Tuning Status

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Overview

Intro – for the new people in the room

Updates – what's happened recently

Plans – where we are going

Physics Validation and Global Comparisons

Systematic global validation is essential for testing models or developing general-purpose tunings.

Generator tuning also helps debugging code and models. Short turn-around is important.

We use two toolkits: Rivet and Professor.

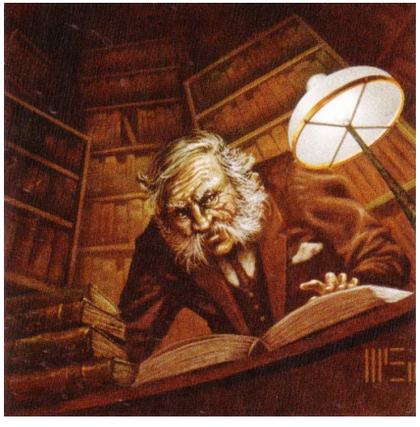
Rivet

Rivet is a library of tools (event shape calculators, jet algorithms, final state definitions, . . .) and so far about 50 analysis routines which use them.

- Can read HepMC events from any generator
- Tools for analysing events, making comparison plots, . . .
- Histograms can be auto-booked from reference data files
- Observables are automatically cached
- User analyses loaded as plugins
- Reference data is included in the Rivet release

Documentation, download etc:
http://projects.hepforge.org/rivet/

Professor



Professor is a tuning tool developed within MCnet, extending the strategy used by Tasso and Delphi.

- Sample N random points in parameter space and run the generator with those settings
- For each bin of each distribution use the N MC runs to fit an interpolation function in order to parametrise the MC output
- Construct overall χ^2 comparing this parametrisation with data and minimise
- Use different combinations of observables, weights etc. to get a feeling for stability, systematics ...

http://projects.hepforge.org/professor/

Pythia 6

- Done and published.
- Results are already being used by various experiments.
- For details and plots: See previous talks and the paper.
- Several studies using different PDFs, developing Professor, convincing ATLAS, . . .

Eur. Phys. J. C (2010) 65: 331–357
DOI 10.1140/epjc/s10052-009-1196-7

THE EUROPEAN PHYSICAL JOURNAL C

Special Article - Tools for Experiment and Theory

Systematic event generator tuning for the LHC

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Received: 17 July 2009 / Revised: 1 October 2009 / Published online: 20 November 2009

Abstract In this article we describe Professor, a new program for tuning model parameters of Monte Carlo event generators to experimental data by parameterising the per-bin generator response to parameter variations and numerically optimising the parameterised behaviour. Simulated experimental analysis data is obtained using the Rivet analysis toolkit. This paper presents the Professor procedure and implementation, illustrated with the application of the method to tunes of the Pythia 6 event generator to data from the LEP/SLD and Tevatron experiments. These tunes are substantial improvements on existing standard choices, and are recommended as base tunes for LHC experiments, to be themselves systematically improved upon when early LHC data is available.

1 Introduction

It is an inevitable consequence of the physics approximations in Monte Carlo event generators that there will be a number of relatively free parameters which must be adjusted if the generator is to describe experimental data. Such parameters may be found in most aspects of generator codes, from the perturbative parton cascade to the non-perturbative hadronisation models, and on the boundaries between such components. Since non-perturbative physics models are by necessity deeply phenomenological, they typically account for the majority of generator parameters: typical hadronisation models require parameters to describe e.g. the kinematic distribution of transverse momentum ($p_\perp$) in hadron fragmentation, baryon/meson ratios, strangeness and $\{\eta, \eta'\}$ suppression, and distribution of orbital angular momentum [1–4]. The result is a proliferation of parameters, of which between $\mathcal{O}(10\text{–}30)$ are of particular importance for collider physics simulations.

Apart from rough arguments about their typical scale, these parameters are freely-floating: they must be matched to experimental data for the generator to perform well. Even parameters which appear fixed by experiment, such as Λ_{QCD}, should be treated in generator tuning as having some degree of flexibility since the generator (unlike nature) can only apply them in a fixed-order scheme, albeit augmented with "resummation" of radiation in divergent (particularly soft and collinear) regions of emission phase space. It is also important that the experimental data to which parameters are tuned covers a wide range of physics, to ensure that in fitting one distribution well, others do not suffer unduly. Performing such a tune manually is slow, does not scale well, and cannot be easily adapted to incorporate new results or generator models. In addition, the results are always sub-optimal: a truly good tuning of a generator, which can highlight deficiencies in the physics model as well as provide improved simulations for experimentalists, requires a more systematic approach.

In this paper, we describe the Professor[1] tuning system, which eliminates the problems with manual and brute-force tunings by parameterising a generator's response to parameter shifts on a bin-by-bin basis, a technique introduced by TASSO and later used by ALEPH and DELPHI [5–10]. This parameterisation, unlike a brute-force method, is then amenable to numerical minimisation within a timescale short enough to make explorations of tuning criteria possible. Adding new data or generator models to the system is also relatively simple. We then apply the Professor system to optimisations of the Pythia 6 event generator against e^+e^- event shape and flavour spectrum data from LEP 1 and SLD, and to minimum bias (MB) and underlying event (UE) data from CDF. The resulting tunes (one for each of the two Pythia 6 parton shower/multiple parton interaction (MPI)

