WORKSHOP ON QCD AND DIFFRACTION AT THE LHC:

CRACOW
POLAND
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QCD issues through the eyes of AFP220 (selected topics)

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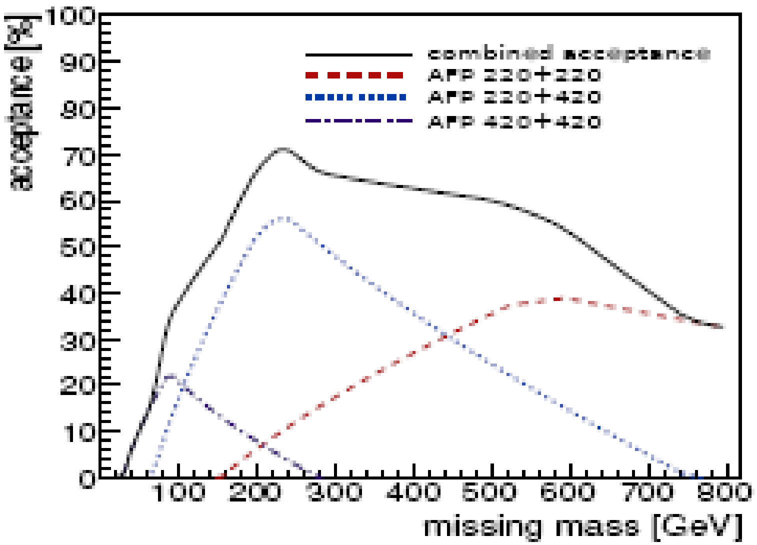
(special thanks to Misha Ryskin and Andy Pilkington for discussions)

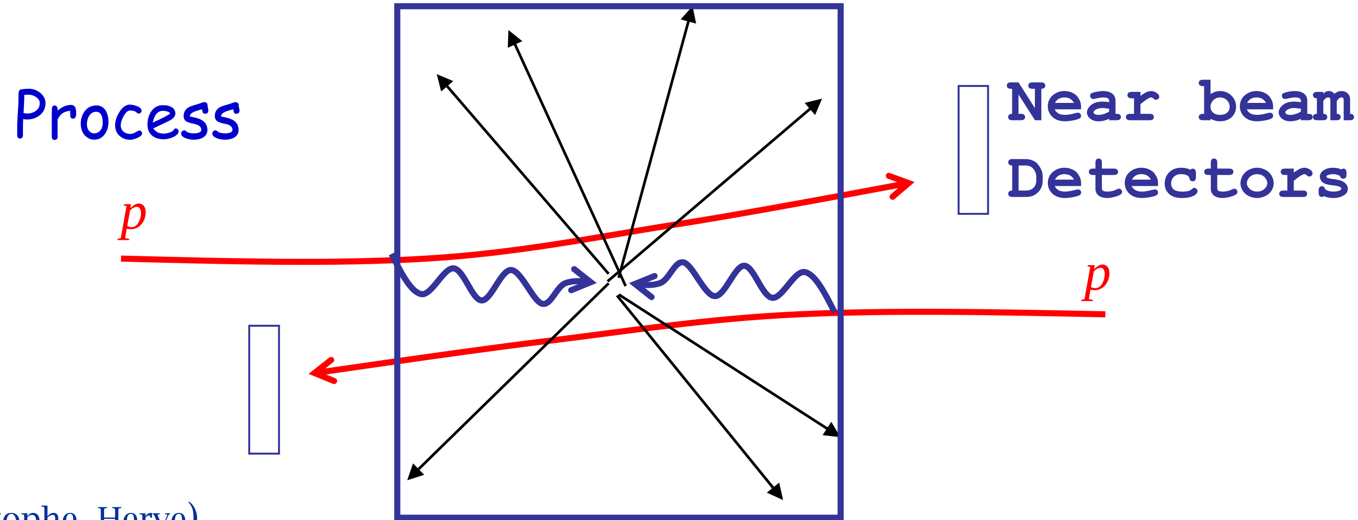
- **AFP220** : possibility to work with the nominal lumi at 14 TeV as well as in the low-lumi runs. Important advantage- Fast Timing.
- Physics program, in particular for minimum-bias studies can start at 7TeV with ALFA (or Totem+CMS). Importance, especially for normalization purposes.
- Comparison of min-bias events with and without proton detectors on.

