Underlying Event & Soft Inclusive Physics
Part II

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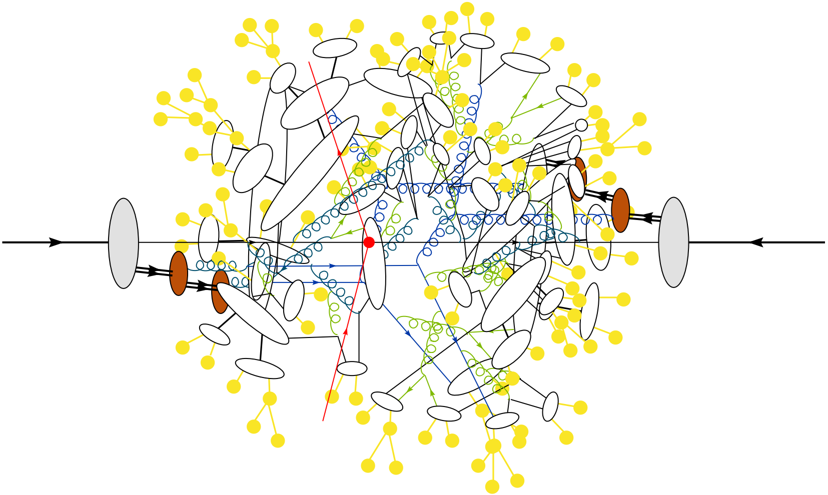
São Paulo, 30th April 2015

MPI



Outline

The first lecture:

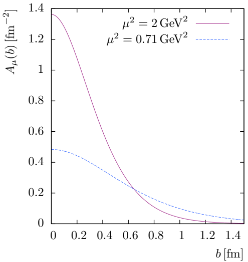
- Definition and Motivation
- Example of MPI model - MPI in Herwig++
- Colour structure of an event
- Summary

Today's lecture:

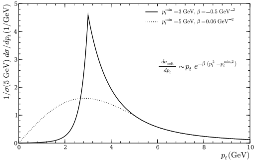
- Short reminder
- Tuning tools - Professor
- Overview of MPI models and comparison with some LHC data
- CDF Min Bias "factorization" mystery
- Outlook
- MCnet studentship and MCnet School

Underlying event in Herwig++ - key components

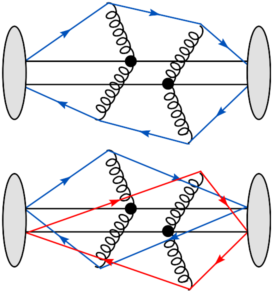
Matter distribution (μ^2)



Extension to soft MPI ($p_t < p_t^{\text{min}}$)



Colour structure (p_{reco}, p_{CD})



Main parameters:

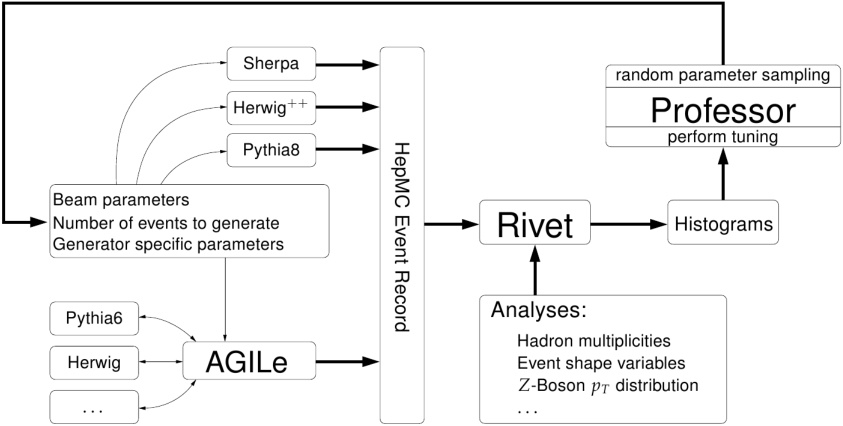
- μ^2 - inverse hadron radius squared (parametrization of overlap function)
- p_t^{min} - transition scale between soft and hard components $\Rightarrow p_t^{\text{min}} = p_{t,0}^{\text{min}} \left(\frac{\sqrt{s}}{E_0}\right)^b$
- p_{reco} - colour reconnection
- p_{CD} - colour structure of the Soft UE

Tuning

- MC models have parameters such as pT cutoff, energy evolution, colour-reconnection... + many parameters of hadronization models
- Tuning (fixing) of soft QCD parameters required to constrain models in order to
  - understanding/exploring the physics of soft QCD
  - data mimicking for best experimental unfolding

