Multiparton Interaction Parameters Tuning in PYTHIA 8 and LHCb Tuning Infrastructure

On behalf of LHCb Simulation Project

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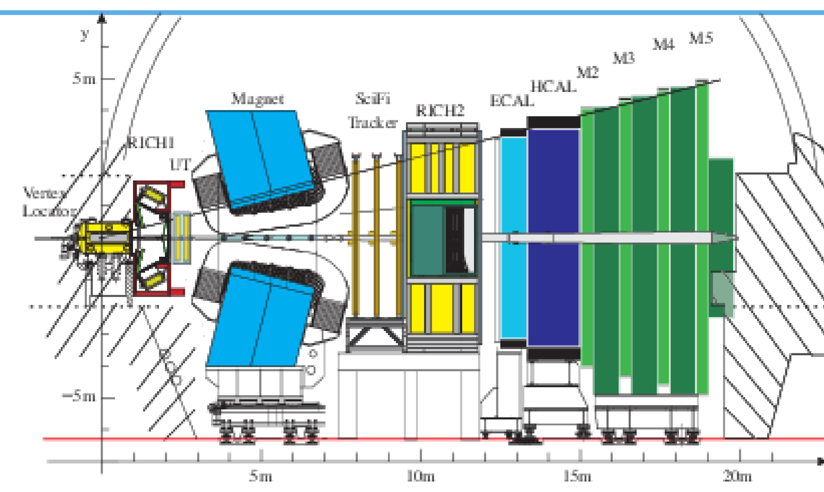
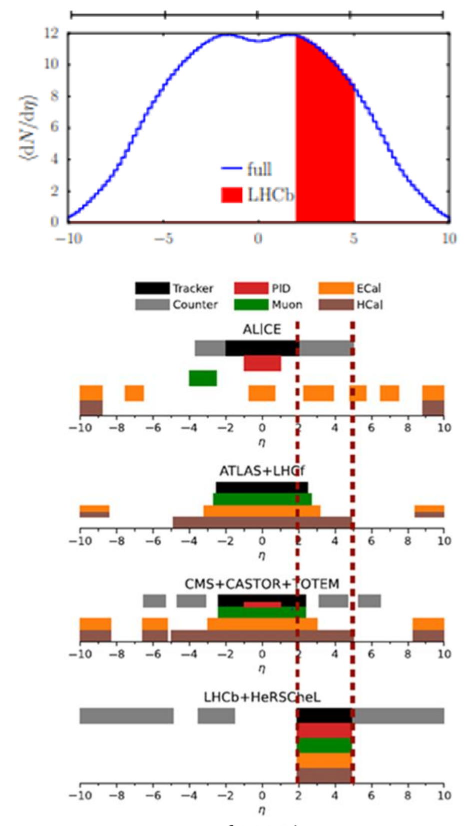
Introduction

Why a PYTHIA 8 LHCb tune?

- Often central detector tunes do not constrain forward region.
- LHCb phase-space coverage complementary to other LHC experiment.
- LHCb minimum bias generation include charm and beauty production.



LHCb detector at CERN.

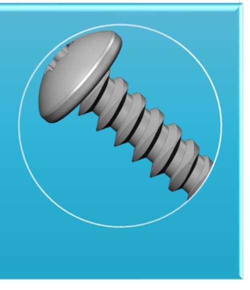


(a) unique η coverage of LHCb experiment.
(b) η coverage of LHC experiments for different detection capabilities.

Tools for Tuning

- It is a set of C++ libraries that allow describing the response of a generator in a standard format.
- For every physics result(s) one needs to build a RIVET plugin i.e.: how to extract the MC results in a standard form to be compared to the HepData reference file.

RIVET (Robust Independent Validation of Experiment and Theory)



