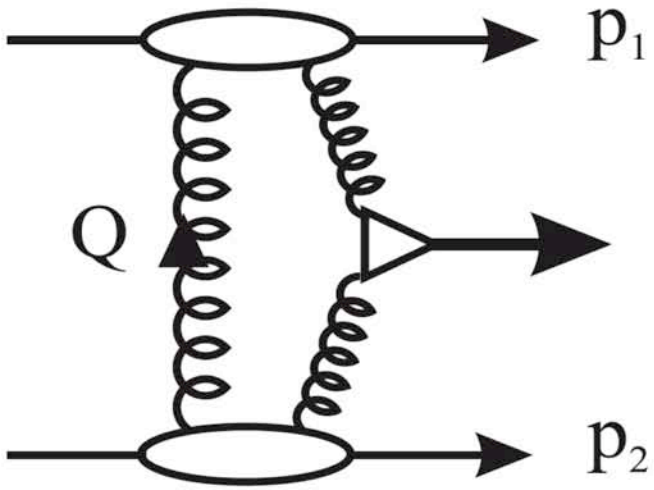
MANCHESTER 1824

The University of Manchester

The FP420 R&D Project



1. Can we detect outgoing protons in interesting x_{IP} range ?
2. Can we use these protons to enhance the discovery potential of the LHC ?

"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 now fully funded : £500k from UK (Silicon, detector stations, beam pipe + LHC optics and cryostat design, DAQ), $100k from US (Fast Timing), €100k Belgium (+Italy / Finland) (mechanics, pocket design, detector stations, slow controls)

Physics case see for example **hep-ph/0409144**

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)
- Management Committee : Mike Albrow (FNAL), Michele Arneodo (Torino / INFN), Andrew Brandt (UTA), Krzysztof Piotrzkowski (Louvain), Risto Orava (Helsinki)
- Key FP420 personnel at CERN and Cockcroft Institute :

  Keith Potter (Manchester, ex-CERN)

  Shrikant Pattalwar (ASTEC - cryogenics),

  Federico Roncarolo (Manchester, RF / Optics / Accelerator)

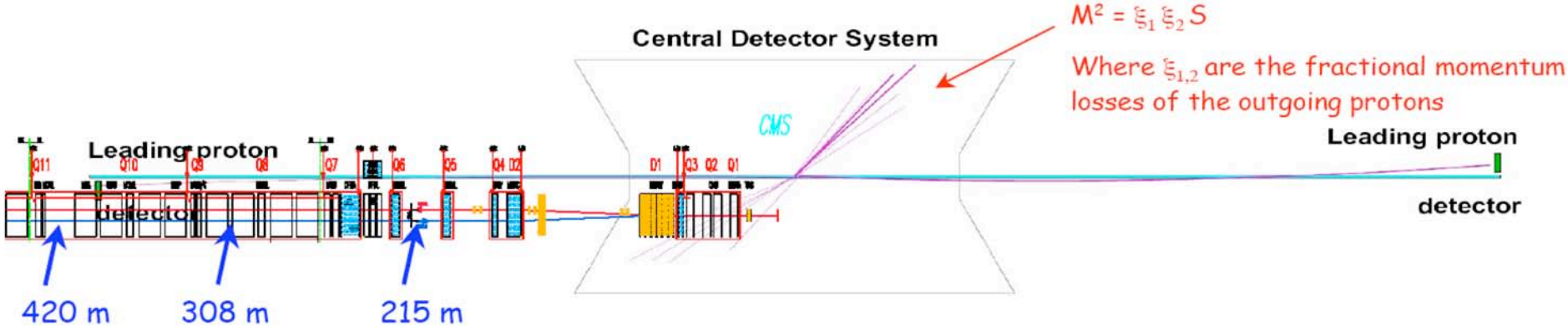
Collaboration : FNAL, The University of Manchester, University of Eastern Piedmont, Novara and INFN-Turin, The Cockcroft Institute, University of Antwerpen, University of Texas at Arlington, The University of Glasgow, University of Calabria and INFN-Cosenza, CERN, Lawrence Livermore National Laboratory, 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

