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

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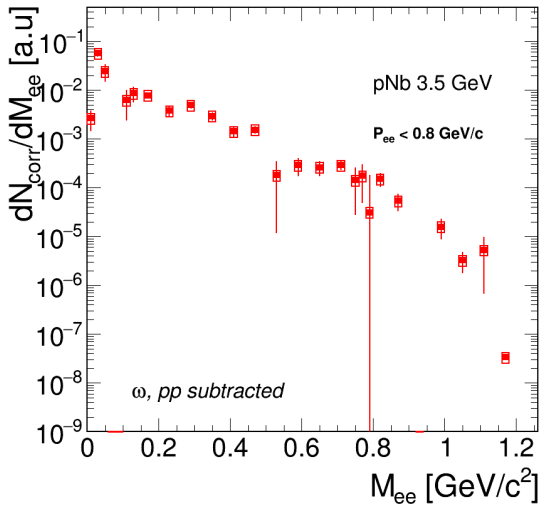
HADES detector

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

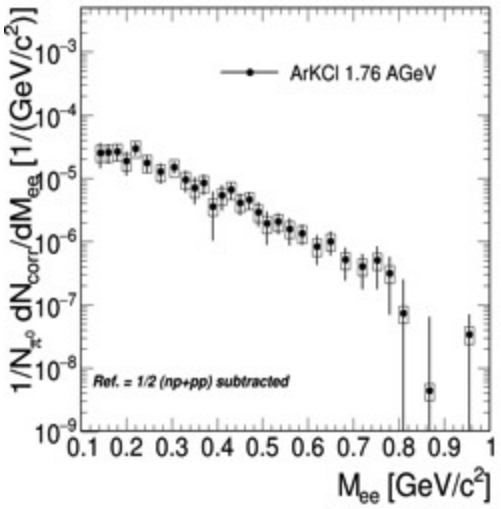
- Acceptance: 85% azimuthal coverage, 18-85deg in polar angle
- 80.000 channels
- Fast DAQ: 50kHz event rate

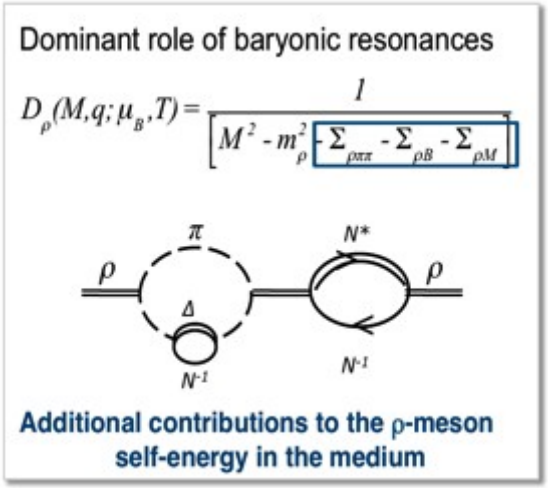
Physics motivation

HADES: Phys.Lett. B715 (2012)



Phys.Rev.C 84 (2011) 014902

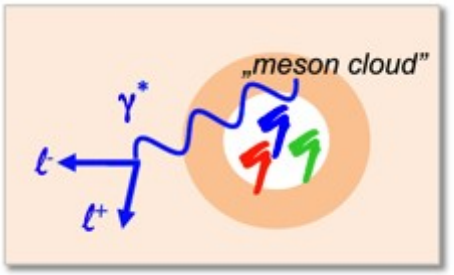




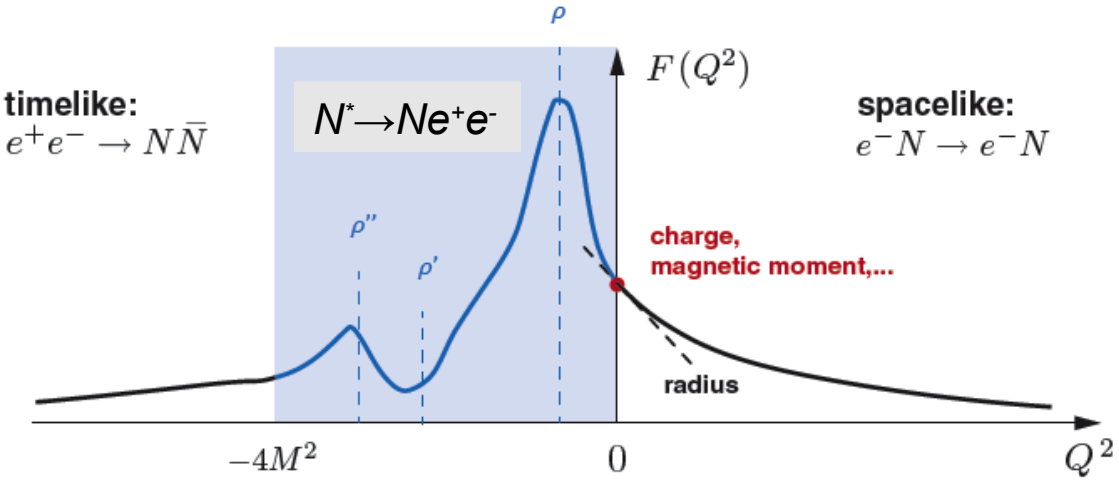
- Strong broadening of in-medium states
- Significant contribution from higher (than Δ) mass resonances

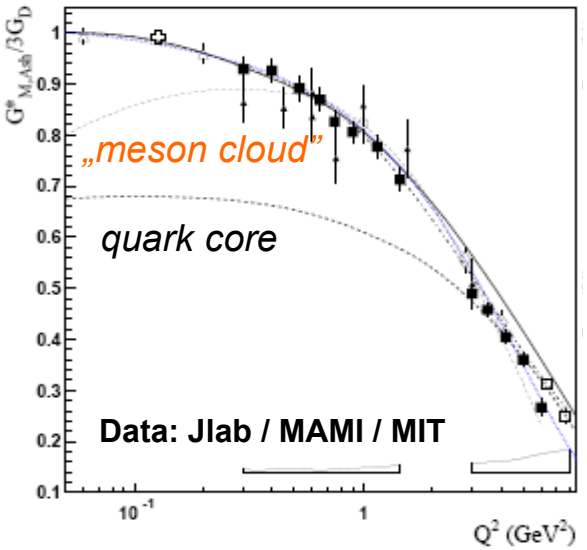
- Understanding of ρ-baryon coupling mechanism
- Crucial to better control medium effects

