Diffractive Higgs production at the LHC: results and open questions

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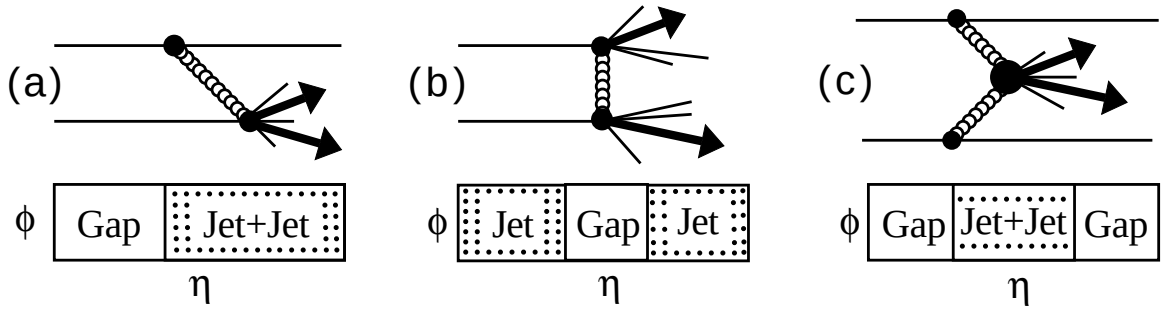
Contents:

- Inclusive Higgs production
- Exclusive Higgs production: S/B
- Exclusive event production at the Tevatron
- Survival probabilities: a new study in DØ
  Alexander 's talk
- Triggering on Higgs events

Diffraction at Tevatron/LHC

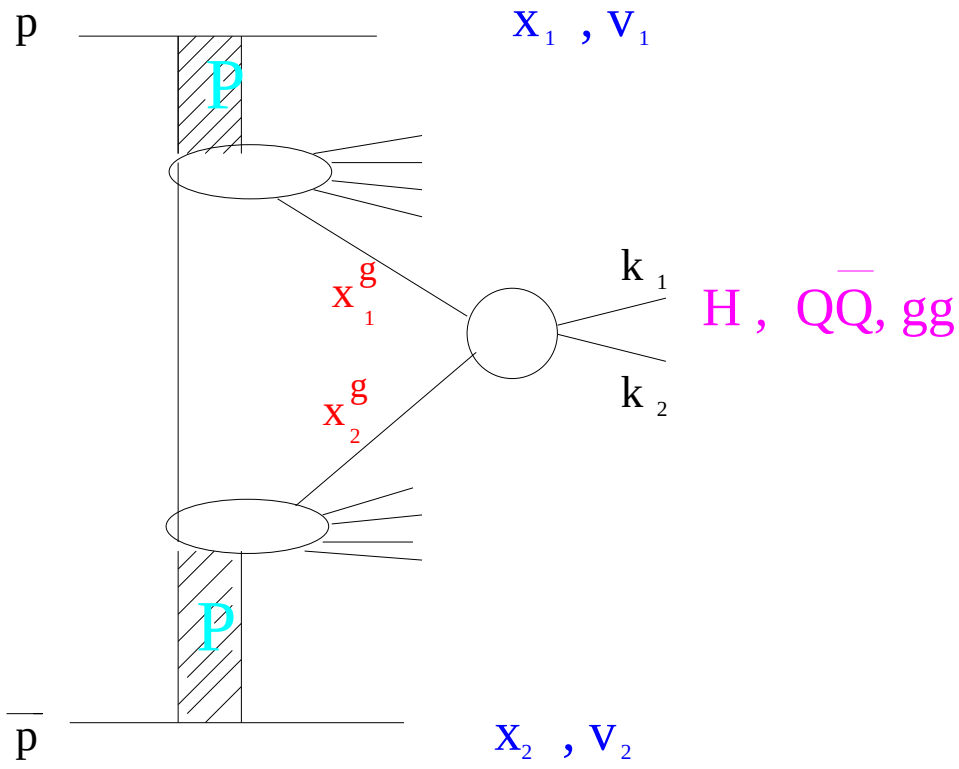


Kinematic variables

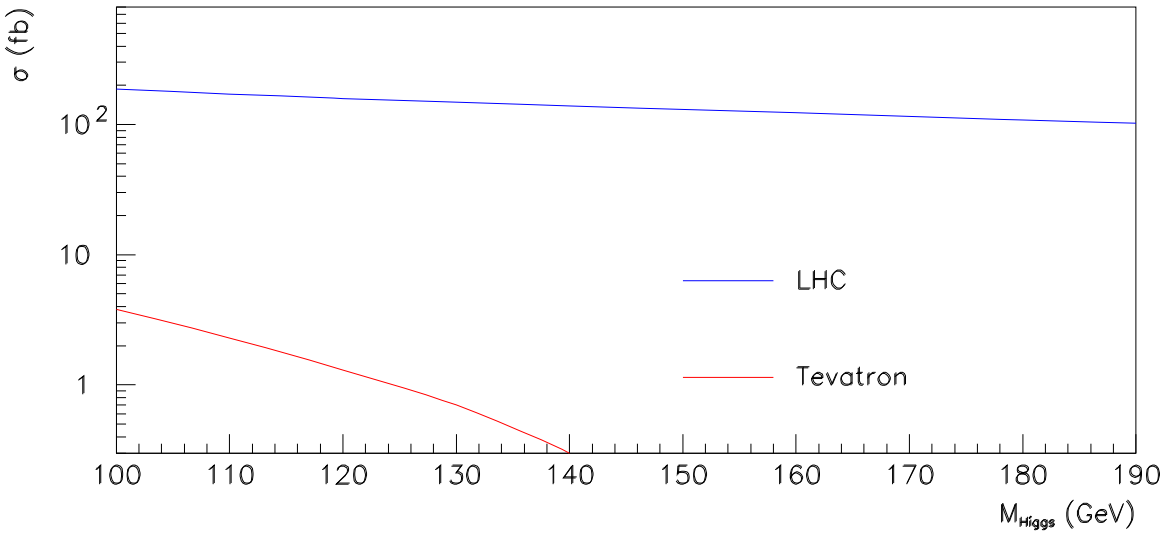
- t: 4-momentum transfer squared
- ξ: proton fractional momentum loss (momentum fraction of the proton carried by the pomeron)
- $\beta = x_{Bj}/\xi$: Bjorken-x of parton inside the pomeron
- $M^2 = s\xi$: diffractive mass produced
- $\Delta y \sim \Delta\eta \sim \log 1/\xi$: rapidity gap

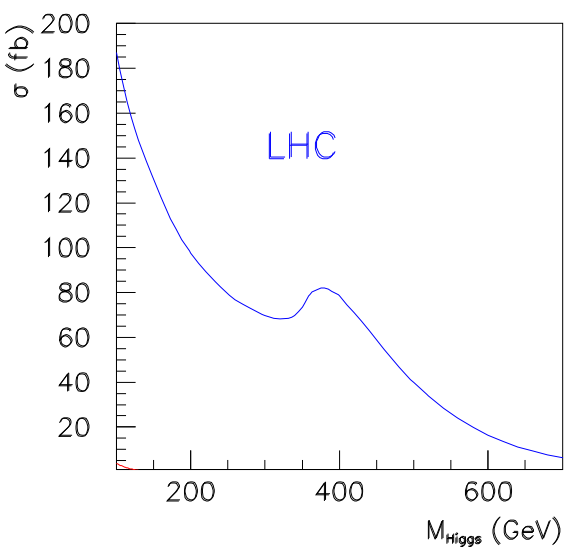
"Inclusive" models

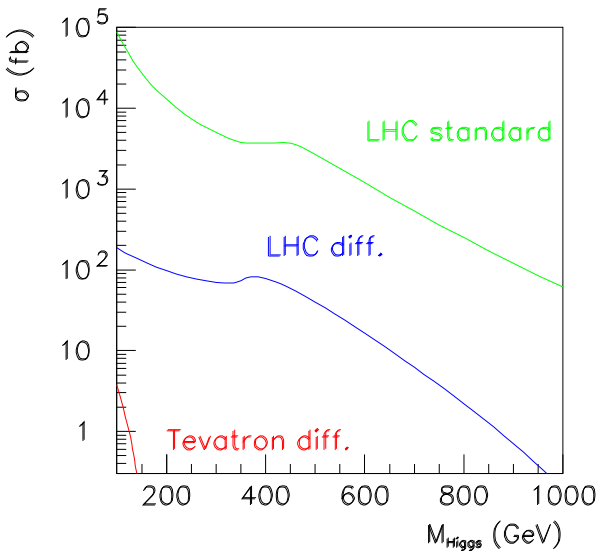
Non-factorizable models: Take the hadron-hadron "usual" cross section convoluted with the parton distributions in the pomeron



