Probing cold nuclear matter with virtual photons

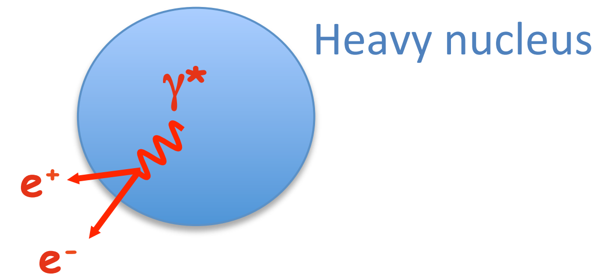
Outline:

- Virtual photons in cold nuclear matter
- HADES
- Slow and fast e^+e^- pairs
- Nuclear modification factor
- Conclusion

Michael Weber, Manuel Lorenz, Anar Rustamov and Pavel Tlusty for the HADES collaboration

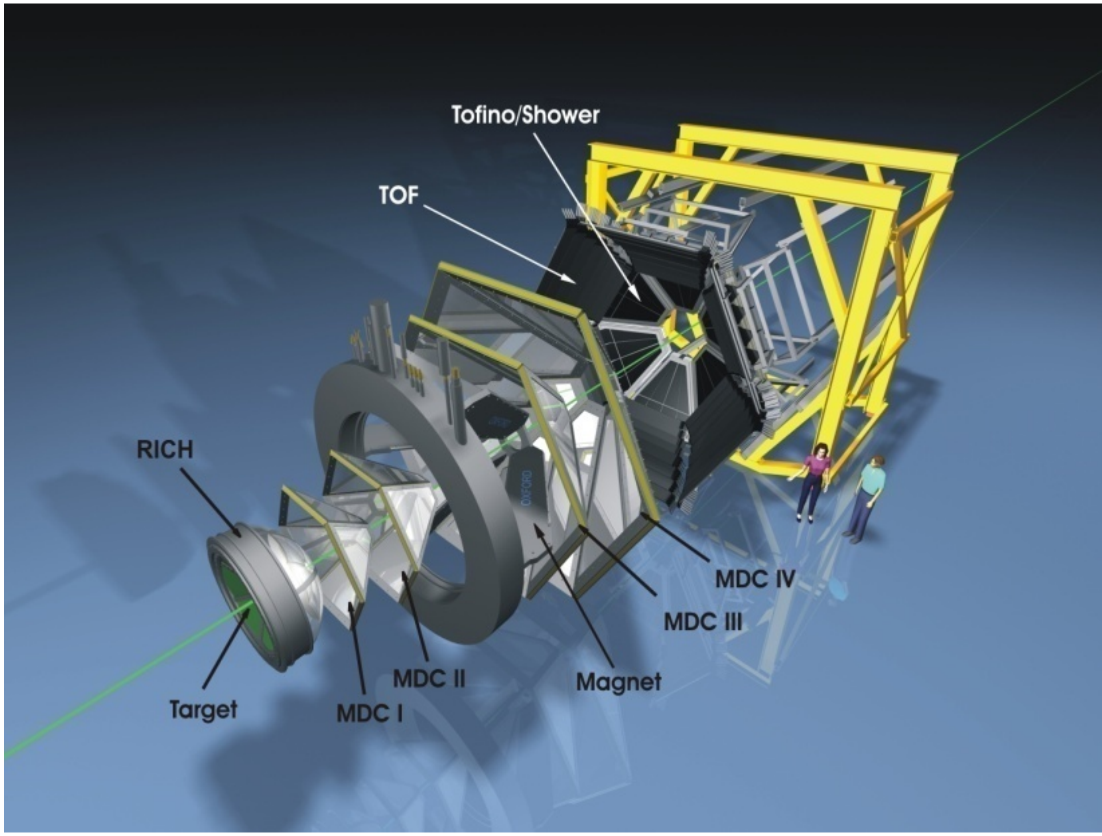
Virtual photons in cold nuclear matter

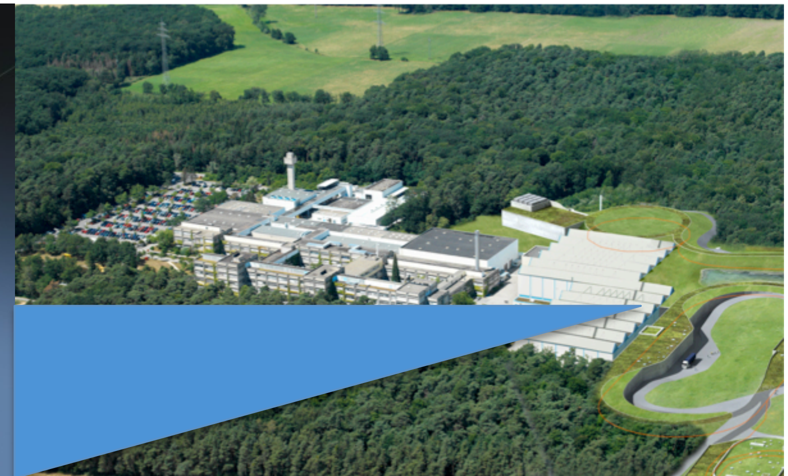
- EM structure / Vector mesons in matter
- Decay in e^+e^-:
  - Weak interactions with surrounding medium
  - Other sources (conversion, Dalitz decays)



- Experiments:
  - Shape measurements (spectral function)
  - Absorption (total width)
- Results (Spring8, KEK - E328, JLab – CLAS, CB/TAPS@ELSA, ANKE)
  - Broadening
  - Pole mass shift?
  - Difficult interpretation (Differences in Background determination, ρ contribution, decay kinematics, …)

HADES@GSI

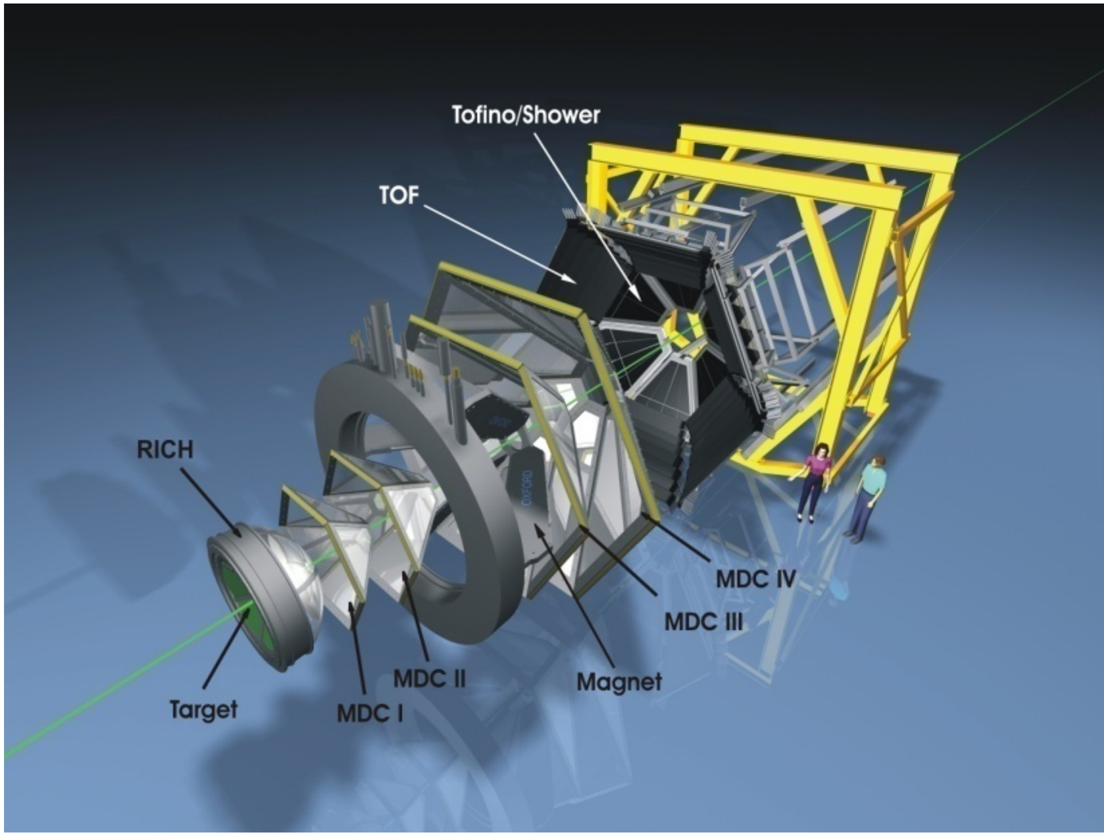


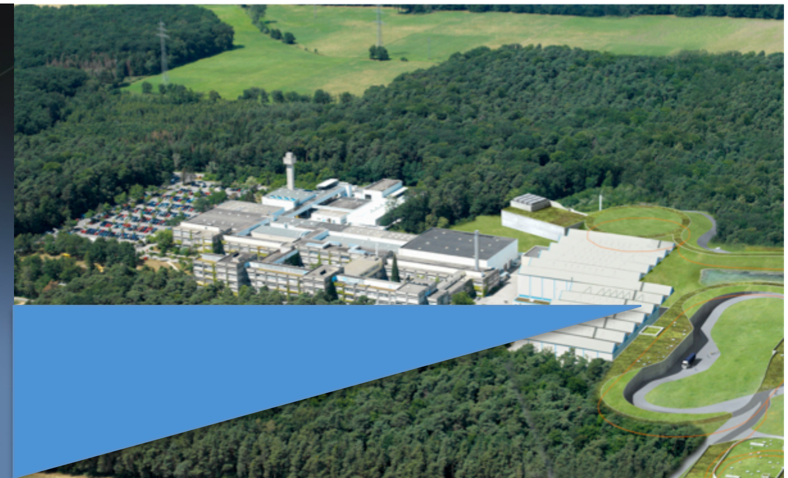


Observable	Detector
p	MDC (Magnet)
β	TOF(ino)
dE/dx	MDC TOF(ino)
e^+/e^-	RICH Pre-Shower

