# Summary WG1 Minimum Bias, Underlying Event and Monte Carlo generators

# Dominic Hirschbühl / Oldrich Kepka





Institute of Physics of the Czech Academy of Sciences



#### Underlying Event Measurements at ATLAS

Zvi Citron for ATLAS MPI@LHC

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بالاندرەنىر دا-دارايا دىدد جامعة بن غوريون في النقب Ben-Gurion University of the Neger

University of Zurich <sup>®®</sup>
Department of Physics

#### Minimum Bias & Underlying Events Overview of Measurements and MC Tuning @CMS

Weijie Jin MPI@LHC, 2022 Madrid, Spain

PATLAS

Tuning Herwig 7 with Lund String Model

#### Particle production as a function of the UE activity in small and large systems and search for jet-like modifications

Omar Vázquez Rueda for the ALICE collaboration

HOUSTON



EPOS4 A MC tool for high-energy scatterings

#### Pratixan Sarmah



in collaboration with Miroslav Myska and Andrzej Siódmok

#### Released few weeks ago https://klaus.pages.in2p3.fr/epos4/ thanks Laurent Aphecetche for explaining gitlab pages, nextjs etc thanks Damien Vintache for managing installation/technical issues

□ a full general purpose approach, public, and testable

tested (by myself) for 4 GeV - 13000 GeV, pp to PbPb, light / heavy flavor, collective / hard

Papers coming soon

#### News on the Cluster Model

Simon Pitzer Institute of Physics — NAWL University of Graz Particle Physics — University of Vienna At the MH@LHC workshop Madrid/Online | 17 November 2022









# $d\sigma \sim L \times d\sigma_H(Q) \times PS(Q \rightarrow \mu) \times MPI \times Had(\mu \rightarrow \Lambda) \times ...$

Simon Platzer

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How do we look at top quarks and CR?

- Select  $t\bar{t}$  events using di-leptonic  $e\mu$  channel
- Look at inclusive\* charged particles as:
  - [\*Not including the leptons or jet tracks]
  - Multiplicity n<sub>ch</sub>
  - Scalar sum of charged particle  $\mathsf{p}_{\mathsf{T}}, \sum_{n_{ch}} p_{T}$
  - $\sum_{n_{ch}} p_T$  in bins of  $\mathsf{n}_{\mathsf{ch}}$
- Pileup and fake contribution subtracted with MC templates

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- Compare data to MC
  - Pythia8 hadronizes with Lund strings ... several CR models
  - Herwig7 hadronizes with clusters ... several CR models
  - Many parameters!

Zvi Citron

 Measuring CR sensitive observables in top quark events, gives us a detailed handle on CR/MPI









# What Do We Know about Upsilon Production and collectivity at the LHC?



 Strong evidence from Upsilon mesons that there is some non-trivial interaction between the "UE" and a hard scattering Seems we don't understand Upsilon meson production in pp

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# $R_{\rm T}$ allows to study the particle fractions in low-UE environments.

PYTHIA and EPOS-LHC describe reasonably the measurements.







#### Analyse the kinematics of jets associated DY processes



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# HADML - towards a deep learning model for hadronization



# Full-event Validation (Full events using HADML integrated into Herwig 7)





Ultimative goal: train directly on data!

Tuning procedure needs to be re-thought

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- HADML is able to reproduce Herwig's light cluster decays
- Integrated with the full Herwig simulation is able to reproduce results from LEP data



#### Recent developments towards Sherpa 3.0





[Ciulli, Kallweit, JML, Pozzorini, Schönherr for LH15]

News to soft physics

- Major re-write of hadronisation module
- Re-written color reconnection
- UE based on Sjöstrand-Zijl
- Implemented now minbias, but un-tuned

Tuning uncertainties:

Eigentunes vs. replica tunes (re-tune with different sub-sets of data)



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### Taming the cross section at low-pt

Cross section divergence of 2->2 parton scattering to low-pt typically regulated by s-dependent energy cutoff (Pythia, Herwig, Sherpa)

- usually referenced to saturation at low-pt

In approaches based on Regge Field Theory, the suppression is coming out as a feature

EPOS and QGSJET - summing many cut Pomeron diagrams



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# Taming the cross section at low-pt

Inclusion of coherent multiple scattering on soft gluons gives rise to an effect the qualitatively resembles s-depend pT-cutoff for minijet production

cross section, mb

150

100

50

p+p

Tames energy rise of both sigma\_tot and nch particle distributions

QGSJET-III-03

 $\sigma_{tot}$  (no HT



 $\sigma_{el}$  (no HT) .





#### S. Ostapchenko



# EPOS 4

Has several components to be able to describe details of pp, p+A, AA scattering within single model

- Core Corona
- strategy to include saturation
- flow

#### Need all components to describe diversity of event properties



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Also now includes jet production and modeling of HF - important for pileup simulation in the LHC experiments

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Klaus Werner

## String versus Cluster hadronization

Big picture

- Lund String model in Pythia seen better for hadronization processes
- Angular Ordered shower in Herwig7 better when studying perturbative effects

The best out of the two  $\rightarrow$  String fragmentation in Herwig7 (pioneered in AutoTunes)

New MAP tunes to LEP measurements

- Seen improvements in several observables
- Deficiencies in some flavor observables (not tuned to)

Robustness of MAP tunes provides setup for systematic studies of NP effects in e+e-

Next, tuning to LHC data









### Mapping between Parton Shower and Hadronization

Simon Platzer

Predicting hadron production is a multiscale process

- Parton shower captures perturbative part stop evolution at some scale mu\_S
- Hadronization takes over below mu\_S

Final state observables should not depend depend on Q in ideal case (tunes can compensate change in Q)

Attempts to connect PS with Hadronization based on deeper theoretical input (RGE)

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We must understand how hadronization models respond to shower variations — they do not live in isolation, and we shouldn't be tuning the shower cutoff.

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### Summary of summaries

A glimpse of light after the week of rain ...



#### Many thanks to all the speakers

... and to the organizers for this nice workshop!

Intense interdisciplinary collaboration in the evenings ...



Lattice + Small-x + MB&MC + ... = ?



