Hard diffraction at the LHC and the AFP project in ATLAS

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Workshop on timing detectors
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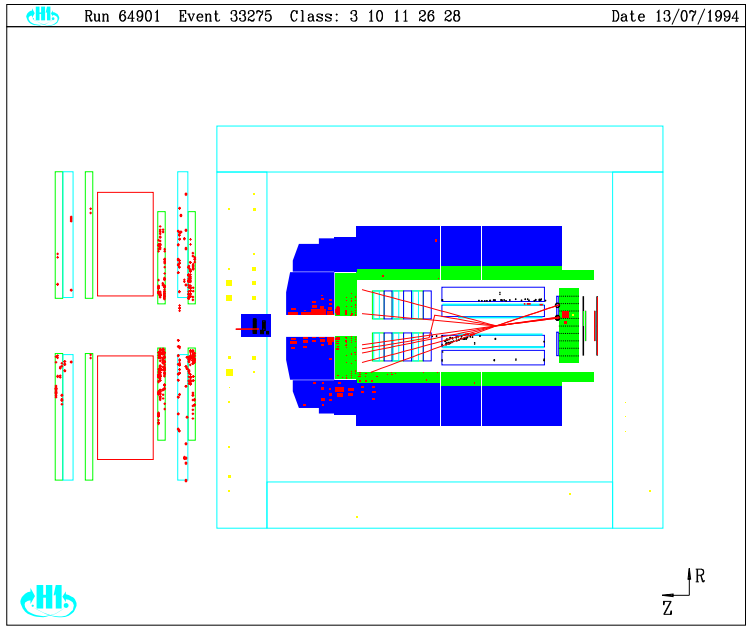
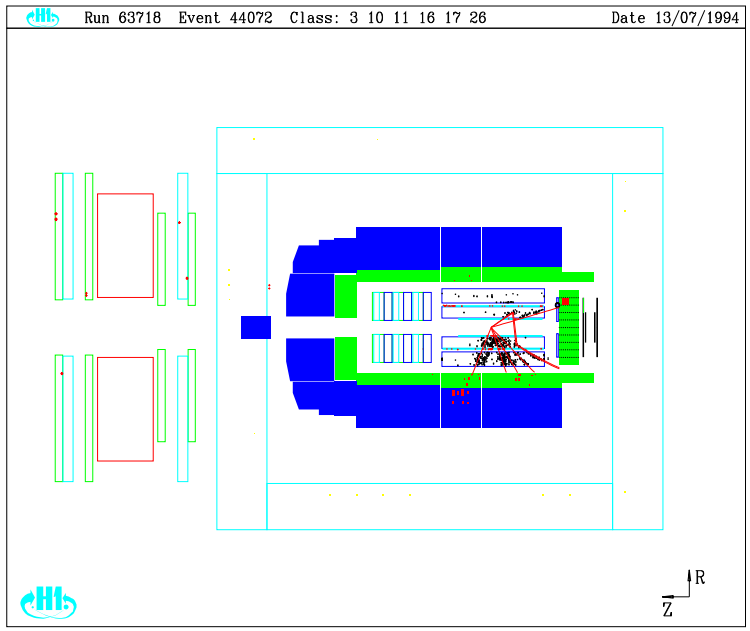
Contents:

- What is diffraction (HERA and Tevatron)?
- Diffractive Higgs production
- ATLAS Forward Physics project

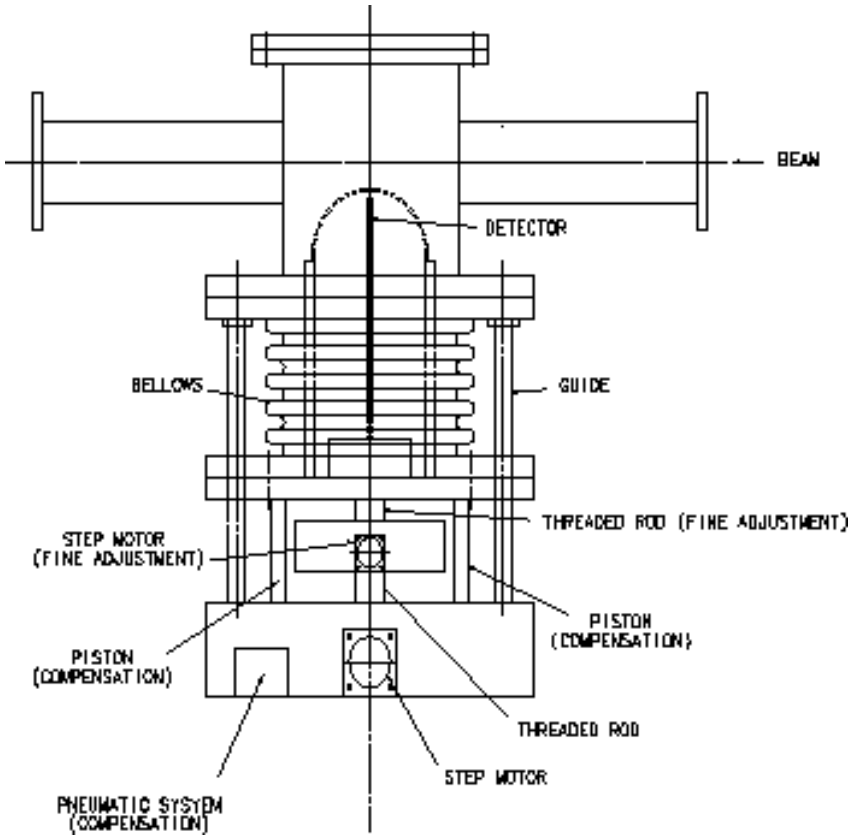
What is diffraction: the example of HERA ep collider

