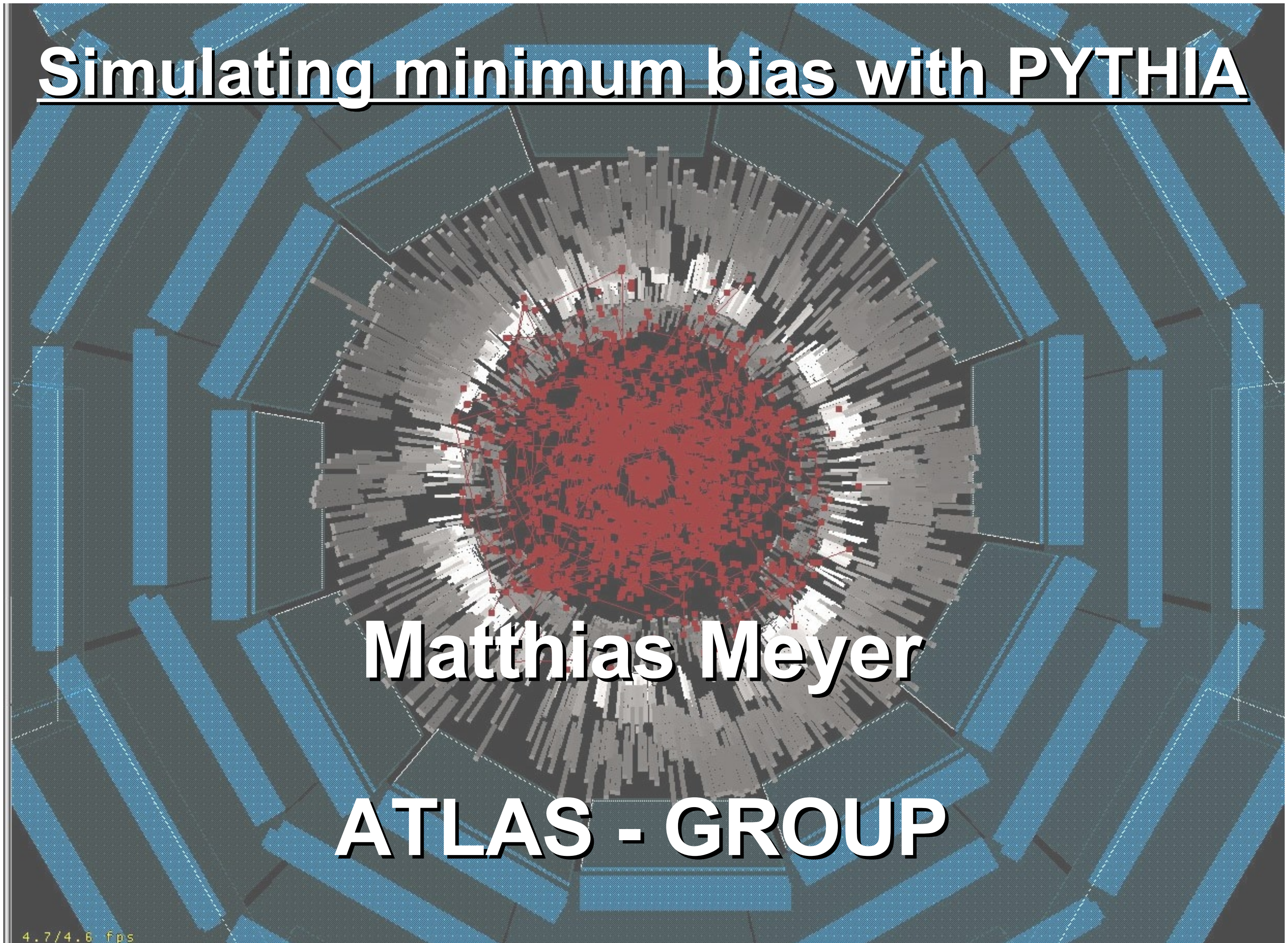
Soft-interaction-simulation with PYTHIA



Overview

Inspired by the paper: “Prediction for minimumbias and the underlying event at LHC energies”
Written by: A. Moras, C. Buttar and I. Dawson

- What is minimum bias?
- Soft scattering
- How PYTHIA deals with soft scattering
- Options to use in PYTHIA for minimum bias event generation
- Summary

What is minimum bias?

