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PYTHIA

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MCnet meeting, CERN, 2018-04-11

Outline

- ▶ PYTHIA8 collaboration
- ▶ News since April 17
- ▶ Heavy-ion collisions



The PYTHIA8 collaboration

Christian Bierlich (Lund/NBI), Nishita Desai (Montpellier),
Nadine Fischer (Monash), Ilkka Helenius (Tübingen),
Philip Ilten (Birmingham), Leif Lönnblad (Lund),
Stephen Mrenna (Fermilab), Stefan Prestel (Fermilab),
Christine O. Rasmussen (Lund), Torbjörn Sjöstrand (Lund),
Peter Skands (Monash)



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PYTHIA8 on one slide

- ▶ pp , e^+e^- , (ep) , γp , $\gamma\gamma$, pA , AA
- ▶ A few simple MEs, the rest from Les Houches
- ▶ k_{\perp} -ordered initial-/final-state dipole-based shower + VINCIA & DIRE as plugins
- ▶ (N)LO multi-leg matching with UNLOPS/UMEPS/CKKW/MLM
- ▶ Multiple interactions interleaved with shower
- ▶ Lund String Fragmentation
- ▶ Particle decays



PYTHIA 8 online manual - Mozilla Firefox

File Edit View History Bookmarks Tools Help

PYTHIA 8 online manual

home.thep.lu.se/~torbjorn/pythia82html/Welcome.html

Error Checks
Tunes

Study Output

Four-Vectors
Particle Properties
Event Record
Event Information
Event Statistics
Event Analysis
Histograms
Advanced Usage

Link to Other Programs

Les Houches Accord
SUSY Les Houches Accord
HepMC Interface
ProMC Files
Semi-Internal Processes
Semi-Internal Resonances
MadGraph5 Processes
HelaOnia Processes
Algeen Event Interface
Matching and Merging
-- POWHEG Merging
-- aMC@NLO Matching
-- CKKW-L Merging
-- Jet Matching
-- UNFES Merging
-- HLO Merging
User Hooks
Hadron-Level Standalone
External Decays
Beam Shape
Parton Distributions
Jet Finders
Random Numbers
Implement New Showers
RIVET usage
ROOT usage
A Python interface

Reference Material

Update History
Bibliography
Glossary
Version

Separate documents

Introduction
Worksheet

Update History

These update notes describe major updates relative to the PYTHIA 8.186 version, which was the last 8.1 release. The step from 8.1 to 8.2 gave an occasion to break backwards compatibility, but this should only affect a small part of the user code.

Main news by version

- 8.235: 27 March 2018
 - o Up until now, PYTHIA has been licensed under GNU GPL v2 or later. This is extended so that alternatively any later version can be used, specifically version 3. The MCNET GUIDELINES are updated accordingly, as are many file headers. Thanks to Christophe Delaere.
 - o The machinery for total, elastic and diffractive cross sections has been rewritten and extended.
 - The ABMST model [App14] has been introduced, and extended from total, elastic and single diffraction to also include double and central diffraction.
 - The RPP 2016 parametrization [Pat16] for total and elastic cross sections has been introduced.
 - The set-it-yourself machinery has been extended and systematized.
 - o The descriptions on the TotalCrossSections and the Diffraction webpages have been regrouped. The former now describes both integrated and differential cross sections of all scenarios, whereas the latter describes parameters related to the hadronization of diffractive systems, and additionally the machinery for hard diffraction.
 - o In the process of this regrouping, several Diffraction::xxx parameters have been renamed SigmaDiffraction::xxx. The most prominent example is PomFlux, but the largest group is the MBR parameters set.
 - o The phase space generation machinery has been rewritten to allow for the extended set of models, to be more general (at the expense of speed). Also the cross section code itself has been restructured.
- o A scenario for hard diffraction with gamma beams has been introduced, applicable for both gamma + gamma and gamma + p processes. Only a resolved photon, currently always associated with a virtual rho state, is assumed to contain a Pomeron flux. See further in the Diffraction description. The framework can be applied also for photoproduction with lepton beams.
- o A new machinery has been introduced to handle soft diffraction in gamma-p and gamma-gamma collisions, based on VMD (Vector Meson Dominance) states assumed present in a photon beams. In detail, diffractive cross sections for gamma + p and gamma + gamma have been introduced, and thus the parameter Photon::SigmaDiffrac has been removed. VMD states have been introduced as possible beam particles inside a photon beam. The standard beam machinery has been extended to pick VMD states when required. New methods in Info.h give access to the current character of such states. Possibility to rescale the pion PDF has been implemented, e.g. when used to represent a VMD state.
- o It is now possible to obtain space-time production points for hadrons as predicted within the string fragmentation model, see further the "Hadron Production Vertices" section of the Hadron Scattering description. Physics and code developed by Silvia Ferreres-Solé, article in preparation.
- o The Angantyr model for Heavy Ion Collisions has been updated with a few extra options and new defaults. To recover old results one needs to set Angantyr::SASMode = 1, Angantyr::ImpactMode = 0, and HIPDF::PomH1xSupp = 4..
- o It is now possible to specify a given impact parameter when generating minimum bias events using a new functions in the UserHooks.
- o The flavour part of the rope hadronization implementation has been updated. The option to always go to the highest possible SU(3) multiplet, relevant when junction CR is used in addition to ropes, has been added. The possibility of a simpler impact parameter model à la Butts needs [Bue16] has also been added.
- o An option is introduced to have a logarithmic parametrization for the energy dependence of pT0, used for the cross section regularization in the MPI framework. This is used as a default for gamma-gamma collisions, with new default parameters listed in the Photoproduction description.
- o A new parameter ContactInteractions::etaLR is introduced into the differential cross section for $q\bar{q} \rightarrow e\bar{\nu} + e\nu$ to distinguish a right-left contact interaction between quarks and leptons. Previously, the same parameter was used for left-right and right-left contact interactions. Results from prior versions of the code can be reproduced only if etaLR and etaRL are set equal.
- o A new Dark Matter production process $f\bar{f} \rightarrow Z\bar{Z}$ has been added, with Z decaying to a DM pair. Some other DM processes have been modified.
- o It is now possible to specify the a and $\langle z \rangle$ values of the Lund fragmentation function, as an alternative to the conventional a and b selection, see further in the Fragmentation description.
- o The shower variations have been extended so that the calculation can be made for an individual member of a PDF family, instead of calculating the effect when averaged over all members.
- o Possibility to enhance rate of gluon branchings to charm and bottom independently from light flavours. New splitting names isr:G2QQ:cc and isr:G2QQ:bb are introduced for initial-state showers, and fsr:G2QQ:cc and fsr:G2QQ:bb for final-state ones. See further the UserHooks documentation.