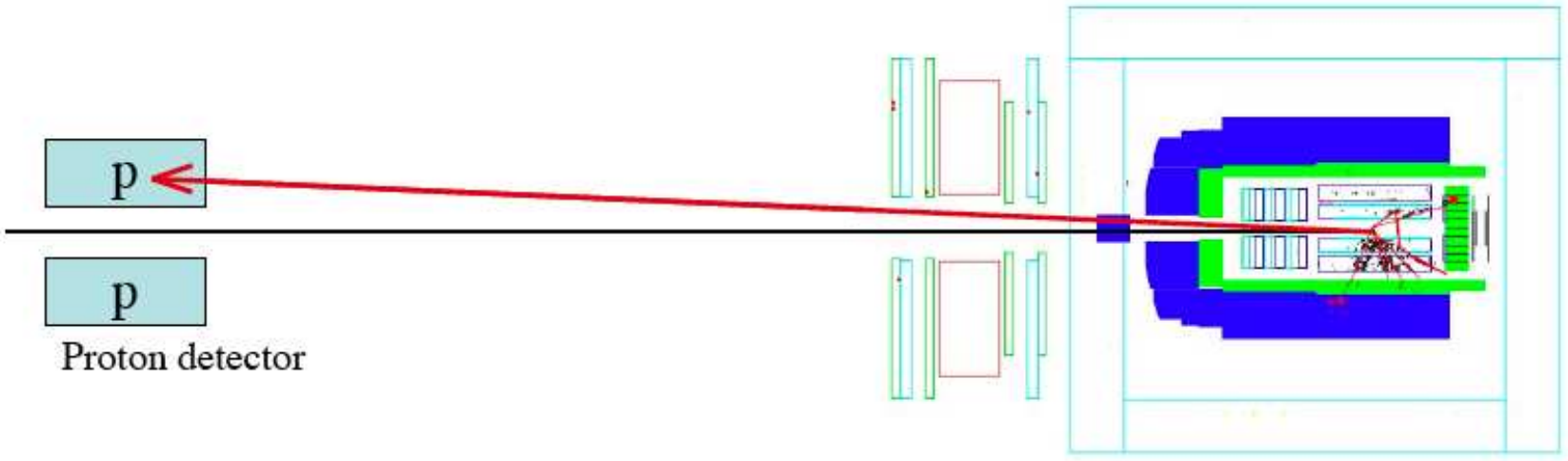




Scheme of a roman pot detector

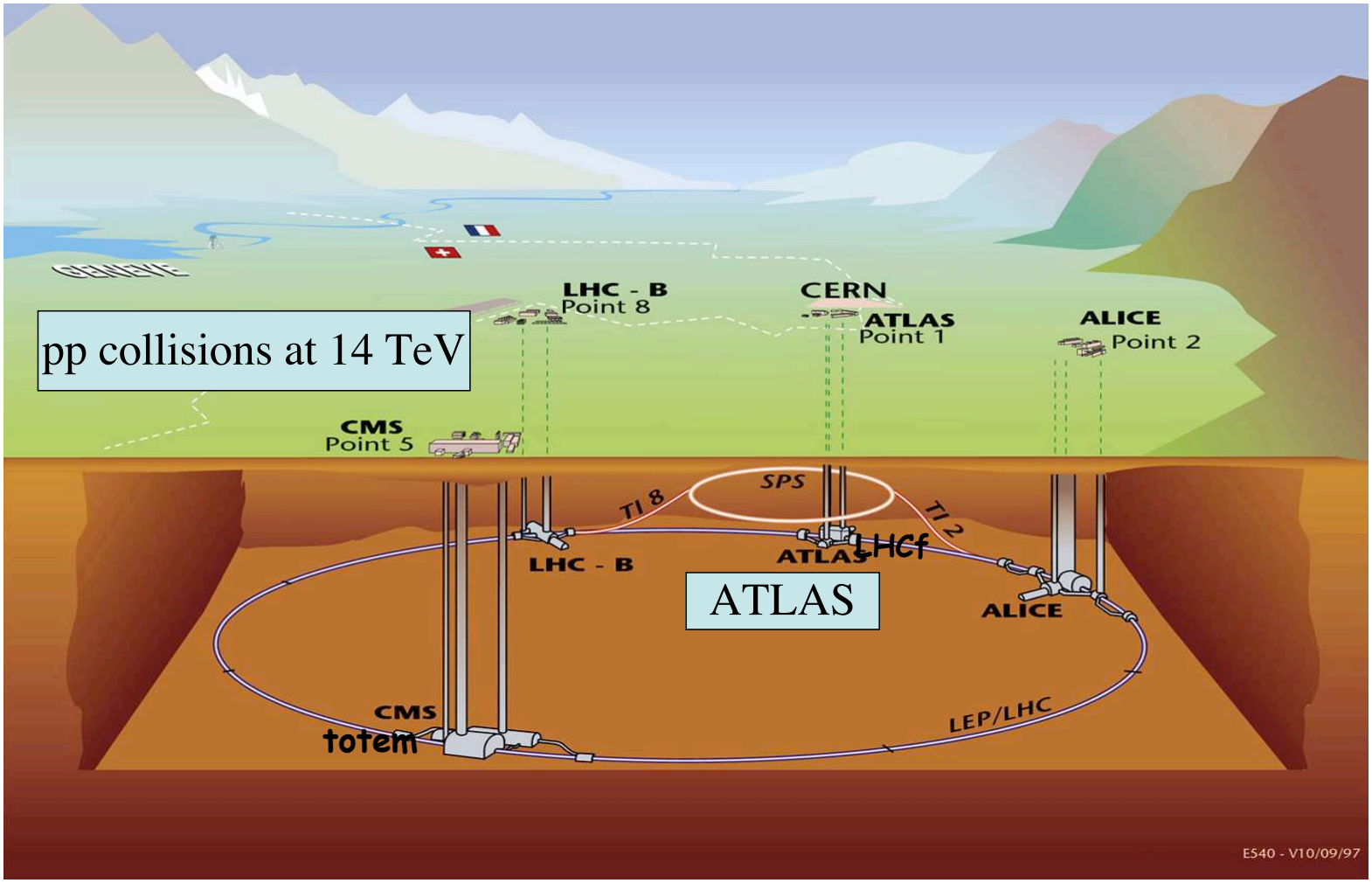
Scheme of roman pot detector: protons can be tagged in the forward region



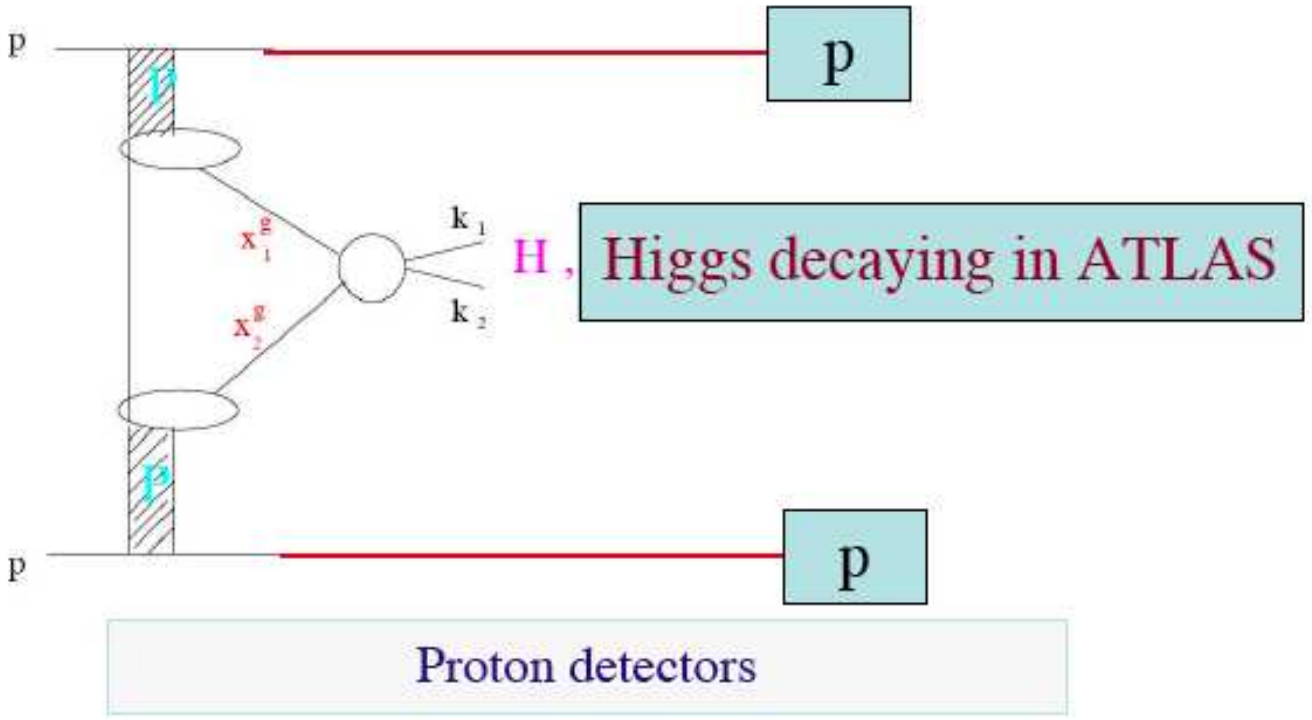


ATLAS at the LHC

Measure diffractive events at the LHC by tagging the protons in the final state



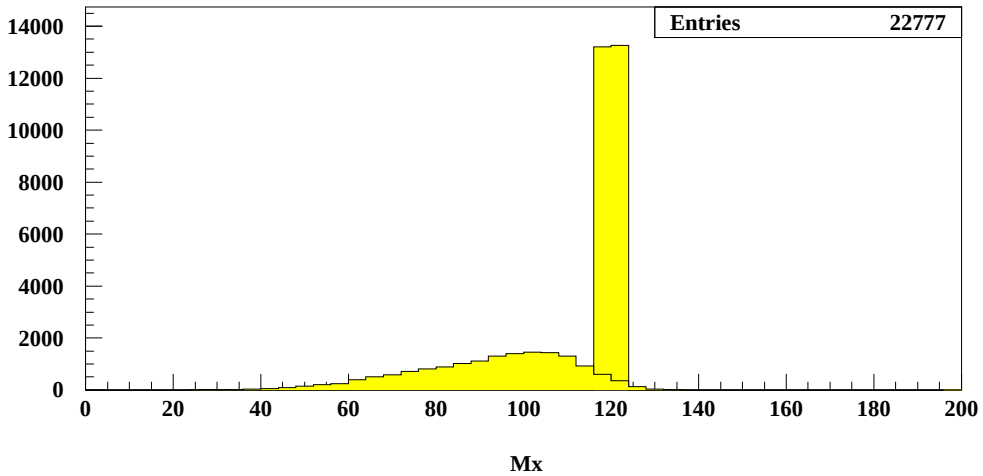
"Exclusive models"