Tevatron and LHC cross sections



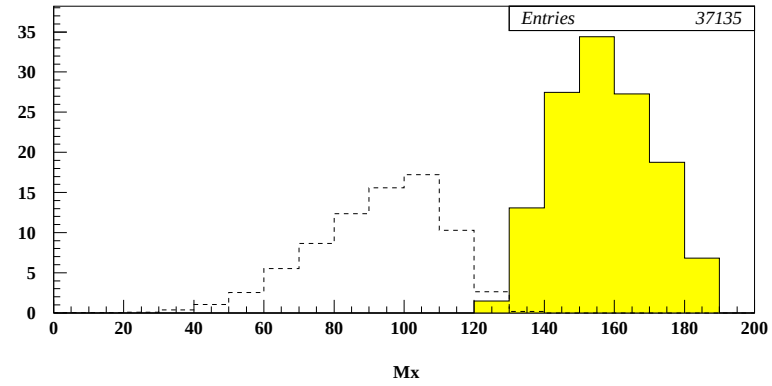


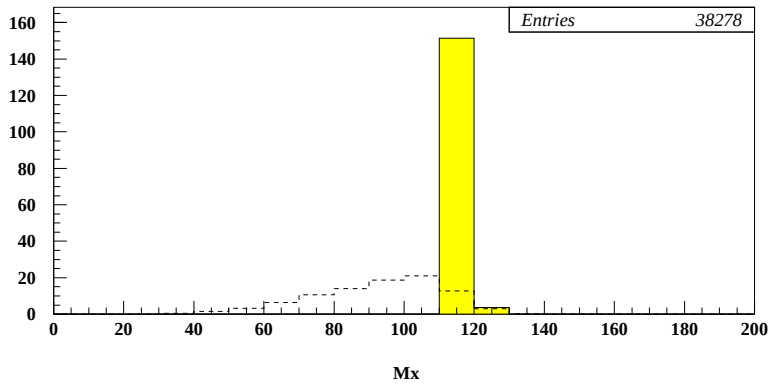


Open questions: can one use xG in Pomeron from HERA???

Remarks on Higgs production (inclusive models)

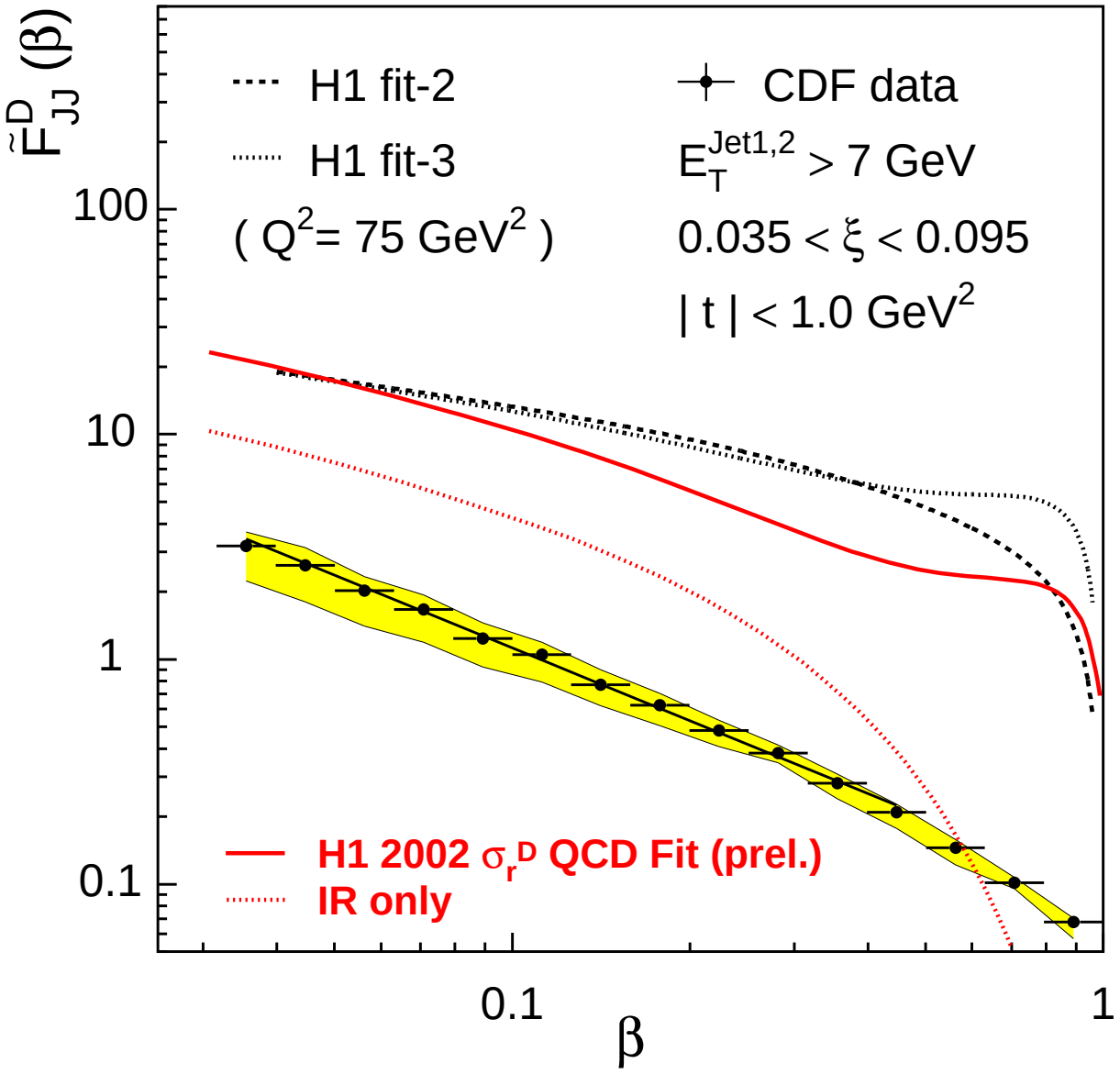
- Gluon density in pomeron from HERA: used for the Tevatron and the LHC
- Energy losses due to pomeron remnants: difficult to reconstruct Higgs masses even using roman pot information → cut on this amount of energy or "exclusive events"





Extraction of xG in pomeron from CDF data

Comparison of xG in pomeron from H1 (full red line) compared to CDF measurement: Difference in normalisation, shapes similar

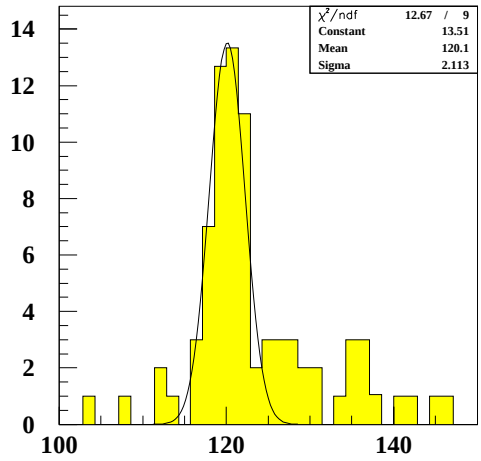


Pomeron remnant tagging possibility

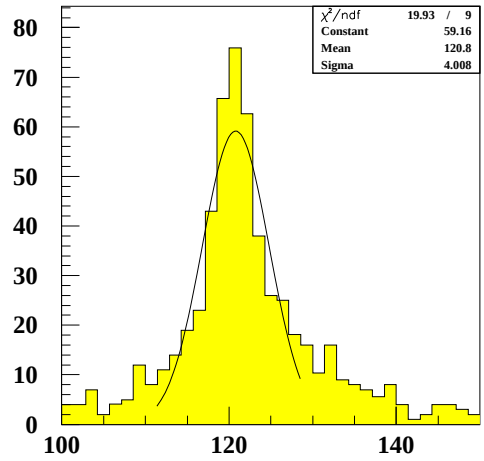
- Higgs mass reconstruction: $M_{Higgs} = \sqrt{\xi_1 \xi_2 S}$ nice method to reconstruct Higgs mass provided radiation is not too big. We just saw that the resolution is much worse without the possibility of measuring the pomeron remnants.
- Question: Where are the pomeron remnants going in pseudorapidity? Is it possible to tag them?
- New taggers at high η: CMS might have the possibility to install such taggers up to $\eta = 7.5$.
- In the simulated plots, we assume a resolution of $100\%/\sqrt{E}$ for the taggers

