Search for exclusive events at the Tevatron and the RP220 project in ATLAS

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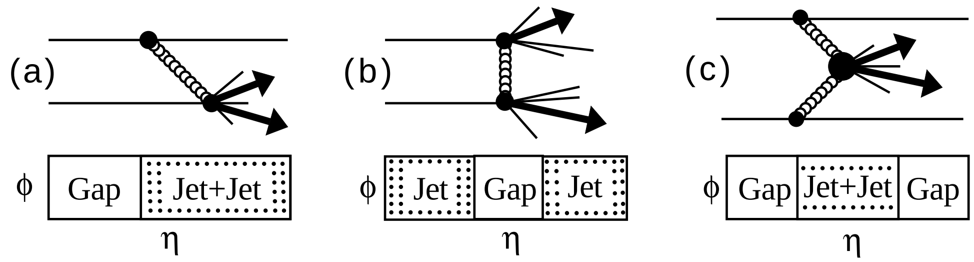
- Inclusive diffraction at the LHC
- Search for exclusive events at the Tevatron (CDF)
- Diffractive Higgs production at the LHC: exclusive and inclusive production
- Background studies: How to measure the high β gluon?
- RP220 project at the LHC in ATLAS

Diffraction at Tevatron/LHC

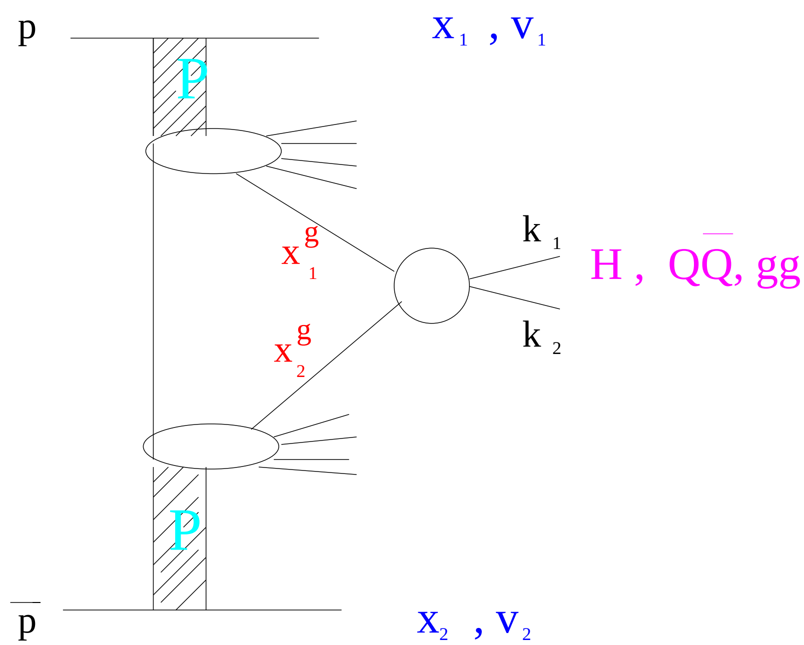


Kinematic variables

- 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

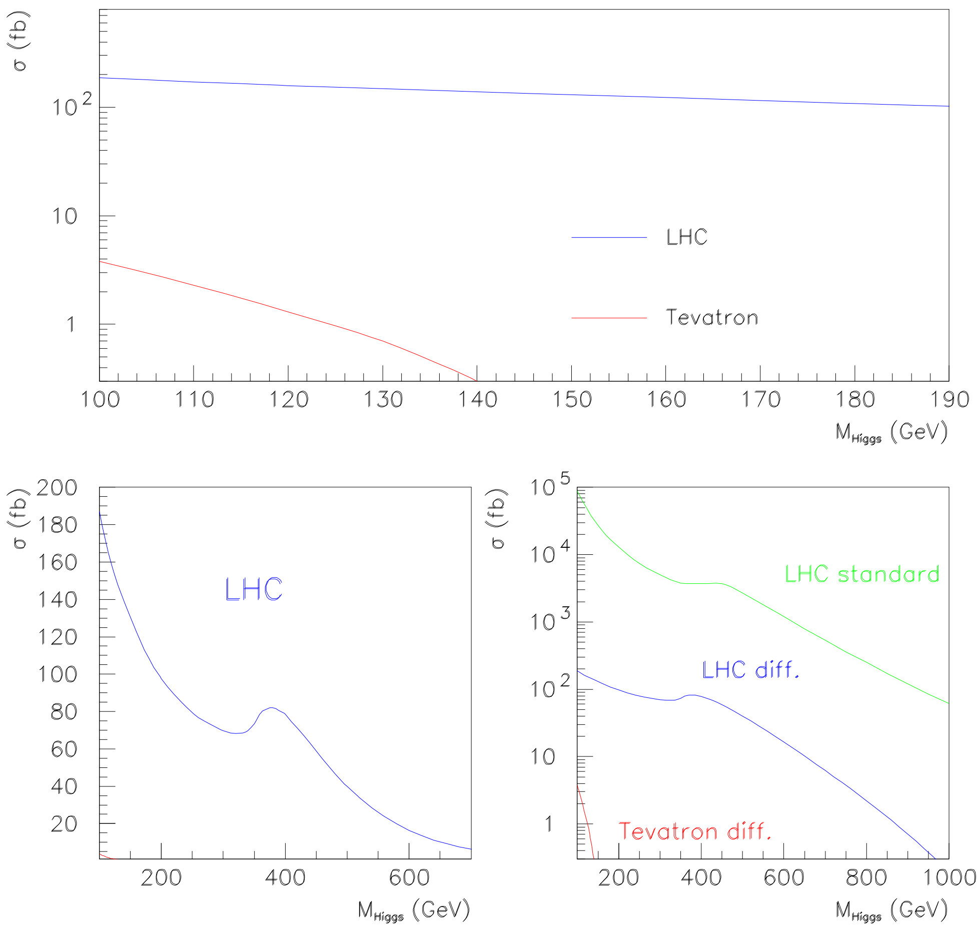
“Inclusive” models

- “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

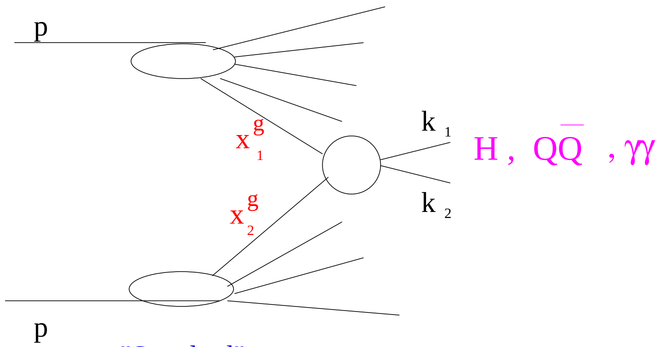


Inclusive Higgs mass production

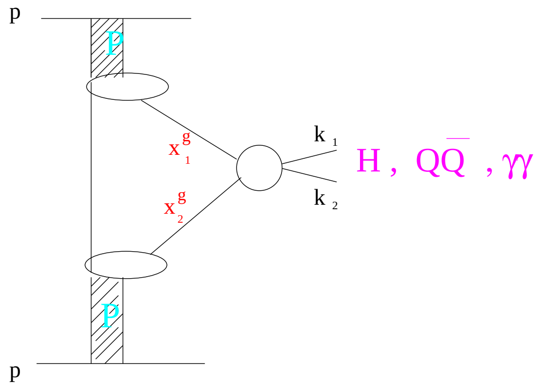
Large cross section, but mass poorly reconstructed since part of the energy lost in pomeron remnants ($M = \sqrt{\xi_1 \xi_2 S}$ ~Higgs + remnant mass)



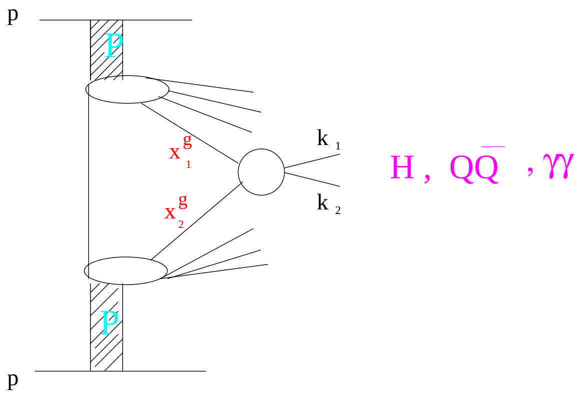
“Exclusive models”



"Standard"



"Exclusive "

