New Forward Detectors for CMS

Krzysztof Piotrzkowski

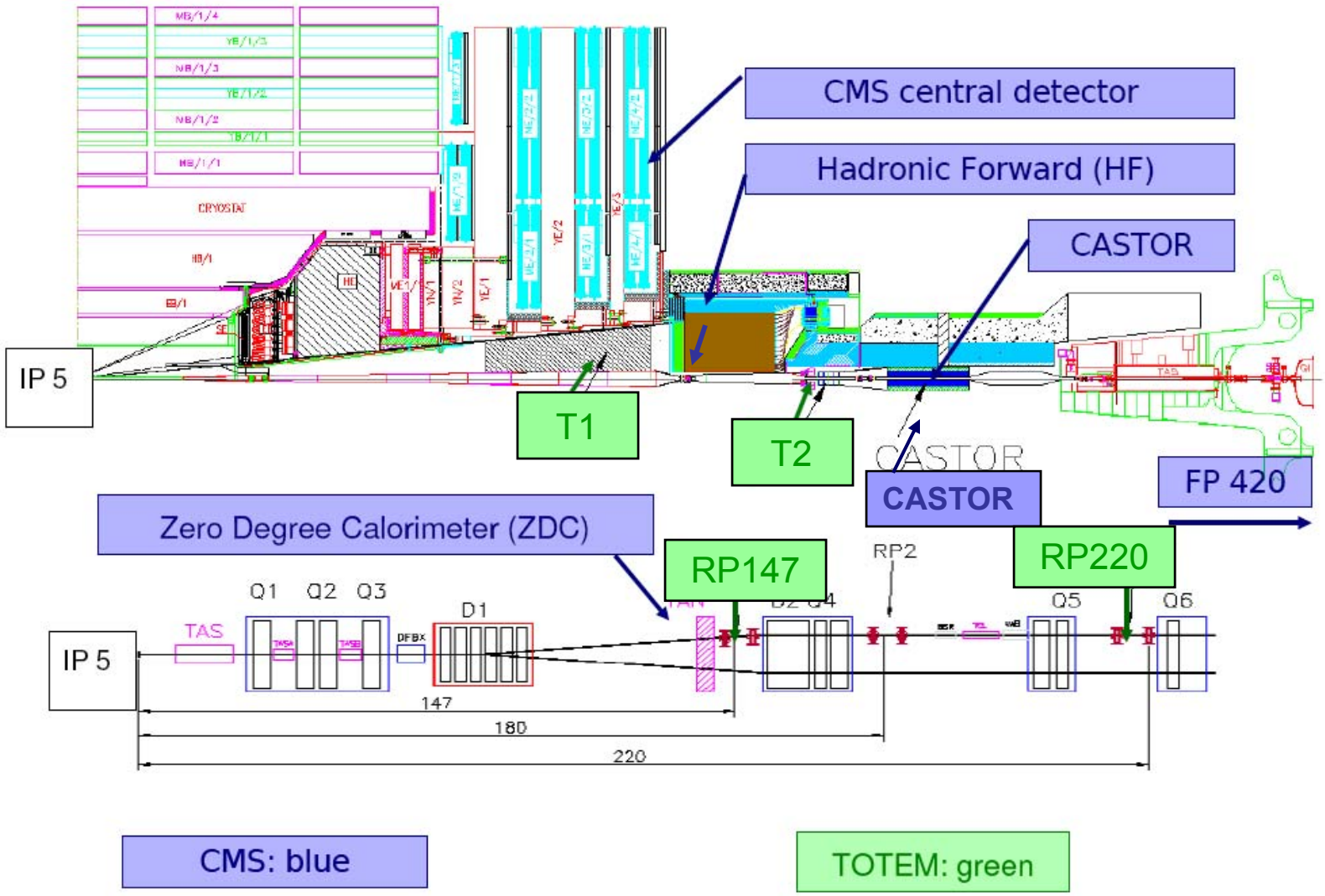
Universite Catholique de Louvain, CP3 Center

- Introduction: Forward view at CMS
- New forward proton detectors for CMS
- Summary/Outlook

XVII International Workshop on Deep-Inelastic Scattering and Related Subjects

Madrid, 26-30 April, 2009

Forward detectors @ IP5



Early forward physics @ CMS

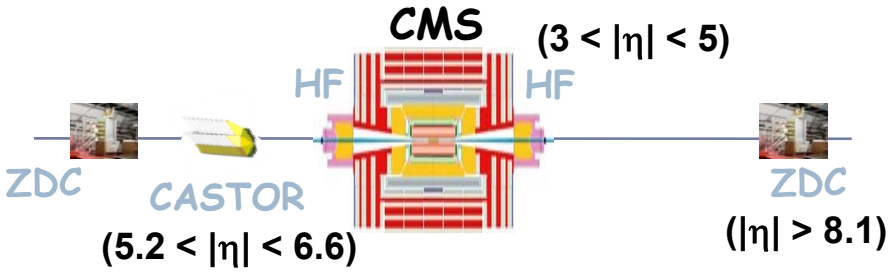
Low-x QCD with forward jets

Underlying event tuning & cosmic rays shower modeling

Exclusive di-jets, di-photons and di-leptons production & absolute luminosity measurements

Vector meson photoproduction

Observation of hard-diffraction



Physics with 1 pb^{-1} - 100 pb^{-1}

Use Large Rapidity Gap signatures

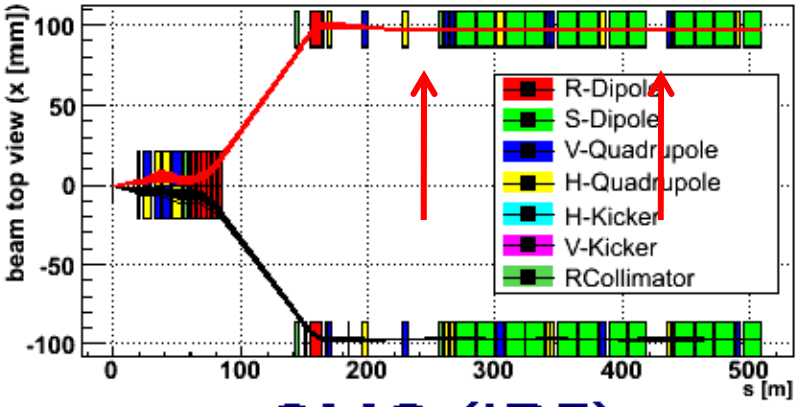
No pile-up conditions assumed

Beyond 2010 (with large event pileup) new techniques needed:

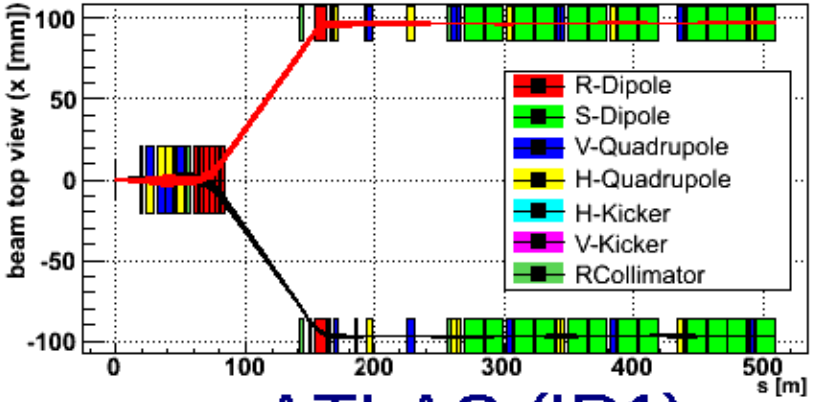
Forward proton detectors @ high-luminosity