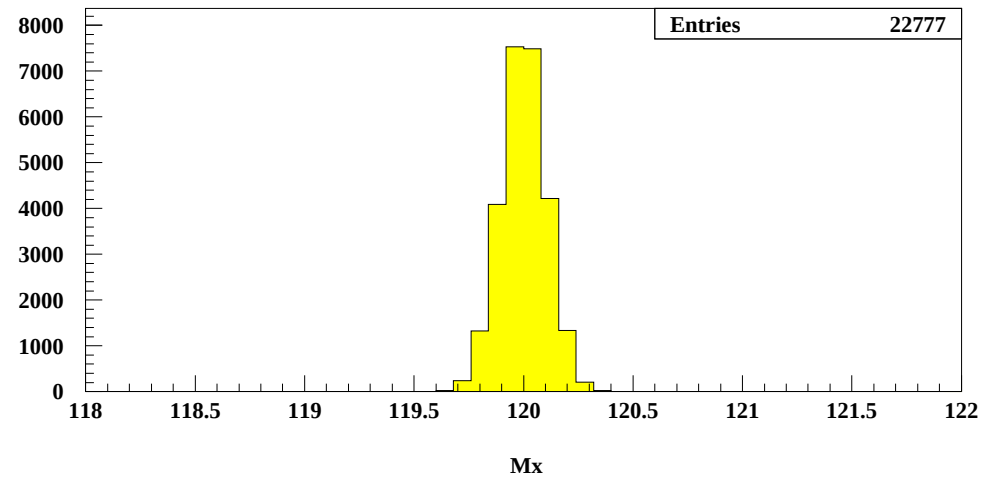


- All the energy is used to produce the Higgs (or the dijets), namely $xG \sim \delta$
- Possibility to reconstruct the Higgs boson properties from the tagged proton: system completely constrained

Advantage of exclusive Higgs production?

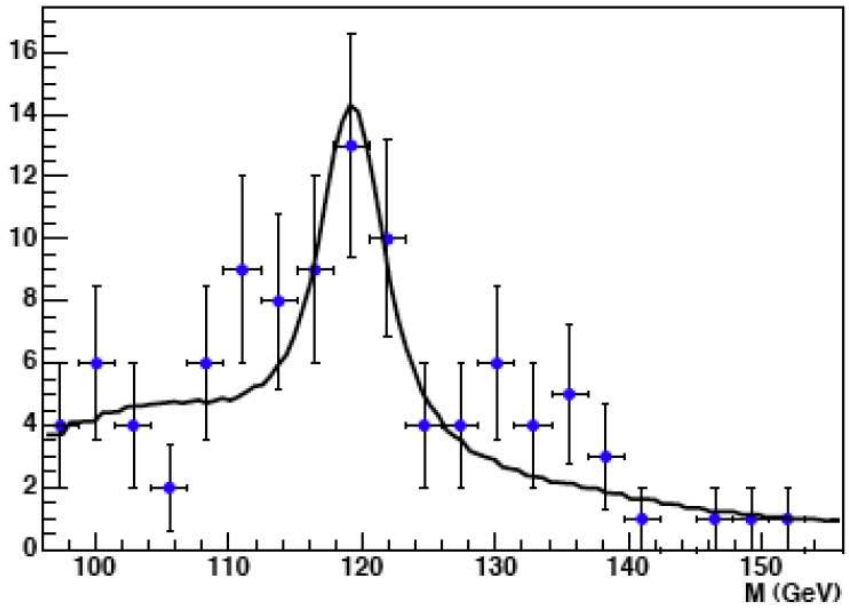
- Good Higgs mass reconstruction: fully constrained system, Higgs mass reconstructed using both tagged protons in the final state ($pp \longrightarrow pHp$)
- No energy loss in pomeron "remnants"

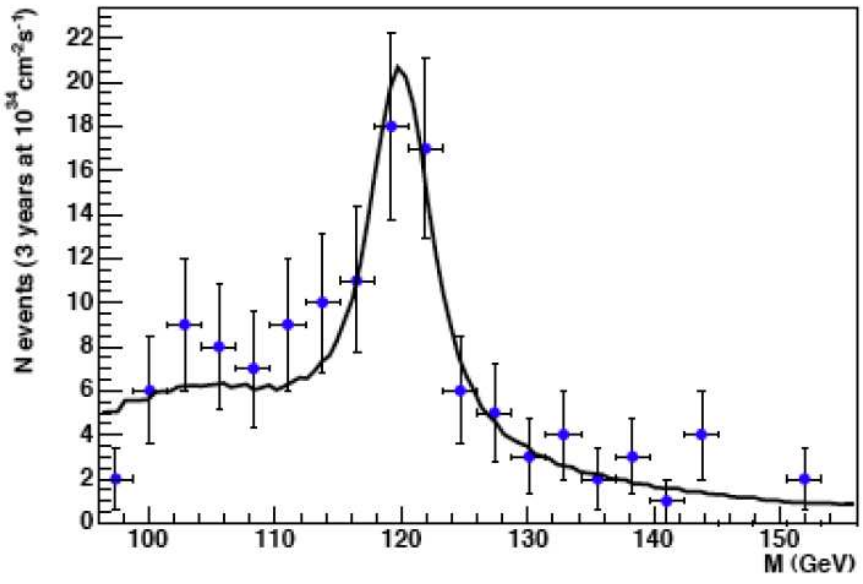




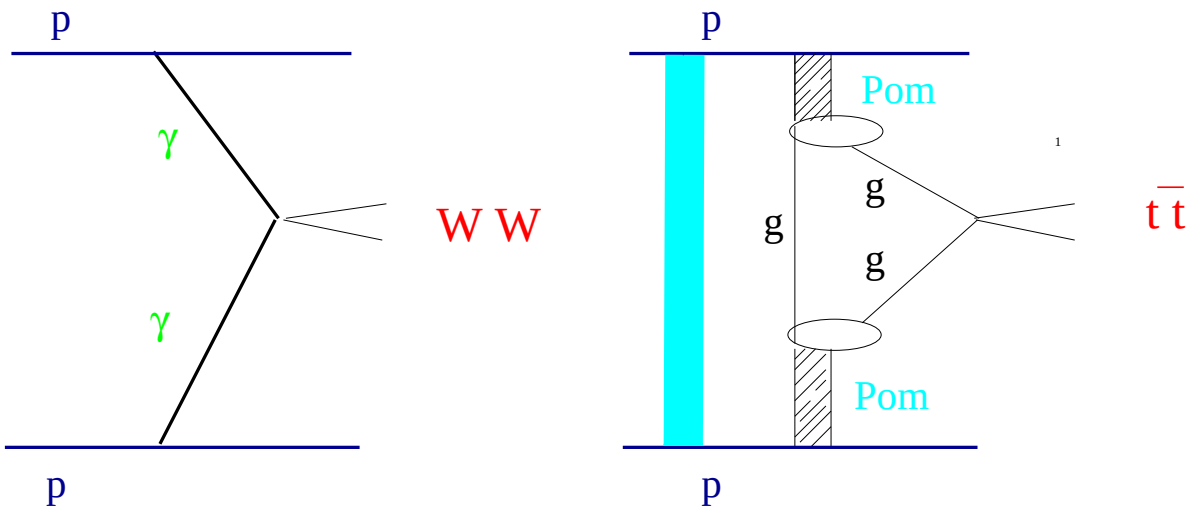
SUSY Signal significance

- Signal and background full simulation, pile up effects taken into account
- Significance $> 3.5\sigma$ for 60 fb^{-1} after detector acceptance
- Significance $> 5\sigma$ in 3 years at 10^{34} with timing detectors
- Diffractive Higgs boson production complementary to the standard search





