

# Generator Tuning w/ Professor/RIVET at LHCb. Status of PYTHIA8 Optimization

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\*W. Bonivento, M. Adinolfi, A.T. Greco, but the list is always open

- ▶ Professor and RIVET in LHCb
- ▶ LHCb Tuning Software Status
- ▶ Preliminary studies for PYTHIA8
- ▶ Conclusions

- ▶ **PRO**cedure **F**or **EST**imating **S**ystematic **errORs**  
project @ HepForge
- ▶ Tuning tool for Monte Carlo event generators  
time  $\sim \exp(N) \rightarrow N^n$ ,  $N$  nb. of parameters
- ▶ Minimize a goodness-of-the-fit function between generated and reference data constructed for a specific parametrisation of MC generator response to the steering params for each observable bin.
  1. Randomly sample parameter “hypercube” ( $N$ -dimensional);
  2. Create observable histograms for each parameter point.  
Use RIVET, but “any source of comparable histogram data is a valid input”;
  3. Fit polynomial interpolation to each observable bin value set;
  4. Construct a  $\chi^2$  and minimize it numerically.

- ▶ Robust Independent Validation of Experiment and Theory
- ▶ project @ HepForge
- ▶ Toolkit for MC event generator validation and tuning, analysis prototyping, MC-data comparison
- ▶ Generator agnostic - expects events in HepMC format
- ▶ Growing library of easy to develop analysis modules (plugins). Plugins mimic data analysis cuts, phases-space, binning – reproduce observable distributions similar to measurement.
- ▶ Filter particles of interest, compute and cache observables to be used by suites of analysis modules

# RIVET in a LHCb Nutshell

Experimentalist  
Community

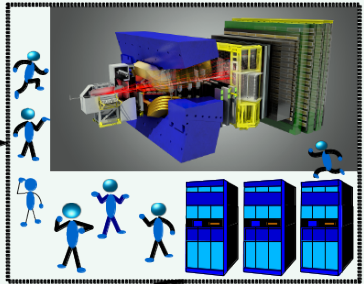
Theoretical Models



Theoretician  
Community

(New)  
MC Generators

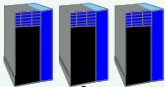
MC Generator  
Tunes



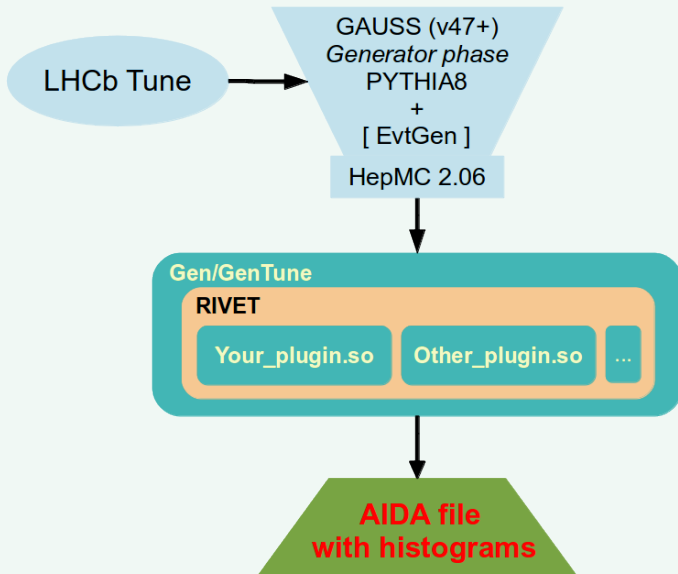
Exp. Data  
Analysis  
Results

Gen/  
GenTune

**RIVET**



# RIVET wrapping @ LHCb



- Generators in LHCb integrated in GAUSS (Pythia6, Pythia8, Herwig++, ...) - uniform control interface
- Tune GAUSS based on **PYTHIA8** + [ EvtGen ](mainly heavy flavour decays – PHOTOS,TAUOLA)
- Professor, RIVET and most generators provided by CERN software group
- Stick to RIVET 1.9.0 for this tuning campaign
- Gauss-RIVET interface ready for production
- Benefit from vast CPU resources available in LHCb distributed computing
- Need large statistics; estimate order of 10k jobs per hypercube

