Hard diffraction at the LHC and the RP220 project in ATLAS

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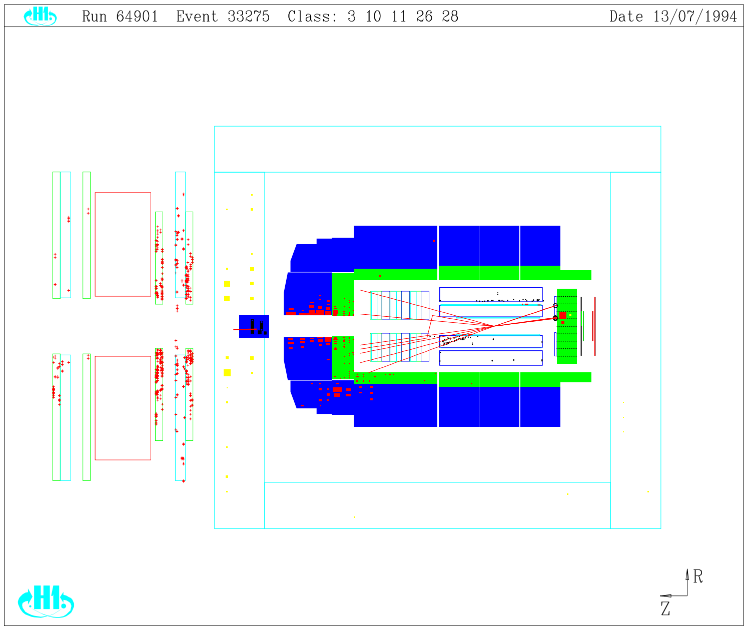
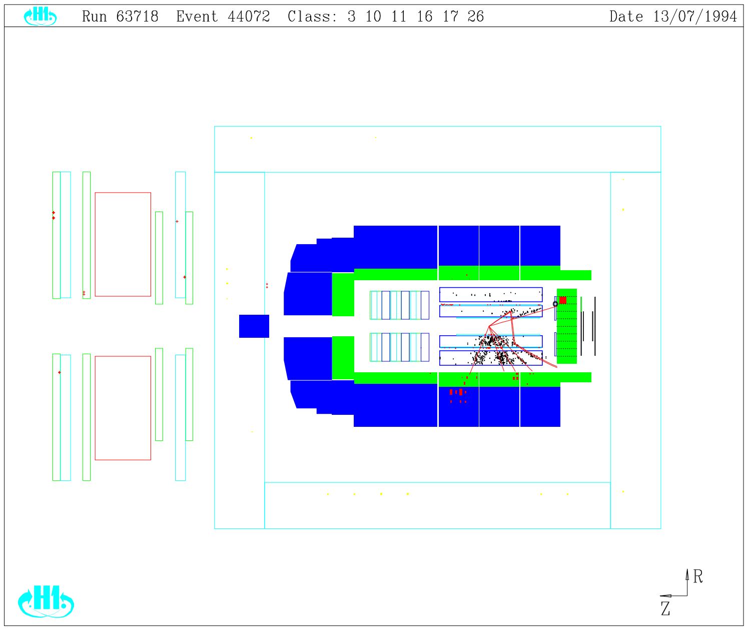
Contents:

Forward physics at the LHC

- TOTEM project accepted, close to CMS: dedicated to measurements at low luminosity (total cross section)
- Alfa project in ATLAS: dedicated to measurements at low luminosity (cross section in the Coulomb region)
- FP420: Project of installing roman pot detectors at 420 m both in ATLAS, CMS
- Roman pot detectors at 220 m in ATLAS: hard diffraction in ATLAS
- For more information, see the web pages of FP420, CMS, TOTEM, ATLAS

DIS and Diffractive event at HERA





Scheme of a roman pot detector

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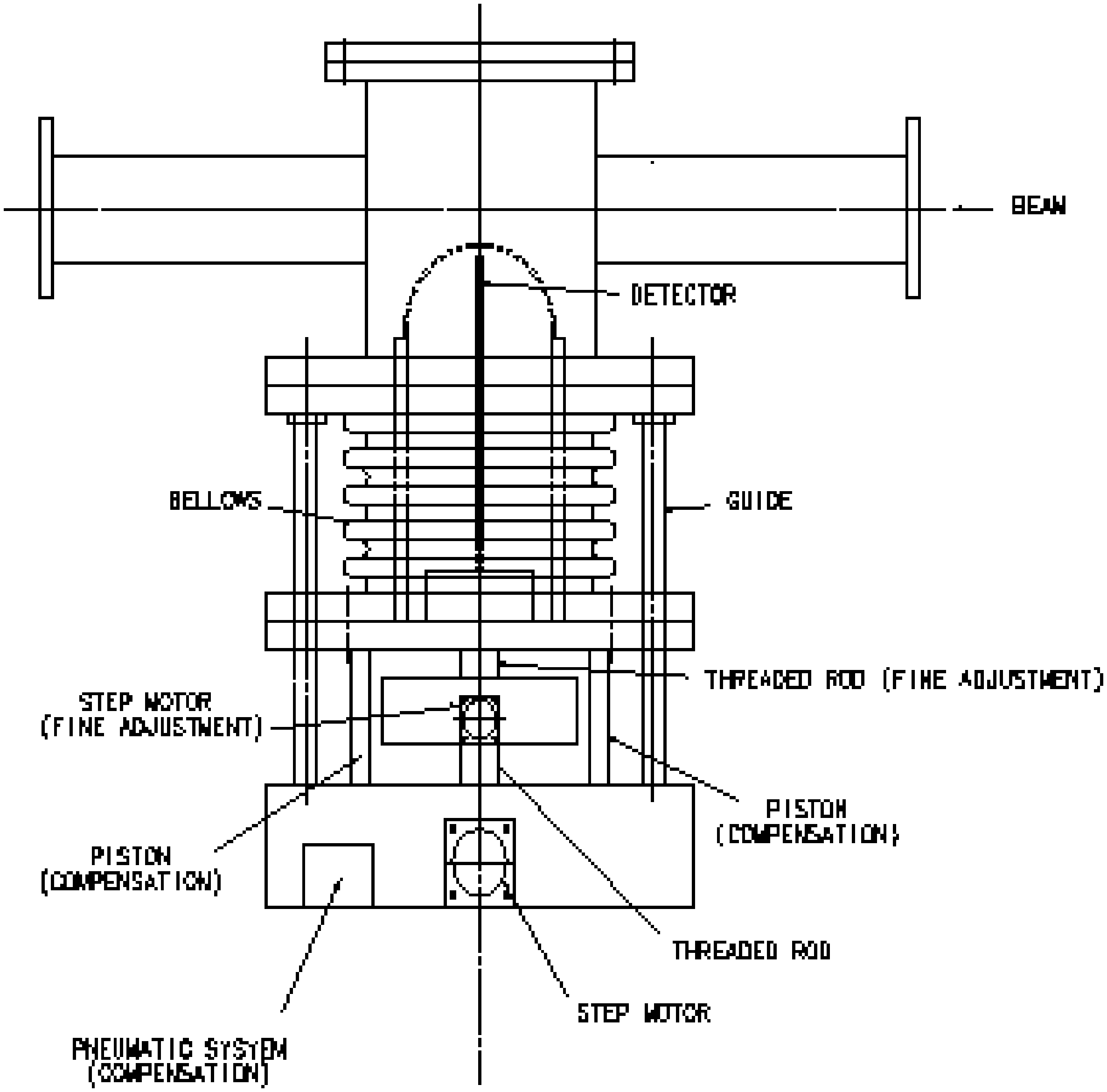
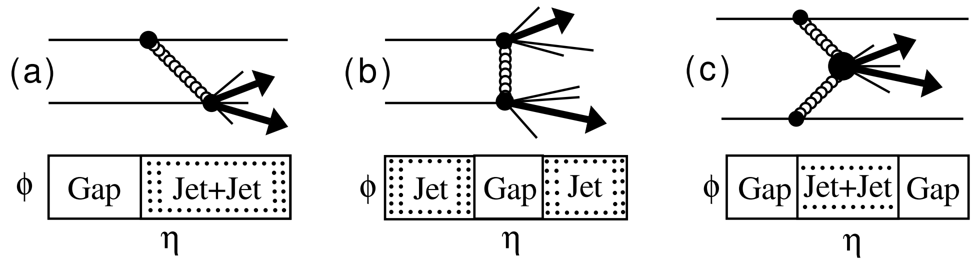


