Diffractive Higgs production and soft colour interactions

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EPS Meeting, Aachen, July 2003

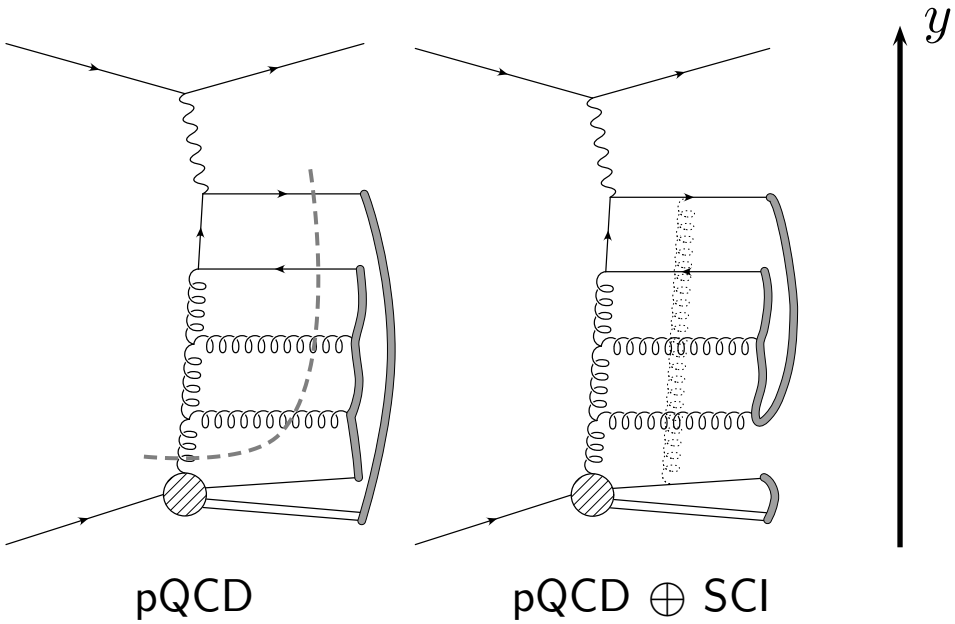
Overview

- Soft Colour Interactions (SCI)
- SCI @ Tevatron and Hard diffraction (hep-ph/0106246, in PRD)
  $\longrightarrow$ W, Z, J/ψ, $b\bar{b}$
  $\longrightarrow$ dijets
- Diffractive Higgs production (hep-ph/0203267, in PRL)
- Diffractive $\gamma\gamma$ production (hep-ph/0210408, in PRD)

The Soft Colour Interaction model (SCI)

- Diffraction $\leftrightarrow$ soft phenomena $\rightarrow$ we want to model the soft physics
- Starting point: partonic final state described by pQCD including parton showers
- Model soft interactions below perturbative cutoff

Introduce SCI with negligible momentum transfer, which change colour topology of the event (given by pQCD) and thus the Lund string configuration:



The Soft Colour Interaction model (SCI)

Colour charged partons interacting with the soft proton colour field
$\longrightarrow$ Implemented in the MC's LEPTO and PYTHIA

Matrix elements + DGLAP PS	$\rightarrow$	Soft Colour Interactions	$\rightarrow$	Hadronization
colour ordered partons		rearranged colour order		complete final states

$\rightarrow$ single model describing all final states, transition diffractive — nondiffractive

- Changed colour topology $\rightarrow$ changed Lund string configuration $\rightarrow$ different hadronic final states

- two slightly different models: SCI and GAL

SCI at HERA and Tevatron

- SCI gives correct magnitude of diffractive cross section in DIS
  [See papers by A. Edin, G. Ingelman, J. Rathsman, e.g. hep-ph/9912539]

