The ϕ-meson production cross section measured with the ATLAS detector at $\sqrt{s}$=7 TeV

Submitted to EPJC

http://arxiv.org/abs/1402.6162

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On behalf of the ATLAS Collaboration

Introduction

- The ϕ-meson is an *ss* resonance, with a mass of 1019.455 ± 0.020 MeV and a natural width of 4.26 ± 0.04 MeV*
- Produced both in hard scatter of *pp* interaction, as well as in hadronisation: φ-meson production can be used to tune phenomenological fragmentation models
- Very short lifetime, decays through $\phi \rightarrow K^+K^-$ with BR = (48.9 ± 0.5)%
- From simulation: about one ϕ meson produced per inelastic *pp* interaction at √s = 7 TeV

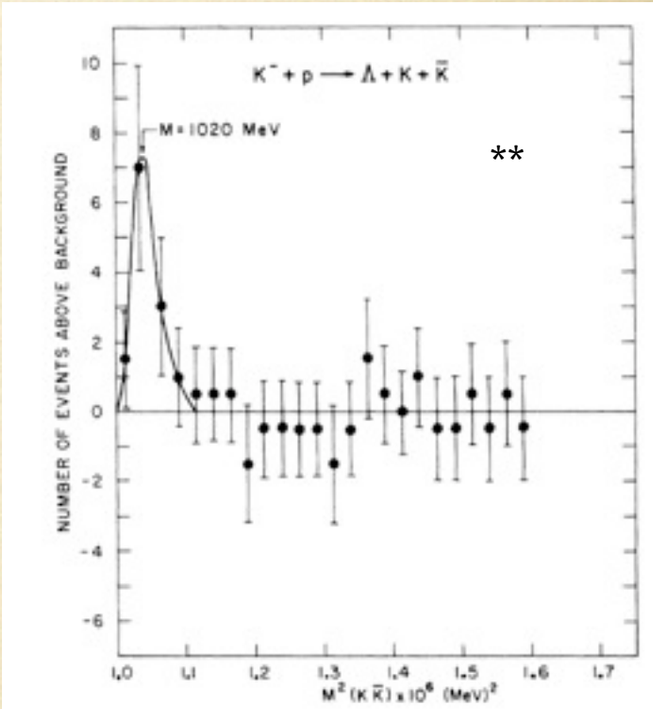


FIG. 4. The (effective mass)^2 distribution for $K\bar{K}$ from the channel $\Lambda K\bar{K}$ for those events above phase space.

* PDG (2012)

** Phys. Rev. Lett. 9 4, (1962)

Analysis overview

The cross section is measured as:

$\sigma_{\varphi \to K^+K^-} = N_{reco} / L$,

where N_{reco} is the number of reconstructed φ mesons, corrected for reconstruction and kaon identification (PID) efficiencies and L the luminosity in the data sample.

N_{reco} is measured with a fit to the invariant mass spectrum of oppositely charged tracks from the interaction point.

To avoid model-dependent extrapolations, the result is presented in the *fiducial volume:*

$500 < p_{T,\varphi} < 1200$ MeV, $|y_\varphi| < 0.8$, $p_{T,K} > 230$ MeV and $p_K < 800$ MeV

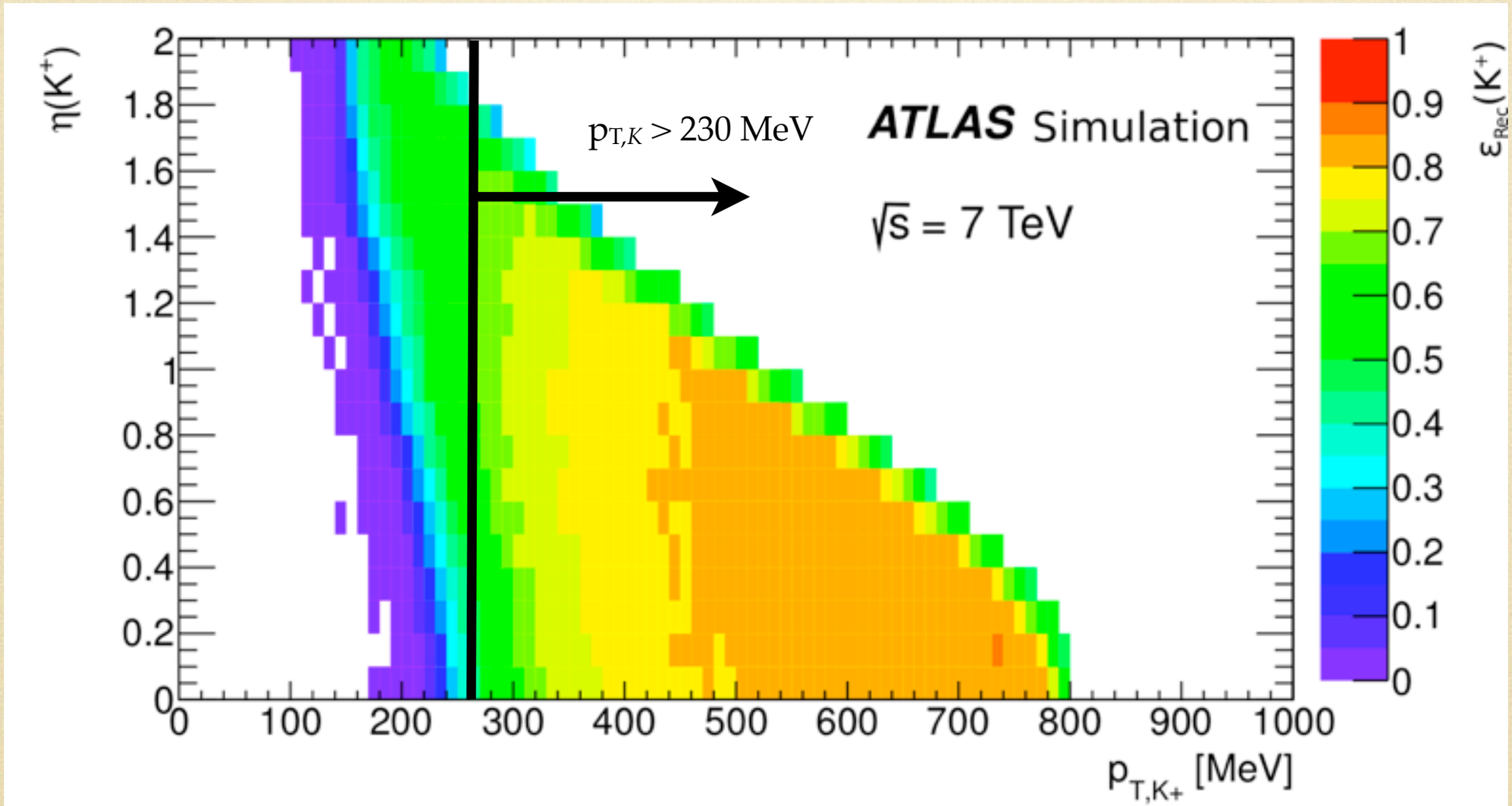
Data sample and event selection

- Data sample of events triggered with Minimum Bias Trigger Scintillators of L = 383 ± 13* μb^{-1} taken in April 2010
- Events were required to have a primary vertex with at least two tracks with p_T=150 MeV
- Track re-fitted to be compatible with primary vertex
- Tracks re-fitted with a kaon-mass assumption
- Tracks required to have N_{pix}>1 and N_{SCT}>1

* Eur Phys J C73, 2518 (2013)

Tracking efficiency, ε_{rec}

ε_{rec} calculated from simulation per kaon as $\varepsilon_{rec} = N_{gen,match} / N_{gen}$ in $p_{T,K}$ and η_K.



The right boundary of the efficiency map corresponds to $p_K = 800$ MeV limit.

Both tracks need to be reconstructed in order to calculate the invariant mass.

