

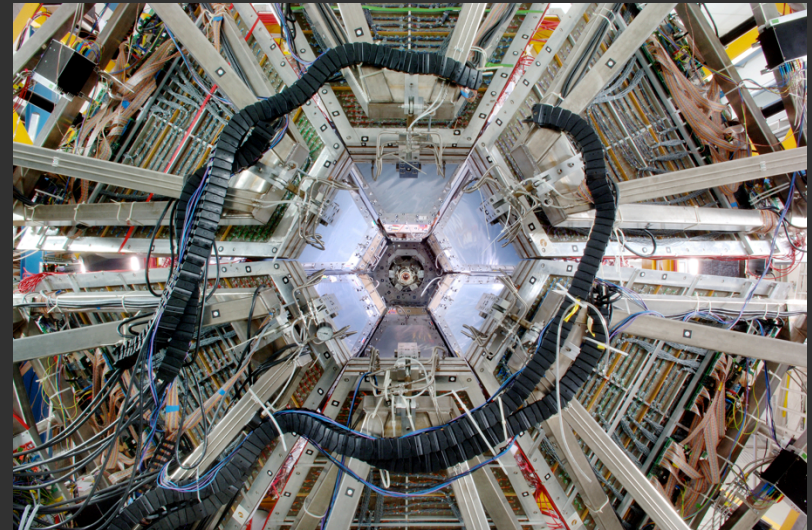
HADES resonance transition form factors

CRC Workshop
Mainz, April 2014

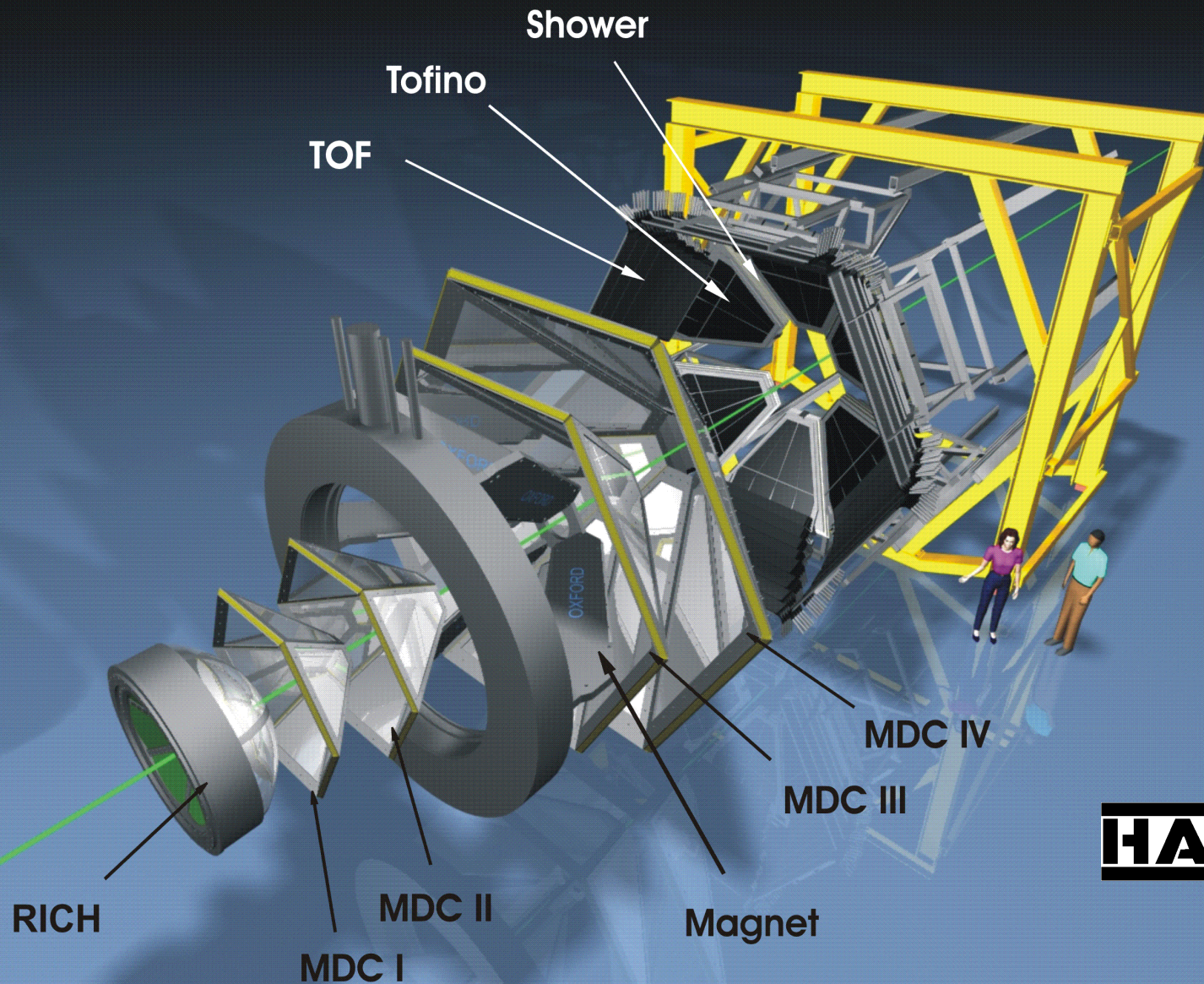
Joachim Stroth, Goethe-University Frankfurt / GSI
the HADES collaboration

Agenda

- Virtual photons from NN collisions
- Exclusive channels
- Pion beam experiments



The HADES experiment @ GSI

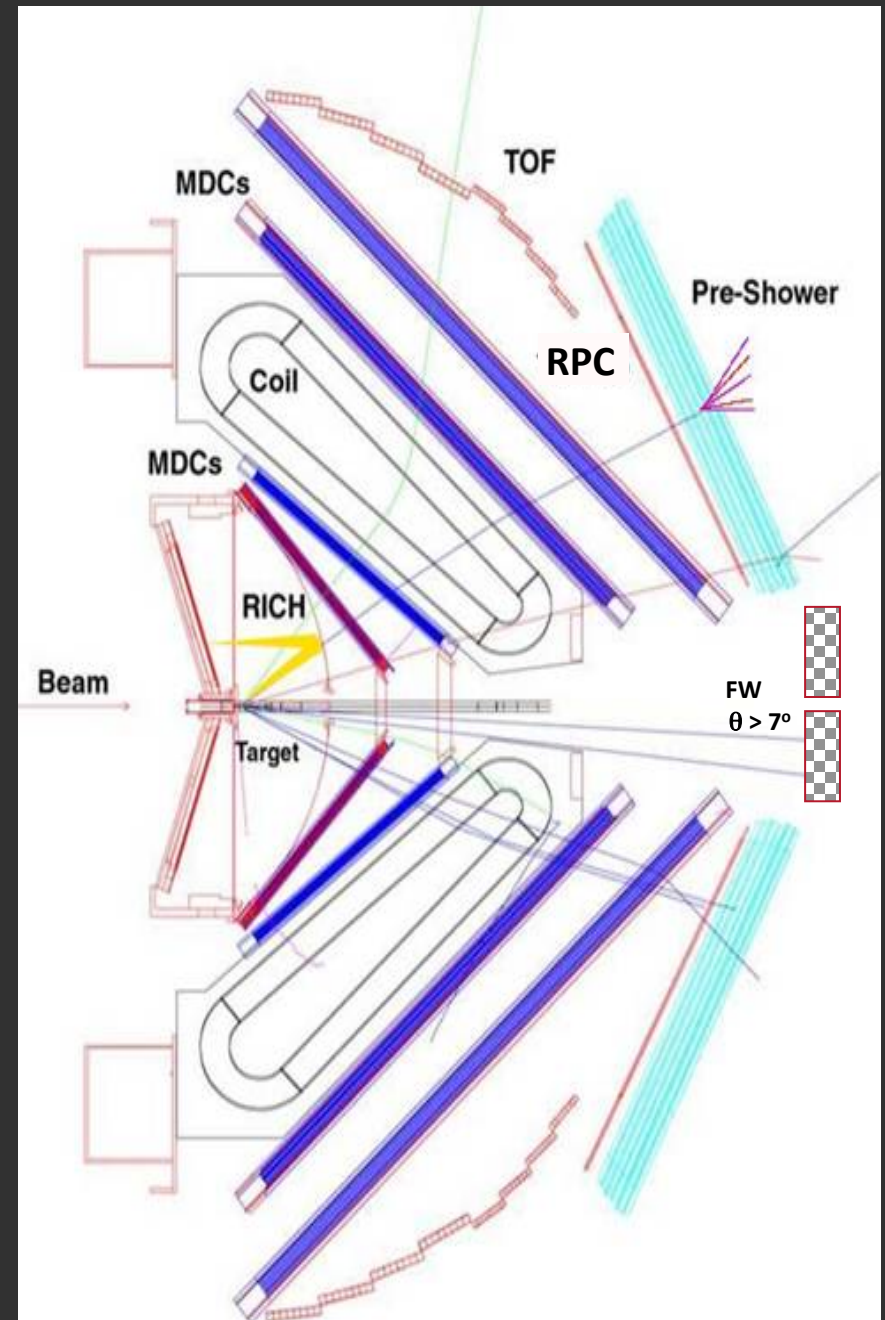
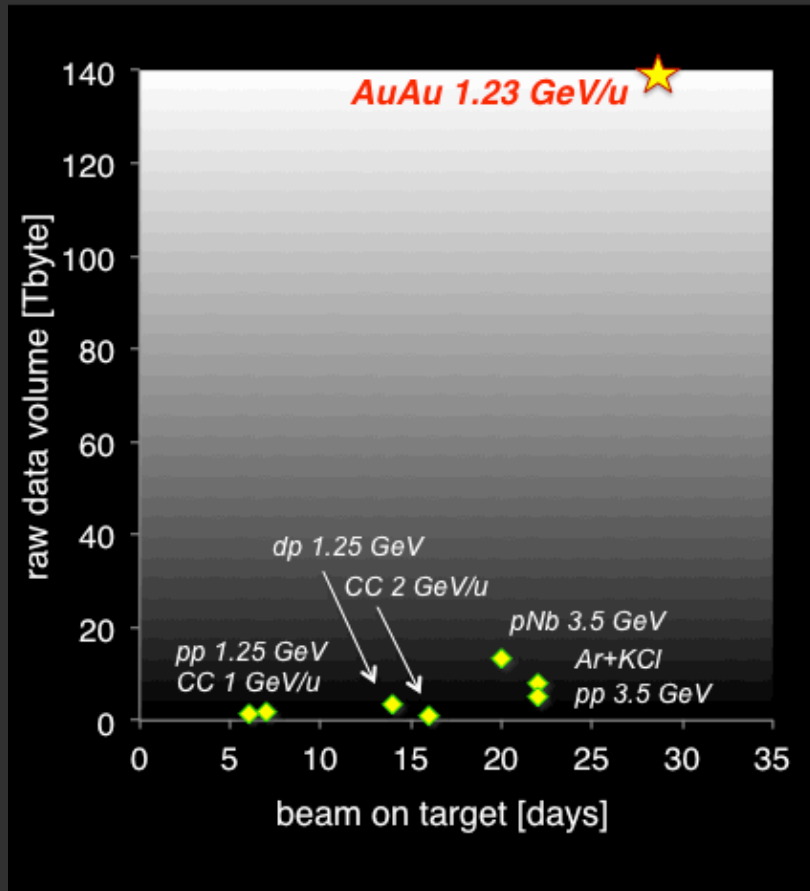


