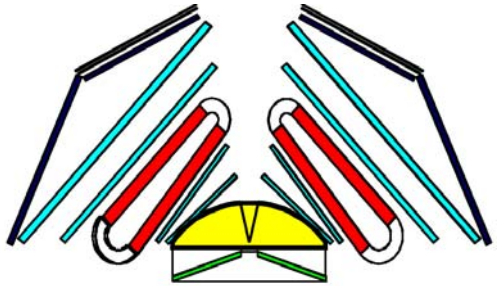
HADES



Probing of the in-medium hadron structure with HADES

P. Salabura

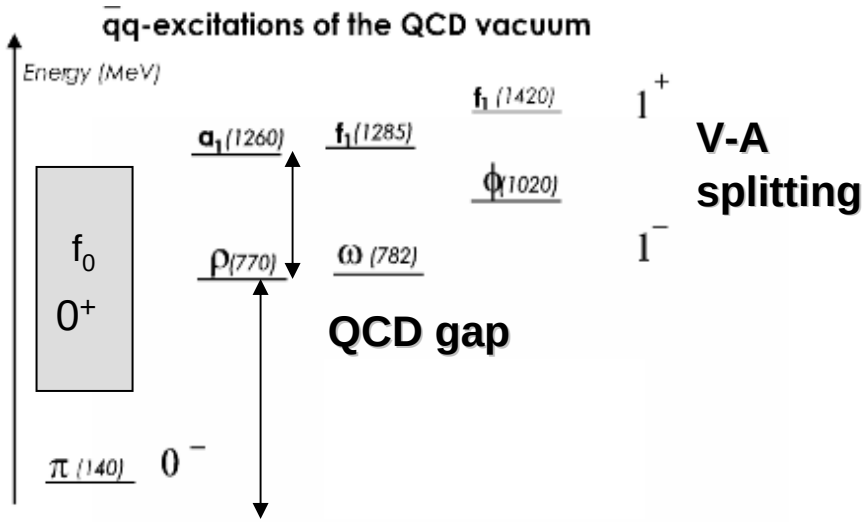
Institute of Physics

Jagiellonian University

- **Motivation**
- **Detector HADES @ GSI**
- **Physics programme of HADES : HI, pp, dp, pA, πN, πA**
- **Outlook**

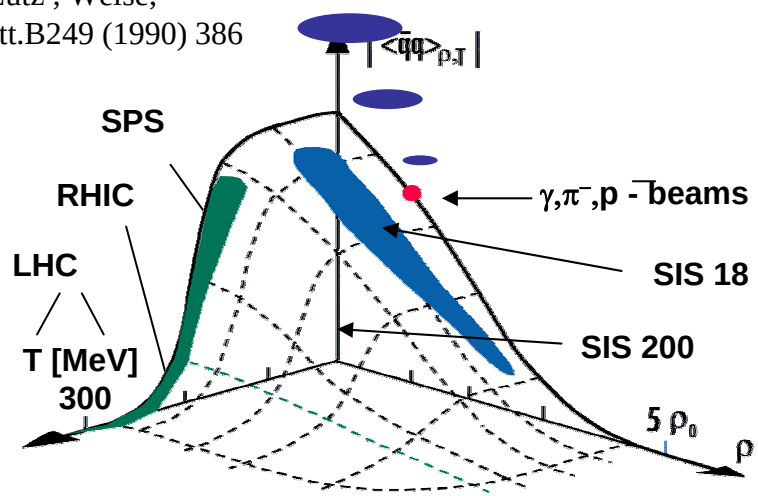
Chiral symmetry and hadron masses

- **Hadron mass spectrum reflects chiral symmetry breakdown - parity doublets**
- **constituent mass of light quarks is generated by** $< q\bar{q} >_{vac} \neq 0$
- $< q\bar{q} >$ **depends on environment (T, ρ)**



Partial restoration of chiral symmetry

Klimt, Lutz , Weise,
Phys.Lett.B249 (1990) 386



Brown-Rho scaling:

$m_\rho / m = (<qq_{bar}>_\rho / <qq_{bar}>_0)^{1/3}$

For low densities:

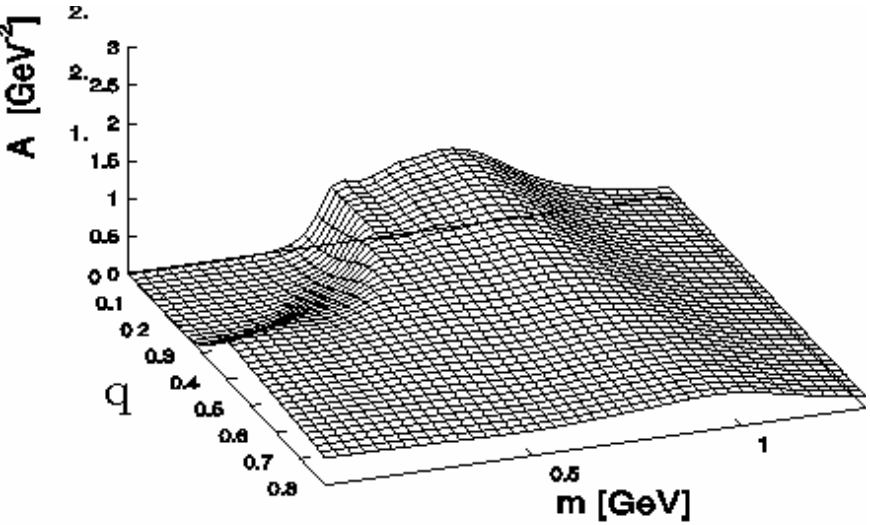
$m_\omega = m_0 (1 - \alpha \rho/\rho_0)$ for T=0 and $\rho \approx \rho_0$

Mesons in nuclear matter: hadronic scenario

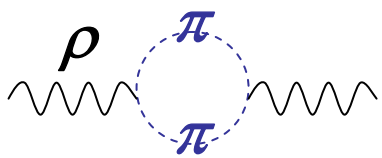
W. Peters et.al. NPA 632(1998)109:

ρ meson spectral function A(q,m)

$$A_\rho(M) = -\frac{2\mathrm{Im}\Sigma_\rho(M)}{[M^2 - m_\rho^2 - \mathrm{Re}\,\Sigma_\rho(M)]^2 + [\mathrm{Im}\Sigma_\rho(M)]^2}$$



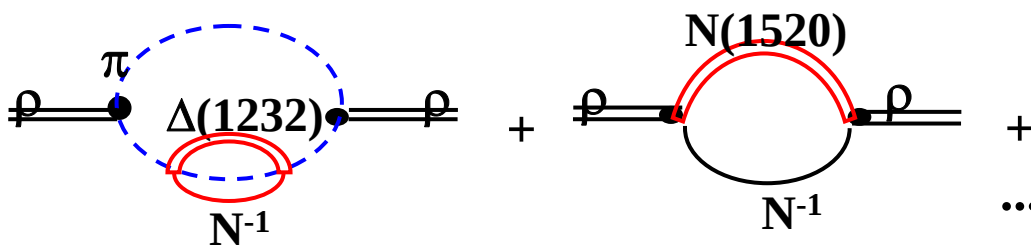
Vacuum:

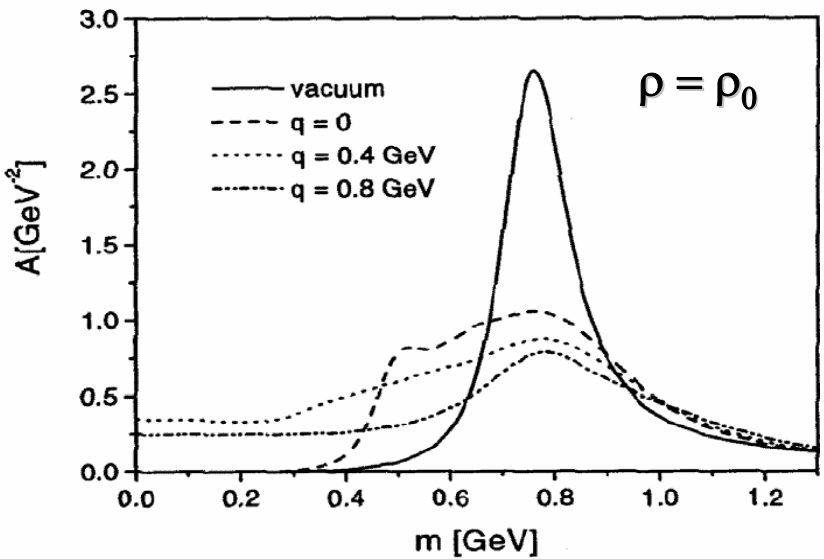


$$\Sigma_\rho(M) = -im_\rho\Gamma_{\pi\pi}(m)$$

$$m_\rho = 0.77GeV$$

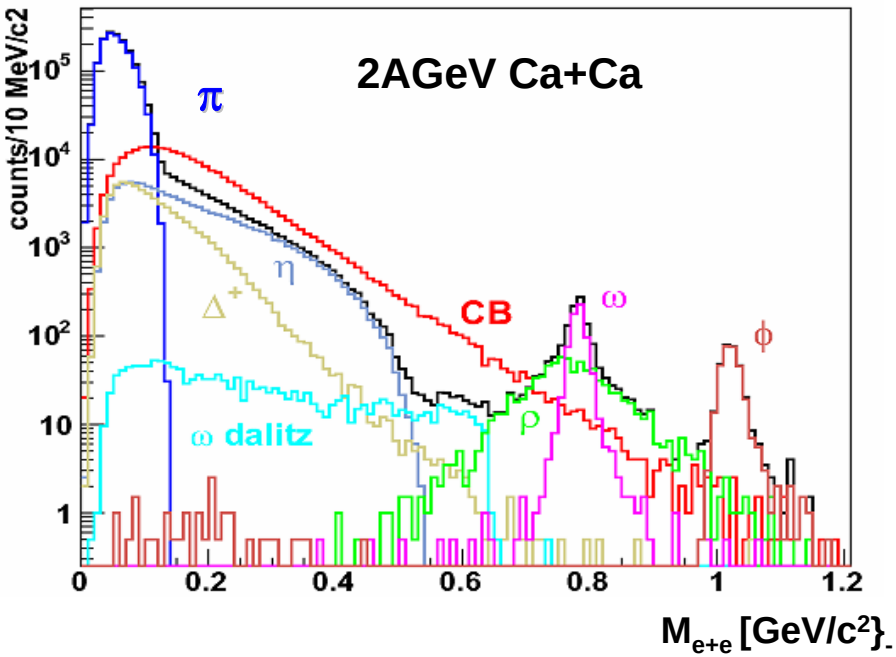
In medium:





What is the right picture?

Dielectron decays of „free" hadrons



Direct meson decays:

$$\Gamma_{\rho\to e^+e^-}/\Gamma_{tot} \approx 4.6\cdot10^{-5}$$

$$\Gamma_{\omega\to e^+e^-}/\Gamma_{tot} \approx 7.2\cdot10^{-5}$$

$$\Gamma_{\phi\to e^+e^-}/\Gamma_{tot} \approx 3.0\cdot10^{-4}$$

Dalitz-meson decays :

$$\Gamma_{\pi^0\to\gamma e^+e^-}/\Gamma_{tot} \approx 1.2\cdot10^{-2}$$

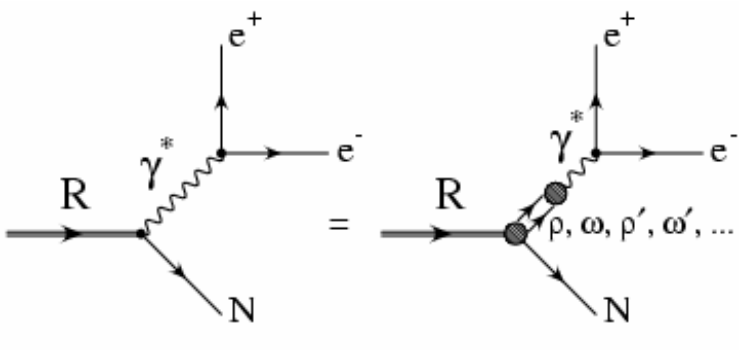
$$\Gamma_{\eta\to\gamma e^+e^-}/\Gamma_{tot} \approx 4.9\cdot10^{-3}$$

$$\Gamma_{\omega\to\pi^0 e^+e^-}/\Gamma_{tot} \approx 5.9\cdot10^{-4}$$

CB - combinatorial background from π^0 decays!

! **1-2 AGeV baryonic matter- baryon decays: NN->NR(N*, Δ)->NNe⁺,e⁻ - not well known !**

! **but very interesting – provides insight into electromagnetic structure of baryons**



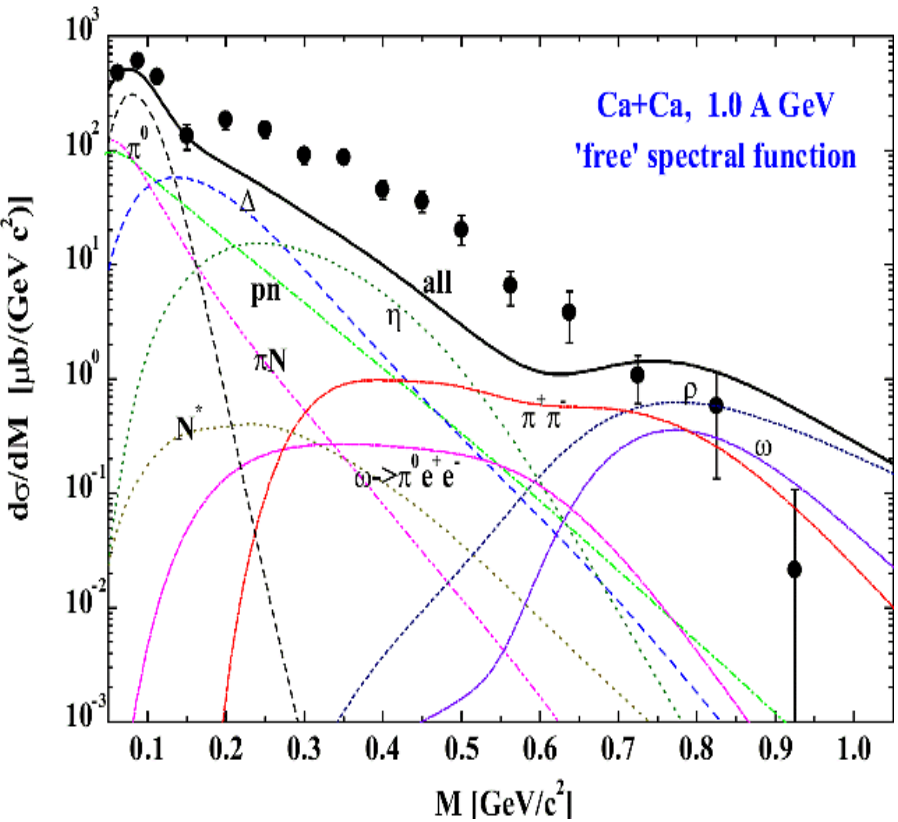
VectorMesonDominance ?

Dielectron from HI collisions

HADES

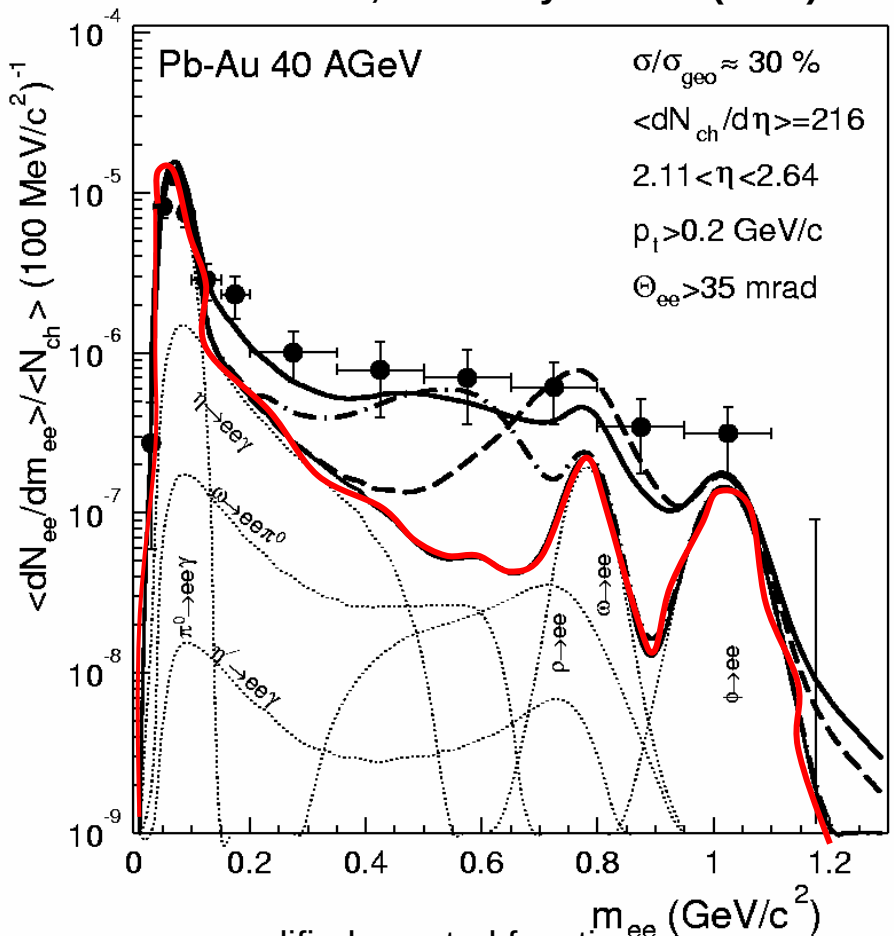
Data: R.J. Porter et al.: PRL 79(97)1229

Model: E.L. Bratkovskaya et al.: NP A634(98)168, BUU, vacuum spectral function



! cannot be described by dropping mass scenario or modified spectral functions

J.P.Wessels et al., Nucl. Phys. A 715 (2003) 262

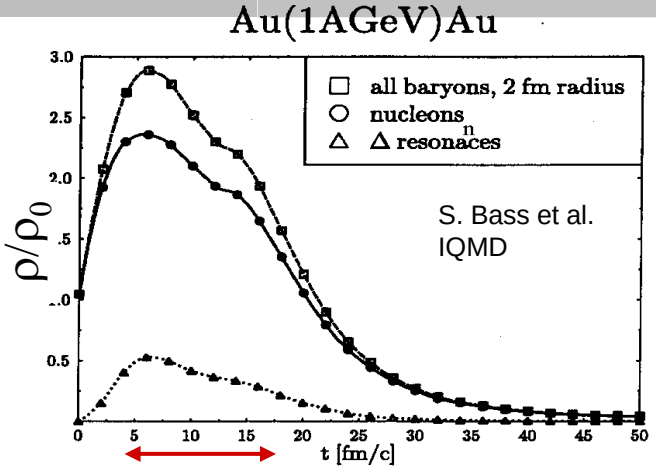


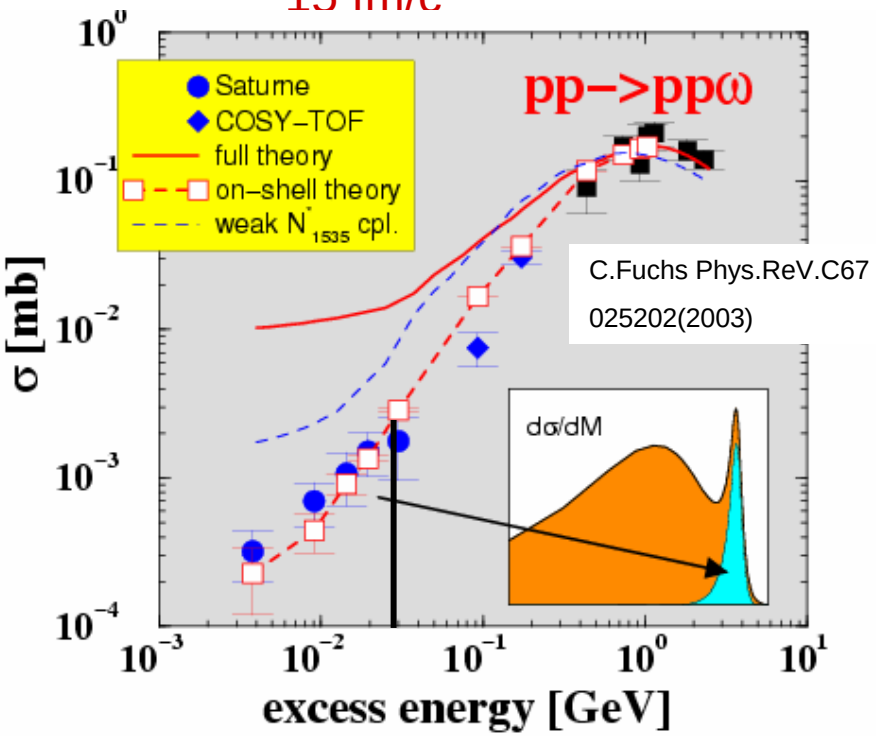
! Enhancement larger than at 158 AGeV!

SIS (BEVALAC) energy regime: 1-2 AGeV

- Final state in heavy ion collisions;
  - up to 200 charged particles (Au+Au)
  - approximately 10 % pions, baryon dominated
  - little strangeness
- Production of vector mesons below threshold
  - co-operative process :NN →N Δ, ΔN →NNω

  πN →N*(Δ) → Nω
  - important role of baryonic resonances
  - production confined to high density phase
  - One vector meson decaying into lepton pair per 10 Million reactions !
- Enhancement of baryon density
  - ↳ $\Delta\tau$ ($3 > \rho/\rho^0 > 2$) = 15 fm/c..
  - Comparable to ρ\ω life times : τ_V=1.3\23 fm/c
- Near threshold dynamics - off-shell effects!





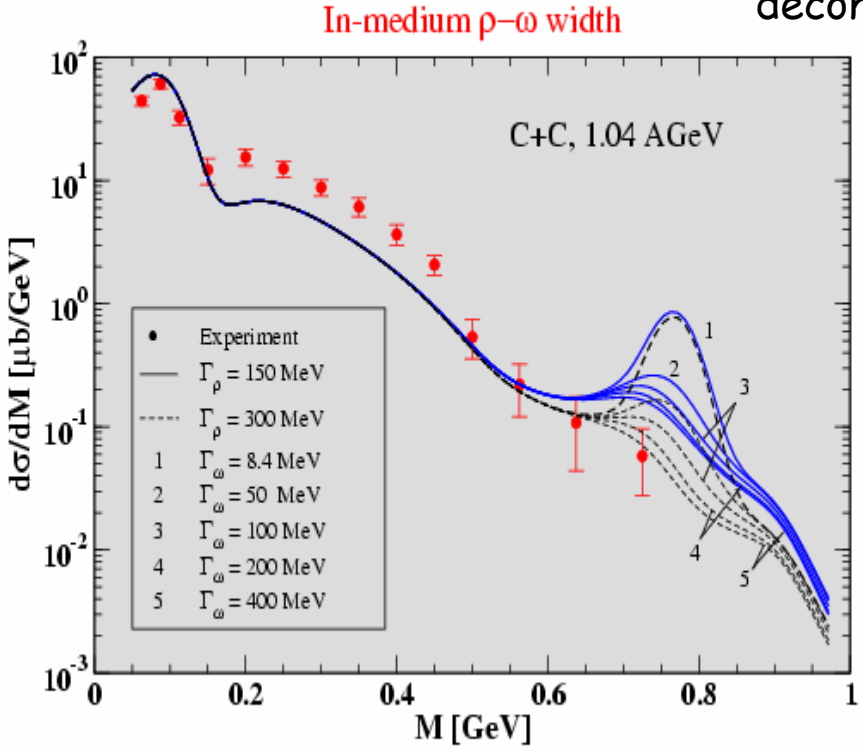
DLS puzzle...

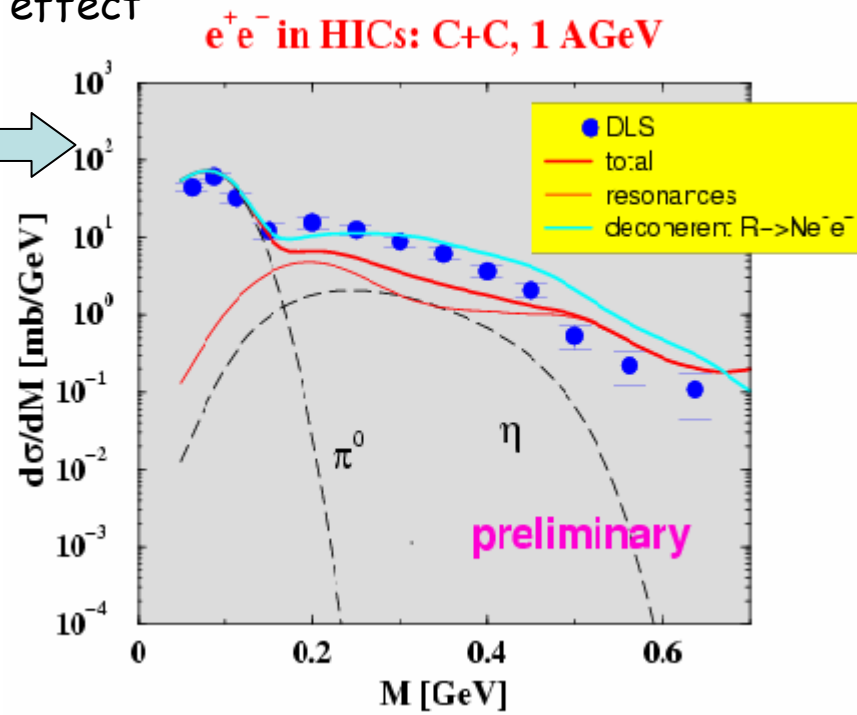
HADES

Calculation: C. Fuchs et al.
Phys. Rev. C67 025202(2003)
Data: R.J. Porter et al.: PRL 79(97)1229

$$B(\mu)^{R\to Ne^+e^-} \sim B(\mu)^{R\to NV}\frac{\Gamma_{V\to e^+e^-}}{\Gamma_V^{tot}}$$

decoherce effect





fit to DLS data:

$\simeq 150$ MeV, $\Gamma_\omega^{coll} \simeq 200 \div 300$ MeV @ $< \rho_B > \sim 1.5\rho_0$

Needs more precise data –

- **HADES C+C at 1 and 2 AGeV**
- **study of elementary processes!**

Spectrometer Concept

HADES

- **Geometry**
  - ✓ Full azimuth , polar angles 18° - 85°
  - ✓ Pair acceptance ≈ 0.35
  - ✓ about 80.000 detector channels

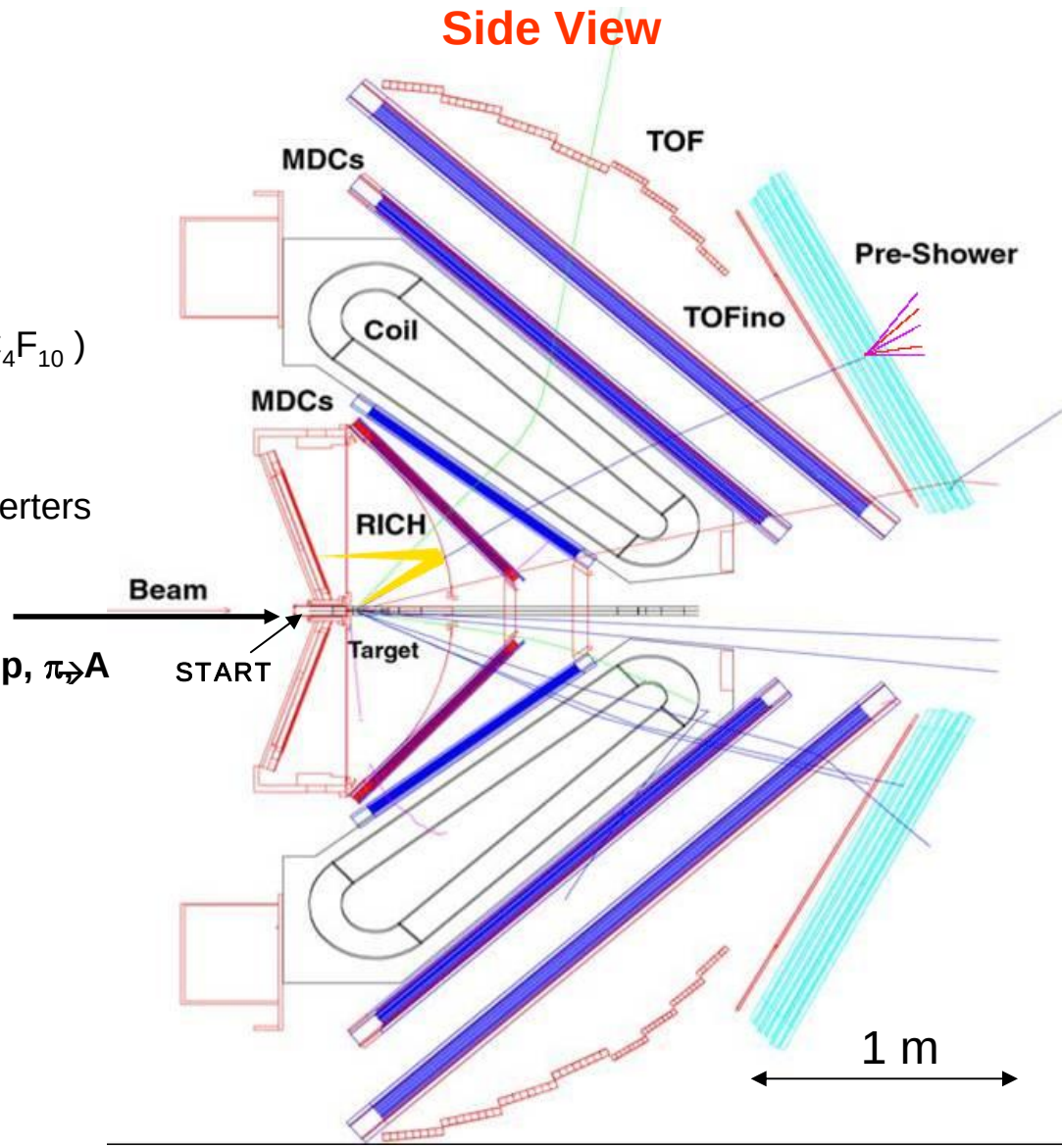
- **Fast particle identification**
  - ✓ Hadron blind RICH : gasous Cherenkov (C_4F_{10}) with CsI photon detector.
  - ✓ TOF (Scintillator rods) : $\sigma \approx 150$ ps
  - ✓ Pre-Shower 18 pad chambers & lead converters for em. shower detection

- **Online e^+e^- identification**
  RICH, TOF, Pre-Shower Image processing

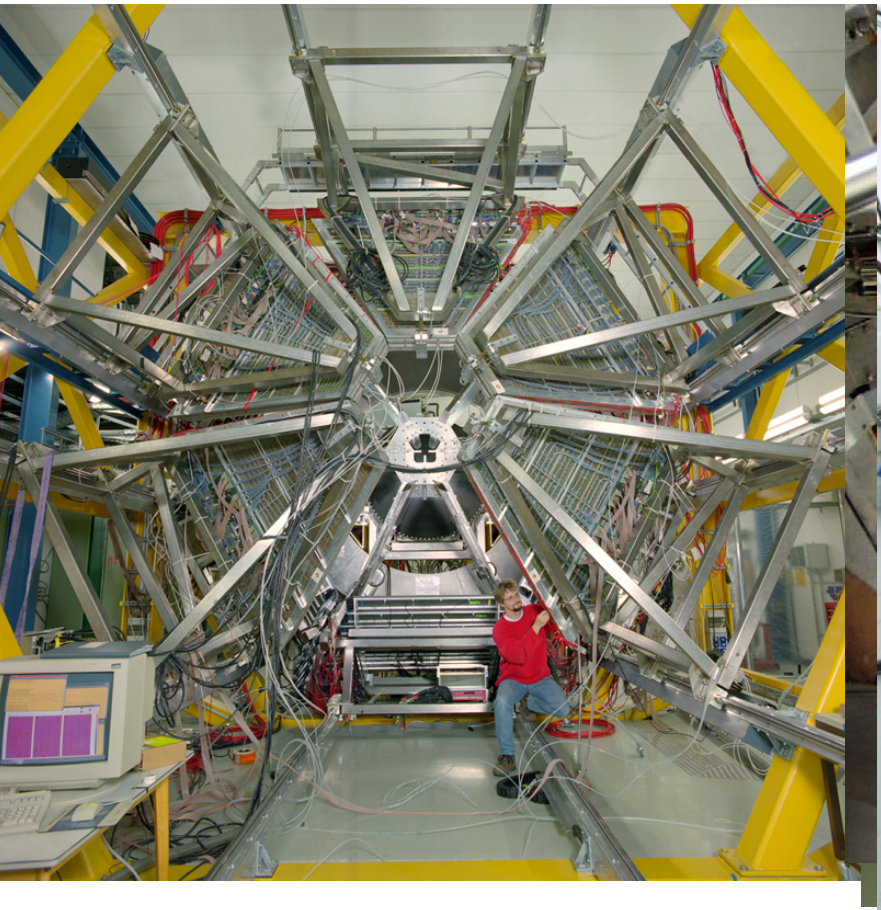
- **Momentum measurement**
  - ✓ ILSE, super conducting toroid $B\rho = 0.7$ Tm
  - ✓ MDC Multi-wire drift chamber, $\sigma_y \approx 100$ μm
  - ✓ $\Delta M_{e+e}/M \approx 1.5\%$ at ρ/ω

1995-2002 R&D construction

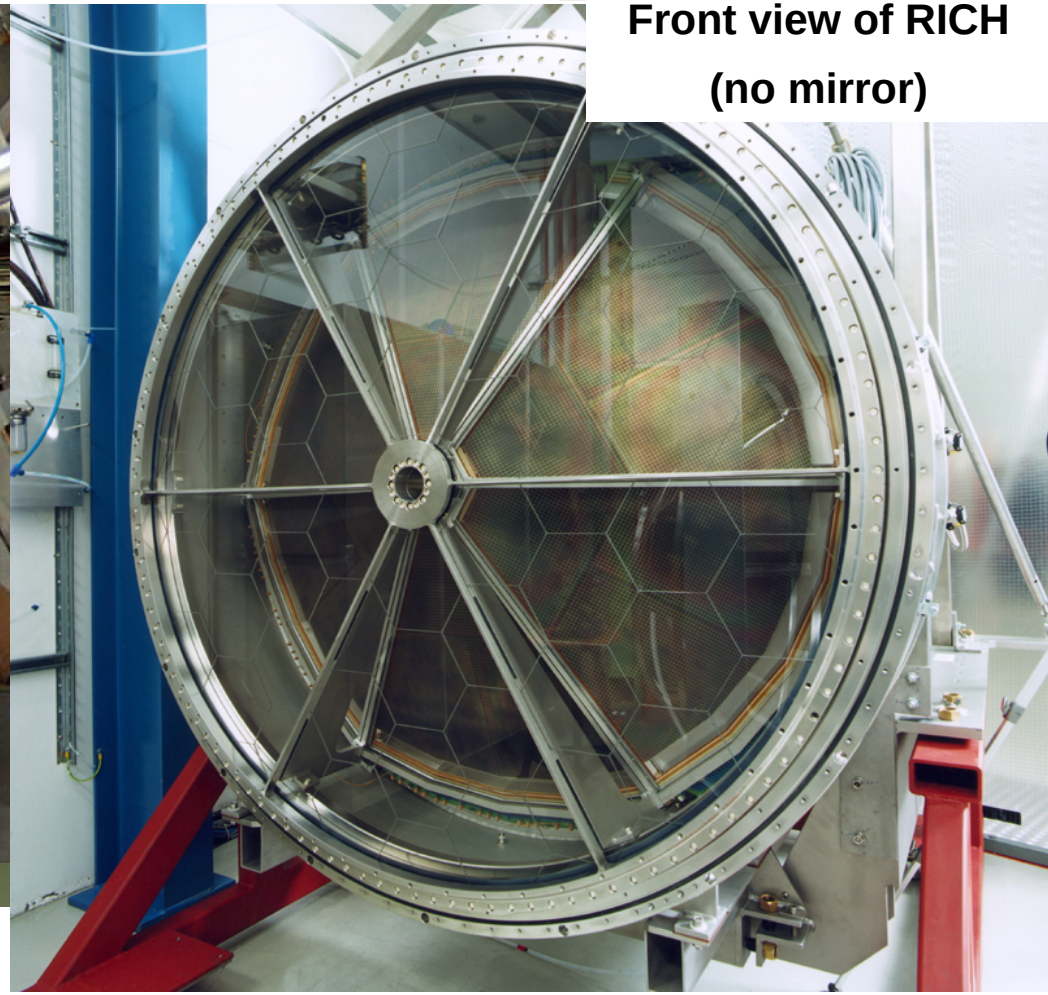
2002- production runs



HADES Spectrometer @ GSI



Beam Upstream View



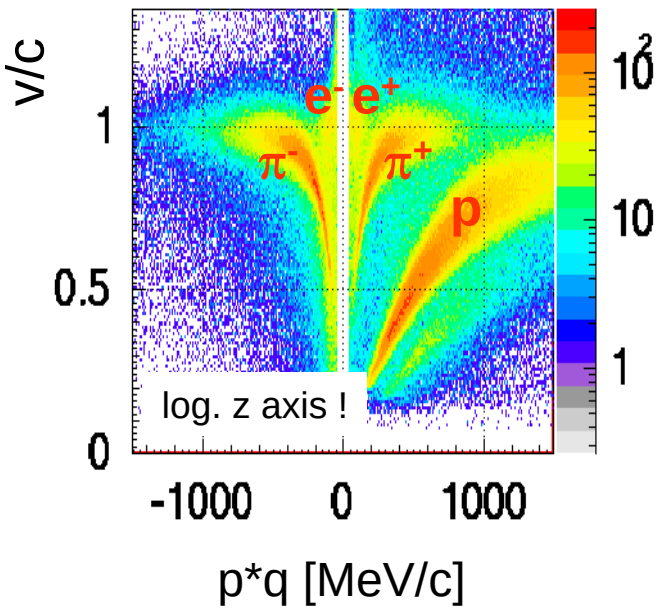
Front view of RICH
(no mirror)

3 production runs: C+C @ 1and 2 AGeV
(2002-2004) p+p @ 2.2 GeV

C+C @ 2 AGeV with HADES

C +C @ 2 AGeV (no outer tracking)

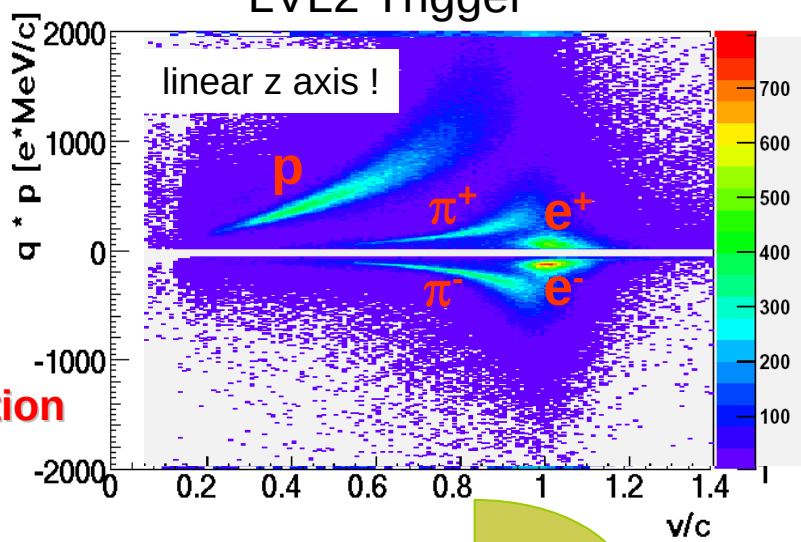
LVL1 Trigger

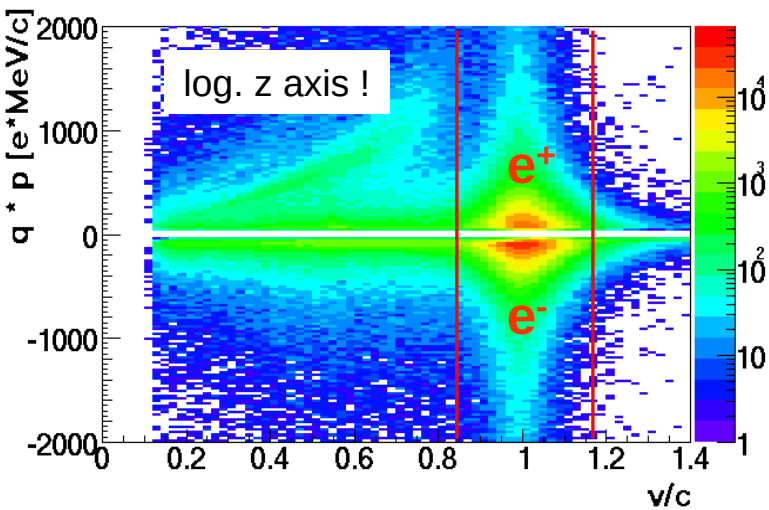


Online
RICH +
META

10 fold event reduction

LVL2 Trigger





Offline Analysis,
Tracking

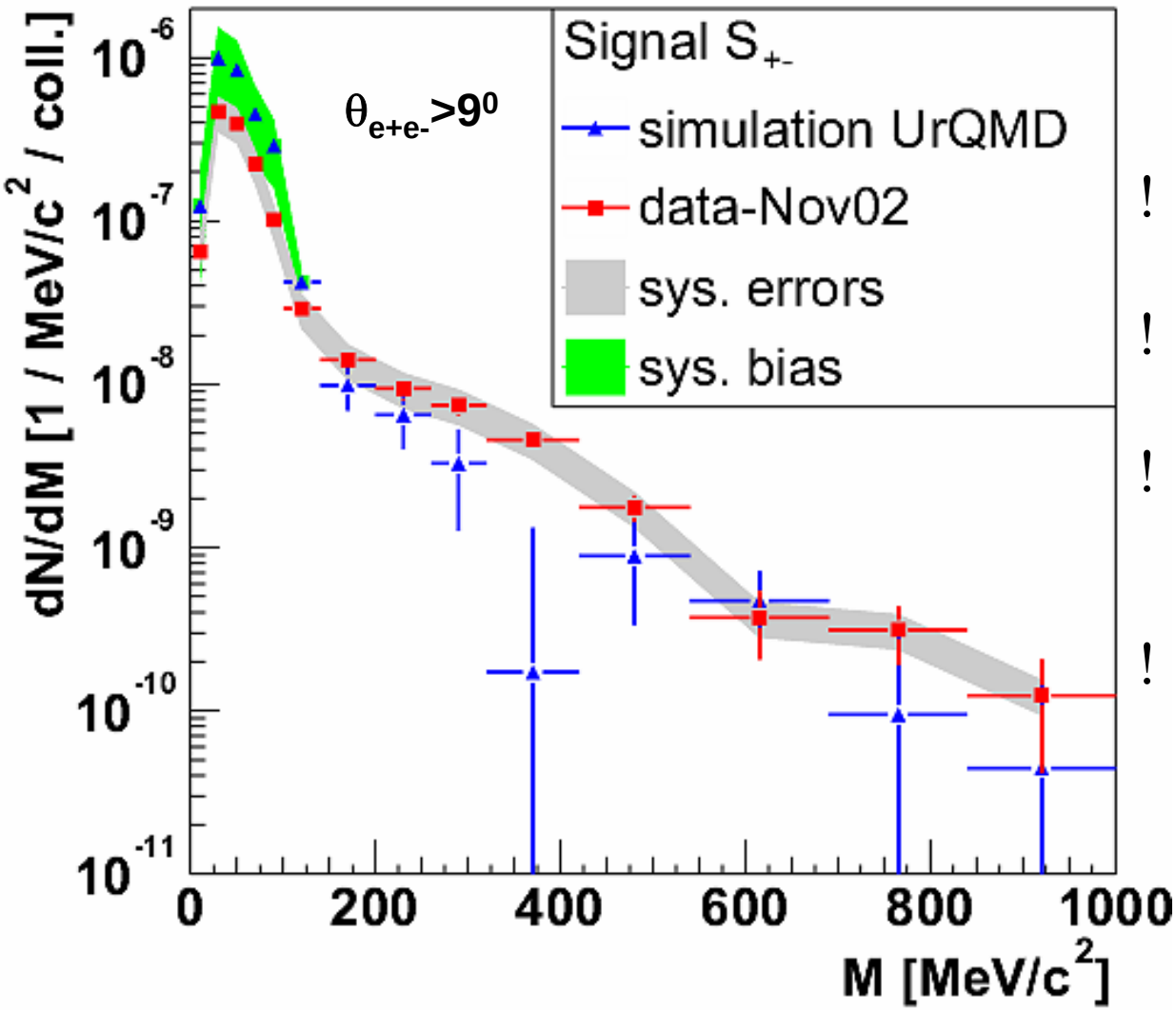
✓ 3% hadron contamination for p>0.6 GeV/c for C+C

Dielectrons from C+C at 2 AGeV

HADES

! ***No*** Efficiency / Acceptance ***Correction***

preliminary



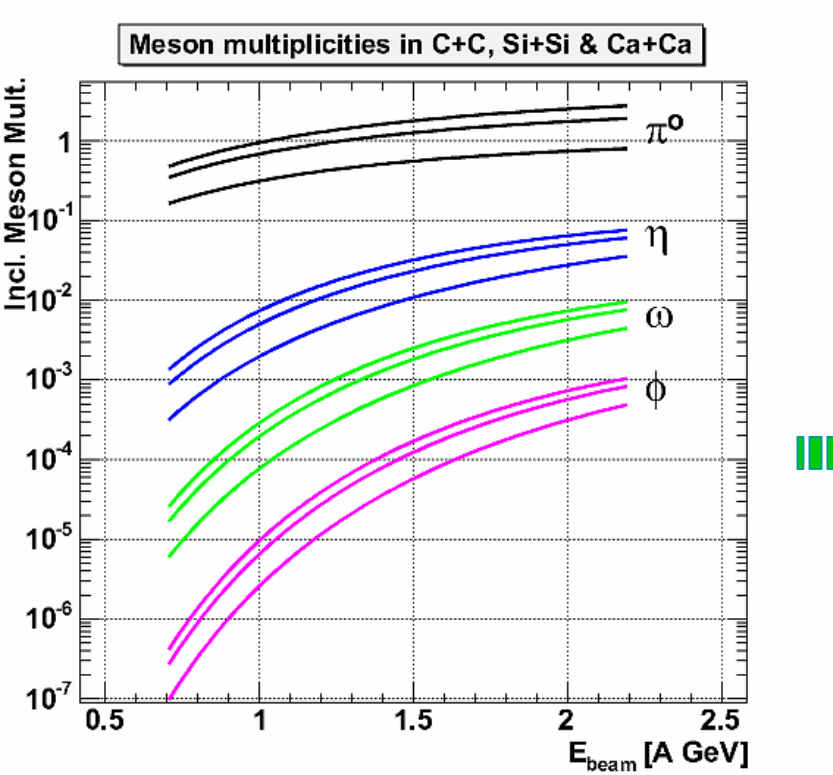
- ! Syst. variations only due to cuts in data & sim
- ! **Simulation**: URQMD 1.3 – hadronic coctail
- ! Charged pion multiplicities agree with calculations and other data (KAOS/TAPS)
- ! Comparable statistics collected for C+C @ 1 AGeV

Dielectrons from Ca+Ca: hunting for vector mesons..

HADES

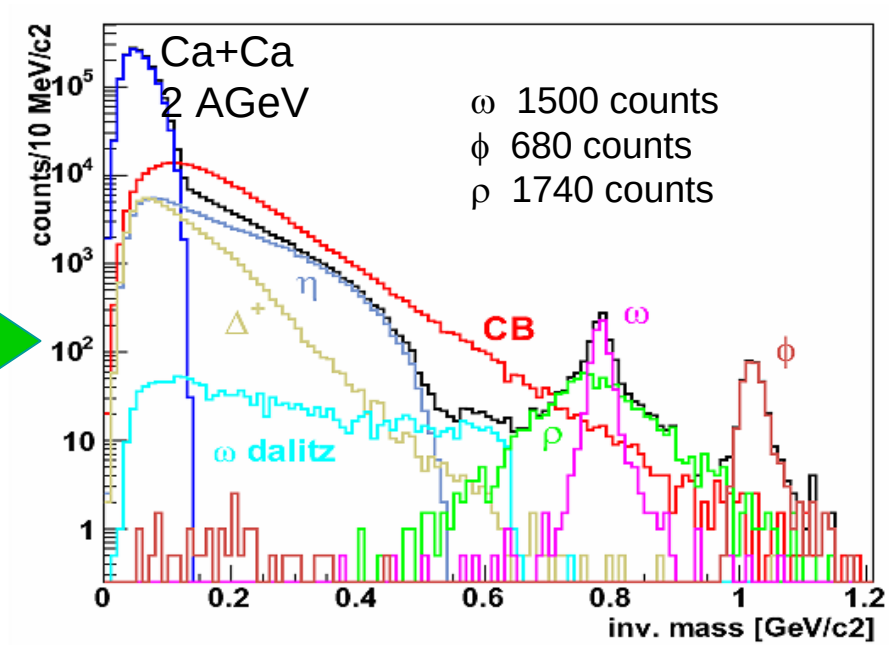
- **in medium vector meson properties- spectral functions $A_V(M_{e+e-}, p)$ – double differential distributions, centrality dependence**

$m_{t\ scaling}$ E. Bratkovskaya Phys.Lett. B424(1997)244



Predictions for HADES – 4 weeks data taking

- no enhancement and in-medium modifications assumed



planned for the next year

Proton and pion beams @ GSI

HADES

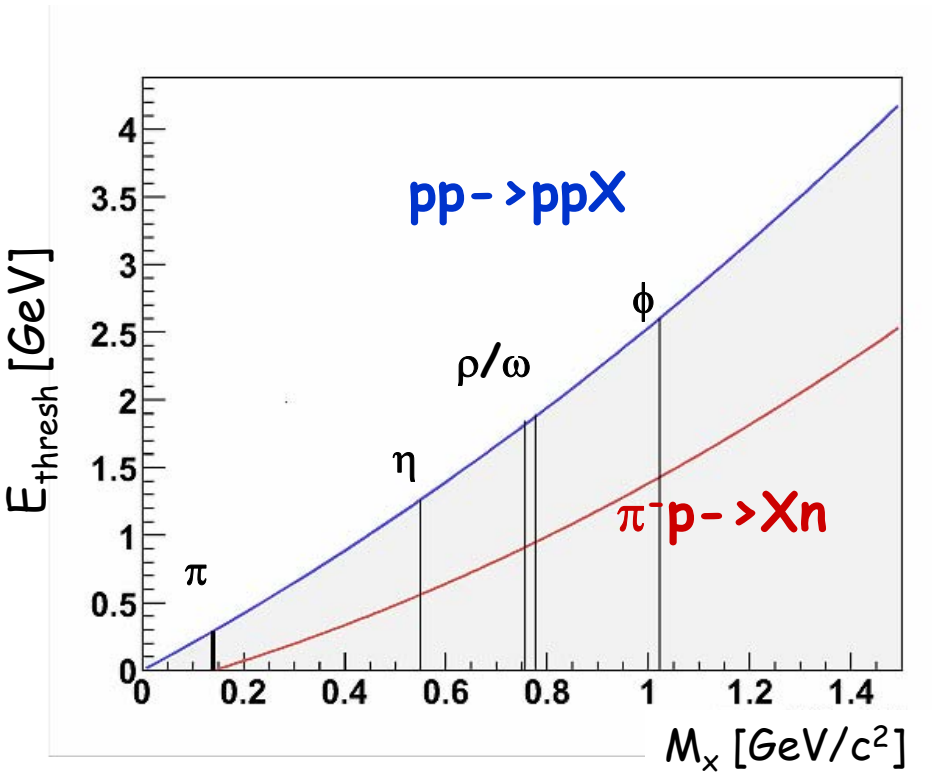
✓ **study elementary dielectron sources**:

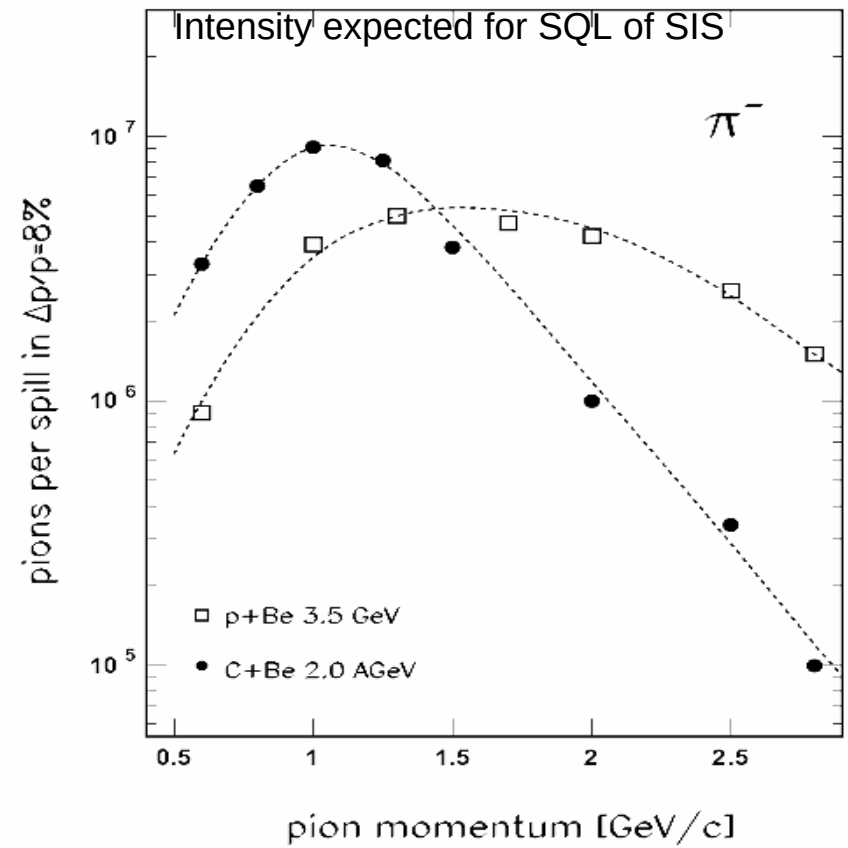
pp , pn, π^-p collsions

✓ **Study in-medium vector meson properties i** pA, πA reactions

✓ proton beams with E< 4.5 GeV

✓secondary π beams: high intenisty primary beams : N_2, C (SQL)



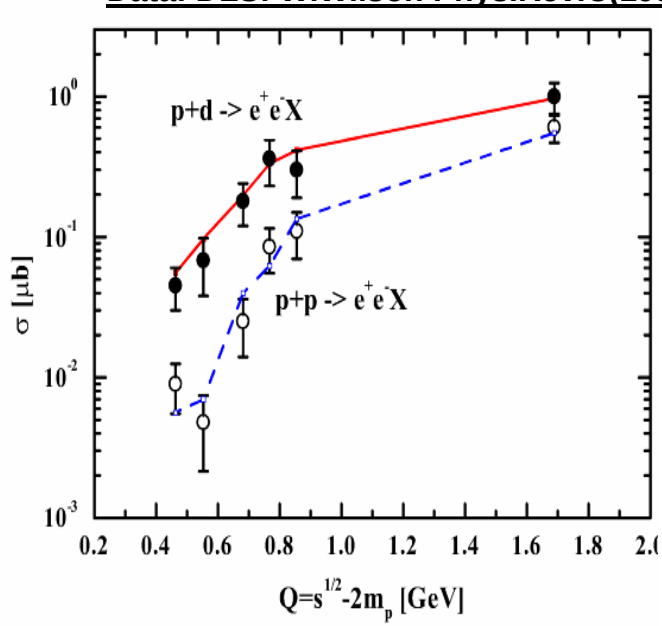


Dielectron from pp pn πN collisions

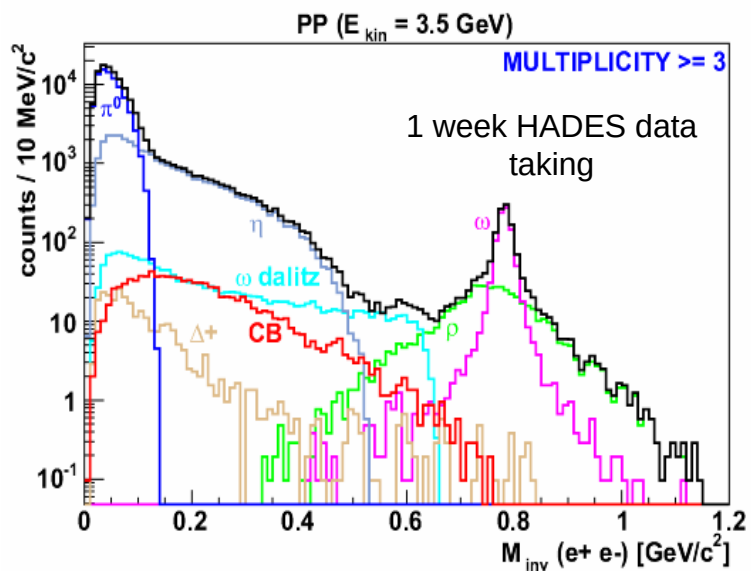
HADES

- **pp and dp collsions at 1.25 AGeV :**
- Dalitz decays of Δ : trans. form-factors (tests of VMD): exclusive **pp→pΔ⁺ →ppe⁺e⁻ ,** NN bremsstrashlung (massive photons)- em. form-factor of nucleon
- Isospin dependence of differential pp/pn cross sections (important for C+C at 1 AGeV !)

Data: DLS: W.Wilson Phys.Rev.C(1998)



- **pp/πp collsions near ρ/ ω production threshold**
- off-shell vector meson production: exclusive **pp→pΔ(N*) →ppρ/ω →ppe⁺e**
- ρ/ω interferences (subthreshold phenomenon)
- vector meson coupling to baryonic resonances → **in-medium modifications**
- Reference for HI data at 2 AGeV



- **vector meson production in pp at 3.5 GeV**
- on shell ω production : ω →π⁰e⁺e⁻ Dalitz decay (test of VMD)
- reference for pA

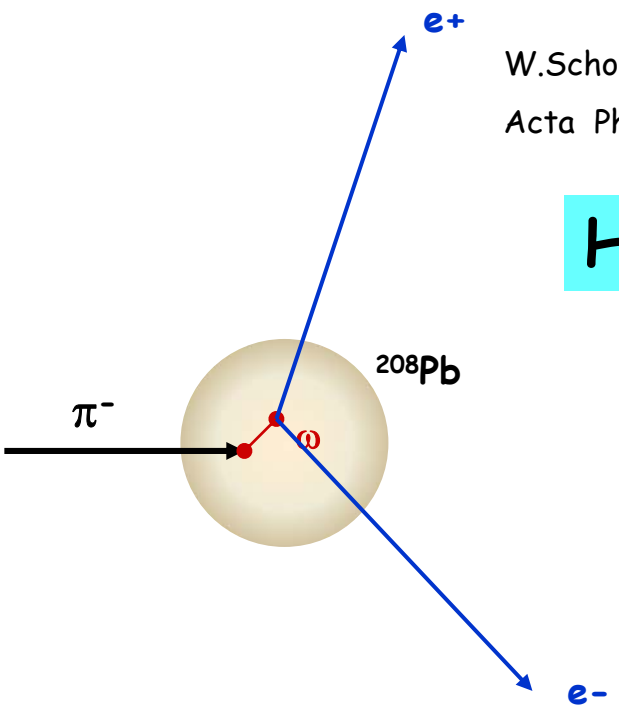
ω production in πA (pA)

HADES

$\pi^- p_{bound} \rightarrow \omega n \rightarrow e^+e^-n$

ω „at rest": p_{e+e-} < **300 MeV/c** (~25% of all decays)

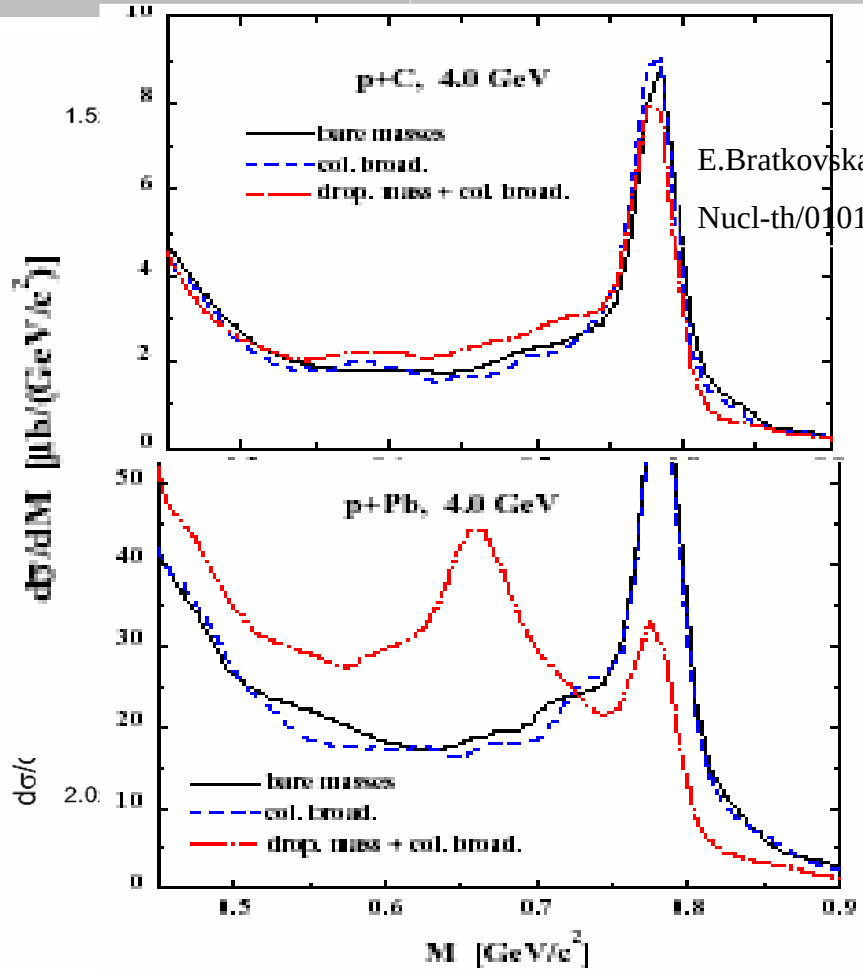
✓ study of ω mass modifications at ρ_0



W.Schoen et al.

Acta Phys.PolB27(1996)2959

HADES



E.Bratkovskaya

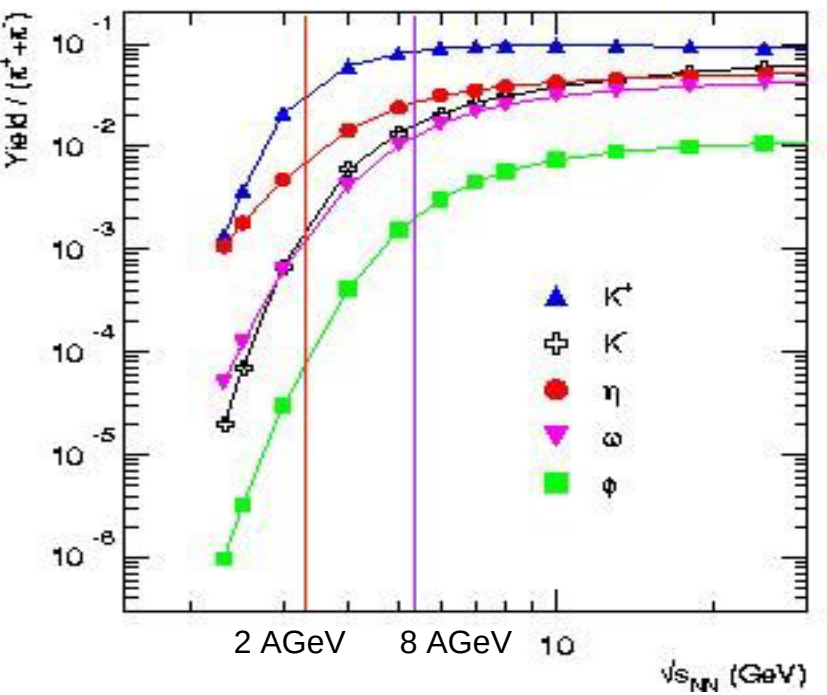
Nucl-th/0101063

- large uncertainties in calculations: em. transion form-factors of resonances R(Δ,N*), resonance decays R→ Δρ
- needs data from $\pi N \rightarrow e^+e^-X$!

Outlook into future: HADES @ 8AGeV

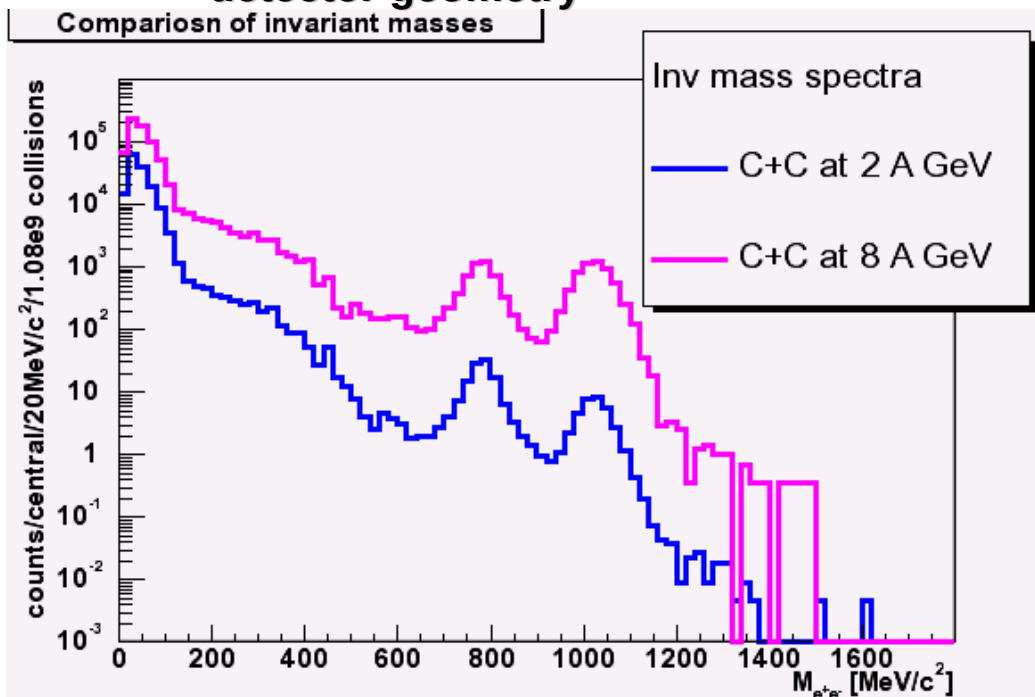
- new GSI Facility for Antiproton and Ion Research (FAIR) : SIS 100/200 will provide beams up to 40 AGeV
- universal CBM spectrometer will measure at highest energies
- can HADES be used at lower energies: i.e 8 AGeV?

Meson yields in C+C



π^0 yields increases from 1.7 to 7./collision

5 days of data taking. No change in detector geometry



- **< y> ≅ 1.5 at 8 AGeV**
- **$\langle y \rangle_{acc} \cong 1$**

Summary and Outlook

HADES

- ✓ HADES measures dielectrons with good statistics : 16500 signal pairs C+C @ 2 AGeV, 1 AGeV measured with similar statistics
- ✓ Good electron identification : hadron misidentification <3% in C+C
- ✓ Real time electron trigger

Physics programme : 2005-2007

- ✓ Investigation of dielectron sources in pp/pd collisions (1.25 AGeV, 2.2 GeV, 3.5 GeV)
- ✓ Dielectron production in πN reactions
- ✓ In-medium vector meson properties: Ca+Ca at 2 AGeV and pA/πA collisions
- ✓ 2007/2008 inner TOF upgrade – heavy system ($\rightarrow$Au+Au)

Considered option: HADES @ 8 AGeV in future GSI FAIR facility

- ✓ Measurement with medium system (C+C, Ca+Ca) possible with present configuration (with upgraded inner TOF)
- ✓ Higher (>10) count rates in vector meson region

Collaboration

HADES

- Bratislava (SAS, PI)
- Catania (INFN - LNS)
- Cracow (Univ.)
- **Darmstadt (GSI)**
- Dresden (FZR)
- Dubna (JINR)
- Frankfurt (Univ.)
- Giessen (Univ.)
- Milano (INFN, Univ.)
- Munich (Tech. Univ.)
- Moscow (ITEP, MEPhI, RAS)
- Nicosia (Univ.)
- Orsay (IPN)
- Rez (CAS, NPI)
- Sant. de Compostela (Univ.)
- Valencia (Univ.)
- Coimbra (Univ.)