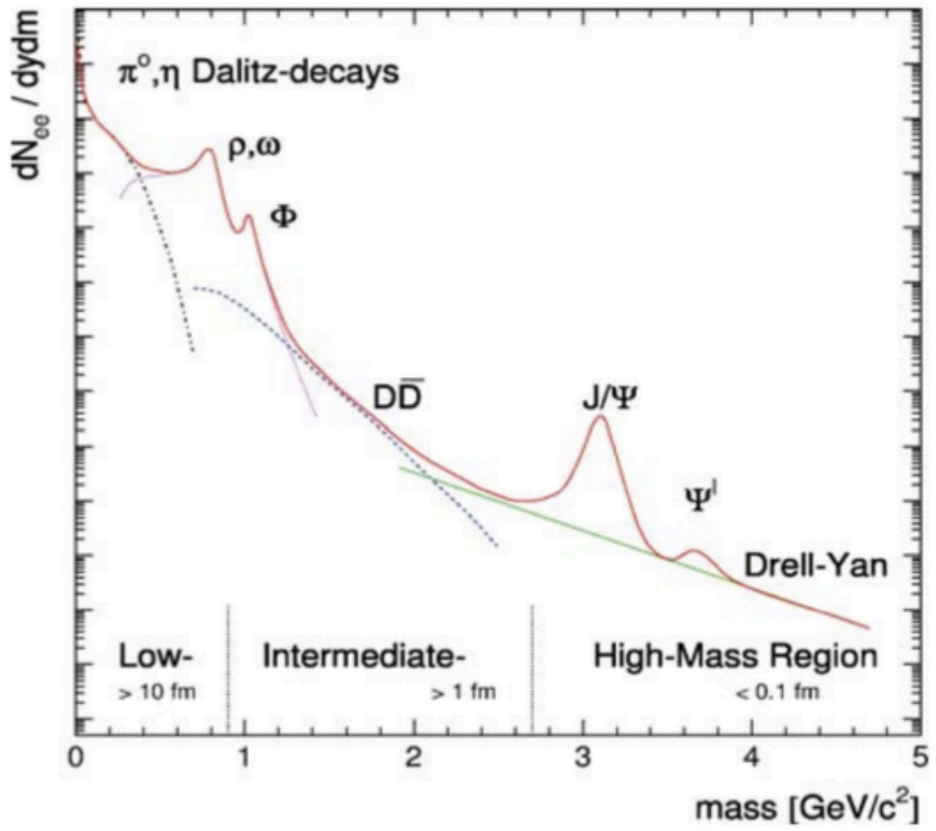
# Motivation




*Schematic view of the expected sources of dilepton production as function of the invariant mass in relativistic heavy-ion collisions.*

- Dilepton spectrum provides insight into fireball evolution.
- Main Background in $\rho/\omega$ region coming from $\pi^0$- and $\eta$-Dalitz decays.
- Precise $\pi^0$- and $\eta$ - yields necessary for proper background subtraction.

# Motivation




*Schematic view of the expected sources of dilepton production as function of the invariant mass in relativistic heavy-ion collisions.*

**Main channels of $\pi^0$ decay:**

$$\pi^0 \rightarrow \gamma\gamma\,(98.8\%)$$

$$\pi^0 \rightarrow \gamma e^- e^+\,(1.2\%)$$

**Main channels of $\eta$ decays:**

$$\eta \rightarrow \gamma\gamma\,(38.8\%)$$

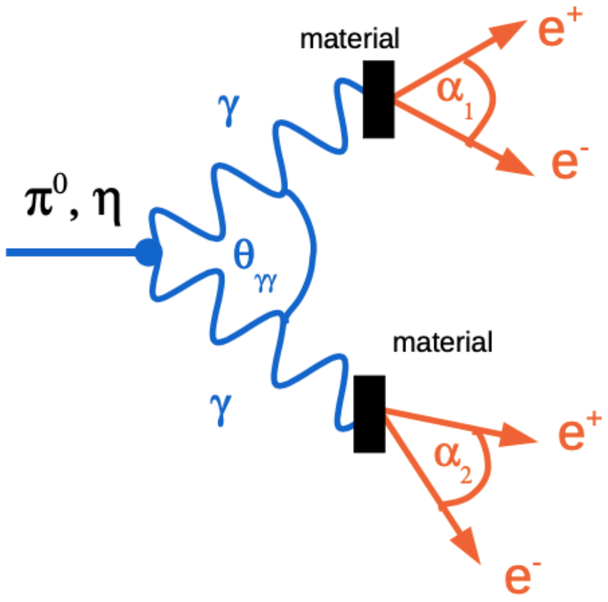
$$\eta \rightarrow 3\pi^0\,(31.9\%)$$

$$\eta \rightarrow \pi^0\pi^-\pi^+\,(23.6\%)$$

$$\eta \rightarrow \gamma\pi^-\pi^+\,(4.88\%)$$

$$\eta \rightarrow \gamma e^- e^+\,(0.5\%)$$

# Conversion method




**Two methods to detect photons:**

- **Directly(Electromagnetic calorimeter).**
- **Conversion method.**

**The main idea of the conversion method is to measure photons indirectly by detecting $e^+e^-$ pairs from conversion of $\gamma \rightarrow e^+e^-$ in the target or in the material of the detectors.**

# Reconstruction algorithm

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## Lepton identification:

Candidate momentum: p<1000 MeV/c

$0.93<\beta<1.2$

## Gamma selection:

Opening angle($e^-e^+$) <5°

$m_{(e^-e^+)}$ <100 MeV/c²

Distance at point of closest approach <4mm

**Inside target:**

Vertex cut(-70mm<$Z_{vertex}$<50mm)

Rich radius cut(18mm<R<30mm)

**Outside target:**

Vertex cut(50mm<$Z_{vertex}$<800mm)

No Rich rings required

## Meson selection:

10° <Opening angle ($\gamma\gamma$)<40° for $\pi^0$

40° <Opening angle ($\gamma\gamma$)<110° for $\eta$

# $\beta$ vs Momentum of lepton candidates

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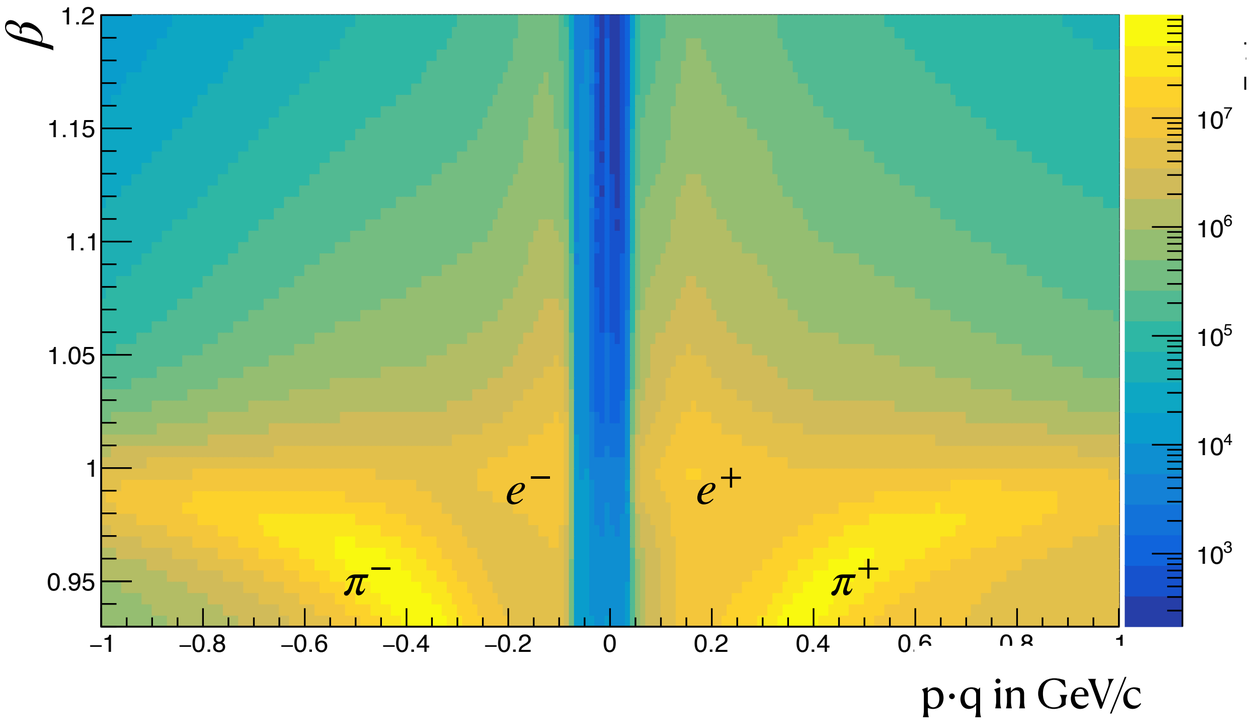
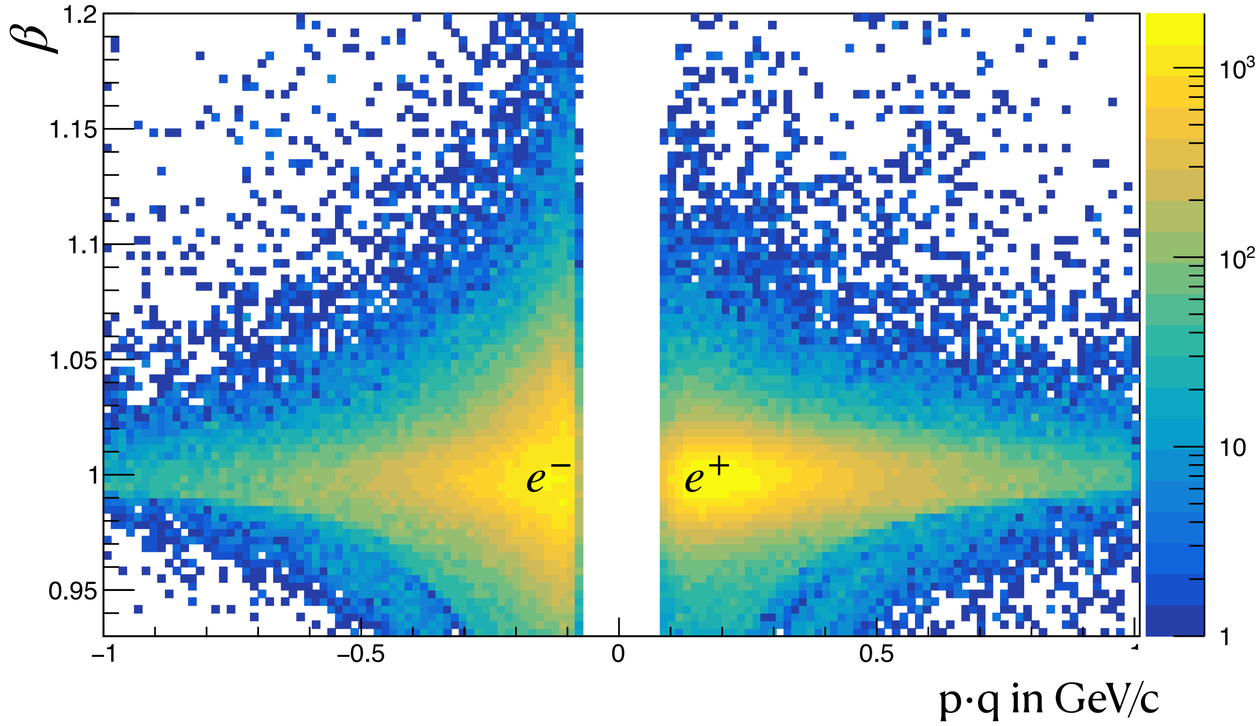
**All Candidates(Before all cut)**