HADES

Operational at GSI since 2002

Upgrade 2008 – 2010

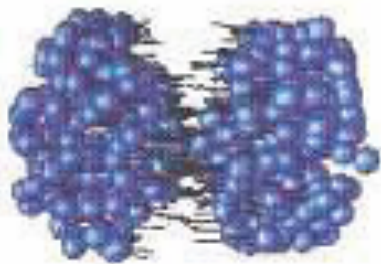
- Time-of-flight (RPC)
- DAQ
- Inner tracking (MDC I)



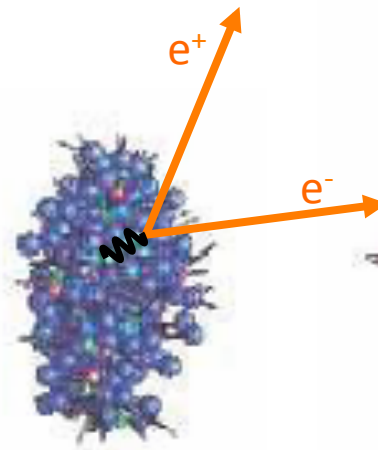
The original goal

Virtual photon radiation from hot and dense strongly interacting matter (SIM)

First chance collisions.
(hard collisions)

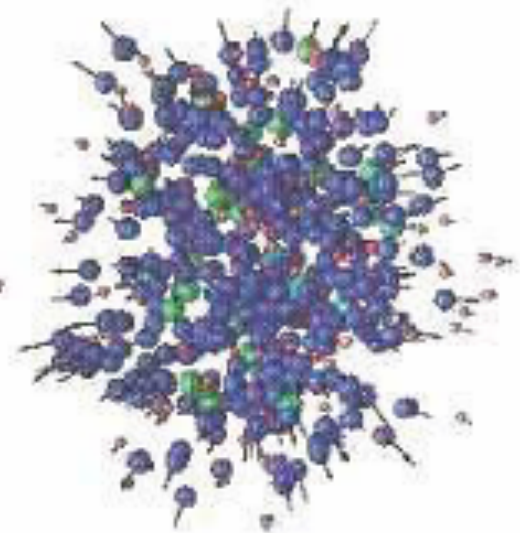


- nucleons
- resonances
- mesons



Hot and dense phase

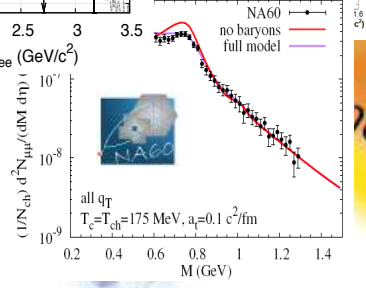
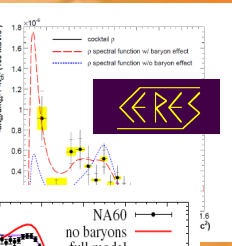
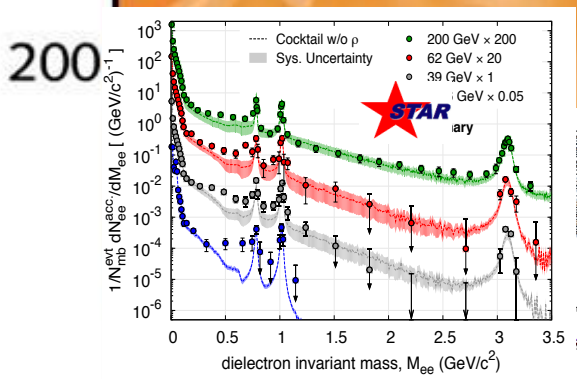
Expanding hadron gas



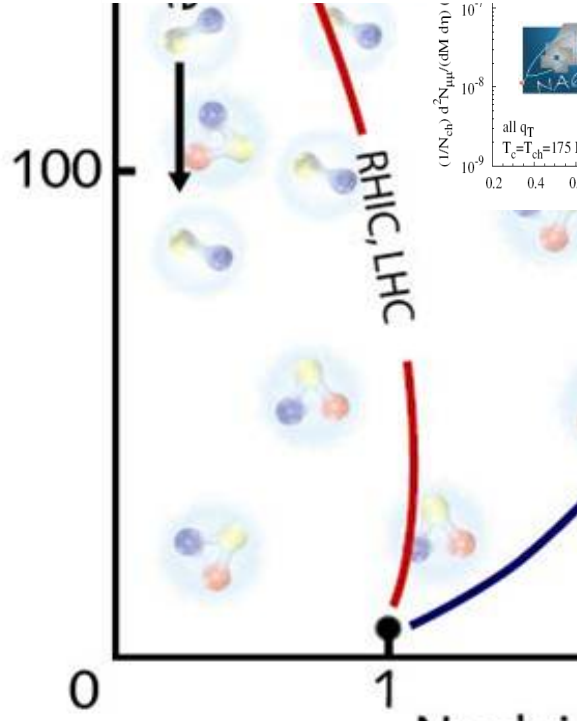
UrQMD transport calculation

Probing the phase diagram of SIM

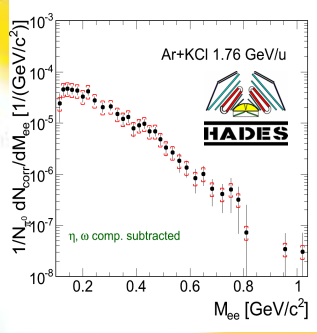
Temperature T [MeV]



Quarks and Gluons



FAIR SIS 300

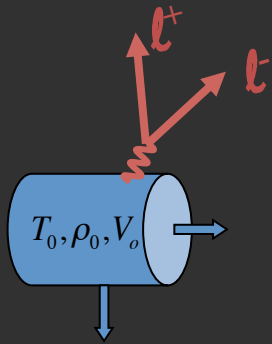


Neutron stars

Color Superconductor?

Net Baryon Density

Spectral emission rates



Thermal emission...

Nuclear many body theory, detailed balance, ..

