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π and η production in elementary and heavy-ion collisions at SIS18 energies

M. Gumberidze

for the HADES collaboration

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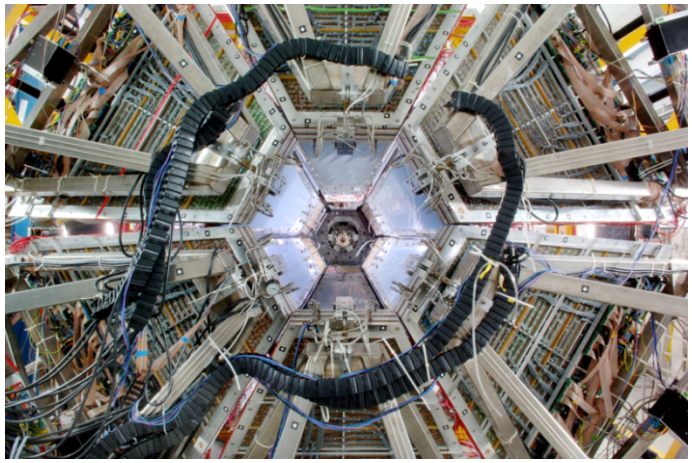
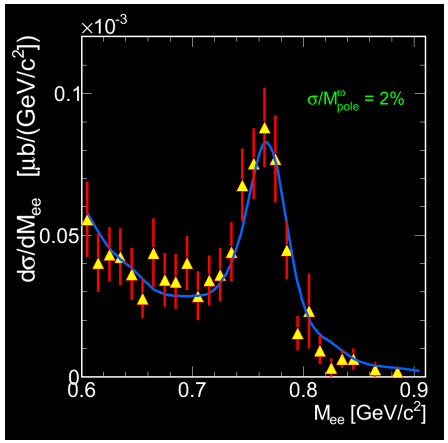
Physics aims of HADES



- Address various aspects of baryon-resonance physics (elementary collisions)
- Explore strongly interacting matter under extreme conditions (heavy ion collisions)

Search for very rare probes

- Di-lepton production governed by the factor α^2
- Branching ratio to e^+e^-: 7.14×10^{-5}
- Vector meson production at SIS18 sub-threshold
- Multi-strange particle production below threshold



- e^+e^- acceptance 35%
- Mass resolution 3% (ρ/ω region)

Meet the HADES

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Measurements at SIS18

Fixed target experiment
π, p, ion beams

Fast detector

HIC: 8 kHz trigger rate

Elementary: 20kHz

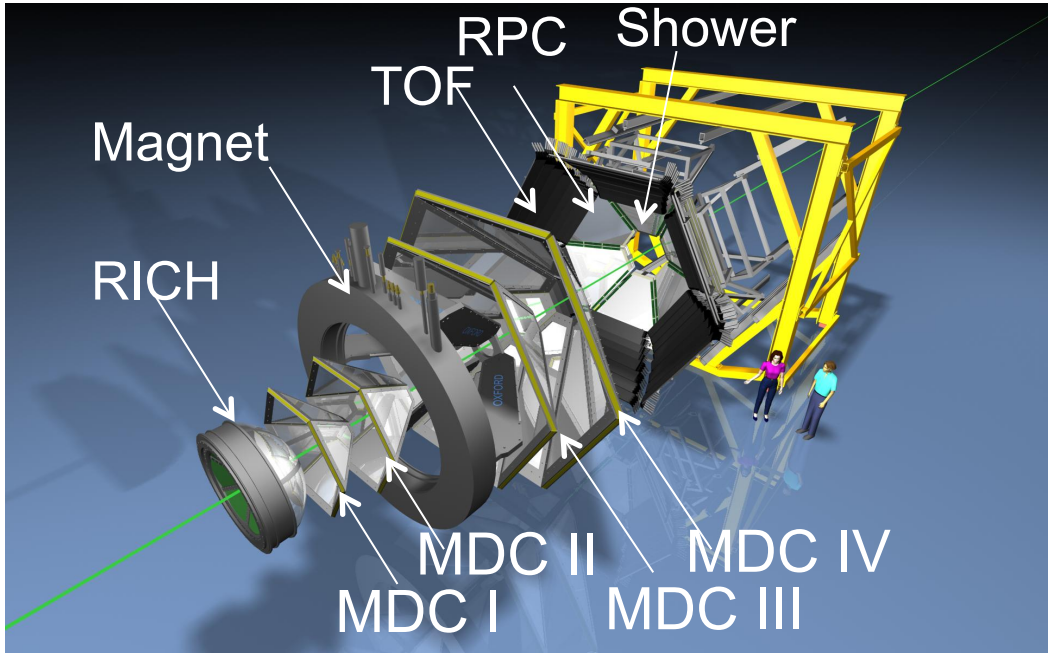
Large acceptance

18° < θ < 85° (polar angle)

Full azimuthal angle

Tracking system

4 drift chamber planes
+ superconducting magnet



The HADES spectrometer [Eur.Phys.J. A41 (2009) 243-277]

Time-of-flight detectors

RPC + TOF for precise hadron identification

RICH and Shower

high purity electron identification

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Outline and strategy

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- Neutral meson reconstruction in elementary (p, π) to AA collisions
  - Crucial reference:
    - Normalization of dileptons
    - Freeze-out part of cocktail – scan in-medium part
    - Baseline for hadron production
  - Constraints on the model calculations:
    - p_T, rapidity, anisotropies (dN/dtheta, flow)
- Natural way → measure π,η → γγ
  - HADES is charged particle detector
  - No EM Calorimeter (yet)
  - Two methods for neutral mesons

