10th International Workshop on Meson Production, Properties and Interaction, 6-10 June, Kraków, Poland

Dielectron measurements in NN interactions at a beam energy of 1.25 GeV with HADES

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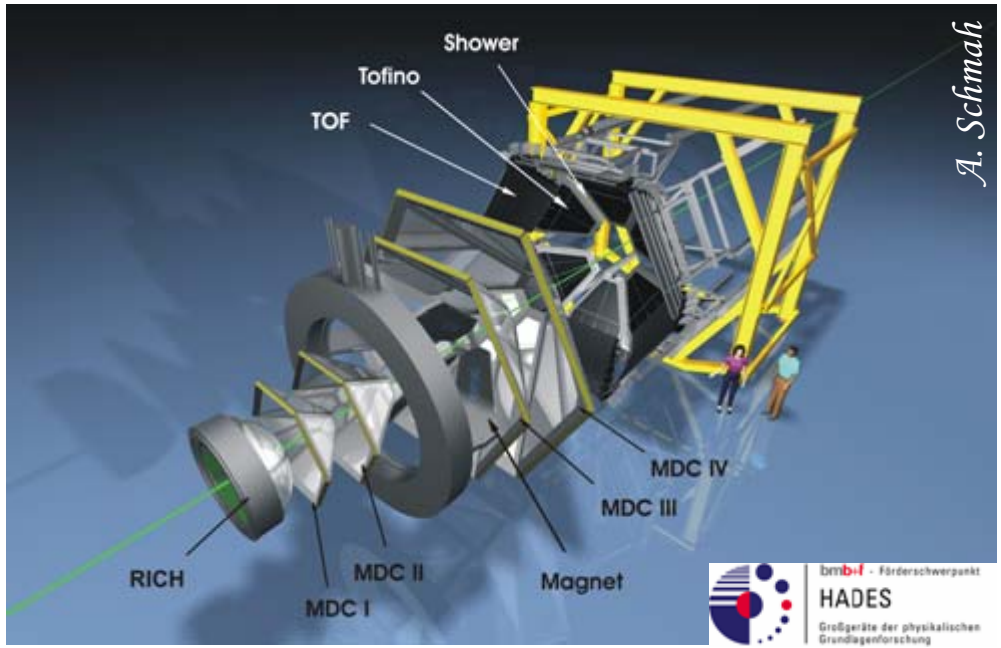
for the HADES collaboration

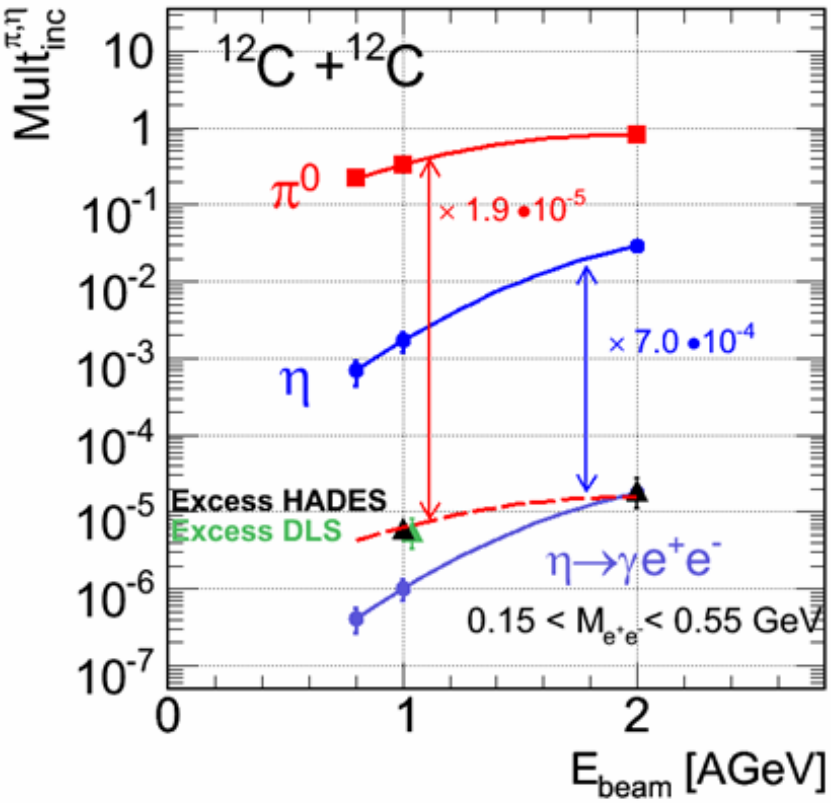
Outline

- Motivation
- The HADES spectrometer
- Data analysis
- Results np / pp at 1.25 GeV
- Summary



Motivation

Excitation function of the multiplicity of excess pairs (triangles) in the mass range $0.15 < M_{ee}/GeV/c^2 < 0.55$ in collisions compared to light hadron production



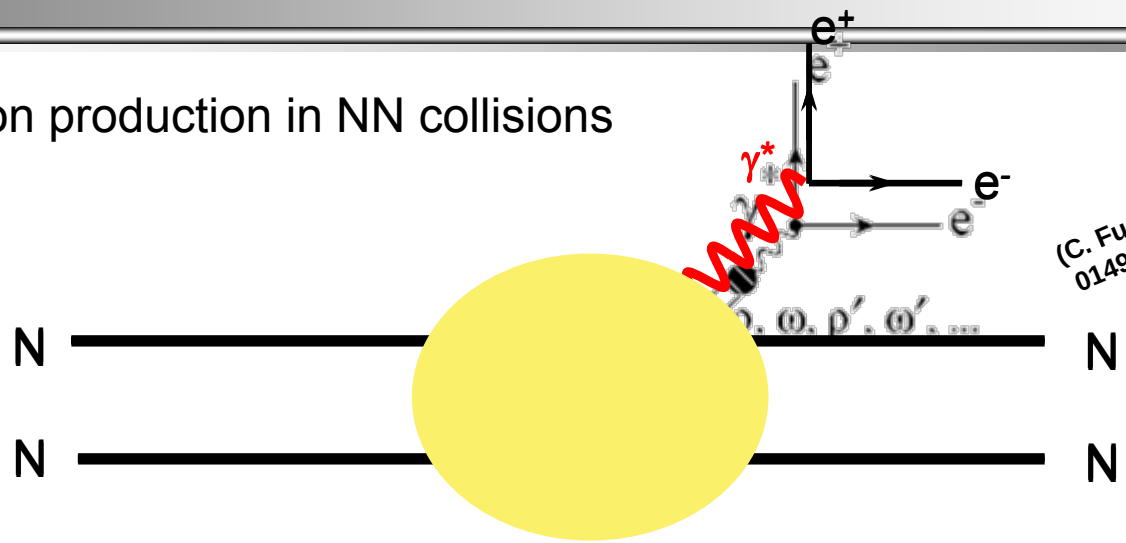
- Measured pair excess in CC scales with beam energy as pion production not like η production!

→ at SIS energies effectively all pions come from resonance decay

Need for a quantitative understanding of elementary processes

Elementary collisions with HADES

Virtual photon production in NN collisions



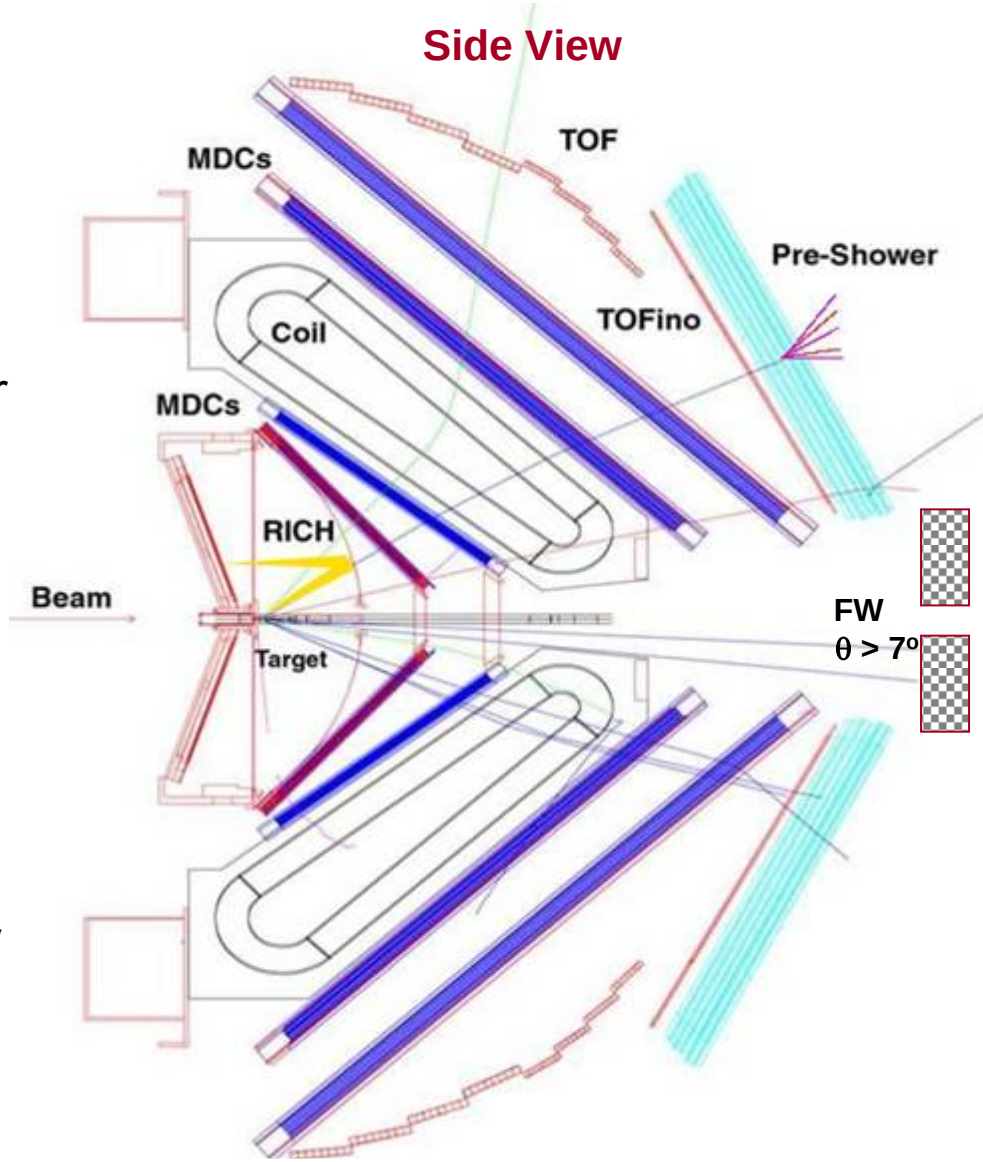
Primary goal of HADES elementary (pp/dp) programme is to establish the cocktail of "free" hadron decays for SIS energies (reference for HI collisions)

Strategy: Study of e^+e^- sources in pp and pn at η production threshold

- Measure $pp \rightarrow \Delta^+ p \rightarrow ppe^+e^-$ (fix Δ^+ assuming σ_{brems} (pp) is small)
  - inclusive: comparison to HI measurement
  - exclusive: select Δ^+ production by appropriate cut on pp missing mass $pp \rightarrow p\,\Delta^+ \rightarrow ppe^+e^-$ and $pp \rightarrow p\Delta^+ \rightarrow pp\pi^0$
- Measure $pn \rightarrow e^+e^-X$ with dp reactions to determine σ_{brems} (pn) (Fermi momentum?)

