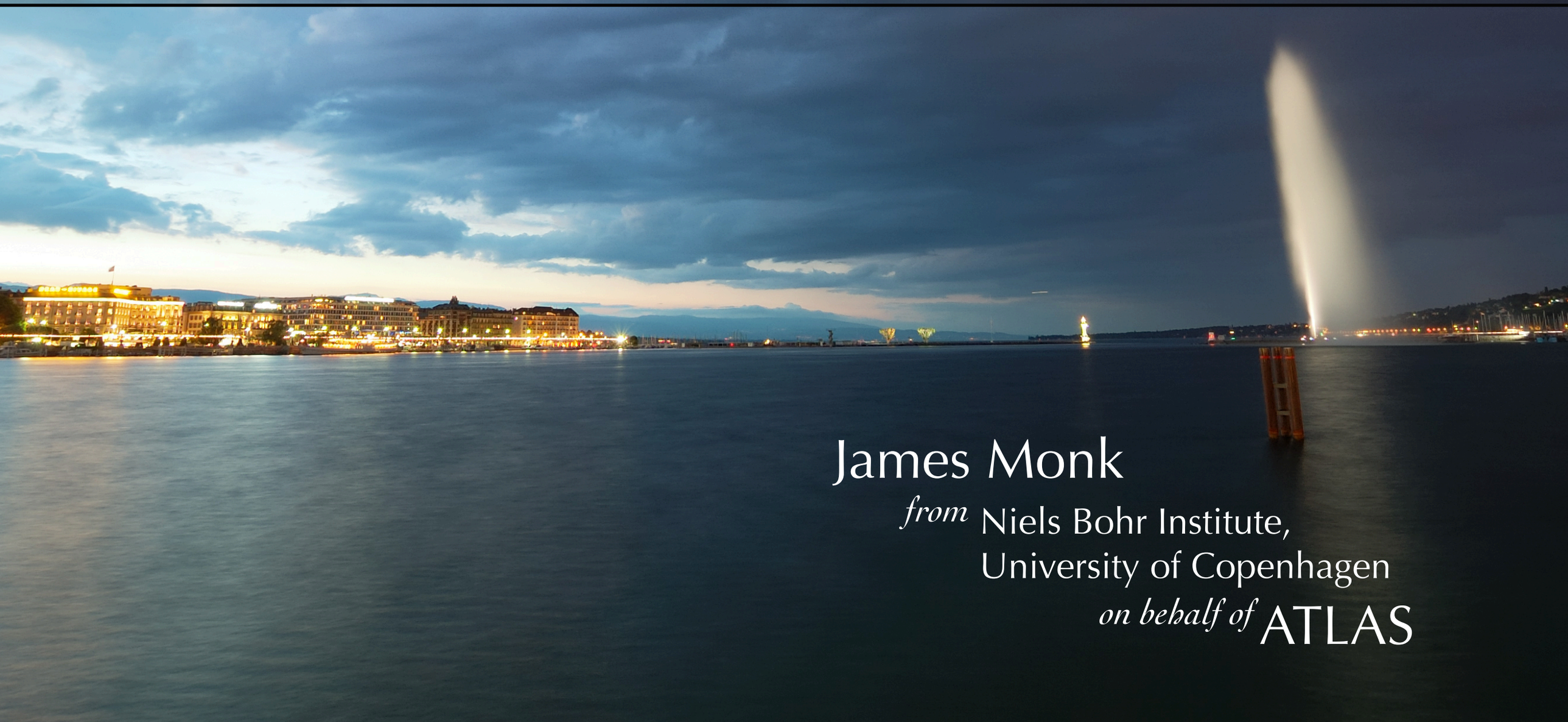
Underlying Event, Transverse Energy Flow & Charged Particle Event Shapes



James Monk
from Niels Bohr Institute,
University of Copenhagen
on behalf of ATLAS

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  - Underlying event with charged track jets
  - Underlying event with jets
- **Transverse energy flow**
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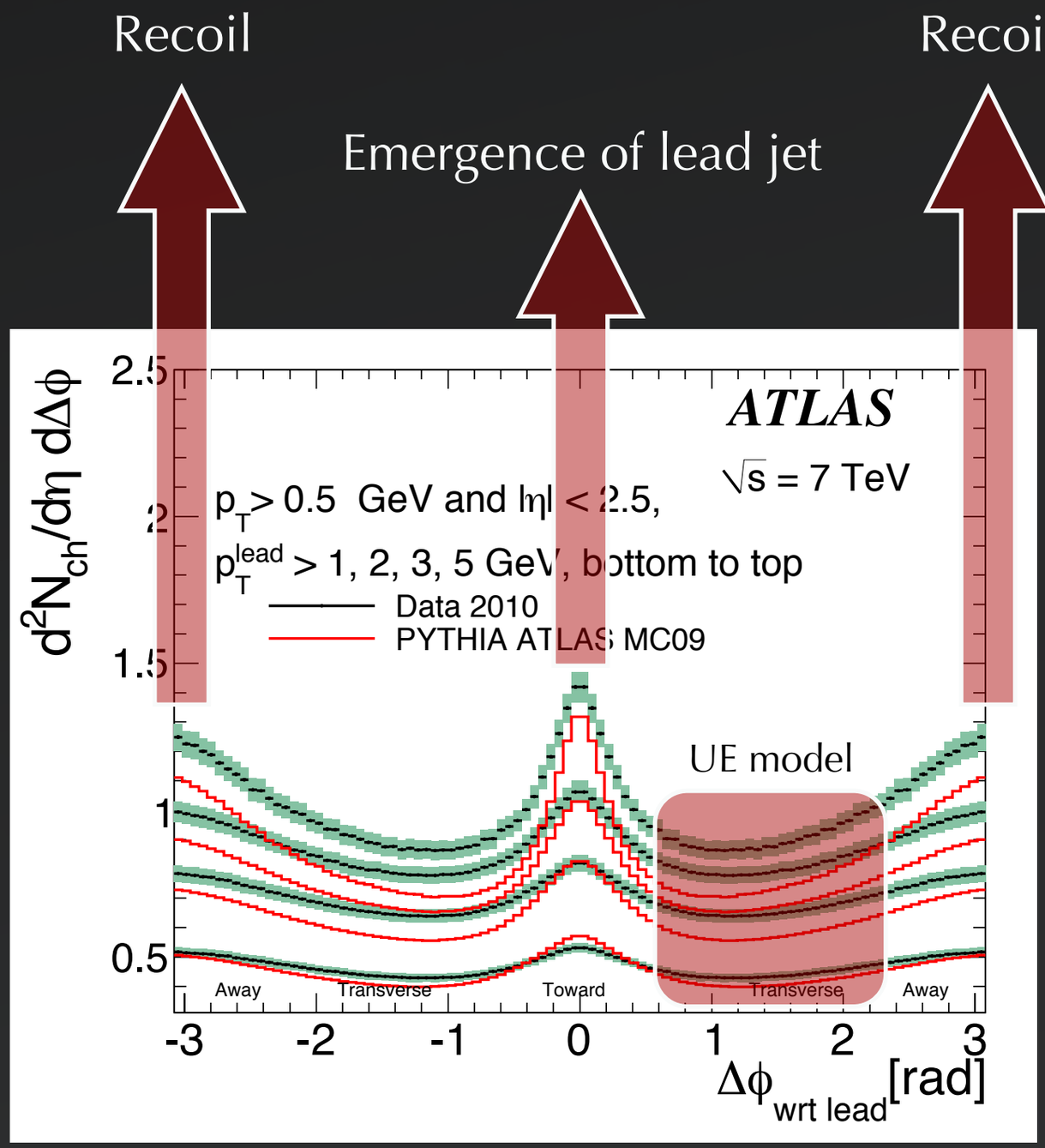
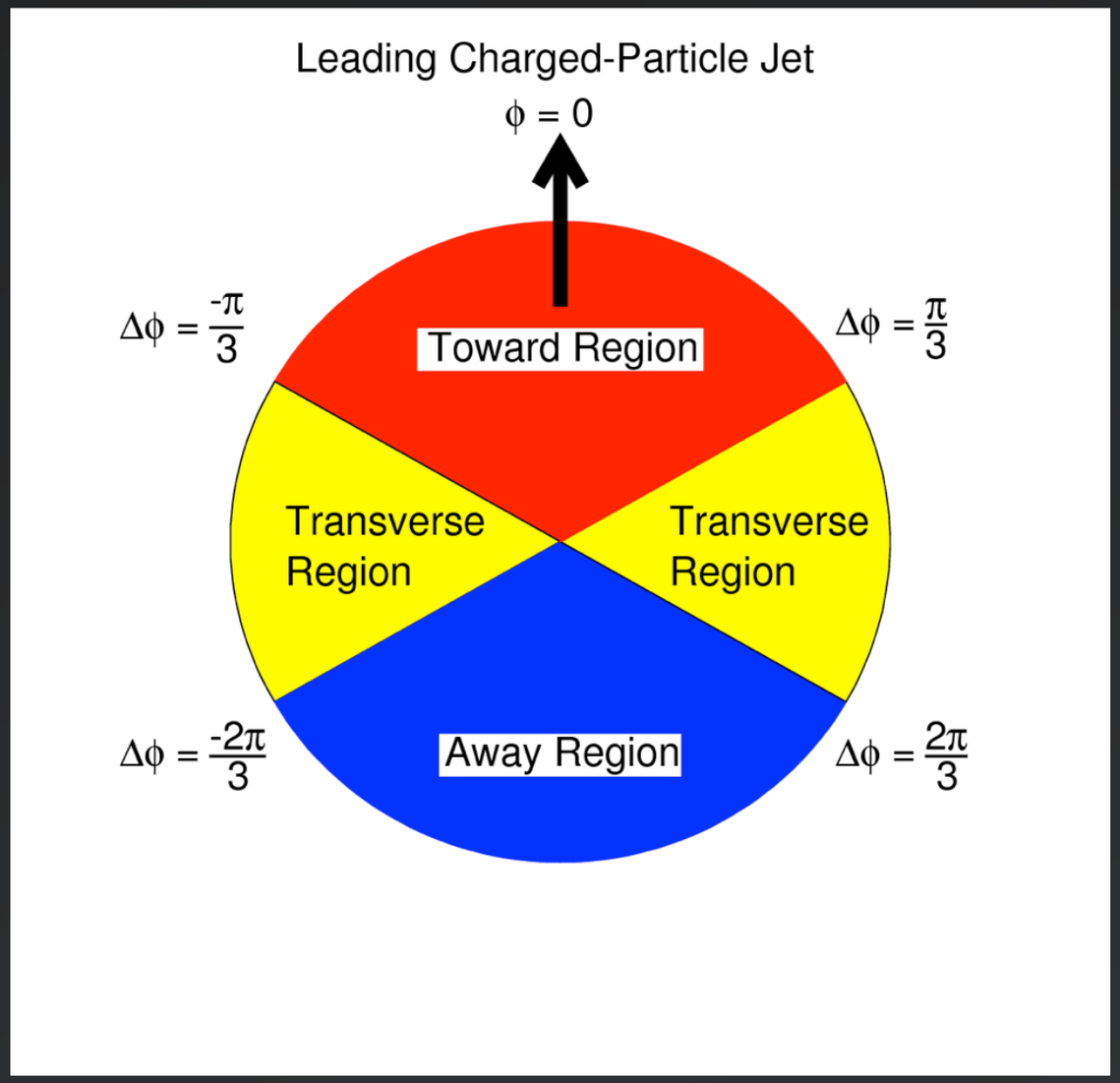
Underlying Event

Underlying Event



From first ATLAS UE in 2010:
http://inspirehep.net/record/879407



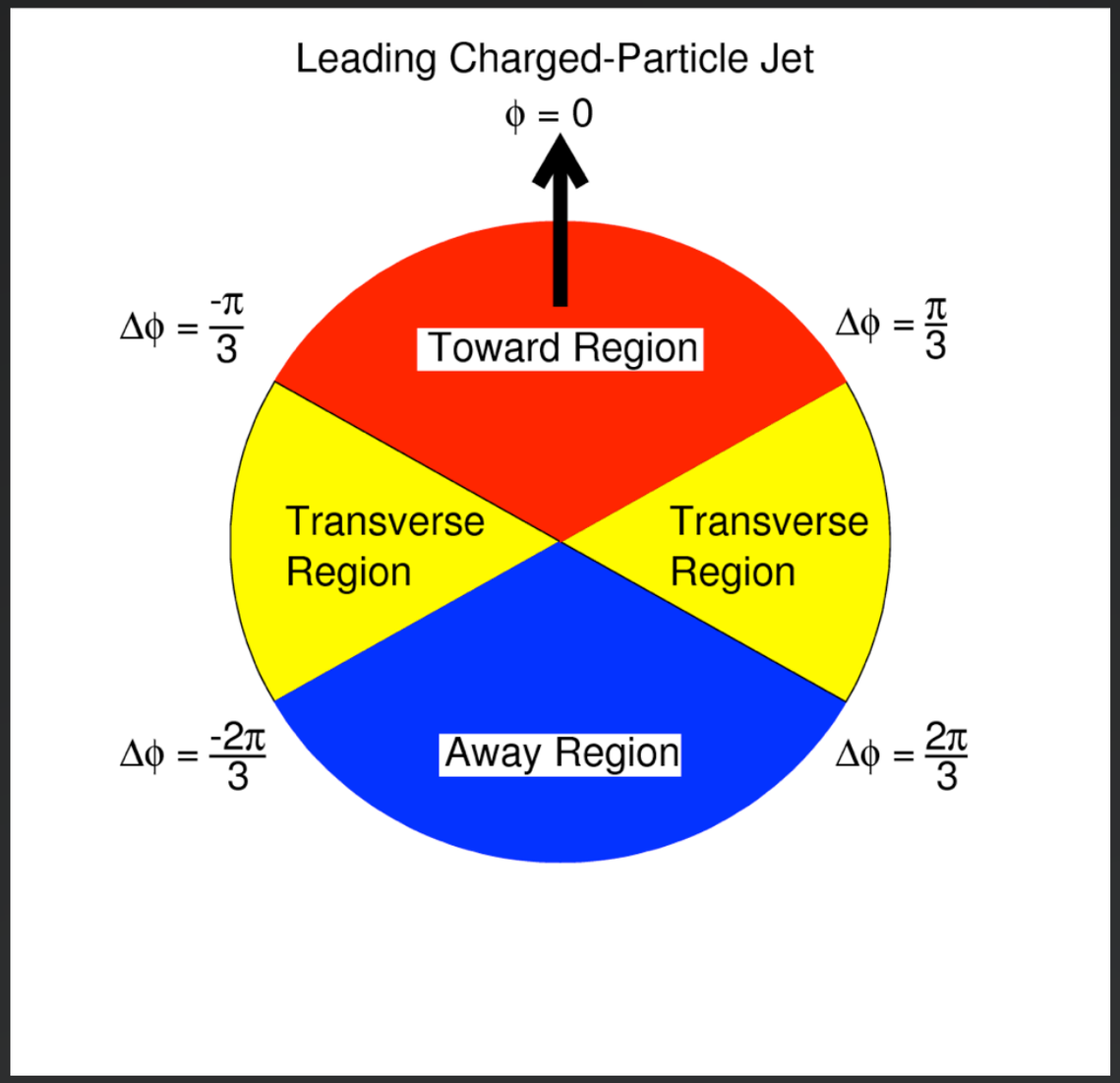
UE is a **model feature** required to describe **data**. It is not a well defined observable!

Underlying Event

Underlying event is often modelled as **multiple scatterings** between **partons** within the proton

ATLAS have investigated and measured the contribution **MPI** makes in **W+di-jet** events

See the separate talk by **Tim Martin**



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Underlying event with charged particle jets

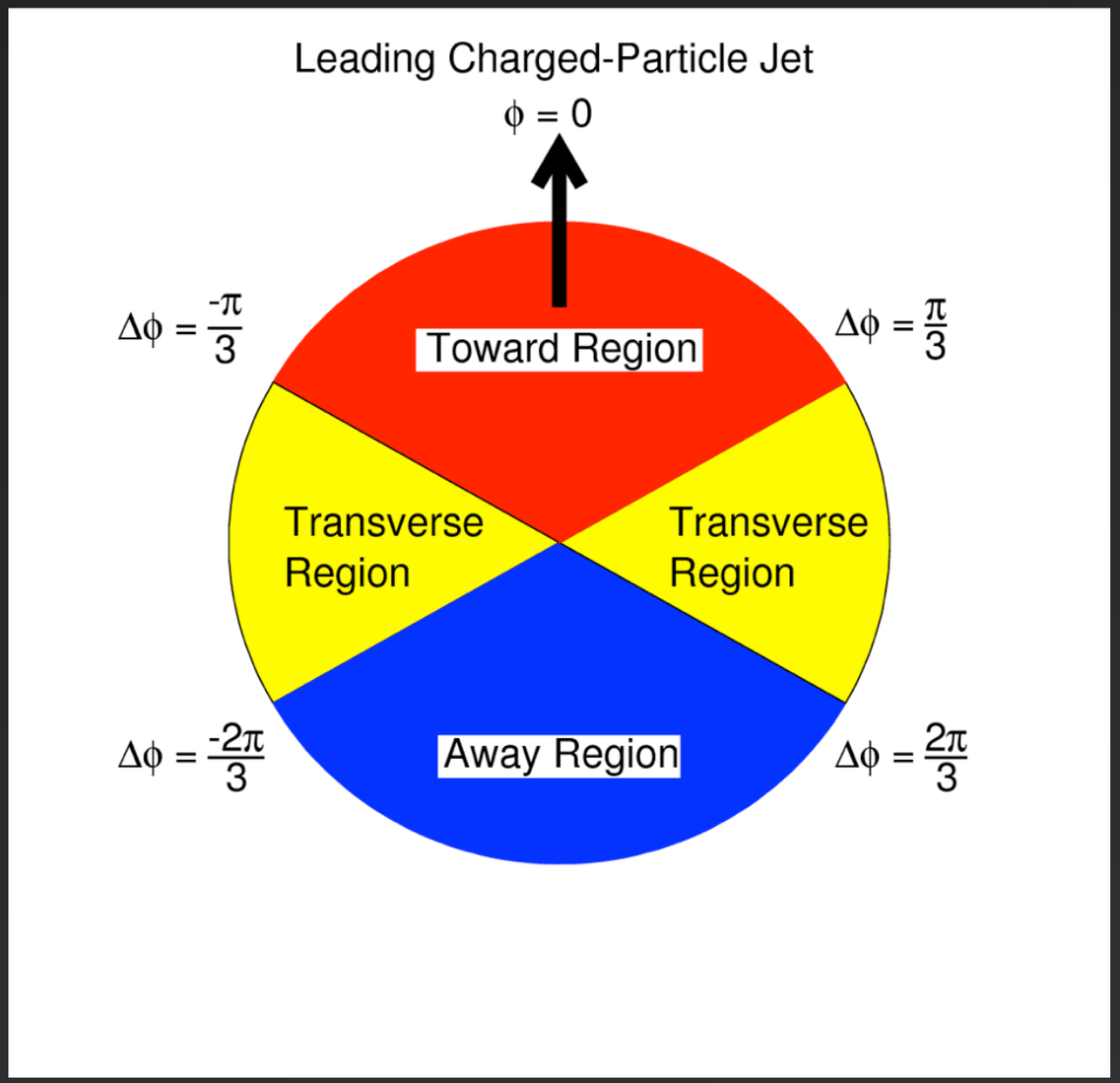
http://inspirehep.net/record/1125575

Select all well reconstructed charged tracks with **pT > 500 MeV** and **|η| < 2.5**

Run the anti-kT jet algorithm on those tracks. Accept jets with pT > 4GeV and |η| < 1.5

Leading such jet defines the toward direction

Count the number of tracks, determine the sum of track pTs and mean track pT in each different azimuthal region.



