Fine Tuning of the HIJNG++ in pp and p-Pb Collsions

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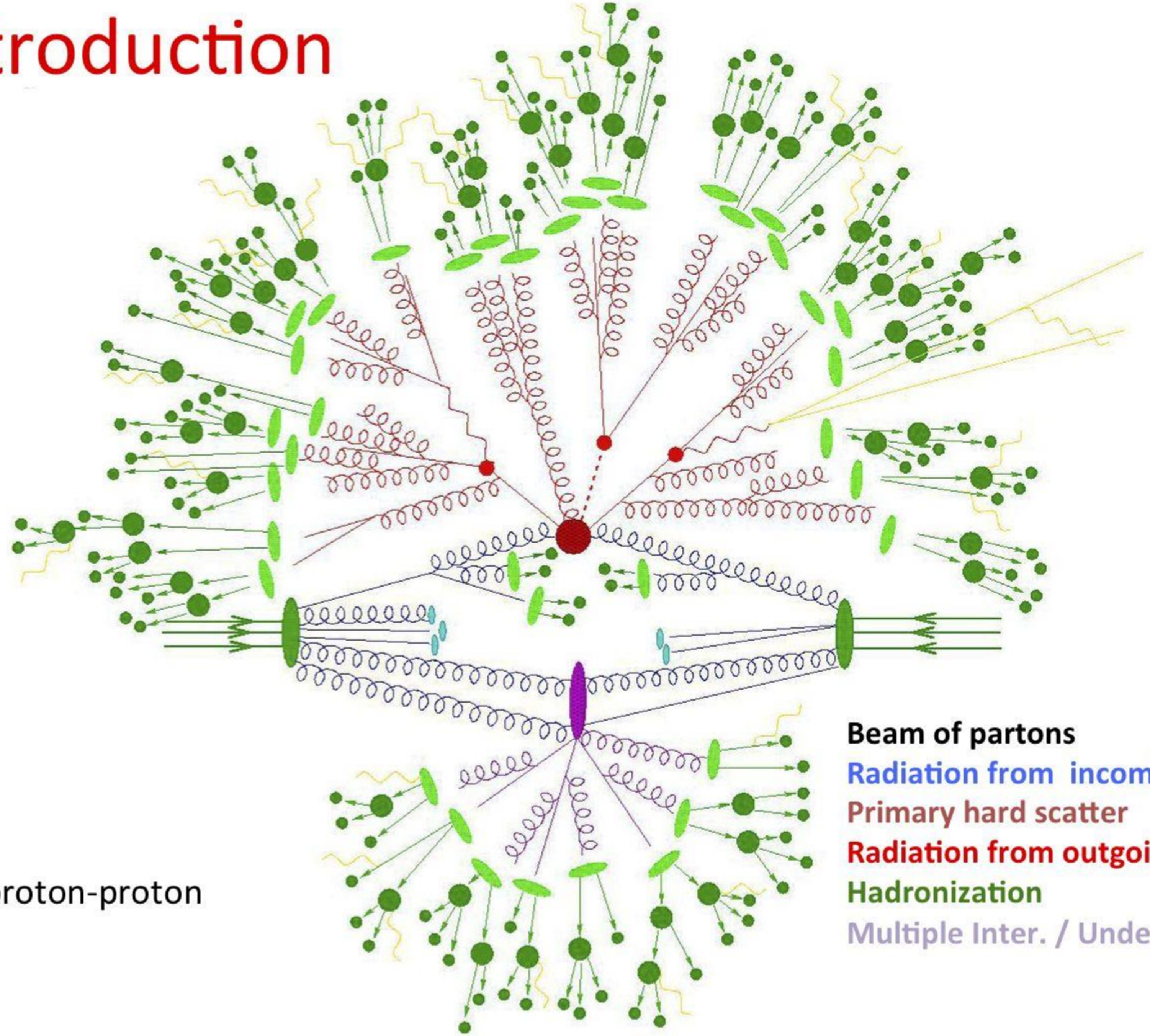
Overview

- Introduction
- The structure of the HIJING++
- First results
- Tuning procedure
- Results of the fine-tuning

Introduction



Beam of partons
Radiation from incoming partons
Primary hard scatter
Radiation from outgoing partons
Hadronization
Multiple Inter. / Underlying event

Typical proton-proton collision

Heavy-ion collisions are much more complicated...

But we can do phenomenology!

In HIJING++ we calculate the cross section:

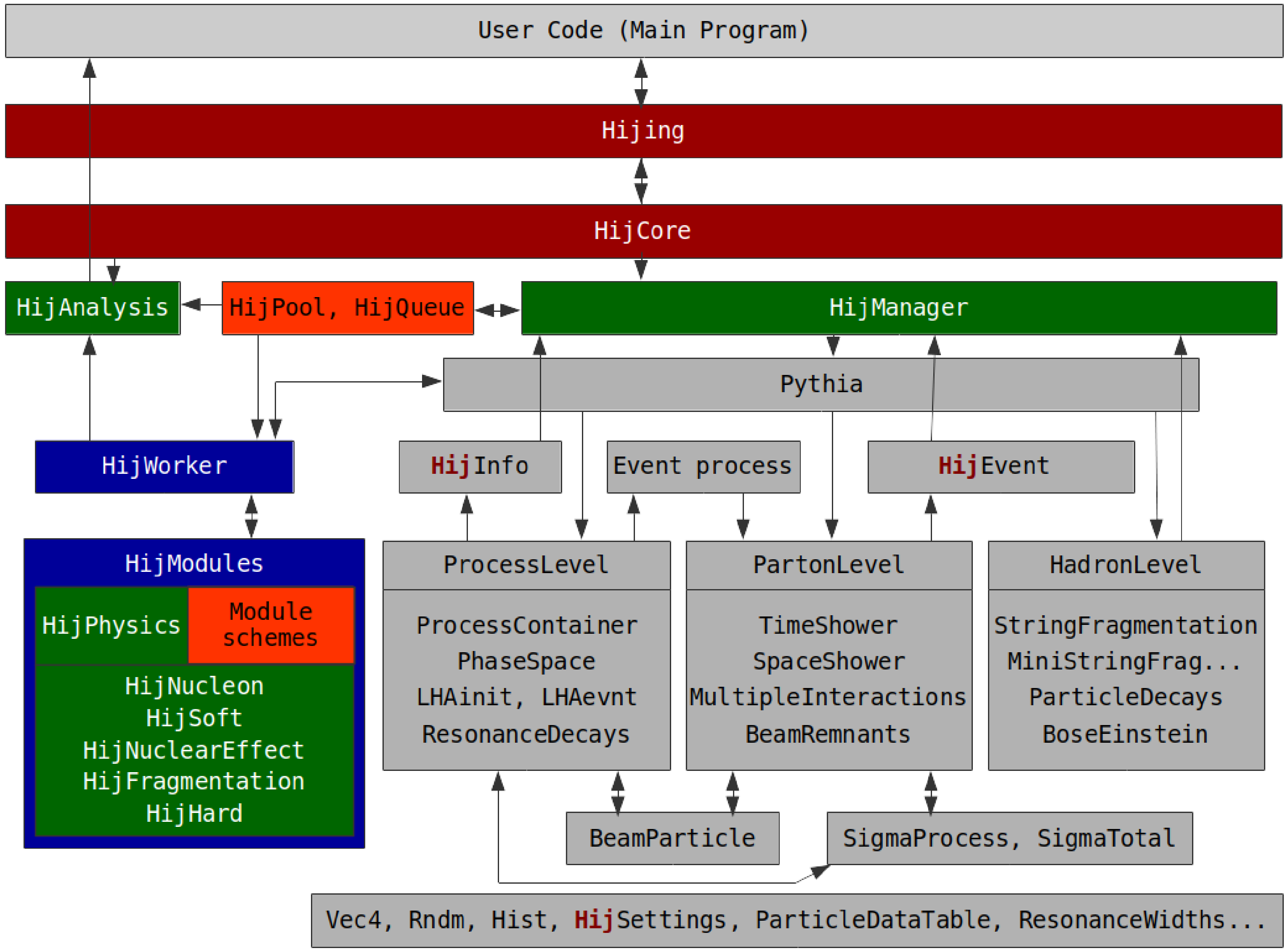
$$\sigma_{total} = \sigma_{elastic} + \sigma_{inelastic} + \sigma_{hard}$$