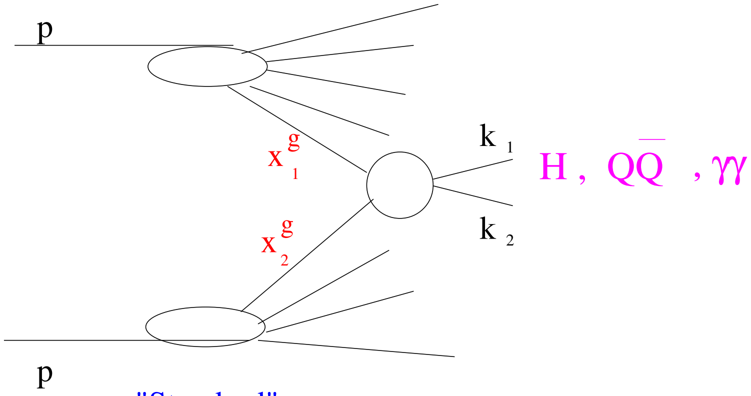
Diffraction at Tevatron/LHC



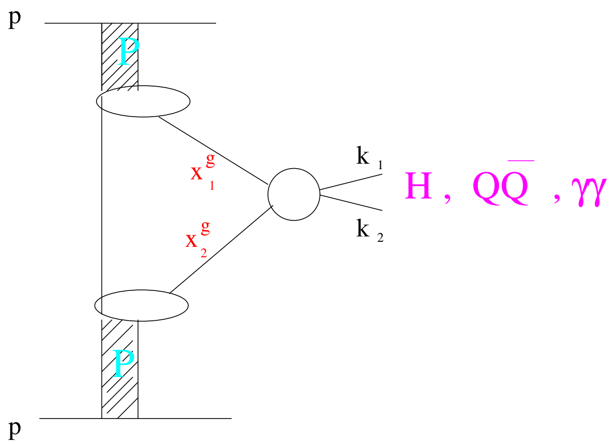
Kinematic variables

- 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

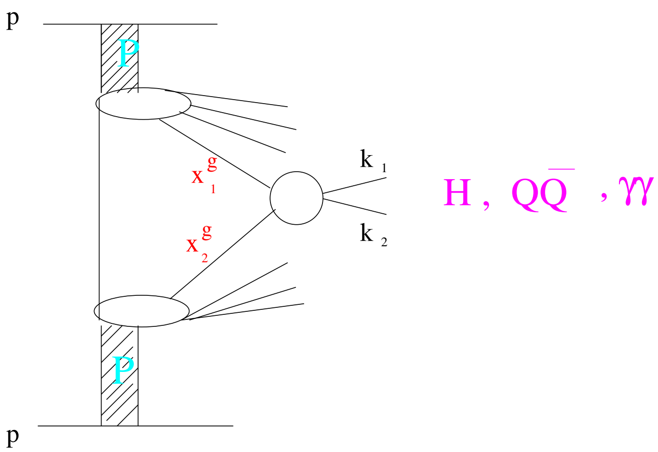
"Exclusive models"



"Standard"



"Exclusive "

