Studying ρ-N couplings with HADES in pion-induced reactions

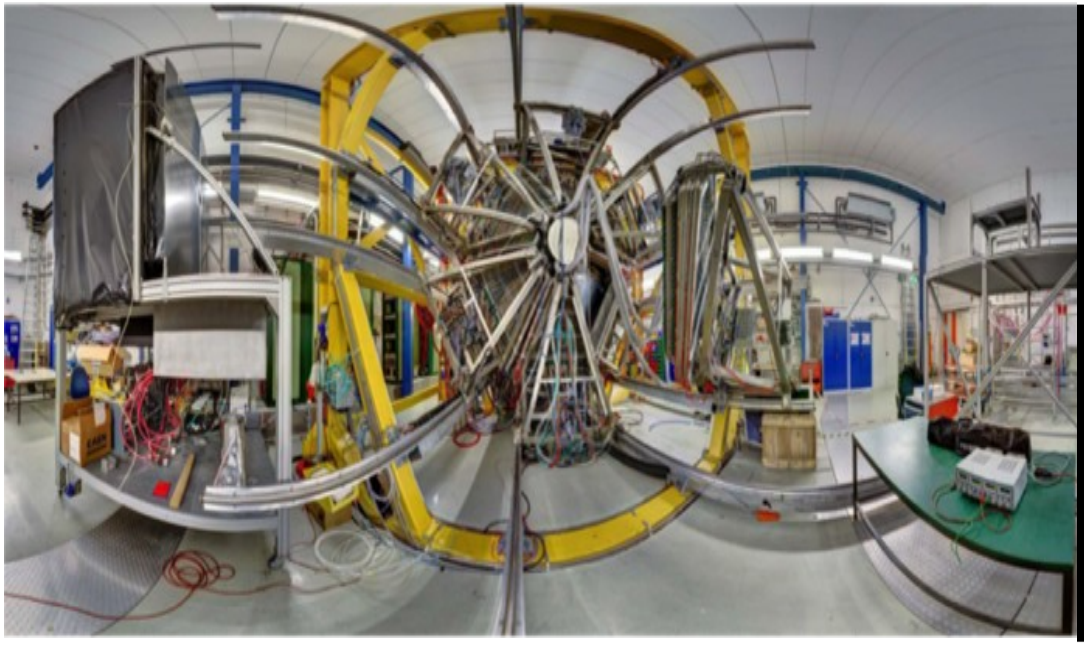
Federico Scozzi for the HADES Collaboration
IPN Orsay/TU Darmstadt

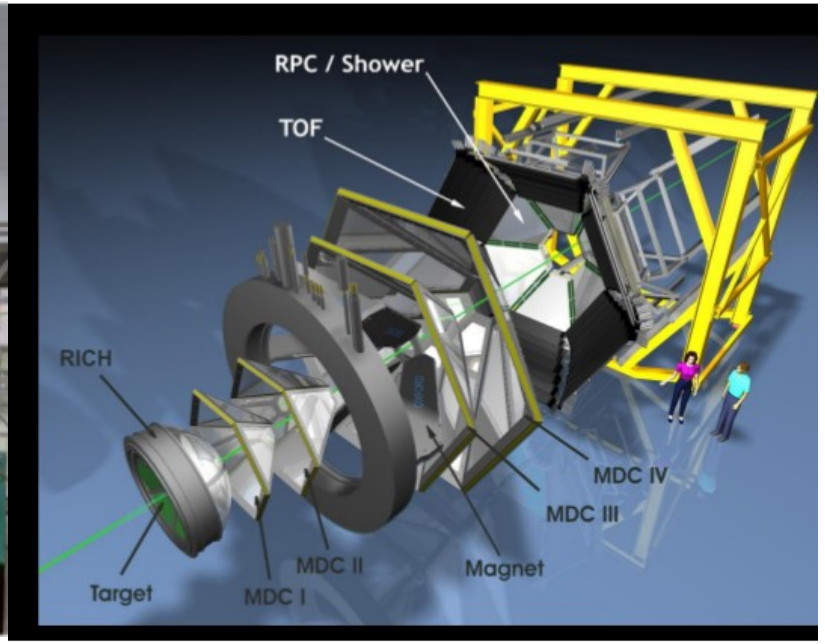
HADES detector

TECHNISCHE UNIVERSITÄT DARMSTADT

- Located at SIS18, GSI
- Beams: heavy-ions, protons, **pions**
- Low-mass fixed-target experiment
- Hadron and lepton identification

- Acceptance: 85% azimuthal coverage, 18-85deg in polar angle
- 80.000 channels
- Fast DAQ: 50kHz event rate

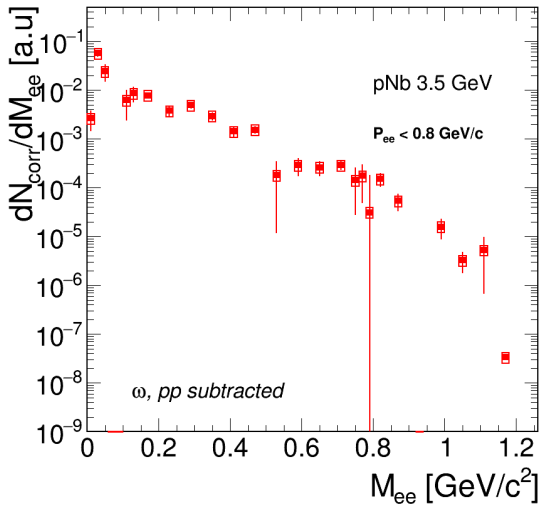




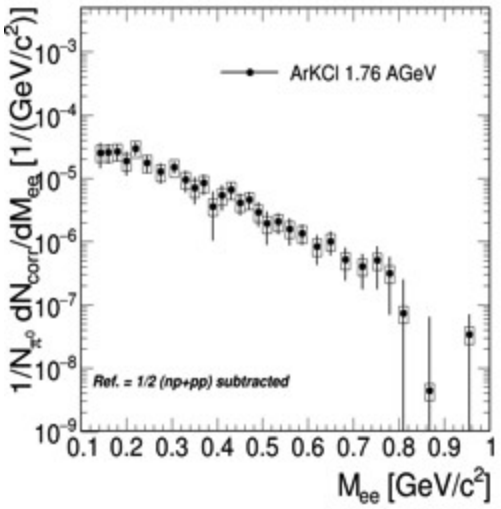
IPN ORSAY

Physics motivation

HADES: Phys.Lett. B715 (2012)

