A new Colour Reconnection model within PYTHIA

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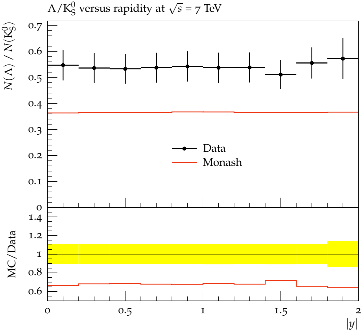
Talk overview

- Motivation
- New beam remnant model
- New colour reconnection model
- Conclusion

Motivation

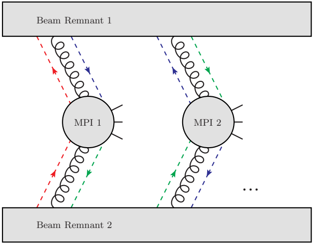
- We want to introduce more of the SU(3) structure from QCD into the description
- Provide a better description of especially Λ production at hadron colliders.



(arXiv:1102.4282)

New beam remnant model

- The beam remnant model comes after the perturbative machinery
- Overall idea of the model:
  - A game of conservation laws
  - Add the minimal required amount of extra particles



- Example of two scattered gluons from a proton:

Flavour conservation

Add two up and one down quark

Baryon number conservation

Turn two quarks into a diquark

Energy/momentum conservation

Choose x according to modified PDFs and rescale to match overall momentum conservation

New beam remnant model - colour conservation

Possible colour states for the two gluons:

$$\mathbf{8} \otimes \mathbf{8} = \mathbf{27} \oplus \mathbf{10} \oplus \overline{\mathbf{10}} \oplus \mathbf{8} \oplus \mathbf{8} \oplus \mathbf{1}$$

27
2 C & 2 AC
+ 1 gluon

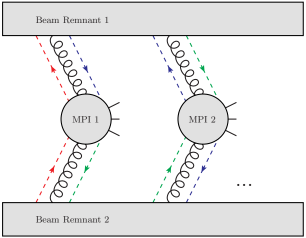
$\overline{\mathbf{10}}$
0 C & 3 AC
+ 0 gluon
(junction)

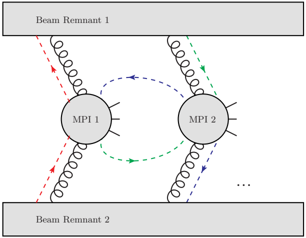
10
3 C & 0 AC
+ 1 gluon
(junction)

8
1 C & 1 AC
+ 0 gluon

1
0 C & 0 AC
+ 0 gluon
(not allowed)

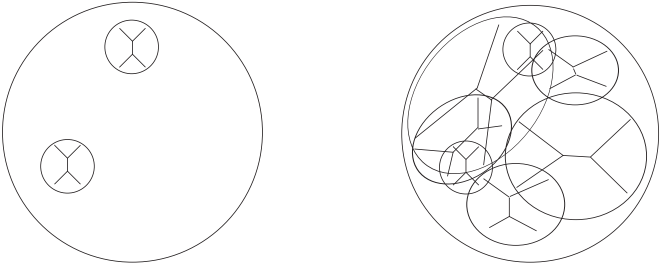
Examples of the **27** and the **8** configurations:





Saturation

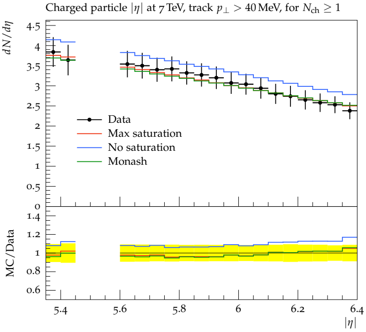
Are the partons uncorrelated?



