Dielectron production in C+C collisions with HADES

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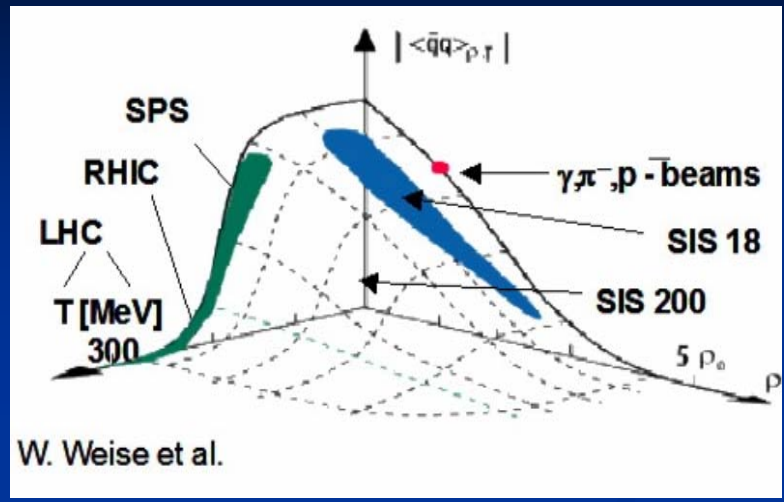
for the Hades Collaboration

Introduction

- Physics motivation.
  - In-medium modifications (predictions)
  - Vector mesons @ SIS energy regime
- Hades Spectrometer.
  - Detector concept
- Experimental results.
  - C+C 2.0 AGeV (2002)
  - P+P @ 2.2 GeV (2004)
    - **See talk: S. Spataro June 10-th Session A 17:50**
  - C+C 1.0 AGeV (2004) PRELIMINARY
    - **See talk: T. Christ June 12-th Session A 15:00**
  - **C+C @ 2.0 AGeV and C+C @ 1.0 AGeV comparison**
- Summary and Outlook.

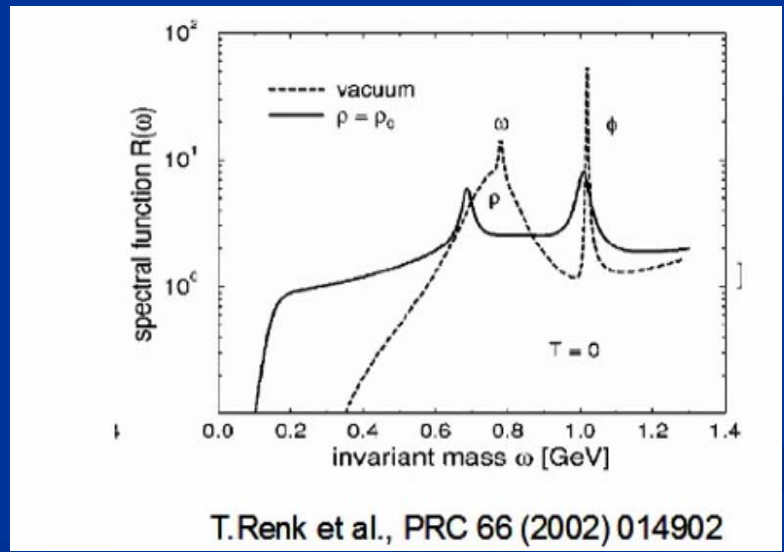
Physics Motivation

- **Chiral symmetry broken in vacuum.**
  - Quark condensate – order parameter
- **Partial restoration of chiral symmetry**
  - At high temperatures (RHIC, LHC)
  - At large baryon density (SIS, AGS)



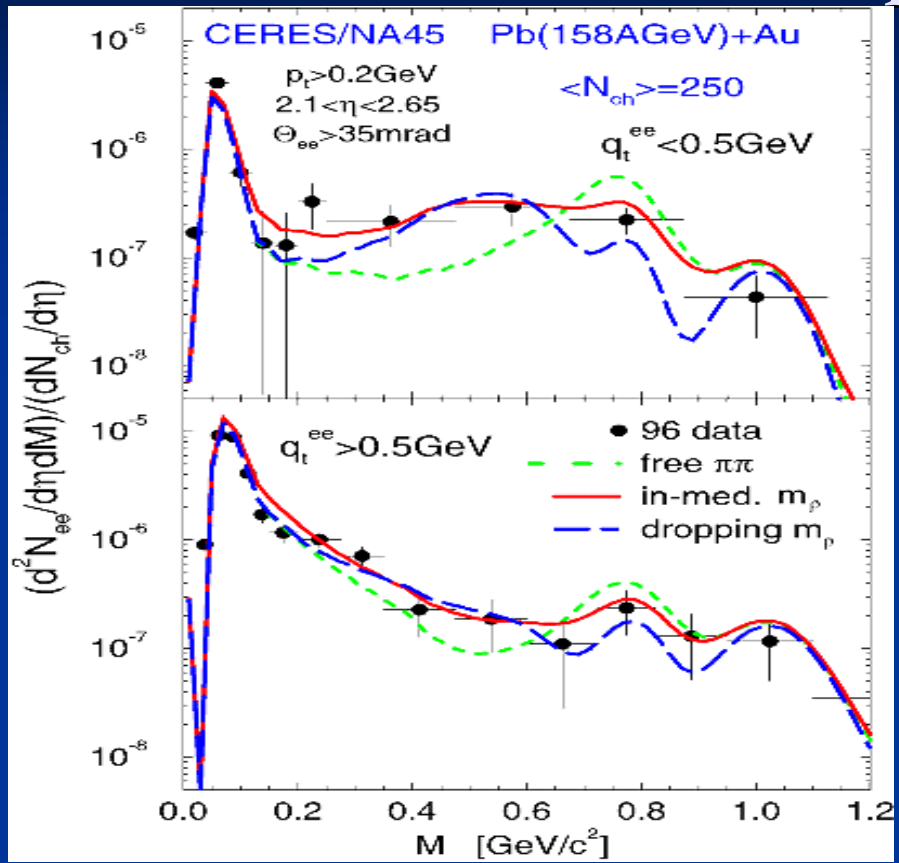
W. Weise et al.

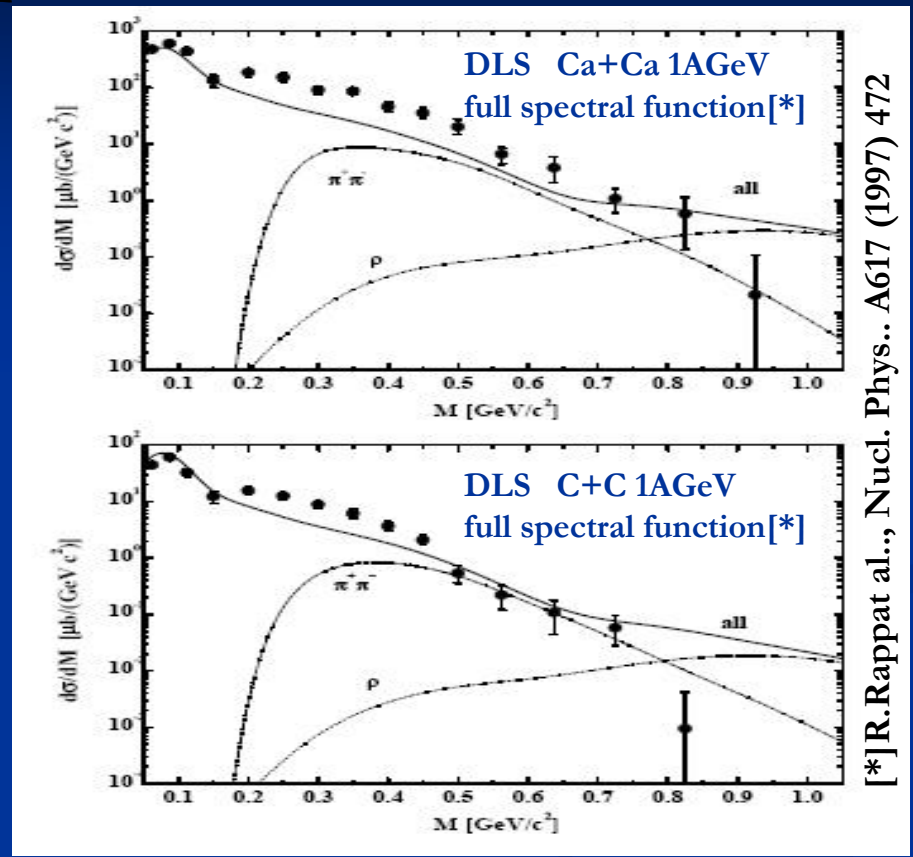
- **Properties of hot and dense matter.**
- Model predictions (one example) for VM
  - „Melting" of the rho meson
  - Mass shift and broadening of the ω
  - Small effects on the φ-meson



