Minimum Bias and Underlying Event Modelling in SHERPA

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Outline

Outline

AMISIC++

- AMISIC++: old/current UE model in SHERPA
- similar to Sjöstrand-van Zijl model
- $\sigma_{\mathrm{h}}(p_\perp) = \int_{p_\perp^2}^{s/4} \mathrm{d}p_\perp'^2 \frac{\mathrm{d}\sigma}{\mathrm{d}p_\perp'^2} > \sigma_{\mathrm{ND}}$ for small(ish) $p_\perp$
- multiple (independent) parton-parton scattering
- probability density for additional scatters

$$p(p_\perp) = \frac{1}{\sigma_{\mathrm{ND}}} \frac{\mathrm{d}\sigma}{\mathrm{d}p_\perp}$$

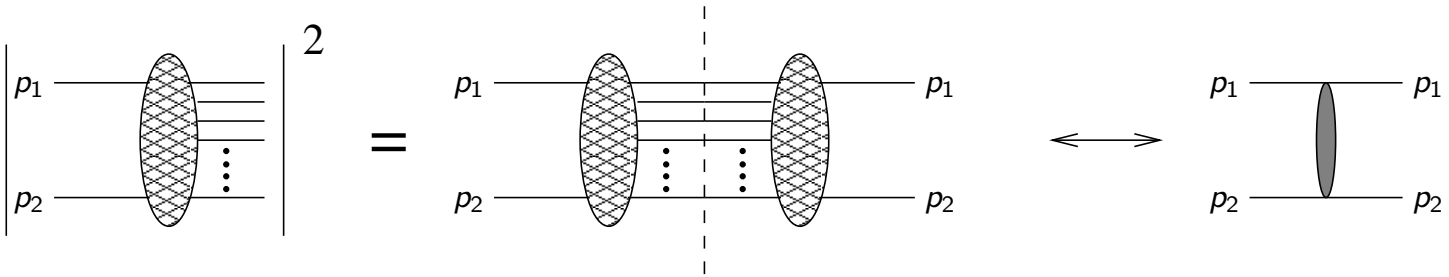
- additional UE scatters: ordinary pQCD $2 \to 2$ processes
- cut-off: $p_{\perp\mathrm{min}}$
- add (independent) parton showers
- impact parameter dependence

Outline

Introduction

- optical theorem

$$\sigma_{\text{tot}}(s) = \frac{1}{s}\,\text{Im}[\mathcal{A}_{\text{el}}(s, t = 0)]$$

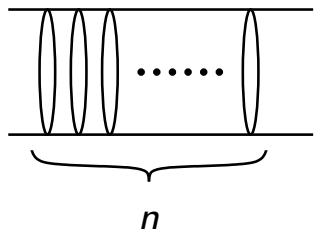


- grey blob: exchange of vacuum quantum numbers
- compute $\mathcal{A}_{\text{el}}$
  - need systematic way of approximating grey blob
  - Khoze-Martin-Ryskin (KMR) model
- cut to obtain differential total cross section
  - allows for MC event generation
  - SHRiMPS model

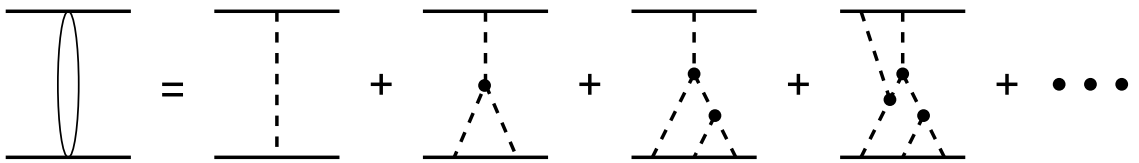
KMR model

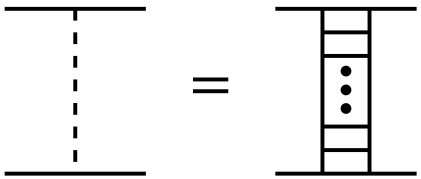
- eikonal ansatz:

$$A(s,b) = i\left(1 - e^{-\Omega(s,b)/2}\right) = i\sum_{n=1}^{\infty}$$



- KMR model:



where  'gluon' ladder with effective vertices and propagators

- write proton as superposition of diffractive eigenstates to allow for low mass diffractive excitation

$$|p\rangle = \sum_i a_i |\phi_i\rangle, \text{ where } \langle\phi_i|\phi_k\rangle = \delta_{ik} \text{ and } \sum_i |a_i|^2 = 1$$

Good-Walker states

KMR model

- 'parton densities'

$$\frac{\mathrm{d}\Omega_k(y)}{\mathrm{d}y} = \Delta\Omega_k(y)e^{-\lambda[\Omega_k(y)+\Omega_i(y)]/2}$$
$$\frac{\mathrm{d}\Omega_i(y)}{\mathrm{d}y} = \Delta\Omega_i(y)e^{-\lambda[\Omega_k(y)+\Omega_i(y)]/2}$$

  with $\lambda = g_{3\mathbb{P}}/g_{\mathbb{P}N}$
  adds rungs to ladder
  absorption on own and other hadron

- boundary condition for parton densities: hadron form factor
- eikonal given by overlap of parton densities

$$\Omega_{ik}(\mathbf{b}) = \frac{1}{2\beta_0^2}\int \mathrm{d}\mathbf{b}_1\mathrm{d}\mathbf{b}_2\,\delta^2(\mathbf{b}-\mathbf{b}_1-\mathbf{b}_2)\Omega_i(\mathbf{b}_1,\mathbf{b}_2,y)\Omega_k(\mathbf{b}_1,\mathbf{b}_2,y)$$

SHRiMPS model

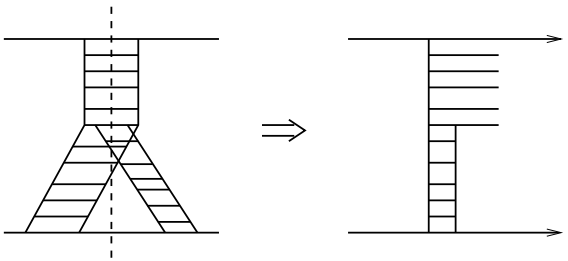
- fill ladders using pseudo Sudakov form factor

$$\mathcal{S}(y_0, y_2) = \exp\left\{ -\int_{y_0}^{y_2} \mathrm{d}y_1 \int \mathrm{d}k_\perp^2 \, \frac{C_A \alpha_s(k_\perp^2)}{\pi k_\perp^2} \right.$$
$$\times \left(\frac{Q_0^2}{q_{01}^2 + Q_0^2} \right)^{\frac{C_A}{\pi}\alpha_s(q_{01,\perp}^2)|y_1 - y_0|}$$
$$\left. \times \left(\frac{1 - \exp\left[-\frac{\lambda}{2}\Omega_i(y_1)\right]}{\frac{\lambda}{2}\Omega_i(y_1)} \right) \left(i \leftarrow k \right) \right\}$$

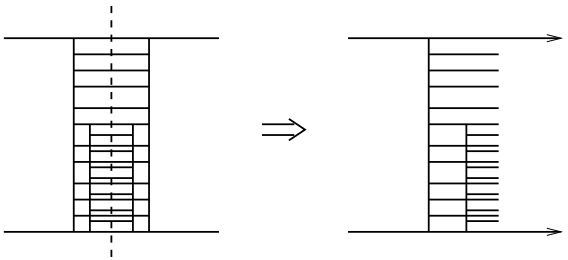
QCD; Regge weight; rescattering weight

SHRiMPS model

- fill ladders using pseudo Sudakov form factor
- cutting the triple-pomeron vertex:



- colour singlet exchange

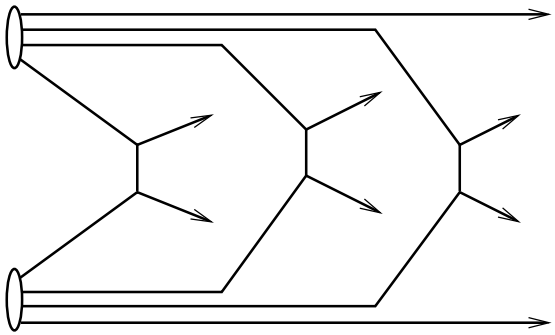


- rescattering

- probabilities for these depend in eikonal
- correct hard emissions to pQCD ME's and shower
- colour reconnections (similar to PYTHIA)
- hadronisation: SHERPA's cluster hadronisation

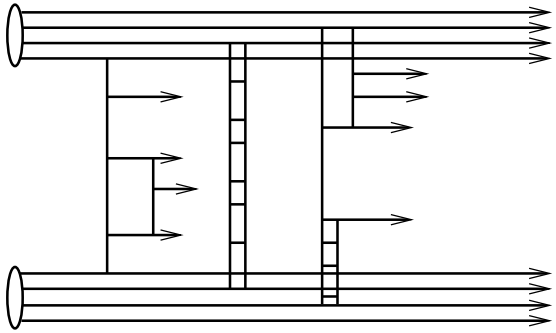
Summary

AMISIC++



- inspired by collinear factorisation
- $\langle n_{\text{exch.}} \rangle = \dfrac{\sigma_{\text{h}}(p_{\perp\text{min}})}{\sigma_{\text{ND}}}$
- exchange: $\hat{\sigma}$ + PS
- UE model also used for MB
- tuned to MB and UE data

