Diffractive Higgs production at the LHC

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- Definition of the model
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Work done in collaboration with M. Boonekamp (DAPNIA-SPP, CEA Saclay/CERN),
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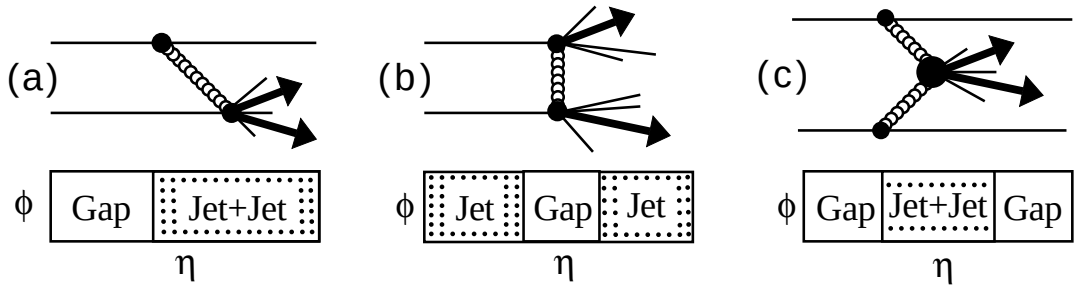
C. Royon (DAPNIA-SPP, CEA Saclay)

Search of the Higgs Boson

- Discovery of the Higgs boson is one of main goals of the present and next hadronic colliders, Tevatron and LHC
- A light Higgs is preferred:
  - precision EW measurements $\Rightarrow M_H < 196$ GeV (95 % C.L.)
  - direct search at LEP $\Rightarrow M_H > 114$ GeV (95 % C.L.)
  - MSSM lightest Higgs $\Rightarrow M_H < 135$ GeV
- Number of interesting channels:
  - $H \rightarrow \gamma\gamma$ ($\approx 0.1\,\%$, $\mathcal{L} \approx 50$ fb^{-1} is needed)
  - $H \rightarrow b\bar{b}$ or $\tau^+\tau^-$ ($\approx 10\,\%$, high background)
  - difficult to explore at low masses ($M_H < 160$ GeV)
    $\Rightarrow$ worthwhile to consider all possible options

Diffraction at Tevatron/LHC



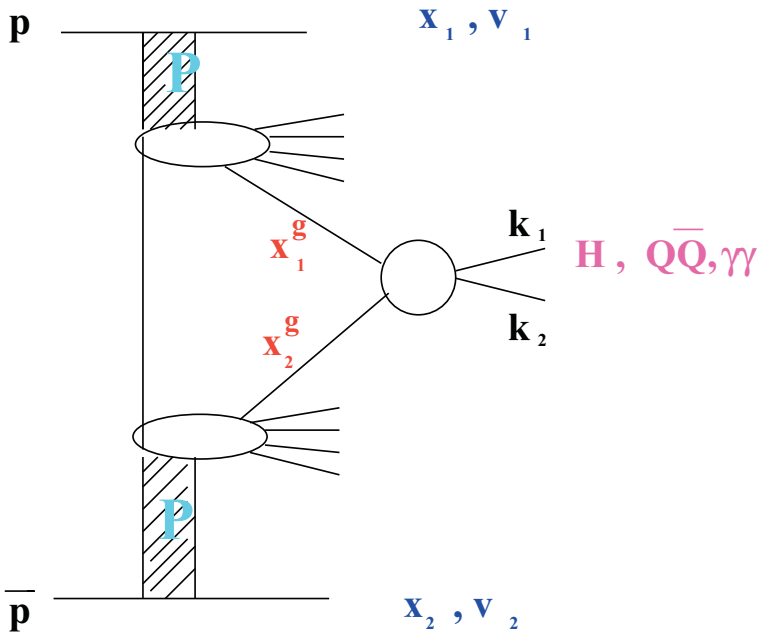
- Kinematic variables
  - t: 4-momentum transfer squared
  - ξ: proton fractional momentum loss (momentum fraction of the proton carried by the pomeron)
  - $\beta = x_{Bj}/\xi$: Bjorken-x of parton inside the pomeron
  - $M^2 = s \cdot \xi_1 \xi_2$: diffractive mass produced

