Herwig++: progress in soft and UE modeling

Minimum Bias and Underlying Event Working Group

Andrzej Siódmok on behalf of Herwig++ group

Karlsruhe Institute of Technology

CERN, 8 January 2011

Outline

This talk:

- Evolution of Underlying Event in Herwig++
- Colour structure
- Results: MB and UE @ 900 GeV and @ 7 TeV
- New Release - Herwig++ 2.5
- Outlook

Underlying event in Herwig++

UA5 model (deprecated, only for reference)

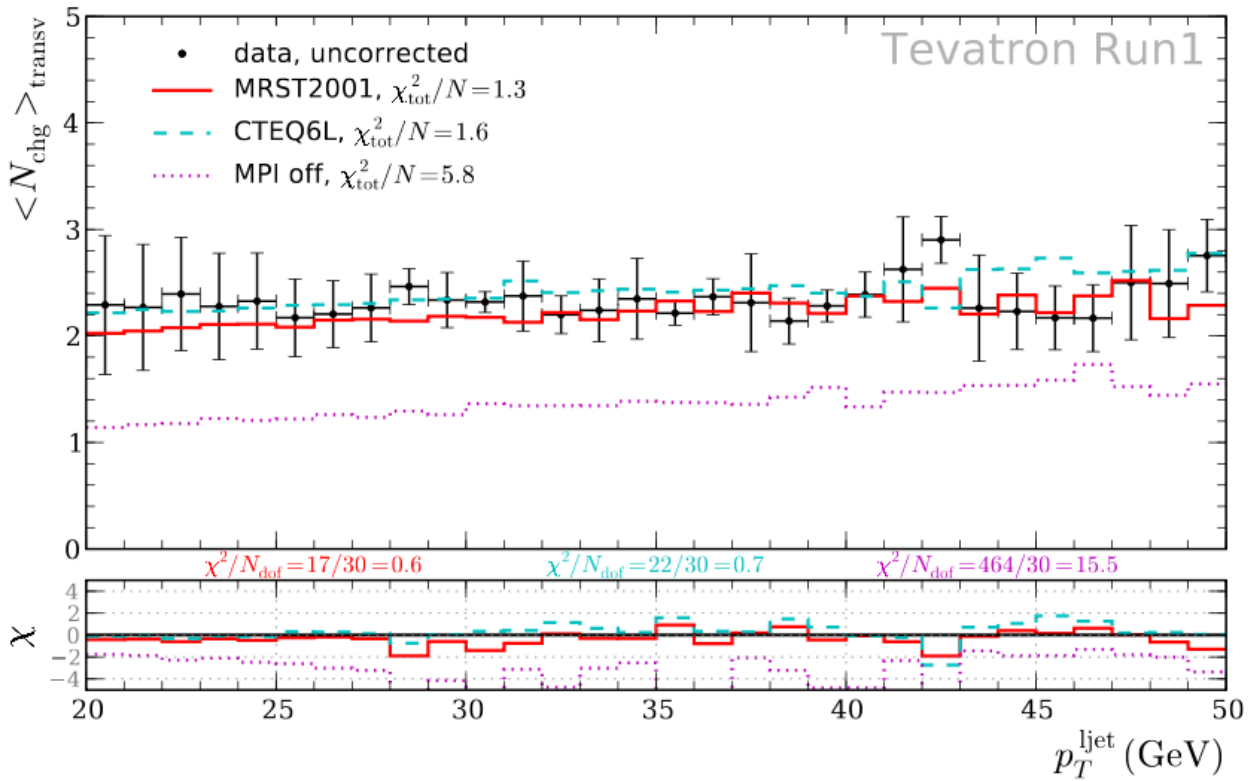
- Included from Herwig++ 2.0. [Herwig++, hep-ph/0609306]
- Little predictive power.
- Was default in fHerwig. Superseded by JIMMY

[JM Butterworth, JR Forshaw, MH Seymour, ZP C72 637 (1996)]

Semihard UE

- Default from Herwig++ 2.1. [Herwig++, 0711.3137]
- Multiple hard interactions, $p_t \geqslant p_t^{min}$ [Bähr, Gieseke, Seymour, JHEP 0807:076]
- Similar to JIMMY
- Good description of harder Run I UE data (Jet20).

Good description of Run I Underlying event data ($\chi^2 = 1.3$).



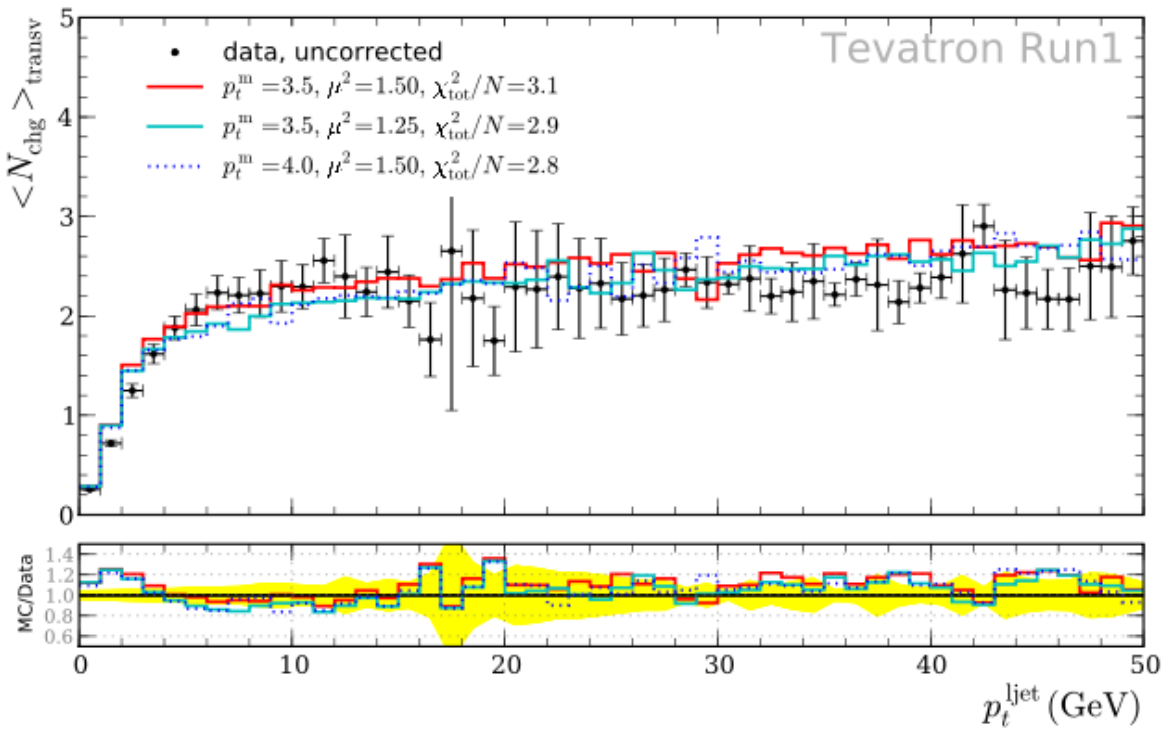
Only $p_T^{ljet} > 20\,\text{GeV}$.

Semihard+Soft UE

- Default from Herwig++ 2.3. [Herwig++, 0812.0529]
- Extension to soft interactions, $p_t \leqslant p_t^{min}$ [Bähr, Gieseke, Seymour, JHEP 0807:076]
- Theoretical work with simplest possible extension. [Bähr, Butterworth, Seymour, JHEP 0901:065]
- "Hot Spot" model. [Bähr, Butterworth, Gieseke, Seymour, 0905.4671]

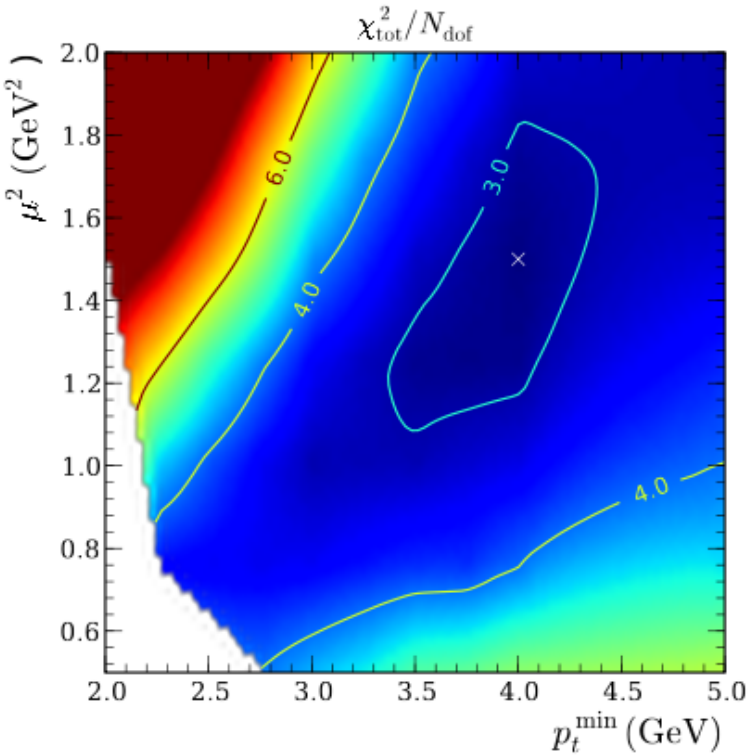
For details look at Herwig++ talk at MB & UE WG - 06 September 2010 - link

TVT results


Tevatron Run1
data, uncorrected
$p_t^{\rm m}$ =3.5, μ^2=1.50, $\chi^2_{\rm tot}/N$=3.1
$p_t^{\rm m}$ =3.5, μ^2=1.25, $\chi^2_{\rm tot}/N$=2.9
$p_t^{\rm m}$ =4.0, μ^2=1.50, $\chi^2_{\rm tot}/N$=2.8
$< N_{\rm chg} >_{\rm transv}$
MC/Data
$p_t^{\rm ljet}$ (GeV)