In HIJING++ we calculate the cross section:

$$\sigma_{total} = \sigma_{elastic} + \sigma_{inelastic} + \sigma_{hard}$$

with several phenomenological parameters

The Structure of the HIJING++ Program Code



Softwares Used for Data Analysis & Plotting

YODA – Yet more Objects for Data Analysis

- Used for defining histograms
- Can contain metadata
  - reference for comparing with experimental data (via RIVET)
  - number of total interactions
- Python interface

RIVET – Robust Independent Validation of Experiment and Theory

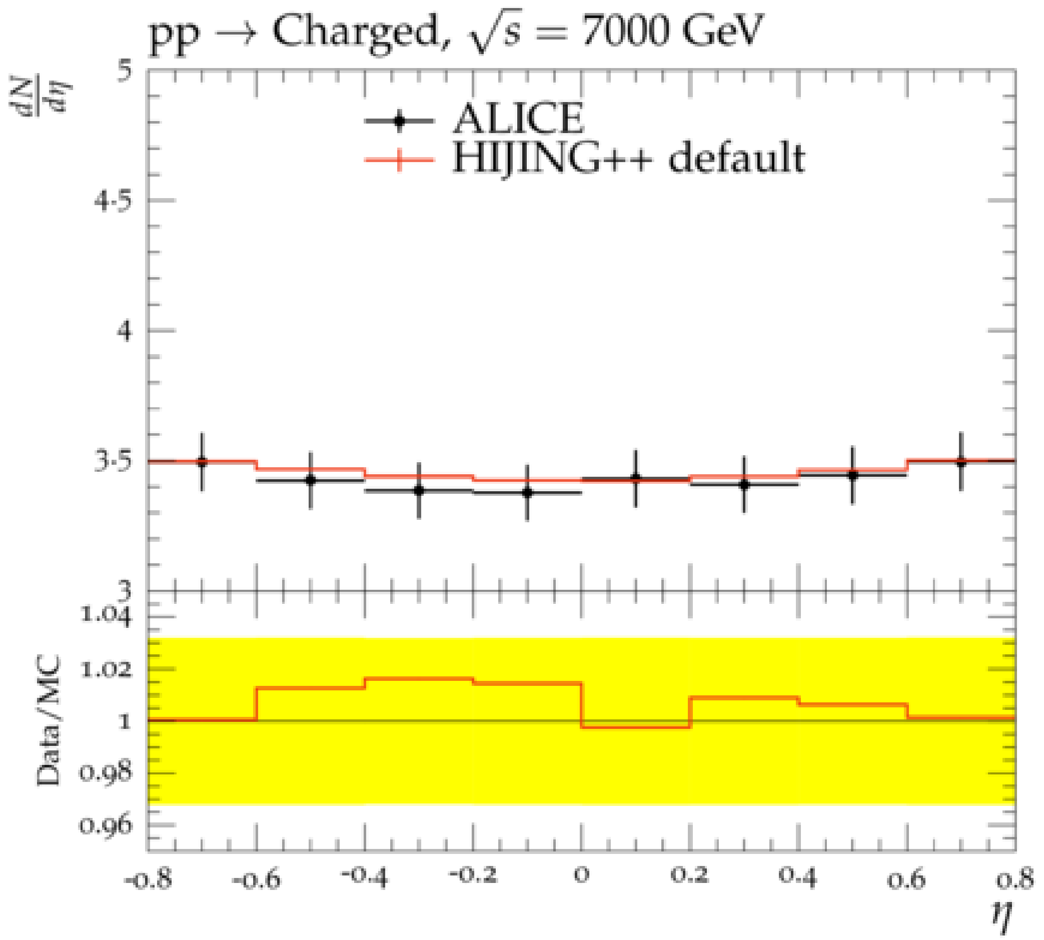
- Used for comparing MC and experimental data
- Formattable plots, including ratio plots

The Investigated Observables in the Analysis

- Pseudorapidity distribution in pp and p-Pb collisions
- Multiplicity distribution in proton-proton (pp) collisions
- Inclusive hadron spectra, pp → $\pi^{\pm}, K^{\pm}, p\bar{p}$ and p-Pb → $h^{\pm}$
- pp at 7000 GeV and p-Pb at 5020 GeV c.m. energies
- Nuclear Modification Factor at 5020 GeV c.m. energy

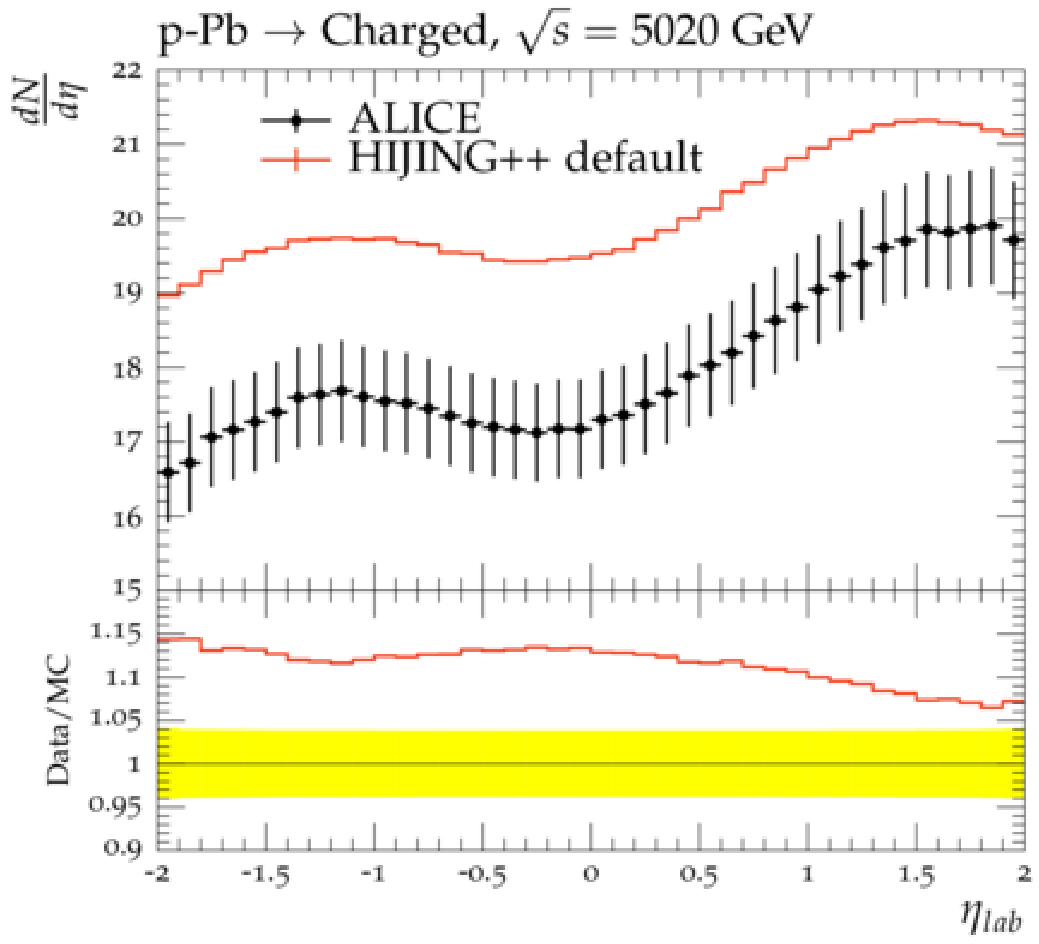
HIJING++ Results Before Fine-tuning

Pseudorapidity Distribution (pp)



