Tuning MCs using ATLAS boson transverse momentum measurements

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OUTLINE

▶ **ATLAS Z p_T and W p_T measurements;**

▶ **Pythia6 AUET2B tune extension with the ATLAS Z p_T data;**

▶ **POWHEG+Pythia studies on ATLAS Z p_T data;**

▶ **Summary.**

We have a pubnote on this studies: ATLAS-PUB-2011-015
«Studies of vector boson transverse momentum simulation by Monte Carlo generators».

This note summarises the status of several ongoing studies to understand the origins of the discrepancy between MC predictions and ATLAS Z p_T and W p_T data and whether it can be reduced or eliminated.

ATLAS Z P_T MEASUREMENT

$Z \rightarrow e^+e^-$ (35 pb^{-1})
$Z \rightarrow \mu^+\mu^-$ (40 pb^{-1})
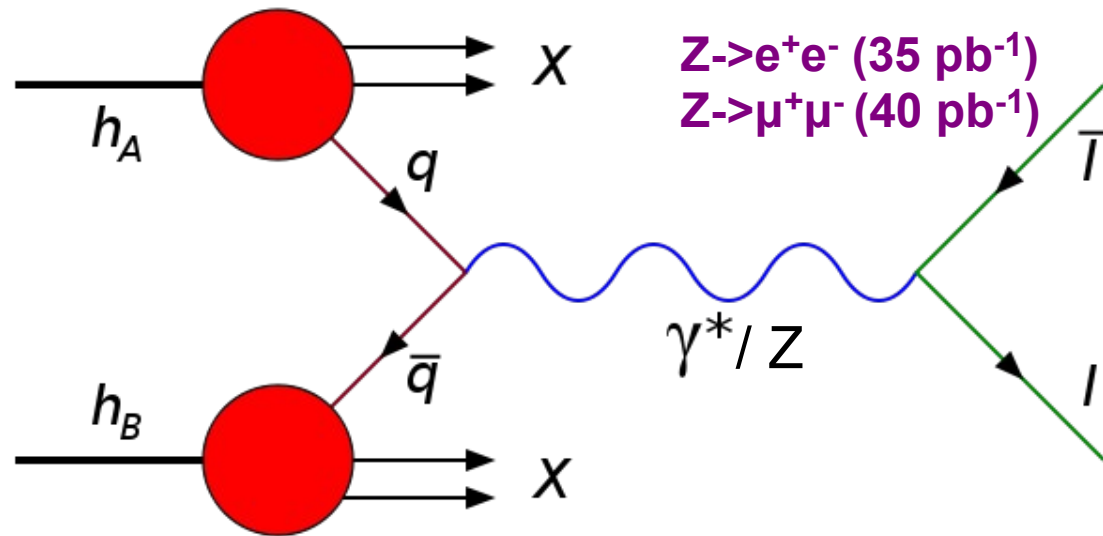
- Z p_T (<350 GeV);
- 66 < M_{ll} < 116 GeV;
- $p_{T_{lepton}}$ > 20 GeV;
- $|\eta|$<2.4.

«Measurement of the transverse momentum distribution of Z/gamma* bosons in proton-proton collisions at sqrt(s)=7 TeV with the ATLAS detector»

Preprint: CERN-PH-EP-2011-095 Archive: ARXIV:1107.2381 (Spires ID: 9131140)

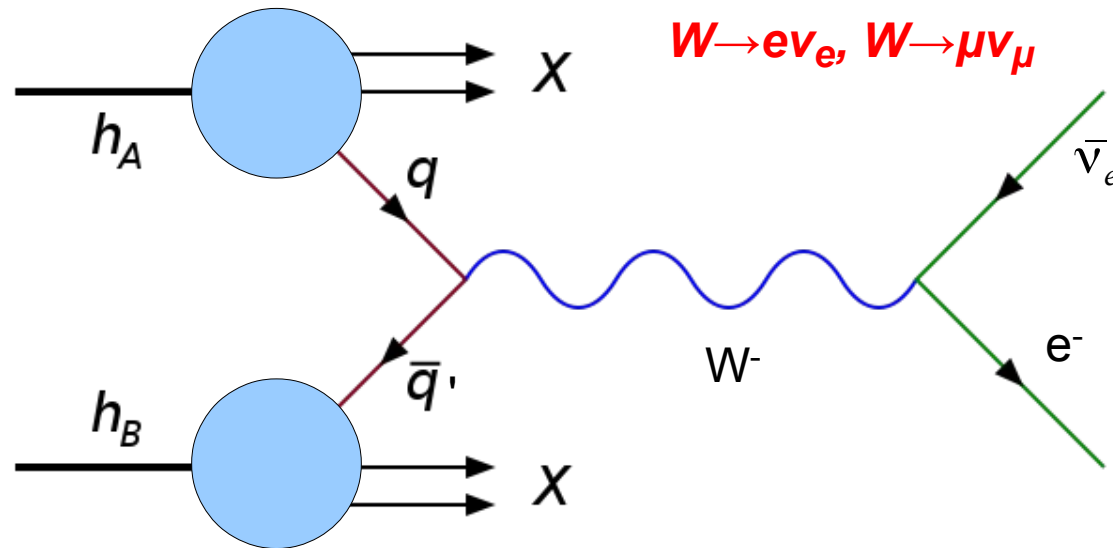http://hepdata.cedar.ac.uk/view/p8054

Data presented for 3 cases:

- ► «dressed» leptons: includes the momenta of photons radiated within a cone centered around the lepton;

- ► «bare» leptons: uses the lepton kinematics after all QED radiation;

- ► «born» («propagator») level: ignores the leptons and takes Z momentum from the propagator (i.e. leptons before FSR radiation).

ATLAS W P_T MEASUREMENT

$W \to e\nu_e$, $W \to \mu\nu_\mu$

- W p_T < 300 GeV;
- $p_{T_{lepton}}$ > 20 GeV;
- $|\eta_l|$ < 2.4;
- missing E_T > 25 GeV;
- m_T > 40 GeV.

«Measurement of the Transverse Momentum Distribution of *W* Bosons in *pp* Collisions at √*s* = 7 TeV with the ATLAS Detector»
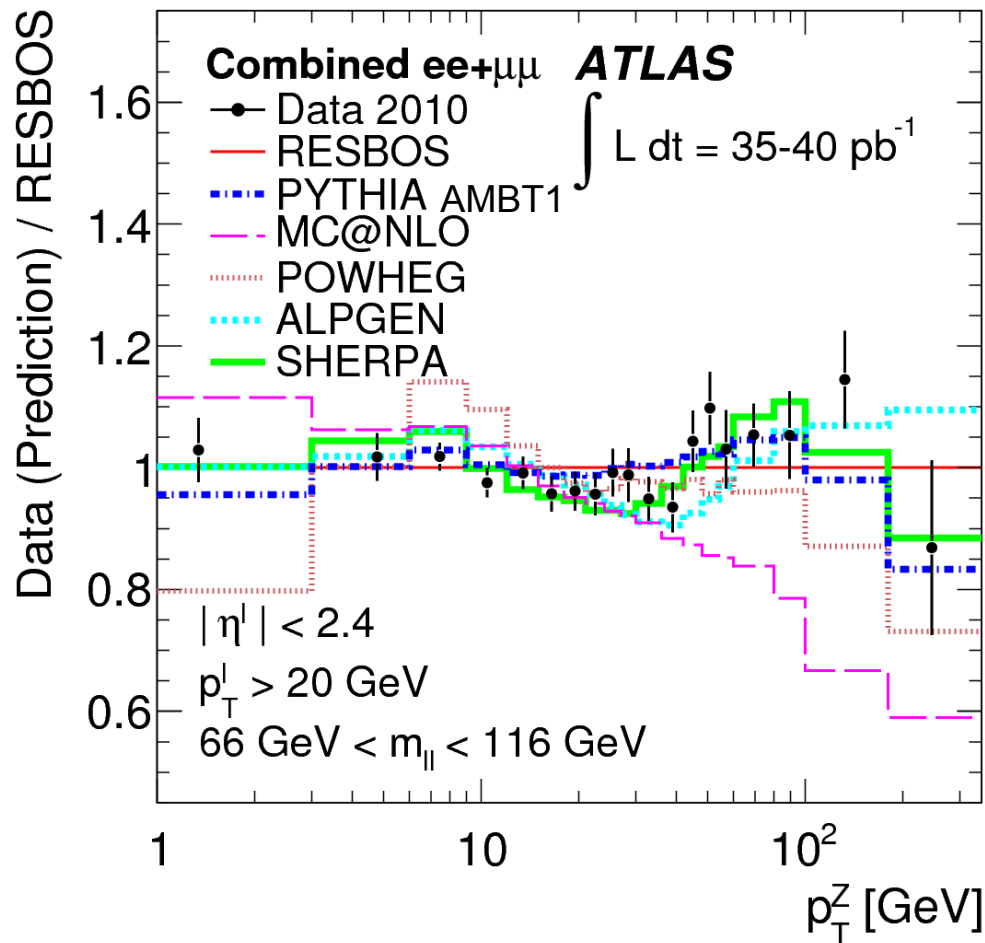
arXiv:1108.6308v1 http://arxiv.org/abs/1108.6308

Data presented for 3 cases:

▶ «dressed» leptons: includes the momenta of photons radiated within a cone centered around the lepton;

