

# The ANGANTYR model for heavy ions in PYTHIA8



LUND  
UNIVERSITY

Leif Lönnblad

with C. Bierlich, S. Shakraborty, G. Gustafson, H. Shaah

Department of Astronomy  
and Theoretical Physics  
Lund University

Quark Matter, 2019-11-06, Wuhan

# Lund = strings = PYTHIA!

- ▶ The string picture works well for  $e^+e^-$ , ep and pp.
- ▶ Why not in pA and AA?
- ▶ Do we really need a QGP?
- ▶ What happens when strings are crammed together.



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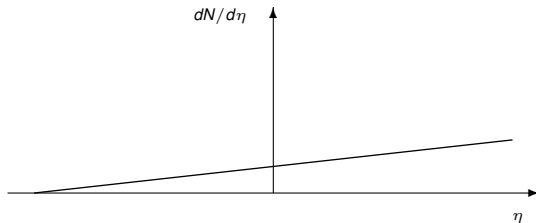
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## Fritiof showed the way in the eighties

A simple model by Białaś and Czyż, implemented in Fritiof

Each wounded nucleon contributes with hadrons according to a function  $F(\eta)$ . Fitted to data, and approximately looks like



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

(single wounded nucleon)

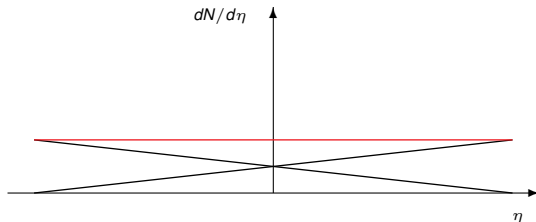
[Nucl.Phys.B111(1976)461, J.Phys.G35(2008)044053, Nucl.Phys.B281(1987)289.]



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

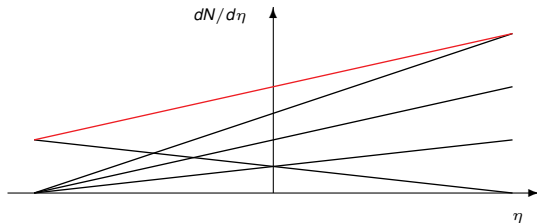
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$$\frac{dN}{d\eta} = w_t F(\eta) + F(-\eta) \quad (\text{pA})$$

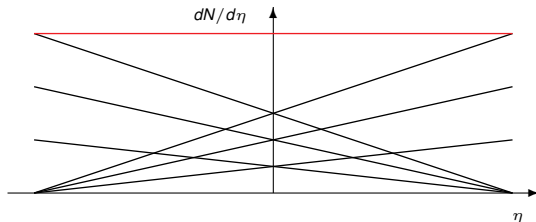
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$$\frac{dN}{d\eta} = w_t F(\eta) + w_p F(-\eta) \quad (AA)$$

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In Fritiof this was modelled by stretching out a string from each wounded nucleon with an invariant mass distributed as  $dm_X/m_X$ .

Each string gives a flat rapidity distribution, so This gives  $F(\eta) \sim \eta - \eta_0$ .

Note that there are no collective effects here. But nevertheless Fritiof reproduced most data: No conclusive evidence for QGP until RHIC.



# What's missing in Fritiof?

- ▶ QGP?
- ▶ Jets and parton showers
- ▶ Multiple interactions
- ▶ Initial state fluctuations
- ▶ Interactions between strings



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## Angantyr: Heavy Ions in PYTHIA8

- ▶ Glauber model with advanced fluctuation treatment
- ▶ Divides  $NN$  interactions into absorptive, single or double diffractive.
- ▶ Also differentiates absorptive interactions:
  - ▶ Primary: is modelled as a PYTHIA non-diffractive  $pp$  event.
  - ▶ Secondary: an interaction with a nucleon that has already had an interaction with another. Modelled as a (modified) diffractive excitation event (with  $dm_X/m_X$  as in Fritiof).
- ▶ All sub-events generated on parton level using the full PYTHIA8 MPI/ISR/FSR machinery and merged together into a consistent  $pA$  or  $AA$  event and then hadronised.  
(No string interactions yet.)