(talk by Christophe)



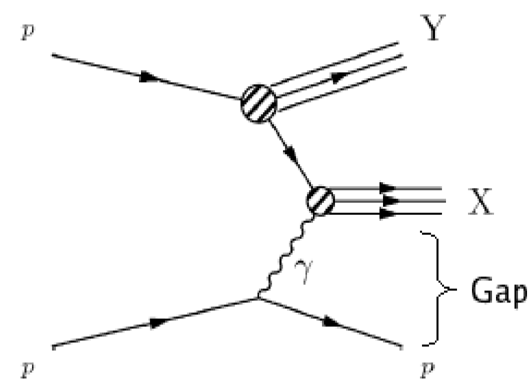
(250Hz→1Hz)

1. LHC as a High Energy photon-photon Collider



(talks by Christophe, Herve)

...and γp



Extensive Program

- $\gamma\gamma \to$ $\mu\mu$, ee QED processes
- $\gamma\gamma \to$ QCD (jets..)
- ~~$\gamma\gamma \to$ WW anomalous couplings~~
- $\gamma\gamma \to$ squark, top... pairs
- $\gamma\gamma \to$ BSM Higgs
- $\gamma\gamma \to$ Charginos
- ...

(accounting for the LHC exclusion zones)

Maybe photon-proton collider @ LHC

LHC as a High Energy $\gamma\gamma$ Collider

$$\sigma = \mathcal{L}(M^2, y)\,\hat{\sigma}(M^2),$$

$$M^2 \frac{\partial \mathcal{L}^{(i)}}{\partial y\,\partial M^2} = \hat{S}^{2(i)}\,L^{(i)}$$

$(S^2)_{\gamma\gamma}$ =0.86

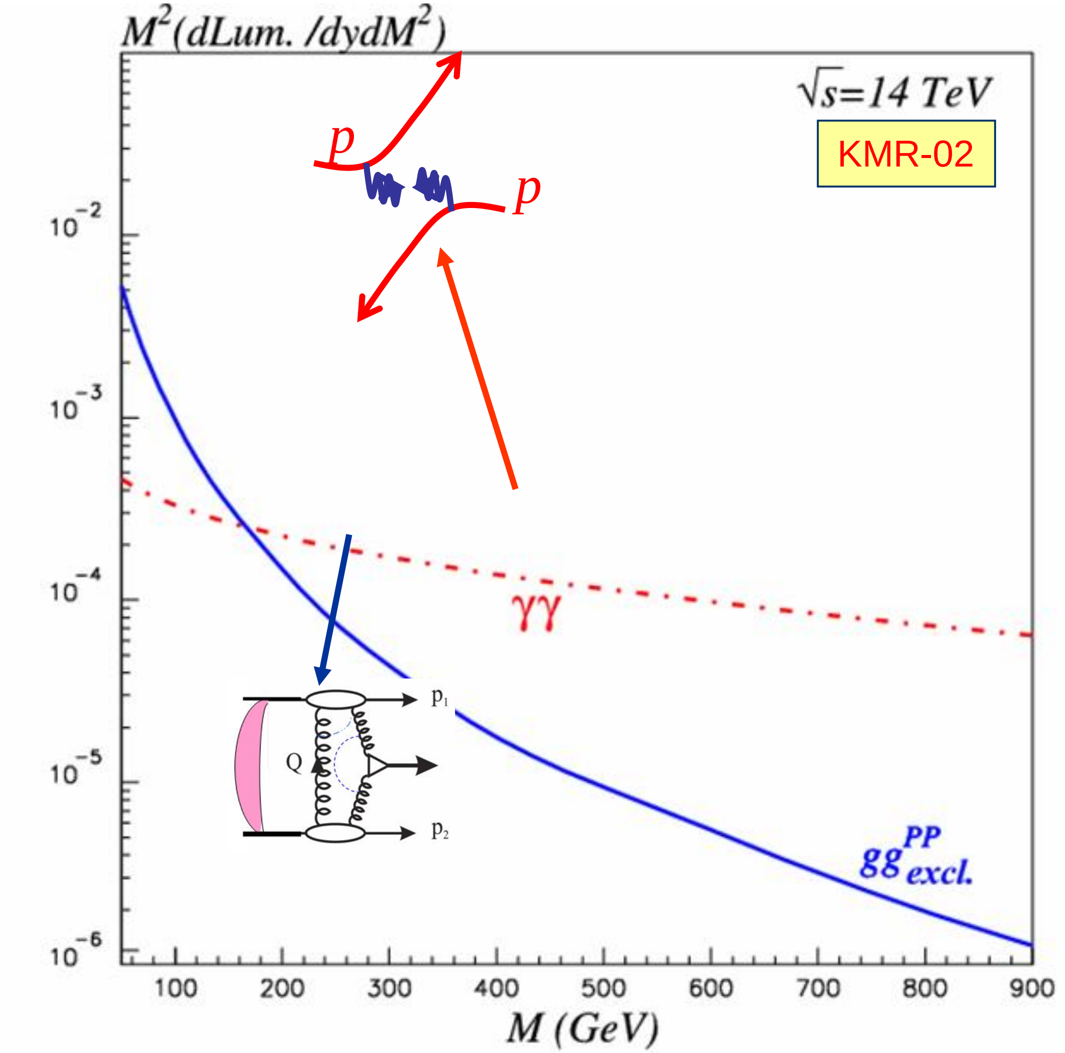
$$\sigma(\gamma\gamma \to SMH) \approx 0.1\,fb$$

