Jet Vetoing and HERWIG++

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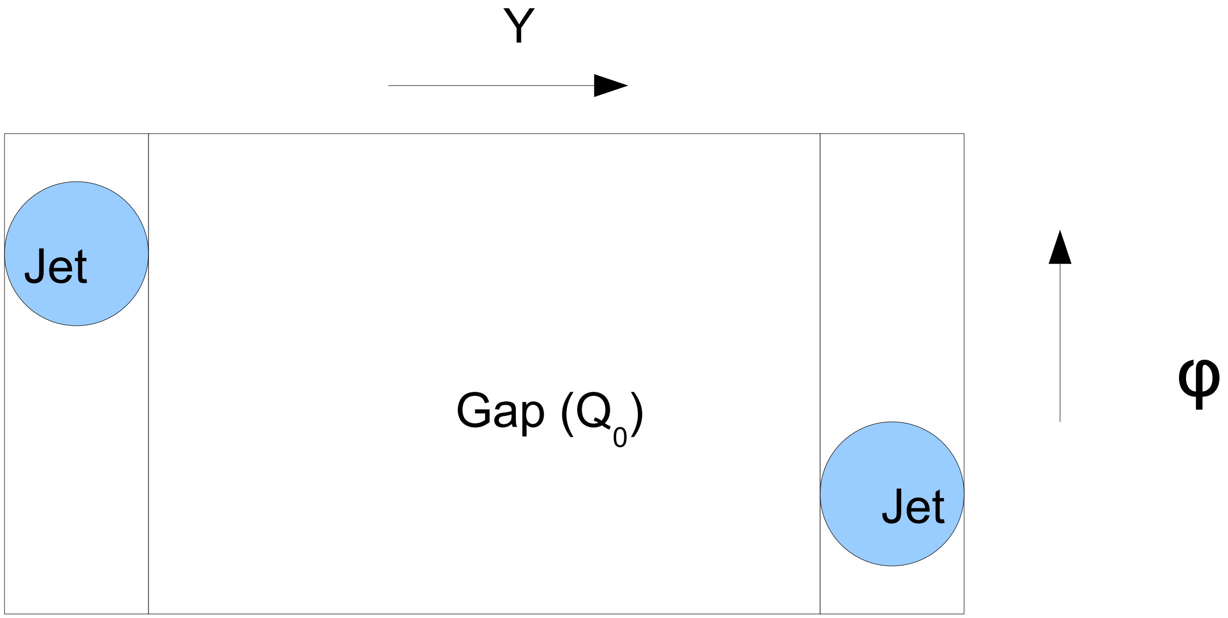
2nd November 2010

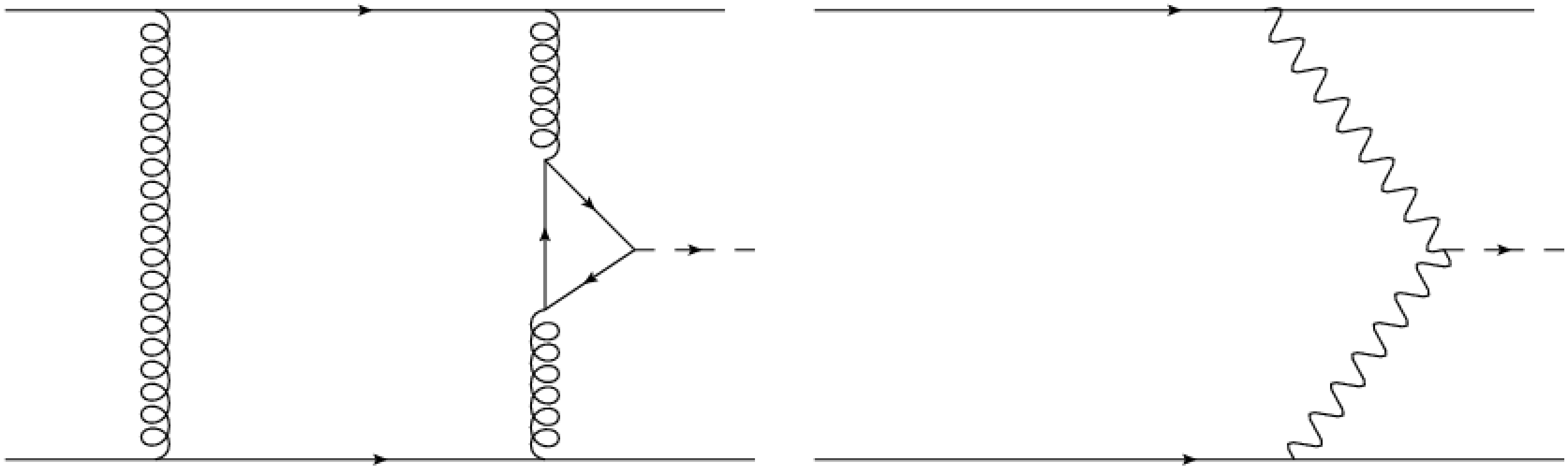
Jet Vetoing

- Gaps between jets



Jet Vetoing

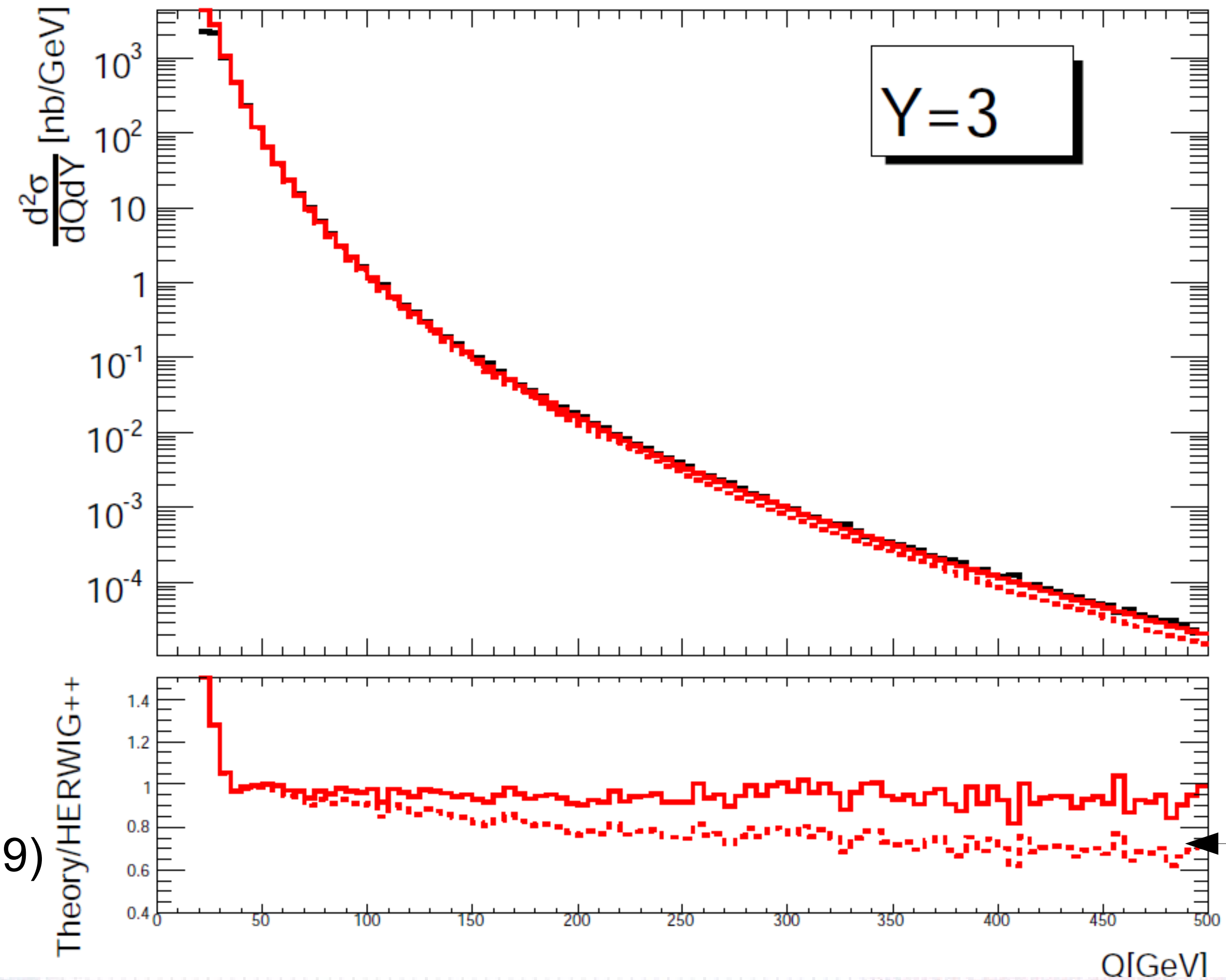
- Gaps between jets: example process (CEP)



FKM Results

- Problem with matching to HERWIG++

Y=3
S=14TeV



Should match?