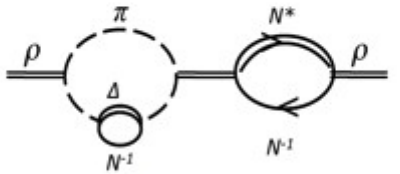


Phys.Rev.C 84 (2011) 014902



Dominant role of baryonic resonances

$$D_\rho(M,q;\mu_B,T) = \frac{1}{\left[M^2 - m_\rho^2 - \Sigma_{\rho\pi\pi} - \Sigma_{\rho B} - \Sigma_{\rho M}\right]}$$

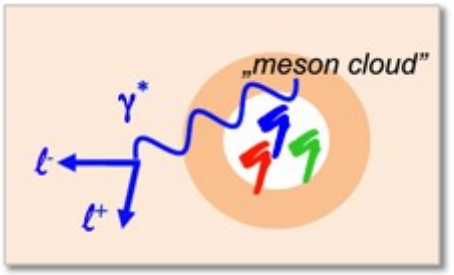


Additional contributions to the ρ-meson self-energy in the medium

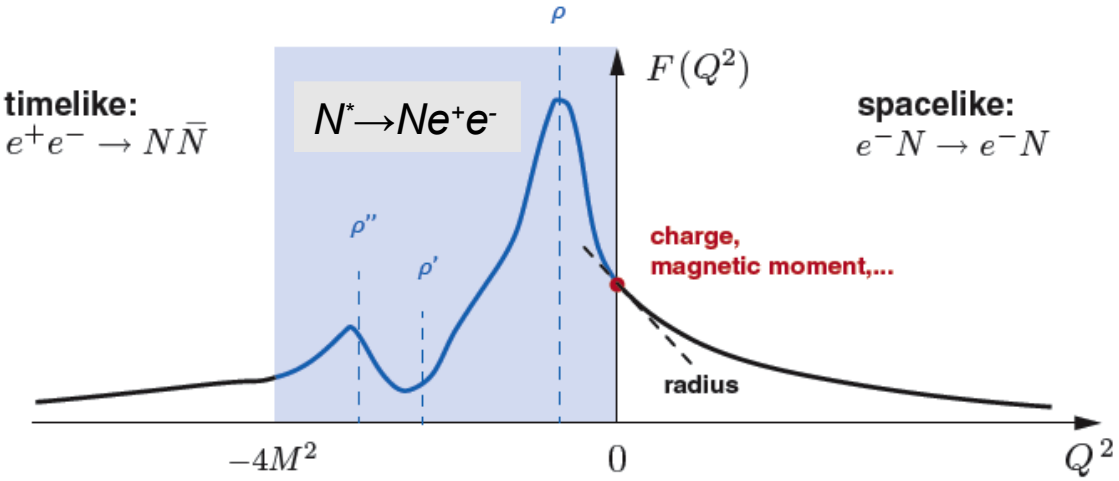
- Strong broadening of in-medium states
- Significant contribution from higher (than Δ) mass resonances

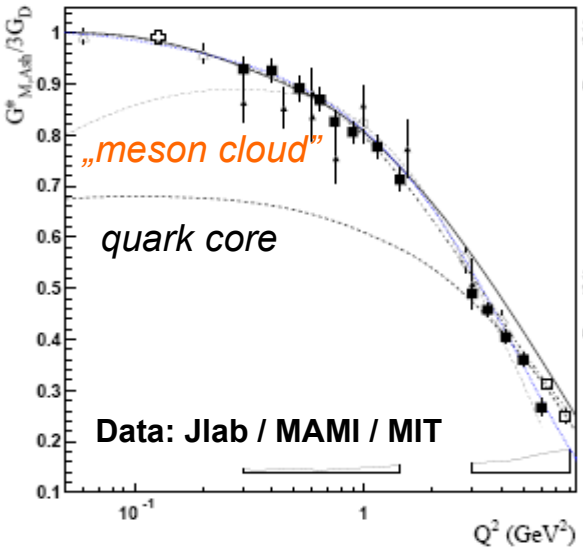
- Understanding of ρ-baryon coupling mechanism
- Crucial to better control medium effects

Physics motivation



- Study of electromagnetic structure of baryons
- Important role of pion cloud at small q^2