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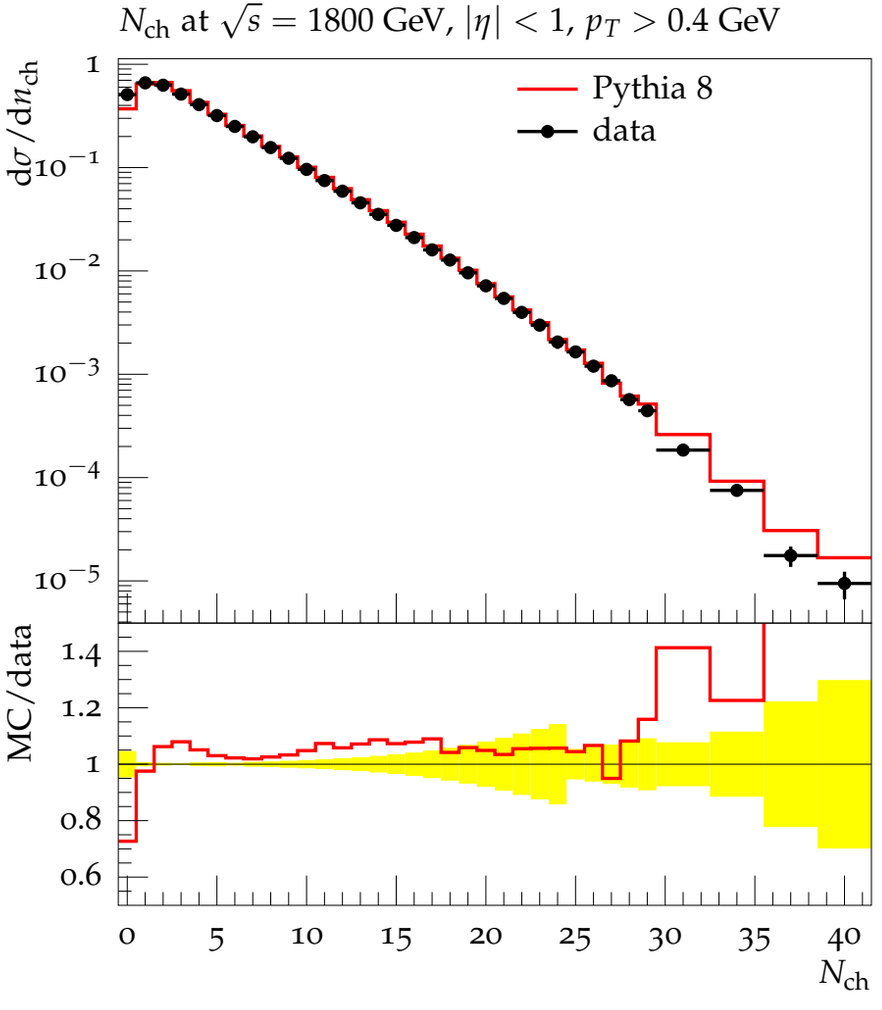
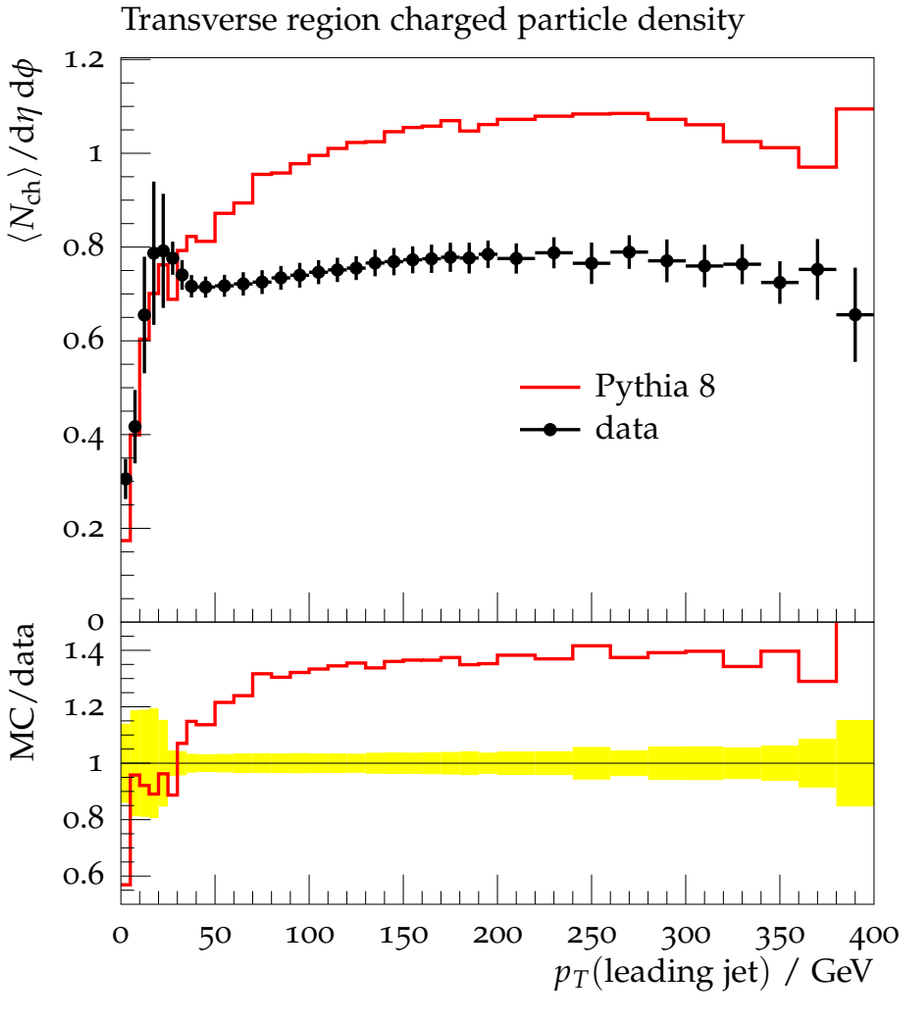
[1] Originally derived from the construction "PROcedure For EStimating Systematic errORs", but aesthetics compel us otherwise.