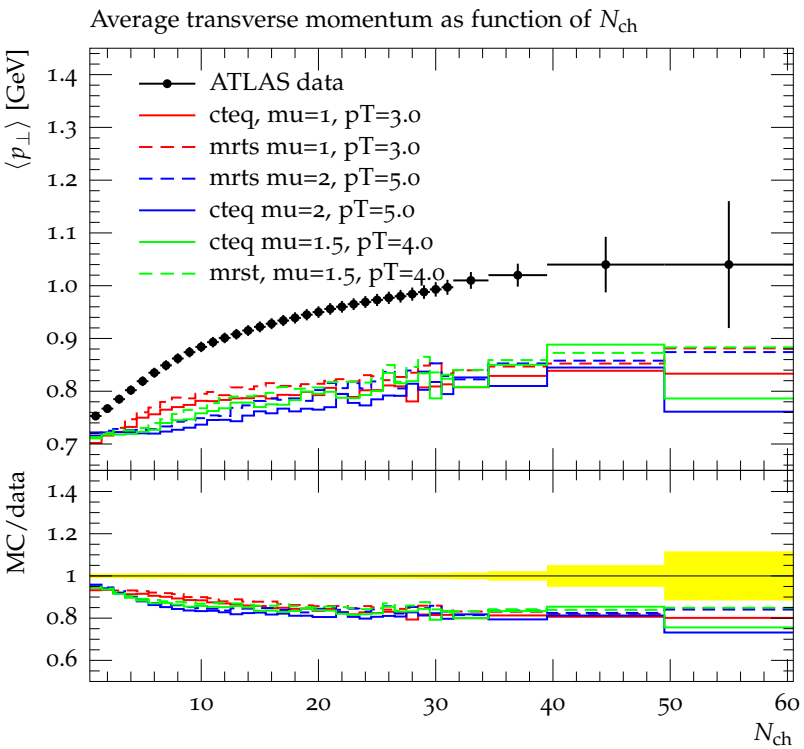
TVT results

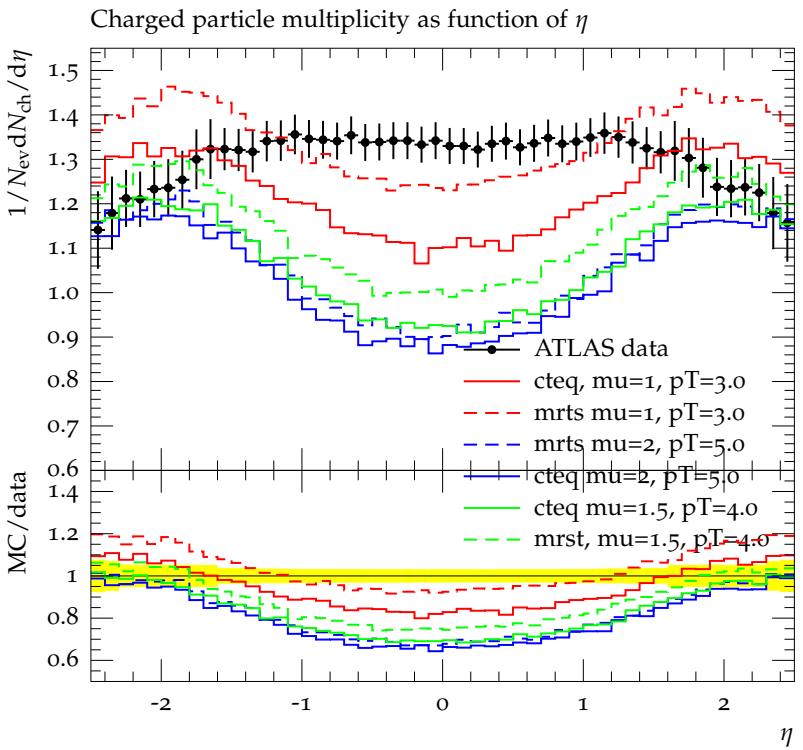
- χ^2 for Rick's Run1 Jet analysis for **all** regions



Comparison with MinBias ATLAS data (900 GeV)

- ATLAS charged particles in Min Bias.
- Convenient as the analysis was quickly available in `RIVET`.



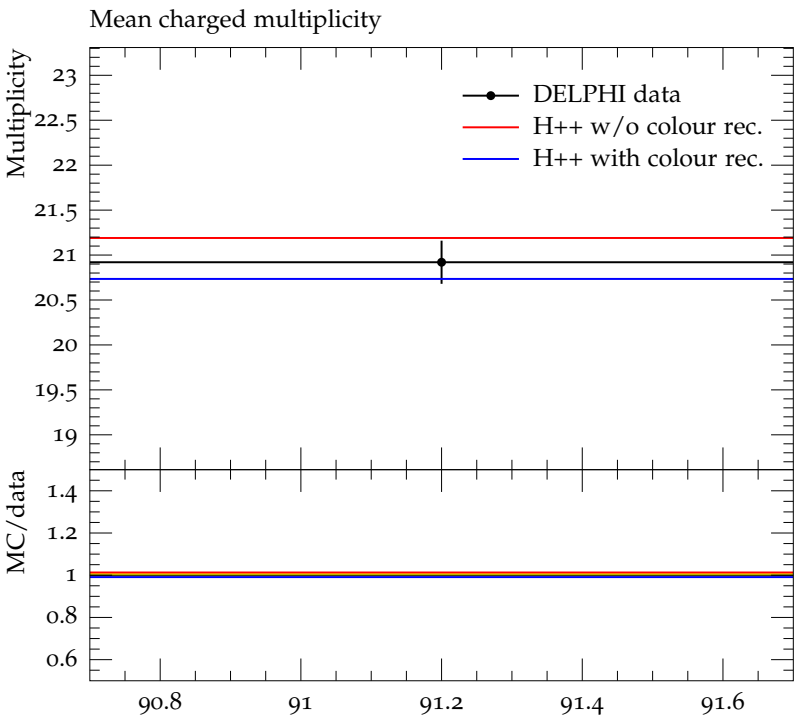


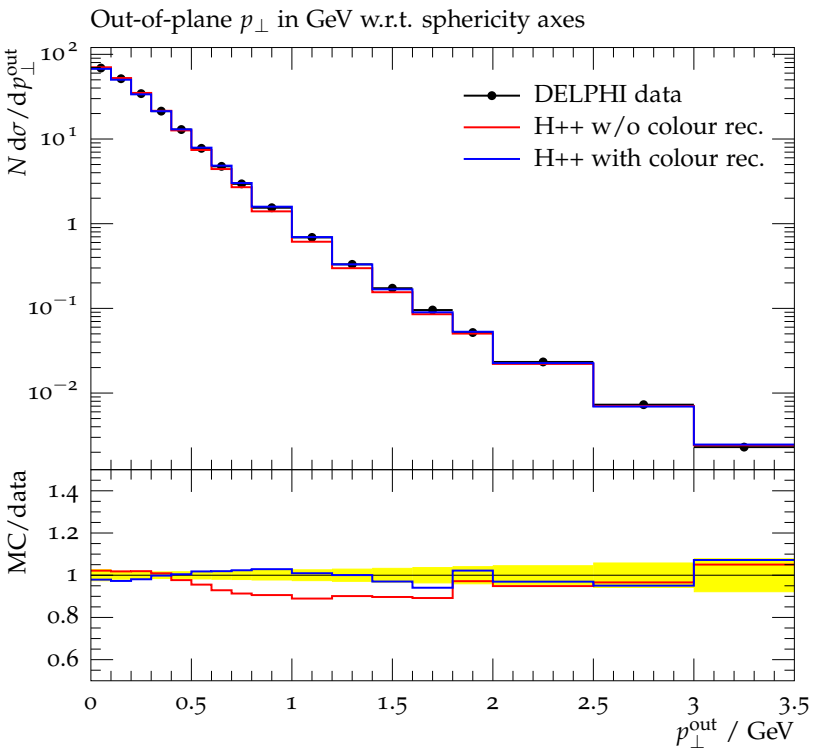
Colour Structure of the Underlying Event

- Colour Reconnection (parameter p_{reco}) - Included from Herwig++ 2.5
- Colour Distribution - only Soft UE (parameter p_{CD})
- Retuning to LEP data needed.
- Tests of Colour Reconnection model.

For details look at Herwig++ talk at MB & UE WG - 06 September 2010 - link

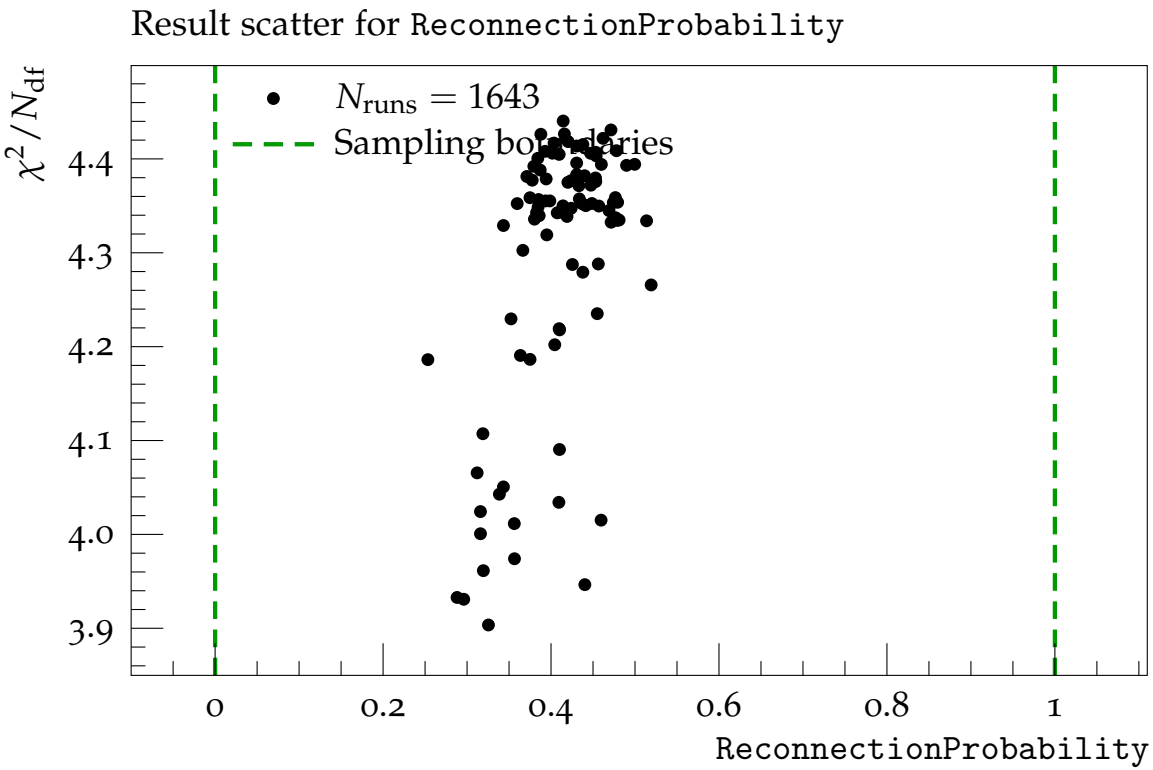
Can we still describe the LEP data similar to Herwig++ w/o colour reconnection?





We repeated tuning of the hadronization to the LEP data (above 2 examples). Both tunings (with and w/o colour rec.) seems to describe the data at the same level.

Can we still describe the LEP data similar to Herwig++ w/o colour reconnection?



Prefered by LEP data is: $0.2 \leq p_{\mathrm{reco}} \leq 0.6$

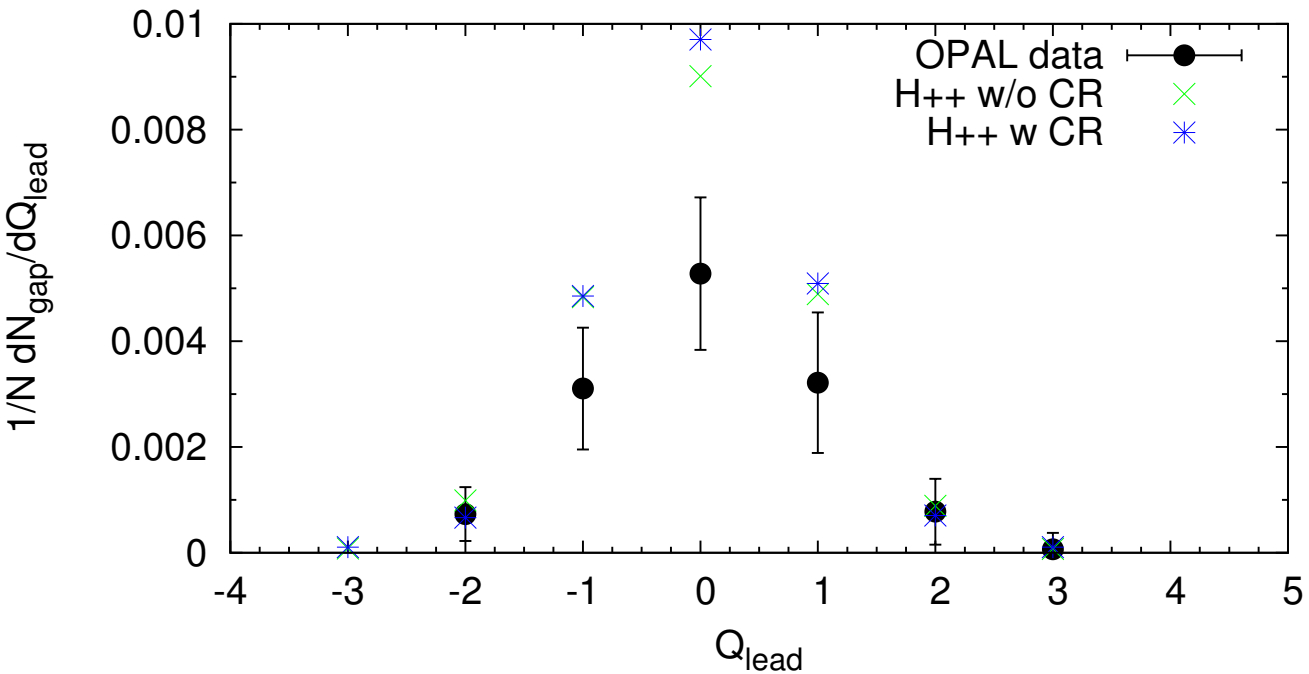
Colour Reconnection model tests - OPAL collaboration arXiv:hep-ex/0306021v1

1. Leif's suggestion: OPAL collaboration arXiv:hep-ex/0306021v1:

"Tests of models of color reconnection and a search for glueballs using gluon jets with a rapidity gap"

A subsample of gluon jets from hadronic Z decay exhibits a large gap in the rapidity. These jets are observed to demonstrate a sensitivity to the presence of color reconnection.