Resolution on Higgs mass

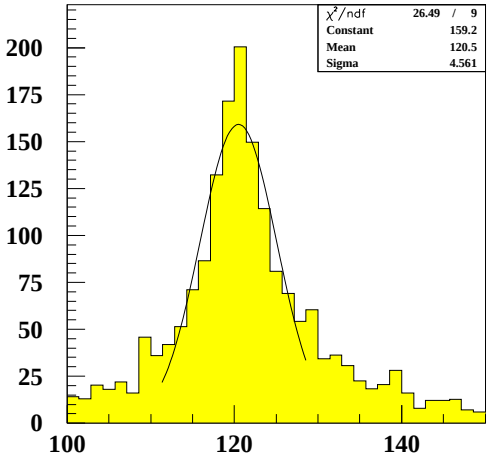
$M_{Higgs} = 120$ GeV at LHC at simulation level
(assumed resolution of taggers $\sim 100\%/\sqrt{E}$)



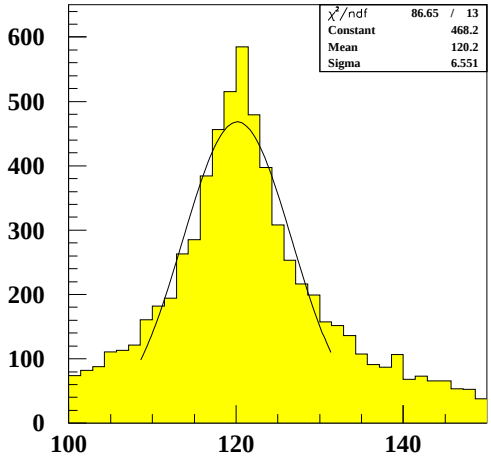
M Higgs - 20 GeV



M Higgs - 50 GeV

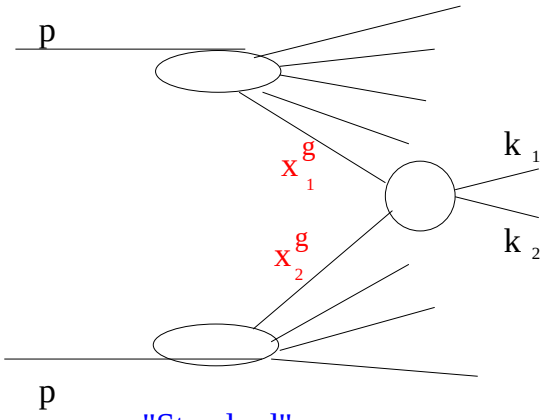


M Higgs - 100 GeV



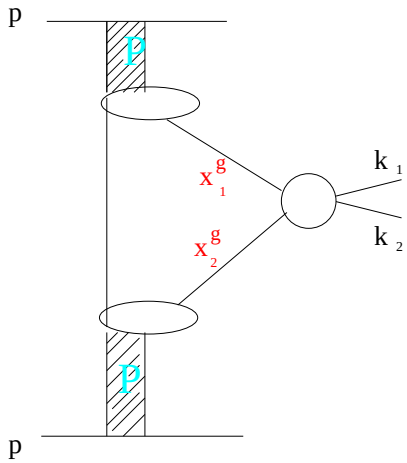
M Higgs - 500 GeV

"Exclusive models"



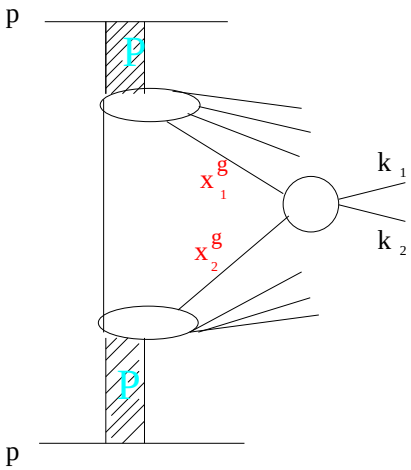
H , $Q\bar{Q}$, $\gamma\gamma$

"Standard"



H , $Q\bar{Q}$, $\gamma\gamma$

"Exclusive "



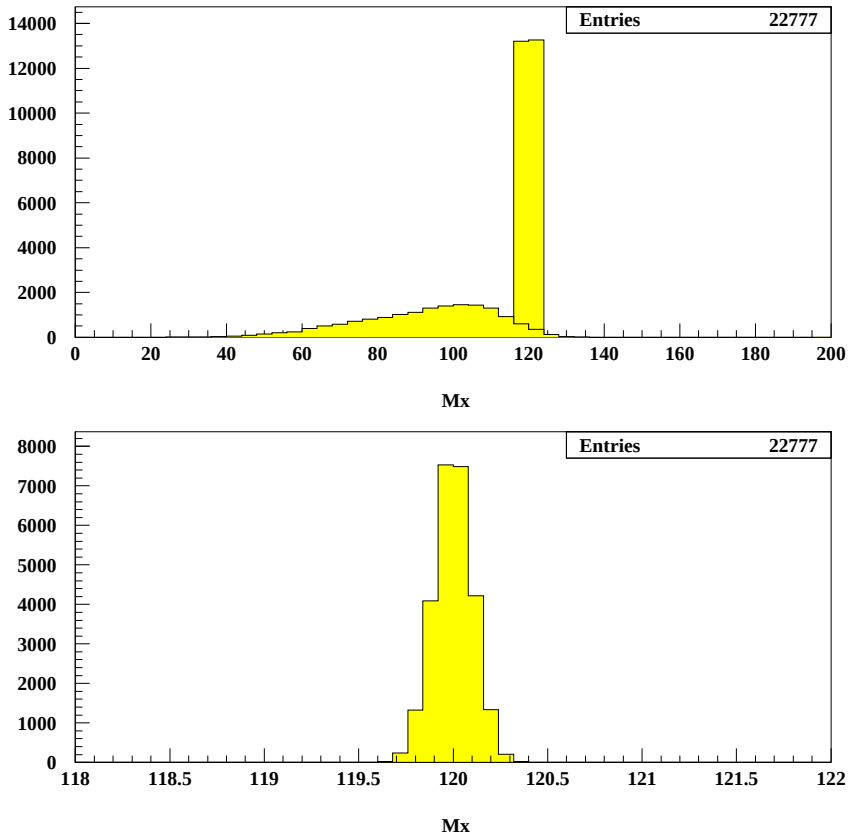
H , $Q\bar{Q}$, $\gamma\gamma$

"Inclusive"

All the energy is used to produce the Higgs (or the dijets), namely $xG \sim \delta$

Advantage of exclusive Higgs production?

