MANCHESTER 1824
The University of Manchester

CFP
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Using sigma effective and Underlying Event data to constrain MPI models

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with

Mike Seymour

[M. H. Seymour, and AS, JHEP 1310 (2013) 113]

MPI @ LHC 2013, Workshop on Multi-Parton Interactions at the LHC
2-6 December 2013, Antwerp

Outline

1. Motivation
2. Doube Parton scattering - sigma effective
3. Constraining MPI models
4. Outlook and conclusions

Motivation

Motivation

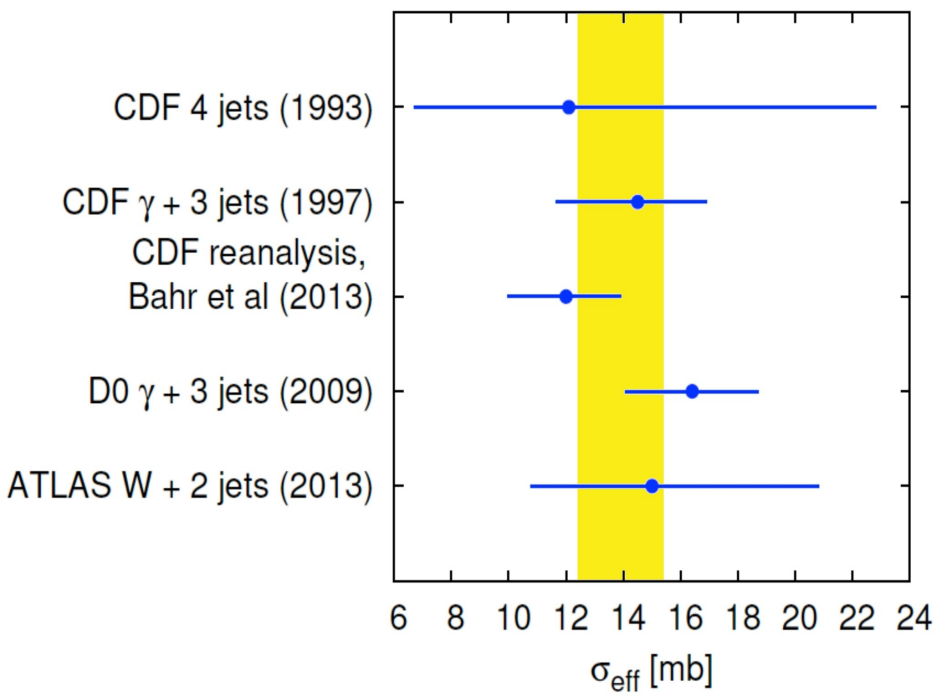
``*Summary of the Workshop on Multi-Parton Interactions (MPI@LHC) 2012''*

> The value of σ_{eff} should serve as a constraint on the Monte Carlo models since the recent tunes of MPI models to the LHC data predict its value to be between 25–42 mb
> (2-3 times bigger then its experimental value)

[H. Abramowicz, P. Bartalini, M. Bähr, N. Cartiglia, E. Dobson, et al., arXiv:1306.5413]

Motivation

Double-parton scattering measurements



The two most precise results D0 and reanalysis of CDF[1]:

$$\sigma_{eff,D0+reCDF} = (13.9 \pm 1.5)\ \mathrm{mb}.$$

Multi-parton interactions models

Different tunes of various different MPI models predict σ_{eff}: 20-40 mb.

For example:

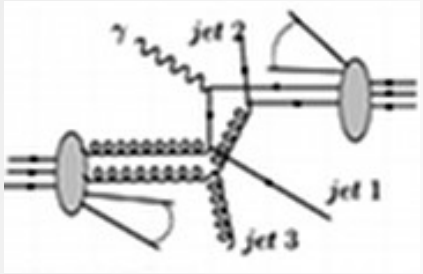
- Herwig++ tune UE-EE-4: $\sigma_{eff} = 30.9$ mb
- Pythia 8 tune 4C: $\sigma_{eff} = 33.7$ mb
- Pythia 6 with various tunes (D6T, Z1, Perugia)

  σ_{eff} values between 20 and 30 mb

These values are all clearly above the experimental value, a fact that has been used to argue that the Monte Carlo MPI models are oversimplied and should be improved.

[1][M. Bahr, M. Myska, M.H. Seymour, A. Siodmok, JHEP 1303 (2013)]

Double parton scattering



The measurements of double-parton scattering are typically phrased interms of an effective cross section parameter: σ_{eff}.

It is defined as the normalization factor that relate the cross section for double parton scattering to the product of the inclusive cross sections of the two individual scatters:

$$\sigma_{\mathrm{ab}} = \frac{m}{2}\frac{\sigma_{\mathrm{a}}\,\sigma_{\mathrm{b}}}{\sigma_{eff}}$$

where *'m'* is a symmetry factor and is equal to two when two processes are different otherwise *'m'* is equal to unity.

In the case that $\sigma_{\mathrm{a,b,ab}}$ are inclusive cross sections, σ_{eff} is independent of a and b.