<u>Data sets:</u> protons with E_{kin} = 3.5 GeV
- pNb (cold nuclear matter)
- pp (reference)

HADES@GSI





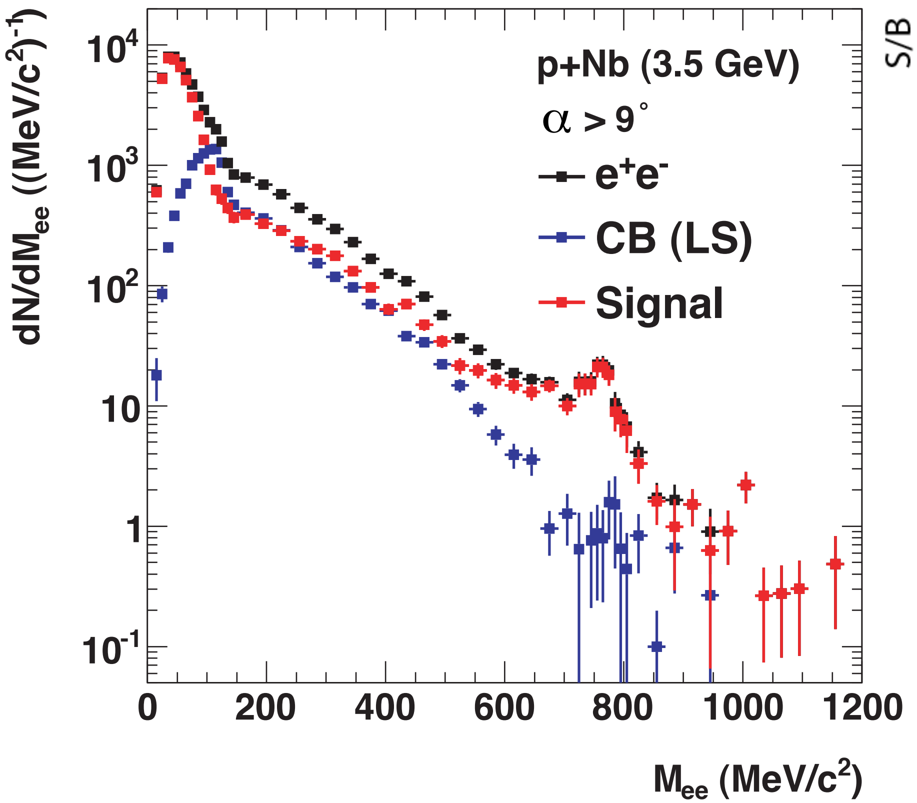
Data sets: protons with $E_{kin} = 3.5$ GeV

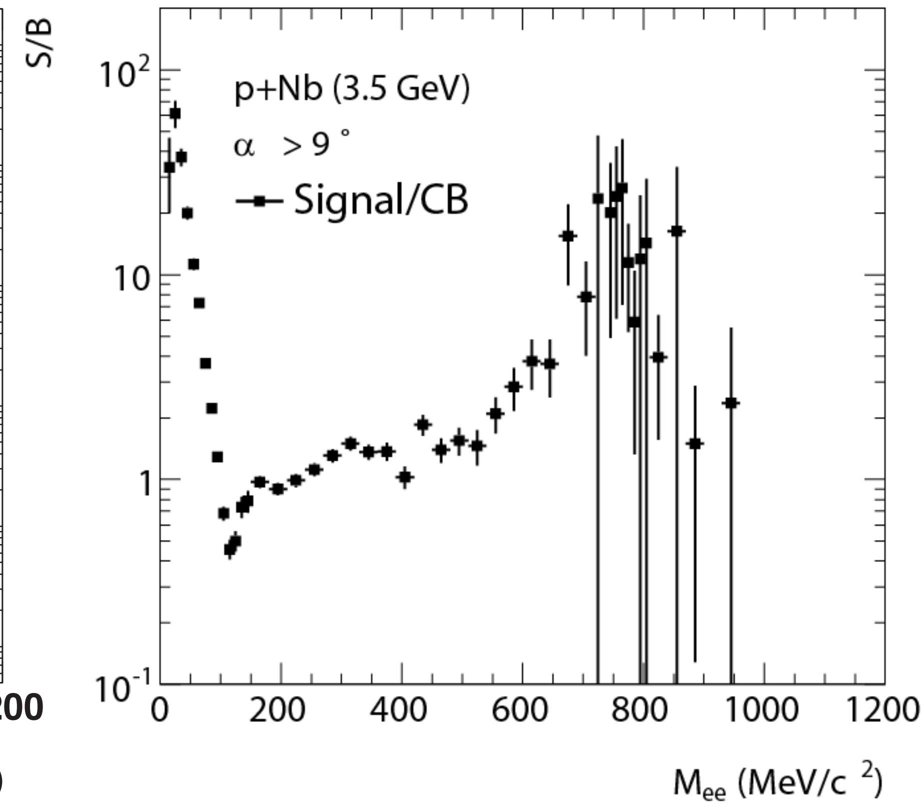
- pNb (cold nuclear matter)
- pp (reference)

See also:

- „In-medium modification of hadrons", Piotr Salabura
- „Neutral kaon production in pp and pNb collisions", Kirill Lapidus

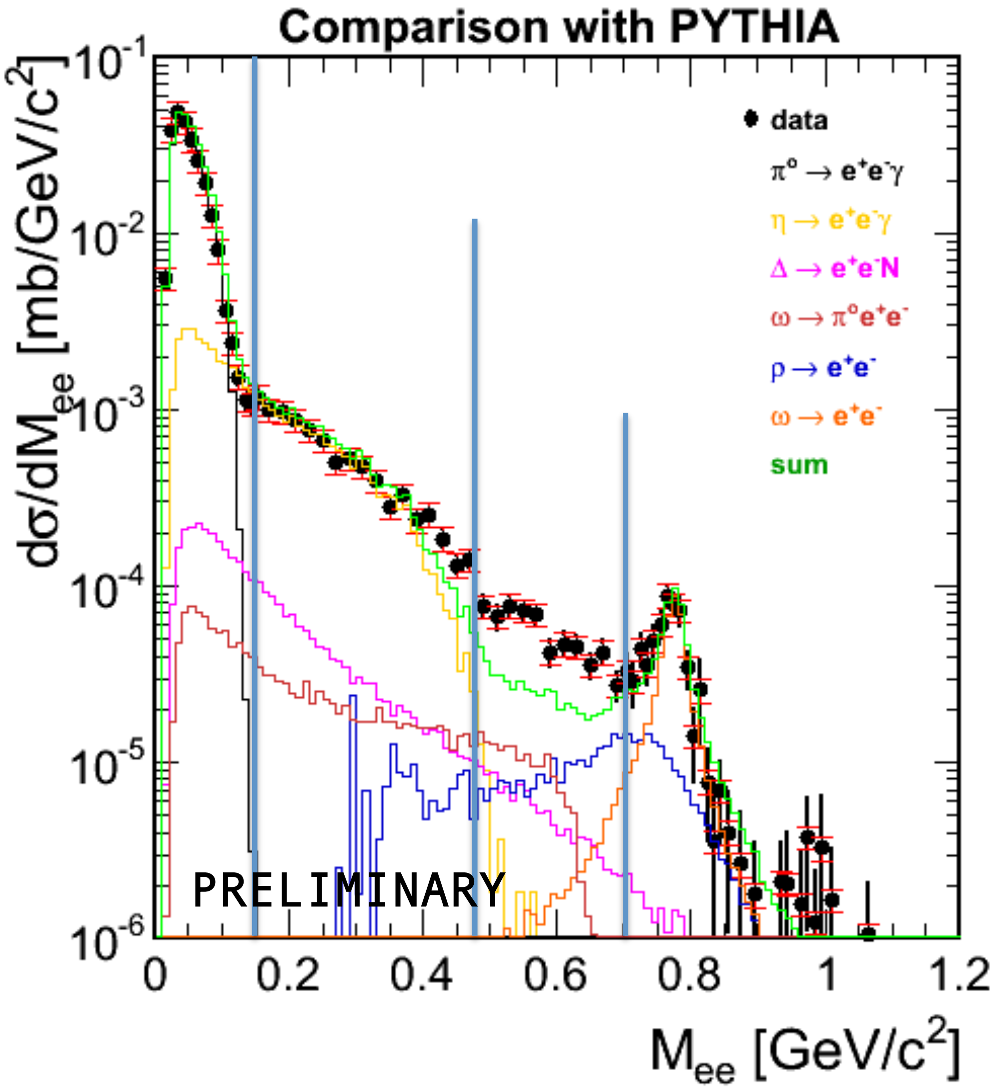
e^+e^- Invariant Mass





- Signal = all e^+e^- pairs – same event Like Sign CB
- S/B ~ 10 in vector meson mass region
- Mass resolution: σ_ω~15 MeV/c^2
- 2 independent PID: **H**ard **C**uts and **M**ulti **V**ariate **A**nalysis

