Non-perturbative aspects of generators for e*A*

Leif Lönnblad

Department of Astronomy
and Theoretical Physics
Lund University

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Outline

- DIS and the dipole picture
- Glauber calculations
- Collective effects
- Plans for PYTHIA8

Why General Purpose Event Generators

(only three GPEGs: Herwig7, Pythia8, Sherpa)

We need event generators to model our data, but also to model the theory.

It's not enough to tune for one analysis/experiment, we need to tune to everything.

- $e^+e^- \Rightarrow$ Hadronisation and FSR
- ep $\Rightarrow$ ISR and remnant jets.
- pp $\Rightarrow$ UE and MPI
- p$A \Rightarrow$ small dense systems, flow
- $AA \Rightarrow$ large dense systems, jet quenching
- e$A \Rightarrow$?

We need to understand what exactly we are measuring.

Are the *general purpose* event generators ready for the EIC?

Can they handle

- e*A*?
- DIS?
- Photo-production?
- Nuclei in general?
- Saturation? Polarisation? Lower energy? Diffraction? ...

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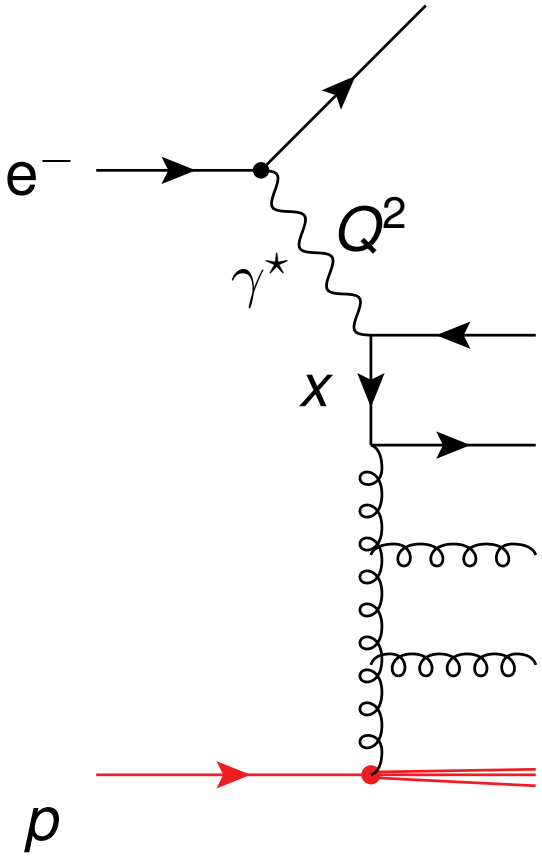
Todo: EVERYTHING

The standard DIS picture



- The Primary (hardest) vertex.
- Standard showers orders in $k_\perp$
- And allows the scattered electron to take recoil. x, Q^2 not preserved in shower.
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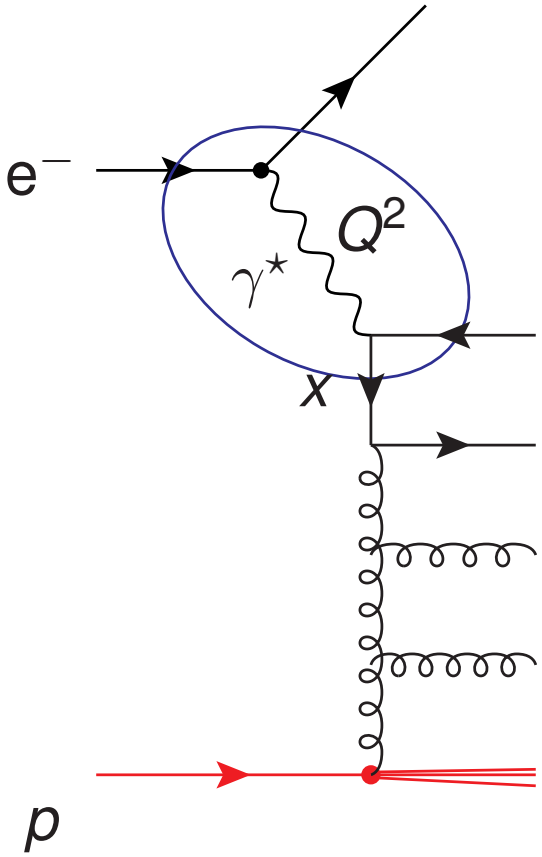

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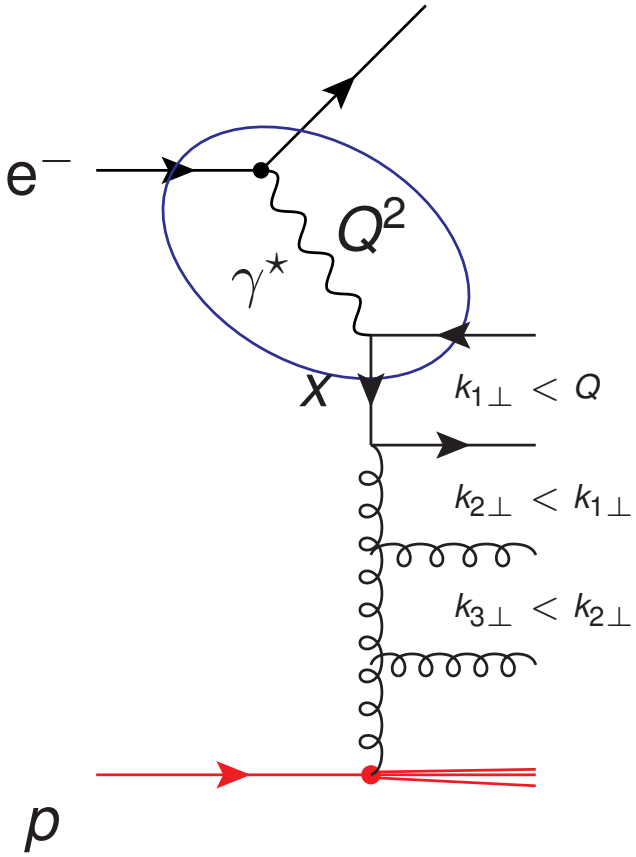

