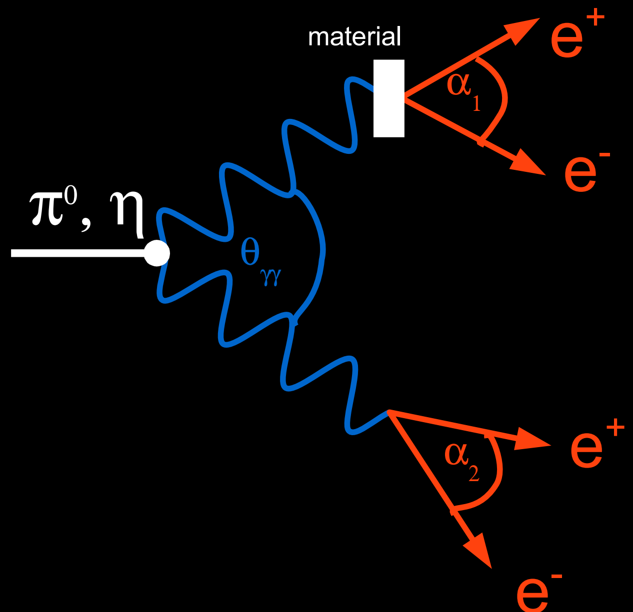
Reconstruction of mesons at freeze-out via conversion

in Au+Au at 1.23 GeV/u with HADES



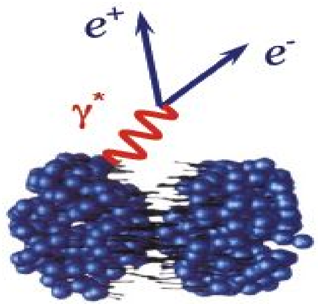
H-QM Helmholtz Research School Quark Matter Studies

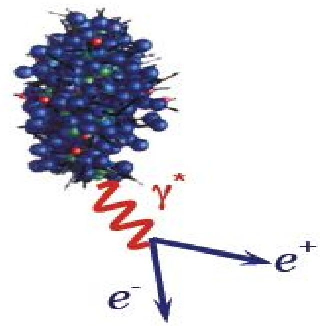
HGS-HIRe for FAIR Helmholtz Graduate School for Hadron and Ion Research

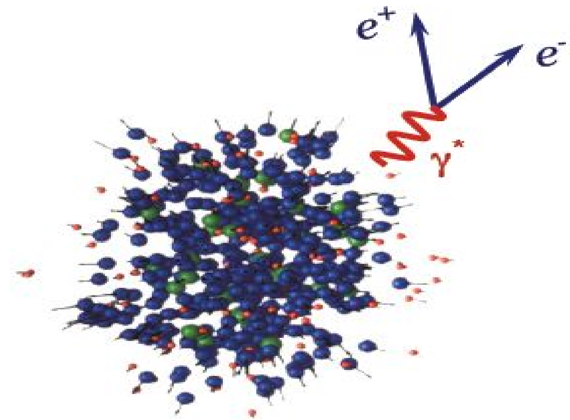
Claudia Behnke
for the HADES collaboration

Motivation

Heavy-ion collision at 1-2 GeV/u







First-chance NN collisions	Hot and dense stage (~ 10 fm/c)	Freeze-out stage

Baryonic sources:
- NN Bremsstrahlung
- $\Delta, N^* \rightarrow Ne^+e^-$

In-medium spectral functions

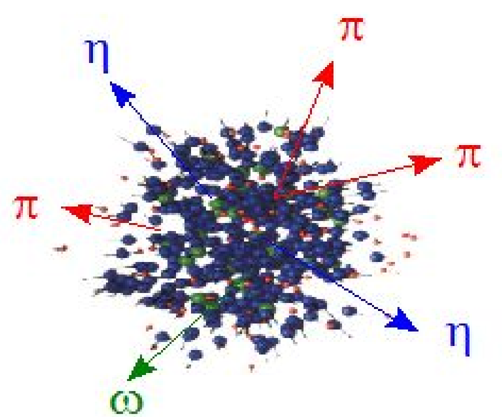
Long-lived mesons:
- π^0, η, ω

$\tau_\pi = 7.7 \times 10^7$ fm/c

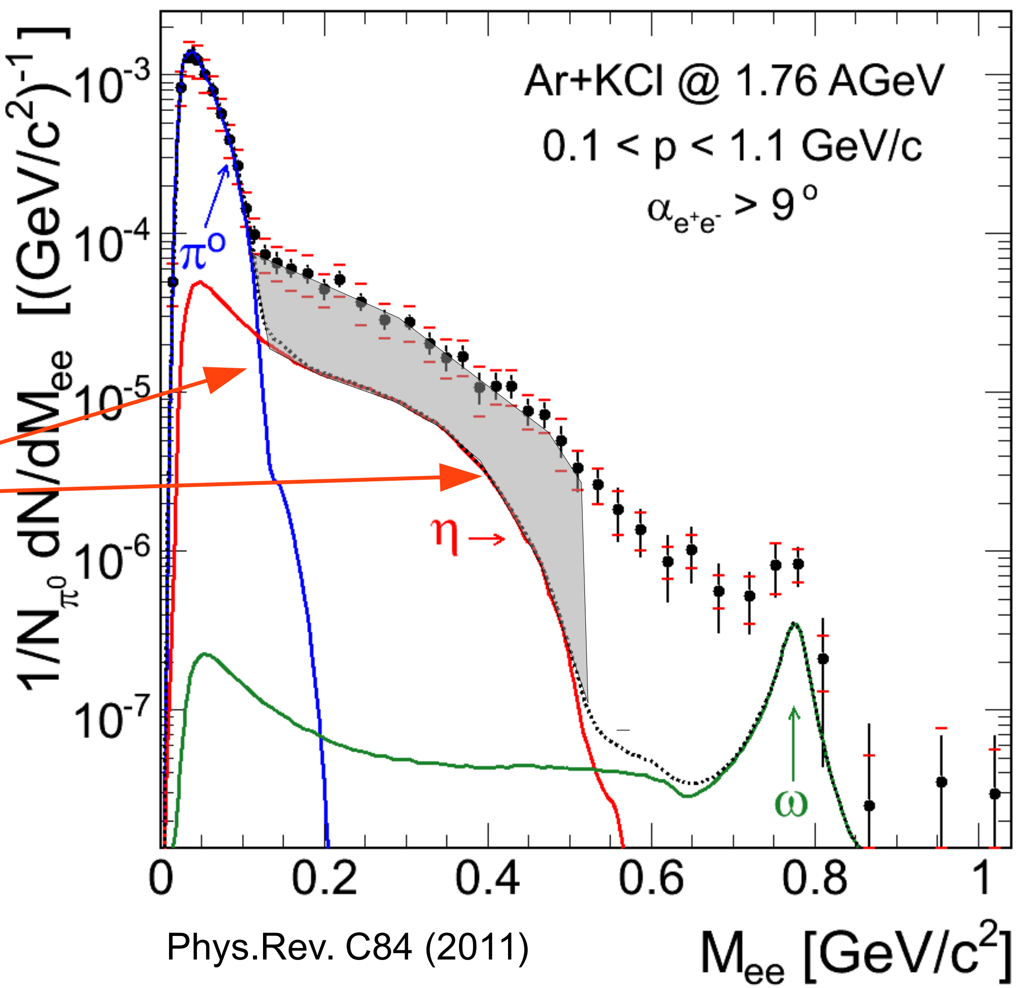
$\tau_\eta = 1.5 \times 10^5$ fm/c

$\tau_\omega = 23$ fm/c

The freeze-out "Cocktail"



$\pi^0, \eta \rightarrow \gamma e^+e^-$



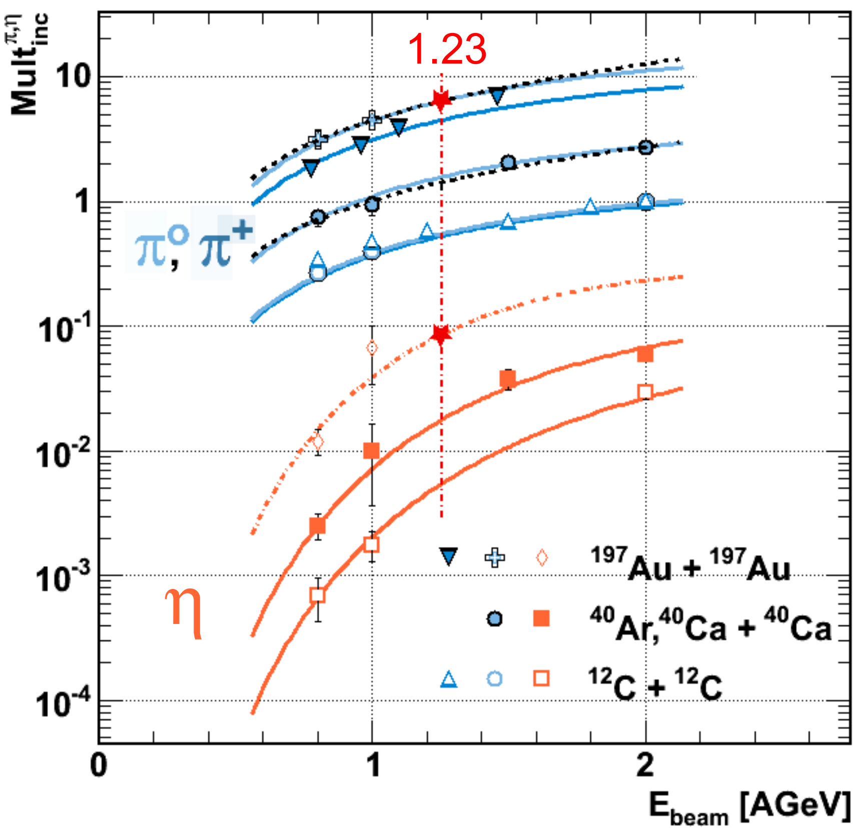
Phys.Rev. C84 (2011)

- ✔ $Mult_{\pi^0}$ is essential for spectrum normalization
- ✔ "no $Mult_\eta$, no $Mult_{Excess}$!"

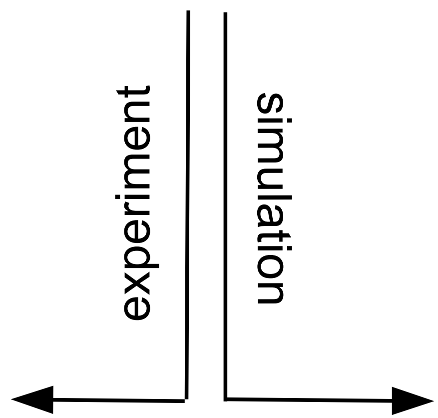
How to reconstruct π^0 and η ?

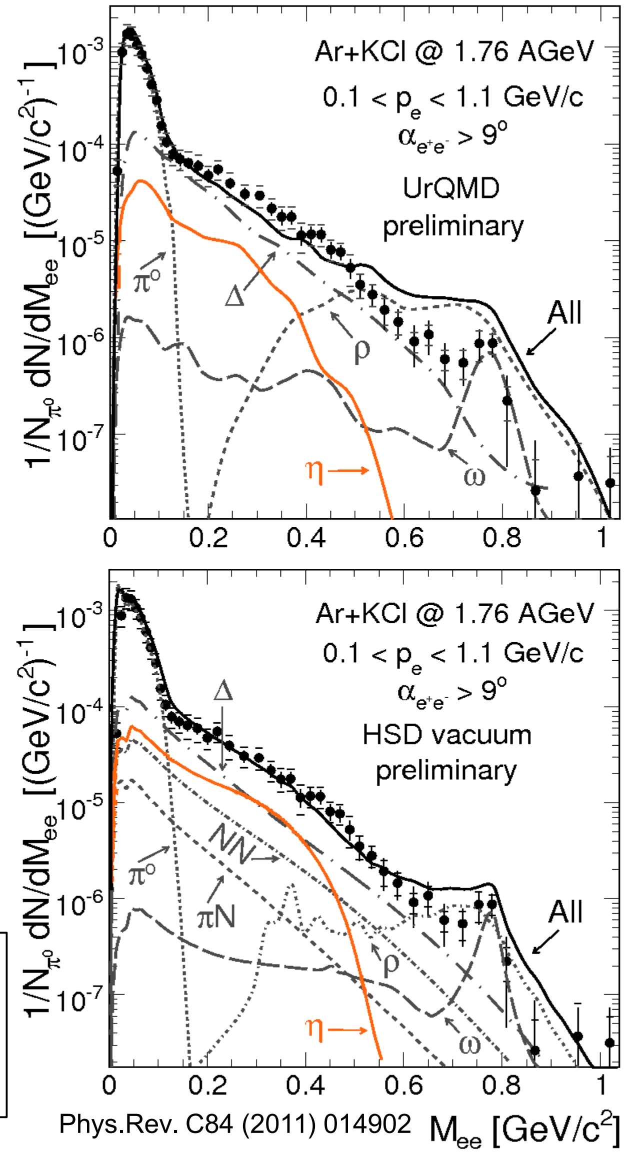
The freeze-out "cocktail"

Phys. Rev. C,67:024903, 2003.



Uncertainties





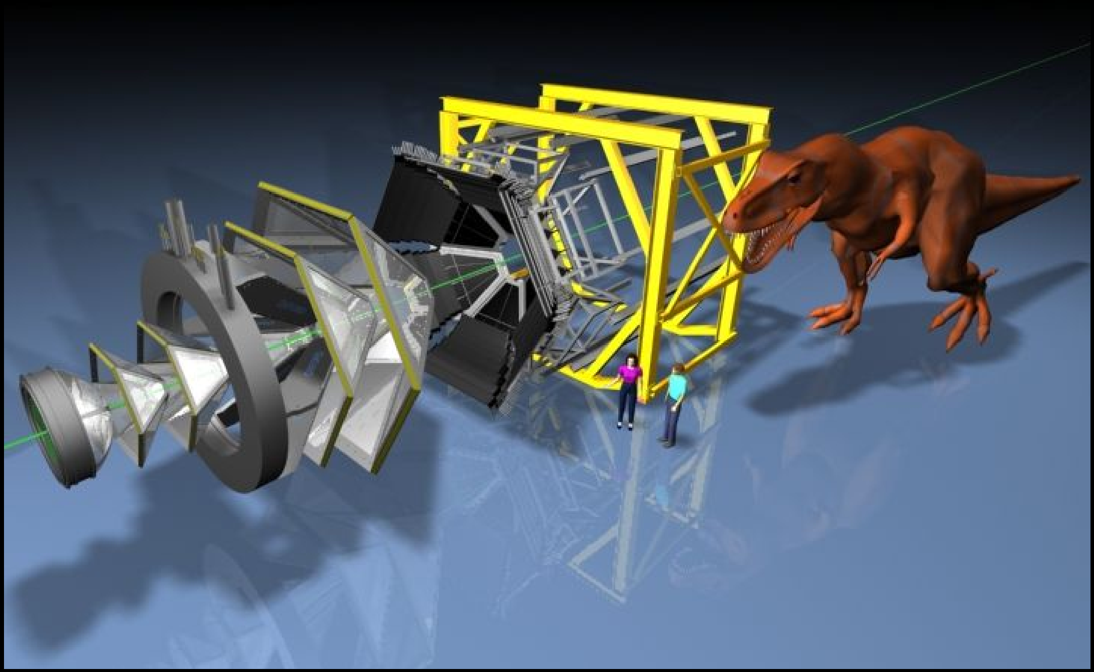
Multiplicity of π^0 and η mesons, as a function of beam energy and system size. Au+Au points from extrapolation to the measured data.
No measurements at 1.23 GeV/u

$Mult_{AuAu}(\pi^0) = 6.4 \pm 15\%$

$Mult_{AuAu}(\eta) = 0.09 \pm 50\%$

THE HADES AT GSI, DARMSTADT, GERMANY

- HADES strategy:
  - Excitation function for low-mass lepton pairs and (multi-)strange baryons and mesons
  - Various aspects of baryon-resonance physics
- Beams provided by SIS18: π, proton, nuclei
- Full azimuthal coverage, 18° to 85° in polar angle
- Hadron and lepton identification
- Event-plane reconstruction
- ~ 80.000 channels



- 50 kHz event rate (400 Mbyte/s peak data rate)

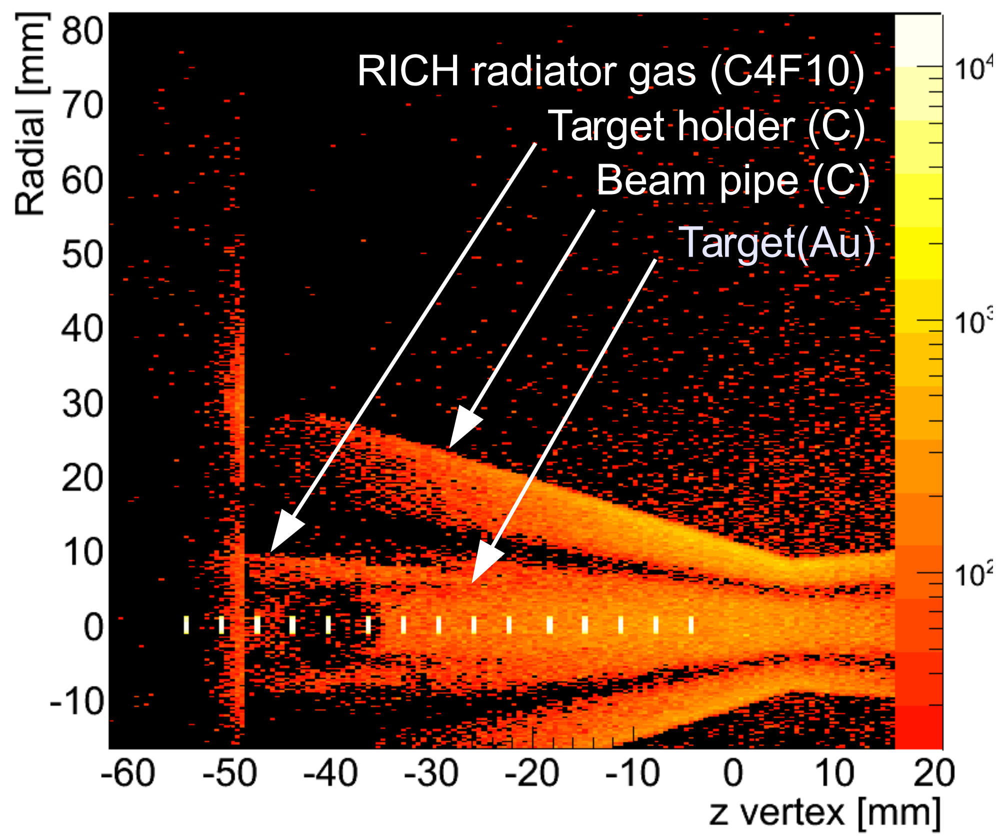
How to measure π^0 and η with HADES?

$$\pi^0,\eta \rightarrow \gamma\gamma \overset{conv}{\Rightarrow} e^+e^-e^+e^-$$

$$\pi^0,\eta \rightarrow \gamma e^+e^- \overset{conv}{\Rightarrow} e^+e^-e^+e^-$$

How to reconstruct γ without dedicated photon detector? ⇒ Identifying 4 leptons using photon conversion!

Material	Conv [%] (π^0)	Conv [%] (η)
Target	0.32	0.54
Target holder	0.02	0.04
Beam pipe	0.26	0.48
Radiator gas	0.59	0.91
Sum*	**1.2**	**2.0**



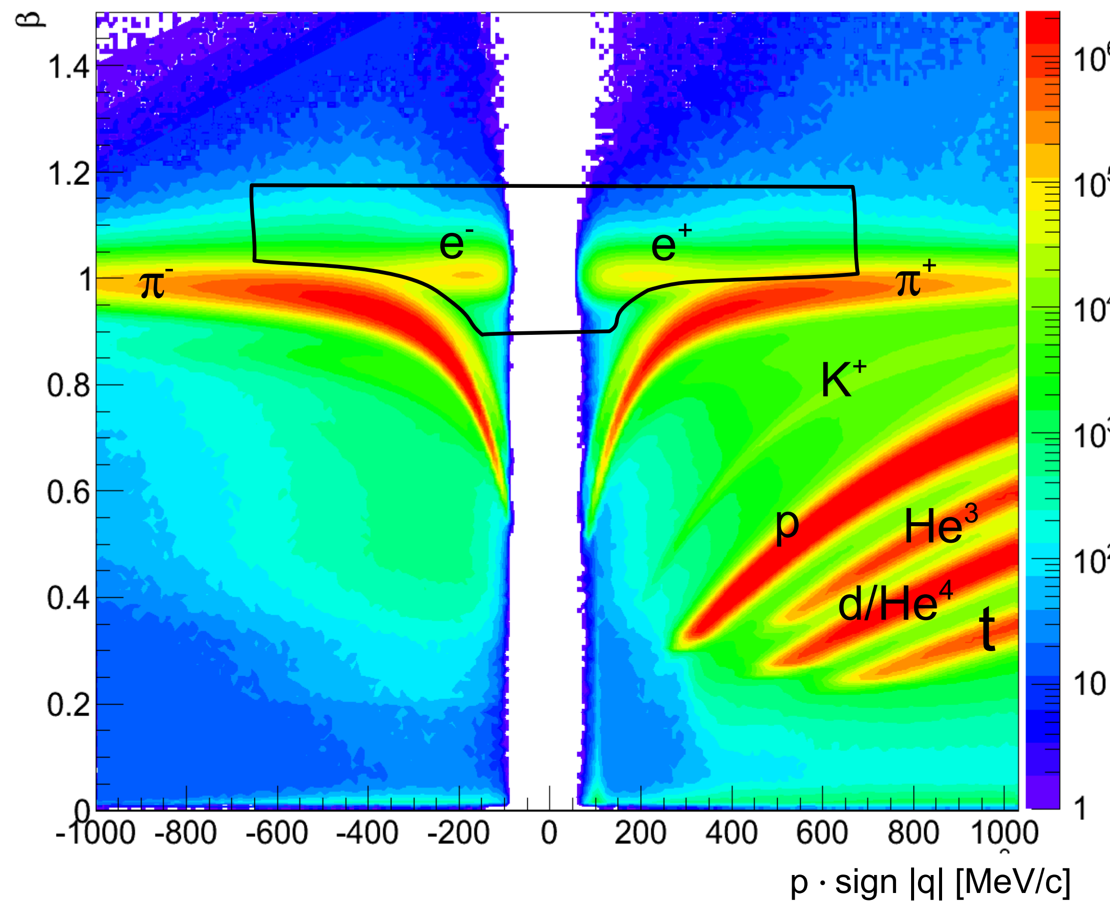
*all values are obtained from Geant3 simulations!

STAR: PhysRevC.70.044902
CDF: PhysRevD.70.074008
ALICE: Phys. Lett. B 717,162
HADES: - p+Nb 3.5 GeV: PhysRevC.88.024904

The analysis strategy - part 1

Lepton identification:

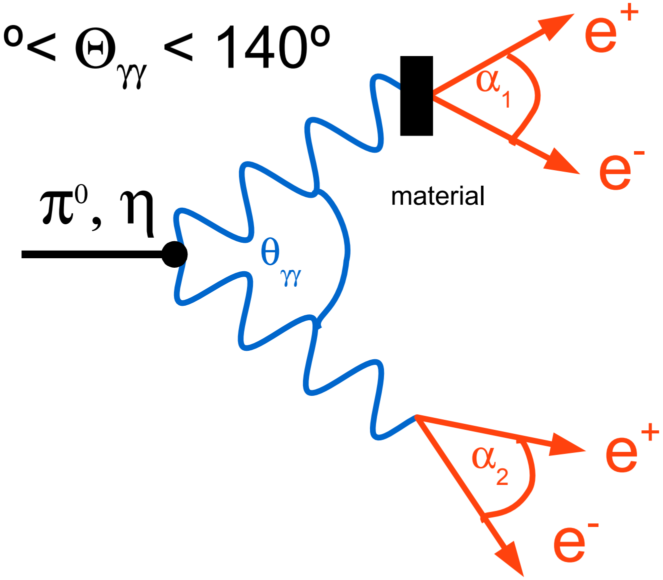
- Momentum < 750 MeV/c
- Momentum dependent velocity cuts
- No RICH information is used
- Sharing of inner MDC segments is allowed

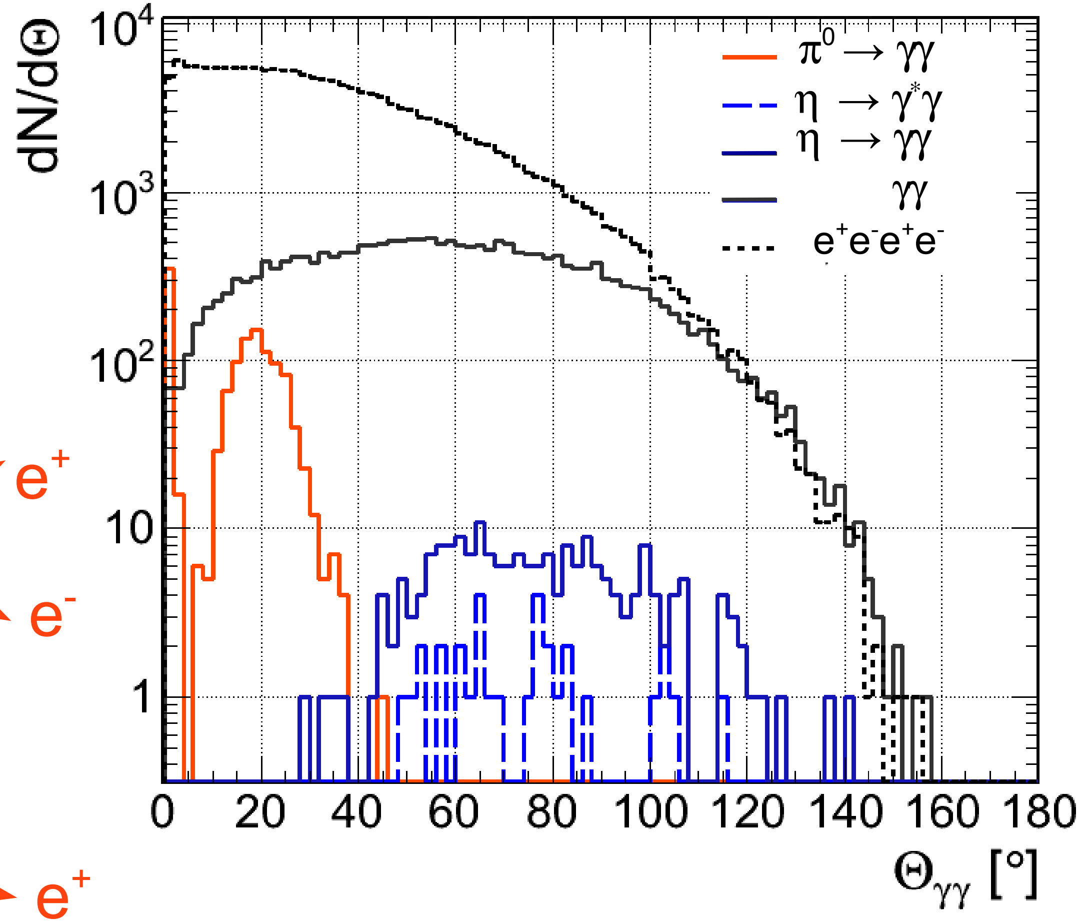


The analysis strategy - part 2

Combine 4 fully reconstructed lepton candidates

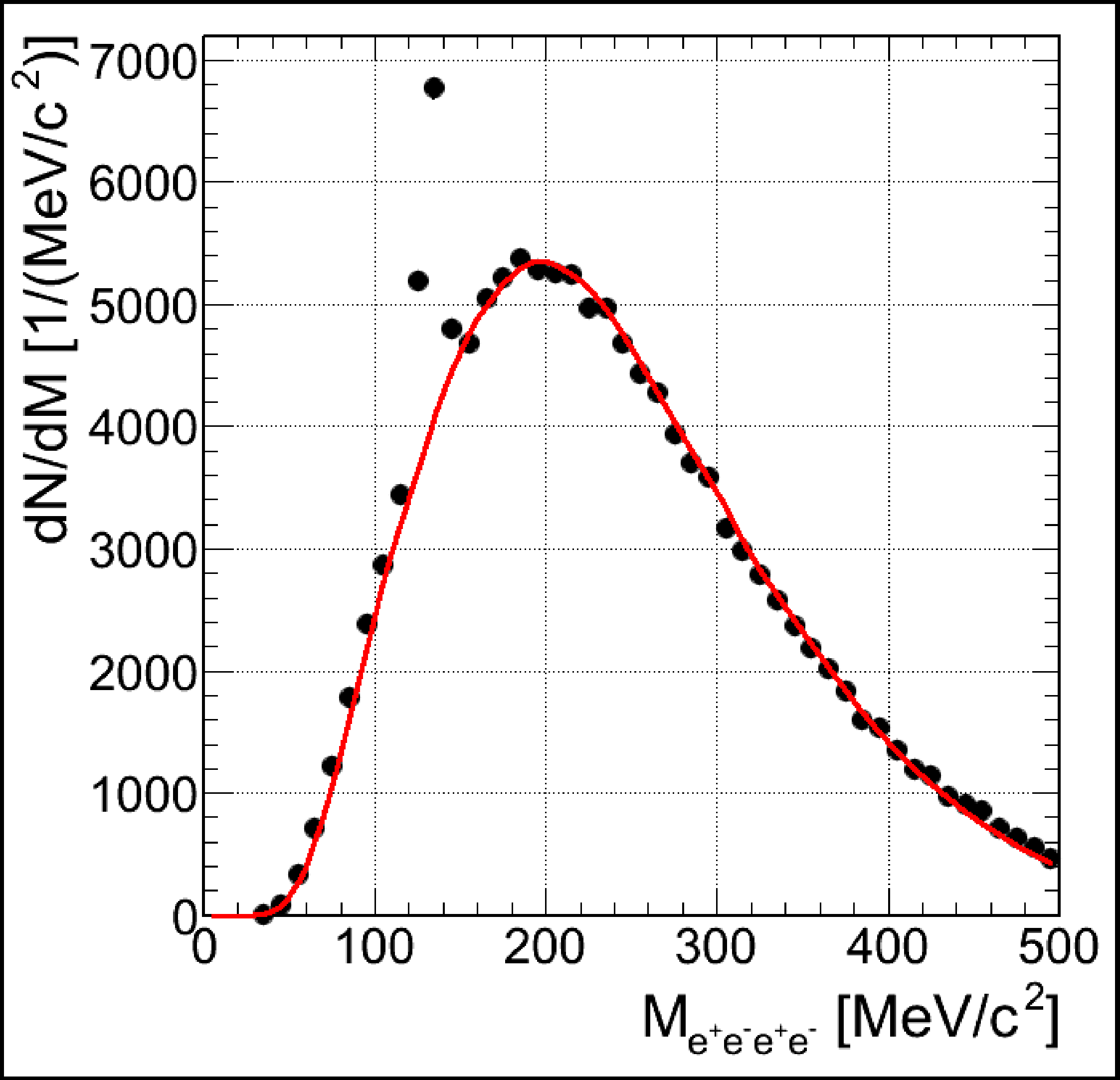
- Background rejection cuts: Topological cuts on angles between e^+e^- and γ:
  - $\alpha_1 < 2.5^o$, $\alpha_2 < 20^o$
  - π^0 : $10^o < \Theta_{\gamma\gamma} < 40^o$
  - η : $40^o < \Theta_{\gamma\gamma} < 140^o$

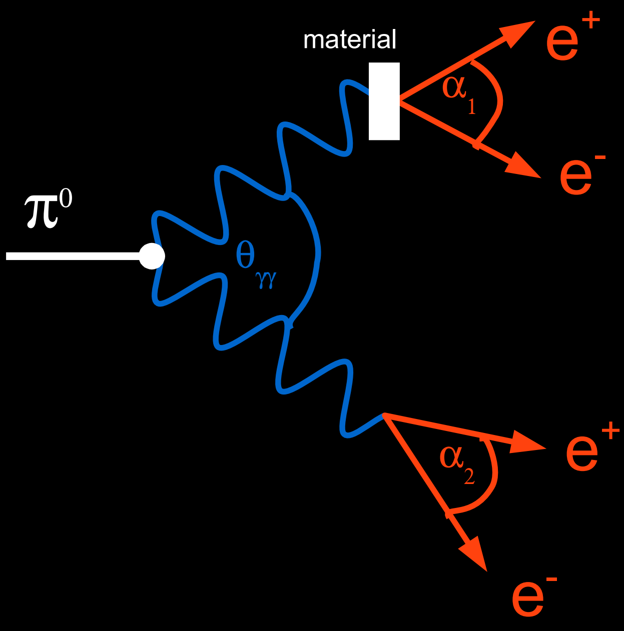




UrQMD simulation

π^0 statistics from 4.3 * 10^9 high multiplicity Au+Au events

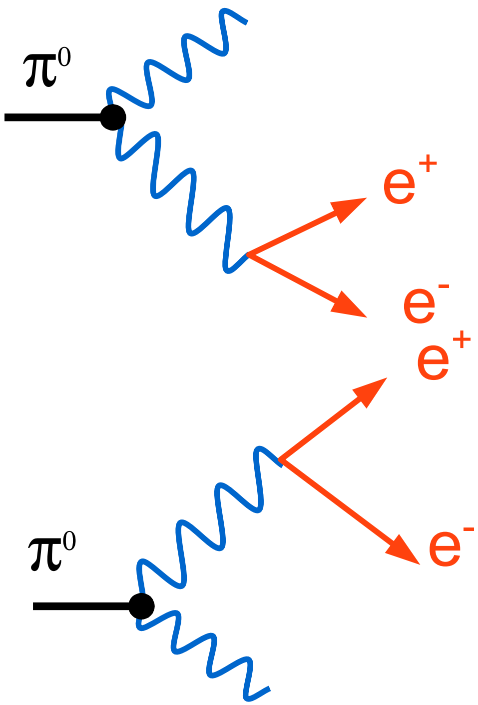


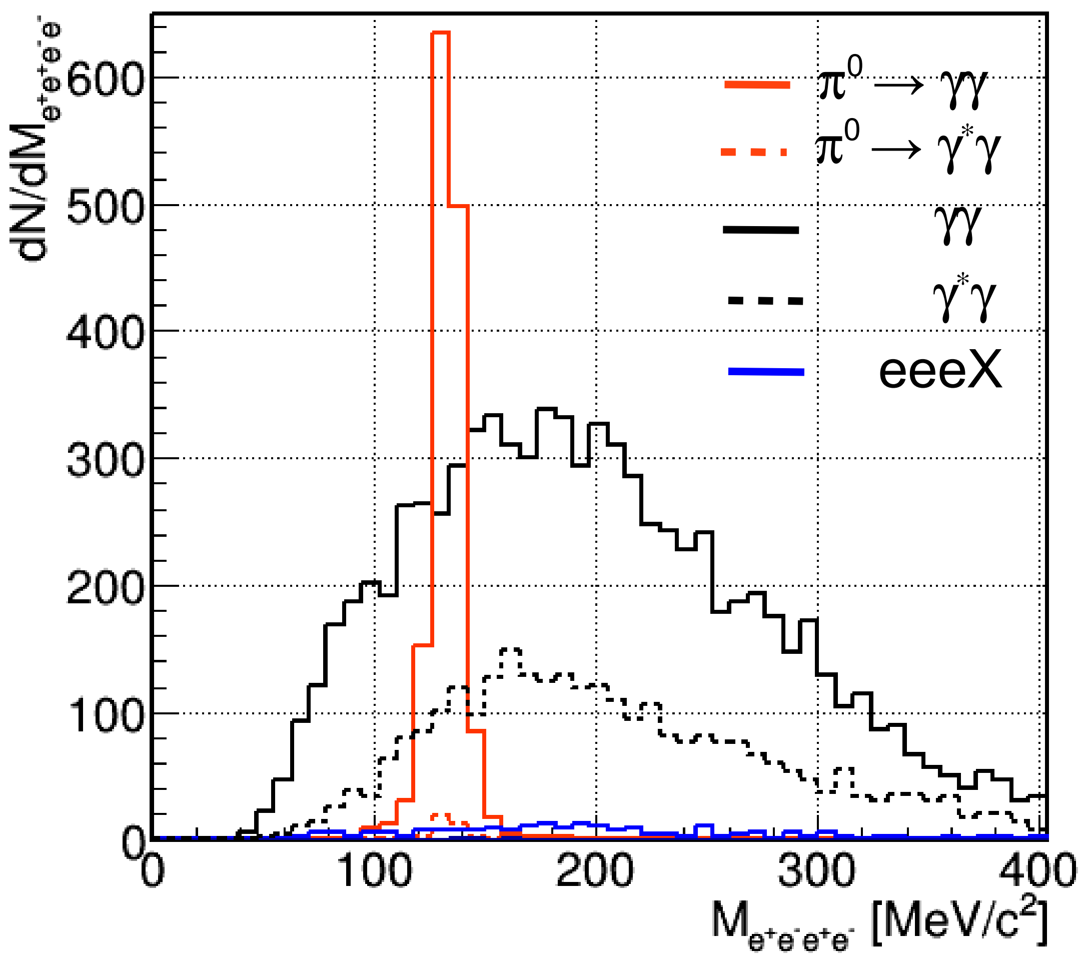


- Background rejection cuts: Topological cuts on angles between e^+e^- and γ:
  - $\alpha_1 < 2.5°$, $\alpha_2 < 15°$
  - π^0 : $10° < \Theta_{\gamma\gamma} < 40°$

Background estimated using event mixing technique (red line)

Uncorrelated $\gamma\gamma$ pairs are the main background.



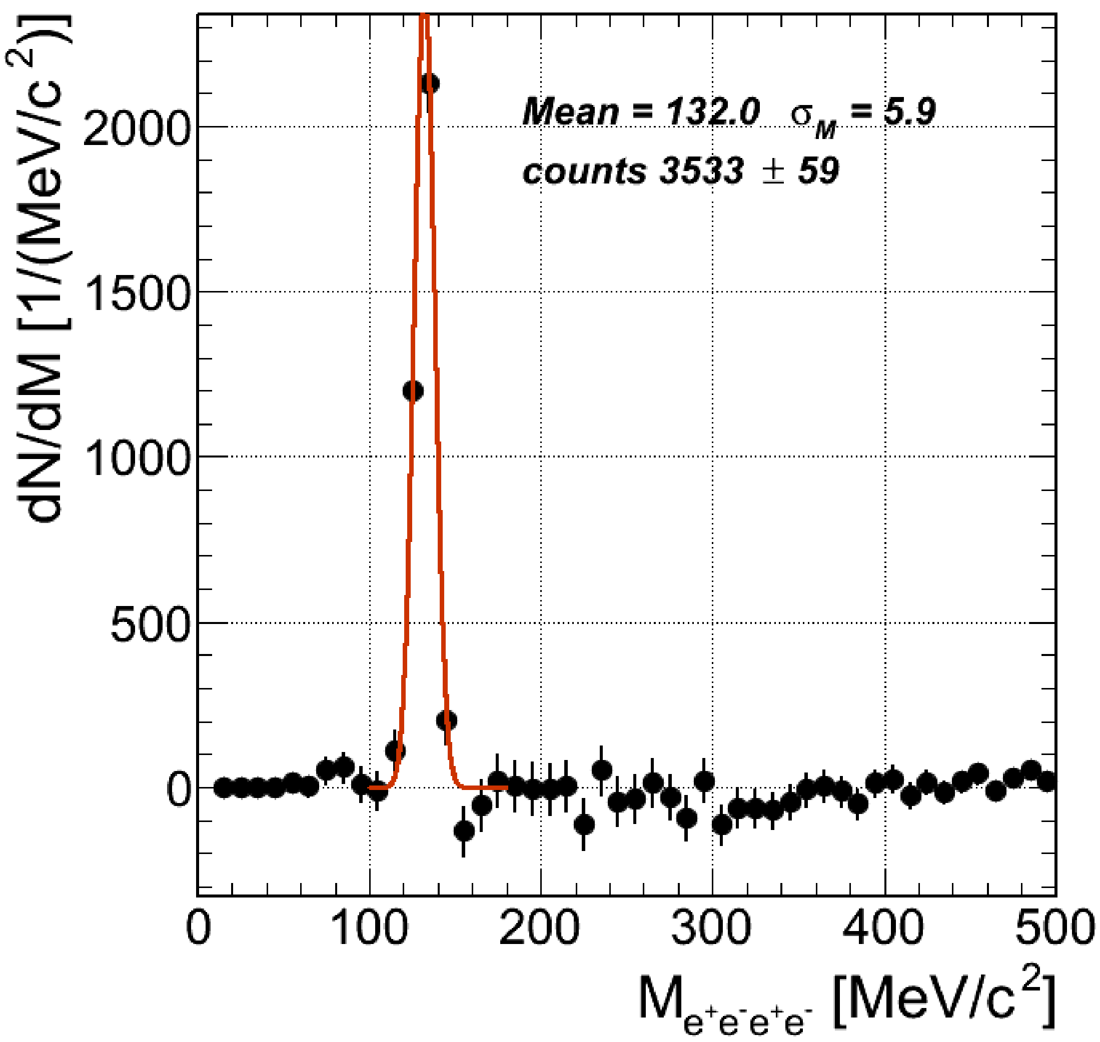


UrQMD simulation analysed with same method

Efficiency and acceptance estimation

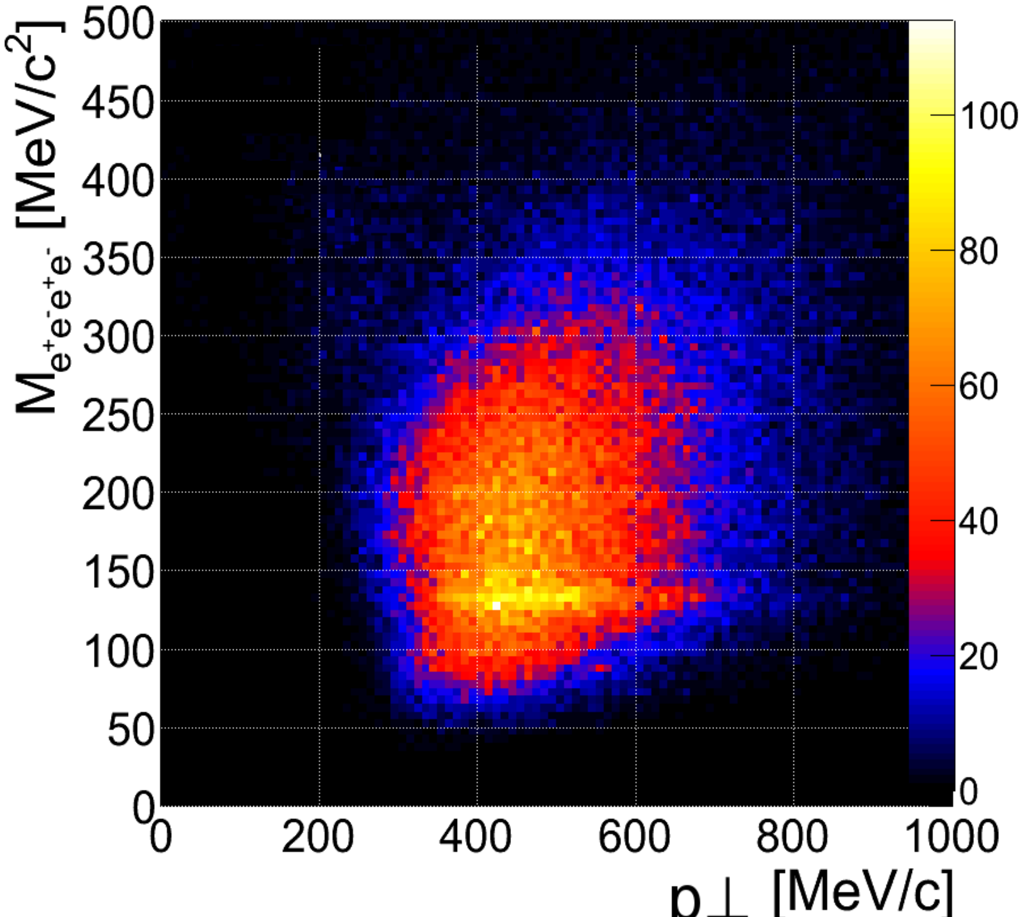
- Simulation:
  - 10^{11} π^0 with Pluto Event Generator *[PoS ACAT2007 076]* $T_1 = 39$ MeV, $T_2 = 79$ MeV
- Propagation through detector geometry using Geant3 package
  - ε_{Acc}
- Tracking and event selection like in measured data
  - ε^{4e}_{reco}
- Conversion and Branching Ratio:
  - $BR_{\gamma\gamma} \cdot conv_{\gamma}^{2} + BR_{e+e-\gamma} \cdot conv_{\gamma}$
- Identification of leptons, γ and π^0
  - ε_{PID}
- $\varepsilon_{Tot} = \varepsilon_{Acc} \cdot \varepsilon^{4e}_{reco} \cdot (BR_{\gamma\gamma} \cdot conv_{\gamma}^{2} + BR_{e+e-\gamma} \cdot conv_{\gamma}) \cdot \varepsilon_{PID}$
  $= 1.7\% \cdot 3.5\% \cdot (3.2 \cdot 10^{-4}) \cdot 44\% = 8.99 \cdot 10^{-8}$

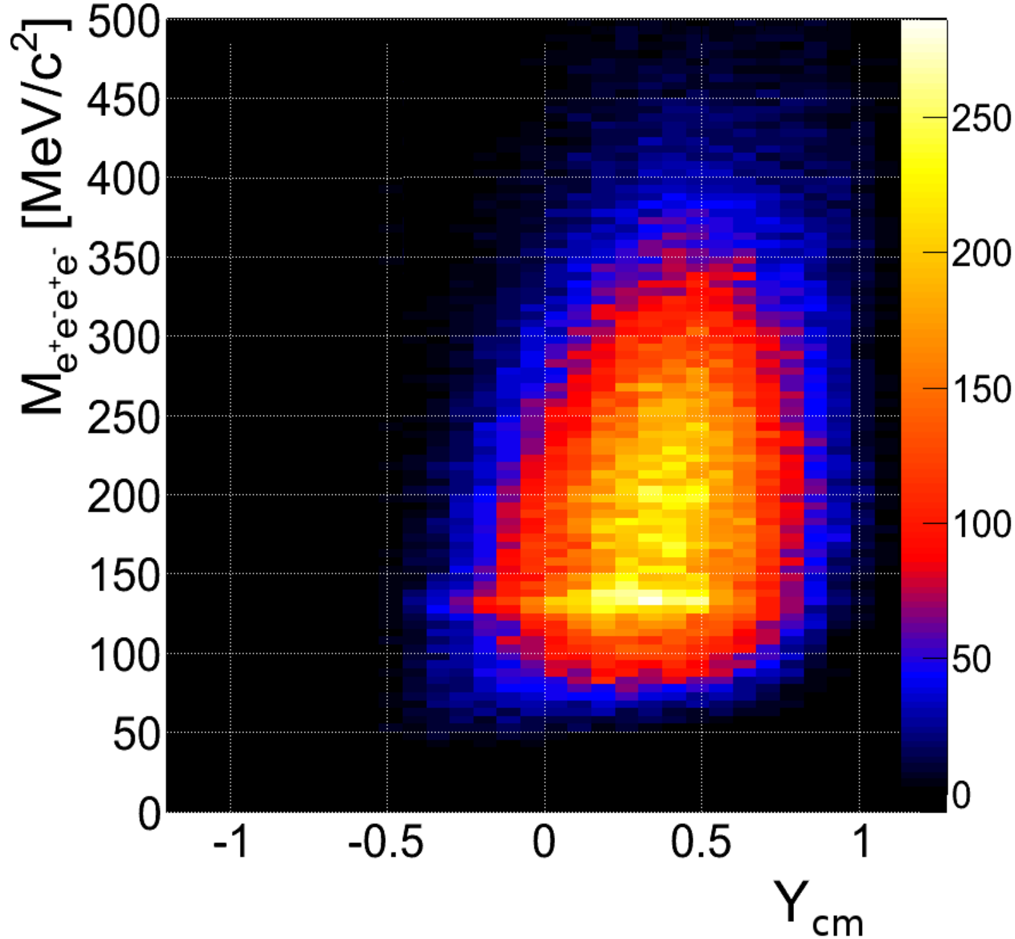
π^0 per Event



- Spectrum after background subtraction is corrected with ε_{tot} and normalized to the number of analysed events ($4.3 \bullet 10^9$)
- Integration of the spectra in the 2σ range gives Mult(π^0): 9.1 ± 3
- Comparable with result of charged π from FOPI Mult(π^0): 10.4 and TAPS Mult(π^0): 6.4 (Min bias!)

Phase space coverage





Transverse momentum coverage:

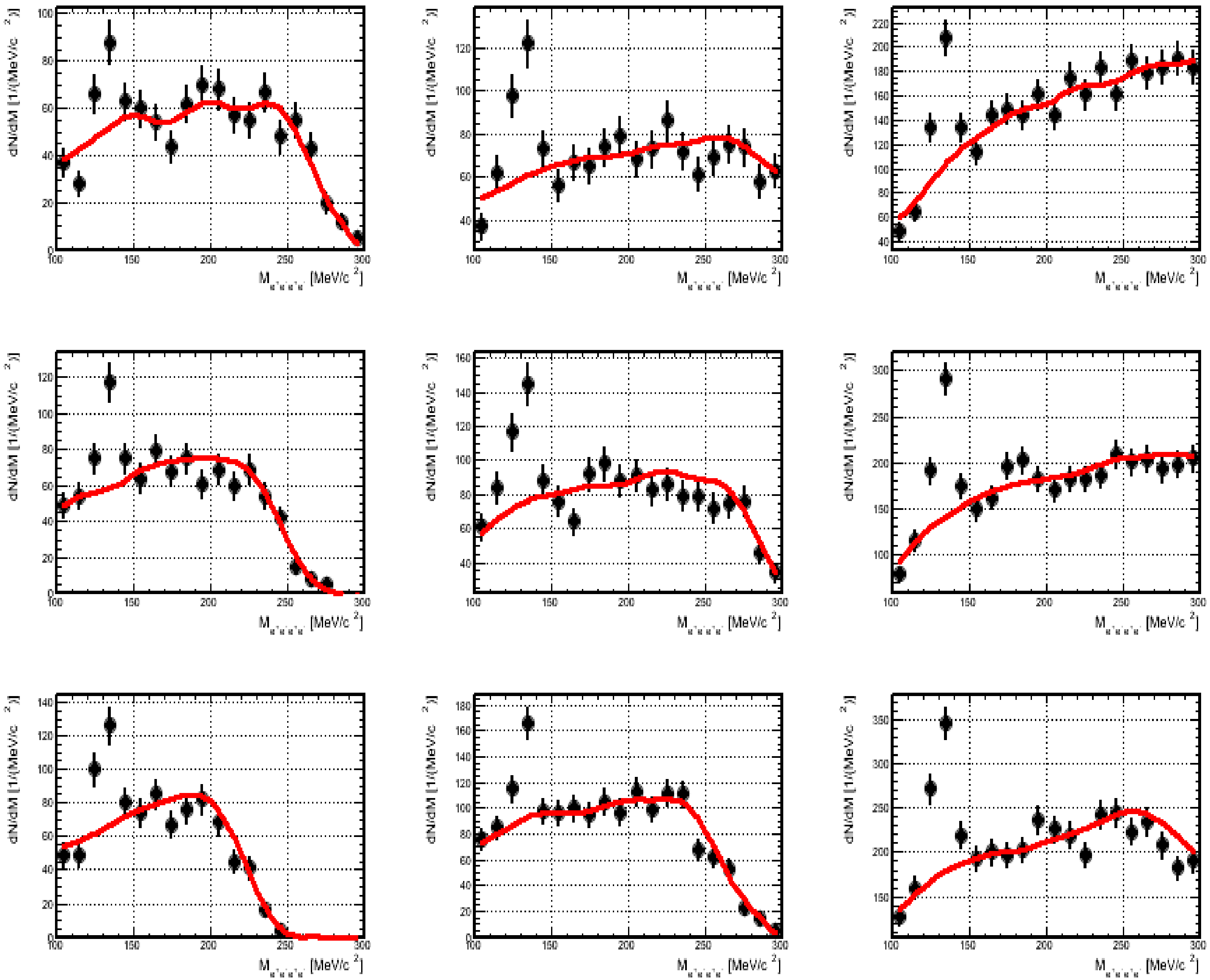
- π^0 with low momentum are not covered due to the acceptance of the decay products in HADES

Coverage: 300 MeV/c $< p_\perp <$ 650 MeV/c

Rapidity coverage:

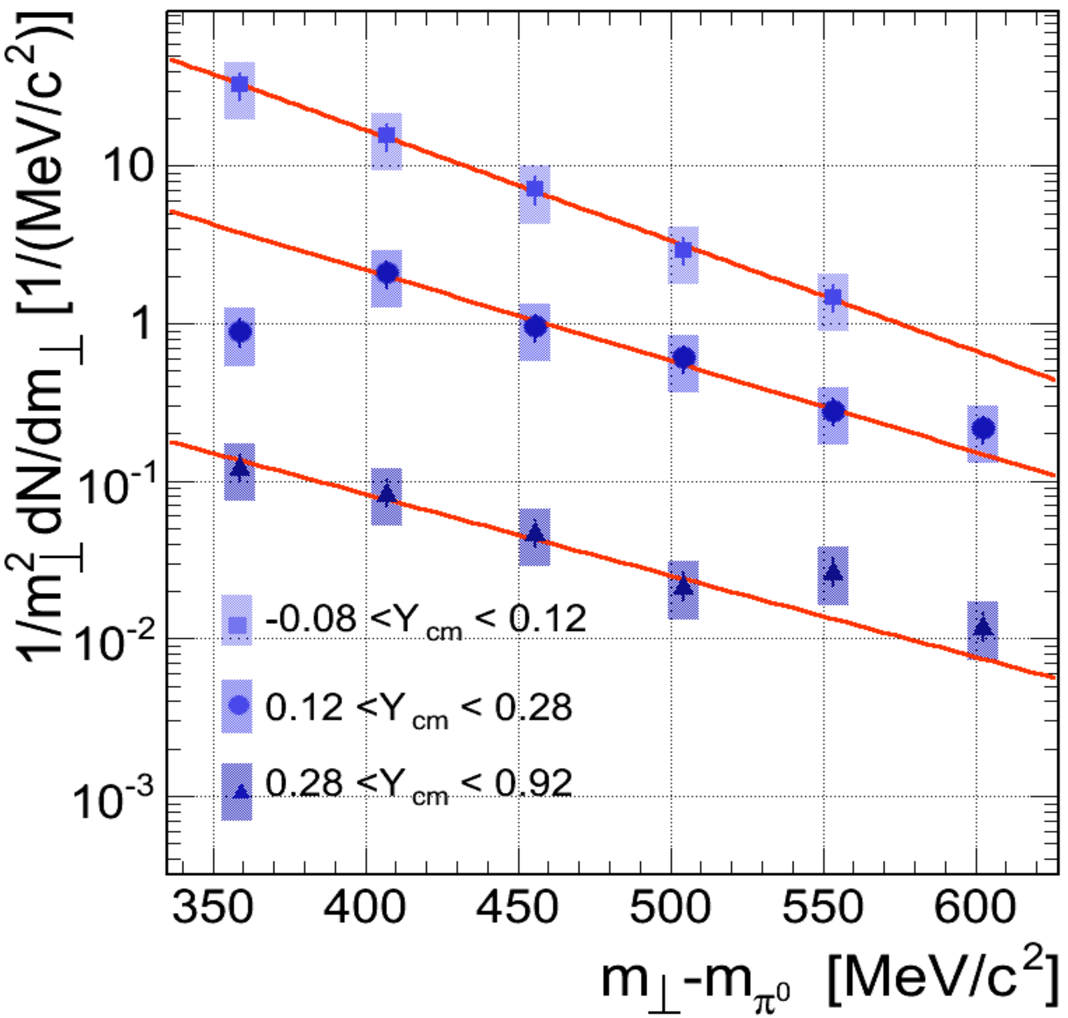
Coverage: $-0.25 < Y_{cm} < 1$

Phase space coverage



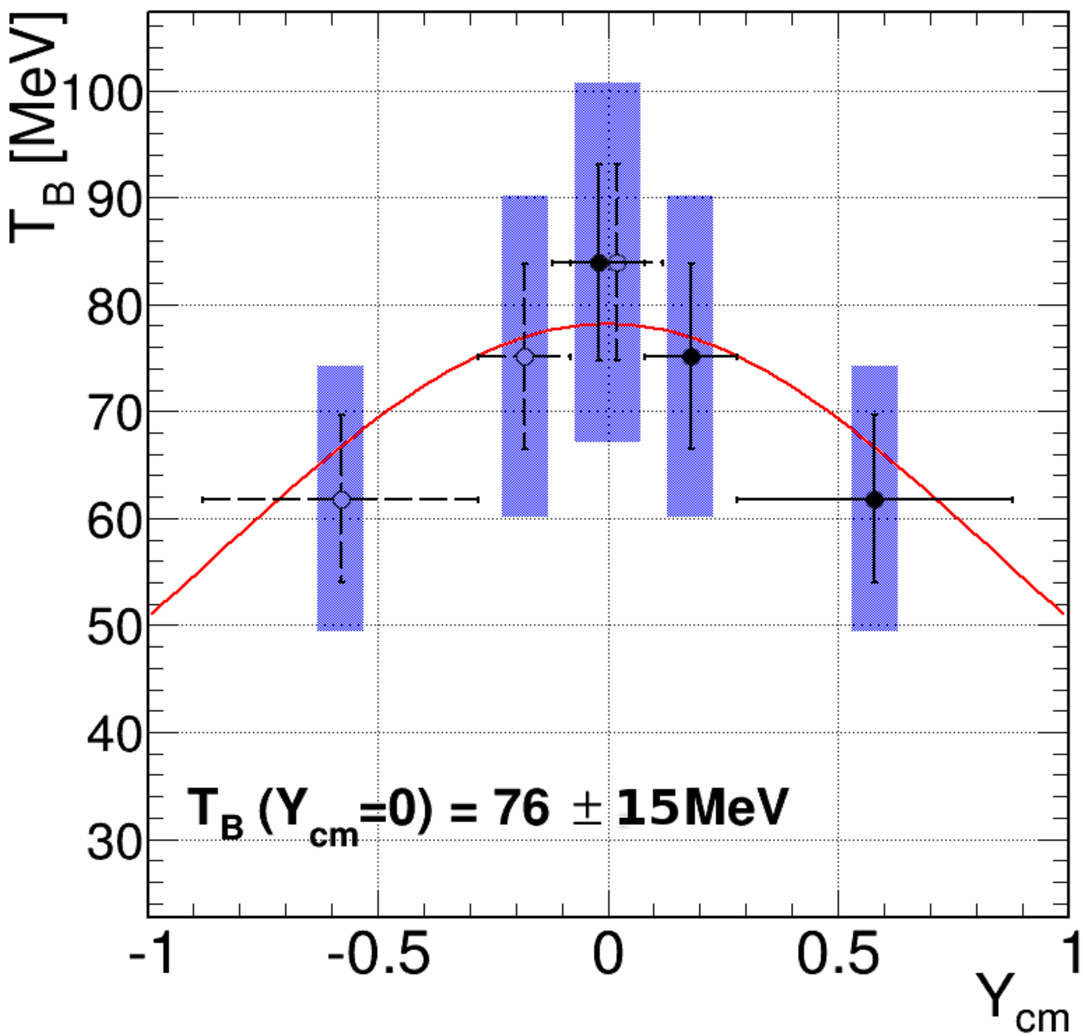
Invariant mass for different phase space bins, together with event-mixing

Yields of π^0 as function of $m_\perp - m_{\pi 0}$



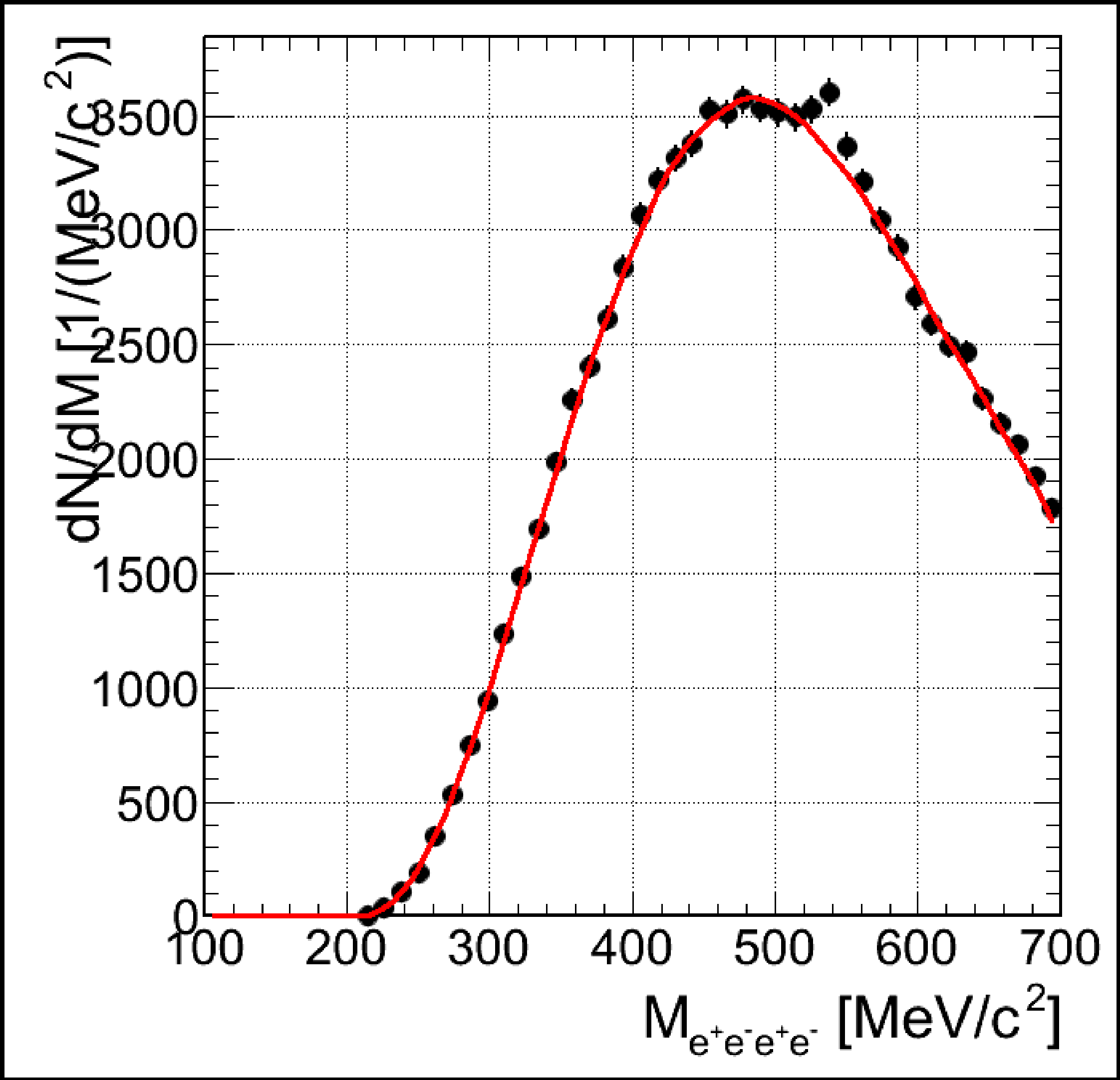
- The efficiency corrected differential yields, together with Boltzmann fits
- Single slope fit can describe the data
- Points with large corrections are excluded from fit

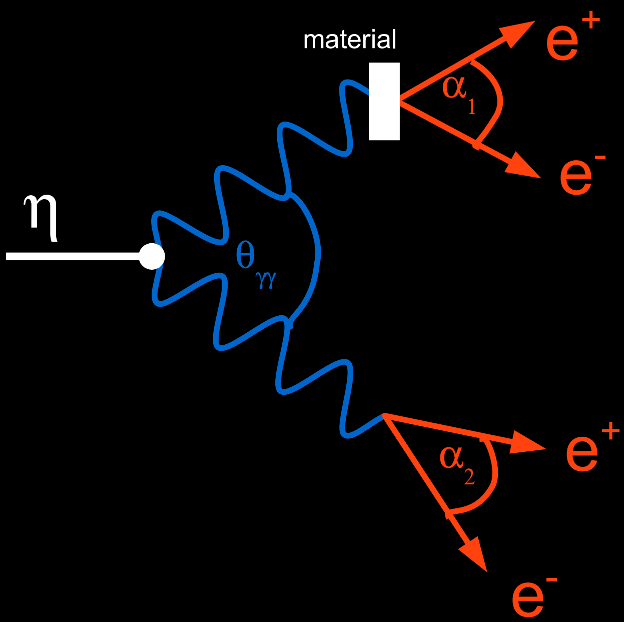
Yields of π^0 as function of $m_\perp - m_{\pi 0}$



- Filled circles: measured points
- Open circles: reflected around mid-rapidiy
- Resulting slopes can be fitted with a 1/cosh(y) distribution
- Inverse slope parameter at mid-rapidity: T_B (Y_{cm}=0): 76 ± 15 MeV

η statistics from 4.3 * 10^9 high multiplicity Au+Au events

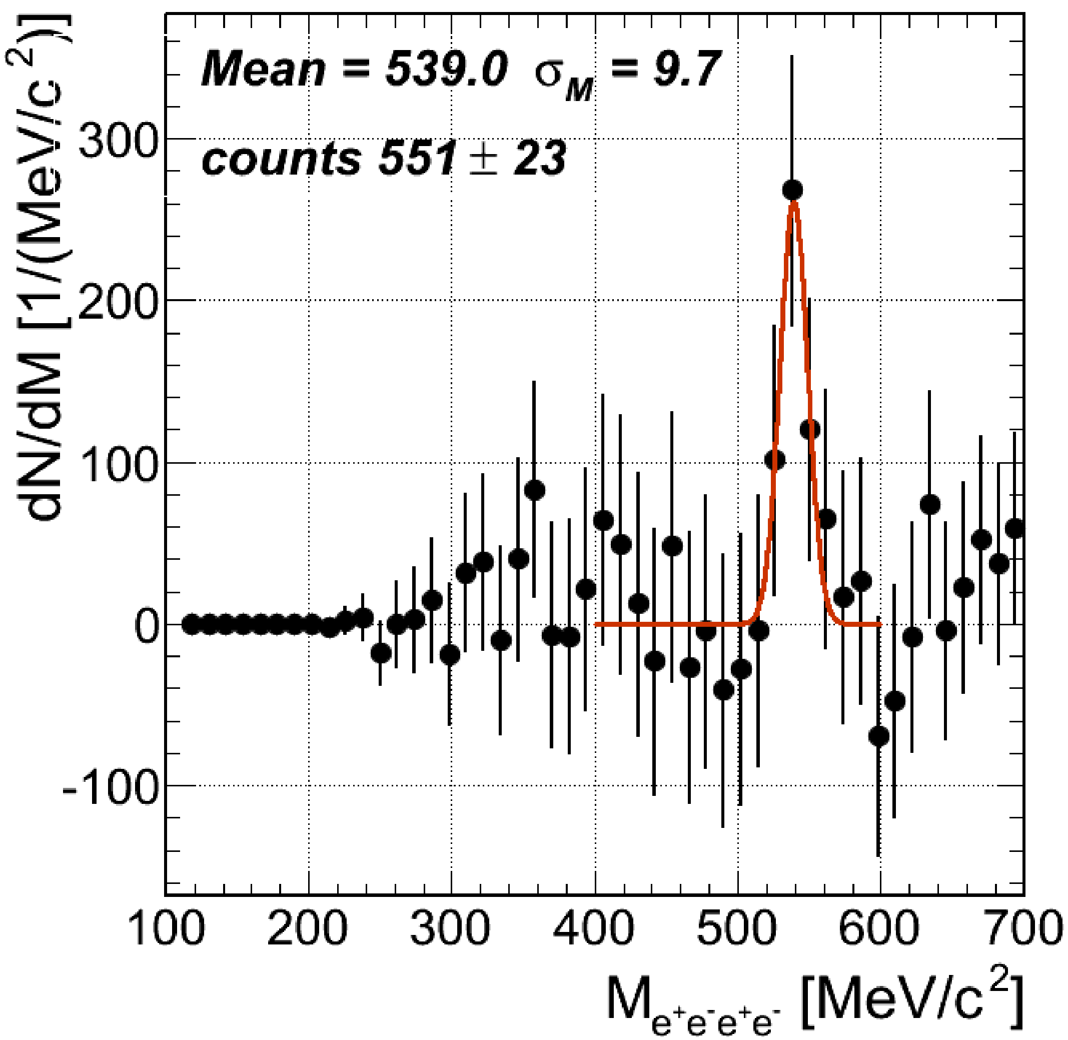




- Background rejection cuts: Topological cuts on angles between e^+e^- and γ:
  - α_1 <2.5º, α_2<15º
  - η : 40º< $\Theta_{\gamma\gamma}$ < 140°

Background estimated using event mixing technique (red line)

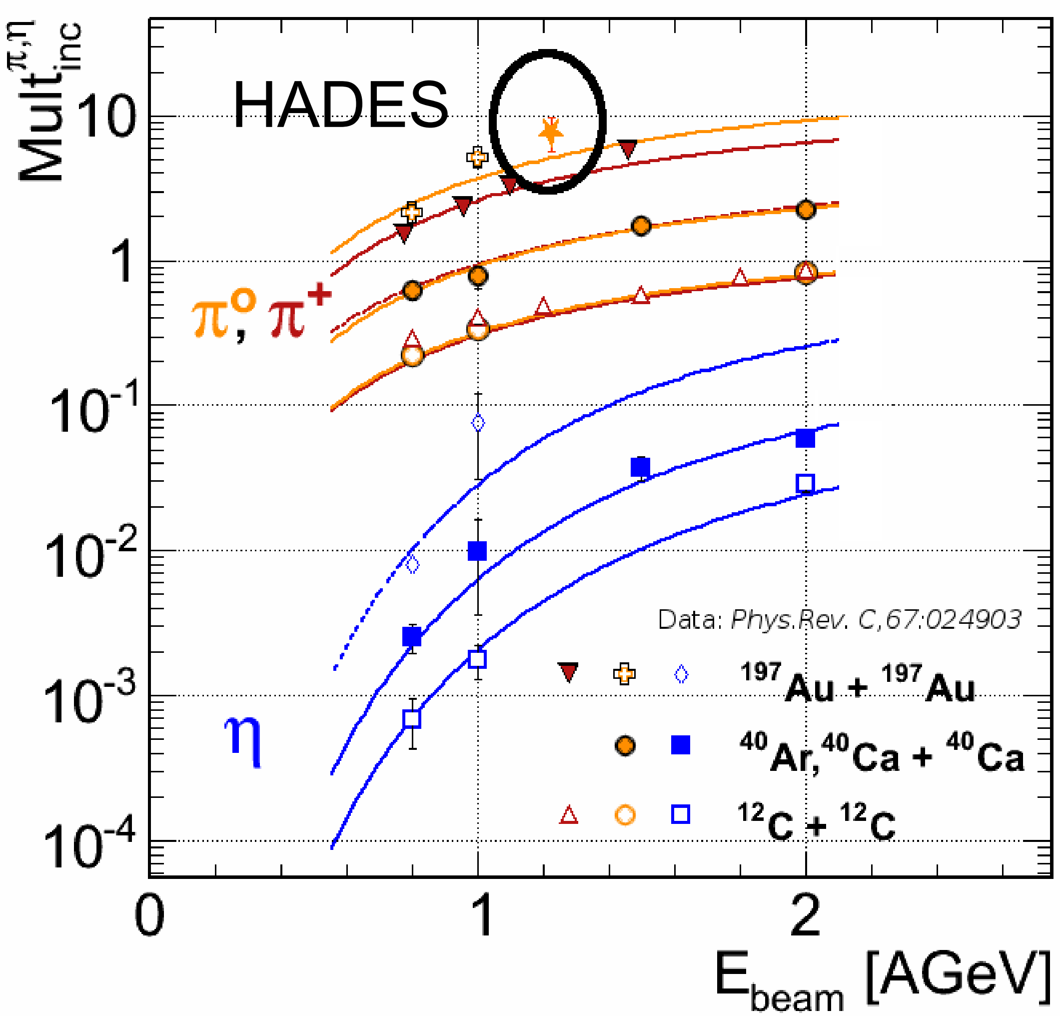
η background - subtracted



- Integration of the spectra in the 2σ range gives raw η counts: #(η): 551 ± 23
- Corrections not yet done

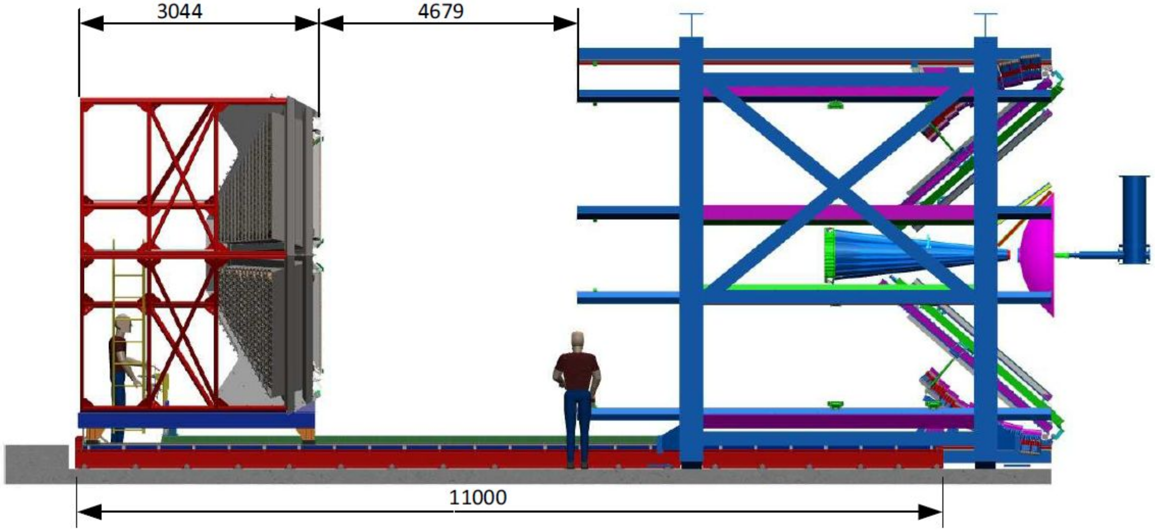
Summary

- Reconstruction of π^0 and η via γ conversion
- Number of π^0 per event:
  - Mult(π^0): 9.1 ± 3
- Phase space coverage of π^0 signal:
  - $-0.25 < Y_{cm} < 1.0$
  - $300 < p_{\perp} < 650$ MeV/c
- Reconstructed inverse slope:
  - T_B (Y_{cm} = 0): 76 ± 15 MeV
- Number of η in full beam time
  - #(η): 551 ± 23



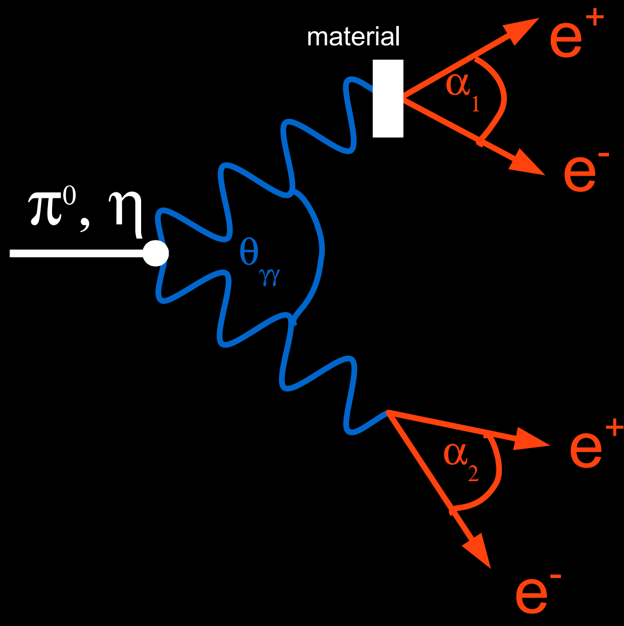
Outlook

- A_{part} dependent analysis of π^0 and η
- Phase space dependent analysis of η
- Systematic error estimations
- Compare the resulting cross sections with the results from dilepton analysis
- EM Calorimeter will be added for SIS100, FAIR



Thank you for your attention

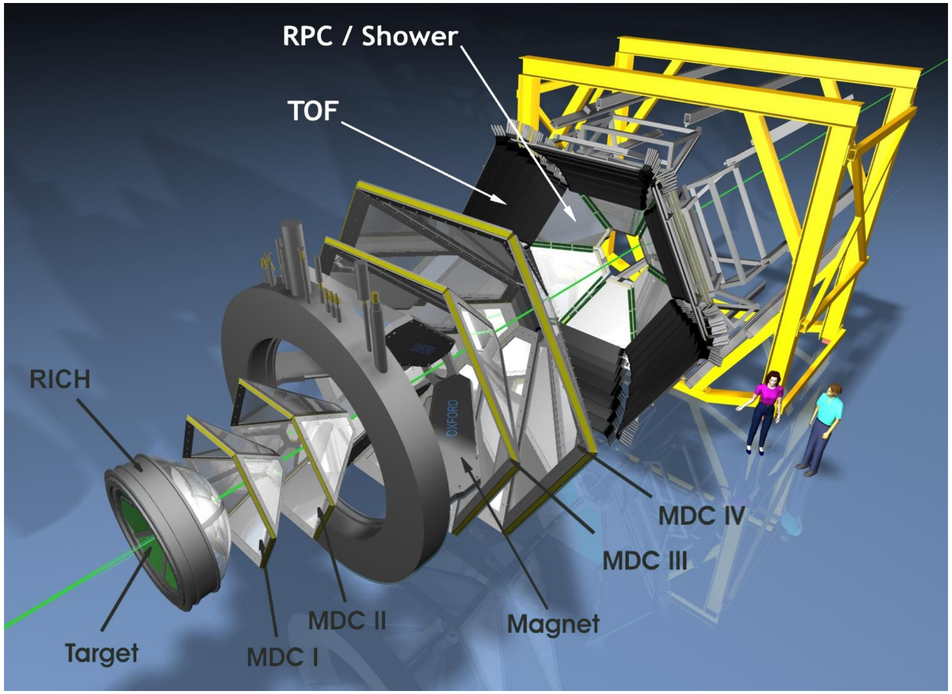
Backup Slides



Au+Au Run @ 1.23 AGeV, April 2012

HADES Au+Au beam time

- 24 days Au beam
- 8 kHz trigger rate
- 7.3 billion events
- Trigger on high multiplicity events (40% of most central collisions)



Simulations

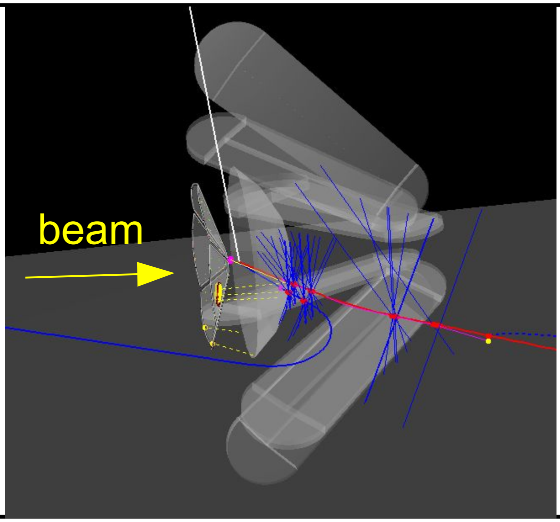
- UrQMD transport model
- Transport through the detector system using Geant3 and realistic digitizers

Analysis of experimental and simulated data is identical

Challenges of (di)lepton reconstruction

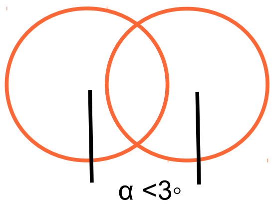
✔ Low momenta

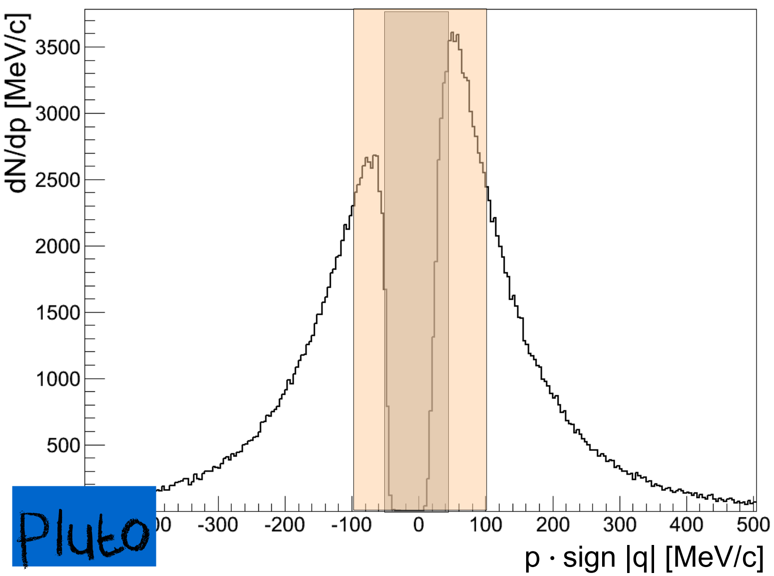
- One lepton can be bend out by the magnetic field behind the inner MDCs
- Reconstruction efficiency is between 15 - 55%



✔ Small opening angle

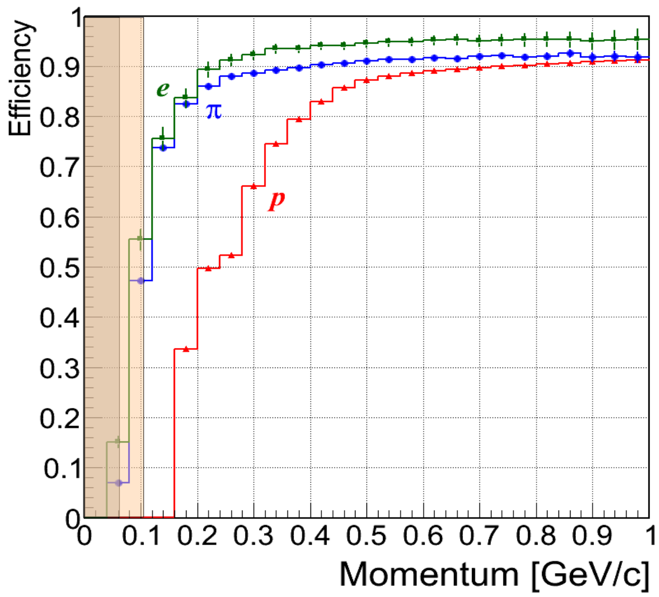
- in 93% cases α is <3°
- RICH ring finder will often identify only 1 ring





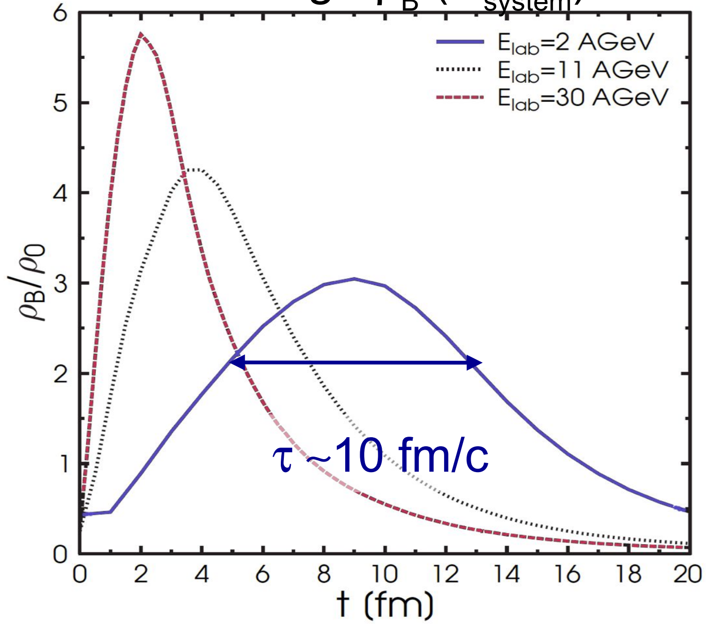
11% of e^+/e^-
p< 50 MeV/c: ε = 15%

44% of e^+/e^-
p< 100 MeV/c: ε = 55%



The SIS18 heavy-ion energy regime

Evolution of average ρ_B (τ_{system})



Probing nuclear matter at:

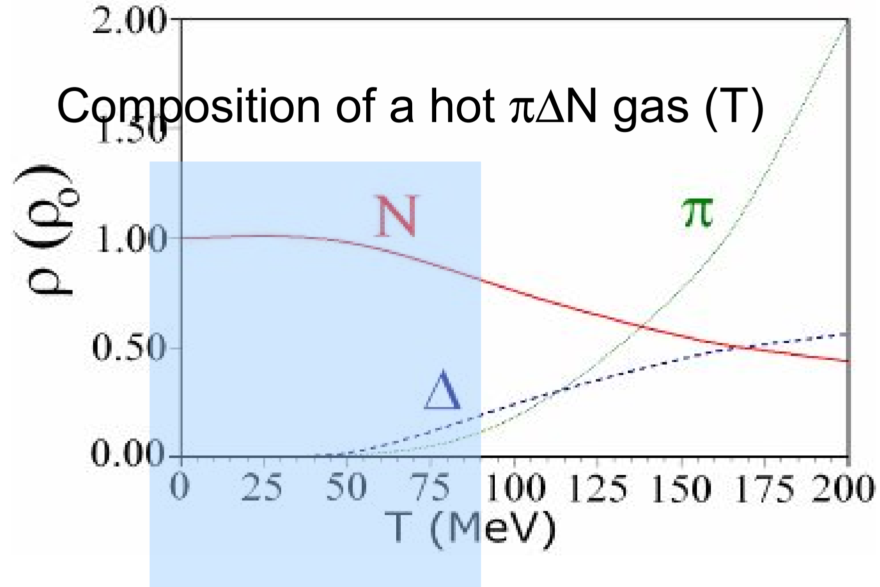
- densities: $\rho_B/\rho_0 > 2$
- temperature: T < 100 MeV

System stays above ground state density for ~10 fm/c

"Resonance matter":

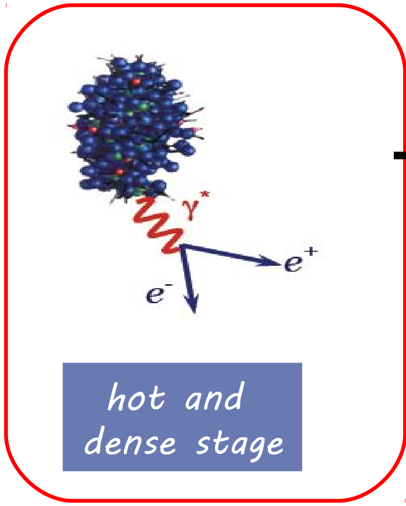
- excitation and decay of baryonic resonances are the dominant contribution
- life time resonance: ~1fm/c

Composition of a hot πΔN gas (T)



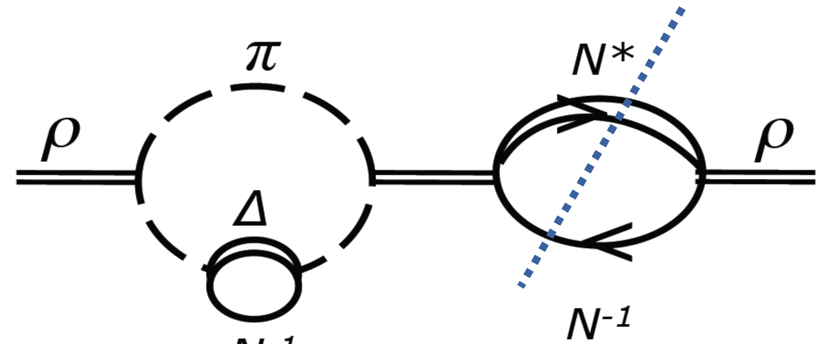
Vogel et al., Phys. Rev. C 78 (2008) 044909

Hot and dense stage: a look inside



In-medium spectral functions

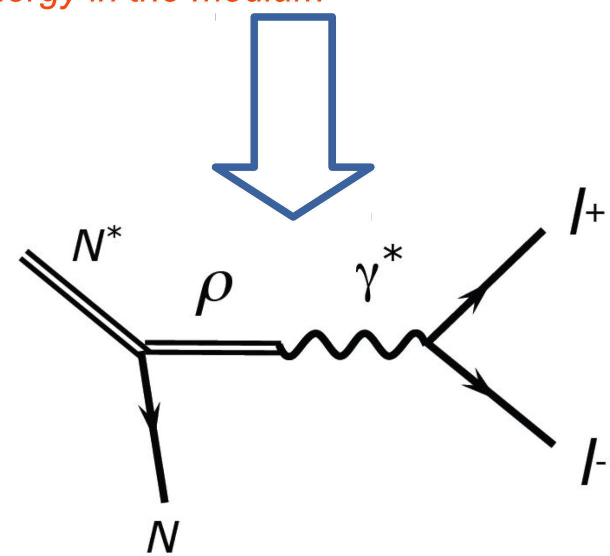
SPS, RHIC, LHC



Additional contributions to the ρ-meson self-energy in the medium

SIS

How to measure?
How to model?

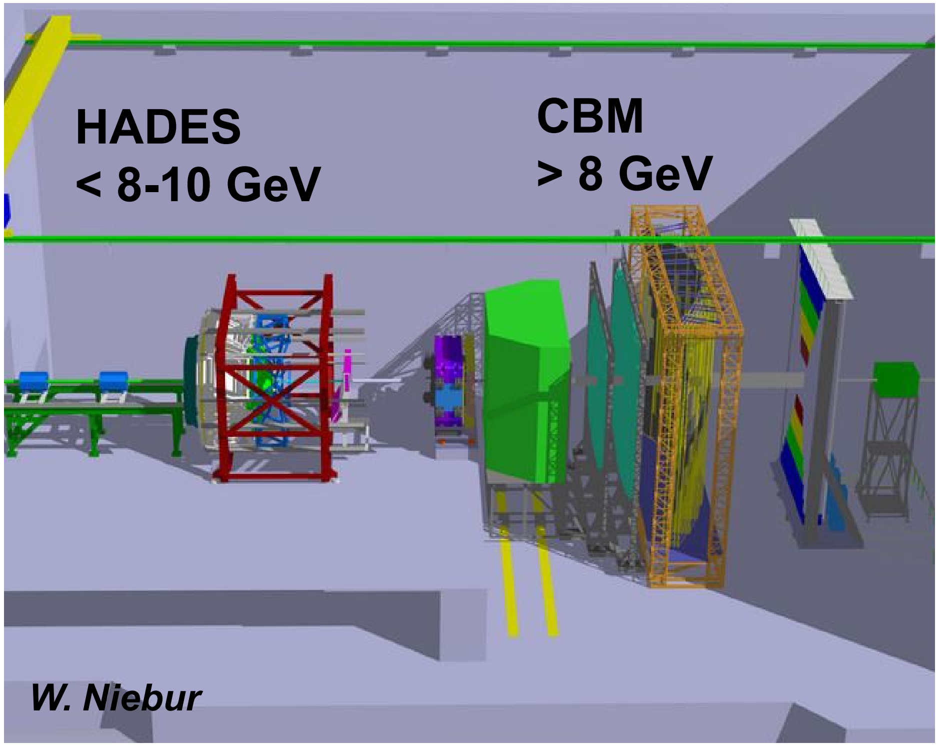


Dalitz-decay of baryonic resonances is dominant source at low beam energies

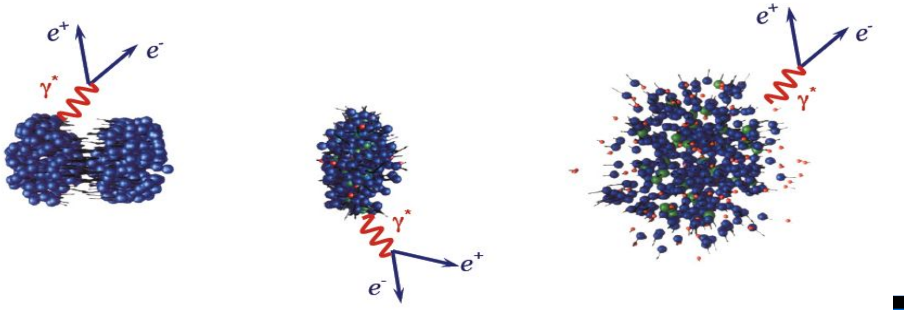
HADES at SIS 18 and SIS 100

- ✓ **Running experiment, well understood performance**
- ✓ **Deliver high quality data**
- ✓ **Setup tests with coming heavy-ion runs at SIS-18**
- ✓ **Upgrade improved stability, DAQ and time resolution of the Spectrometer**

Date	System	E_{kin} beam
2002	C+C	2.0 GeV/u
2004	C+C	1.0 GeV/u
2005	Ar+KCl	1.76 GeV/u
2006	p+p	1.25, 2.2, 3.5 GeV
2007	d+p	1.25 GeV
2008	p+Nb	3.5 GeV
2012	*Au+Au*	*1.25 GeV/u*

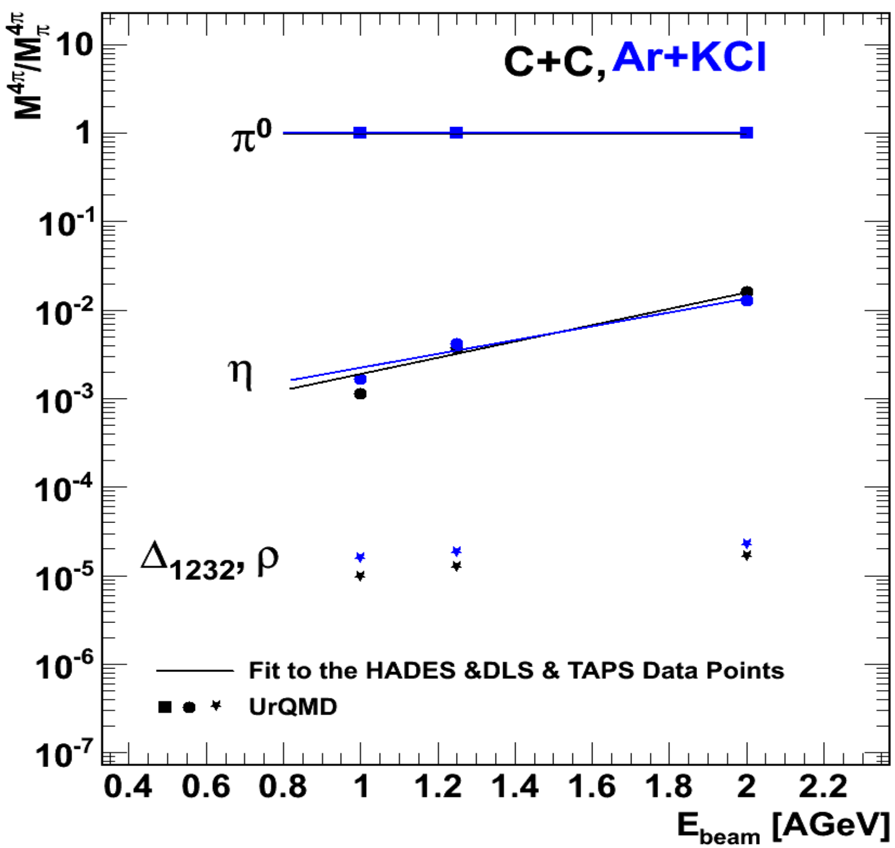


Measure the whole evolution of the fireball...



Energy and system size dependence of the excess yield

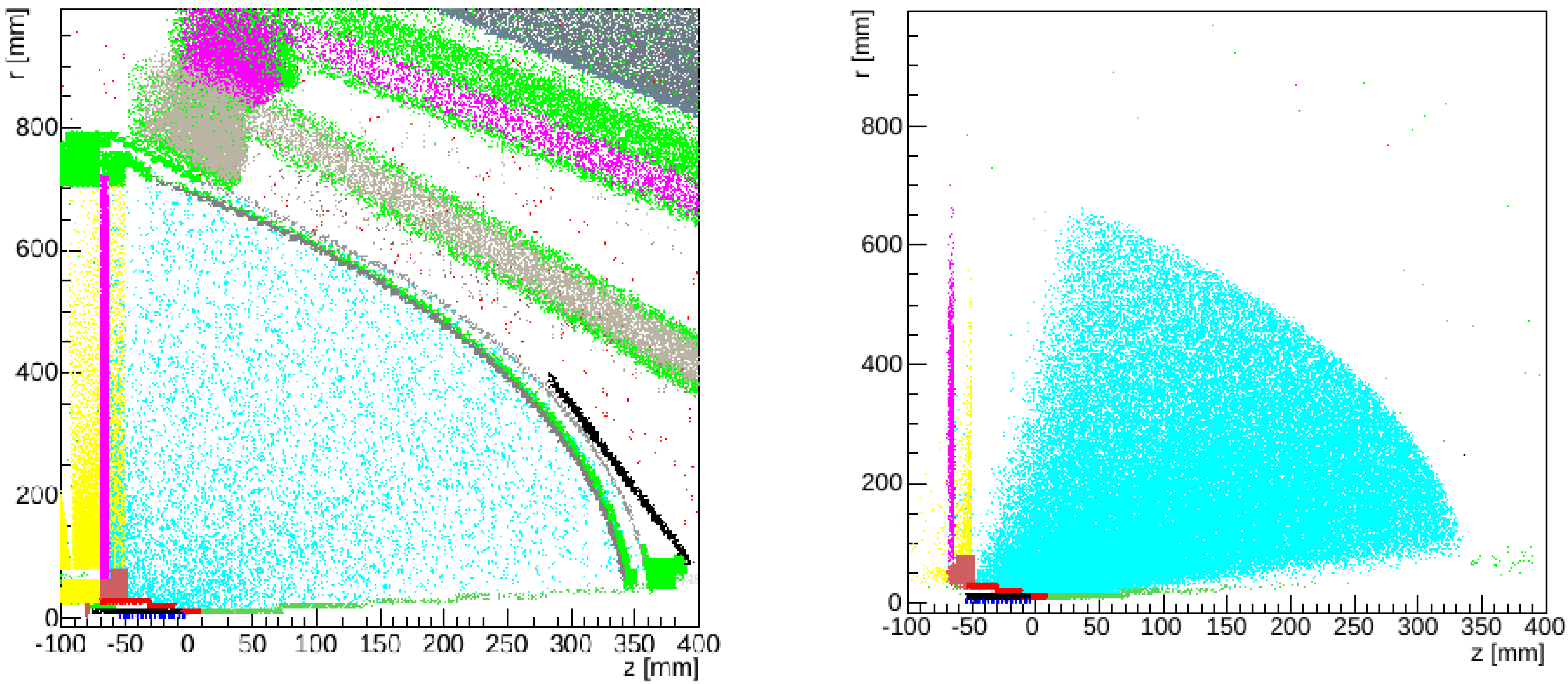
UrQMD



- Multiplicity of e^+e^- pairs from π^0, η, Δ and ρ
- Good agreement for π^0 and η (implemented according to the TAPS data)

UrQMD can't fully account for the enhanced pair yield in the intermediate mass region

"Effect" of acceptance



Vertex of leptons coming from conversion in full phase space (left) and in acceptance (right)

Different colours represent different materials

Pluto