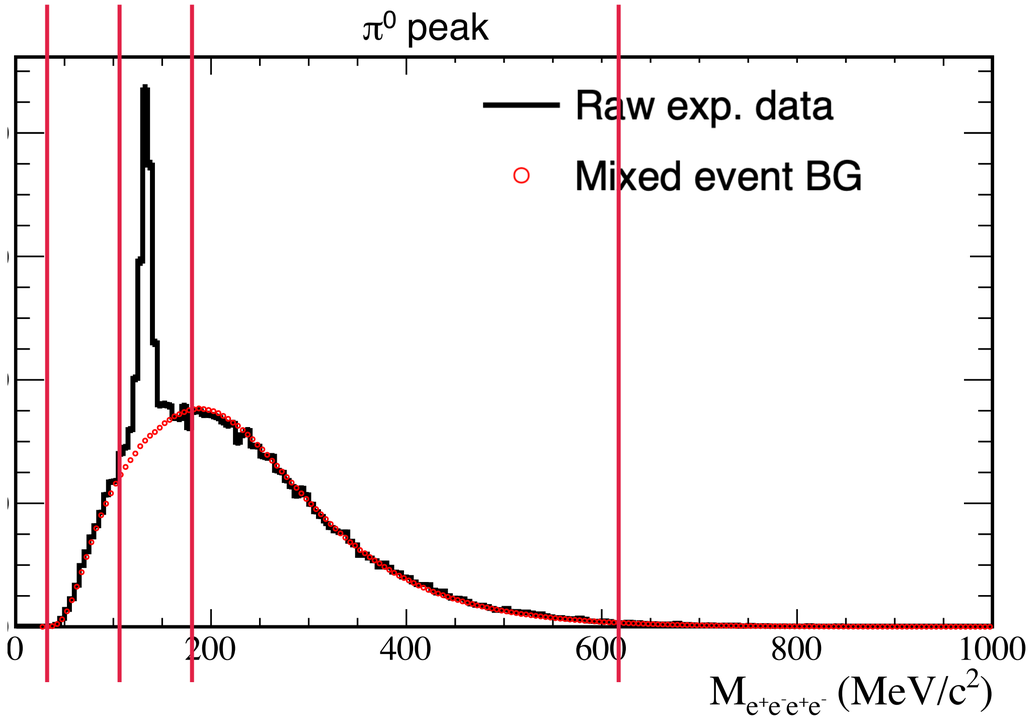

**Selected candidates(After all cut)**



# Background approximation using event mixing

Mixing e+/e- pairs from different events with **same centrality and target segment.**

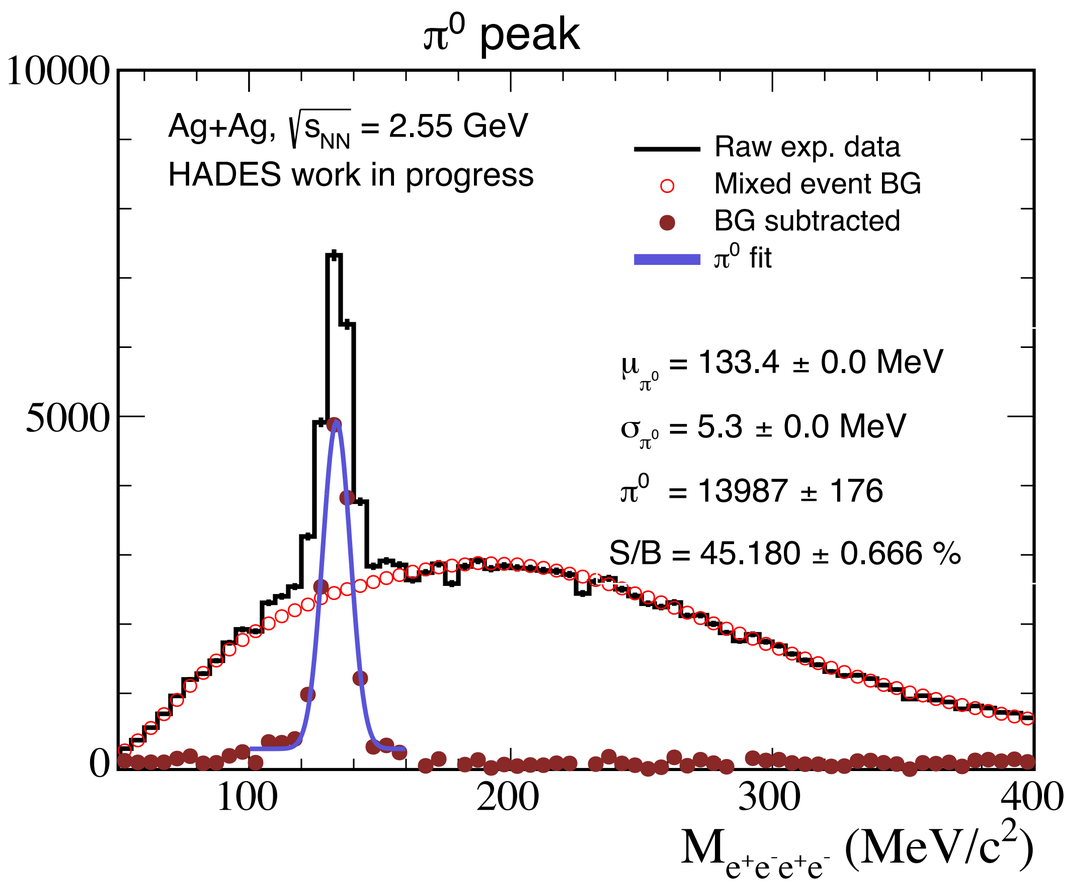
Mix every 10000 events( mixed events  are close together in time).

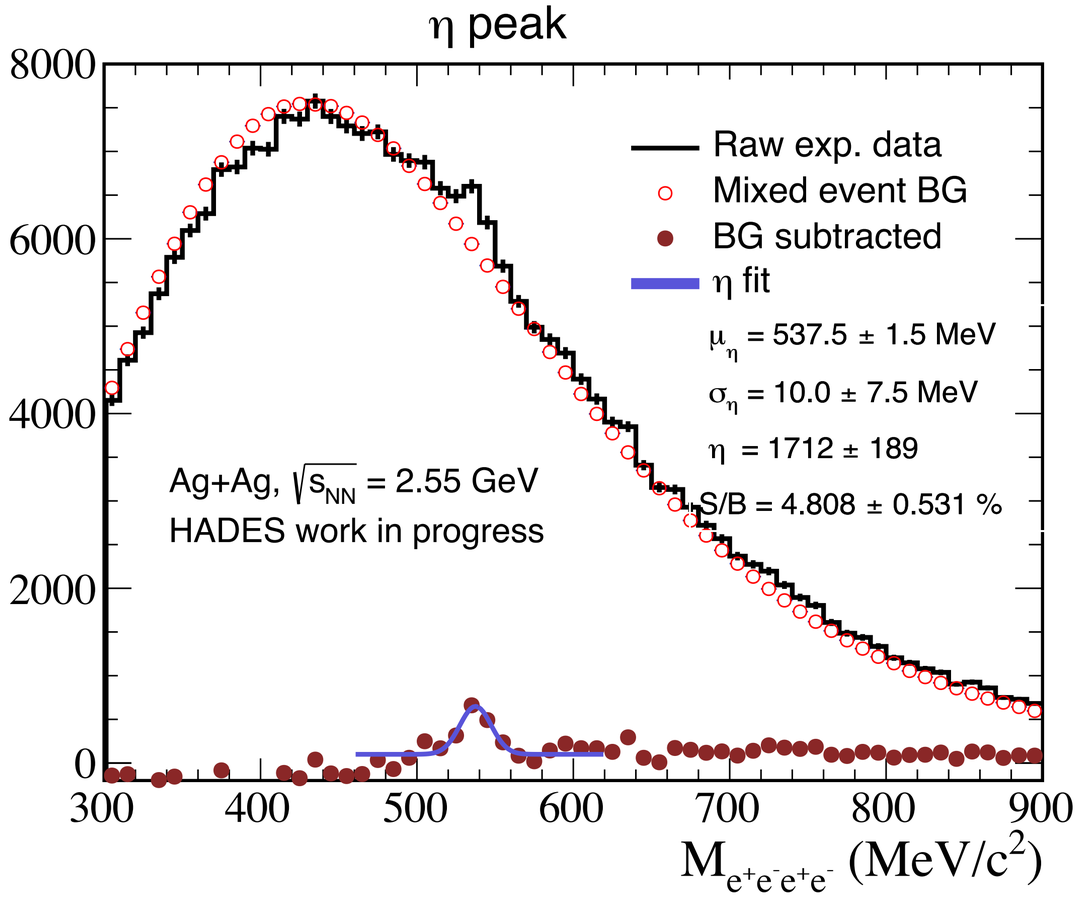



Combinatorial background is wrong pair combinations( particles from different decays).