  Lots of correlated parameters, 200k-10M events per run (kin. binning): tuning is non-trivial. Brute-force grid-scans: tough in higher dimensions of parameter space (limited data sets and model's parameters)
- No unique way of tuning: which data samples should be used? divide and conquer (split parameters in subgroups which can be tune separately) ...
- "manual" tunning - hard and inefficient - lots of time and man and CPU power needed.
- new tools help to automatize this process -> however still you need to think it is not "Fire-and-forget"

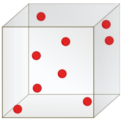
Rivet and Professor

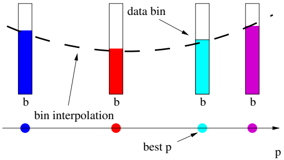


Rivet and Professor

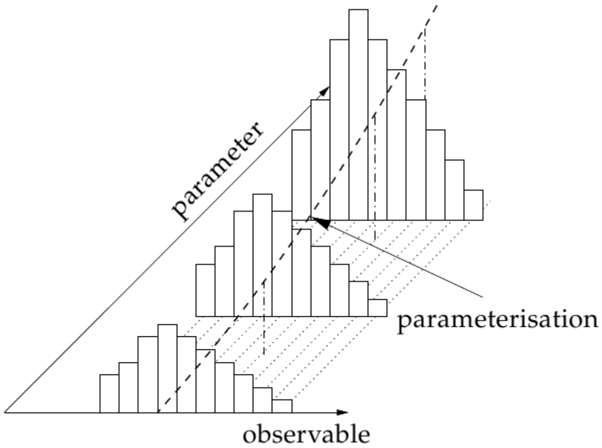
Tuning procedure in Professor (1D, 1Bin)

1. Random sampling: N parameter points in n-dimensional space
2. Run generator and fill histograms
3. For each bin: use N points to fit interpolation (2^{nd} or 3^{rd} order polynomial)
4. Construct overall (now trivial) $^2 \approx \sum_{bins} \frac{(interpolation - data)^2}{error^2}$
5. and Numerically *minimize* `pyMinuit, SciPy`





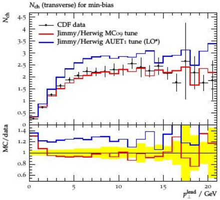
Rivet and Professor



Rivet and Professor
Observables and Weights

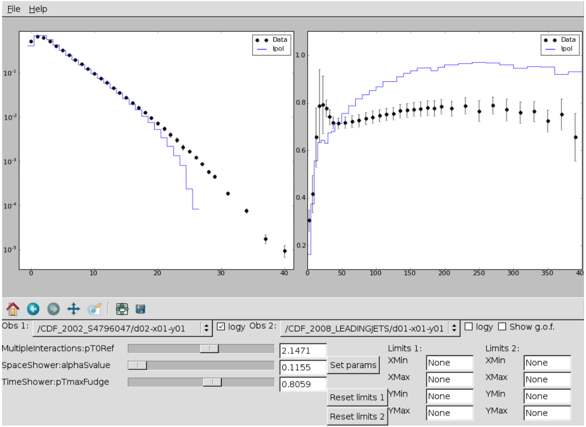
- This is what Professor minimises: $\chi^2(\vec{p}) = \sum_{\mathcal{O}} \sum_{b \in \mathcal{O}} w_b \frac{(f^{(b)}(\vec{p}) - \mathcal{R}_b)^2}{\Delta_b^2}$
- Slightly more art than science
- Garbage in, garbage out
- Use weights w_b to:
    - emphasize certain observables
    - emphasize certain bins of an observable
    - switch off single bins (e.g. MinBias region for Jimmy Herwig)

- No MinBias physics in Jimmy Herwig
- Cannot get first 3 bins or so right
- Transition from MinBias to UE type physics
- ⇒ Exclude these bins from Professor minimisation



