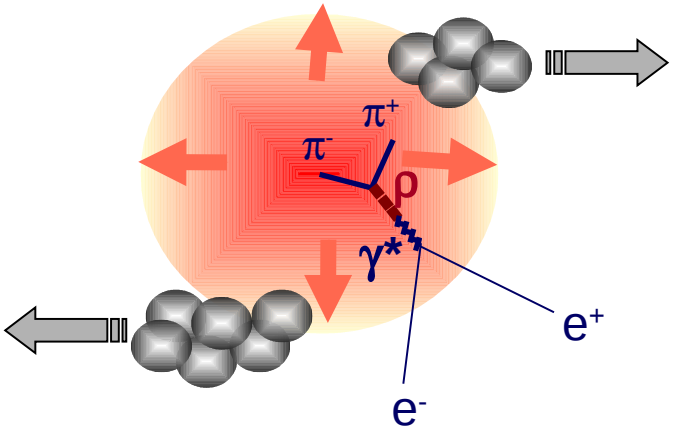
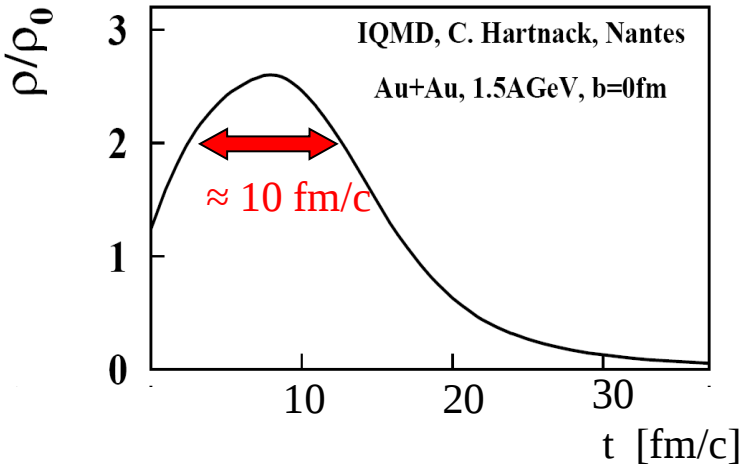
Measurement of low-mass e^+e^- pair production in 1-2AGeV C+C collisions with HADES

Małgorzata Sudoł
Yvonne Pachmayer

Physics motivation. Why are lepton pairs an ideal probe?

- Medium modifications of hadrons:
  - In-medium mass shift
  - In-medium broadening
  - Or both





	mass [MeV/c^2]	cτ [fm]	e$^+$e$^-$ branching ratio
ρ	768	1.3	4.4 x 10^{-5}
ω	782	23.4	7.2 x 10^{-5}
Φ	1019	44.4	3.1 x 10^{-4}

- **Advantage:**
  - Sufficiently short life time
    - decay at least partially inside the hadronic medium
  - Decay channel into lepton pairs
    - no strong final state interaction
    - reconstruction of in-medium properties possible

Physics motivation. Why are lepton pairs an ideal probe?

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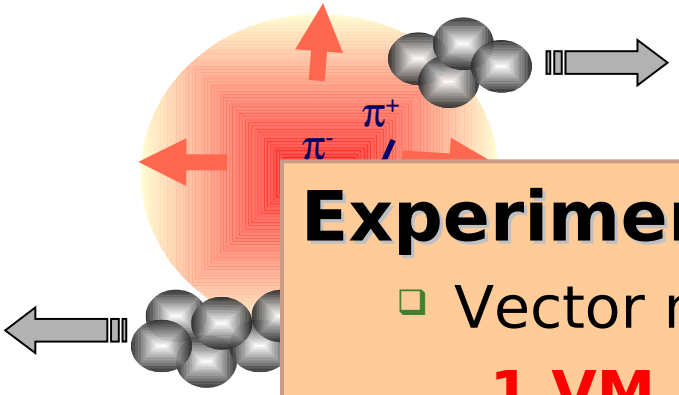
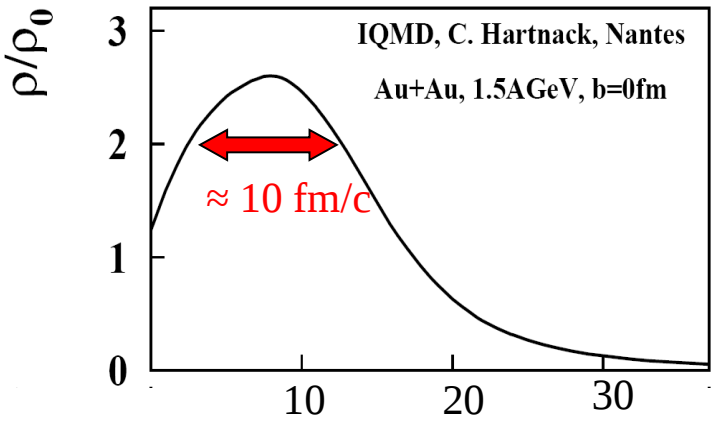




Experimental challenge!

- Vector mesons are rare probe:

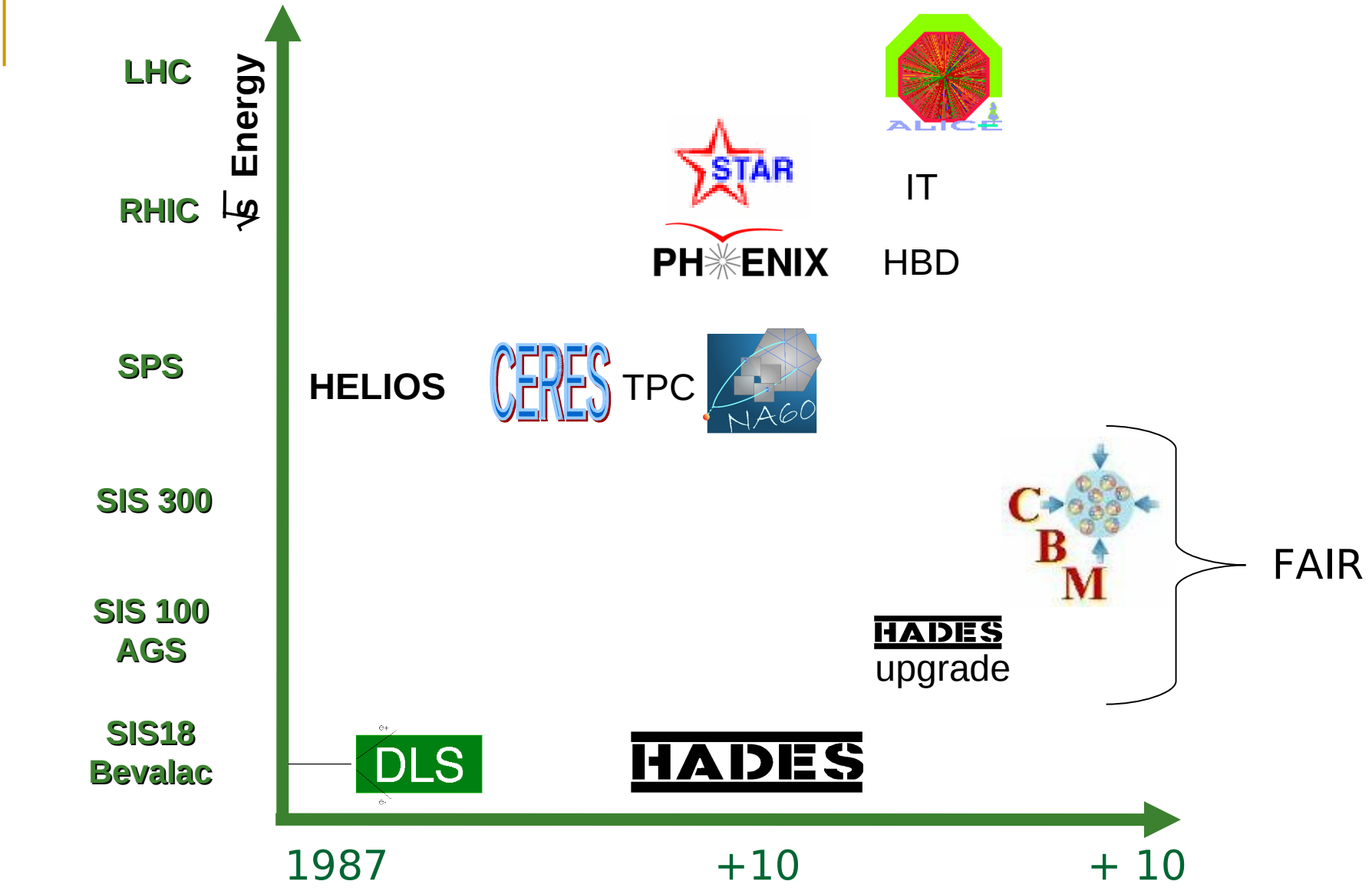
  1 VM per 1-10 Million reactions!

- Large background $\pi^0 \rightarrow \gamma\gamma$ (BR 99%)

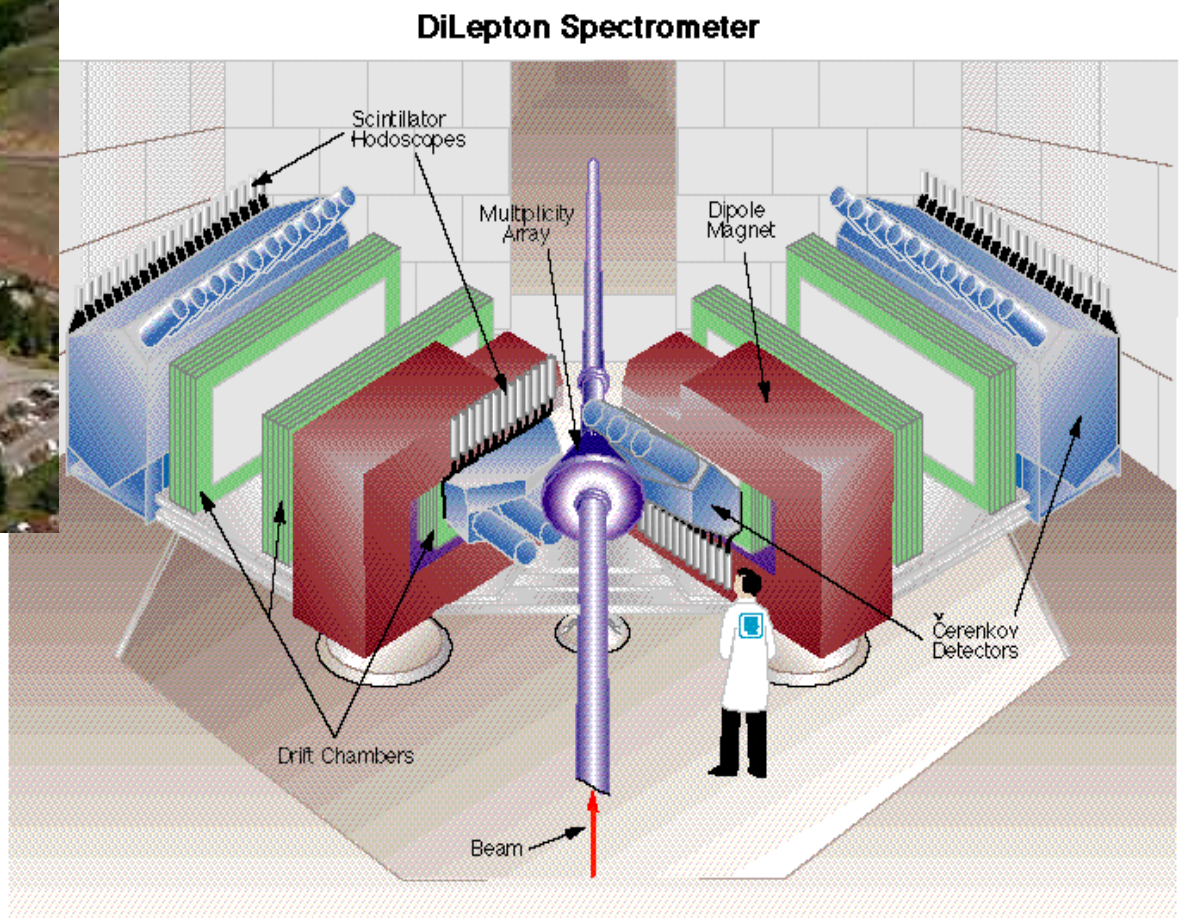
  $\pi^0 \rightarrow \gamma e^+e^-$ (BR 1%)