$\varepsilon_{rec,\varphi\rightarrow K^+K^-}$

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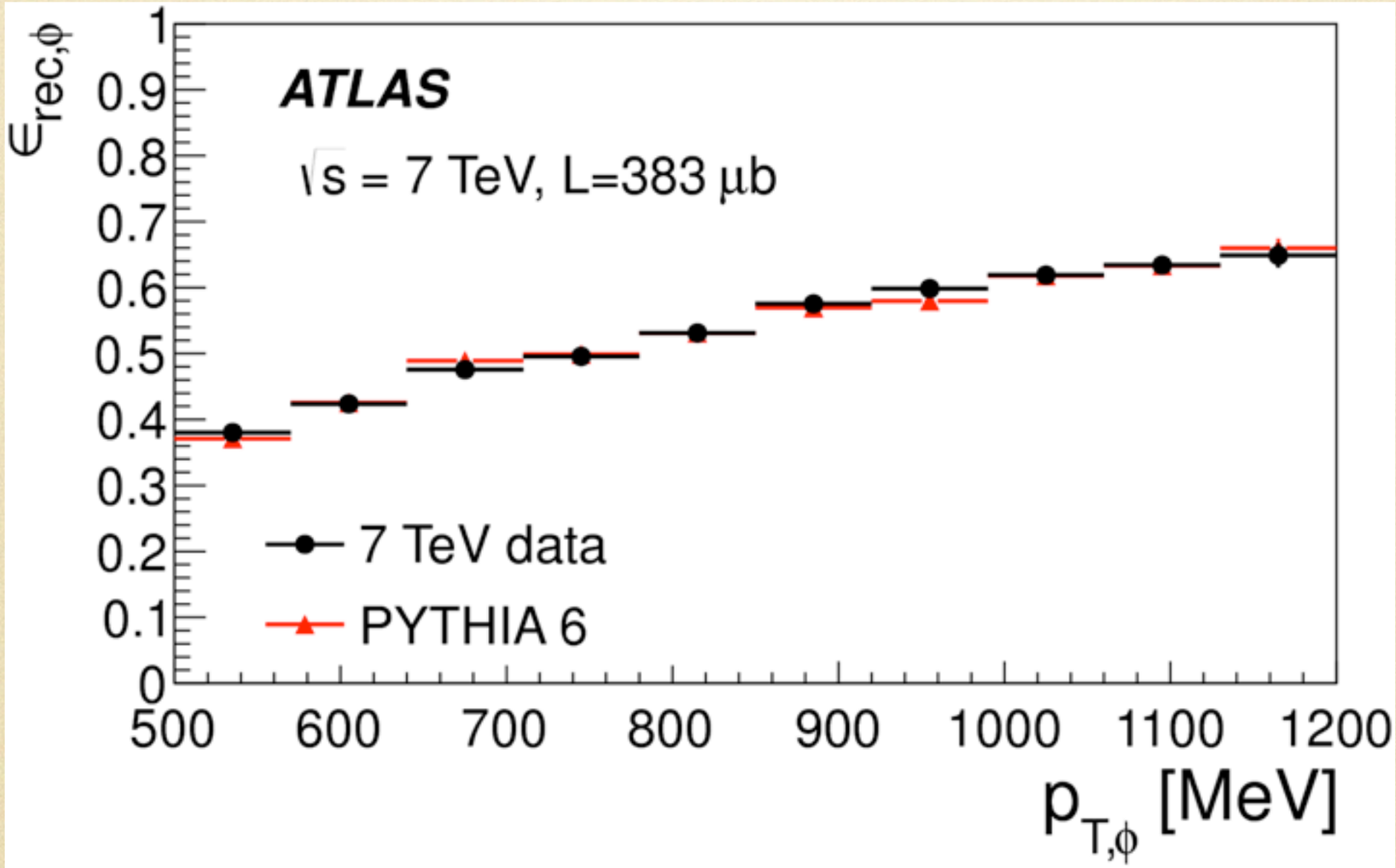
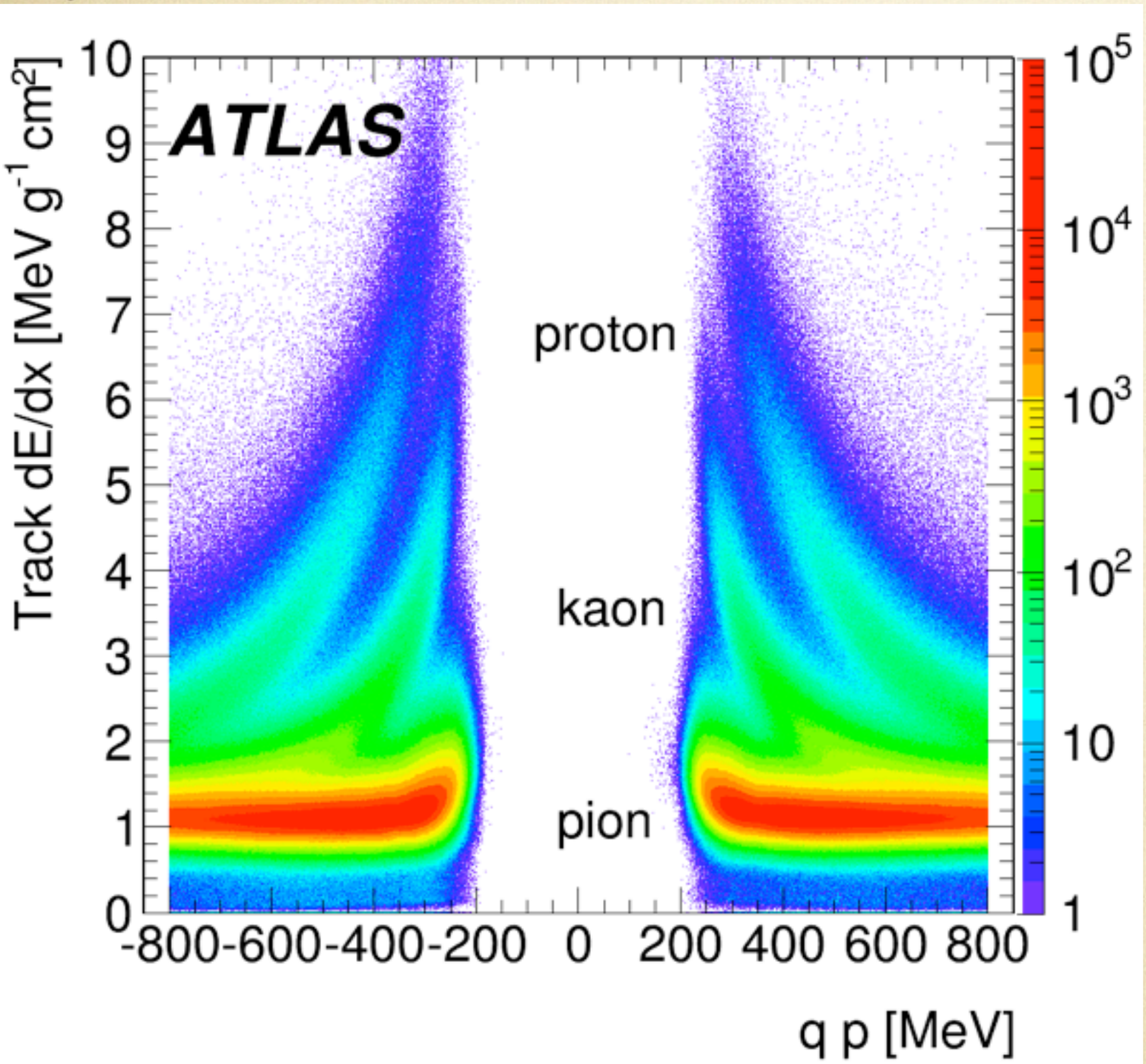


$\varepsilon_{rec,\varphi\rightarrow K^+K^-}$ ranges from 38% to 67% , Monte Carlo simulation follows the data.

Tracking efficiency expected to increase with increasing p_T.

Energy loss for particle ID



Time over threshold in pixel detector is proportional to deposited energy by traversing particle

Bethe Bloch: $\Delta E/\Delta x \propto 1/\beta^2$

→ mass differences visible

dE/dx for kaon identification*

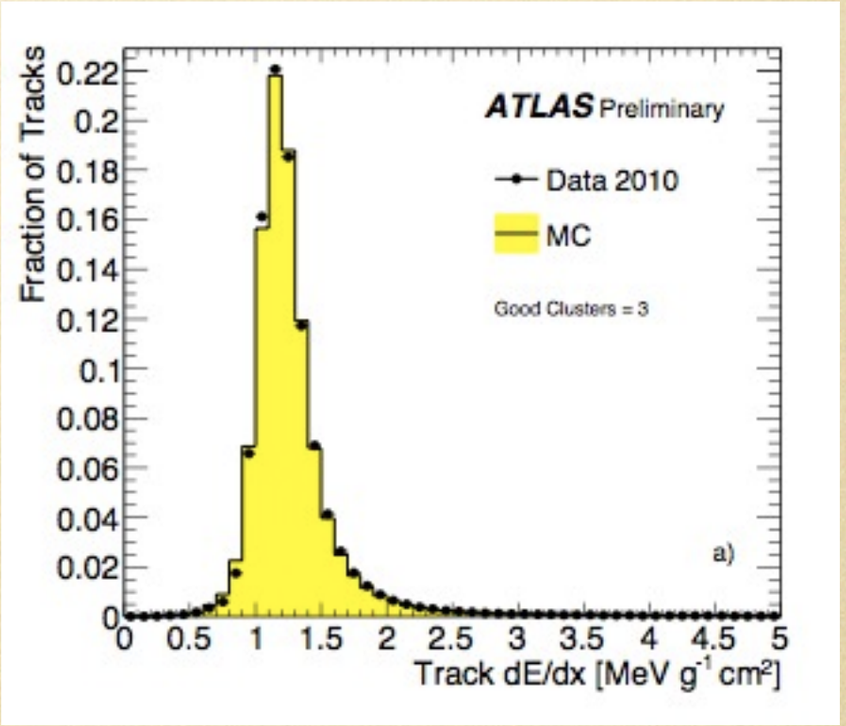
dE/dx calculated from time over threshold in pixel detector.

$$\frac{dE}{dx} = \frac{Q}{e}\frac{W\cos\alpha}{\rho d}$$

Q = charge, W=3.68±0.02 eV/pair,
$x = d$ / cosα, e = electron charge,
ϱ = silicon density

dE/dx per track calculated as truncated mean of energy lost per hit on track.

