XIX International Baldin Seminar on High Energy Physics Problems

Dielectron production in pp and dp collisions at 1.25 GeV/u with HADES

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for the HADES Collaboration

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Dubna

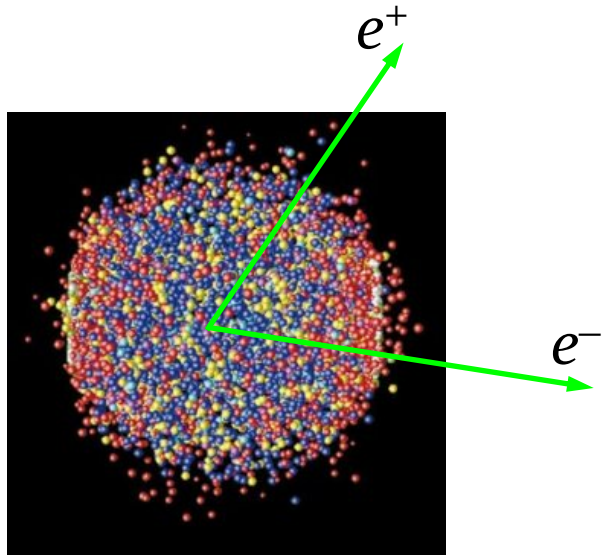
Outline of the talk

1. HADES experiment
2. Elementary collisions: what's peculiar?
3. Experimental results
4. Physical interpretation and discussion
5. Summary

Experimental observables in nuclear collisions: **dileptons**

Features of electromagnetic probes

- ✓ Produced during all stages of collision
- ✓ Do not interact strongly
- ✓ Kinematical characteristics are not disturbed by surrounding media

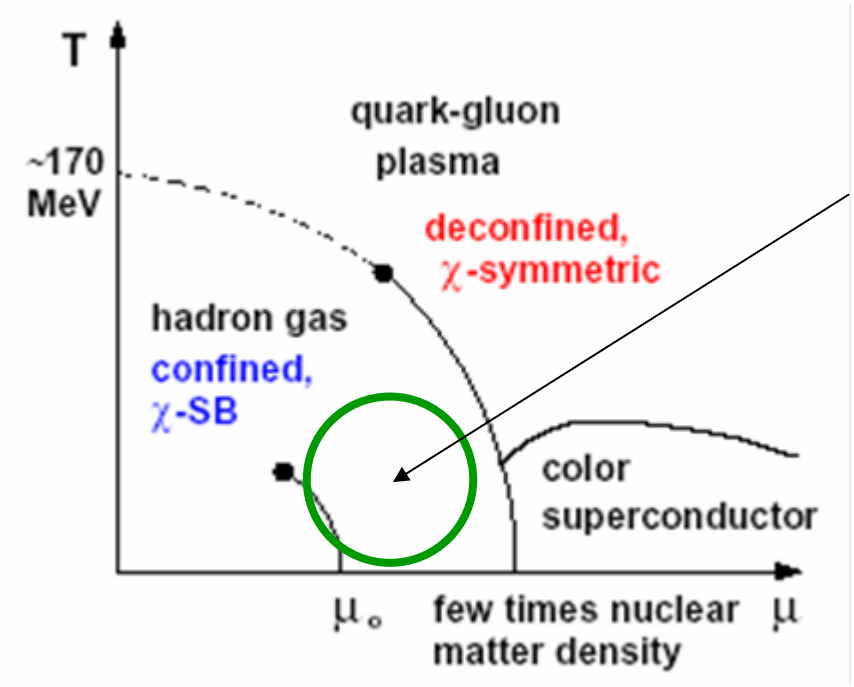


HADES experiment

Location: GSI, Darmstadt

Ultimate goal: study of chiral symmetry restoration at non-zero μ_B

Program: vector meson spectroscopy and study of elementary channels, investigation of dilepton production in heavy ion colissions



HADES (SIS 18):
1-2 AGeV
ρ/ρ_N = 1-3
T < 80 MeV
"resonace matter"

High Acceptance Dielectron Spectrometer

Pair acceptance

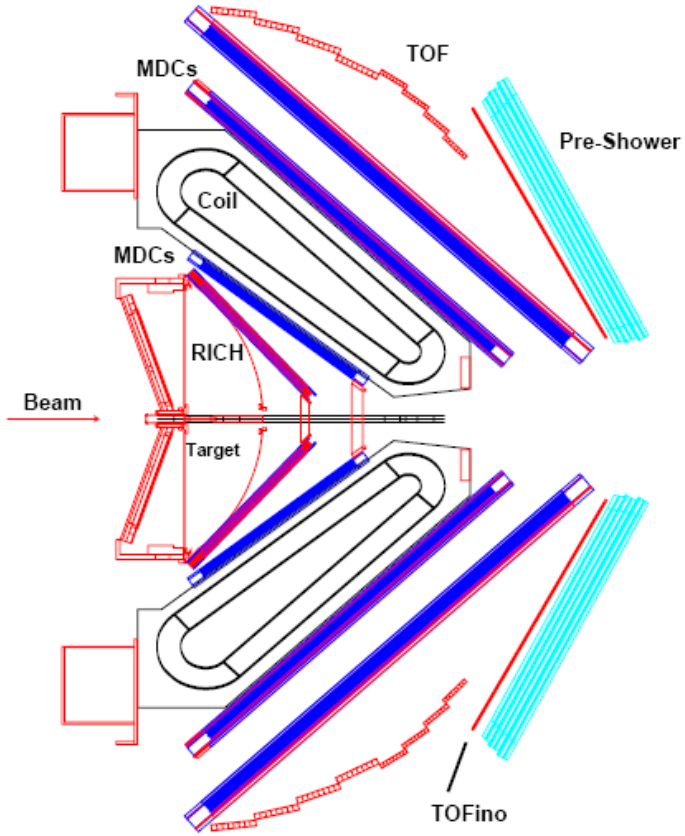
≈ 0.24 (0.35)
Full azimuth, polar angles 18^o-85^o

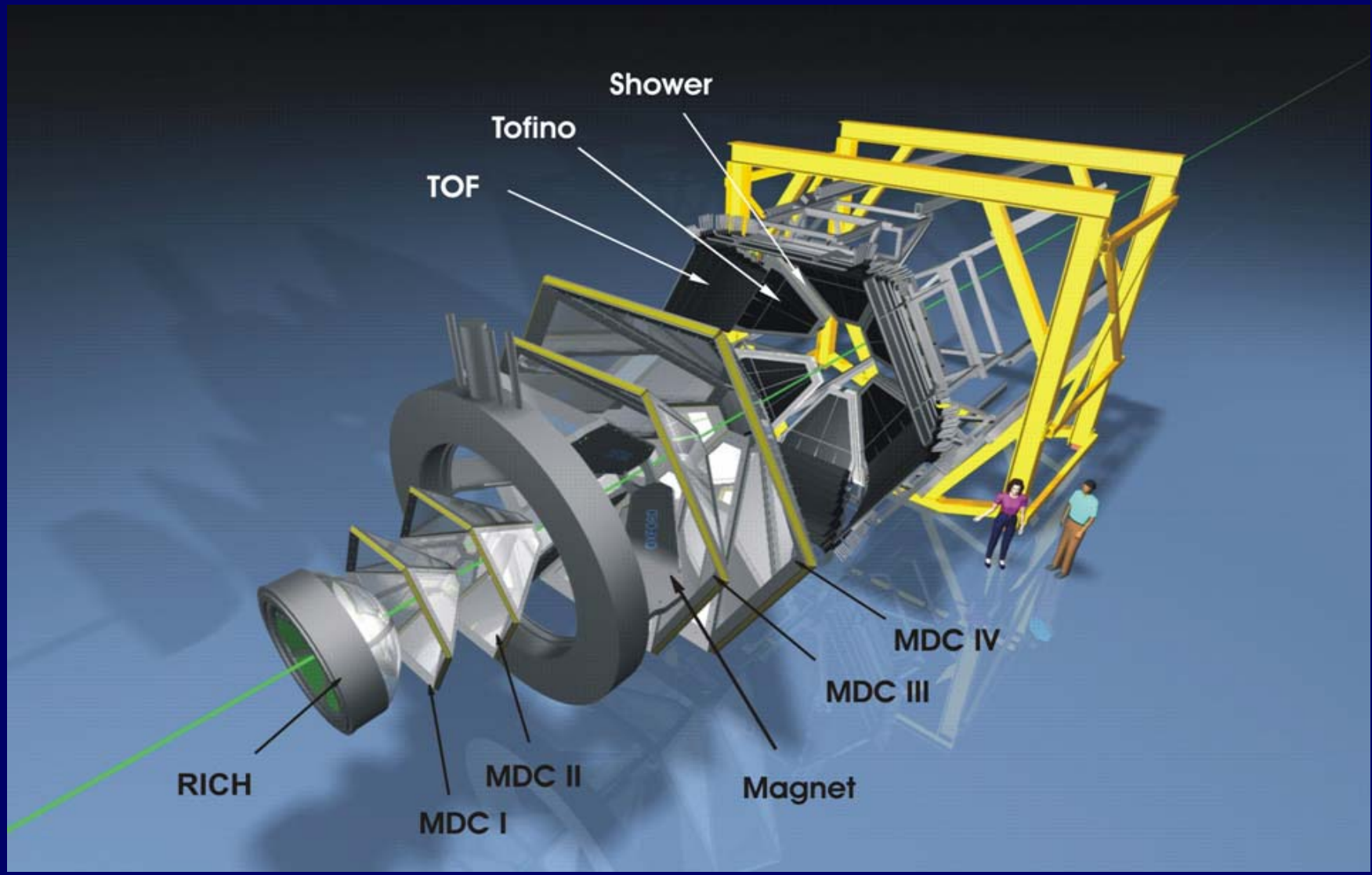
Particle identification:

RICH: CsI solid photocathode, C_4F_{10} radiator
Time Of Flight: Scintillator paddles
→ MUL limitation $\theta<45^0$, RPC from 2009
Pre-Shower: pad chambers & lead converter

Momentum measurement

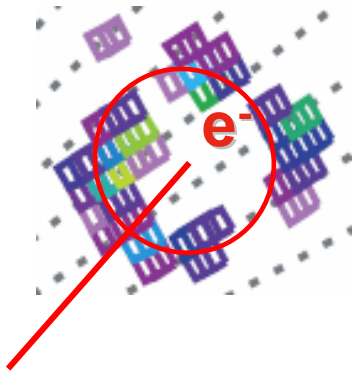
Magnet: $B\rho$ = 0.36 Tm
MDC: 24 Midi Drift Chambers,
single-cell resolution ≈ 140 μm