# Invariant mass spectrum of $e^-e^+e^-e^+$

Number of events(0-40% centrality): $4.81*10^9$

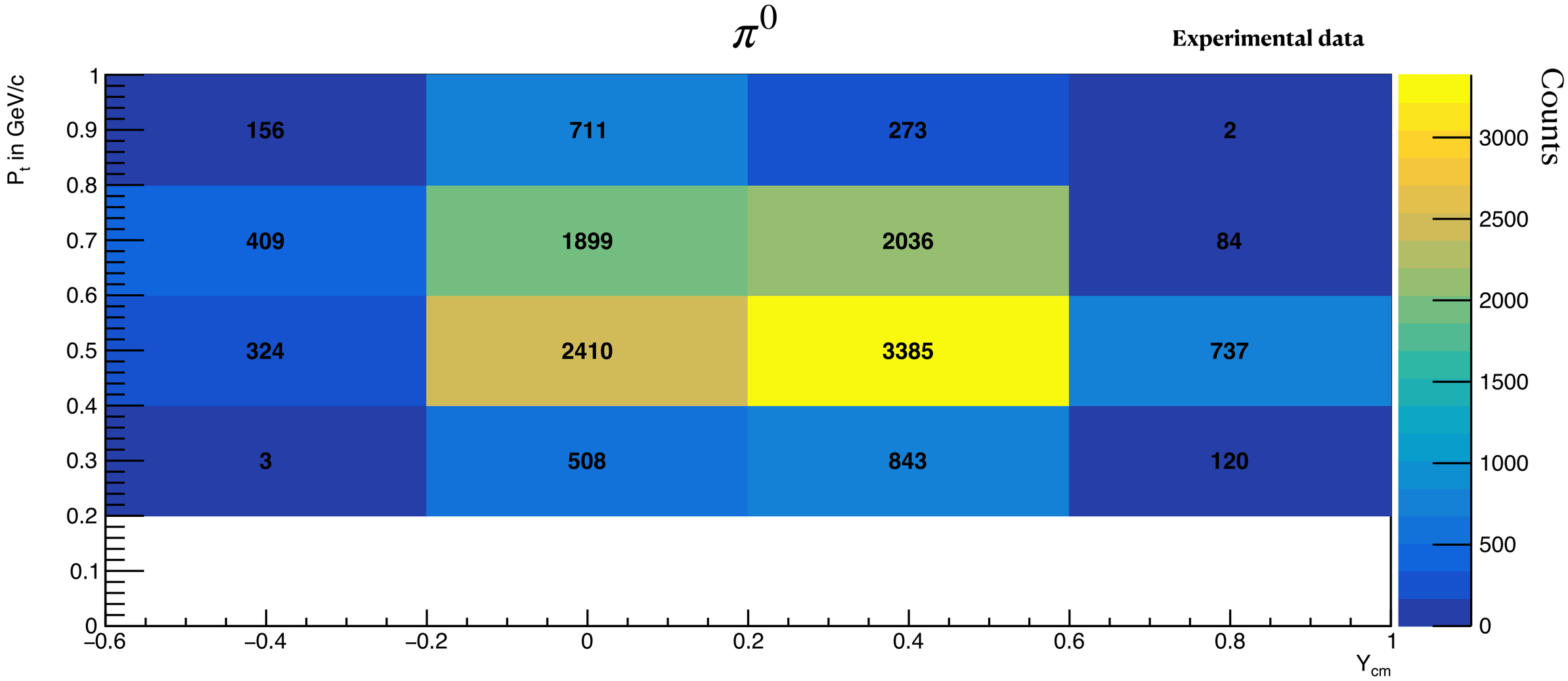



$$\pi^0 = 13987 \pm 176$$

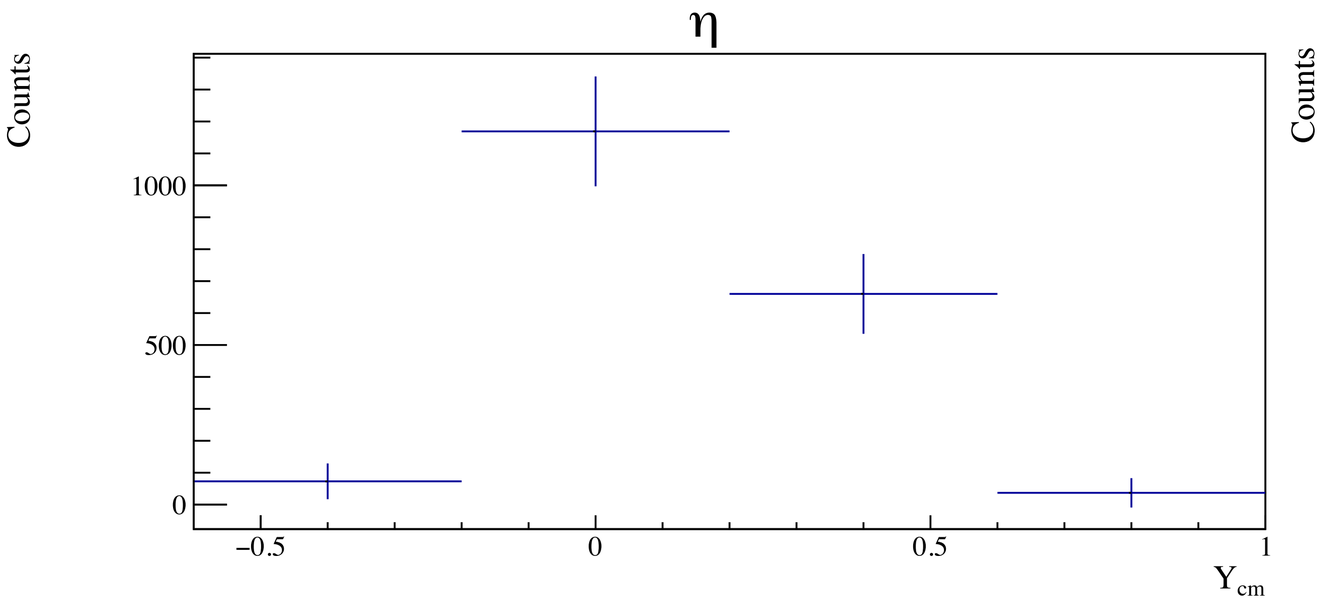
$$\eta = 1712 \pm 189$$

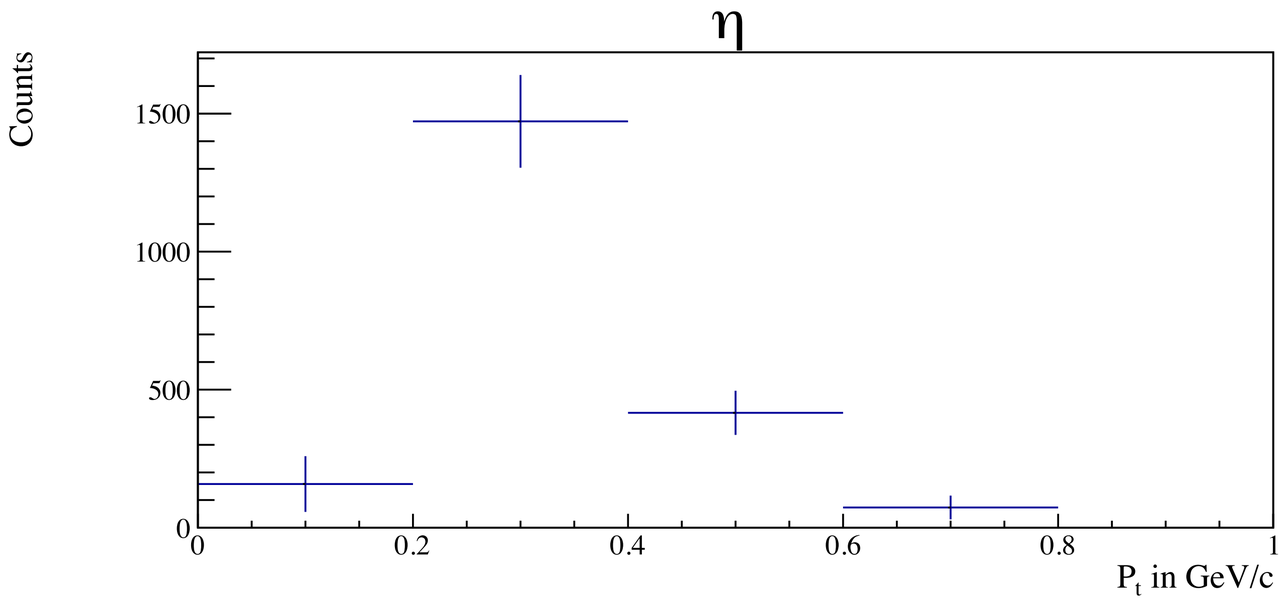
# Raw $\pi^0$ yield in $Y_{cm}$-$P_t$ bin



# Raw $\eta$ yield in $Y_{cm}$ and $P_t$ bin

**Experimental data**



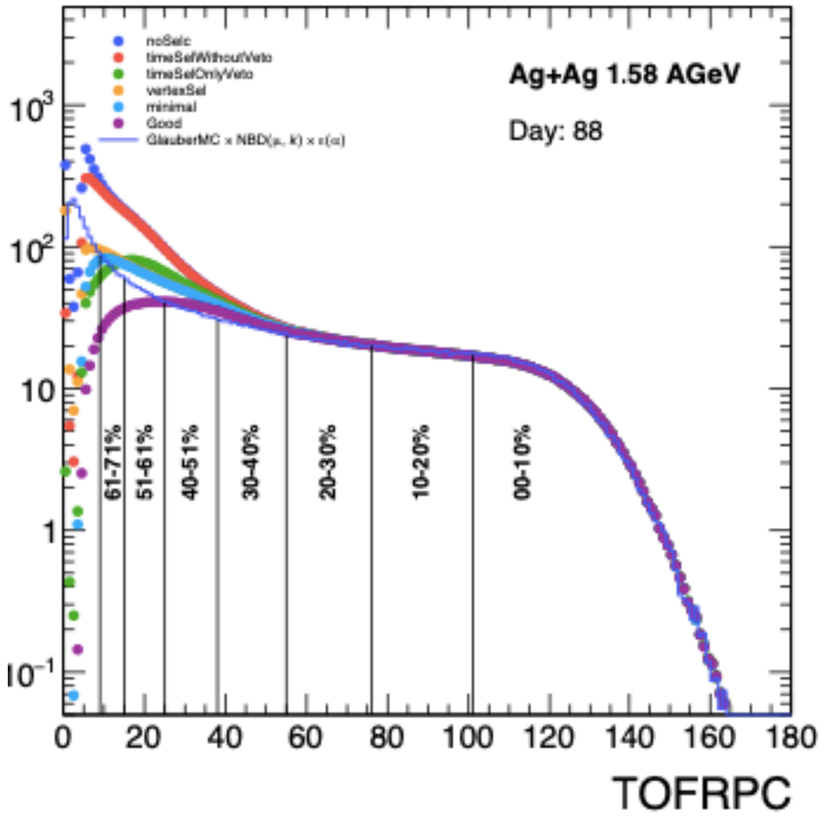

- Small statistics → hard to use $P_t$-Y bin.
- More statistics are reconstructed in [-0,2;0,2] for Y and [0,2;0,4] GeV/c for $P_t$-bin.

# Centrality classes

- Centrality is the fraction of total cross section in relation to impact parameter:

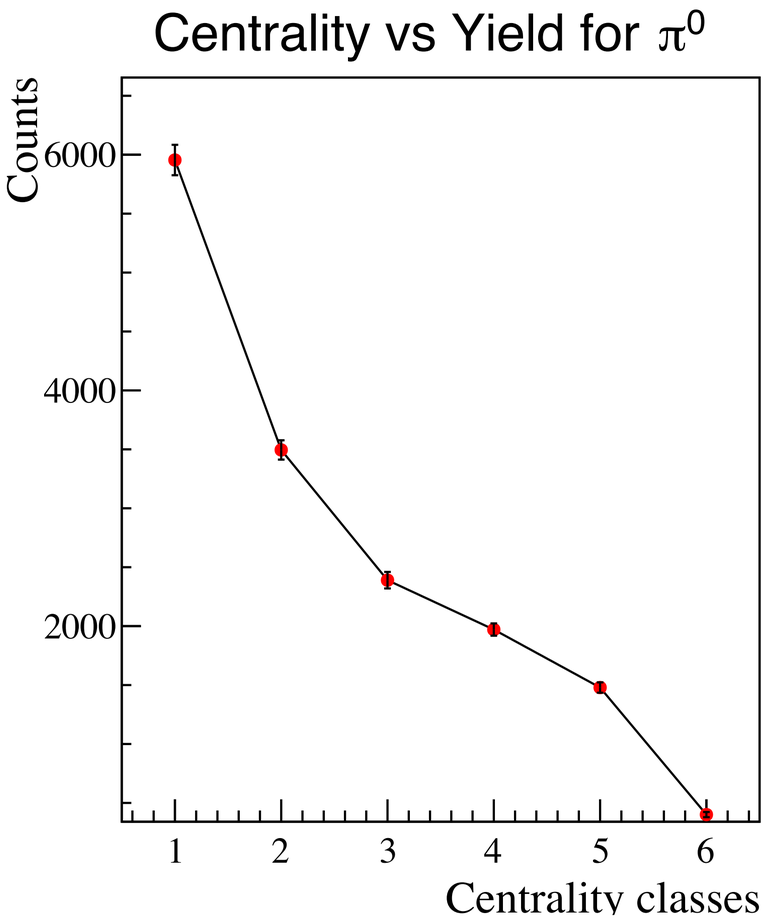
$$C = \frac{\int_0^b d\sigma/db'\,db'}{\int_0^\infty d\sigma/db'\,db'} = \frac{1}{\sigma_{AA}}\int_0^b \frac{d\sigma}{db'}\,db', \qquad C \approx \frac{1}{\sigma_{AA}}\int_{N^{\mathrm{thr}}}^\infty \frac{d\sigma}{dN'}\,dN',$$

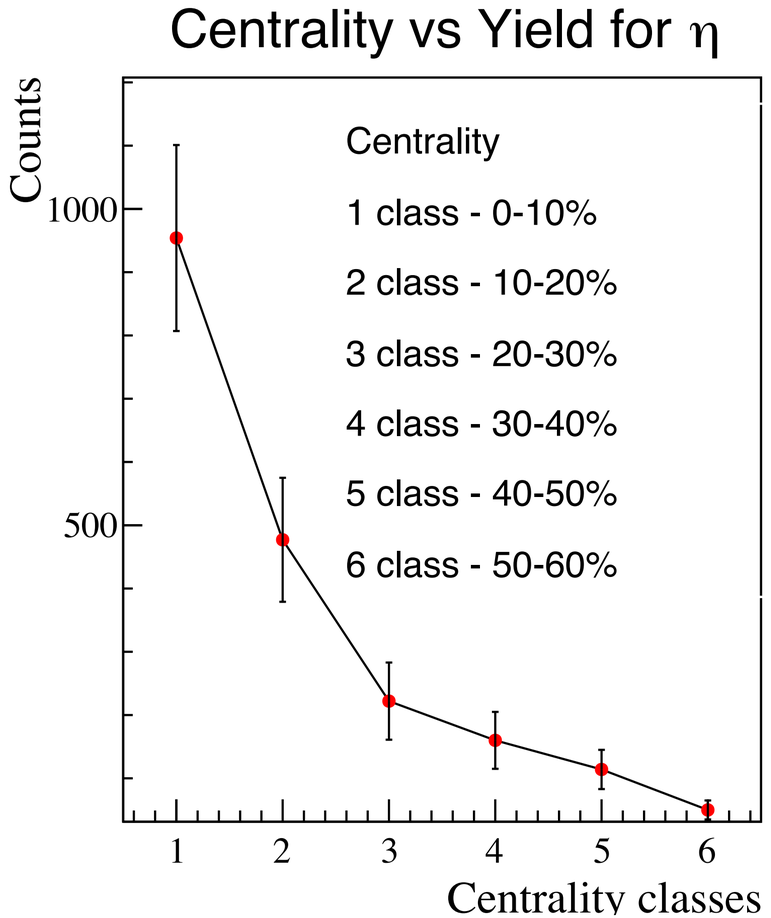
- Centrality class determined based on hit multiplicity in HADES