Rivet and Professor

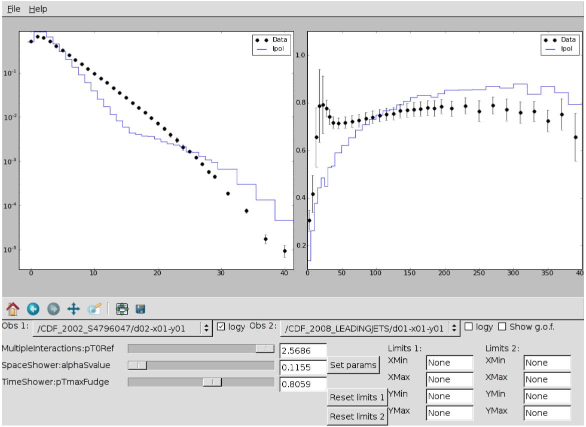
PROF-I



Usage: `prof-I --datadir .`

Rivet and Professor

PROF-I



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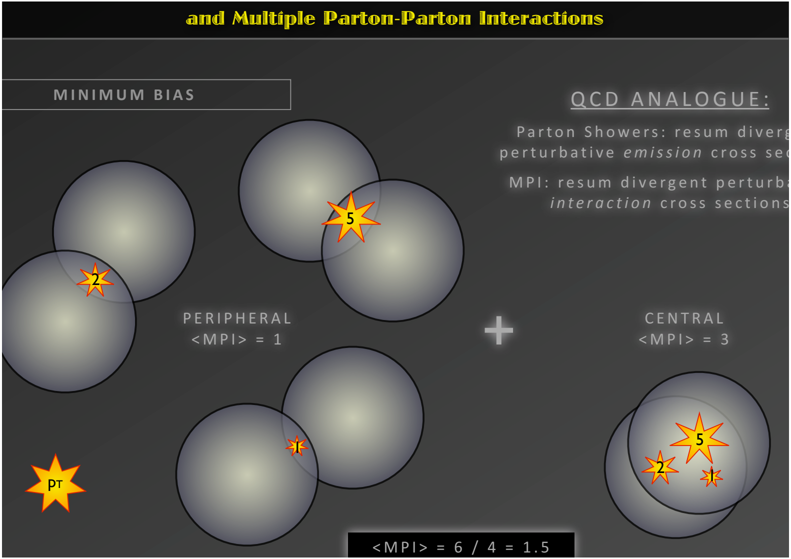
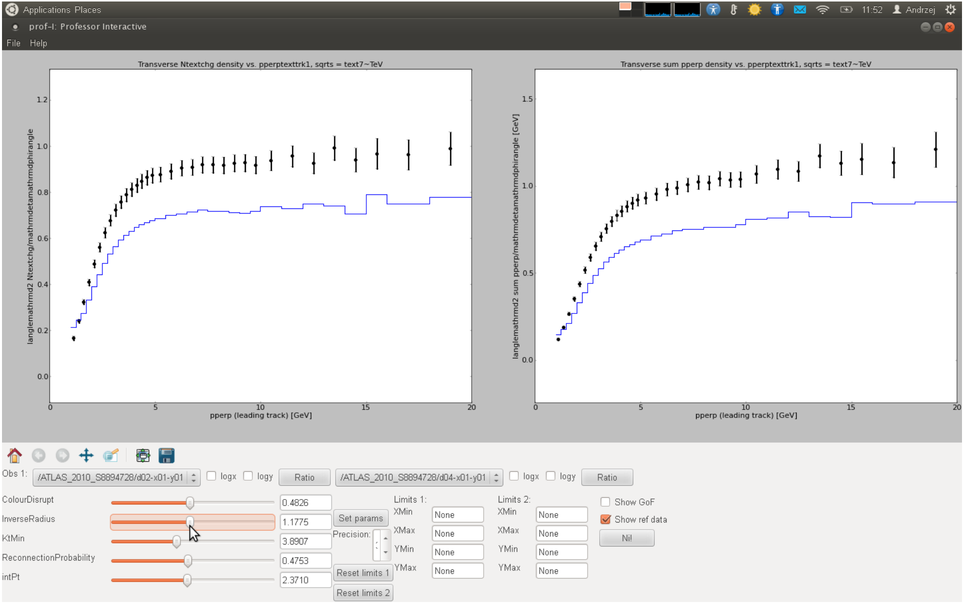
Semi hard underlying event

Taken from Peter Skands:

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Andrzej
prof-I: Professor Interactive
File
Help
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langlemathrmd2 Ntextchg/mathrmdetamathrmdphirangle
pperp (leading track) [GeV]
Transverse sum pperp density vs. pperptexttrk1, sqrts = text7~TeV
langlemathrmd2 sum pperp/mathrmdetamathrmdphirangle [GeV]
pperp (leading track) [GeV]
Obs 1:
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/ATLAS_2010_S8894728/d04-x01-y01
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logy
Ratio
ColourDisrupt
0.4826
InverseRadius
1.1775
Set params
KtMin
3.8907
Precision:
ReconnectionProbability
0.4753
intPt
2.3710
Reset limits 1
Reset limits 2
Limits 1:
XMin
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Show ref data
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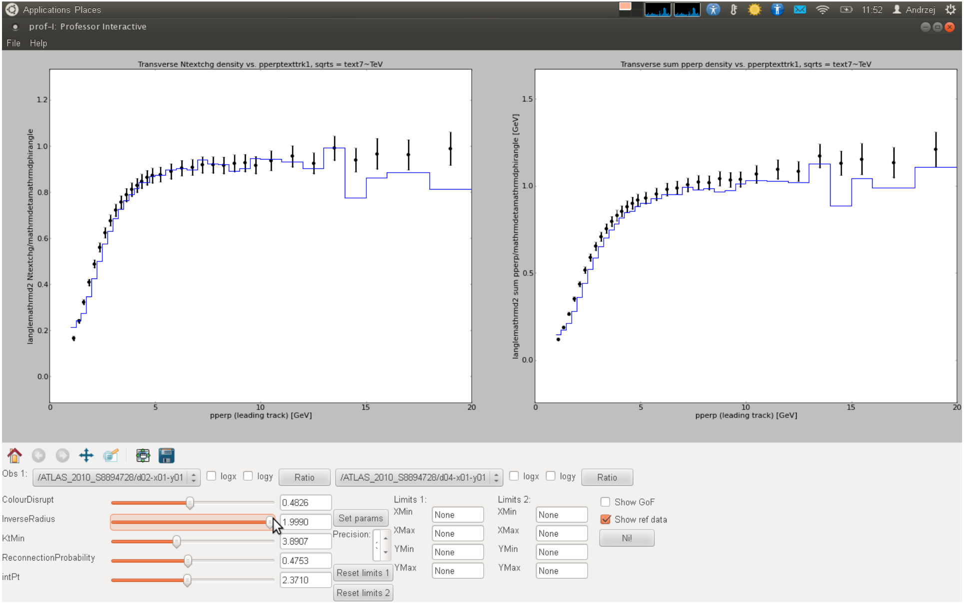
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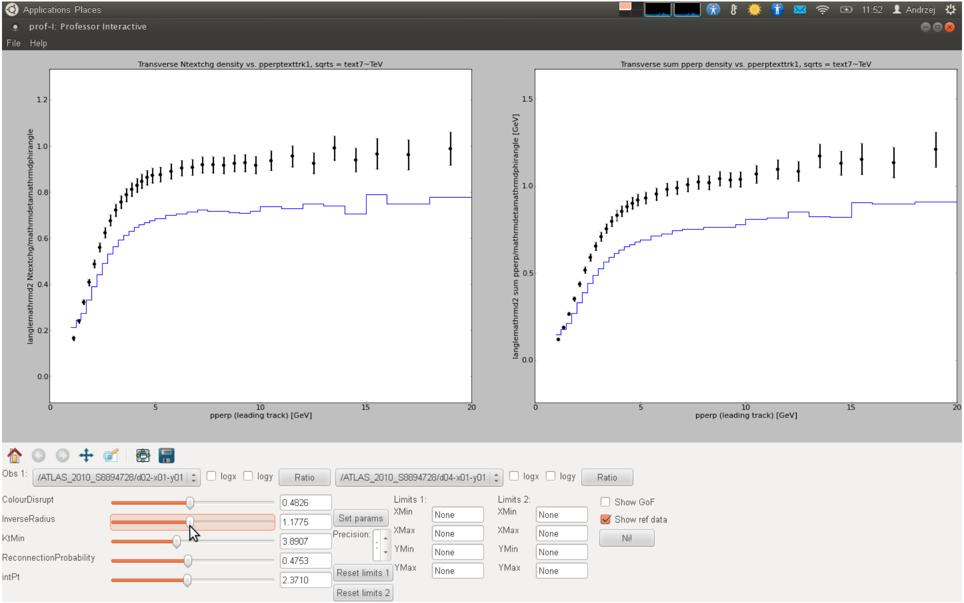