HADES experiment at SIS18, GSI

- **Geometry**
  - Full azimuth, polar angles 18° - 85°
  - Pair acceptance ≈ 0.35
- **Particle identification**
  - RICH, TOF/TOFino, Pre-Shower Detector, FW hodoscope: added 2007
- **Low-mass tracking**
  - Super conducting toroid magnet
  - Multi-wire drift chamber (MDC), single cell resolution ≈ 100 μm
- **Trigger**
  - LVL1: charge particle multiplicity
  - LVL2: single electron trigger

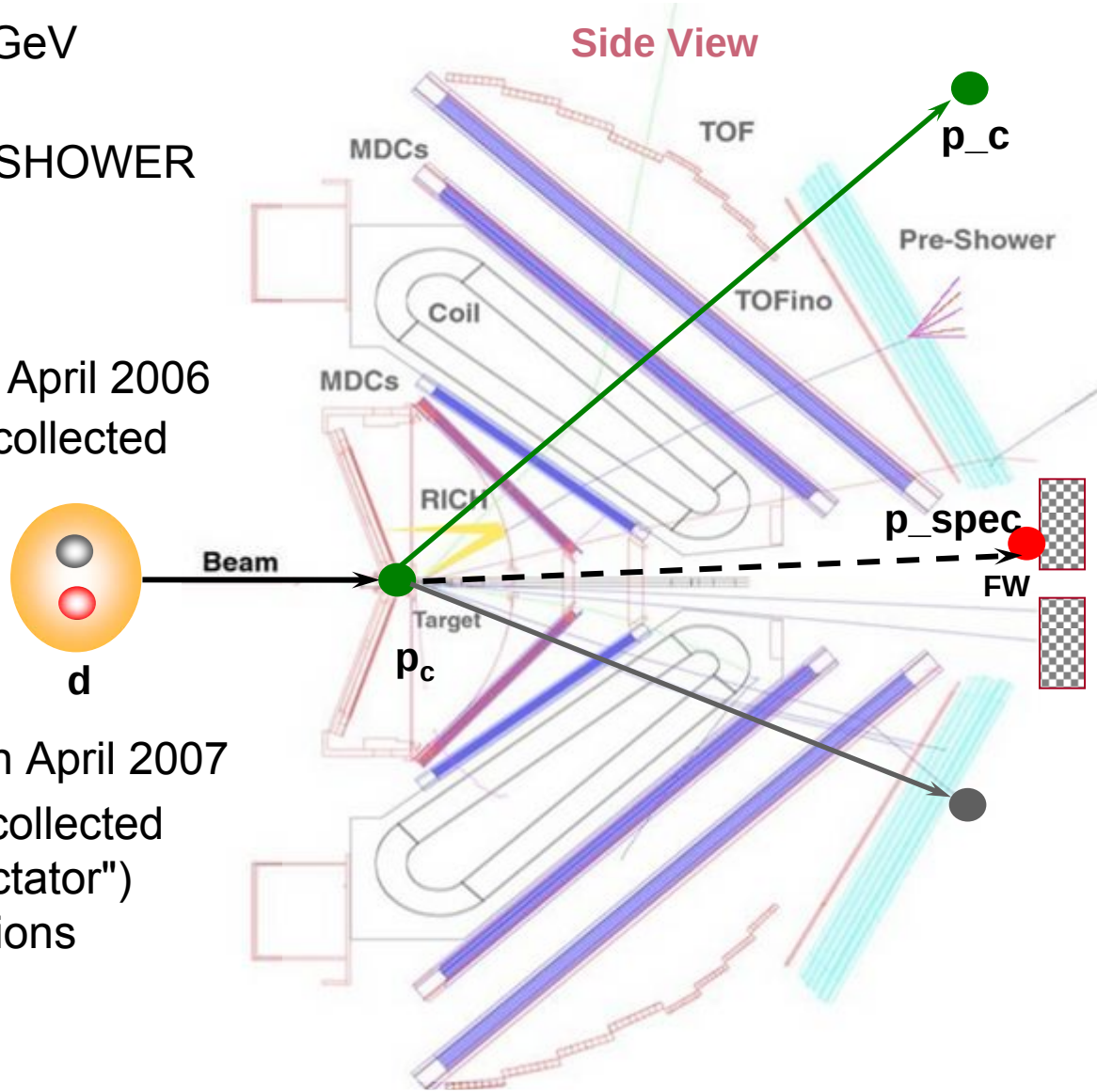


HADES experiment at SIS18, GSI

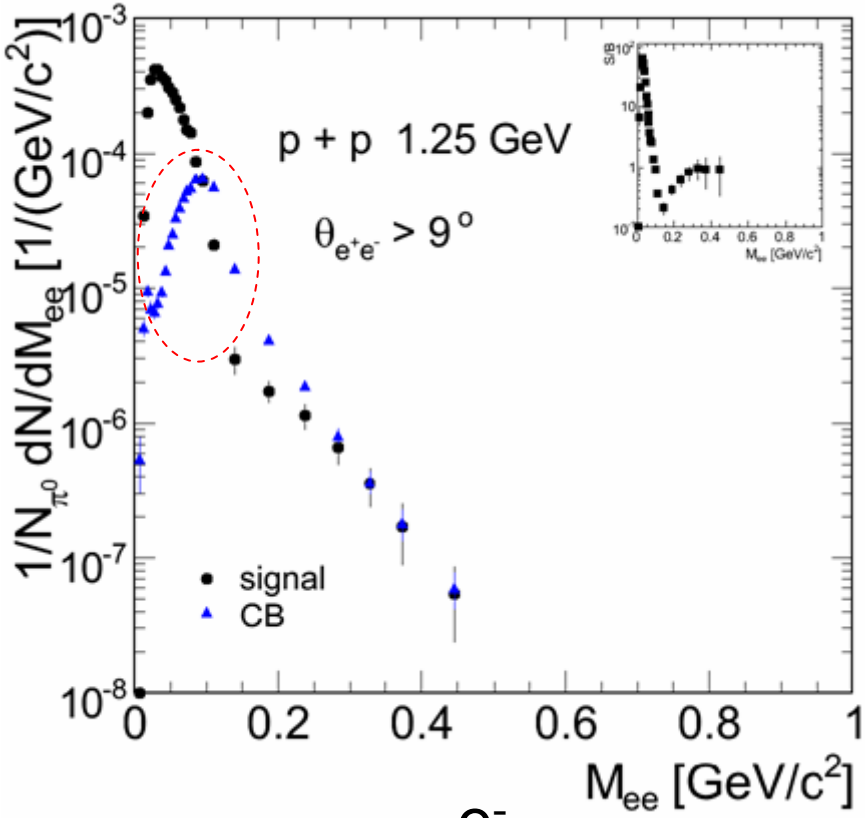
- Beam energy E_{beam} = 1.25 GeV
- LH2 target
- RICH, MDC+magnet, TOF/SHOWER

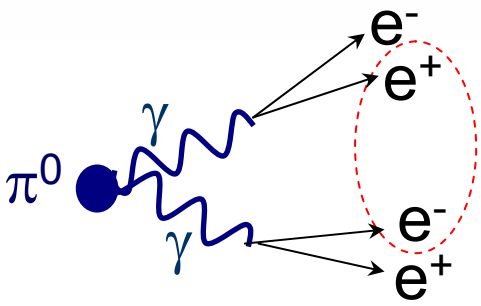
- **p+p:**
  - one week of running in April 2006
  - ~2.6*10^9 LVL1 events collected (MUL=>3 trigger)

- **d+p:**
  - two weeks of running in April 2007
  - ~4.8·10^9 LVL1 events collected (MUL=>2 && FW "p spectator") tag on np -> e^+e^- X reactions



Experimental data (raw data)





Correlated background

1st step

- Subtraction of combinatorial background
  - same event like-sign pairs ($N_{--}+N_{++}$)

