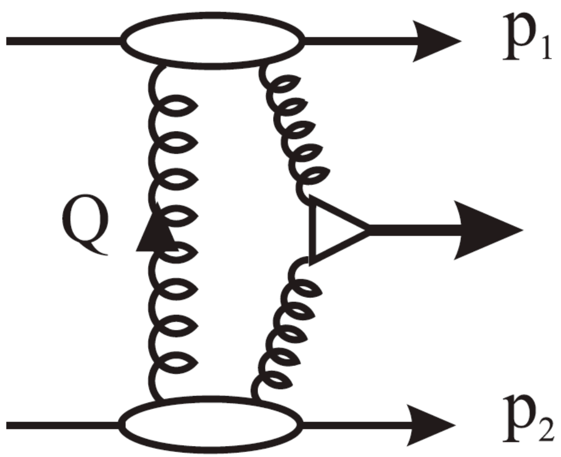
MANCHESTER 1824

The University of Manchester

Forward Proton Tagging at the LHC

1. There are no known remaining technical issues to installing FP420 and operating at the highest LHC design luminosity
2. FP420 can detect the decay of Higgs bosons in the b, τ and W channels, significantly enhancing the discovery potential of the LHC



FP420 R&D Funding (ATLAS & CMS) :

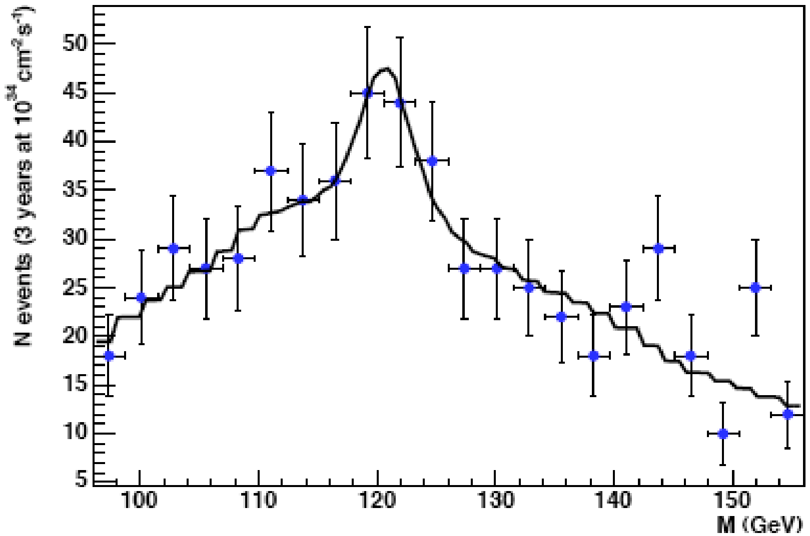
"The panel believed that this offers a unique opportunity to extend the potential of the LHC and has the potential to give a high scientific return." - UK PPRP (PPARC)

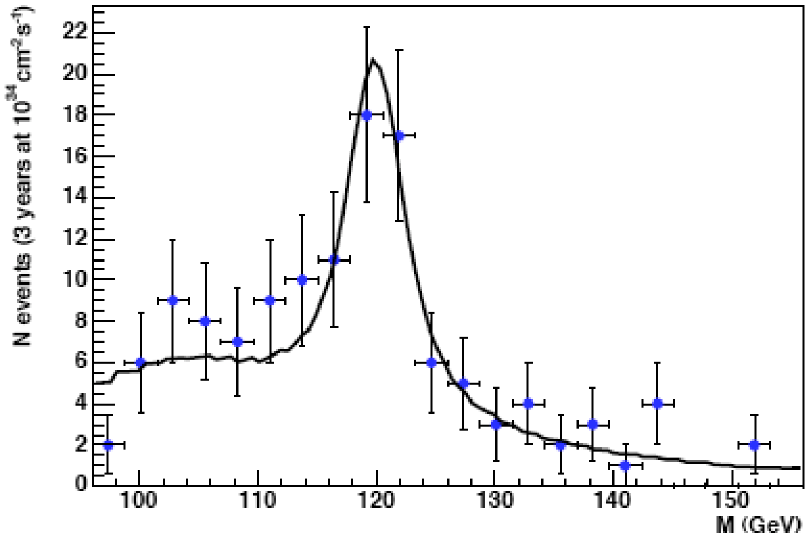
R&D funding : £500k from UK (Silicon, detector stations, beam pipe + LHC optics and cryostat design), $100k from US / Canada (QUARTIC, UTA/FNAL/Alberta), €100k Belgium (+Italy / Finland) (mechanics)

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, tanβ = 40, 300fb^{-1} @ 10^{34} cm^{-2}s^{-1}, $\sigma_{h\text{->}bb}$ =20 fb)





The critical challenge:

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

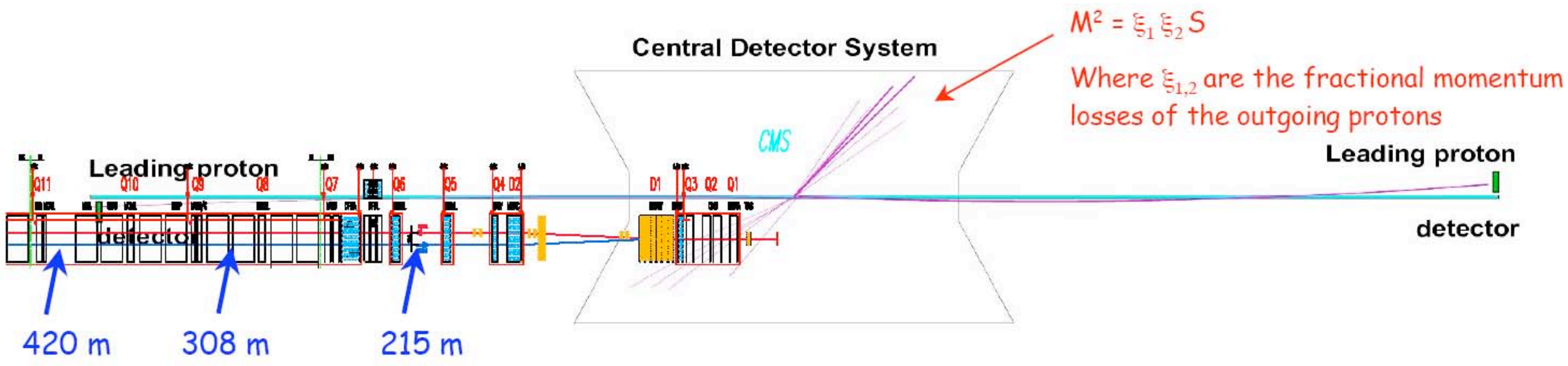
Bottom line : Higgs -> b-jets can be detected if σ > 10 fb

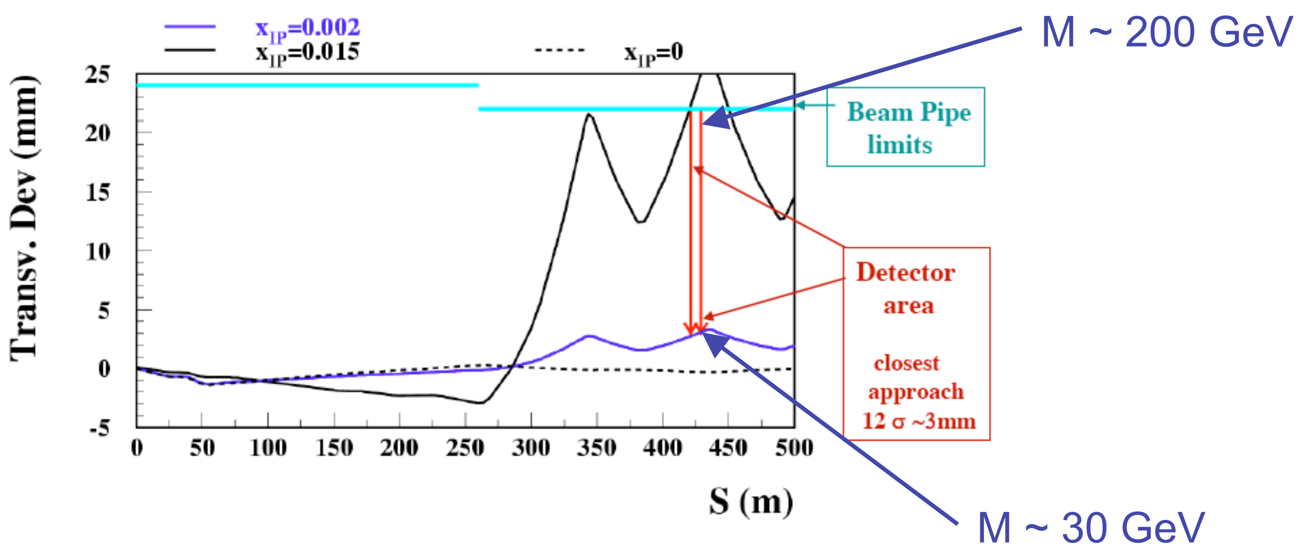
Better than 1 GeV mass resolution in certain MSSM scenarios

Cox, Loebinger & Pilkington, arXiv:0709.3035

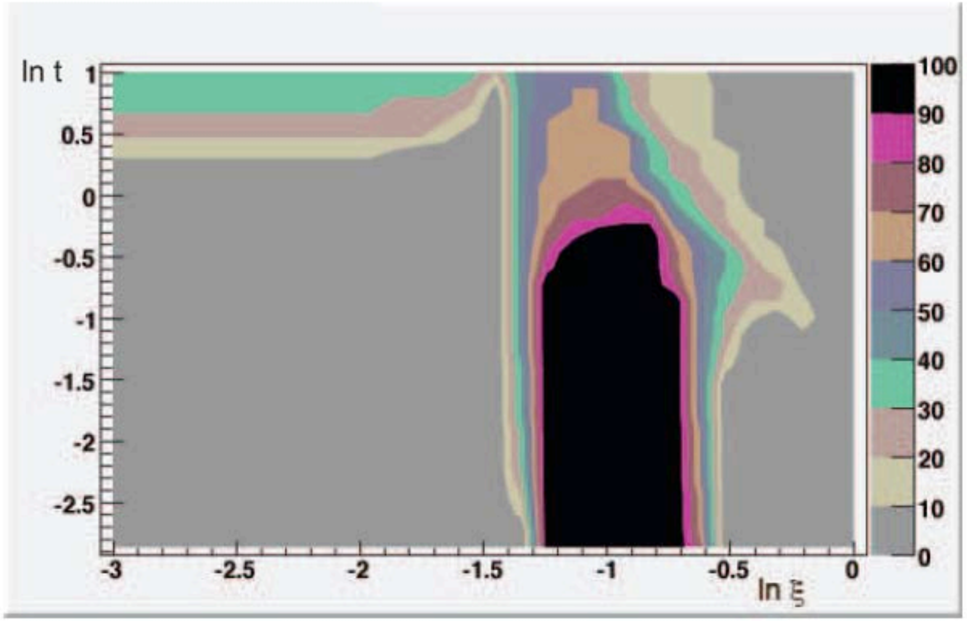
Schematic Outline

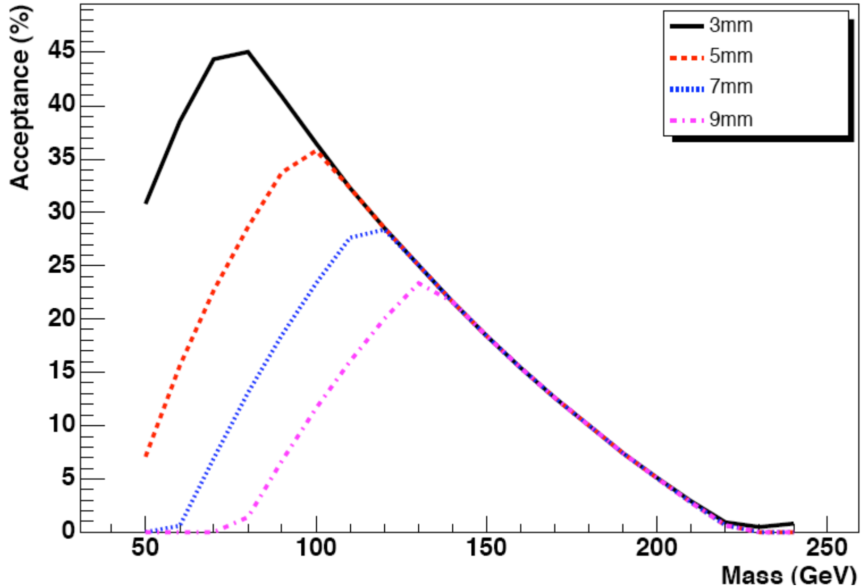
Spectrometer using LHC magnets to bend protons with small momentum loss out of the beam