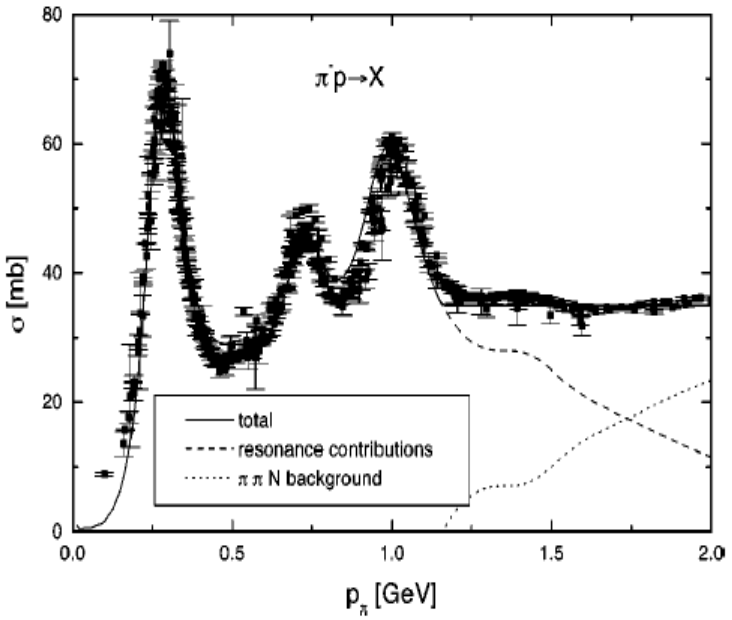


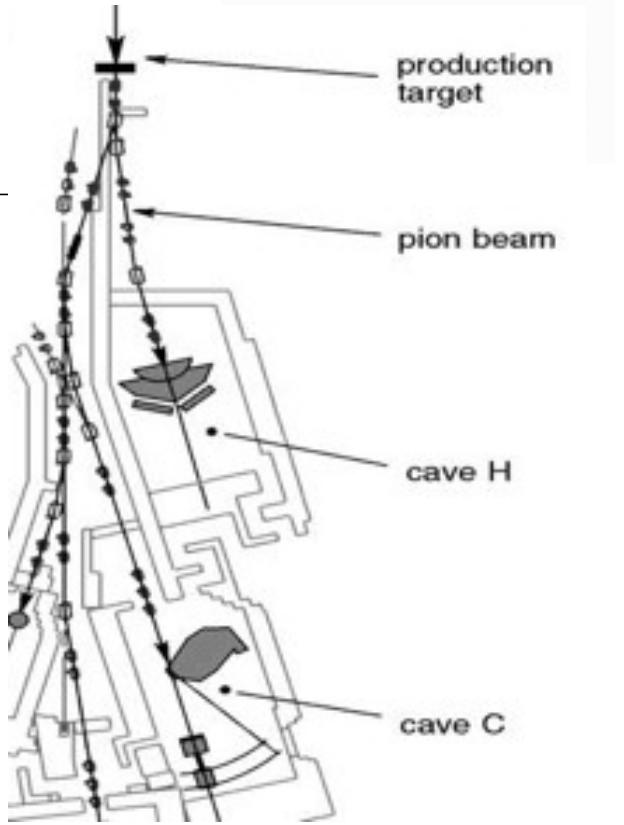
I.G. Aznauryan, V.D. Burkert Prog. Part. Nucl. Phys. 67, 1 (2012)

Pion beams with HADES

Secondary π momentum p_π = 0.69 GeV/c

- Excitation of N(1520) baryonic resonance
- Beam intensity I = 3-4 × 10^5 π/s
- Target: Polyethylene $(CH_2)_n$ and Carbon

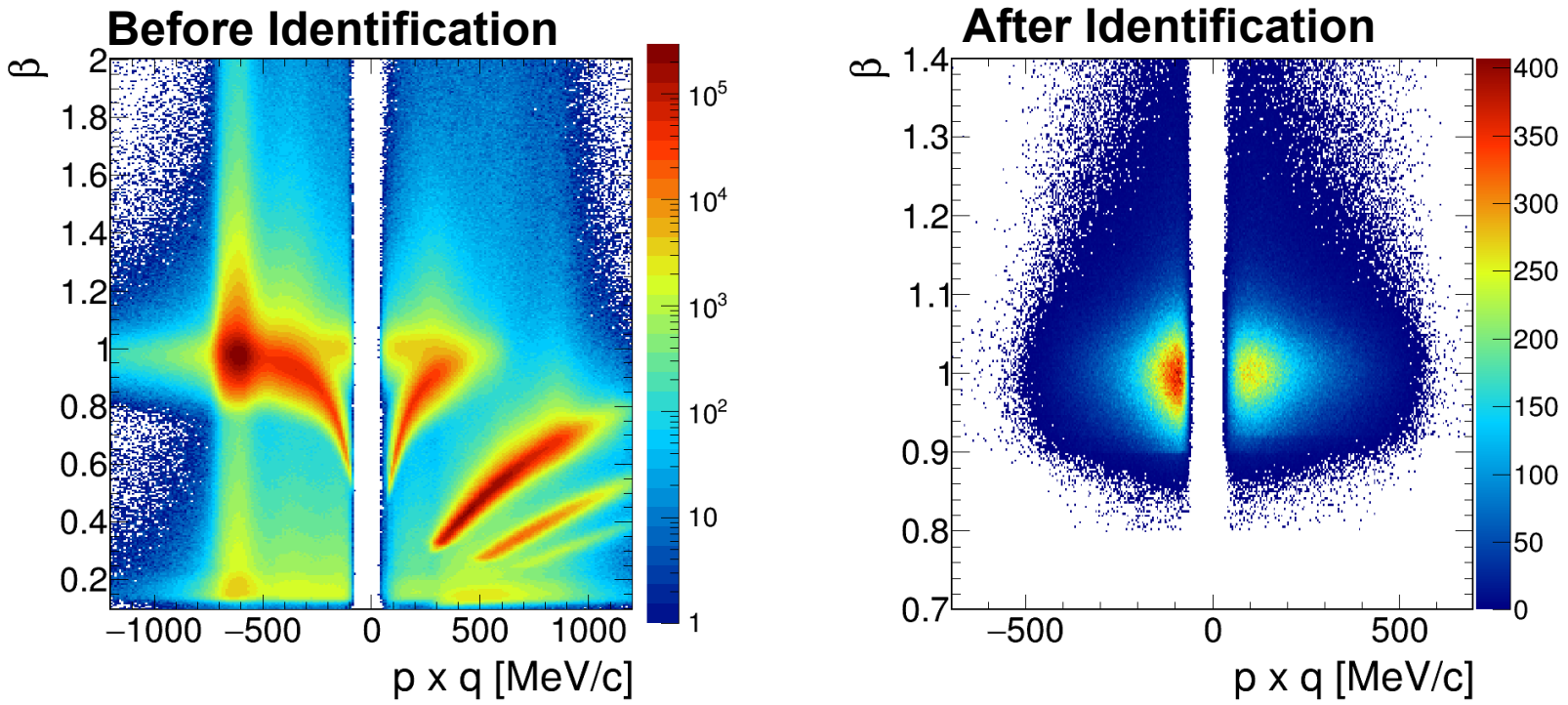




- Primary beam: 8 × 10^{10} N_2 ions/spill
- Spill: 4s cycle
- Total ~15 days of continues measurement