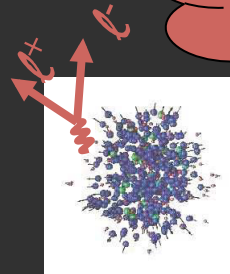
isentropic expansion

$$\frac{d^3 N}{dM dy dp_t} \equiv \int_{t=0}^{\infty} \frac{d^4 R}{dp} [T(\mathbf{x}), \mu_B(\mathbf{x}), \vec{v}_{coll}(\mathbf{x}), \dots] d\mathbf{x}$$

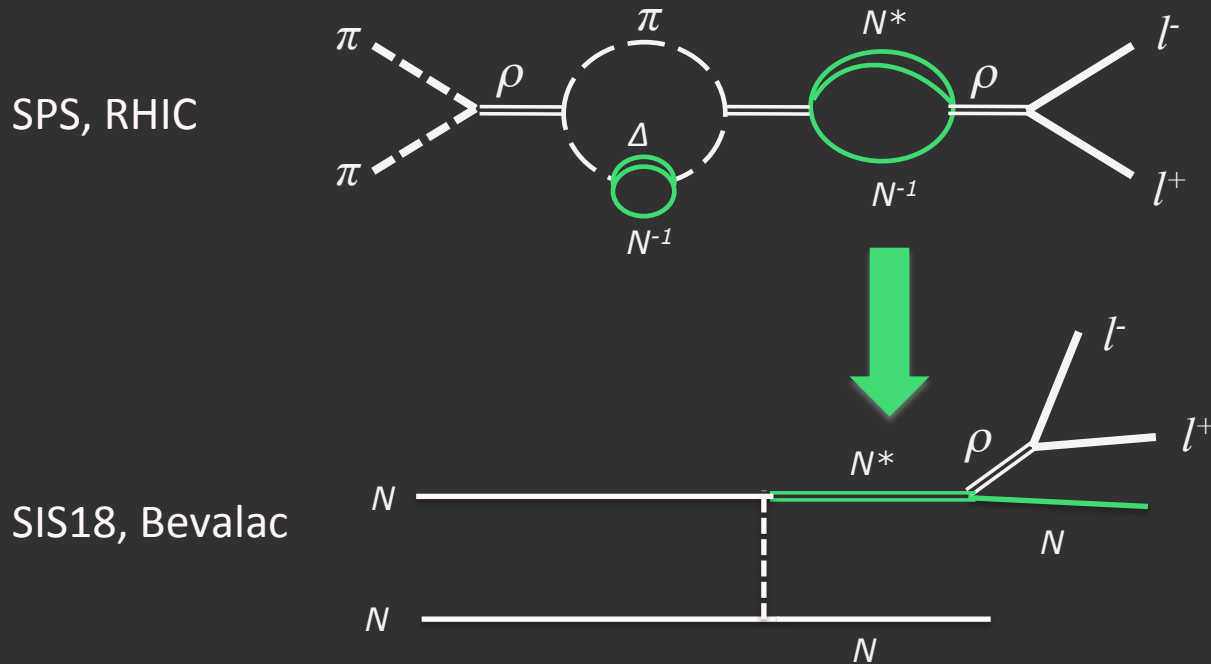
Spectrometer

Hydro, statistical expansion models, ..

... or microscopic transport



In-medium self energy of the ρ



○ For details see e.g. (reviews):

✘ arXiv:9909.229, R. Rapp and J. Wambach

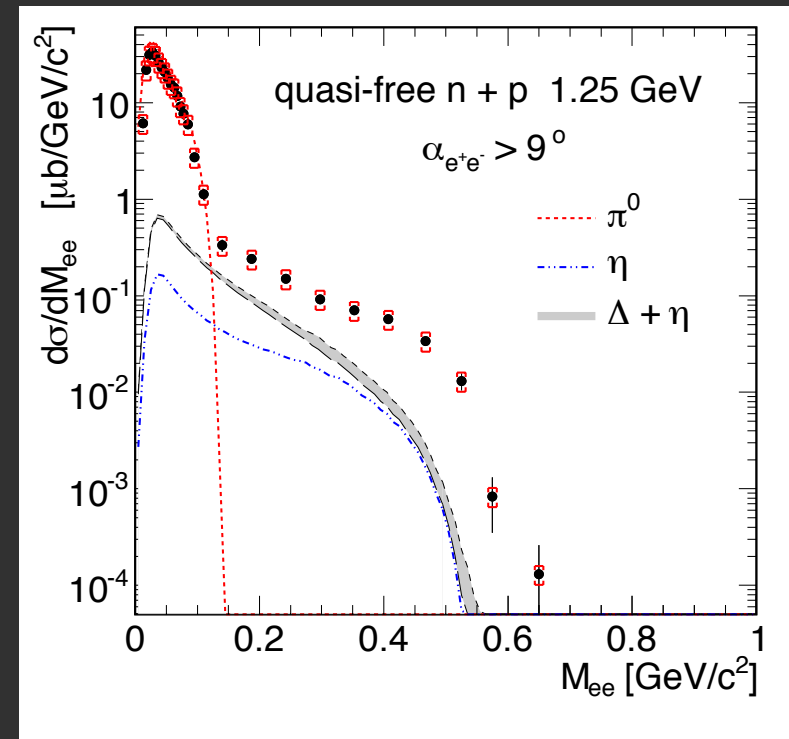
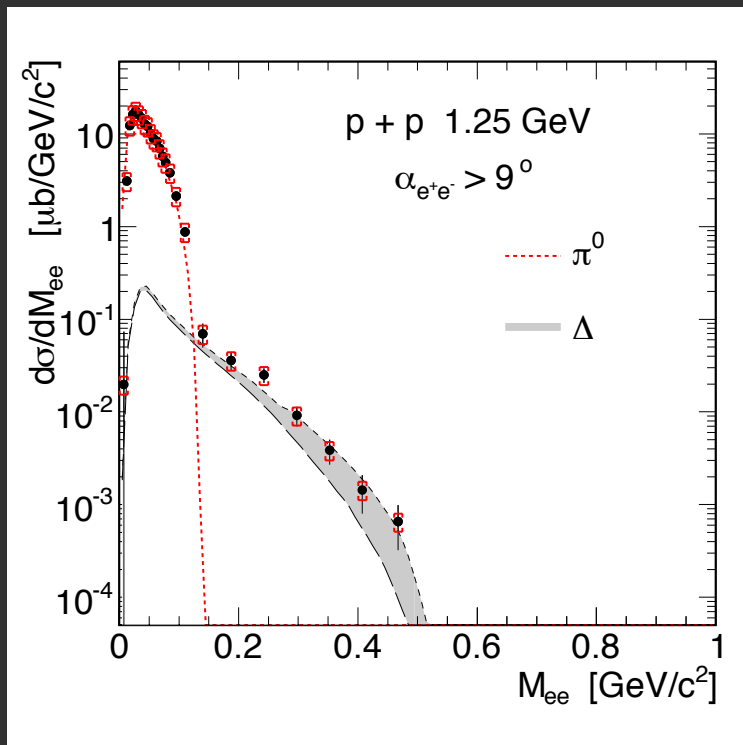
✘ arXiv:0907.2388: S.Leupold, V. Metag, U. Mosel

Towards an understanding of virtual photon radiation off baryons

e^+e^- pairs from pp and np reactions (HADES)

Data from HADES pp and dp (tagged n) at 1.25 GeV/u

- Remarkable isospin effect
- Beam energy dependence observed by DLS

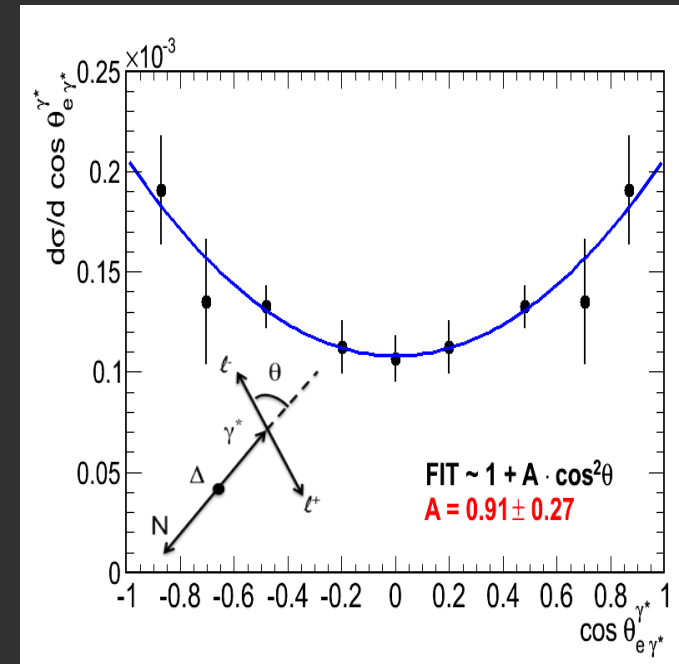
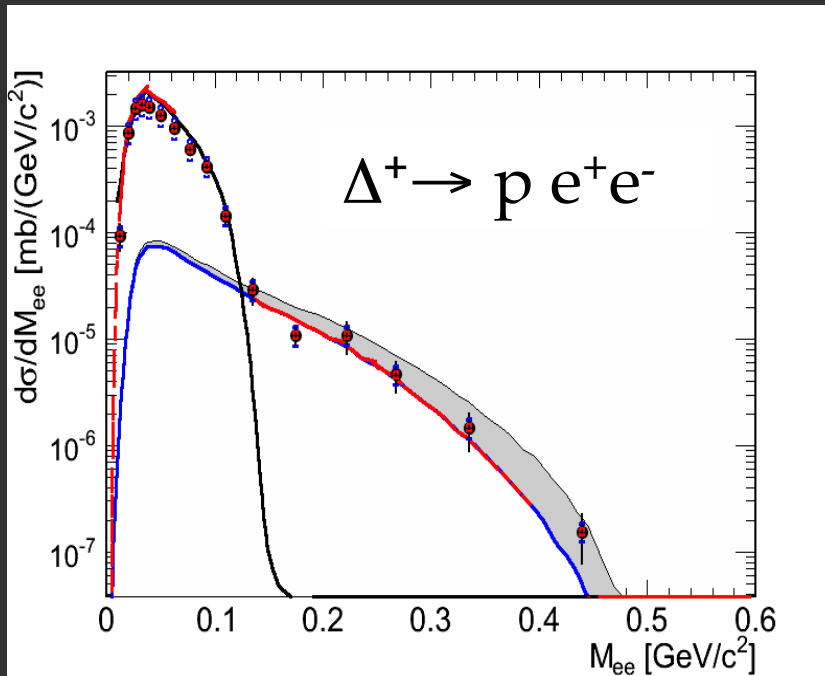


