The ATLAS Forward Physics Project (AFP)

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On behalf of the ATLAS collaboration

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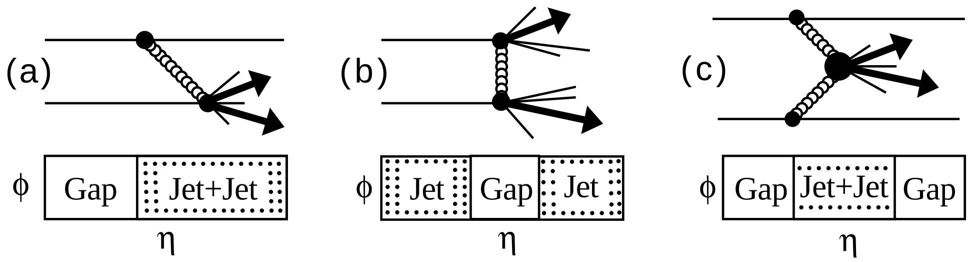
Diffraction at Tevatron/LHC

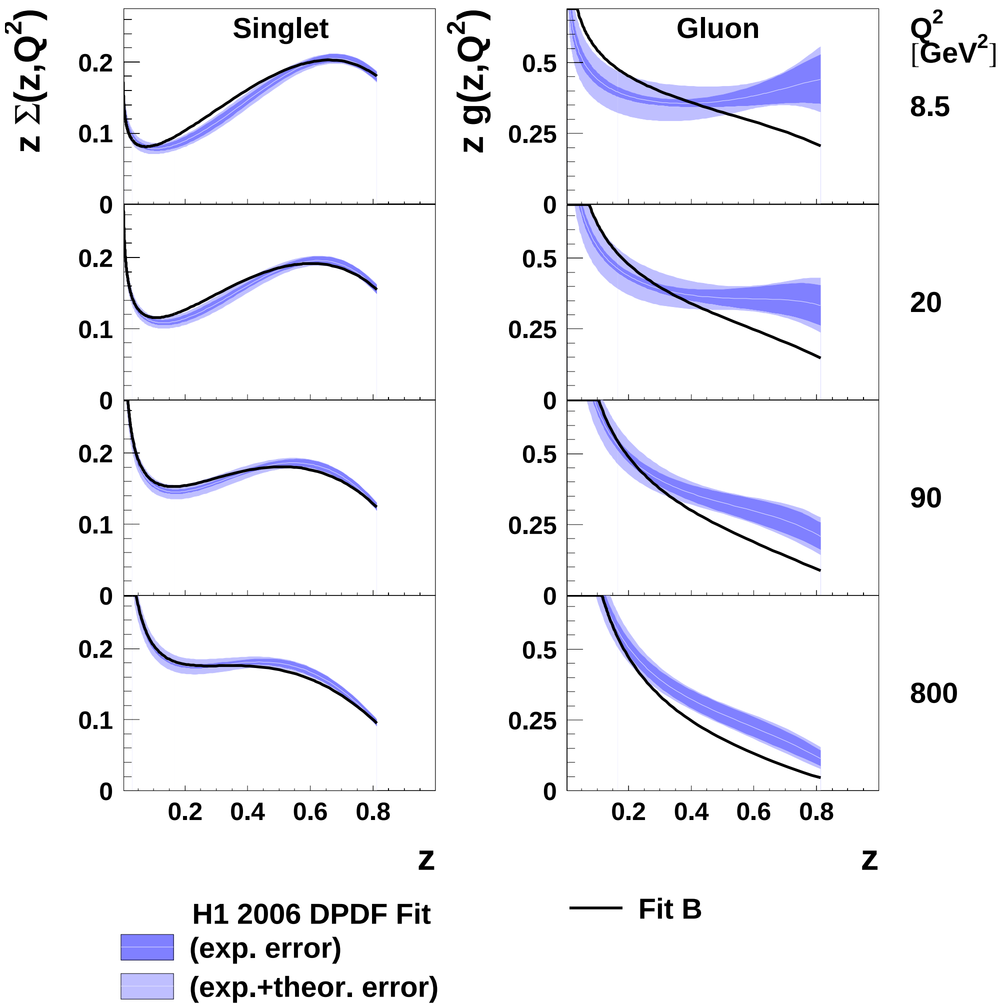


Kinematic variables

- 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
- Inclusive diffraction at LHC: Better understanding of the pomeron structure, study of survival probability

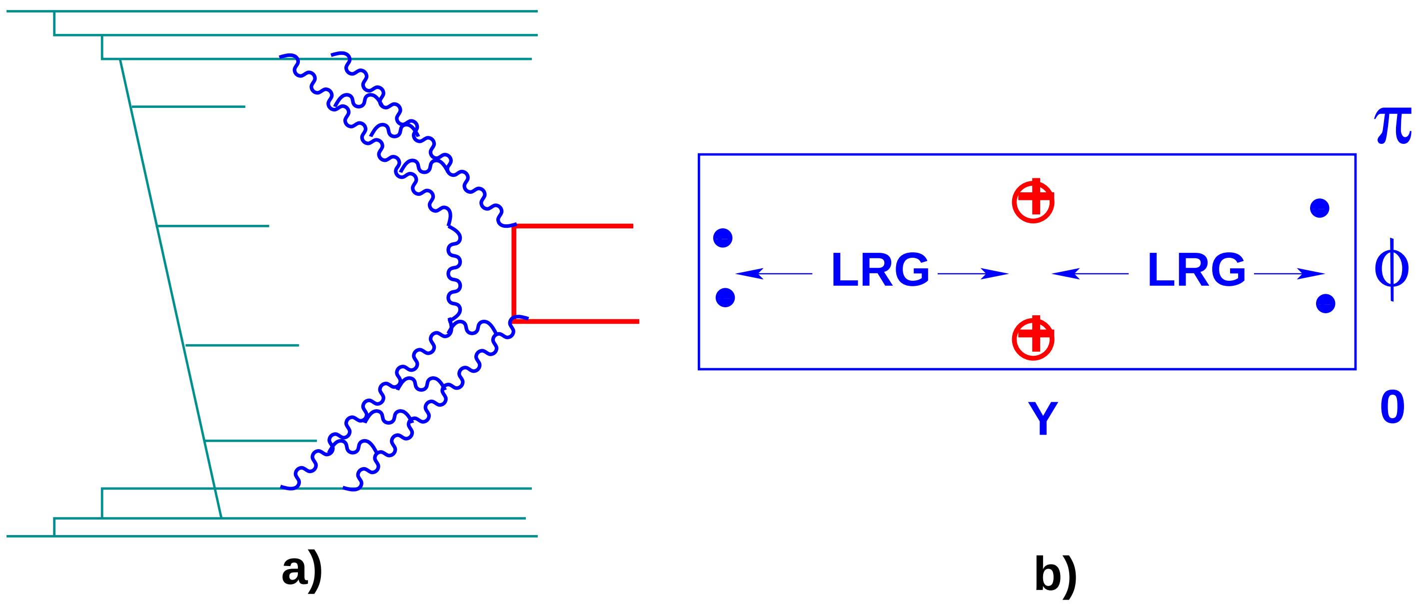
Parton densities in the pomeron (H1)

- Extraction of gluon and quarks densities in pomeron: gluon dominated
- Gluon density poorly constrained at high β (imposing $C_g = 0$ leads to a good fit as well, Fit B)
- Good description of final states

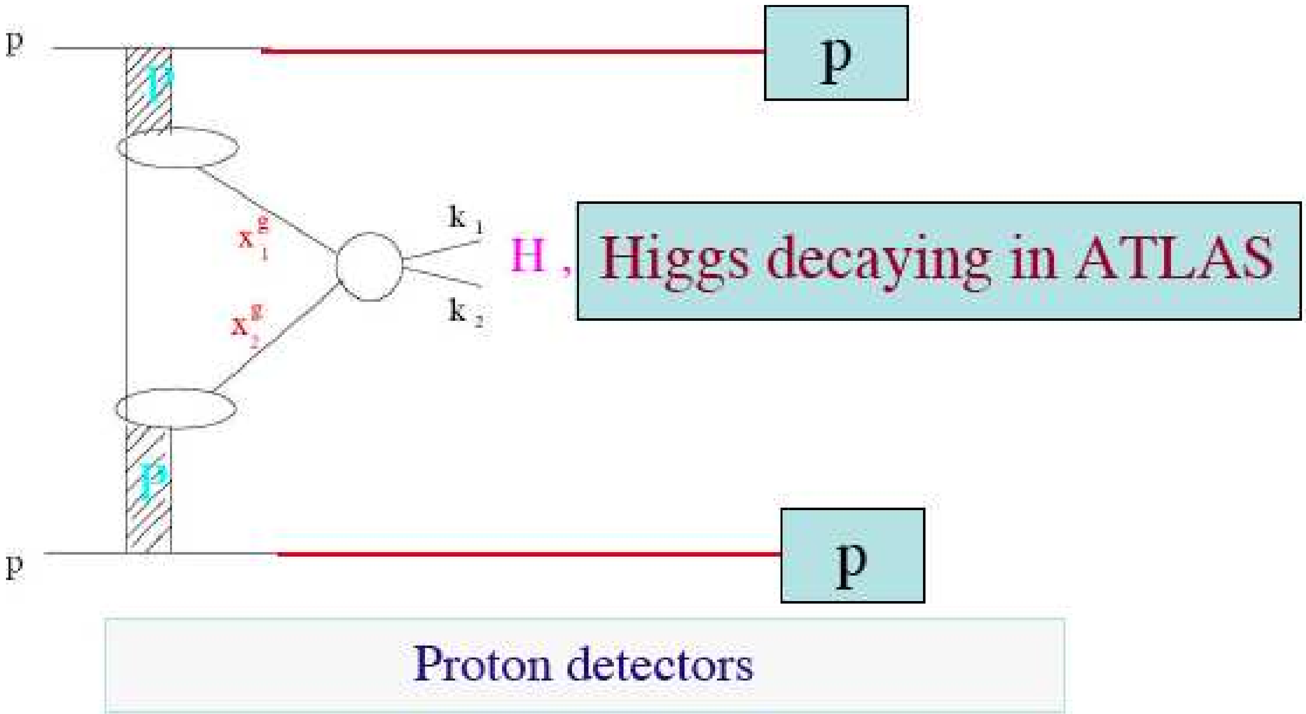


Concept of survival probability

- Understanding of factorisation breaking at Tevatron/LHC? Can we use the parton densities measured at HERA to use them at the Tevatron/LHC?
- Factorisation is not expected to hold: soft gluon exchanges in initial/final states, independant of hard scattering
- Survival probability: Probability that there is no soft additional interaction, that the diffractive event is kept
- Measurement of survival probability using first data: J/Ψ, Υ...



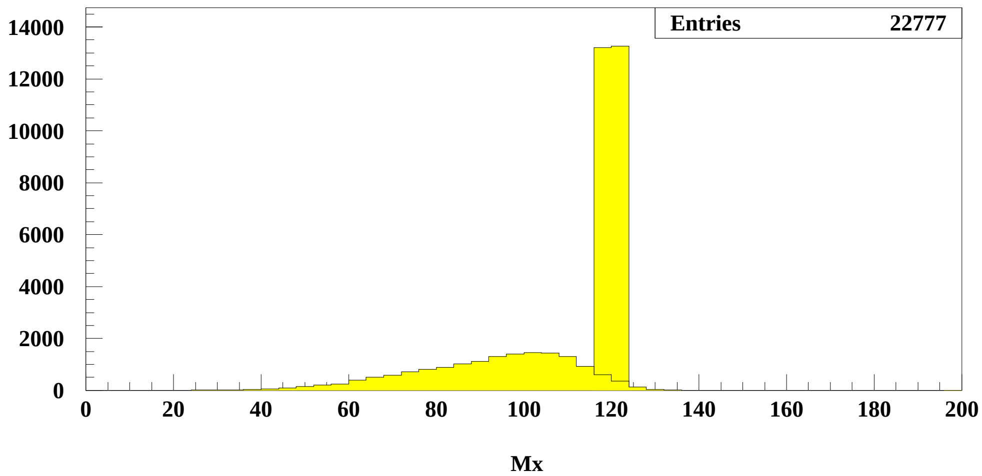
“Exclusive models” in diffraction

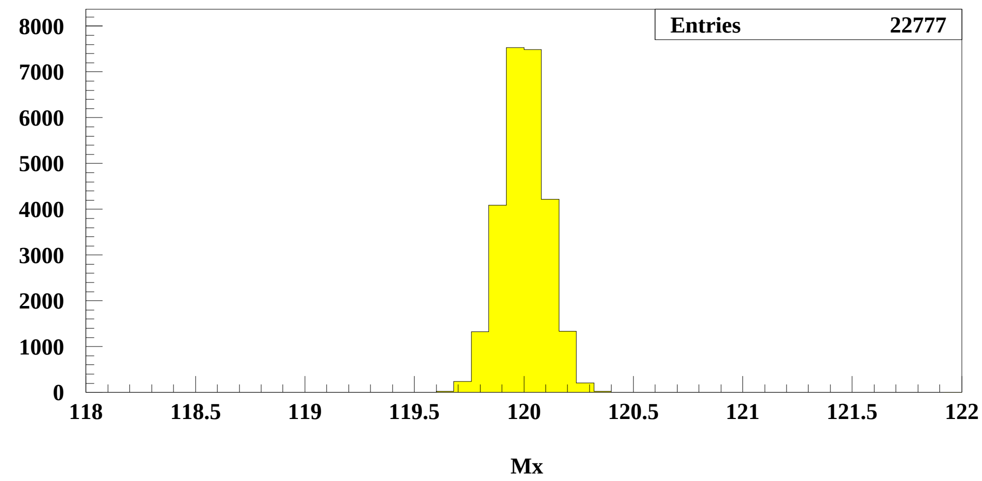


- All the energy is used to produce the Higgs (or the dijets), namely $xG \sim \delta$
- Possibility to reconstruct the Higgs boson properties from the tagged proton: system completely constrained
- See papers by Khoze, Martin, Ryskin; Boonekamp, Peschanski, Royon...

Advantage of exclusive Higgs production?

