AFP – ATLAS Forward Physics project

Marek Taševský (Inst. of Physics Prague)

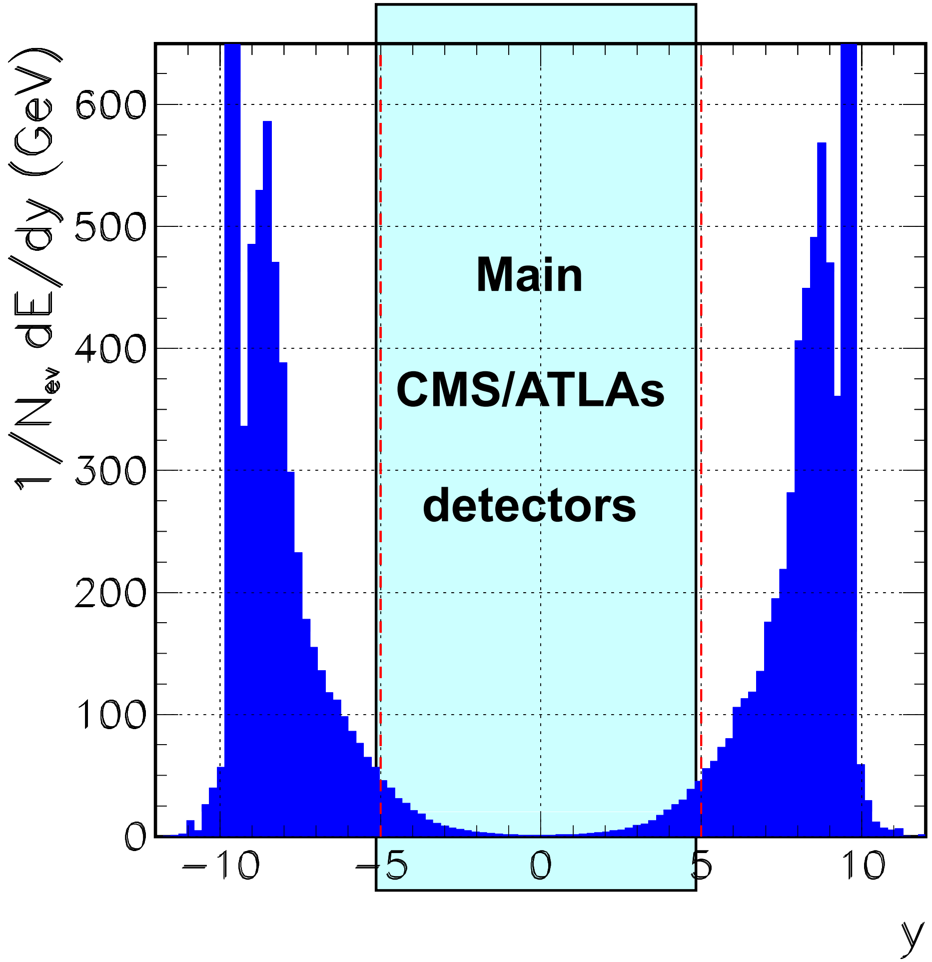
Low x workshop - Kolimbari, Crete 09/07 2008

Forward and diffraction physics

FP420 project

RP220 project

Energy flow and acceptance



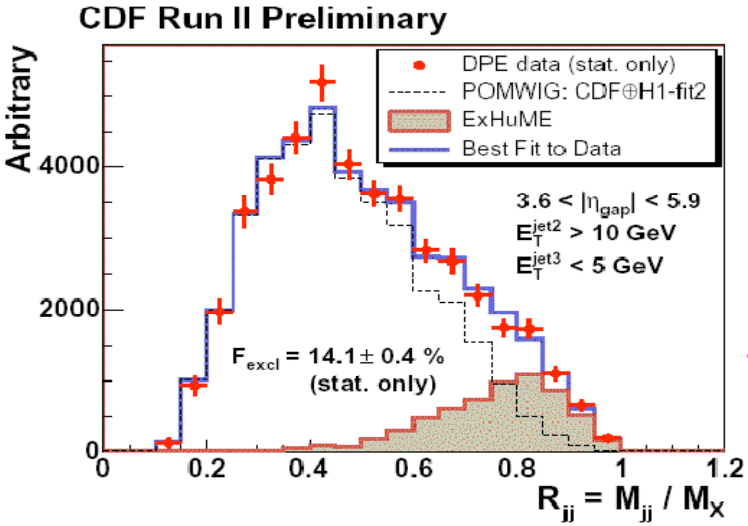
Energy flows forwards and undetected by central calorimeters

Lots of interesting physics would remain undiscovered

Equip the forward region by detectors

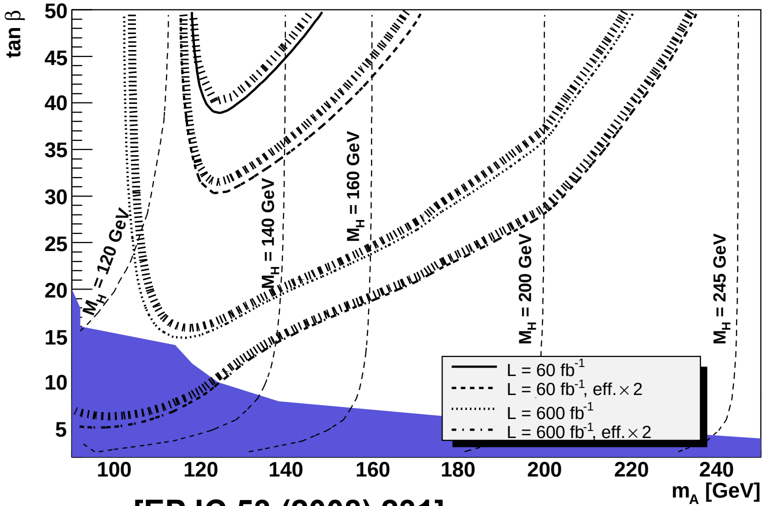
Physics program with proton taggers

Diffraction



Evidence for CEP?

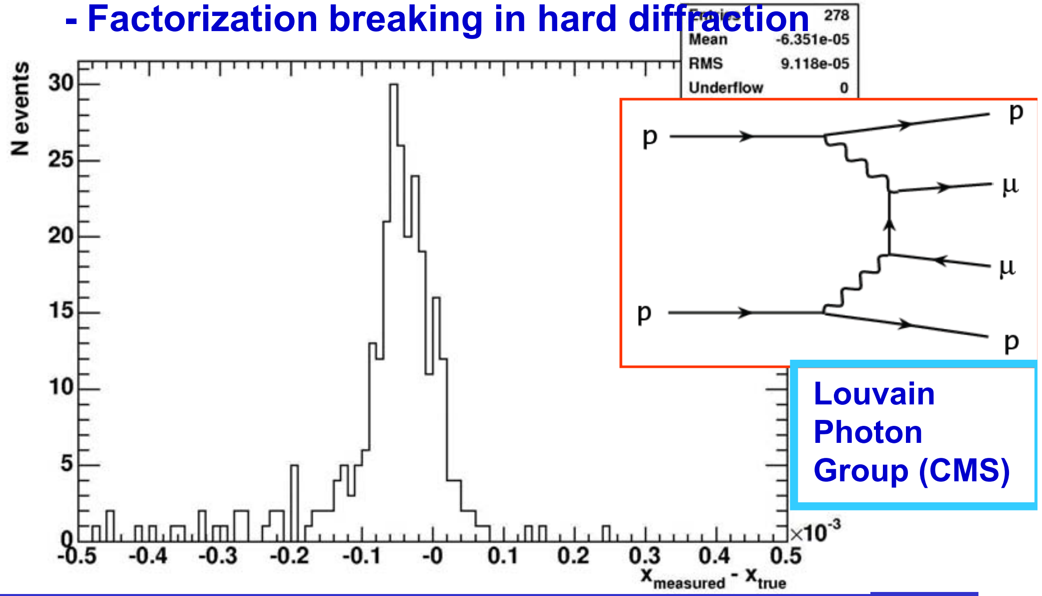
5σ-contours, H→bb, mhmax, μ=200GeV



[EPJC 53 (2008) 231]

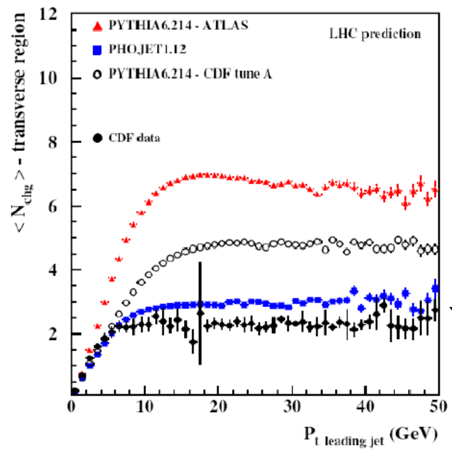
Two-photon interactions

- **Absolute lumi calibration, calibration of FPS**
- **Factorization breaking in hard diffraction**



Louvain Photon Group (CMS)

Underlying event/Multiple interactions



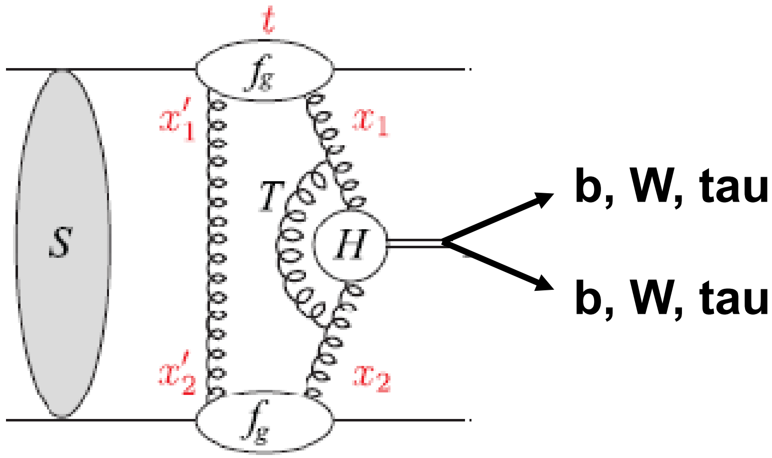
Long dist. Correl. in rap. (need to cover fwd region)

Huge differences for diff. generators and diff. tunes

Average mult. transv. to leading jet at LHC

[C.Buttar et al., HERA-LHC proc.]

Central Exclusive Diffraction: Higgs production



1) Protons remain undestroyed and can be detected in forward detectors

2) Rapidity gaps between leading protons and Higgs decay products

Advantages:

I) Roman Pots give much better mass resolution than central detector

II) J_Z = 0, CP-even selection rule:

- strong suppression of QCD bg
- produced central system is 0^{++}

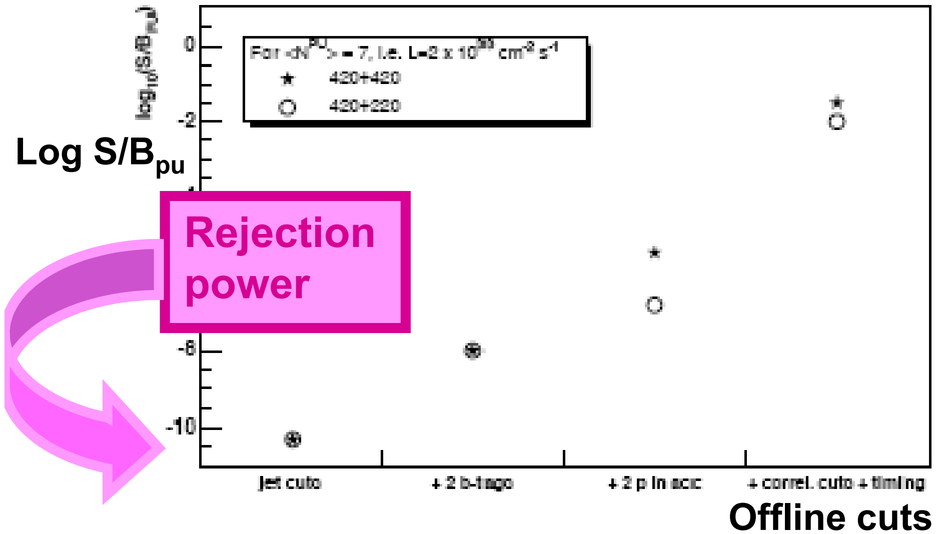
III) Access to main Higgs decay modes: bb, WW, tautau → information about Yukawa coupling

Disadvantages: Large Pile-up + Irreducible BG, Low signal x-section

SM Higgs discovery challenging: low signal yield ⟶ try MSSM

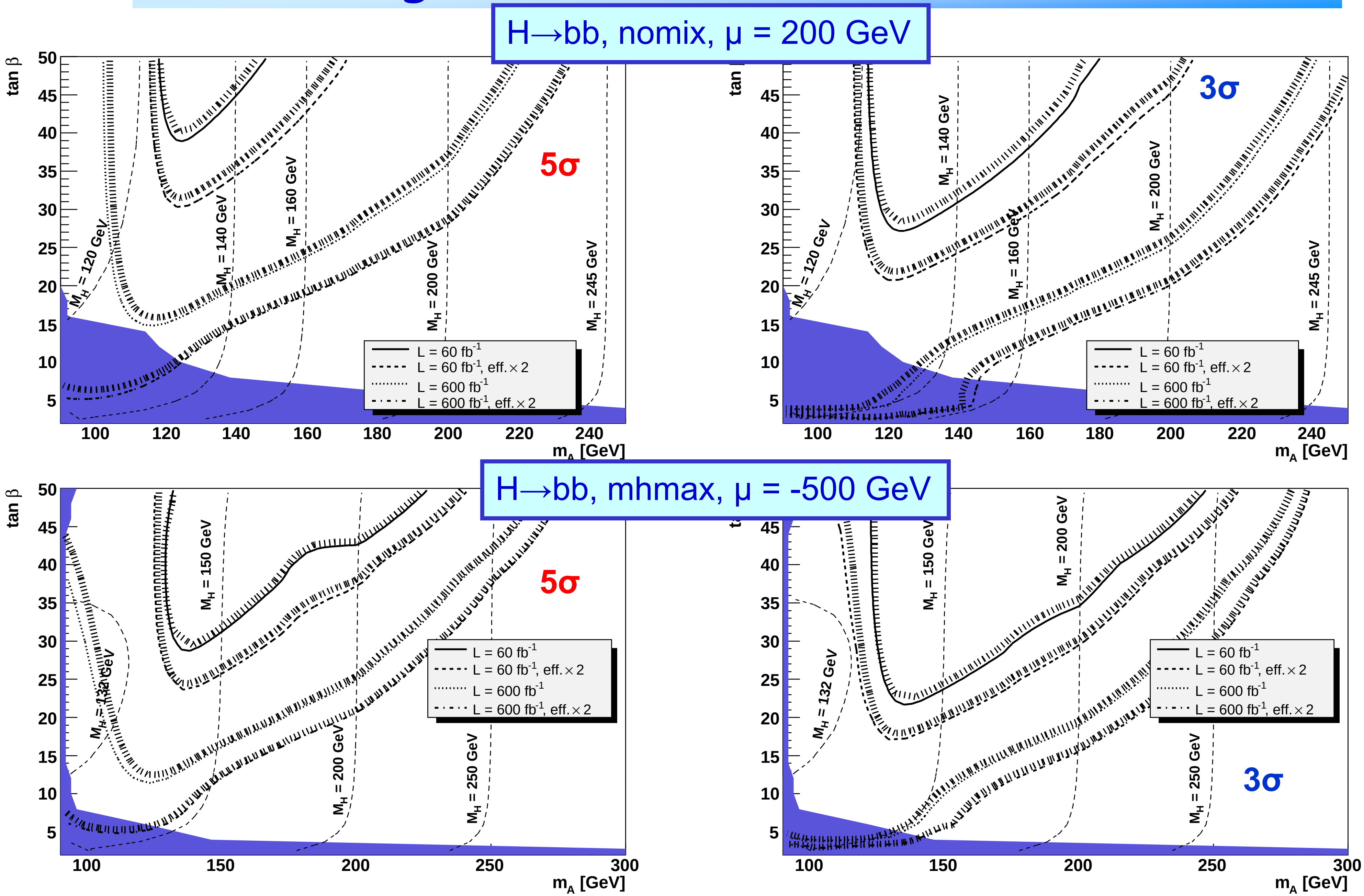
Pile-up is issue for Diffraction at LHC!