# LHCb RIVET (1.x) plug-ins

Title	LHCb no.	Plugin	HepData	Rivet
Prompt $K_s^0$ production in pp collisions at $\sqrt{s}=0.9$ TeV	PAPER-2010-001	LHCB_2010_S8758301	yes	1.9.0 2.x
Measurement of $\sigma(pp \rightarrow bbX)$ at $\sqrt{s}=7$ TeV in the forward region	PAPER-2010-002	LHCB_2010_I867355	yes	1.9.0 2.x
Measurement of $V^0$ production ratios in pp collisions at $\sqrt{s} = 0.9$ and 7 TeV	PAPER-2011-005	LHCB_2011_I917009	yes	1.9.0 2.x
Measurement of the inclusive phi cross-section in pp collisions at $\sqrt{s} = 7$ TeV	PAPER-2011-007	LHCB_2011_I919315	yes	1.9.0 2.x
Measurement of prompt hadron production ratios in pp collisions at $\sqrt{s} = 0.9$ and 7 TeV	PAPER-2011-037	LHCB_2012_I1119400	yes	1.9.0 2.x
Prompt charm production in pp collisions at $\sqrt{s} = 7$ TeV	PAPER-2012-041	LHCB_2013_I1218996	yes	1.9.0 2.x
Measurement of the forward energy flow in $pp$ collisions at $\sqrt{s} = 7$ TeV	PAPER-2012-034	LHCB_2013_I1208105	yes	1.9.0 2.x



# New Rivet plug-ins for LHCb

Title	LHCb no.	Plugin	HepData	Rivet
Measurement of charged particle multiplicities and densities in pp collisions at $\sqrt{s}=7$ TeV in the forward region	<a href="#">PAPER-2013-070</a>	LHCB_2014_I1281685	yes	<b>1.9.0*</b> <b>2.x*</b>
Measurement of $J/\psi$ production in pp collisions at $\sqrt{s} = 7$ TeV	<a href="#">PAPER-2011-003</a>	LHCB_2011_I891233	yes	no
Measurement of charged multiplicities in pp collisions at $\sqrt{s}=7$ TeV in the forward region	<a href="#">PAPER-2011-011</a>	LHCB_2011_I1082369	yes	no
Measurement of B meson production cross-sections in proton-proton collisions at $\sqrt{s} = 7$ TeV	<a href="#">PAPER-2013-004</a>	LHCB_2013_I1238809	yes	soon**
Measurement of the cross-section for $Z \rightarrow e^+ e^-$ production in pp collisions at $\sqrt{s} = 7$ TeV	<a href="#">PAPER-2012-036</a>	LHCB_2013_I1208102	soon	no
Study of forward Z + jet production in pp collisions at $\sqrt{s}=7$ TeV	<a href="#">PAPER-2013-058</a>	LHCB_2014_I1258496	soon	no
Measurement of the cross-section for $Z \rightarrow \mu^+ \mu^-$ production with $1 \text{ fb}^{-1}$ of pp collisions at $\sqrt{s}=7$ TeV	To be published	LHCB_2014_I1262703	no	no

\* temporarily available at <https://www.hepforge.org/archive/rivet/contrib/>

\*\* to be released with histogram interface compatible to both Rivet 1.x and 2.x

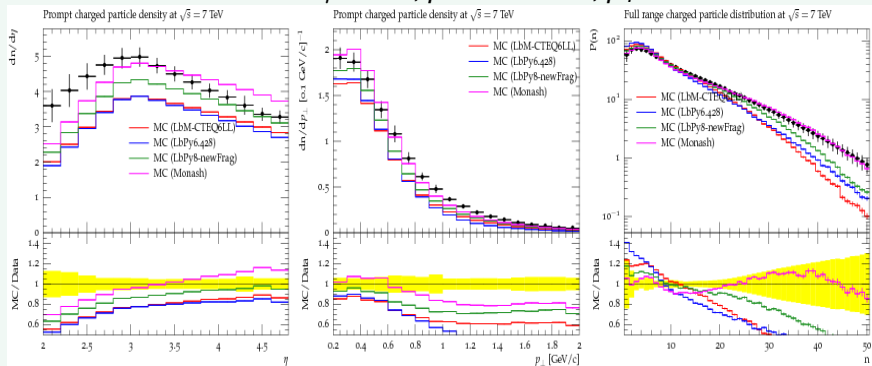
- ▶ Choose compatible plugins for LHC central region detectors
- ▶ Determine parameters, variation intervals, reference models
- ▶ Tuning steps:
  1. Tune parameters controlling heavy flavour production
  2. Light hadron/strangeness production parameters tuning
  3. Optimization of parameters controlling UE characteristics (energy flow, particle multiplicity and densities, etc.)

