Hadron production in pA collisions

T. Lappi

University of Jyväskylä, Finland

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Abstract

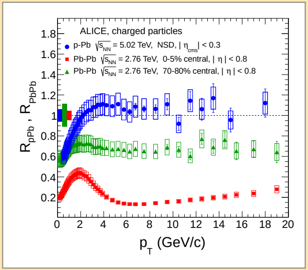
This talk discusses theory predictions for charged hadron production in pA collisions at LHC energies. In particular the emphasis is on the difference between models incorporating initial and final state effects on the production of (semi)hard particles.

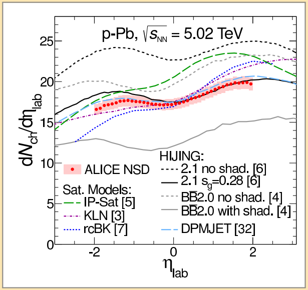
Outline

1. Theory predictions in light of first pA data
2. Saturation & shadowing
3. Generators: HIJING, AMPT
4. Final state interactions

- Discuss some theory predictions (not my own)
- Exhaustive review impossible

The data; so far





Data available for this talk:

- $\frac{dN_{ch}}{d\eta}$ around midrapidity (ALICE)
- Nuclear modification factor R_{pA} ALICE

Lots of data not discussed here:

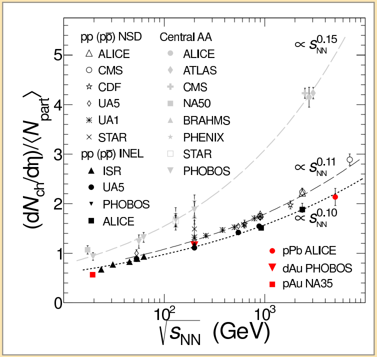
- Identified particles, dihadron correlations CMS
- Heavy flavor LHCB
- Jets ATLAS, CMS

Starting point: predictions at the Wuhan workshop, Oct 2012

J. L. Albacete *et al.*, Int. J. Mod. Phys. E **22** (2013) 1330007 [arXiv:1301.3395 [hep-ph]].

Pseudorapidity density, energy dependence

$\sqrt{s}$-dependence



- 1^{st} approximation: particle production like pp
- Fluctuations: is N_{part} right thing to do?

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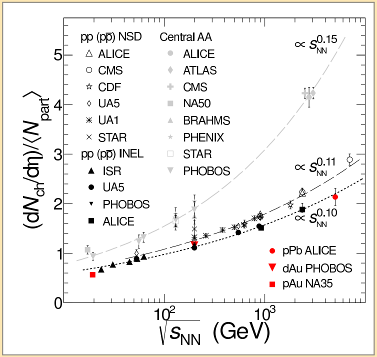

- 1^{st} approximation: particle production like pp
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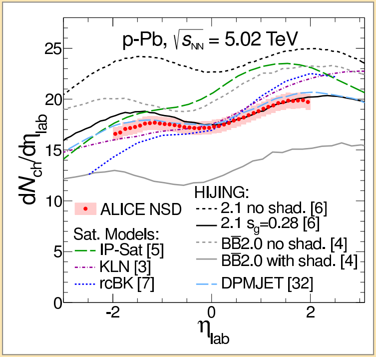
$\frac{dN_{ch}}{d\eta}$

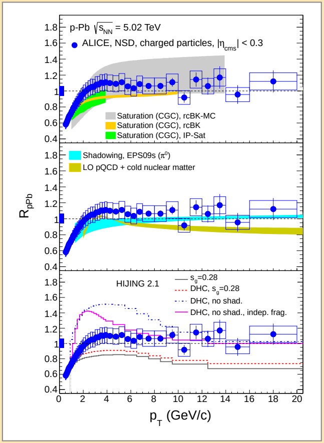
- Given pp & AA data theory should do this pretty well
- Monte Carlos will improve with modest additional tuning



R_{pA} predictions/theories discussed here

Plot: ALICE R_{pA} paper

arXiv:1210.4520



Initial state

Nucleus different from proton

- Saturation CGC: rcBK, IPsat
- Shadowing ($\sim$ saturation) EPS, HKN ...
- Event generators: HIJING, AMPT

Final state

Medium effects after scattering

- Cold nuclear matter energy loss ($\sim$)
- Final state rescatterings AMPT ...
- Hydrodynamics See talk by K. Werner