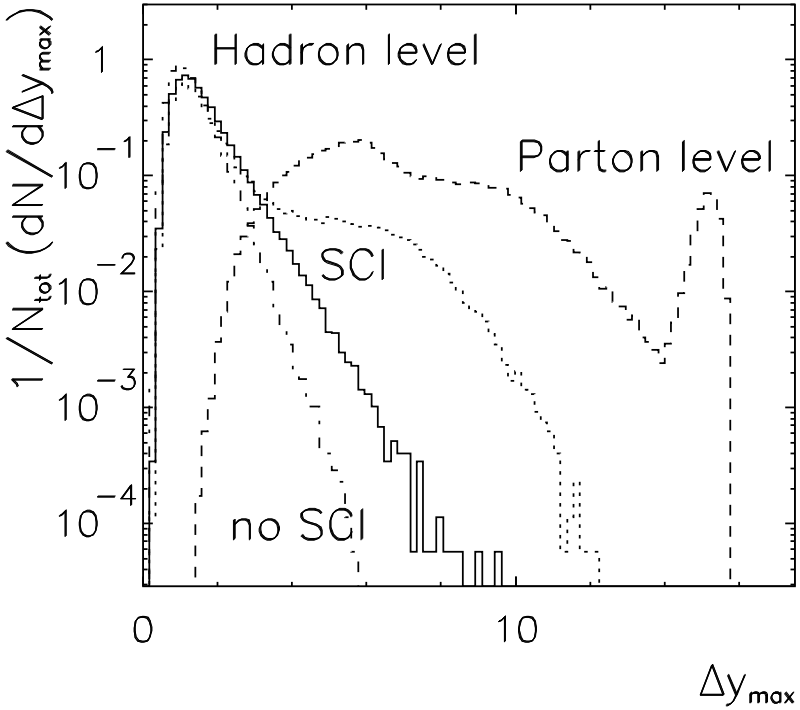
- I will show that SCI also gives correct cross sections at Tevatron
  (for *all* observables in diffractive hard scattering)

- I.e., they correctly account for the difference between ep and $p\bar{p}$ collisions!

- This is a non-trivial result. . .

SCI and hard diffraction at the Tevatron: W, Z, $b\bar{b}$, J/ψ

[Enberg, Ingelman, Tîmneanu, Phys. Rev. D 64 (2001) 114015]



W production @ 1800 GeV.

SCI/GAL reproduce well measured gap fractions

$$R_{\rm hard} = \frac{1}{\sigma^{\rm tot}_{\rm hard}} \int_{x_{F\,\rm min}}^{1} dx_F \, \frac{d\sigma_{\rm hard}}{dx_F}$$

R_{hard}	Exp. [%]	SCI	GAL
W	1.15 ± 0.55	1.2	0.8
$b\bar{b}$	0.62 ± 0.25	0.7	1.4
Z	$1.44\ ^{+0.62}_{-0.54}$	1.0	0.5
J/ψ	1.45 ± 0.25	1.4	1.7

predictions

SCI and hard diffraction at the Tevatron: dijets in SD & DPE

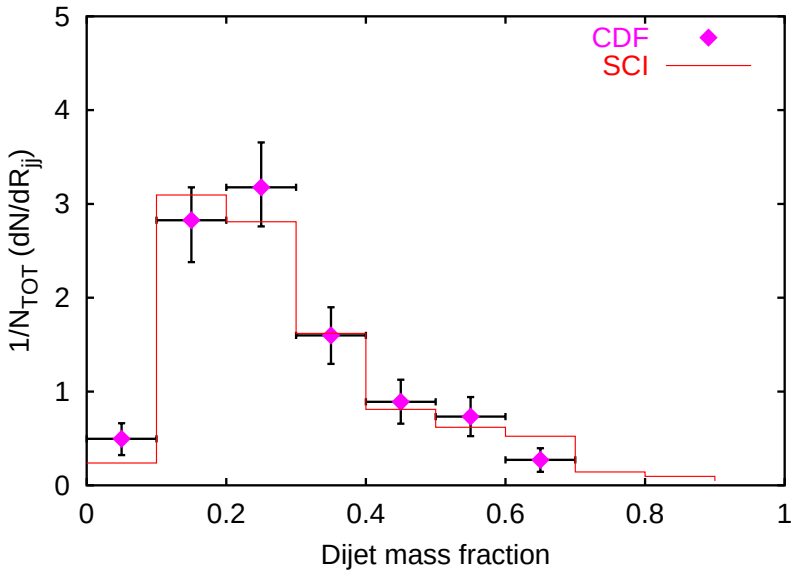
SCI/GAL reproduce well single diffractive ratios for dijets with gaps or leading anti-protons.

Also in DPE (Double Pomeron Exchange) the models give good ratios and cross-sections.

	$\tilde{R}_{SD}^{DPE}$ [%]	σ^{DPE} [nb]
CDF	0.80 ± 0.26	$43.6 \pm 4.4 \pm 21.6$
SCI	0.54 ± 0.05	$5 - 25$
GAL	0.44 ± 0.05	$6 - 40$

↑ proton ↑ gap

While reproducing the overall behaviour, the models have a strong dependence on remnant treatment.