[CMS-Totem : Prospects for Diffractive and Fwd physics at LHC]

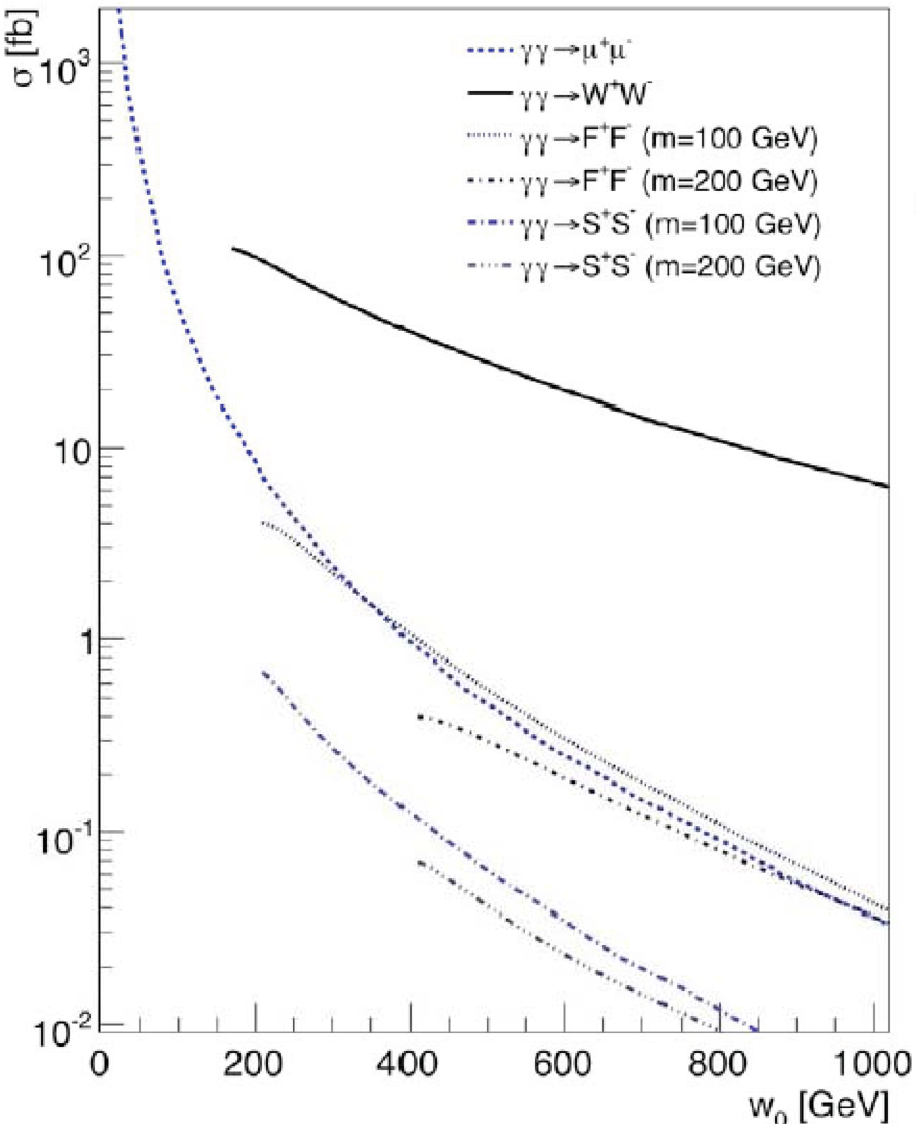


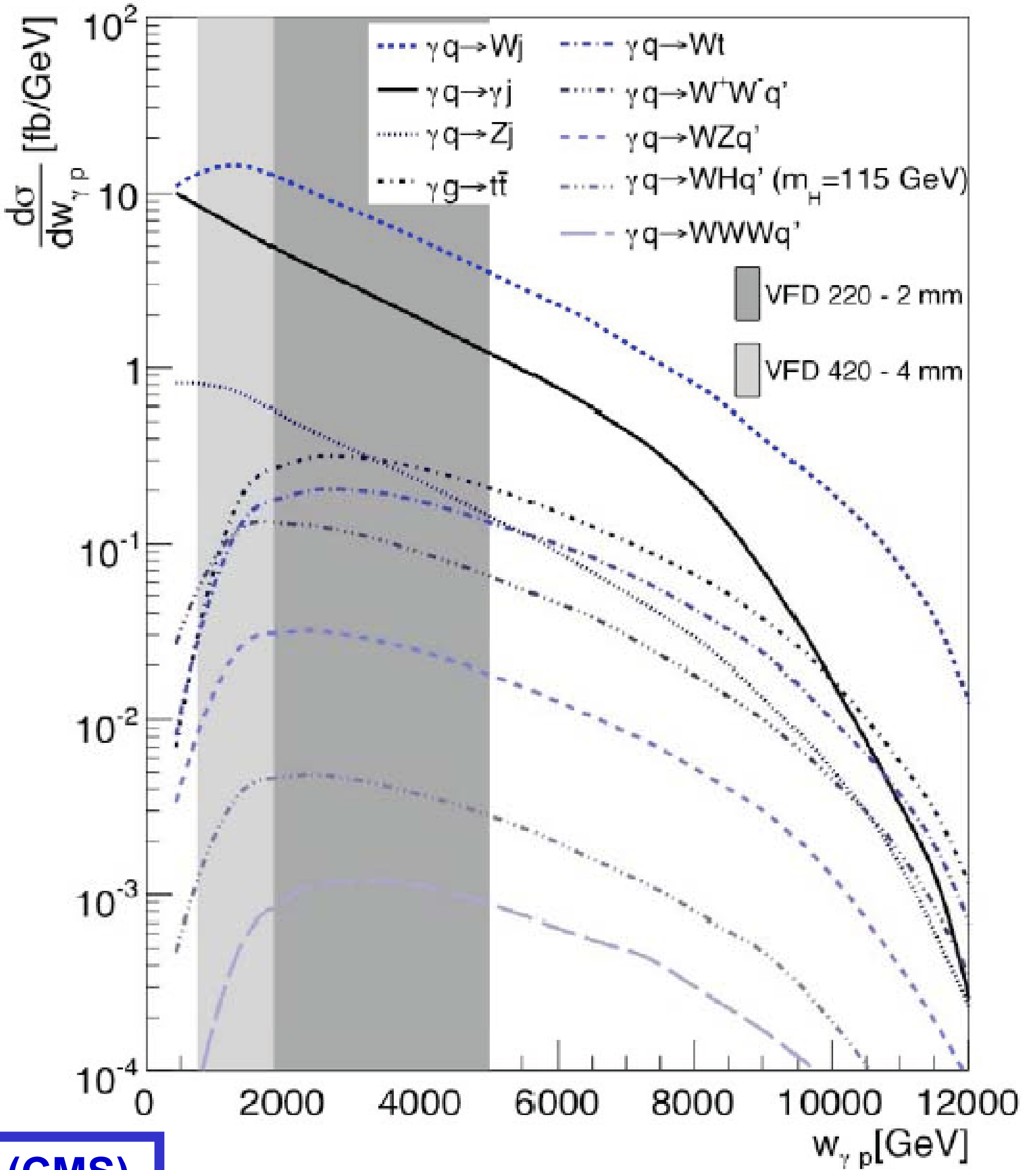
But can be kept under control !

Stat. significance for H→bb: from 5 to 3



Rich γγ and γp physics via forward proton tagging

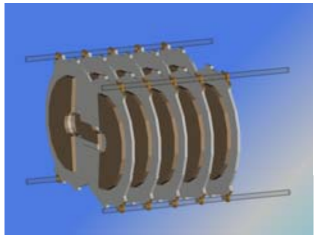


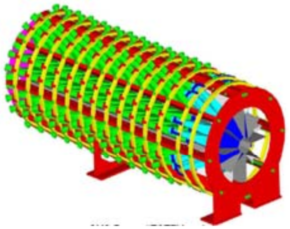


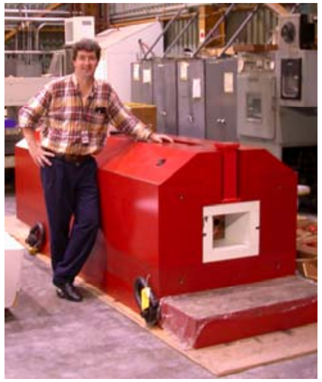
Louvain Photon Group (CMS)

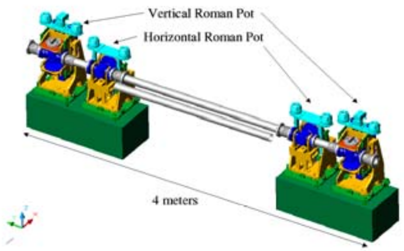
Forward detectors at LHC

TOTEM -T2 CASTOR ZDC/FwdCal TOTEM-RP FP420







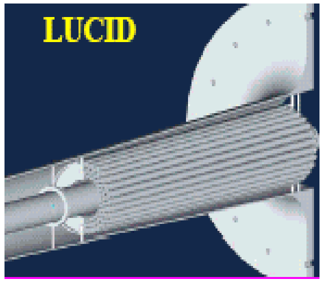


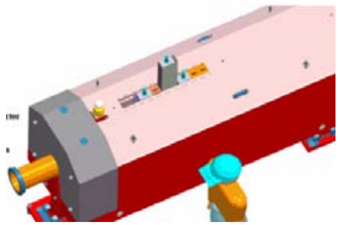
IP5

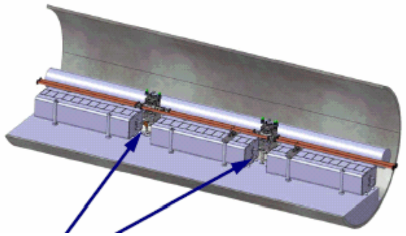
14 m 16 m 140 m 147m - 220 m

420 m

IP1



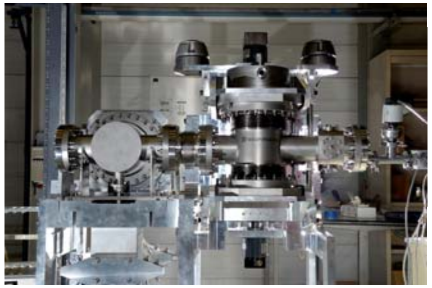




LUCID ZDC ALFA/RP220 FP420

Proton taggers for high luminosity

TOTEM-RP FP420



IP5

14 m 16 m 140 m 147m - 220 m

420 m

IP1

RP220

FP420

MANCHESTER 1824

The University of Manchester

FP420 R&D Collaboration

- Spokes : Brian Cox (Manchester, ATLAS) and Albert DeRoeck (CERN,CMS)
- Technical Co-ordinator : Cinzia DaVia (Manchester)

Collaboration : FNAL, The University of Manchester, University of Eastern Piedmont, Novara and INFN-Turin, The Cockcroft Institute, University of Antwerpen, University of Texas at Arlington, The University of Glasgow, University of Calabria and INFN-Cosenza, CERN, Lawrence Livermore National Laboratory, University of Turin and INFN-Turin, University of Lund, Rutherford Appleton Laboratory, Molecular Biology Consortium, Institute for Particle Physics Phenomenology, Durham University, DESY, Helsinki Institute of Physics and University of Helsinki, UC Louvain, University of Hawaii, LAL Orsay, University of Alberta, Stony Brook University, Boston University, University of Nebraska, Institute of Physics, Academy of Sciences of the Czech Republic, Brookhaven National Laboratory, University College London, Cambridge University

R&D phase has just ended. R&D report published, hep-ex/0806.0302

Roman pot upgrade at 220m with additional horizontal pots

France : Saclay, Paris 6

Czech Republic : Prague

US : Stony Brook

Poland : Cracow

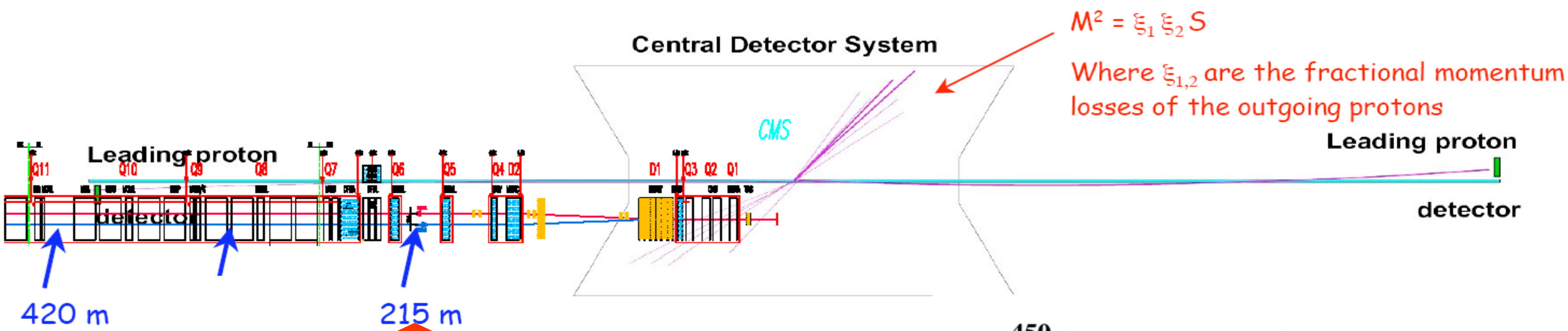
Germany : Giessen

Michigan State Univ.

Univ. of Chicago, Argonne (timing det.)