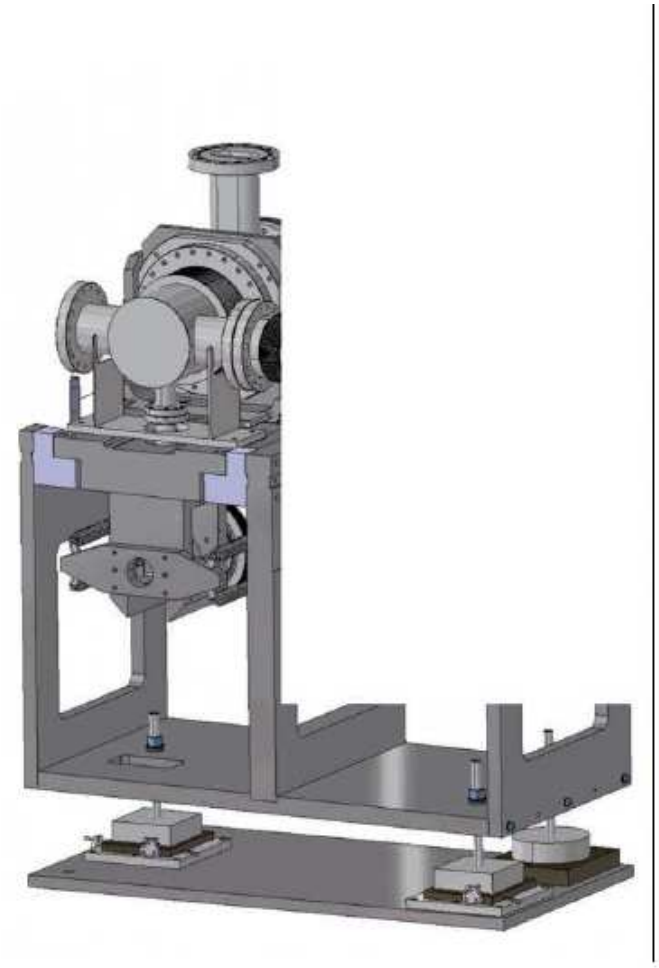
W, top and stops

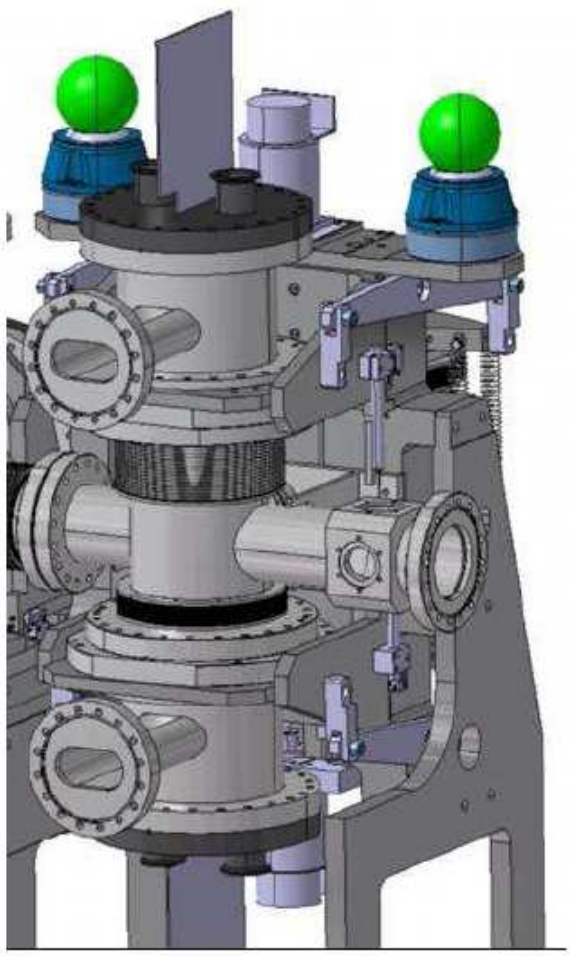


- All the energy is used to produce the W, top (stop) pairs
- W: QED process, cross section perfectly known, top: QCD diffractive process
- Precise study of photon anomalous coupling: WW cross section perfectly known (QED), any changes due to photon anomalous coupling, high sensitivity since anomalous couling to the 4th power in cross section

Detector location

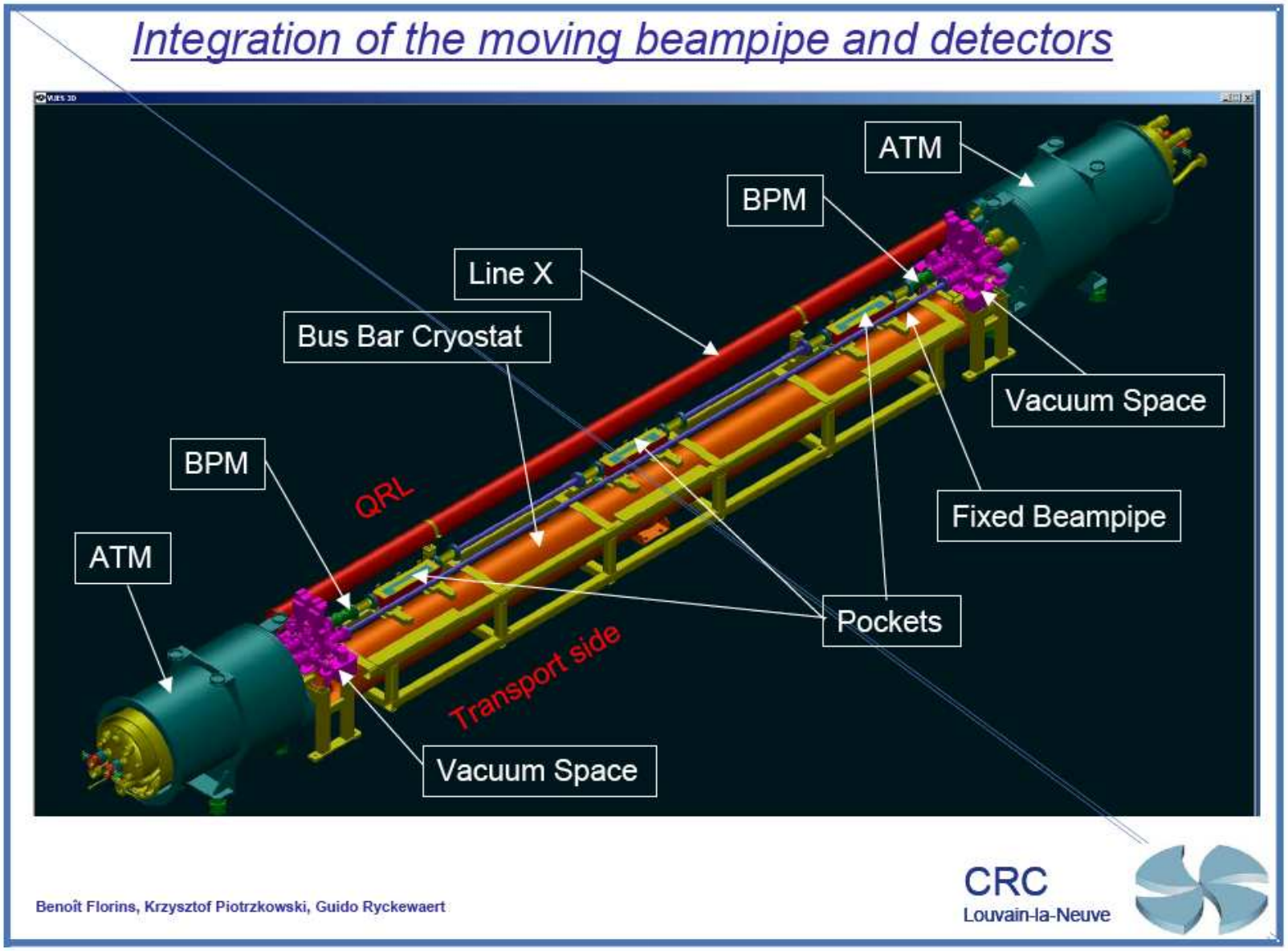
- what is needed? Good position and good timing mrasurements
- 220 m: roman pots and movable beam pipes
- 420 m: movable beam pipe (roman pots impossible because of lack of space available and cold region of LHC)





