NUCLEAR MODIFICATION ON PARTICLE PRODUCTION & ISOSPIN EFFECT

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in collaboration with:
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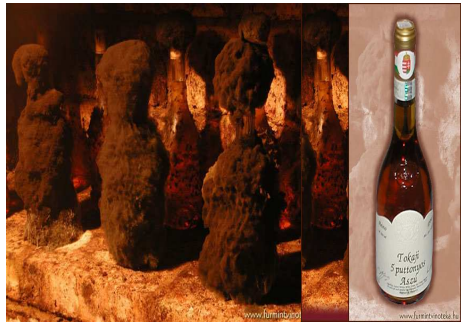
3rd International Workshop on High p_T Physics at LHC, Tokaj '08
16-19 March 2008 – Tokaj, Hungary

... and now, something completely different ...

In Tokaj, the the pieces of grapes become 'slightly' different, like protons and neutrons inside the nucleus at the initial state.

...this small difference can result 'some' modifications at the final state production. Modifications can be tested in comparisions.



Here we can measure the VMF – vine modification factor, which magnifies the differences of the pieces of grapes. Enjoy the aszú, the "Vinum Regum, Rex Vinorum" and then, test & measure the isospin effect via R_{dA} in pp, np or dd.

O U T L I N E

0. Motivation – effects on R_{dA} at high p_T

– EMC effect at high-p_T at RHIC and LHC?

– Direct γ is always tricky: R_{dAu} and R_{AuAu} at high-p_T...

I. Signature of isospin effect in PDFs

– Test of the high-p_T jet production

– Differences in pp, and $(pn)dd$ normalizations at RHIC

II. Is there isospin effect in $S_{a/A}(x)$ and FF?

– Differences in pp, nn and $(pn)dd$ or $R^{p/\pi}_{dAu}$

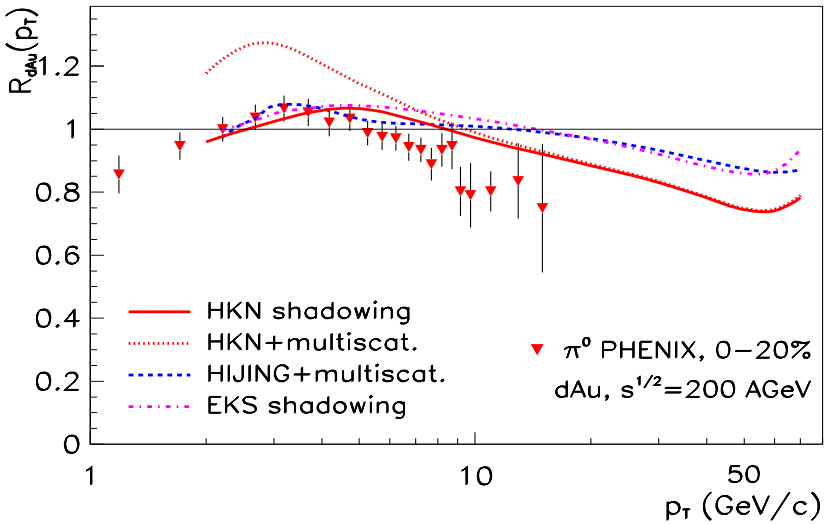
III. Nuclear modifications and isospin effect at LHC

– Coming soon: results for LHC

M O T I V A T I O N – test on RHIC data

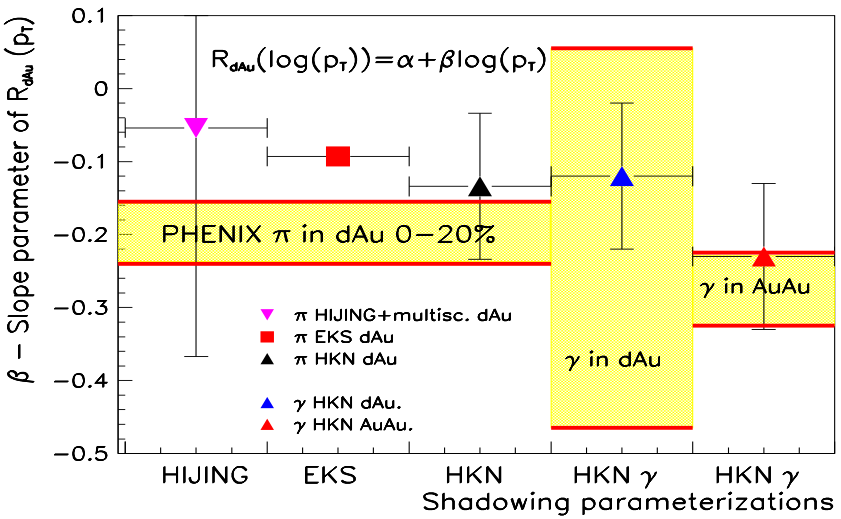
PHENIX π^0 data in dAu

- arXiv:0801.4020v1 (2008)
- $2-3\sigma$ effect in R^{π}_{dAu} at high p_T
- This should be the EMC effect,
  B.A. Cole *et al.*: hep-ph/0702101



Models vs. PHENIX data

- We have slope structure at high p_T
- This slope is linear in $\log(p_T)$
- π^0 and γ data are similar in dAu
- Stronger effect in R^{γ}_{AuAu}



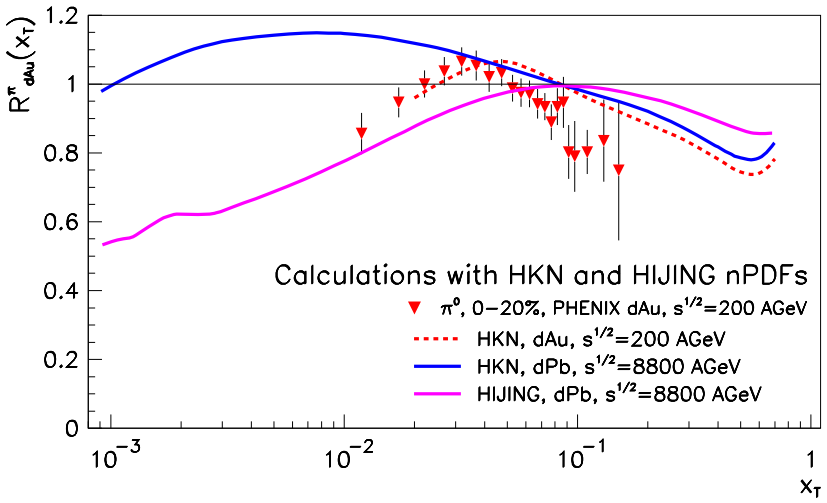
M O T I V A T I O N – predictions for LHC

Calculations for LHC in dPb

– GGB@QM'08, x scaling in $R^{\pi}_{dAu}(x)$

– Comparison with scaled RHIC data

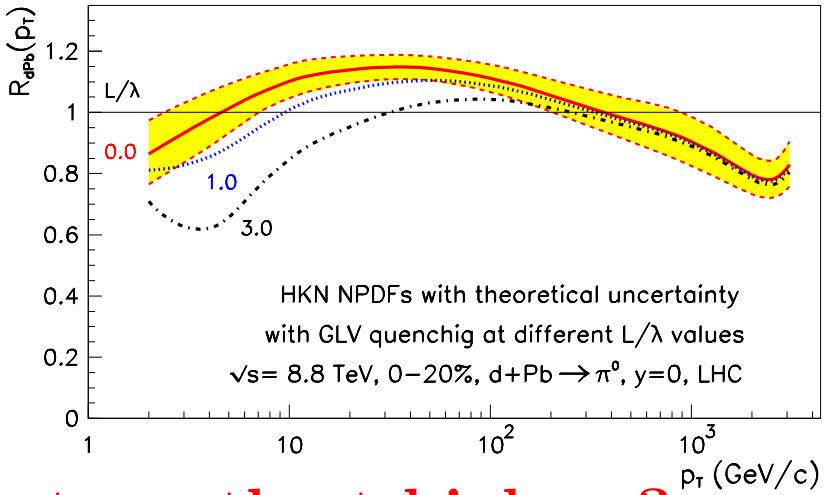
– HKN shadowing is a recent one,
and HIJING is the strongest.