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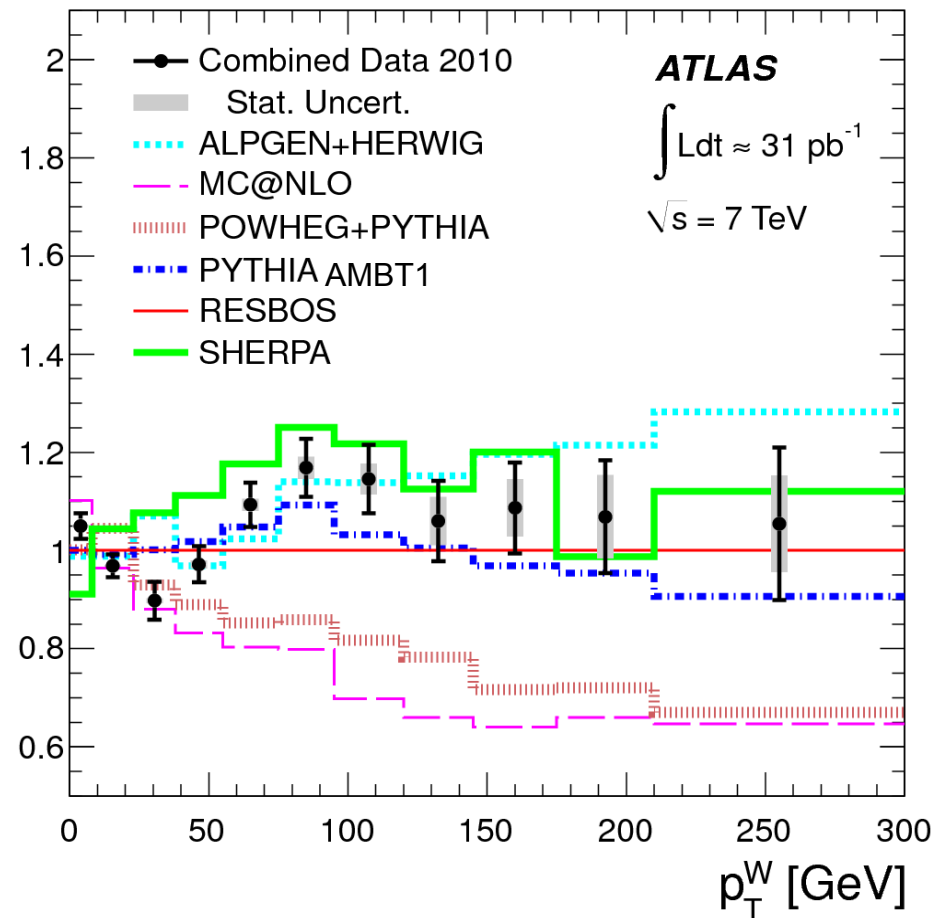
ATLAS Z p_T AND W p_T MEASUREMENTS

This is the ratios of the combined data and predictions from the different generators over the RESBOS prediction.

- LO multi-leg ME generators AlpGen + SHERPA describe data well.
- NLO generators off at low and high-p_T and have wrong shape.

Pythia6 AUET2B tunes

AUET2B shower tunes optimised to describe:

- Jet shapes (ATLAS and CDF)
- Track Jet fragmentation (ATLAS)
- Dijet dicorrelation (ATLAS and D0)

PDFs used for tunes:
- CT09
- CT10
- CTEQ6.6
- CTEQ6L1
- LO**
- MSTW2008LO

Parameters considered are:

- **ISR p_T cut-off** (PARP(62));
- **ISR scale factor on α_S evaluation scale** (PARP(64));
- **Λ_{QCD} for FSR showering from ISR parton emissions** (PARP(72)).

Intrinsic k_T fixed to 2 GeV for all tunes.

AUET2B tunes ATLAS Note: ATL-PHYS-PUB-2011-009
NLO tunesATLAS Note: ATL-PHYS-PUB-2011-014

Pythia6 AUET2B tune extension with Z p_T

Since the Z p_T data were not available at the time of current AUET2B Pythia6 tunes

- it does not include Z p_T data from LHC;
- the optimised shower configuration obtained from the other observables does not describe ATLAS Z p_T data to the desired level;
- therefore a tune including these new data was necessary.

AUET2B tunes ATLAS Note: ATL-PHYS-PUB-2011-009
*NLO tunesATLAS Note: ATL-PHYS-PUB-2011-014*

AUET2B CTEQ6L1 extension:

- ▶ use 3 parameter AUET2B_CTEQ6L1 tune as a basis;
- ▶ add the Z p_T distribution to the tune; keep all other observables as before;
- ▶ restrict Z p_T distribution to $p_T <$ 25 GeV to avoid regions with multiple hard radiation;
- ▶ investigate the influence of the Z p_T distribution by increasing its weight.