- Good Higgs mass reconstruction: fully constrained system, Higgs mass reconstructed using both tagged protons in the final state ($p\bar{p} \to p\bar{p}H$)
- $M_H = \sqrt{\xi_p \xi_{\bar{p}} S}$
- No energy loss in pomeron "remnants"



Remarks on quasi-exclusive events

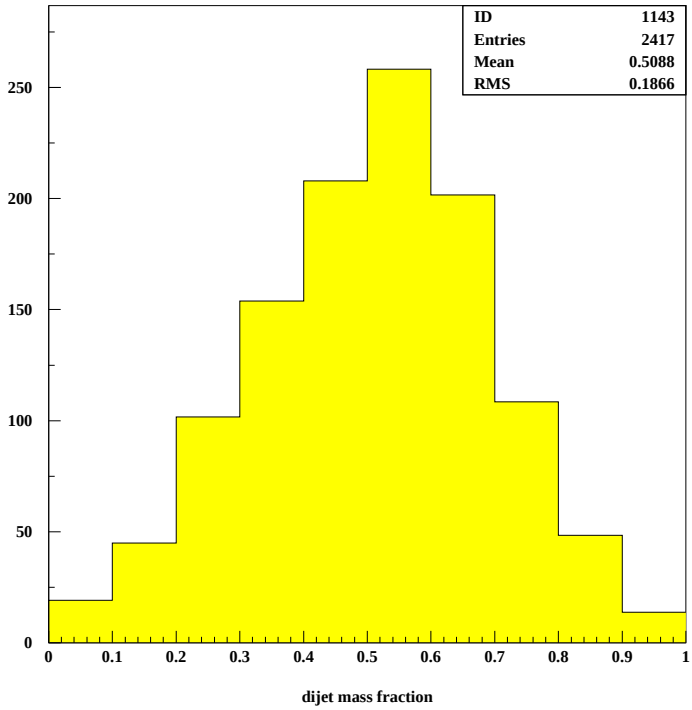
- Quasi-exclusive events: events for which the pomeron remnant energy is very small and cannot be measured experimentally (cannot be distinguished experimentally from pure exclusive events)
- Cross section: about the same as exclusive events ($xG > 0.95$), their existence is certain (tail of inclusive distributions but not well constrained yet)
- Quasi-exclusive b-jet background: to be added for exclusive background to exclusive signal, Can we apply the J_z=0 rule to those events?????
- Quasi-exclusive events: interesting to be studied in more details (S/B...)

DPEMC Monte Carlo

- DPEMC (Double Pomeron Exchange Monte Carlo): New generator with Bialas Landshoff formalism, http://boonekam.home.cern.ch/boonekam/dpemc.htm, hep-ph/0312273
- Interface with Herwig: for hadronisation, same interface as for Pomwig
- Exclusive and inclusive processes included: Higgs, dijets, diphotons, dileptons, SUSY, QED, Z, W..., Durham formalism being implemented
- New MC in preparation: based on Durham formalism, B. Cox, J. Monk..., useful for comparison, will also be included in DPEMC

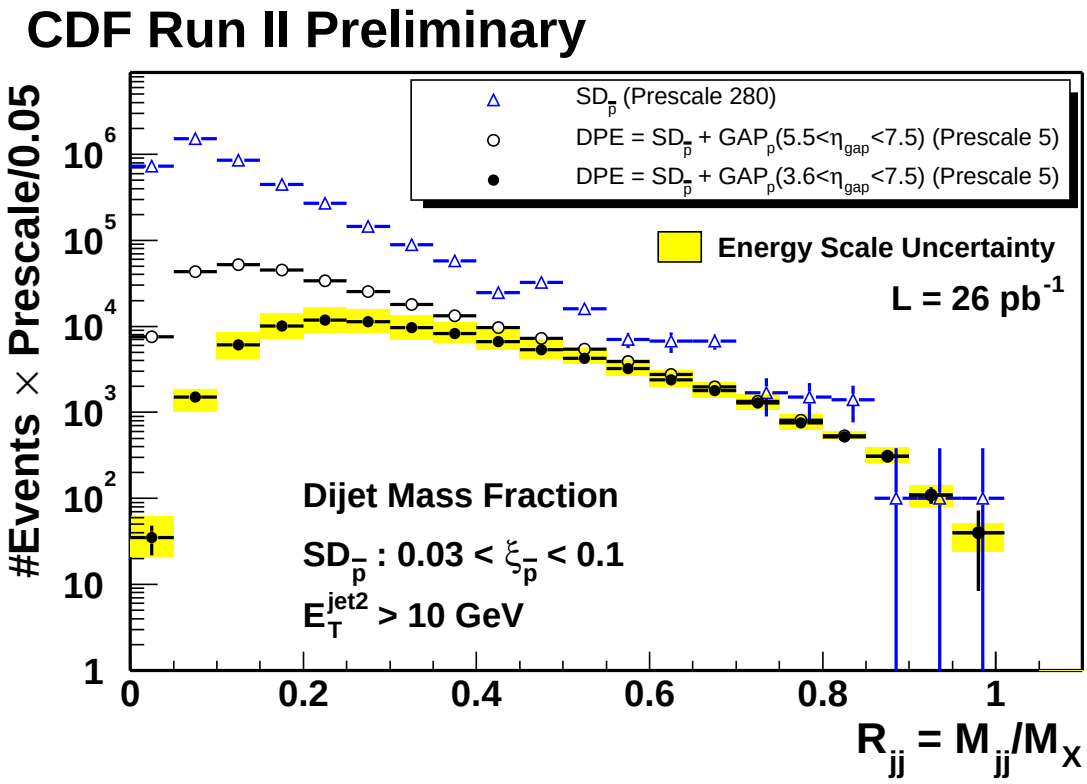
"Exclusive" jet production at the Tevatron

- Cross section for exclusive jets within the CDF run I acceptance (jets with $p_T > 7GeV$): 64 nb, after survival gap probability: $\sim$ 6.4 nb
- Cross section after cut on dijet mass fraction at 0.8: 0.16 nb (limit from CDF: 3.7 nb) Very few events at high values of the dijet mass fraction: huge smearing after simulation...



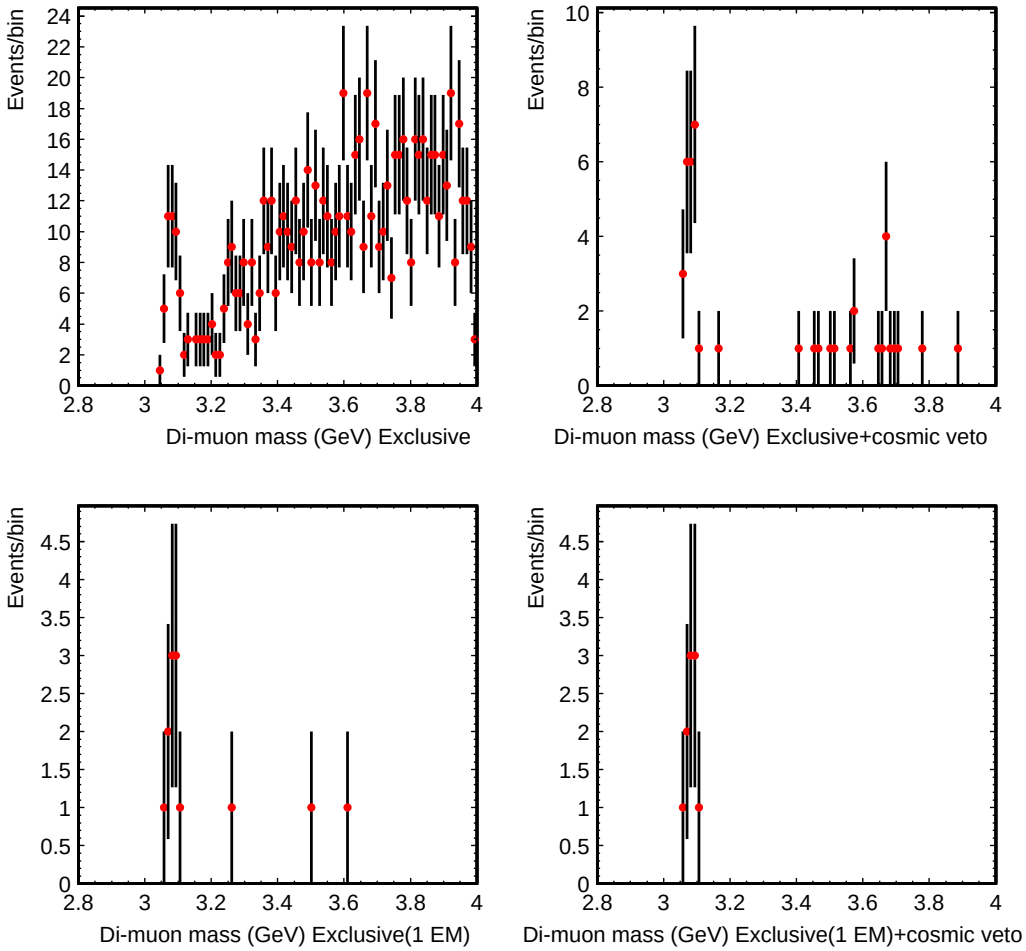
"Exclusive" jet production at CDF

Look for diffractive dijets at high dijet mass fraction: difficult to distinguish between exclusive or quasi-exclusive events