See also tomorrow's talk on:
"Extracting sigma_effective from the LHCb double-charm measurement"

Main parameters of MPI model in Herwig++

Main parameters:

- μ^2 - inverse hadron radius squared (parametrization of overlap function)
- $p_t^{\min}$ - minimal pT $\Rightarrow$ $p_\perp^{\min} = p_{\perp,0}^{\min} \left(\frac{\sqrt{s}}{E_0}\right)^b$
- p_{reco} - colour reconnection
  [Gieseke, Rohr, AS, Eur.Phys.J. C72 (2012)]
- p_{CD} - colour structure of the Soft UE

From eikonal approximation:

$$\sigma_{eff} = \frac{1}{\int \mathrm{d}^2 b\, A(b)^2} = \frac{28\pi}{\mu^2}$$

$$\sigma_{eff,D0+reCDF} = (13.9 \pm 1.5)\ \mathrm{mb} \implies \mu^2 \sim (2.45^{+0.30}_{-0.25})\ \mathrm{GeV}^2.$$

Overlap function

From eikonal approximation:

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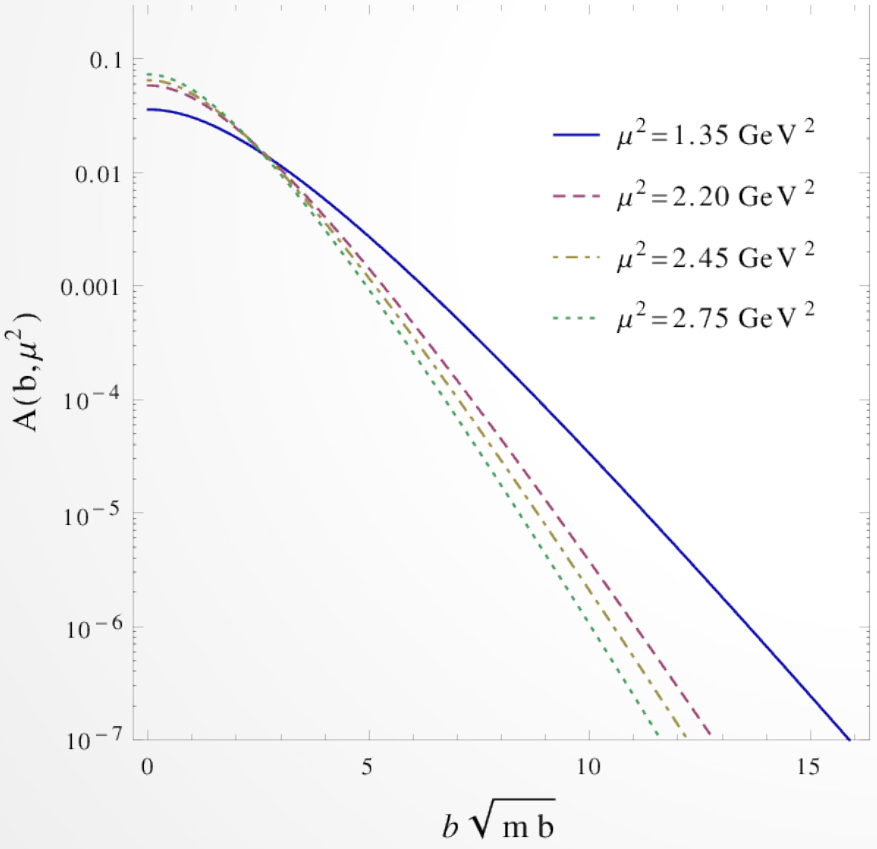
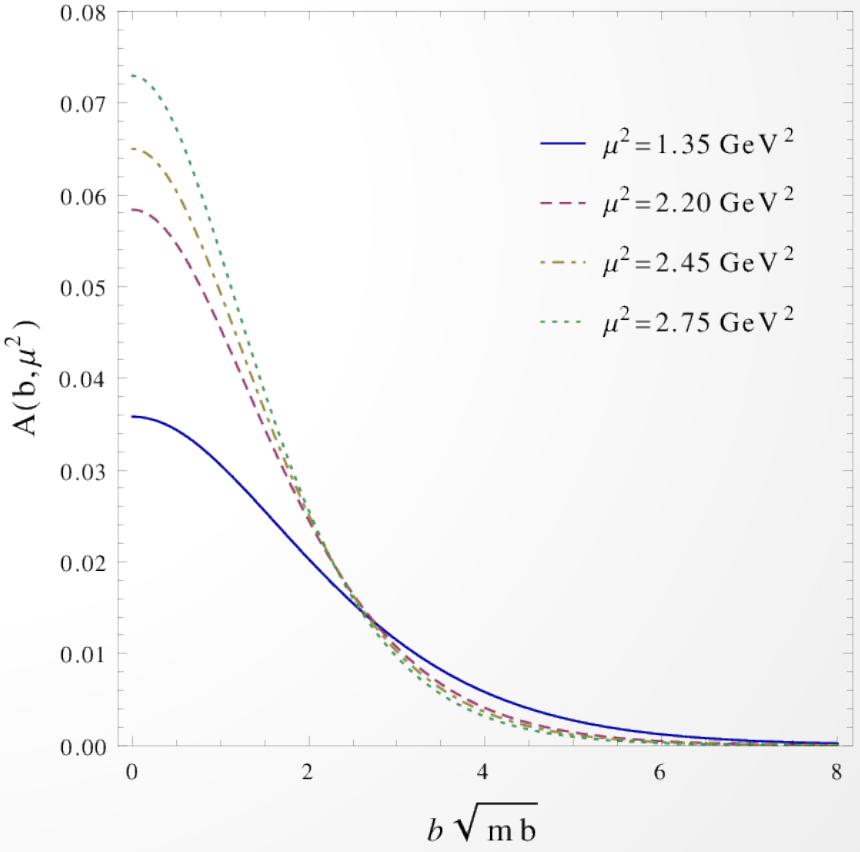




Tuning procedure

Observables:

The UE experimental data used for the tune should be measured at a wide-range of collider energies in similar phase-space regions and under not too different trigger conditions:

- The mean number of stable charged particles in the transverse region.
- The mean scalar pT sum of stable particles in the transverse region.