Fig14 Opal



- Small difference between Herwig++ with and w/o colour rec.!
- Not sure about the normalsization...

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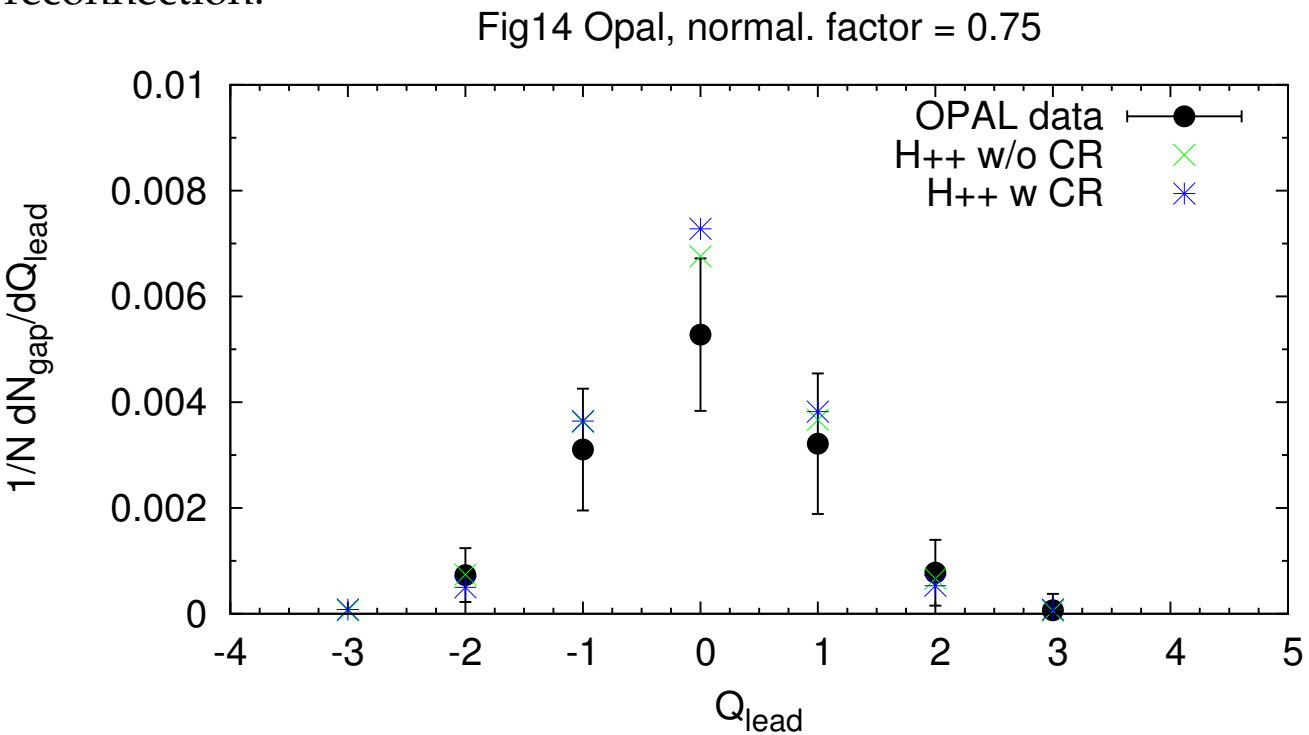

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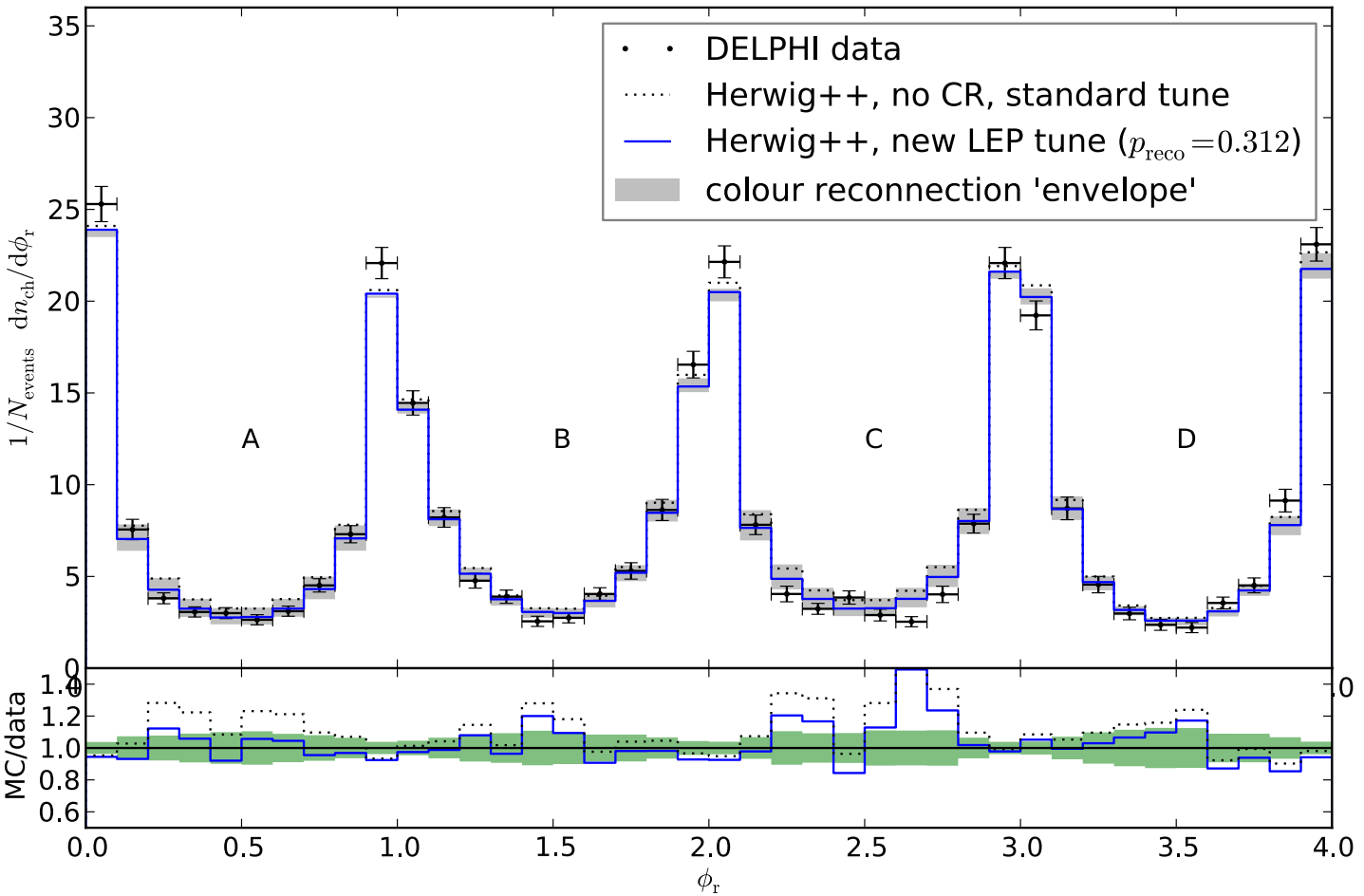
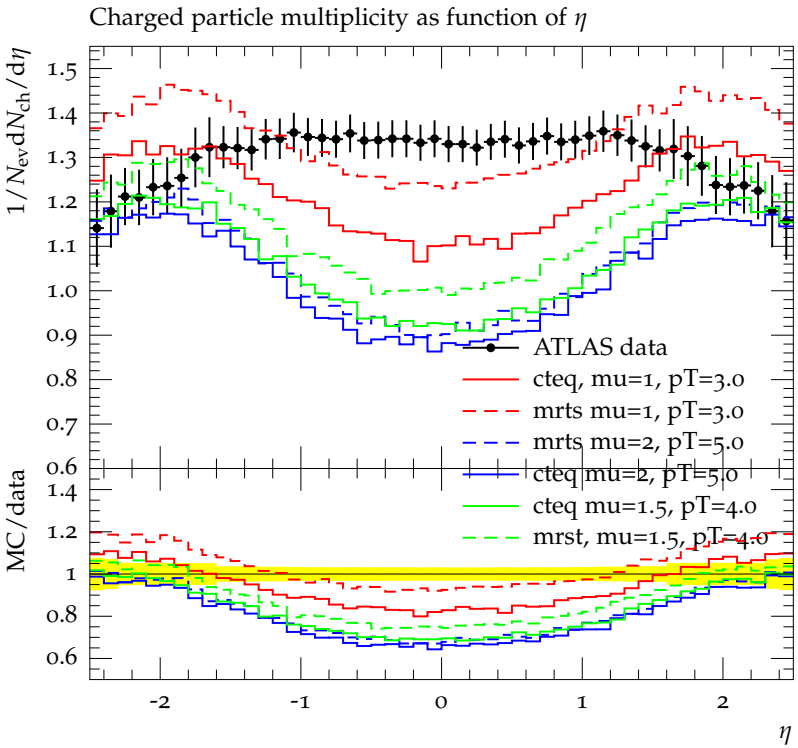
Retrospective: particle flow in $WW \to 4j$ at LEP

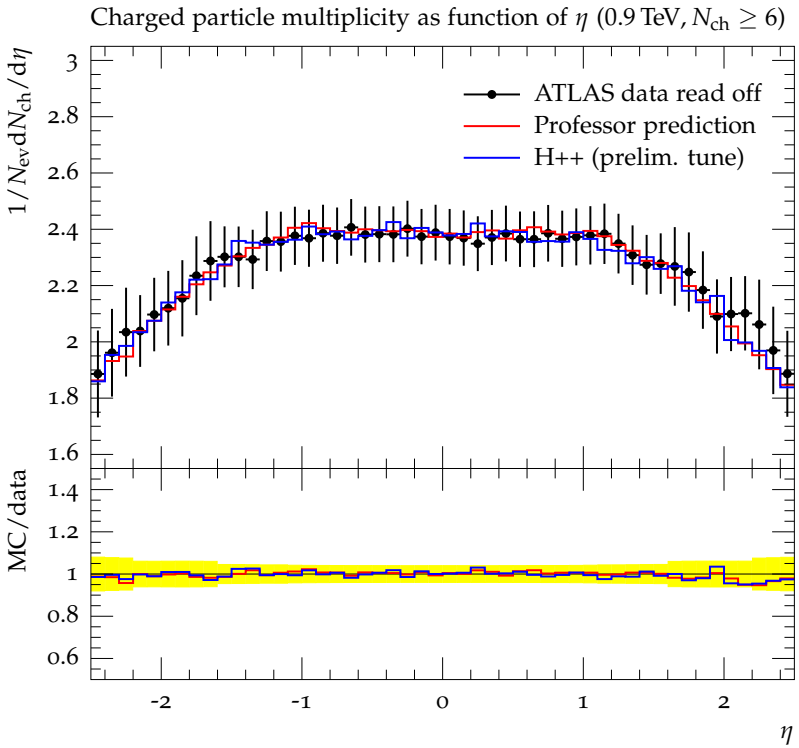


- small effects here
- marginal improvement (if at all)

data from [DELPHI Collaboration, Eur. Phys. J. C51 (2007) 249-269]

MinBias ATLAS 900 GeV





Many thanks to the Professor team for help and hints how to use their program!