Most probably (MPV) energy loss for pion, kaon and proton mass assumption calculated using a parametrization.



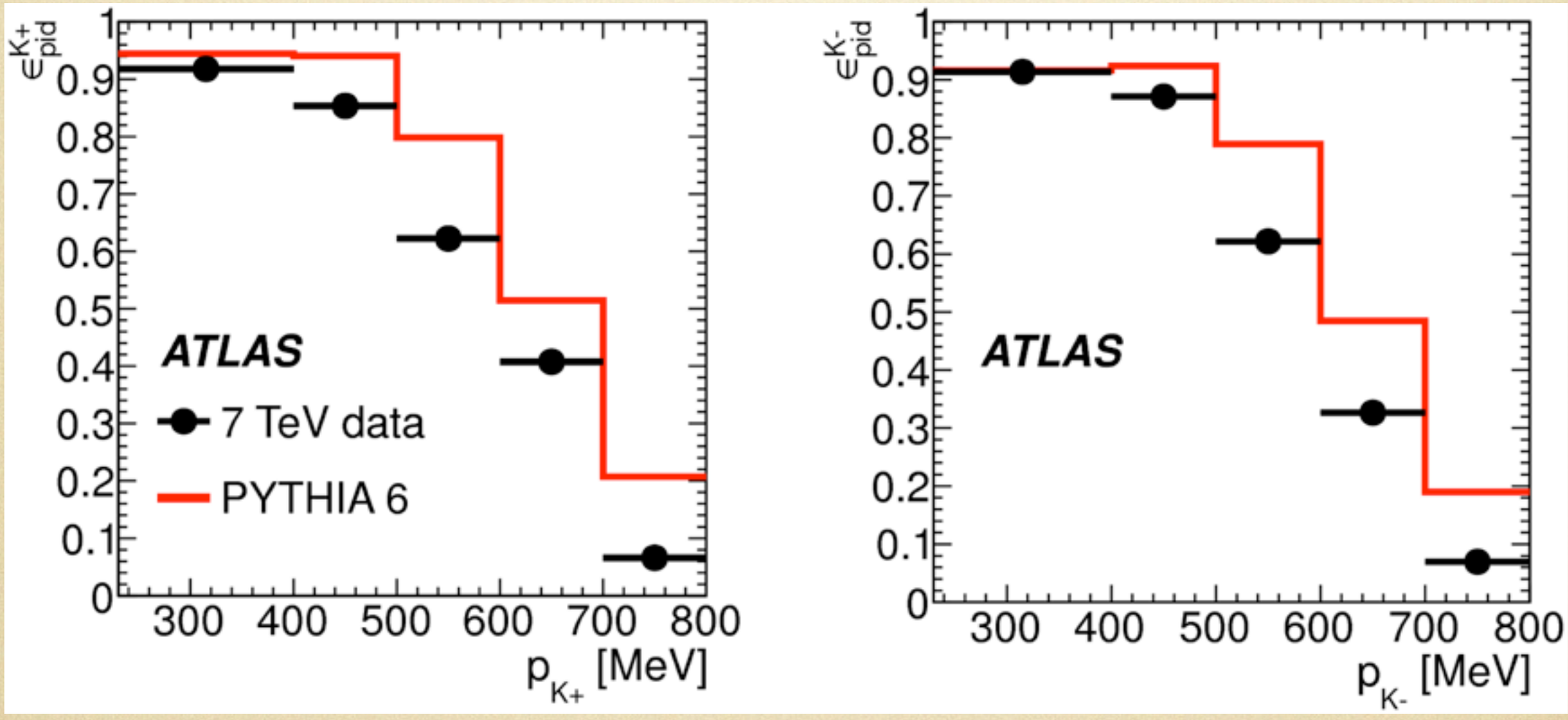
$$MPV_{\frac{dE}{dx}}(\beta\gamma) = \frac{p_1}{\beta^{p_3}}\ln(1+(|p_2|\beta\gamma)^{p_5}) - p_4$$

*ATLAS-CONF-2011-016

Tag & Probe

The kaon identification efficiency for positive kaons is obtained using a tag-and-probe method in data. To obtain N_{tag}- , only the negative kaons from $\phi \rightarrow K+K-$ decays are required to pass the PID cuts. In the next step both kaons are to pass the PID requirements and the number of extracted ϕ-mesons corresponds to N_{probe}:

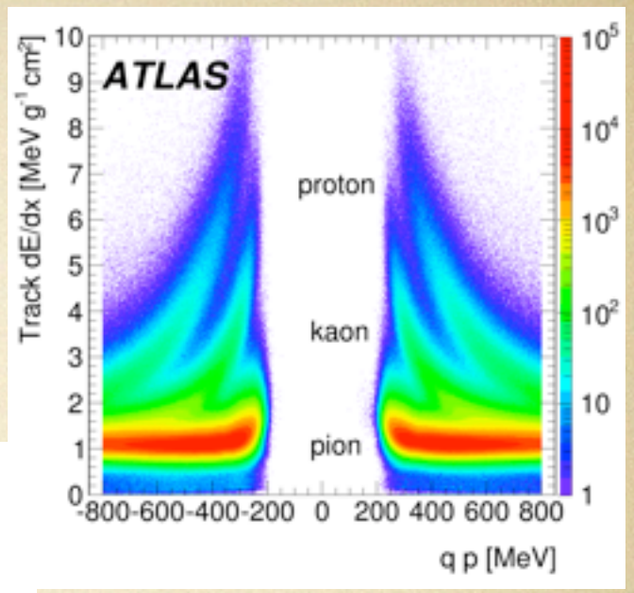
$$\varepsilon_{TnP} = \frac{N_{probe}}{N_{tag}}.$$

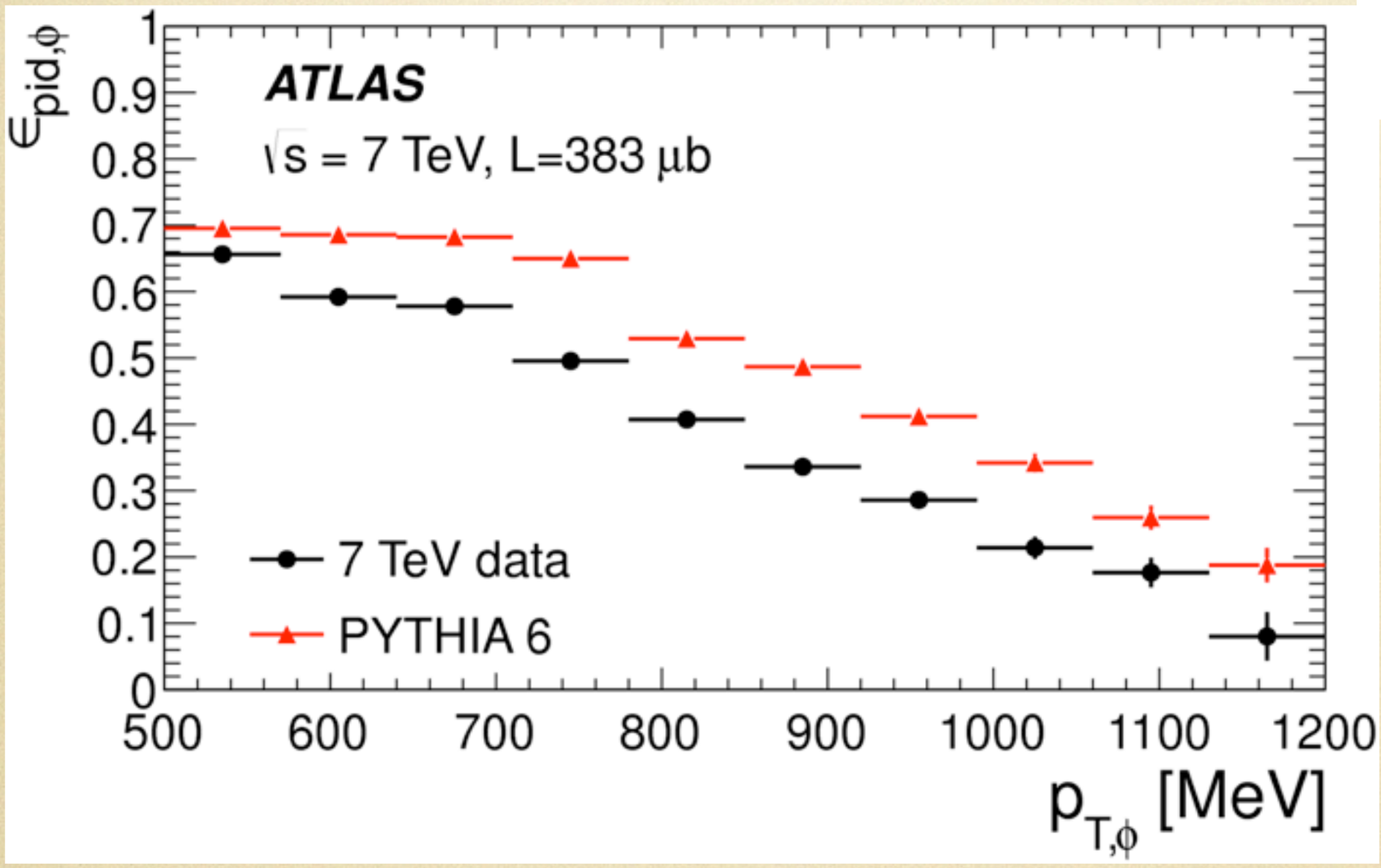


Simulation overestimates the tagging efficiency, especially with increasing kaon momentum.