Consider the following tunes

- ▶ **LbPy6.428**– Pythia 6.428 w/ default LHCb tunes
- ▶ **Monash**– Monash tune w/ NNPDF 2.3 run through Gauss (EvtGen OFF)
- ▶ **LbM-CTEQ6LL**– Monash tune w/ LHCb specific parameter values using CTEQ6LL PDF (EvtGen ON)
- ▶ **LbPy8-newFrag**– Pythia 8.186 w/ alternative fragmentation model to Lund model

All runs for  $pp$  collisions at  $\sqrt{s} = 7$  TeV, 1M minbias events.

Kinematic cuts:  $2.0 < \eta < 4.8$ ;  $p > 2 \text{ GeV}/c$ ;  $p_T > 0.2 \text{ GeV}/c$

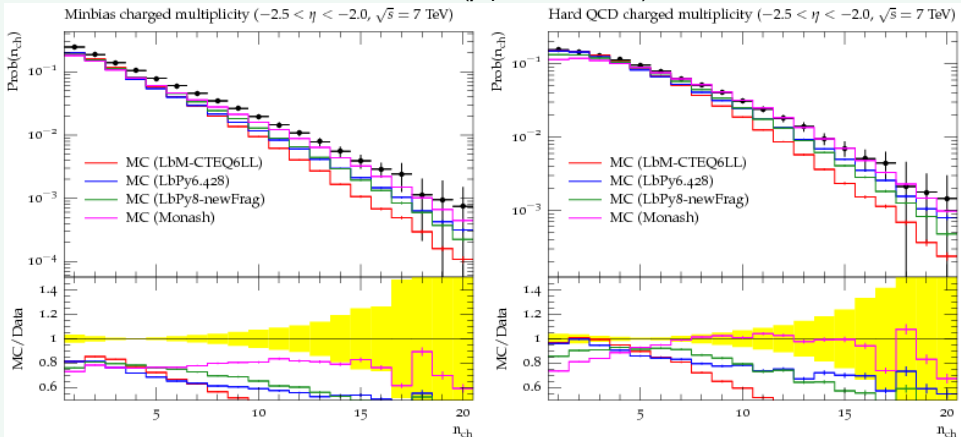


Best description by Monash tune.

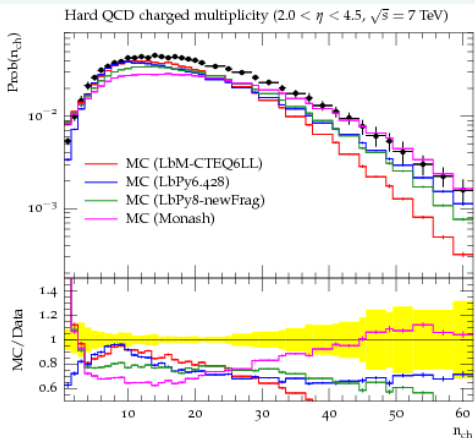
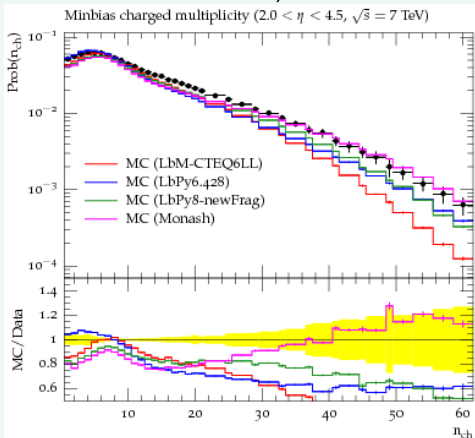
# LHCb Multiplicity - I1082369



Kinematic cuts:  $-2.5 < \eta < -2.0$ ;  $2.0 < \eta < 4.5$ ; Minbias events and Hard QCD events ( $p_T > 1\text{GeV}/c$ )



Best description by Monash tune (Pythia8 included NNPDF2.3 QCD+ LO QED).



