On the need for isospin averaged elementary reference data in A+A analyses.

H. Ströbele, Univ. Frankfurt

References NA49:

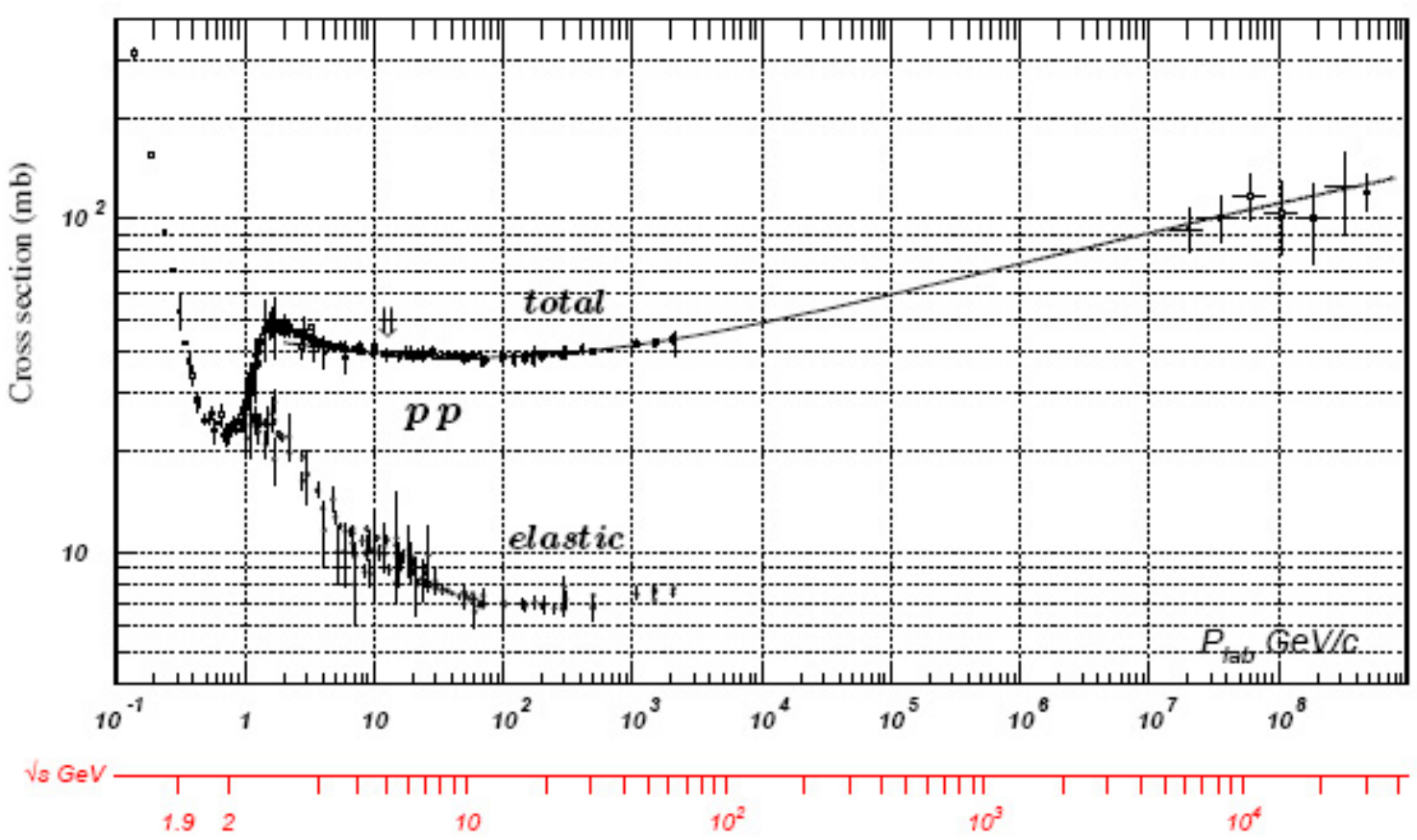
“On the importance of isospin effects for the interpretation of nuclear collisions”
O. Chvala, Eur. Phys. J C33(2004)s615

“Elementary Hadronic Interactions at the CERN SPS”
H. G. Fischer
Nucl. Phys. A715(2003)118c