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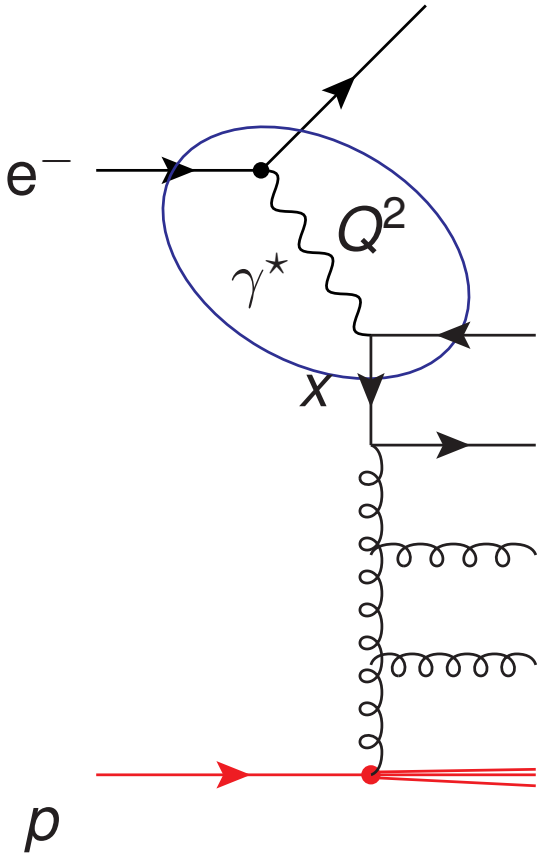

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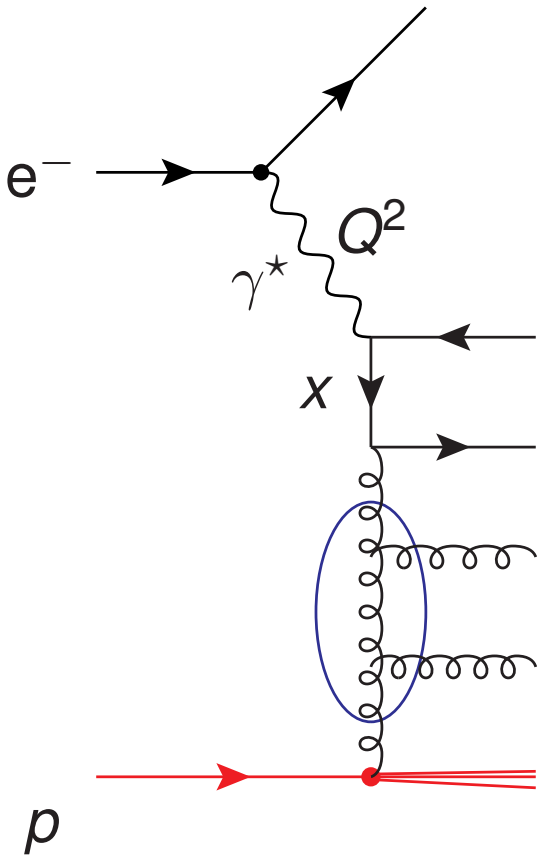

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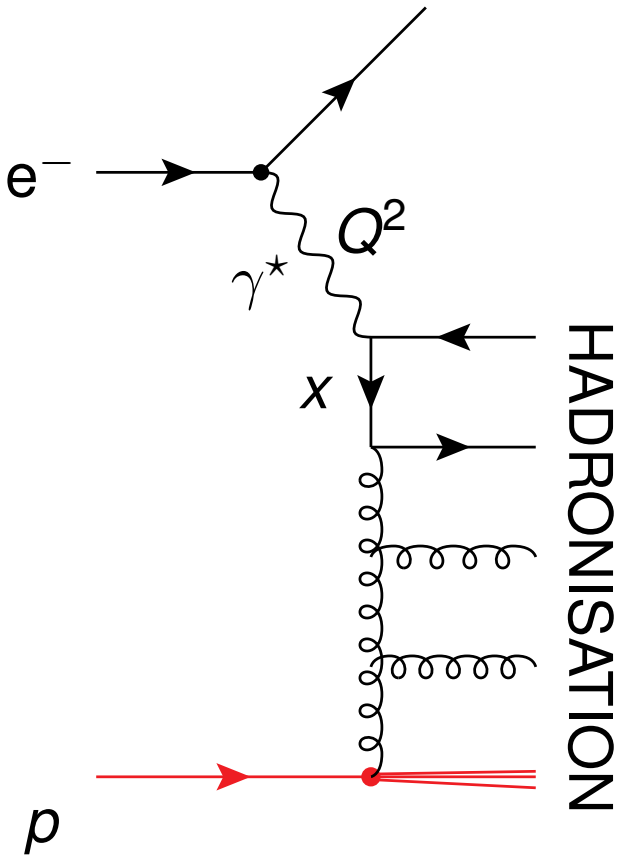

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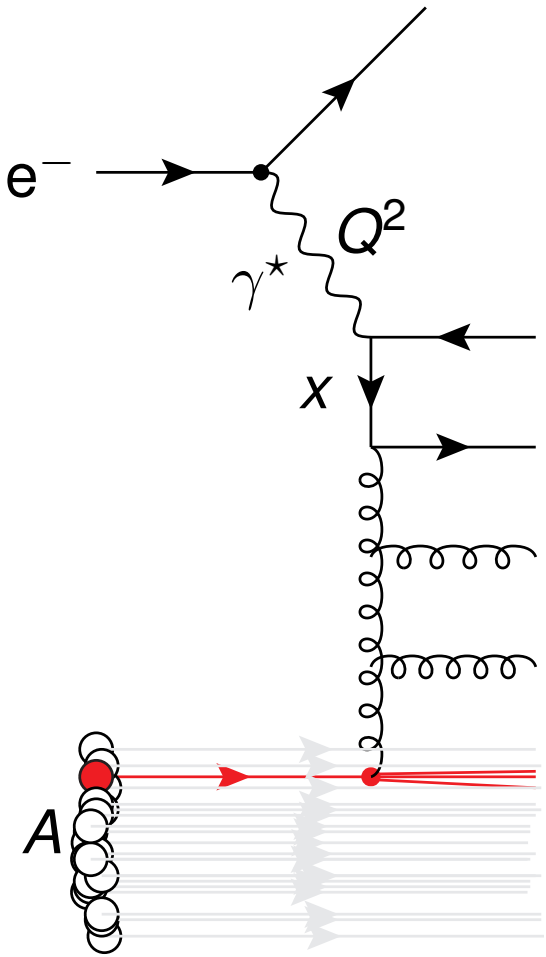