Physics motivation



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



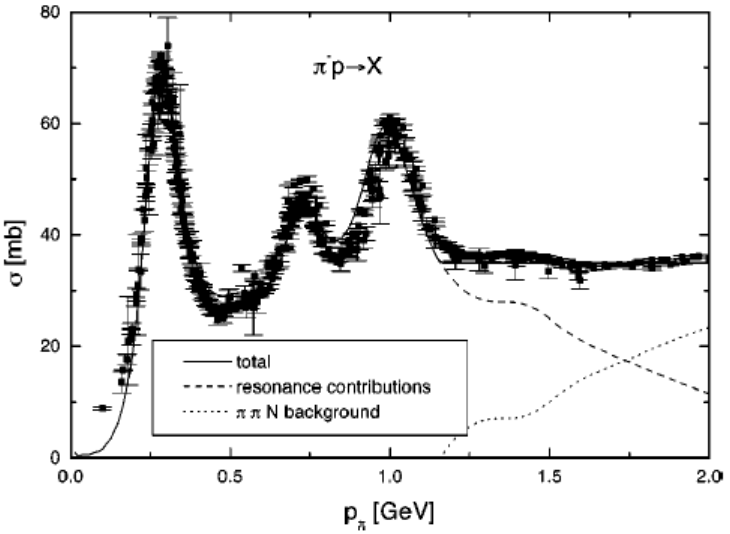


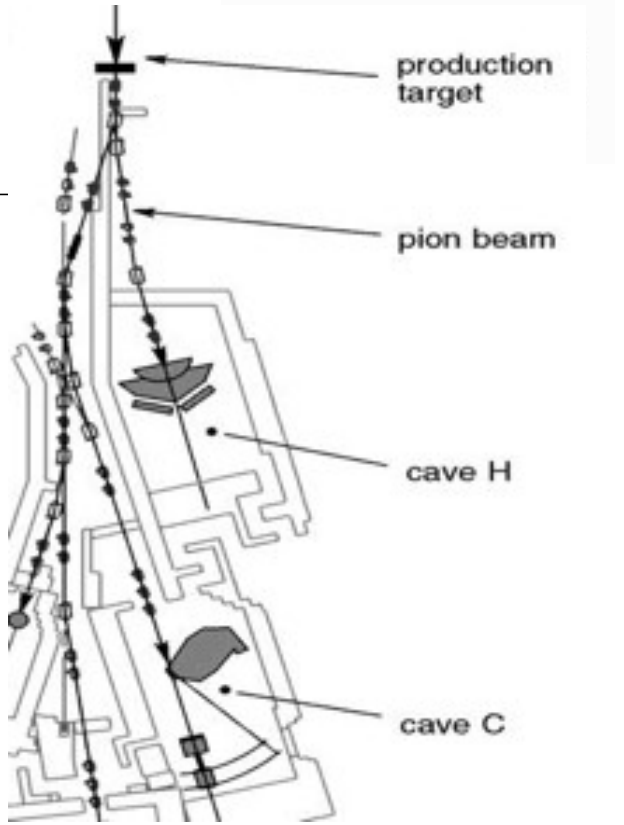
I.G. Aznauryan, V.D. Burkert Prog. Part. Nucl. Phys. 67, 1 (2012)

Pion beams with HADES

Secondary π momentum p_π = 0.69 GeV/c, 0.656 GeV/c, 0.748 GeV/c, 0.800 GeV/c in order to perform PWA analysis

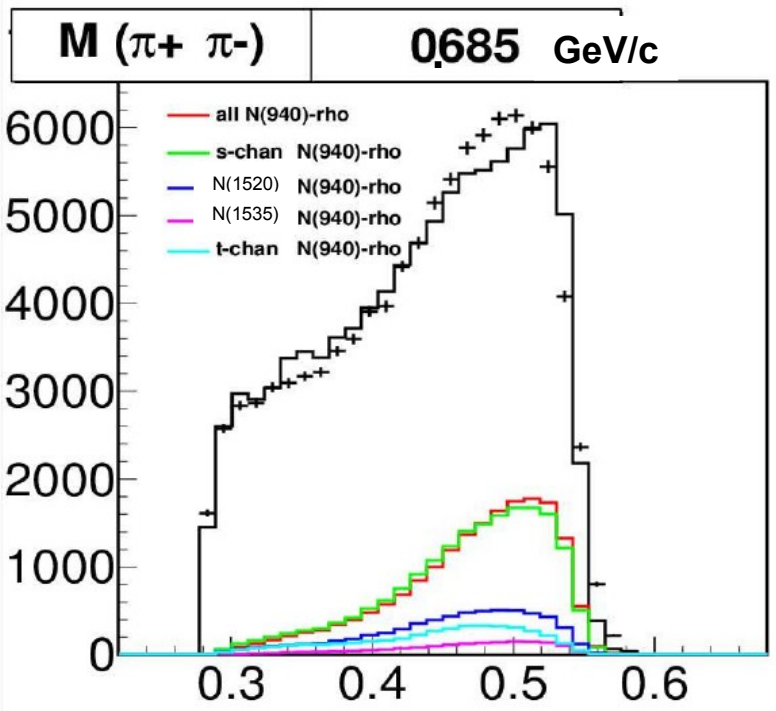
- Excitation of the second resonance region
- Beam intensity I = 3-4 × 10^5 π/s
- Target: Polyethylene $(CH_2)_n$ and Carbon





- Primary beam: 8 × 10^{10} N_2 ions/spill
- E = 2 AGeV/c
- Spill: 4s cycle
- Total ~15 days of effective measurements

Constraining the ρ contribution



See W. Przygoda talk on Monday Plenary session

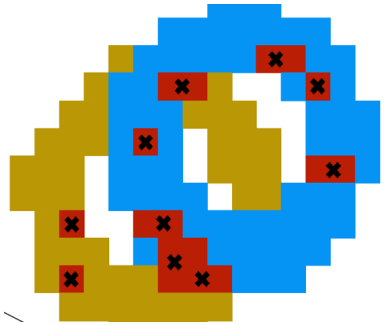
- Cross section for ρ → $\pi^+\pi^-$ determined from PWA (Bonn-Gatchina)
- PWA analysis performed in 4π and inside HADES acceptance
- Dominant N(1520) + interferences between resonances N(1535)-Δ(1620)

→ N(1520) branching ratio to ρN: 17%

→ Total ρN contribution: 2.3 mb

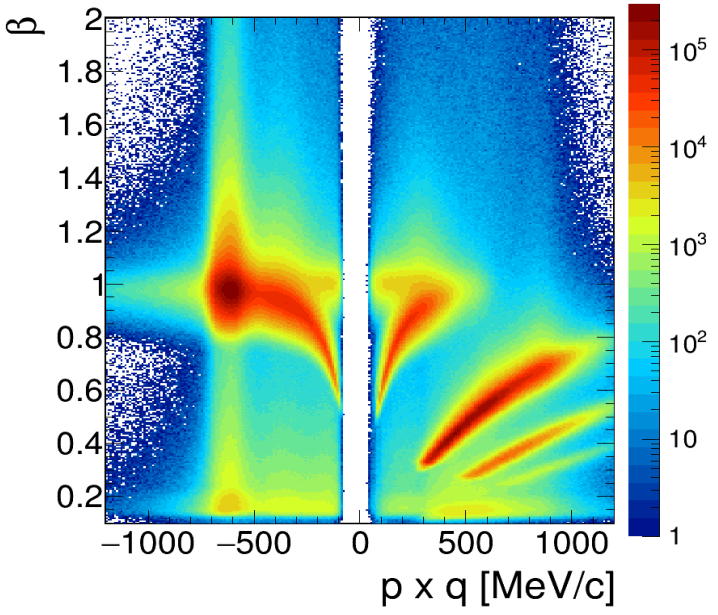
Electron ID

- Particle velocity vs momentum
- RICH information using
  backtracking algorithm
  ring finder