HADES collaboration, PLB 690 (2010) 118

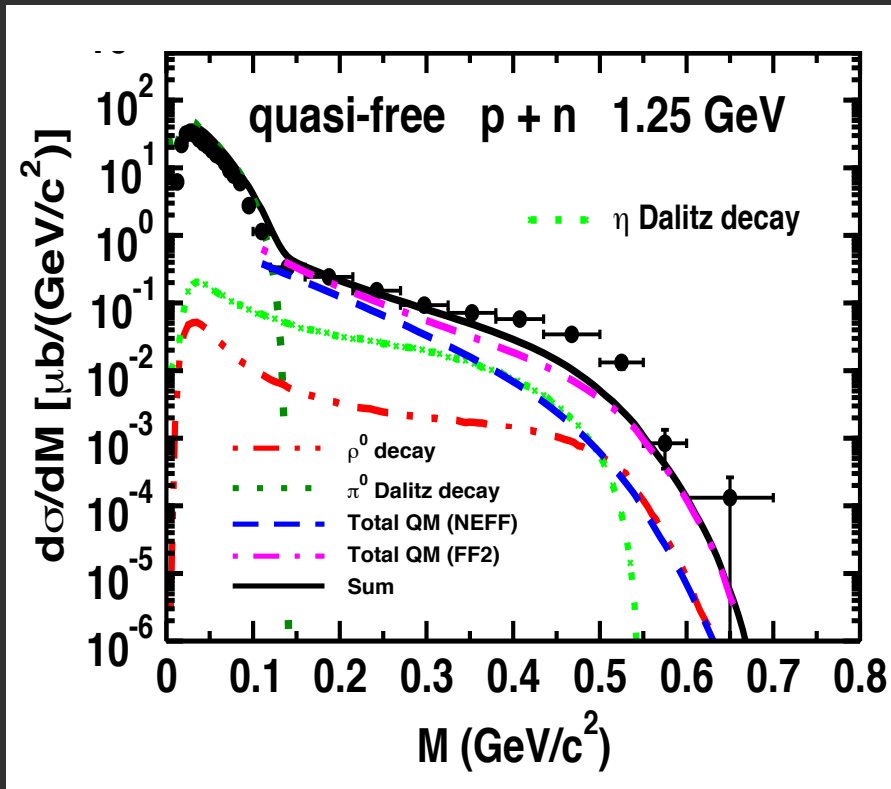


One- π production at 1.25 GeV/u essentially due to delta excitation

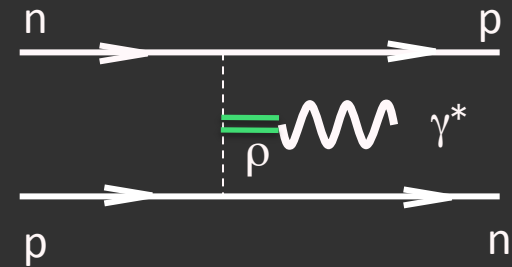
- Allows to extract the $\Delta \rightarrow p \gamma^*$ branching ratio
- moderate effect of Δ transition form factor (TFF) (grey band)



Close to a theoretical explanation(?!)!



OBE calculation including pion electromagnetic form factor for the internal pion line.

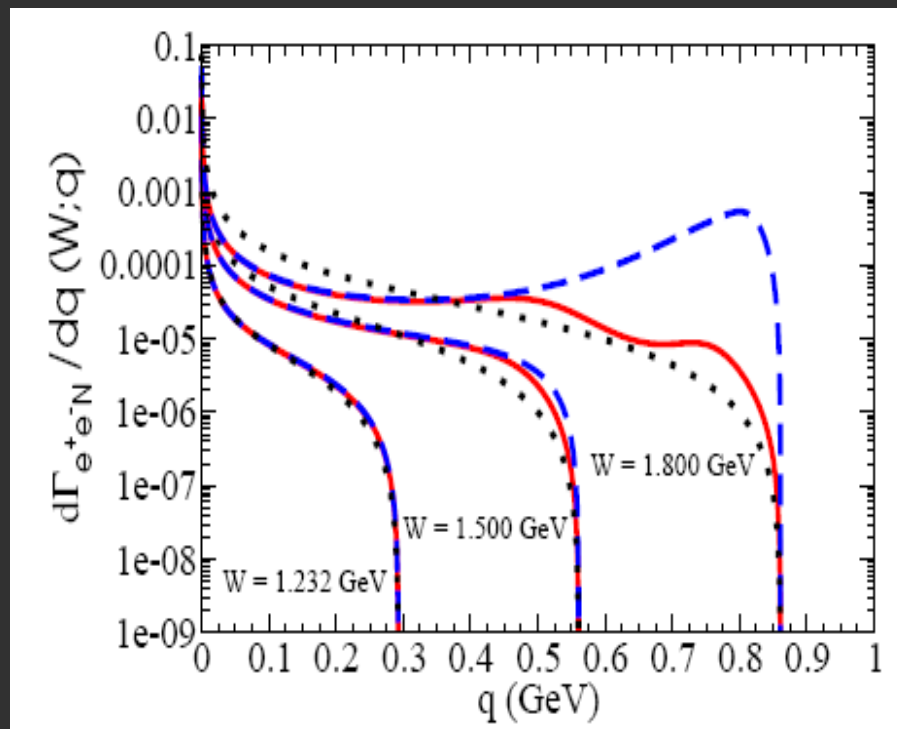


t-channel charged pion exchange

R. Shyam and U. Mosel, arXiv 1006.3873

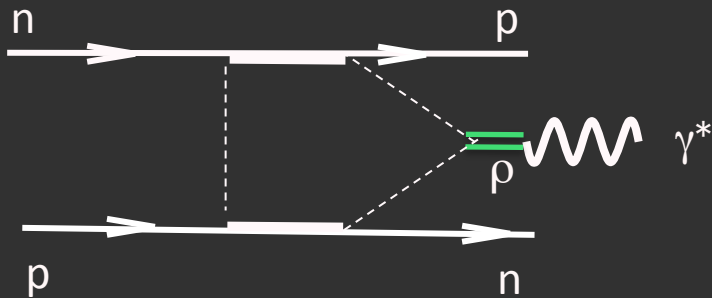
Close to a theoretical explanation(?)!

- The Δ -Dalitz decay in an effective "core + cloud" model
- Strong effect, if in the tail of the Δ -resonance