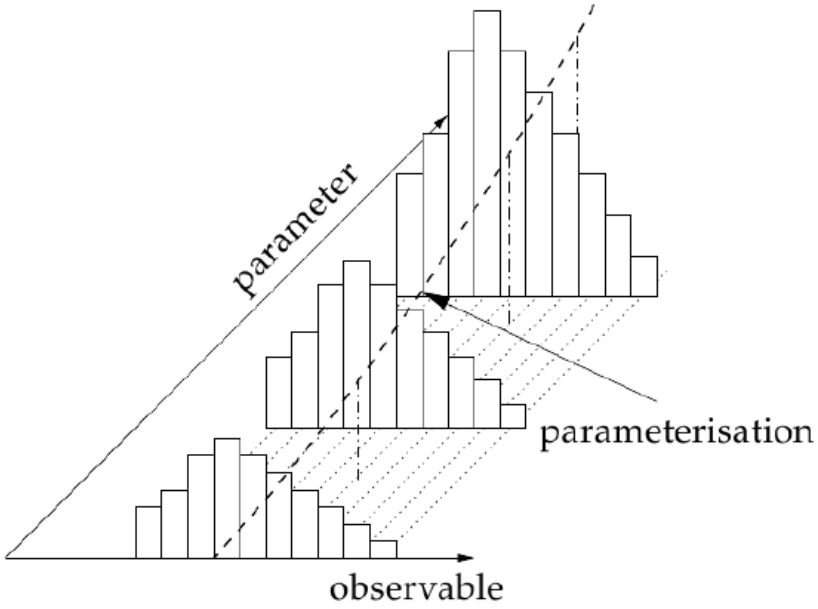
Leading track UE by CDF (Rick) at 300 GeV, 900 GeV and 1960 GeV and ATLAS at 900 GeV and 7TeV

The sigma effective data

$$\sigma_{eff,D0+reCDF} = (13.9 \pm 1.5)\ \mathrm{mb}.$$

Tools:

Rivet [arXiv:1003.0694]
Professor [A. Buckley, H. Hoeth, H. Lacker, H. Schulz, J. Eike von Seggern, D. Weyh]



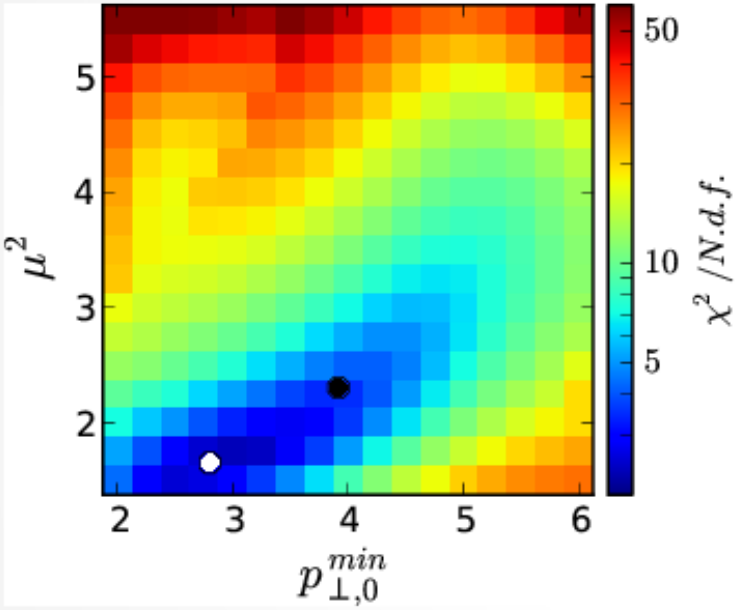
Tuning procedure factorizes:

- can use (well tested) default LEP tune for parton shower and hadronization parameters
- We tune only the MPI parameters

Constraining MPI models

Tuning of the model to UE data with and without sigma eff constrain.