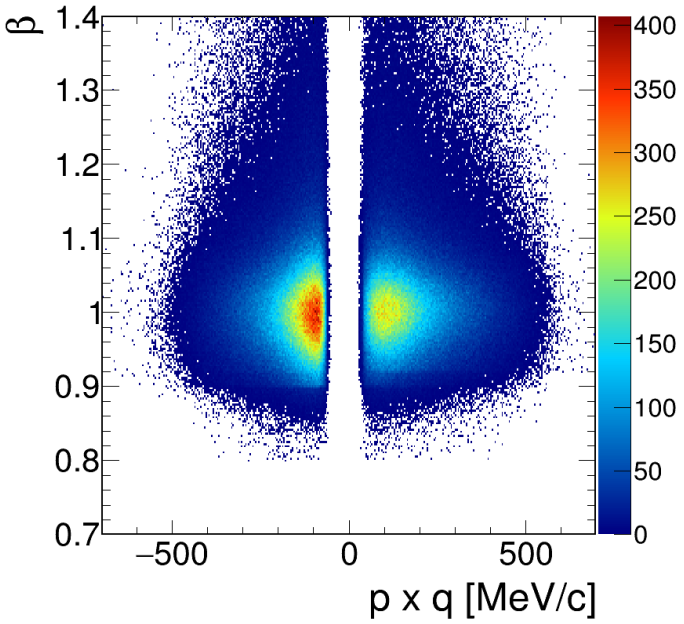


Fired RICH pad
Maximum position
Lepton 1
Lepton 2

Before Identification



After Identification



Signal-to-background estimates using RICH rotation technique

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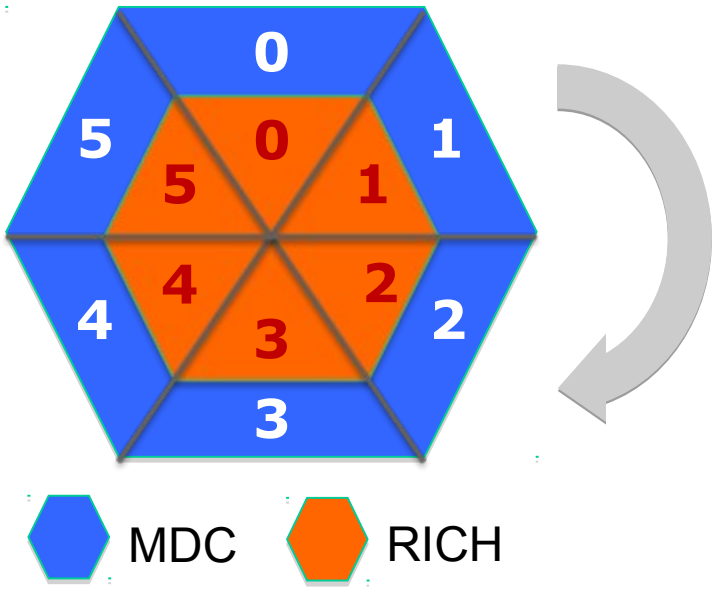
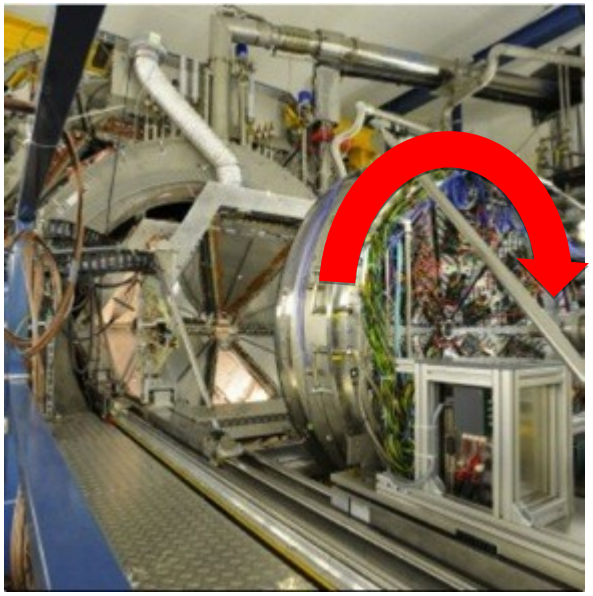
Characterizing "true" (signal) and "random" (background) track-RICH ring matches





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

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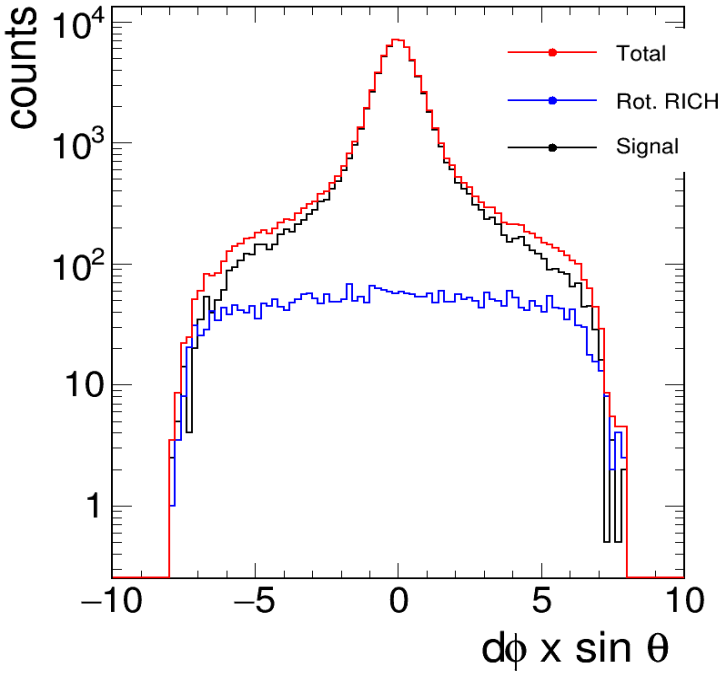
Purity of the electron sample

