Possibility of eD collisions in Pythia 8 / Angantyr

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EIC ad hoc meeting: Deuteron Simulations, JLab

Where heavy ions meet proton–proton

- Heavy ion capabilities of PYTHIA8 recently introduced with the Angantyr model (arXiv:1806.10820 [hep-ph]).
- Development focused on High Energy Heavy Ion collisions (PbPb @ LHC etc.).
- Model can be extended to cover EiC/deuteron use cases.

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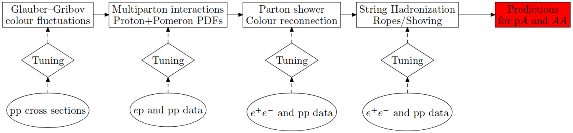
- This talk:
  1. The Angantyr model.
  2. Results for pPb and PbPb.
  3. Possible inclusion of deuterons.
  4. Possible inclusion of γ^*.

Angantyr from helicopter perspective

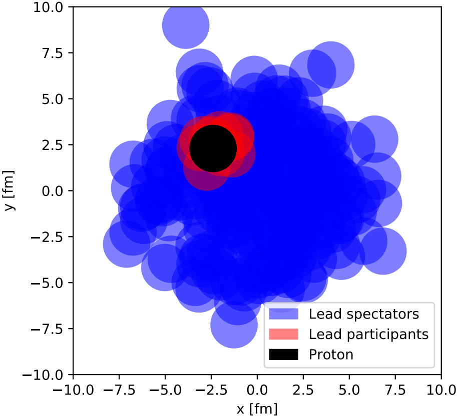
- Extending the PYTHIA8 MPI model to HI.
  1. Only tuning to pp, add Glauber for nuclear geometry.



- Strategy for deuteron and γ^* to be added.

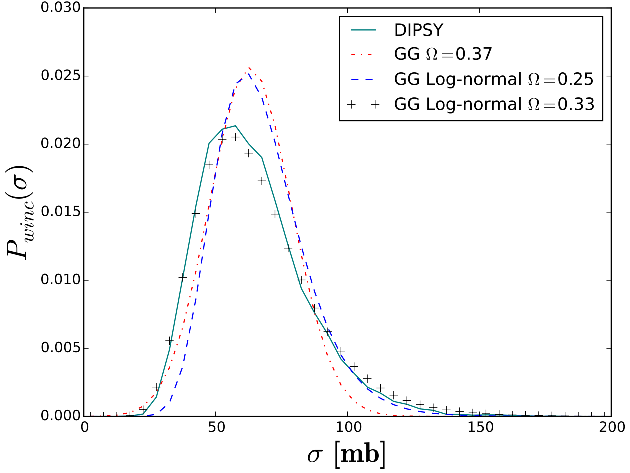
Glauber initial state

- Determine which nucleons are "wounded".
- Geometric picture only relies on pp cross section.



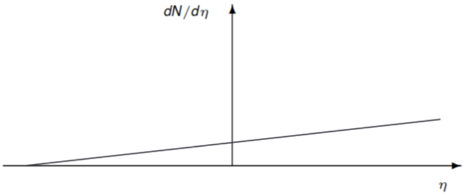
Glauber–Gribov colour fluctuations

- Cross section has EbE colour fluctuations.
- Parametrized in Angantyr, fitted to pp (total, elastic, diffractive).



Particle production: Wounded nucleons

- Simple model by Białas and Czyz.
- Wounded nucleons contribute equally to multiplicity in η.
- Originally: Emission function $F(\eta)$ fitted to data.



$$\frac{dN}{d\eta} = F(\eta)$$ (single wounded nucleon

- Angantyr: No fitting to HI data, but include model for emission function.
- Model fitted to reproduce pp case, high $\sqrt{s}$, can be retuned down to 10 GeV.

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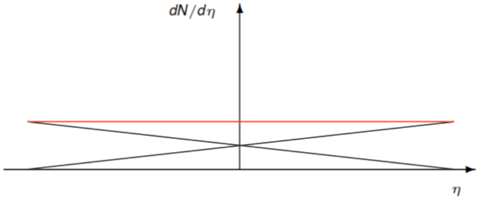

$$\frac{dN}{d\eta} = F(\eta) + F(-\eta) \qquad \text{(pp)}$$

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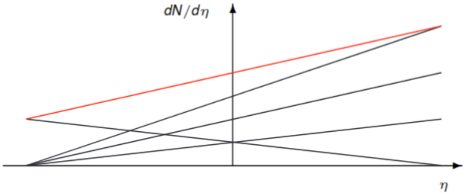

$$\frac{dN}{d\eta} = w_t F(\eta) + \quad F(-\eta) \qquad\qquad (pA)$$

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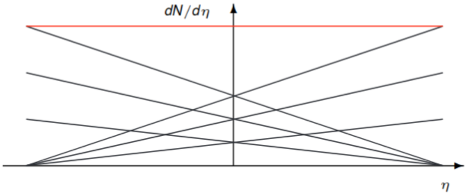