Included as a simple suppression: $\exp(-M/k)$,
where M is the multiplet size and k is a free parameter

Comparisons to data

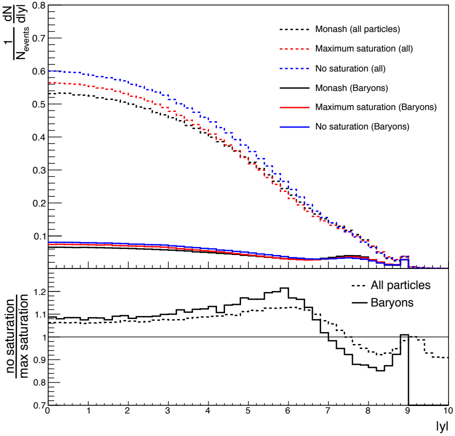
- Relative large x and small $p_\perp \Rightarrow$ forward physics
- Comparison to forward TOTEM measurements.
- 10 % difference between no and maximal saturation
- The old model is similar to maximal saturation



(arXiv:1205.4105)

Baryon production

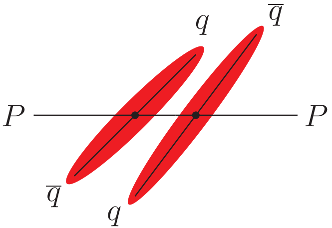
- The new models allow for additional production of junction structures
- Comparison between maximal saturation and no saturation as a function rapidity.
- Only directly produced particles (HadronLevel:decay = off)



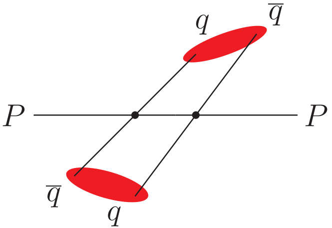
New colour reconnection model

- Colour reconnection allows us to reshuffle the colours before hadronization
- Experimentally observed in average $p_\perp$ vs multiplicity
- New model relies on two main principles
  - SU(3) colour rules from QCD - tells us which reconnections are allowed
  - minimize λ measure - tells us which reconnections are preferred

Before colour reconnection



After colour reconnection

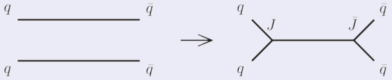


Possible reconnections

Ordinary string reconnection

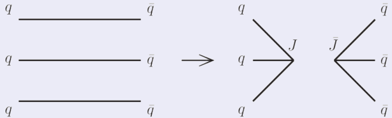
(q$\bar{\text{q}}$: 1/9, gg: 1/8, model: 1/9)

Double junction reconnection



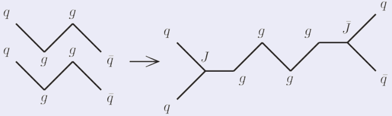
(qq: 1/3, gg: 10/64, model: 2/9)

Triple junction reconnection



(q$\bar{\text{q}}$: 1/27, gg: 5/256, model: 2/81)

Zipping reconnection



(Depends on number of gluons)

The λ measure

- The λ-measure is the rapidity span of a string
- For a $q\bar{q}$ dipole: $\lambda = \log(1 + \frac{s}{2m_0^2})$
- Sum over all $q\bar{q}$-, qg- and gg-dipoles to get total string length
- Add free parameter for minimum gain for junction structures (allow negative for enhancement)

Generalization of λ-measure ($s \gg m_0^2$)

$$\lambda = \log(1 + \frac{s}{2m_0^2}) \Rightarrow$$
$$\lambda = \log(\frac{s}{2m_0^2}) \quad (s \gg m_0^2) \Rightarrow$$
$$\lambda = \log(\frac{4E_1E_2}{2m_0^2}) \text{ (restframe)} \Rightarrow$$
$$\lambda = \log(\frac{\sqrt{2}E_1}{m_0}) + \log(\frac{\sqrt{2}E_2}{m_0})$$

Interpret as contributions from each dipole end, similar for junctions except for three legs:

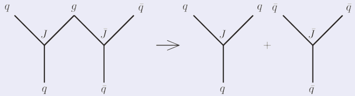
$$\lambda = \log(\frac{\sqrt{2}E_1}{m_0}) + \log(\frac{\sqrt{2}E_2}{m_0}) + \log(\frac{\sqrt{2}E_3}{m_0})$$