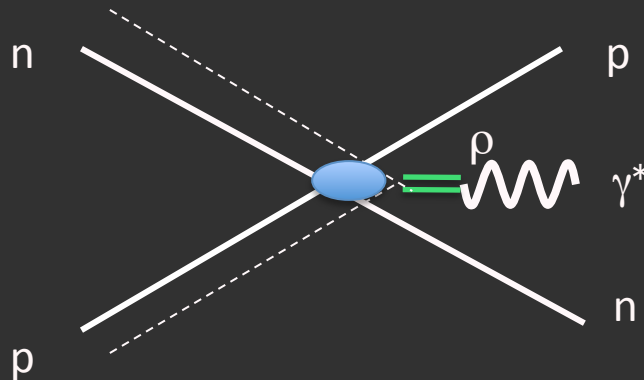


M. Pena, G. Ramahlo PRD85 (2012) 113014

More scenarios



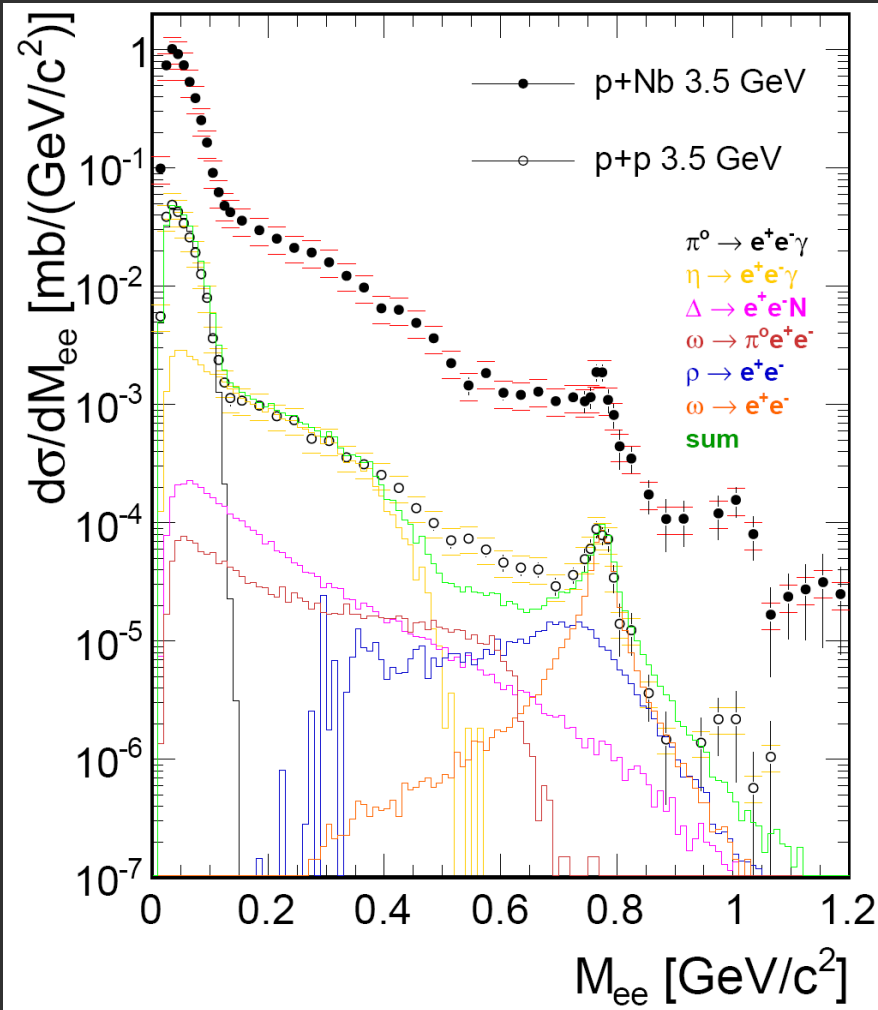
Double Δ excitation plus
"final state" interaction.
ABC inspired,
Clement et al.



s-channel process of two
"cloud pions".

p+p at 3.5 GeV

p+p and p+Nb reactions (3.5 GeV)



p+p:

extraction of **inclusive cross sections** by fitting conventional sources to the experimental spectrum:

$$\pi^0: 17 \pm 2.7 \pm 1 \text{ mb}$$

$$\Delta: 7.5 \pm 1.7 \text{ mb}$$

$$\eta: 1.14 \pm 0.2 \text{ mb}$$

$$\omega: 0.273 \pm 0.07 \text{ mb}$$

$$\rho: 0.223 \pm 0.06 \text{ mb}$$

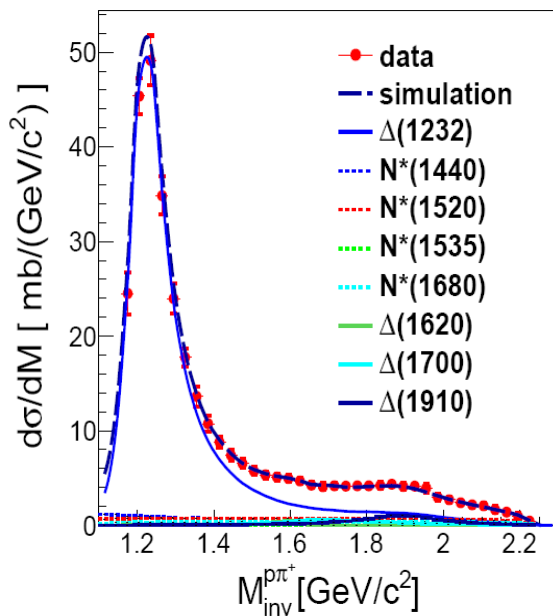
p+Nb:

ω production suppressed

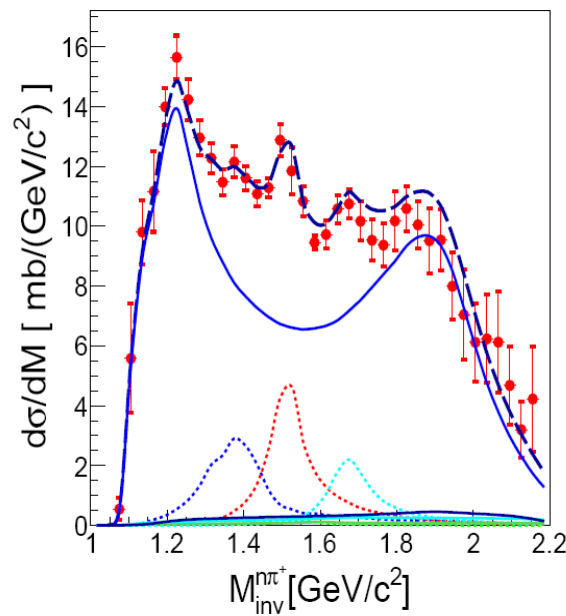
Exclusive channels in $p+p$ 3.5 GeV

- $pp \rightarrow p n \pi^+$ and $pp \rightarrow pp \pi^0$ (missing mass analysis)

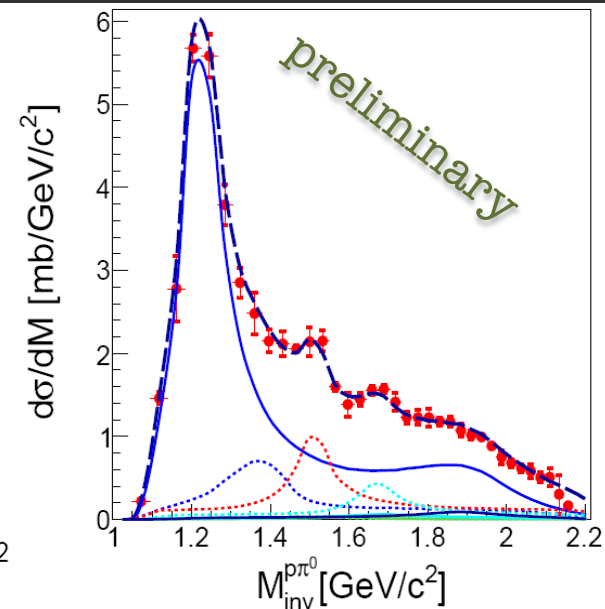
$\rho\pi^+$



$n\pi^+$



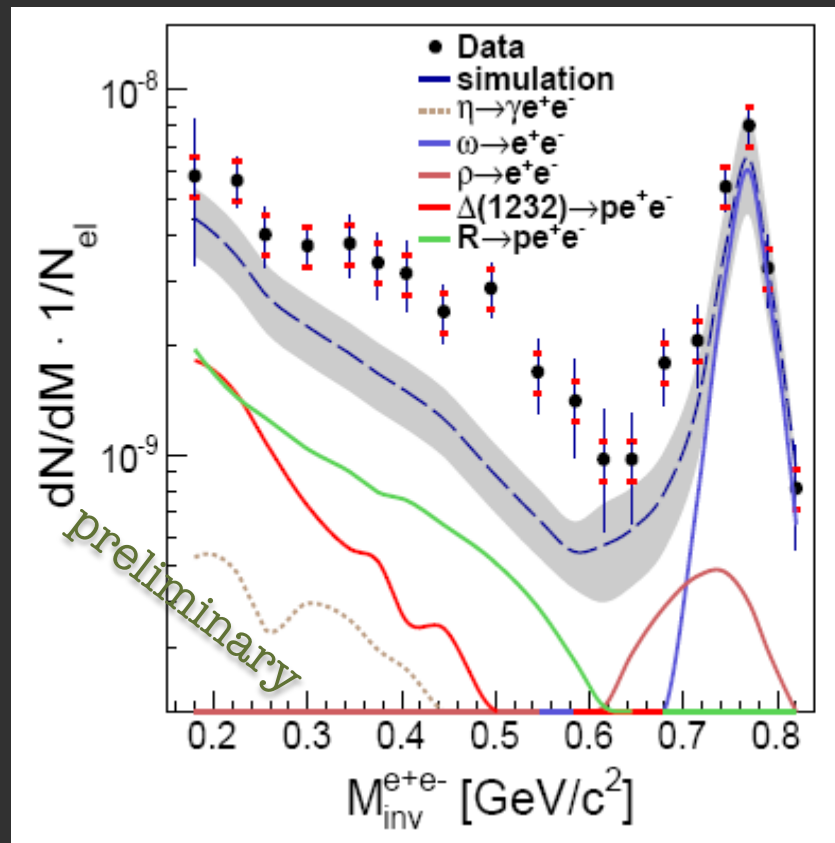
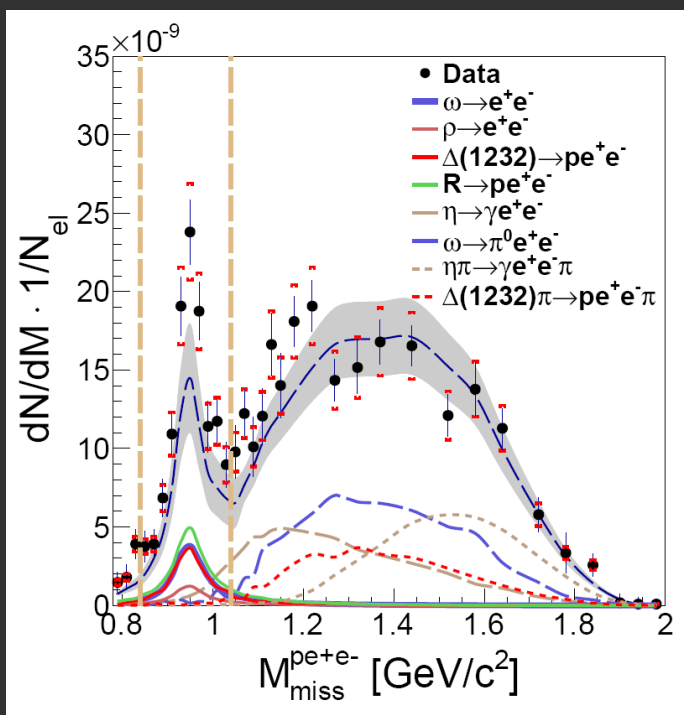
$\rho\pi^0$