Dijet mass fraction in DPE

CDF data well reproduced by SCI

SCI and Higgs in hadron-hadron collisions

[Enberg, Ingelman, Kissavos, Tîmneanu, Phys. Rev. Lett. 89 (2002) 081801]

- We have already seen that the SCI/GAL models give good descriptions of cross sections for diffractive processes

  $\longrightarrow$ Apply it to diffractive Higgs

  $\longrightarrow$ Lots of recent interest
  [See e.g. review by Khoze, Martin, Ryskin (hep-ph/0207313)]

- $gg \to H$ accounts for 50–70% of the cross section,
  but include all subprocesses in PYTHIA 6

SCI results for diffractive Higgs

Diffractive criteria: gap $(2.4 < |\eta| < 5.9)$ or leading proton $(x_F > 0.9)$

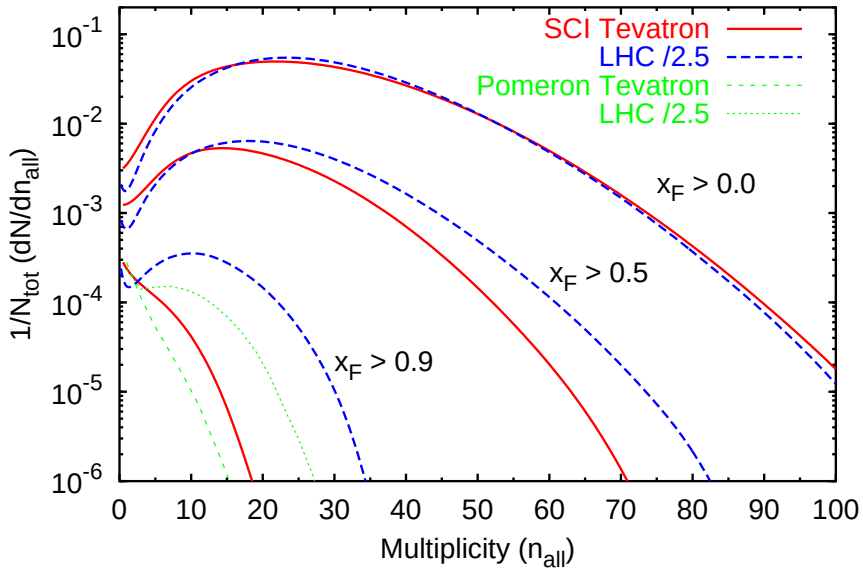
In Khoze-Martin-Ryskin nomenclature : "Central inelastic production"

		Tevatron	LHC	Others (Tev/LHC)	
	σ[fb] Higgs-total	600	27000	Cox et al	Khoze et al
SD	σ [fb] leading-p	1.2	190		
	σ [fb] gap	2.4	27		
	# H + leading-p	24	5700		
	$\hookrightarrow$ # H $\rightarrow \gamma\gamma$	0.024	6		
DPE	σ [fb] leading-p's	$1.2 \cdot 10^{-4}$	0.19	0.02 / 6	0.03 / 50
	σ [fb] gaps	$2.4 \cdot 10^{-3}$	$2.7 \cdot 10^{-4}$		
	# H + leading-p's	0.0024	6		

large m_H + large x_F proton $\rightarrow$ kinematical conflict $\rightarrow$ reduced cross-section

Clean diffractive events at LHC?

Energy = production of hard subsystem + one/two leading protons + particles in forward η regions



Particle multiplicity in the rapidity region $2.4 < |\eta| < 5.9$ of the expected gap, in the hemisphere of a leading proton.

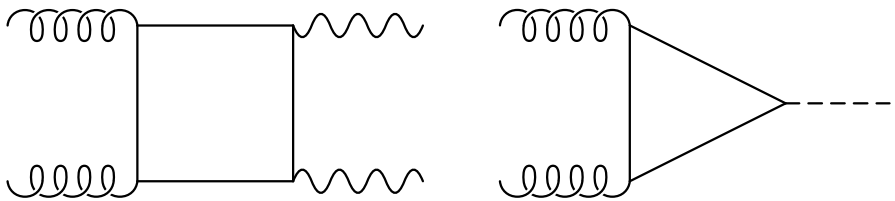
Not so clean diffractive Higgs events

$\longrightarrow$ gap region in detector is filled even though there is a leading proton

Diffractive prompt $\gamma\gamma$ production

[Enberg, Ingelman, Tîmneanu, Phys. Rev. D 67 (2003) 011301]