- Advantage:
  - Sufficiently
    - decay
  - Decay channel into lepton pairs
    - no strong final state interaction
    - reconstruction of in-medium properties possible

Overview of heavy-ion experiments



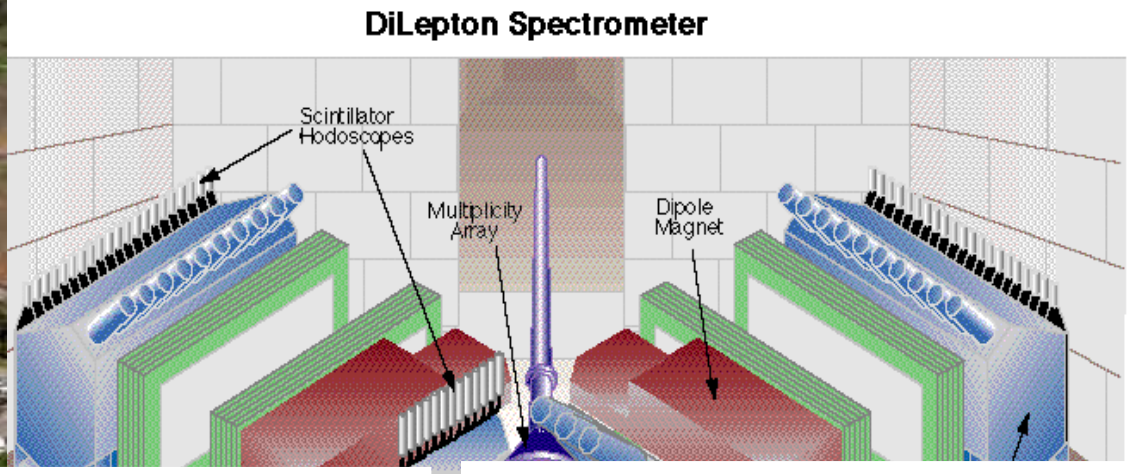
DLS at the Bevalac: e^+e^- pairs



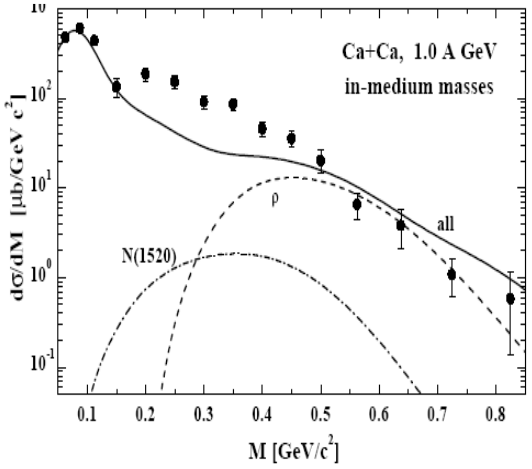
DLS at the Bevalac (1987-1995)

DLS at the Bevalac: e^+e^- pairs

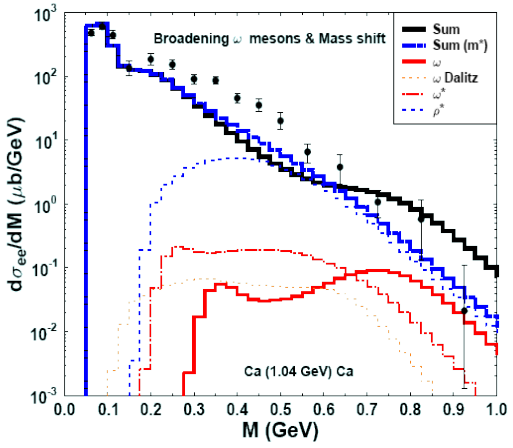
VOLUME 79, NUMBER 7 PHYSICAL REVIEW LETTERS 18 AUGUST 1997



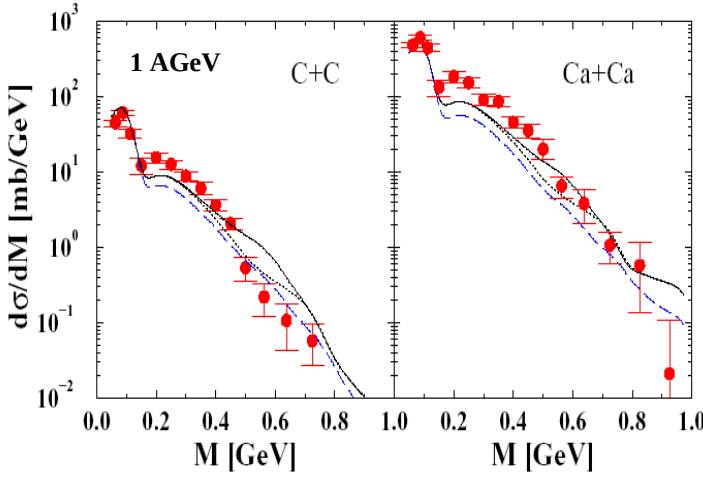
Calculation: E.LBratkovskaya e nucl-th/9809056v2



Calculation: Ernst et al. PRC 58 ('98) 447



Calculation: C. Fuchs et al. Phys. Rev. C68 (2003) 014904



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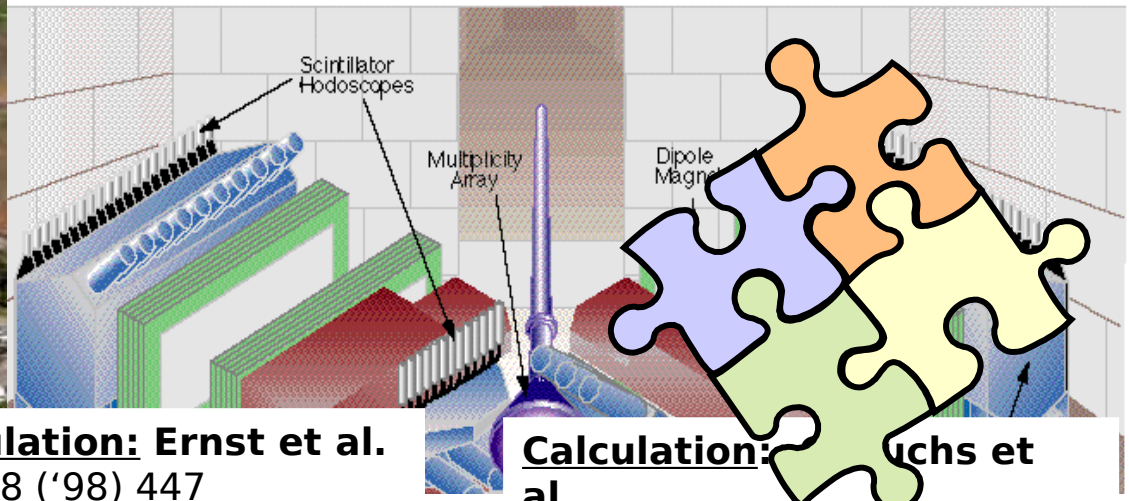

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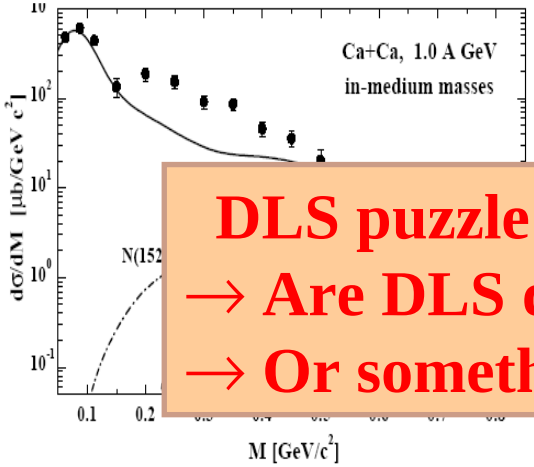

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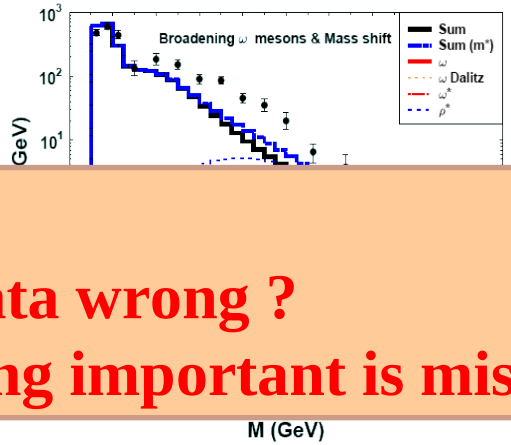
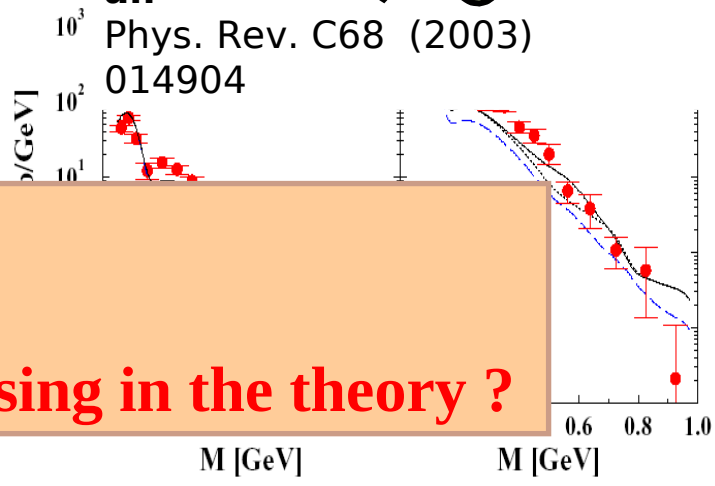