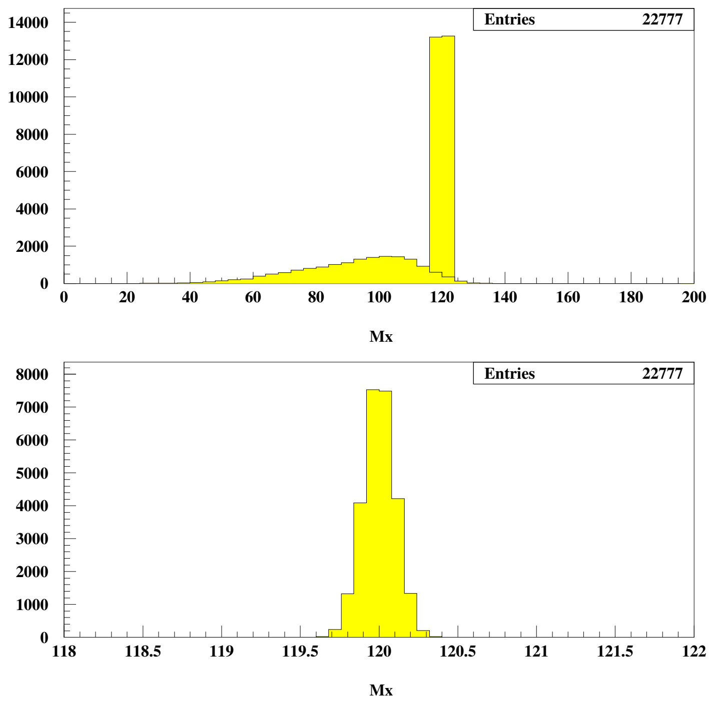


"Inclusive"

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

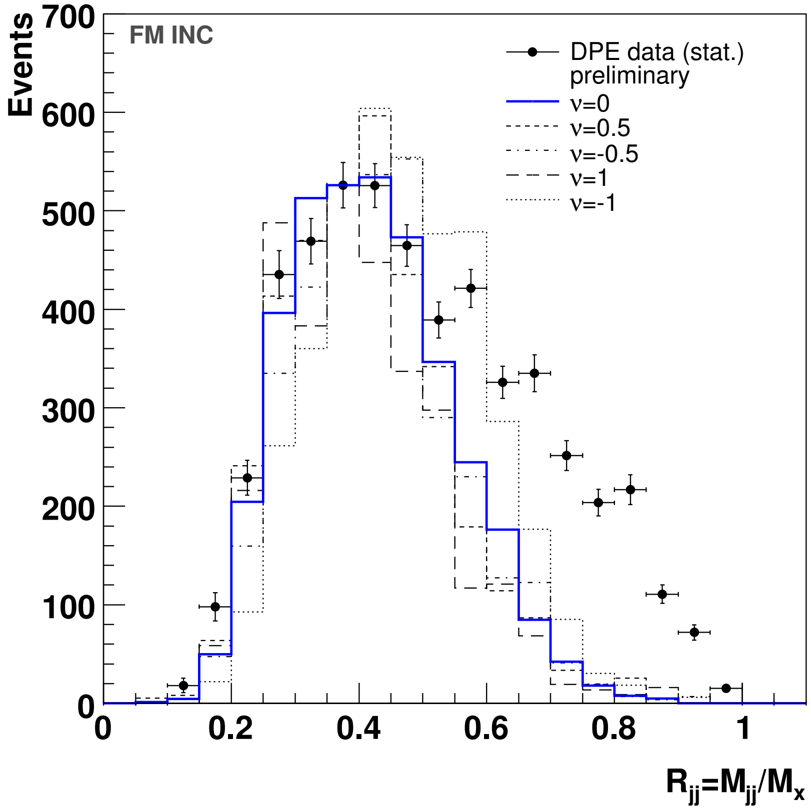
Advantage of exclusive Higgs production?

- Good Higgs mass reconstruction: fully constrained system, Higgs mass reconstructed using both tagged protons in the final state ($pp \rightarrow pHp$)
- $M_H = \sqrt{\xi_p \xi_{\bar{p}} S}$
- 2 questions: Cross section and signal over background for diffractive Higgs? Have exclusive events already been seen at the Tevatron?



