Status of FP420 project

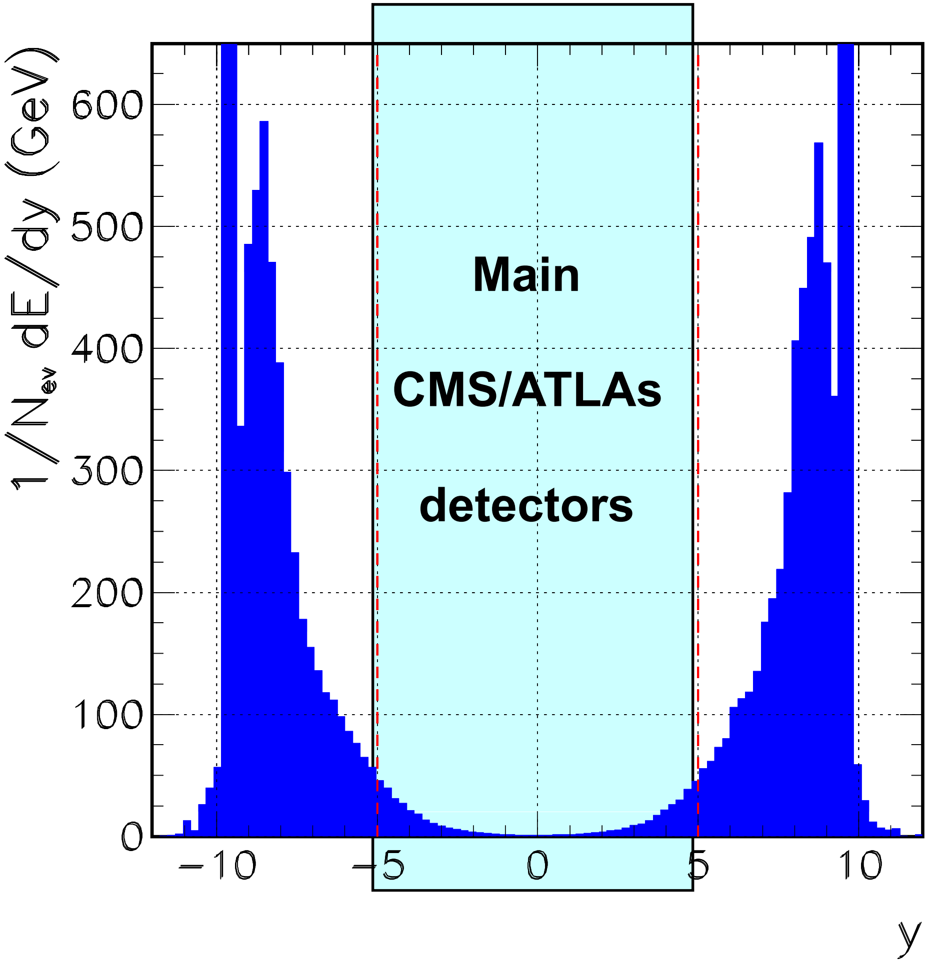
Marek Taševský (Physics Inst. Prague)

Workshop on Diffraction at LHC - Cracow 19/10 2007

Forward and diffraction physics

FP420 project

Energy flow and acceptance

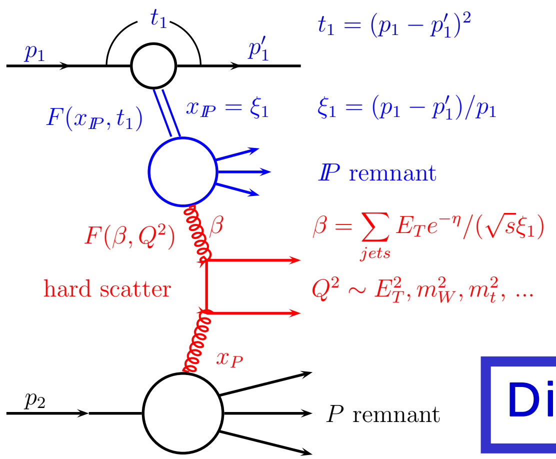


Energy flows forwards and undetected by central calorimeters

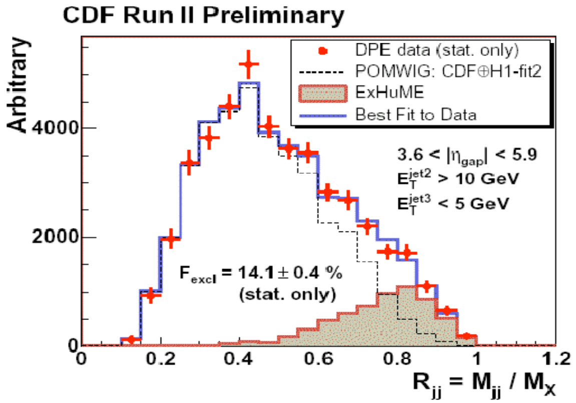
Lots of interesting physics would remain undiscovered

Equip the forward region by detectors

Rich program for Forward Physics



Diffraction

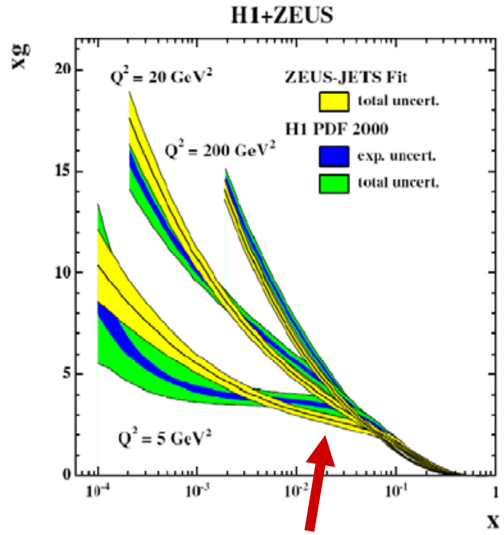


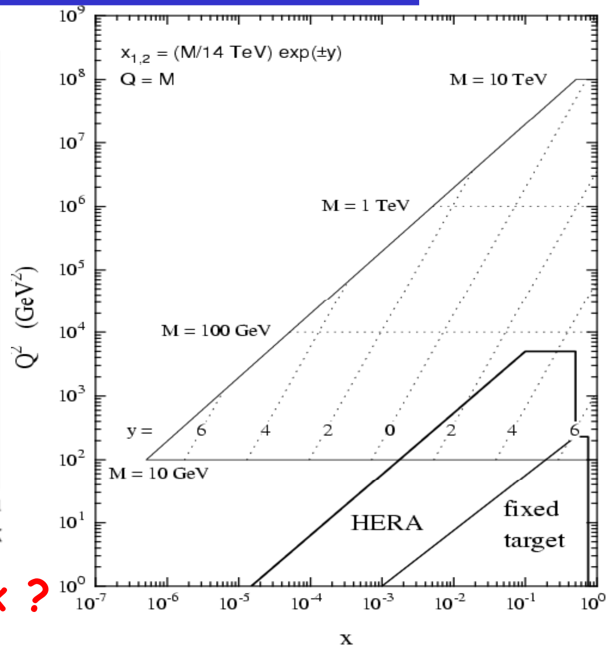
Evidence for CEP?

Two-photon interactions

- Absolute lumi calibration
- Calibration, resolution for FPS
- Factorization breaking in hard diffr.

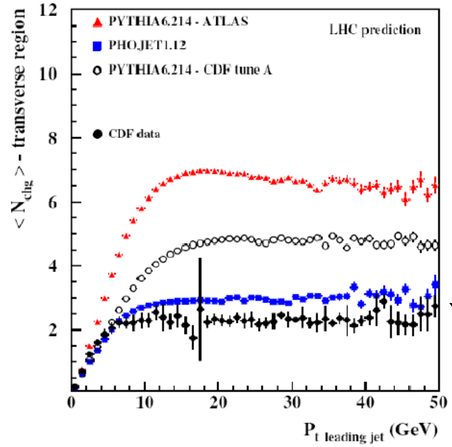
F_2^p at very low x





Saturation at very low x ?

Underlying event/Multiple interactions



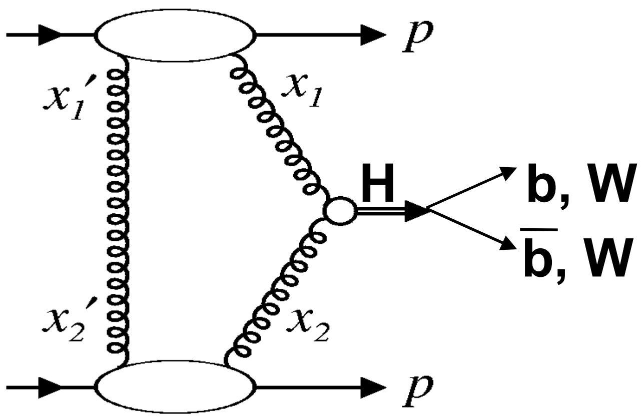
Long dist. Correl. in rap. (need to cover fwd region)

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

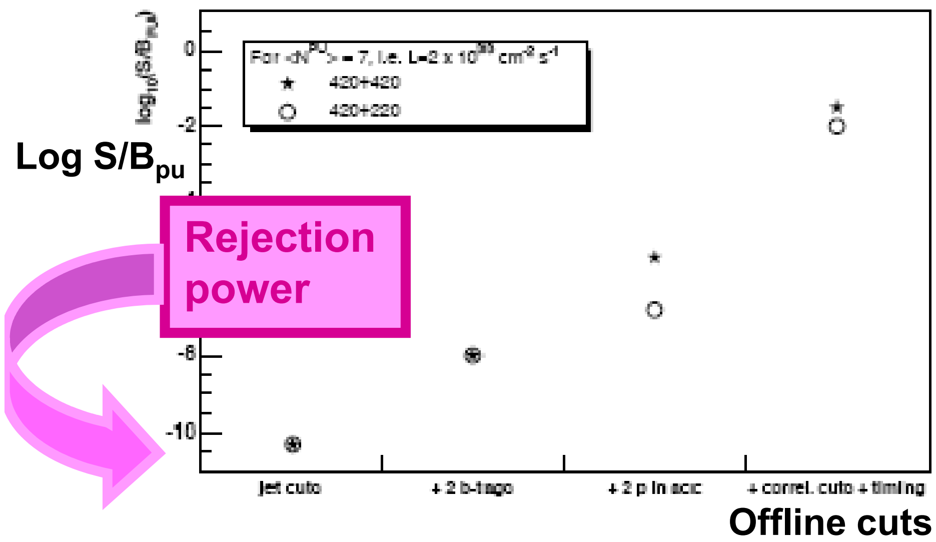


- Khoze, Martin, Ryskin hep-ph/0111078
- Central system is 0^{++}
- If you see a new particle produced exclusively and with proton tags you know its quantum numbers
- Roman Pots give much better mass resolution than central detector

Discovery difficult in SM but well possible in MSSM

Pile-up is issue for Diffraction at LHC!

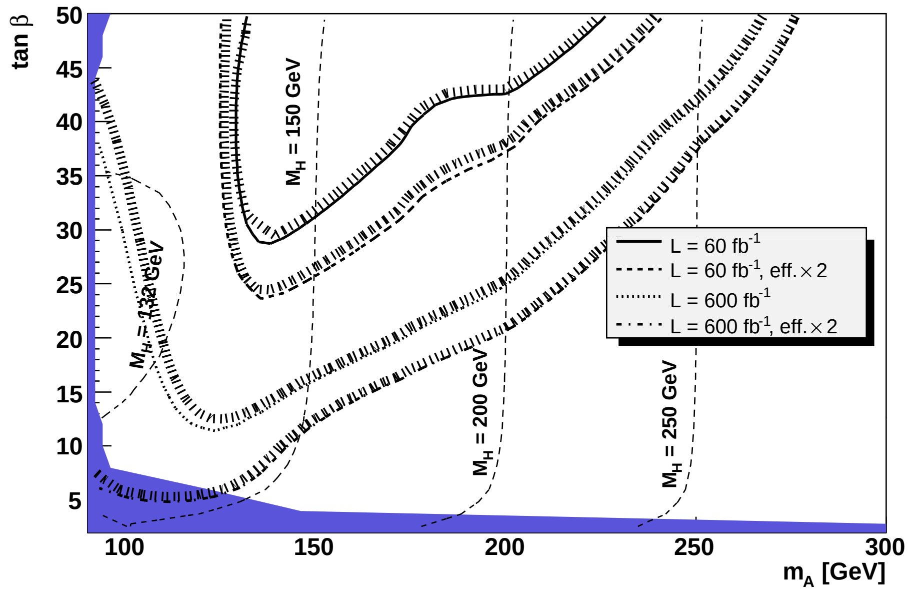
[CMS-Totem : Prospects for Diffractive and Fwd physics at LHC]



But can be kept under control !

5sigma contours:H→bb, mhmax scen., μ=-500GeV

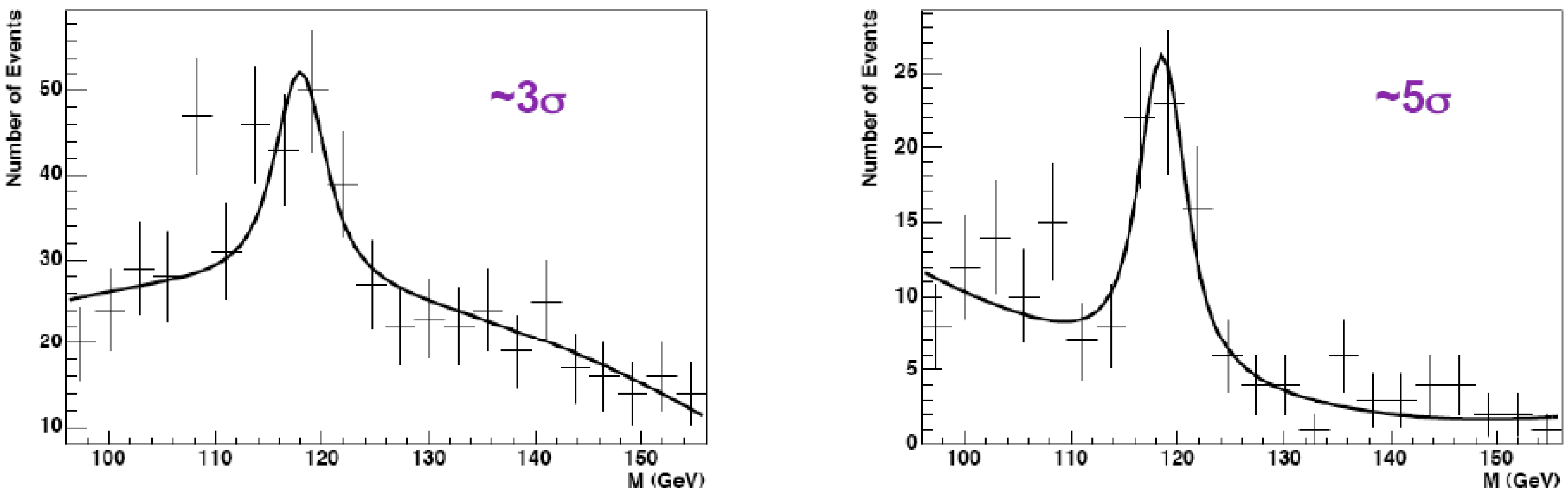
[Heinemayer, Khoze, Ryskin, Stirling, M.T., Weiglein]



An example of what forward proton tagging could do

M_h^{max} MSSM scenario, b-jet channel, standard ATLAS L1 trigger hardware, 420m only, 5mm from beam, 10ps timing (left) or ~2ps / 10ps central (right):