Result

▶ Λ_{QCD} for FSR showering from ISR parton emissions (PARP(72)) not affected by Z p_T - this expected from the model;

▶ Z p_T data prefer lower ISR cut-off (PARP(62)) and higher scale factor for α_s renormalisation scale (PARP(64)).
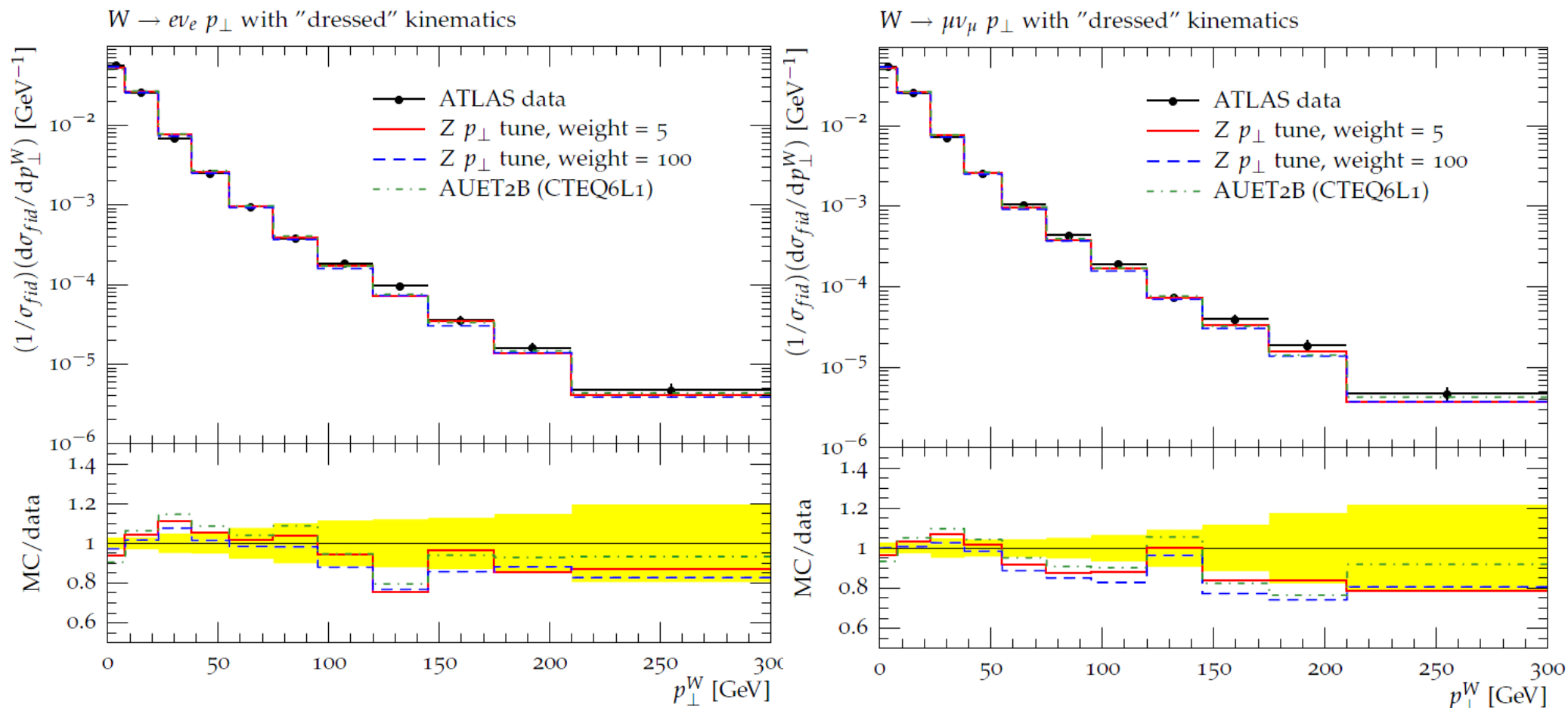
