Generator Tuning at LHCb

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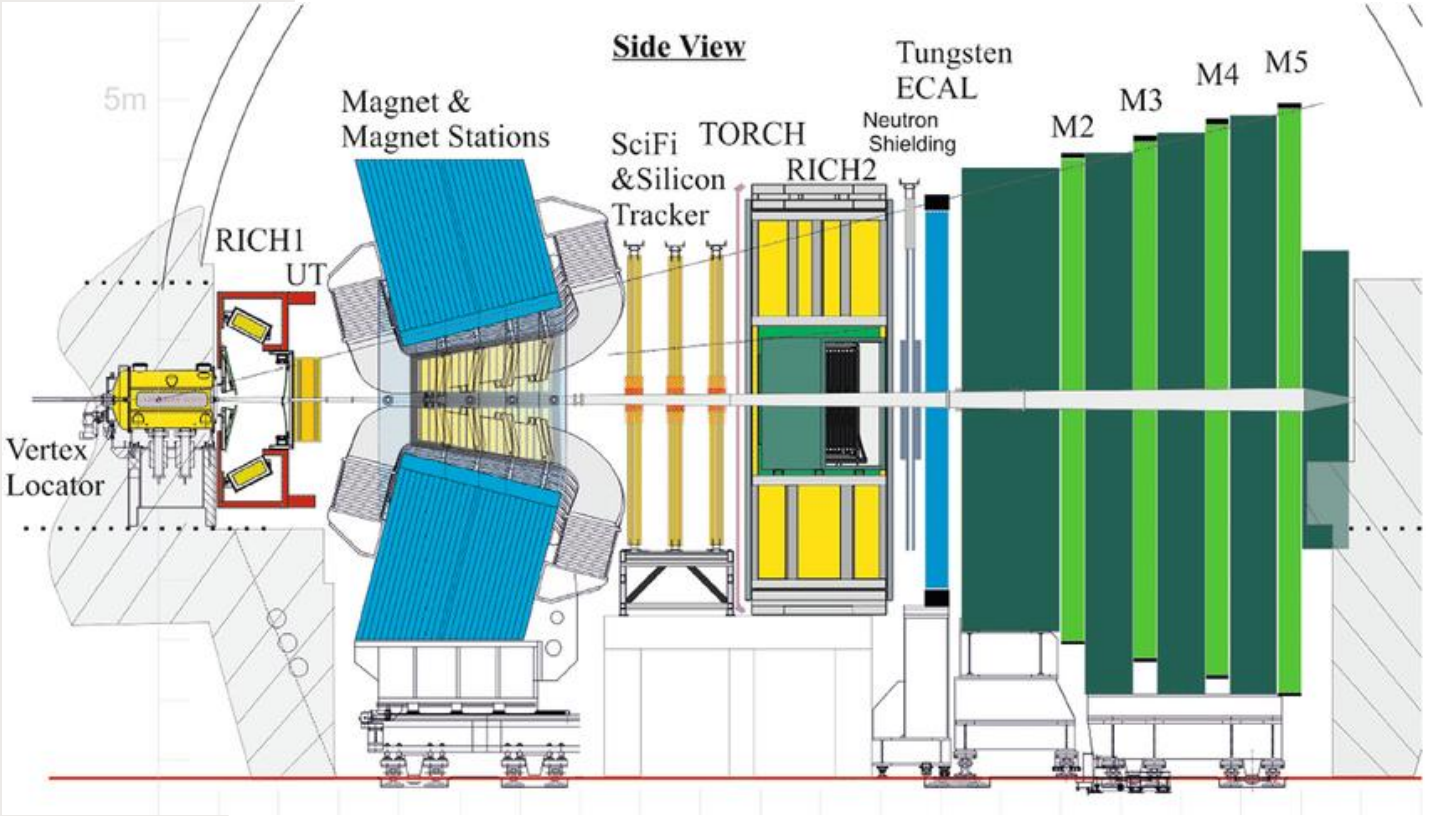
Outline