Definition of the model

- "Inclusive" double diffractive production:

M. Boonekamp, R. Peschanski, C. Royon,
hep-ph/0107113, Phys. Rev. Lett. 87 (2001) 251806

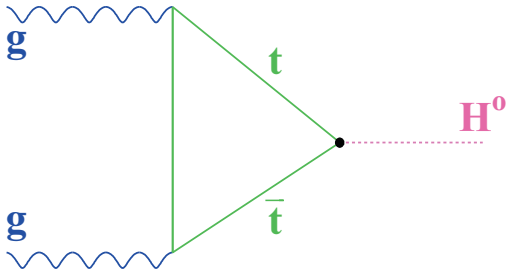
  - protons emit color singlets which collide
  - sub-process: $\mathbb{P} + \mathbb{P} \longrightarrow H + X$
  - protons emerge intact: $pp \longrightarrow pp + (H + X)$
  - take "usual" hadron-hadron cross section to produce hard scattering (Higgs, dijets, $\gamma\gamma$)
  - convolute it with parton distributions in $\mathbb{P}$



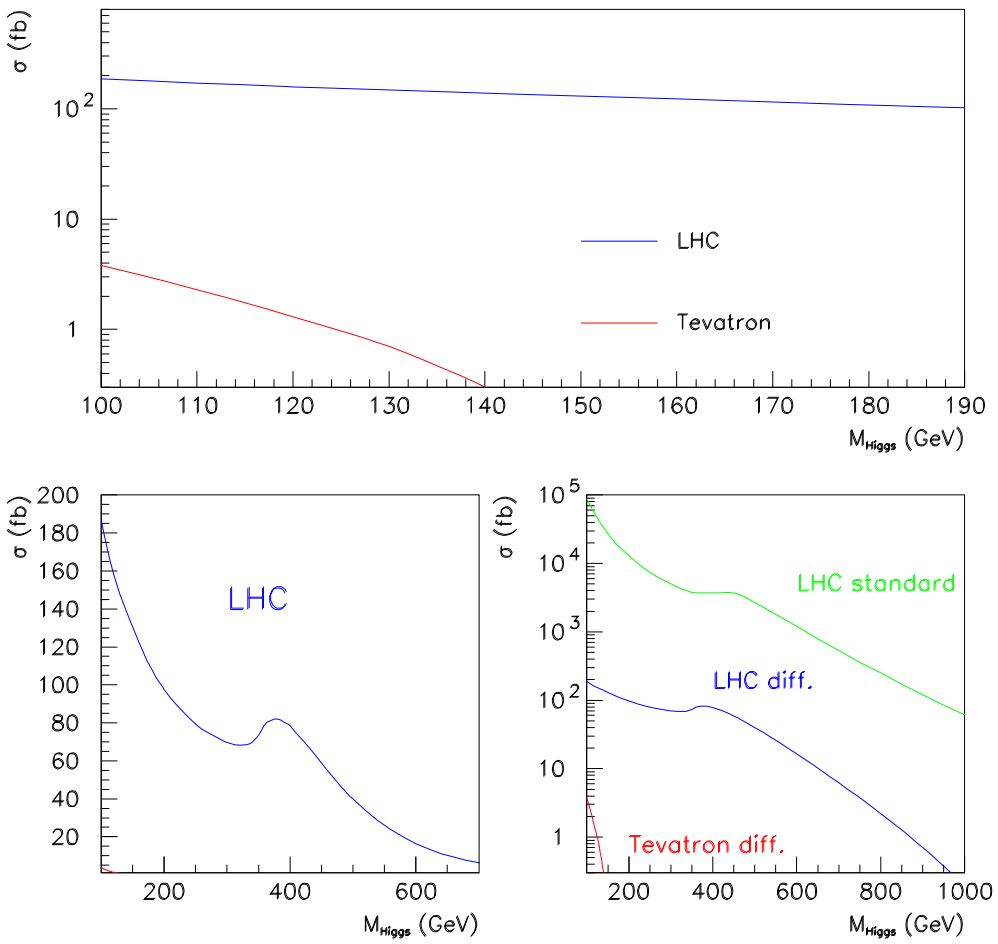
- H1 measured F_2^D and fitted to Regge param.:

Z. Phys. C 76 (1997) 613

  - $zG(z)$, $zQ(z)$ ($\mathbb{P}$ parton densities)



Diffractive Higgs cross sections



- almost impossible for the Tevatron
- probably feasible at the LHC

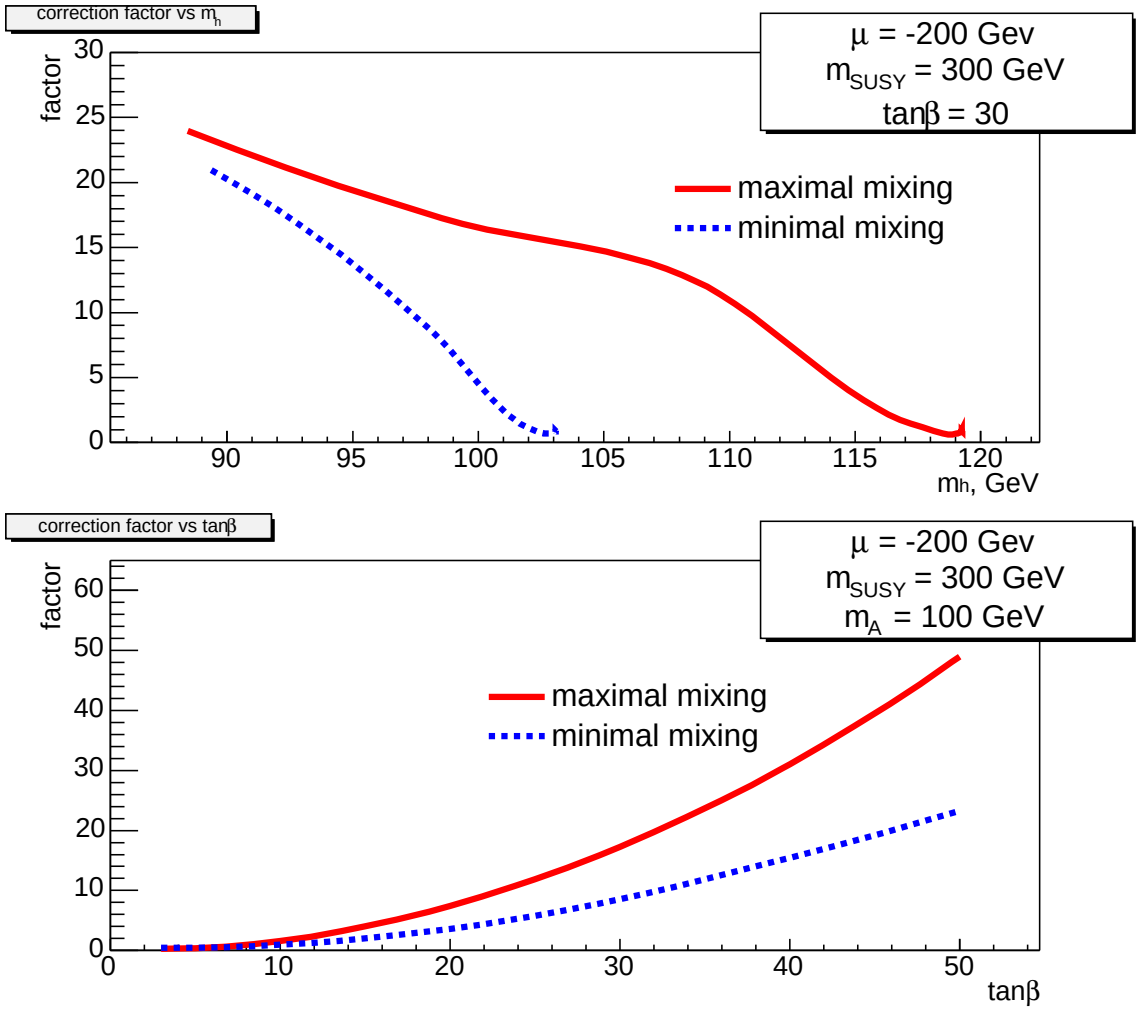
Light MSSM Higgs

- Why consider MSSM?
  - fits to the precision EW observables (for sufficiently heavy SUSY spectrum)
  - MSSM lightest Higgs with $M_H < 135$ GeV
  - richer Higgs boson spectrum:
    - two CP-even Higgs bosons h and H
    - one CP-odd Higgs boson A
    - one charged Higgs boson $H^{\pm}$
  - top and also bottom quark loops should be considered to produce MSSM Higgs
  - using two-loops calculations for MSSM Higgs boson masses and couplings `FeynHiggs`, S. Heinemeyer et al., hep-ph/0002213
  - considerable effects of the squark mixing (M. Carena, H. E. Haber, hep-ph/0208209):

$$m_h^2 \lesssim m_Z^2 + \frac{3g^2 m_t^4}{8\pi^2 m_W^2}\left[\ln\left(\frac{M_S^2}{m_t^2}\right) + \frac{X_t^2}{M_S^2}\left(1 - \frac{X_t^2}{12M_S^2}\right)\right]$$