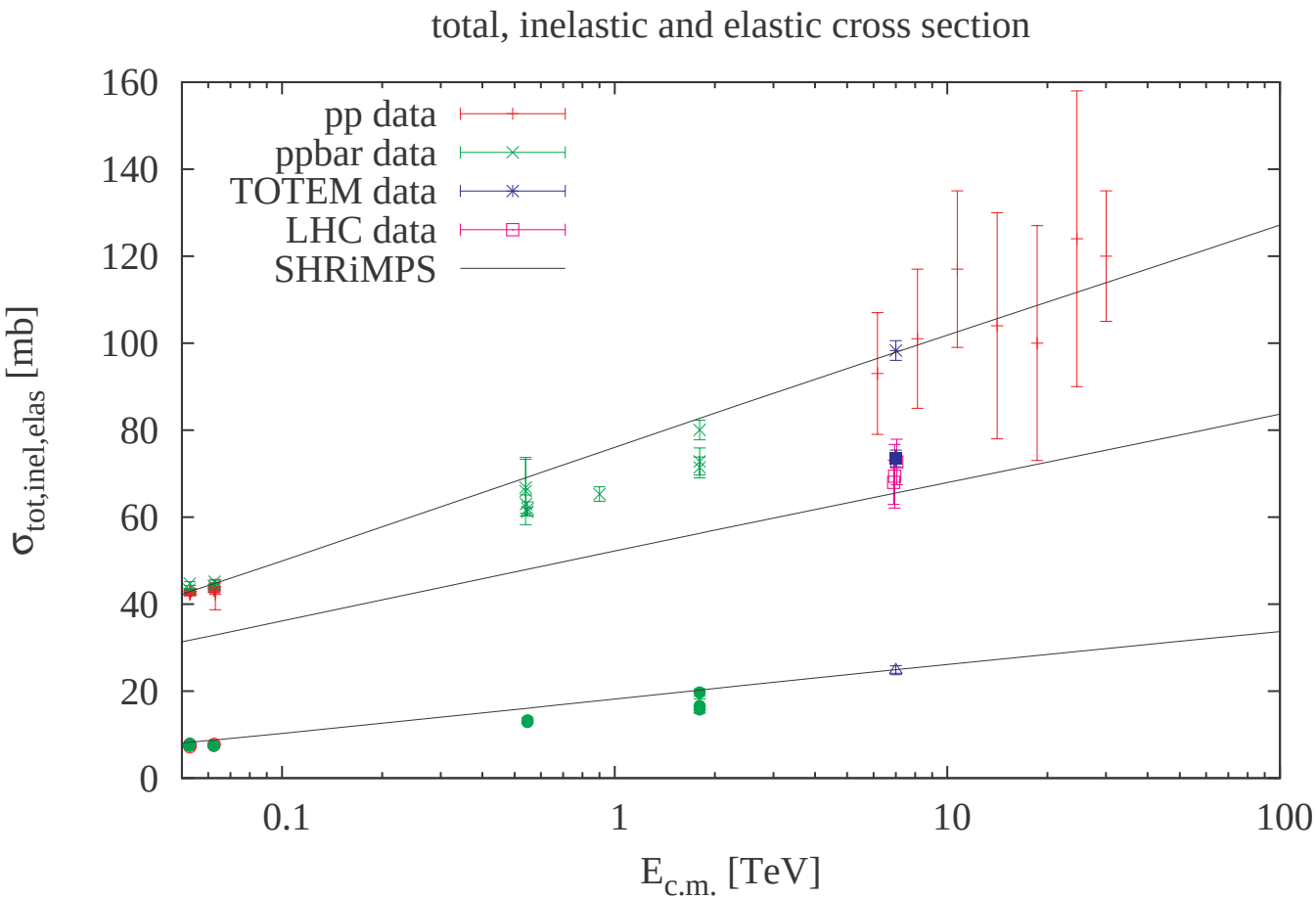
SHRiMPS



- inspired by BFKL evolution
- $\langle n_{\text{exch.}} \rangle = \Omega_{ik}(s, b)$
- exchange: Ω_{ik} (cut)
- MB model also used for UE
- tuned to σ_{tot}, σ_{elas}, σ_{inel}, $\mathrm{d}\sigma_{\text{el}}/\mathrm{d}t$ and MB and UE data

Outline

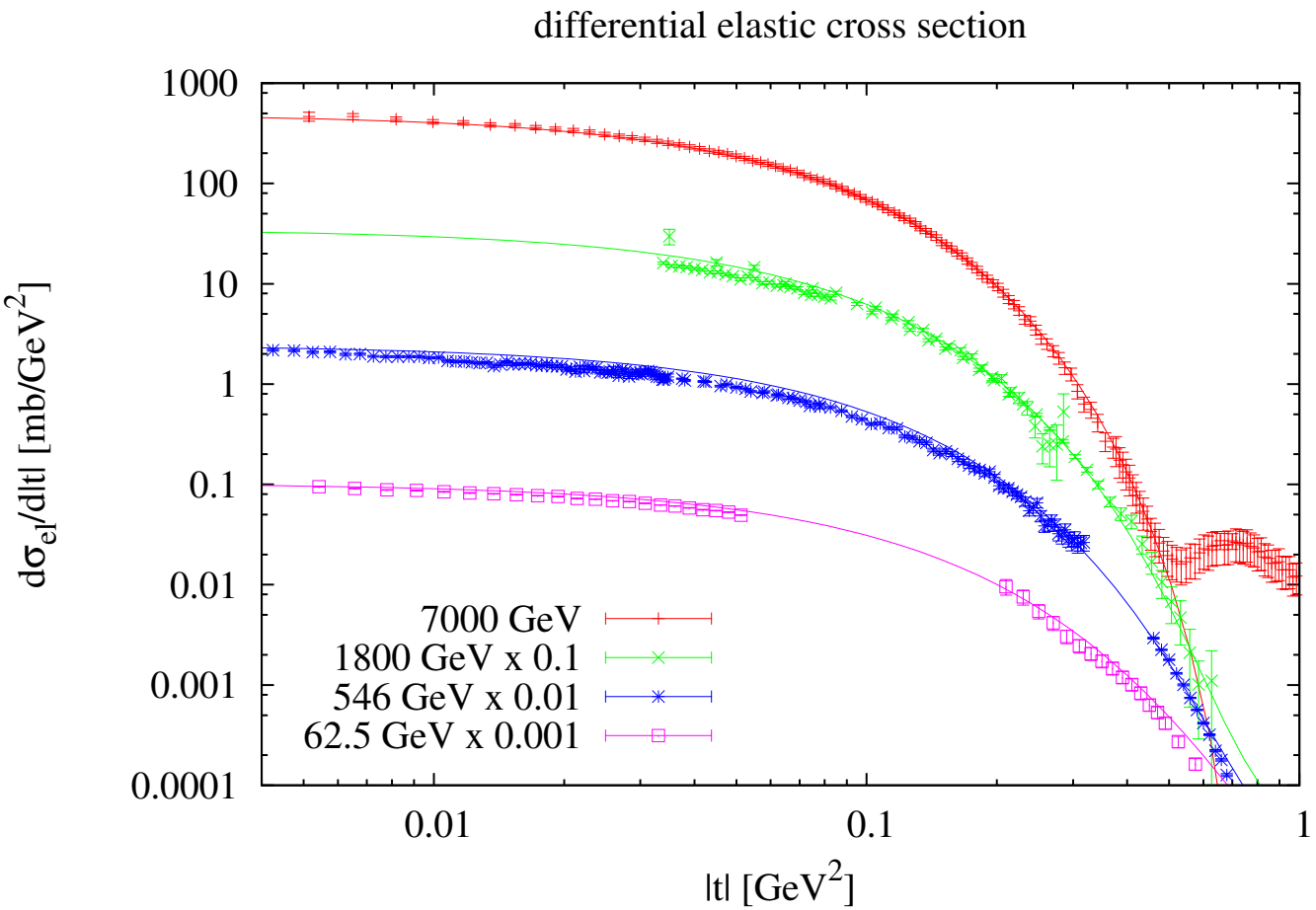
Cross Sections



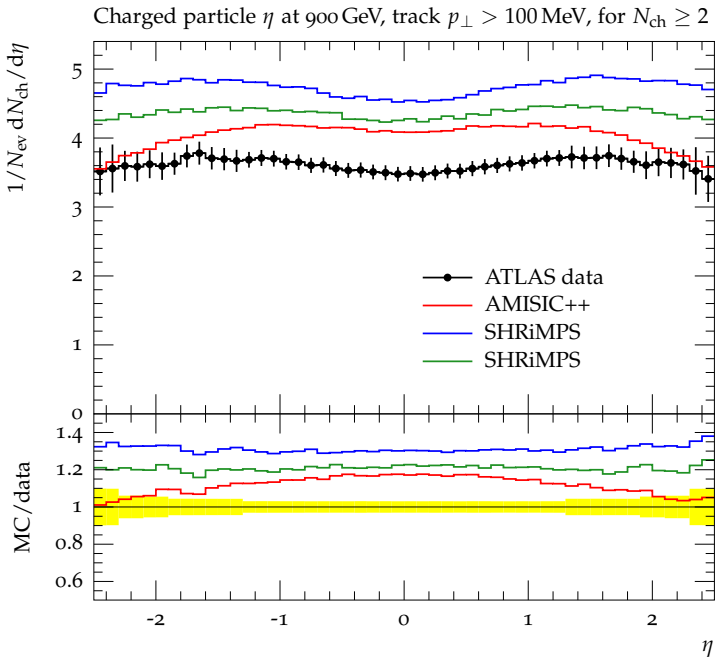
$$\Delta = 0.32,\ \lambda = 0.25,\ \delta y = 1.62,\ \beta_0^2 = 26\,\text{mb}$$