Electron ID

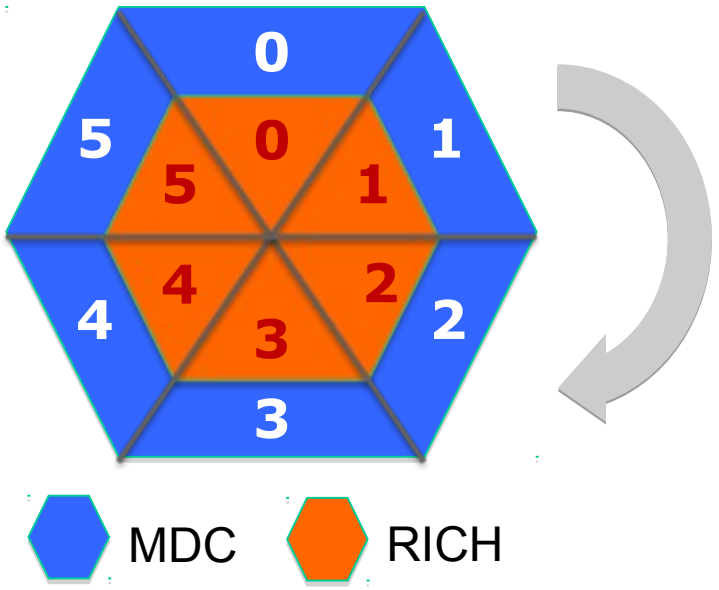
- Particle velocity vs momentum
- RICH information using backtracking algorithms