Final distributions are unfolded to particle-level to remove all detector effects and compared to a variety of Monte Carlo models

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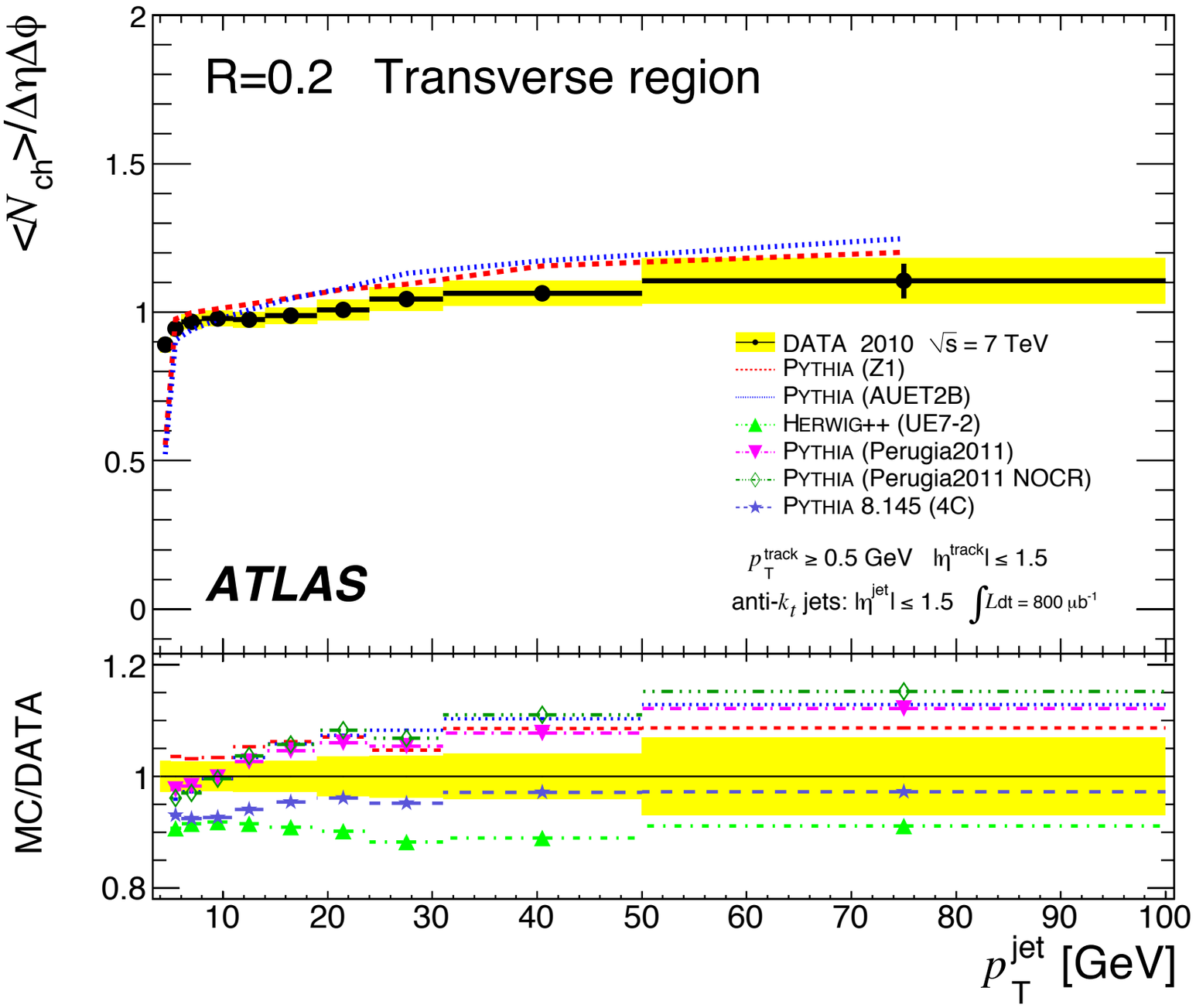

Av. **number** of charged particles per unit η-Φ in the **transverse** (UE-sensitive) region

Rises with leading charged-particle jet **pT**

Turns over onto a **plateau**, the height of which has a **low dependence** on jet radius

Changing **jet radius** has a similar effect to rescaling x axis, alters the **sharpness** of the **turn over**

Underlying event with charged particle jets

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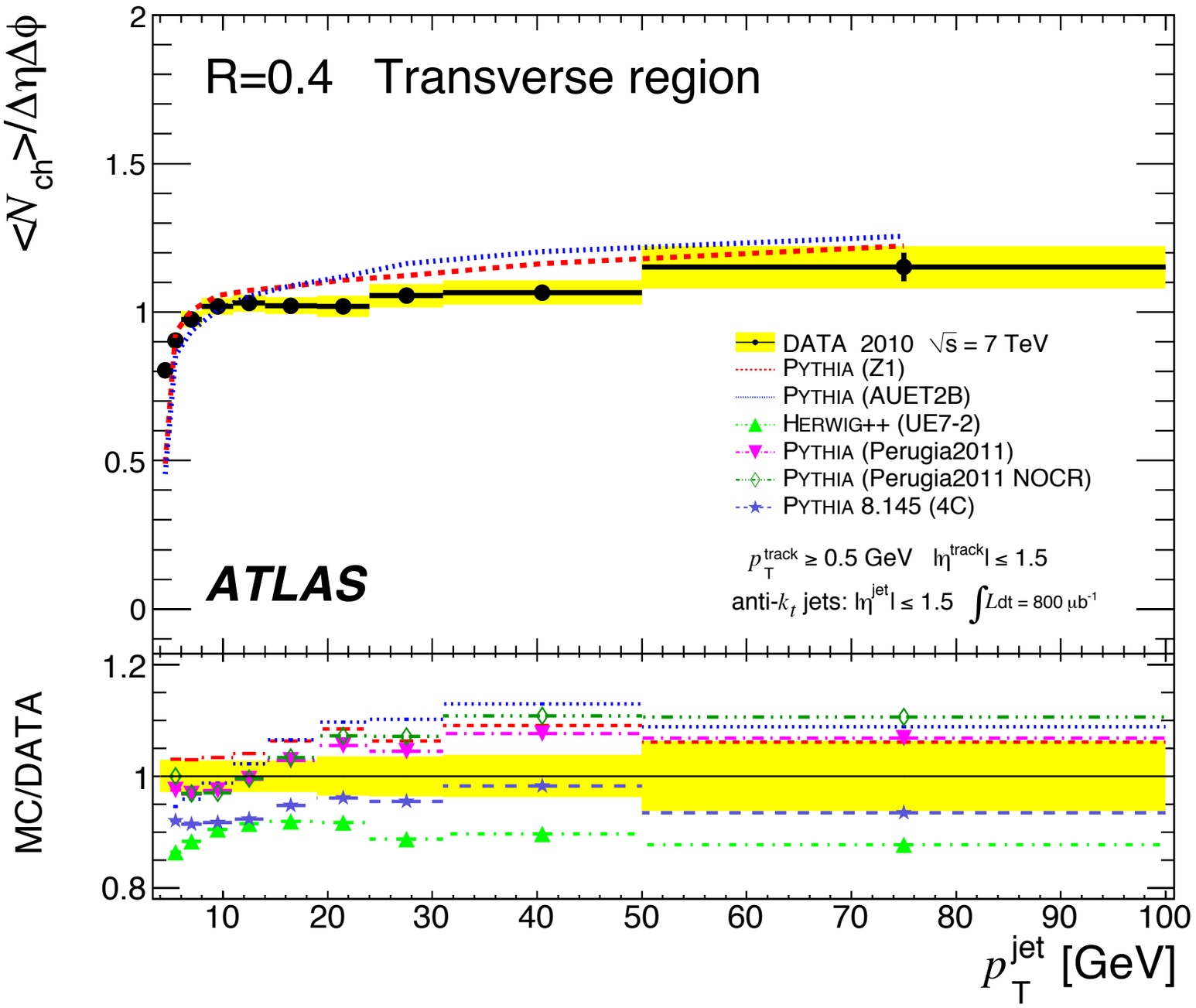

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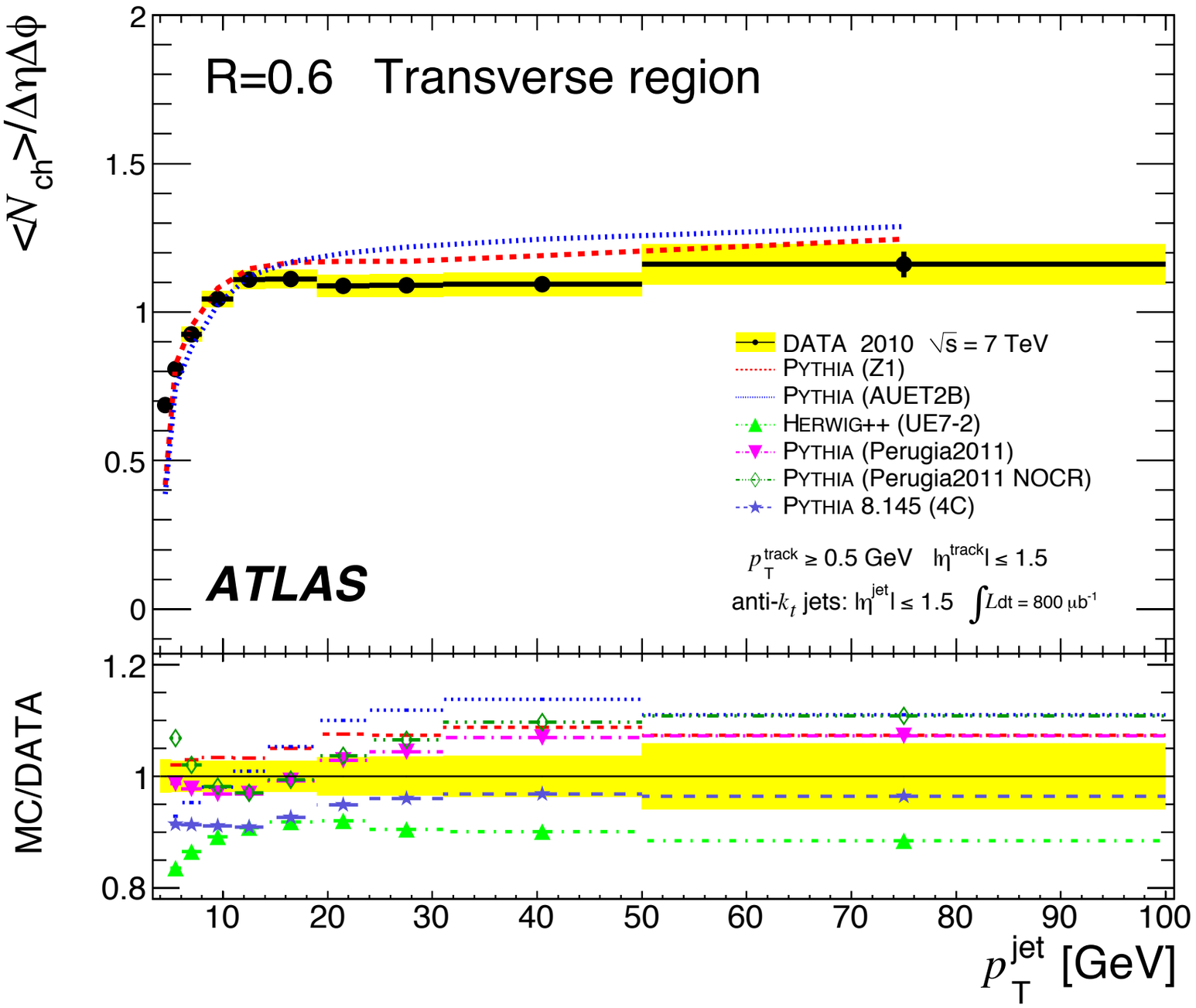

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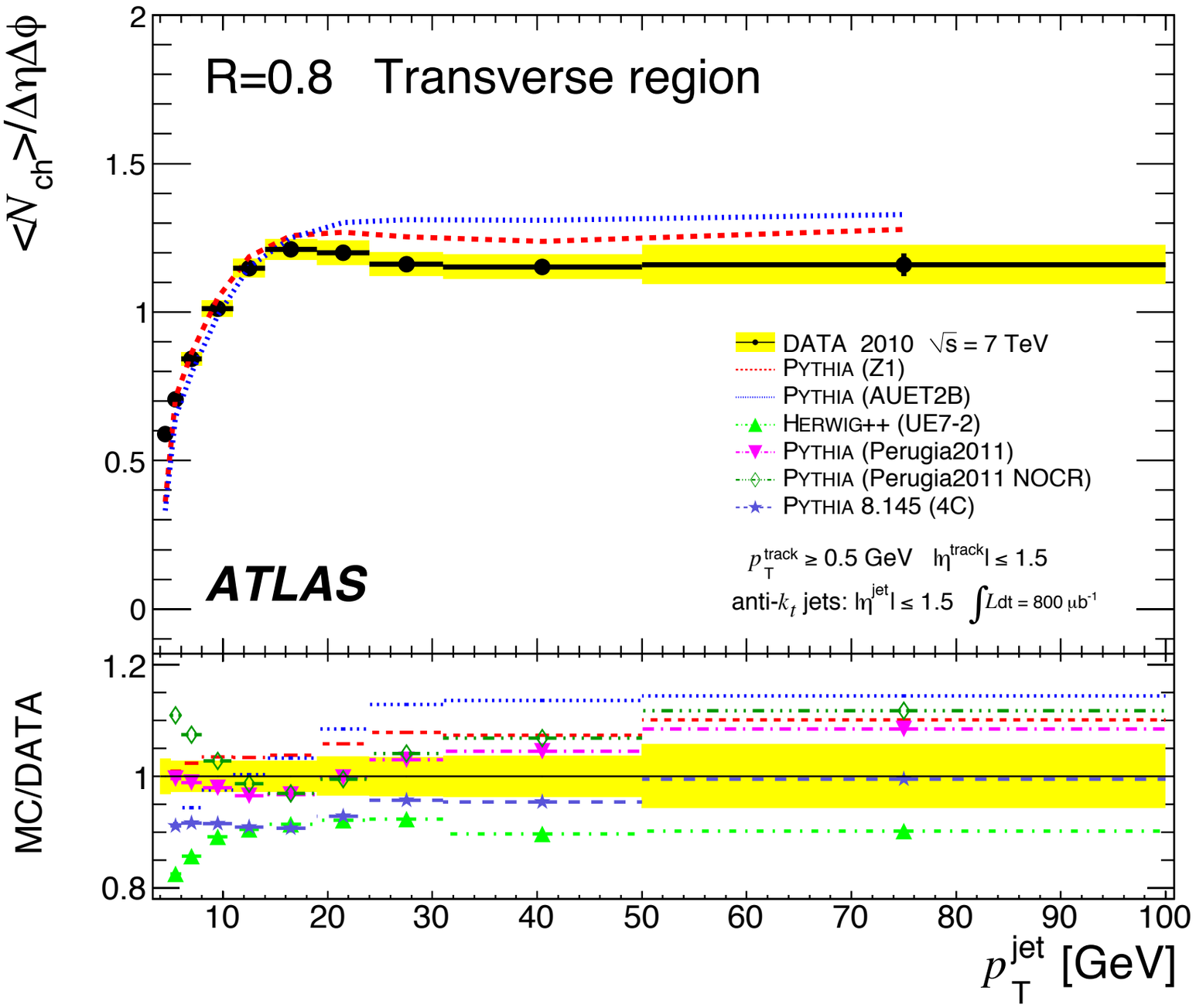