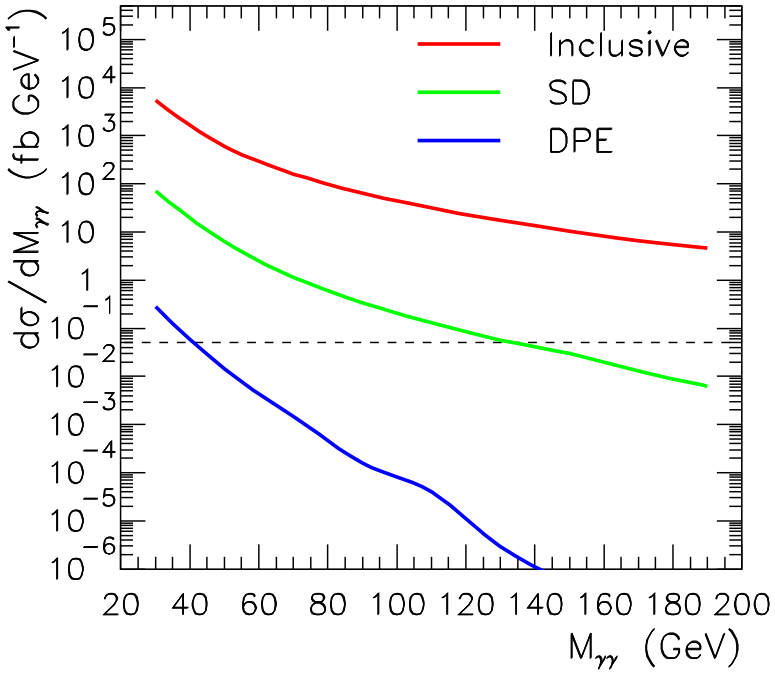
- Apply exactly the same Monte Carlo model to prompt two-photon production
- $gg \to \gamma\gamma$ similar to $gg \to H$:



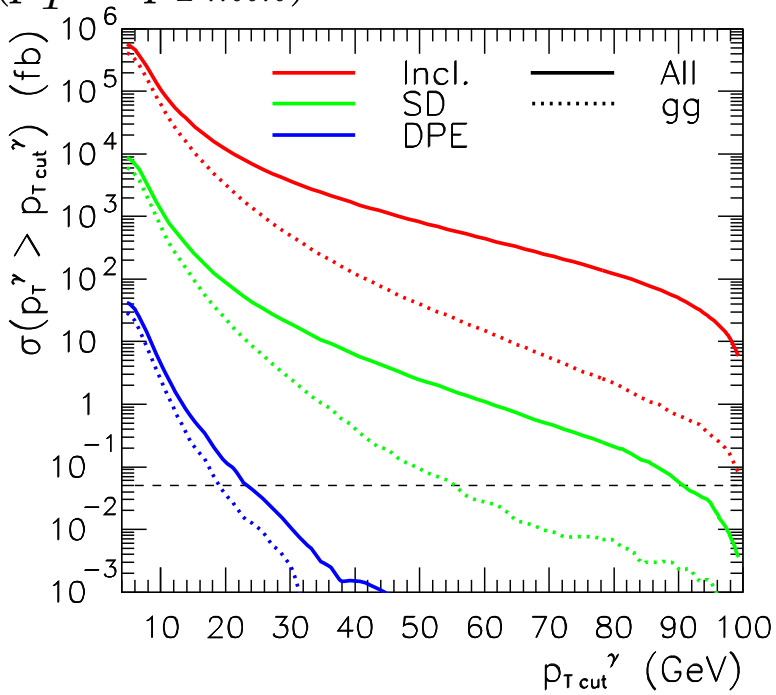
- Background processes to $H \to \gamma\gamma$
- Use this to test models for diffractive Higgs production?
  $\to$ we are interested in $M_{\gamma\gamma} \sim M_H$

TEVATRON: (dashed line = 1 event in Run II)