Berhuz Kardan.Event Characterization II Ag+Ag gen4. Low level meeting.(08.12.20)

# Centrality vs Yield



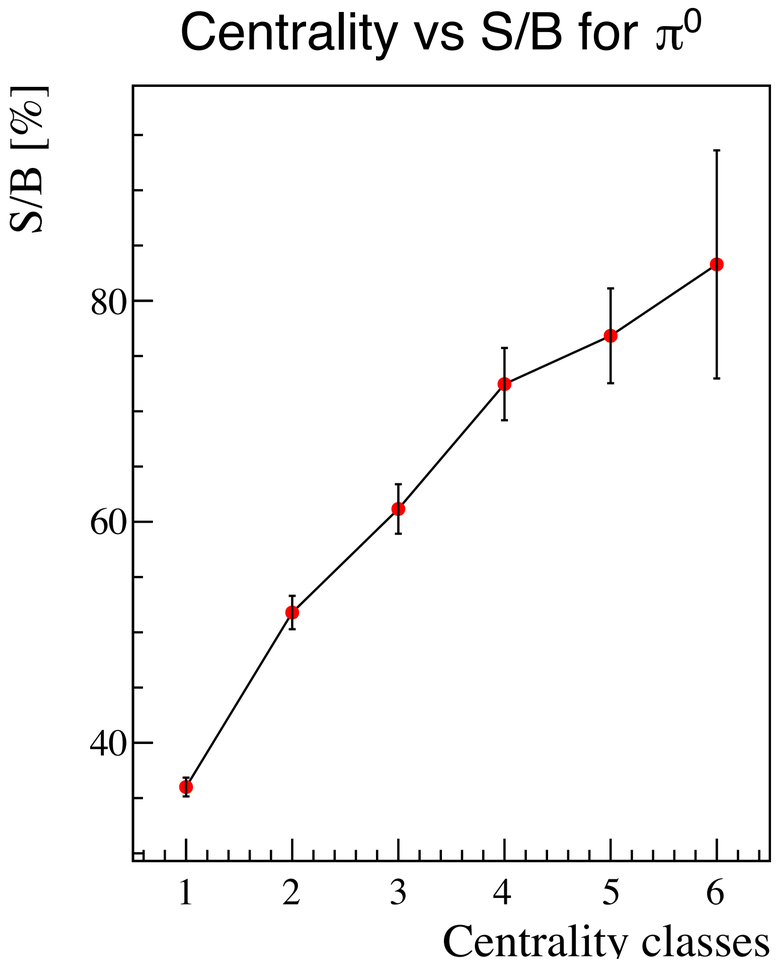



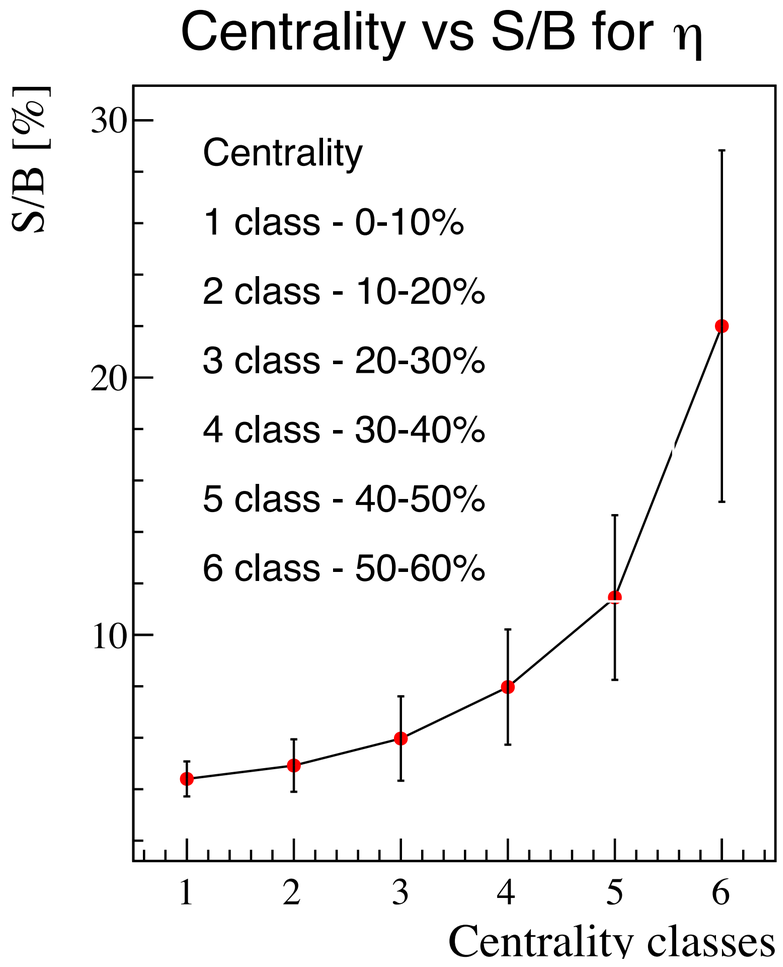

Yield decreasing with increasing centrality class.

Reconstructed $\pi^0$ signal more pronounced in the most central collisions.

**Central** ← **Peripheral**

# Centrality vs S/B




Background decreasing with increasing centrality class.

Large statistic error for most peripheral class - low statistics for precise fit.

**Central** ← **Peripheral**

# Conclusion

- Raw $\pi^0$ and $\eta$ signal have been reconstructed in 1.58A GeV Ag-Ag collisions in 0-40% centrality class.
- Raw IM spectrum has been extracted as a function of y, $p_t$ for $\pi^0$ and $\eta$ .

  (before acceptance / efficiency correction).
- Centrality dependance of $\pi^0/\eta$ has been determined (before acceptance / efficiency correction).
- Signal / background ratio is rising in larger centrality classes .
- Derive efficiency correction for the data (as function of $p_t$ / y).
- Derive acceptance correction for the data (as function of p / $\theta$/ $\phi$).

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# Back up

# Background approximation using event mixing

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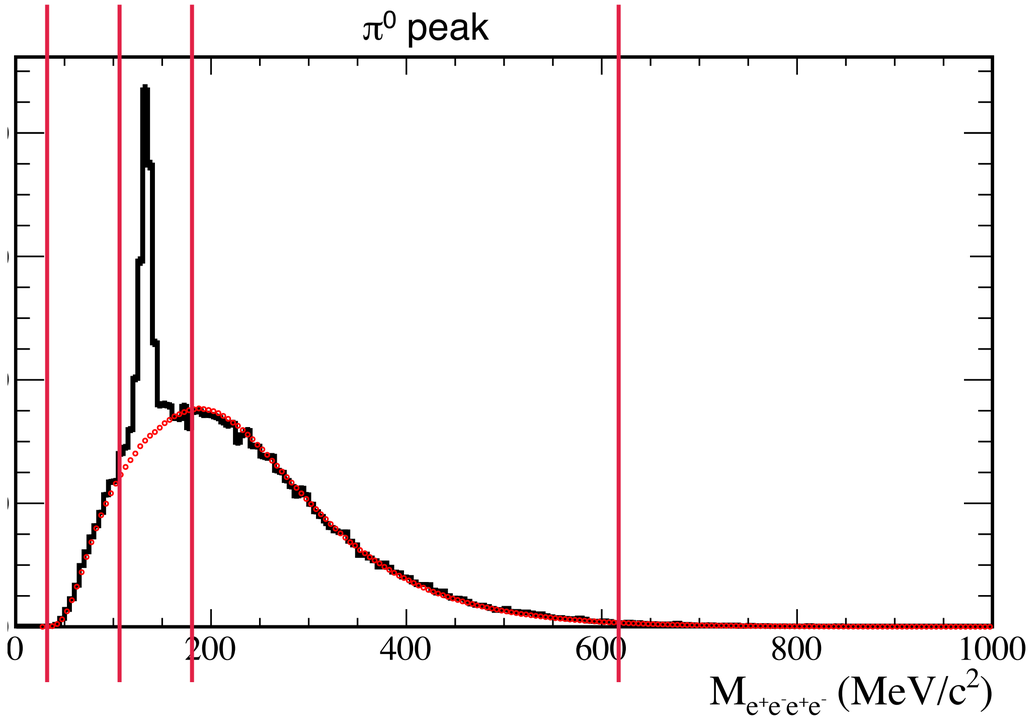
Mixing e+/e- pairs from different events with **same centrality and target segment.**

Mix every 10000 events( mixed events are close together in time).




$\pi^0$

Scaling of background distribution estimated using data in range:

30 MeV/$c^2$<$M_{ee}$< 100 MeV/$c^2$

& 160 MeV/$c^2$<$M_{ee}$< 600 MeV/$c^2$

$\eta$

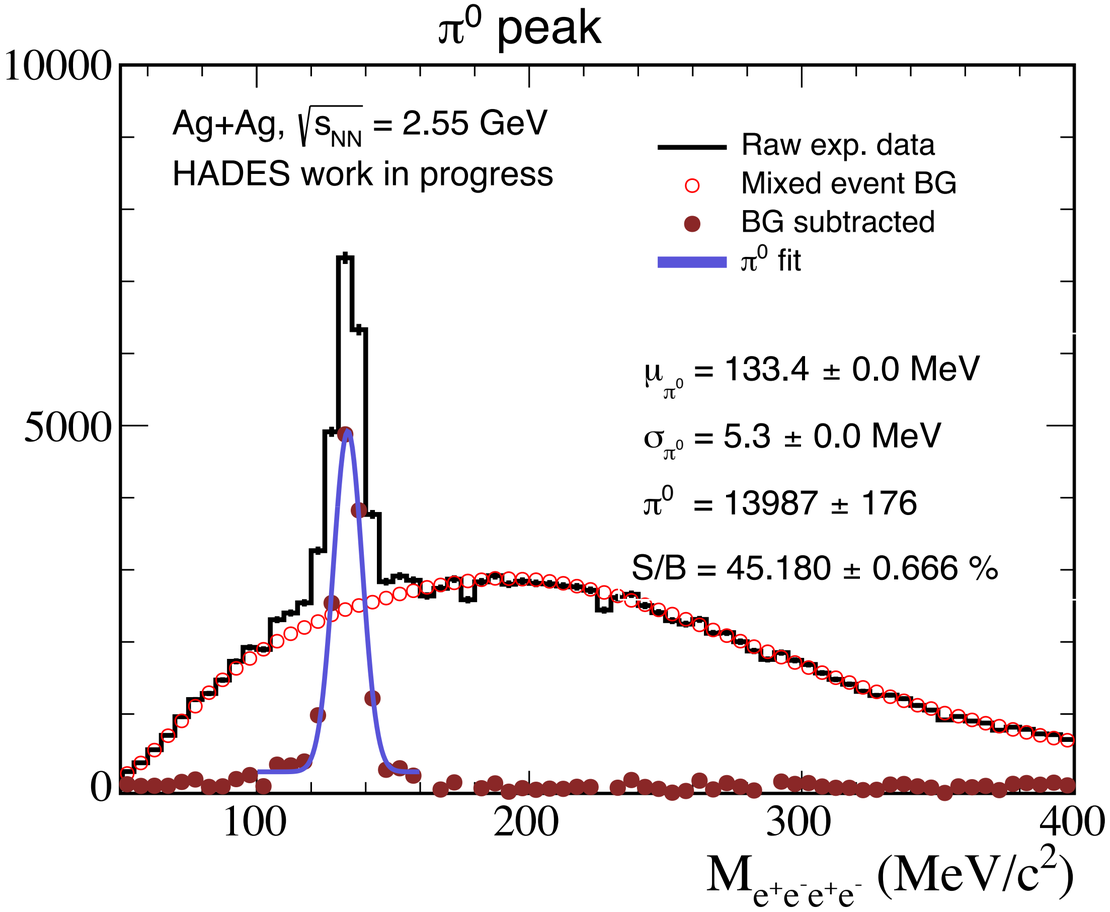
Scaling of background distribution estimated using data in range:

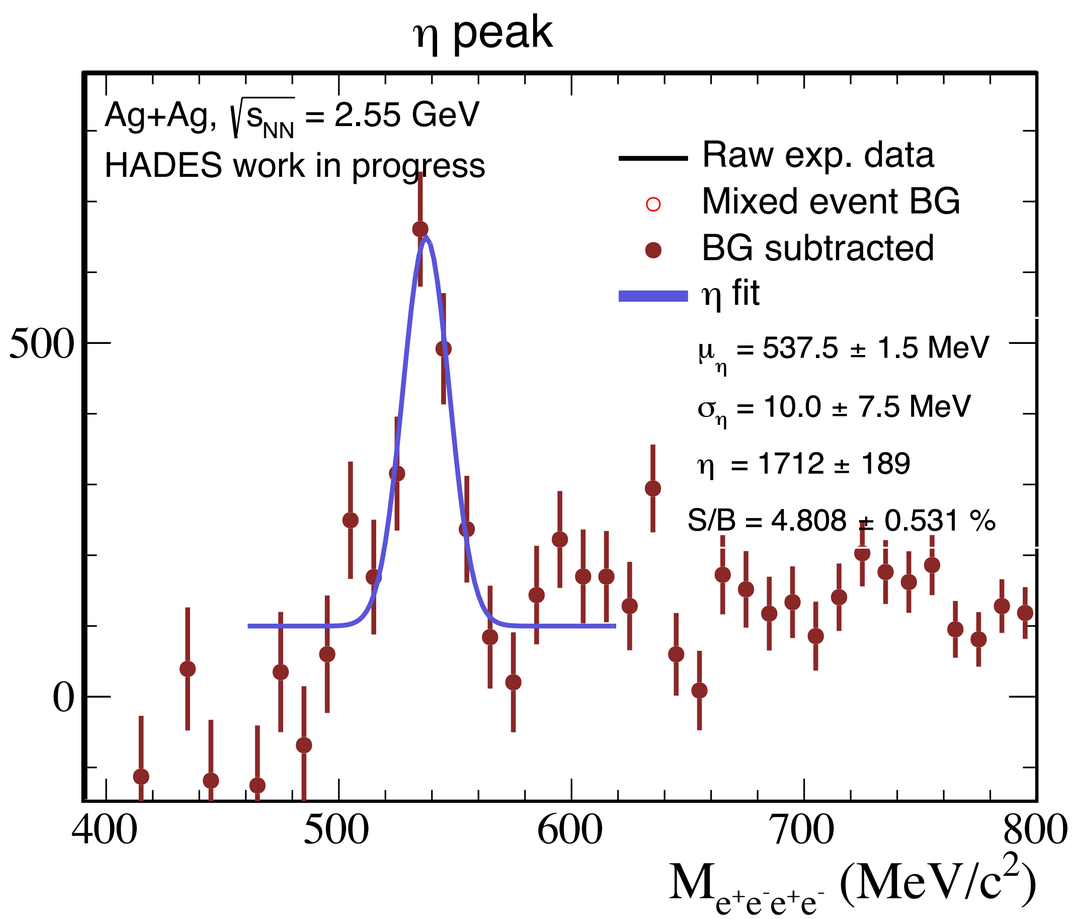
200 MeV/$c^2$<$M_{ee}$< 400 MeV/$c^2$

& 600 MeV/$c^2$<$M_{ee}$< 800 MeV/$c^2$

# Invariant mass spectrum of $e^-e^+e^-e^+$

Number of events(0-40% centrality): $4.81*10^9$



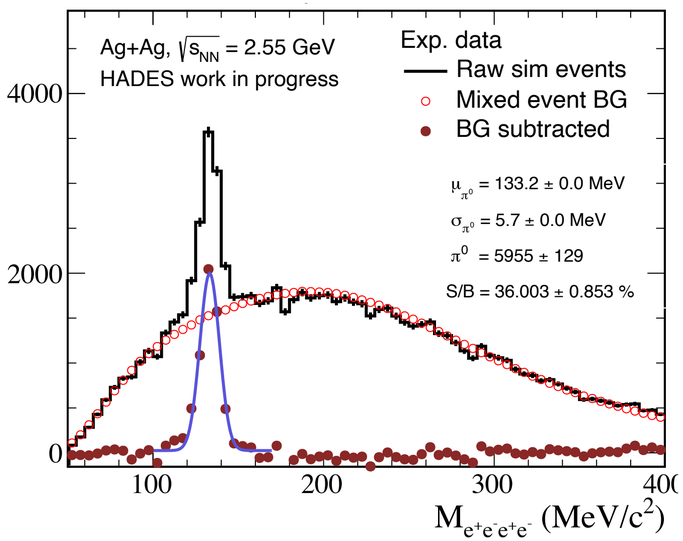




$\pi^0 = 13987 \pm 176$

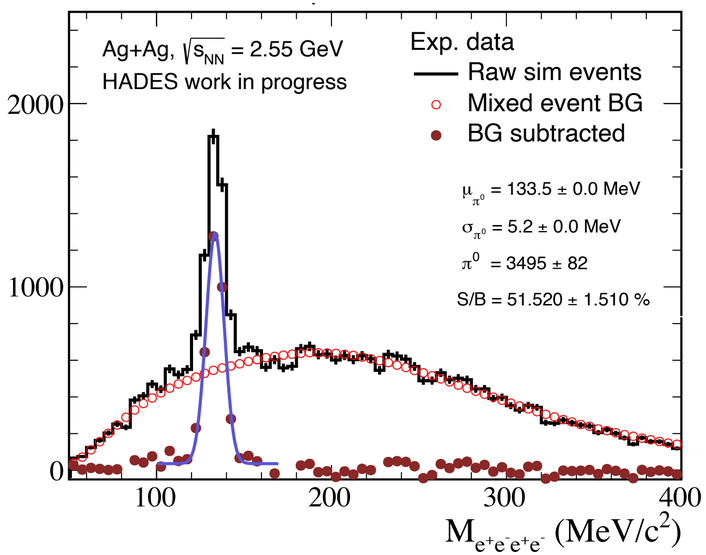
$\eta = 1712 \pm 189$

# Invariant mass of $e^-e^+e^-e^+$ in centrality bin

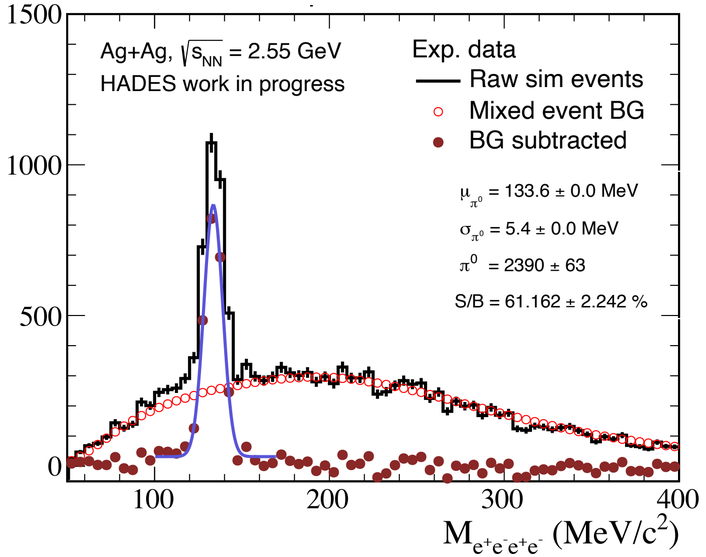
## 0-10% centrality



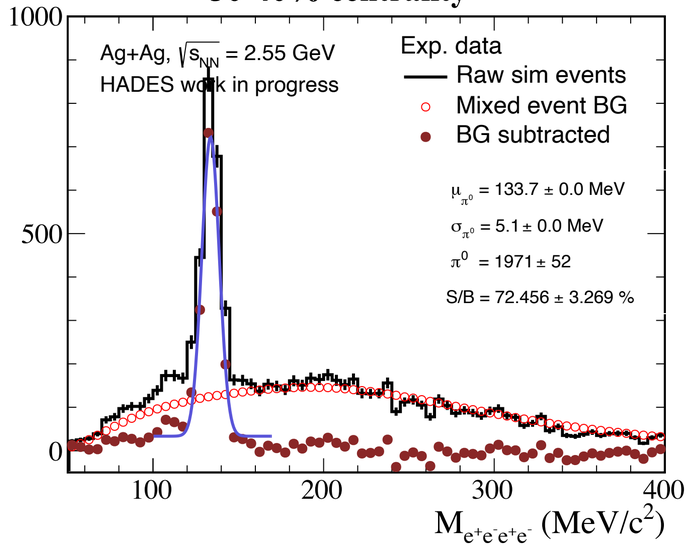

## 10-20% centrality



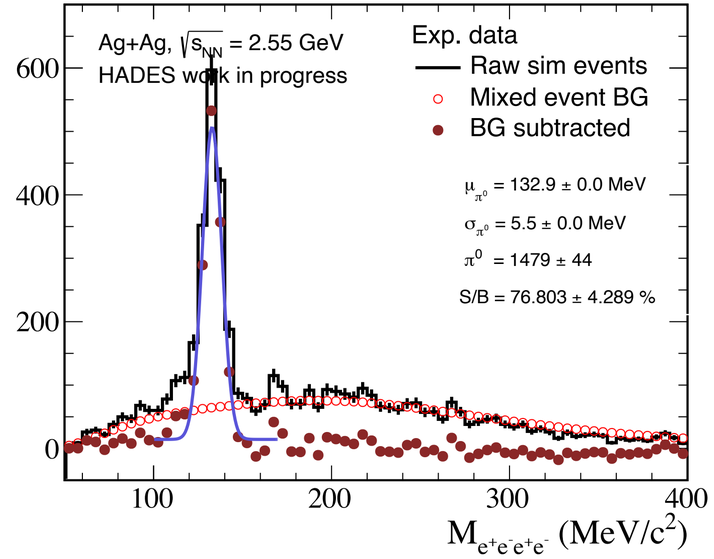

## 20-30% centrality



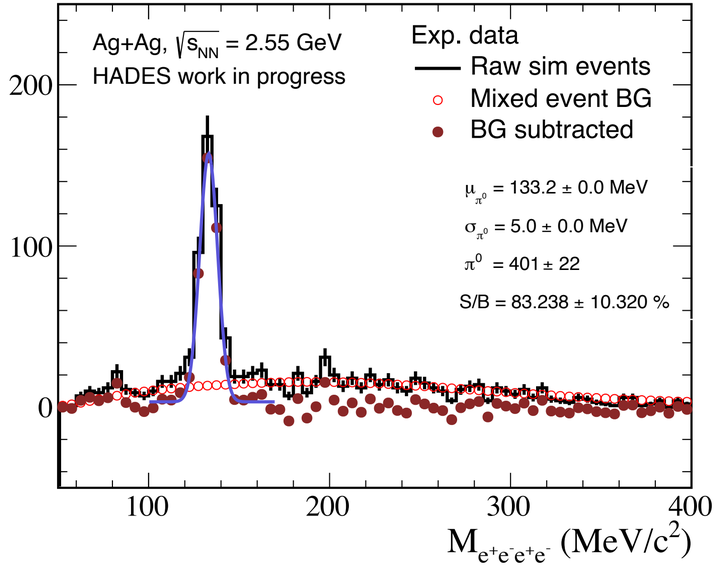

## 30-40% centrality



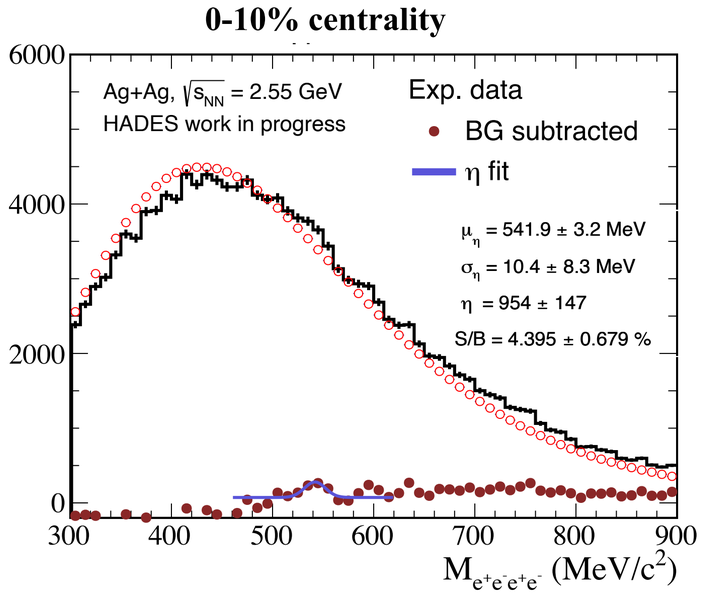

## 40-50% centrality

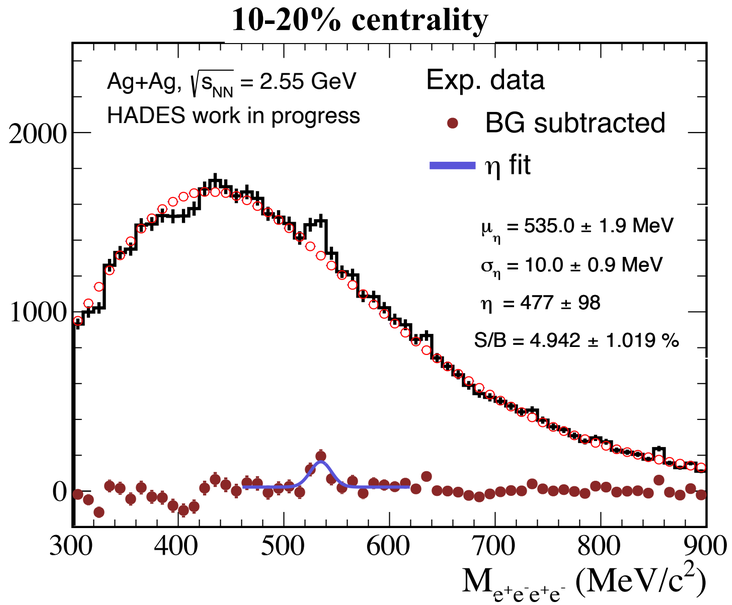


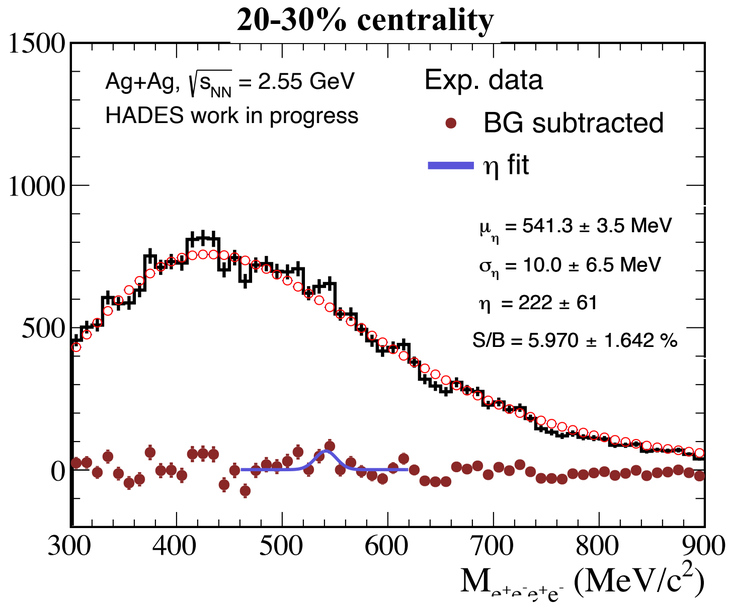

## 50-60% centrality

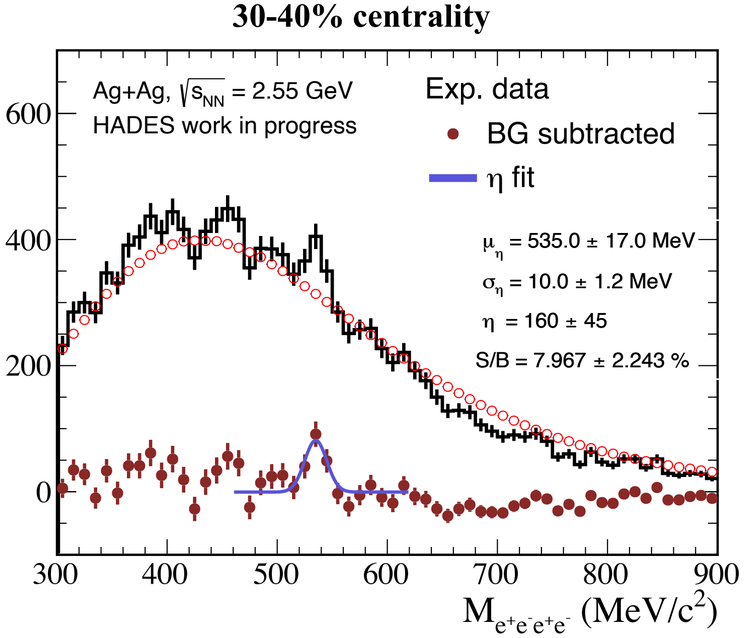


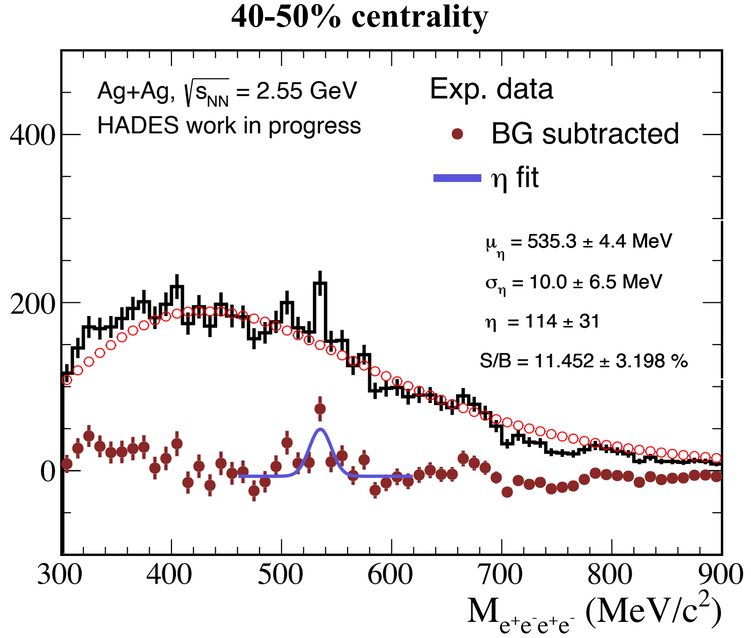
# Invariant mass of $e^-e^+e^-e^+$ in centrality bin