$$\sigma(PP -> SMH) \approx 3\,fb$$

$$\alpha_S^{\,2}/8 \to \alpha^2$$

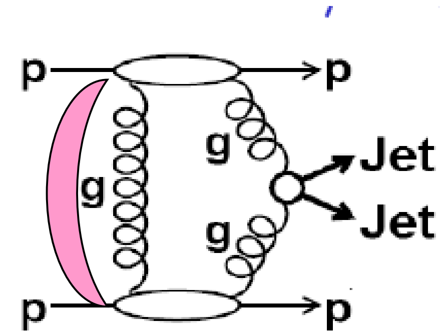
QCD 'radiation damage' in action

QCD Sudakov Formfactor



2. High Intensity Gluon Factory
(underrated un-biased gluons)

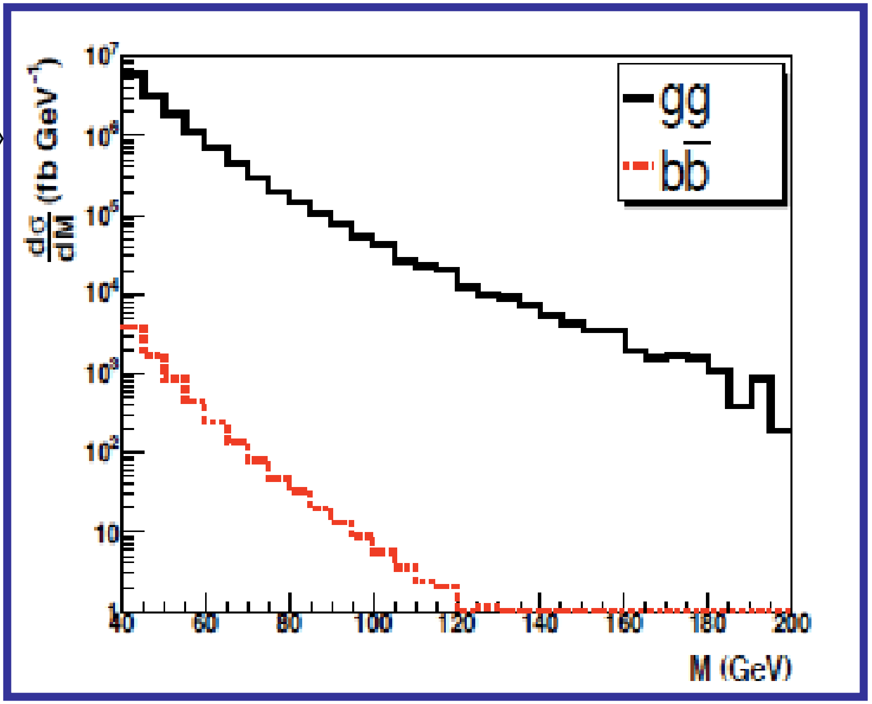
KMR-00, 01



- (~20 M q-jets vs 417 glue-jets at LEP)
- CDF and D0 each have a few exclusive JJ events > 100 GeV
- Strong suppression of b-jet CEP production- confimed by CDF

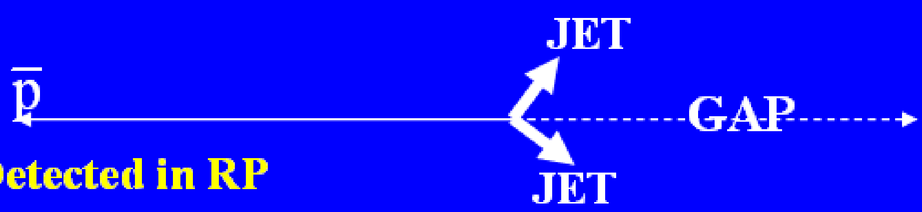
Prediction of ExHuME:
14 TeV, |η| <~ 3

For illustrative purposes only, (factor about 8 down)
FPMC



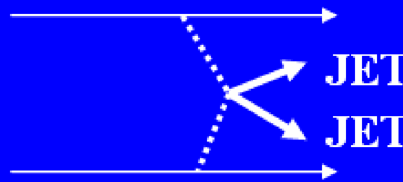
Unique possibility for a comprehensive study of the gluon jet properties in the **extremely clean environment** (hadron spectra/correlations, particle content, maybe even searches for glueballs…)