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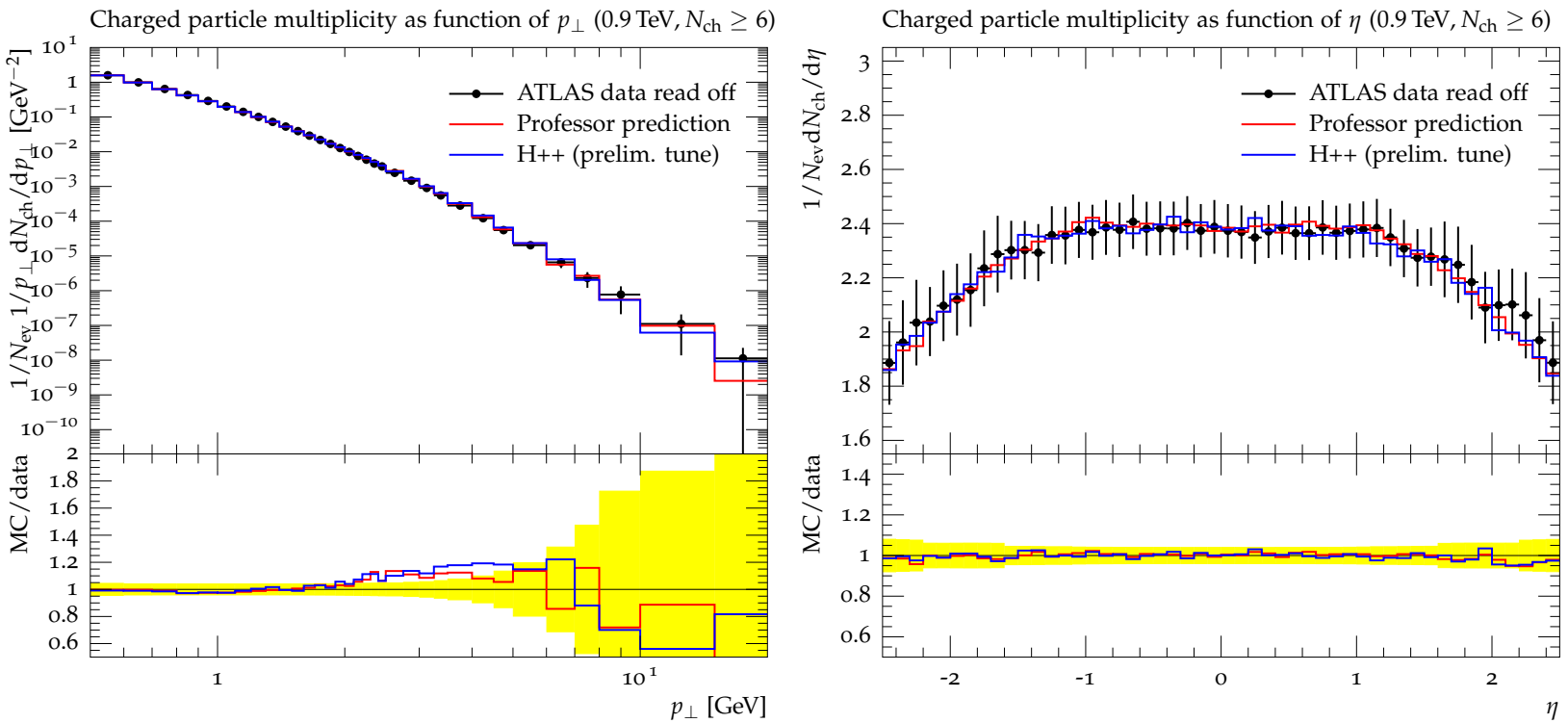

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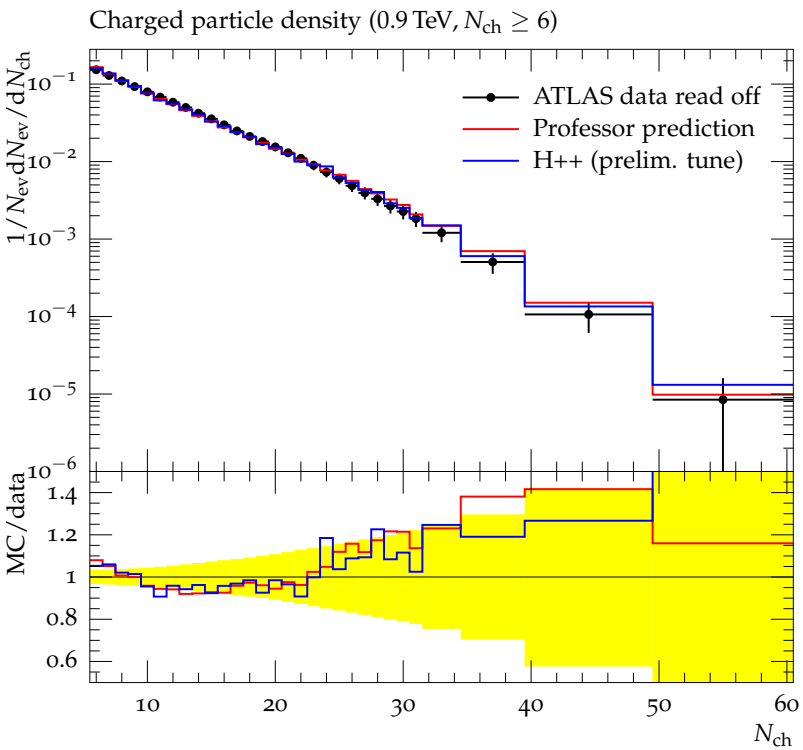

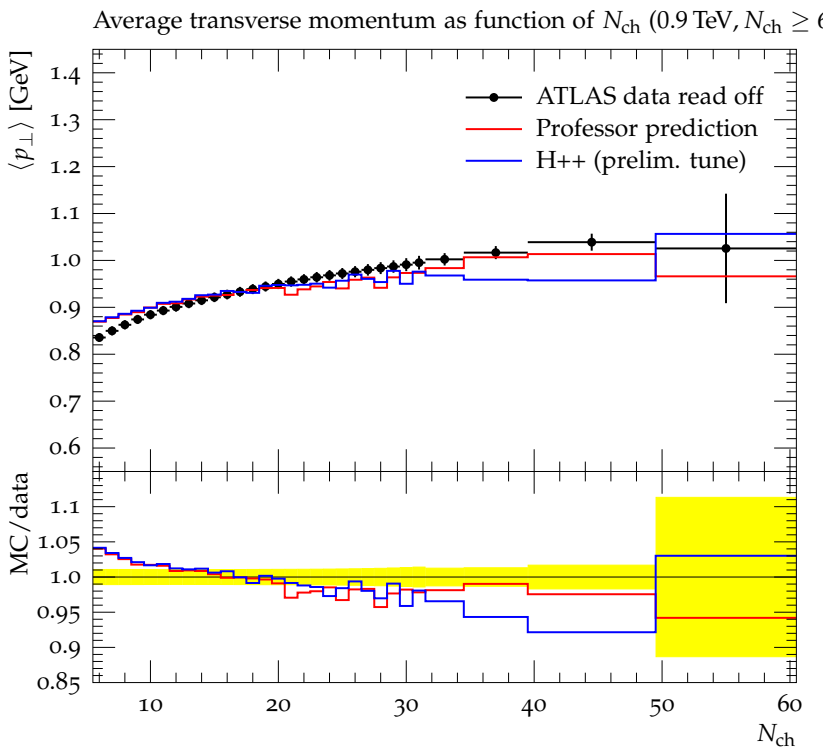

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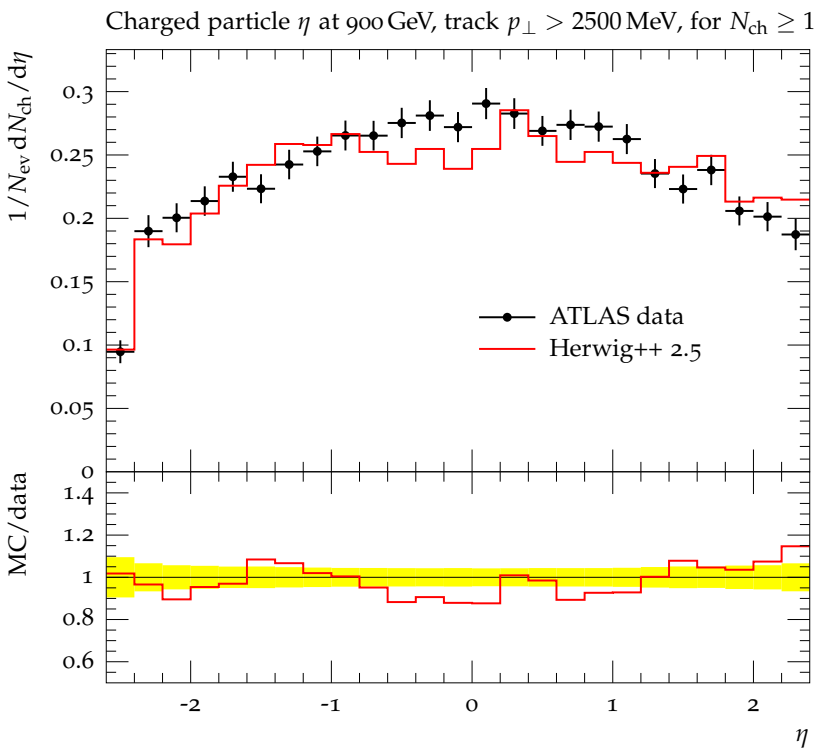