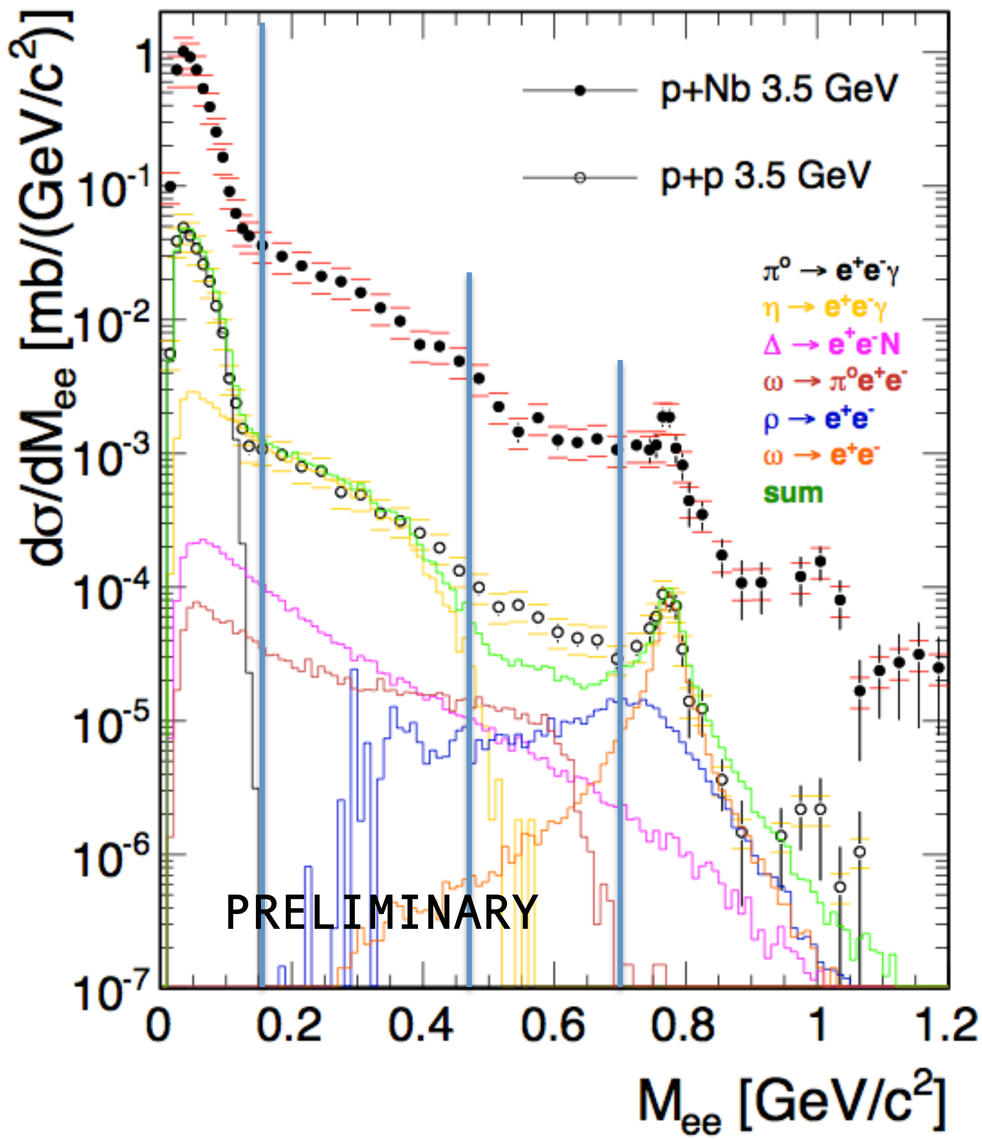
Reference: pp (E_{kin} = 3.5 GeV)



Separate 4 mass regions:

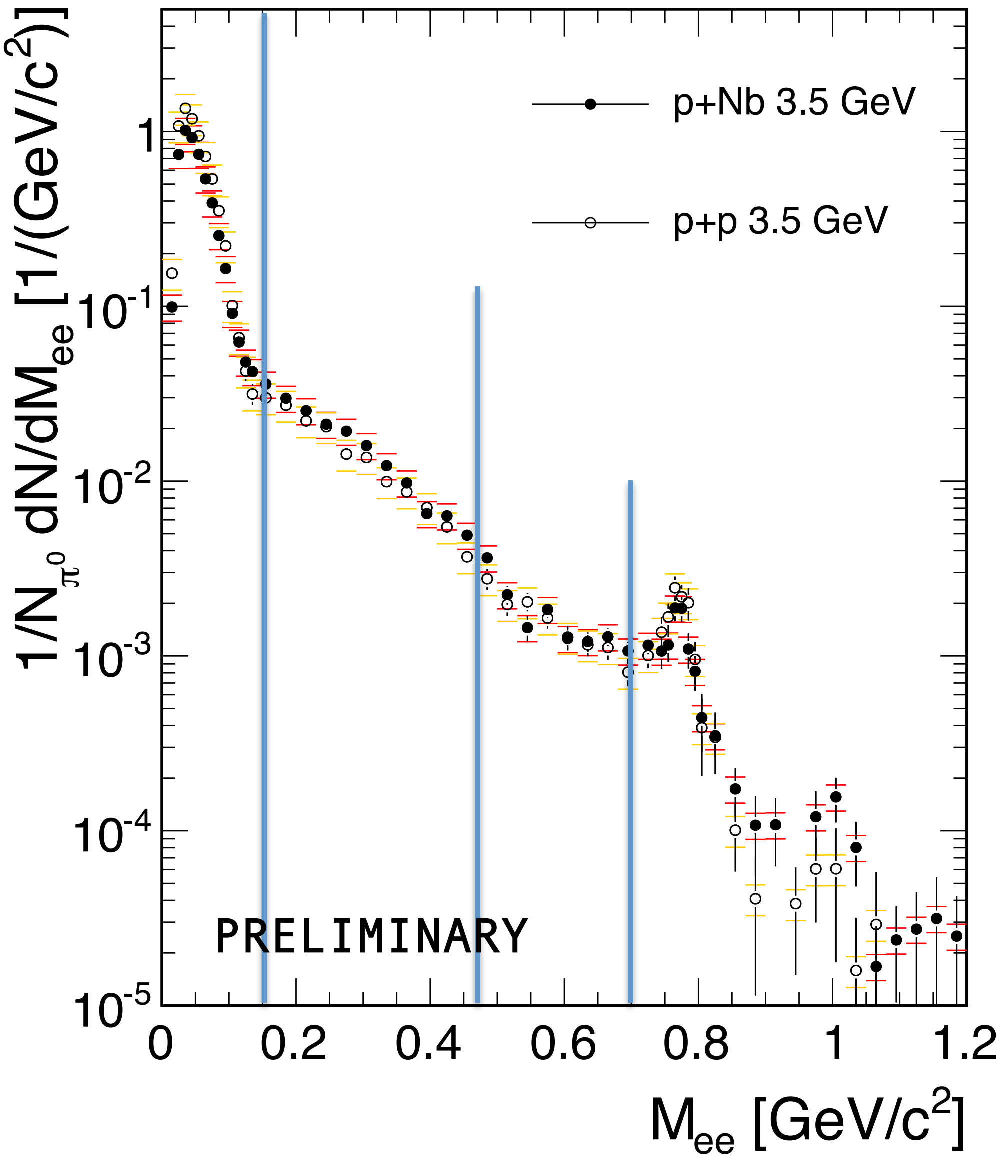
- π^0 :
  $0.00 < M_{ee}$ (GeV/c^2) < 0.15
- η :
  $0.15 < M_{ee}$ (GeV/c^2) < 0.47
- Δ, ρ, ω Dalitz :
  $0.47 < M_{ee}$ (GeV/c^2) < 0.70
- ω, ρ, ϕ :
  $0.70 < M_{ee}$ (GeV/c^2) < 1.20

Cold nuclear matter: pNb (E_{kin} = 3.5 GeV)



- Normalization:
  - pp: elastic collisions
  - pNb: negative pion yield
- Pion scale with ~ $A^{0.7}$
  - Expected for surface production
- Shape analysis:
  - Relative to π^0 yield
- Nuclear modification factor