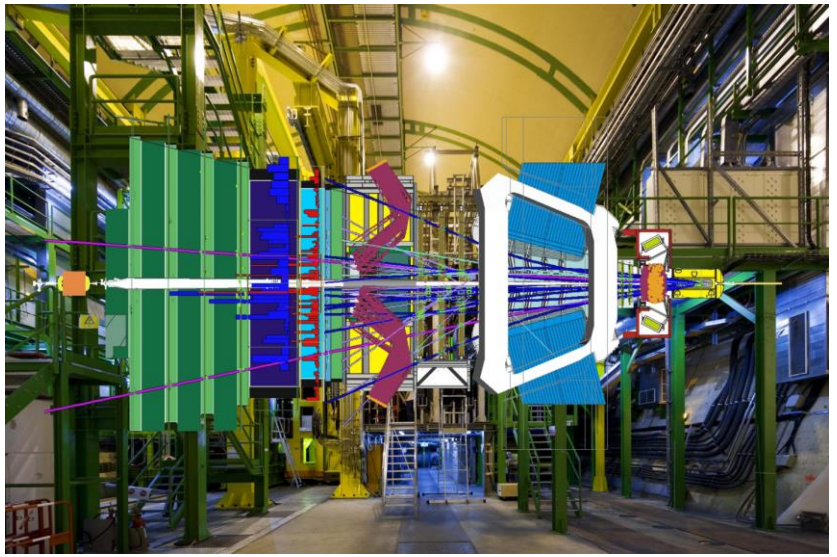
- LHCb in a nutshell
- LHCb strategy for tuning
- Tuning infrastructure and framework
- Current tuning effort
- Other parameters to tune
- Checks with EvtGen
- Conclusion



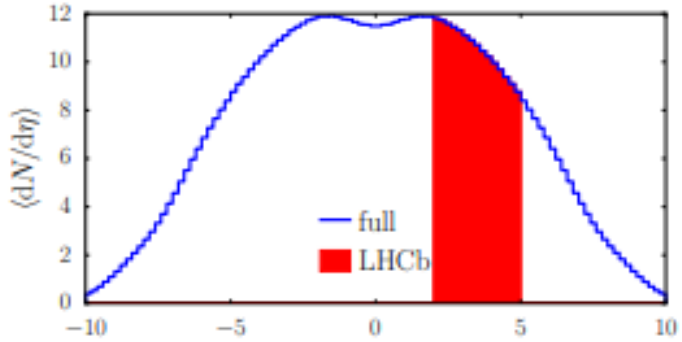
LHCb in a nutshell

For most of the MC sample use Pythia8 w EvtGen for decays

Fully Instrumented single-arm spectrometer
Unique pseudorapidity range
- Forward: $2 < \eta < 5$

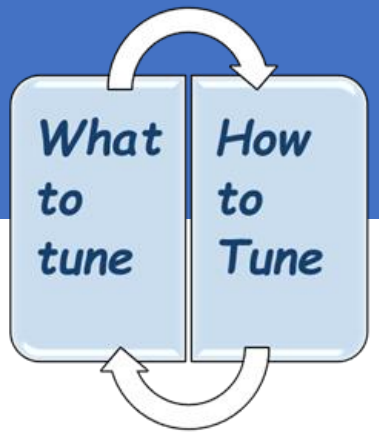


LHCb physics focus are unique:
- Optimized for the study of heavy flavour decays
- Often central detector tunes do not constrain forward region much.
- Almost all Monte Carlo comes from minbias generation.
- Also, Heavy ion collision (pAr, pO, pNe, pPb, PbPb)



We're a forward detector!!!

What to tune and how to tune?



Start from Pythia version 8.244 (Tune 4C)

- Hard process matrix elements – NO, but precise measurements may provide new/better values.
- Hadronisation – many parameters for flavor selection including b and c fragmentation functions, some for kinematics.
- Multiple Parton Interactions (MPI) – last before completing a tune to give as strict boundaries as possible.
- Showers – very sensitive in some generators. Optimize cut-off scale and coupling constant(s).

