

# Soft Physics in Herwig

or:  
Why you should switch to Herwig 7.x

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[S.Gieseke, PK, F.Loshaj [arXiv:1612.04701](https://arxiv.org/abs/1612.04701)] [S.Gieseke, PK, S.Plätzer [arXiv:1710.10906](https://arxiv.org/abs/1710.10906)]



# Outline

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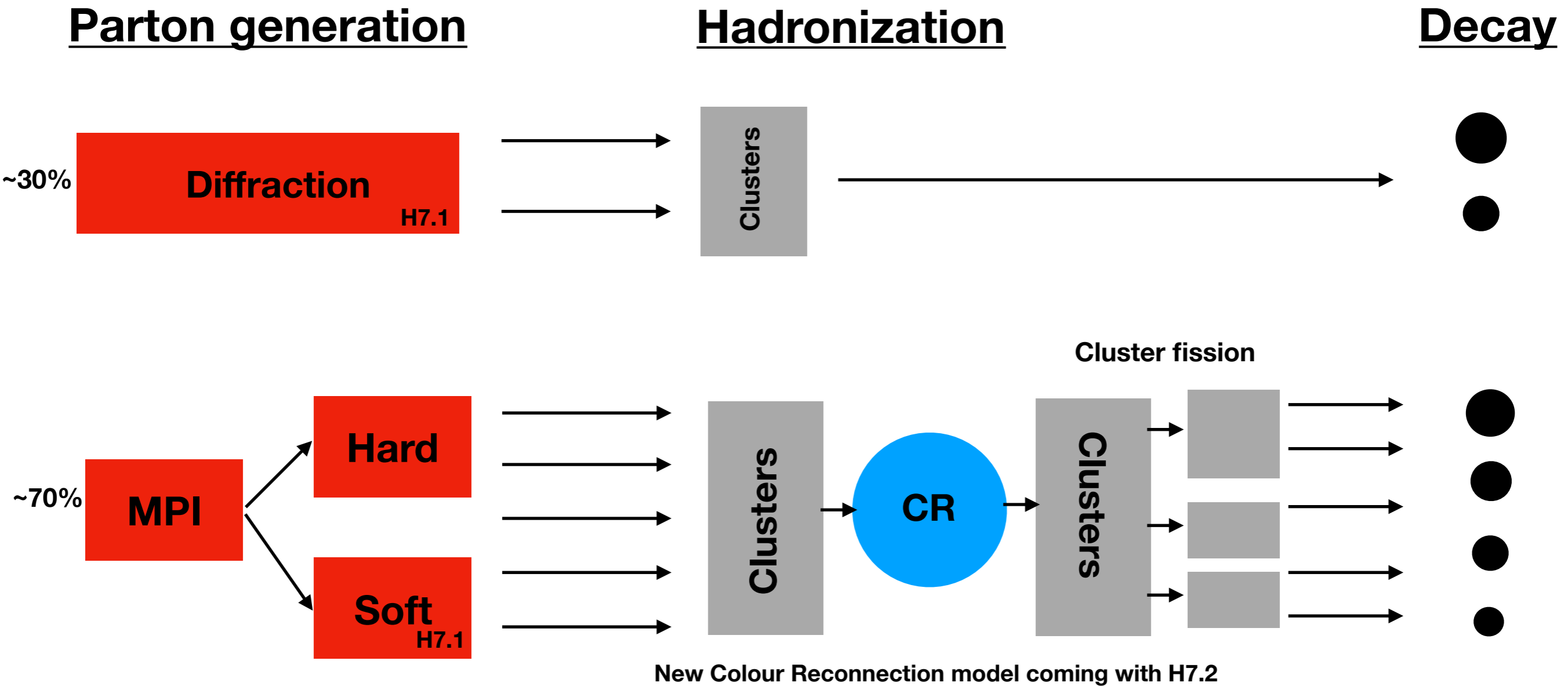
## I. Overview of soft physics in Herwig

- **Structure of the UE model**
- **Diffraction**
- **Soft multiparton interactions**

## II. Colour Reconnection

- **Colour Reconnections in Herwig**
- **New model**
- **Comparison with data**

# I. Structure of the UE model in Herwig



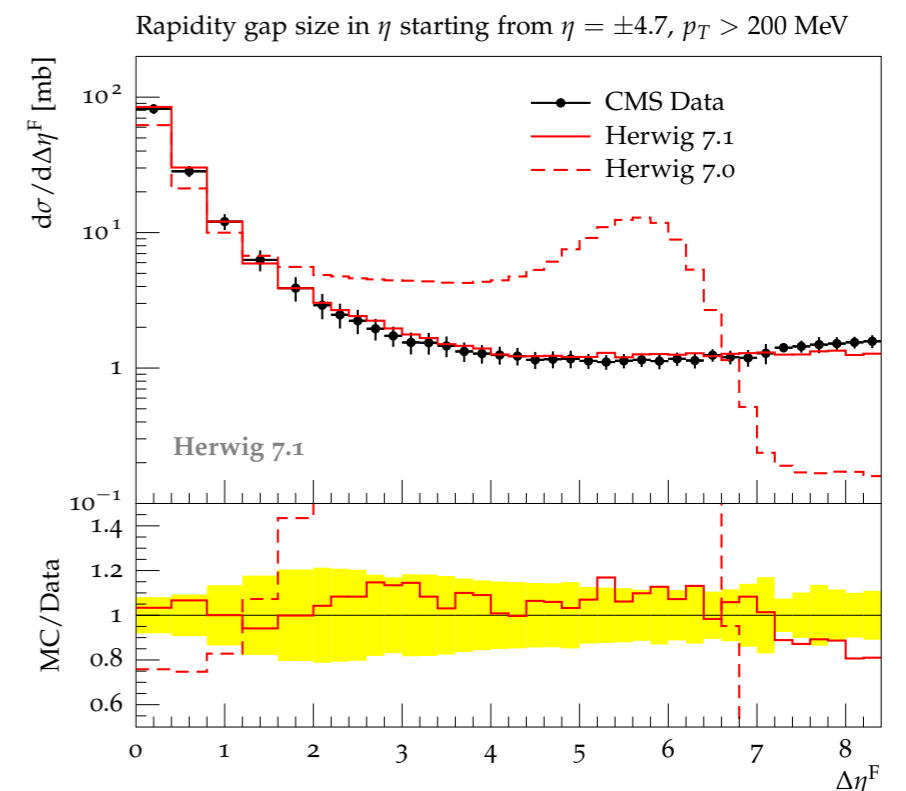
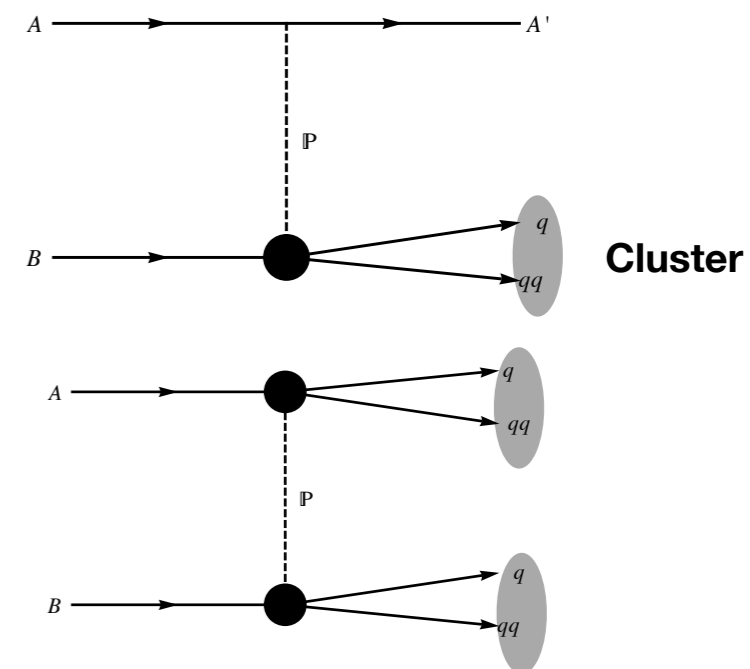
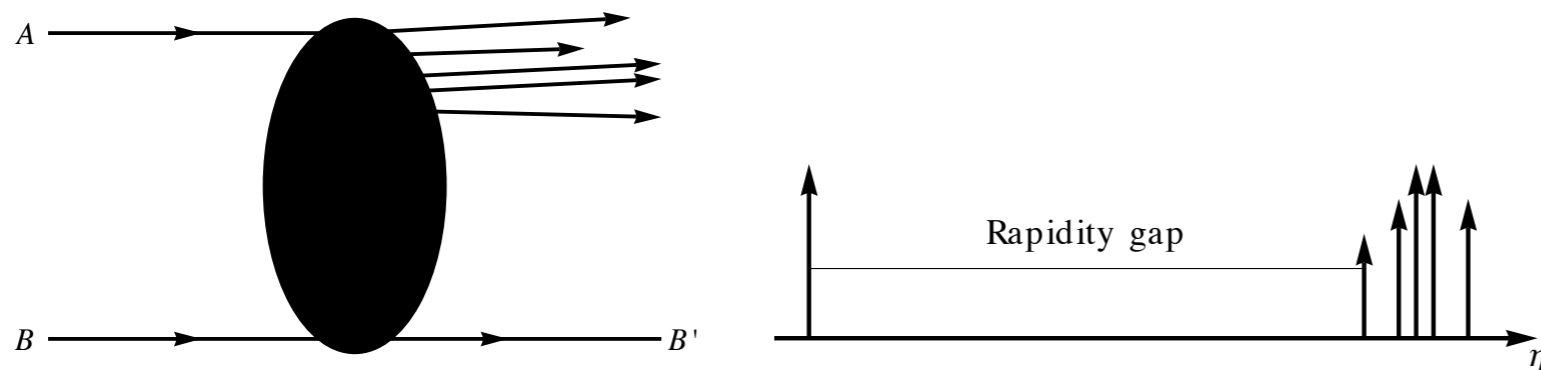
➔ Every aspect has a big impact on the accurate modeling of MB/UE data

# I. Diffraction

$$\sigma_{\text{tot}} = \sigma_{\text{el}} + \sigma_{\text{inel}}$$

$$\sigma_{\text{inel}} = \sigma_{\text{ND}} + \sigma_{\text{SD}} + \sigma_{\text{DD}} + \sigma_{\text{CD}}$$

- **Characterized through large rapidity gap**
- **Implemented for soft diffraction (small  $p_T$ )**
- **Final state treated fully non-perturbatively**
- **[S.Gieseke, PK, F.Loshaj [arXiv:1612.04701](https://arxiv.org/abs/1612.04701)]**

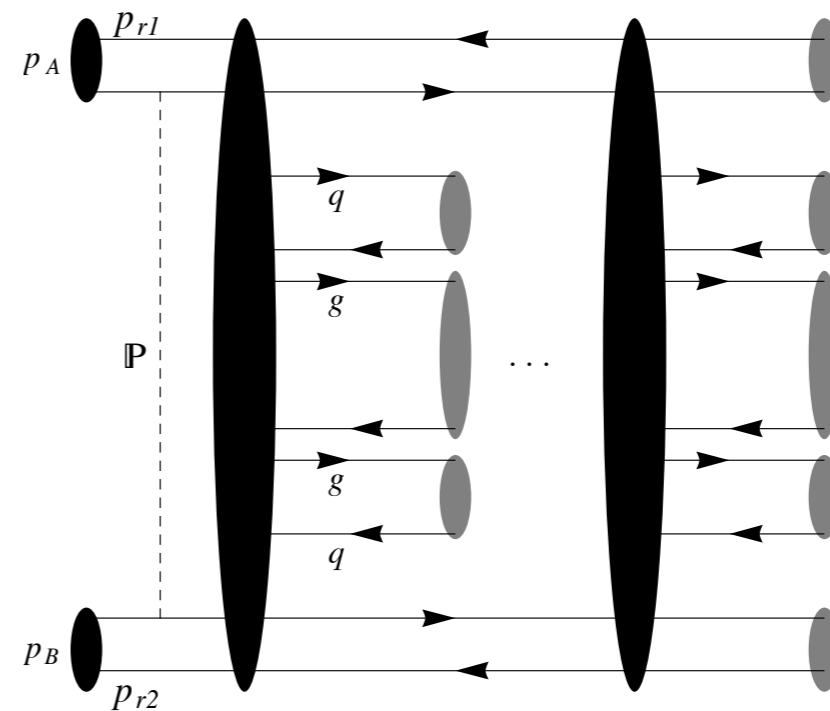
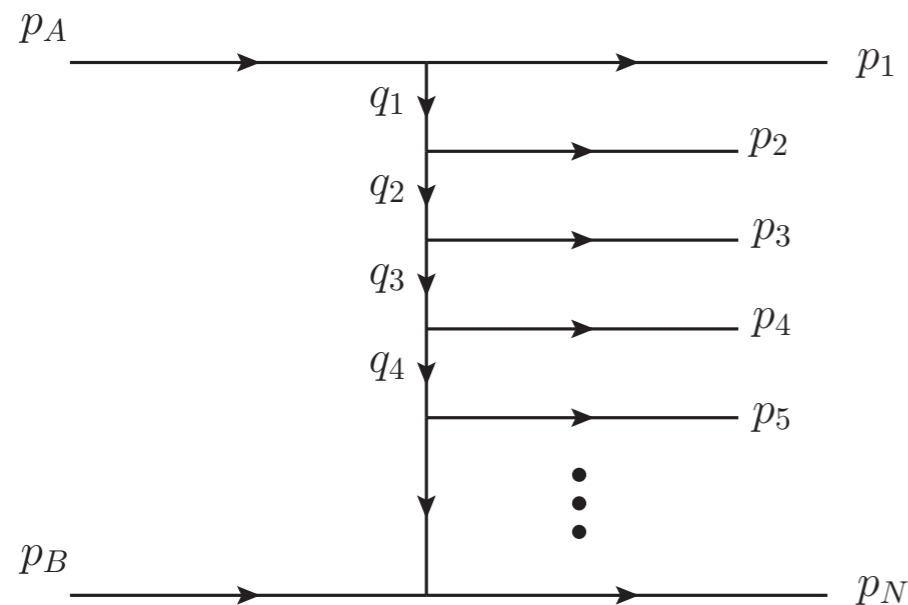