T.Renk et al., PRC 66 (2002) 014902

Physics Motivation
DLS puzzle

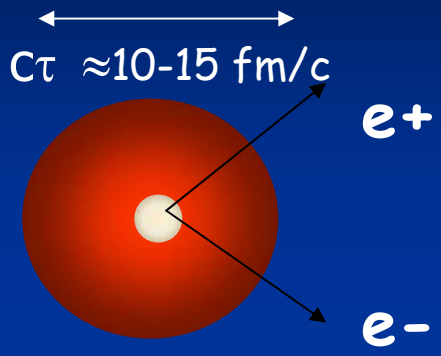




- **CERN data (Ceres/NA45) explaind by medium effects**
- **Models failed to explain DLS data for 0.15 ≤ M ≤ 0.4 GeV**

Probes for hot/dense medium

- Ideal probes for medium effects:
- Short life time
  - Decay inside hadronic medium
- Decay channel into lepton pairs
  - No strong final interaction
  - Reconstruction of in-medium properties possible

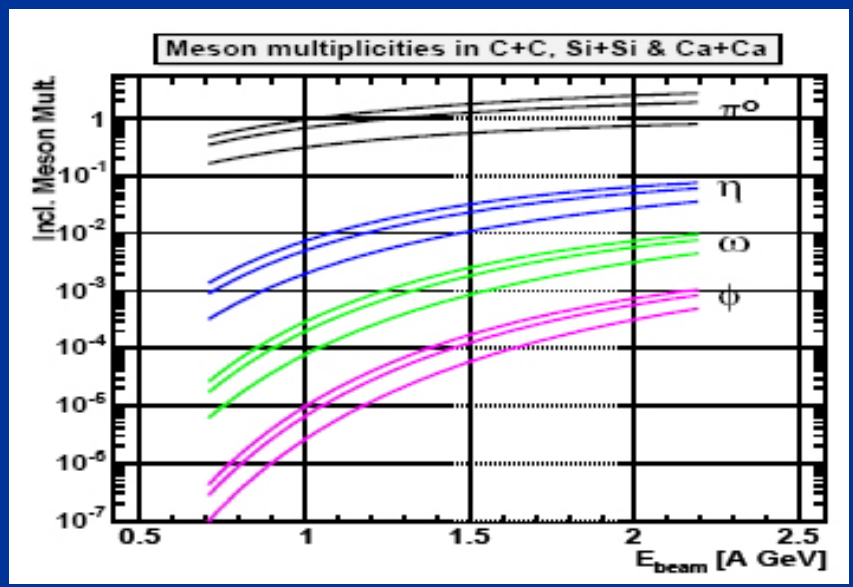


$$m_{e+e-} = \sqrt{p_{e+}p_{e-}}\,\sin\frac{\vartheta_{e+e-}}{2}$$

Meson	Mass (MeV/c^2)	Γ (MeV/c^2)	cτ (fm)	Main decay	e^+e^- BR
ρ	768	152	1.3	$\pi^+\pi^-$	4.4×10^{-5}
ω	782	8.43	23.4	$\pi^+\pi^-\pi^0$	7.2×10^{-5}
ϕ	1019	4.43	44.4	K^+K^-	3.1×10^{-4}

Meson production at SIS energy regime (1-2 AGeV)

$$NN \rightarrow N\Delta$$
$$\downarrow$$
$$\pi N$$
$$\downarrow$$
$$\pi N \rightarrow \rho N$$

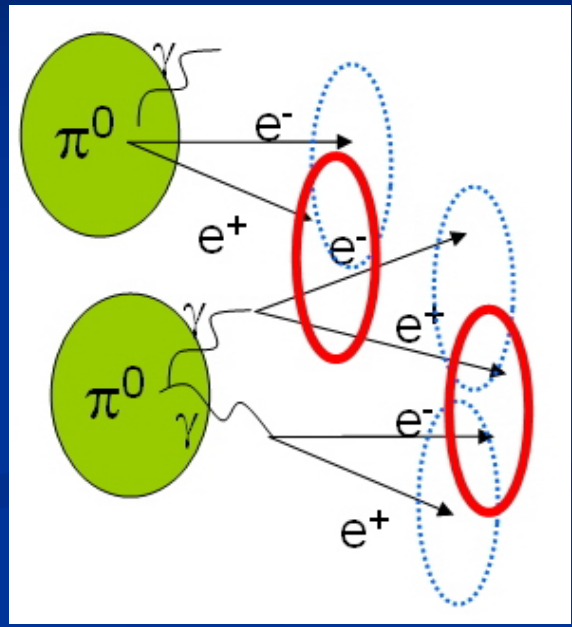


- **VM production (1-2 AGeV):**
  - at or below threshold
  - ⇒ multi step processes
  - ⇒ production confined to the high density phase

- **Meson multiplicity:**
  - π^0, η known from TAPS
    F.D.Berg. At al., PRL 72,977 (1994)
  - ρ, ω, φ - m_t scaling
    M.Bourquin, Nucl. Phys. B114, 334 (1976)

Experimental challenges

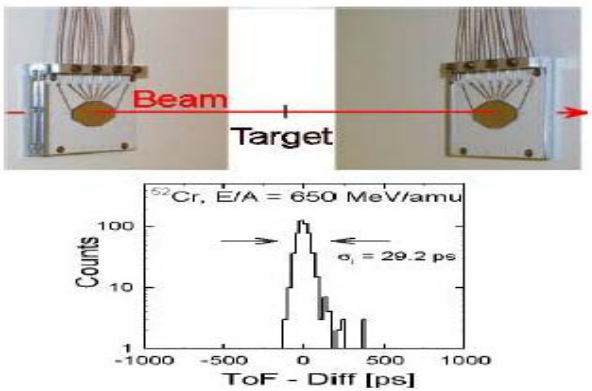
- **Small production rates:**
  - 1 dilepton rho decay / 10^7 central collisions
- **Large background:**
  - Hadronic (particle misidentification)
  - Electromagnetic (conversion, mainly from π^0)
  - Combinatorial (false combination of e^+e^-)
- **Detector requirements:**
  - Excellent particle id
  - Perfect lepton identification (hadron-blind detector)
  - Low mass/low Z- design for reduced background
  - Highly selective trigger
  - High performance data acquisition.



HADES

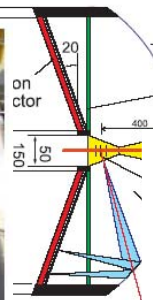
A High-Acceptance Di-Electron Spectrometer

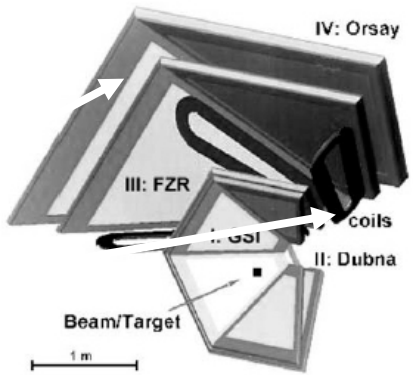
(expanded view)

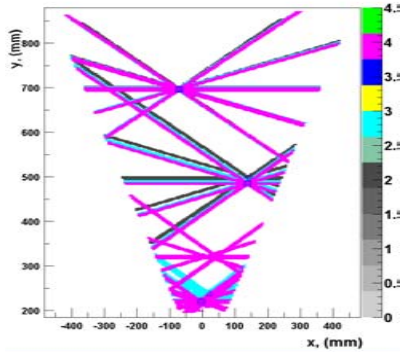


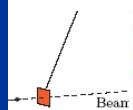
Start-Veto detector

- Diamond, 8 strips, widths 1.55 – 5.4mm
- Time res.: 29.2 ps (Chromium beam)









TOF detector

- **Meta at θ > 45 deg.**
- **Time res. 190 ps (electrons)**
- **Position res. 27 mm.**
- Cons
- Time
- Spatial res: 1.5 cm (low res. tracking)
- Limitation: multihit capability (-> RPC)

