Bayesian unfolding of charged-particle p_T spectra measured with ALICE at the LHC

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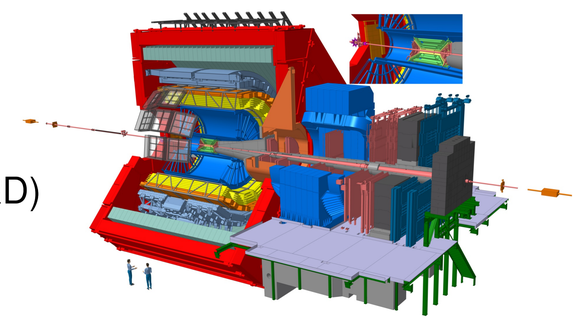
Motivation

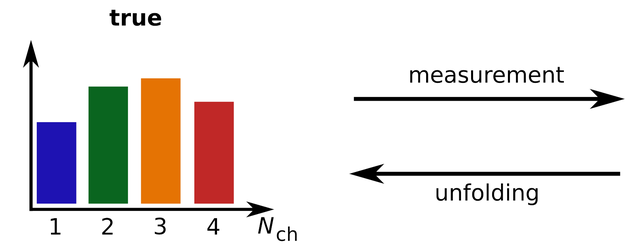
- ALICE experiment is dedicated to study the Quark-Gluon-Plasma created in ultrarelativistic heavy-ion collisions.
- Complementary reference measurements in proton-lead (p–Pb) and proton-proton (pp) collisions.
- Study effects of multiple-parton interactions and hadronization beyond independent string fragmentation.
- Fundamental observable:
  correlation between transverse-momentum (p_T) spectra of charged particles and corresponding charged-particle multiplicities.

ALICE tracking detectors

- Inner Tracking System (ITS)
- Time Projection Chamber (TPC)
- Transition Radiation Detector (TRD)



True vs. Measured Multiplicity



- Detector efficiency affects multiplicity
  → N_{ch} (true) ≠ N_{acc} (measured).
- Events with many different N_{ch} can be measured as same N_{acc}.
- Probability for N_{ch} to be measured as N_{acc} is given by detector response $P(N_{acc}|N_{ch})$ from MC simulations (fig. 1).
- Measurement needs to be unfolded to reconstruct correlation between yield and true multiplicity.

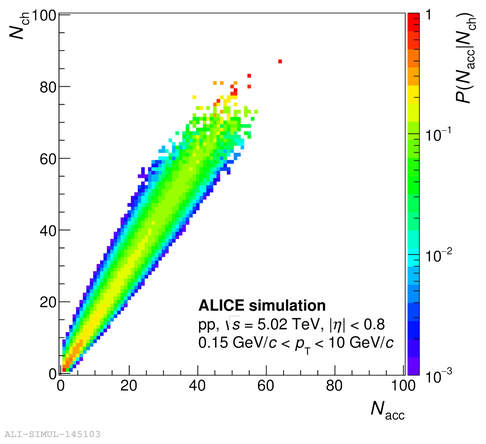


Figure 1: Detector response matrix.

Unfolding of p_T Spectra

- Transverse-momentum spectra measured as function of N_{acc}.
- Correlation between N_{ch} and p_T spectra is unknown in experiment.
- Particles from events of different N_{ch} contribute to same N_{acc}.

- Stochastic method to reconstruct p_T spectra as function of N_{ch} from p_T spectra as function of N_{acc}.
- Iterative procedure based on Bayes' theorem [1]:
  – Input: detector response + p_T-dependent N_{acc} distribution.
  – Output: p_T-dependent N_{ch} distribution.

- Example (figure 2):
  pp collisions simulated with PYTHIA8 [2] Monash-2013 at $\sqrt{s}$ = 5.02 TeV propagated through GEANT-3 [3] model of ALICE.

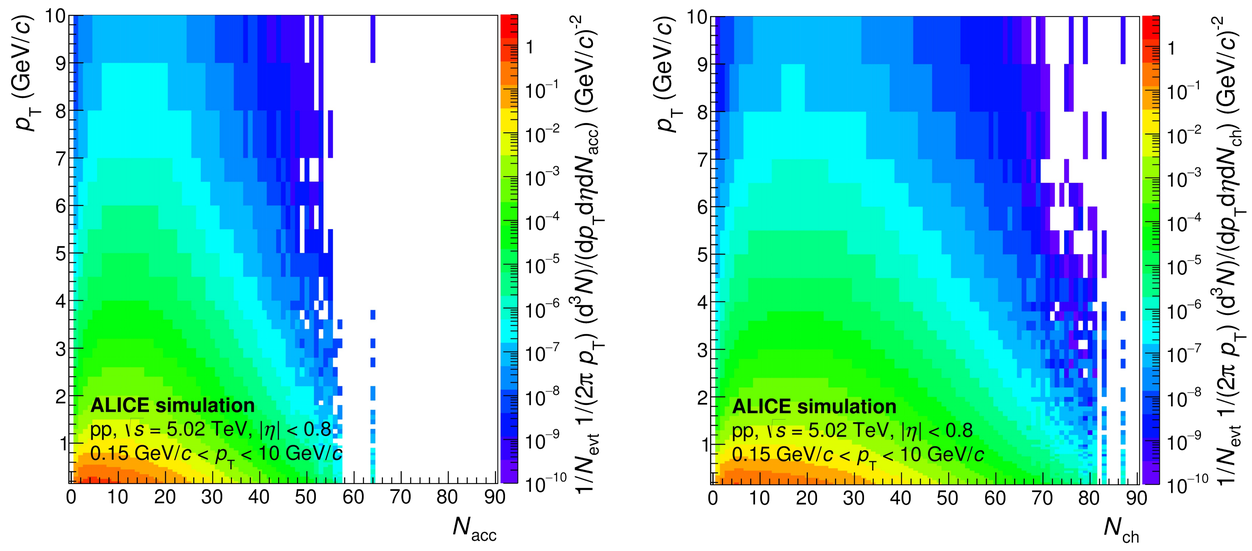


Figure 2: Transverse-momentum spectra of inclusive charged particles as function of the measured multiplicity N_{acc} (left) and as function of the true multiplicity N_{ch} after unfolding (right).