Final(?) prediction: dPb with HKN

– weak suppression at low p_T

– Tested also with 'cold quenching'
in the GLV framework for
two cases: $L/\lambda = 1$ and 3.



Is there any new effect with same strength at high p_T?

Isospin Effects in Heavy-Ion Collisions

a) Differences in Inelastic Cross Section (σ^{in}_{NN})

- Small differences, but changes with the $\sqrt{s}$
- The pp, nn and $(pn)dd$ cross sections are different

b) The 'real' isospin effect is in the PDFs

- Differences in pp, nn and $(pn)dd$ in R_{dAu}

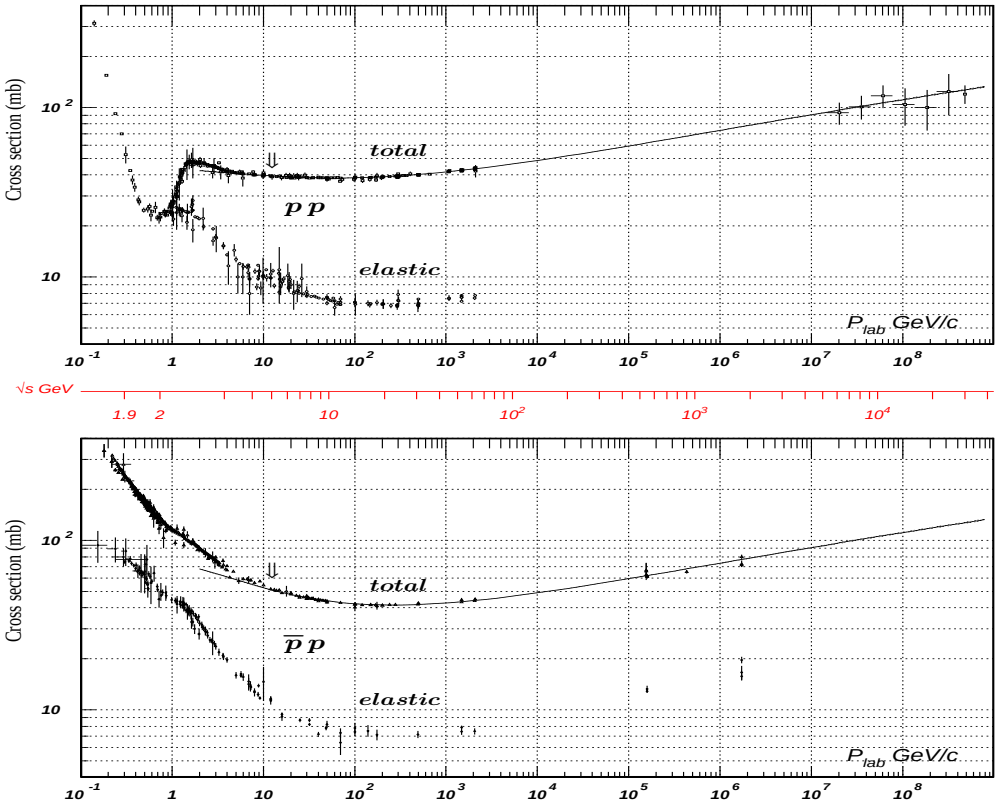
c) Is there isospin effect in $S_{a/A}(x)$?

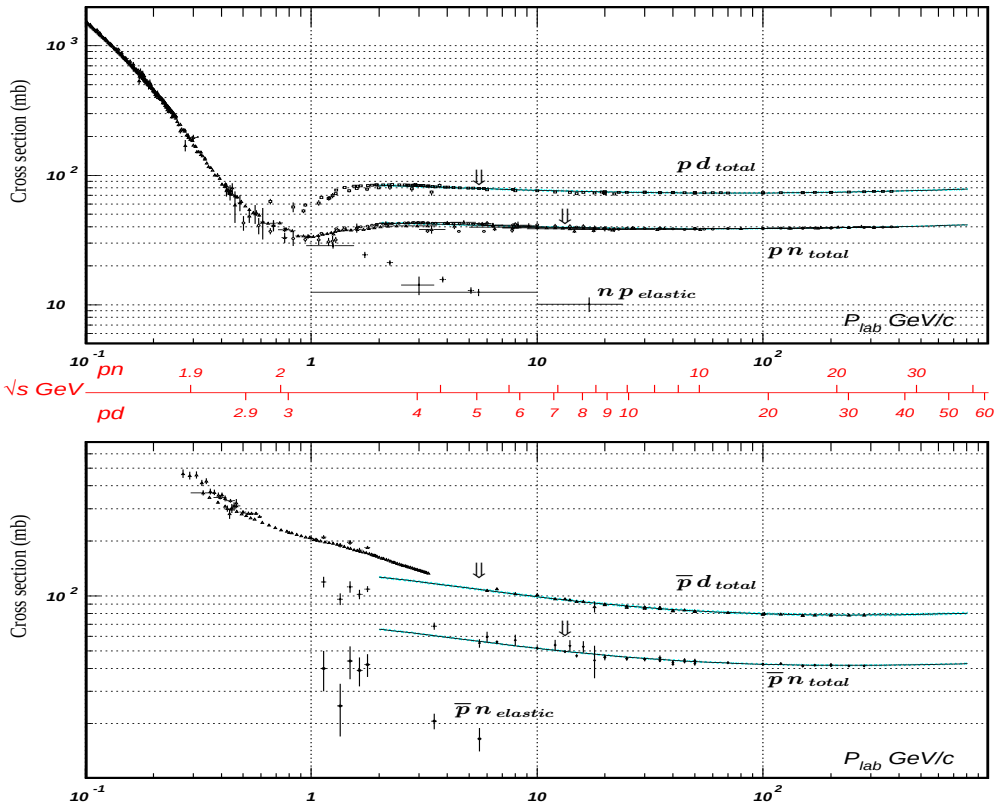
- Of course, YES! Handled differently in various shadowing parameterizations.

d) Are there isospin differences in fragmentation function?

- Can we see the effect in hadron ratios in R_{dAu}?

a) Differences in the Inelastic Cross Section – 1.





– At a given c.m. energy: $\sigma_{NN}^{in} = \sigma_{NN}^{tot} - \sigma_{NN}^{el}$

– But $\sigma_{pp}^{in}(\sqrt{s})$ and $\sigma_{pn}^{in}(\sqrt{s})$ are different $\Longrightarrow$ isospin effect

Can we see such a small variation in e.g. R_{dAu}? – NOT YET!

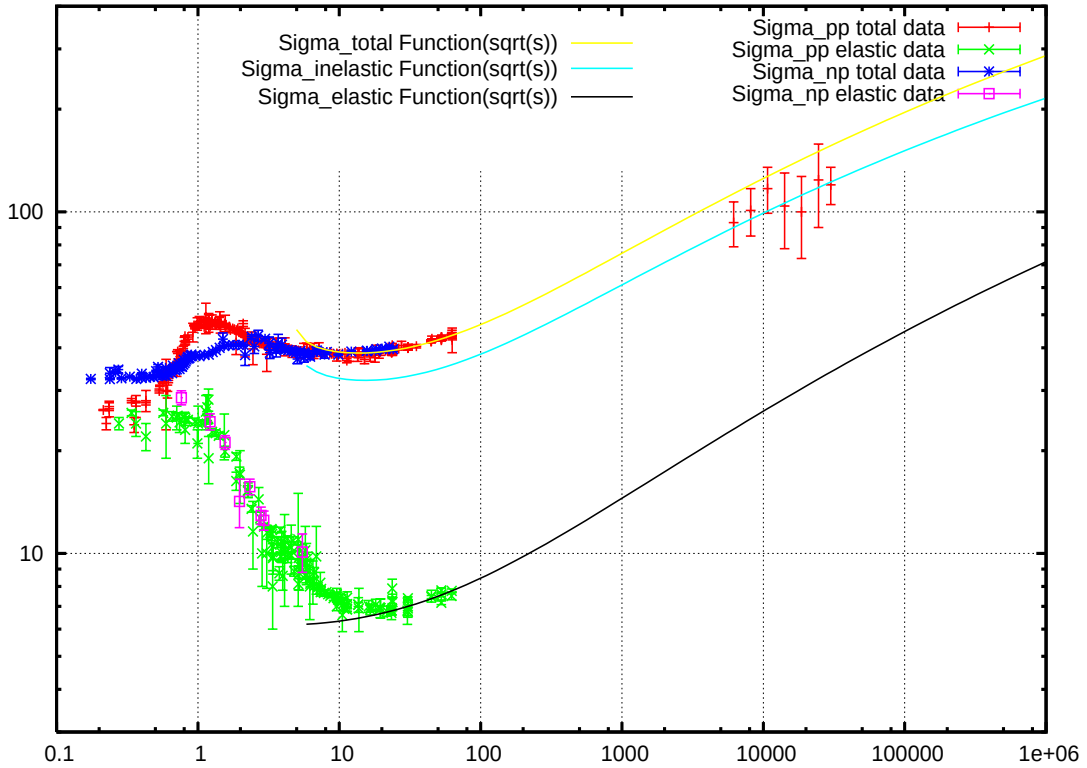
a) Differences in the Inelastic Cross Section – 2.