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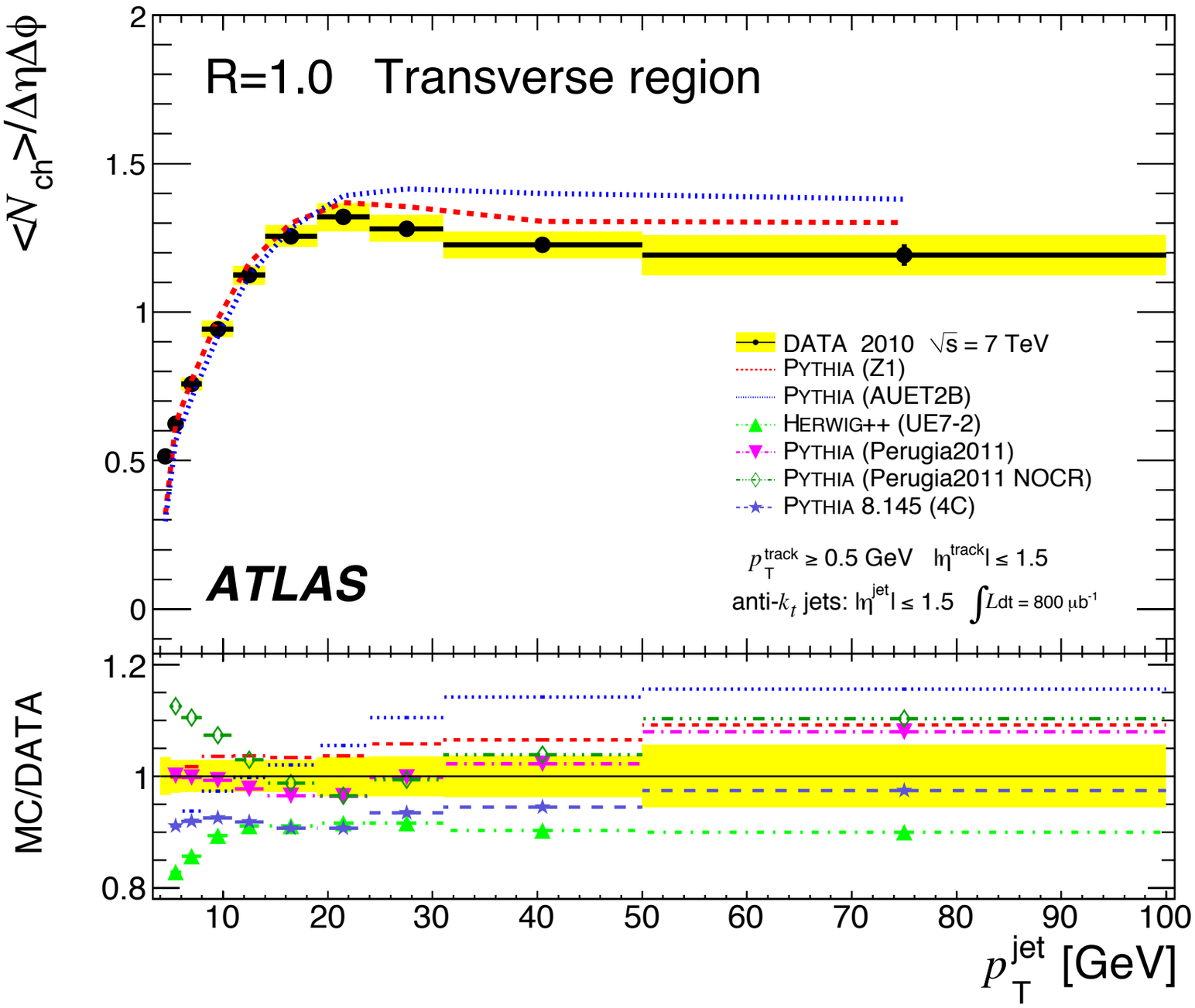

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Av. ΣpT density in the **transverse** (UE-sensitive) region

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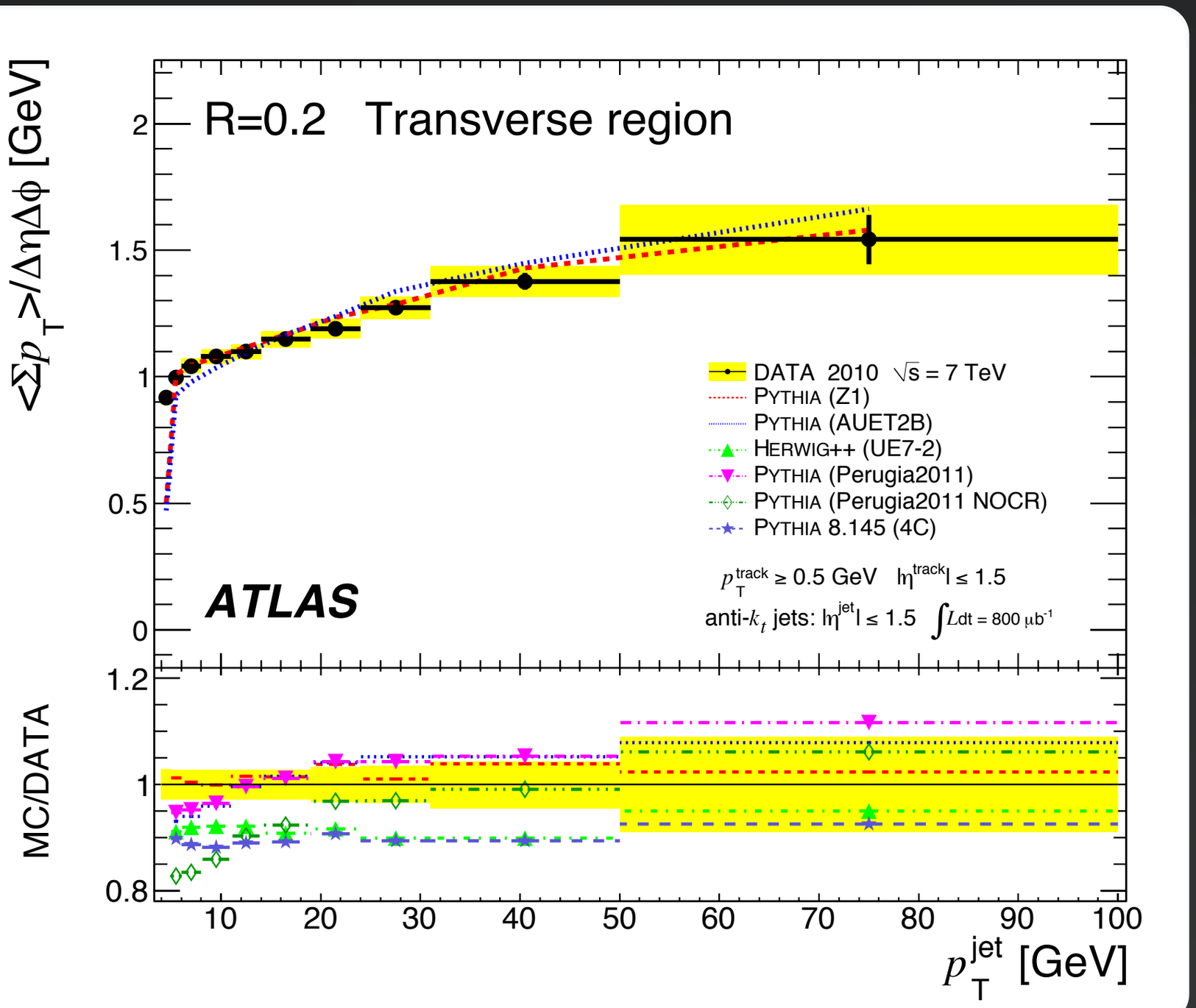
Plateau is **less flat** than for charged particle density

Changing **jet radius** alters the **sharpness** of the **turn over**



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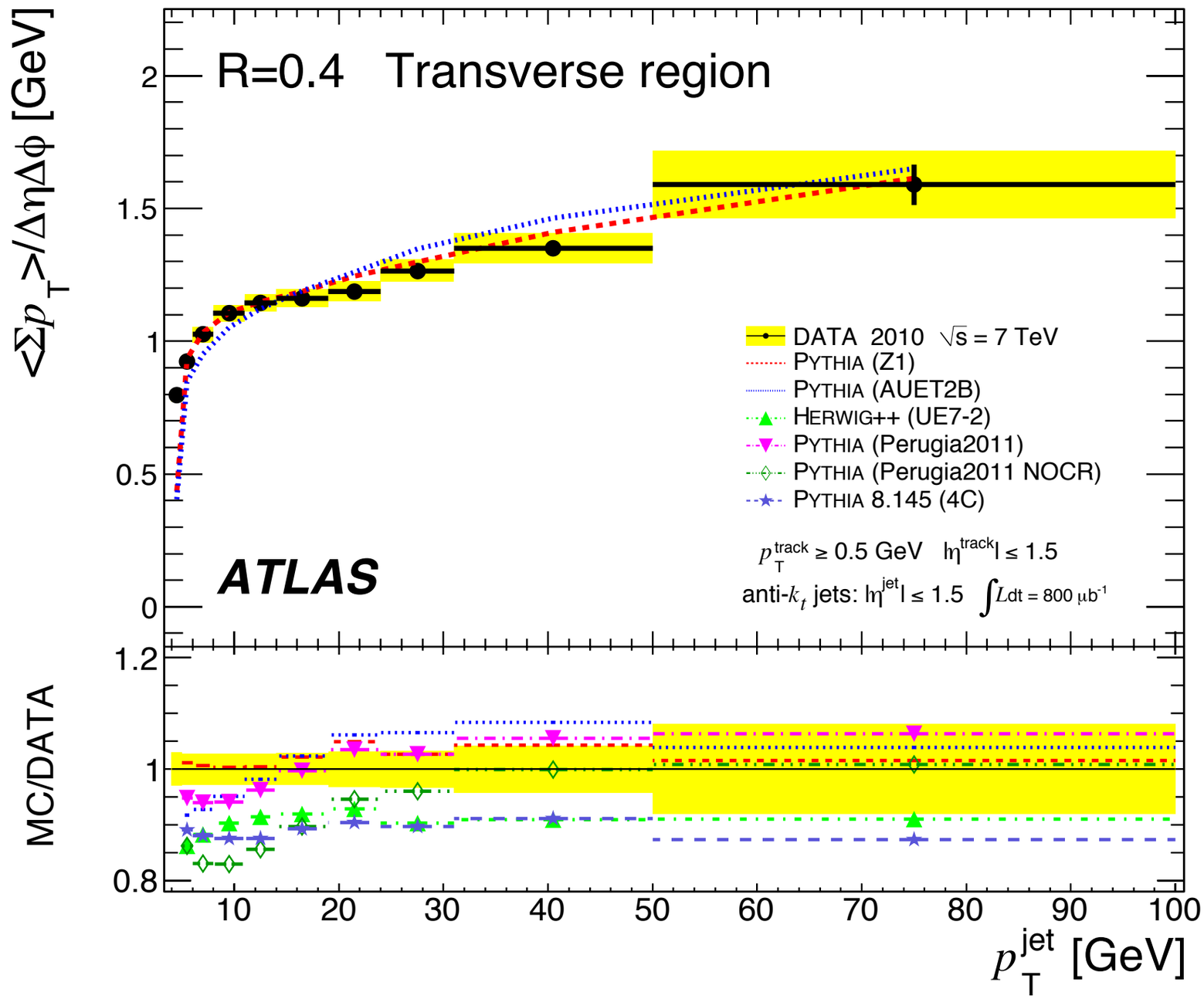

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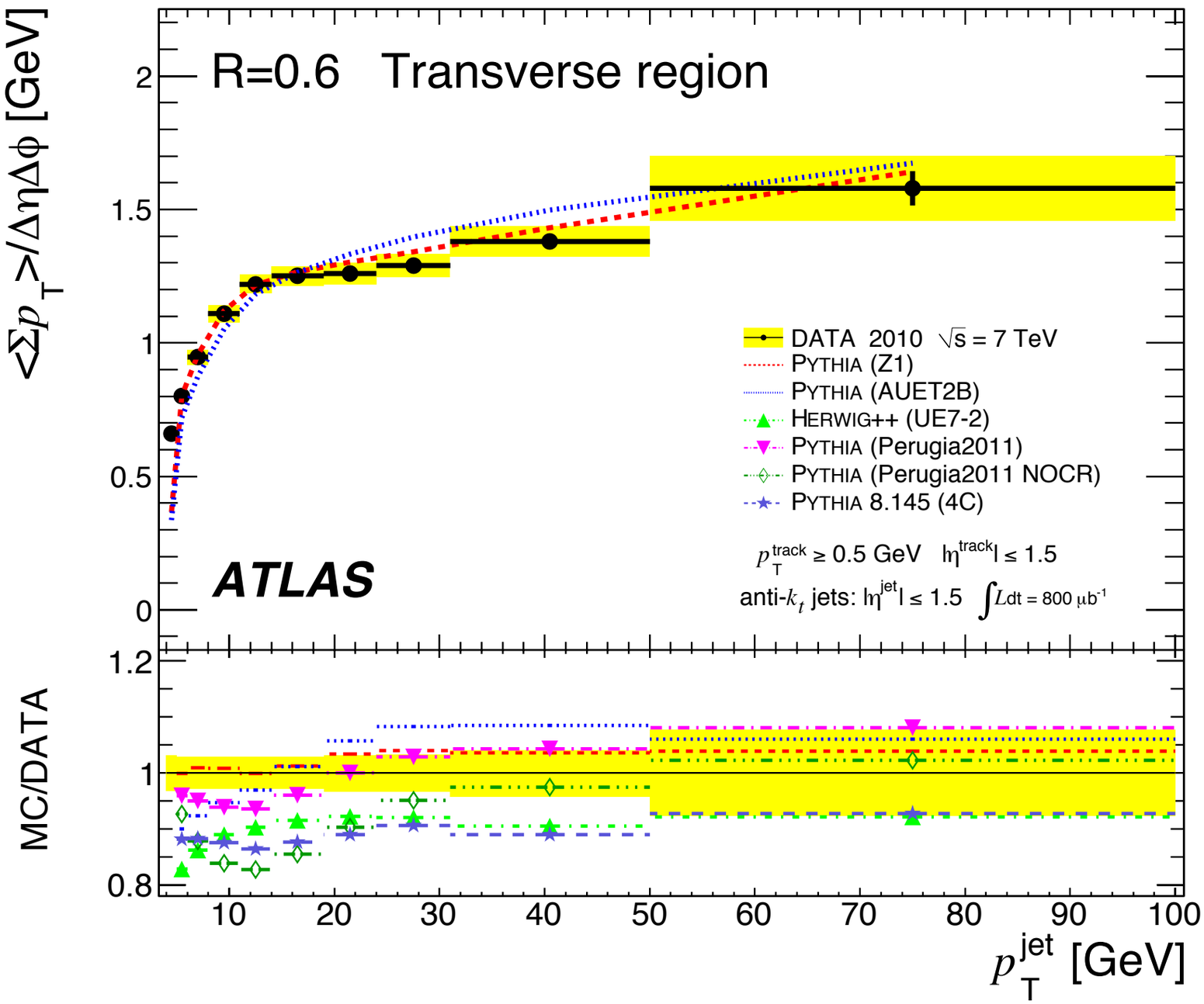

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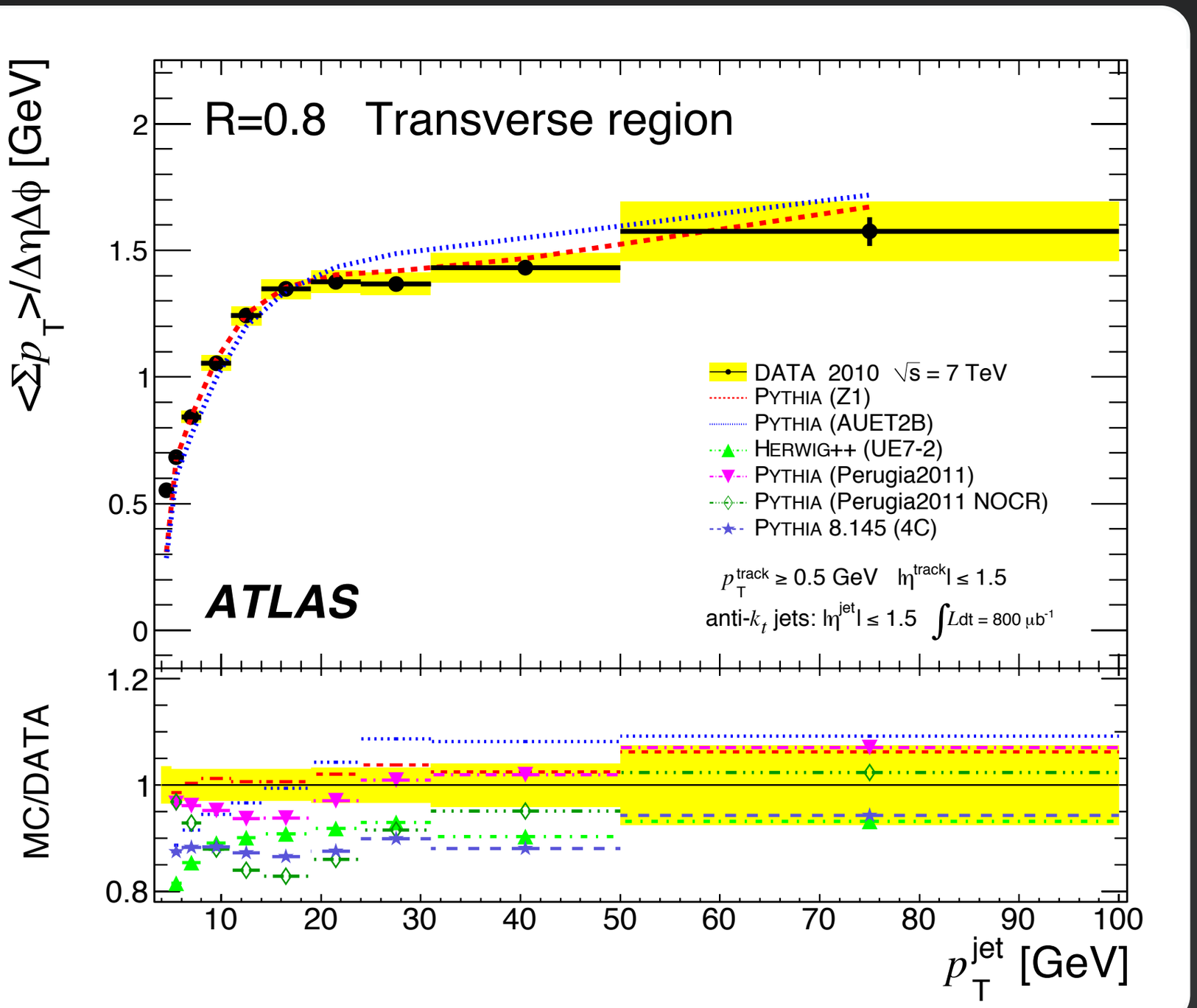