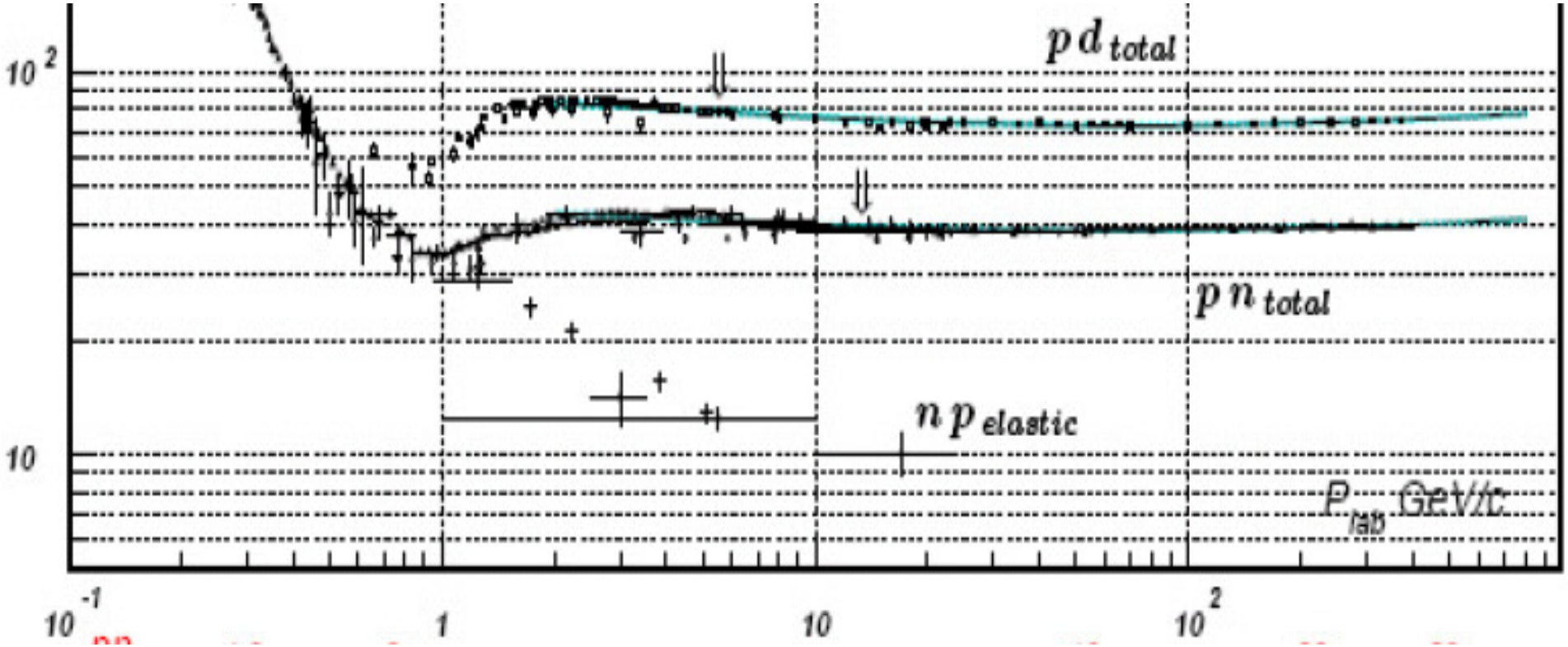
Introduction/Motivation

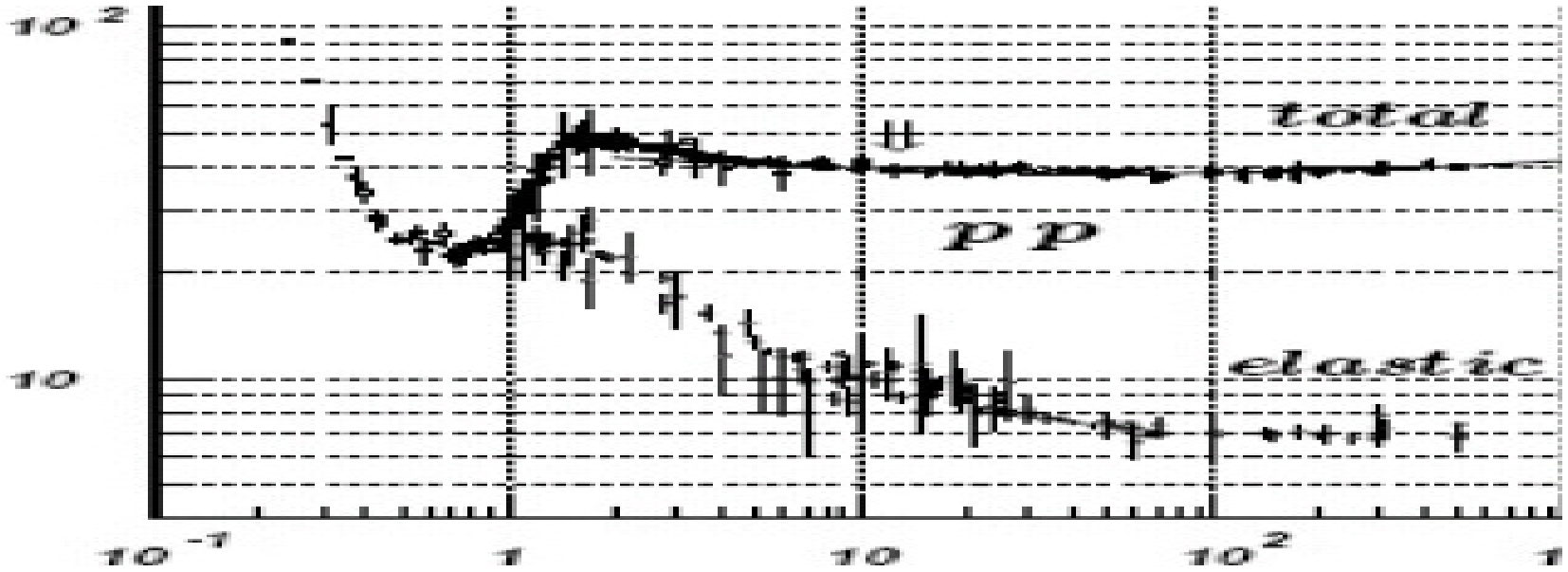
- “New” phenomena in heavy ion reactions are those which are different from what is observed in or extrapolated from elementary interactions.
- The most appropriate reference would be properly averaged p+p, n+p, p+n, and n+n interactions.
- p+p and n+n are isospin 1 states with $I_3=\pm1$, and n+n can be obtained from p+p.
- p+n is a mix of I=1 and I=0! The latter configuration needs a separate measurement.

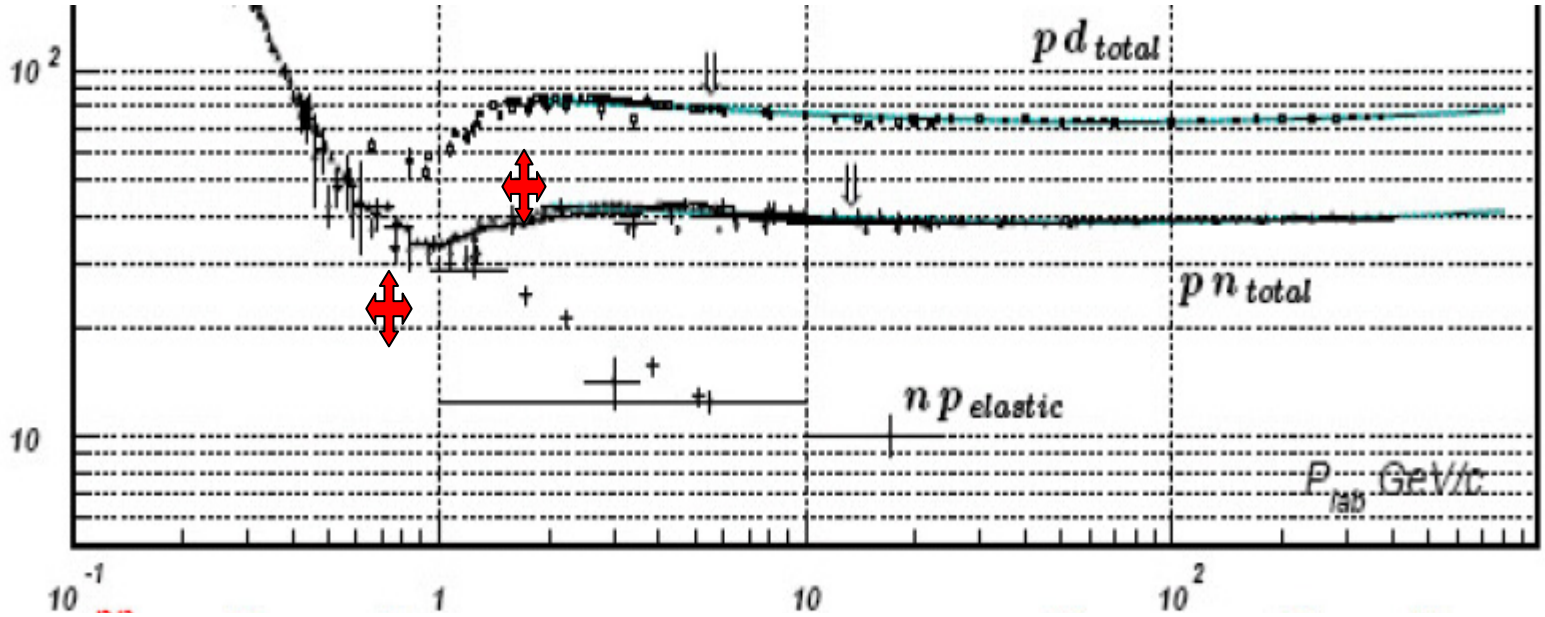
Elementary cross sections p+p (from PDG)