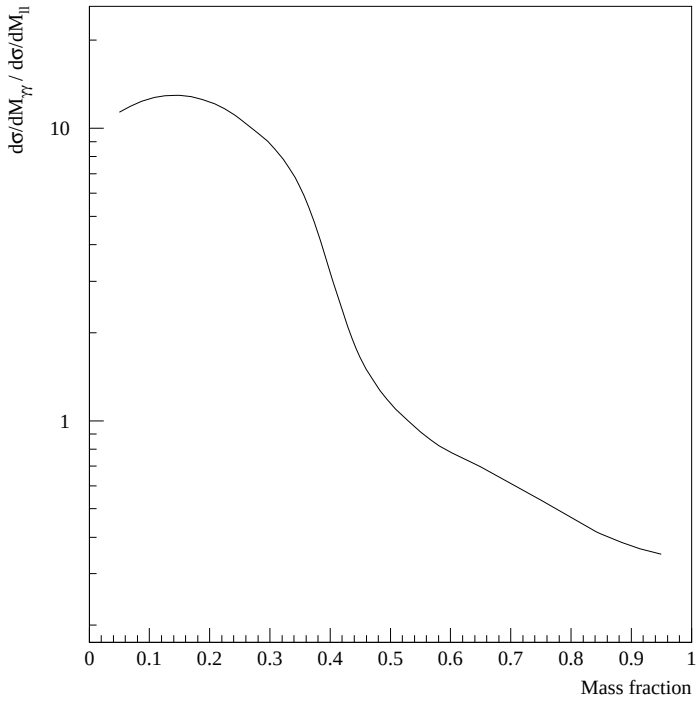
Exclusive χ_c production at CDF

Look for events with two muons and two rapidity gaps ($\chi_C^0 \to J/\Psi\gamma \to \mu^+\mu^-\gamma$)



Existence of exclusive events

Test of the existence of exclusive events

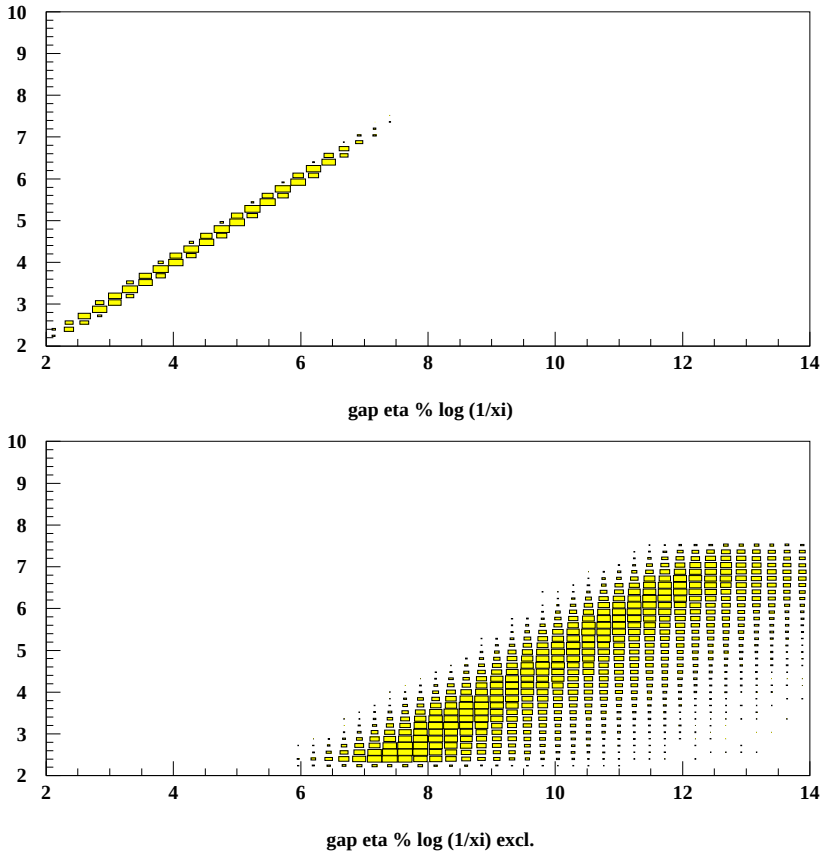


Dilepton and diphoton cross section ratio as a function of the diphoton/dilepton mass: no dilepton event for exclusive models: change of slope of ratio if exclusive events exist

Other methods: ratio b-jets / all jets, compare $log(1/\xi)$ computed using roman pots and size or rapidity gap since the gap is larger for exclusive events

Existence of exclusive events

Correlation between size of rapidity gap and $log1/\xi$ for inclusive and exclusive (or quasi-exclusive) events



"Exclusive" production at the LHC

- Survival probability: estimated to be ~ 0.03
- Exclusive $b\bar{b}$ cross section (for jets with $p_T > 25$ GeV): 70.1 pb * 0.03 = 2.1 pb
- Exclusive Higgs production (in fb) after applying the gap survival probability

M_{Higgs}	σ (fb)
120	3.9
125	3.5
130	3.1
135	2.5
140	2.0

Background and signal

- Signal: DPEMC in exclusive mode production with the Bialas Landshoff formalism
- Exclusive background: Exclusive $b\bar{b}$ production with DPEMC in exclusive mode
- Roman pot acceptance: $t < 2$ GeV^2, $0.002 < \xi < 0.2$ (roman pots at 215 m, 308-336 m, 420 m) (roman pot acceptance from Helsinki group (full simulation of the beam line using the MAD program)
- Simulation: Fast simulation of the CMS detector

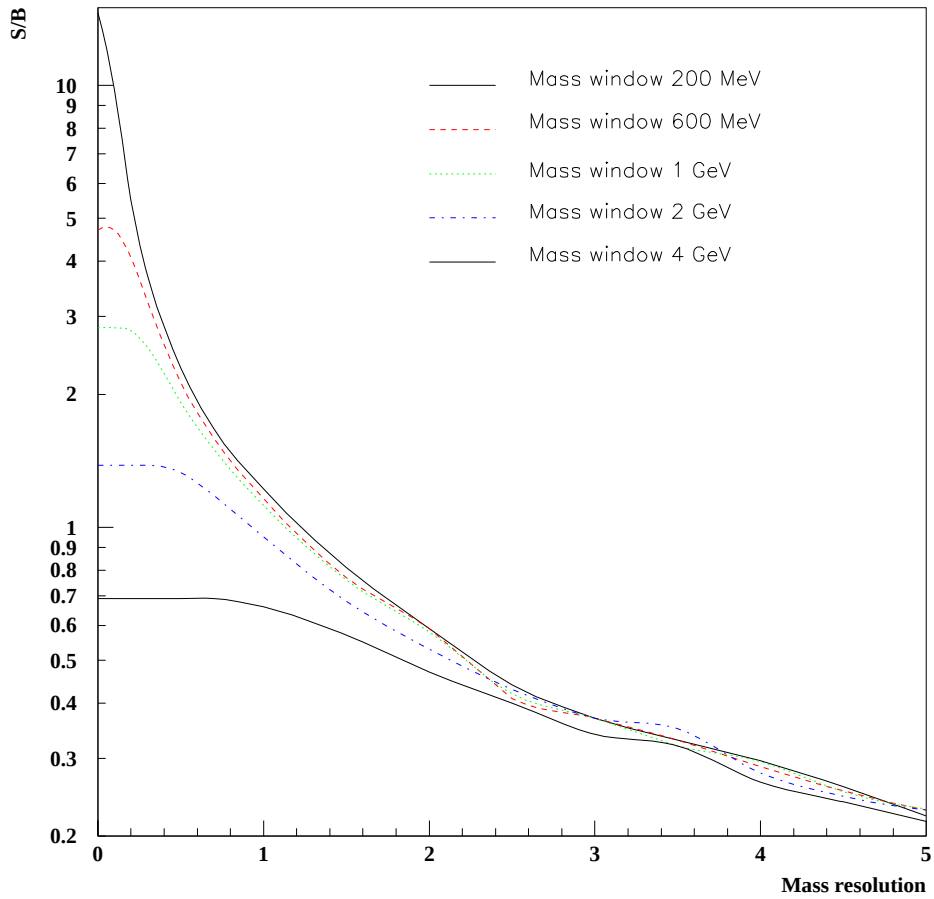
LHC: where to put roman pot detectors

3 different options to implement roman pot detectors

- (1) 215 meter pots (warm section) in addition to Totem $|t| < 2$ GeV^2, $0.02 < \xi > 0.2$, can be introduced in trigger and for luminosity determination
- (2) 308-336 meter pots (cold section) $|t| < 2$ GeV^2, $0.003 < \xi < 0.025$ difficult technically
- (3) 420 meter pots $|t| < 2$ GeV^2, $0.002 < \xi > 0.016$