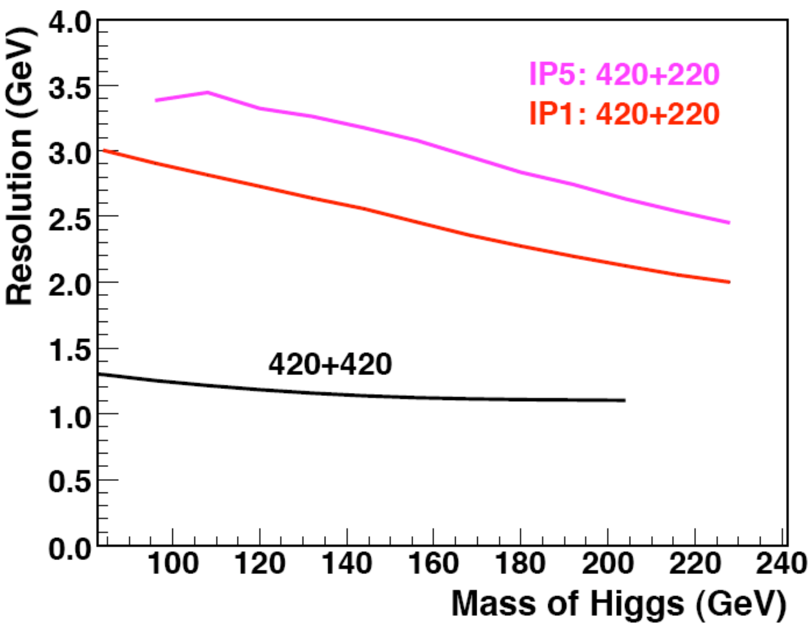


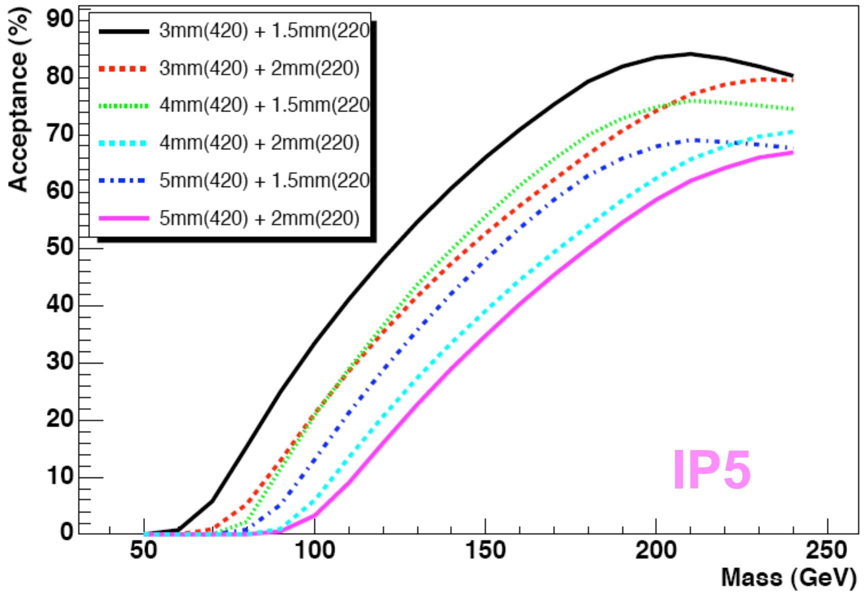


Acceptance and Resolution

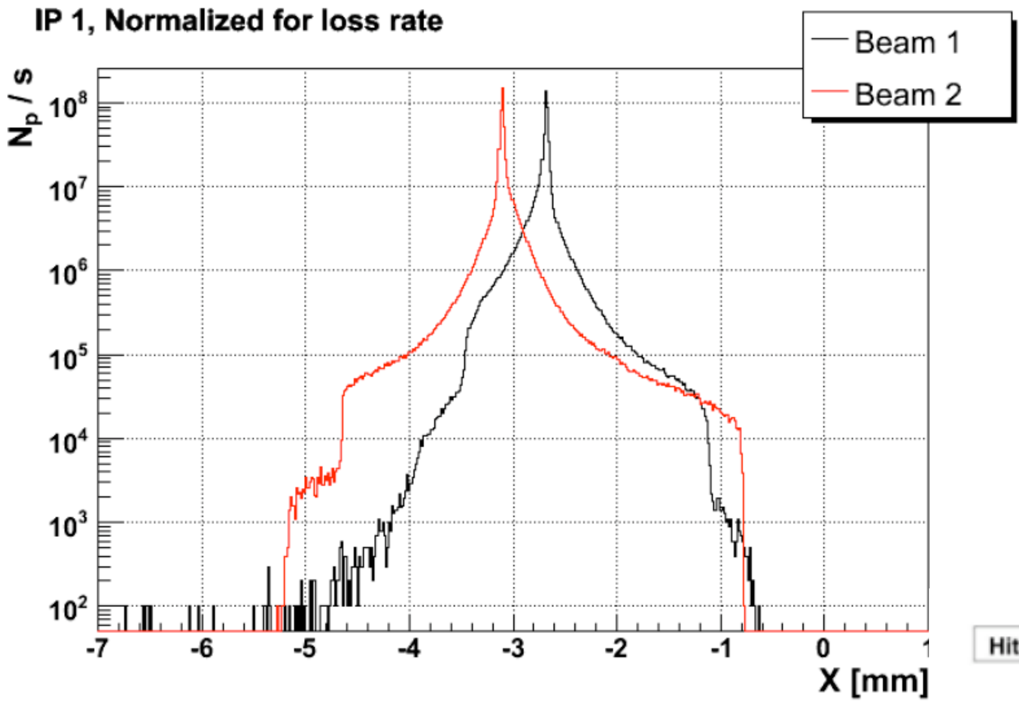




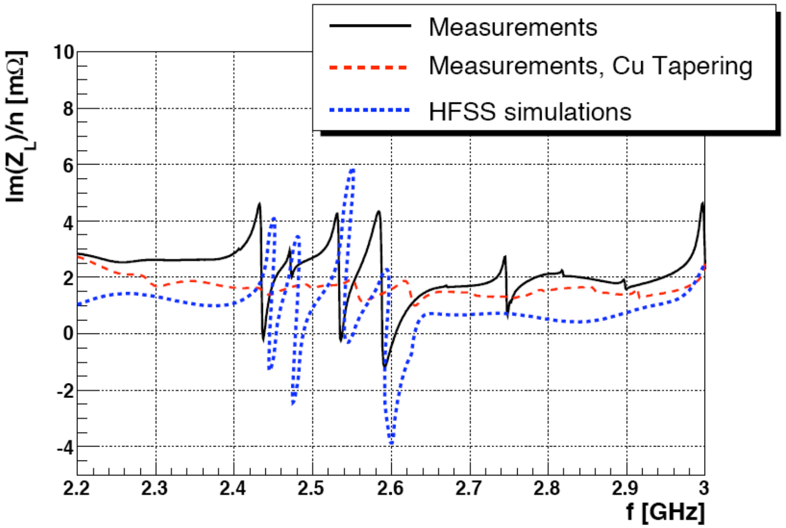


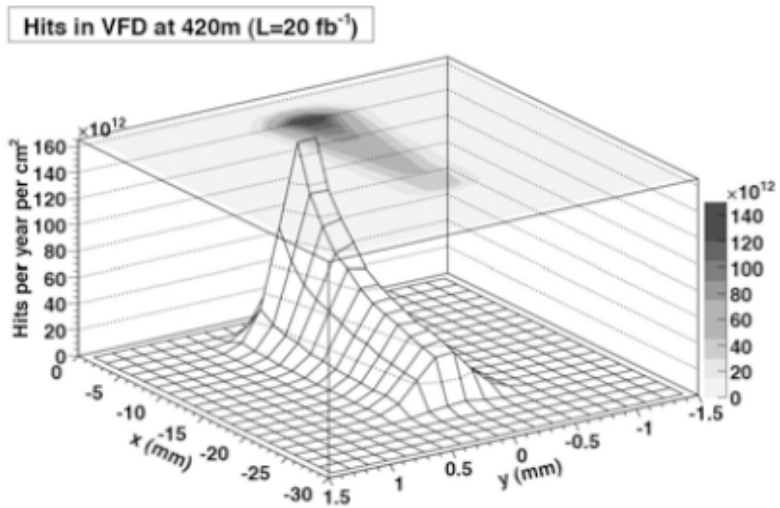


Backgrounds and distance of approach



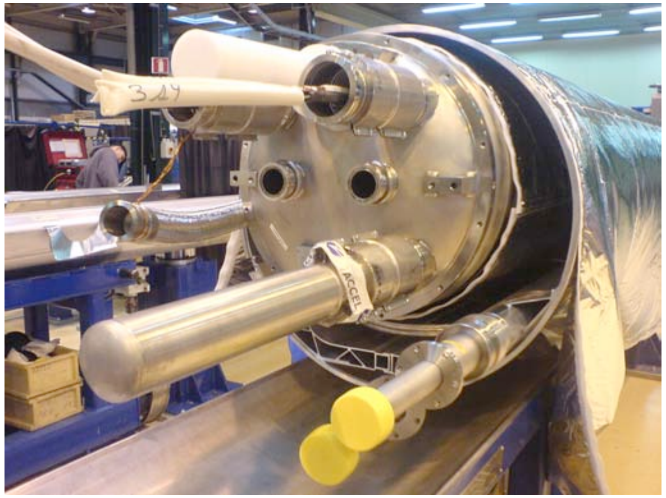
System	n1 $[\sigma_{\beta x}]$	n2 $[\sigma_{\beta x}]$
Betatron Cleaning	6	7
Momentum Cleaning	15	18