Comparison to ATLAS Z p_T Data
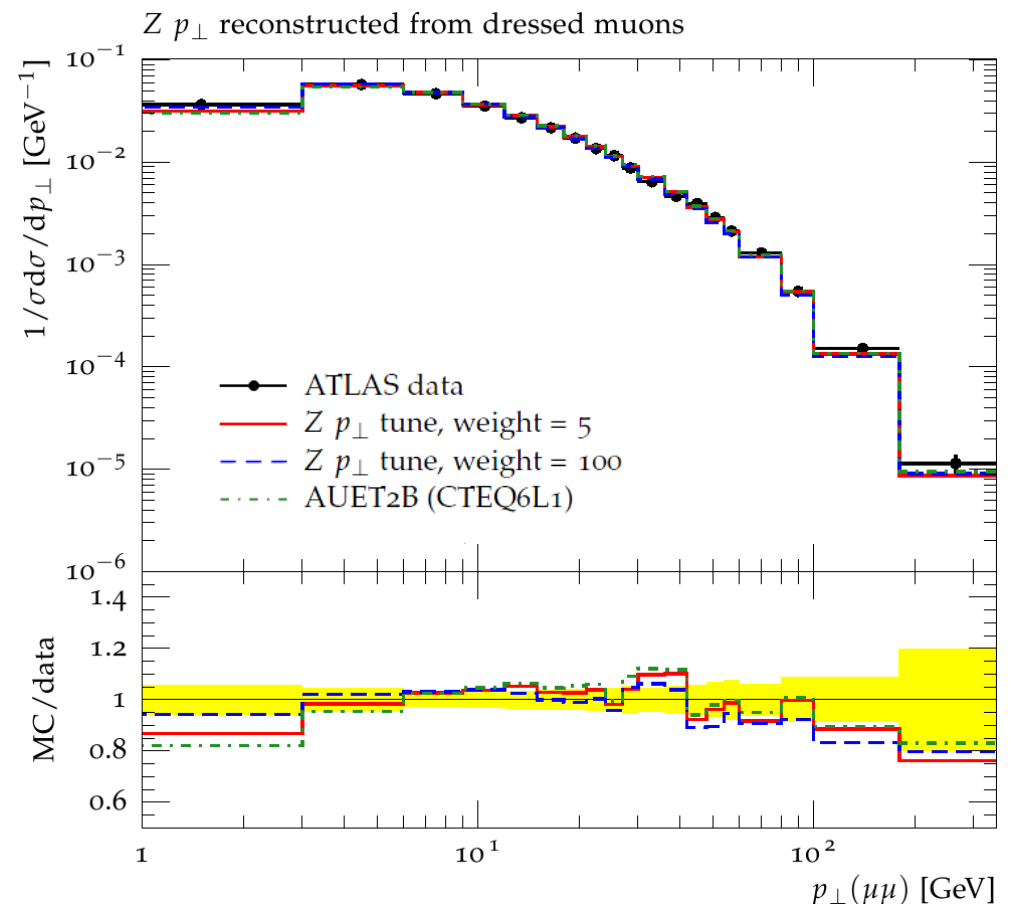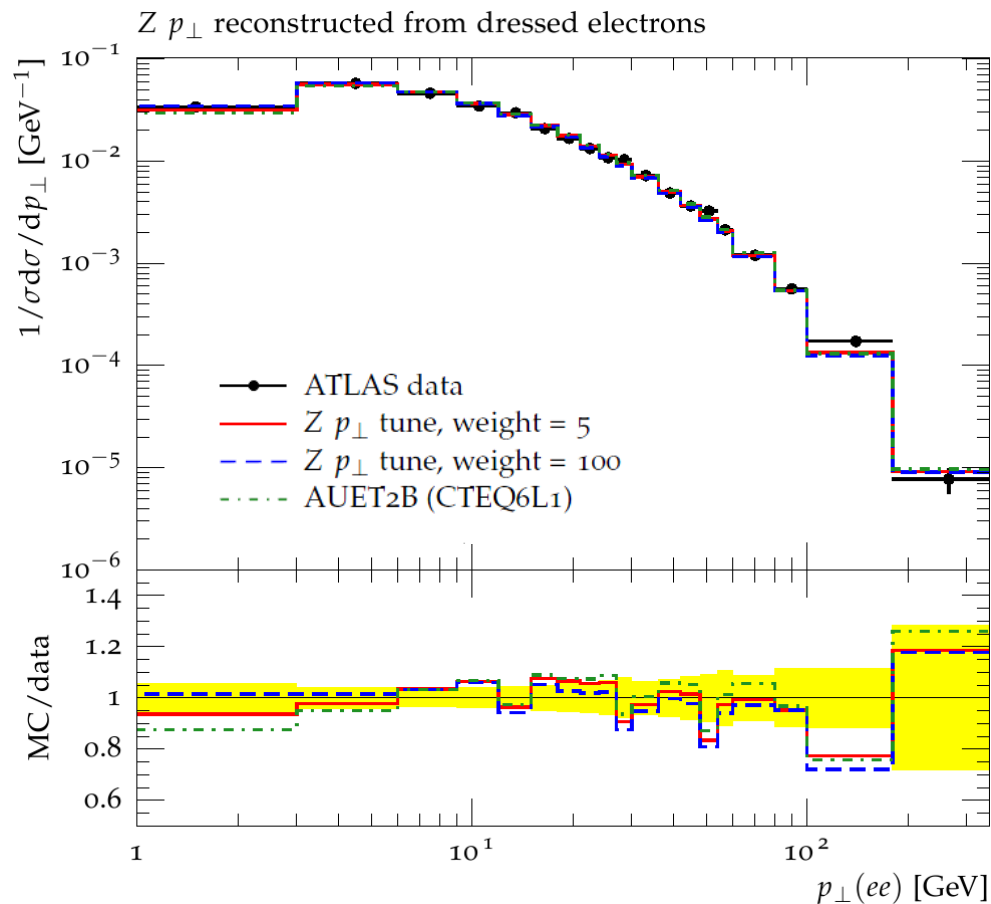
Comparisons of the AUET2B (CTEQ6L1) Pythia6 tune (green) and the new tunes including this measurement with a weight of 5 (red) or 100 (blue) to ATLAS Z p_T data at 7 TeV.

