Testing gap survival probability models at the Tevatron

The Future of Forward Physics at LHC

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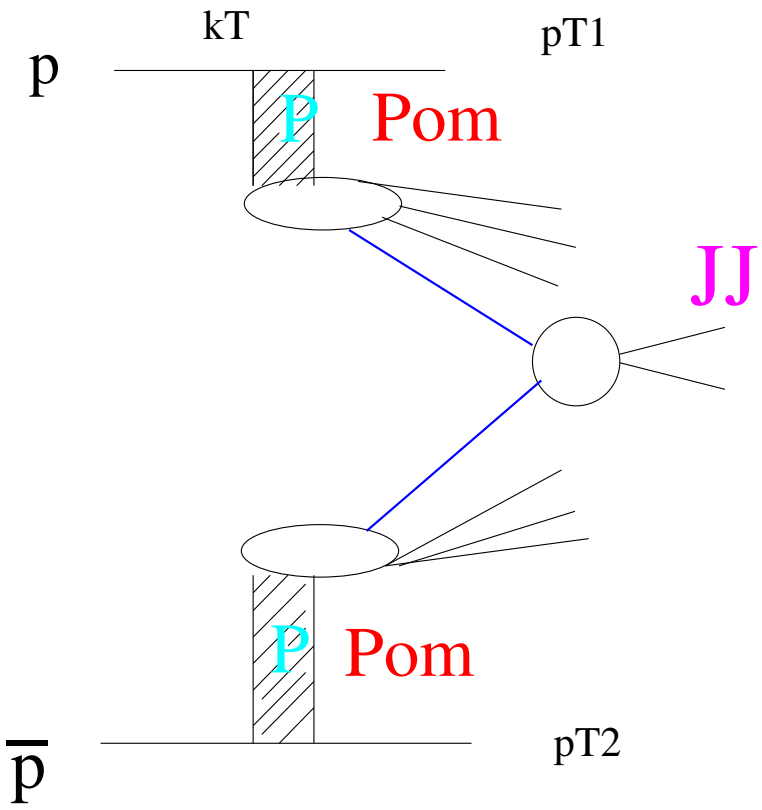
Outline

- two concepts of description of DPE hard diffractive phenomena
  - pomeron based models
  - soft color interaction
- factorization breaking in hard diffractive events
  - survival probabilities
- $\Delta\phi_{p\bar{p}}$ dependence - a way how to distinguish between these two concenpts
- proposal of new measurement that can be performed by DØ Forward Proton Detector
- MC simulations of results of this experiment

hep-ph/0407222 (accepted by Phys. Lett. B)