CMS [Phys.Rev. D92 (2015) no.1, 012003]

# I. Soft multiparton interactions

- **MB data: uniform and flat in rapidity (flat and narrow)**
- **Exchange of multiple soft cut pomerons**
- **Cut pomerons = particle ladder with multi-peripheral kinematics**
- **See for more details [S.Gieseke, PK, F.Loshaj [arXiv:1612.04701](https://arxiv.org/abs/1612.04701)]**

$$\langle N \rangle \approx N_{\text{ladder}} \times \ln \frac{s}{m^2} \quad N_{\text{ladder}} = N_0 \left( \frac{s}{\text{TeV}^2} \right)^{-0.08}$$

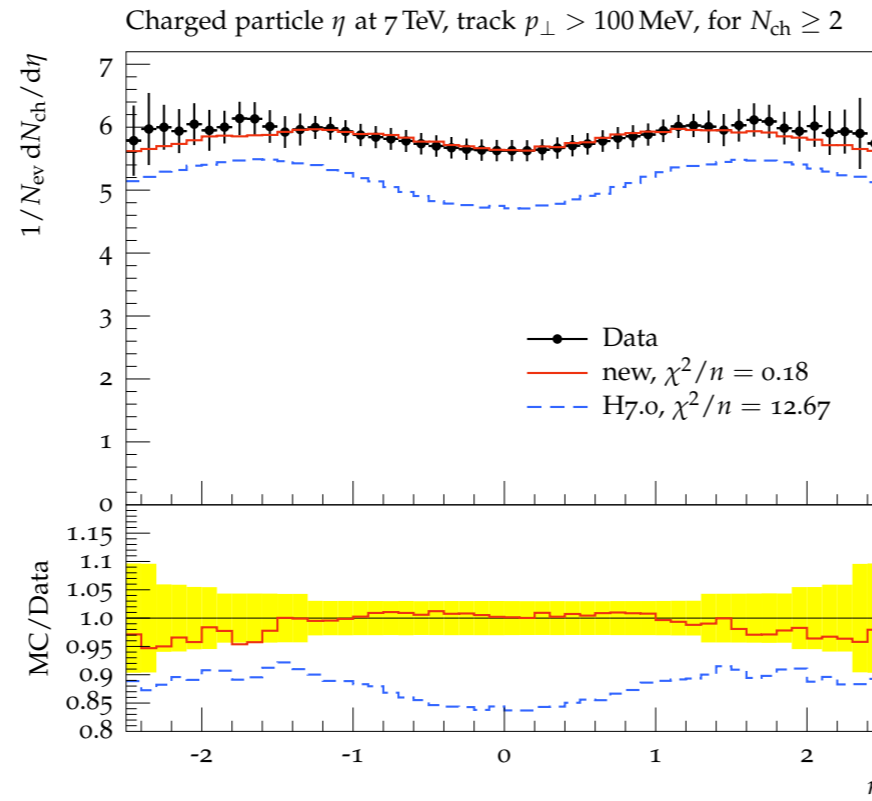


# Herwig 7.1

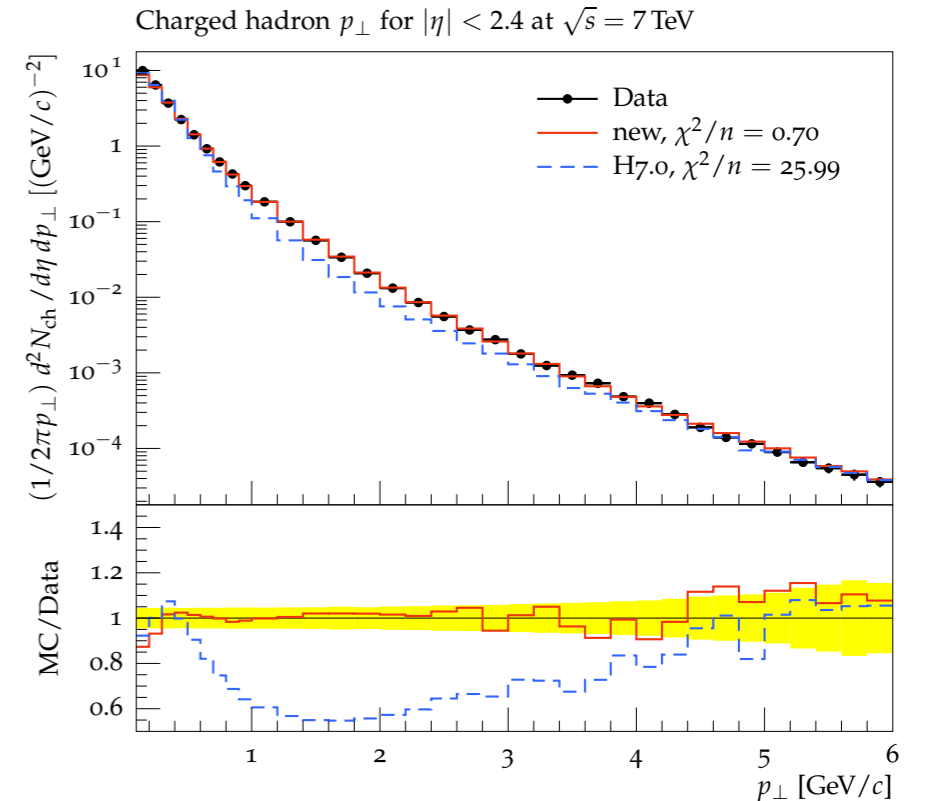
Model for diffraction and new model for soft MPI

Good description of general features of MB observables

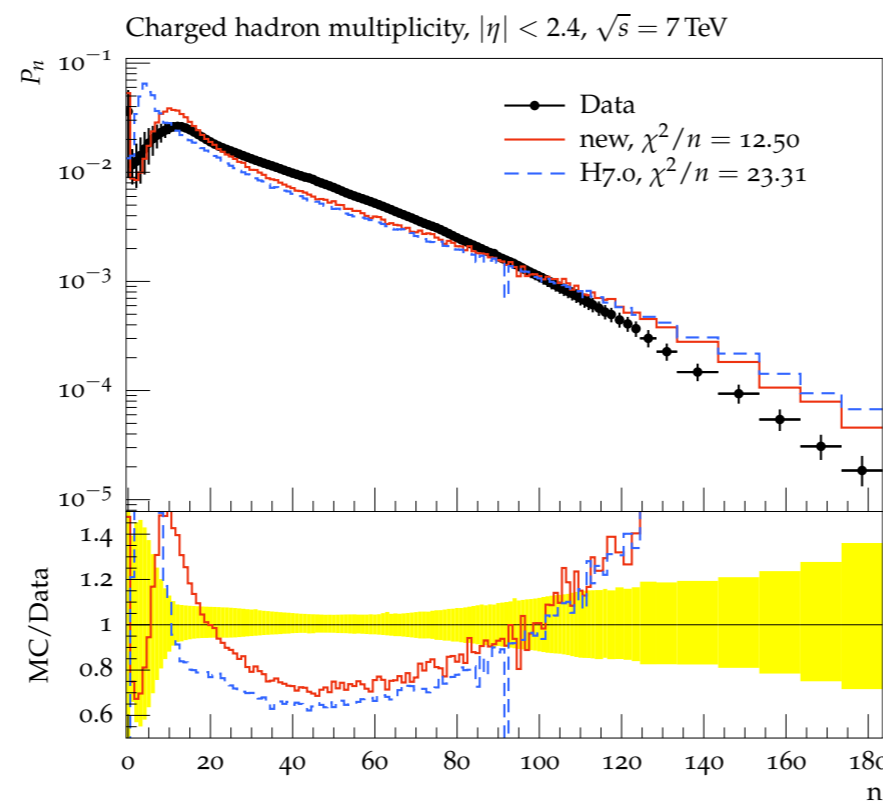
High  $p_T$  and high multiplicity region difficult



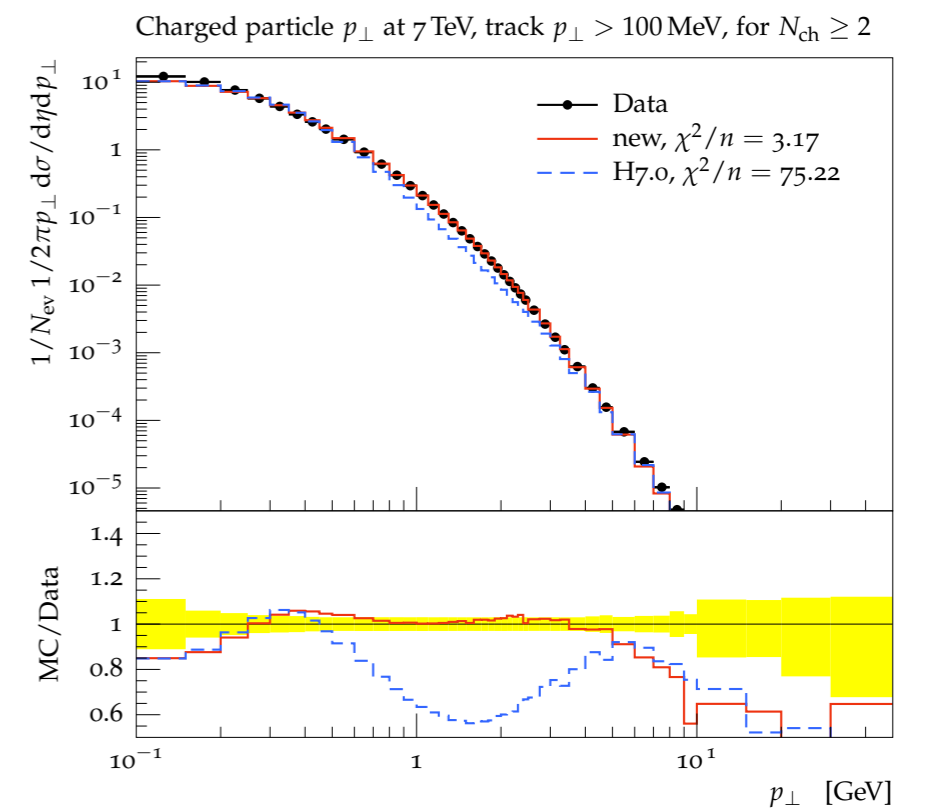
[New J.Phys.13:053033,2011]



[Phys.Rev.Lett.105:022002,2010]



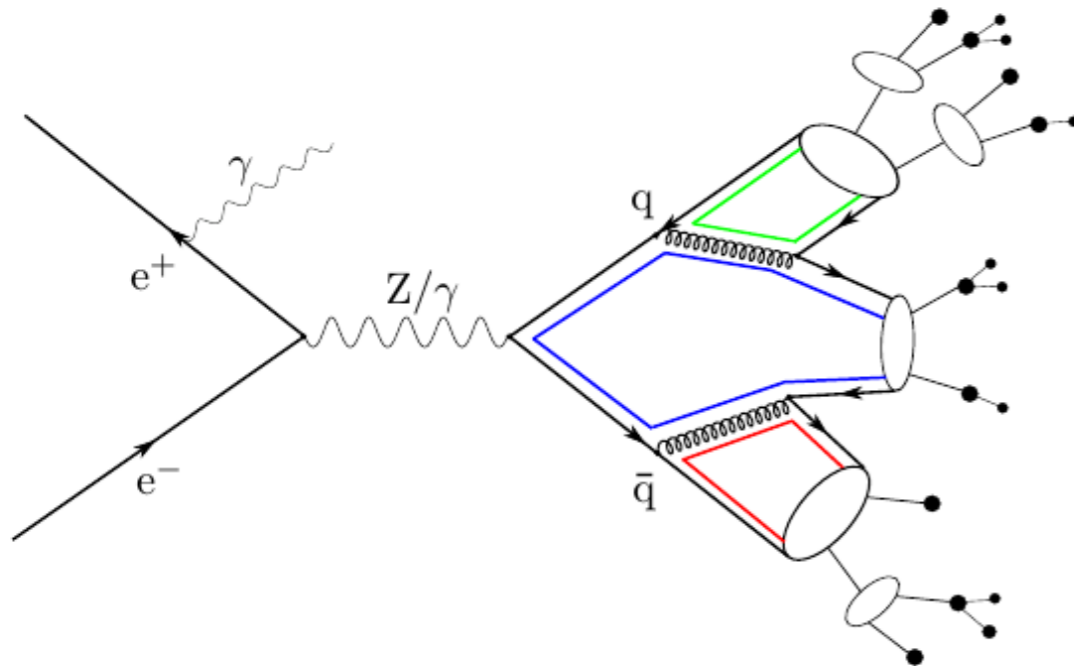
[J. High Energy Phys. 01 (2011) 079]