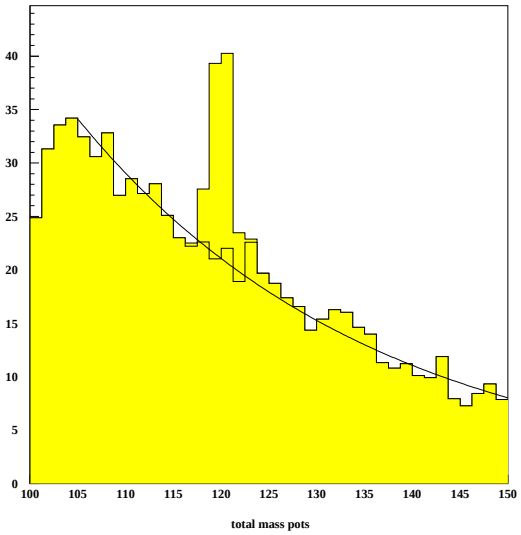
Signal over background

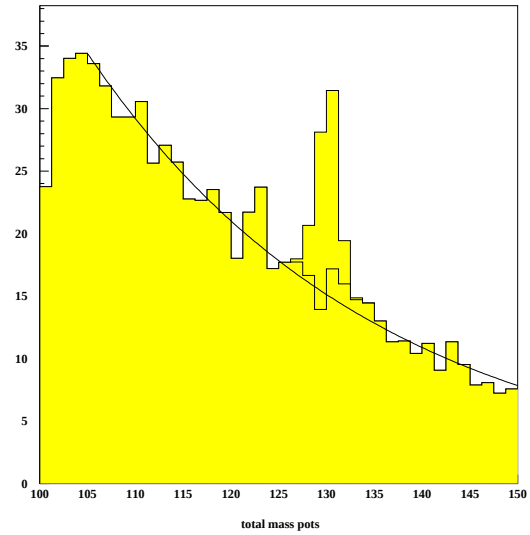
For a Higgs mass of 120 GeV and for different mass windows as a function of the Higgs mass resolution

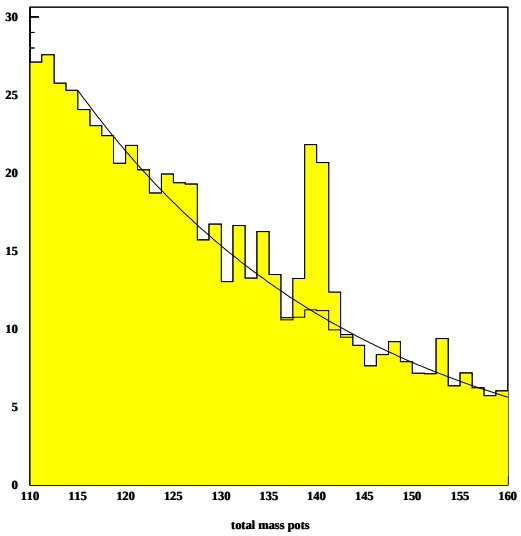


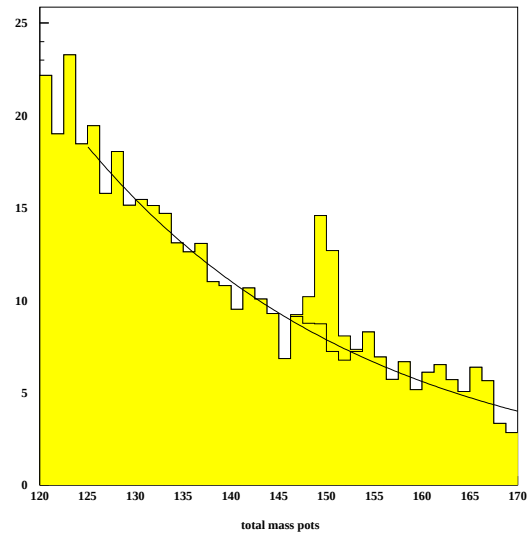
Signal and background

Signal and background for different Higgs masses for 100 fb^{-1}









Signal over background

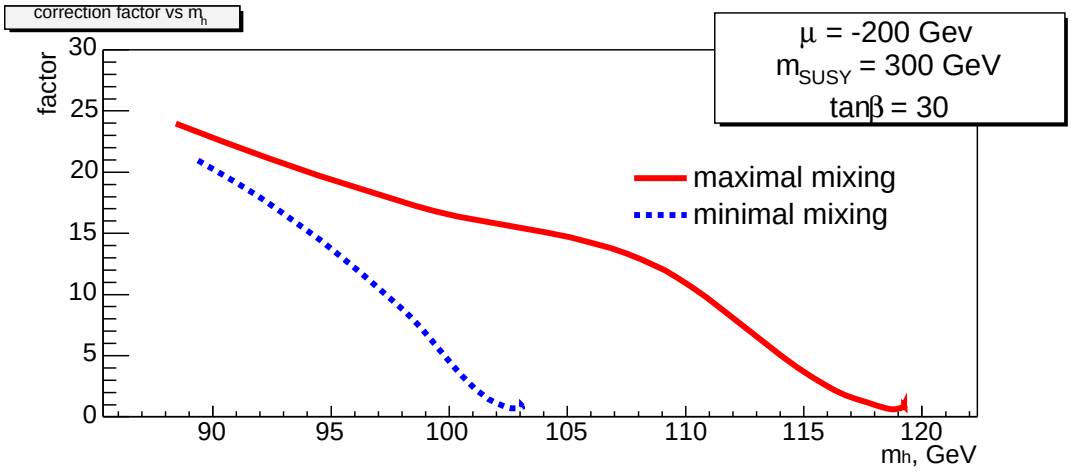
Signal over background for 1 mass window (2 GeV wide) for 100 fb^{-1} assuming a Higgs mass resolution of 1 GeV

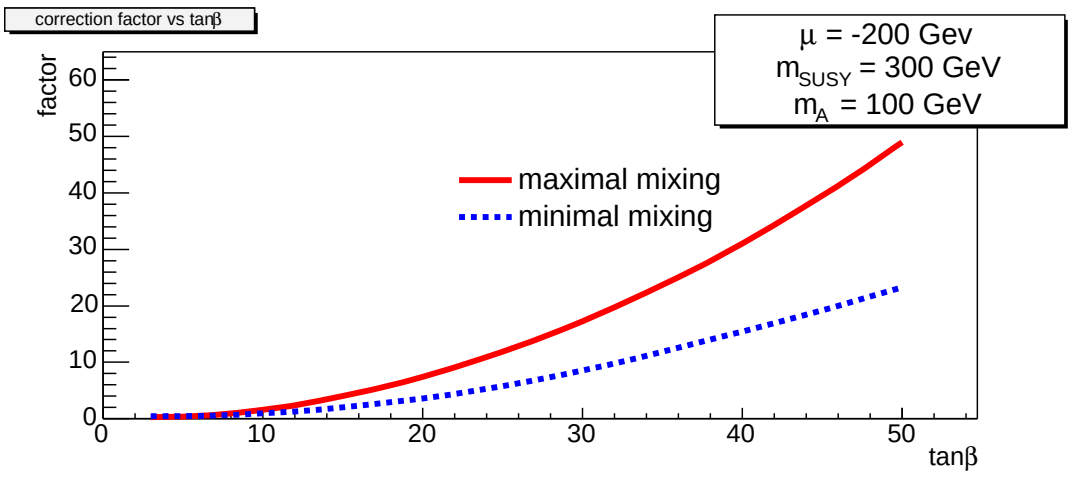
M_{Higgs}	signal	background	S/B	σ
120	27.1	28.5	0.95	5.1
130	20.6	18.8	1.10	4.8
140	12.6	11.7	1.08	3.7
150	7.0	8.9	0.69	2.3

NB: if only tags at 420 m, numbers have to be divided by about 50%

Diffractive SUSY Higgs production

High $\tan\beta$: top and bottom loops to be considered, enhance the cross section by up to a factor 50 (worth looking into Higgs decaying into $b\bar{b}$ since branching ratio of Higgs decaying into $\gamma\gamma$ smaller at high $\tan\beta$, standard search in $\gamma\gamma$ does not benefit from the increase of cross section)