Problems: Let's see the data above $\sqrt{s} \sim 10$ GeV

– NO measurements at these high energies, only σ_{pp}^{tot} from cosmic data

– We have nuclear physics theories for σ_{nn}^{tot} $(\approx \sigma_{pp}^{tot})$

– But, NO data for these, and even for σ_{pn}^{tot}, which has NOT ONLY the singlet channel



– However the uncertainty is huge, especially in σ_{NN}^{el}, we can make parameterization for ∼TeV energies – without isospin differences

b) The 'Real' Isospin Effect is in the PDFs – 1.

PDFs are different for proton ($f_{a/p}(x,Q)$) & neutron ($f_{a/n}(x,Q)$)

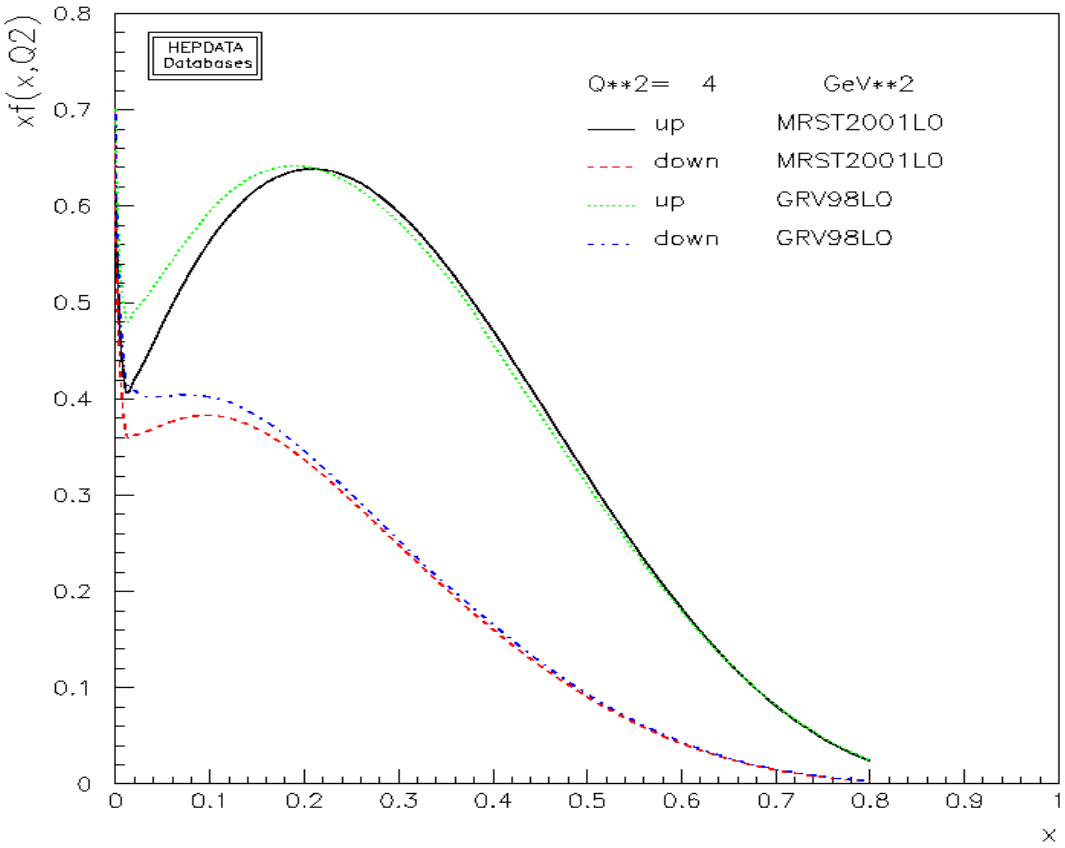
- Here are some basic rules:

  $f_{u(d)/p}(x,Q) = f_{d(u)/n}(x,Q)$

  $f_{\bar{u}(\bar{d})/p}(x,Q) = f_{\bar{d}(\bar{u})/n}(x,Q)$

- But s, c, b, t and g have same contributions.

- Thus symmetric nuclei like d or e.g. ^{40}Ca are OK!



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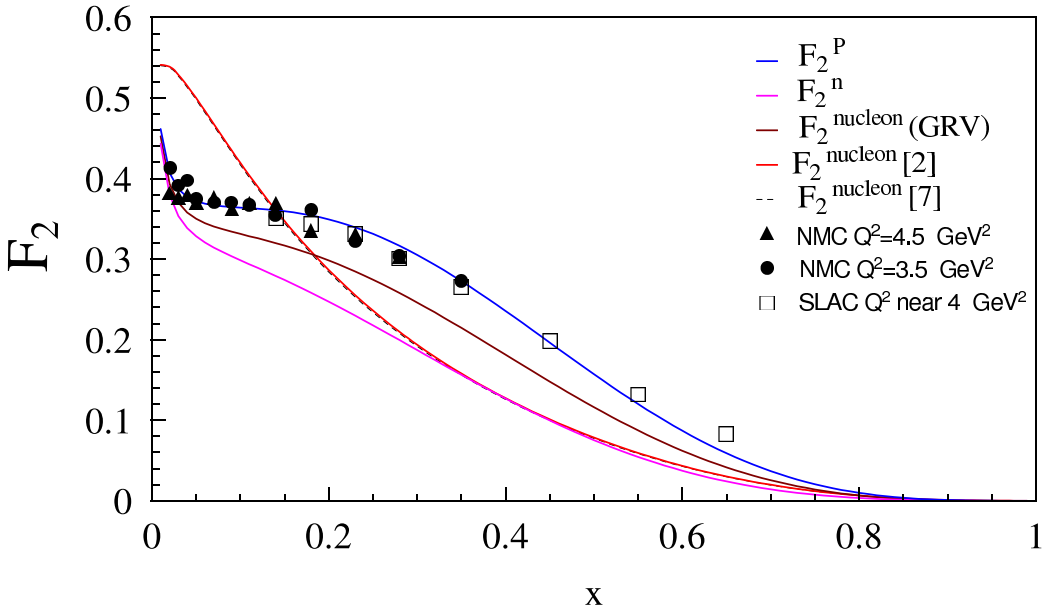
- Experimental information for pp (dp) at high-x only.



F. Zolfagharpour: arXiv:0802.1623v1

b) The 'Real' Isospin Effect is in the PDFs – 3.