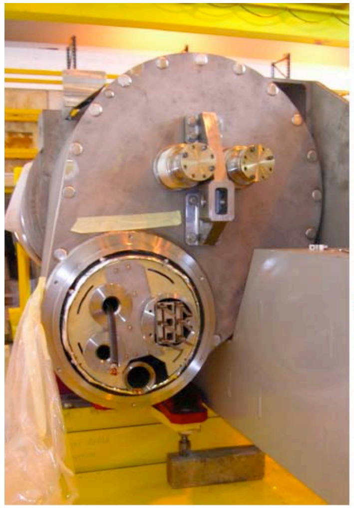


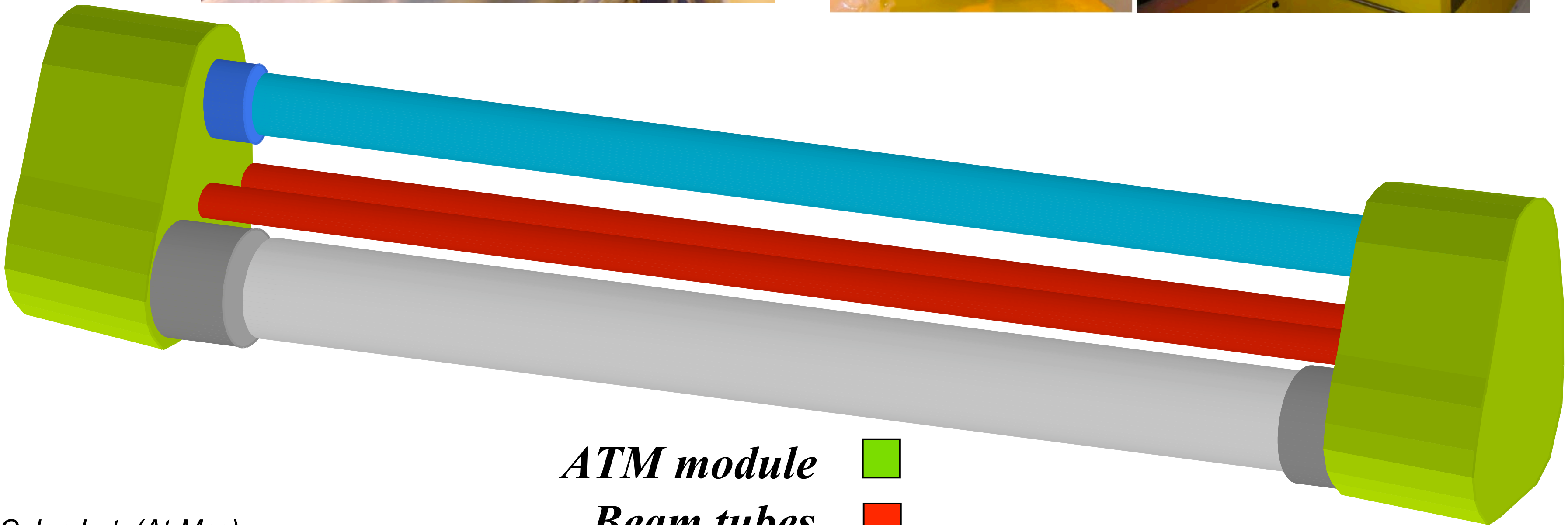


pp -> pX

FP420 Connection Cryostat







ATM module

Beam tubes

Line X vacuum vessel

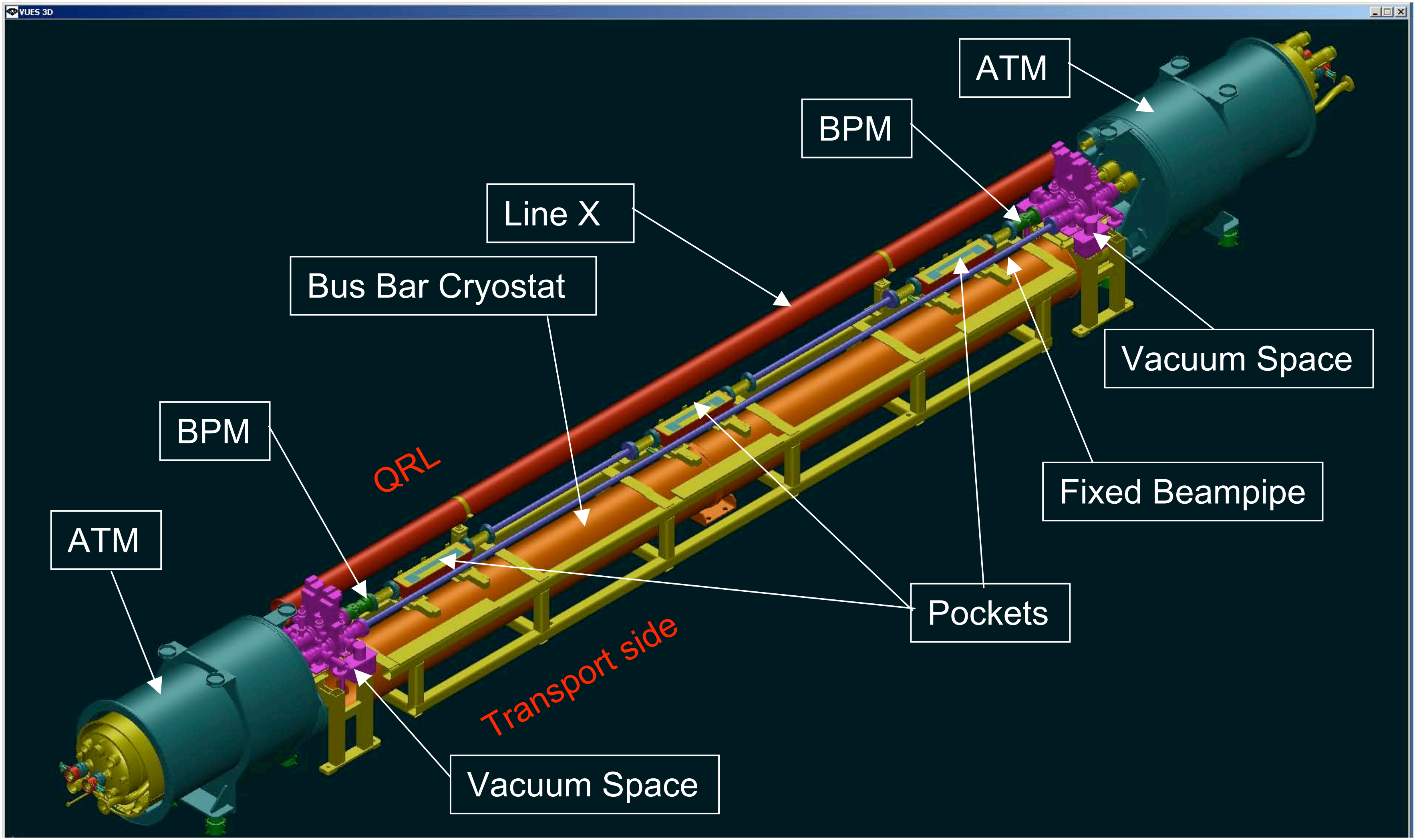
Connection Module

T. Colombet (At-Mcs)

T. Renaglia,

R. Folch

Integration of the moving beampipe and detectors

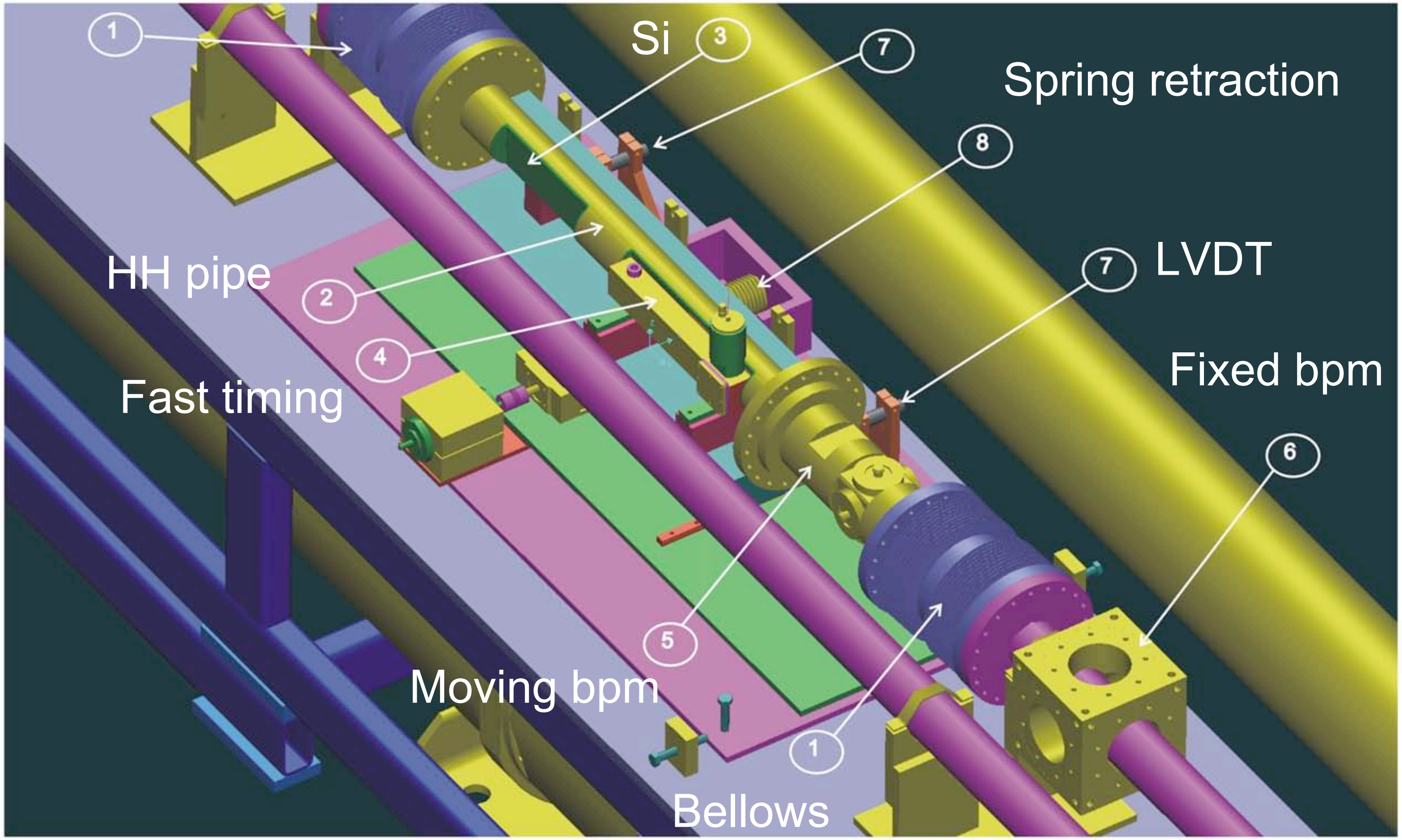


Benoît Florins, Krzysztof Piotrzkowski, Guido Ryckewaert

CRC
Louvain-la-Neuve

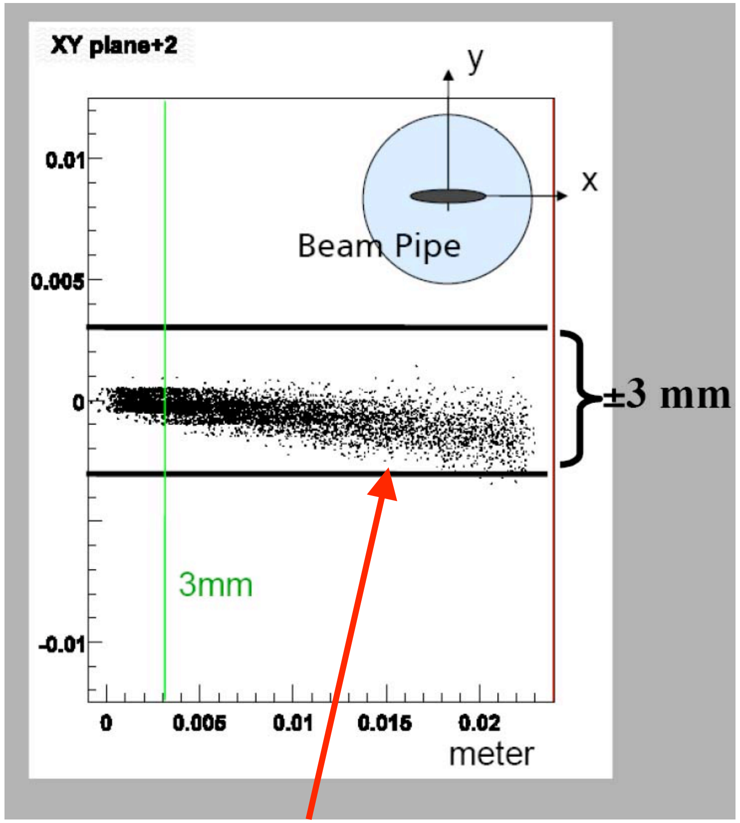
MANCHESTER 1824

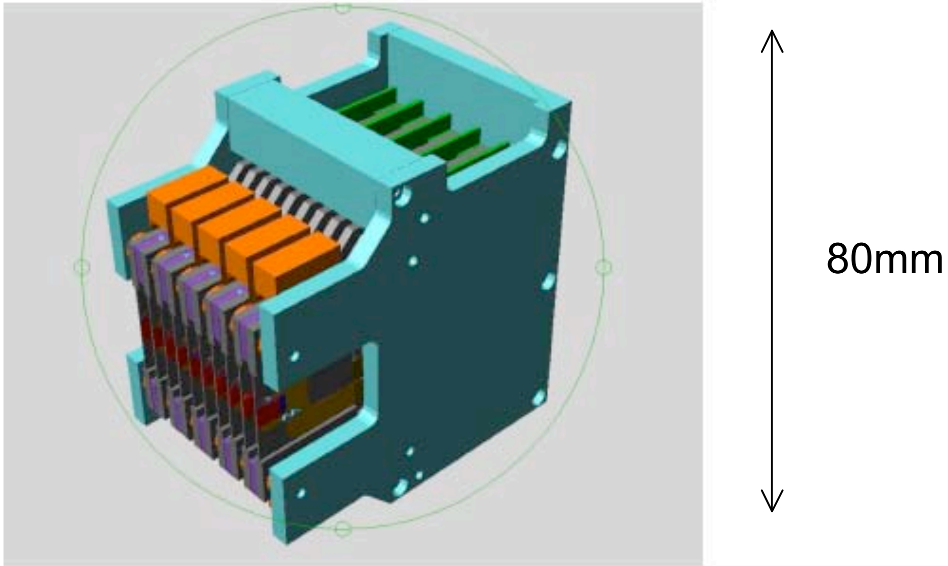
The University of Manchester



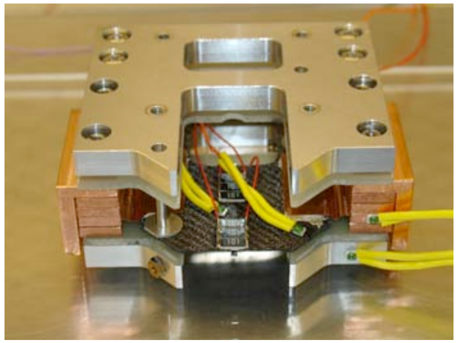
The University of Manchester

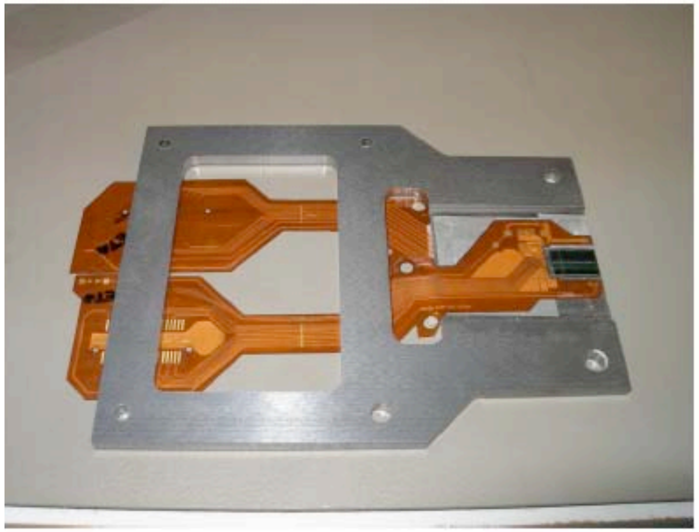
FP420 Silicon Detector Stations





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



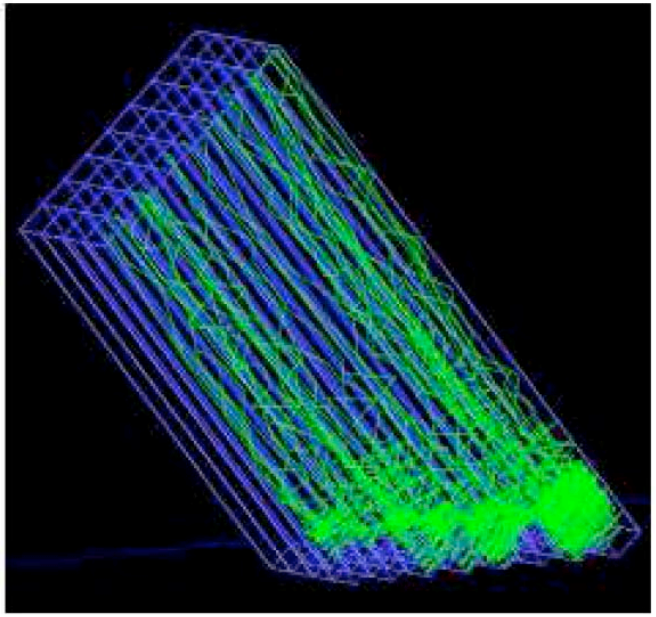


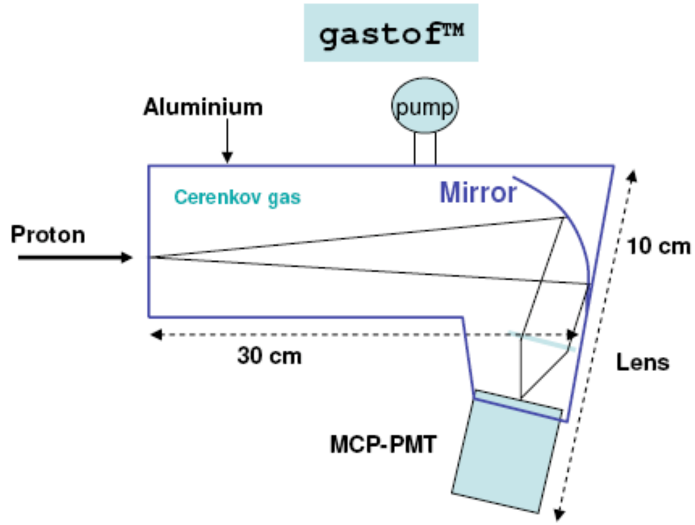
MANCHESTER
1824
The University of Manchester

Fast timing detectors

Quartic (FNAL, Alberta, UTA)

GASTOF (Louvain)





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

all the photons arrive within ≈ 3 ps

Burle 85011-501 with 25 μm pores

Hamamatsu R3809U-50 with 6 μm pores

Test beam FNAL:

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

$$\delta t(\text{QB4}) = 40 \text{ ps}$$

Burle 85011-501 with 10 μm pores

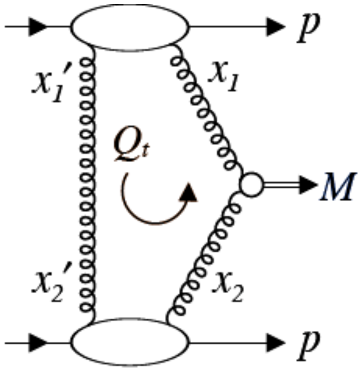
MANCHESTER 1824

The University of Manchester

Predictions for discovery potential of FP420 at LHC

- Do we really know the errors on the CEP rates calculated by Khoze, Martin and Ryskin ?
- Can 420m detectors operate at 10^{34} cm^{-2} s^{-1} ?
- Can the backgrounds (particularly overlap) be controlled ?
- Can the events be triggered, given that 420m detectors cannot be included at L1 ?
- Could FP420 see Higgs production in the b-decay channel ?

Do we know the errors on the CEP rates?



$$\frac{d\sigma_M^{\text{excl}}}{d(lnM^2)dy} = \frac{d\mathcal{L}}{d(lnM^2)dy}\hat{\sigma}_{gg\to M}(M^2)$$

$$M^2\frac{d\mathcal{L}}{dM^2dy} = S^2 L$$

$$L = \left(\frac{\pi}{(N_c^2-1)b}\int\frac{dQ_t^2}{Q_t^4}f_g(x_1,x_1',Q_t^2,M^2/4)f_g(x_2,x_2',Q_t^2,M^2/4)\right)^2$$

f_g is the amplitude related to the un-integrated, off-diagonal gluon density.

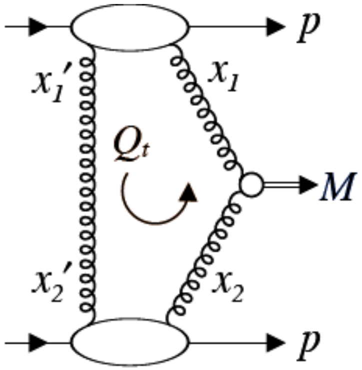
S^2 is a soft survival probability

S^2 : **KMR** calculate to be 0.03 at 14 TeV in CEP. In HERA / LHC workshop all groups broadly agree (hep-ph/0601012) .

Recently GLM revised downwards (0.007) (arXiv:0708.1506). Frankfurt et al. also have new comments, no definitive statement (hep-ph/0608271)

Lonnblad & Sjodahl, JHEP 0402:042,2004

Do we know the errors on the CEP rates?