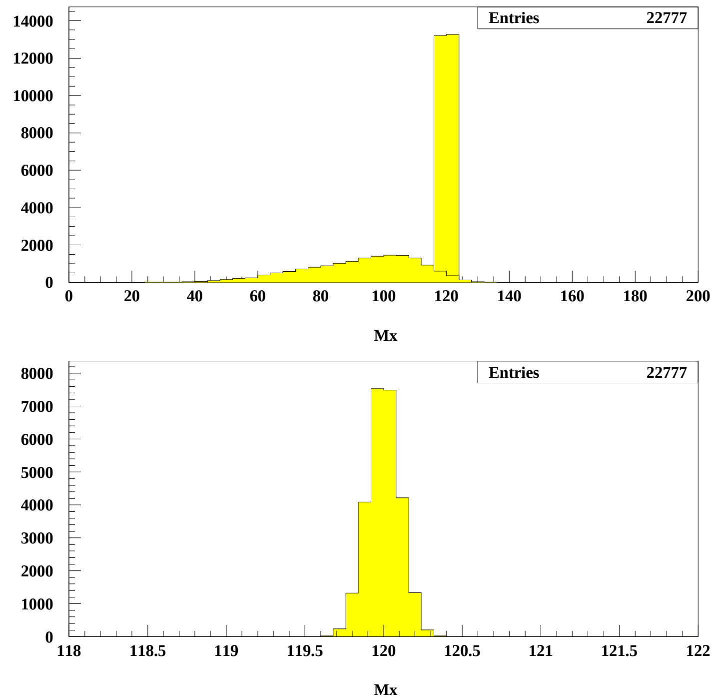


"Inclusive"

All the energy is used to produce the Higgs (or the dijets), namely $xG \sim \delta$ (See: R. Peschanski, M. Boonekamp, J. Cammin, C. R. and Durham group: A. Martin, V. Khoze, M. Ryskin,
see the talks by A. Martin, M. Tasevsky, V. Juranek

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"

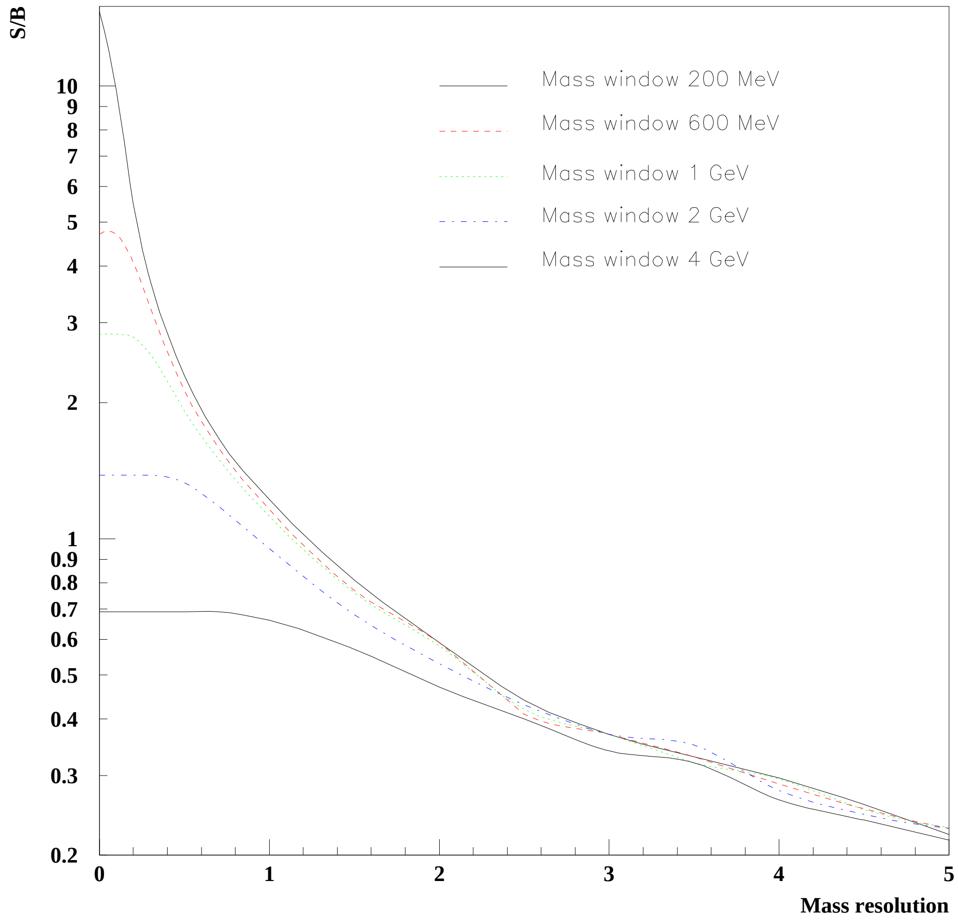


DPEMC Monte Carlo

- DPEMC (Double Pomeron Exchange Monte Carlo): New generator to produce events with double pomeron exchange (both “Durham” and “Saclay” models) 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?
- Another available MC: “Exhume” for Durham model

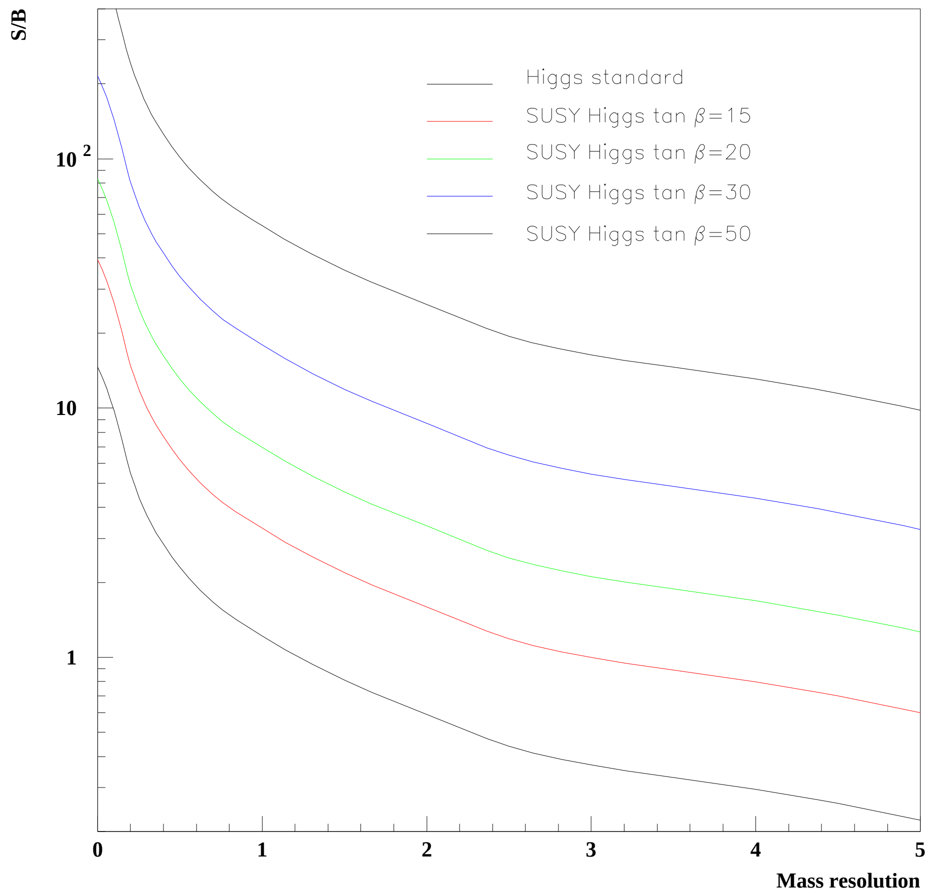
Signal over background: standard model Higgs