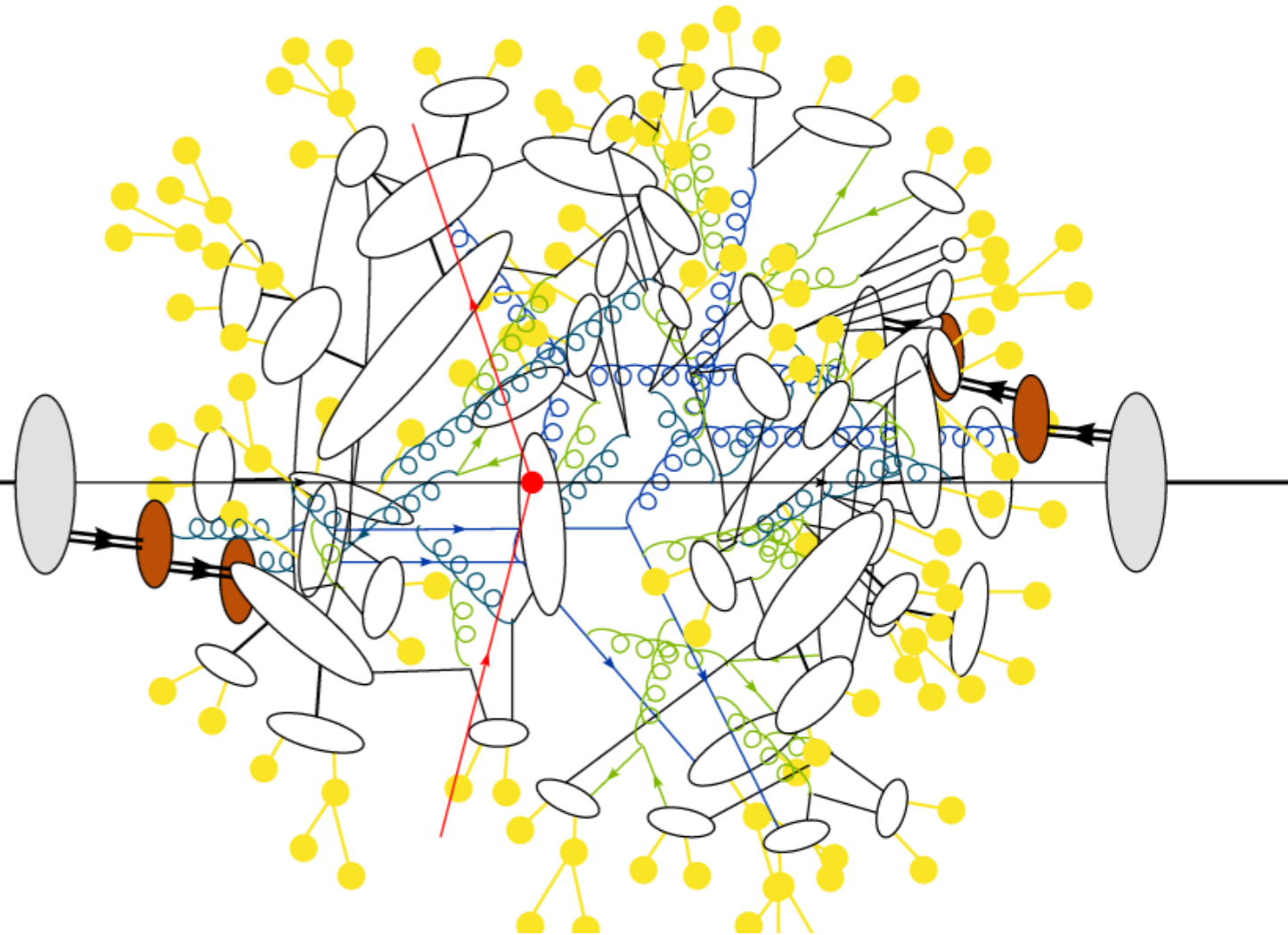
[New J.Phys.13:053033,2011]

# II. Colour Reconnection

**Colour connections already well defined through the parton shower at LEP (Colour pre-confinement)**



**~O(5) clusters**



**~O(30) clusters**

**Colour connections between different scattering centers unclear -> need CR**

# II. Colour Reconnections in Herwig

Two algorithms implemented  
[S.Gieseke, C.Röhr, A.Siodmok, 1206.0041]

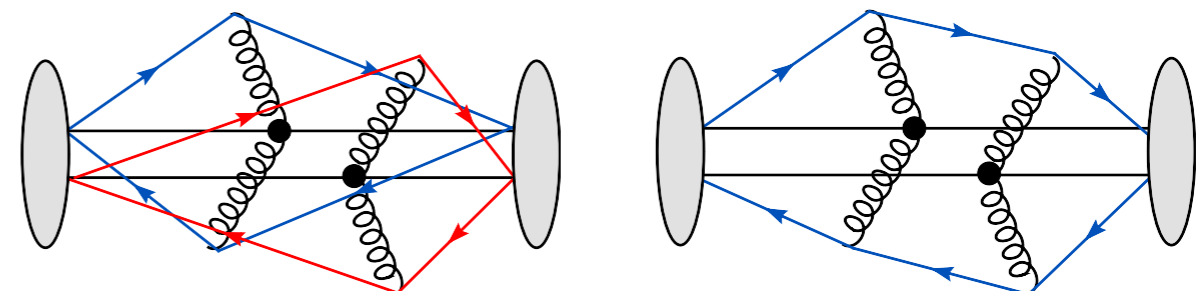
CR needed to connect MPI  
in a sensible way

Plain Colour Reconnection

Statistical Colour Reconnection



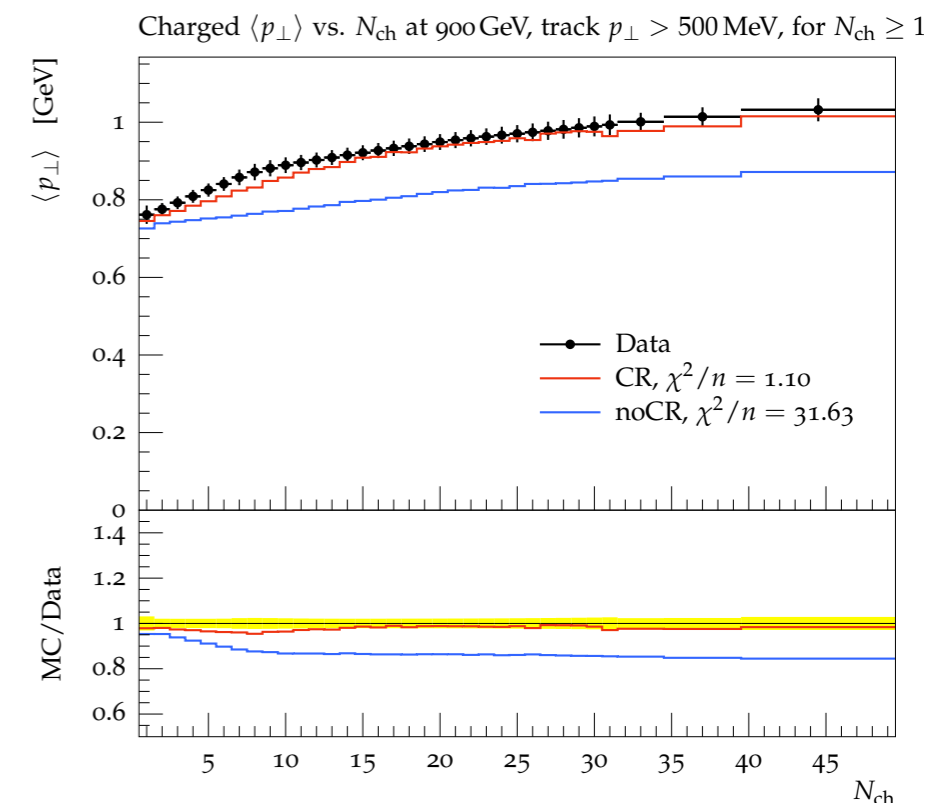
Minimize cluster masses



Sum of cluster masses

$$\lambda = \sum_{i=1}^{N_{cl}} M_i^2$$

Colour reconnections  
necessary to describe  
MB observables



[New J.Phys.13:053033,2011]

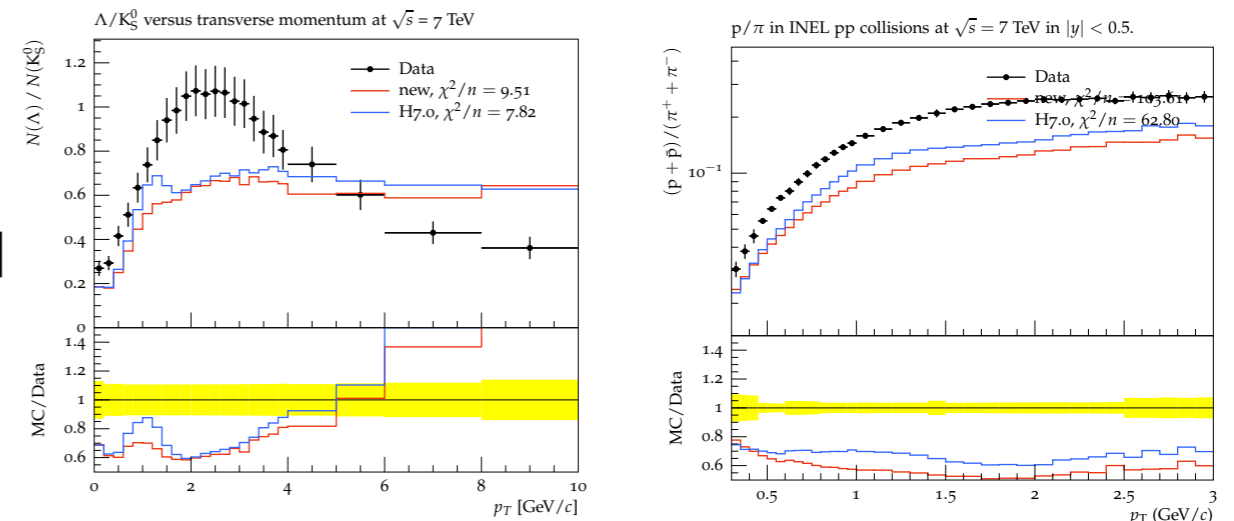


# II. New model for Colour Reconnection

## Motivation:

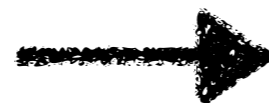
- Too many high multiplicity events
- Baryon to meson ratio
- Flavour observables not well described
- Strangeness
- New ALICE data

## H7.1 with default CR



Event with many light clusters means high multiplicity with light particles  
More clusters -> more possibilities for CR (possible overlap)  
-> reduce multiplicity but produce heavier particles through baryonic clusters to force the production of baryons

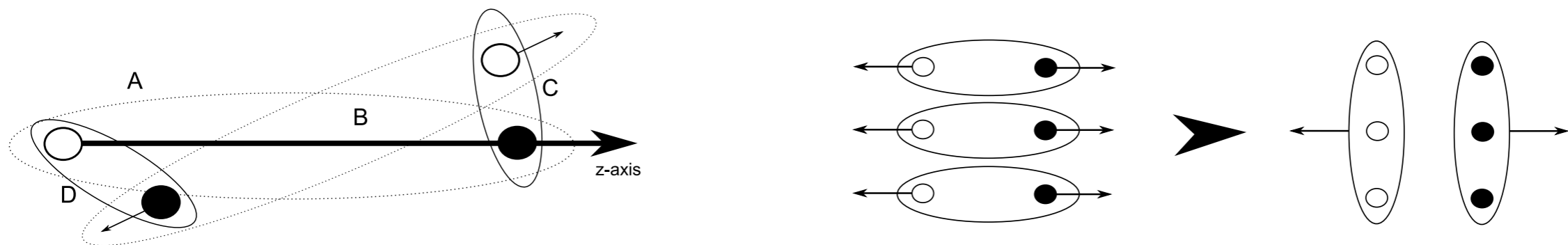
Fusing of clusters opens up the phase space for the production of heavier particles



