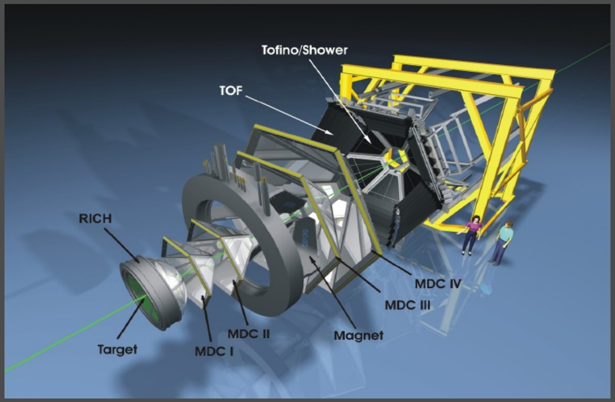
Virtual photons and rare strange probes in resonance matter
-
Going from p+p/p+n over p+A to A+A at kinetic beam energies of 1-3 GeV

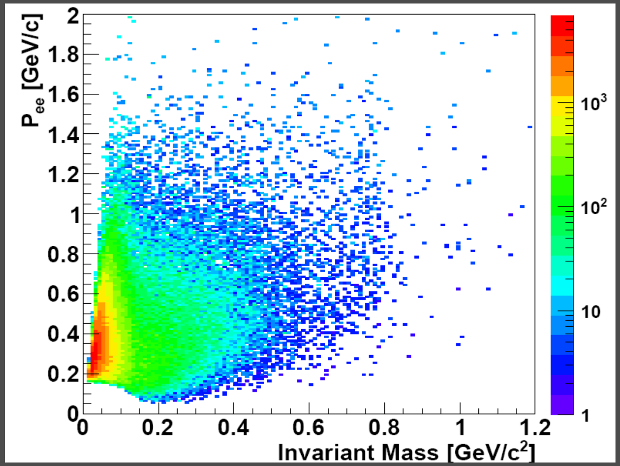
Manuel Lorenz
for the HADES collaboration

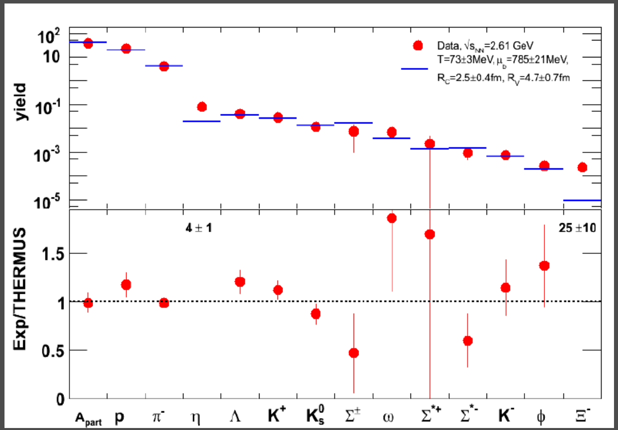
FAIRNESS Workshop,
Hersonissos 2012

Outline

- **Introduction**
  - Experimental access to medium modifications
- **Elementary reactions**
  - Isospin effects and ρ line shape
  - Resonances containing strangeness
- **Cold nuclear matter**
  - Modification of vector mesons
  - Strange probes
- **HIC**
  - Global characteristics
  - Dielectrons
- **Summary and the Future**





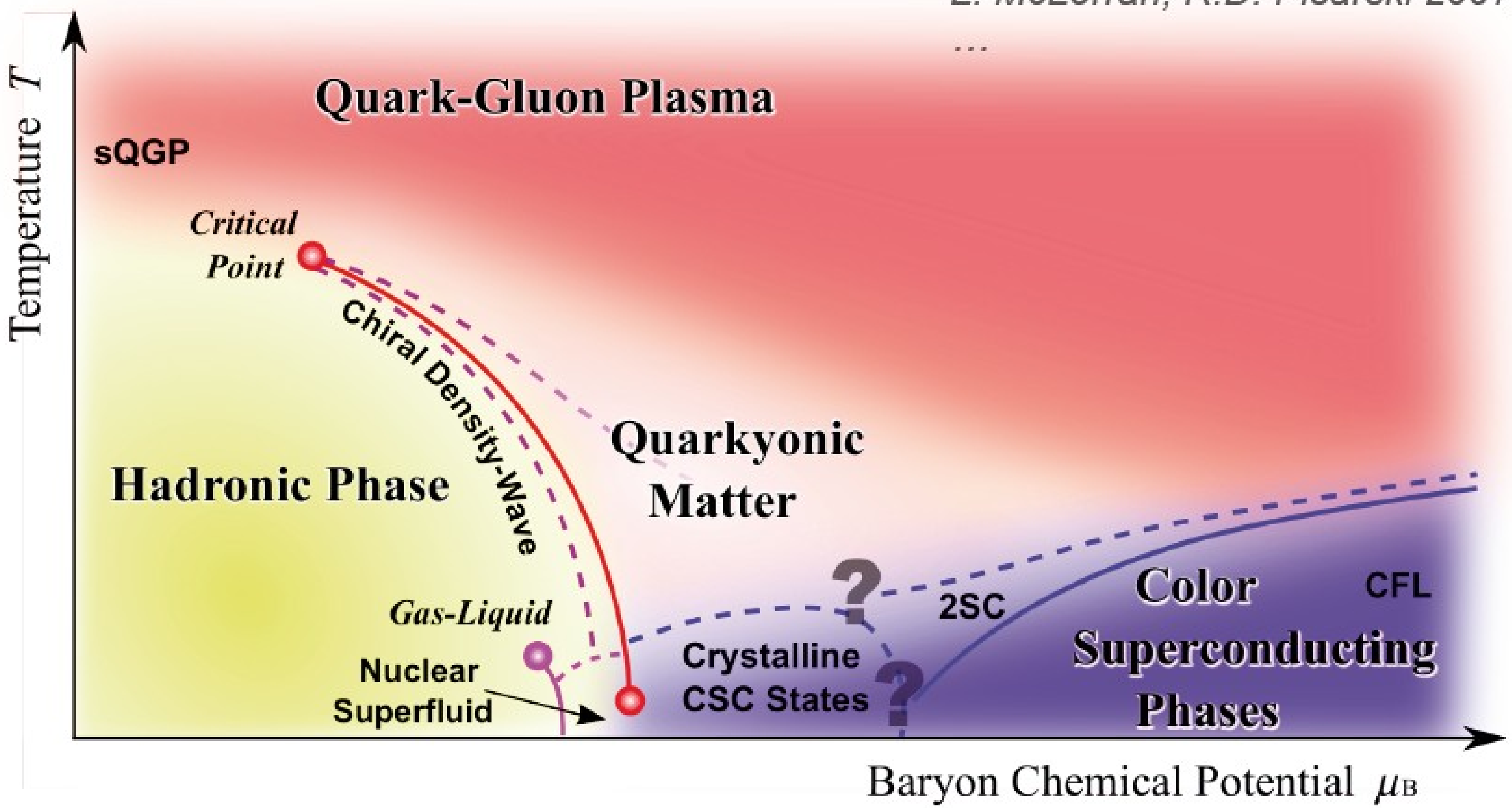


The QCD phase diagram

Tremendous interest:

RHIC-BES (STAR, PHENIX), CERN SPS (NA61), NICA, FAIR (CBM/HADES)

L. McLerran, R.D. Pisarski 2007, ...

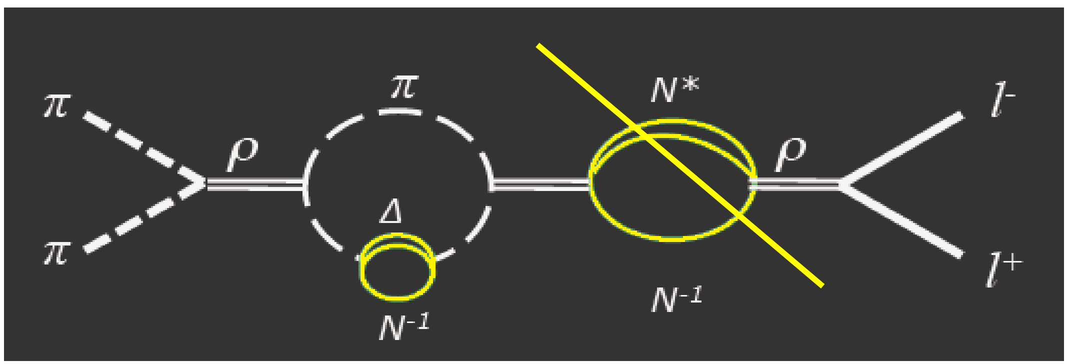


Hadronic models

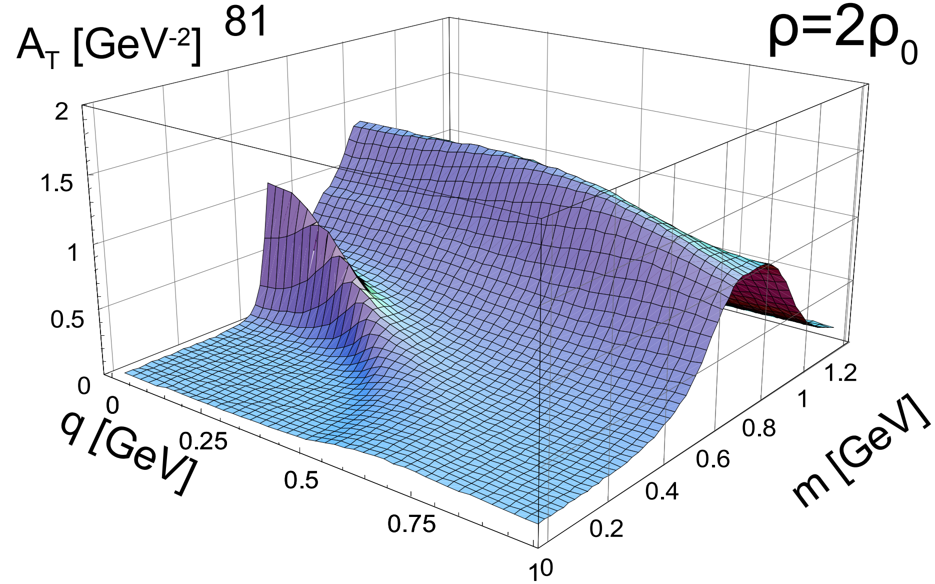
The connection between the QCD vacuum and particle properties is not trivial and can not be clearly defined at the moment.

→ **Hadronic models needed to predict hadron properties inside the medium**

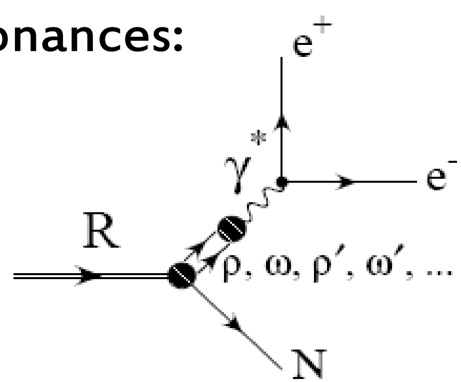
Additional contributions to particle self energy by coupling to resonances inside the medium:



M. Post et al., NPA 741 (2004) 81



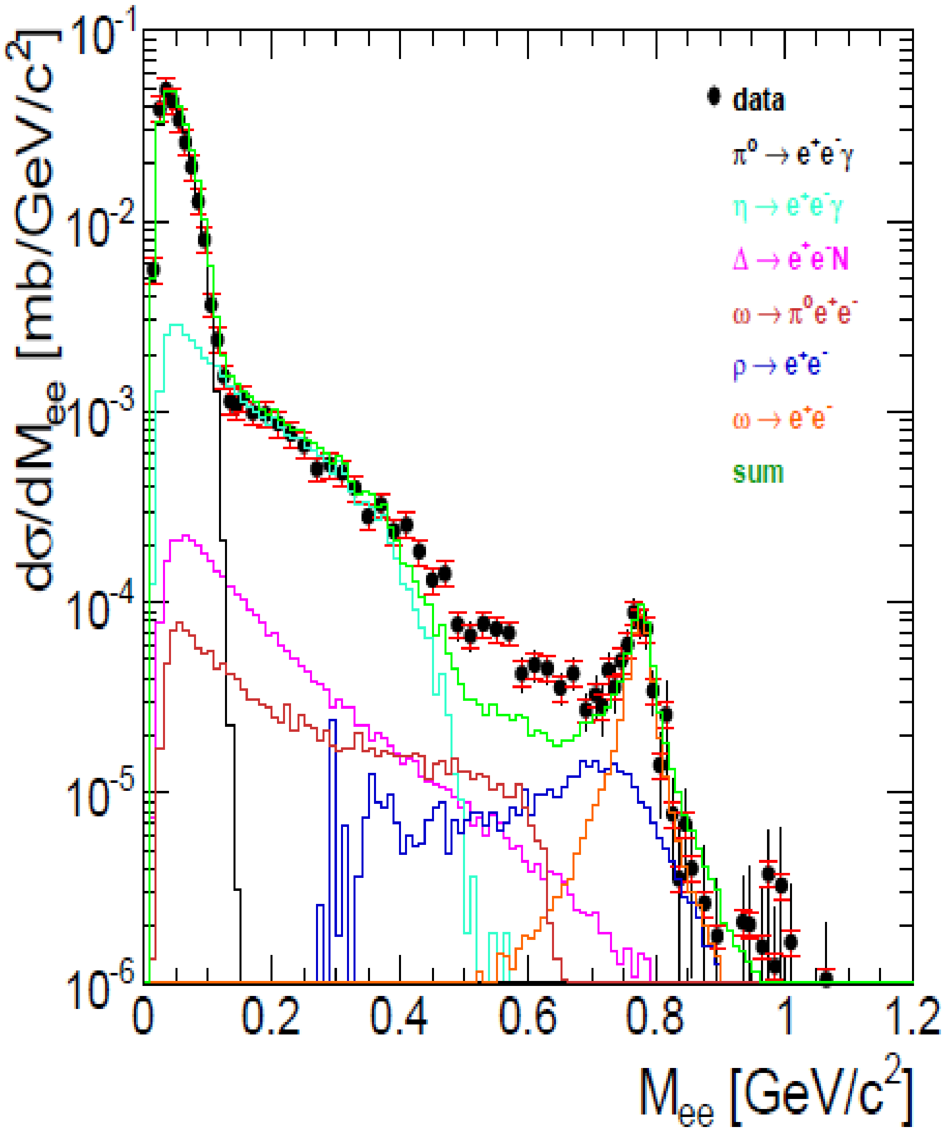
Note the similarity to Dalitz decays of baryonic resonances:



Effects restricted to momenta smaller 0.8 GeV

→ **ensure acceptance**

Experimental access: meeting reality



EPJ. A, V48, I5, 2012

- dilepton spectra:
several broad overlapping contributions

Understand your reference!

- The general properties in p+p, p+A and A+A vary strongly (e.g. rapidity shift).
If compared to models:
Understand the global characteristics of your system! (e.g. baryon kinematics)

Systematic measurements of different observables in p+p, p+A and A+A collisions needed to make solid statements about medium modifications!