Elementary cross sections p+d and p+n (from PDG)




total
pp
elastic


pd total
pn total
np elastic
P lab GeV/c

Total cross sections of p+p and n+p

- At high energies no difference.
- In the range $1.3 < p_{lab} < 4$ GeV/c $\sigma(p+p)$ becomes (significantly) larger than $\sigma(n+p)$
- In the range $0.5 < p_{lab} < 1.3$ GeV/c $\sigma(n+p) = \mathbf{1.5} \cdot \sigma(p+p)$ (due to Isospin 0!)

Net baryon distributions

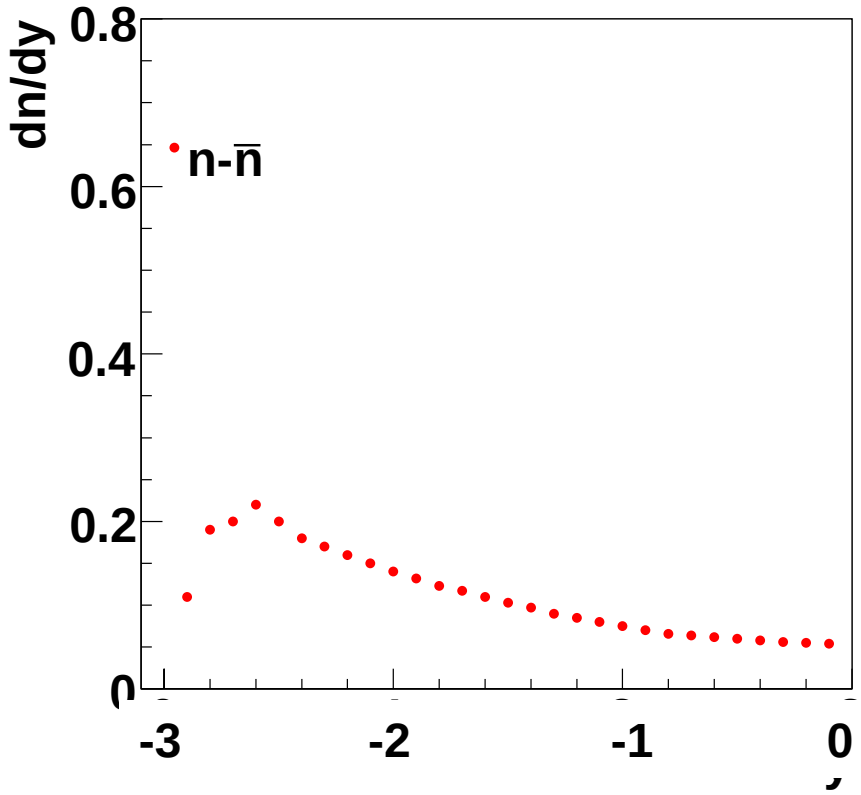
- Important to quantify stopping
- Needs **p+p**, n+n, n+p (or p+n)
  - **p+p** => (b – anti-b) with
    - b = p + n + hyperon
    - n = p ?? => no!

Net baryon distributions
b = p + n + hyperon (n = p ?? => no!)

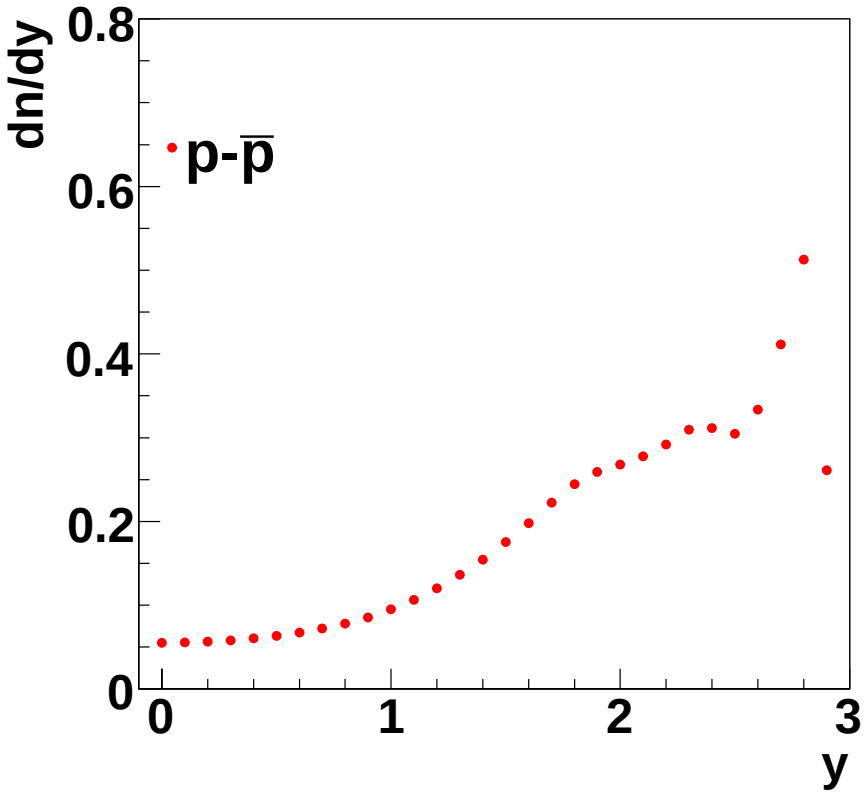
T.Anticic *et al.*, NA49 Collaboration, EPJ C**65**(2010)9