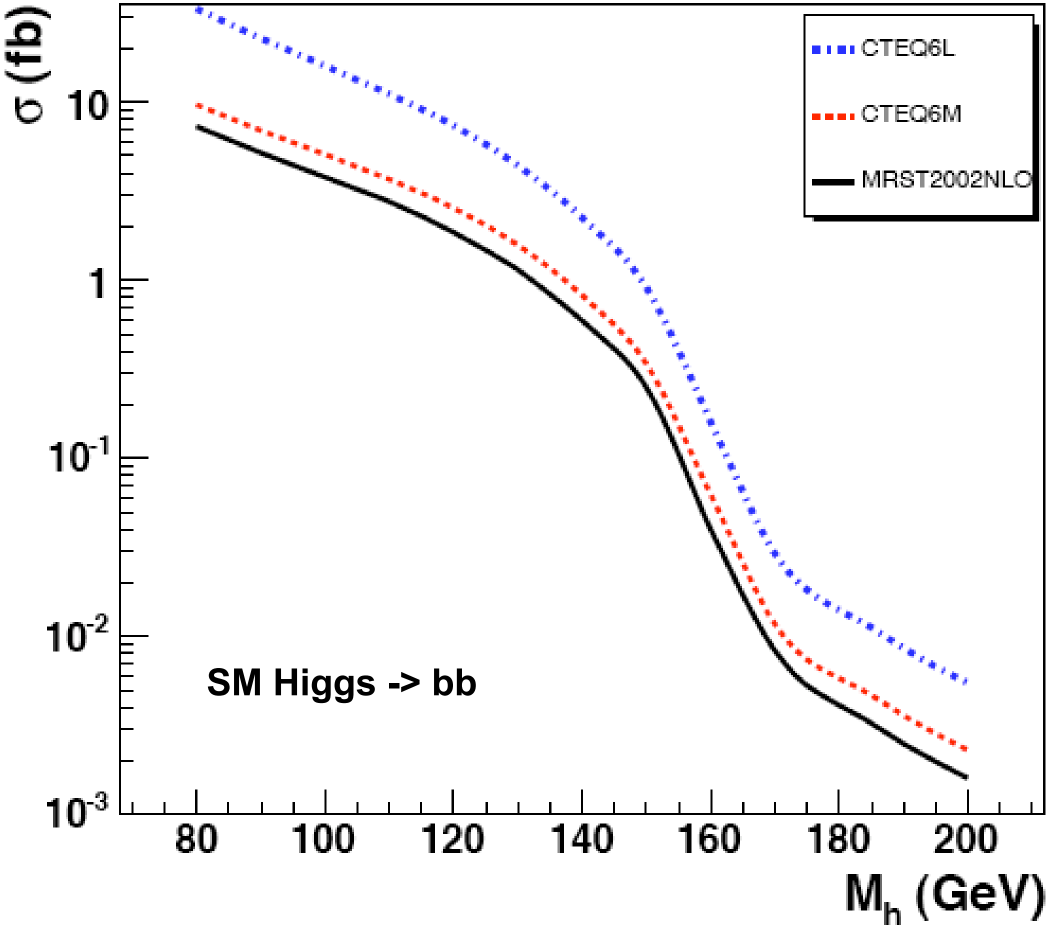


$$L = \left(\frac{\pi}{(N_c^2 - 1)b} \int \frac{dQ}{Q_t^4}$$

f_g is the amplitude relat

density.

S^2 is a soft survival prol



S^2 : **KMR** calculate to be 0.03 at 14

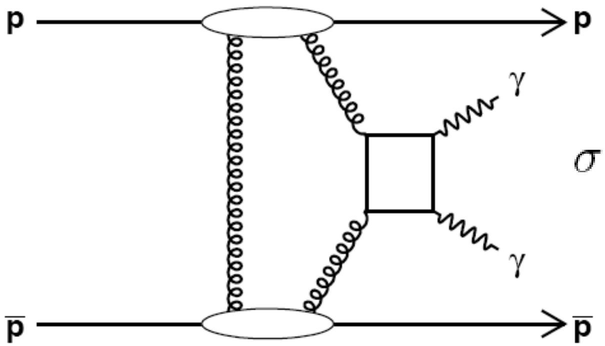
agree (hep-ph/0601012) .

Recently GLM revised downwards [illegible]

comments, no definitive statement (hep-ph/0608271)

Lonnblad & Sjodahl, JHEP 0402:042,2004

Do we know the errors on the CEP rates?

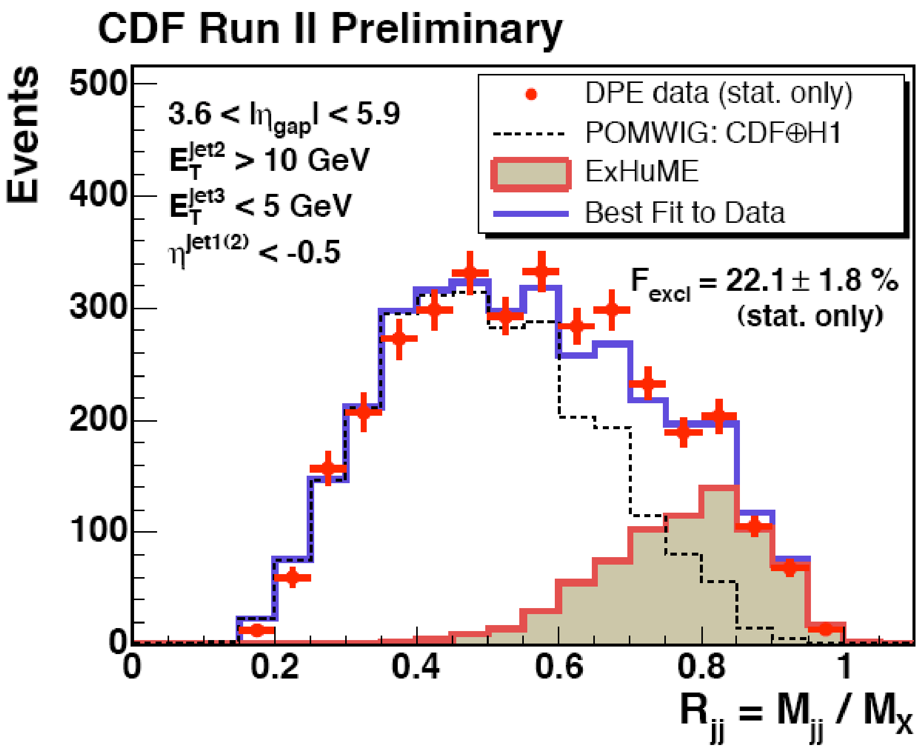


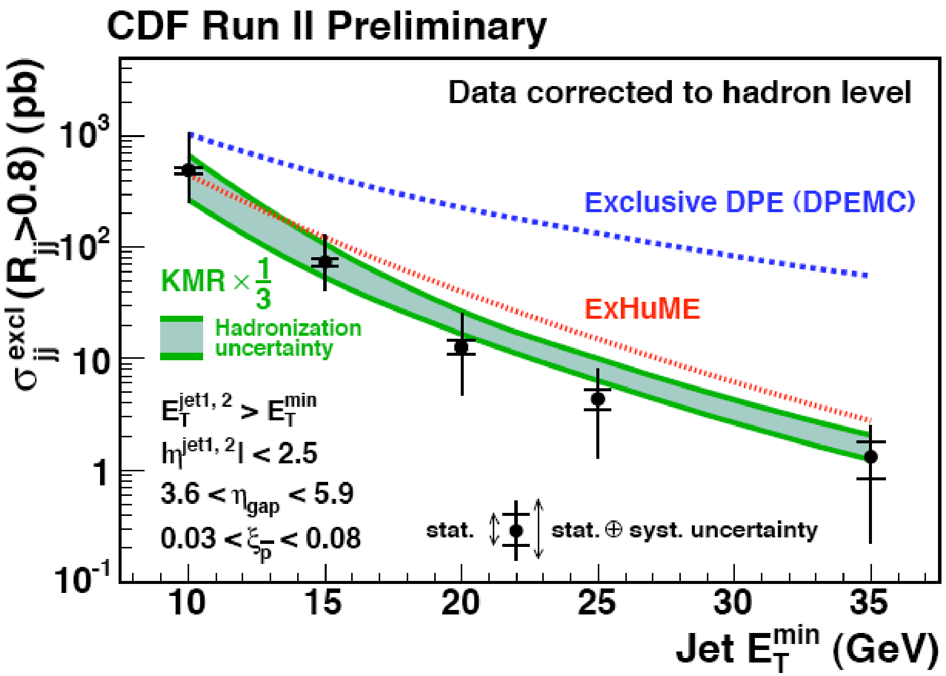
Assuming 2 di-photon candidates are photons:

$$\sigma(p+\bar{p} \rightarrow p+\gamma\gamma+\bar{p}) = 90^{+120}_{-30}(\text{stat.}) \pm 16(\text{syst.})\ \text{fb}$$

KMR predict 40 fb

CDF Collaboration arXiv:0707.2374





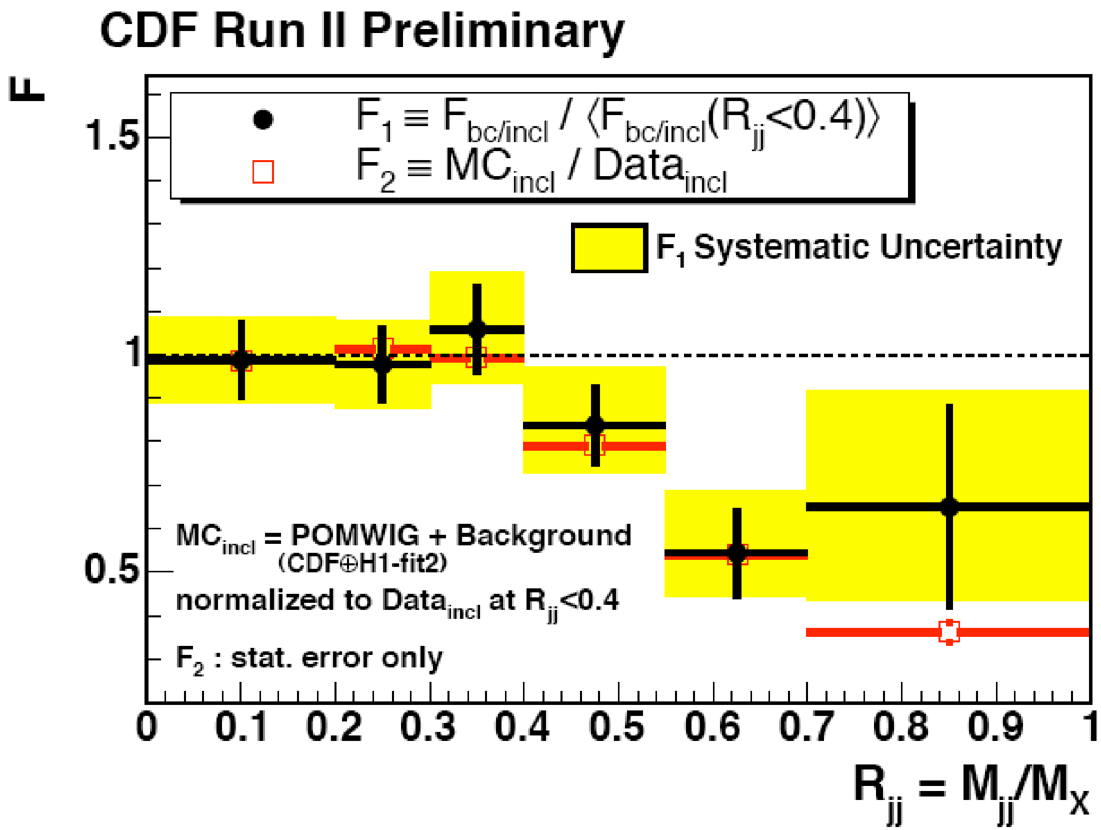
K. Terashi, arXiv:0705.3804

Do we know the errors on the CEP rates?

Khoze, Ryskin & Stirling : Eur.Phys.J.C48:797-804,2006

0^{++} Selection rule

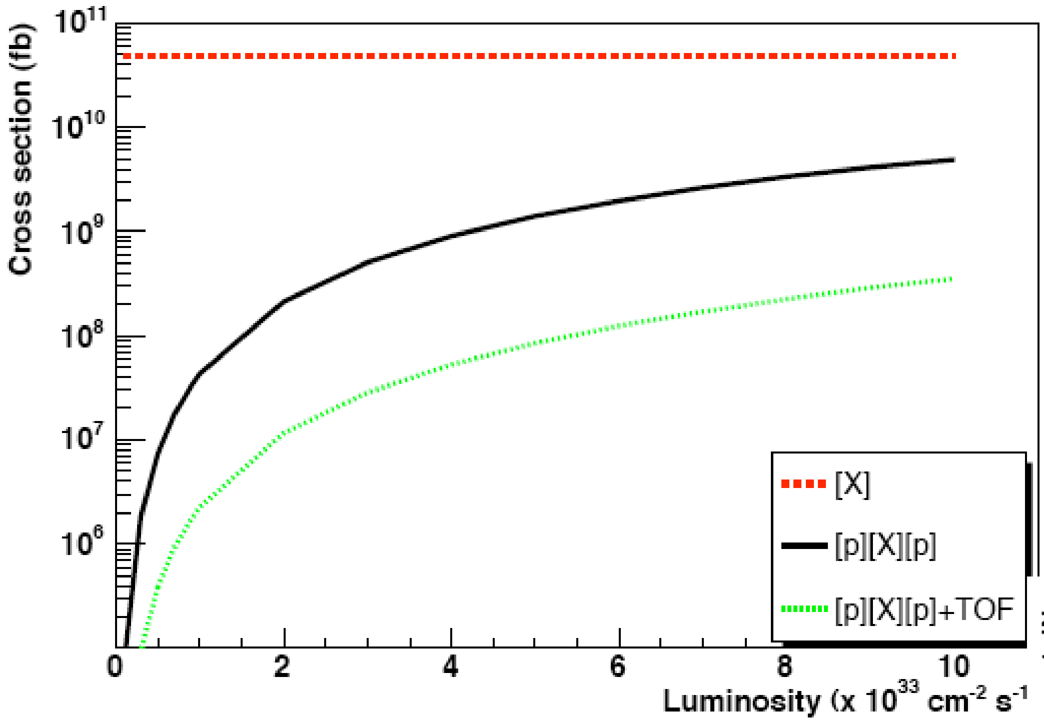
QCD Background ~ $\frac{m_b^2}{E_T^2}\frac{\alpha_S^2}{M_{b\bar{b}}^2 E_T^2}$