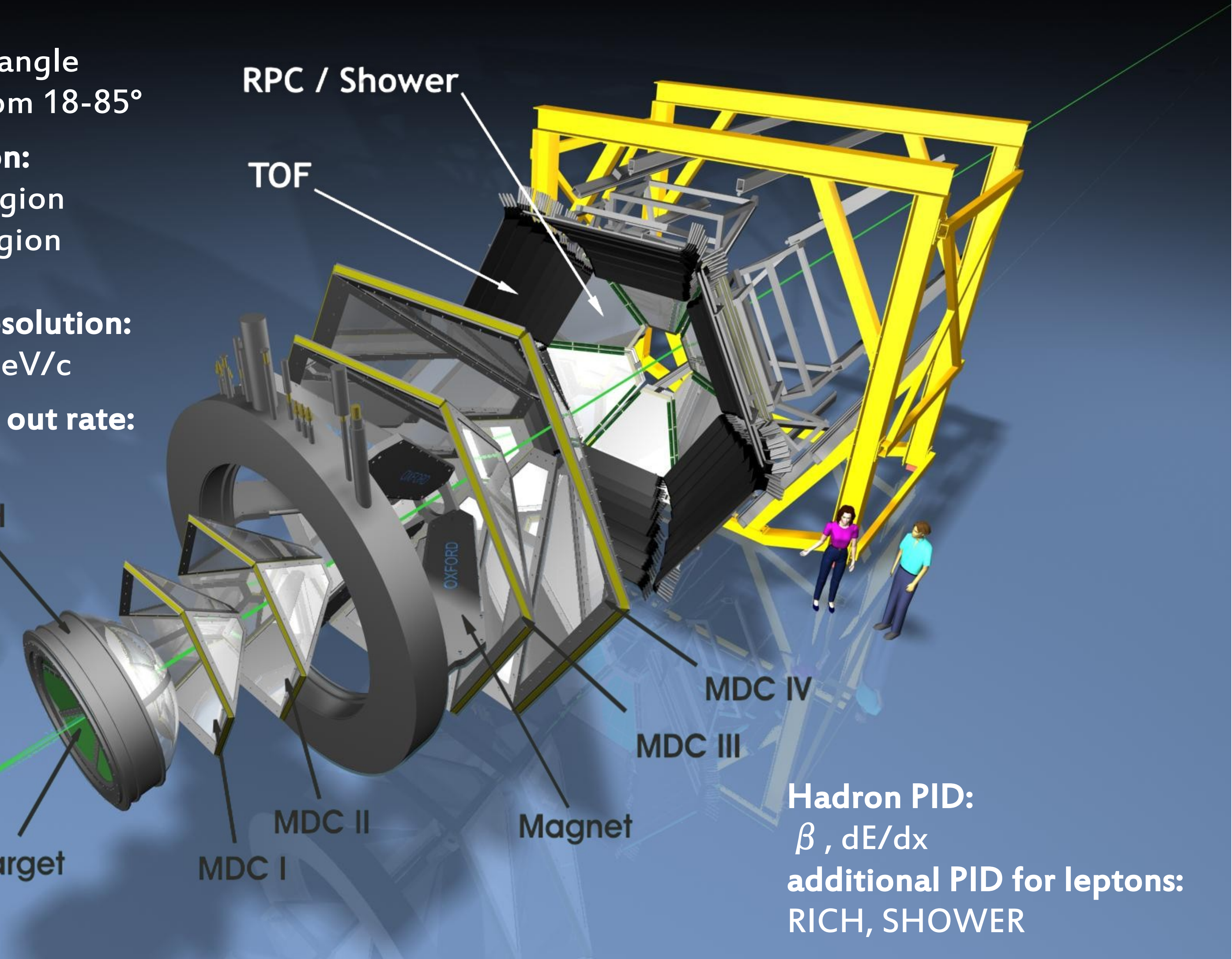
HADES

Acceptance:
full azimuthal angle
polar angle from 18-85°

Time resolution:
150 ps TOF region
90 ps RPC region

Momentum resolution:
1.5% at 500 MeV/c

Detector read out rate:
max. 50 kHz



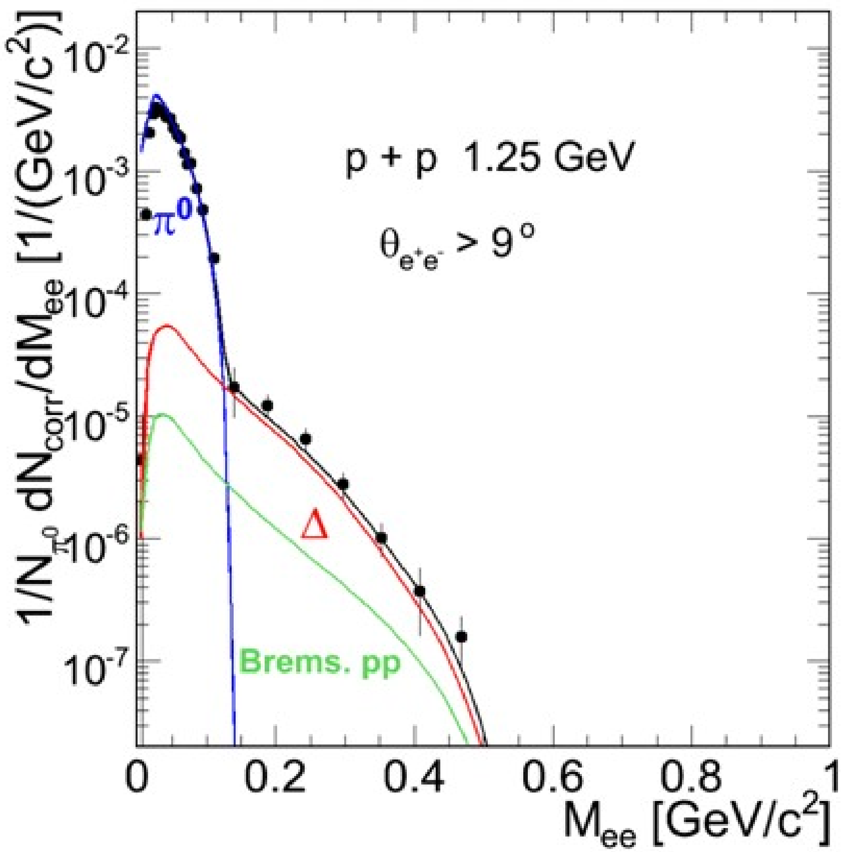
Hadron PID:
β , dE/dx
additional PID for leptons:
RICH, SHOWER

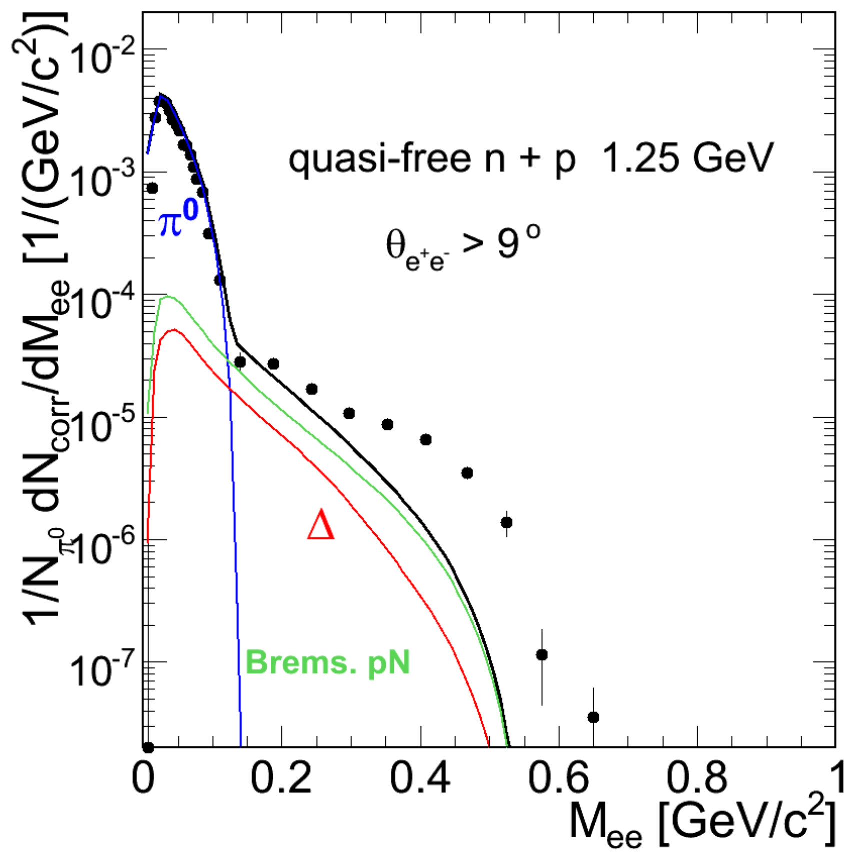
Elementary reference: N+N reactions

1. Isospin effects

Dielectron data from p+p and d+p (tagged n) collisions at 1.25 GeV

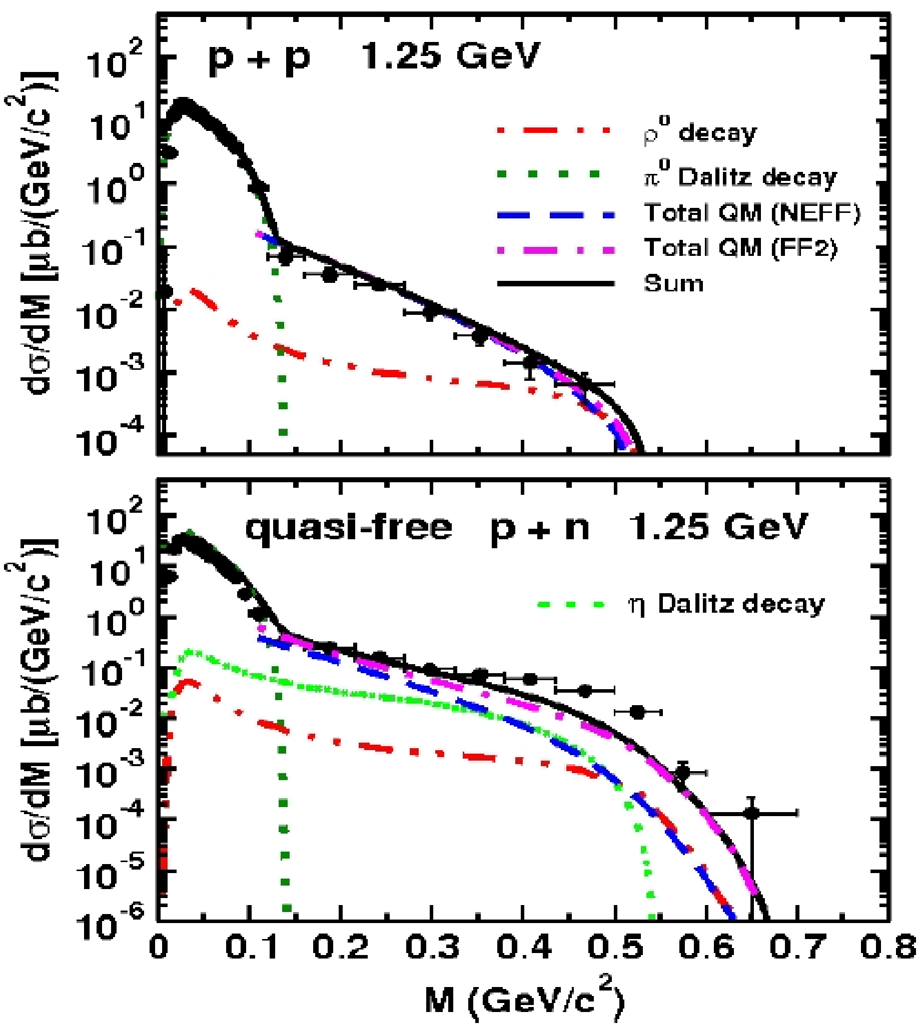
Cocktail from HSD calculation 2008 with revised description of Bremsstrahlung