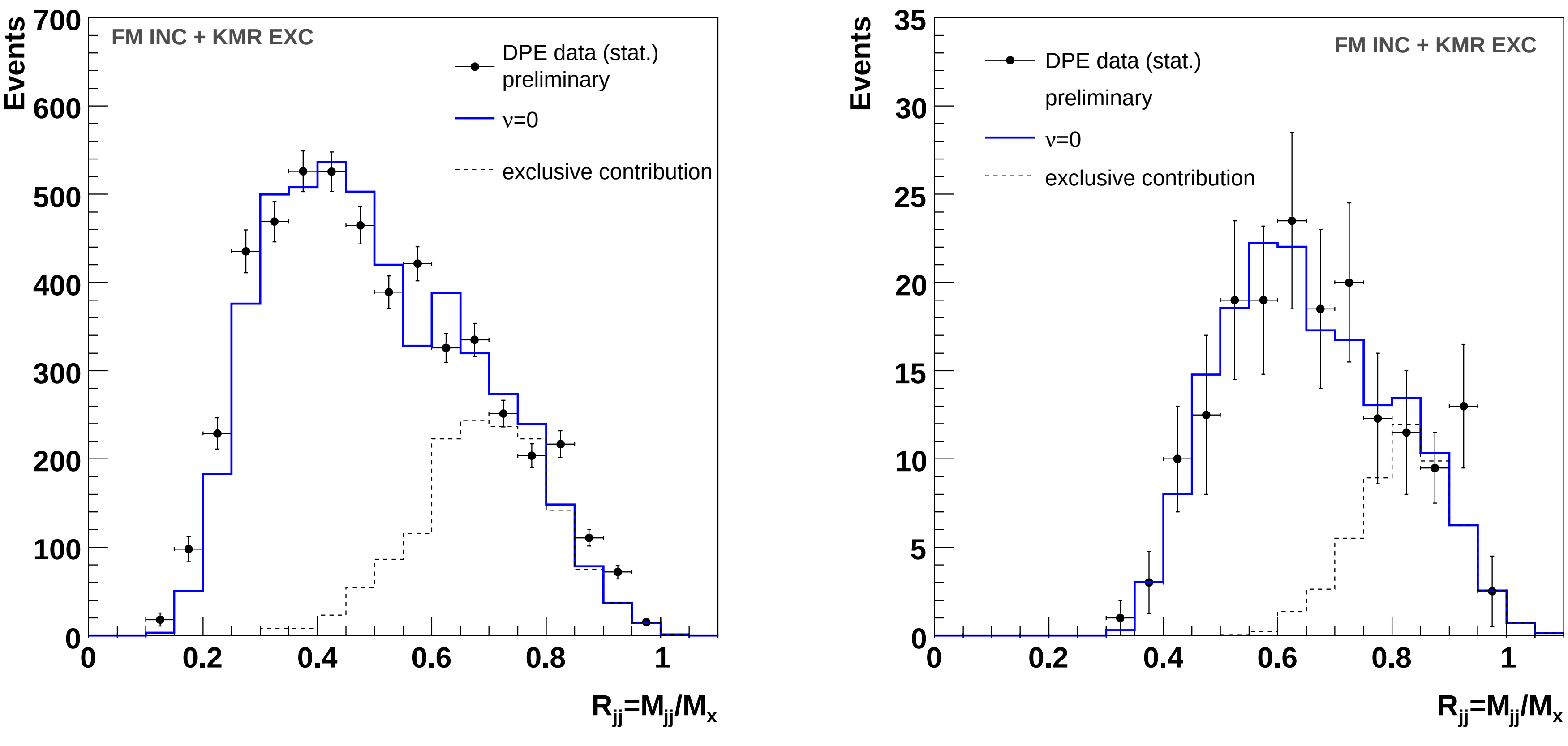
- Good Higgs mass reconstruction: fully constrained system, Higgs mass reconstructed using both tagged protons in the final state ($pp \rightarrow pHp$)
- No energy loss in pomeron "remnants"
- Mass resolution of the order of 2-3% after detector simulation





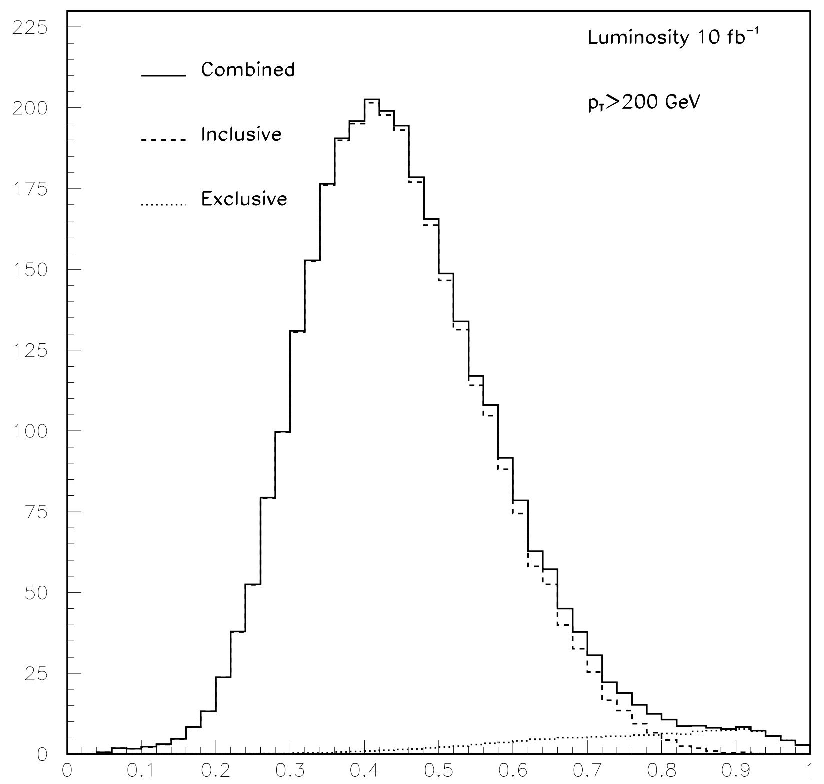
Search for exclusive events in CDF

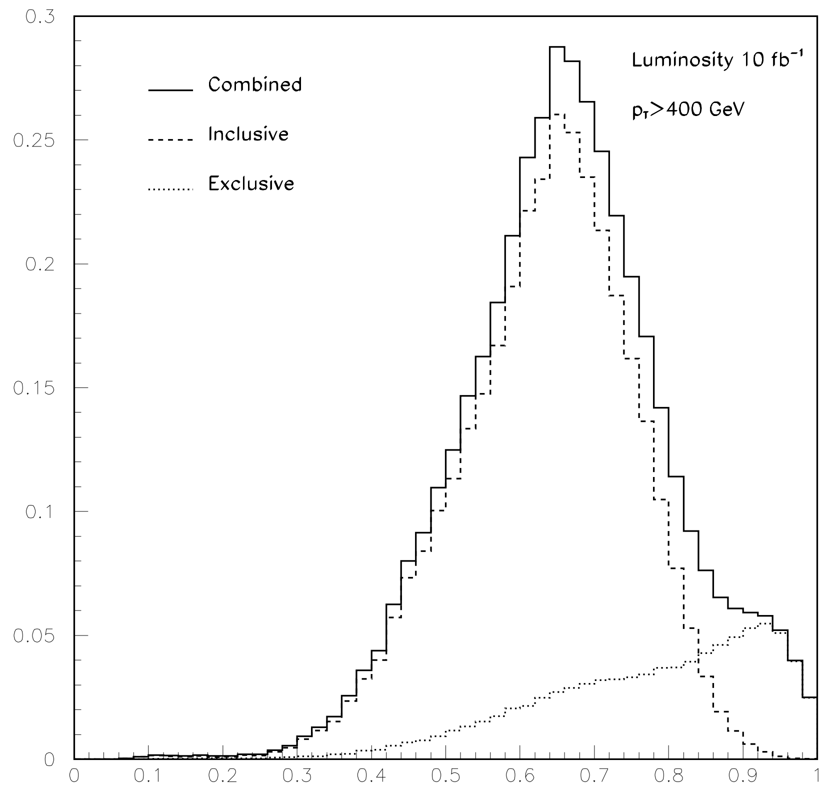
- Inclusive diffraction cannot explain CDF measurement of dijet mass fraction for jet $p_T > 10$ and $p_T > 25$ GeV
- Measurements compatible with inclusive and exclusive diffraction (Khoze Martin Ryskin) added
- See O. Kepka, C. Royon, Phys.Rev.D76 (2007) 034012; arXiv0706.1798
- Other measurements by CDF: χ_C, exclusive diphoton production, exclusive b jets...



LHC: Exclusive and inclusive events

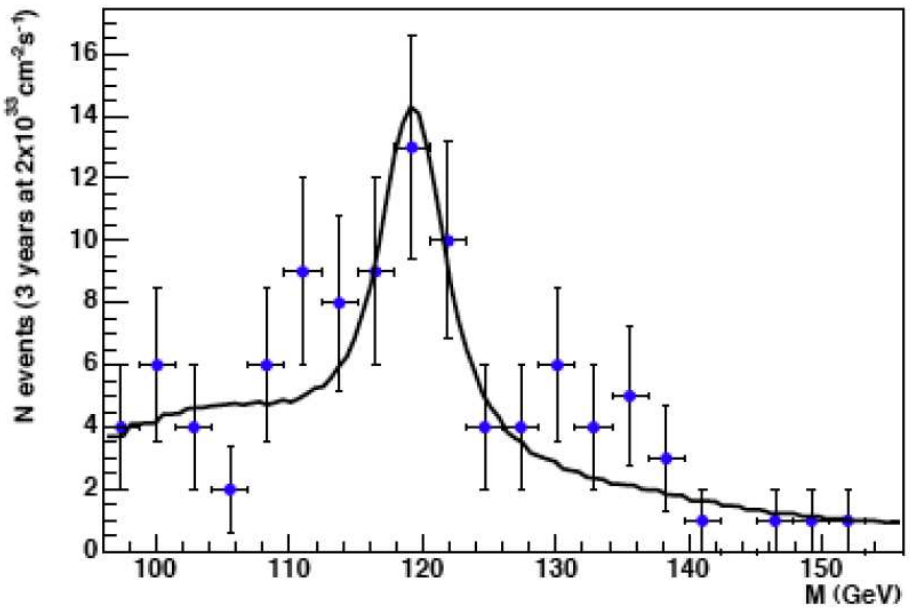
- Study of exclusive and inclusive production to be made at the LHC: study cross section of both components as a function of jet p_T and perform DGLAP QCD fits
- Important to understand background and signal for exclusive production of rare events: Higgs, SUSY...

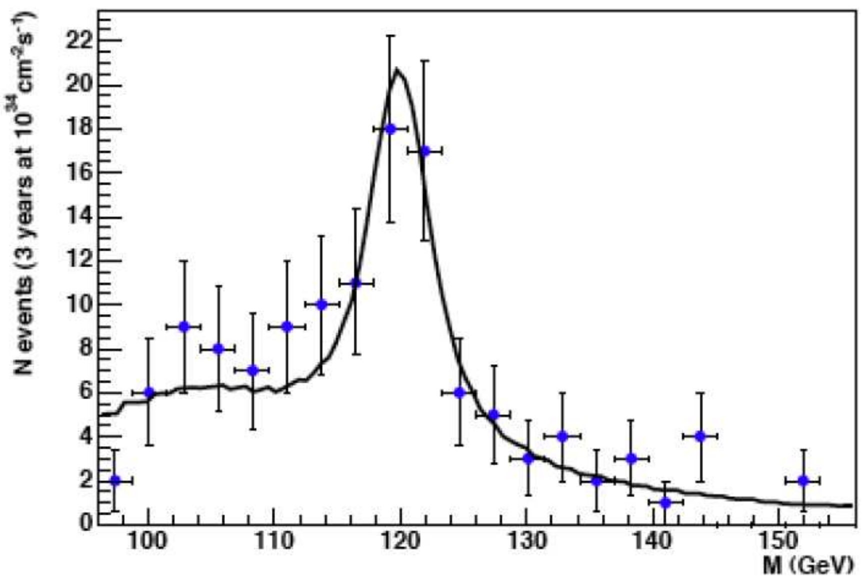




SUSY Signal significance

- Signal and background full simulation, pile up effects taken into account: see B. Cox, F. Loebinger, A. Pilkington, JHEP 0710 (2007) 090 for h production at $\tan\beta \sim 40$, 8 times higher cross section than SM
- 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

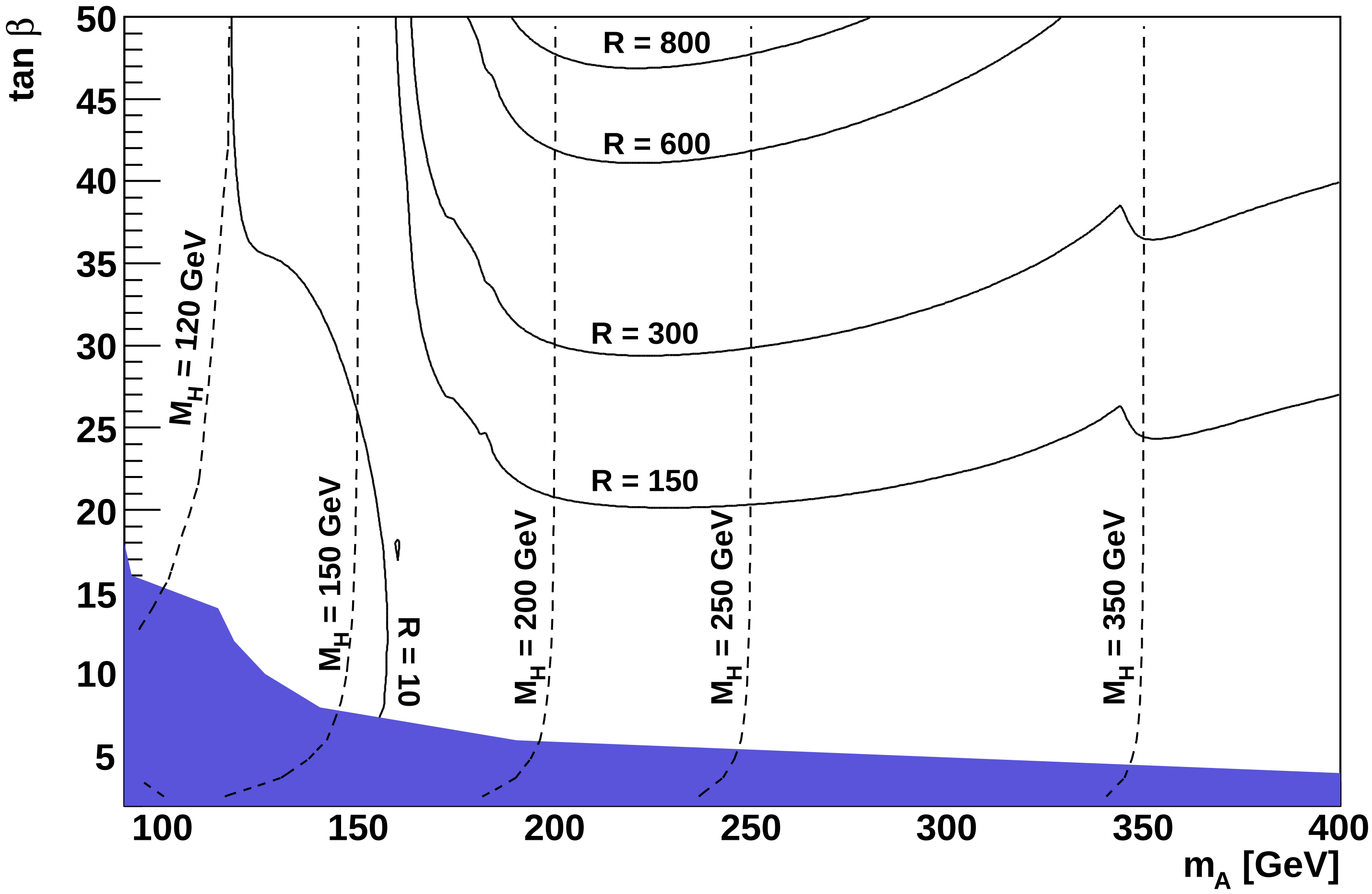




Diffractive SUSY Higgs production

Contour for the ratio of signal events in the MSSM and SM scenarios for $H \rightarrow b\bar{b}$