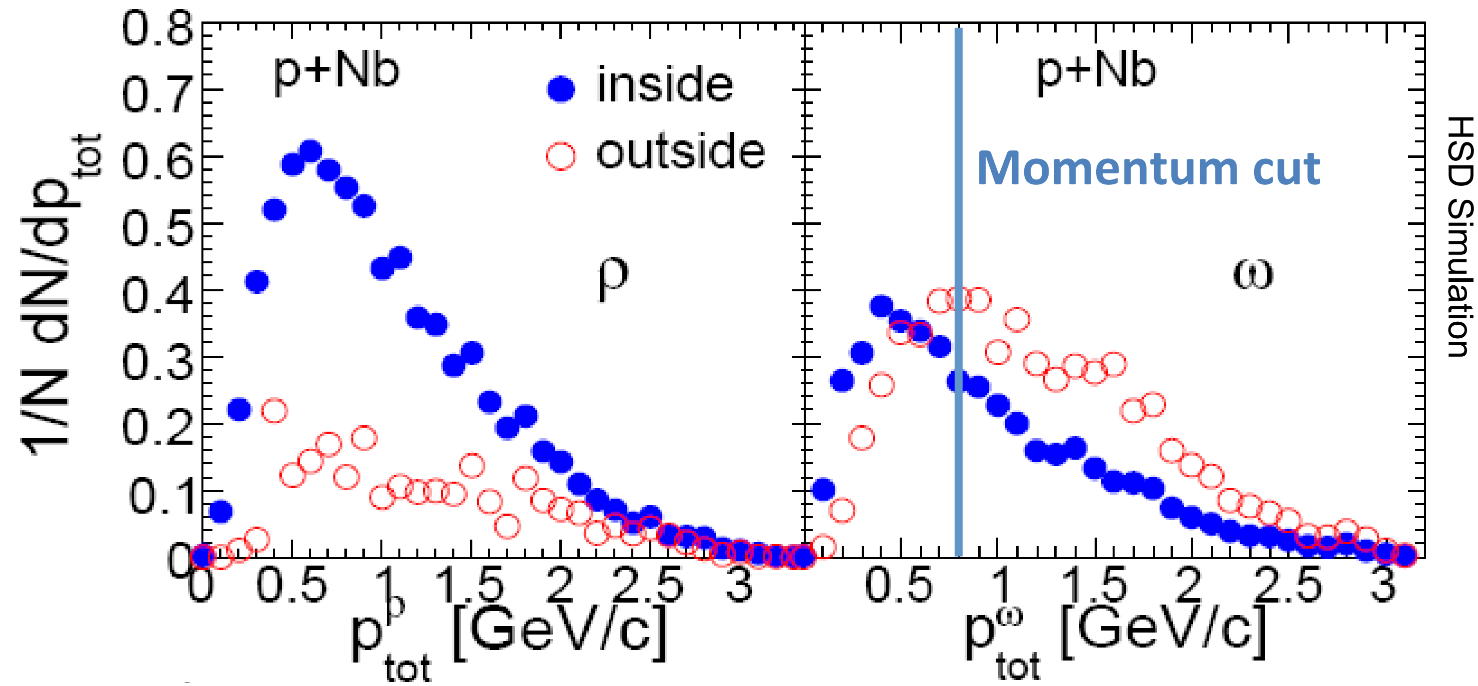
Comparison: pNb vs. pp



- Shape analysis
- Scaled with the number of π^0

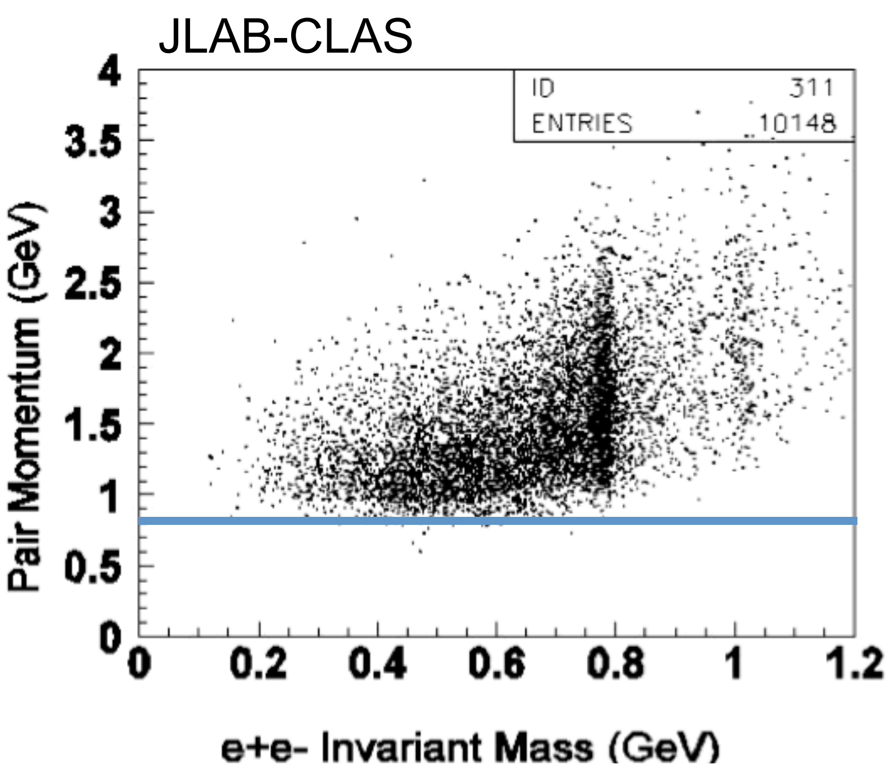
- Different production and/or absorption processes dominant for different e^+e^- sources