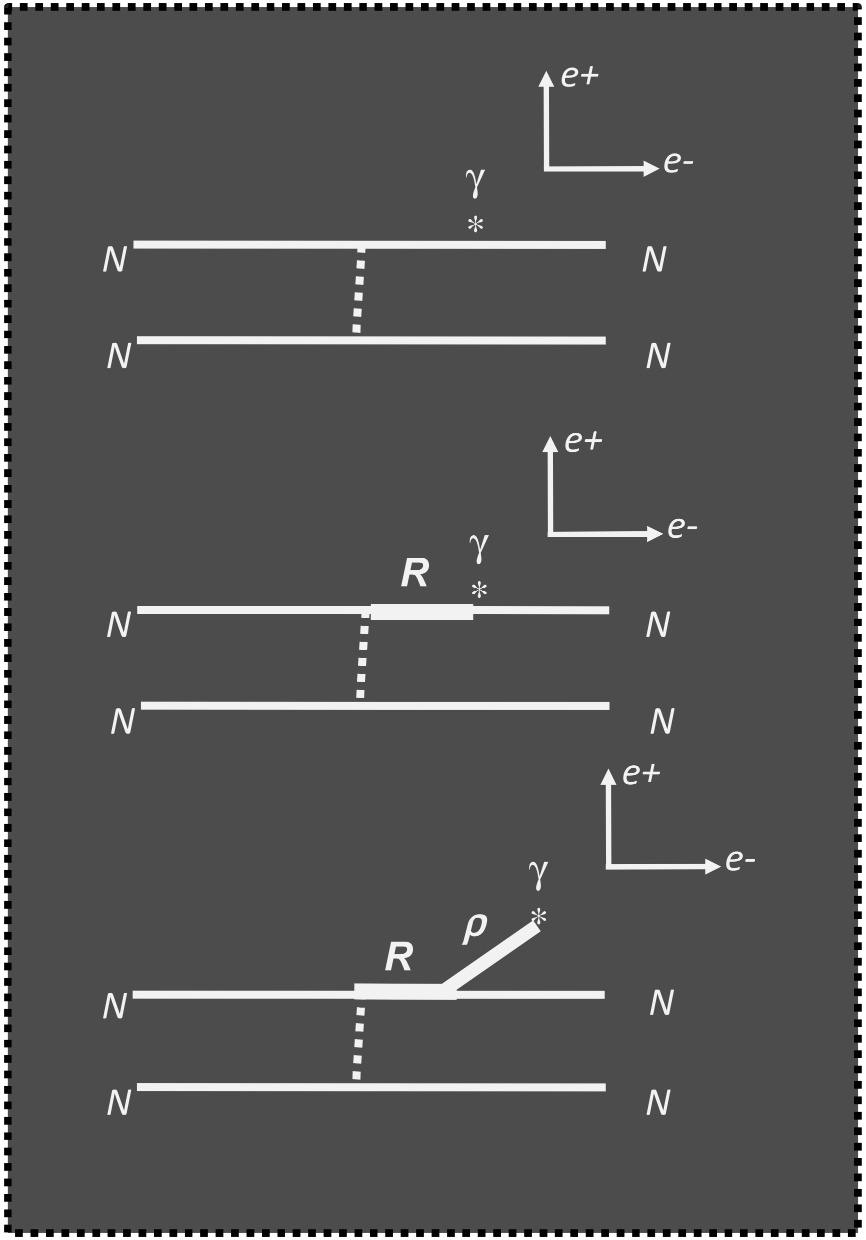




HADES collaboration, PLB 690 (2010) 118

1. Isospin effects

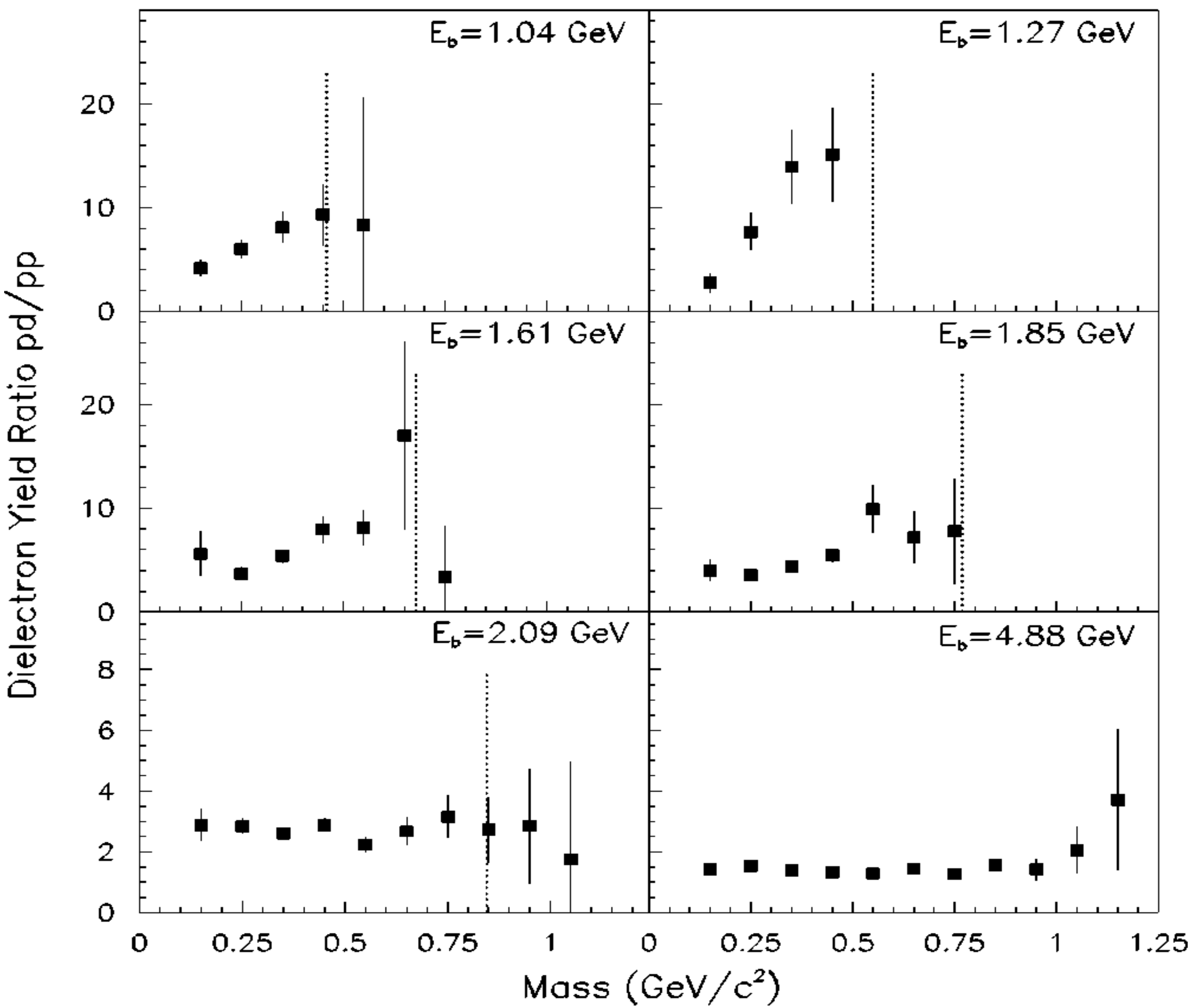




One Boson exchange including pion EM form factor for internal pion line

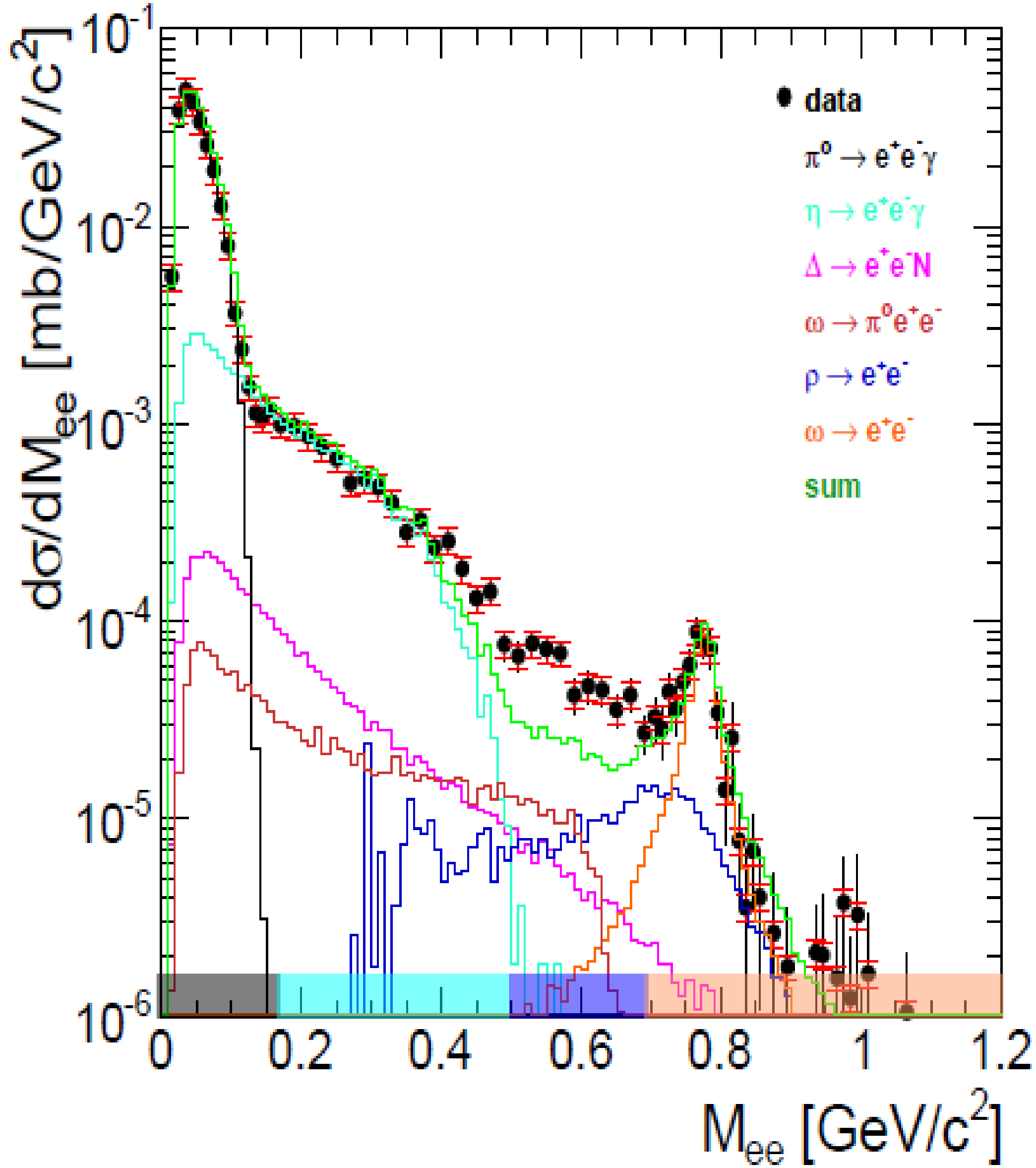
R. Shyam and U. Mosel, arXiv 1006.3873

1. Isospin effects: energy dependence



DLS collaboration, PRC 57 (1998)

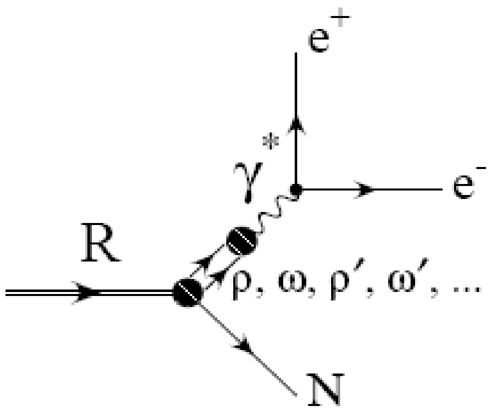
2. The shape of the ρ meson: e^+e^- from p+p @3.5 GeV



HADES collaboration, EPJ. A, V48, I5, 2012

Dielectron Cocktail:

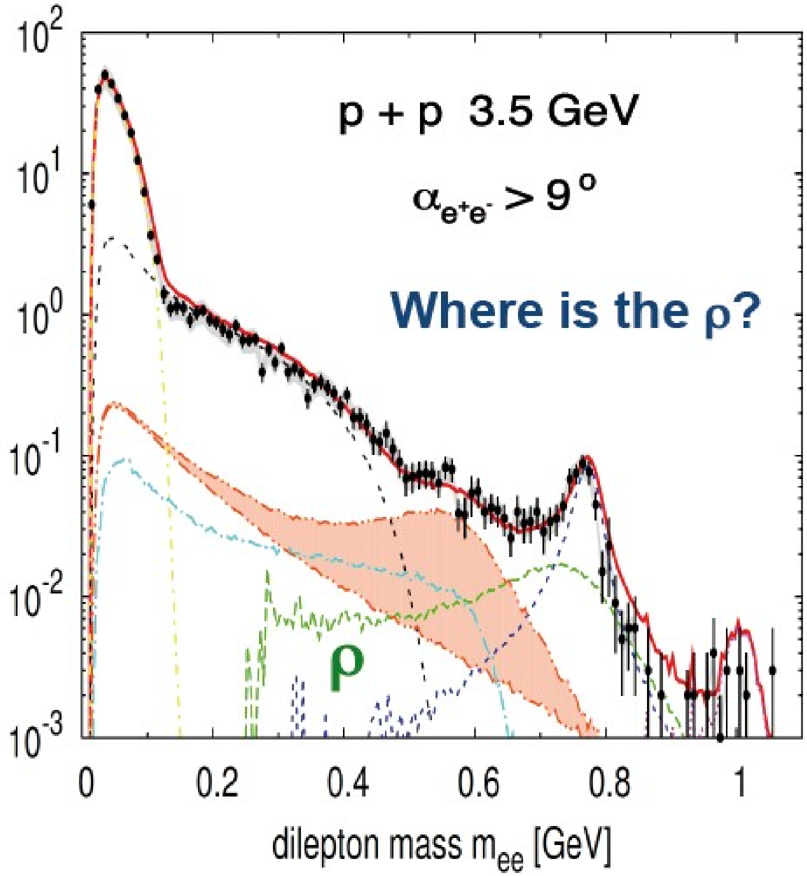
- very similar to GiBUU
- also p_t distributions used to constrain cocktail
- Missing yield between 0.5 and 0.7 GeV/c^2

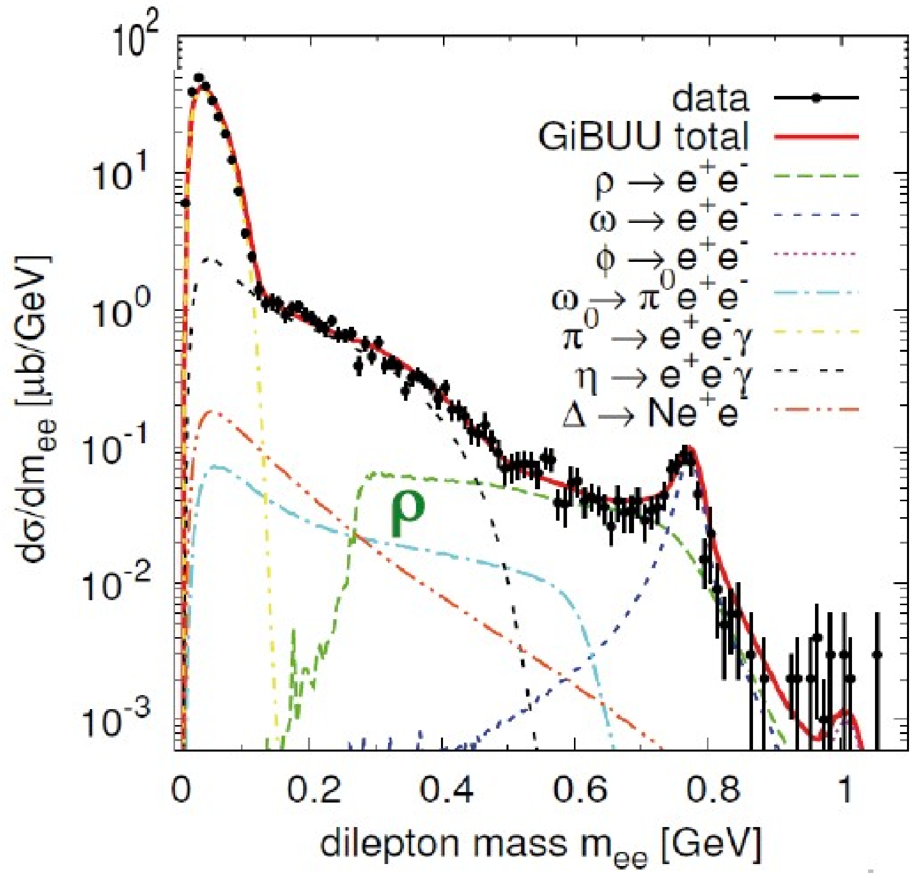


ρ baryon-resonance coupling: enhances yield below ρ pole mass due to kinematical constraints;

See next talk from Janus Weil for more details.

2. The shape of the ρ meson: e^+e^- from p+p @3.5 GeV





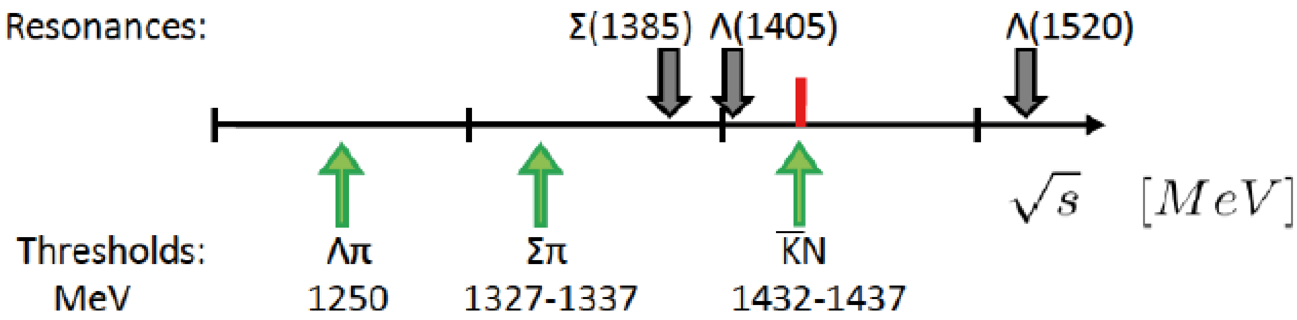
Better description when introducing
→ Δ -N EM transition form factor

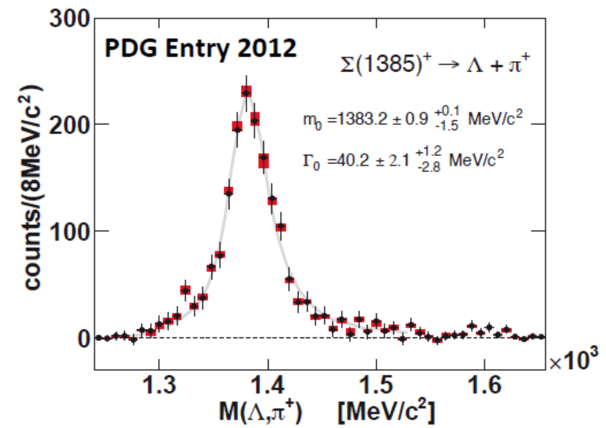
→ or when all ρ mesons are produced via baryonic resonances
Resonance cross section:
see Talk of Adrian Dybczak from Thursday

Is it meaningful to distinguish between baryon resonance and ρ contribution?
→ baryonic contributions

GiBUU simulation: by J.Weil arXiv:1106.1344v1[hep-ph]

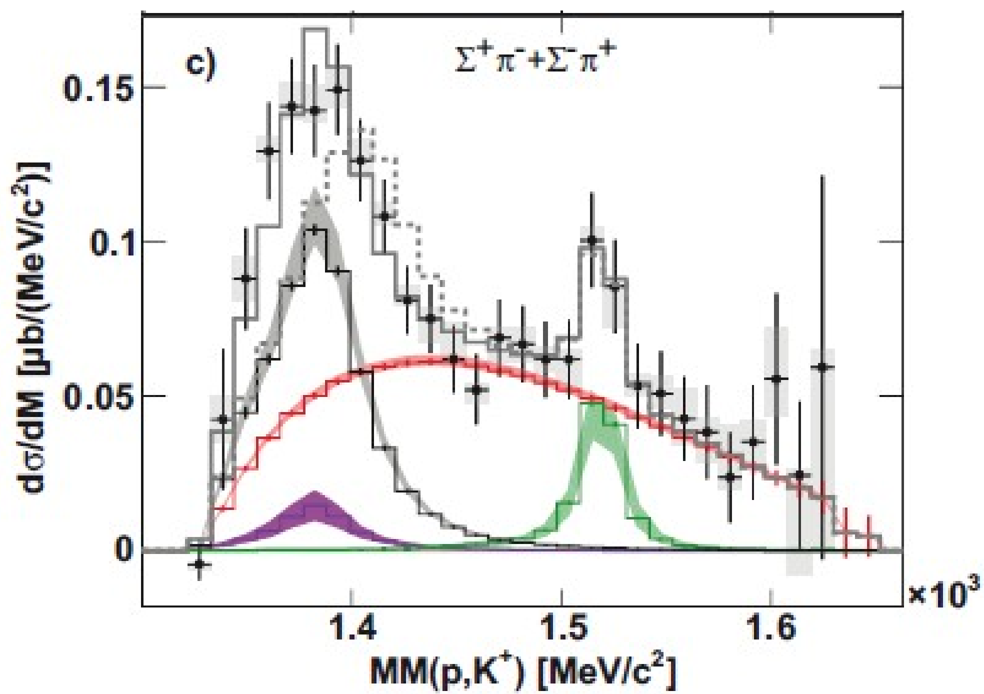
3. Strange resonances and the $\bar{K}N$ potential





Λ (1405):

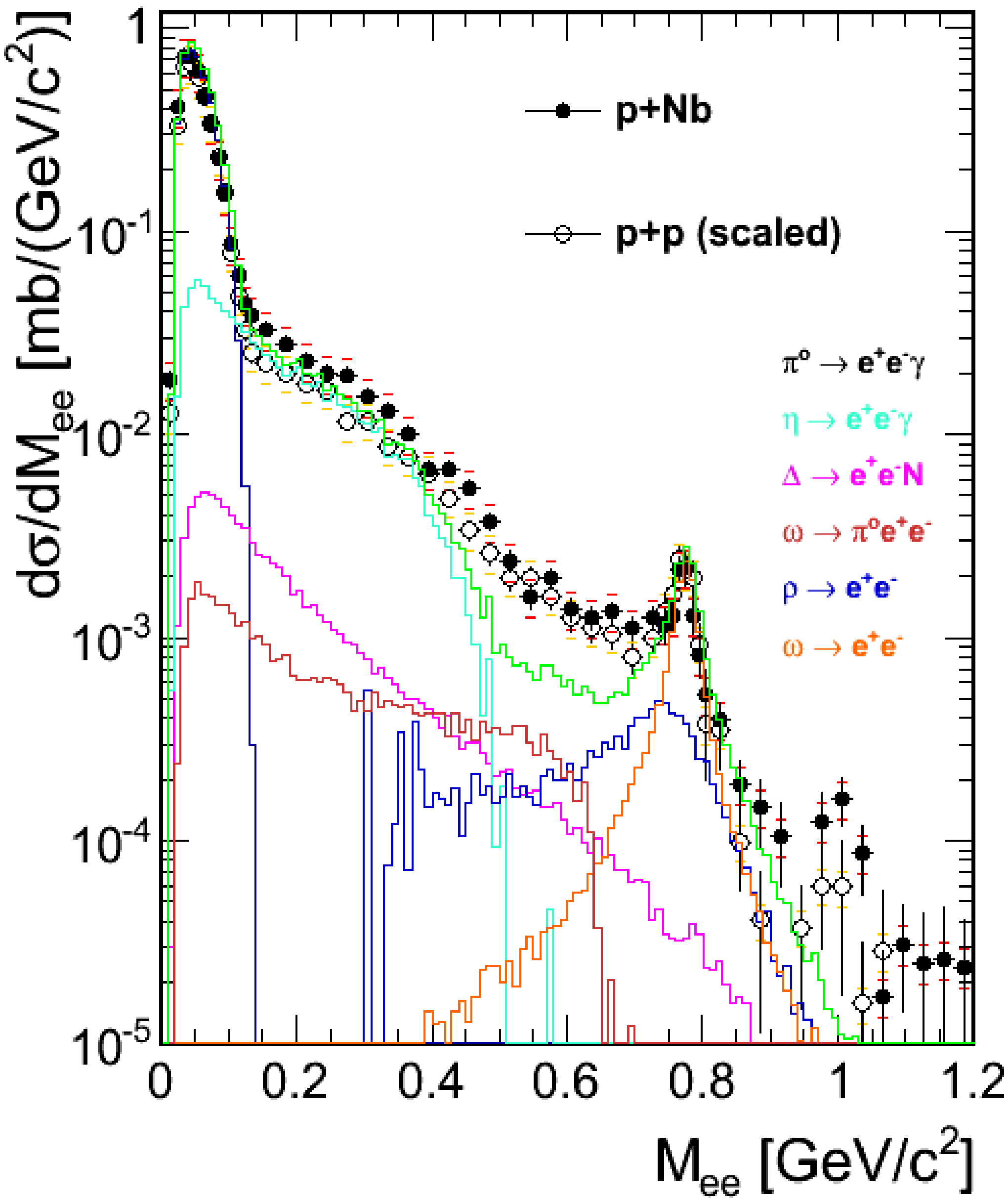
- theoretically treated via coupled channel approach and dynamically generated by superpositions of different states
- experimental constrain: line shape extracted from its decays to different final states
- pole mass well below 1.4 GeV/c^2