Shower
Tofino
TOF
MDC IV
MDC III
RICH
MDC II
MDC I
Magnet

Lepton Identification with HADES

RICH pattern



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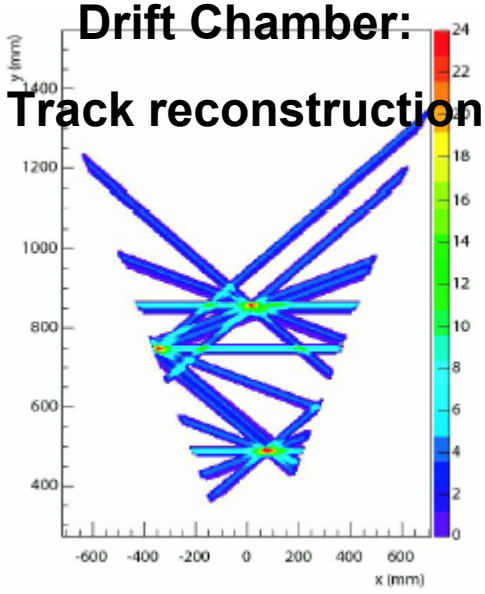
Drift Chamber: Track reconstruction



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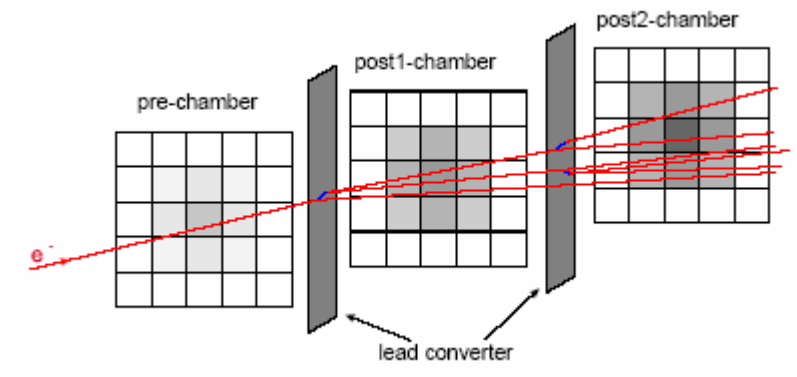
Pre-Shower condition



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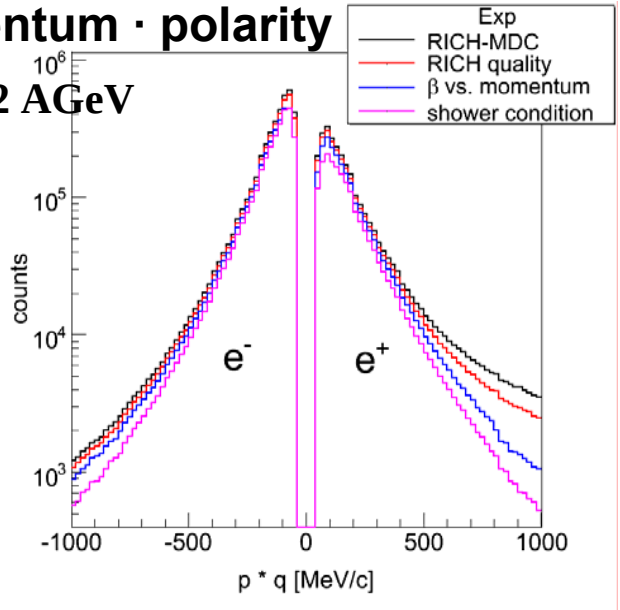
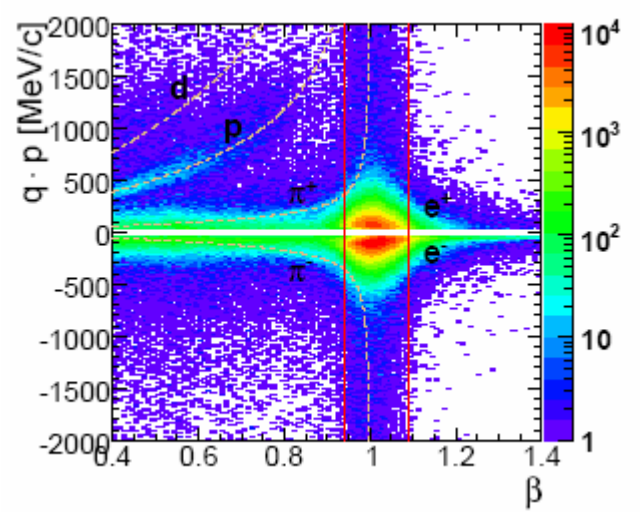
momentum · polarity

C+C 2 AGeV



velocity vs momentum



HADES Experimental Program

AA

2002 $^{12}C+^{12}C$ 2 AGeV

2004 $^{12}C+^{12}C$ 1 AGeV

2005 Ar+KCl 1.76 AGeV

NN

2004 p+p 2.2 GeV

2006 p+p 1.25 GeV

2007 d+p (n+p) 1.25 AGeV

2007 p+p 3.5 GeV

HADES Experimental Program

AA

PRL 2002 $^{12}C+^{12}C$ 2 AGeV

PLB 2004 $^{12}C+^{12}C$ 1 AGeV

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NN

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2006 p+p 1.25 GeV

2007 d+p (n+p) 1.25 AGeV

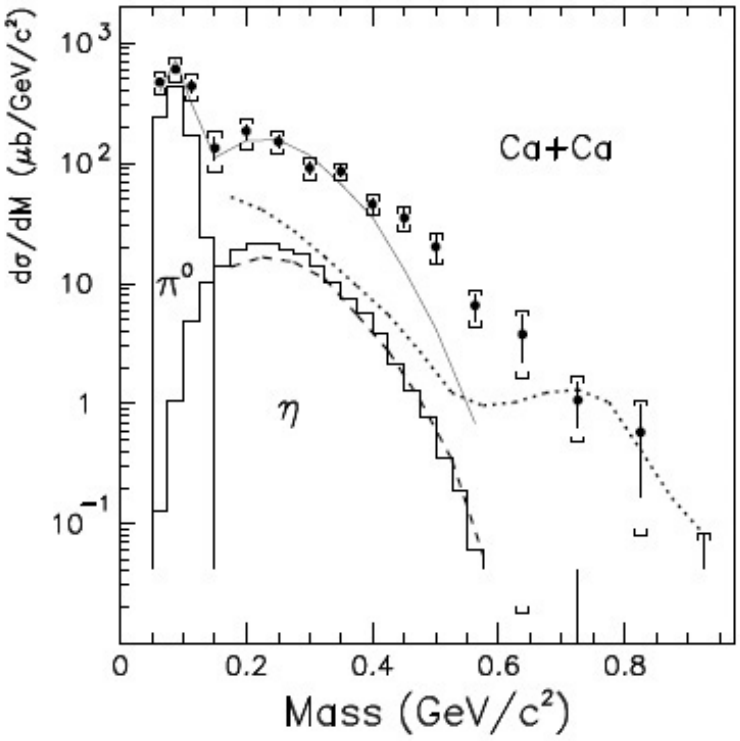
2007 p+p 3.5 GeV

pA? → ongoing data taking p+Nb 3.5 GeV

Future: heavier systems, pion beam, HADES8 at SIS100

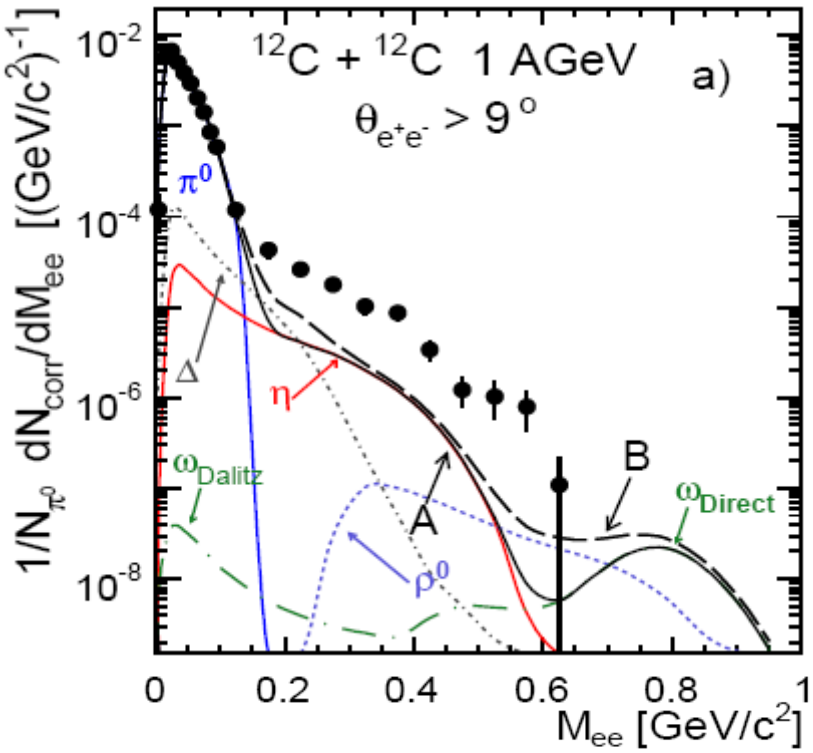
Nucleus-nucleus collisions at 1 GeV/u

DLS



R. J. Porter *et al.*,
Phys. Rev. Lett. 79 (1997) 1229.

HADES



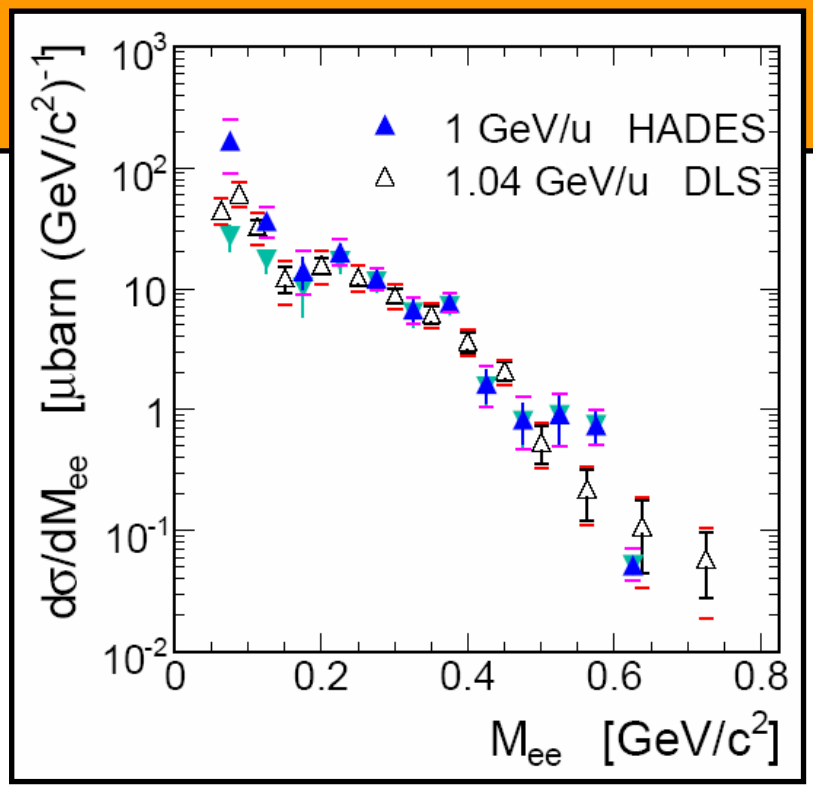
G. Agakishiev *et al.*,
Phys. Lett. B 663 (2008) 43.