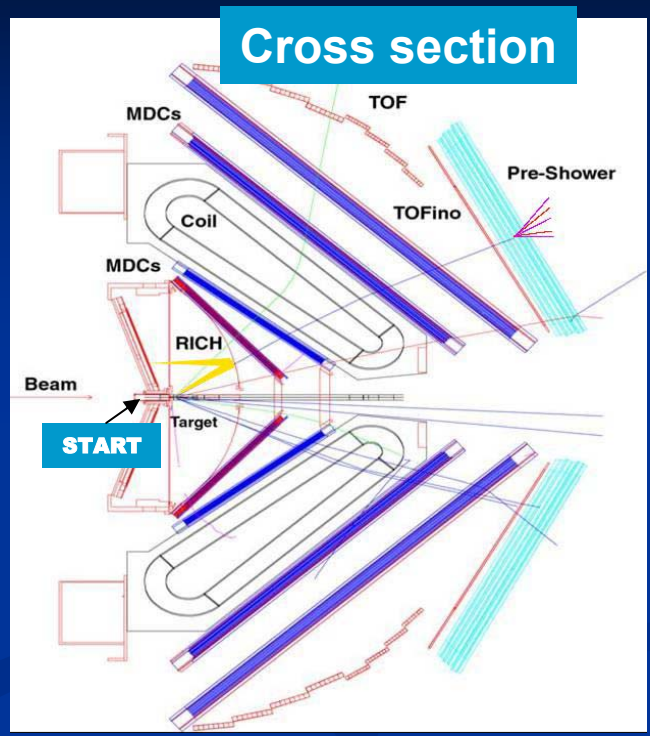
Low mass tracking system

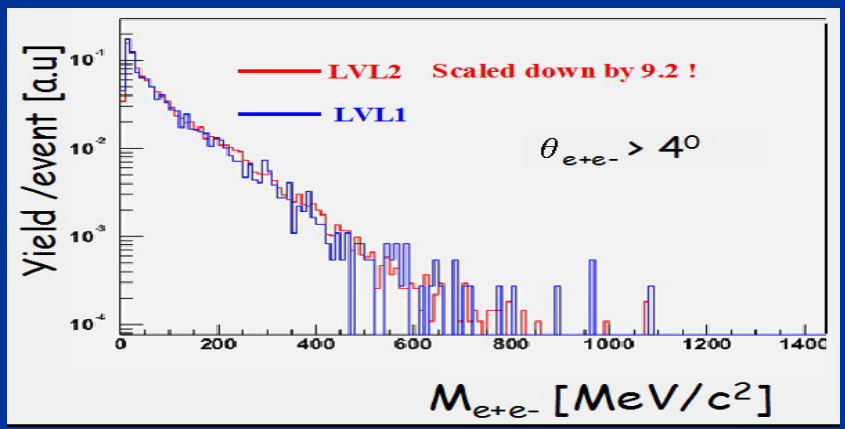
- **single cell resolution: 100 μm**
- **4 planes / sector (high res. mode)**
- **2 planes + META**

(low res. mode, 10% at 0.7 GeV/c)

Spectrometer concept

- **Geometry:** Six sectors form a hexagonal structure:
  - Acceptance: 2π in φ ; $18^0 < \theta < 85^0$
  - Pair acceptance ≈ 35 %
- **Tracking:** Magnet, MDC
  - Superconducting toroid magnet (6 coils)
    B_{max} = 0.7 T, Bending power 0.34 Tm
  - low-mass MDC (multiwire drift chamber)
- **PID and Lepton Identification**
  - RICH
    - hadron blind
    - photon detector: CsI photo cathode
  - META (TOF, TOFino, Pre-Shower)
  - Start detector
    - diamond. (time res. 30 ps)

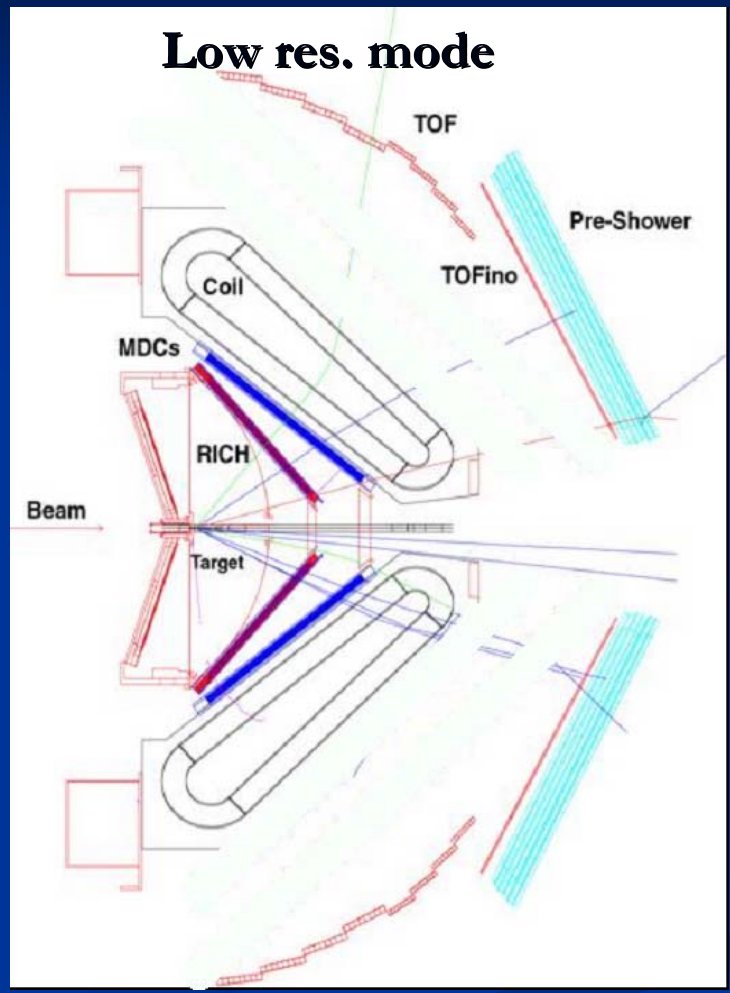




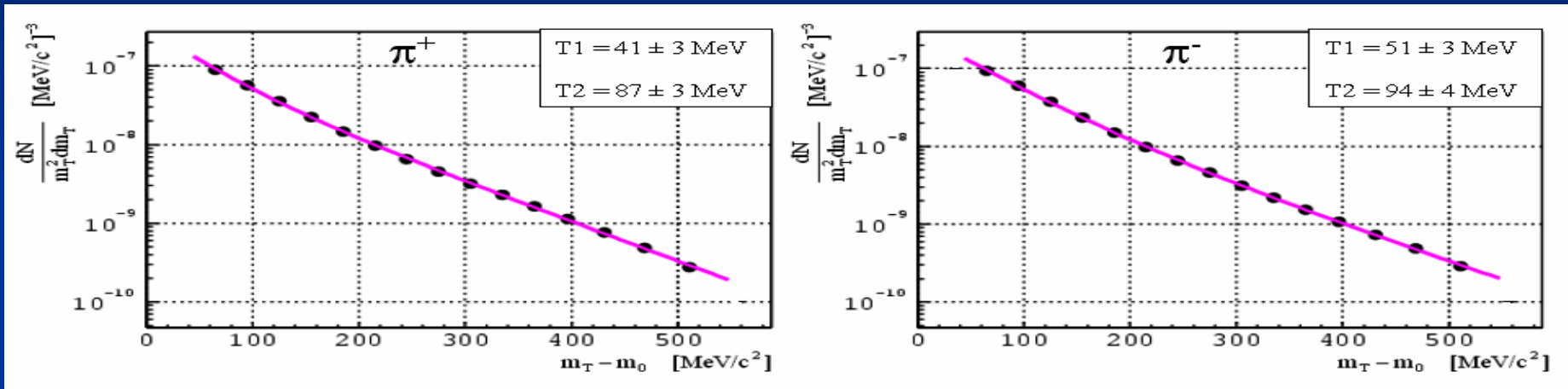
- **Selective multi-level trigger system**
  - Pair enhancement factor close to 10
  - No bias on data
  - LVL2 efficiency (pairs) 82 %
  - Suppression 10 - 100

