Hard diffraction at the LHC

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- How to measure the high β gluon?
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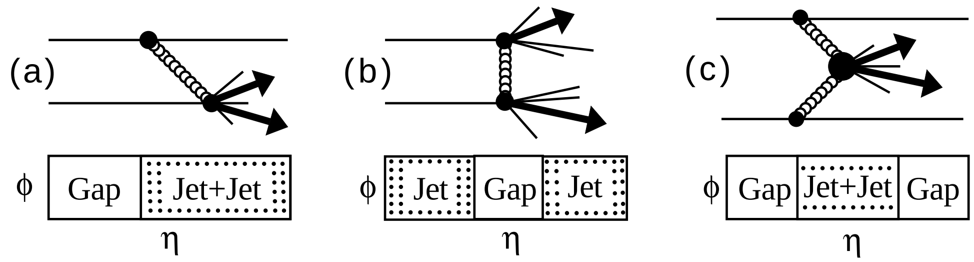
Work done in collaboration with M. Boonekamp. J. Cammin, A. Kupco, R. Peschanski, L. Schoeffel

Ref: hep-ph/0602228, hep-ph/0506275, hep-ph/0504199, hep-ph/0407222, hep-ph/0406061, hep-ph/0406061, hep-ph/0205332, hep-ph/0107113

Diffraction at Tevatron/LHC

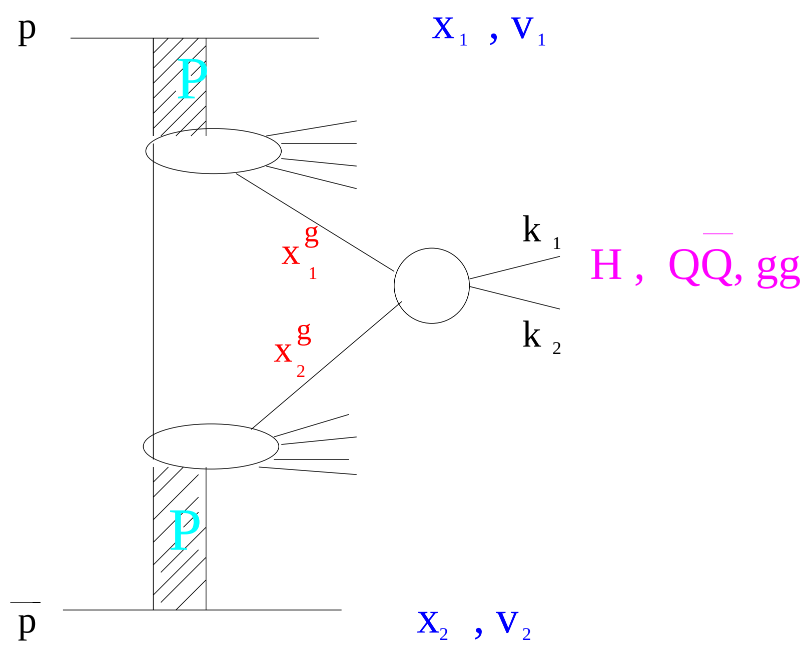


Kinematic variables

- t: 4-momentum transfer squared
- ξ_1, ξ_2: proton fractional momentum loss (momentum fraction of the proton carried by the pomeron)
- $\beta_{1,2} = x_{Bj,1,2}/\xi_{1,2}$: Bjorken-x of parton inside the pomeron
- $M^2 = s\xi_1\xi_2$: diffractive mass produced
- $\Delta y_{1,2} \sim \Delta\eta \sim \log 1/\xi_{1,2}$: rapidity gap

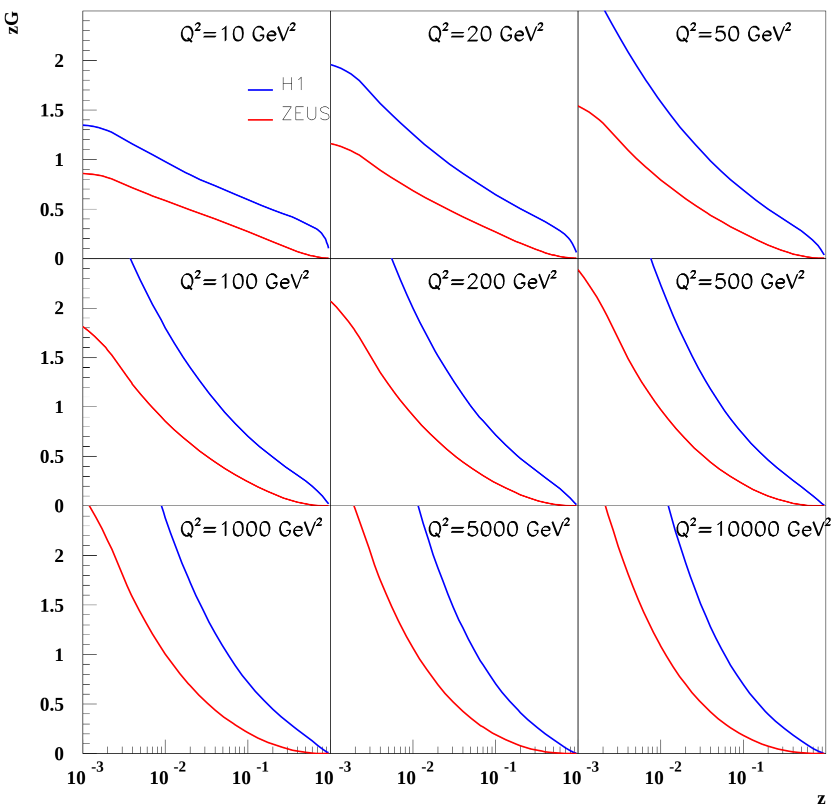
“Inclusive” models

- “Inclusive” models: Take the hadron-hadron “usual” cross section convoluted with the parton distributions in the pomeron
- Take shape of H1 measurement of gluon density
- Normalisation coming from CDF run I cross section measurement
- Inclusive cross sections need to be known in detail since it is a direct background to search for exclusive events