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



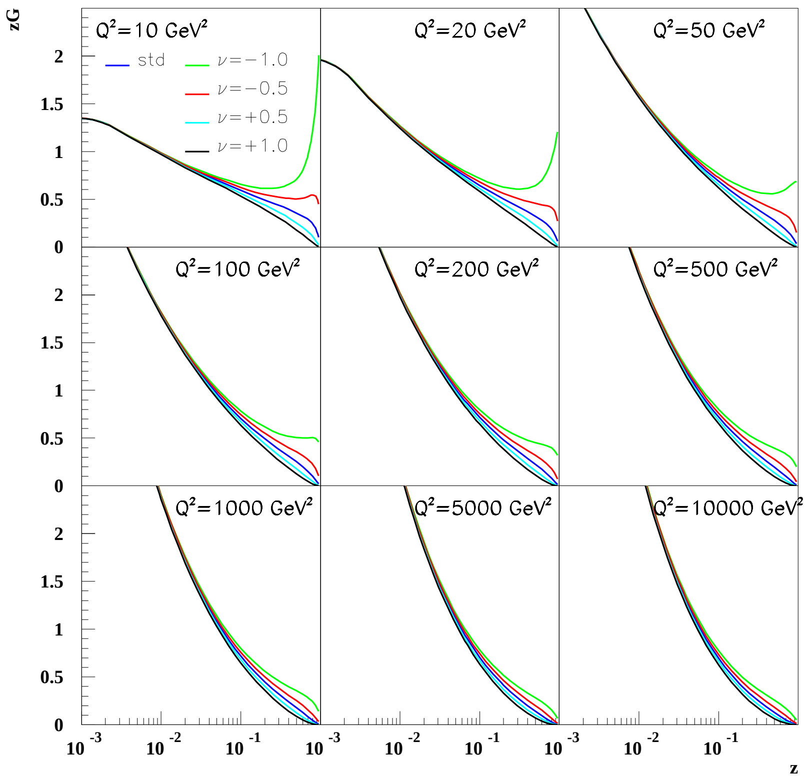
Diffractive SUSY Higgs production

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



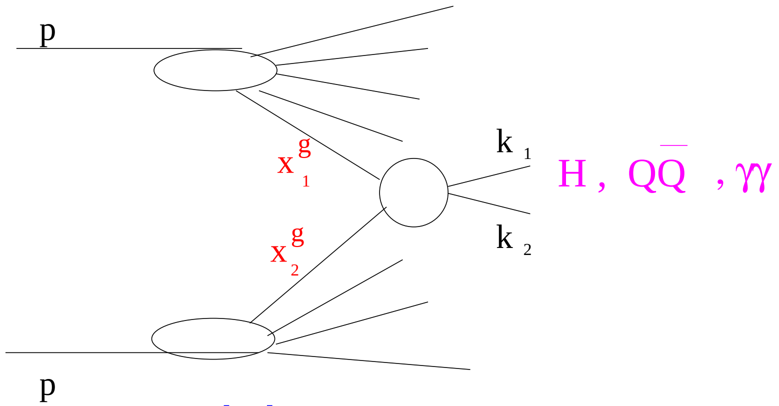
Uncertainty on high β gluon

- 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: $\nu = 0.0 \pm 0.6$)

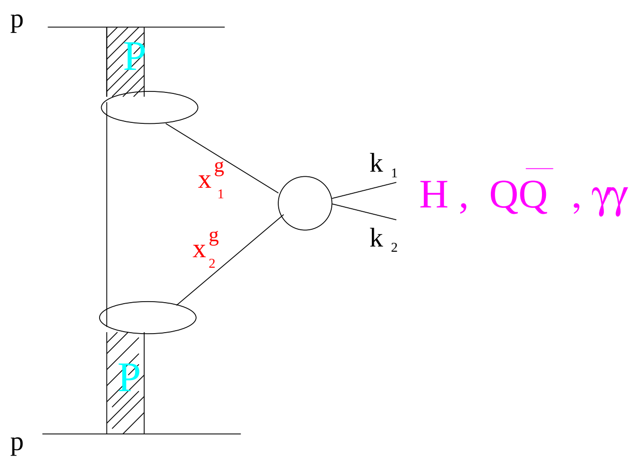


Look for exclusive events at the Tevatron

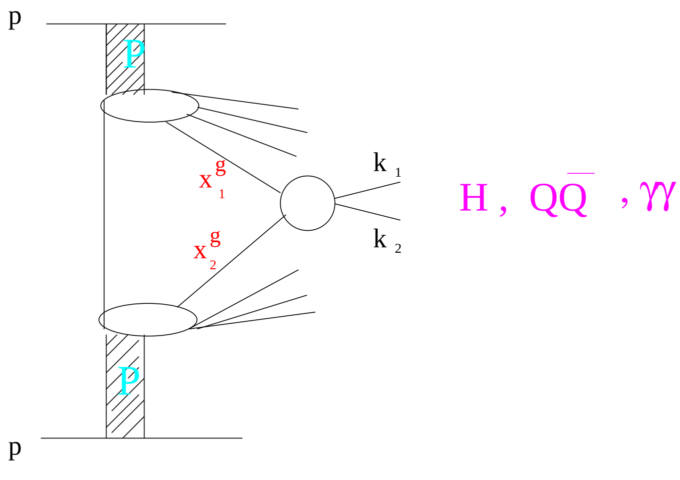
- "exclusive" events: events without pomeron remnant, search for exclusive events in dijet, diphoton, χ_C channels
- The full available energy is used in the hard interaction
- Interesting for LHC... (diffractive W, Higgs, photon anomalous couling...



"Standard"



"Exclusive "



"Inclusive"

χ_C exclusive production at the Tevatron?

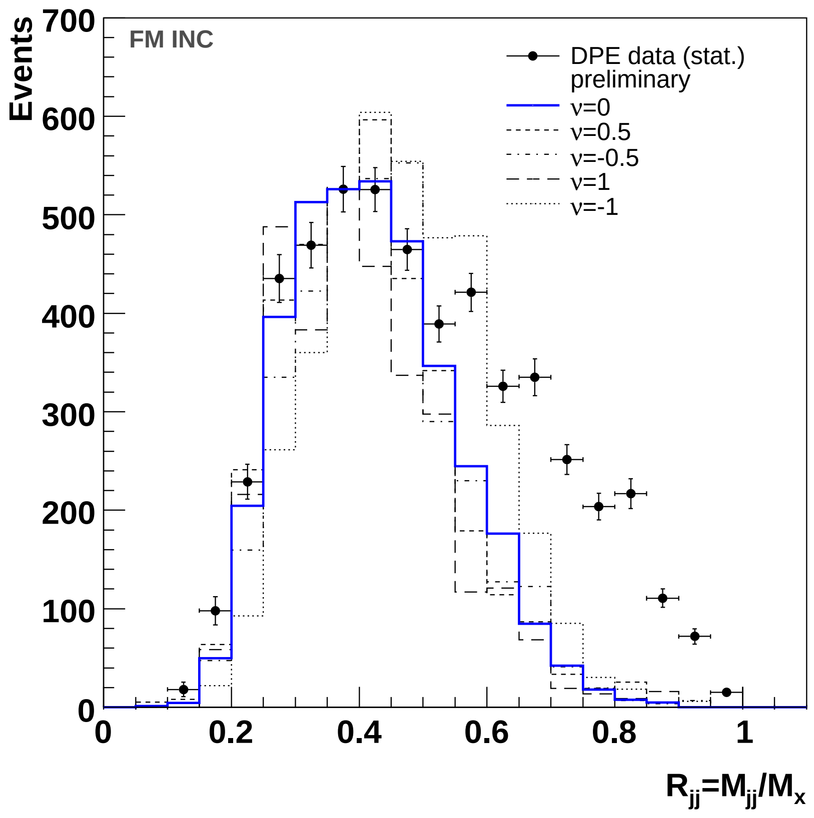
- CDF observation: Upper limit of χ_C exclusive production at the Tevatron in the $J/\Psi\gamma$ channel $\sigma \sim 49$ pb ±18 ± 39 pb for $y < 0.6$ (result not corrected for cosmics, χ_2 contamination)
- Exclusive prediction: 59 pb
- Quasi-exclusive contamination:

mass fraction	$\nu = 0$	$\nu = -1$	$\nu = -0.5$	$\nu = +0.5$	$\nu = +1.0$
$\geq$ 0.8	5.4	119.1	27.2	0.9	0.2
$\geq$ 0.85	2.0	62.0	11.2	0.2	0.0
$\geq$ 0.9	0.3	19.6	2.9	0.0	0.0
$\geq$ 0.95	0.8	1.7	0.8	0.0	0.0

- Contamination of quasi-exclusive events strongly dependent on assumption on high-β gluon density in pomeron (completely unknown...), and also on precision and smearing of dijet mass distribution (a cut at 0.9 at generator level corresponds to ??? at reconstructed level), true also for jet studies...