[arXiv:1607.04434, arXiv:1806.10820]



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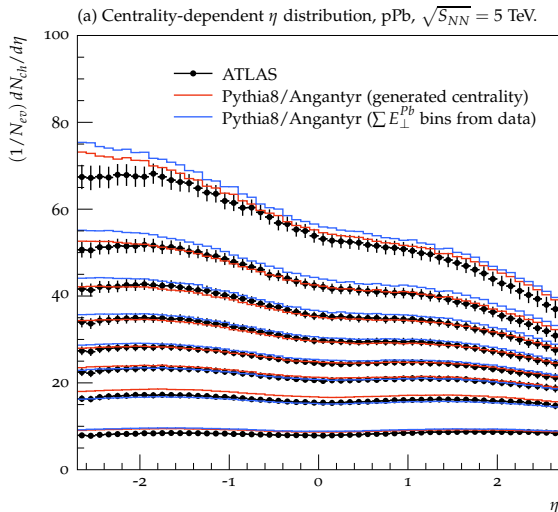
[arXiv:1607.04434, arXiv:1806.10820]



# Angantyr: Heavy Ions in PYTHIA8



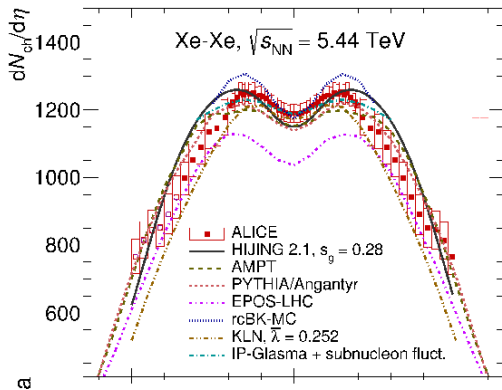
## It works!



[arXiv:1508.00848]



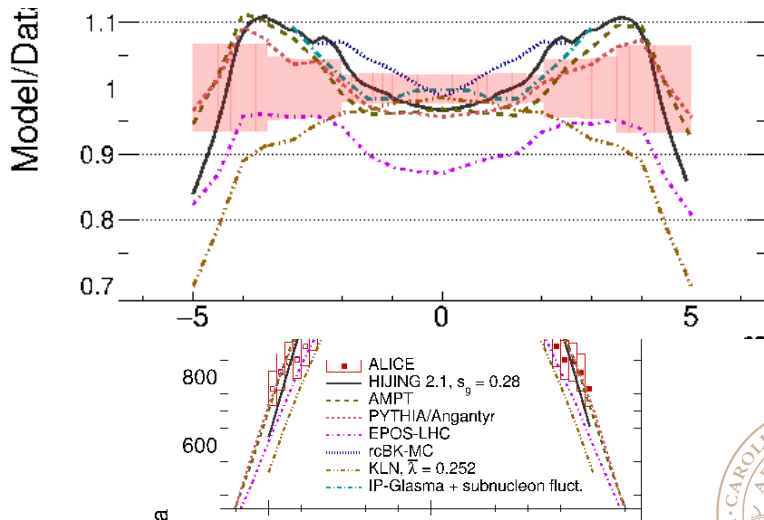
# It works even in AA!



[arXiv:1805.04432]



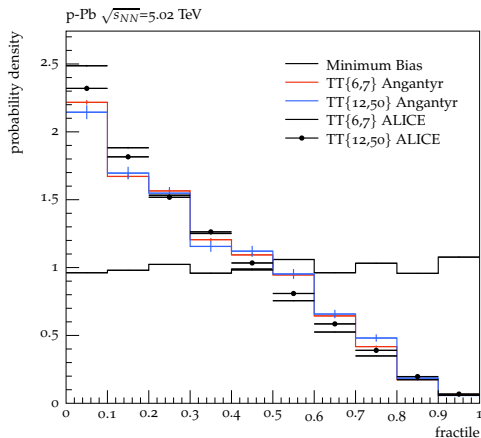
# It works even in AA!