J. Forshaw,
J. Keates,
S. Marzani (2009)

Jet Vetoing

- Calculating matrix elements

$$|M|^2 = \mathrm{Tr}[\underbrace{H}_{\text{Hard matrix element}}\ \underbrace{e^{-\xi\Gamma^\dagger}\ S\ e^{-\xi\Gamma}]}_{\text{Soft radiation and colour structure}}$$

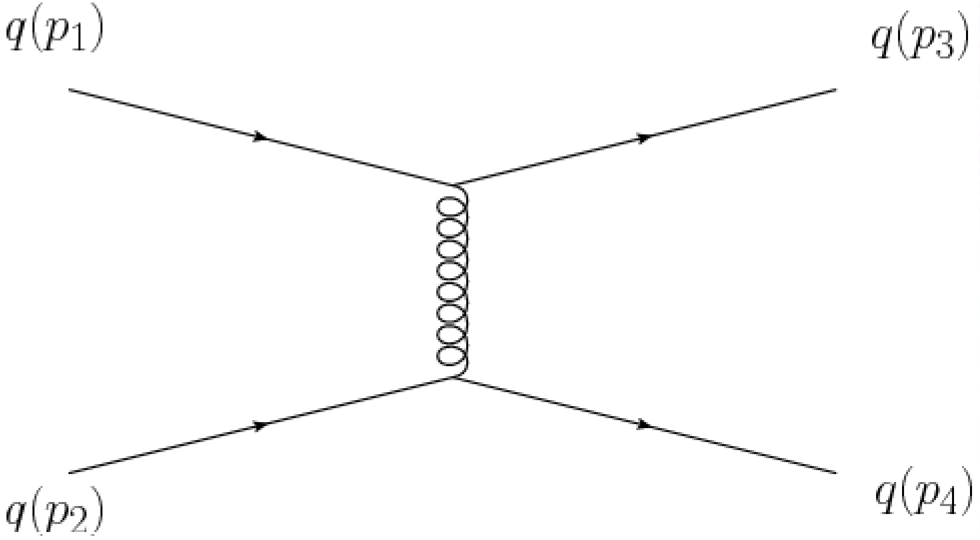
$$\xi \sim 2\alpha_s/\pi\ \mathrm{Log}[Q/Q_0]$$

J. Forshaw, J. Keates, S. Marzani (2009)

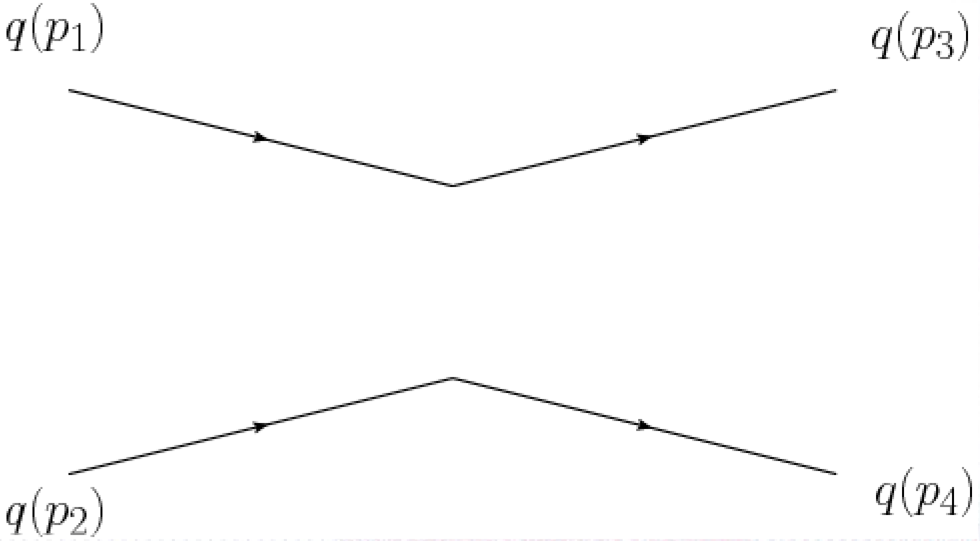
FKM Basis

- FKM Basis (qq)

$C_1 =$



$C_2 =$



J. Forshaw,
J. Keates,
S. Marzani (2009)

Hard scattering matrix

The matrix element for an arbitrary process can be decomposed into Lorentz structures multiplying colour basis states

$$M^{(i)} = A^{(i)}_j \, C^{(i)}_j$$

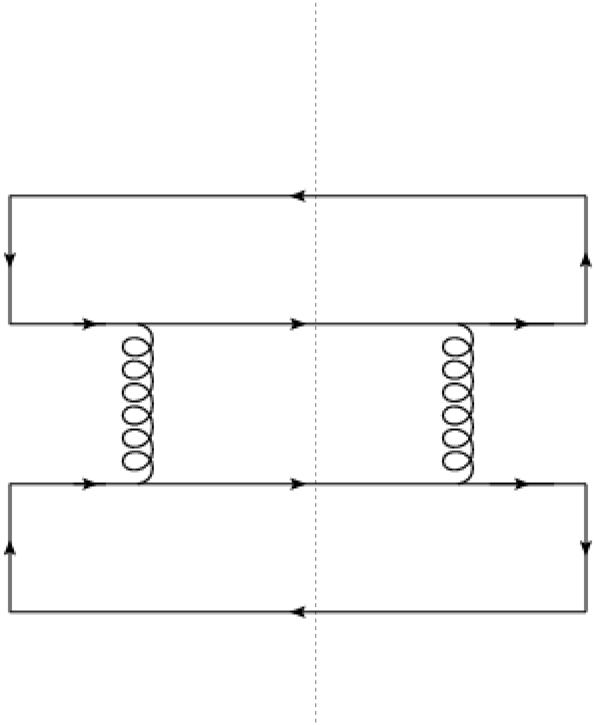
$$H_{ij} = A_i \, A_j^{\dagger}$$

F. Maltoni et al. (2002)

Colour Metric

- Representation of colour structures

$(S)_{11} =$



Anomalous dimension

- In colour basis independent notation

$$\Gamma = \tfrac{1}{2} Y\, t_t^2 + i\pi\, t_1 t_2 + \tfrac{1}{4} \rho\, (t_3^2 + t_4^2)$$

Radiation into gap
“Soft, wide angle gluons”

Coulomb gluons

Radiation at edges of jets

J. Forshaw, A. Kyrieleis, M. Seymour (2008)

Wide angle gluons

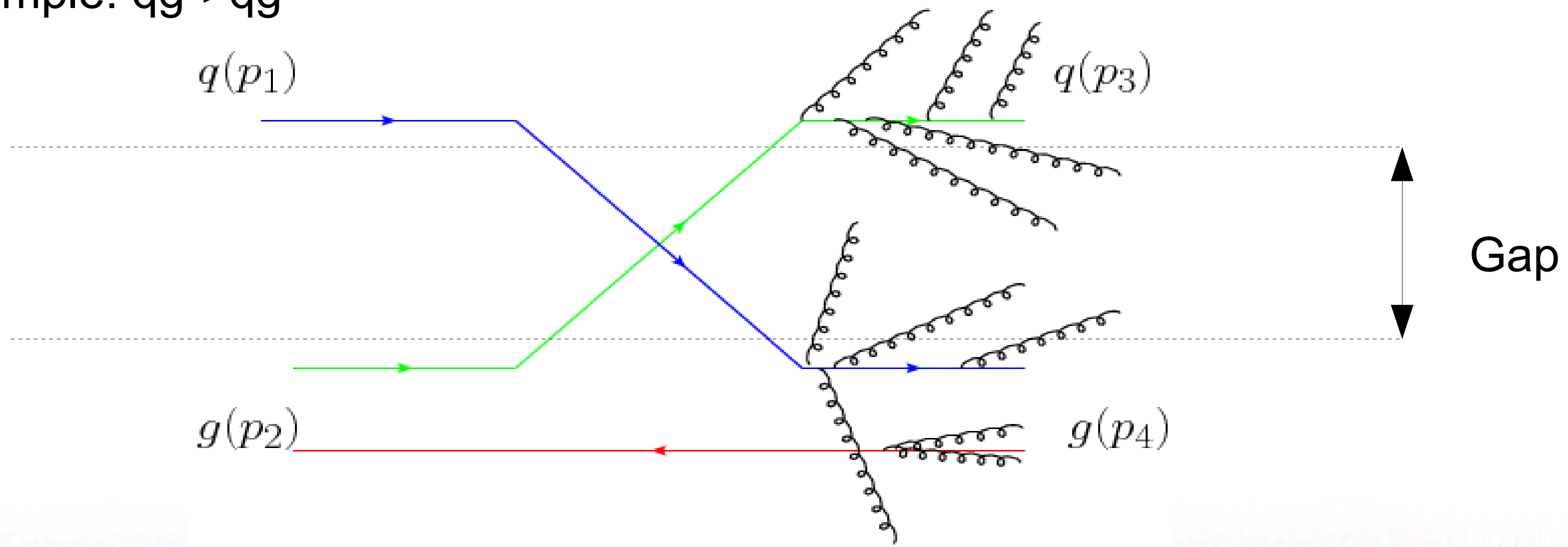
$$\Gamma = ½ Y t_t^2$$

Colour exchange across the gap

Size of Rapidity gap

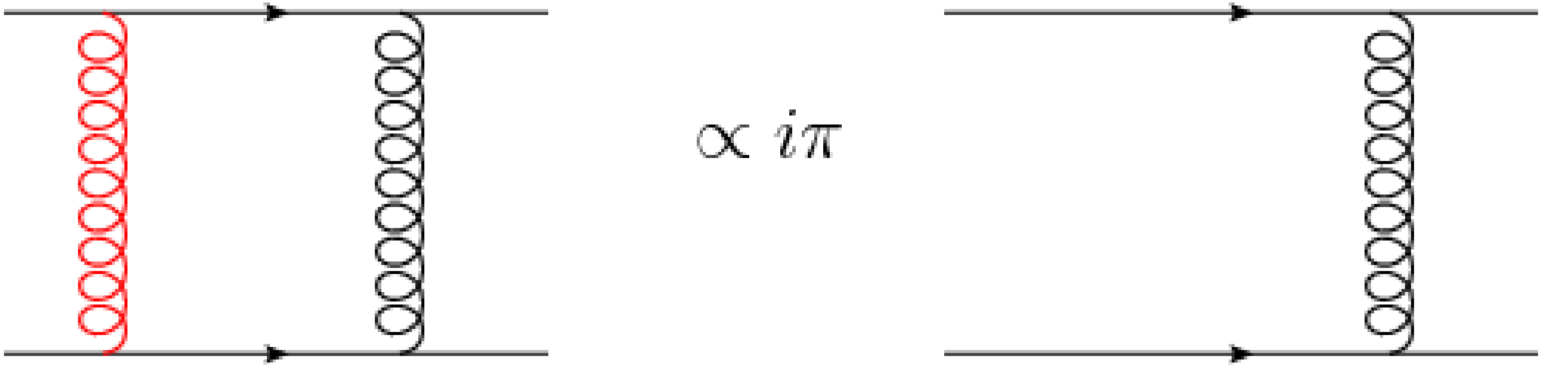
Colour lines which are scattering across the gap will radiate throughout the whole of phase space