Saturation and shadowing

Two different frames:

IMF

- Nucleus made of partons
- DGLAP/BFKL: parton splitting
- For dense system (nucleus) also recombination (BK)

(I.e. parton density saturates)

TRF

- Nucleus target for H.E. probe
- $P(\text{scatter}) \leq 1 \implies$ upper limit on cross section

(I.e. constituents shadow each other)

Observable consequences same in both pictures:

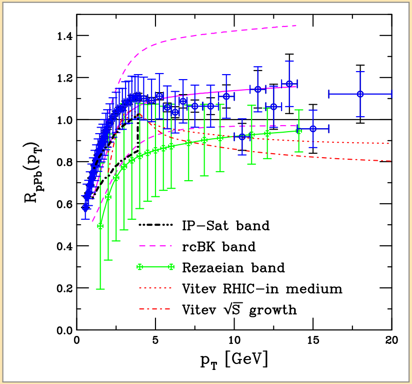
- Nucleus is less than A nucleons
- Effect increases with σ: small Q^2 and small x

"Shadowing" and "saturation" are descriptions of same physics;
choice of term is strongly author-dependent.

CGC predictions for R_{pA}

Typical CGC-calculation for R_{pA}: k_T-factorization:

- Spectrum is convolution of **unintegrated** gluon distributions
- Olden days of RHIC: updf's à la Stetson
- Now: proton updf's used must fit HERA data
- Normalization corrected with "K-factor" (Cancels in R_{pA})



IPsat, rcBK, Rezaeian like this.

- "Theory error" mostly from: p updf $\Longrightarrow$ A updf; N_{ncoll}
- IPsat: more detailed b-dep. $\Longrightarrow$ smaller "theory error" (but different physics for Q^2, x-dependence)

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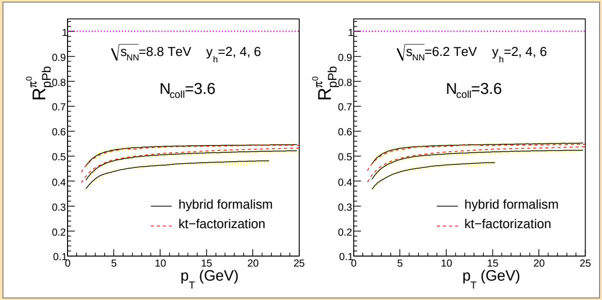
Compare with state of the art BK evolution in 2010:

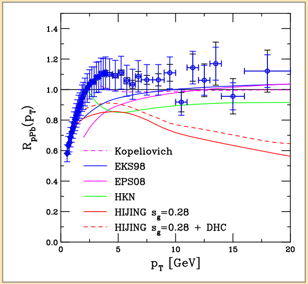
Albacete, Marquet arXiv:1001:1378



only difference is nuclear geometry

Shadowing in R_{pA}, collinear approach

- Particle production from collinear **integrated** parton distributions
- Pdf's fit to nuclear data, DGLAP-evolved
- Also large x



- Basically works: $R_{pA} \to 1$

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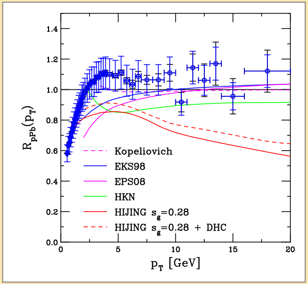
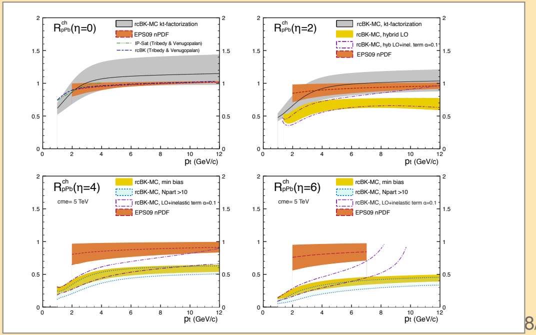
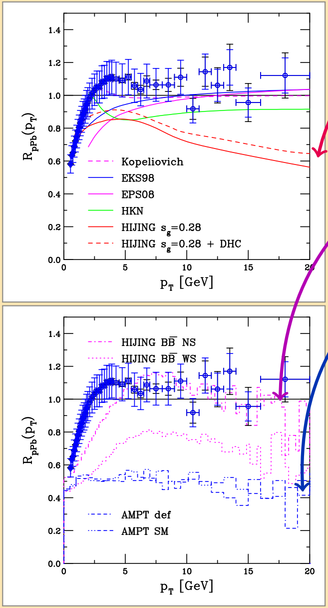