(m_A=120 GeV, $\tan\beta$ = 40, 300fb^{-1} @ 10^{34} cm^{-2}s^{-1}, $\sigma_{h\to bb}$ = 17.9fb)



The critical challenge:

- Fast timing resolution: To operate at 10^{34} cm^{-2}s^{-1} we must achieve 10ps

Bottom line : Higgs -> b-jets can be detected if $\sigma > 10$ fb

Better than 1 GeV mass resolution in certain MSSM scenarios

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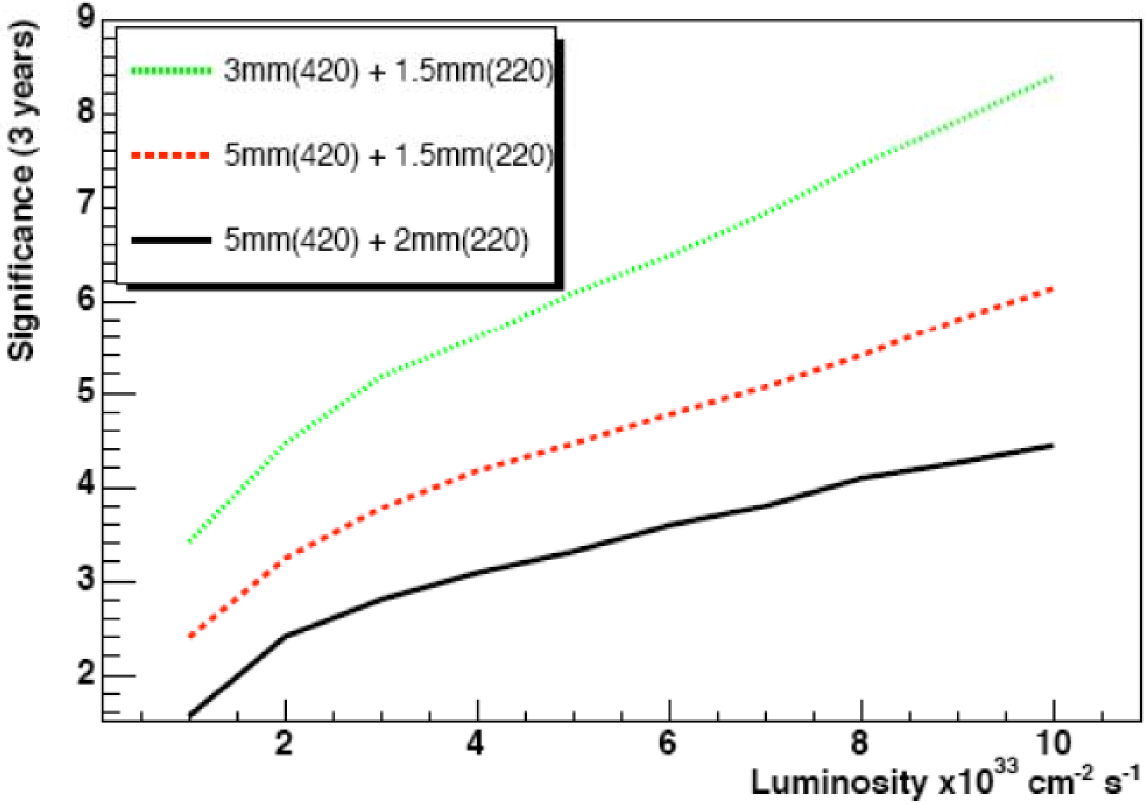
The University of Manchester

An example of what forward proton tagging could do

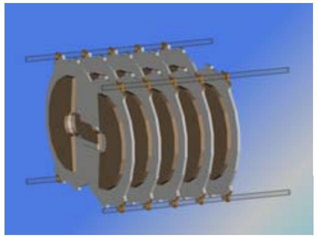
Also important at 220m is the distance of approach to the beams :

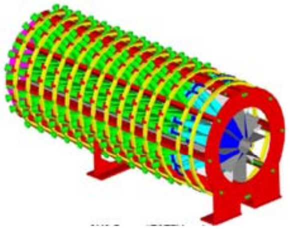
If assume 220m pots at L1, combined analysis achieves very high significance IF silicon can approach close to beam

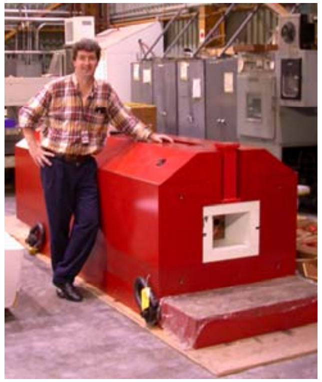


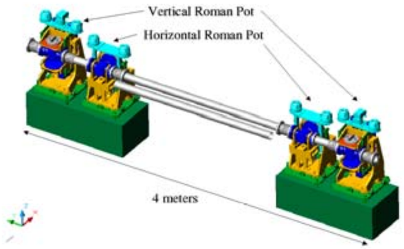
Forward detectors at LHC

TOTEM -T2 CASTOR ZDC/FwdCal TOTEM-RP FP420







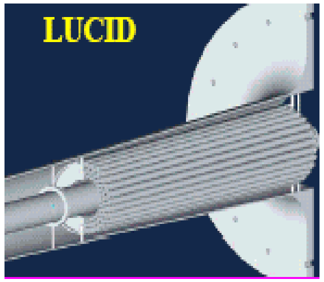


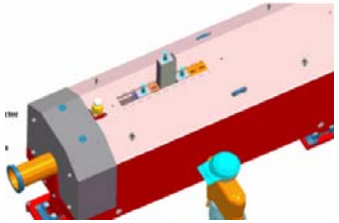
IP5

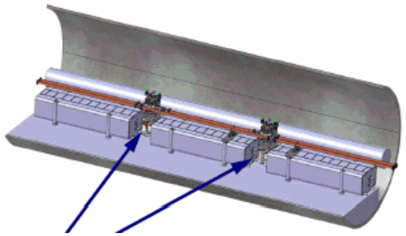
14 m 16 m 140 m 147m - 220 m

420 m

IP1



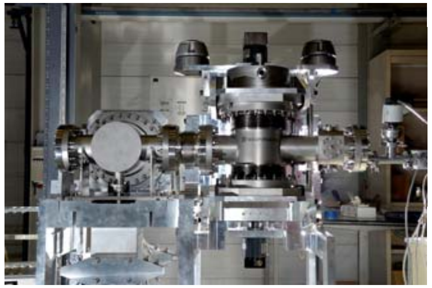




LUCID ZDC ALFA/RP220 FP420

Proton taggers for high luminosity

TOTEM-RP FP420



IP5

14 m 16 m 140 m 147m - 220 m

420 m

IP1

RP220

FP420

Proton taggers for high luminosity

- At CMS: TOTEM: Roman Pots at 147 and 220m

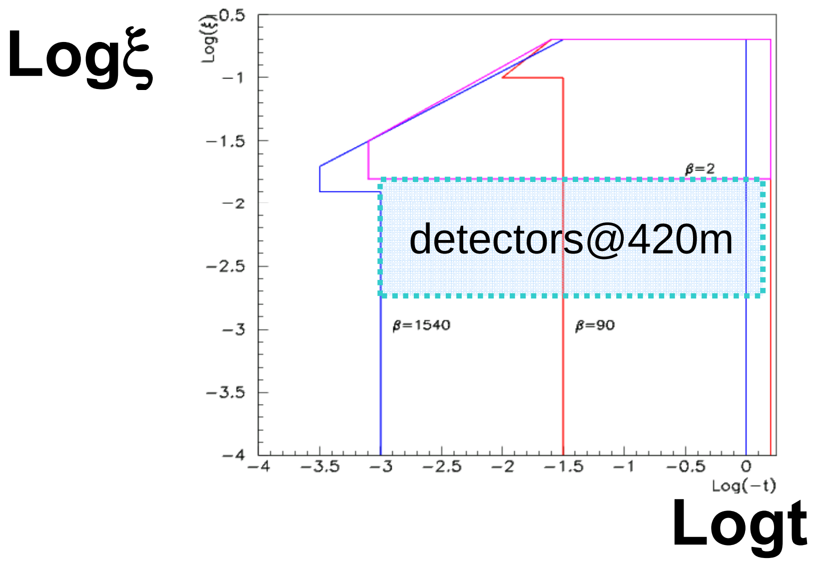
Excellent coverage in ξ and t at low luminosity optics (β*=90, 1540m) [talk of M.Deile]
Coverage 0.02<ξ<0.2 at high luminosity optics (β*=0.5m)

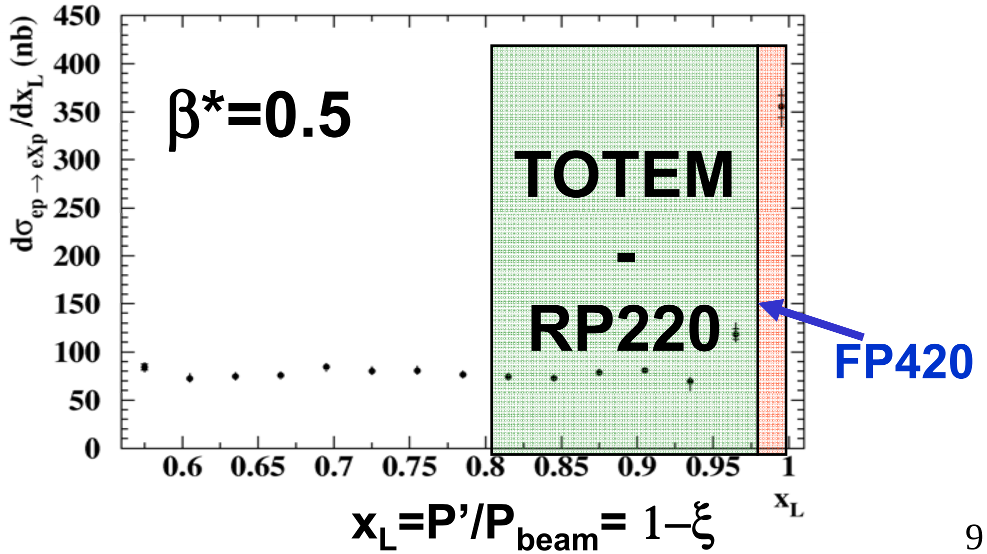
- At ATLAS: RP220 Roman Pots (of Totem design) at 220m

Coverage similar to TOTEM at high luminosity optics

- At CMS and ATLAS: FP420: R&D project, aim to instrument region at 420m

0.002<ξ<0.02 (high luminosity optics only)





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

Roman pot upgrade at 220m with additional horizontal pots

France : Saclay, Paris 6

Czech Republic : Prague

US : Stony Brook

Poland : Cracow

Germany : Giessen

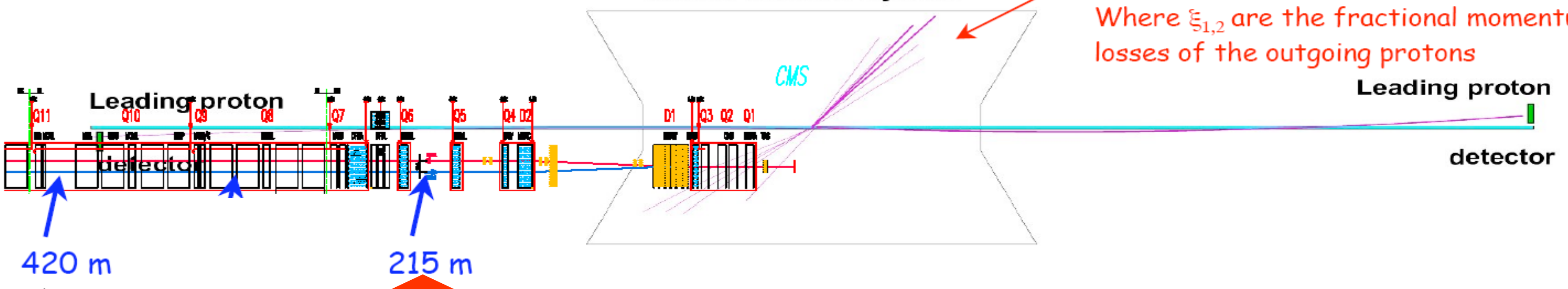
Michigan State Univ.

Univ. of Chicago, Argonne (timing det.)

How to measure the protons

$M^2 = \xi_1 \xi_2 S$

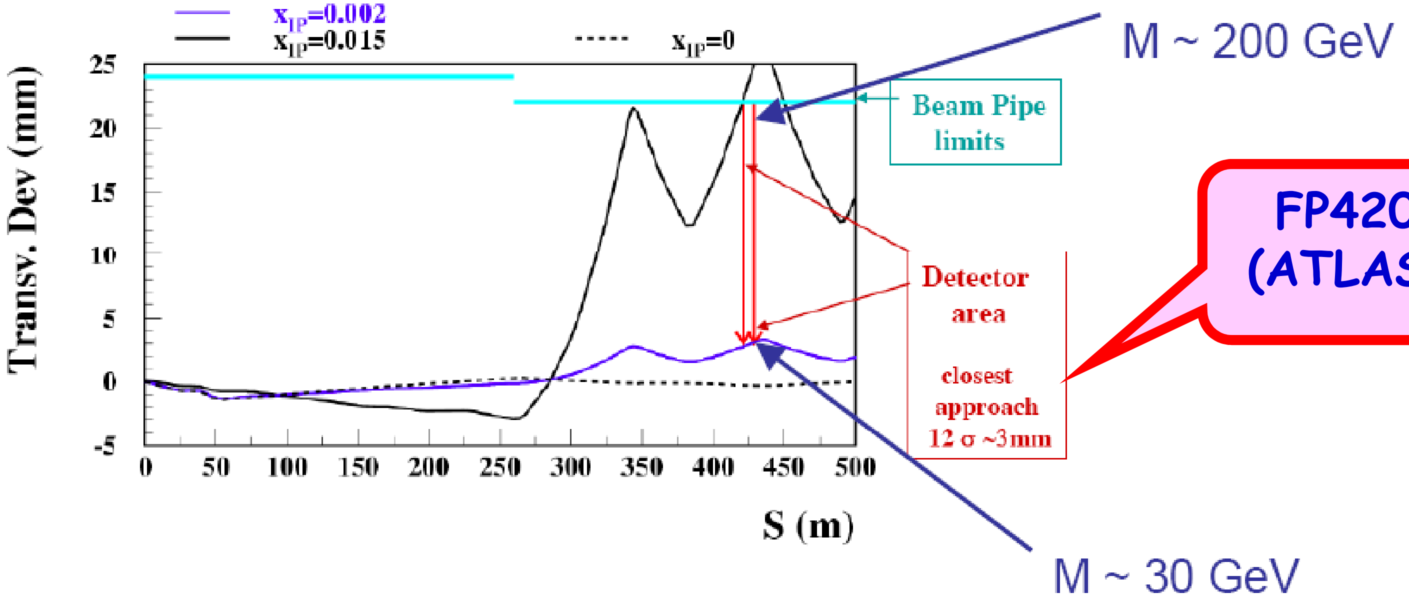
Where $\xi_{1,2}$ are the fractional momentum losses of the outgoing protons