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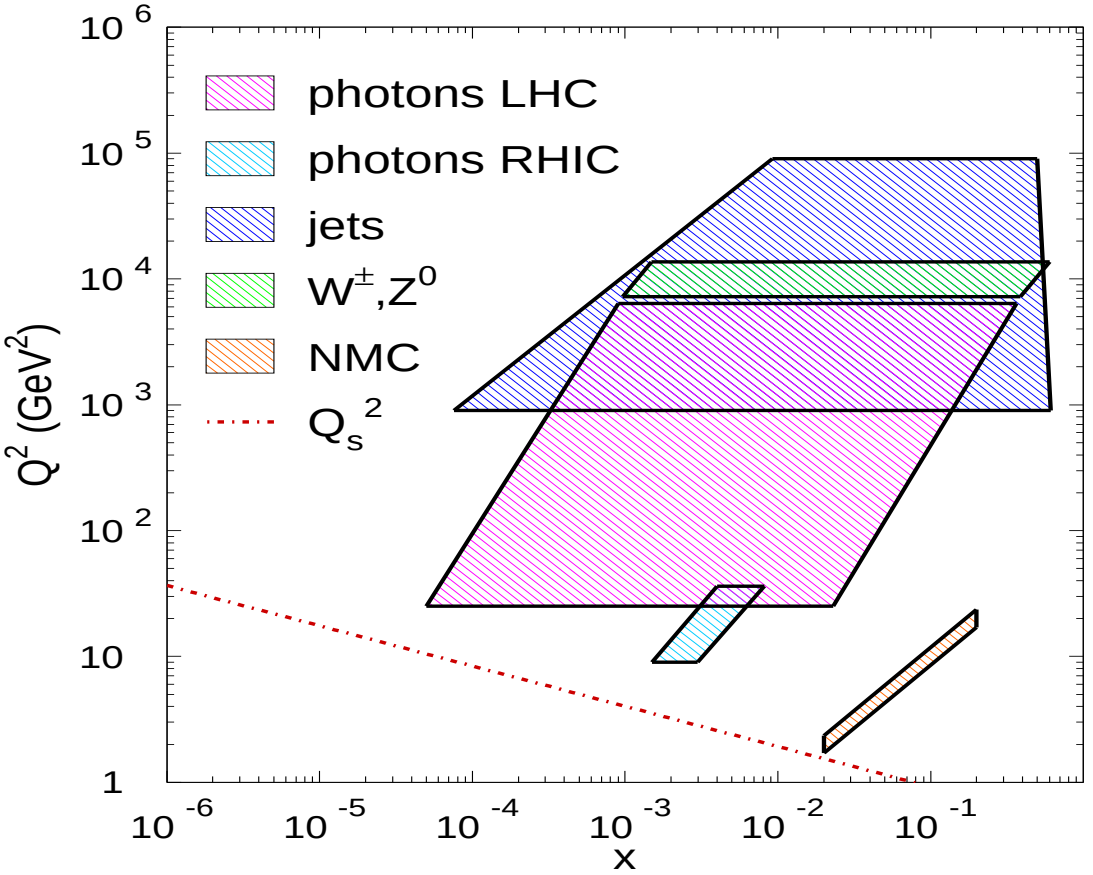


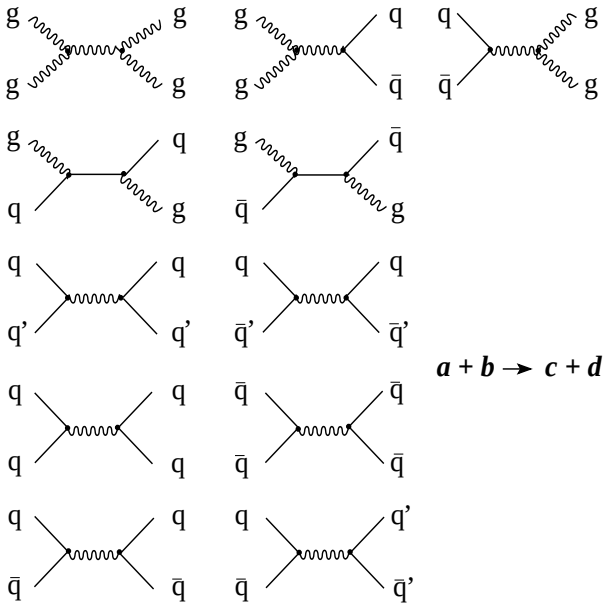
F.Arleo & T.Gousset: PLB 660 (2008) 181

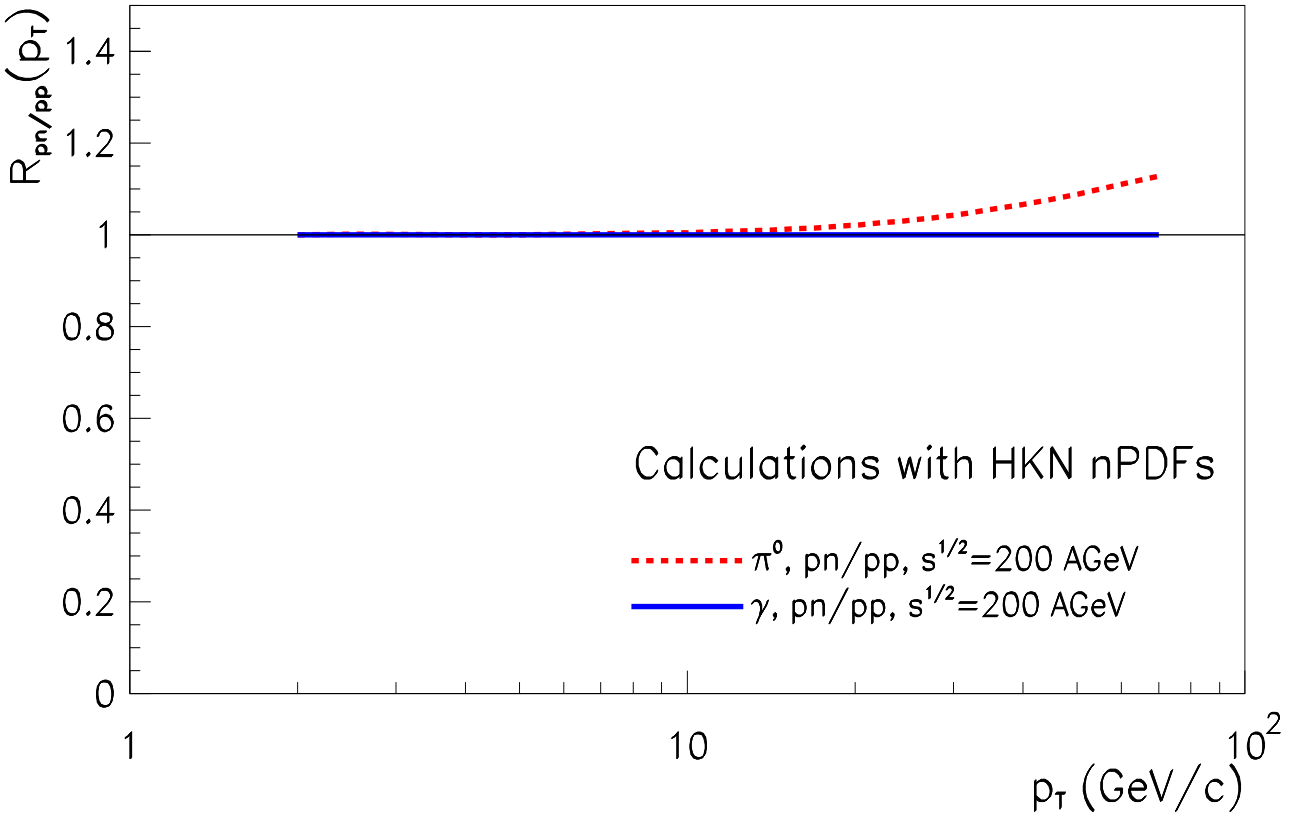
b) The 'Real' Isospin Effect is in the PDFs – pn/pp