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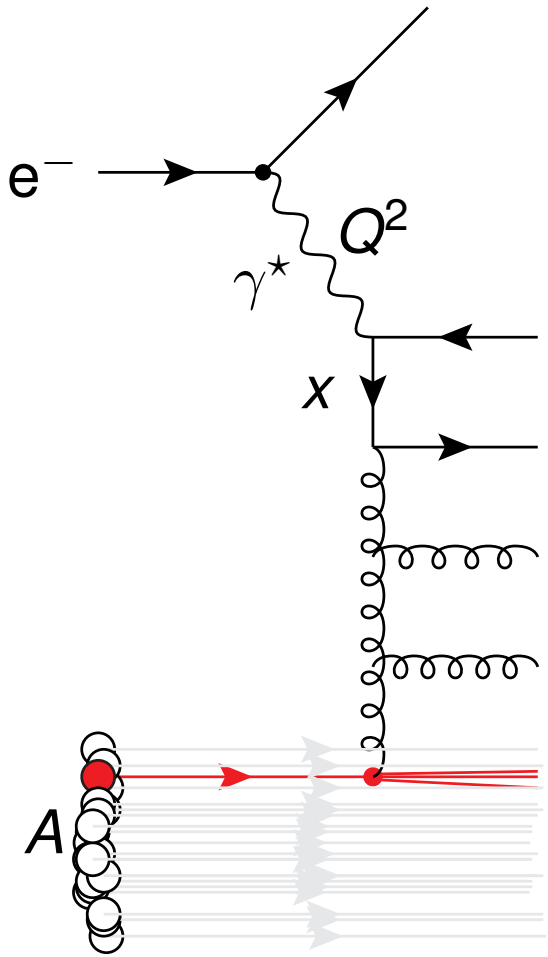

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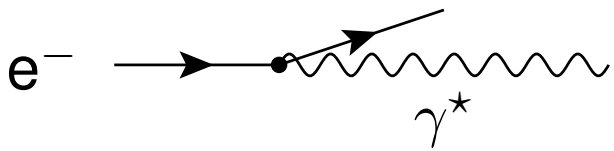
The dipole picture



- In the frame where the target is at rest the photon is emitted long before the ineraction.
- Also the photon splits up long before the interacton
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- . . . before hitting the target.
- Hitting another nucleon comes at little extra cost.

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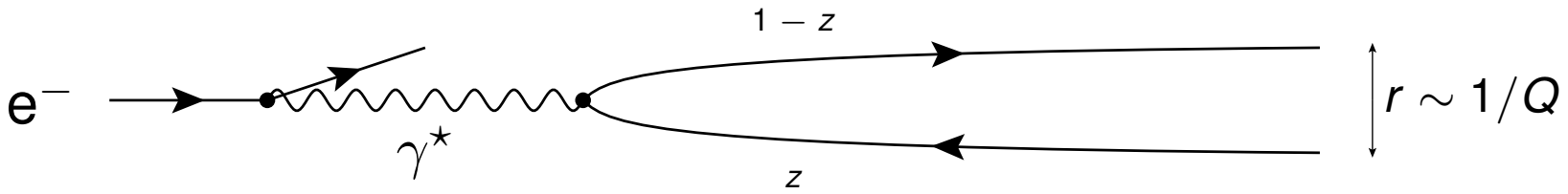

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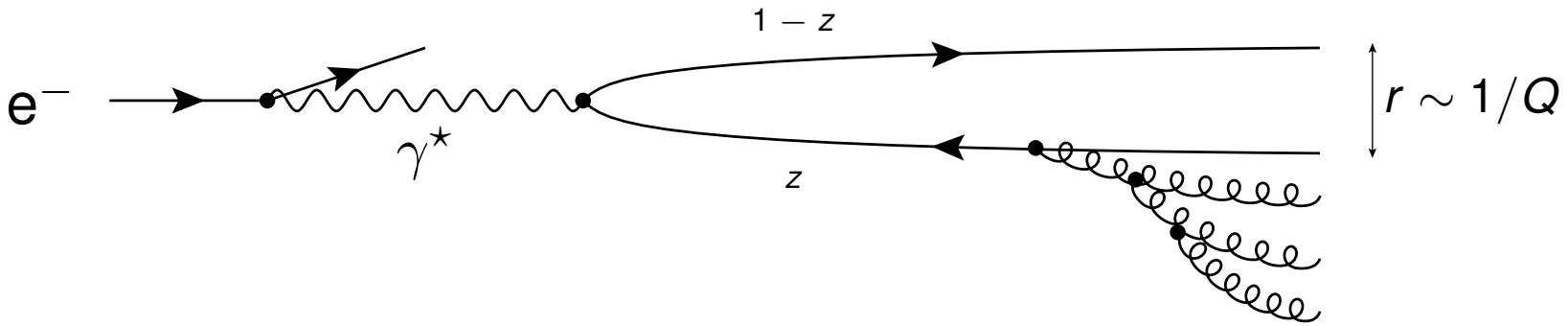