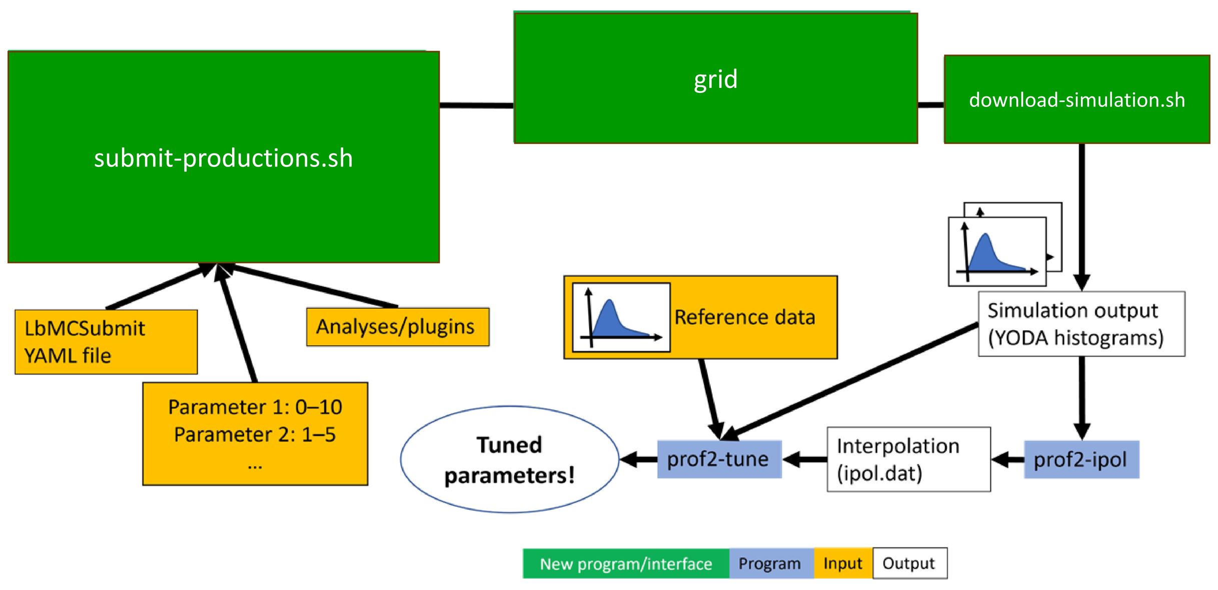
https://rivet.hepforge.org/

- PROFESSOR is a tuning tool for Monte Carlo event generators.
- Parameters are sampled across a provided range, and for every set a MC sample can be produced to find the one agreeing best with the data (LHCb utilises the Grid for parallel processing).

PROFESSOR (PROcesure For EStimating Systematic errORs)

https://professor.hepforge.org/

Tuning Infrastructure at LHCb Experiment



Tuning in a nutshell

Motivation

- All generators are based on phenomenological models with free unknown parameters. We want MC to describe the data as accurately as possible.
- So, parameters need to be TUNED..!!!

Problems

- Many parameters are highly correlated.
- Tuning all parameters at the same time puts us into high dimensional parameter space.

