DIPSY and Angantyr: Towards eA exclusive final states

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DIPSY and Angantyr – what are they?

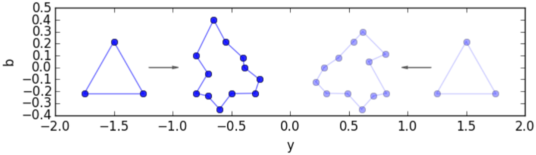
- To separate models capable of generating full HI collisions, implemented as MC generators.
  1. DIPSY: A dipole cascade model, built on BFKL in impact parameter space.
  2. Angantyr: Extending Pythia8 to include heavy ion collisions, inspired by wounded nucleons/Fritiof/DIPSY.
- DIPSY: E. Avsar, T. Csörgő, C. Flensburg, G. Gustafson, L. Lönnblad, A. Ster.
- Angantyr: G. Gustafson, L. Lönnblad, H. Shah.
- This talk:
  1. The DIPSY model and inclusive observables.
  2. Prospects for collectivity studies.
  3. The Angantyr model for pA and AA.
  4. Extending Angantyr.

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.

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



- 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.

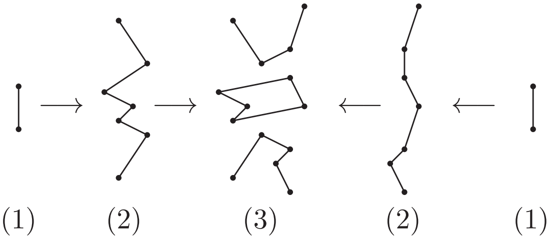
$$\frac{d\sigma_{tot}}{d^2b} = 2\langle T\rangle_{t,p}, \quad \frac{d\sigma_{el}}{d^2b} = \langle T\rangle^2_{t,p}, \quad \frac{d\sigma_{SD,(p|t)}}{d^2b} = \left\langle \langle T\rangle^2_{(t|p)} \right\rangle_{(p|t)} - \langle T\rangle^2_{p,t}$$

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

- 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).

Saturation in the cascade

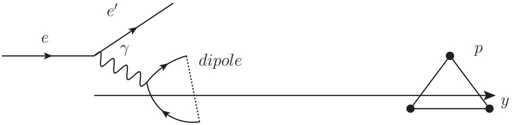
- Cascade evolution BFKL-like, non-linearities from unitarisation.
- Unitarisation → MPIs → colour loops.



- Evolution also frame dependent – missing loops in "wrong" frame.
- In the dipole rest frame, all loops must come from cascade.
- Allow colour compatible dipoles to reconnect, favouring smaller dipoles.

Nuclei and photon initial states

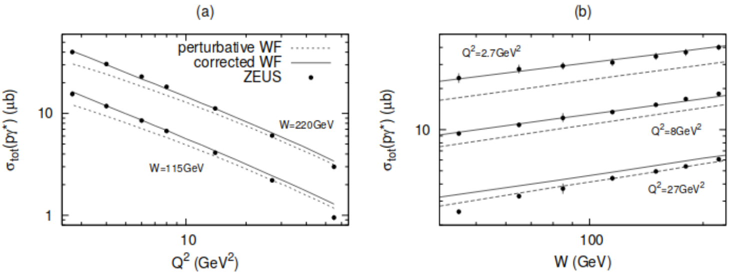
- Nuclei = protons in a WS potential. Swing between nuclei can be switched on/off.
- Photon treated as dipole, for large Q^2 the splitting can be calculated perturbatively.
- For smaller Q^2 a hadronic component must be added.



- This determines the starting point of the cascade.
- (For simplicity imagine $r_{\perp,dipole} \sim 1/Q$)

Inclusive results ep (Flensburg et al: arXiv:0807.0325 [hep-ph])

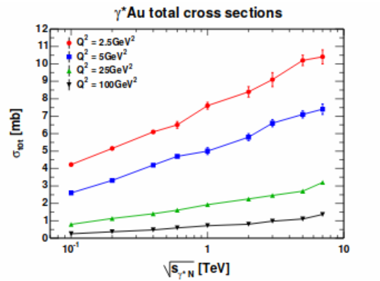
- Adding a hadronic component predictably has larger effect at low Q^2.