Submitted to PRL

Cold nuclear matter: p+Nb @ 3.5 GeV

1. Modifications of Vector Mesons



Nuclear Modificationfactor:

$$R_{pA} = \frac{d\sigma^{pNb}/dp}{d\sigma^{pp}/dp} \times \frac{\langle A^{pp}_{part}\rangle}{\langle A^{pNb}_{part}\rangle} \times \frac{\sigma^{pp}_{reaction}}{\sigma^{pNb}_{reaction}}$$

Change in line shape:
decay inside the medium,
$\rightarrow$ short-lived,
$\rightarrow$ initial momentum as low as possible

Hadronic models:
Effects restricted to momenta smaller 0.8 GeV
$\rightarrow$ ensure acceptance

Momentum dependence

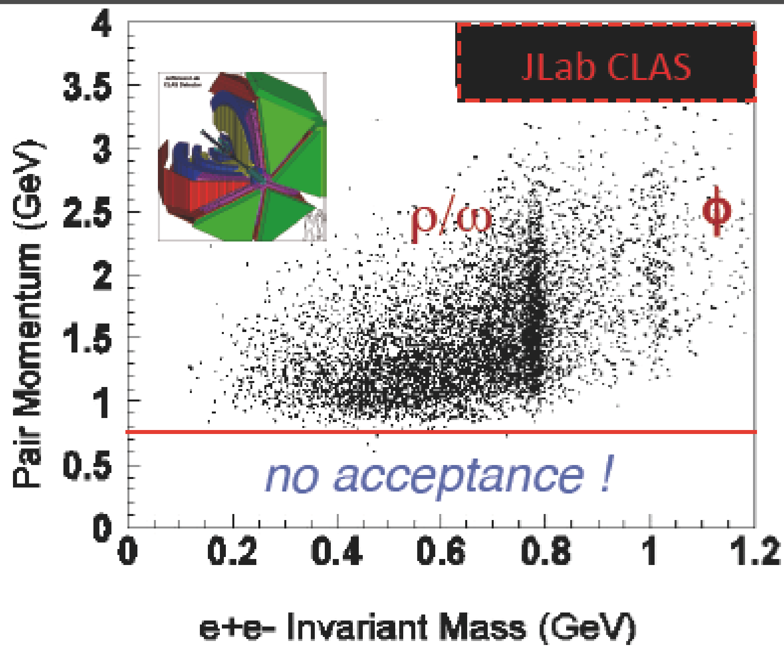
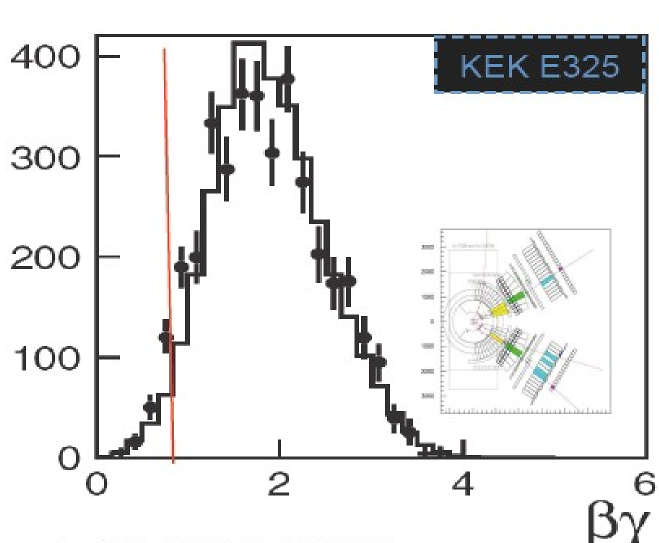
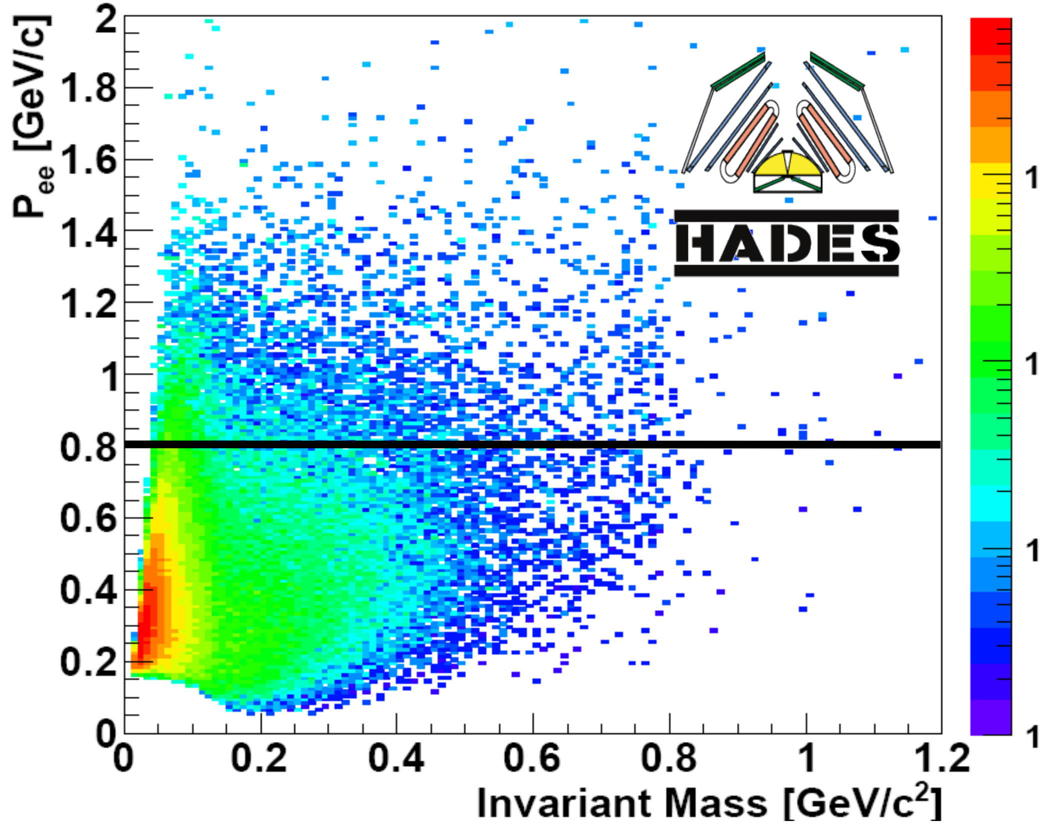


Fig. from S.Leupold et al., nucl-th 0907.2388

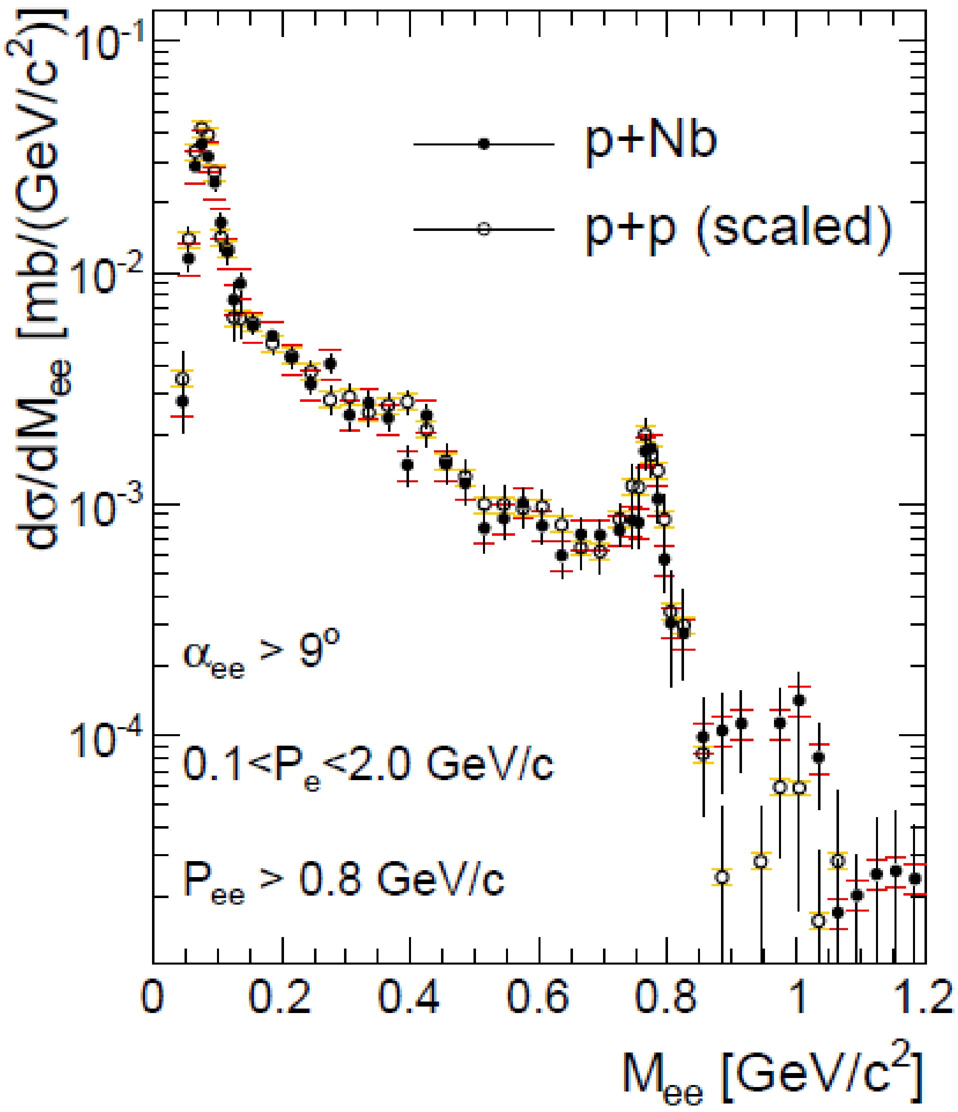


R.Muto et al., PRL 98 (2007) 042501

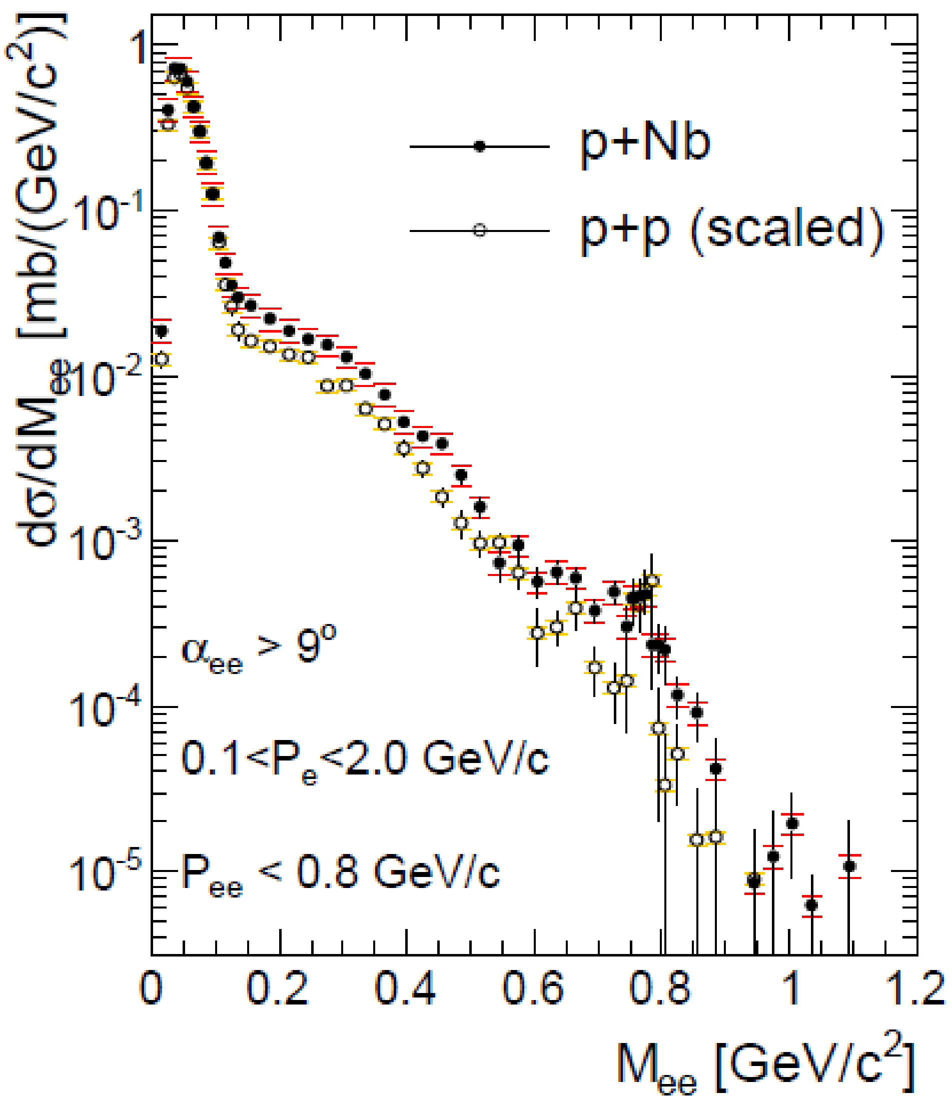


Compared to CLAS and KEK-E325 better coverage of slow vector mesons
→ compare high and low momentum vector mesons with p+p reference