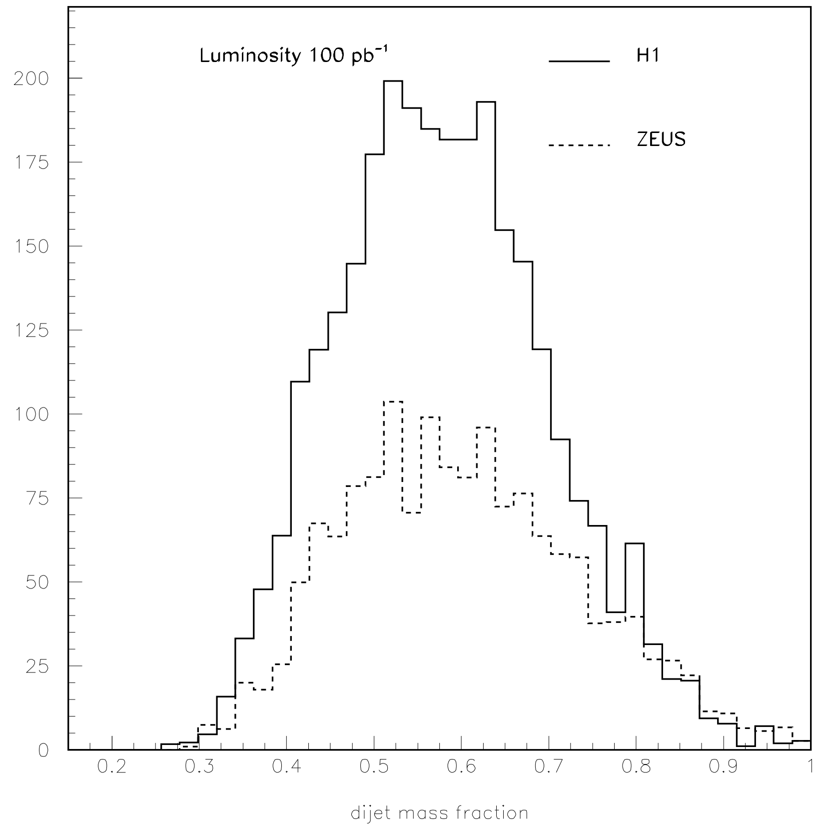
xG measured at HERA

- Large differences in shape and normalisation between H1 and ZEUS gluon densities L. Schoeffel, C. Royon, R.. Peschanski, E. Sauvan hep-ph/0602228
- Assumption: take the same shape of gluon distribution as at HERA: needs to be checked with a measurement of gluon density at the Tevatron



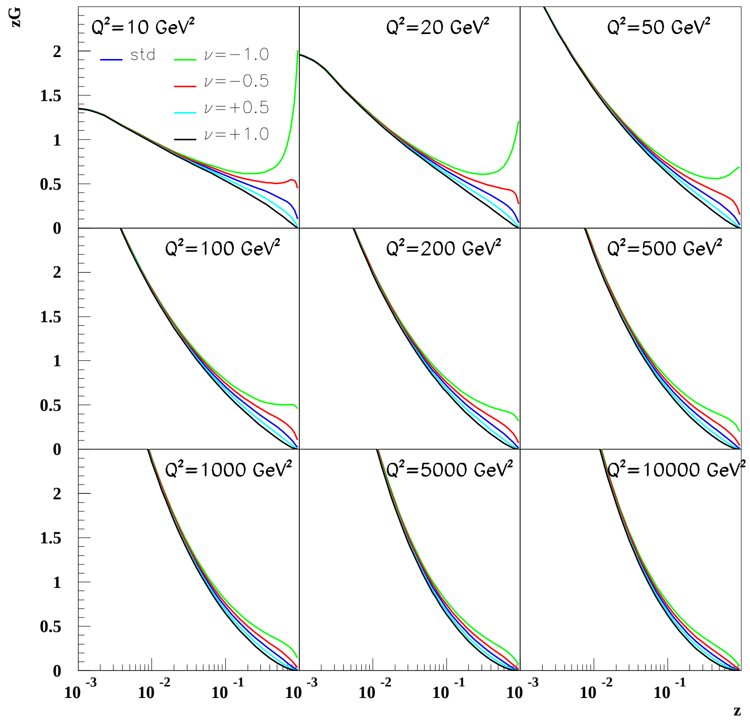
Contrain better xG measured at Tevatron

- Possible measurement of the dijet mass fraction at the Tevatron sensitive to gluon density
- Request two jets of 25 GeV and a $\bar{p}$ tagged in the DØ dipole roman pot detector as an example



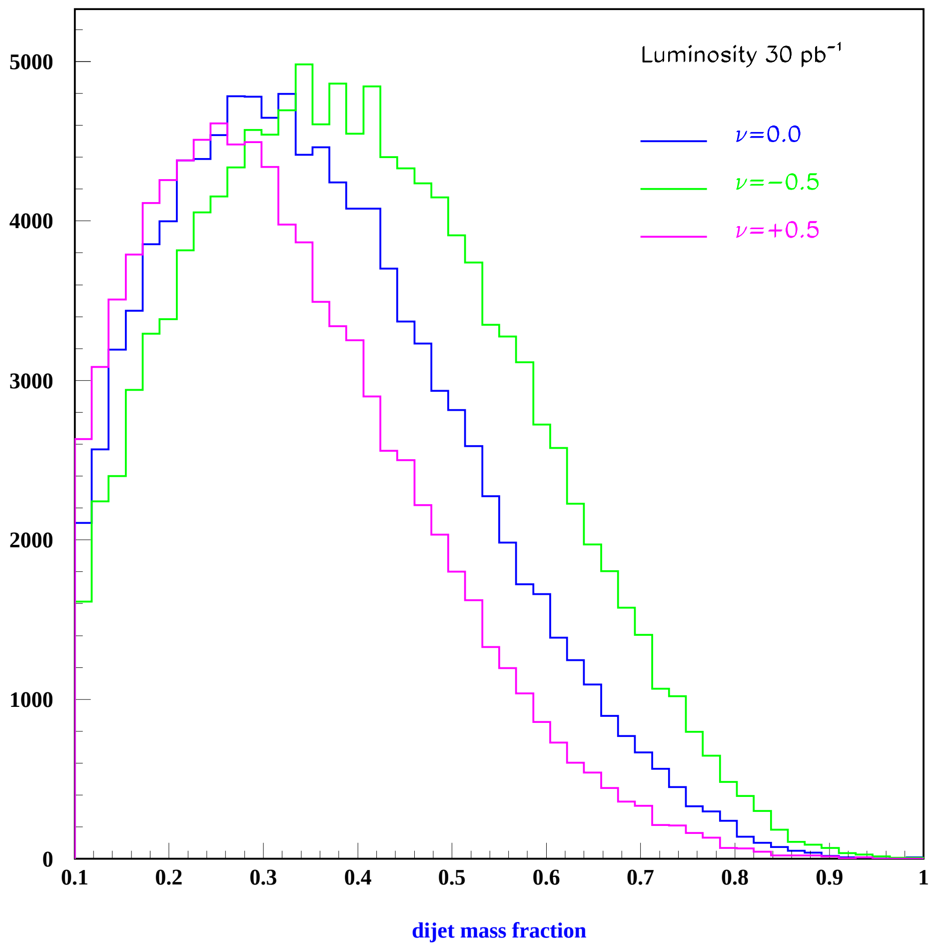
Uncertainty on high β gluon

- Important to know the high β gluon since it is a contamination to exclusive events
- Experimentally, quasi-exclusive events indistinguishable from purely exclusive ones
- Uncertainty on gluon density at high β: multiply the gluon density by $(1-\beta)^{\nu}$ (fit: $\nu = 0.0 \pm 0.6$)