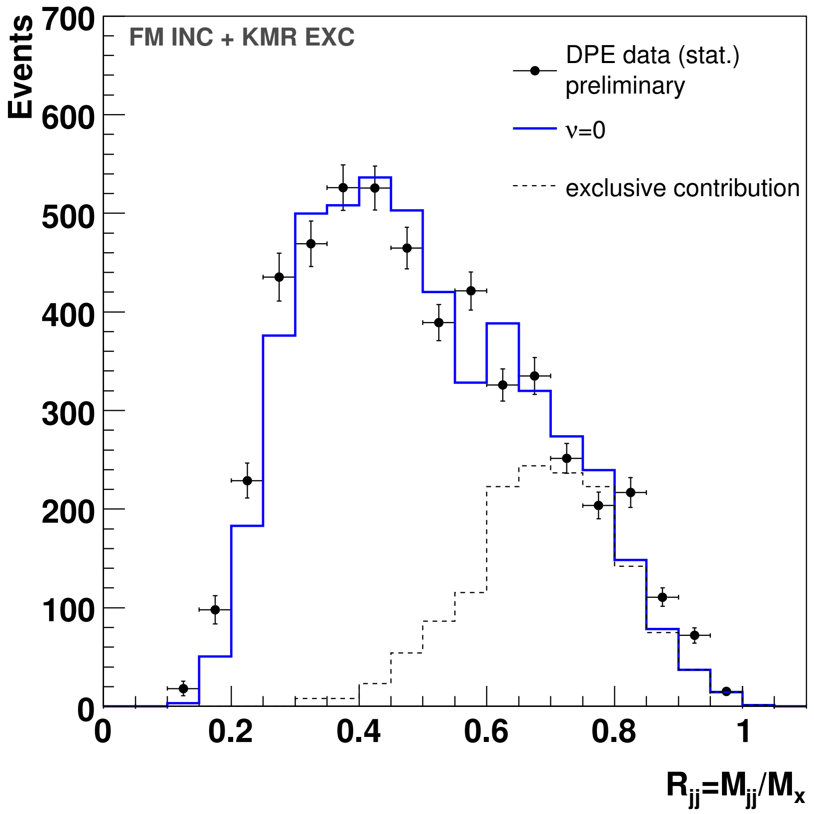
Dijet mass fraction measurement in CDF

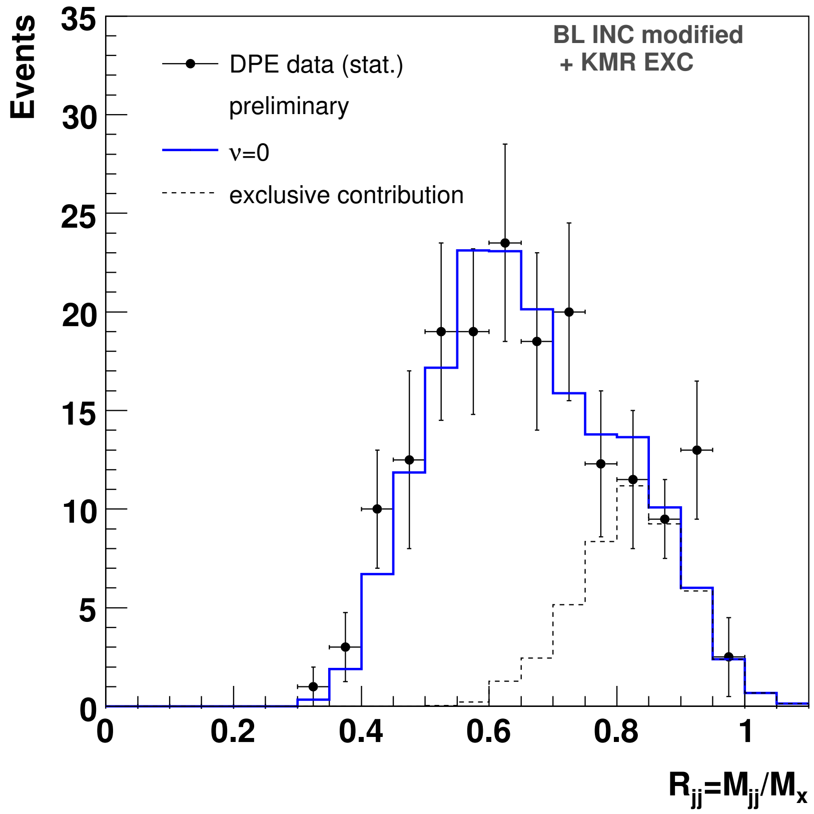
- Look for exclusive events (events where there is no pomeron remnants or when the full energy available is used to produce diffractively the high mass object)
- Select events with two jets only, one proton tagged in roman pot detector and a rapidity gap on the other side
- Predictions from inclusive diffraction diffraction models for Jet $p_T > 10$ GeV
- Inclusive diffraction cannot explain alone CDF data!



Prediction from inclusive and exclusive diffraction

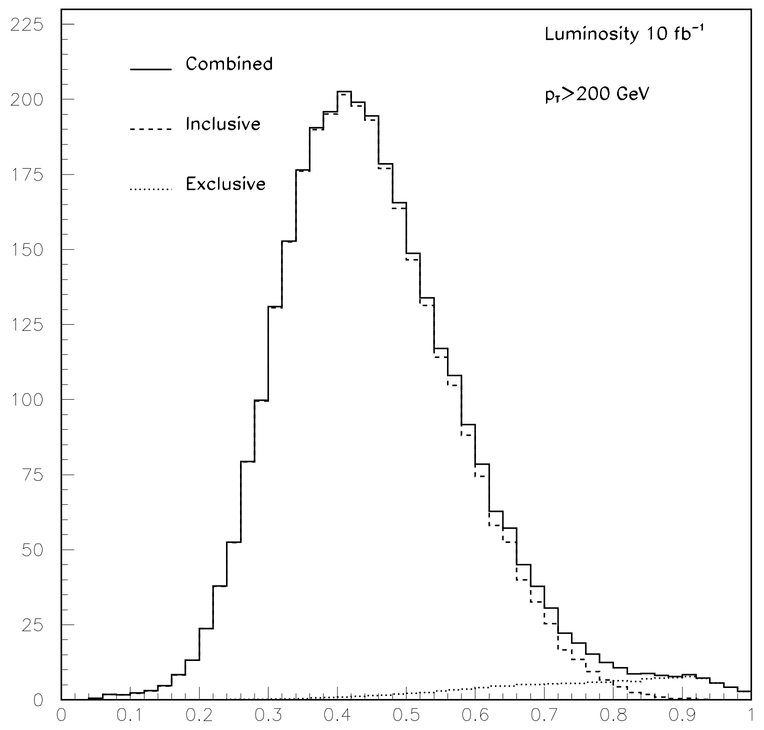
- Add the exclusive contribution from Durham
- Good agreement between measurement and predictions
- Need of an "exclusive" contribution to describe CDF data and cross section in rough agreeement with theoretical calculation (50% uncertainty)