[arXiv:1805.04432]



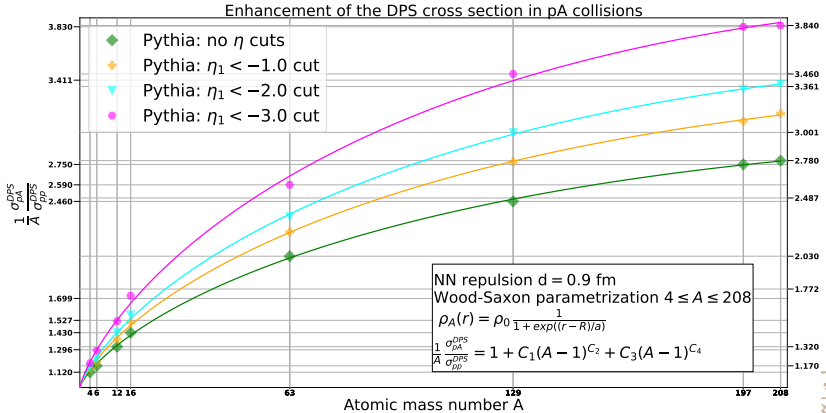
# Trigger bias in pA



[arXiv:1712.05603]



# Double Parton Scattering in pA



[arXiv:hep-ph/0111468, L.L. & O. Fedkevych in prep.]



## String Interactions

- ▶ Overlapping strings will have an increased string tension, making it easier to produce eg. strange hadrons.
- ▶ Overlapping anti-parallel strings may attenuate each other.
- ▶ Overlapping strings may repel each other



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**Rope Hadronisation**  $\Rightarrow$  strangeness enhancement
- ▶ Overlapping anti-parallel strings may attenuate each other.  
**Swing, Colour reconnections**
- ▶ Overlapping strings may repel each other  
**String Shoving**  $\Rightarrow$  ridges and flow

[arXiv:1009.4122, arXiv:1710.09725]



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Fairly rudimentary models.

- Assumes string (pieces) parallel to beam-axis.
- Or to each other in pairwise interactions.
- Over-simplified space-time picture
- Only implemented for pp.

[arXiv:1009.4122, arXiv:1710.09725]



# Introducing GLEIPNIR (XFMIC+IR)

The string endpoints (quarks and gluons) carry longitudinal momentum, but the string itself cannot.

The shoving gives a transverse push according to a

$$\frac{dp_{\perp}}{dt dz} = \frac{g_{\kappa} \delta_{\perp}(t)}{R^2} \exp\left(-\frac{\delta_{\perp}^2(t)}{4R^2}\right).$$

This push must be parallel to both string pieces.

There is no frame where two random sting pieces are parallel.

But there is always a frame where they lie in parallel planes at any given time.

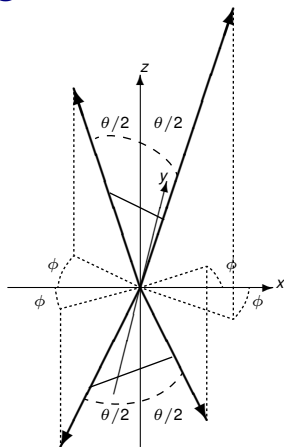
[work in progress]