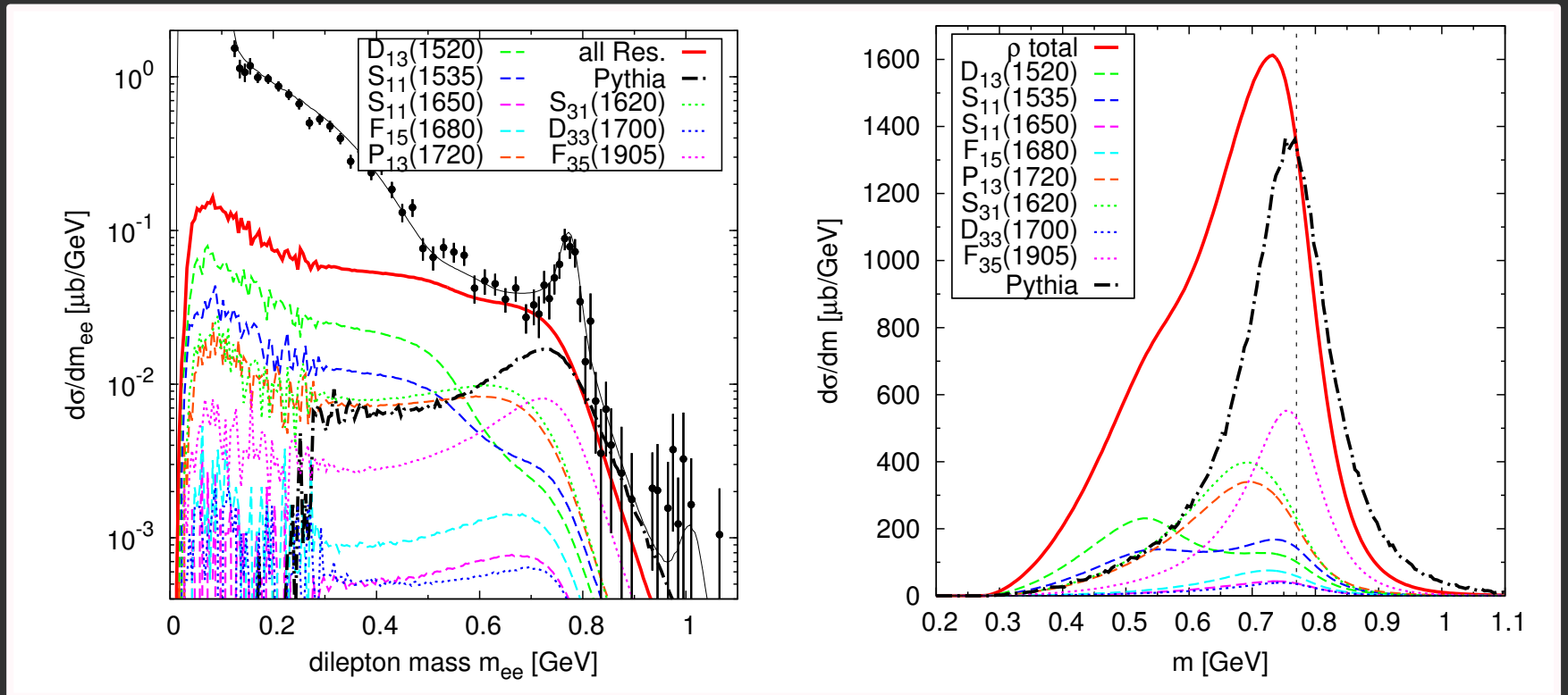
- Hadronic observables to fix the resonance contributions, analysis inspired by S. Teis et al. (Z. Phys. A356, 421 (1997))

Semi-inclusive e^+e^- Invariant Mass $pp(3.5 \text{ GeV})$

Selection on pe^+e^- invariant mass to suppress mesonic Dalitz-decays



HADES pp 3.5 GeV with GiBUU

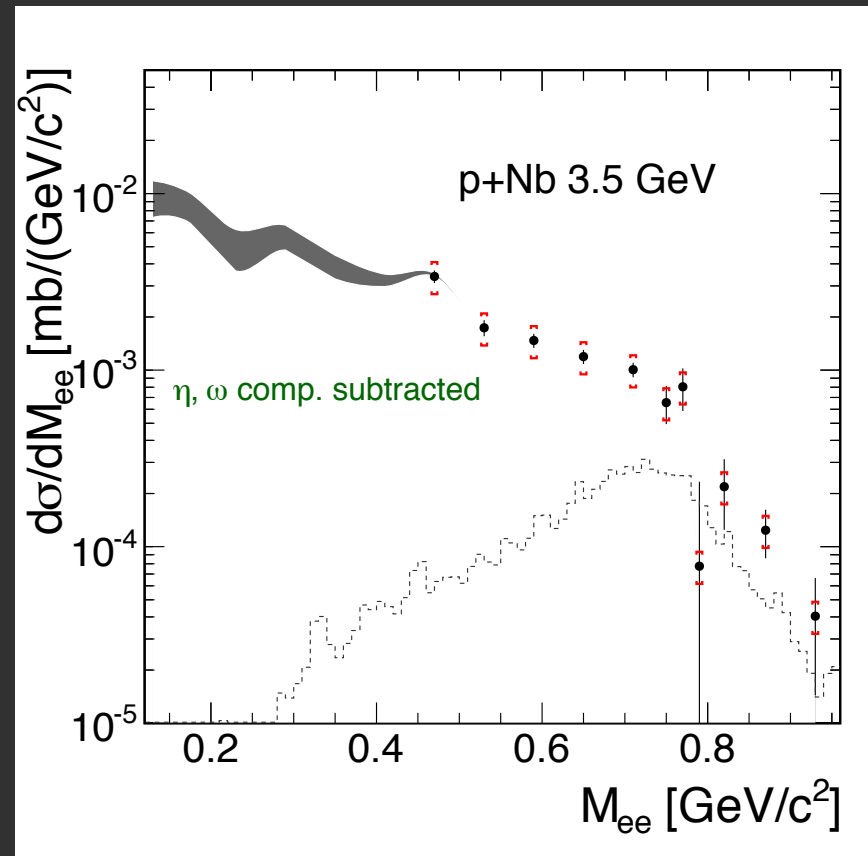
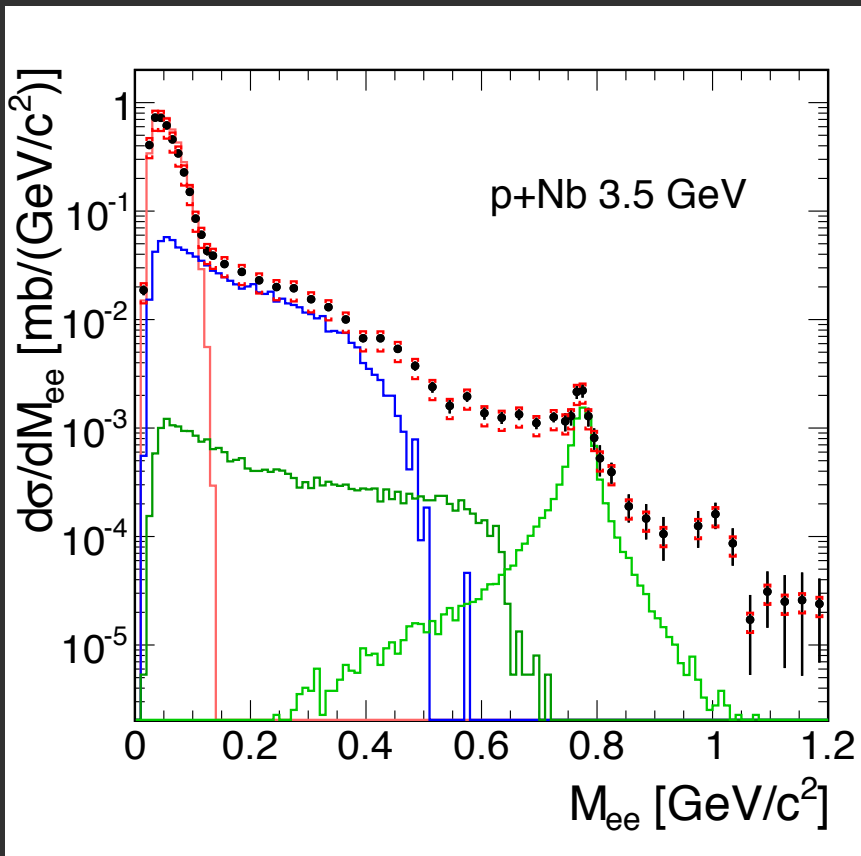


Resonance production cross sections from resonance model (based on Teis et al.)