Fast and slow vector mesons

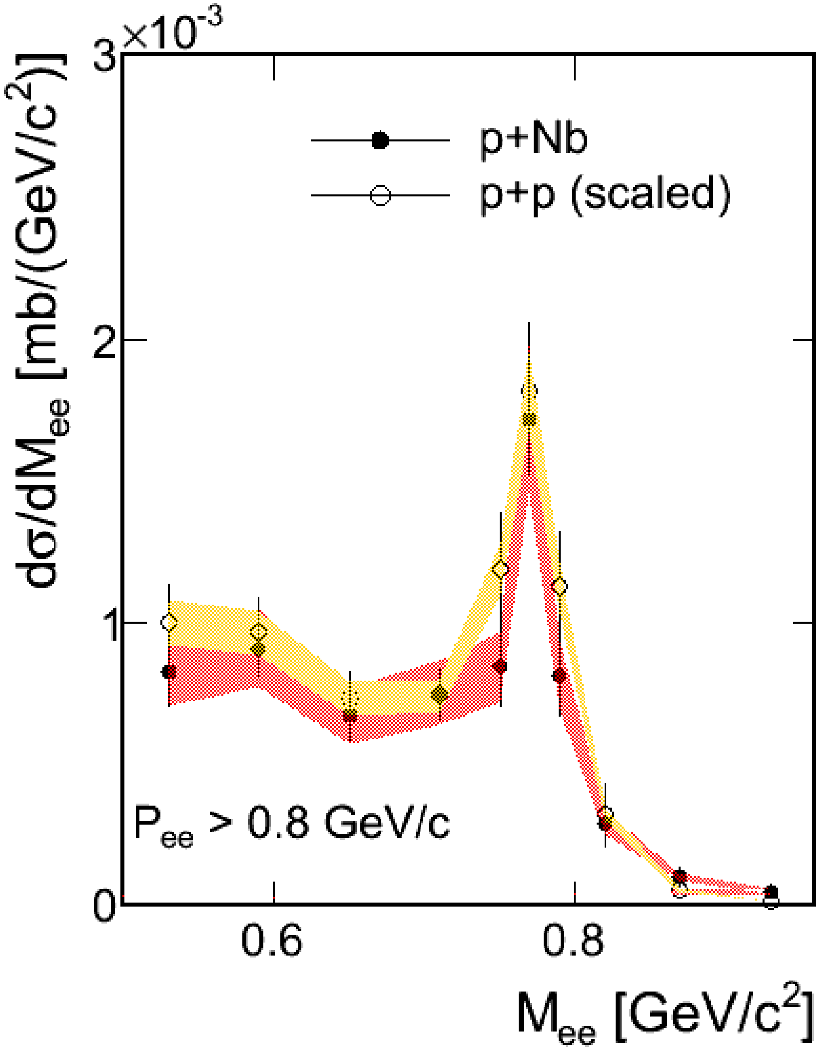


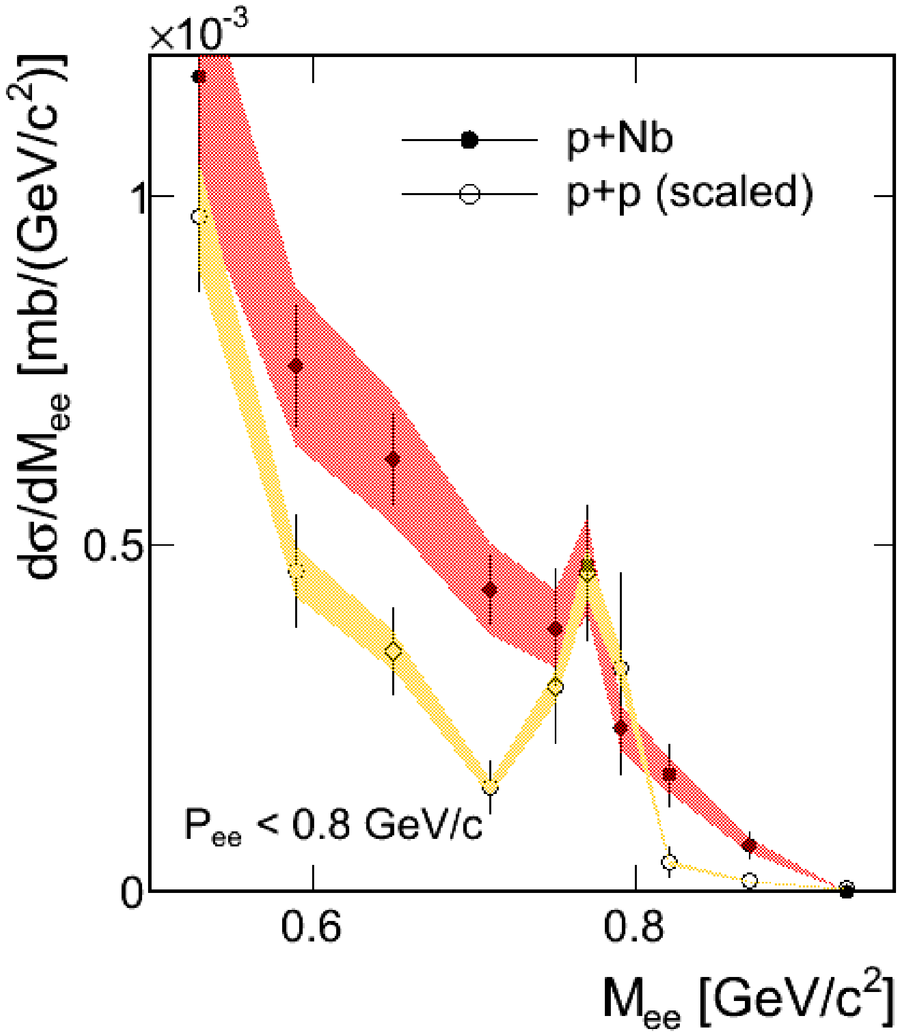
Scaled p+p data agree with p+Nb data



Excess in low and vector meson mass region

Fast and slow vector mesons

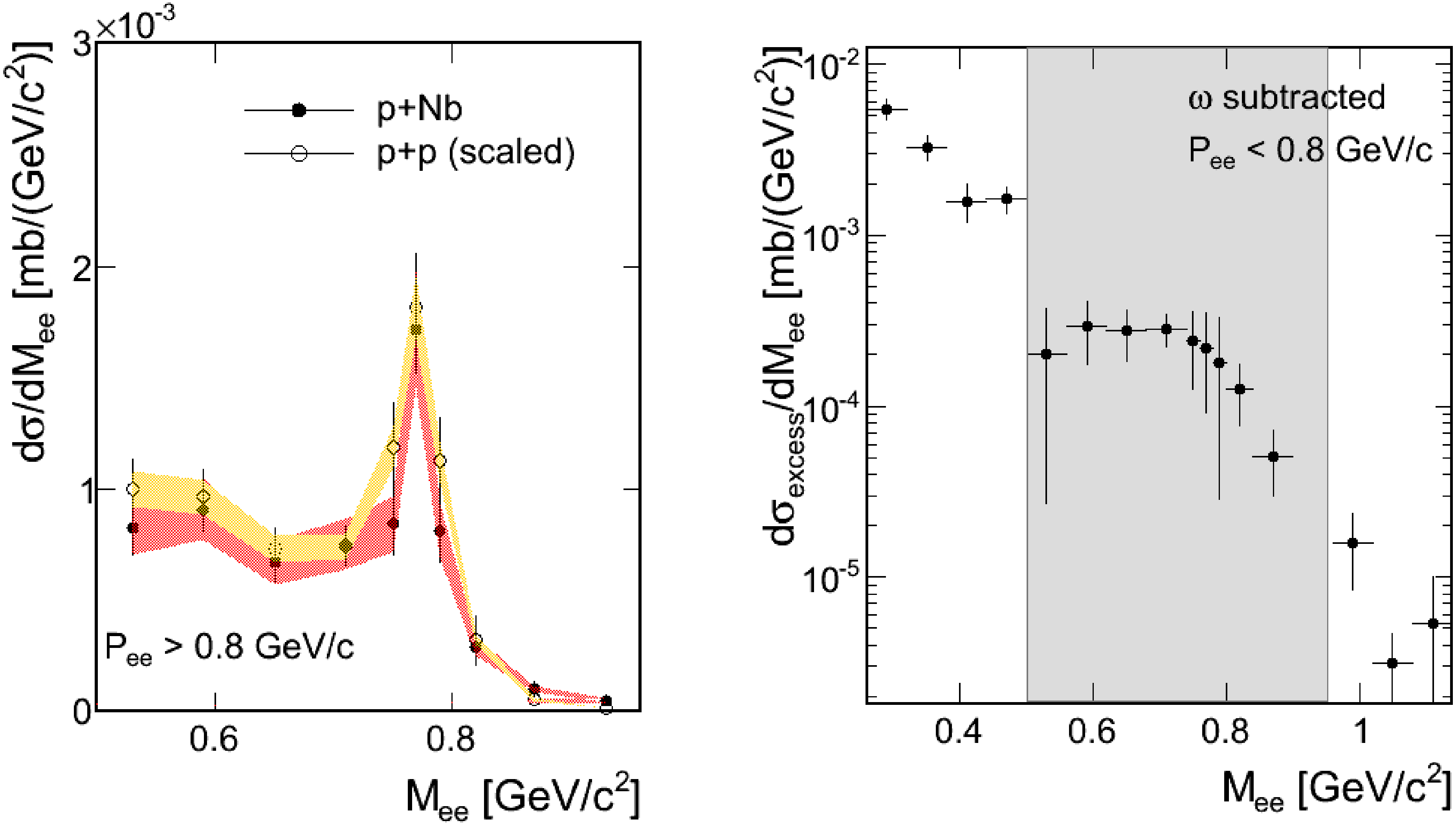




High momentum: pairs no significant difference in line shape of dielectrons and ω mesons

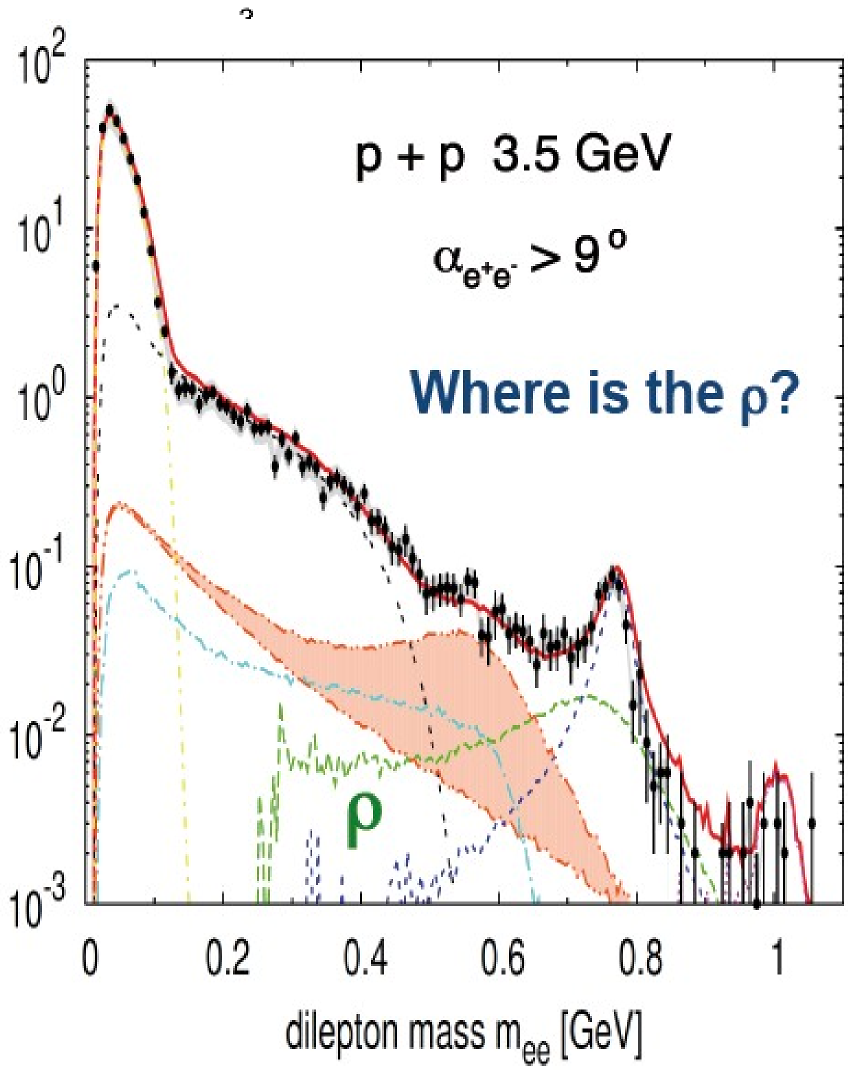
Low momentum: strong difference due to additional ρ -like contribution and suppression of ω 's

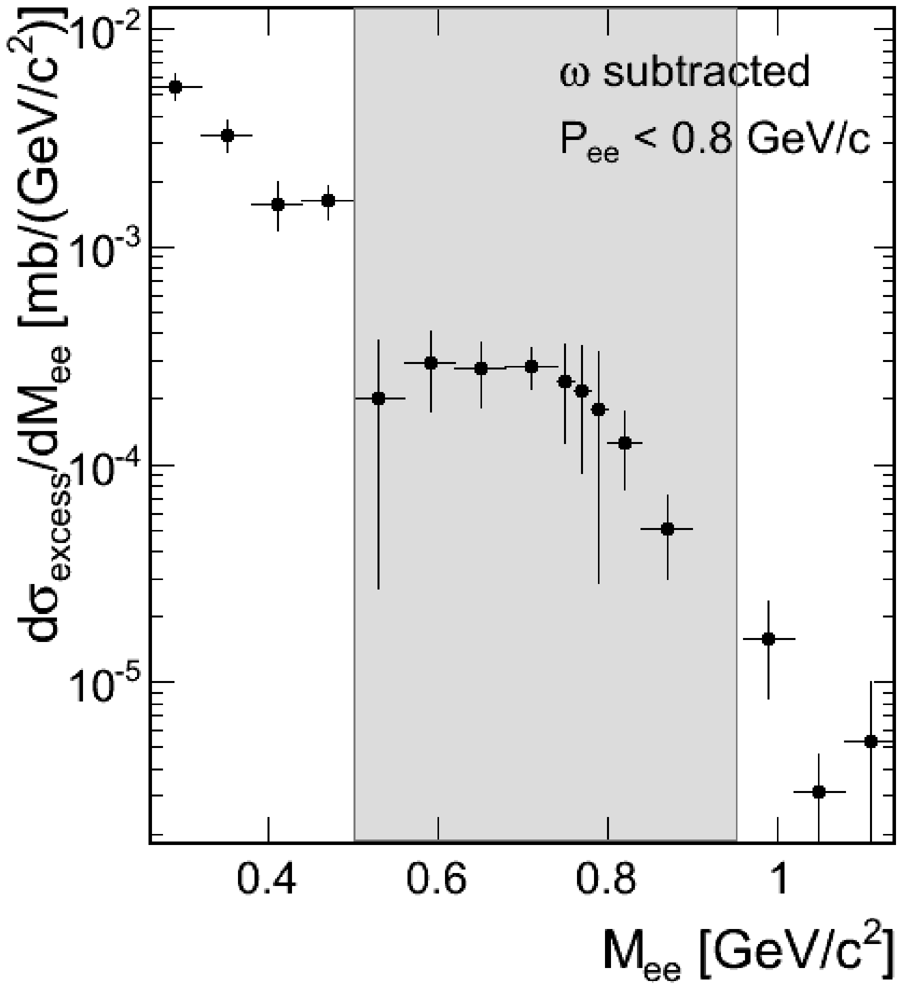
Fast and slow vector mesons



Looks familiar?

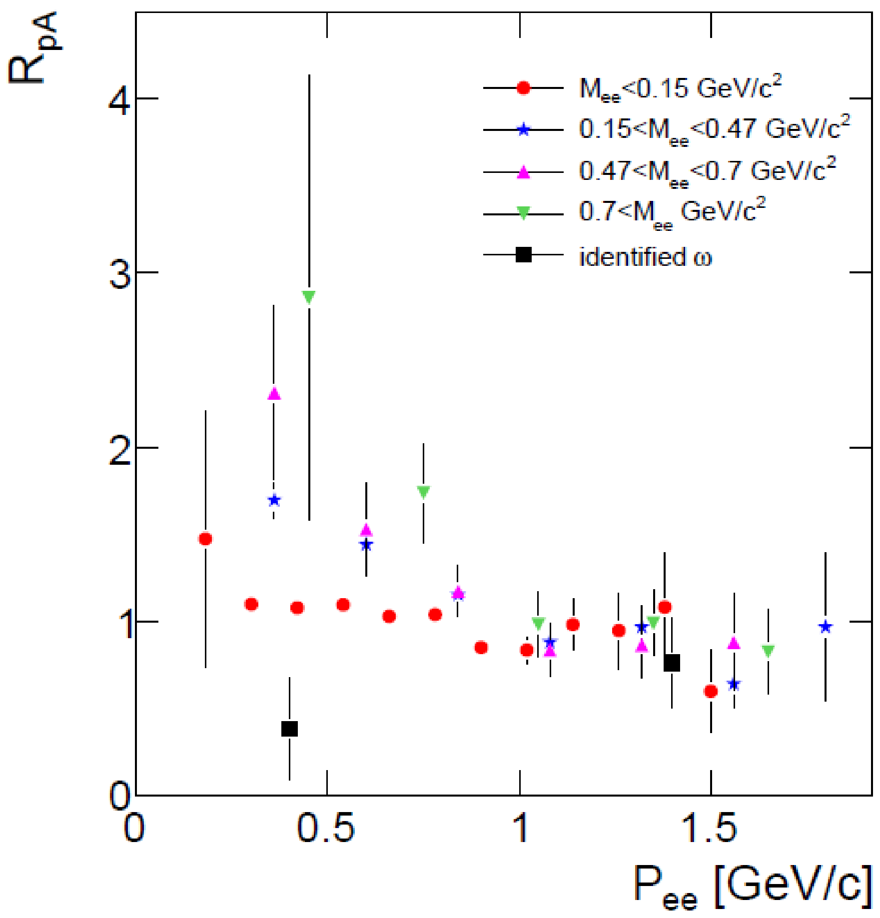
Fast and slow vector mesons





Looks familiar?

Nuclear modification factor as function of the momentum



Two opposite effects:

- absorption

- secondary particle production

Rise in all invariant mass regions for low P_{ee}:

Secondary particle production stronger than absorption, except for the ω meson.