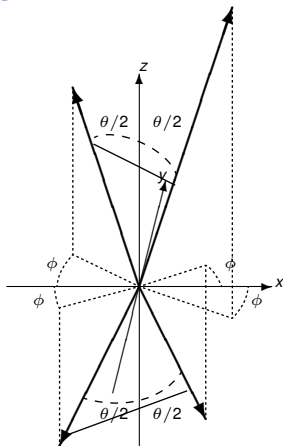




# The parallel string frame



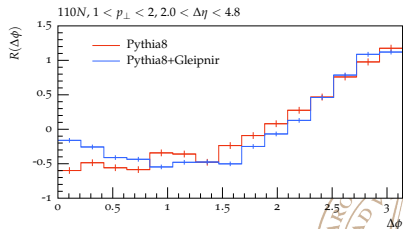
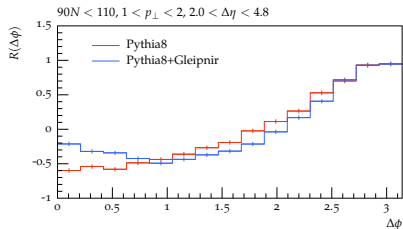
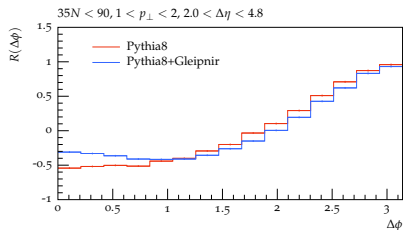
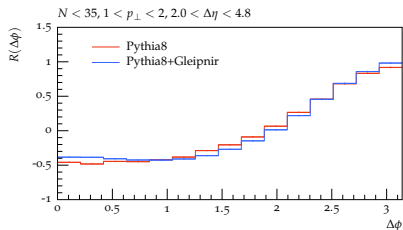
# The parallel string frame



- ▶ Use (simplified) space-time information of all partons.
- ▶ Transform to parallel frame for every pair of string pieces.
- ▶ Calculate and collect small nudges, ordered in time
- ▶ Apply the pushes to the produced primary hadrons.



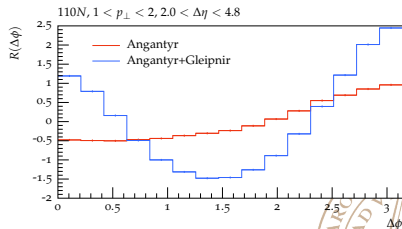
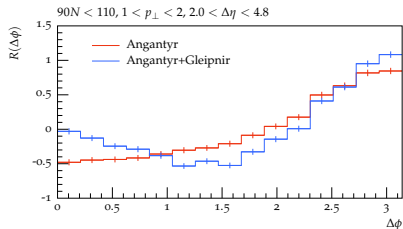
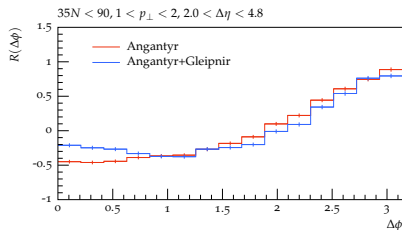
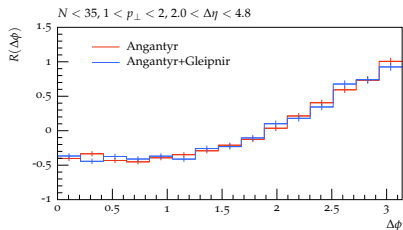
# We have a ridge!



[arXiv:1009.4122]



# Also in pPb!



[Very preliminary]



# Outlook

- ▶ **Angantyr** gives a reasonable description of inclusive particle production of (pp), pA and AA.
- ▶ Successfully extrapolates the pp dynamics of PYTHIA8 via pA to AA without introducing QGP dynamics.
- ▶ PYTHIA8/Angantyr brings general purpose event generators to heavy ion physics.
- ▶ Collective behaviour can be introduced via the **Gleipnir** models (Ropes, Swing, Shoving).



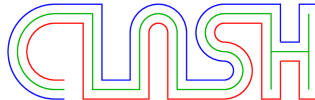
# Thanks!



Vetenskapsrådet



European Research Council  
Established by the European Commission



The screenshot shows a Mozilla Firefox browser window displaying the INSPIRE HEP website. The page title is "Researcher in heavy ion phenomenology - INSPIRE - Mozilla Firefox". The address bar shows the URL "https://labs.inspirehep.net/jobs/1762948". The website header includes the INSPIRE HEP logo, a search bar with the word "jobs" entered, and a magnifying glass icon. The main content area features the following information:

## Researcher in heavy ion phenomenology

Lund U., Dept. Theor. Phys. • Europe

hep-ph nucl-th PostDoc

**Deadline on Dec 1, 2019**

**Job description:**  
The Theoretical Particle Physics group at Lund University has an opening for up to two two-year researchers in Particle Physics Phenomenology, starting in the autumn of 2020, or by agreement.