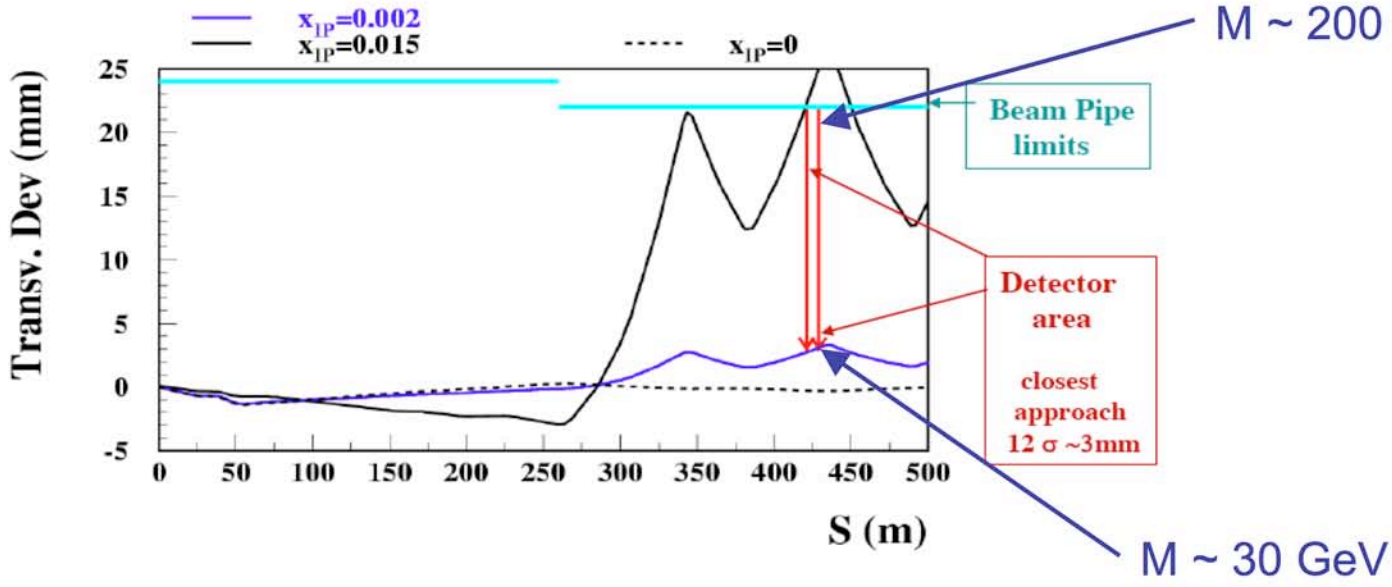
MANCHESTER 1824

The University of Manchester

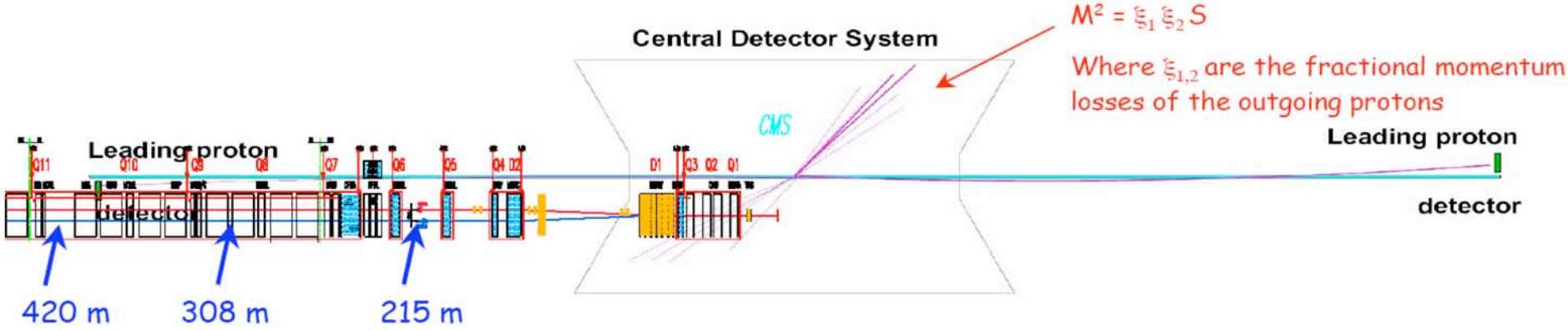
FP420 Schematic Outline