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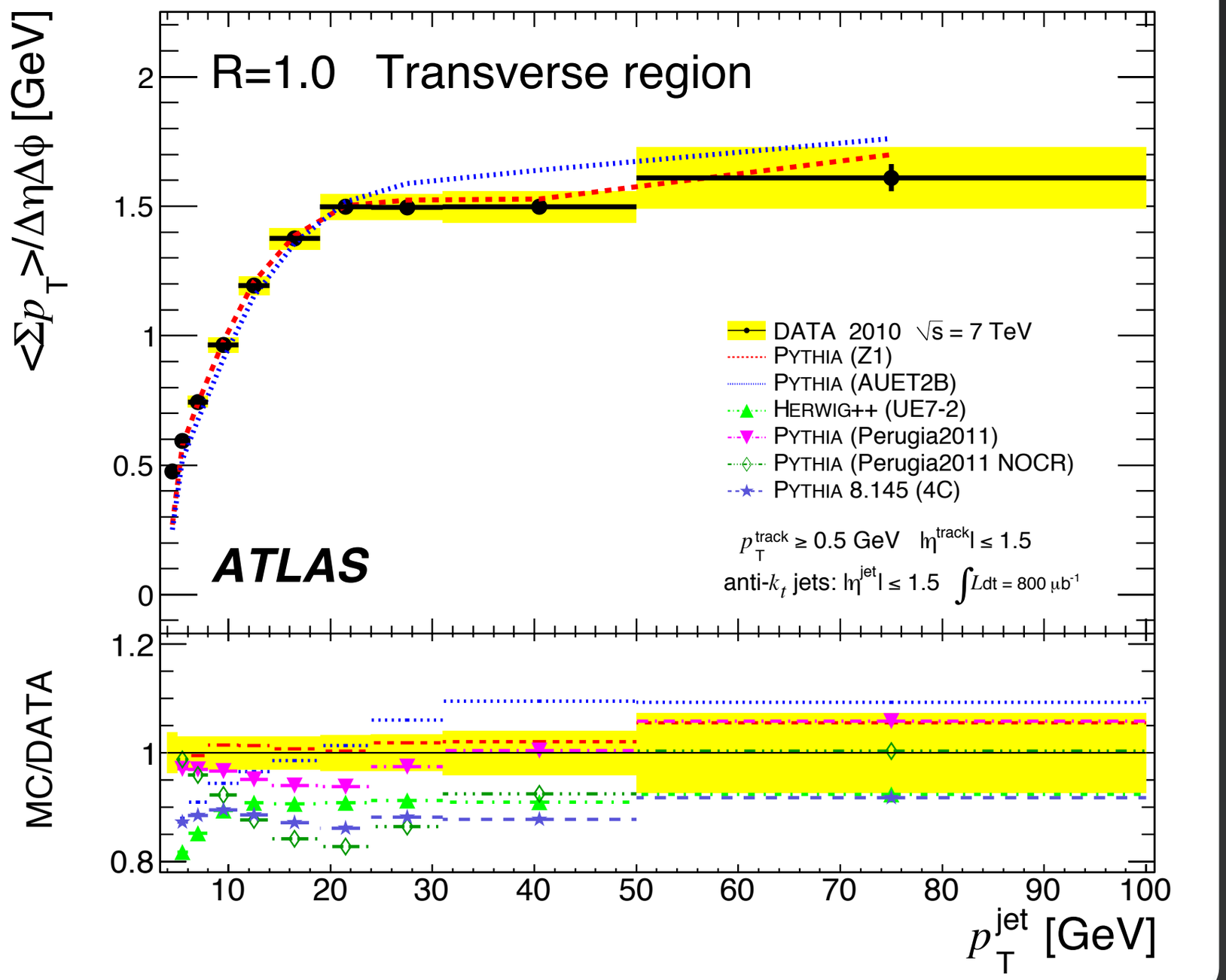

Underlying event with charged particle jets

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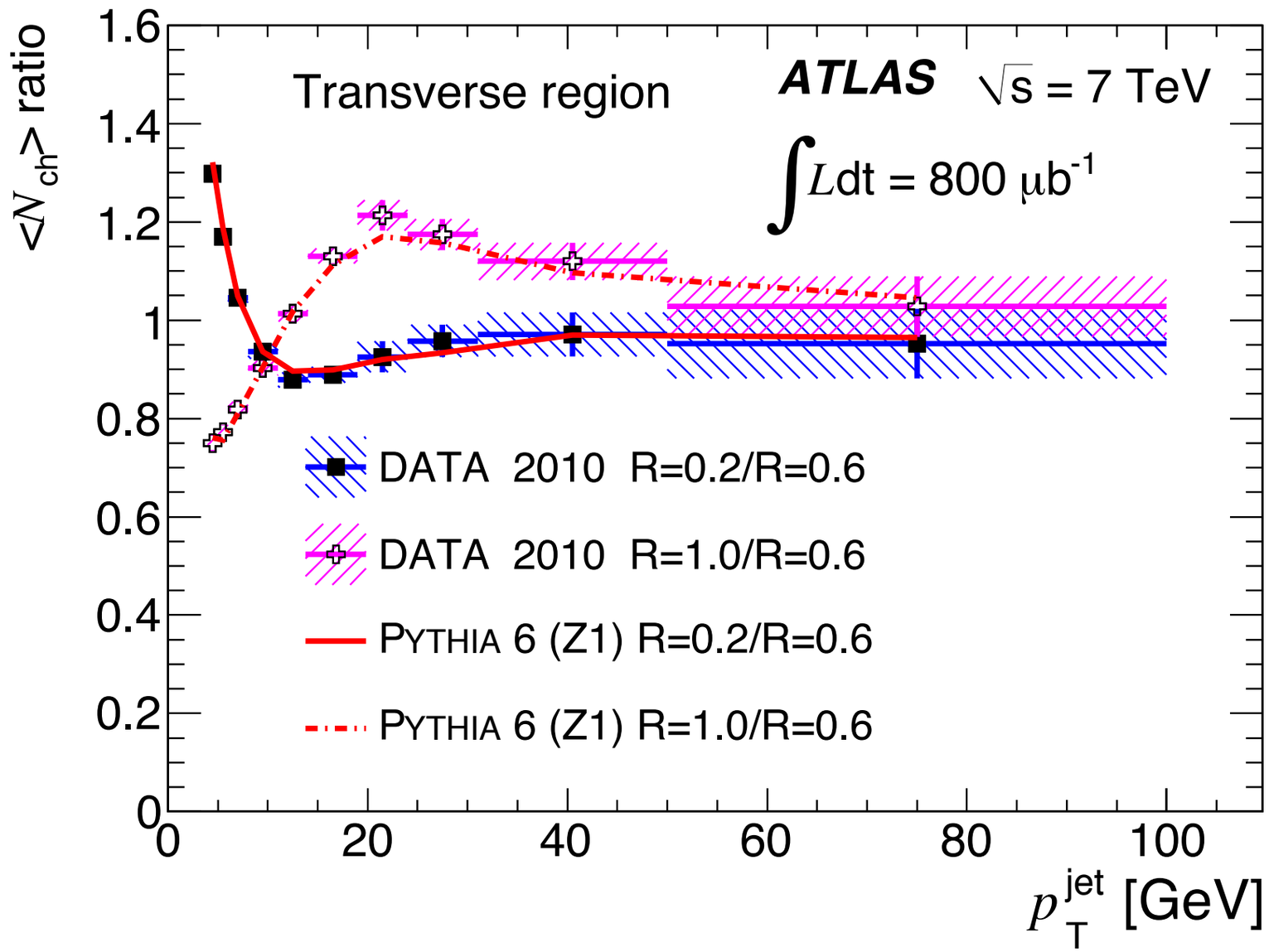
Using R=0.6 as the denominator, take the ratio of <Nch> using different jet radii to define the lead direction

At high jet pT the ratio is close to one, indicating low R dependence

At low pT there is a relative rise for low R. This is because, for a lower R, one needs a higher overall activity to achieve the same jet pT



Underlying event in jet events

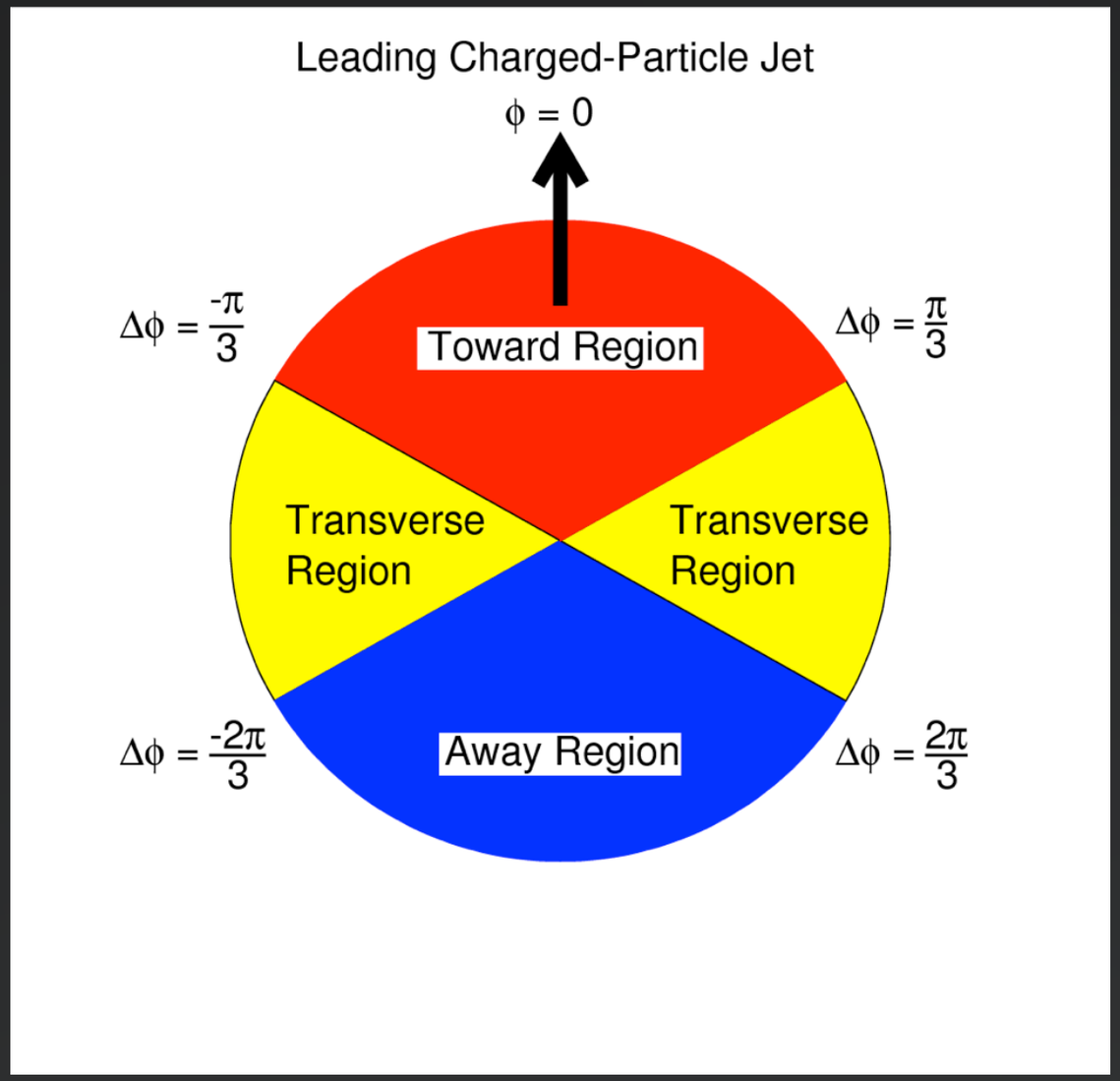
https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/CONFNOTES/ATLAS-CONF-2012-164/

Preliminary ATLAS measurement

Construct **R=0.4 anti-kT** jets from calorimeter clusters. Accept all jets with **pT > 20 GeV and |η|<2.8**

Leading such **jet** defines the **towards** direction

Also define **exclusive** sample, which has **exactly** two such jets



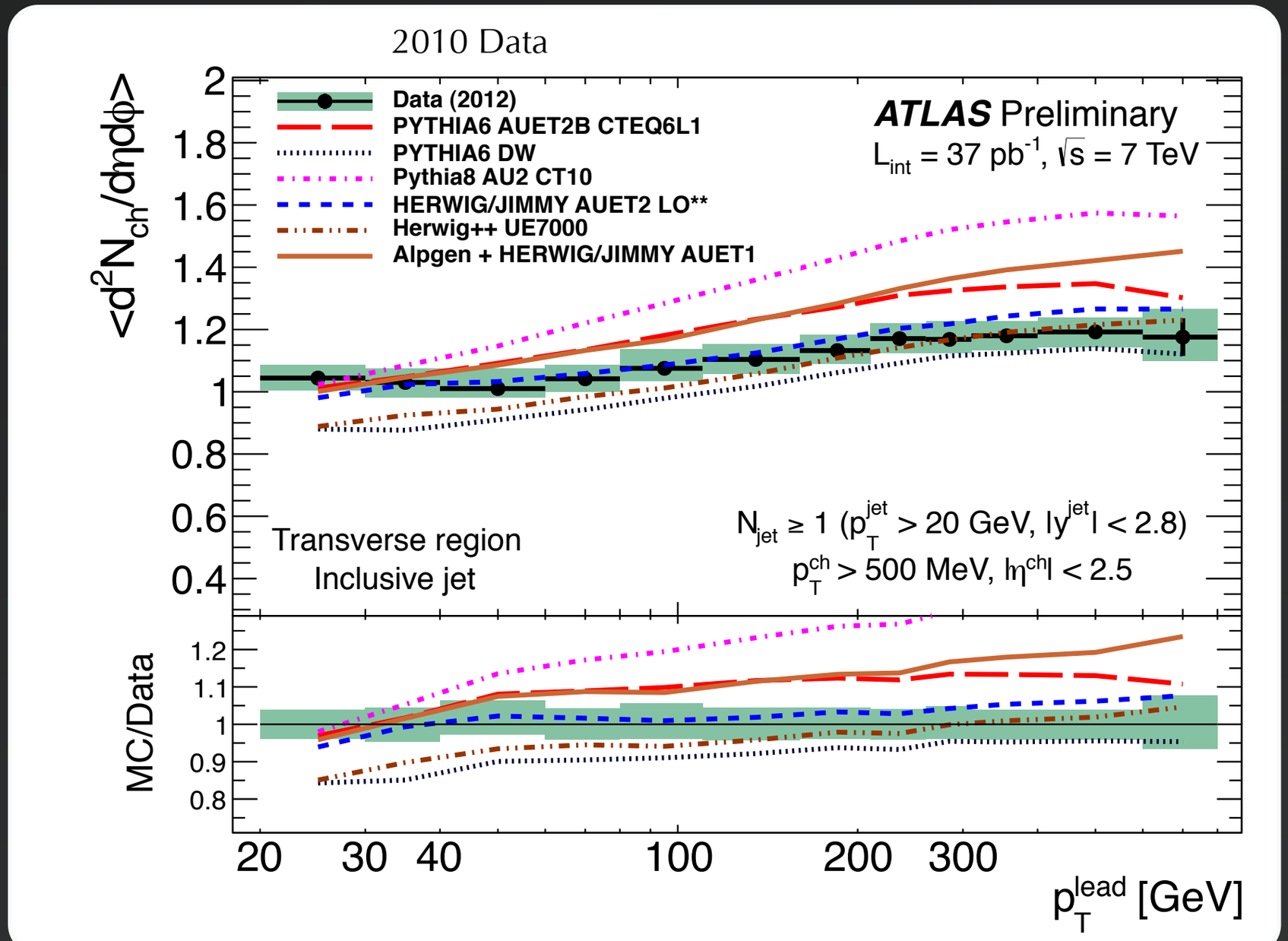
Count **tracks** as before, and also **ΣET** from **calo-clusters**. Clusters allow **forward** activity to be probed

Final distributions are unfolded to particle-level to remove all detector effects and compared to a variety of Monte Carlo models

Underlying event in jet events

https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/CONFNOTES/ATLAS-CONF-2012-164/

Av. **number** of charged particles per unit η-ϕ in the **transverse** (UE-sensitive) region



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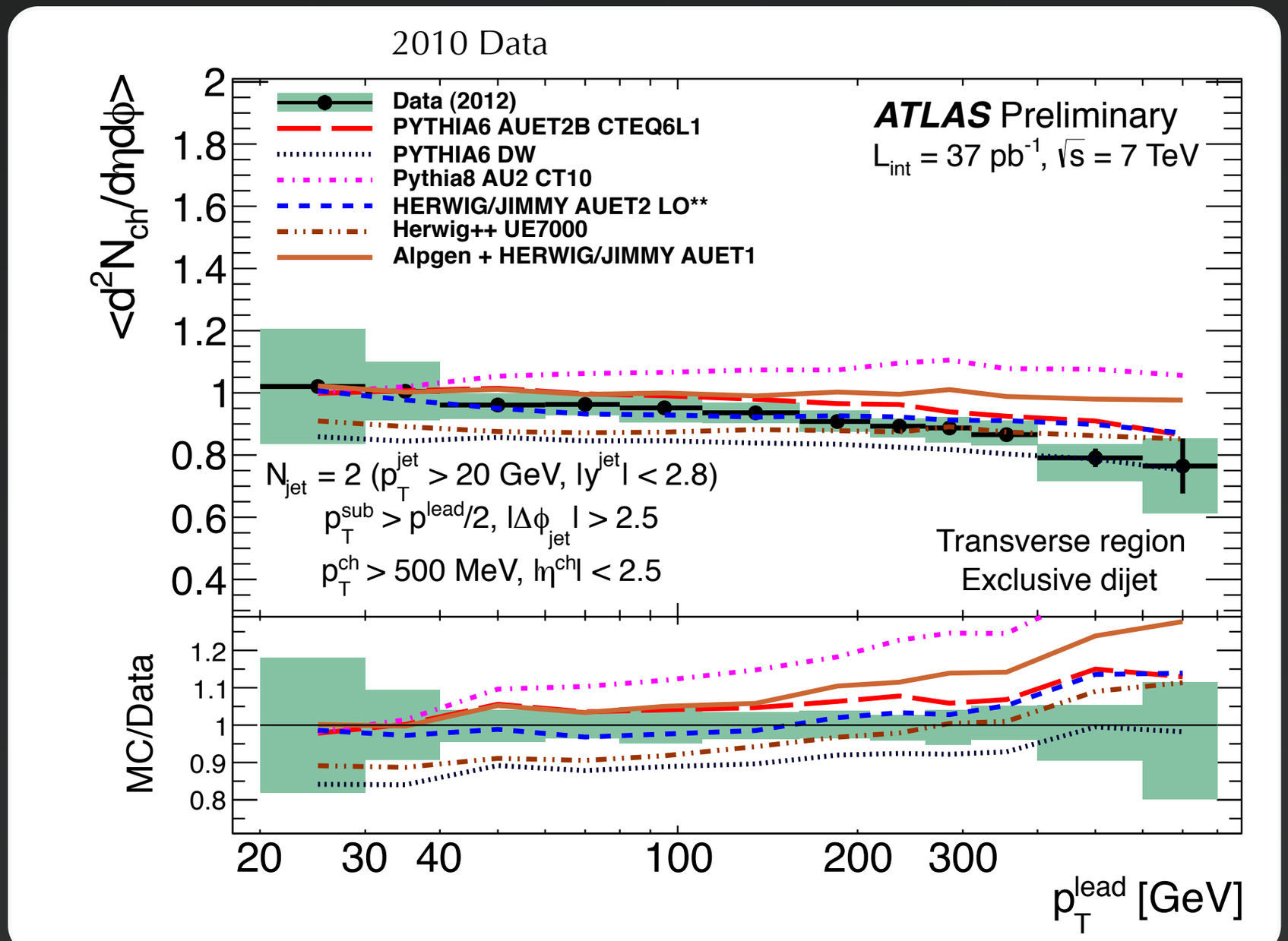
Av. **number** of charged particles per unit η-ϕ in the **transverse** (UE-sensitive) region