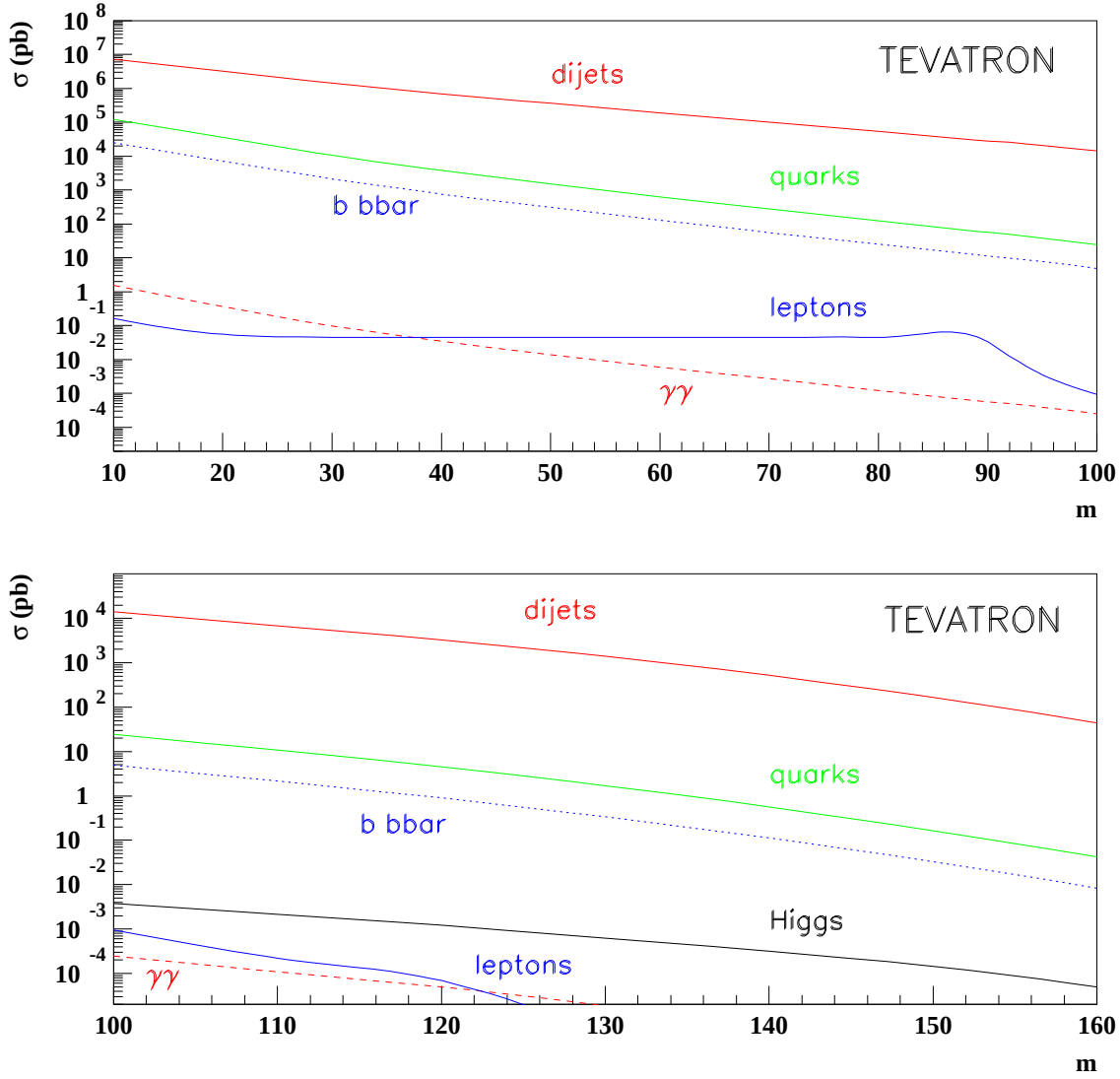
X_t - top-squark mixing parameter, M_S – average of two top-squark squared-masses
$X_t \approx 0$ – "minimal mixing", $X_t \approx \sqrt{6}M_S$ – "maximal mixing"