$\gamma^* \rightarrow$ Reconstruction of Dalitz decays through inclusive e^+e^-

$\gamma \rightarrow$ Full conversion method

- Summary and Outlook

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Elementary reactions

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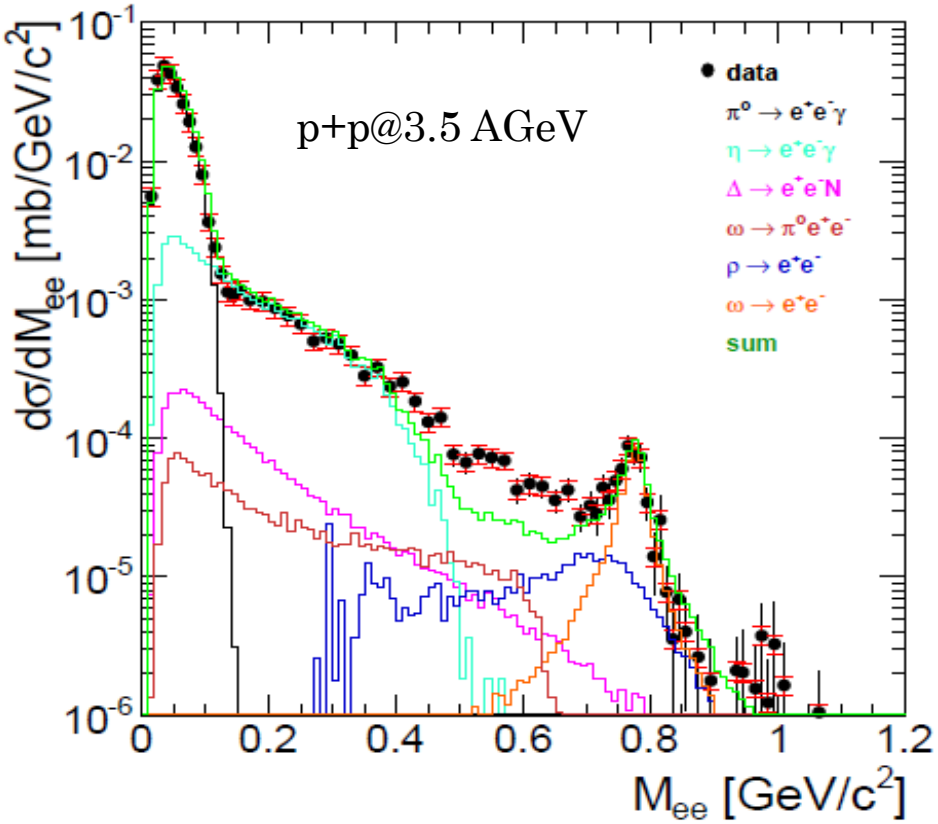
Inclusive dilepton : p+p@ 3.5GeV



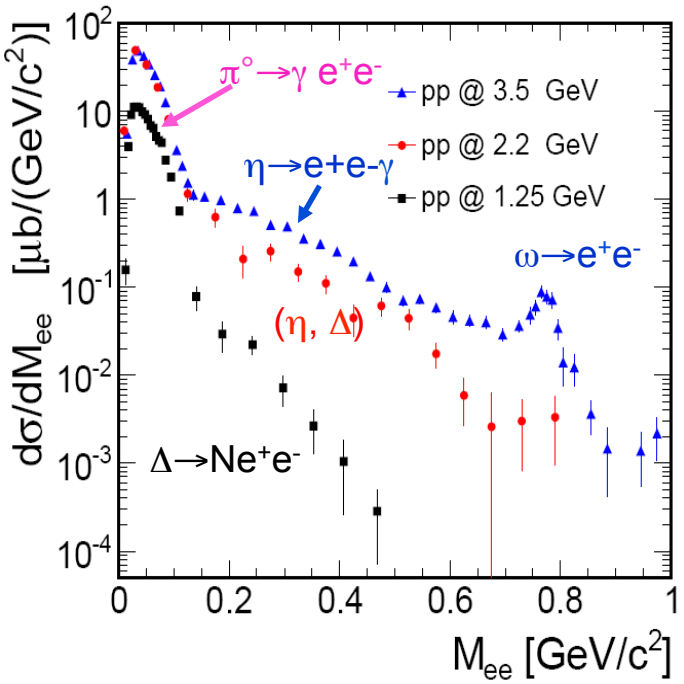
Eur.Phys.J. A48 (2012) 64

e^+e^- mass spectrum is a cocktail of various sources:

- π^0 Dalitz $\pi^0 \rightarrow \gamma\, e^+e^-$
- η Dalitz $\eta \rightarrow \gamma\, e^+e^-$
- Δ Dalitz
- $N^* \rightarrow N\, \rho \rightarrow N\, e^+e^-$
- ω Dalitz
- ρ^0, ω direct $\rightarrow e^+e^-$

Distinct features (invariant) allow to disentangle the cocktail and get π^0, η, ω cross sections

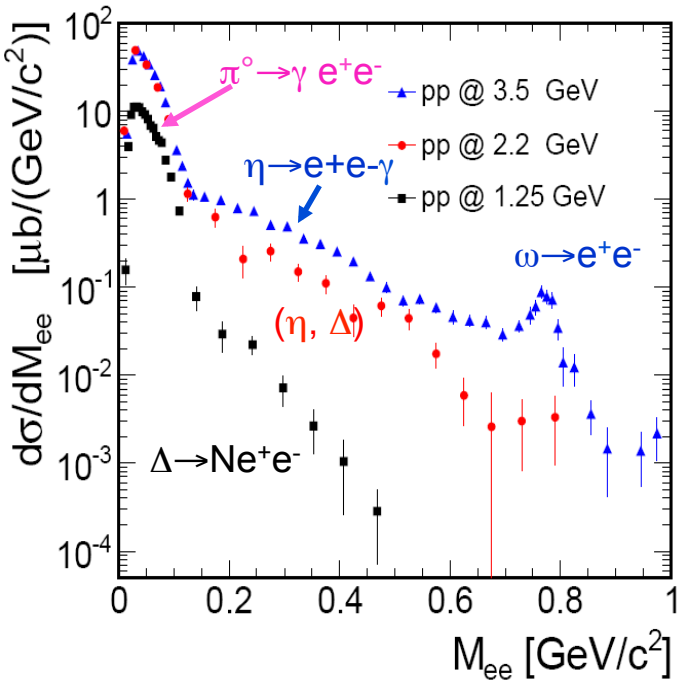
Inclusive meson production in elementary reaction

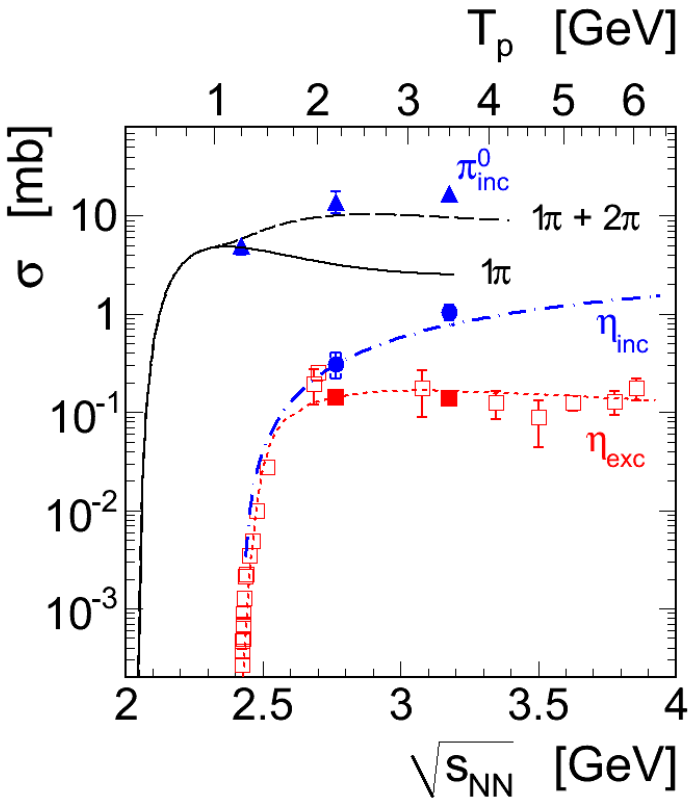


- Good understanding of elementary processes is mandatory for interpretation of pA and AA data
  - Excess radiation in ArKCl and AuAu
  - ω line-shape modification in pNb

