

# $\pi^0$ production in Ag+Ag collisions at 1.23 A GeV beam energy

**Arseniy Shabanov**

for the HADES collaboration

*arseniy.shabanov@phystech.edu*

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# Outline

- HADES experiment
- ECal detector
- Reconstruction of neutral pions
- Preliminary results
- Summary

# Motivation

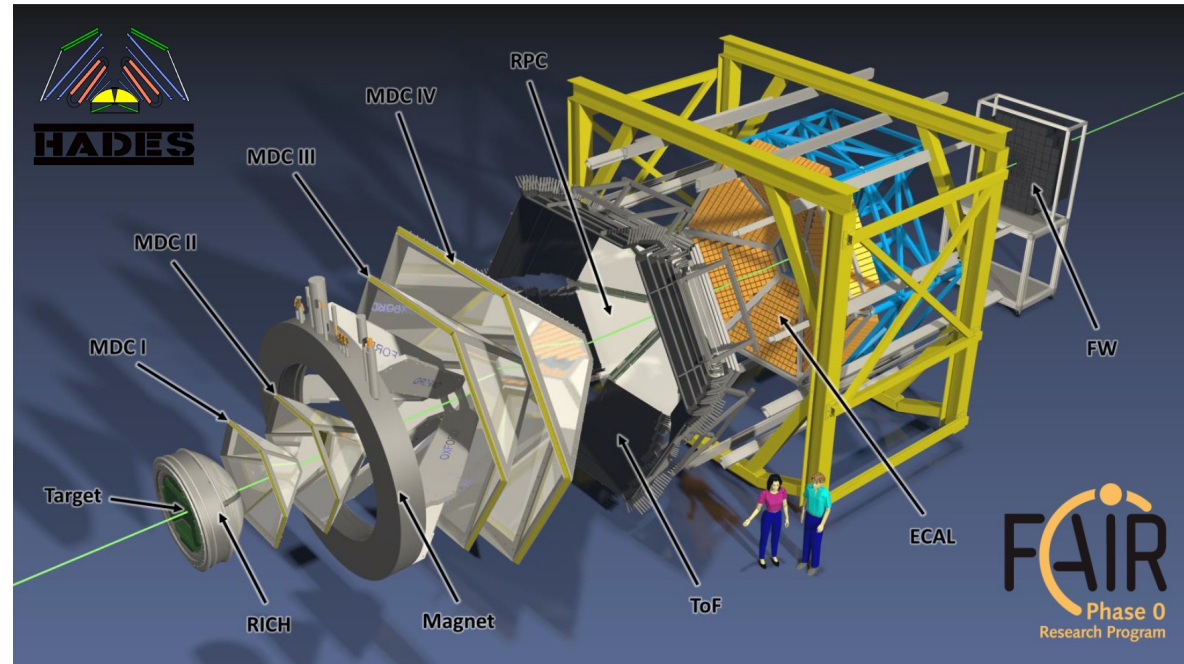
- $\pi^0$  is an important part of hadronic cocktail
- Measurement of decay  $\pi^0 \rightarrow \gamma\gamma$  allows to directly find the yield of neutral pions
- Cross check with charged pions production
- Other methods to determine  $\pi^0$  yield
  - conversion method
  - Dalitz decay

have large systematic uncertainties and low statistics

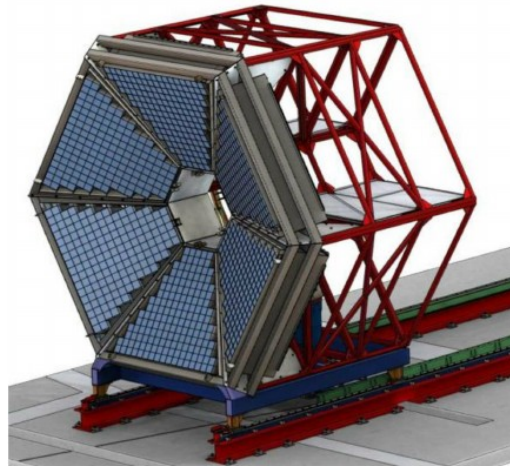
# HADES experiment

Fixed target experiment at SIS18,  
Darmstadt

- Covers full azimuthal angle and  $18^\circ < \theta < 85^\circ$  polar angle
- Tracking system
- Time-of-flight system
- Ring imaging Cherenkov detector
- Electromagnetic calorimeter ECal
- Forward hodoscope

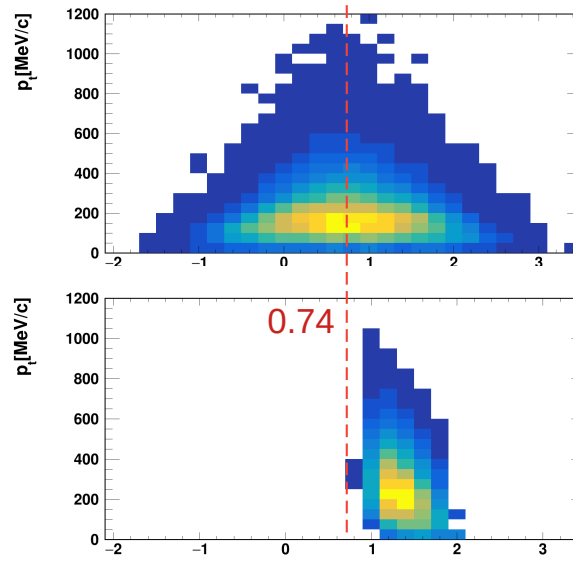


# Electromagnetic calorimeter ECal



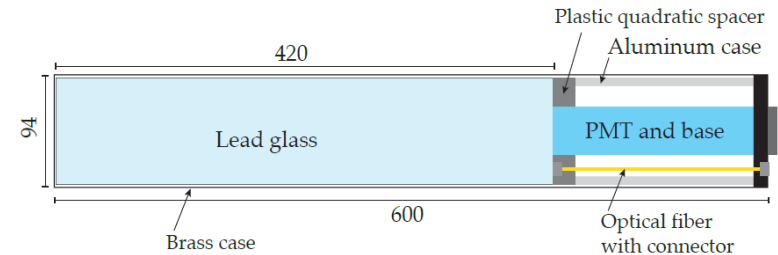
6 sectors covering  
 $12^\circ < \theta < 45^\circ$

phase space of  $\pi^0$  in  
Ag+Ag 1.23 A GeV



acceptance of ECal  
(3 sectors out of 6  
were in operation)

- 978 modules
- Homogeneous Cherenkov radiator is made of CEREN25 lead glass (16.7 radiation length long)
- PMT:  
EMI 9903kB (1.5") or  
Hamamatsu R6091 (3")



# Analyzed data

- March 2019
- Ag + Ag at 1.23 A GeV
- $7 * 10^8$  events

- February-March 2019
- Ag + Ag at 1.58 A GeV
- $14 * 10^9$  events

# Selection criteria

## Selection of events

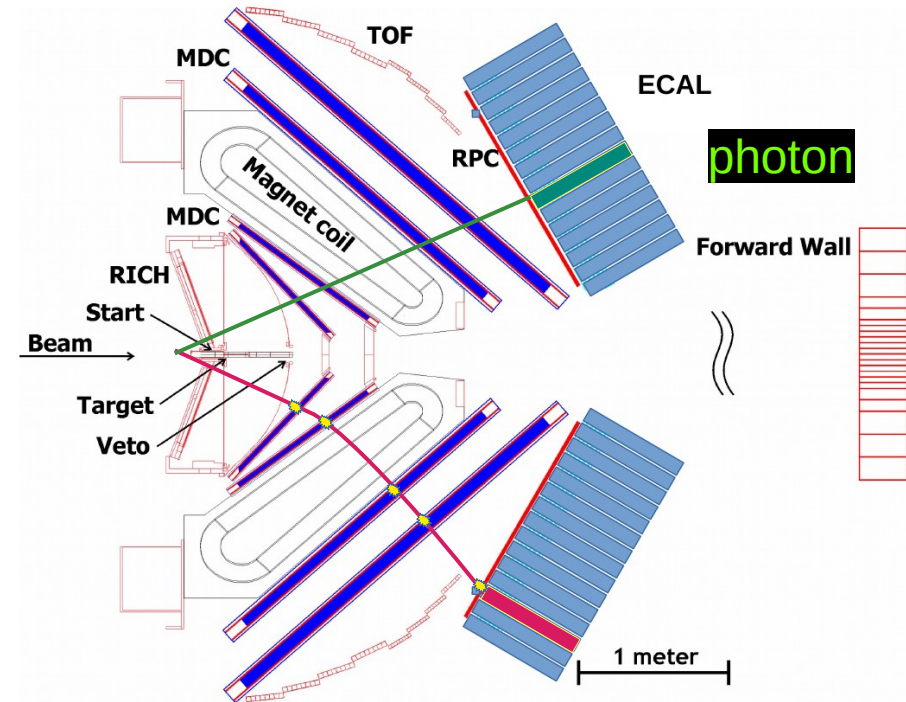
- centrality 0-30%

## Photon:

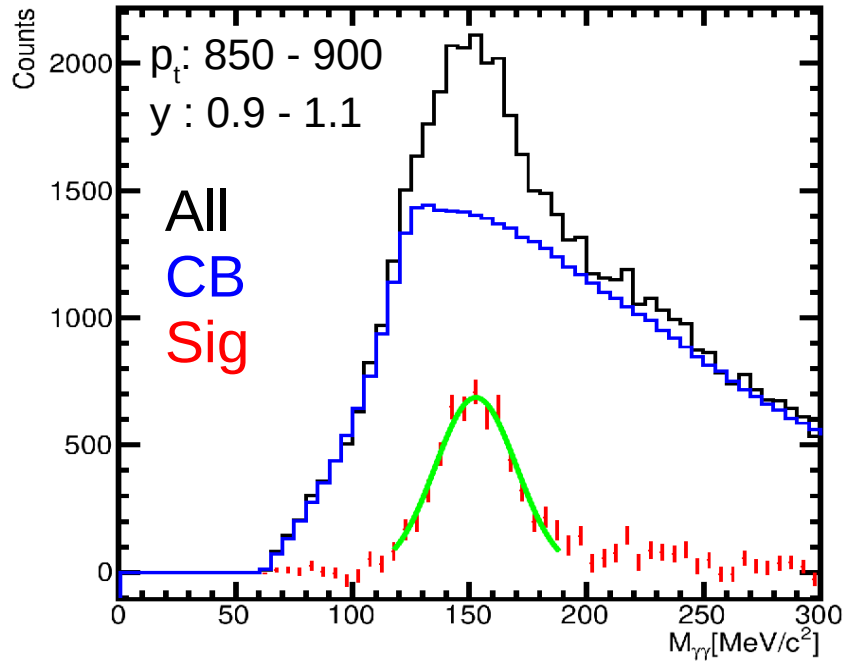
- No hit in RPC (closest detector to ECal)
- No match with any track
- $0.9 < \beta < 1.1$
- $E > 100$  MeV (reject neutrons)