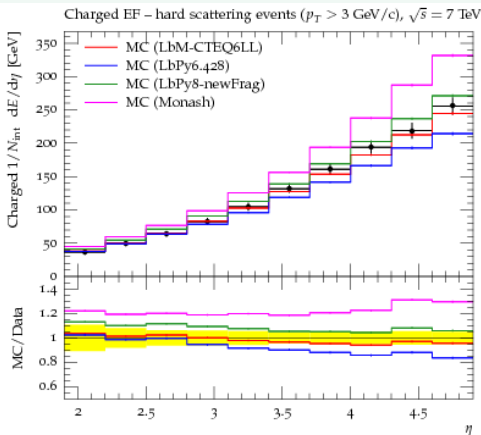
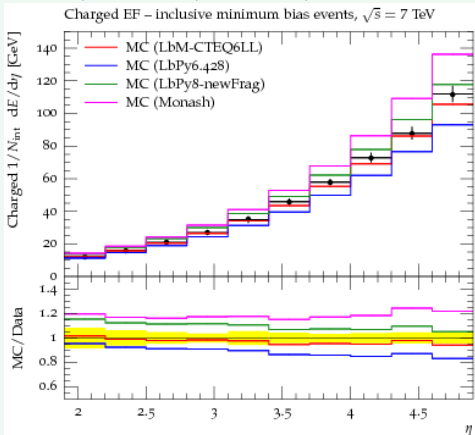
# LHCb Energy Flow - I1208105

Kinematic cuts:  $1.9 < \eta < 4.9$ ; Four event classes:

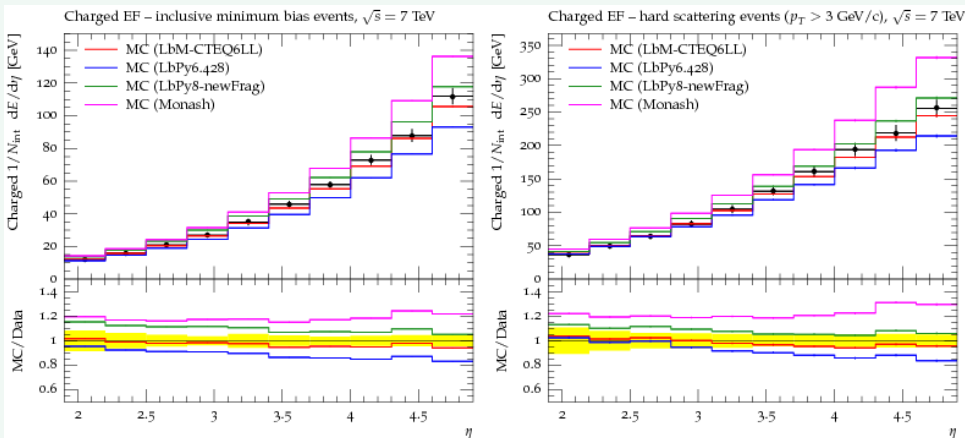
**Inclusive minBias; Hard scattering** –  $p_T > 3 \text{ GeV}/c$ ;

**Diffractive enriched** – no backward tracks ( $-3.5 < \eta < -1.5$ );

**Non-diffractive enriched** – at least one backward track  
( $-3.5 < \eta < -1.5$ )



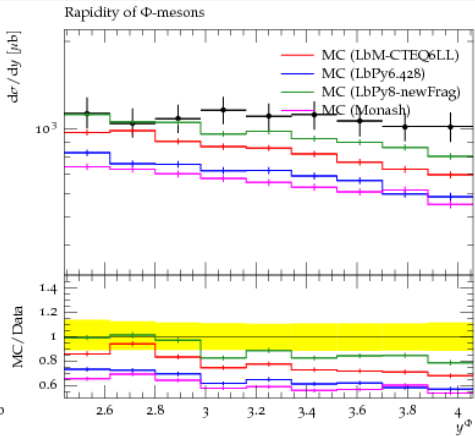
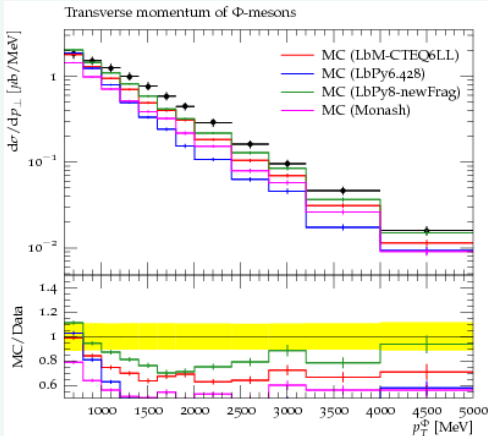
# LHCb Energy Flow - I1208105



Monash overestimates. Best description by Pythia8 w/  
Lund-alternative fragmentation model and Monash w/  
LHCb specific configuration and CTEQ6LL PDF set.