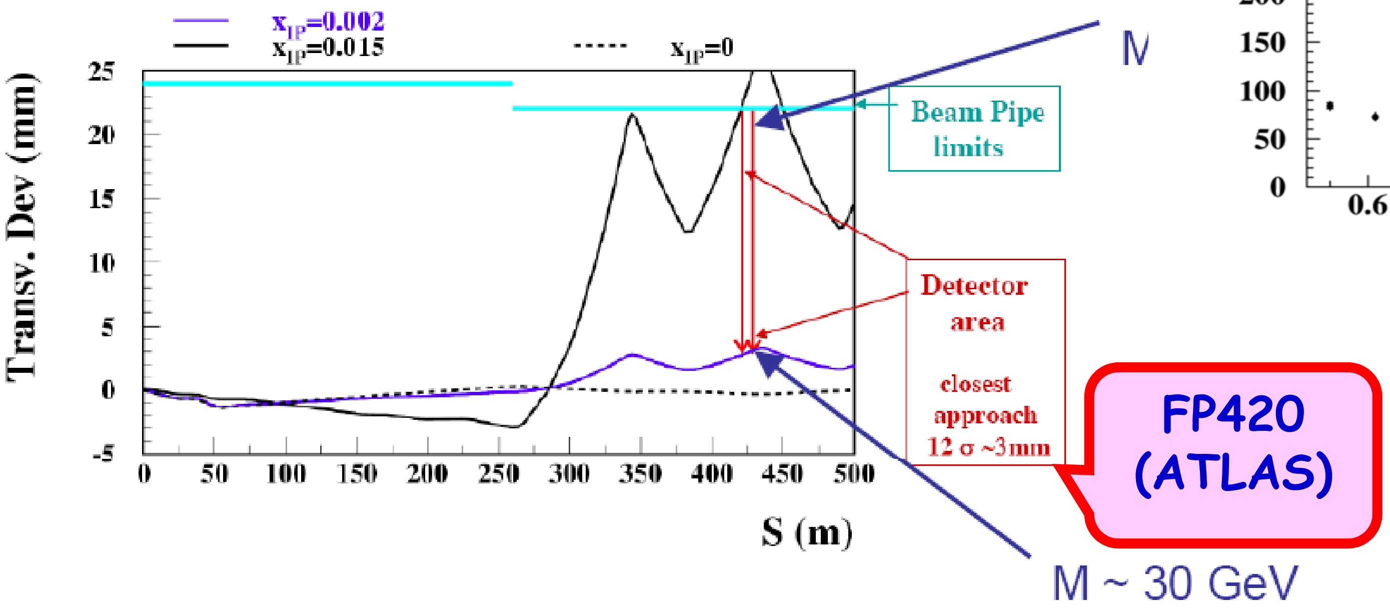
FP420 and RP220 ATLAS projects have merged into the AFP project. The LoI has just been produced.

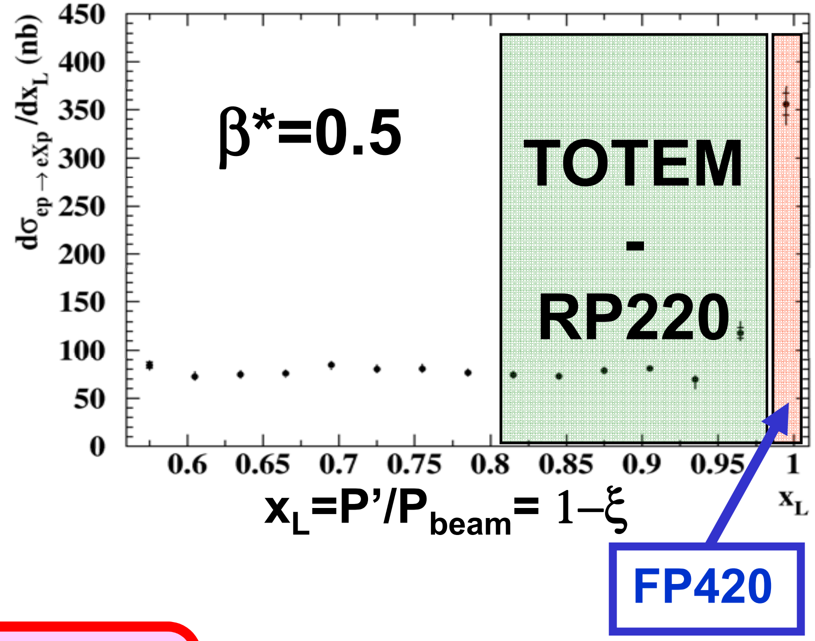
How to measure the protons



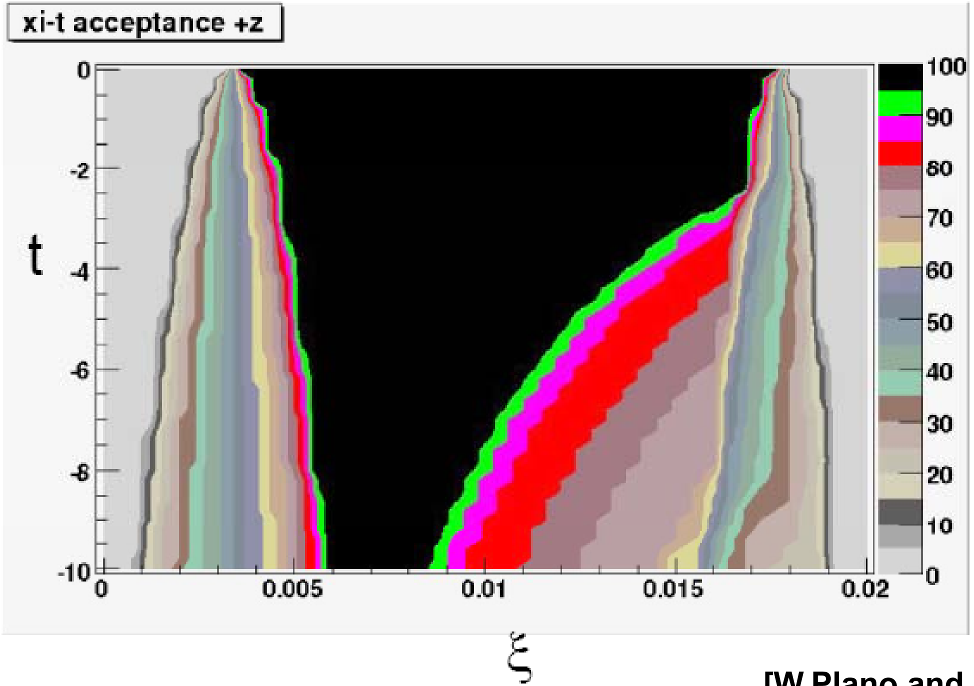
FP420

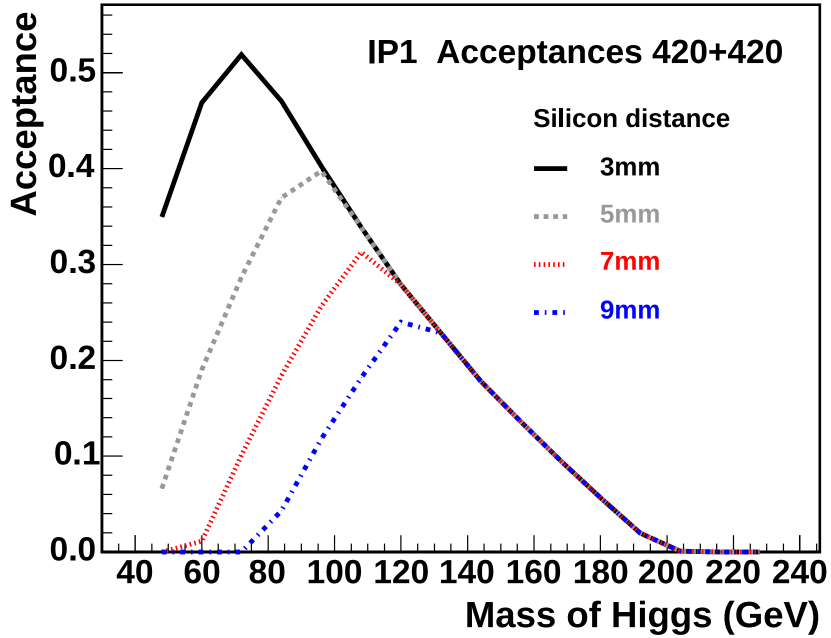
TOTEM on CMS side
RP220 on ATLAS side



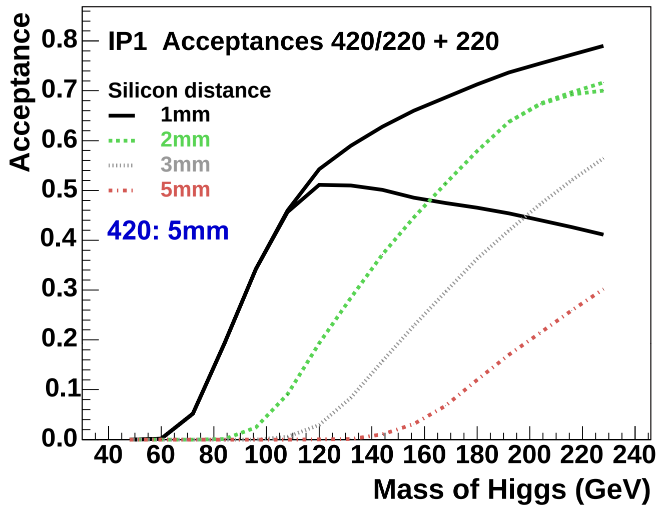


Acceptance for RP220 and FP420 at ATLAS

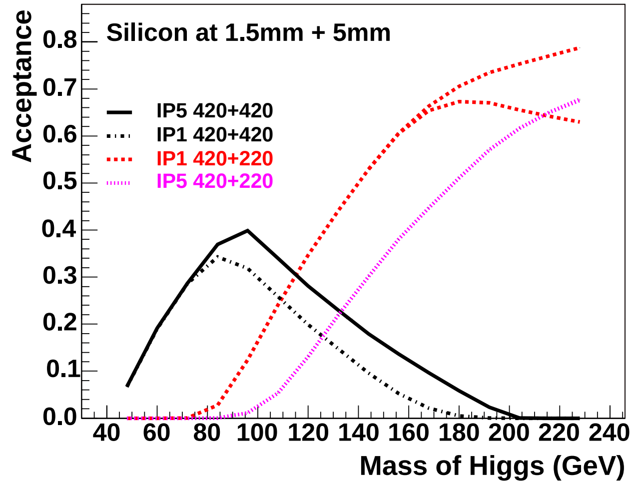




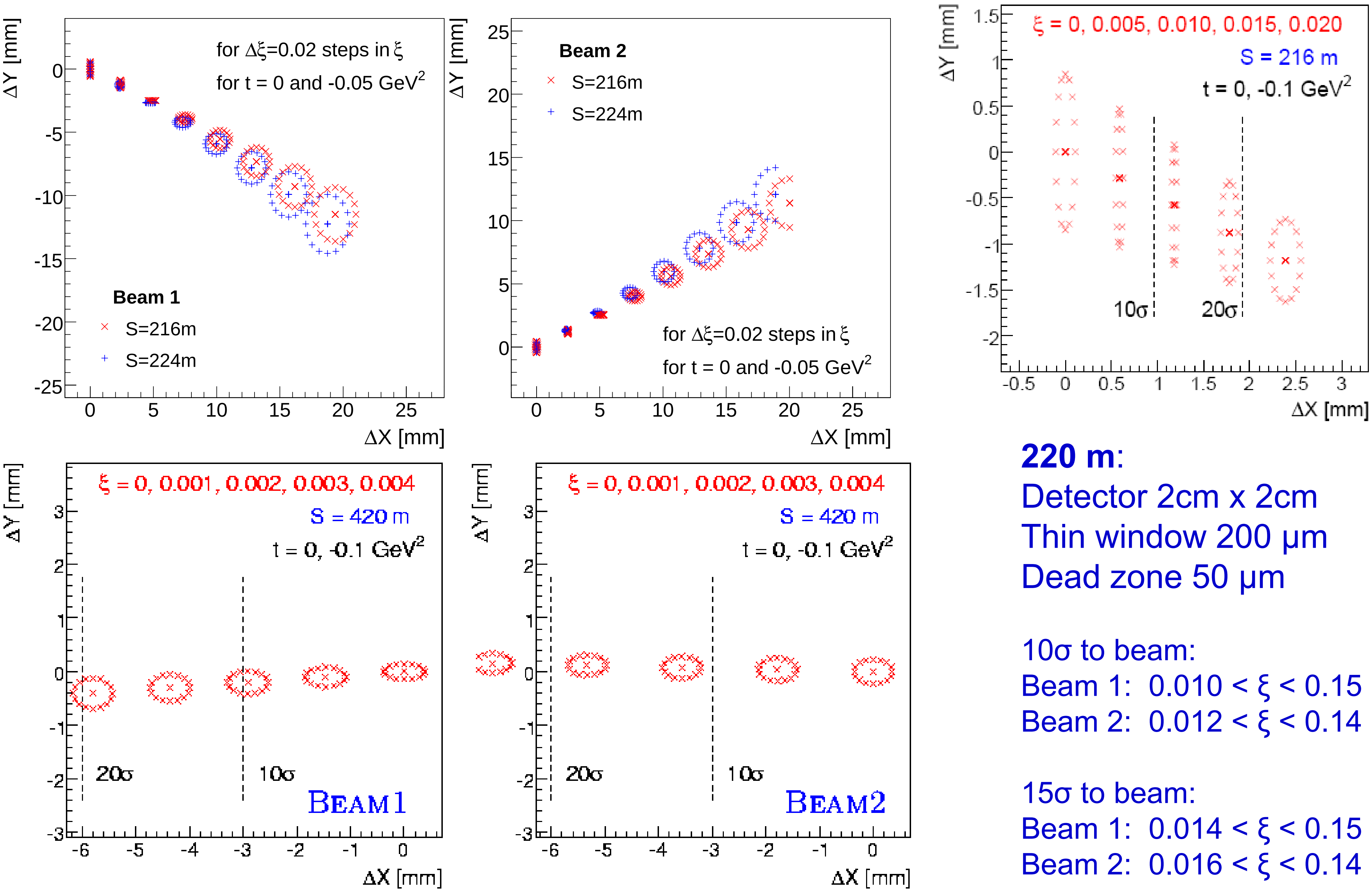
[W.Plano and P.Bussey, FP420 TDR]



420+420 acceptance vanishes at 180 GeV. By adding the 220 system, we increase acceptance and reach higher central masses