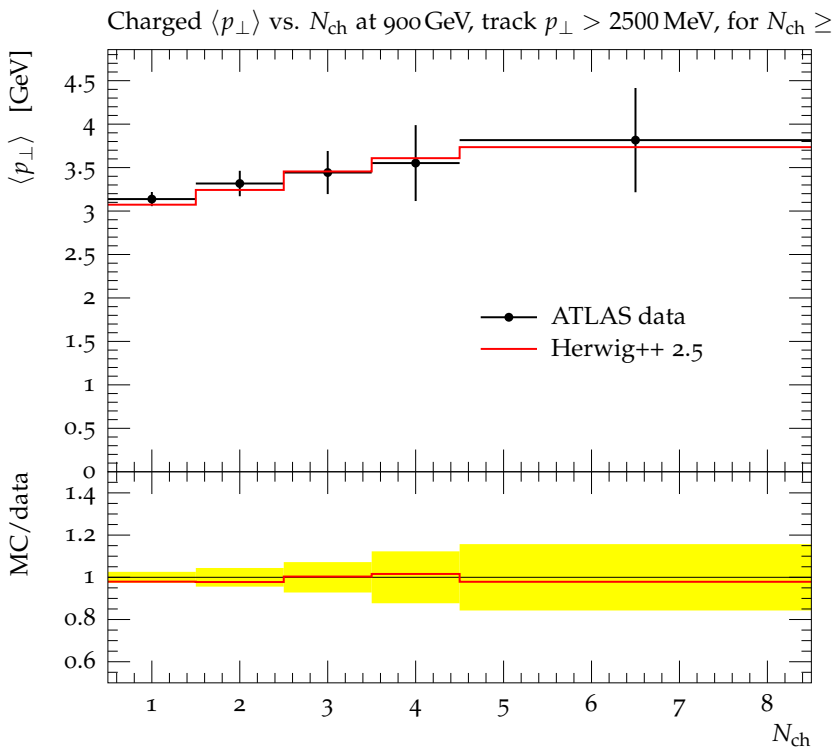

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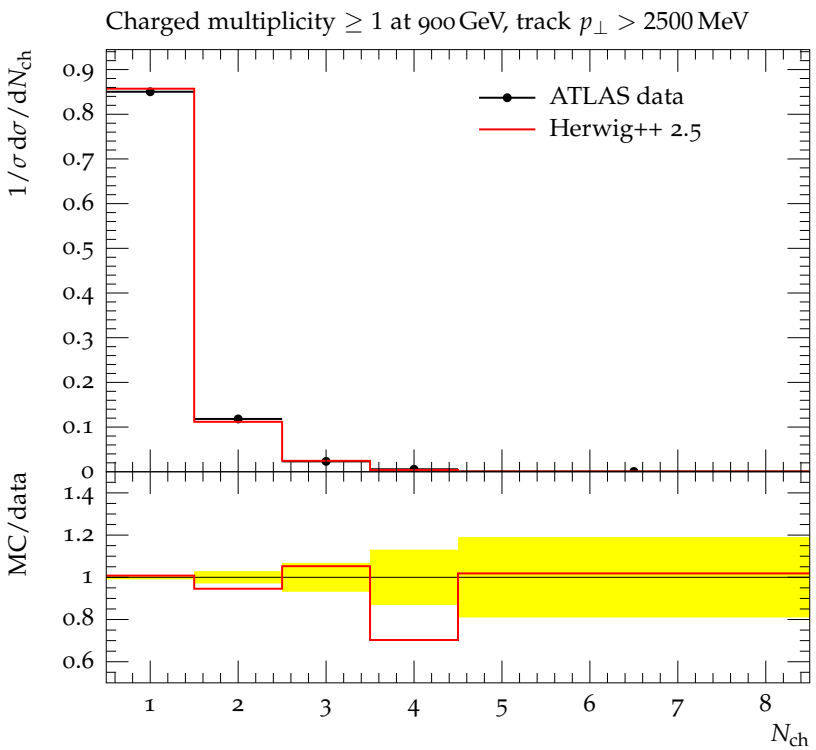

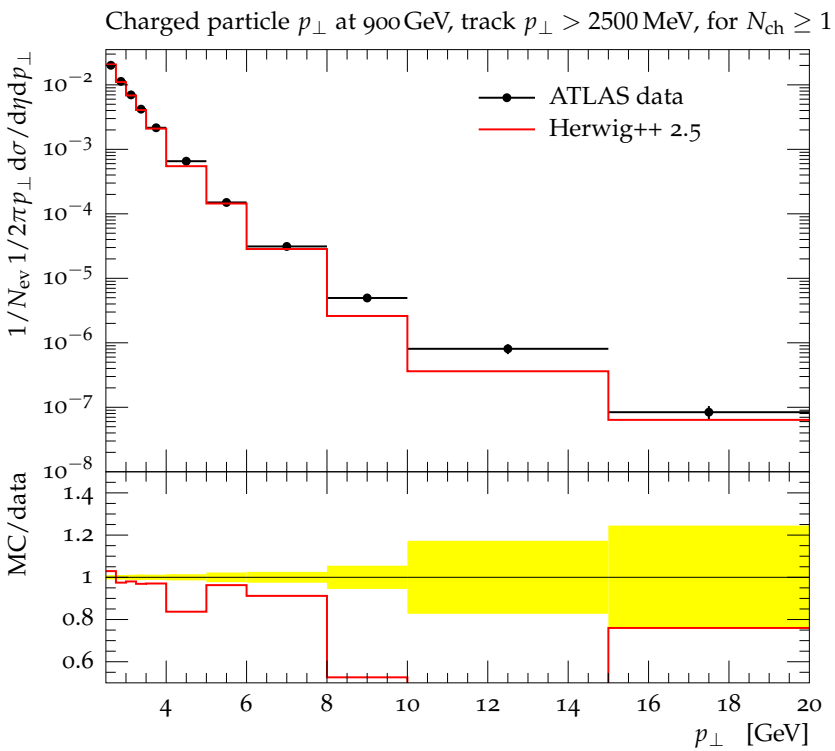

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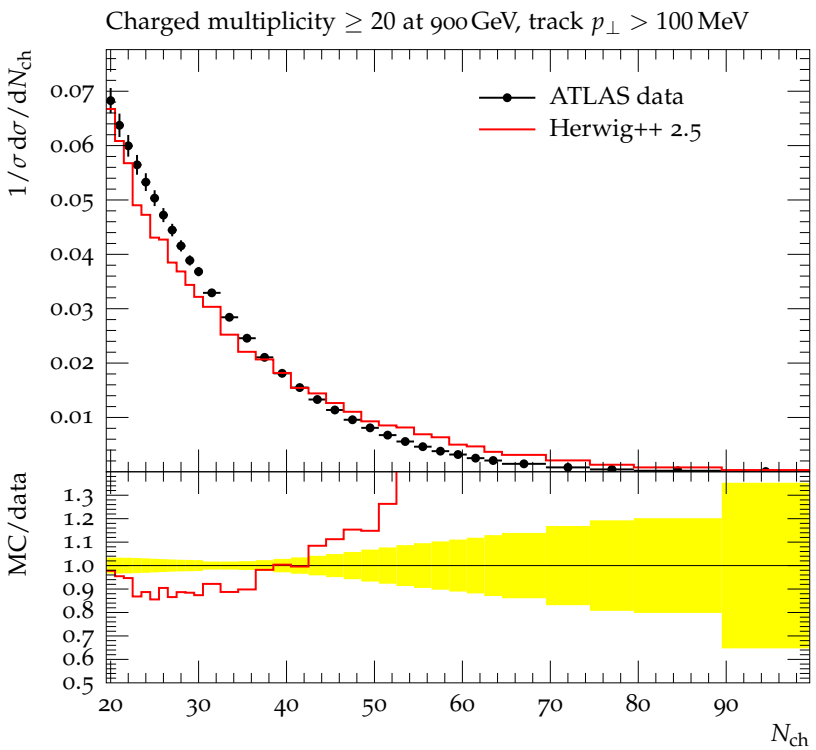

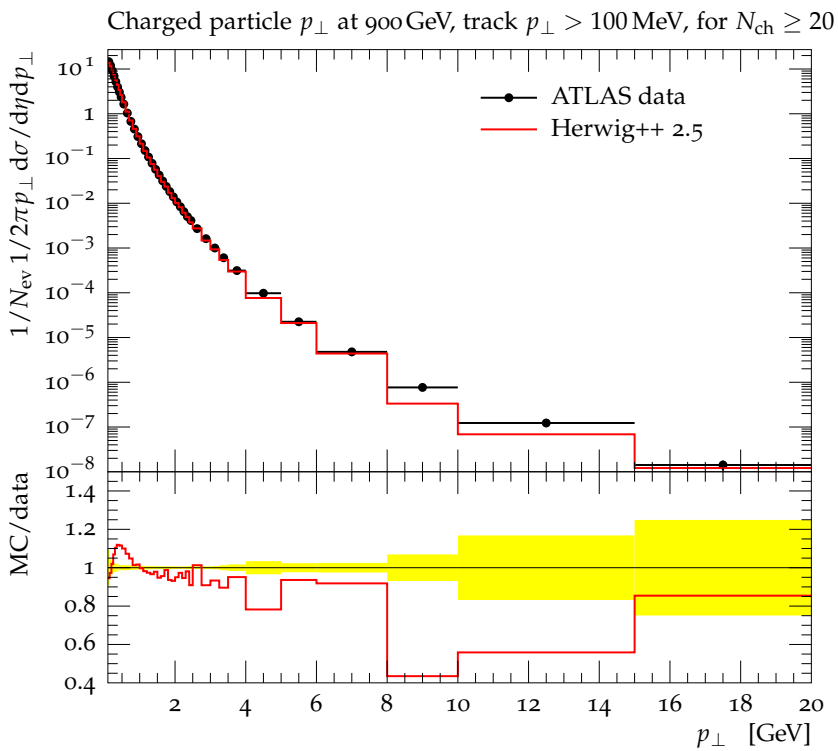

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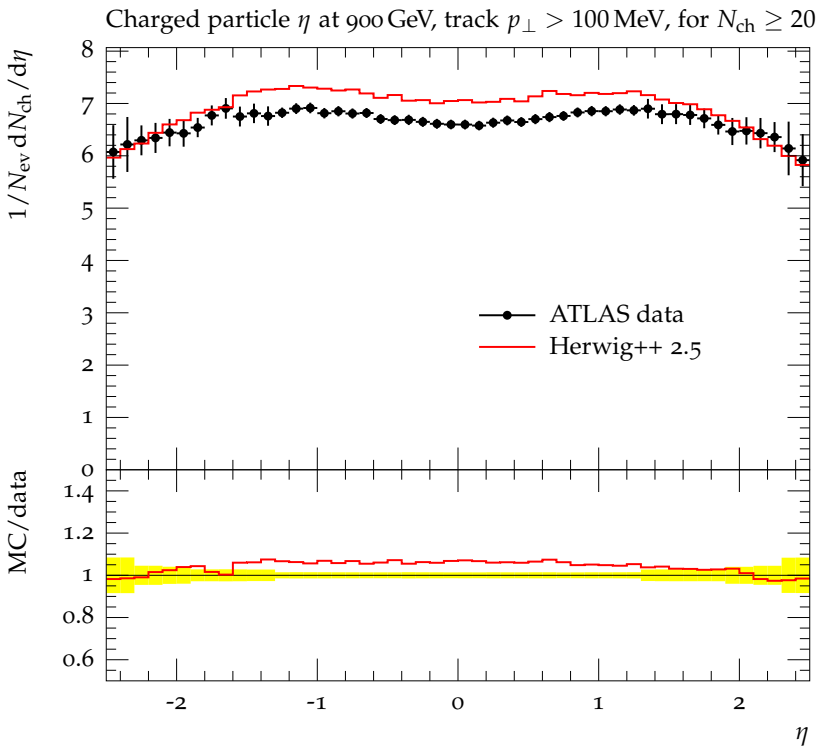