Low cross-sections exclusive states: New Physics

Optimal places for tagging at the LHC: @ 220/240m and 420m from IP

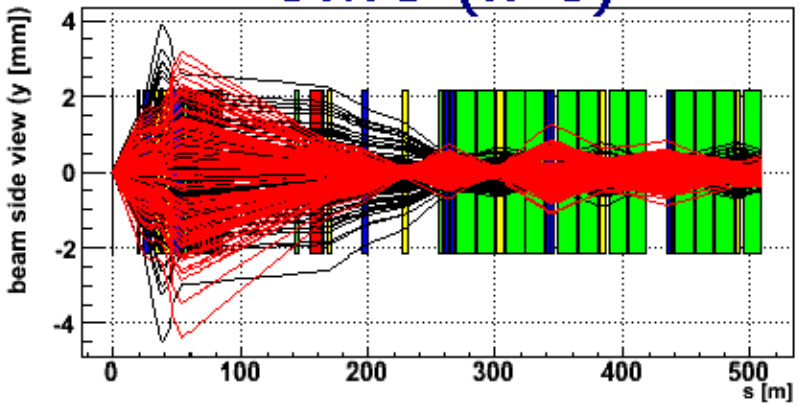


top

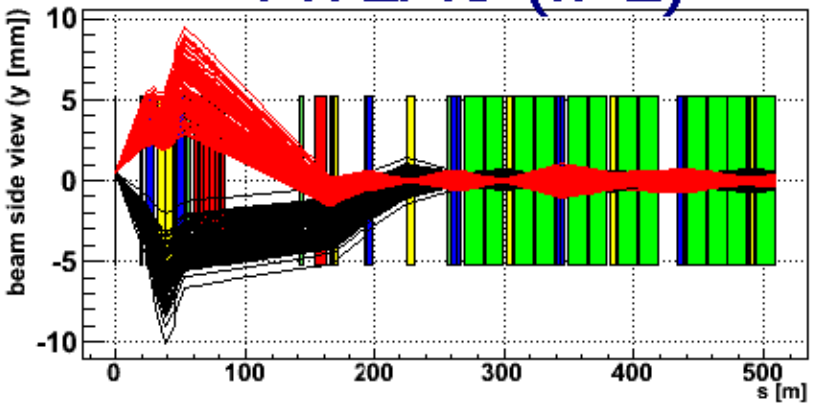


CMS (IP5)

ATLAS (IP1)



side



Horizontal crossing plane

Vertical crossing plane

HECTOR: **JINST 2, P09005 (2007)**

FP420 proposal

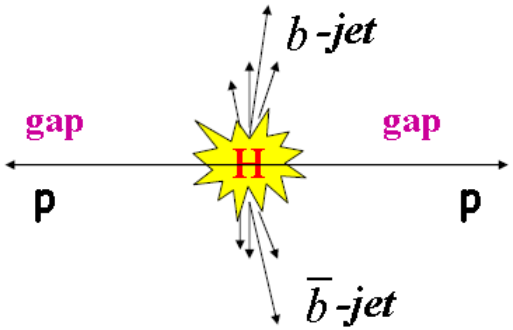
The FP420 R&D Project: Higgs and New Physics with forward protons at the LHC

M. G. Albrow[1], R. B. Appleby[2], M. Arneodo[3], G. Atoian[4], I.L. Azhgirey[5], R. Barlow[2], I.S. Bayshev[5], W. Beaumont[6], L. Bonnet[7], A. Brandt[8], P. Bussey[9], C. Buttar[9], J. M. Butterworth[10], M. Carter[11], B.E. Cox[2,], D. Dattola[12], C. Da Via[13], J. de Favereau[7], D. d'Enterria[14], P. De Remigis[12], A. De Roeck[14,6,*], E.A. De Wolf[6], P. Duarte[8,†], J. R. Ellis[14], B. Florins[7], J. R. Forshaw[13], J. Freestone[13], K. Goulianos[15], J. Gronberg[16], M. Grothe[17], J. F. Gunion[18], J. Hasi[13], S. Heinemeyer[19], J. J. Hollar[16], S. Houston[9], V. Issakov[4], R. M. Jones[2], M. Kelly[13], C. Kenney[20], V.A. Khoze[21], S. Kolya[13], N. Konstantinidis[10], H. Kowalski[22], H.E. Larsen[23], V. Lemaitre[7], S.-L. Liu[24], A. Lyapine[10], F.K. Loebinger[13], R. Marshall[13], A. D. Martin[21], J. Monk[10], I. Nasteva[13], P. Nemegeer[7], M. M. Obertino[3], R. Orava[25], V. O'Shea[9], S. Ovyn[7], A. Pal[8], S. Parker[20], J. Pater[13], A.-L. Perrot[26], T. Pierzchala[7], A. D. Pilkington[13], J. Pinfold[24], K. Piotrzkowski[7], W. Plano[13], A. Poblaguev[4], V. Popov[27], K. M. Potter[2], S. Rescia[28], F. Roncarolo[2], A. Rostovtsev[27], X. Rouby[7], M. Ruspa[3], M.G. Ryskin[21], A. Santoro[29], N. Schul[7], G. Sellers[2], A. Solano[23], S. Spivey[8], W.J. Stirling[21], D. Swoboda[26], M. Tasevsky[30], R. Thompson[13], T. Tsang[28], P. Van Mechelen[6], A. Vilela Pereira[23], S.J. Watts[13], M. R. M. Warren[10], G. Weiglein[21], T. Wengler[13], S.N. White[28], B. Winter[11], Y. Yao[24], D. Zaborov[27], A. Zampieri[12], M. Zeller[4], A. Zhokin[6,27]*