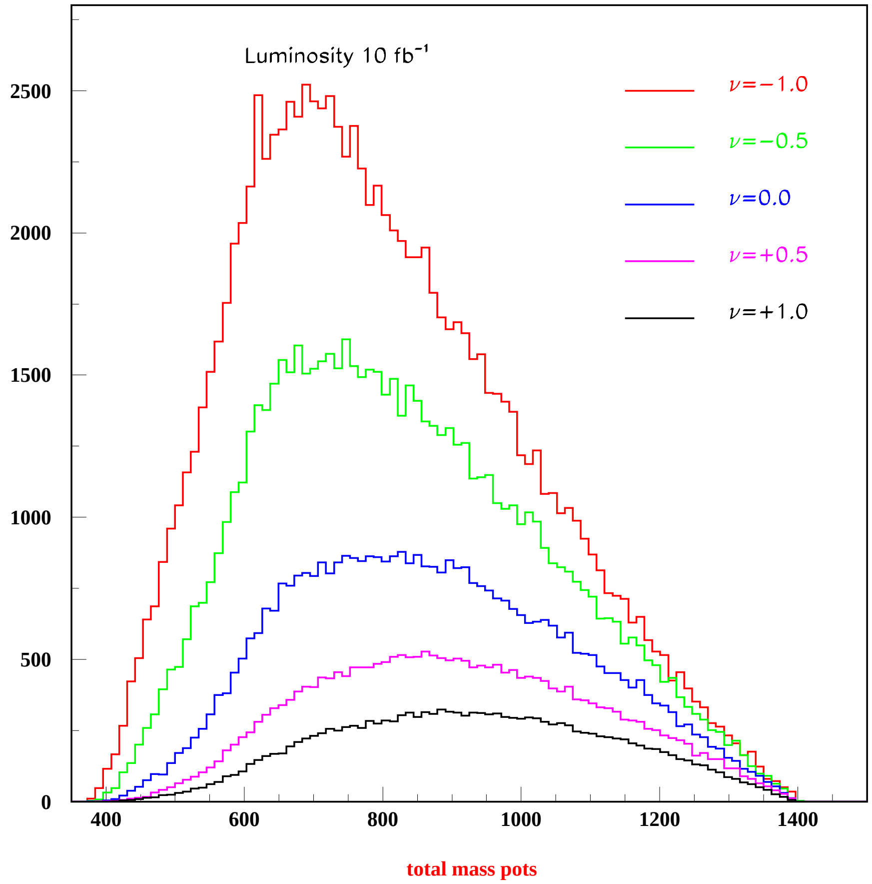
Dijet mass measurement

Measure the dijet mass distribution at the Tevatron or the LHC: dependent on high-β gluon



$t\bar{t}$ inclusive events

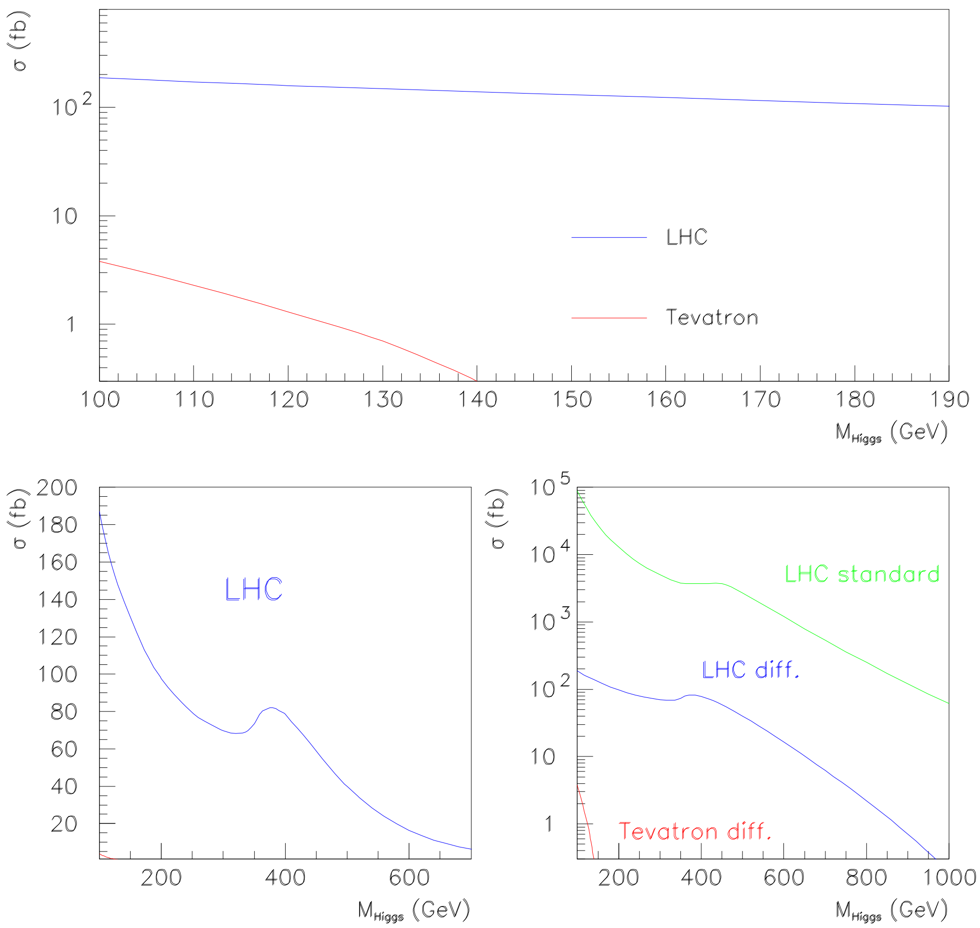
Idea: Measure the diffractive mass produced in $t\bar{t}$ events at the LHC ($M = \sqrt{\xi_1 \xi_2 S}$): high sensitivity on high-β gluon



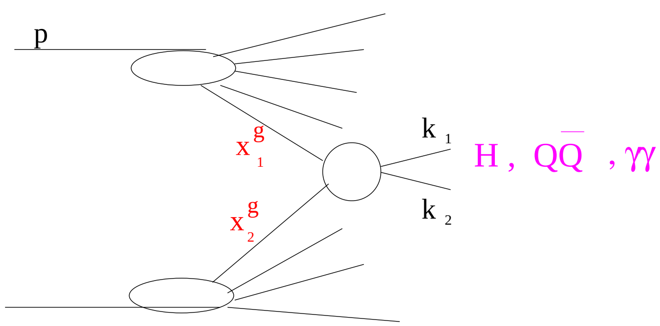
Inclusive Higgs mass production

Large cross section, but mass poorly reconstructed since part of the energy lost in pomeron remnants

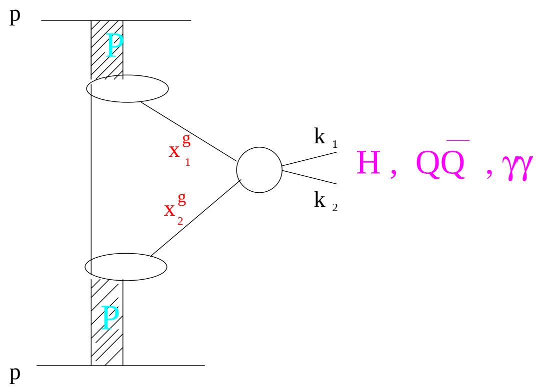
($M = \sqrt{\xi_1 \xi_2 S}$ ~Higgs + remnant mass)