- Reduced dielectron yield due to strong broadening in medium

$$N_{e^+e^-} \propto \Gamma_{e^+e^-} \cdot \tau_{meson} \propto \frac{\Gamma_{e^+e^-}}{\Gamma_{tot}}$$

$$\Gamma_{tot} = \Gamma_{vac} + \Gamma_{med}$$

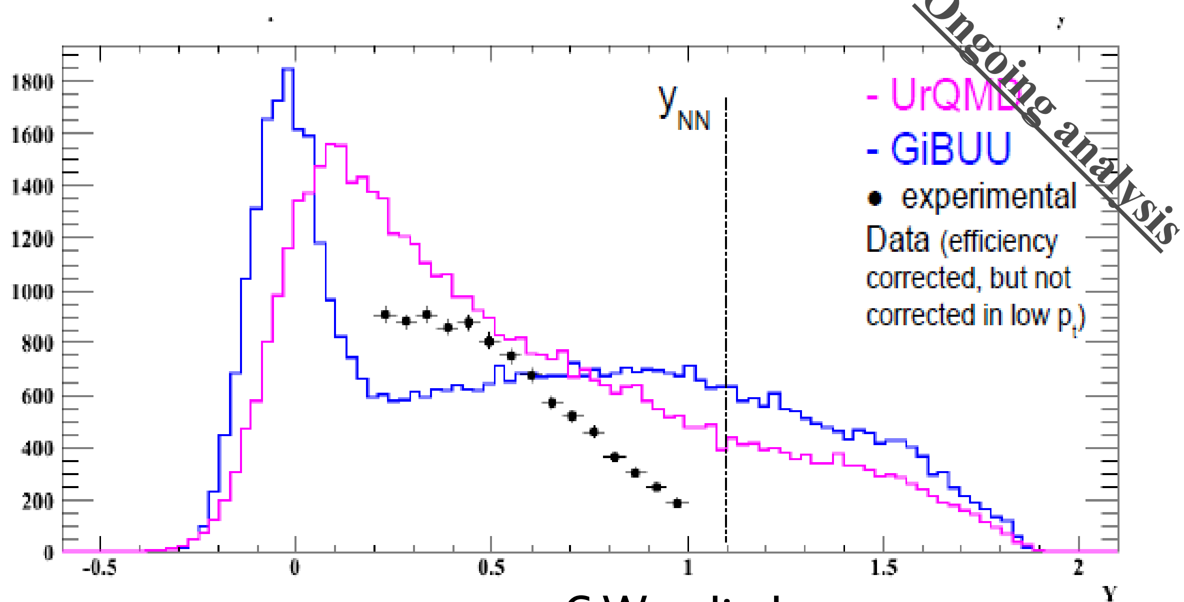
Two aspects of in medium modifications:

- absorption of particle like states (ω)

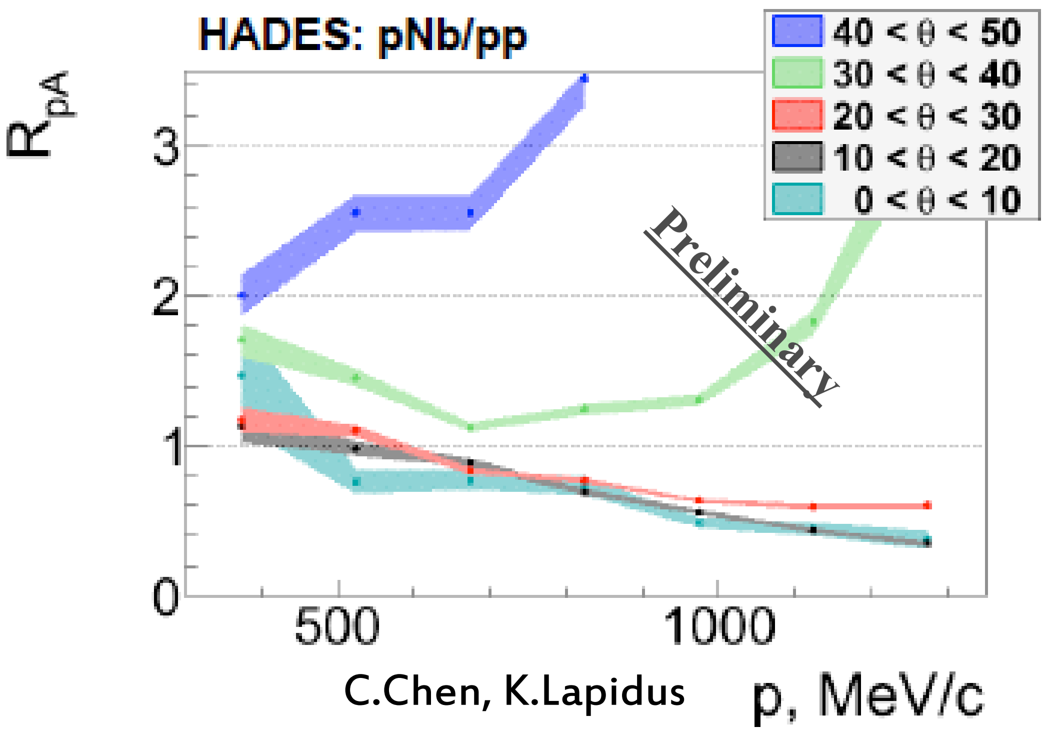
- modification of the dielectron shape

Characterization of the system and KN potential

Constrains for bayron kinematics:
rapidity distributions of Λ **hyperons**



C.Wendisch

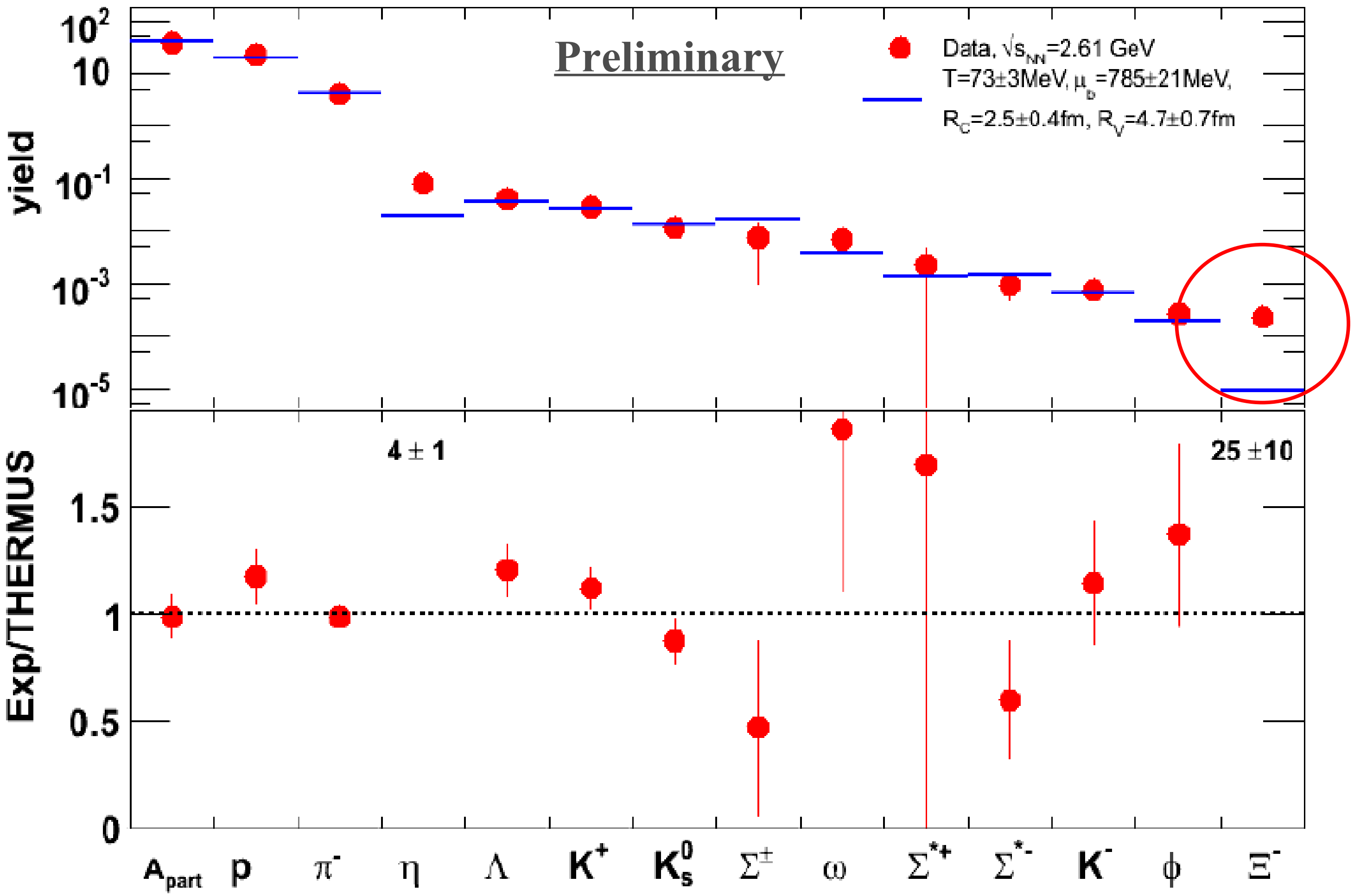


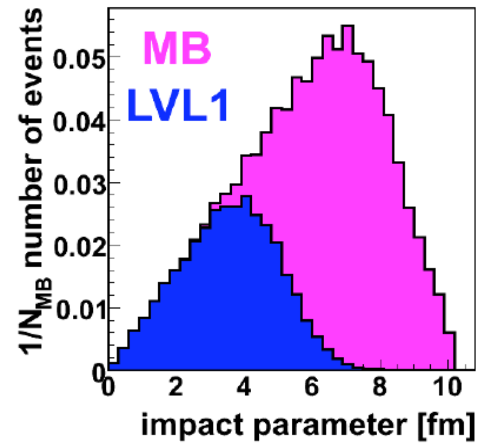
C.Chen, K.Lapidus

R_{pA} for **neutral kaons** for different polar angles:
- Strong rescattering of forward kaons
- Sensitive to KN potential

HIC

Ar+KCl @ 1.76 A GeV: Hadron yields





- η meson yield not described

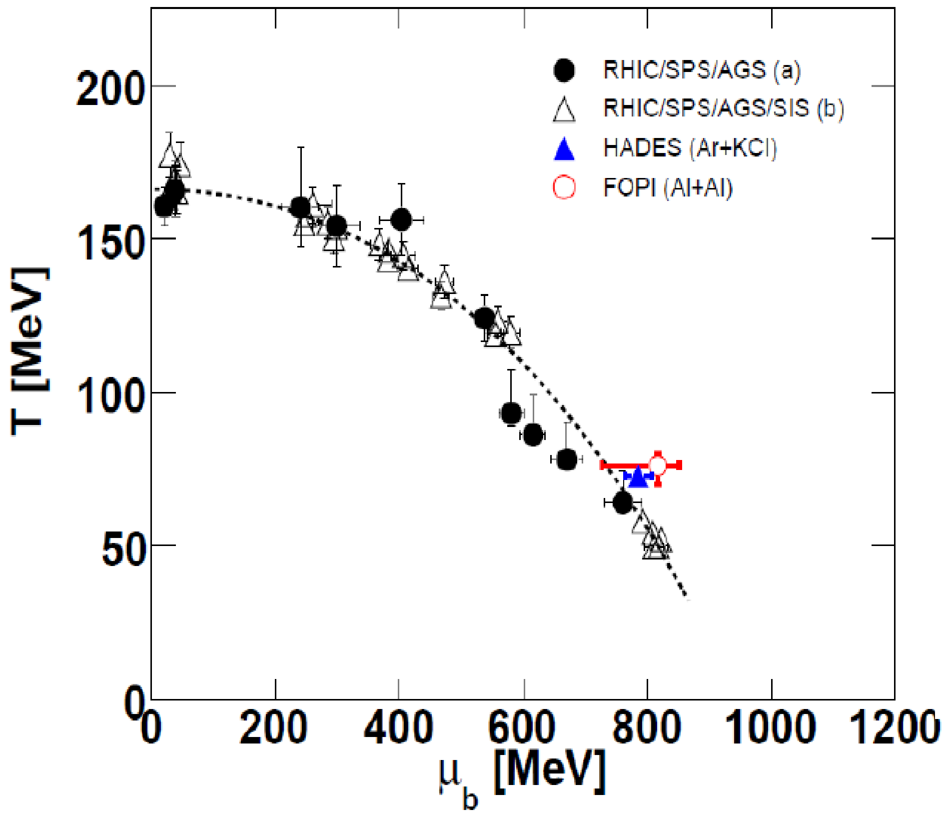
- ϕ meson described without suppression parameter!

- Probability to produce a strange quark pair
  $M_{ss} \approx 0.05$
  $\rightarrow M_{\Xi} \approx 0.1\, M_{ss}^2$

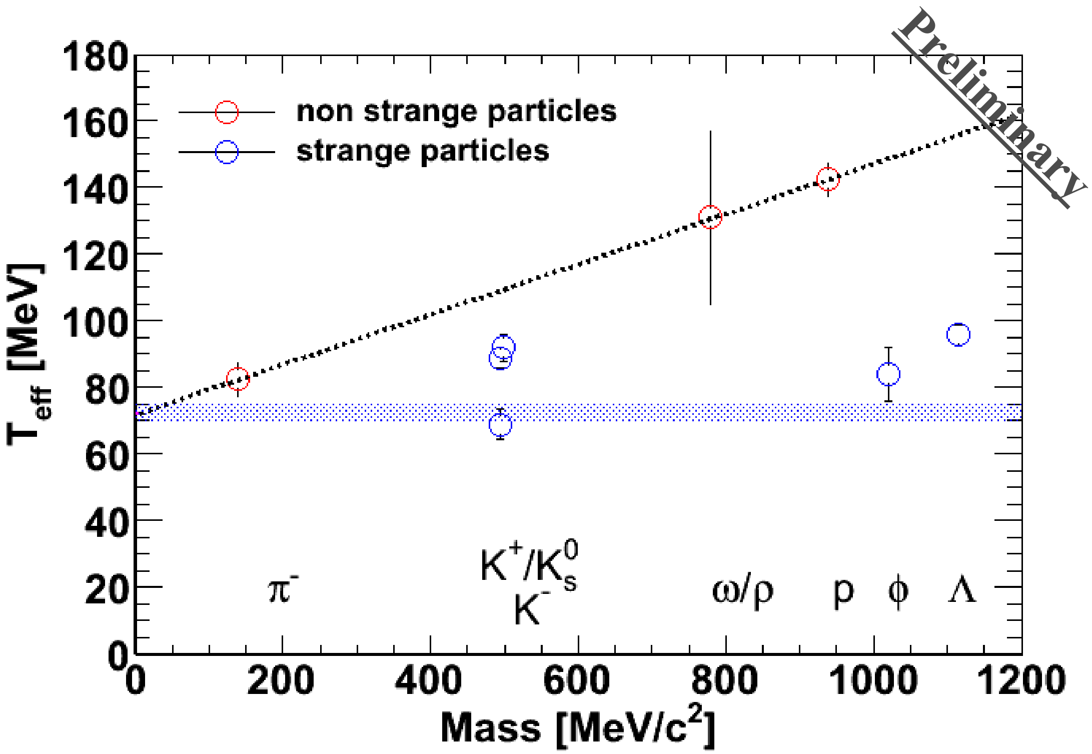
THERMUS: S. Wheaton, J.Cleymans: Comput.Phys.Commun.180:84-106,2009
SHM fit: Eur. Phys. J.\ A 47 (2011) [arXiv:1010.1675 [nucl-ex]].

η interpolated from TAPS measurement

Ar+KCl @ 1.76 A GeV: Freeze out:



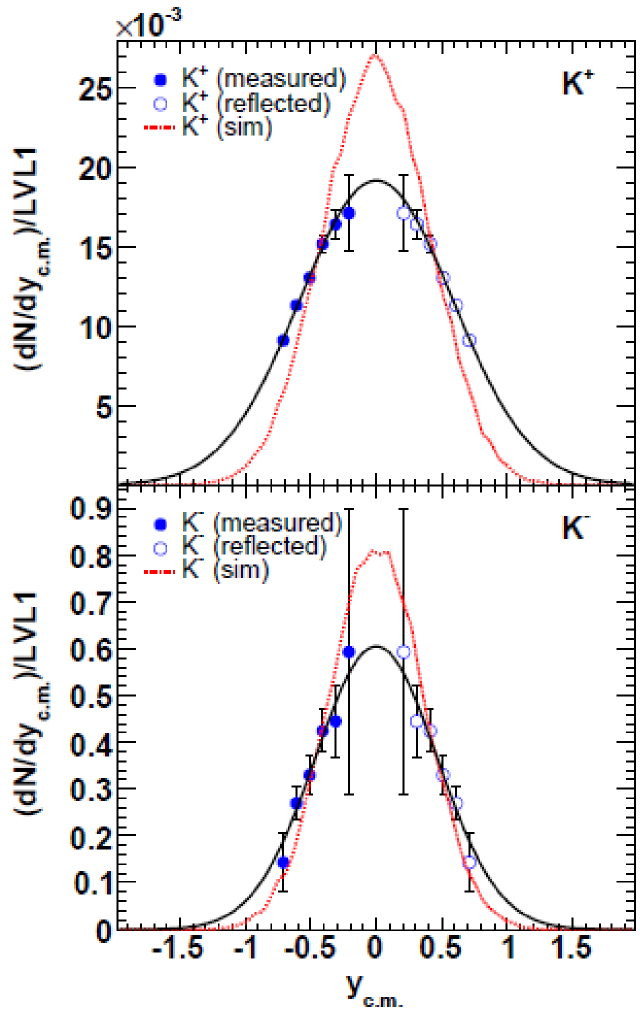
Obtained freeze out point in the T-μ plane fits into the previously obtained systematics