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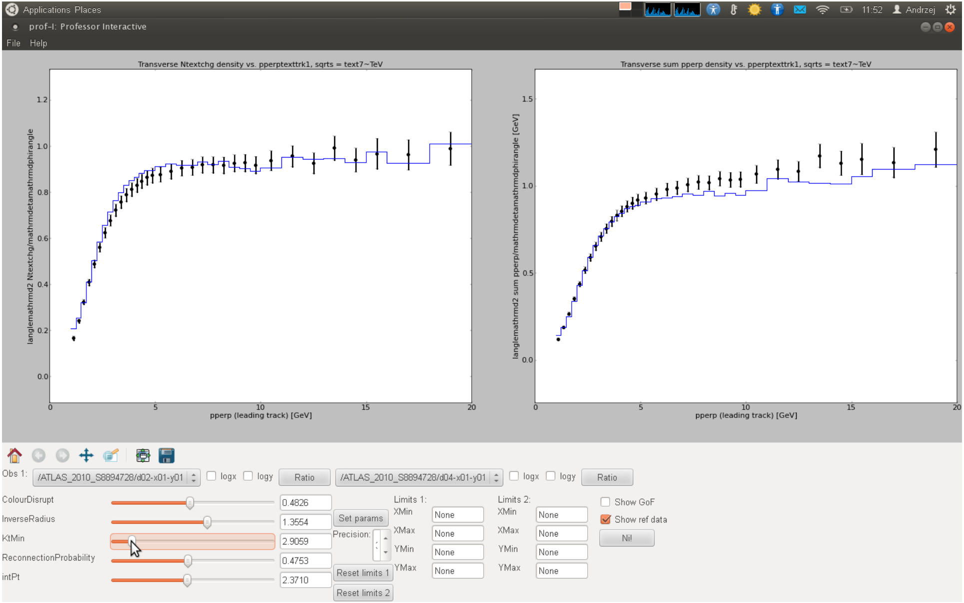
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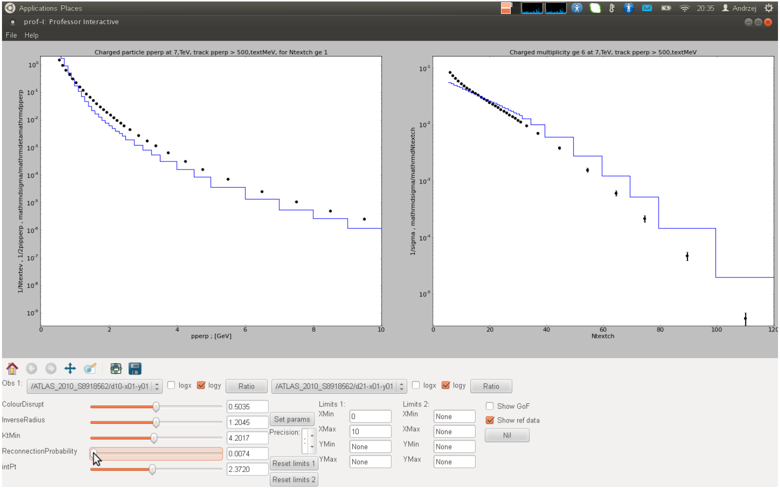

Applications Places
20:35 Andrzej
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File Help
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1/Ntextev , 1/2pipperp , mathrmdsigma/mathrmdetamathrmdpperp
pperp ; [GeV]
Charged multiplicity ge 6 at 7,TeV, track pperp > 500,textMeV
1/sigma , mathrmdsigma/mathrmdNtextch
Ntextch
Obs 1:
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logy
Ratio
/ATLAS_2010_S8918562/d21-x01-y01
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logy
Ratio
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InverseRadius
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KtMin
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ReconnectionProbability
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Reset limits 2
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XMax 10
YMin None
YMax None
Limits 2:
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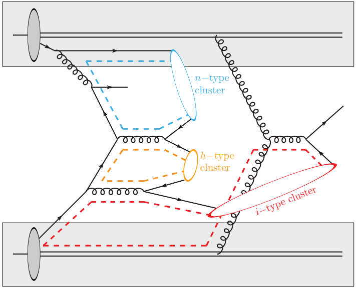
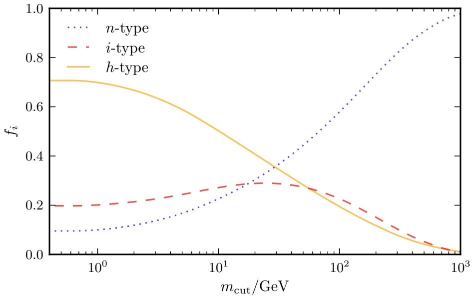
XMax None
YMin None
YMax None
Show GoF
Show ref data
Nil

Colour reconnections in Herwig++ [Gieseke, Röhr, AS, Eur.Phys.J. C72 (2012) 2225]

$$f_a(m_{cut}) \equiv N_a(m_{cut}) / \sum_{b=h,i,n} N_b(m_{cut}) = \frac{N_a(m_{cut})}{N_{cl}}\,, \qquad (1)$$





Since these n-clusters can lie at very different rapidities (the extreme case being the two opposite beam remnants), the strings or clusters spanned between them can have very large invariant masses (though normally low *pT*), and give rise to large amounts of (soft) particle production.

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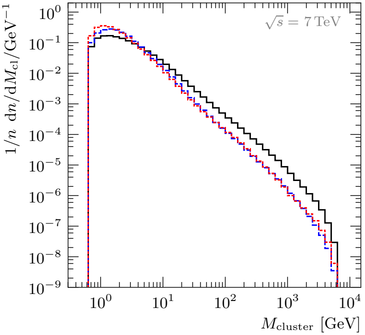