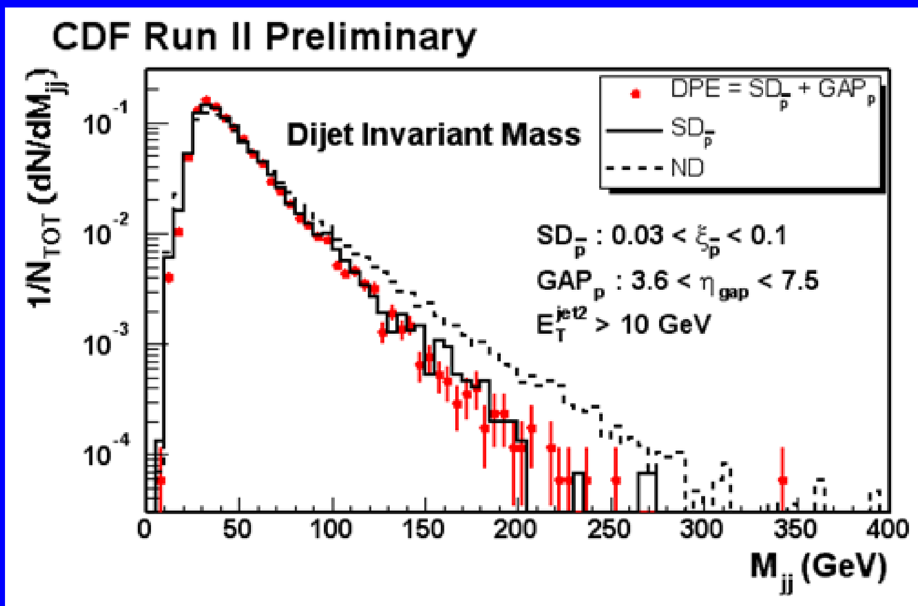
Double Pomeron Exchange Di-Jets in CDF

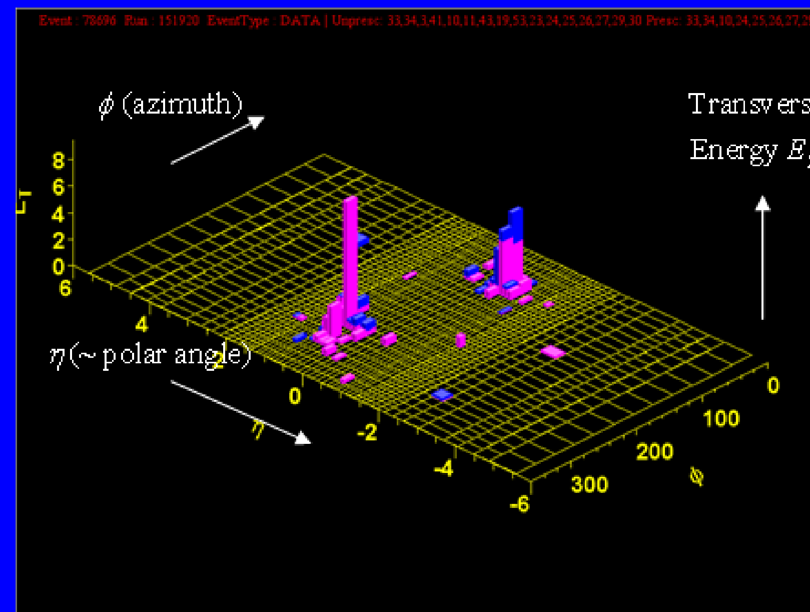


Detected in RP

(p not seen)







Jet <ET> spectra ~ same in SD and DPE

"Almost" exclusive di-jet,

No pile-up essential; low-L
(at LHC if both p detected, some PU allowed)

Today PU is a very serious issue!
Special efforts are needed!

> 0.8

M_{CEN}

Rates

Simplified conservative formula: $d\sigma_{jj} / dM \simeq 1.2(300GeV / M)^6 fb / GeV$

Extra factor of 2 (up) ?

With ΔM =20(50)GeV for M=300 GeV at $100 fb^{-1}$ we expect:
About 2500 (5000) events.

- Tests of various basic ingredients: Sudakov effects, pdfs, absorption , enhanced screenning….

Experimental issues

- Fast Timing Detectors (**FTD**) could allow to diminish PUs.:
  'Exclusive trigger' + kinematic matching similar to that discussed by