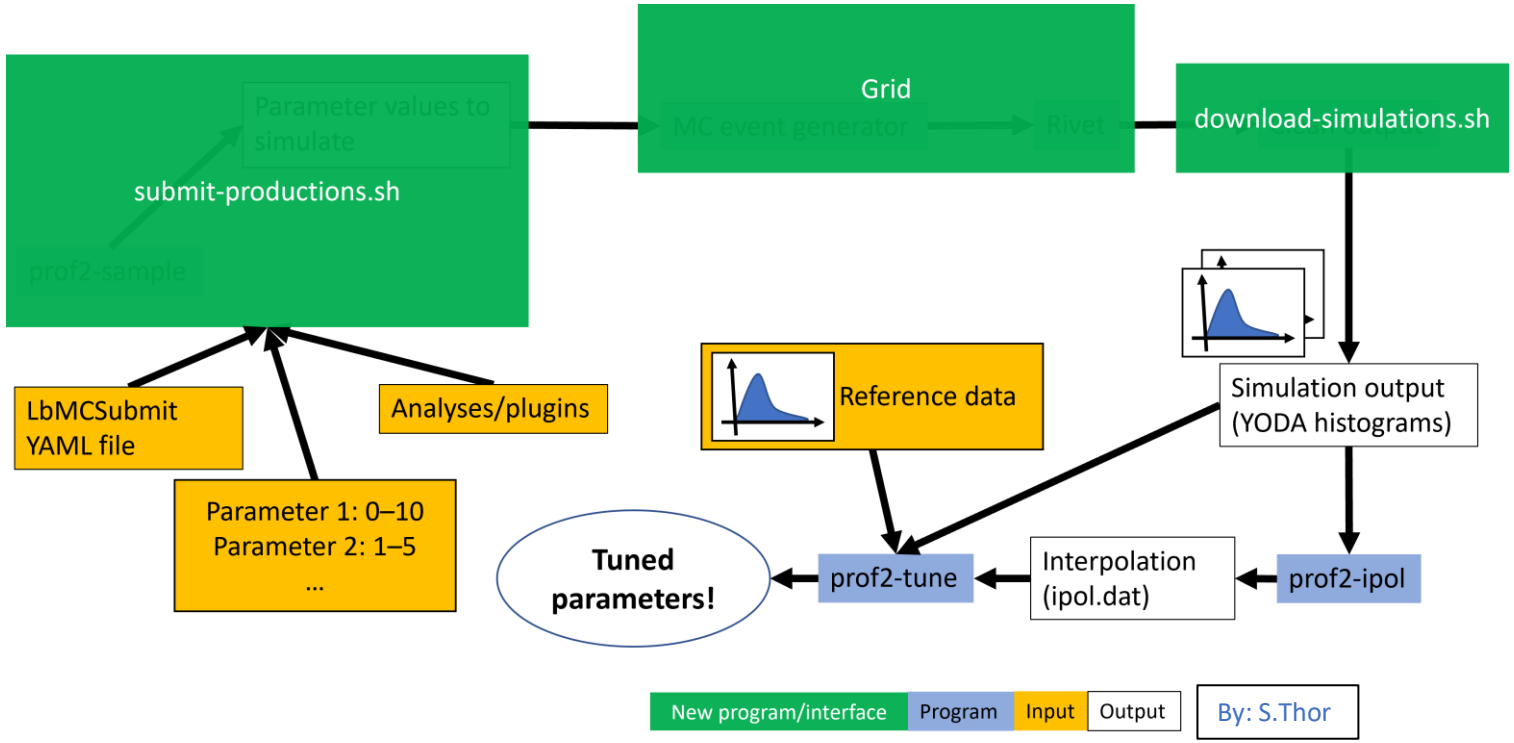
LHCb Strategy for Tuning

- Preliminary tune of light flavour production with new CR scheme.
  - Freeze a set of StringFlav parameters and use it as input for a tune of the new CR model.
  - Freeze a set of CR parameters for each model and use it as input for a tune of the Flavor parameters.
- Tune the MPI models and choose best result.
- Use it to explore the flavor, CR and MPI parameters ignored so far.
- Hope for a quick convergence if not repeat the measurements.
- Make sure the models we left behind were really worse.
- Continue exploring the possibility of tuning many parameters at the same time.

- Limited by available measurements: use as many compatible sets as possible from different experiments at multiple energies; weight the plugins based on which data is to be described.
- Keep in mind tunes in central region may not be best for forward region and vice versa.

