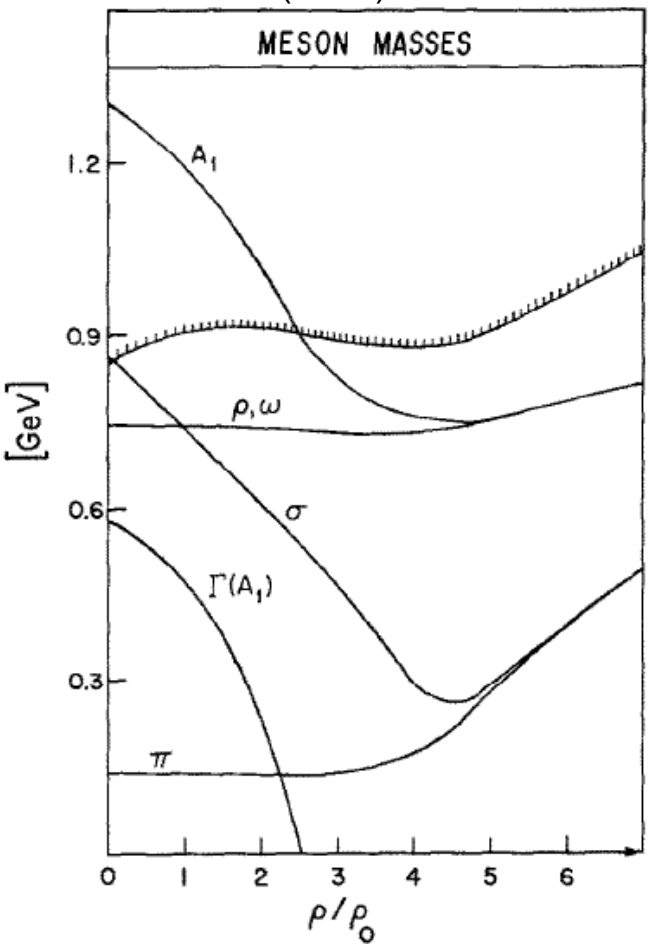
Inclusive e^+e^- pair production in cold nuclear matter

- Motivation:
  the ω meson in matter
- HADES experiment:
  p + Nb E_{kin} = 3.5 GeV
- M_{inv} and momentum distributions
- Comparison:
  p + p E_{kin} = 3.5 GeV
- Conclusion

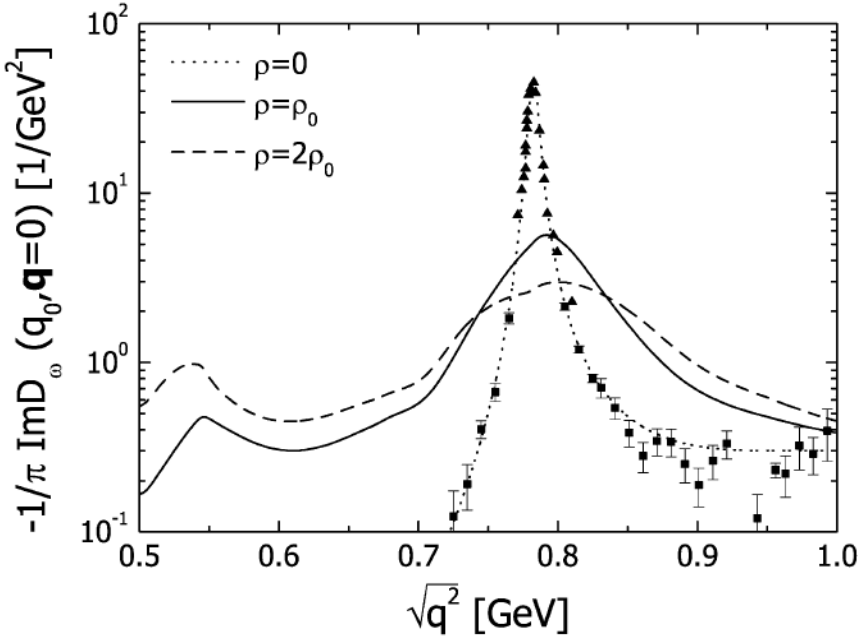
Michael Weber
for the HADES Collaboration

ω in matter: some predictions

V.Bernard and U.G.Meissner,
NPA 489 (1988) 647

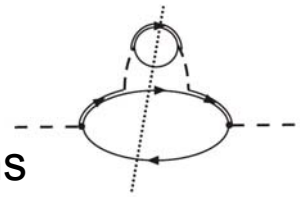


P.Mühlich et al.,
NPA 780 (2006) 187



Coupled channel eff. Lagrangian:

- Broadening (~60 MeV)
- Coupling to D13, S11 resonance-hole excitations



NJL Lagrangian:

- mass degeneracy with increasing density

Experimental data

Courtesy V. Metag

	KEK	JLab	CBELSA/ TAPS	CERES	NA60
reaction	pA 12 GeV	γA 0.6-3.8 GeV	γA 0.7-2.5 Gev	Au+Au 158 AGeV	In+In 158 AGeV
momentum acceptance	p > 0.5 GeV/c	p > 0.8 GeV/c	p > 0.0 GeV/c	p_t > 0.0 GeV/c	p_t > 0.0 GeV/c
ρ	$\frac{\Delta m}{m} = -9\%$	Δm ≈ 0 some broadening		broadening favoured over density dependent mass shift	Δm ≈ 0 strong broadening
ω	no broadening		$\frac{\Delta m}{m} \approx ??$ $\frac{\Gamma_\omega(\rho_0)}{\Gamma_\omega} \approx 16$		
Φ	$\frac{\Delta m}{m} = -3.4\%$ $\frac{\Gamma_\phi(\rho_0)}{\Gamma_\phi} = 3.6$				
	M.Naruki et al., PRL 96 (2006) 092301 R.Muto et al., PRL 98 (2007) 042501	R.Nasseripour et al., PRL 99 (2007) 272302 M.H.Wood et al., PRC 78 (2008) 015201	M.Kotulla et al., PRL 100 (2008) 192302 M.Nanova et al., nucl-ex 1005.5694	D. Adamova et al., nucl-ex 0611022	R. Arnaldi et al., PRL 96 (2006)

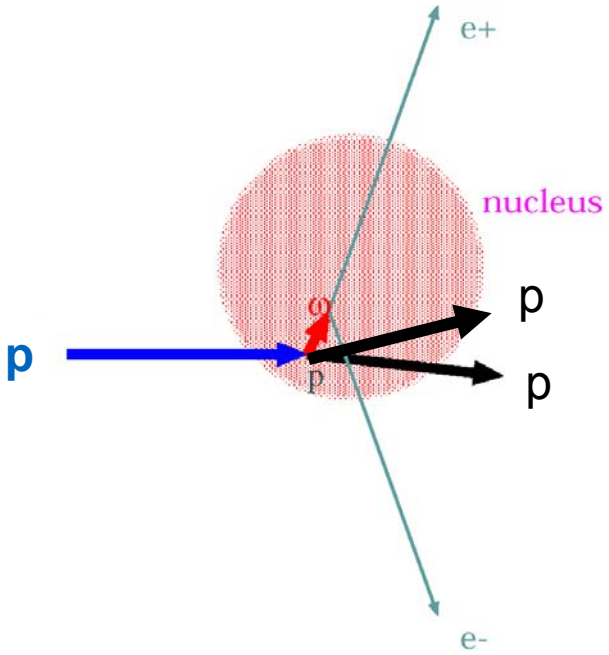
ω production and decay

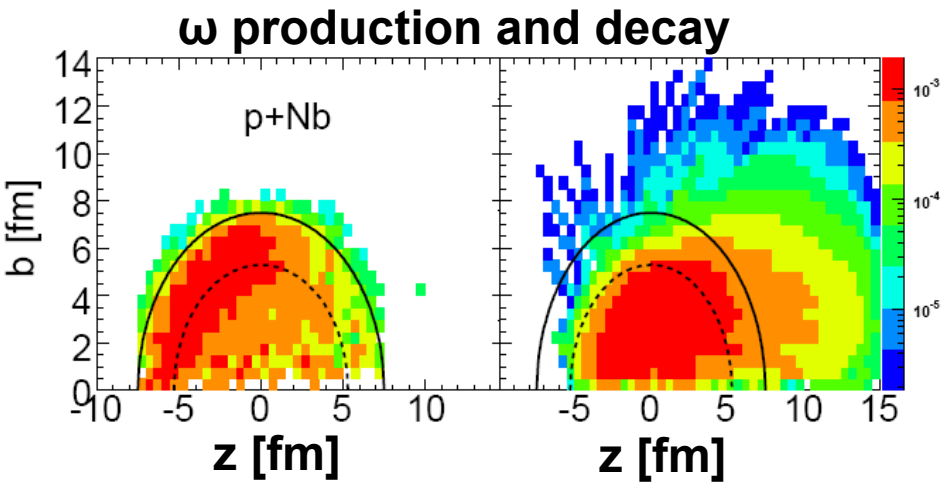
Small energies above threshold (Q ~ 500 MeV)

$pN_{bound} \rightarrow pN\omega \rightarrow pNe^+e^-$

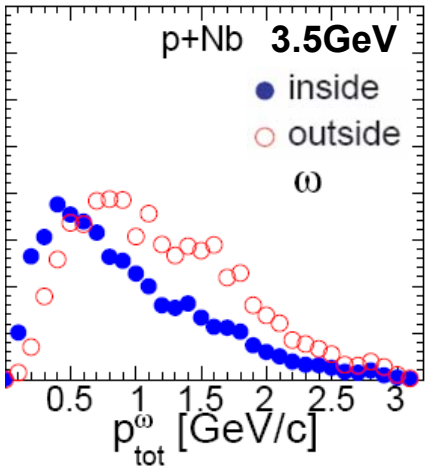
e^+e^-: reconstruct ω mass

$$m_\omega = \sqrt{(\sum E_i)^2 - (\sum p_i)^2}$$





momentum distribution

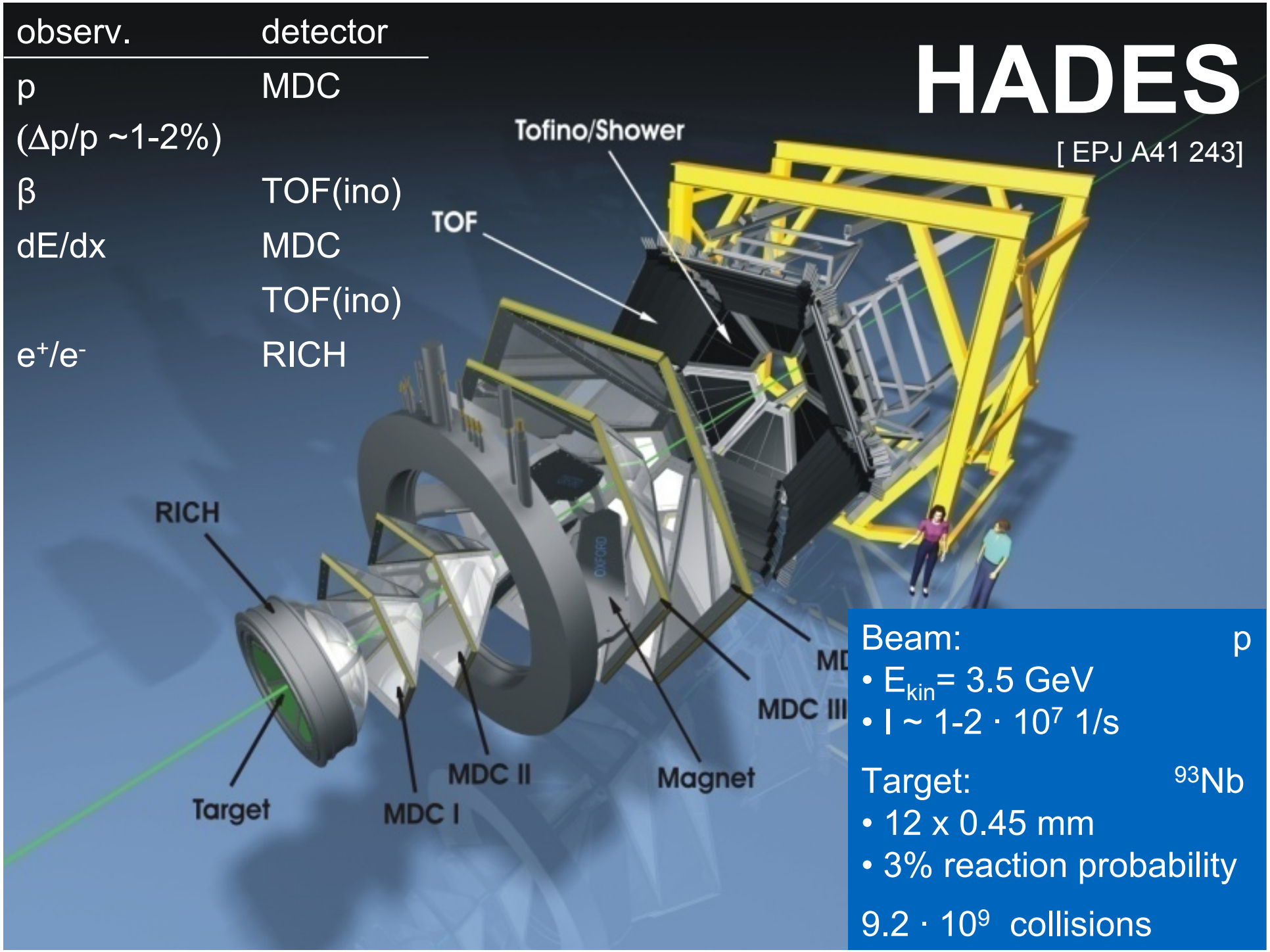


HADES proposal 2006

HADES

[EPJ A41 243]

observ.	detector
p	MDC
($\Delta p/p$ ~1-2%)	
β	TOF(ino)
dE/dx	MDC
	TOF(ino)
e^+/e^-	RICH