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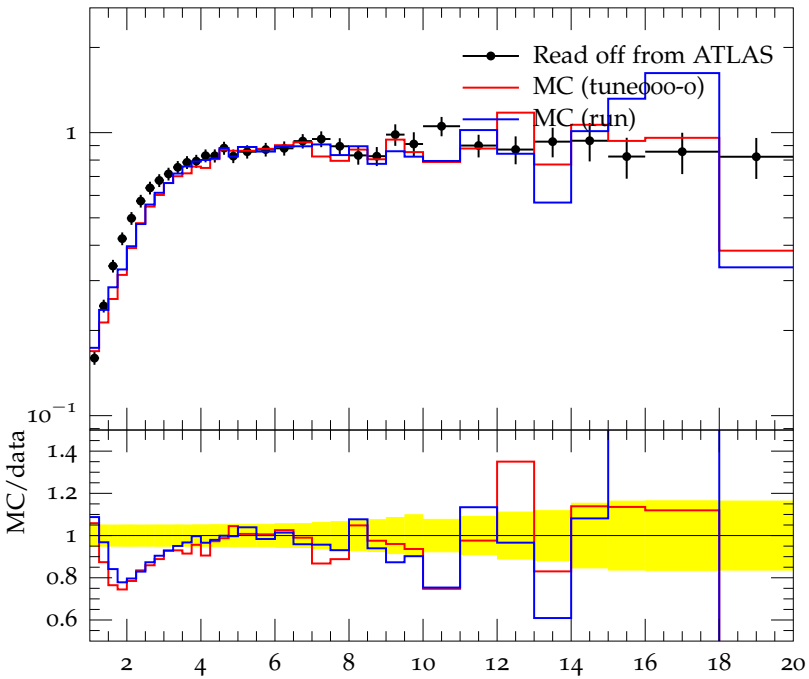
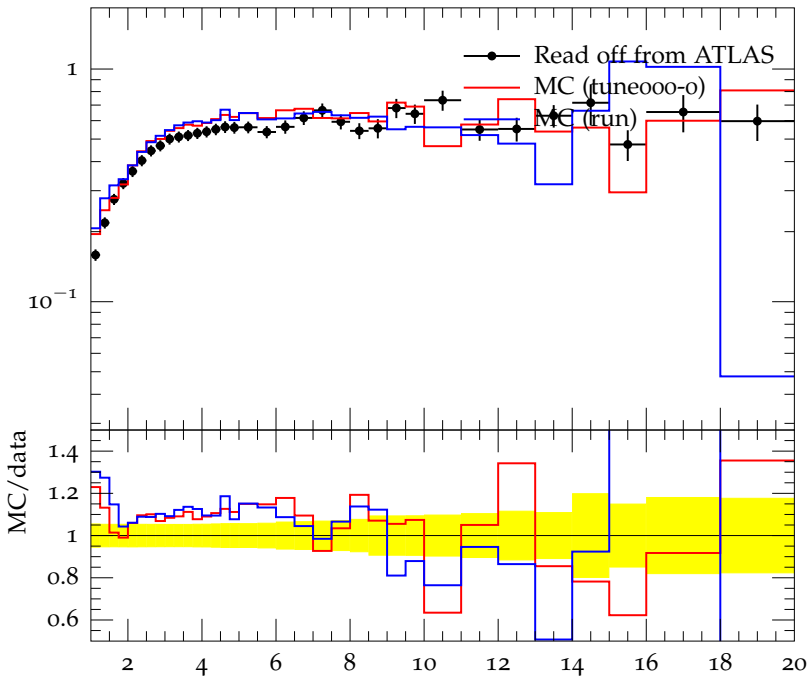
Underlying Event 7000 GeV (ATLAS-CONF-2010-029)

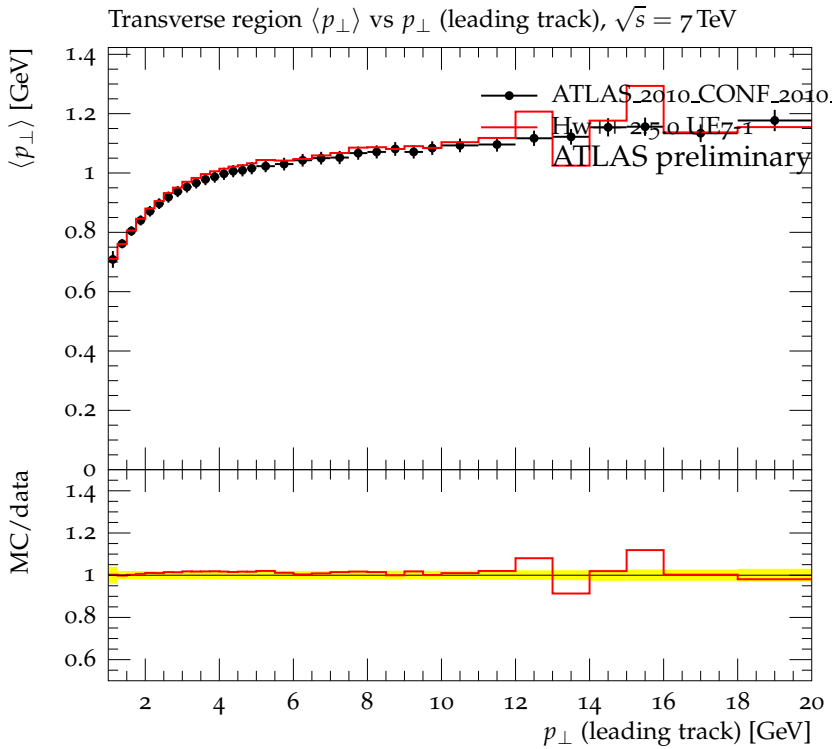
N_{ch}/StdDev transverse vs p_t^{lead}/GeV

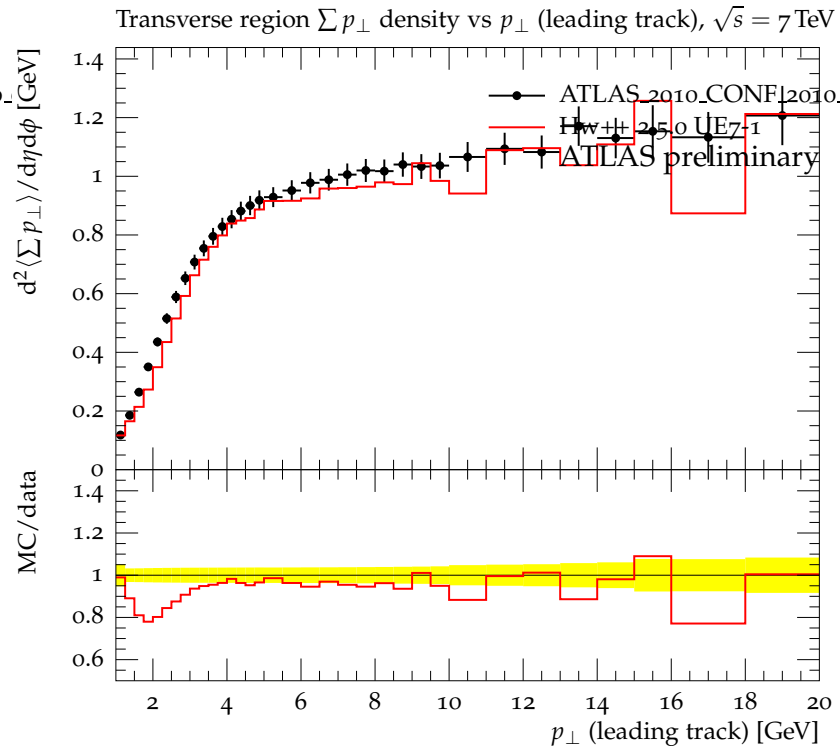




Slide from MPI@LHC 2010 in Glasgow

$p_t^{min} = 3.2\,GeV\,, \quad \mu^2 = 0.81\,GeV^2, \quad p_{\text{reco}} = 0.61, \quad p_{\text{disrupt}} = 0.34$


Transverse region $\langle p_\perp \rangle$ vs $p_\perp$ (leading track), $\sqrt{s} = 7$ TeV
$\langle p_\perp \rangle$ [GeV]
ATLAS_2010_CONF_2010_
Herwig++ 2.5.0 UE7-1
ATLAS preliminary
MC/data
$p_\perp$ (leading track) [GeV]


Transverse region $\sum p_\perp$ density vs $p_\perp$ (leading track), $\sqrt{s} = 7$ TeV
$d^2\langle \sum p_\perp \rangle / d\eta d\phi$ [GeV]
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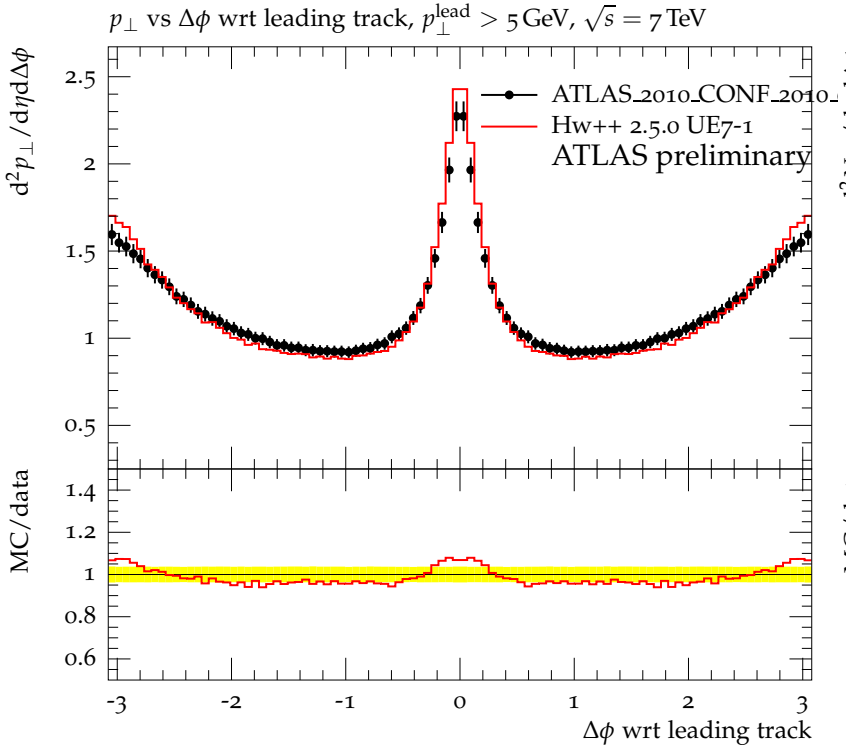