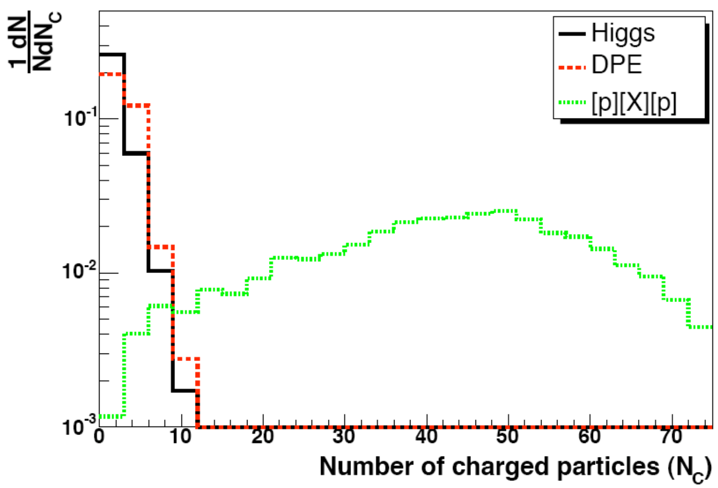


MANCHESTER 1824
The University of Manchester

A simulated analysis of Higgs -> bb

Primary background (before cuts) is overlap at high luminosity





- Fast timing detectors the key to 10^{34} cm^{-2}s^{-1}
- Track-based cuts becoming more important for FP420 analysis

Cox, Loebinger & Pilkington, arXiv:0708.3052

MANCHESTER 1824

The University of Manchester

Important backgrounds in the b-channel

Generator	Process	$\sigma_{420-420}$ (fb) K_T	$\sigma_{420-420}$ (fb) CONE	$\sigma_{420-220}$ (fb), CONE 5mm/2mm	$\sigma_{420-220}$ (fb), CONE 3mm/1.5mm
ExHuME	$H \to b\bar{b}$	0.071	0.072	0.038	0.115
ExHuME	$b\bar{b}$	0.076	0.070	0.067	0.203
	gg	0.066	0.084	0.091	0.278
POMWIG	$b\bar{b}$	0.011	0.004	0.004	0.013
	jj	0.0005	0.0002	0.0002	0.0007
[p][X][p] (L)	$b\bar{b}$	0.0029	0.0037	0.0032	0.0097
	jj	0.0003	0.0003	0.0003	0.0009
[p][X][p] (H)	$b\bar{b}$	0.46	0.59	0.46	1.41
	jj	0.04	0.05	0.04	0.13
[pp][X] (L)	$b\bar{b}$	0.008	0.009	0.009	0.028
[pp][X] (H)	$b\bar{b}$	0.11	0.13	0.12	0.38
[p][pX] (L)	$b\bar{b}$	0.003	0.002	0.002	0.006
[p][pX] (H)	$b\bar{b}$	0.05	0.03	0.03	0.08
Total bgrd (L)		0.17	0.17	0.18	0.54
Total bgrd (H)		0.81	0.96	0.81	2.48

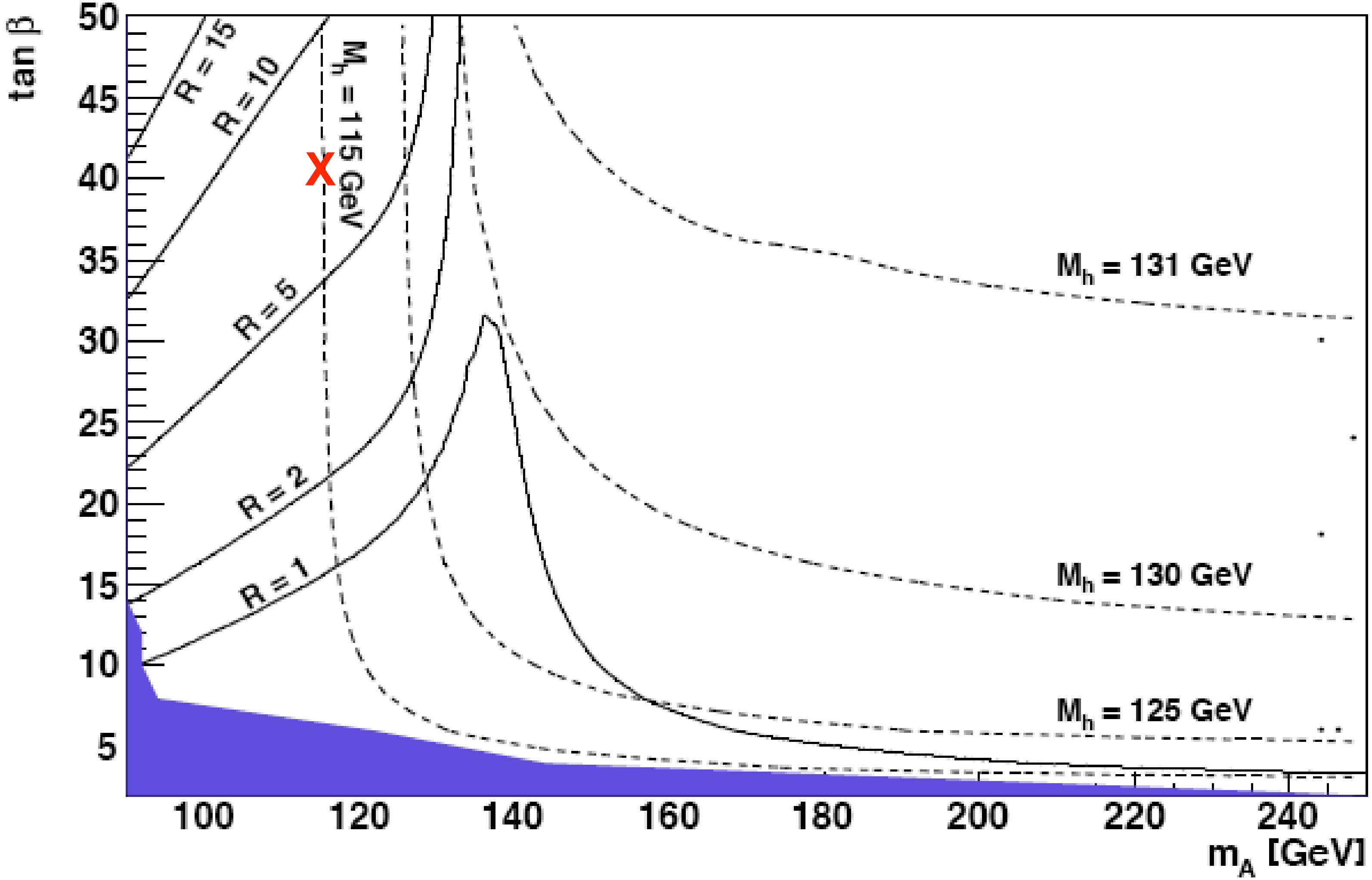
All cuts, acceptance and detector smearing, excluding L1 trigger