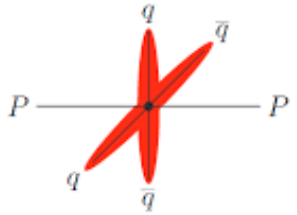
Tuning infrastructure and framework

- Infrastructure for tuning to run on the grid
- Wrapper to prepare options from parameters (Professor).
- Compatible with running plugin (Rivet) within the LHCb simulation framework (Gauss) and submit jobs on the GRID (LbMCSubmit).
- Rivet version 3.1.6
- Professor version 2.3.3

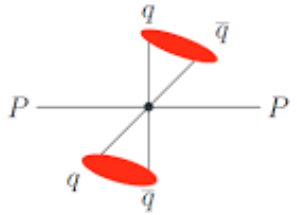


Current Tuning Efforts for Light Flavor Production

Before colour reconnection

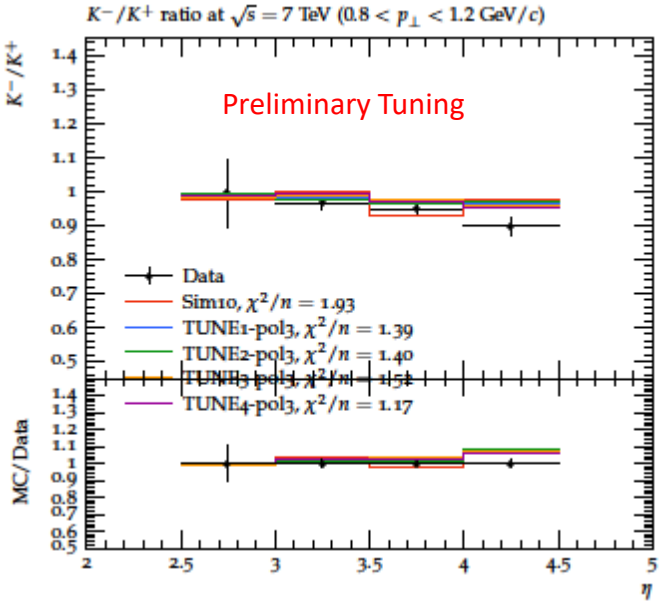


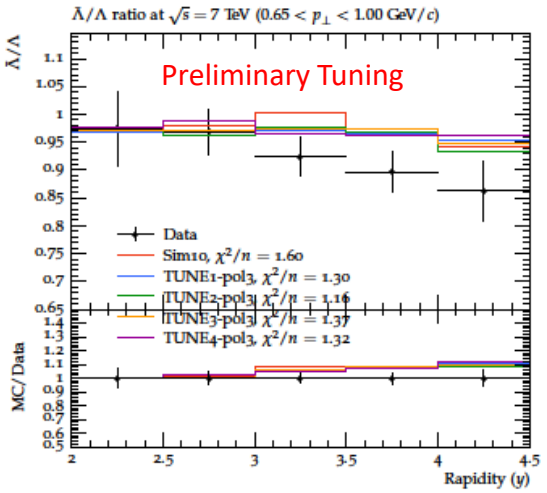
After colour reconnection?

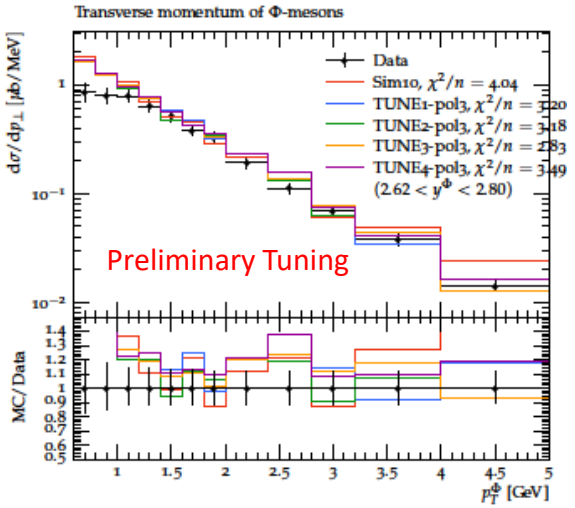


- Colour reconnection allows us to reshuffle the colours before hadronization
- Experimentally observed in average p⊥ vs multiplicity