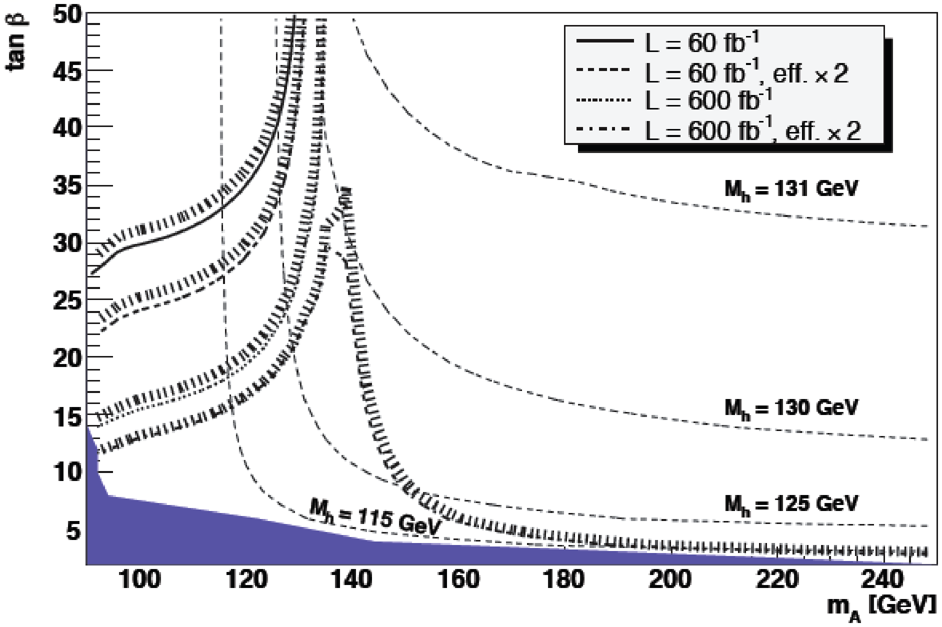
S. Heinemeyer et al., Eur.Phys.J.C53:231-256,2008

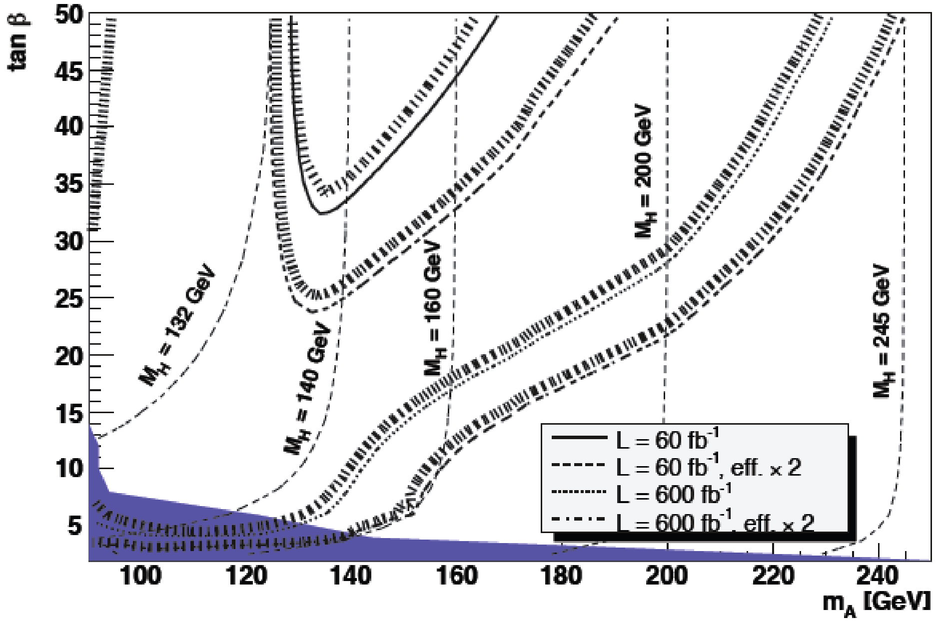


Diffractive SUSY Higgs production

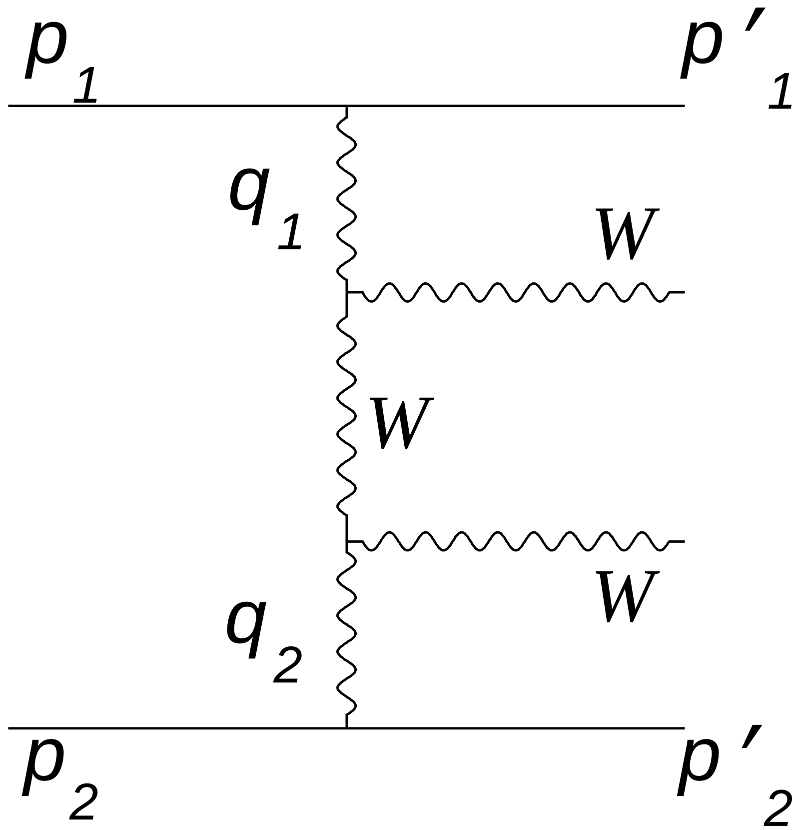
Exclusion plane in the (M_H, m_A) and (M_h, m_A) planes for different luminosities

S. Heinemeyer et al., Eur.Phys.J.C53:231-256,2008





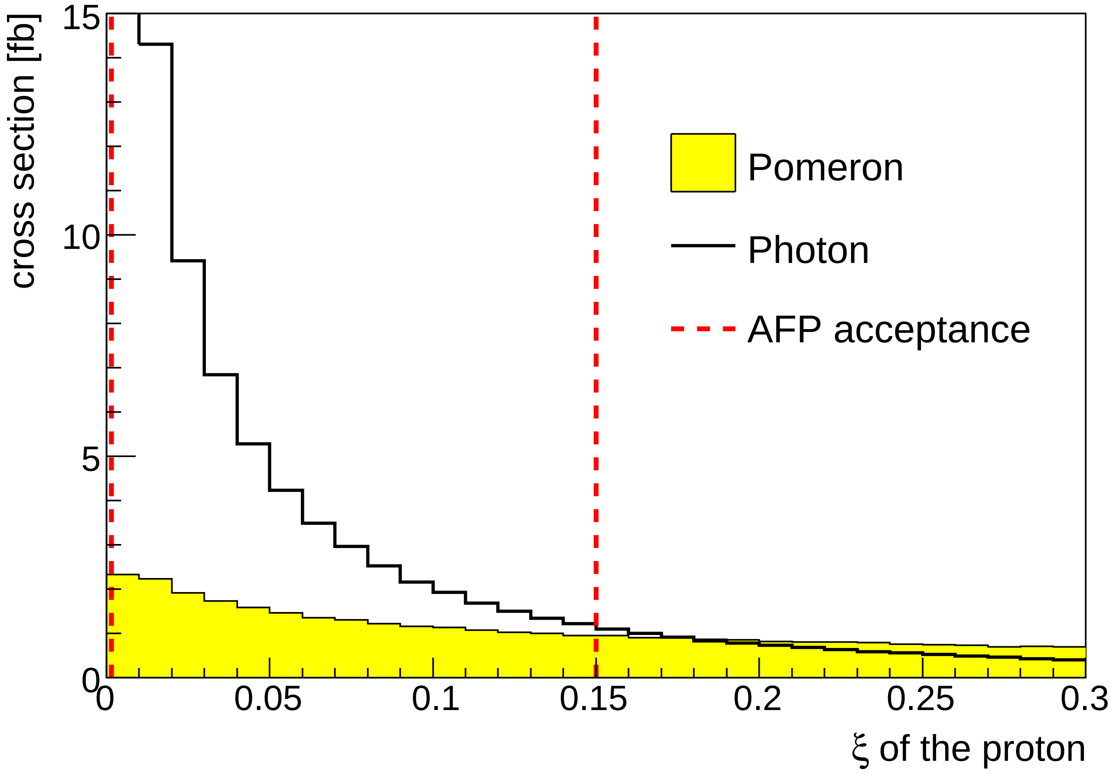
WW production at the LHC



- Study of the process: $pp \rightarrow ppWW$
- Exclusive production of W pairs via photon exchange: QED process, cross section perfectly known
- Two steps: SM observation of WW events, anomalous coupling study
- $\sigma_{WW} = 95.6$ fb, $\sigma_{WW}(W > 1TeV) = 5.9$ fb
- See: O. Kepka, C. Royon, arXiv:0808.0322, in press in Phys. Rev. D

Experimental study of WW production at the LHC

- ATLAS/CMS-TOTEM: Proton taggers at 220 and 420 m: $0.0015 < \xi < 0.15$
- W detected in main ATLAS/CMS detector: electron or muon detected with $p_T > 30$ GeV and $|\eta| < 2.5$
- Higher cut on ξ allows to remove part of the double pomeron exchange background: cross section of 14 fb for $0.0015 < \xi < 0.05$ (double pomeron exchange background: 0.2 fb)
- For a luminosity of 200 pb^{-1}, observation of 5.6 W pair events for a background less than 0.4, which leads to a signal of 8.6 σ



Anomalous $WW\gamma$ triple gauge coupling

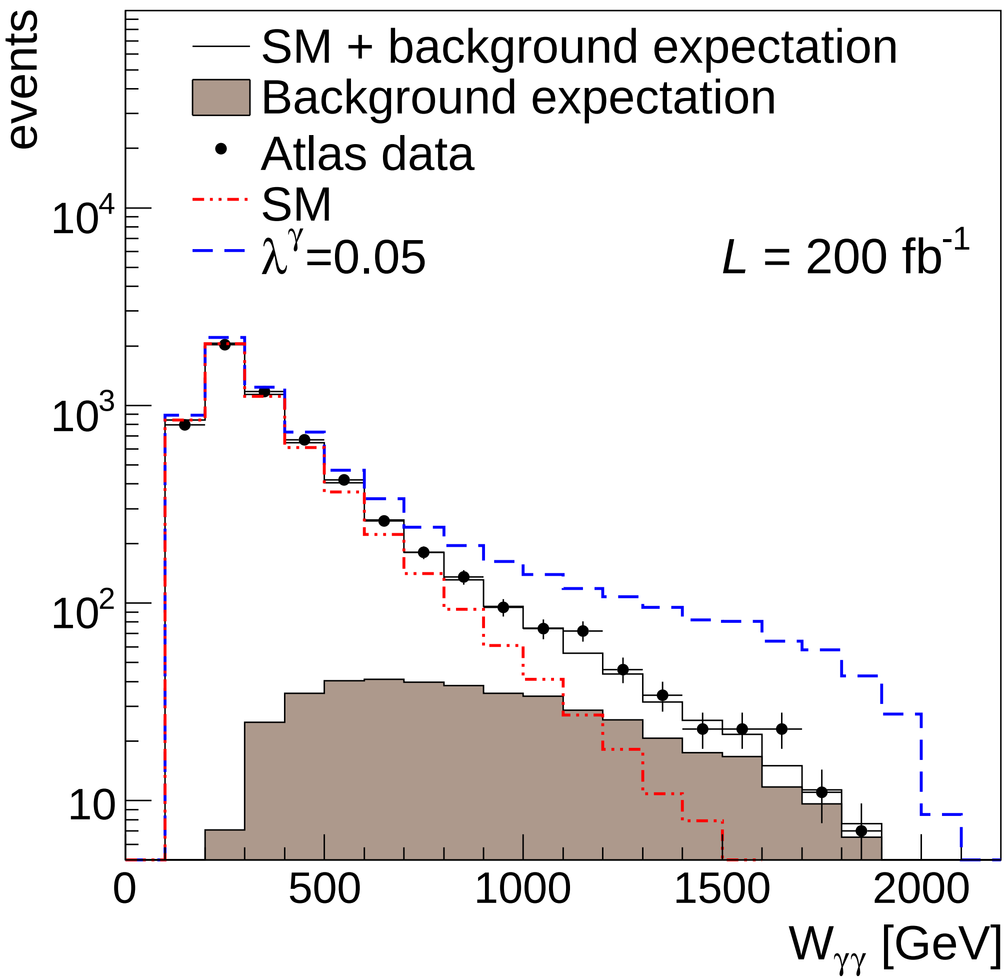
- Lagrangian with anomalous couplings λ^γ

$$\mathcal{L} \sim (W^\dagger_{\mu\nu} W^\mu A^\nu - W_{\mu\nu} W^{\dagger\mu} A^\nu) + (1 + \Delta\kappa^\gamma) W^\dagger_\mu W_\nu A^{\mu\nu} + \frac{\lambda^\gamma}{M_W^2} W^\dagger_{\rho\mu} W^\mu{}_\nu A^{\nu\rho}$$