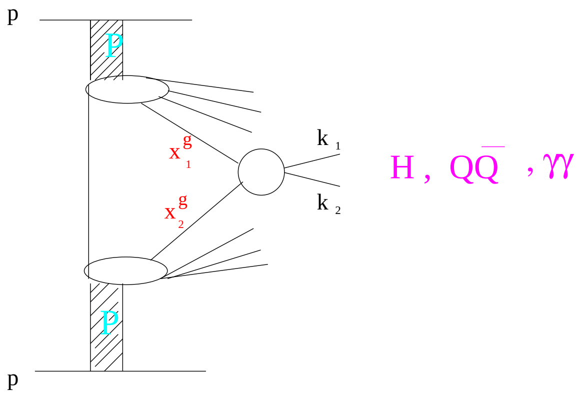
“Exclusive models”



"Standard"



"Exclusive "

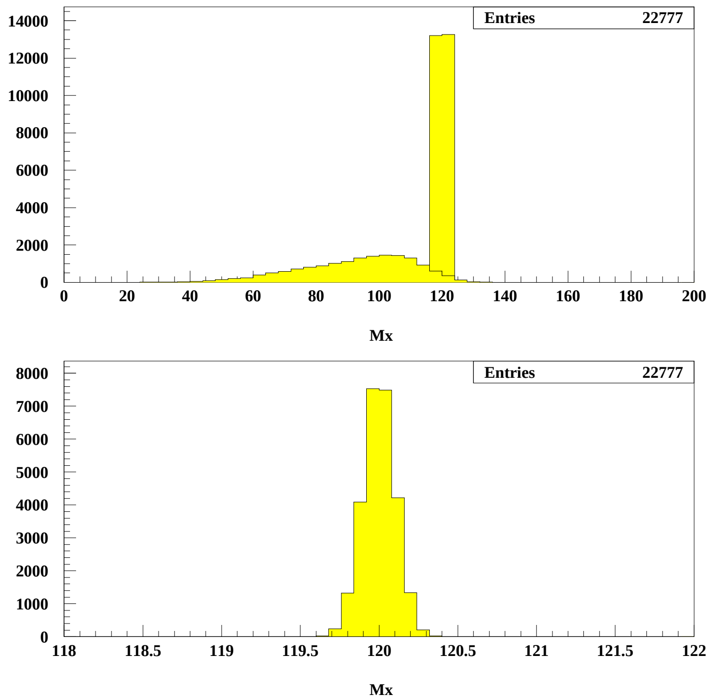


"Inclusive"

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 ($pp \rightarrow pHp$)
- $M_H = \sqrt{\xi_p \xi_{\bar{p}} S}$
- No energy loss in pomeron “remnants”

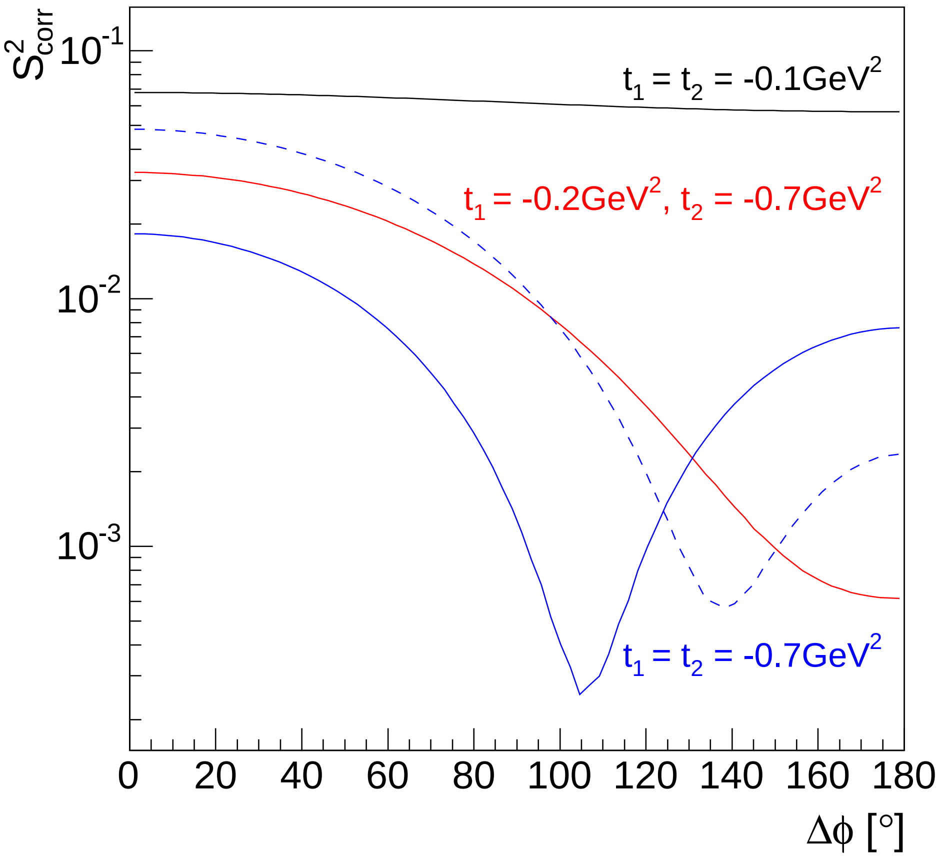


DPEMC Monte Carlo

- DPEMC (Double Pomeron Exchange Monte Carlo): New generator to produce events with double pomeron exchange http://boonekam.home.cern.ch/boonekam /dpemc.htm, hep-ph/0312273
- Interface with Herwig: for hadronisation
- Exclusive and inclusive processes included: Higgs, dijets, diphotons, dileptons, SUSY, QED, Z, W...
- DPEMC generator interfaced with a fast simulation of LHC detector (as an example CMS, same for ATLAS), and a detailled simulation of roman pot acceptance
- Gap survival probability of 0.03 put for the LHC: is it possible to check this at the Tevatron?

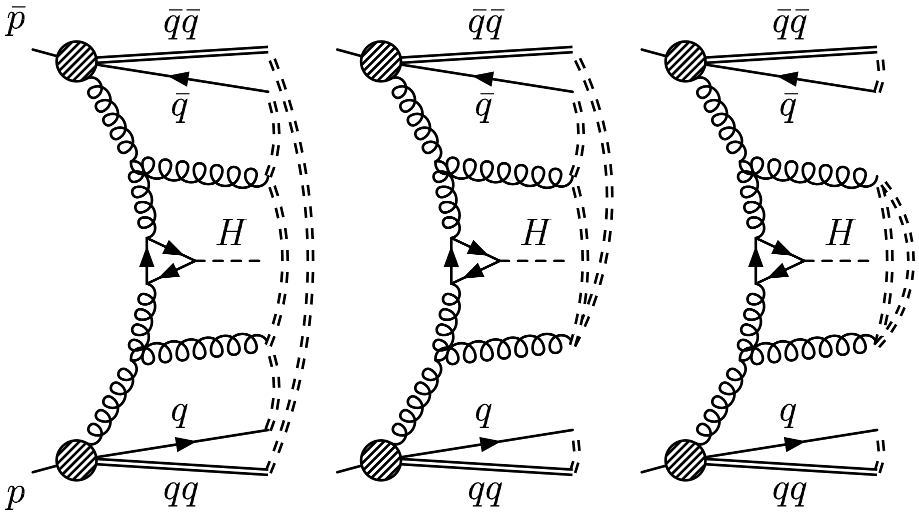
$\Delta\Phi$ dependence of survival probabilities