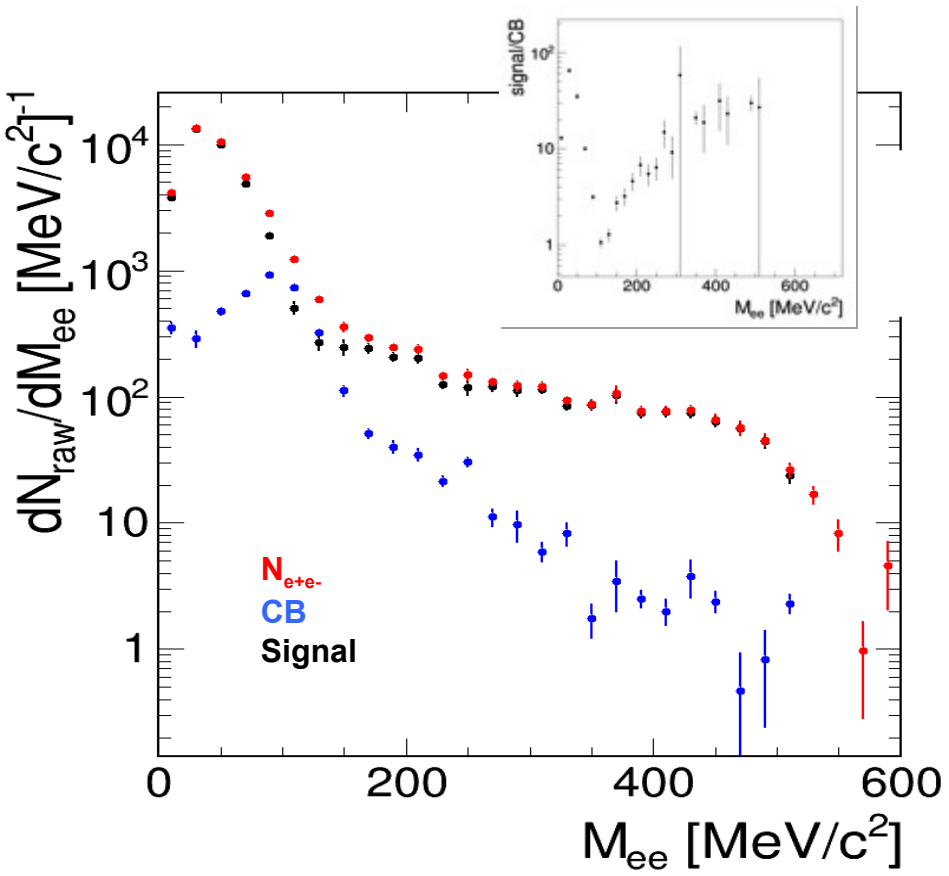


$$\text{Purity} = 1 - \frac{\text{rot. RICH}}{\text{not rot. RICH}}$$

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) = **2209**

Efficiency corrections based on Monte Carlo simulations

Normalization factor

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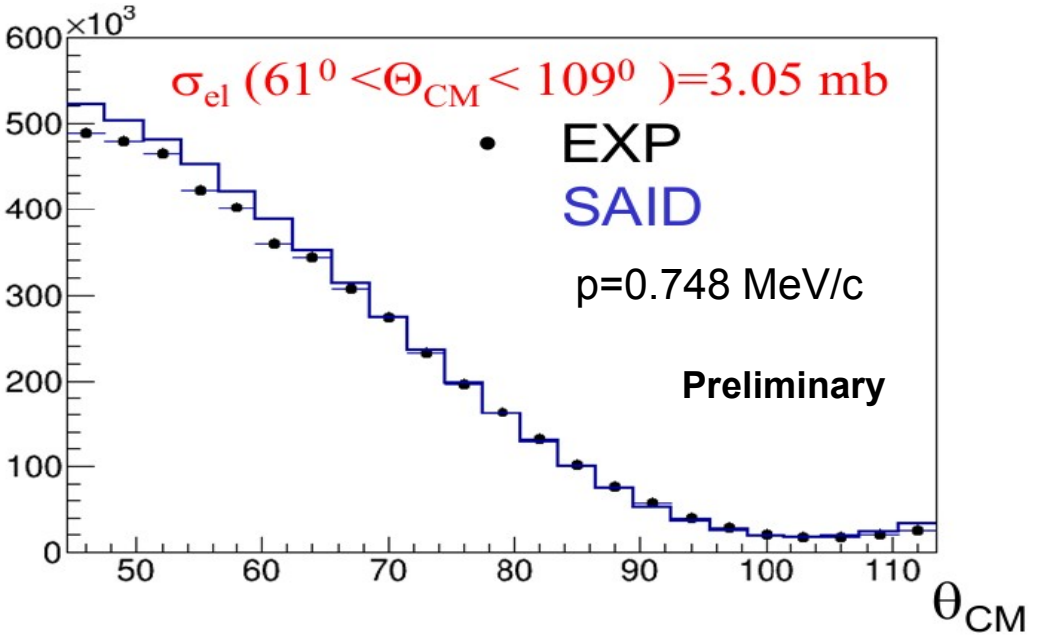
$N_{PE} = (\sigma_P + 0.5\sigma_C)*4\ x10^{23}*N_{beam}$ (there are 4.0e23 protons/cm^2 and 2 x 10^{23} C/cm^2 atoms in target)

$N_{norm} = N_{elastic} = \sigma_{elastic\ p}\ *4\ x10^{23}*N_{beam}$

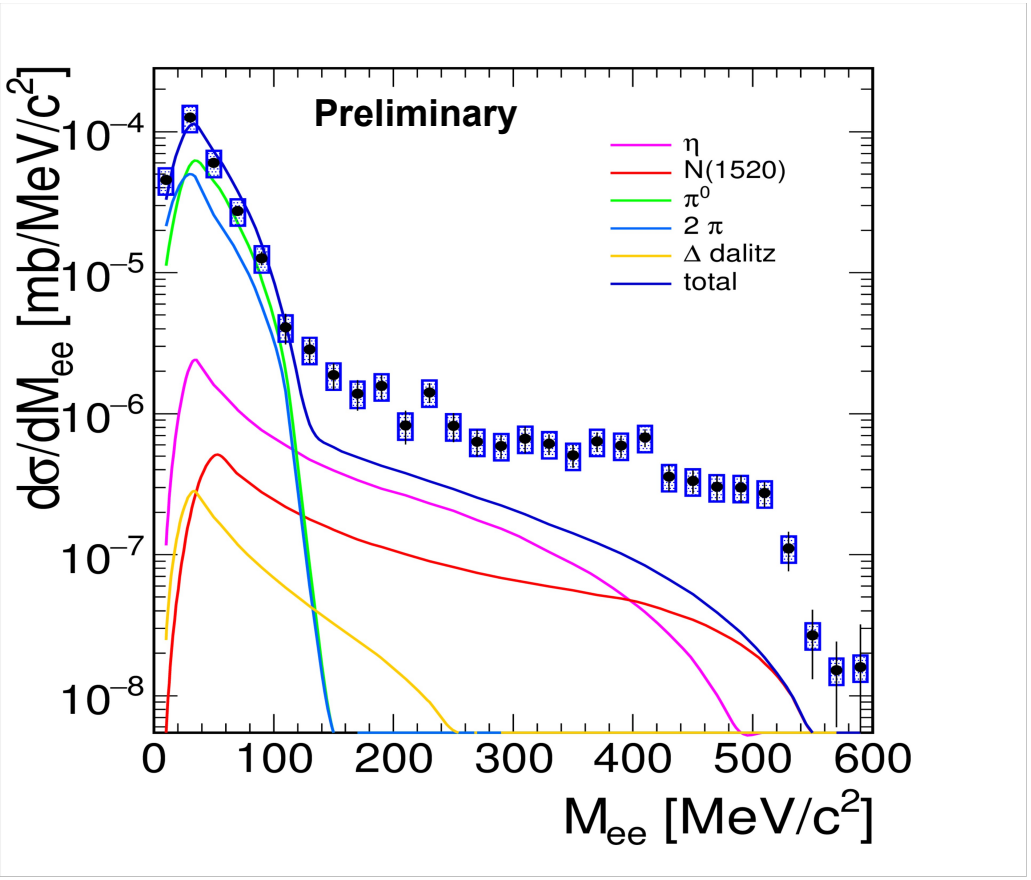
Normalization:

$N_{PE} * \sigma_{elastic} / N_{elastic} = \sigma_P + 0.5\sigma_C$

Normalization via measured π^- p elastic scattering of known σ (SAID partial wave solution)



Comparison with simulation



- π^-+C treated as a quasi-free process
- Simulation results are combined according the ratio p/C 1:2

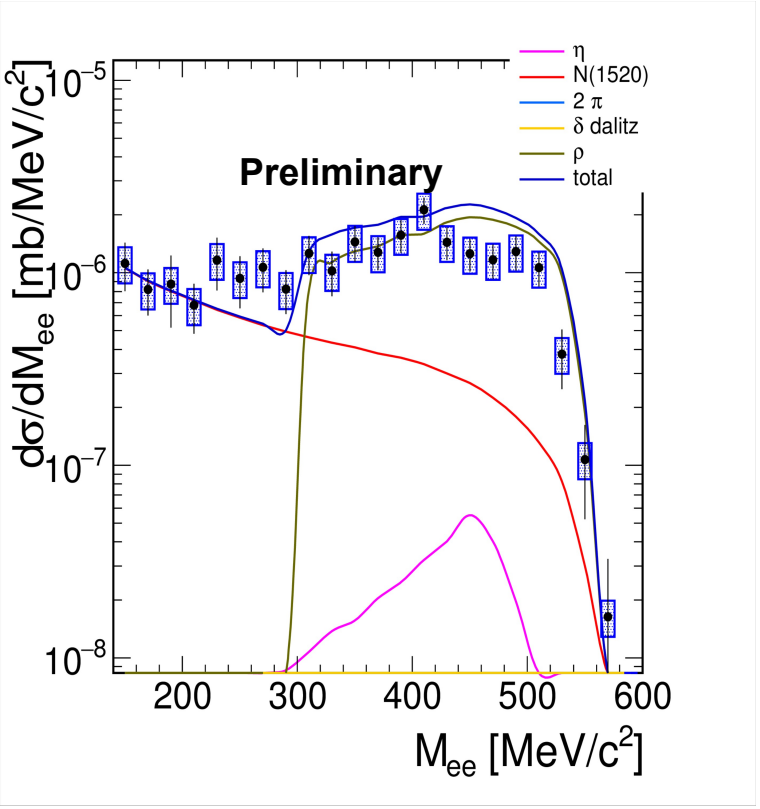
Sources:

- $\sigma(\pi^- \rightarrow \pi^0 X)$ = 16.1 mb $\pi^0 \rightarrow e^+e^-\gamma$
- $\pi^- p \rightarrow N(1520)$ = 20.4 mb Wolf / Zetenyi „QED" model with BR = 4×10^{-5} in $\rightarrow ne^+e^-$
- $\sigma(\eta)$ = 0.3 mb (p); 0.7 (C) mb $\eta \rightarrow e^+e^-\gamma$

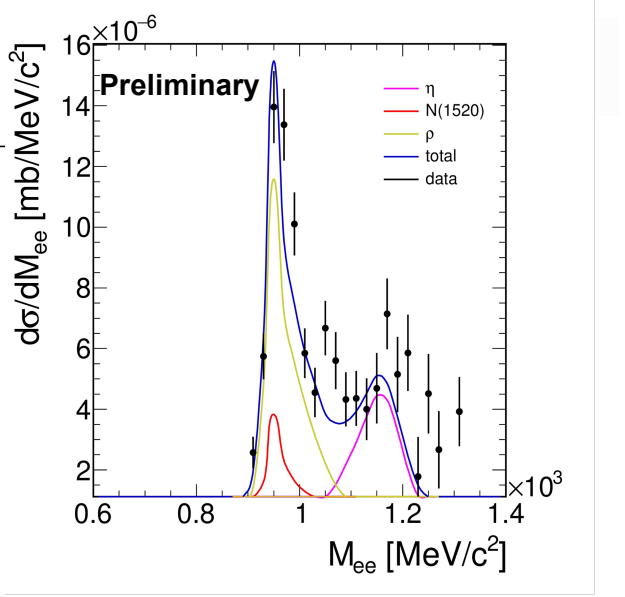
- Efficiency corrected data and simulations filtered through the HADES acceptance

- Cocktail without ρ contribution does not describe measured data!