HADES data
Eur.Phys.J. A48 (2012) 64
Phys.Rev. C85 (2012) 054005
Phys.Lett.B690:118-122,2010

Inclusive meson production cross-section





HADES data points

P. Moskal et al., Prog. Part. Nucl. Phys. 49, 1 (2002)

A. Baldini et al., In Landolt-Bornstein, new Series I/12b, (Springr 1988)

HADES data
Eur.Phys.J. A48 (2012) 64
Phys.Rev. C85 (2012) 054005
Phys.Lett.B690:118-122,2010

J. Bystricky et. Al., J. Physique 48, 1901 (1987)

A.Sibirtsev et at. Z. Phys. A 358, 357 (1997)

S. Teis et al. Z. Phys. A 356, 421 (1997)

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Conversion method

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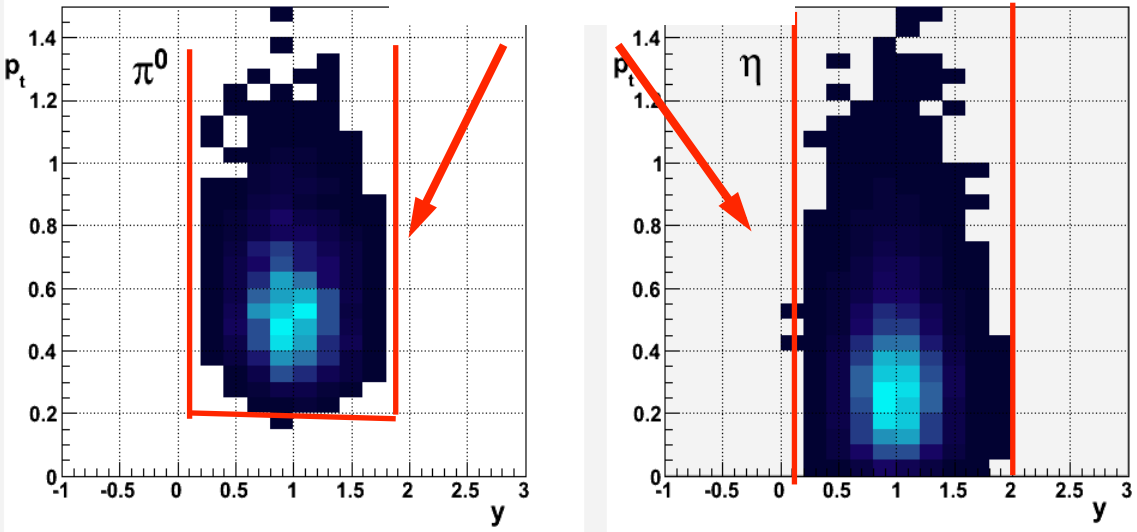
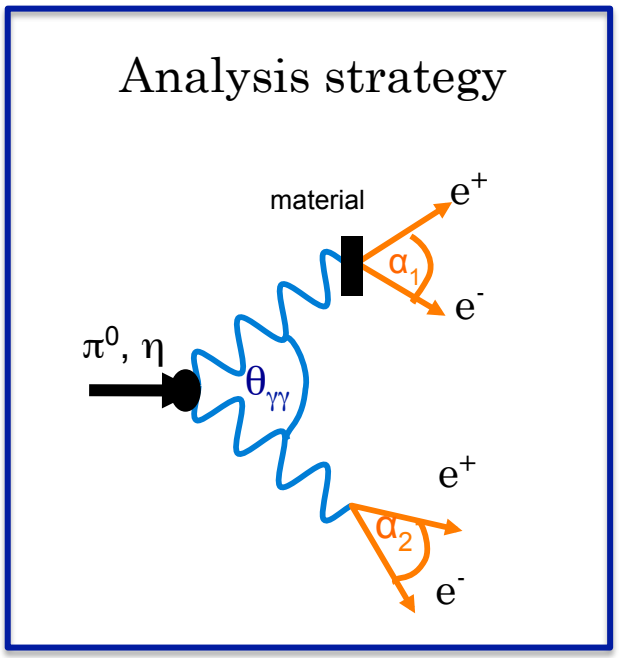
Conversion method

$\pi^0/\eta \rightarrow \gamma\, e^+e^-$, $\gamma\,\gamma$ + γ conversion : $\pi^0/\eta \longrightarrow e^+e^-e^+e^-$

HADES coverage

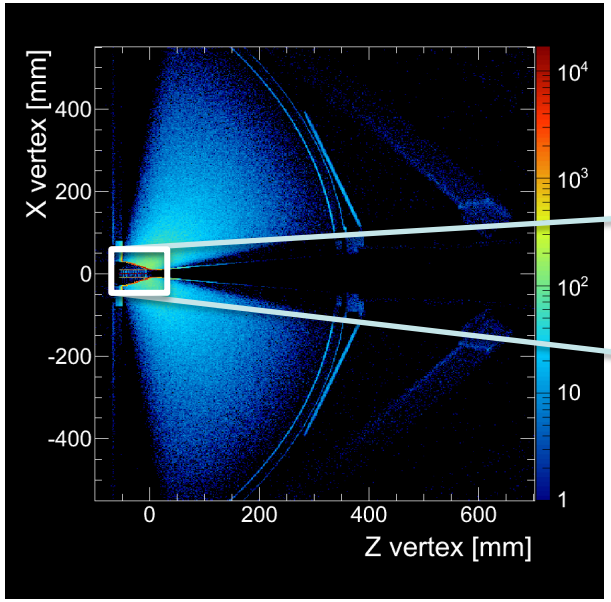




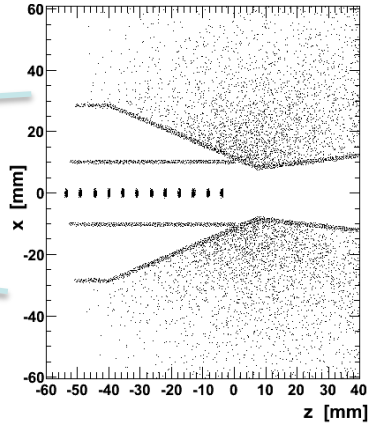
$p_t > 0.25$ GeV/c
y = 0.2 - 1.8

full p_t coverage !
y = 0.2 - 1.9

Conversion method



Zoom to the target region



- HADES low mass spectrometer
  - Segmented target
  - RICH : X/X0 < 1% ,
  - MDC: X/X0 0.42 %

→ specially optimized to minimize conversion and multiple scattering

Conversion probabilities from GEANT simulation

Target	(Nb)	2.5%
Holder	(C)	0.15 %
Beam pipe	(C)	0.5 %
Radiator	(C_4F_{10})	0.92 %

Total : 4.10 % for η

π and η reconstruction using conversion method
Cold nuclear matter : p + Nb @ 3.5 AGeV