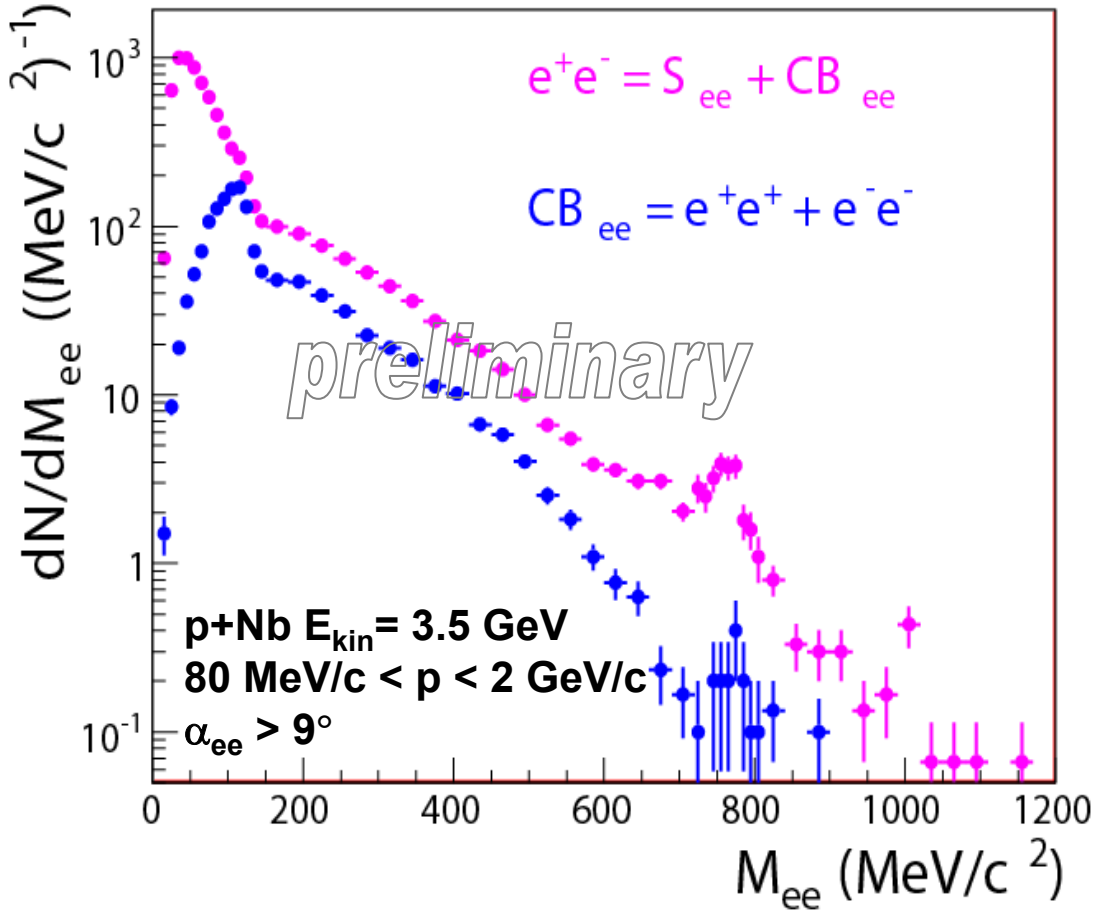


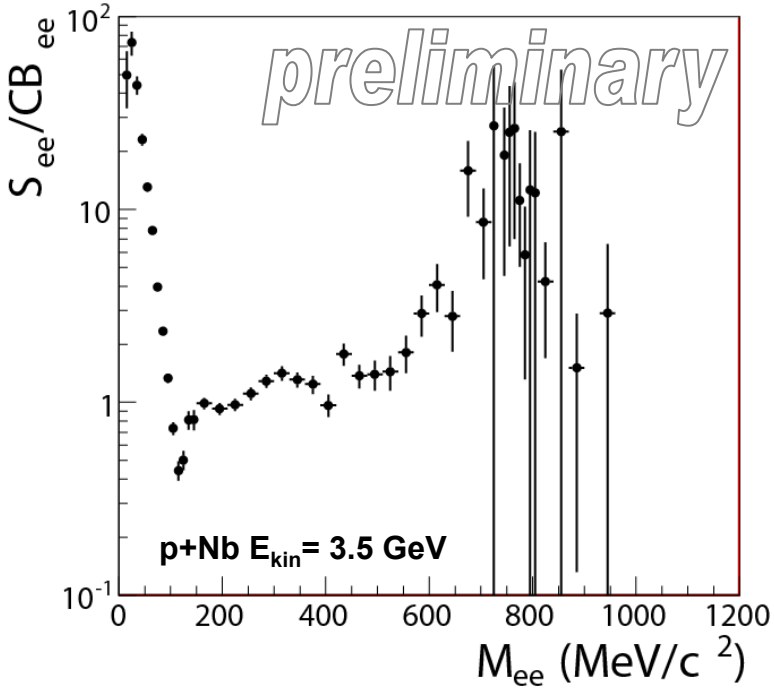
Beam: p
- E_{kin}= 3.5 GeV
- I ~ 1-2 · 10^7 1/s

Target: ^{93}Nb
- 12 x 0.45 mm
- 3% reaction probability

9.2 · 10^9 collisions

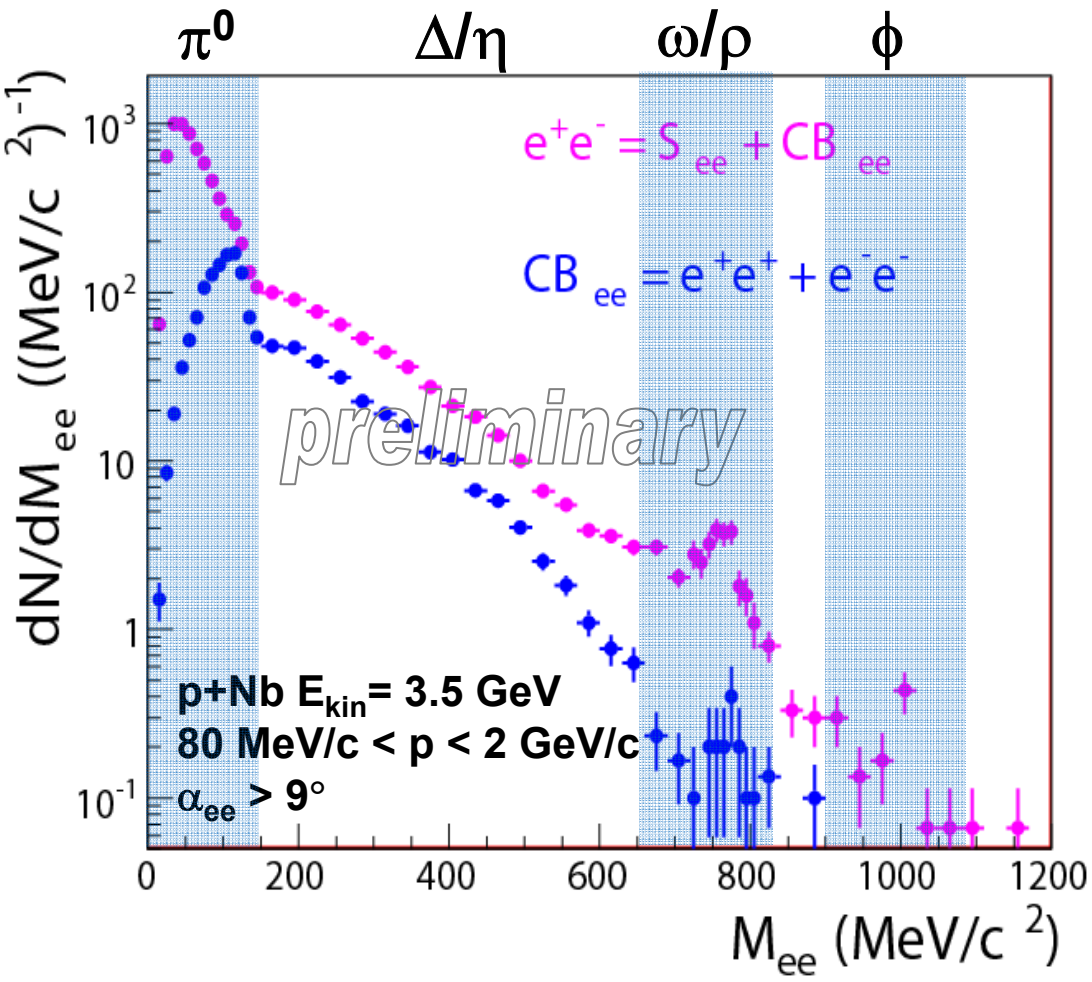
M_{inv} of e^+e^- pairs





S/N ~ 10 in ω/ρ region

M_{inv} of e^+e^- pairs



Sources of e^+e^- pairs:

γ	→		e^+e^-
π^0	→	γ	e^+e^-
Δ	→	N	e^+e^-
η	→	γ	e^+e^-
ω	→	π^0	e^+e^-
ω/ρ	→		e^+e^-
ϕ	→		e^+e^-

Normalization

- to π^0 yield:
  - compare measured $\pi^{\pm}$ yield with transport model (UrQMD)
  - conclude from reproduced $\pi^{\pm}$ yield to π^0 yield and extrapolate to 4π

- to reaction cross section:

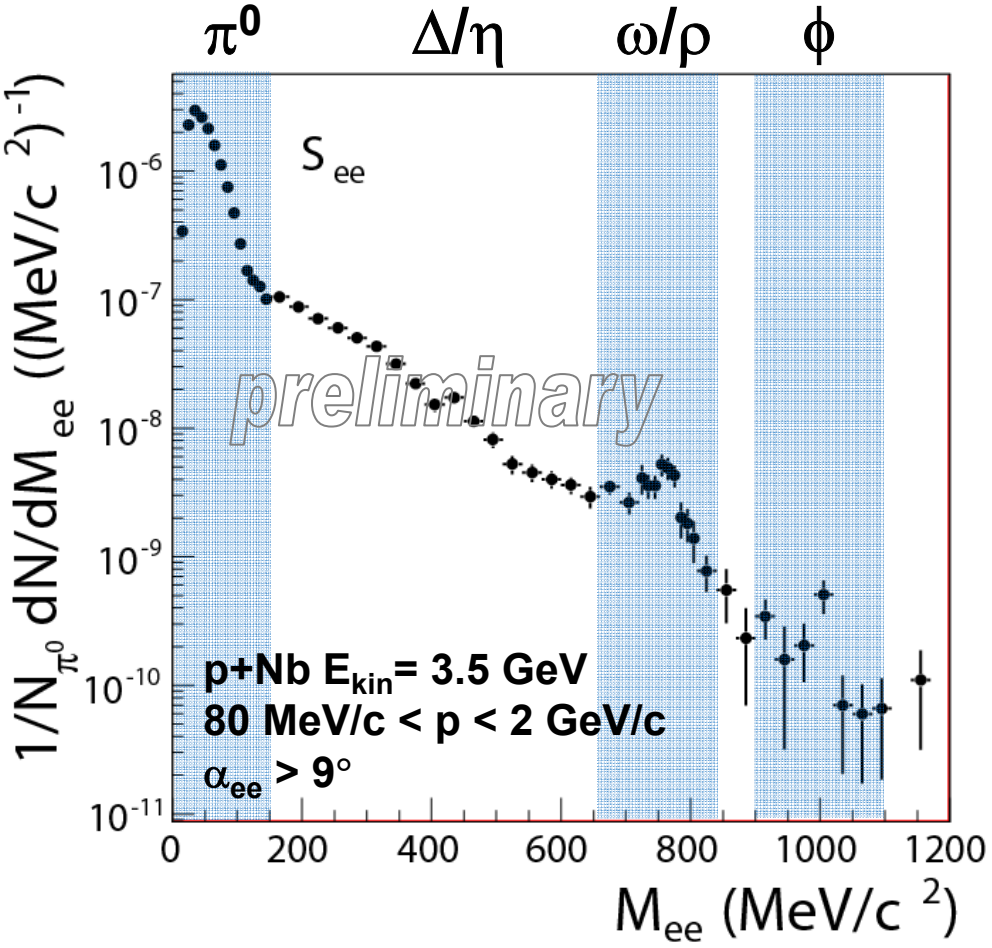
p+Nb : σ_R = 1080 mb — Wellisch et al., PRC 54 (1996) 1329

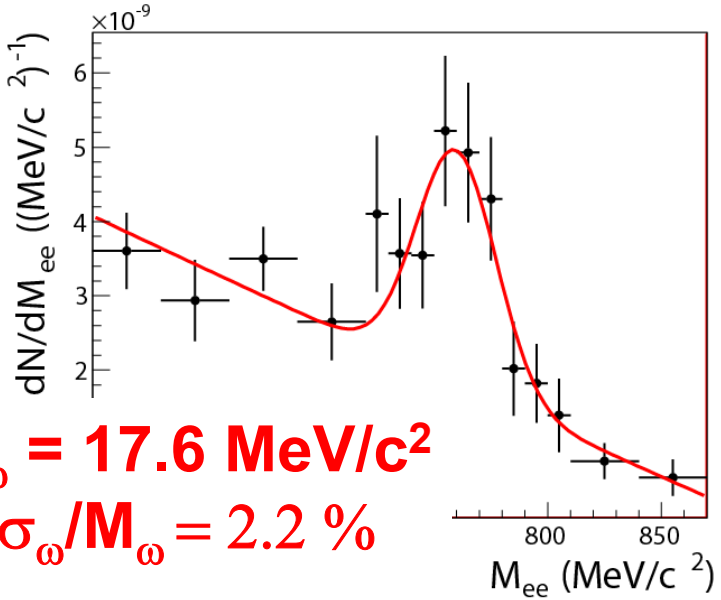
$\sigma(\pi^0)/\sigma_R$ = 0.66 — from UrQMD calculation