Cross section enhancement factor

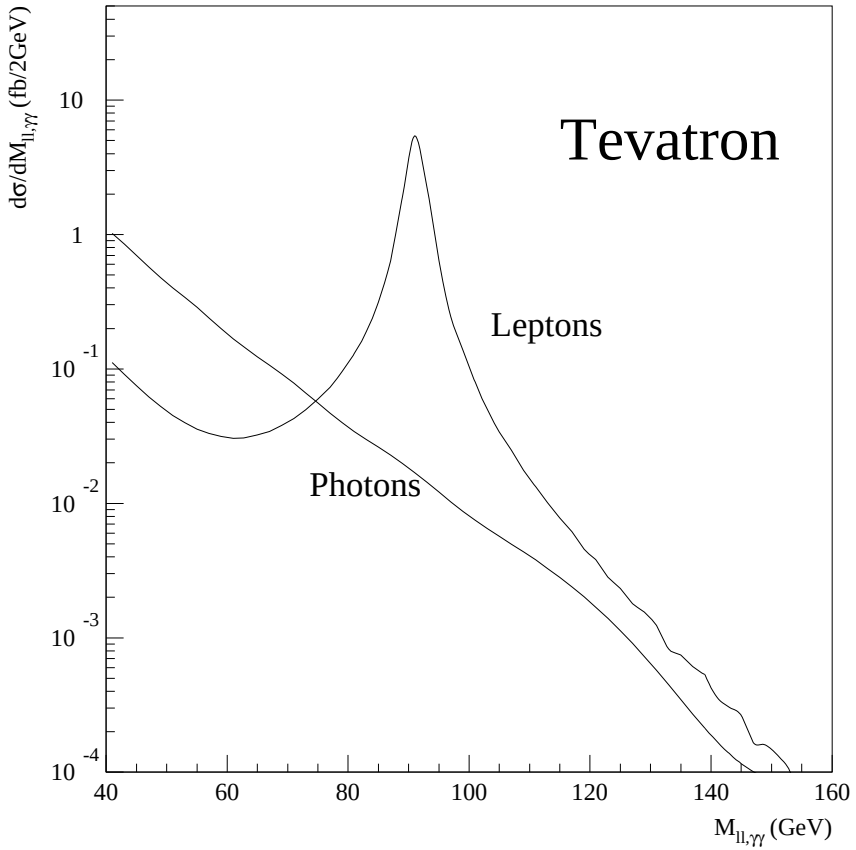


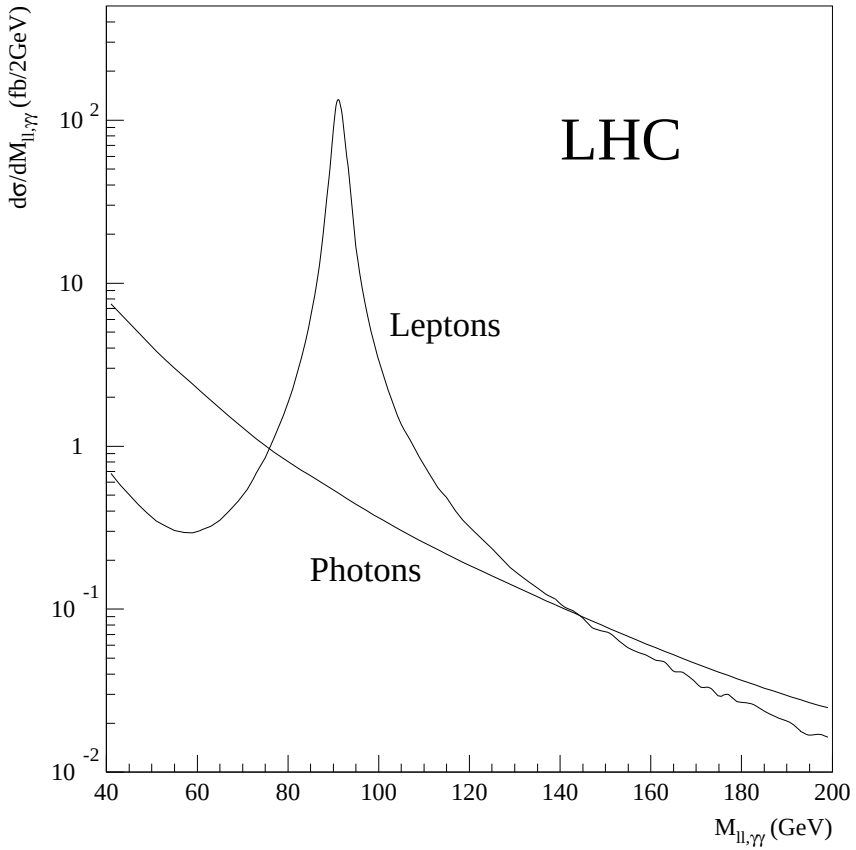
What can be done before LHC?

- Testing model using the Tevatron data
- Measure diffractive cross sections:
  - dijet
  - $\gamma\gamma$
  - ll