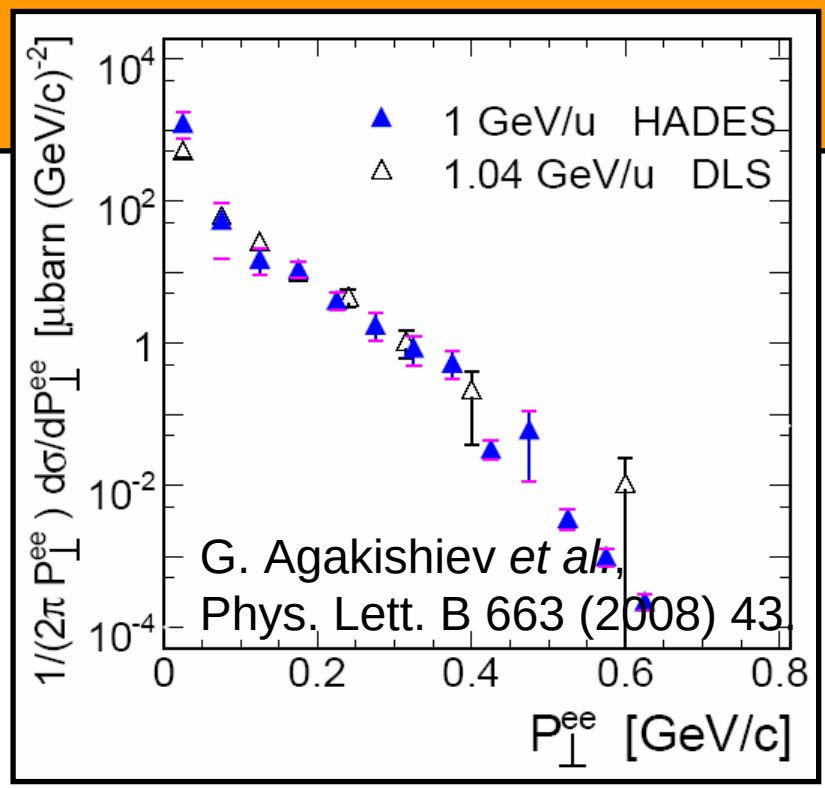
Nucleus-nucleus collisions at 1 GeV/u

Discrepancy of the data with cocktail of long lived components (mainly eta):

established by DLS, confirmed by HADES (results agree)

excess factor Y_tot/Y_eta = 6.8





Study of elementary collisions

Origin of the excess?

Specific nuclear environment effects?

Poor knowledge of NN contribution?

<u>Need to study elementary reactions in this energy regime</u>

2006: p + p 1.25 GeV

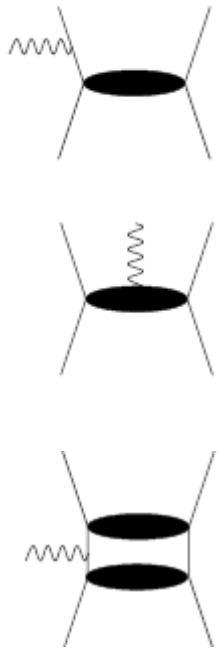
2007: d + p 1.25 GeV/u (tagging of QF np)

<u>Note:</u> eta production threshold is 1.27 GeV

np bremsstrahlung

Promising candidate: **neutron-proton bremsstrahlung**

- Radiation of (virtual) photon in NN scattering
- sigma_np >> sigma_pp
- recent theoretical consideration by L.P. Kaptari and B. Kämpfer, NPA 764 (2006) 338, gives much bigger cross section than previous calculations
- no definitive predictions, see also R. Shyam and U. Mosel, PRC 67 (2003) 065202

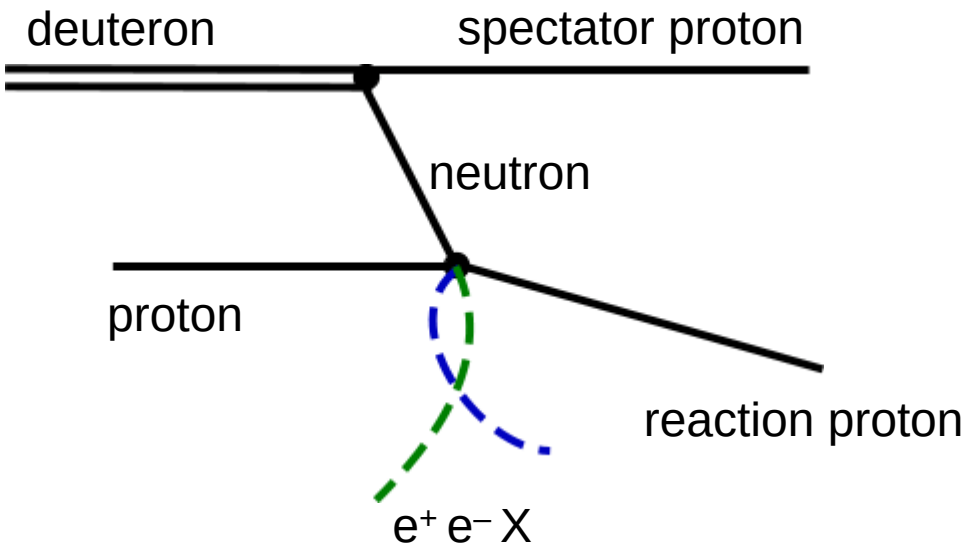


Bottomline:

np-brem *predicted to be* very important process in context of pair production at energies ~1 GeV/u

Need for experimental study

quasi-free np reaction within IA



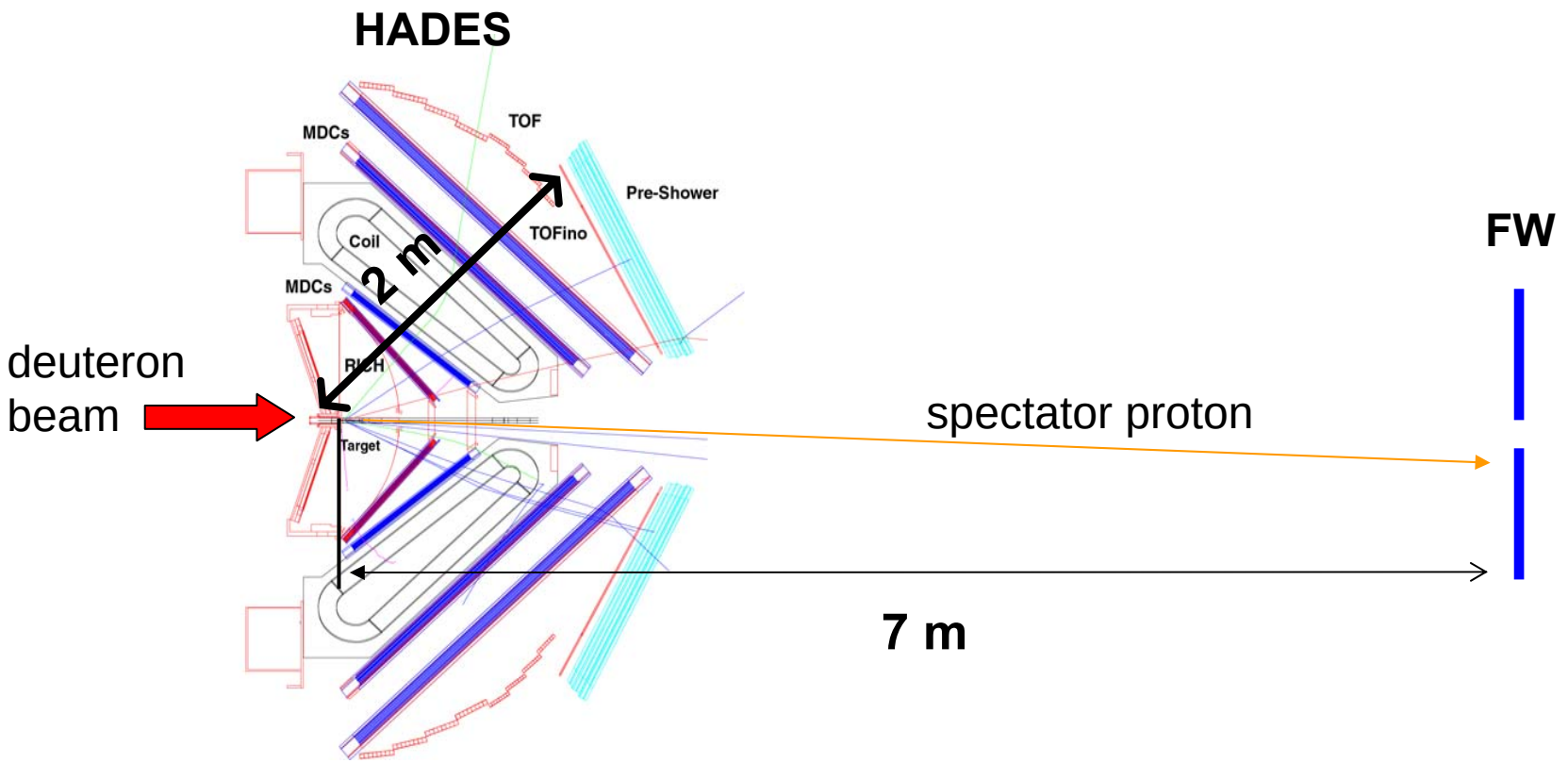
spectator p:
small angles (p_t), $p \sim p_d/2$

reaction p:
larger angles (p_t), $p < p_d/2$

<u>np selection</u>:

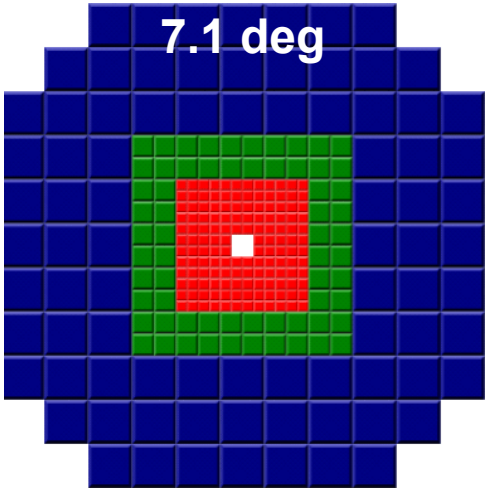
need to register spectator proton in very forward direction

dp experiment with Forward Wall



Forward Wall

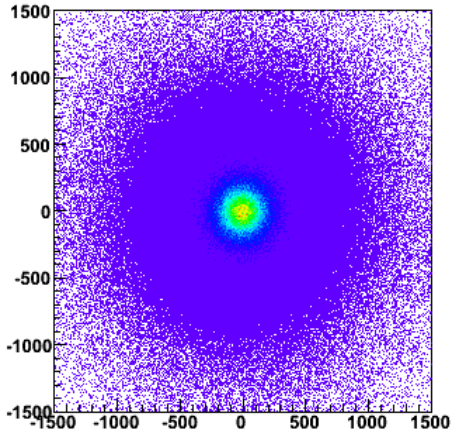
Scintillator hodoscope located 7 meters downstream the target

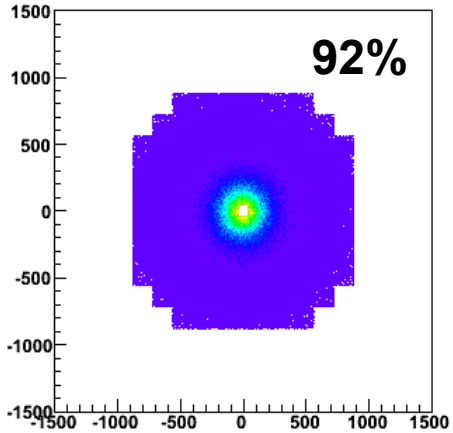


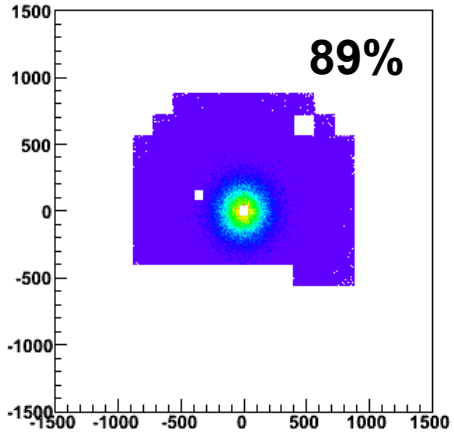
Information from the Wall:

1. **Time of flight**
2. **Coordinate of the fired cell**
3. **TAT ~ dE/dx**

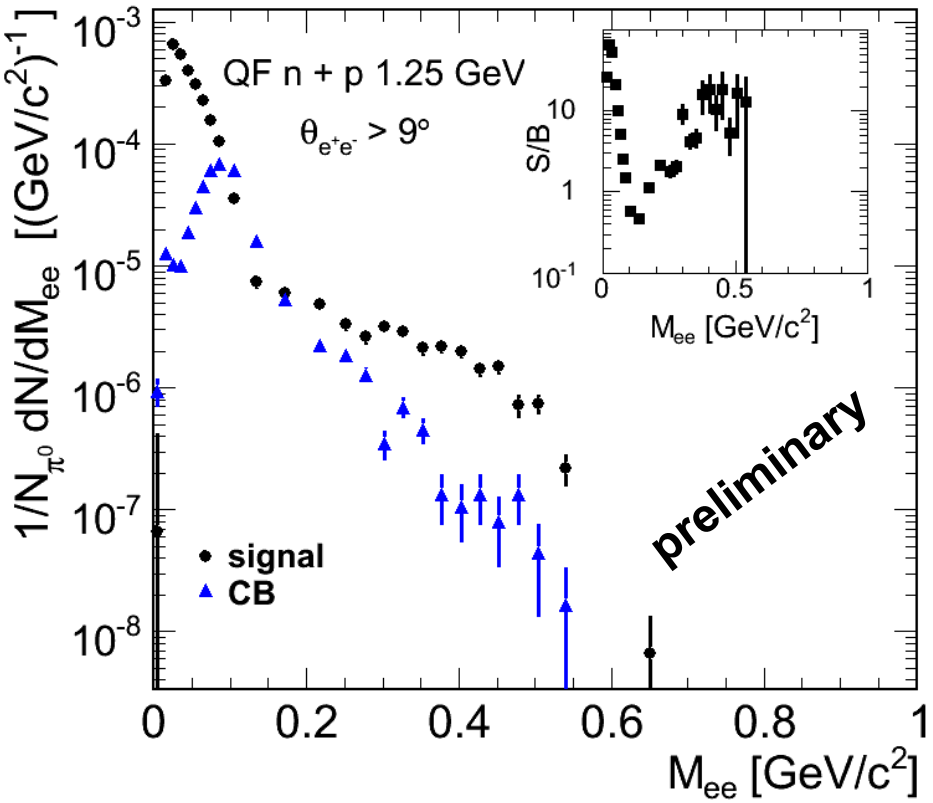
FW acceptance to spectator protons







QF np: raw pair spectra



Note:

~2200 pairs above pi0

Nice S/B ratio

FW cuts (np selection):

1. **fwMult > 0**
2. **search for particle with 1.6 GeV < p < 2.6 GeV**

Pair cuts:

1. **no double hit**
2. **openangle > 9.**
3. **closestnonfitted cuts**
4. **RKchi2 < 100000.**

BG: arithmetical mean

Normalization:

Nel = 5.41E+9

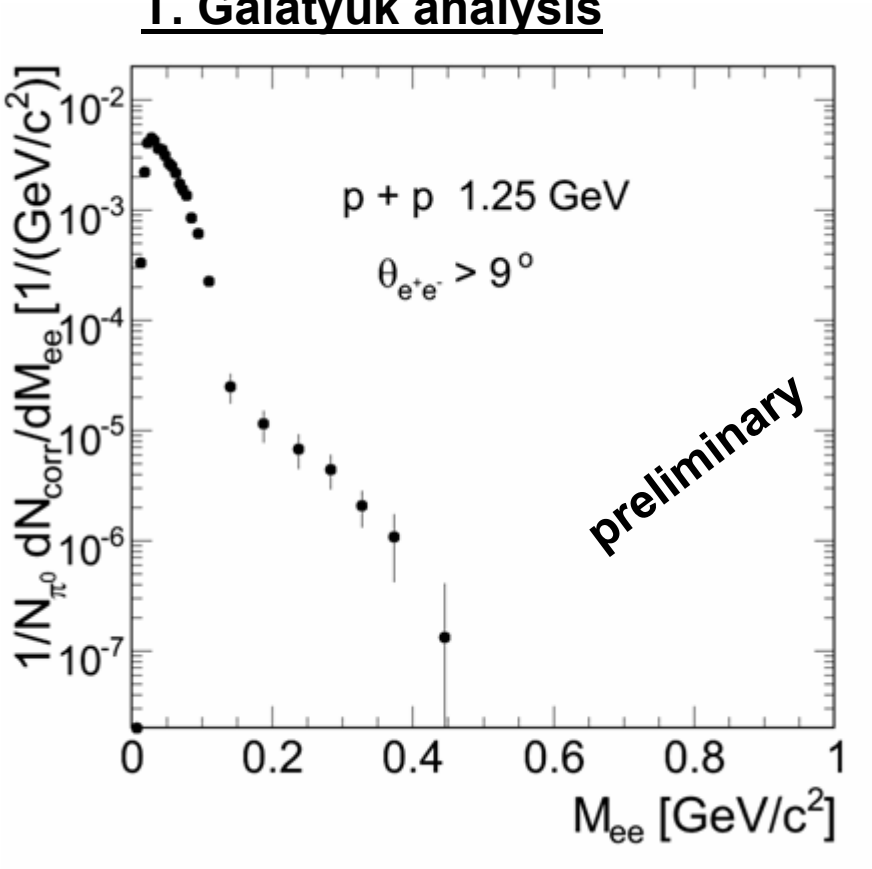
sigma_ppel = 22.1 mb

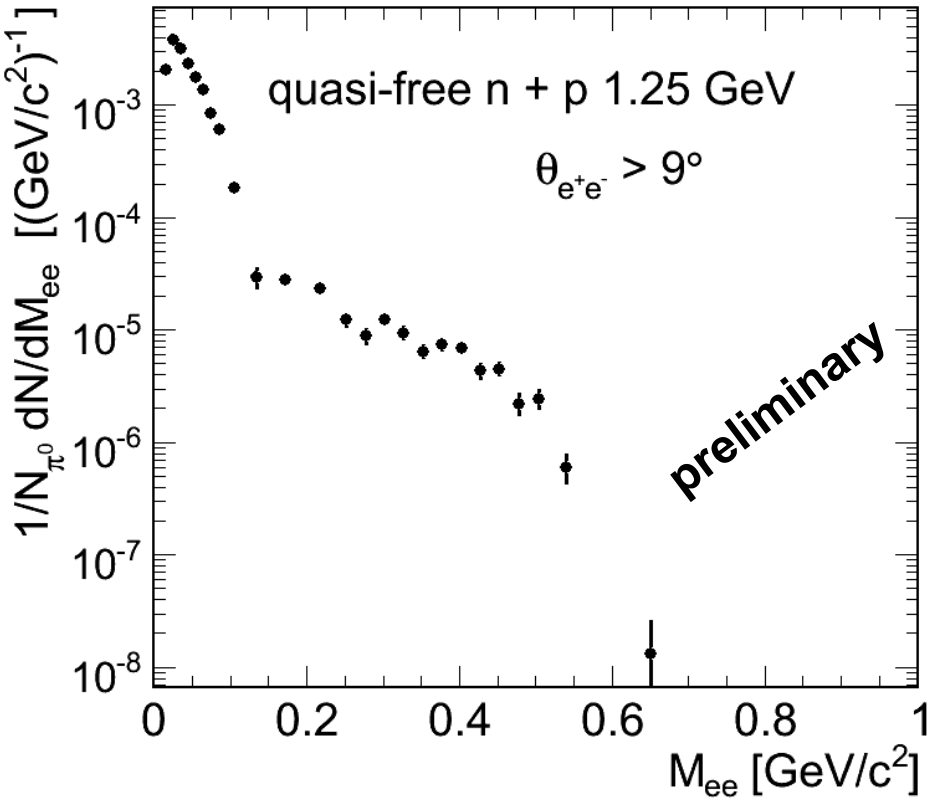
sigma_pi = 8 + 0.56 mb

Npi = 2.1E+9

np versus pp (efficiency corrected)