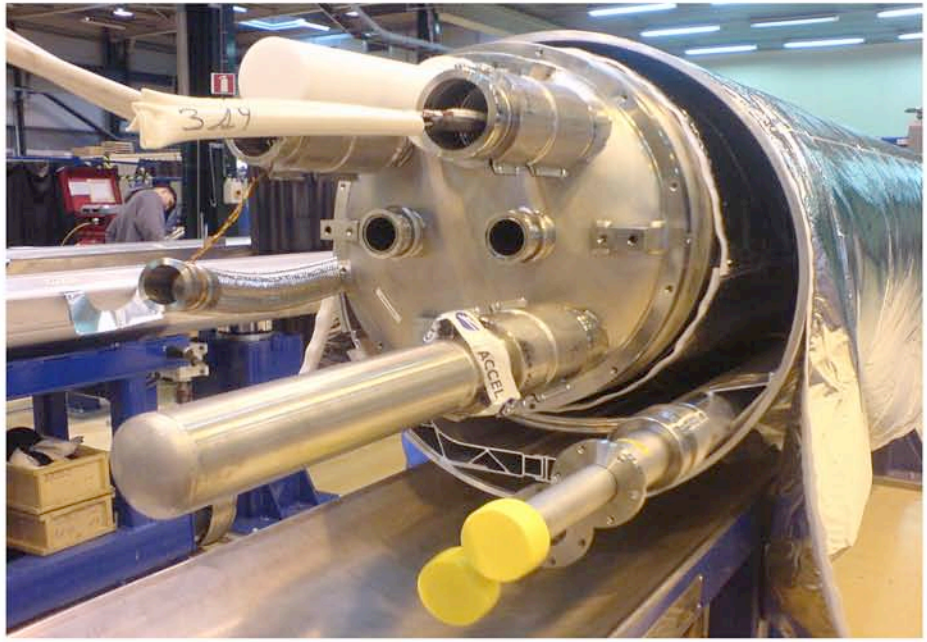
Spectrometer using LHC magnets to bend protons with small momentum loss out of the beam