Hard diffraction - pomeron based models



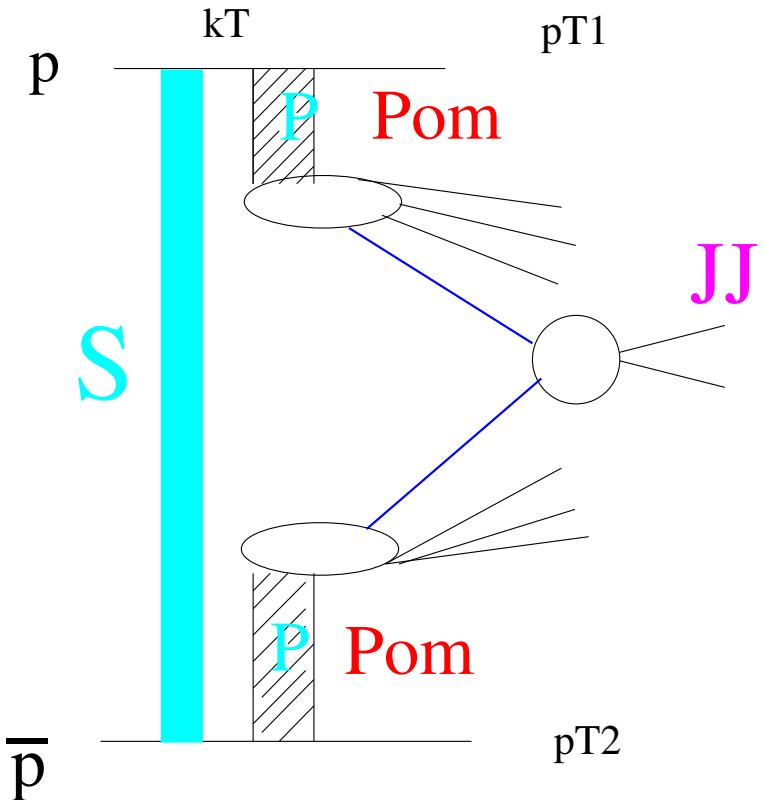
POMERON MODEL

- experimental signitures:
  - central heavy object (for example two jets with high p_T)
  - proton and antriproton are not destroyed
  - rapdity gaps between proton and central object

- explained as an exchange of colorless objects - Pomerons
  - central interaction is then explained as a hard scattering of Pomeron constituents $\Rightarrow$ Pomeron structure functions

Factorization breaking observed between Hera and Tevatron data

Survival probability



$$\mathcal{A}_{rescat} = \mathcal{A}_{soft} \otimes \mathcal{A}_{hard}$$

- Factorization breaking due to additional soft interactions between protons