FP420 R&D Collaboration

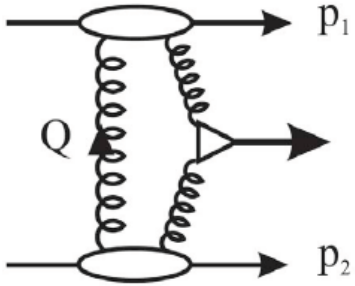
To appear in *JINST*

Exclusive Higgs bosons at LHC

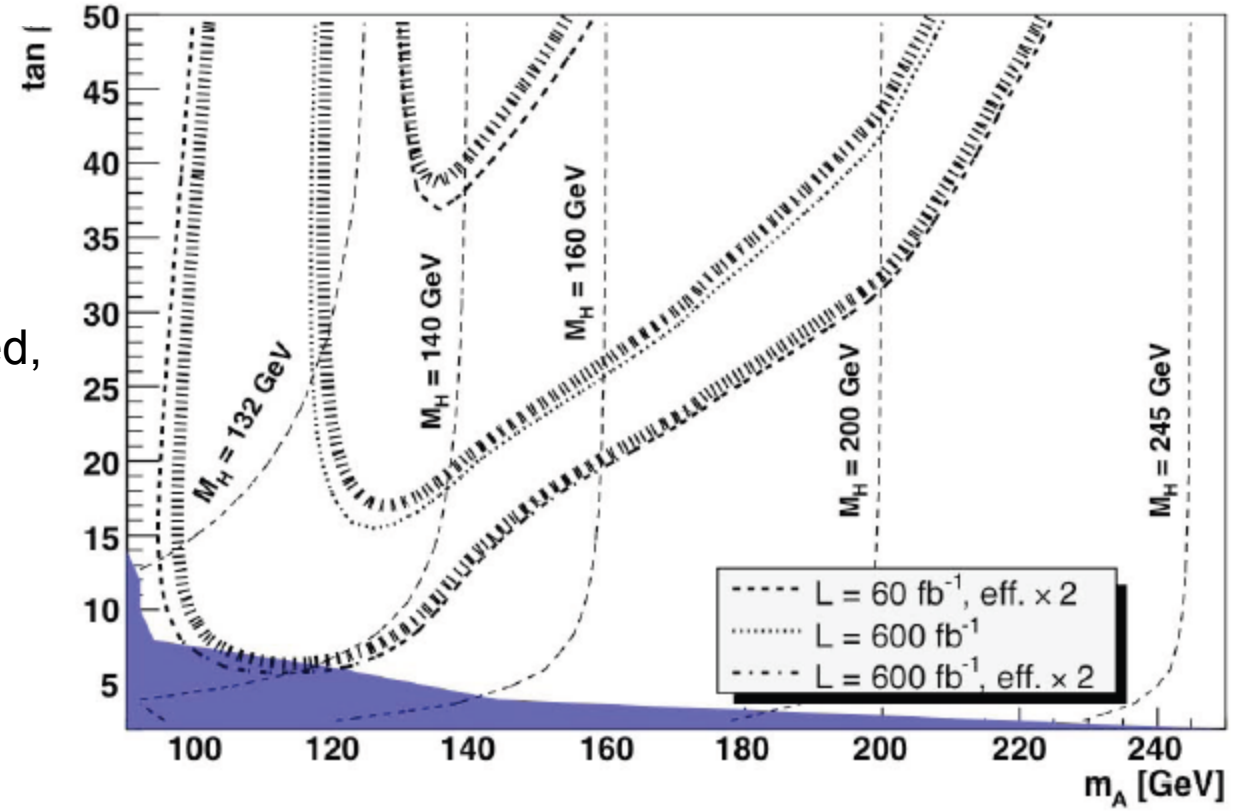


Main motivation for FP420

Higgs kinematics fully reconstructed with forward detectors! Access to Higgs mass and quantum numbers.

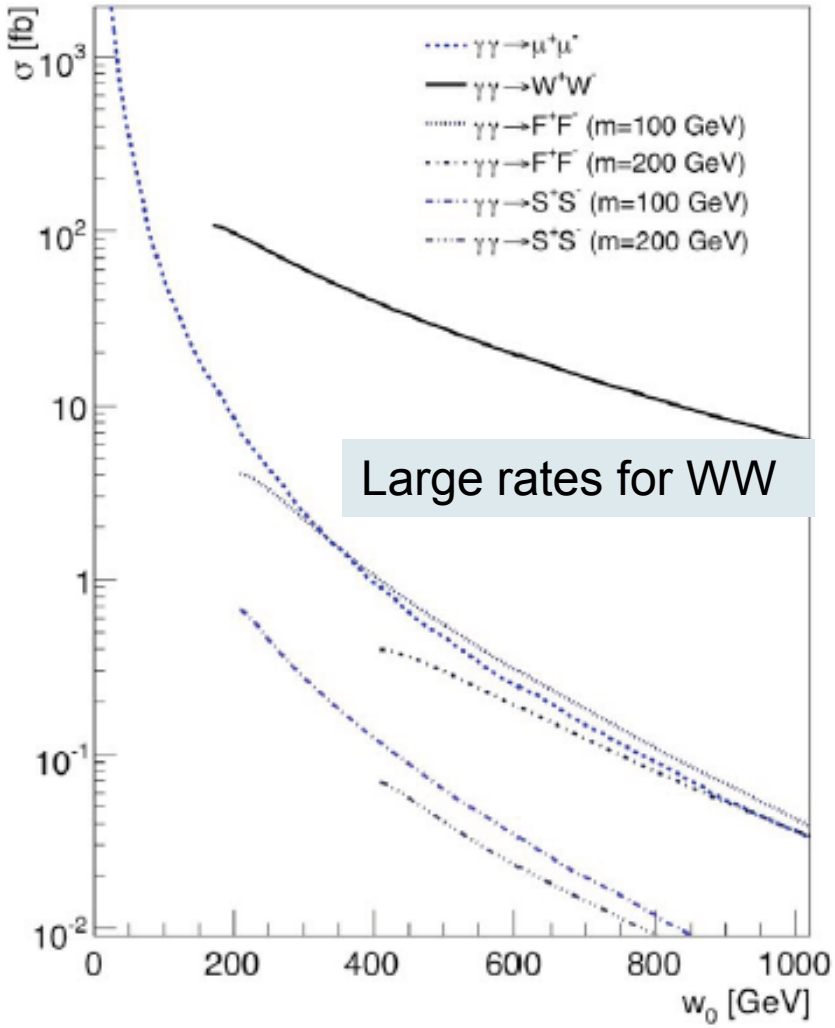


SM Higgs signal statistically limited, larger for MSSM case:



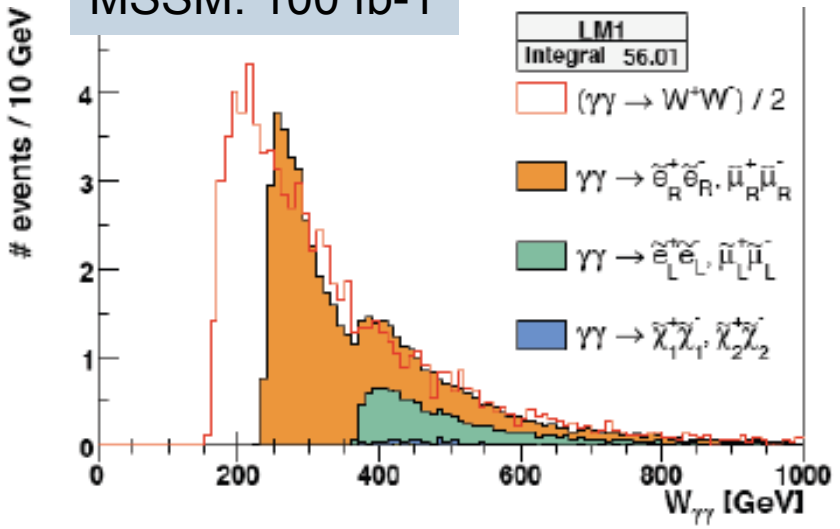
5σ H → bb, M_h^{max}, μ = +200 GeV, arXiv:0708.3052