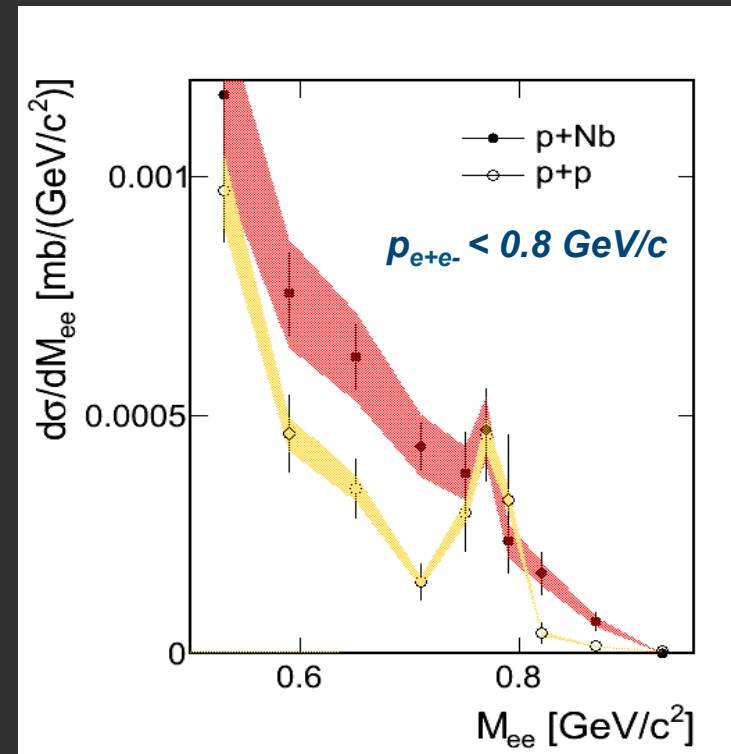
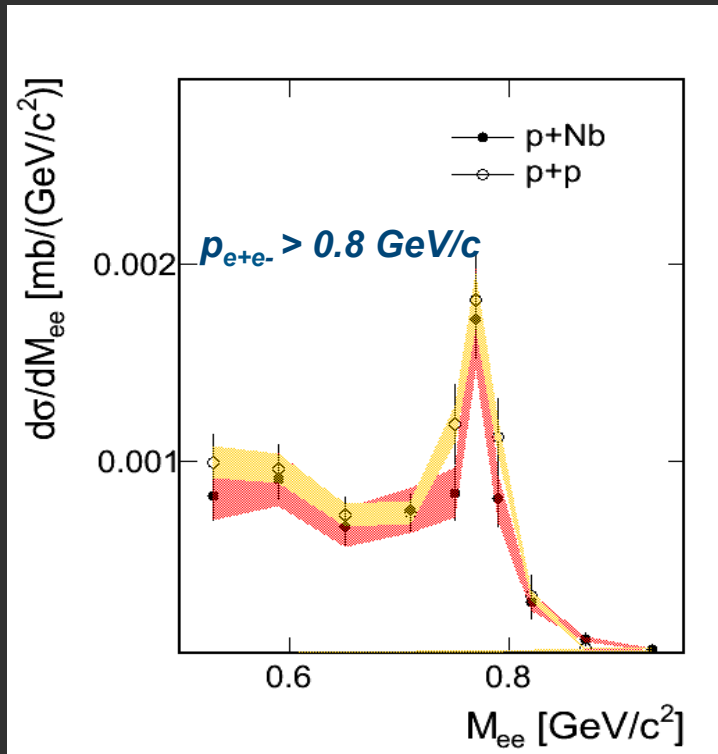
Giessen group, J. Weil, U. Mosel and colleagues: arXiv:1203.3557v2

Cold nuclear matter effects

Prompt dielectrons from p+Nb



Momentum binned invariant mass spectra

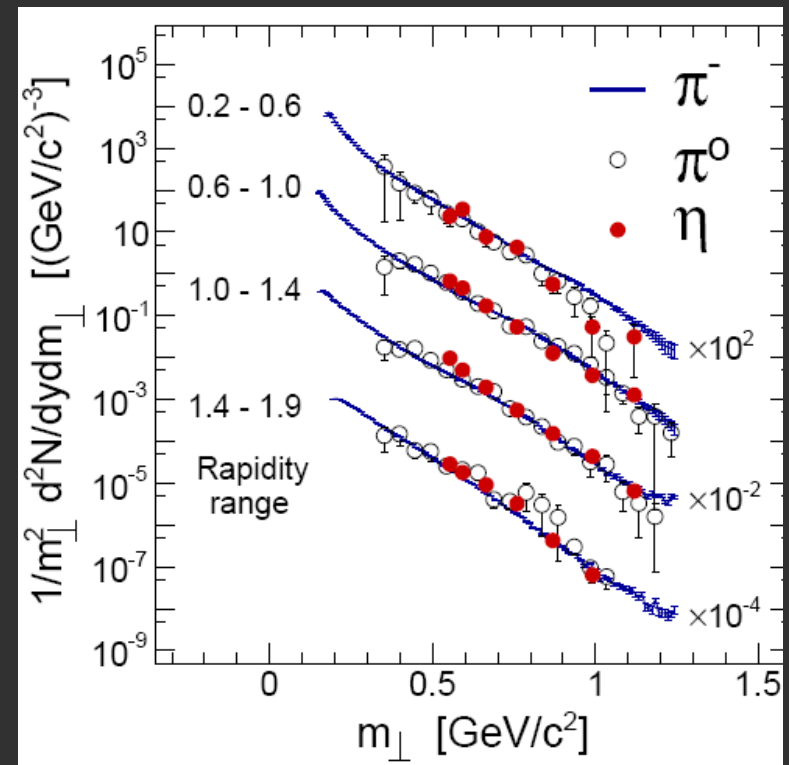
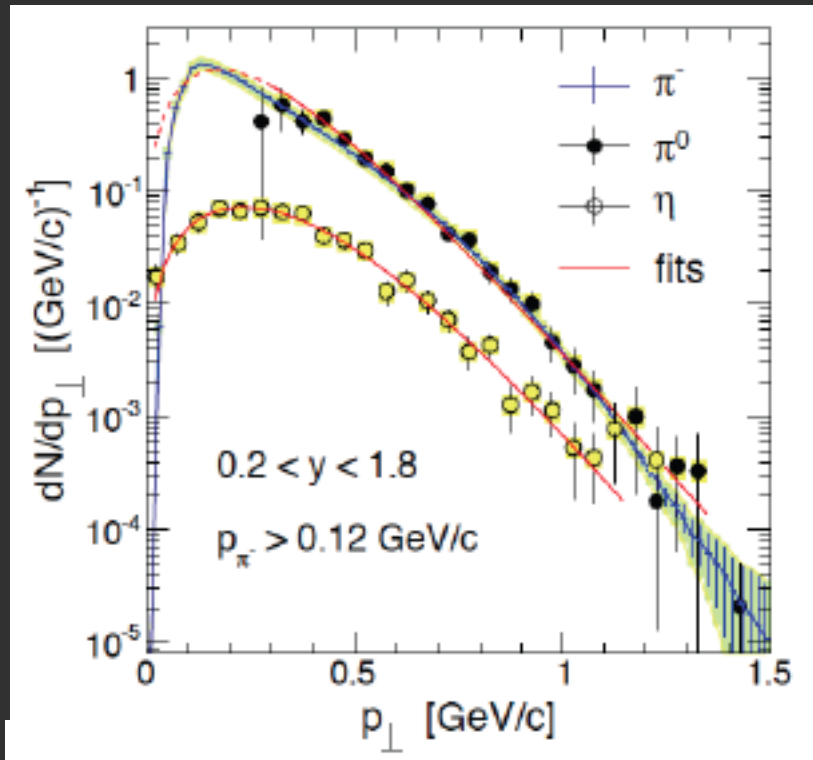