Sim10: Tune used in current production
TUNE1: only flavor parameters tuning
TUNE2: only CR parameters tuning
TUNE3: fix CR and tune flavor
TUNE4: fix flavor and tune CR







LHCb Experimental Input to Generator Tuning

- Several production and production ratios measurements by LHCb at 7 TeV:
- V^0 : LHCB_2011_I917009p1
- Φ: LHCB_2011_I919315p1
- Prompt hadron production ratios: LHCB_2012_I1119400p2

⚠ Tuning work in progress

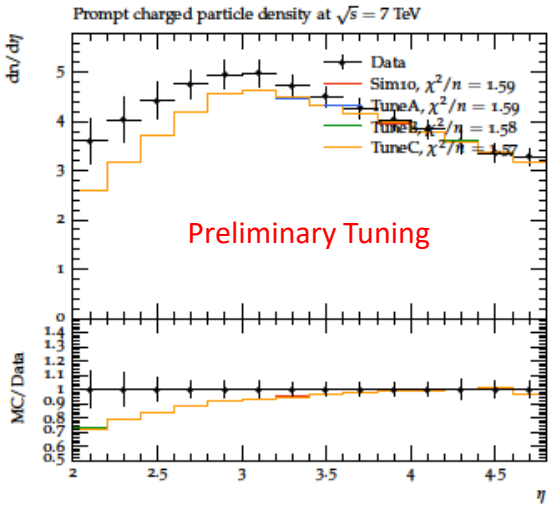
Current Tuning Efforts for Multiplicity

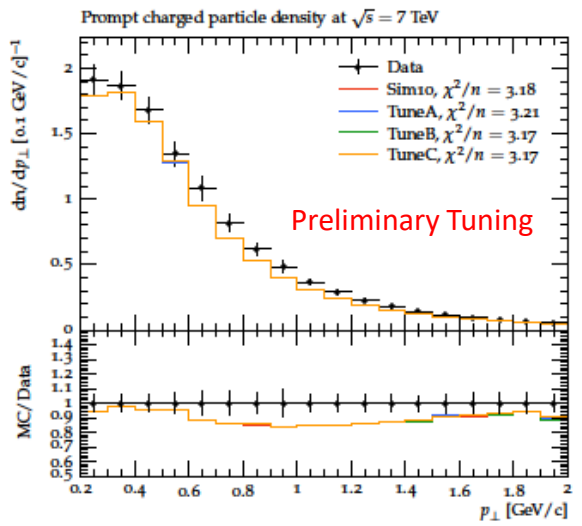
- Multiplicity and energy flow measurements by LHCb at 7 TeV:
  - LHCB_2014_I1281685
  - LHCB_2013_I1208105
- Track based minimum bias measurements at 7 TeV
  - ATLAS_2010_S8918562
- Underlying event in forward rapidity at 7 TeV
  - CMS_2011_S8978280

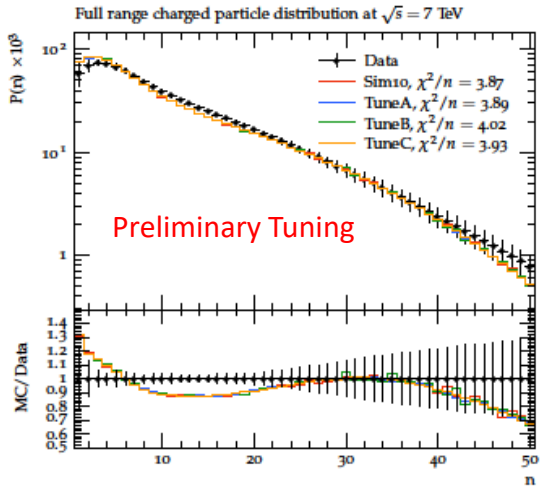
Comparison with different jobs (1 million events)

Sim10: Tune used in current production
TuneA: Measurements with same weights.
TuneB: Measurements with different weights (LHCb is favored)
TuneC: Only LHCb measurements

- None of the settings can fully describe data distribution.
- TuneC has a better agreement with the data.