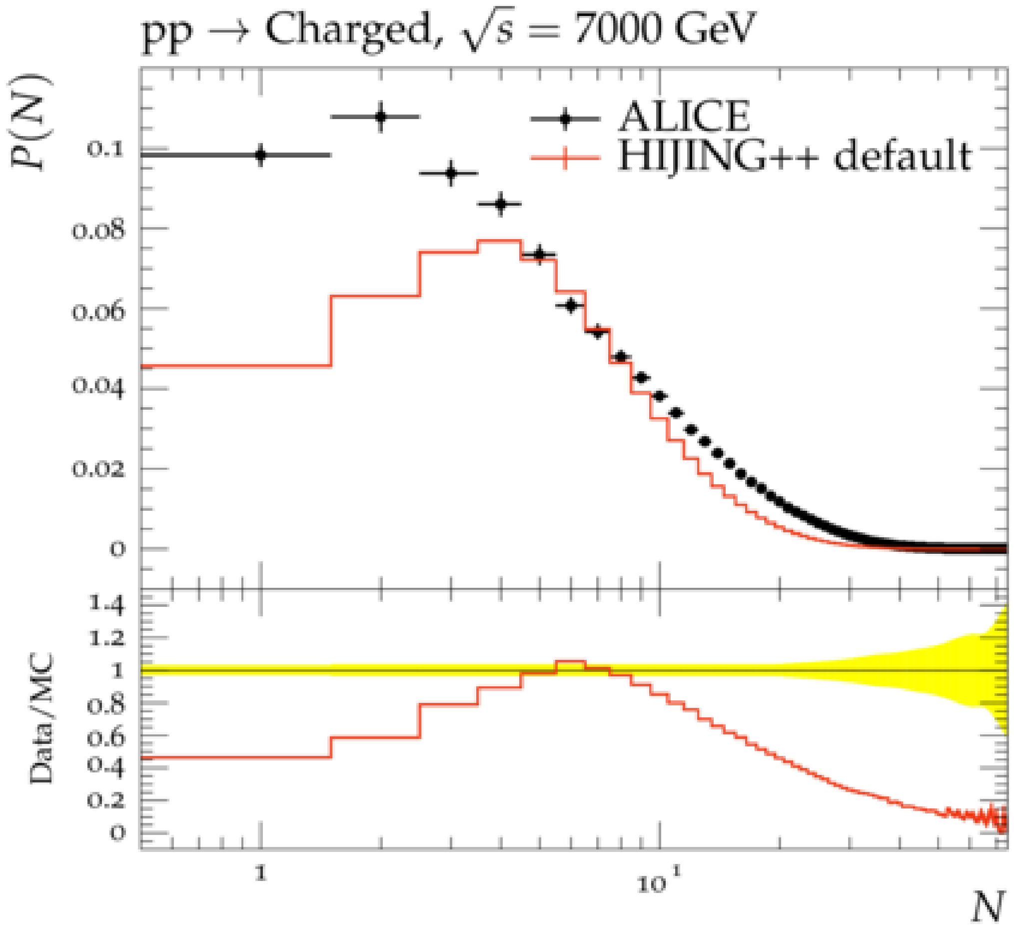
- Proton-proton (pp) collisions at 7 TeV c.m. energy at midrapidity
- ALICE data compared to HIJING++
- Results:
  - Good agreement between data and HIJING++ < 2 %
  - Well within the experimental errors

Pseudorapidity Distribution (p-Pb)



- Proton-lead (p-Pb) collisions at 5.02 TeV c.m. at midrapidity
- ALICE data compared to HIJING++
- Results:
  - Data and HIJING++ disagree
  - Difference is 10-15 %
  - The assymetric shape is similar

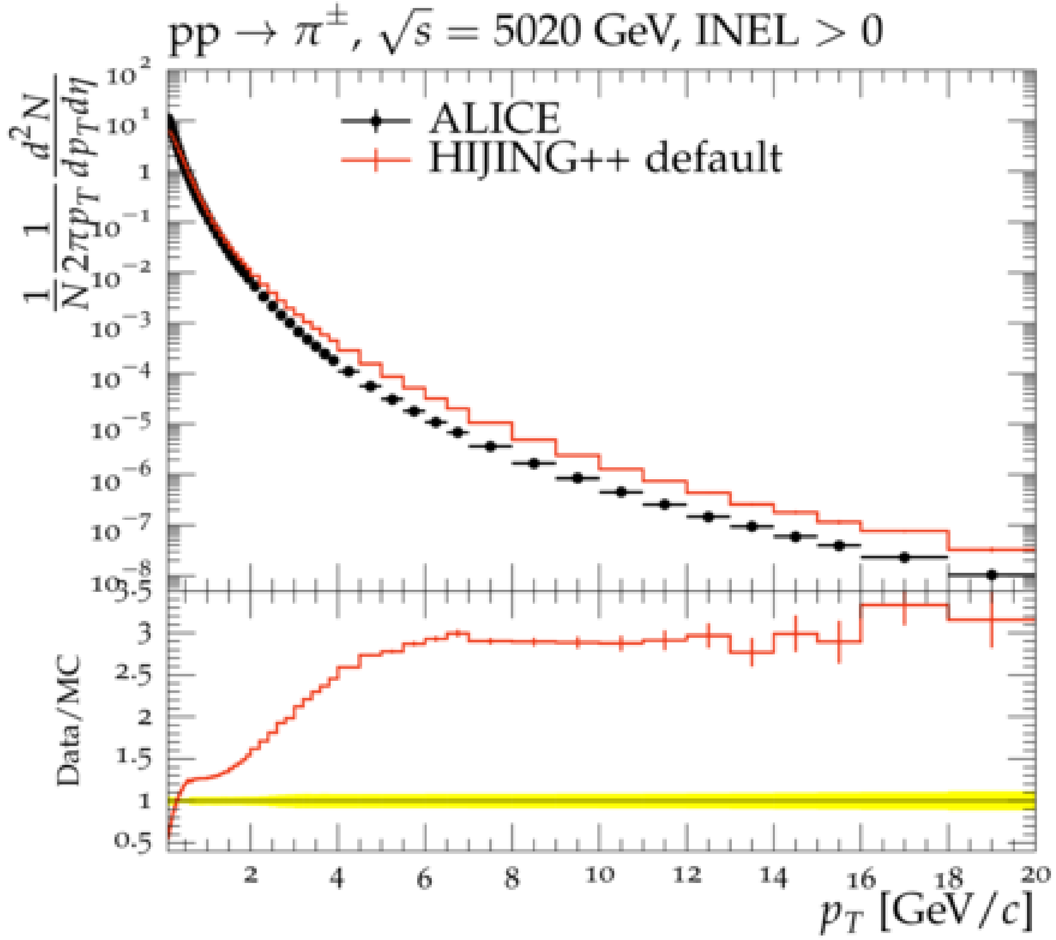
Multiplicity Distribution (pp)