Exclusivity requirement vetoes third jet, reducing UE activity (especially at high lead jet pT)



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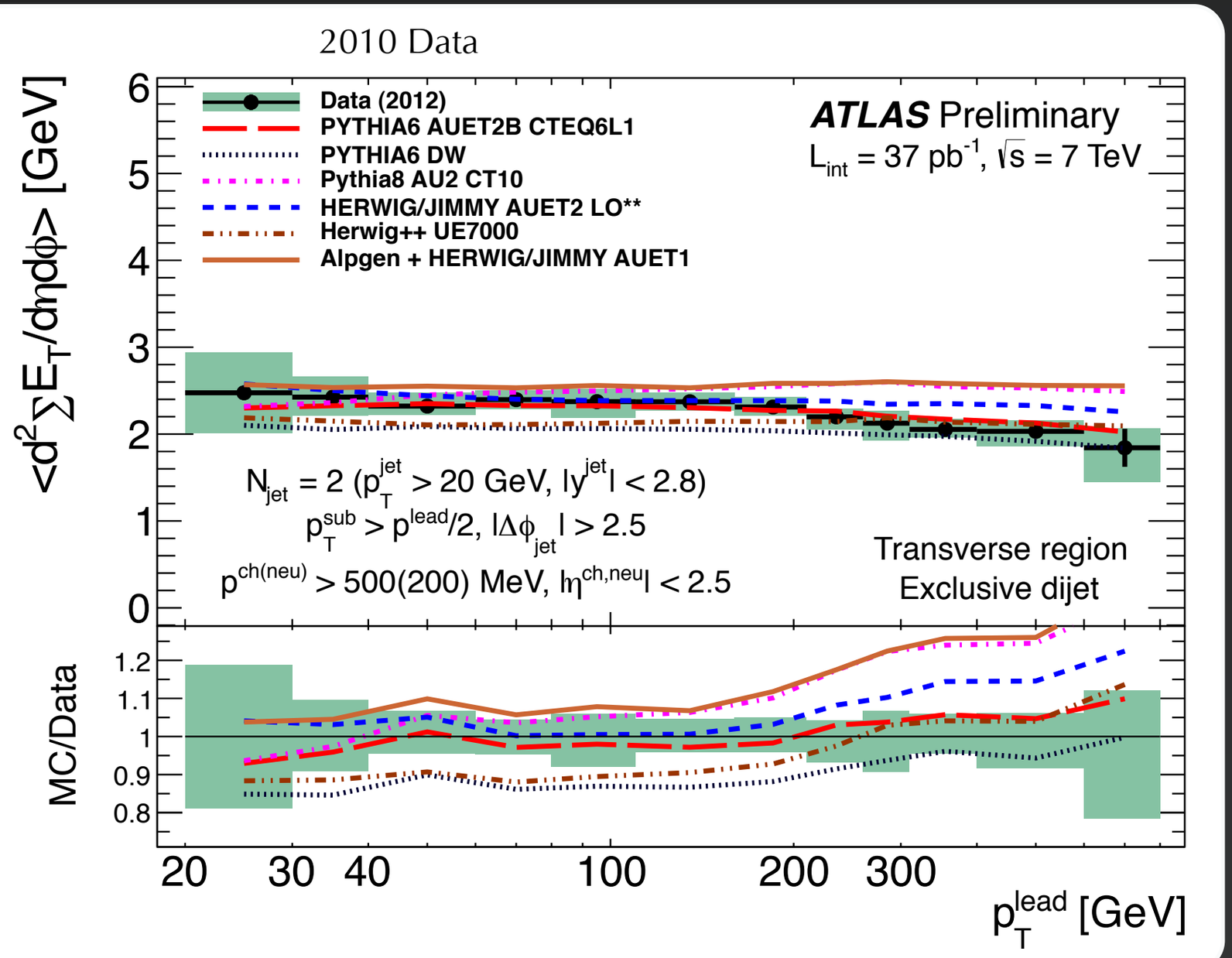
Exclusivity requirement vetoes third jet, reducing UE activity (especially at high lead jet pT)

Av. sum of transverse **particle** ET in $|\eta|<2.5$



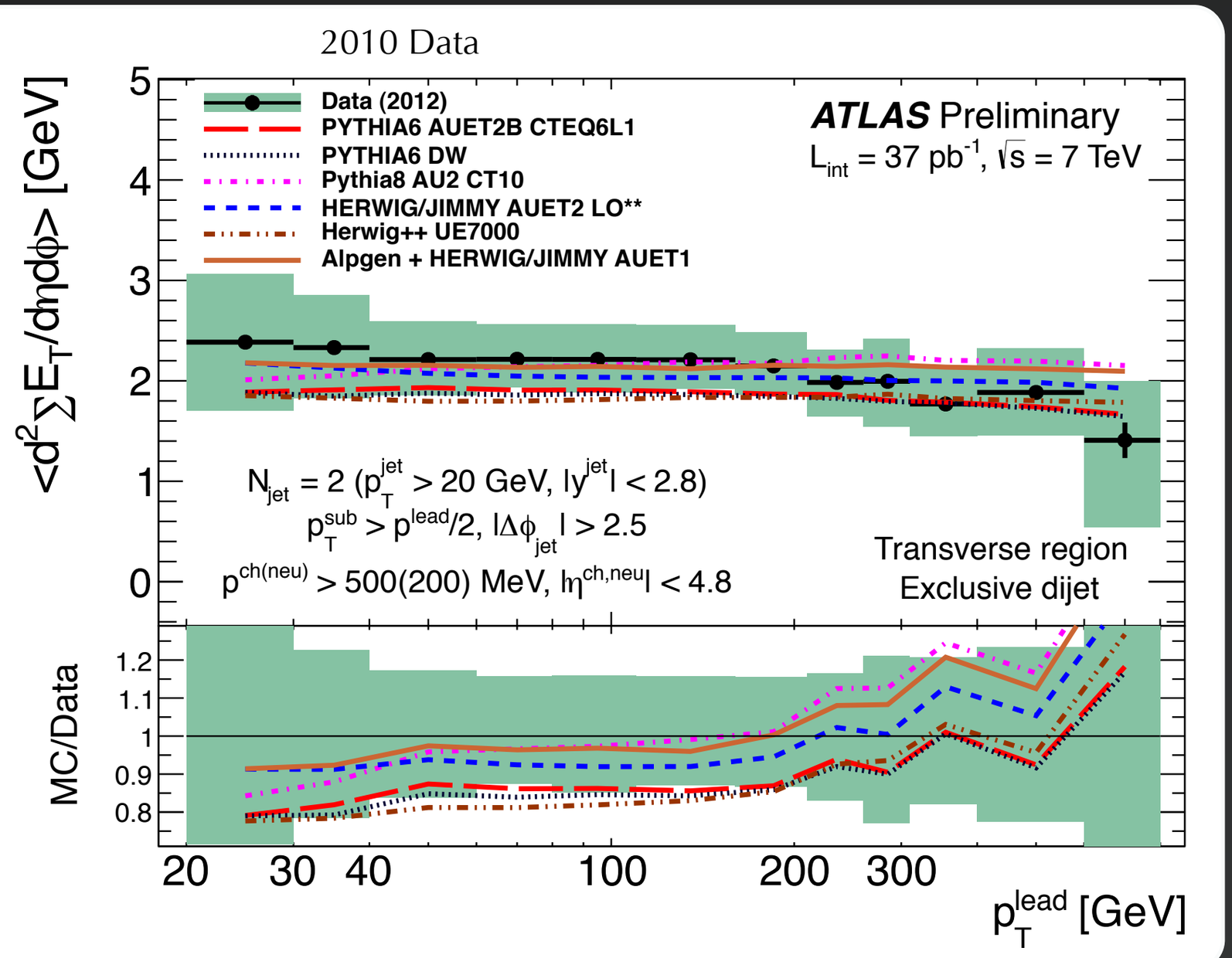
Underlying event in jet events

https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/CONFNOTES/ATLAS-CONF-2012-164/

Exclusivity requirement vetoes third jet, reducing UE activity (especially at high lead jet pT)

Including particles inside $|\eta| < 4.8$ does not make much difference to the **exclusive** distribution

Implies the high-pT UE activity is a **third jet**



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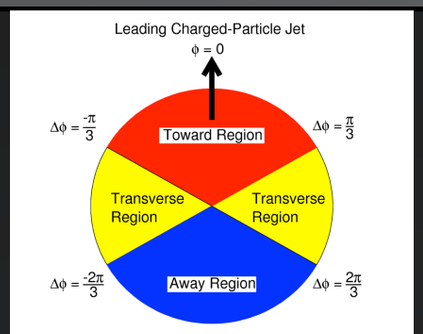
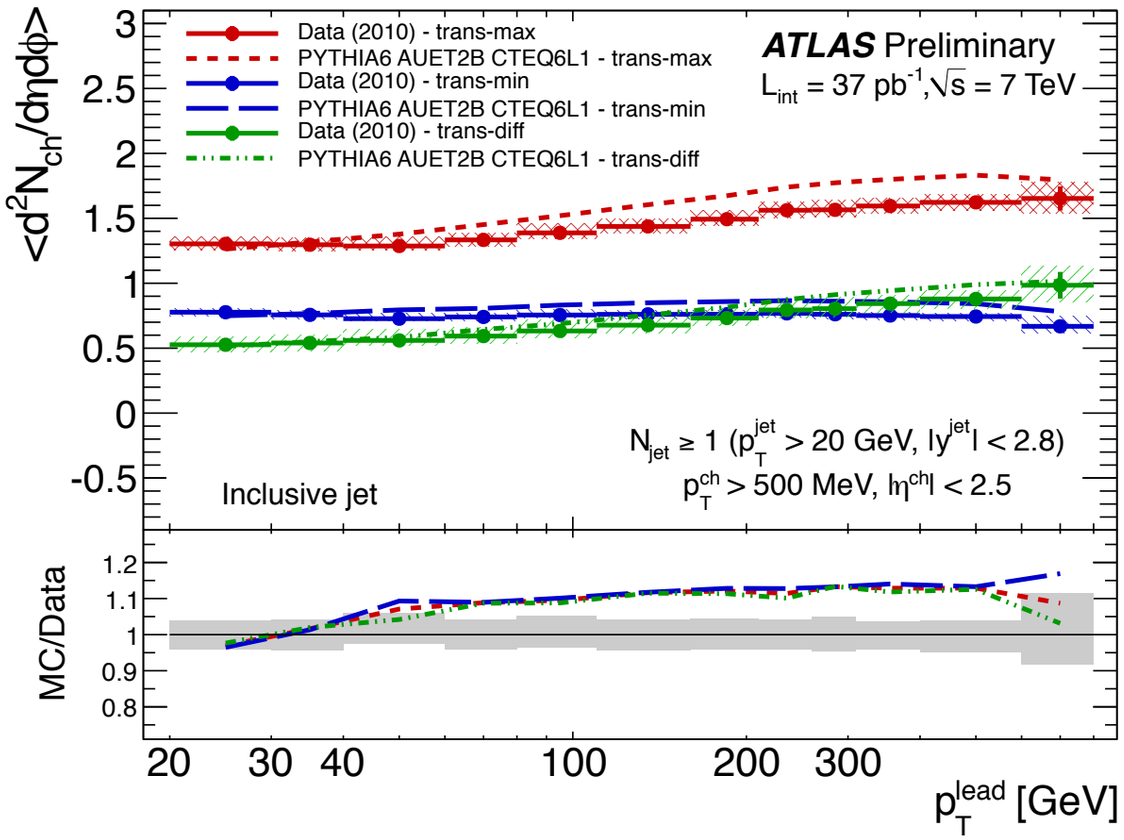
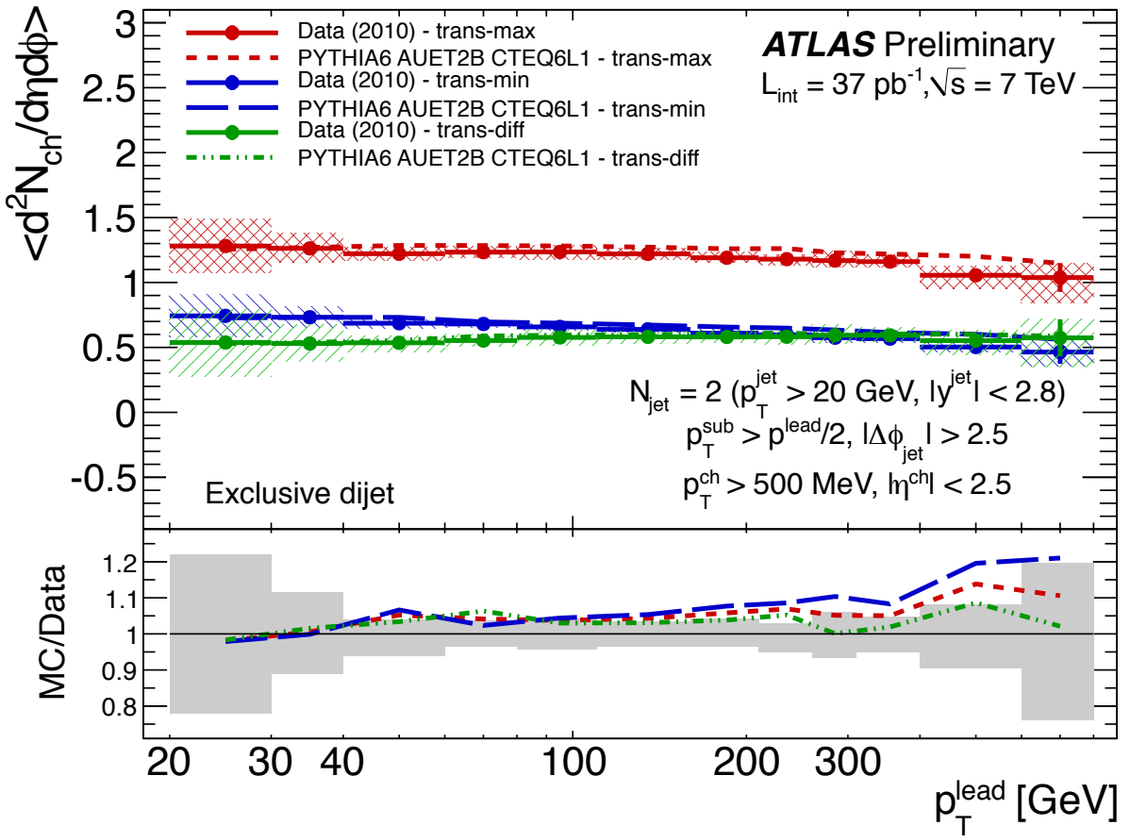


Trans-**max** region = transverse region with **highest** Nch

Trans-**min** region = transverse region with **lowest** Nch





Making the **exclusivity** cut **reduces** the **trans-max** distribution, but **not** the **trans-min**. Further indicates that the trans-max activity is a **third jet**!

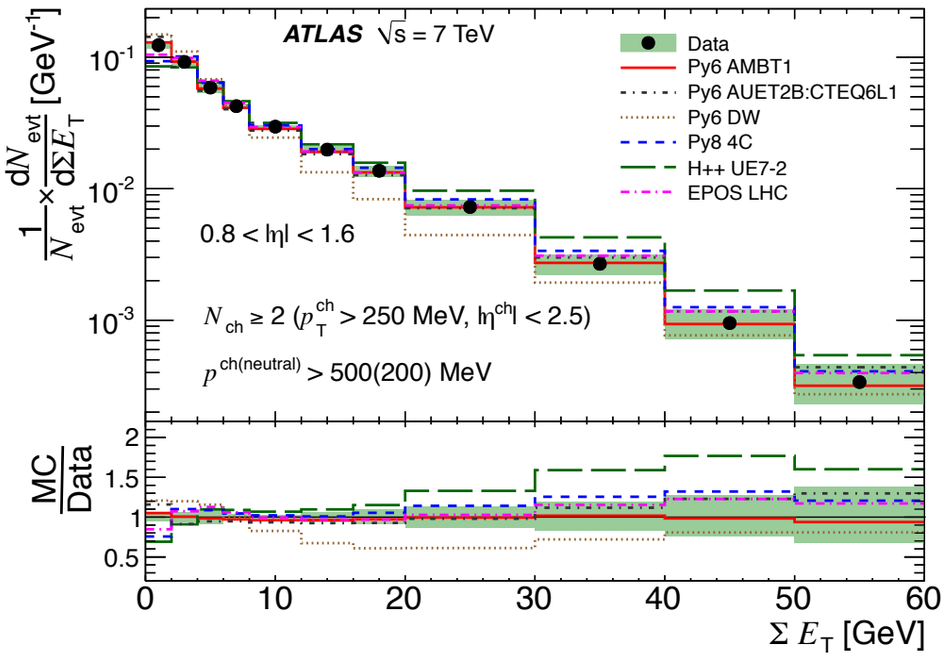
Transverse Energy Flow

Transverse Energy Flow

http://inspirehep.net/record/1183818

Take events triggered by minimum bias (MBTS) trigger and passing single good vertex requirement

Sum the calorimeter cluster energies in |η| bins. See right (corrected to particle level)



Calculate the average ΣET in a given |η| bin and plot Vs. |η|.