Example: qg->qg



Coulomb gluons

- Virtual gluons connecting two initial or two final state partons generate imaginary terms



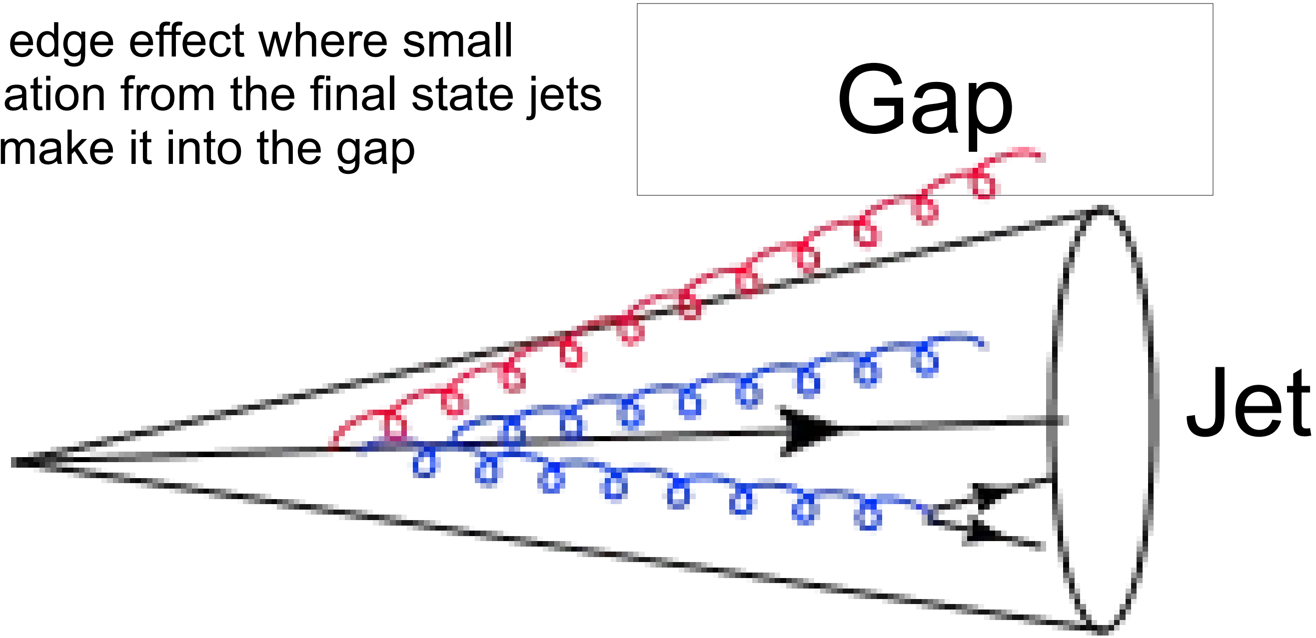
$\propto i\pi$

- Can generate additional “Super-leading” logarithms

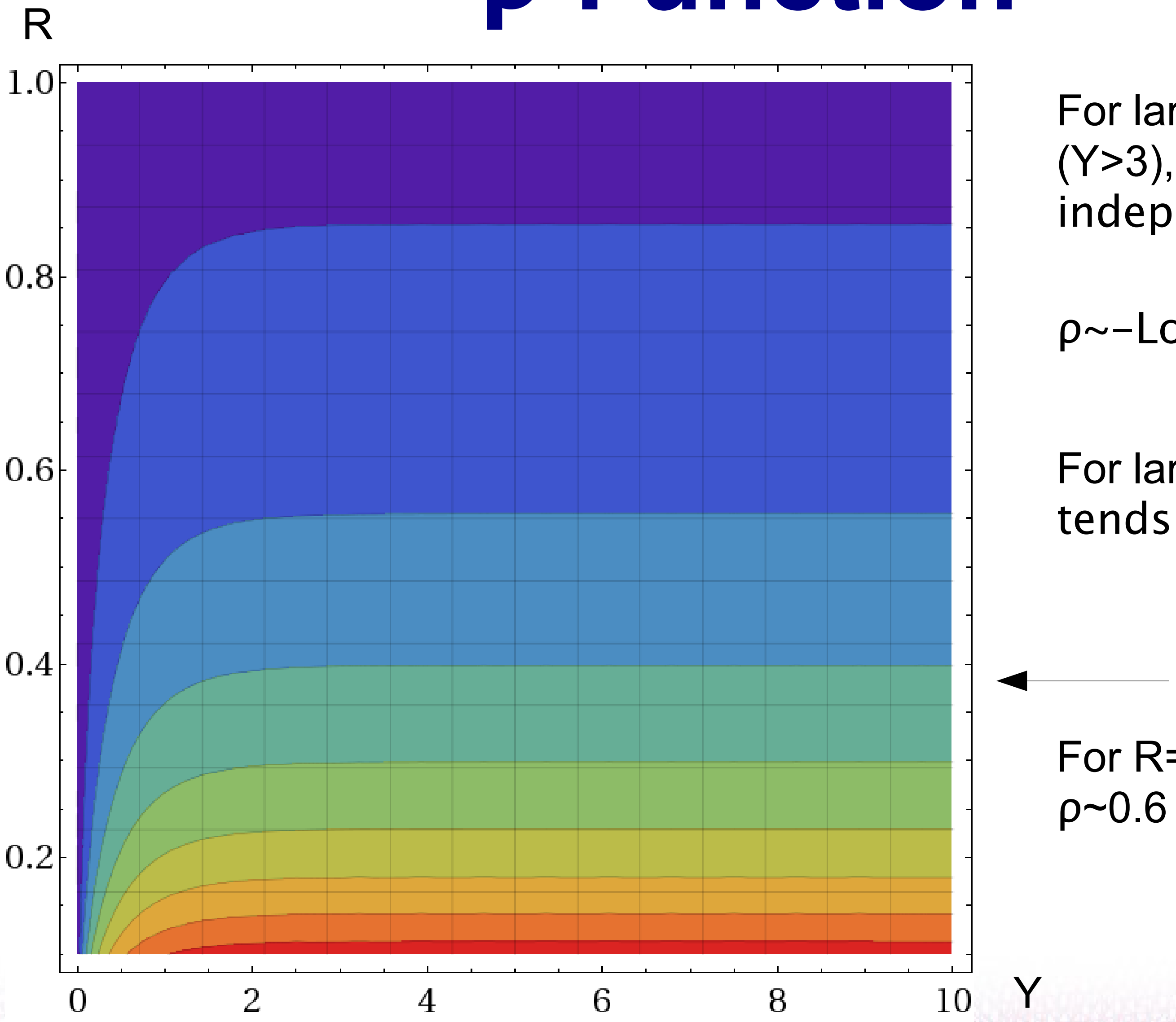
ρ Function

$$\rho = \mathrm{Log}[\mathrm{Sinh}[Y+R] / \mathrm{Sinh}[R]] - Y$$

Rho is an edge effect where small angle radiation from the final state jets is able to make it into the gap



ρ Function



For large rapidity gaps (Y>3), ρ becomes independent of Y

ρ~-Log[1-e^{-2R}]