MANCHESTER 1824

The University of Manchester

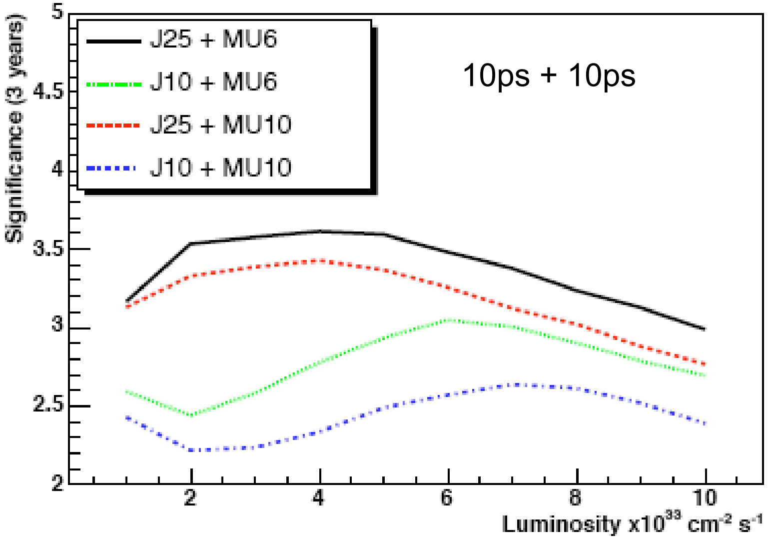
A simulated analysis of Higgs -> bb

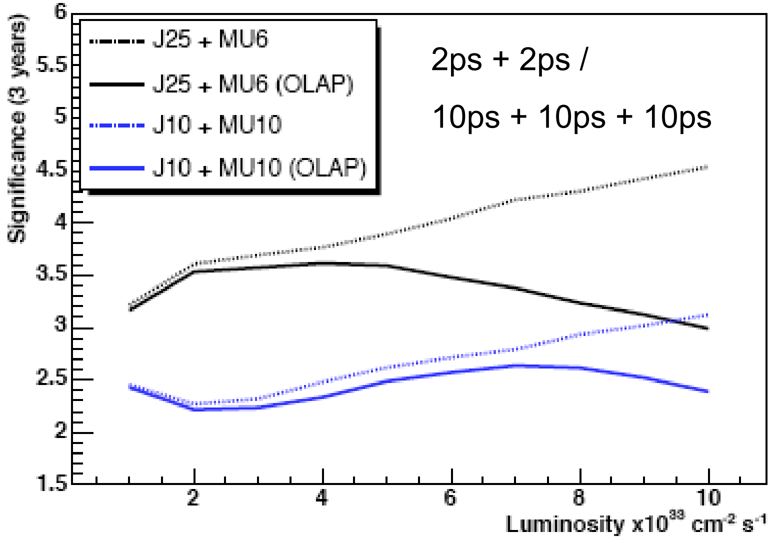
M_h^{max}, μ=200 GeV

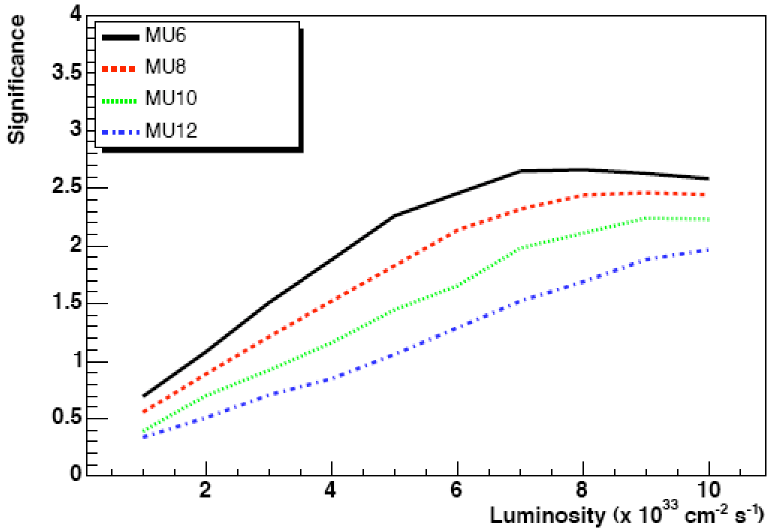


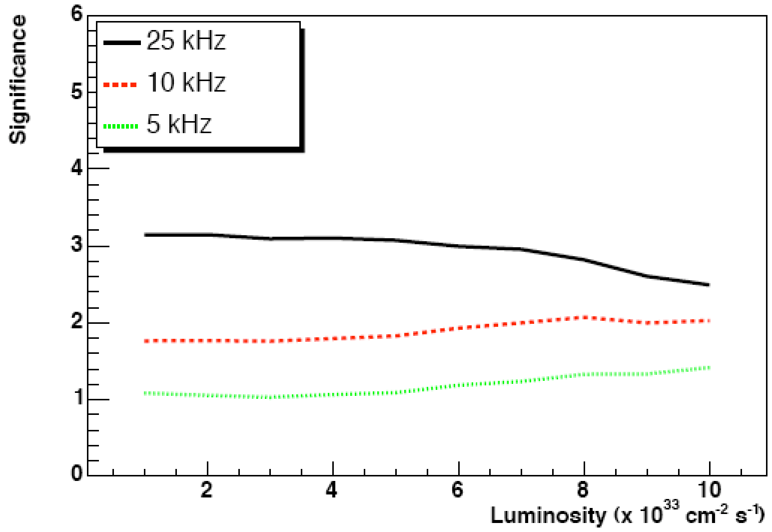
Heinemeyer et al., arXiv:0708.3052

Different L1 trigger strategies for M_h = 120 GeV



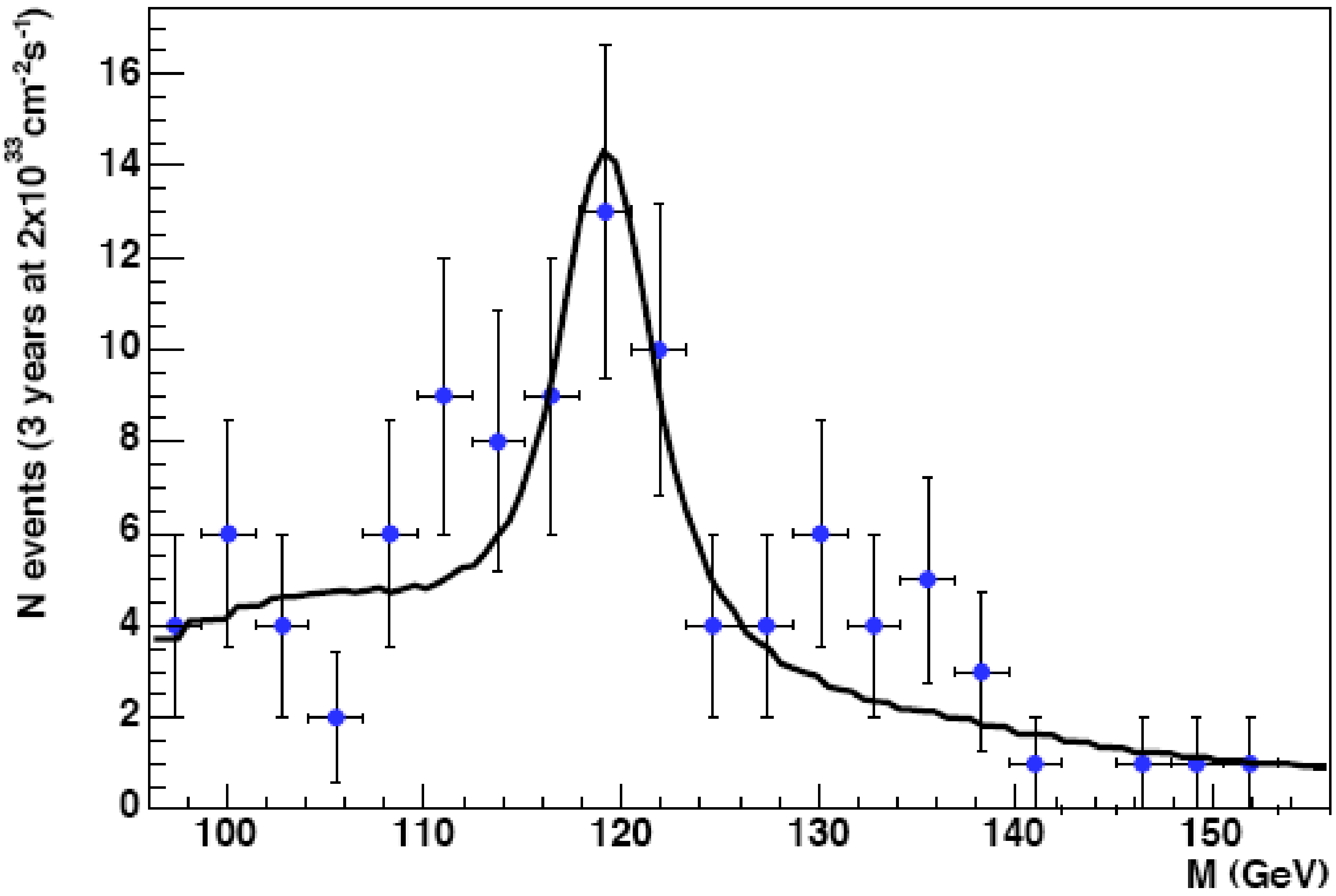






MANCHESTER
1824
The University of Manchester

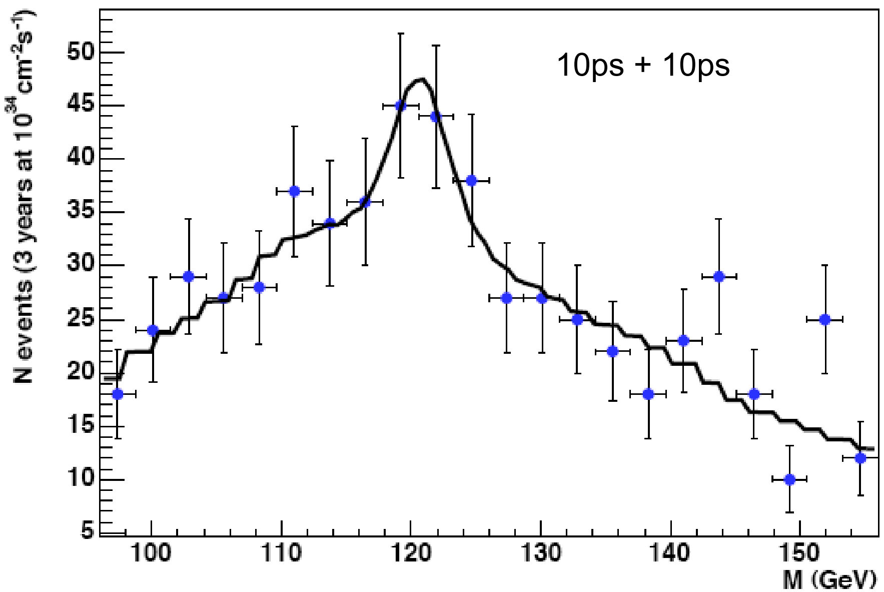
Results for M_h^{max} scenario (m_A=120 GeV, $\tan\beta$ = 40)

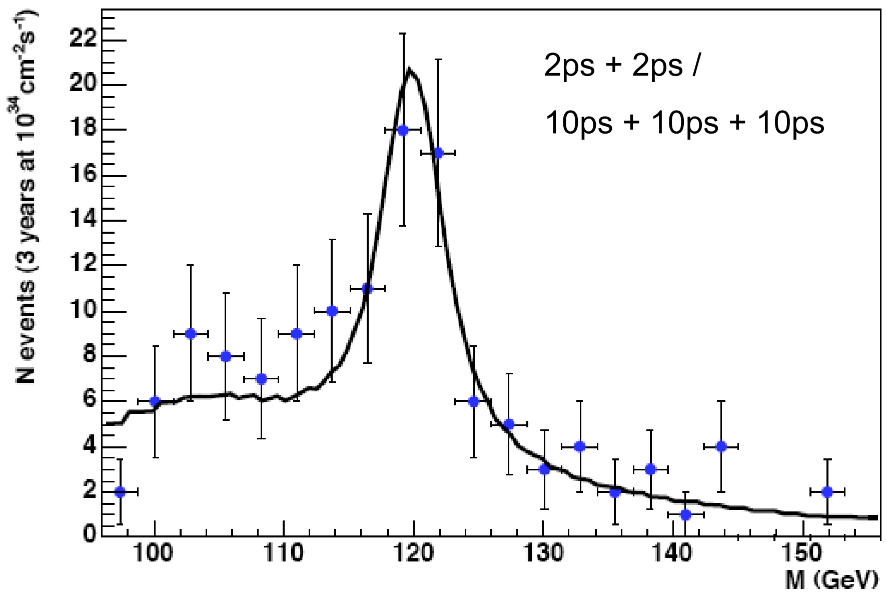


60 fb^{-1} taken at 2 x 10^{33} (3 yrs), σ = 20fb (~ 8 x σ_{SM})

Cox, Loebinger & Pilkington, arXiv:0708.3052

Results for M_h^{max} scenario (m_A=120 GeV, $\tan\beta$ = 40)



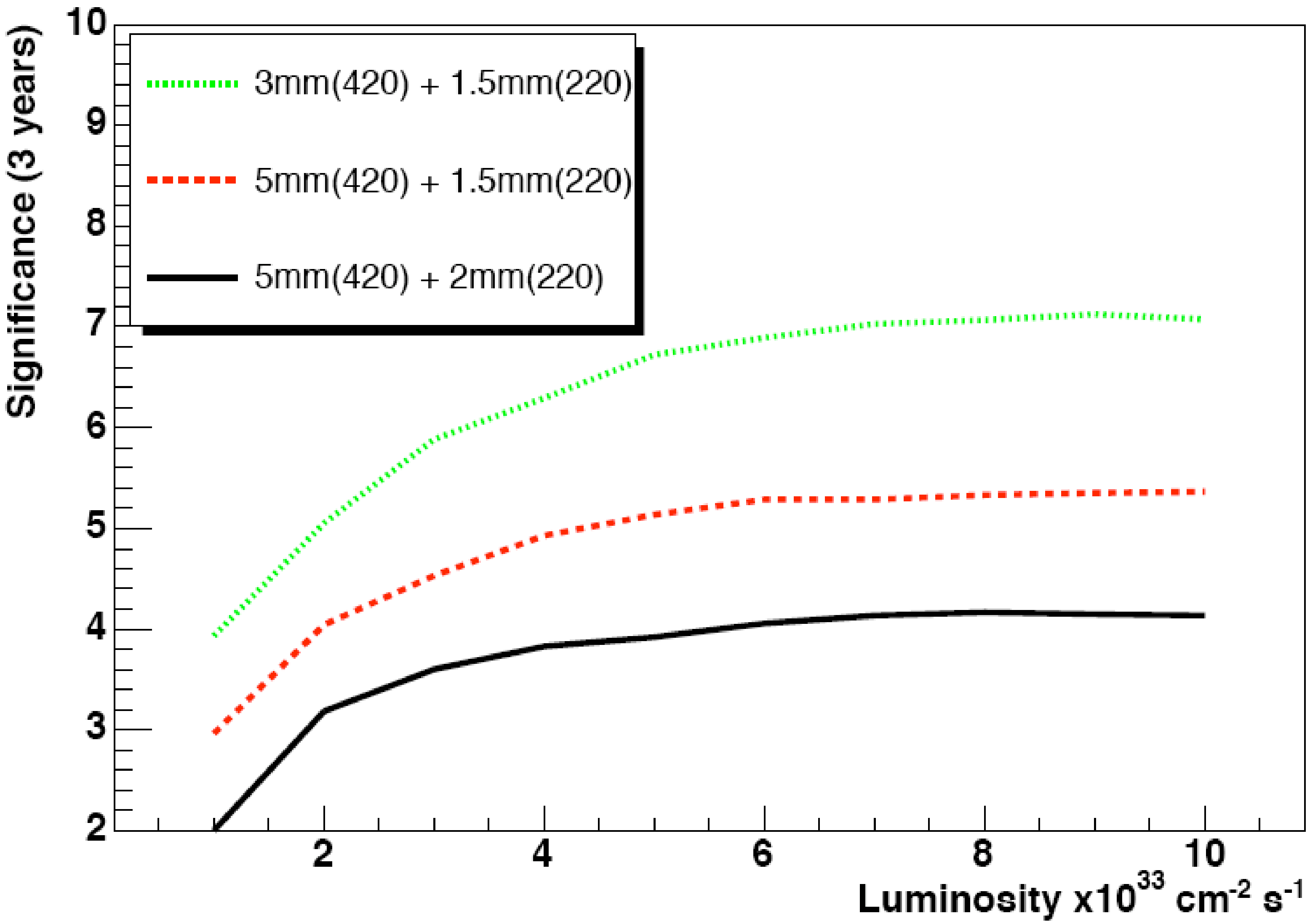


300 fb^{-1} taken at 10^{34} (3 yrs), σ = 20fb (~ 8 x σ_{SM})

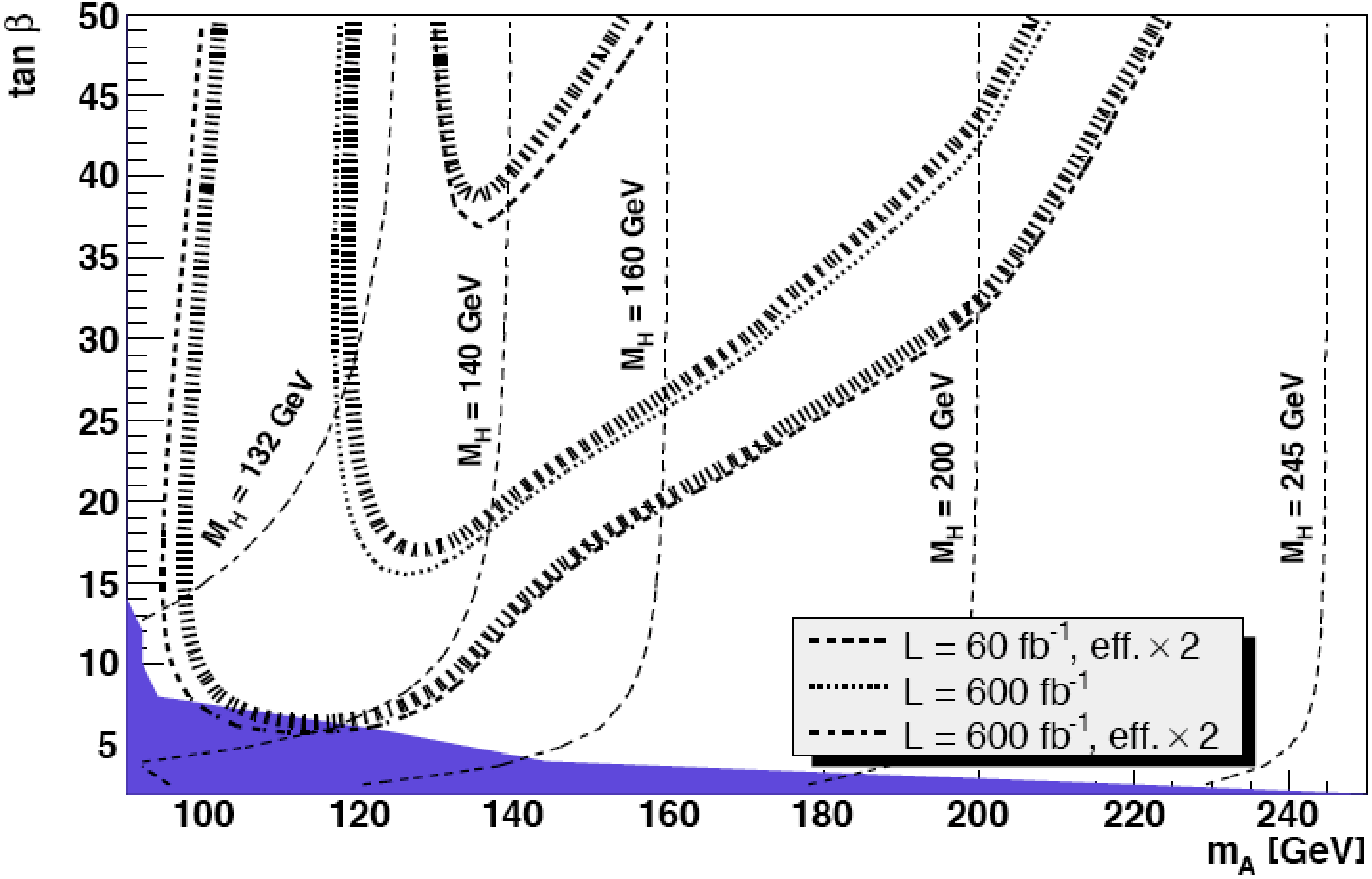
Cox, Loebinger & Pilkington, arXiv:0708.3052