Calculation: …chs et al. Phys. Rev. C68 (2003) 014904

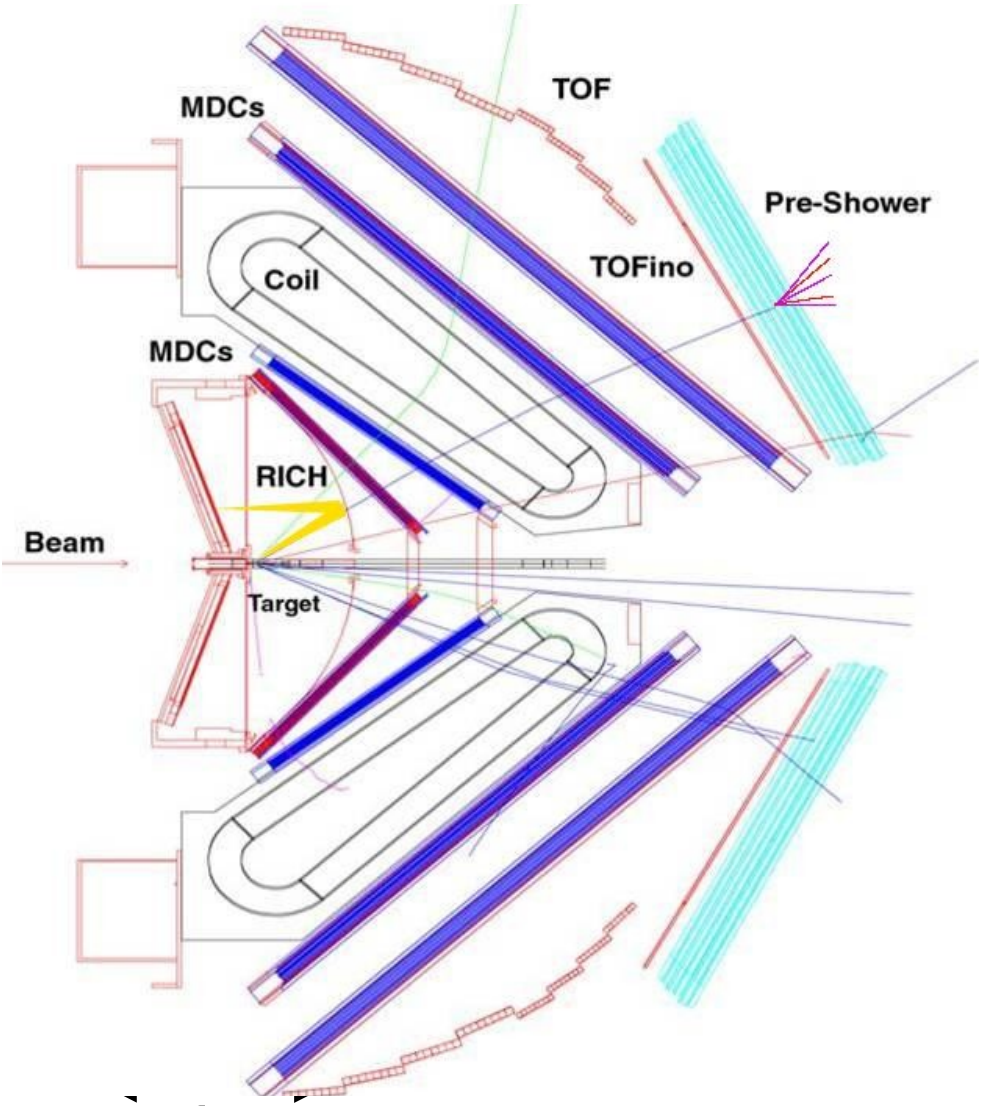


DLS puzzle!

→ Are DLS data wrong ?

→ Or something important is missing in the theory ?

The HADES spectrometer



Geometry

Six sectors form a hexagonal frustum:

- 2π in φ
- $18^0 < \theta < 85^0$
- Pair acceptance ≈ 0.35

Tracking

Superconducting toroid magnet (6 coils)

- Bmax = 0.7 T

MDC (multiwire drift chamber)

Lepton Identification

RICH , TOF & PreSHOWER

Trigger

LVL1: particle multiplicity > 3

LVL2: RICH - META correlation

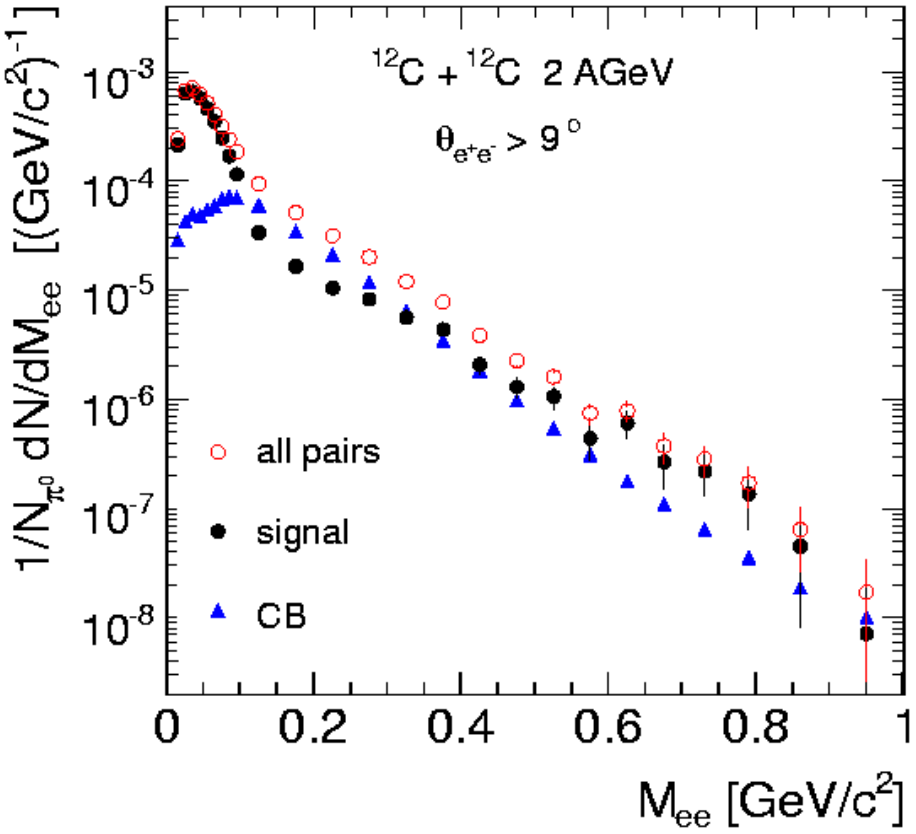
Total statistics

650M LVL1 events

Completed Runs

Physics Runs in…	p, d, π - induced	A + A	Status/Comment
2002		C + C 2 AGeV	Published!
2004		C + C 1 AGeV	Published!
2004	p + p 2.2 GeV		Analysis finished
2005		Ar + KCl 1.75 AGeV	Analysis ongoing
2006	p + p 1.25 GeV		Analysis ongoing
2007	p + p 3.5 GeV d + p 1.25 AGeV		… online results!
2008	p + A 3.5 GeV		Analysis ongoing
2008/9	Upgrade RPC, DAQ		
2009		Ni + Ni	Planned
2010	π + N, A		
2011		Au + Au	
> 2011	Hades goes FAIR (8 AGeV)		

Experimental dilepton spectrum before efficiency correction



Combinatorial Background

- M_{ee}<0.15GeV/c^2: Same event like-sign
- M_{ee} > 0.15GeV/c^2 : Event mixing

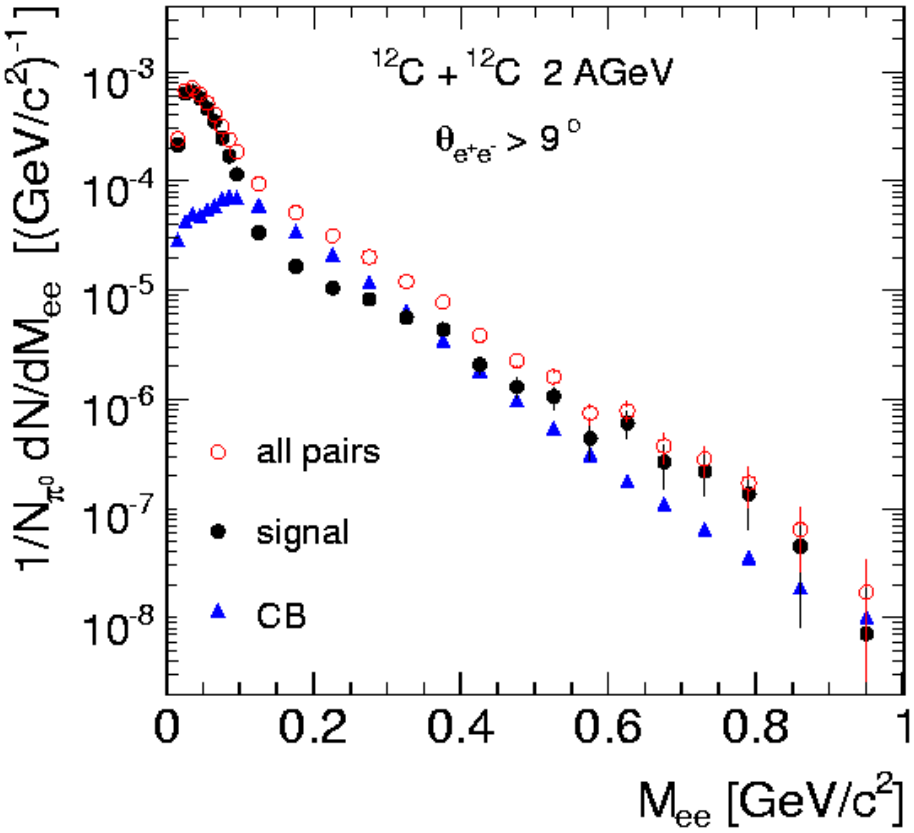
Spectrum normalization:

to total number of events
and to π^0 multiplicity: $N_{\pi 0} = (N_{\pi+} + N_{\pi-}) / 2$

~ **23000** S_{e+e-}, full M_{ee} range

~ **2000** S_{e+e-}, M_{ee} > 0.15 GeV/c^2

Experimental dilepton spectrum before efficiency correction



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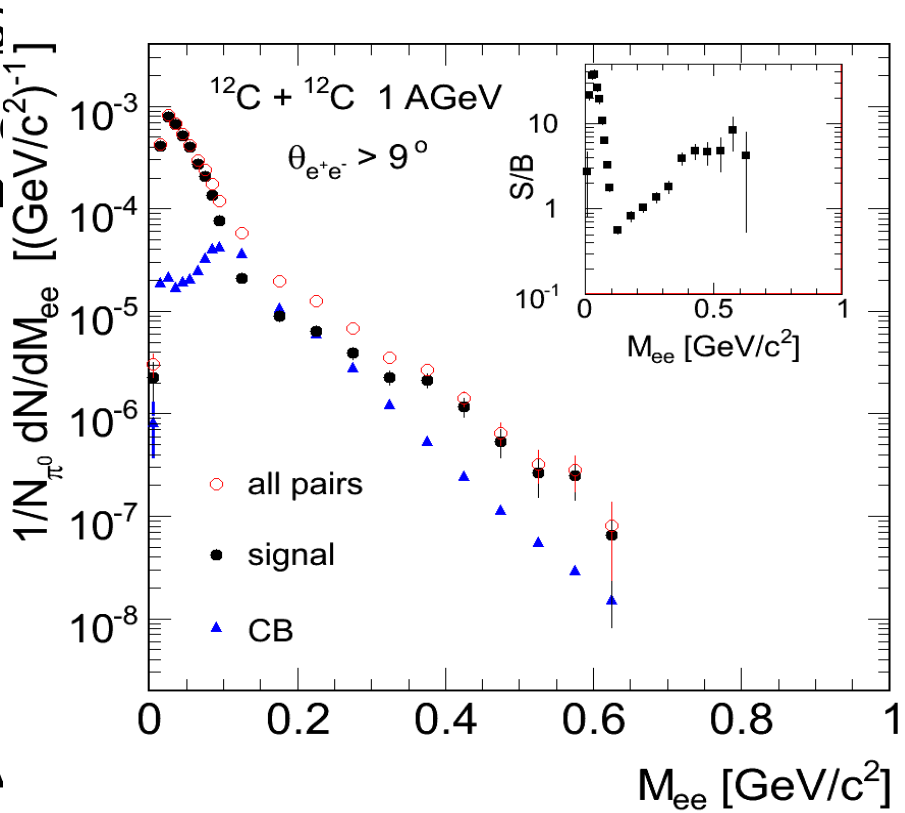