What's new?

- ▶ γp and $\gamma\gamma$. Resolved photons and diffraction (hard and soft)
- ▶ Automated Parton Shower Variations with PDF variations
- ▶ ISR recoils for dipole shower
- ▶ Nuclear PDFs
- ▶ Production vertices in MPI/ISR/FSR and Hadronisation
- ▶ Rope Hadronization
- ▶ MixMax random numbers
- ▶ GNU GPL v2 *or later*



Heavy ion collisions



Heavy ion collisions



The Angantyr model for heavy-ion collisions

- ▶ Glauber modelling with fluctuations
- ▶ Identifying NN sub-collisions
 - ▶ Which nucleons interact with which?
 - ▶ How do they interact?
 - ▶ Primary and secondary sub-collisions.
- ▶ Generating NN sub-events using PYTHIA8 MPI machinery.
 - ▶ Inserting signal processes if needed.
- ▶ Mergeing parton-level sub-events together.
- ▶ Hadronise.



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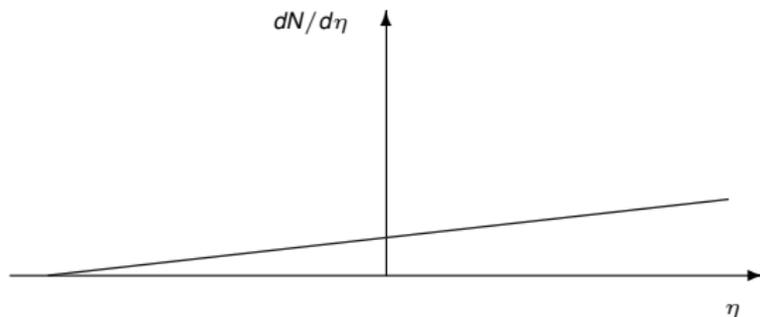
Complete, fully exclusive hadronic heavy-ion final states.



Wounded nucleons

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)

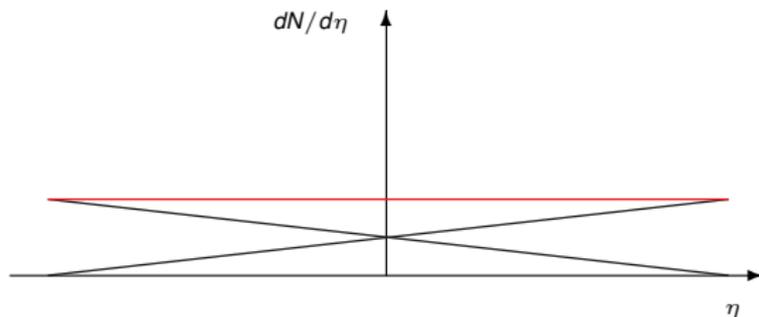
[Nucl.Phys.B111(1976)461, J.Phys.G35(2008)044053, Nucl.Phys.B281(1987)289.]



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

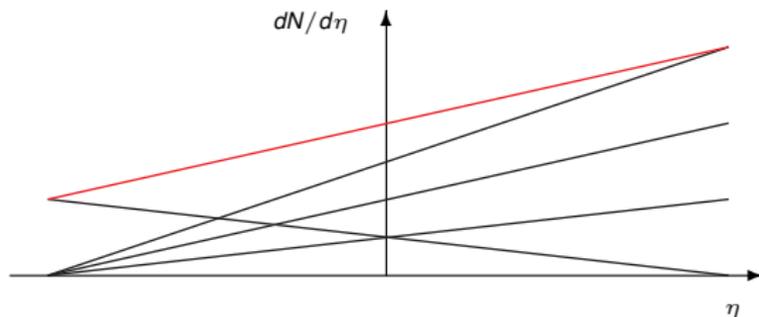
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$$\frac{dN}{d\eta} = w_t F(\eta) + F(-\eta) \quad (\text{pA})$$