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



Missing mass with M>140 MeV/c²



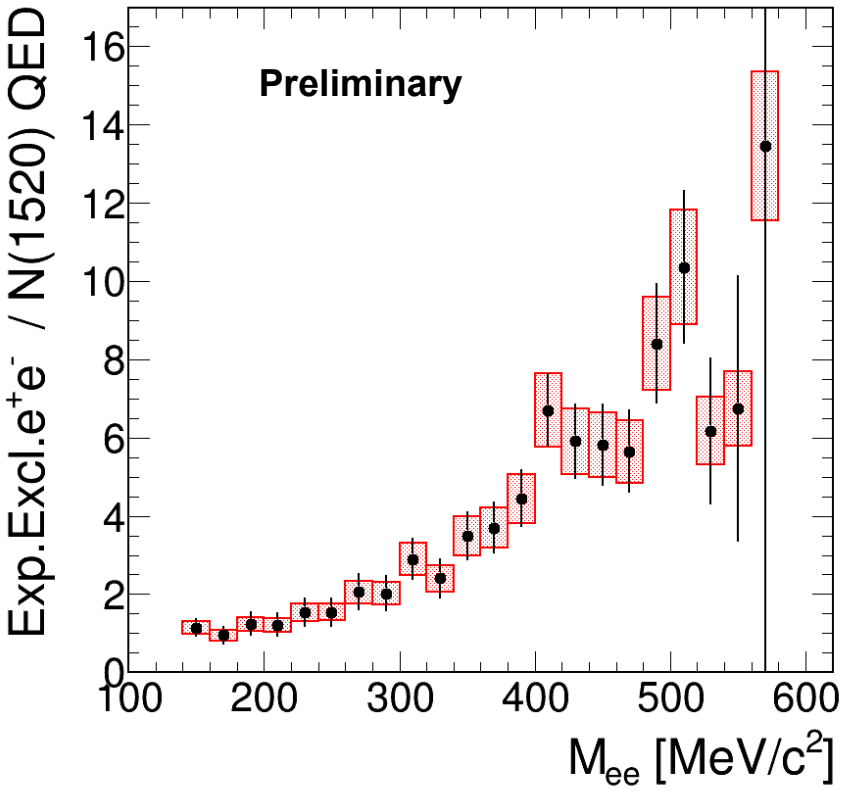
900 < Miss.Mass < 1020 MeV/c²

good description using a cocktail of point-like baryons+ρ contribution

ρ contribution from PWA and using the **Strict Vector Dominance Model**

$$\frac{d\sigma}{dM_{ee}} = \frac{d\sigma}{dM_{\pi\pi}} c_p \left(\frac{m_\rho}{m_{ee}}\right)^3 \qquad C_p = 4.7\text{x}10^{-5}$$

Deviation from point-like behaviour



- Ratio between:
- Efficiency corrected exclusive e^+e^- spectra
- N(1520) QED calculation, filtered through the HADES acceptance
- Clear deviation from unity in the high mass region!
- Indication for VDM like form factors

The GiBUU Transport Model

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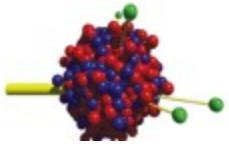
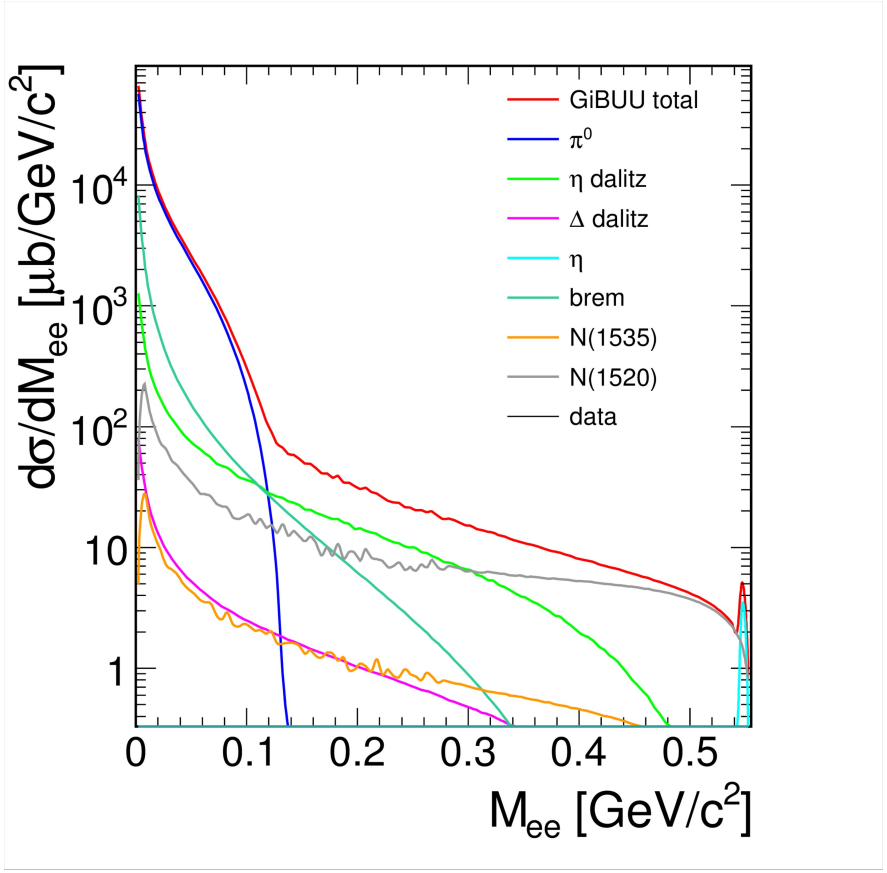
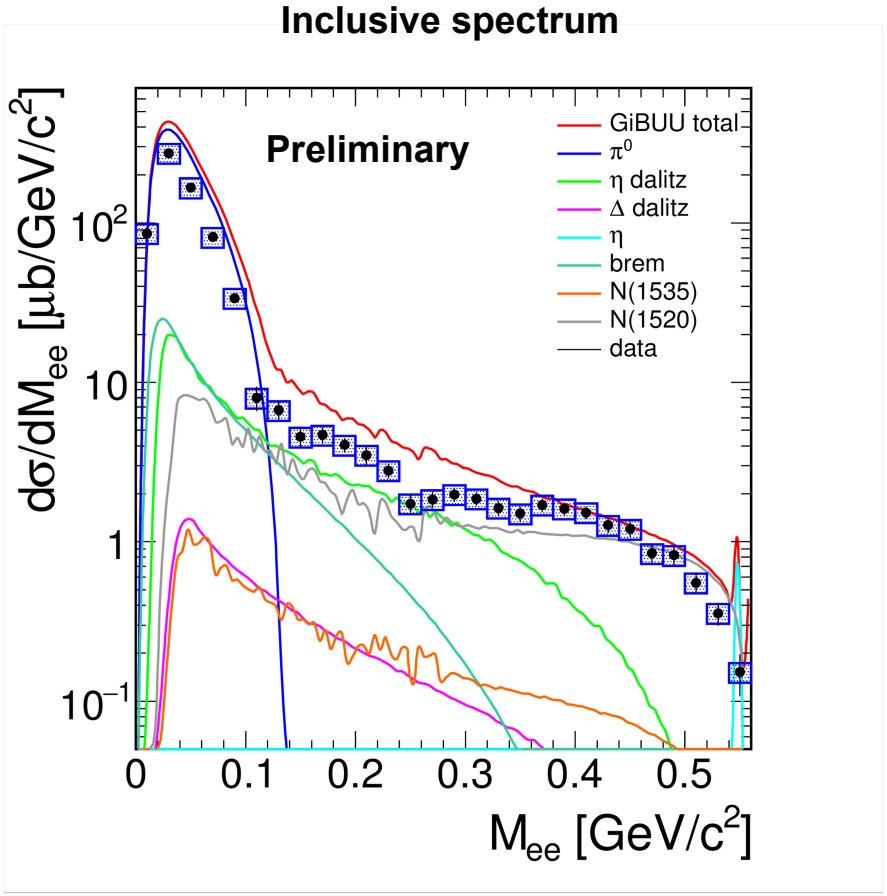