~ **23000** S_{e+e-}, full M_{ee} range

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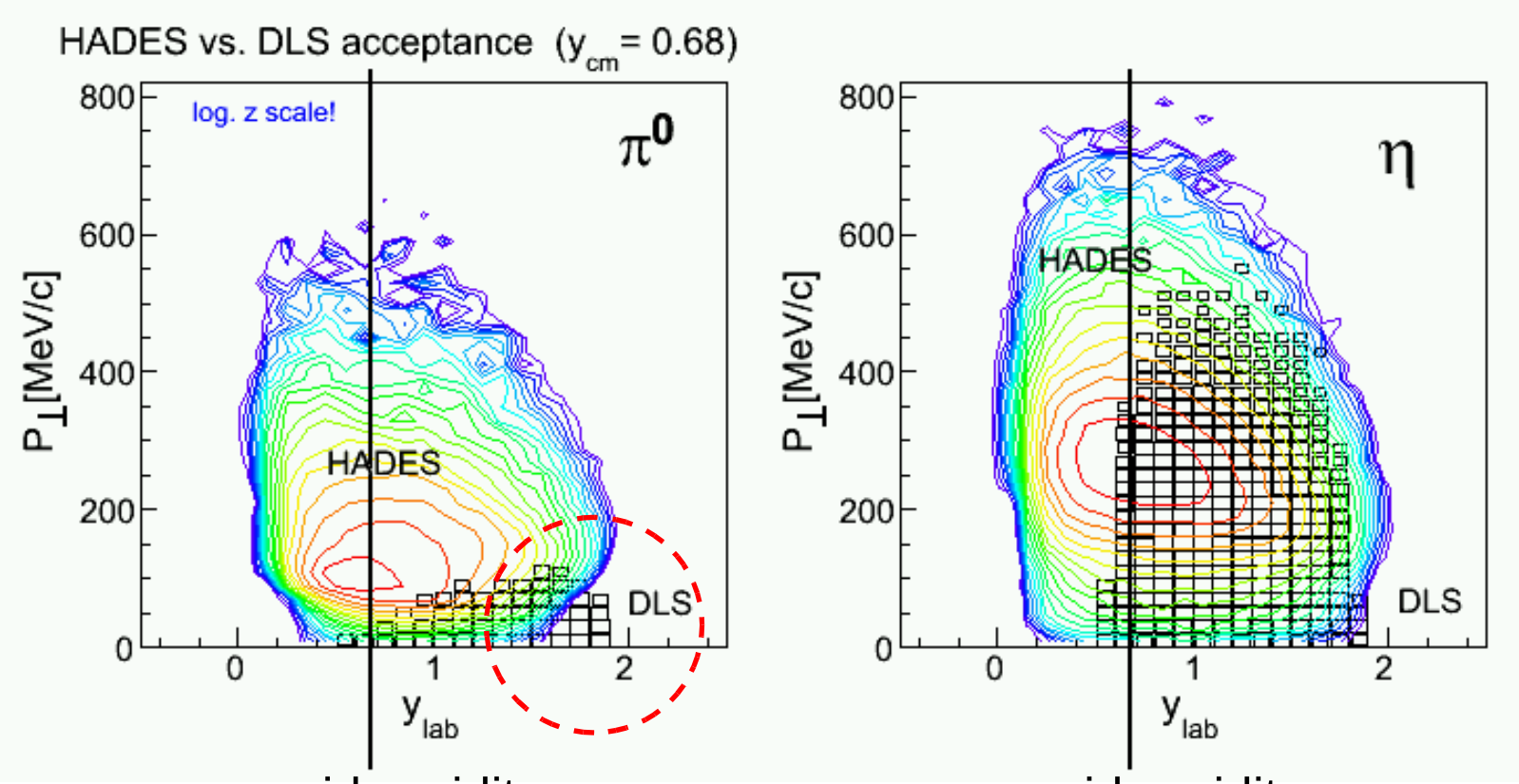
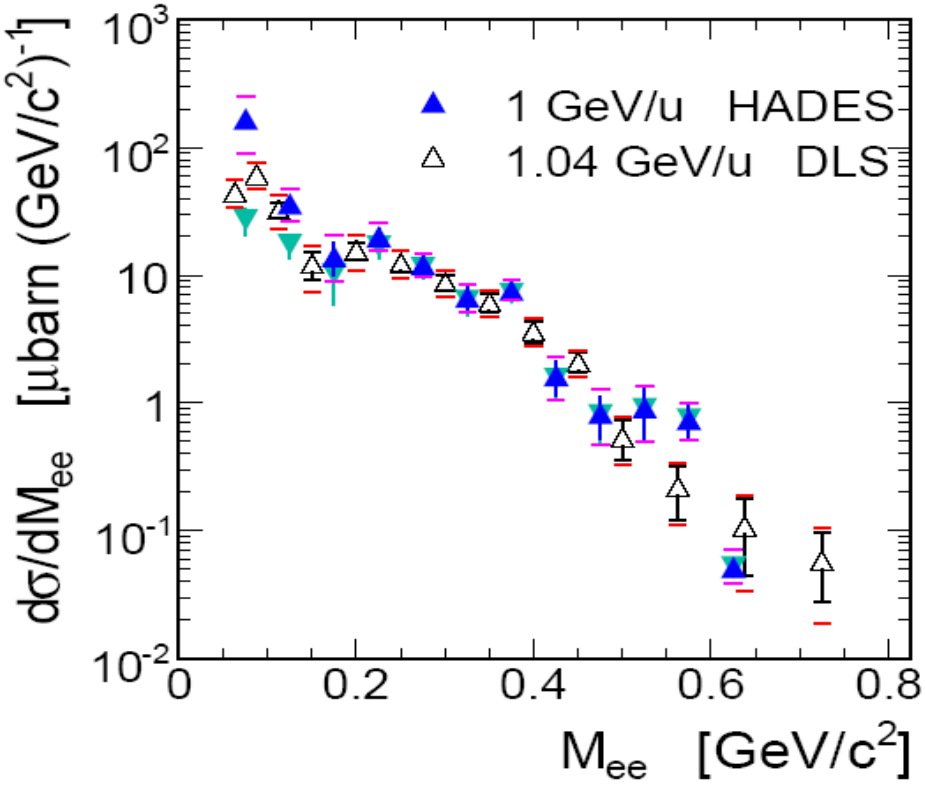
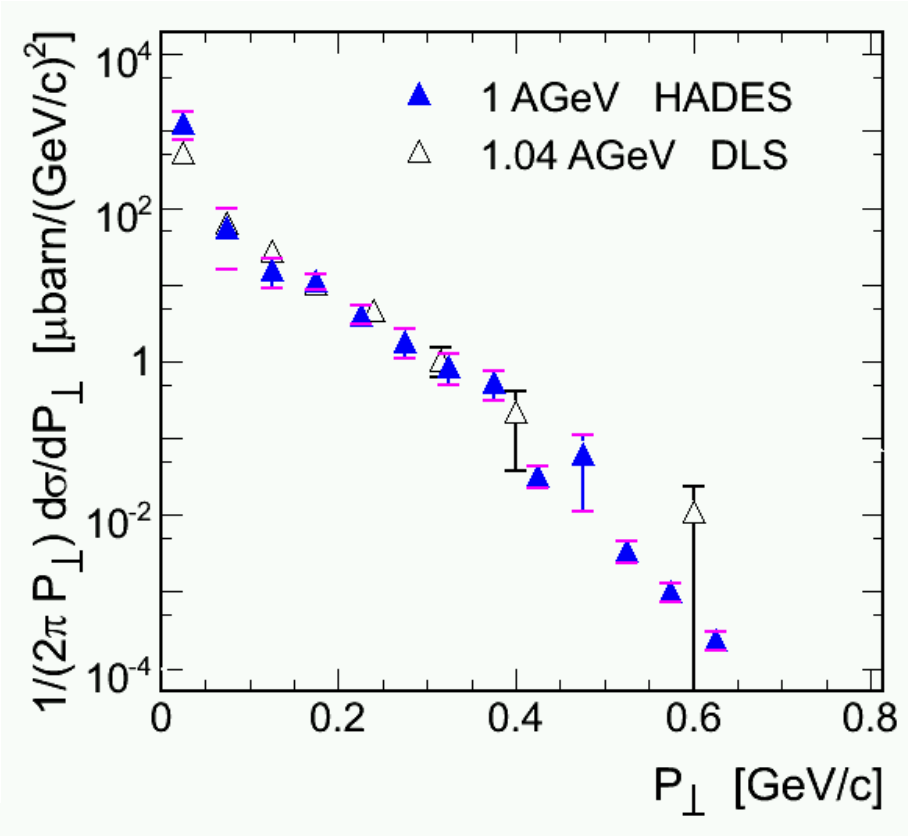
Direct Comparison of HADES with DLS Data



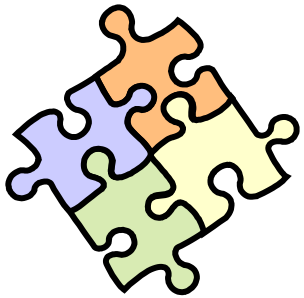
- Different phase space coverage of HADES and DLS
- Projection of HADES data onto the DLS acceptance & extrapolated to the region where HADES has no acceptance

Direct Comparison of HADES with DLS Data





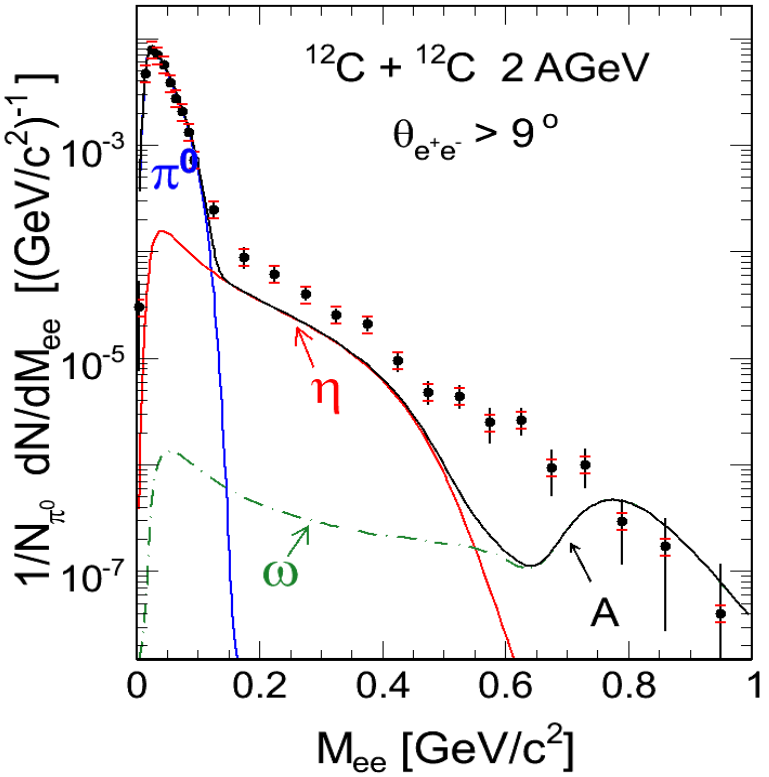
DLS Data: R.J. Porter et al.:
Phys.Rev.Lett. 79 (1997) 1229



J. Carroll – presentation
International Workshop on Soft Dilepton Production
August 20-22,1997, LBNL

Direct Confirmation of DLS results

Comparison of the data with generated cocktail



Event generator PLUTO :

- Thermal source (T=80MeV)