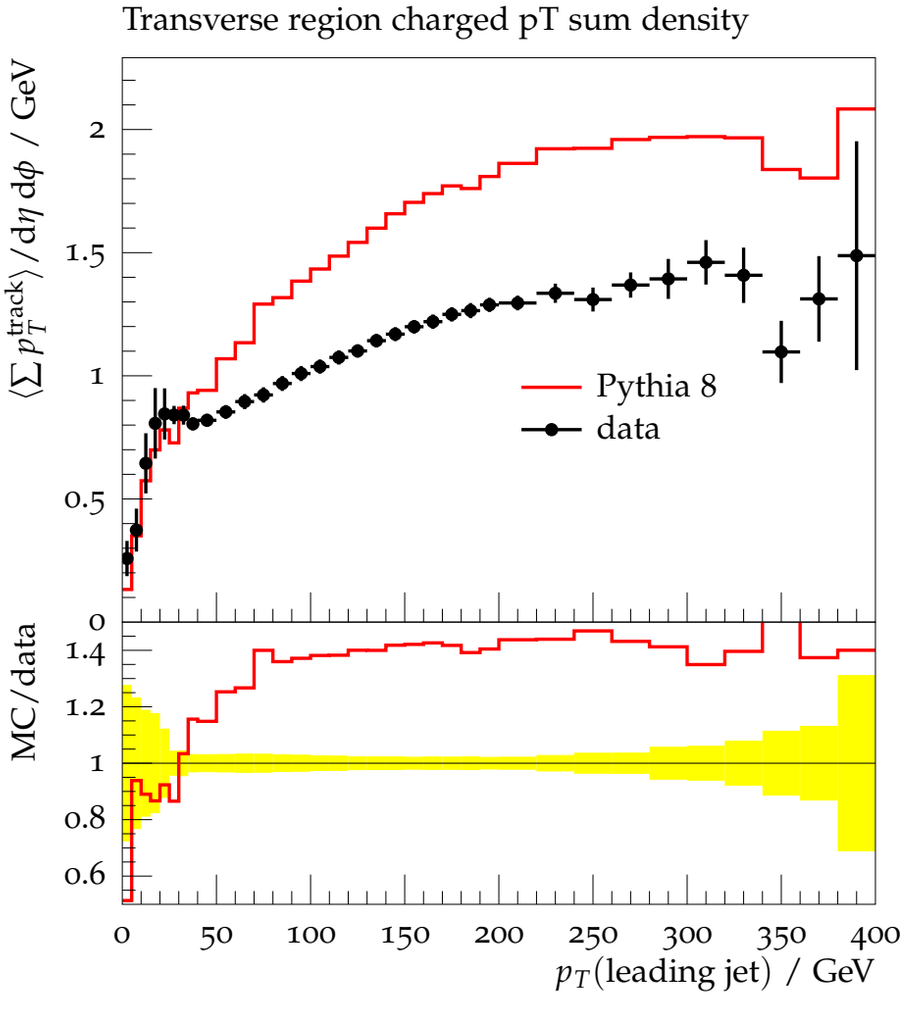
Pythia 8

- Flavour and fragmentation parameters are tuned to e^+e^-. Results are now default.
- UE/MB parameters roughly tuned by Peter Skands, this is currently the default.
- Several tuning attempts showed that Pythia 8 currently is unable to describe the UE in QCD events.
  Under investigation.