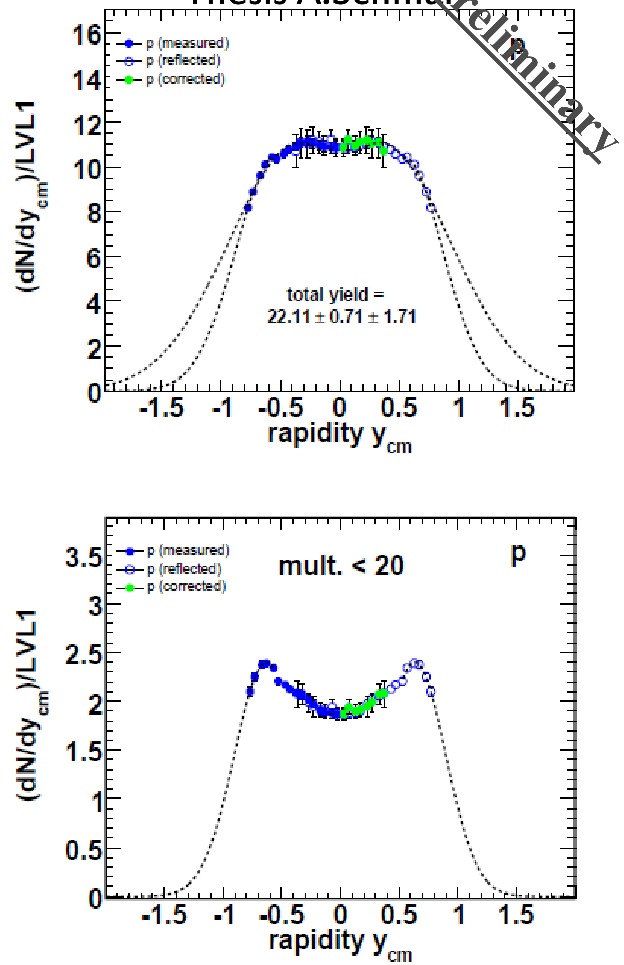
- K^- not feed down corrected for Φ decays
- Low hadronic cross section of strange particles? Contradiction to experiments probing cold nuclear matter?
  (Anke, KEK-E325, Spring-8)

G. Agakishiev et al. [HADES Collaboration]. Hyperon production in Ar+KCl collisions at 1.76A GeV. Eur. Phys. J., A 47(21), [arXiv:1010.1675 [nucl-ex]]. 2011

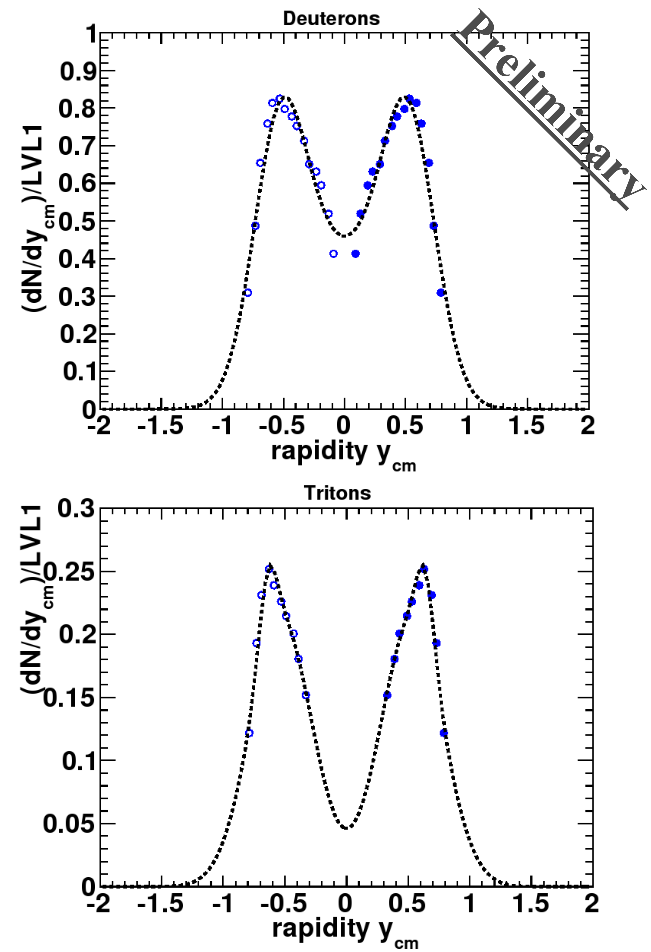
Ar+KCl @ 1.76 A GeV: Rapidity distributions



Thesis A.Schmah



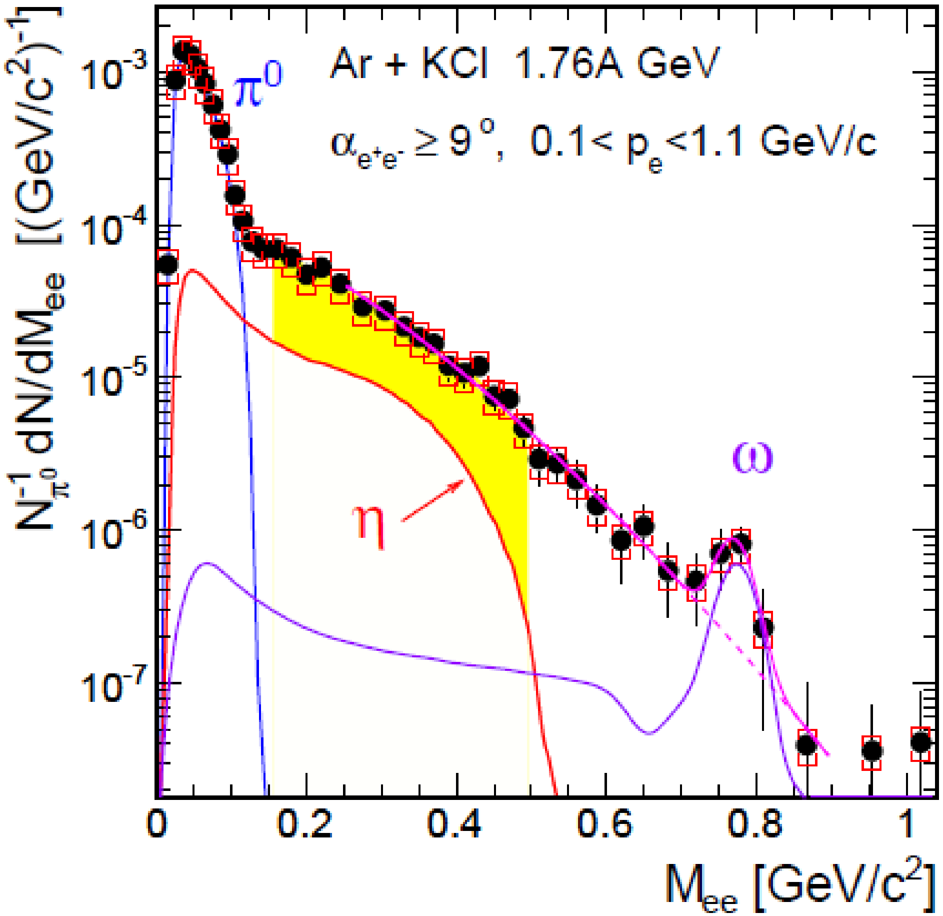
Thesis H.Schuldes

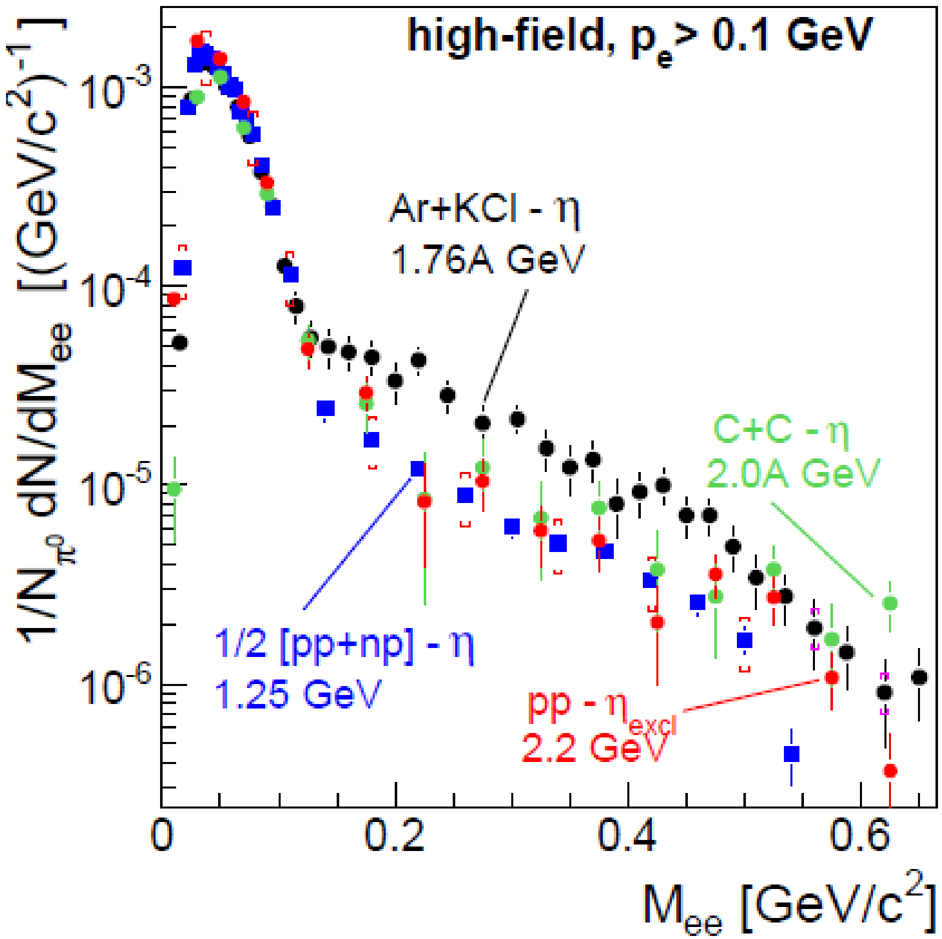


Widths of rapidity distributions deviate from thermal source already for mesons, 2 peak structure for fragments and protons for peripheral collisions.

No indication for static thermal source at mid-rapidity.

Ar+KCl @ 1.76 A GeV: low mass dielepton enhancement





First measurements of ω's at these energies
subthreshold + electromagnetic decay channel:
$\rightarrow$ **50 million events for one ω!**

Excess over long-lived cocktail components

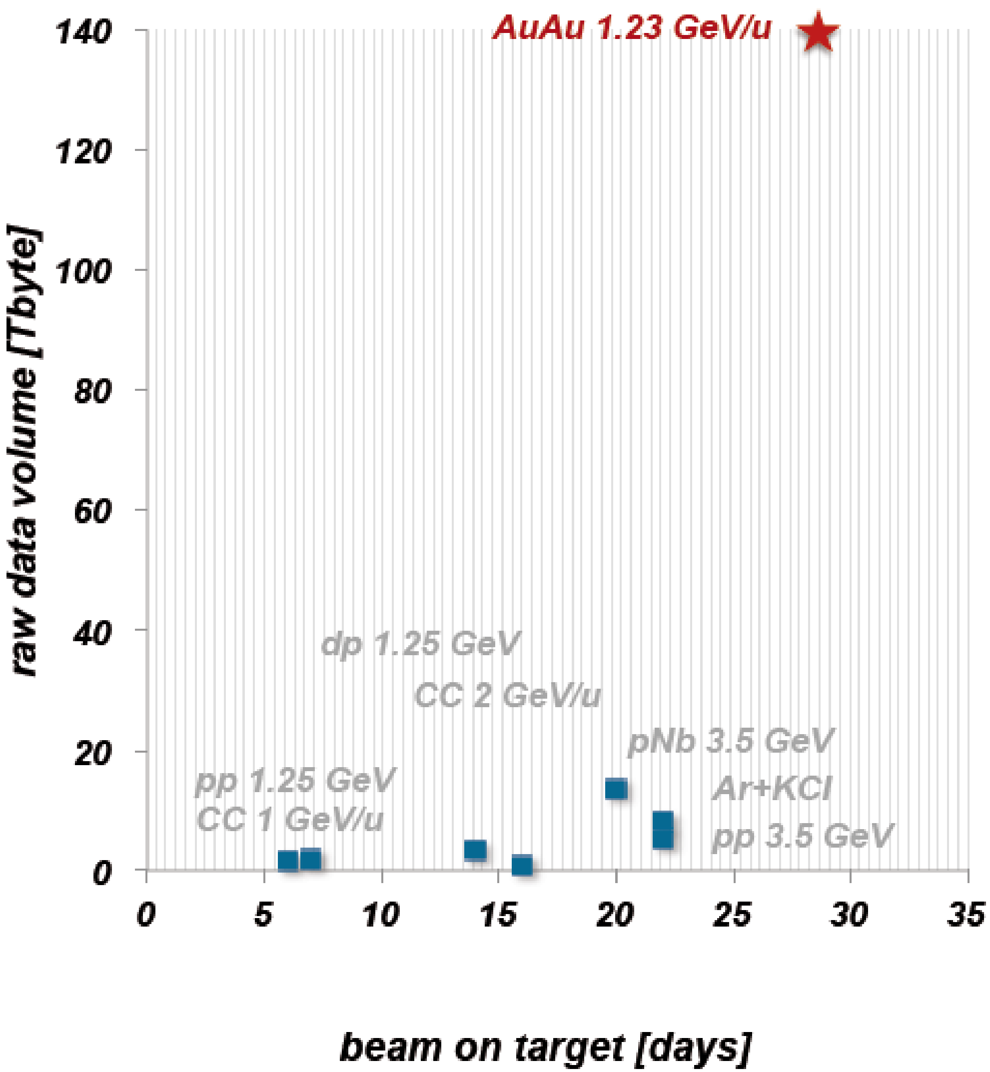
- C+C data agree with elementary reference
- Ar+KCl: radiation from the medium

Due to enhanced contributions of baryonic resonances or modification of the ρ meson?

$\rightarrow$ **Is this a relevant question to ask?**

Phys.RevC84:014902, 2011

Au+Au @ 1.25 A GeV: April 2012



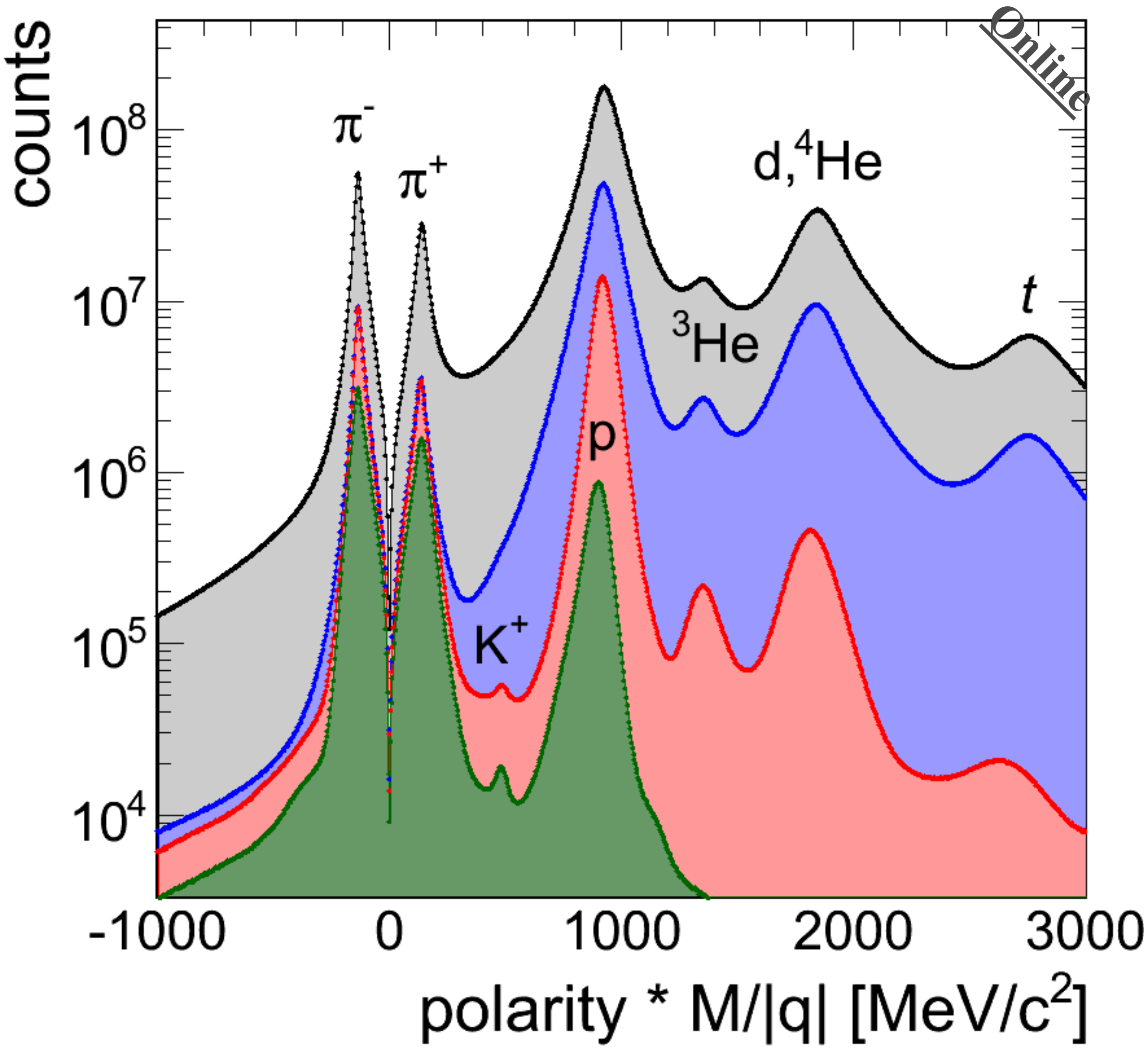
Several major upgrades:

- DAQ and readout electronics
- Time of flight wall (RPC)
- Drift chambers
- Forward wall
- Tracking algorithm

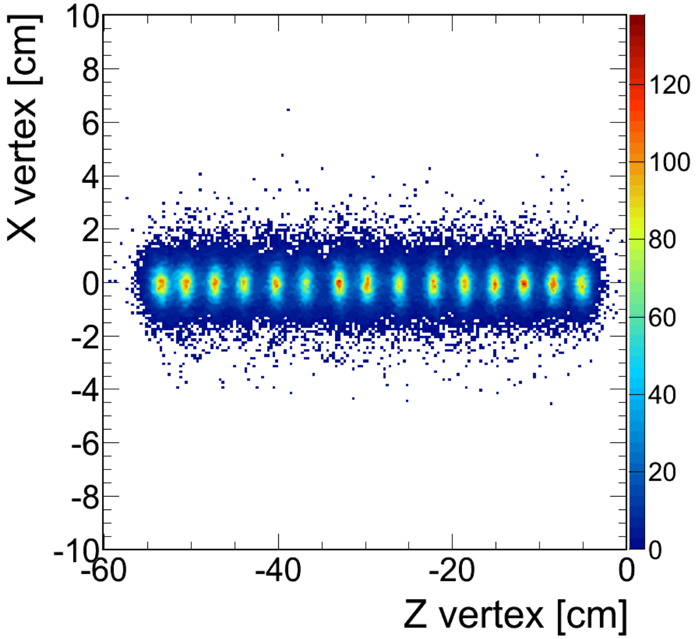
- 557 hours beam Au on Au target
- (1.2 - 1.5) x 10^6 ions per second
- 8 kHz trigger rate
- 200 Mbyte/s data rate
- 7.3 x 10^9 events
- 140 x 10^{12} Bytes of data

Au+Au @ 1.25 A GeV: online spectra

T.Galatyuk, K.Gill



O. and V. Pechnov



-Segmented target (to minimize γ conversion)
-online spectra, including cuts for identification of charged kaons (subthreshold)

Dielectron excess and multi-strange particles??