$$\frac{dN}{d\eta} = w_t F(\eta) + w_p F(-\eta) \qquad (AA)$$

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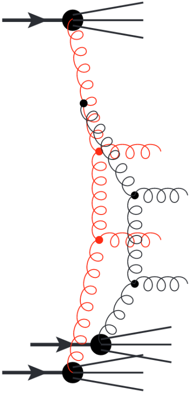
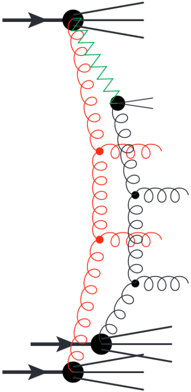
The emission function

- A schematic view of a pD collision. Contains 3 wounded nucleons.
- First two are a normal non-diffractive pp event.
- The second one is modelled as a single diffractive event.
- Generalizes to all pA and AA collisions.



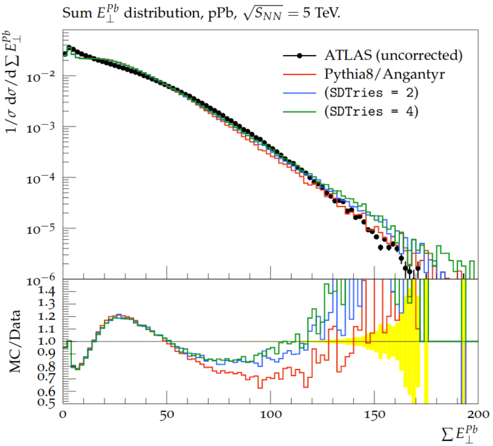
(a)



(b)

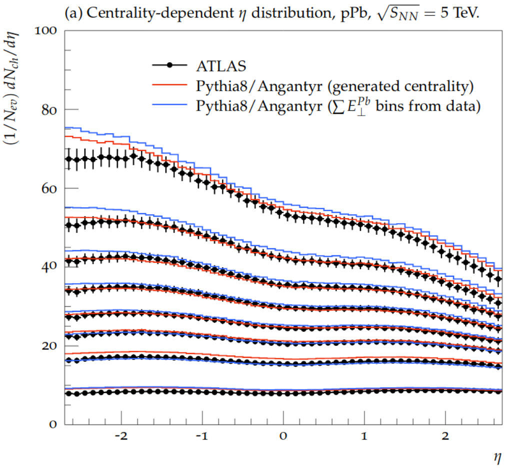
Some results - pPb

- Centrality measures are delicate, but well reproduced.



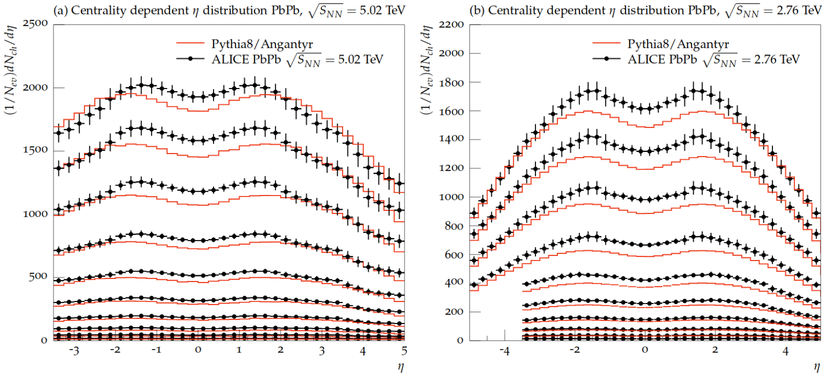
Some results - pPb

- Multiplicity distributions well reproduced.



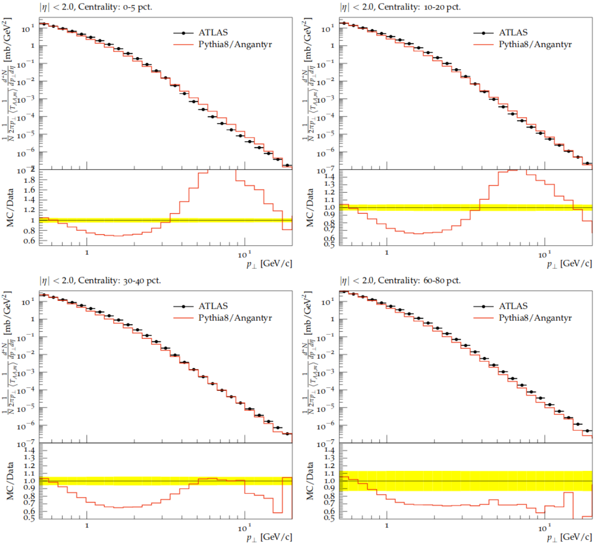
Some results - PbPb

- Multiplicity distributions well reproduced.