Diphoton and dilepton cross sections

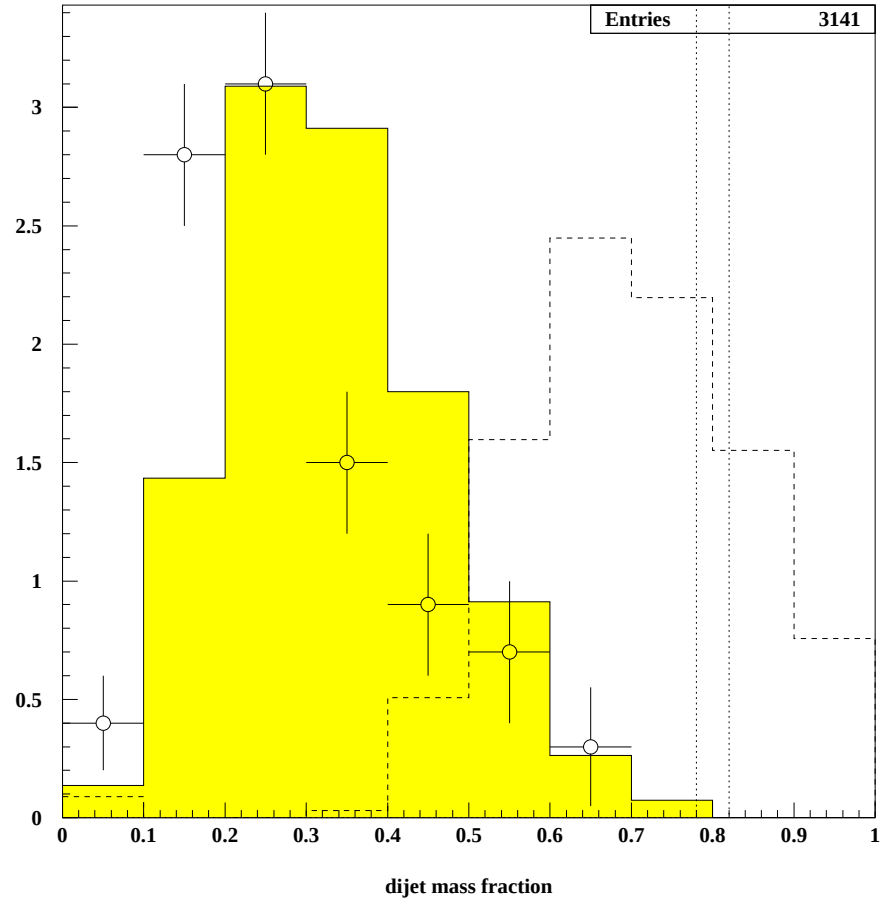




- Diphoton and dilepton production differential cross sections (fb) at the Tevatron and LHC. $E_T > 10$ GeV, $|\eta| < 4$

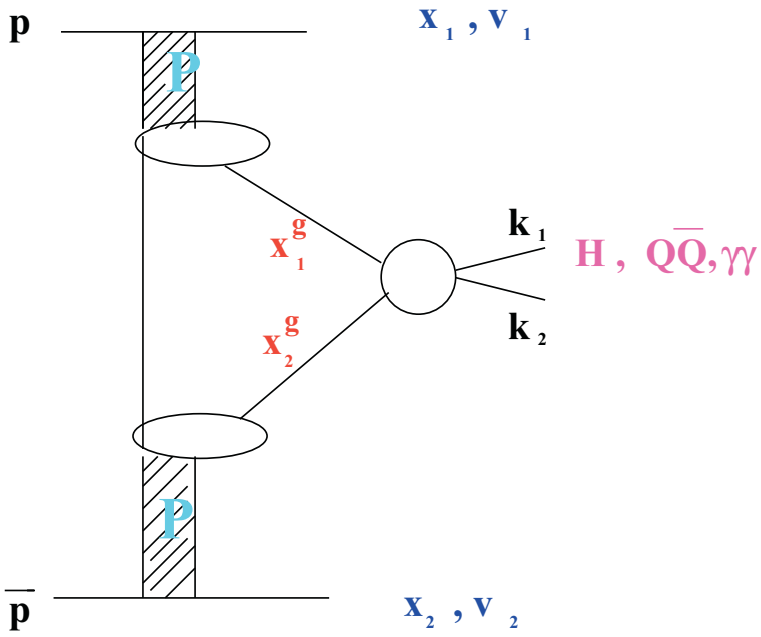
Dijet mass fraction

- Dijet mass fraction measured at the Tevatron (CDF Run I) compared with:
  - inclusive model prediction (solid line) – shape is in good agreement with data