2nd step

- Efficiency correction
- Normalisation

$$N_{\pi^0} = \frac{\sigma_{\pi^0}}{\sigma_{elastic}} \cdot N^{elastic}$$

$N^{elastic}$ - *total number of elastic scattering in* 4π

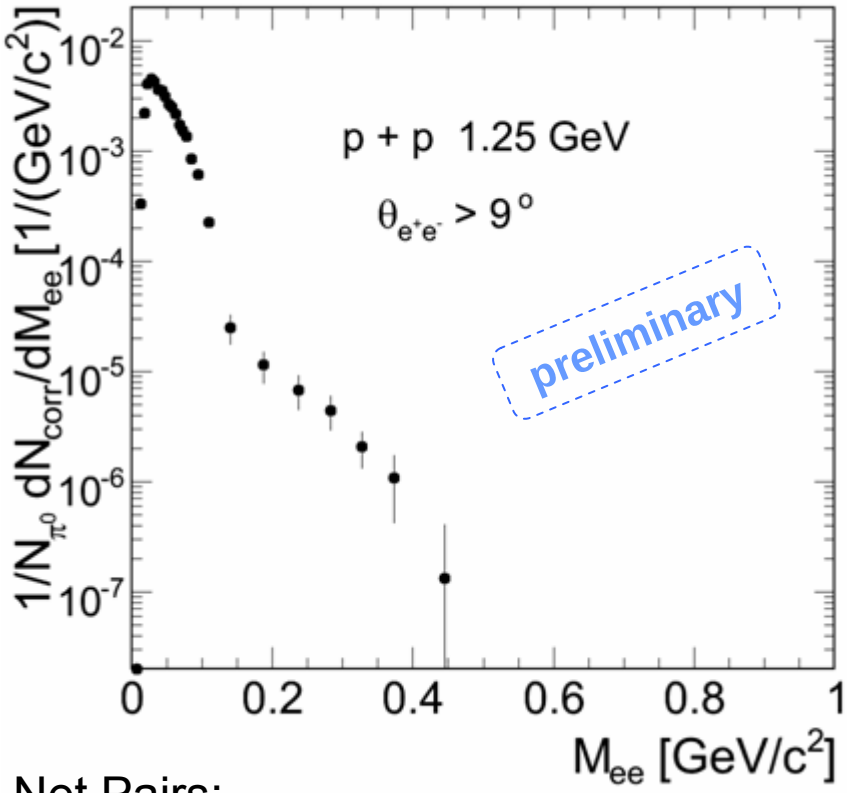
$N^{elastic} = N^{elastic}_{HADES} * F$

F – efficiency and trigger correction factor

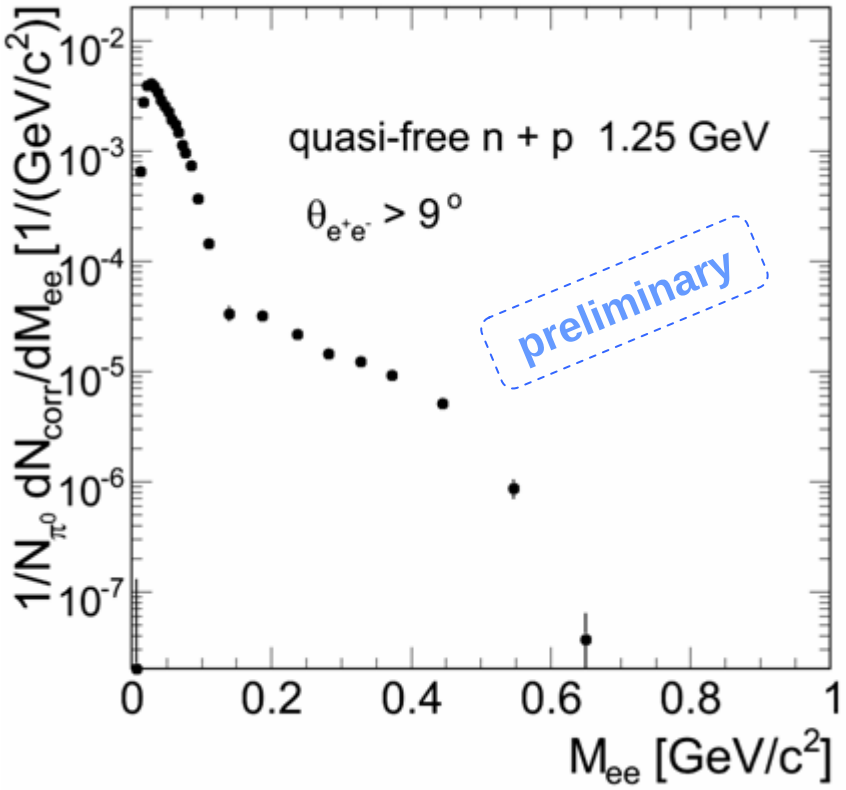
$N^{elastic}_{HADES}$ *= number of elastic events in HADES*

Efficiency corrected spectra

pp data



np data



Net Pairs:

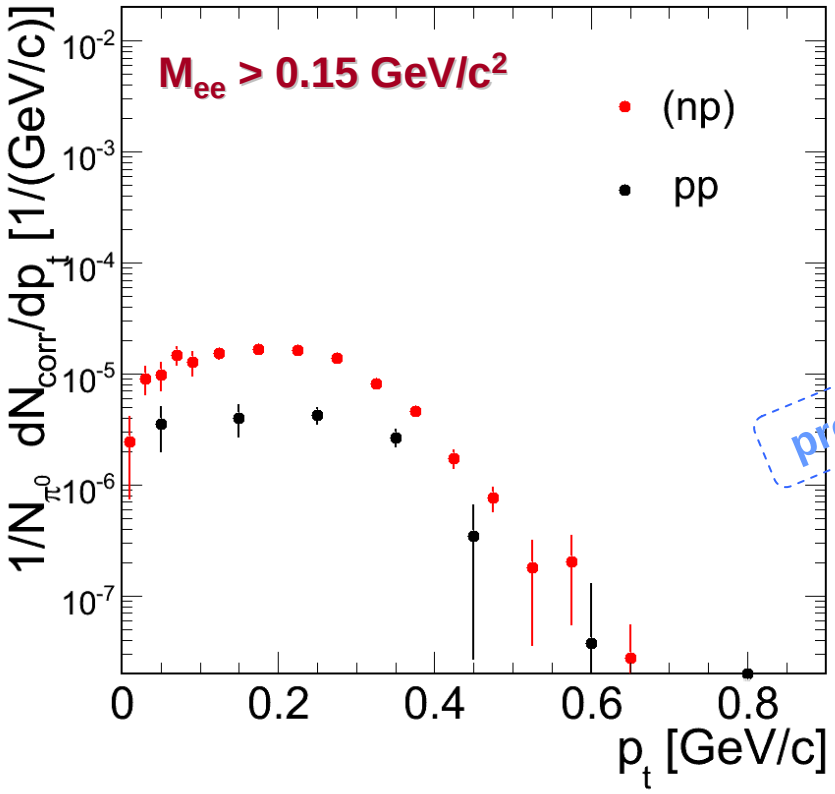
pp data : M_{ee} < 150 MeV/c^2: 37156 counts, M_{ee} ≥ 150 MeV/c^2: 418 counts

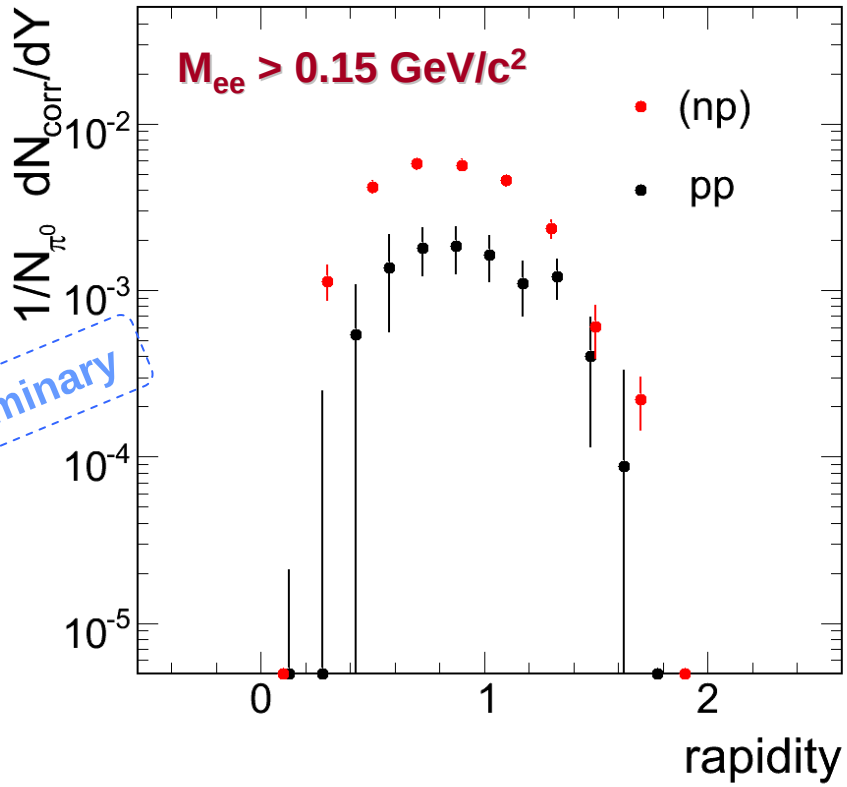
np data : M_{ee} < 150 MeV/c^2: 61472 counts, M_{ee} ≥ 150 MeV/c^2: 2207 counts