MC Closure Tests

- Self-consistency check of procedure via MC simulation:
  unfold measured p_T spectra and compare with MC truth.
- Study of first three moments as function of N_{ch}.
- Alternative re-weighting method used in previous publications ([4], [5]) shows deviation from MC truth (bias was included to full extent in systematic uncertainties).
- Bayesian unfolding provides better results and reduces systematic uncertainties.

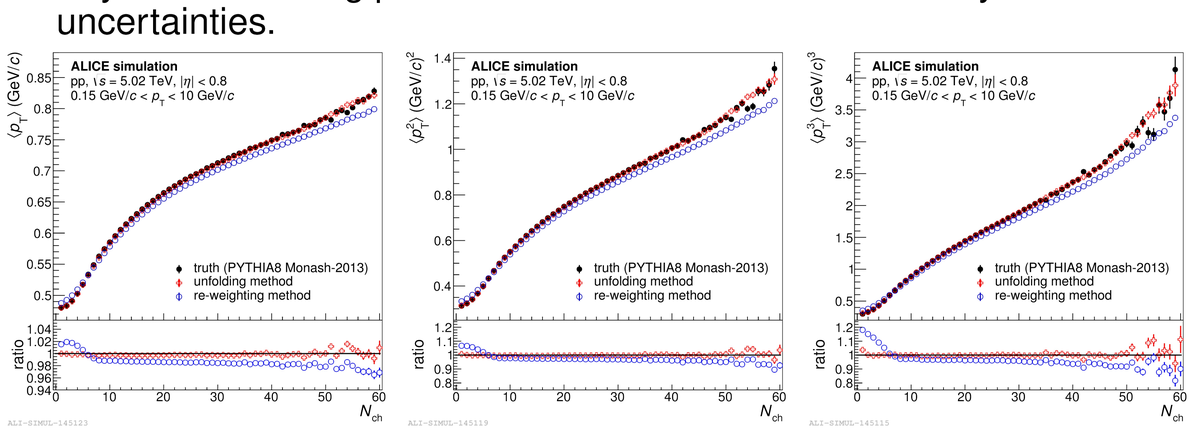


Figure 3: Closure tests for first three moments of the unfolded transverse-momentum spectra as function of N_{ch}.

Energy and System Size Dependence

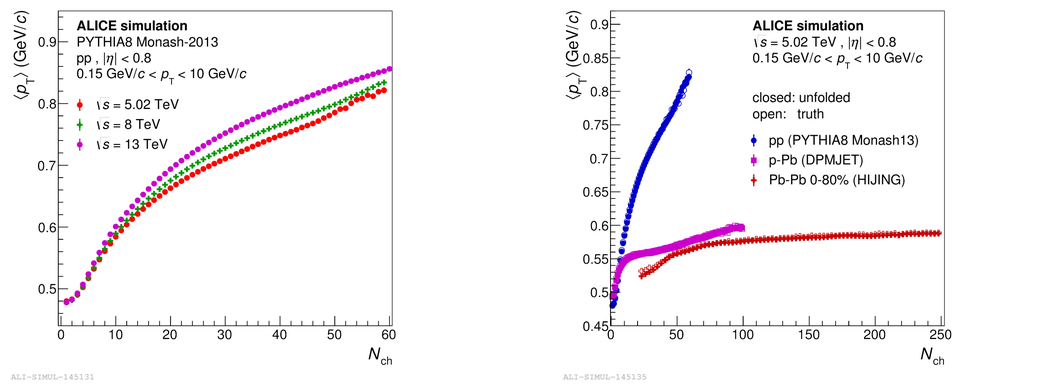


Figure 4: $\langle p_T \rangle$ vs. N_{ch} of unfolded transverse-momentum spectra.
Left panel: pp collisions at $\sqrt{s}$ = 5.02, 8 and 13 TeV.
Right panel: pp, p–Pb and Pb–Pb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV.

Outlook

- Study energy dependence of p_T spectra in pp collisions measured by ALICE at $\sqrt{s}$ = 0.9, 2.76, 5.02, 7, 8 and 13 TeV.
- Study system size dependence of p_T spectra in pp, p–Pb and Pb–Pb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV.

[1] G. D'Agostini. A multidimensional unfolding method based on Bayes' theorem. Nucl. Instr. Meth. Phys. Res. A 362 (1995) 487-498.
[2] T. Sjöstrand, S. Ask et al. An introduction to PYTHIA 8.2. Computer Physics Communications (2015).
[3] R. Brun, F. Bruyant et al. GEANT detector description and simulation tool. CERN Program Library long writeup W5013 (1994).
[4] ALICE Collaboration. Transverse momentum spectra of charged particles in proton-proton collisions at $\sqrt{s}$ = 900 GeV with ALICE at the LHC. Phys. Lett. B 693 (2010) 53-68.
[5] ALICE Collaboration. Multiplicity dependence of the average transverse momentum in pp, p-Pb, and Pb-Pb collisions at the LHC. Phys. Lett. B 727 (2013) 371-380.

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