MANCHESTER
1824
The University
of Manchester

Significance if 220m pots used and included at L1

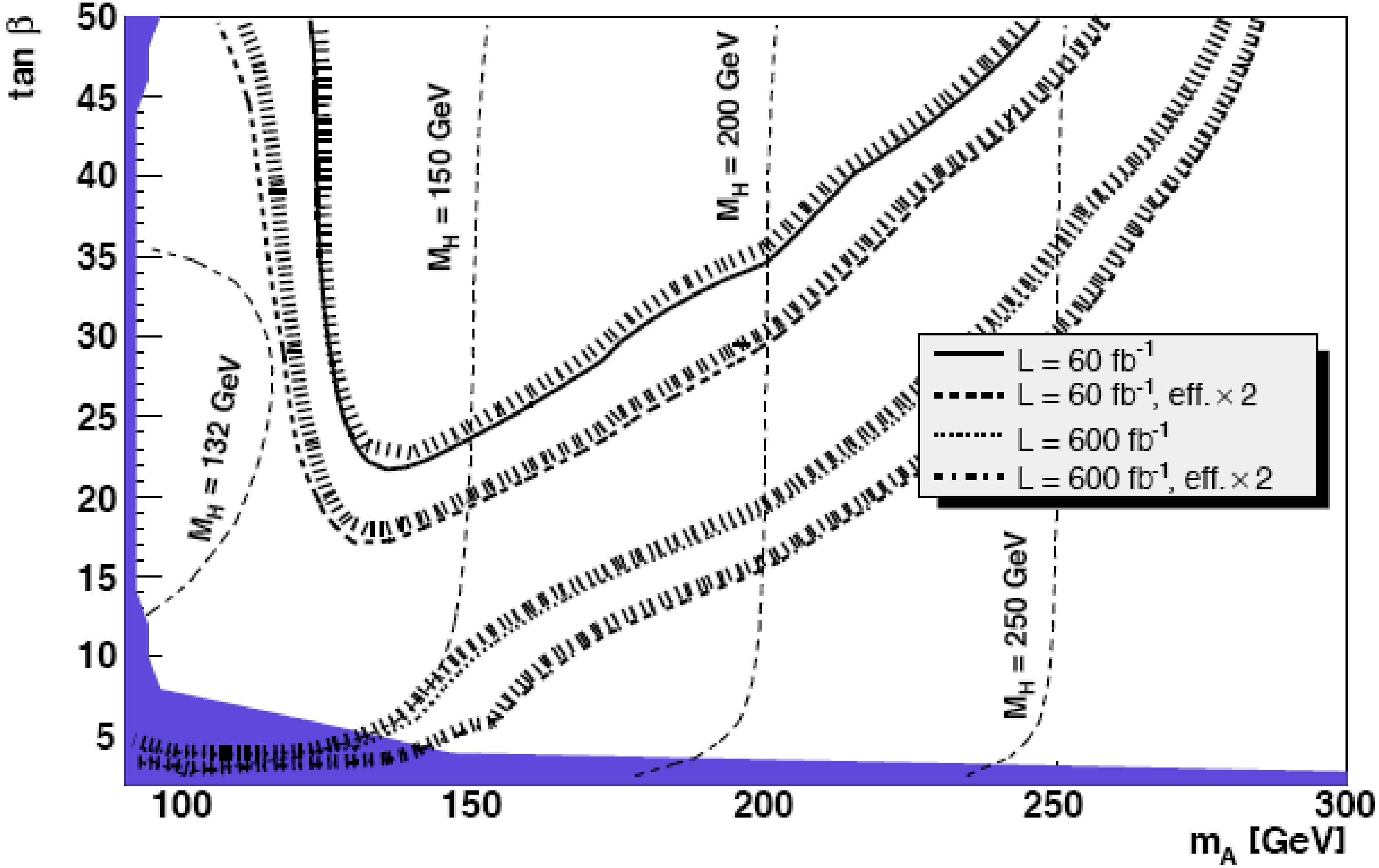


MANCHESTER 1824
The University of Manchester

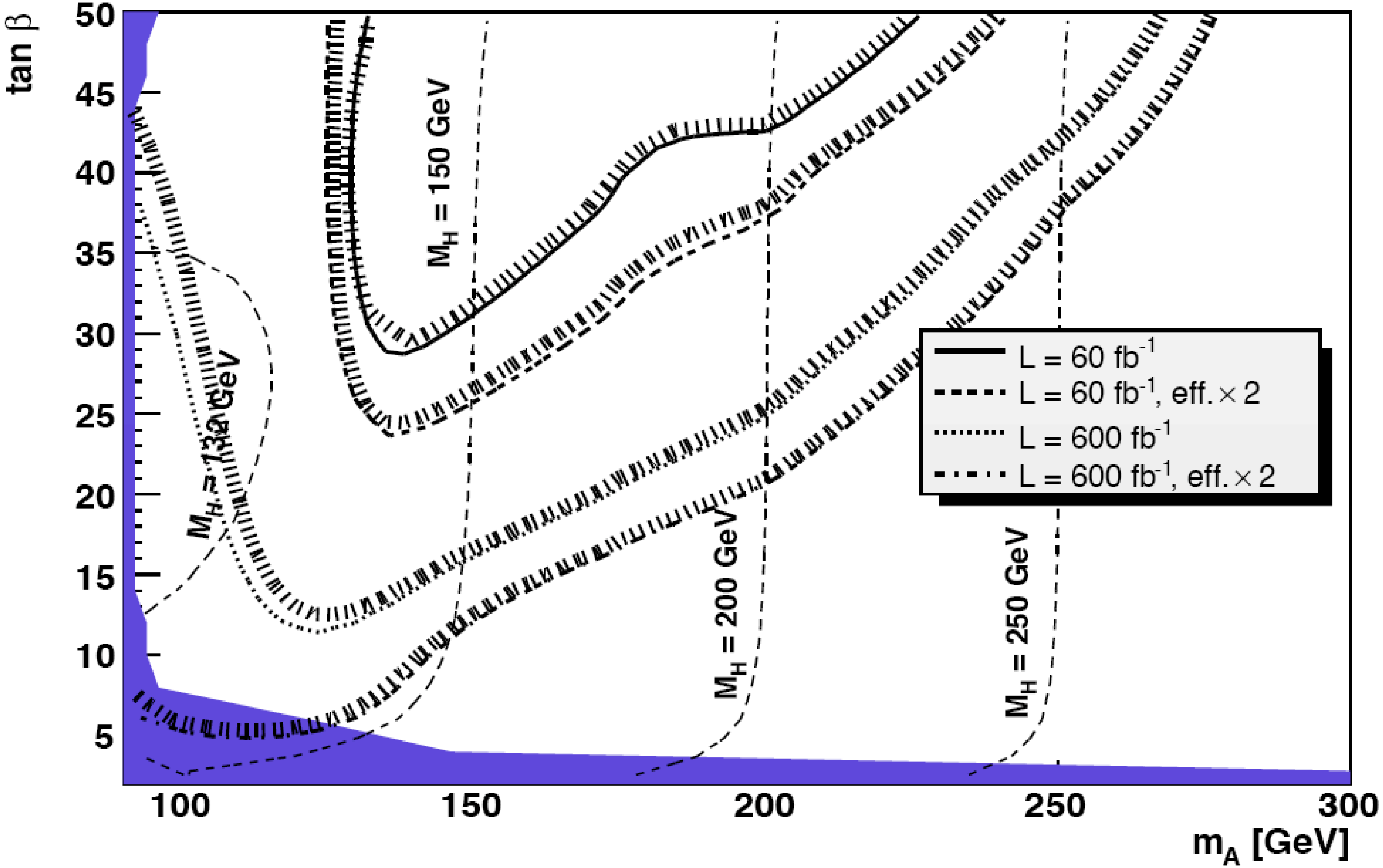


M_H^{max} 5σ discovery contours for H, μ=200 GeV

Heinemeyer et al., arXiv:0708.3052



M_H^{max}, 3σ contours, μ = -500 GeV



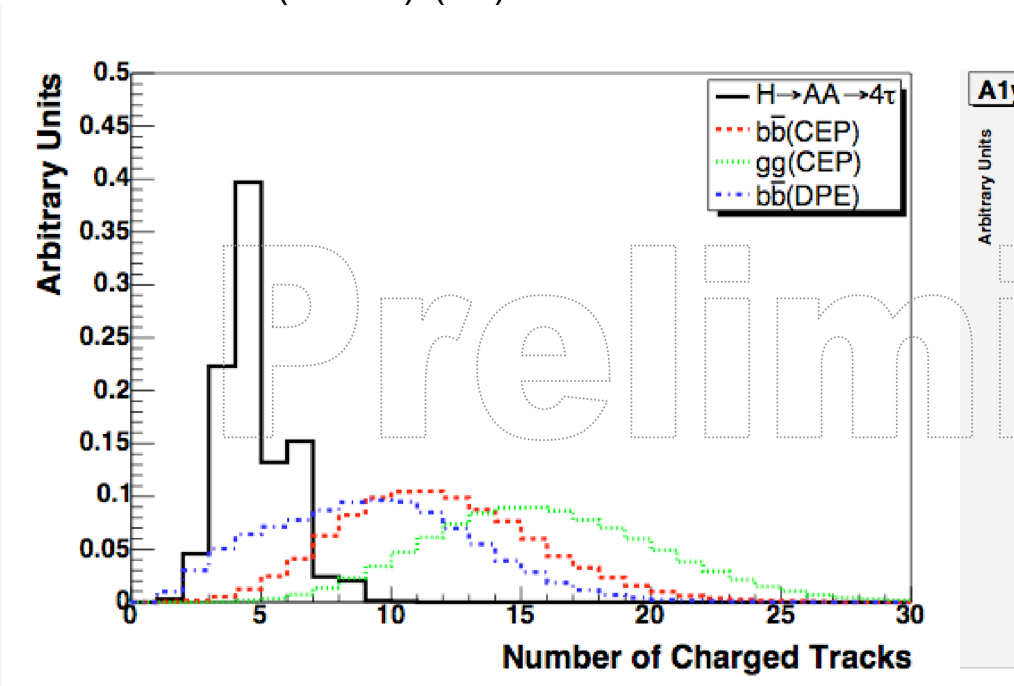
M_H^{max}, 5σ contours, μ = -500 GeV

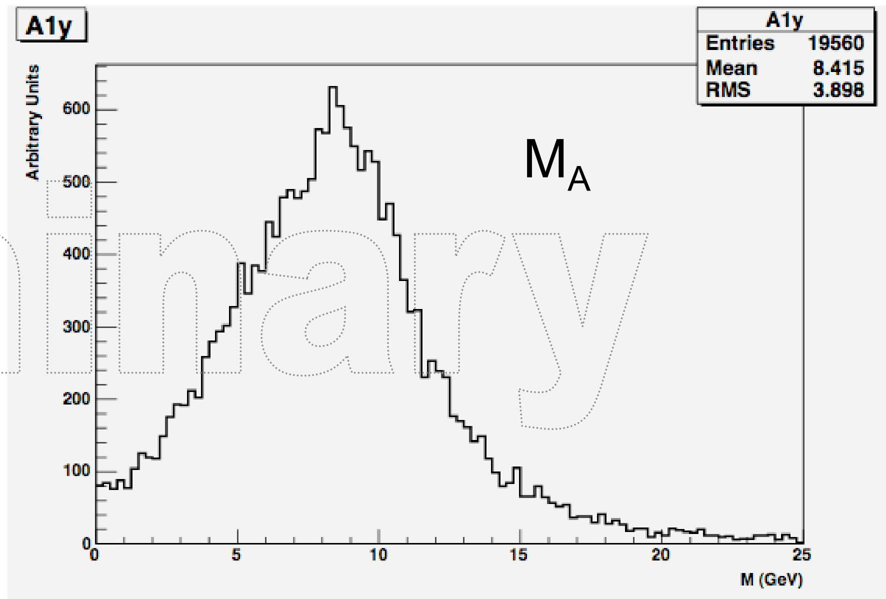
Heinemeyer et al., arXiv:0708.3052

H -> AA -> ττττ in NMSSM

Preliminary results for M_H = 91 GeV, MU6 trigger

Process	σ(fb)
H->AA->4tau	0.1
bb (CEP)	~0.004
gg (CEP)	~0.01
jj (DPE)	~0.01
bb(OLAP) (LL)	~0.02fb





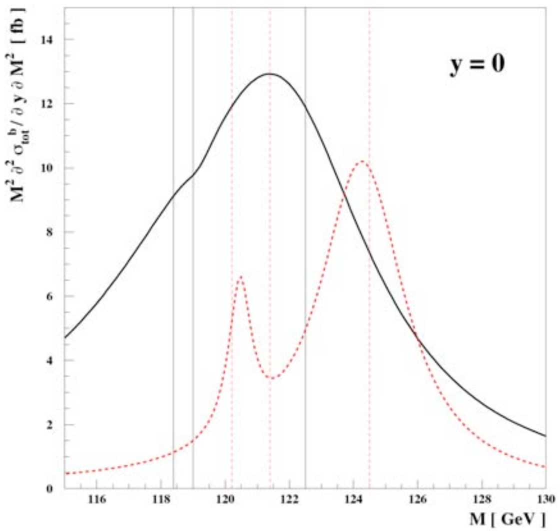
Forshaw, Gunion & Pilkington, to be published.

MANCHESTER 1824

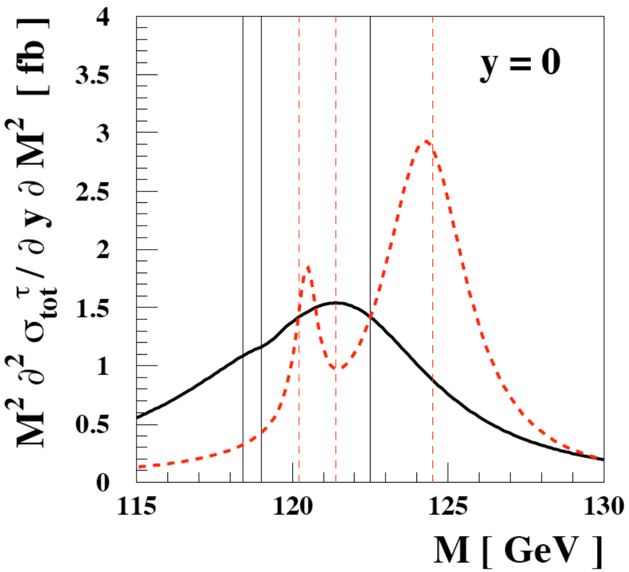
The University of Manchester

CP violation in the Higgs Sector

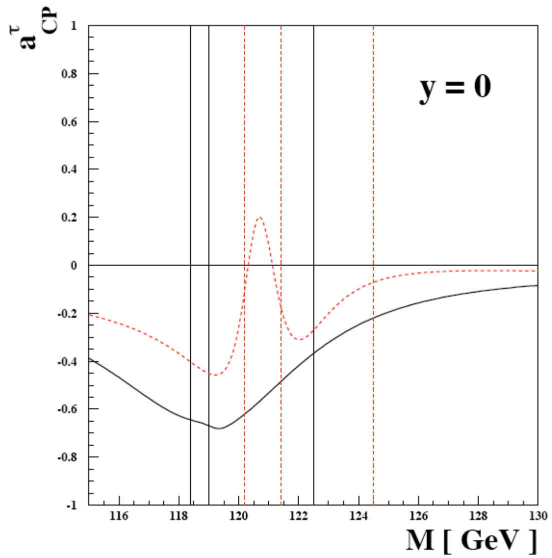
bb decay



ττ decay



ττ decay



This example shows that exclusive double diffraction may offer unique possibilities for exploring Higgs physics in ways that would be difficult or even impossible in inclusive Higgs production. In particular, we have shown that exclusive double diffraction constitutes an efficient CP and lineshape analyzer of the resonant Higgs-boson dynamics in multi-Higgs models. In the specific case of CP-violating MSSM Higgs physics discussed here, which is potentially of great importance for electroweak baryogenesis, diffractive production may be the most promising probe at the LHC.