No σ_{eff} in fit



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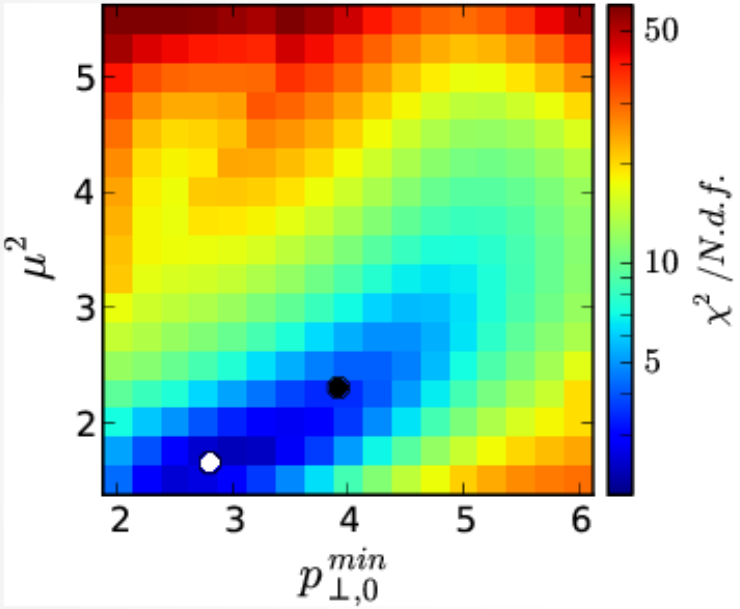
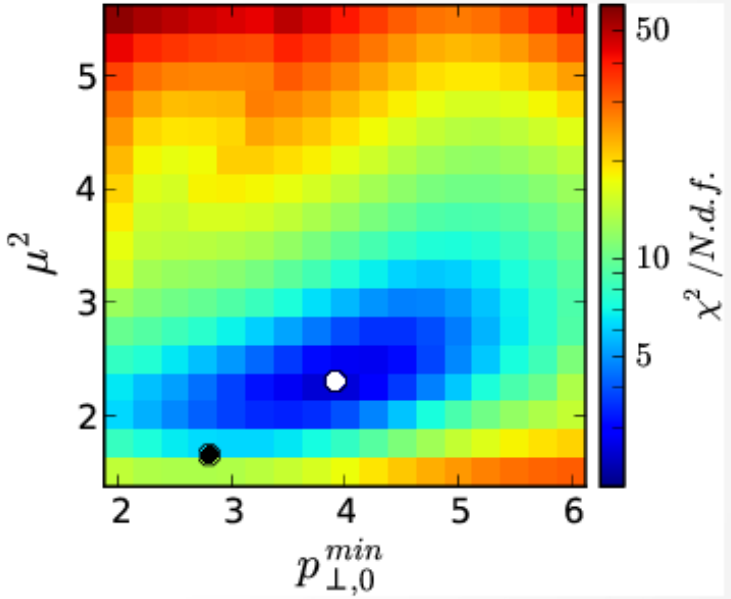


σ_{eff} in fit



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Constraining MPI models

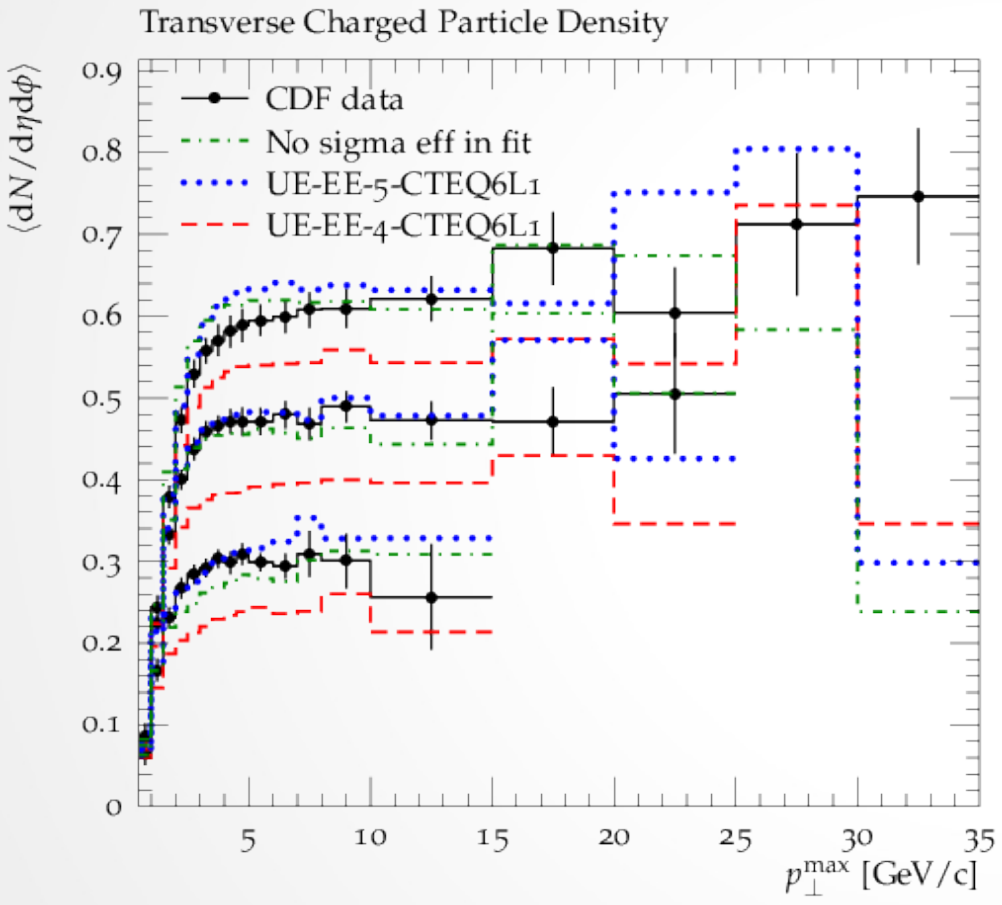
Tuned parameters for CTEQ6L1 and MRST LO** PDFs sets

	UE-EE-5-CTEQ6L1	UE-EE-5 (MRST LO✶✶)
ptmin0 / GeV	3.91	4.620
Power	0.33	0.314
InvRadius / GeV^2	2.30	2.240
pdisrupt	0.80	0.860
preco	0.49	0.420