Some results - PbPb

- Spectra to a lesser degree, no collective effects so far.

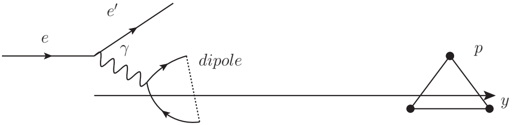


Future I: The deuteron

- Currently only Woods–Saxon distributed nuclei.
- Using GLISSANDO parametrization – for deuteron Hulthen potential could be used.
- ... or external Glauber provider.
- Important test case for the model, a wealth of DAu data available.
- Missing: High energy pD data.

Future II: The electron

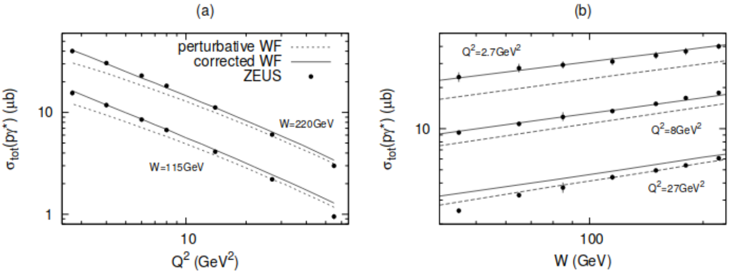
- Borrow from dipole models: Treat virtual photon as $q\bar{q}$ pair.
- Possible to construct a photon "Glauber".
- For large Q^2 splitting pertubatively calculable.
- For smaller Q^2 a hadronic component must be added.



- Only the (fluctuating) ep cross section is needed, everything else is in place.

Borrowing from DIPSY (Flensburg et al: arXiv:1103.4321 [hep-ph])

- The approach for cross sections is well tested.
- Wealth of data to test a new implementation on.



Conclusions

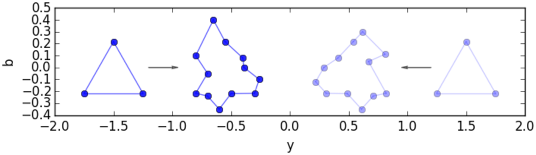
- Heavy ion model PYTHIA8 /Angantyr. Available in present version.
- Works well for large nuclei, high energies.
- Lower energies: Need pp data for tuning.
- Directly extendable to deuterons (on the TODO list).
- Virtual photon can be included through dipole formalism.

The DIPSY dipole cascade (Flensburg et al: arXiv:1103.4321 [hep-ph])

- Dipole models have been very succesful for *e*A collisions.
- DIPSY is a dipole cascade ⇒ builds up initial states event by event.

  Dipole evolution in **I**mpact **P**arameter **S**pace and rapidit**Y**.
- Been applied to: pp, *e*p, pA, AA, *e*A.

$$\frac{dP}{dY} = \frac{3\alpha_s}{2\pi^2} d^2\vec{z} \frac{(\vec{x}-\vec{y})^2}{(\vec{x}-\vec{z})^2(\vec{z}-\vec{y})^2}, \; f_{ij} = \frac{\alpha_s^2}{8}\left[\log\left(\frac{(\vec{x}_i-\vec{y}_j)^2(\vec{y}_i-\vec{x}_j)^2}{(\vec{x}_i-\vec{x}_j)^2(\vec{y}_i-\vec{y}_j)^2}\right)\right]^2$$



- Full event generator using Ariadne FS cascade + Pythia hadronization.

Cross sections, MPIs and unitarisation

- Eikonal approximation $\Rightarrow$ unitarized amplitude:

$$T \equiv -iA_{el} = 1 - \exp(-\sum f_{ij})$$

- Good–Walker formalism allows for diffraction.

$$\frac{d\sigma_{tot}}{d^2b} = 2\left\langle T\right\rangle_{t,p}, \; \frac{d\sigma_{el}}{d^2b} = \left\langle T\right\rangle_{t,p}^2, \; \frac{d\sigma_{SD,(p|t)}}{d^2b} = \left\langle\left\langle T\right\rangle_{(t|p)}^2\right\rangle_{(p|t)} - \left\langle T\right\rangle_{p,t}^2$$

$$\frac{d\sigma_{DD}}{d^2b} = \left\langle T^2\right\rangle_{p,t} - \left\langle\left\langle T\right\rangle_t^2\right\rangle_p - \left\langle\left\langle T\right\rangle_p^2\right\rangle_t + \left\langle T\right\rangle_{p,t}^2$$

- Includes MPIs by construction.
- Diffractive excitation determined by fluctuations in cascade.
- Not as precise as fine tuned PDFs.
- Not obvious how to include a signal process (everything is fluctuations).