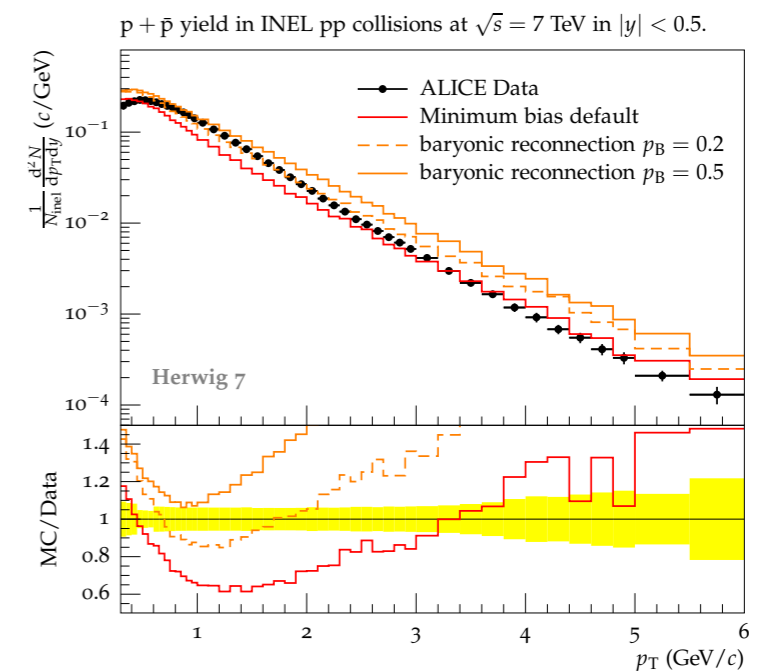
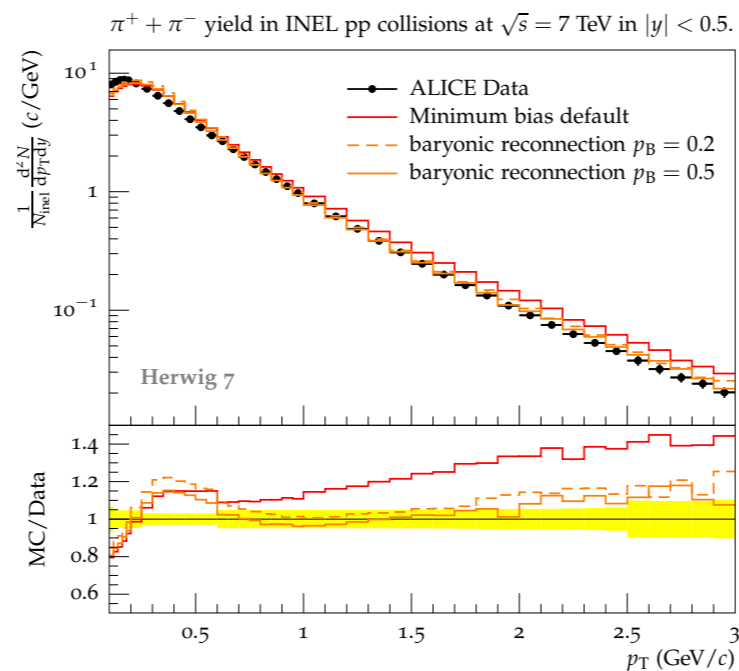
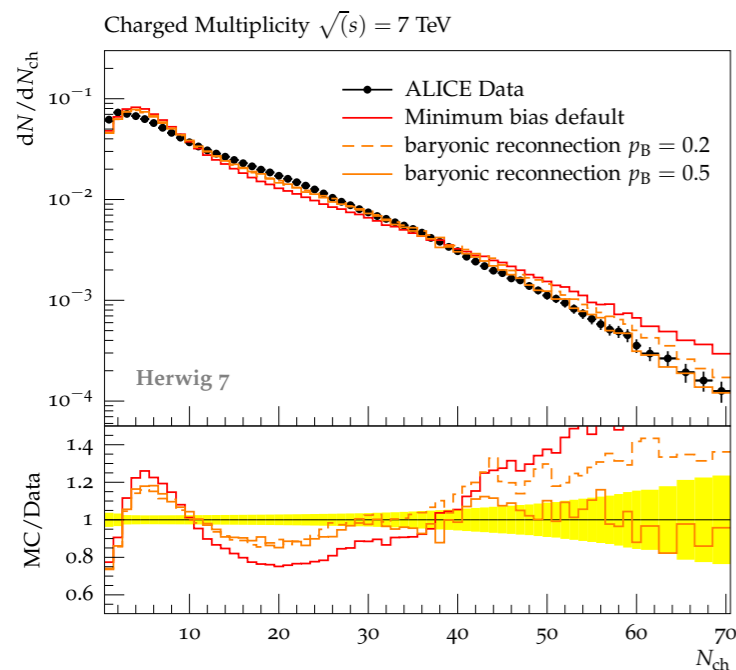
More details in [S.Gieseke, PK, S.Plätzer [arXiv:1710.10906](https://arxiv.org/abs/1710.10906)]

# II. Baryonic Colour Reconnection

Geometrical CR with the possibility to produce **baryonic clusters**

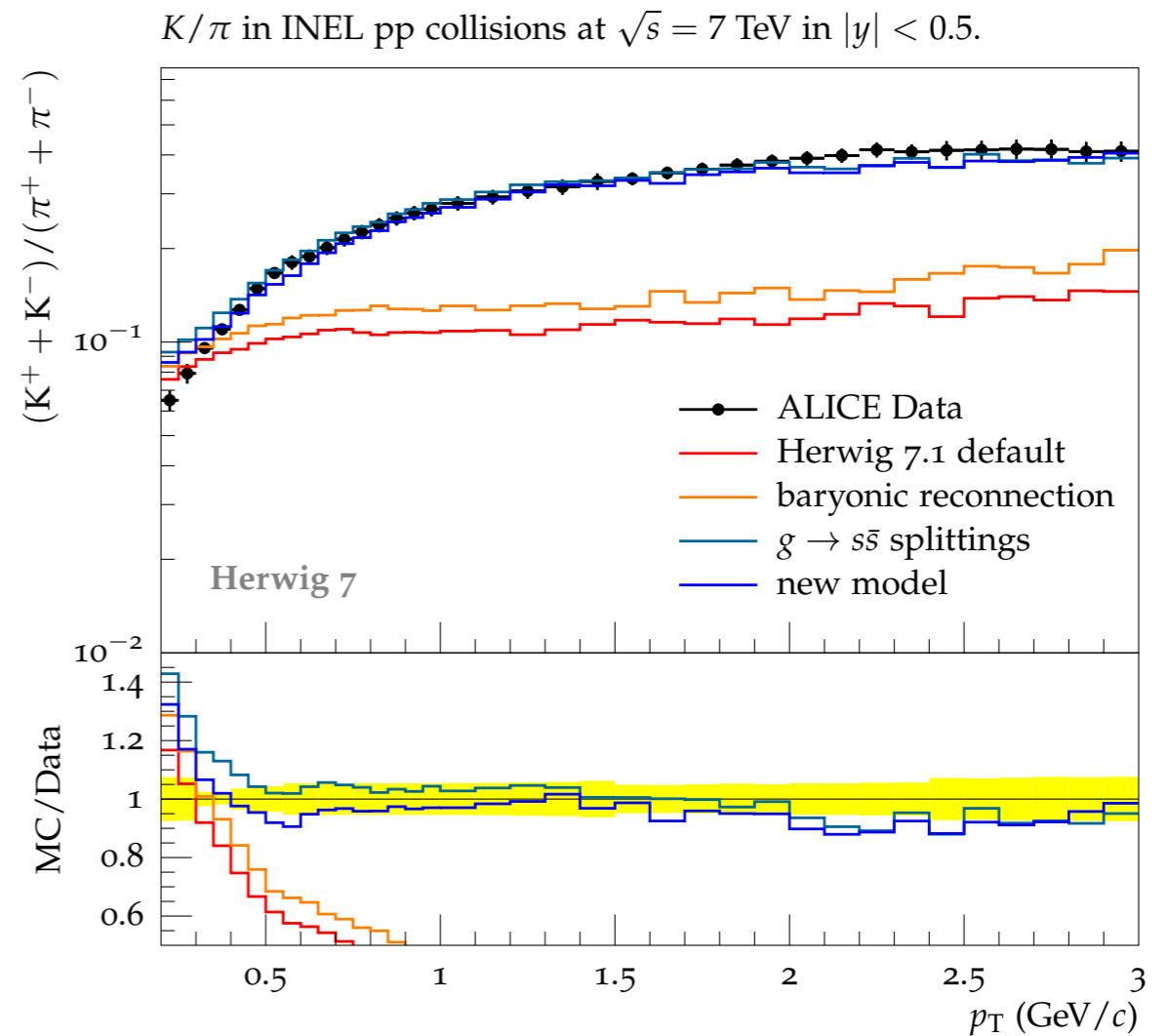
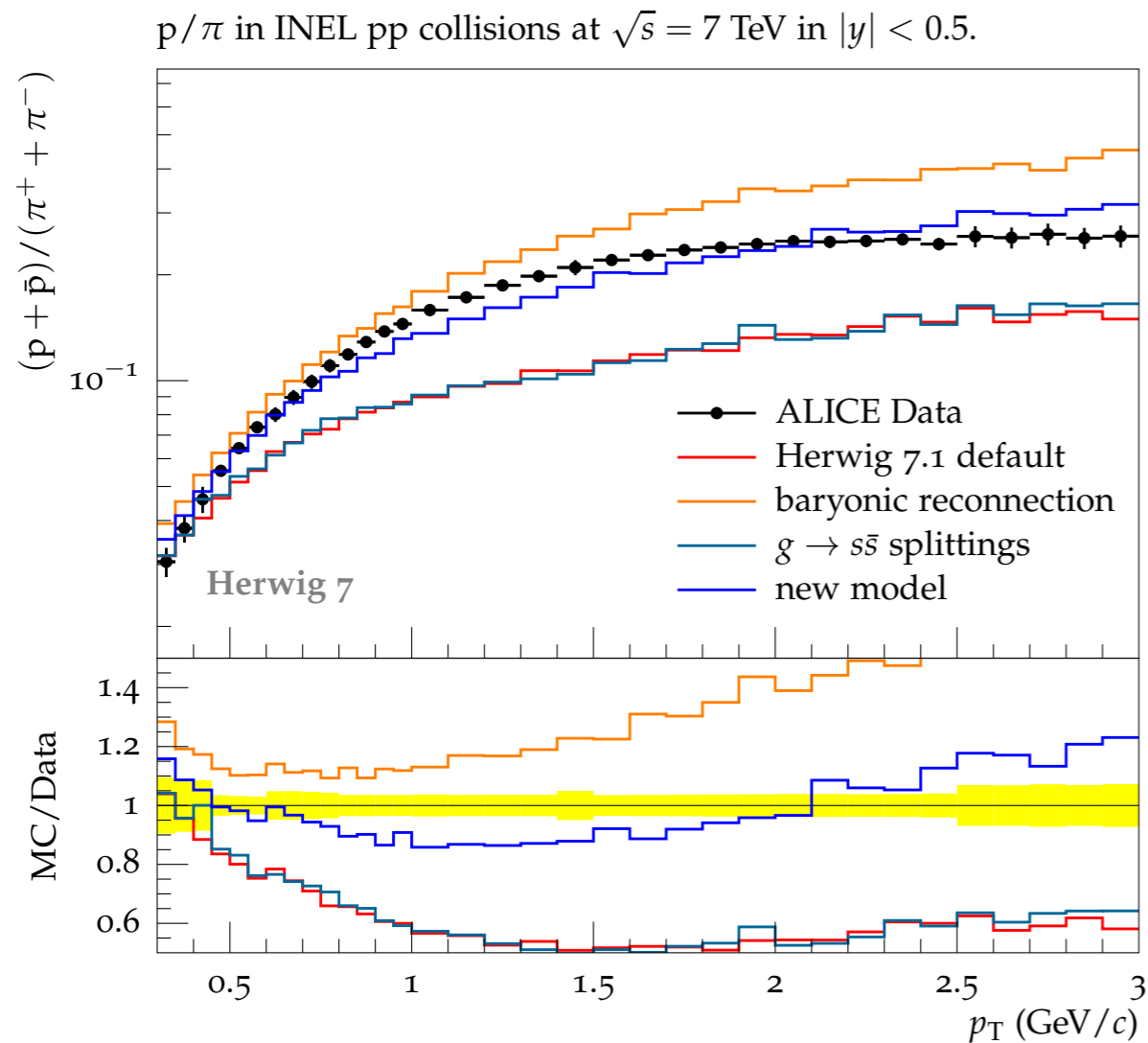


Charged multiplicity, pion and proton yields with different reconnection probabilities



[ALICE\_2010\_S8625980]

# II. Results



[Nucl. Phys. A956 (2016)]