- Proton-proton (pp) collisions at 7 TeV c.m. energy at midrapidity
- ALICE data compared to HIJING++
- Results:
  - Best agreement between data and HIJING++ at medium multiplicities around 10
  - At low multiplicity it is deviate
  - At high multiplicity far from data

→ Need FOR TUNE

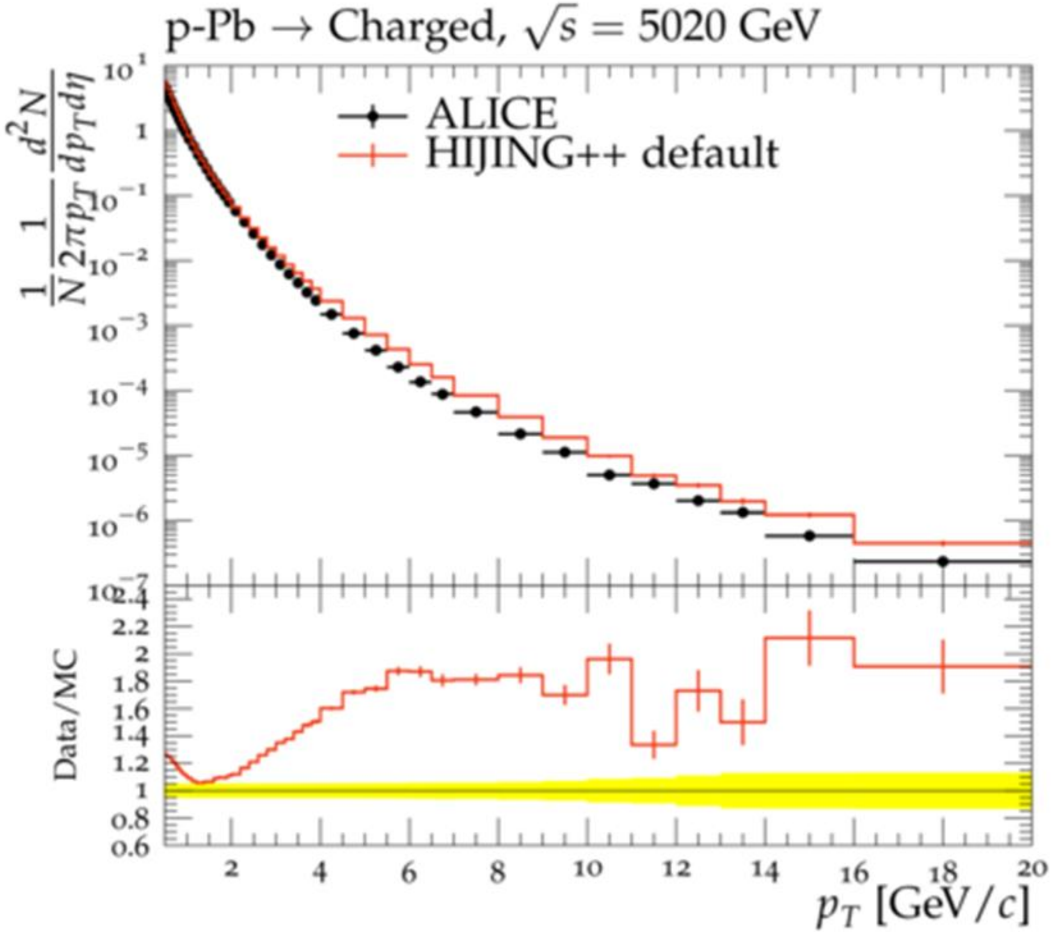
Identified Hadron Spectra (pp)



- Proton-proton (pp) collisions at 5.02 TeV at midrapidity
- ALICE data compared to HIJING++
- Results:
  - Agreement between data and HIJING++ has room for improvement
  - 3 times larger MC at high p_T values

→ Need FOR TUNE

Identified Hadron Spectra (p-Pb)



- Proton-lead (pPb) collisions at 5.02 TeV at midrapidity
- ALICE data compared to HIJING++
- Results:
  - Agreement between data and HIJING++ has room for improvement
  - 2 times larger MC at high p_T values

→ Need FOR TUNE

Fine-tuning of the HIJING++ Parameters

Some parameters with $\sqrt{s_{NN}}$-dependence

- Hardcut: soft – hard separation

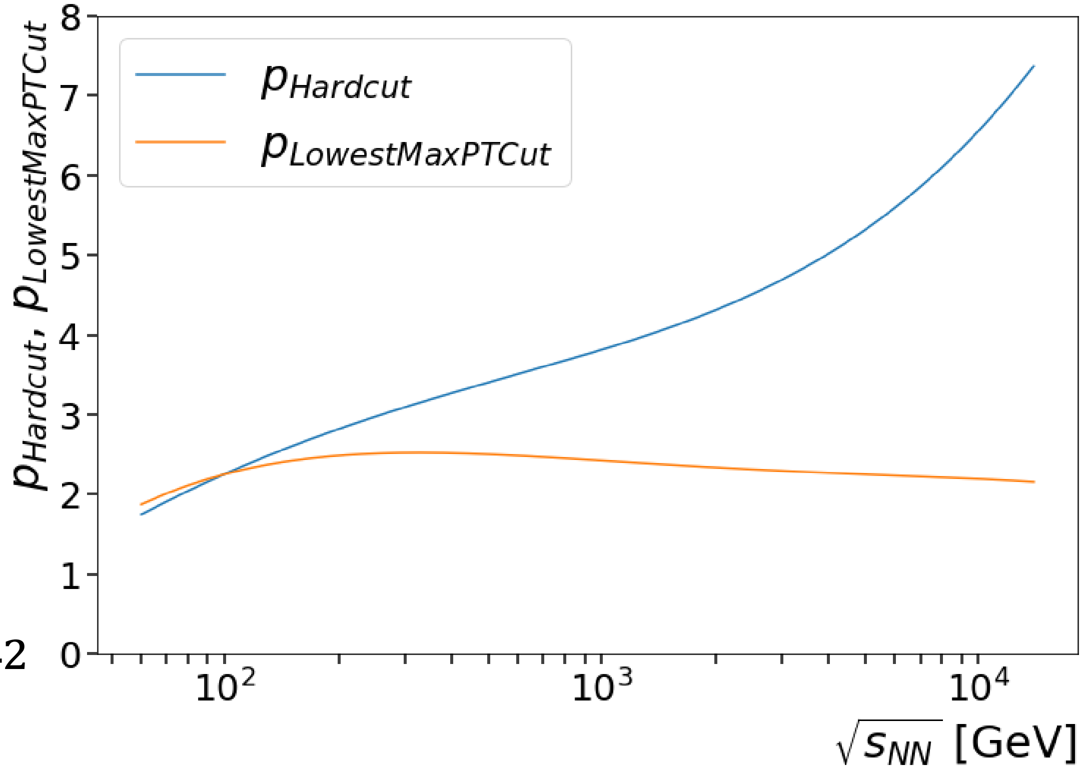
$$p_{HardCut} = -4.2 + 1.2 \ln \sqrt{s} + 0.3 \ln \sqrt{s}^2 - 0.08 \ln \sqrt{s}^3 + 0.005 \ln \sqrt{s}^4$$