Baseline: First at the LO QCD level π and γ production

π means $D_{\pi/a}(z)$

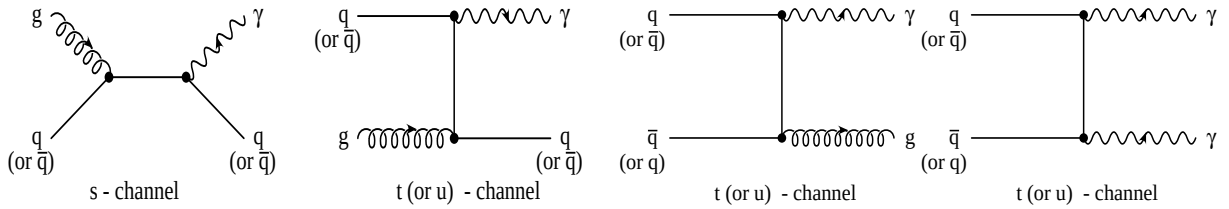
all channel contribute





Direct γ reflects the

Compton and annihilation

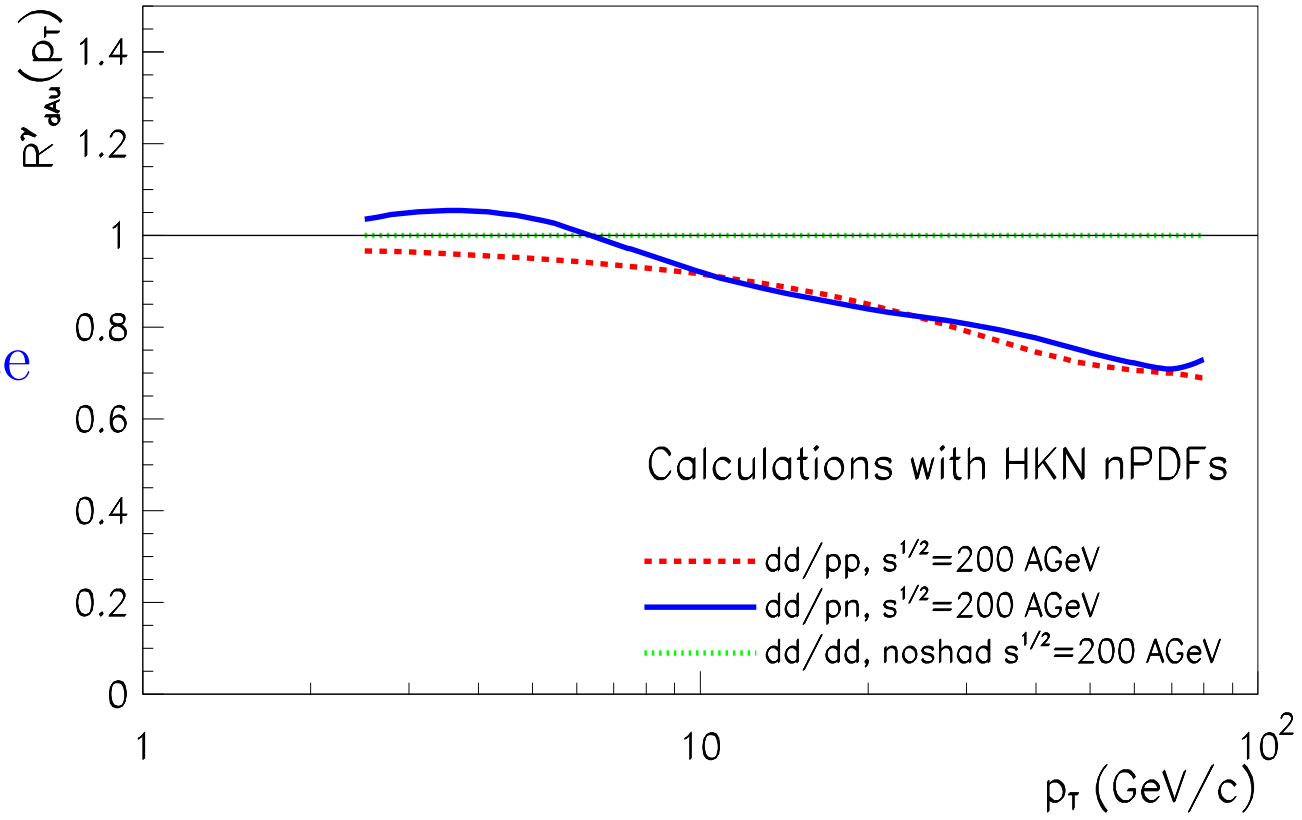


b) The 'Real' Isospin Effect is in the PDFs – dd/pp

2. baseline: dd analysis for γ

– Nuclear modification factor has negative slope.

– NO relevant difference between np and pp normalizations of dd

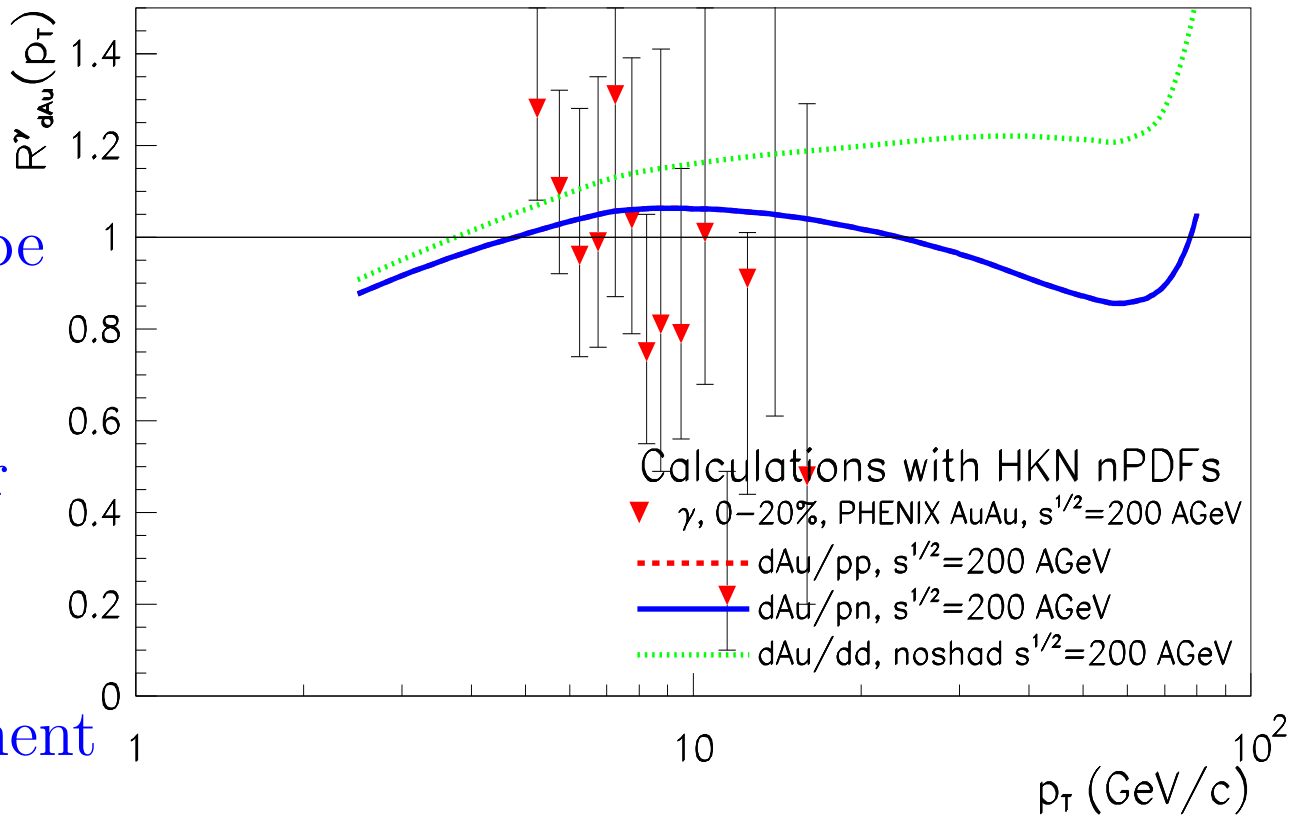


After normalizatioan this is similar to the EMC slope.

b) The 'Real' Isospin Effect is in the PDFs – $dAu \to \gamma$

dAu analysis for γ

- Experimental data have huge erros.
- We measured the slope of the EMC effect
- Multiple scattering or anti-shadowing can make some enhancement