Survival probability strongly $\Delta\Phi$-dependent where $\Delta\Phi$ is the difference in azimuthal angles between p and $\bar{p}$



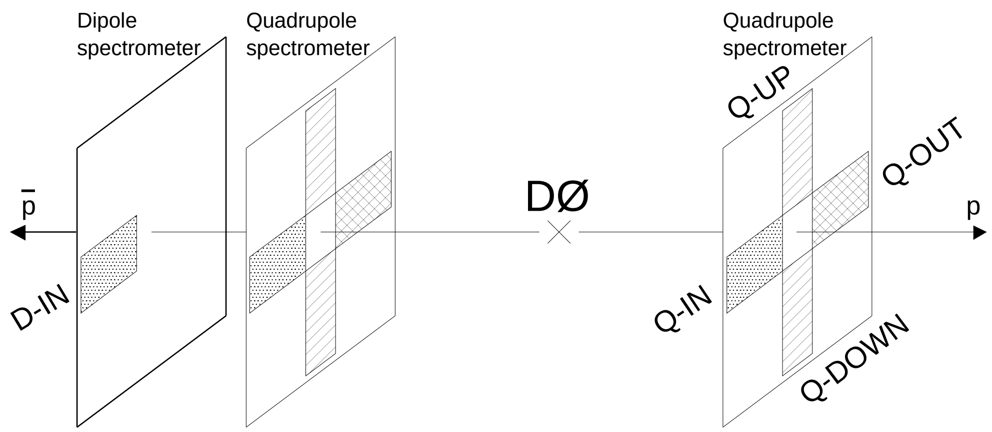
Soft Colour Interaction Models

- A completely different model to explain diffractive events: Soft Colour Interaction (R.Enberg, G.Ingelman, N.Timneanu, hep-ph/0106246)
- Principle: Variation of colour string topologies, giving a unified description of final states for diffractive and non-diffractive events
- No survival probability for SCI models



Forward Proton Detector in DØ

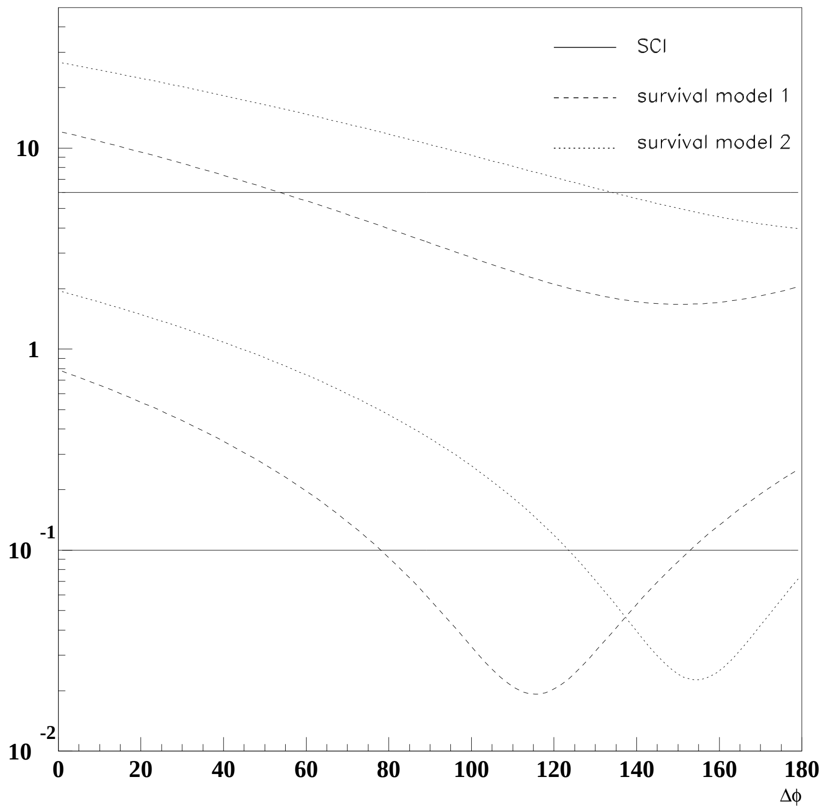
Forward Proton Detector (FPD) installed by DØ allowing to measure directly $\Delta\Phi$



Possibility to combine D-IN with quadrupole on the other side, or two quadrupole detectors (Q-UP and Q-UP, or Q-UP and Q-DOWN...)

Results

Relative $\Delta\Phi$ dependence for SCI and pomeron-based models (upper plots: ($|t_p| > 0.6$, $|t_{\bar{p}}| > 0.1$ GeV^2, lower ones $|t_p| > 0.5$, $|t_{\bar{p}}| > 0.5$ GeV^2)



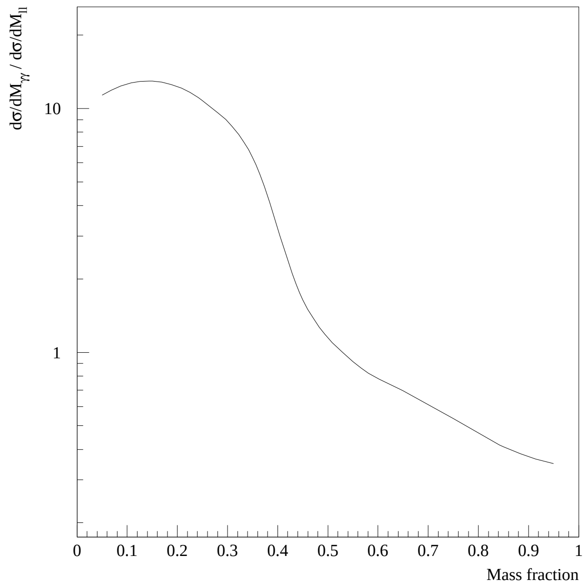
Possible measurement at DØ

- Diffractive cross section ratios in different regions of $\Delta\Phi$ at the Tevatron
- same side: $\Delta\Phi < 45$ degrees, opposite side: $\Delta\Phi > 135$, middle: $45 < \Delta\Phi < 135$ degrees;
- 1st measurement: asymmetric cuts on t (dipole and quadrupole), 2nd measurement: symmetric cuts on t (quadrupole on both sides)
- Possible to distinguish between SCI and pomeron-based models, and test the survival probabilities

Configuration	model	middle/same	opp./same
Quad. + Dip.	SCI	1.3	1.1
	Pom.	0.36	0.18
Quad. + Quad.	SCI	1.4	1.2
	Pom.	0.14	0.31