dn/dy at 158 GeV/c

n-nbar



p-pbar



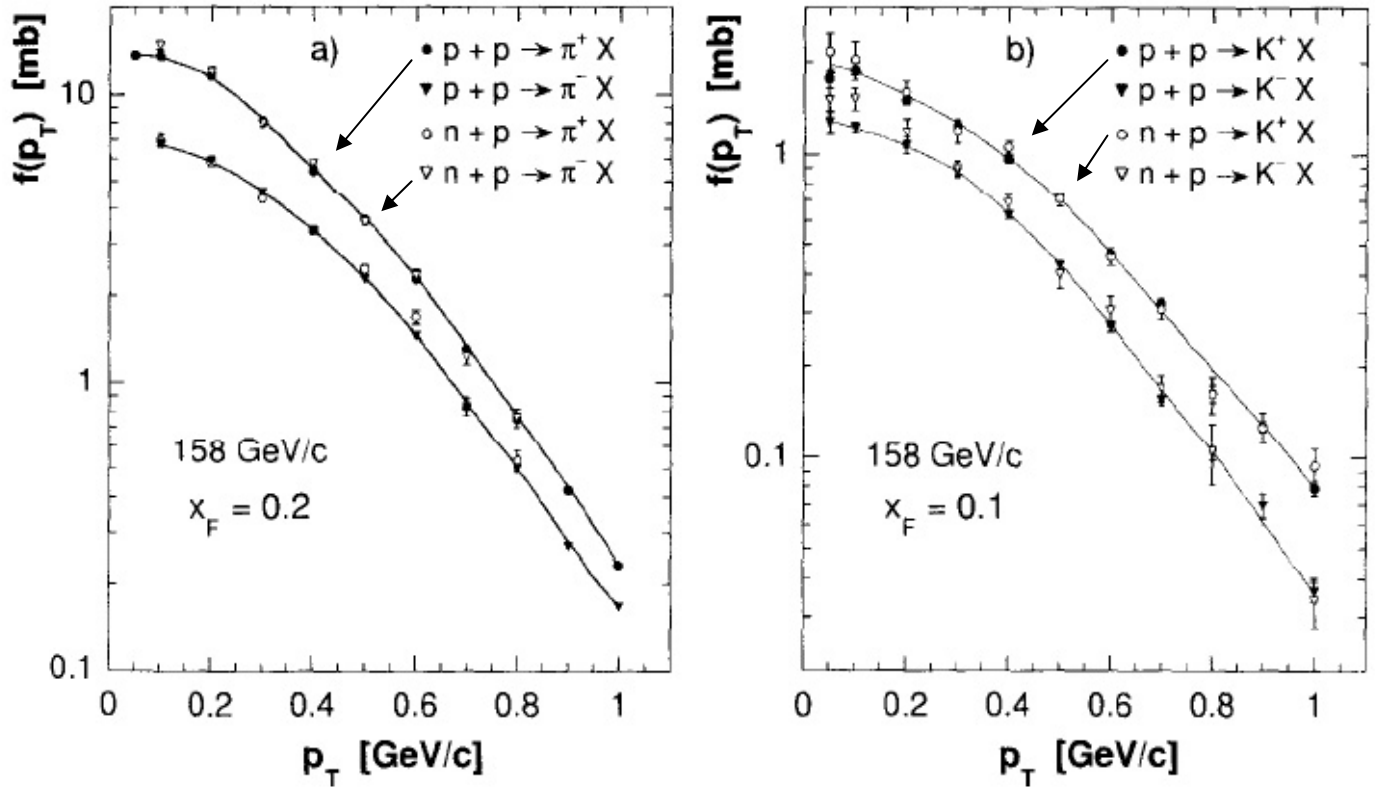
Net baryon distributions

- Important to quantify stopping
- Needs p+p, **n+n**, **n+p** (or p+n)
  - p+p => (b – anti-b) with
    - b = p + n + hyperon
    - n = p ?? => no!
  - **n+n** from p+p
  - **n+p** => I = 0 missing

Inclusive particle production

Pion and kaon production in p+p and n+p at 158 GeV/c

H.-G. Fischer ,Nuclear Physics A715 (2003) 118c, preliminary results



Is n+p different from p+p?

At 158 GeV/c

- pion production feels isospin, but
- strangeness productions NOT.

- more n- than p-stopping in p+p.

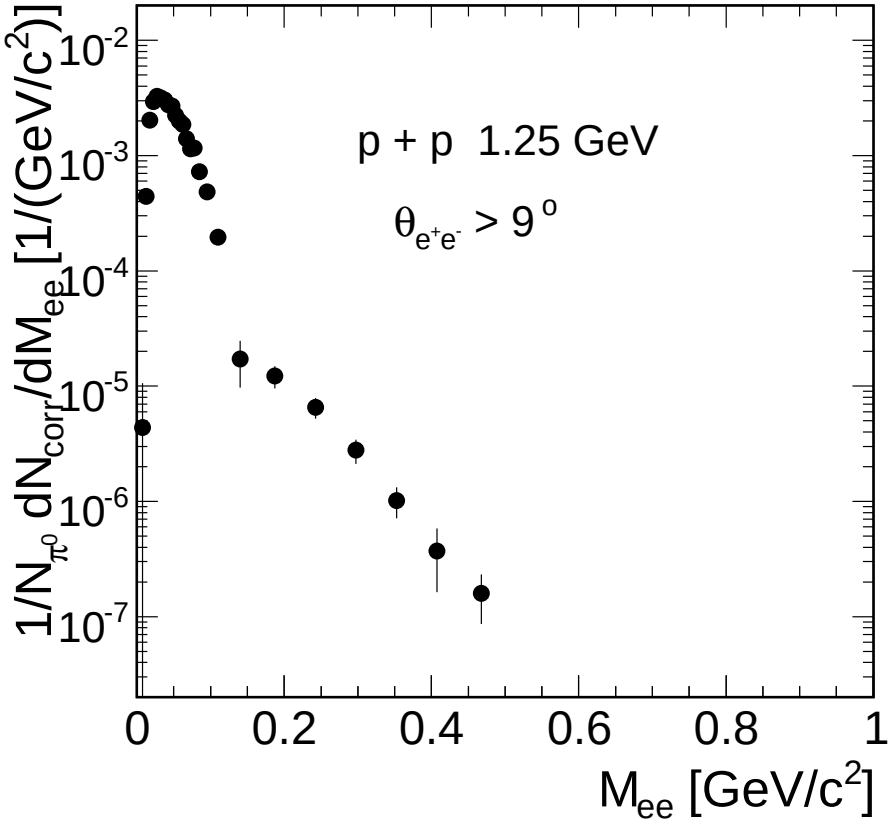
Needs measurements at all energies!