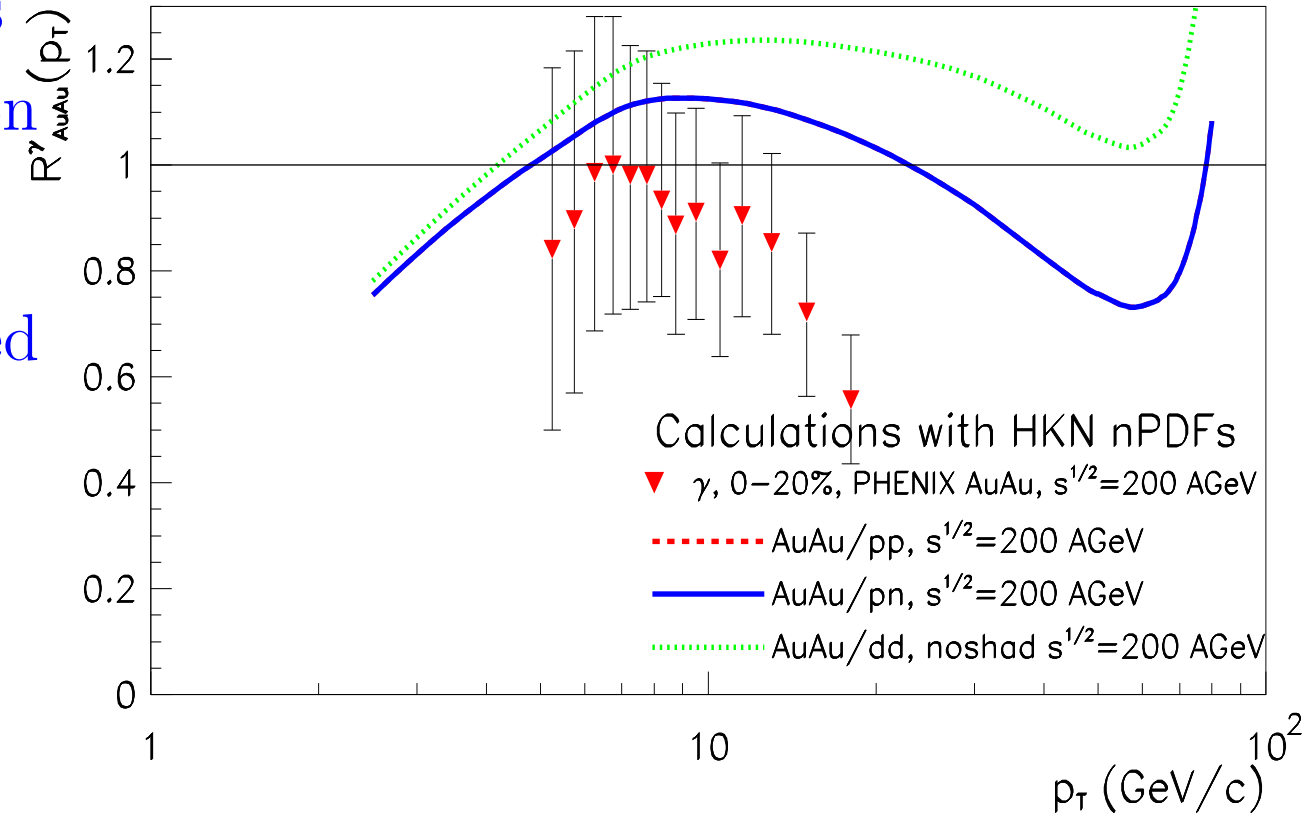


more precise data, but more difficult theoretical case : $AuAu$

b) The 'Real' Isospin Effect is in the PDFs – $AuAu \to \gamma$

$AuAu$ analysis for γ production

- NO final state effects in direct γ production
- Initial state effects are doubled compared to the dAu case
- Multiple

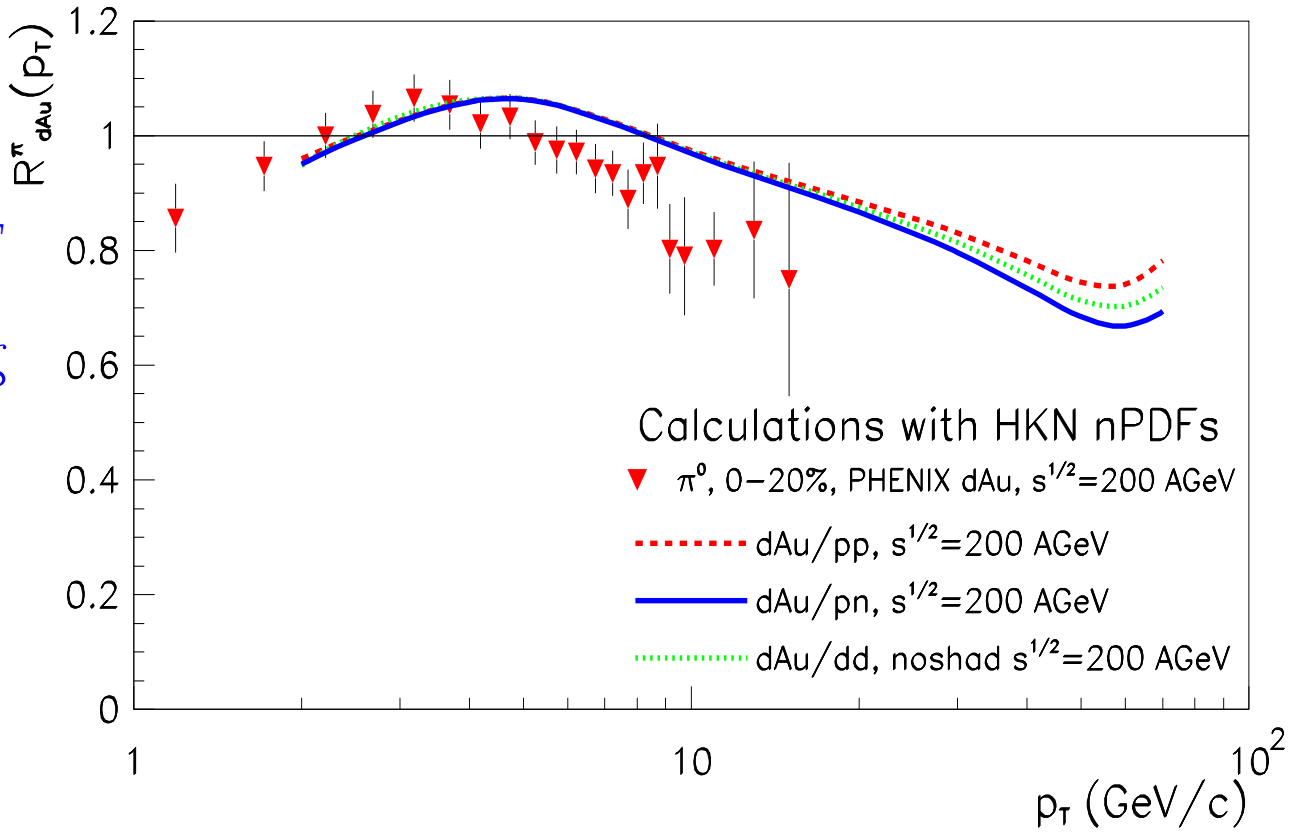


In sense of this the $dAu \to \pi$ is more complicated

b) The 'Real' Isospin Effect is in the PDFs – π^0

Next level LO dAu analysis for π^0

- Here the difference is really small effect only $\sim 5\%$ at high-p_T
- dd has NO shadowing but isospin avearged
- Slopes are similar



...and now let's try to extract the real isospin part...