$\Rightarrow$ Survival probability S^2

- probability that these additional interactions will not destroy protons or the rapidity gaps

$$S^2 = \frac{|\mathcal{A}_{hard} + \mathcal{A}_{rescat}|^2}{|\mathcal{A}_{hard}|^2}$$

Survival probability, part II

- hard amplitude $\mathcal{A}_{hard}$ - factorization of the t-dependence at small t

$$\mathcal{A}_{hard}(\vec{p}_{T1}, \vec{p}_{T2}, \ldots) = \beta(t_1)\beta(t_2)A_0(\sqrt{s}, y, M)$$

  where $\beta(t)$ is pomeron-proton vertex form-factor

$\Rightarrow$ survival probability factor independent on the hard interaction

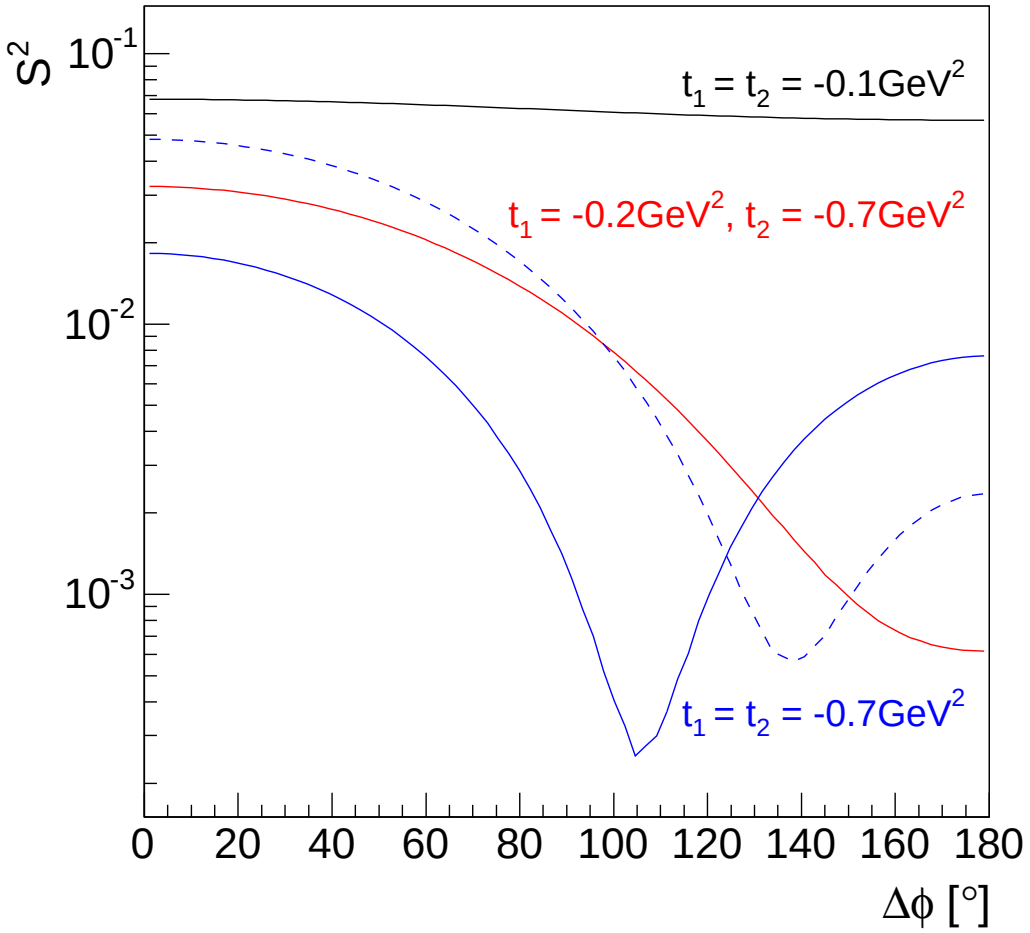
$$S^2(\vec{p}_{T1}, \vec{p}_{T2}) = S^2(t_1, t_2, \Delta\phi_{p\bar{p}})$$