$\varepsilon_{pid,\varphi}$

Both kaons need to pass kaon identification cuts.

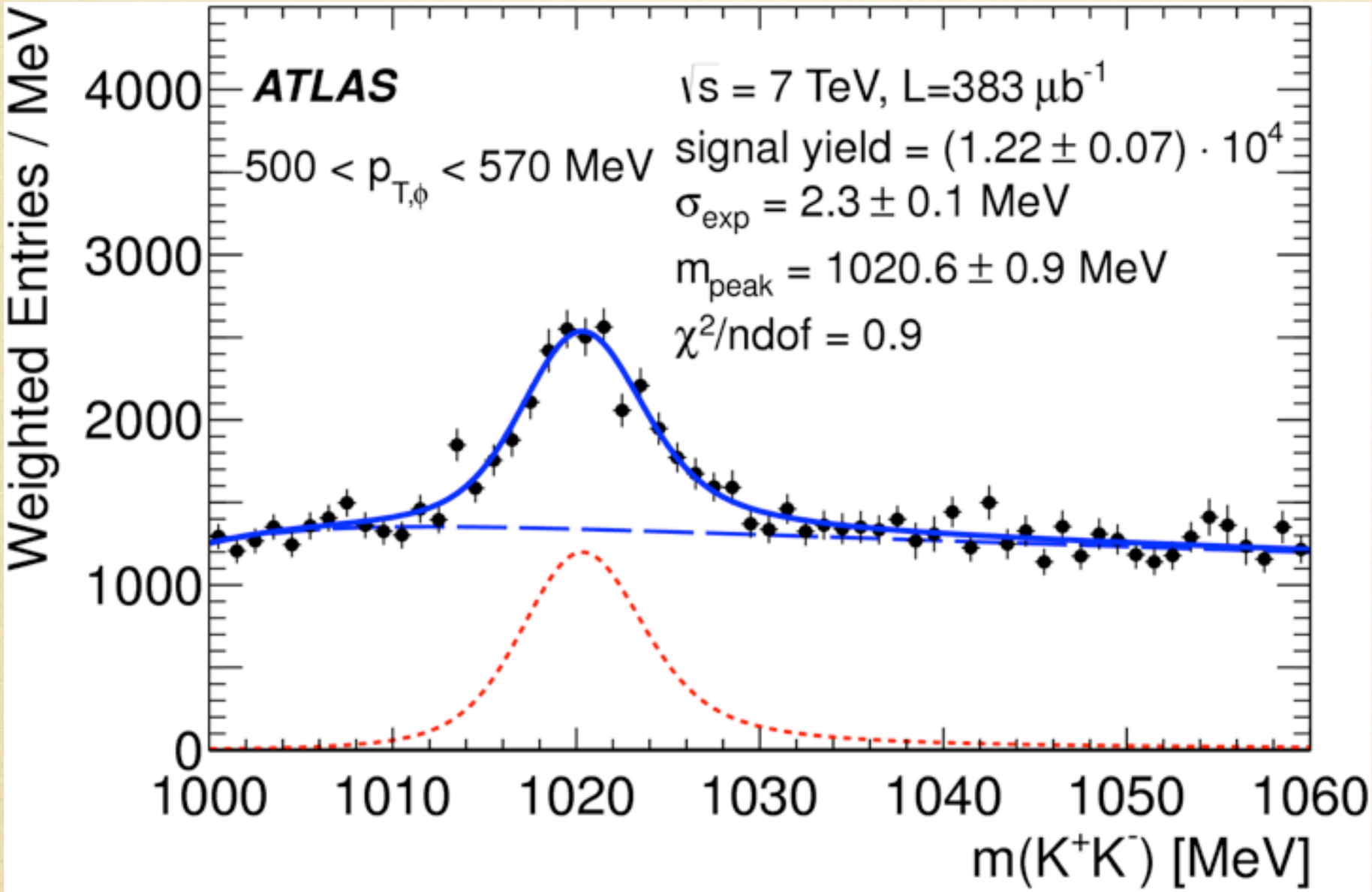




$\varepsilon_{pid,\varphi}$ ranges from ~65% to less than 10% and decreases with decreasing p_T. Simulation overestimates the tagging power.

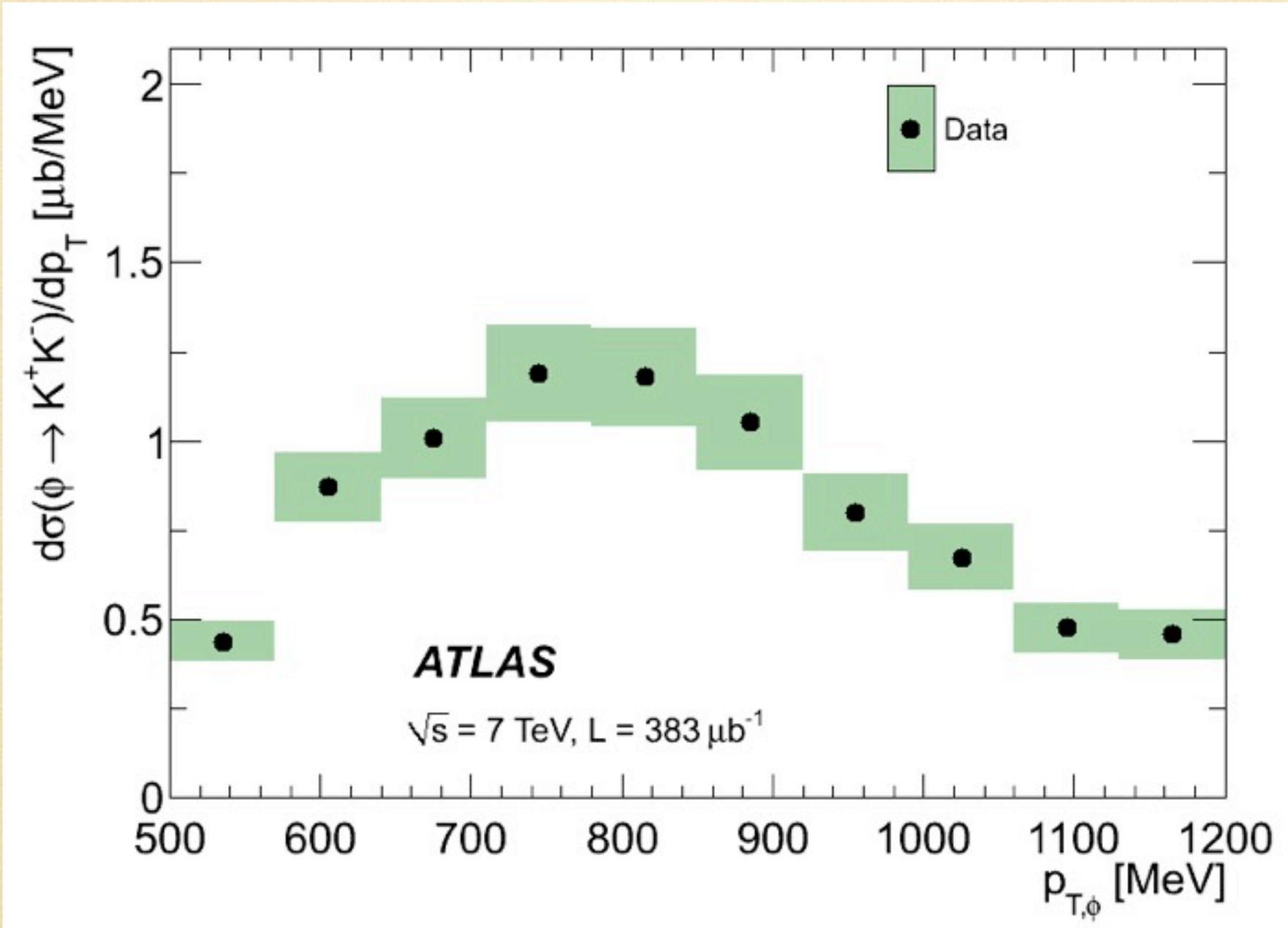
Yield extraction

Both tracks are given a weight for tracking and PID efficiency.