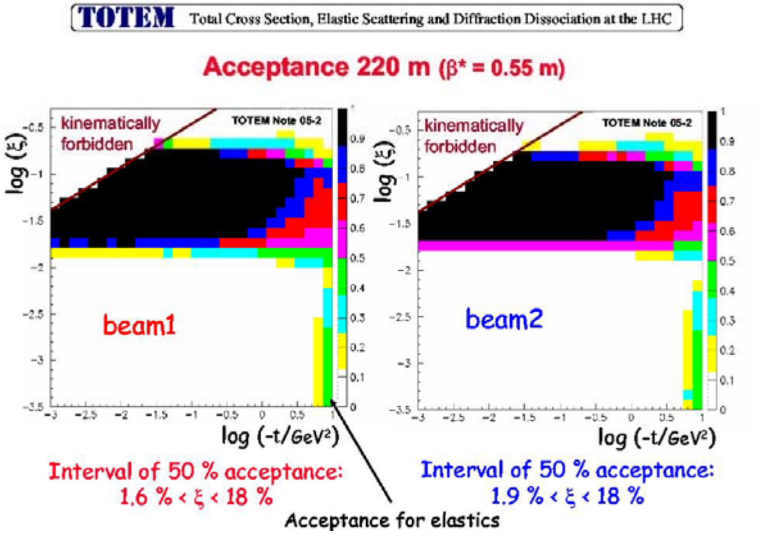
FP420

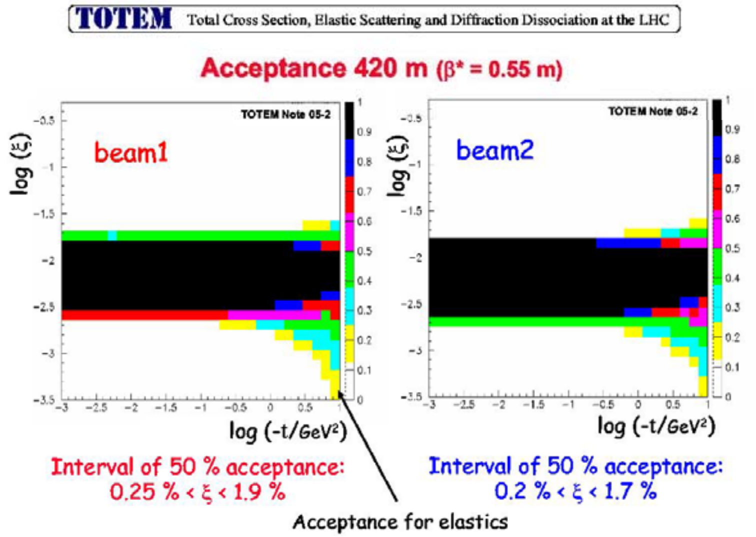
TOTEM on CMS side
RP220 on ATLAS side

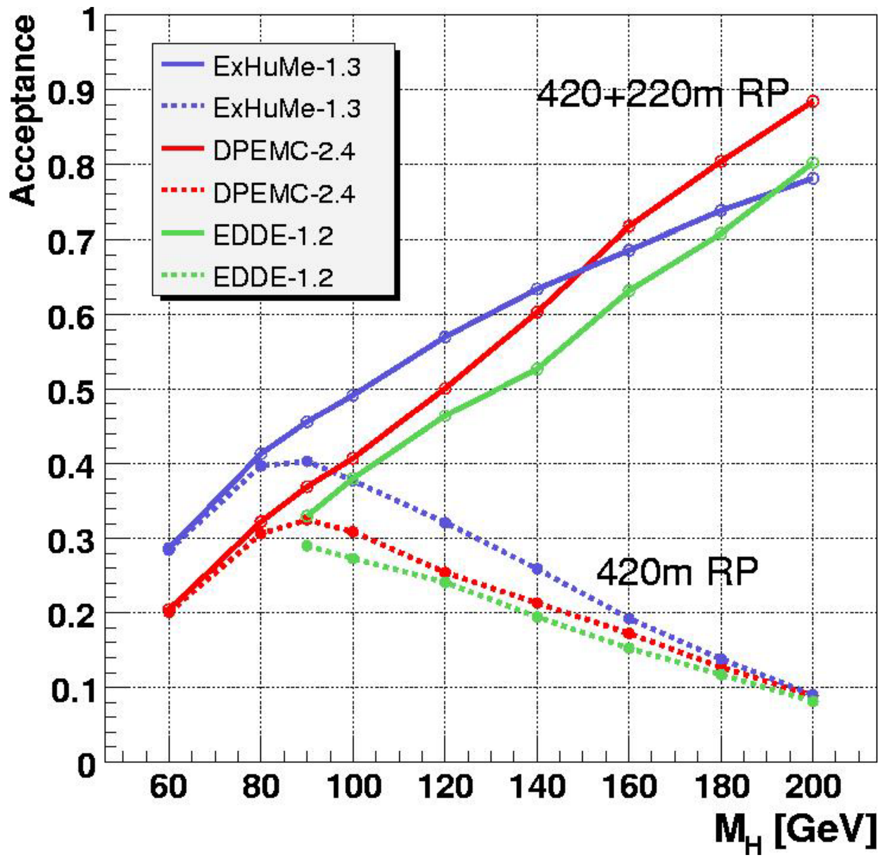
- Cold region of LHC
- Too far for L1 trigger



Roman Pot acceptances for Totem and CMS

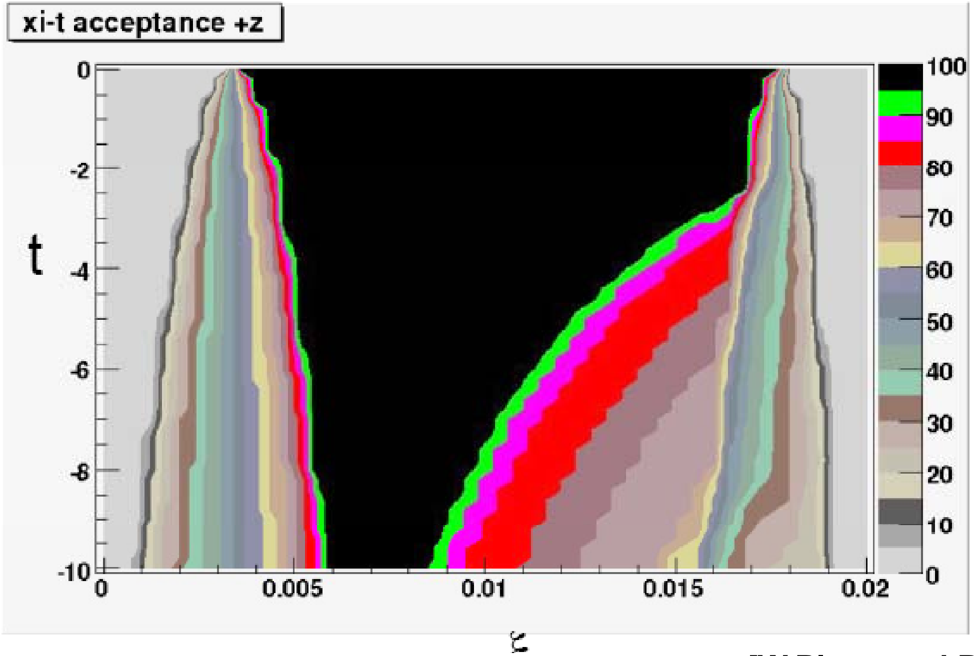


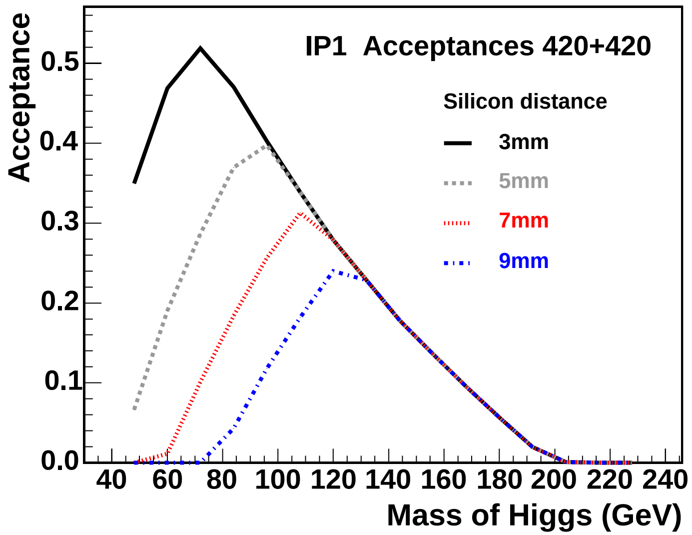




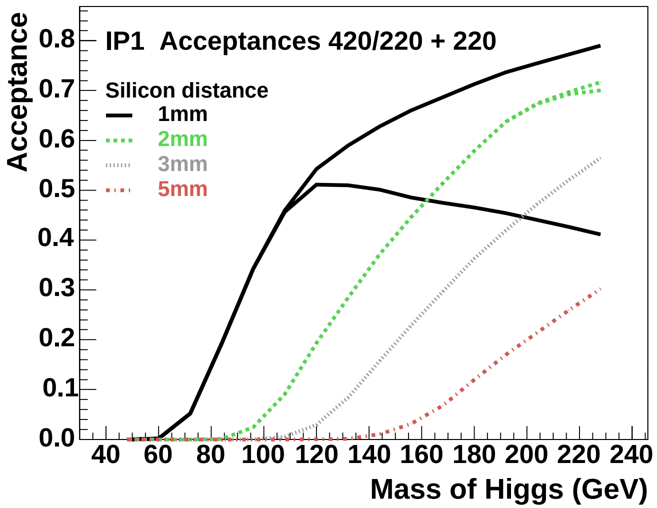
[CMS-TOTEM: Prospects for Diffractive and Fwd physics at LHC]

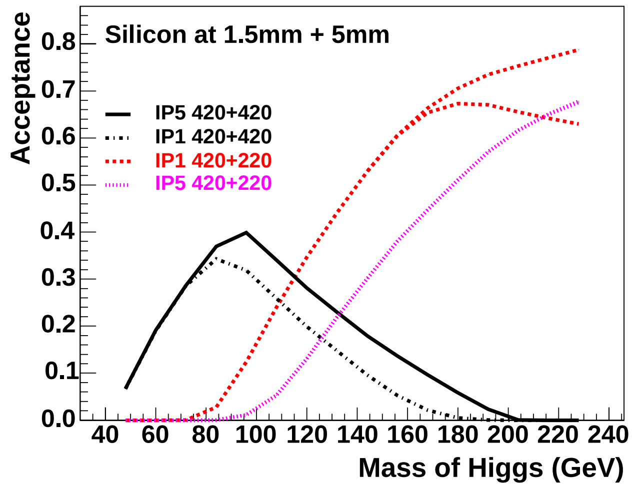
Acceptance for RP220 and FP420 at ATLAS



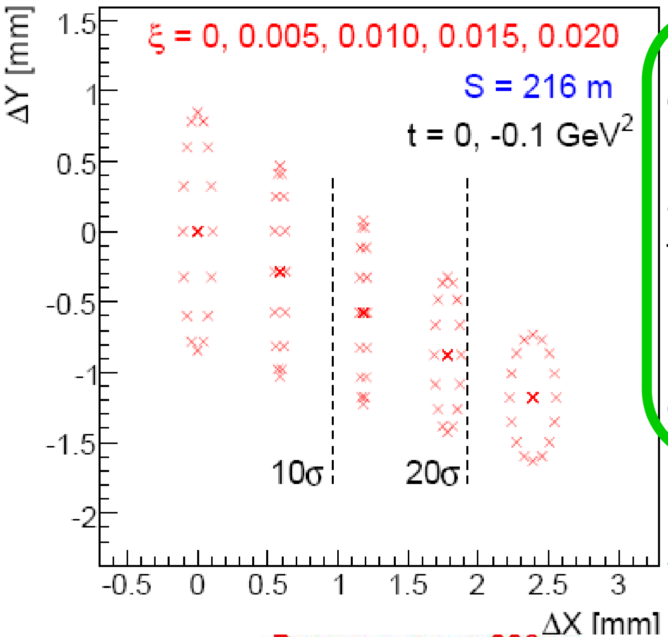


[W.Plano and P.Bussey, FP420]





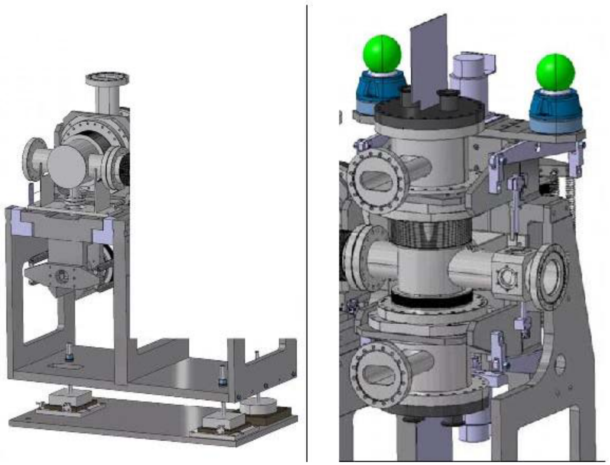
Integration into LHC structure



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

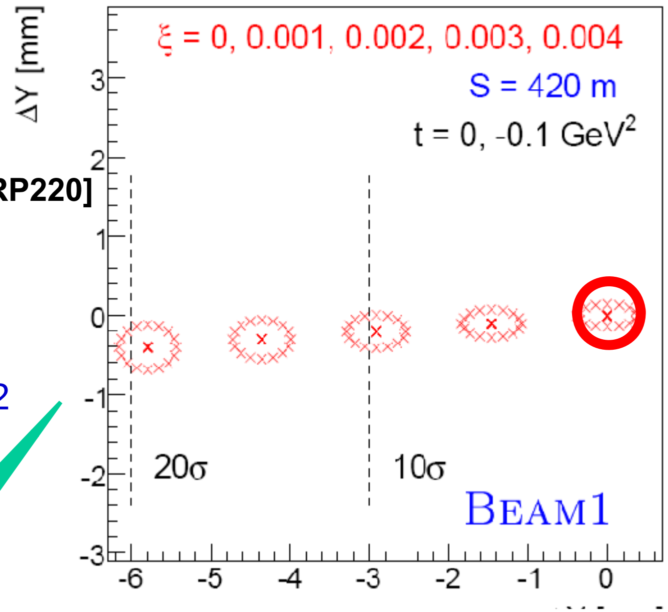
Roman pots at 220 m

Schematic view of 220 m pots: keep horizontal pots only from the TOTEM pots



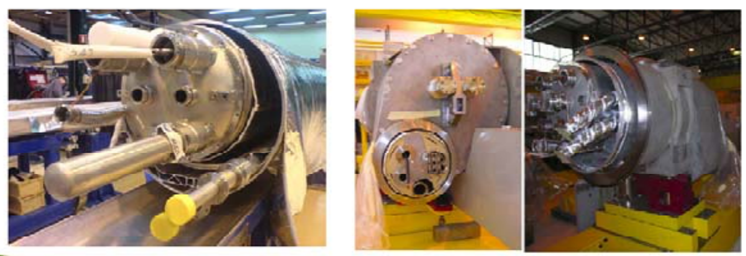
[A.Kupčo, RP220]