- Anomalous coupling matrix elements obtained using OMEGA interfaced with FPMC (Forward Physics Monte Carlo to get DPE (inclusive and exclusive KMR) and Photon exchanges at the LHC, and also single diffraction in the same framework)
- Present limits on anomalous couplings:
  - From Tevatron: $-0.51 < \Delta\kappa^\gamma < 0.51$; $-0.12 < \lambda^\gamma < 0.13$ (direct limits)
  - NB: Indirect limits from LEP: $-0.098 < \Delta\kappa^\gamma < 0.101$; $-0.044 < \lambda^\gamma < 0.047$ (Inconvenient: mixture of γ and Z exchanges in $e^+e^- \rightarrow WW$)
- Reach on anomalous coupling at the LHC using a luminosity of 30 fb^{-1}: gain of a factor 20 on $\Delta\kappa^\gamma$ and λ^γ

Reach on triple gauge anomalous coupling

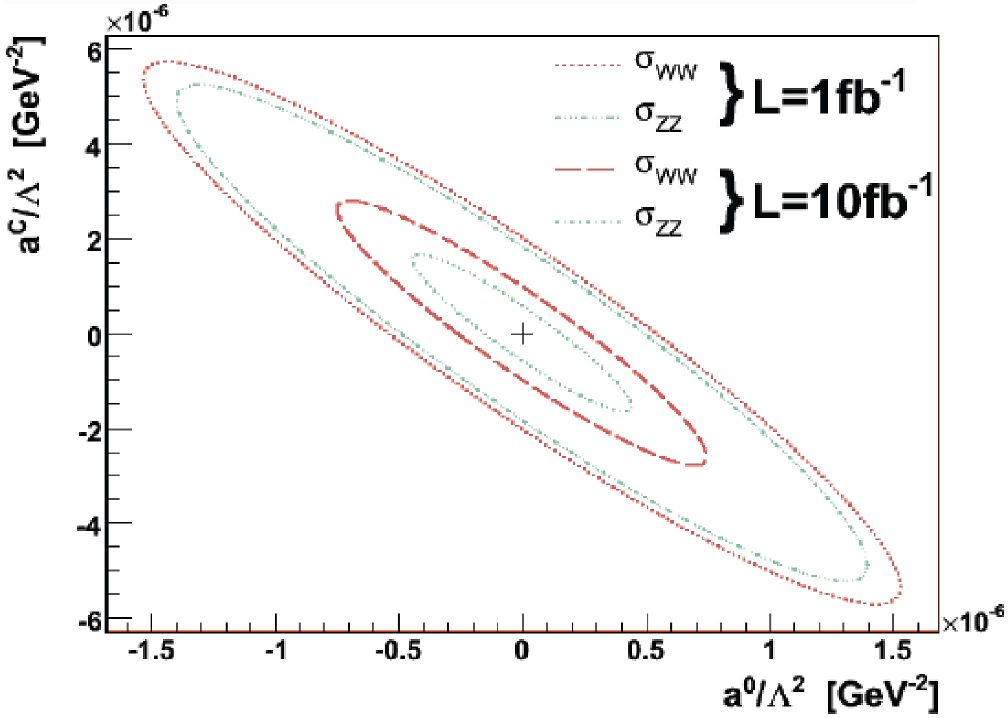
- Distribution of the $\gamma\gamma$ invariant mass $W_{\gamma\gamma}$:
- Specially interesting at high $W_{\gamma\gamma}$ where about 400 events are expected above 1 TeV for 200 fb^{-1}
- Sensitive to anomalous coupling but also to SUSY, new strong dynamics at the TeV scale



Sensitivity on quartic anomalous coupling

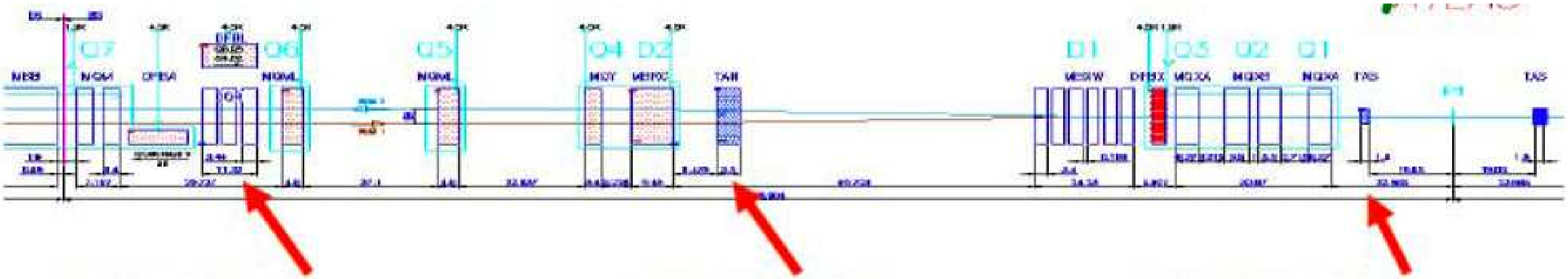
See K. Piotrzkowski, T. Pierzchala : improvement of 3 orders of magnitude compared to LEP sensitivity

significance limits on the AQGC



Coupling	Limits [GeV^{-2}] L=1fb^{-1}	L=10fb^{-1}
$\lvert a_0^Z/\Lambda^2\rvert$	$0.49 \cdot 10^{-6}$	$0.16 \cdot 10^{-6}$
$\lvert a_0^W/\Lambda^2\rvert$	$0.54 \cdot 10^{-6}$	$0.27 \cdot 10^{-6}$
$\lvert a_C^Z/\Lambda^2\rvert$	$1.84 \cdot 10^{-6}$	$0.58 \cdot 10^{-6}$
$\lvert a_C^W/\Lambda^2\rvert$	$2.02 \cdot 10^{-6}$	$0.99 \cdot 10^{-6}$

Forward detectors in ATLAS

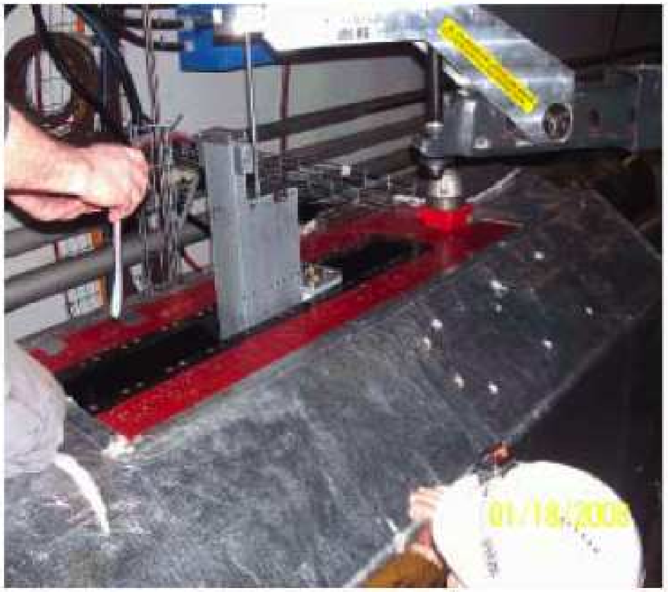


ALFA at 240 m

Absolute Luminosity for ATLAS

TDR submitted
CERN/LHCC/2008-004

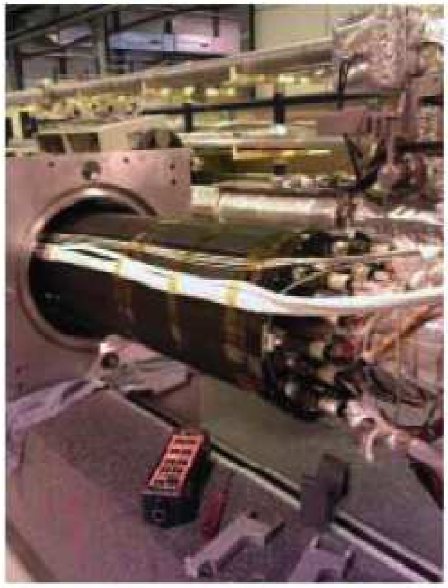
ZDC at 140 m



Zero Degree Calorimeter

Phase I (partially) installed

LUCID at 17 m



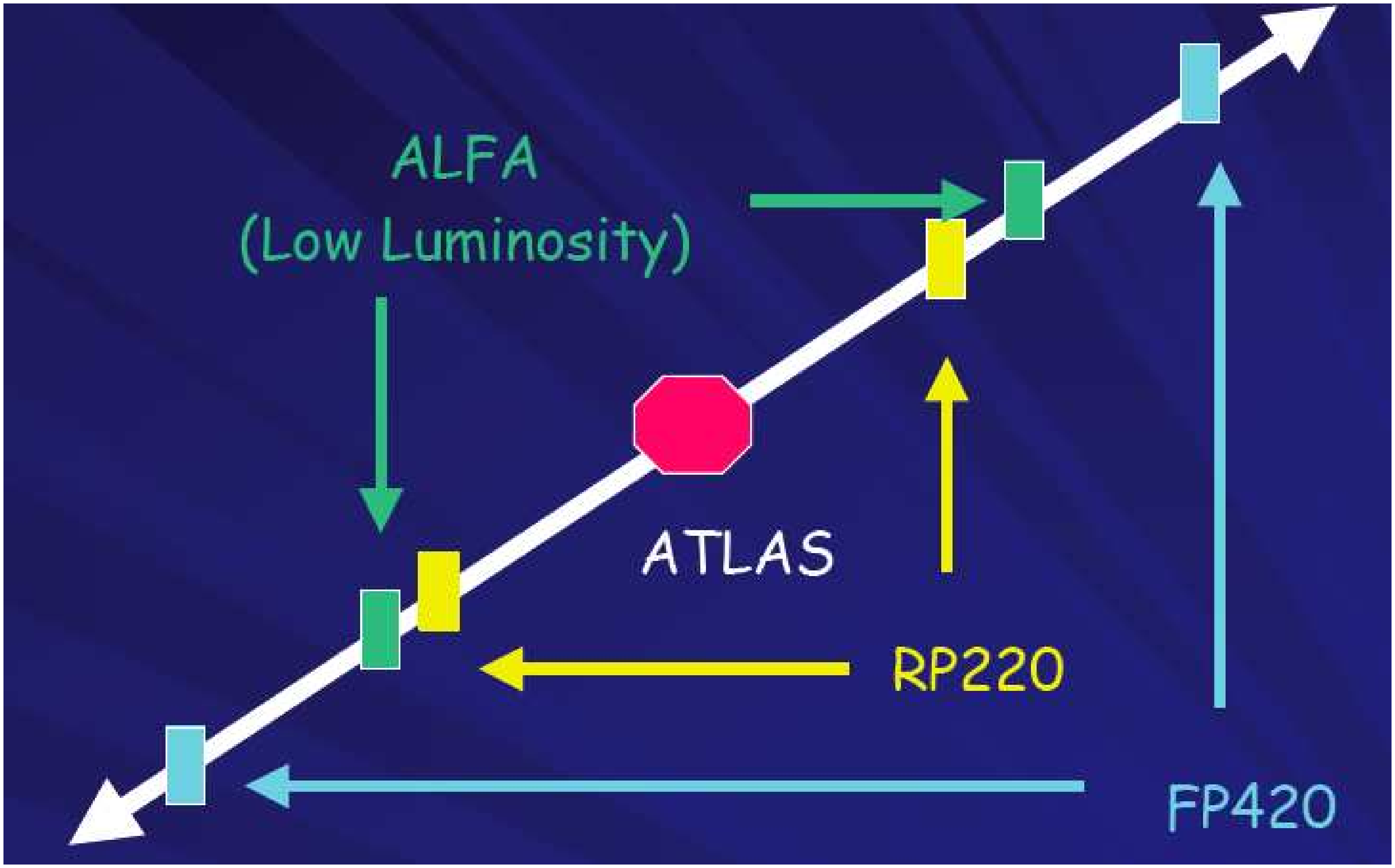
Luminosity Cerenkov Integrating Detector

Phase I ready for installation

From P. Grafstorm, Saclay May 08

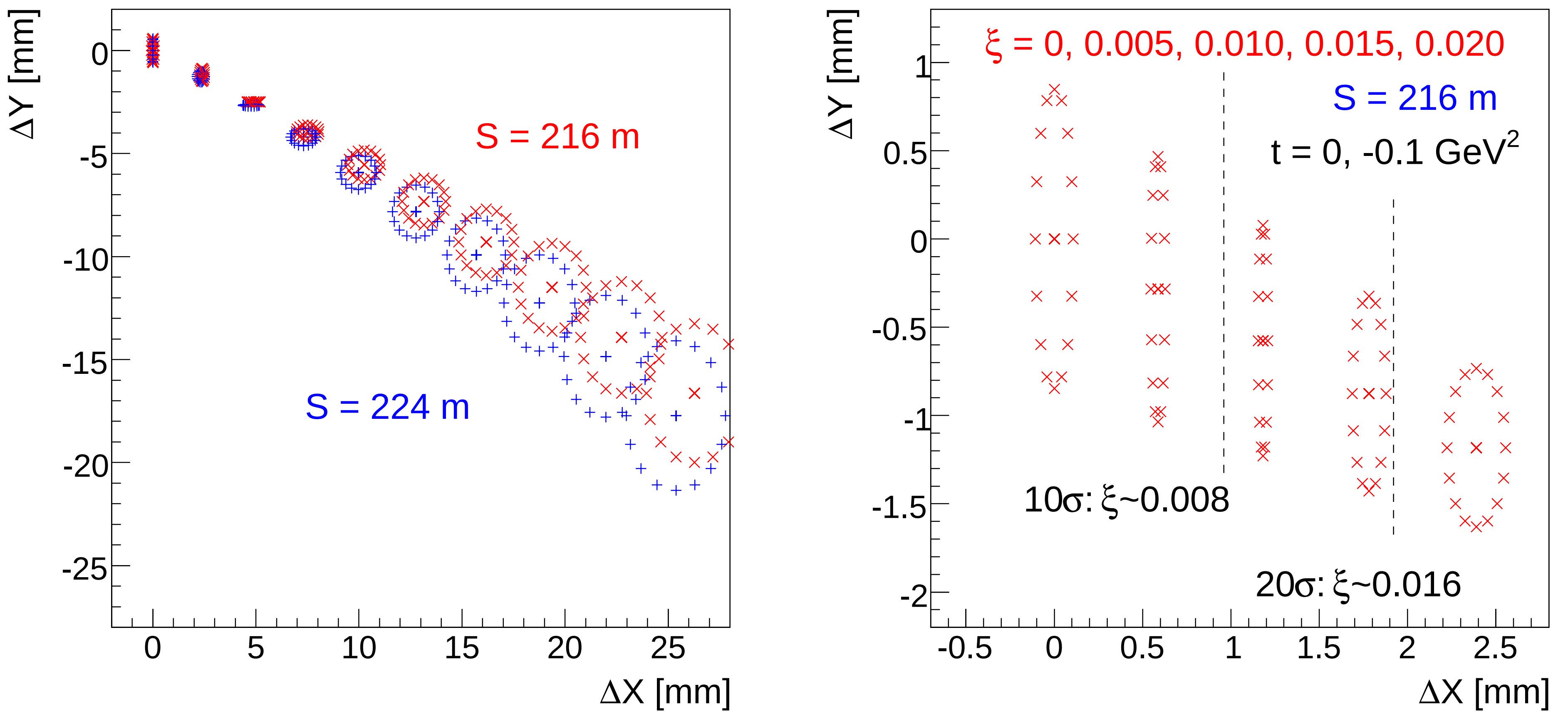
Detector location

- what is needed? Good position and good timing measurements
- 220 m: movable beam pipes (in addition vertical roman pots for alignment purposes under study)
- 420 m: movable beam pipe (roman pots impossible because of lack of space available and cold region of LHC)