$\forall\pi$ polar angle distribution from charged π analysis

- **η** taken from the published data (TAPS)
- **ω** : $m_\perp$ -scaling

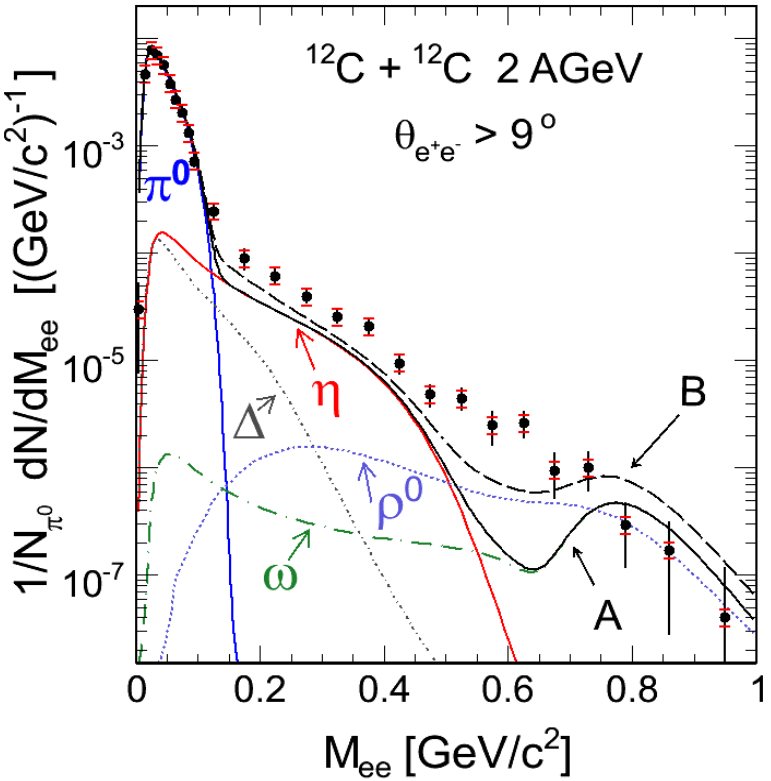
- Cocktail A: **π^0** + η + ω

"long lived components"

systematic errors:

11 % - π^0 normalization
10 % - combinatorial background
15 % - efficiency correction

Comparison of the data with generated cocktail



Event generator PLUTO :

- Thermal source (T=80MeV)
- $\forall\pi$ polar angle distribution from charged π analysis
- **η** taken from the published data (TAPS)
- **ω, ρ^0** : $m_\perp$ -scaling
- Δ scales with π

- Cocktail A: **π^0** + η + ω
  "long lived components"

- Cocktail B: Cocktail A + **Δ** + ρ^0

systematic errors:

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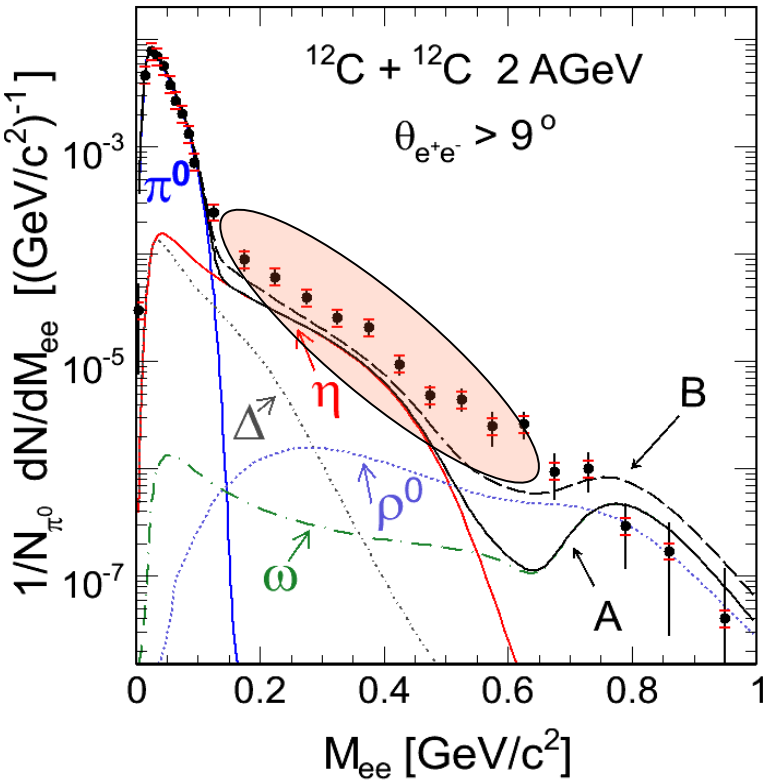
Comparison of the data with generated cocktail



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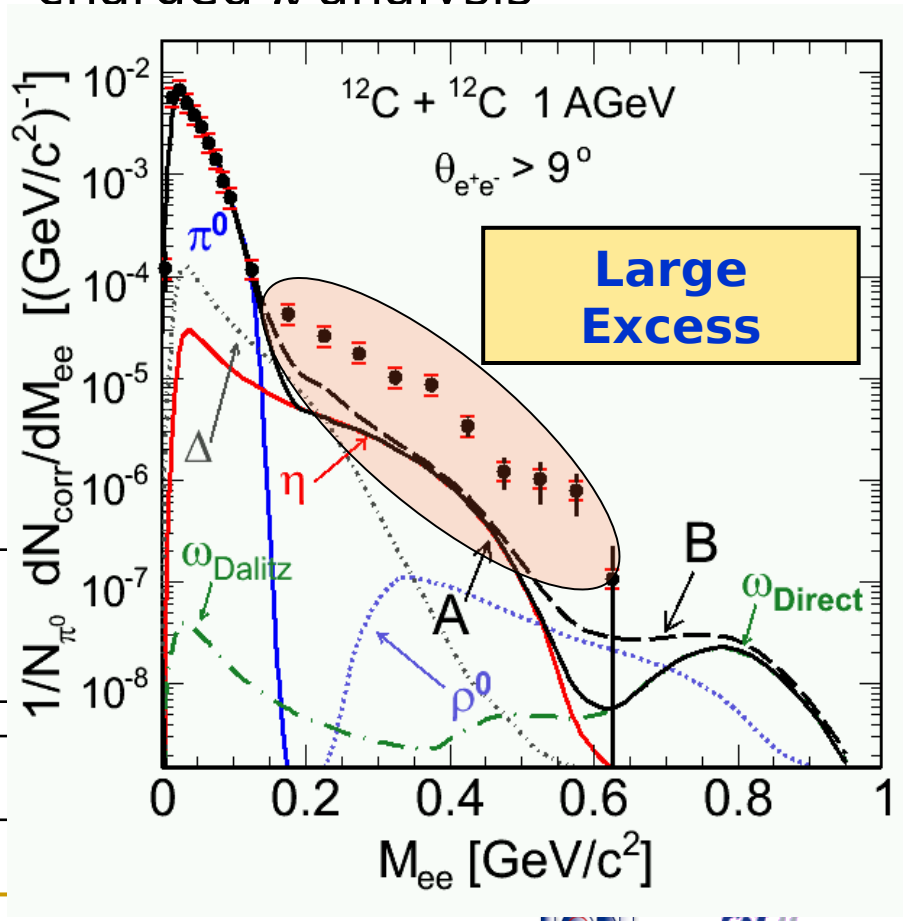

- Cocktail A: $\pi^0 + \eta + \omega$
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- Cocktail B: Cocktail A + $\Delta + \rho^0$

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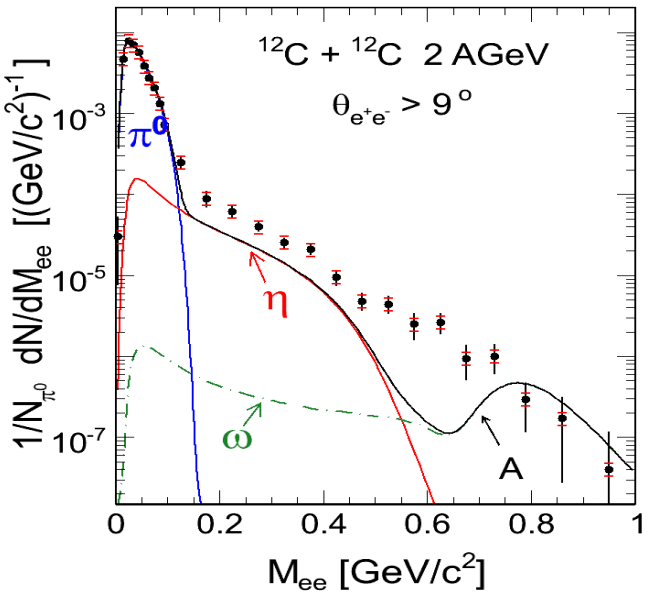
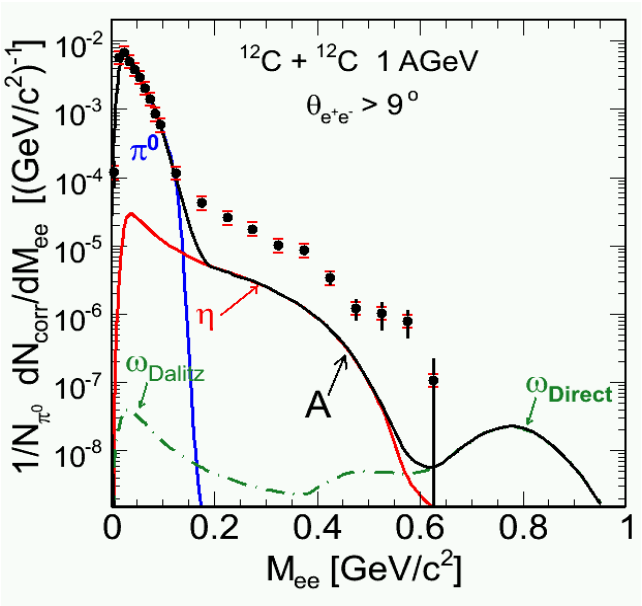
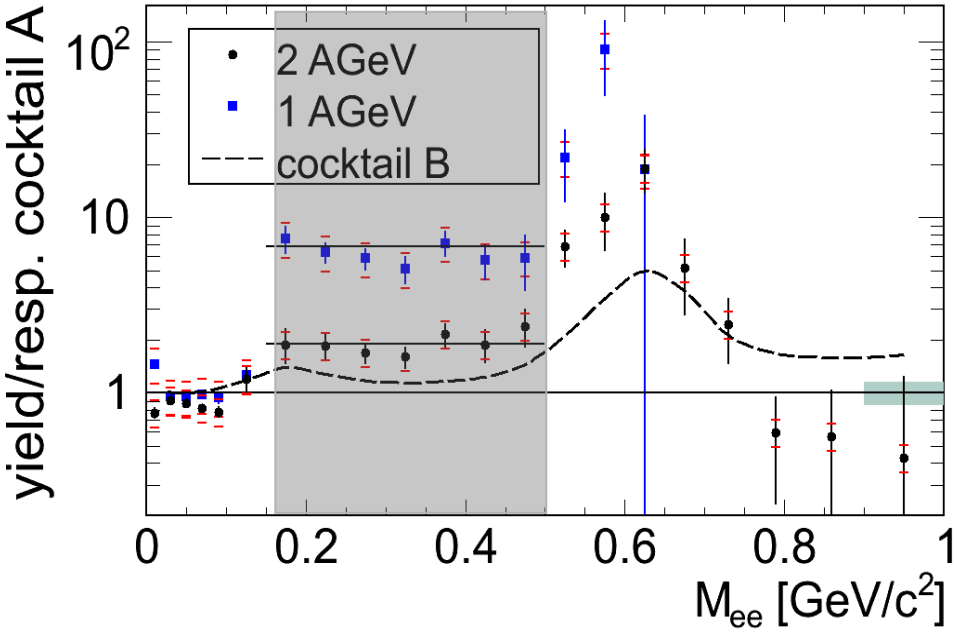




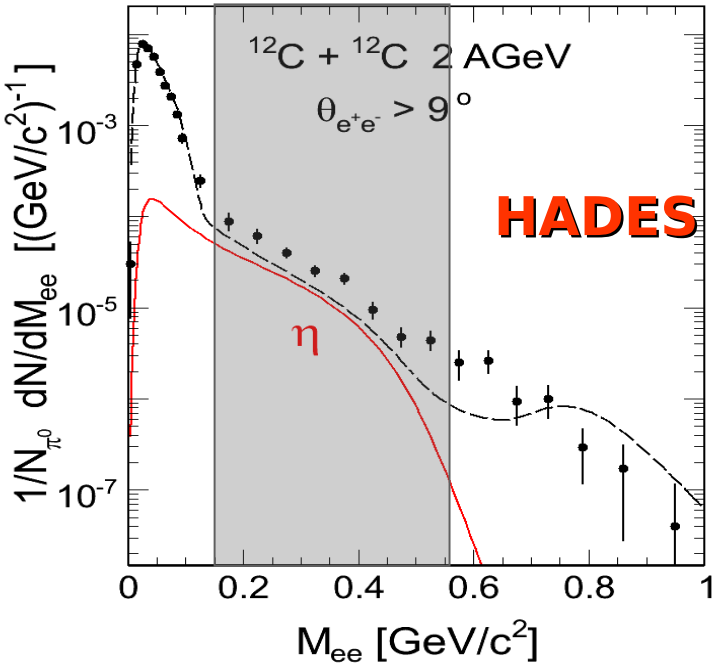


Excess yield in the range of $0.15 < M_{ee} < 0.55$ GeV/c² seams to be constant in case of both beam energy.