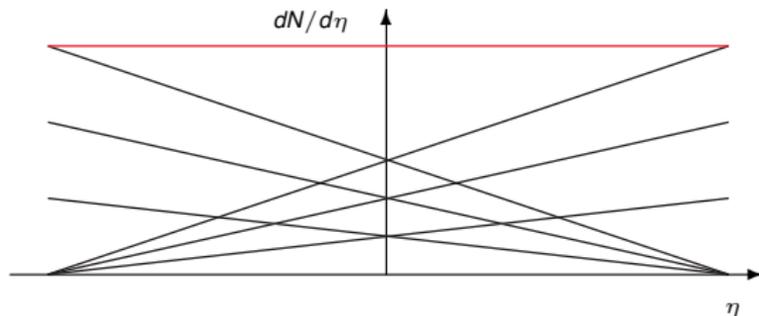
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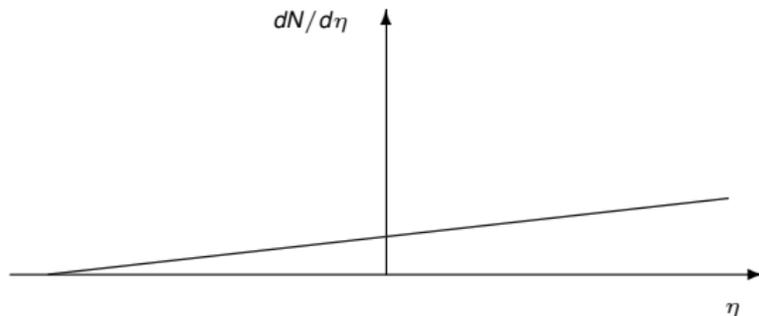
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Fritiof: single string dM_x^2/M_X^2

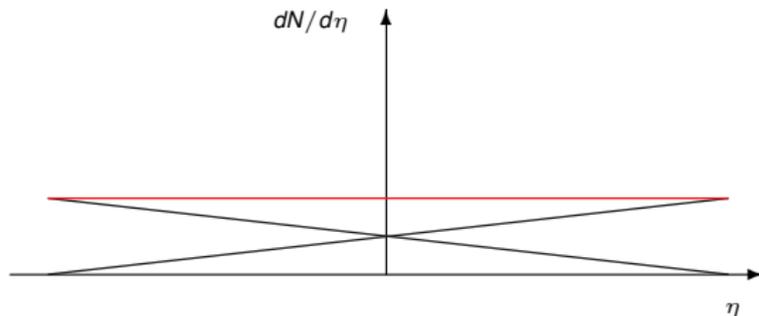
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Fritiof: pp