Total systematic error is about 28 %

- efficiency correction ~20%
- normalization to π^0 ~20%

Phase space coverage

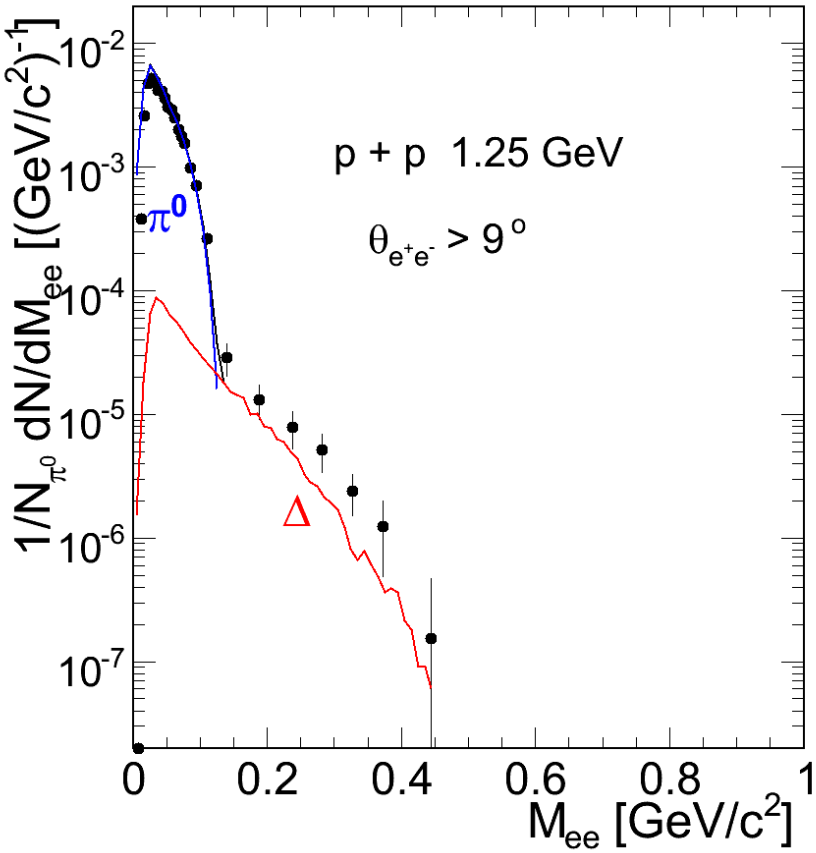


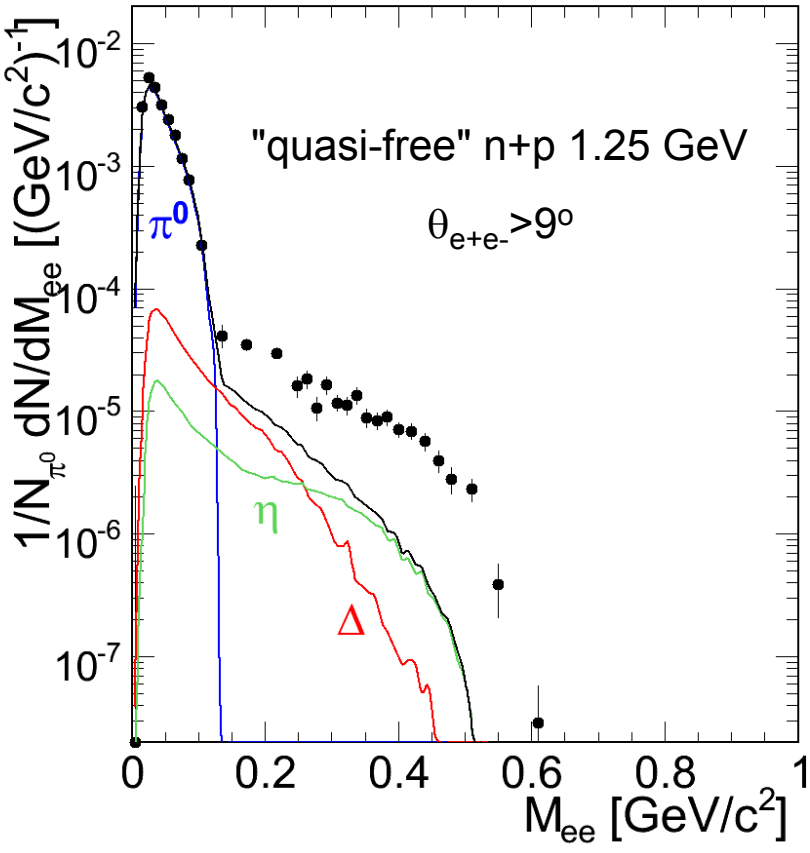


preliminary

- n+p p_t spectrum is more soft!
- recent calculation on di-electron bremsstrahlung in intermediate-energy pn collisions [*L.P. Kaptari and B. Kämpfer Nucl. Phys. A 764 (2006)*] show an enhancement of NN-Bremss. in the pn case
- **does enhanced NN-Bremss. explain measured np data?**

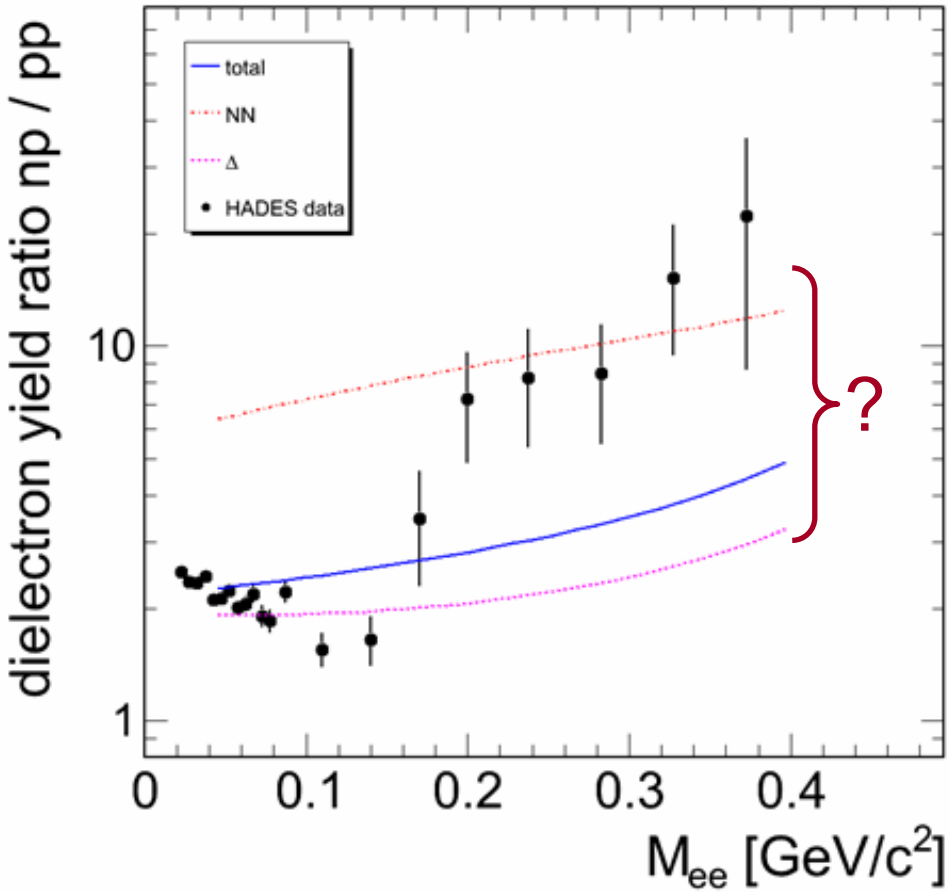
pp and np data compared to model (PLUTO – known sources)





- model calculations: Δ, η (constrained by CELSIUS/WASA data)
- large excess in n+p reactions (~ factor 5) above Δ, η
- **no "quasielastic" Bremsstrahlung included!!!**

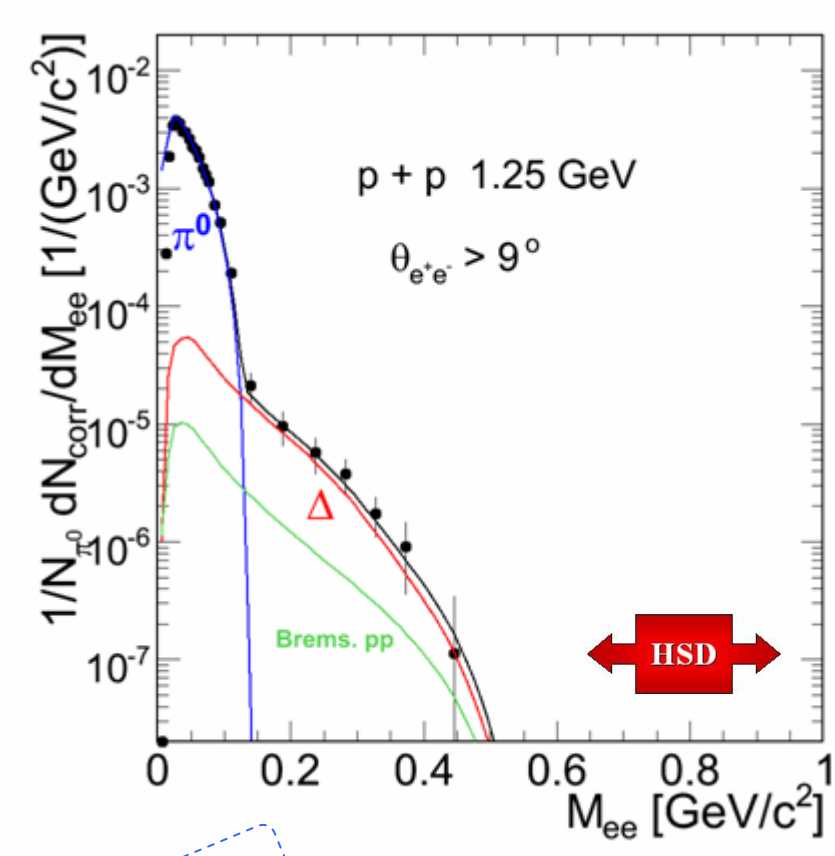
Dielectron yield ratio pn / pp

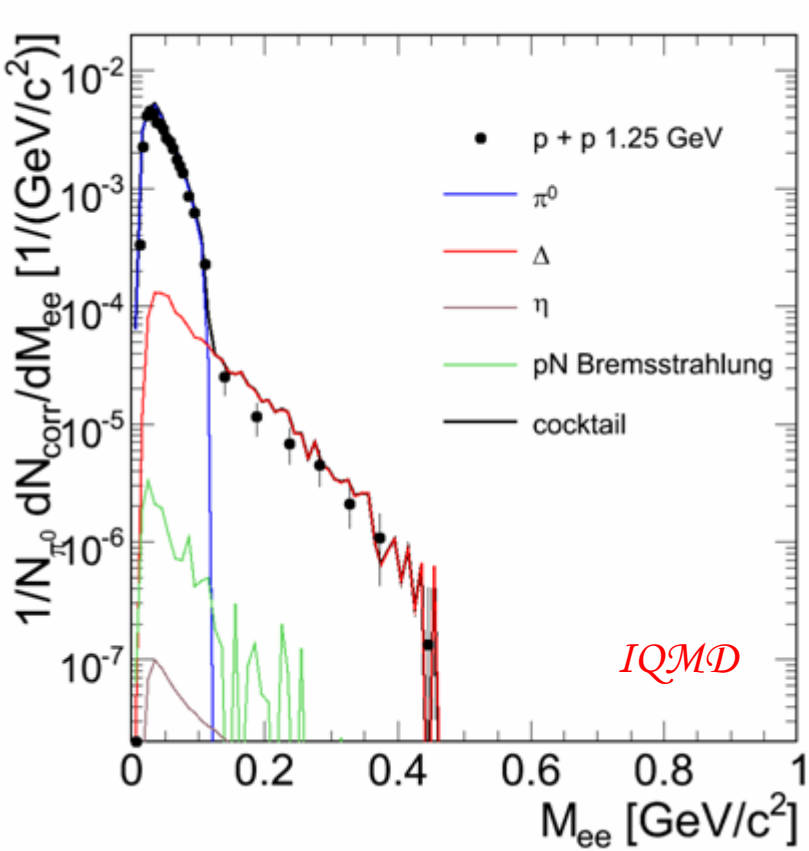


preliminary

- Efficiency and acceptance corrected data, normalized to the number of pp elastic events
- π^0 yield in p+n larger by factor ~2 as predicted by resonance model!
- *NN* Bremstrahlung model does not explain np data

Efficiency and acceptance corrected *pp* data, comparison to transport model calculation