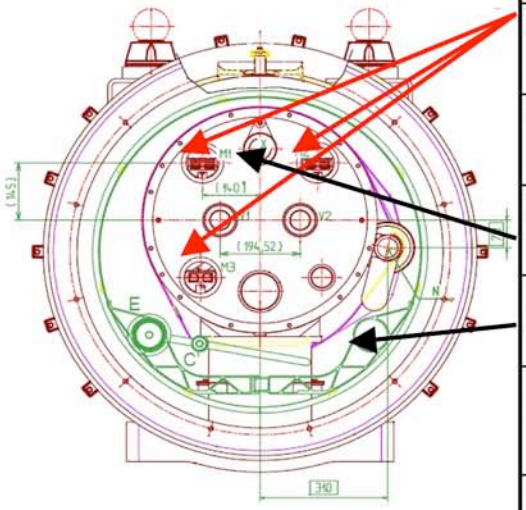




The 420m region at the LHC





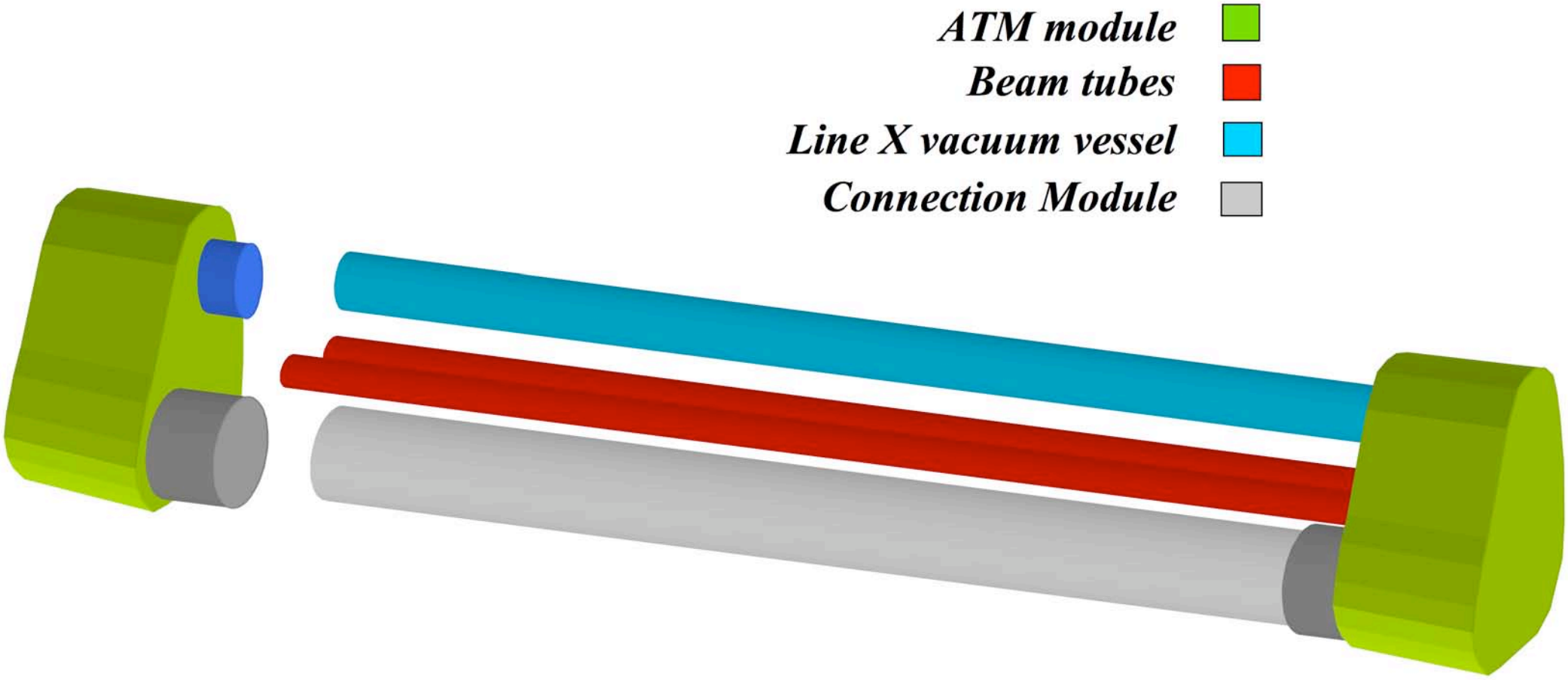


Line	T(K)	$Ø_i$ - $Ø_e$(mm)
M1, M2, M3 Bus-bars	1.9	80-84
N Auxiliary bus-bars	1.9	50-53
X Heat exchanger	1.8	54-58
E Thermal shield	50-65	79-86
C' Supports posts and beam screens	4.6	15-17.2
V1, V2 He jackets	1.9	50-53 66-70

MANCHESTER 1824

The University of Manchester

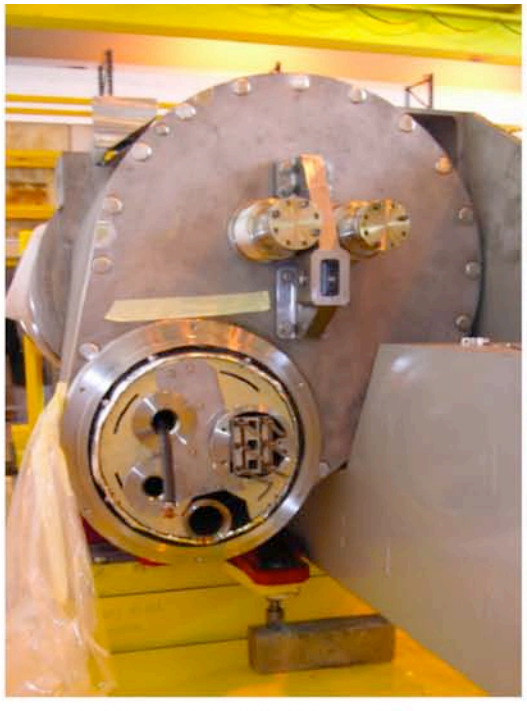
The FP420 connection cryostat :