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projectile



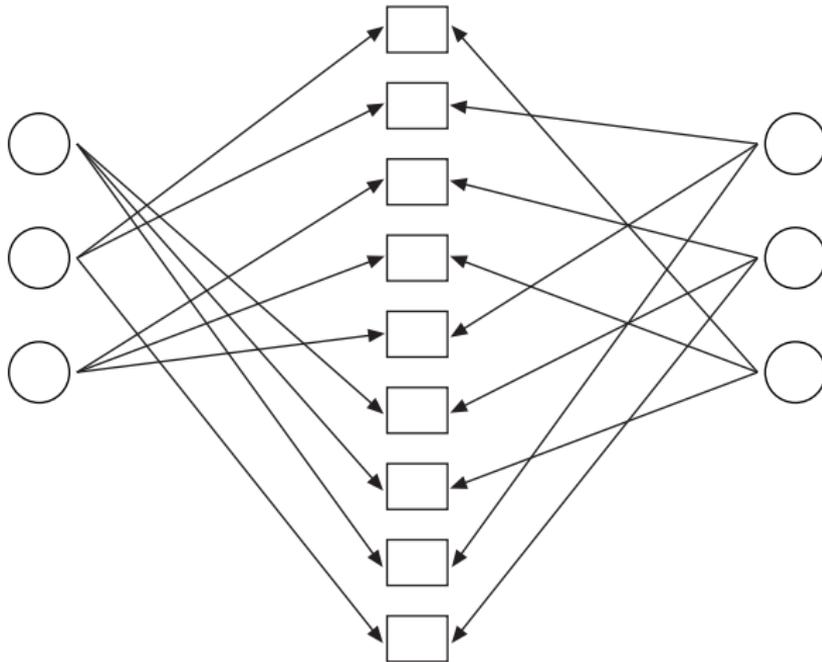
target



projectile

collisions

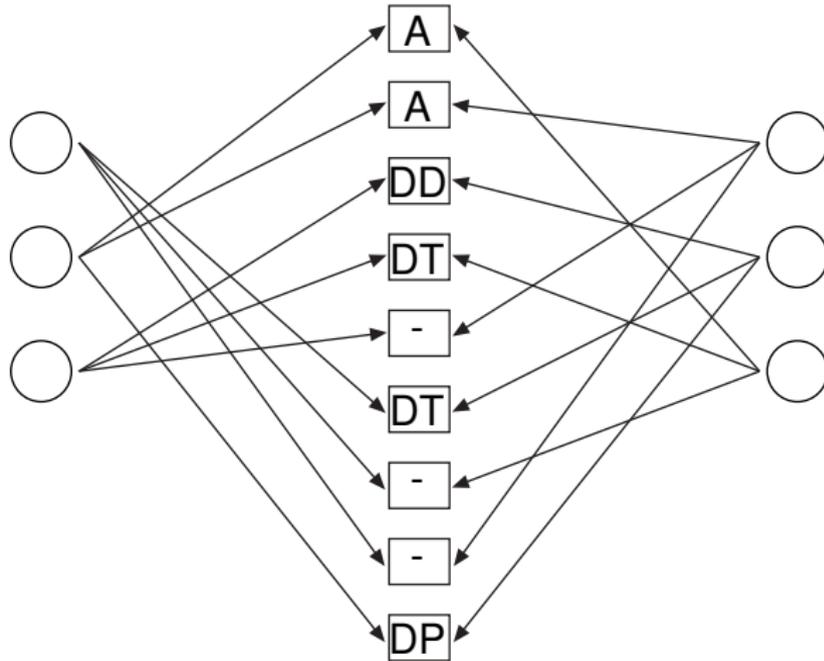
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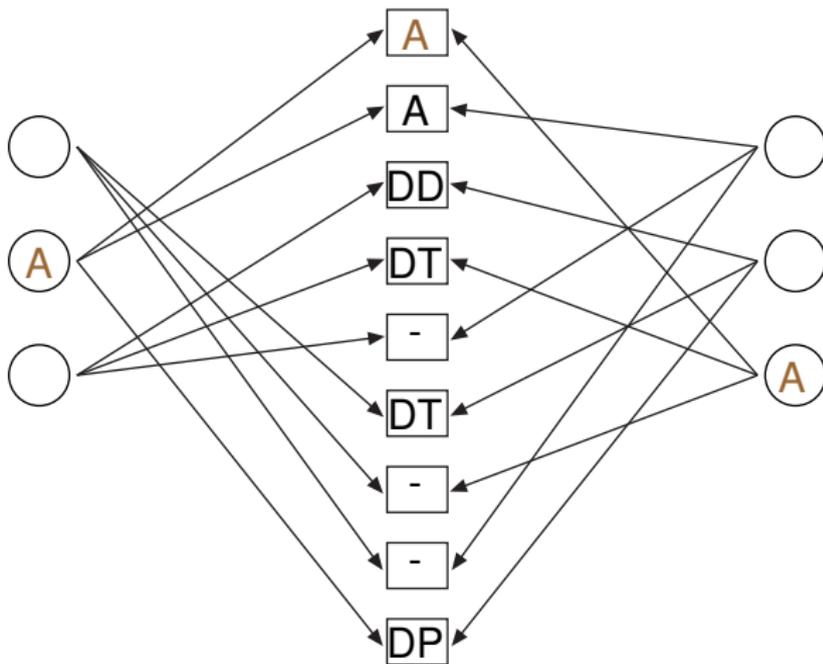
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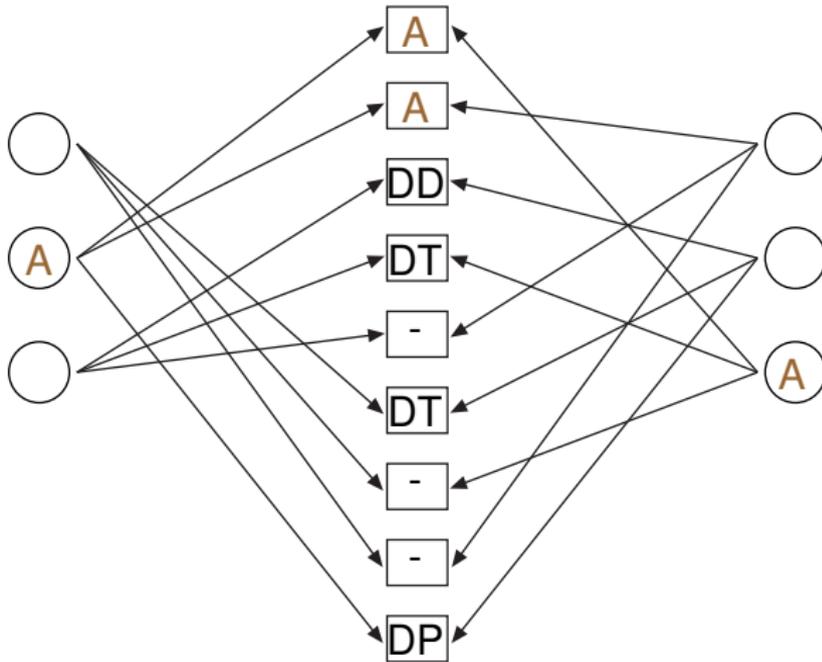