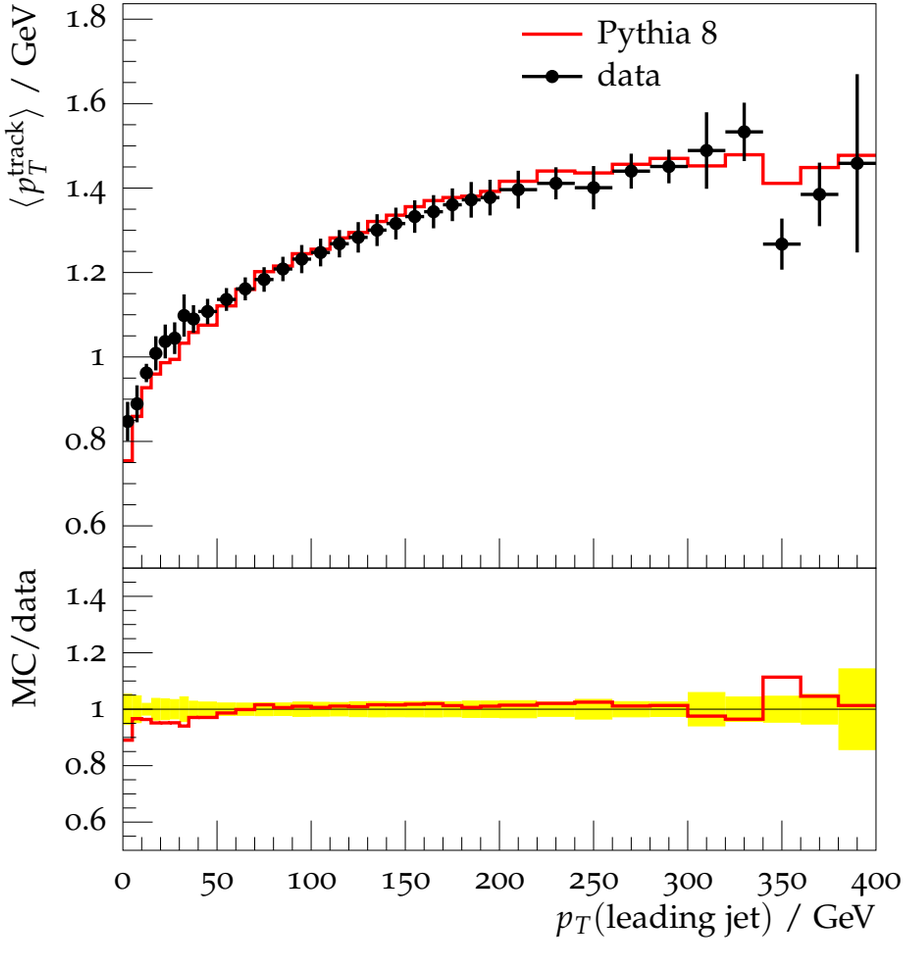
Pythia 8


Transverse region charged particle density
$\langle N_{ch} \rangle / d\eta\, d\phi$
Pythia 8
data
MC/data
p_T(leading jet) / GeV

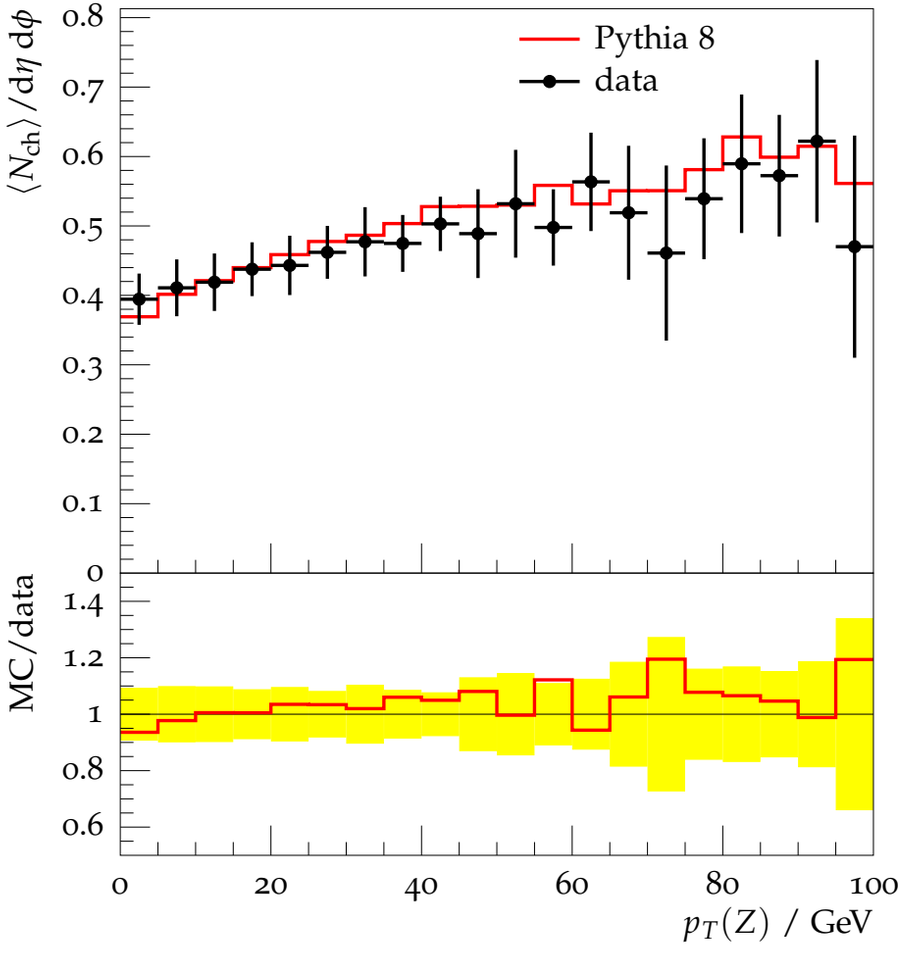

Transverse region charged pT sum density
$\langle \sum p_T^{track} \rangle / d\eta\, d\phi$ / GeV
Pythia 8
data
MC/data
p_T(leading jet) / GeV