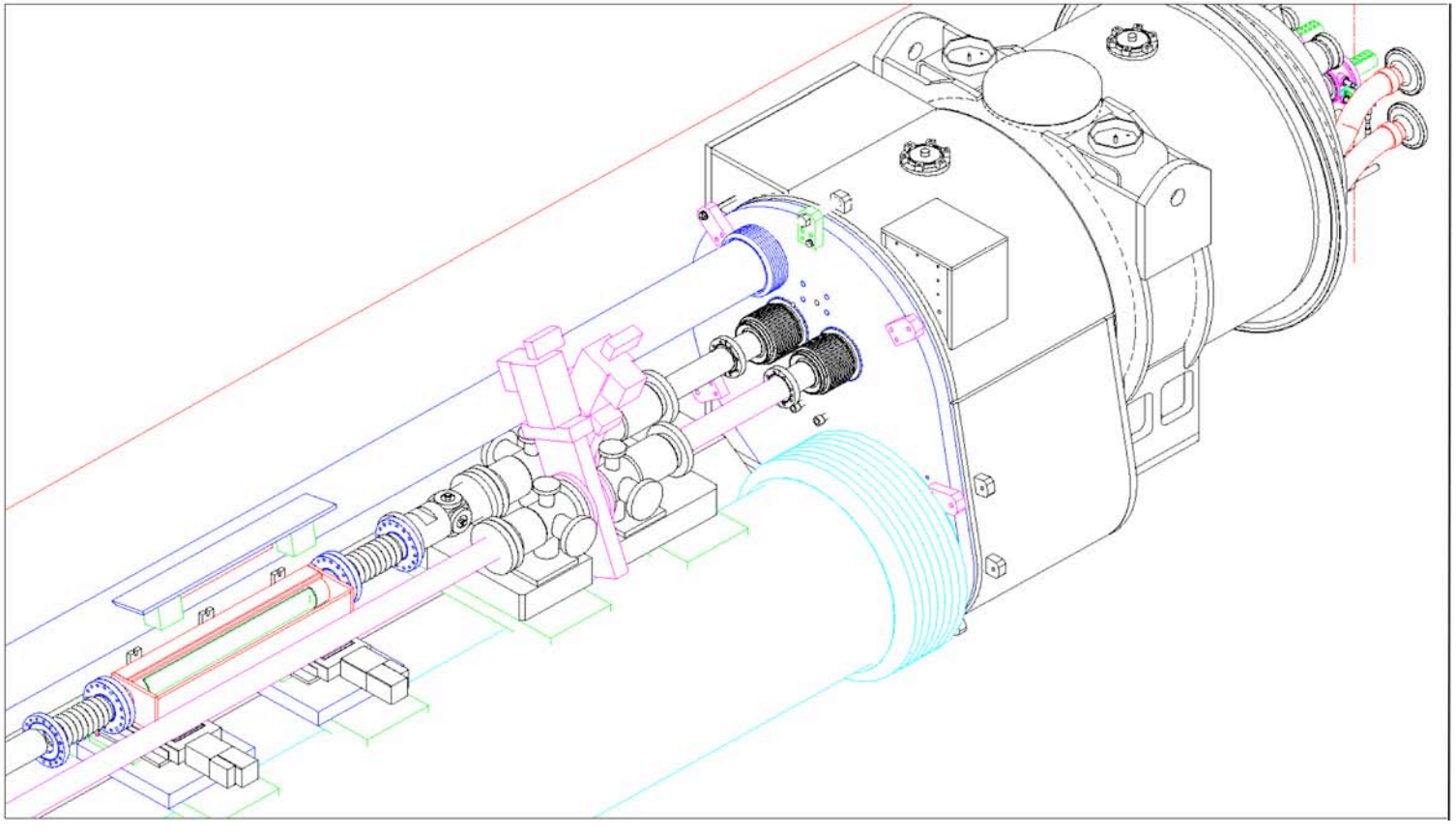


MANCHESTER 1824

The University of Manchester

FP420 ATMs





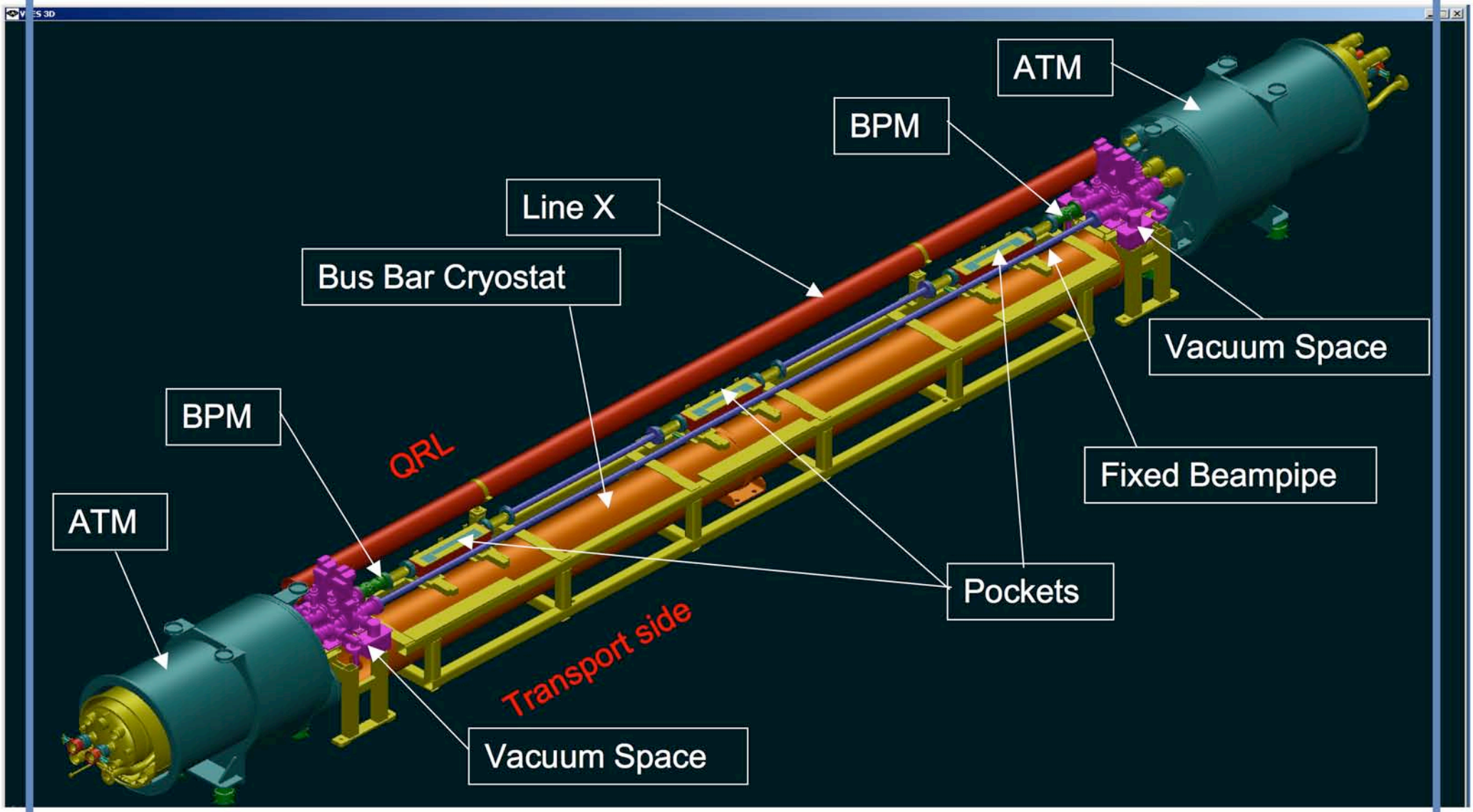
T. Colombet,