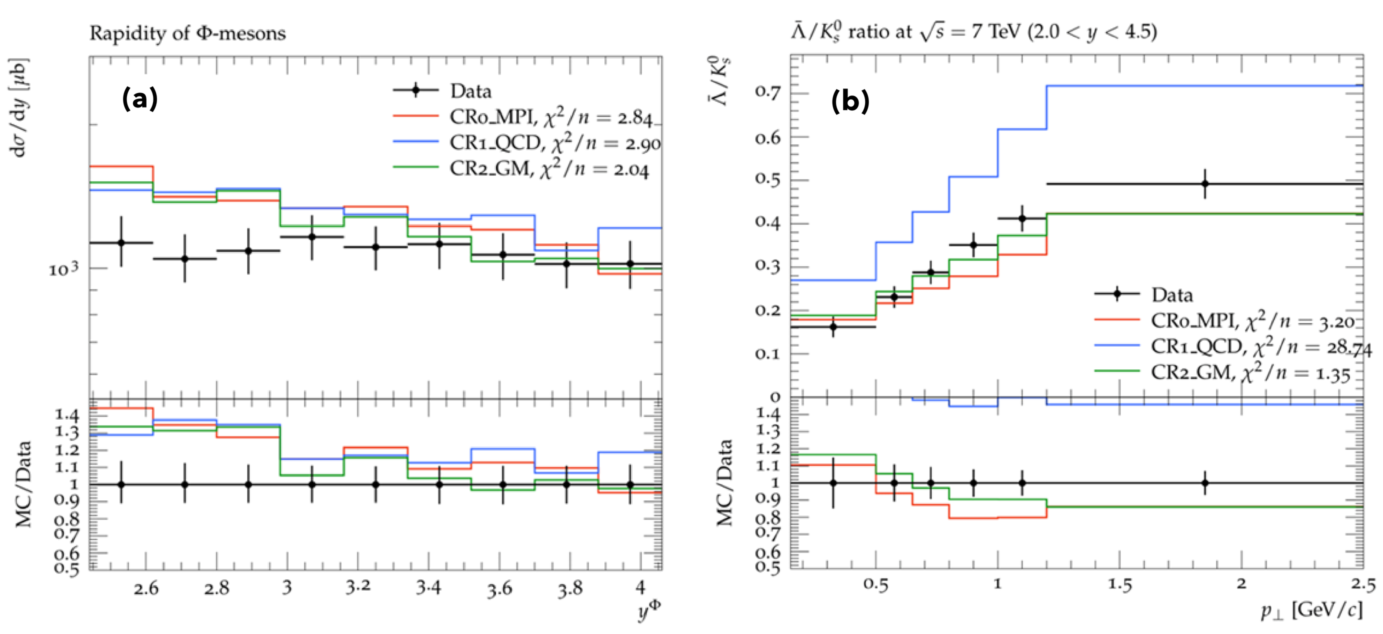
Strategies

- Tunings are based on parameters chosen from generator response using "RIVET" and "PROFESSOR".

Steps to Tuning

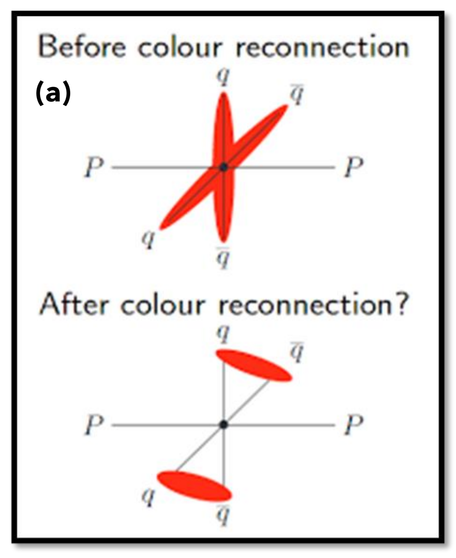
- Decide what to tune?
  - Cross-section
  - Light flavor
  - Color Reconnection
  - MPI
  - Heavy flavor
  - Details: PYTHIA Manual
- Check if we have appropriate plugin:
  - ✓Yes: Start the Procedure
  - ×No: if LHCb measurements are there are they in HepData
    - ✓Yes: Make the plugin
    - ×No: Use the HepDataExtractor to do so and make them public
- Find out the tuning parameters and the boundary conditions from PYTHIA manual.
- Prepare the PROFESSOR parameters with the LHCb wrapper.
- Submit the tuning jobs via LbMCSubmit.
- Look at the results and analyse the best tuning ….

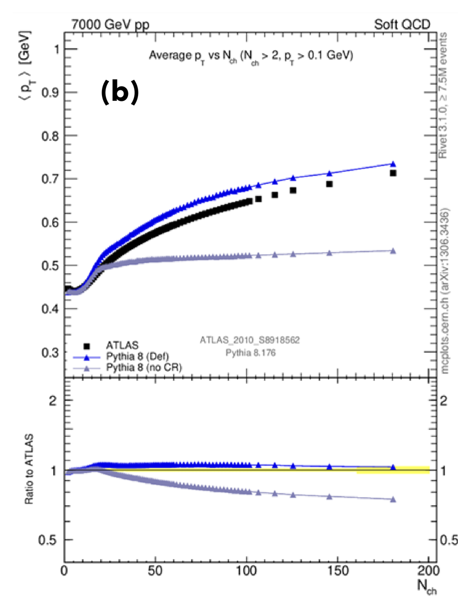
Colour Reconnection Schemes



- Color reconnection addresses the problem of how the color fields rearrange themselves during the parton showers.
- Monte Carlo event generators (e.g. PYTHIA 8) have various model to implement such arrangements:
  - MPI based scheme
  - QCD inspired scheme
  - Gluon move scheme
- The aim of all these schemes is to reduce the total string length of the partonic configuration before the hadronization process.