- soft scattering amplitude $\mathcal{A}_{soft}$
  - two-channel eikonal model (elastic and low-mass diffraction)

    V. A. Khoze, A. D. Martin and M. Ryskin, Eur. Phys. J. **C21** (2001) 521
  - elastic channel model

    A. Bialas, R. Peschanski, Phys. Lett. **B575** (2003) 30

Survival probability - $\Delta\phi_{p\bar{p}}$ dependence



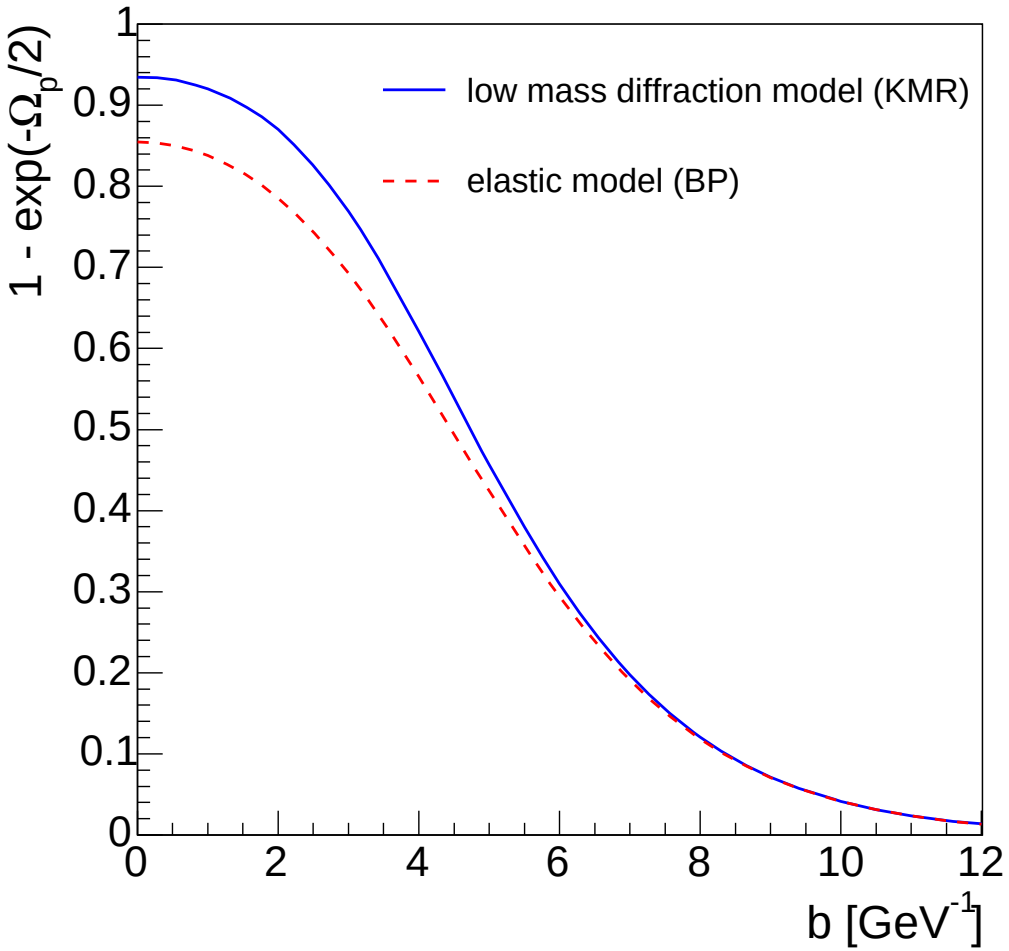
- rich structure in $\Delta\phi$

  V. A. Khoze, A. D. Martin and M. Ryskin, Eur. Phys. J. **C24** (2002) 581

- the same origin as the diffractive dips in $d\sigma_{el}/dt$
- the position of the dip depends on the details of the model

This is a general feature of all pomeron based models

Proton opacity

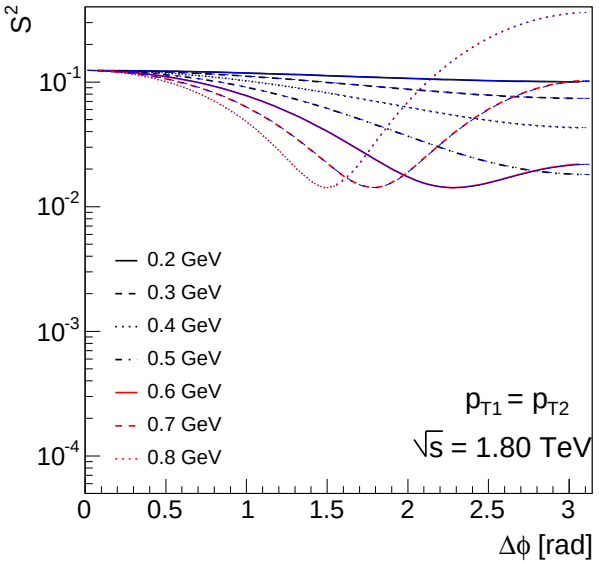


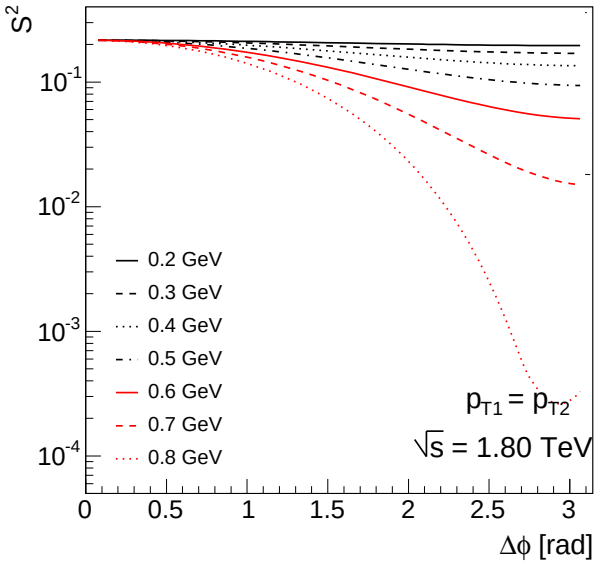
$$\mathrm{Im}\,\mathcal{A}_{el} \propto 1 - \exp(\Omega/2)$$