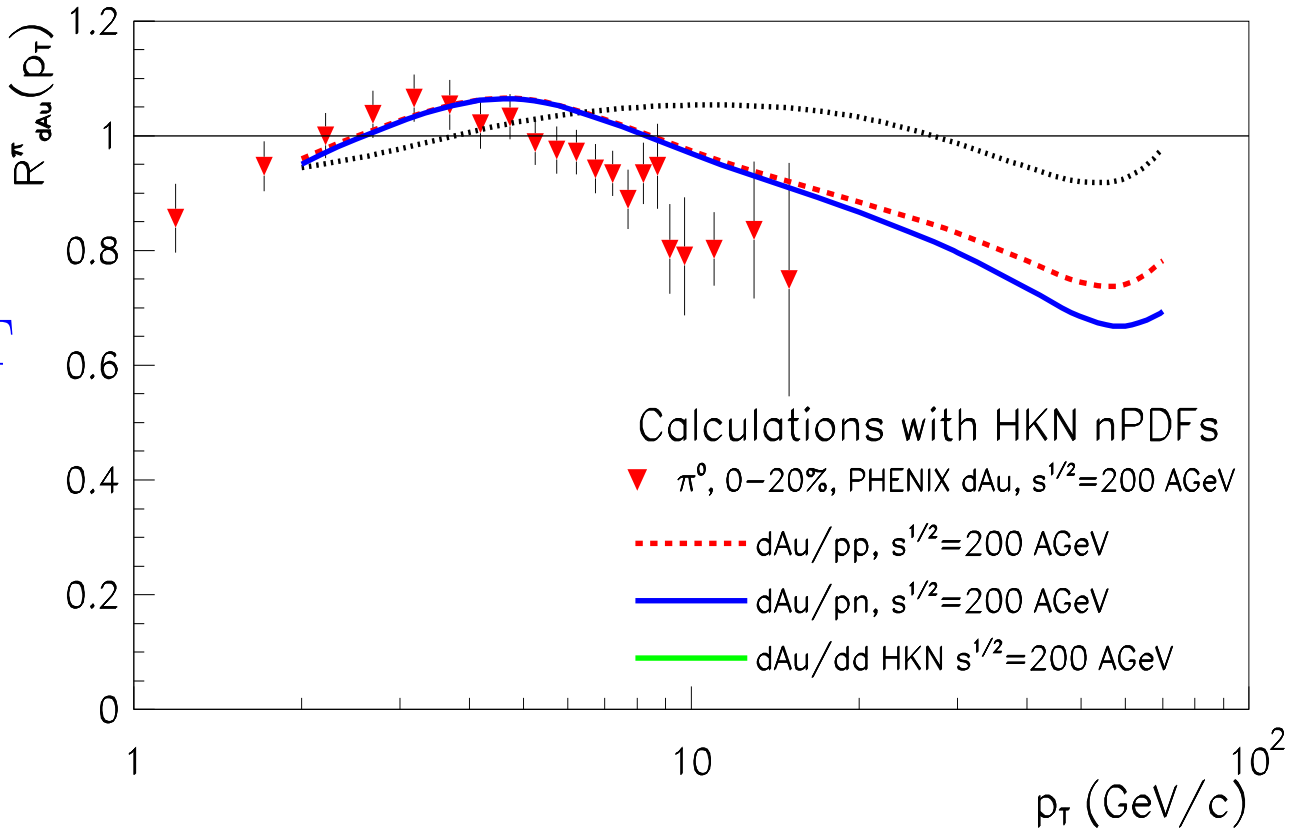
The Real 'Real' Isospin Effect or 'whatever' in dAu

Here dAu were normalised by 'true' dd from HKN for π^0

– Here EMC is killed since $F_2^A(x)/F_2^d(x)$ is relative to the d.

– Of course, Au is NOT symmetric nucleus

$\delta = 1 - 2 \cdot \frac{79}{197} = 20\%$



Note: this is for the most central region....

c) Shadowing Functions and the Isospin Assymetry – 1.

Of course – PDFs are modified inside the nucleus differently:

I. PDF based: genereal, but model dependent (HIJING)

factorise the isospin assymetry by the linear combination

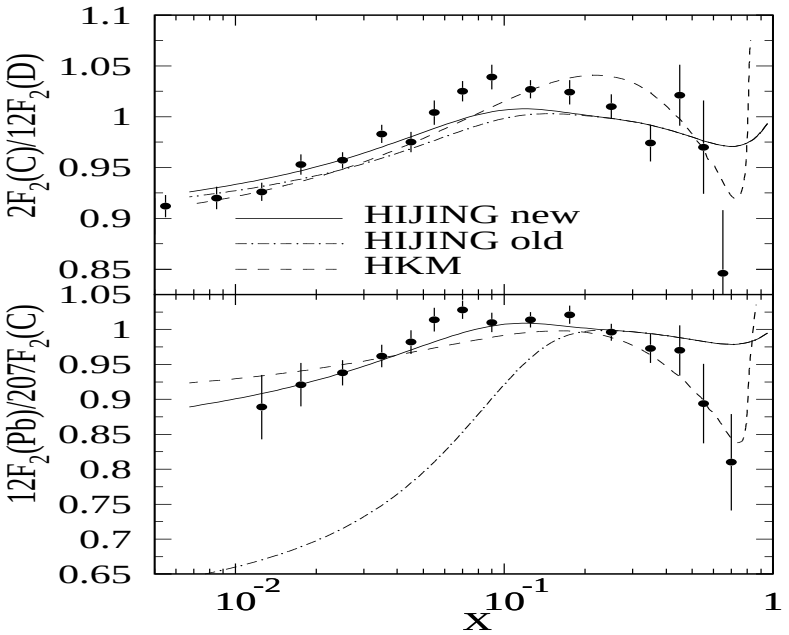
$$f_{a/A}\left(x,Q^2\right) = S_{a/A}(x,b)\left[\frac{Z}{A}f_{a/p}\left(x,Q^2\right) + \left(1-\frac{Z}{A}\right)f_{a/n}\left(x,Q^2\right)\right]$$

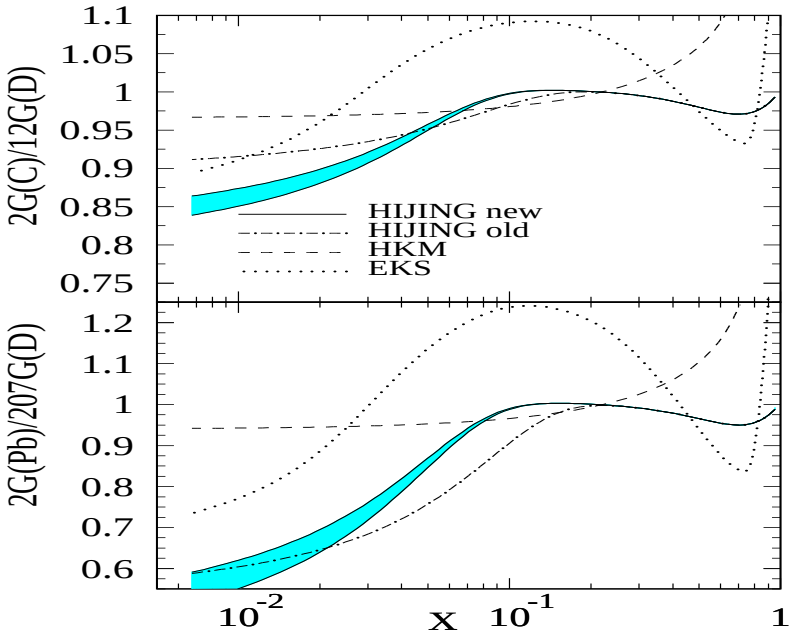
$S_{a/A}(x,b)$: Shadowing function (e.g.: HIJING);
A atomic- and Z the proton number

Here the PDF has only isospin effect, and its heritage varies by the separation between the p and n based PDFs

c) Shadowing Functions and the Isospin Assymetry – 2.

II. True NPDFs: only for special nuclei, more precise (HKN, new EKS?) this require more different measurements, time, money...





More specific measurements can help us to separate PDFs better from $Sa/A(x,Q)$ and understand isospin effects...

d) Is There Isospin Modification at the Final State?

Partially: can we see changes in the hadron ratios?

– At mesonic level: π^+/π^- ratio is ≈ 1 theoretically, and it seem to be ≈ 1 at high-p_T at CERN SPS and RHIC energies

– At baryonic level the 'clean test': $(n+\bar{n})/(p+\bar{p})$ should be ≈ 1. But hard to measure neutrons. Maybe some dedicated future high-p_T experiment e.g at PHENIX or LHC?