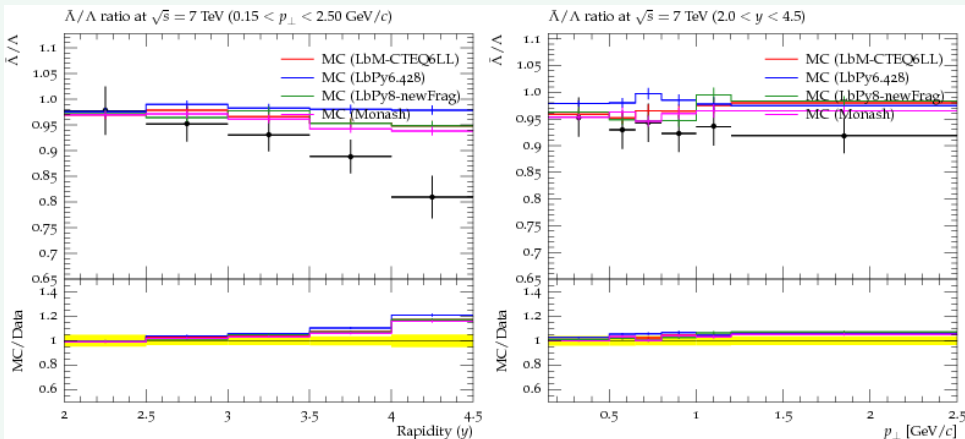


Kinematic cuts:  $0.6 < p_T < 5.0$  GeV/c and  $2.44 < y < 4.06$



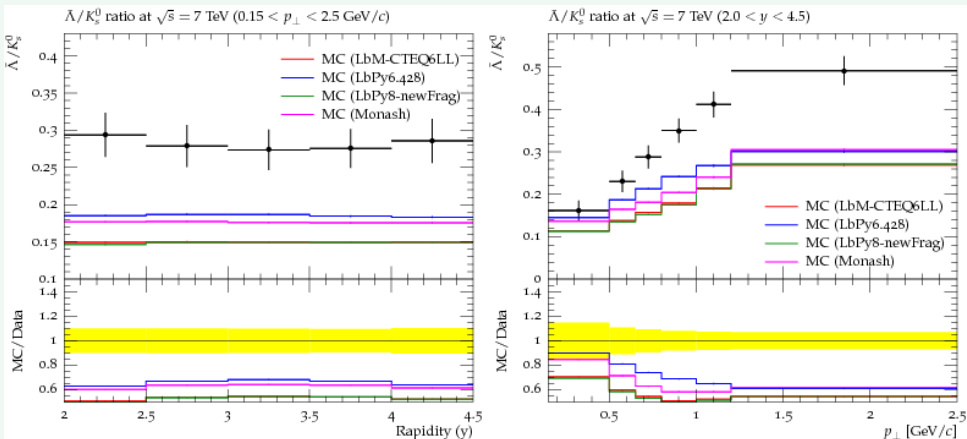
Best description when considering Lund-alternative fragmentation model.

# Prompt $V^0$ Ratios - I917009



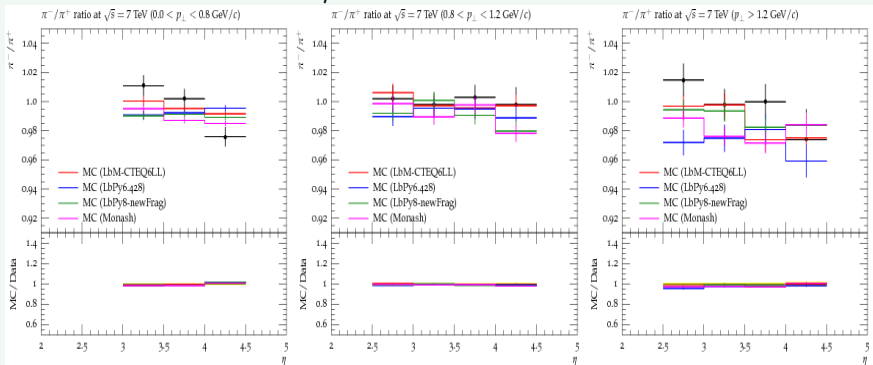
Baryon/anti-baryon overestimated.