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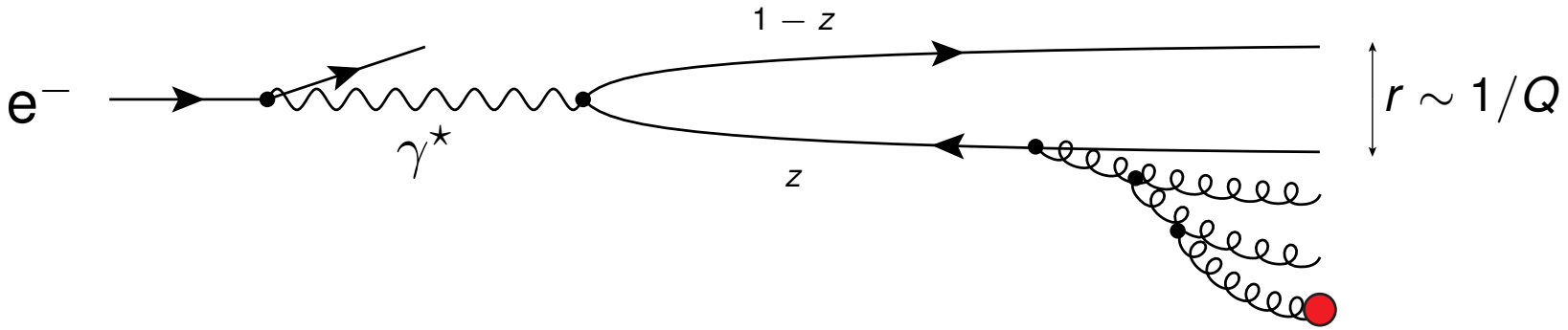

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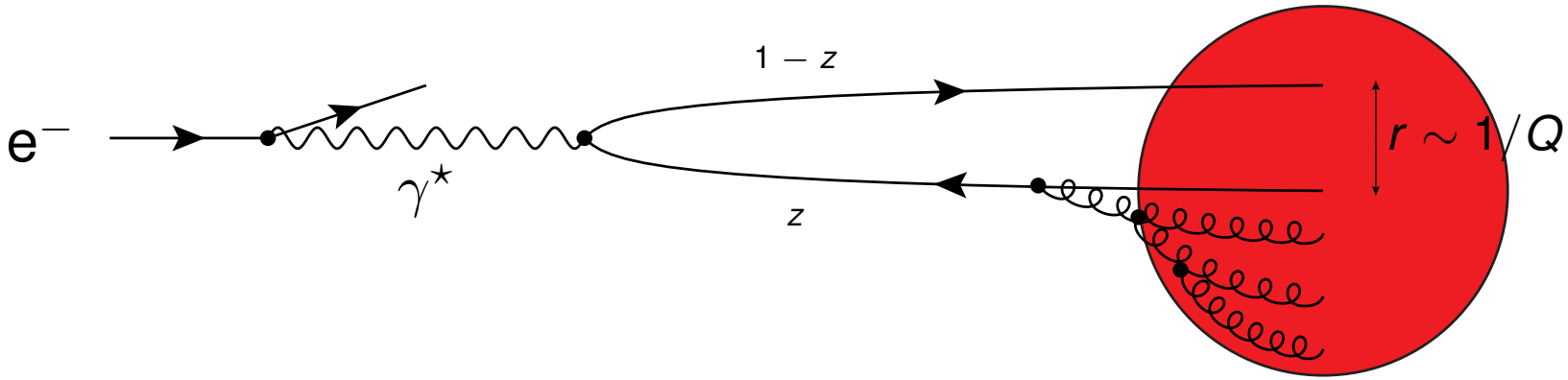

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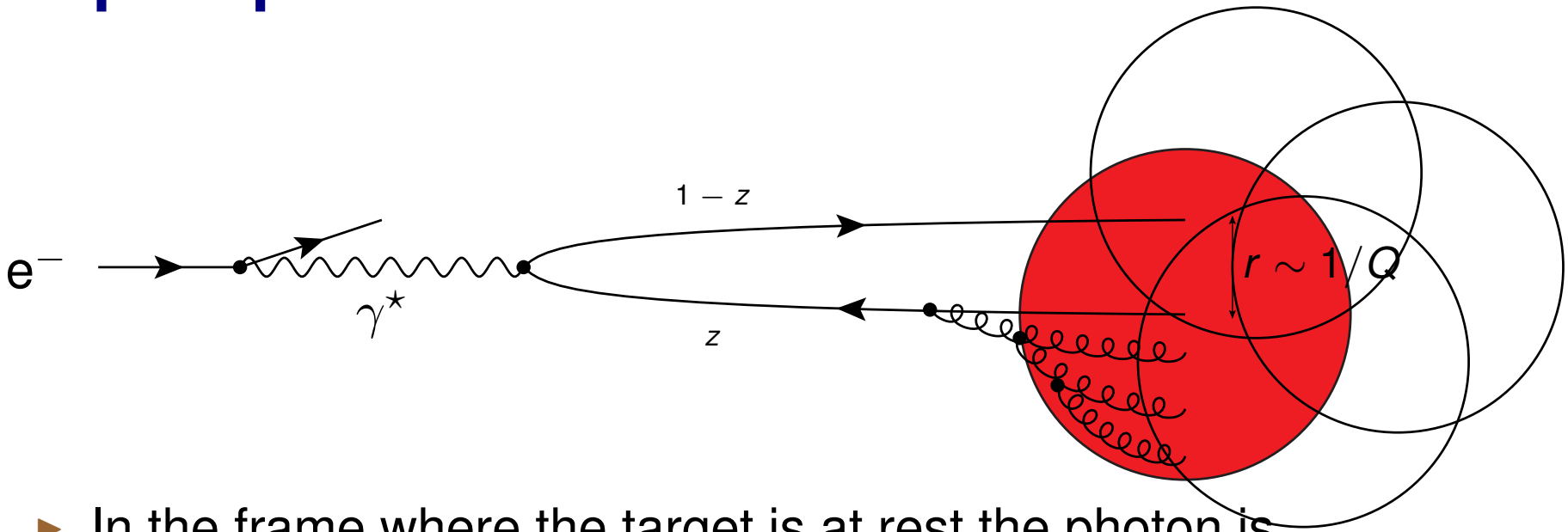

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Glauber Calculations

To get a reasonable handle on hadronic final states in eA we need to add together several eN collisions, and for that we need to do some kind of Glauber calculation to obtain N_{part} (or N_{wounded})