→ Continuously increasing with $\sqrt{s}$

- LMPTCut (Lowest Max p_T Cut): the boundary for gluon radiation

$$p_{LMPTCut} = -17.9 + 11.0 \ln \sqrt{s} - 2.2 \ln \sqrt{s}^2 + 0.2 \ln \sqrt{s}^3 - 0.006 \ln \sqrt{s}^4$$

→ Almost constant, except for low $\sqrt{s}$



Some parameters with $\sqrt{s_{NN}}$-dependence

- σ_{soft}: soft cross section

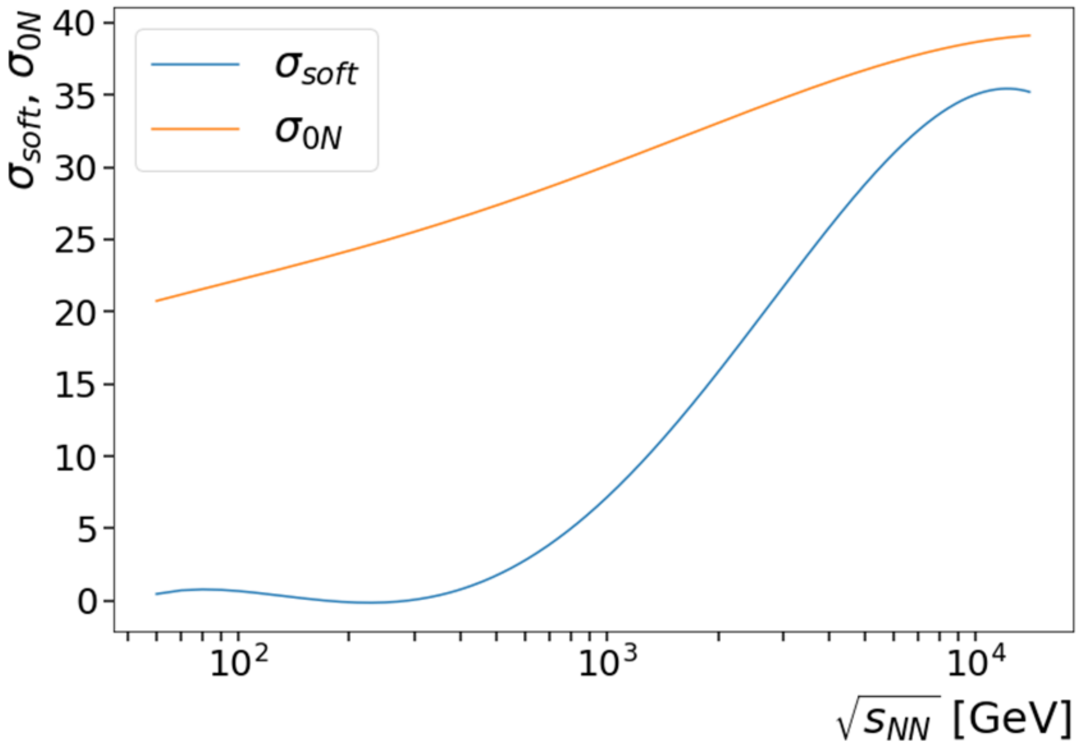
  $$\sigma_{soft} = -348.8 + 249.8 \ln \sqrt{s} - 64.8 \ln \sqrt{s}^2 + 7.1 \ln \sqrt{s}^3 - 0.3 \ln \sqrt{s}^4$$

  → Jump between RHIC and LHC energies

- σ_{0N}: cross section of nucleons

  - $\sigma_{0N} = -19.0 + 24.4 \ln \sqrt{s} - 6.0 \ln \sqrt{s}^2 + 0.7 \ln \sqrt{s}^3 - 0.03 \ln \sqrt{s}^4$

  → Continuously increasing from 20 to 35 mb



Further Parameters to Tune...

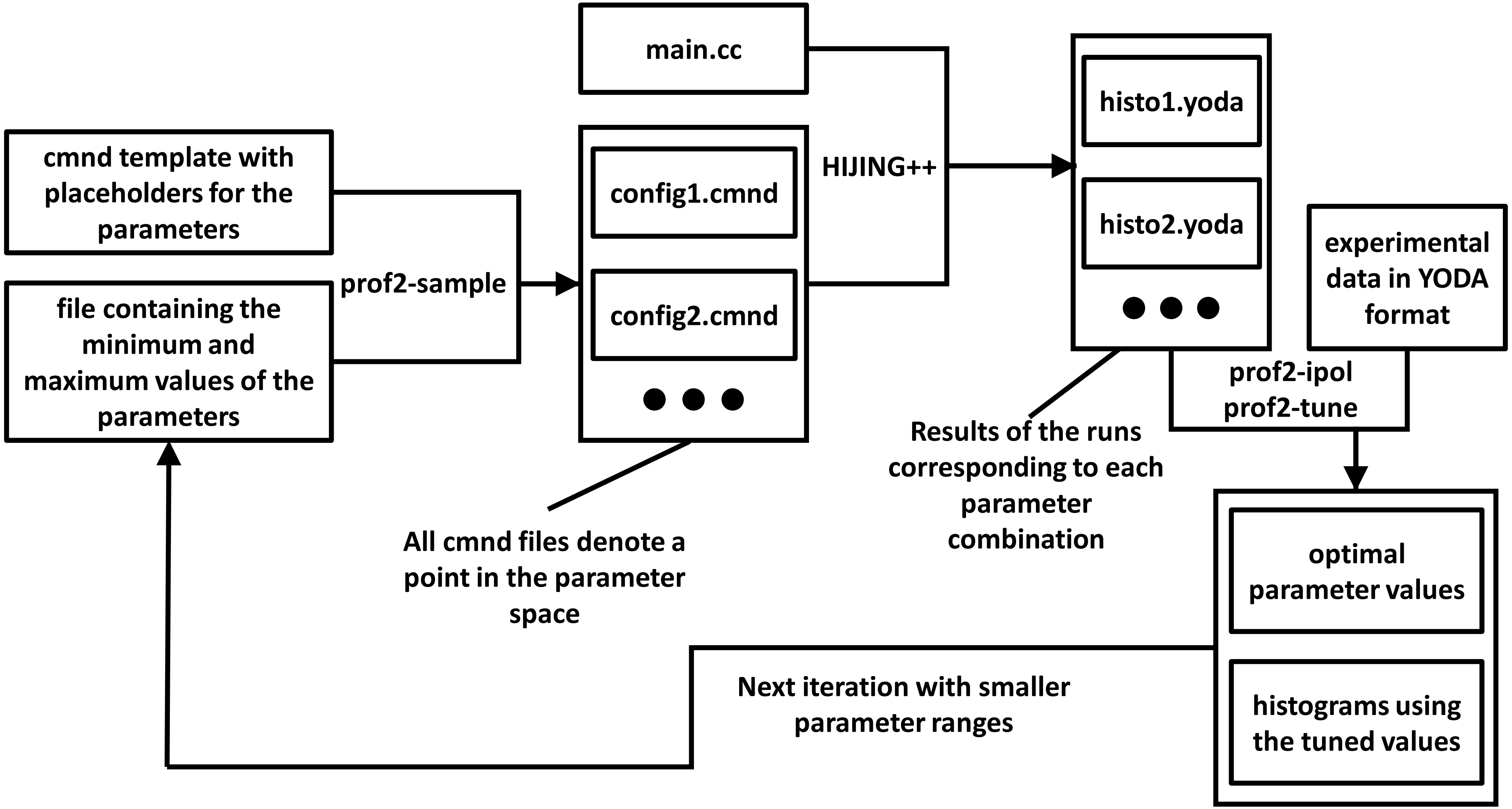
- sqparm1: p_T kick value
- sqparm2-3: Feynman parameter of the NSD valence quarks
- vqparm1-3: Feynman parameter of the NSD sea quarks
- PtkickScale1-2: p_T kick distribution
- FormFactScale: quark rearranging
- MinJetPT: jet quenching boundary
- DLambda: Λ_{QCD}
- InvMassCut: gluon radiation
- Kfac: ratio of the LO and NLO corrections
- μ_0: collision geometry in AA collisions
- MinInvMassExStr: energy boundary of the strong processes