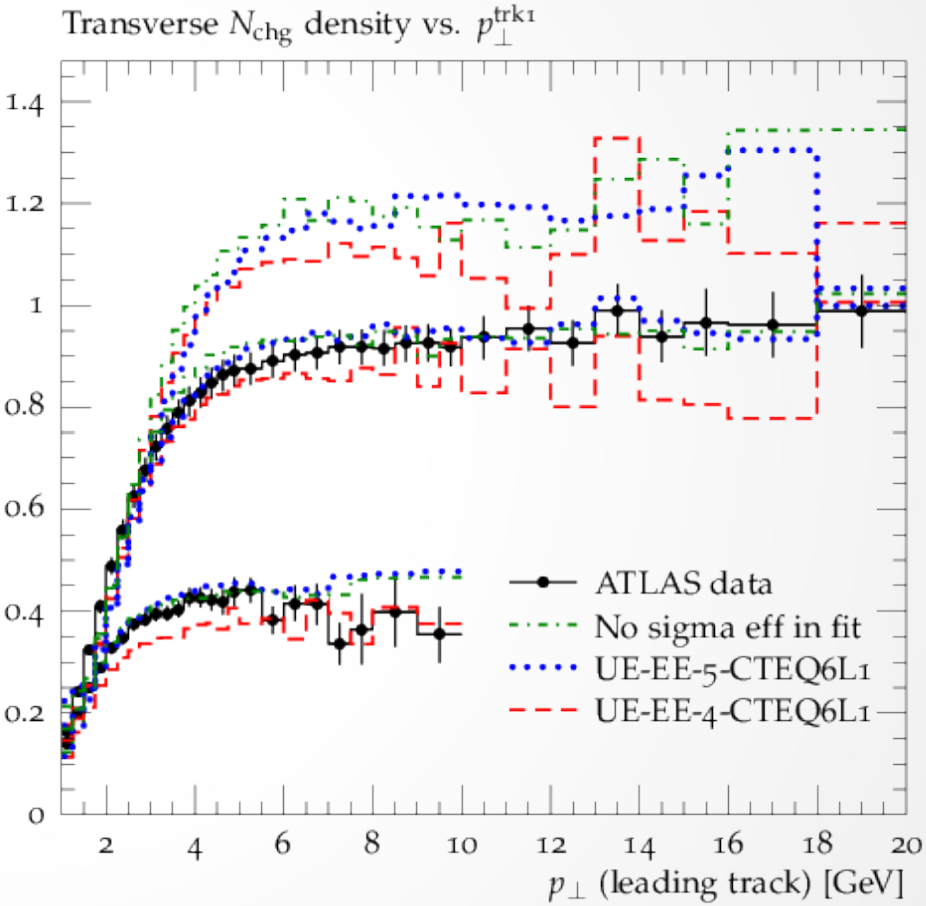
Constraining MPI models

Results

CDF (300, 900, 1960 GeV)



LHC (900, 7000 GeV)

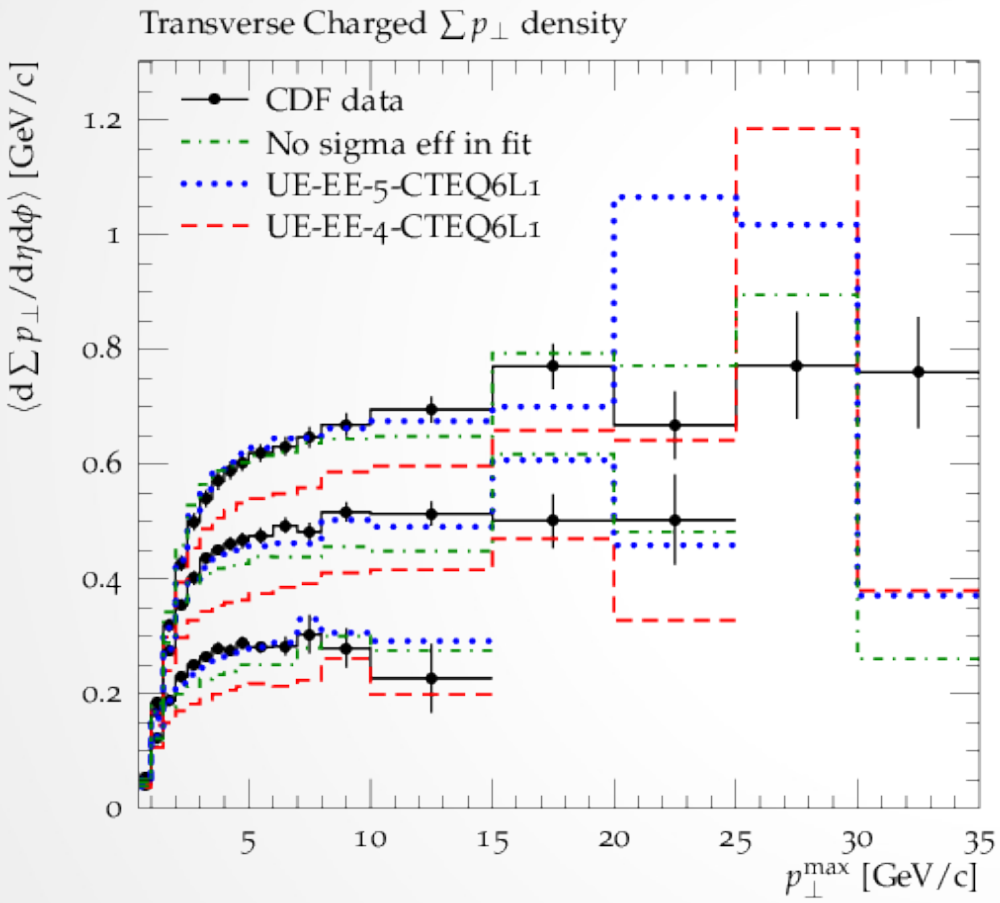


- Very good description of UE data over the collision energy range: 300 GeV to 7 TeV.