T. Galatyuk analysis





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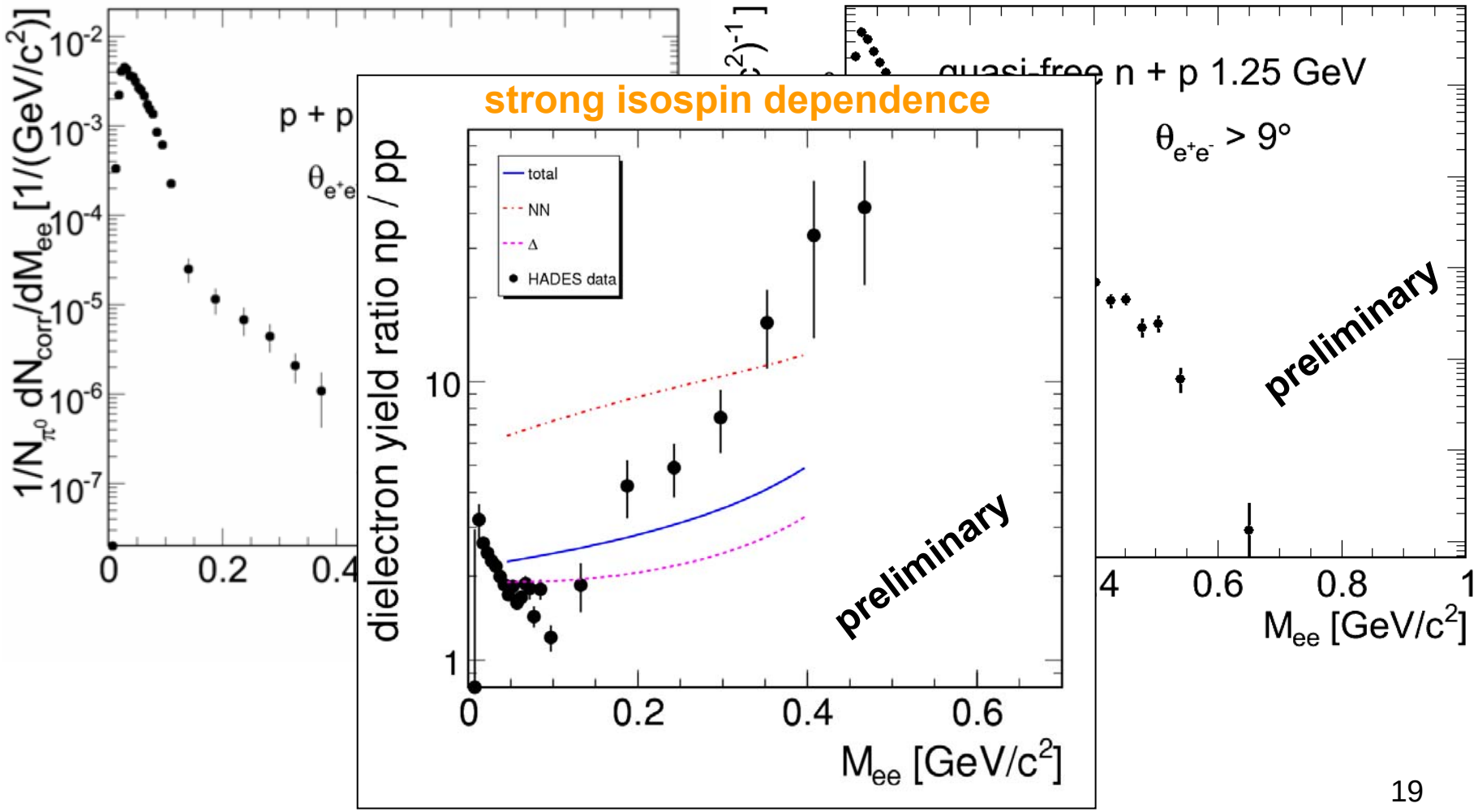

Comparison with PLUTO* cocktails

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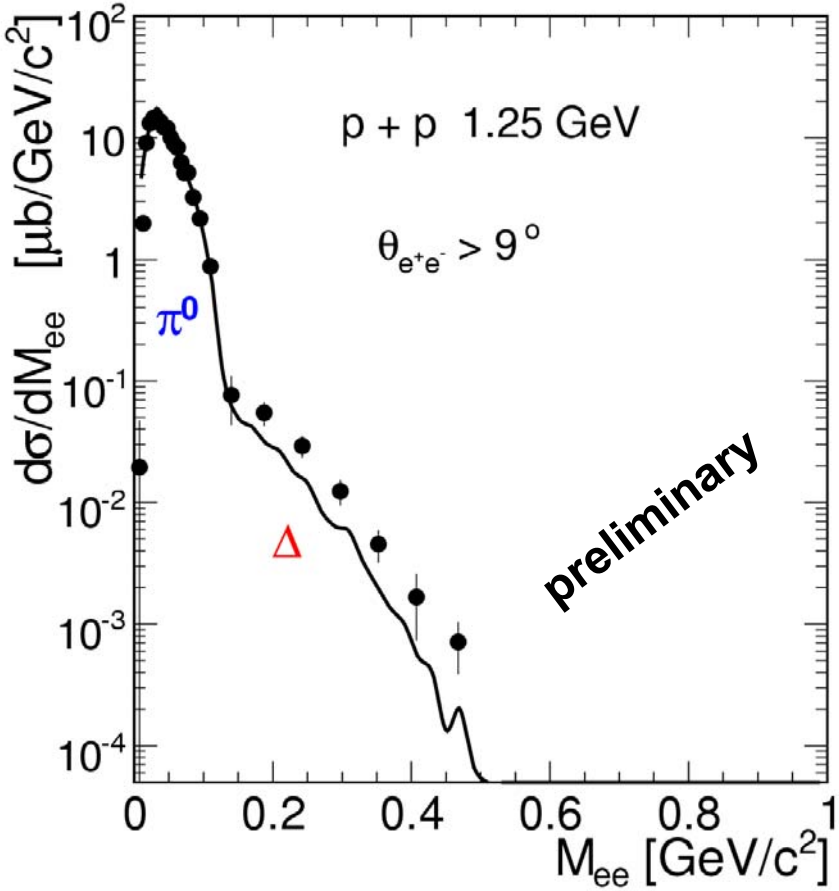
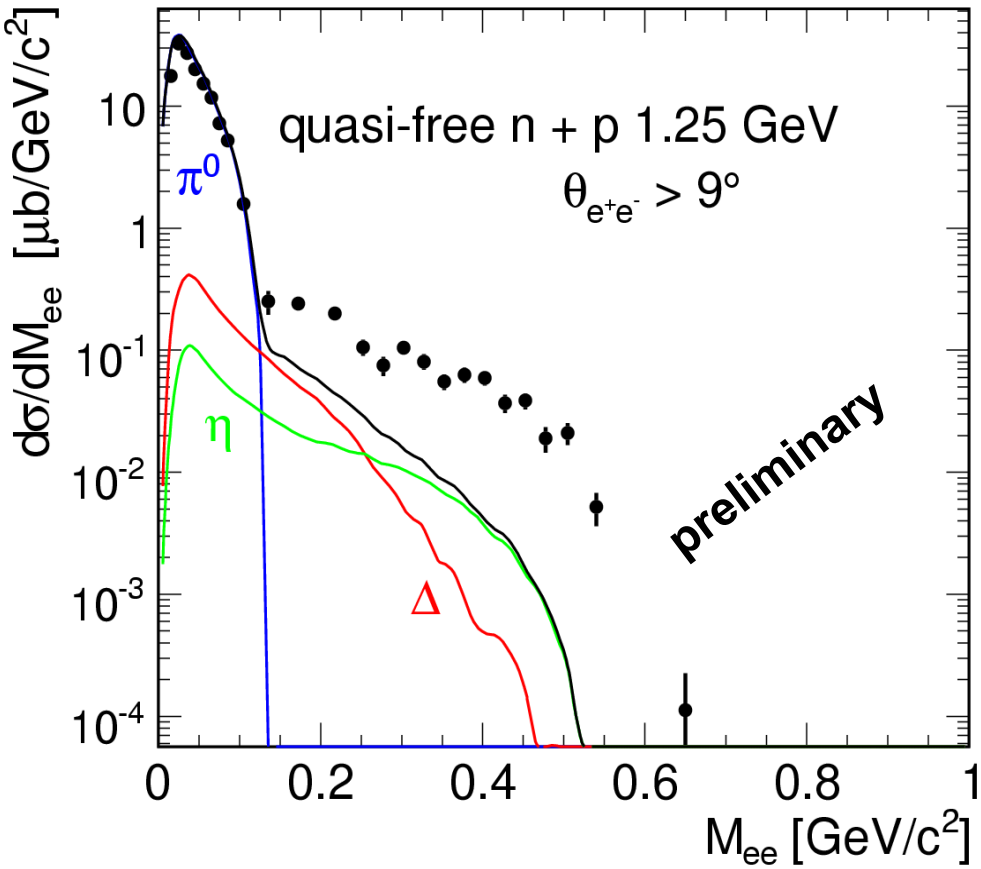


R. Trebacz PLUTO simulations



***PLUTO — Monte Carlo event generator**
arXiv:0708.2382 [nucl-ex]

Comparison with PLUTO* cocktails

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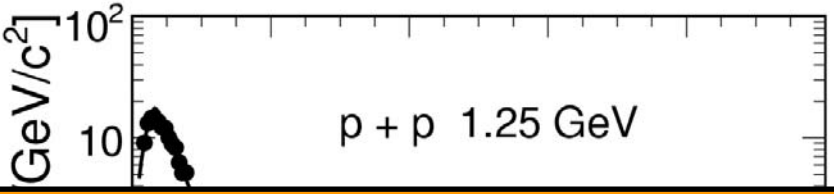