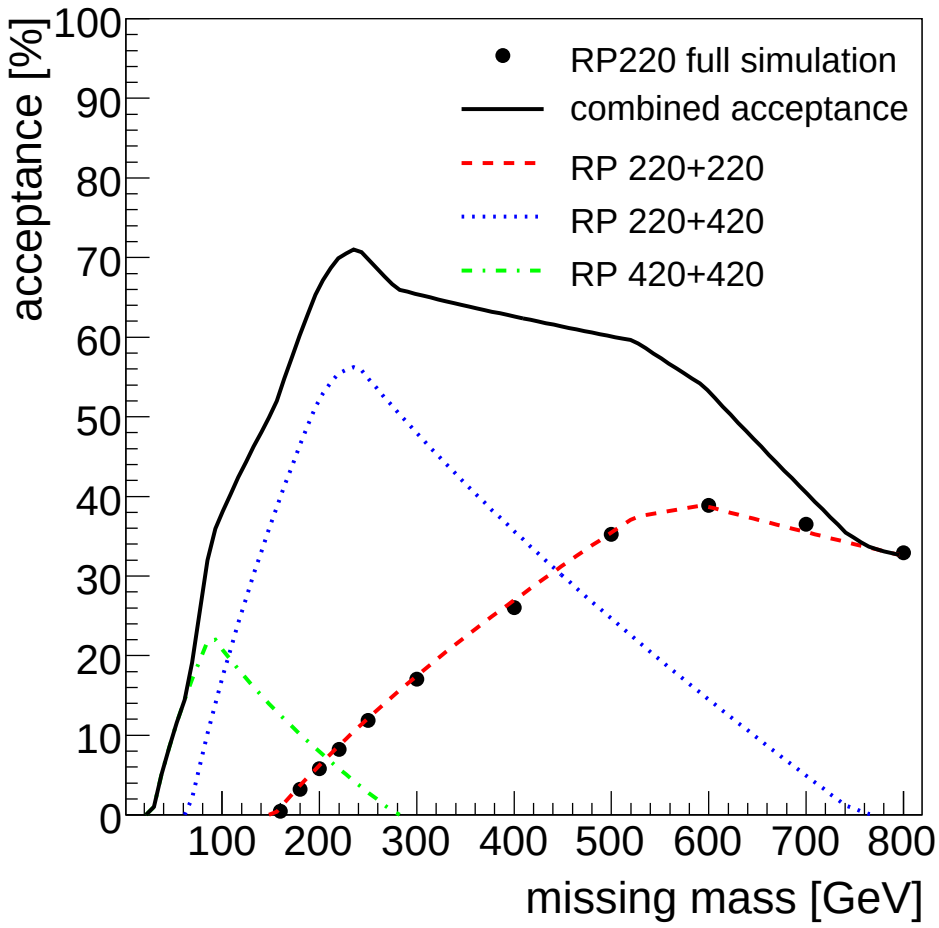
New concept: Movable beam pipe at 220-420 m

Simple idea: use movable beam pipe to locate detectors, takes less space than roman pots



Forward detector projects

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

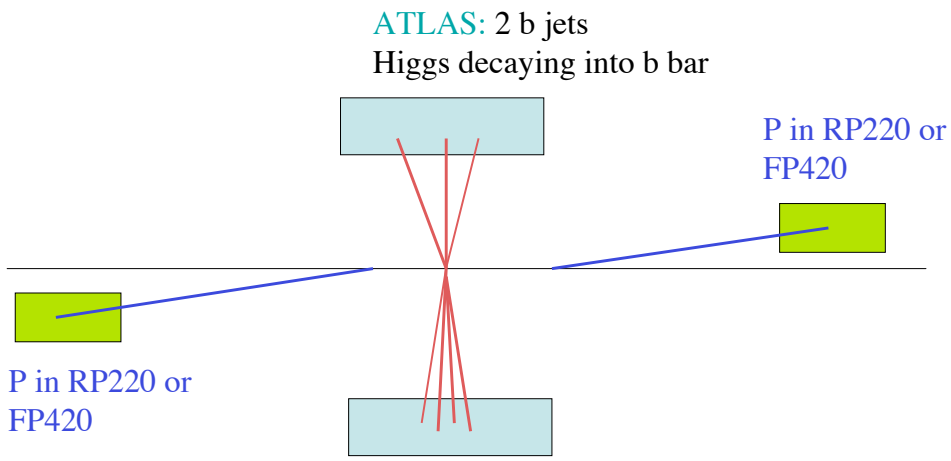


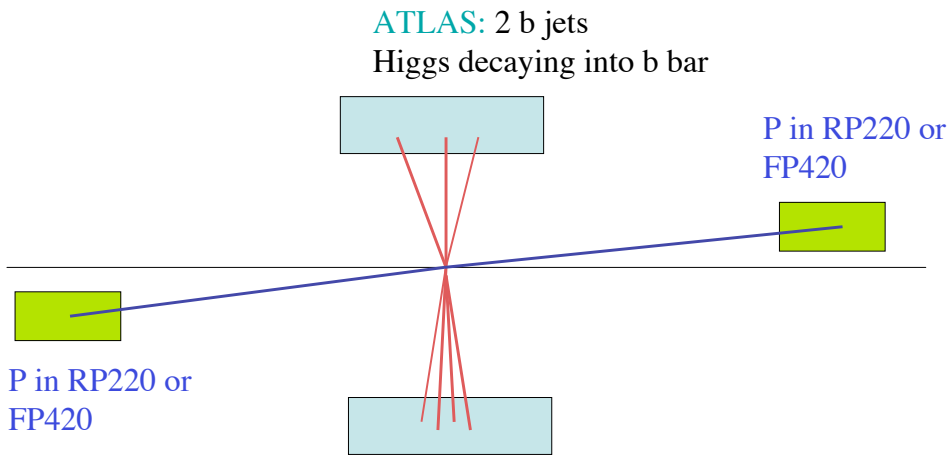
Which kind of detectors?

- Silicon detectors
  - Precise reconstruction of proton position, and then mass: position resolution of 10-15 μm
  - Radiation hardness
  - 3D Si detectors: 10 planes per supermodule, pixels of 50 $\times$ 400 μm; 10 layers
  - Modification of readout chip to include L1 trigger: address of vertical line hit to know ξ at L1
- 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 resolution needed: of the order of a couple of picoseconds
  - Detector space resolution: few mm, the total width of the detectors being 2.5 cm (4.5 cm available in roman pot)
- Same detectors at 220 and 420 m

Why do we need timing detectors?