## Diphoton:

- Opening angle  $> 10^\circ$



# Reconstruction of $\pi^0$ -mesons



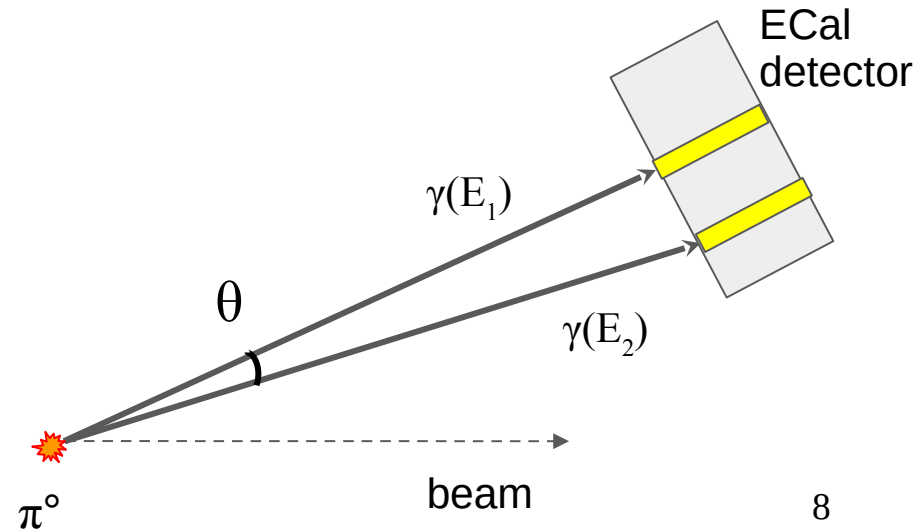
All – experimental data

CB – mixed-event combinatorial background

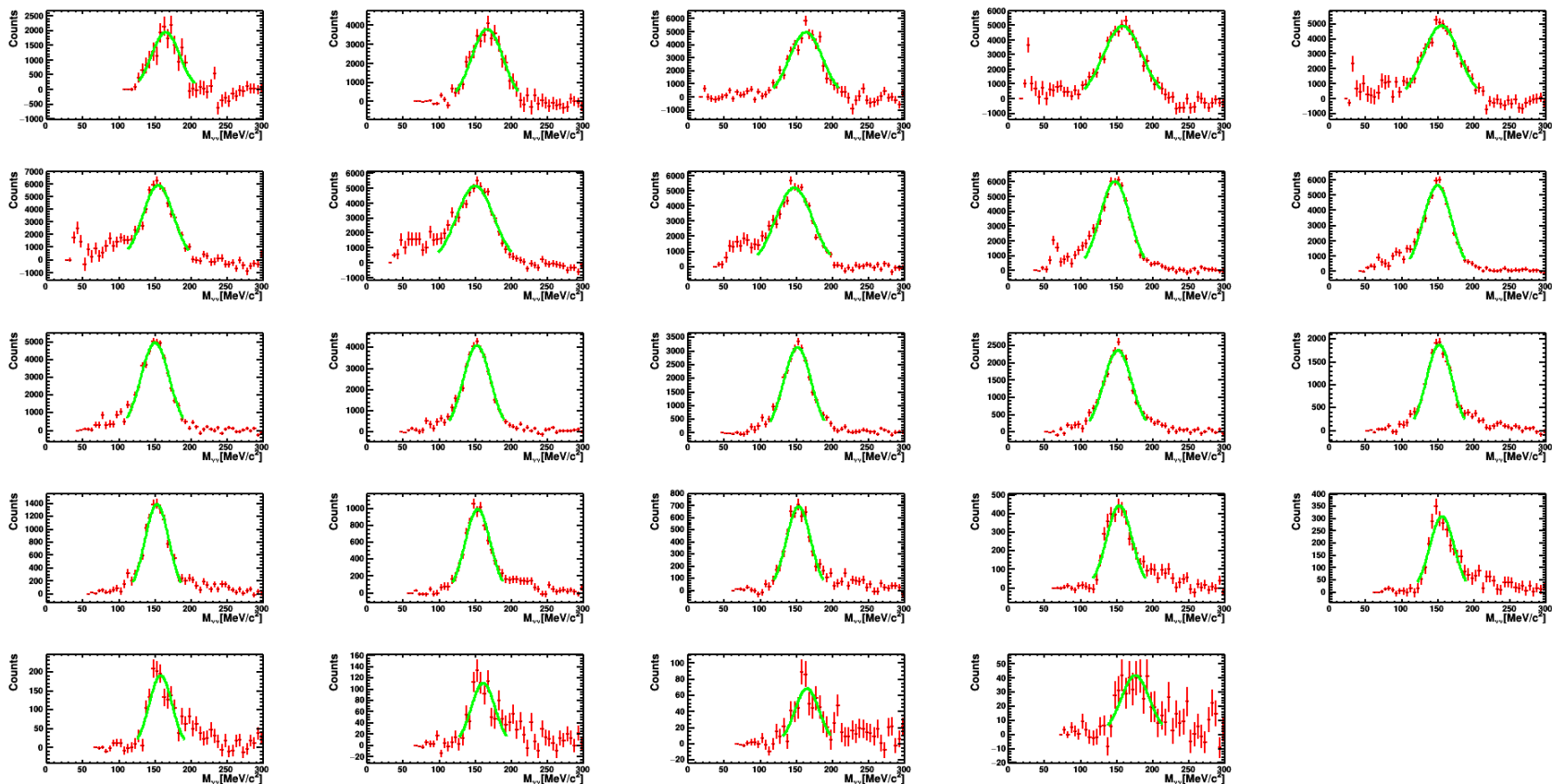
Sig – signal

Signal is fitted with Gauss

$$m_{\pi^0} = \sqrt{E_1 \cdot E_2 \cdot (1 - \cos \theta)}$$

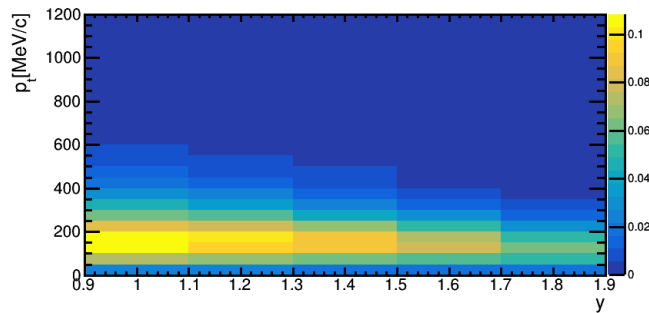


$$0.9 < y < 1.1$$

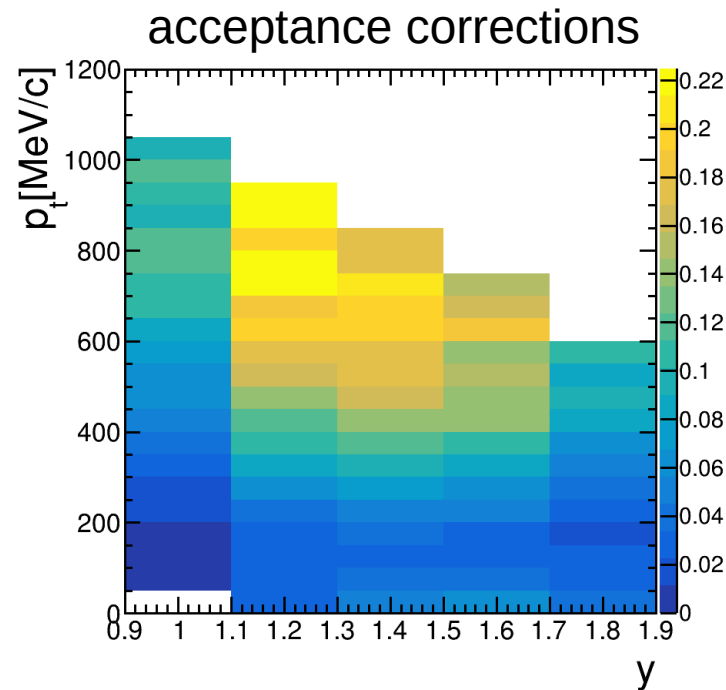
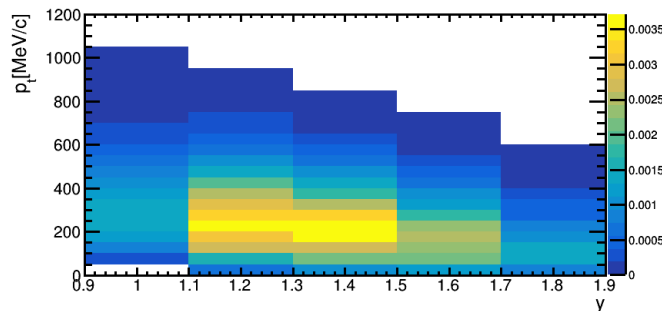