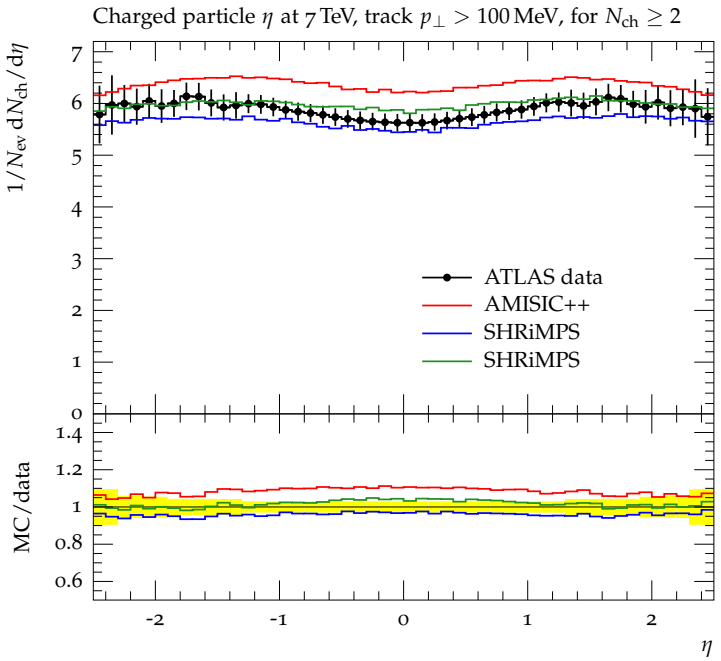
$$\Lambda^2 = 1.45\,\text{GeV}^2,\ \kappa = 0.6,\ \xi = 0.145$$

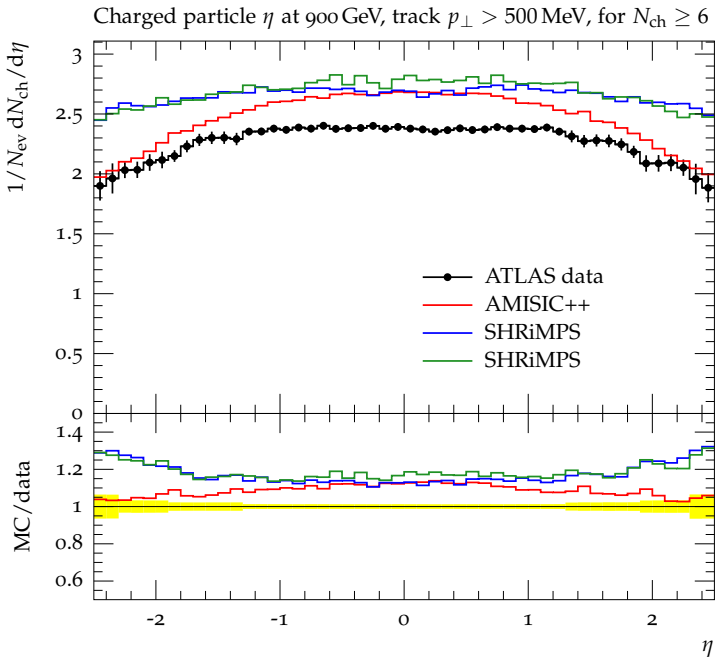
Differential Elastic Cross Section

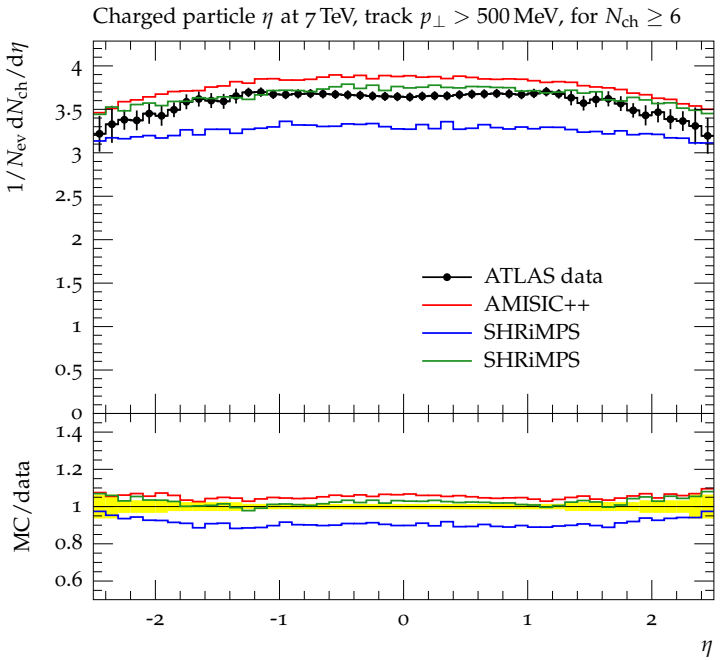


Minimum Bias @900 GeV & 7 TeV









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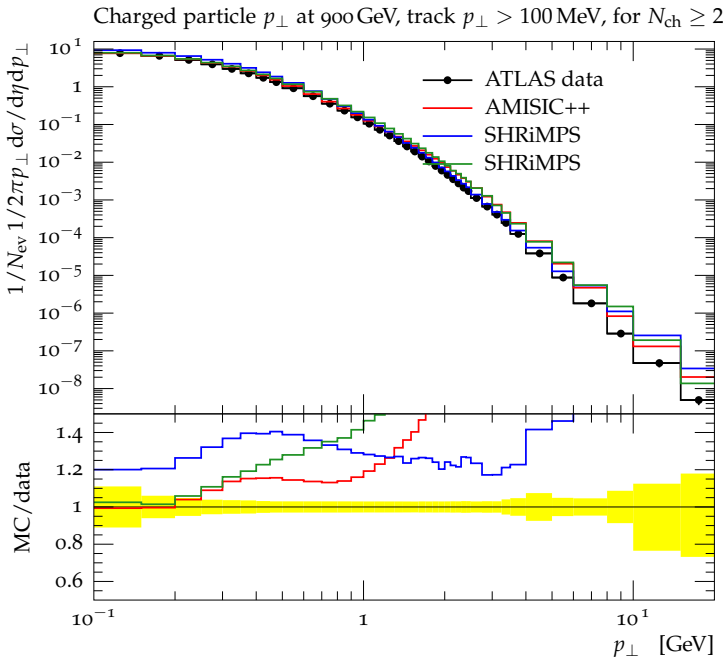