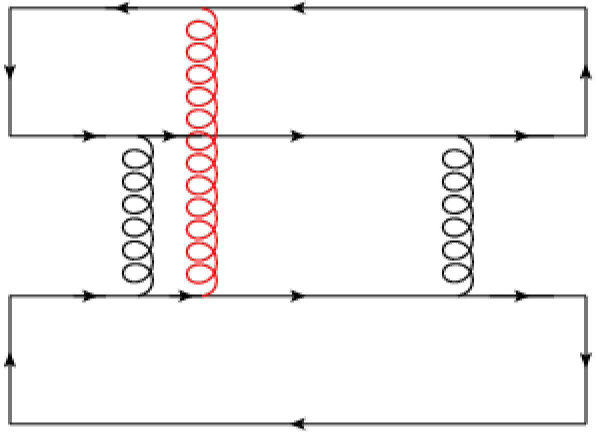
For large R, ρ tends to zero

For R=0.4 and large Y, ρ~0.6

Anomalous dimension

- For a general basis the parts of the anomalous dimension can be represented as colour traces

$$(S\,t_1.t_4)_{11} =$$



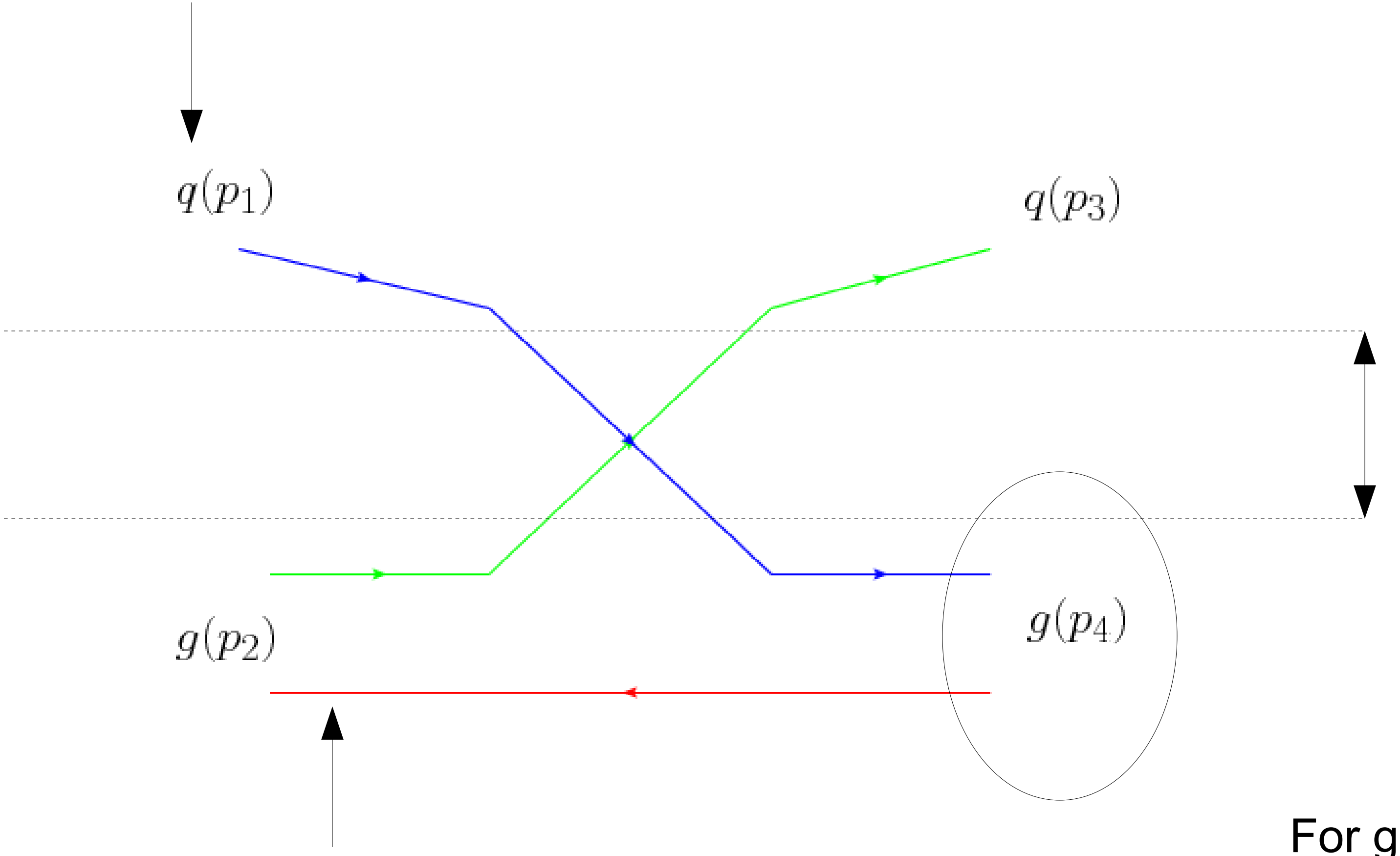
For non-orthonormal bases the colour metric needs to be included.

Differences in HERWIG++

- Different choice of basis: Colour flow basis
- Removal of colour interferences (large Nc)
- Removal of Coulomb gluon contributions
- **Changes to gluon evolution**
- Non-global logarithms
- Energy-Momentum conservation
- Hadronization

Colour partners

Partner one:
Across the gap



Gap

Partner two: Same side of the gap

For gg->gg this can lead to “singlets”

Colour partners: Model

Gluon evolution (Both partners across the gap)

$$\mathrm{Exp}[-\Gamma_g]$$

Gluon evolution (Only one partner across the gap)