Pythia 8

Transverse region charged pT average

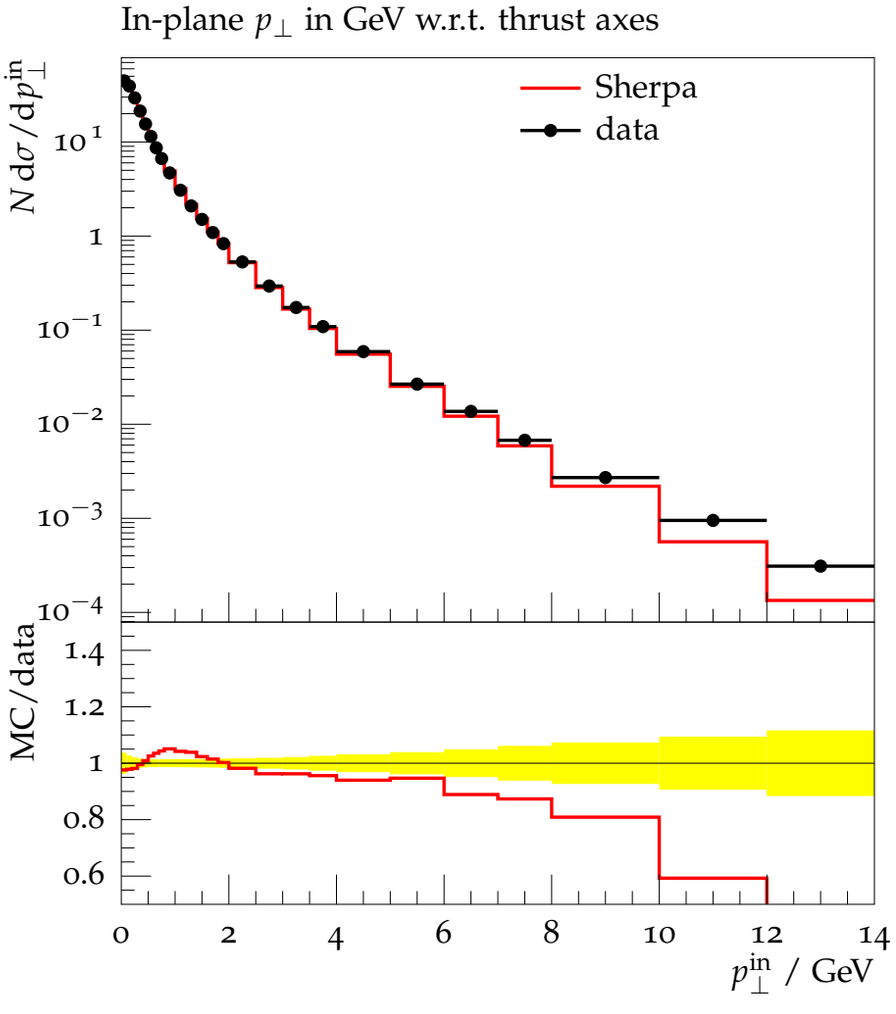


Toward region charged particle density, DY

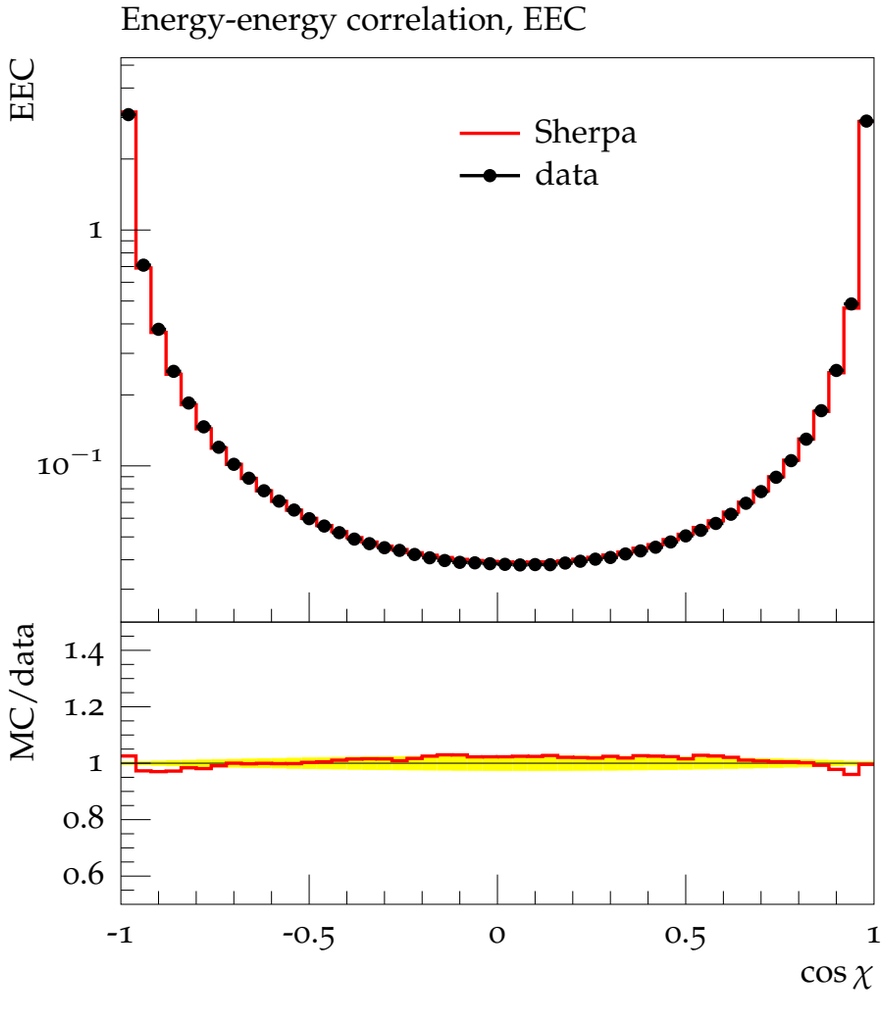


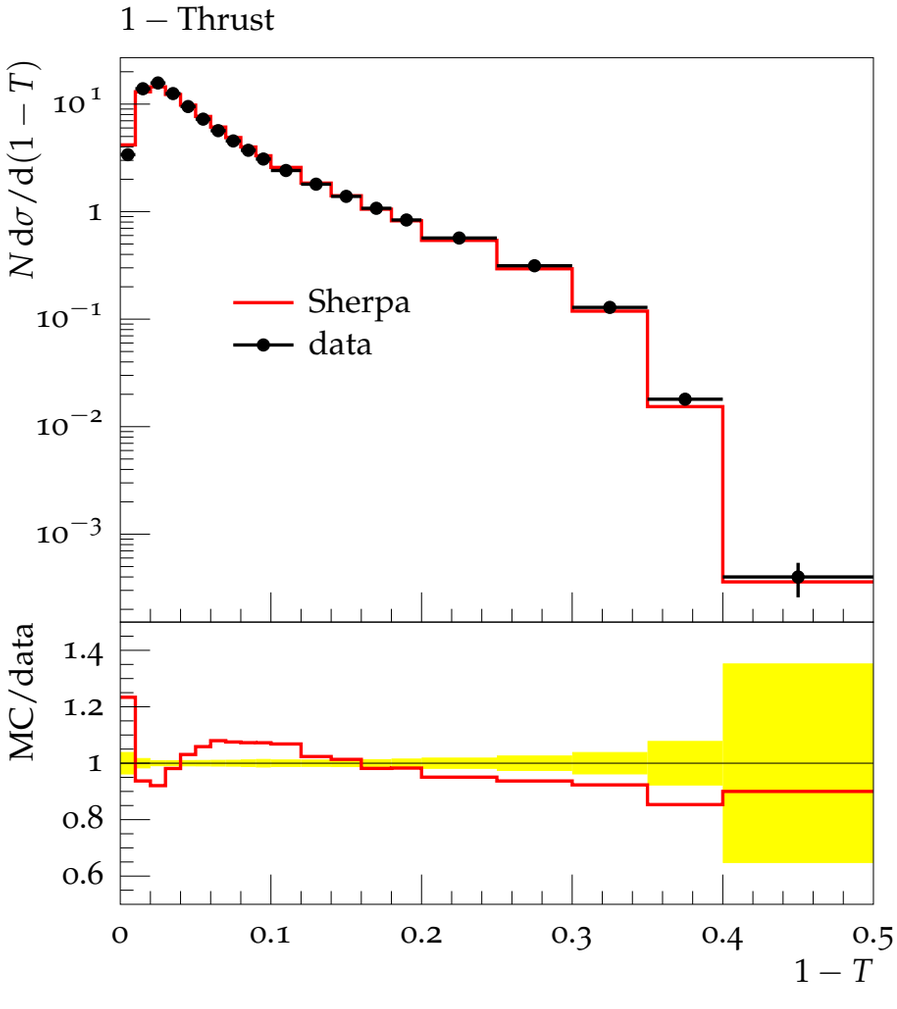
Sherpa

- The e^+e^- part of the tuning is now in relatively good shape (thanks to Eike von Seggern). Hadronisation still needs more work.
- Tuning Sherpa is a highly iterative process. Several bugfixes and model improvements were triggered by the tuning.
- Currently working on soft physics, UE, . . . Hoping to publish this soon.