# Acceptance corrections

UrQMD generated  
number of pions  
within pt-y bin  
per event

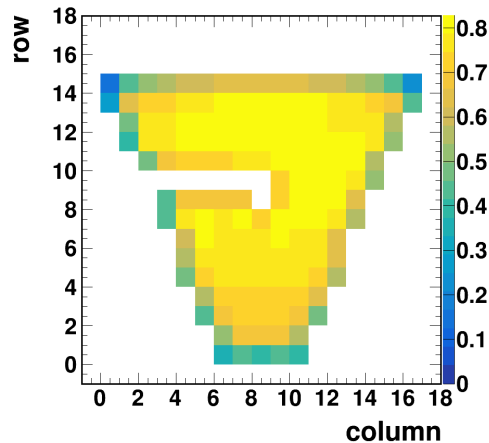


Reconstructed from  
**simulation** number of  
pions  
within pt-y bin  
per event

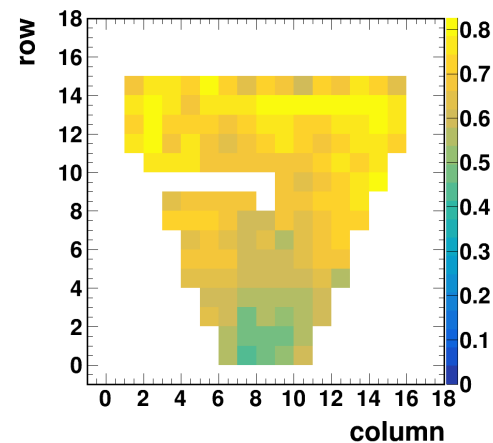


# Efficiency corrections

efficiency of detection  
of positrons  
(simulation)



efficiency of detection  
of positrons  
(experiment)

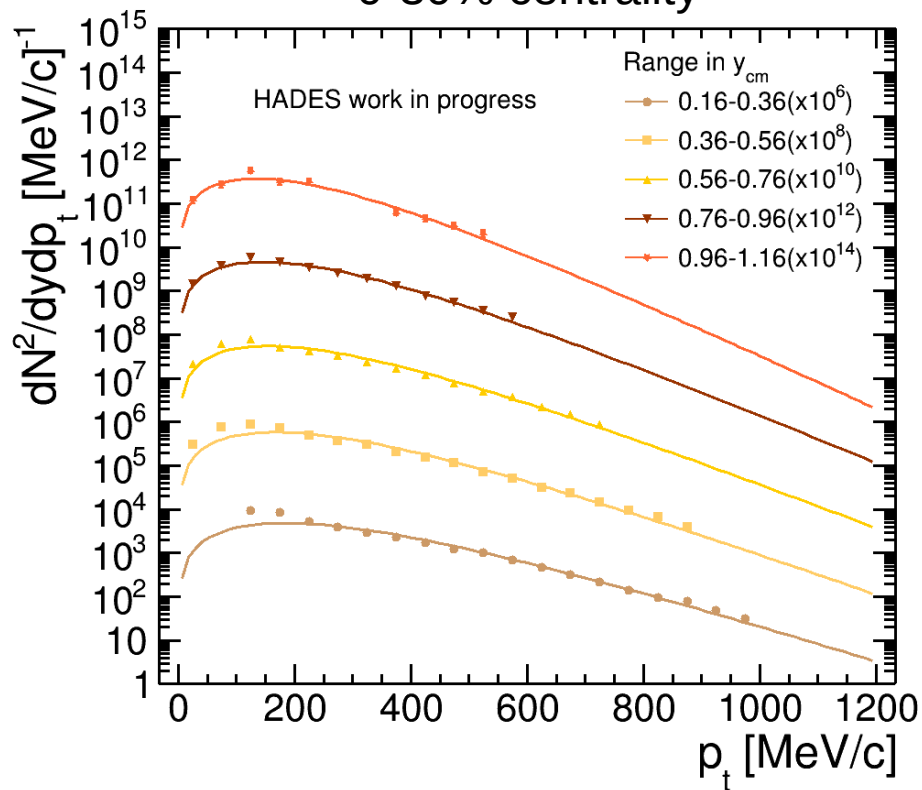


$$efficiency_{\gamma} = efficiency_{\gamma simulation} \cdot \frac{efficiency_{e experiment}}{efficiency_{e simulation}}$$

# Extraction of $\pi^0$ yield

$$Ag + Ag \sqrt{s_{NN}} = 2.42 \text{ A GeV}$$

0-30% centrality



Extrapolation to  $p_t$  range  
which is not covered by  
acceptance of ECal:

$$\frac{dN}{dp_t} = C p_t m_t e^{-\frac{m_t}{T}}$$

(Boltzmann fit)

# Full $\pi^0$ yield per event

$$Ag + Ag \sqrt{s_{NN}} = 2.42 \text{ A GeV}$$

0-30% centrality

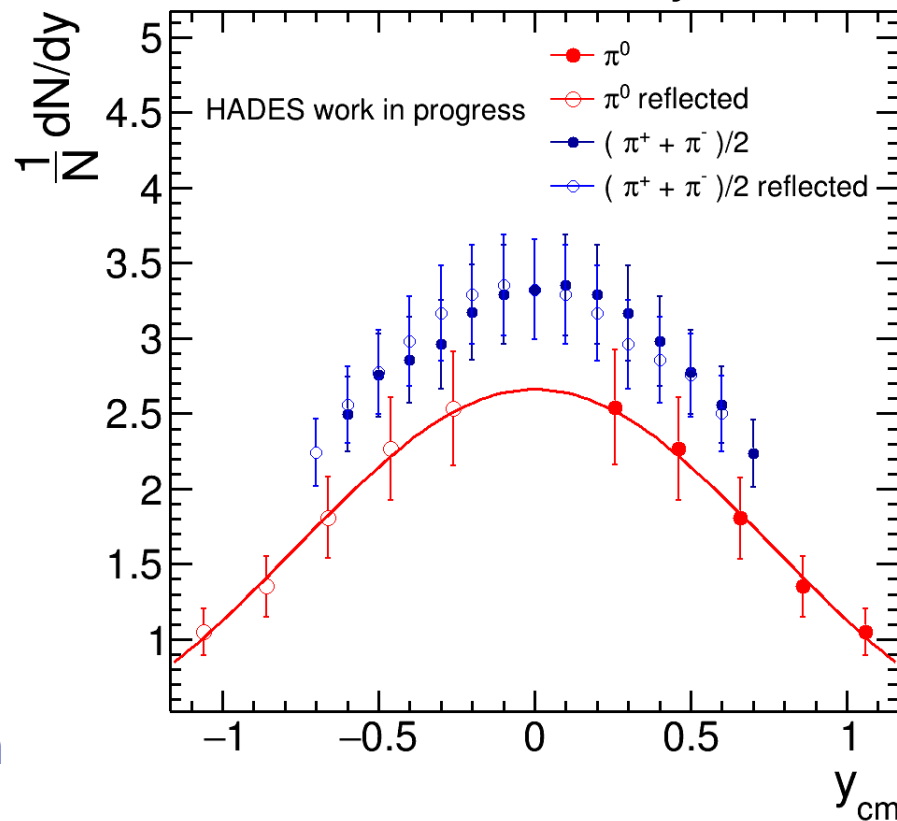
Extrapolation to y range  
which is not covered by  
acceptance of ECal:

Gauss fit

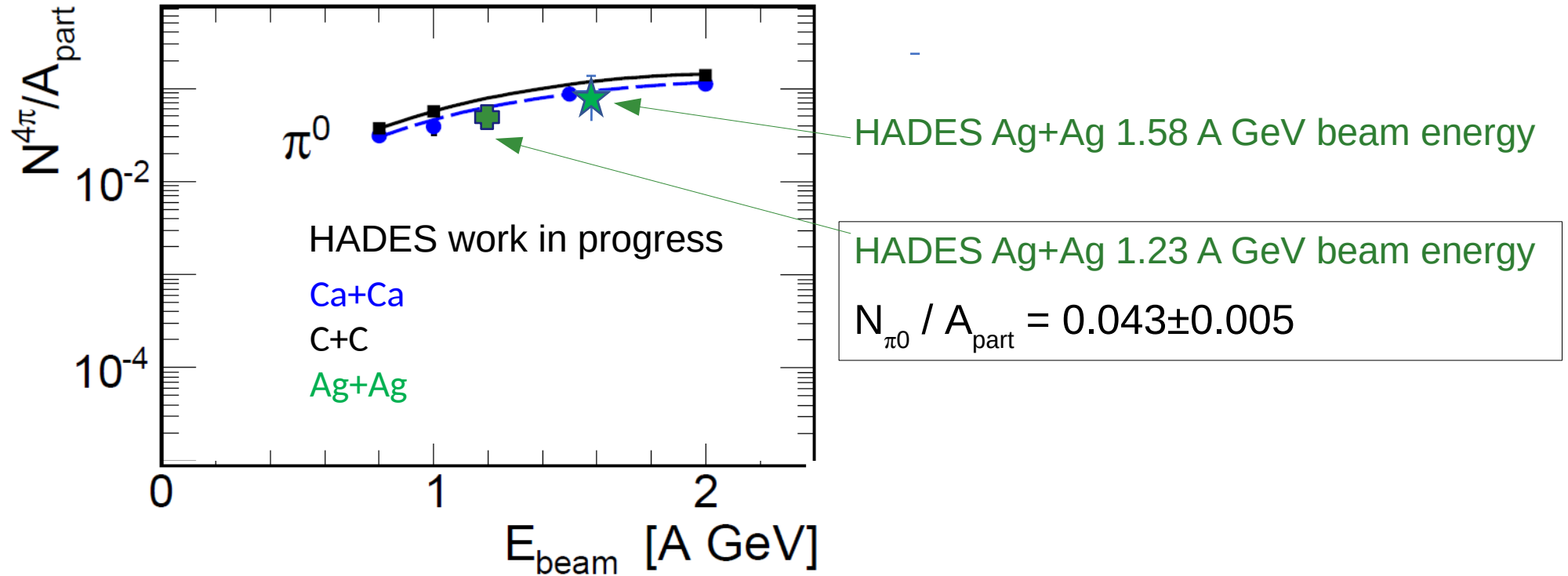
$$\frac{N_{\pi^0}}{N_{\text{events}}} = 5.1 \pm 0.3$$

preliminary estimate of  
systematic error:  $\sim 15\%$  due to  
efficiency determination