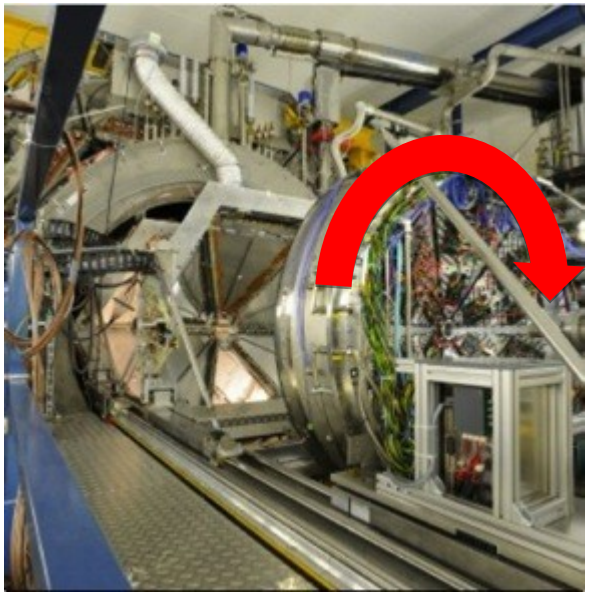


Signal-to-background estimates using RICH rotation technique

TECHNISCHE UNIVERSITÄT DARMSTADT

Characterizing "true" (signal) and "random" (background) track-RICH ring matches

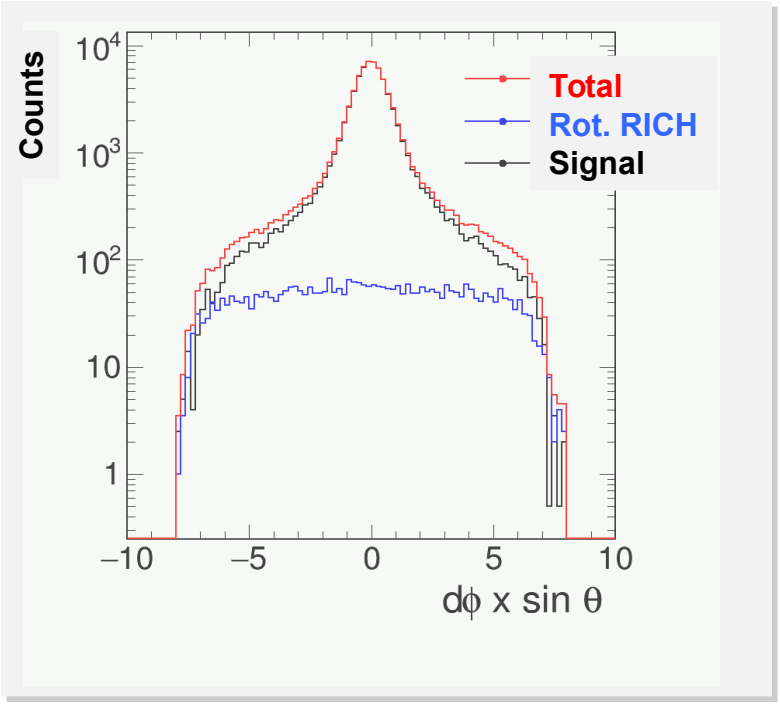




1. Rotate RICH software-wise by 60^{O}
2. Match tracks with rings
3. Lose correlations and get only random matches

IPN ORSAY

Purity of the electron sample

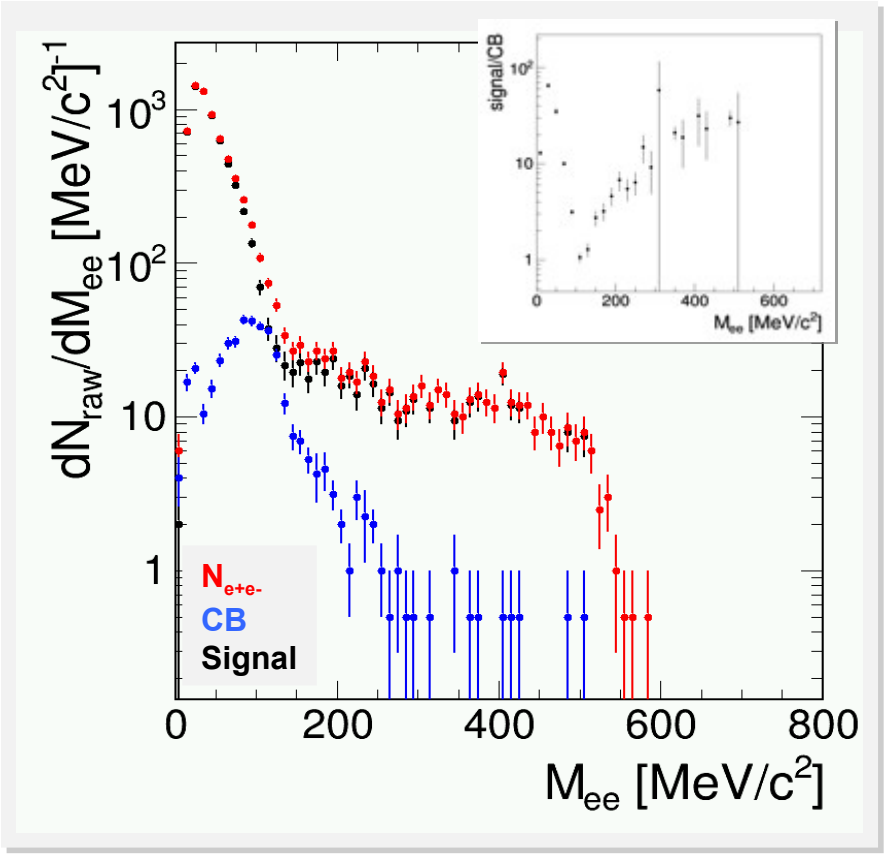


$$\text{Purity} = 1 - \frac{\text{rot. RICH}}{\text{not rot. RICH}}$$

p [MeV/c]	e^+	e^-
p < 100	99.7 %	99.1 %
100<p<200	99.4 %	98.7 %
200<p<300	97.7 %	93.7 %
300<p<400	97.3 %	89.0 %

- Background (red curve) from rotated RICH data sample
- Total (black curve) from the standard sample
- **Signal = Total - Background**

Inclusive invariant mass spectrum (raw)



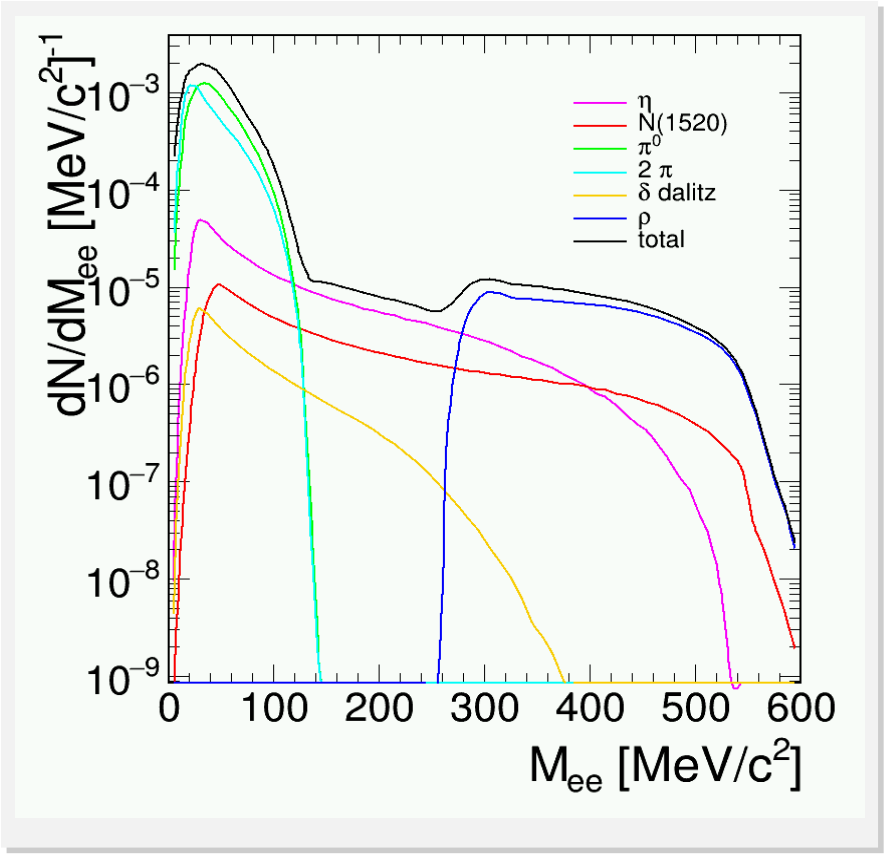
- Signal = N_{e+e-} - CB
- Same-event like-sign CB geometric and/or arithmetic mean

- **CB rejection cuts:**
  - Opening angle > 9°
  - Tracks with a not fitted track in the vicinity of 4° are excluded from further analysis