"Exclusive" model

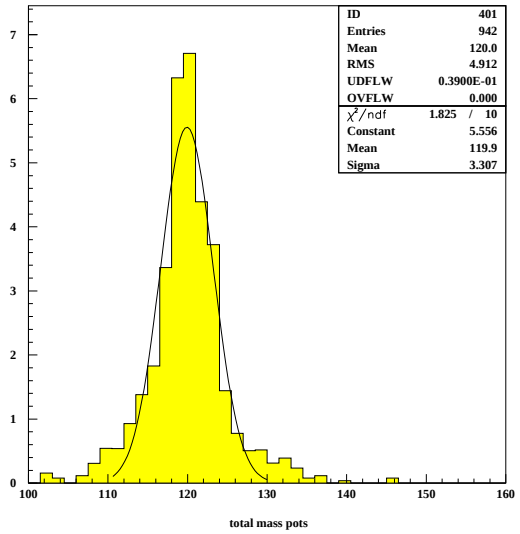
- For events without radiation ($p + p \rightarrow p + H + p$):
  - all energy is used to produce the Higgs boson
  - $xG \sim \delta$ (leading to similar results as Durham)
  - rapidity gaps between protons and H
  - H mass reconstruction from the protons missing mass:
    - $M_H^2 = (p_1 + p_2 - p_1' - p_2')^2 = s \cdot \xi_1 \xi_2$
      (ξ - fractional momentum loss of proton)
    - not affected by central mass resolution



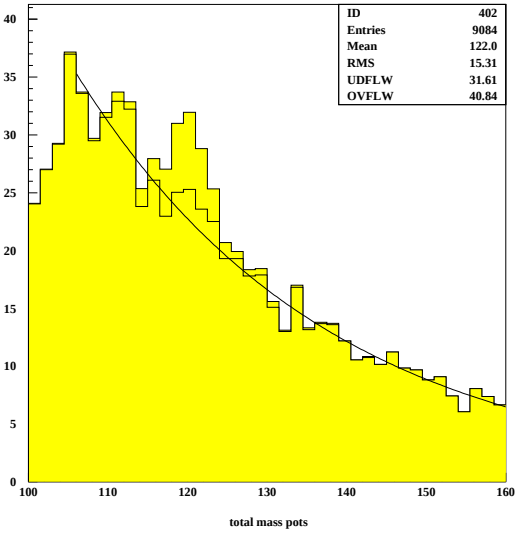
- cross section after cut on dijet mass fraction at 0.8: 0.16 nb
- limit from CDF Run I: 3.7 nb

Background and signal

- Normalization: All plots normalized to 100 fb^{-1}
- Simulation: Fast simulation of the CMS detector, roman pot acceptance and resolution
- Take into account one bin of 2 GeV width, one of 4 GeV



M_H	Signal		Background	
	2 GeV	4 GeV	2 GeV	4 GeV
120	8.4	15.6	26.9	55.6
125	7.4	13.3	21.9	45.4
130	6.5	12.6	19.5	38.0
135	5.8	11.0	15.9	32.1
140	4.2	8.2	13.9	27.3



Summary

- Exclusive Higgs production:
  - mass constraint using forward proton detectors
  - moderate background
  - small cross section
  - need experimental evidence
- Inclusive Higgs production:
  - larger cross sections but less clean signal
  - can be tested at the Tevatron (photon and lepton production, dijet cross sections and dijet mass fraction)
- light MSSM Higgs $\Rightarrow$ much higher cross section
- Experimental studies in progress
  - starting from Tevatron measurements we can get better prediction for LHC
  - gluon densities in pomeron will be measured by CDF and DØ