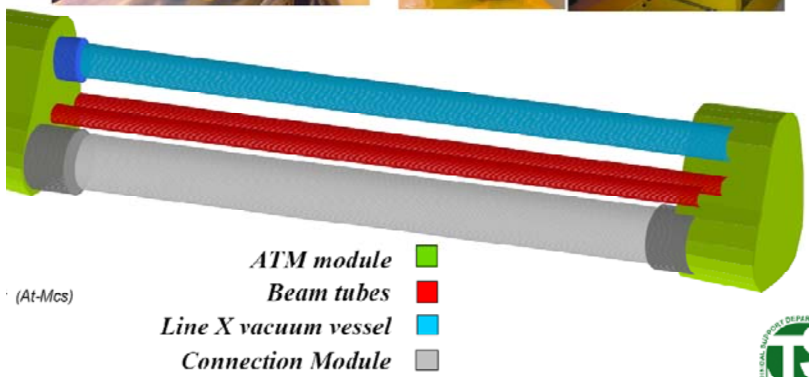
BEAM 2



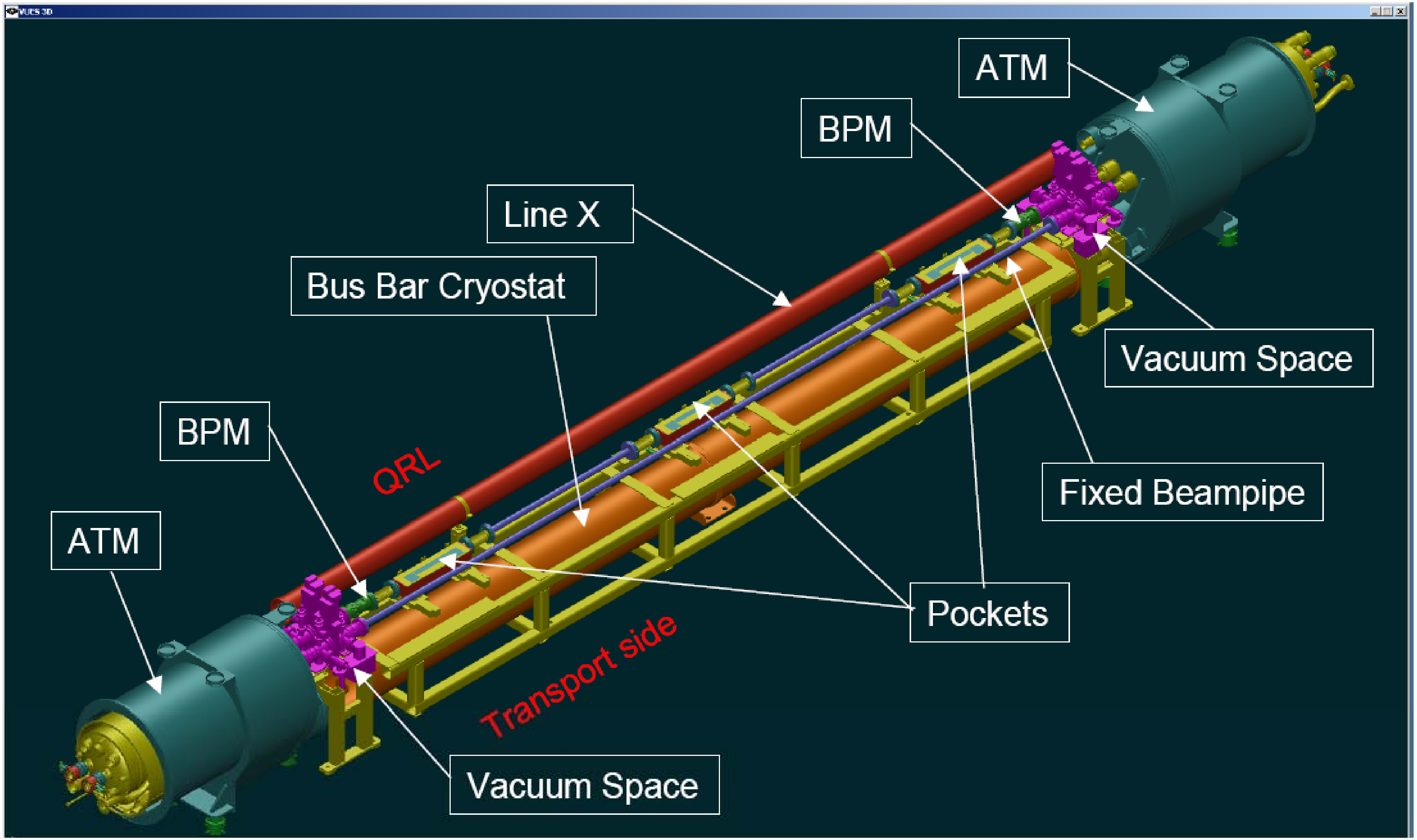
Diffraction p's deflected horizontally but inside the ring

FP420 Connection Cryostat





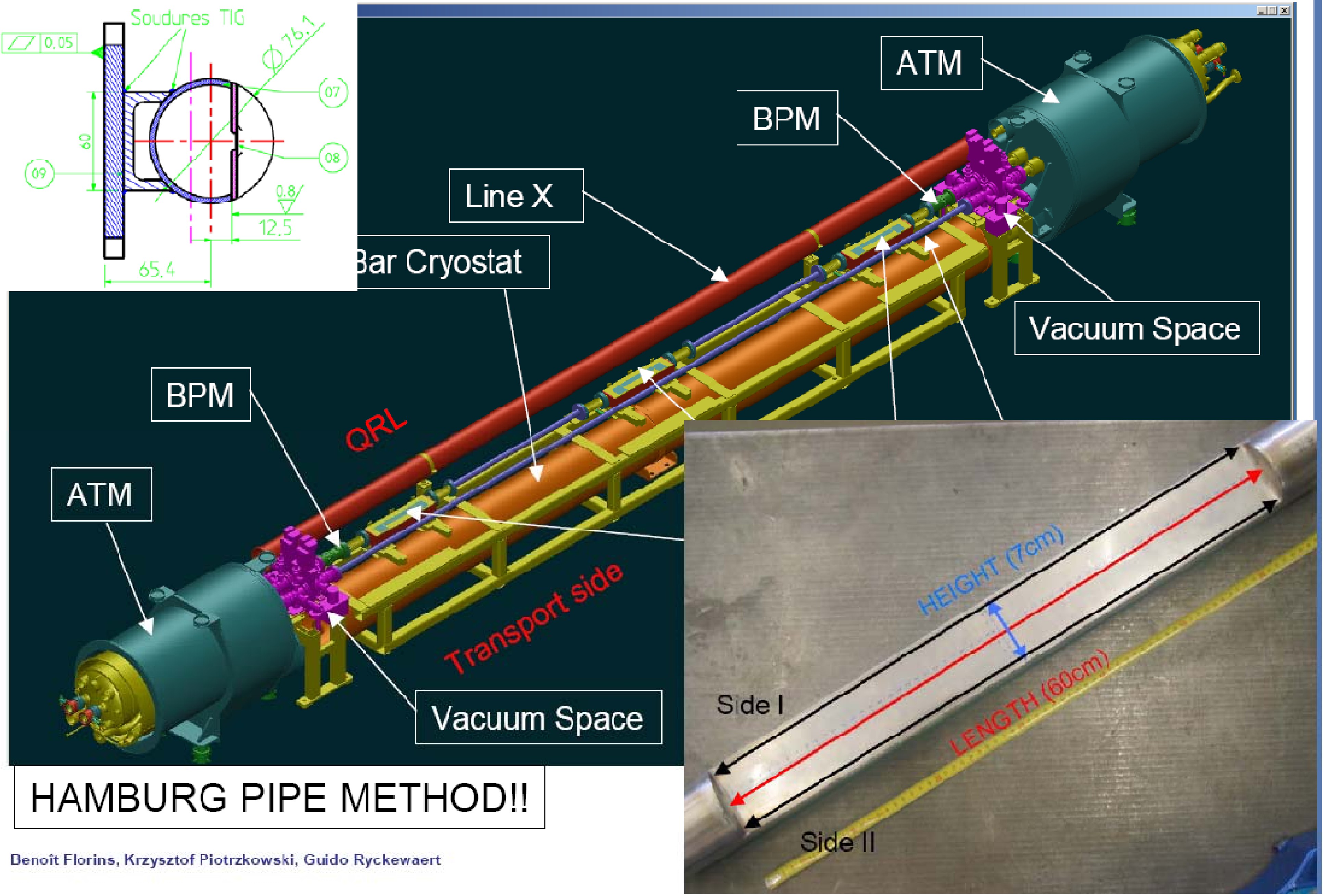
Integration of the moving beampipe and detectors



Benoît Florins, Krzysztof Piotrzkowski, Guido Ryckewaert

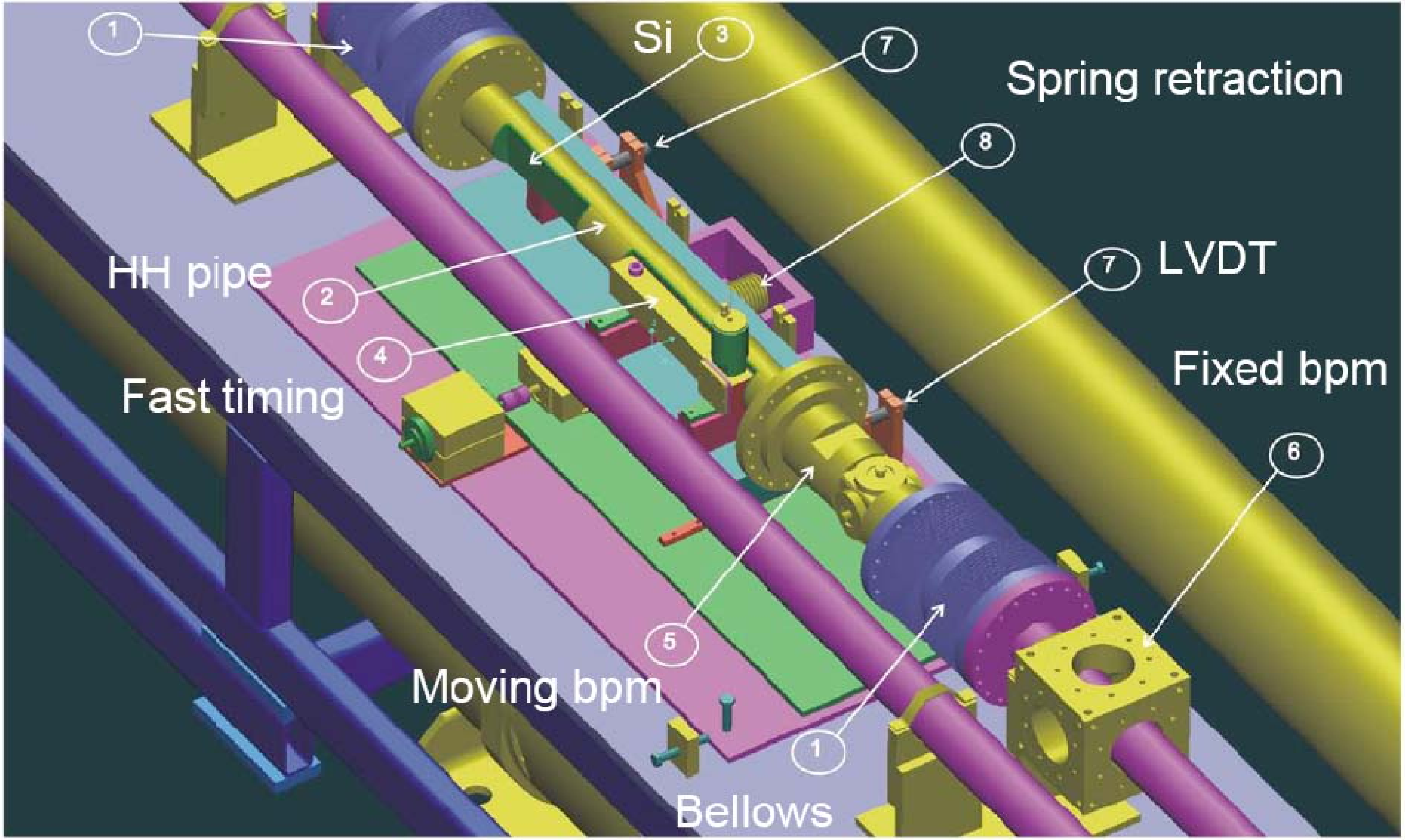
CRC
Louvain-la-Neuve

Integration of the moving beampipe and detectors



HAMBURG PIPE METHOD!!

Denoît Florins, Krzysztof Piotrzkowski, Guido Ryckewaert


1
Si
3
7
Spring retraction
8
HH pipe
2
7
LVDT
4
Fast timing
Fixed bpm
6
5
Moving bpm
1
Bellows

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Installation Schedule

	Normal Days
Warmup from 1.9K to 4.5 K	1
Warmup from 4.5K to 300 K	15
Venting	2
Dismantling interconnection	10
Removal of the connection cryostat	2
Installation of the FP420 cryostat	5
Realization of the interconnections	15
Leak test and electrical test	4
Closing of the vacuum vessel	1
Evacuation/repump	10
Leak test	2
Pressure test	4
Cooldown from 300 K to 4.5 K	15
Cooldown from 4.5K to 1.9 K	3
Total [days]	89

Table 4: The estimated time in days required to install one NCC

Tracking - Resolutions

Requirements:

Close to the beam => edgeless detectors

High lumi operation => very radiation hard

Few µm precision, 1µrad precision

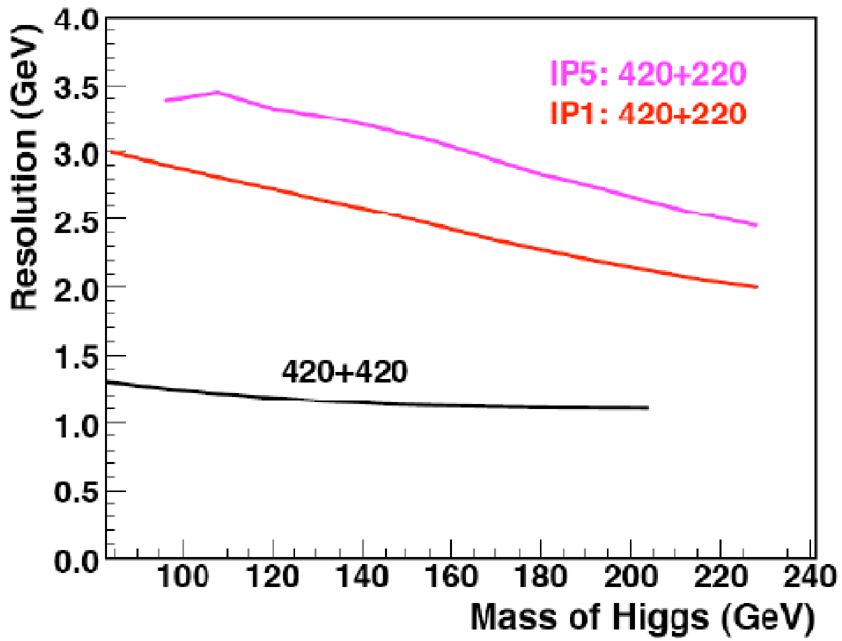
Suppress pile-up => add fast timing det.