C+C @ 2.0 AGeV

- **Experimental Setup:**
  - Full HADES set-up with low res. tracking.
  - Low resolution tracking:
    - Inner Mdc,
    - Meta detector (spatial. res. 1.5 cm)
    - mom. res. 10% @ 0.7 GeV/c
  - Target: 2 x 2.5 %
- **Data and trigger:**
  - 220 Mevents
  - 56 % LVL1 trigger, 44 % LVL2 trigger



Pion spectra (C+C, 2 AGeV)



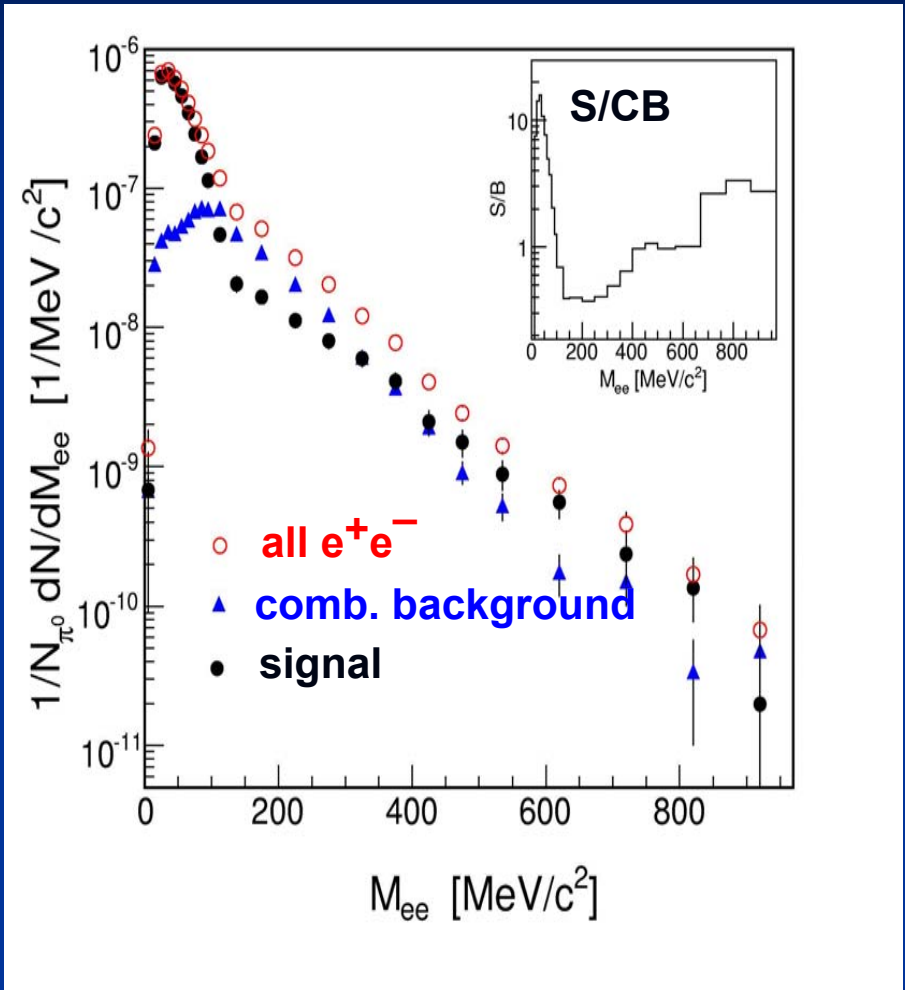
2 parameter fit

$$\frac{1}{m_T^2}\frac{d\sigma}{dm_T} = C_1 \cdot e^{-m_T/T_1} + C_2 \cdot e^{-m_T/T_2}$$

	Multiplicity	"Temperature"
HADES	$N_{<\pi^-\pi^+>}/A_{part}$ = 0.148 ± 0.018	T_{π^+} = 41 ± 3; 87 ± 3 T_{π^-} = 51 ± 3; 91 ± 4
TAPS	$N_{<\pi^0>}/A_{part}$ = 0.138 ± 0.014	
KaoS	$N_{<\pi^->}/A_{part}$ = 0.126 ± 0.010	T_{π^-} = 40 ± 3; 86 ± 3

good agreement with TAPS/KaoS results!

Raw e^+e^- mass spectrum (C+C, 2 AGeV)



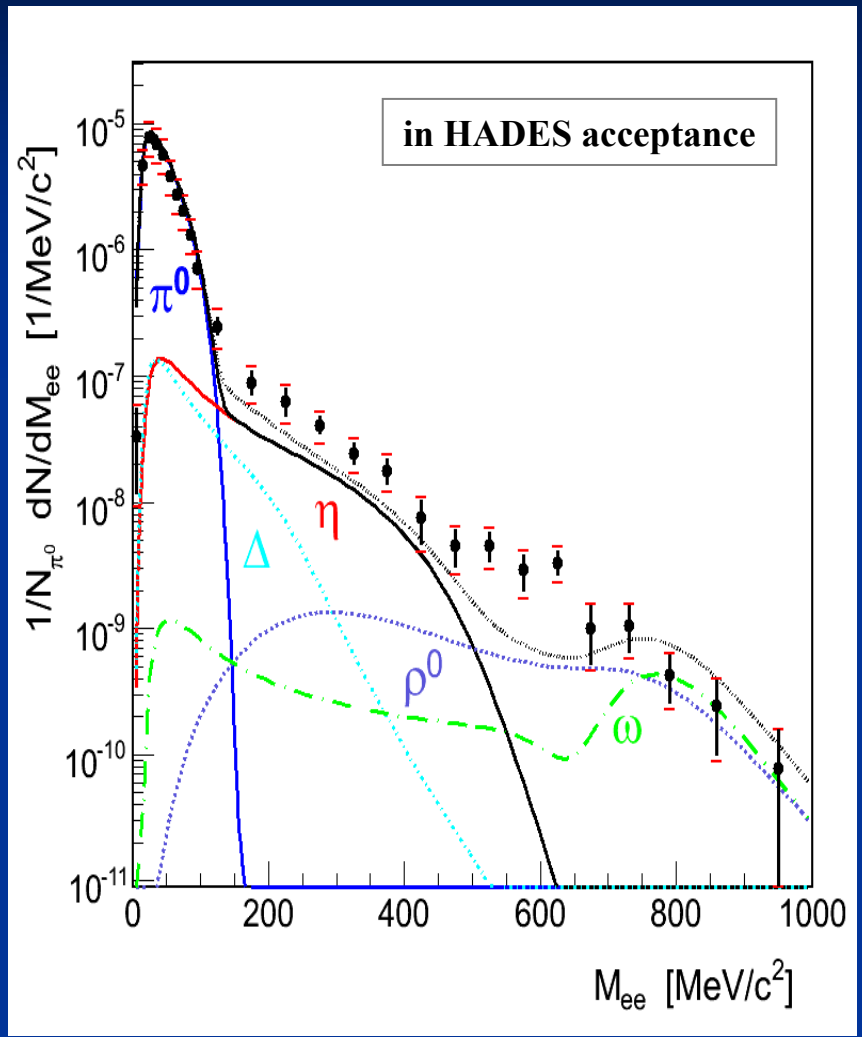
- **Raw exp. Spectrum**
  - No eff. correction
  - No acc. correction
- **Comb. Background (CB)**
  - Like-sign pairs
  - Formula: $2\bullet\sqrt{N_{e^+e^+}N_{e^-e^-}}$
- **Signal:**
  - Formula: $S_{+-} = N_{e+e-} - CB_{+-}$
  - Counts:

$S_{+-} < 140$ MeV/c^2: 20 971 counts

$S_{+-} > 140$ MeV/c^2: 1 937 counts

- Measured rates span over 5 orders of magnitude
- Good Signal/CB ratio

e^+e^- mass spectrum (C+C, 2 AGeV)



- Efficiency corrected spectra
  - Detector efficiency
  - Reconstruction efficiency
- normalized to the pion yield

  $N_{\pi 0} = ½ (N_{\pi-} + N_{\pi+})$
- low resolution tracking

  (10% at 0.7 GeV/c)
- systematical errors
  - Norm. to the pion mult.(11 %)
  - Eff. corrections (20 %)
  - CB construction (20 %)
- Simulated cocktail (PLUTO)
  - Based on known (TAPS) or m_t-scaled meson multiplicities and their vacuum decay properties.