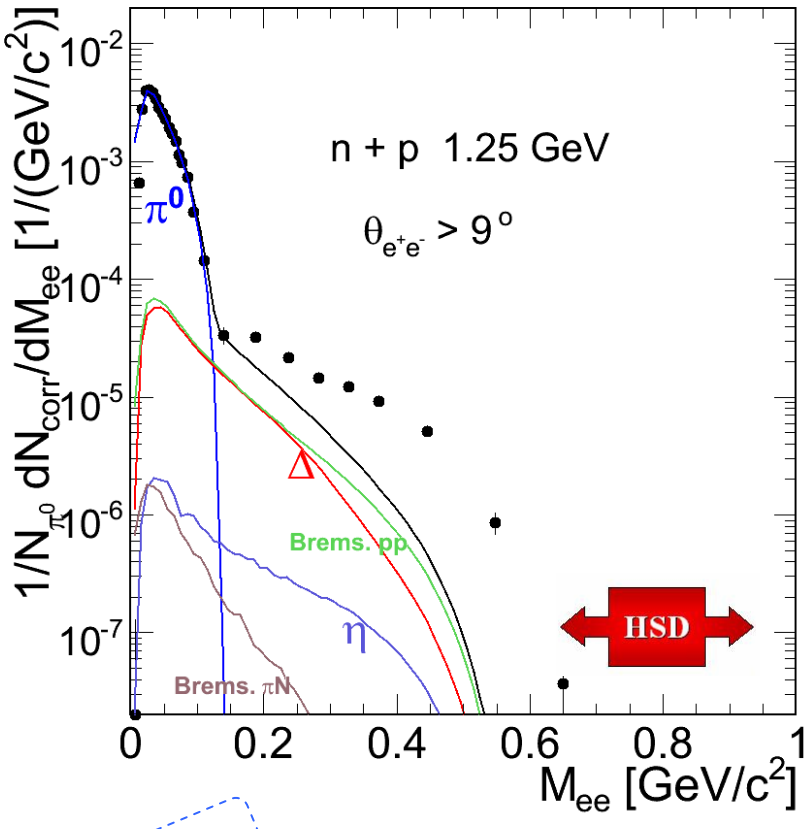


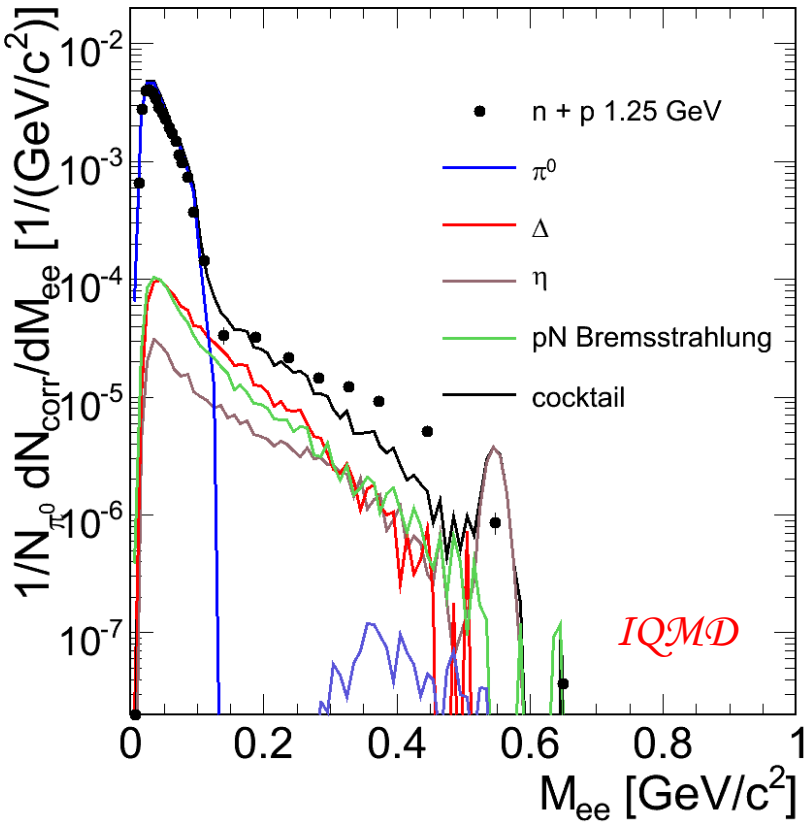


preliminary

$\Delta \rightarrow e^+e^-N$ seems to explain e^+e^- yield in p+p at 1.25 GeV

Efficiency and acceptance corrected *np* data, comparison to transport model calculation



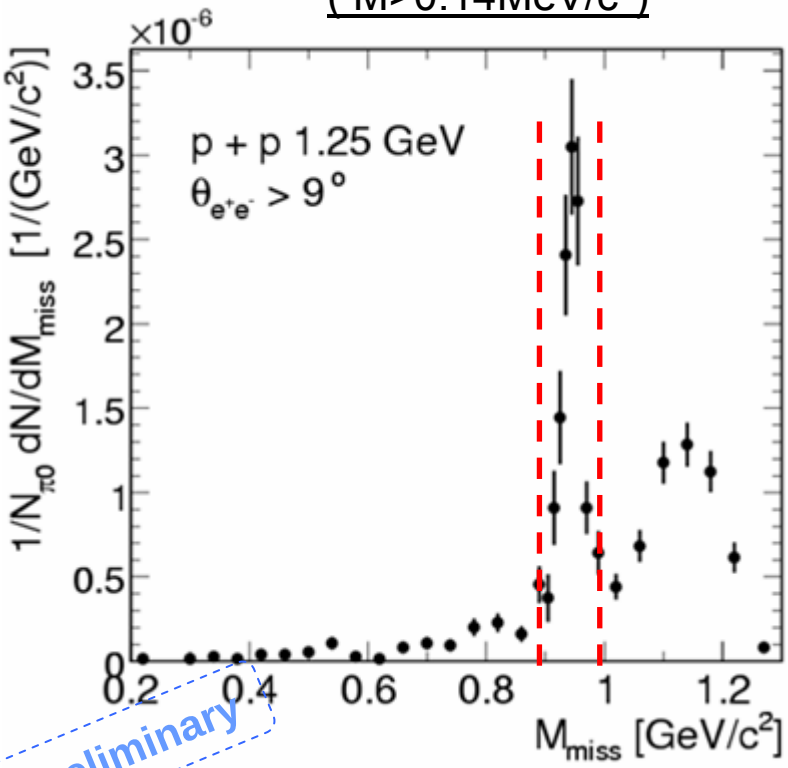


preliminary

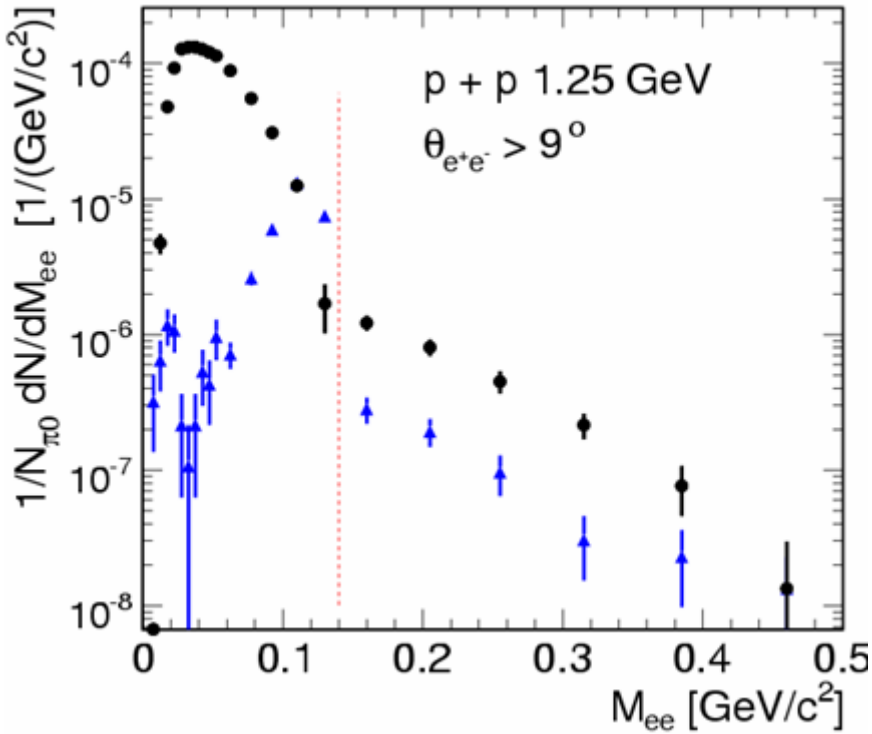
Data are not explained satisfactorily!

Exclusive e^+e^- spectrum

Missing (proton) mass spectrum
(M>0.14MeV/c^2)

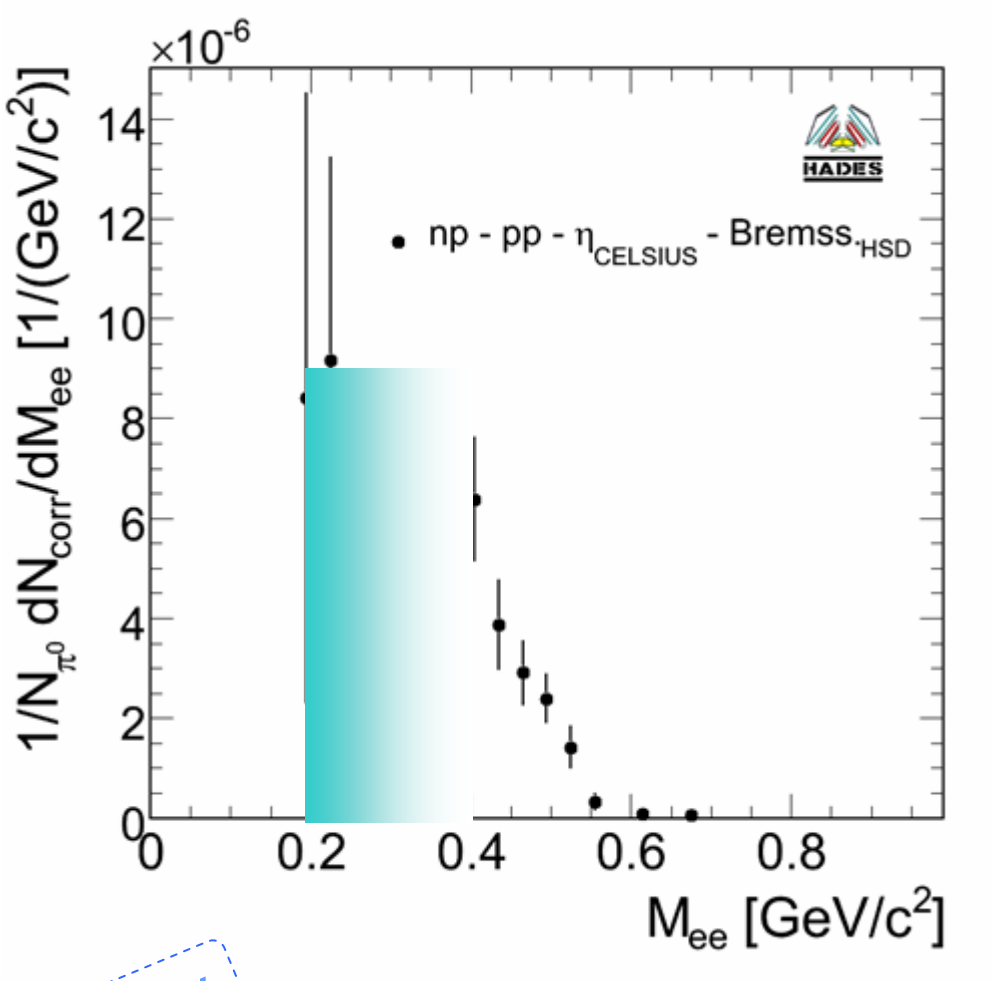


Invariant mass spectrum of e^+e^-



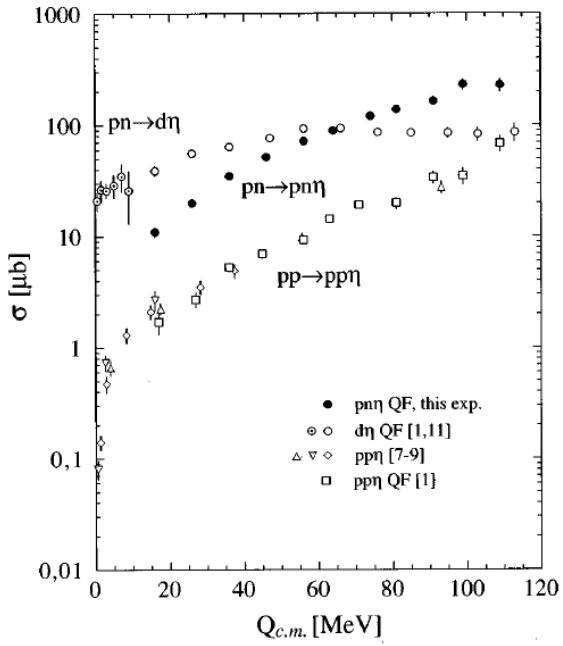
- Identification of the final state vs. less acceptance (~factor 2 less compare to inclusive analysis)
- Much lower background
- Allows determination of the ($\Delta \rightarrow pe^+e^-$) branching ratio and, with sufficient statistics, of the electromagnetic transition formfactor