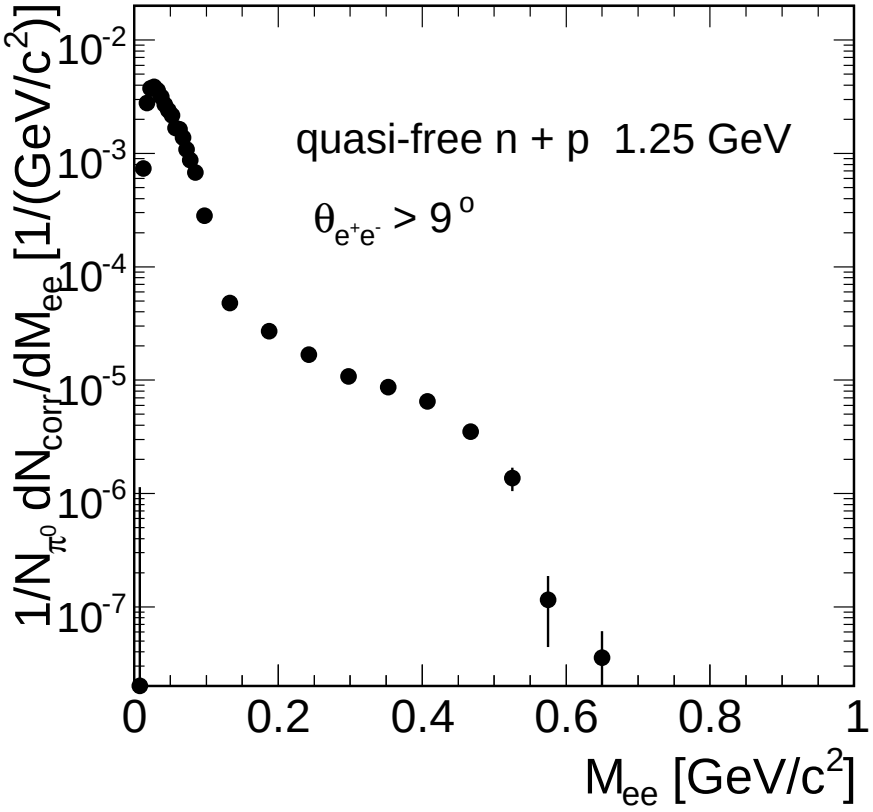
Examples for isospin effects in A+A

p(n) + p => e^+ + e^- + X at 1.2 GeV/c

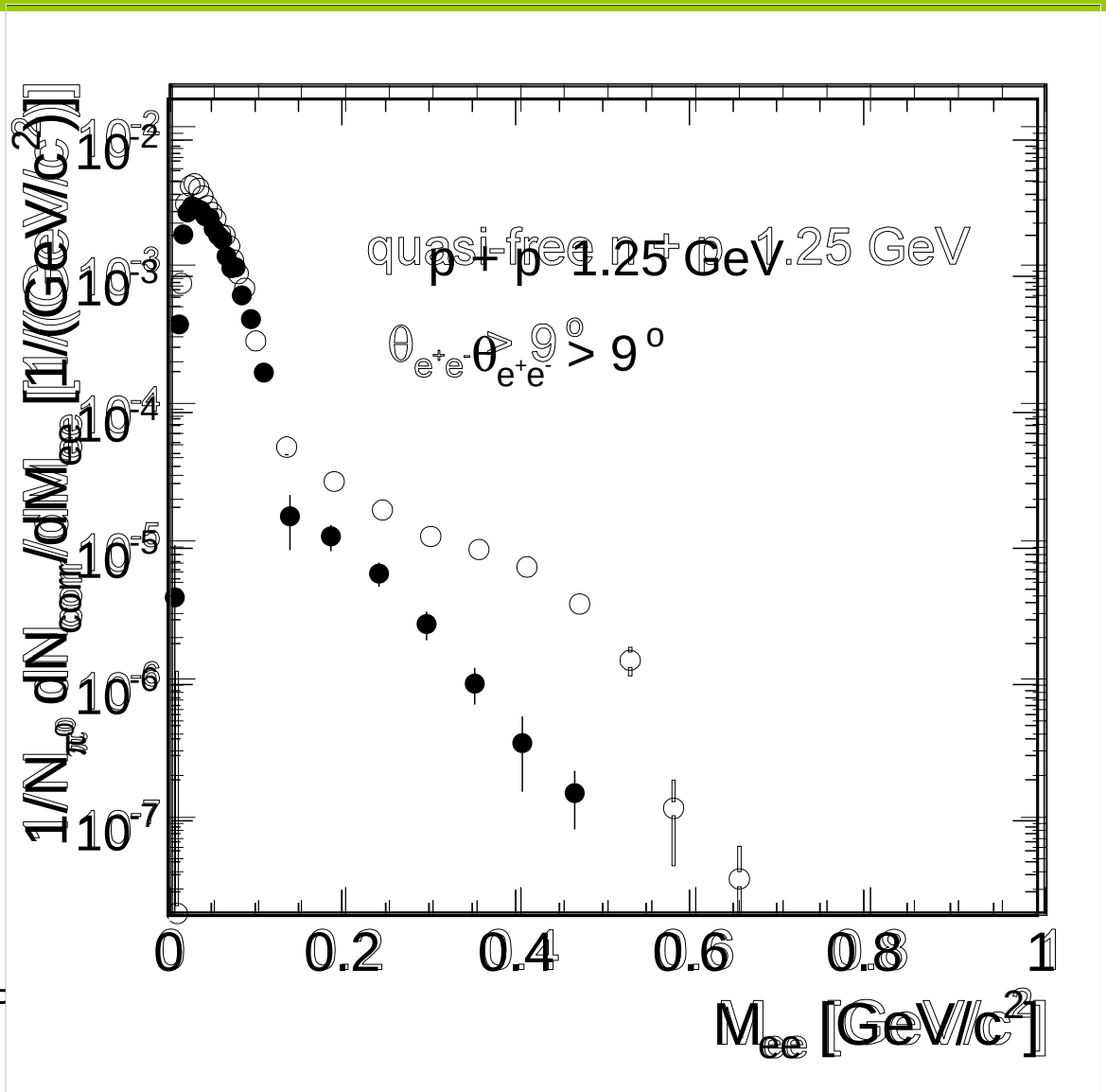
Electron pair production in p+p and n+p at 1.2 GeV