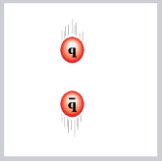


Tuning work in progress

Other Parameters Important to tune

Prompt c-hadrons: D^0 , D^+, D_s, D^{*+}, Λ_c

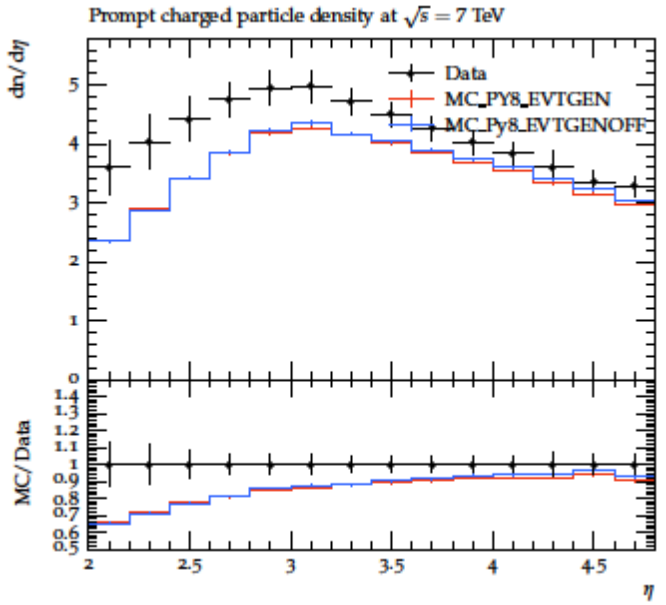
b-hadrons: $B^0, B^{\pm}, B_s^0$

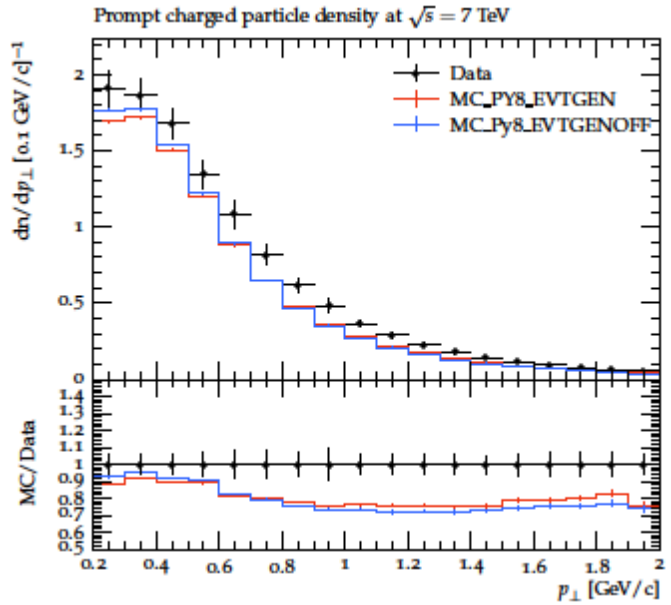


Quarkonia production: J/ψ , ϒ(nS)

Pythia + EvtGen

- Comparison is made to check if the tune changes when using Pythia only or Pythia w EvtGen for the decays
- Because we use Pythia + EvtGen together.





Conclusion

- LHCb has produced a wide variety of measurements in its unique fiducial volume.
- Work has already started to tune Pythia parameters using many of the LHCb results as reference, particularly in the description of light flavour production and particles multiplicity.
- Future measurements in the light and heavy flavor sectors – ensure better description of flavor production in the forward region.
- LHCb heavy flavour results will also provide valuable input in the optimization of the current and the development of new fragmentation and hadronization models.
- Many more results are expected in the near future, thus providing further references for improved generators tuning.