For Tuning we need the PROFESSOR

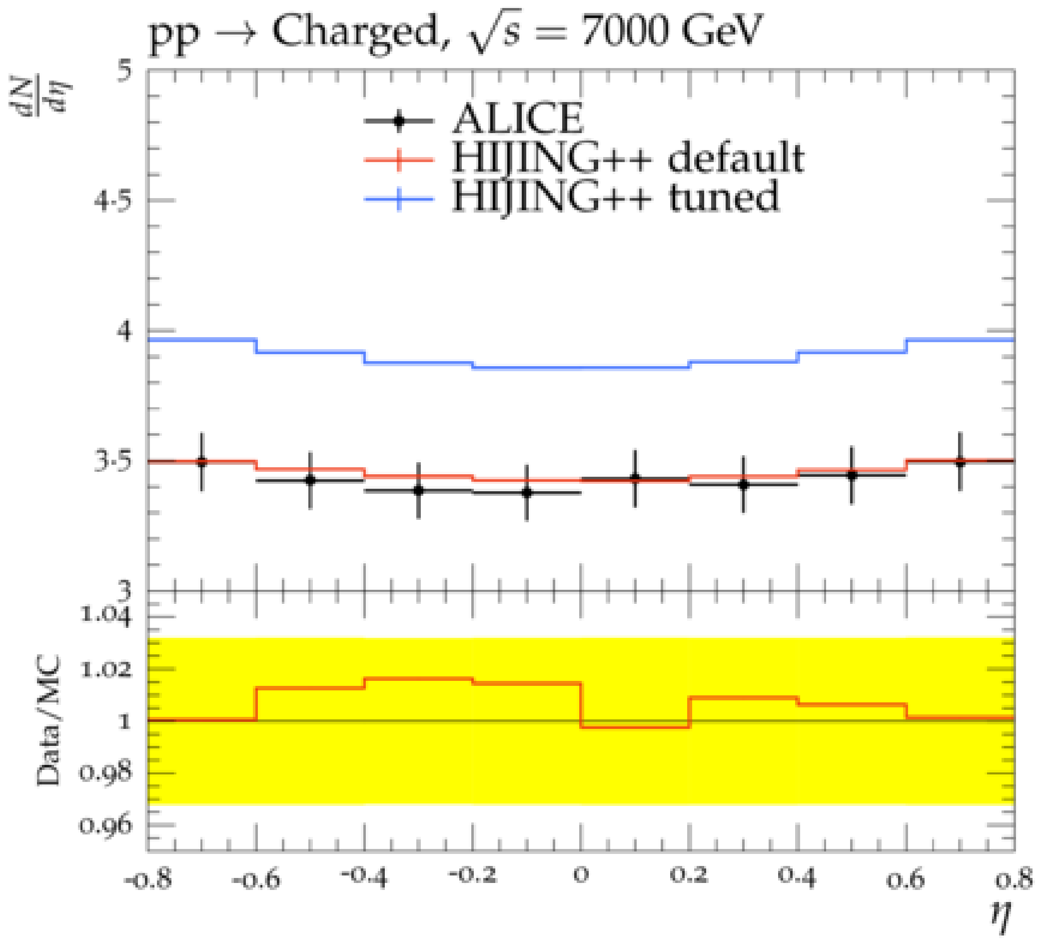
- The Professor is a code used for tuning parameters of Monte Carlo codes at ’’large scale’’
- Interpolates the optimal values based on several runs with different parameter combinations
- Runtimes:

	pp, $\sqrt{s_{NN}} = 7000$ GeV	pPb, $\sqrt{s_{NN}} = 5020$ GeV
Number of parallel runs	25	15
Average time of one run	12.6 min	43.8 min
Total runtime	4.2 hrs	24.3 hrs
Total CPU time	210.6 hrs	730.3 hrs

Tuning Procedure with the Professor Code

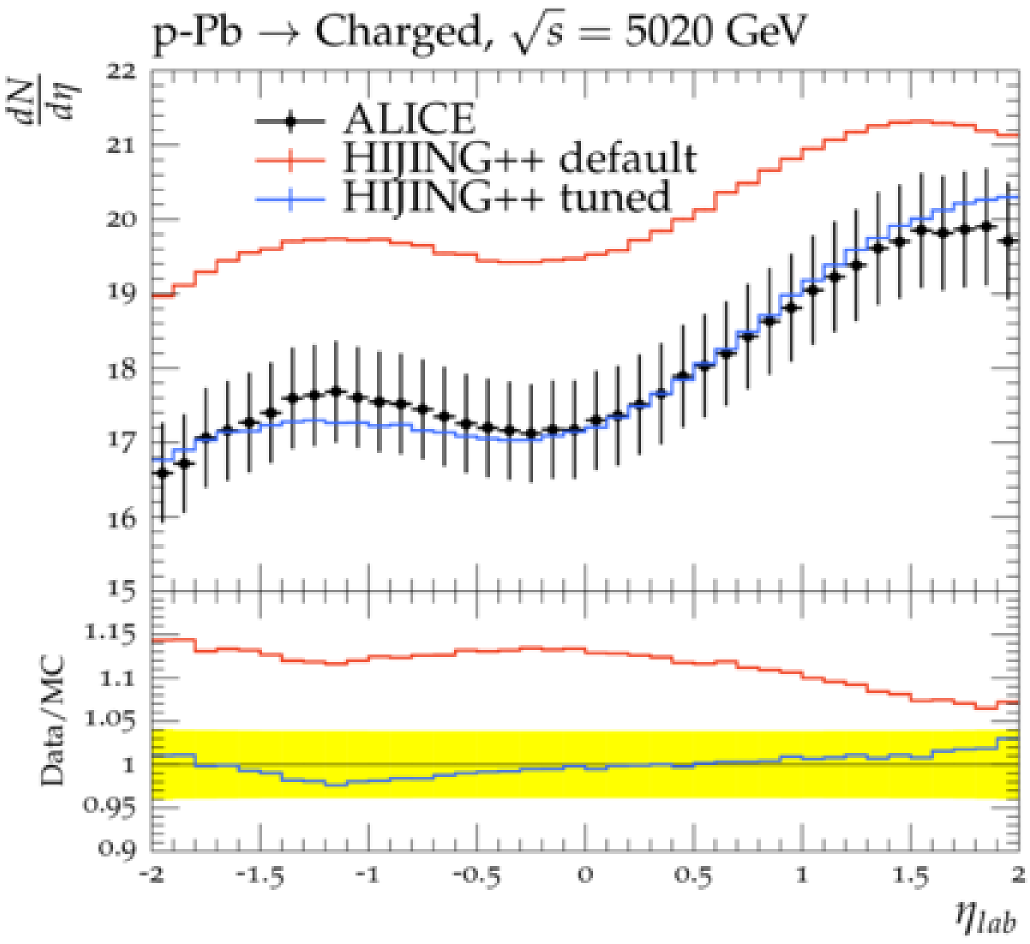


Pseudorapidity Distribution (pp)