$(\pi^+ + \pi^-) / 2$  is drawn for comparison



# Comparison to the world data



# Summary

- ECal detector successfully operated during 4 weeks of physics run in 2019
- $\pi^0$  peak is clearly reconstructed in Ag+Ag 1.23 and 1.58 A GeV
- First results show agreement with world data

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To be done:

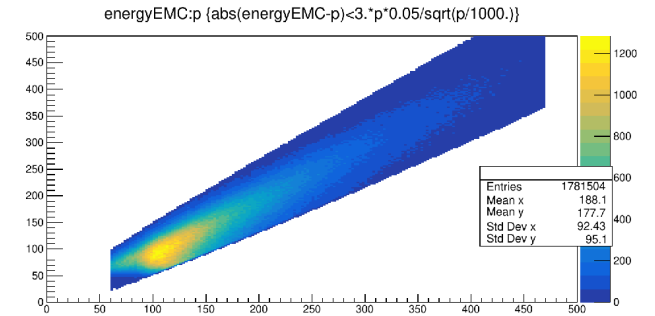
- flow analysis
- centrality dependence
- study of systematic errors
- comparison to transport models and other methods  
(Dalitz decay, conversion method)

Thank you for your attention!

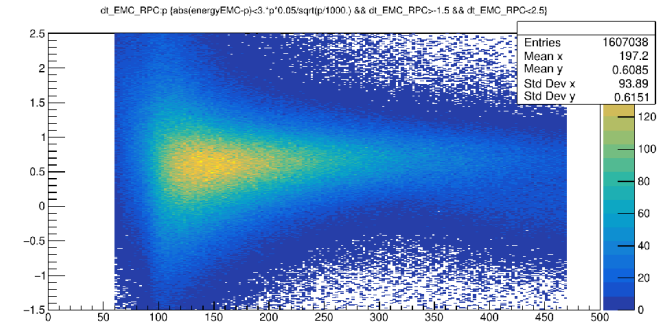
# Efficiency

- Study efficiency with  $e^+$
- Predict the hitted cell using ML
- Check:
  - $E_{e-3\sigma} < E_{ecal} < E_{e+3\sigma}$
  - $t_{RPC} - 1.5 \text{ ns} < t_{ECal} < t_{RPC} + 2.5 \text{ ns}$
- Divide