Pair momenta

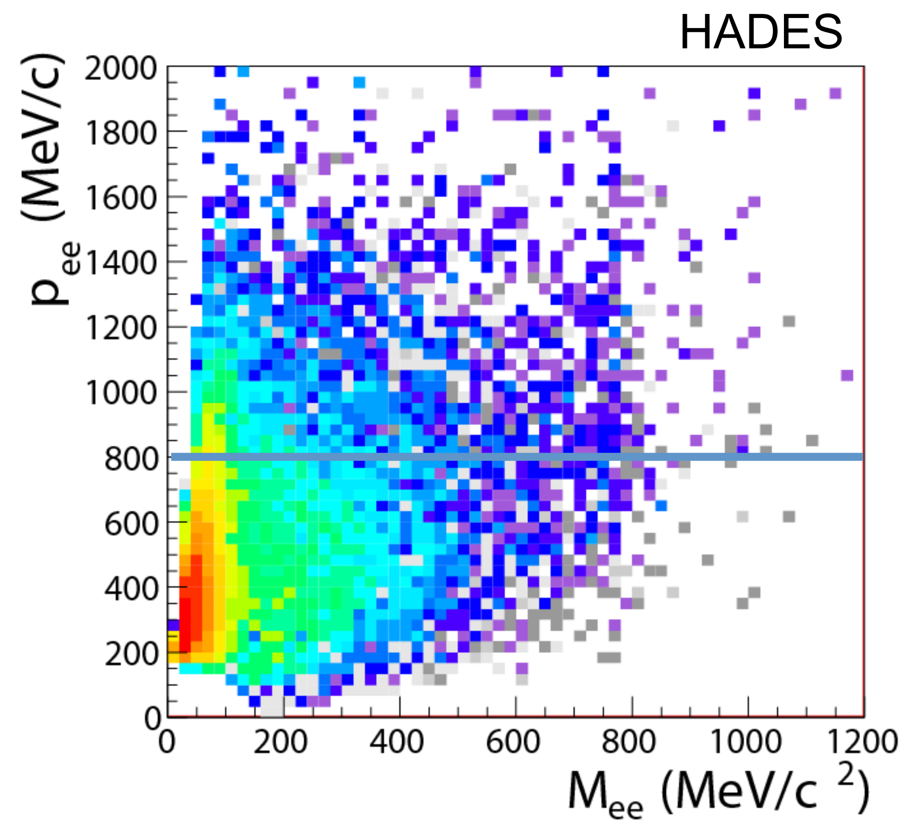


- Enrich in-medium decays of vector mesons

Pair momenta

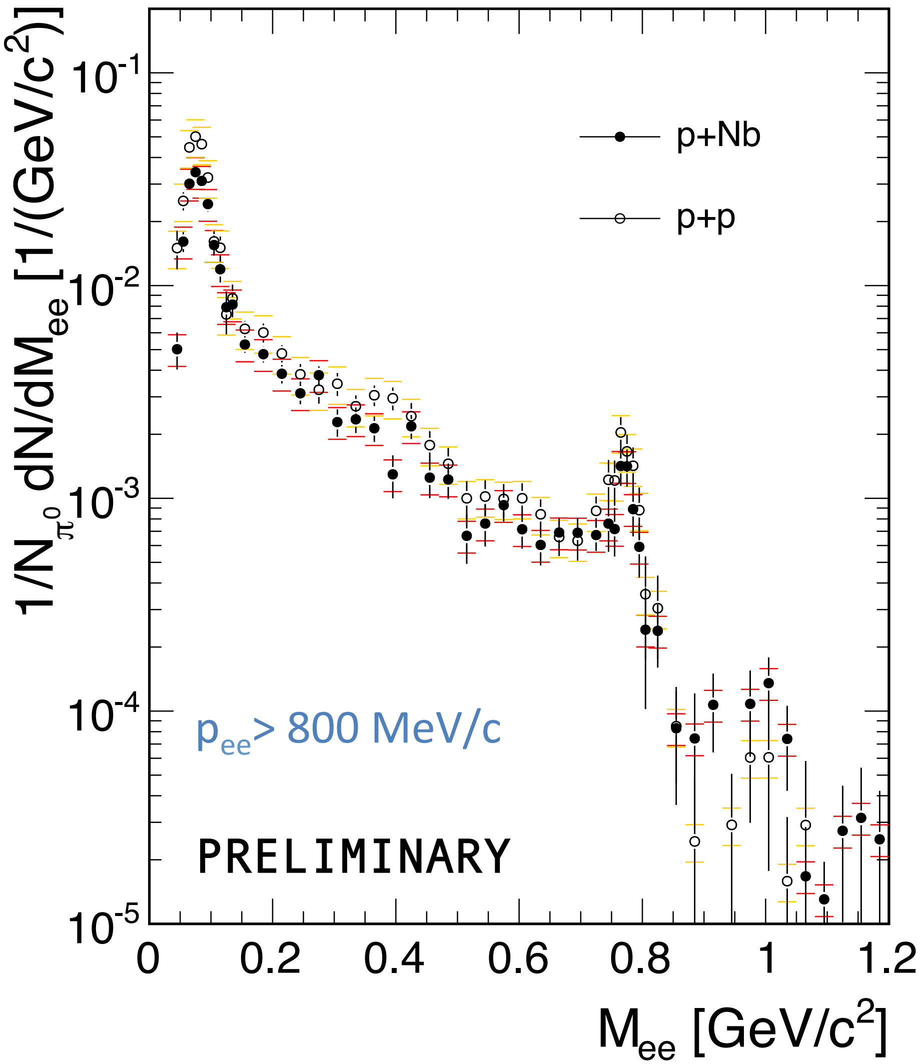


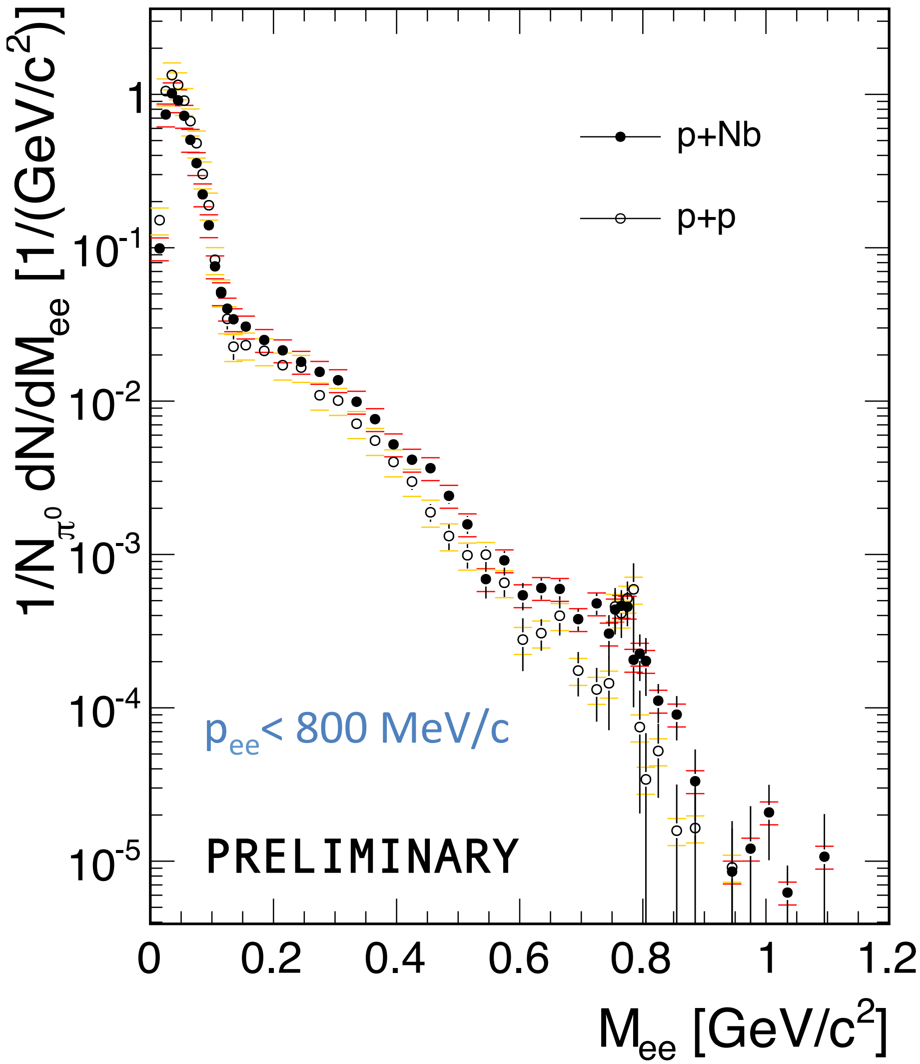
S.Leupold, V.Metag and U.Mosel, nucl-th 0907.2388



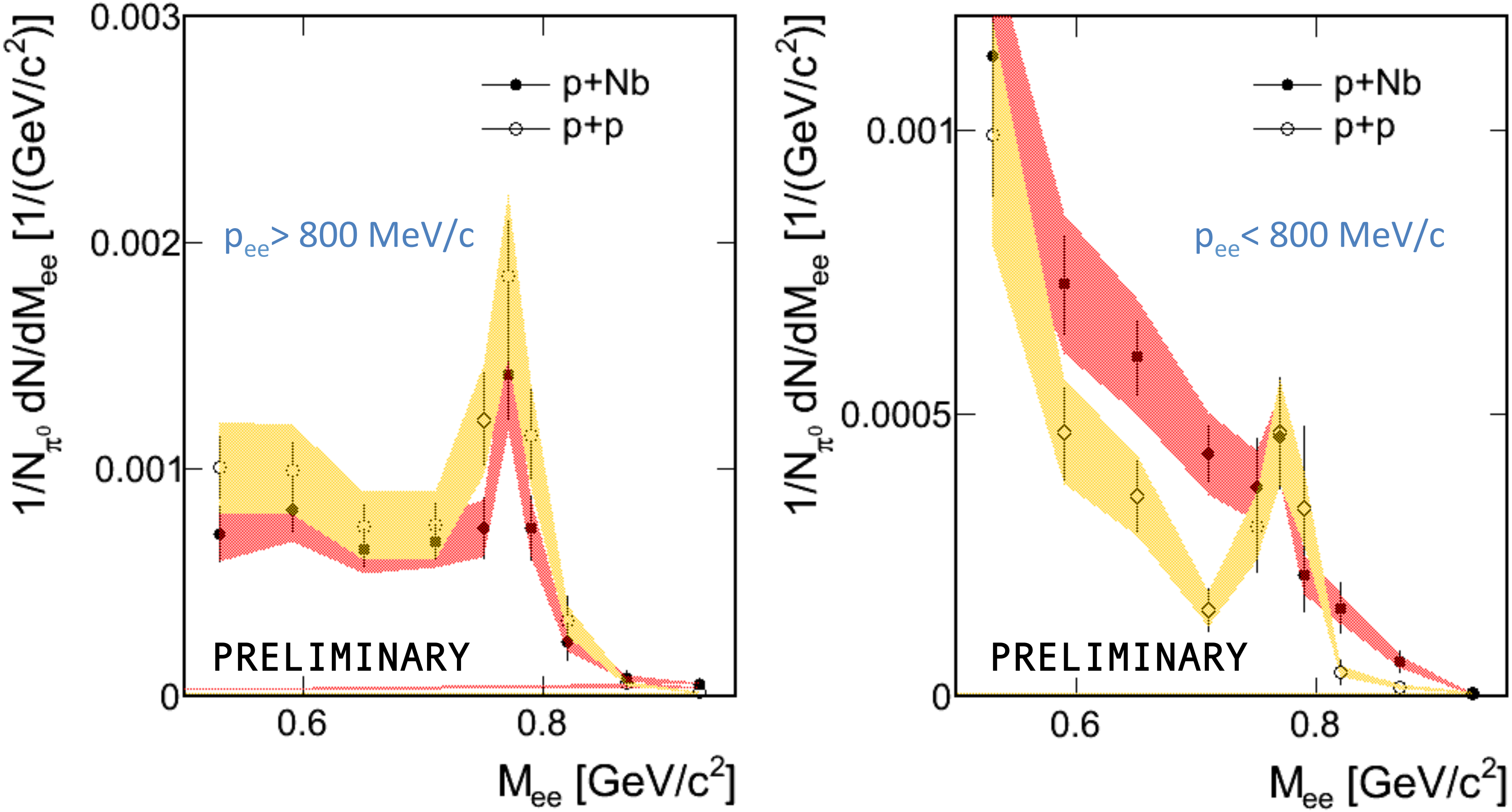
- Enrich in-medium decays of vector mesons
- HADES: Significant e^+e^- yield with p_{ee}< 800 MeV/c (~ 35 % in VM mass region)

Slow and fast pairs



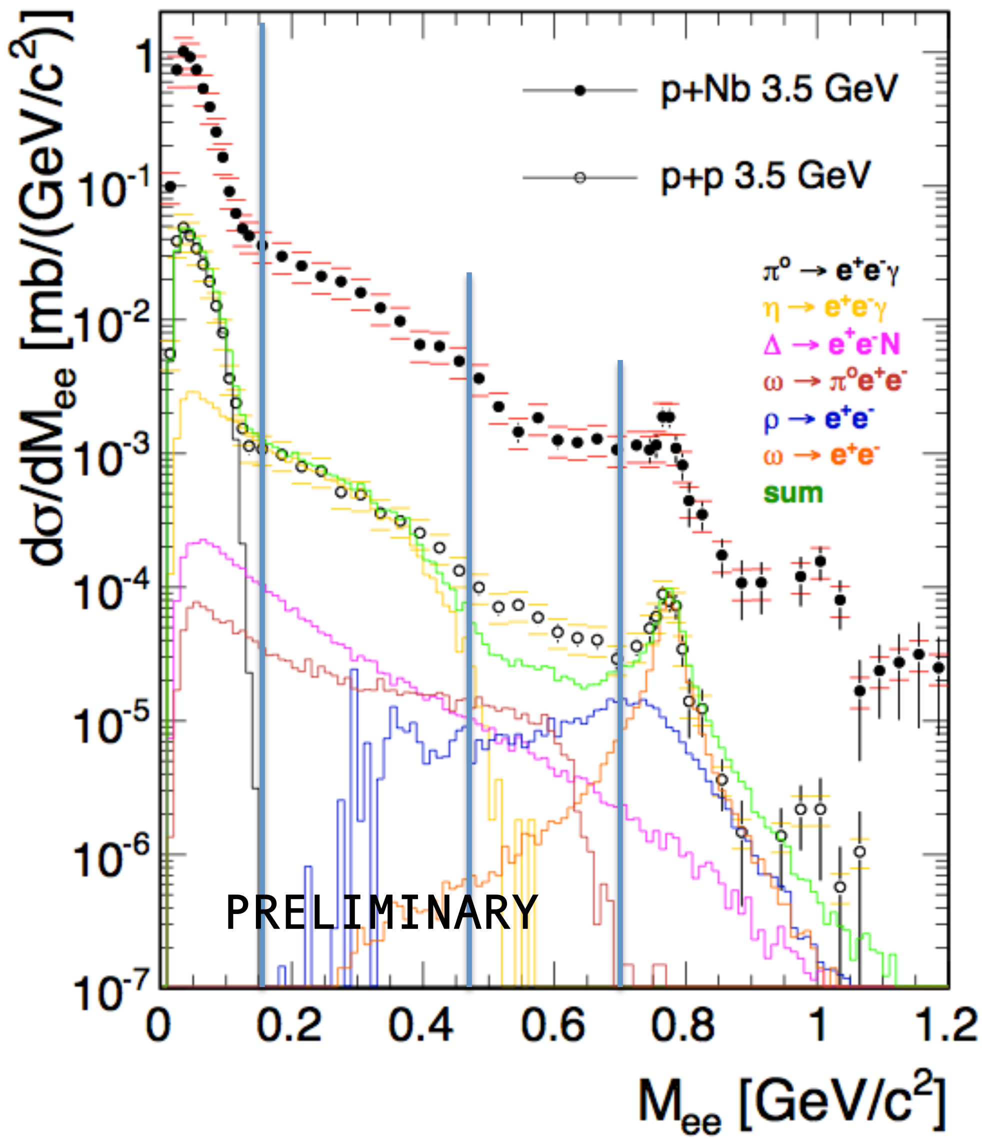


Slow and fast pairs



- High p: free p+p production
- Low p: overshoot over p+p - different for ρ, ω, and ϕ