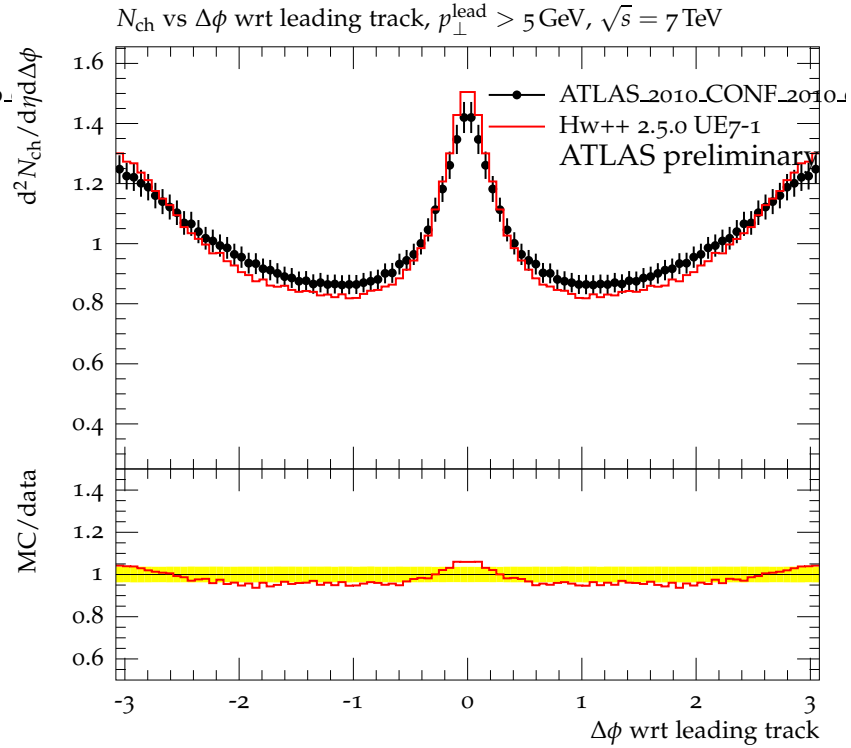

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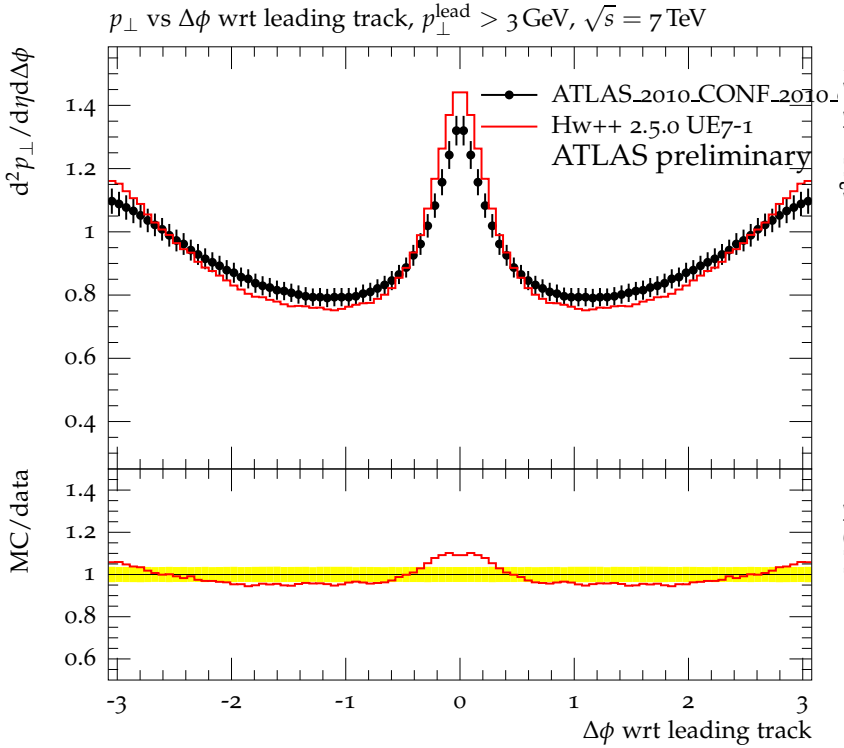

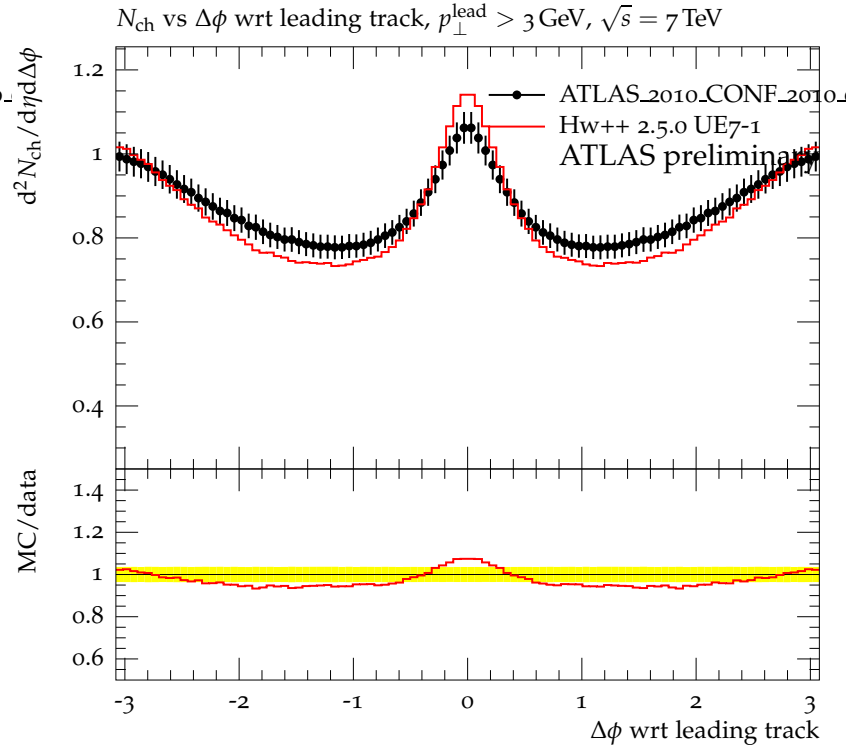

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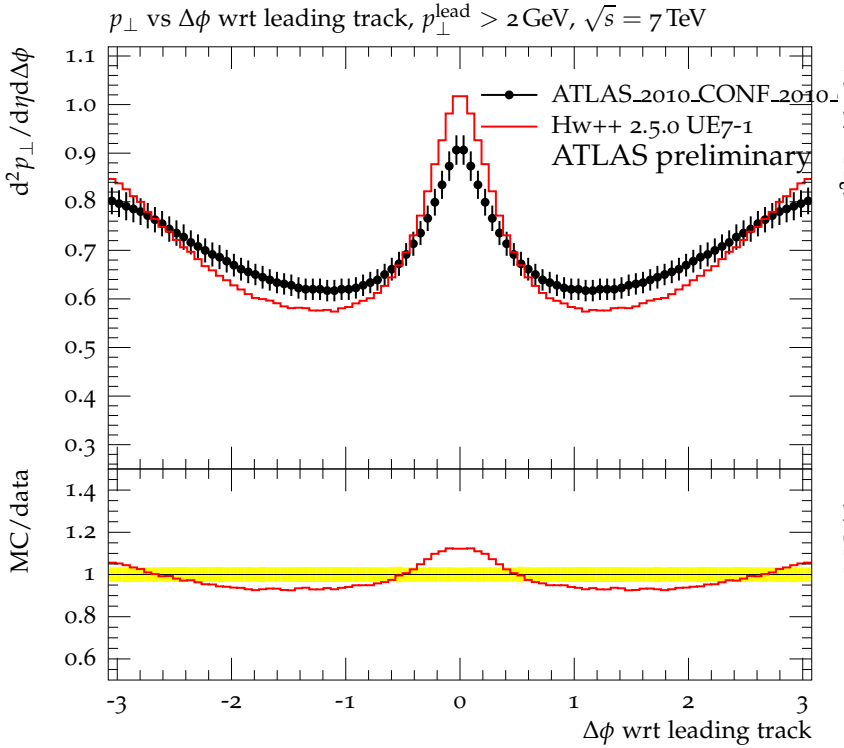

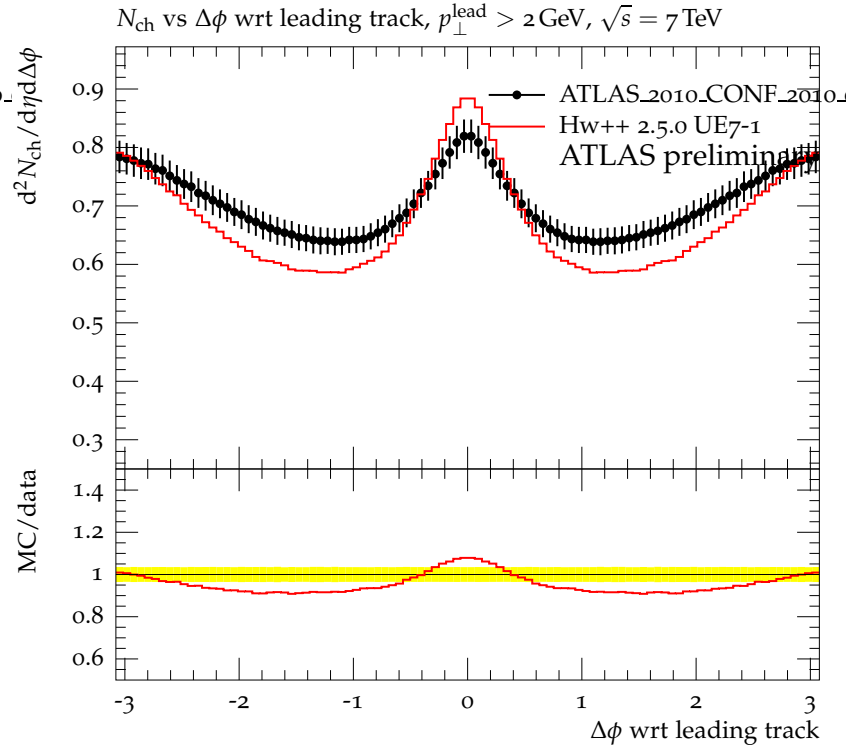

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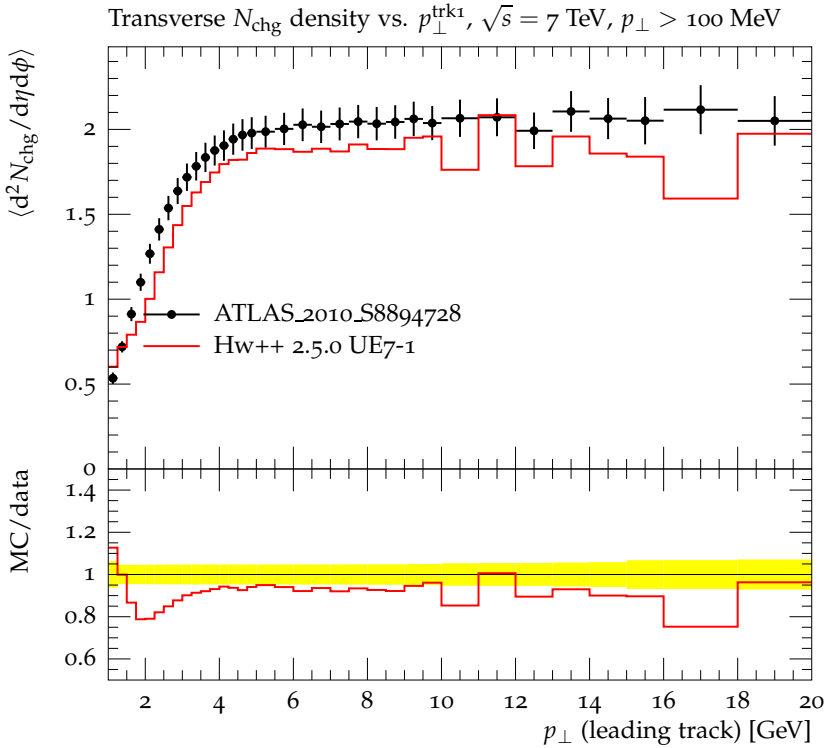

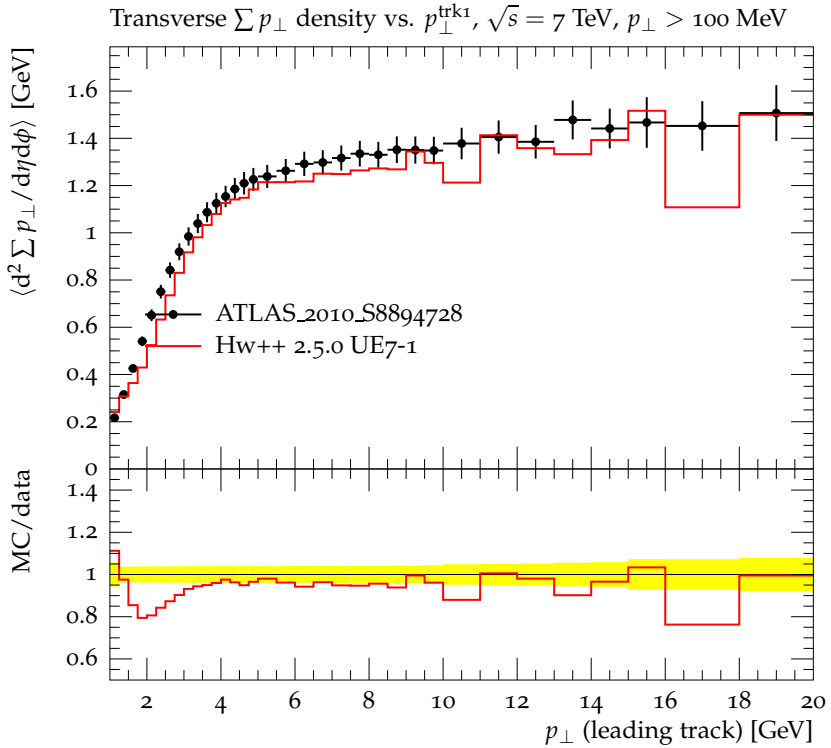

In Glasgow Arthur Moraes asked us how it would look like for $p_T = 100$
Tunes (input files, plots) are available at Herwig++ wiki page.