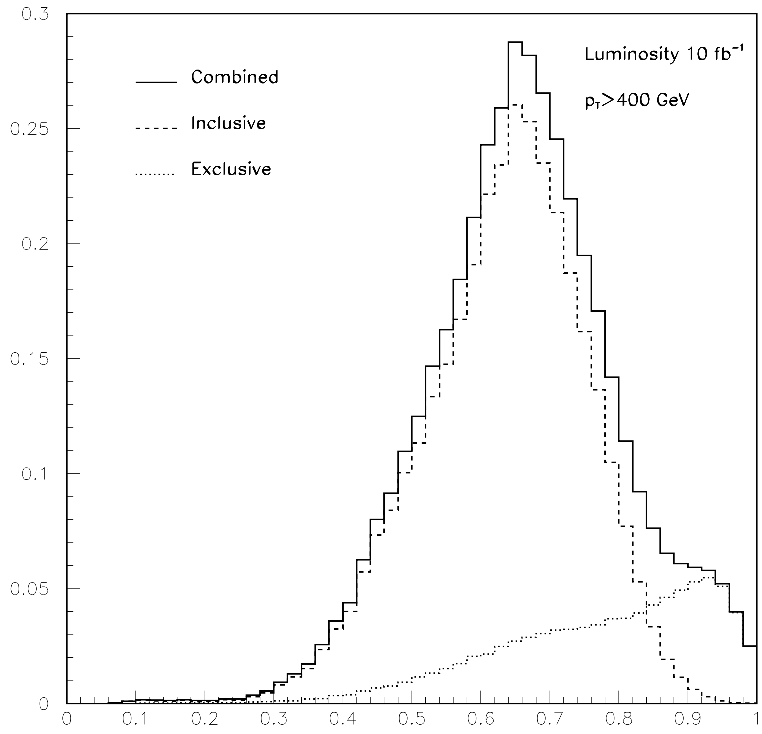




LHC: Exclusive and inclusive events

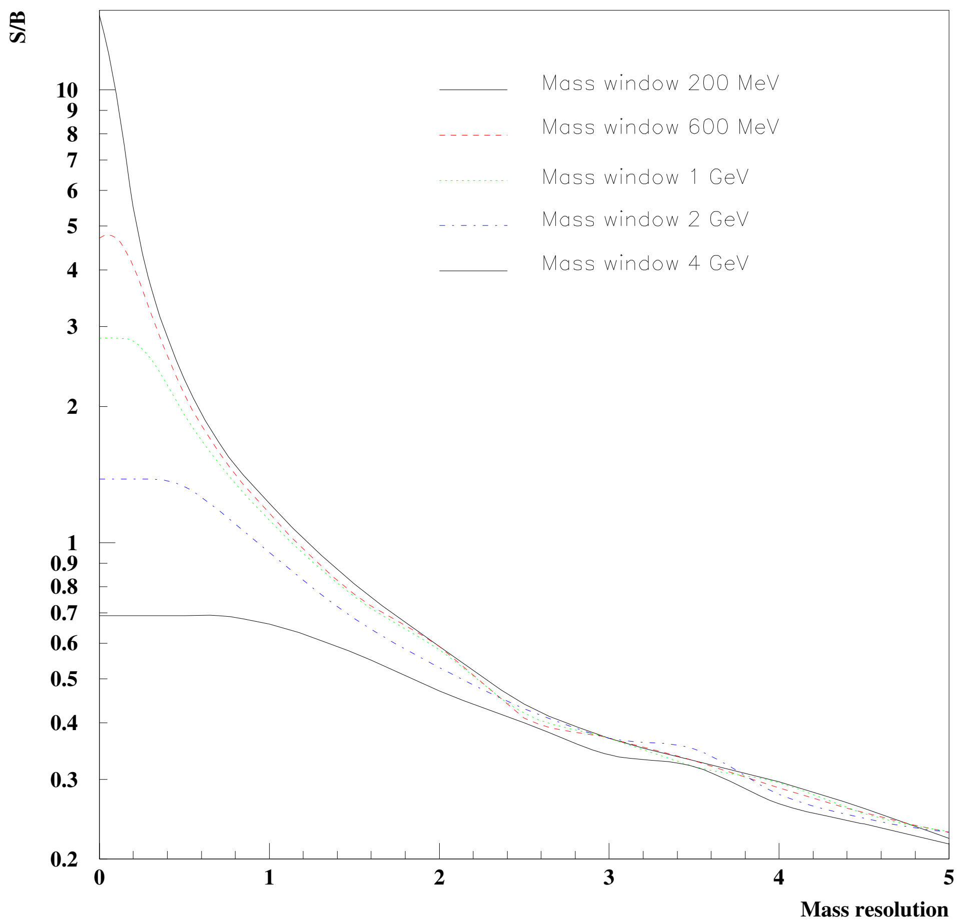
- Study of exclusive and inclusive production to be made at the LHC: study cross section of both components as a function of jet p_T and perform DGLAP QCD fits
- Important to understand background and signal for exclusive production of rare events: Higgs, SUSY...





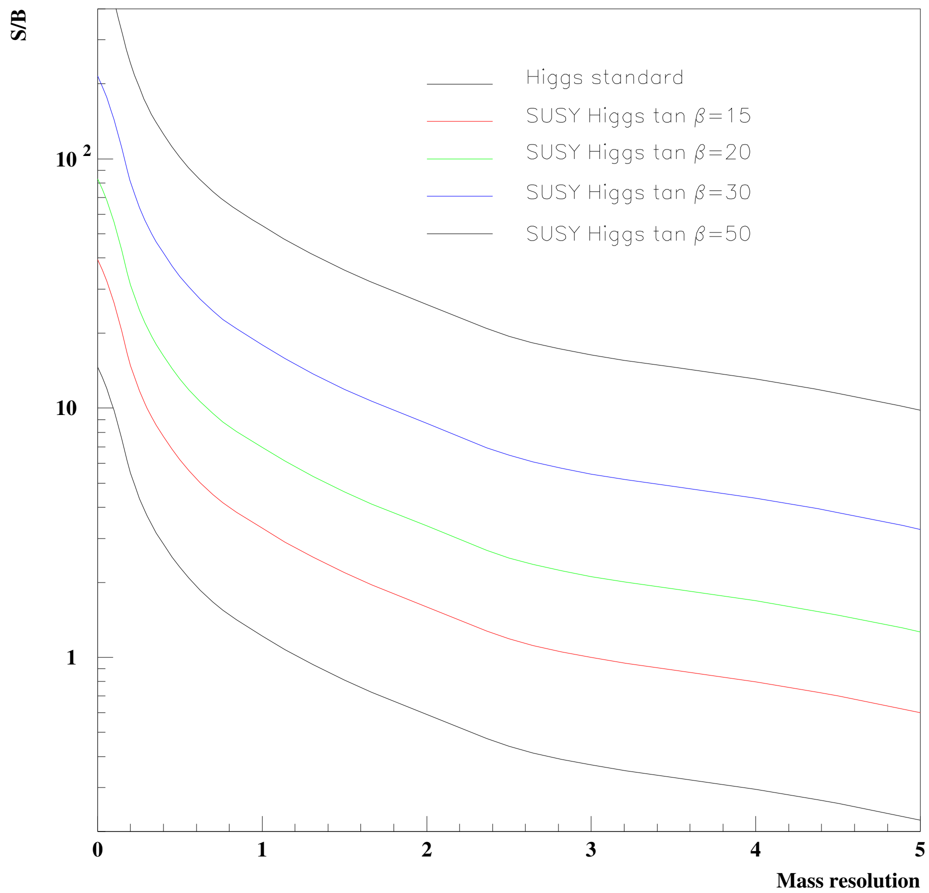
Signal over background: standard model Higgs