Acceptances at 220m and 420m at ATLAS

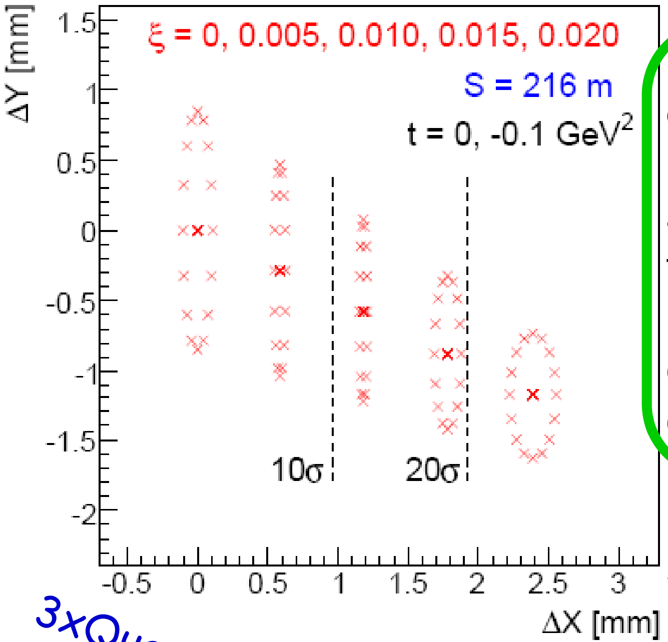


220 m:
Detector 2cm x 2cm
Thin window 200 μm
Dead zone 50 μm

10σ to beam:
Beam 1: $0.010 < \xi < 0.15$
Beam 2: $0.012 < \xi < 0.14$

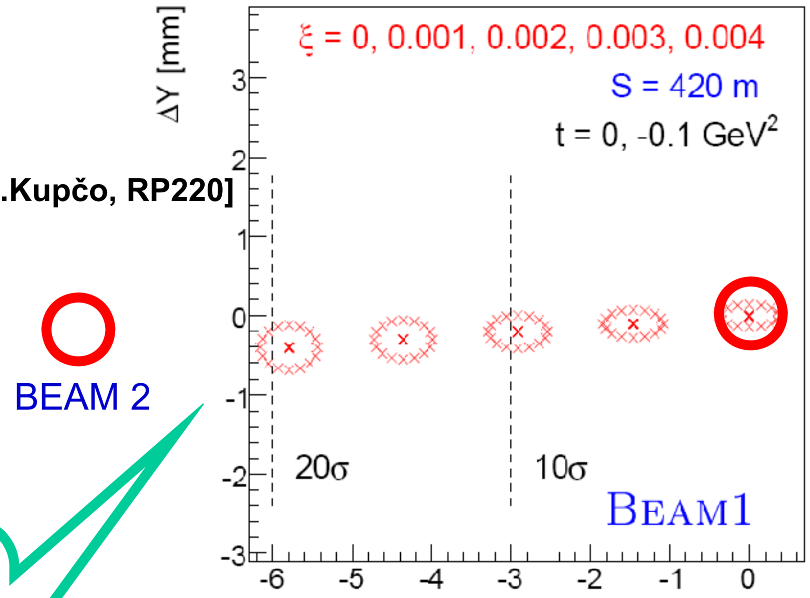
15σ to beam:
Beam 1: $0.014 < \xi < 0.15$
Beam 2: $0.016 < \xi < 0.14$

Integration into LHC structure

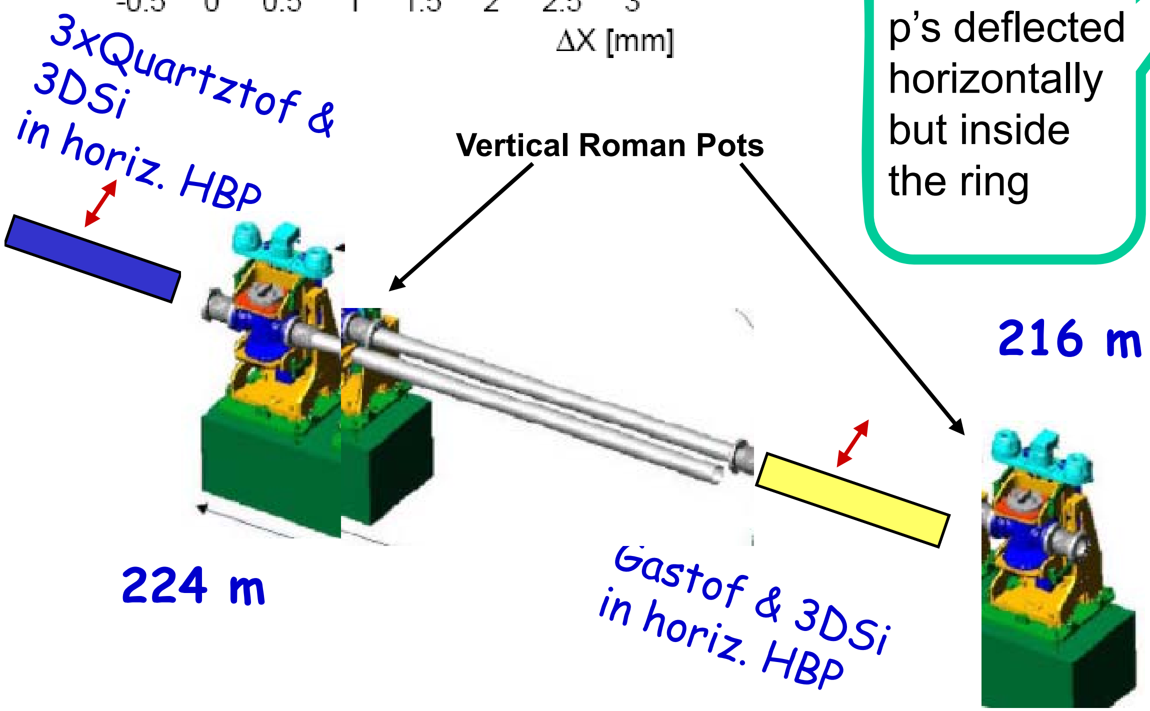


Diffraction protons deflected horizontally and away from the ring
Only horizontal detectors from outside needed!

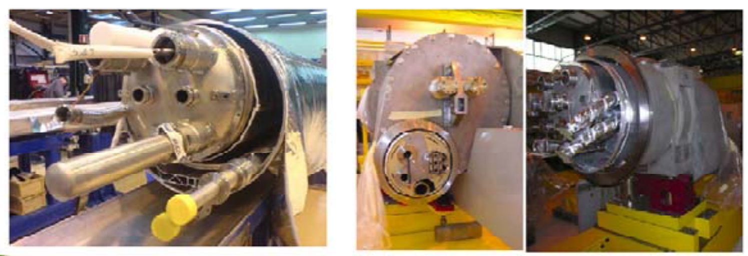
[A.Kupčo, RP220]

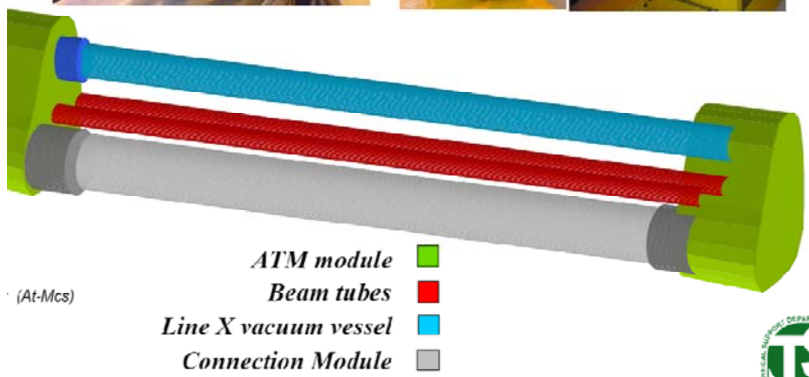


Diffraction p's deflected horizontally but inside the ring



FP420 Connection Cryostat

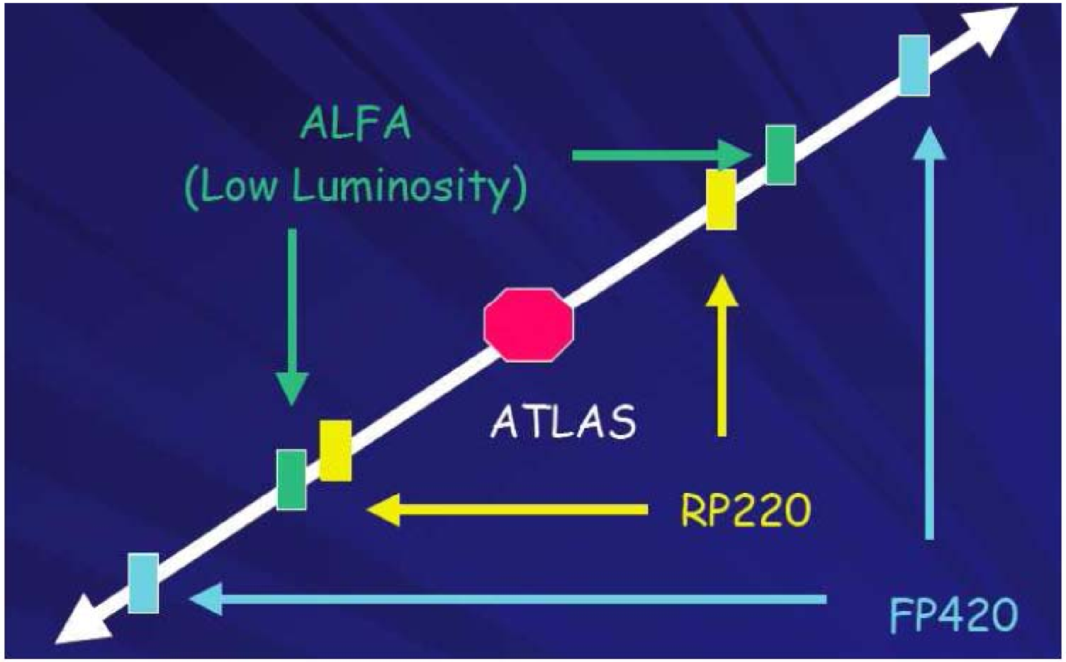




Detector location and placement

220 m: Position and timing detectors in horizontally moving beam pipe and Vertical Roman Pots for alignment and calibration of position detectors in horizontal movable beam pipe, http://cern.ch/projects-rp220

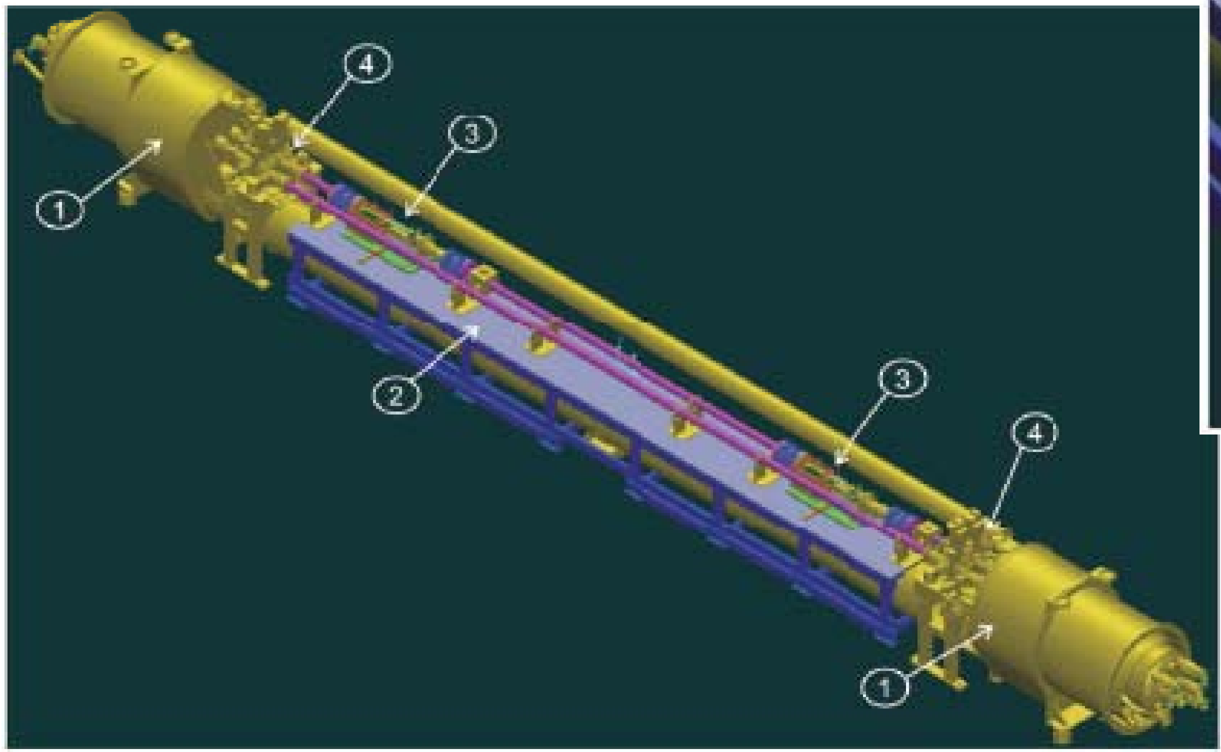
420 m: Position and timing detectors in horizontally moving beam pipe placed in a new connection cryostat.
R&D phase just ended with a complete cryostat design and a prototyped, tested concept for high precision and high radiation resistive detectors.
R&D report: hep-ex/0806.0302, http://www.fp420.com

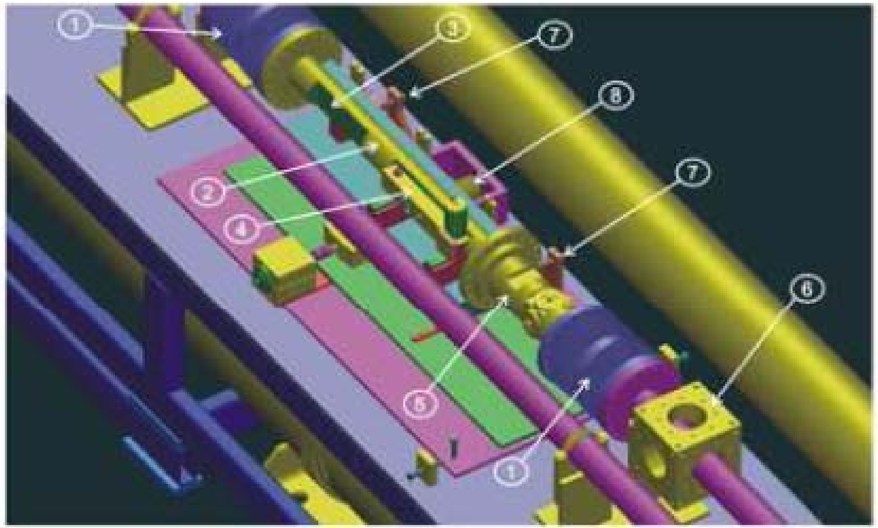


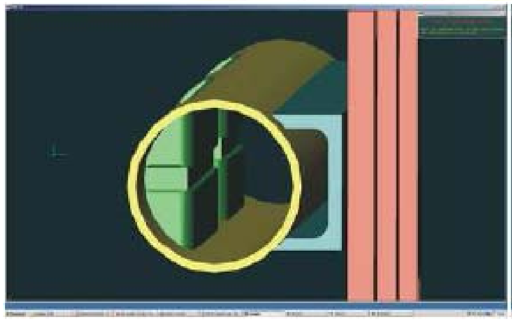
Movable beam pipes at 220 and 420 m

- Movable beam pipe (Hamburg beam pipe) technique used to move the detectors to and from the beam – in horizontal direction.
- First used at PETRA collider, then proven to be viable at ZEUS (for e-tagger)
- Takes less space than Roman Pots
- It will host position as well as timing detectors at 220 and 420 m.