  A. Pilkington et al ATLAS_DAQ_PUB-2009-006
  and in JHEP 0905:011,2009.

- In principle, protons can be used at the level 1
  trigger (now it is 220m not 420m !).

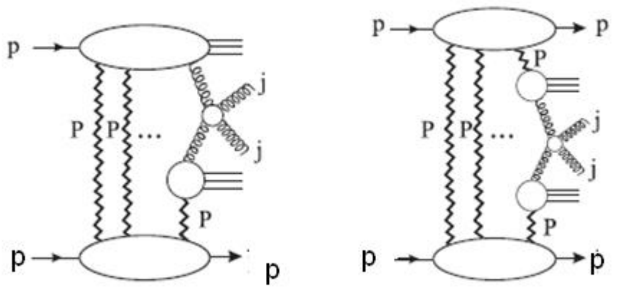
3. Dijet production in the events with one and two gaps

Is suppression universal?

- **Detailed probe of factorization breaking in diffractive processes.**

(Within the multi-Pomeron exchange approach the suppression factors are not universal in different diffractive processes- KKMR, Phys.Lett.B559:235-238,2003)

$$D = \frac{R^{SD}_{ND}}{R^{DP}_{SD}}$$



$$R^{SD}_{ND} \equiv \frac{\sigma^{SD}_{jj}}{\sigma^{ND}_{jj}} \qquad R^{DP}_{SD} \equiv \frac{\sigma^{DP}_{jj}}{\sigma^{SD}_{jj}}$$

$$D = \frac{S_1^2}{S_2}.$$ $S_1 = 0.10, \quad S_2 = 0.05.$ (for the CDF-2000 kinematics)

$D = 0.19 \pm 0.07$ (in agreement with D=0.2)