Beam en.smearing σ_E = 0.77 GeV

Beam spot smearing $\sigma_{x,y}$ = 10 µm

Detector angular resolution = 1, 2 µrad

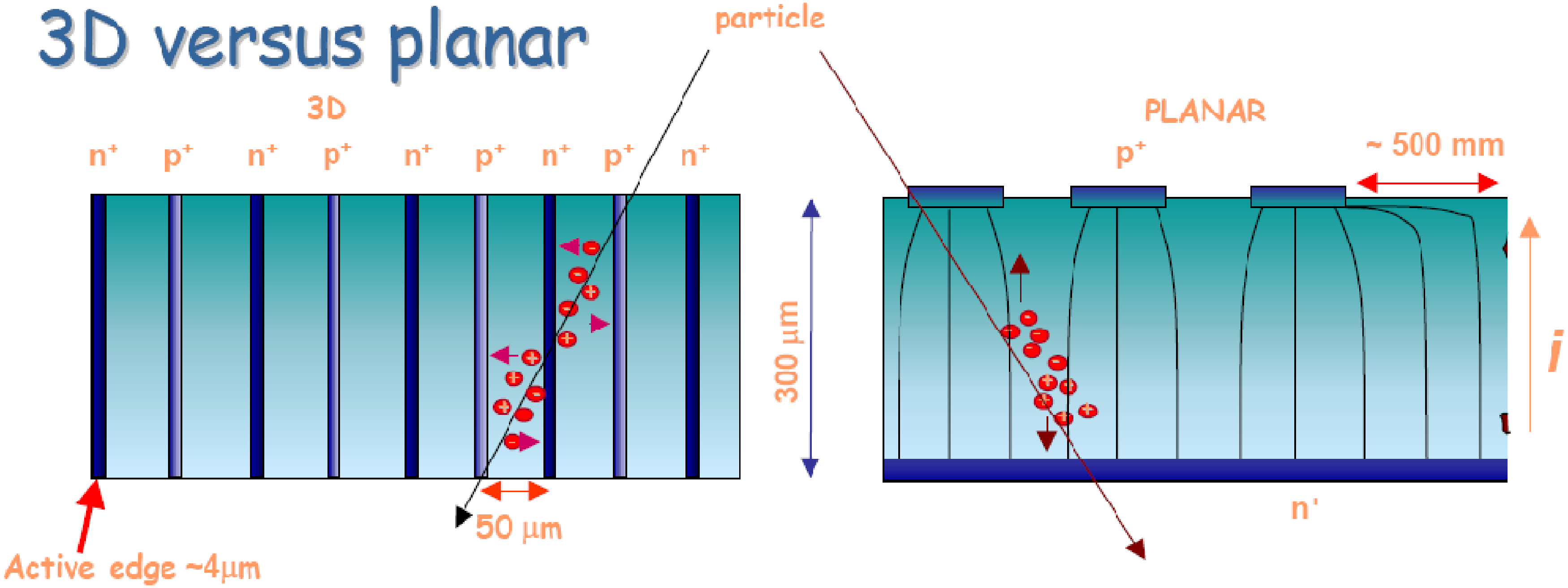
ATLAS, 1.5 mm (220) and 5 mm (420) from beam



[P.Bussey, FP420]

3D Silicon Detector Development

3D versus planar



Manchester/Stanford/MBC

3DC Collaboration

Transfer to Industry in progress – SINTEF

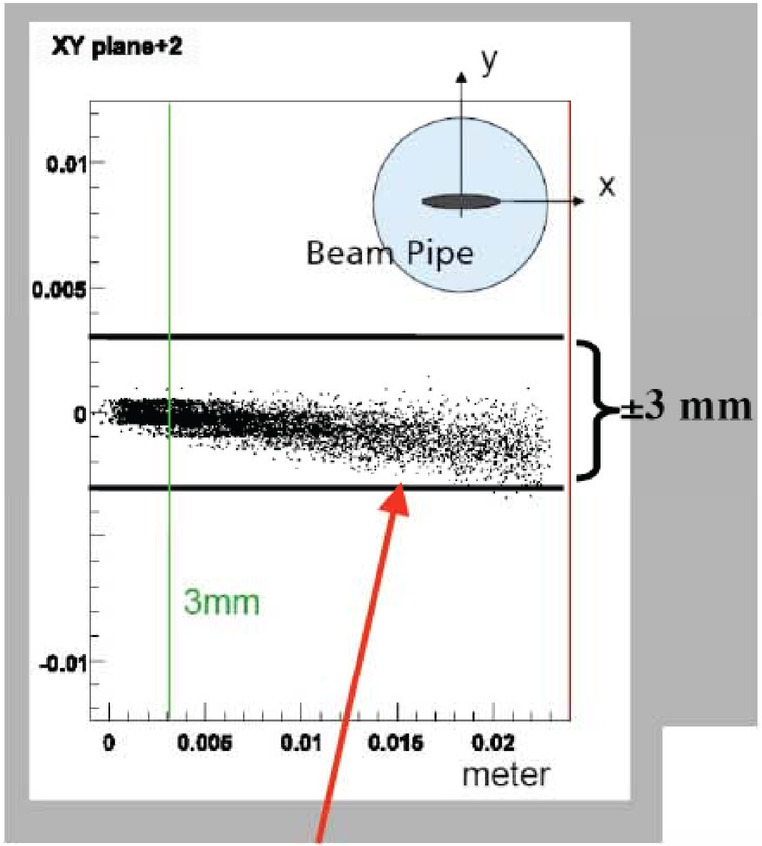
Also support from Bonn/LBL/Prague

Note: 3D ATLAS R&D Collaboration forming

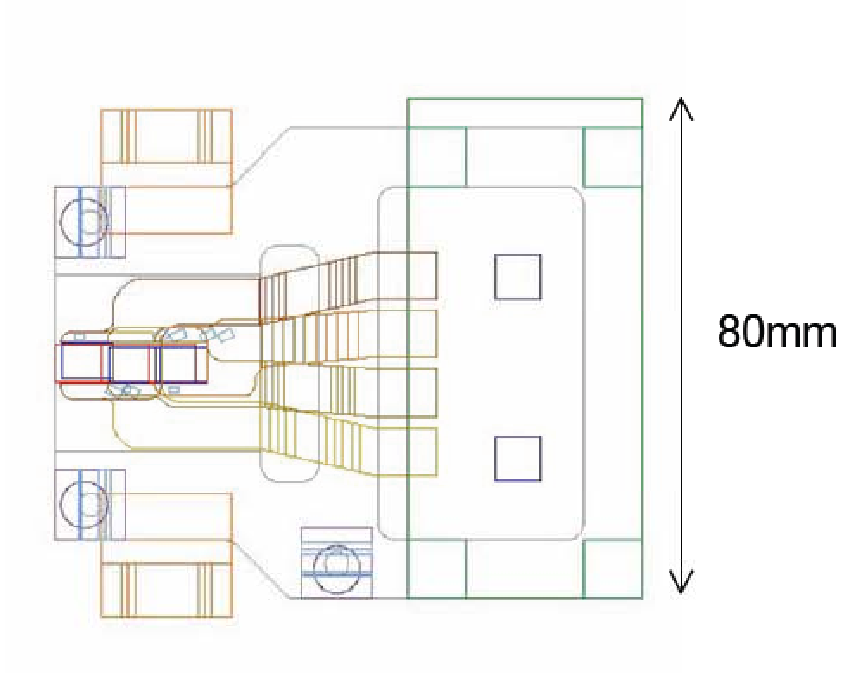
	3D	planar
V_{dep}	< 5-10 V	50-70 V
Q_{1mip}	24000e⁻	24000e⁻
C	40-80fF	50-200fF

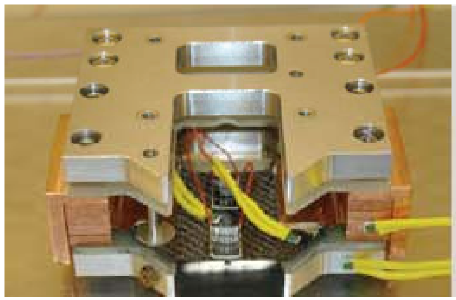
)

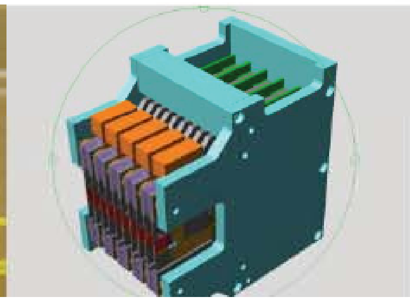
FP420 Silicon Detector Stations

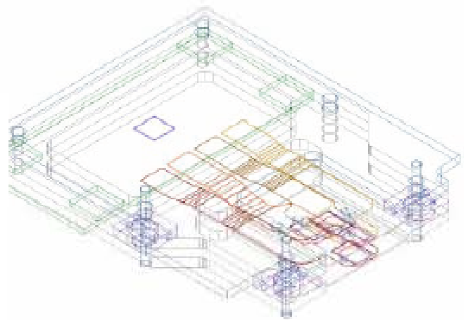


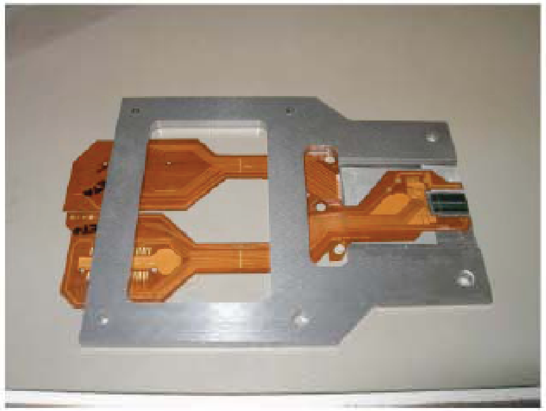
7.2 mm x 24mm (7.2 x 8 mm^2 sensors)











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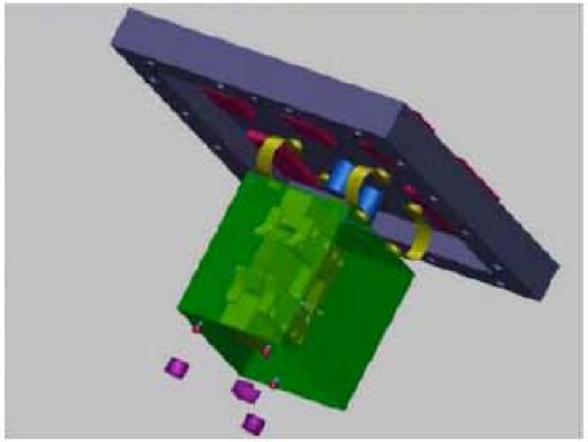
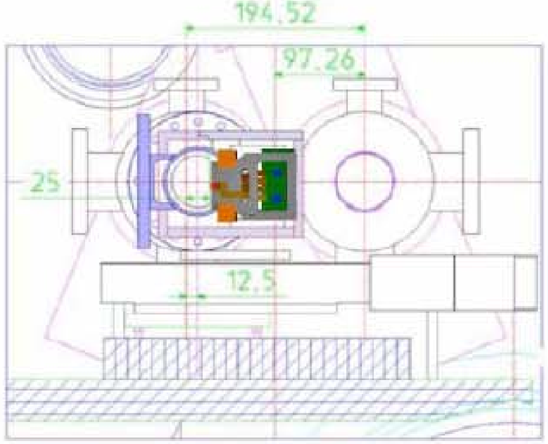
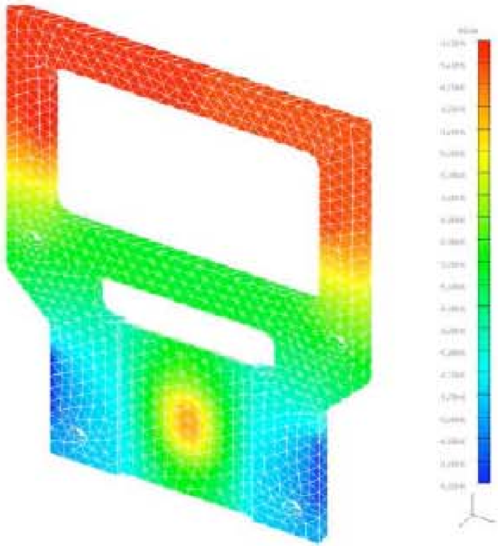
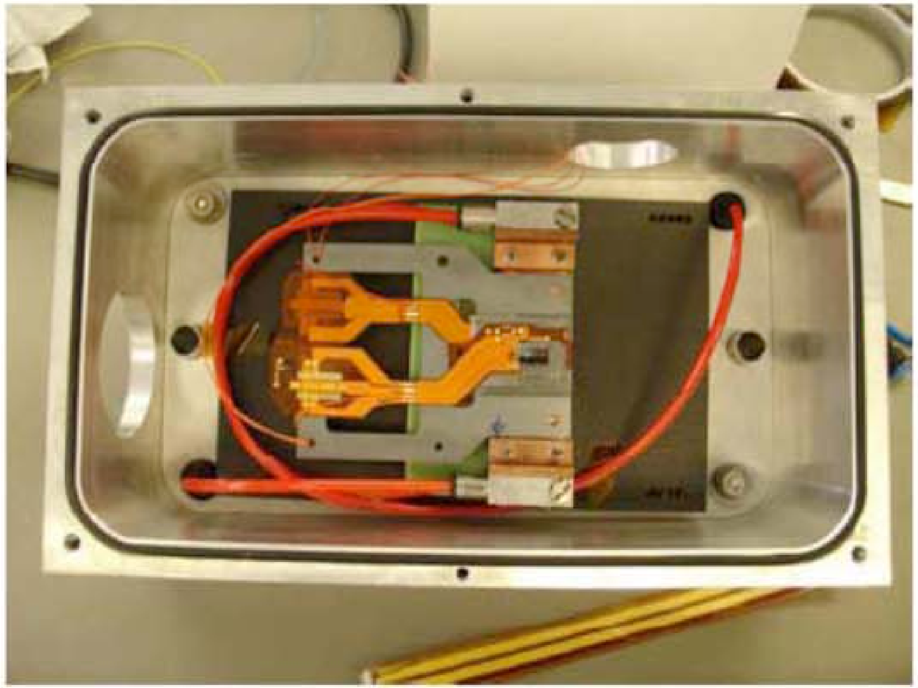
Silicon detector housings









CE7 alloy (70 / 30 Si / Al)