▶ Including the Z p_T distribution raises the low p_T MC predictions and a very high weight on the Z p_T would improve the description of this particular observable even further.
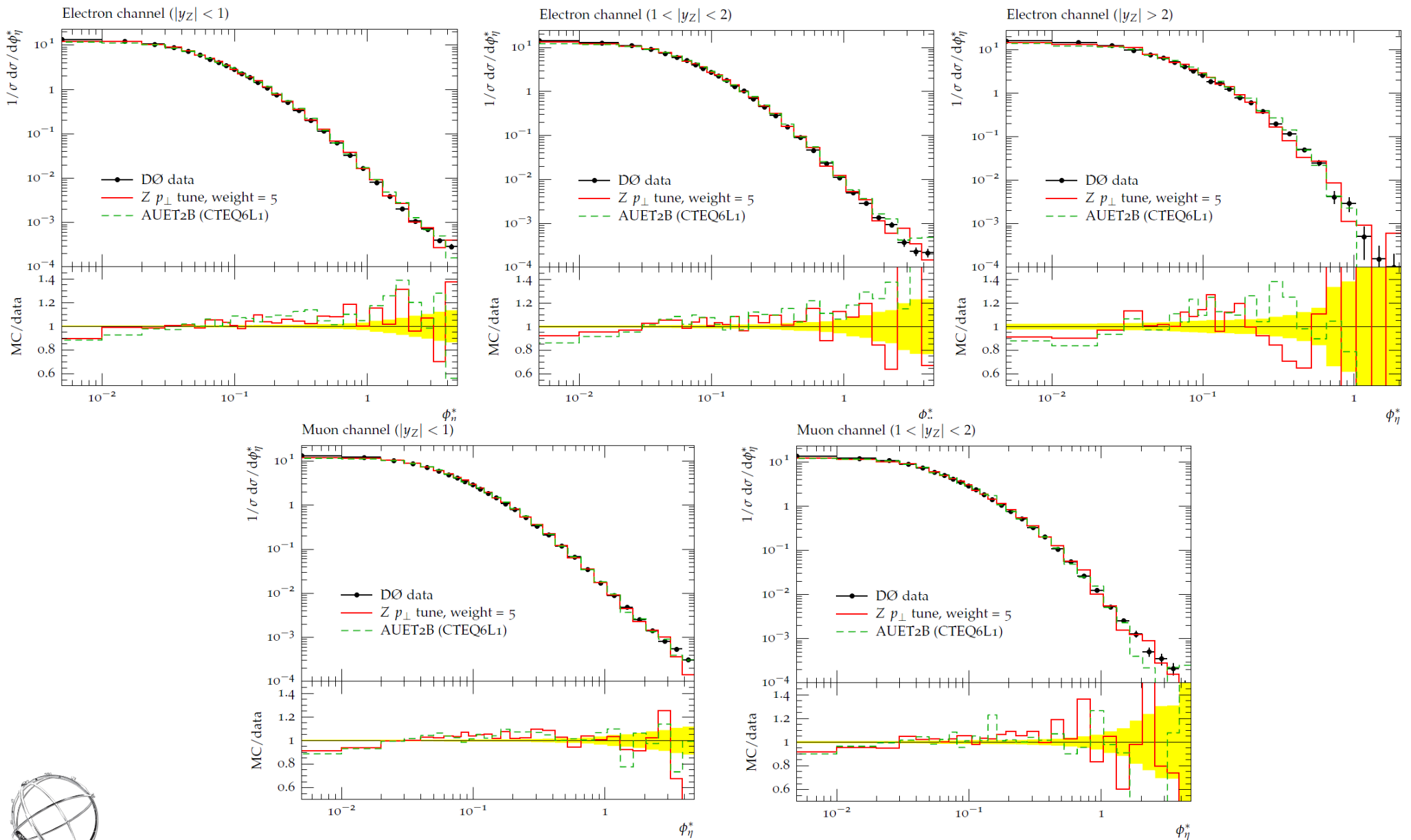
Comparisons of the AUET2B (CTEQ6L1) Pythia6 tune (green) and the new tunes including this measurement with a weight of 5 (red) or 100 (blue) to ATLAS W p_T data at 7 TeV.