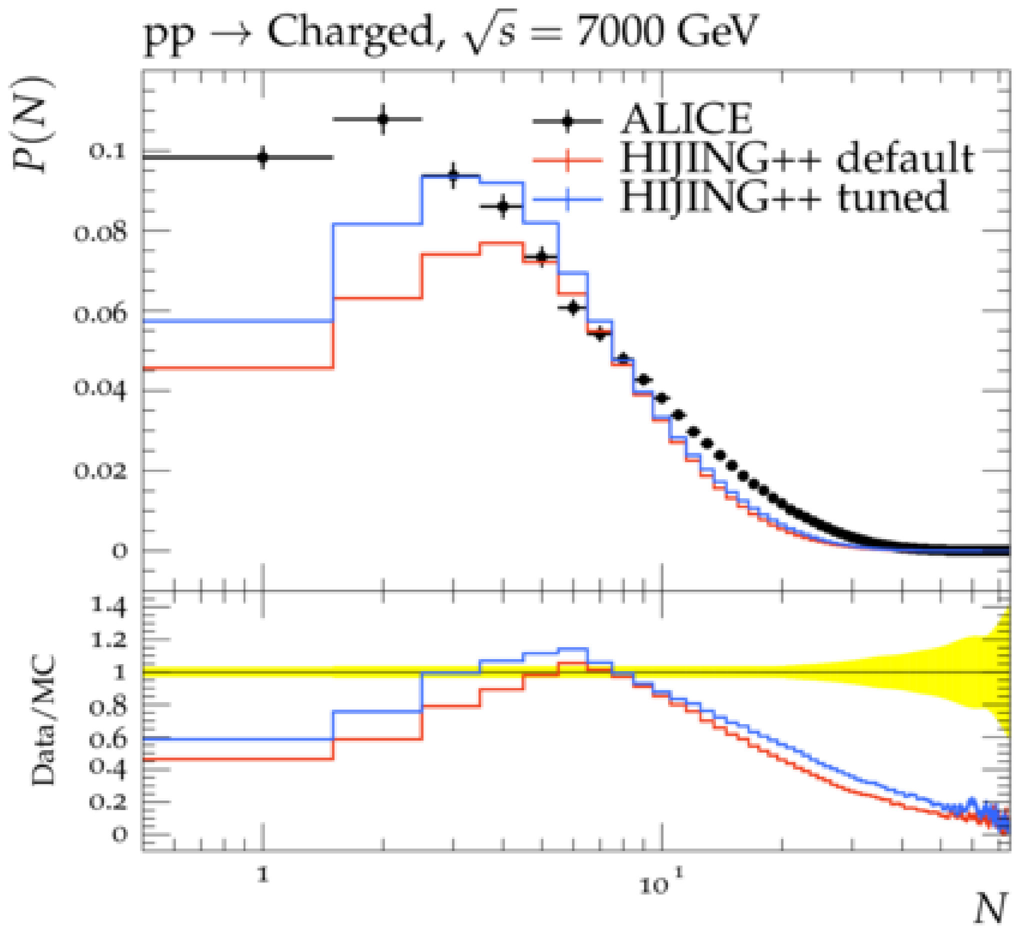
- Proton-proton (pp) collisions at 7 TeV c.m. energy at midrapidity
- ALICE data compared to HIJING++
- Tuning results:
  - It is getting worse by 25 %
  - The shape remains the same

Pseudorapidity Distribution (p-Pb)



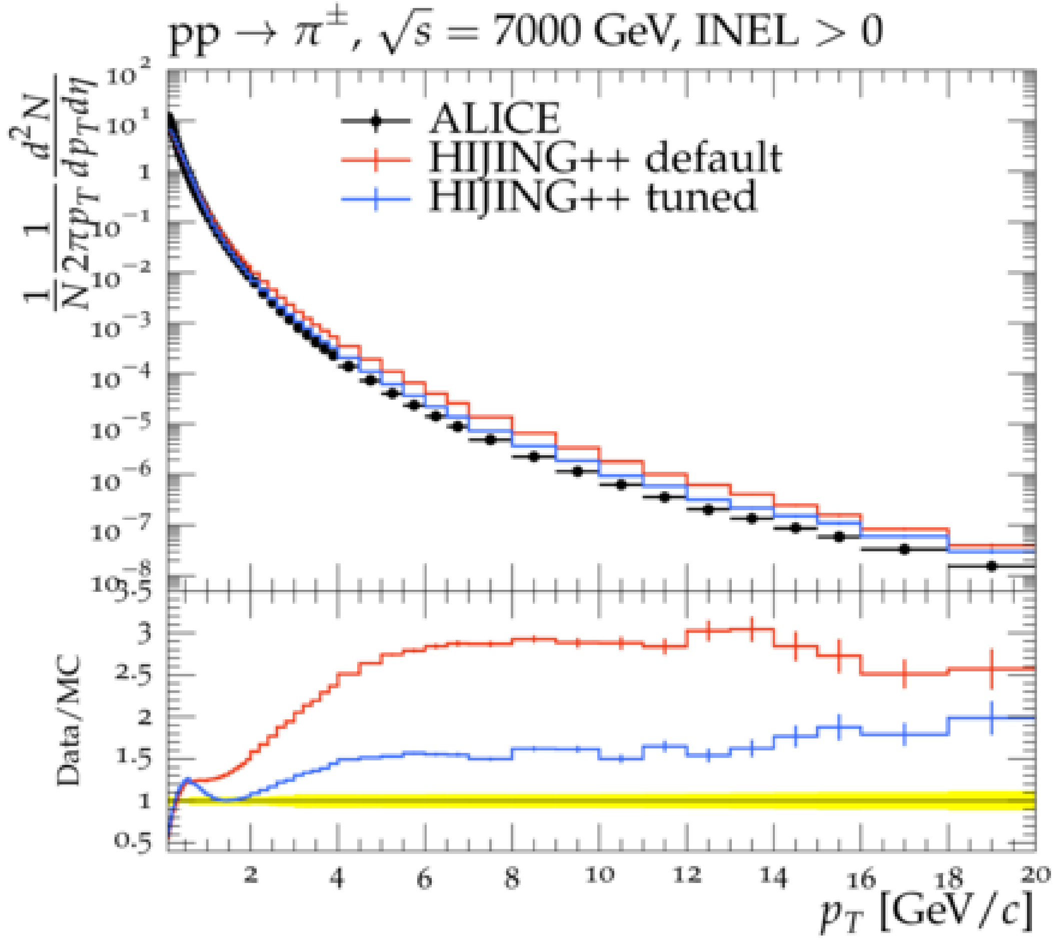
- Proton-lead (p-Pb) collisions at 5.02 TeV c.m. at midrapidity
- ALICE data compared to HIJING++
- Tuning results:
  - Data & HIJING++ are in agreement
  - Difference is only 5 %
  - Perfect shape within the experimental data

Multiplicity Distribution (pp)