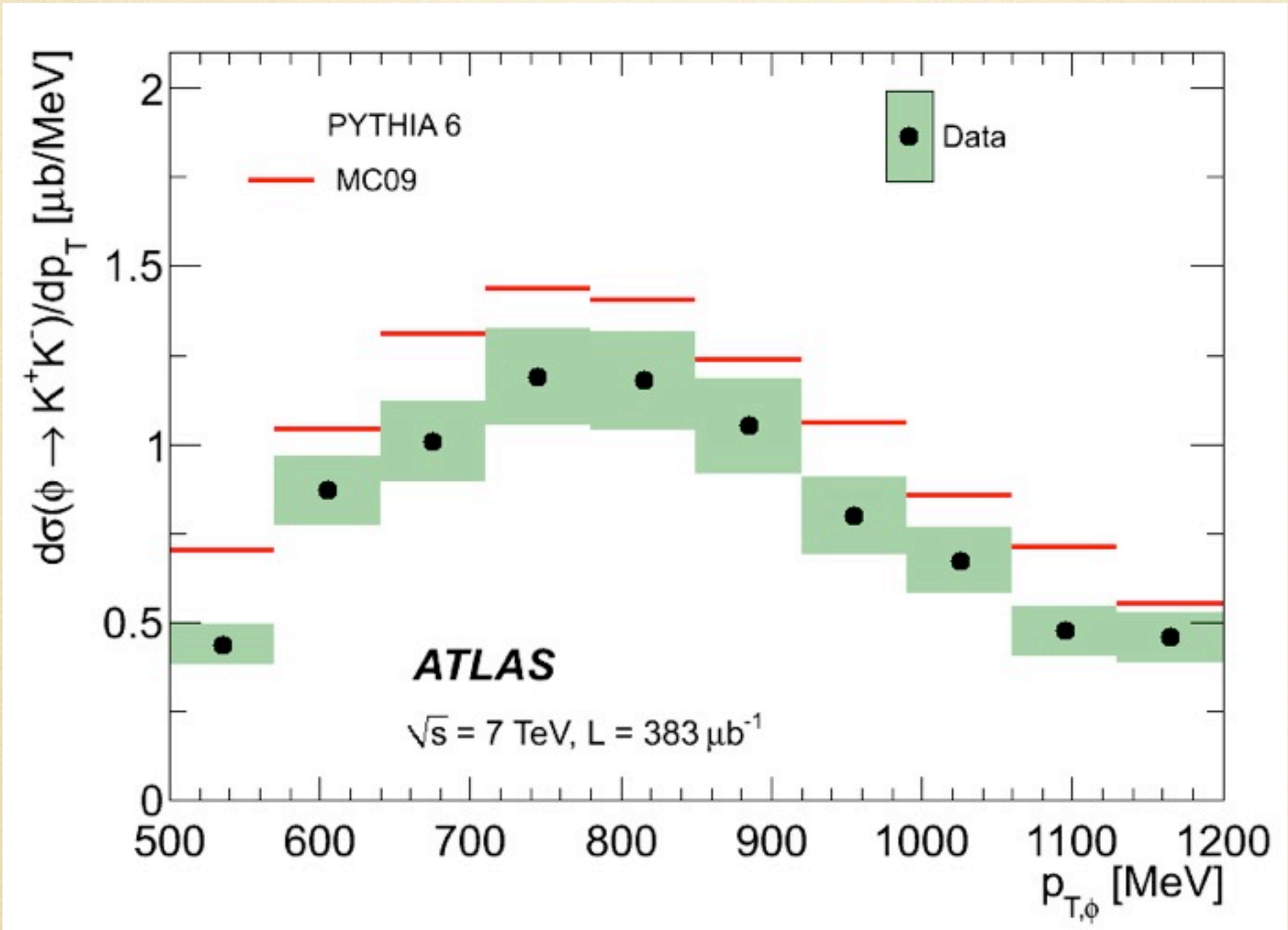
The signal yield divided by the luminosity gives the cross section. The location of the peak is described well within the expectation of the PDG.

The result as a function of $p_{T,\phi}$



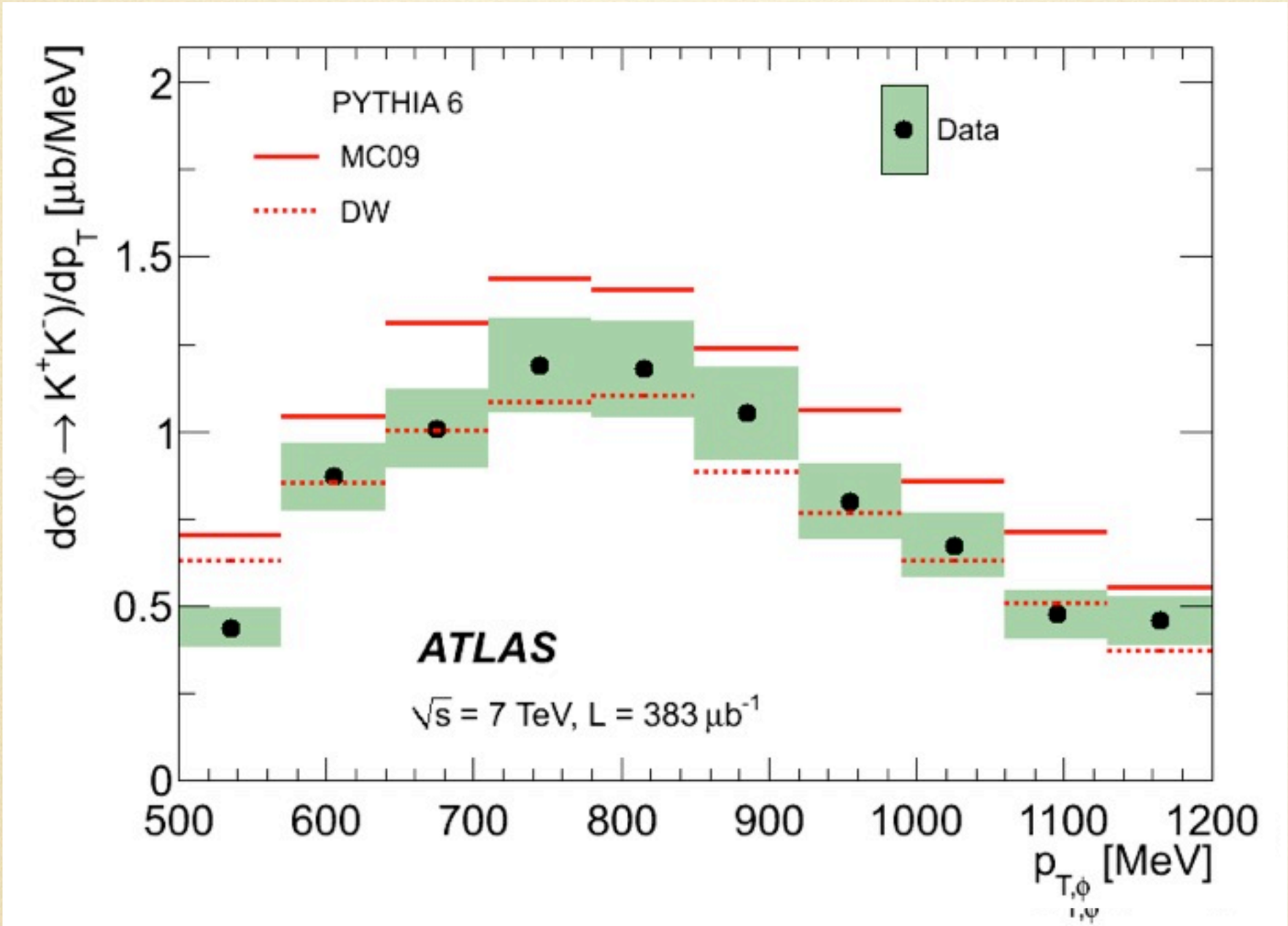
The cross section increases with $p_{T,\varphi}$ for $p_{T,\varphi} < 800$ MeV, due to the increasing phase space and the $p_{T,K} > 230$ MeV requirement.