**Baryonic reconnection (baryonic clusters) necessary**

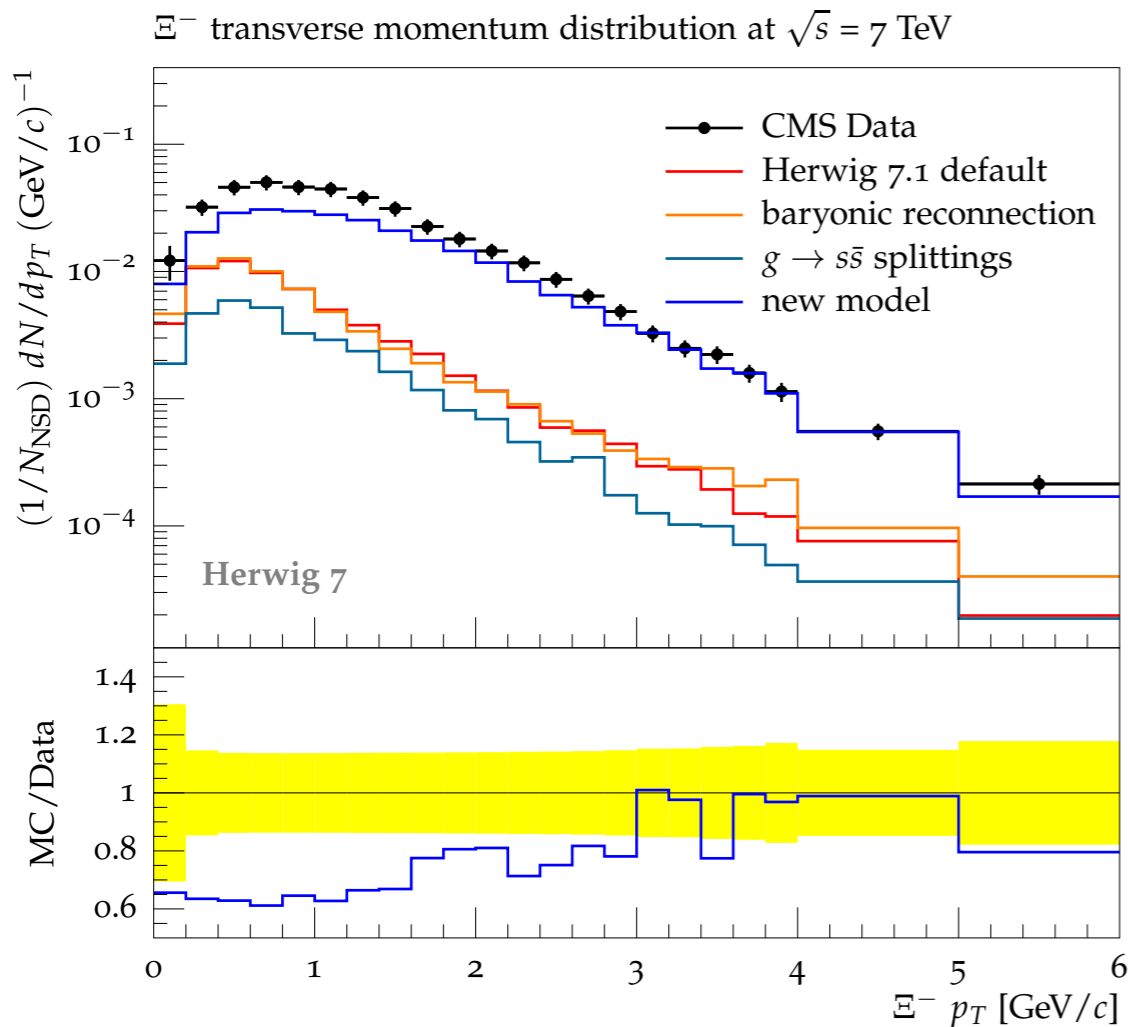
**Need additional source of strangeness**

$$g \rightarrow s\bar{s}$$

**Glueon splitting necessary in order to account for strangeness production**

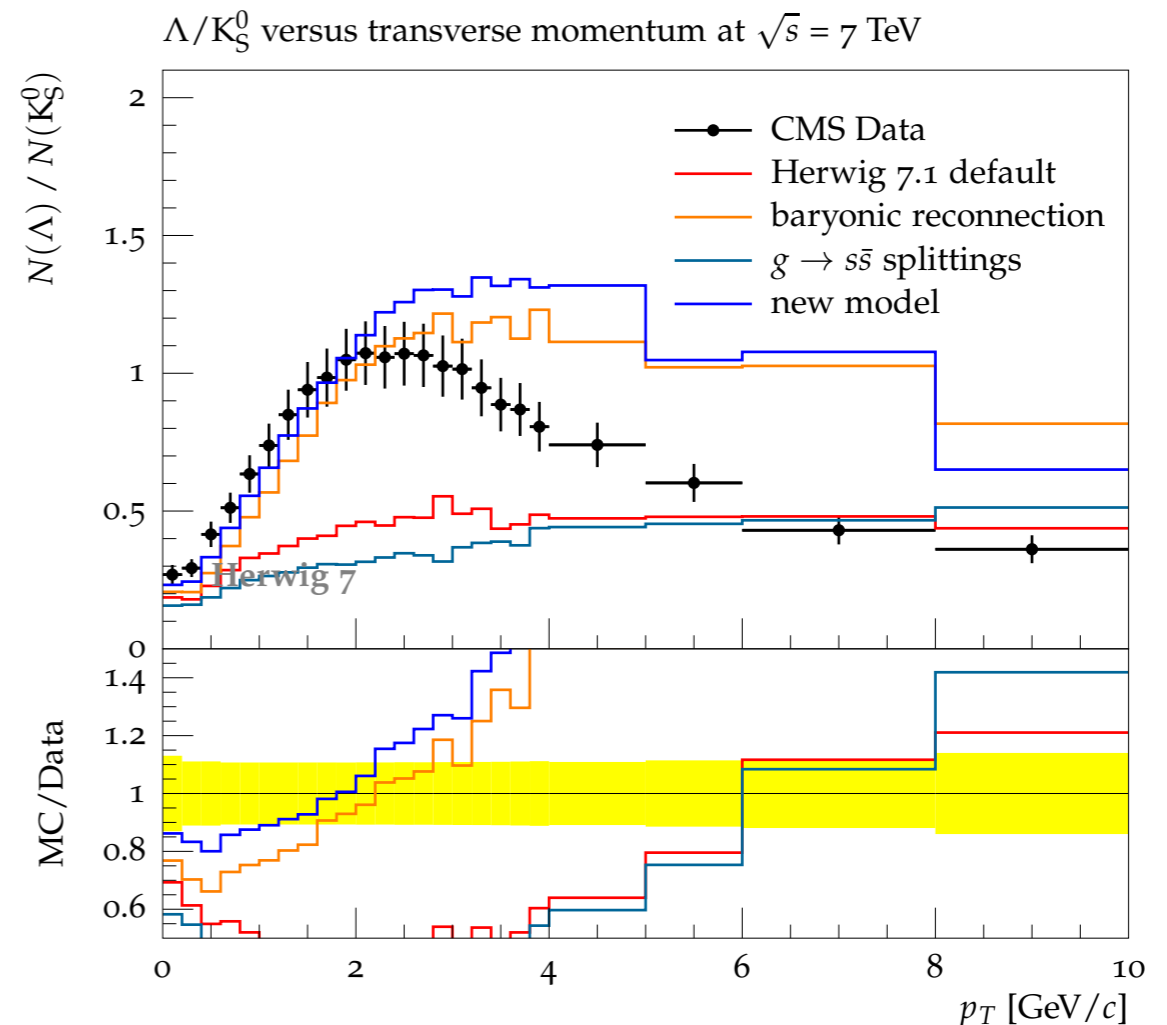
**new model = baryonic CR + gluon splitting**

# II. Results



[J. High Energy Physics. 05 (2011) 064]

**Gluon splitting and baryonic reconnection necessary**

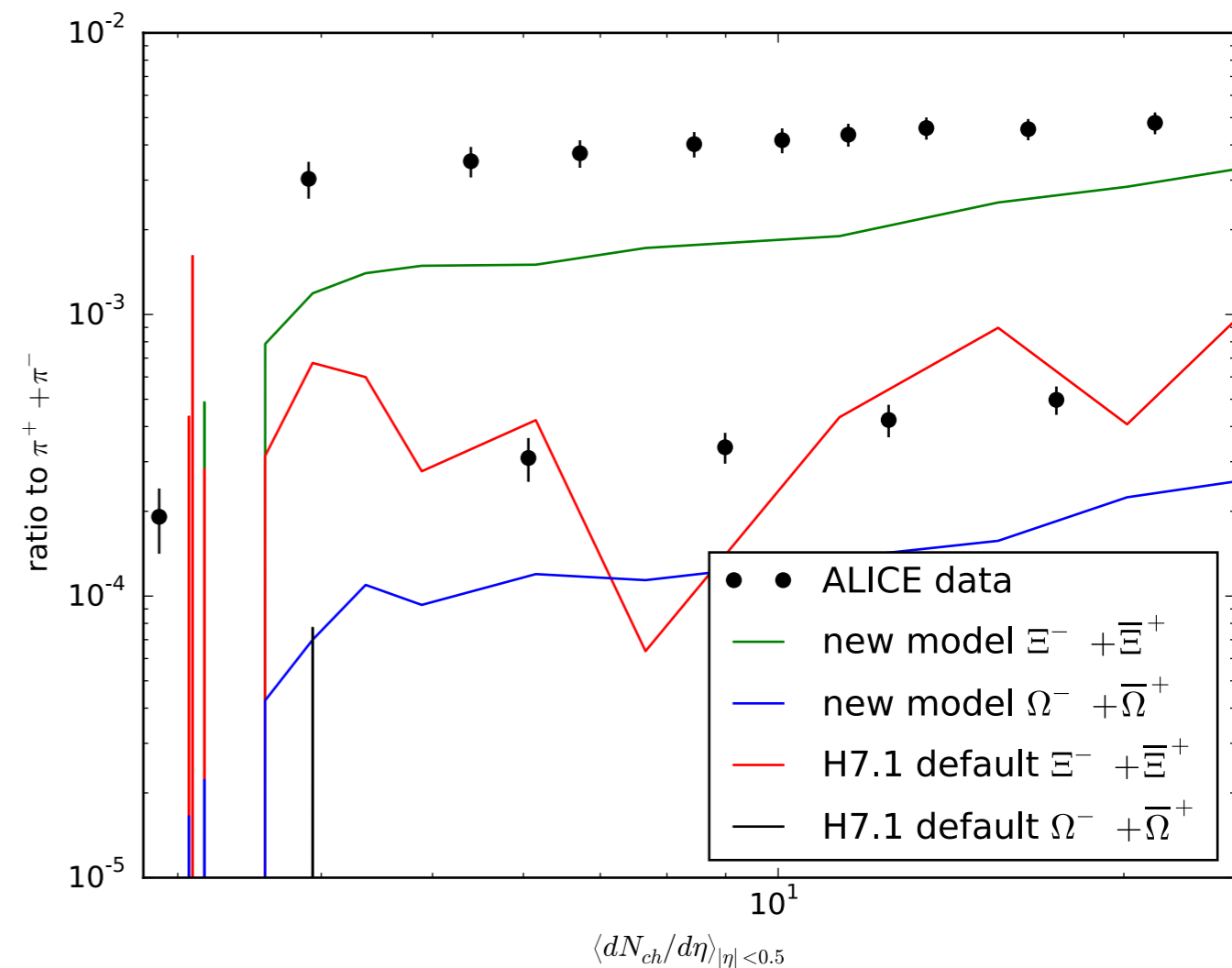
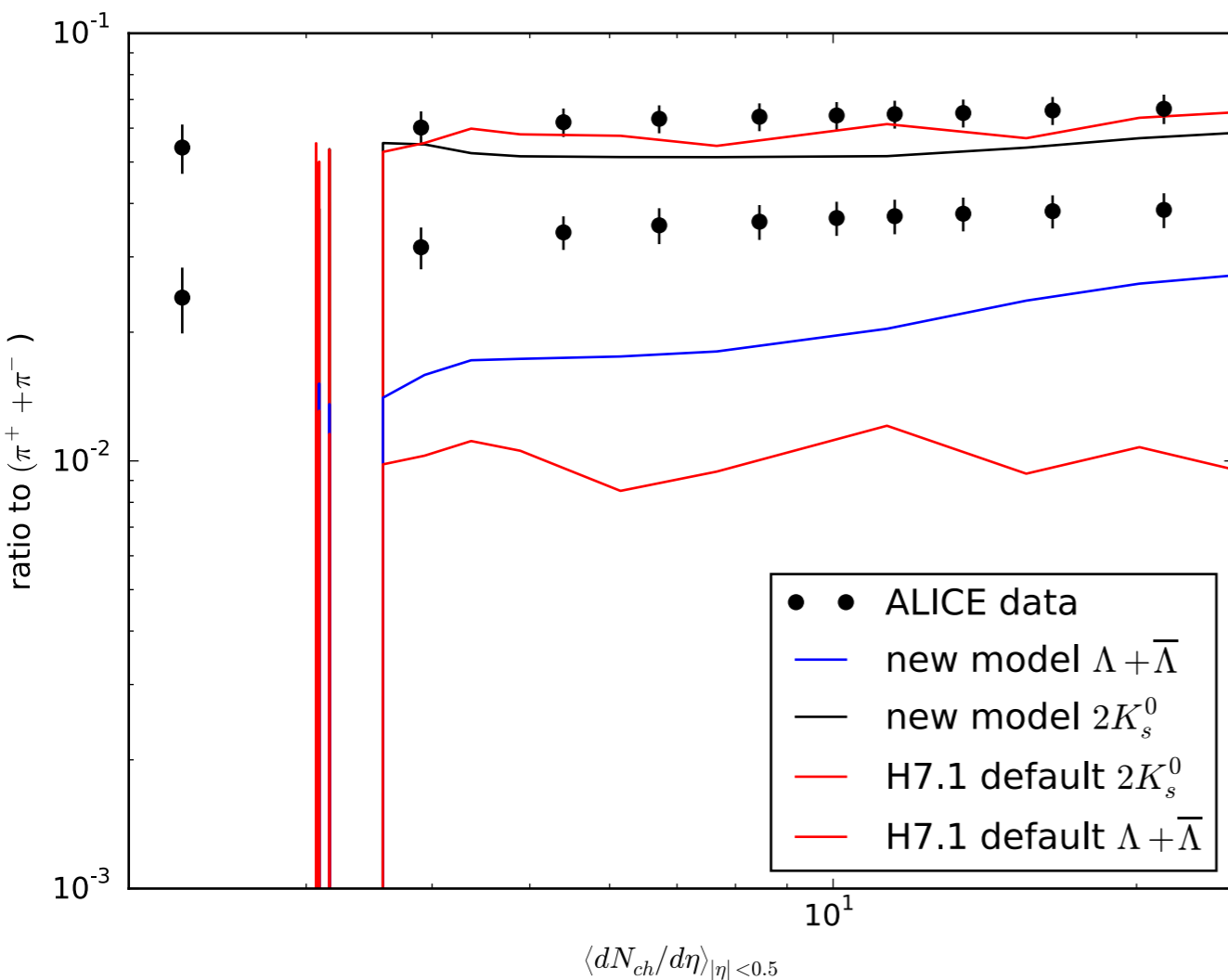