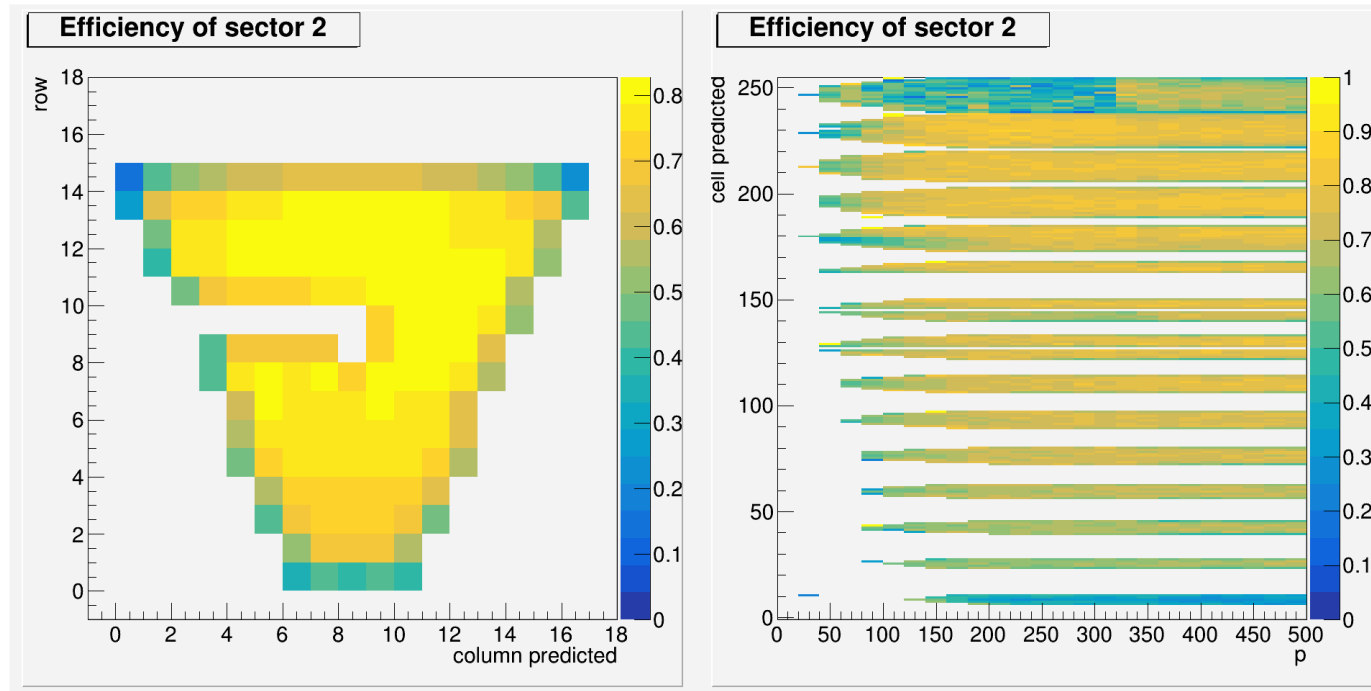
Energy cut



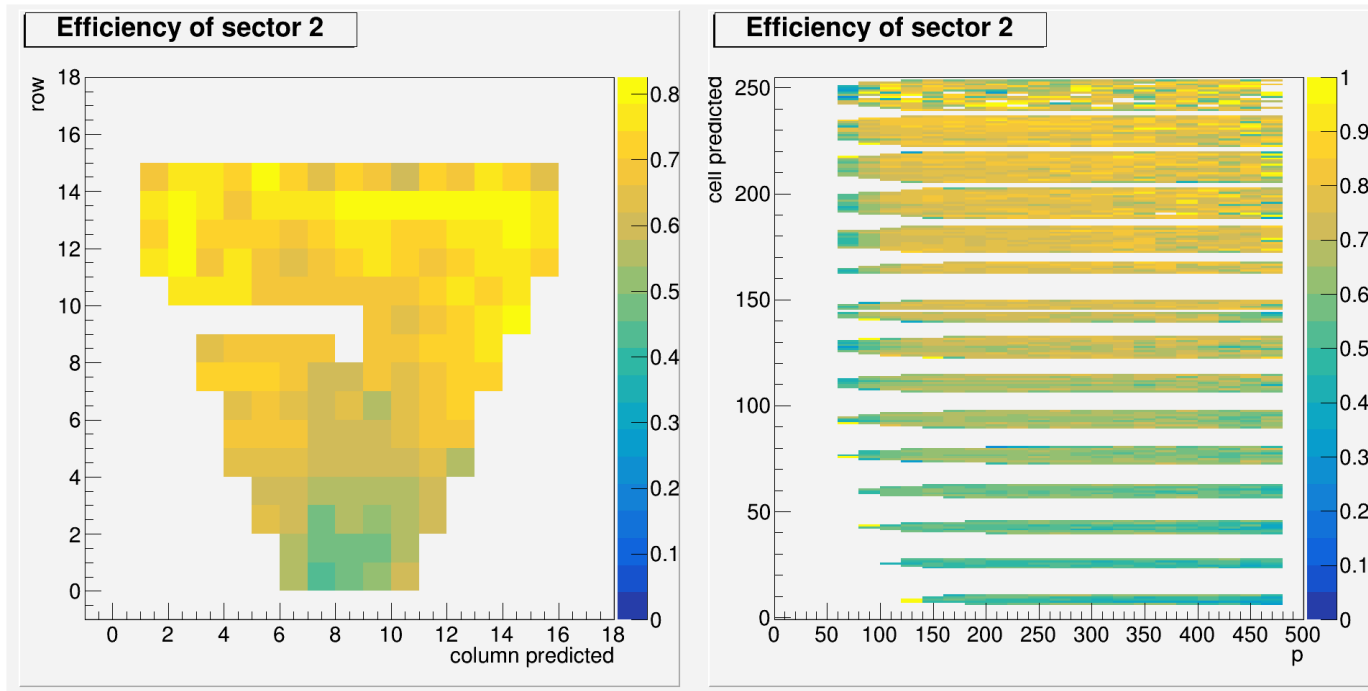
Time cut



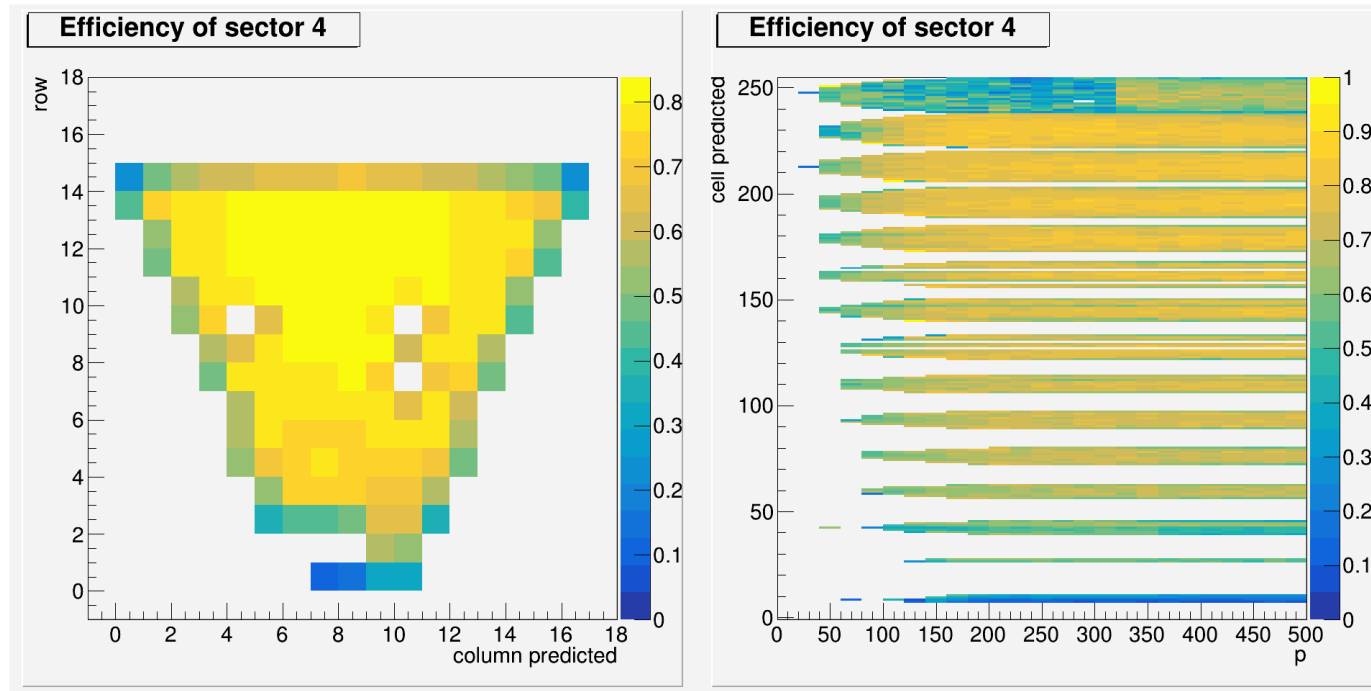
# 2 sector simulation



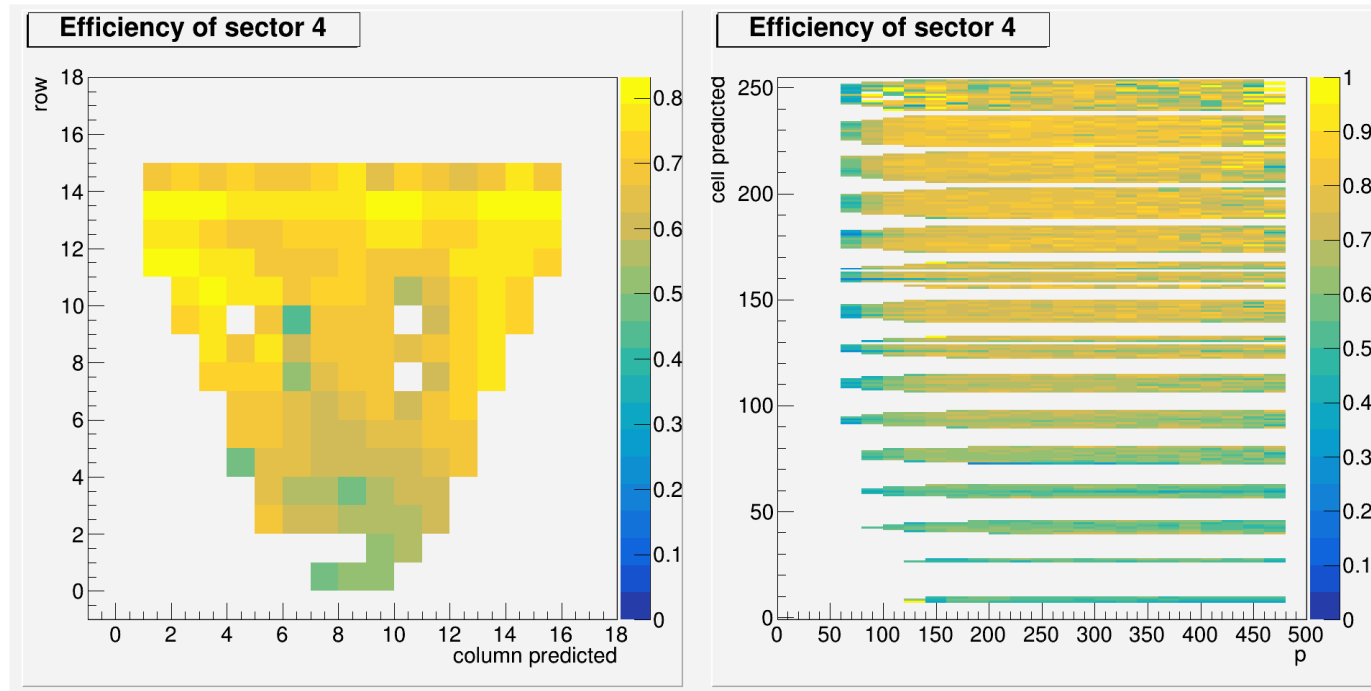
# 2 sector experiment



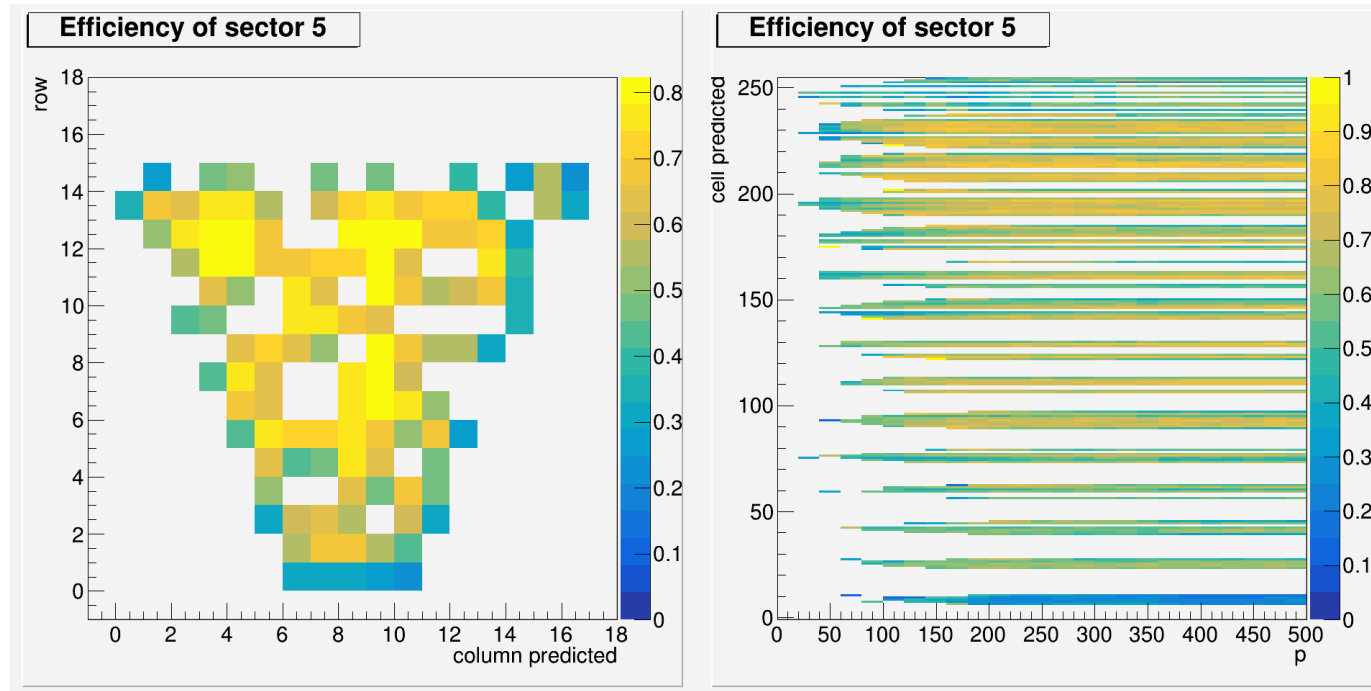