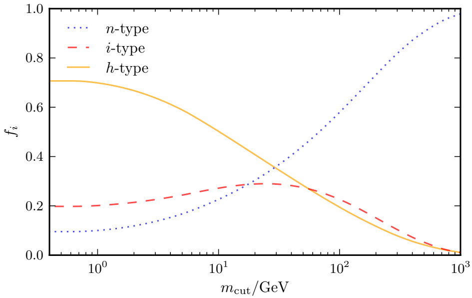

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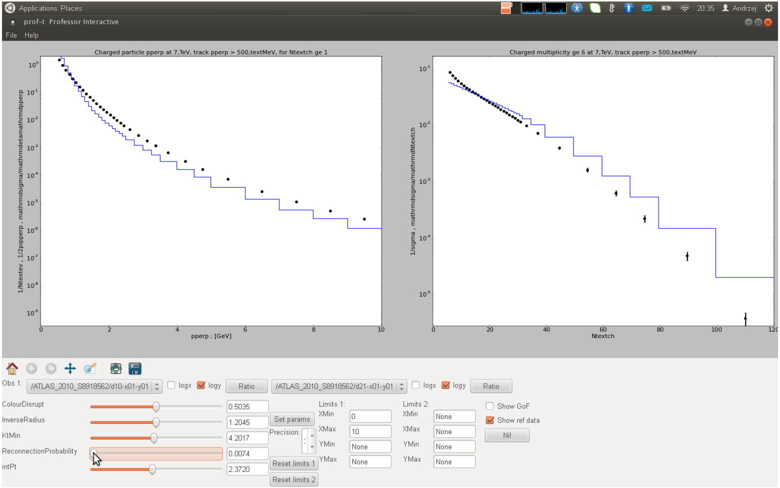

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Ntextch
Obs 1:
/ATLAS_2010_S8918562/d10-x01-y01
logx
logy
Ratio
/ATLAS_2010_S8918562/d21-x01-y01
ColourDisrupt
InverseRadius
KtMin
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0.5035
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Set params
Precision:
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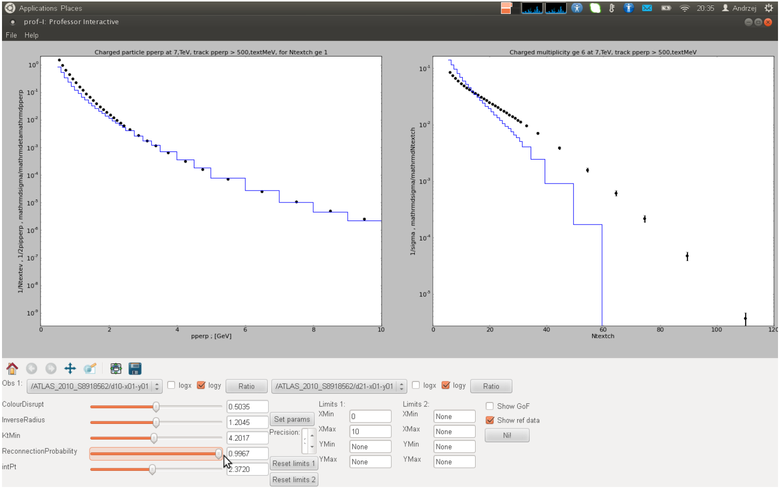
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KtMin
4.2017
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intPt
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Limits 2:
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Show GoF
Show ref data
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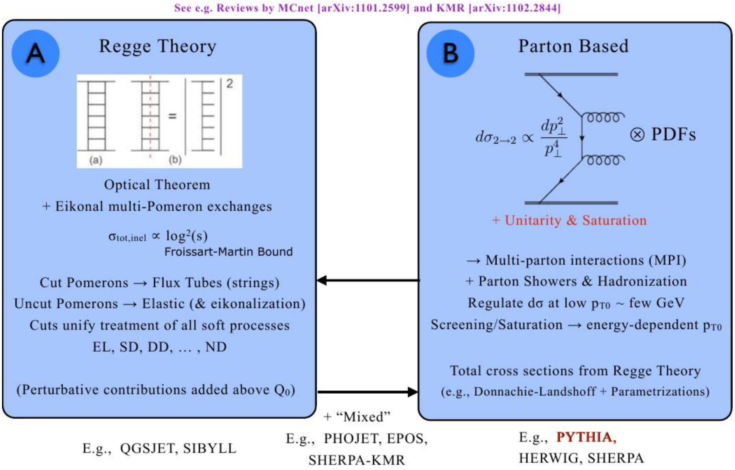
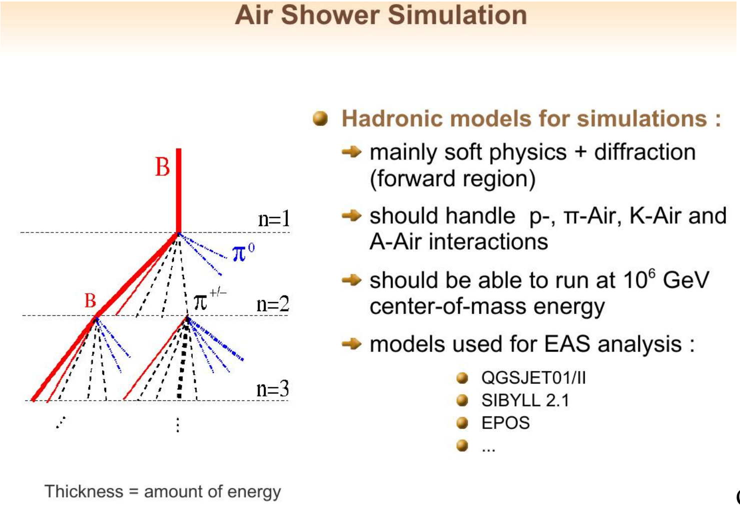
MPI models overview and comparison with data