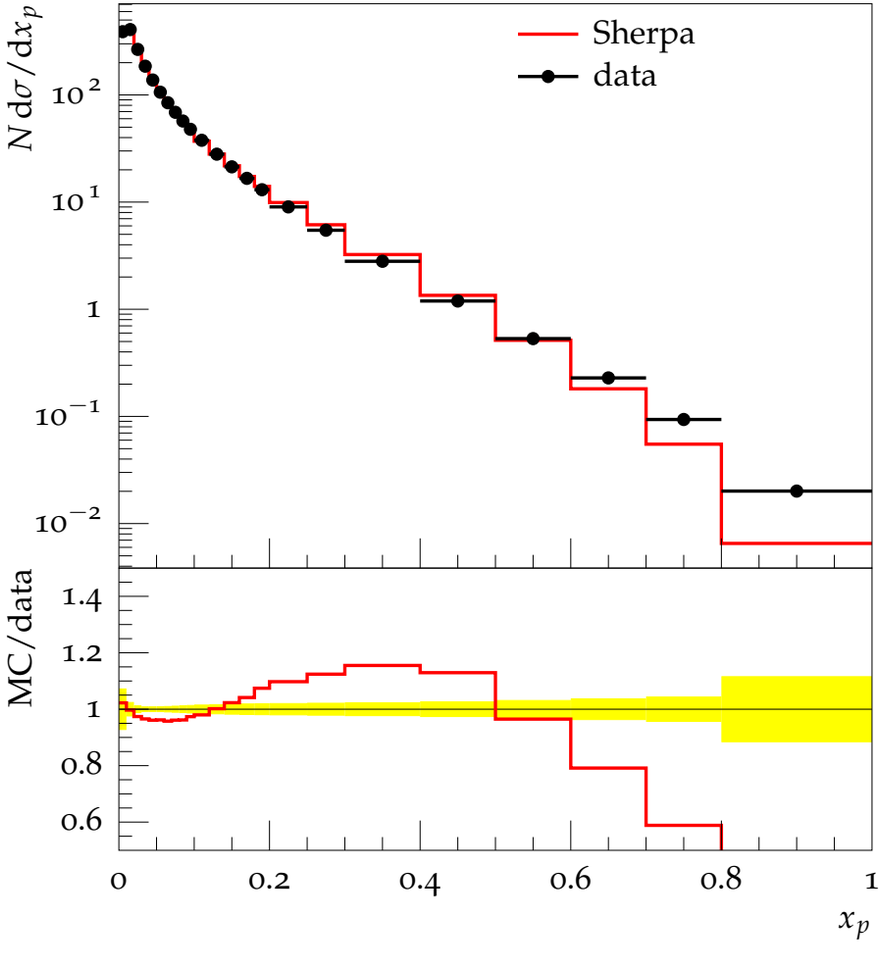
Sherpa


Energy-energy correlation, EEC
EEC
Sherpa
data
1
10^{-1}
MC/data
1.4
1.2
1
0.8
0.6
-1
-0.5
0
0.5
1
$\cos\chi$

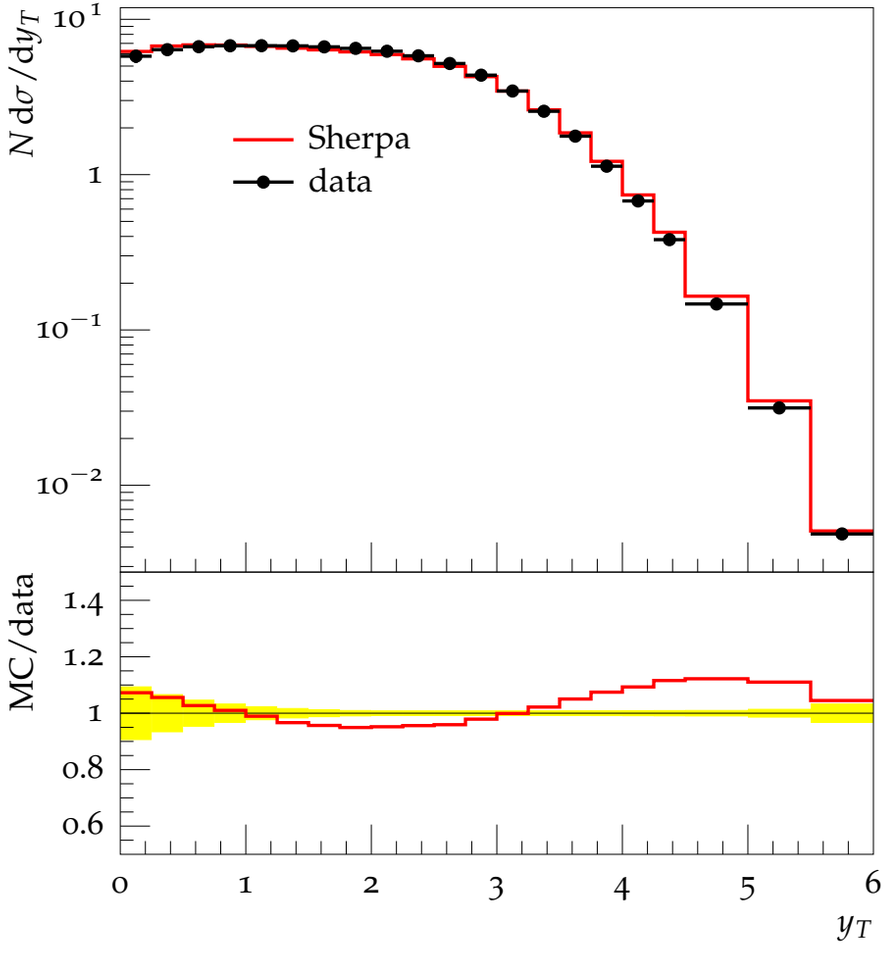

1 – Thrust
$N\,\mathrm{d}\sigma/\mathrm{d}(1-T)$
10^{1}
1
10^{-1}
10^{-2}
10^{-3}
Sherpa
data
MC/data
1.4
1.2
1
0.8
0.6
0
0.1
0.2
0.3
0.4
0.5
$1-T$