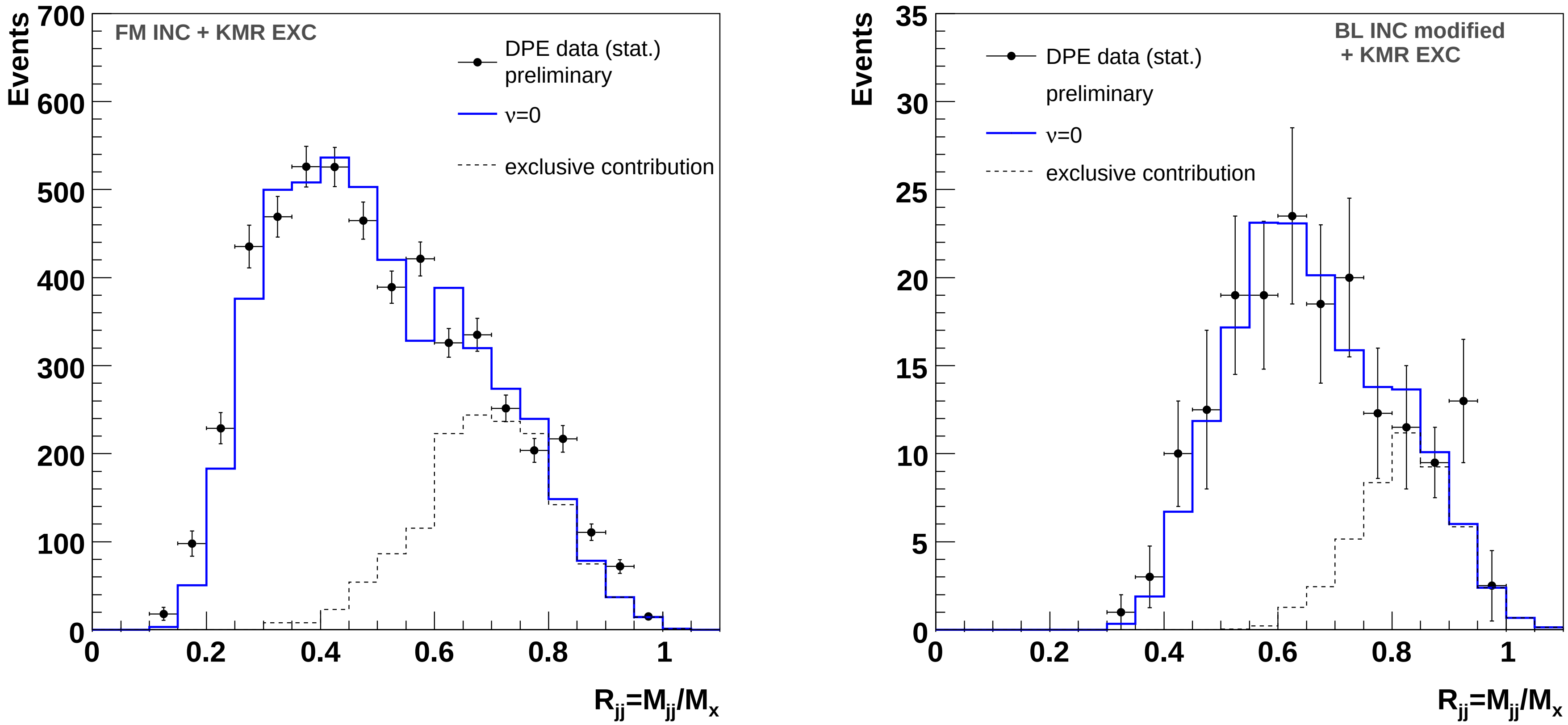
Dijet mass fraction measurement in CDF

- 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
- Predictions from inclusive diffraction models for Jet $p_T > 10$ GeV



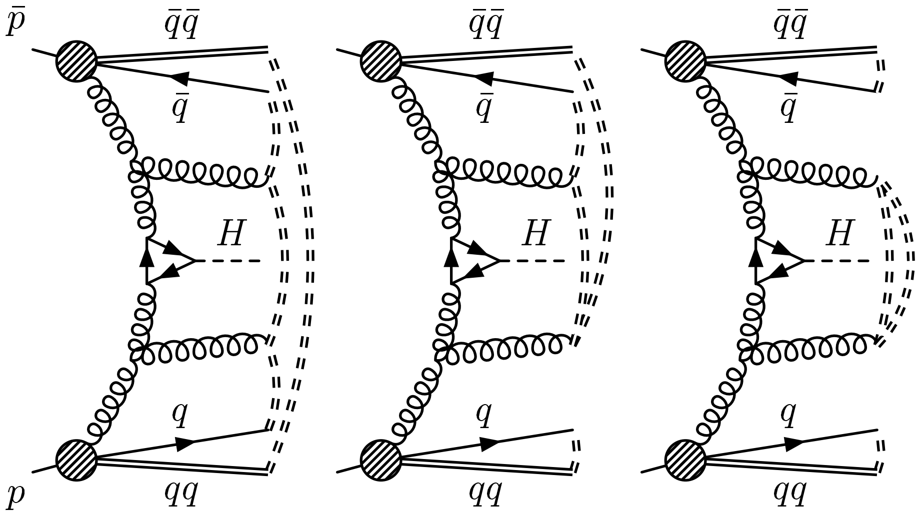
Prediction from inclusive and exclusive diffraction

- Add the exclusive contribution (free relative normalisation between inclusive and exclusive contribution)
- Good agreement between measurement and predictions
- As an example: exclusive and inclusive models for $p_T > 10$ GeV and for $p_T > 25$ GeV
- See O. Kepka, C. Royon, arXiv:0704.19956 accepted by Phys. Rev. D, arXiv0706.1798



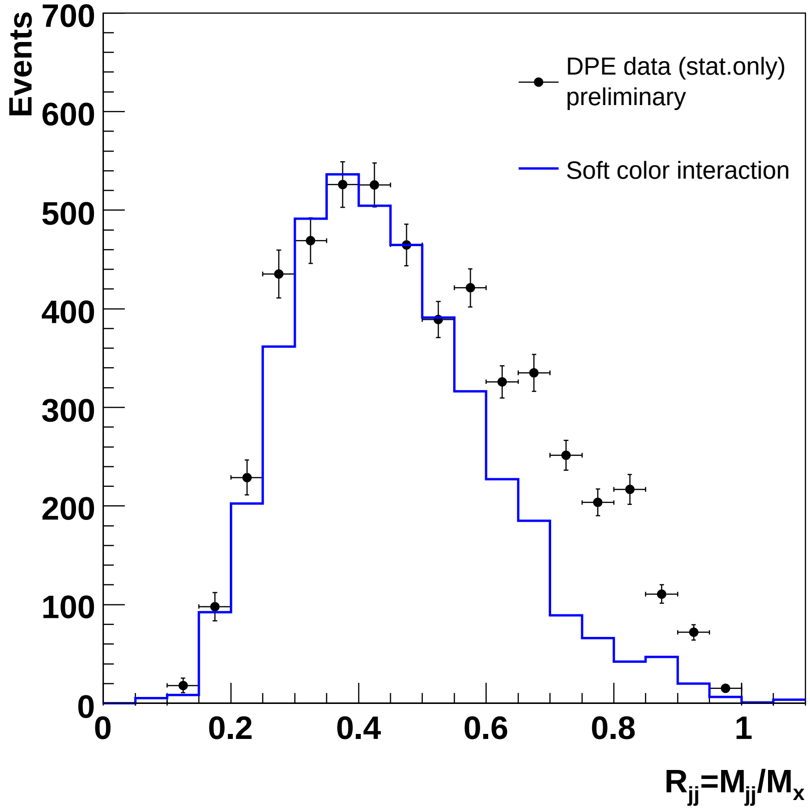
Soft Colour Interaction models

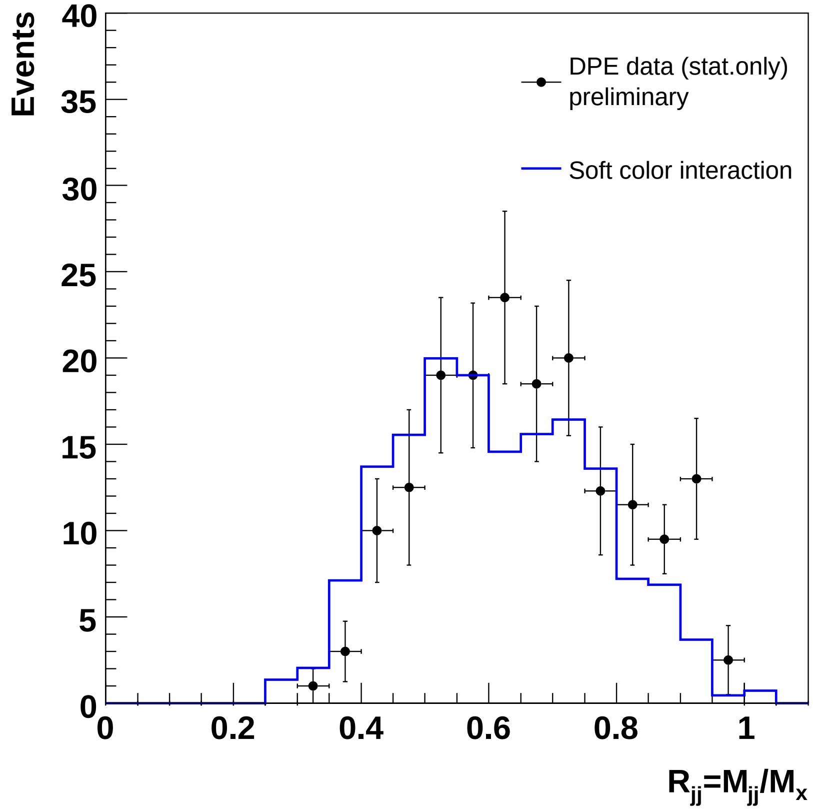
- A completely different model to explain diffractive events: Soft Colour Interaction (R.Enberg, G.Ingelman, N.Timneanu, hep-ph/0106246)
- Principle: Variation of colour string topologies, giving a unified description of final states for diffractive and non-diffractive events
- No survival probability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



What about SCI?