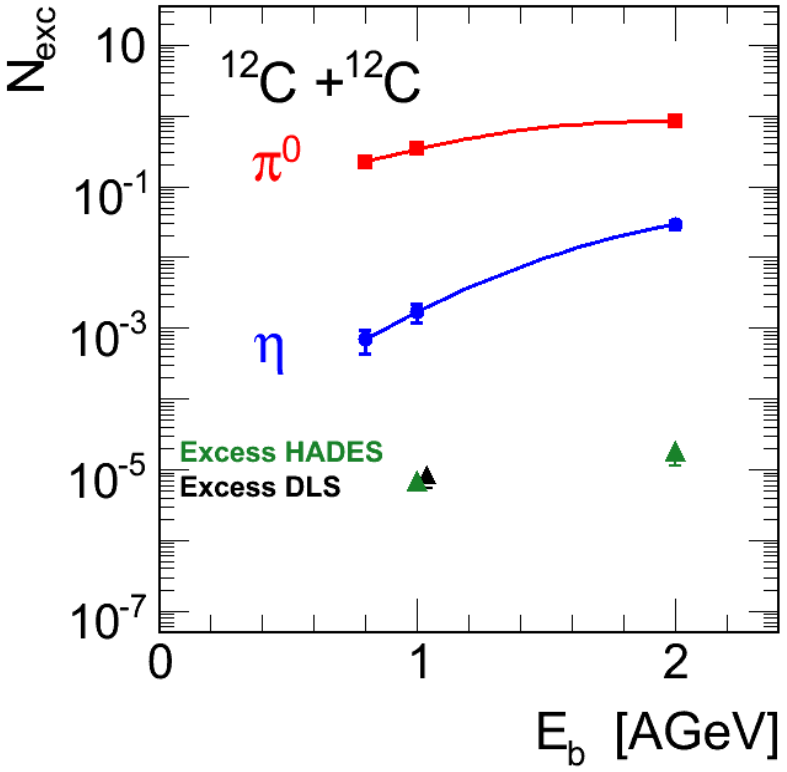
Quantify the pair excess

➔ **Determination of the excess above the known η-yield (TAPS)**

Energy dependence of the excess yield



Excess: pair yield above known η-yield (TAPS)



Photon data

R. Averbeck et al., TAPS Col., Z.Phys. A 359 (1997) 65
R. Holzmann et al., TAPS Col., Phys.Rev. C 56 (1997) R2920

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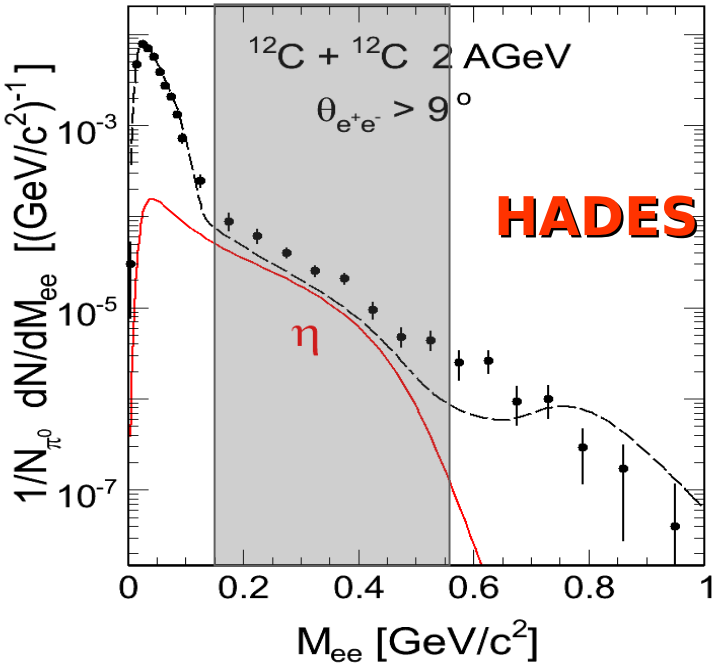

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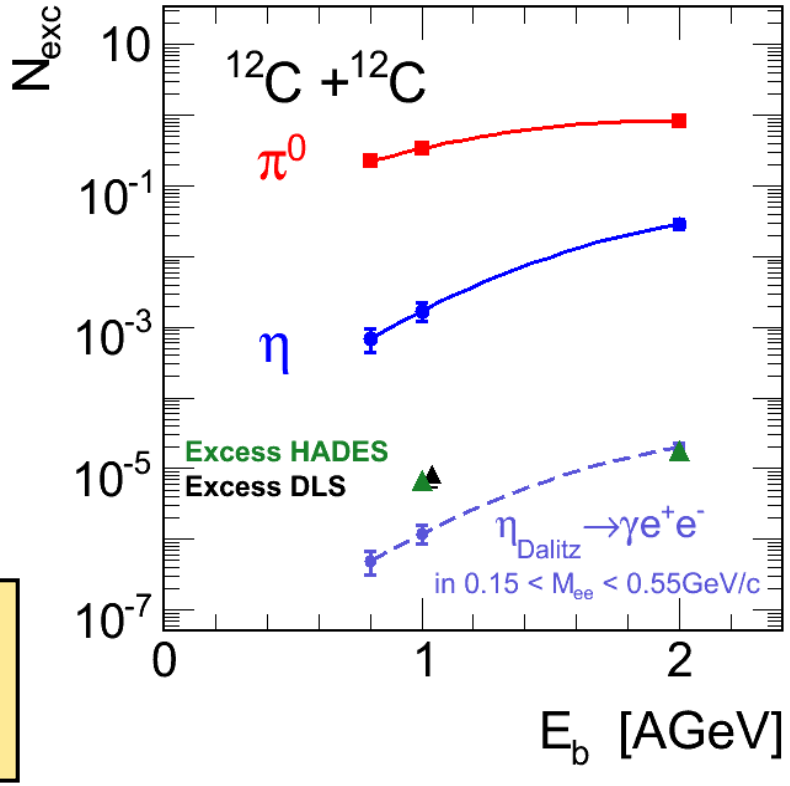

Excess dilepton yield do not scale with E_{beam} like eta production!

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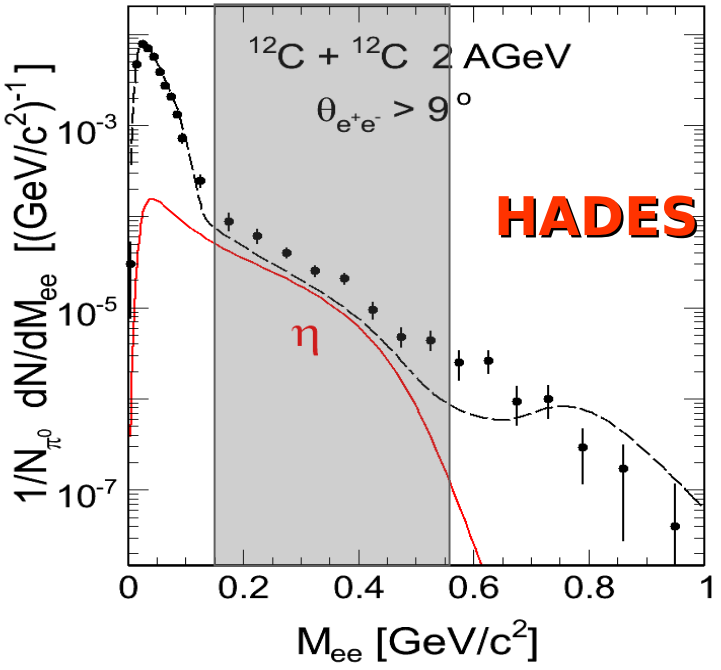
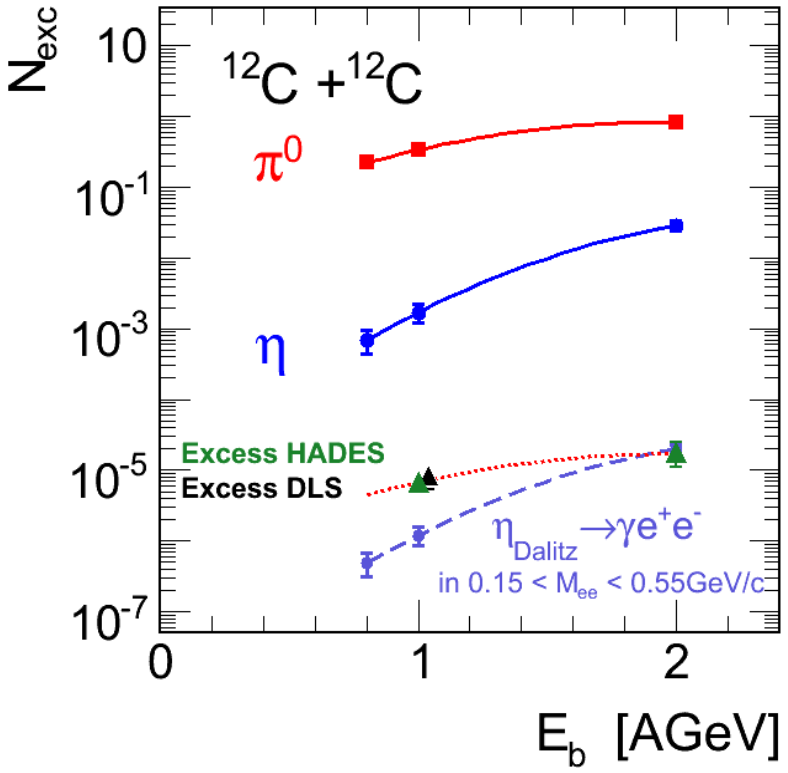


Excess: pair yield above known η-yield (TAPS)



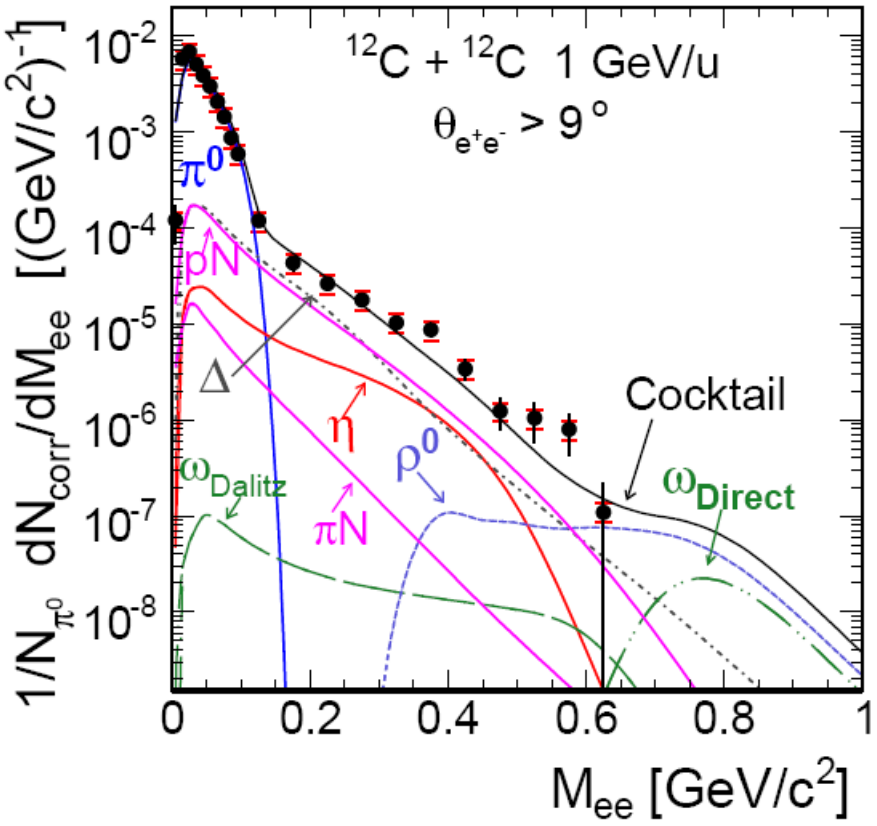
Excess dilepton yield seems to scale with E_{beam} like pion production!