$\sigma(\pi^0)$ = 713 mb

M_{inv} eff. corrected

Normalized to π^0 yield



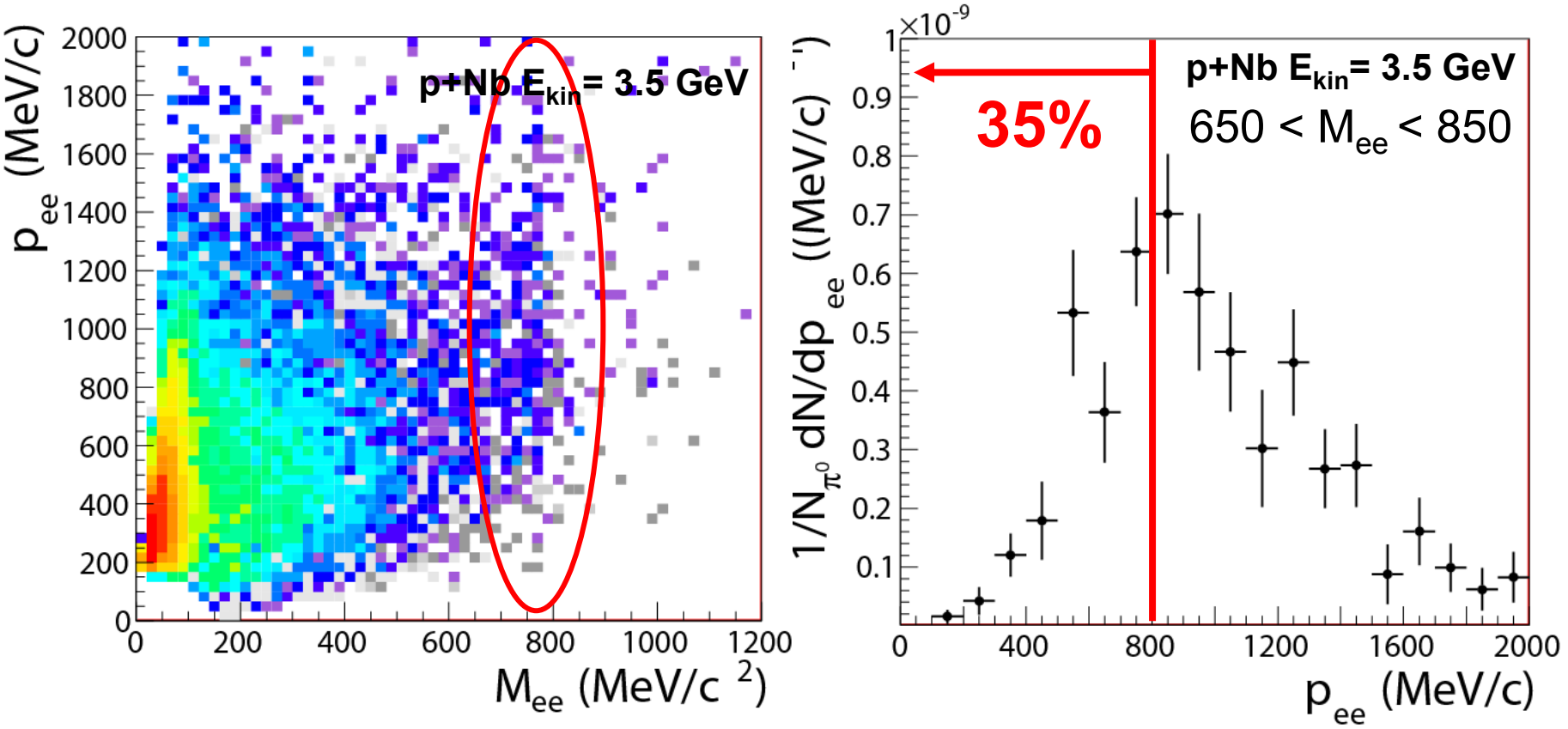


$\sigma_\omega = 17.6$ MeV/c²

$\sigma_\omega / M_\omega = 2.2$ %

signal pairs	$6.5 \cdot 10^5$
π^0 region	$5.5 \cdot 10^5$
ω/ρ region	463
ϕ region	36

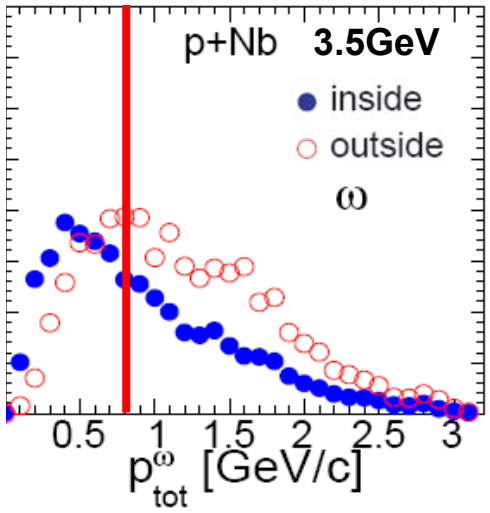
Momenta of e^+e^- pairs

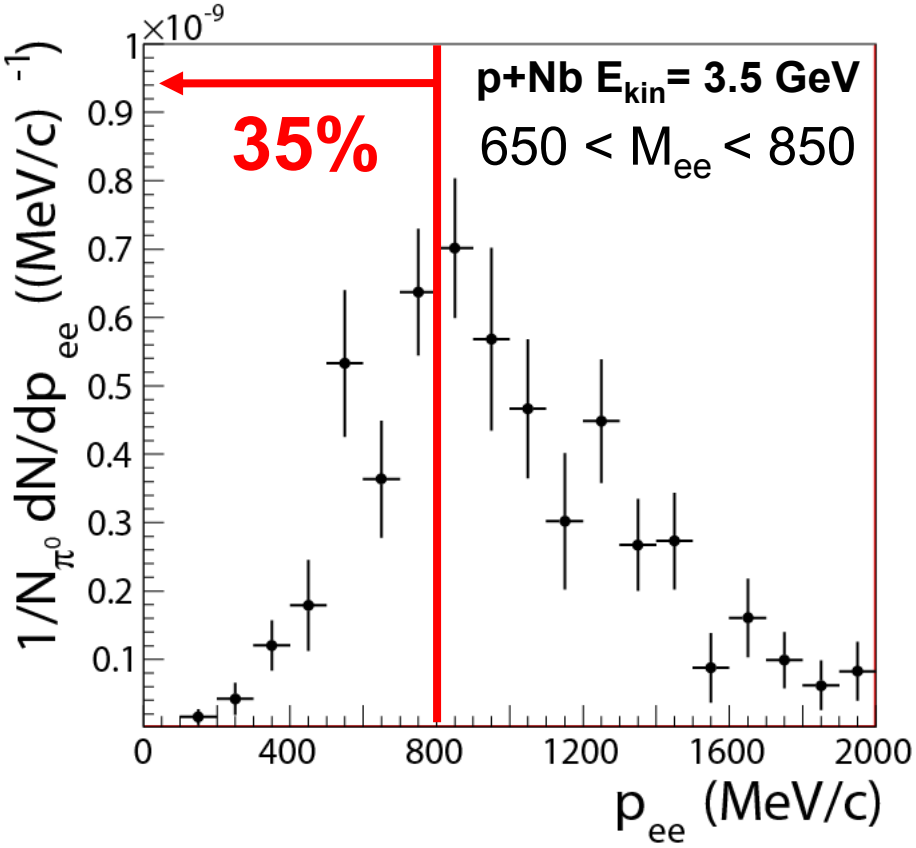


HADES: Significant e^+e^- yield with low pair momenta

Momenta of e^+e^- pairs

decays inside nucleus

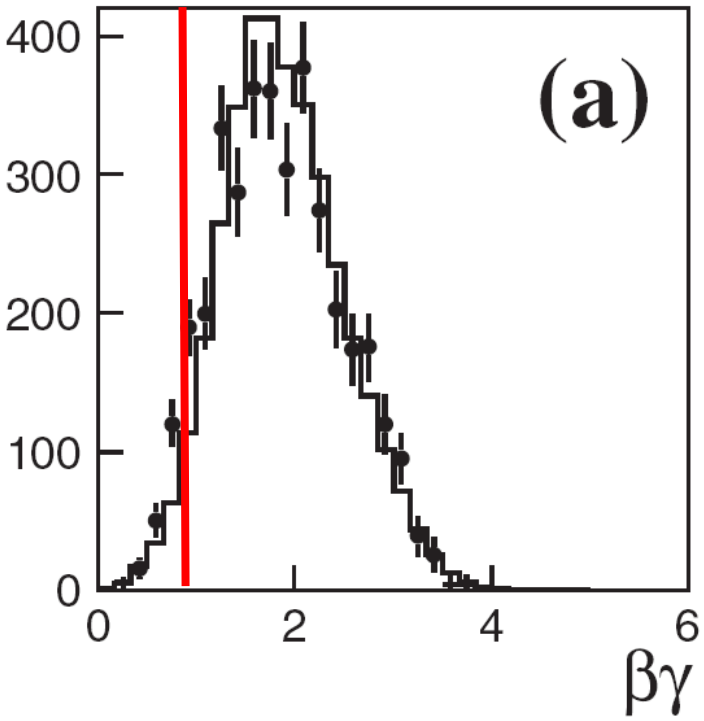




HADES: Significant e^+e^- yield with low pair momenta

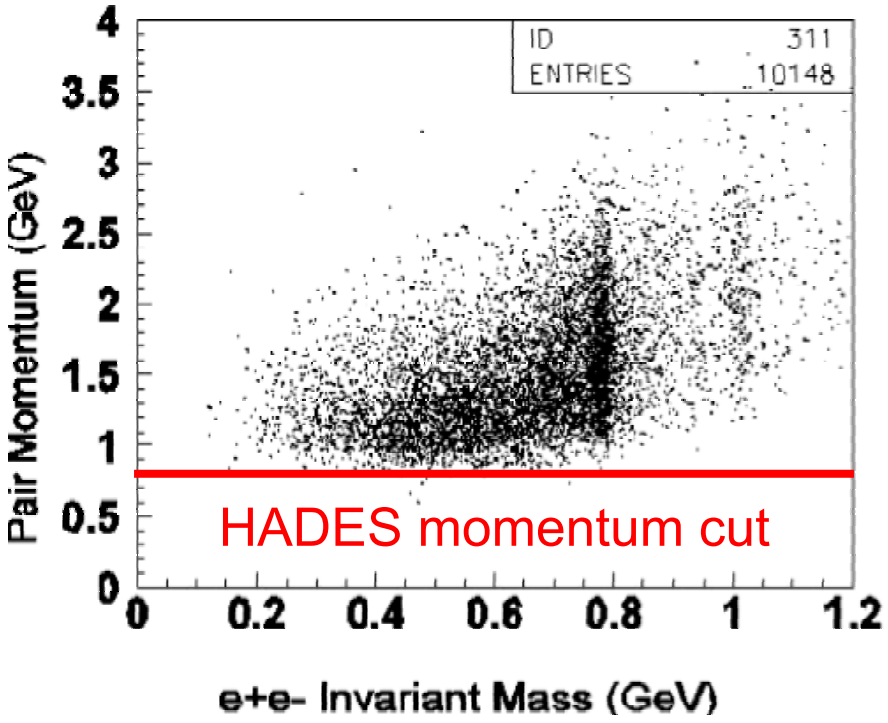
Momenta of e^+e^- pairs

KEK:



R.Muto et al., PRL 98 (2007) 042501

JLAB:



S.Leupold, V.Metag and U.Mosel, nucl-th 0907.2388

Comparison to p + p

Beam: p
- E_{kin}= 3.5 GeV
- I ~ 1 · 10^7 1/s

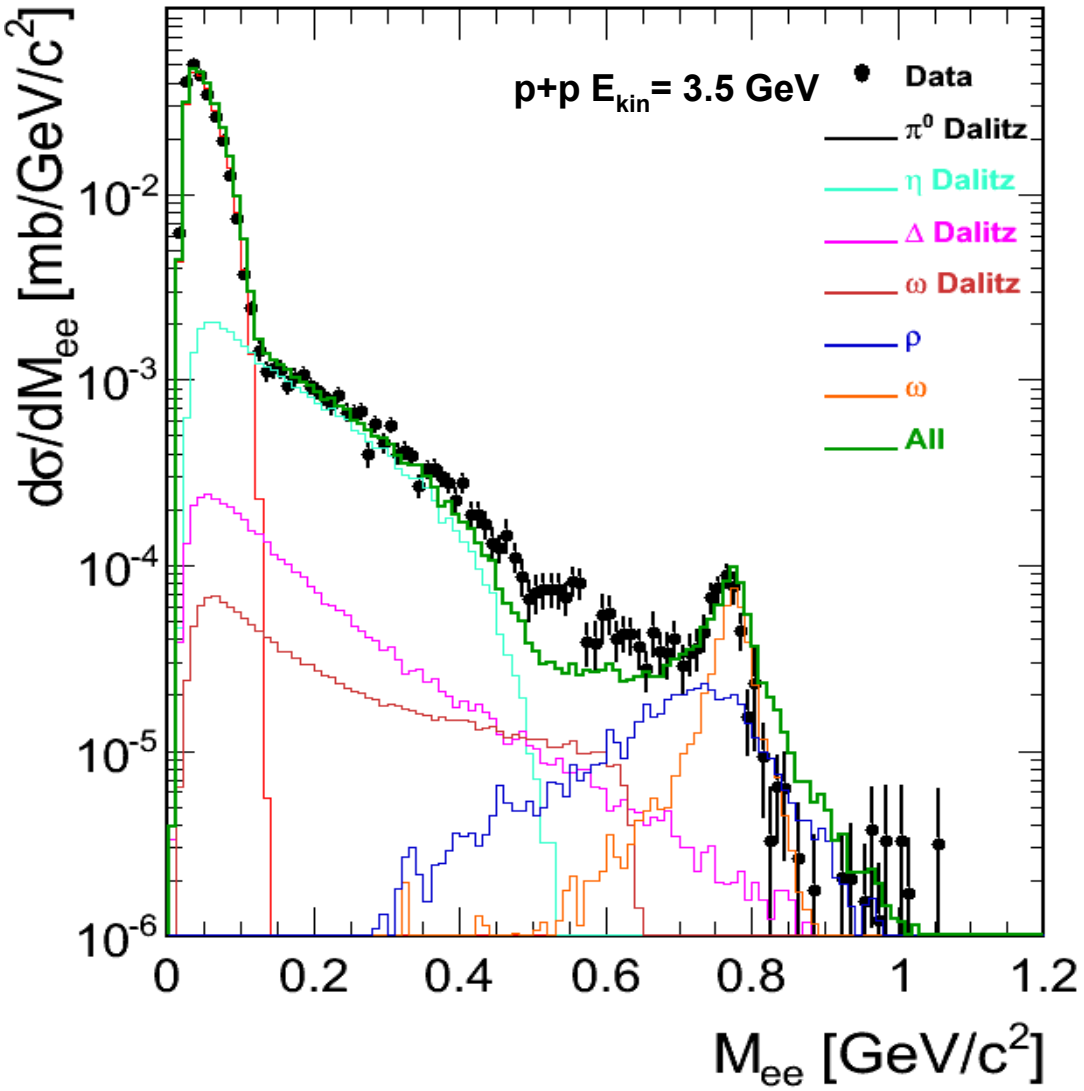
Target: p
- 4.4 cm liquid hydrogen

3.5 · 10^9 events

Normalization to elastic scattering:

Inclusive cross sections (mb)

π^0	16.1	± 2.6
η	0.93	± 0.2
ω	0.25	± 0.05
ρ	0.38	± 0.07



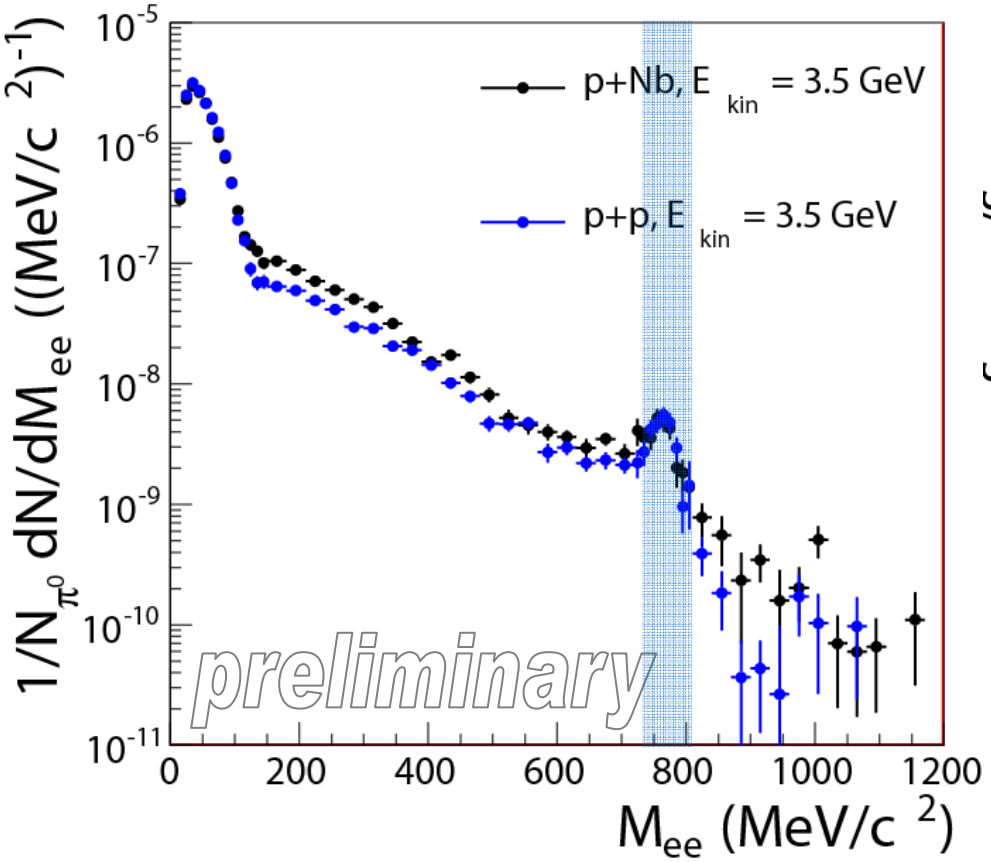
Shown on Thursday by A. Rustamov

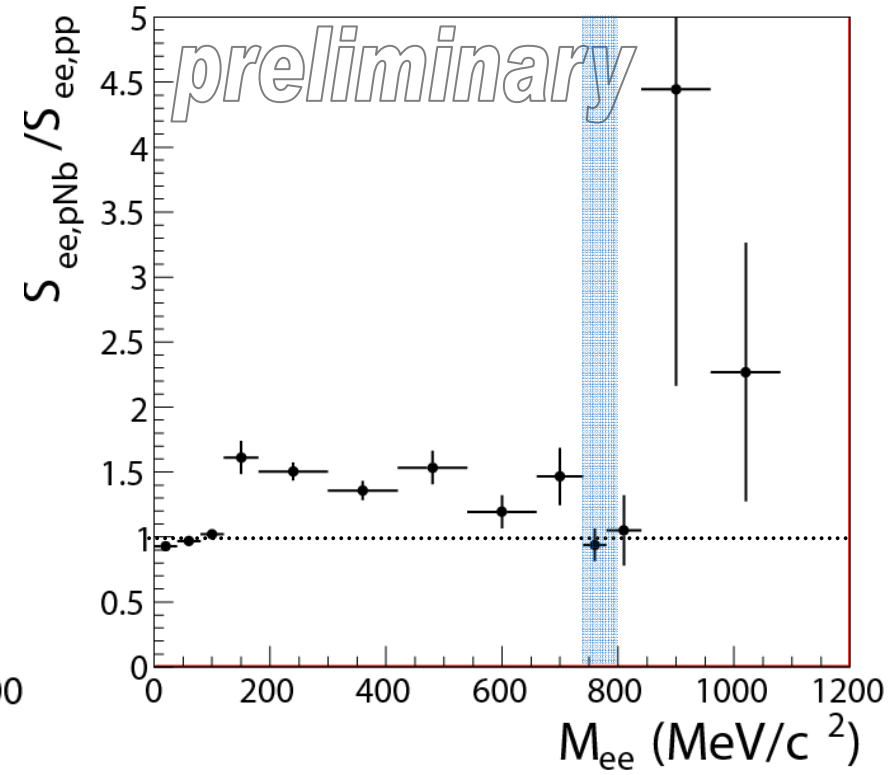
M_{inv} eff. corrected

Technische Universität München

Normalized to π^0 yield

All momenta

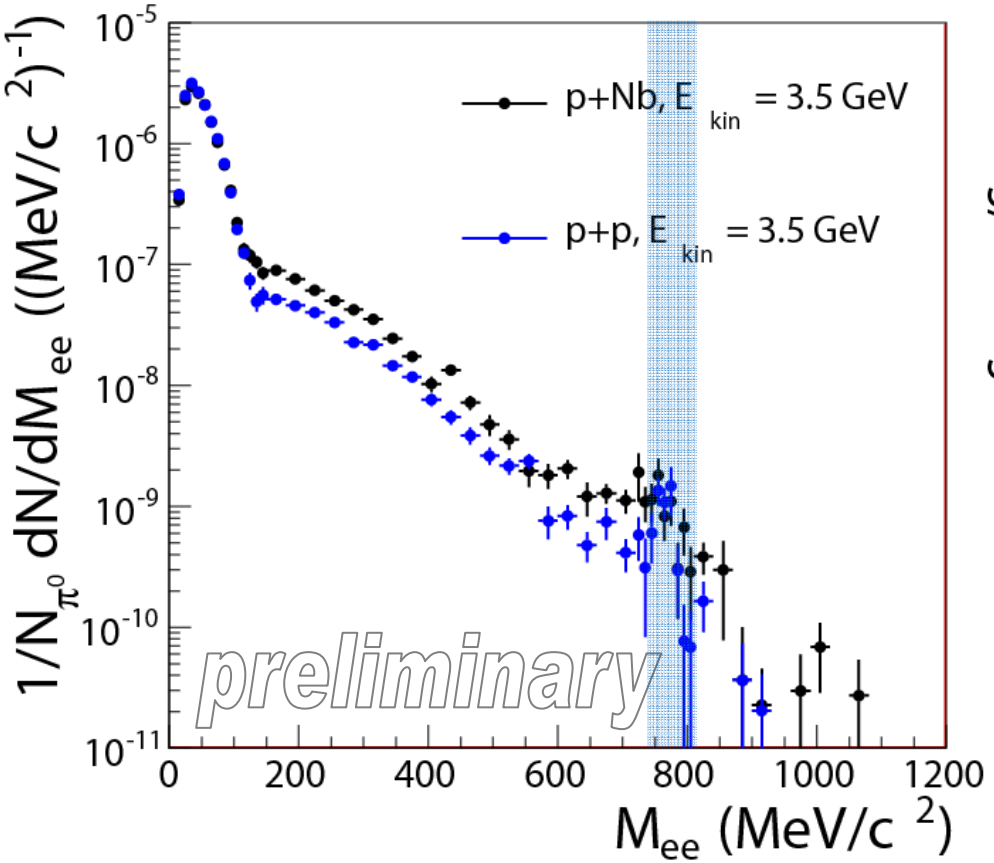


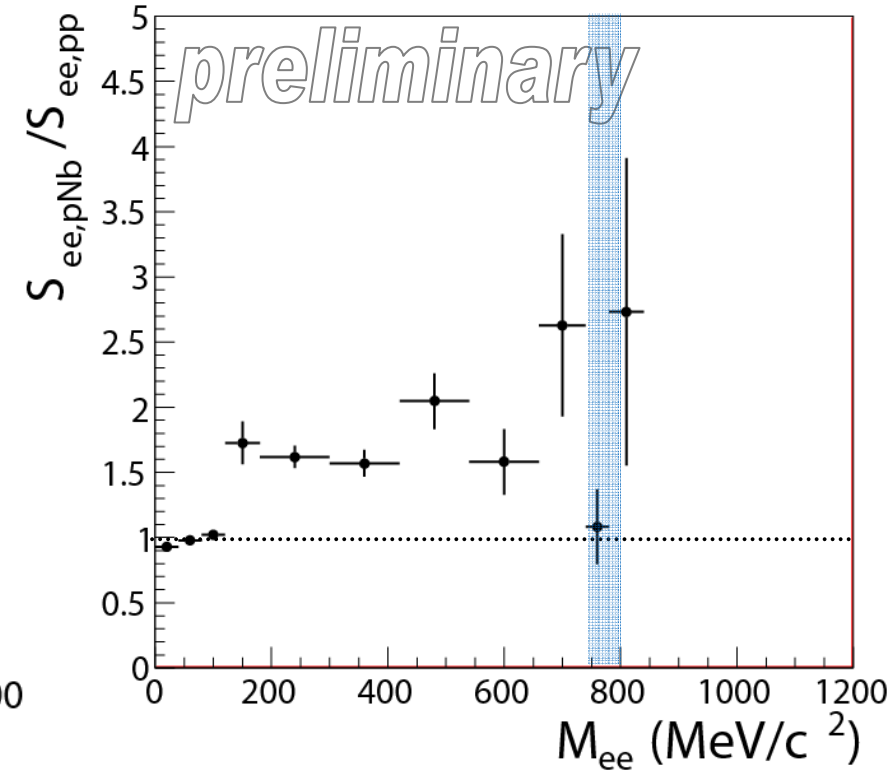


M_{inv} eff. corrected

Normalized to π^0 yield

p_{ee} < 800 MeV/c





Cross sections

- $\sigma_{pd} = 2\,\sigma_{pp}$ $E_{kin} = 4.88$ GeV
  → neglect isospin effects