To handle ($s \sim m_0^2$):
$$\log(\frac{\sqrt{2}E_1}{m_0}) \rightarrow \log(1 + \frac{\sqrt{2}E_1}{m_0})$$

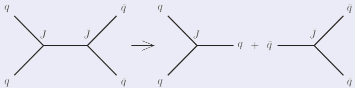
Additional details

- Only local minimization
- Ignore dipoles with invariant mass below m_0
- No annihilation of junctions - Start with ordinary reconnection
- The hadronization can not handle junction connected with other junctions - need to split them up (see examples)

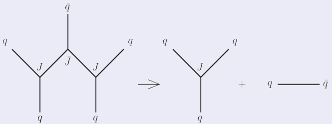
Gluon splitting



Double junction



Multi junction



Tuning

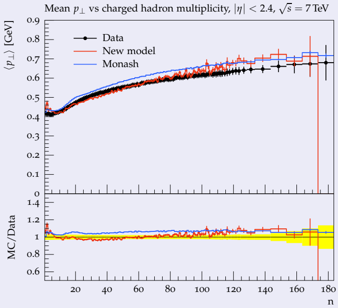
LEP tuning

par	Monash	new
$\sigma_{p_\perp}$	0.335	0.305
aLund	0.68	0.38
bLund	0.98	0.64
StoUD	0.217	0.19

- First tune iteration, still needs several additional iterations

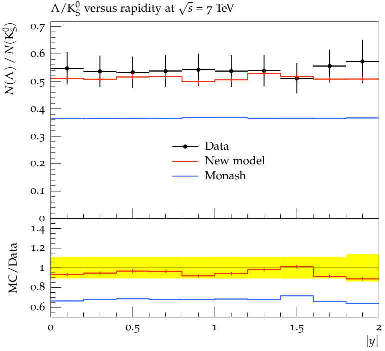
LHC tuning

par	Monash	new
$p_{\perp 0}^{\mathrm{ref}}$	2.28	2.15
m_0	-	2.8
MinGainJun	-	-0.65

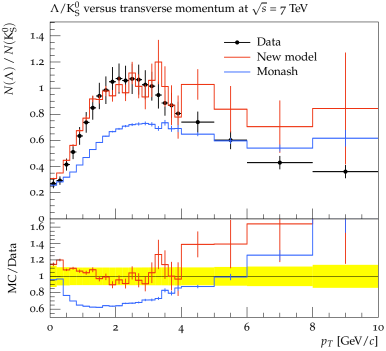


(arXiv:1011.5531)

Comparison to LHC data



(arXiv:1102.4282)

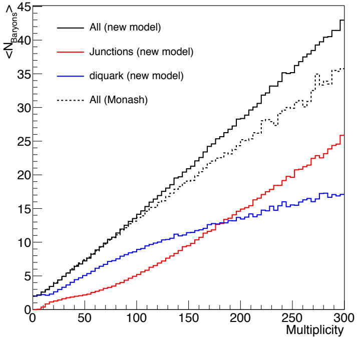


(arXiv:1102.4282)

- Can describe Λ/K_s ratios (tuned)

Distinguish new model from old model

- Observables to distinguish junction baryons from diquark baryons
- Best observable found so far can be seen on the right (again hadron decays are turned off)
- Still looking for more observables
- The difference between Monash and the diquark curve can be understood by looking at the masses of the strings



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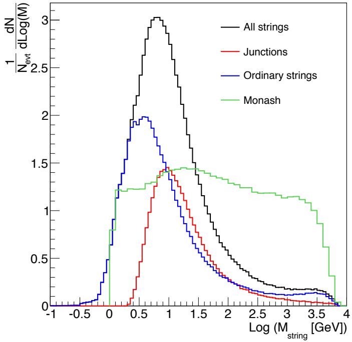

Conclusion

- Only possible to distinguish new beam remnant model from old model in very forward regions
- The new colour reconnection model can be used to describe the Λ-production
- Both models will be released along with Pythia 8.2
- Future plan:
  - Identify more observables that can distinguish junction baryons from diquark baryons
  - Apply model to the top mass measurement

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