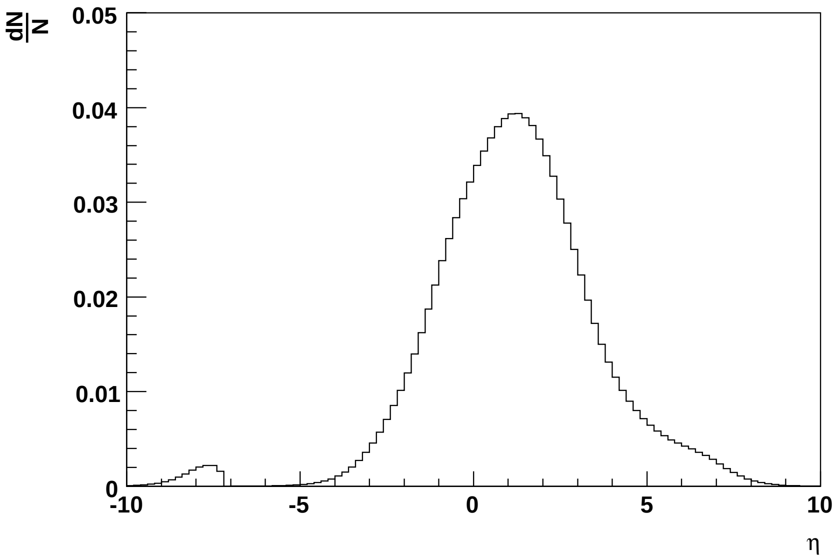
- SCI models give correct normalisation for single diffraction at Tevatron and diffraction at HERA without any additional parameter
- Exclusive events and SCI: Contribution of exclusive events needed much lower compared to Pomeron-like models, even vanishes for jet $p_T > 25$ GeV...

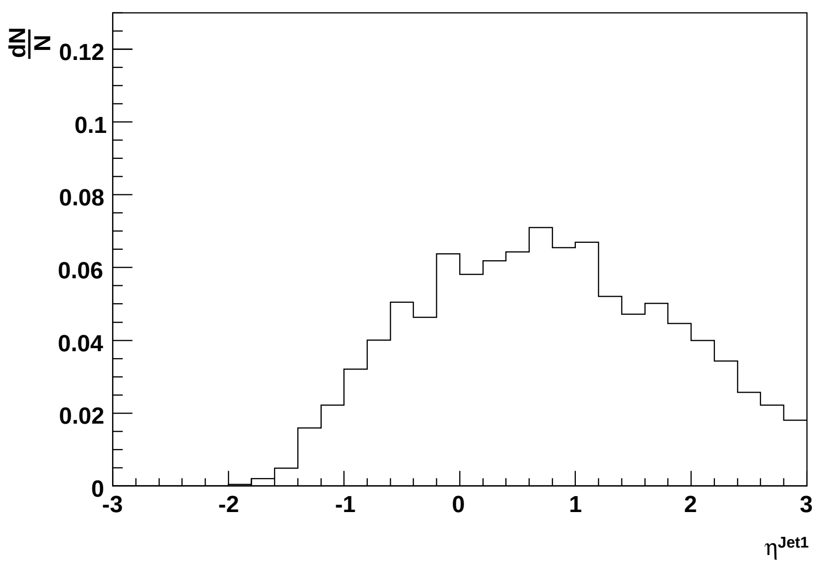




Comments about SCI

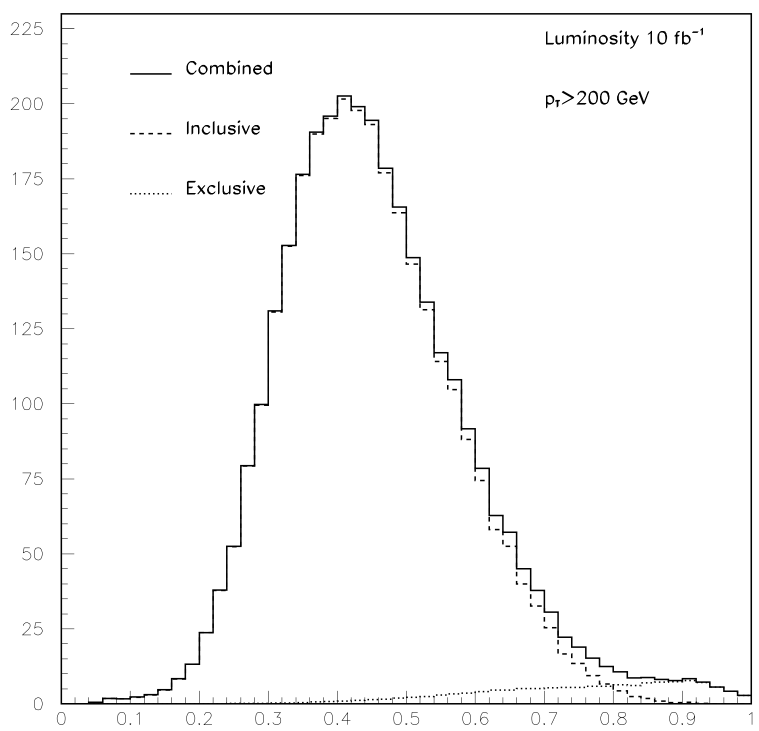
- Contribution of exclusive events much smaller for SCI
- "DPE" exchange in SCI models dominated by the following configuration for CDF events: 1 antiproton tagged in the final state, a bunch of particles going through the beam pipe on the other side (dominated by pions), no proton in the final state, due to the fact that only a rapidity gap is requested
- Jet rapidity boosted towards high rapidity: SCI model worth to be studied in more detail, but needs further improvement

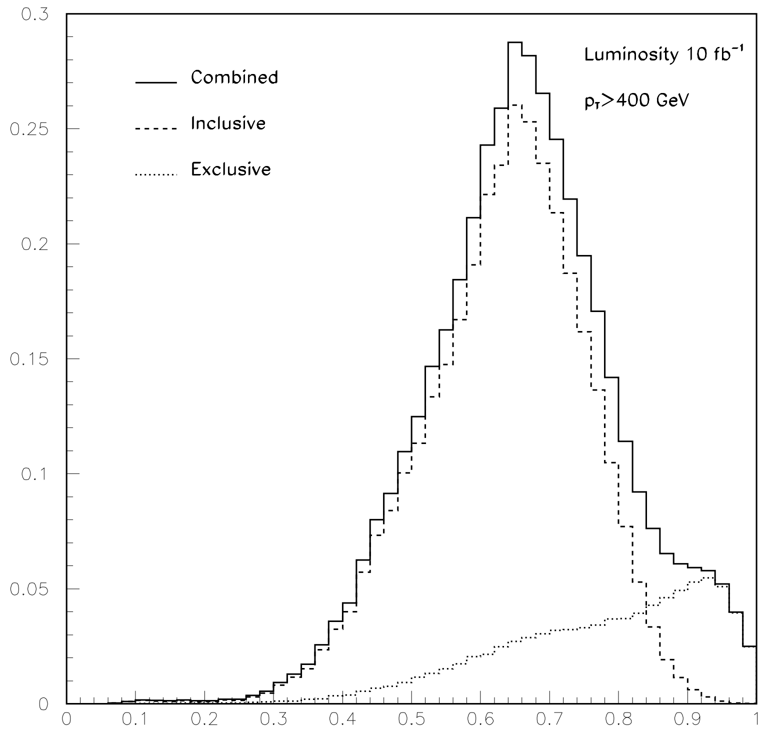




LHC: Exclusive and inclusive events

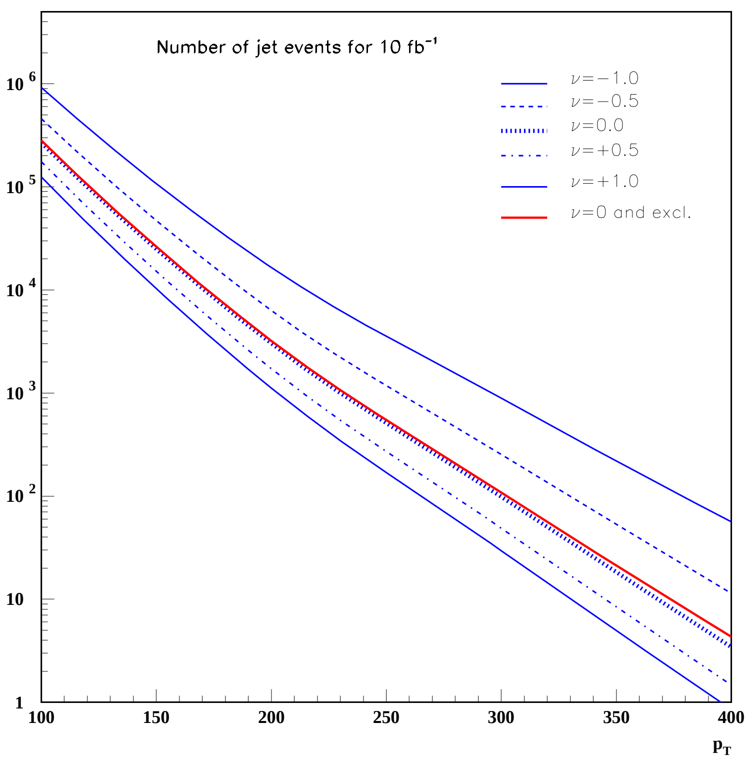
- Study of exclusive and inclusive production to be made at the LHC: study cross section of both components as a function of jet p_T and perform DGLAP QCD fits
- Important to understand background and signal for exclusive production of rare events: Higgs, SUSY...