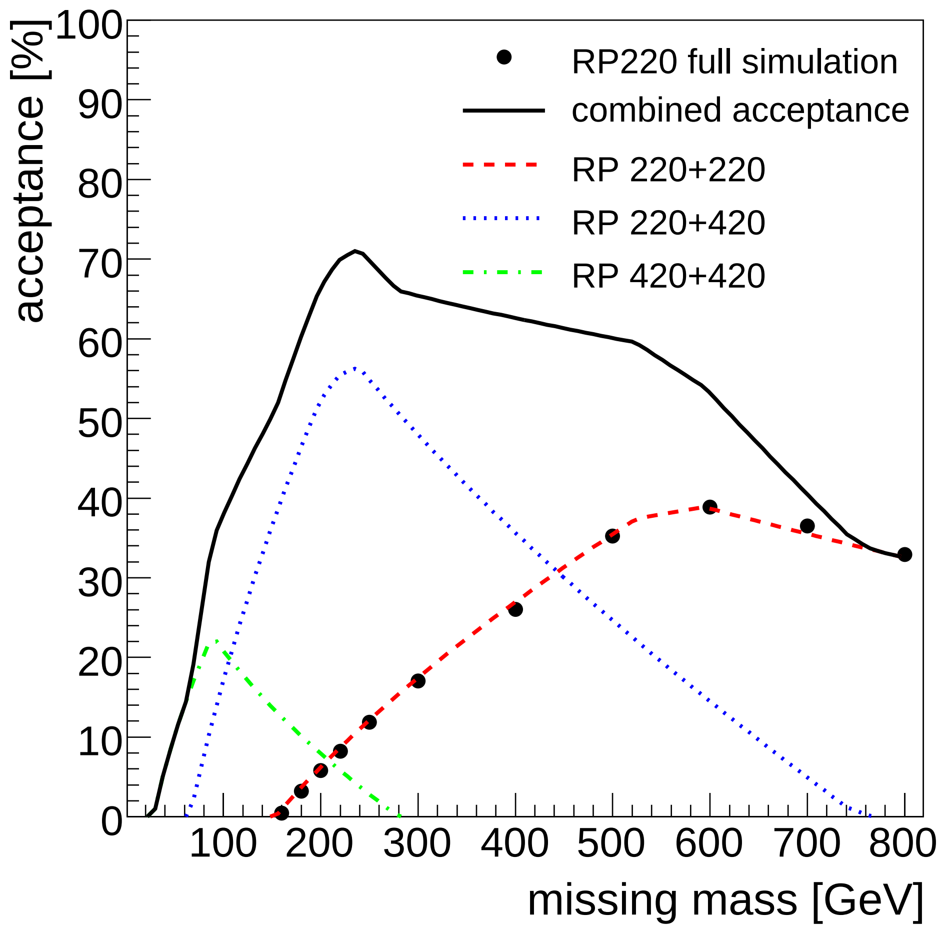
Example: Acceptance for 220 m detectors

- 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
- Estimate: possibility to insert the detectors up to $\sim 15\sigma$ from the beam routinely
- Detector coverage of 2 cm $\times$ 2 cm needed



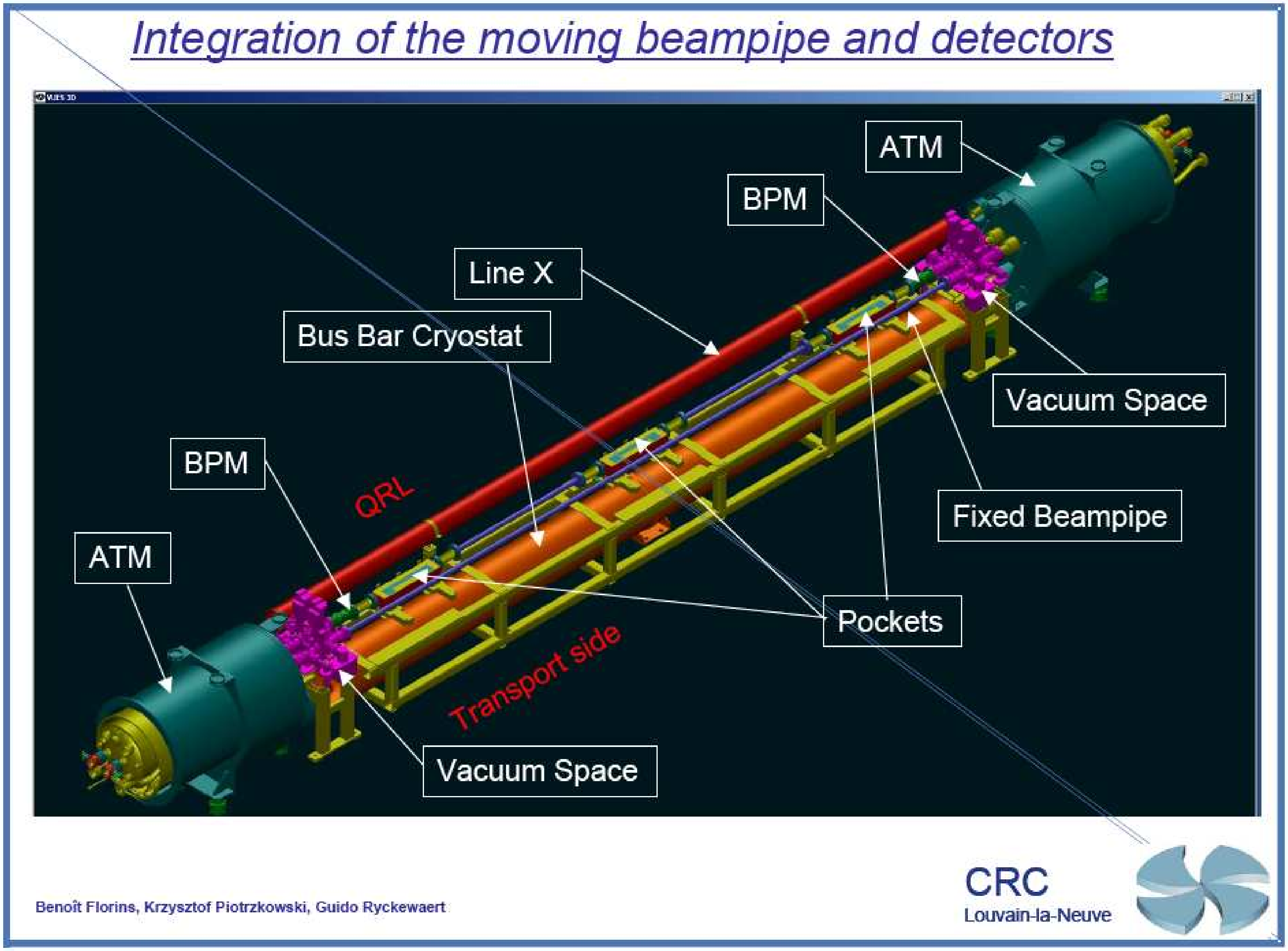
ATLAS Forward Physics detector acceptance

Both detectors at 420 and 220 m needed to have a good coverage of acceptance (NB: acceptance slightly smaller in CMS than in ATLAS)

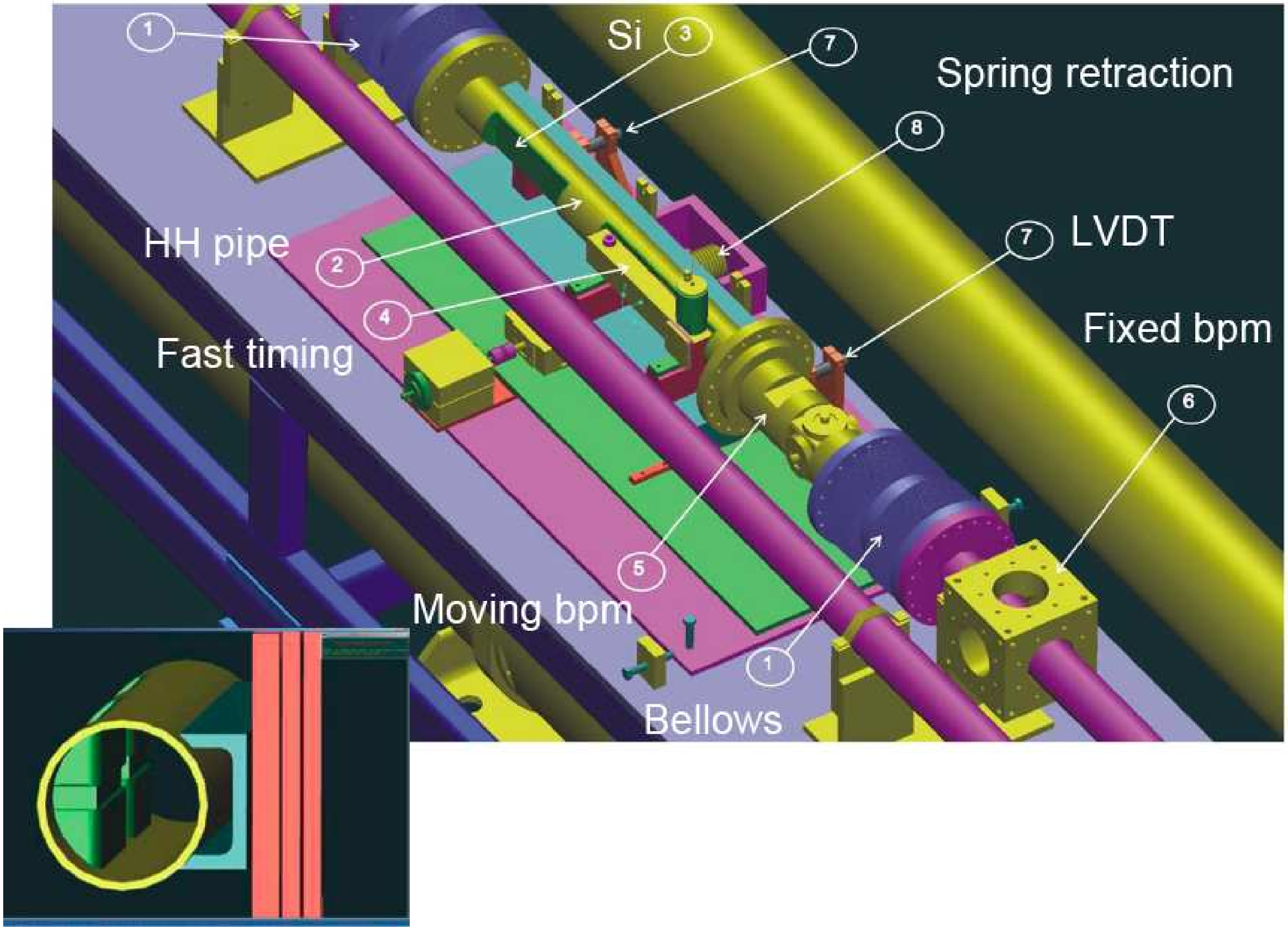


Which detectors: Movable beam pipe at 220-420 m

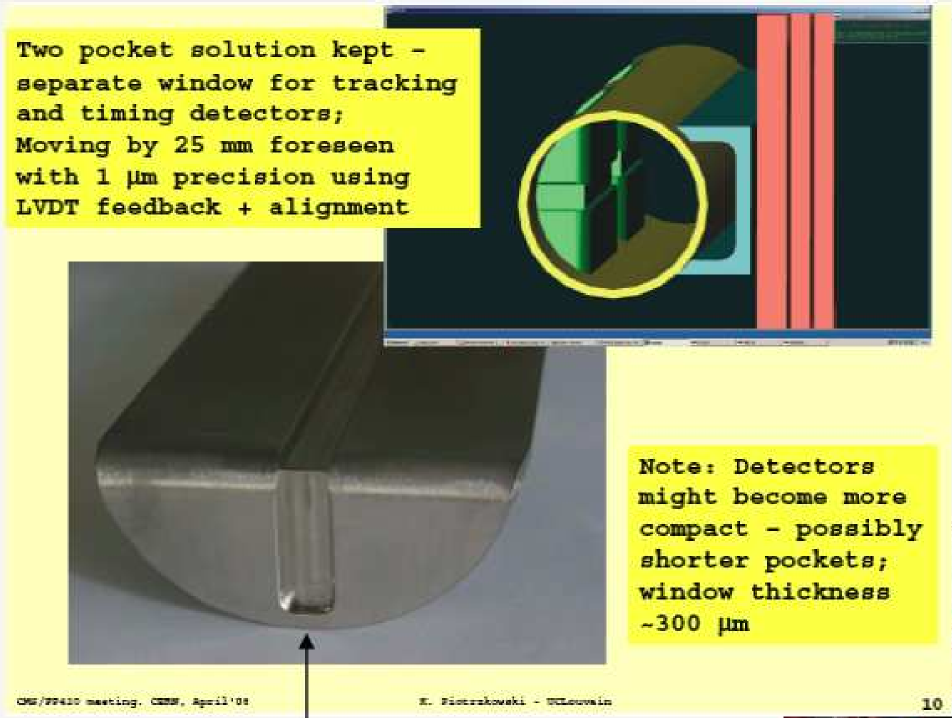
- Simple idea: use movable beam pipe to locate detectors, takes less space than roman pots
- Use movable beam pipes at 220 and 420 m to host position (3D silicon) and timing detectors
- Beam position known with very precise Beam Position Monitors (5 μm)