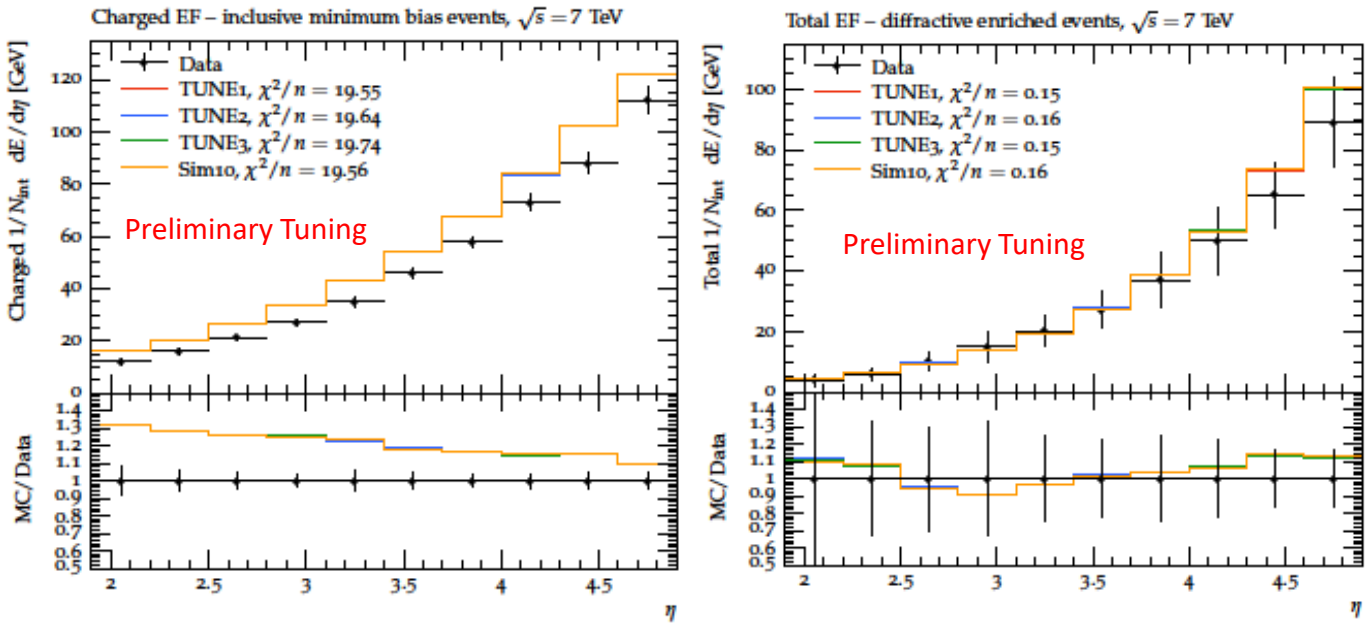

THANK YOU

Back-up

History of Tuning in LHCb

Current Tuning Efforts for Energy Flow

- Charged (and neutral) energy flow test the soft component of a collision (MPI).
- The simulation jobs are submitted for 1 million events with the similar settings of TUNES.
- The settings for charged EF, inclusive MB events overestimates the data.
- The settings for total EF, diffractive events, all the tunes are closer to the current settings of tune at LHCb. These TUNES are within about 0.2 χ^2 deviation from the observed data.



Tuning work in progress

Tune 4C

- "Tune 4C", newer tune, introduced with 8.145
- Starts out from tune 2C, but with a reduced cross section for diffraction, plus modified multiparton interactions parameters to give a higher and more rapidly increasing charged pseudorapidity plateau, for better agreement with some early key LHC numbers.
- The starting point for many later tunes.

Pythia8 4C - MB+UE tune with CTEQ6L1

Parameter	Tune 2C	Tune 2M	Tune 4C
SigmaProcess:alphaSvalue	0.135	0.1265	0.135
SpaceShower:rapidityOrder	on	on	on
SpaceShower:alphaSvalue	0.137	0.130	0.137
SpaceShower:pT0Ref	2.0	2.0	2.0
MultipleInteractions:alphaSvalue	0.135	0.127	0.135
MultipleInteractions:pT0Ref	2.320	2.455	2.085
MultipleInteractions:ecmPow	0.21	0.26	0.19
MultipleInteractions:bProfile	3	3	3
MultipleInteractions:expPow	1.60	1.15	2.00
BeamRemnants:reconnectRange	3.0	3.0	1.5
SigmaDiffractive:dampen	off	off	on
SigmaDiffractive:maxXB	N/A	N/A	65
SigmaDiffractive:maxAX	N/A	N/A	65
SigmaDiffractive:maxXX	N/A	N/A	65

https://arxiv.org/pdf/1011.1759.pdf