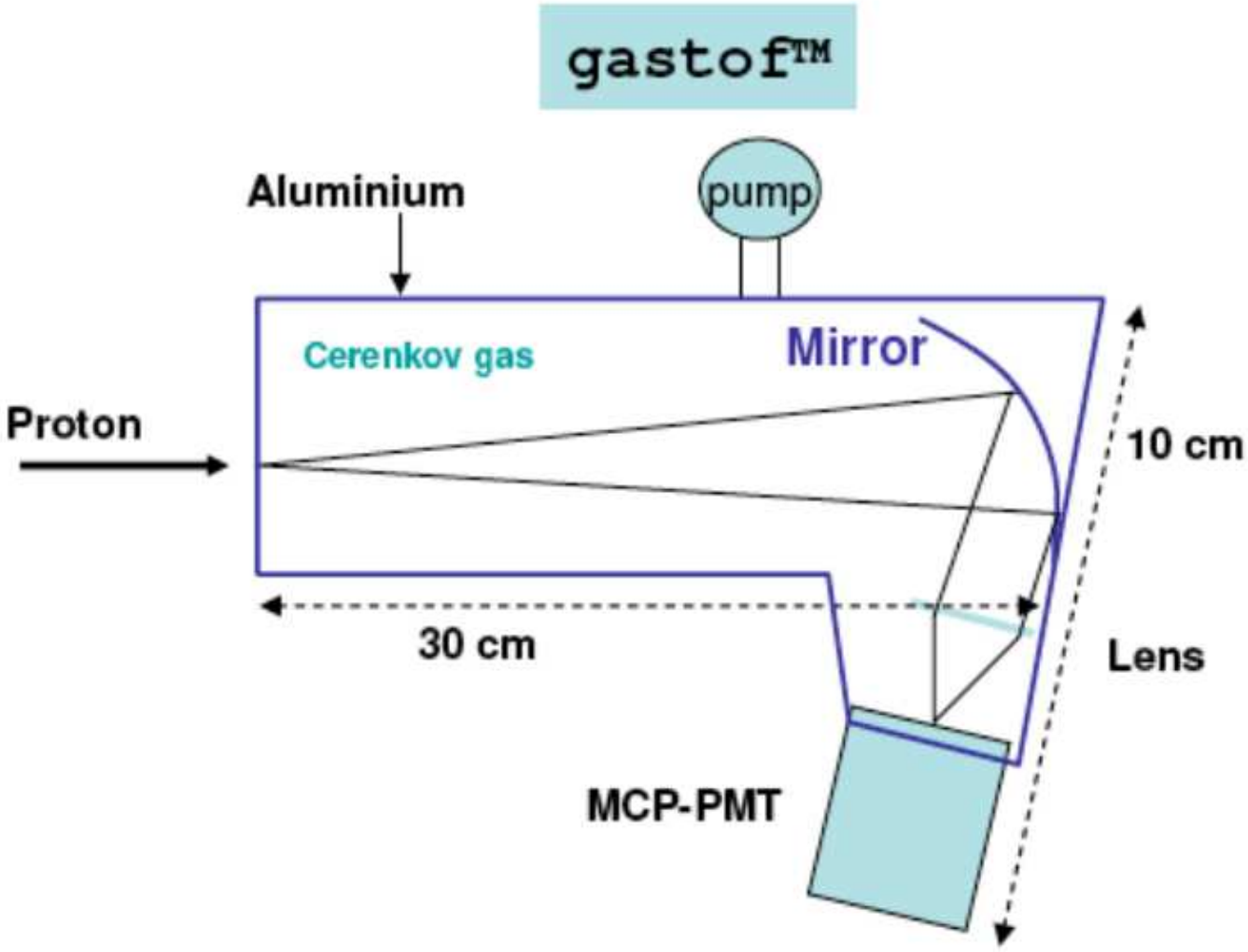
We want to find the events where the protons are related to Higgs production and not to another soft event (up to 35 events occuring at the same time at the LHC!!!!





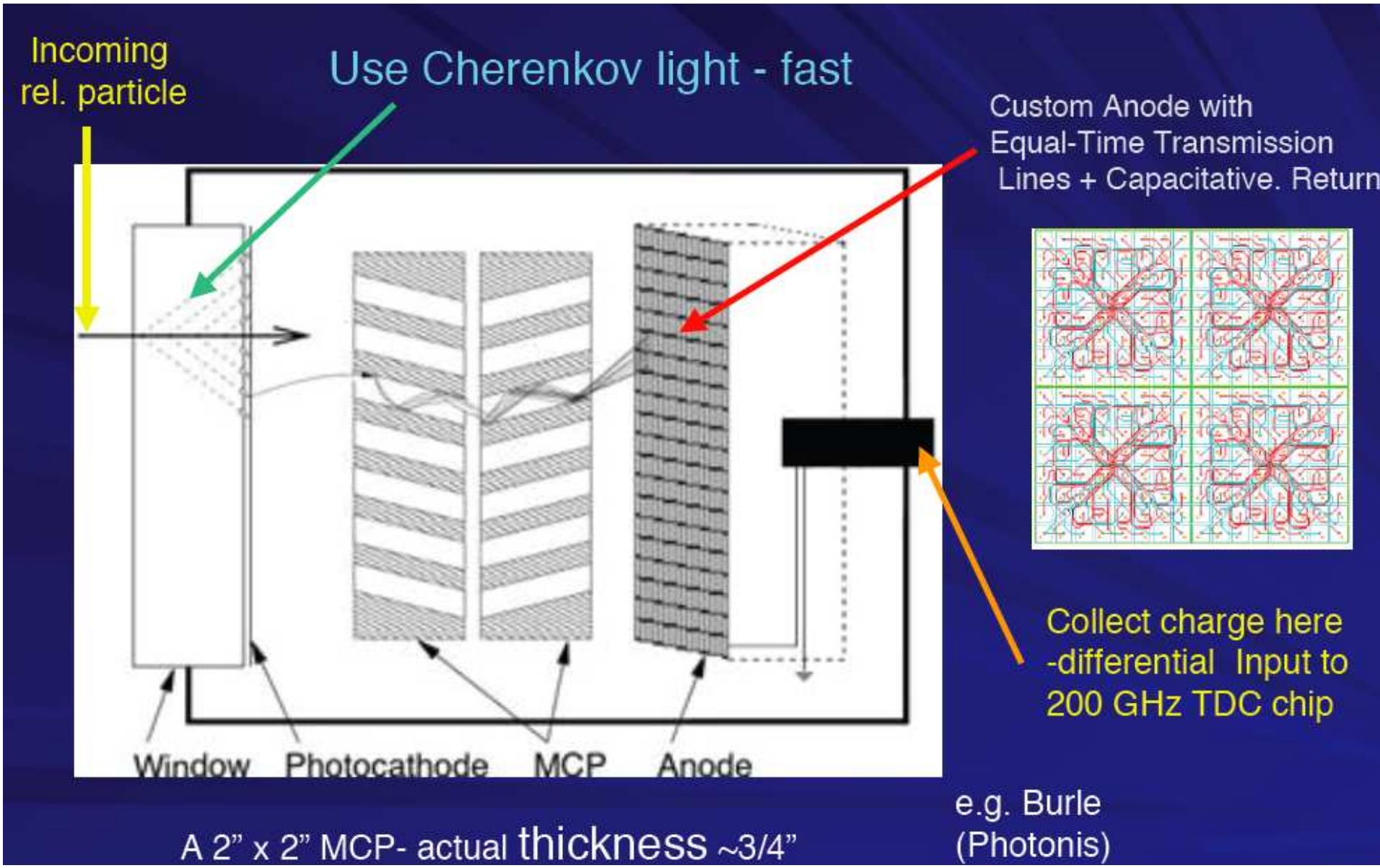
Timing measurements

- Possibility to get presently a timing resolution of $10 - 15$ ps using gas based detectors, and $30 - 40$ ps using quartz detector
- Inconvenient of present gas detectors: no space resolution
- See the talks by Mike and Krzysztof



Future timing detectors: towards 1-2 ps

- Aim: reach a couple of picosecond precision
- Issue: number of photoelectrons to be produced to get enough resolution
- Solution: combination of GAS and QUARTZ detectors?