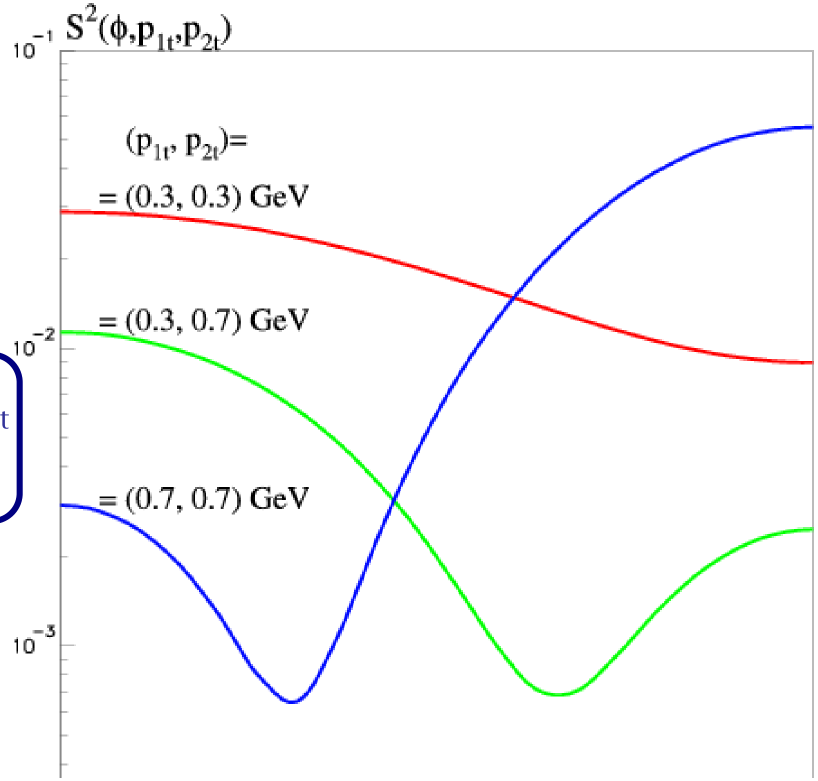
- In the low-lumi runs for moderate jet E_T (up to~ 50GeV) we can hope to measure jets in the central detector and to have timing with both protons.

4. Proton momentum-correlations: opacity scanner

- High sensitivity to the parameters of the soft model.
- Low sensitivity to the pdfs and Sudakov effects.

  We do not need very high p_T jets.
- Sufficient to measure a signal from proton detectors +jets (or leptons from W/Z, charm, b..)
- Signal (jet, muon…) in the central detector + timing with both protons.

Rich diffractive structure of the cross sections as a function of proton momenta



proton pt allows to sample different impact parameters bt
→Opacity Scanner

Figure 3: The dependence of the survival probability, S^2, of the rapidity gaps on the azimuthal [illegible] between the transverse momenta $\vec{p}_{it}$ of the forward going protons in the process $pp \to p + M + p$, for typical values of p_{1t} and p_{2t}.

5. SOFT QCD (MIN MIAS) STUDIES

Main aim: to illuminate our understanding of of multiparticle production. (Alan's talk)

- Detailed comparison of the event structure/correlations… in the Pomeron-Pomeron and Pomeron-proton and pp-collisions.
- Probes of the Pomeron (transverse) size and of the size of the triple (multi)-Pomeron vertex.
- Special (low –lumi) runs with a standard min-bias trigger +2 protons on level 1.
  (Recall: event rate is high!)
  Use of MCS tuned to the LHC min-bias date. if no data available ?
  Smooth variation of the effective energy $s_{PP} = M^2{}_{PP}$

KMR studies: Acta Phys. Polon. B40, 1841 (2009), Eur.Phys.J.C71:1617,2011

Particle distributions, content, correlations (at the same effective energy)

$$dN_{ch}/d\eta, dNi/d\eta, dN_{ch}/dp_t, dNi/dp_t (i = \pi, K, p, \eta, \phi ...)$$

In the PP collisions we expect:

- possible higher yield of η, η',….glueballs;
- larger p_T of secondaries near the edge of a LRG)
- smaller (by a factor of~ 2) radius of BEC.

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Probability of double (multi) parton interactions in PP as compared to pp collisions.
For instance, 2 pairs of dijets with moderate p_T (could expect to be higher ?).