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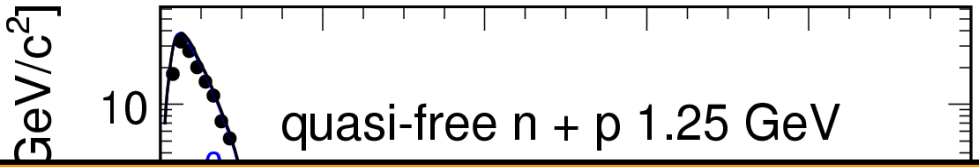
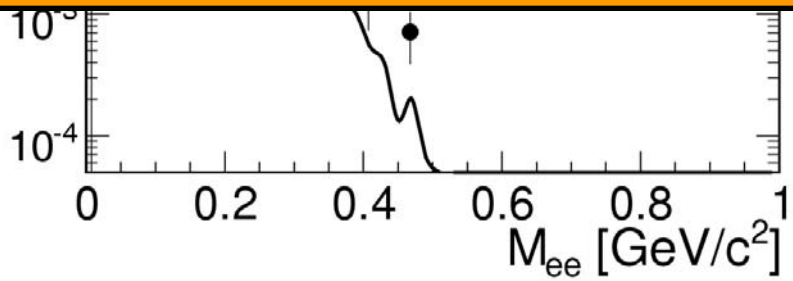
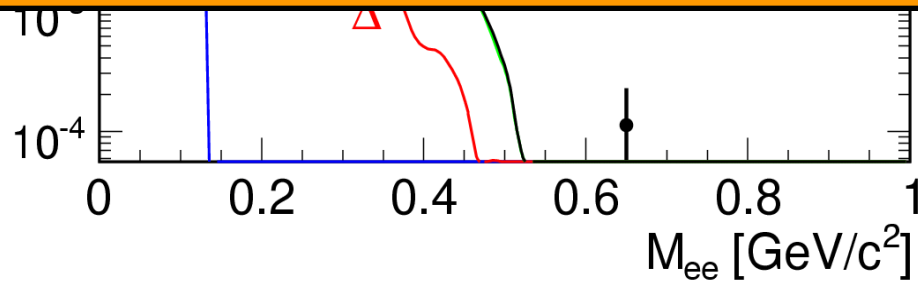


A. pp data is almost saturated by delta Dalitz

B. np shows strong excess over delta + subthreshold eta

C. clear need for additional sources: np-brem, excitation of resonances





***PLUTO — Monte Carlo event generator**
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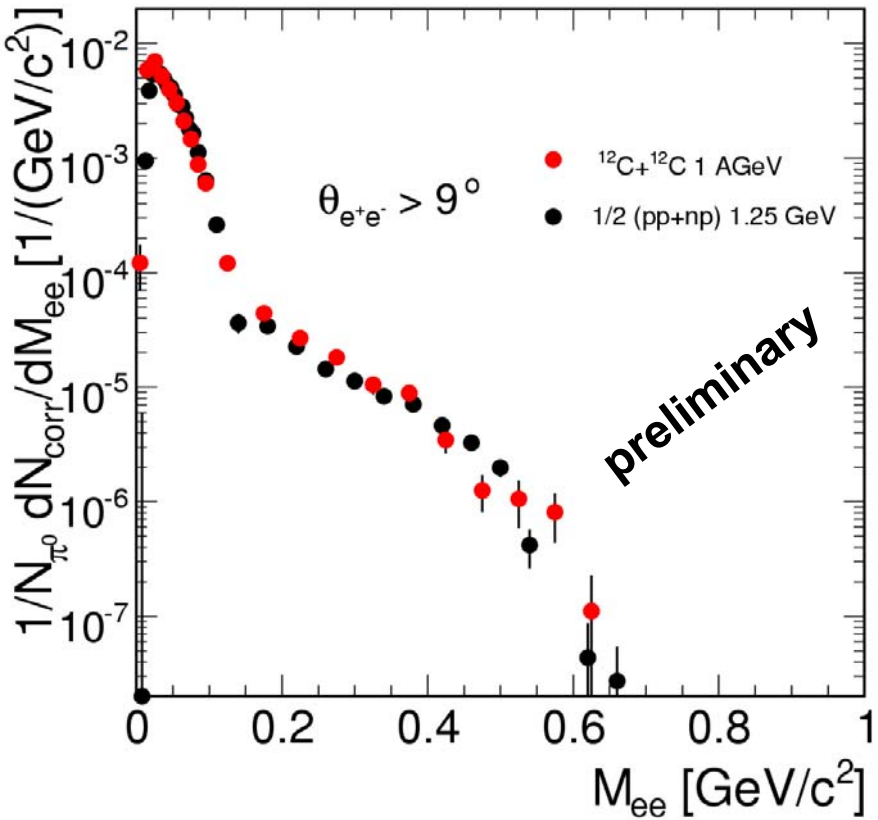
Preparing experimental cocktail



Mean of properly scaled yields in pp and np versus CC data

Overlap suggests that the observed yield in CC is caused by np channel

Absence of extra dilepton sources in nucleus collisions at this energy regime?

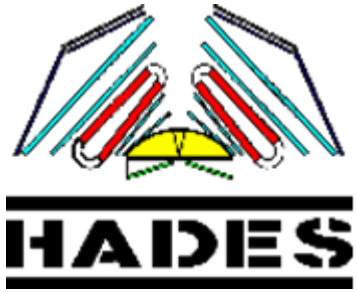
Summary

1. First measurement of dilepton production in QF np
2. np/pp: strong isospin dependence of the pair yield
3. np data can't be described by conventional cocktail
4. Experimental cocktail saturate C+C data

Outlook:

1. Extracting additional sources:

   np bremsstrahlung, resonance contribution
2. Differential analysis with Wall



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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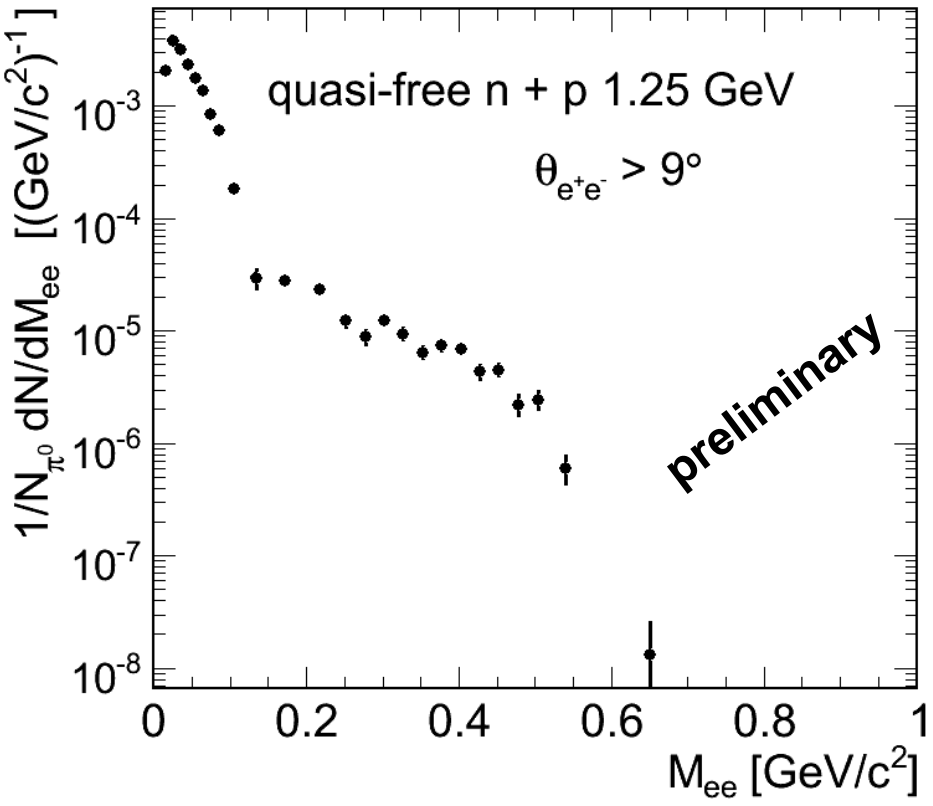
Additional slides

QF np: efficiency corrected spectra



Efficiency correction
based on apr06 pp data

Minimum efficiency
cut applied: 5% for single leg

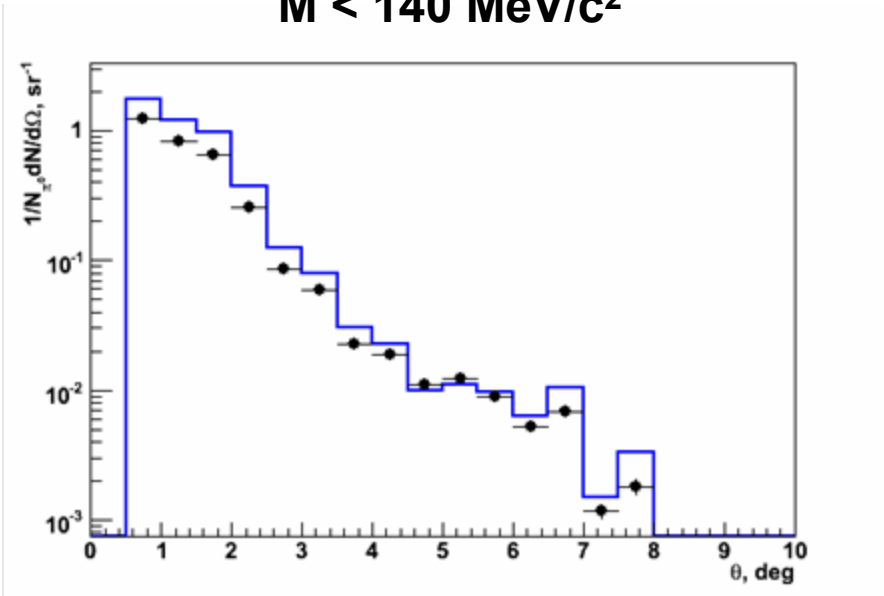
F_LVL2 = 0.85
F_FW = 0.84

Systematic error from Wall: < 10%

1. **registration efficiency**
2. **time resolution**

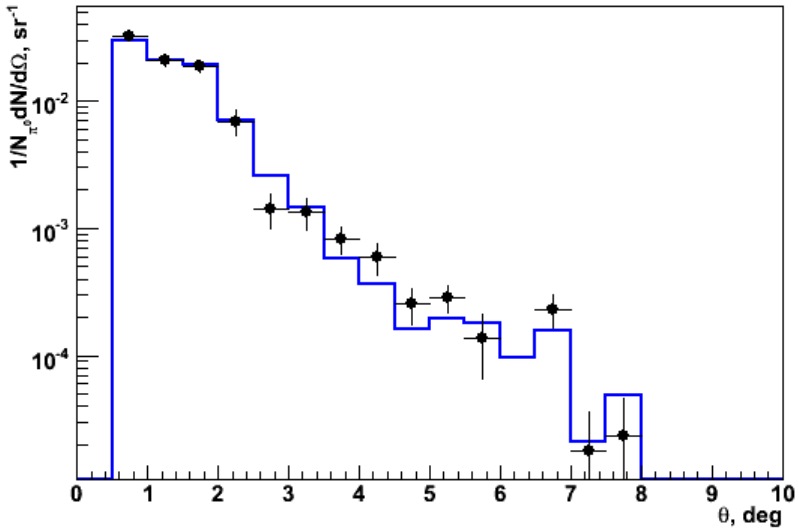
Angular distributions: comparison with PLUTO

M < 140 MeV/c²



Note: absolute normalization!