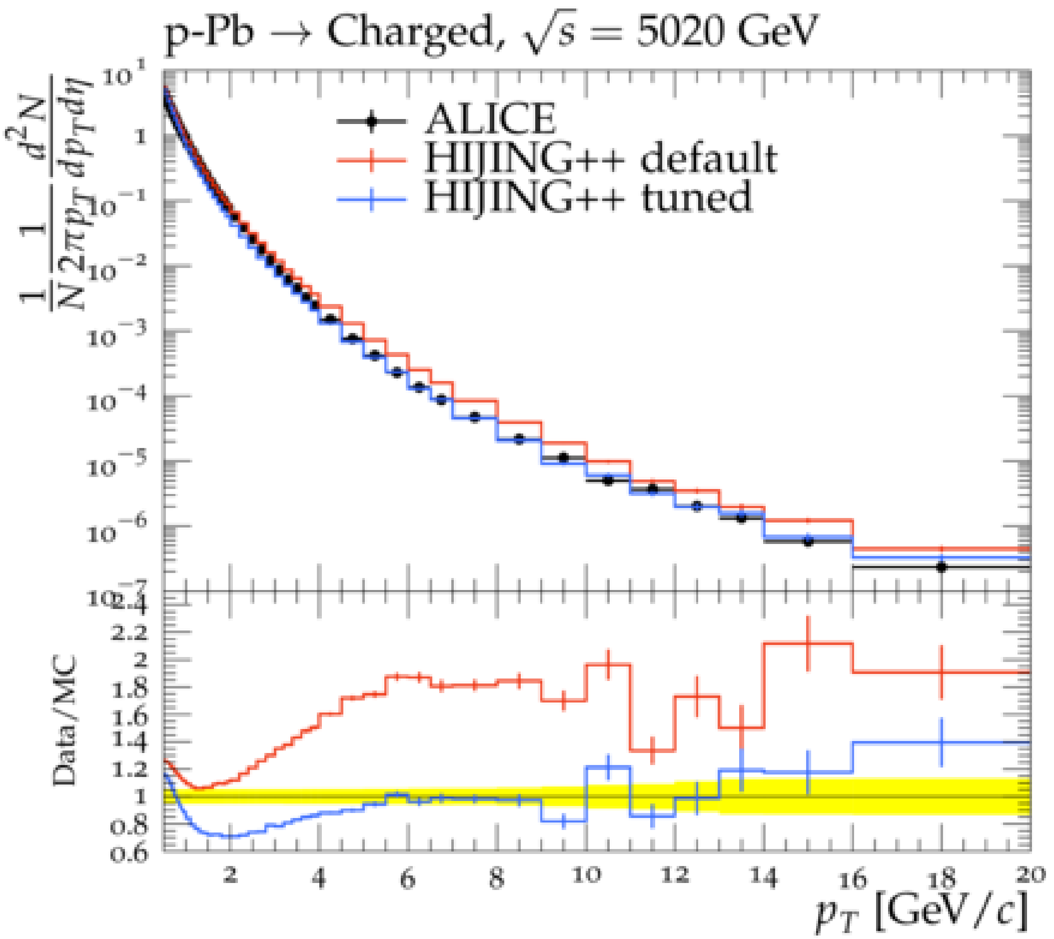
- Proton-proton (pp) collisions at 7 TeV c.m. energy at midrapidity
- ALICE data compared to HIJING++
- Tuning results:
  - Better agreement with experimental data at medium multiplicities
  - It is even closer at low- and high multiplicity

Transverse Momentum Spectra (pp)



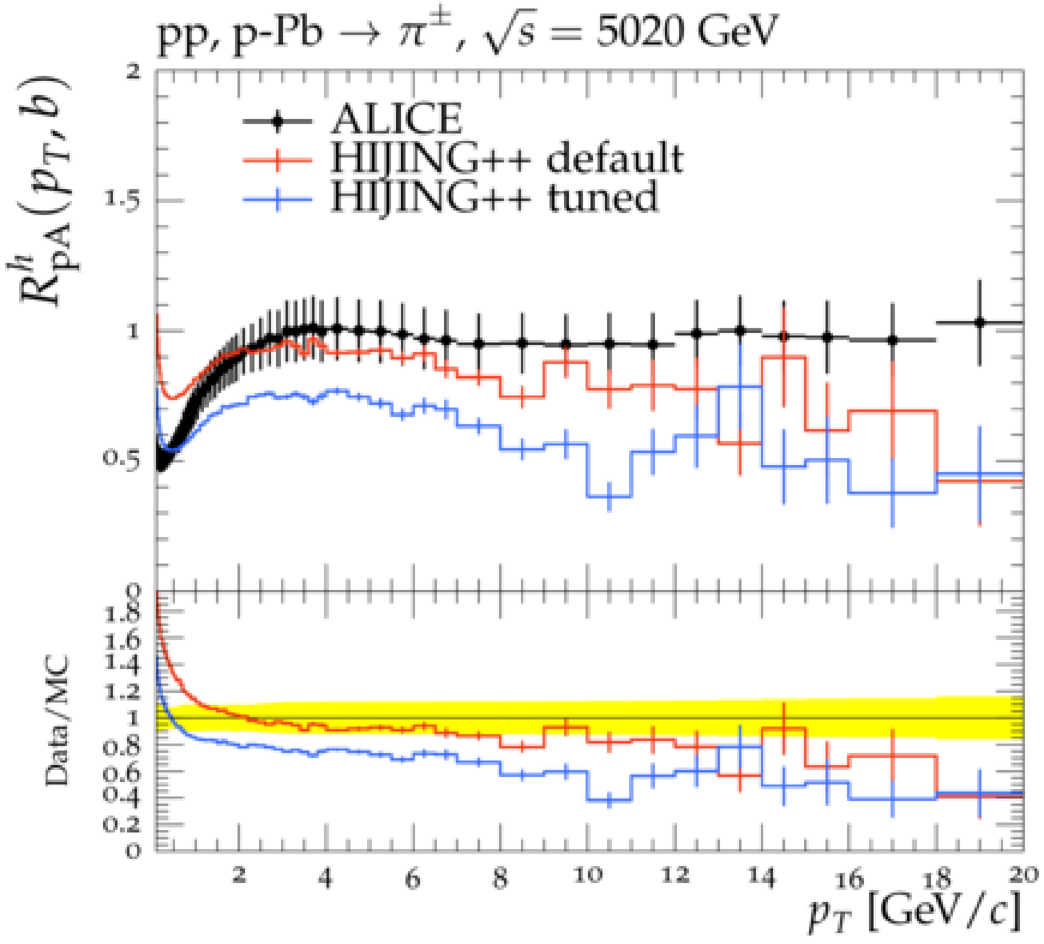
- Proton-proton (pp) collisions at 7 TeV c.m. energy at midrapidity
- ALICE data compared to HIJING++
- Tuning results:
  - Better agreement at all p_T values
  - Data and HIJING++ agrees within 50 % even at high p_T values

Transverse Momentum Spectra (p-Pb)



- Proton-lead (p-Pb) collisions at 5.02 TeV c.m. at midrapidity
- ALICE data compared to HIJING++
- Tuning results:
  - Data & HIJING++ are in agreement
  - Difference is only 20 to 40 % at the lowest and highest p_T values
  - Perfect agreement at intermediate p_T values

Nuclear Modification Factor – a Sensitive Tool



- Proton-lead (p-Pb) collisions at 5.02 TeV c.m. at midrapidity

$$R^h_{pA}(p_T, b) = \frac{1}{\langle N_{bin} \rangle} \frac{\mathrm{d}\sigma^{pA\to h}(p_T)/\mathrm{d}p_T^3}{\mathrm{d}\sigma^{pp\to h}(p_T)/\mathrm{d}p_T^3}$$

- Tuning results:
  - Better agreement for the spectra,
  - but difference has changed from 10-20 % to 20-60 %

  → Determining the correct weights for tuning is important

Conclusion and the Next Steps

- Improvements in some observables and the opposite in others
- For a better tune:
  - more runs
  - more statistics → larger sampling number to avoid local minima
  - using a wider set of experimental data including new energy scales
  - tuning even more parameters

  → Computationally expensive task

Thank you for your attention!