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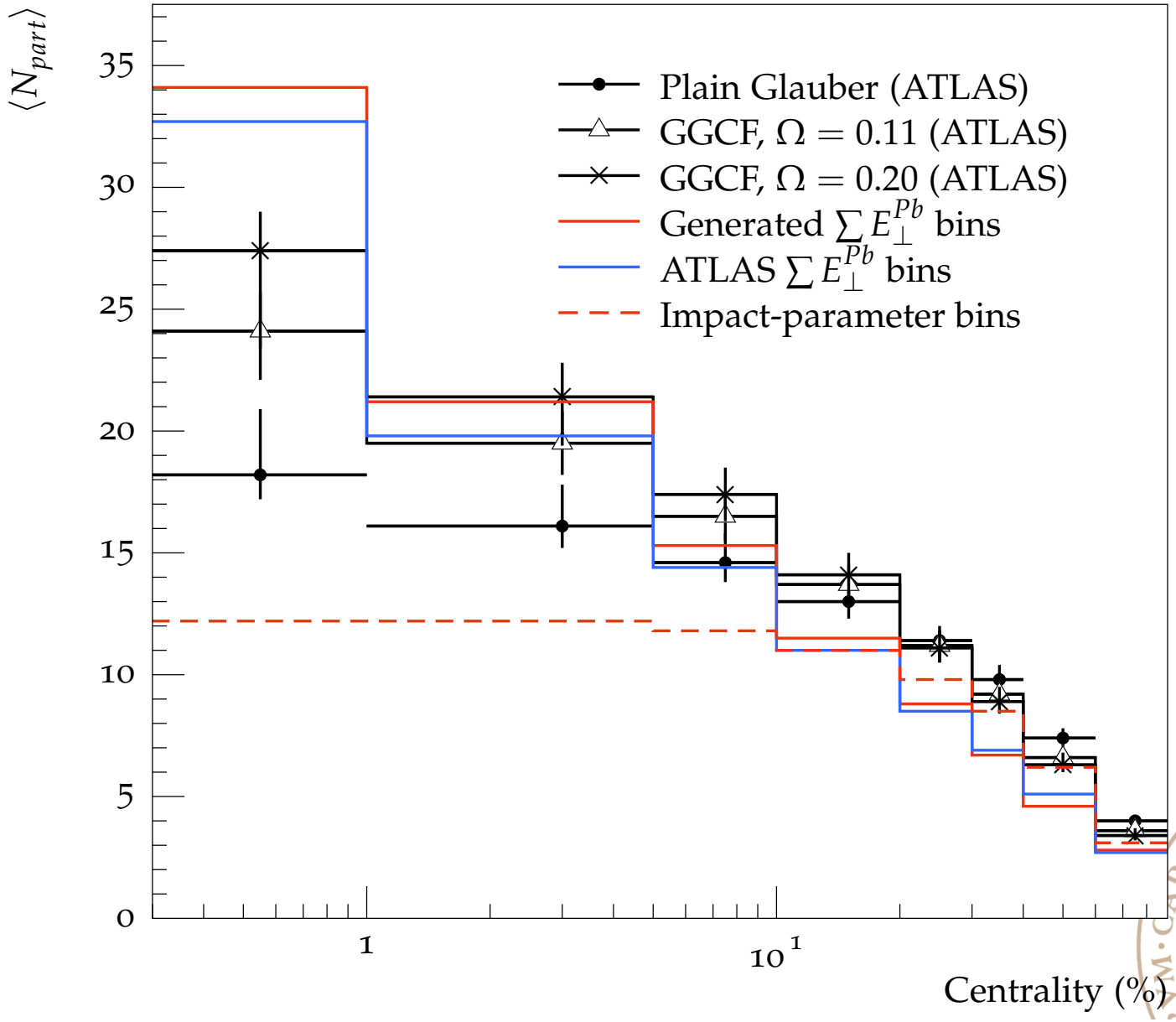
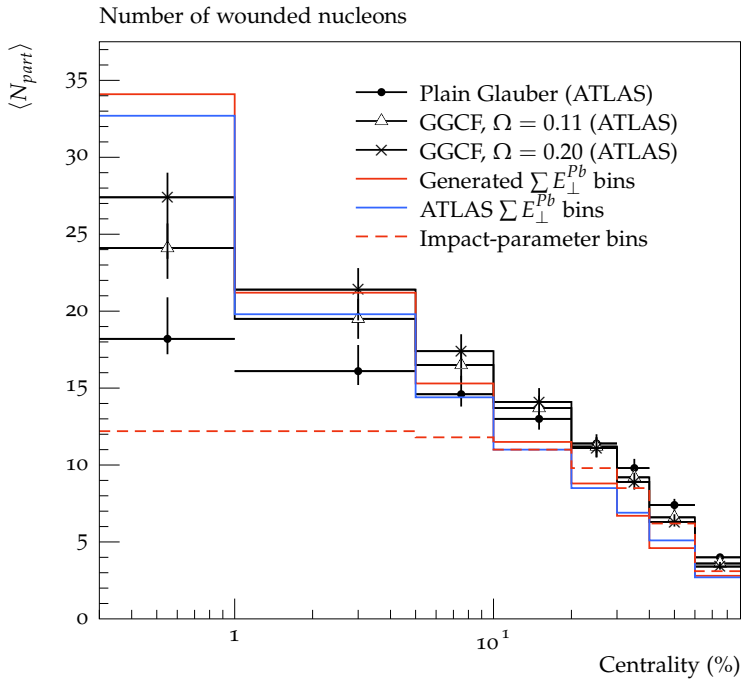
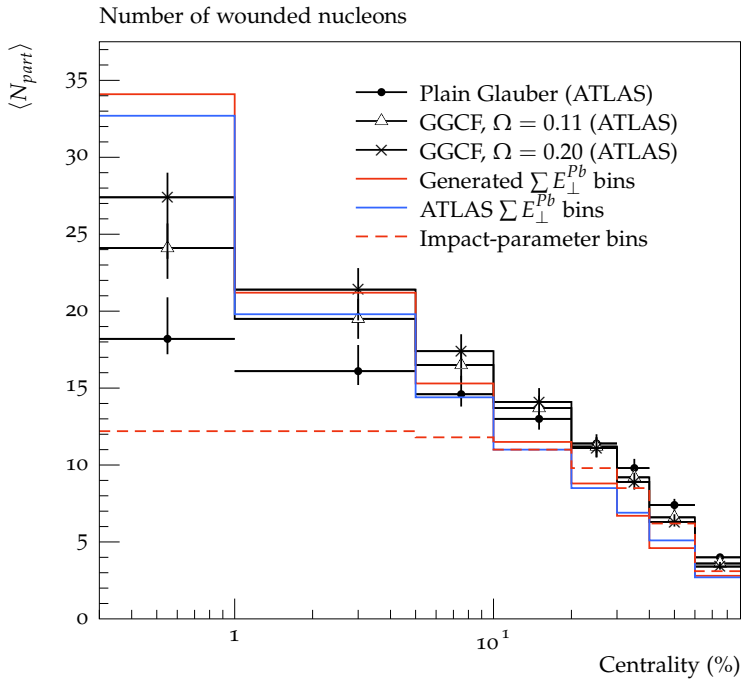
The lesson from pA collisions at the LHC is that we need to worry about fluctuations.