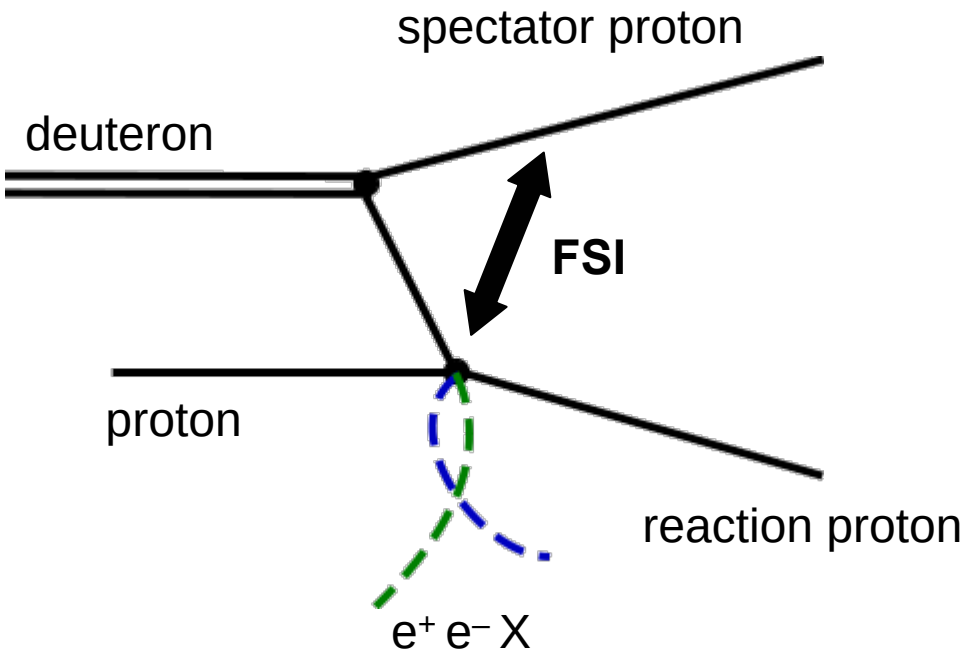
M > 140 MeV/c²

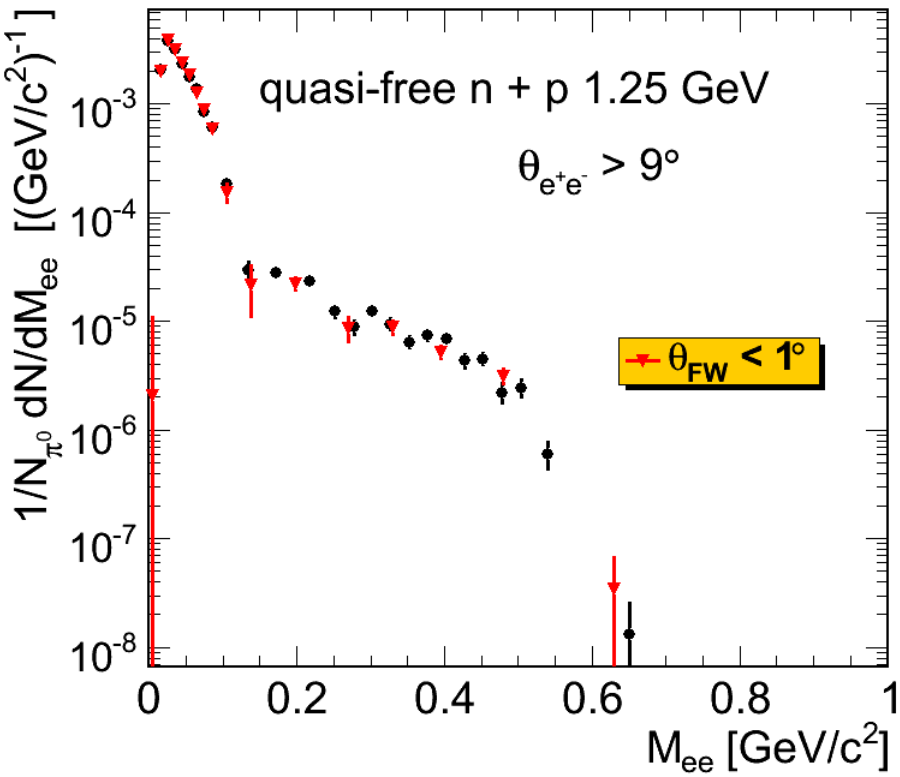


Scaling factor for massive pairs

Spectator tagging is under control

Correlation with Wall: II. Polar angle

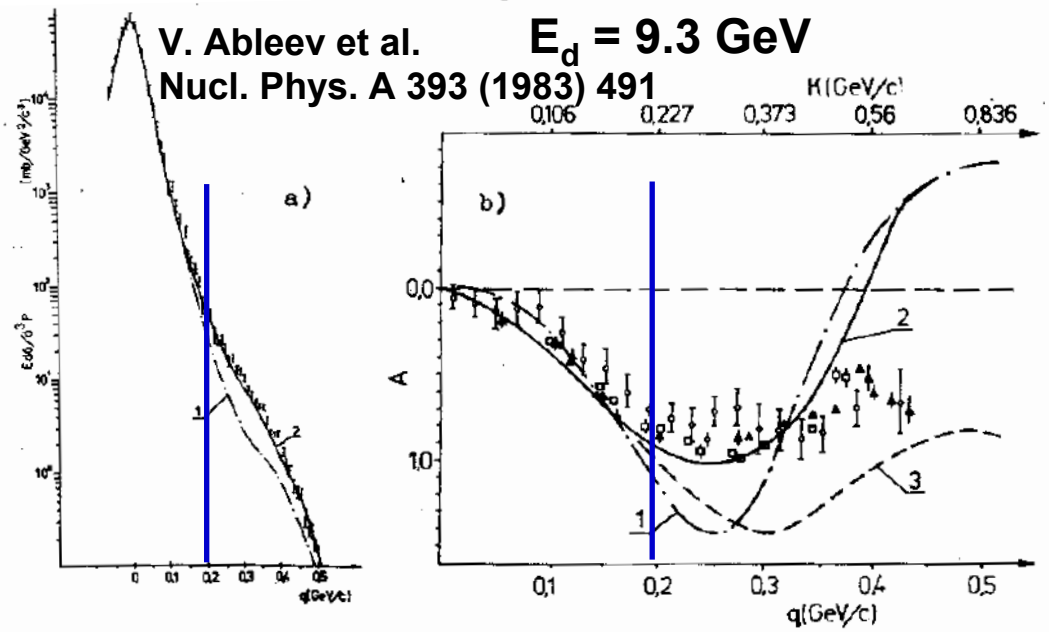




Spectra measured at very small FW angles shows same pair excess!