Constraining MPI models

Results

CDF (300, 900, 1960 GeV)



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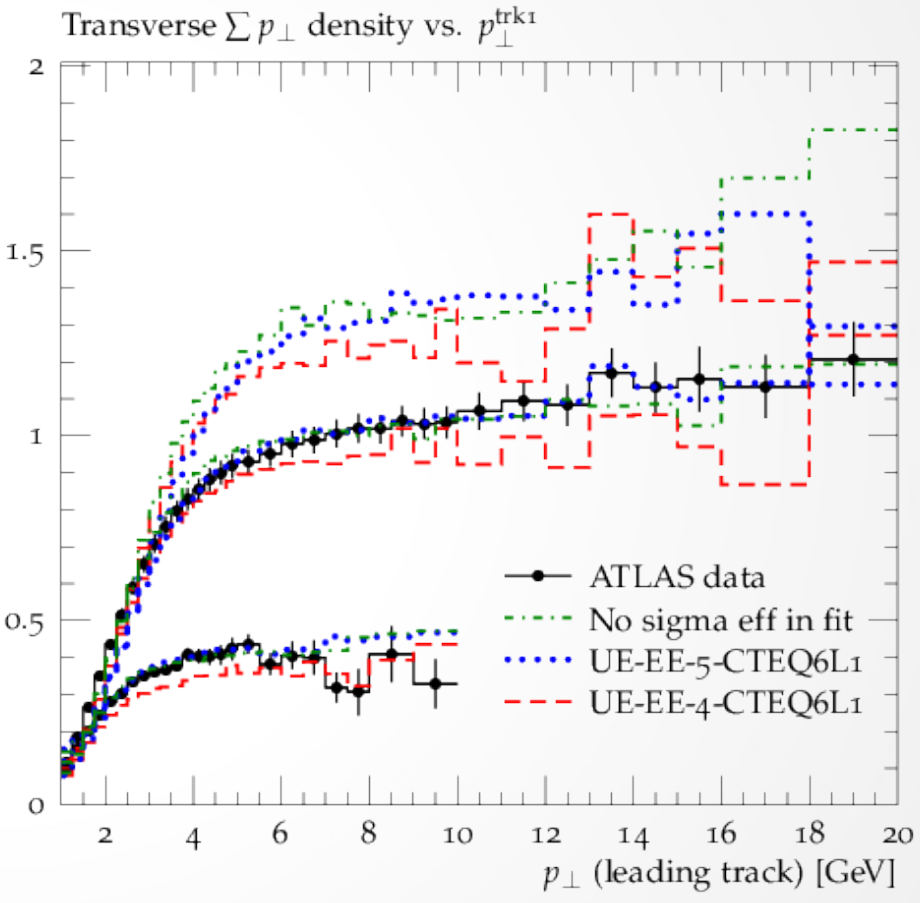
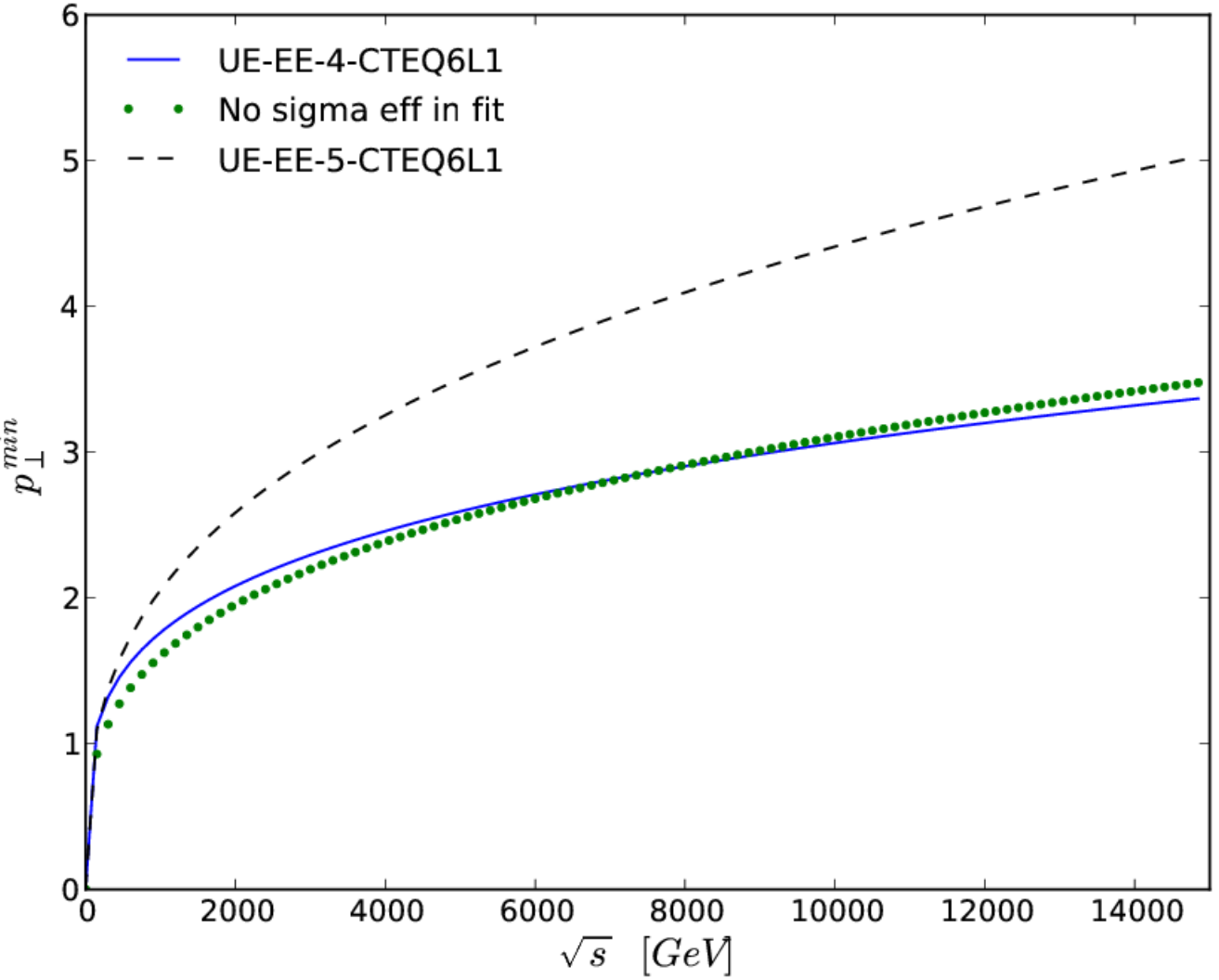