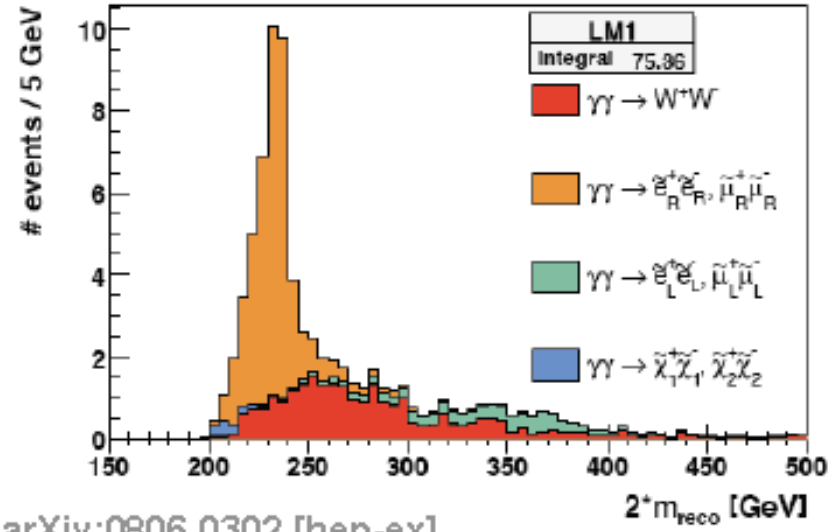
Two-photon physics



Large rates for WW

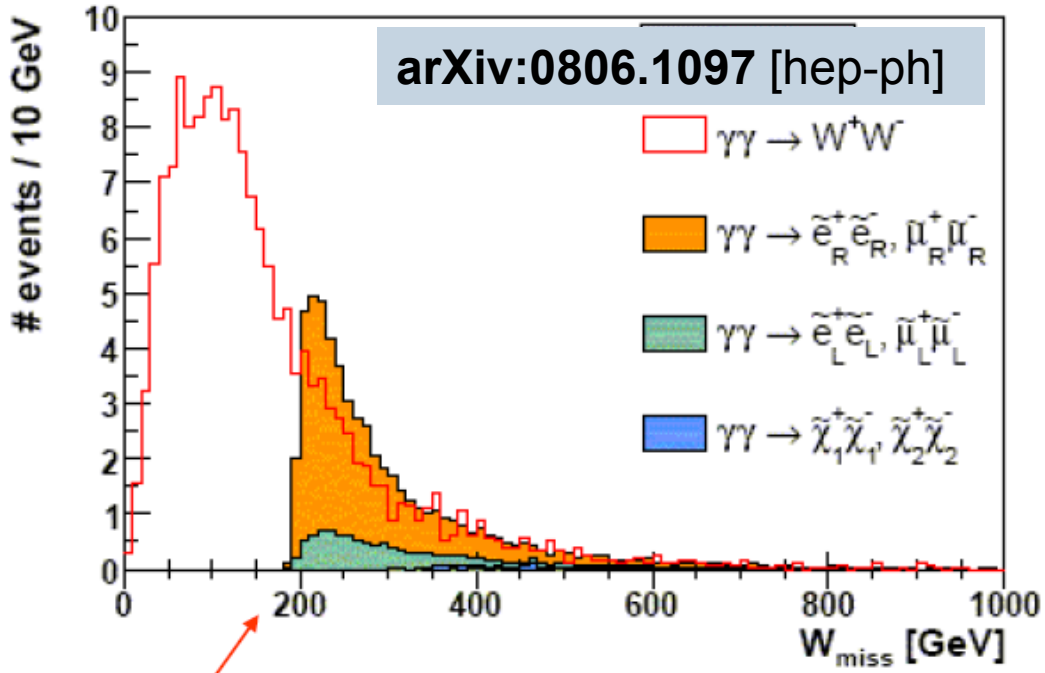
MSSM: 100 fb-1





:iv:0808.0322 [hep-ph],arXiv:0806.1097 [hep-ph], arXiv:0806.0302 [hep-ex]

(Light) SUSY case



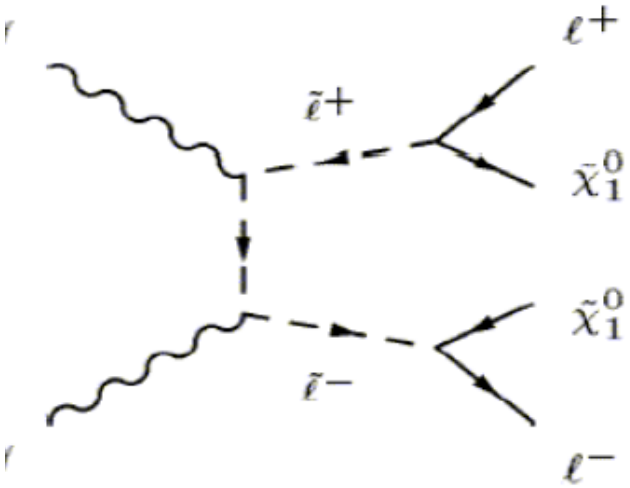


Figure 3. Distribution of missing invariant mass W_{miss} for the LM1 MSSM benchmark for the integrated luminosity L = 100 fb^{-1}. It starts at about 2 m_{LSP} for SUSY, at zero for the WW background.

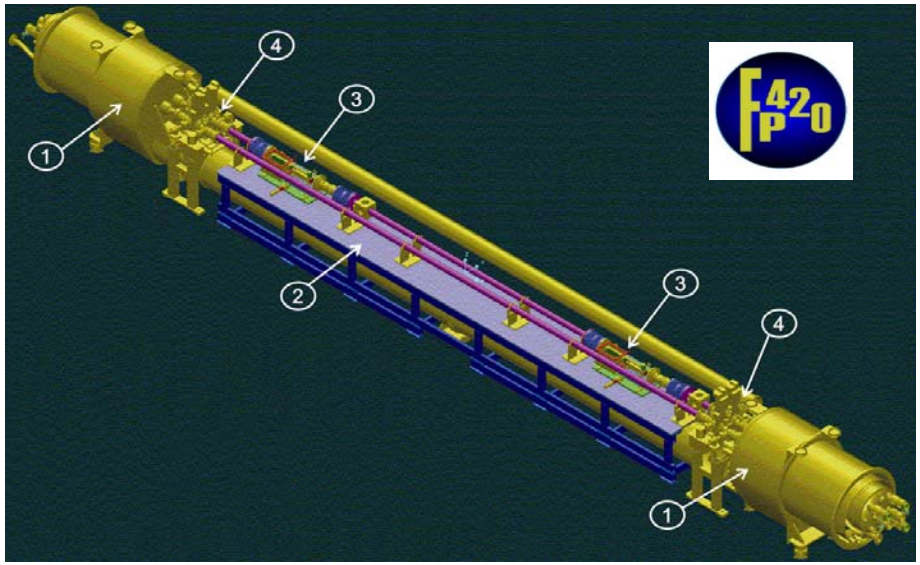
$$W_{miss} = \sqrt{E^2_{miss} - P^2_{miss}}$$

Forward detectors crucial for kinematics reconstruction (charged dilepton states only!):

Unique contribution!

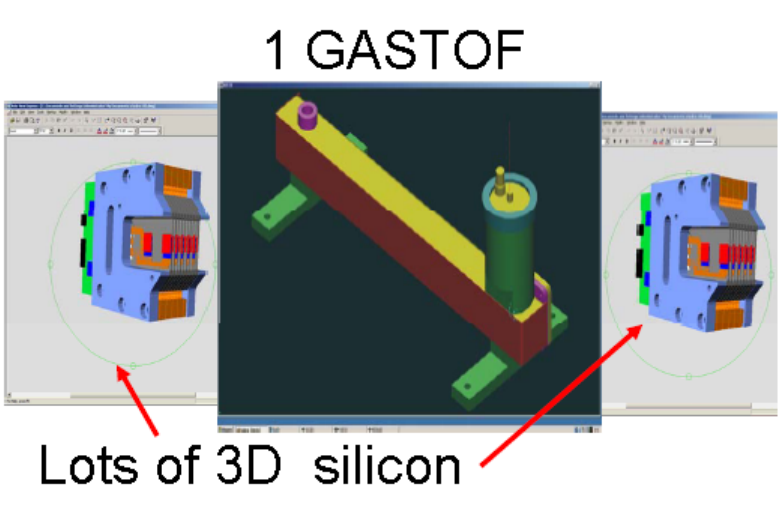
Forward proton detectors @ 420 m

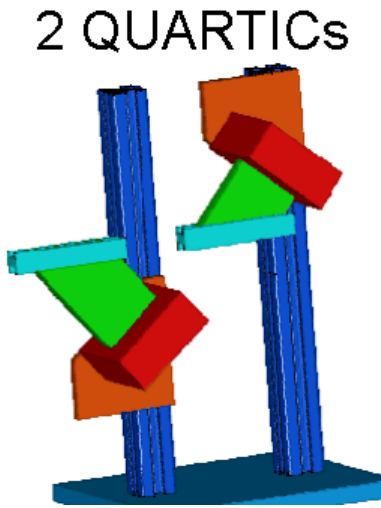
- Installation of Si detectors in cryogenic region of LHC, i.e. cryostat redesign needed
- Strict space limitations rule out Roman Pot technology, use movable beampipe instead
- Radiation hardness required of Si is comparable to those at SLHC, use novel 3-D Silicon technology
- To control pile-up background use very fast timing detectors ($\sigma \sim 10$ps)