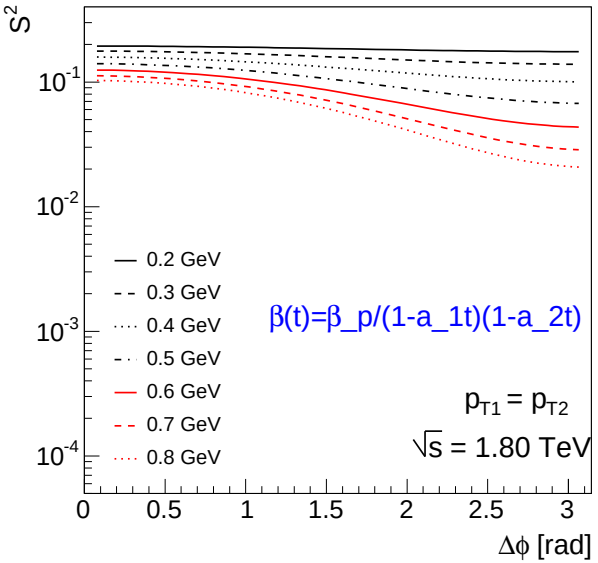
- the same behaviour at large values of impact parameter b
- central part of the proton is slightly more transparent in the BP model

$\Rightarrow$ the origin of the differencies for the $\Delta\phi_{p\bar{p}}$ distribution

Sensitivity of $\Delta\phi_{p\bar{p}}$ to the details of the models







$$\beta(t) = \beta_p \exp(bt/2)$$

$$\Omega(b_t) \propto \exp[-b_t^2/4B_p]$$

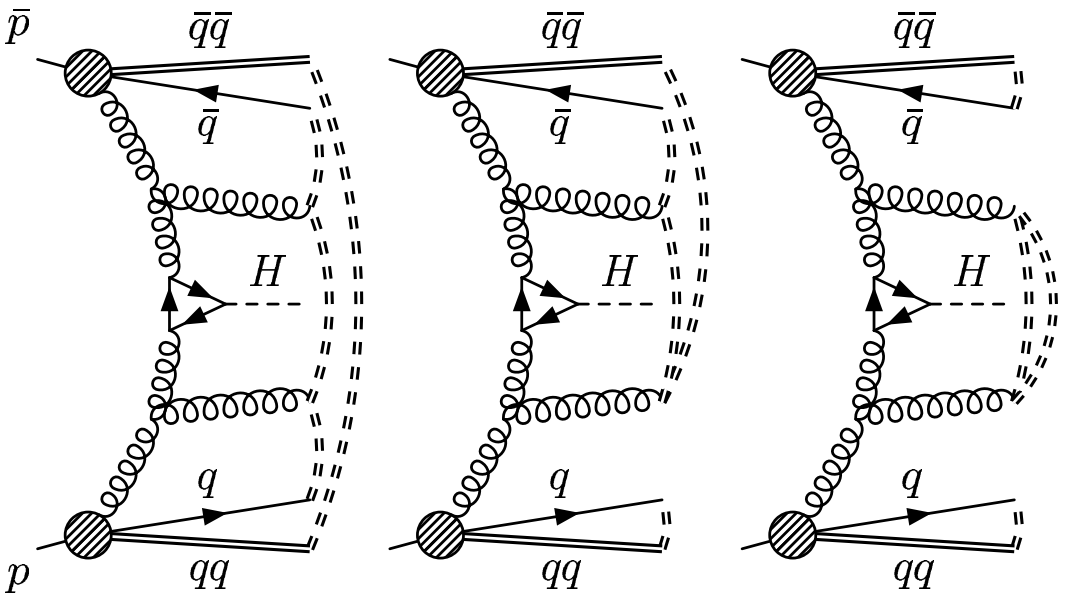
$$ImA_{el} = \Omega/2$$

$$\mathrm{Im}\,\mathcal{A}_{el} = 1 - \exp(\Omega/2)$$

$$\beta(t) = \frac{\beta_p}{(1-a_1 t)(1-a_2 t)}$$

- $\Delta\phi_{p\bar{p}}$ is very sensitive to the details of model
- rich diffractive structure in $\Delta\phi_{p\bar{p}}$ is general feature of pomeron based models