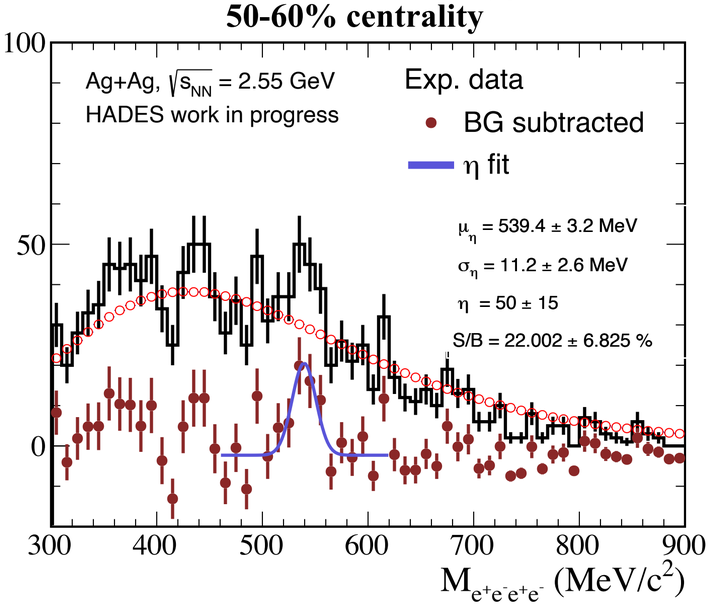


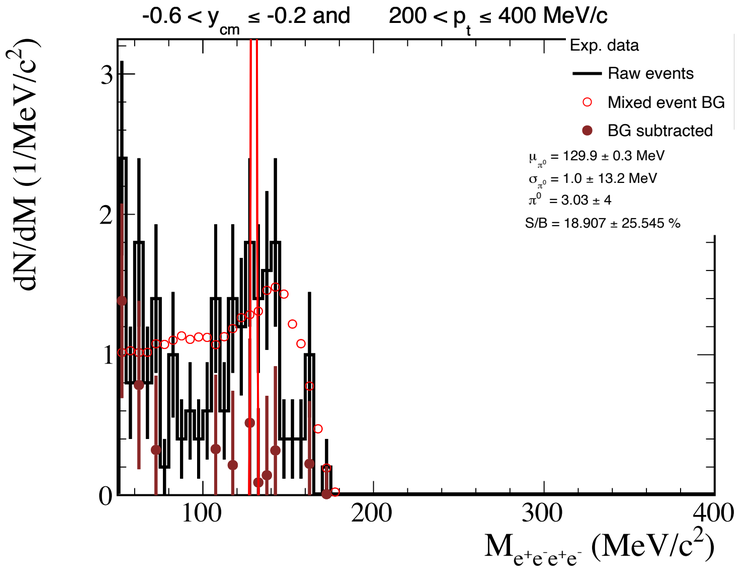



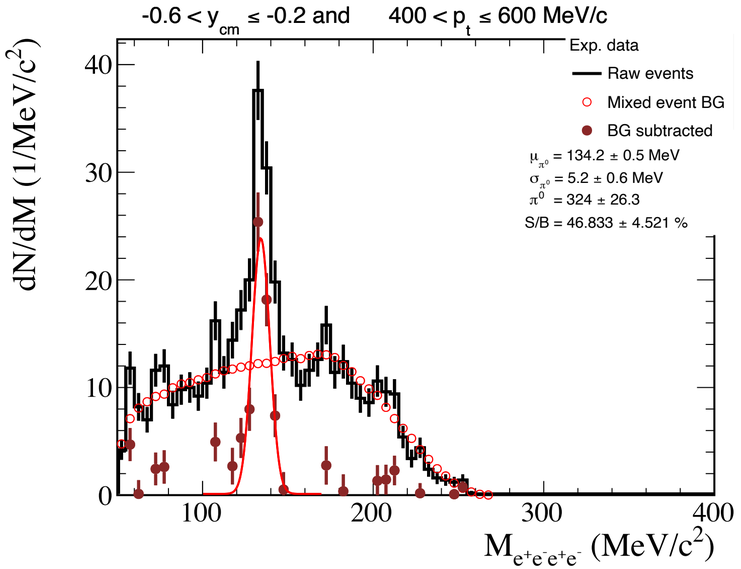



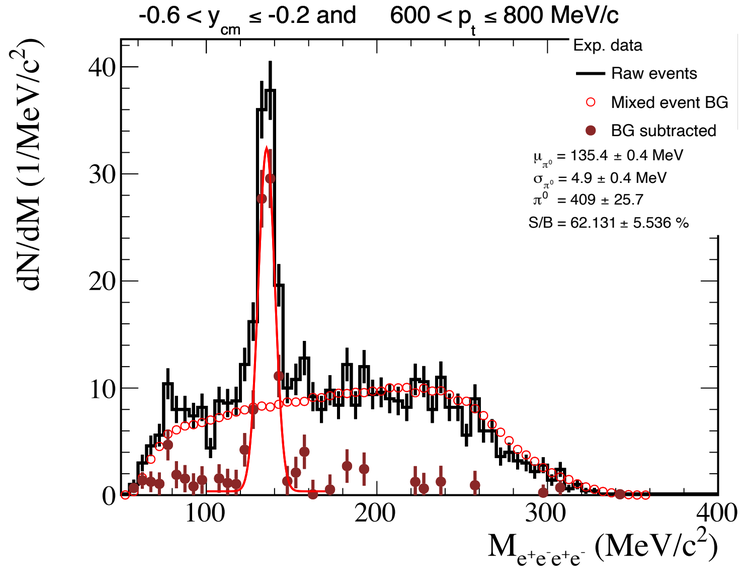



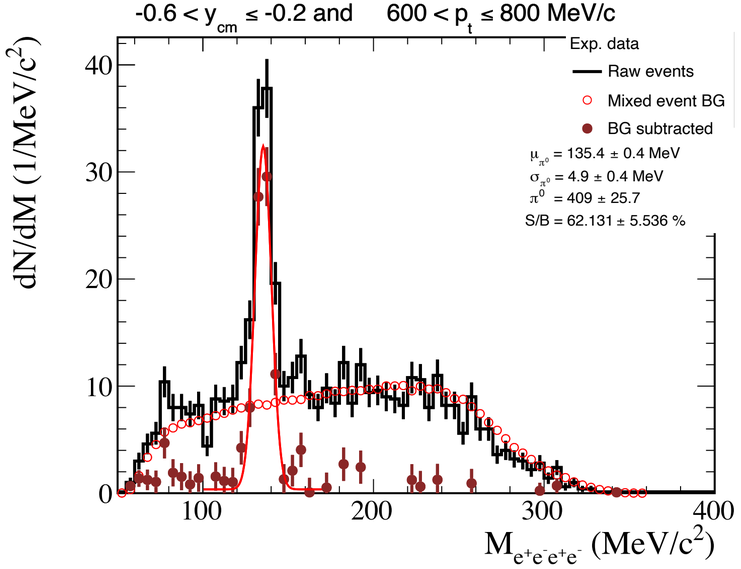



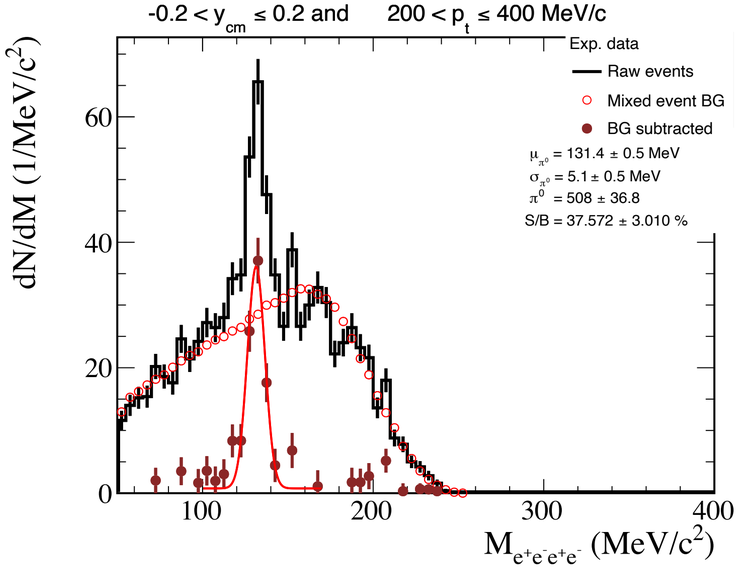
# Invariant mass of $e^-e^+e^-e^+$ in $P_t$ and $Y_{cm}$ bin(0-40% centrality)

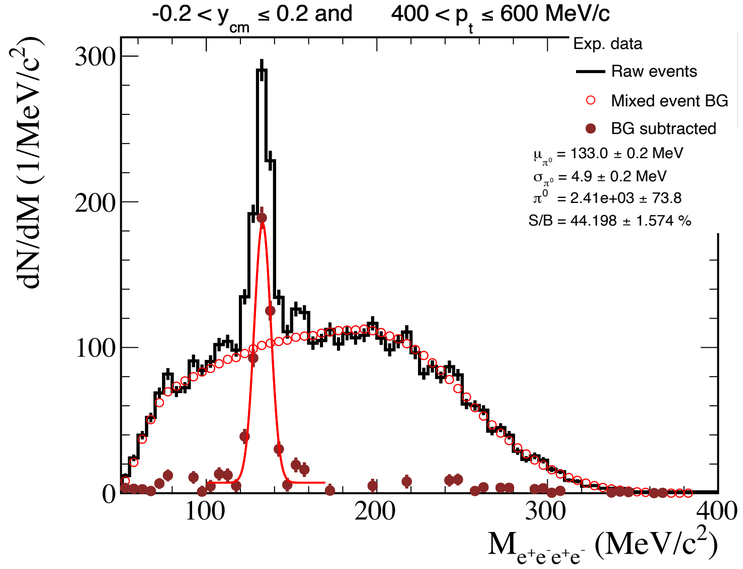