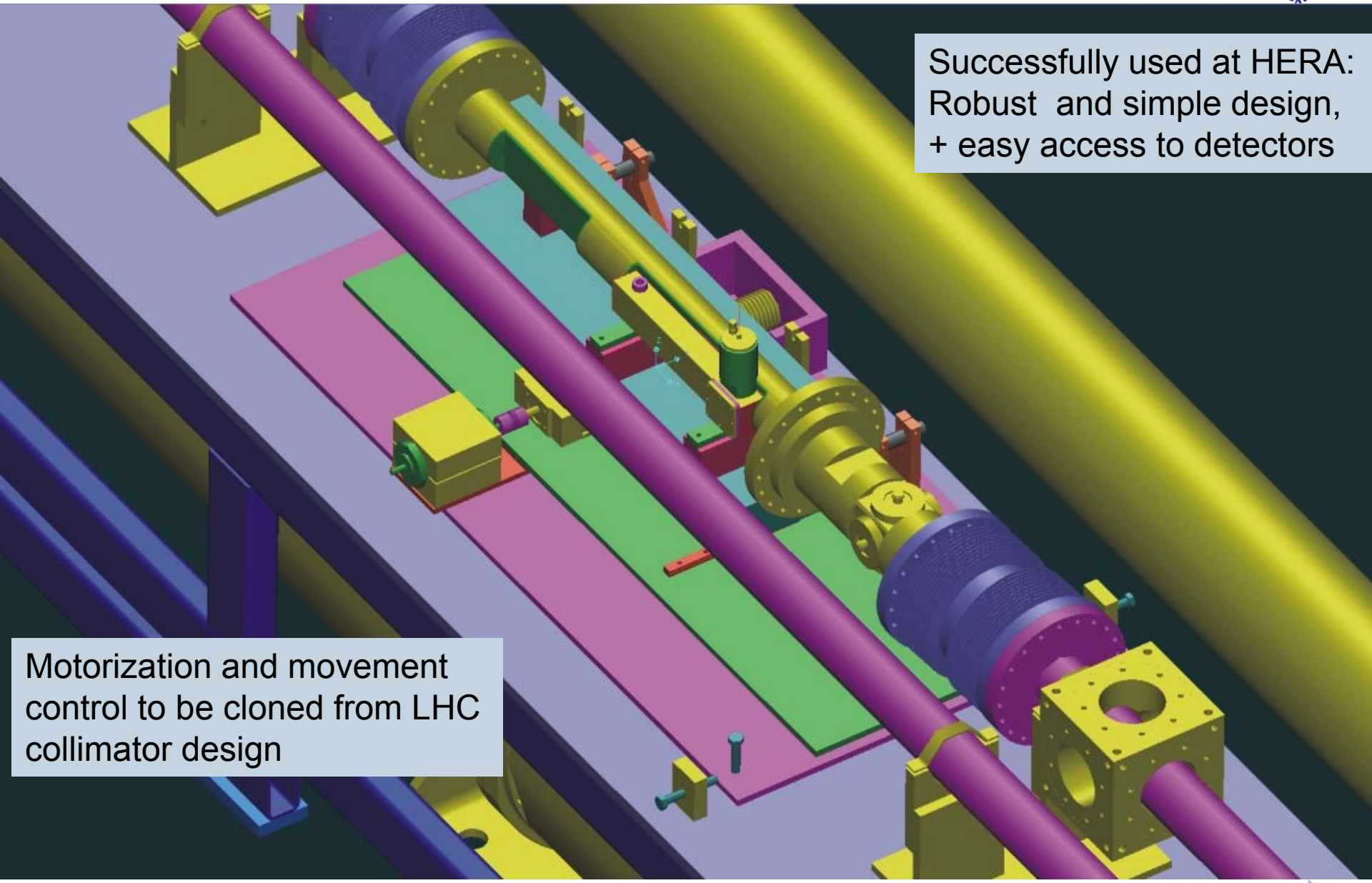
Acceptance: (At nominal LHC $\beta^* = 0.5$ m)
$0.002 < \xi < 0.02$

Two detector stations per arm (4 in total): each station contain tracking and timing detectors





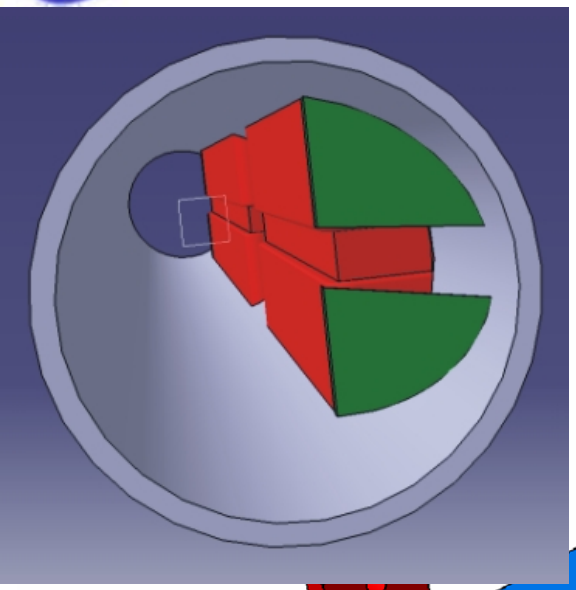
Moving Hamburg pipe concept



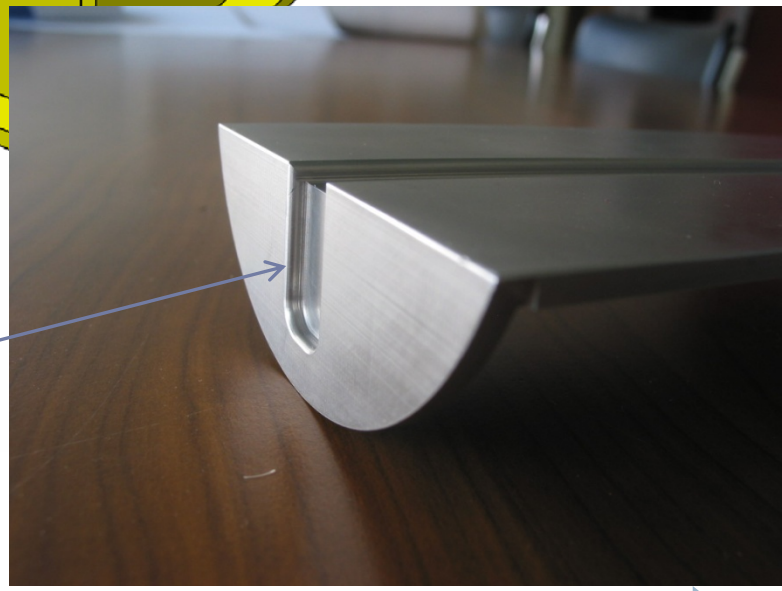
Successfully used at HERA:
Robust and simple design,
+ easy access to detectors

Motorization and movement control to be cloned from LHC collimator design

Moving pipe: Detector ‘pockets’



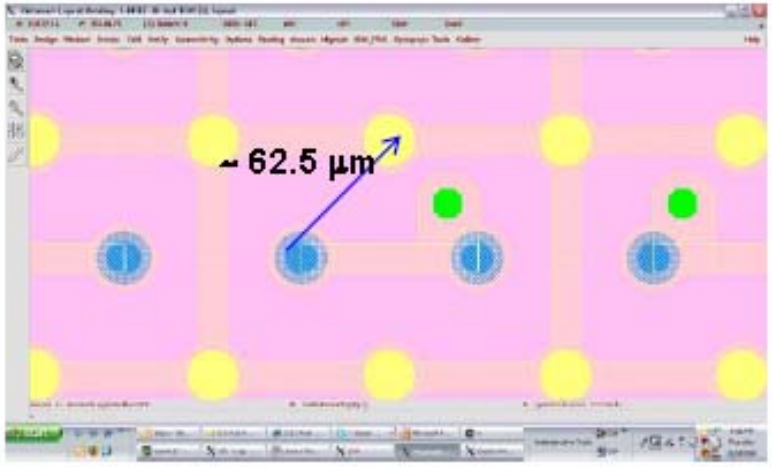
In preparation for 2009 beam tests:

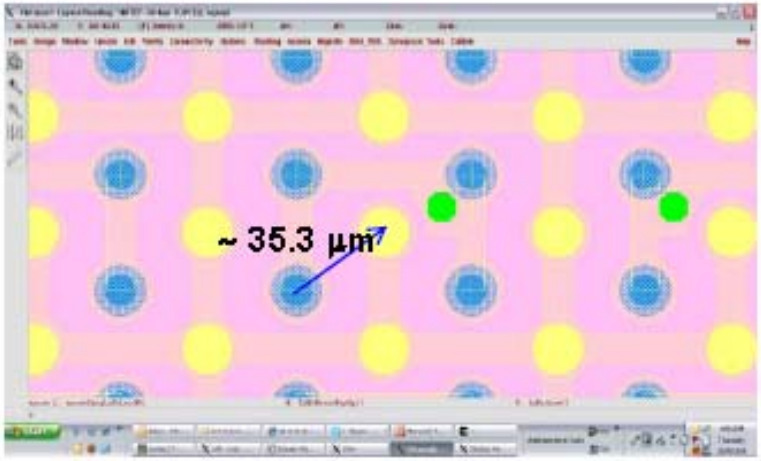


Thin ~ 300 μm entrance and side windows

CMS 3 D configurations

BOLLA, PURDUE





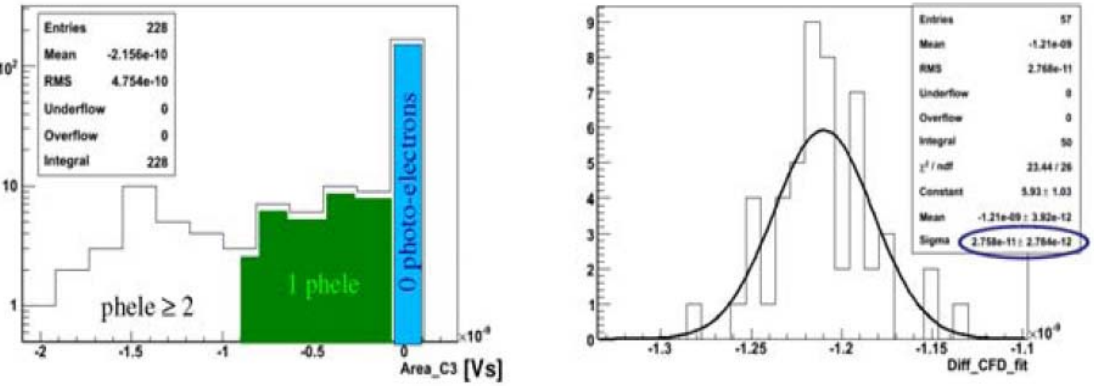
- CMS PSI46 100 µm ×150 µm
- Implemented 2 variations
  - 2 columns pixel
  - 4 columns pixel

Profit from CMS R&D for SLHC:

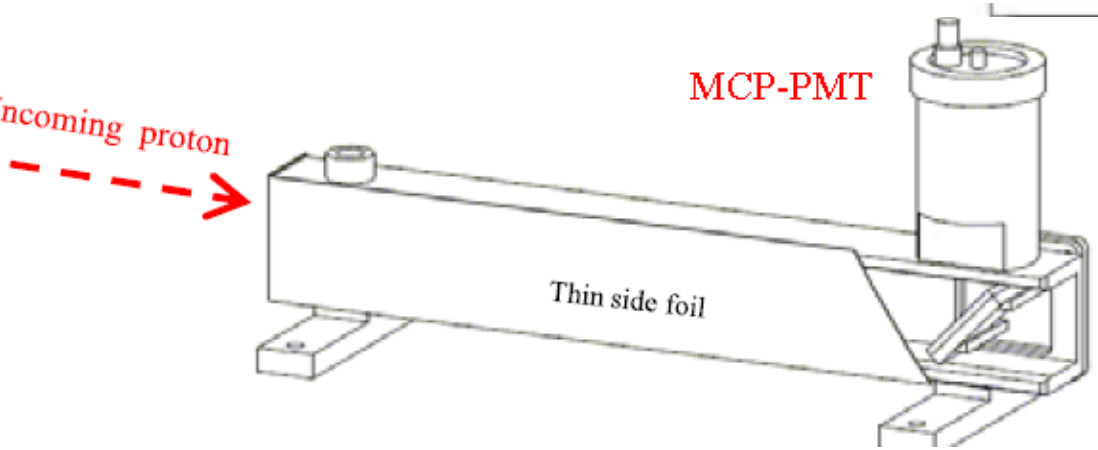
Beam tests of first 3D modules with CMS pixel chips planned this summer

GasToF News: Cosmic-ray tests

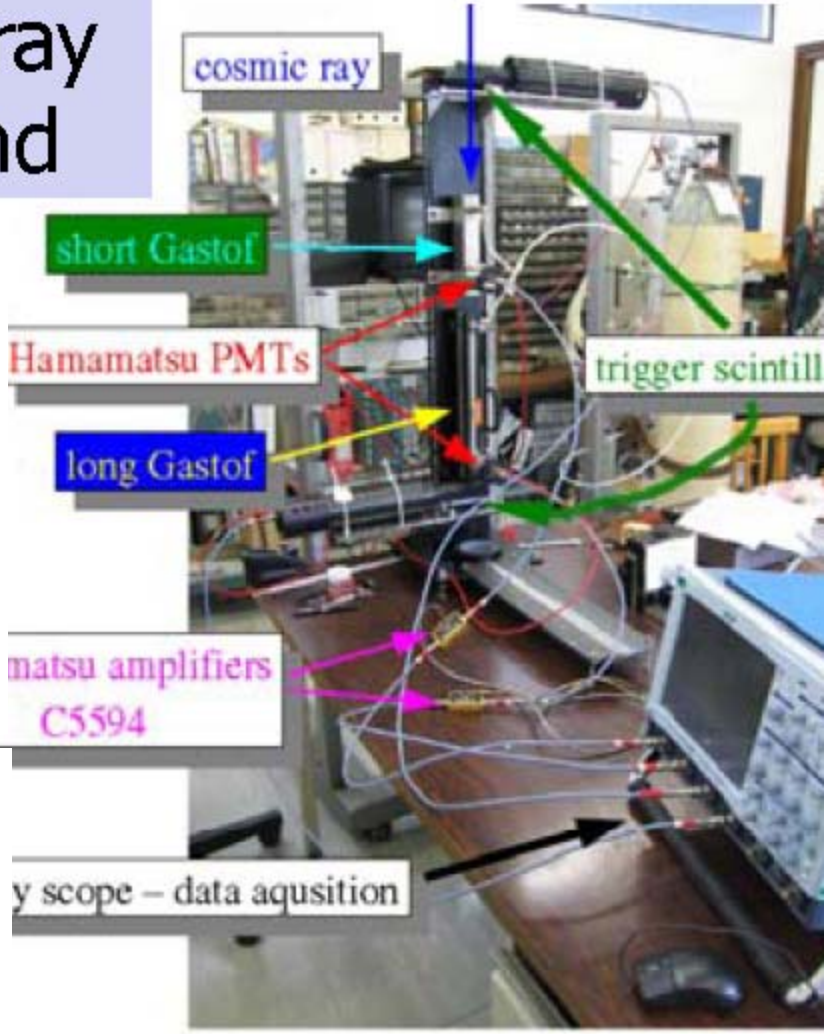
From TIPP09 (KEK, March):
Resolution < 20 ps for 1 p.e.!