Nuclear modification factor



$$R_{pA} = \frac{A_{part}^{pp} \cdot dN / dp^{pNb}}{A_{part}^{pNb} \cdot dN / dp^{pp}}$$

$$= \frac{A_{part}^{pp} \cdot \sigma_{reaction(pp)} \cdot d\sigma / dp^{pNb}}{A_{part}^{pNb} \cdot \sigma_{reaction(pNb)} \cdot d\sigma / dp^{pp}}$$

$$\frac{\sigma_{reaction(pNb)}}{\sigma_{reaction(pp)}} = 20,5 = (A)^{0.67}$$

$R_{pA} = 1$: No In-Medium effects

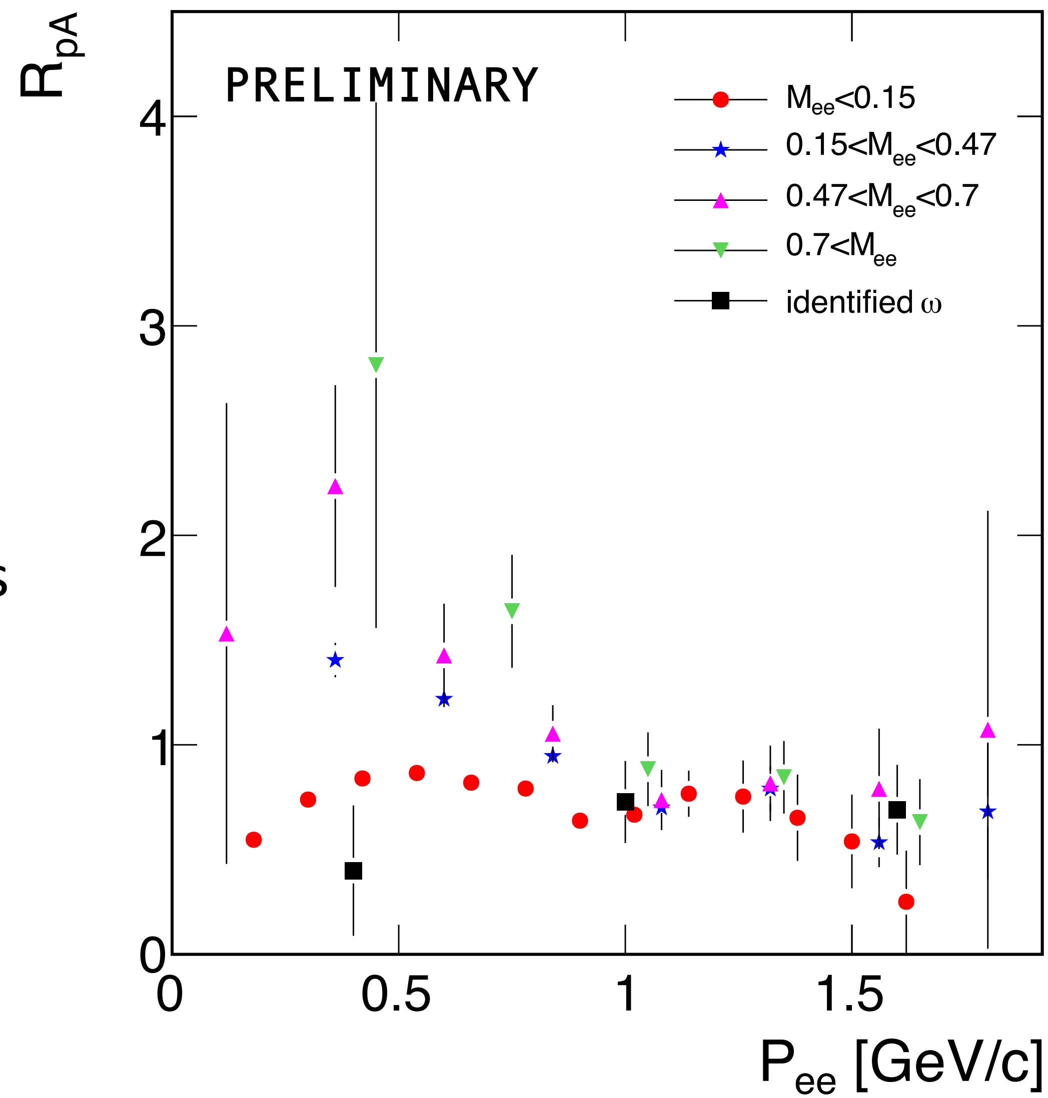
$R_{pA} > 1$: Excess

$R_{pA} < 1$: Suppression

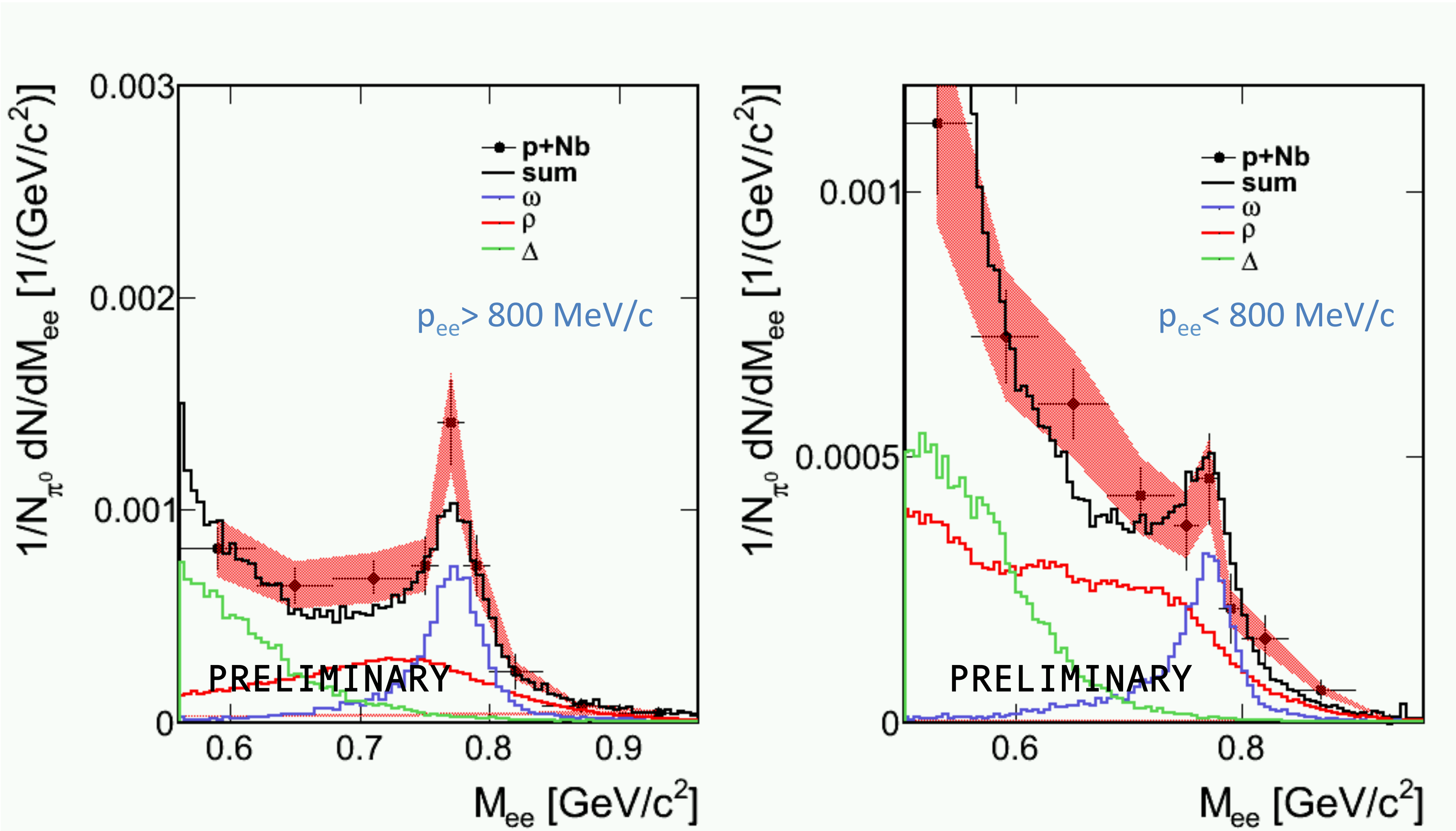
Nuclear modification factor

At low pair momenta:

- Pions ~ const
- Strong excess of
  ρ, Δ type sources
  – Secondary reactions
  – Isospin dependence
- ω: Trend to absorption