$$\tfrac{1}{2}\left(1 + \mathrm{Exp}[-2\Gamma_g]\right)$$

Parton shower chooses one of the two colour partners with 50-50 chance

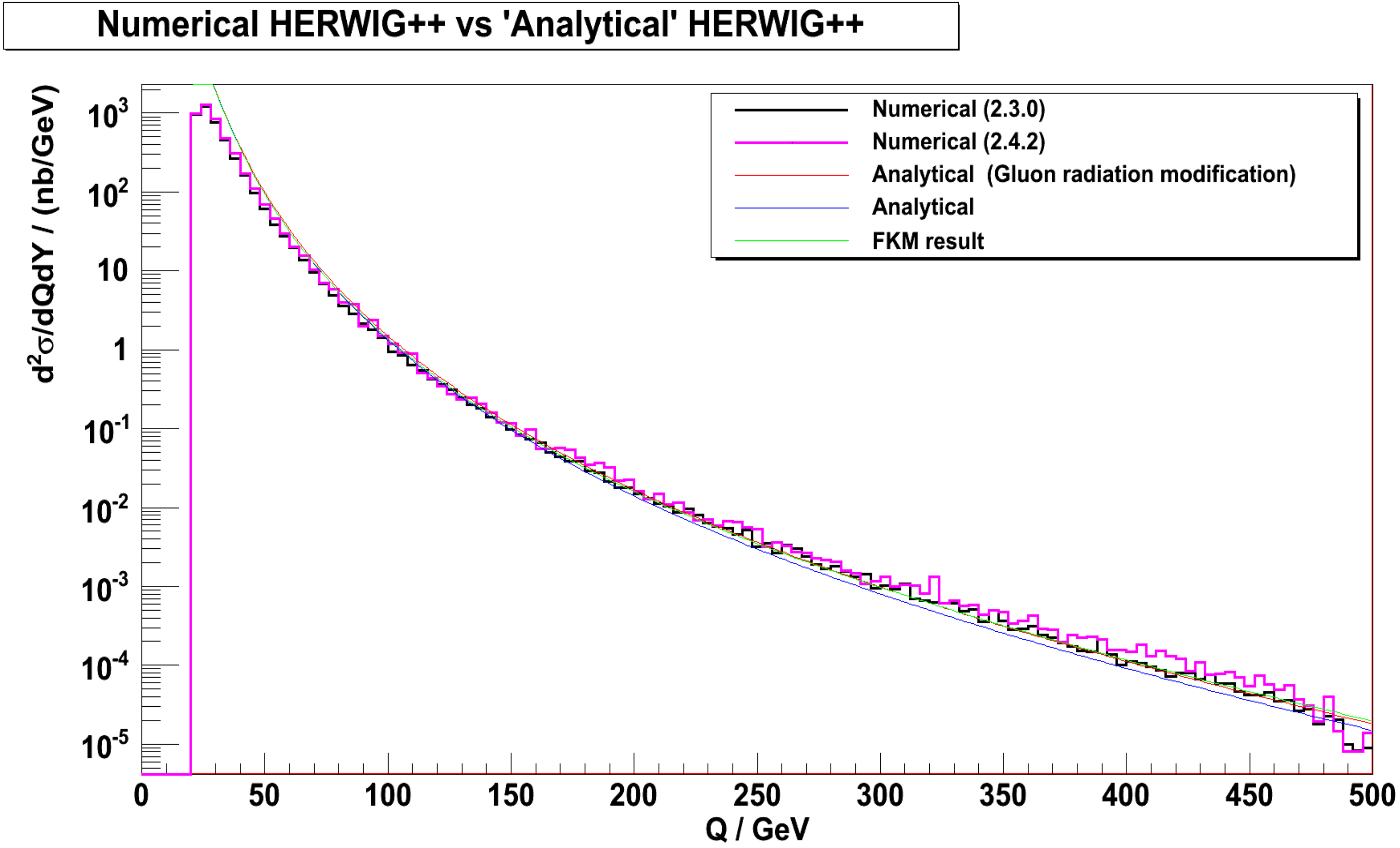
Partner on the same side of the gap

Partner is across the gap

Quark evolution is unchanged

Y=3
S=14TeV

Cross section results



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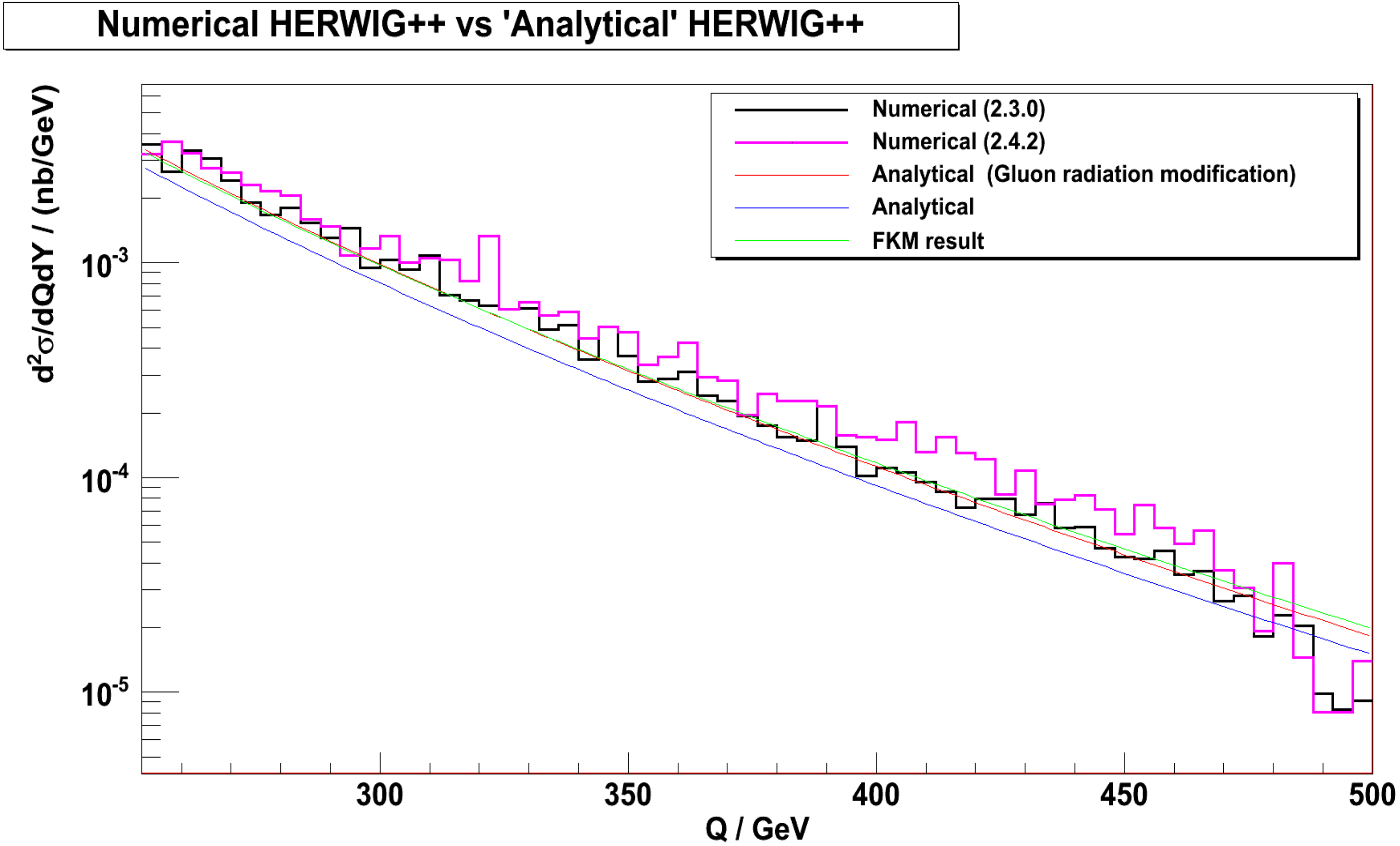
Cross section results

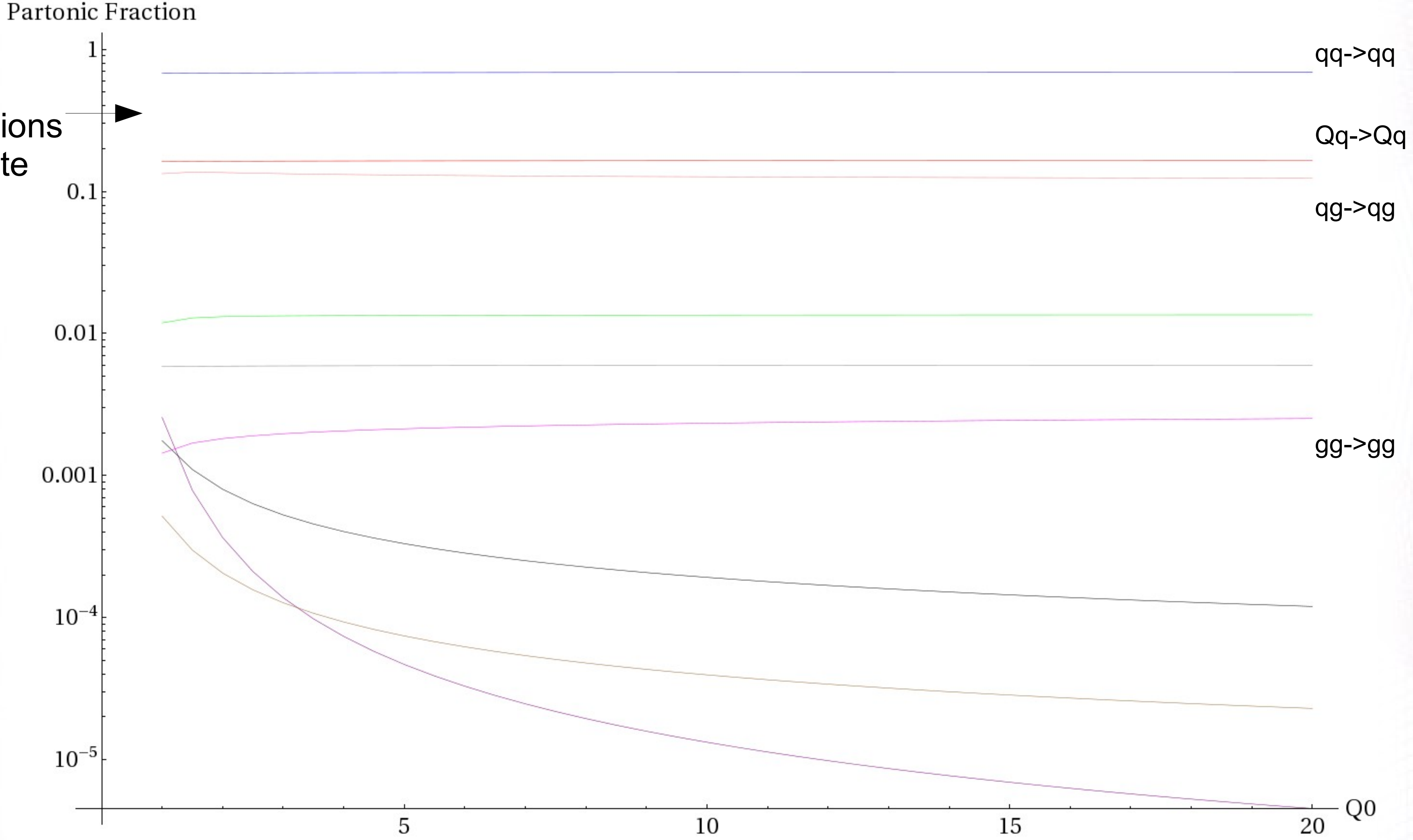


Choice of variables

- Varying Q or Y changes PDFs, partonic cross sections and the colour suppression
- Instead one can choose to vary only Q0 and therefore the effects of the colour suppression