Two Gastof detectors are coupled to R3809U-50 MCP-PMTs. Anode charge distribution (on 50 Ω) of a Gastof detector (left plot) shows two peaks corresponding to 1 and 2 photoelectrons, and the measured time difference spread (right plot) corresponds to a single detector resolution below 20 ps. The MCP-PMTs were operated at 3000 V.

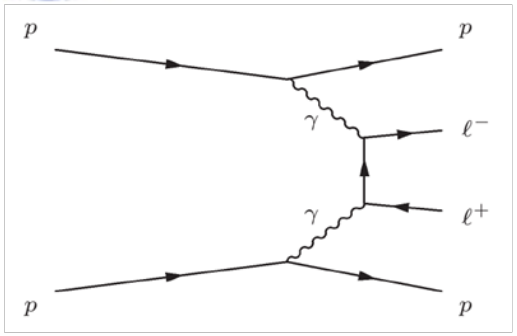


Cosmic ray test stand



Quartic at test-beam in May

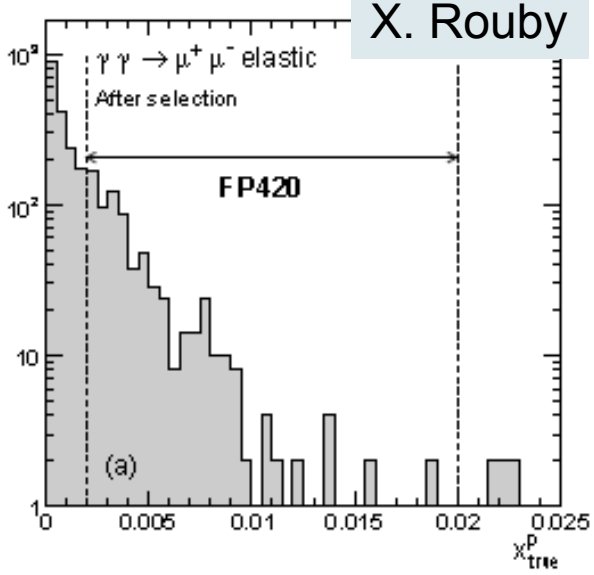
Calibration with exclusive di-muons



pp → pp l^+l^-

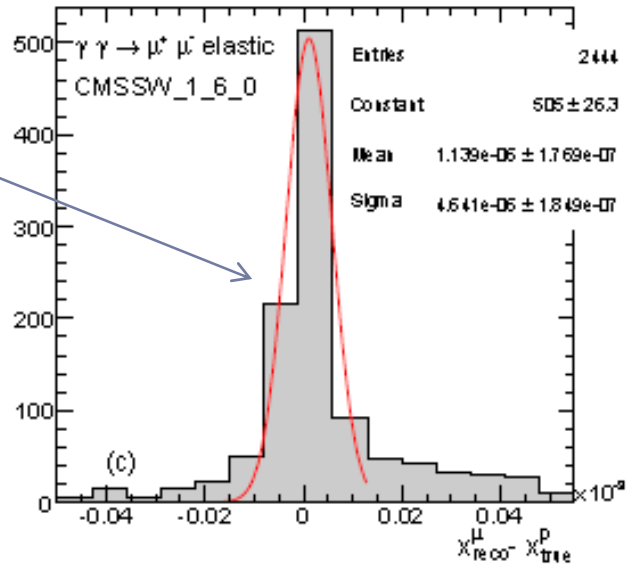
~ 700 μμ events in 100 pb^{-1}
(single-interaction data @ 14TeV)

X. Rouby



- Nearly pure QED process
- Calibration/alignment of FP420 detectors (about 40% protons detected!):

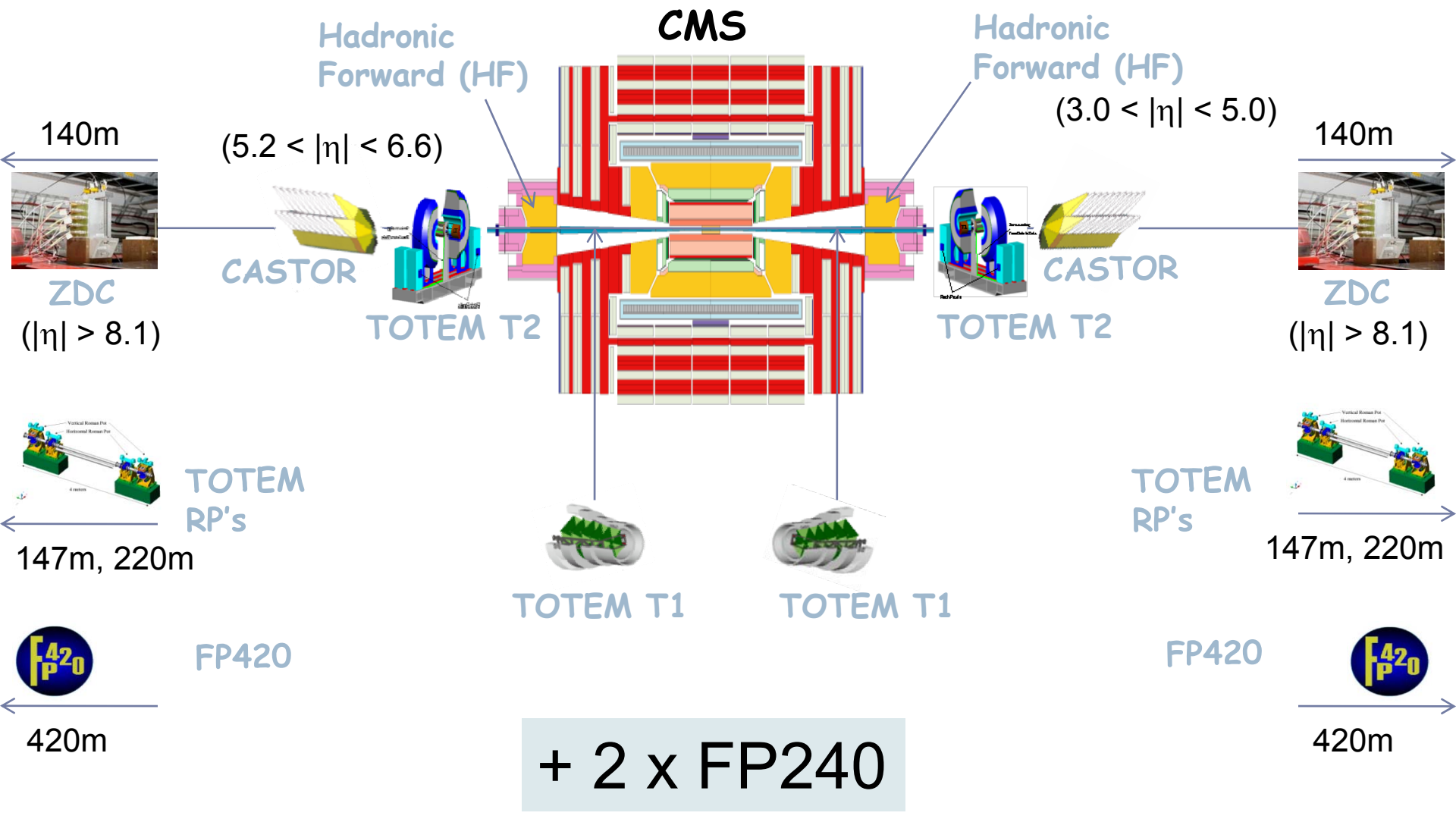
Expected resolution of x=Eγ/E is ~5.10-6 !



Calibration procedure itself can be very well controlled using exclusive Upsilon data!

BOTTOMLINE:
Exclusive low-mass dimuons crucial for FP420

Forward detectors @ IP5



+ 2 x FP240

Motivation for FP240

- Tagging at 420m and 220/240m is complementary – together $\sim 0.1\text{–}10\%$ energy loss range is covered !