# 4 sector simulation



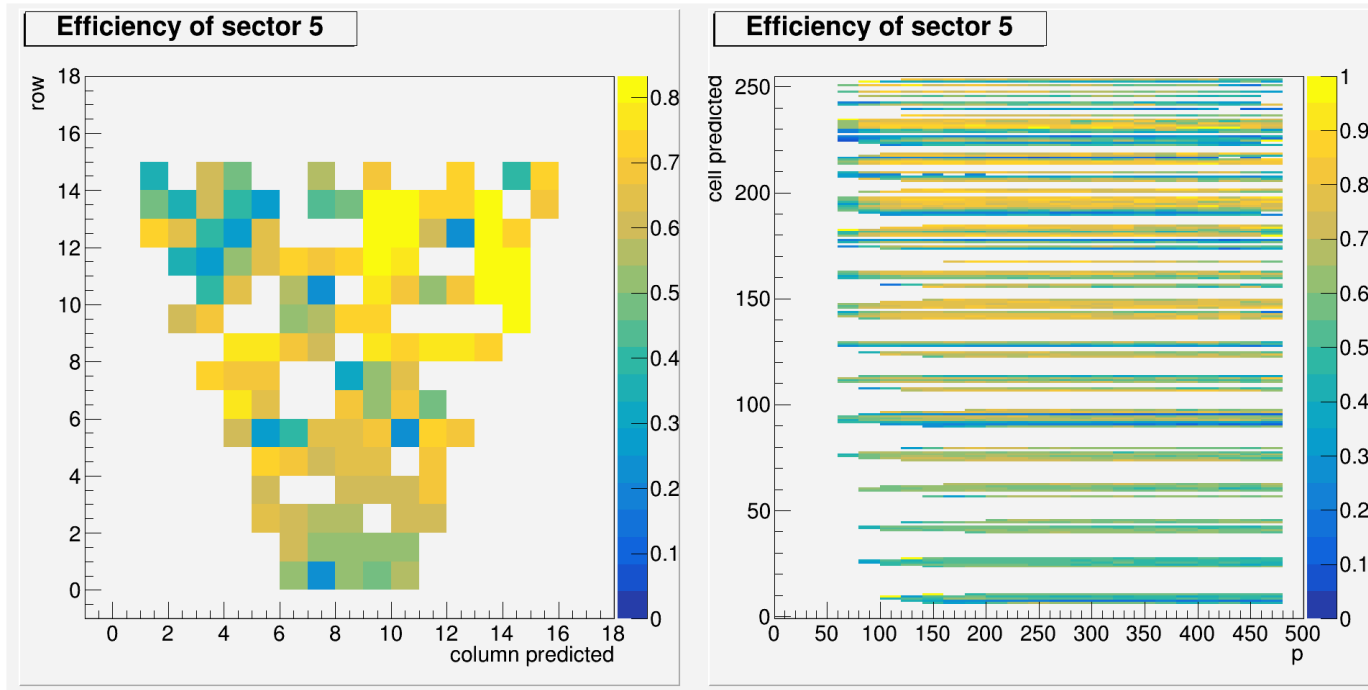
# 4 sector experiment



# 5 sector simulation

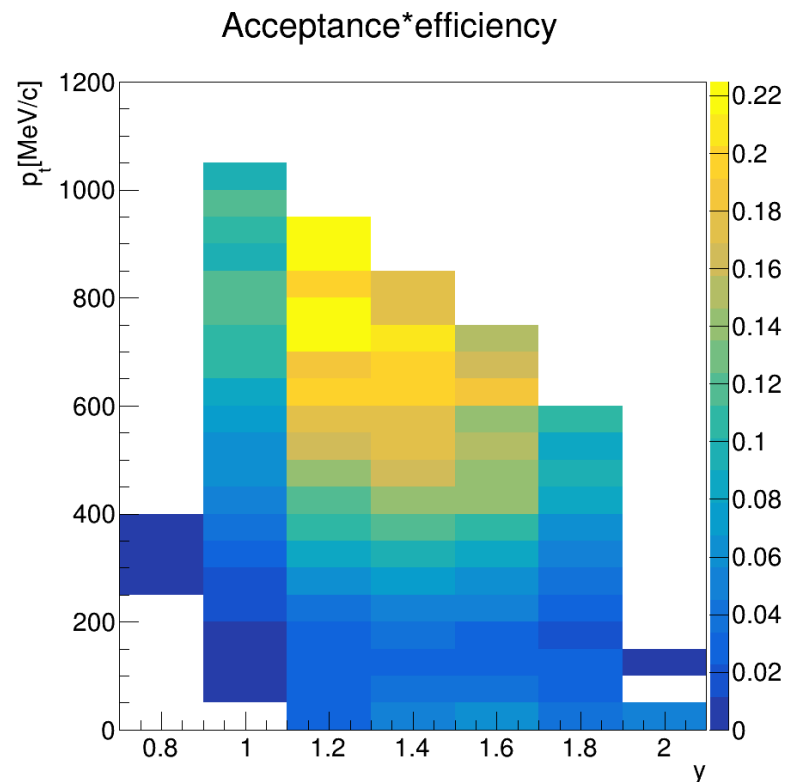
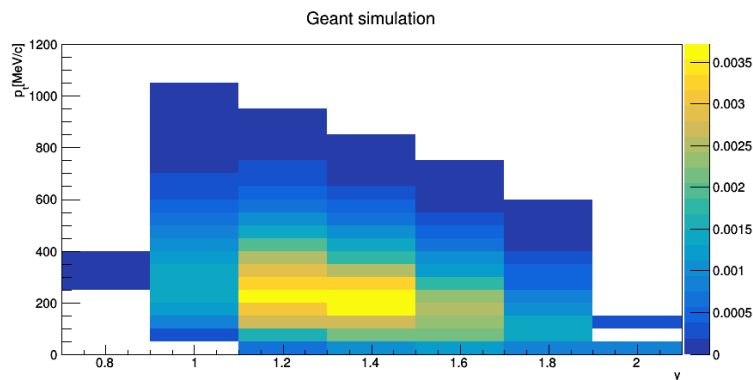
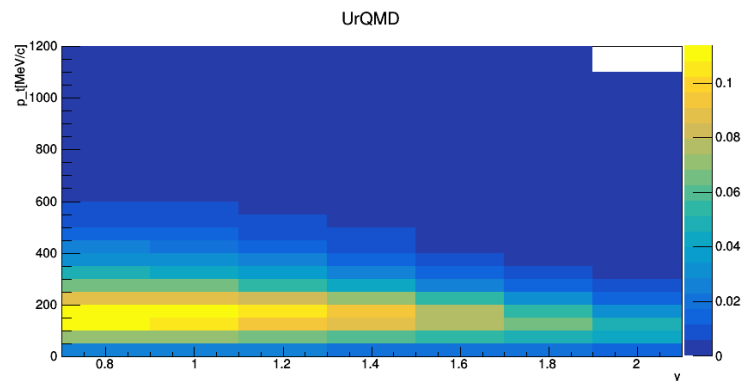