GiBUU
The Giessen Boltzmann-Uehling-Uhlenbeck Project

- BUU-type hadronic transport model
- unified framework for various types of reactions (pA, πA, γA, eA, A, AA) and observables
- publicly available releases (open source) http://gibuu.physik.uni-giessen.de



Comparison with GiBUU model

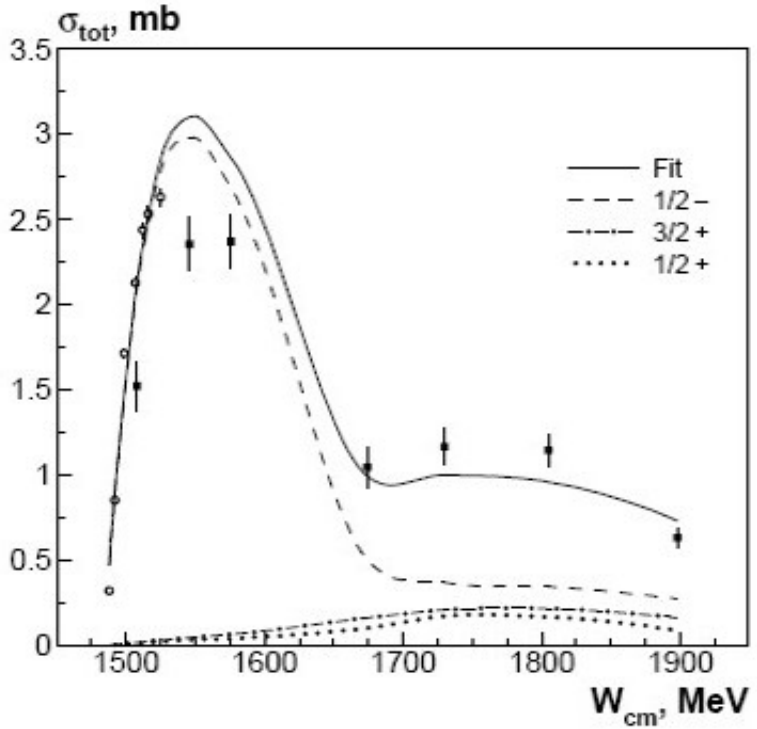


- Incoherent sum of the cocktail components
- σ_p (π^0) = 19 mb
- σ_p (η) = 0.9 mb
- σ_p (Δ) = 4.24 mb

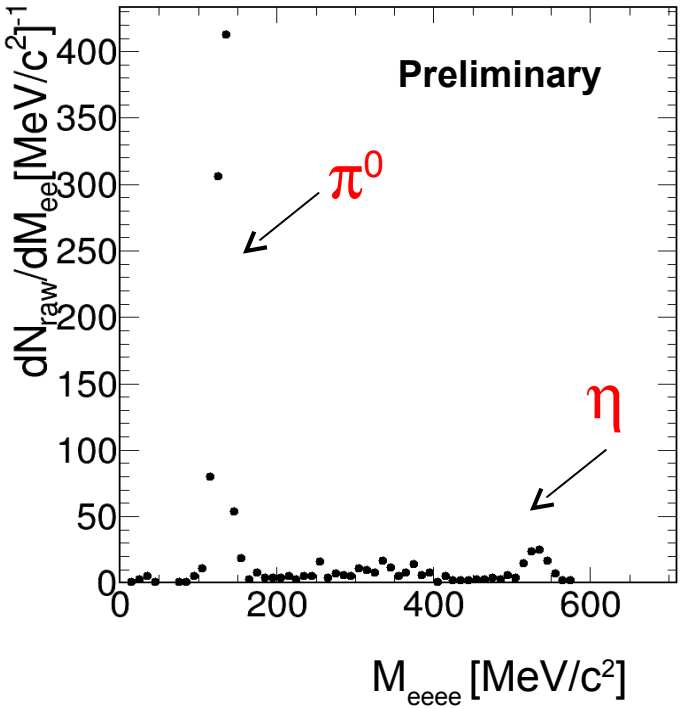
- Some overestimation in π^0 region and above 140 MeV/c^2 dominated by N(1520) and η

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!

Comparison with GiBUU model

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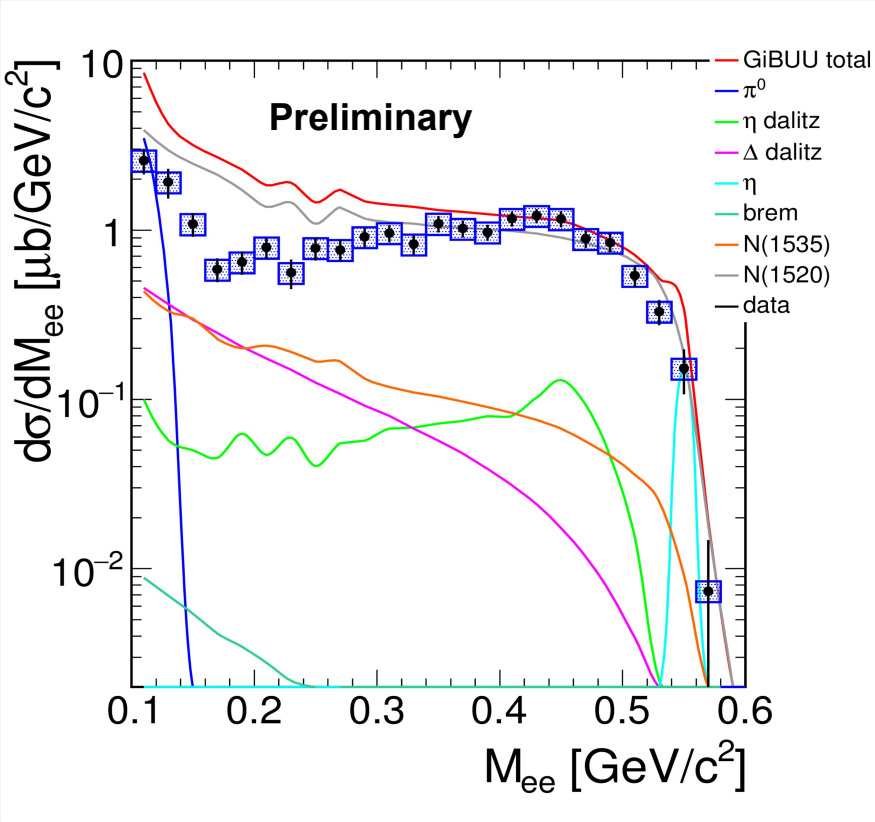
Exclusive spectrum



- Overestimation in π^0 region
- $N(1520) \rightarrow N\rho \rightarrow Ne^+e^-$ with $\rho \rightarrow e^+e^-$ following pure VDM form factor for N(1520)