The result as a function of $p_{T,\phi}$



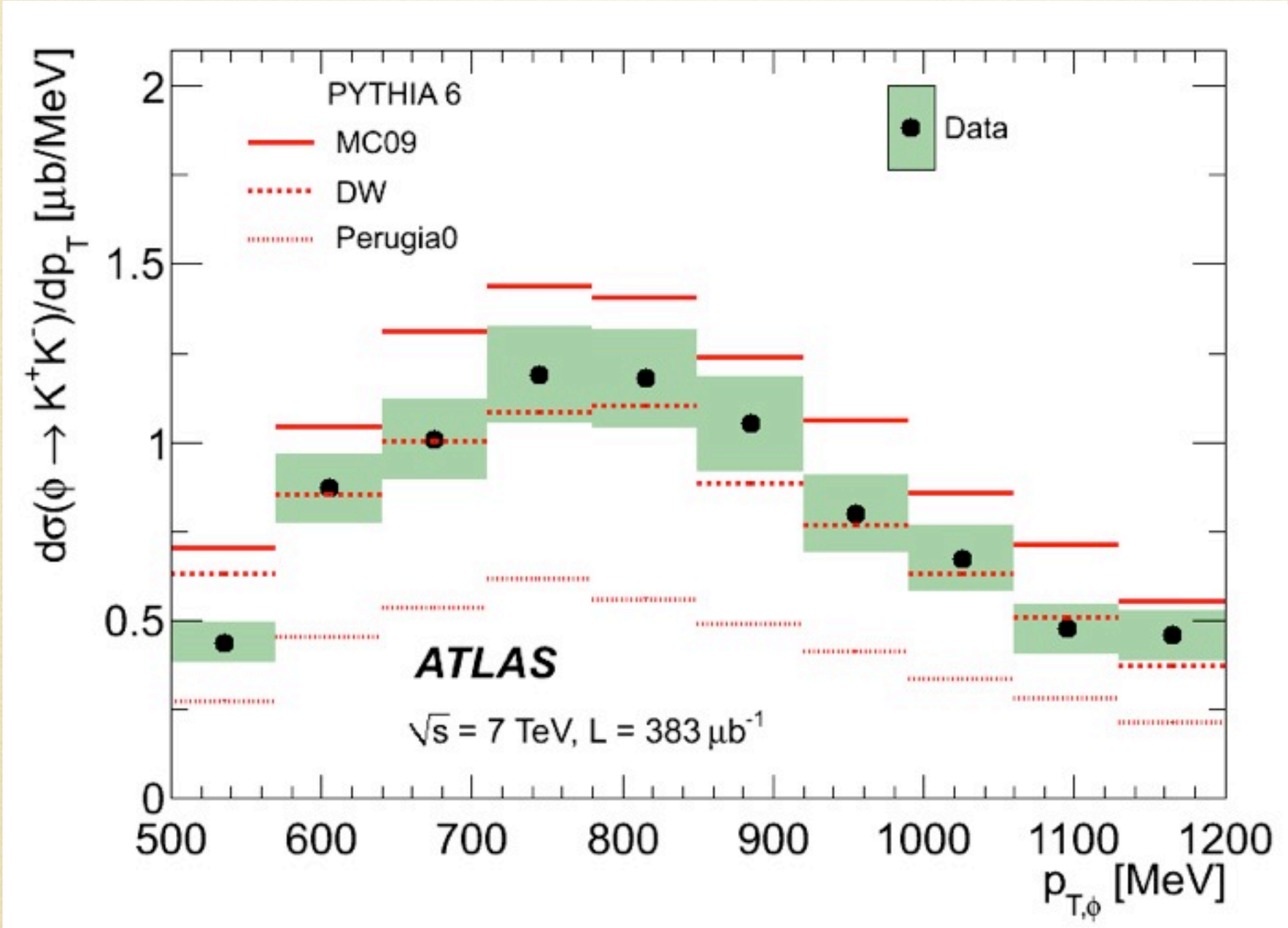
The **Pythia 6 MC09** tune was used for cross checks and for the calculation of ε_{rec}. This an 'old' ATLAS tune, from before LHC data.

The result as a function of $p_{T,\phi}$



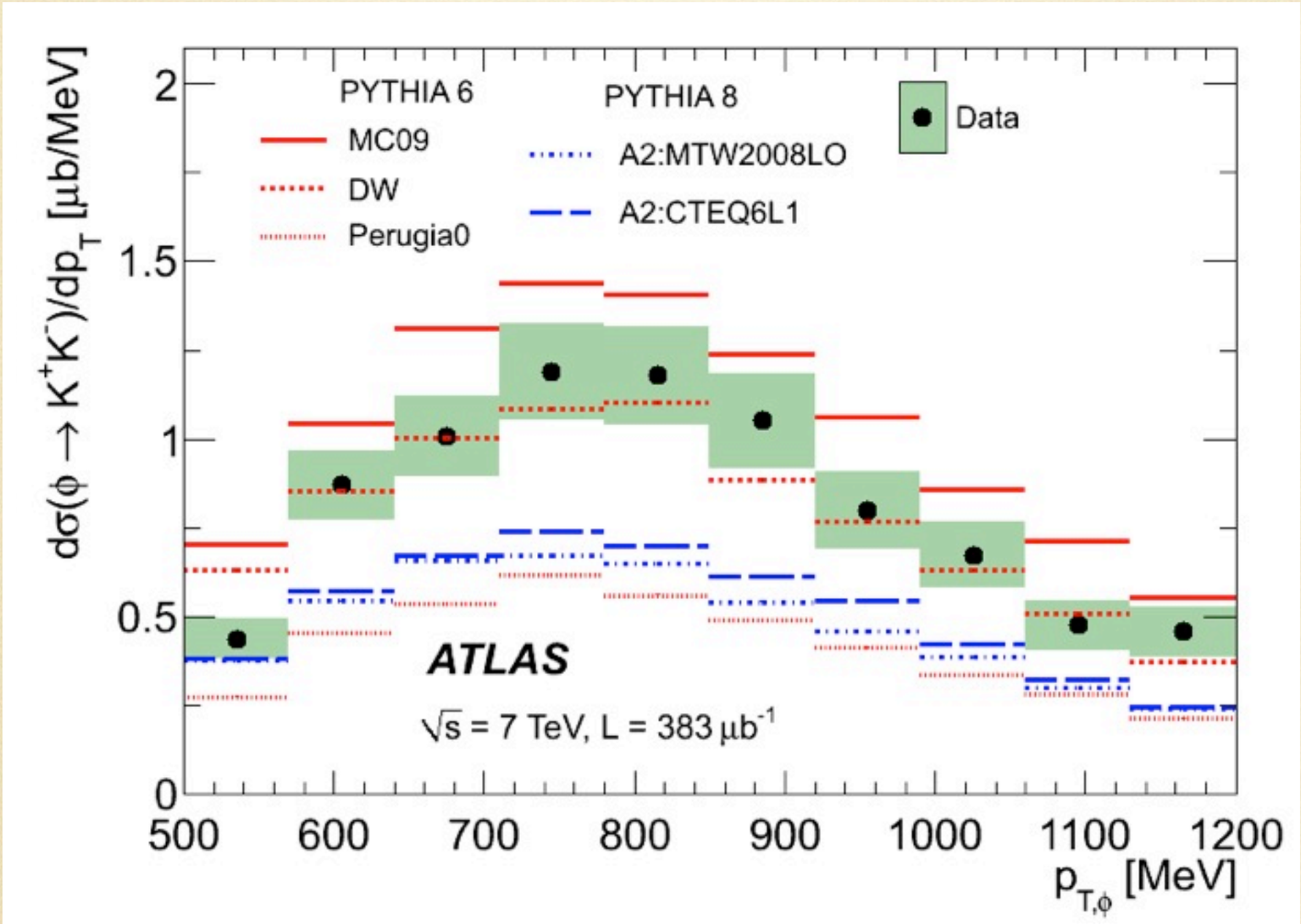
The **Pythia 6 DW** is newer and describes the cross section relatively well.

The result as a function of $p_{T,\phi}$



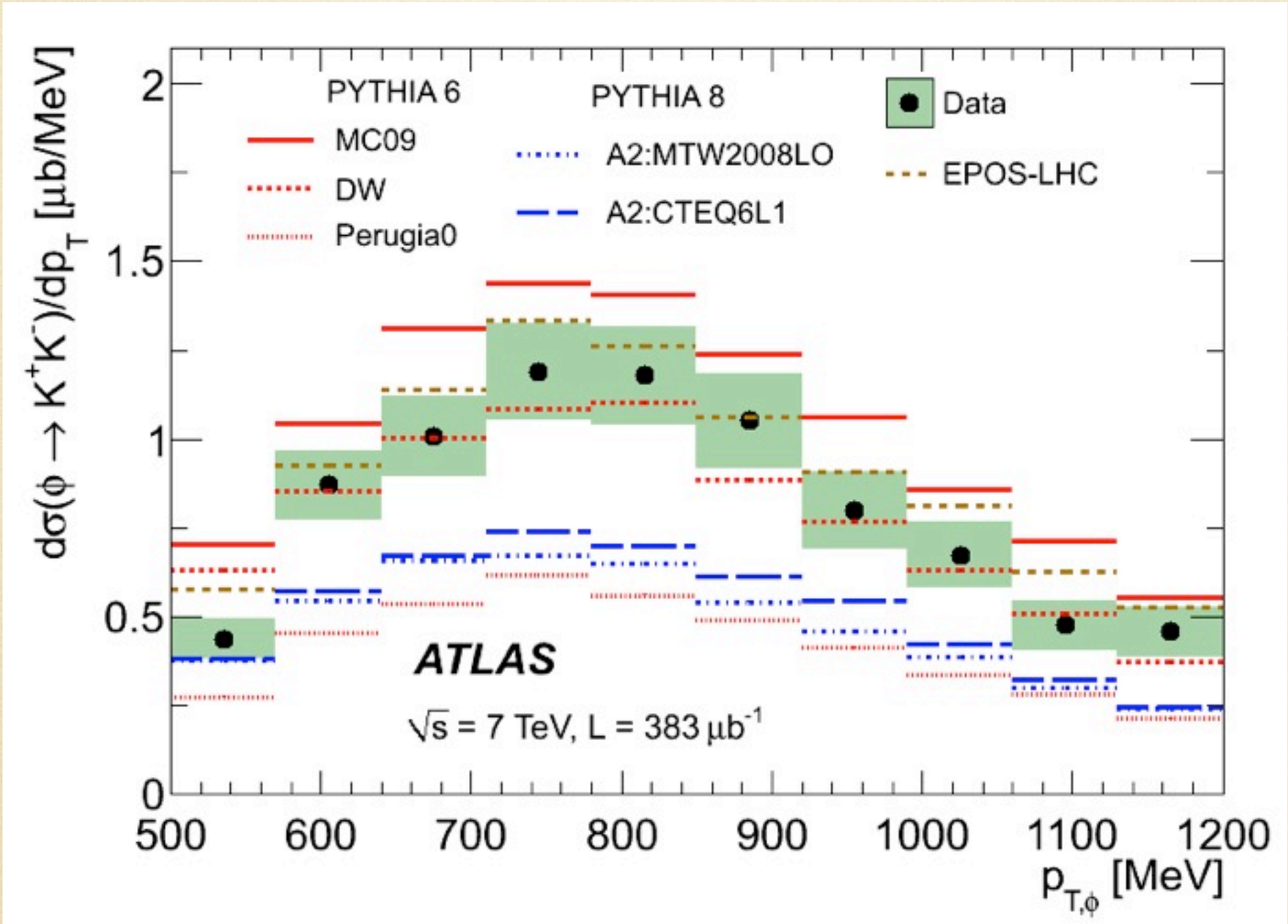
The **Pythia PerugiaO** is even newer and underestimates the cross section by a factor of two.