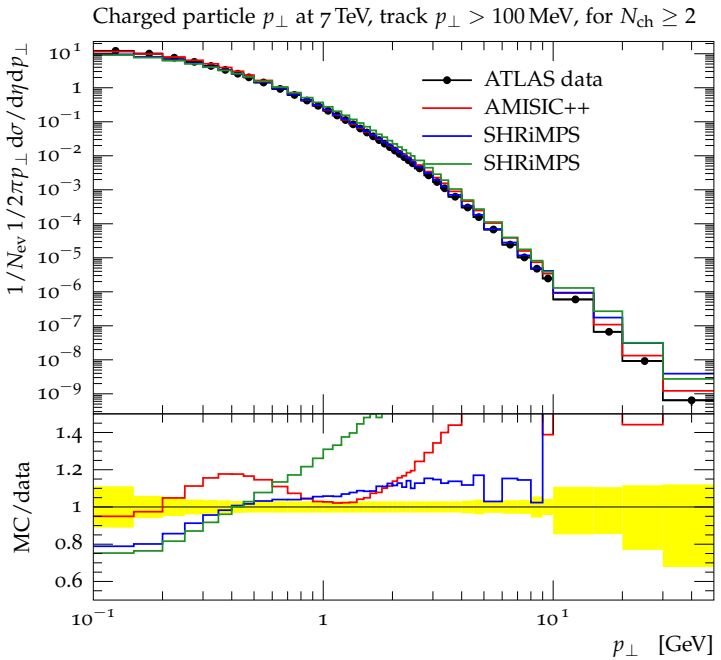

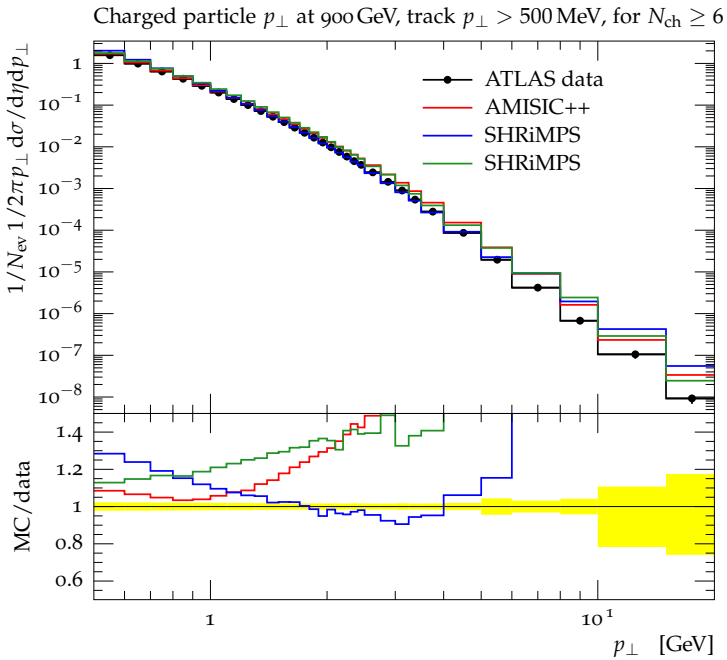

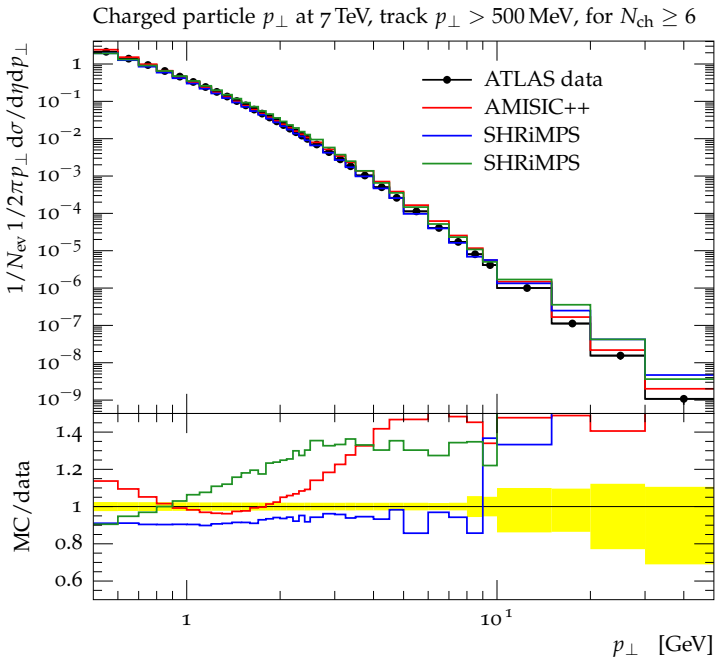

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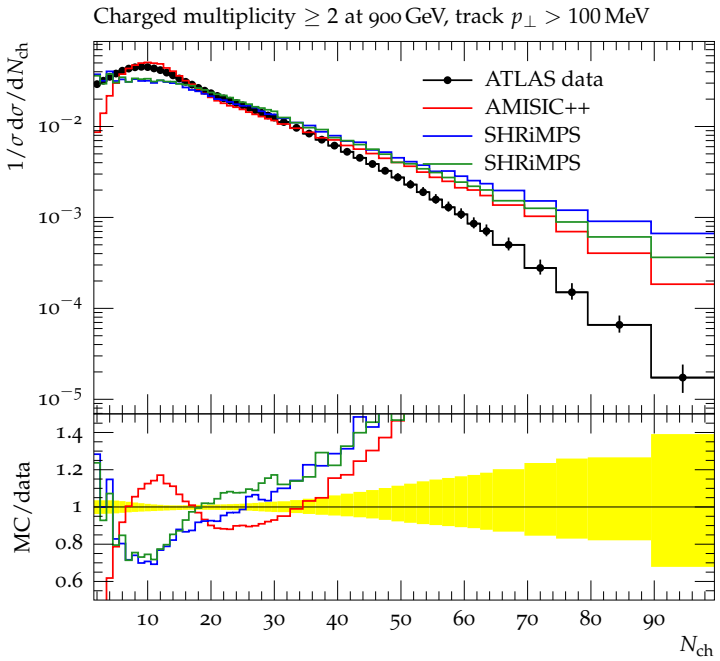