Identification of the excess



preliminary

1. $\sigma(pp \rightarrow pp\eta) \sim 0$

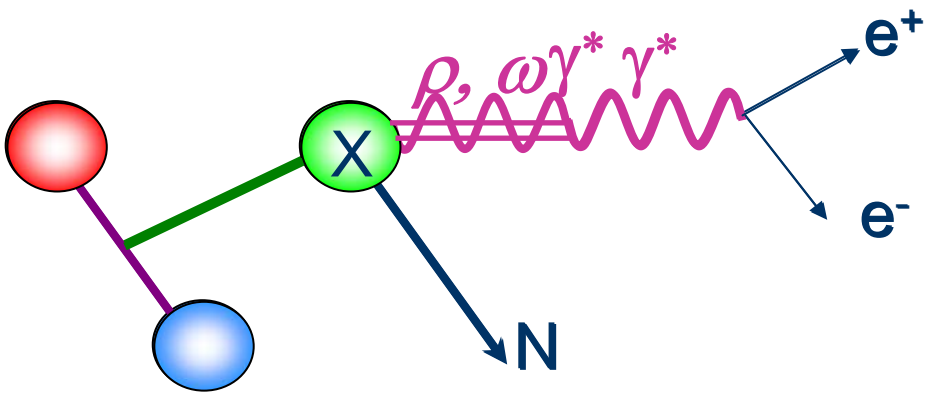


[Phys. Rev. C 58, 2667 - 2670 (1998), H. Calén et al., "Measurement of the quasifree pn→pnη reaction"]

2. $np_{Bremss.} - pp_{Bremss}$

[L.P. Kaptari, B. Kämpfer, Nucl. Phys. A 764 (2006)]

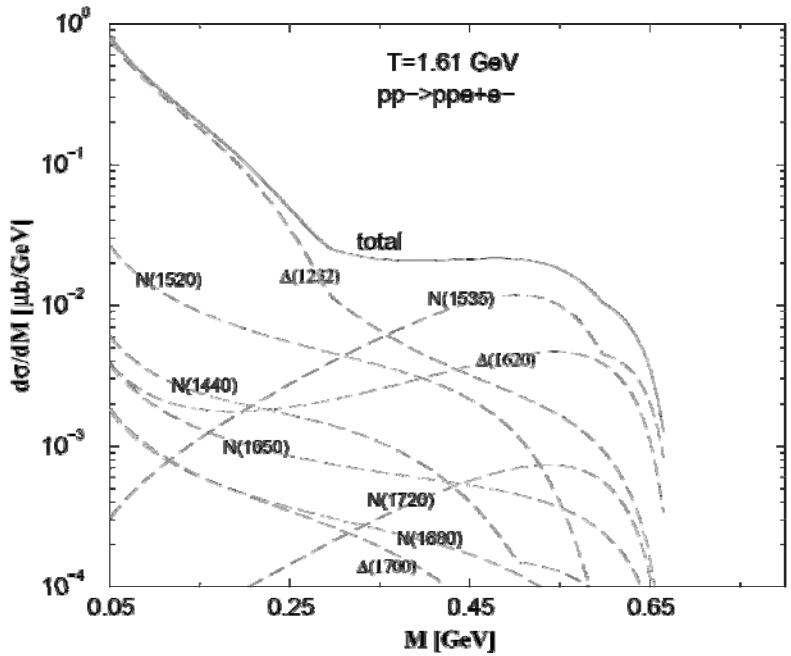
Resonance Dalitz decay



X=

Δ(1232)
N(1440) (ρ)
N(1520) (ρ)
N(1535) (η,ω)

The dilepton production cross sections $pp \rightarrow e^+e^-pp$ through the nucleon resonances R = Δ, N*, and Δ* at an kinetic proton energy of T = 1.61 GeV

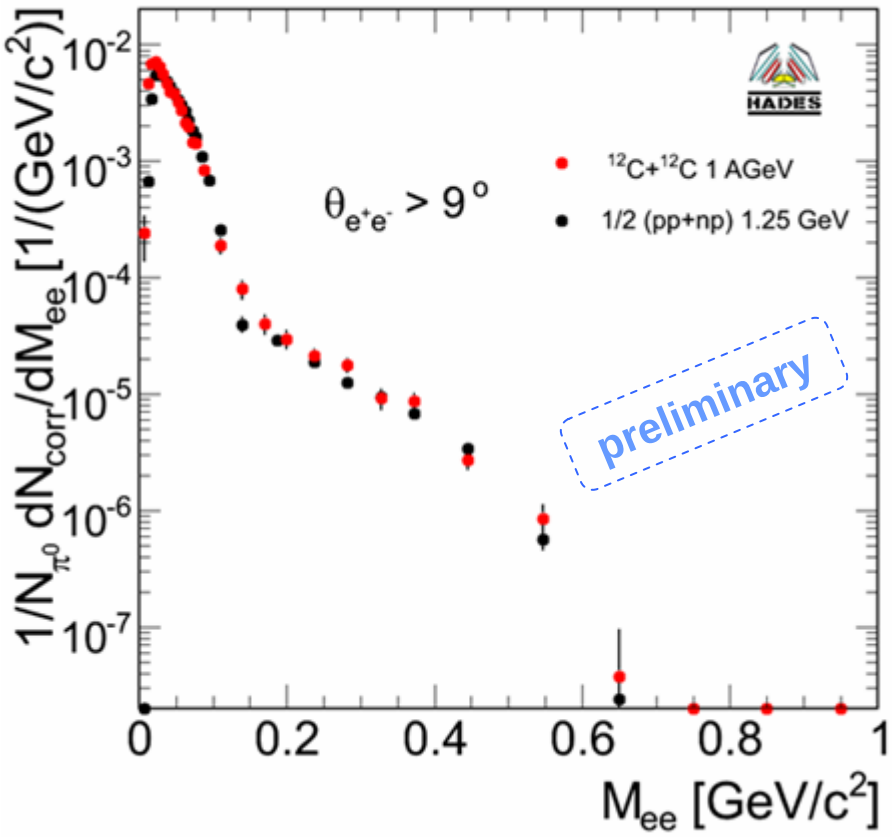


[Krivoruchenko et al., arXiv:nucl-th/0010056v2 14 Feb 2003]

Higher lying baryonic resonances fully contribute to the mass region below the vector meson pole mass due to off-shell propagation of intermediate VM!

Can comparisons between the CC, pp, and pd data shed light on the question of the excess?

Comparison of CC data to NN collisions



- Pair excess observed in CC data has been traced back to anomalous pair production in np collisions
- Dielectron yield in CC data reproduced by proper scaling of measured e^+e^- production in NN interactions

e^+e^- yield in C+C data underestimated theoretically because of insufficient treatment of electromagnetic transition formfactor!

"The most beautiful sea hasn't been crossed yet. And the most beautiful words I wanted to tell you I haven't said yet ..."

(Nazim Hikmet)

Sep. 2008	**p + A 3.5 GeV**		
2008/9	**Upgrade RPC, DAQ**		
2009		**Ni + Ni**	**Planned**
2010	**π + N, A**		
2011		**Au + Au**	
> 2011	**Hades goes FAIR (8 AGeV)**		

HADES 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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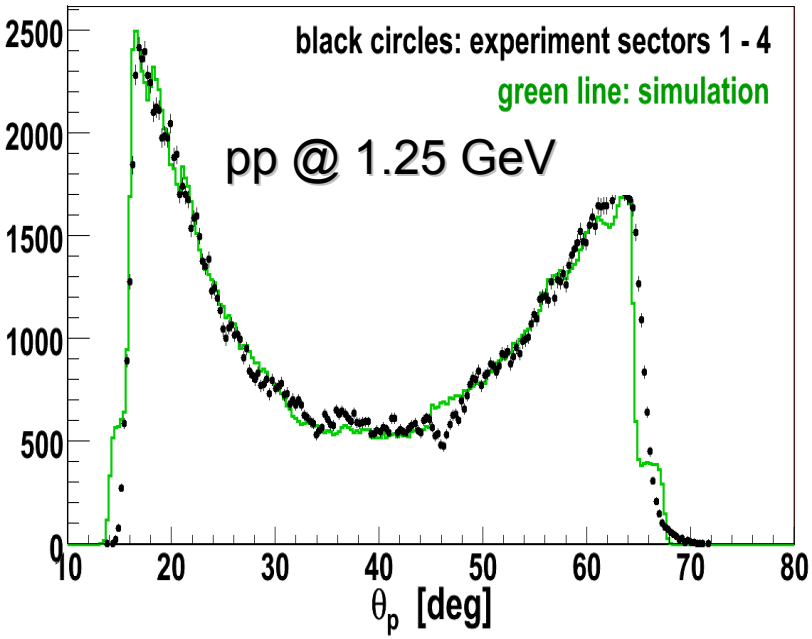
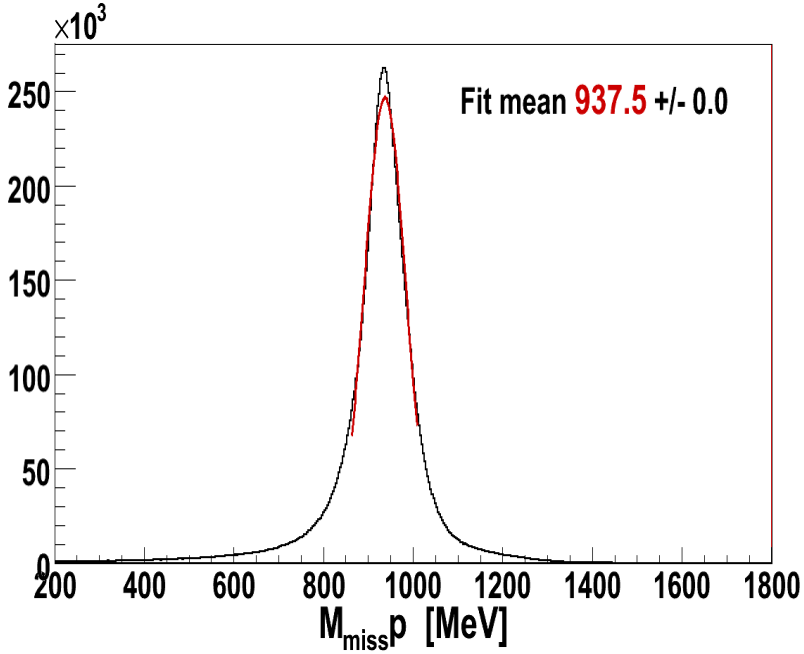
BONUS SLIDES