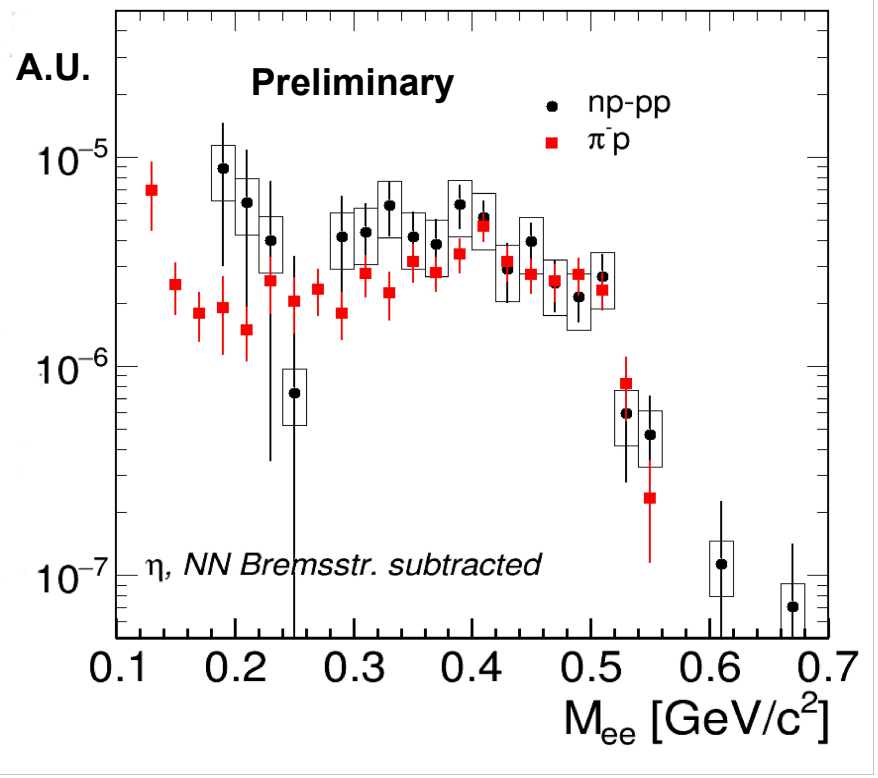
→ Overestimation below 0.3 GeV due to no absence of 2π threshold in $N(1520) \rightarrow e^+e^-$ and strict VDM (1/M^3)

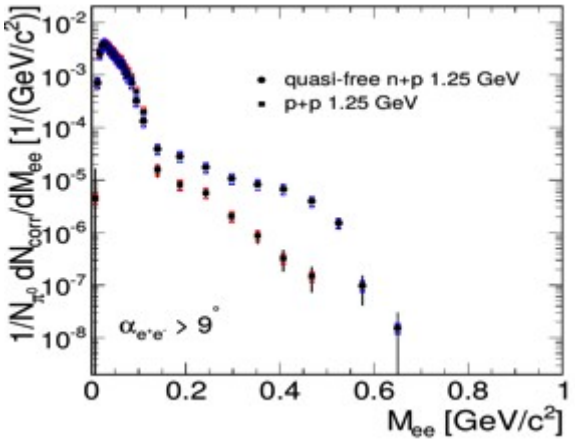
→ Points to problem with strict VDM at small q^2 known from mismatch to Resonance->Nγ branching ratio

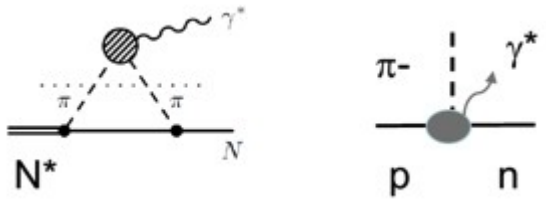
Comparison with np-pp data

$\sqrt{s} - m_n = 1.49 - 0.94 =$ **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?

Outlook – possibility to separate resonances

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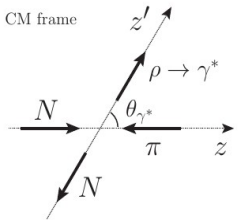
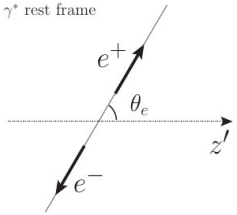
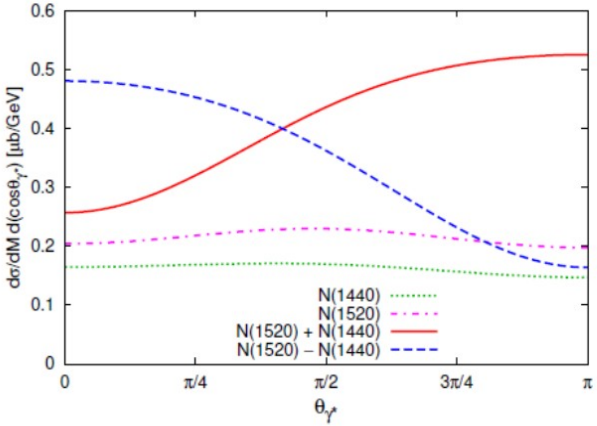
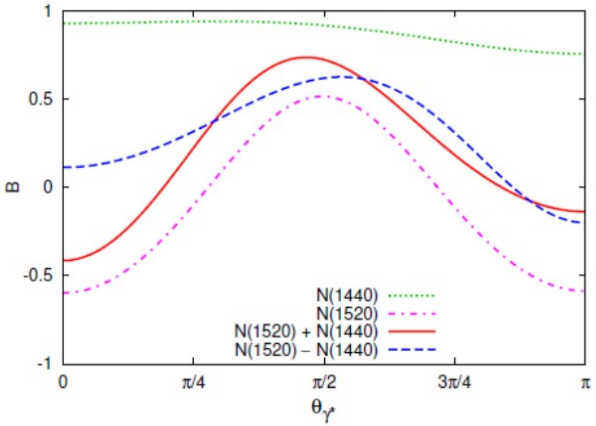
- Microscopic model (B. Friman, M. Zetenyi, E. Speranza)
- Distribution of virtual photon angle in CM: sensitive to interference between amplitudes for different contributions
- Distribution of helicity angle: for each contribution, it reflects the electromagnetic structure of the transition

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









Summary

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- HADES – Di-Electron spectrometer in combination with pion beam is an unique tool to understand in details baryon-ρ couplings using both e^+e^- and $\pi^+\pi^-$ measurements
- Measurement of e^+e^- invariant mass spectra for inclusive and exclusive channels
- Good agreement with a cocktail of point-like source + ρ contribution deduced from PWA of $\pi^+\pi^-$ data
- Comparison to GiBUU points to too large N(1520) contributions (due to pure VDM model?)

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