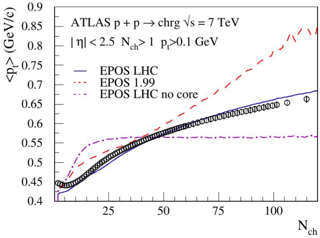


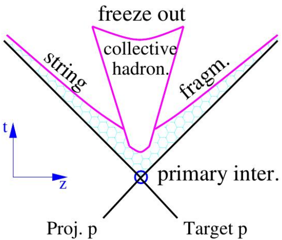
Only EPOS, Herwig++, Pythia (see Leif's talk for details) and Sherpa used at the LHC.

EPOS



Quite different model to Pythia/Herwig, for example no color reconnection but collective hadronization instead.





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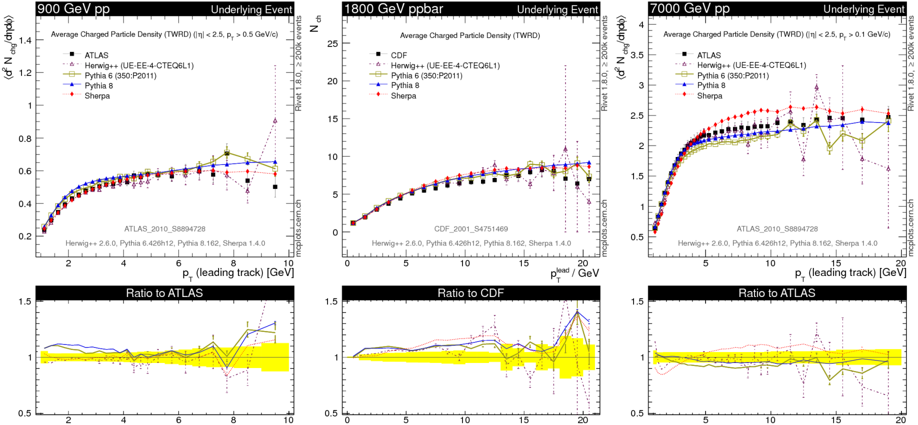
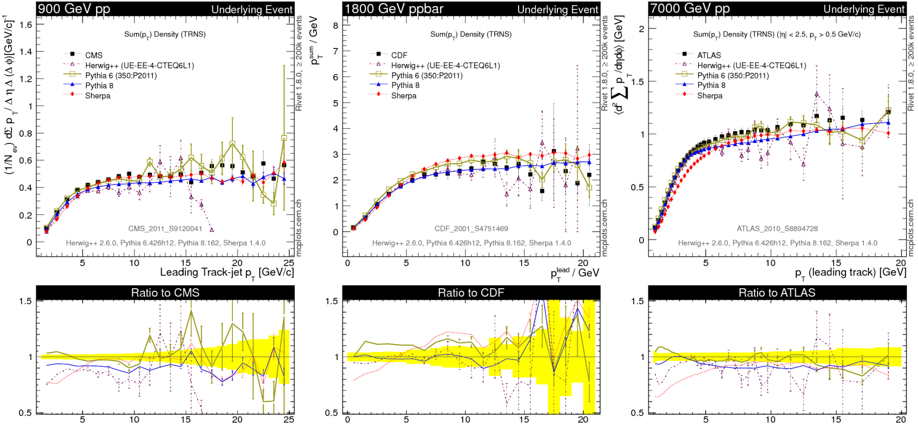
UE measurements - Energy Overview



Many LHC UE observables (not tuned since not available) and well described ...