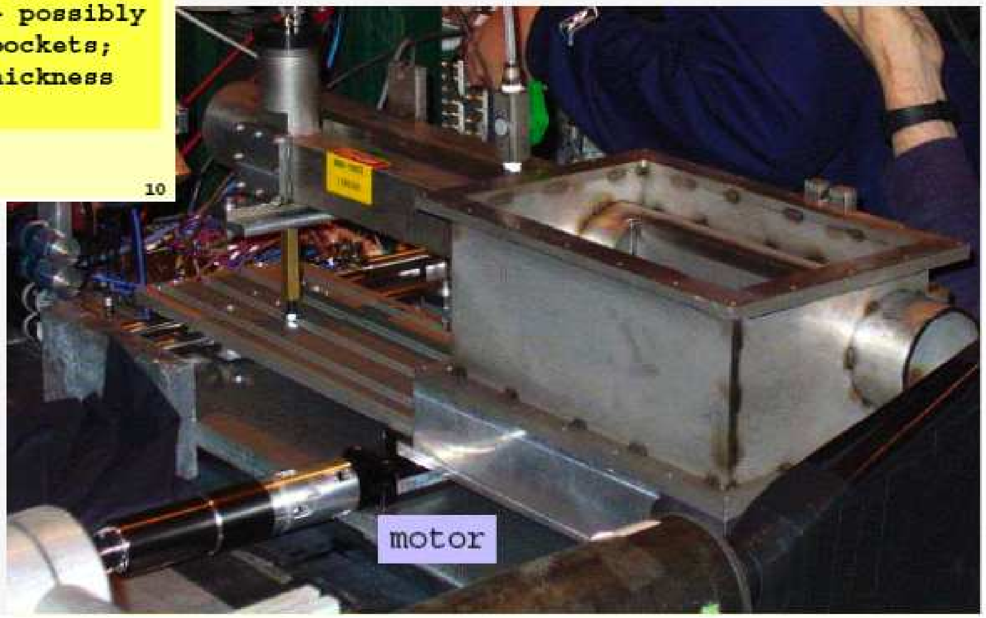
Movable beam pipe at 220-420 m



Movable beam pipes and pockets



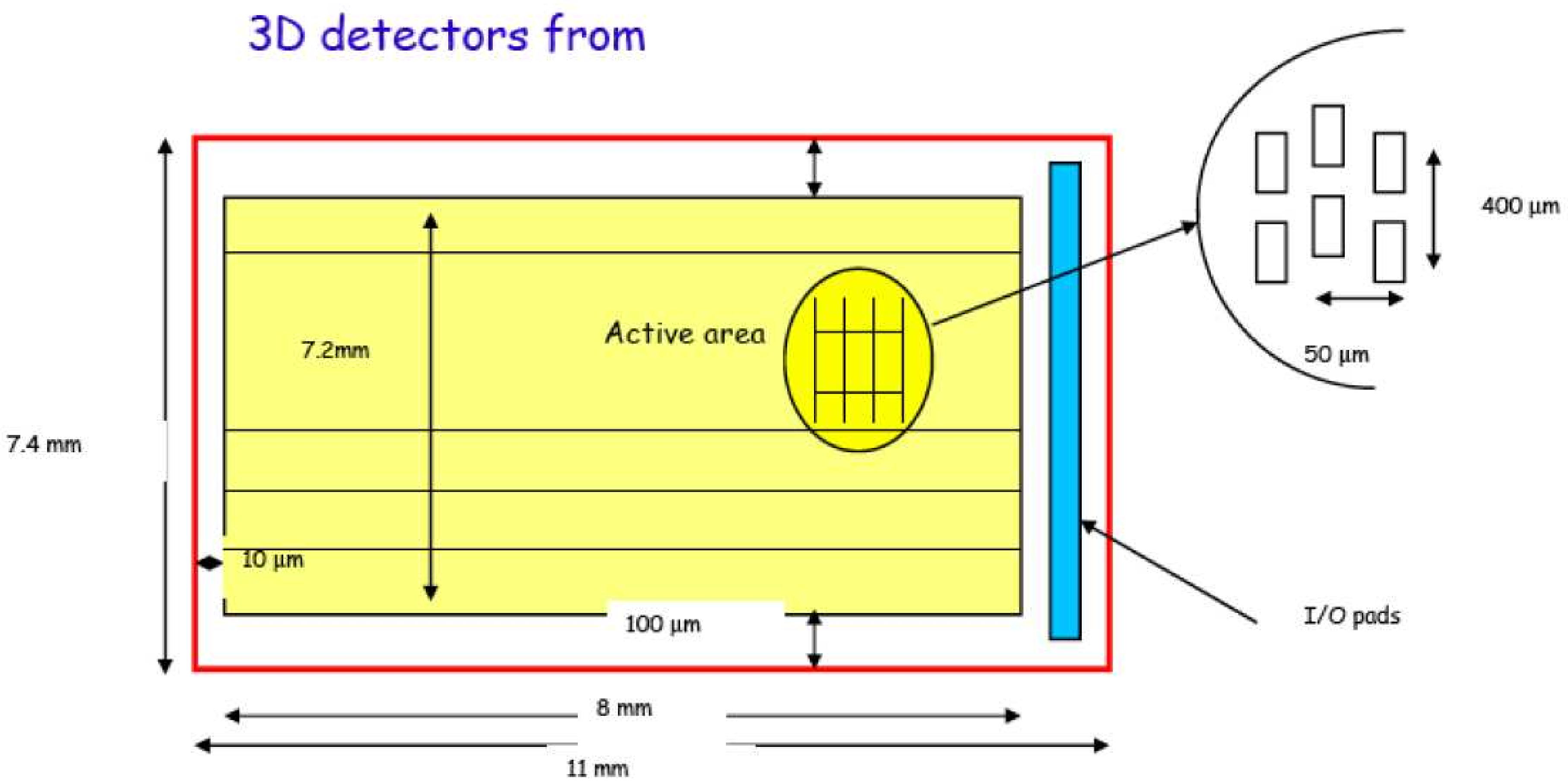
Details of the movable Beam-pipe during the 2007 test beam



300 µm window Louvain

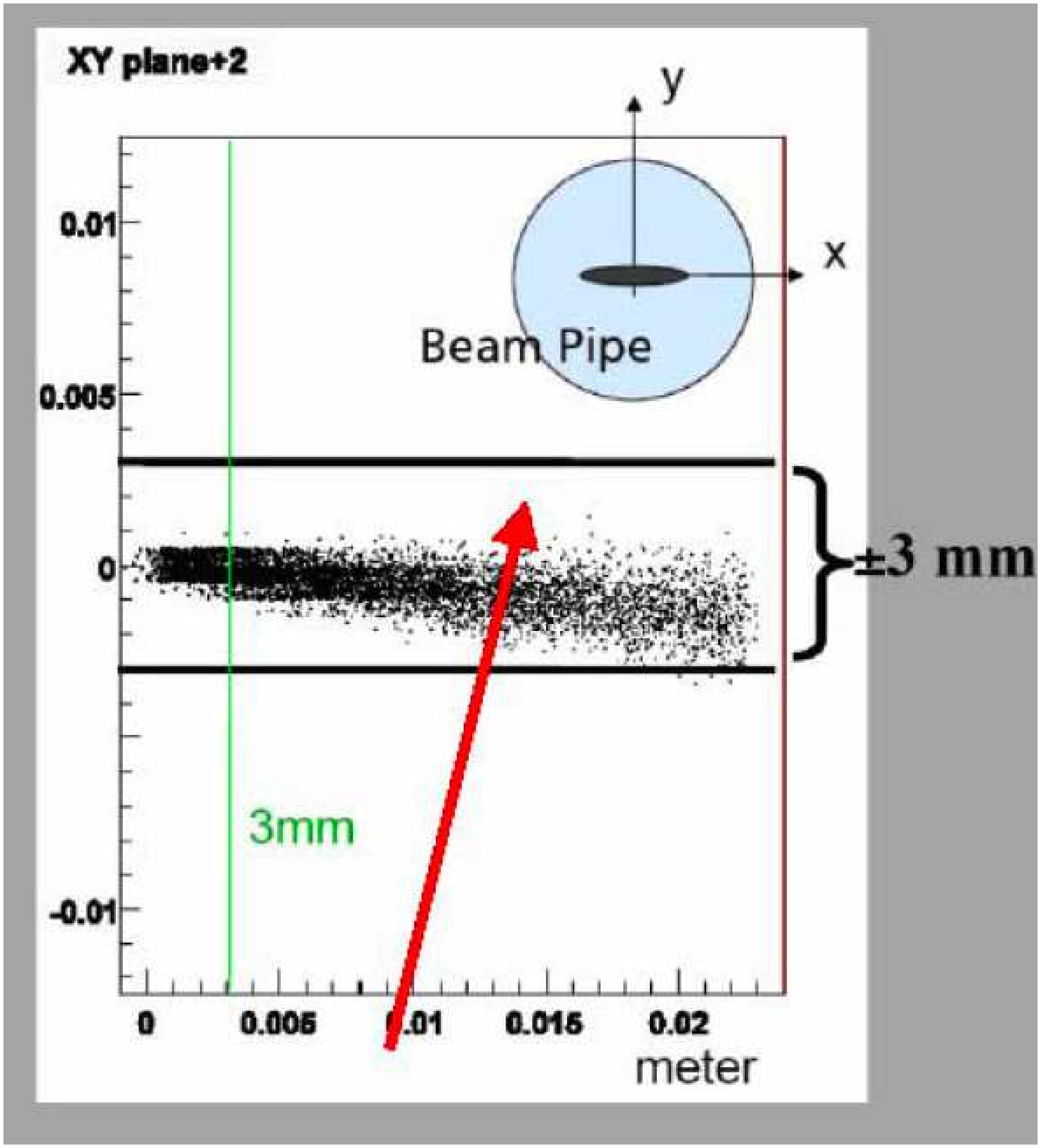
3D Silicon Detectors (Manchester/SLAC)