Peltier cooling probable solution

Achieved thermal + mechanical stability @ 10 microns in thermal tests

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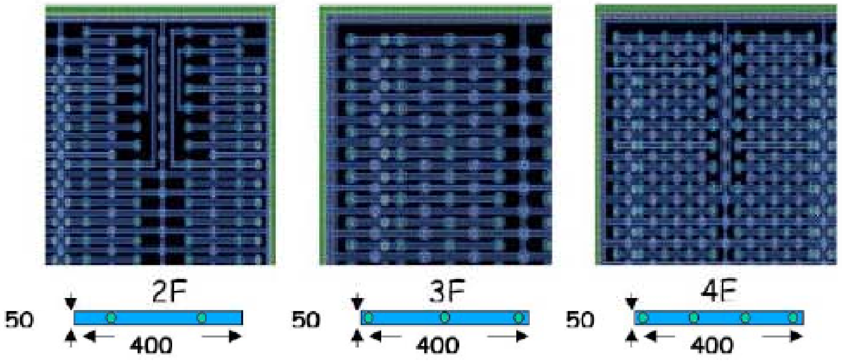
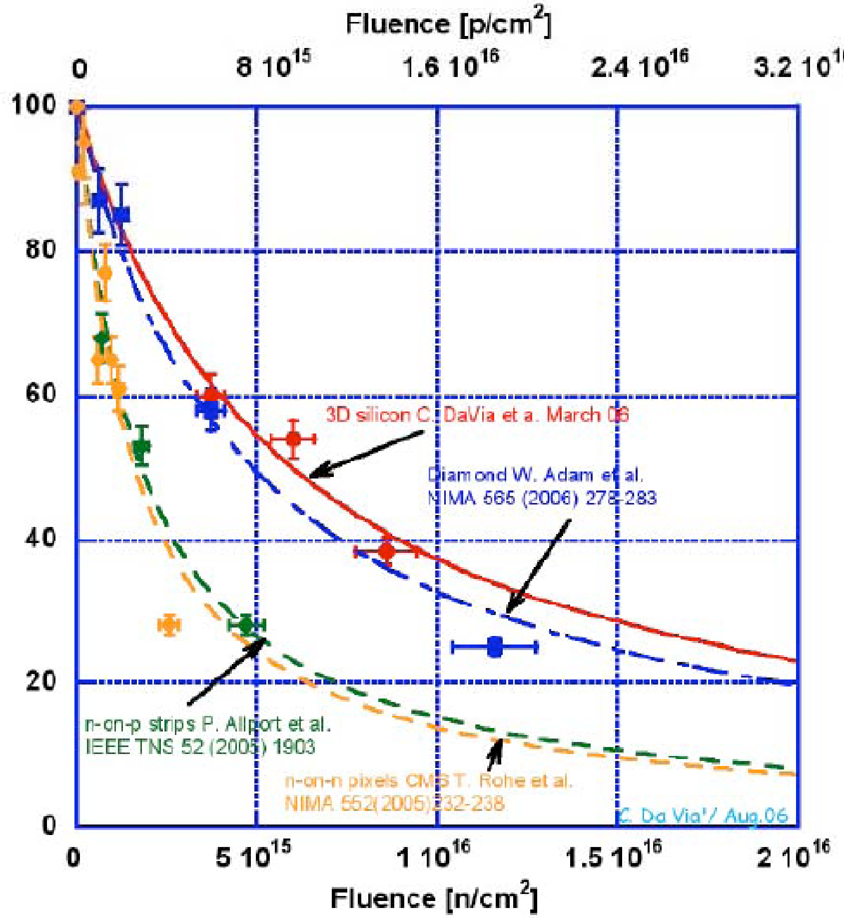
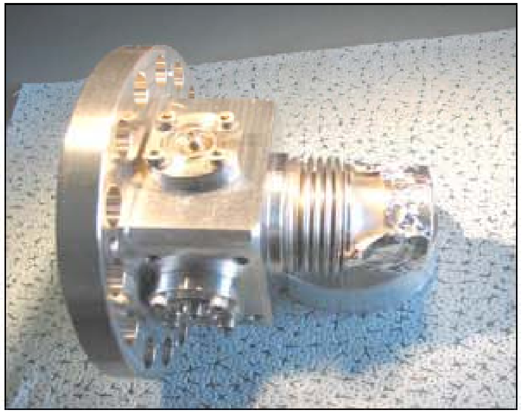
3D Silicon Sensors



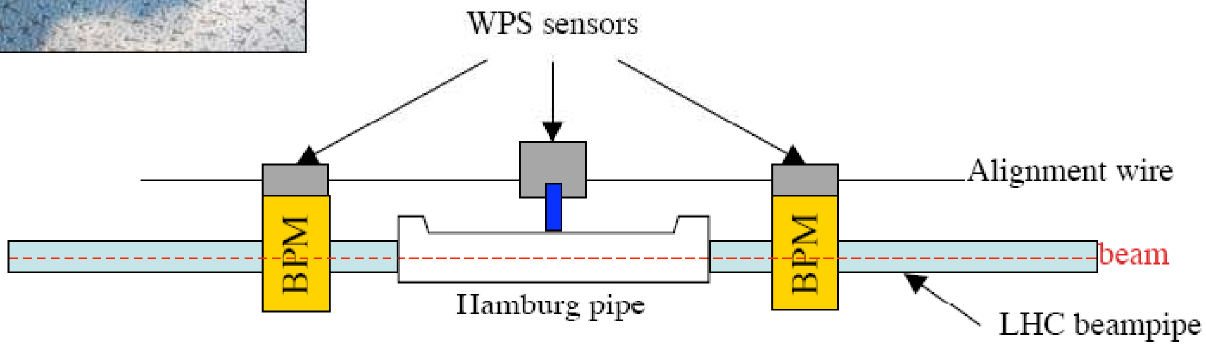
- 3D extremely rad-hard
- Successfully tested in TOTEM pot in SPS in 2004 + H8 (CERN) 2006
- Sensors bump-bonded onto ATLAS pixel readout chips
- Standard ATLAS pixel DAQ

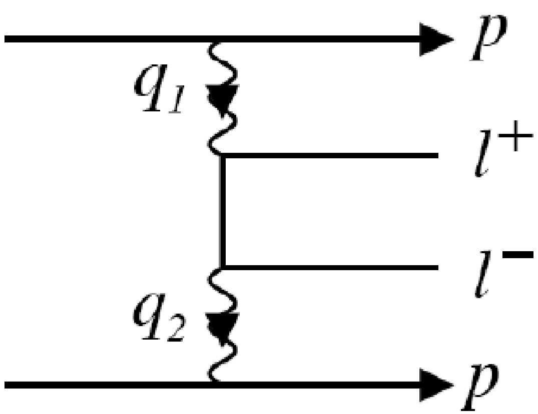


FP420 Alignment



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 (σ ~ 7pb)

Thanks to Lars Soby, Rhodri Jones, Helene Mainaud-Durand,

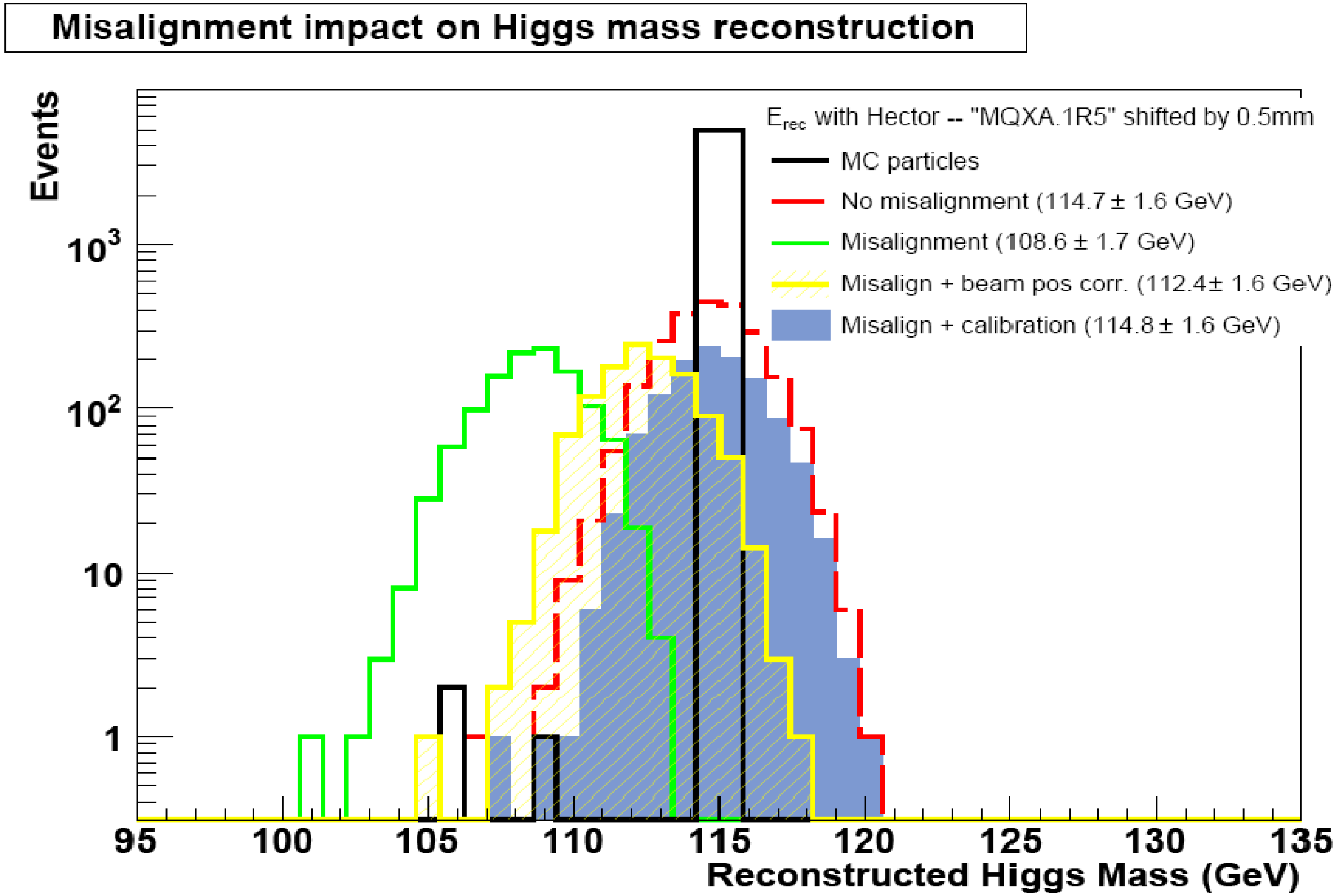
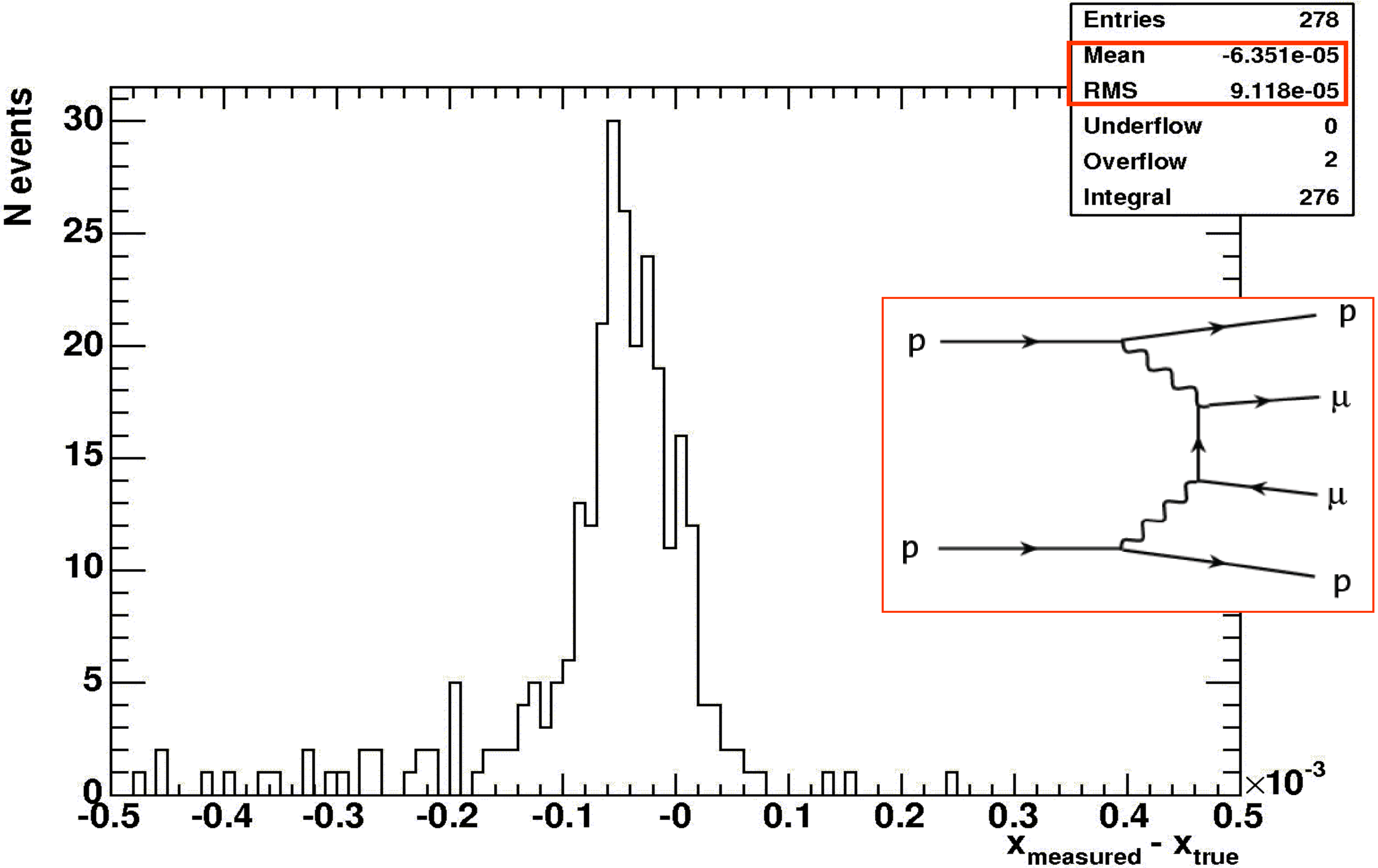


Figure 20: Illustration of the effects in the energy reconstruction due to the misalignment of LHC quadrupoles. The graphs show the reconstructed Higgs boson mass in the two-photon exclusive production, using energy of two forward scattered protons. In the upper plot, a quadrupole (MQM9R5, $s = 347$ m) close to the detector has been shifted by 100 μm. Misaligning an optical element (MQXA1R5, $s = 29$ m) close to the IP leads to a loss of acceptance (lower plot). The reconstructed values including the correction due to the dimuon calibration is also plotted. In brackets, the average reconstructed mass and its resolution are given, without including the beam energy dispersion.

Resolution of the proton energy loss for the reconstructed dimuon pairs:



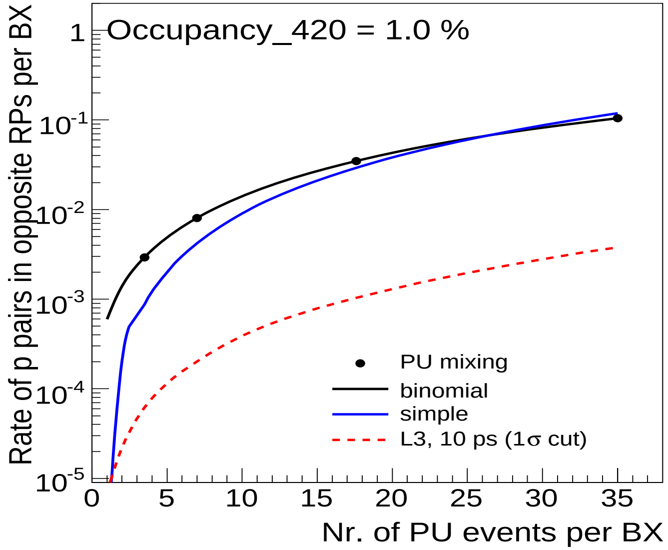
Fast timing detectors

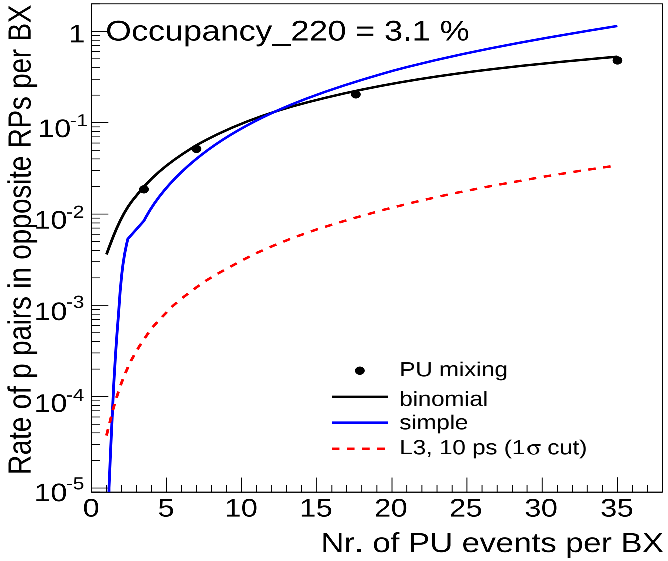
Fast development on several fronts for several applications !