- Very good description of UE data over the collision energy range: 300 GeV to 7 TeV.

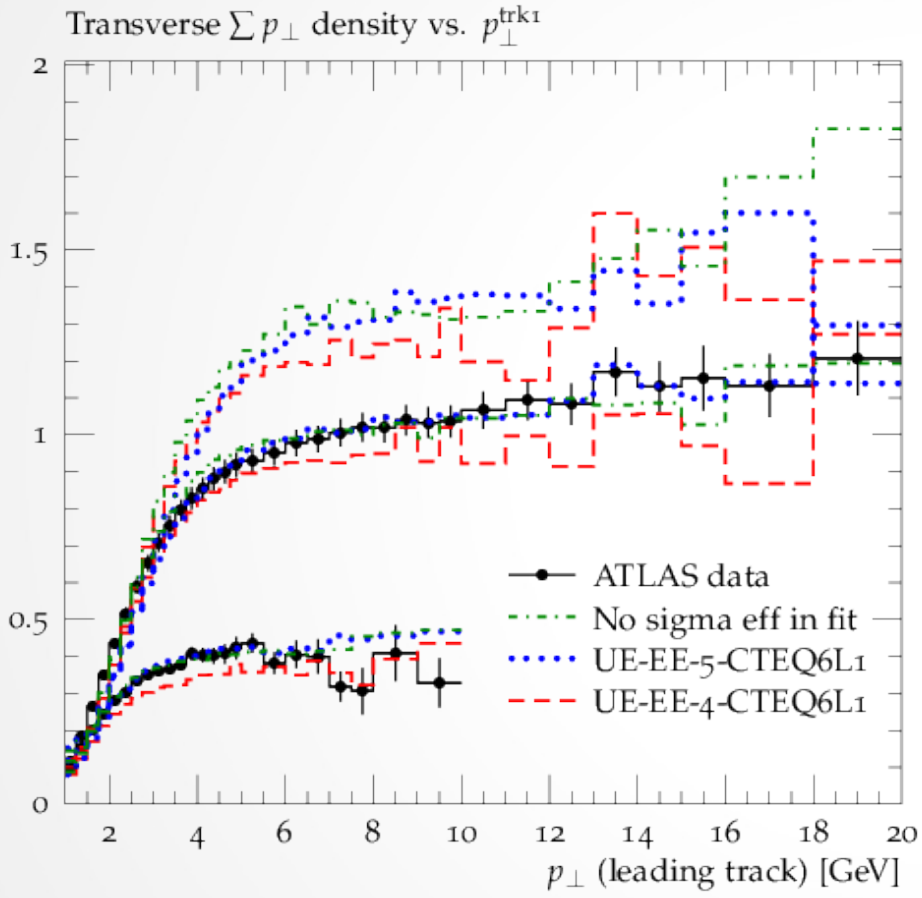
Extrapolation to 14 TeV

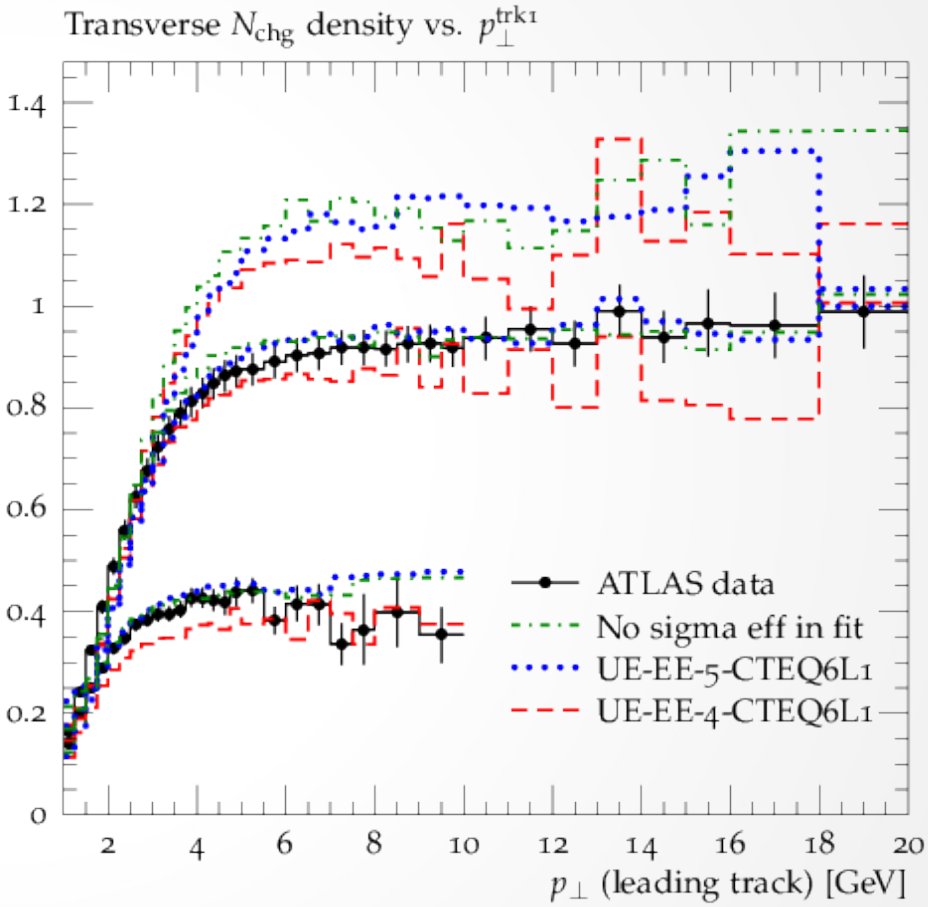
$$p_{\perp}^{\min} = p_{\perp,0}^{\min} \left(\frac{\sqrt{s}}{E_0} \right)^b$$