Current design for the 420 m region:







Position detectors

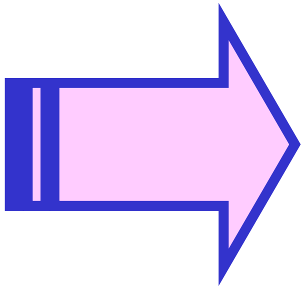
The same requirements for 220 and 420 m regions:

Close to the beam => edgeless detectors

High lumi operation => very radiation hard

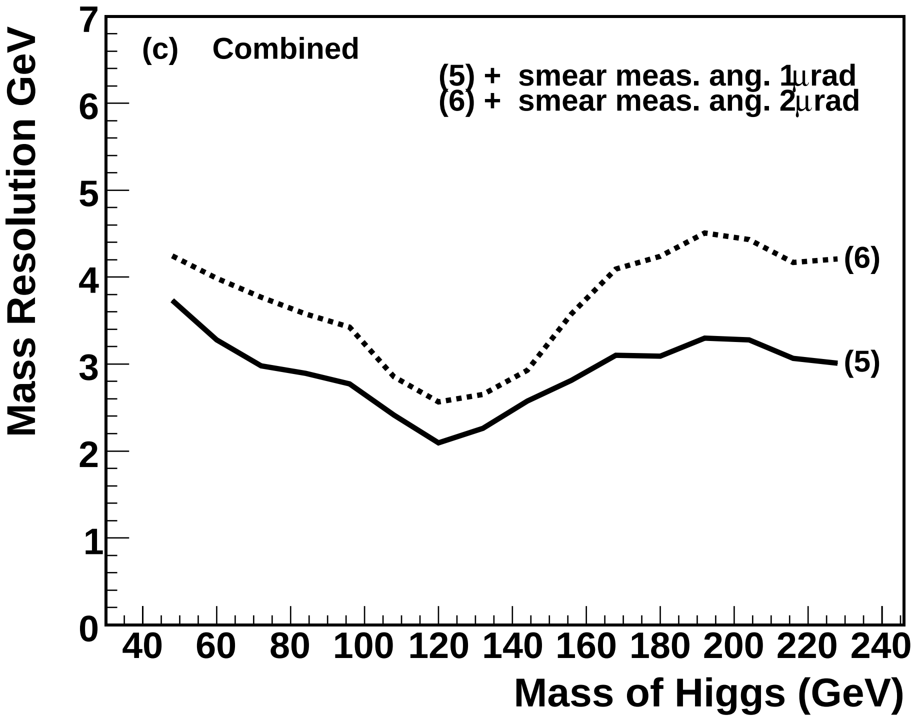
Mass resolution of 2-3% => 10-15 µm precision

Suppress pile-up => add fast timing det.



3D Silicon

ATLAS, 1.5 mm (220) and 5 mm (420) from beam

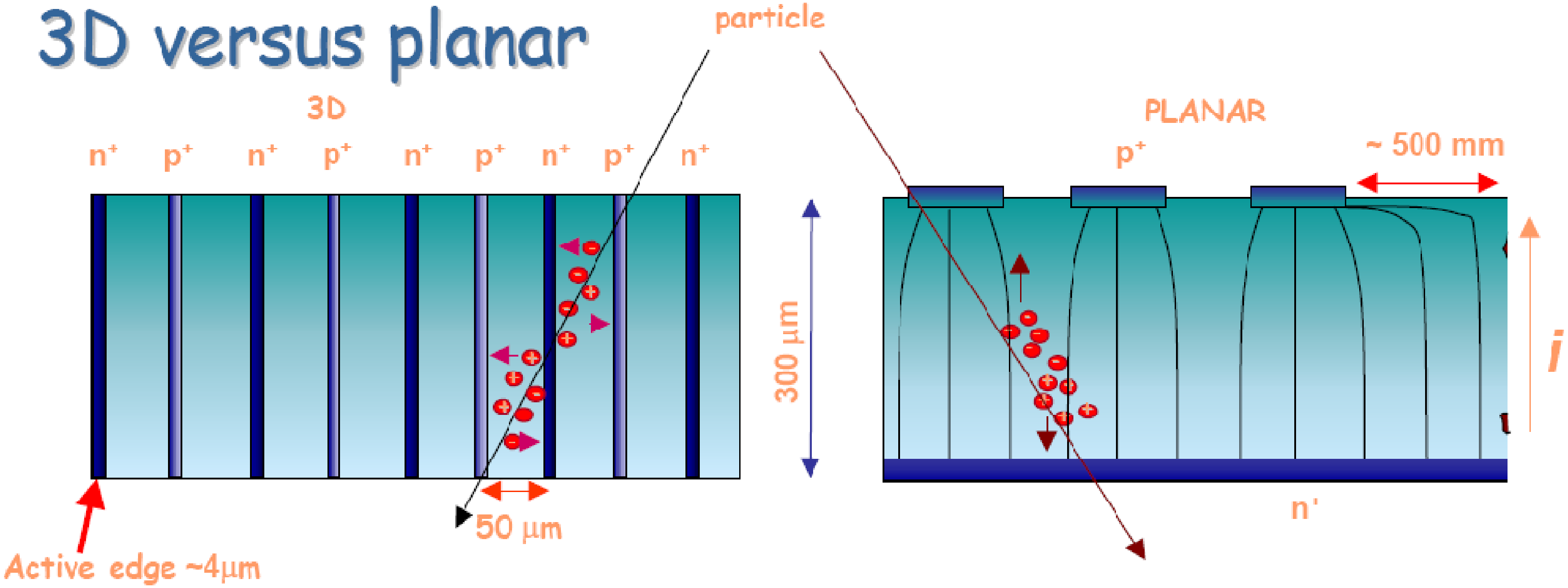


Reconstruct the central mass from from the two tagged protons (from their trajectories and incorporating experim. uncertainties):

Beam en.smearing σ_E= 0.77 GeV
Beam spot smearing $\sigma_{x,y}$ = 10 µm
Detector x-position resol. σ_x = 10µm
Detector angular resolution = 1, 2 µrad

[P.Bussey, FP420 TDR]

3D Silicon Detector Development



Manchester/Stanford/MBC

3DC Collaboration

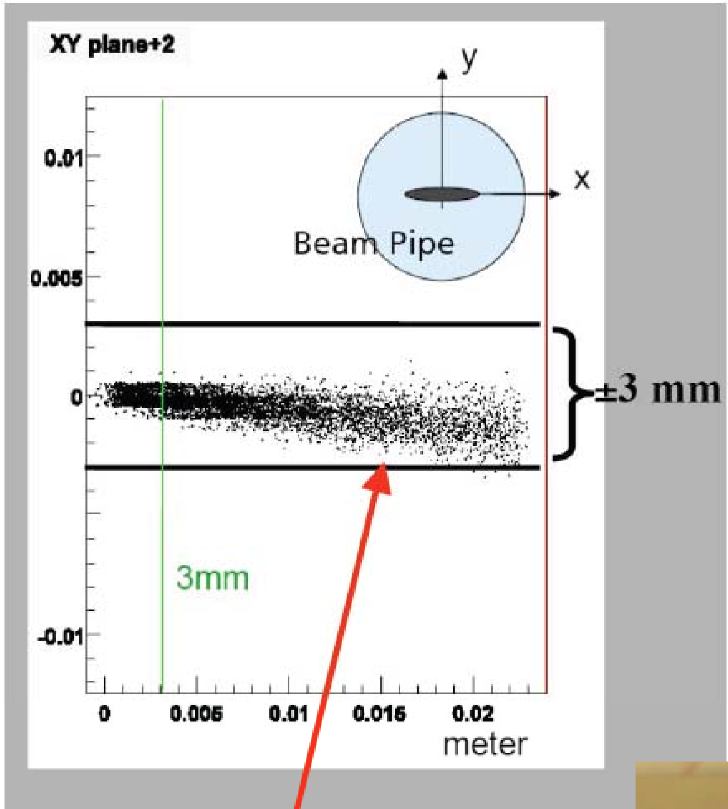
Transfer to Industry in progress – SINTEF

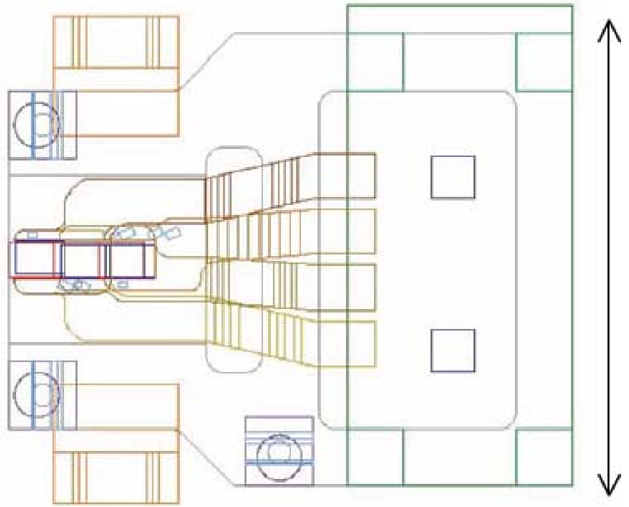
Also support from Bonn/LBL/Prague

Note: 3D ATLAS R&D Collaboration forming

	3D	planar
V_{dep}	< 5-10 V	50-70 V
Q_{1mip}	24000e-	24000e-
C	40-80fF	50-200fF

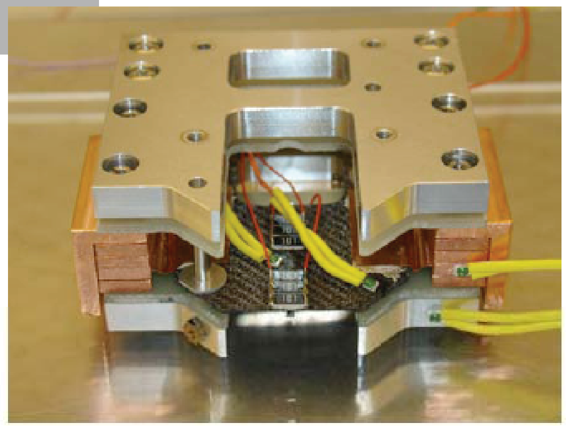
FP420 Silicon Detector Stations

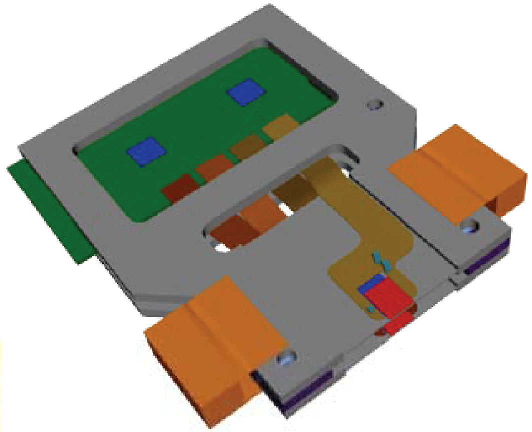




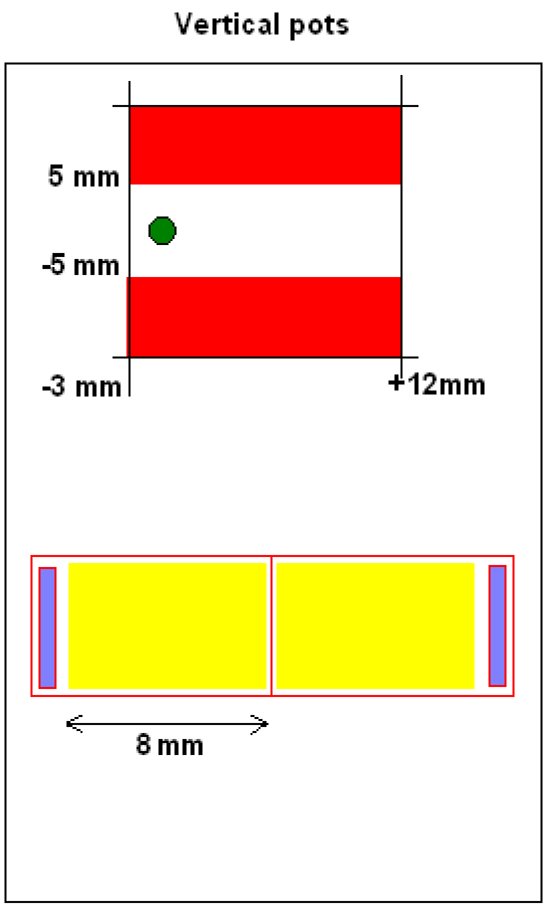
7.2 mm x 24mm (7.2 x 8 mm² sensors)