- Signal (M<140 MeV/c^2) = **13138**
- Signal (M>140 MeV/c^2) = **1084**

→ **Efficiency corrections based on Monte Carlo simulations**

Cocktail simulations



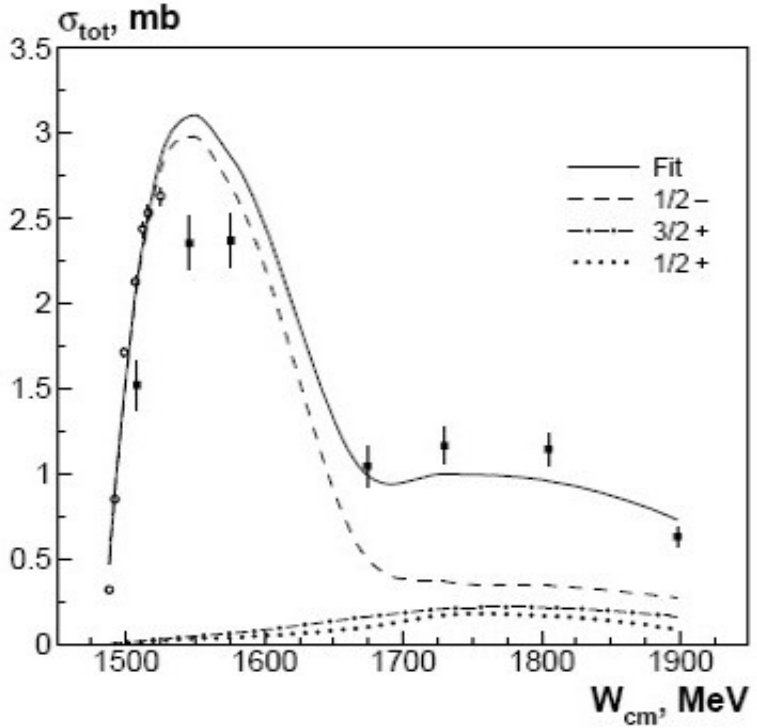
Sources:

- $\sigma(\pi^0)$ = 16.6 mb
- $\pi^- p \rightarrow N(1520) \rightarrow n e^+ e^-$ = 20 mb
  Wolf / Zetenyi „QED" model with BR = 4×10^{-5}
- $\sigma(\eta)$ = 0.3 mb (p); 0.7 mb (C)

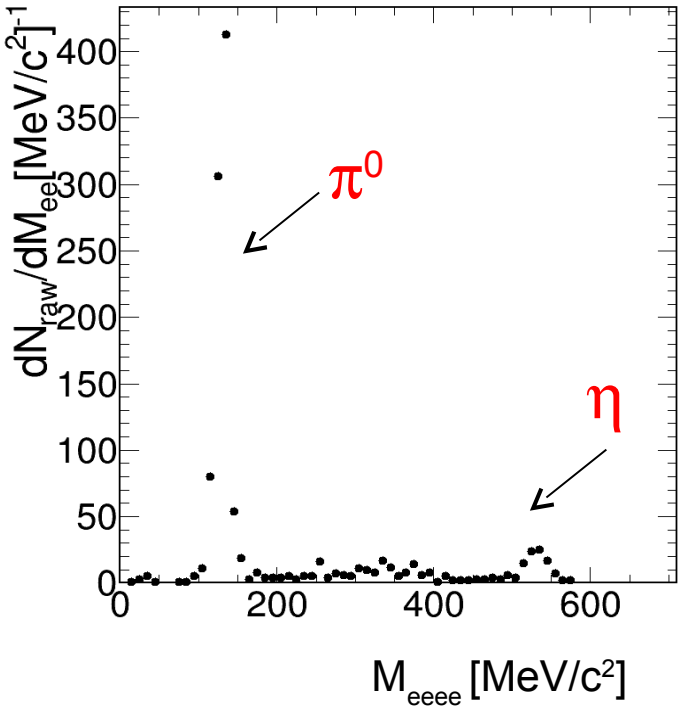
from Landolt-Bornstein

Searching for π^0 and η with full conversion method

A.V. Anisovichet al.(Bn-Ga) Eur. Phys. J. A 47 (2011)27

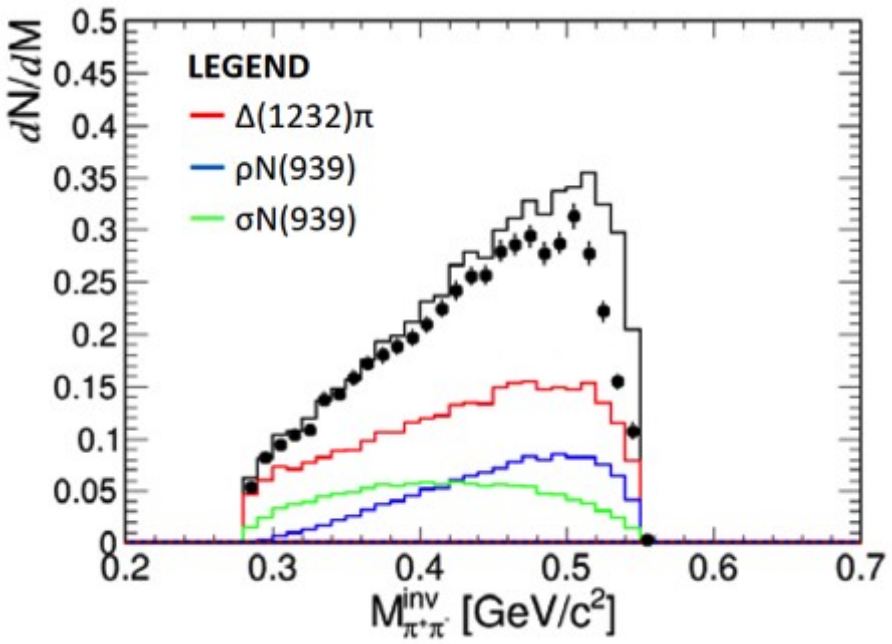


Large uncertainties on experiment and theory side



π^0 and η peaks are clearly visible!