➔ **hints at importance of pion dynamics!**

Radiation from baryonic resonances?
➔ Need for a quantitative understanding of elementary processes

Comparison with up-to-date Transport Calculations -HSD

HADES



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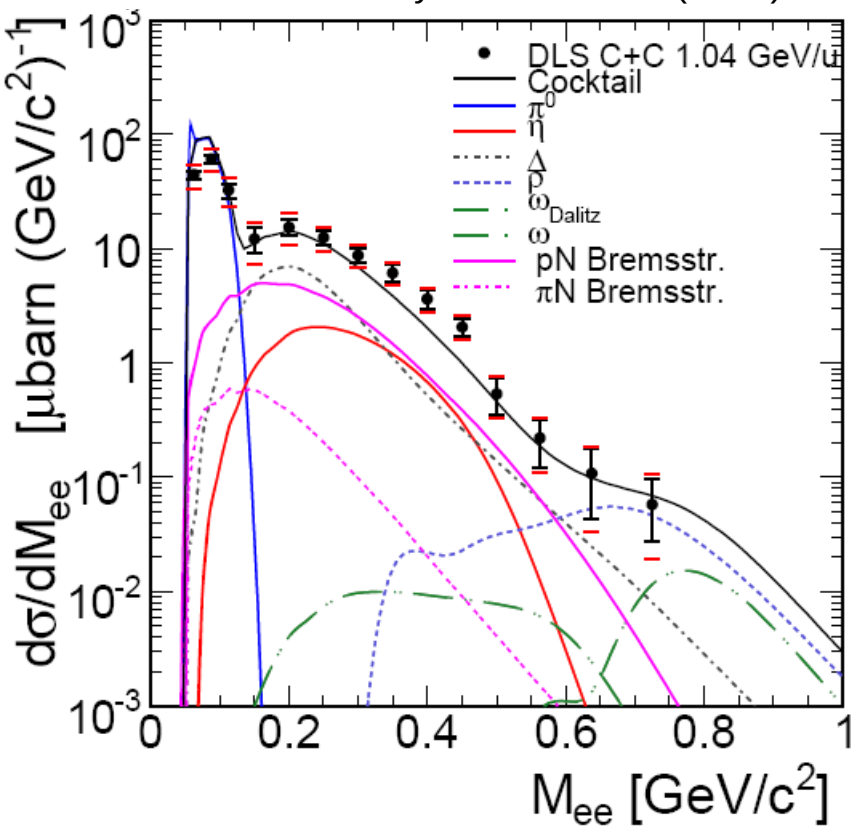
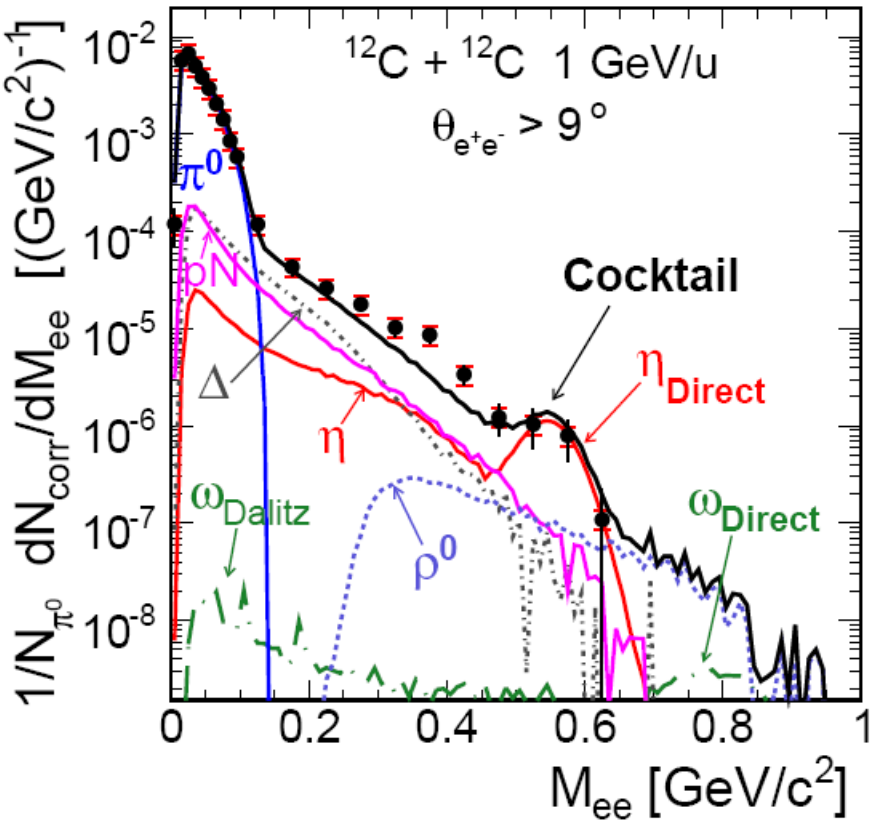
DLS



- Dominated by Δ-Dalitz decay and Bremsstrahlung
- Factor 2 difference at $M_{ee} \approx 0.4$ GeV/c^2 → additional contributions

Comparison of HADES and DLS data with IQMD calculations

Hades CC@1AGeV



IQMD: M. Thomère et al.

Phys.Rev.C75 064902 (2007) and private communication

HSD: E.L. Bratkovskaya and W. Cassing

arXiv:0712.0635v1 and private communication

Hades CC@2AGeV

M.Thomere et al., PRC 75 (2007) 064902

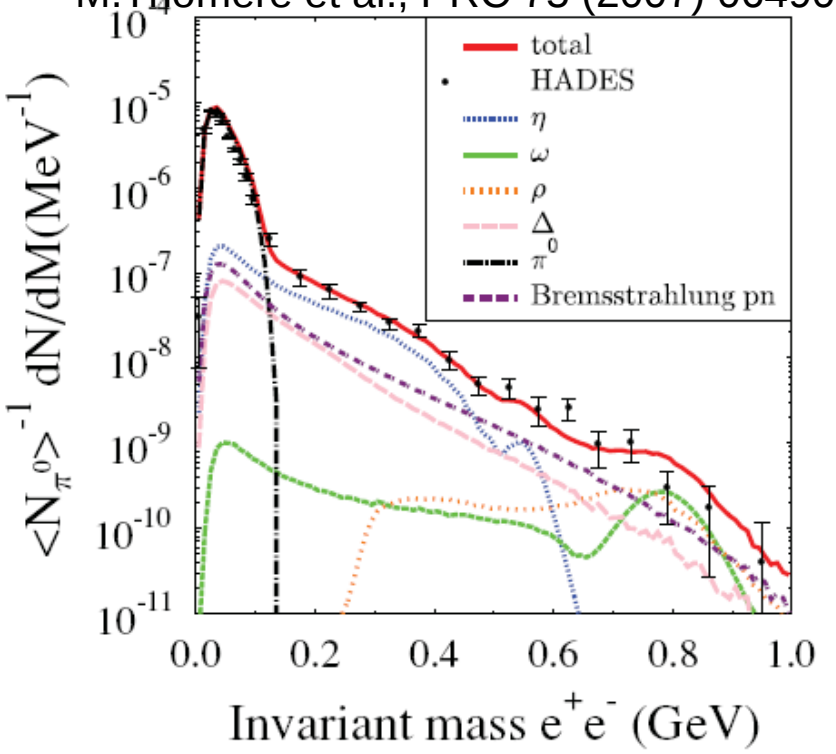


FIG. 7. (Color online) The invariant mass spectrum of the HADES Collaboration as compared with IQMD simulations for C + C at 2*A* GeV using $\sigma(np \to np\eta) = 2\sigma(pp \to pp\eta)$, $\sigma(np \to np\omega) = \sigma(pp \to pp\omega)$, $M_\omega = M^0_\omega$, and the branching ratio $(\eta \to e^+e^-) = 7.7 \times 10^{-6}$ (model B).

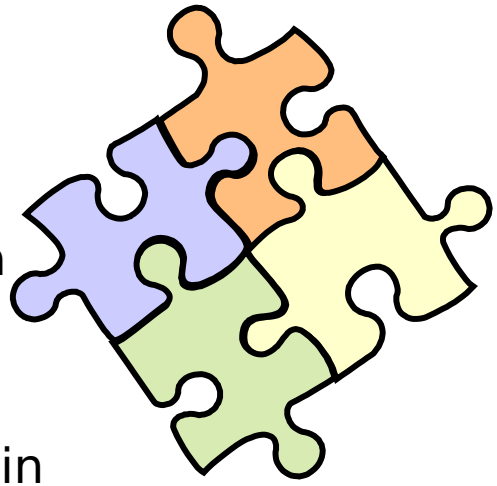
Outline and Conclusion

Conclusion

✓ HADES + DLS: enhancement scales with beam energy as pion production

✓ HADES confirms the DLS results

→ DLS puzzle is solved experimentally



✓ HADES will soon finalize set of the elementary data which will put boundary conditions for the theory.

✓A lot of theoretical effort is made up to now to explain HADES and the DLS data.