200 GHz electronics
MultiChannel Plates
Simul. tools

FP420 and RP220 need to reduce PILE-UP background heavily

At least for 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 applying strict central-matching-RP conditions + fast timing det.

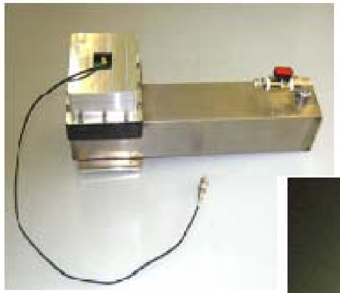


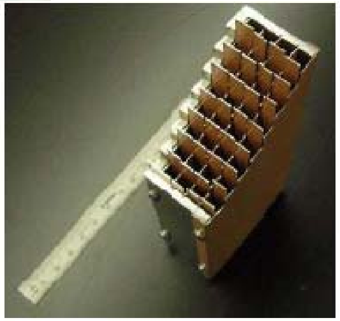


[A.Kupčo and M.T]

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

Rejection of up to 40

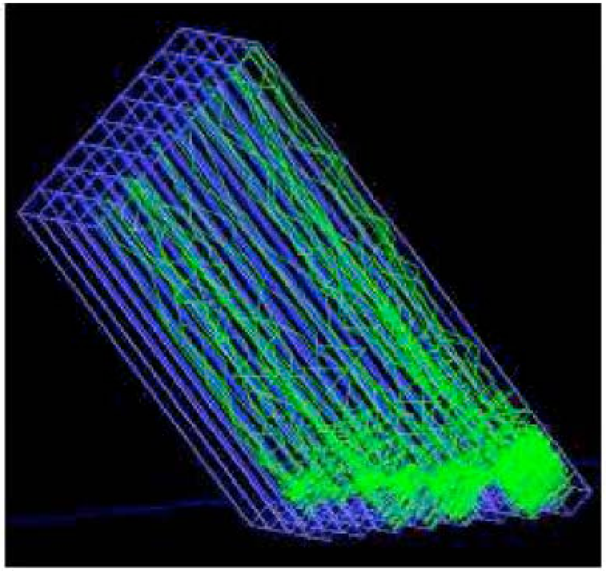




FP420: UTA/ Alberta/ FNAL/ Louvain: first tests with Quartic det.
RP220: collaboration with Univ. Chicago, Stony Brook, Argonne and Photonis
see also workshop on timing det.: Saclay, 8-9.3.2007,
http://www-d0.fnal.gov/royon/timing

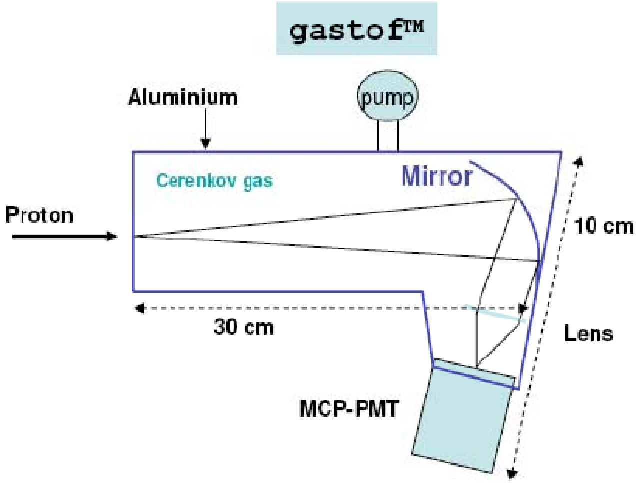
Fast timing detectors

Quartic (FNAL, Alberta, UTA)



More than 50% of the photons arrive within the first 5 ps.

GASTOF (Louvain)



all the photons arrive within ≈ 3 ps

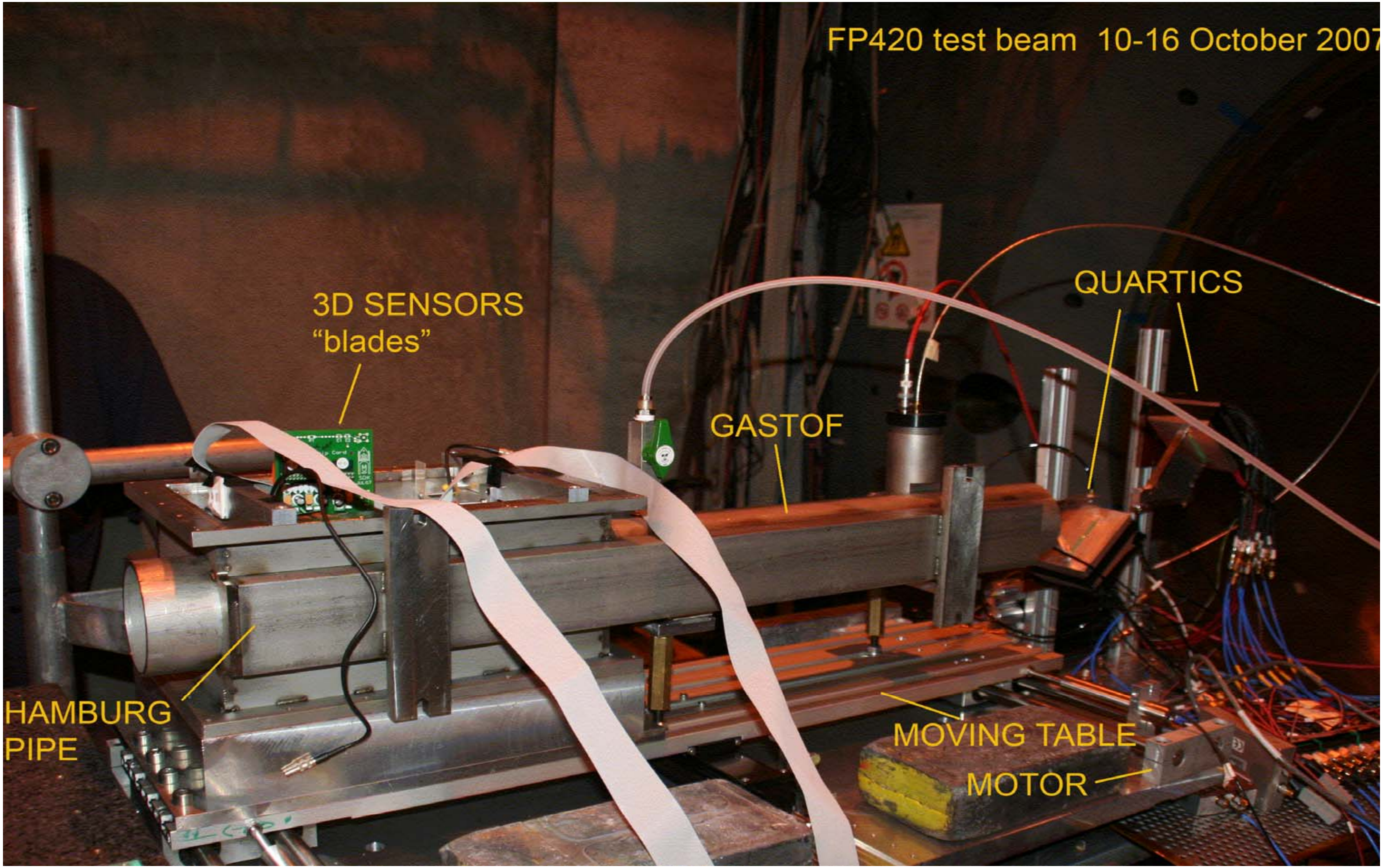
Burle 85011-501 with 25 μm pores

Hamamatsu R3809U-50 with 6 μm pores

Test beam FNAL:

$\delta t(G1) = 42$ ps and $\delta t(G2) = 24$ ps.

$\delta t(\mathrm{QB4}) = 40$ ps ← Burle 85011-501 with 10 μm pores


FP420 test beam 10-16 October 2007
3D SENSORS
“blades”
GASTOF
QUARTICS
HAMBURG
PIPE
MOVING TABLE
MOTOR

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 3 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	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: A BIG added value to FP420! Very similar trigger rates as for foreseen CMS-TOTEM L1 trigger:

CMS-TOTEM L1 trigger STUDY

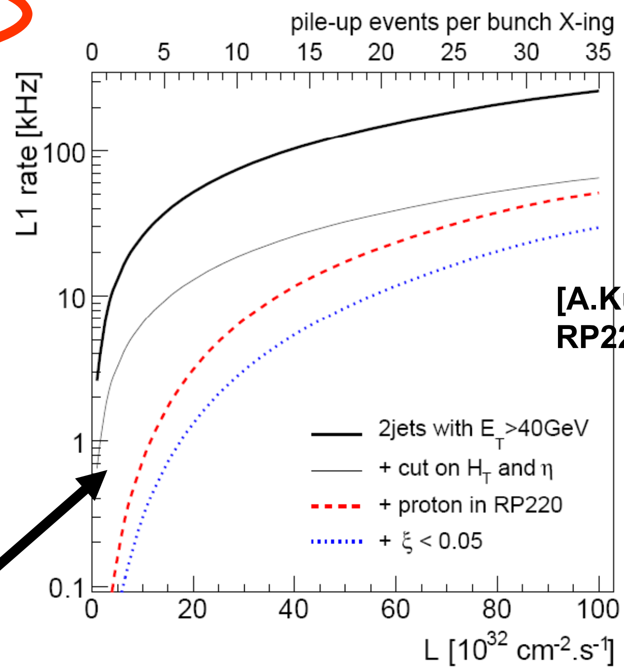
E_T^{jet} > 40 && RP220-1side

Luminosity [$cm^{-2}s^{-1}$]	# Pile-up events per bunch crossing	L1 2-jet rate [kHz] for $E_T > 40$GeV per jet	Total reduction needed	Reduction when requiring track in RP detect at 220 m	at 220 m $\xi < 0.1$	at 420 m	at 220 m & 420 (asymmetric)	$\xi < 0.$
1×10^{32}	0	2.6	2	370				
1×10^{33}	3.5	26	20	7	15	27	160	380
2×10^{33}	7	52	40	4	10	14	80	190
5×10^{33}	17.5	130	100	3	5	6	32	75
1×10^{34}	35	260	200	2	3	4	17	39

Total reduction: 10 (RP) x 2 (jet isol) x 2 (2 jets same hemisph as p) = 40

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

RP220 L1 trigger study



[A.Kupčo, RP220]

Trigger strategies

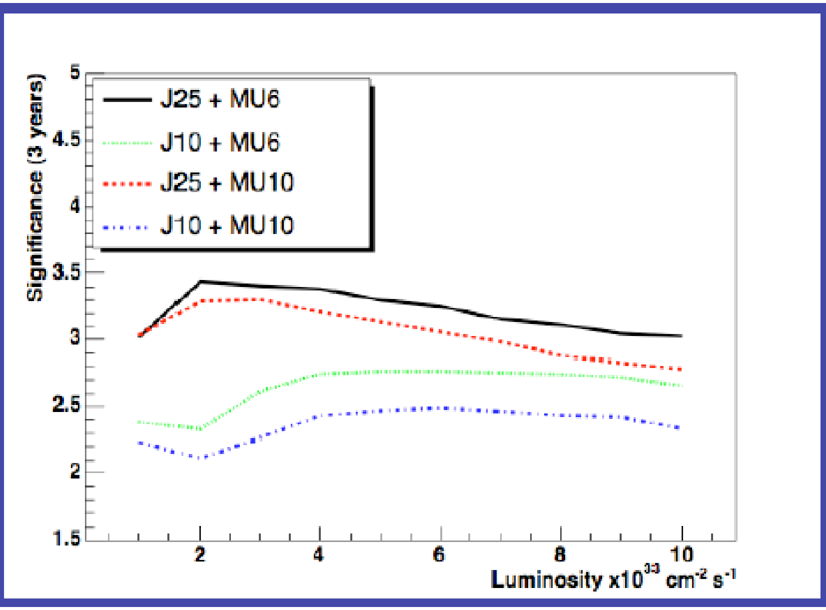
- 420m detectors too far away to be included in level 1, but information can be used at level 2 to substantially reduce the non-diffractive background by requiring two proton hits plus vertex matching from time-of-flight.

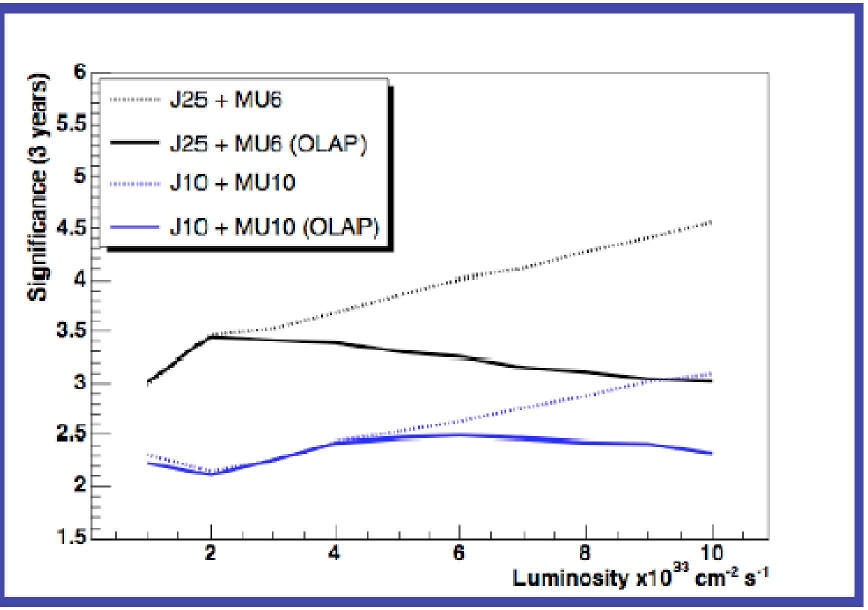
- Two triggers:
  - Low transverse momentum muon in conjunction with a 40 GeV jet (jet requirement to reduce rate at high luminosity). Notation MU6 = muon with $p_T > 6$ GeV.

  - Fixed L1 jet rate (pre-scaled if necessary) for jets that satisfy $E_T > 40$ GeV. Notation J10 = 10kHz rate at level 1.

- Efficiencies:
  - MU6 approximately 11%. MU10 approximately 6%.
  - J10 is 40% efficient at $L=10^{33}cm^{-2}s^{-1}$ and 4% efficient at $L=10^{34}cm^{-2}s^{-1}$.
  - J25 is 100% efficient at $L=10^{33}cm^{-2}s^{-1}$ and 10% efficient at $L=10^{34}cm^{-2}s^{-1}$.