Number of wounded nucleons





For low Q^2 eA we expect Vector Meson Dominance and the situation looks like pA.



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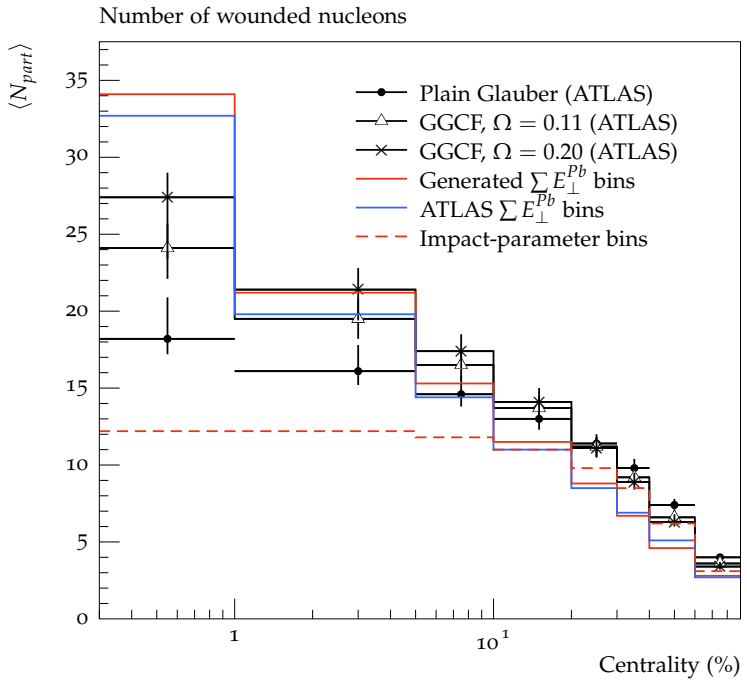

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More on this in Christian Bierlich's talk

Hadronisation

We believe that we know how to model the non-perturbative hadronisation process. But there are caveats.

- $\sqrt{S_{eN}} = 100$ GeV, sounds like LEP energies
  But hadronic system has lower mass and a lots of energy goes into the nucleon remnant (largely ignored by GPEGs).
- How well does string fragmentation describe a small number of hadrons? Cluster fragmentation?
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Since there are collective effects even in pp, we need to be able to model them at the EIC!

Collective effects in PYTHIA8 (Gleipnir)

- Colour reconnections (swing)
- String repulsion (shoving)
- Increased string tension (ropes)
- Hadron rescattering

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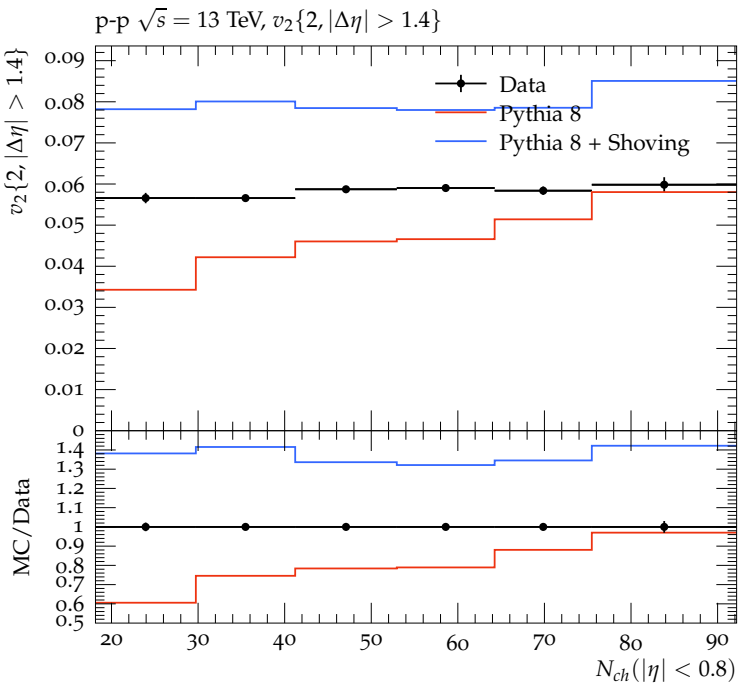
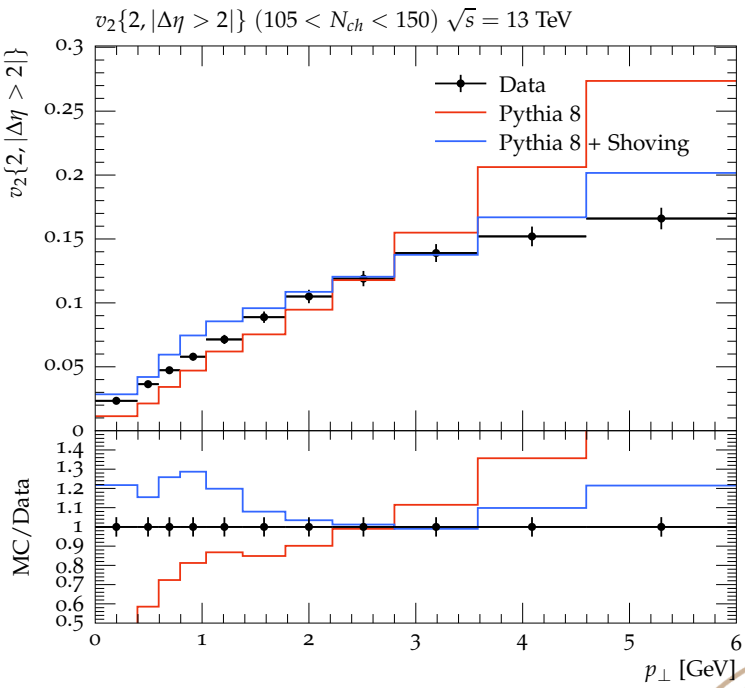
- String repulsion (shoving)
  Gives flow
- Increased string tension (ropes)
  Gives strangeness enhancement
- Hadron rescattering
  More flow