Soft Colour Interaction Models



- a completely different model for hard diffraction events

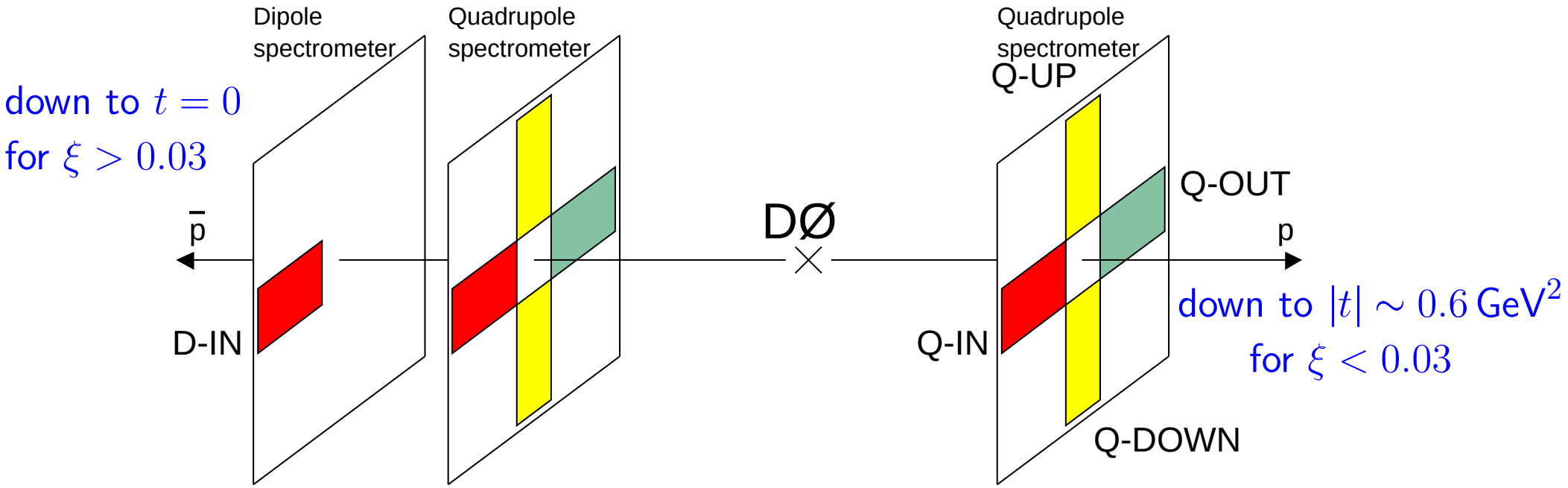
  R. Enberg, G. Ingelman, N. Timneanu, Phys. Rev. **D64** (2001) 114015
- based on Lund string model

- Unified description of diffractive and non-diffractive final states
- diffractive phenomena explained by color string reconnections
- no survival probability for SCI models
  - model can explain both Hera and Tevatron hard diffraction data

No strong $\Delta\phi_{p\bar{p}}$ dependence for the hard diffractive production

DØ Forward Proton Detector

- Forward Proton Detector installed by DØ provides an unique opportunity to measure the $\Delta\phi$ dependence of the hard diffractive production