HADES, Int.J.Mod.Phys.A24:599-602,2009





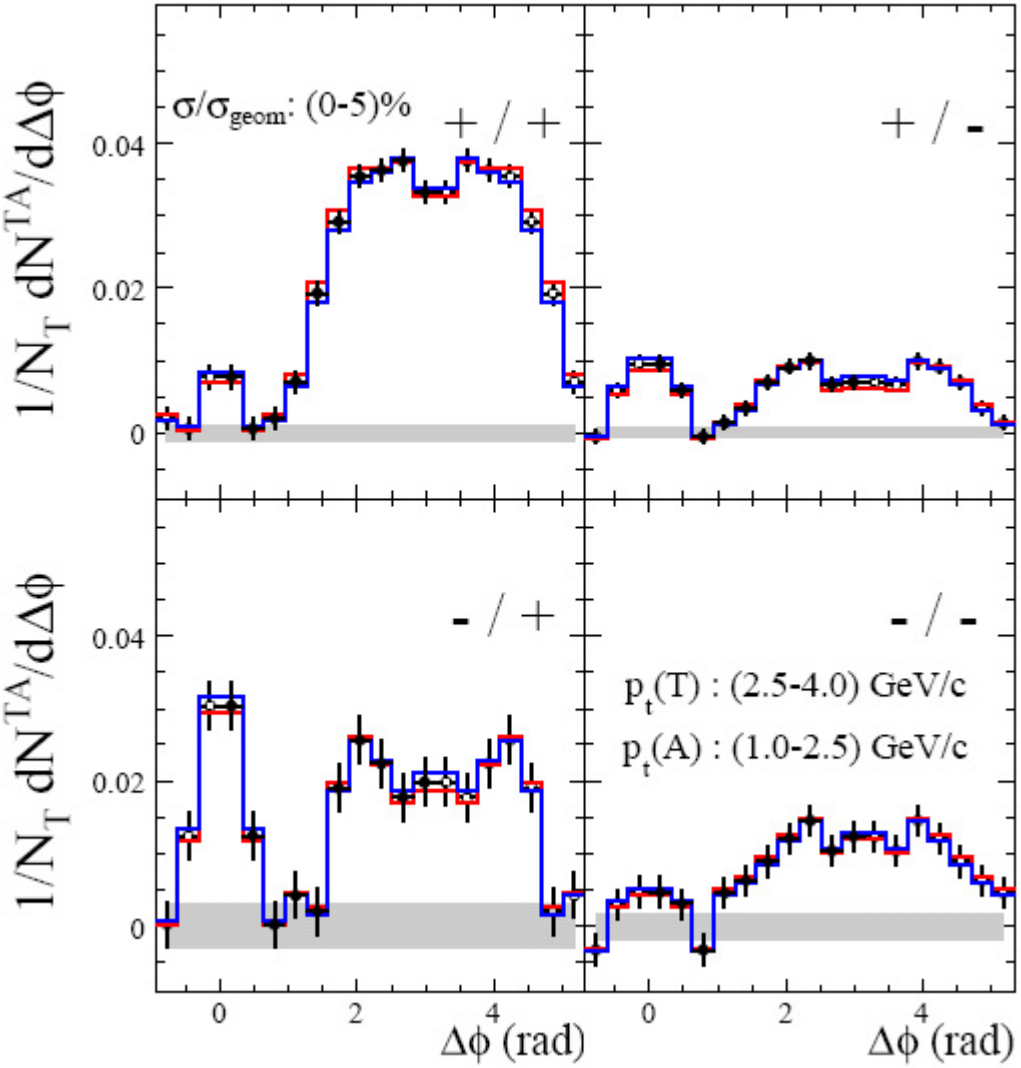
n + p at 1.2 GeV/c



The whole story in A. Rustamov's talk on Thursday

Examples for isospin effects in A+A

two particle phi correlations (conditional yields)

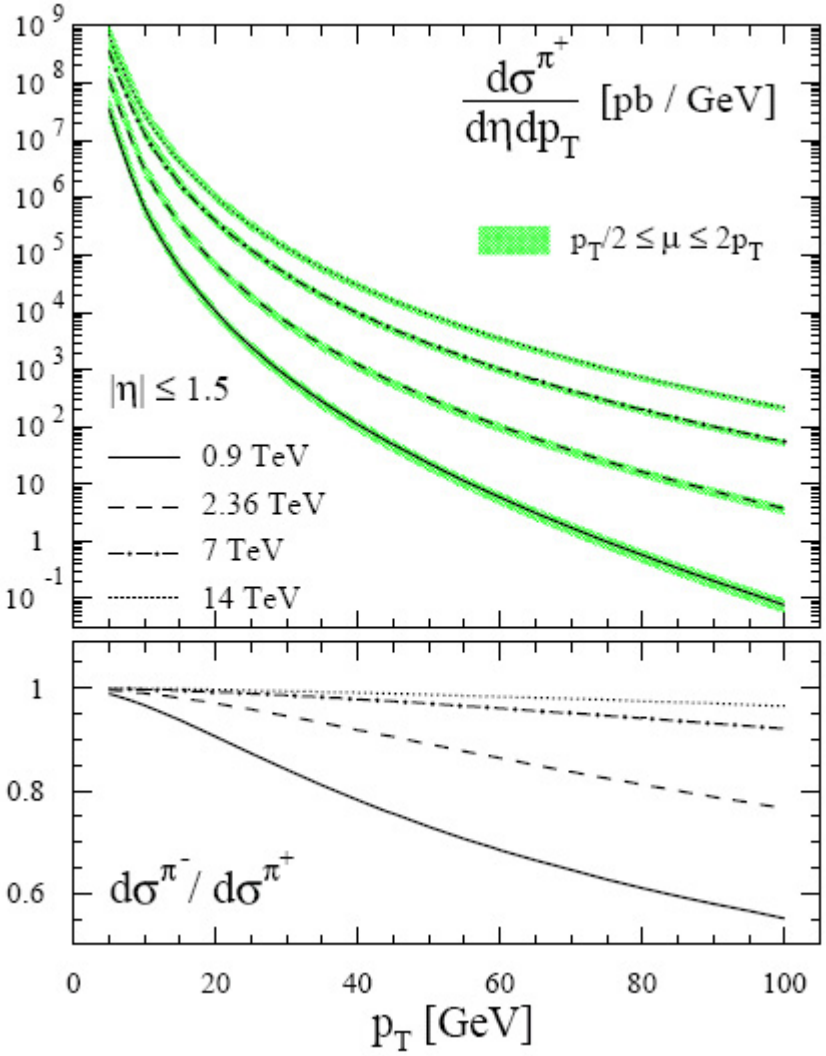


Two particle correlations for “jet” triggered events and different charge selections from Pb+Au at 158 GeV/u.
charge:
trigger/associated
=>trigger side: suppression for equal charge due to charge conservation.
⇒Away side: positive dominates due to initial isospin state.