The result as a function of $p_{T,\phi}$



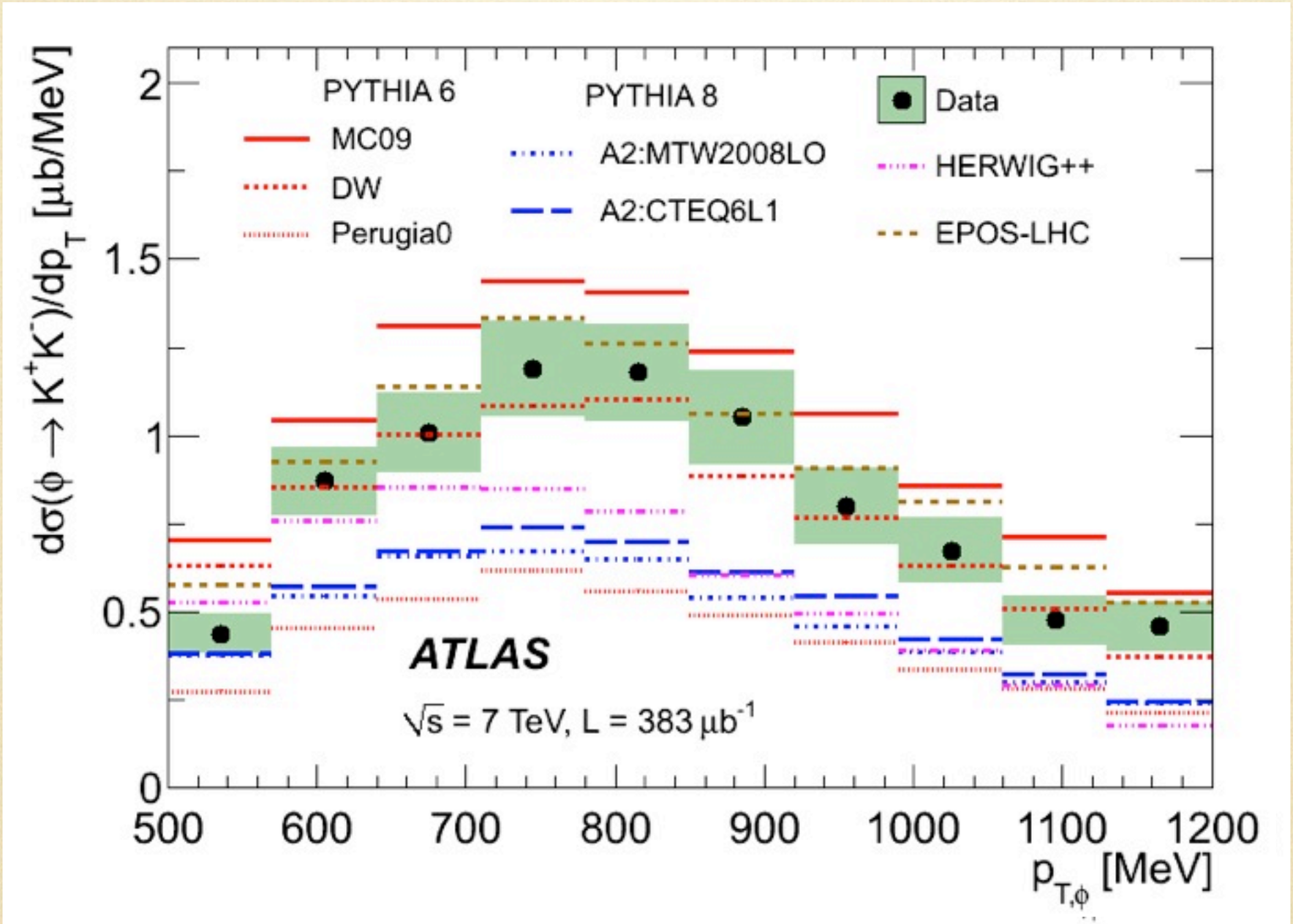
Two **Pythia 8** itunes with different PDFs show similar predictions, but a factor of ~2 too low.

The result as a function of $p_{T,\phi}$



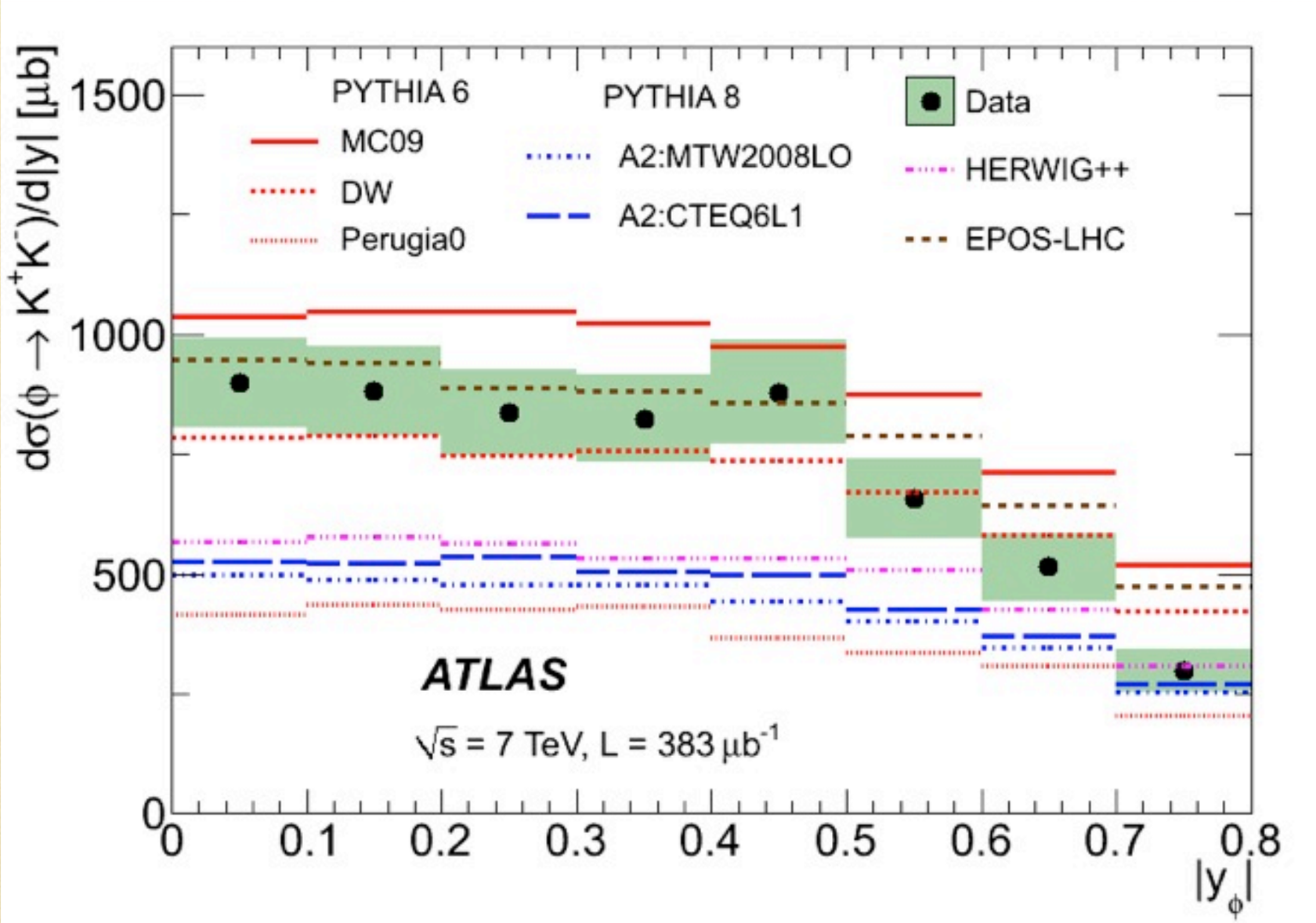
The **Epos** generator with the **LHC** tune describes the cross section well. **Epos** simulates the whole event in one go.

The result as a function of $p_{T,\phi}$



The HERWIG++ generator, based on a different hadronization model, underestimates the cross section and predict a too steep $p_{T,\varphi}$ dependence.