Dipole-Quadrupole combination

D-IN & Q-IN, D-IN & Q-OUT

D-IN & Q-UP or D-IN & Q-DOWN

- asymmetric cuts in t

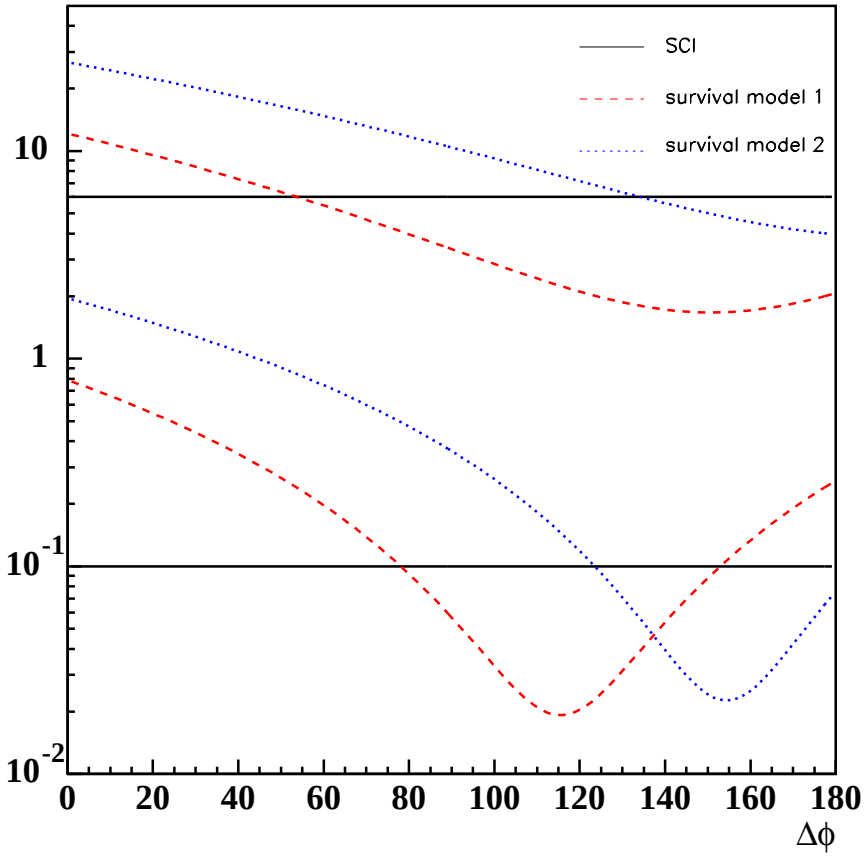
Quadrupole-Quadrupole combination

same side, opposite side

middle (90°) configuration

- symmetric cuts in t

Results for double diffractive dijet production



- dijet production with $p_T > 5\,\text{GeV}$ at Tevatron
  - upper plots: $|t_p| > 0.6,\ |t_{\bar{p}}| > 0.1\,\text{GeV}^2$
  - lower plots: $|t_p| > 0.5,\ |t_{\bar{p}}| > 0.5\,\text{GeV}^2$
- Pomeron models
  - POMWIG interfaced with the calculation of survival probability
  - two-channel eikonal model (Model 1)
  - elastic channel model (Model 2)

- SCI model - modified version of Pythia with color string reconnection

Results for proposed measurement

- after full simulation of DØ Forward Proton Detector acceptances

Config.	model	$N_{90}/2 \times N_{SS}$	N_{OS}/N_{SS}
Quad.	SCI	1.3	1.1
+	P-Model 1	0.36	0.18
Dip.	P-Model 2	0.47	0.20
Quad.	SCI	1.4	1.2
+	P-Model 1	0.14	0.31
Quad.	P-Model 2	0.20	0.049

$\Rightarrow$ this measurement can easily distinguish between SCI and Pomeron based models

- for $10\,\text{pb}^{-1}$ (1 week of running of Tevatron) POMWIG predicts about 1000 (resp. 25) dijet events in the Q+D (resp. Q+Q) configurations
  - possibility to increase the cut on jet p_T
  - use final states with vector mesons (J/Ψ) or even W and Z at higher luminosities
  - measure differential cross section $d\sigma/d\Delta\phi$

Summary

- Dependence of hard diffractive production on the azimuthal angle $\Delta\phi$ between leading proton and antiproton is connected with the factorization breaking mechanism
- two types of models (i.e. Pomeron based models and soft colour interaction model) give significanlty different predictions
- We showed that the DØ FPD is suitable for this kind of measurement
- Observed strong dependence
  - would confirm the Pomeron based models of gap survival probabilies
  - would disfavor SCI model (concept of colour reconnection in Pythia would have to be revisited)
- Observed weak dependence
  - conceptual problems of the Pomeron based models
- This measurement can bring new information about the factorization breaking in hard diffraction which may lead to more precise predictions for diffractive cross sections at the LHC