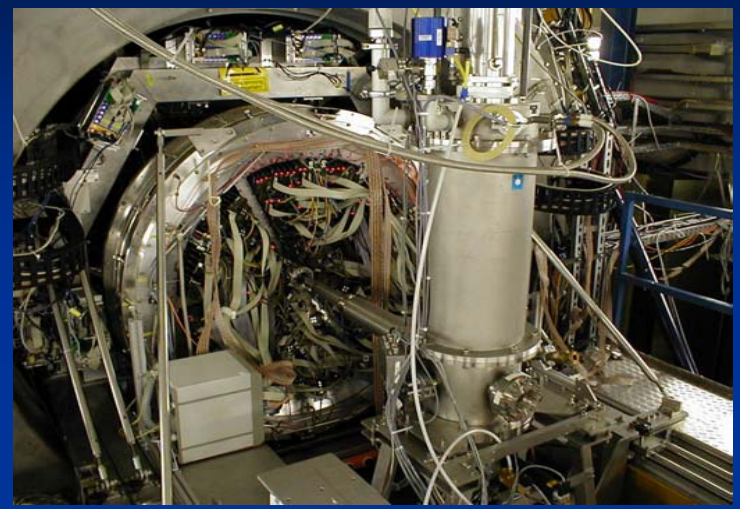
☝ Only π^0, η not sufficient.

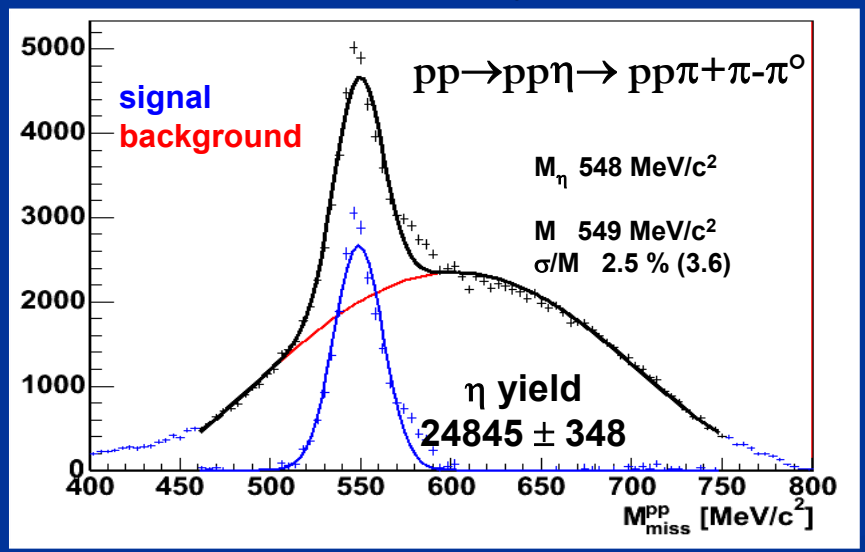
pp collisions @ 2.2 GeV (2004)

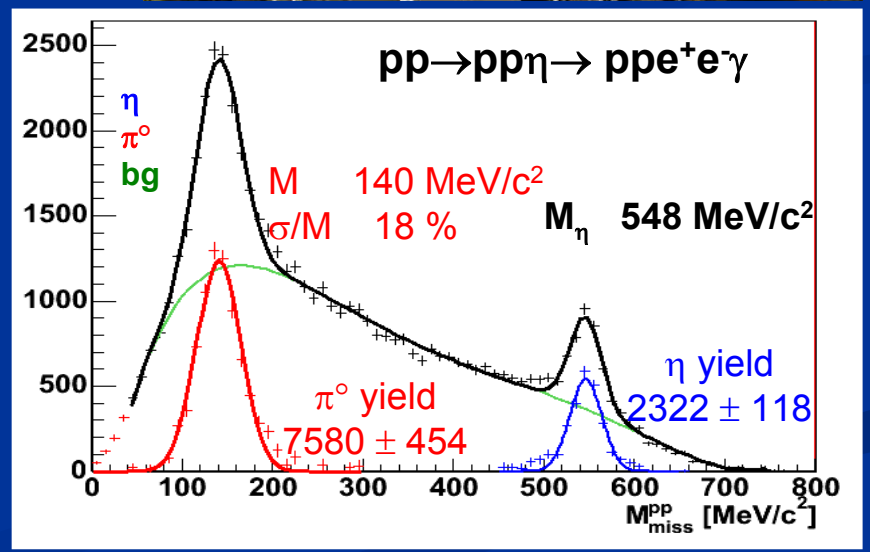
See talk: S. Spataro June 10-th Session A 17:50

- **Experimental goal:**
- Verify dielectron efficiency:
  - dielectron and hadron channels of π^0, η
- **Conditions:**
  - Beam intensity: 10^7 p/second
  - Target: LH2 (5 cm length)

⇒ **Dielectron efficiency well under control**







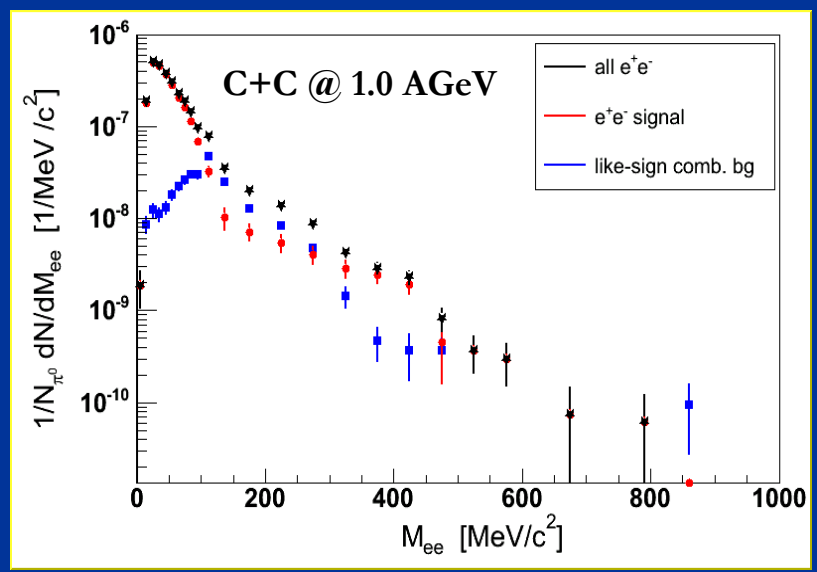
C+C @ 1.0 AGeV (2004)

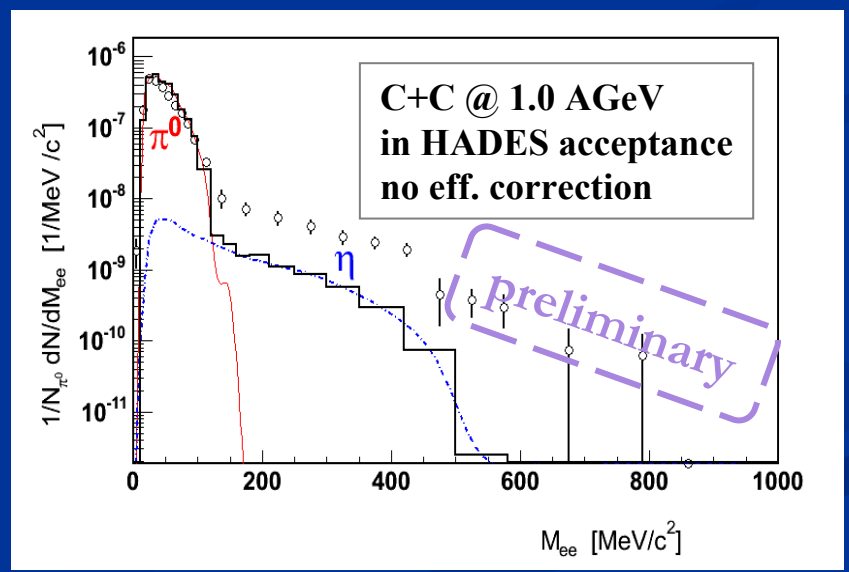
See talk: T. Christ June 12-th Session A 15:00

- Raw exp. Spectrum
  - No eff. Correction
  - No acc. correction
- Comb. Background (CB)
  - Like-sign pairs
  - Formula: $2 \bullet \sqrt{N_{e^+e^+} N_{e^-e^-}}$
- Signal: Formula: $S_{+-} = N_{e^+e^-} - CB_{+-}$