$d\sigma/dM_{\gamma\gamma}$



$\sigma(p_T^\gamma > p_{Tmin})$



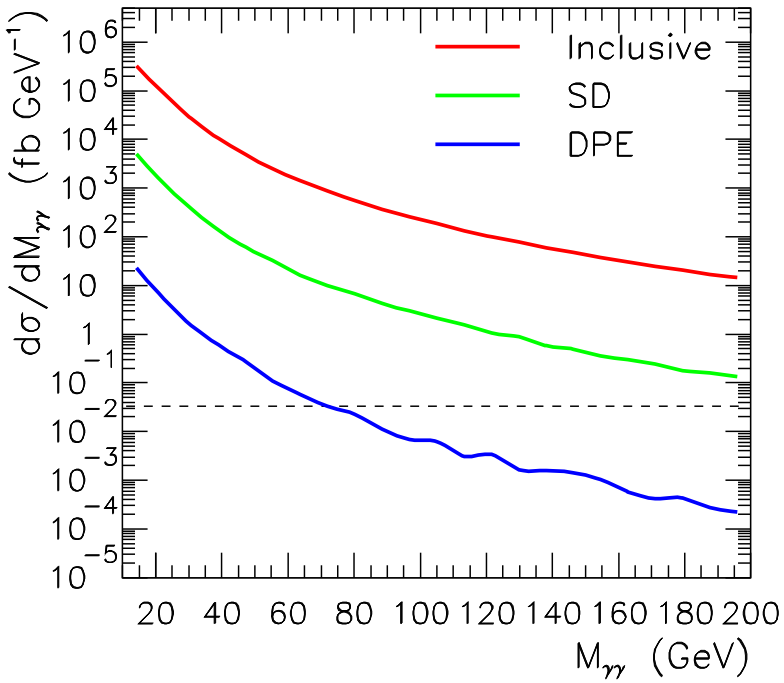
→ For large $M_{\gamma\gamma}$ the process is dominated by the $q\bar{q}$ channel

$$\sigma_{\gamma\gamma}^{DPE}(p_T^\gamma > 12 \text{ GeV}) = 2 \text{ fb}$$

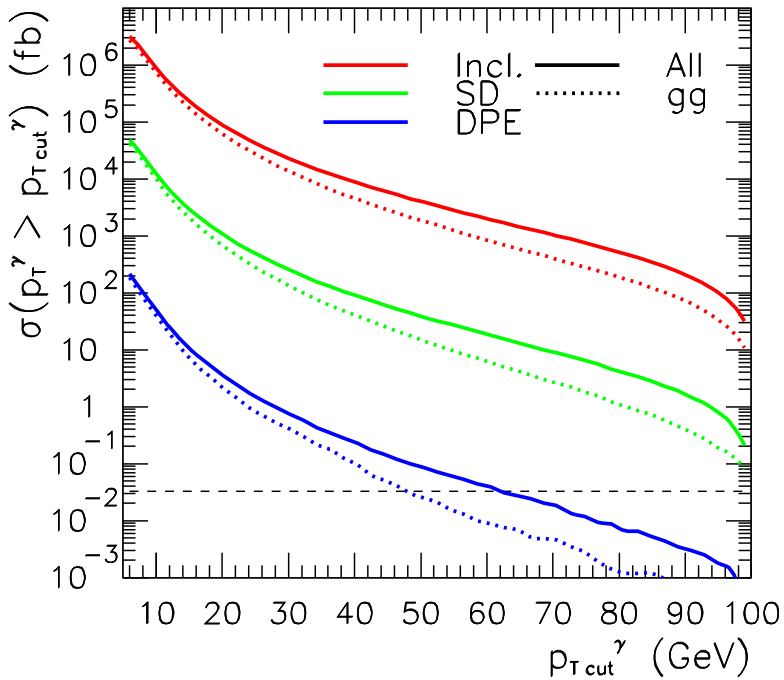
but: $$\int_{M_H \pm 1GeV} \frac{d\sigma}{dM_{\gamma\gamma}} dM_{\gamma\gamma} \sim 10^{-5} \text{ fb}$$ (larger than $\sigma_{H\to\gamma\gamma}$)

LHC: (dashed line = 1 event in low luminosity run)

$d\sigma/dM_{\gamma\gamma}$



$\sigma(p_T^\gamma > p_{Tmin})$



$$\sigma_{\gamma\gamma}^{DPE}(p_T^\gamma > 12 \text{ GeV}) = 30 \text{ fb}$$

Summary

- SCI describes well all diffractive hard scattering rates at HERA and Tevatron
  $\rightarrow$ correctly account for the difference between ep and $p\bar{p}$ collisions

- SCI's @ Tevatron
  - Cross section of single diffractive Higgs events is too low to be useful
  - Higgs in DPE events are far below an observable rate

- SCI's @ LHC
  - Diffractive events are not as clean as expected/wanted

- Prompt photons:
  - cross section is small at Tevatron
  - important background to $H \rightarrow \gamma\gamma$