UE measurements - Energy Overview



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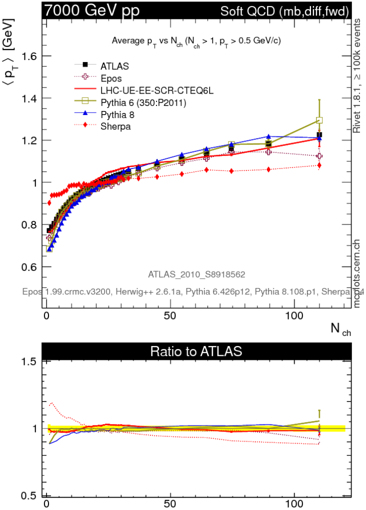
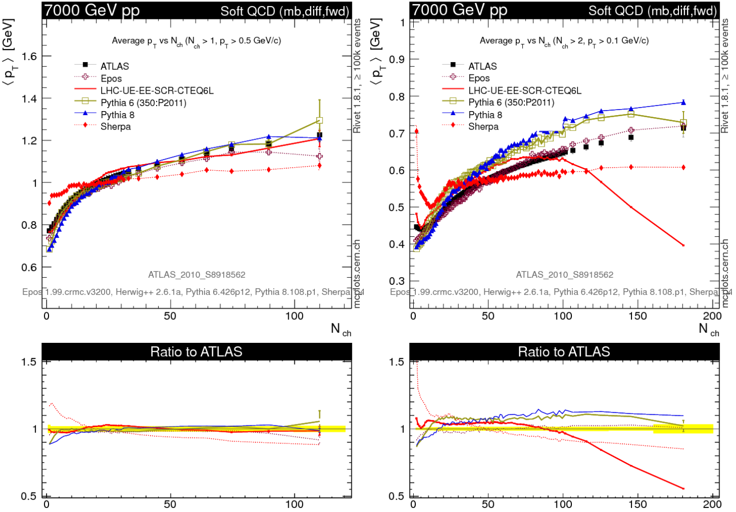
Problems - very soft MinBias ATLAS



Need of the colour reconnection.

Problems - very soft MinBias ATLAS



Need of the colour reconnection. MB 7000 TeV, problem at low p_T, high Nch
Epos seems to describe MB data but fails to describe UE data.

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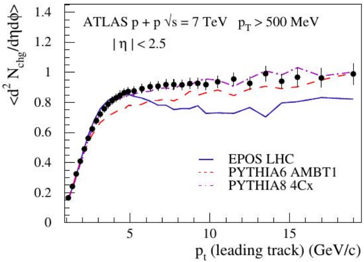

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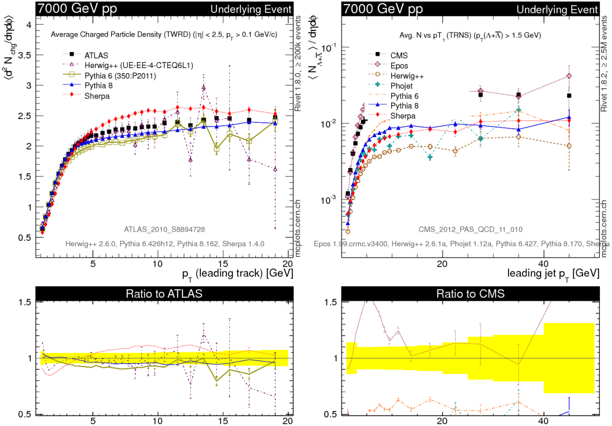
Problems - Identified particles



More plots: mcplots.cern.ch (and mcplots-dev.cern.ch less stable but more recent results)

Summary:

- Motivation and experimental evidence for MPI
- Underlying event model (MPI) is an integral part of MC event generators!
- Non perturbative regime -> need for models with several parameters, no unique way -> few models on the market
- Parameters constrained using data - new LHC results lead to new developments in MB/UE simulation. Good tunes available by now.
- Minimum bias/underlying event/diffraction under constant improvement (DIPSY, new MPI model Shrimps in Sherpa, improvements in Pythia and Herwig, Epos for LHC)!
- Good first round of LHC data well described...
- ... but still a lot space for improvements.
- Not-too-soft not-too-high-multiplicity physics under good control (if you use modern models with modern tunes).
- "It doesn't matter how beautiful your theory/model is, it doesn't matter how smart you are. If it doesn't agree with experiment, it's wrong" Richard P. Feynman

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- “It doesn’t matter how beautiful your theory/model is, it doesn’t matter how smart you are. If it doesn’t agree with experiment, it’s wrong“ Richard P. Feynman (ok sometimes experiment is wrong ;))
- As LHC needs to study more rare phenomena and more subtle effects, generators must keep up by increased precision.

MCnet Short-term studentships

Monte Carlo
training studentships

3-6 month fully funded studentships for current PhD students at one of the MCnet nodes. An excellent opportunity to really understand and improve the Monte Carlos you use!

Application rounds every 3 months.

MCnet

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MARIE CURIE ACTIONS

for details go to:
www.montecarlonet.org

MC*net* projects

Pythia
Herwig
Sherpa
MadGraph
Ariadne
CEDAR

MCnet School

Thank you for the attention!