- 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



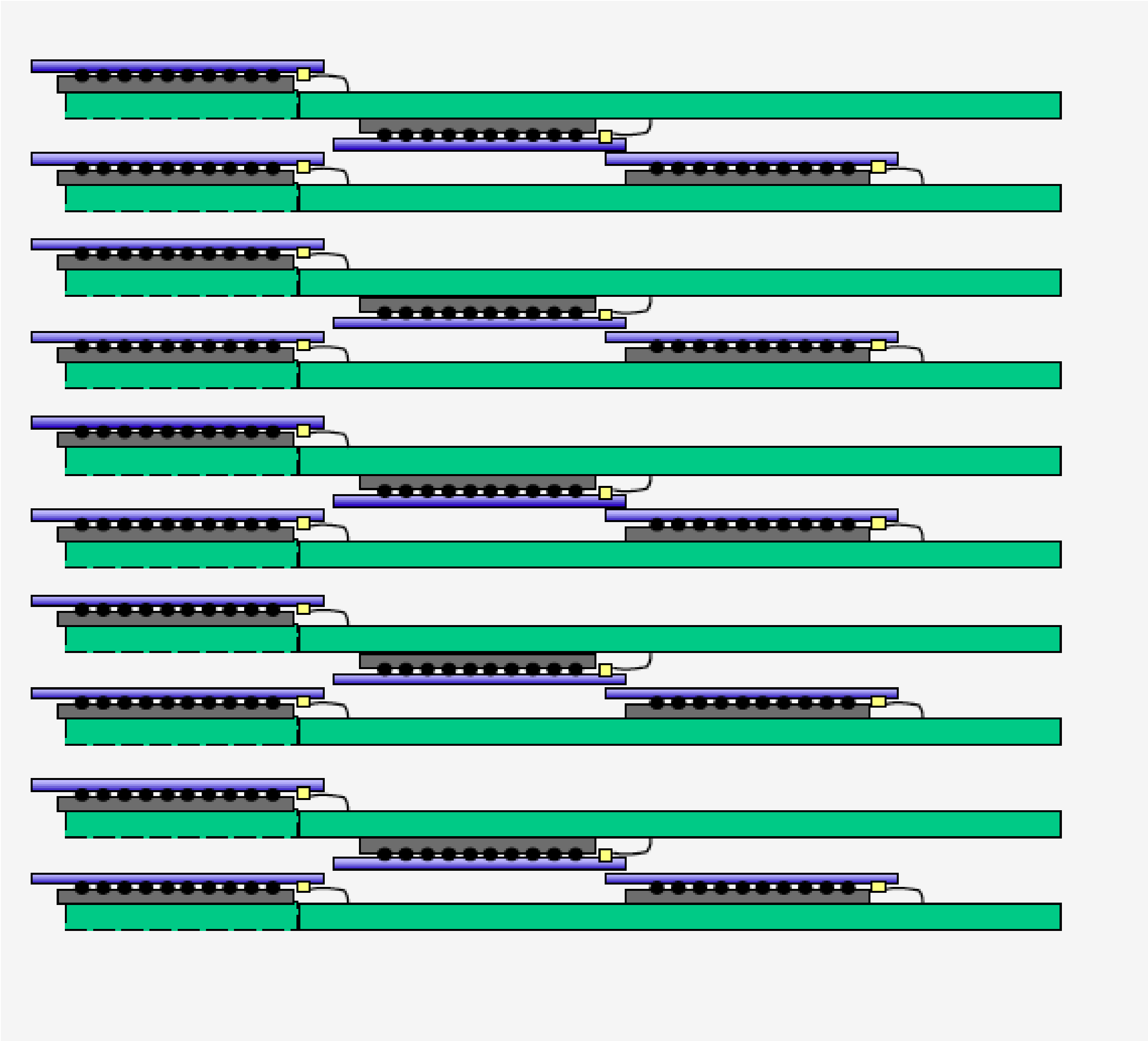
3D Silicon detectors at 420 m

3 "supermodules" of 3D Si detectors needed at 420 m



3D Silicon detectors at 420 m

Si supermodule arrangement at 420 m

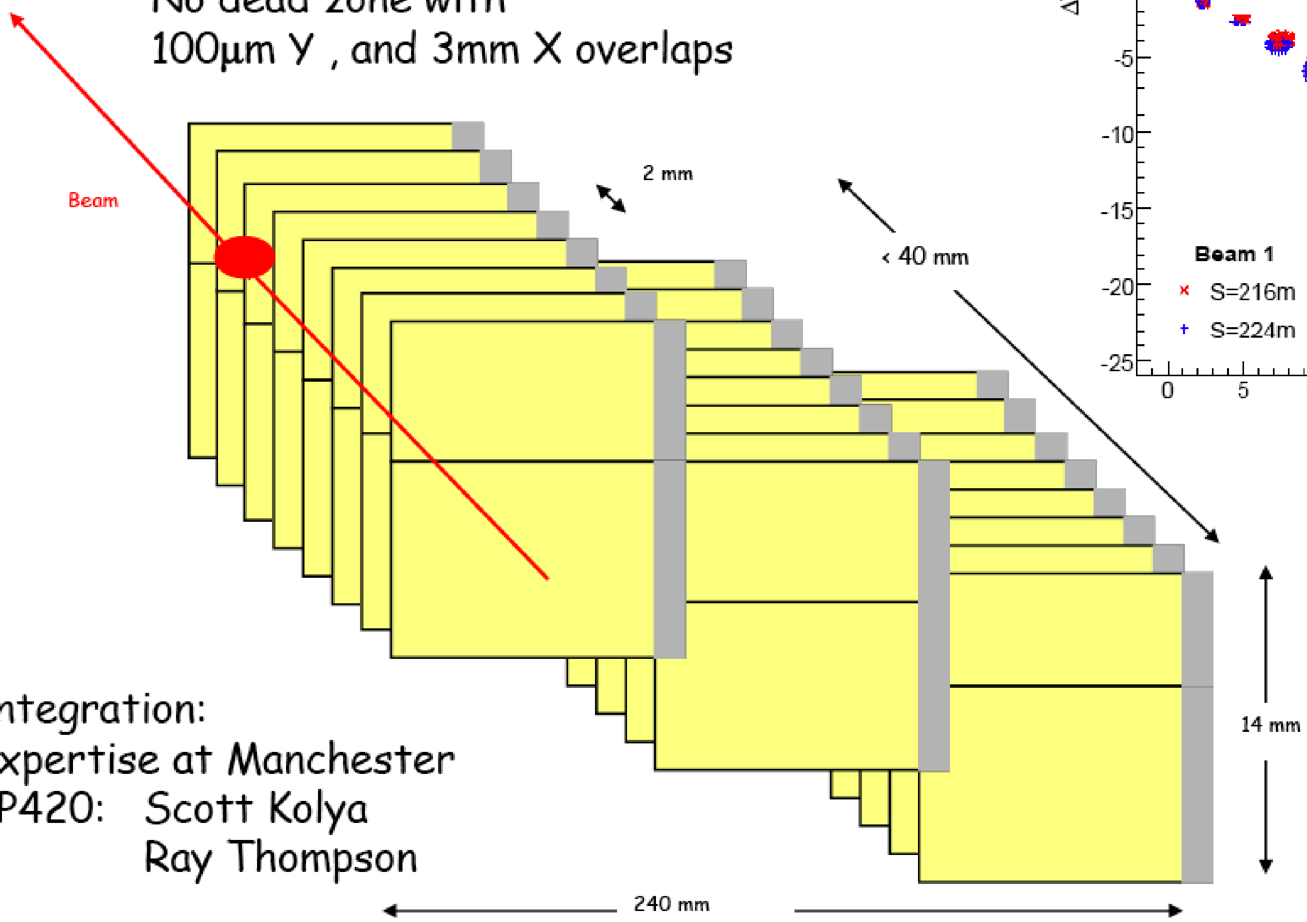


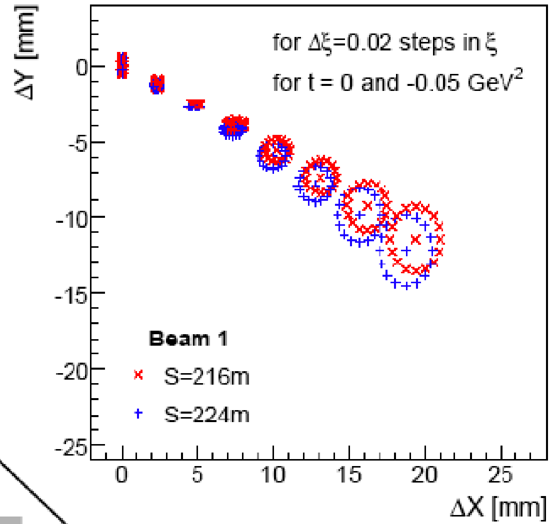
3D Silicon detectors

3D silicon detectors at 220 m: 6 supermodule per horizontal detector (in addition: 2 supermodules for vertical detectors in roman pots)

3D Detectors Layout for Horiz. Pots

Existing FP 420 modules
No dead zone with
100µm Y , and 3mm X overlaps

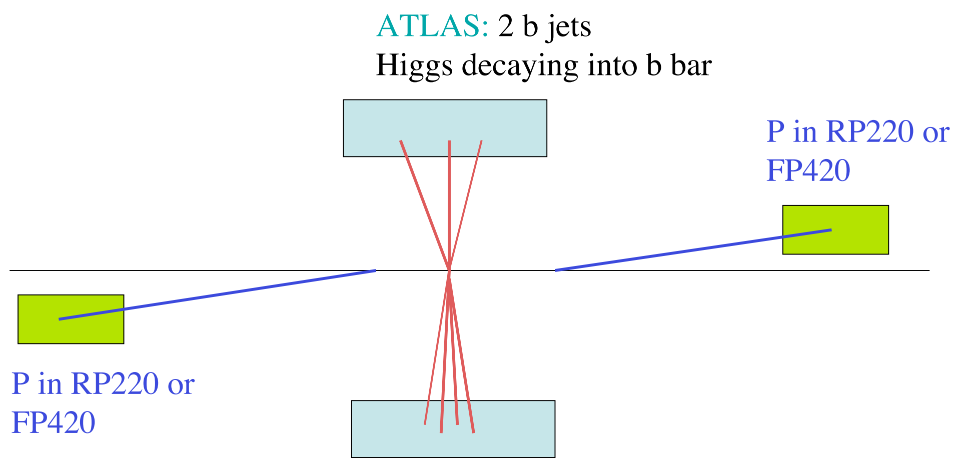


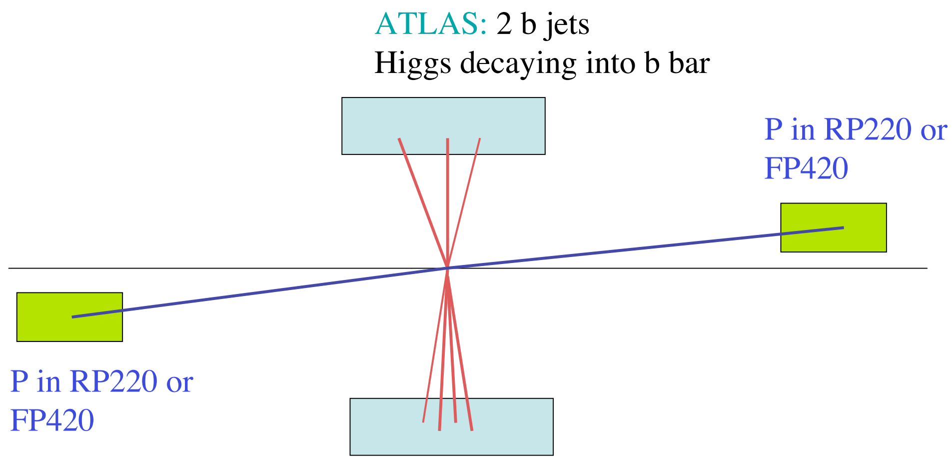


Integration:
Expertise at Manchester
FP420: Scott Kolya
Ray Thompson

Why do we need timing detectors?

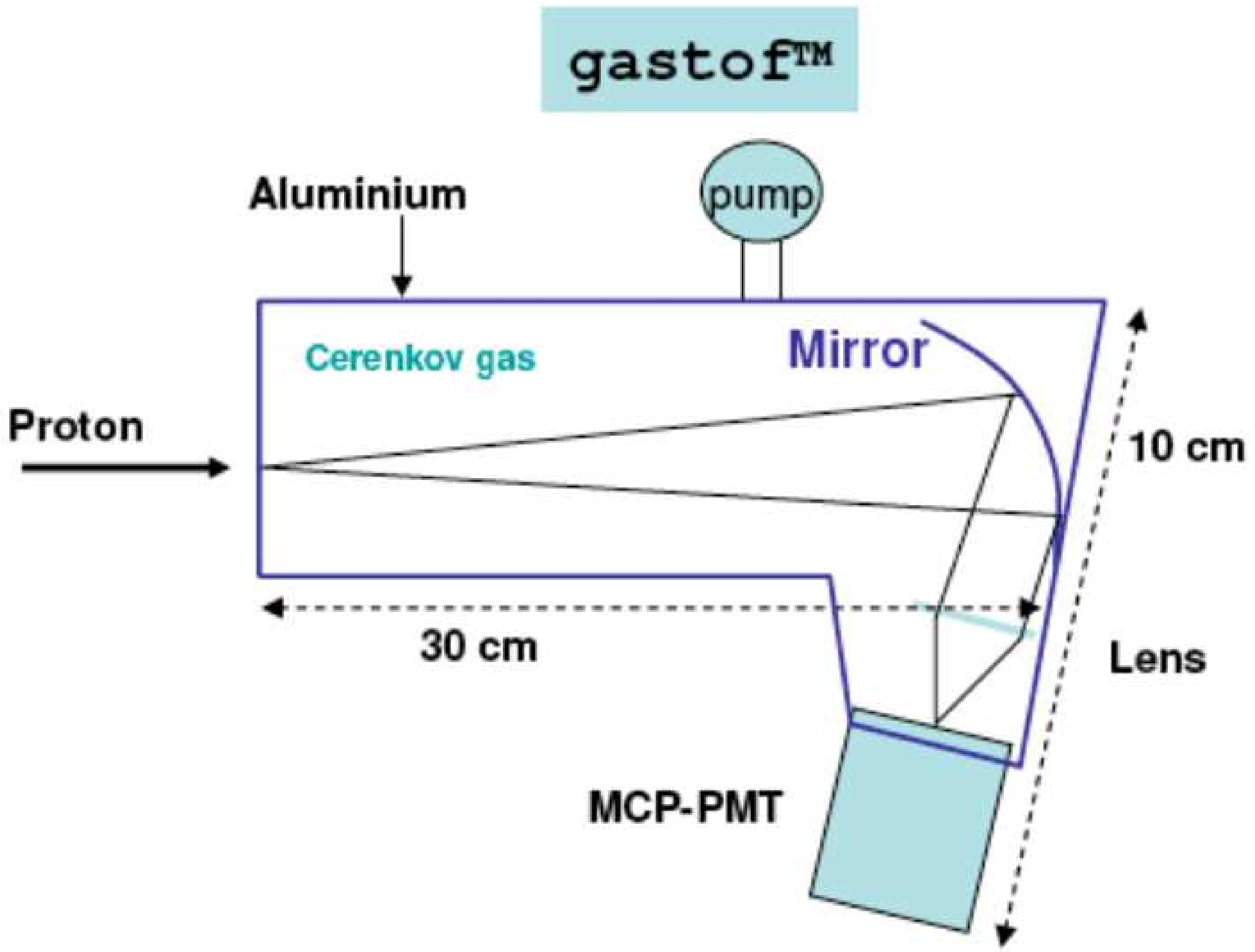
We want to find the events where the protons are related to Higgs production and not to another soft event (up to 35 events occuring at the same time at the LHC!!!!)





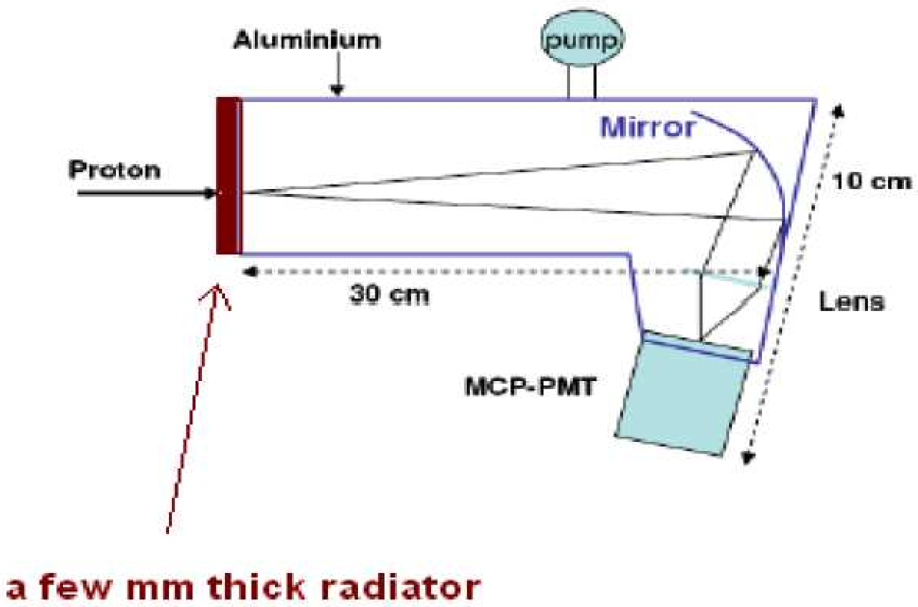
Timing measurements

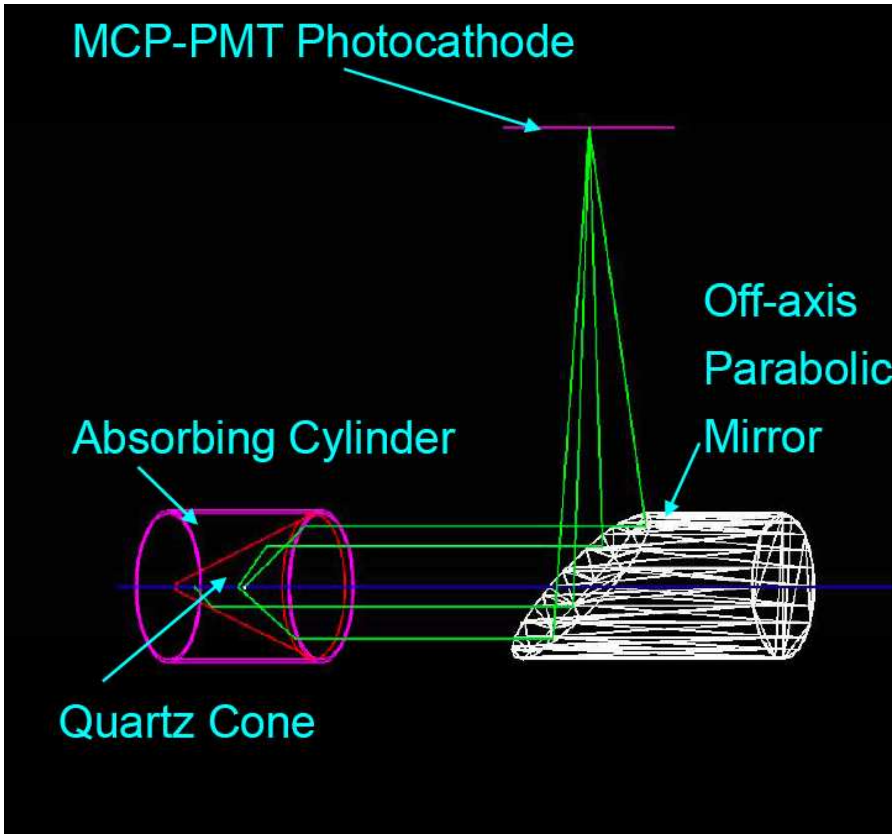
- Possibility to get presently a timing resolution of $10 - 15$ ps using gas based detectors, and $30 - 40$ ps per plane using quartz detector (Louvain, UTA, Alberta, Fermilab)
- Inconvenient of present gas detectors: no space resolution
- Upgrades under study: quartz in front of GASTOF, reconstruct Cerenkov light cone