Rates

KMR, Eur.Phys.J.C60:249-264,2009

$$\int d\sigma_{DPE} / d\xi_1 d\xi_2 \sim (10-30)\,\mu b$$

$$0.02 < \xi_{1,2} < 0.2$$

First encouraging results from TOTEM:

- Central mass distribution: (2010, RPs+T2) with 3.m optics
- Double arm coincidence data (Oct. 2011) 90m optics.

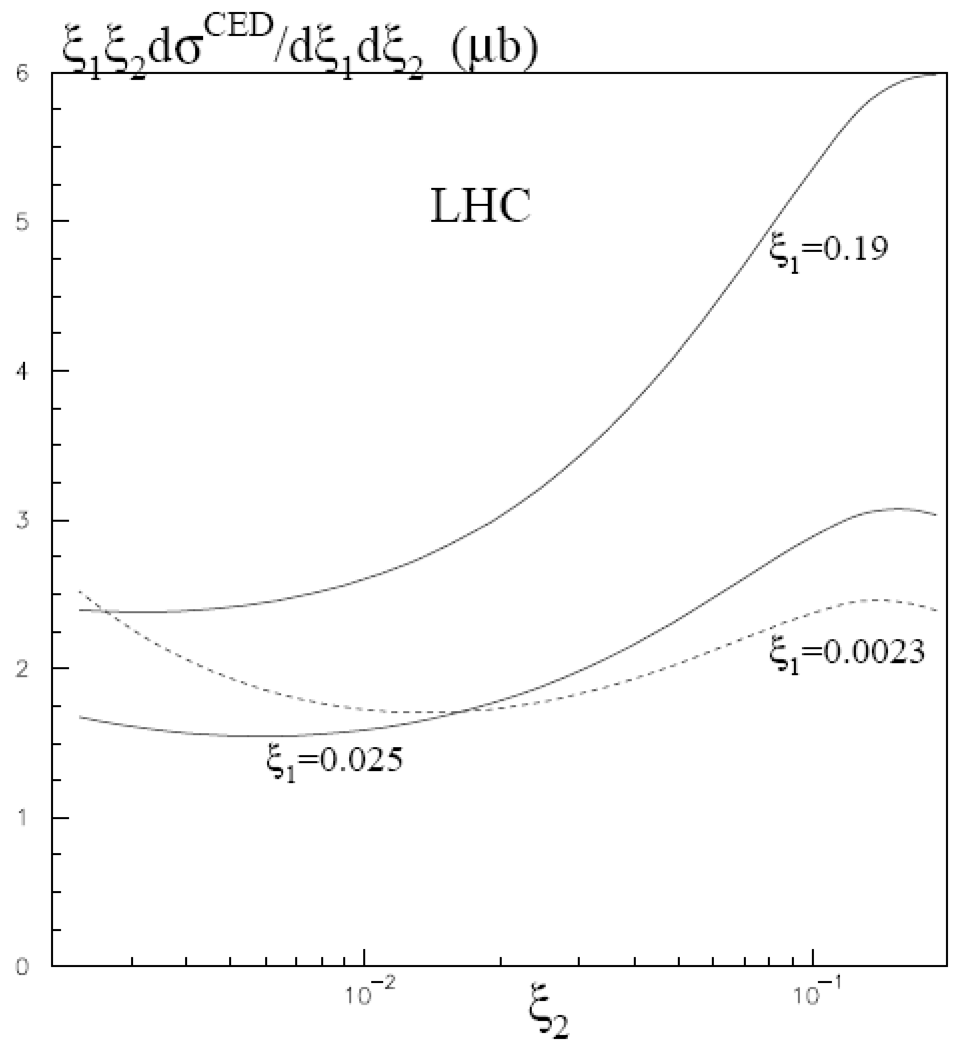
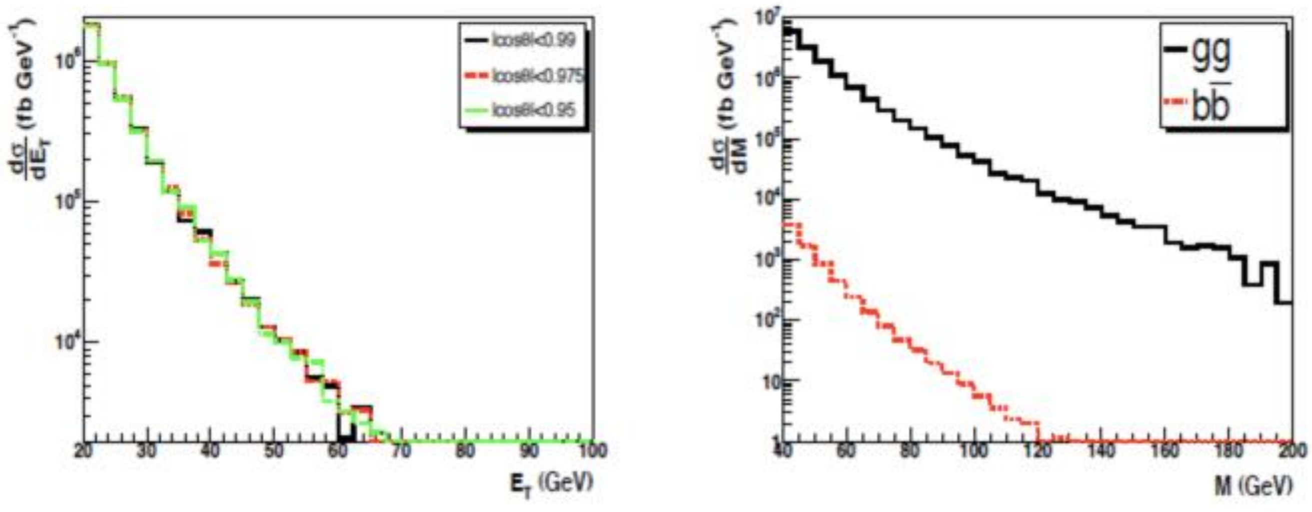