# Prompt $V^0$ Ratios - I917009



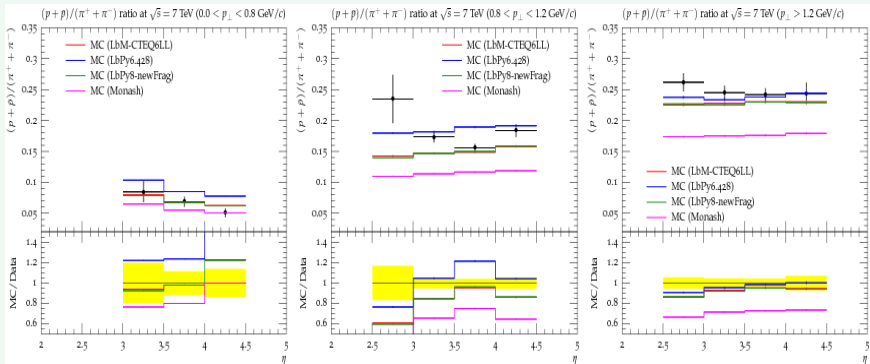
Baryons/Meson is largely underestimated.

Kinematic cuts:  $2.5 < \eta < 4.5$



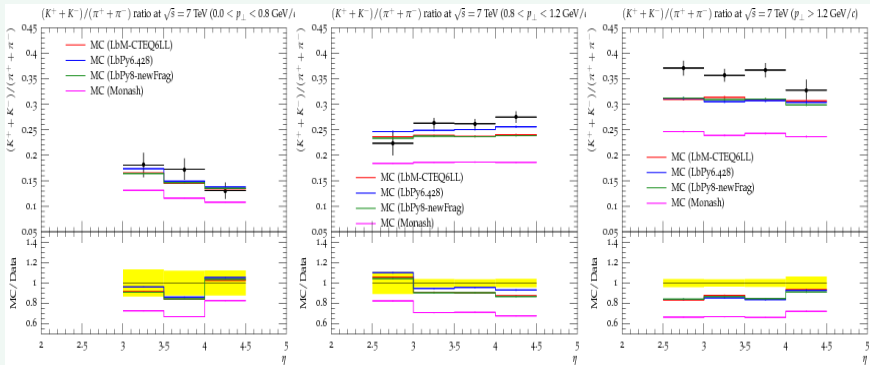
Main source of statistical error for following distributions.

# Prompt Light Hadron Ratios - I1119400



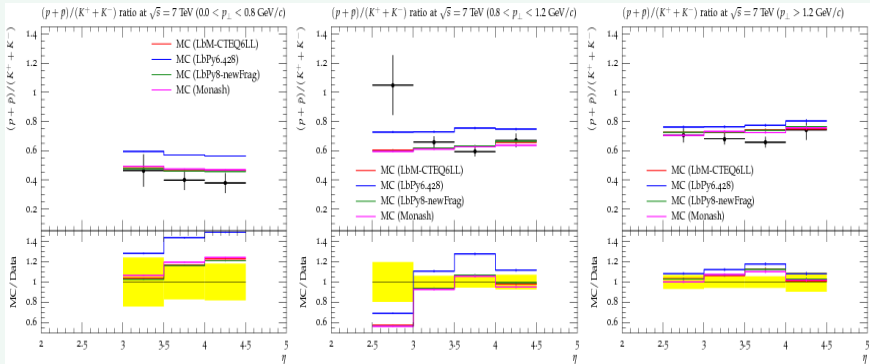
Best description by Lund-alternative frag. model at low  $p_T$ .

# Prompt Light Hadron Ratios - I1119400



Charged strange to light meson ratios are over all underestimated.

# Prompt Light Hadron Ratios - I1119400



All Pythia8 considered configurations seem to describe better the light baryon to strange meson ratios.

- ▶ Software support for tuning - minimally complete, tested also on the GRID (Ganga, Dirac)
- ▶ Technical support available at least for another 18-20 months
- ▶ Number of released RIVET plugins and release speed limited by human resources.  
RIVET suggests analysis proponents should try write the corresponding plugins.
- ▶ Better understand Pythia8 models and behaviour starting from Pythia6 well-known parameters
- ▶ Consider also similar analysis modules from other LHC experiments
- ▶ Forward region measurements → valuable input to future Pythia8 tunes w/ Professor