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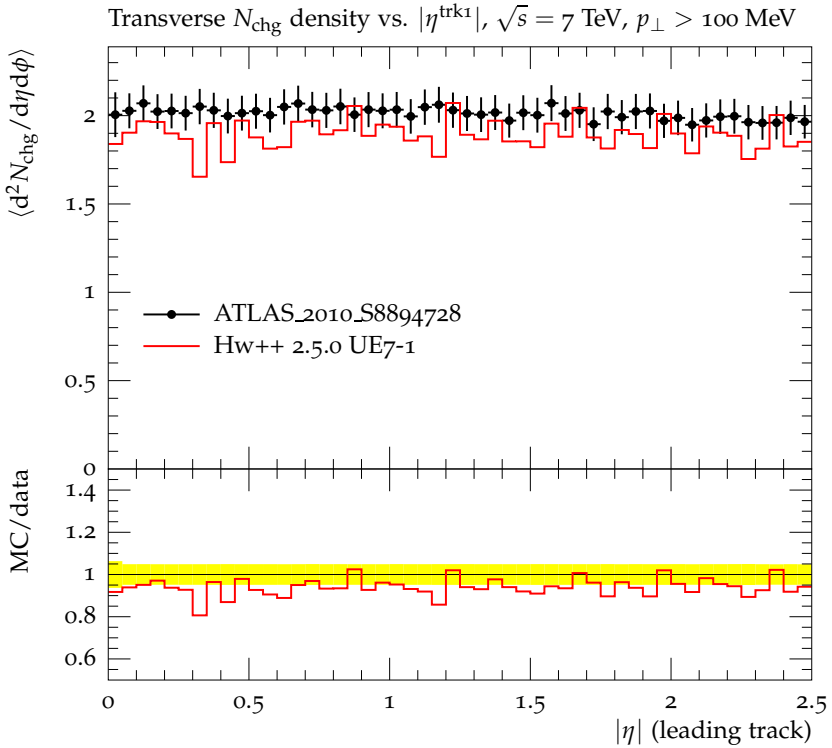

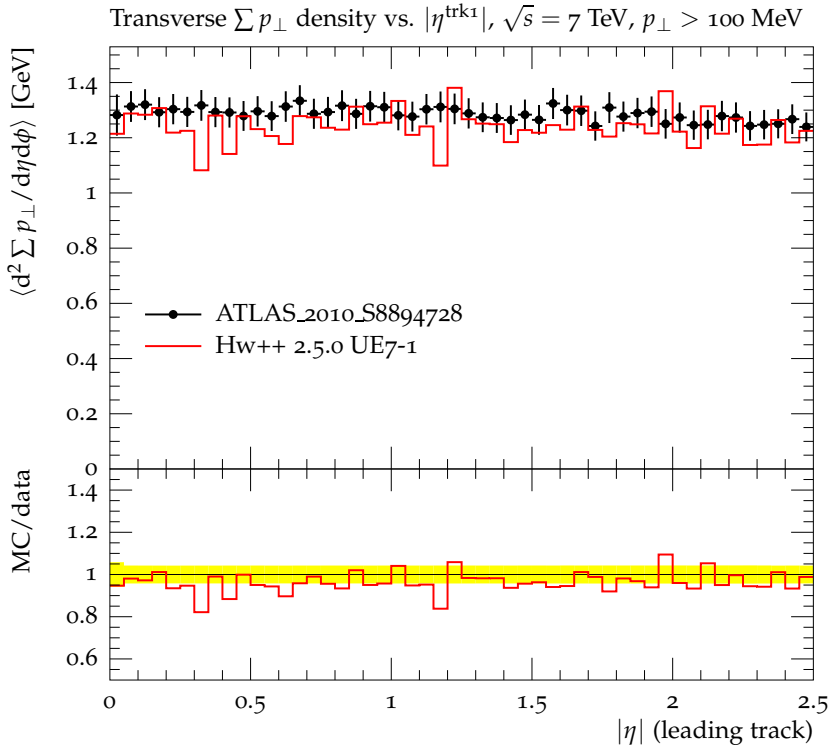

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New release: Herwig++ 2.5 (today?)

Herwig++ 2.5

- POWHEG NLO parton shower matching scheme with:
  - Vector Boson Pair Production
  - $e^+e^- \longrightarrow q\bar{q}$
  - Higgs Decay
- MC@NLO program now can be use with Herwig++
- Colour Reconnection
- Diffractive and Photon Initiated Processes
- BSM Physics
  (ADD Model, Leptoquarks, NMSSM, Transplanckian Scattering)
- New Matrix Elements

For details look at release note.

Summary

- New implementation of colour reconnection is validated, also tested against LEP analyses and seems to work very well.
  You can test it - Herwig++ 2.5!
- First tunes to 900 GeV and 7000 GeV Min Bias ($N_{ch} \geqslant 6$) and UE give good results.
- Tunes (input files, plots) are available at Herwig++ wiki page.
- Non-diffractive physics under good control

Open questions:

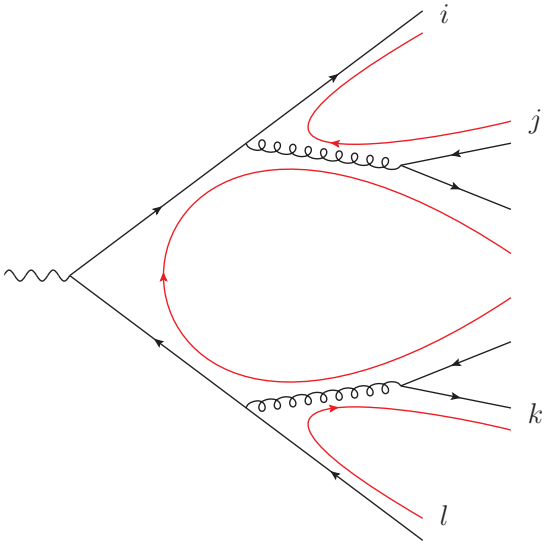
- Treatment of remnant pdfs too naive?
- More involved overlap function (x-dependent)?

Outlook:

- Look at more data from LHC experiments (strange particle and proton production).
- Energy dependent parameters?
- More tunes.
- Minimum bias/underlying event/diffraction under constant improvement!
- Stay tuned!

Backup

Colour reconnection (CR) in Herwig++



Extending the hadronization model in Herwig(++):

- QCD parton showers provide *pre-confinement* $\Rightarrow$ colour-anticolour pairs form highly excited hadronic states, the *clusters*

[1] For details look at Christians Röhr's Diploma thesis

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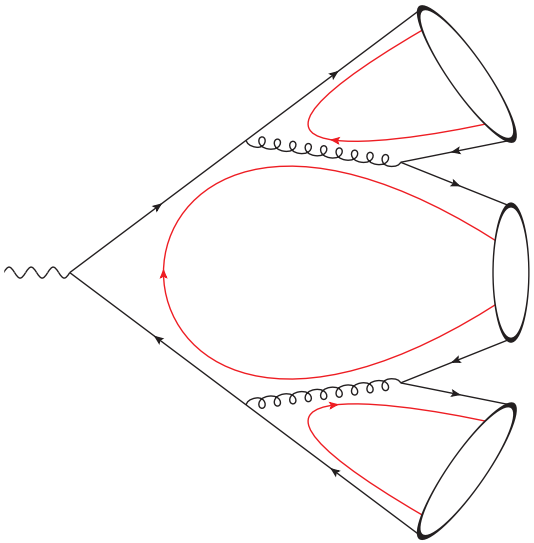

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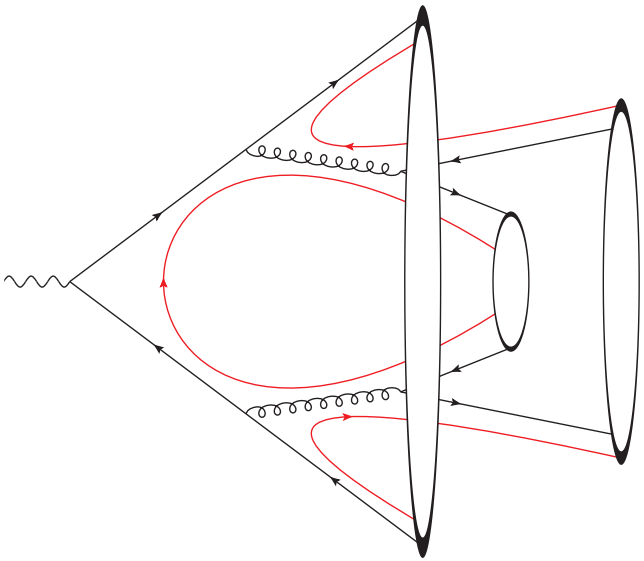

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- QCD parton showers provide *pre-confinement* $\Rightarrow$ colour-anticolour pairs form highly excited hadronic states, the *clusters*
- CR in the cluster hadronization model: allow *reformation* of clusters, *e.g.* $(il) + (jk)$
- Physical motivation: exchange of soft gluons during non-perturbative hadronization phase

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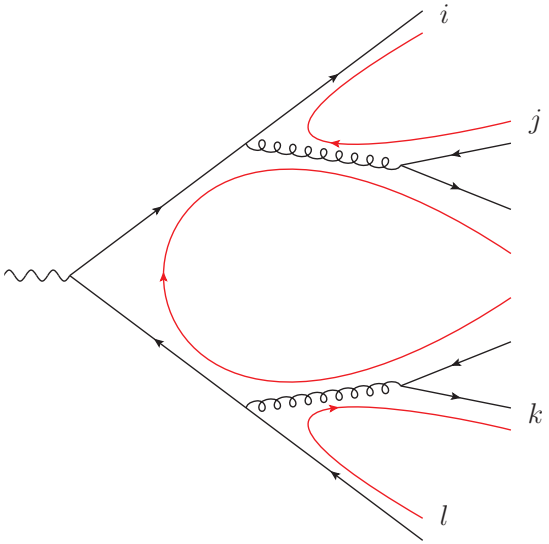

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Implementation[1]

- Allow CR if the cluster mass decreases,

$$M_{il} + M_{kj} < M_{ij} + M_{kl},$$

  where $M_{ab}^2 = (p_a + p_b)^2$ is the (squared) cluster mass
- Accept alternative clustering with probability p_{reco} (model parameter) $\Rightarrow$ this allows to switch on CR smoothly

[1] For details look at Christians Röhr's Diploma thesis