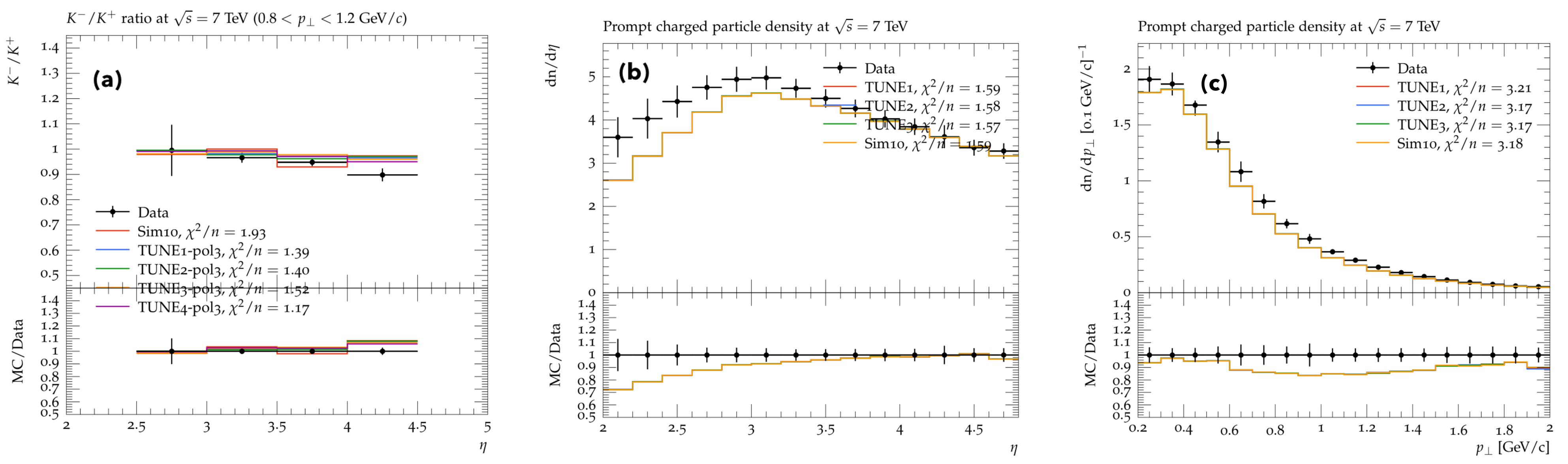
Different color reconnection schemes within the color reconnection model. (a) the rapidity of ϕ −mesons with the GM scheme depicting the least χ^2 values [Phys.Lett.B703:267-273,2011]. (b) the hadron production ratios with respect to p_T with GM scheme showing the least χ^2 values [JHEP08(2011)034].





(a) The changings in the pairing before and after color reconnection scheme.
(b) The rise of average transverse momentum as a function of number of particles with and without the color reconnection scheme. Source: mcplots.cern.ch

Tuning Campaign at 7 TeV



(a) Ratio of the charged kaons with respect to η with different settings for tuning flavor parameters with the color reconnection model where Tune3 has a better agreement with data [Eur. Phys. J. C 72 (2012) 2168]. (b) Prompt charged particle density with respect to η measurements, with different settings of fixing the flavor and tuning the MPI parameters with different weights assigned to plugins where TuneC has a better agreement with the data. (c) Prompt charged particle density with respect to p_T measurements, with different settings of weights plugins where TuneC has a better agreement with the data [Eur. Phys. J. C (2014) 74:2888].

Fluence in LHCb MinBias Data

- Data collected during low-luminosity runs can be used for the determination of fluence with different models for multiparton interaction.
- The fluence of different types of particles can be expressed by the standard neutron equivalence fluence φ_{eq}.

$$\varphi_{eq} = \kappa \int \phi(E)dE \quad where \quad \varphi = \frac{dN}{dt}$$

- The observation of multiparton interactions (MPIs) enforce the tuning of the event generators to the latest experimental results.
- It therefore is interesting to investigate the discrepancies between Monte Carlo simulations, especially in low-transverse momentum particles which have a severe impact on φ_{eq}.
- This region also holds crucial implications for radiation damage.

Conclusions

- LHCb has produced a wide variety of measurements in its unique fiducial volume.
- Work is in progress to tune PYTHIA parameters using many of the LHCb results as reference.
- More LHCb RIVET plugins at higher energies will ensure better tuning.
- Many more results are expected soon, thus providing further references for improved generators tuning.

Outlook

- Future measurements in the light and heavy flavor sectors :
  - ensure better description of flavor production in the forward region.
  - may lead to the development of new fragmentation and hadronization models.
- Exploit new possibility to check different versions (and tunes) of PYTHIA in LHCb nightly builds before building them in production releases.
  - to understand both their physics effect and CPU implications.

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