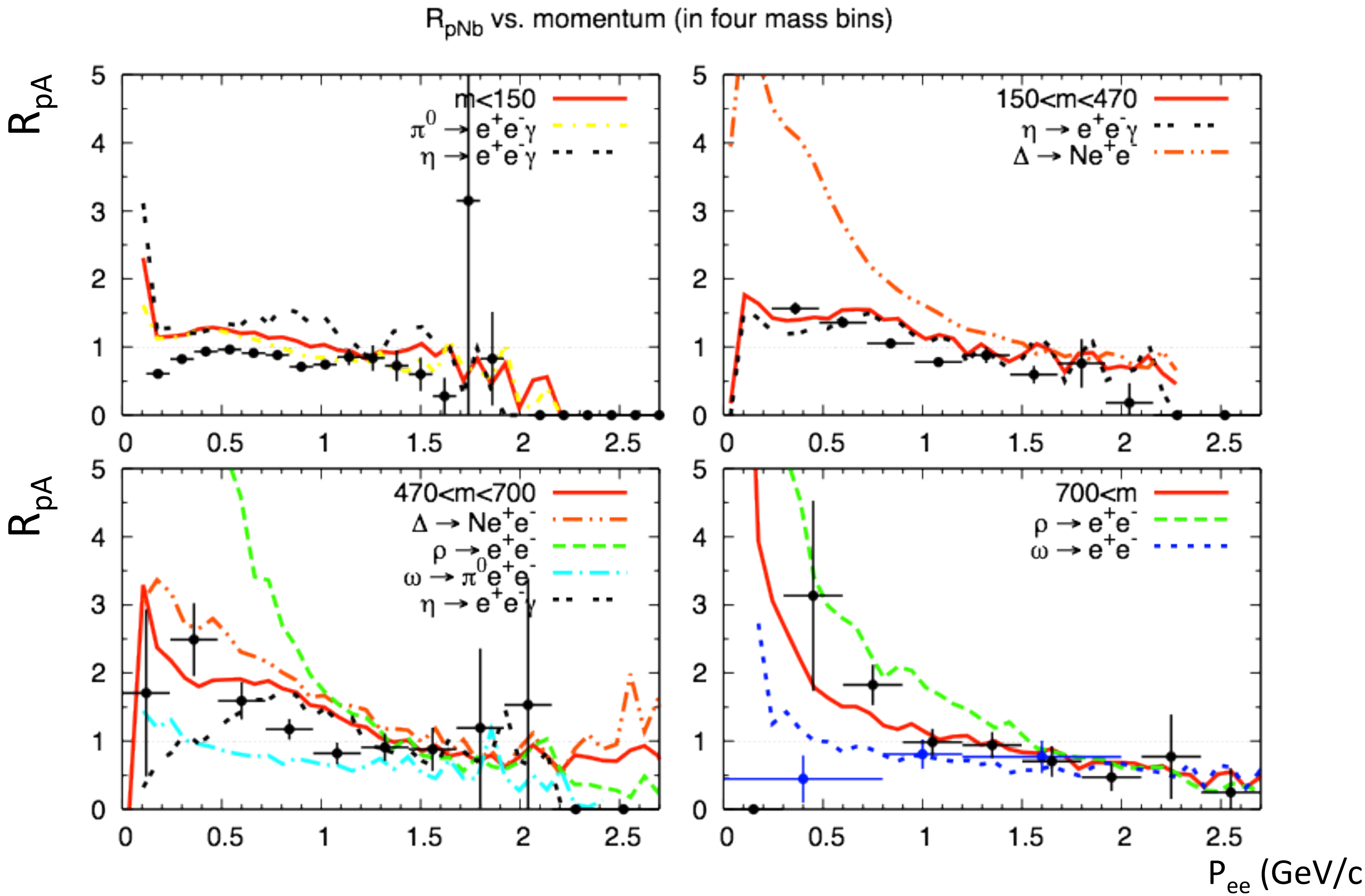


Transport model calculations



J. Weil, GIBUU [http://arxiv.org/abs/1106.1344]

Transport model calculations



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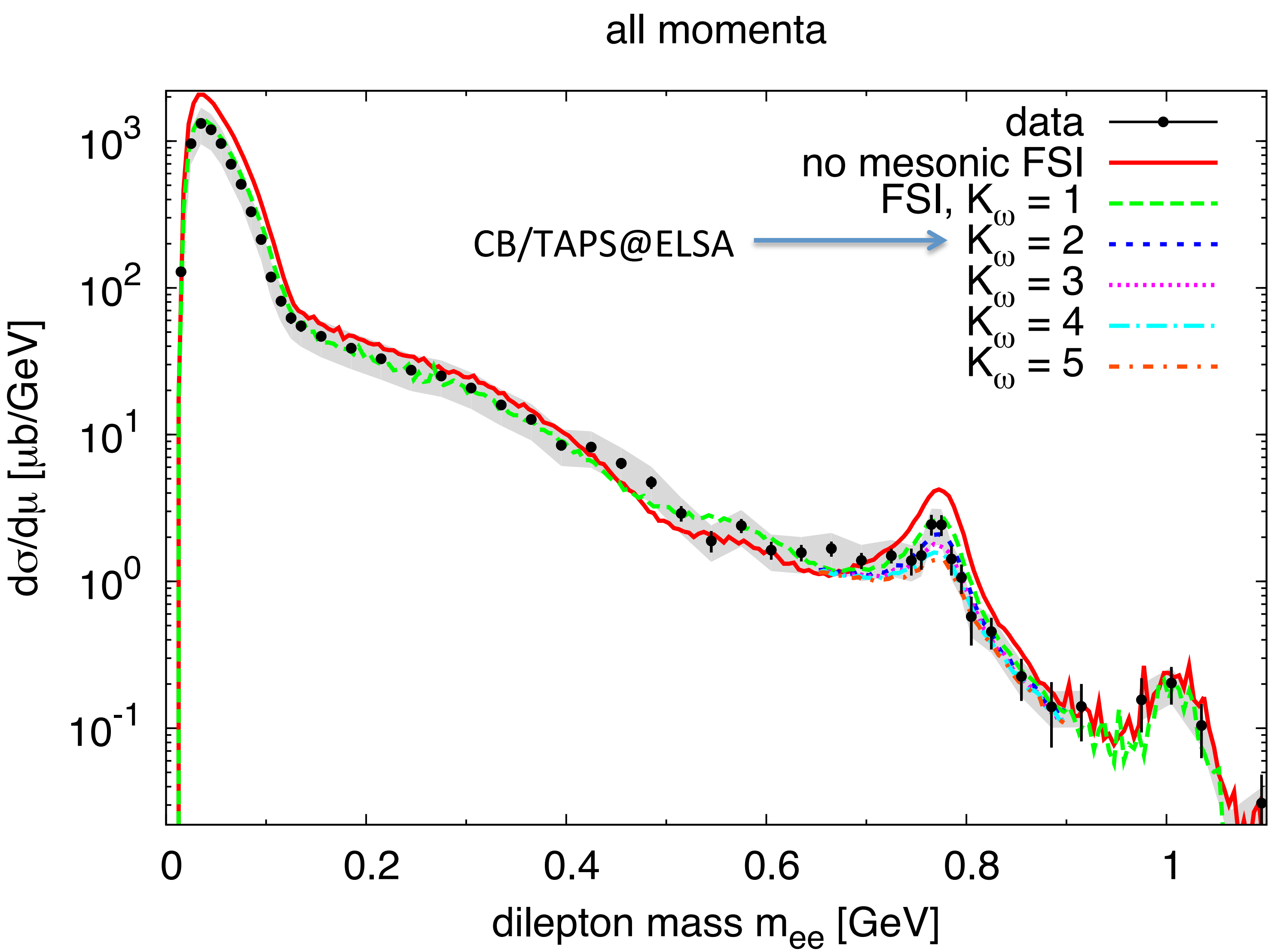
Transport model calculations



J. Weil, GIBUU [http://arxiv.org/abs/1106.1344]

Conclusion

- Relative yield

  In π^0/ω region ~ 1.0
  Other sources ~ 1.5

- Fast and slow pairs

  High p: p+Nb = p+p
  Low p: excess (secondary reactions)
  ω absorption?