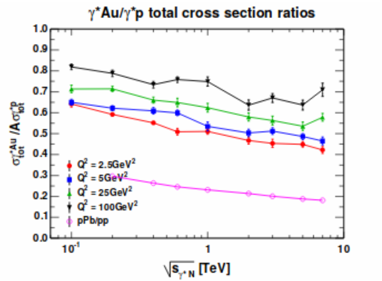


- Cross sections is essential starting point for Angantyr.
- (More results in the paper).

Inclusive results γ^*A (Gustafson et al: arXiv:1506.09095 [hep-ph])

- Formalism directly applicaple (here γ^*Au, disclaimer: not precision predictions).
- Nuclear volume scaling ($\propto A$) broken – nucleus asymptotically black.
- Still easier for dipole to pass through that for a proton.

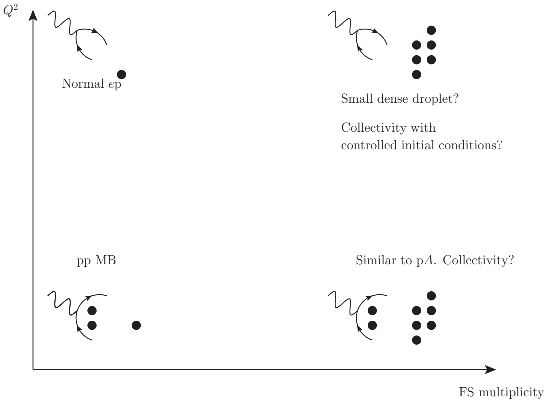




- Clear geometrical picture!
- Should be able to produce a "Glauber model" reproducing this.

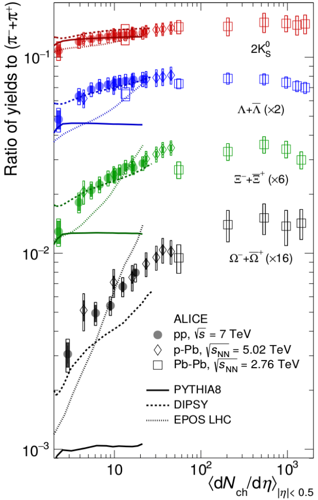
Is $\gamma^* A$ a new venue for collectivity

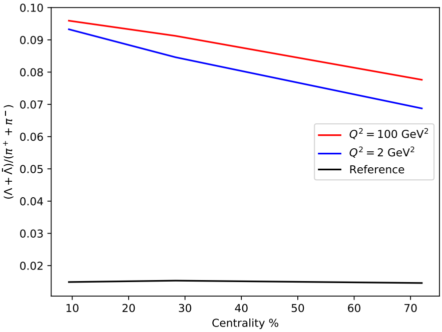
- Collectivity in small systems is currently a hot topic.
- Constrained by lacking knowledge of initial conditions.
- Knowledge of Q^2 provides an additional handle.



Preliminary results

- Very preliminary, easily improved ($\gamma^* Au$, $\sqrt{s_{\gamma^* N}} = 200$ GeV).
- Better observables would be sensitive to geometry not density.



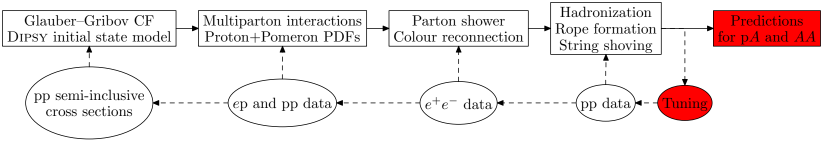


Partial conclusion

- Dipole models have had considerable success for $\gamma^* p$, DIPSY usable right away.
- DIPSY best for initial state evolution, and inclusive observables.
- Recent attempts to port the best parts to Pythia: Project Angantyr.
- Collisions of $\gamma^* A$ might be a new venue for collectivity.
- Initial state geometry under better control $\rightarrow$ better understanding of geometry sensitive observables.