**Description of work**  
The researchers should work on topics related to simulation of heavy ion collisions within the scope of the KAW project CLASH and the ERC project collectiveQCD. These projects are led by Leif Lönnblad and Korinna Zapp, respectively, and both projects involve the development of new models for collective effects, and the

A vertical "Feedback" button is visible on the right side of the page.

# Monte Carlo

## training studentships



**3-6 month** fully funded studentships for current PhD students at one of the MCnet nodes. An excellent opportunity to really understand and improve the Monte Carlos you use!

**Application rounds every 3 months.**

### MCnet projects

Pythia+Vincia

Herwig

Sherpa

MadGraph

“Plugin” – Ariadne+HEJ

CEDAR – Rivet+Professor

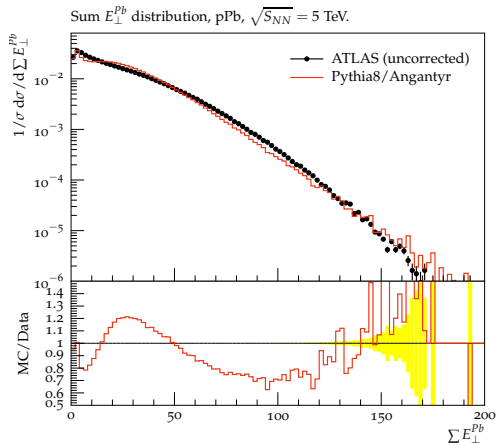
+Contur+hepforge+...



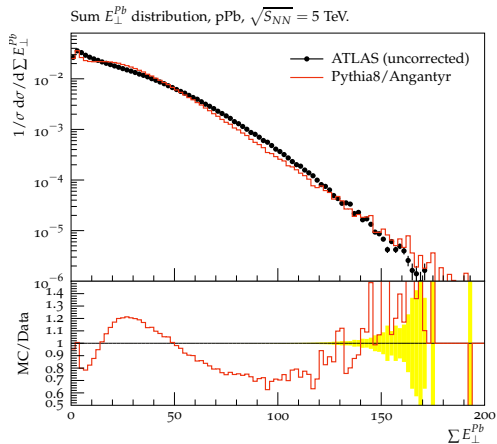
for details go to:  
[www.montecarlonet.org](http://www.montecarlonet.org)

backup slides

# Centrality in pPb

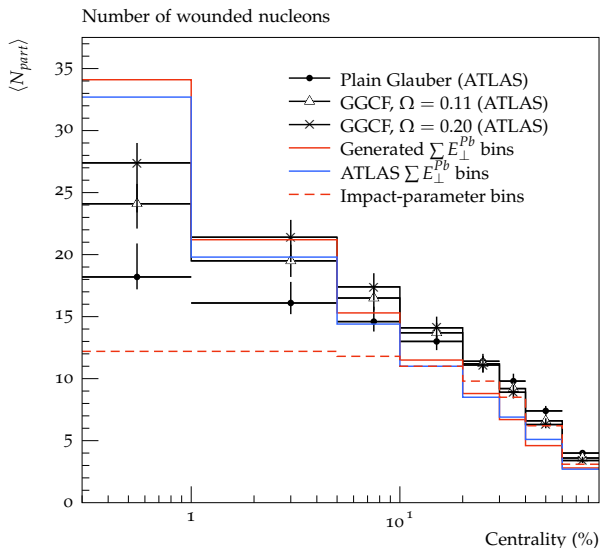


# Centrality in pPb



What was actually measured in the previous slide is a correlation between the  $\eta$ -distribution and the forward activity.

# p-Pb number of participants



# It works even in AA!