Y=5
Q=500GeV
S=14TeV

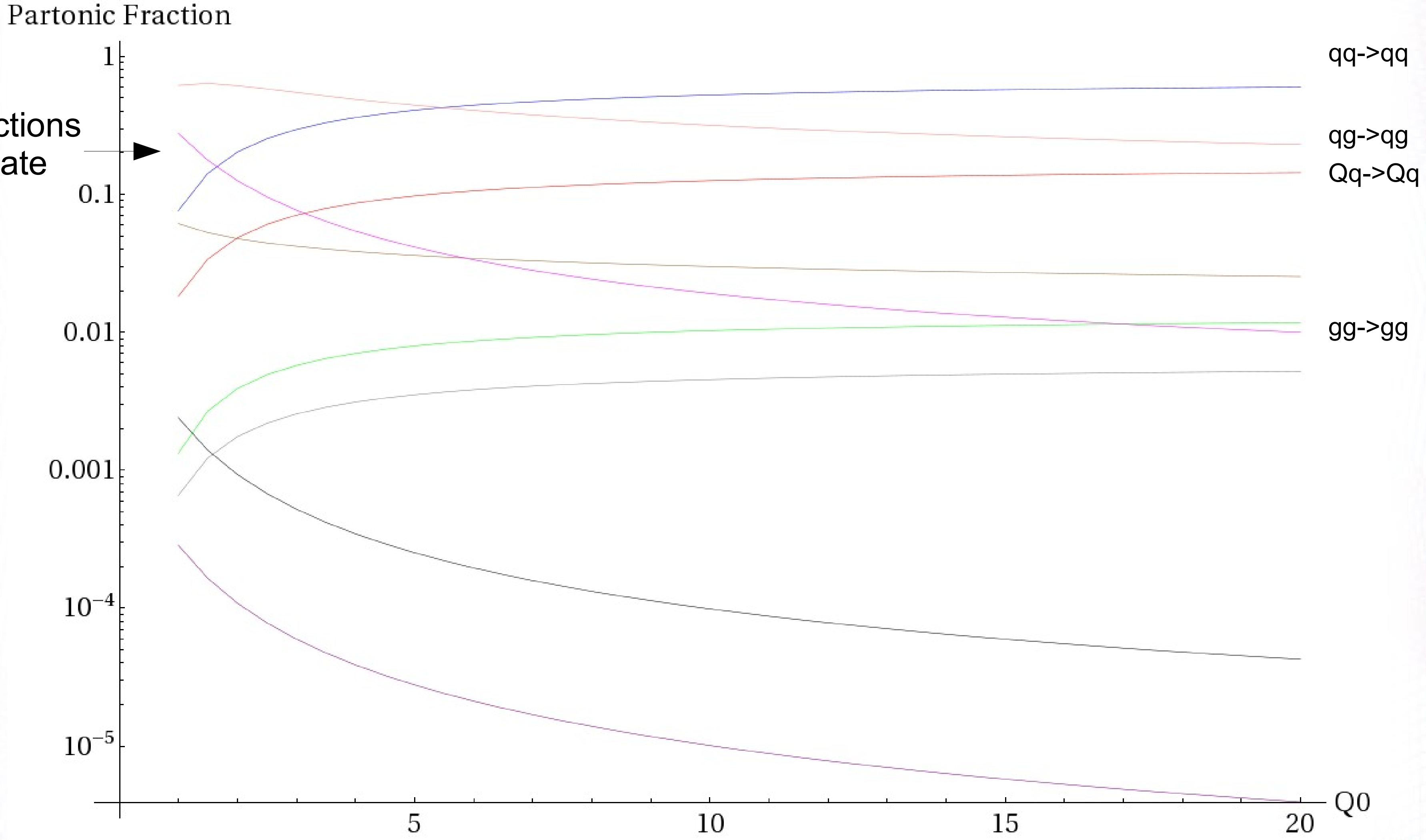
Partonic Fractions



qq interactions dominate

Y=5
Q=500GeV
S=14TeV

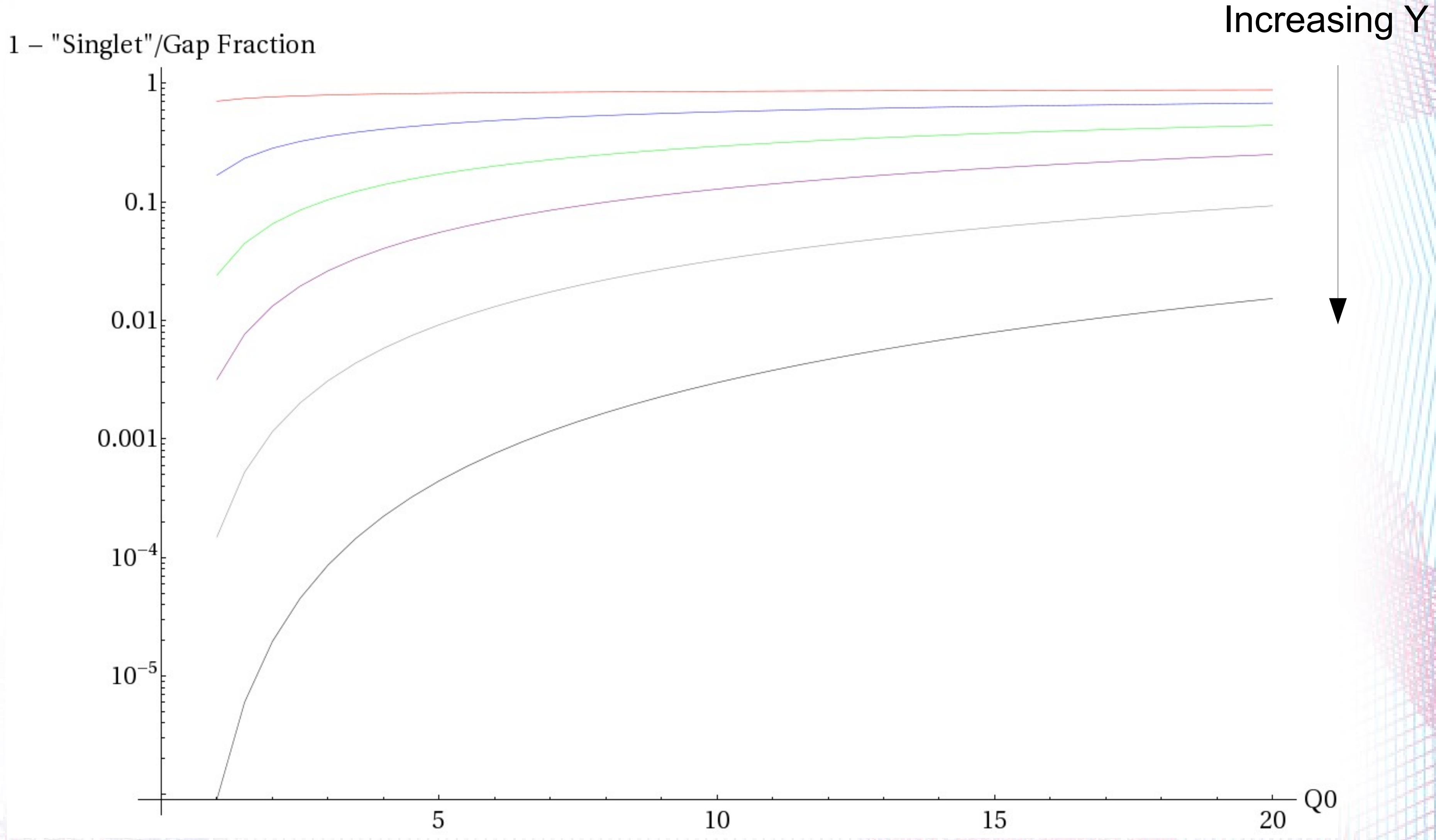
Partonic Fractions (H++)



gg,qg
interactions
dominate

Q=500GeV
S=14TeV

"Singlet" Term



Y=3
Q=500GeV
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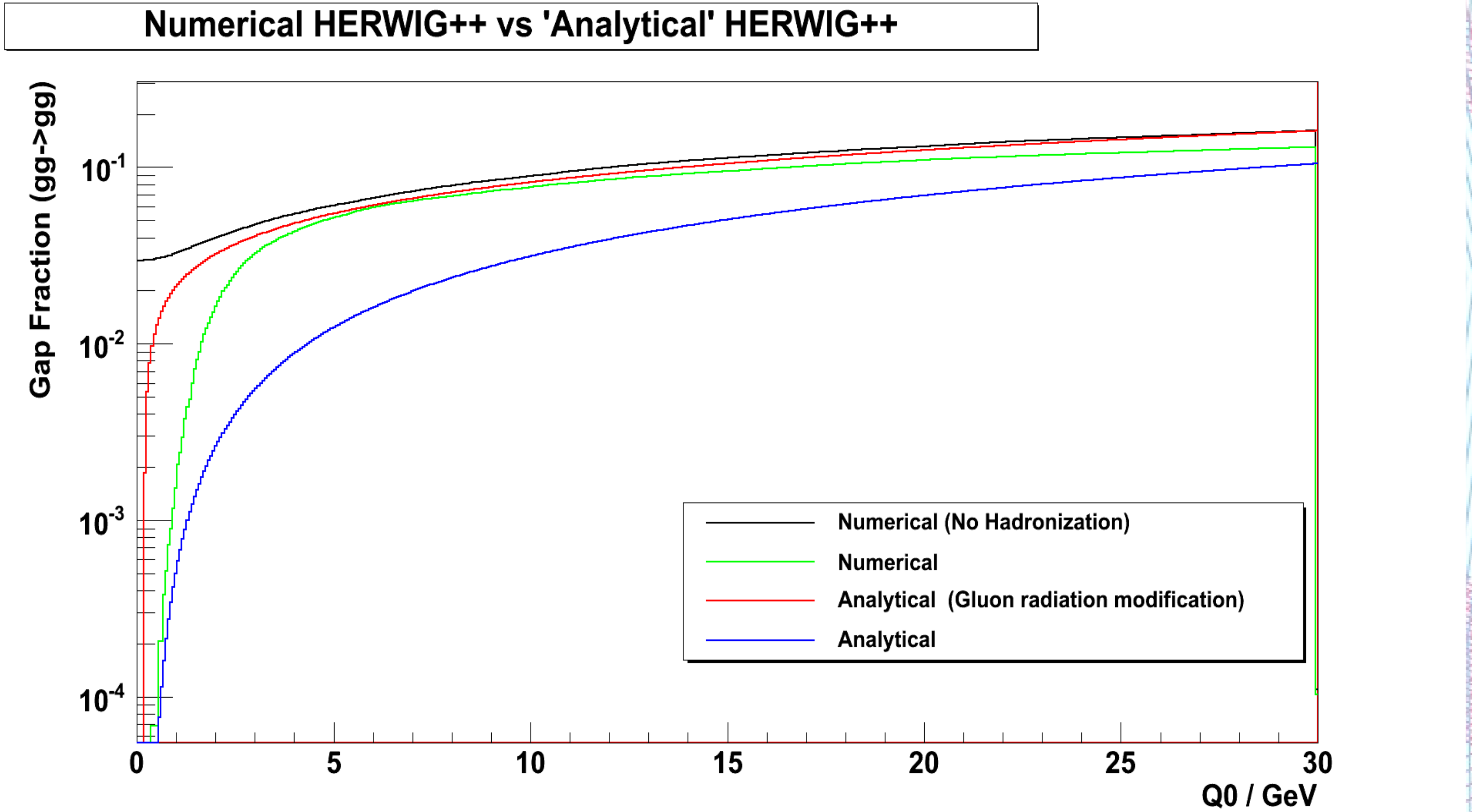
gg->gg Gap Fractions