Normalization via pp elastic scattering



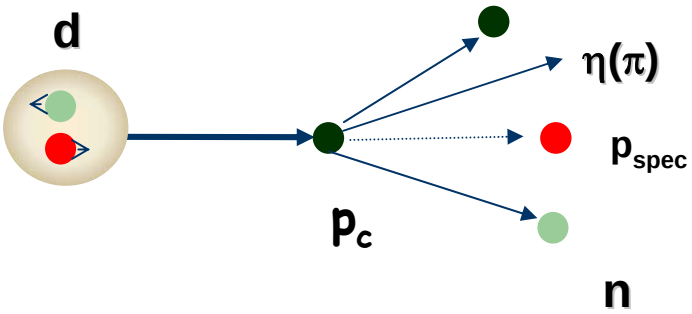


- Large acceptance (16% at 1.25 GeV), sys error in reconstruction ≤10%,
- sys. error of σ(elastic) = 21% @ 1.25 GeV

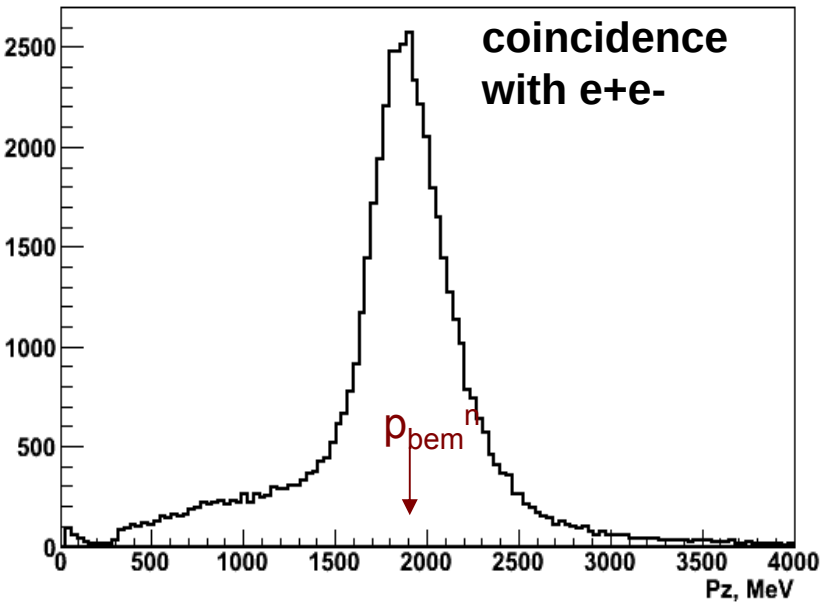
Tagging of quasi-free p+n reactions in d+p with FW

Forward Wall: 0.5^0- 7^0

86% of p+n selected by p_{spec} in FW

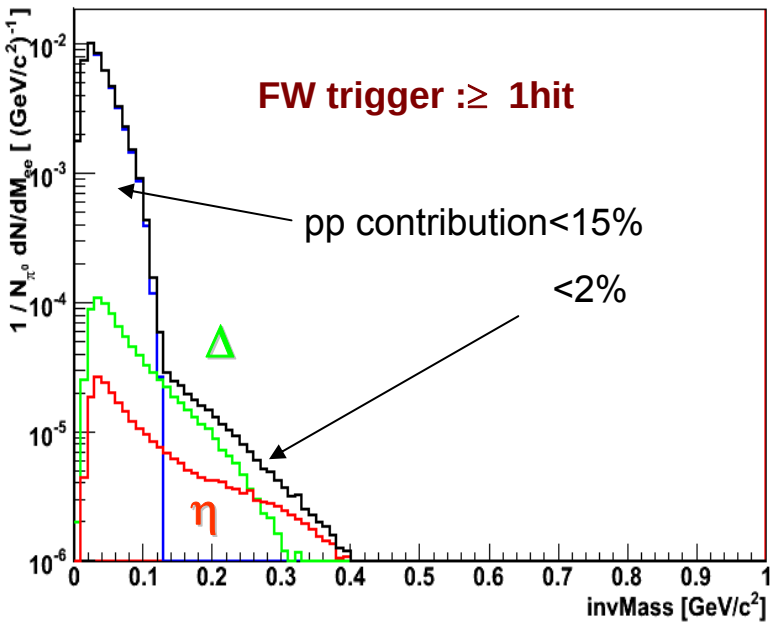


Spectator momentum distribution
TOF in FW

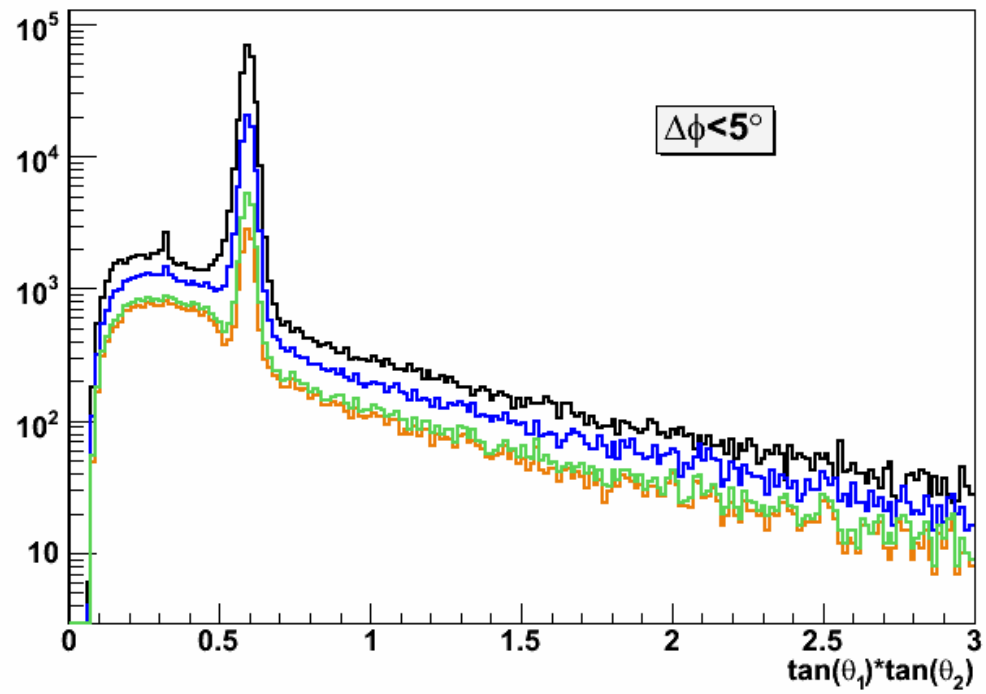


Expected signal: spectator model:

- η contribution from measured data:
- Celsius/WASA Calen et al.: Phys.Rev.C58(1998)2667, Phys.Rev.Lett 80(1998)2069,Phys.Rev.Lett.79(1997)2642
- fermi momentum distribution – Paris potential : COSY-TOF EPJ A 29, 353-361 (2006)



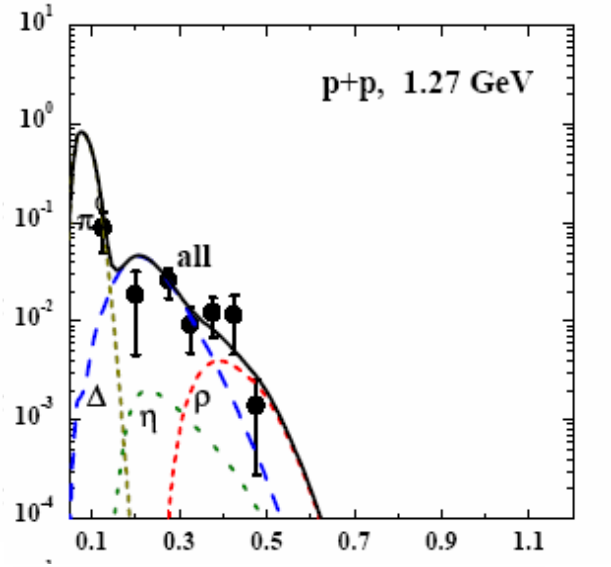
Suppression of pp-elastic with FW conditions and TAT spectra

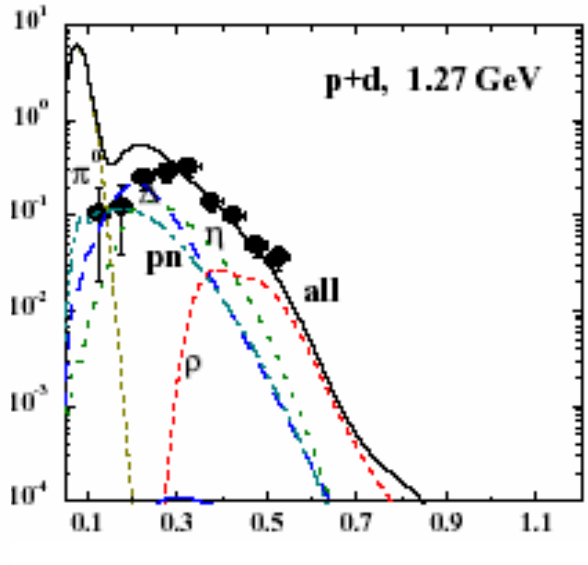


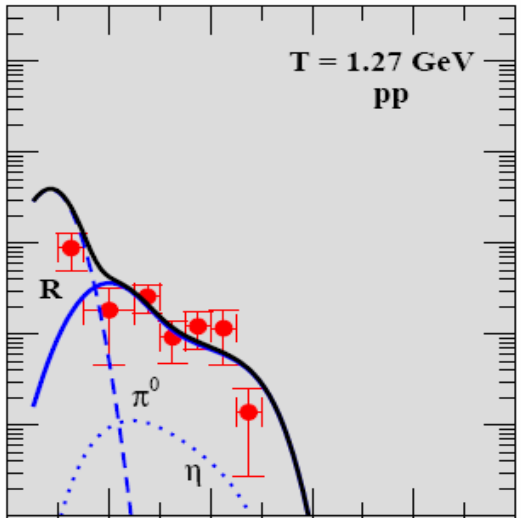
4 curves (from top to bottom):