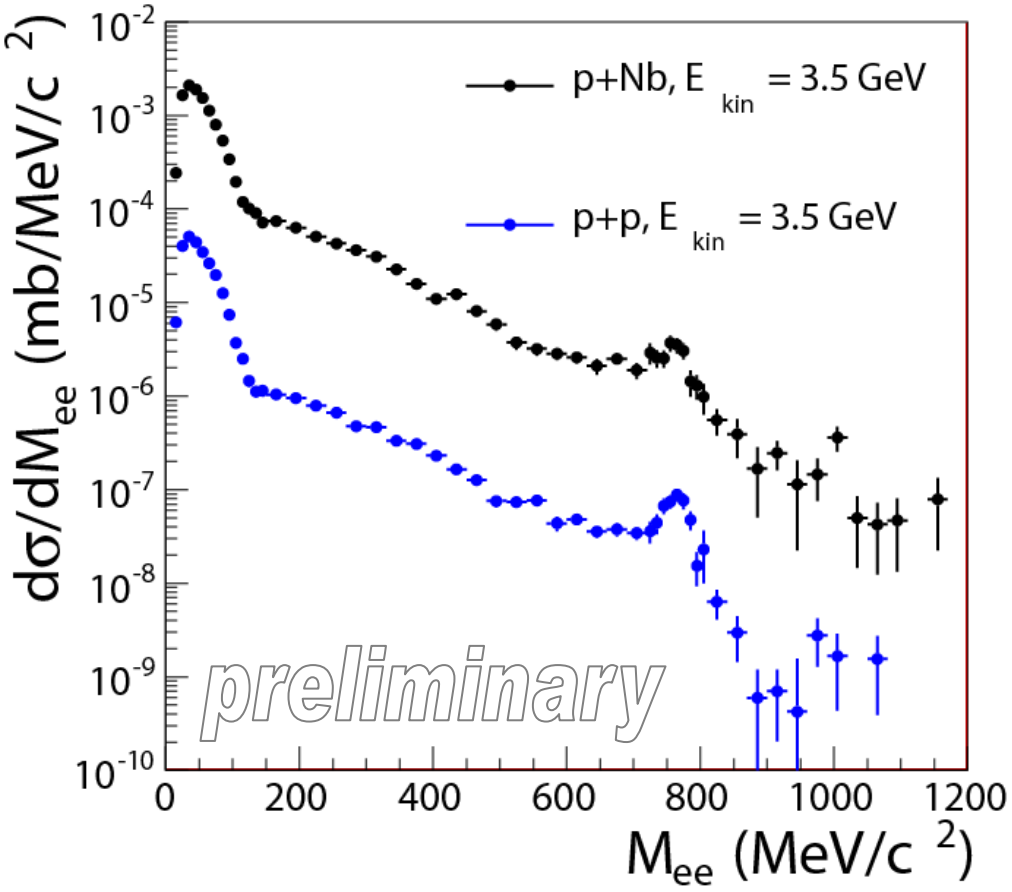
  Wilson et al., PRC 57(1997) 1865

- A dependence of production / absorption:

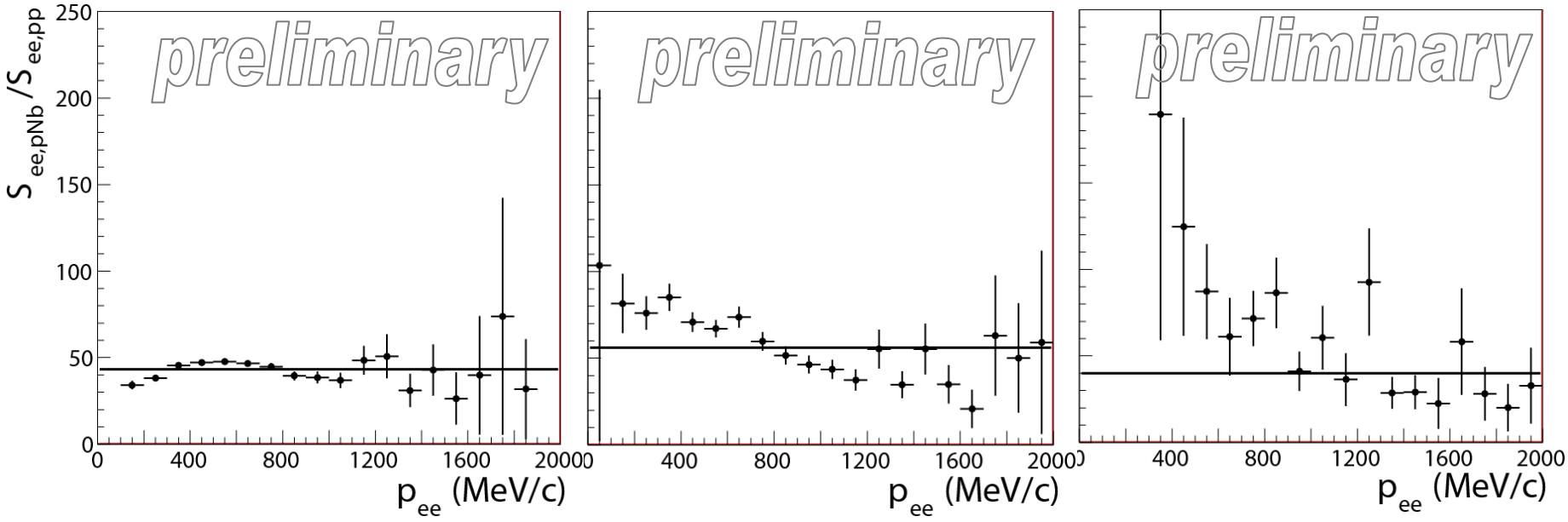
$$R_{pA} = \frac{(d\sigma/dM)_{pA}}{(d\sigma/dM)_{pp}} = A^{\alpha}$$

- Expectation:
  - Surface production: $\alpha = 2/3$
  - Glauber scaling for π: $\alpha \sim 0.8$

    W.Cassing et al., PLB 238 (1990) 25



Momentum distributions



π^0:
- ratio = 43
- $\alpha = 0.83$

η:
- ratio = 56
- $\alpha = 0.89$

ω/ρ:
- ratio = 40
- $\alpha = 0.81$

Findings:
- π^0 region : no p dependence, scaling with Glauber model
- M_{ee} > 150 MeV/c^2 : p dependence
- M_{ee} > 150 MeV/c^2 : production / absorption different for ω and η

Summary

- e^+e^- - pair production in ground state nuclei
- clear ω signal observed ($\sigma_\omega/M_\omega \sim 2\%$)
- significant e^+e^- - yield with low pair momenta ($p < 800$ MeV/c)
- A dependence I :
  $\alpha_{\pi 0} \sim 0.83$, $\alpha_\eta \sim 0.89$ and $\alpha_{\omega/\rho} \sim 0.81$
- A dependence II :
  α_η and $\alpha_{\omega/\rho}$ decrease with momentum

Summary

- e^+e^- - pair production in ground state nuclei
- clear ω signal observed ($\sigma_\omega/M_\omega \sim 2\%$)
- significant e^+e^- - yield with low pair momenta ($p < 800$ MeV/c)
- A dependence I :
  $\alpha_{\pi 0} \sim 0.83$, $\alpha_\eta \sim 0.89$ and $\alpha_{\omega/\rho} \sim 0.81$
- A dependence II :
  α_η and $\alpha_{\omega/\rho}$ decrease with momentum

Perspectives

- Comparison to transport models
- p - dependence and absorption of ρ/ω in matter ?

$$N_{e^+e^-} \propto \Gamma_{V\to e^+e^-} \cdot \tau_V = \Gamma_{V\to e^+e^-} / \Gamma_{Tot}$$

- ρ/ω in HI reactions: lifetime of the fireball (regeneration)

$$N_{e^+e^-} \propto \Gamma_{V\to e^+e^-} \cdot \tau_{FB}$$

HADES collaboration

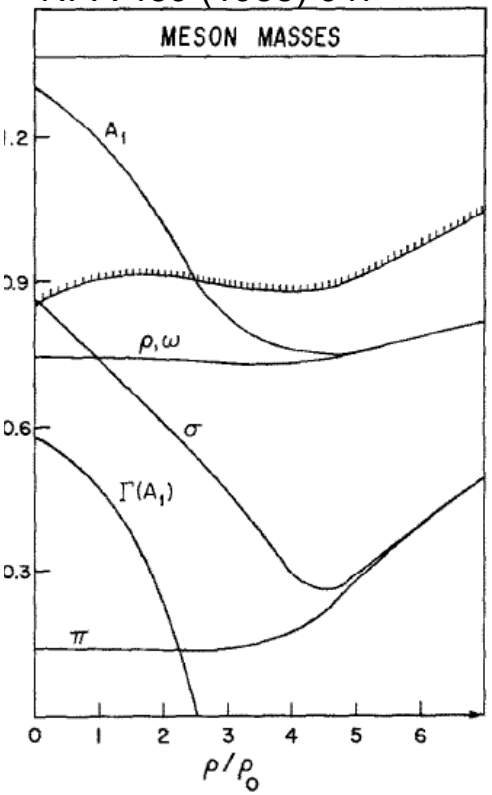
Technische Universität München

G. Agakishiev, A. Balanda, D. Belver, A. Belyaev, A. Blanco, M. Böhmer, J. L. Boyard, P. Cabanelas, E. Castro, S. Chernenko, J. Díaz, A. Dybczak, E. Epple, L. Fabbietti, O. Fateev, P. Finocchiaro, P. Fonte, J. Friese, I. Fröhlich, T. Galat va, D. González-Díaz, F. Guber, T. H erusalimov, I. Iori, A. Ivashkin, M. J Koenig, B. W. Kolb, A. Kopp, G. Korcy , A. Krása, F. Krizek, R. Krücken, H Kuc Kurilkin, P.K. Kähllitz, V. Ladygin, J. L , T. Liu, L. Lopes, M. Lorenz, L. Ma etag, B. Michalska, J. Michel, C. Müntz Palka, Y. Parpottas, V. Pechenov, O goda, B. Ramstein, A. Reshetin, J. Rosl Salabura, A. Schmah, J. Siebenson, Yu.G. Sobolev, T. Solovieva, S. Spataro, B. Spruck, H. Ströbele, J. Stroth, C. Sturm, M. Sudol, A. Tarantola, K. Teilab, P. Tlusty, M. Traxler, R. Trebacz, H. Tsertos, V. Wagner, M. Weber, J. Wüstenfeld, S. Yurevich, Y. Zanevsky

BONUS slides

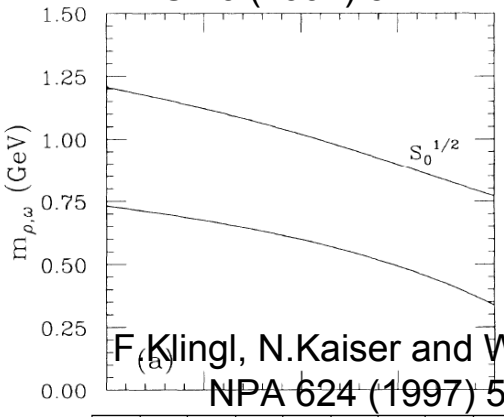
Model predictions

V.Bernard and U.G.Meissner, NPA 489 (1988) 647

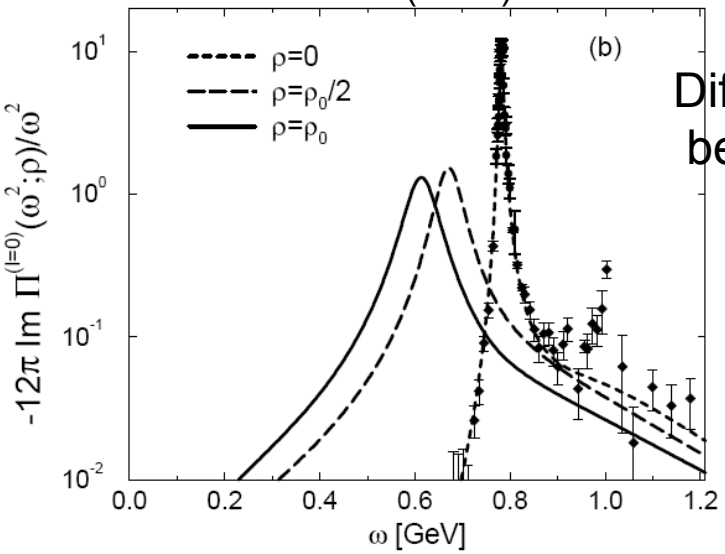


mass degeneracy with density

T.Hatsuda and S.H.Lee, PRC 46 (1992) 34

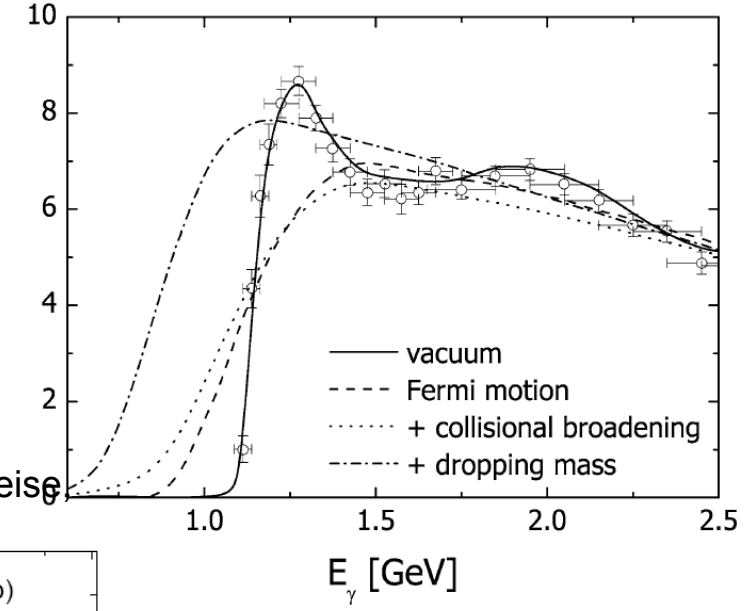


F.Klingl, N.Kaiser and W.Weise NPA 624 (1997) 527



Mass shift + Broadening

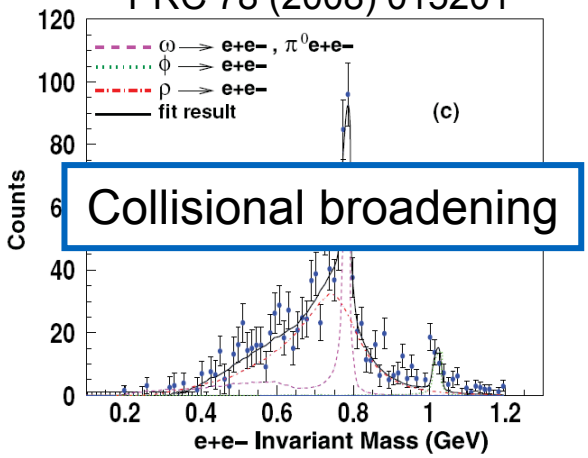
P.Mühlich and U.Mosel, NPA 773 (2006) 256