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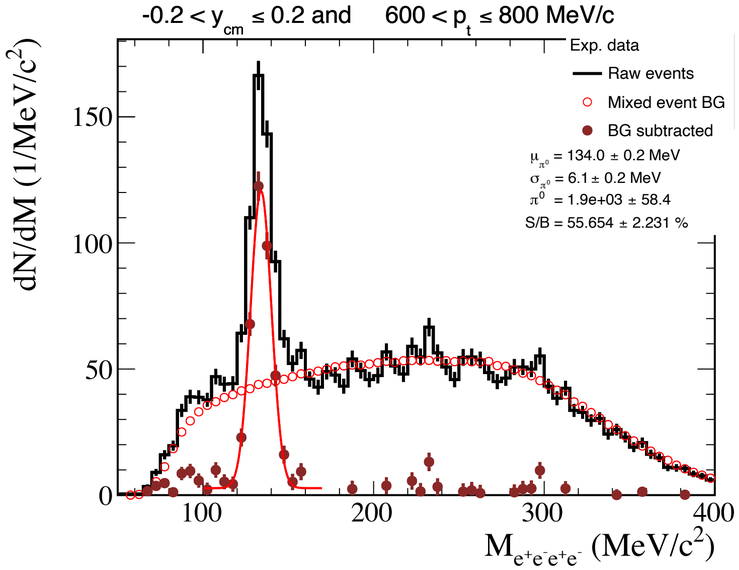


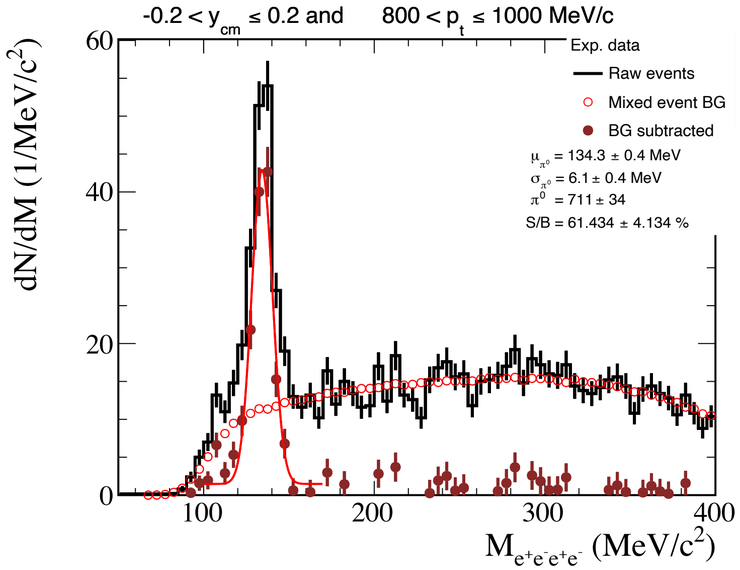


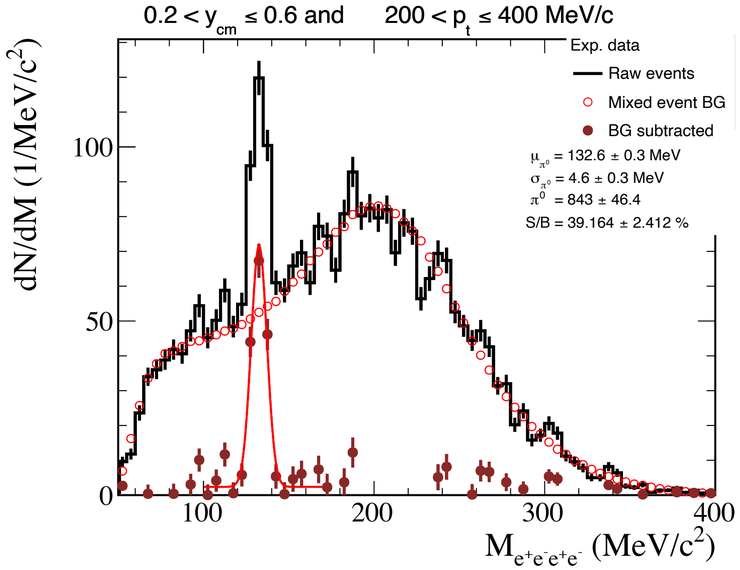


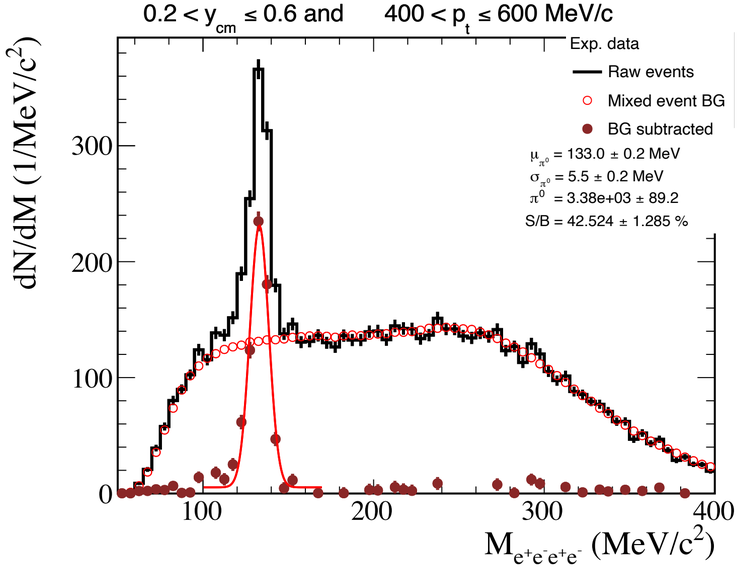


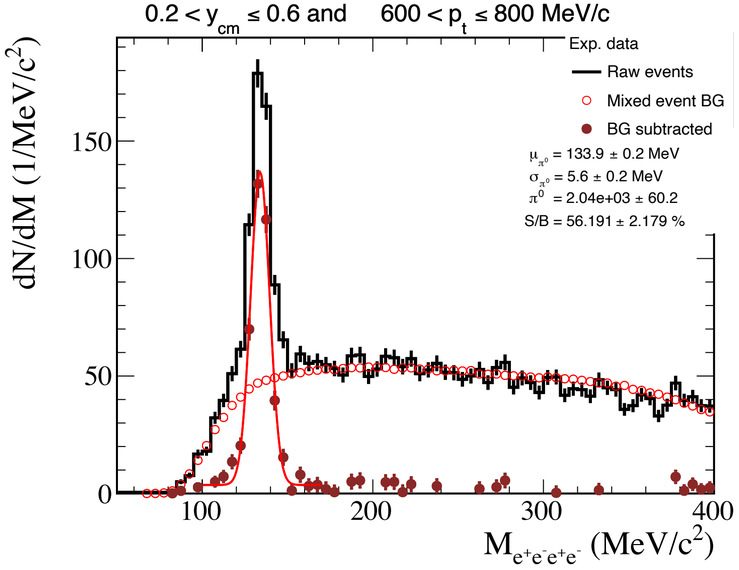


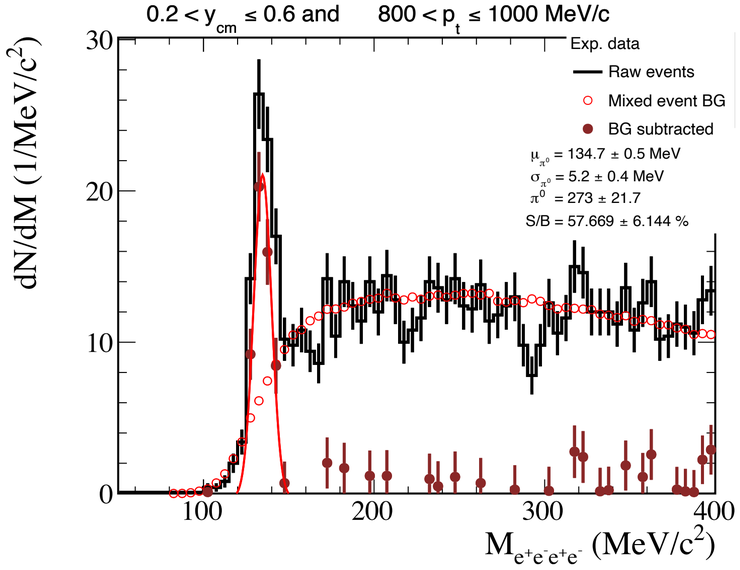

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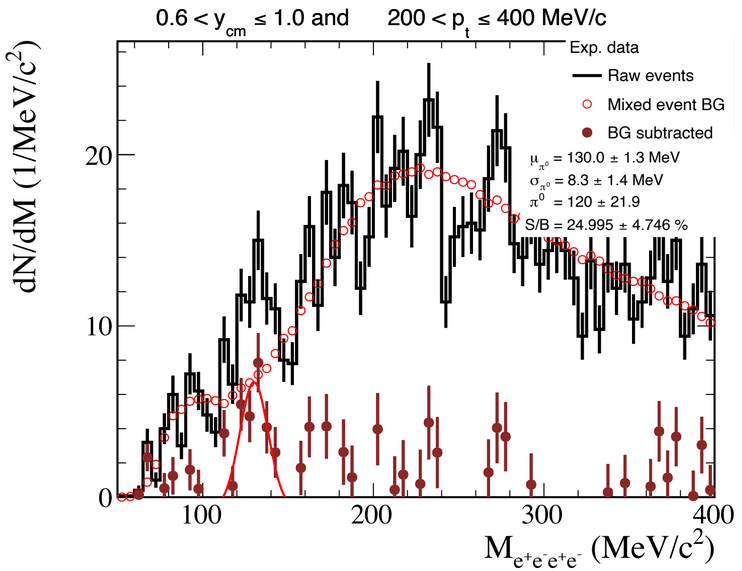