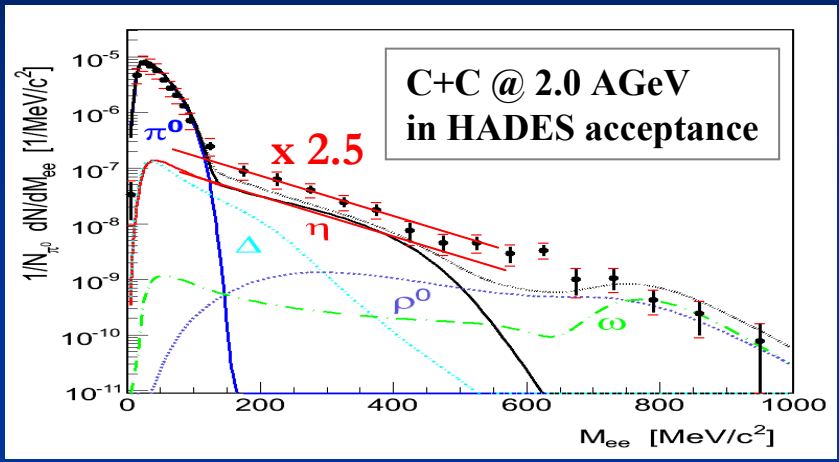
- Experimental Setup:
  - Full HADES set-up
  - high res. Tracking.
  - Target: 3 x 1.5 % target.

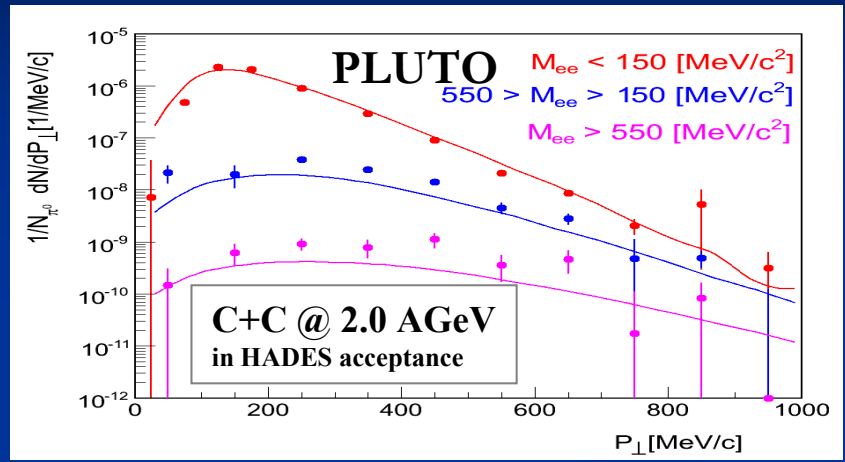
☝ Only π^0, η not sufficient.

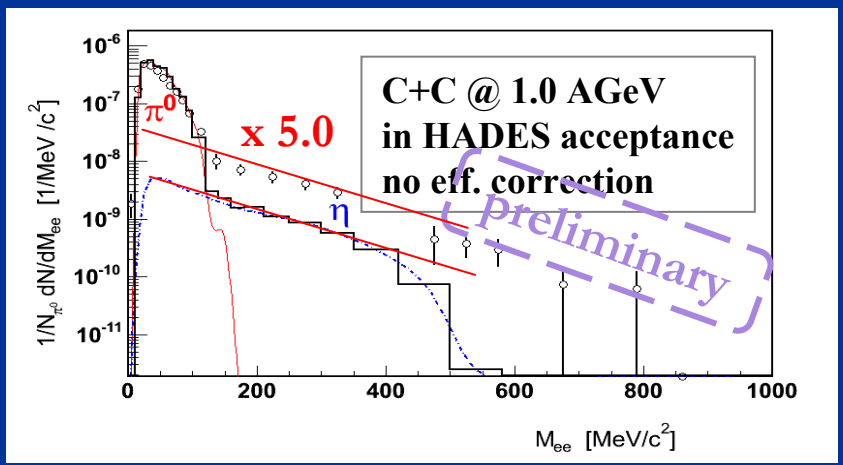




C+C @ 2.0 and @ 1.0 AGeV - comparison





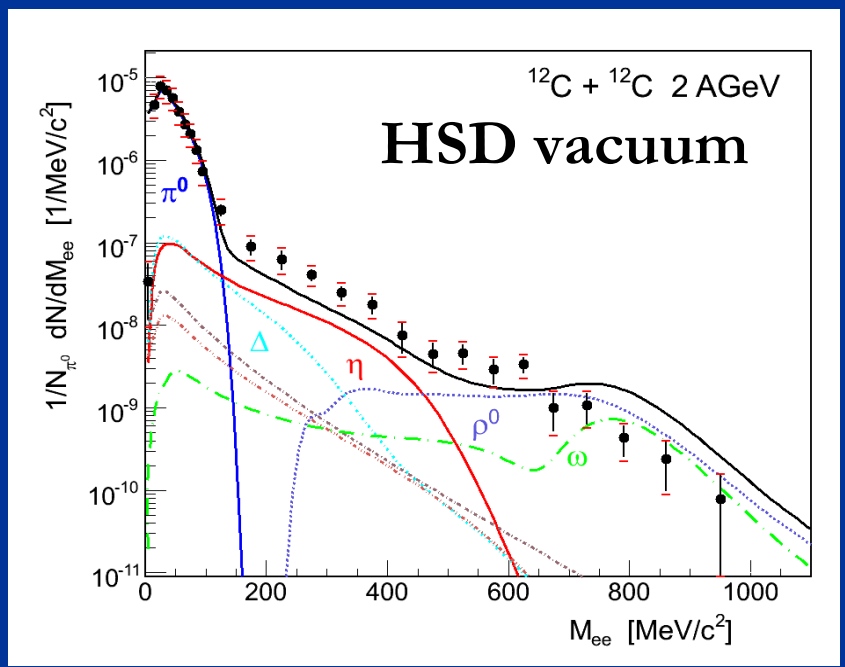


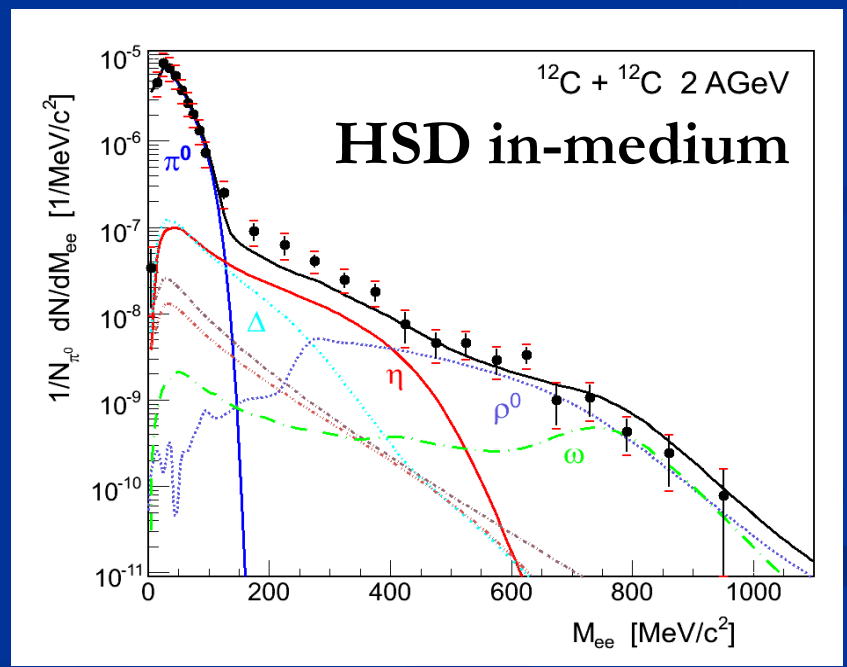
- HADES data compared with Pluto model.
  - C+C @ 2.0 AGeV
  - C+C @ 1.0 AGeV
- Substantial yield above the η contribution
  - 2.0 AGeV factor 2.5
  - 1.0 AGeV factor 5 (preliminary !)

Comparison with transport: HSD* Mass Spectrum (C+C, 2 AGeV).