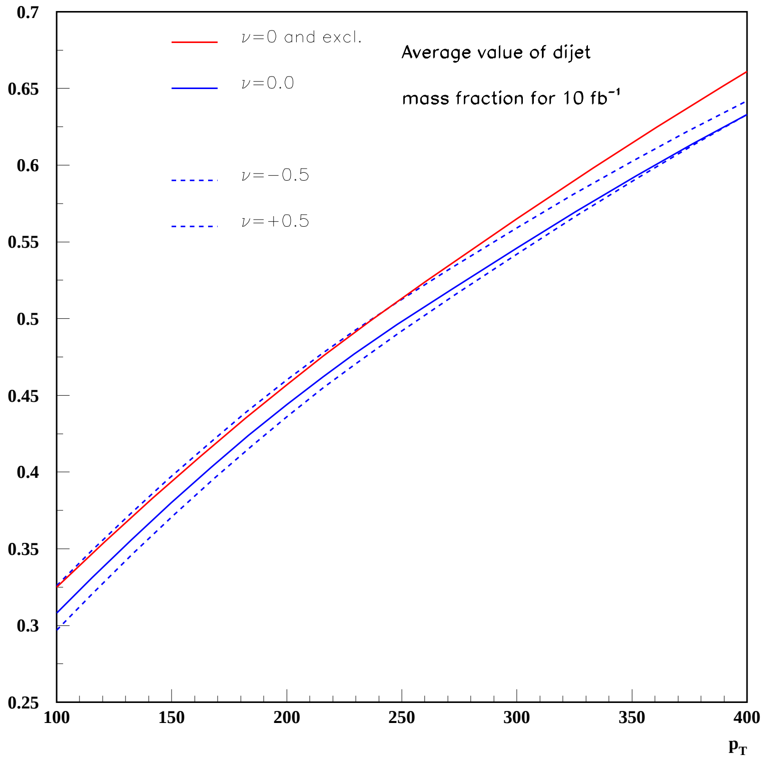




LHC: Exclusive and inclusive events

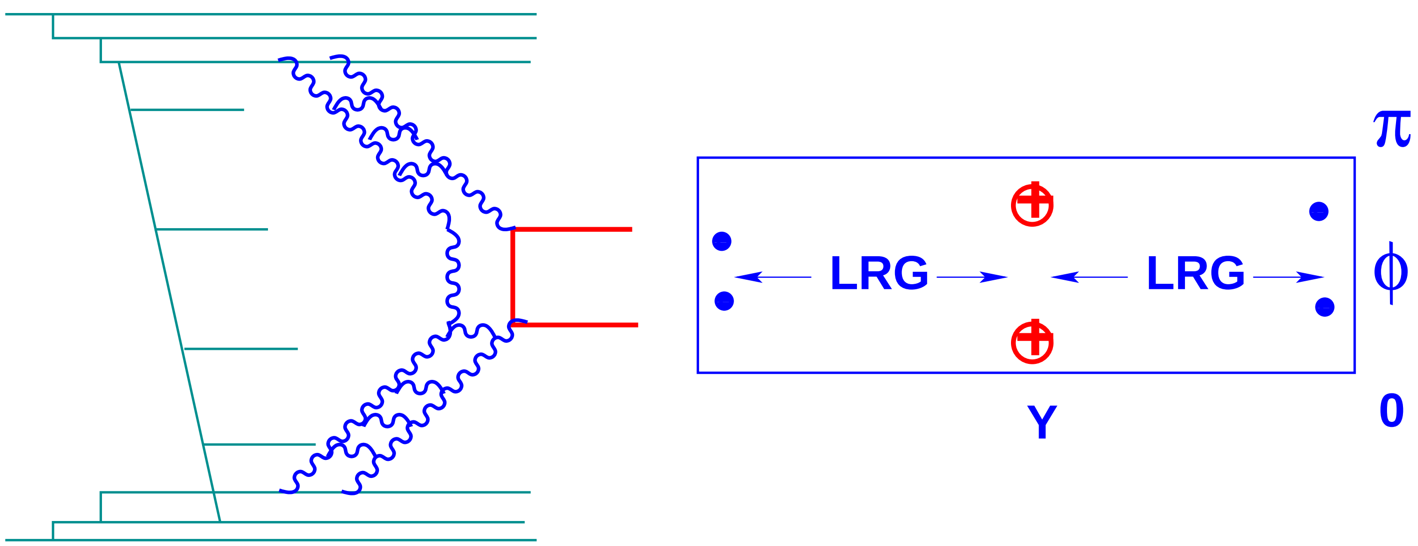
- Number of dijet events as a function of jet p_T:
  dominated by uncertainty on gluon density
- Dijet mass fraction (average value as an example):
  sensitive to exclusive production, quite easy to measure





Concept of survival probability

- Survival probability: Probability that there is no soft additional interaction, that the diffractive event is kept
- Important to measure the survival probability in data: estimated to be of the order of 0.1 at the Tevatron



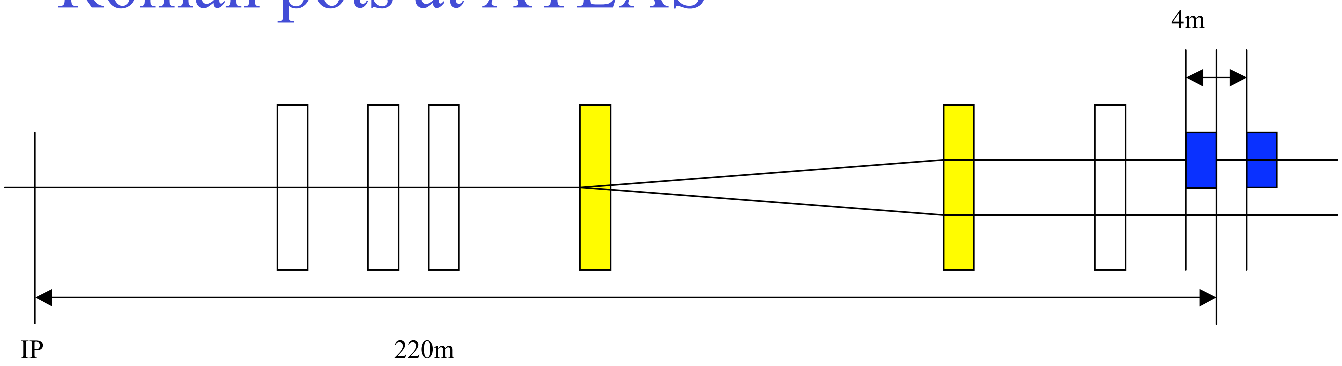
a) b)

Roman pot projects

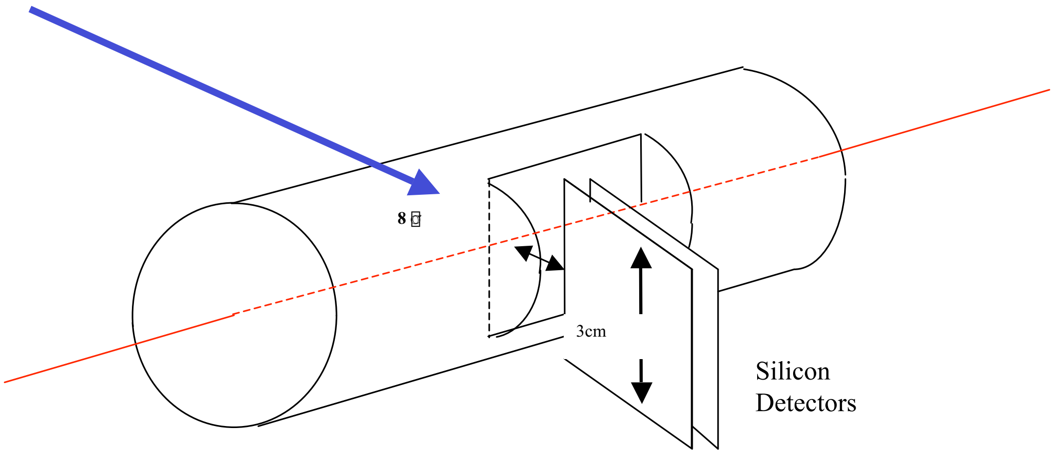
- TOTEM project accepted, close to CMS
- FP420: Project of installing roman pot detectors at 420 m both in ATLAS, CMS; collaboration being built
- Roman pot detectors at 220 m in ATLAS:
  - Natural follow-up of the ATLAS luminosity project at 240 m to measure total cross section
  - Complete nicely the FP420 m project
  - Collaboration between Saclay. Prague, Cracow, Stony Brook, Pars 6, Michigan State University, Heidelberg, Giessen and also University of Chicago and Argonne for timing detectors (so far) being pursued
  - Collaboration with the FP420 m project concerning detectors, triggers, simulation...
- For more information, see the web pages of FP420, CMS, TOTEM, ATLAS