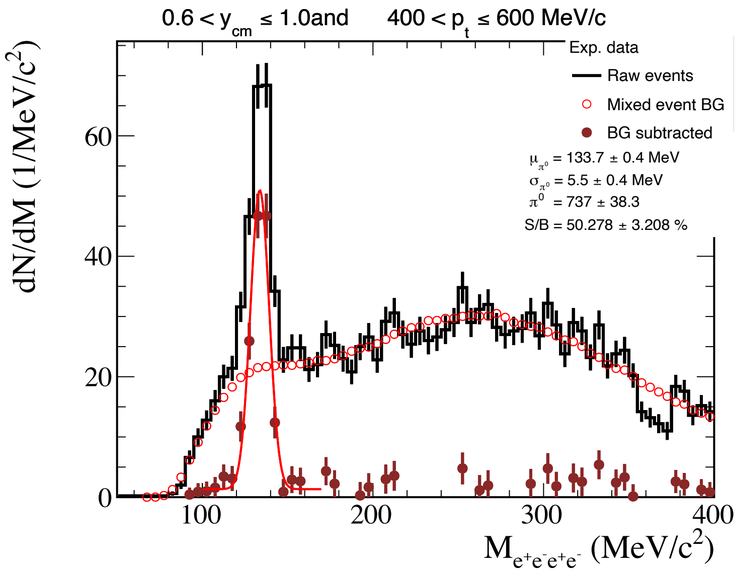


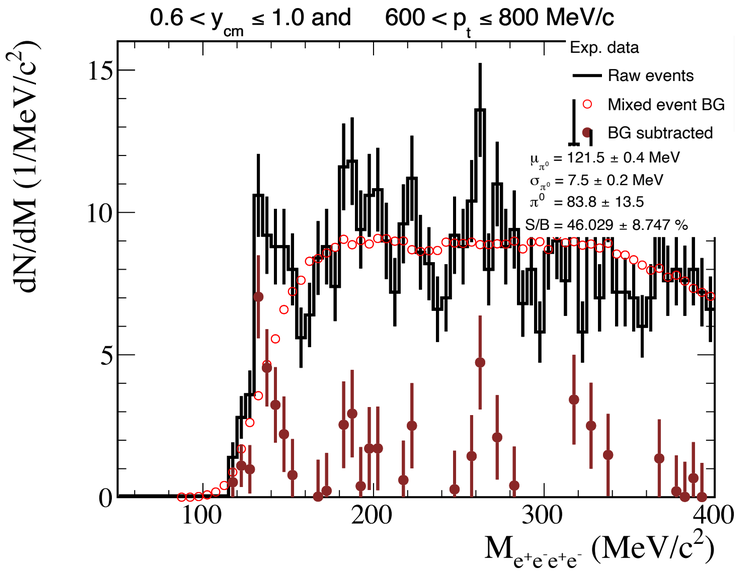


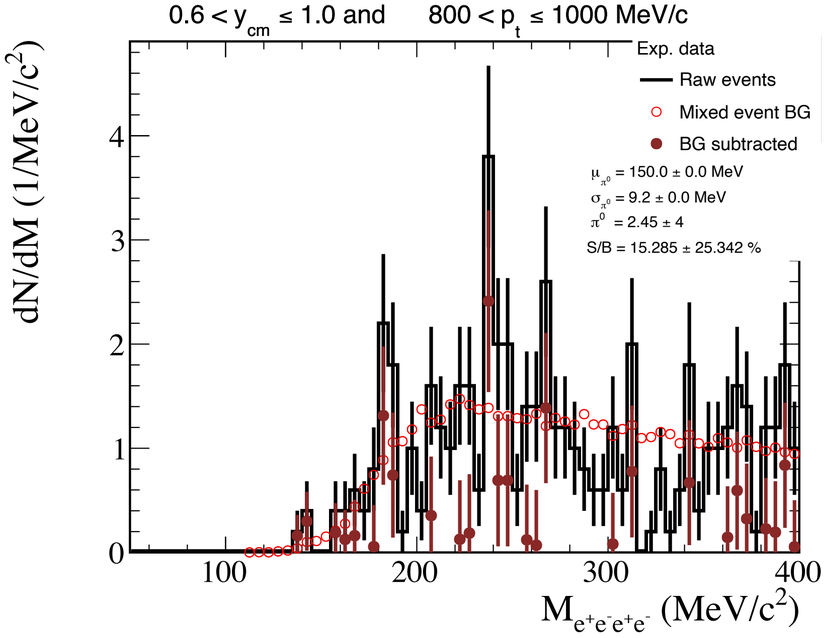

# Acceptance derivation based on photon level

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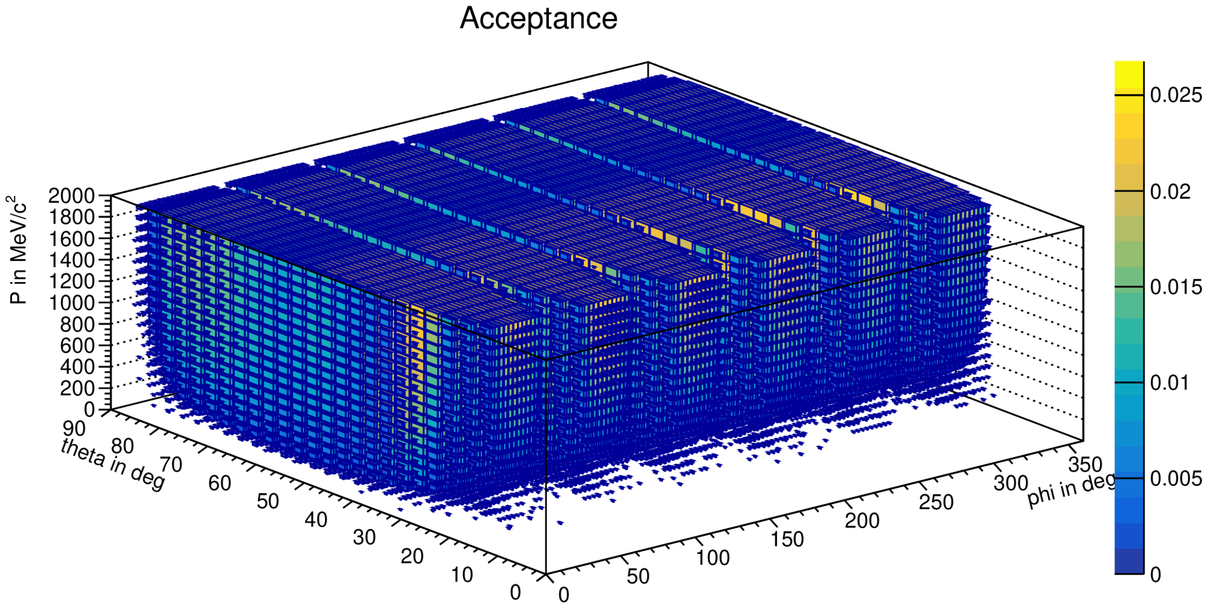
Generation photos using HGEANT simulation.

Choose only photons which convert into lepton pair.

Check acceptance of both leptons (need signal in all tracking system).

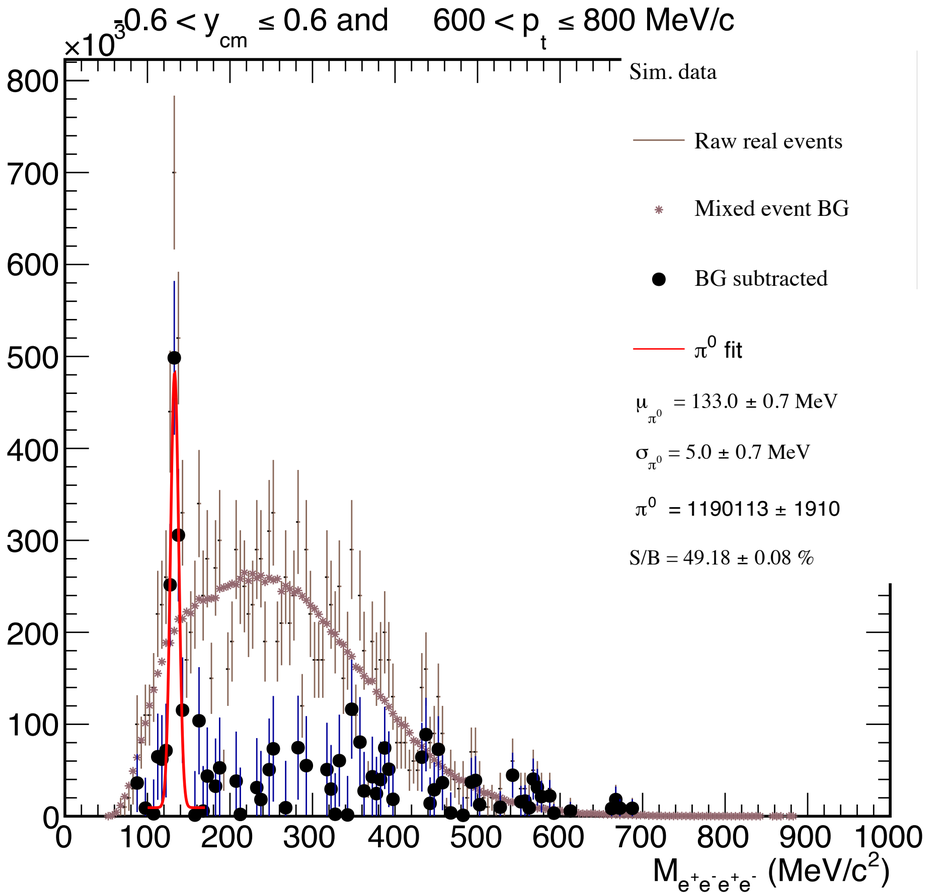
Photon is accepted if both leptons are accepted.




$$\text{Acceptance correction factor} = \frac{1}{Acceptance(P, \Phi, \Theta)}$$

$$\text{Acceptance} = \frac{N_{acc}(P, \Phi, \Theta)}{N_{all}(P, \Phi, \Theta)}$$

# Deriving reconstruction efficiency




Full URQMD simulation

Apply full reconstruction algorithm on simulated data

Build invariant mass spectrum IM($\gamma_1\gamma_2$) as a function of y, $p_t$

Find yield with respect to y and $p_t$ after Acceptance correction.

$$\text{Eff} = \frac{N_{acc,rec.corr.}(Y, P_t)}{N_{all}(Y, P_t)}$$

$$\text{Efficiency corr. factor} = \frac{1}{Eff(Y, P_t)}$$