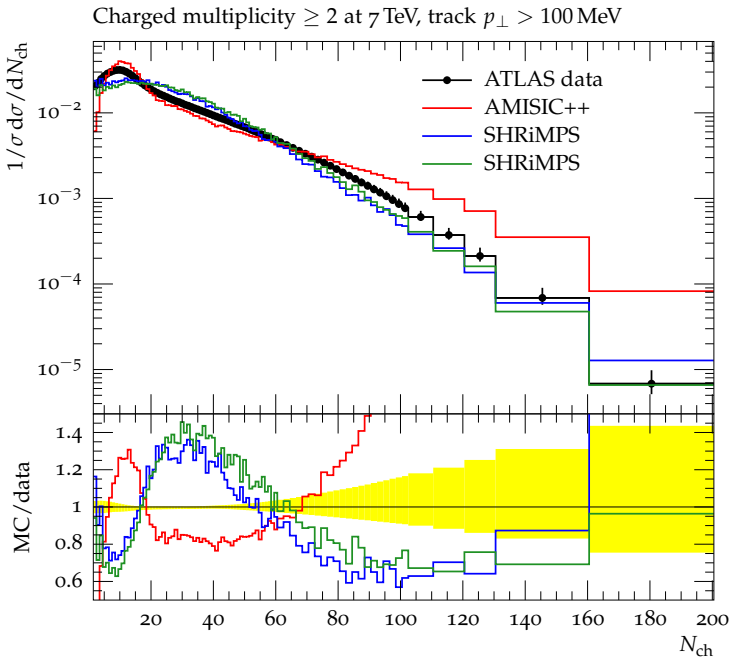

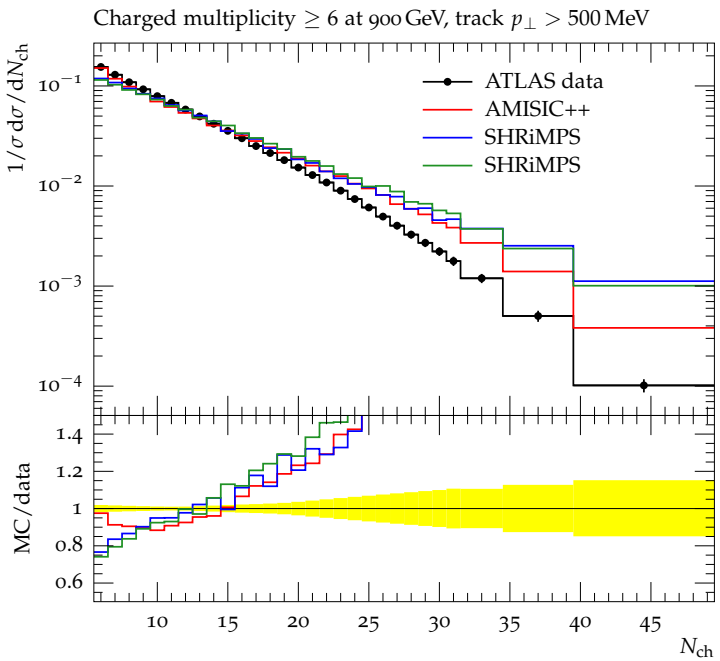

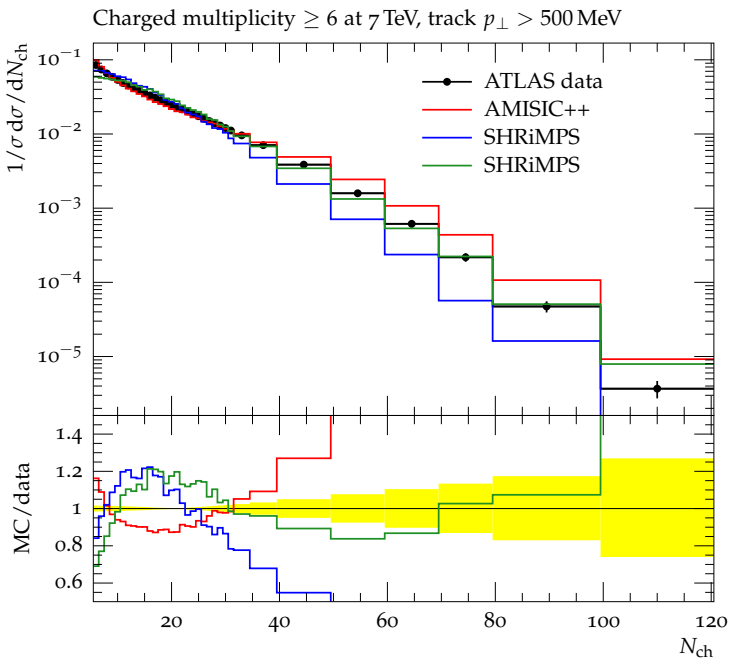

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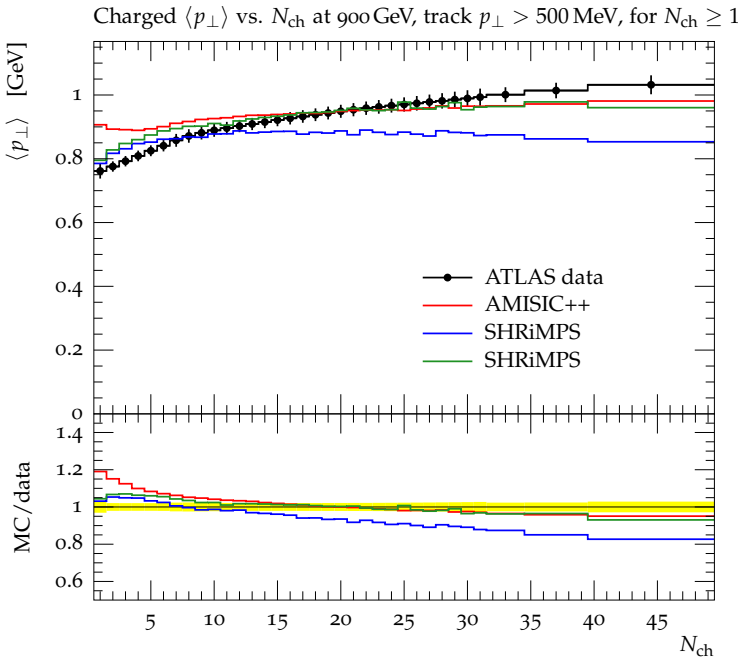
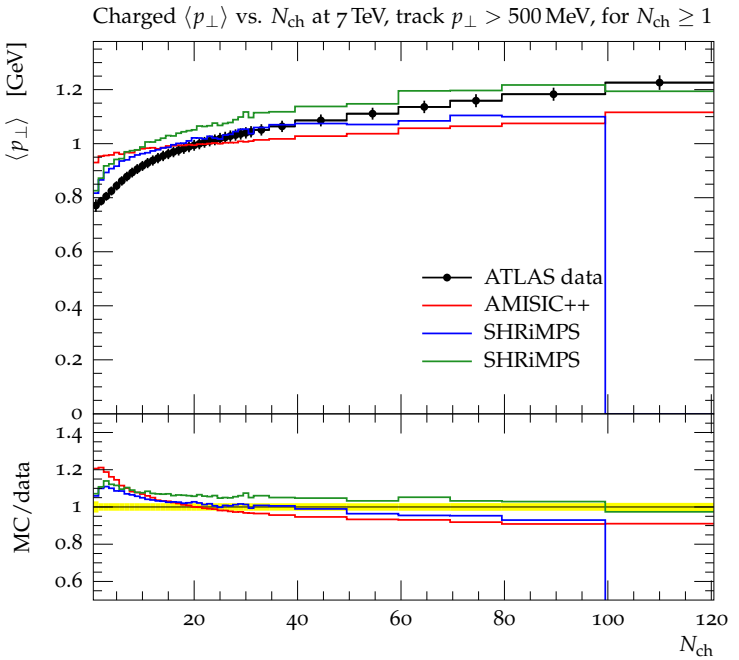
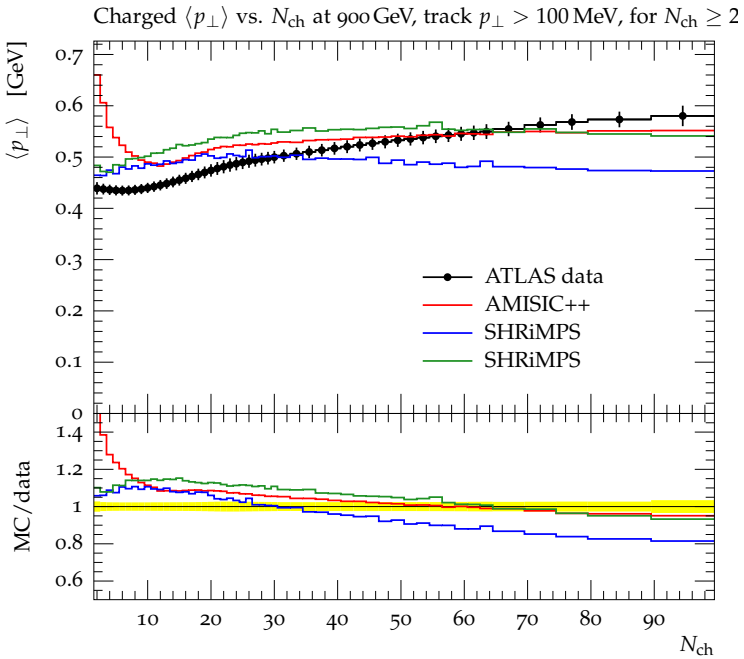
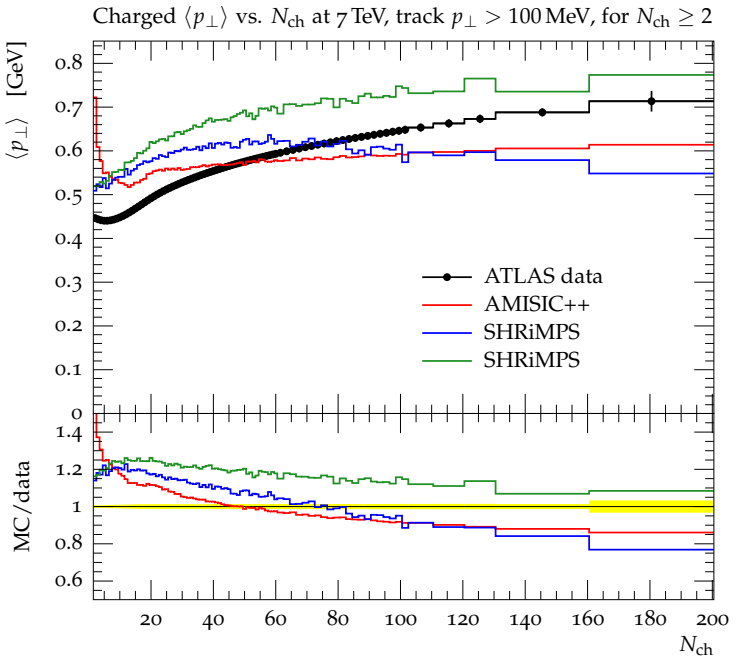
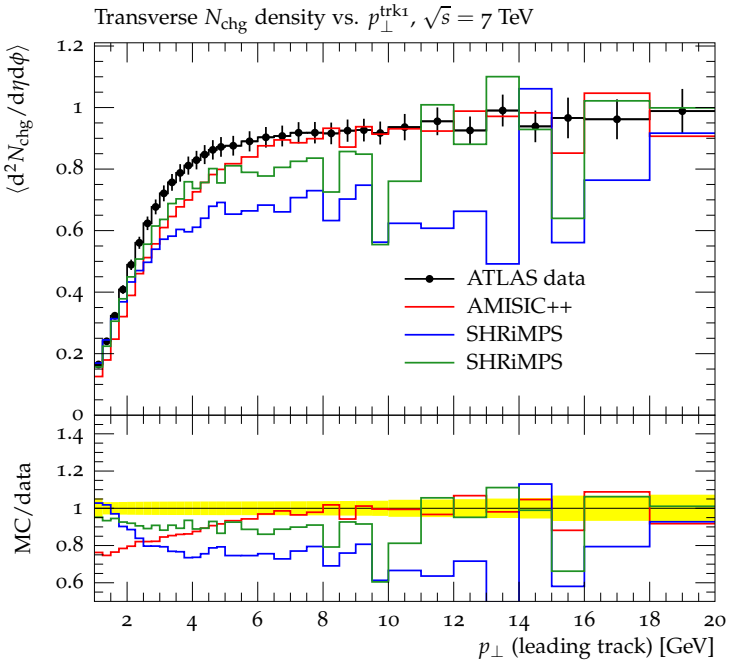