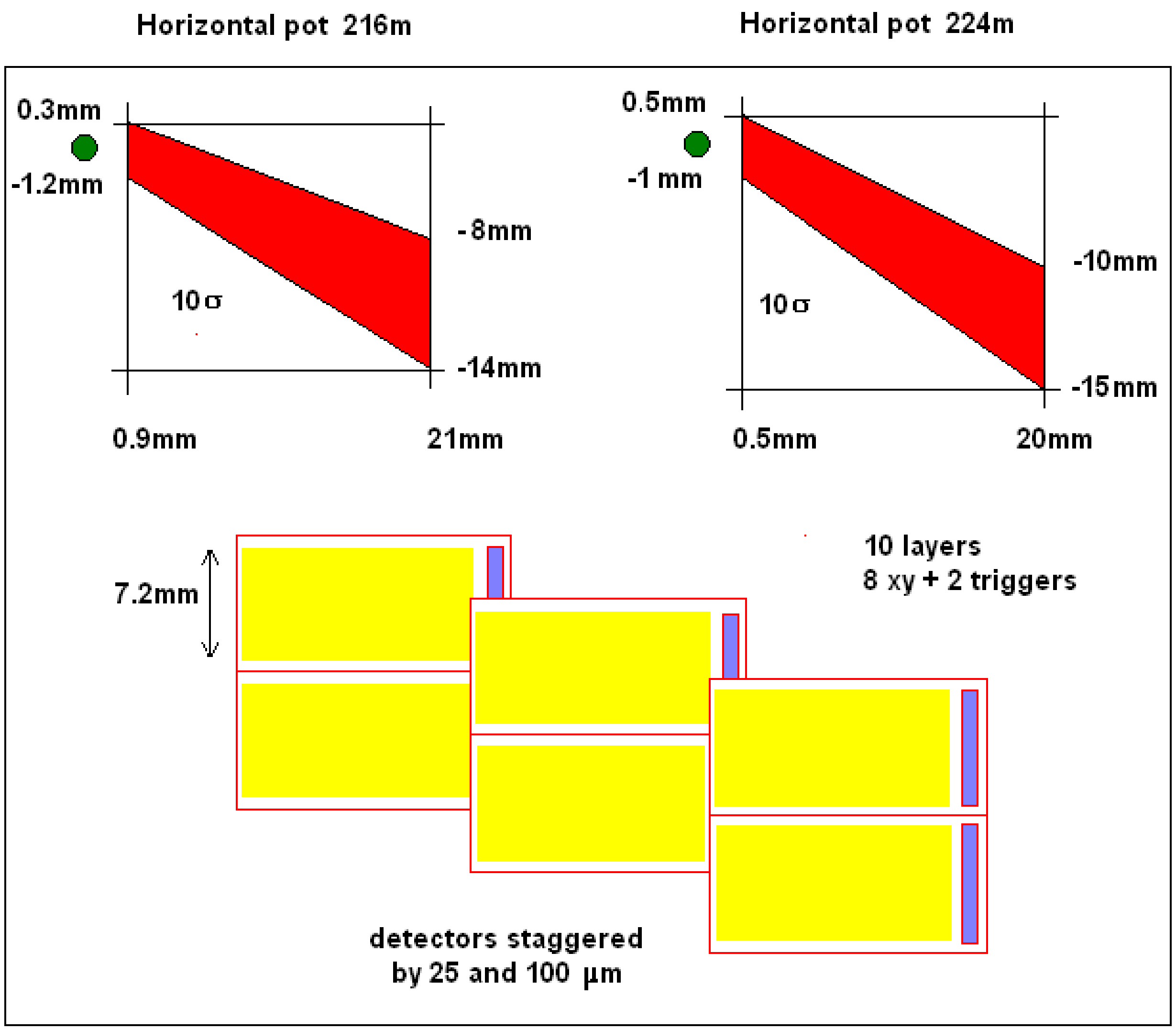
FP420 Mask





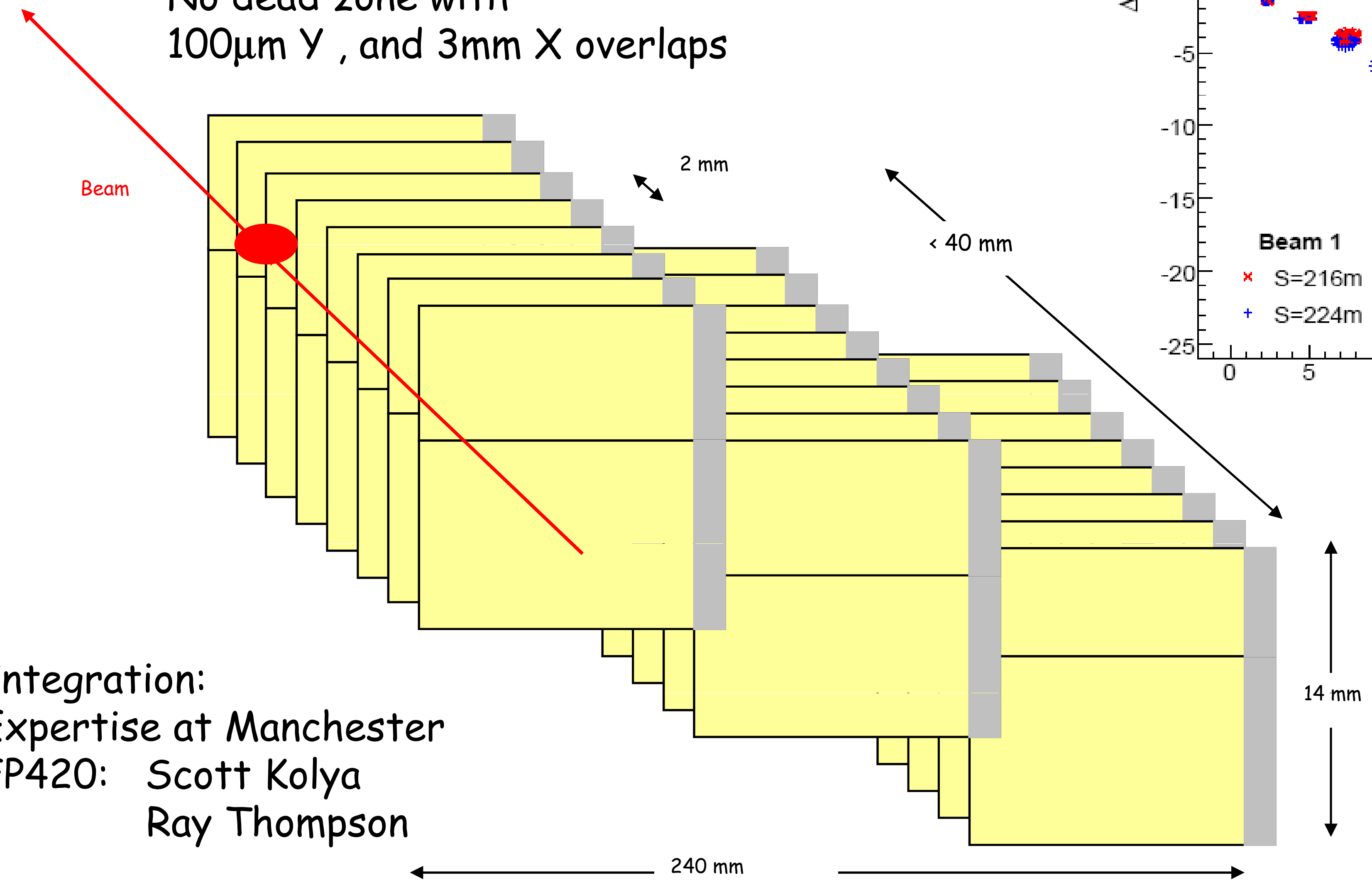
3D Si detector layout for 220 m region

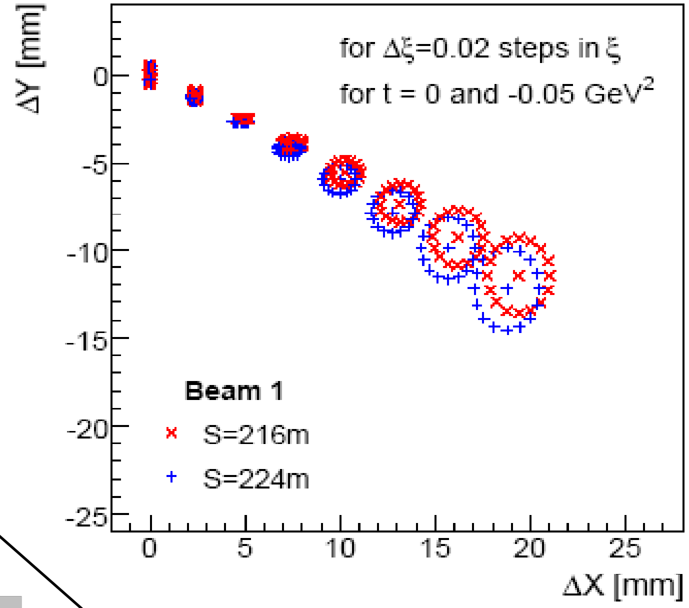




3D Si detectors in horizontal section at 220 m

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



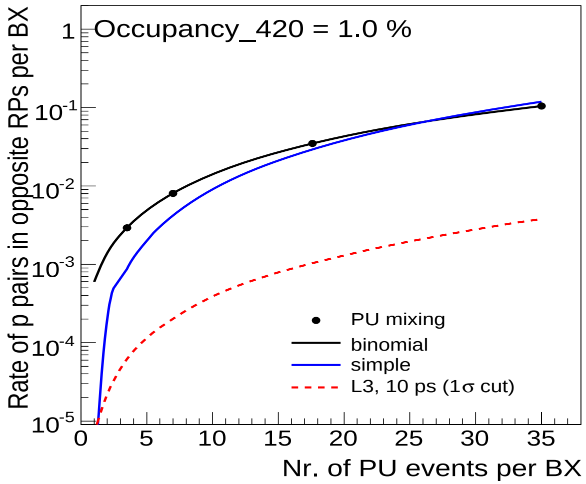


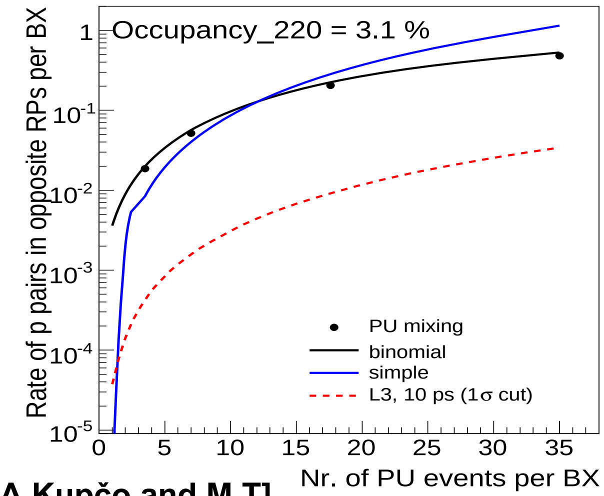
Integration:
Expertise at Manchester
FP420: Scott Kolya
Ray Thompson

Fast timing detectors

Diffraction makes up 20-30% of σ_{TOT}: diffractive p's from pile-up fake signal diffr. p's

Example of H->bb: overlay of 3 events (2 SD + non-diffr. dijets) fakes signal perfectly and with prob. 10^{10} x higher than signal. Can be reduced by fast timing det.



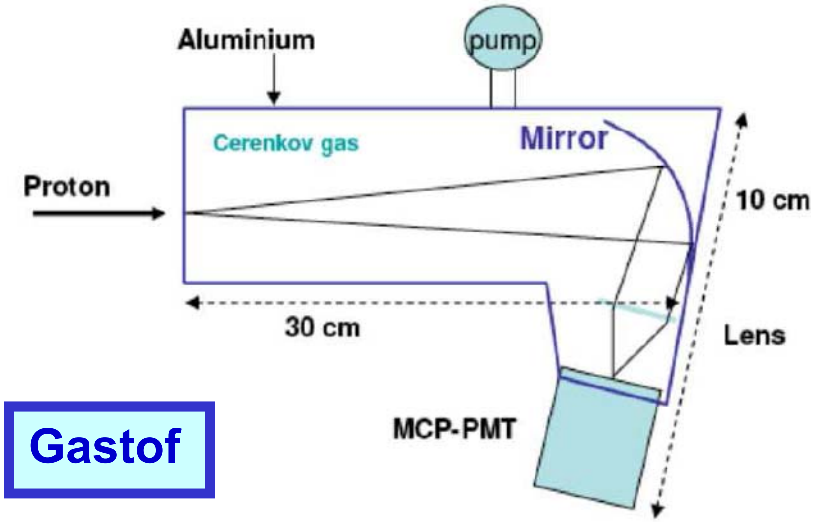


[A.Kupčo and M.T]

10ps (2-3mm) resol. may separate different vertices

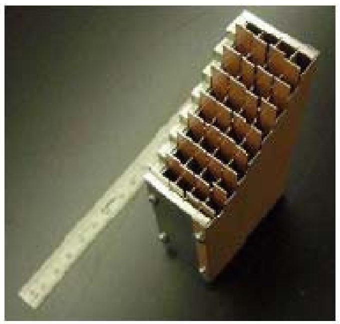
BG Rejection up to 40

UTA, Louvain, Fermilab, Saclay, Stony Brook, Chicago, Alberta, Argonne



Gastof

Quartz



Test beams indicate:
10-20 ps by Gastof
20-30 ps by Quartz

Disadvantage of Gastof: no space resol

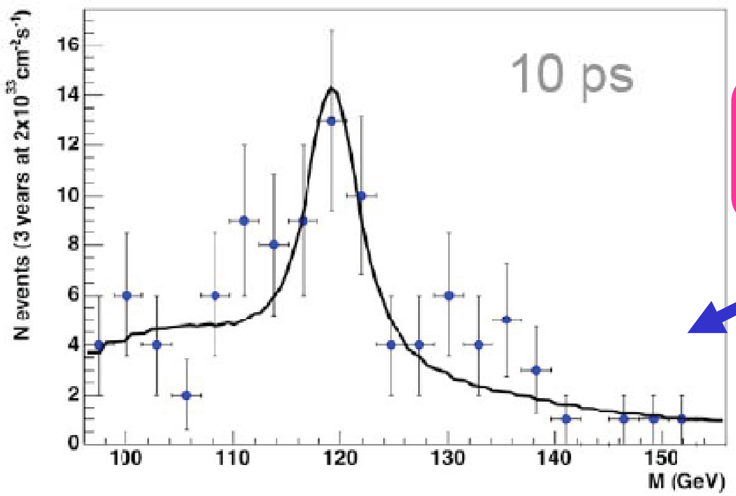
Future: 1-2 ps? Space resolution?
Combination of Gas and Quartz

Key point: yield of photoelectrons

CED H→bb using Forward Proton Tagging

h→bb, mhmax scenario, standard ATLAS L1 triggers, 420m only, 5 mm from beam

Huge Pile-up bg for diffractive processes: overlap of three events (2* SD + non-diffr. Dijets). Can be reduced by Fast Timing detectors: t-resol. required: 2 ps for high lumi!

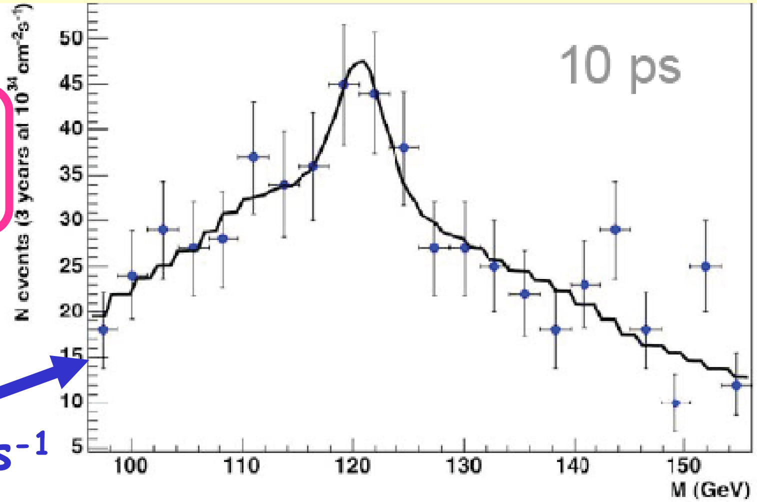


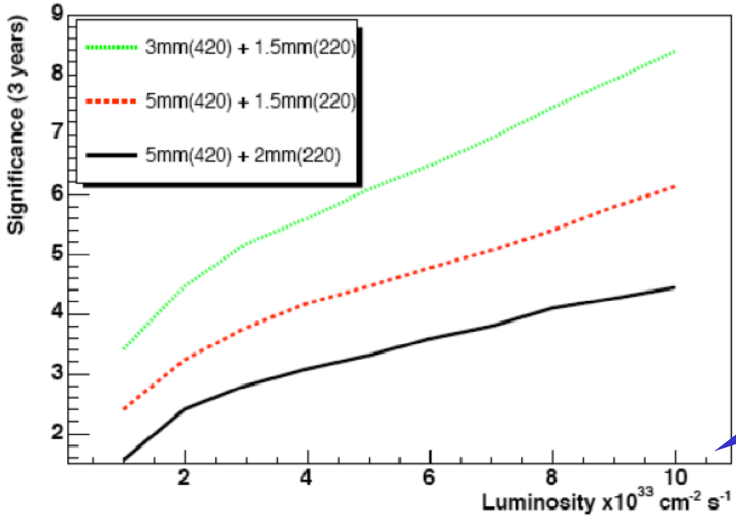
JHEP 0710:090,2007

m_A=120 GeV, tanβ=40
$\sigma_{h\rightarrow bb}$=17.9 fb

3 years at $2\times10^{33}cm^{-2}s^{-1}$

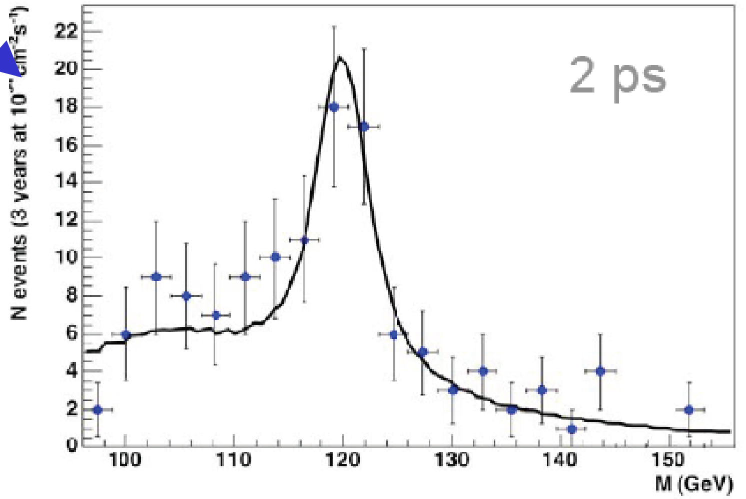
3 yrs at $10^{34}cm^{-2}s^{-1}$





Assume 220m Pots at L1

High signific. for detectors close to beams



Level 1 Trigger

FP420: cannot be put directly into L1 – only in special runs with larger L1 latency

available triggers: 2j, μ (L1 threshold for 2μ is 6 GeV), e, j+lepton

- μ-triggers can save up to 20% of bb signal
- WW signal saved by lepton triggers