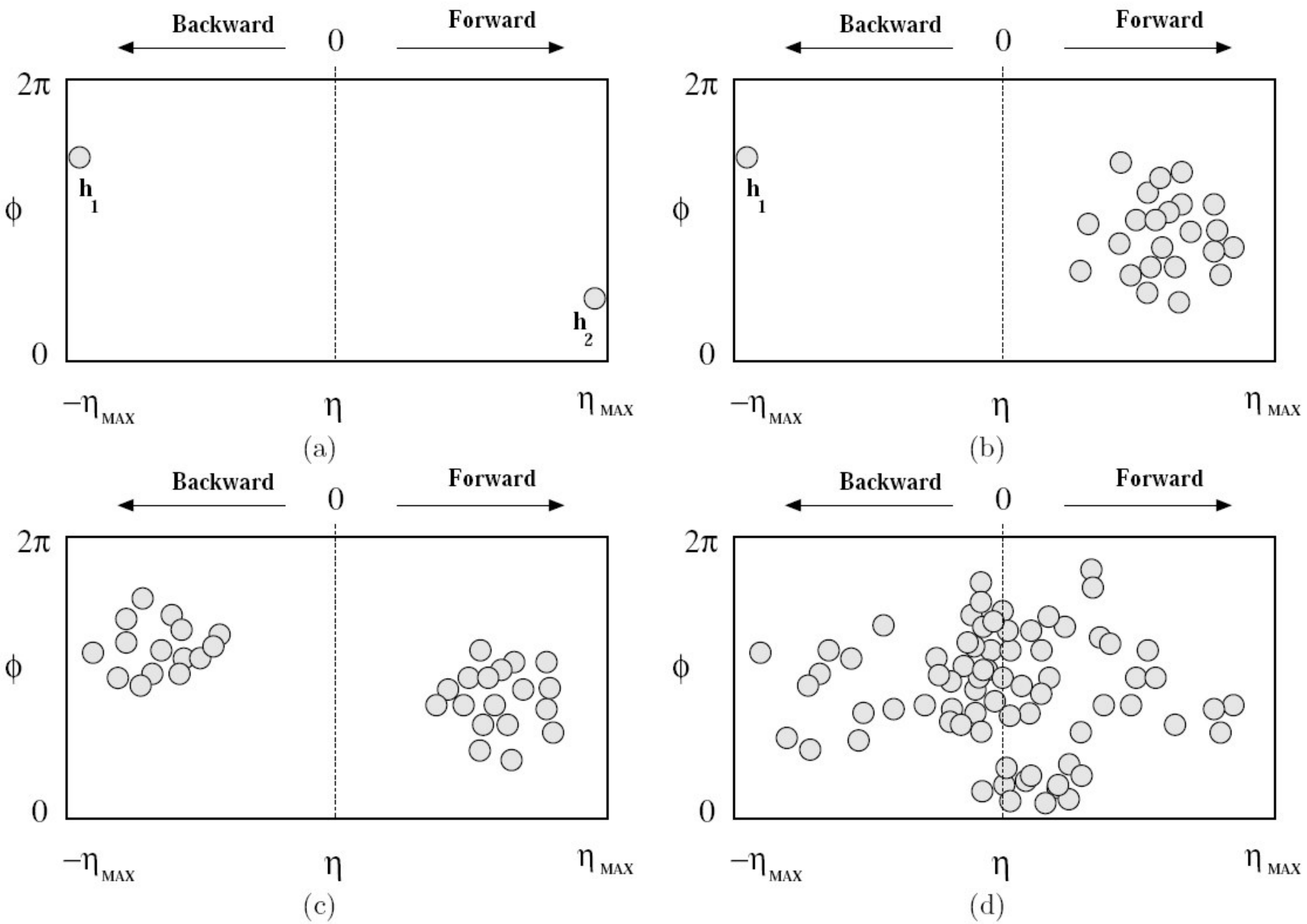
High-energy pp and $p\bar{p}$ collisions are dominated by soft partonic collisions, so called minimum bias events.

Minimum bias events also occur beside hard scattering events at high luminosity – important for many physics analysis.

There are two different main definitions:

- Practical = non-single diffractive (NSD) inelastic interactions
- Theoretical = non-diffractive inelastic interactions

What is minimum bias?



What is minimum bias?

Practically (non-single diffractive (NSD) inelastic interactions):

The definition is chosen by trigger properties, it contains non-diffractive and double-diffractive interaction.

$$\sigma_{nsd} = \sigma_{tot} - \sigma_{elast} - \sigma_{sd}$$

Theoretical (non-diffractive inelastic interactions):

This definition is chosen by some groups, to describe soft interactions and diffractive processes theoretically.