Summary

Elementary collisions:

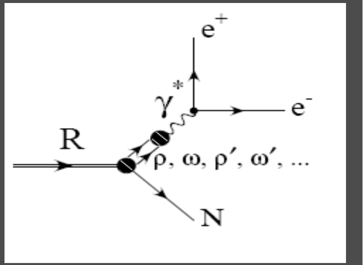
- Strong isospin effects for energies around 1 GeV
- ρ line shape deviates from ideal Breit-Wigner already in p+p due to the production via resonances
- Precision measurements of strange resonances lying close to KN threshold, L1405 pole mass below 1.4 GeV/c^2

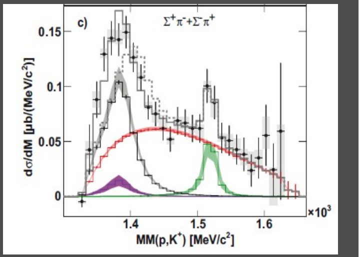
Cold nuclear matter:

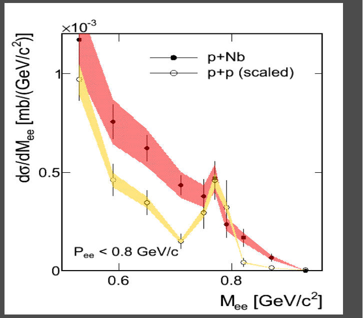
- Two aspects of medium modification: Suppression of ω mesons and modifications of dielectron line shape for P_{ee}<0.8 GeV/c
- Strange particles can be used to characterize the system and to study the KN potential

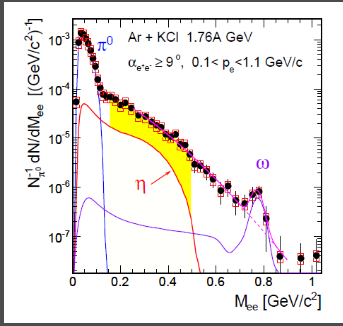
HIC:

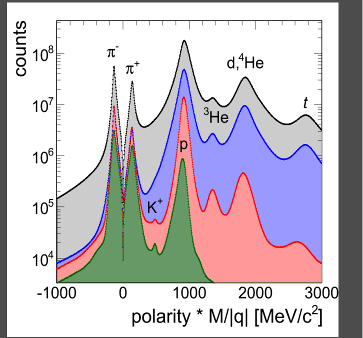
- Particle yields are described reasonable by a thermal fit except the Ξ^-
- No indication for stopping of particles with masses larger 1 GeV/c^2
- Enhancement in low mass dilepton yield
- Successful Au+Au run in April, 140 x 10^{12} Bytes of data wait to be analyzed









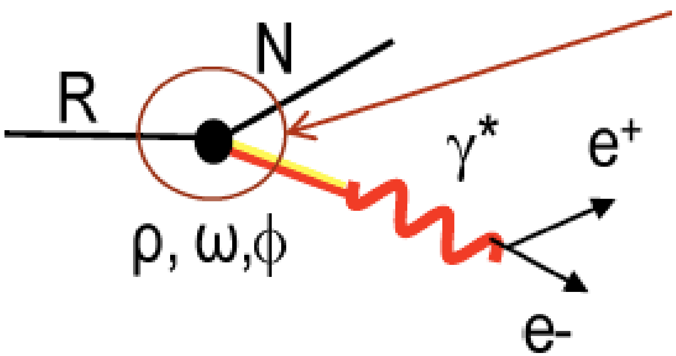


Outlook I: Pion beam

Elementary reactions:

$\pi^- + p \rightarrow R \rightarrow e^+e^-$

Direct mesaurement of baryonic resonance EM from factors

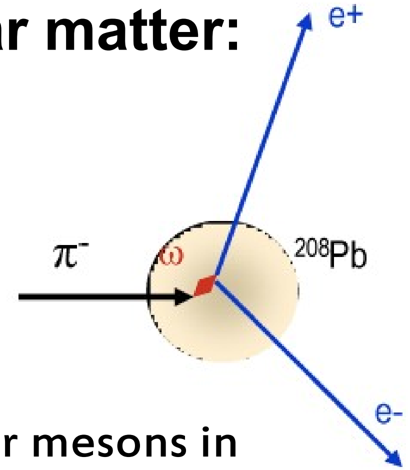


$\pi^- + p \rightarrow R \rightarrow N + \pi + \pi$

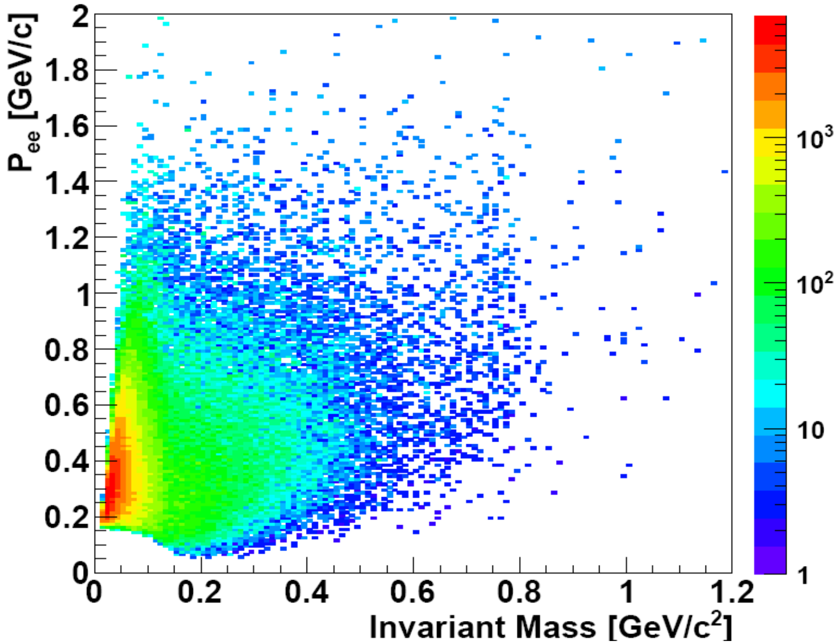
PWA: branching ratios of baryonic resonances

Cold nuclear matter:

$\pi^- + A \rightarrow X + e^+e^-$



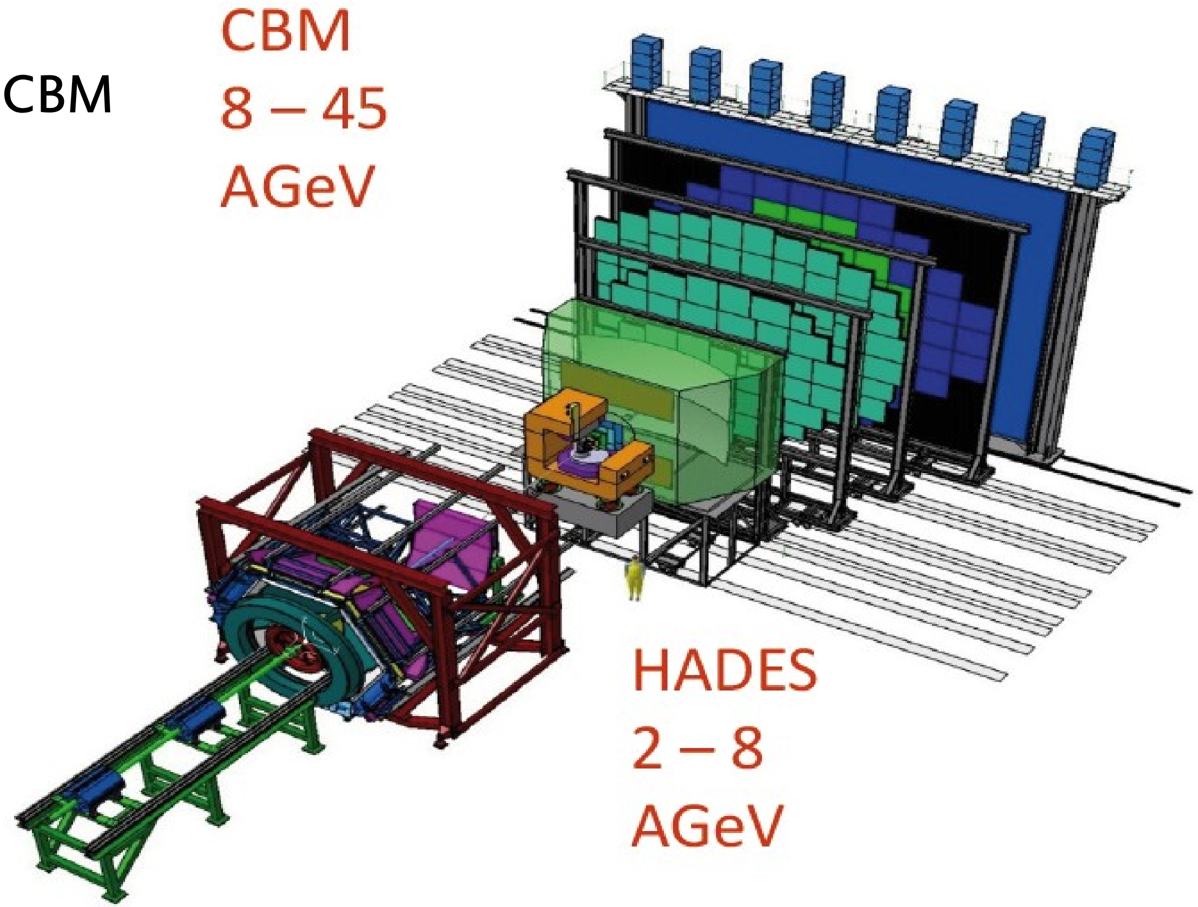
Recoilless vector mesons in nuclear matter (from original HADES proposal)



Outlook II: SIS 100

HADES @ SIS100:

- Close the gap between SIS18 and CBM
- Multi strange hadron and lepton pair excitation functions
- Calibration measurements for CBM



The HADES collaboration

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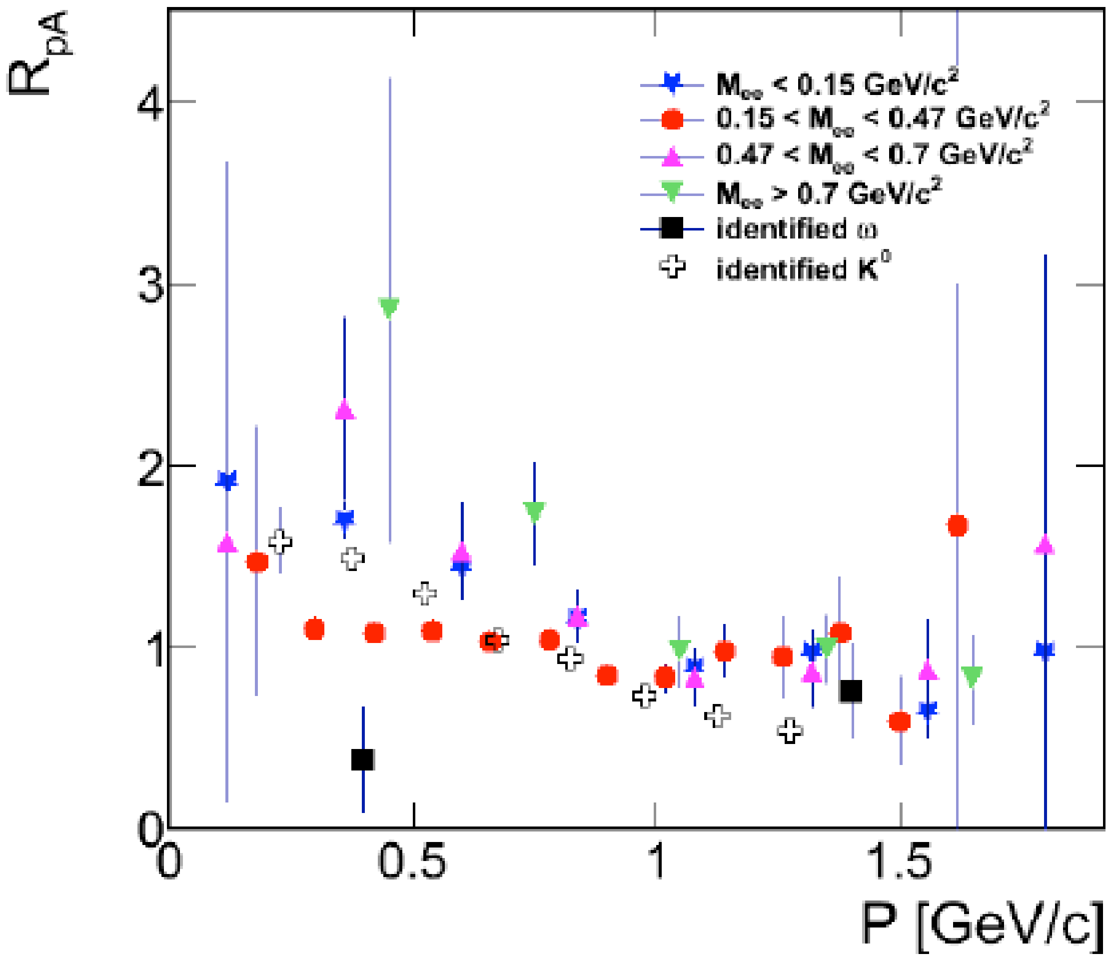
Backup

1. Modifications of Vector Mesons: Overview

experiment	reaction	momentum [GeV/c]	ρ $\Delta\Gamma$ [MeV] Δm [%]	ω $\Delta\Gamma$ [MeV] Δm [%]	ϕ $\Delta\Gamma$ [MeV] Δm [%]
SPring-8	γ+A 1.5-2.4 GeV	p >1.0			$\Delta\Gamma \approx 56$
ANKE	p+A 2.83 GeV	p >0.6			$\Delta\Gamma \approx$ 29-46
KEK -E325	p+A 12 GeV	p >0.5	$\Delta\Gamma$=0 $\Delta m \approx$-9	$\Delta\Gamma$=0 $\Delta m \approx$-9	$\Delta\Gamma \approx 12$ $\Delta m \approx$-3
CLAS	γ+A 0.6-3.6 GeV	p >0.8	$\Delta\Gamma \approx 70$ Δm=0	$\Delta\Gamma > 130$	
CBELSA -TAPS	γ+A 0.7-2.5 GeV	p >0.0		$\Delta\Gamma \approx 130$ Δm=0	
CERES	Au+Pb 158A GeV	p_t >0.0	broadening favored		
NA60	In+In 158A GeV	p_t >0.0	$\Delta\Gamma$: central. dep. Δm=0		



R_{pA}
M_{ee} < 0.15 GeV/c^2
0.15 < M_{ee} < 0.47 GeV/c^2
0.47 < M_{ee} < 0.7 GeV/c^2
M_{ee} > 0.7 GeV/c^2
identified ω
identified K^0
P [GeV/c]