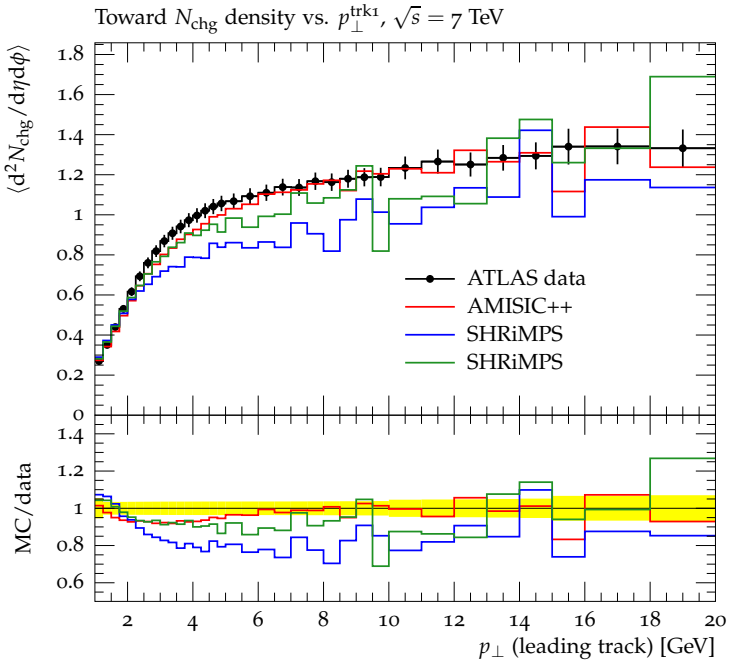


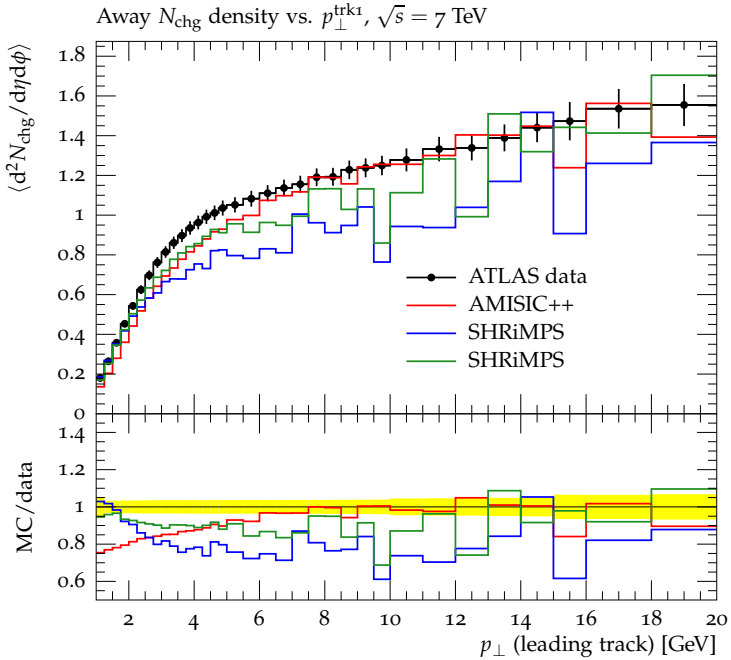




Underlying Event @7 TeV







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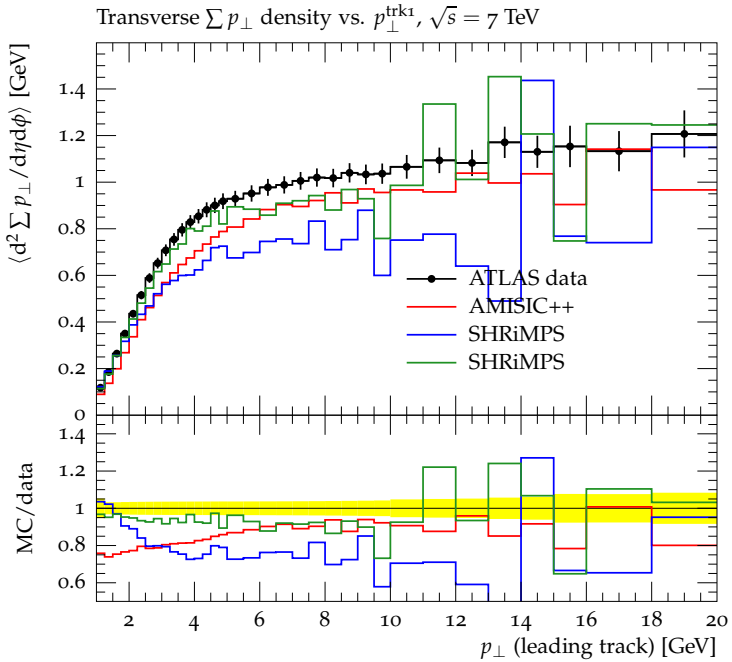
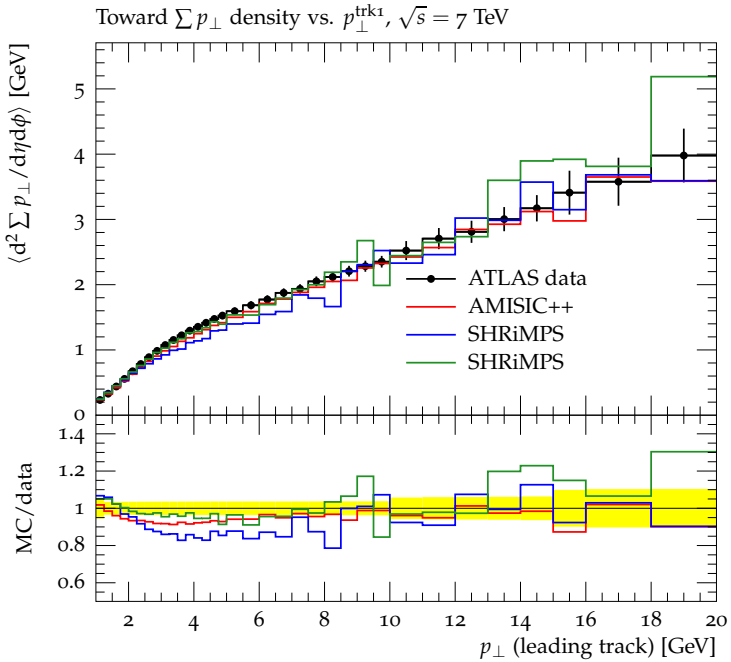
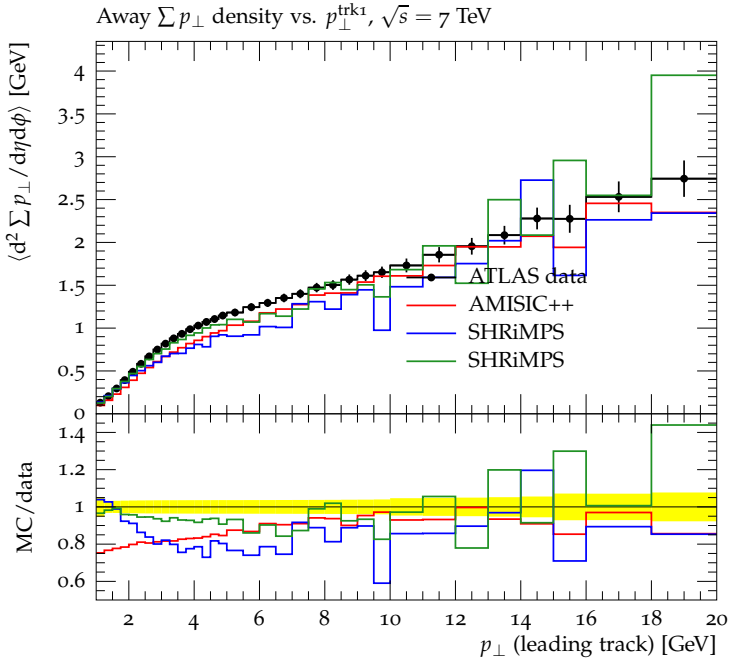
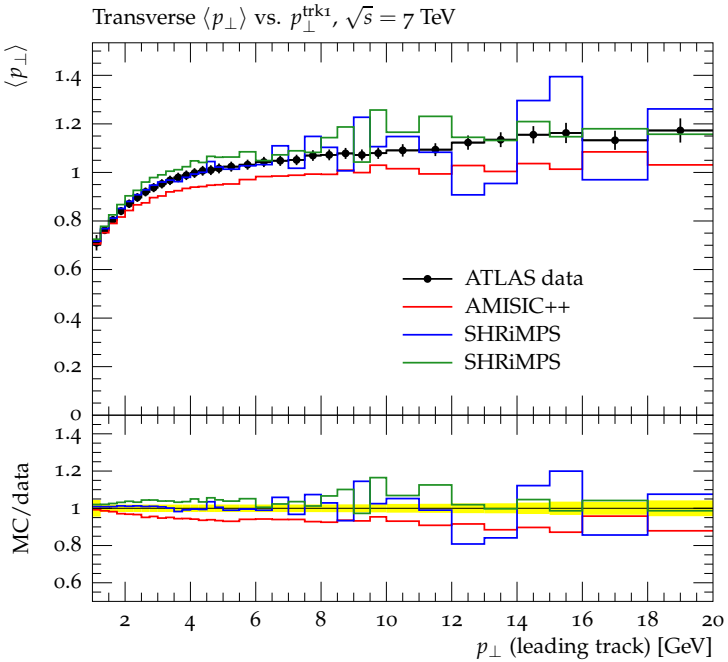
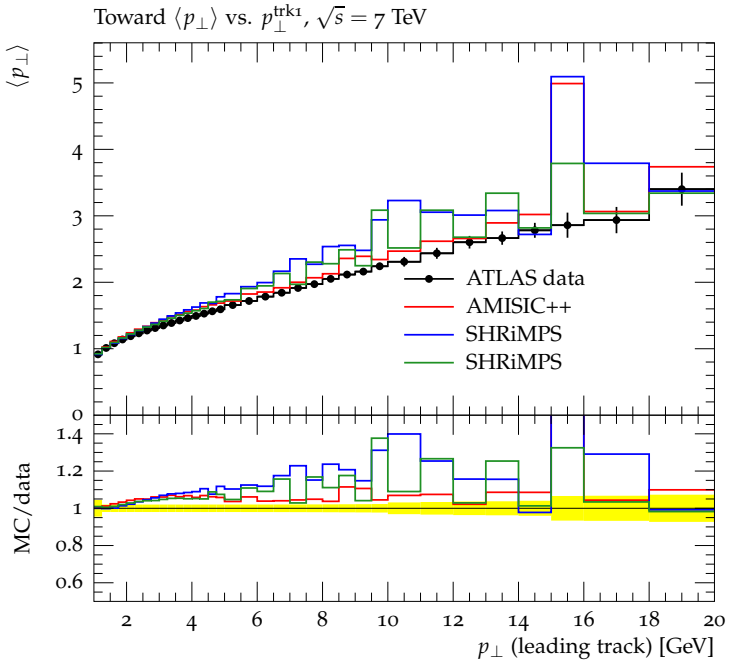