T. Renaglia,

R. Folch

TECHNICAL SUPPORT DEPARTMENT

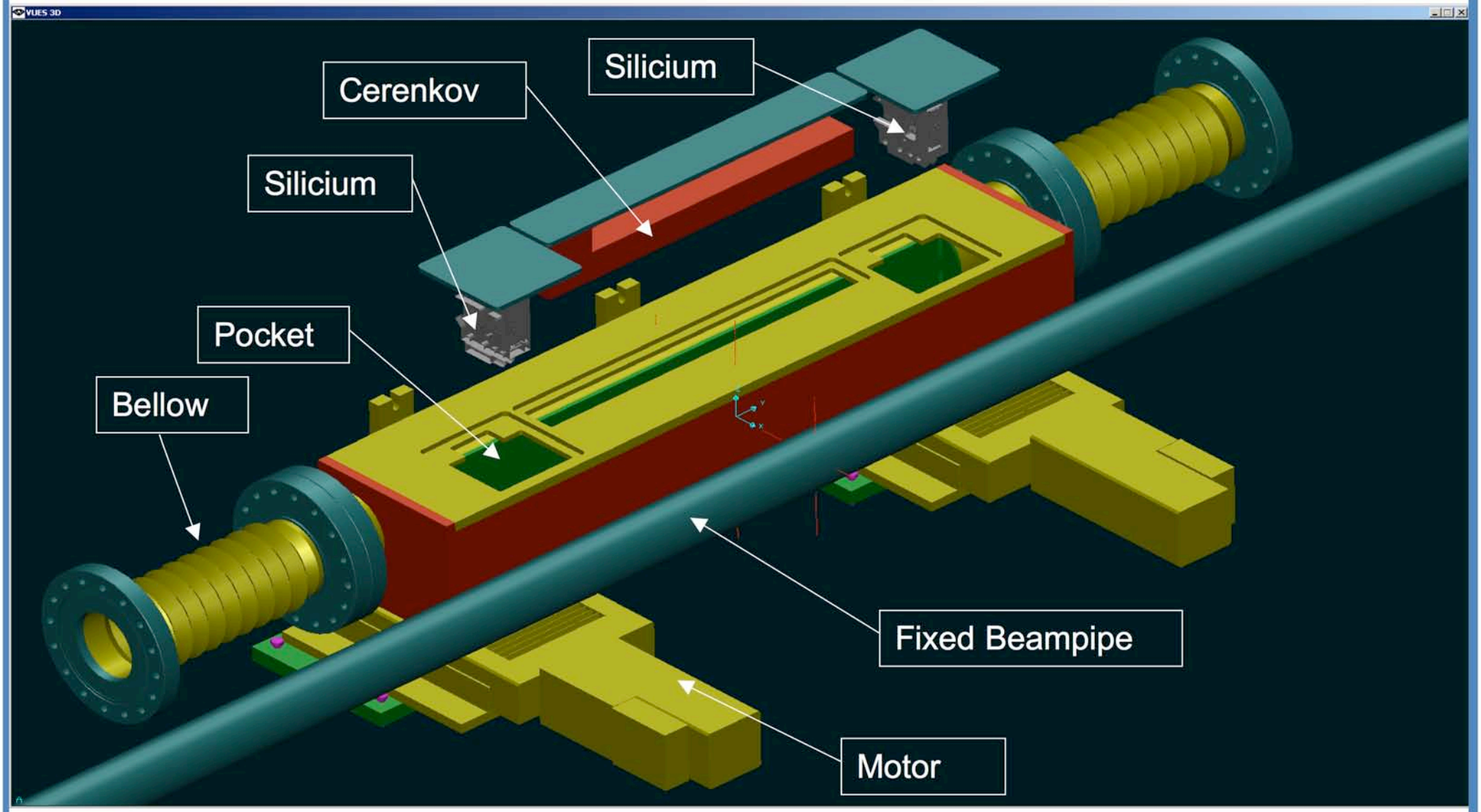
Integration of the moving beampipe and detectors