Constraining the ρ contribution



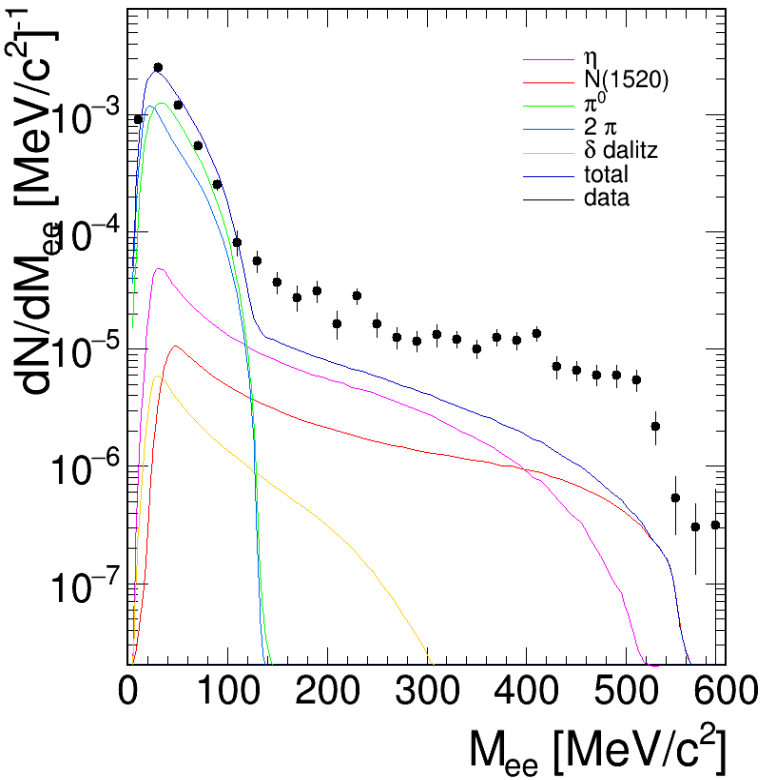
Analysis HADES Cracow group

- Cross section for ρ → $\pi^+\pi^-$ determined from PWA (Bonn-Gatcina)
- PWA analysis performed in 4π and inside HADES acceptance

→ N(1520) coupling to ρN: 17%

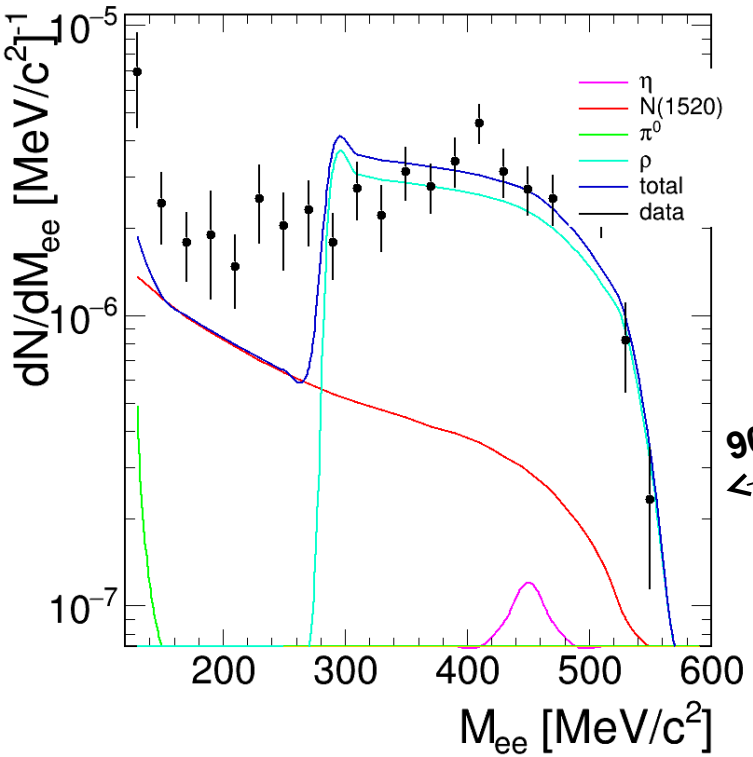
→ Total ρN contribution: 2.3 mb

Comparison with simulation

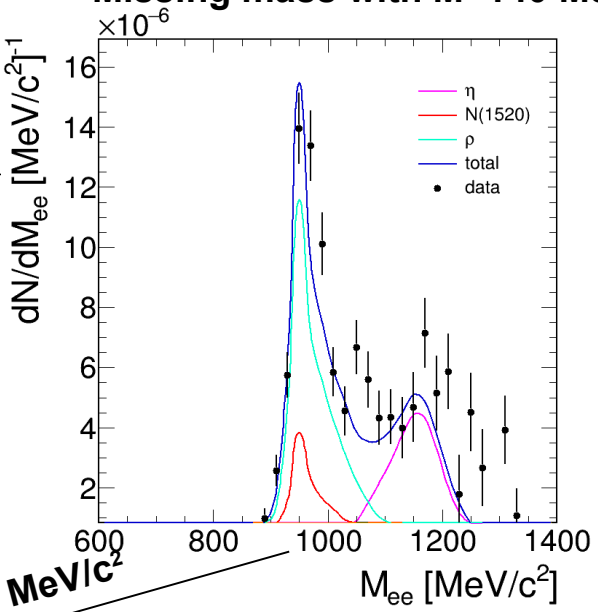


- Efficiency corrected data and simulations filtered through the HADES acceptance
- Cocktail without ρ contribution do not describe measured data!