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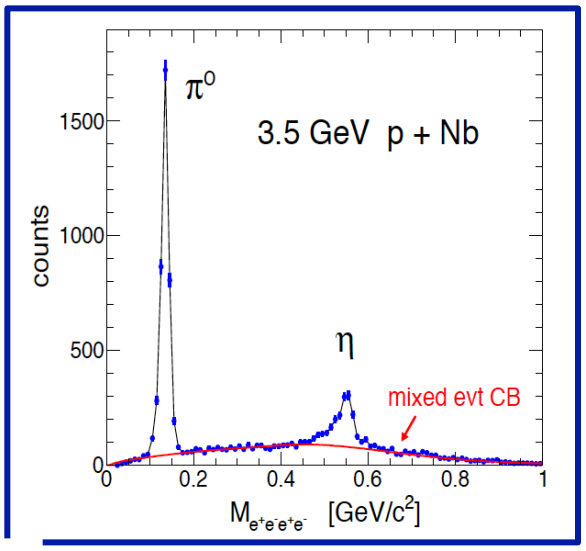
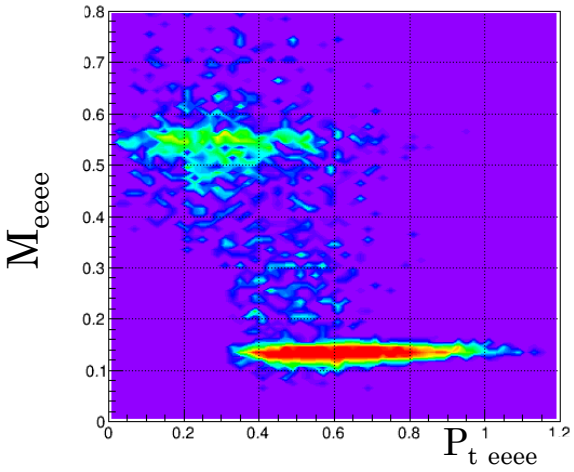
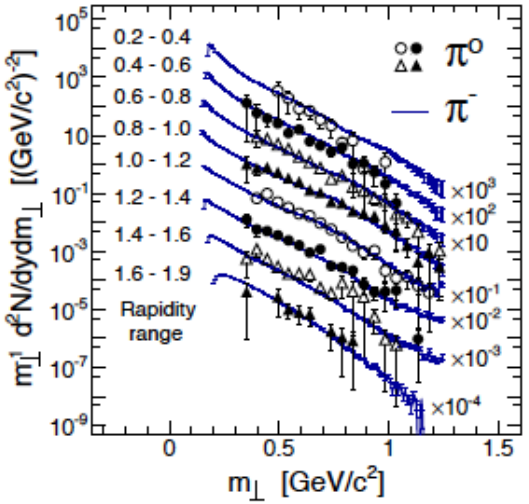


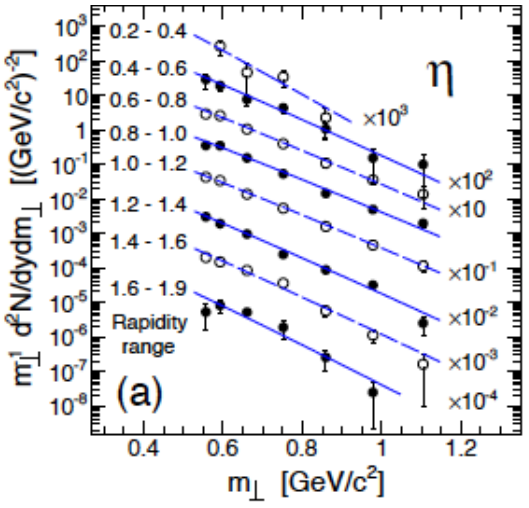
Phys. Rev. C 88, 024904 (2013)

identified meson	π^0	η
signal [counts]	3800 ± 63	1240 ± 49
signal/CB	18.1	1.1
position [MeV]	134 ± 1	547 ± 2
width [MeV]	8.0 ± 0.6	19 ± 2



- Large acceptance
  - Allows for multi-differential analysis





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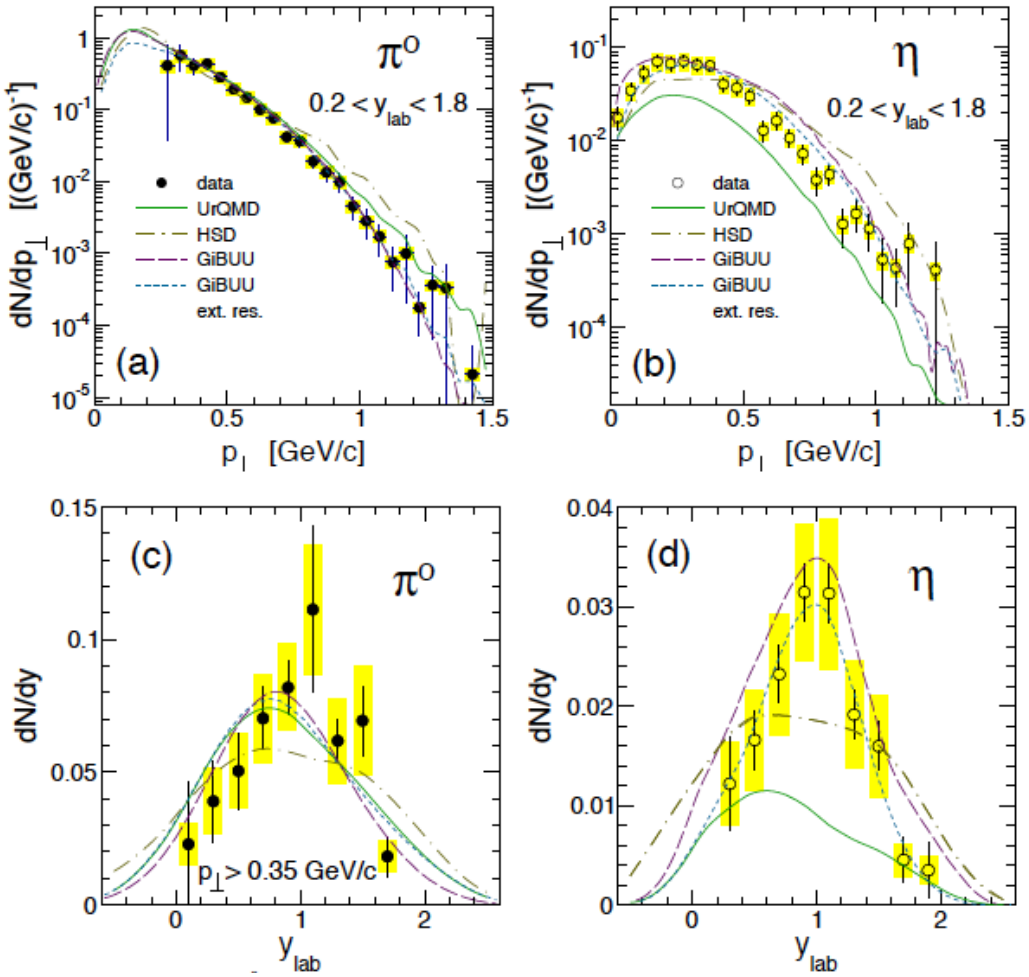
Comparison with transport models



π^0 production is fairly well described by all models,

The pion yields reproduced within 10-25%.