**Improvements in the low  $p_T$  region**



**Getting closer to an accurate description of flavor observables**

# II. Comparison with ALICE data



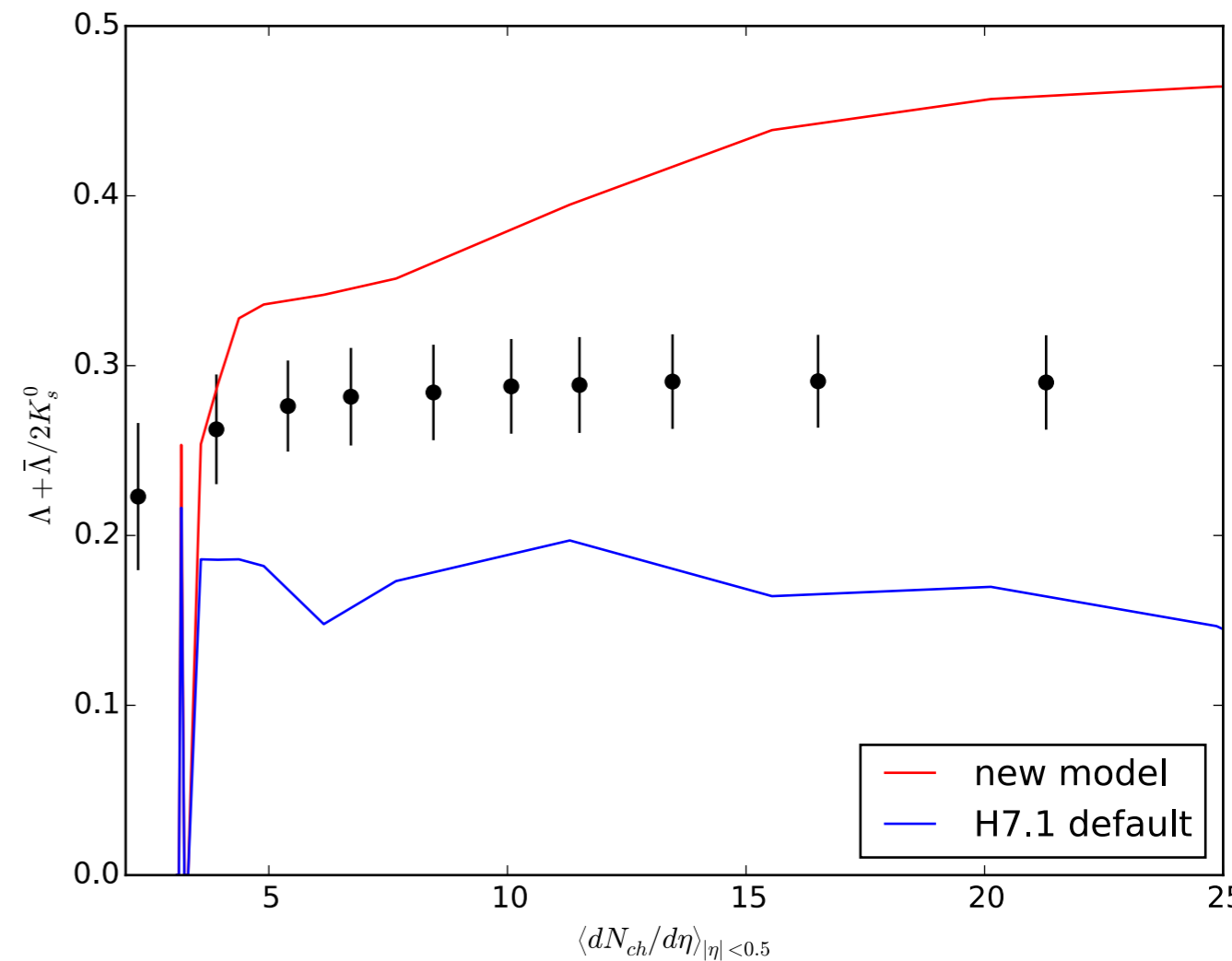
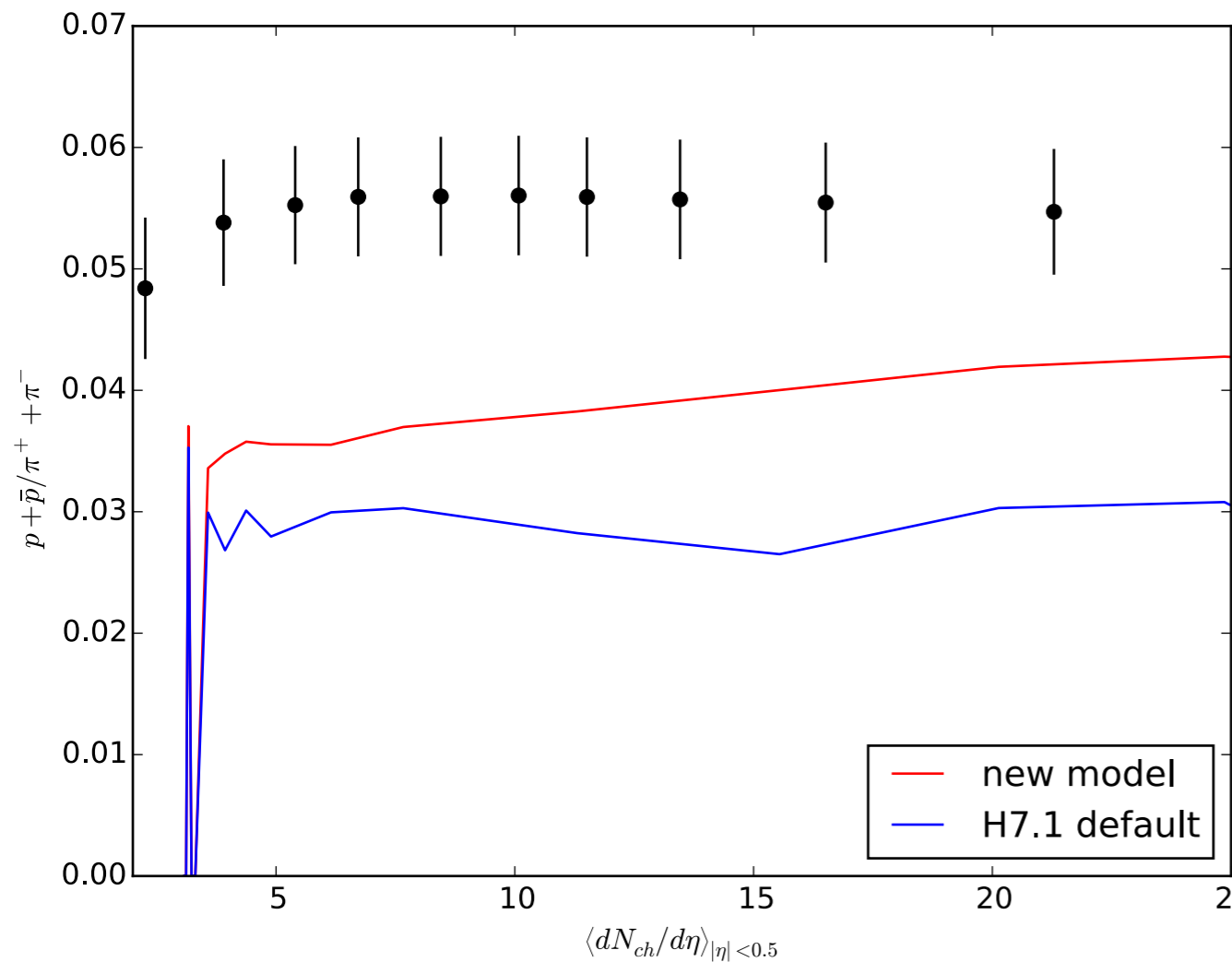
Data from [Nature Phys. 13 (2017) 535-539]

**New model able to reproduce trend of rising strange baryon production for multi-strange particle production**

**No tuning done so far**

Special thanks to Christian Bierlich and Christian Holm for providing the ALICE analysis

# II. Comparison with ALICE data



Data from [Nature Phys. 13 (2017) 535-539]

**Proton fraction too low**

**Lambda baryons grow too strong**

**Rise due to the baryonic CR and overall enhanced strangeness production**

# Summary and Outlook

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## I. Review of the UE model in Herwig

- Herwig 7.1: Model for diffraction and new model for soft interactions based on multiperipheral kinematics
- Achieves a general improvement of all observables considered and captures main properties of relevant MB data

## II. Colour Reconnection

- Implemented a new model for CR (Baryonic Colour Reconnection)
- Able to improve the description of flavour observables
- Trend for multi-strange baryons in the high multiplicity region compatible with ALICE data

### Next:

- More sophisticated generation of soft MPI
- Space-time picture of clusters and colour reconnection
- Get more into ALICE data and study interplay between different CR models