Heavy ion collisions with Angantyr (Bierlich et al: in preparation)

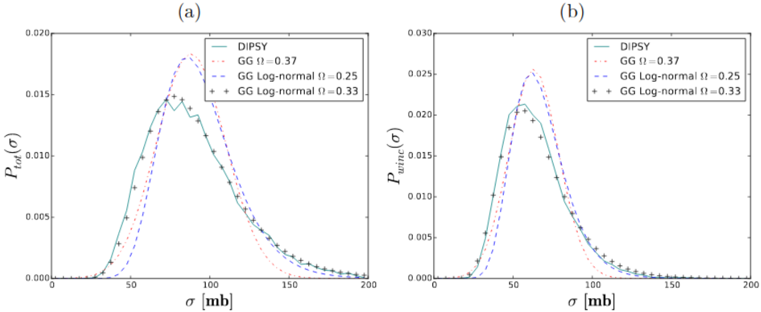
- Goal: Take the most useful parts of DIPSY, and put them into Pythia.
- Created to facilitate pA and AA...
- ...but with inclusion of photon dipoles, *e*A is also possible.



- Remaining talk: Current capabilities of Angantyr.

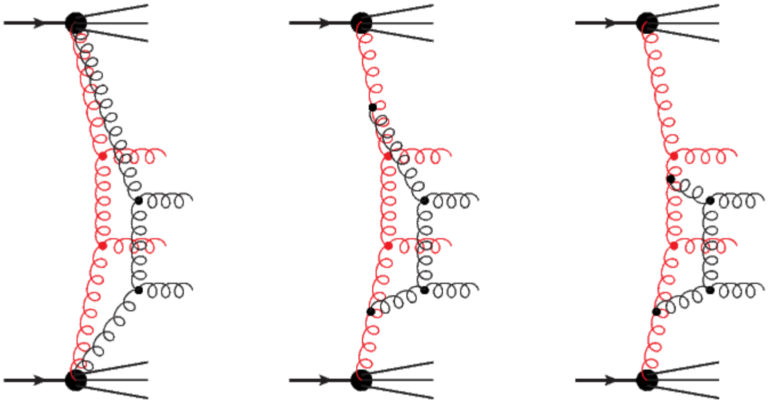
Translating DIPSY to Glauber (Bierlich et al: arXiv:1607.04434 [hep-ph])

- Angantyr philosopy:
  1. Extend the wounded nucleon model a bit...
  2. All nuclear subcollisions are similar to *some* pX collision.
- Parameterize DIPSY fluctuations to get the "wounded" cross section right.
- Allows for calculation of number of pX subcollisions.



Secondary wounded nucleons – what is pX?

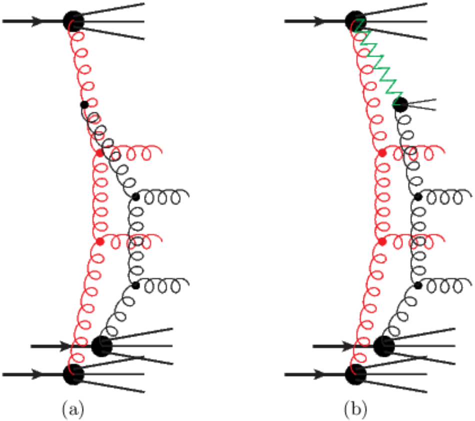
- Not all subcollisions are created equal! Even on partonic level.
- DIPSY: All interactions connected to proton cascade.
- Pythia MPI: soft interactions are "colour reconnected" to harder ones.