Sherpa

Scaled momentum, $x_p = |p|/|p_{\text{beam}}|$



Rapidity w.r.t. thrust axes, y_T



Herwig++

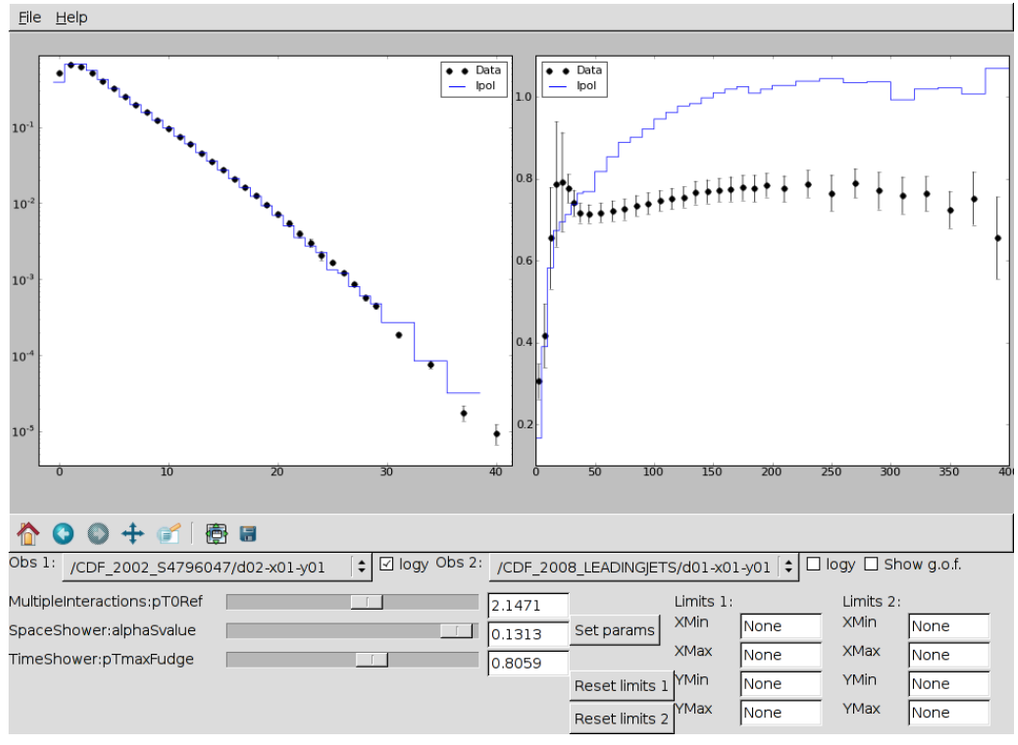
- Brute-force tuning available, doing a good job, so this is not extremely urgent.
- Andy Buckley and Andrzej Siodmok are working on a Professor tune.
- LEP had already been started last year, got buried under other work and needs to be revived. Manpower . . .

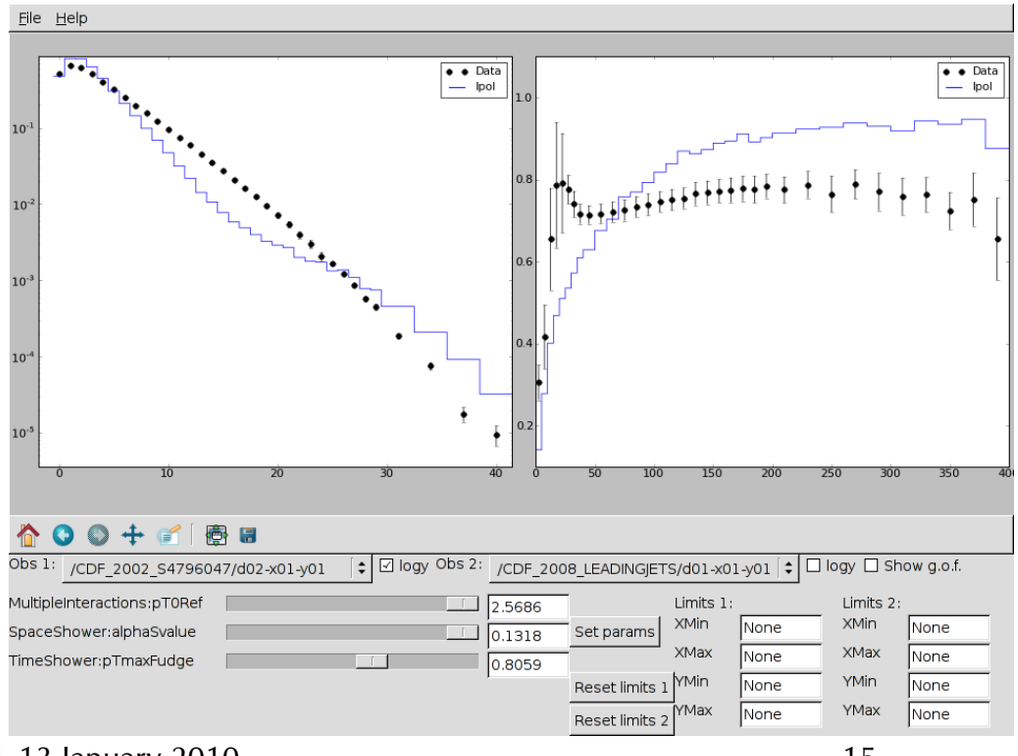
Jimmy

- Tuned using Tevatron data and LO* PDFs (Holger Schulz).
- Simple 2-parameter tune.
- This is mainly a playground for our uncertainty studies (see Holger's talk).

prof-I

- Interactive gui for visualising parameter changes.
- Uses Professor's MC parameterisations, allows manual parameter changes and updates plots in real-time.
- Extremely useful for getting a feeling for parameters, or checking if an observable can be described at all.





Usage in Experiments

- Tunings based on Professor results are being used at LHC, Tevatron, and RHIC.
- Professor is now a validated tool in ATLAS.
- Frank Siegert works on making Rivet/Professor suitable for early data tunes in ATLAS.
- CMS plans to use Professor for private tunes to early data.
- DØ has started Alpgen + Pythia studies using Rivet/Professor.

Outlook

- Uncertainty estimations are well on their way to publication (see Holger's talk).
- Push the Sherpa tuning – currently good progess.
- Revive the Herwig++ tuning.
- Debug the Pythia 8 UE issue – urgent, as experiments want to use it.
- User support, so that the experiments can use Rivet/Professor themselves.