Existence of exclusive events

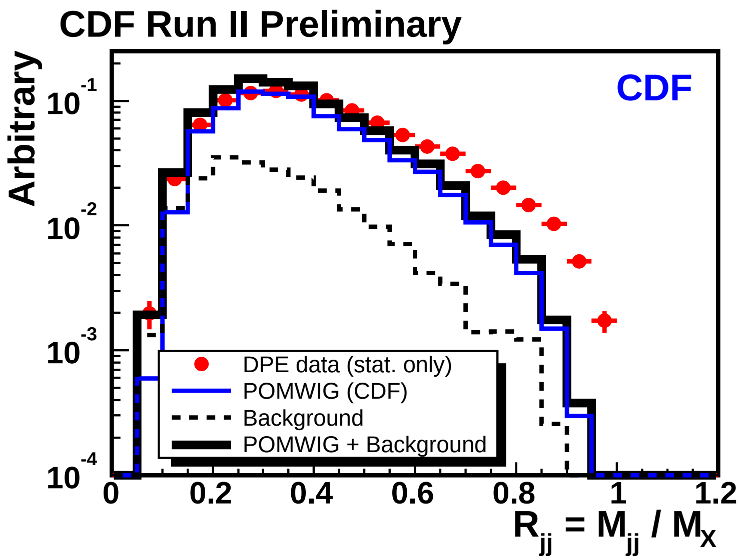
Test of the existence of exclusive events

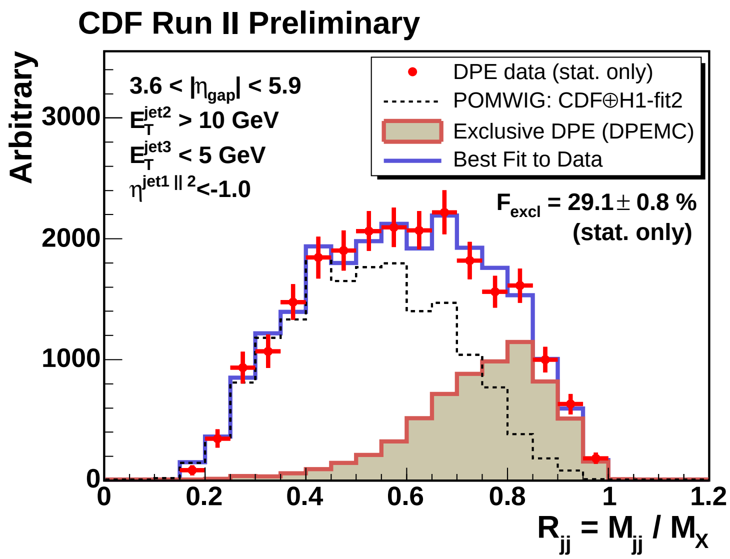


- Dilepton and diphoton cross section ratio as a function of the diphoton/dilepton mass: no dilepton event for exclusive models ($gg \to \gamma\gamma$ ok, $gg \to l^+l^-$ direct: impossible)
- Change of slope of ratio if exclusive events exist
- Other method: ratio b-jets / all jets,

Look for exclusive events at the Tevatron

- Look for exclusive events (events where there is no pomeron remnants or when the full energy available is used to produce diffractively the high mass object)
- Select events with two jets only, one proton tagged in roman pot detector and a rapidity gap on the other side
- Comparison with POMWIG Monte Carlo using H1 gluon density in pomeron and DPEMC for exclusive signal
- Will be interesting to see the effect of new H1/ZEUS PDFs in pomeron on these results





“Exclusive” production at the LHC

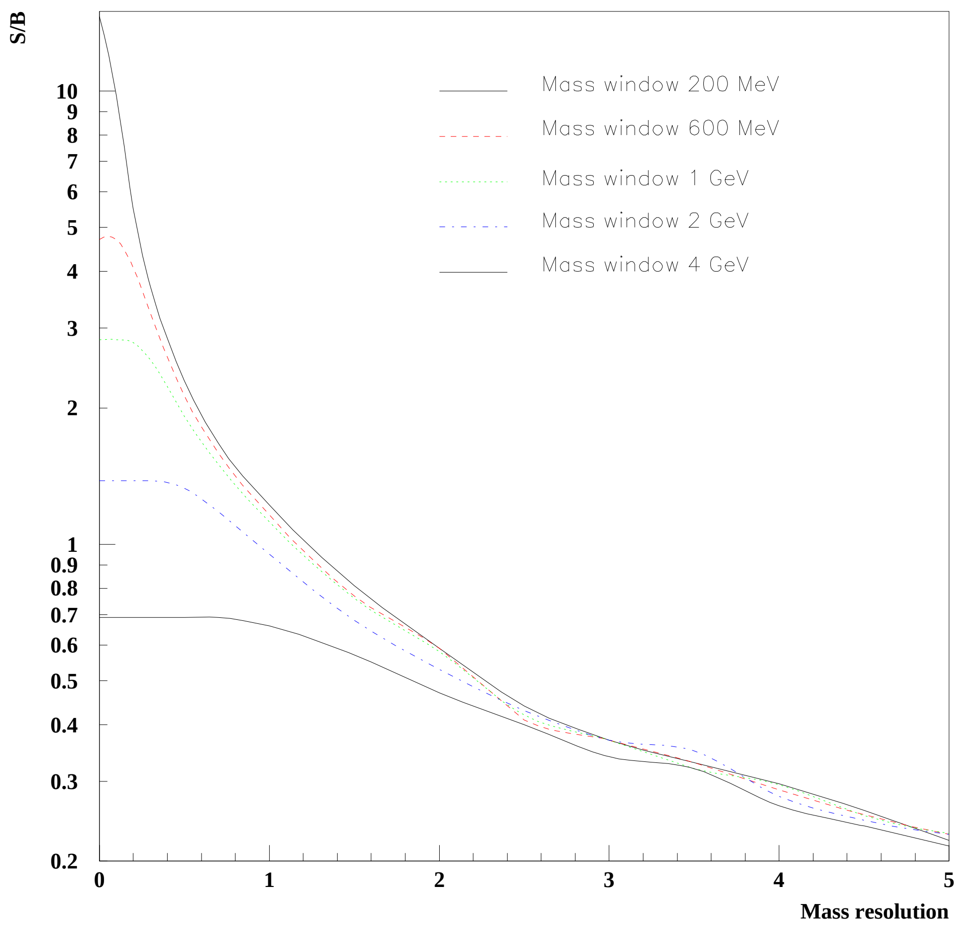
- Higgs decaying into $b\bar{b}$: study S/B
- Exclusive $b\bar{b}$ cross section (for jets with $p_T > 25$ GeV): 2.1 pb
- Exclusive Higgs production (in fb)