Soft scattering

Soft scattering is interaction with small momentum exchange.

Here it is bound to the transverse momentum exchange.

One talks of soft scattering for $p_t < 2\text{GeV}$.

The interaction cross-section above any chosen p_{tmin}, given by perturbative QCD, is written as:

$$\sigma_{\text{int}}(p_{t_{min}}) = \int_{p_{t_{min}}^2}^{s/4} \frac{d\sigma}{dp_t'^2} dp_t'^2$$

Soft scattering

In the p_t-region of soft scattering perturbative QCD has two serious problems:

1) at $p_t \sim$ 2GeV the interaction cross-section exceeds the total cross-section.

2) for $p_t \to 0$ the differential cross-section diverges like dp_t^2 / p_t^4

$$\sigma_{\mathrm{int}}(p_{t_{min}}) = \int_{p_{t_{min}}^2}^{s/4} \frac{d\sigma}{dp_t'^2} dp_t'^2$$

How PYTHIA deals with soft scattering

The first problem (p_t ~ 2GeV) is solved in PYTHIA by using the concept of multiple parton interactions:

At high-energy, each incoming hadron is viewed as a partonic beam.

So there is a possibility of having several parton – parton interactions when the hadrons collides.

Those events with $\sigma_{\mathrm{int}}(p_{t_{min}}) > \sigma_{\mathrm{tot}}$ are interpreted as having N parton – parton interaction.

$$N = \frac{\sigma_{\mathrm{int}}(p_{t_{min}})}{\sigma_{nd}}$$

σ_{nd} = non-diffractive inelastic interac. cross-section.

How PYTHIA deals with soft scattering

The second problem ($p_t \rightarrow 0$) is handled by using the Lund model.

It uses a cut-off parameter $p_{tmin}(s)$.

There are two different scenarios, one called “simple” and the “complex” scenario.

$$p_{t_{min}}(s) = (1.9\text{GeV}) \left(\frac{s}{1\,TeV^2} \right)^{0.08}$$

How PYTHIA deals with soft scattering

The simple scenario:

It uses multiple scattering and a sharp cut-off at p_{tmin}.

That means: $$\frac{d\sigma}{dp_t^2} = 0 \; for \; p_t < p_{t_{min}}$$

This is equivalent to a maximum impact parameter b_{max}, above which there is no interaction.

This may also be interpreted as a consequence of the parton confinement.

The complex scenario:

In this scenario, the impact parameter b is correlated to the chosen matter distribution of the Hadron.

One can chose between three matter distributions:
- Poissonian distribution
- Gaussian distribution
- Double Gaussian distribution

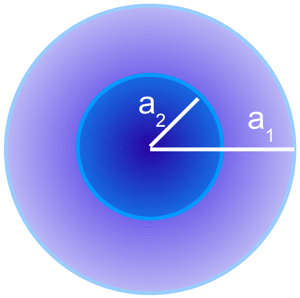
The divergences at $p_t \rightarrow 0$ are corrected by multiplying the matrix elements by a factor $p_t^4 / (p_t^2 + p_{t_{min}}^2)^2$.

and replacing p_t^2 by $(p_t^2 + p_{t_{min}}^2)$ in α_s.

How PYTHIA deals with soft scattering

Double Gaussian matter distribution:

$$\rho(r) \propto \frac{1-\beta}{a_1^3} \exp\left[\frac{-r^2}{a_1^2}\right] + \frac{\beta}{a_2^3} \exp\left[\frac{-r^2}{a_2^2}\right]$$



Hadrons described by this distribution have a small core region of radius a_2, containing a fraction β of the total hadronic matter.

This core is embedded in a larger volume of radius a_1 containing the remaining fraction of matter.

One can control β and the ratio a_2/a_1, to tune PYTHIA.

Options to use in PYTHIA for min bias event generation

Switches for the scenarios:

MSTP(82) = 1	simple scenario –	multiple scattering, hard cut-off at ptmin.
MSTP(82) = 2	complex scenario –	Poissonian distribution
MSTP(82) = 3	complex scenario –	Gaussian distribution
MSTP(82) = 4	complex scenario –	double Gaussian Distribution.