Shoving (pp)


p-p $\sqrt{s} = 13$ TeV, $v_2\{2, |\Delta\eta| > 1.4\}$
Data
Pythia 8
Pythia 8 + Shoving
$v_2\{2, |\Delta\eta| > 1.4\}$
MC/Data
$N_{ch}(|\eta| < 0.8)$


$v_2\{2, |\Delta\eta > 2|\}$ $(105 < N_{ch} < 150)$ $\sqrt{s} = 13$ TeV
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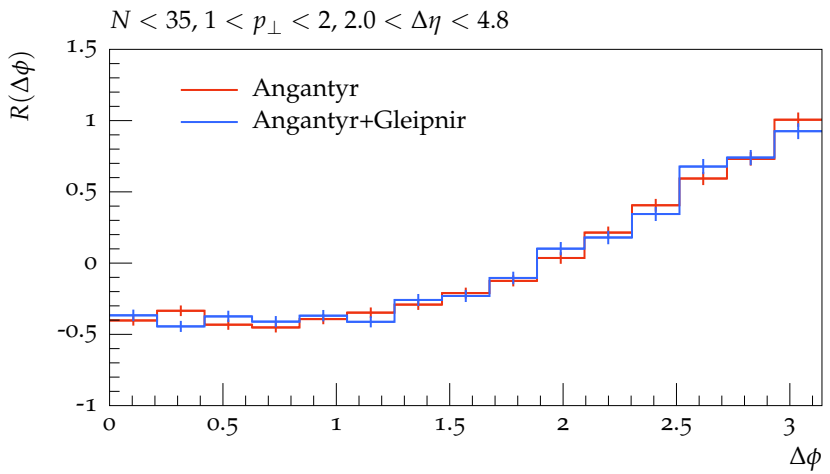
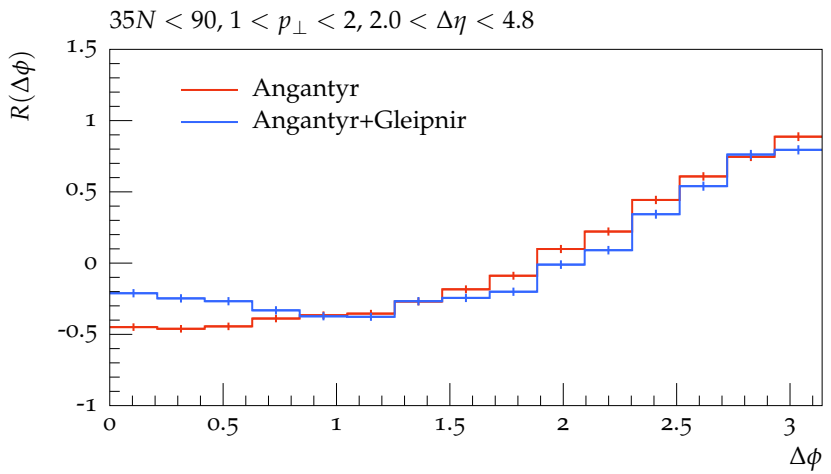
$v_2\{2, |\Delta\eta > 2|\}$
MC/Data
$p_\perp$ [GeV]

Shoving (pPb)


$N < 35, 1 < p_\perp < 2, 2.0 < \Delta\eta < 4.8$
$R(\Delta\phi)$
Angantyr
Angantyr+Gleipnir
$\Delta\phi$