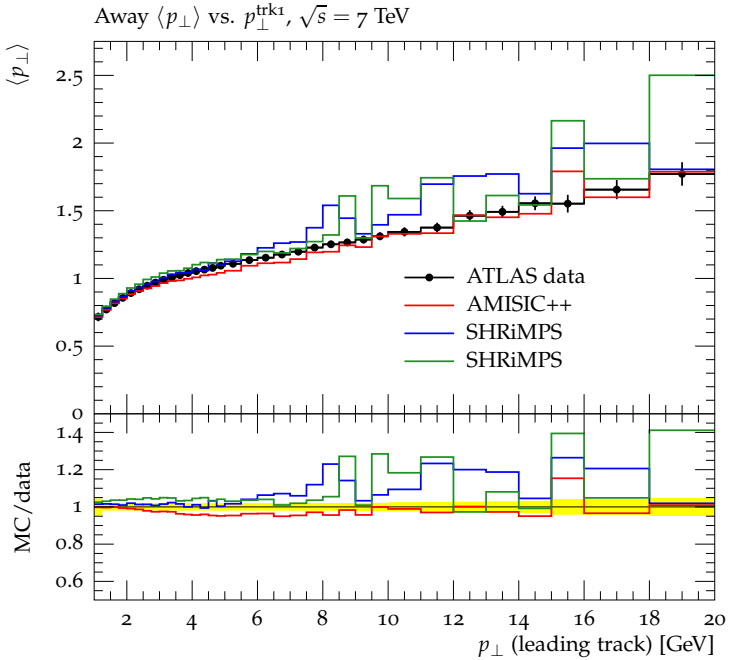




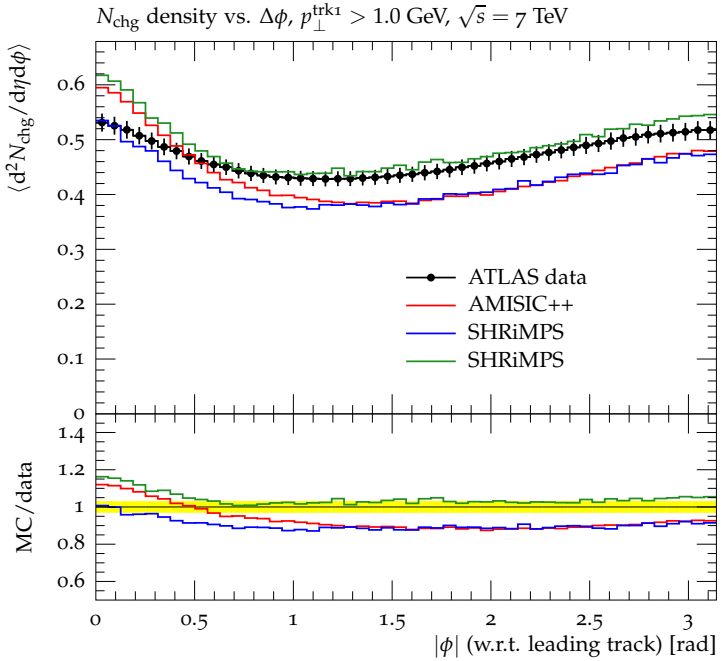
Underlying Event @7 TeV

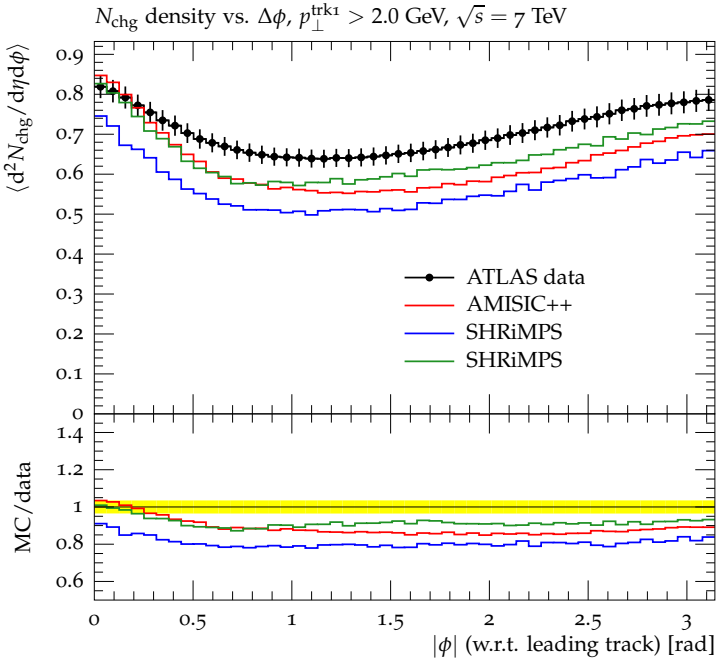


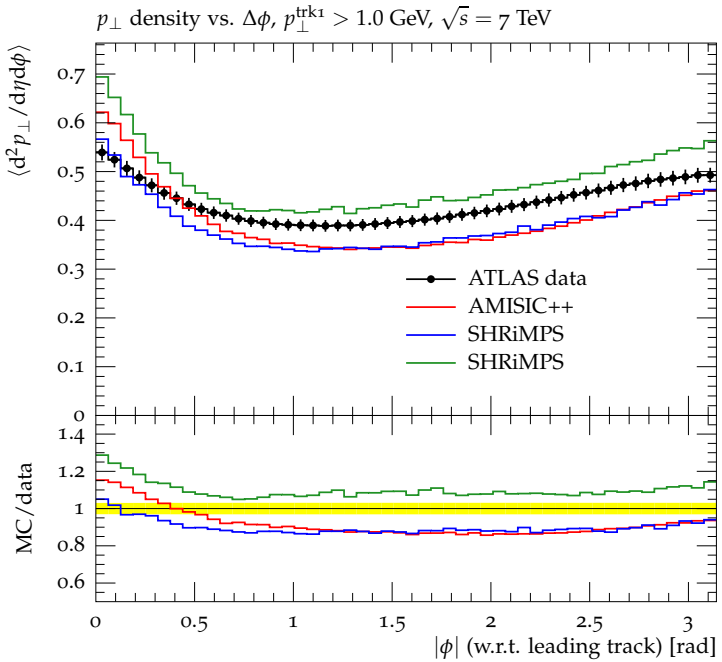


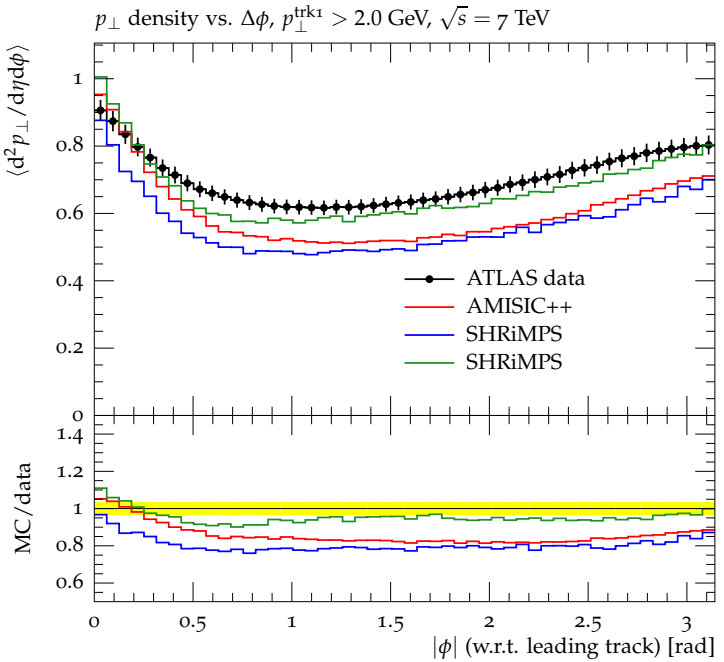


Underlying Event @7 TeV

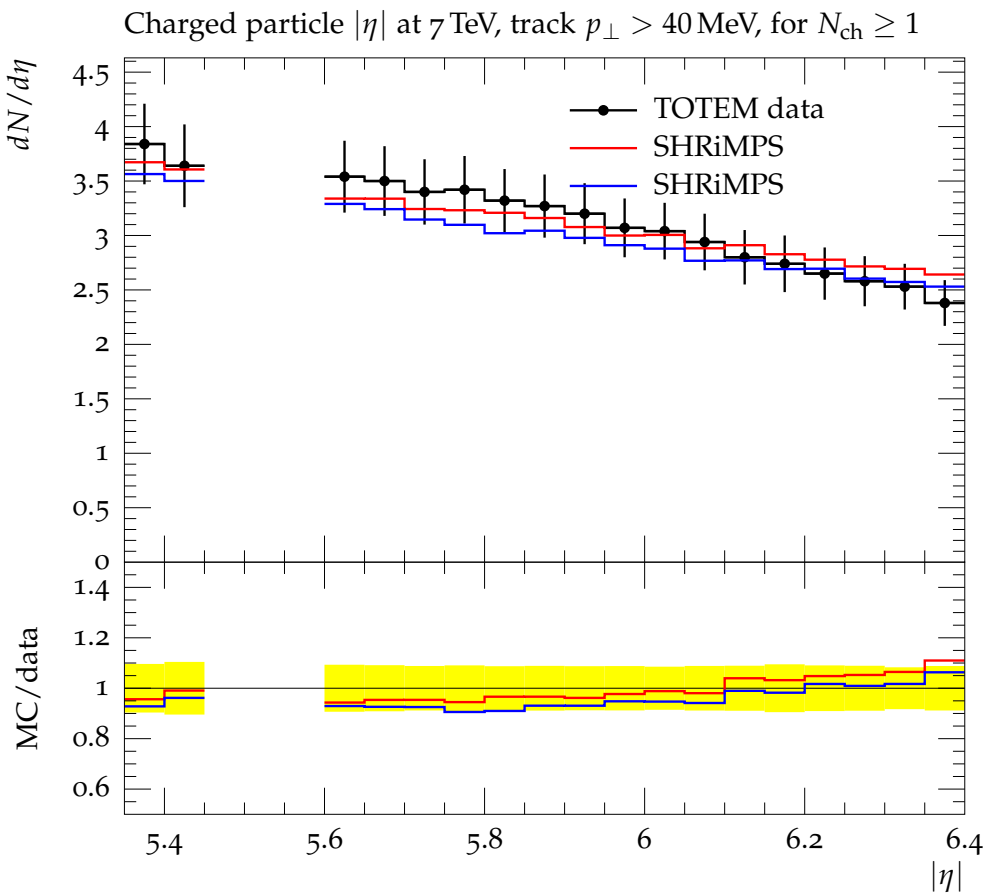




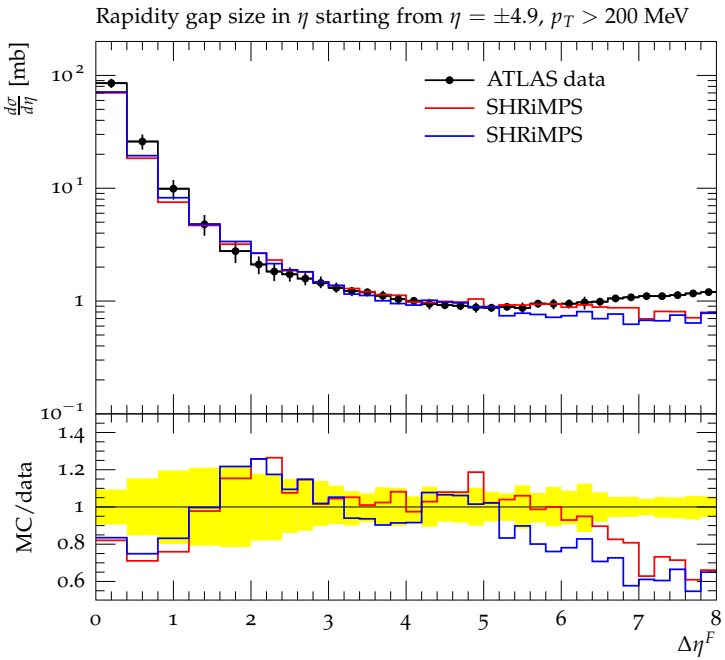


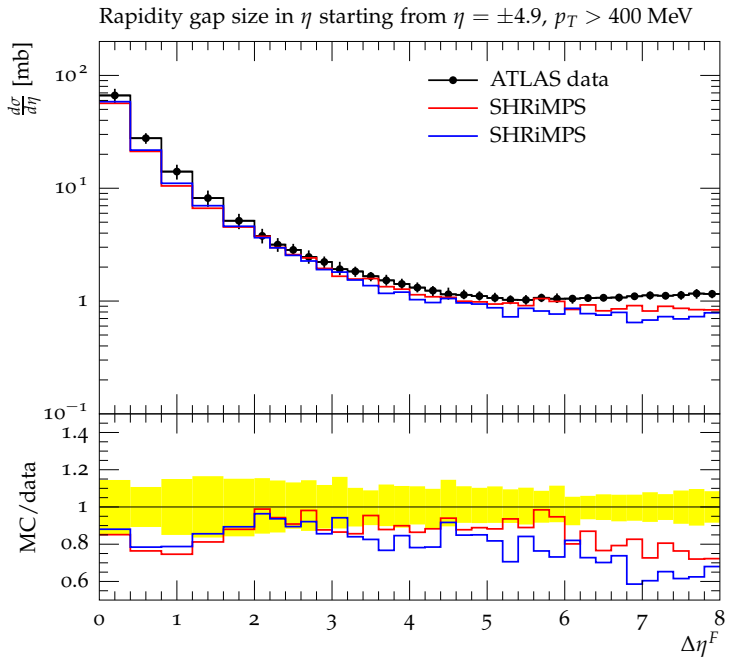


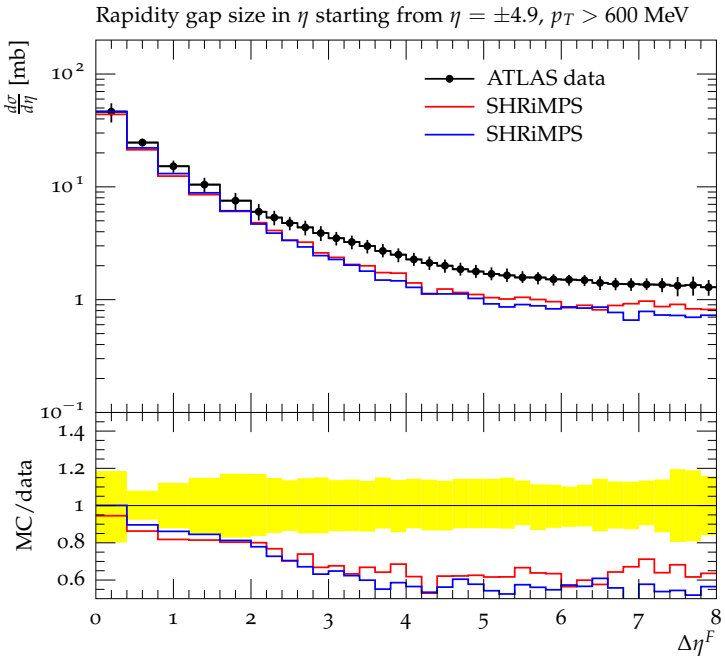
Forward Multiplicity @7 TeV

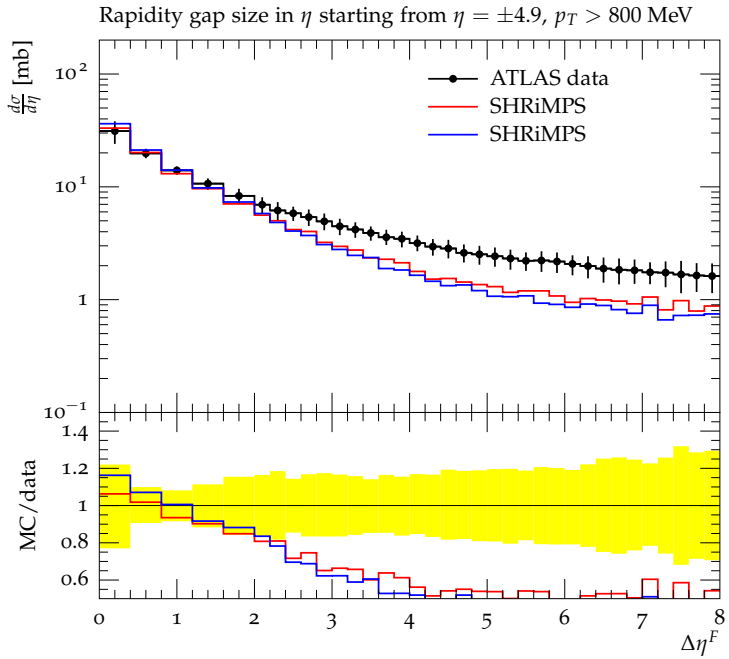


Rapidity Gap Cross Section @7 TeV









Outline

Conclusions & Outlook

Conclusions

- AMISIC++ & SHRiMPS: conceptually very different
  - AMISIC++: inspired by collinear factorisation
    similar to Sjöstrand-van Zijl model
  - SHRiMPS: consistent model for soft and semi-hard QCD based on KMR model
- SHRiMPS offers more complete picture
- both describe data reasonably well

Outlook (SHRiMPS)

- validate the physics/tune the parameters
- formulate as underlying event model
- include secondary Reggeons (quarks)
- allow for open and closed heavy flavour production
- will become default MinBias model in SHERPA