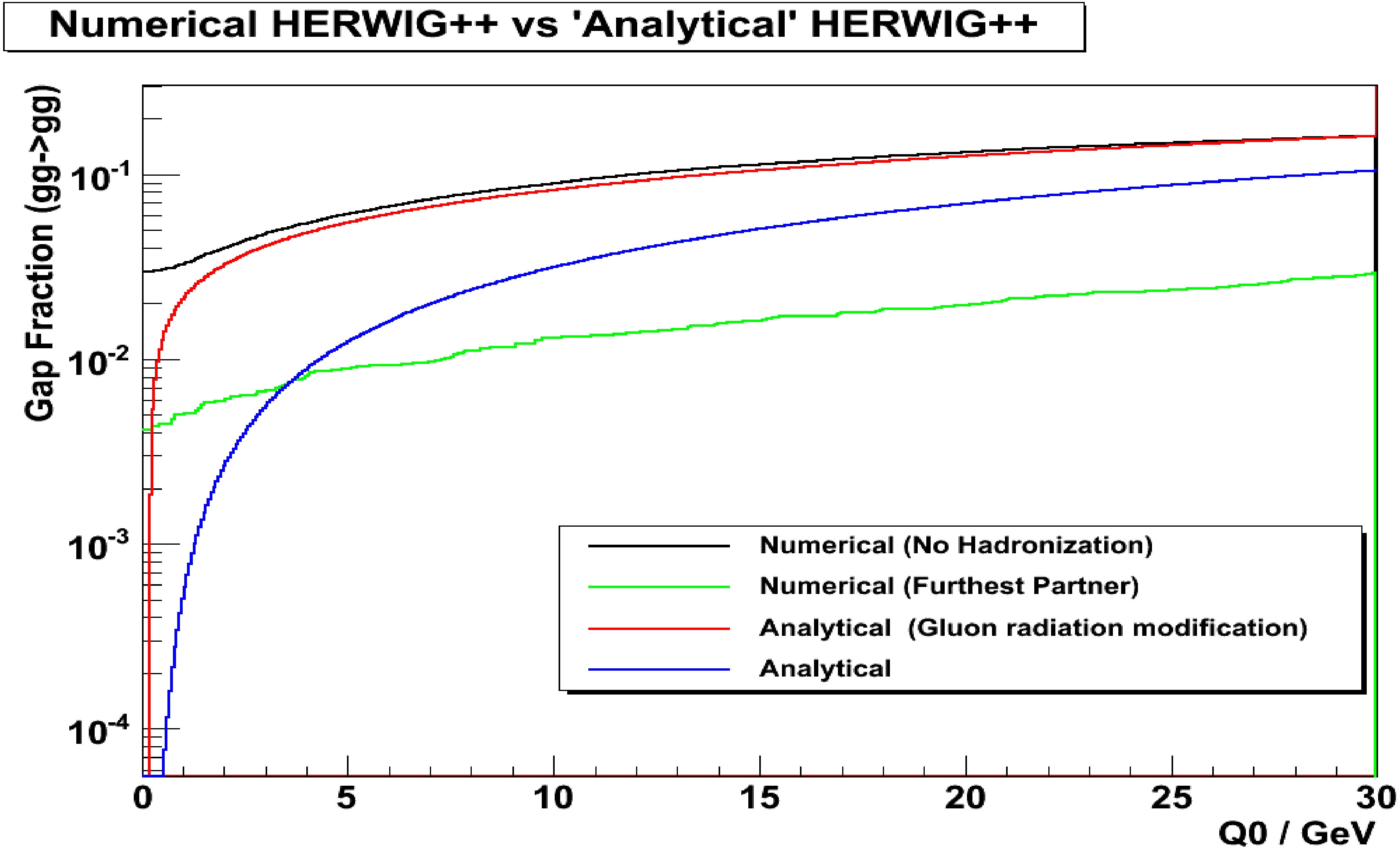


Modification to shower

- The act of choosing one of the two colour partners is one of the possible causes of the problems for exclusive events
- To further demonstrate this we now modify the parton shower to always pick the furthest partner

Y=3
Q=500GeV
S=14TeV

Modifications to shower



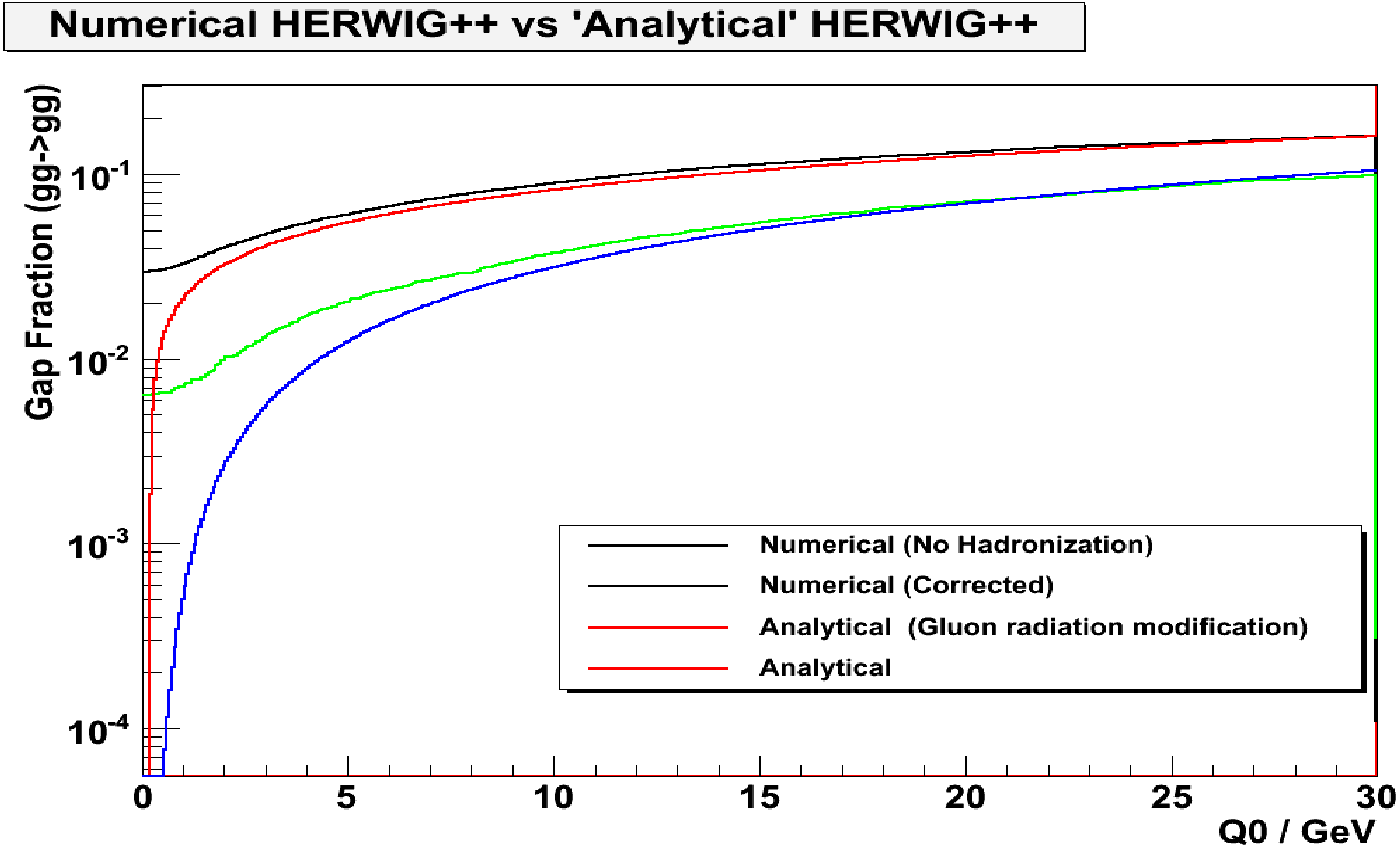
Modifications to shower

- Having seen the problem, we now modify the HERWIG++ parton shower to radiate only half as much until the scale is less than that of both lines.
- In terms of the analytical calculation this is equivalent to the modification

$$\tfrac{1}{2}\left(1 + \mathrm{Exp}[-2\Gamma_g]\right) \longrightarrow \mathrm{Exp}[-\Gamma_g]$$

Y=3
Q=500GeV
S=14TeV

Modifications to shower



Conclusions

- The current version of HERWIG++ does not correctly simulate the emission of gluons in jet veto events.
- The proposed corrections to the behaviour have been implemented and show promising results for the gg->gg gap fraction.

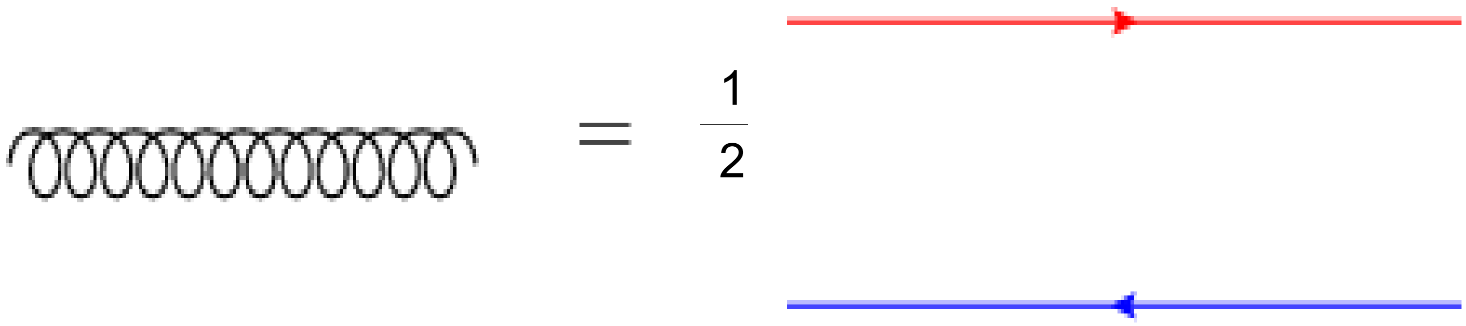
Future work

- Check how these modifications change in HERWIG++ 2.4.2
- Finish modifications to HERWIG++ parton shower