$35N < 90, 1 < p_\perp < 2, 2.0 < \Delta\eta < 4.8$
$R(\Delta\phi)$
Angantyr
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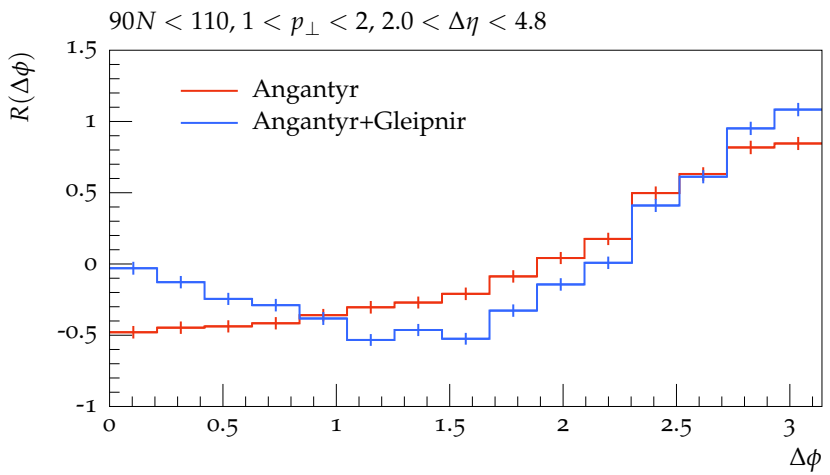
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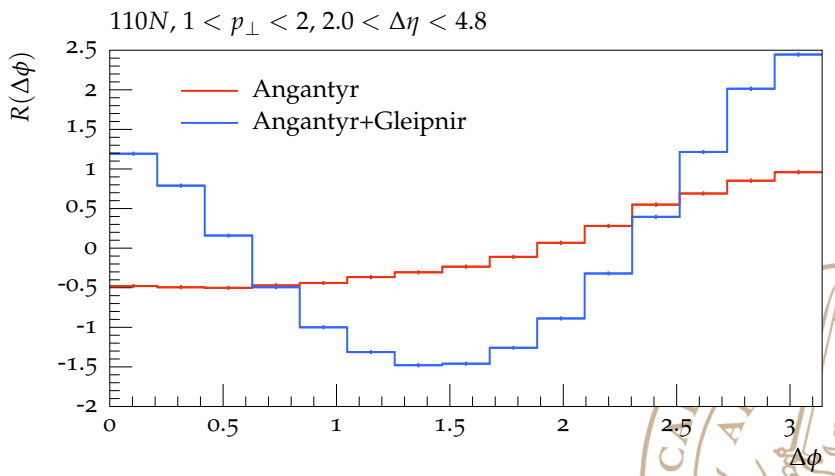
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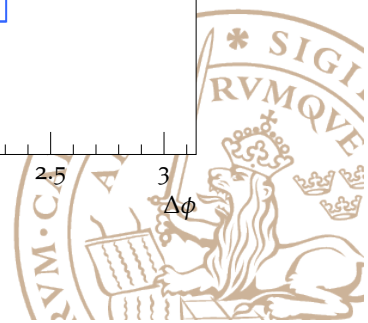
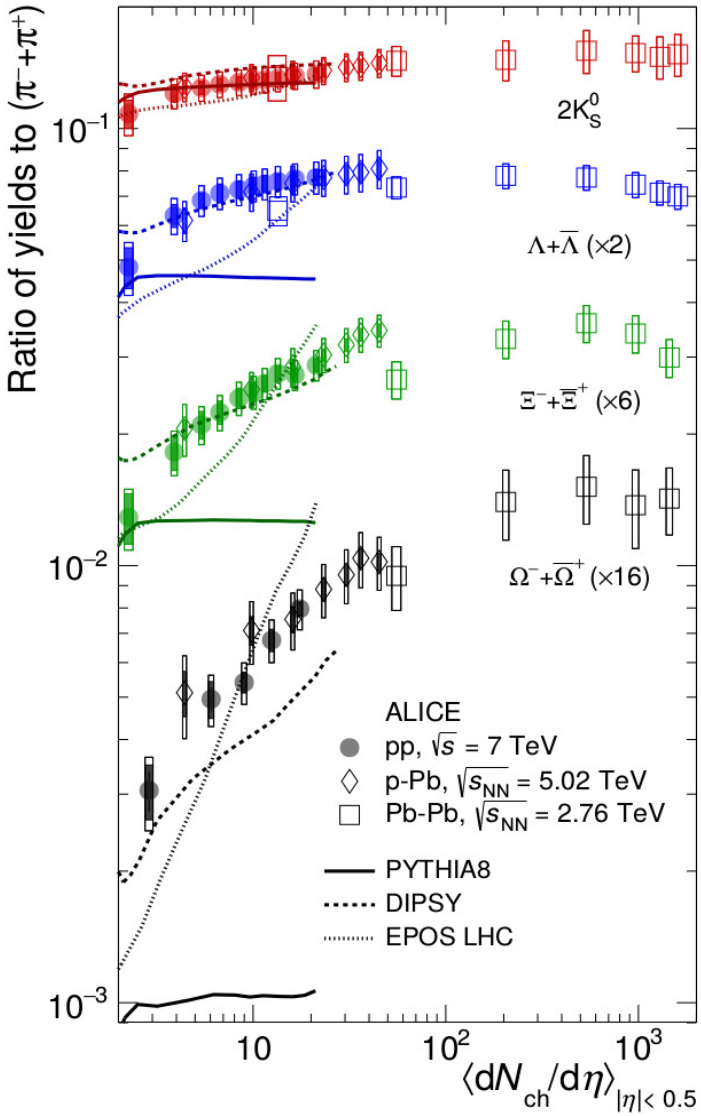
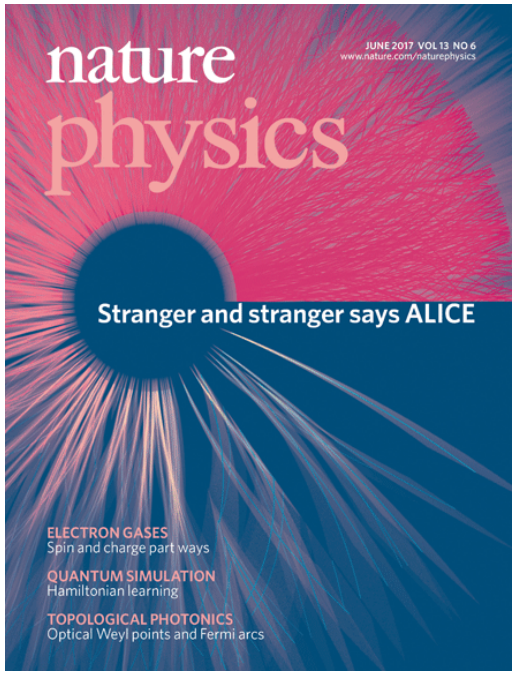


Ropes





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EIC plans for PYTHIA8

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- Shoving
- Ropes
- Hadronic rescattering
- Nuclear PDFs
- Photon PDFs
- Polarised string fragmentation (w. Albi Kerbizi)
- TMD-based shower (w. Mees van Kampen)

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The Conlusion

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But there are at least PYTHIA8 authors that are willing to have a go at it.

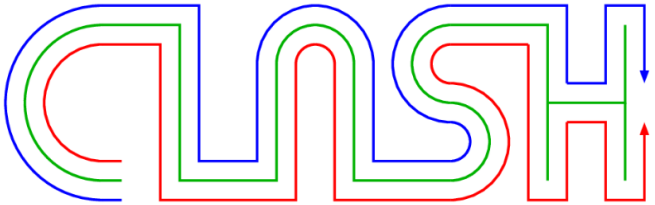
Thanks!


Vetenskapsrådet


MCnet
Marie Curie Actions
Human resources and mobility


erc
European Research Council
Established by the European Commission


Knut and Alice
Wallenberg
Foundation


CLASH