Different excitation function behaviour for different scenarios

Some experimental results

M.H.Wood et al.,
PRC 78 (2008) 015201

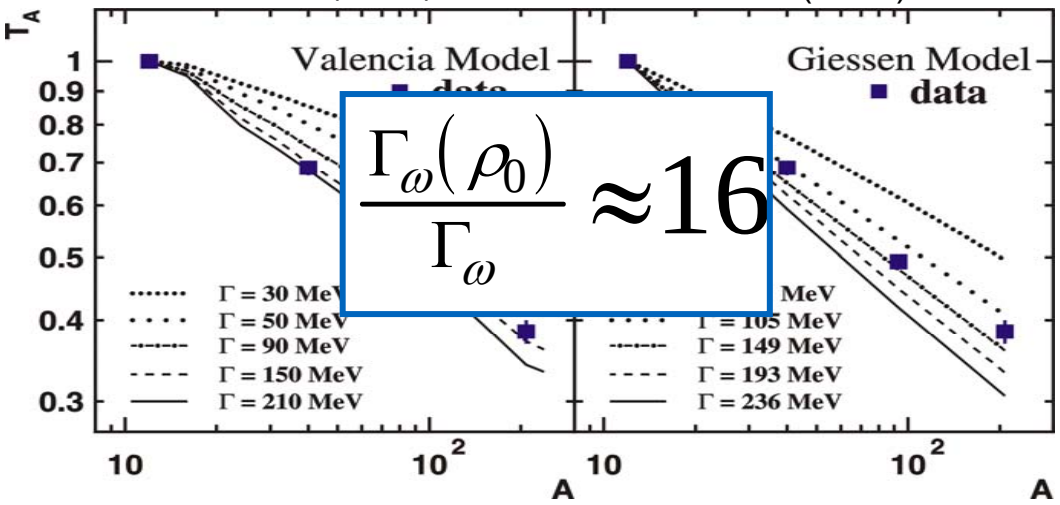


Collisional broadening

M.Kotulla et al., PRL 100 (2008) 192302

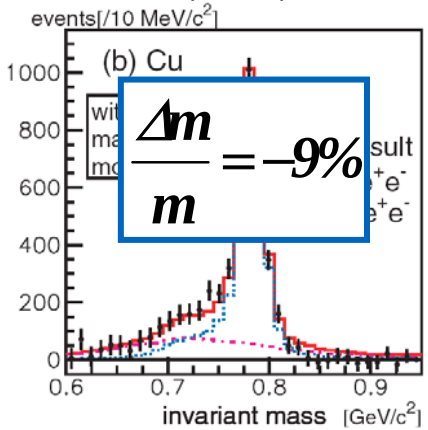
M.Kaskulov et al.,
EPJ A 31 (2007) 245

P. Mühlich and U. Mosel
NPA 773 (2006) 156

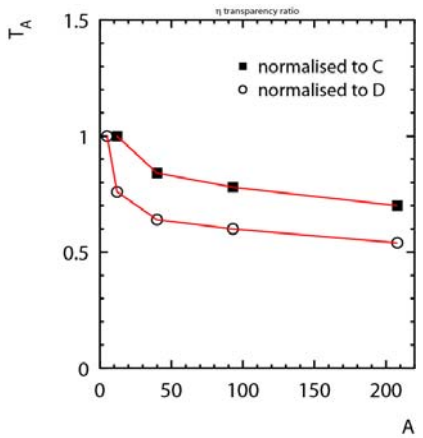


$$\frac{\Gamma_\omega(\rho_0)}{\Gamma_\omega} \approx 16$$

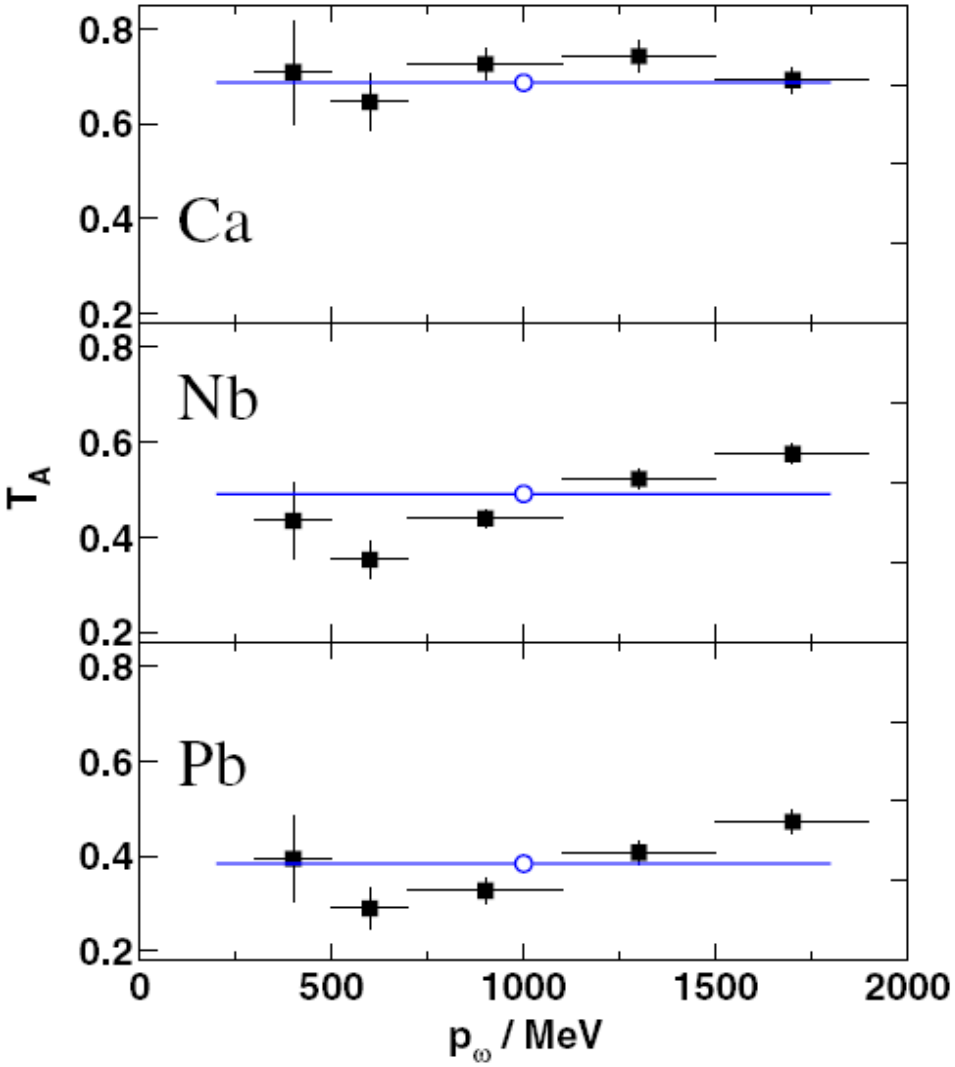
M.Naruki et al.,
PRL 96 (2006) 092301



$$\frac{\Delta m}{m} = -9\%$$

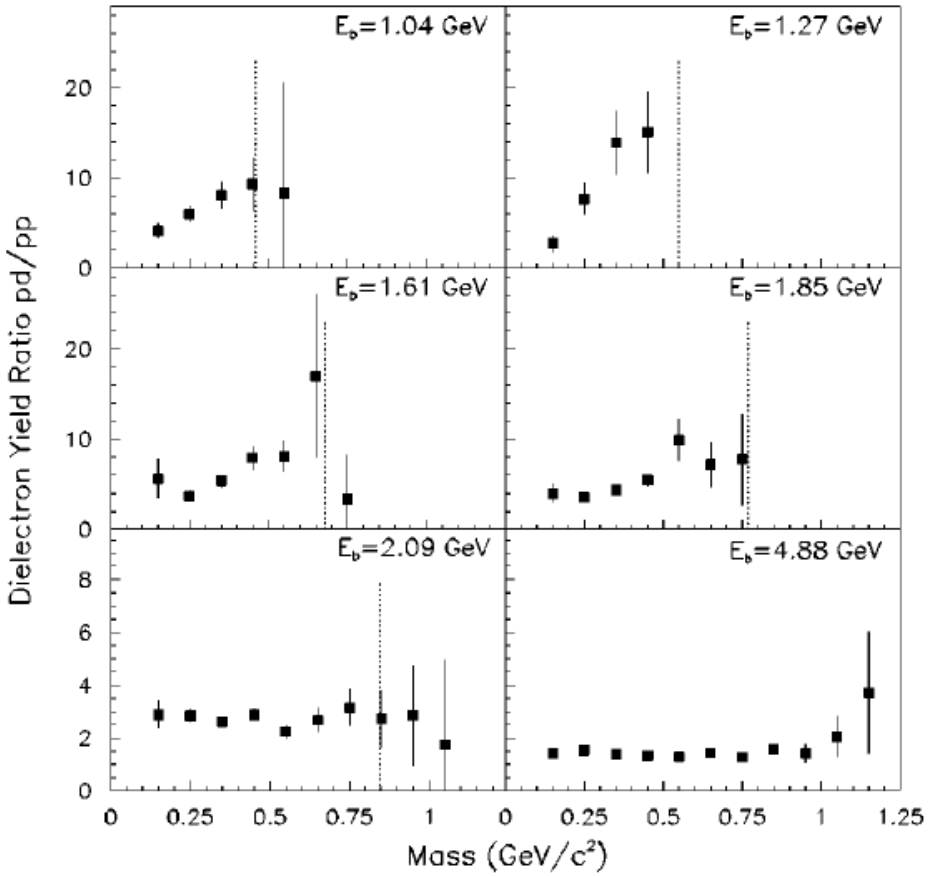


Transparency ratio



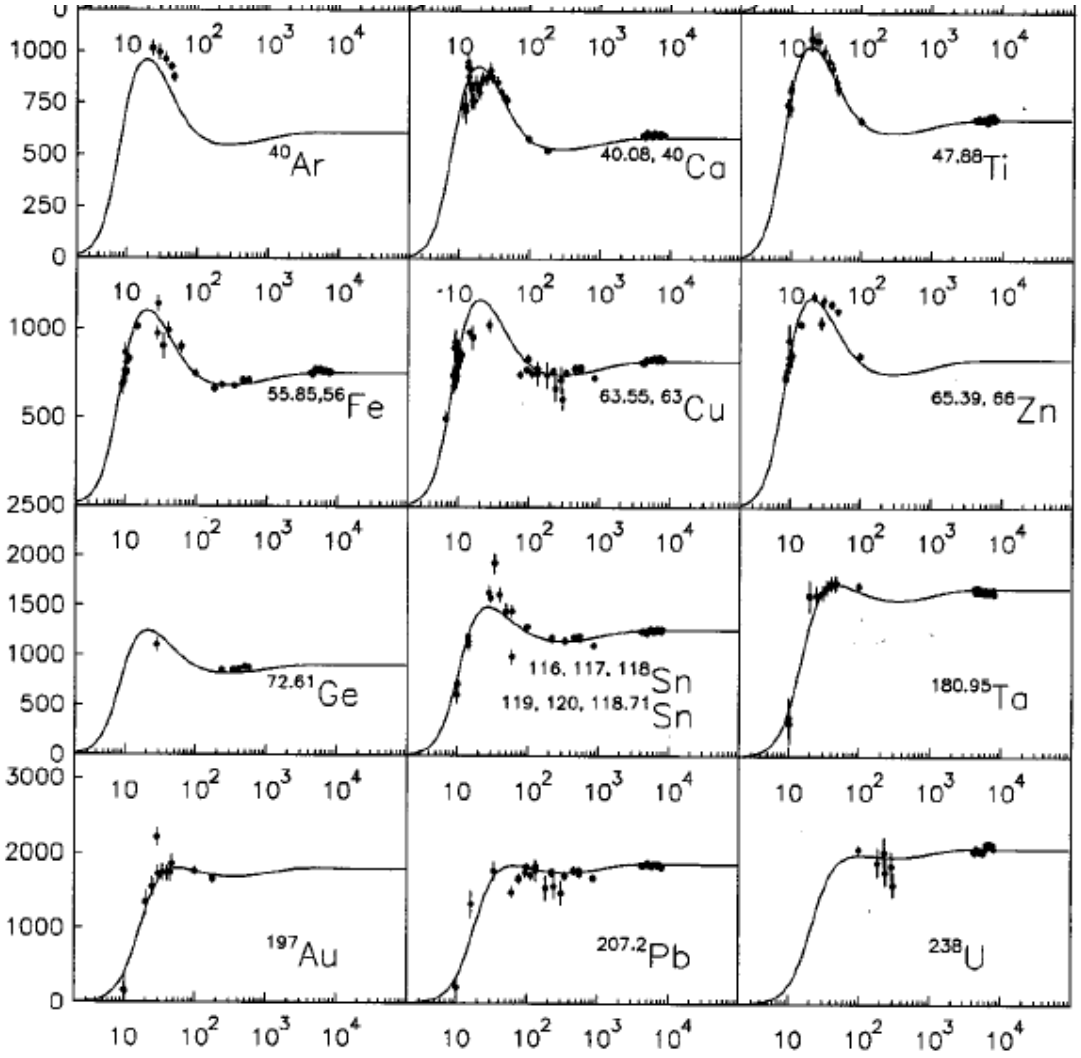
Isospin dependence

- Dielectron cross sections in p+p and p+d at beam energies from 1.04 to 4.88 GeV measured with DLS
- Decreasing mass dependence of pd/pp with increasing beam energy
- pd cross section becomes approximately twice the pp cross section at all masses with increasing beam energy