Two event samples: the "minimum bias" sample, which has at least 2 charged particles with pT > 250 MeV and |η| < 2.5

the di-jet sample, which has at least 2 anti-kT R=0.4 jets with pT > 20 GeV and |η| < 2.5

Final distributions are unfolded to particle-level to remove all detector effects and compared to a variety of Monte Carlo models

Transverse Energy Flow

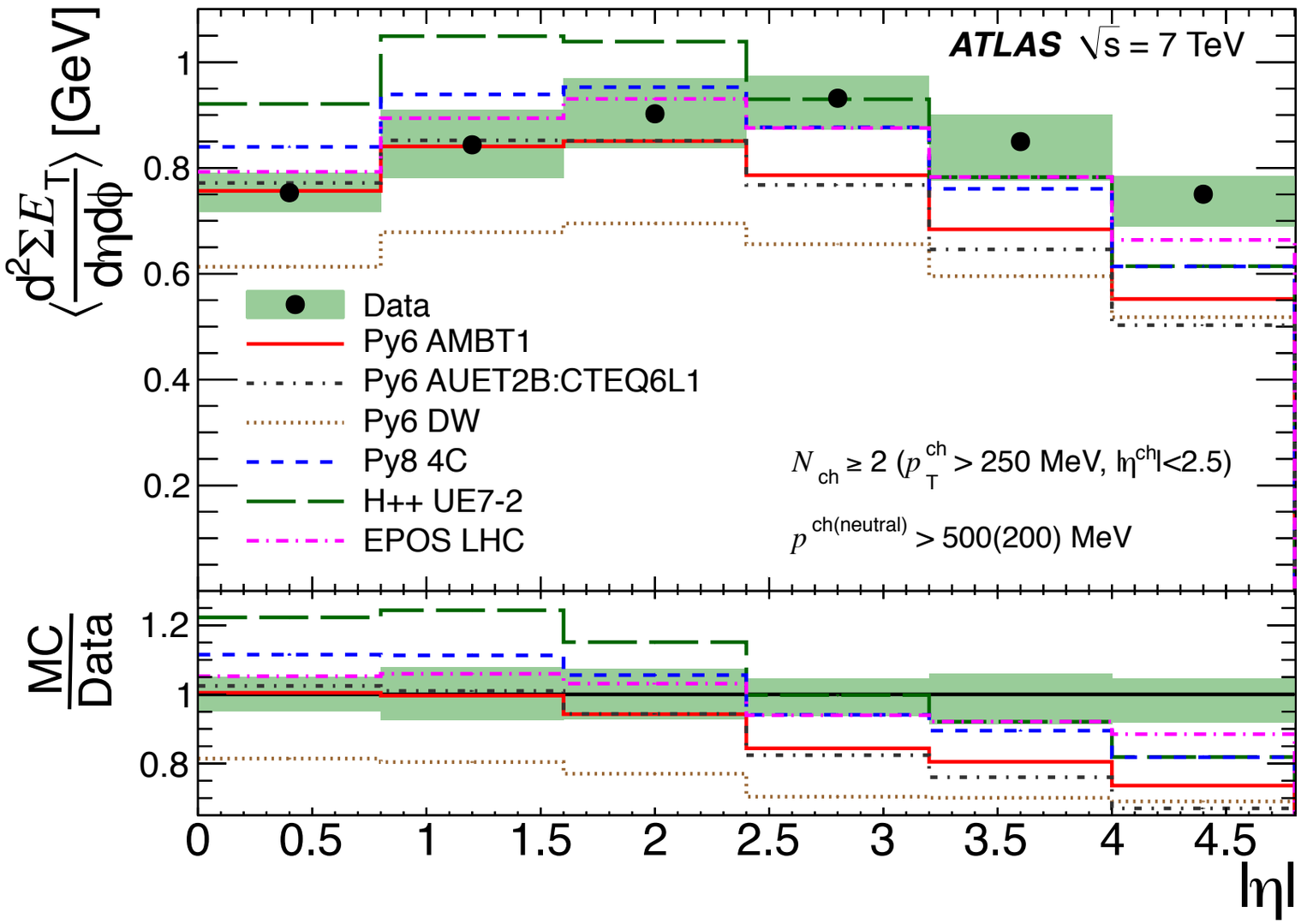
http://inspirehep.net/record/1183818

Av. **ΣET** in bins of |η| for the **minimum bias** sample

Diffraction becomes important in the **high |η|** bins

The **low |η|** bins are very **important** for the **pile-up** description (note AMBT1 and AUET2B)

Note the **trade-off** in the models between high and low |η|. Fixing the **central** cross section can worsen the **forward**



Transverse Energy Flow

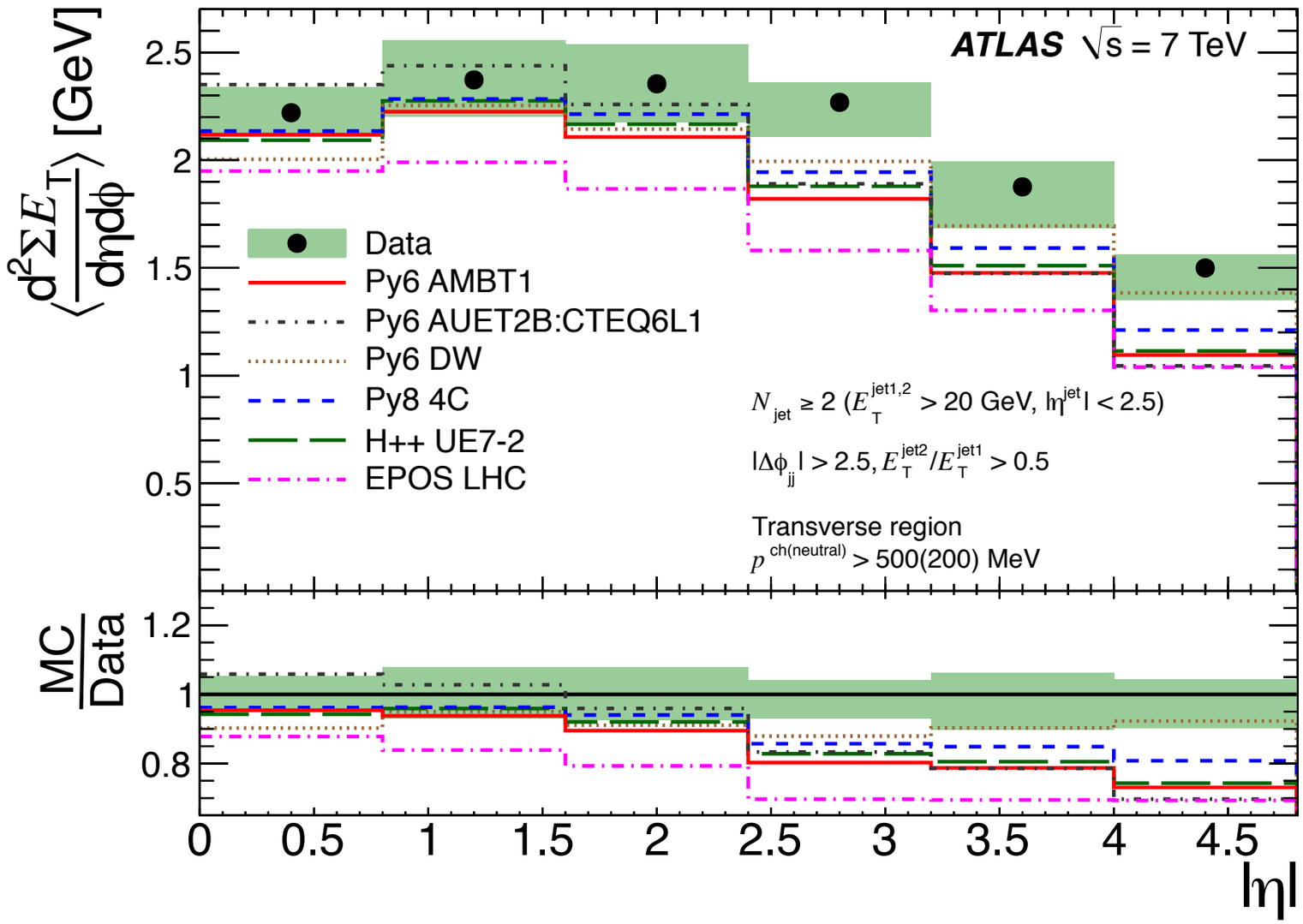
http://inspirehep.net/record/1183818

Av. **ΣET** in bins of |η| for the **di-jet** sample

ΣET is taken from the **transverse** azimuthal region (c.f. UE measurement)

This distribution is less important for the pile-up description

Gives a measure of forward activity in di-jet events



Transverse Energy Flow

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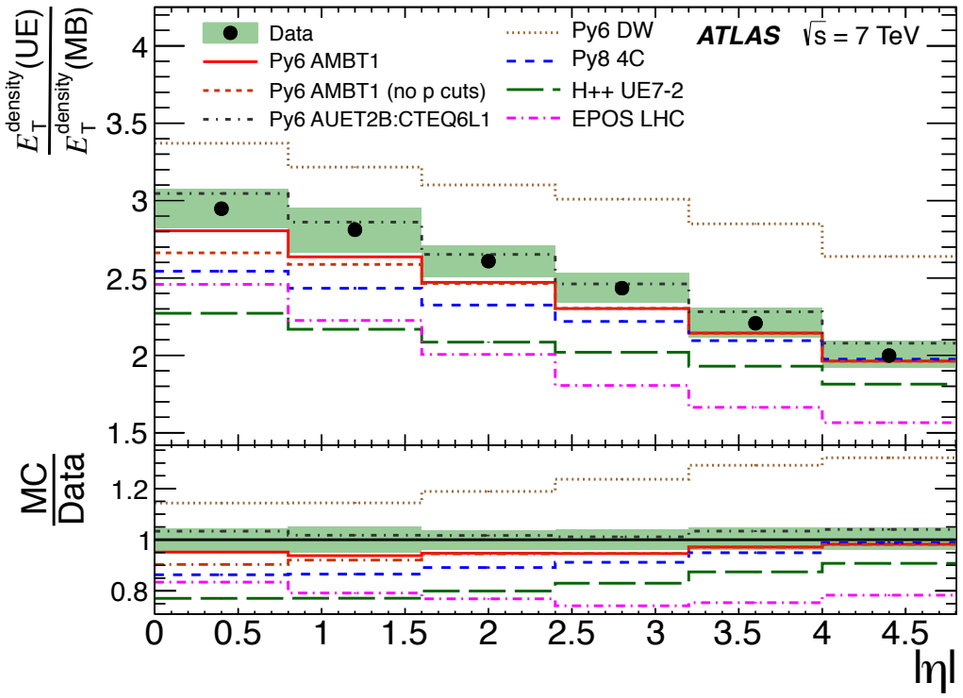
The ratio of activity in the di-jet to minbias samples falls at high pseudo-rapidity

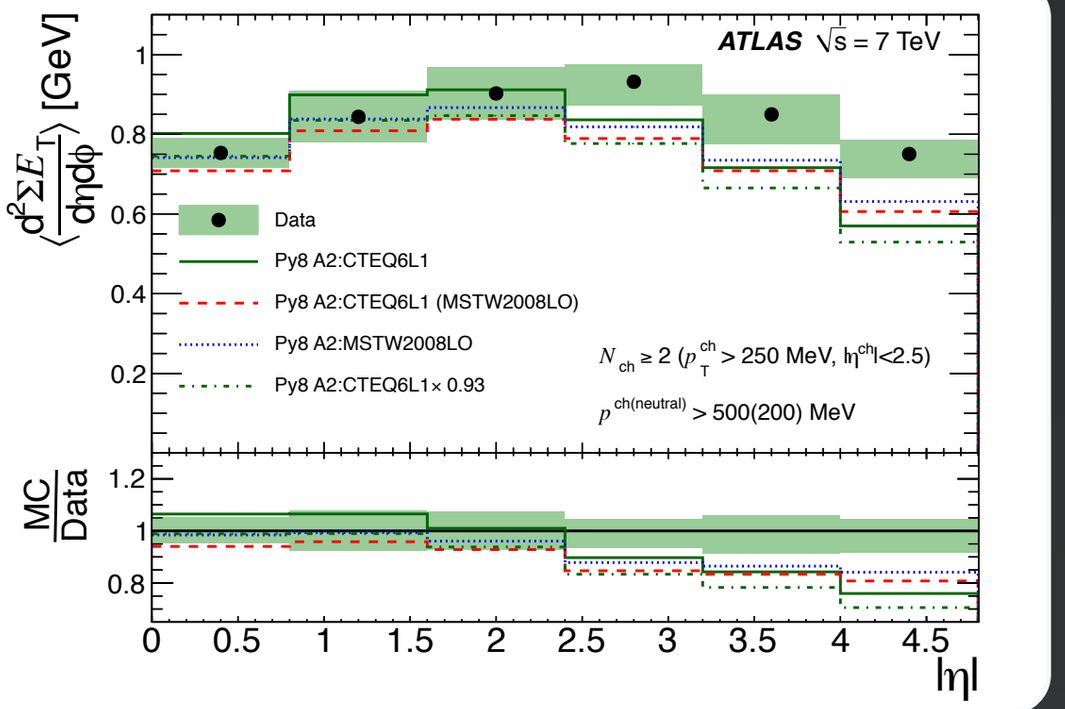
Forward activity is then to some extent independent of central jets

Background to VBF



Pythia 8 has a more sophisticated, harder diffractive model than Pythia 6 -> higher forward cross section

It was crucial to re-tune Pythia 8 to get an excellent description of the first two |η| bins



Charged Particle Event Shapes

Charged particle event shapes

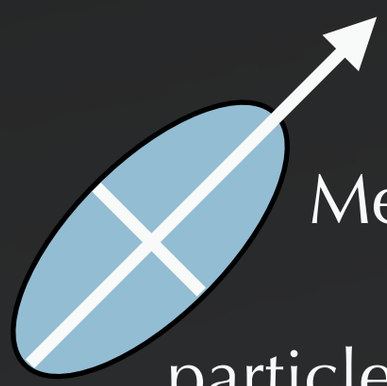
http://inspirehep.net/record/1124167

Take events triggered by minimum bias (MBTS) trigger and passing single good vertex requirement

Take all charged particles with pT > 500 MeV and $|\eta| < 2.5$. There must be at least six for an event to be selected.

Thrust:

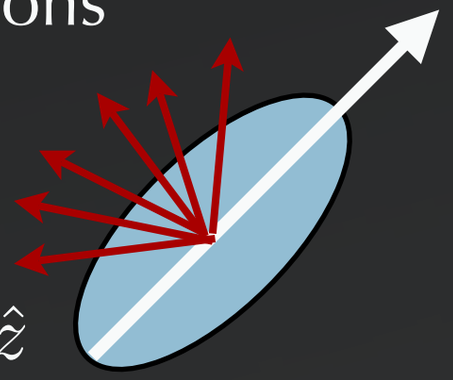
$$T_\perp = \max_{\hat{n}} \frac{\sum_i |\vec{p}_{T\,i} \cdot \hat{n}|}{\sum_i |\vec{p}_{T\,i}|}$$



Measures how collimated particle emission is

Thrust minor:

Measures emissions out of plane of thrust and beam



$$\hat{m} = \hat{n} \times \hat{z}$$

$$T_m = \frac{\sum_i |\vec{p}_{T\,i} \cdot \hat{m}|}{\sum_i |\vec{p}_{T\,i}|}$$

Sphericity:

$$S^{\alpha\beta} = \frac{\sum_i p_i^\alpha p_i^\beta}{\sum_i |\vec{p}_i|^2}$$

$$S = \frac{3}{2}(\lambda_2 + \lambda_3)$$

Balanced di-jet has S=0. Isotropic emission has S=1

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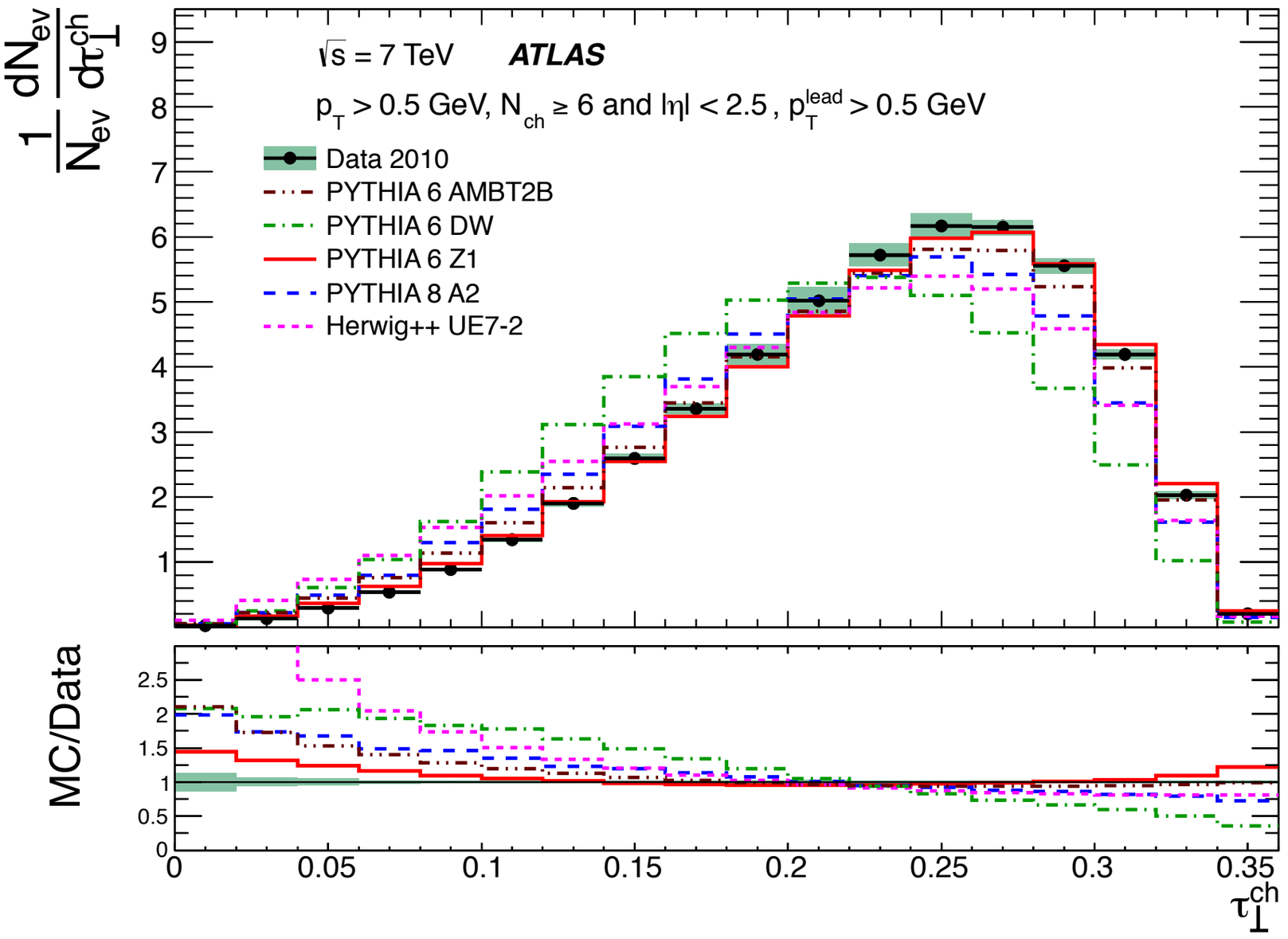