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

- NB: a survival probability of 0.03 was applied to all cross sections

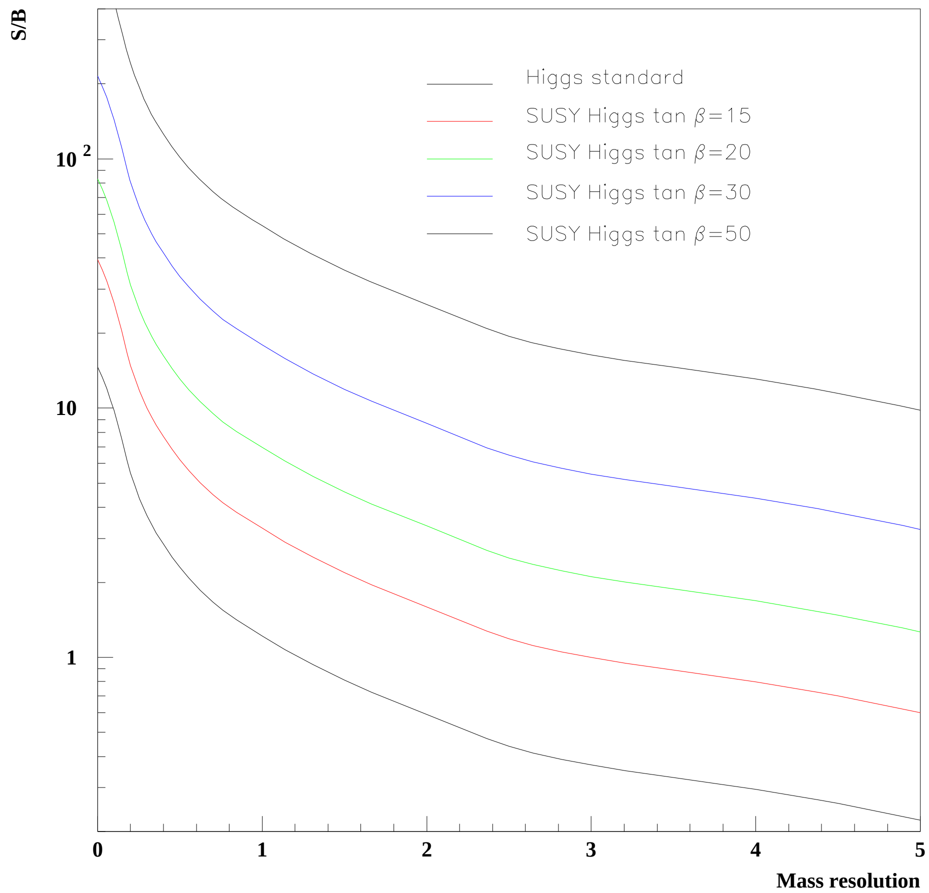
Signal over background: standard model Higgs

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

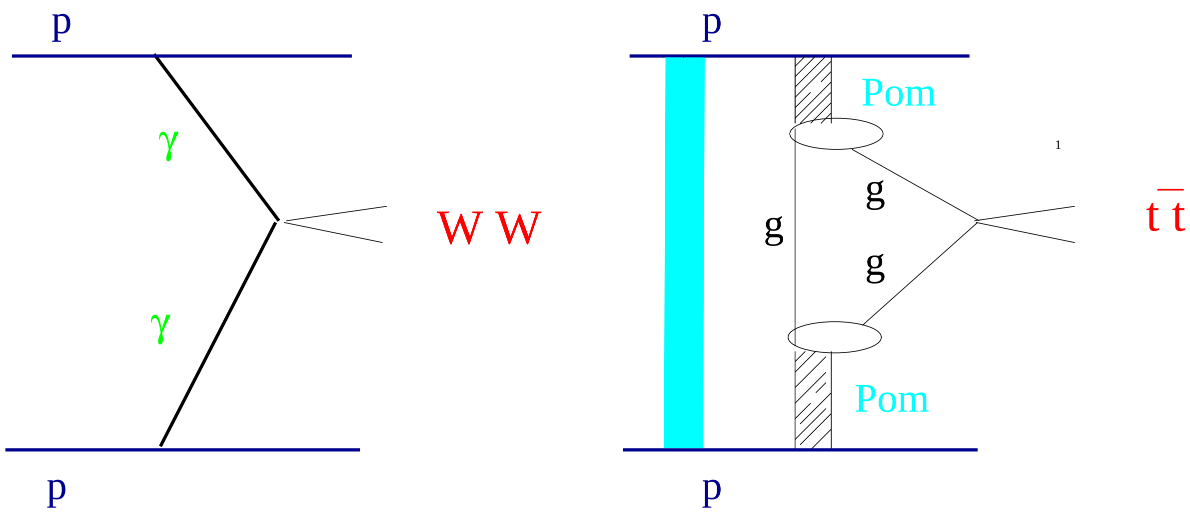


Diffractive SUSY Higgs production

At high $\tan\beta$, possibility to get a S/B over 50 (resp. 5.) for 100 (resp.10) fb^{-1}!

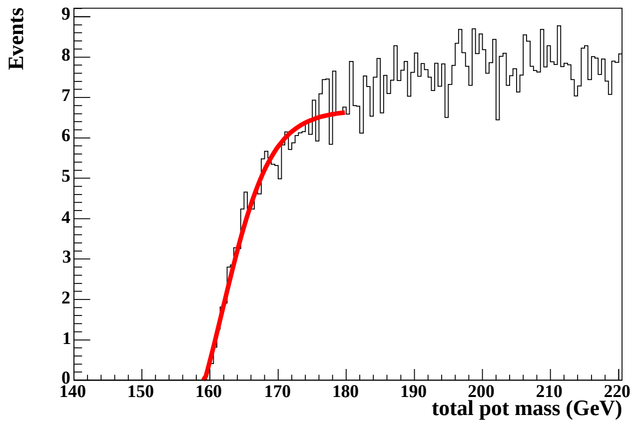


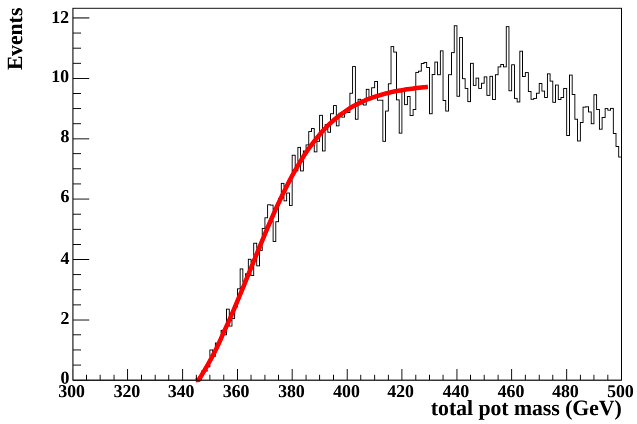
W, top and stops



All the energy is used to produce the W, top (stop) pairs: W: QED process, cross section perfectly known, top: QCD diffractive process