# 5 sector experiment

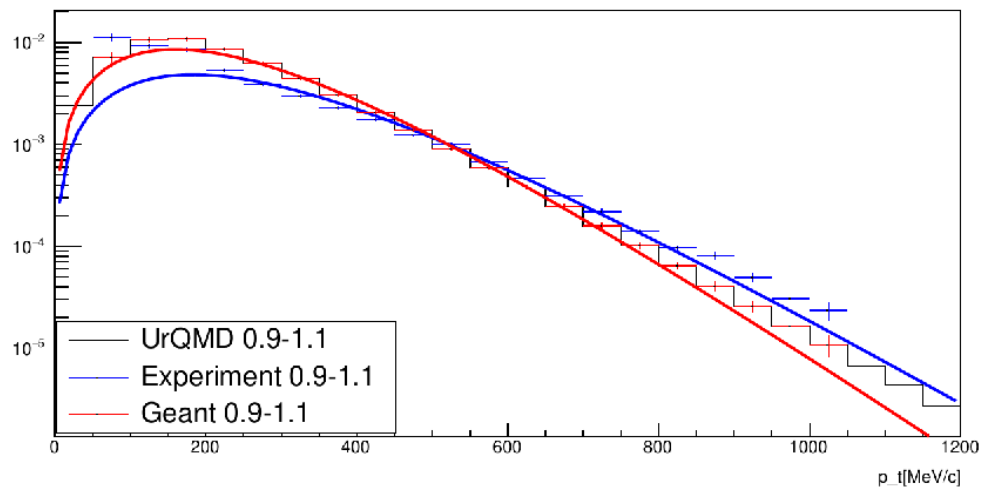


# Acceptance \* efficiency

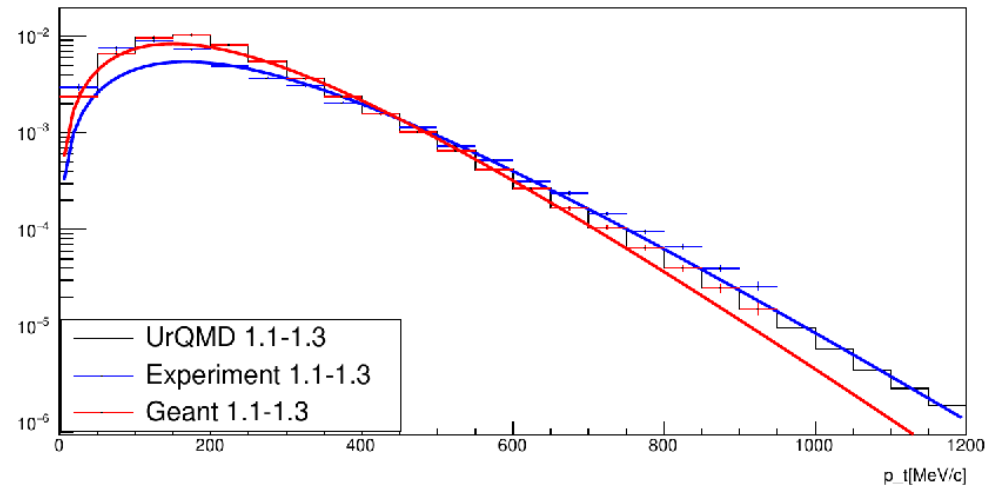
## 2, 4, 5 sectors



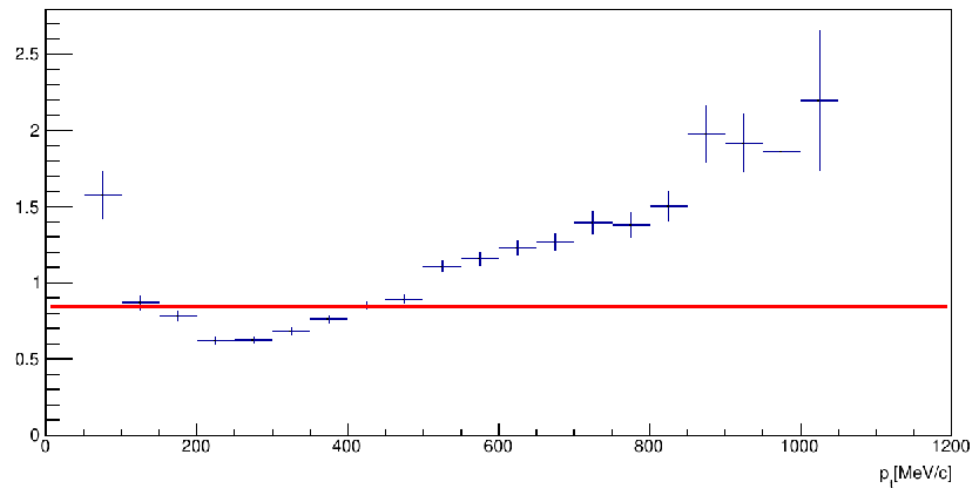
UrQMD 0.9-1.1



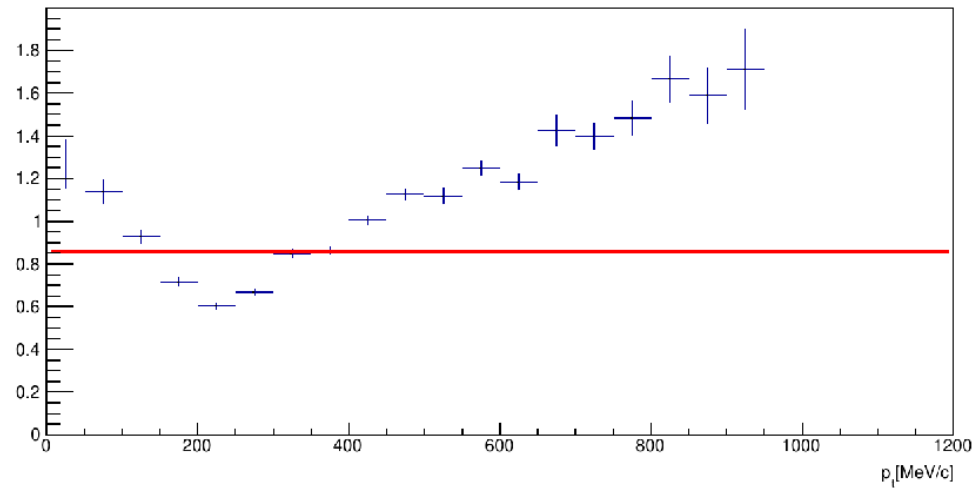
UrQMD 1.1-1.3



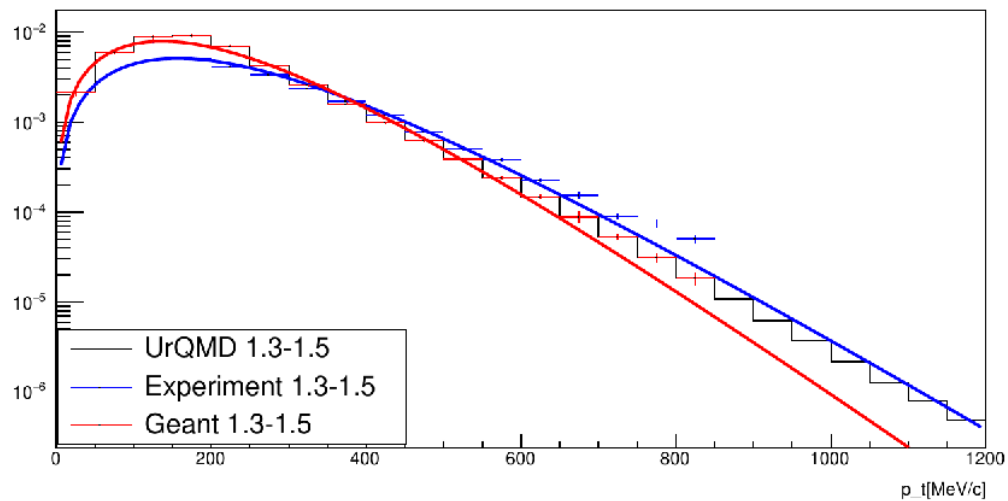
Exp / Geant



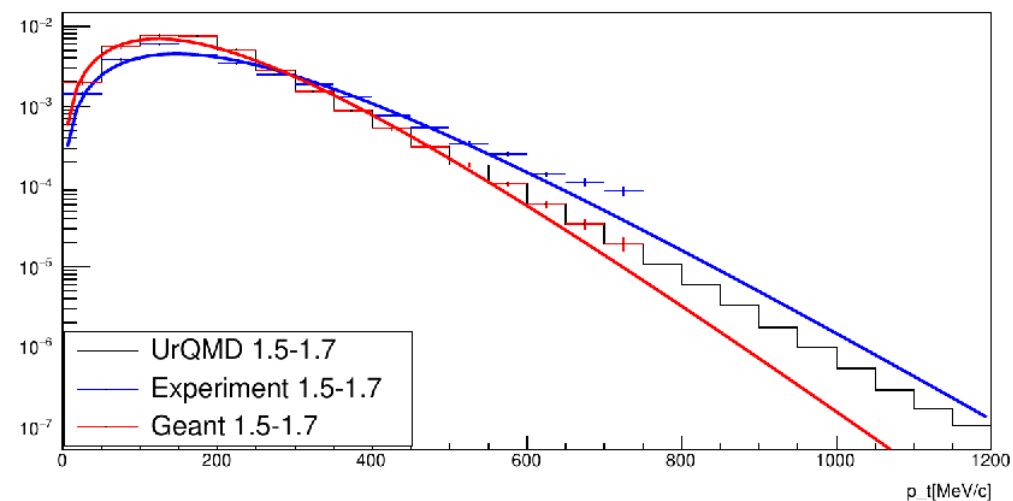
Exp / Geant



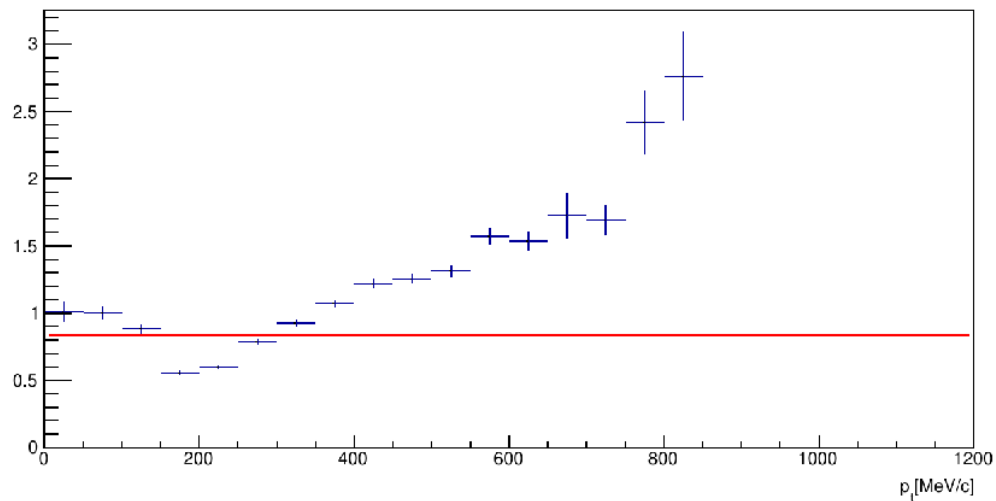
UrQMD 1.3-1.5



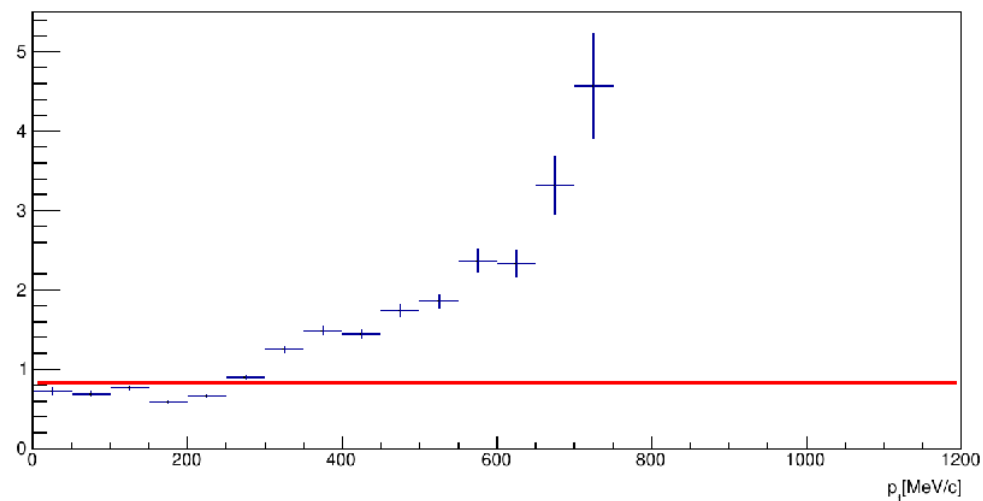
UrQMD 1.5-1.7