CERES/NA45,
S. Kniege PhD thesis,
Frankfurt

And even at LHC?

Stratmann, Sassot, Zurita, arXiv:1008.0540 [hep-ph]

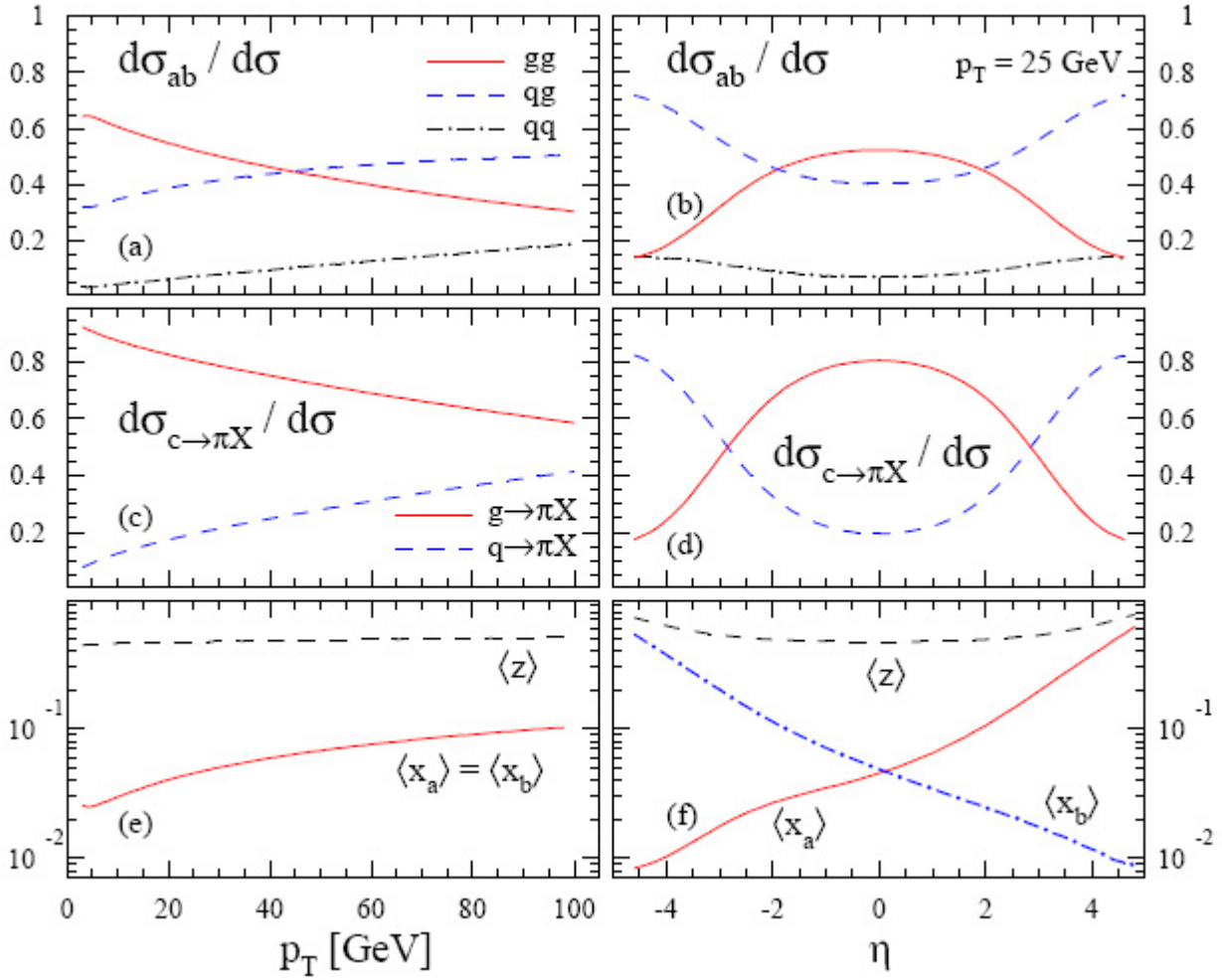


pQCD calculations for p+p => pi± + X at high transverse momenta and different energies.

More pi+ than pi- at high transverse momenta.

And even at LHC?

Stratmann, Sassot, Zurita, arXiv:1008.0540 [hep-ph]



Explanation:
g+q jets

Models of nuclear collisions

Models need differential elementary cross sections as function of $\sqrt{s}$ for

-particle production

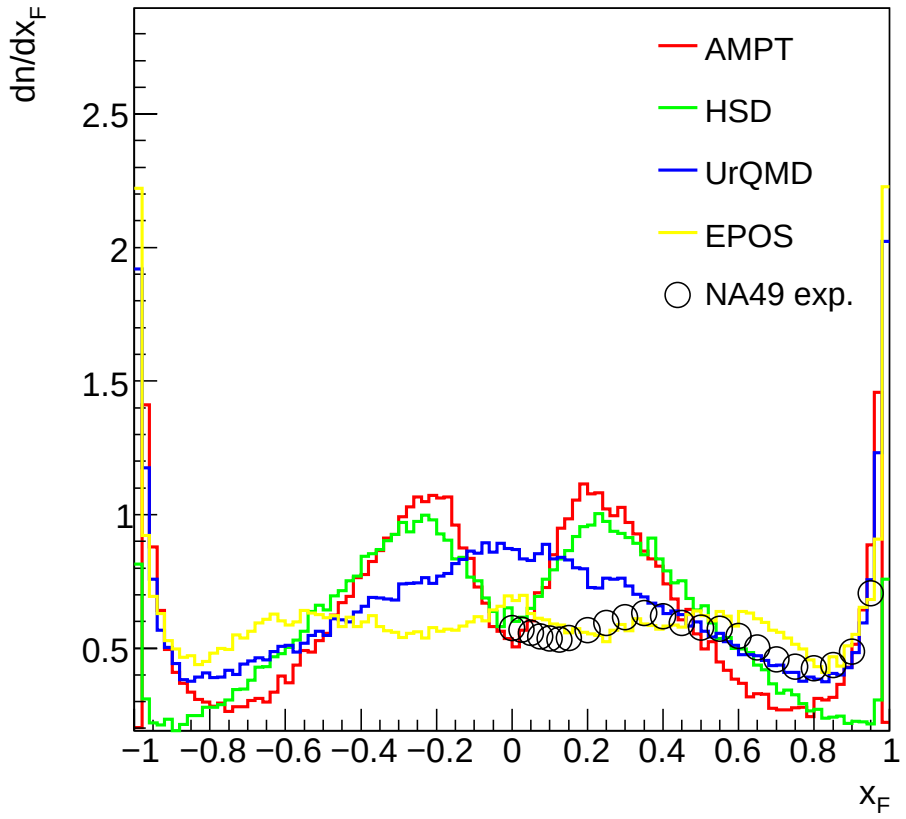
-stopping (net baryon distributions)!!