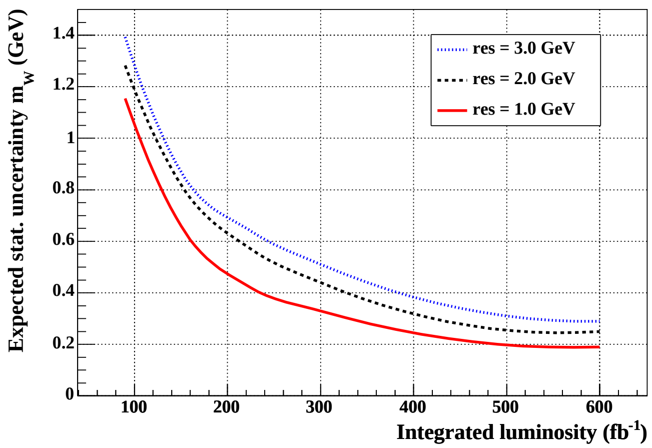
Top and W events

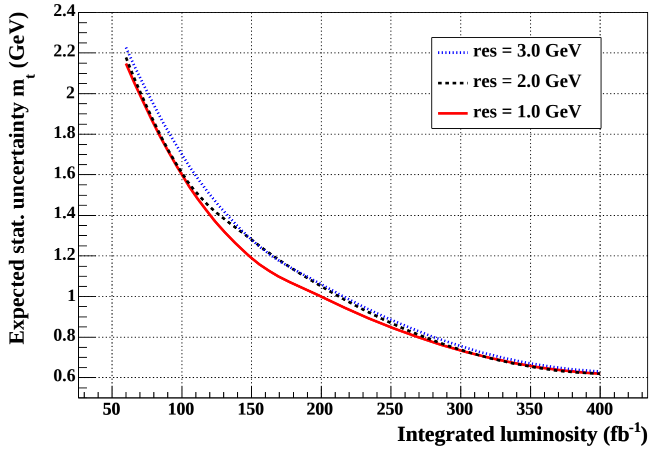




- W boson cross section and acceptance: $\sigma \sim 56$ fb, pots at 420 m needed, about 60%
- Top quark cross section and acceptance: $\sigma \sim 40$ fb, pots at 220 m, about 85%, model dependent
- Reconstruct the W and top mass using the threshold scan method: Fit the increase of the cross section at threshold

Resolution on W and top masses

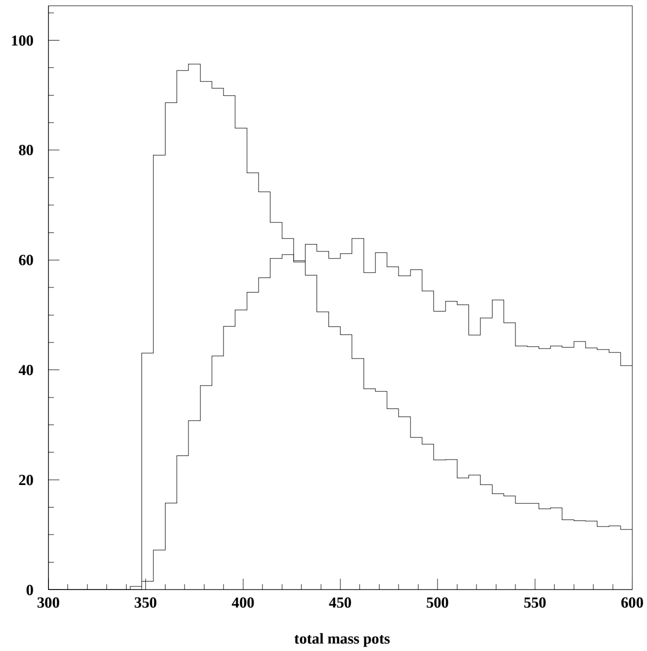




- 2 methods uaed to reconstruct the top mass: histogram: (compute χ^2 between number of events in bins in MC and data for the same lumi), turn-on fit: fit the turn-on point of the missing mass distribution at threshold
- W mass resolution: $\sim$ 400 MeV, not competitive, but allows to check the roman pot alignment very precisely
- Top mass resolution: $\sim$ 1 GeV, competitive measurement provided the corss section is high enough

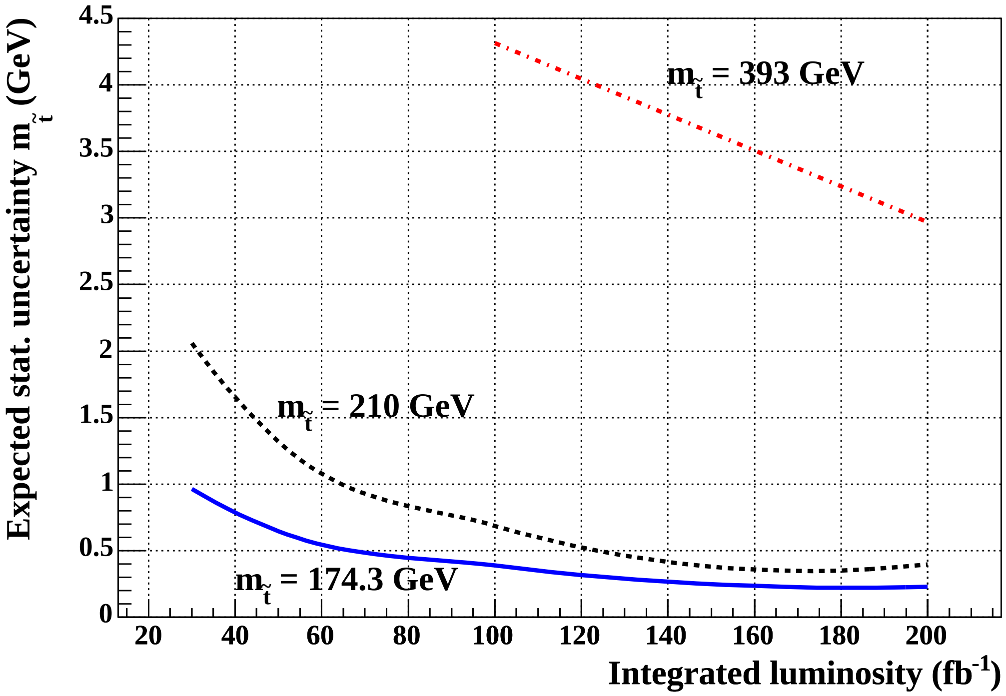
Top and stops

- Cross section for a stop mass of 250 GeV: $\sigma_{tot} = 8$ fb, $\sigma_{acc} = 6$ fb
- Possibility to distinguish between top and stop even if they have about the same mass: using the differences in spin (as an example: $m_{\tilde{t}} = m_{top}$)
- Very fast turn-on for stops



Resolution on stop mass

Resolution on stop mass by using roman pot detectors with a resolution of 1 GeV $\longrightarrow$ Resolution better than 1 GeV at high lumi!



Roman pot projects

- TOTEM project accepted, close to CMS
- FP420: Project of installing roman pot detectors at 420 m both in ATLAS, CMS; collaboration being built
- Roman pot detectors at 220 m in ATLAS:
  - Natural follow-up of the ATLAS luminosity project at 240 m to measure total cross section
  - Complete nicely the FP420 m project
  - Collaboration between Saclay. Prague and Stony Brook (so far) being pursued
  - Collaboration with the FP420 m project concerning detectors, triggers, simulation...

Conclusion

- Study of inclusive events (the only events which are existing for sure): determination of gluon at high β, search for SUSY events (or any resonance) when dijet background is known
- Exclusive events still to be observed in particular at the Tevatron
- Exclusive Higgs: Signal over background: ~ 1 if one gets a very good resolution using roman pots (better than 1 GeV), enhanced by a factor up to 50 for SUSY Higgs at high $tan\beta$
- QED WW pair production: cross section known precisely, allow to calibrate prescisely the roman pot detectors
- Diffractive top, stop pair production: possibility to measure top and stop masses by performing a threshold scan with a precision better than 1 GeV if cross section high enough (same idea as linear collider, without ISR problem),