Scheme of roman pot detectors

Roman pots at ATLAS



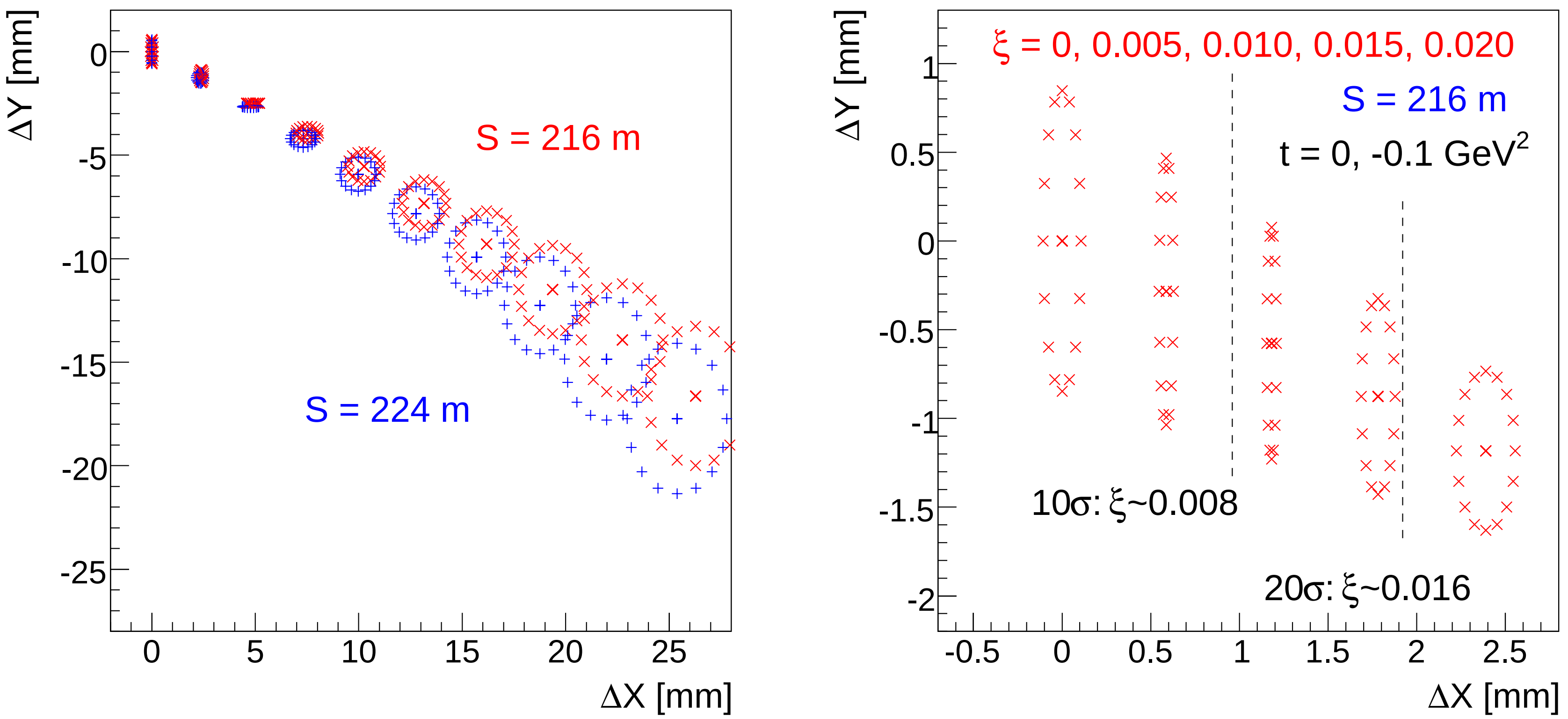
As close as possible
to the beam:
10 □ = 1mm



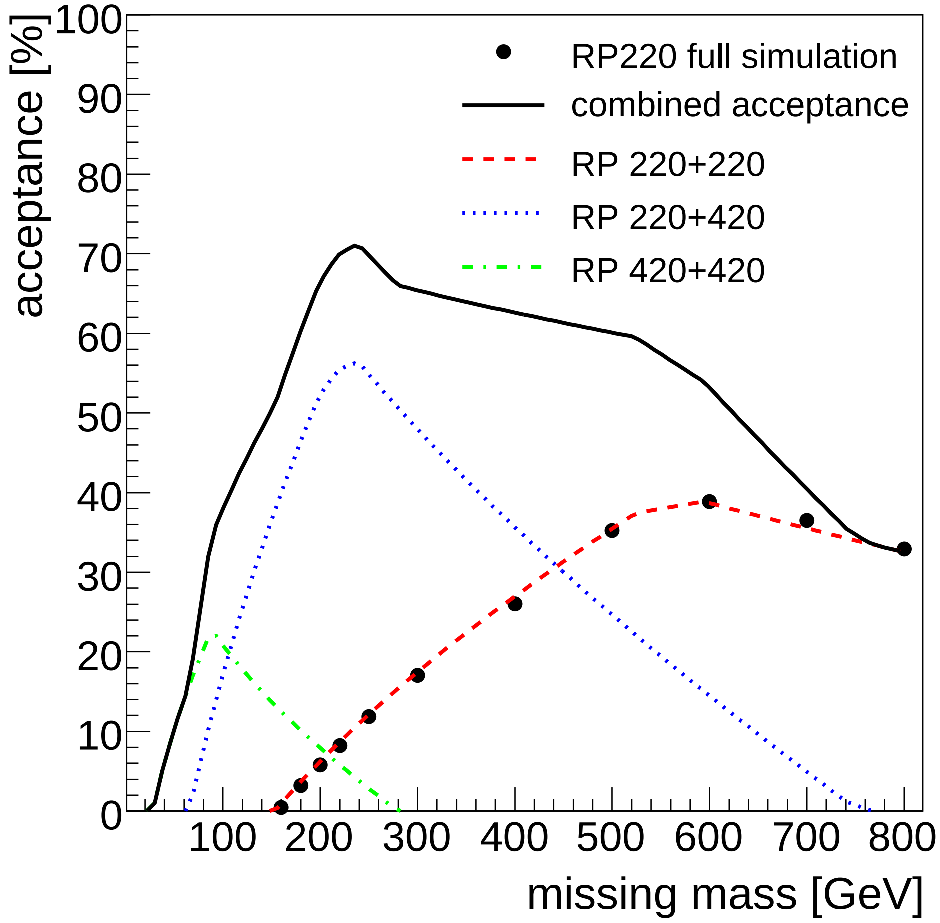
Assume roman pots located at 216 and 224 m

Acceptance for 220 m pots

- Steps in ξ: 0.02 (left), 0.005 (right), $|t|$=0 or 0.05 GeV^2
- Detector of 2 cm $\times$ 2 cm will have an acceptance up to $\xi \sim 0.16$, down to 0.008 at 10 σ, 0.016 at 20 σ
- As an example Higgs mass acceptance using 220 m pots down to 135 GeV and upper limit due to cross section and not kinematics



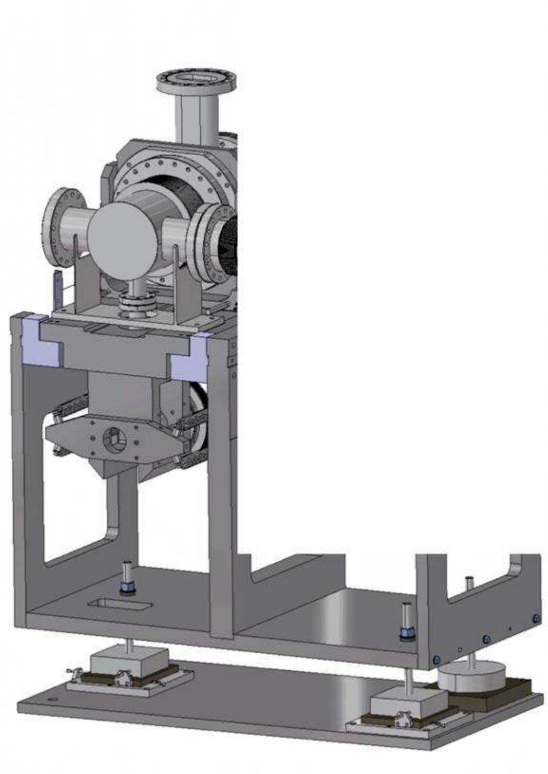
Roman pot projects

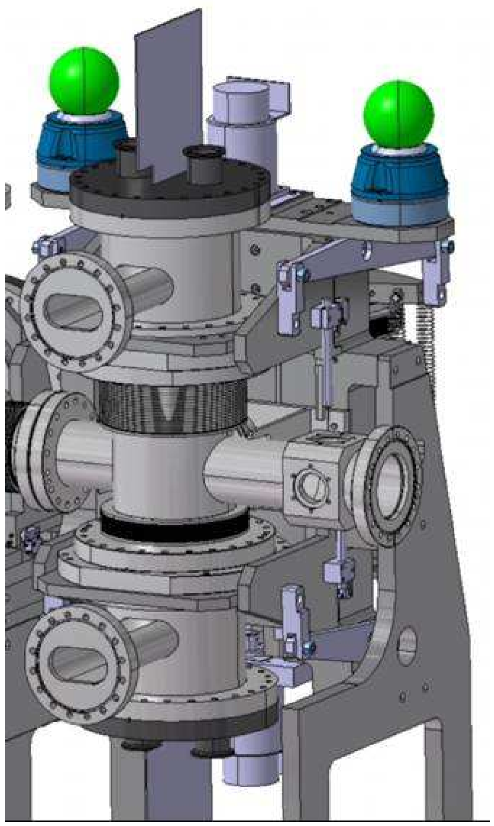


Both FP420 and RP220 needed to have a good coverage of acceptance (NB: acceptance slightly smaller in CMS than in ATLAS)