PARP(83) – controls β
PARP(84) – controls the ratio a_1/a_2

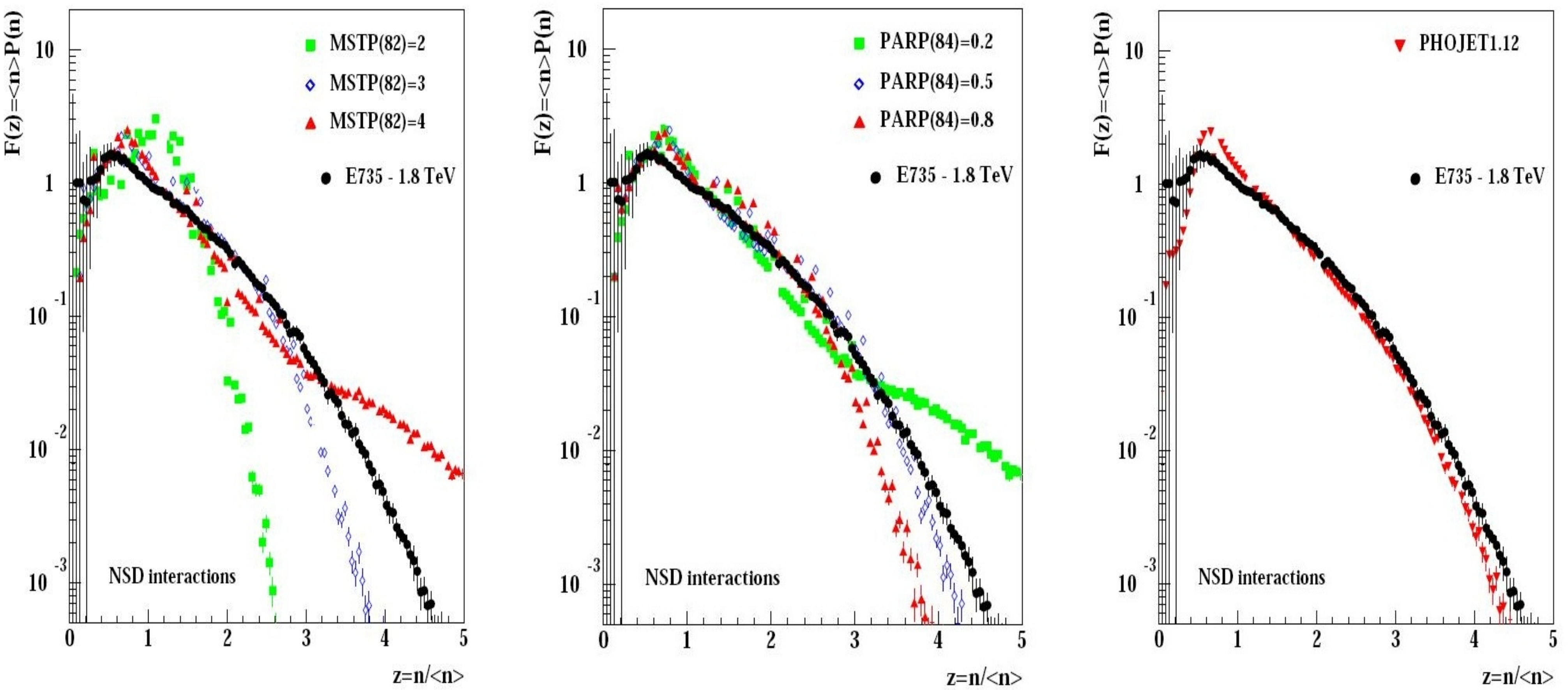
Options to use in PYTHIA for min bias event generation

$\mathbf{p}_{t_{min}}$ parameters	
PARP(81)=1.9	simple scenario
PARP(82)=1.9	complex scenario
PARP(89)=1 TeV	energy scale
PARP(90)=0.16	power which regulates $\mathrm{p}_{t_{min}}$'s energy dependence

Options to use in PYTHIA for min bias event generation

Charged multiplicity distributions:

Var. mod complex scenario — Var. matter density in d. Gaus. — PHOJET



Summary

PYTHIA is able to handle soft scattering.

The model witch is used is more parameter fitting then a theoretical model.

Comparing PYTHIA with minimum bias data, witch are collected at the CDF-Detector, shows that it is able to reconstruct the data quite well.

Comparing with PHOJET, witch uses the Dual Parton Model (DPM), PYTHIA might be not the best choice for minimum bias prediction.