Open questions on exclusive Higgs production

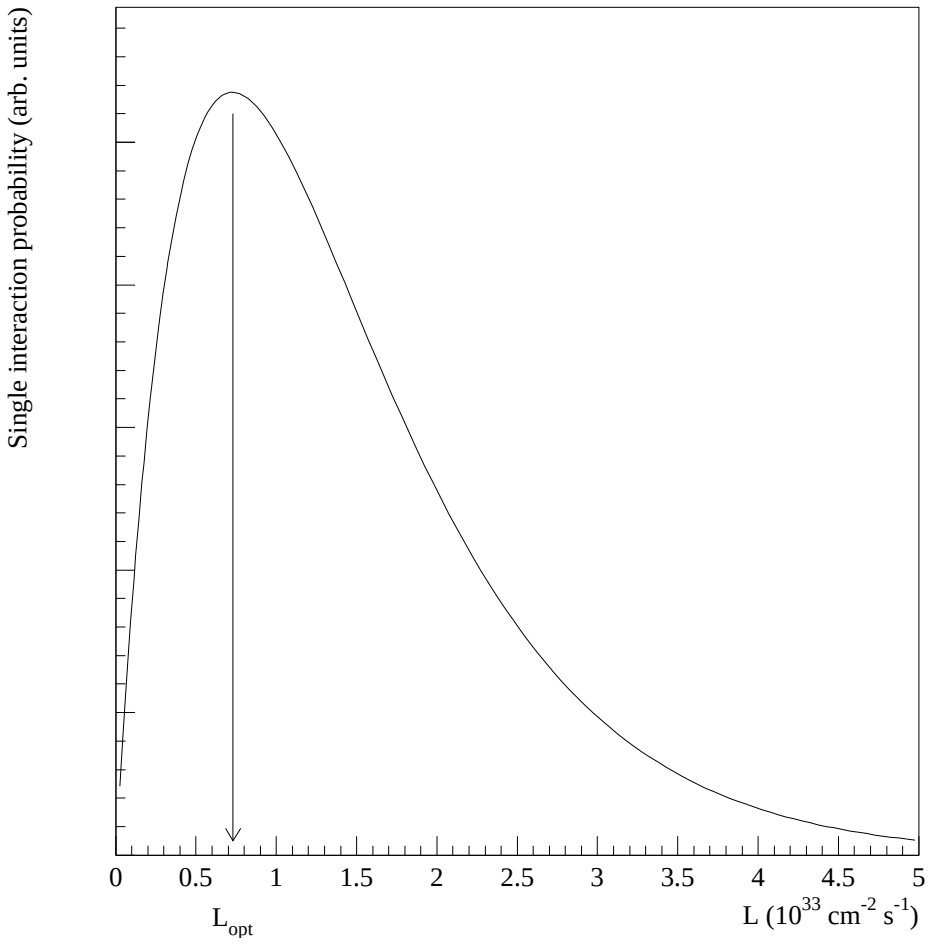
- More precise extraction of parton densities in pomeron: both using HERA and Tevatron data, comparison between them to compare the shape
- Survival probability: Can we test them using Tevatron data, how to go from Tevatron to LHC? Study correlations in DØ roman pot detectors
- Position of roman pot detectors
- How to trigger on exclusive Higgs events?

How to trigger at low luminosity?

- General idea: cut on energetic jets at L1 requiring rapidity gaps
- L1: Rapidity gaps: between 2.5 and 5 at L1 on each side ($\sim$ 200 Hz for a luminosity of 10^{33} cm^{-2} s^{-1})
- L1: Require two central jets: ($|\eta| < 2.5$) with $p_T > 40$ and 30 GeV resp.
- L2: require positive taggings in roman pot detectors, and on mass reconstructed at L2: $M = \sqrt{\xi_1 \xi_2 S}$ between 80 and 250 GeV, leads to a rate less than 0.1 Hz
- What low luminosity means?

How low should be the luminosity?

Evolution of the probability to observe exactly one interaction per bunch crossing, $L \sim 8.10^{32}$ cm^{-2} s^{-1})

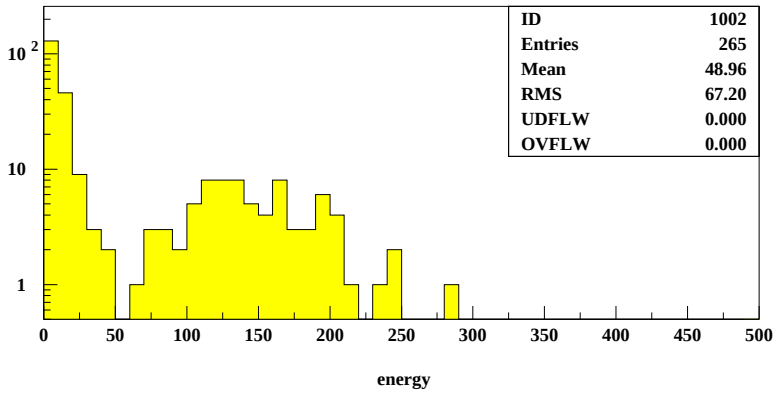


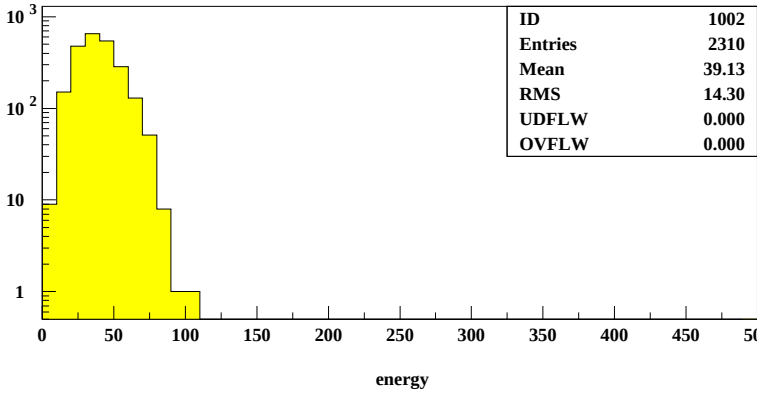
How to trigger at high luminosity?

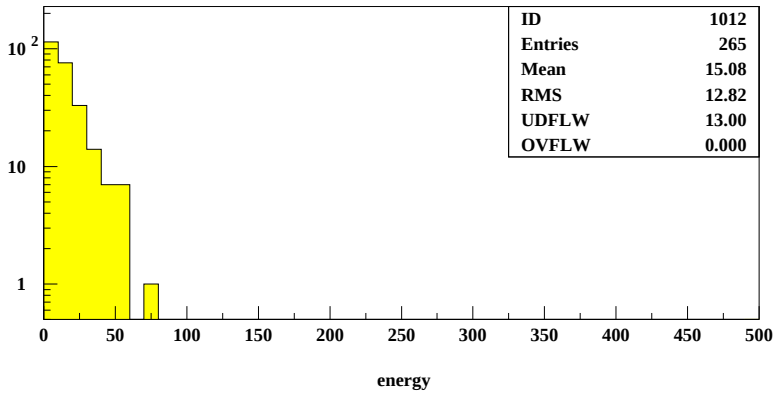
- Only in the case when we cannot use the roman pots in the trigger
- Look at topology of diffractive jets from Higgs with respect to standard jets (use the fact that there is hadronic activity outside the jet for diffraction, and that diffractive jets are more collimated)
- L1 cuts (loose): $p_T(jet1)$ >30 GeV, $p_T(jet2)$ >20 GeV, $|\eta| < 2.5$, $150 < \Delta\Phi < 210$
- Compute the sum of cells E_T: taking into account only cells with a $p_T > 2$ GeV and $|\eta| < 2.5$
- Cuts: on the amount of transverse energy, under study

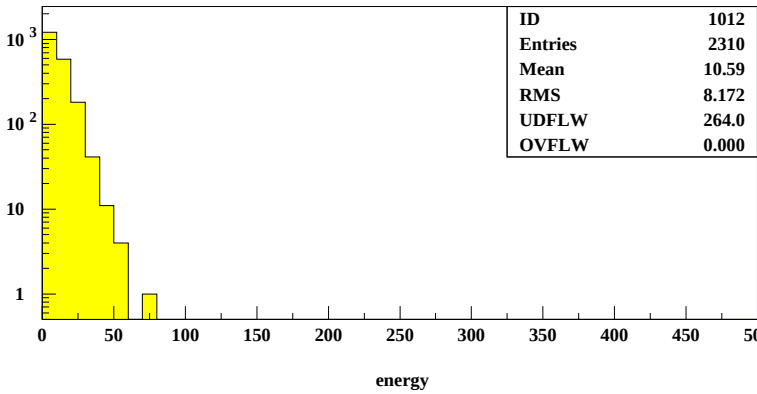
How to trigger at high luminosity?