- Exclusive diffractive Higgs production cross section in the roman pot acceptance: $\sim$ 1 fb
- S/B for a Higgs mass of 120 GeV and for different mass windows as a function of the Higgs mass resolution
- Study being done using a full simulation and full model analysis, will lead to a predicted number of events for 20-30 fb^{-1}

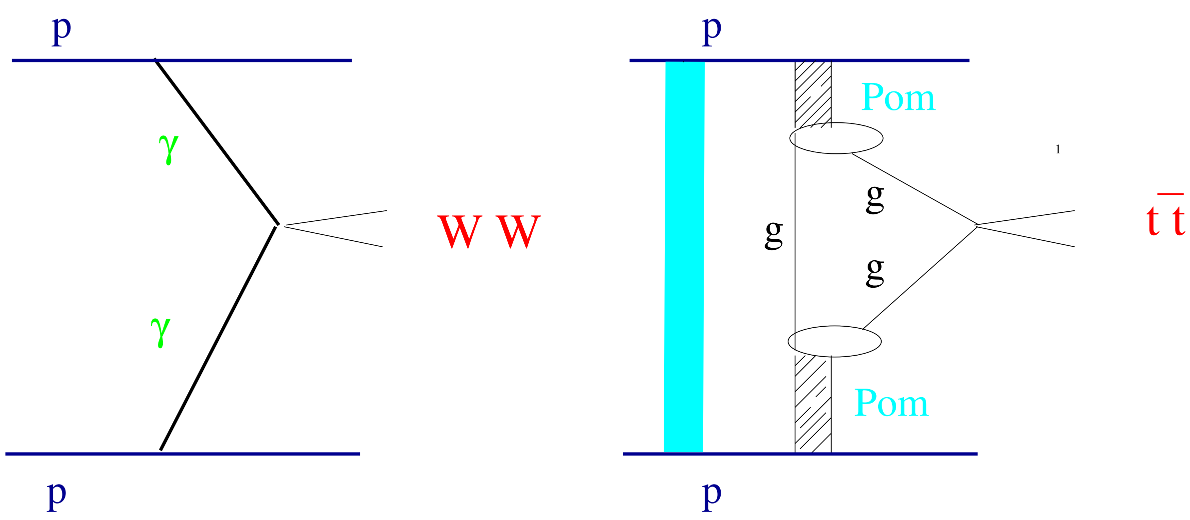


Diffractive SUSY Higgs production

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



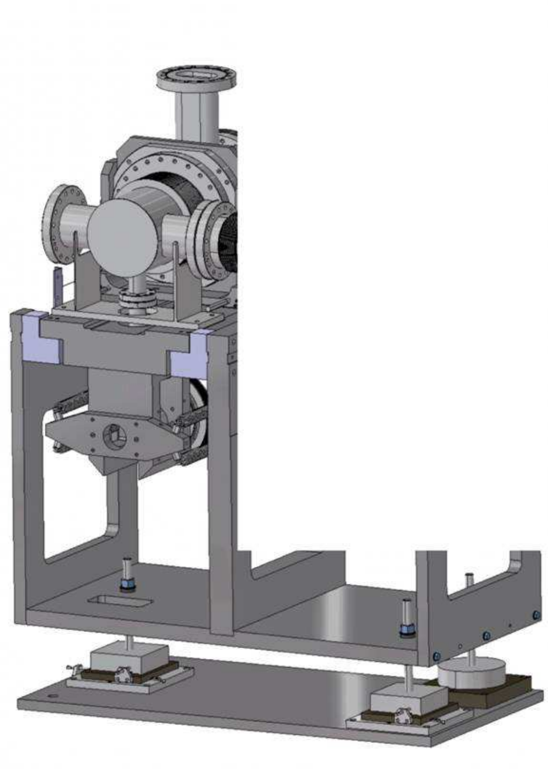
W, top and stops

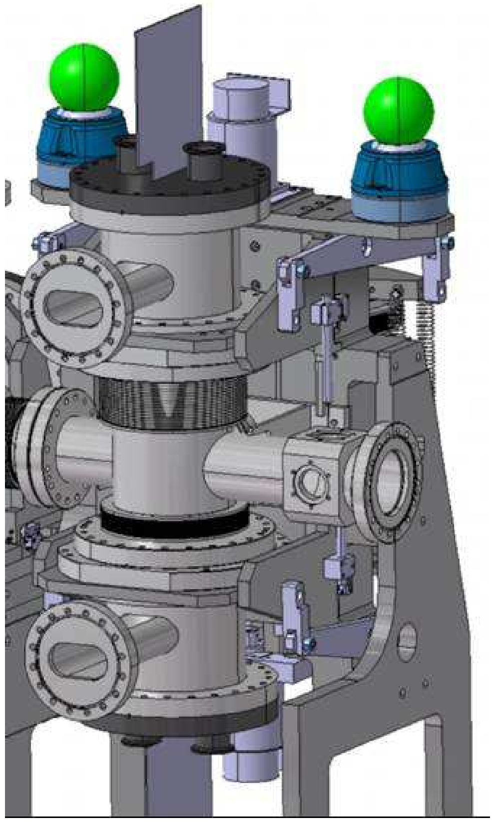


- All the energy is used to produce the W, top (stop) pairs:
- W: QED process, cross section perfectly known, top: QCD diffractive process
- Measurement of the photon anomalous coupling: WW production cross section perfectly known (QED) and any anomalous coupling between γ and W will reveal itself in a modification of the production cross section, and by different anbgular distributions. The WW production cross section is proportional to the 4th power of the γW coupling $\longrightarrow$ GOOD SENSITIVITY