Luminosity ($\times 10^{33}$)	Non-diffractive reduction by FP420 without QUARTIC	Non-diffractive reduction by FP420 with QUARTIC
1	2.7×10^{-4}	6.8×10^{-6}
3	5.8×10^{-3}	1.5×10^{-4}
5	1.8×10^{-2}	4.6×10^{-4}
10	8.1×10^{-2}	2×10^{-3}

[A.Pilkington, FP420]

RP220: Can be put into L1!

Double-sided RP220: retains events with M_h>160-200 GeV

Single-sided RP220: allows asymmetric 420+220 events

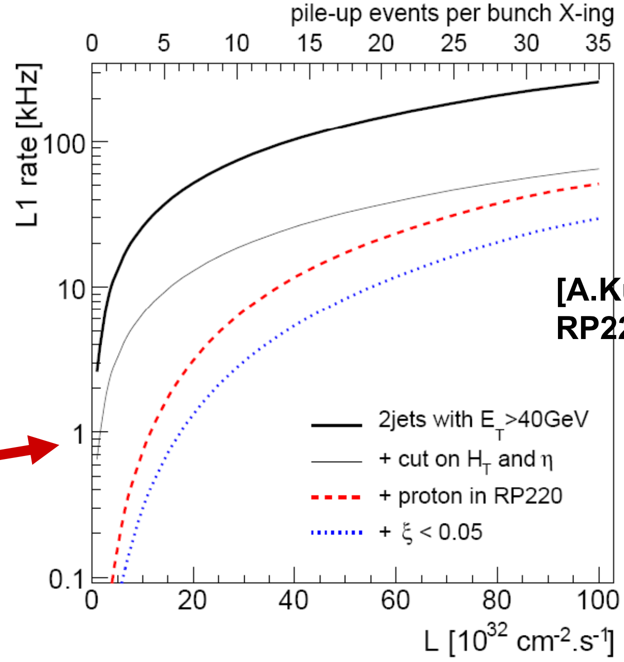
L1 trigger for CED H->bb, M_h~120 GeV:

1) Single-sided RP220 .and. 2 jets E_T>40 GeV
2) Exclusivity: $(E_{Tjet1}+E_{Tjet2})/E_{TOT} > 0.9$
3) Mom.conservation: $(\eta_{jet1}+\eta_{jet2})*\eta_{RP220} > 0$
4) $\xi_1 < 0.05$ .or. $\xi_2 < 0.05$

Output rate of this trigger ~ 1kHz up to $2*10^{33}cm^{-2}s^{-1}$

L2, L3: add info from FP420 and fast timing det.

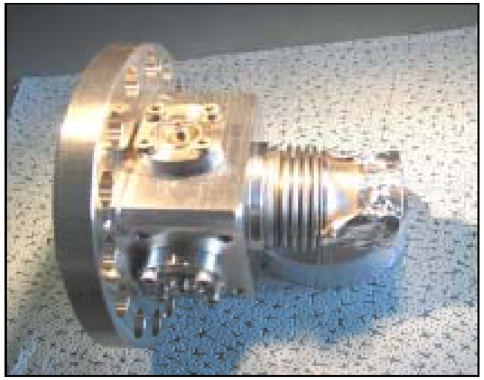
RP220 L1 trigger study



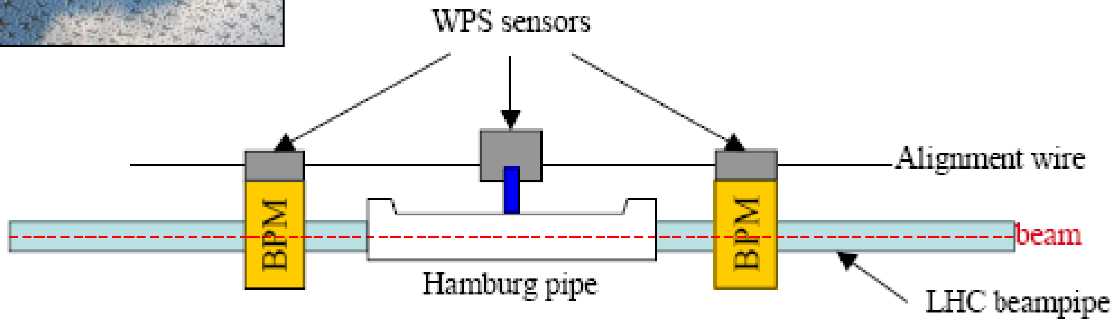
[A.Kupčo, RP220]

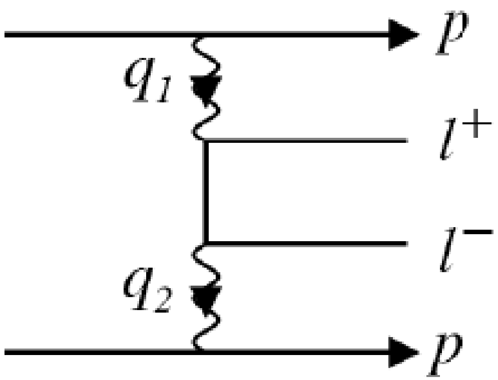
[M.Grothe et al., CMS Note 2006-054]

FP420 Alignment



CLIC BPMs + wire positioning system : aim for 10 microns relative to beam





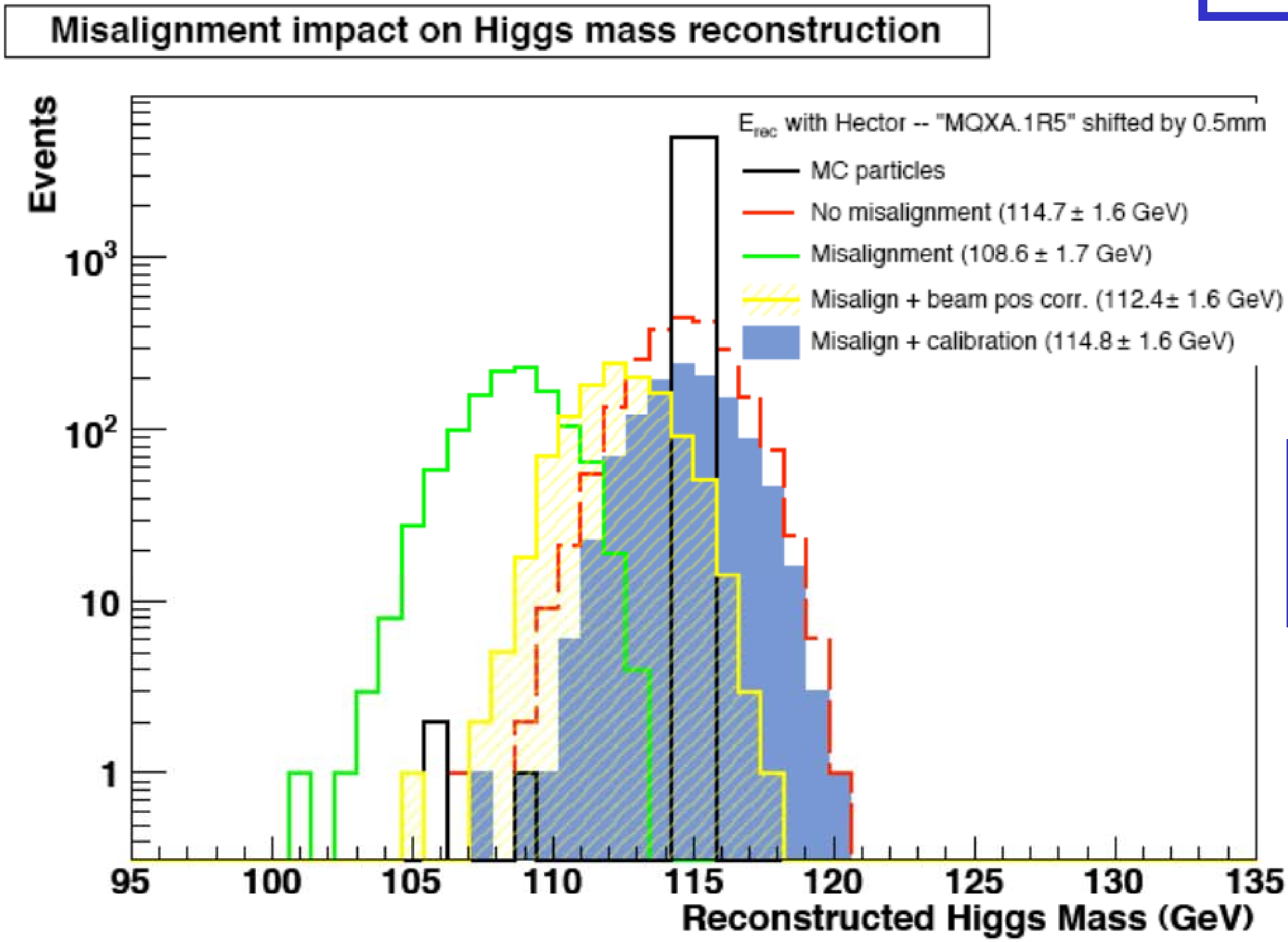
@ 10^{33} $cm^{-2}s^{-1}$ with standard ATLAS triggers, have ~ 30 di-muon events / fill in FP420 acceptance

See also P. Bussey Talk – Manchester Dec 06

Thanks to Lars Soby, Rhodri Jones, Helene Mainaud-Durand, Andreas Herty and Robert Boudot

Mass reconstruction

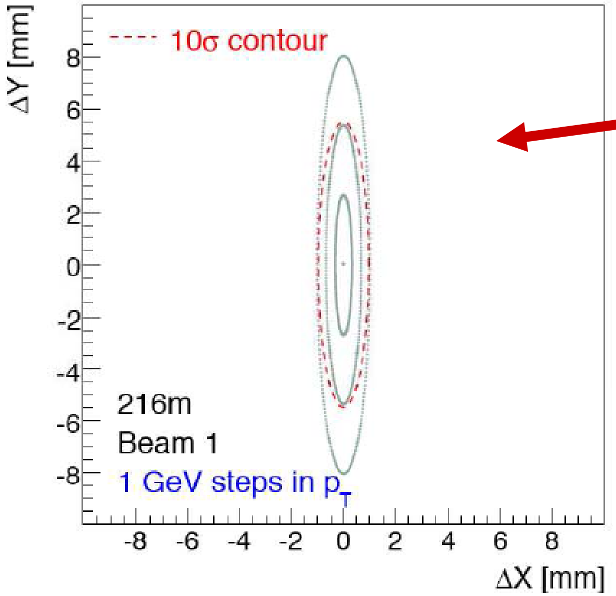
At IP5 (CMS)



Louvain Photon Group (CMS)

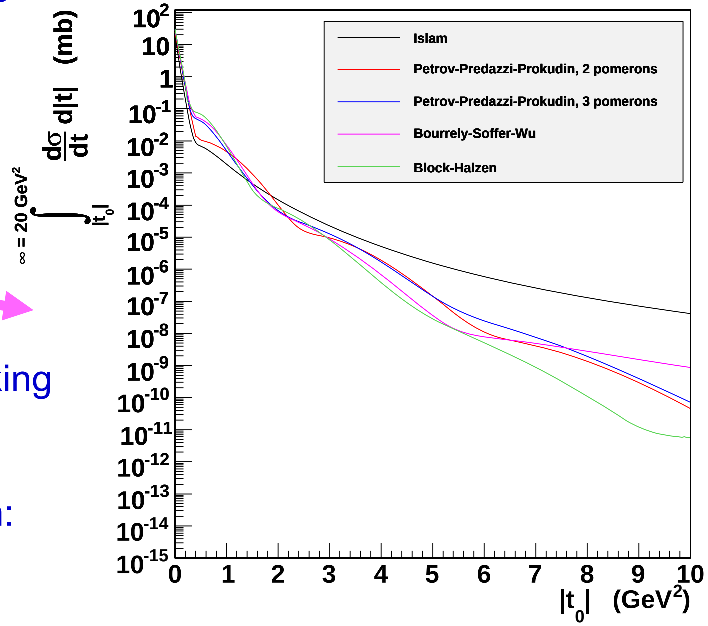
Alignment/Calibration at 220 m

Alignment/Calibration must be done store-by store. Try elastic events:



Accept. starts at: p_T=3 GeV in horiz. dir.
p_T=2 GeV in vertical dir.

Huge differences between models at such high t!



2-step procedure

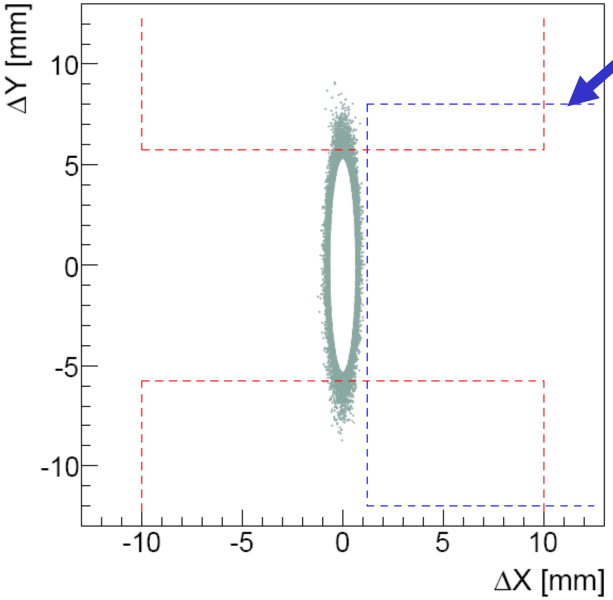
Assuming 50% detector efficiency and taking Islam (most optimistic) model

1) Align vertical Roman Pots wrt beam

Detector distance from beam 10σ+250μm:
(corresp. to p_T~2 GeV in vertical dir.)
~5000 events/day in vertical dir.
~1 event/day in horizontal dir.