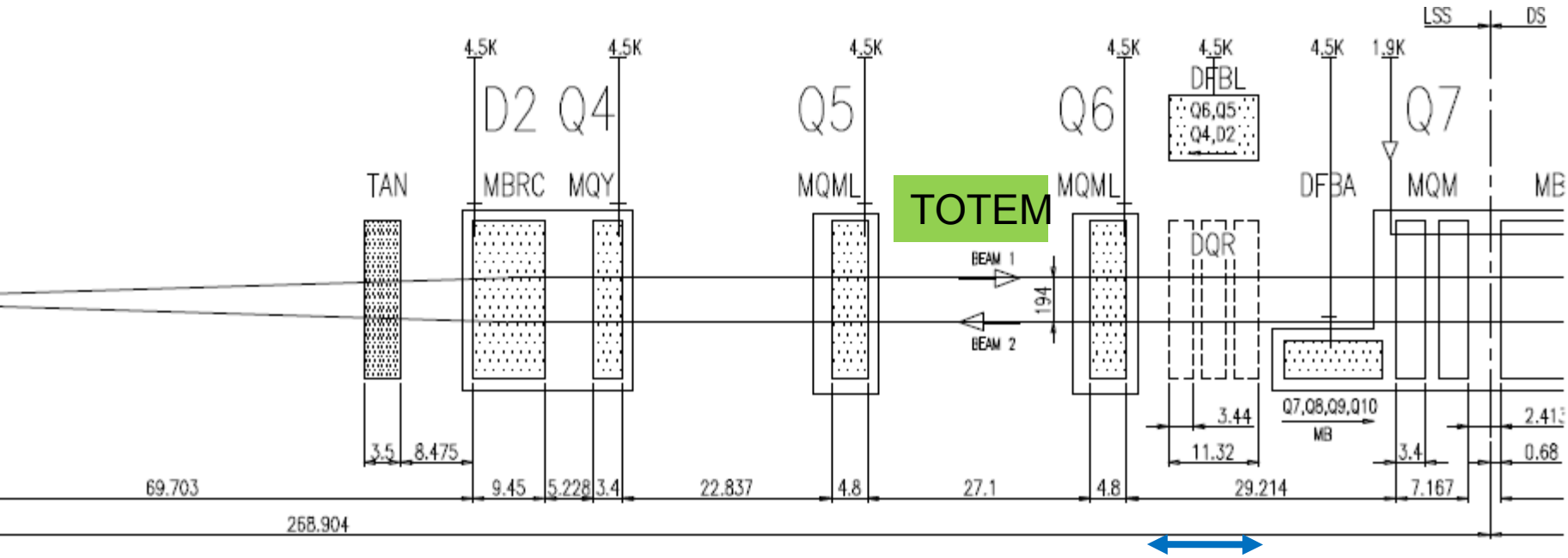
- This leads to significantly higher tagged cross sections

- Both 240 m locations are 'warm&free' – just bare beam-pipes

- At IP5, locations at 220 m are occupied by TOTEM -> go at 240m - it is still possible to send triggers to CMS!

- One does not need to modify the LHC beamline -> can be done before FP420 and be treated as *proof-of-principle* project + interesting physics as a bonus

LHC beam-line close to 240 m



Available space of ~ 12 m !

Summary/Outlook

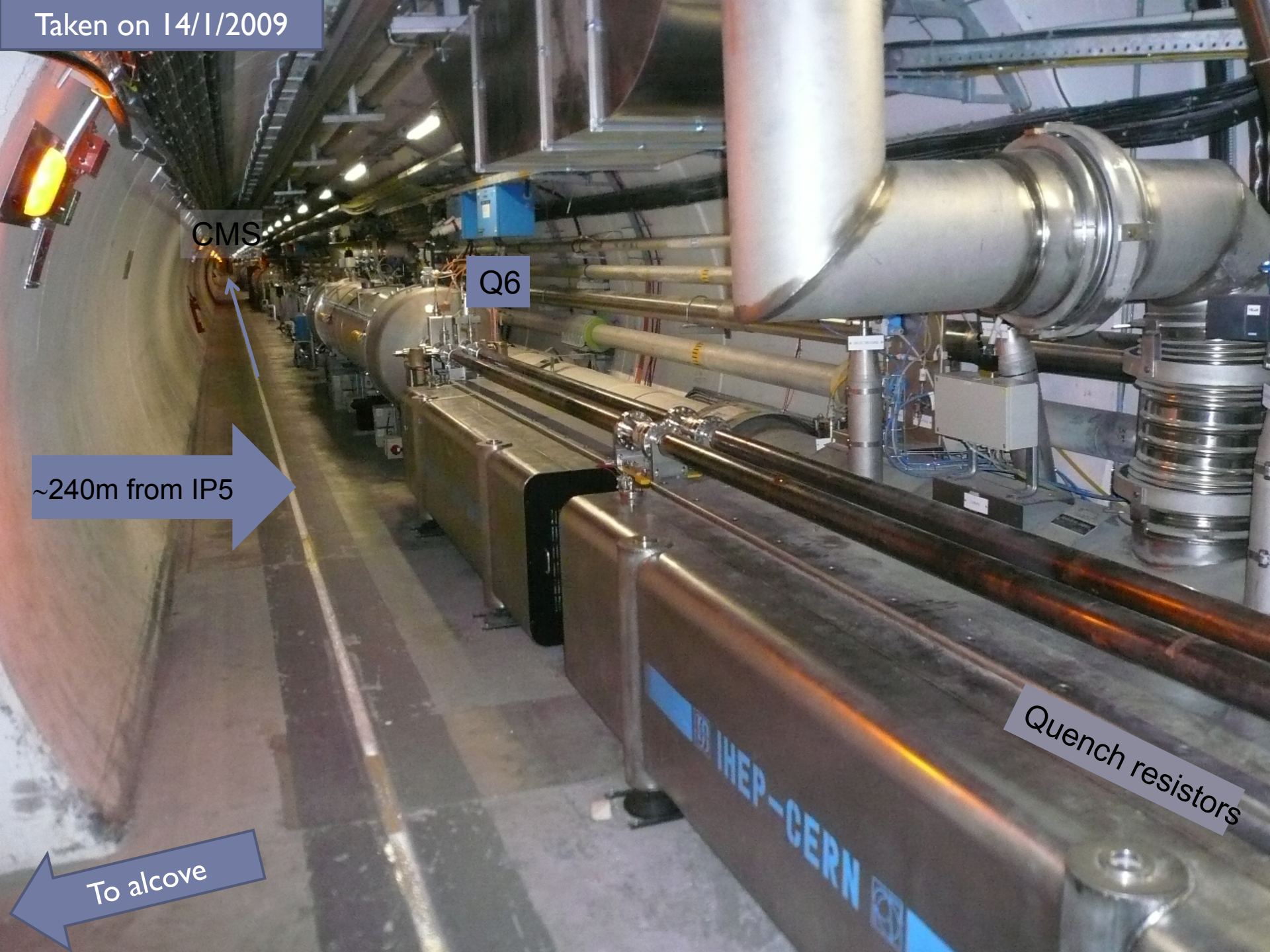
• The FP420 R&D report published, is basis of the CMS (and ATLAS) FP420 proposal

• The R&D phase ends with a complete cryostat design and a prototyped, tested concept for high precision near-beam detectors at LHC

• CMS evaluated the FP420 proposal and asked for some further work before preparation of TDR – we are in position to start it now; we will propose to include FP240 detectors

• The physics case for forward proton tagging spans central exclusive production, $\gamma\gamma$ and photon-proton physics, diffractive physics, gap survival /underlying event, study of gluon jets …..

• For low incremental cost, forward proton detectors add significant physics potential to CMS with no effect on the operation of the LHC.


Taken on 14/1/2009
CMS
Q6
~240m from IP5
Quench resistors
To alcove
IHEP-CERN