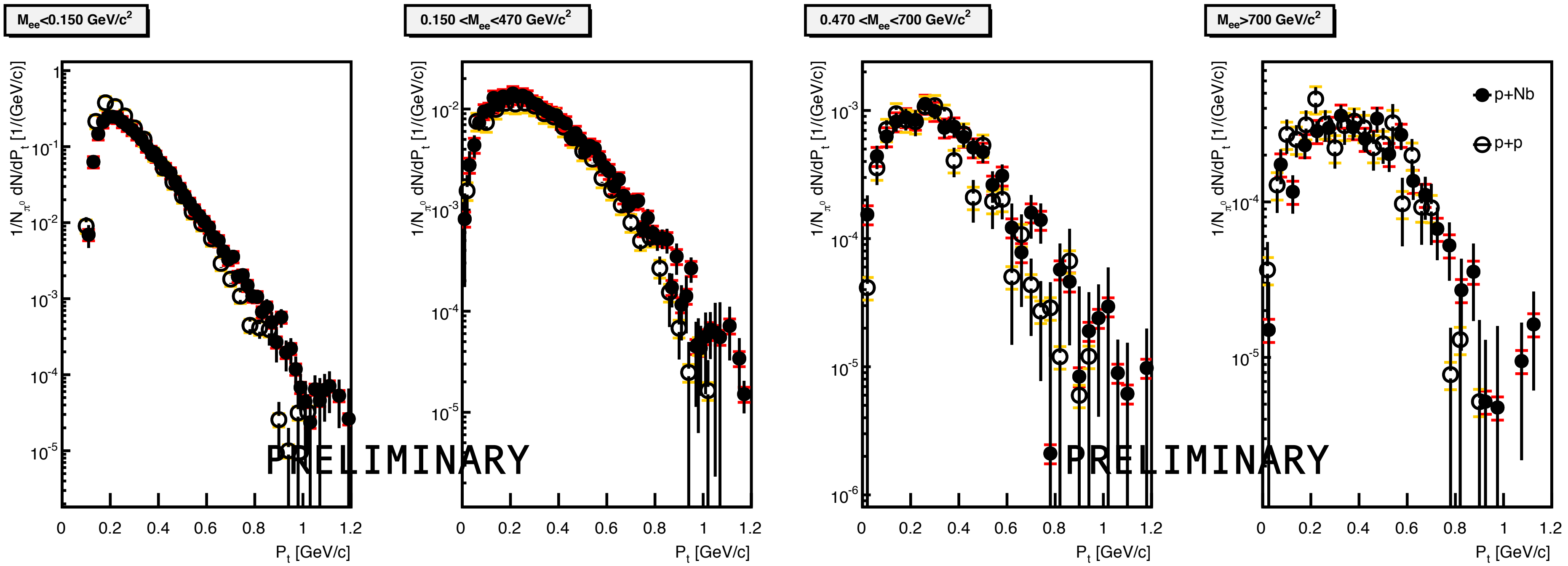
- Nuclear modification factor

  High p: $R_{pNb} = 0.8 – 0.9$
  Low p: $R_{pNb} = 0.8 – 2.5$

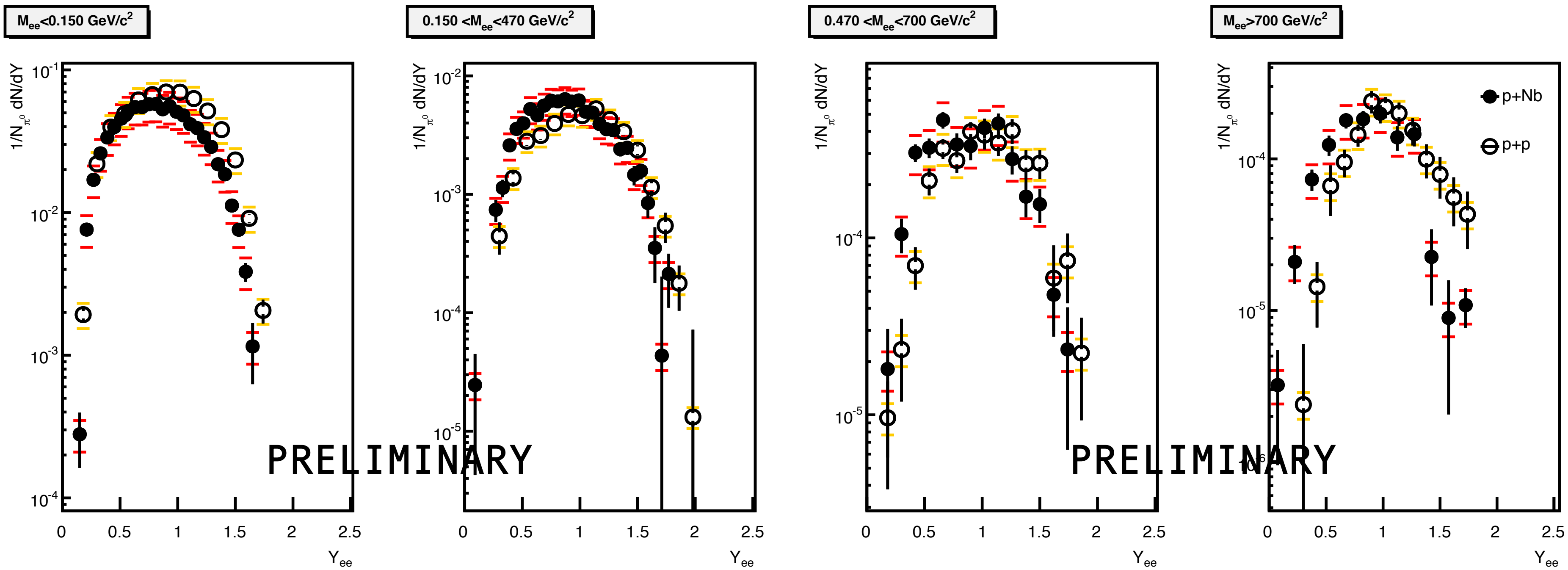
- Have to understand production mechanisms in primary and secondary reactions:
  - Transport models
  - π beam experiments

BACKUP

Transverse momenta



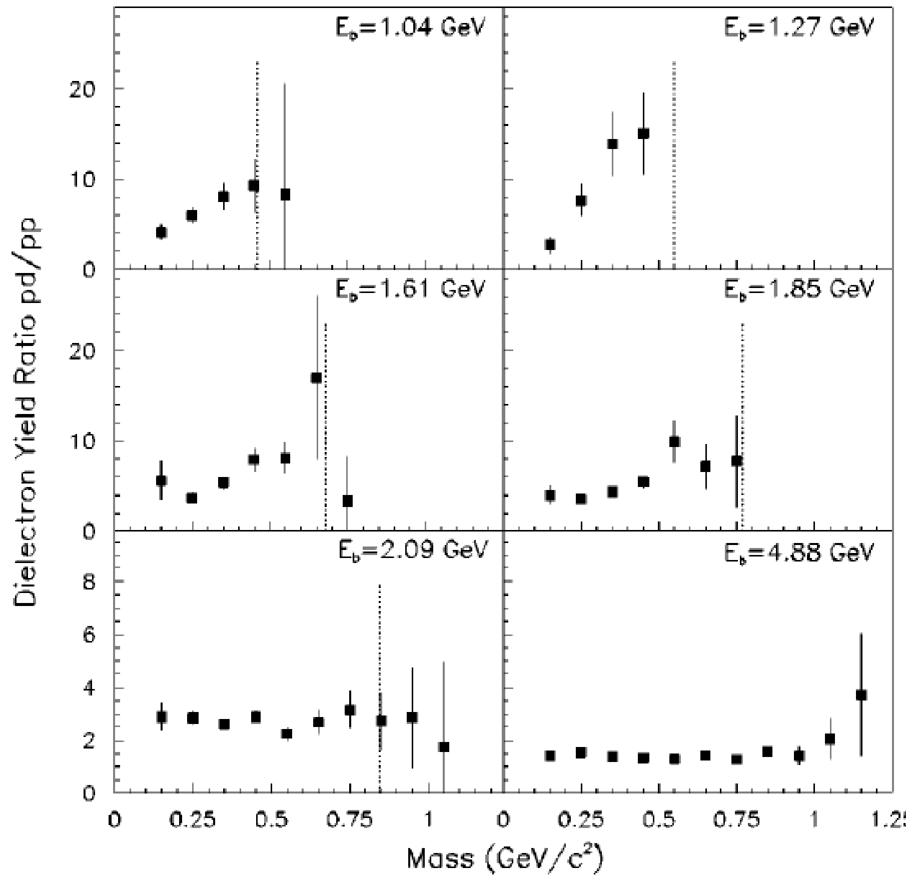
Rapidities



M_{ee}<0.150 GeV/c^2
0.150 <M_{ee}<470 GeV/c^2
0.470 <M_{ee}<700 GeV/c^2
M_{ee}>700 GeV/c^2
$1/N_{\pi^0}$ dN/dY
Y_{ee}
p+Nb
p+p
PRELIMINARY
PRELIMINARY

Isospin dependence

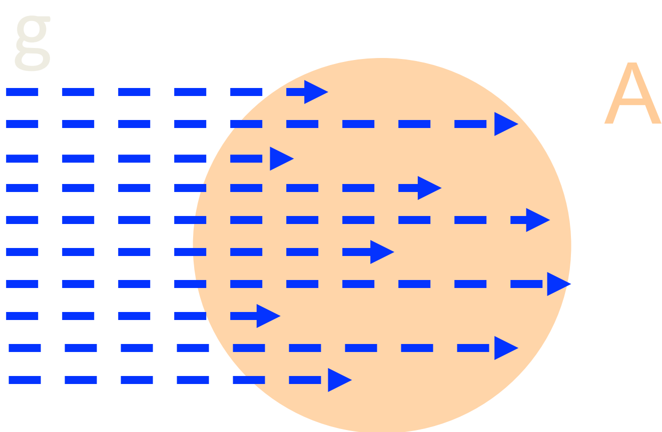
- Dielectron cross sections in p +p and p+d at beam energies from 1.04 to 4.88 GeV measured with DLS
- Decreasing mass dependence of pd/pp with increasing beam energy
- pd cross section becomes approximately twice the pp cross section at all masses with increasing beam energy



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

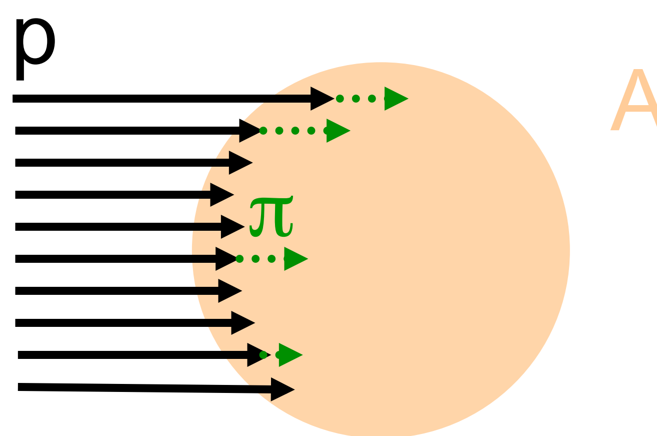
Transparency ratio ?

γ + A → ω/ρ + X



Low interaction probability
→ Production in whole volume
→ ~ A^{α}, $\alpha = 1$

p + A → ω/ρ + X



Strong interaction
→ Production on surface
→ ~ A^{α}, $\alpha = 2/3$
BUT: secondary proction via pions
→ ~ A^{α}, $\alpha > 2/3$

T_A → absorption in nucleus
→ in medium width

T_A → disentanglement of production and absorption
→ Model dependence