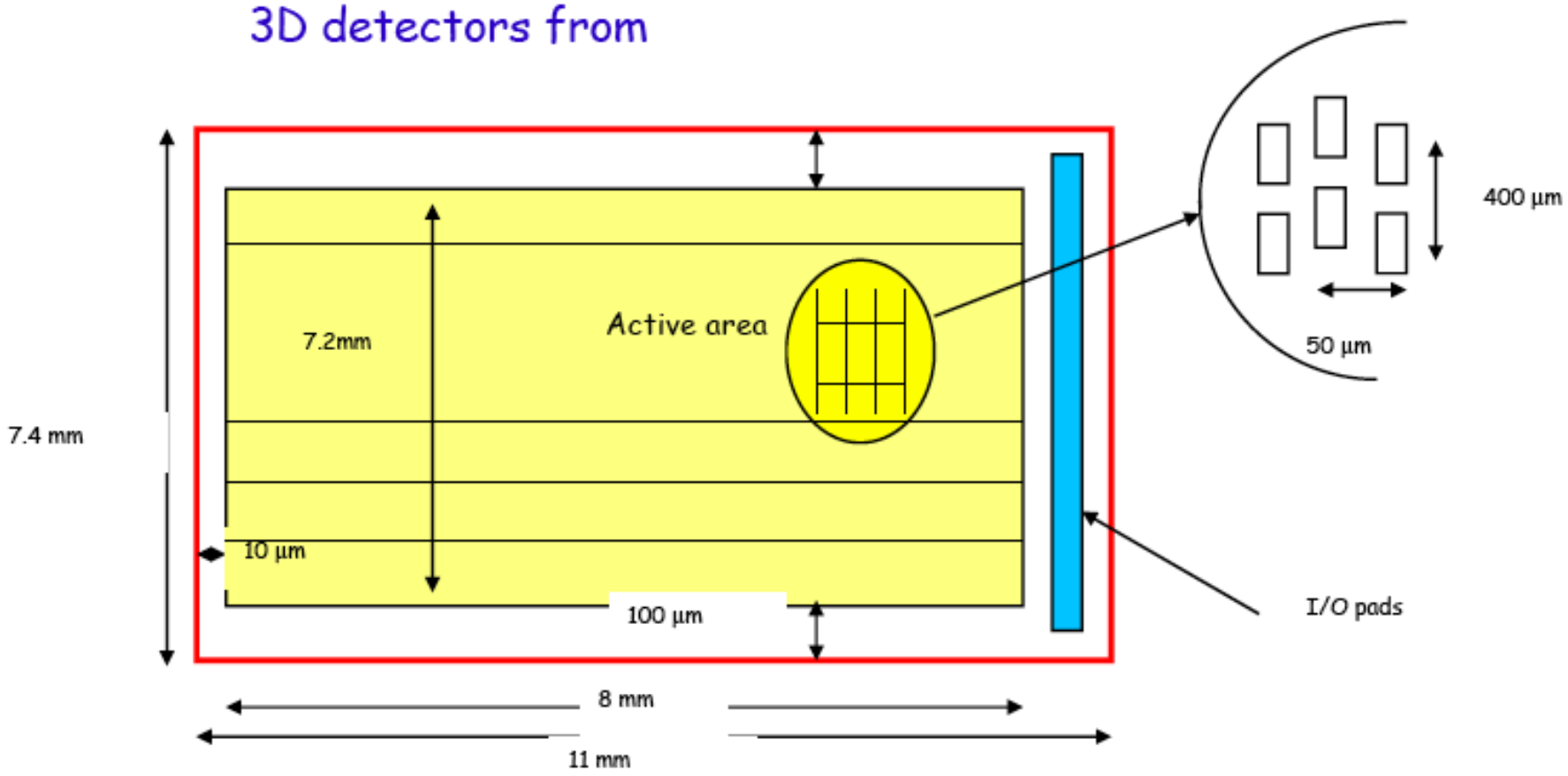


3D Silicon detectors

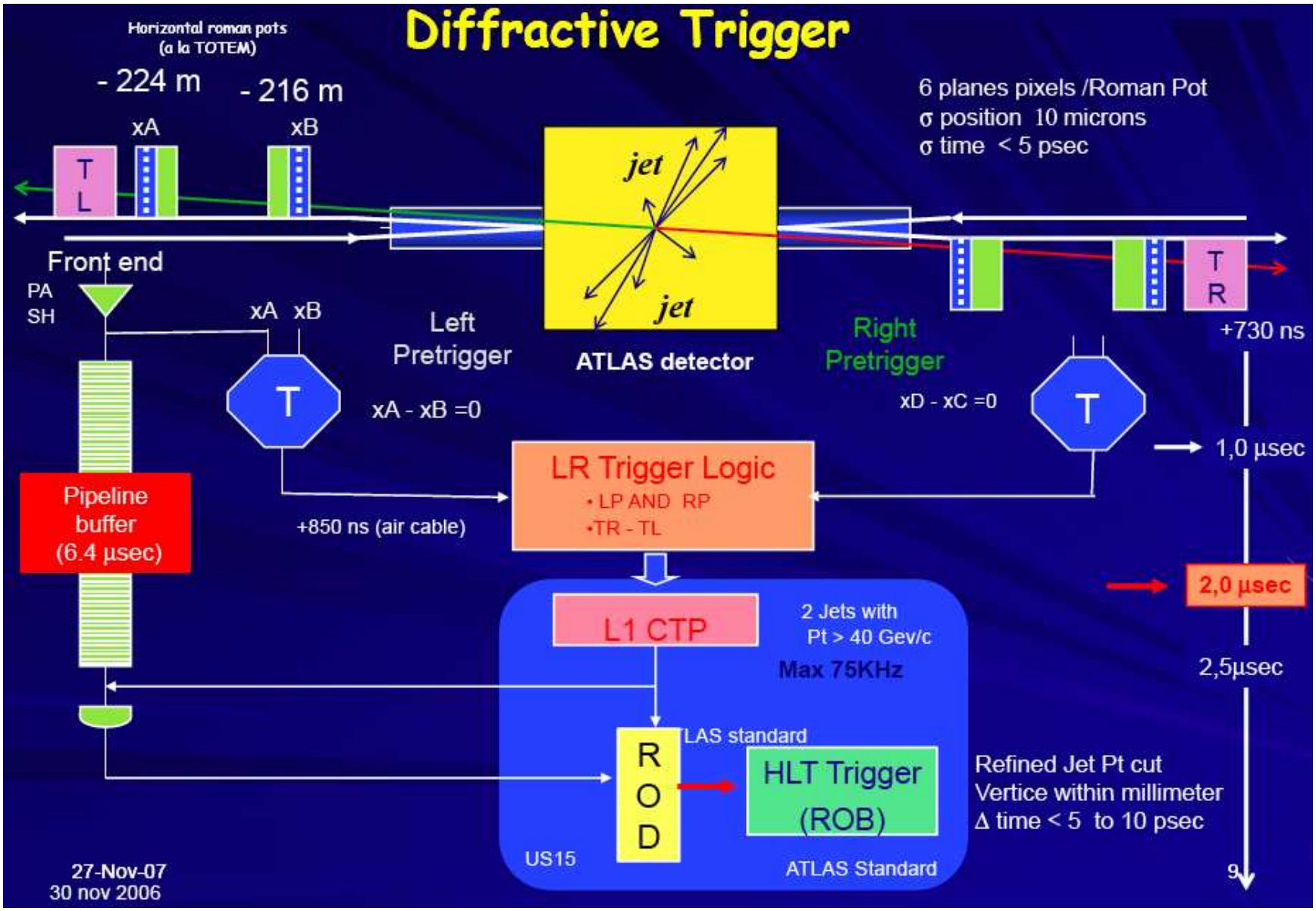
3D Silicon detectors from Manchester (Cinzia Da Via) and SLAC

- 9 pairs of columns of 160 pixels 50 x 400 µm.
- 7.2 x 8 mm2 detector, 7.4 x 11 mm2 readout chip
- Thickness allows > 1.2 mm inter-layer distance