▶The same improved behaviour seen for W p_T.

Comparison of AUET2B (CTEQ6L1) Pythia6 tune (blue) the new Z pT tune with weight 5 (red) to D0 data.

▶ The tune to ATLAS Z p_T data also slightly improves the description of the D0 data.

- POWHEG NLO event generator, with showering, MPI and hadronisation provided by Pythia6 with the AMBT1 tune, fails to describe the ATLAS Z p_T;

- while the AMBT1 tune employed in standalone Pythia describes the data reasonably well.
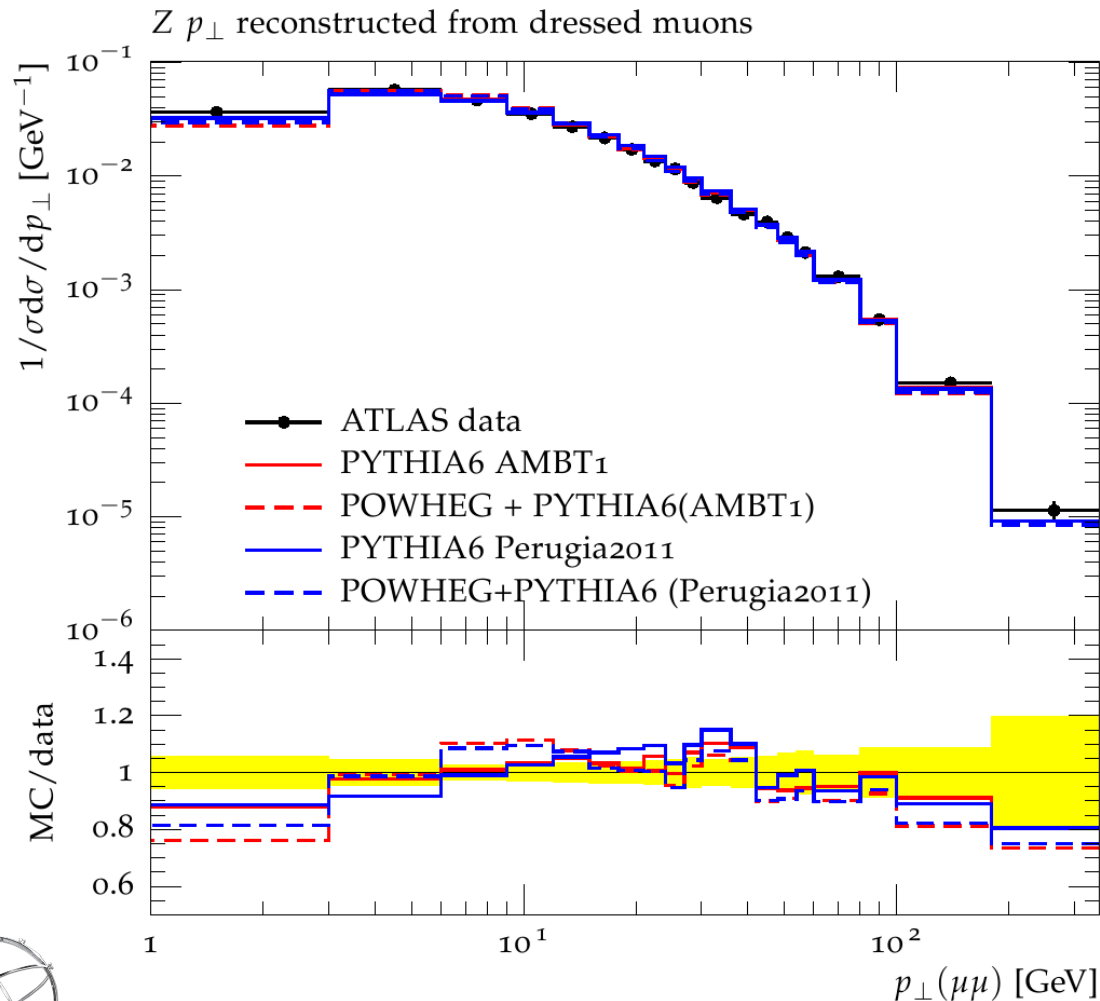
Comparison of different Pythia6 tunes to ATLAS Z p_T data for Pythia6 standalone and when Pythia6 is used a shower generator for POWHEG.

To investigate the origin of the deviation in POWHEG+Pythia6 matched samples, different Pythia6 tunes were trialled with the same POWHEG events.

▶ POWHEG+Pythia6 in the MC10 production: **CT10 PDF** for the NLO matrix element
▶ the AMBT1 Pythia6 tune: **LO* PDF**.

▶ With this setup the MC prediction undershoots the data by ~ 20% at both low and high p_T, while the AMBT1 tune for standalone Pythia6 describes the data reasonable well.