Roman pots at 220 m

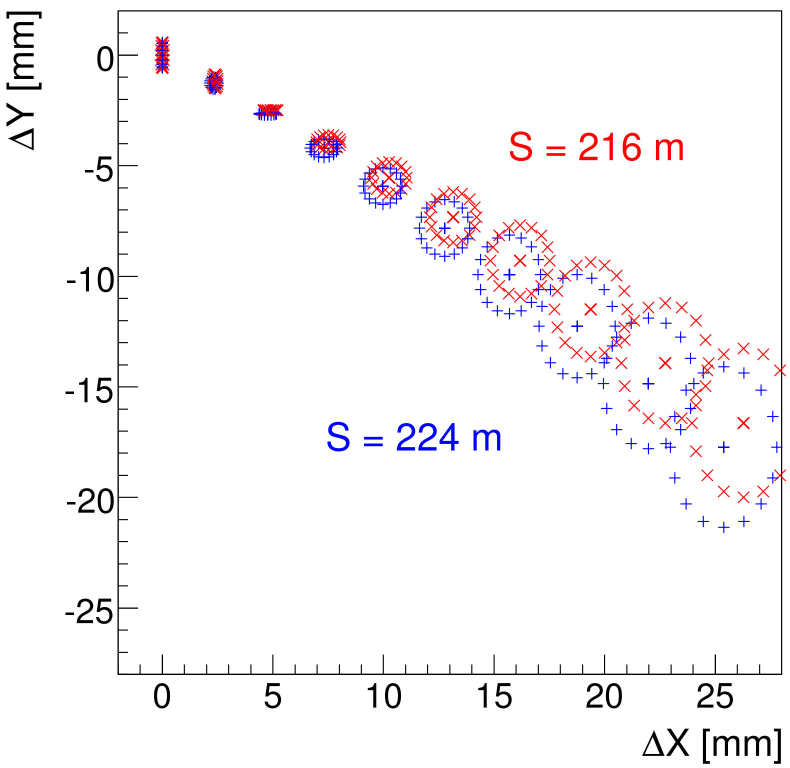
- Two sets of roman pots at 216-224 m
- Schematic view of 220 m pots: keep horizontal pots only from the TOTEM pots
- Present collaboration: Cracow, Prague, Saclay, Paris 6, Giessen, Heidelberg, Michigan State University, Stony Brook, and also The University of Chicago and Argonne National Laboratory for the timing detectors
- Two options: Short timescale for installation depending on results for Higgs, and longer timescale for QCD studies, Need to be proposed soon when full studies available