Future timing detectors: towards 5 ps

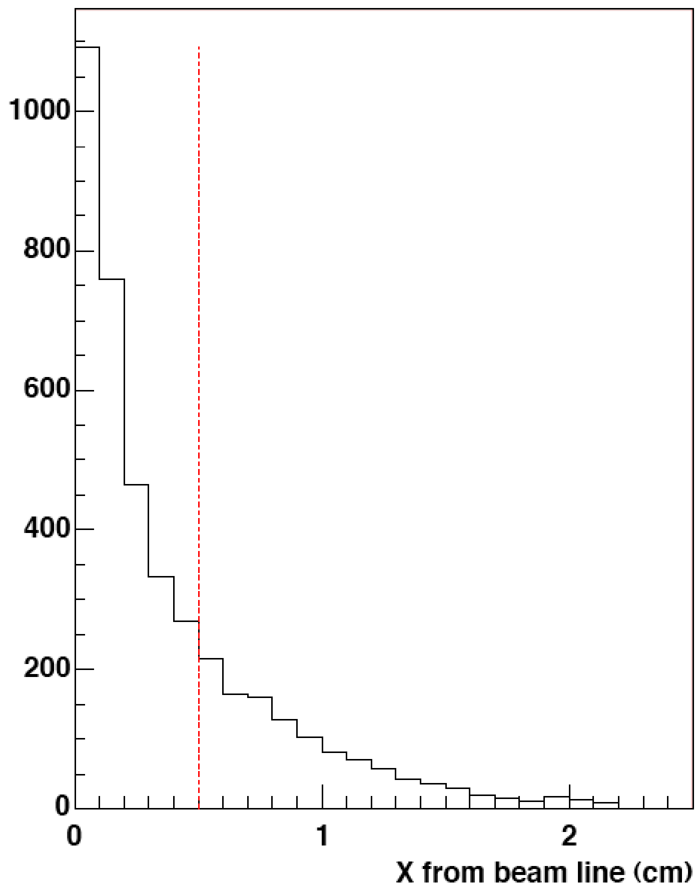
- Aim: reach a couple of picosecond precision
- Issue: number of photoelectrons to be produced to get enough resolution
- Solution: combination of GAS and QUARTZ detectors? (Louvain, Saclay, Stony Brook, Chicago, Argonne), new concept with absorptive cylinder and off-axis parabolic mirror (Fermilab, M. Albrow)





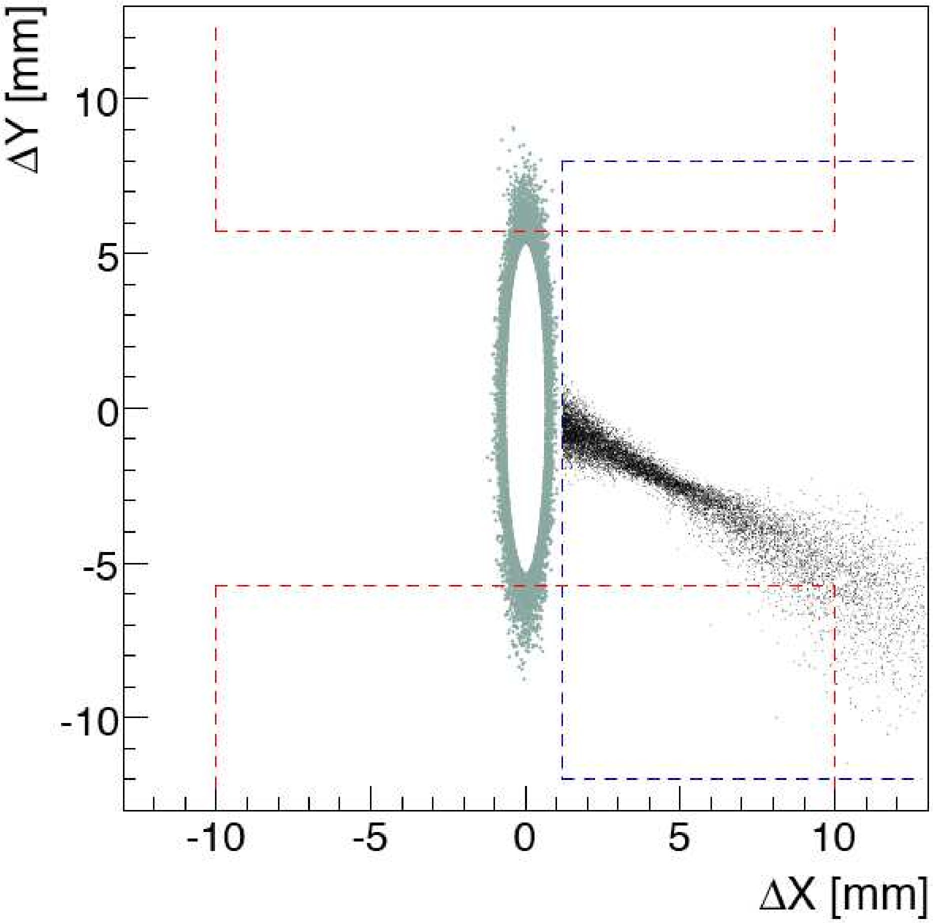
Forward detector alignement using exclusive muons

- Alignment using dimuon events at 420 m: Compare exclusive dimuon mass reconstructed using muon detectors and forward detectors, possibility to perform a store-by-store calibration
- Same method at 220 m? More difficult since dimuon cross section lower (higher mass), can be used only to perform a measurement every 2 weeks or so
- Beam Position Monitors: high precision of 5-10 μm, can be used to get a store-by-store calibration

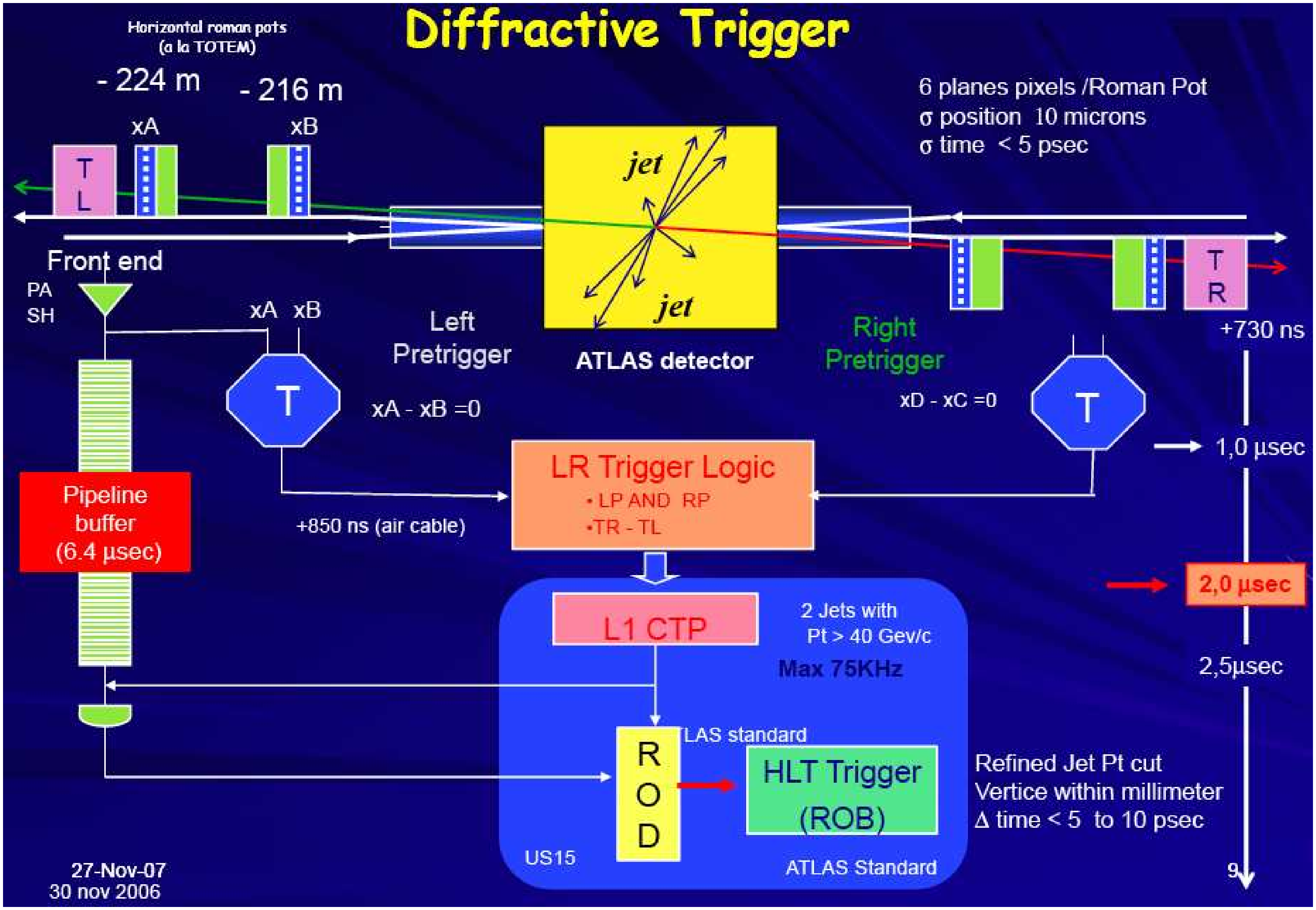


Forward detector alignment (220 m): Another method?

- Additional detectors to detect elastics at high t for alignment: vertical roman pots: 100 events per day at 15 σ, precision of 5 μm
- Single diffractive events to align horizontal movable beam pipes with respect to vertical pots: 10^{12} single diffractive events per day + halo events, with a acceptance $> 0.005\%$ at 15 σ, gives many many events...
- 5-10 μm precision with 100 elastic events
- Issues: Elastic cross section for $t \sim 5 - 9$ GeV^2, proton intact or dissociate?

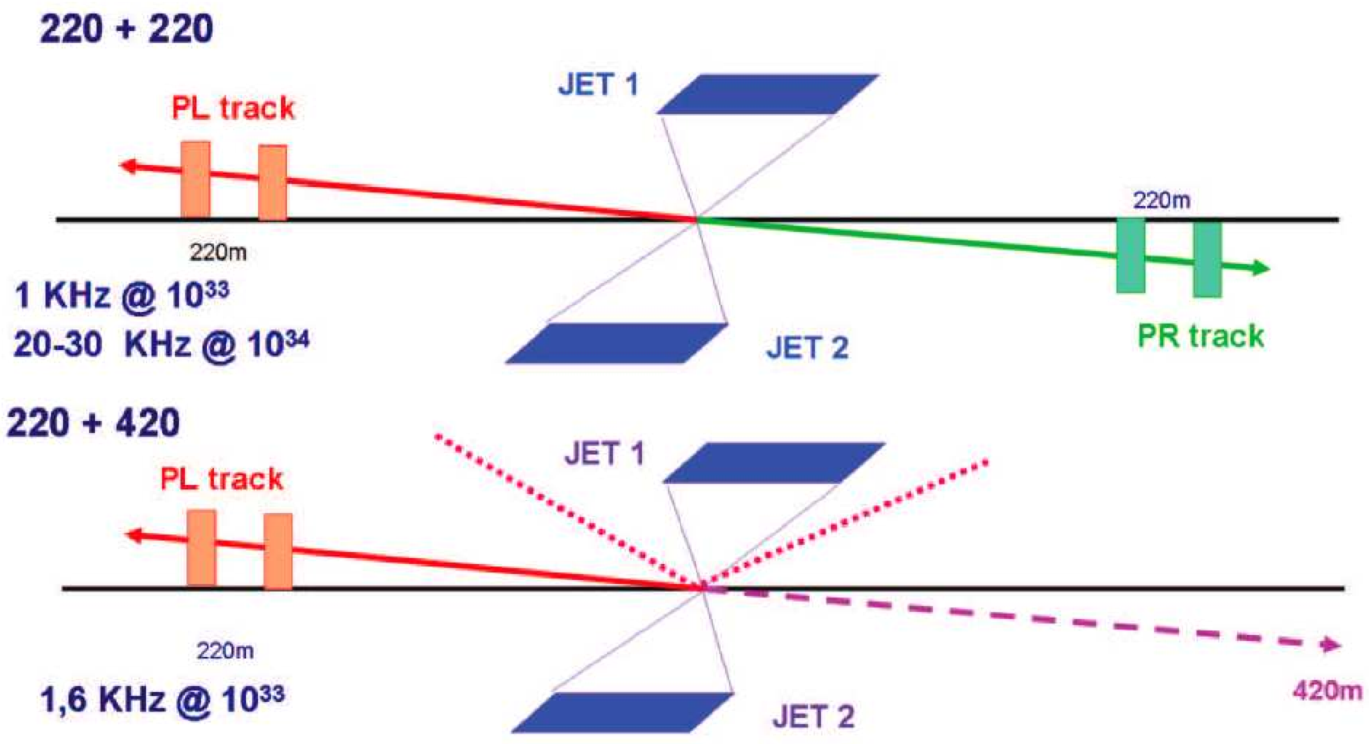


Trigger schematics



Trigger: principle

- 420 m detectors cannot make it to ATLAS L1 (decision time too short)
- Level 1 trigger: Either two tags at 220 m (easy..., possibility to cut on diffractive mass), or one single tag at 220 m (difficult...)
- In that case, cut on acceptance at 220 m corresponding to the possibility of a tag at 420 m: 2 jets $p_T > 40$ GeV; one proton at 220 m ($\xi < 0.05$, compatible with the presence of a proton at 420 m on the other side); Exclusiveness $(E_{T_1} + E_{T_2})/H_T > 0.9$; Kinematics requirement $(\eta_1 + \eta_2) \times \eta_{220} > 0$ (requires modif of L1 ATLAS trigger)
- L1 rate <1 kHz for $L < 3.10^{33}$cm^{-2} s^{-1}
- Level 2: 420 m info and timing info: rates of a couple of Hz



Conclusion

- Diffraction at HERA: QCD fits allowing to determine the gluon and quark components of the pomeron
- Diffraction at Tevatron/LHC: need survival probability, measurement to be done at LHC
- Exclusive events: many indications at Tevatron, especially in dijet channel
- Exclusive events at LHC: diffractive Higgs production, almost all kinematical plane covered with 30 fb^{-1}
- Photon anomalous coupling studies: high sensitivity
- AFP project: movable beam pipes needed at 220/420 m, 3D Silicon for position measurement (ξ), timing detectors
- Timescale: LOI presented in ATLAS in September, ATLAS answer in February, TDR submission to ATLAS/LHCC by the end of 2009
- Brian Cox and Christophe Royon are coordinating the work on the LOI and TDR to be submitted to ATLAS
- Many devolopments performed/in progress for the project and extremly useful for the future in particle physics or medical applications: 3D Si, timing detectors