*HSD – Hadron-String-Dynamics (Gießen, E. Bratkovskaya, W. Cassing)

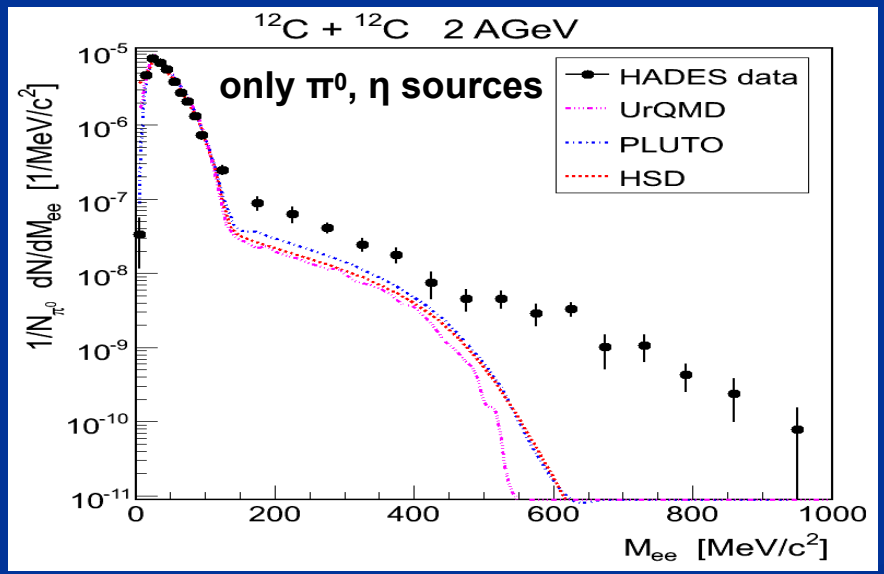
- **efficiency-corrected data compared with model.**
  - **folded with HADES filter:**
    - geometrical acceptance
    - momentum resolution (low resolution mode, 10% at 0.7 GeV/c)

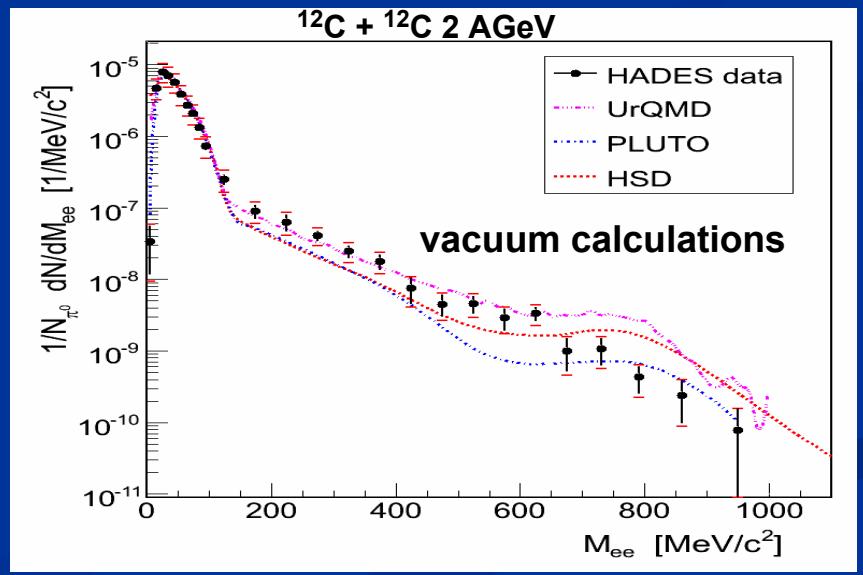




Comparison with transport: HSD, Pluto, UrQMD.

- **Model vacuum calculations:**
  - **UrQMD Frankfurt** (M. Bleicher, D. Schumacher)
  - **Pluto Hades**
  - **HSD Giessen** (E. Bratkovskaya, W. Cassing)
- **π^0, η sources in agreement (20 %),**
- **Only π^0, η sources not sufficient to explain the data,**
- **Discrepancy for full cocktail.**





Summary

- **C+C, 2 AGeV**
  - Final spectrum available.
  - Comparison with transport models ongoing.
- **C+C, 1 AGeV**
  - Preliminary spectrum,

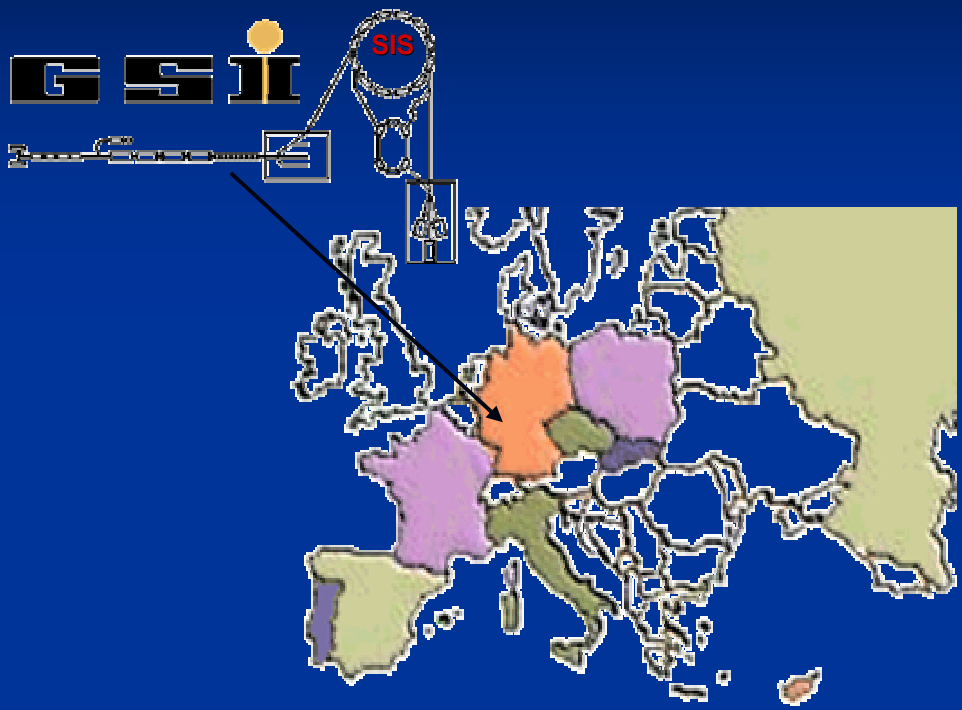
⇒ **Substantial yield above the η contribution**

- **P+P, 2.2 GeV**
  - Dielectron efficiency under control.

Outlook

- **Collected data, ongoing data analysis:**
  - C+C 1.0 AGeV, Ar+KCl 1.757 AGeV, P+P 1.25 GeV
- **Upgrade of Tofino subsystem with RPC (2007)**
  - Ni+Ni, Au+Au runs feasible
- **Hades at FAIR: 2-8 AGeV runs.**