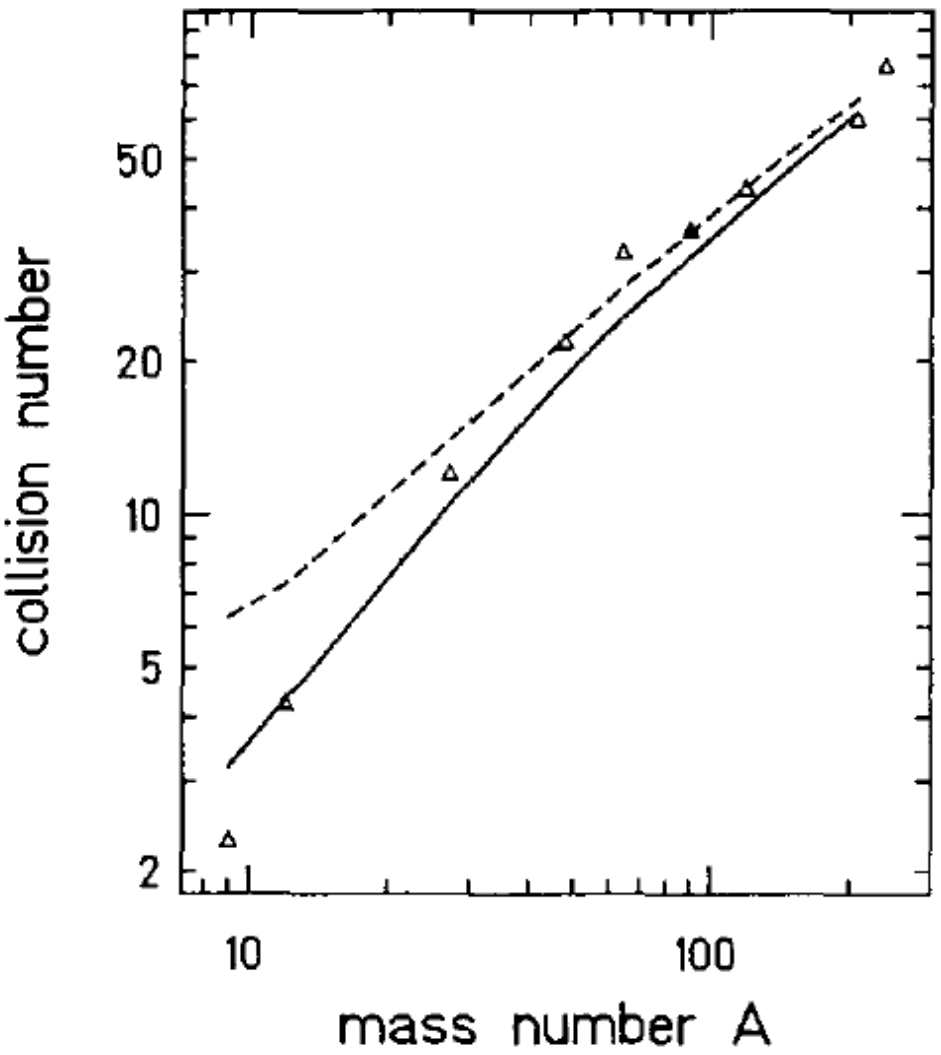


W.K.Wilson et al., PRC 57 (1997) 1865

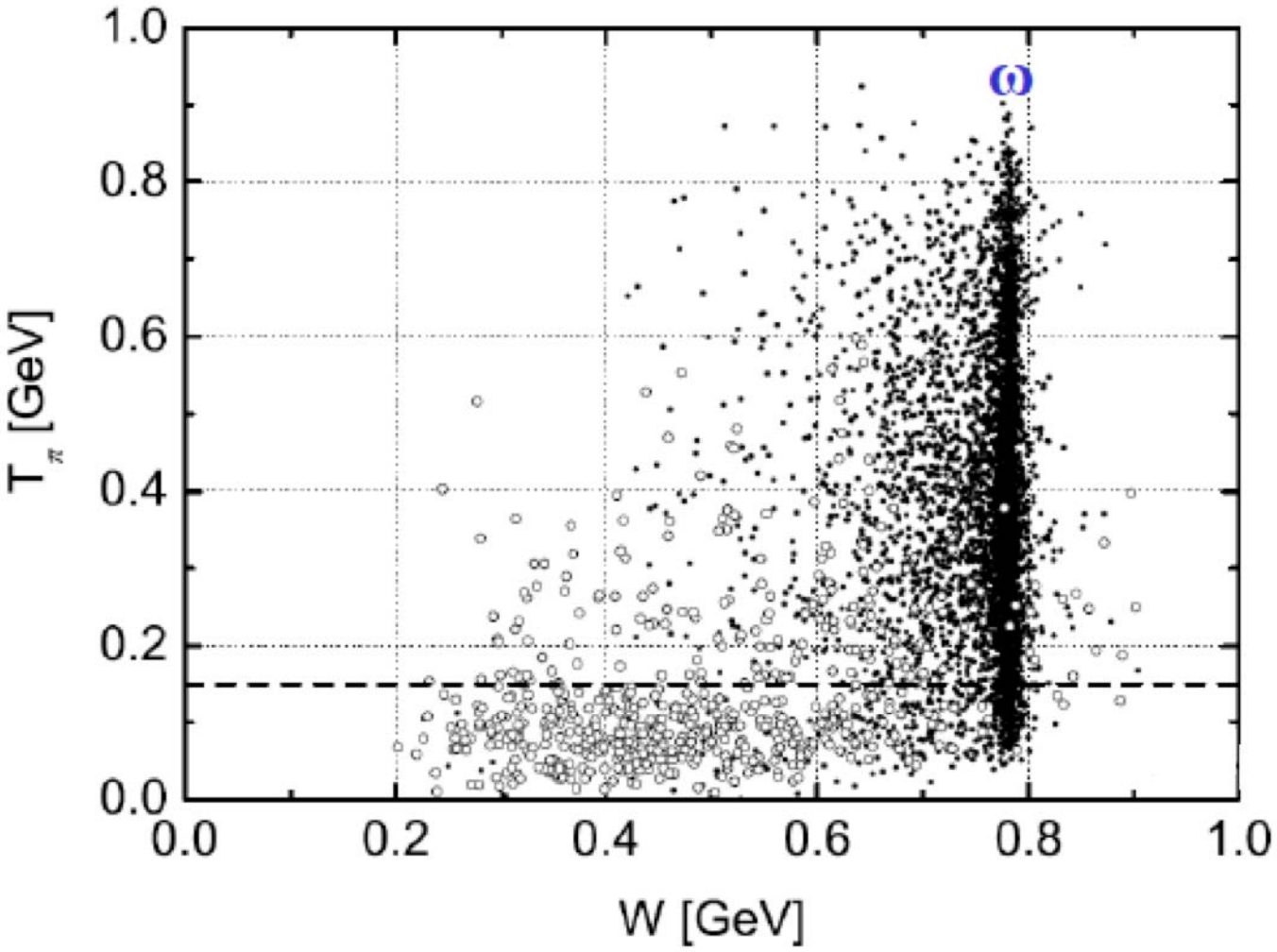
Normalization to cross section



Glauber model

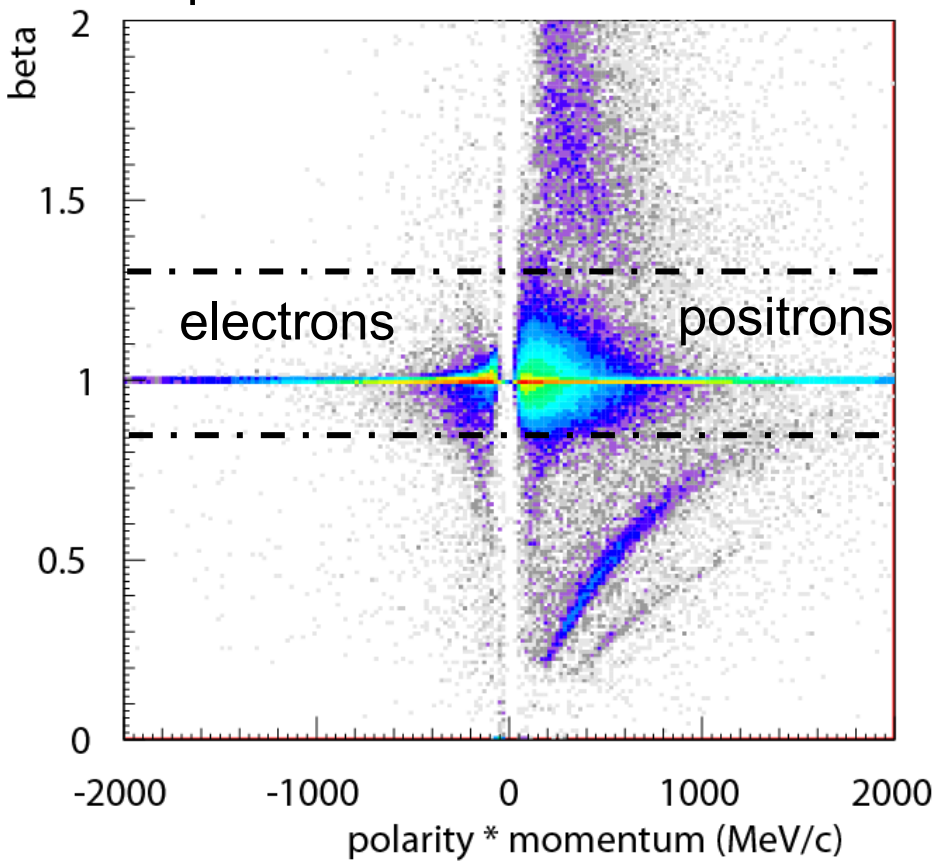


CB-ELSA/TAPS (sim)



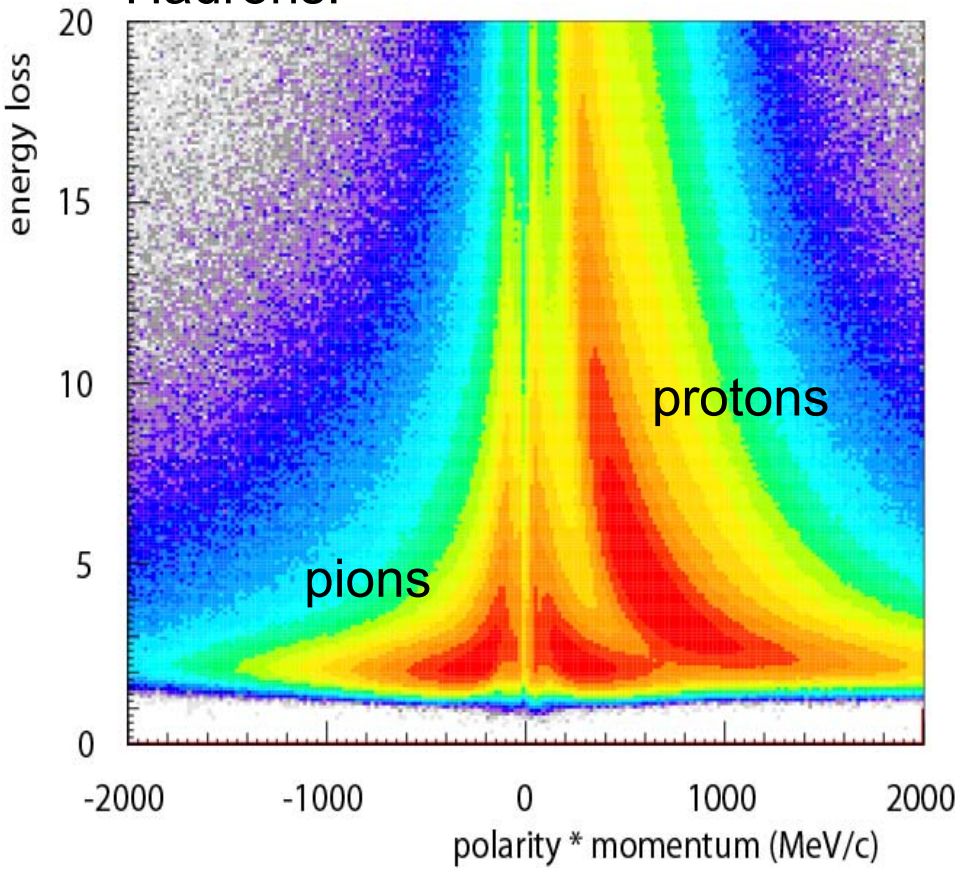
Particle identification (raus)

Leptons:



- RICH – track correlation
- Particle velocity

Hadrons:

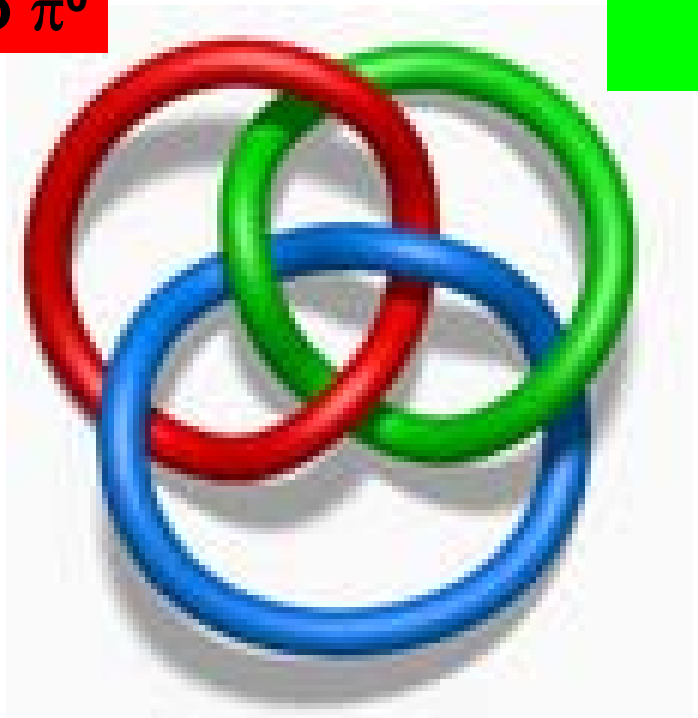


- energy loss

BUT: How to get information on ω?