Exclusive channel: $\pi^- p \rightarrow n e^+ e^-$



Missing mass with M>140 MeV/c²



900 < Miss.Mass < 1020 MeV/c²

ρ contribution **scaled 1/M³** to account for the **Vector Dominance Model**

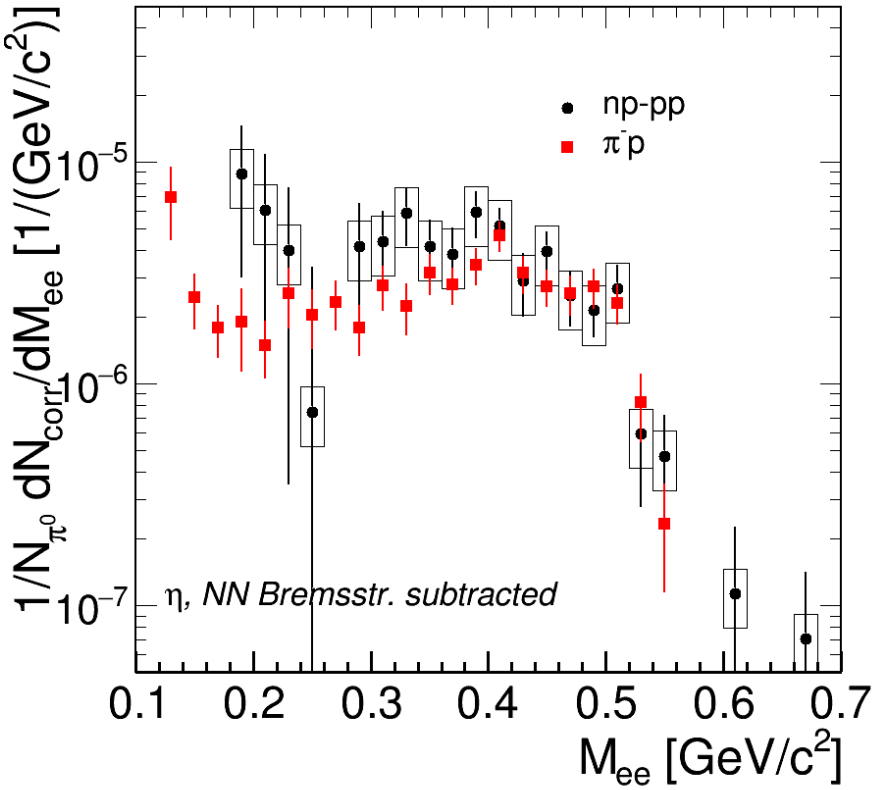
IPN ORSAY

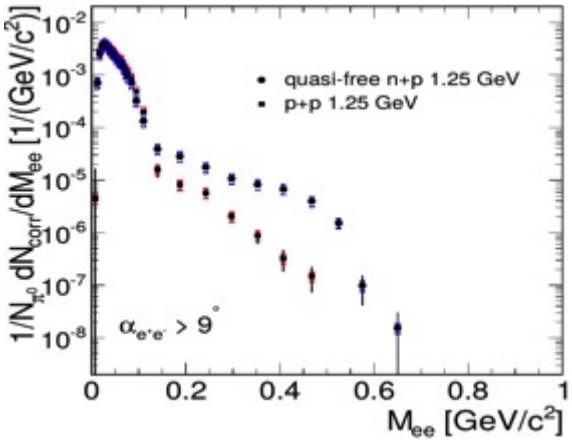
Comparison with np-pp data

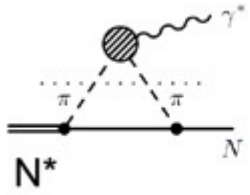
TECHNISCHE UNIVERSITÄT DARMSTADT

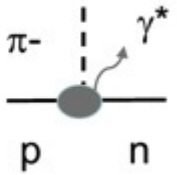
$\sqrt{s} - m_n = 1.49 - 0.94 =$ **0.55 GeV** in πp

$\sqrt{s} - 2m_n = 2.43 - 2\times0.94 =$ **0.55 GeV** in pn









Very similar trend!
Role of the pion cloud?

IPN ORSAY

Summary

- HADES – Di-Electron spectrometer in combination with pion beam is an unique tool to understand in details baryon-ρ couplings
- Significant off-shell ρ contribution originating from N(1520) shown by combined PWA and e^+e^- data
- The comparison between dilepton spectra coming from π-p and pn-pp interactions show spectacular similarities

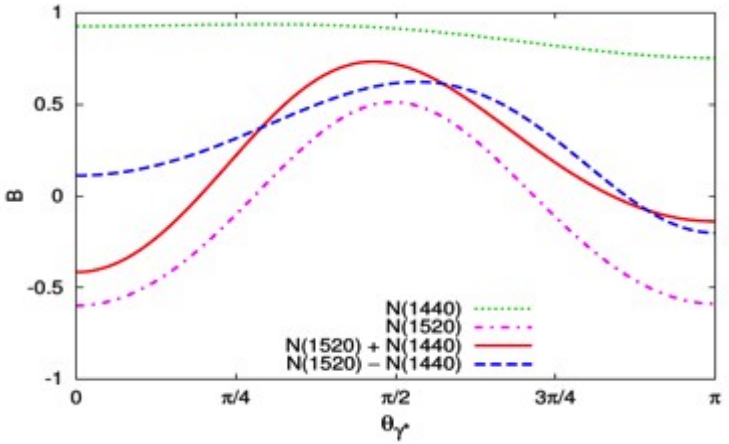
Summary

- HADES – Di-Electron spectrometer in combination with pion beam is an unique tool to understand in details baryon-ρ couplings
- Significant off-shell ρ contribution originating from N(1520) shown by combined PWA and e^+e^- data
- The comparison between dilepton spectra coming from π-p and pn-pp interactions show spectacular similarities

Outlook

Additional insights from the angular distribution of dileptons

$$\frac{d\sigma}{dM d\cos\theta_{\gamma^*} d\cos_e} \propto \Sigma_\perp(1+\cos^2\theta_e) + \Sigma_\parallel(1-\cos^2\theta_e)$$
$$\propto A(1 + B(\theta_{\gamma^*}, M)\cos^2\theta_e)$$



B. Friman, E. Speranza and M. Zetenyi