# Thanks

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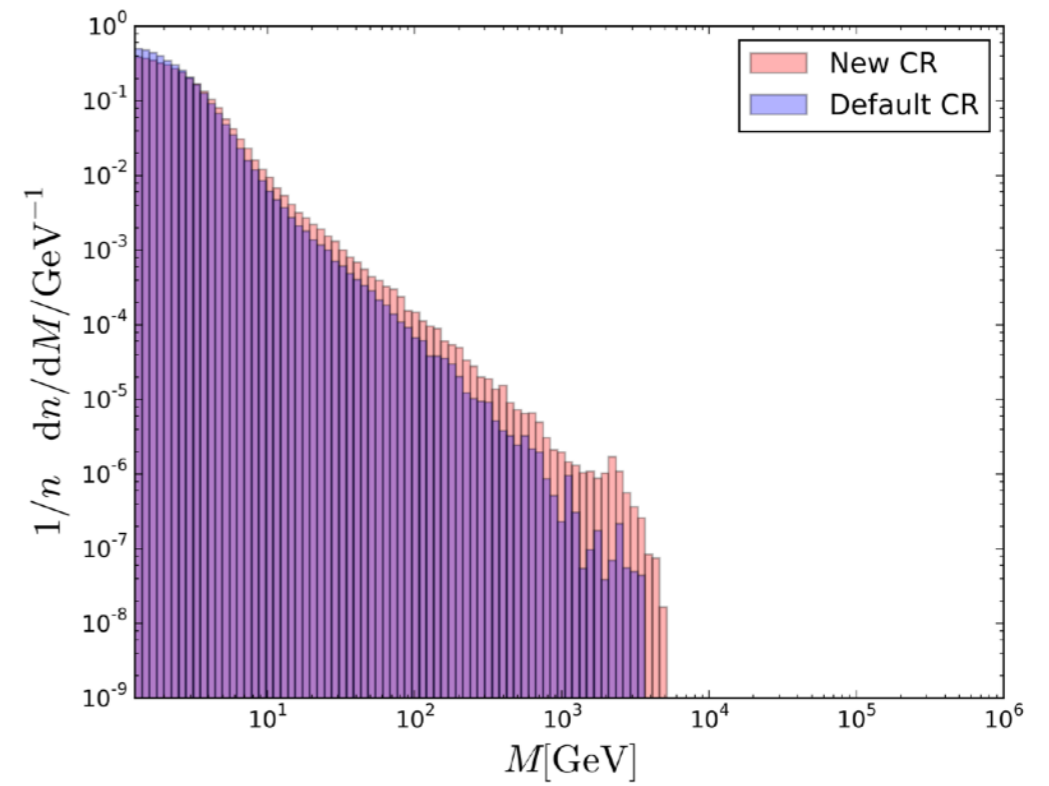
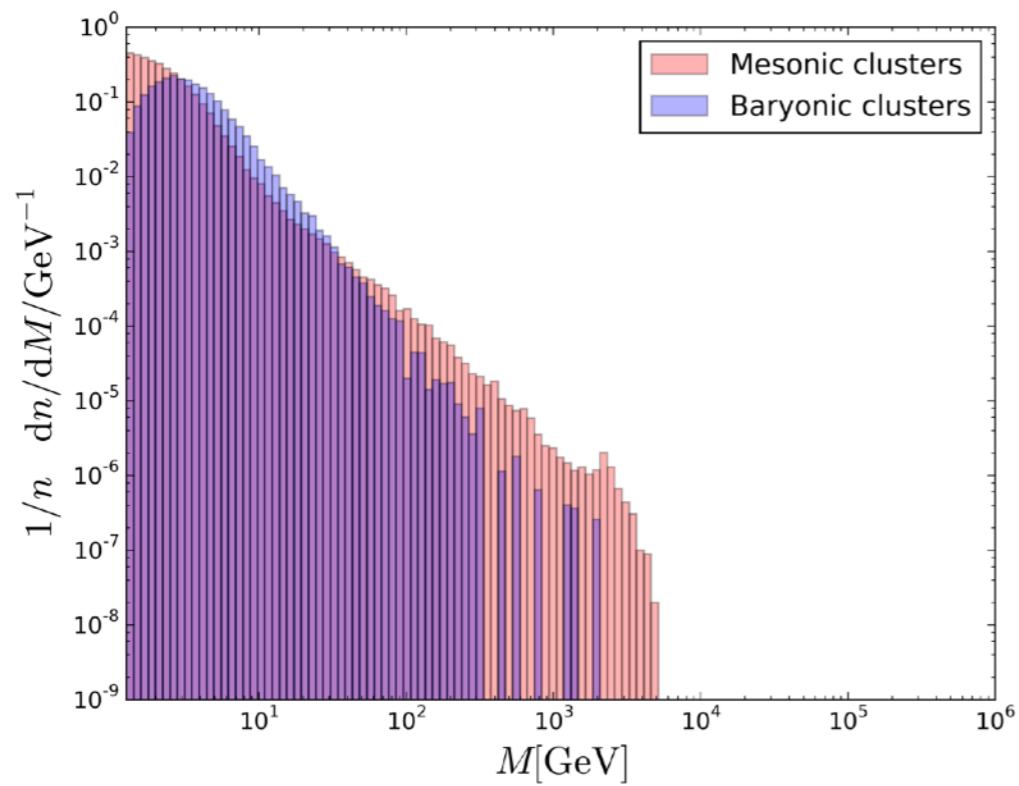
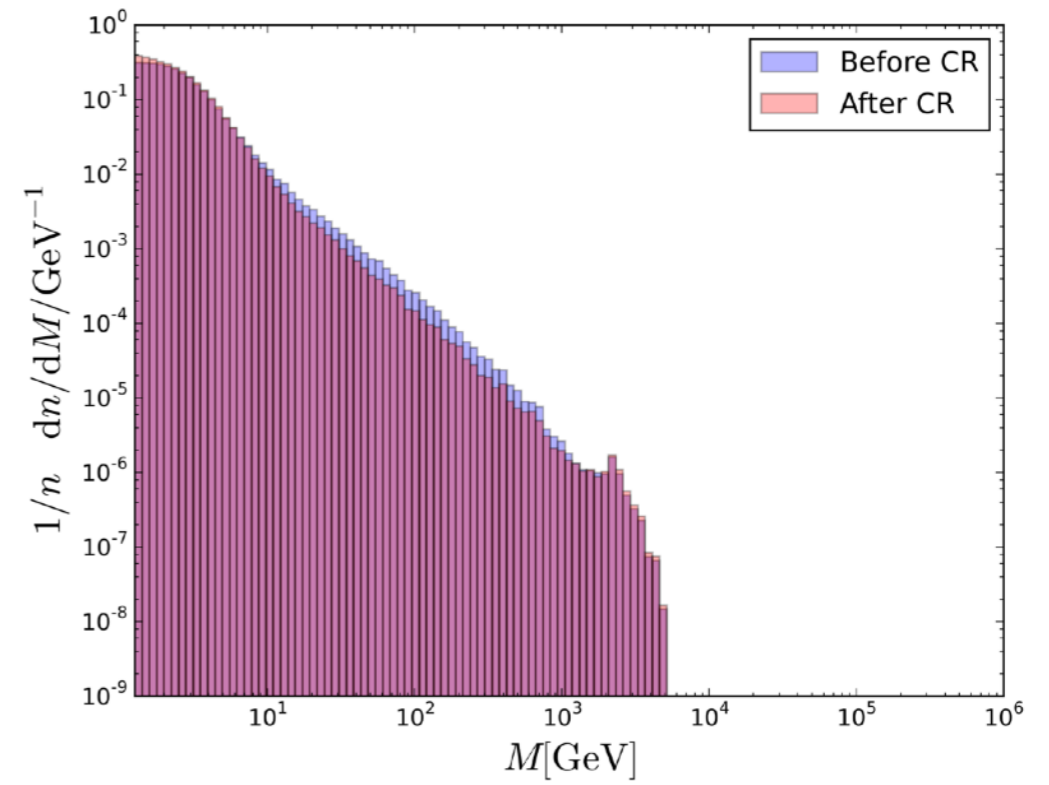
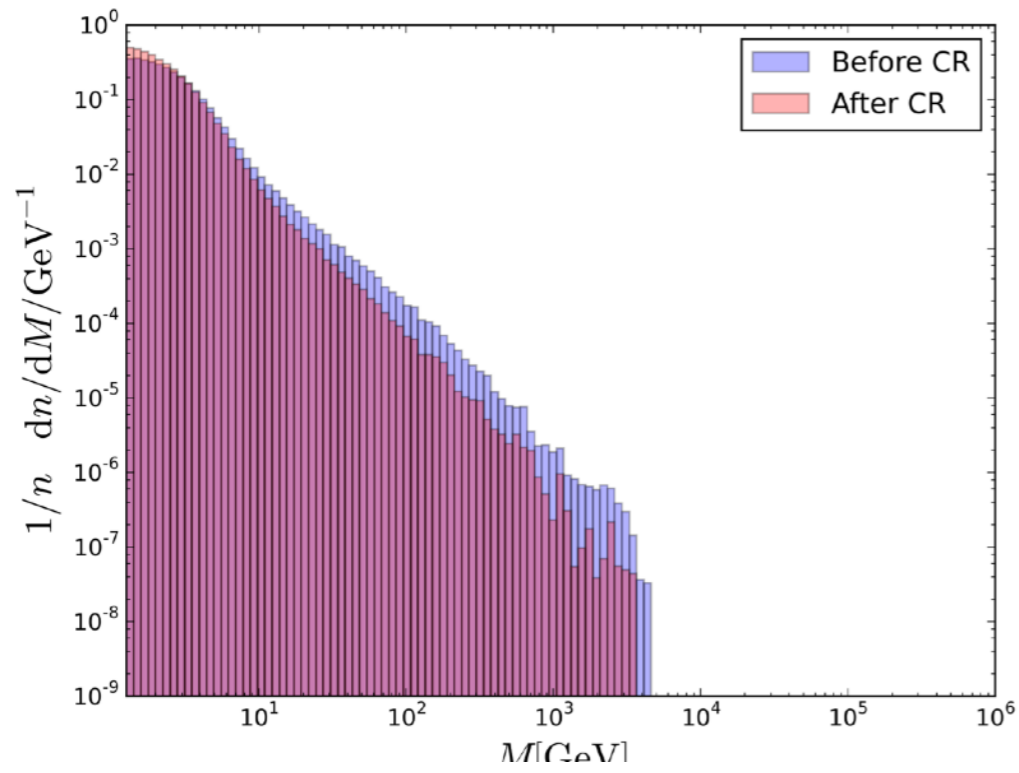


[xkcd: 1781: Artifacts]

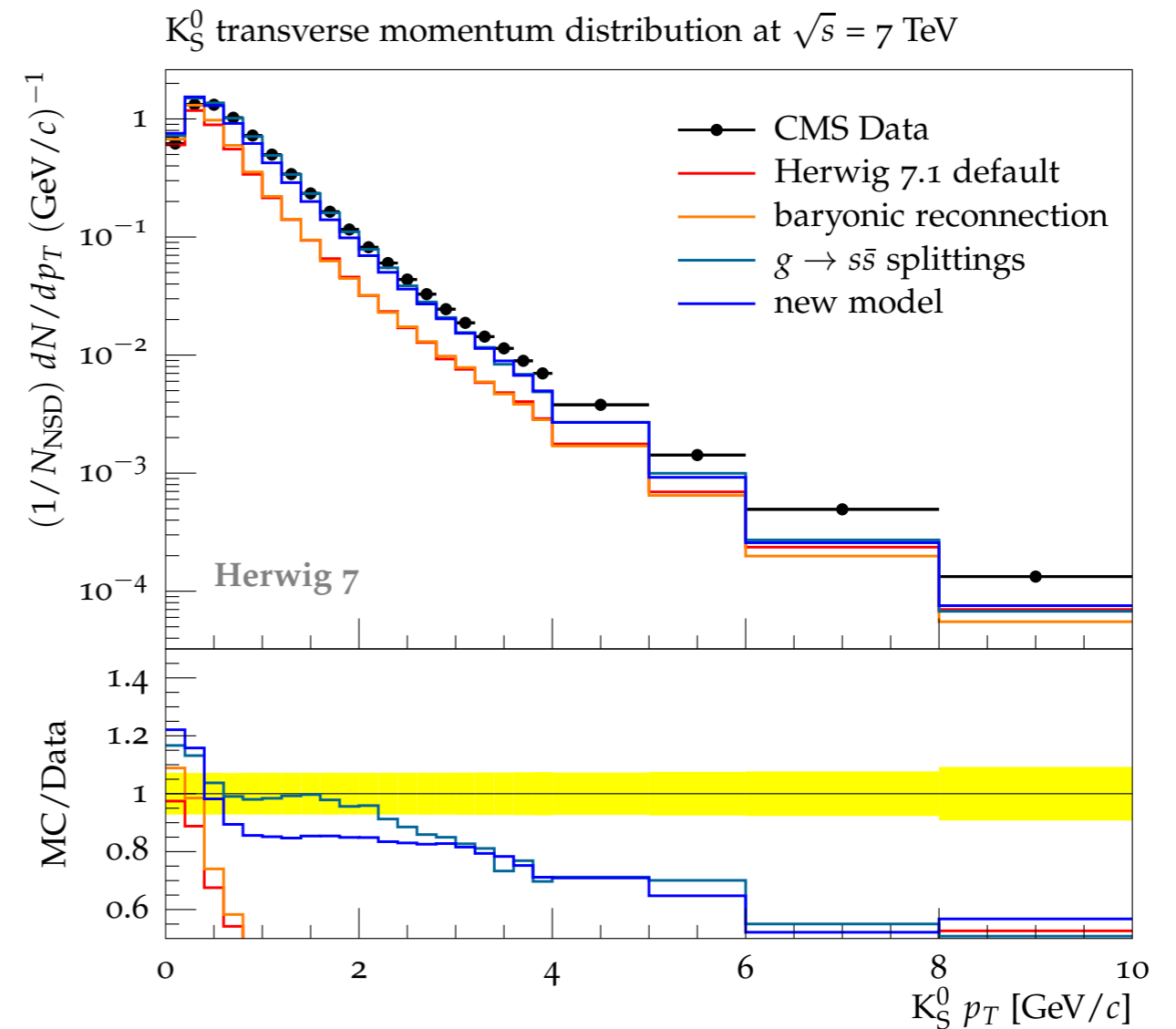
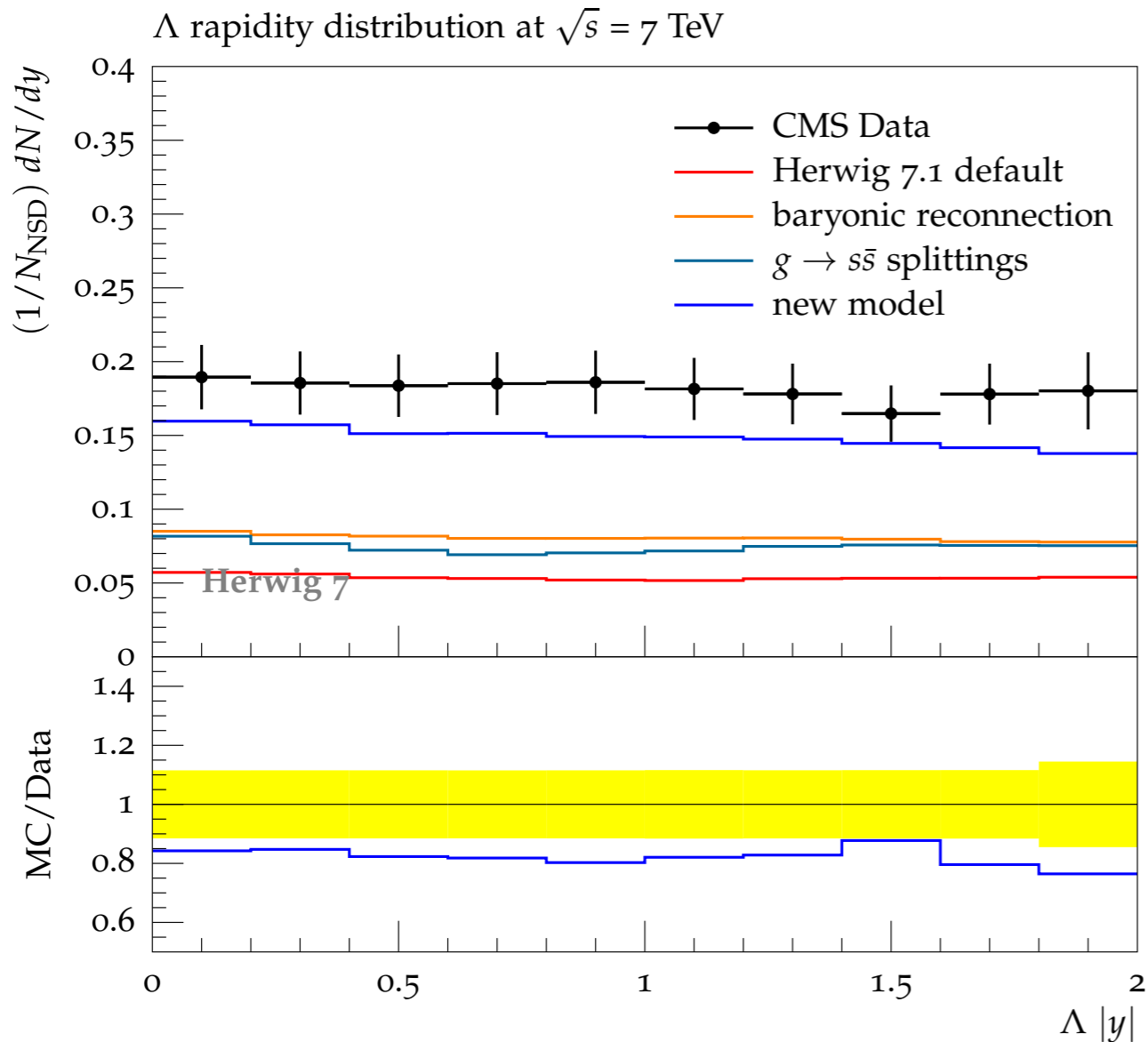