- 20 (top), 10 (bottom) min bias added to Higgs/jet events
- left: Higgs, right: jets









How to trigger at high luminosity?

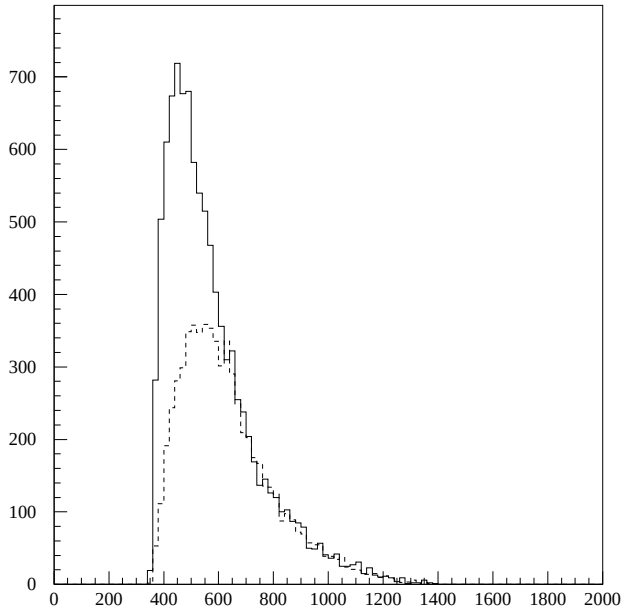
Determination of efficiencies and rates after cutting on the $15 < \Sigma E_T < 70$ GeV after L1 cuts

min. bias	Higgs	QCD	L1 rate
0	93.2%	2.3%	1.4 kHz
1	93.4%	3.0%	1.8 kHz
2	93.9%	3.3%	2.0 kHz
3	93.8%	3.7%	2.3 kHz
5	94.3%	4.0%	2.4 kHz
10	95.3%	5.0%	3.1 kHz
20	95.1%	10.4%	6.3 kHz

NB: Cuts to be tuned online..., VERY PRELIMINARY

Acceptance for top events with 200m pots

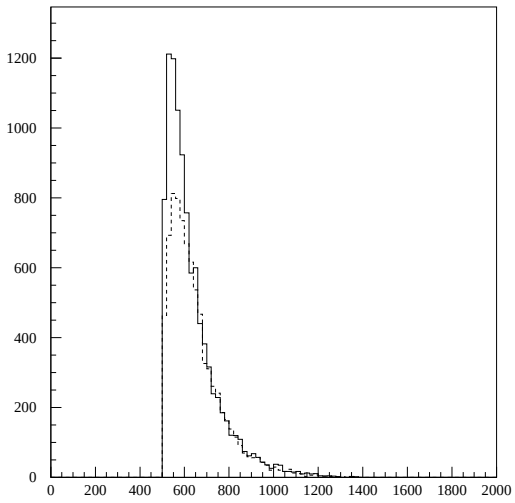
Number of events as a function of central mass

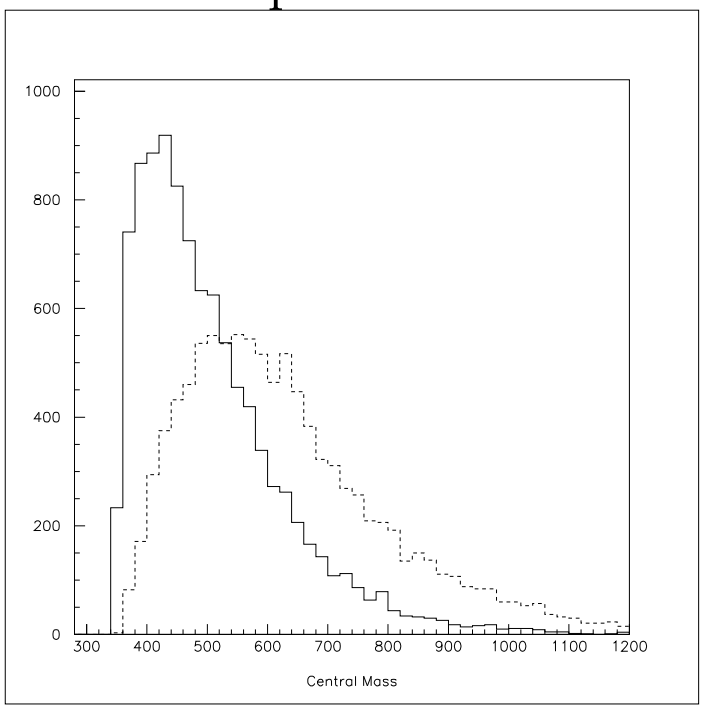


- For a top mass of 175 GeV: $\sigma_{tot} = 40$ fb, $\sigma_{acc} = 26$ fb
- High cross section to make precise measurement of top properties: measurement of top mass using production at threshold (measurement of $t\bar{t}$ production cross section as a function of the missing mass computed using missing mass method)

Acceptance for stop events with 200m pots

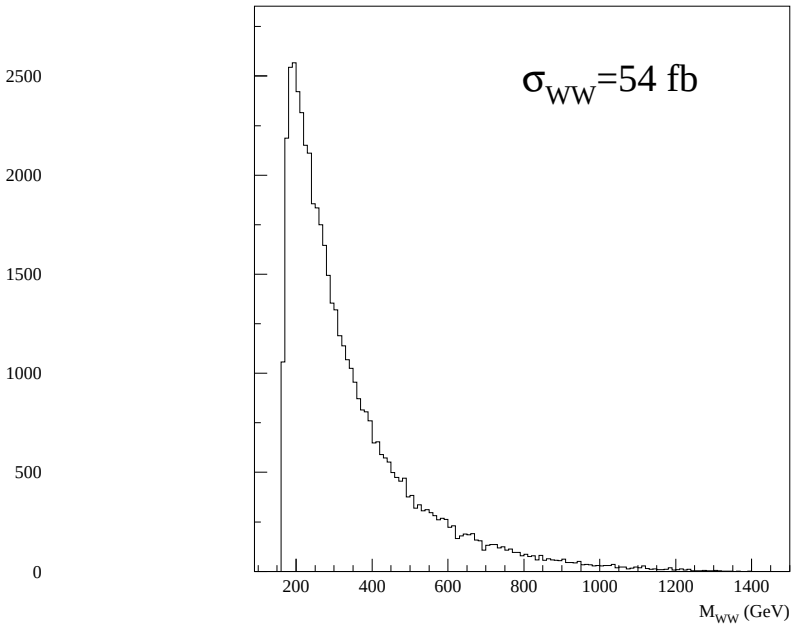
- Cross section for a stop mass of 250 GeV: $\sigma_{tot} = 8$ fb, $\sigma_{acc} = 6$ fb
- Possibility to distinguish between top and stop: using the differences in spin





W mass and properties (420 m pots)

WW events produced via QED ($\gamma\gamma$) processes: cross section perfectly known $\longrightarrow$ Precise measurement of W mass, W properties



Conclusion

- Studies of exclusive Higgs production, fast simulation of the CMS detector, quasi-exclusive events
- Signal over background: ~ 1 if one gets a very good resolution using roman pots (better than 1 GeV)
- survival probabilities: possibility to test survival probabilities at DØ
- SCI vs Pomeron: possibility to test the models (and thus predictions for Higgs) using $\Delta\Phi$ correlations between tagged protons
- Interesting processes in addition to Higgs: top, stop, W..., possibility to measure top and W mass by performing a threshold scan (same idea as linear collider, without ISR problem)
- Full diffractive program at the LHC: pomeron structure in a new kinematical domain (single diffraction and double pomeron exchange)