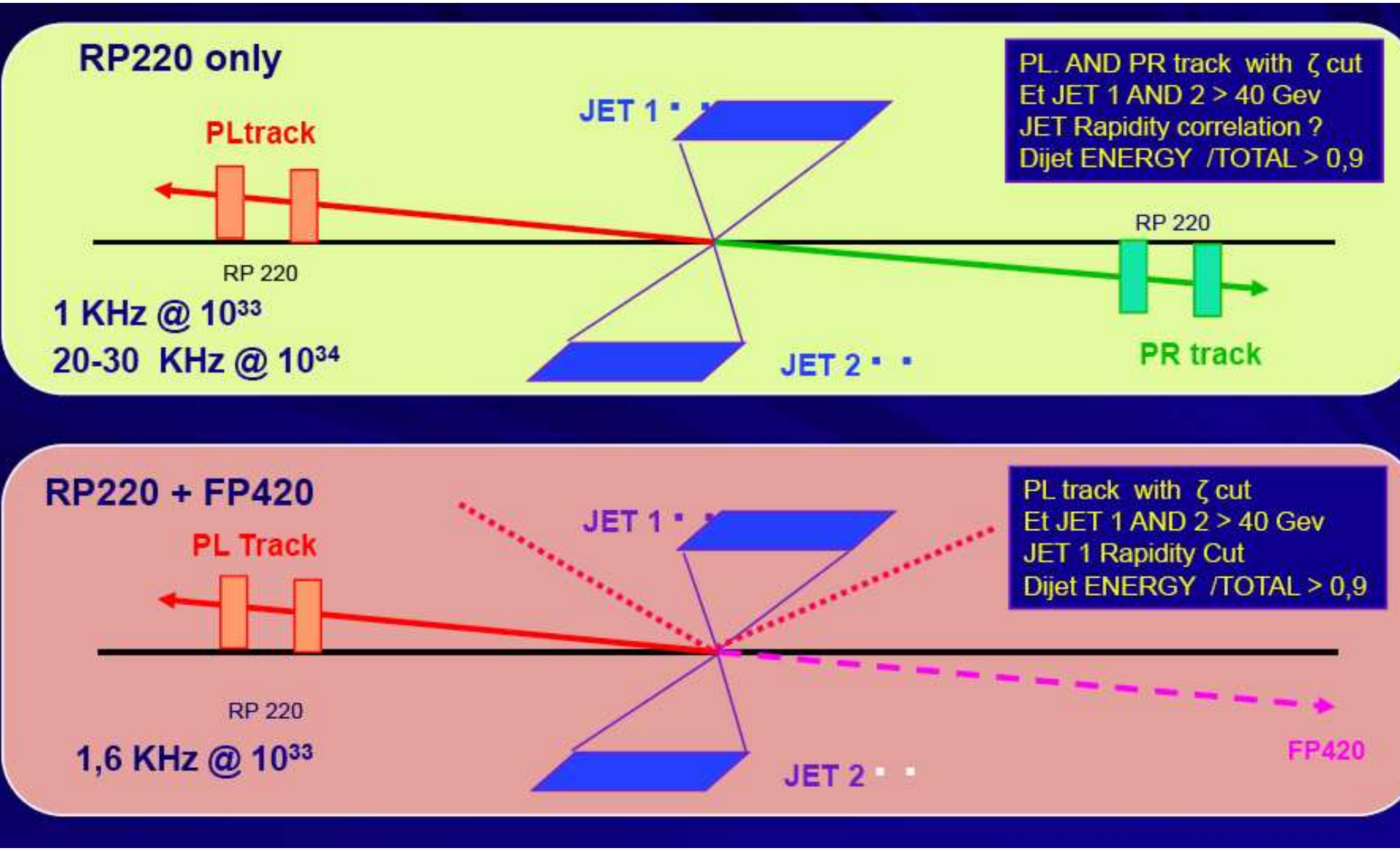
3D detectors from



Trigger schematics



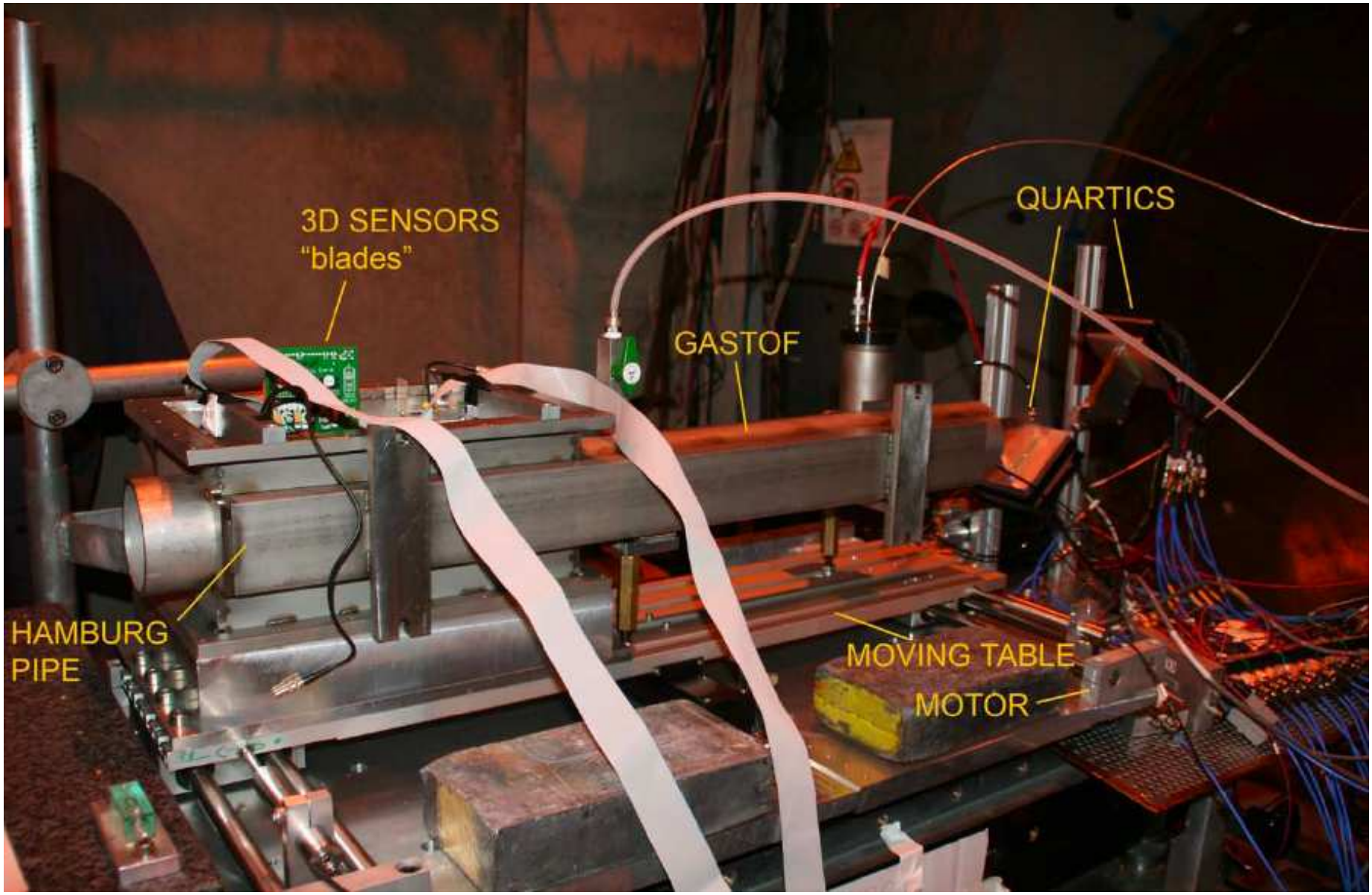
Trigger: principle



Trigger: strategy and rates

- 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}
- At Level 2: send timing information and combine it with vertex position: reduces the rates to a couple of Hz

Test beams at CERN/FERMILAB



Conclusion

- Diffractive exclusive events at the LHC: interesting events at the LHC to look for Higgs boson production, SUSY events, photon anomalous coupling (studied in W production)
- AFP project: Well advanced, roman pots, movable beam pipes needed
- Position detectors to be used: 3D Silicon
- Timing detectors: High precision needed especially for high luminosity at the LHC (couple of picoseconds), possibility to use a combination of GAS and QUARTZ detectors?