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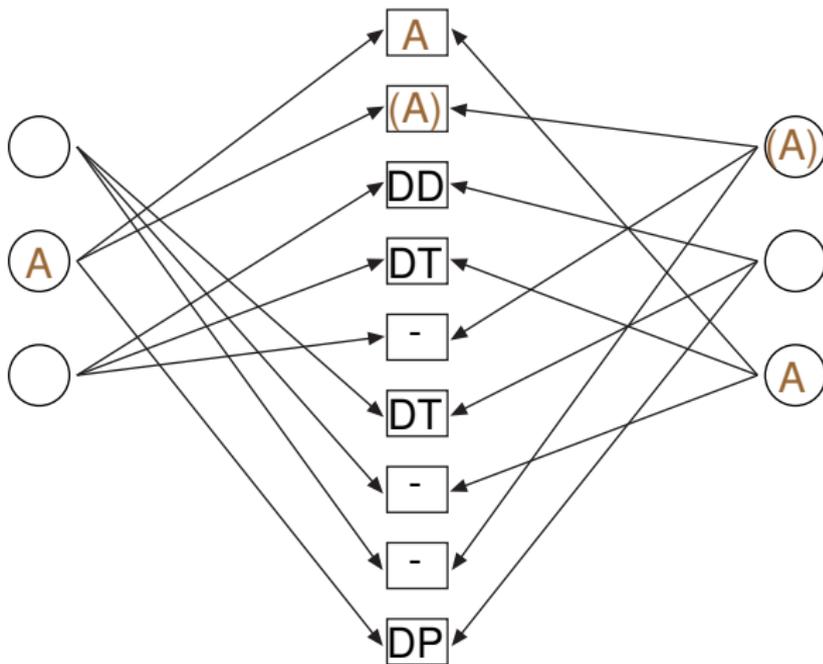
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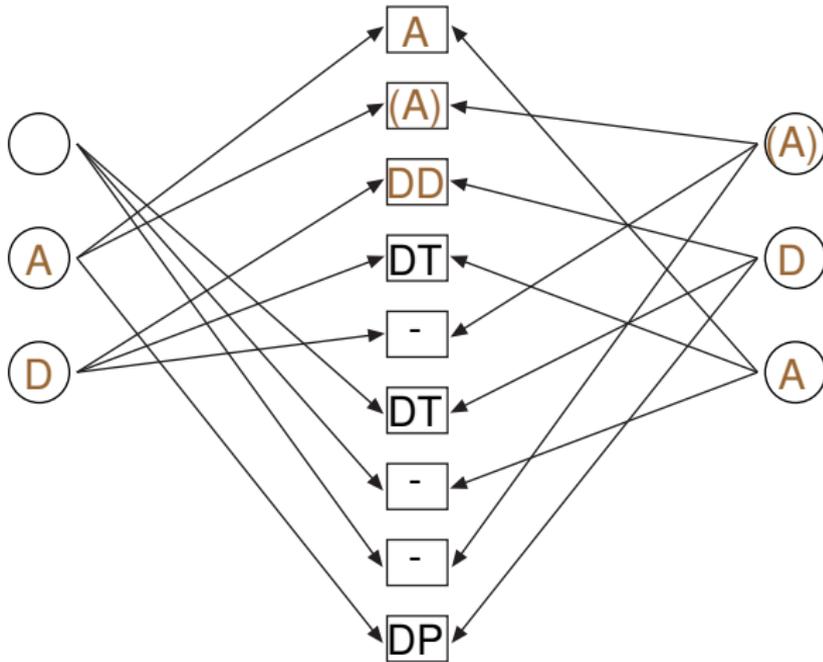
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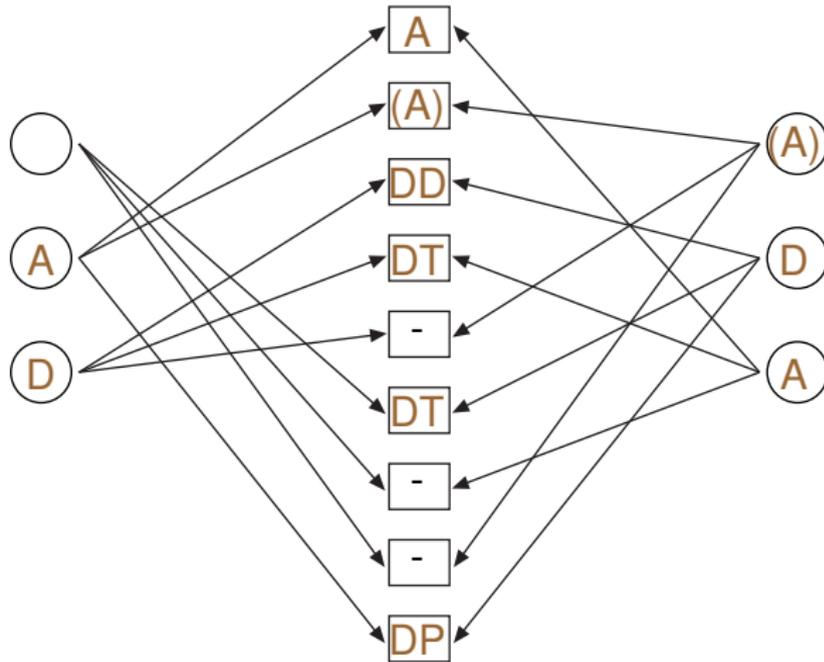
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projectile