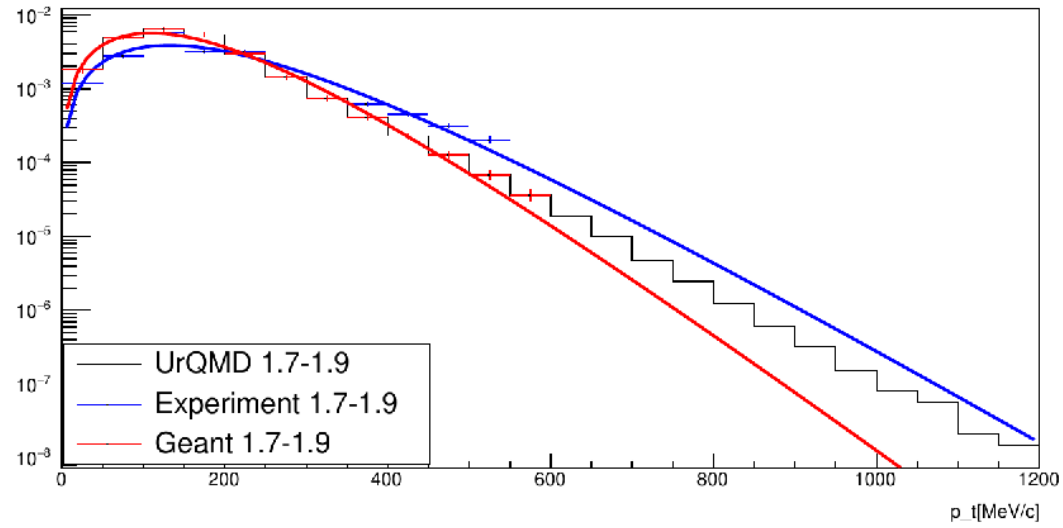
Exp / Geant



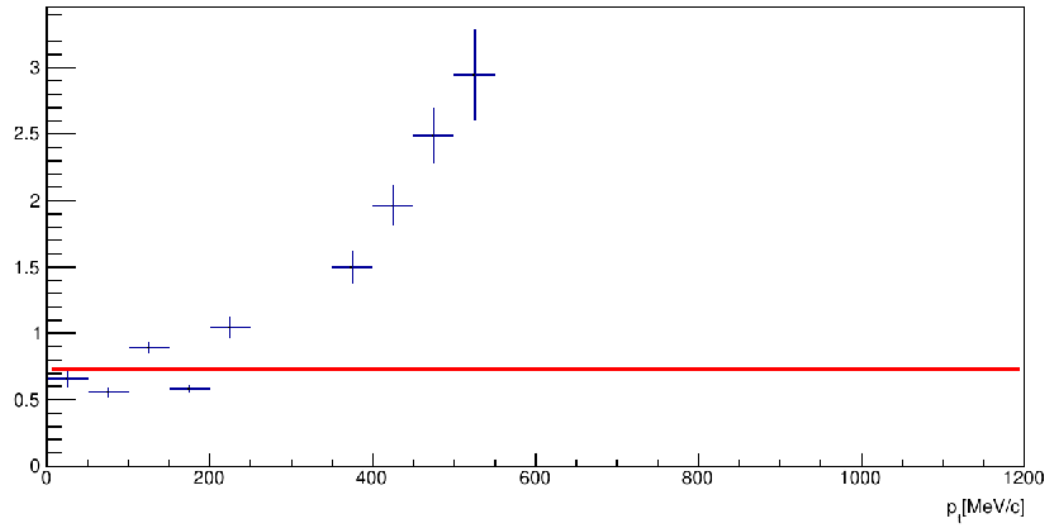
Exp / Geant



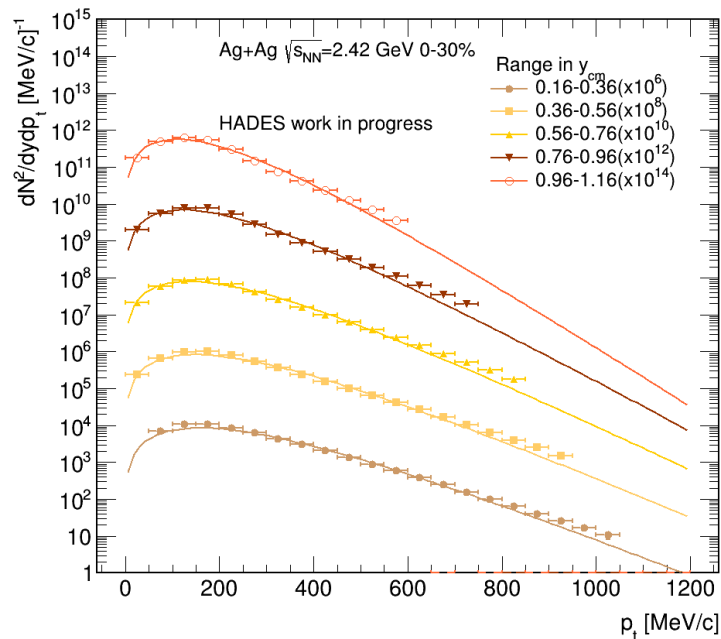
UrQMD 1.7-1.9



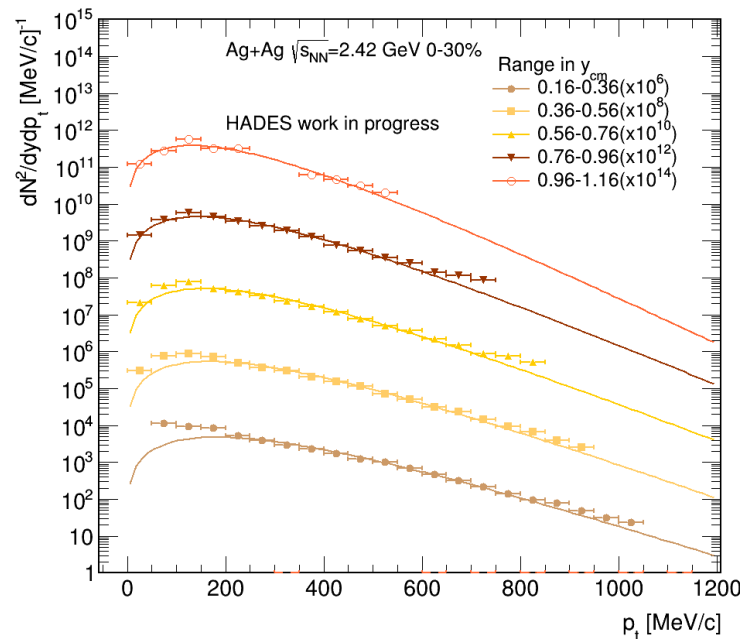
Exp / Geant



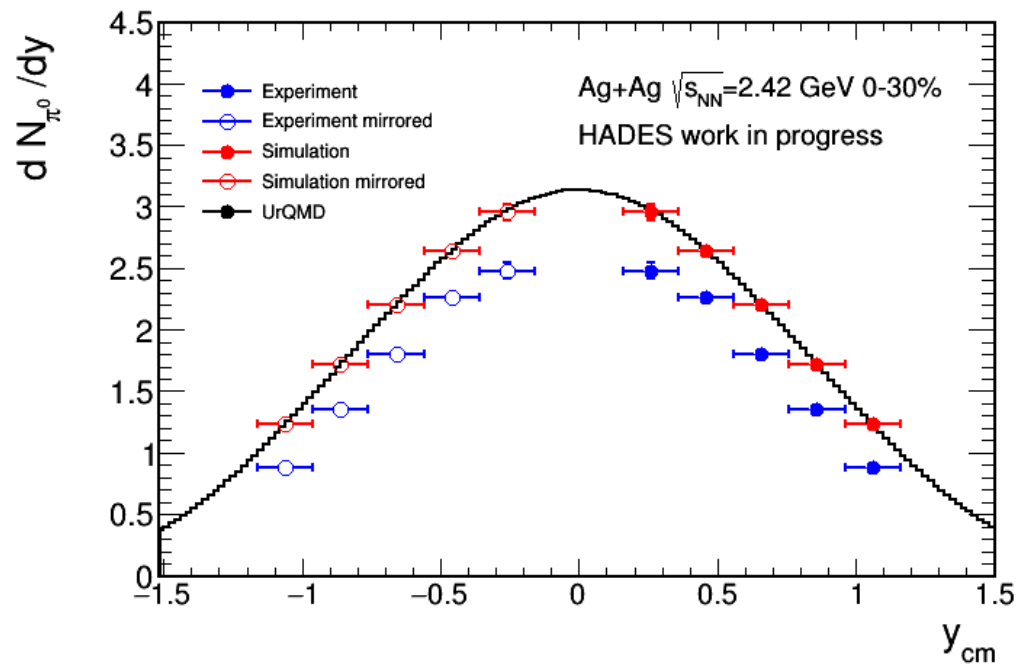
# Preliminary results



Simulation



Experiment



- conversion method
- Dalitz decay  $\pi^0 \rightarrow e^+e^-\gamma$
- $\pi^+ + \pi^- / 2$
- low statistics, large systematic errors
- low statistics (1% decays vs 99%)
-