S U M M A R Y

I. Signature of isospin effect in PDFs

– Differences in pp, nn and $(pn)dd$ normalizations at RHIC

– Test of the high-p_T jet production

II. Is there isospin effect in $S_{a/A}(x)$ and FF?

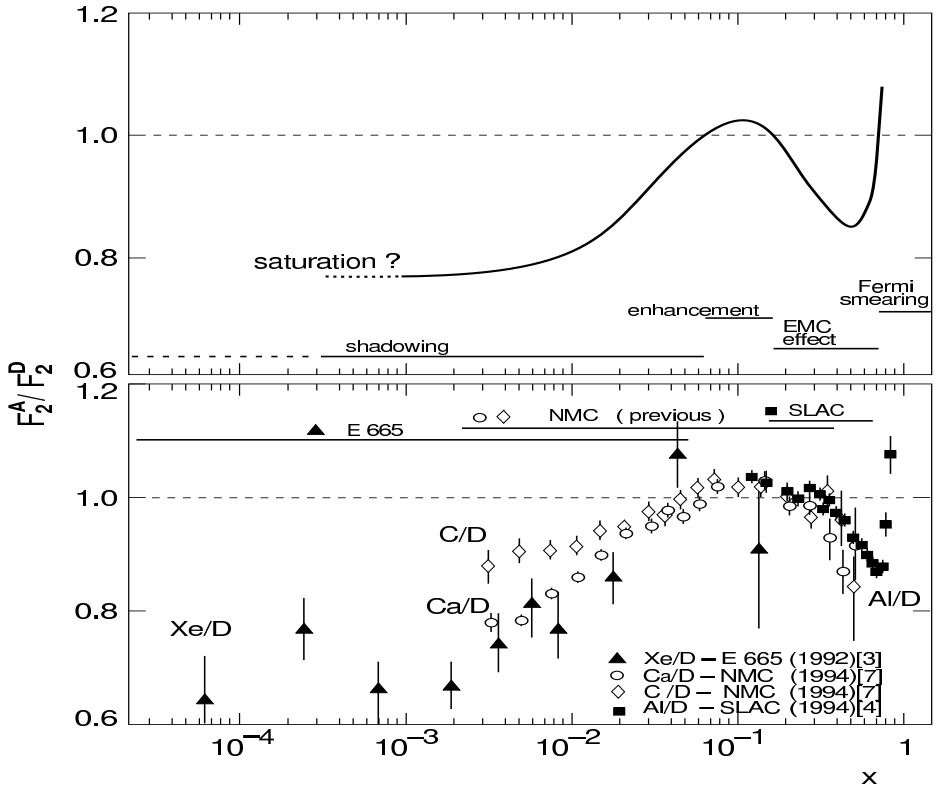
– Differences in pp, nn and $(pn)dd$ or $R^{p/\pi}_{dAu}$

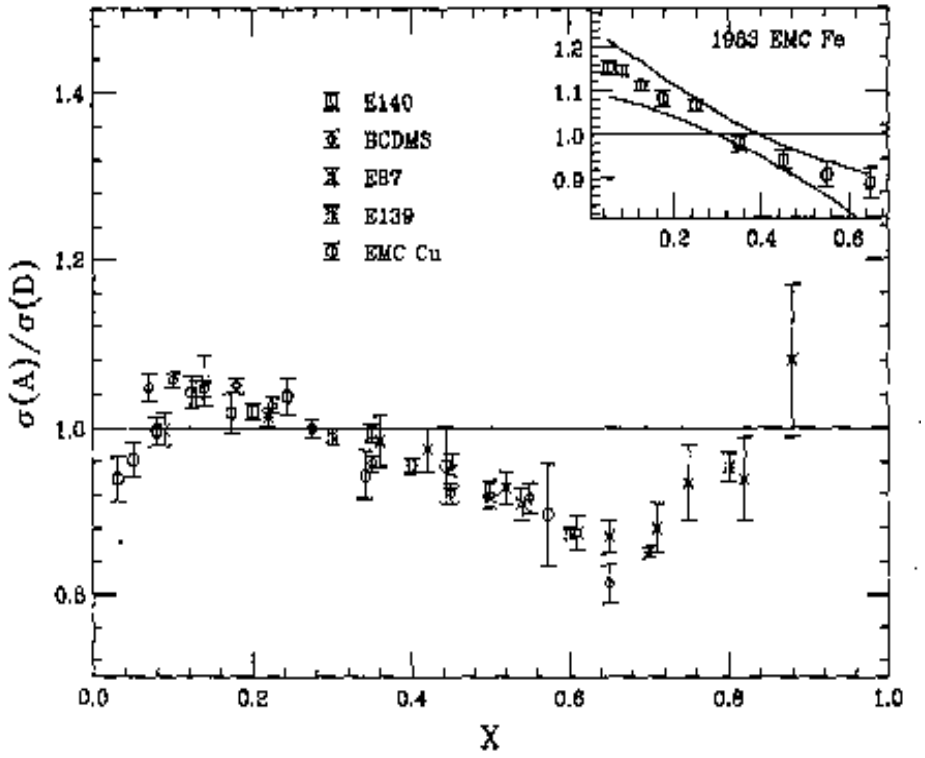
III. Nuclear modifications and isospin effect at LHC

– Coming soon LHC at 8.8 TeV pPb, nPb and dPb collisions

BACKUP SLIDES

Nominate Nuclear Modifications

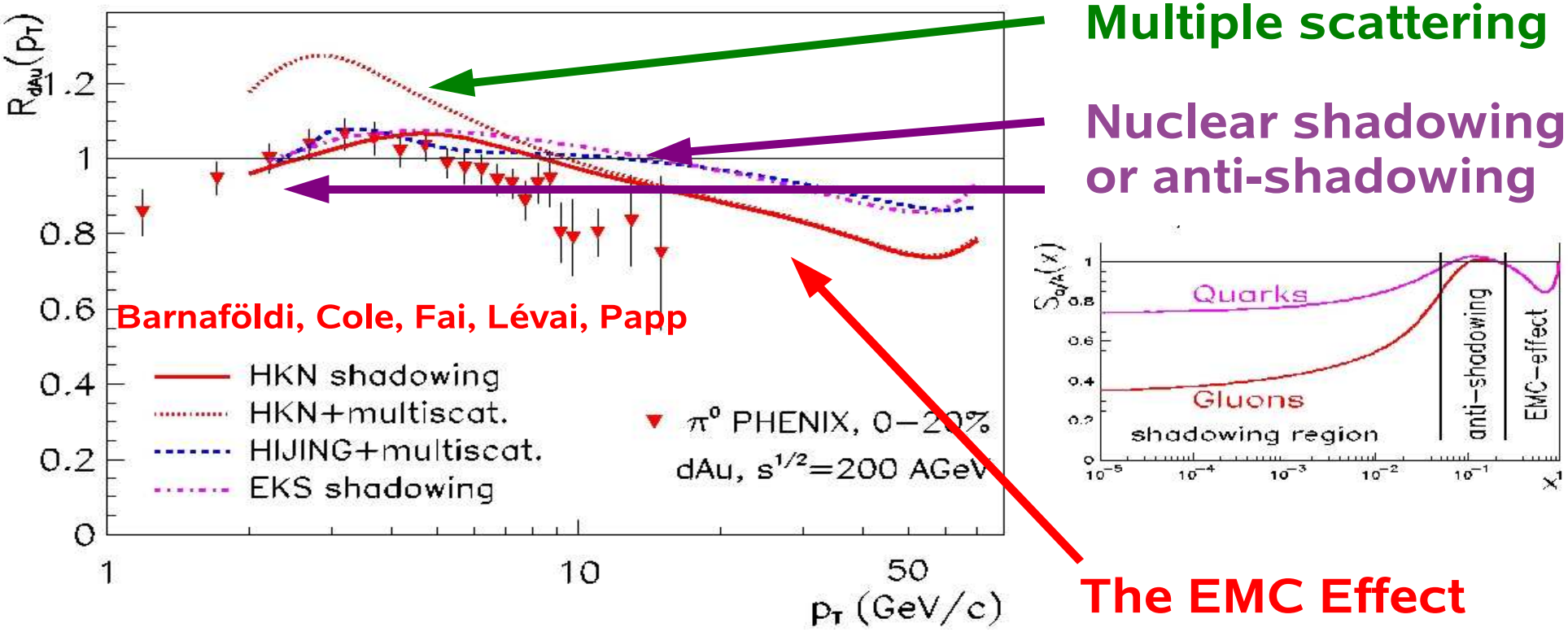




EMC were measured by many experimental collaborations

- Strict def.: EMC effect is in $[0.3; 0.8] \ni x$, where $F_2^A/F_2^D \lesssim 1$
- Non-strict: Where the slope is negative: $[0.1; 0.7] \ni x$
- at RHIC these are $[30; 80]$ and $[10; 70]$ GeV/c $\ni p_T$ respectively

Nuclear effects at very high-p_T in central dAu collision



MULTIPLE SCATTERING: $2\ \mathrm{GeV/c} \leq p_T \leq 7\ \mathrm{GeV/c}$

(GLUON) SHADOWING: $p_T \leq 1 - 5\ \mathrm{GeV/c}$

THE EMC REGION: $p_T \geq 10 - 20\ \mathrm{GeV/c}$