collisions

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Comparison to data

Several parameters in addition to the pp PYTHIA8 ones.

- ▶ Nucleon distributions can in principle be measured independently.
- ▶ NN cross section fluctuations are fitted to (semi-) inclusive pp cross sections (total, non-diffractive, single and double diffractive, elastic, and elastic slope) for given $\sqrt{s_{NN}}$.
- ▶ Diffractive parameters for secondary absorptive collisions, “tuned” to non-diffractive PYTHIA pp.
- ▶ M_X distribution: $dM_X^2/M_X^{2(1+\epsilon)}$, could be tuned (to pA), but we choose $\epsilon = 0$.
- ▶ Few other choices related energy momentum conservation which do not have large impact.



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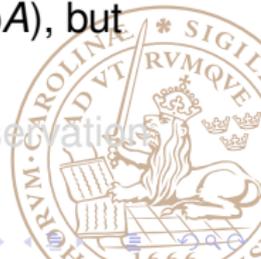
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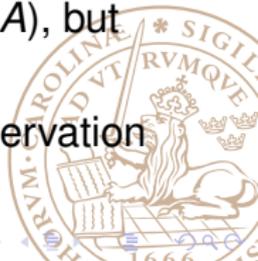
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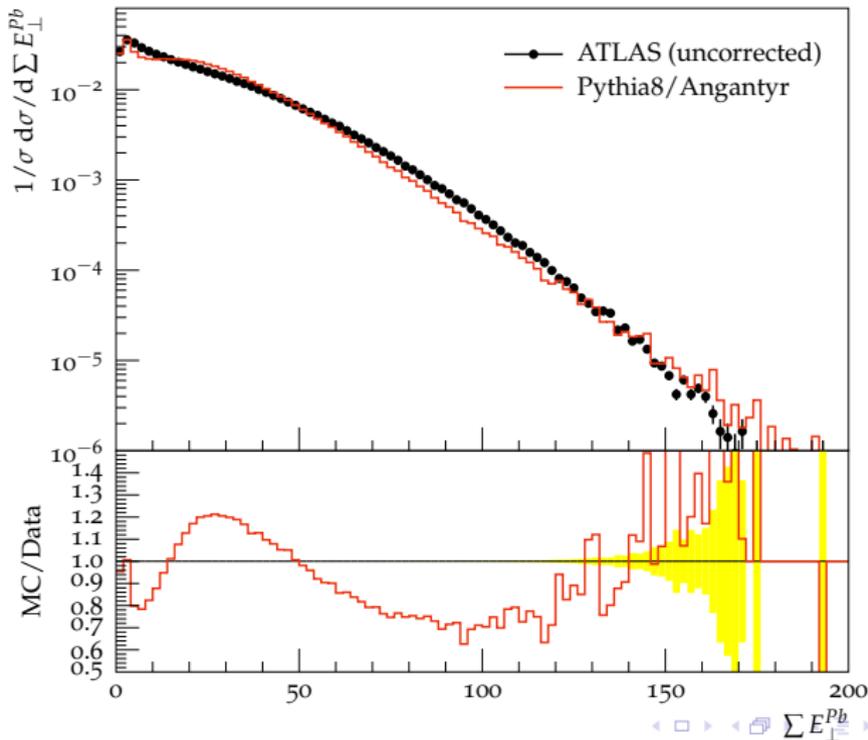
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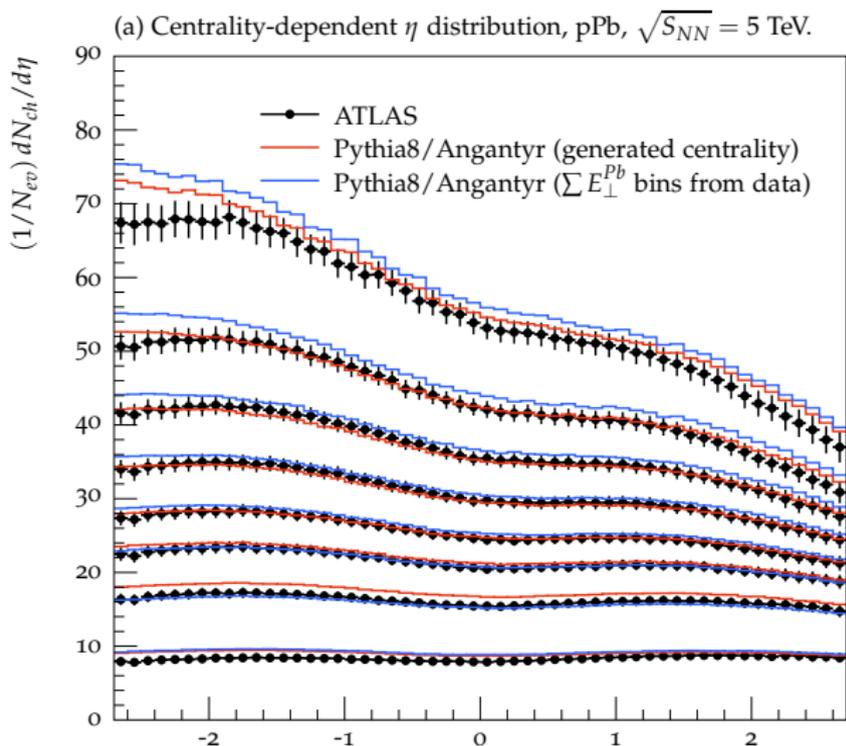