Require lead charged particle pT > 500 MeV

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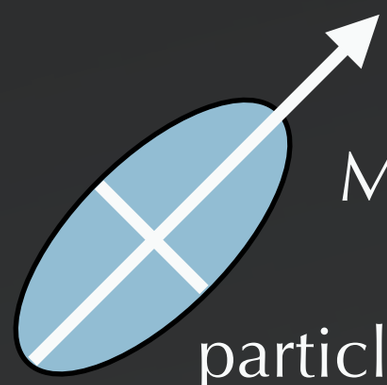

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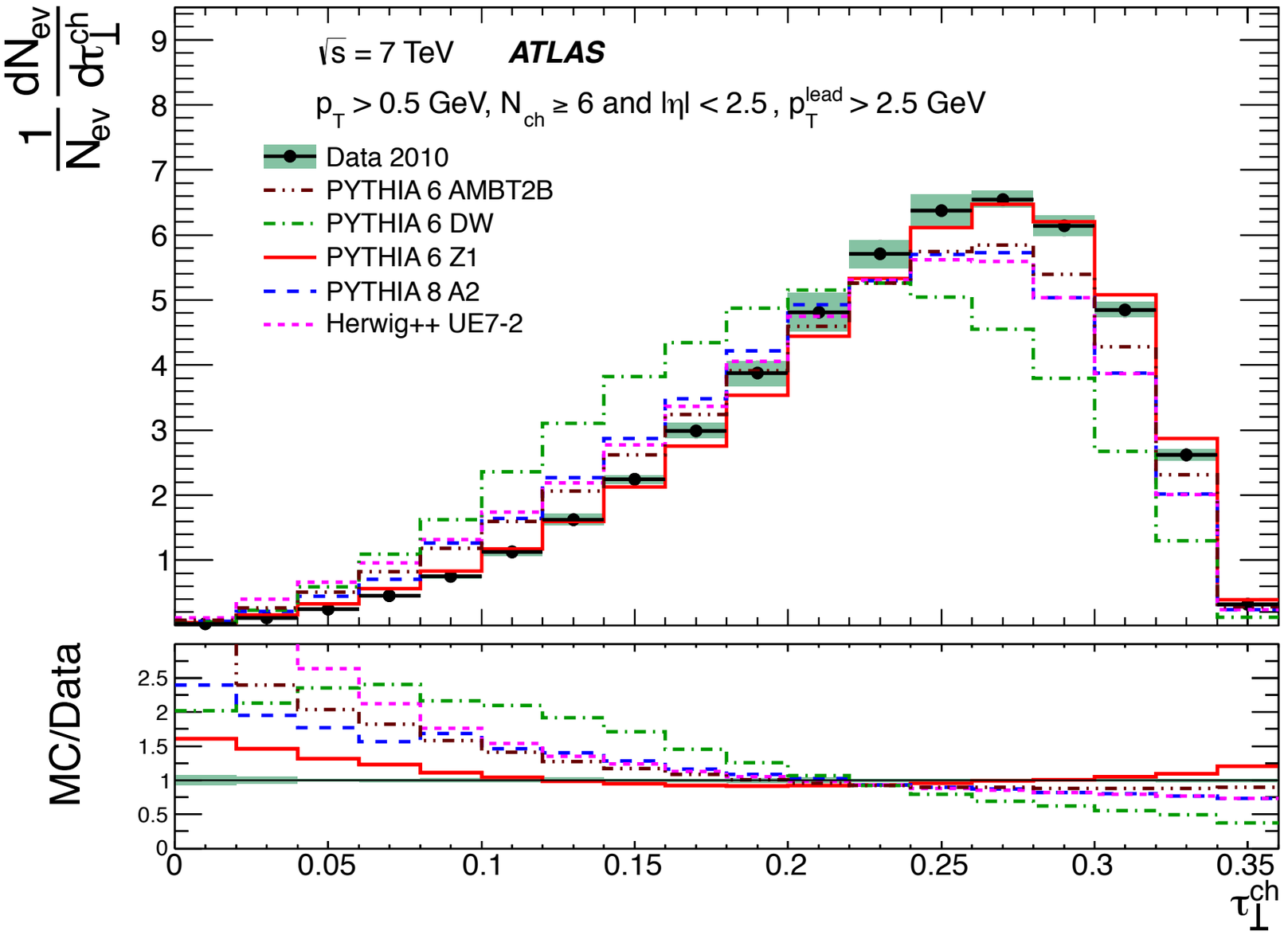

Require lead charged particle pT > 2.5 GeV

Thrust

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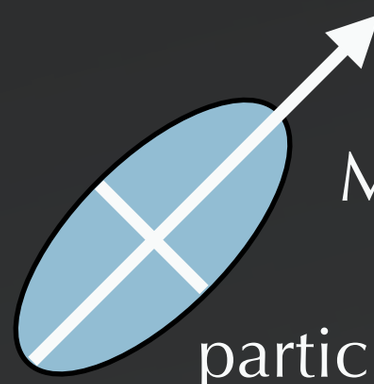

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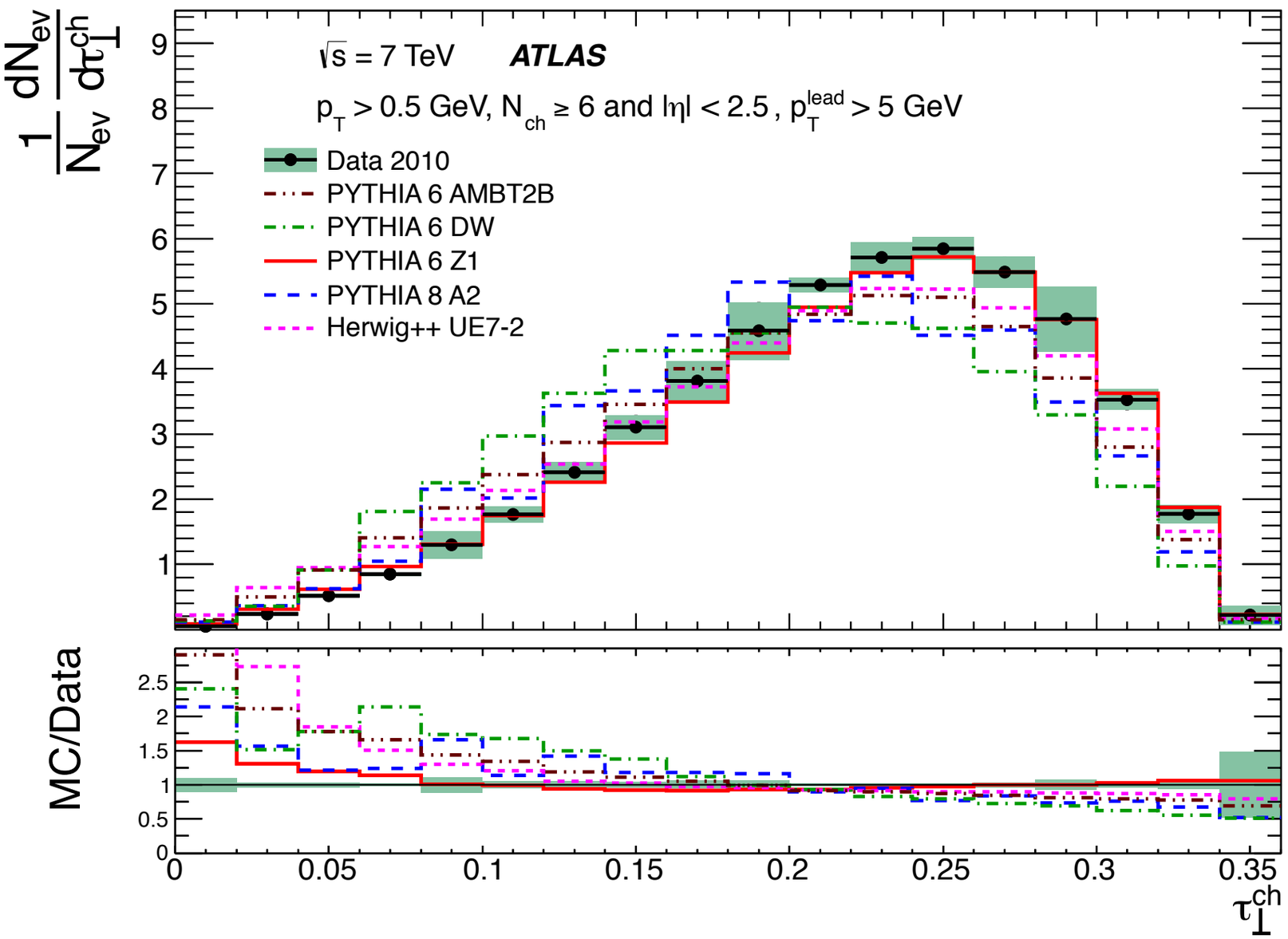
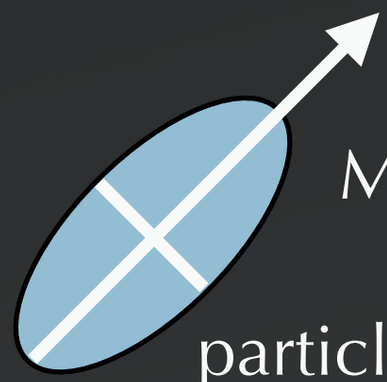


Require lead charged particle pT > 5 GeV

Thrust

$$T_\perp = \max_{\hat{n}} \frac{\sum_i |\vec{p}_{T\,i} \cdot \hat{n}|}{\sum_i |\vec{p}_{T\,i}|}$$



Measures how collimated particle emission is

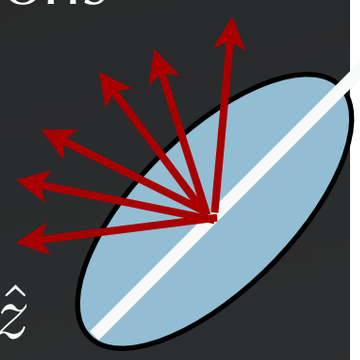
Charged particle event shapes

http://inspirehep.net/record/1124167

Require lead charged particle pT > 500 MeV

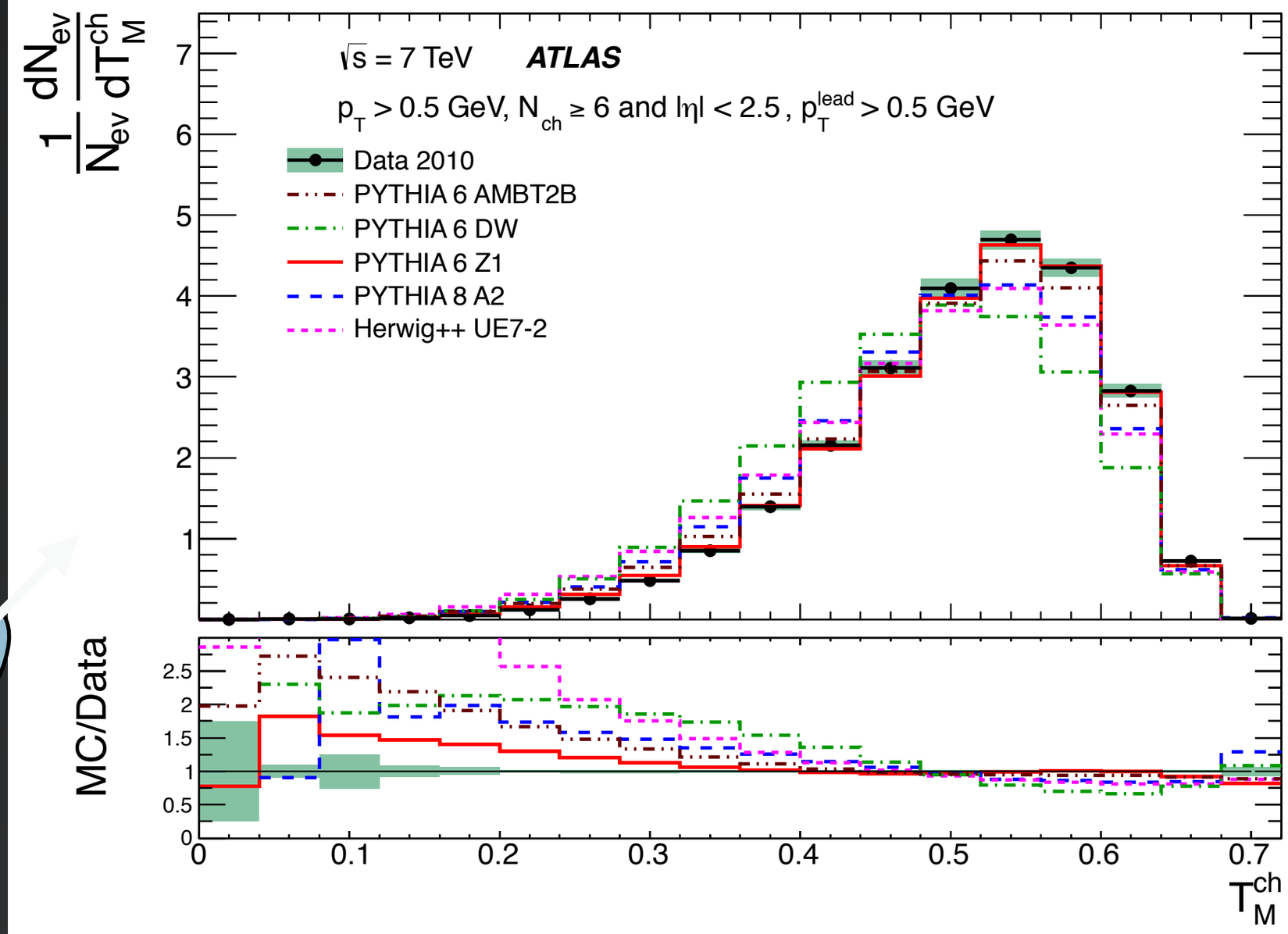
Thrust minor:

Measures emissions out of plane of thrust and beam



$$\hat{m} = \hat{n} \times \hat{z}$$

$$T_m = \frac{\sum_i |\vec{p}_{T\,i} \cdot \hat{m}|}{\sum_i |\vec{p}_{T\,i}|}$$



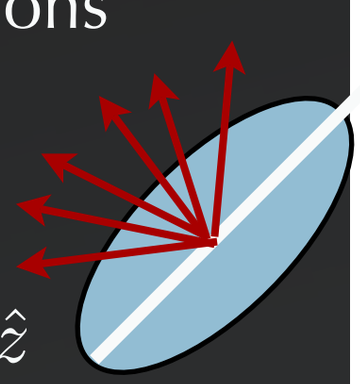
Charged particle event shapes

http://inspirehep.net/record/1124167

Require lead charged particle pT > 2.5 GeV

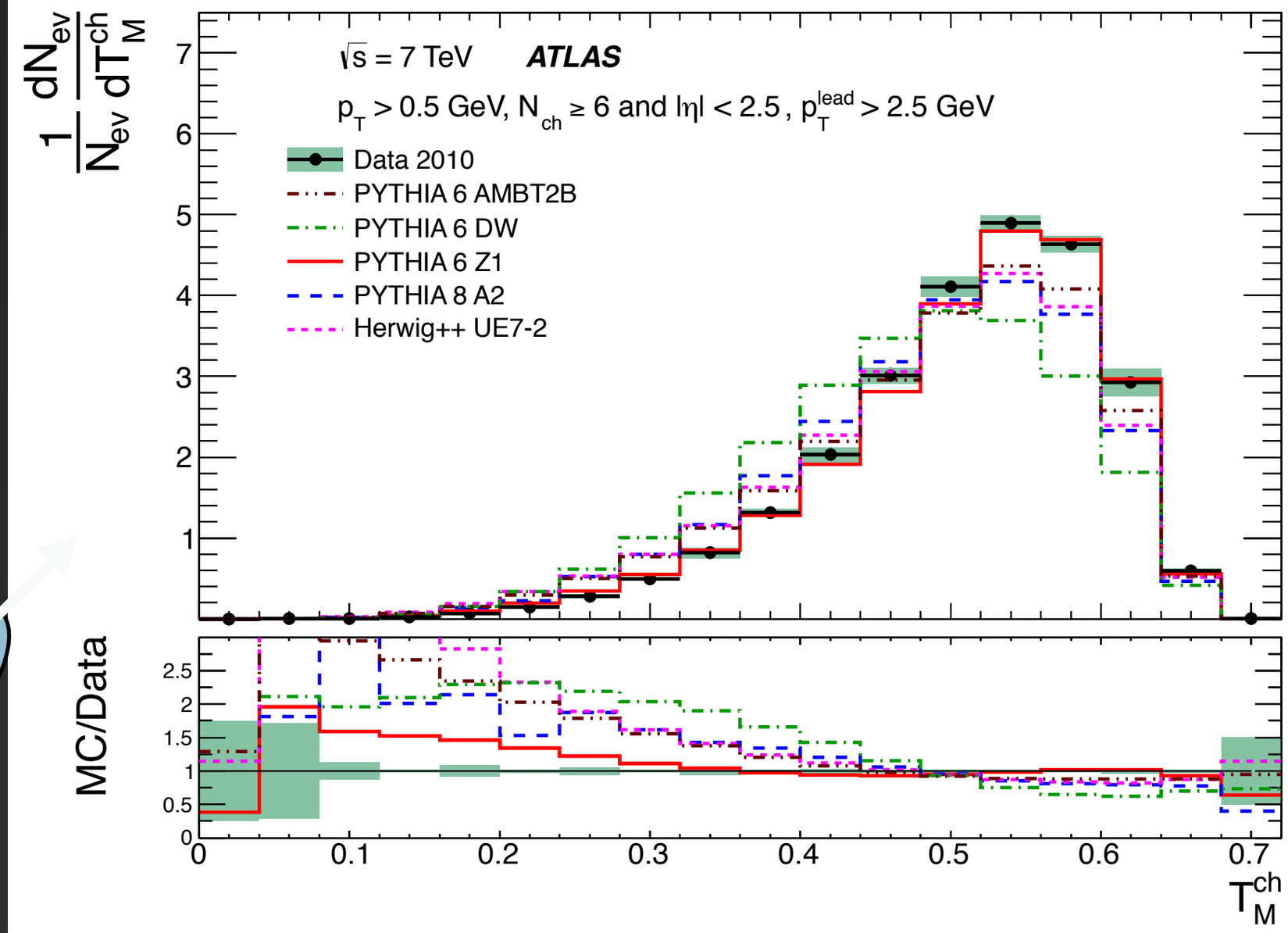
Thrust minor:

Measures emissions out of plane of thrust and beam



$$\hat{m} = \hat{n} \times \hat{z}$$

$$T_m = \frac{\sum_i |\vec{p}_{T\,i} \cdot \hat{m}|}{\sum_i |\vec{p}_{T\,i}|}$$



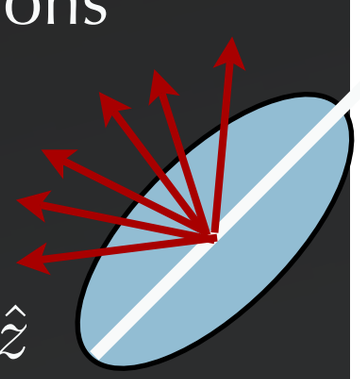
Charged particle event shapes

http://inspirehep.net/record/1124167

Require lead charged particle pT > 5 GeV

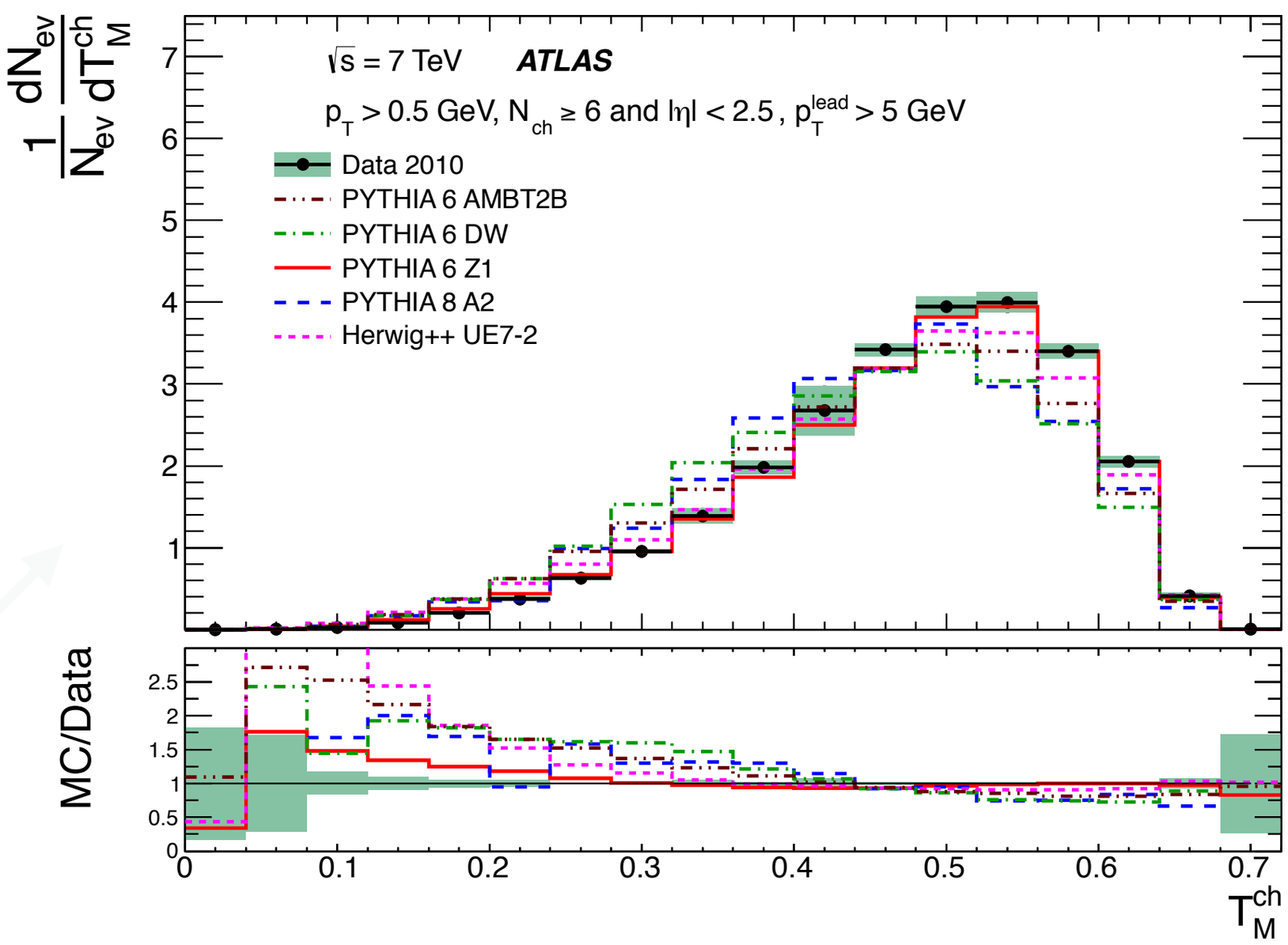
Thrust minor:

Measures emissions out of plane of thrust and beam



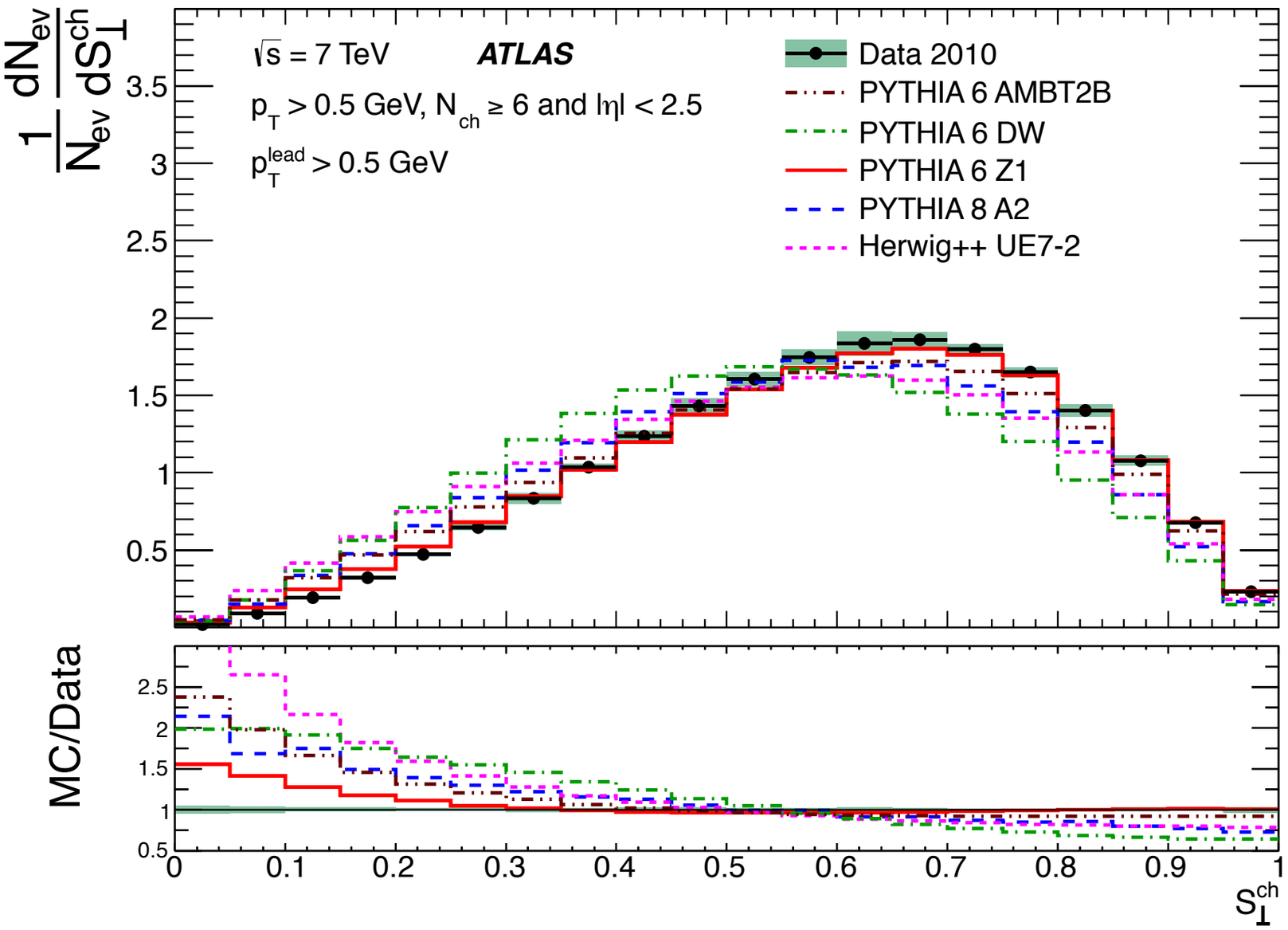
$$\hat{m} = \hat{n} \times \hat{z}$$

$$T_m = \frac{\sum_i |\vec{p}_{T\,i} \cdot \hat{m}|}{\sum_i |\vec{p}_{T\,i}|}$$



Charged particle event shapes

http://inspirehep.net/record/1124167



Require lead charged particle pT > 500 MeV

Sphericity:

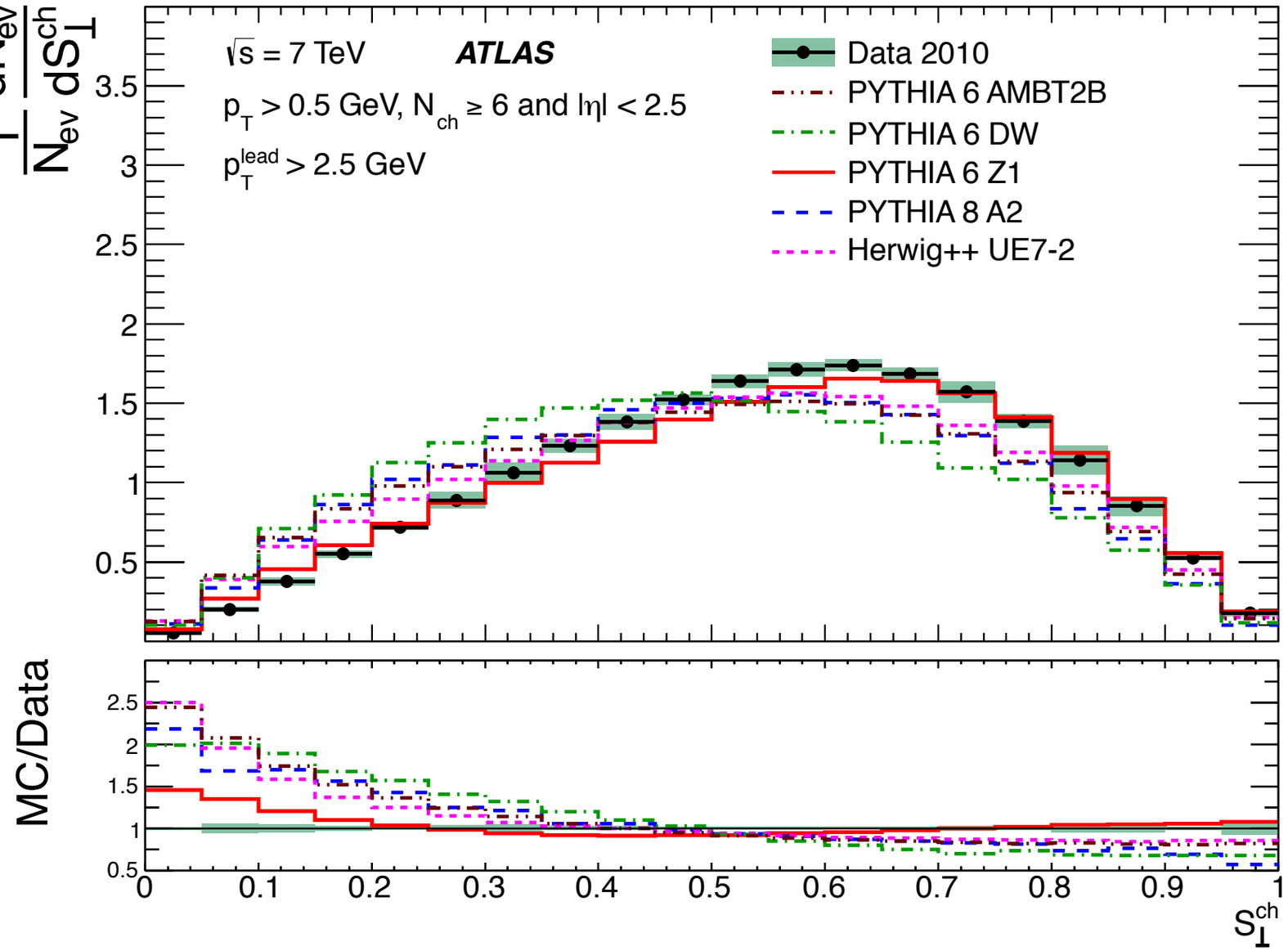
$$S^{\alpha\beta} = \frac{\sum_i p_i^\alpha p_i^\beta}{\sum_i |\vec{p}_i|^2}$$

$$S = \frac{3}{2}(\lambda_2 + \lambda_3)$$

Balanced di-jet has S=0. Isotropic emission has S=1

Charged particle event shapes

http://inspirehep.net/record/1124167



Require lead charged particle pT > 2.5 GeV

Sphericity:

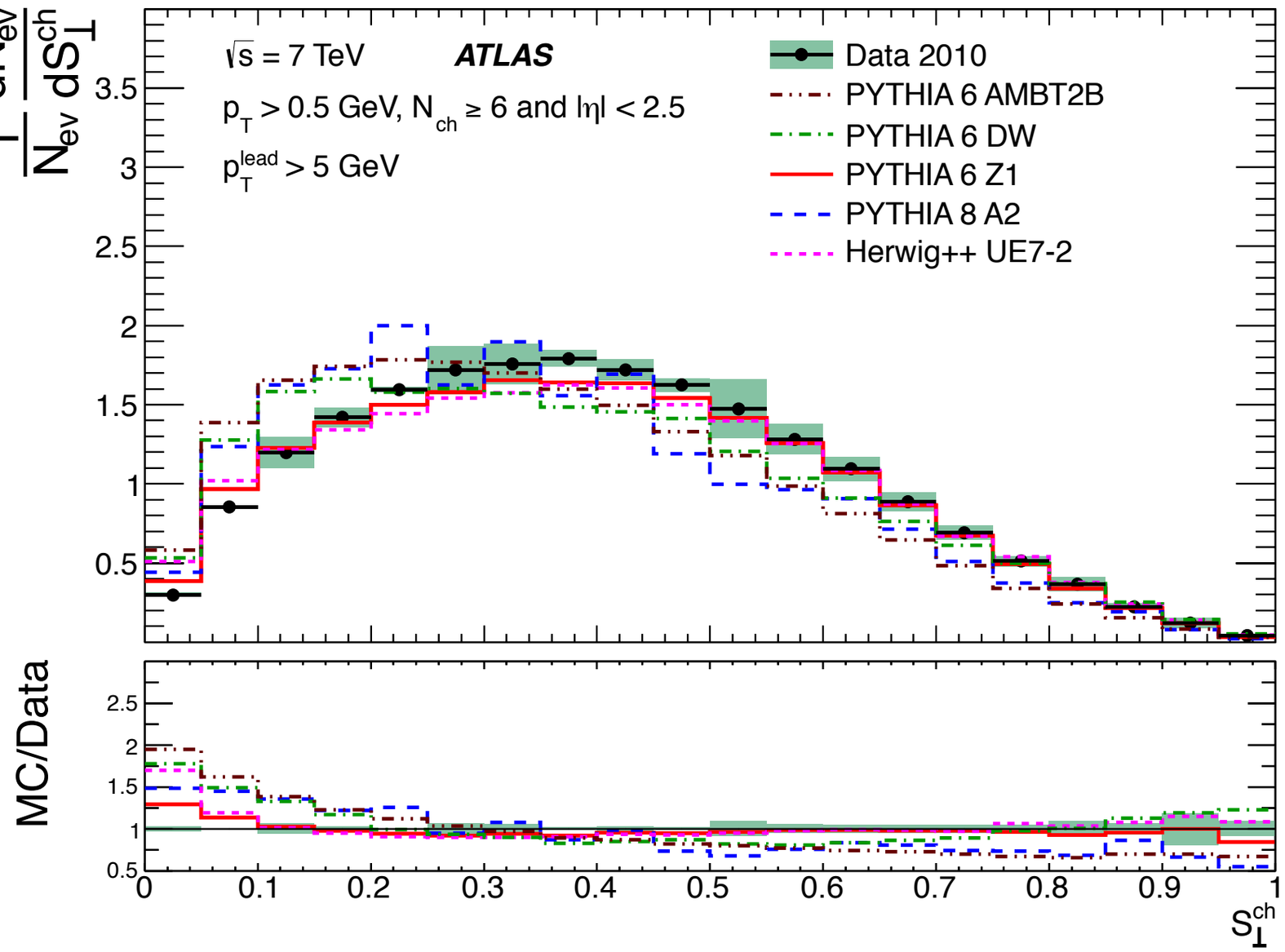
$$S^{\alpha\beta} = \frac{\sum_i p_i^\alpha p_i^\beta}{\sum_i |\vec{p}_i|^2}$$

$$S = \frac{3}{2}(\lambda_2 + \lambda_3)$$

Balanced di-jet has S=0. Isotropic emission has S=1

Charged particle event shapes

http://inspirehep.net/record/1124167



Require lead charged particle pT > 5 GeV

Sphericity:

$$S^{\alpha\beta} = \frac{\sum_i p_i^\alpha p_i^\beta}{\sum_i |\vec{p}_i|^2}$$

$$S = \frac{3}{2}(\lambda_2 + \lambda_3)$$

Balanced di-jet has S=0. Isotropic emission has S=1

Summary

- Underlying Event has been measured under a wide range of conditions (charged particles, neutral particles, different jet radii, exclusive, forward…)
- Transverse energy flow has been measured for minimum bias and higher pT conditions. Crucial for a good MC pile-up description
- A range of event shapes have been measured for different lead particle pT
- All distributions are unfolded and directly comparable to particle-level generator Monte Carlos