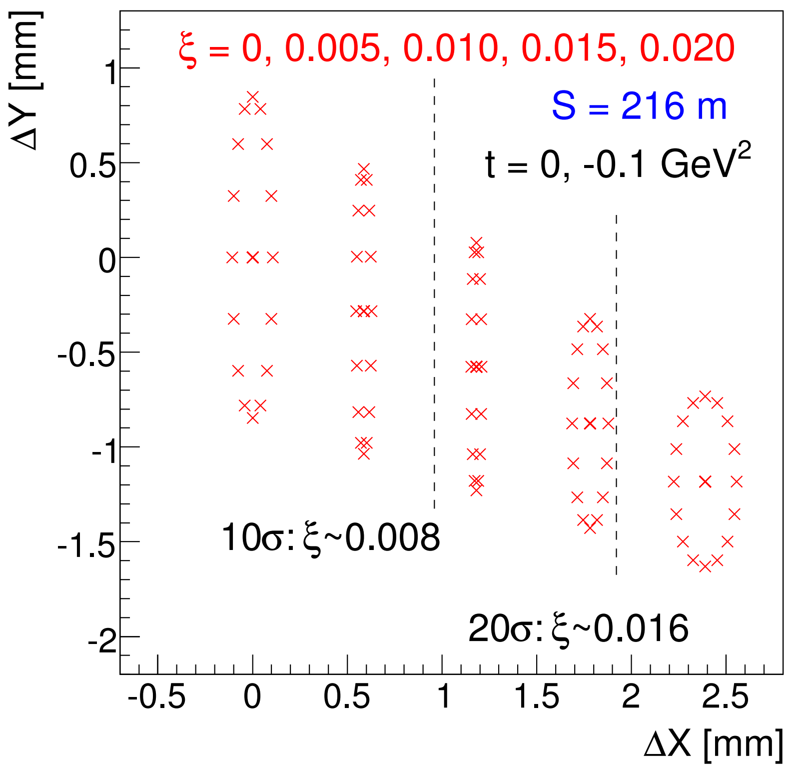




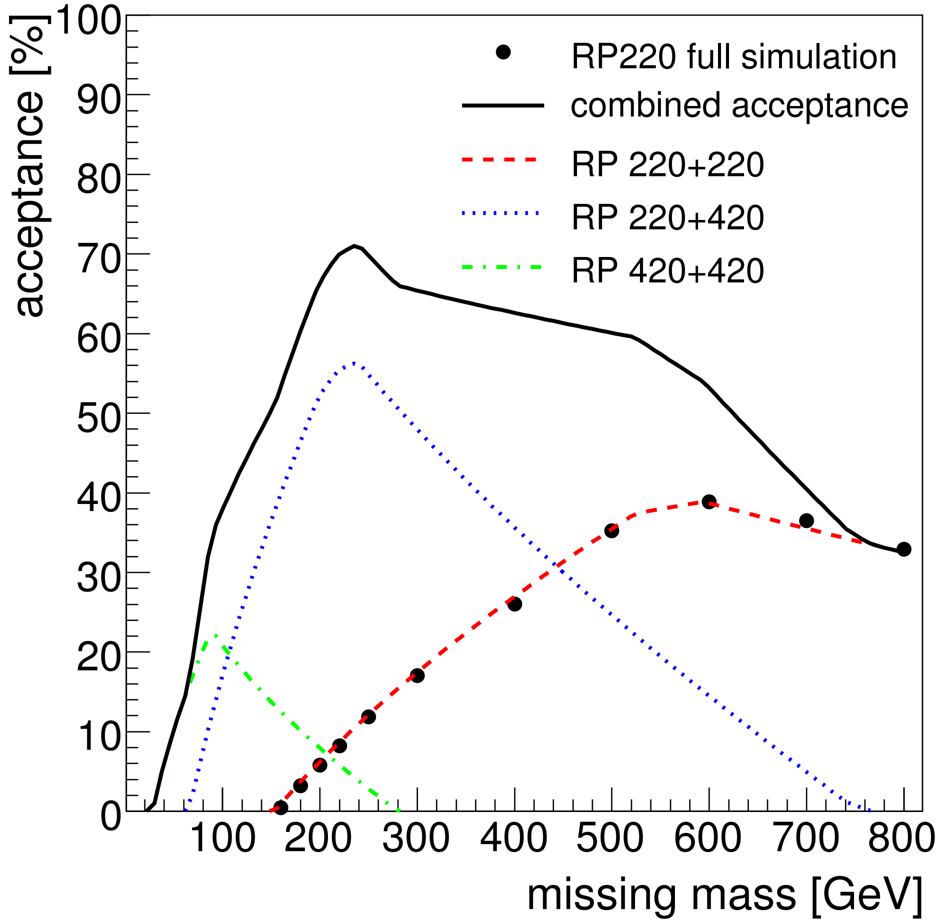
Acceptance for 220 m pots

- 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

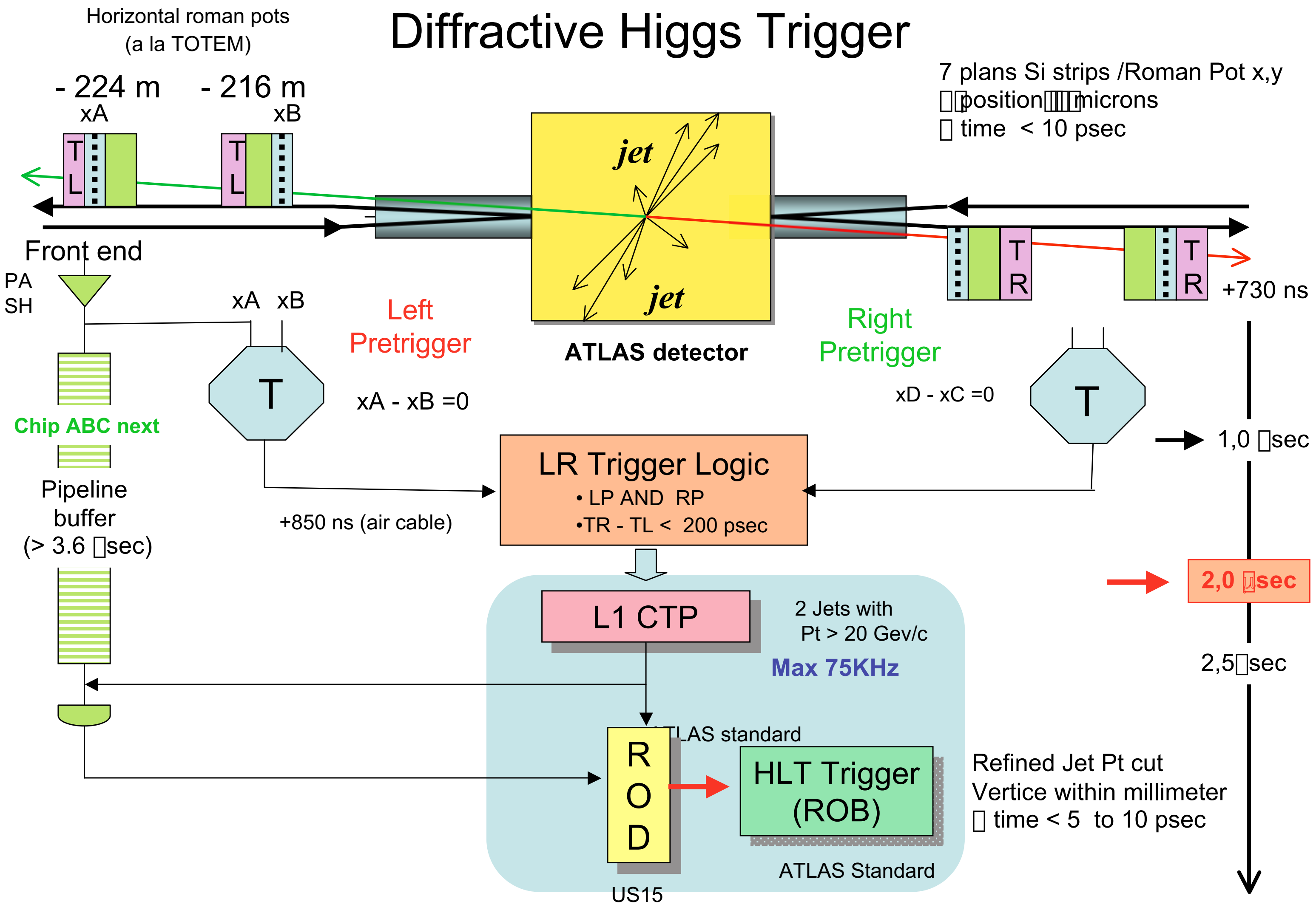


- Both FP420 and RP220 needed to have a good coverage of acceptance (NB: acceptance slightly smaller in CMS than in ATLAS)
- Resolution on Higgs mass varies between 1% and 2.5% depending on configuration

Which kind of detectors?

- Requirement: good resolution in position (good measurement of mass, kinematical propwerties), and in timing
- Position detectors:
  - Size of Si detectors: 2cm $\times$ 2cm
  - Spatial resolution of the order of 10-15 μm: Si strip detectors of 50 μm, as a first proposal: 5 layers, 2 vertical, 1 horizontal, 1 U, 1 V (45 degrees), and two additional layers used for L1 trigger
  - Edgeless detectors: Between 30 to 60 μm
  - First prototype of detector made by CANBERRA
  - Other option in collaboration with FP420: 3D Silicon
- 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, resolution of 5-10 ps needed
  - Detector space resolution: few mm, the total width of the detectors being 2.5 cm (4.5 cm available in roman pot)
  - 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}: means a possibility to accumulate about 20 fb^{-1} in 3 years of data taking

Conclusion on diffraction at LHC

- RP220: New project in ATLAS to measure diffractive protons at high luminbosity in ATLAS
- Strong link with FP420: same kind of physics, complementarity, one single TDR to be submitted to ATLAS/LHCC. Project timing will depend on main physics topics (mainly Higgs or QCD)
- Physics interests: QCD and hard diffraction, W and phhoton anomalous coupling, diffractive Higgs
- Present collaboration: Prague, Cracow, Heidelberg, Saclay, Giessen, Stony Brook, Michigan State University, Paris 6, The University of Chicago and Argonne National Laboratory, Other French groups interested very much welcome!