p-Pb centrality

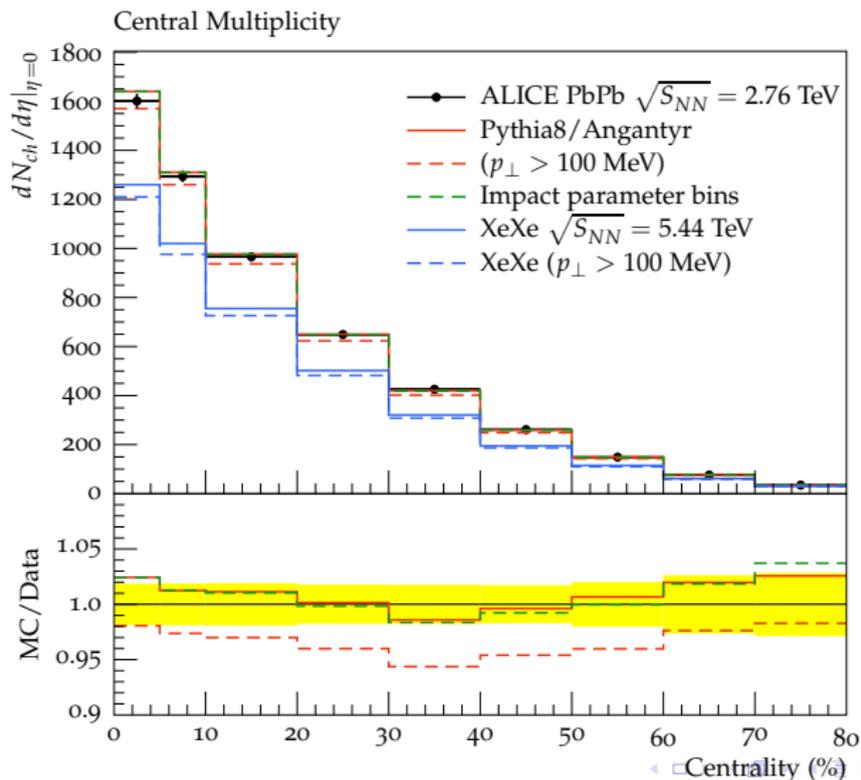
Sum E_{\perp}^{Pb} distribution, pPb, $\sqrt{s_{NN}} = 5$ TeV.