The collaboration



- Bratislava (SAS, PI), Slovakia
- Catania (INFN - LNS), Italy
- Cracow (Univ.), Poland
- Darmstadt (GSI), Germany
- Dresden (FZR), Germany
- Dubna (JINR), Russia
- Frankfurt (Univ.), Germany
- Giessen (Univ.), Germany
- Milano (INFN, Univ.), Italy
- Munich (TUM), Germany
- Moscow (ITEP,MEPhI,RAS), Russia
- Nicosia (Univ.), Cyprus
- Orsay (IPN), France
- Rez (CAS, NPI), Czech Rep.
- Sant. de Compostela (Univ.), Spain
- Valencia (Univ.), Spain
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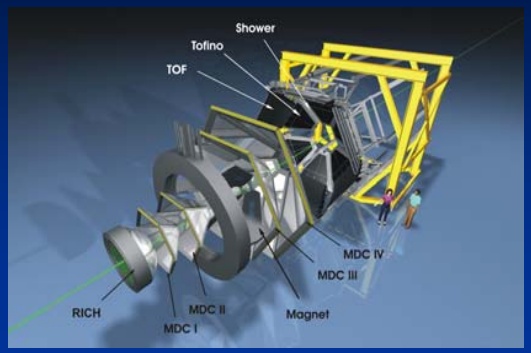
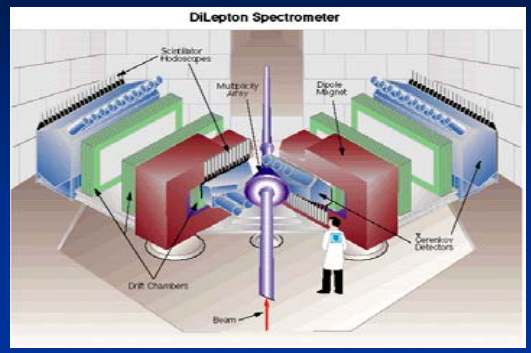
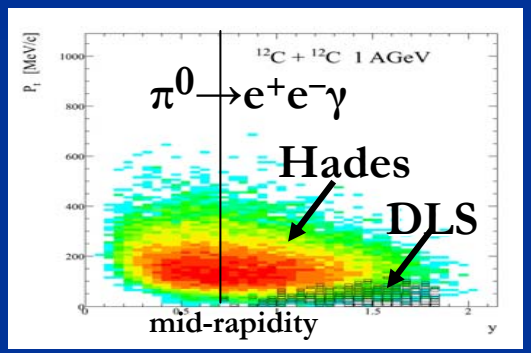
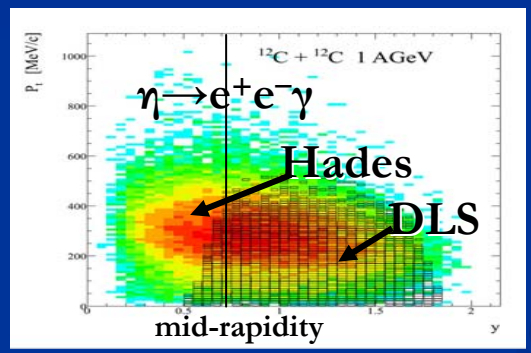
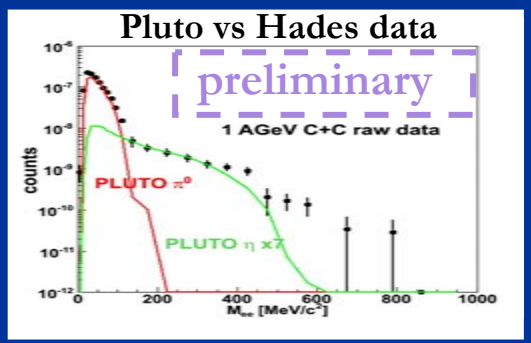
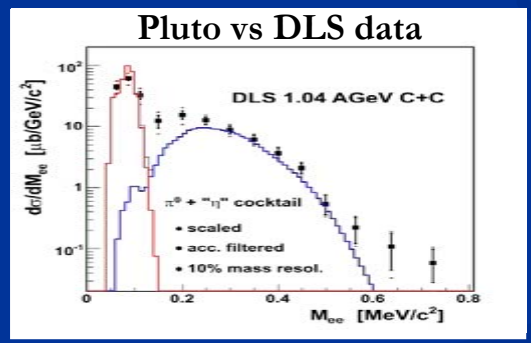










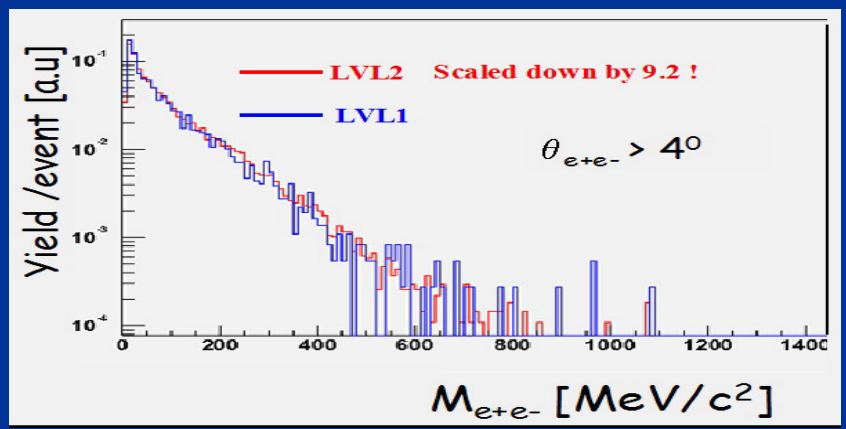


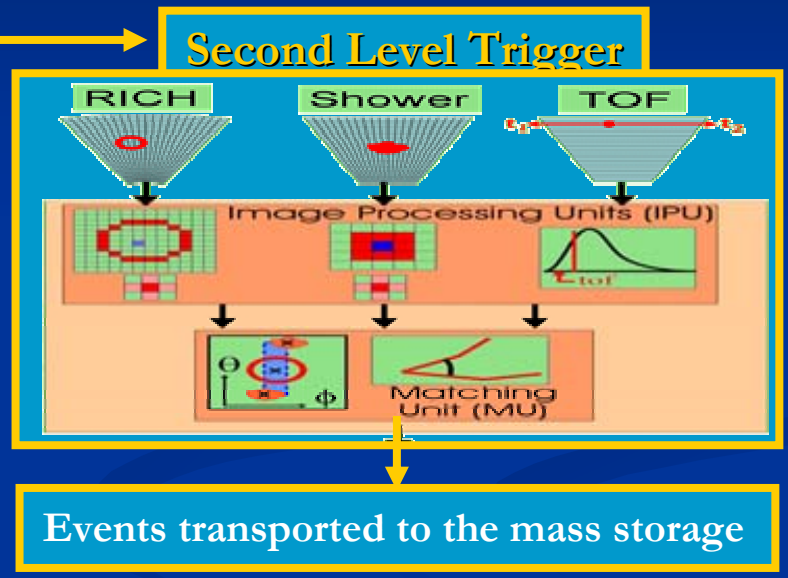
- design
- π^0, η acceptance
- C+C @ 1AGeV
  - Comparison with Pluto cocktail

Selective multi-level trigger system

- **Fast First Level Trigger:**
  (50 ns, up to 20 kHz)
  - Meta multiplicity
  - Start detector (time signal)

- **Second Level Trigger:**
  - Online hit finders (Rich, Tof, Shower)
  - Online hit matching (MU)
  - Trigger decision (within 20 μs)
  - ~3 Gbyte/s raw data

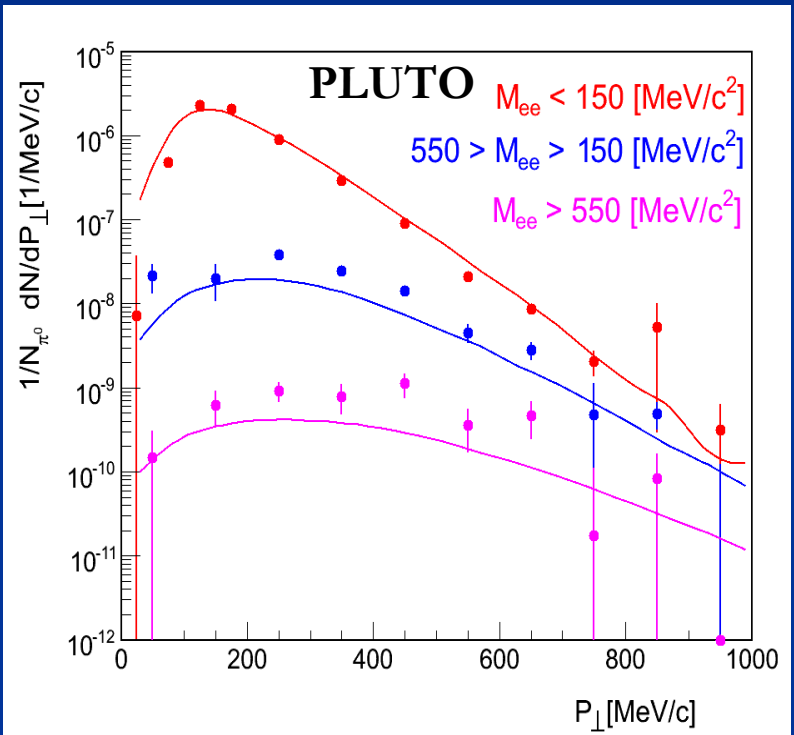




- **Performance:**
  - Pair enhancement factor close to 10
  - No bias on data
  - LVL2 efficiency (pairs) 82 %
  - Suppression 10 - 100

Comparison with models: Pluto
Transverse momentum (C+C, 2 AGeV)

- **efficiency-corrected data compared with Pluto model.**



- $M_{ee} < 150$ MeV/c^2
  - Data well described,
- $150 < M_{ee} < 550$ MeV/c^2
  - Underestimation over whole $p_\perp$ range (factor 2.5).
- $M_{ee} > 550$ MeV/c^2
  - Underestimation for high $p_\perp$

☝ **Factor 2,5 missing in the η region**