In addition to the ATLAS tunes, Perugia2011 was included in the study.
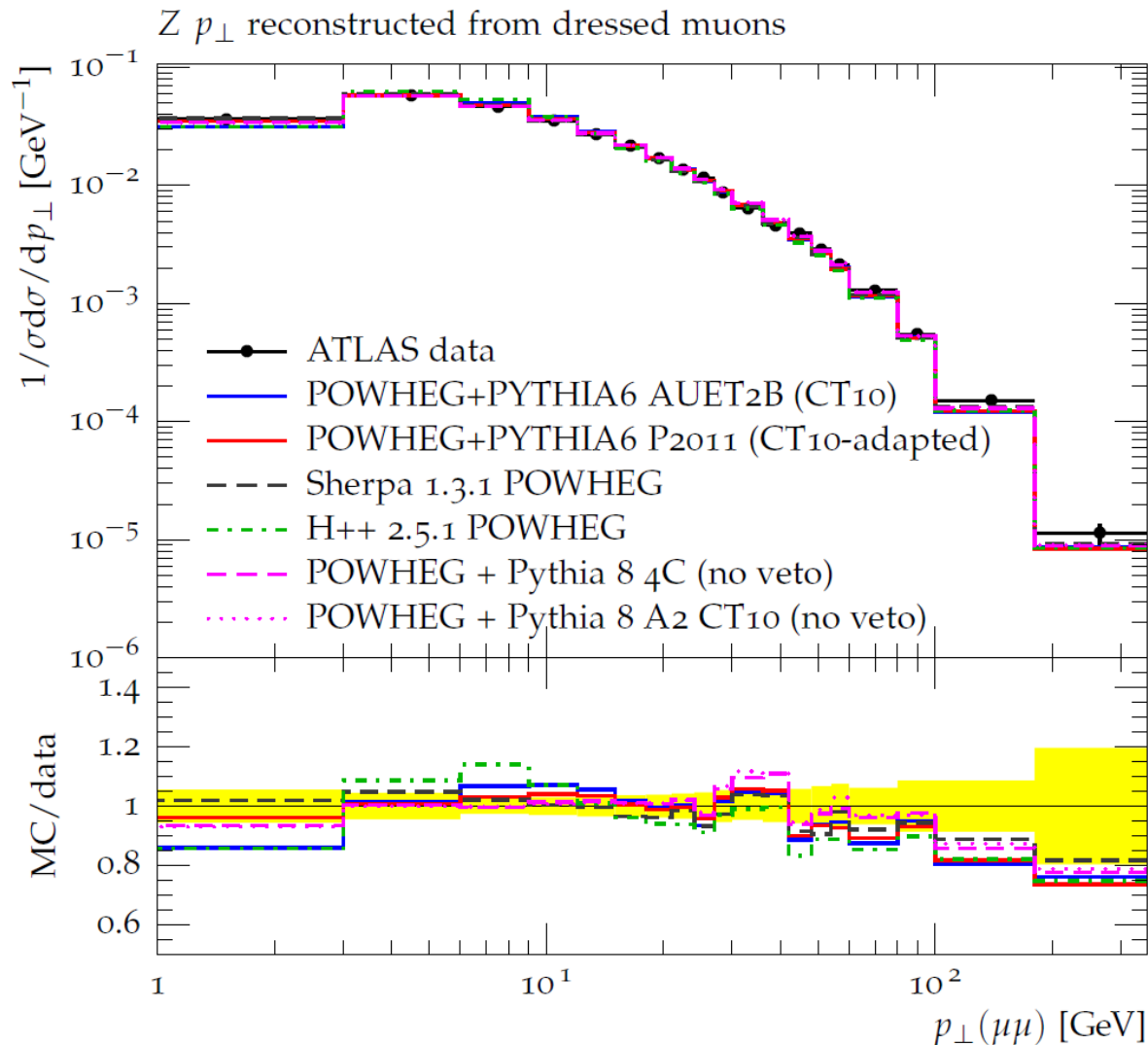
A similar behaviour is visible for the P2011 tune.

Reminder of the Perugia2011 tune:

- developed to be used in setups where Pythia6 is matched to LO multileg ME generators such as AlpGen;

- consistent Λ_{QCD} treatment throughout all parts of the shower;

- Λ_{QCD} = 0.26;

- intrinsic k_T of 1 GeV;

- CTEQ5L PDF.

Z $p_\perp$ reconstructed from dressed muons

Legend:
- ATLAS data
- POWHEG+PYTHIA6 AUET2B (CT10)
- POWHEG+PYTHIA6 P2011 (CT10-adapted)
- Sherpa 1.3.1 POWHEG
- H++ 2.5.1 POWHEG
- POWHEG + Pythia 8 4C (no veto)
- POWHEG + Pythia 8 A2 CT10 (no veto)

▶ SHERPA version 1.3.1 was run using its automated POWHEG implementation. For the present study of NLO+PS matching, only the inclusive Z production process was generated at NLO and matched to the parton shower. No matrix elements for higher-order jet multiplicities, as possible e.g. in the MENLOPS approach, were included.

▶ POWHEG+Pythia8 describes the data very well, but in contrast to Pythia6 doesn't actually appear to have any substantial dependence on the PDF.

The quality of description of ATLAS Z p_T data with several different POWHEG implementations.

Description of Z boson pT data, by the POWHEG method, demonstrating the effect of a PDF mismatch (P2011+POWHEG), and the improvement due to using the same PDF (P2011'+POWHEG), and the POWHEG implementations in Sherpa and Herwig++, and as interfaced to Pythia 8 (4C and A2 CT10 tunes).

SUMMARY

▶ Poor descriptions of the Z and W boson p_T spectra by the Pythia6 and POWHEG+Pyhia6 can be addressed through tuning of parameters in the Pythia parton showers.

▶ AUET2B Pythia6 tune including ATLAS Z p_T data in a much-improved description of both that data and the ATLAS W p_T data.

▶ Sherpa gives a good description of the Z p_T data and Herwig++ needs in improvement.

▶ POWHEG+Pythia8 already gives a very good description of the Z p_T data.

Thank you for your attention!