(a) (b) (c)

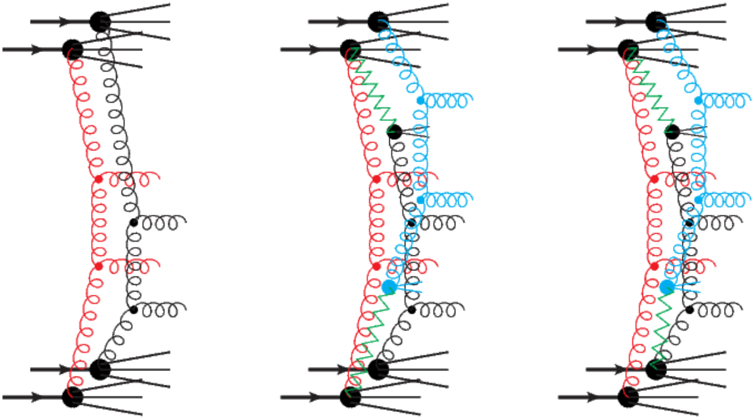
Secondary wounded nucleons – what is pX?

- Apply same picture to pA.
- Use a "pseudo-diffractive" collision to create the rapidity gap to beam.
- In the end we just want to recreate the DIPSY cascade.



Secondary wounded nucleons – what is pX?

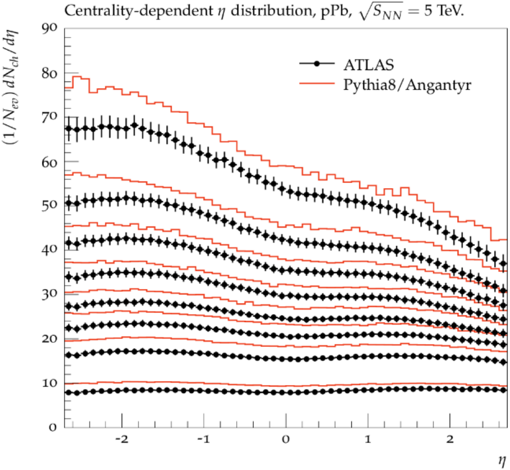
- Can generalize to AA.
- Figure looks complicated, but principle is the same.



(a) (b) (c)

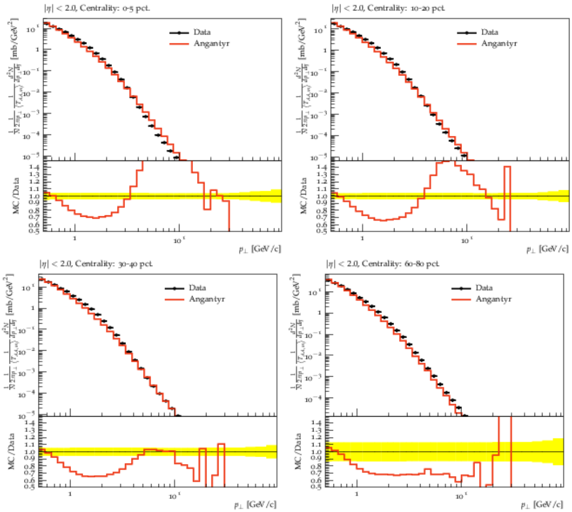
Results for pPb

- Model still in development, but seems to work fairly well.



Results for PbPb

- Future work includes support for collective effects.



Summary: Towards $\gamma^* A$; What to do?

- The DIPSY model natively supports $\gamma^* A$, and have been used mostly for inclusive observables.
- DIPSY can be run as-is, but might be better for inspiration than predictions.
- Angantyr extends Pythia8 to pA and AA collisions, model is work-in-progress.
- Including capabilities for $\gamma^* A$ in Angantyr is an interesting prospect.
  1. Requires parametrization of fluctuations in $\sigma_{\gamma^* p}$, some ground work already done (Flensburg and Gustafson: arXiv:0807.0325 [hep-ph]).
  2. Merging with Pythia8 photon MPI framework (see talk by I. Helenius), support for diffractive events in the pipeline.
  3. Would be nice to include also a better model for space-distribution of MPIs, to study collectivity.

Thank you!