Backup slides

Colour Flow Basis

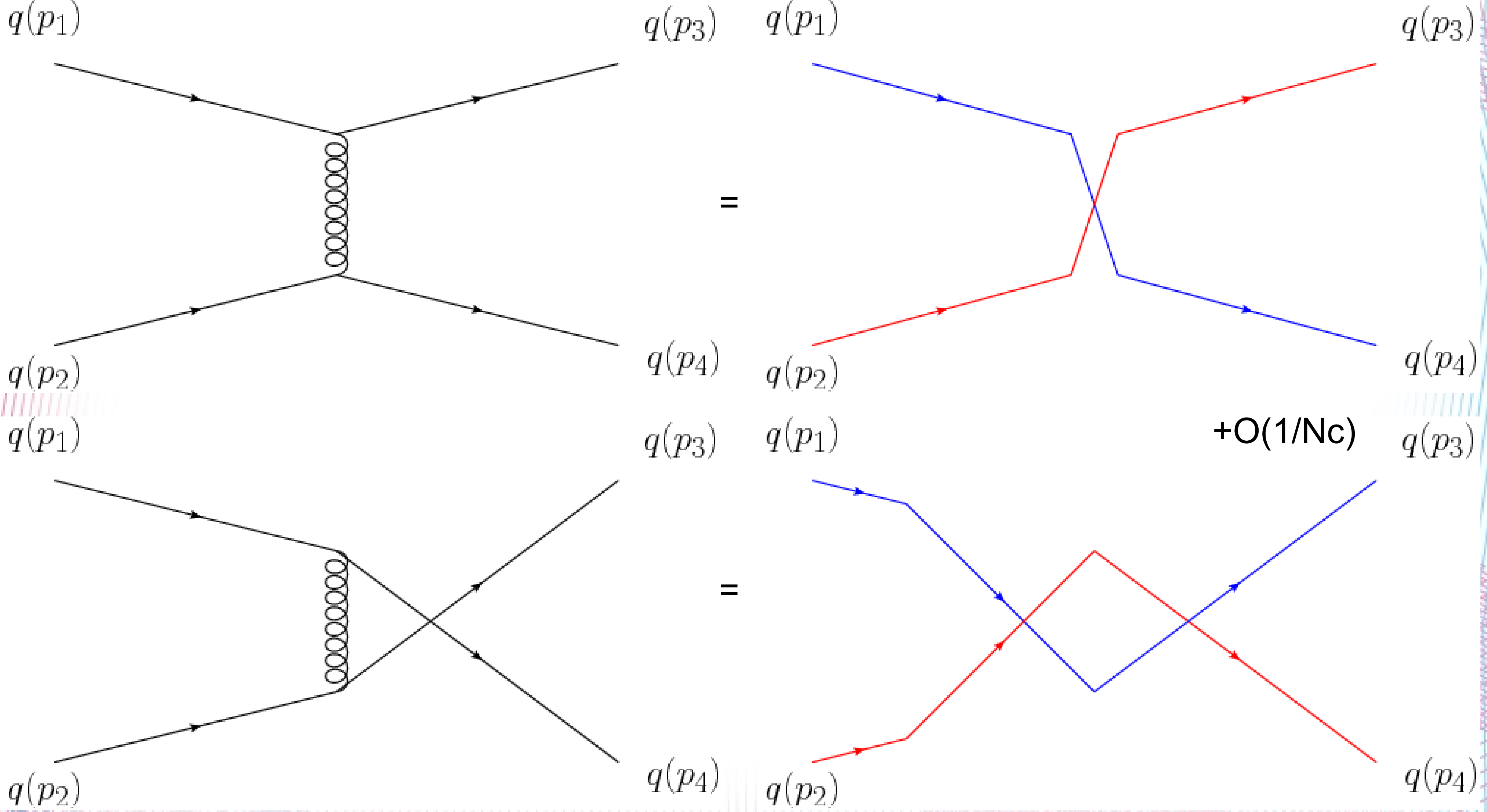
- Colour flow basis



$= \frac{1}{2}$

+O(1/Nc)

Colour Flow Basis

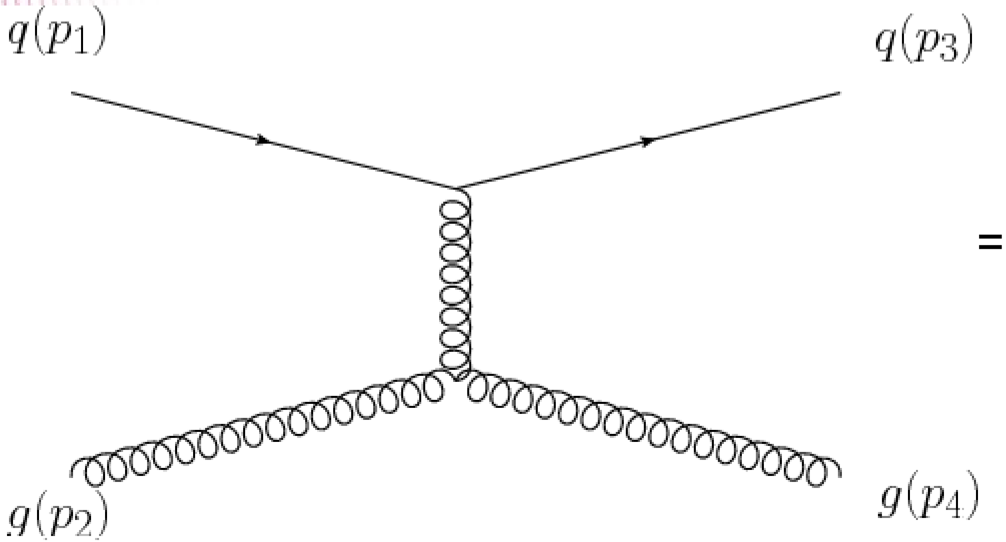


=

=

+O(1/Nc)

Colour Flow Basis



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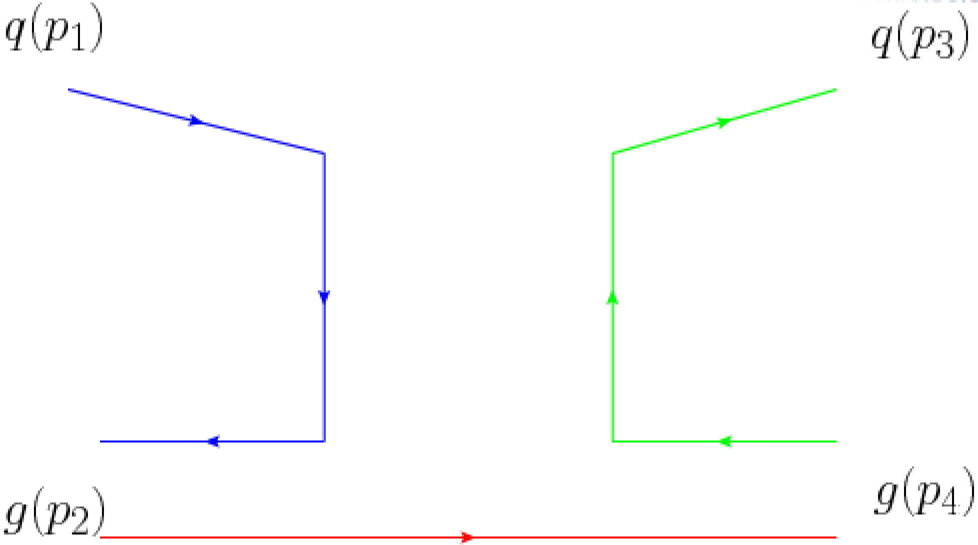
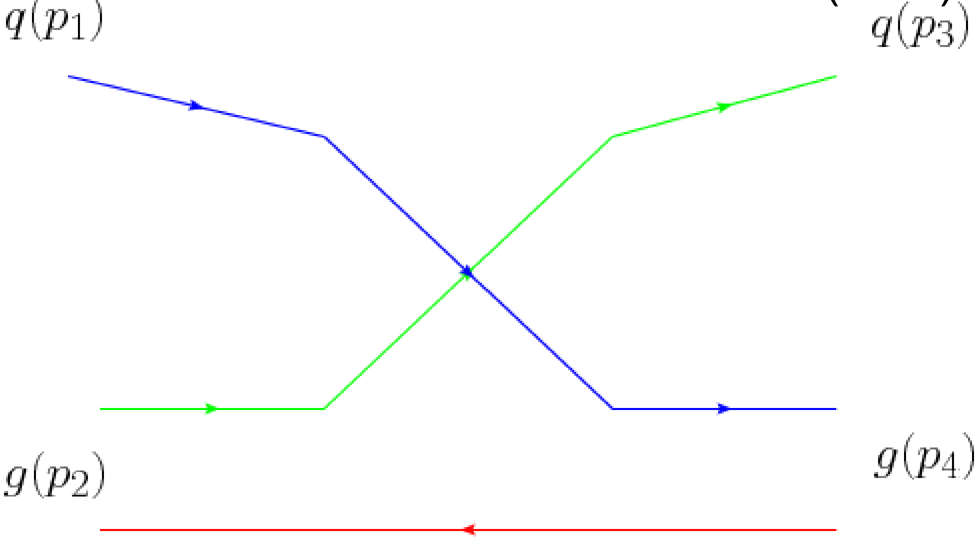


+O(1/Nc)



Large Nc limit

- Colour interferences are subleading in Nc
- Redefine hard scattering matrix

$$H'_{ii} = H_{ii} \frac{\mathrm{Tr}[HS]}{\mathrm{Tr}[H]}$$

- Born cross section unchanged

K. Odagiri (1998)

Experimental Results - 20th August

Atlas Collaboration (2010)