- First measurement of **in-medium vector mesons** in the **relevant momentum region**
- ω suppressed, in-medium decays buried under ρ -like contribution

From Background to Signal

Neutral mesons from conversion channels

- Data from p+Nb (3.5 GeV)
- Fixes important components of the cocktail



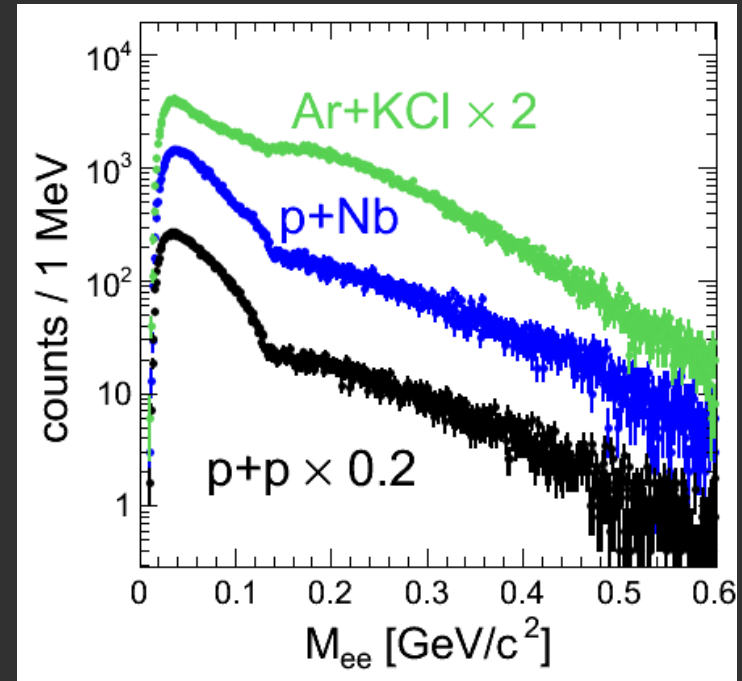
HADES: Phys. Rev. C 88, 024904 (2013)

What else ... ?

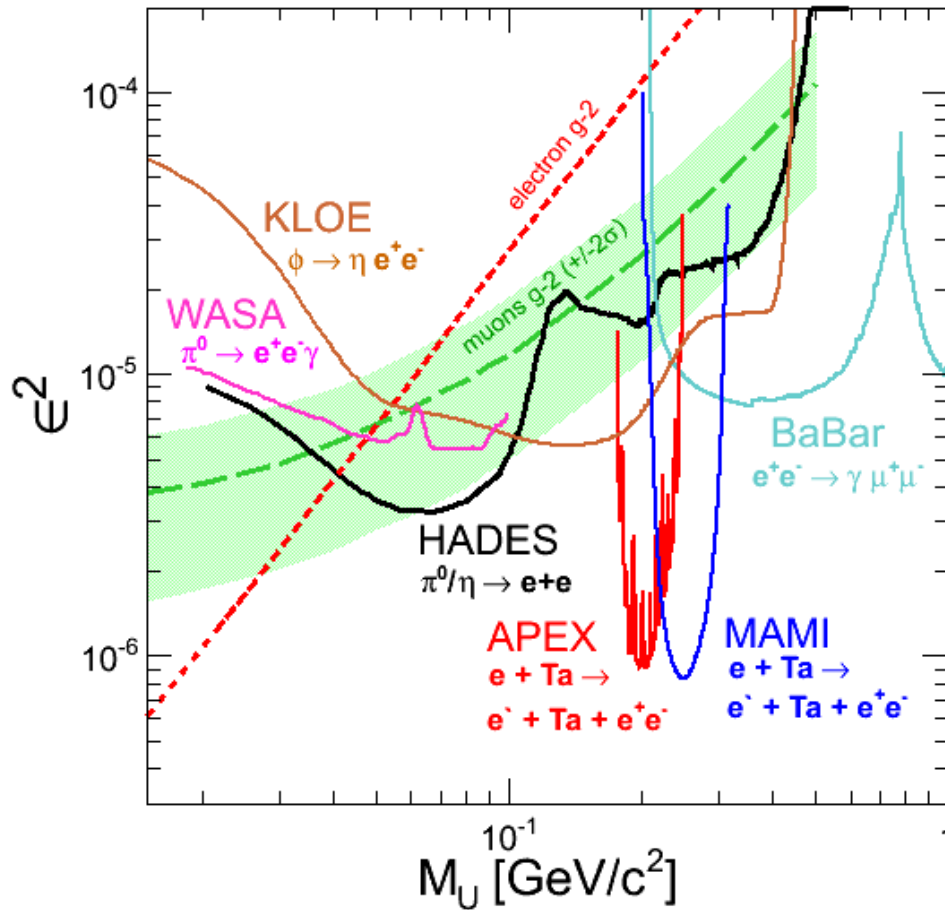
Search for a U-Boson (Dark Photon)

The HADES approach

1. Search for a peak structure in the raw dN/dM_{ee} spectrum of known mass resolution
2. If no peak found, get an UL on peak
3. Transform this UL into an UL on the mixing parameter ε^2
4. Compare with other experiments
5. If better, publish result
→ HADES collaboration, *PLB*, Volume 731, 265-271



HADES contribution to the dark photon search

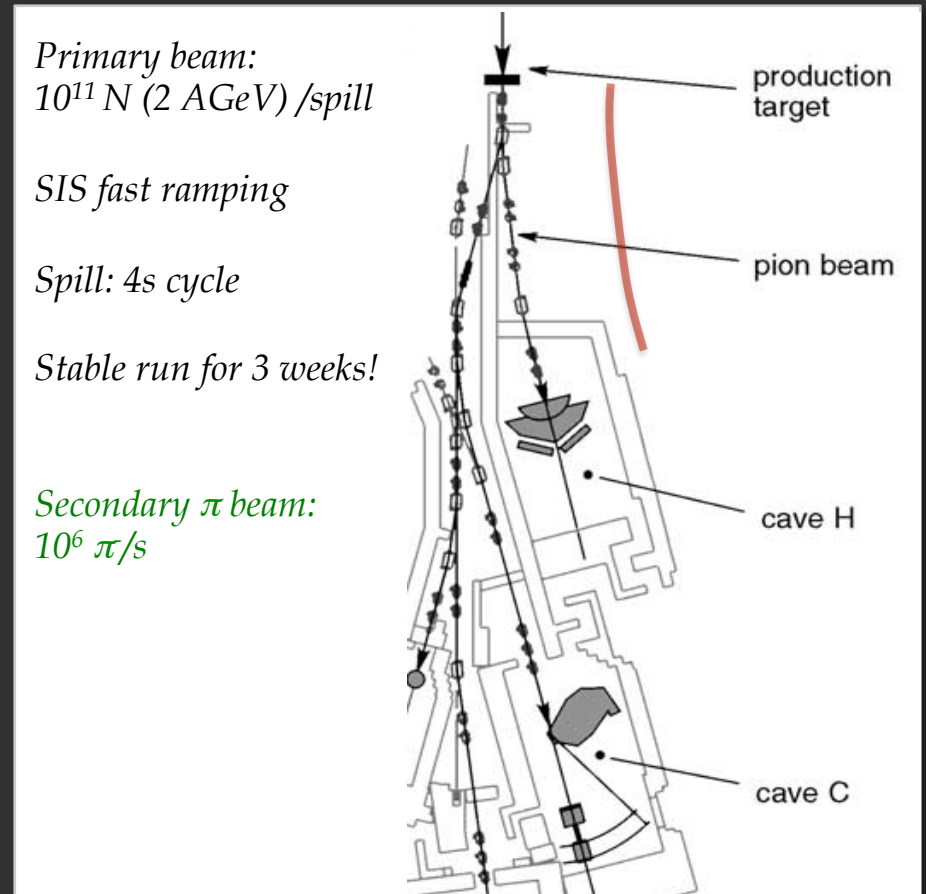


HADES collaboration,
Physics Letters B, Volume 731,
4 April 2014, Pages 265-271

coming next!

π -beam run in 2014

- **Physics with πN experiments:**
 - ✗ Resonance-Dalitz decays
 - ✗ Special interest to **sub-threshold vector meson** production
 - ✗ In-medium effects (strange and vector mesons)
- **Pion beam**
 - ✗ Momentum: $0.6 < p < 1.5 \text{ GeV}/c$
 - ✗ Intensity $I = 10^6 \pi/s$



Perspektives for Pion Beam Experiments with HADES in 2014

$\pi^-p \rightarrow n e^+e^-$ at 0.8 GeV/c

- ✗ Important to understand radiation from hot and dense medium
- ✗ Complementary approach to time-like form factors of baryons

Strangeness production in π^-A at 1.7 GeV/c

- ✗ Propagation of strangeness in cold nuclear matter
- ✗ Kaon in-medium potential

Excitation function of π^- and $2\pi^-$ -production

- ✗ Meson-baryon coupling (PWA)

The HADES collaboration

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Thank you !