Figure 12: Sample predictions for Central Exclusive Diffractive production at the LHC. The ξ_i's are the momentum fractions of the incoming protons transferred across the rapidity gaps on either side of the centrally produced system of mass $M = \sqrt{\xi_1 \xi_2 s}$.

AFP220 Physics Program

A lot of further theoretical & experimental studies needed



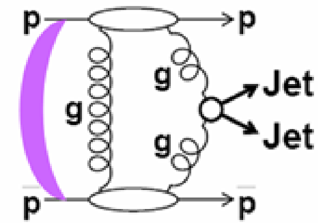
(a) (b)

Figure 4.10: The transverse energy distribution dependence of the gg final state on the $\cos\theta$ (CM) cut for central exclusive masses in the range $40 \leq M \leq 400$ (a). Figure (b) shows the mass distribution for both the gg and $b\bar{b}$ subprocesses with a $|\cos\theta| < 0.95$ cut imposed for comparative purposes.

14 TeV

(From Andy Pilkington)

Exclusive dijet Monitor & Interferometer



- CEP of diphotons (rate permitting) would provide an excellent combined test at M>10-20 GeV (better accuracy!)
- Dijet rate- combined effect of all basic ingredients (Surviv, Sudakov, pdfs, Enhanc. Absp) (E_T > 10 GeV)
- E_T-dependence -dominantly Sudakov (+anom dimens), weaker dependence on S^2.
  At low E_T- higher sensitivity to the Enhanced Absorption
- **When having the proton detectors operational**
  Correlations between proton transverse momenta, azimuthal distribts
  Practically insensitive to pdfs and Sudakov effects.
  High sensitivity to soft model parameters.
  Proton opacity scanner (KMR-02, also Kupco et al-05, Petrov et al -05)
- Comparing dijet signals in different rapidity intervals & pt → study of Sudakov suppression

Advantages

- Comparatively high rate (3 orders of magnitude higher than for the Higgs at the same E_T).

$$\sigma_{jj}^{DPE}(E_T > 20GeV) \sim 10nb, \quad \sigma(DPE) \sim 1-10\mu b$$

- Possibility to separate different effects and to restrict different uncertainties by studying the same process