η shows larger discrepancies between the models

GiBUU with tuning fits best

The complete lack of data for 3.5AGeV explains why the models tend to perform worse for η production than they do for π.

Phys. Rev. C 88, 024904 (2013)

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HI collisions

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Au+Au data sample

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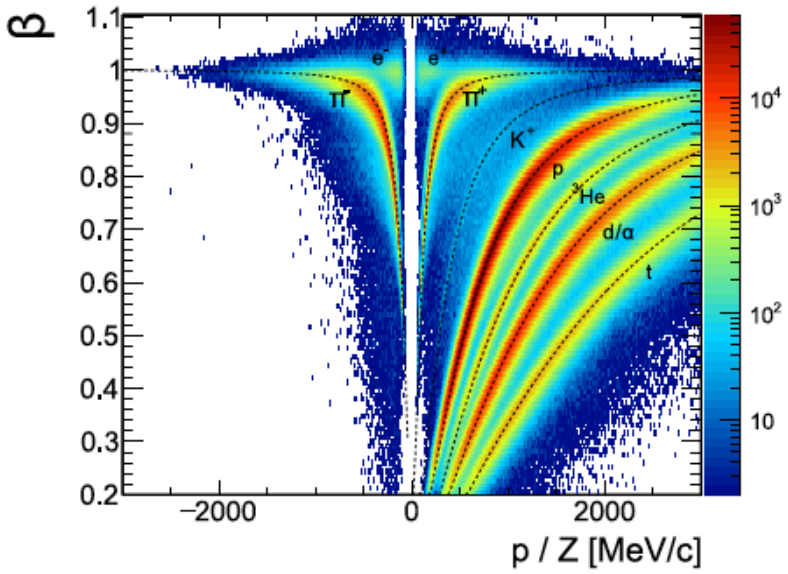
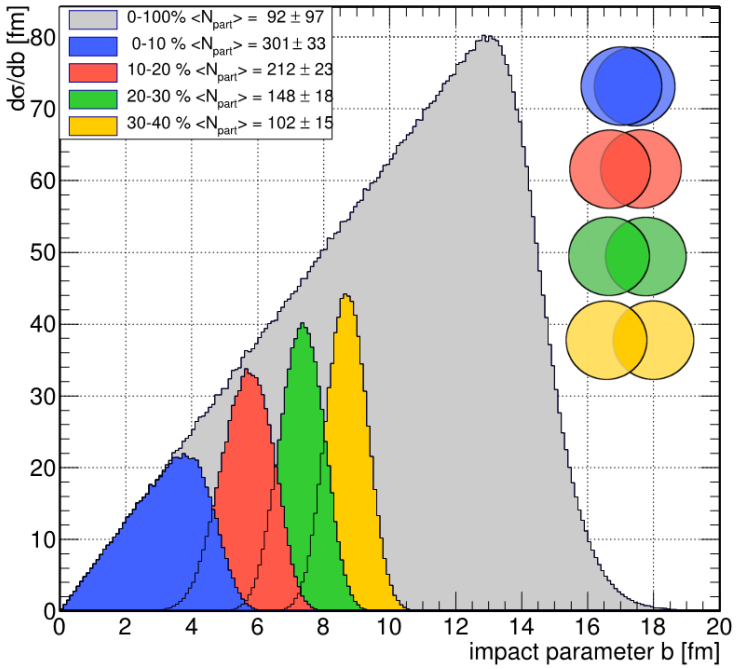
Data sample

- 47% most central Au+Au collisions recorded
- First-level trigger conditions:
  hit multiplicity in outer ToF detector
  > 16 + signal in the START detector



Glauber Monte Carlo



- 40% most central events used for analysis : 4.98 x 10^9 events

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Heavy ion : Au+Au

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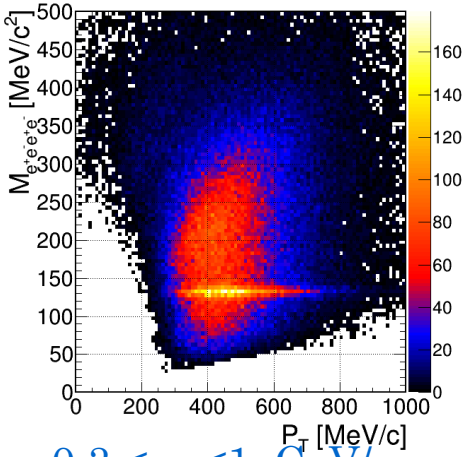
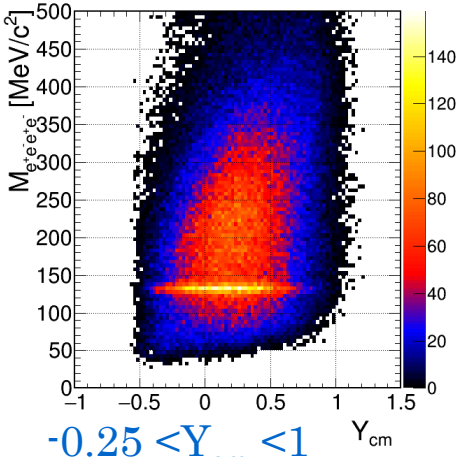
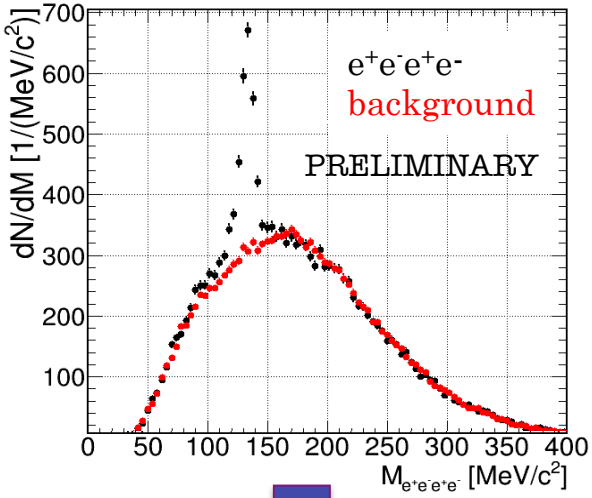
Phase-space coverage

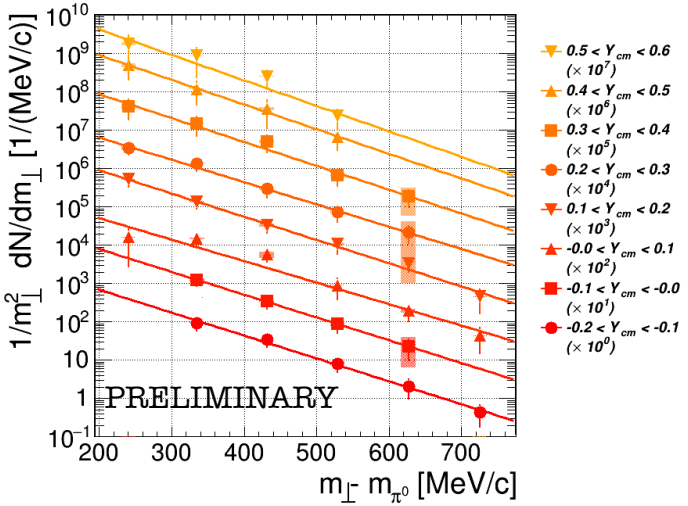


$0.3 < p_\perp < 1.$ GeV/c



$-0.25 < Y_{cm} < 1$





- N(π^0) : 4900 ± 90
- Significance : 38
- $\sigma(\pi^0)$: 11.6
- $\mu(\pi^0)$: 133.7

✓ Conversion probability for Au target :

- π^0 : 0.14%
- η : 0.34%

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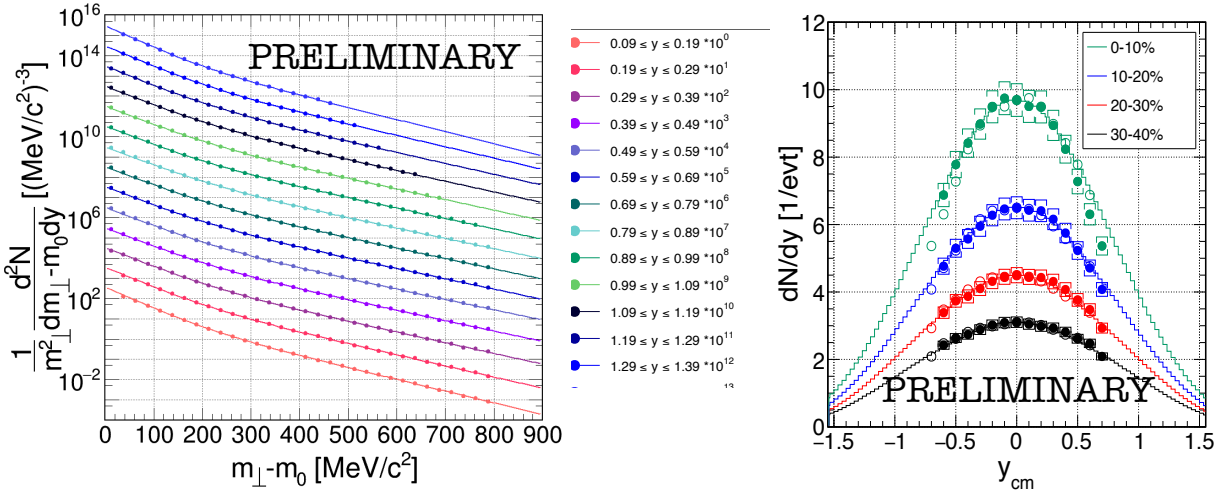
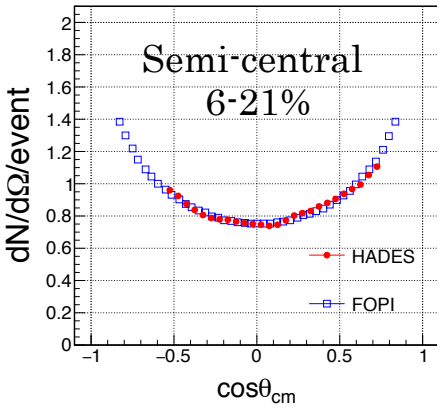
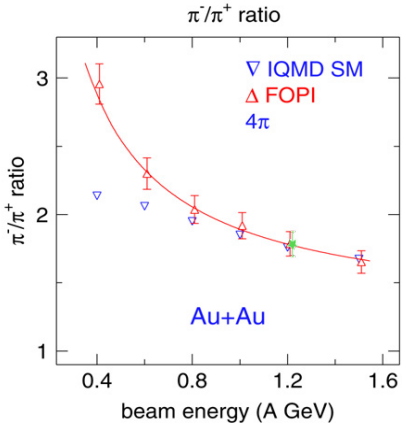
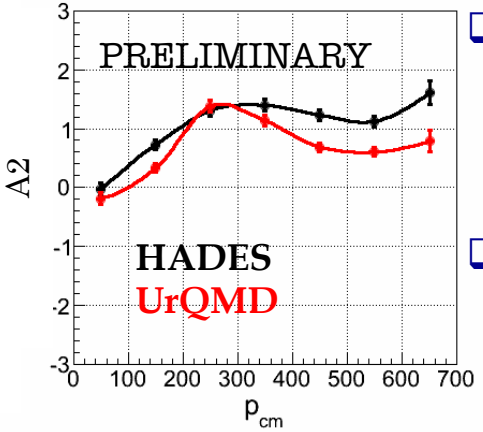
Charged pion measurements



- Very large sample of data
- Large acceptance
  - Allows for multi-differential analysis







- Pion production is :
  - Strongly anisotropic
  - p_{cm} dependence
- Effects fairly reproduced by the UrQMD model

System size , A_{part} dependence

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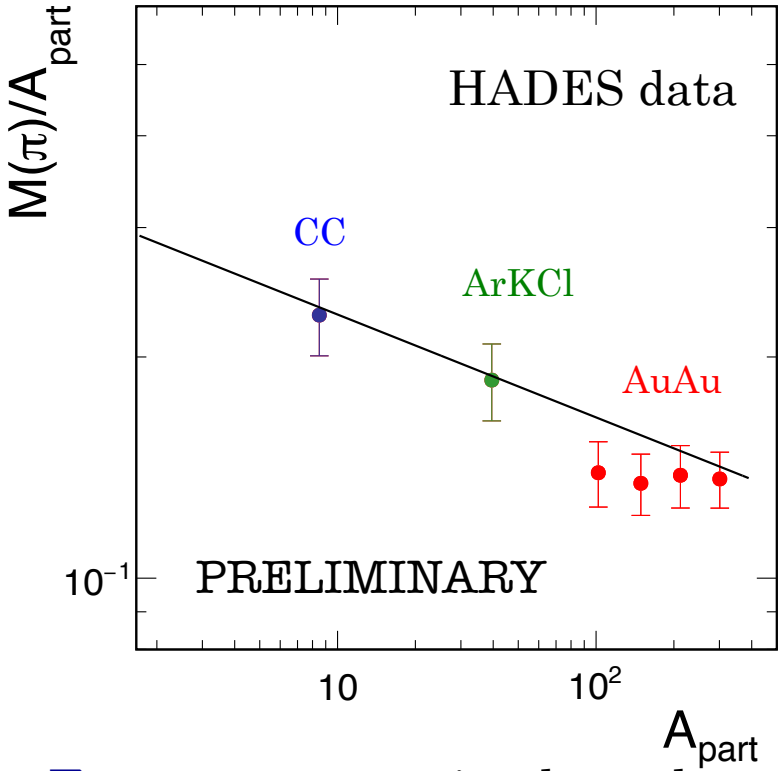
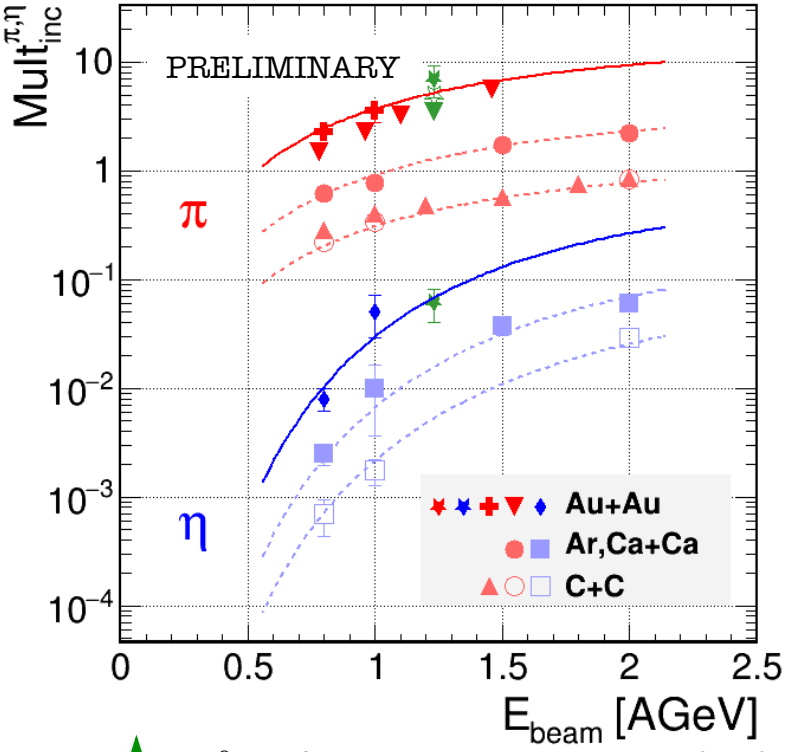
$M(\pi) = 3./2*(M(\pi^+) + M(\pi^-))$



- strong system size dependence,
- but no dependence on Apart in same system (Au+Au)



★ π^0, η from conversion method

☆ π^0 from charge pions

▼ π^+

HADES AuAu@ 1.23AGeV

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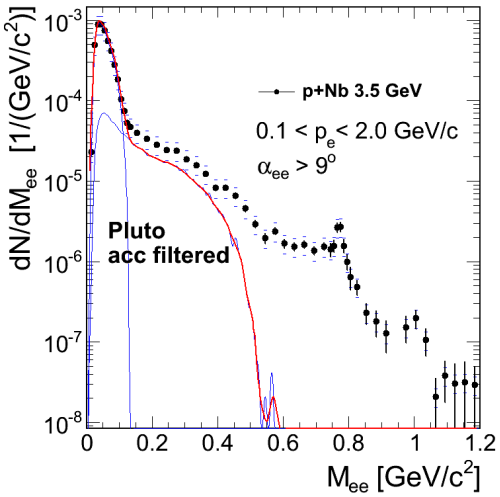
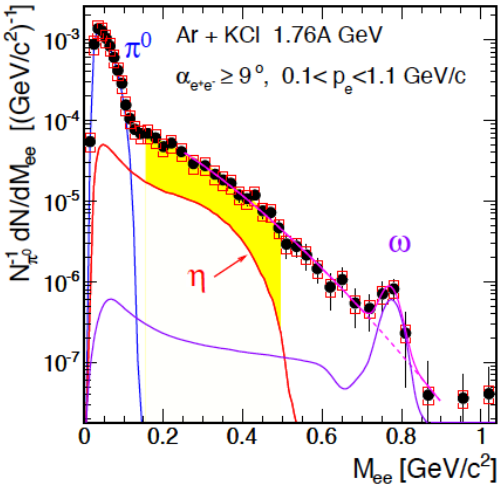
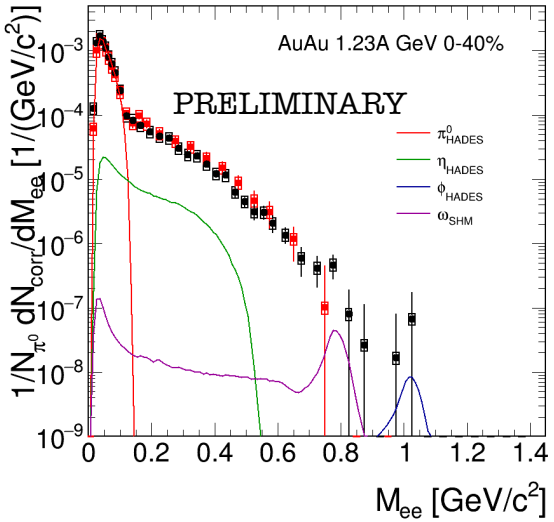
Inclusive dilepton spectra

Phys. Lett. B715 (2012) 304



Phys. Rev. C84 (2011) 014902





- Agreement with in the π^0-Dalitz region
- Above pi0 clear enhancement
  - → Medium radiation!

Summary and Outlook

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- Neutral meson reconstruction in elementary (p, π) to AA collisions
  - Crucial reference:
    - Normalization of dileptons
    - Freeze-out part of cocktail – scan in-medium part
    - Baseline for hadron production
  - Constrains on the model calculations

- Pion observables help to characterize resonance matter
  (see Saturday poster G. Kornakov)

- More data runs planned
  - at SIS18 (>2018) with upgraded HADES (ECAL, RICH, FW) using pion beams, proton beams and HI beams
  - at SIS100 (> 2021) to extend the pp and pA program to higher beam energies and provide a reference for A+A

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THANK YOU!

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See also other Hades talks :

G. Kornakov 04.06 Poster

F.Scozzi 03.06 : Parallel A4

W. Przygoda 06.06 Plenary

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Backup slides

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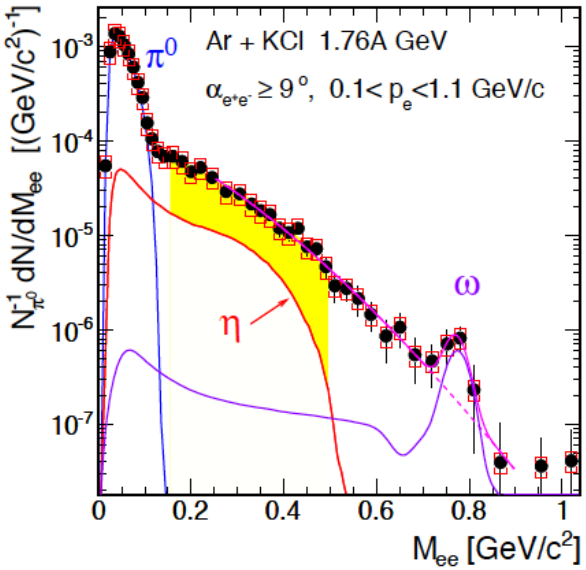
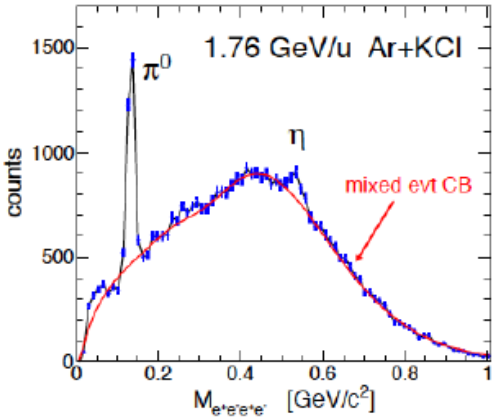
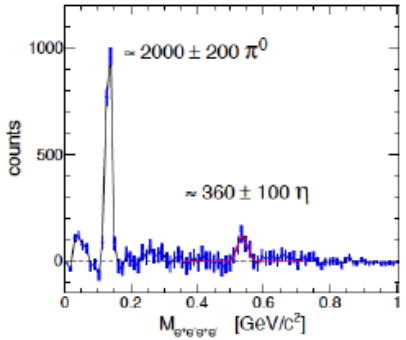
Conversion method : light system ArKCl



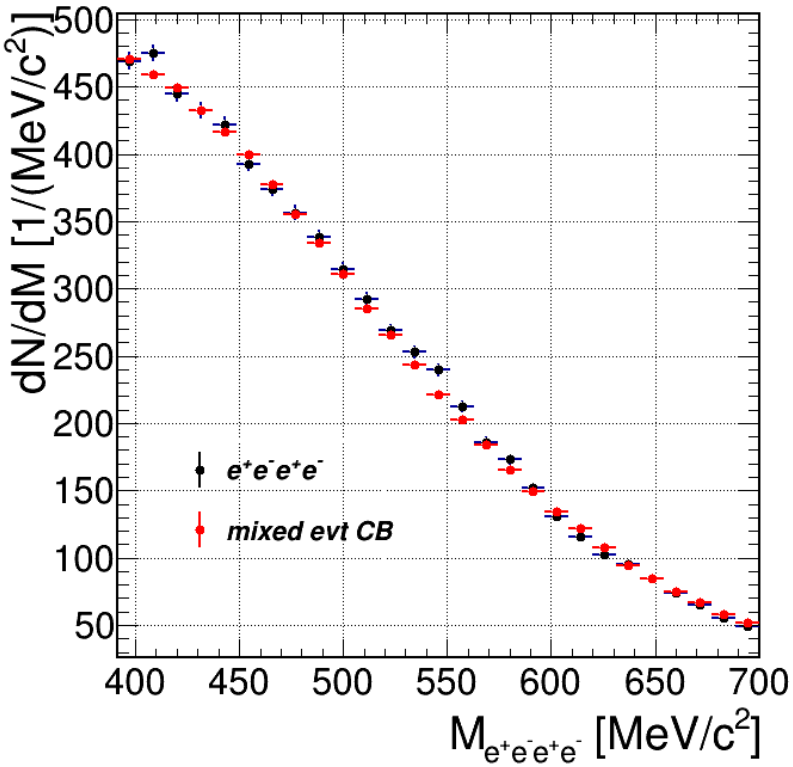


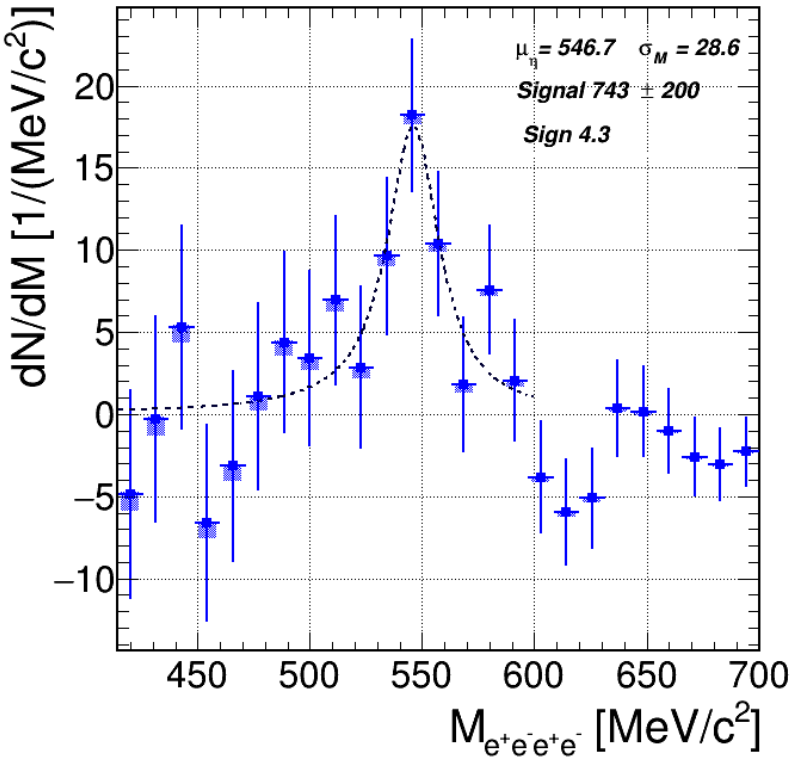
after CB subtraction



- Limited statistics
- High background

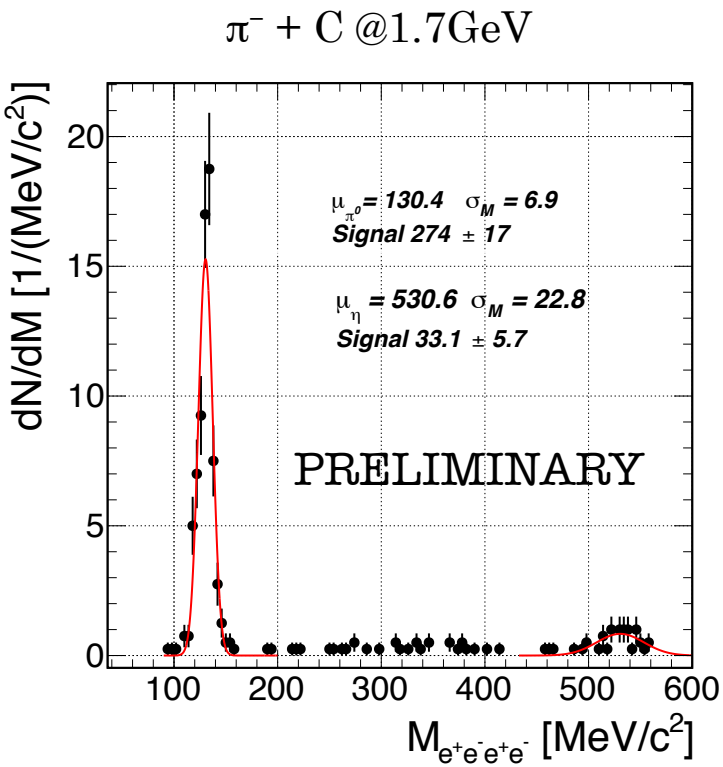
η from conversion method : Au+Au@1.23AGeV





- On-going analysis
- High background coming from pions

π- beam



- On-line spectra
- Analysis on-going