The result as a function of y_ϕ

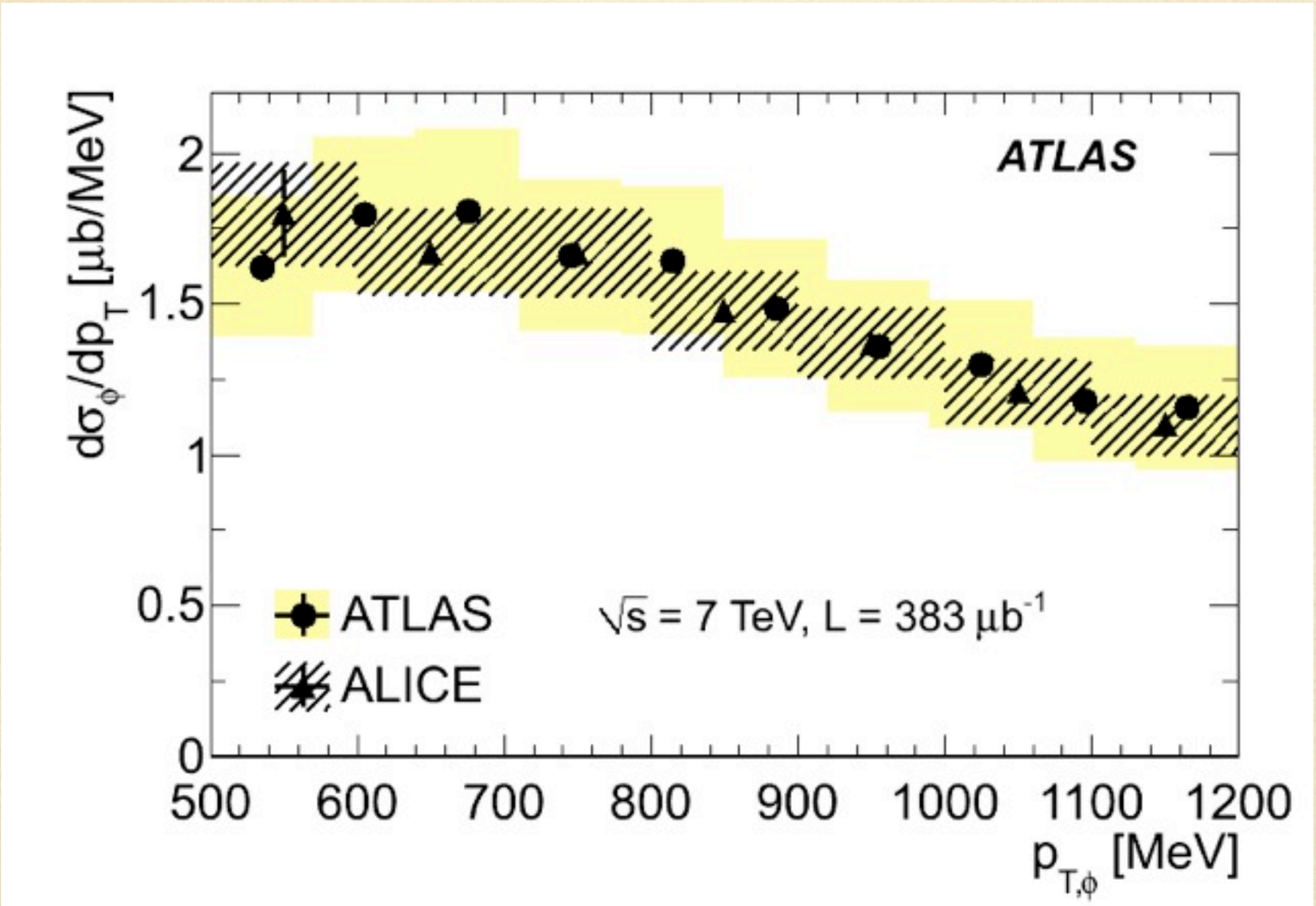


The decreasing behaviour as a function of y_φ is mostly caused by the $p_K < 800$ MeV requirement.

Comparison to generators

- PYTHIA 6 and 8 and EPOS use Lund string model, HERWIG++ uses cluster hadronisation.
- Two tunes based on different PDFs for PYTHIA 8 predict very similar φ cross section. Almost factor of two too low.
- Significant difference observed between different tunes of PYTHIA 6.

The result as function of $p_{T,\phi}$ with $|y_\phi|<0.5$



After correcttion for the kaon-momentum cuts, the cross section in a limited rapidity range, $|y_\phi|<0.5$, agrees with the published result by the ALICE Collaboration*. The ATLAS systematic error band includes the extrapolation error of 10%. The size of the systematic uncertainties are comparable.

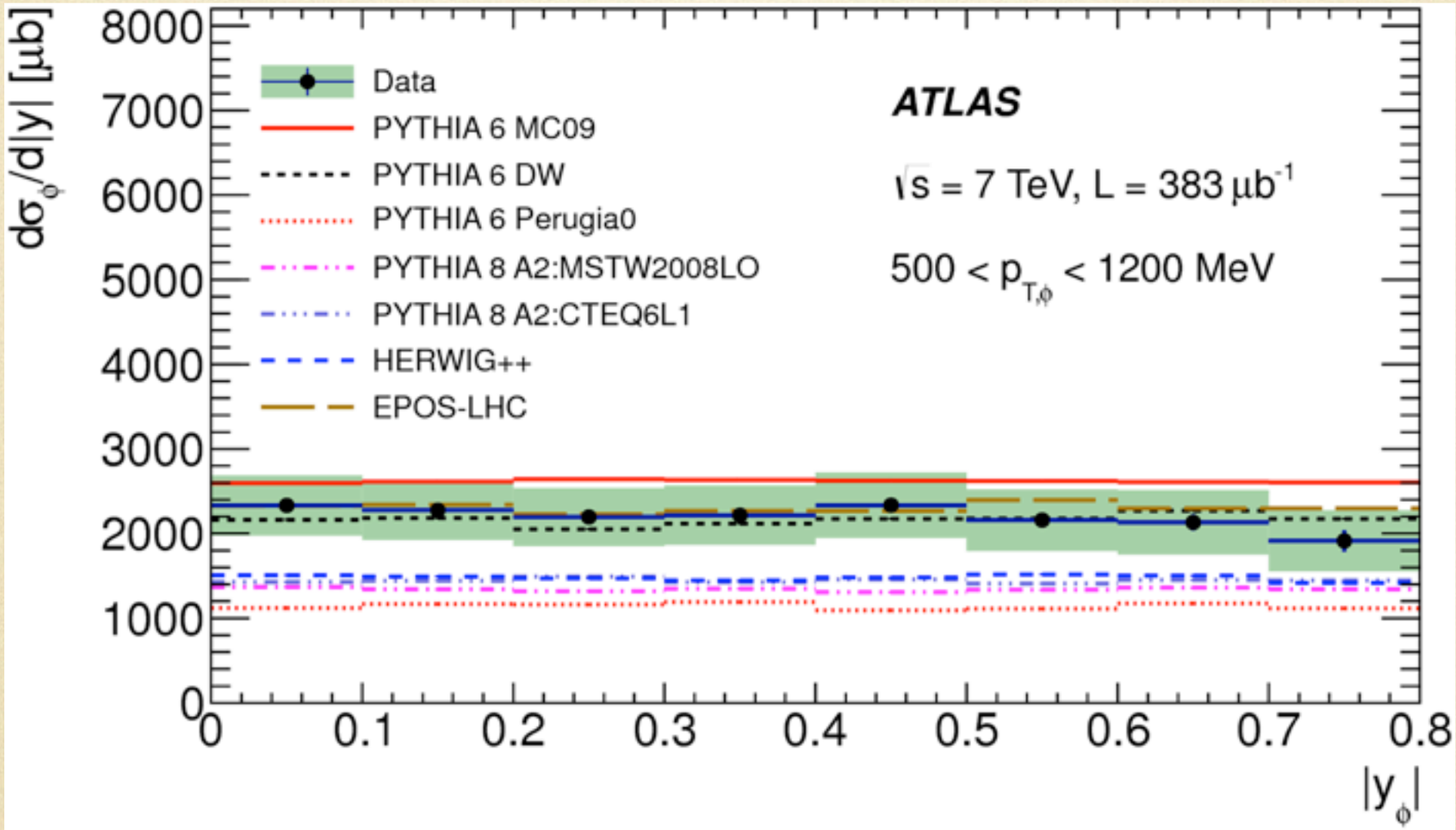
* Eur. Phys. J. C72, 2183 (2012)

Conclusions

- Presented a measurement of the ϕ-meson production cross section at $\sqrt{s} = 7$ TeV measured with the ATLAS detector.
- Energy loss in pixel detector is used for kaon identification.
- Kaon track reconstruction and identification limit visible range.
- Measurement compared to several models: significant difference in observed ϕ-meson yield between different tunes of the same generator.

BACK UP

Extrapolation in |yϕ|<0.8



In order to correct for the kaon momentum requirements, a re-weighted extrapolation is used. For details see: http://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PAPERS/STDM-2011-47/