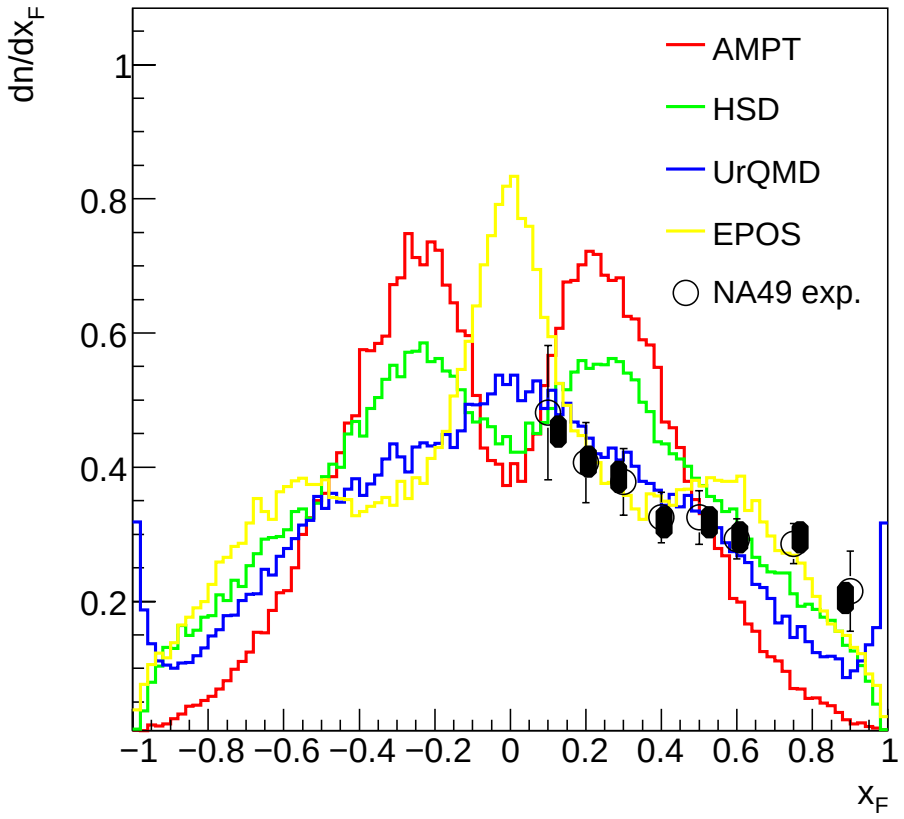
- Microscopic models
- Statistical models
- Core-corona model
- ….

Example at 158 GeV/c

p+p => p + X p+p = n + X

NA49 data: Anticic *et al.*, NA49 Collaboration, Phys. Rev. C**80** (2008) 034906.





Experiments to study n+p or p+n reactions

- d+d collisions for direct comparison to A+A. Critical items:
  - Fermi motion
  - Final state interaction (relevant for rare processes)
  - Z/A = 0.5 versus Z/A = 82/208 = 0.4
  - Non trivial separation of I=1 and I=0 components
- References from deuteron beams in the past:
  - **ISR ?**
  - **JINR ?**
    - **Only exclusive channels and exotica (in English)**

Experiments to study n+p or p+n reactions

- n+p from d+p. Critical items:
  - Proton projectile spectator detection/identification
  - Fermi motion
  - References
    - HADES: only inclusive electron-pair production
    - NA49: only in conference proceedings
    - Bubble chamber experiments with low statistics and exclusive reaction channels.

Experiments to study n+p or p+n reactions

- p+n from p+d. Critical items:
  - Proton target spectator detection/identification
  - Fermi motion
  - References
    - Bubble chamber experiments with low statistics and exclusive reaction channels

Experiments to study n+p or p+n reactions

- n+p from secondary neutron beams
  - d-dissociation on primary target (K^0_s admixture)
    - Low intensity, bubble chamber, exclusive p p pi- channel
    - Reference
      - Tsuboyama et al., NPA486(1988)669 KEK
  - e+Be => n +X
    - Low intensity, bubble chamber, exclusive p p pi- channel
    - Reference
      - Alexander et al., NPB52(1973)221 DESY

Scenarios for new n+p experiments

- Fixed target
- High intensity deuteron beam and H_2 target
  - Trigger on forward proton or neutron spectator based on
    - Energy measurement (calorimeter e.g. PSD in NA61)
    - Charge measurement (scintillator)
    - Allows to cross check p+p from d+p versus true p+p.
  - High intensity deuteron beam on primary target plus spectator tagging.

Scenarios for new n+p experiments

- Collider
- d+p collision system
  - Trigger on forward spectator proton
    - Half rigidity spectrometer for momentum and theta determination.
    - Energy measurement (calorimeter).
  - Trigger on forward spectator neutron
    - energy measurement with zero degree calorimeter
    - Charged particle veto (scintillator)
    - Shower max detector (for el. magn. interaction separation)
  - **Both are realized in the ALICE setup**
    - De Marco et al., ALICE Collaboration, IEE Trans.N S 54(2007)567

Scenarios for new n+p experiments

- Note that in d+p experiments
  - there is only one spectator, thus it is an easy task for the spectator detector and
  - one may select small spectator momenta (in the deuteron rest frame) to reduce the detector area and the probability for secondary interactions.

Scenarios for new n+p experiments

- d+d in a collider
  - technically identical to d+p.
  - Could be used without spectator identification/selection
    - Uncontrolled final state interactions may hamper precision measurements.
    - Better than p+p but still not the same isospin as Pb+Pb (Au+Au).

summary

- For second generation A+A studies d+d or d+p is a “must”.
- Detectors for proton and neutron spectators are needed.
- Even at low SPS/FAIR/NICA energies, where the “spectator cone” gets large, spectator identification/selection is possible.
- Isospin effects seen/expected in jet physics at high p_T (truly elementary interactions?).

thank you