J. Ellis et al hep-ph/0502251

MANCHESTER
1824

The University
of Manchester

Forward Physics upgardes at the 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 at ATLAS

• 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 has been completed

• If full funding is secured, cryostats (built by TS-MME) and baseline detectors could be ready for installation in Autumn 2008, likely goal 2010

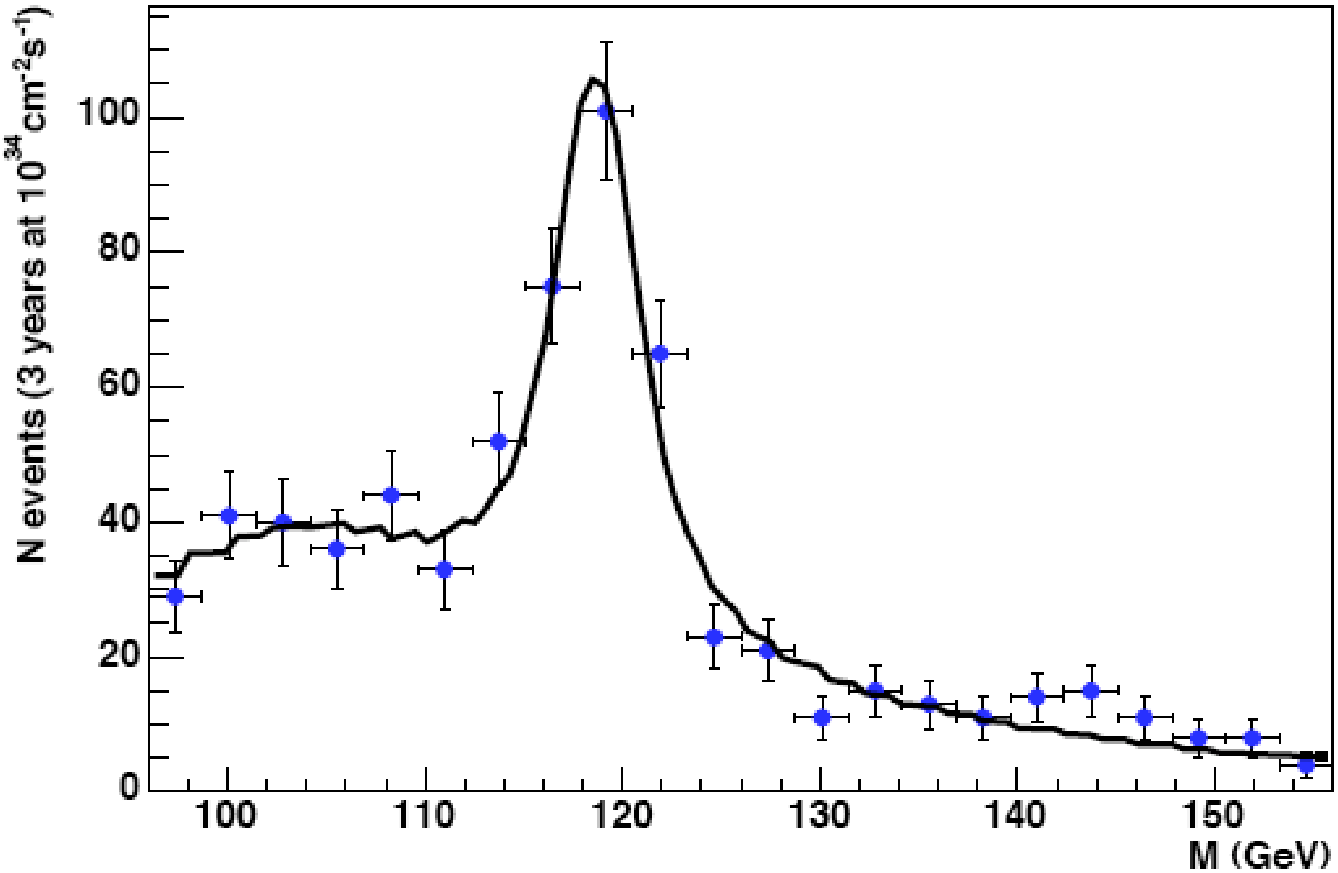
• 220m and 420m tagging detectors have the potential to add significantly to the discovery reach of ATLAS and CMS for modest cost, particularly in certain regions of MSSM parameter space.

• SM Higgs in WW channel $M_H > 140$ GeV

• in b-channel, wide range of MSSM parameter space covered, $\tau\tau$ channels in NMSSM allow discovery + M_A measurement

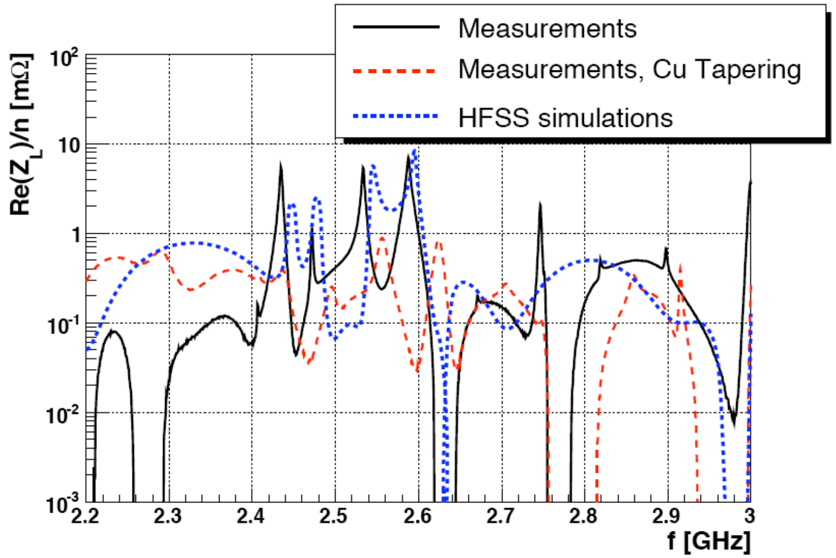
• There is a rich QCD and electroweak physics program in parallel with discovery physics

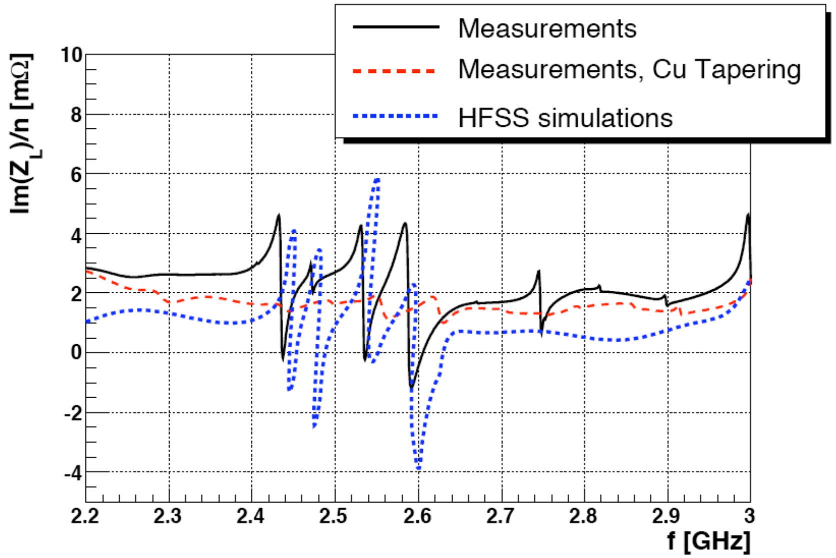
Forward Physics upgardes at the LHC

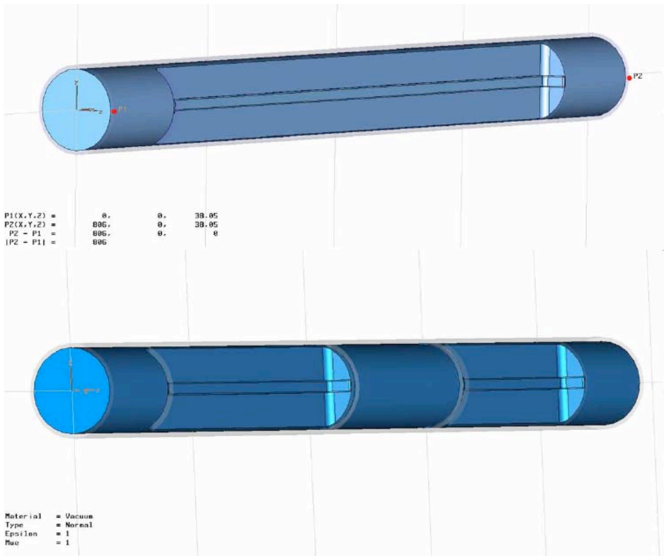


- in b-channel, wide range of MSSM parameter space covered, ττ channels in NMSSM allow discovery + M_A measurement
- There is a rich QCD and electroweak physics program in parallel with discovery physics

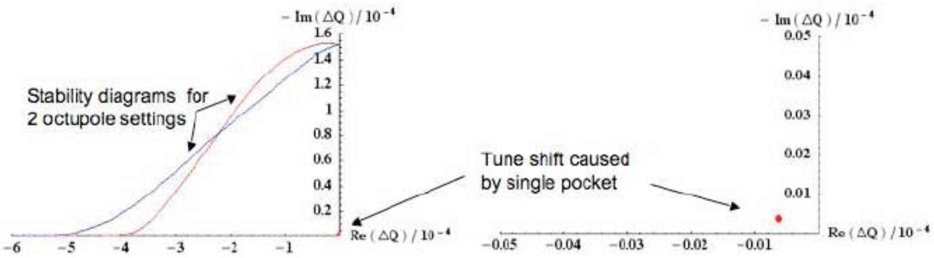
Impact of FP420 on LHC







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



MANCHESTER 1824

The University of Manchester

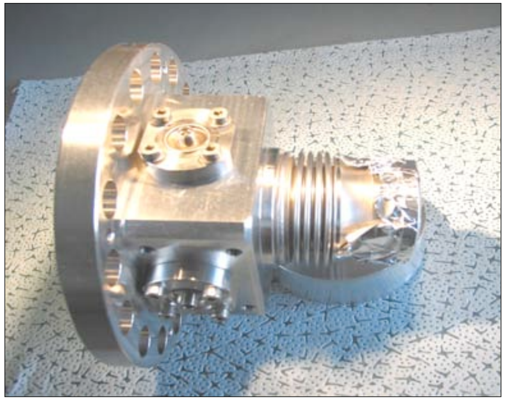
Installation Schedule

	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

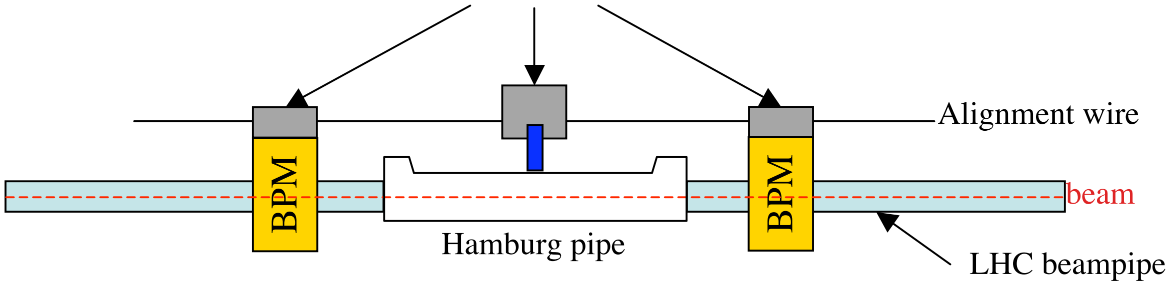
Table 4: The estimated time in days required to install one NCC

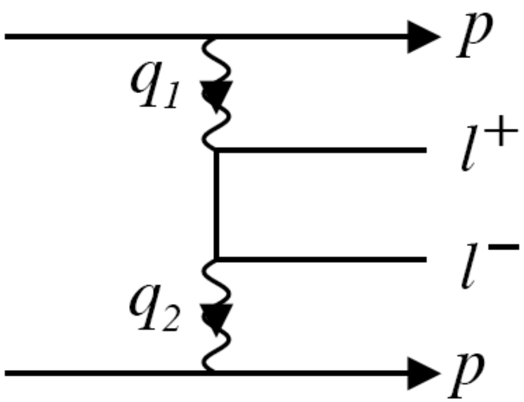
The University of Manchester

FP420 Alignment



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

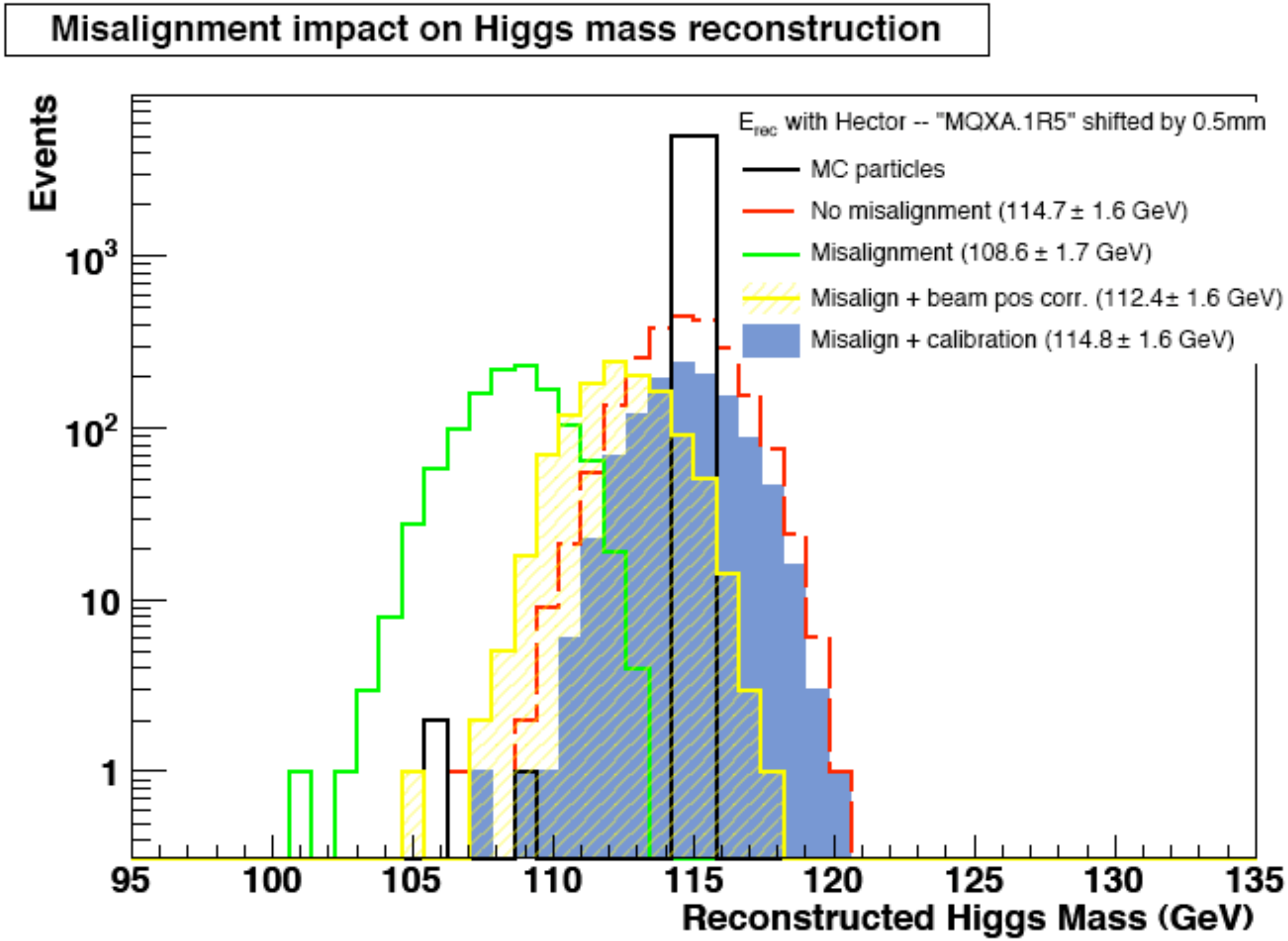




@ 10^{33} $cm^{-2}s^{-1}$ with standard ATLAS triggers, have ~ 30 di-muon events / fill in FP420 acceptance (σ ~ 7pb)

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

Mass reconstruction



Preliminary planning of interconnection: