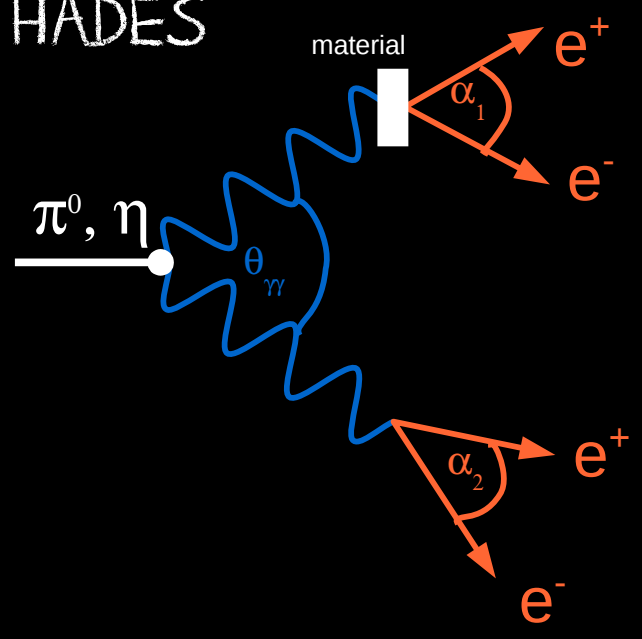
Reconstruction of mesons at freeze out via conversion

in Au+Au at 1.23 AGeV with HADES



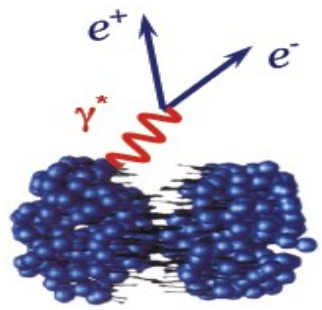
Claudia Behnke
for the HADES collaboration

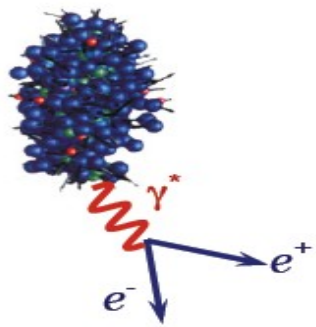
Outline

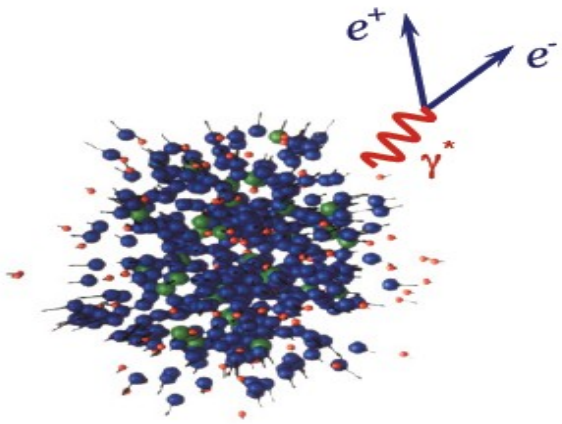
- Motivation: the freeze out cocktail of Au+Au
- Technique: γ reconstruction with HADES
- Simulations: the “ideal case”
- Experimental data:
  - the reality
  - topological background rejection cuts
  - the reality again
- Summary & Outlook

Motivation

HIC at SIS energies







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

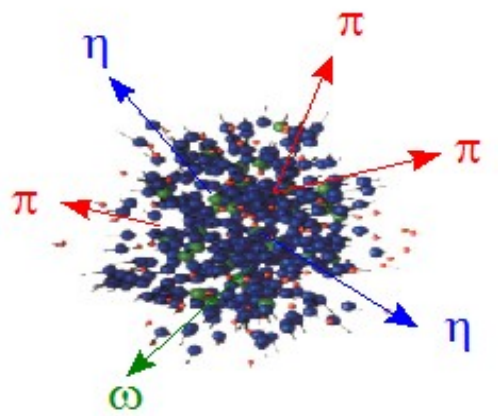
Baryonic sources:
- NN Bremsstrahlung
- $\Delta, N^* \rightarrow Ne^+e^-$

In-medium spectral functions

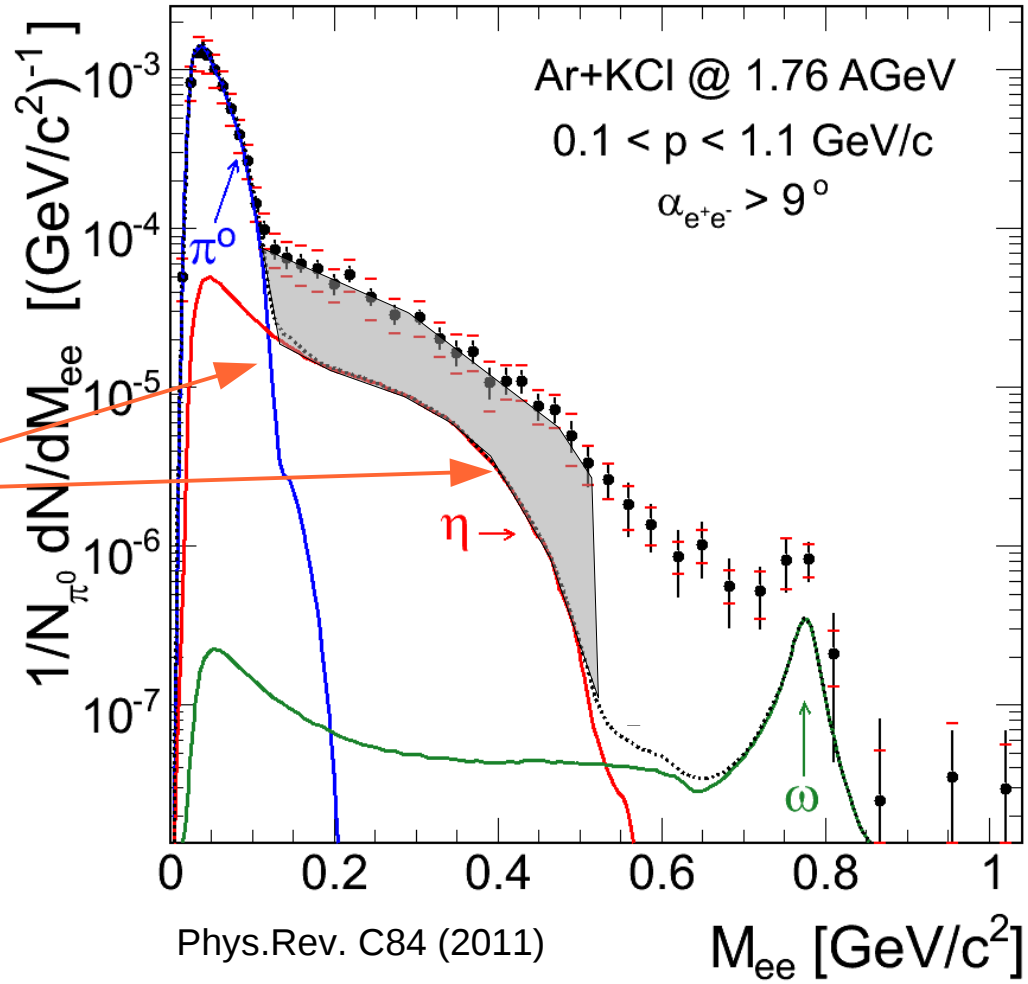
Long-lived mesons:
- π^0, η, ω

$\tau_\pi = 7.7 \times 10^7$ fm/c
$\tau_\eta = 1.5 \times 10^5$ fm/c
$\tau_\omega = 23$ fm/c

The freeze out "cocktail"



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



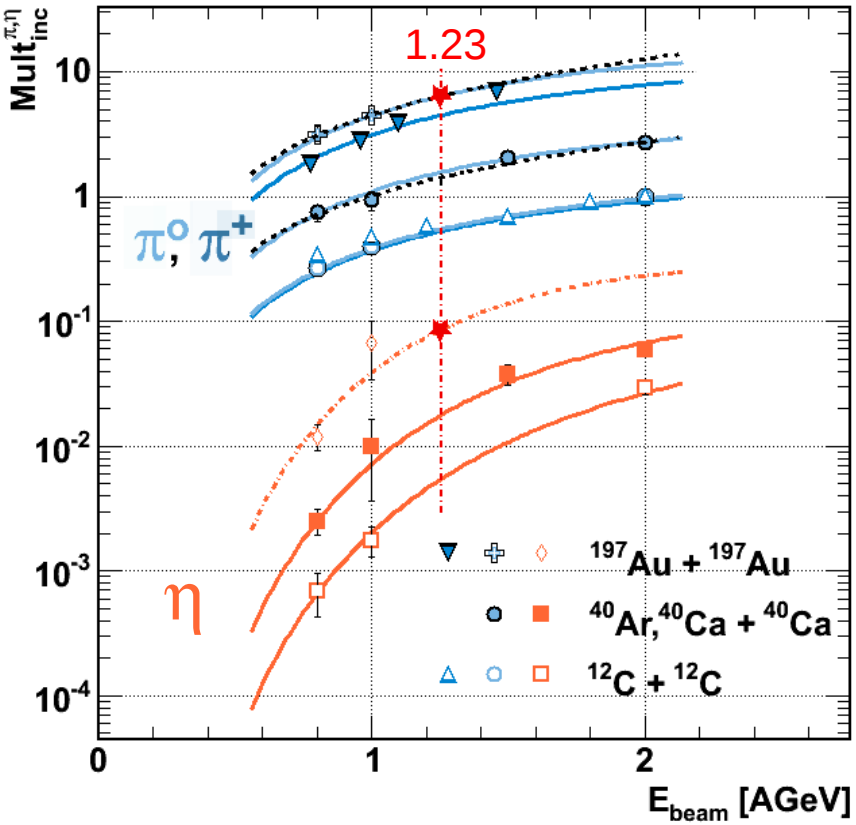
Phys.Rev. C84 (2011)

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

How to reconstruct $Mult_{\pi^0}$ and $Mult_{\eta}$?

The freeze out "cocktail"

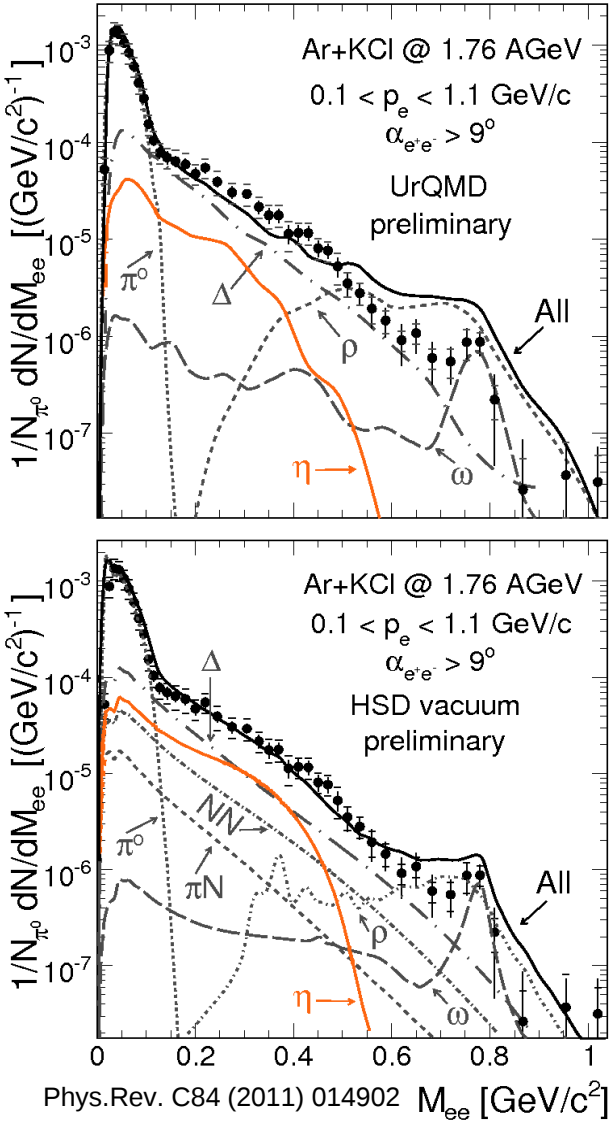
Phys. Rev. C,67:024903, 2003.



Uncertainties

experiment

simulation



Phys.Rev. C84 (2011) 014902

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.

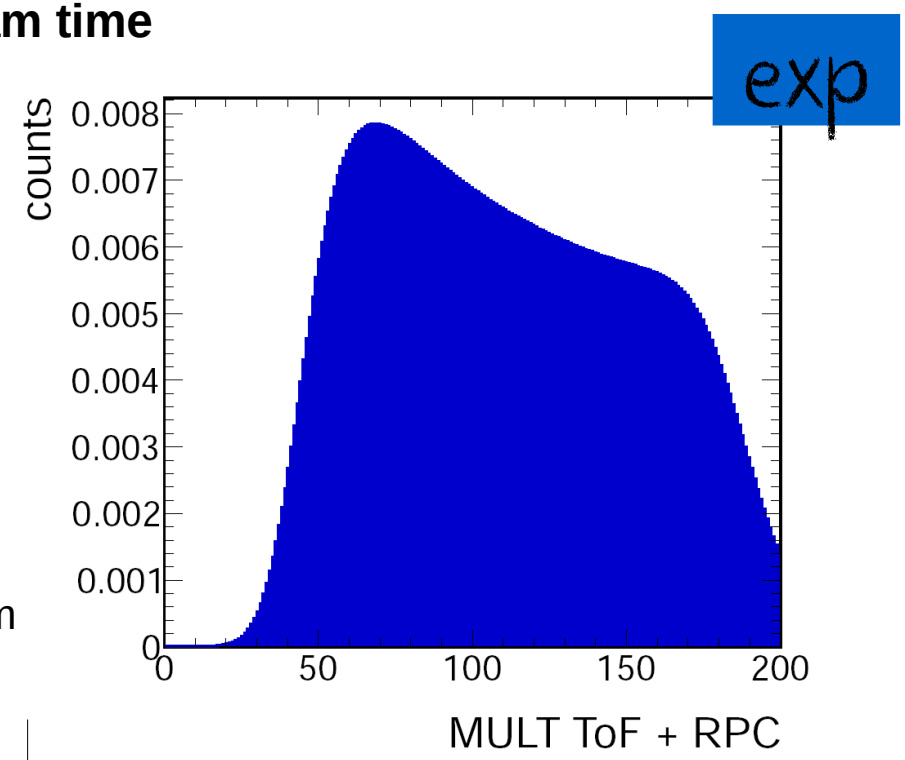
$$\mathrm{Mult}_{AuAu}(\pi^0) = 6.4 \pm 15\%$$

$$\mathrm{Mult}_{AuAu}(\eta) = 0.09 \pm 50\%$$

Au+Au Run @ 1.23 AGeV, April 2012

HADES DAQ performance during AuAu beam time

- ✔ 557 hours Au beam on Au target
- ✔ Beam energy 1.23 AGeV
- ✔ (1.2-1.5) x 10^6 ions per second
- ✔ 8 kHz trigger rate
- ✔ 200 MByte/s data rate
- ✔ 7.3 x 10^9 events 140 TByte of data
- ✔ Trigger on multiplicity in TOF ≥ 20 (PT3) → b_{max} ≈ 9fm

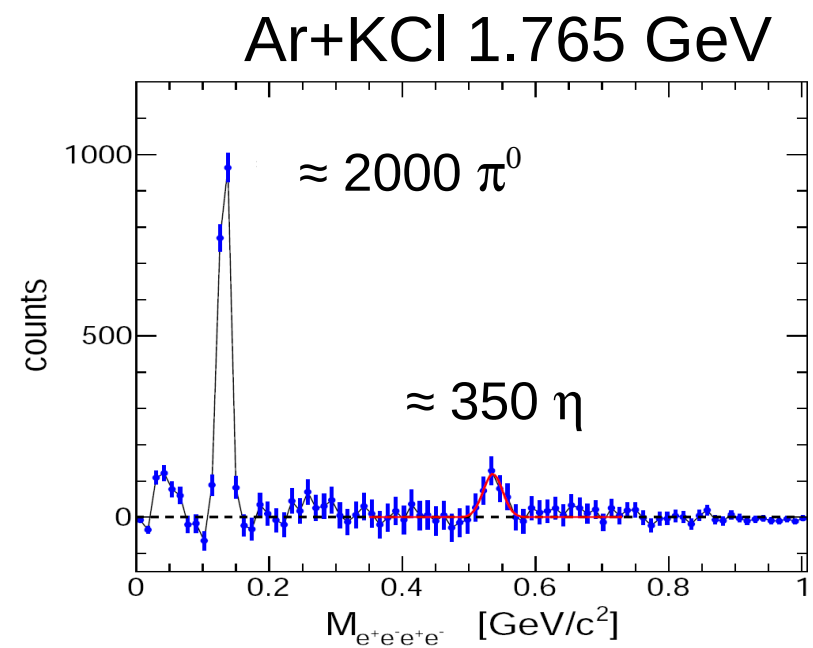


Simulations

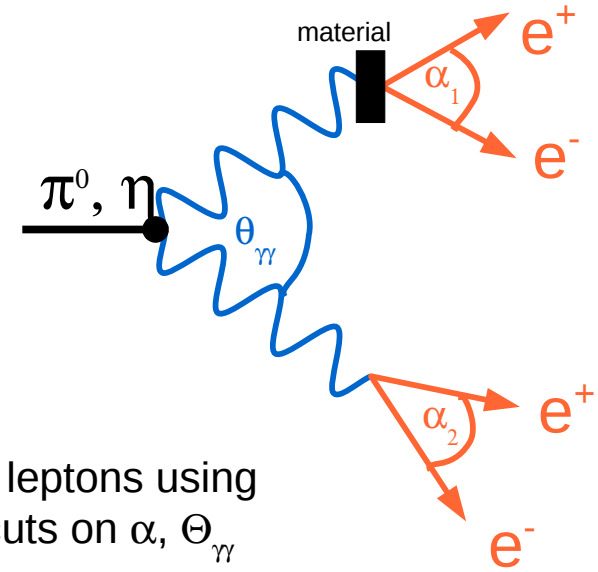
- ✔ Pluto event generator:
  - ✔ π^0 and η from a thermal source (T= 70MeV) + 100% decay into 2γ
- ✔ UrQMD transport model
  - ✔ Au + Au at 1.23 AGeV b_{max} = 9fm
- ✔ Conversion in HGeant2 with realistic detector geometry
- ✔ Analysis of experimental and simulated data is identical

How to measure π^0 and η with HADES?

	Branching Ratio
$\pi^0, \eta \rightarrow \gamma\gamma$	0.98 , 0.39
$\pi^0, \eta \rightarrow \gamma e^+e^-$	$1.17 \cdot 10^{-2}$, $0.7 \cdot 10^{-2}$
$\pi^0, \eta \rightarrow e^+e^-e^+e^-$	$3.34 \cdot 10^{-5}$, $<7 \cdot 10^{-5}$



How to reconstruct γ without dedicated detector ?



Identifying 4 leptons using topological cuts on α, $\Theta_{\gamma\gamma}$

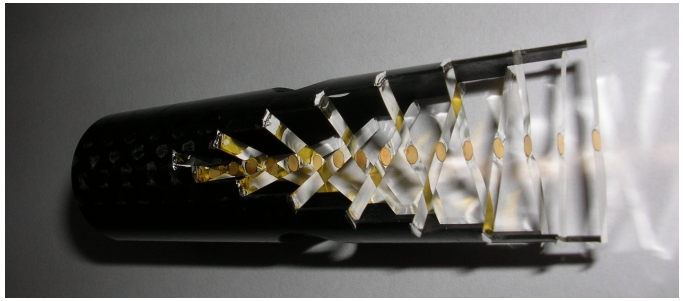
STAR: PhysRevC.70.044902
CDF: PhysRevD.70.074008
ALICE: Phys. Lett. B 717,162

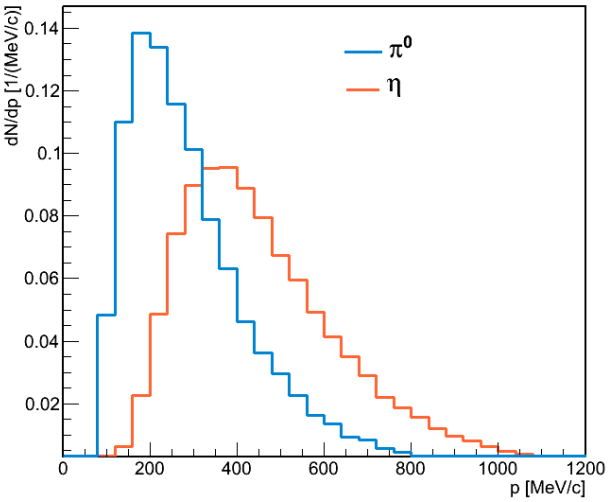
HADES:
- p+Nb 3.5 GeV: PhysRevC.88.024904
- Ar+KCl 1.765 GeV/u: GSI annual report 2012

Conversion probability

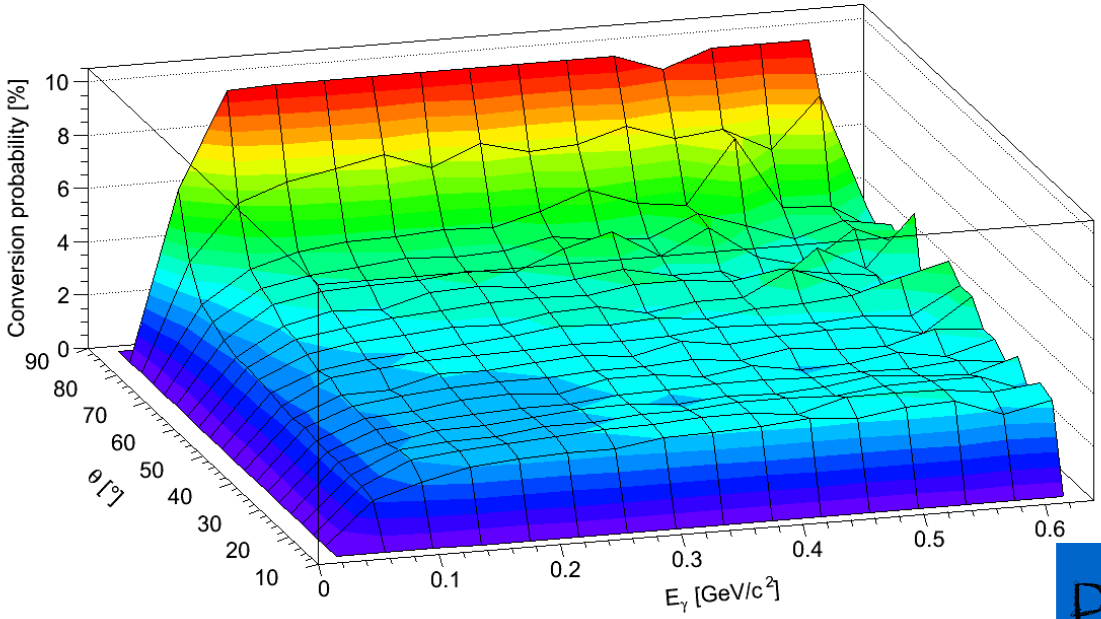
$$Prob(Z_i, E_\gamma) = \frac{n_{ati}\sigma(Z_i, E_\gamma)}{\sum_i [n_{ati} \cdot \sigma_i(E_\gamma)]}$$

GSI target lab: B. Kindler et al., NIMP 655, 2011



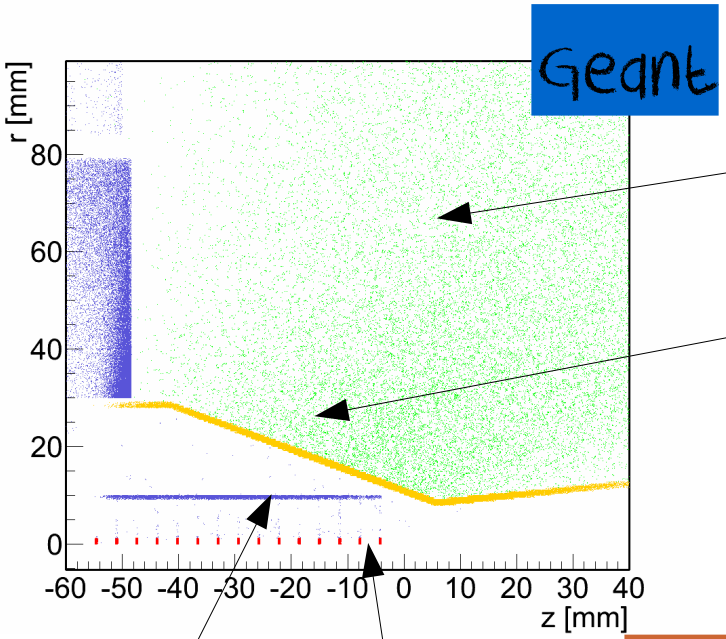


π^0 and η from a thermal source
100% decay into 2γ



Pluto

Conversion probability



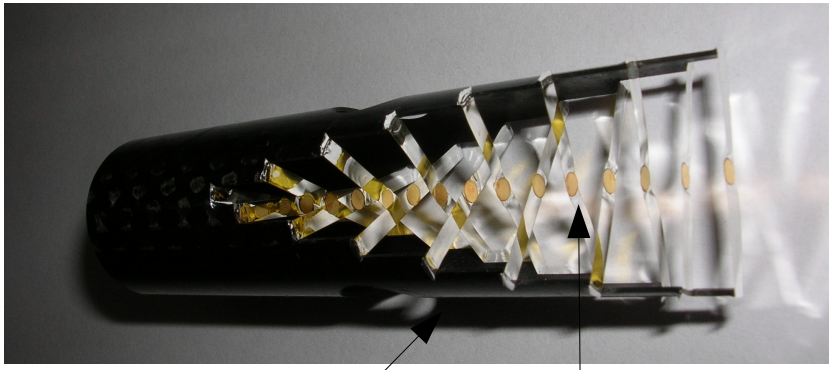
RICH Radiator gas

Beam pipe

Target holder

Target

GSI target lab: B. Kindler et al., NIMP 655, 2011



Target holder

Target

Material	Material	Conv [%] (π^0)	Conv [%] (η)
Target	Au	0.32	0.54
Target holder	C	0.02	0.04
Beam pipe	C	0.26	0.48
Radiator gas	C4F10	0.59	0.91
Sum		1.2	2.0

Multiplicities

$$N_{AuAu} = Mult \cdot N_{events} \cdot BR \cdot Conv \cdot \varepsilon_{reconstruction} \cdot \varepsilon_{acceptance}$$

	BR	Conv	$\varepsilon_{rec} \cdot \varepsilon_{acc}$	Total
$\pi^0 \rightarrow \gamma\gamma(\rightarrow e^+e^-e^+e^-)$	0.98	1.44 %	0.1 x 0.01	$1.4 \cdot 10^{-7}$
$\pi^0 \rightarrow \gamma e^+e^-(\rightarrow e^+e^-e^+e^-)$	$1.17 \cdot 10^{-2}$	1.2 %		$1.4 \cdot 10^{-7}$
$\pi^0 \rightarrow e^+e^-e^+e^-$	$3.34 \cdot 10^{-5}$			$0.3 \cdot 10^{-7}$
				$3.1 \cdot 10^{-7}$
$\eta \rightarrow \gamma\gamma(\rightarrow e^+e^-e^+e^-)$	0.39	4 %	0.15 x 0.02	$4.7 \cdot 10^{-7}$
$\eta \rightarrow \gamma e^+e(^- \rightarrow e^+e^-e^+e^-)$	$7.0 \cdot 10^{-3}$	2 %		$4.2 \cdot 10^{-7}$
$\eta \rightarrow e^+e^-e^+e^-$	$<6.9 \cdot 10^{-5}$			$2.1 \cdot 10^{-7}$
				$11.0 \cdot 10^{-7}$

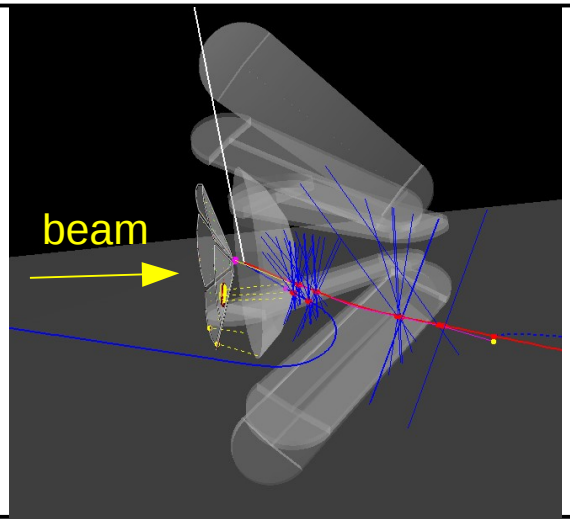
$$N(\pi^0)_{AuAu} = 1.5 \cdot 10^4$$

$$N(\eta)_{AuAu} = 725$$

Challenges of (di)lepton reconstruction

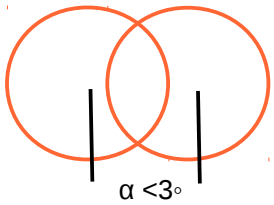
✔ Low momenta

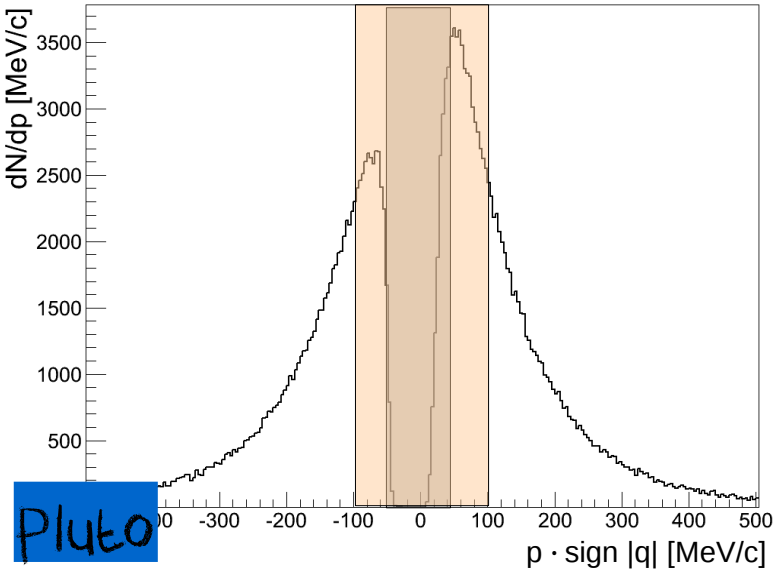
- One lepton can be bend out by the magnetic field behind the inner MDCs
- Reconstruction efficiency is between 15 - 55%



✔ Small opening angle

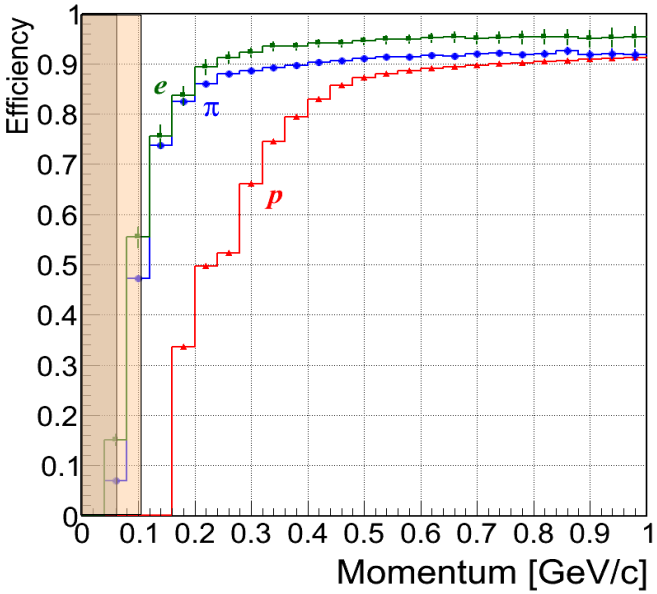
- in 93% cases α is <3◦
- RICH ring finder will often identify only 1 ring





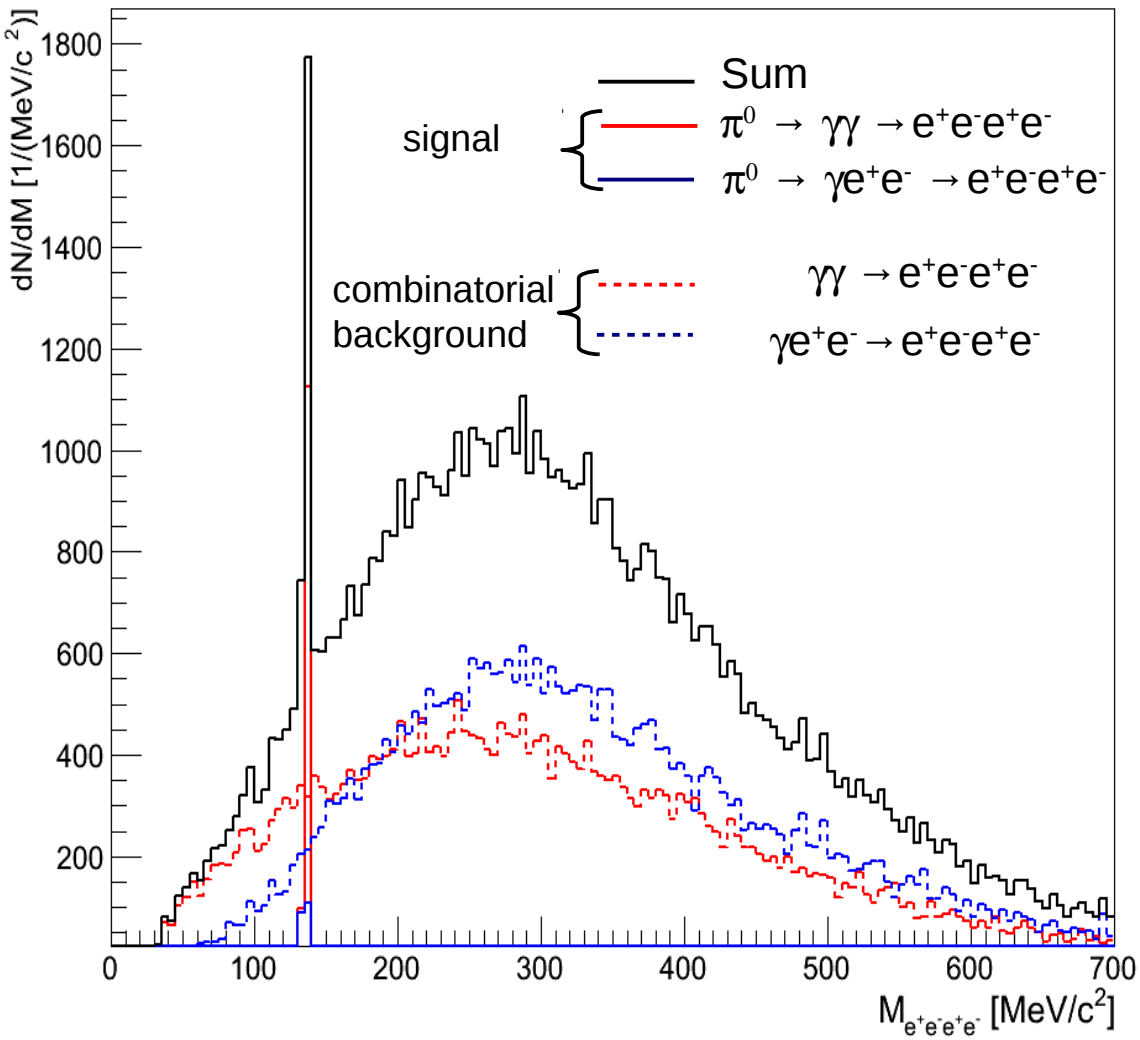
11% of e^+/e^-
p< 50 MeV/c: ε = 15%

44% of e^+/e^-
p< 100 MeV/c: ε = 55%



UrQMD Simulations : ideal case

4 lepton simulated invariant mass distribution

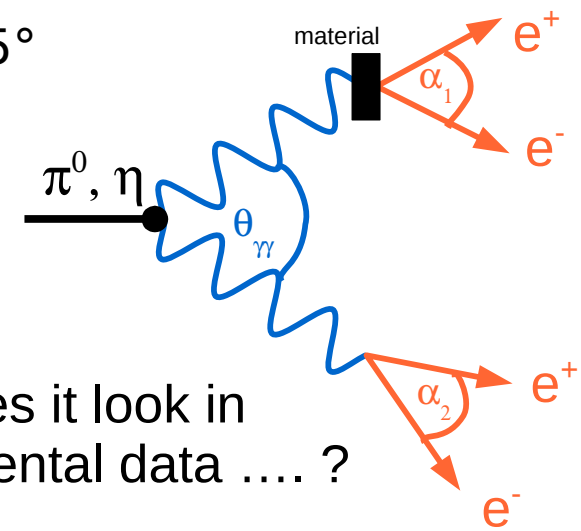


Lepton selection

- ✔ Ideal Geant information:
  - No detector response
  - No detector inefficiencies
  - Ideal Tracking efficiency

Topological cuts

- ✔ $\alpha_1 < 2.5°$ and $\alpha_2 < 20°$
- ✔ $\theta_{\gamma\gamma} > 5°$

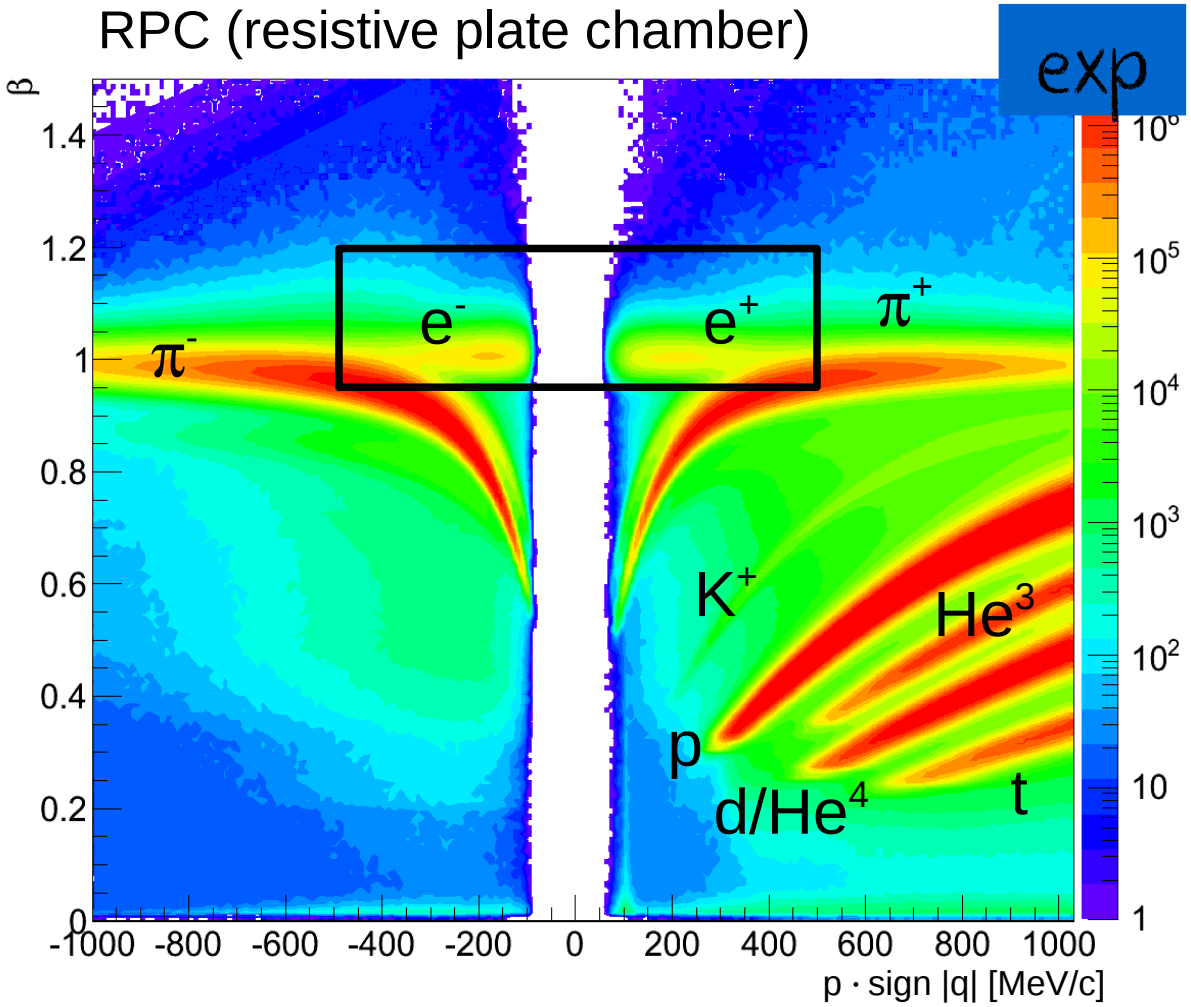


How does it look in experimental data …. ?

Lepton identification in experiment

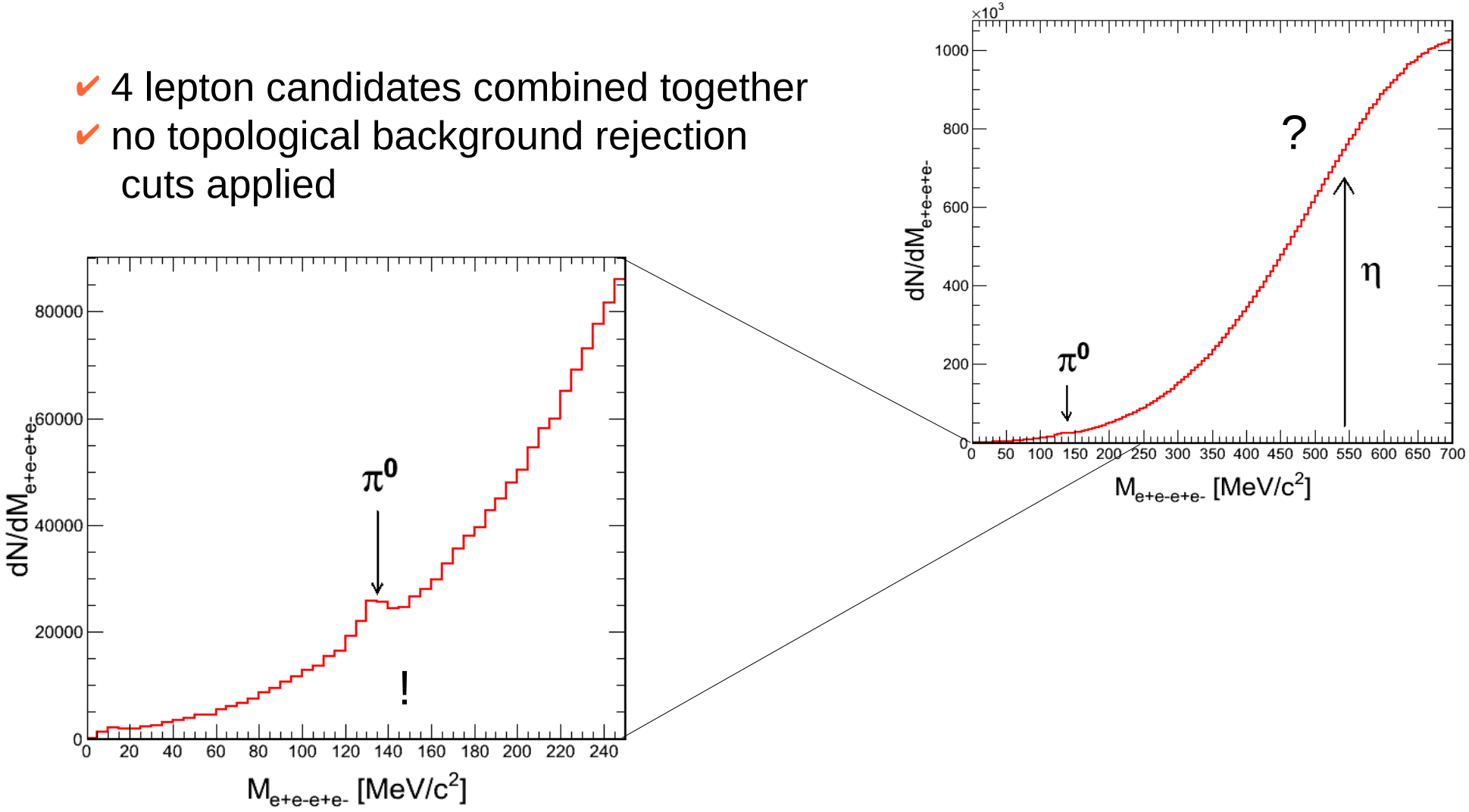
- Statistic:
  - Full Statistic Apr12: $7.3 \cdot 10^9$ PT3 Trigger evts.
- Combine 2 negative and 2 positive lepton candidates
- Lepton candidate selection
  - momentum < |500| MeV/c
  - $\beta > 0.97$

velocity vs. momentum measured with RPC (resistive plate chamber)



Experimental invariant mass distribution

- ✔ 4 lepton candidates combined together
- ✔ no topological background rejection cuts applied

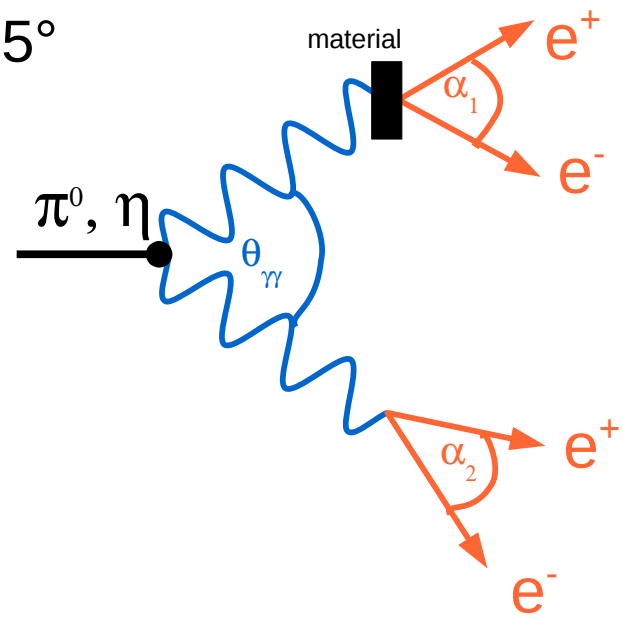


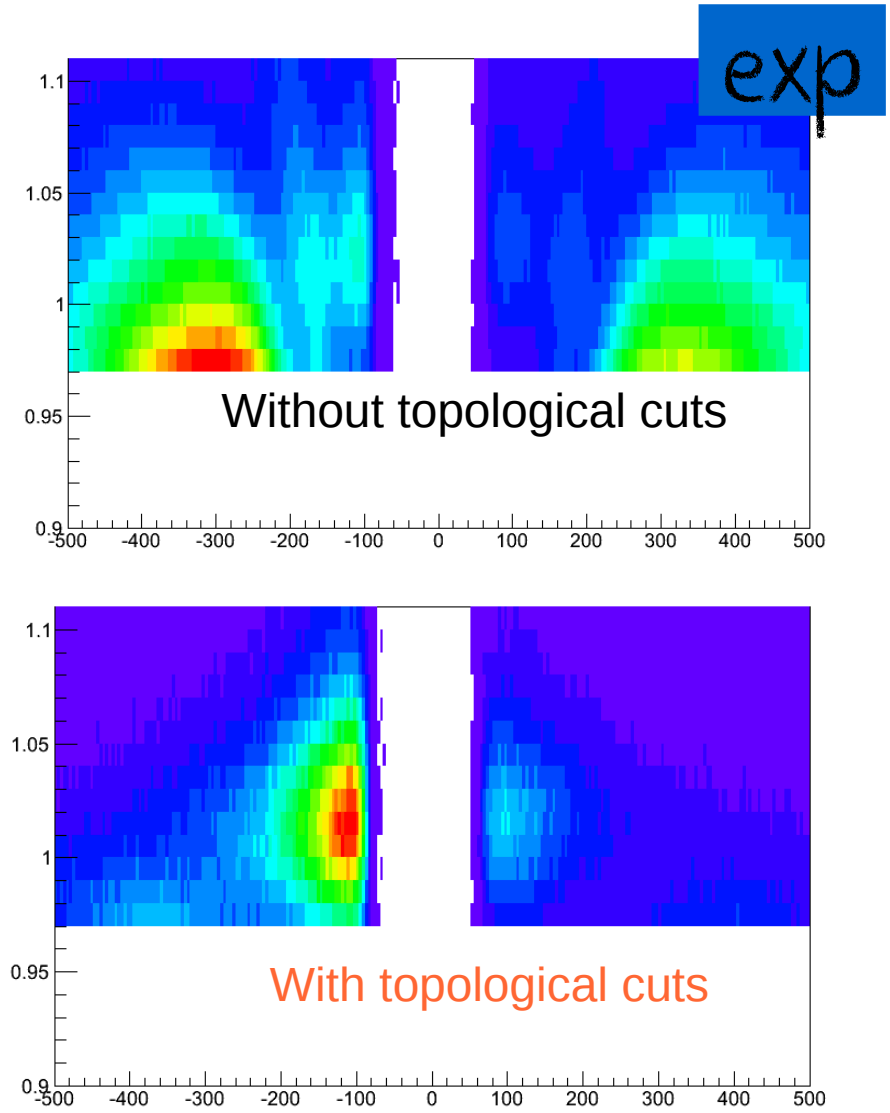
Topological BG rejection cuts

- Events with 4 lepton candidates
- Topological cuts to suppress combinatorial background

$\alpha_1 < 2.5°$ and $\alpha_2 < 20°$

$\theta_{\gamma\gamma} > 5°$





Experimental invariant mass distribution

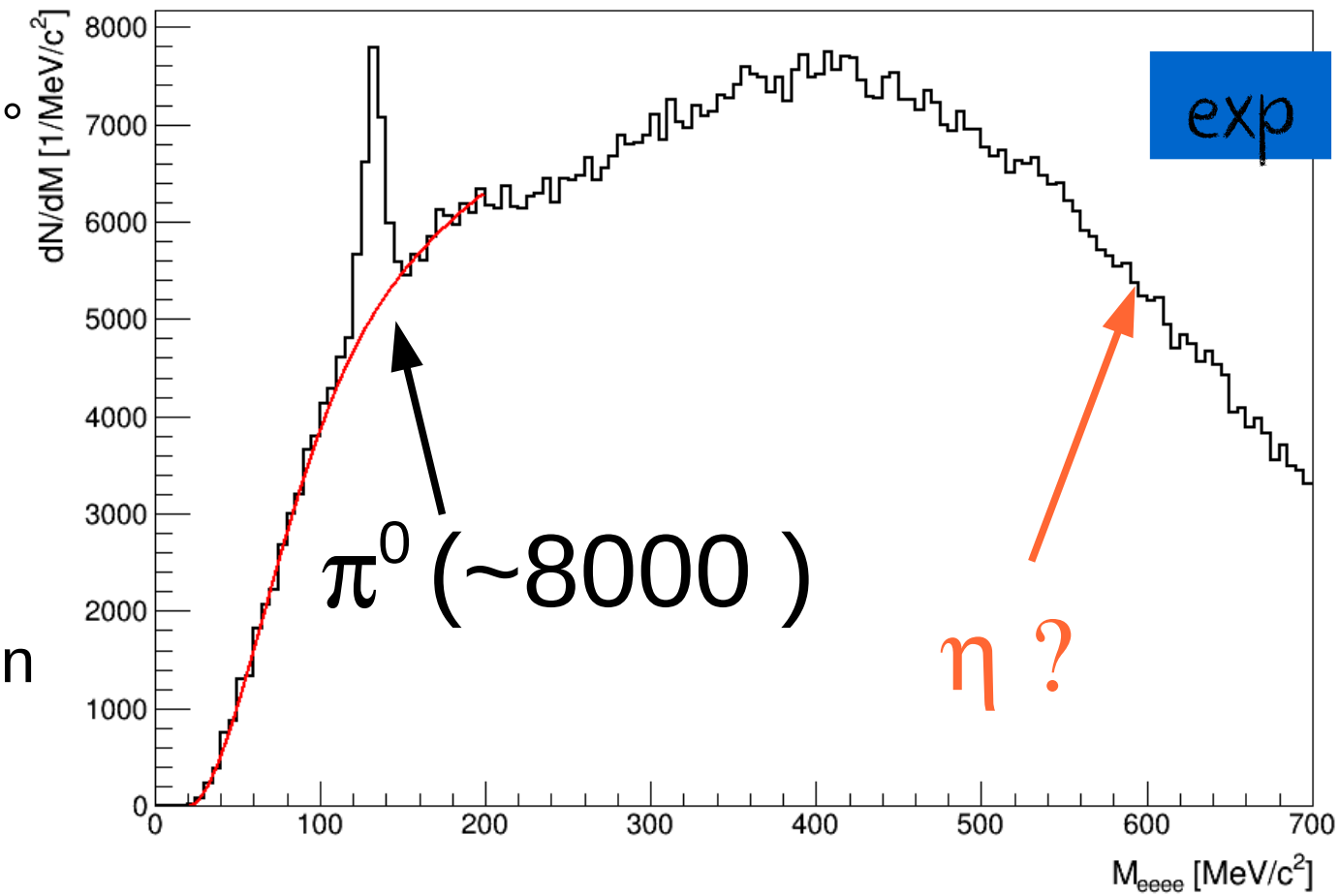
… after combinatorial background rejection

Topological cuts

$\alpha_1 < 2.5°$ and $\alpha_2 < 20°$

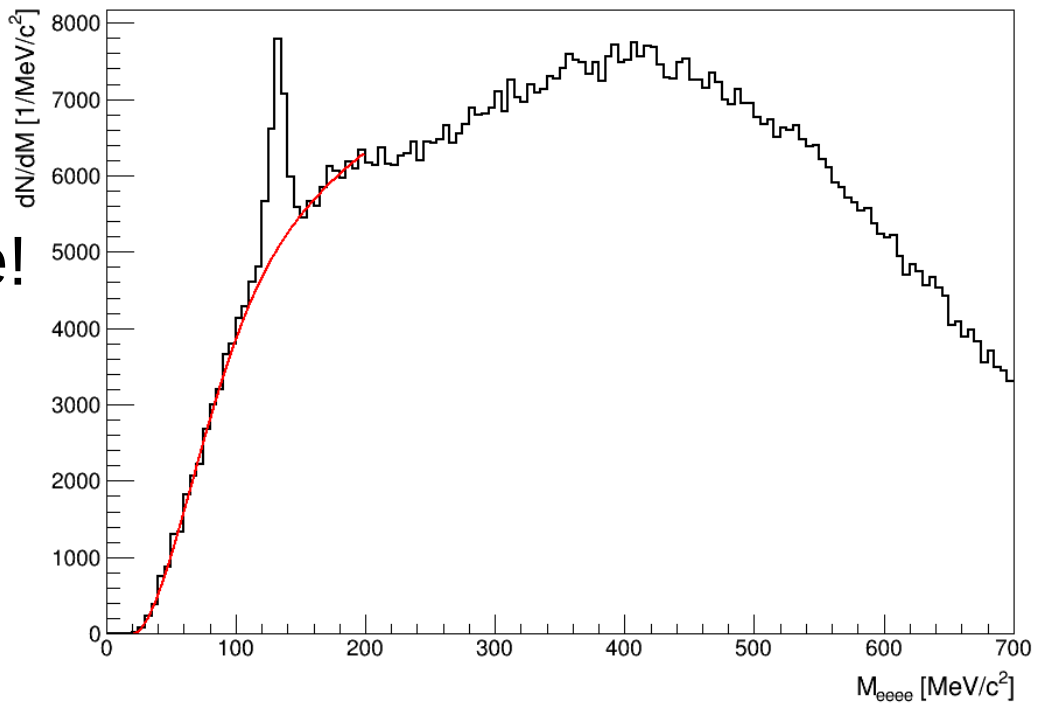
$\theta_{\gamma\gamma} > 5°$

η needs harder cuts on lepton identification and topology



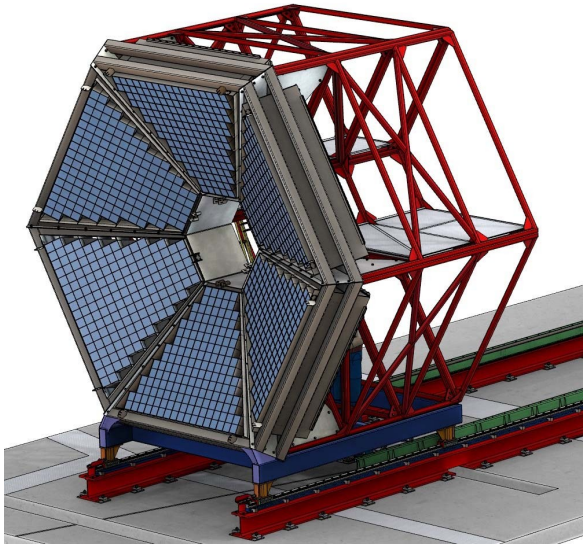
Summary

- Full reconstruction of π^0 and of η in Au + Au 1.23 AGeV is feasible
- First spectrum of 4 lepton invariant mass has been reconstructed
  - π^0 peak is clearly visible!
  - Reconstruction of η is ongoing



Outlook/ Future

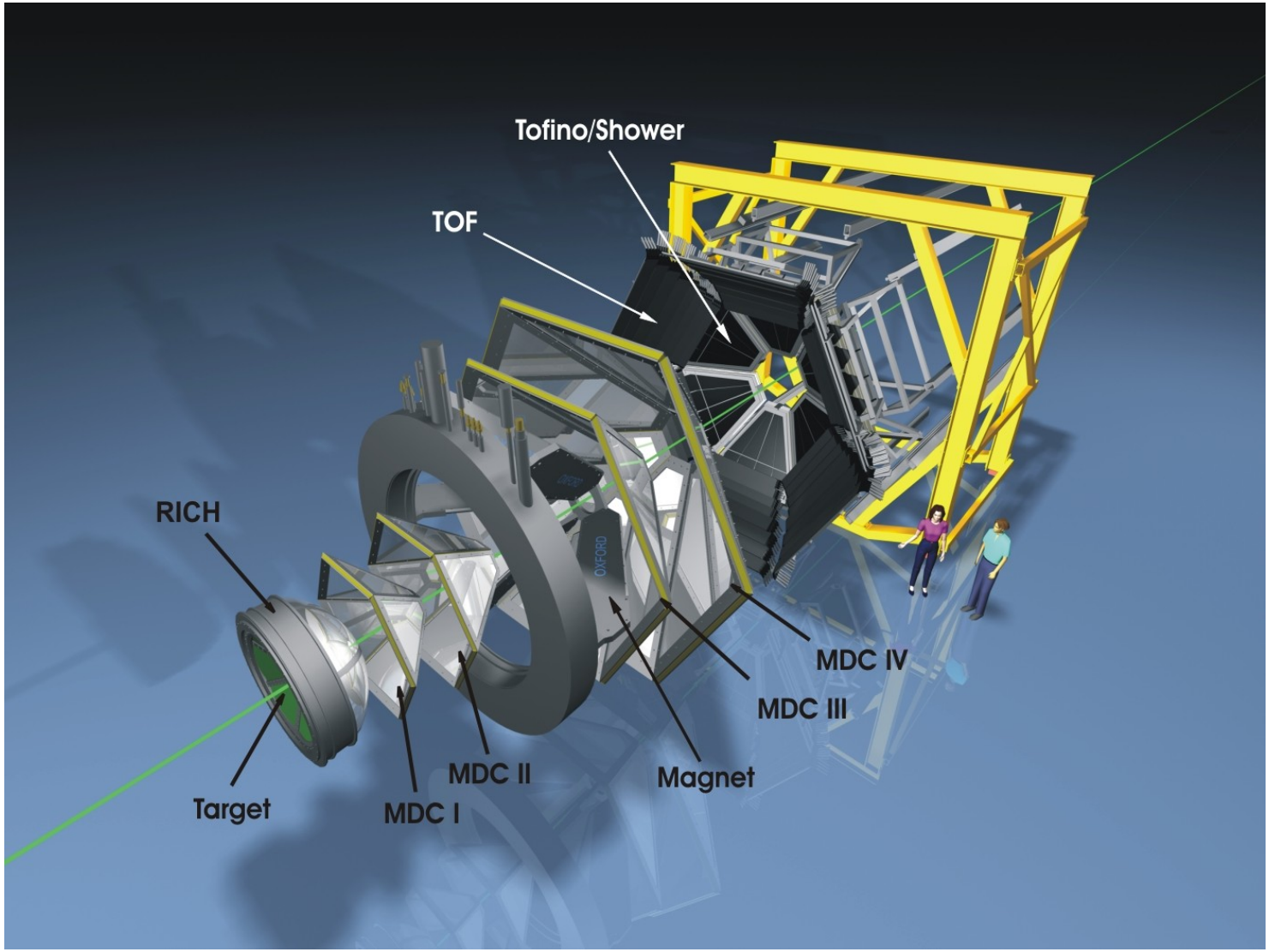
- Find η ;)
- Corrections for detector inefficiencies and acceptance
- Improve electron identification cuts
  (TMVA, close pair analysis)
- Improve topological background rejection cuts
- Extract multiplicities of π^0 and η mesons
  in Au+Au at 1.23 AGeV
- Additional measurements before SIS 100?
  Increase π^0 and η rates by:
  - Lowering the magnetic field (acceptance)
  - Additional material in the target region
    (conversion probability)
- Measurements at SIS 100 with electromagnetic calorimeter



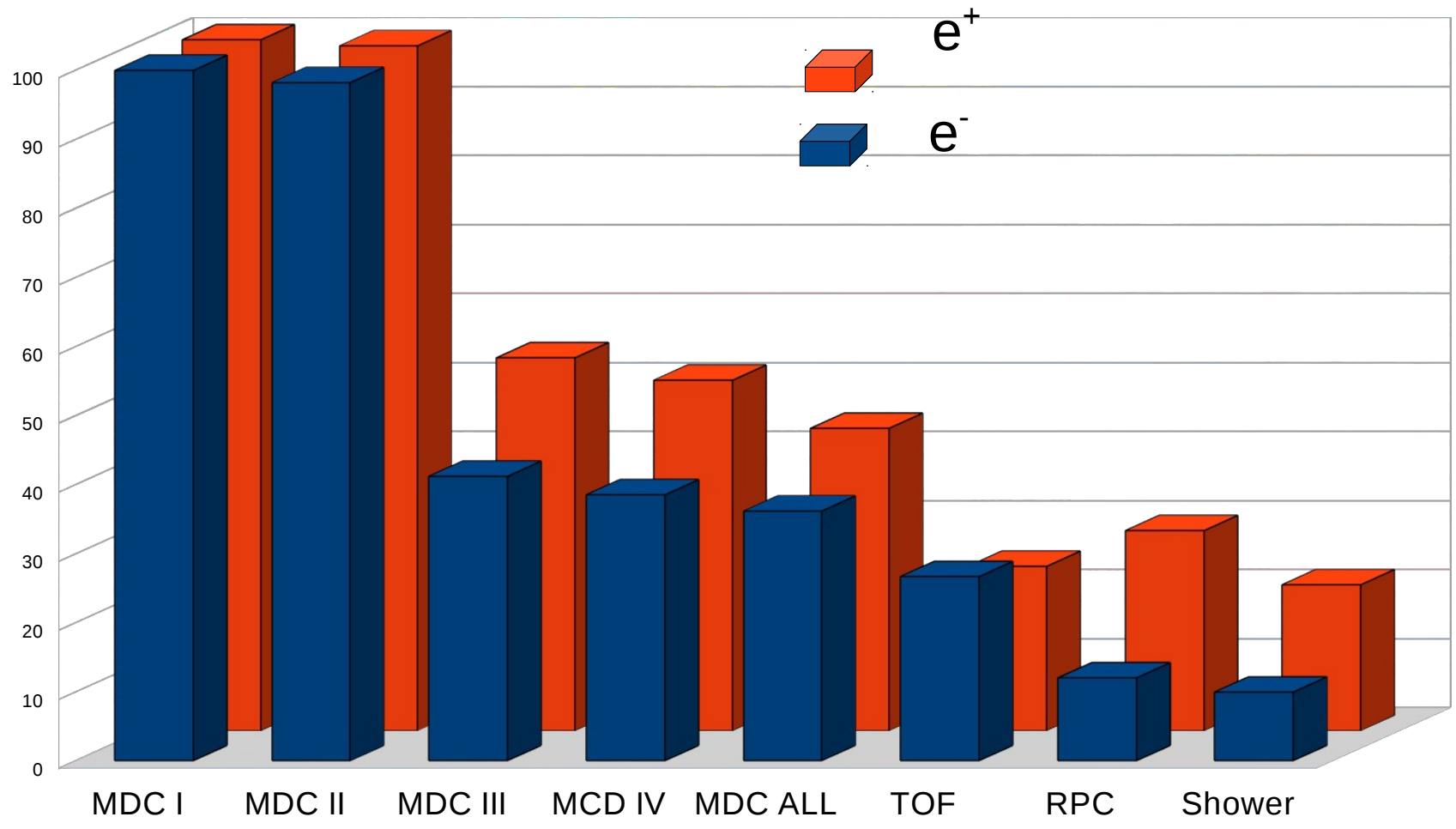
Thank you for your attention

Backup Slides

HADES Detector

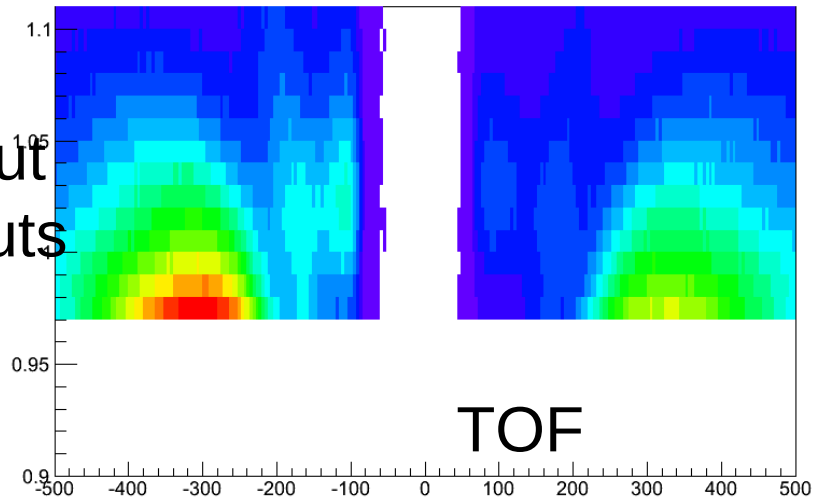


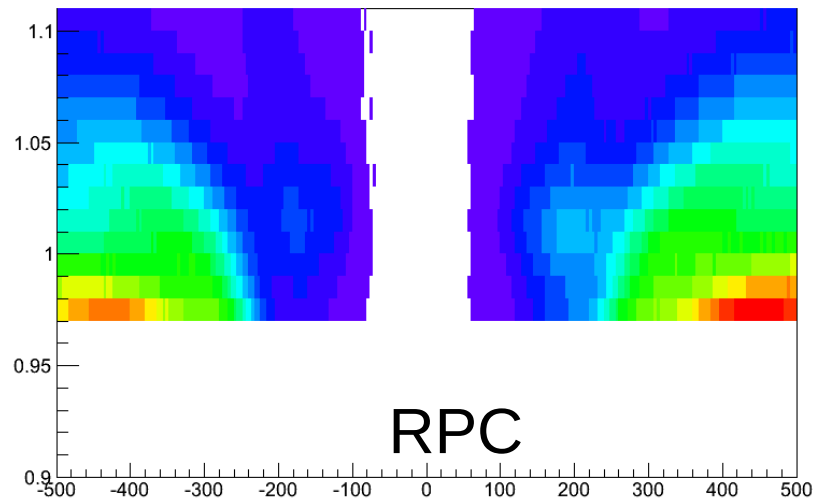
Low momenta leptons



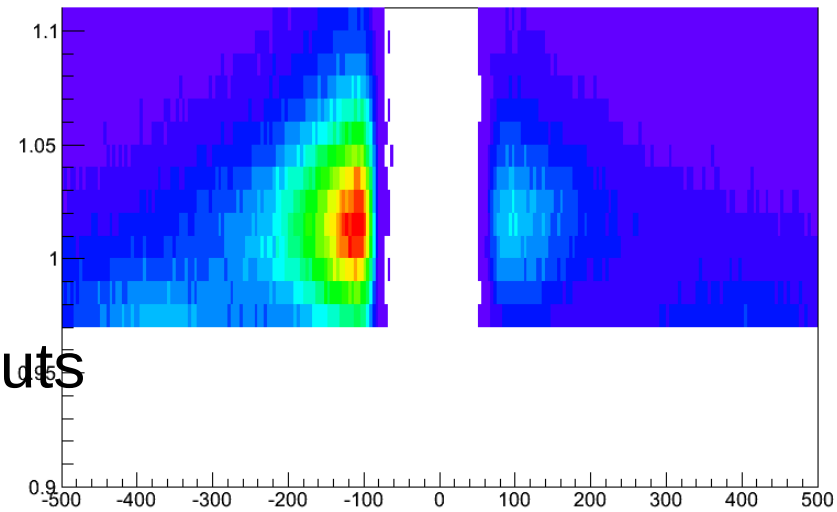
beta vs mom

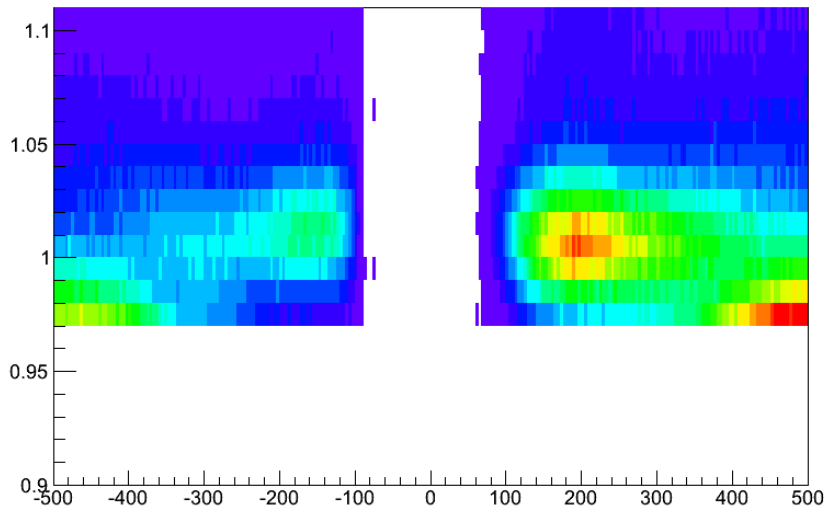
without
top cuts





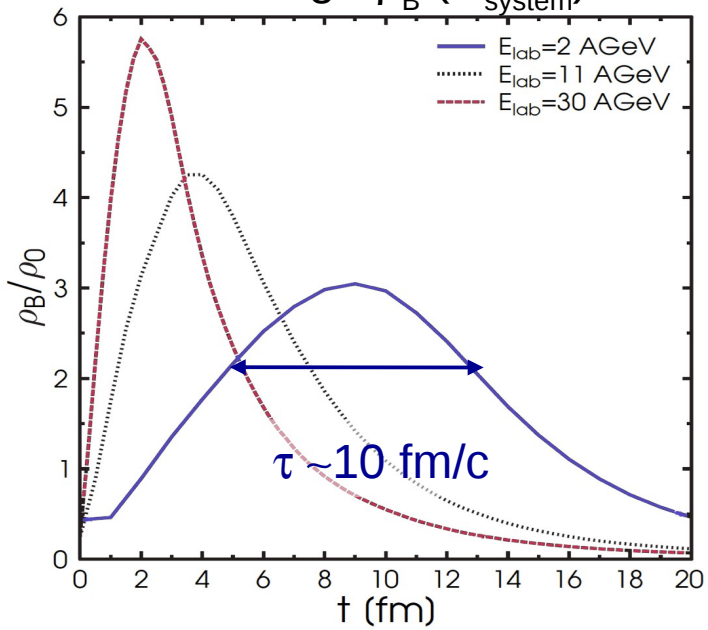
with
top cuts





The SIS18 heavy-ion energy regime

Evolution of average ρ_B (τ_{system})

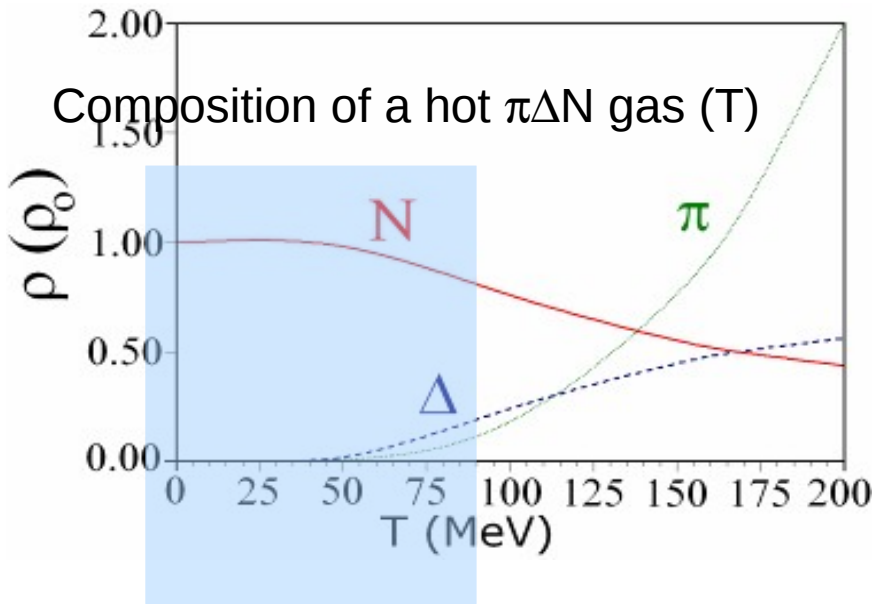


Probing nuclear matter at:

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

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

Composition of a hot πΔN gas (T)

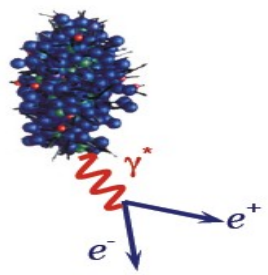


"Resonance matter":

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

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

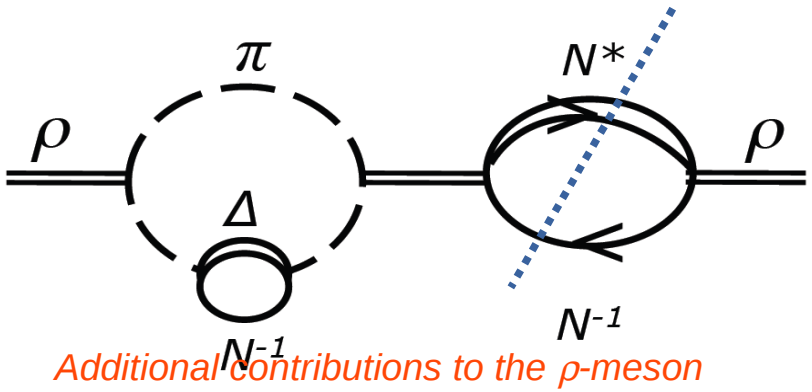
Hot and dense stage: a look inside



hot and dense stage

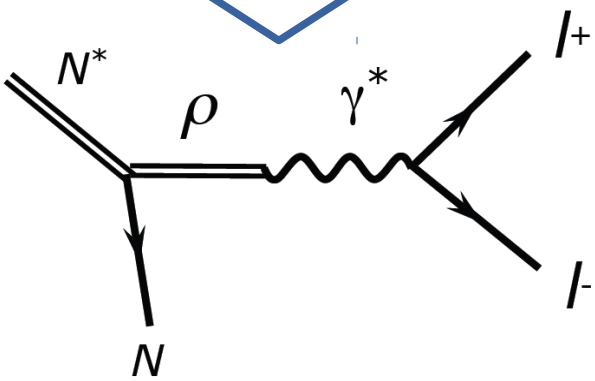
In-medium spectral functions →

SPS, RHIC, LHC



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

SIS

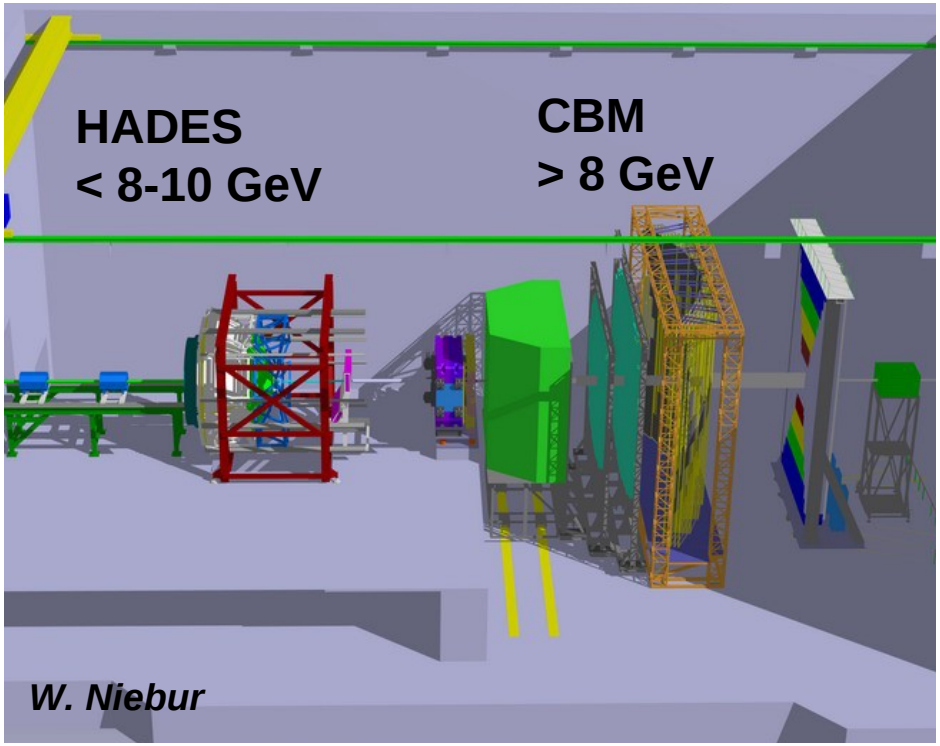


How to measure?
How to model?

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

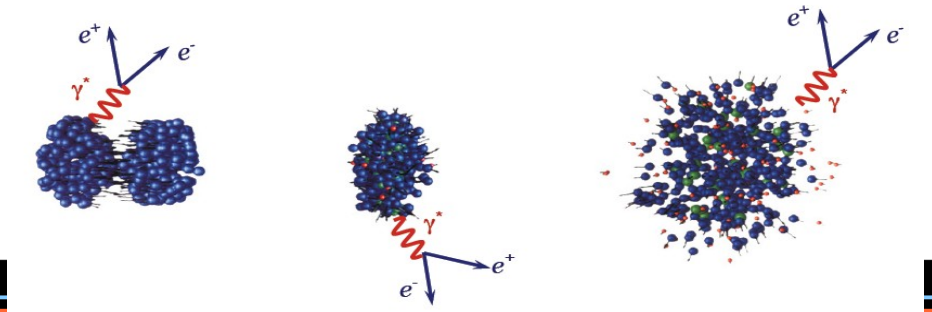
HADES at SIS 18 and SIS 100

- ✓ **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**

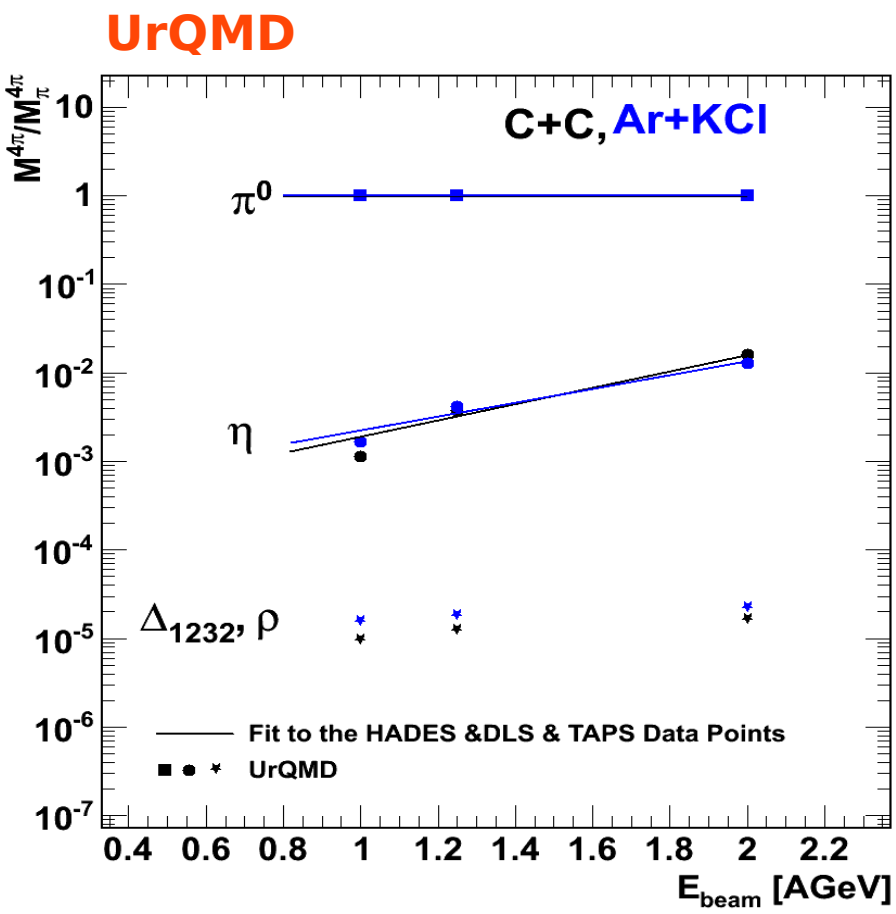


Date	System	E_{kin} beam
2002	C+C	2.0 GeV/u
2004	C+C	1.0 GeV/u
2005	Ar+KCl	1.76 GeV/u
2006	p+p	1.25, 2.2, 3.5 GeV
2007	d+p	1.25 GeV
2008	p+Nb	3.5 GeV
2012	*Au+Au*	*1.25 GeV/u*

Measure the whole evolution of the fireball...



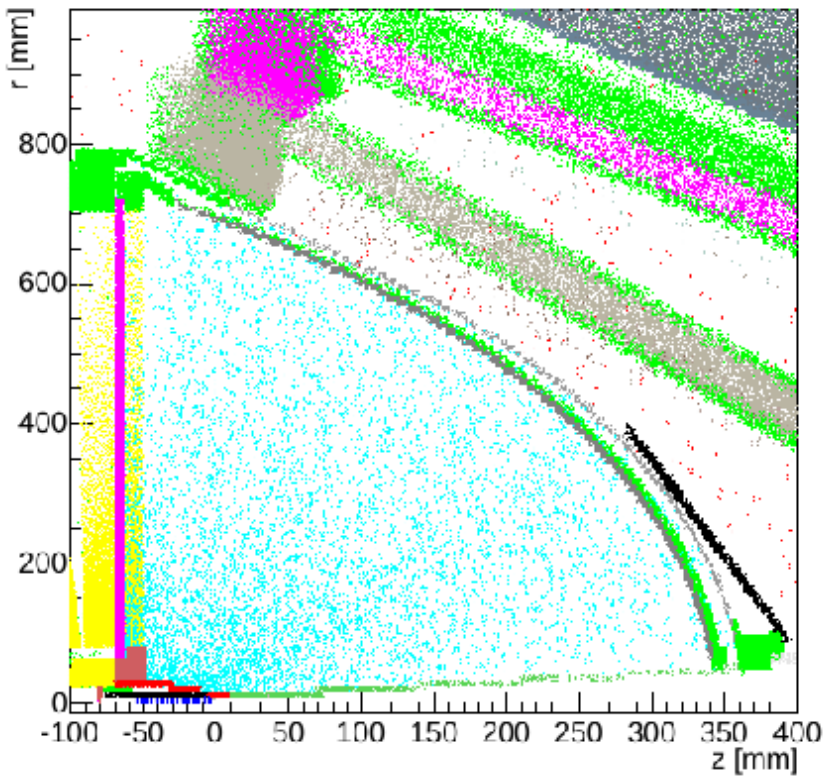
Energy and system size dependence of the excess yield

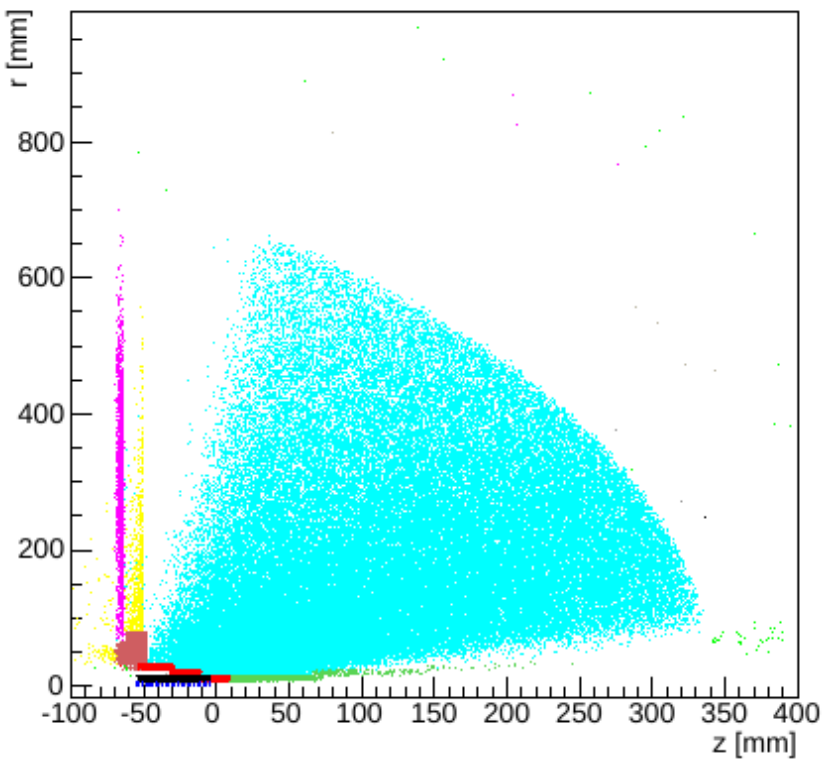


- Multiplicity of e^+e^- pairs from π^0, η, Δ and ρ
- Good agreement for π^0 and η (implemented according to the TAPS data)

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 colors represent different materials

Pluto