Benoît Florins, Krzysztof Piotrzkowski, Guido Ryckewaert

CRC
Louvain-la-Neuve

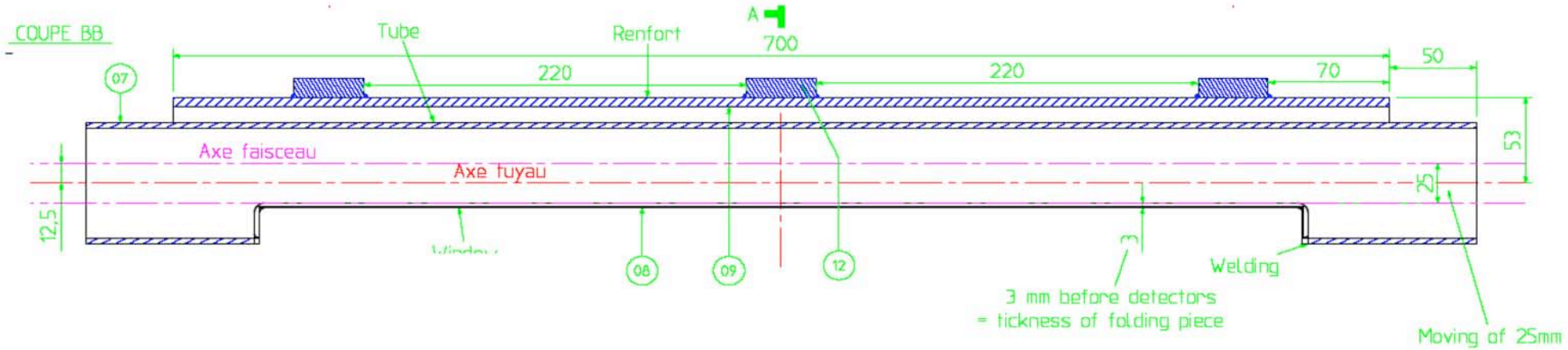
Integration of the moving beampipe and detectors