Normalization to π^0

Isospin dependence (production)

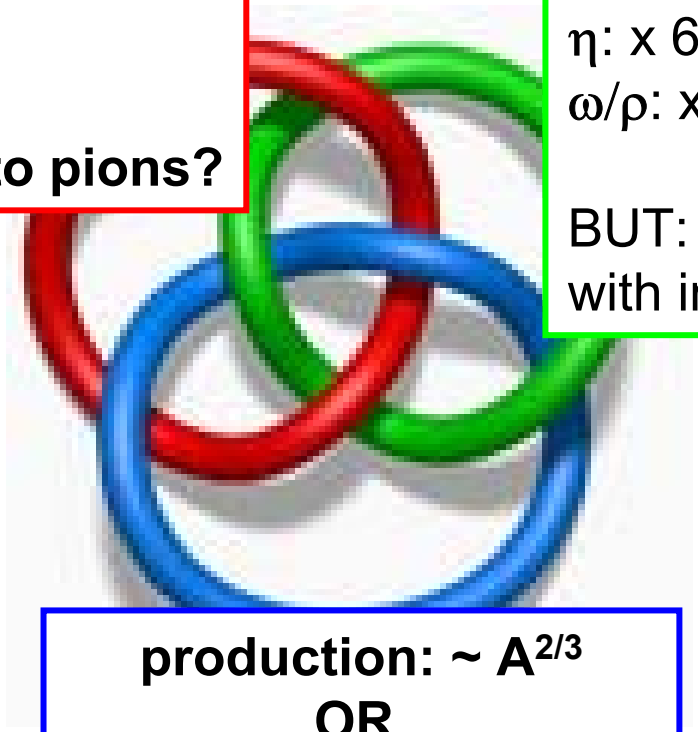


Mass dependence (production/absorption)

BUT: How to get information on ω?

- **isospin dependence ???**
- **mass dependence ???**
- **absorption**

→ **Do not normalize to pions?**



pn/pp production at threshold:

η: x 6.5 (Q_{HADES} = 750 MeV)
ω/ρ: x 2 (Q_{HADES} = 520 MeV)

BUT: decresing difference with increasing energy

H.Calen et al., PRC 58 (1998) 2667
S.Barsov et al., EPJA 21 (2004) 521

DLS

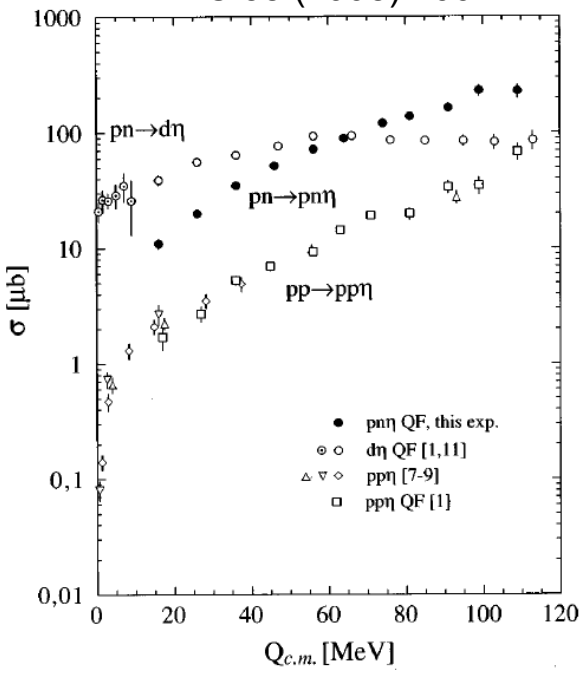
production: ~ $A^{2/3}$
OR
assume production ~ A
→ absorption

T.Tabaru et al.,
PRC 74 (2006) 025201

M.Kotulla et al.,
PRL 100 (2008) 192302

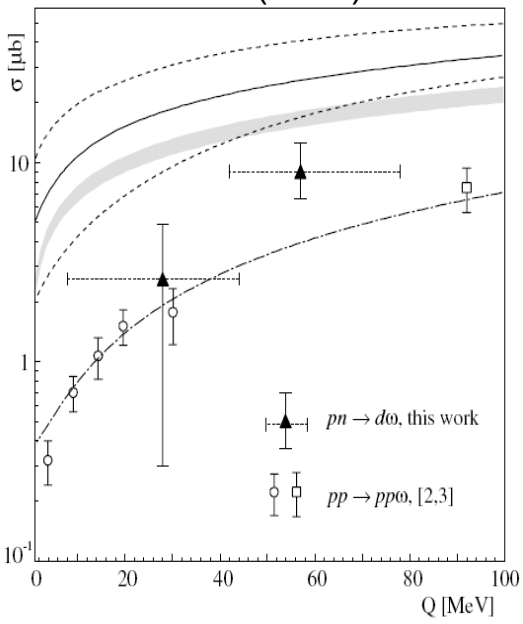
Meson production

H.Calen et al.,
PRC 58 (1998) 2667



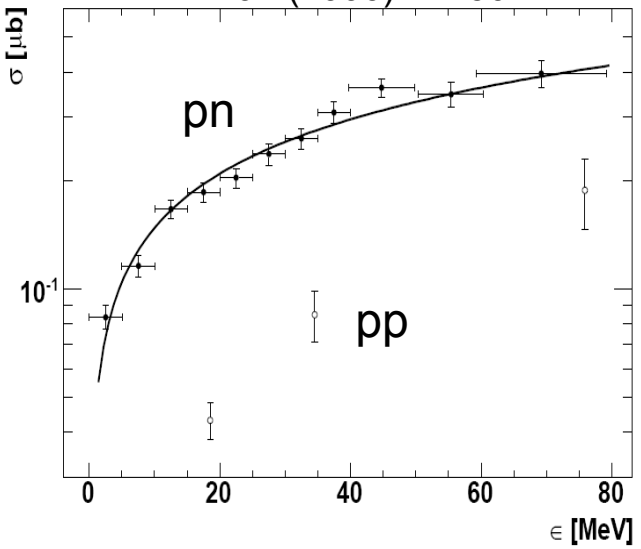
η: ×6.5

S.Barsov et al.,
EPJA 21 (2004) 521



ω: ×2

Y.Maeda et al.,
PRL 97 (2006) 142301

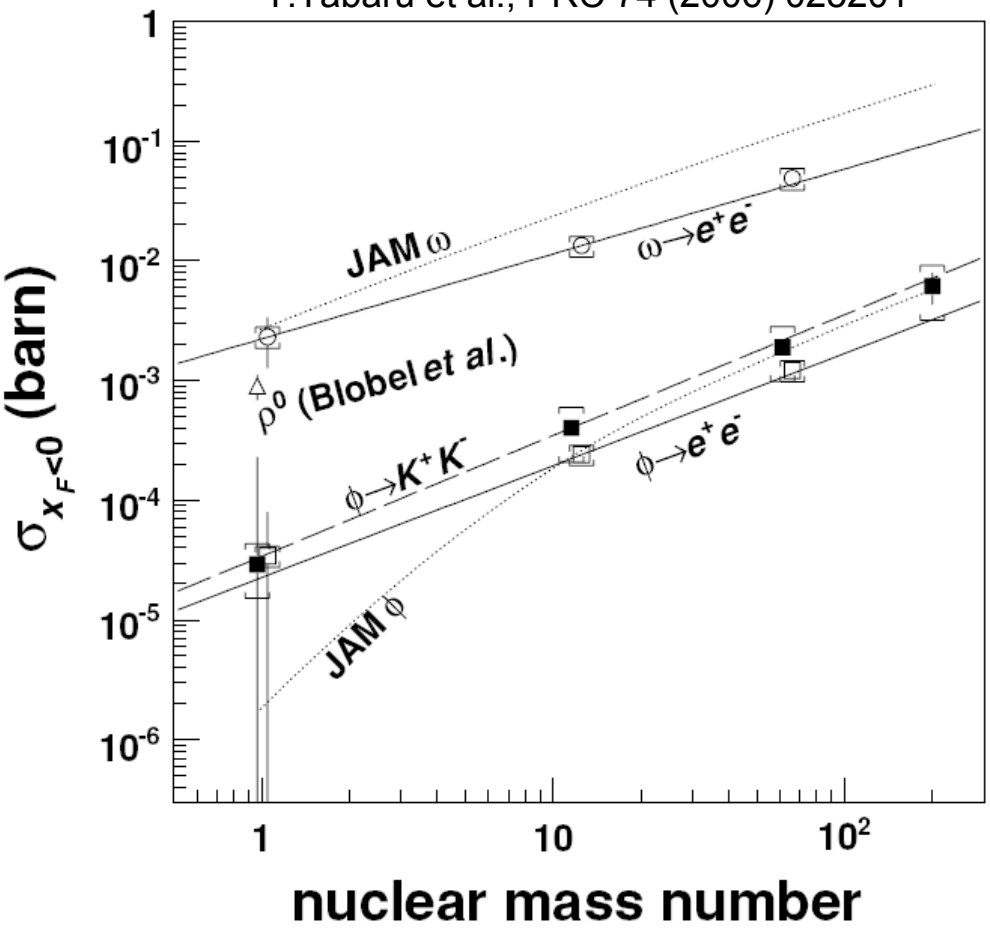


Φ: ×2

Excess of meson production in pn over pp
expected close to threshold (factor 2) and smaller at higher energies
→ See more omegas and phis in pA than pp

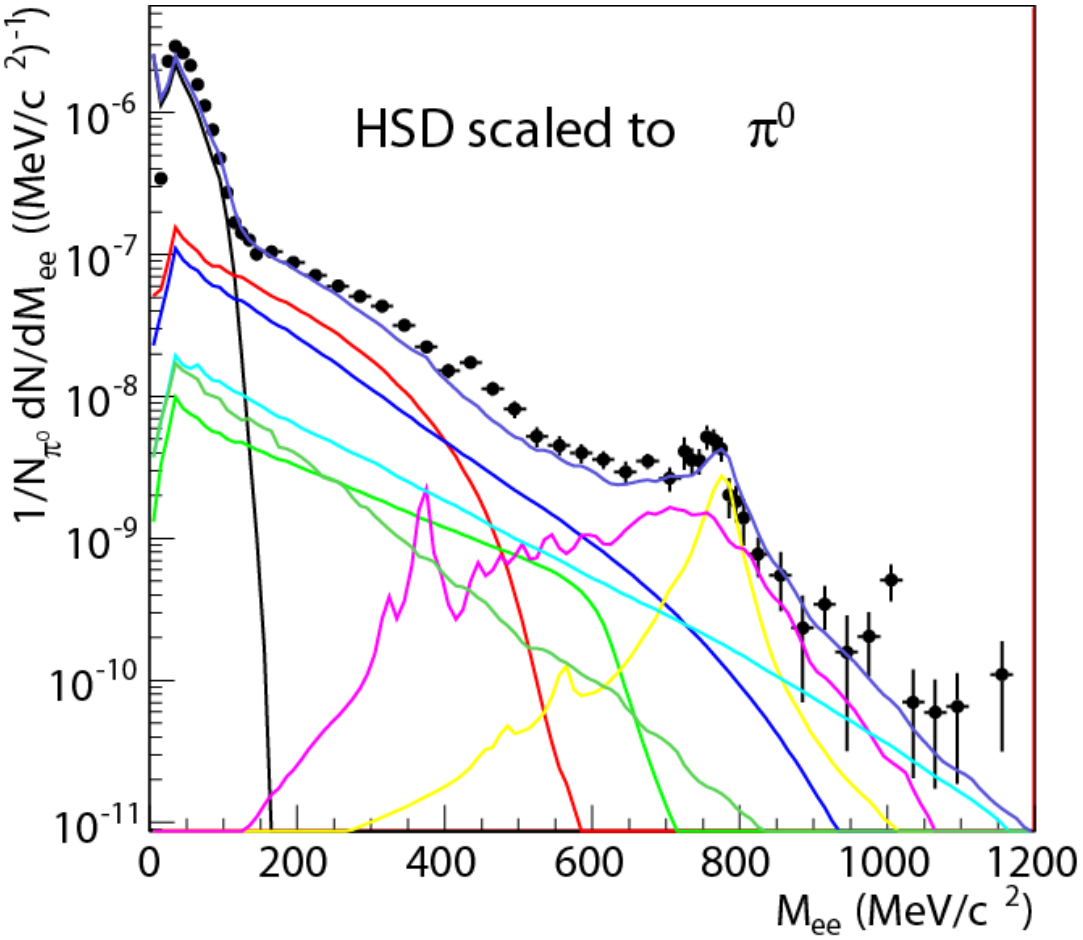
Meson production

T.Tabaru et al., PRC 74 (2006) 025201



- Phi : A^0.937
- Omega: A^0.710

HSD


HSD scaled to π0
1/Nπ0 dN/dMee ((MeV/c 2)-1)
10-6
10-7
10-8
10-9
10-10
10-11
0
200
400
600
800
1000
1200
Mee (MeV/c 2)