Roman pots / movable beam pipe at 220 m

Schematic view of 220 m pots: horizontal pots to detect diffractive events, vertical pots used for alignment





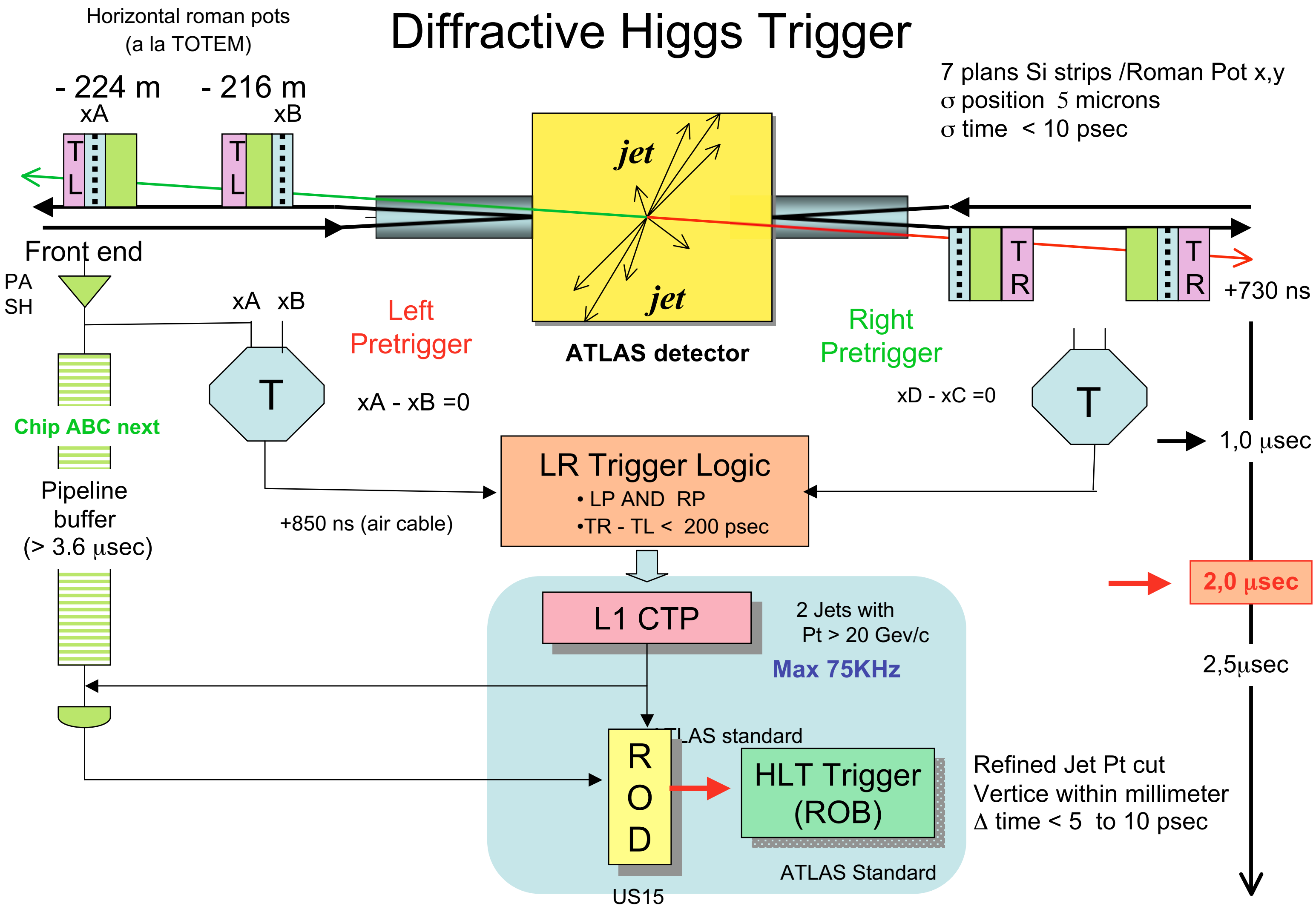
Which kind of detectors?

- Requirement: good resolution in position (good measurement of mass, kinematical propwerties), and in timing
- Position detectors:
  - Size of Si detectors (either 3D or strips) to be put in roman pots: 2cm $\times$ 2cm
  - Spatial resolution of the order of 10-15 μm: Si strip detectors of 50 μm: 5 layers, 2 vertical, 1 horizontal, 1 U, 1 V (45 degrees)
  - Edgeless detectors: Between 30 to 60 μm
  - First prototype of strip detector made by CANBERRA, 3D detectors made for FP420: test-stand (laser and radioactive source) being installed in Saclay, tests also possible at CERN/Prague
  - Trigger: Strip detectors of 100-200 μm, Si or pixel chip to be modified to include trigger possibility

Which kind of detectors?

- Timing detectors
  - Why do we need timing detectors? At the LHC, up to 30 interactions by bunch crossing, and we need to identify from which vertex the protons are coming, same problem for FP420
  - Timing detector in movable beam pipe: resolution needed: of the order of 5 picoseconds (space resolution slightly more than 1 mm)
  - Radiation hardness
  - Detector space resolution: few mm, the total width of the detectors being 2.5 cm (4.5 cm available in roman pot)
  - Reference clock: either the LHC clock (resolution of 7-8 ps), or atomic clock (they need to be calibrated on each side)
  - Trigger information: at L1 (rough compatibility between both sides of ATLAS) and specially at L2 (compatibility with vertex position)
  - Development: new timing detectors in collaboration with the Universities of Chicago, Stony Brook, and Argonne, and with Photonis

Trigger: principle



Trigger: strategy

- L1 trigger when two protons tagged at 220 m
- L1 trigger when only one proton is tagged at 220 m: in that case, cut on acceptance at 220 m corresponding to the possibility of a tag at 420 m
- Cuts used:
  - 2 jets in central detector with $p_T > 40$ GeV
  - Exclusiveness of the process (2 jets carrying 90% of the energy) $(E_{T_1} + E_{T_2})/H_T > 0.9$
  - Kinematics requirement $(\eta_1 + \eta_2) \times \eta_{220} > 0$
  - At least one proton tagged at 220 m with $\xi < 0.05$ (compatible with the eventual presence of a proton at 420 m on the other side) **or** one proton tagged at 220 m on each side
- With those cuts, possibility to get a L1 rate less than 1 kHz for a luminosity less than 3.10^{33}cm^{-2} s^{-1}

Collaboration between FP420 and RP220

- Development for RP220 project:
  - Roman pots: 3 arms (horizontal, up and down for diffractive events and elastics, do we need a magnet between pots? (avoid low energy particles coming from the first pot)
  - Pixel detectors: modify size of pixel detector to 2 cm $\times$ 2 cm
  - Trigger capability: trigger performed by reading lines of pixels to be able to compute ξ at L1
  - Final timing detectors: 5 ps resolution, aim to develop by 2012, MCP technology, (to be used also by FP420)
- FP420 and RP220 together:
  - Pixel detector technology and readout
  - Movable beam pipe technique: used for timing detectors in RP220
  - Timing detectors for 2010: temporary MCP (resolution of 30-40 ps?), gastof developped by Louvain (15 ps?)
  - RF pickup: to be computed by Manchester team
- FP420 and RP220 backup: Si strip detectors

Conclusion

- Study of inclusive events: determination of gluon at high β, QCD studies, search for SUSY events (or any resonance) when dijet background is known
- Exclusive events: promising results in dijet channel at the Tevatron
- Exclusive Higgs: Signal over background: ~ 1 if one gets a very good resolution using roman pots (better than 1.5 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, study of photon anomalous coupling
- Project of installing roman pot detectors in ATLAS well started: collaboration between Prague, Cracow, Saclay, Stony Brook, Heidelberg, Giessen, Paris 6, Michigan State University
- Collaboration about timing detectors (and medical applications): University of Chicago, Argonne, Saclay
- TDR to be presented in ATLAS together with FP420 in the beginning of next year