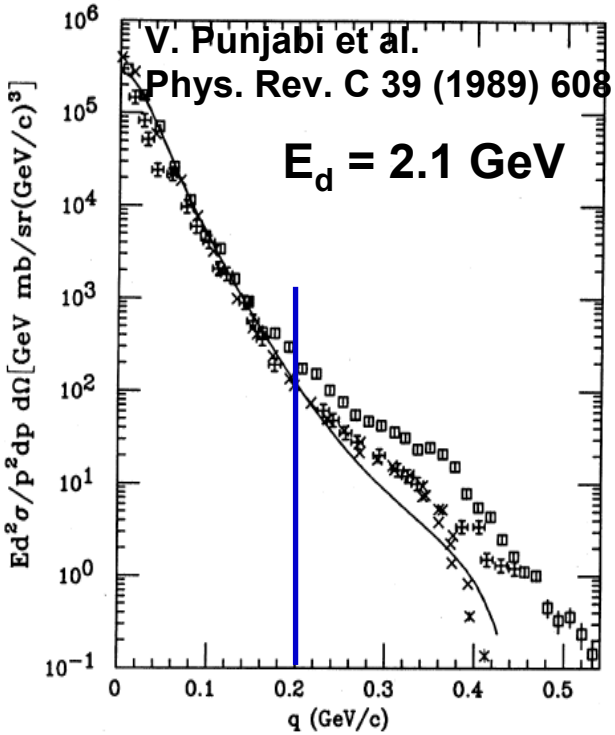
Experimental tests of IA

V. Ableev et al. E_d = 9.3 GeV
Nucl. Phys. A 393 (1983) 491

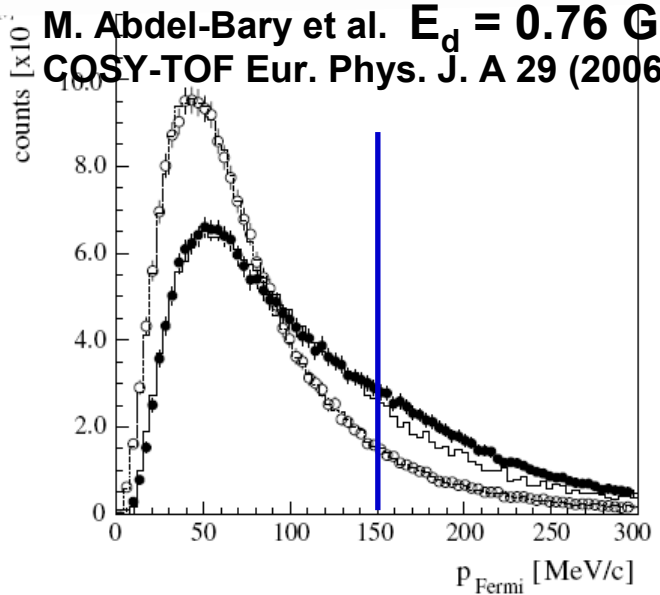


V. Punjabi et al.
Phys. Rev. C 39 (1989) 608

E_d = 2.1 GeV



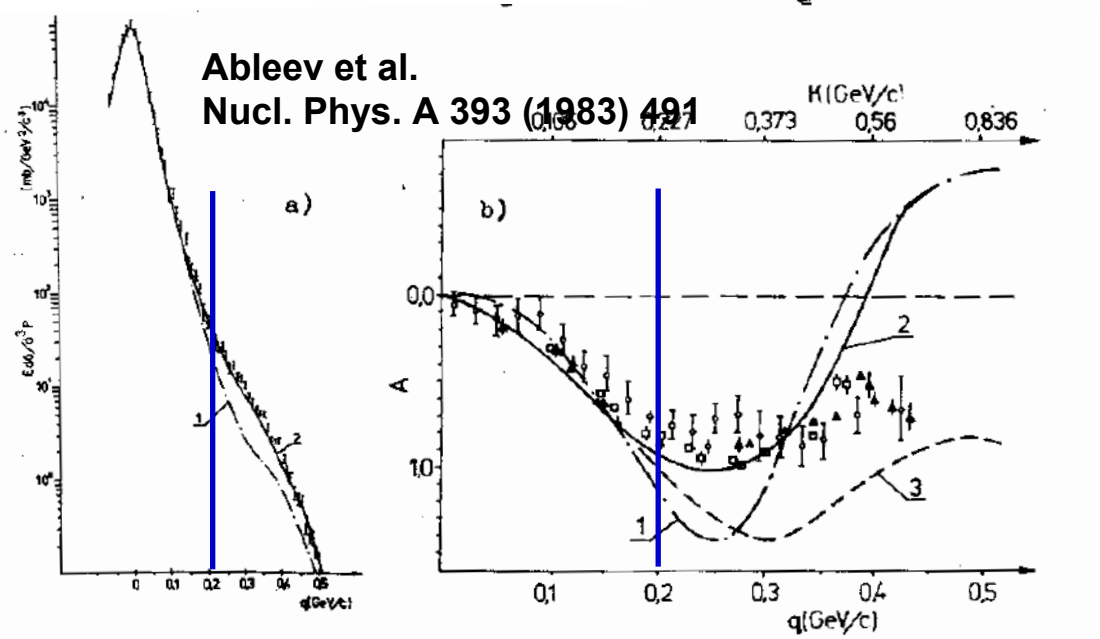
M. Abdel-Bary et al. E_d = 0.76 GeV
COSY-TOF Eur. Phys. J. A 29 (2006) 353

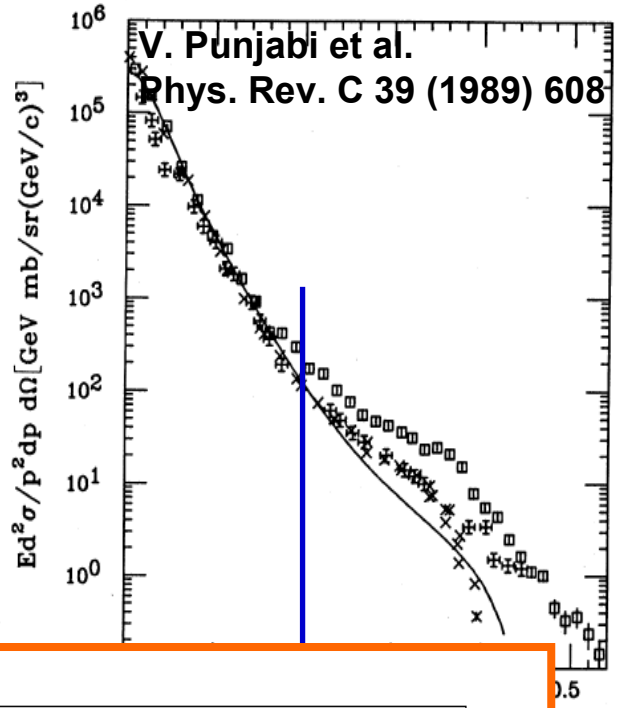


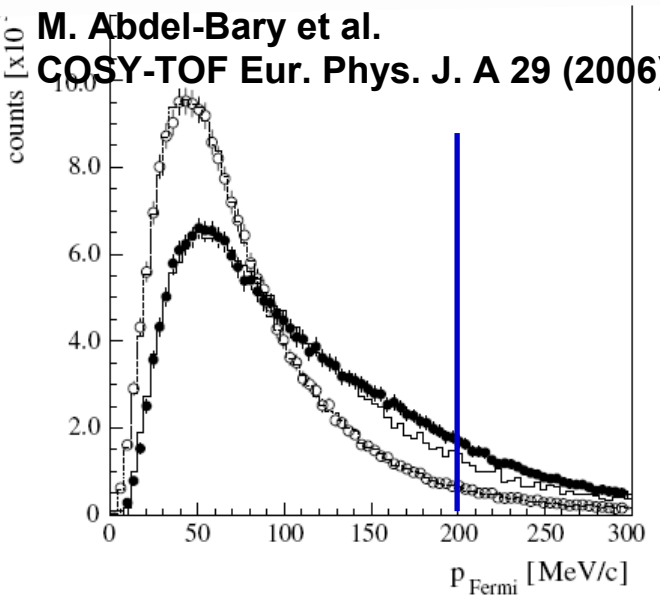
IA works fine up to 200 MeV/c

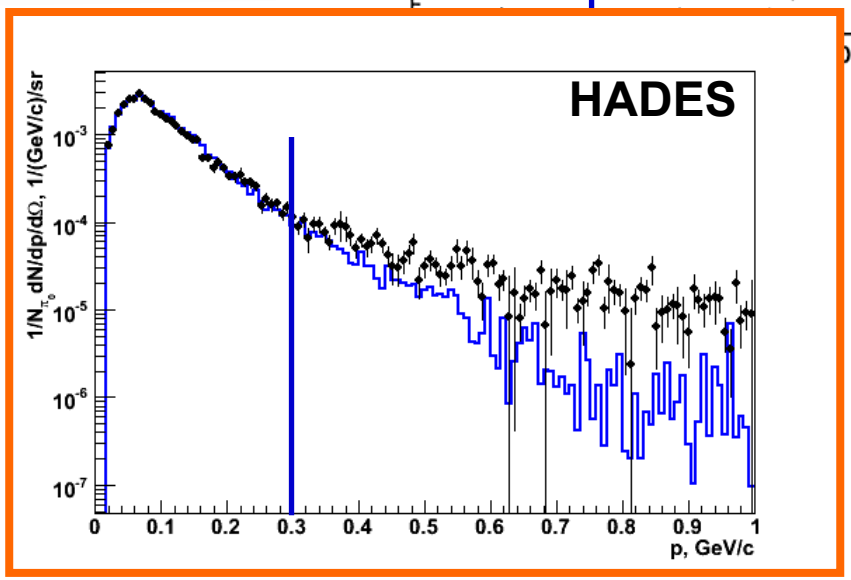
Above 200 MeV/c:
pion exchange, 6q contribution, etc.

Experimental tests of IA: HADES data



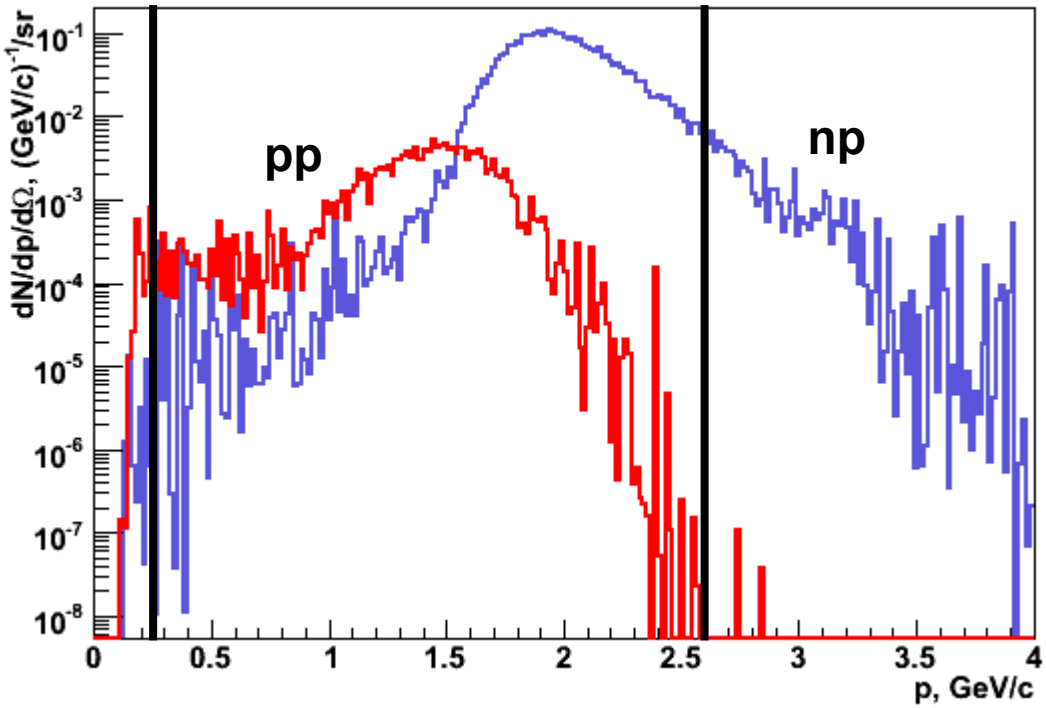






np/pp channels separation

PLUTO proton momentum distributions from np and pp channels (within Wall acceptance, smeared by time resolution)

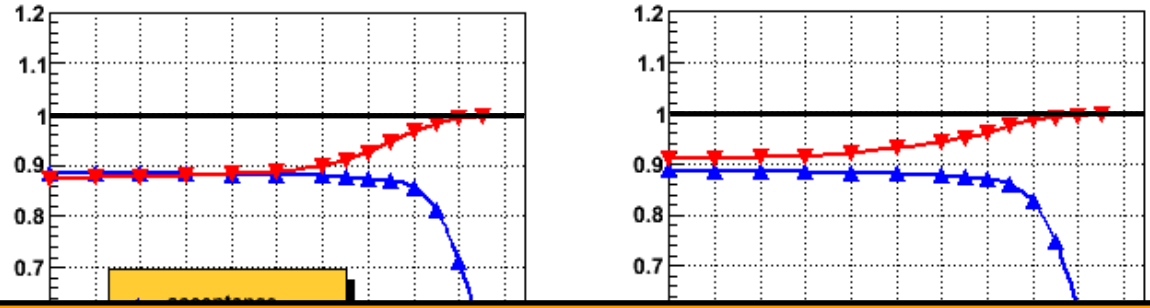


Selection of optimal momentum window to purify np

Acceptance to np/pp reactions and purity of resulting spectra

M < 140 | M > 140

np



For 1.6 < p < 2.6 GeV/c simulation gives:

np acceptance: 84%

np share in the cocktail: 97%

pp contamination: less than 2% for M > 140 GeV/c²

pp