Significance for 420+420

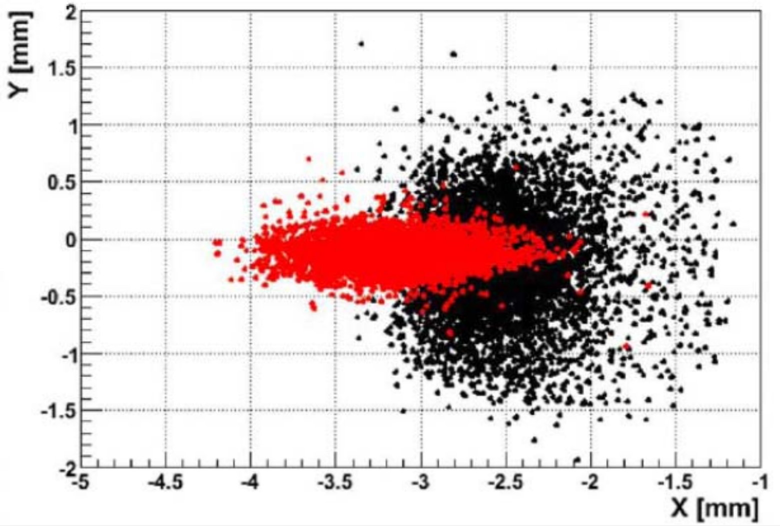




Machine induced background

- 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

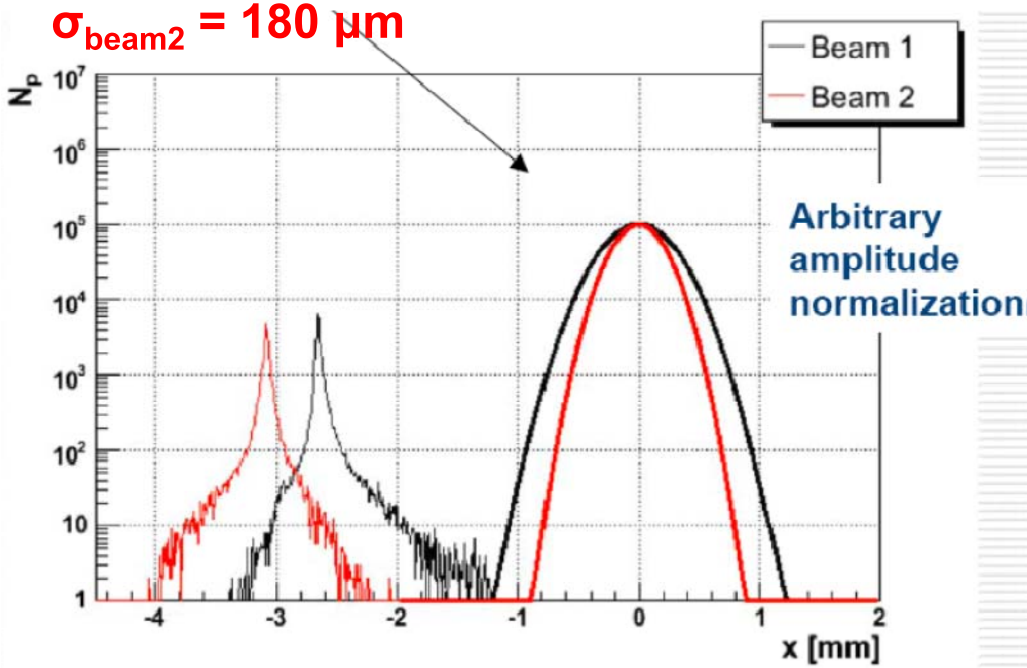
I Baishev, F. Roncarolo, K. Potter



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]

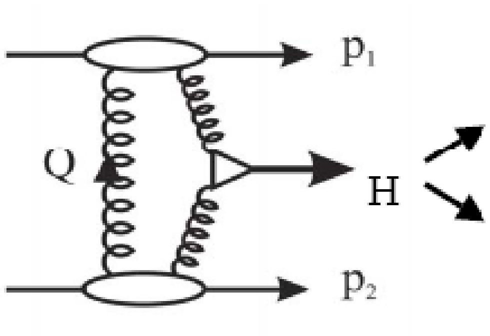
	p	n	π^+	π^-	e^+	e^-	γ
Pot at 220m	344	174	616	406	4630	3361	9.4×10^4

Upgrades of forward detectors at LHC

- FP420 is currently an R&D collaboration between ATLAS, CMS and non-affiliated groups.
- In addition, there is a strong, complementary program to upgrade the 220m region which adds value to 420m program
- Aim is to submit proposal for a sub-detector upgrade this year for 420m and 220m upgrades
- If accepted by ATLAS and / or CMS, this would lead to TDR from experiments late 2007 / early 2008
- The FP420 design phase is fully funded, and will be completed in summer 2007
- If funding is secured, cryostats (built by TS-MME) and baseline detectors could be ready for installation in Autumn 2008.
- However, more likely goal is autumn 2010
- 220m and 420m tagging detectors have the potential to add significantly to the discovery reach of ATLAS and CMS for modest cost, particularly in certain regions of MSSM parameter space
- There is a rich QCD and electroweak physics program in parallel with discovery physics

BACKUP SLIDES

Prime Motivation : Higgs Production



0⁺⁺ Selection rule

QCD Background ~ $\frac{m_b^2}{E_T^2}\,\frac{\alpha_S^2}{M_{b\bar{b}}^2 E_T^2}$

Higgs Quantum Numbers / mass resolution

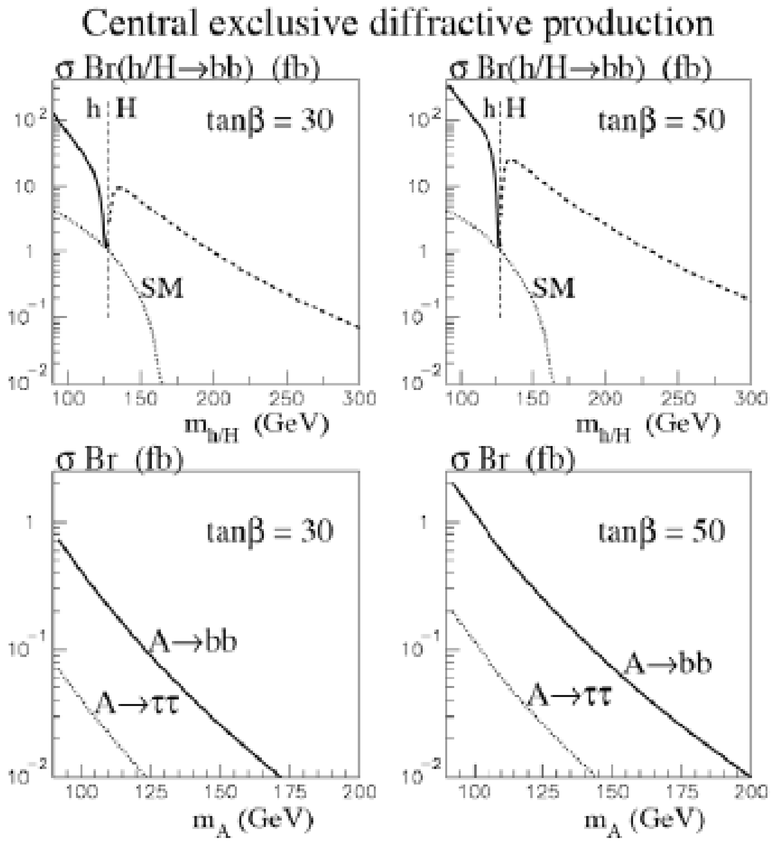
WW* : M_H = 120 GeV σ = 0.4 fb

M_H = 140 GeV σ = 1 fb

M_H = 200 GeV σ = 0.5 fb

M_H = 140 GeV : 5 (10) signal (1 (2) "gold platted" dl), very small backgrounds in 30 fb^{-1}

B.E. Cox. et al, Eur. Phys. J. C 45, 401-407 (2006)



M_A = 130 GeV, tan β = 50

M_h = 124 GeV : 71 signal in 30 fb^{-1}

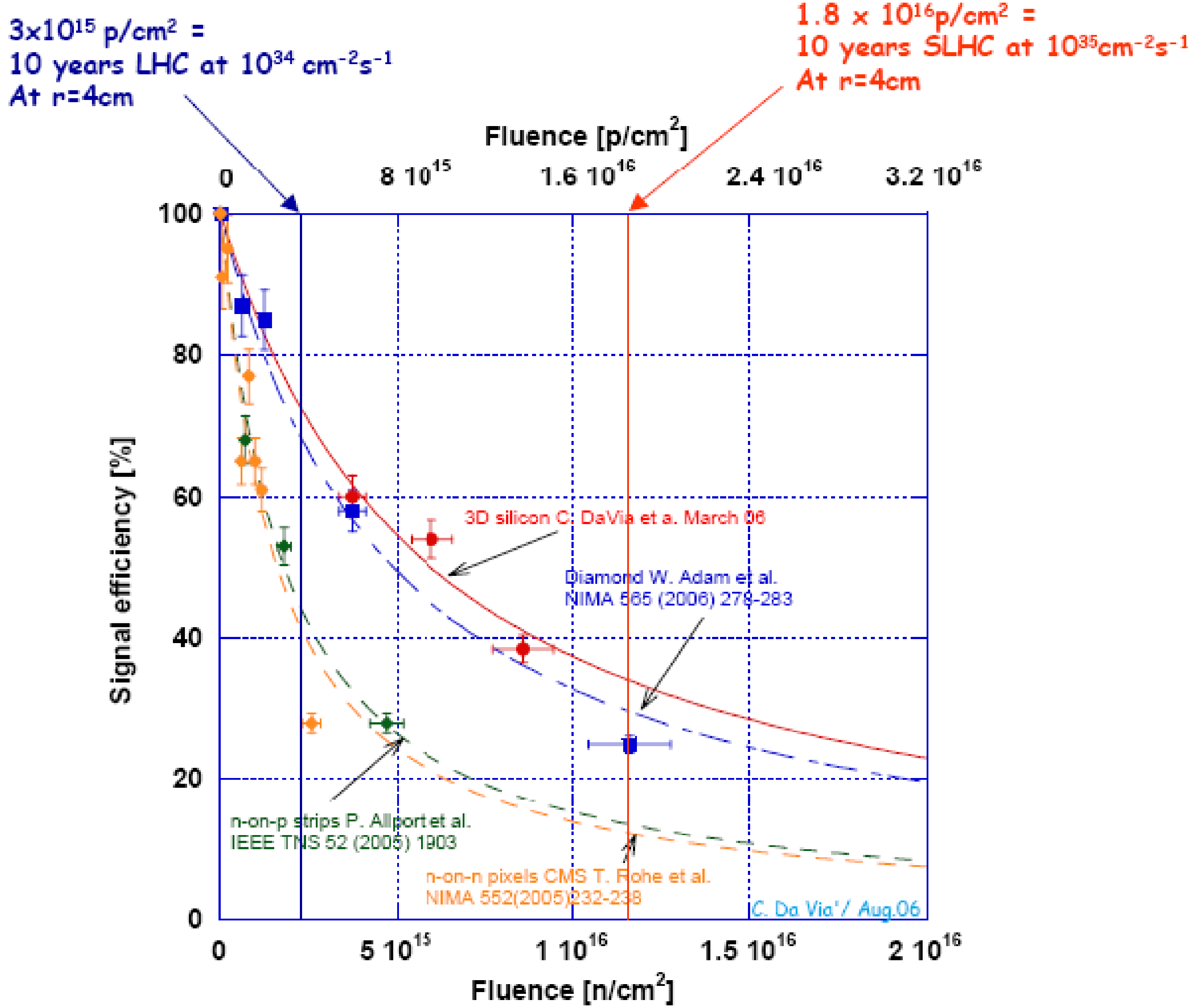
M_H = 135 GeV : 124 signal in 30 fb^{-1}

M_A = 130 GeV : 1 signal in 30 fb^{-1}

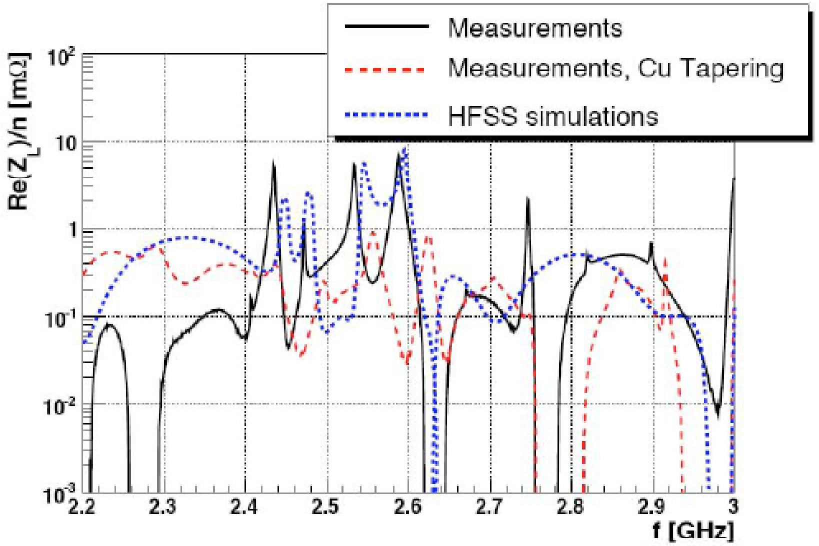
A. B. Kaidalov. et al, Eur.Phys.J. C33 (2004) 261-271

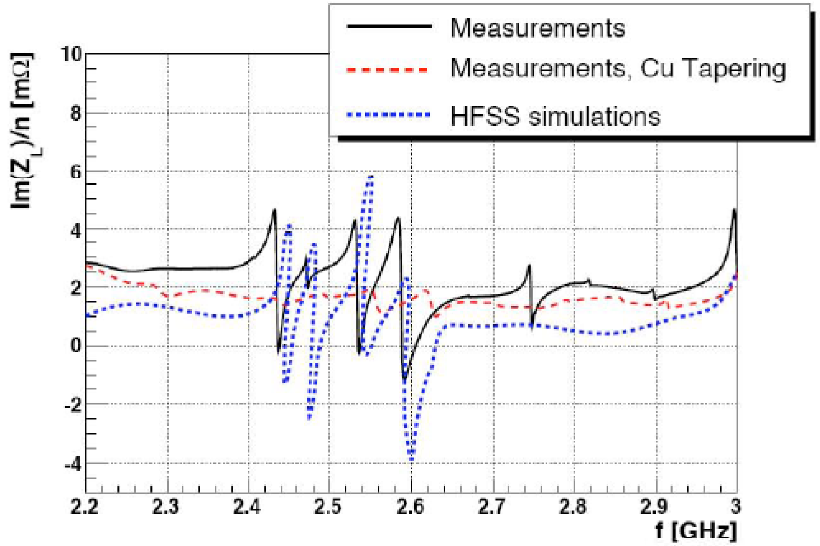
Radiation Hardness

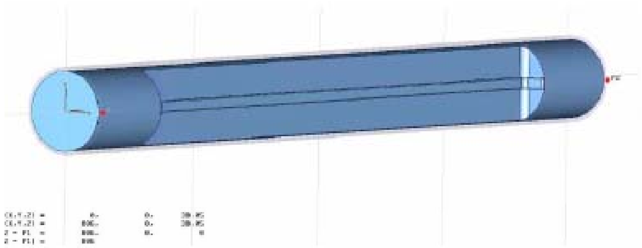
Cinzia DaVia – Hiroshima Conf. 2006

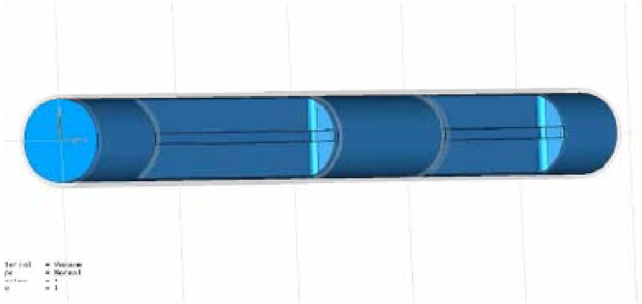


Impact of FP420 on LHC









Ran simulations and measurements for 2 geometries - very small impact on LHC impedance budget