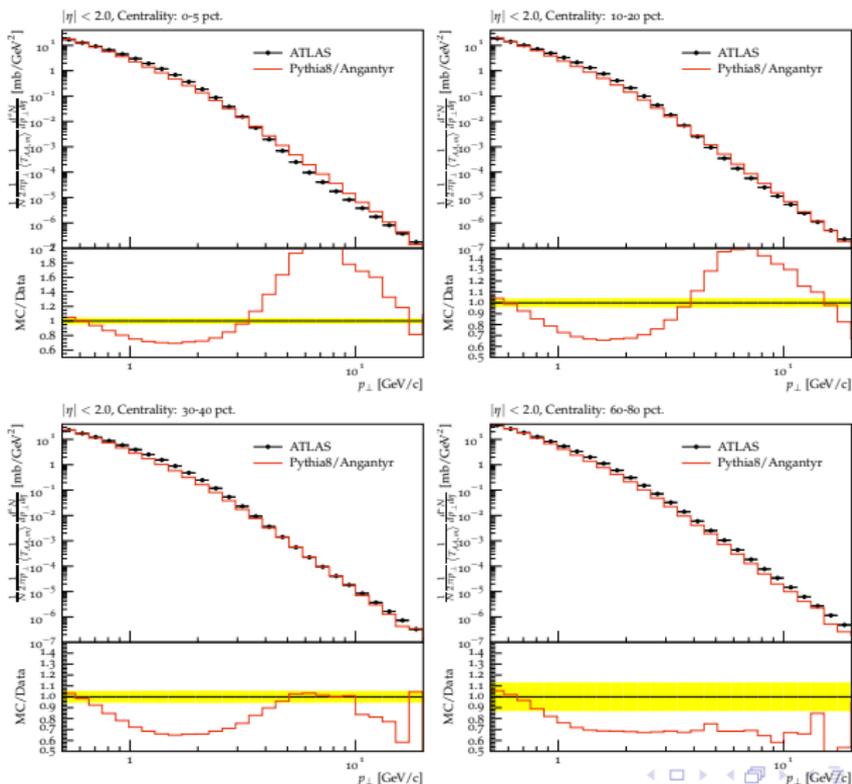
p-Pb η -distribution



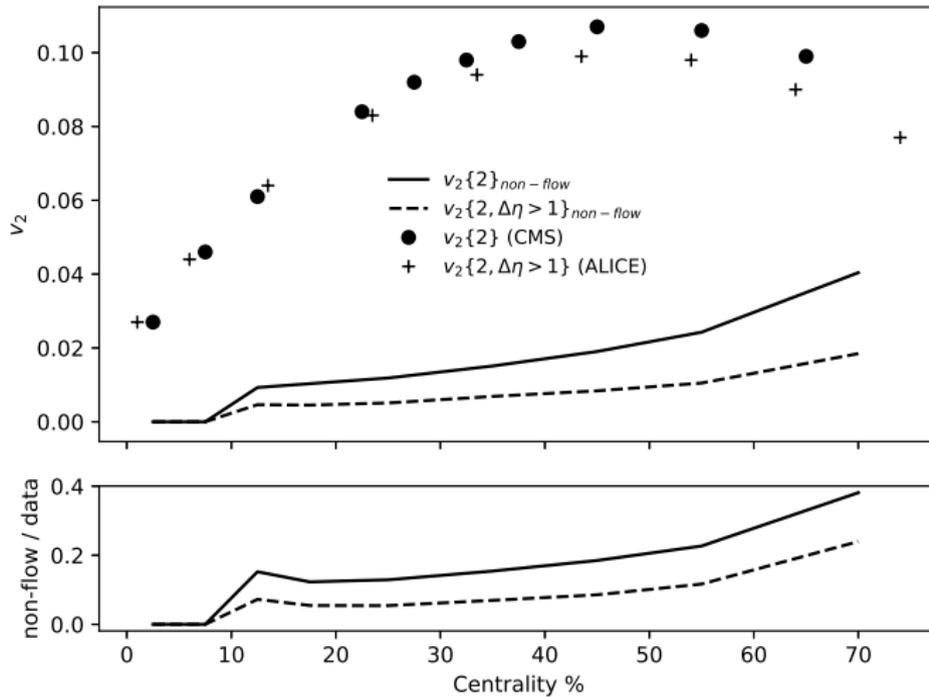
Pb–Pb central multiplicity



Pb-Pb p_{\perp} -spectra



Pb–Pb flow



Future developments

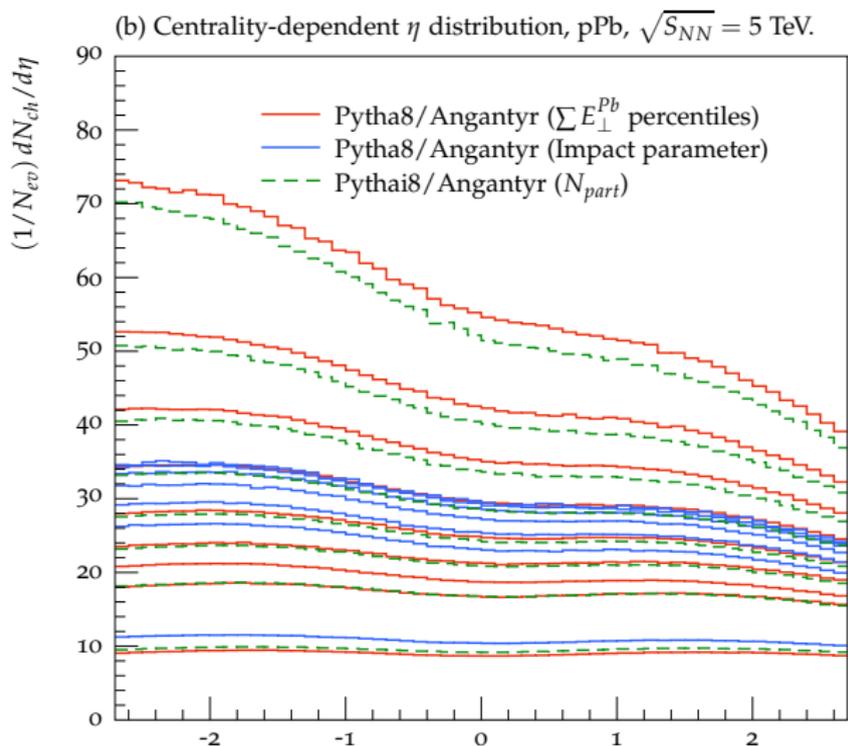
- ▶ Rope hadronisation
- ▶ String *shoving*
- ▶ eA



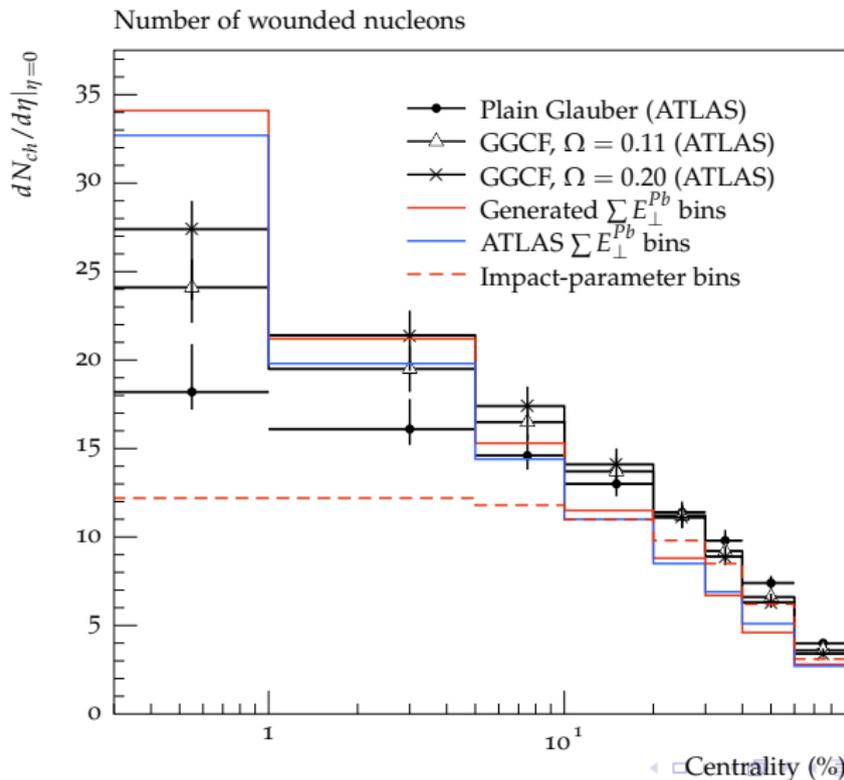
Thanks!



p-Pb η -distribution



p-Pb number of participants



Pb–Pb number of participants