# Backup

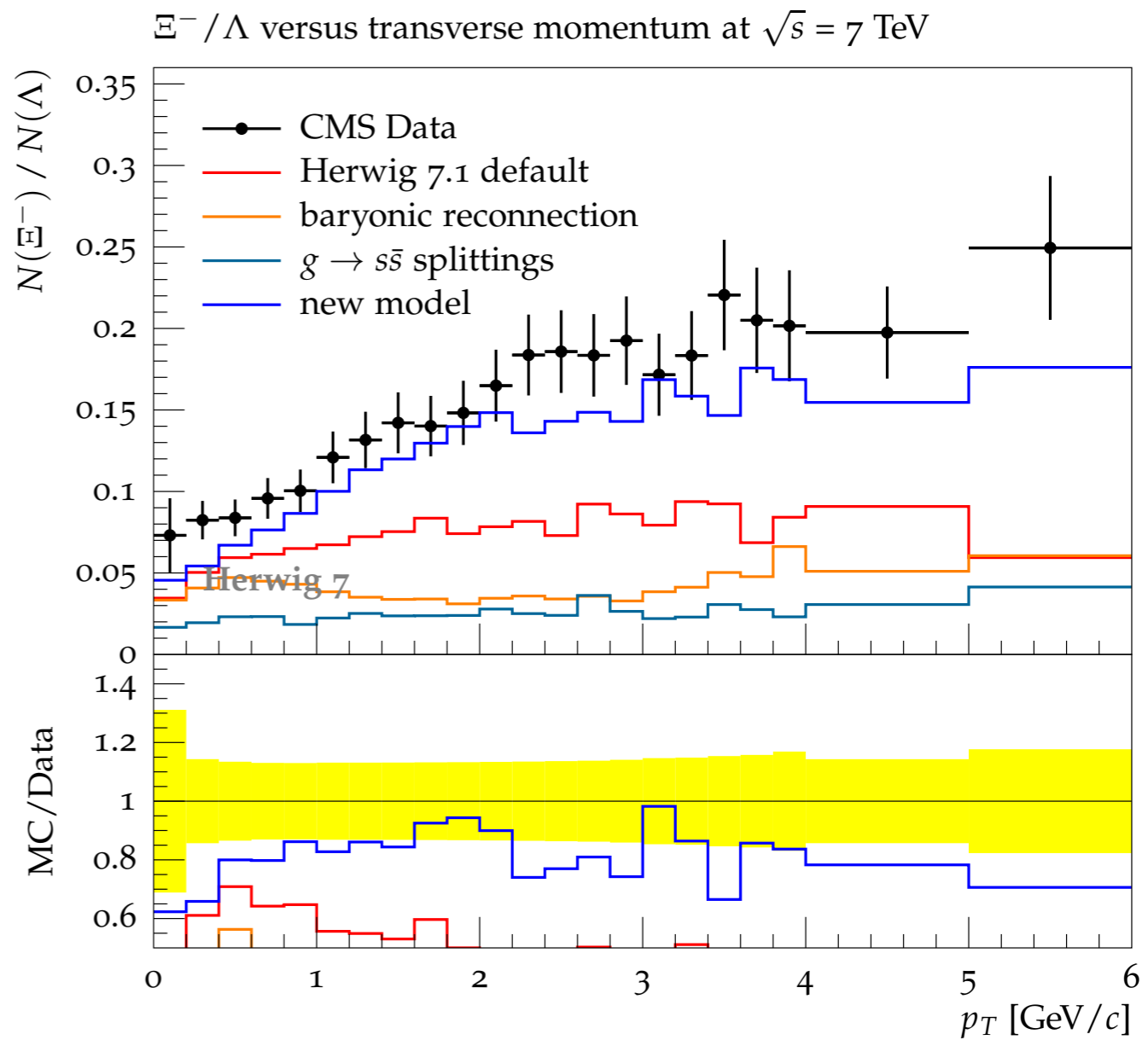
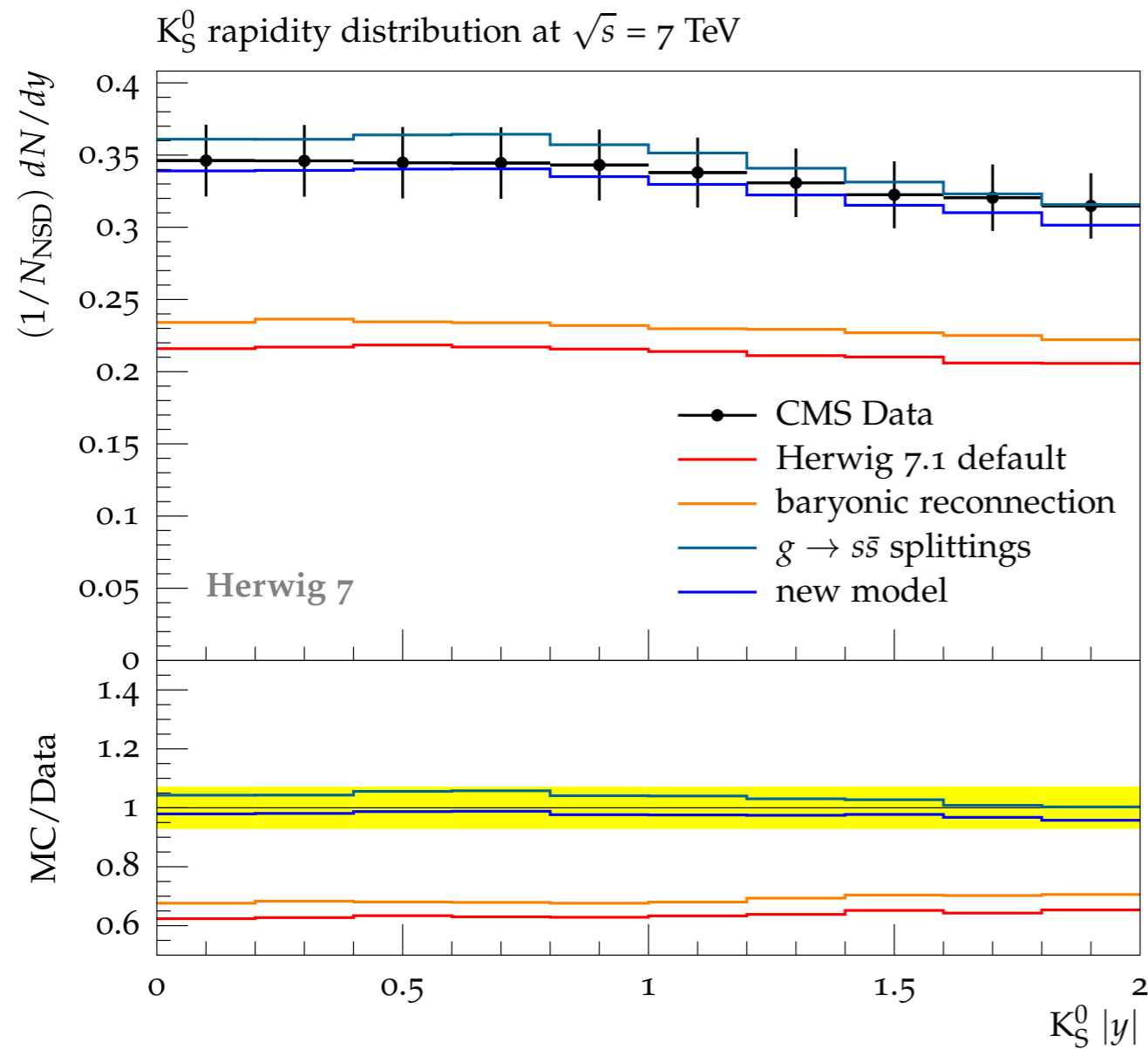
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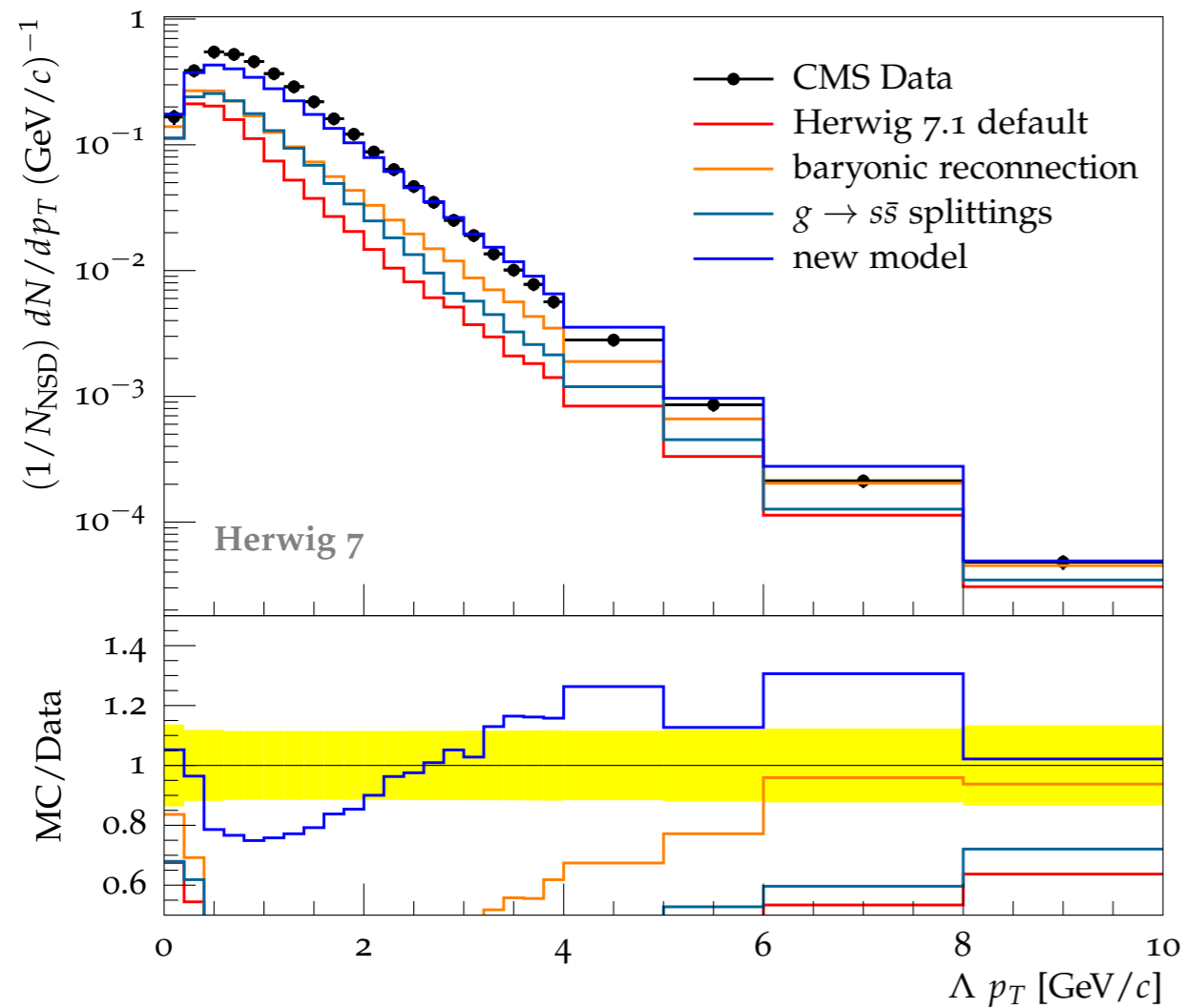


# Backup



# Backup

$\Lambda$  transverse momentum distribution at  $\sqrt{s} = 7$  TeV



Charged Multiplicity  $\sqrt{s} = 7$  TeV