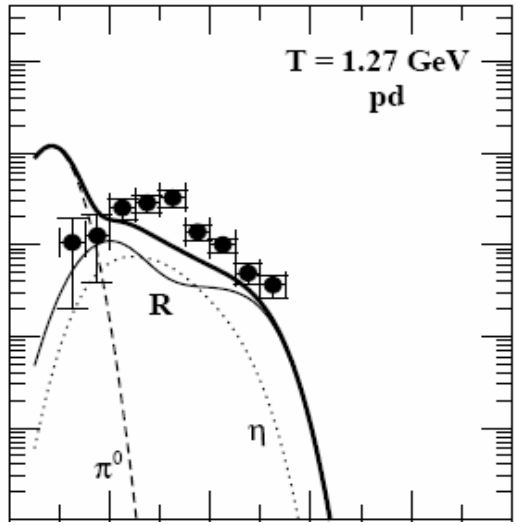
1. multFW == 0;
2. multFW == 1;
3. && 0 < TOF < 40;
4. && 30 < TAT < 120.

pp and dp from DLS









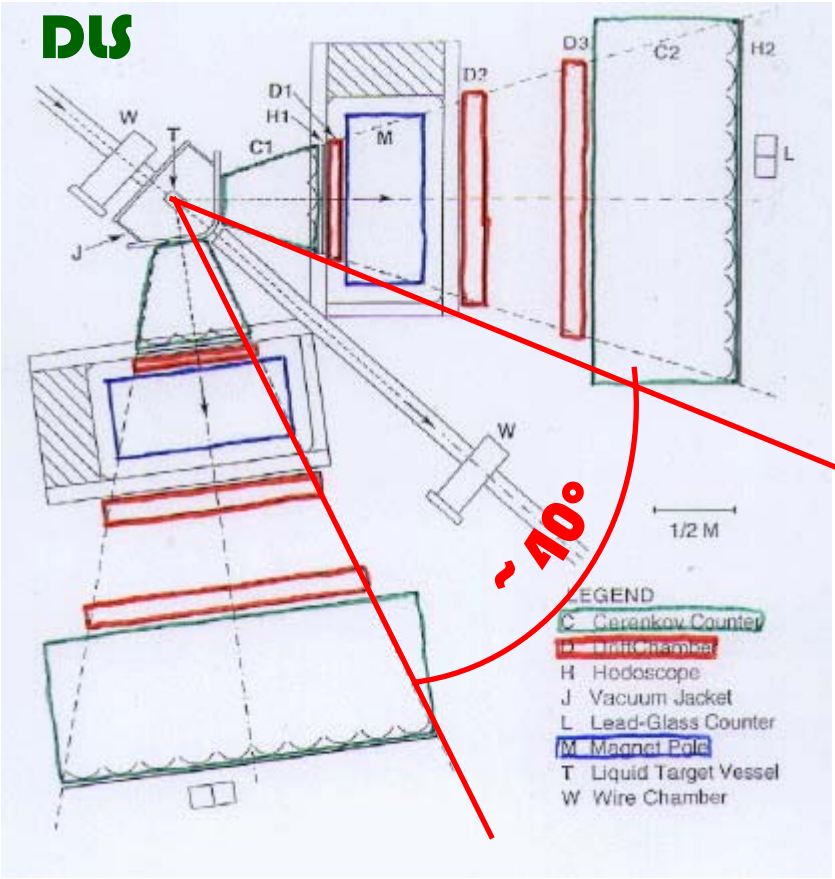
- Problems in description
  - Bremstrahlung?
  - Δ contribution ?

- No π^0 visible in data ! cross-check with "known" physics" missing
- $N\Delta$ and $N\pi^0$ are related!

E. Bratkovskaya et al. nucl-th\0008037 (2000)

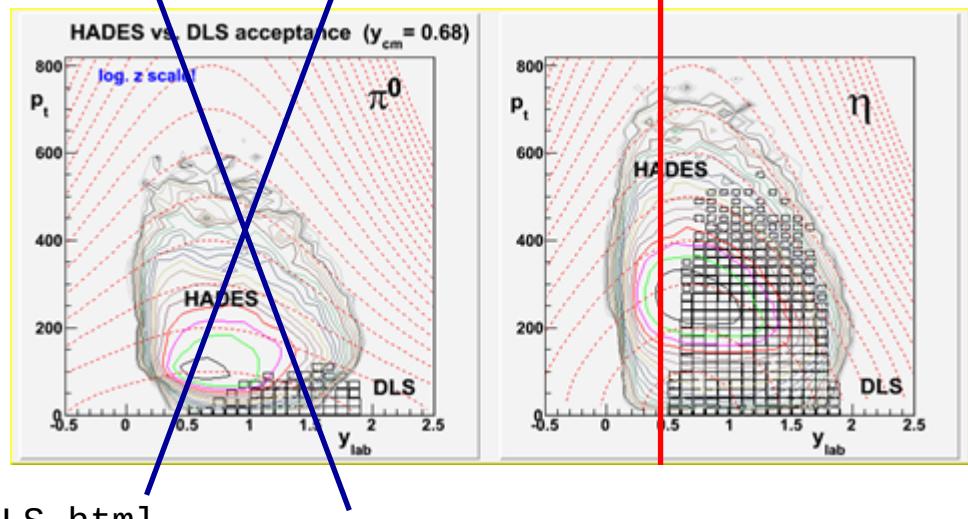
C. Fuchs et al. Phys. Rev. C68 014904(2003)

Comparison to DLS elementary reactions @ 1.04 GeV



Opening angle > 40°

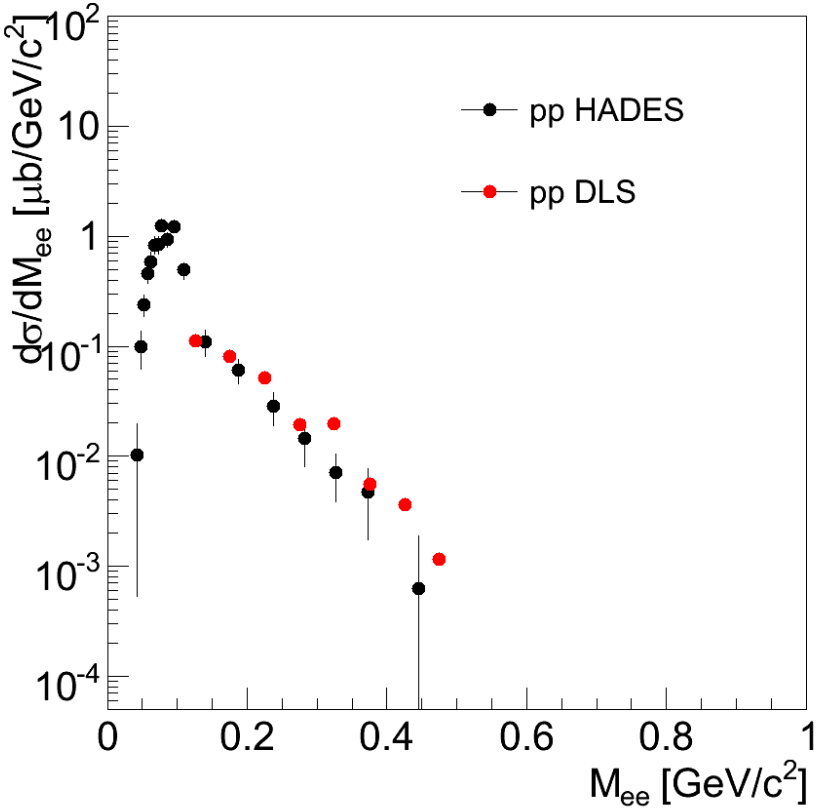
Rapidity > 0.5

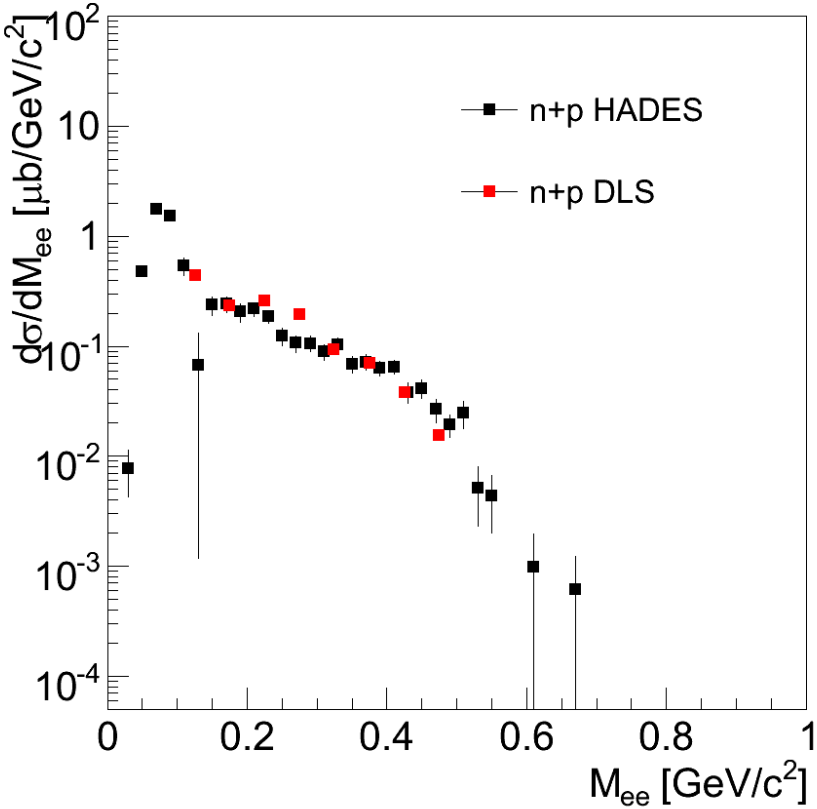


http://macdls.lbl.gov/DLS_WWW_Files/DLS.html
http://macdls.lbl.gov/DLS_WWW_Files/PP_PD_Paper/data/m_spectra.txt

Comparison HADES with DLS

Opening angle > 40 deg. rapidity > 0.5





Bremsstrahlung from theory 1994 - 2006