15σ+250μm (p_T~3 GeV in vertical dir.):
~50 events/day

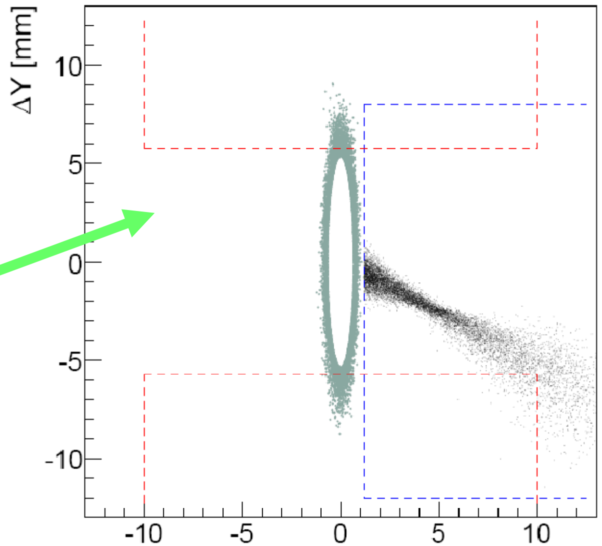
No overlap between horizontal and vertical



2) Align horizontal wrt vertical

Overlap in SD: statistics is huge (+halo)
σ_{SD}~12mb->10^{12}events/store
Acceptance for the overlap:
0.02% for 10σ, 0.005% for 15σ in vert.dir.

Precision of 5-10μm with 100 elast.events



Position of vert.RP not fixed

Summary and Timetable

- **AFP = 220 m: horizontal movable beam pipe for position and timing detectors plus vertical Roman Pots for alignment/calibration**
  420 m: movable beam pipe for position and timing detectors inside a new connection cryostat
- Position detectors at 220 and 420 m: 3D Silicon
- Timing detectors: a few ps needed to reject pile-up bg at high lumi
- **Time scale:**
  - Brian's introductory talk today at ATLAS week in Bern
  - LoI ready to be distributed to ATLAS immediately
  - If accepted by ATLAS, LoI will be submitted to LHCC
  - If accepted by LHCC, this would lead to TDR from ATLAS to LHCC in Winter 2008

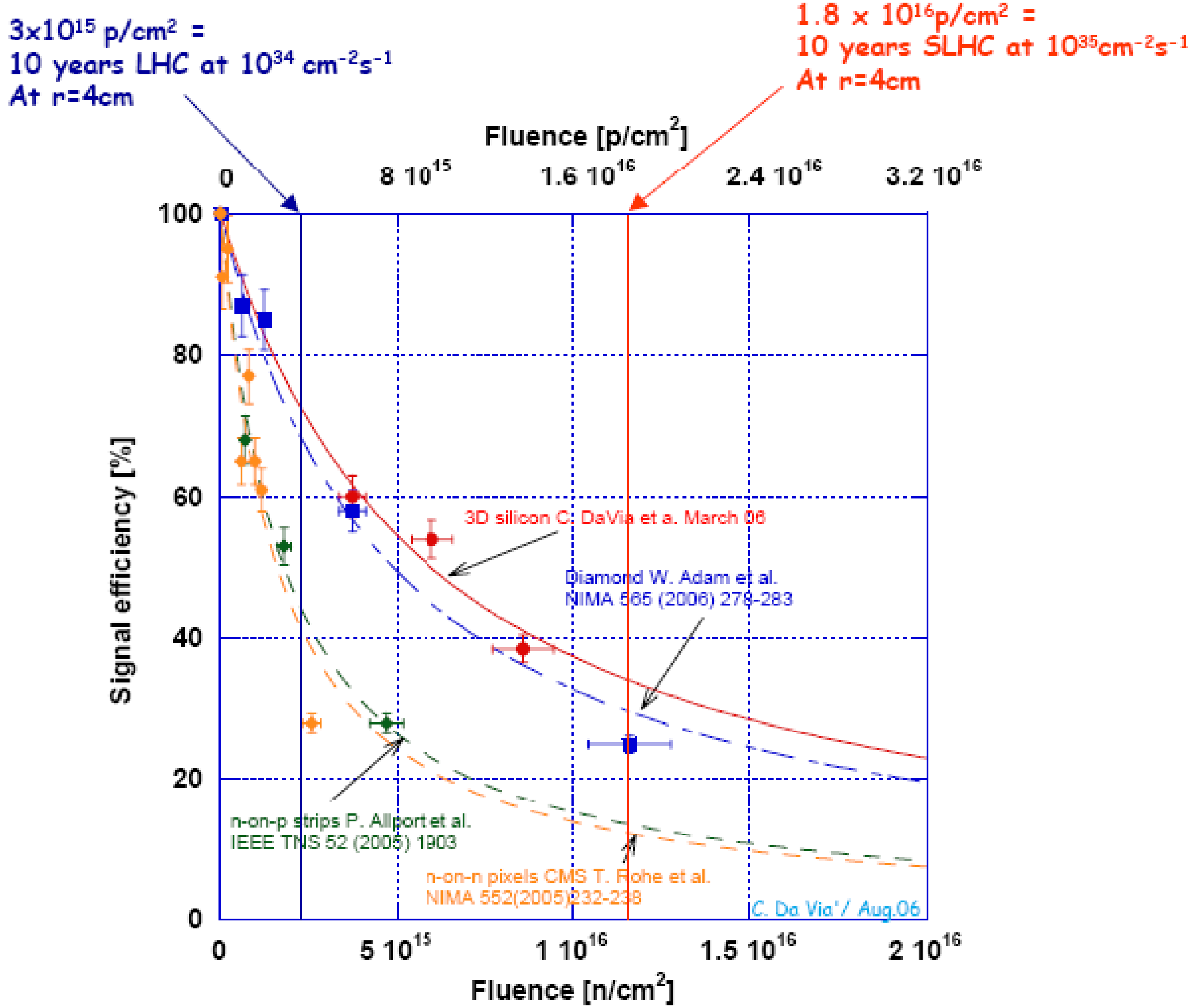
- Test beams at Fermilab (June), at CERN (June, September)
- Developments in 3D Silicon and fast timing detectors very useful for other projects in particle physics and medical applications

220m and 420m tagging detectors have the potential to add significantly to the discovery reach of ATLAS for modest cost, particularly in certain regions of MSSM. Besides the discovery physics, there is a rich QCD and EW physics program

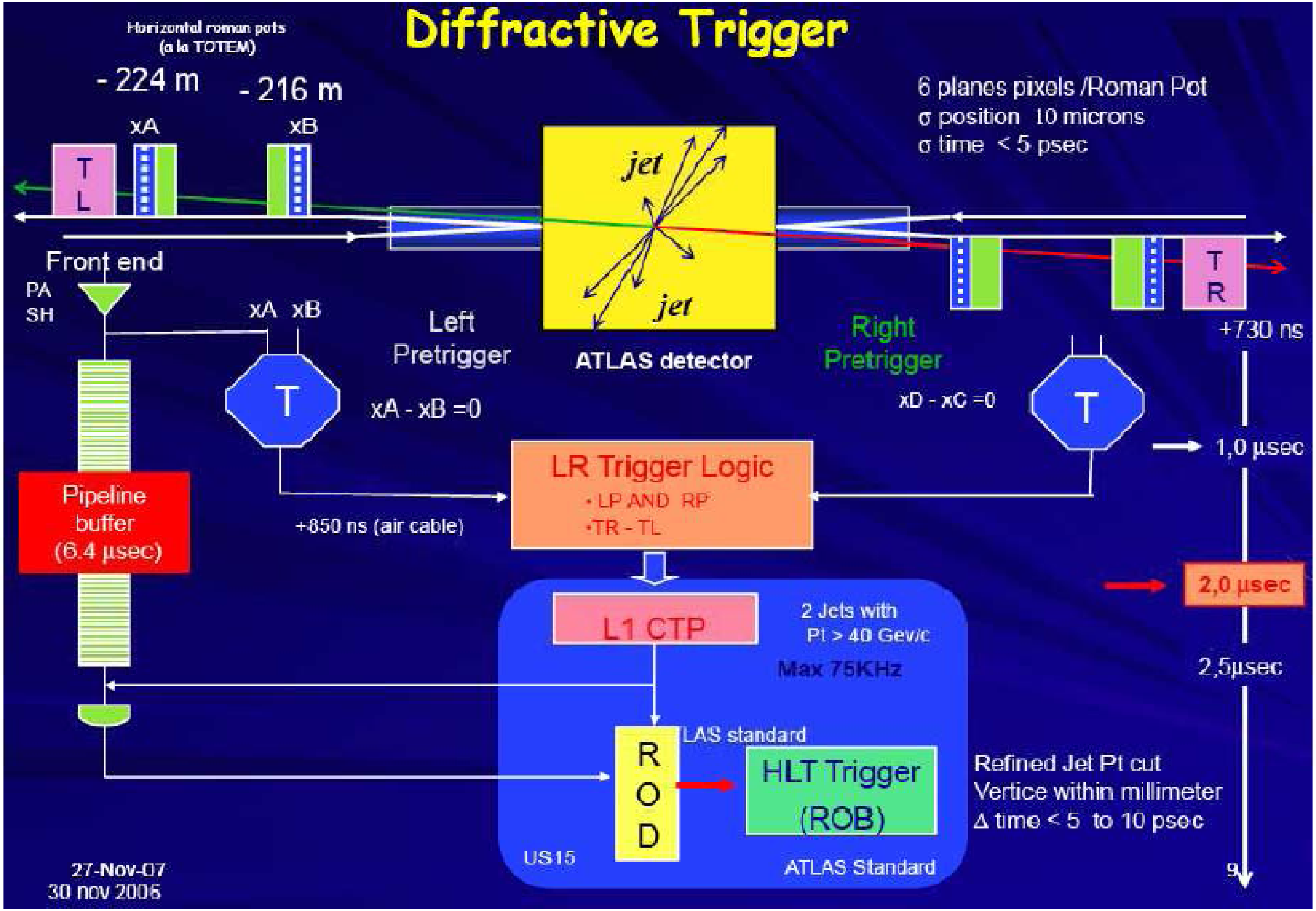
BACKUP SLIDES

Radiation Hardness

Cinzia DaVia – Hiroshima Conf. 2006



RP220 in L1

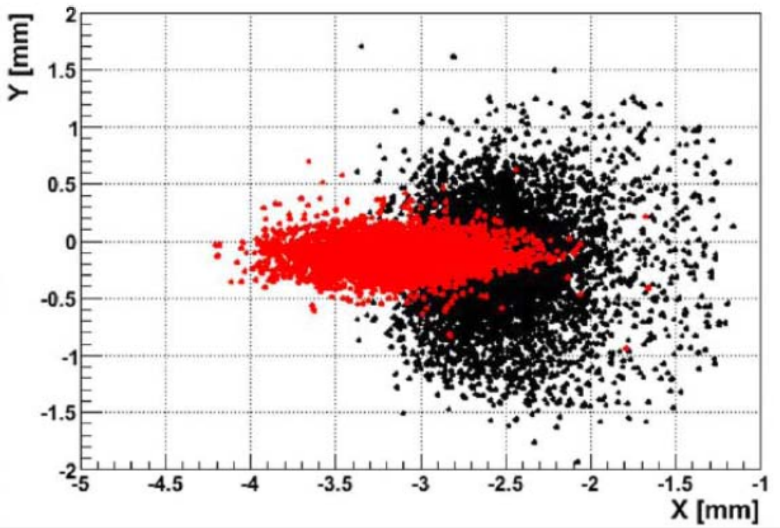


[P. Le Du, RP220]

Machine induced background

- 20000 momentum cleaning events at IR3 collimators
- Track emerging off-momentum halo protons
- Count hits at FP420 location in x,x',y,y',dp/p until when all protons are absorbed at collimators or other aperture limits (NOT FP420)
- I'll show plots for FP420 IP5

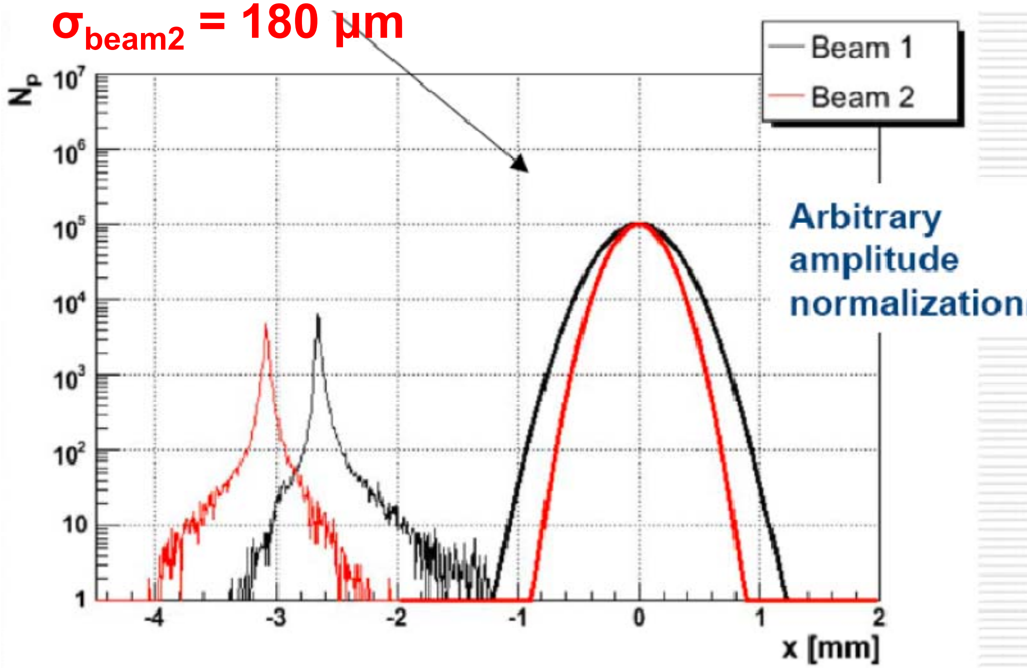
I Baishev, F. Roncarolo, K. Potter



Horizontal beam profiles for nominal beam optics and momentum spread

σ_{beam1} = 250 μm

σ_{beam2} = 180 μm



RP220: SIGNAL/Background ~ 10

RATE EVOLUTION WITH CUTS [MD2005]

Particle flux in [Hz]

	p	n	π+	π−	e+	e−	γ
Pot at 220m	344	174	616	406	4630	3361	9.4×10^4