Constraining MPI models

Results





- All tunes give stable/similar prediction for 14 TeV.

Outlook/Conclusions

- We presented the first tune which took into account sigma_eff
- Very good description of UE leading track data over the collision energy range from 300 GeV to 7 TeV.
- Good agreement with sigma effective data: 14.8 mb (less than 1σ from its measured value)
- All tunes give stable/similar prediction for 14 TeV.
- It is default tune in Herwig++ version 2.7
- Correction to the sigma effective LHCb results - in progress.

  [M. H. Seymour, and AS, arXiv:1308.6749, see also talk tomorrow]

- It would be interesting to use more experimental data in the tune (for example UE jet measurements, Pt spectra)

Motivation

Backup

MPI model basics (Herwig++)

Average number of parton collisions

$$\bar{n}(b,s) = A(b) \cdot \sigma^{\text{inc}}(s, p_t^{\min})$$

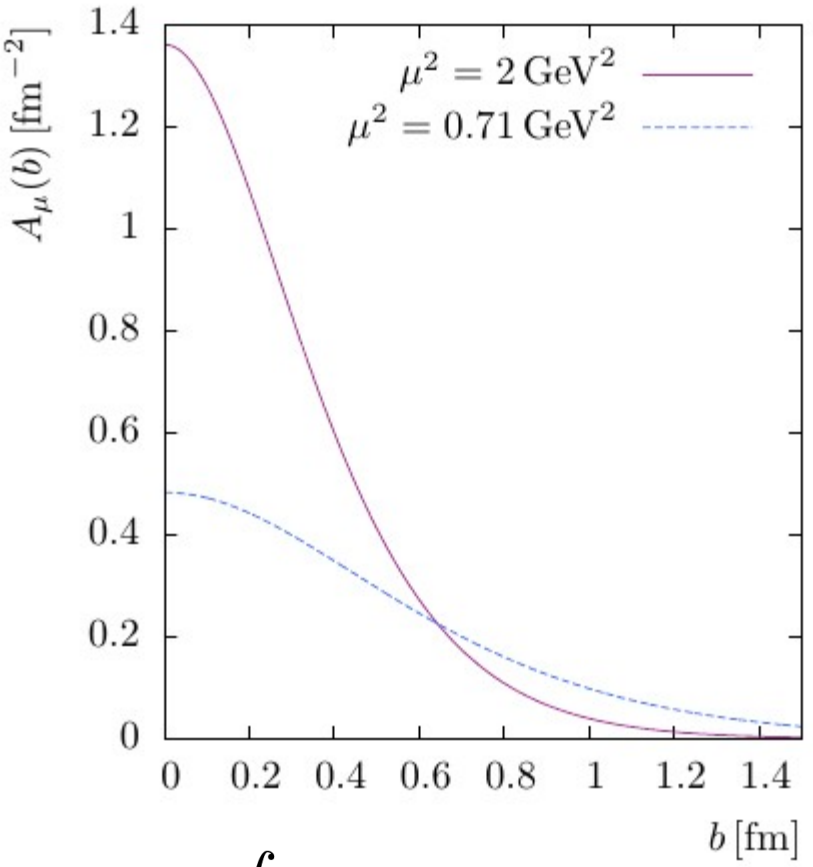
$$A(b,\mu) = \int \mathrm{d}^2 b' \; S_A(\mathbf{b}') \; S_B(\mathbf{b} - \mathbf{b}')$$

$S(\mathbf{b})$ from electromagnetic FF:

$$S_p(\mathbf{b}) = S_{\bar{p}}(\mathbf{b}) = \int \frac{\mathrm{d}^2 k}{(2\pi)^2} \frac{\mathrm{e}^{i\mathbf{k}\cdot\mathbf{b}}}{(1 + \mathbf{k}^2/\mu^2)^2}$$

But μ^2 *not fixed* to the *electromagnetic* $0.71\,\text{GeV}^2$.

Free for colour charges.



$$\int \mathrm{d}^2 b \, A(b) = 1$$

$\Rightarrow$ Two main parameters: μ^2 and $p_t^{\min}$

Tention between UE track and jet measurments?