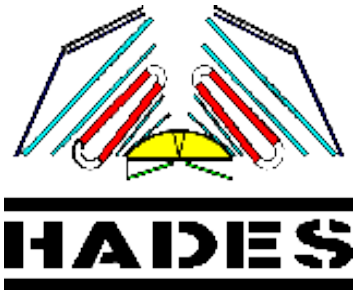
Outline

•Further systematic studies in progress (system size, centrality, beam energy)

•pA and heavy AA to investigate in-medium effects

•Elementary reactions

✓> 2011 Hades at FAIR (8 AGeV)



Collaboration

G. Agakishiev[8], C. Agodi[1], A. Balanda[3,e], G. Bellia[1,a], D. Belver[15], A. Belyaev[6], A. Blanco[2], M. Böhmer[11], J. L. Boyard[13], P. Braun-Munzinger[4], P. Cabanelas[15], E. Castro[15], S. Chernenko[6], T. Christ[11], M. Destefanis[8], J. Díaz[16], F. Dohrmann[5], A. Dybczak[3], T. Eberl[11], L. Fabbietti[11], O. Fateev[6], P. Finocchiaro[1], P. Fonte[2,b], J. Friese[11], I. Fröhlich[7], T. Galatyuk[4], J. A. Garzón[15], R. Gernhäuser[11], A. Gil[16], C. Gilardi[8], M. Golubeva[10], D. González-Díaz[4], E. Grosse[5,c], F. Guber[10], M. Heilmann[7], T. Hennino[13], R. Holzmann[4], A. Ierusalimov[6], I. Iori[9,d], A. Ivashkin[10], M. Jurkovic[11], B. Kämpfer[5], K. Kanaki[5], T. Karavicheva[10], D. Kirschner[8], I. Koenig[4], W. Koenig[4], B. W. Kolb[4], R. Kotte[5], A. Kozuch[3,e], A. Krása[14], F. Krizek[14], R. Krücken[11], W. Kühn[8], A. Kugler[14], A. Kurepin[10], J. Lamas-Valverde[15], S. Lang[4], J. S. Lange[8], K. Lapidus[10], L. Lopes[2], M. Lorenz[7], L. Maier[11], A. Mangiarotti[2], J. Marín[15], J. Markert[7], V. Metag[8], J. Micel[7], B. Michalska[3], D. Mishra[8], E. Morinière[13], J. Mousa[12], C. Müntz[7], L. Naumann[5], R. Novotny[8], J. Otwinowski[3], Y. C. Pachmayer[7], M. Palka[4], Y. Parpottas[12], V. Pechenov[8], O. Pechenova[8], T. Pérez Cavalcanti[8], J. Pietraszko[4], W. Przygoda[3,e], B. Ramstein[13], A. Reshetin[10], M. Roy-Stephan[13], A. Rustamov[4], A. Sadovsky[10], B. Sailer[11], P. Salabura[3], A. Schmah[4], R. Simon[4], Yu.G. Sobolev[14], S. Spataro[8], B. Spruck[8], H. Ströbele[7], J. Stroth[7,4], C. Sturm[7], M. Sudol[4], A. Tarantola[7], K. Teilab[7], P. Tlusty[14], M. Traxler[4], R. Trebacz[3], H. Tsertos[12], I. Veretenkin[10], V. Wagner[14], H. Wen[8], M. Wisniowski[3], T. Wojcik[3], J. Wüstenfeld[5], S. Yurevich[4], Y. Zanevsky[6], P. Zhou[5], P. Zumbruch[4]

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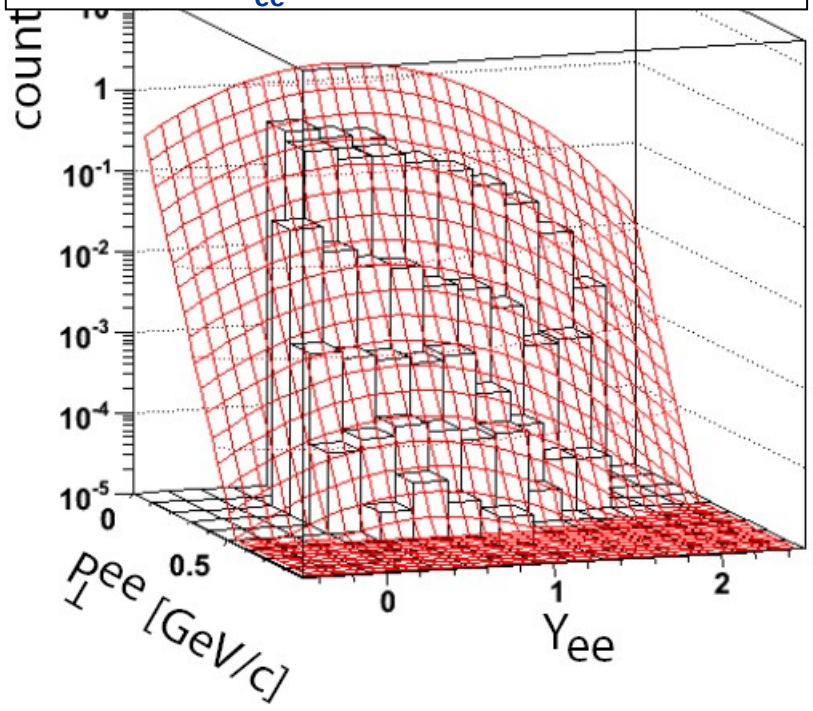
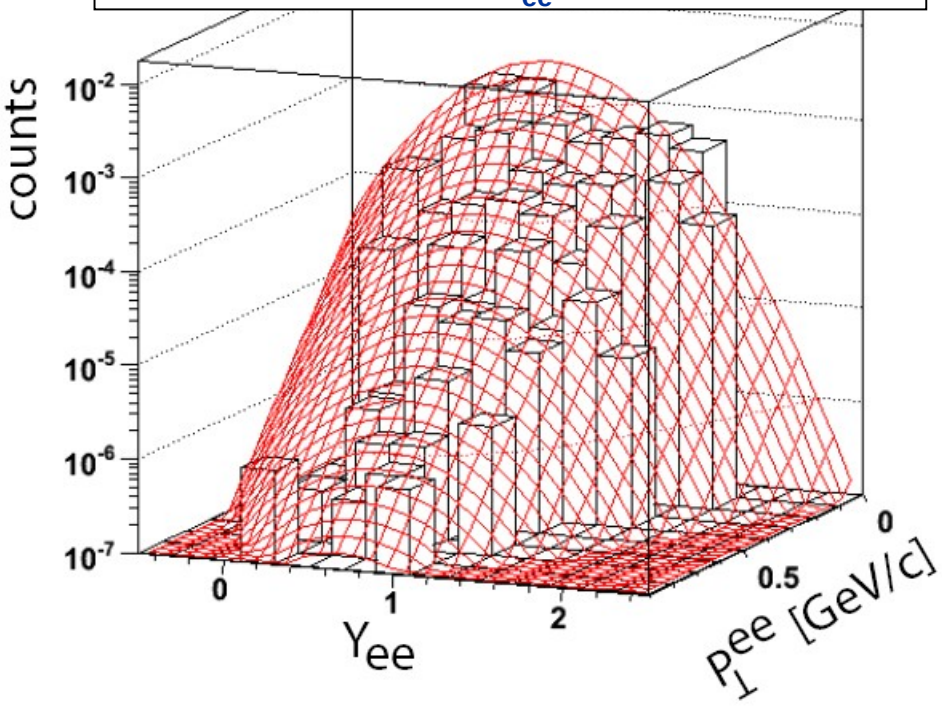
Extrapolation of Hades Data

Fit: $1/P_t\, d^2N/dP_t dy \in \exp(-c_0 - c_1 P_t - c_2 (y - y_{1/2})^2)$

M_{ee} < 0.15 GeV/c²



0.15 GeV/c² ≤ M_{ee} ≤ 0.55 GeV/c²

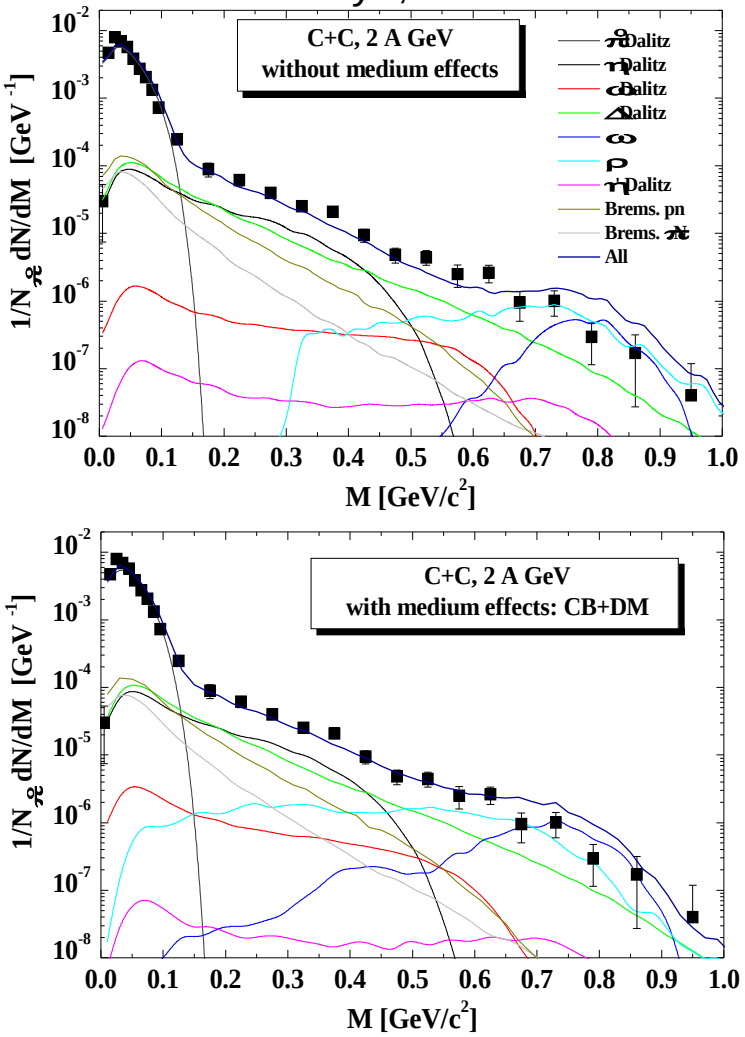


- Efficiency- and acceptance-corrected pairs (HADES exp. data)
- Fit 2d functions
- using resulting fits to extrapolate (extrapolation in excess region ≤ 25%)

Comparison C + C 2GeV to transport calculations

Calculation: HSD

E.Bratkovskaya, ECT Trento 2007



Calculation: IQMD

M.Thomere et al., PRC 75 (2007) 064902

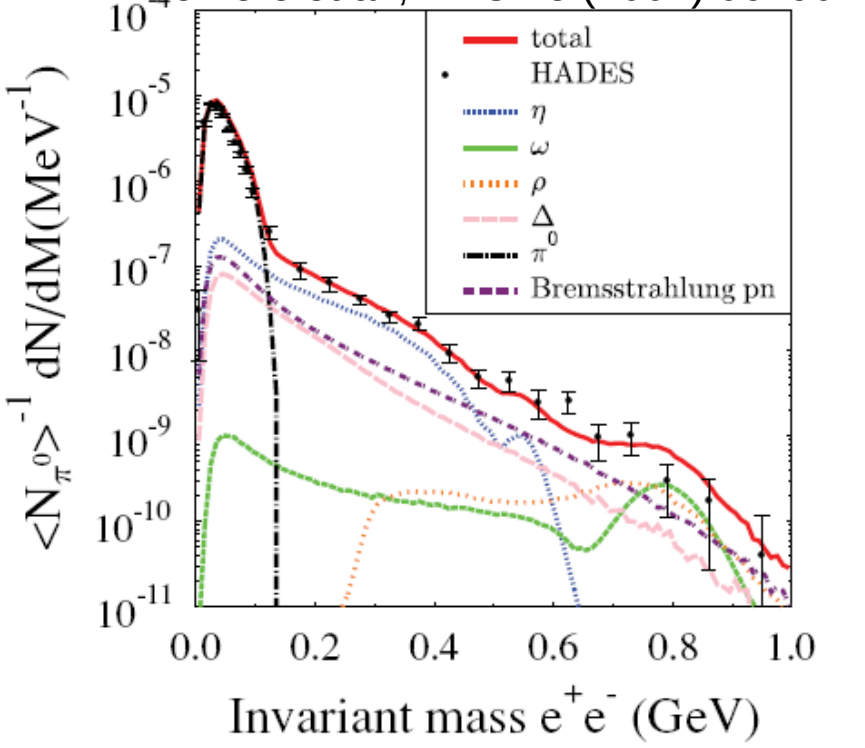


FIG. 7. (Color online) The invariant mass spectrum of the HADES Collaboration as compared with IQMD simulations for C + C at 2*A* GeV using $\sigma(np \to np\eta) = 2\sigma(pp \to pp\eta)$, $\sigma(np \to np\omega) = \sigma(pp \to pp\omega)$, $M_\omega = M^0_\omega$, and the branching ratio $(\eta \to e^+e^-) = 7.7 \times 10^{-6}$ (model B).