- Basically works: $R_{pA} \to 1$
- Real test of shadowing vs. CGC calculations will be ***y*-dependence**



R_{pA} from generators



- HIJING (this version) shadowing indep. of Q^2 $\Longrightarrow$ R_{pA} stays < 1.
  (Cf. EPS @ $p_T = 2$GeV)
- HIJING without shadowing (NS): $R_{pA} \to 1$ (unsurprisingly)
- AMPT is HIJING + final state

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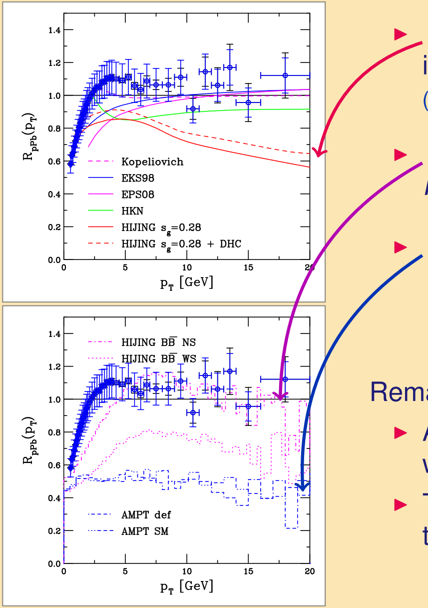

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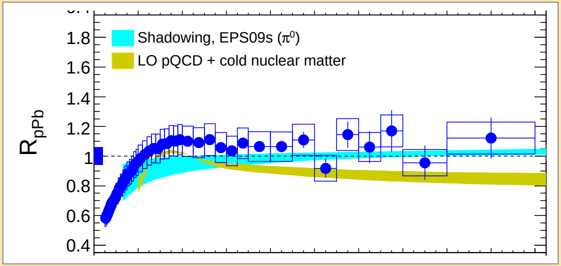
Remarks:

- A theory prediction is most useful when it fails!
- The real use of generators is after they have been tuned to data

CNM energy loss



CNM Energy loss calculation here Vitev $\Longrightarrow$ depletion @ high p_T

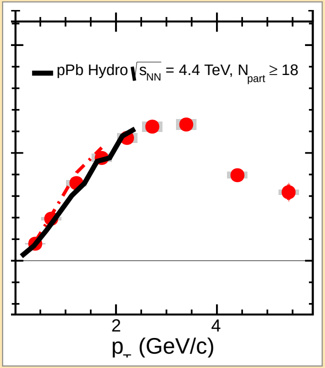
What loses energy is the incoming parton — not like jet quenching

CNM & coherence timescale:

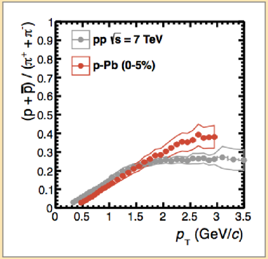
- Coherence length $\ell \sim 1/(x m_N)$ (TRF)
- $y = 0$: for $p_T \lesssim 100\text{GeV}$ scattering coherent over whole nucleus.
- In CGC this is eikonal: parton from p does not lose energy
- CNM energy loss attempts to treat kinematics more exactly.

Multiparticle correlation data $\Longrightarrow$ hydro?

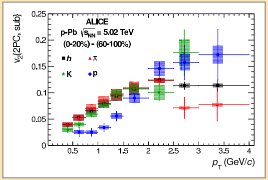
- "v_2" also from initial state effects, but:
- Hadron species dependence & v_3 point to collective final state effects
- Note: lower momenta than R_{pA}



CMS v_3 in pPb; hydro: Bozek



ALICE p/π ratio



ALICE identified particle v_2

Conclusion

Miscellaneous points:

- Big “theory errors” in CGC calculations from treatments of nuclear geometry; actual small-x theory is better than this!
- Event generators: need to do DGLAP properly for high p_T.
  (LHC kinematical reach in x, Q^2 is qualitatively different)
- CNM e-loss predicts R_{pA} slowly decreasing with p_T
- Semihard particle production data does not indicate final state effects: smaller p_T and correlations do.
- Forward rapidity data very important for initial state physics!