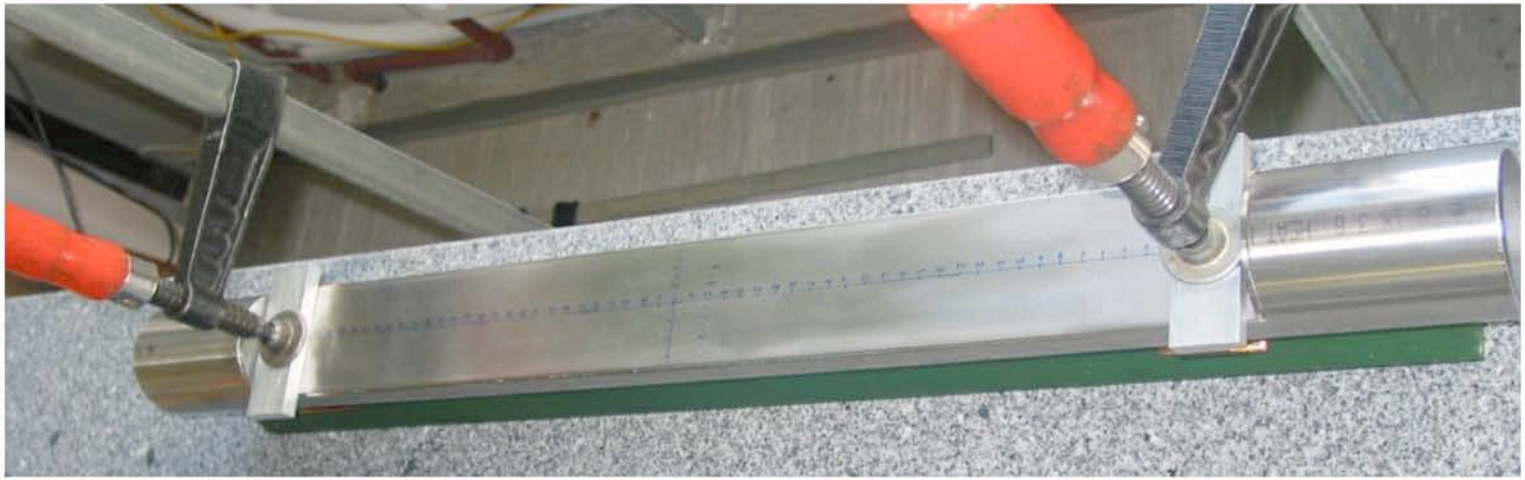


Benoît Florins, Krzysztof Piotrzkowski, Guido Ryckewaert

CRC
Louvain -la -Neuve

Prototype FP420 Pocket

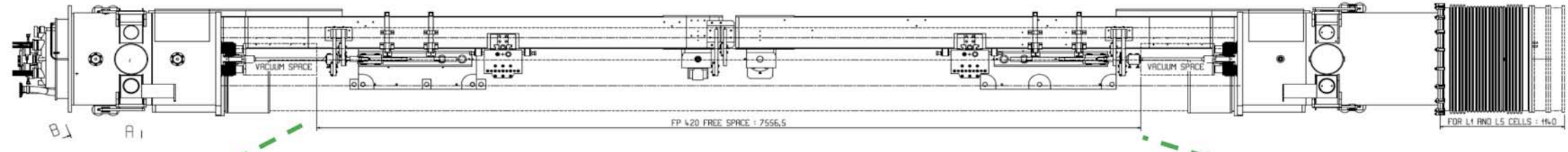


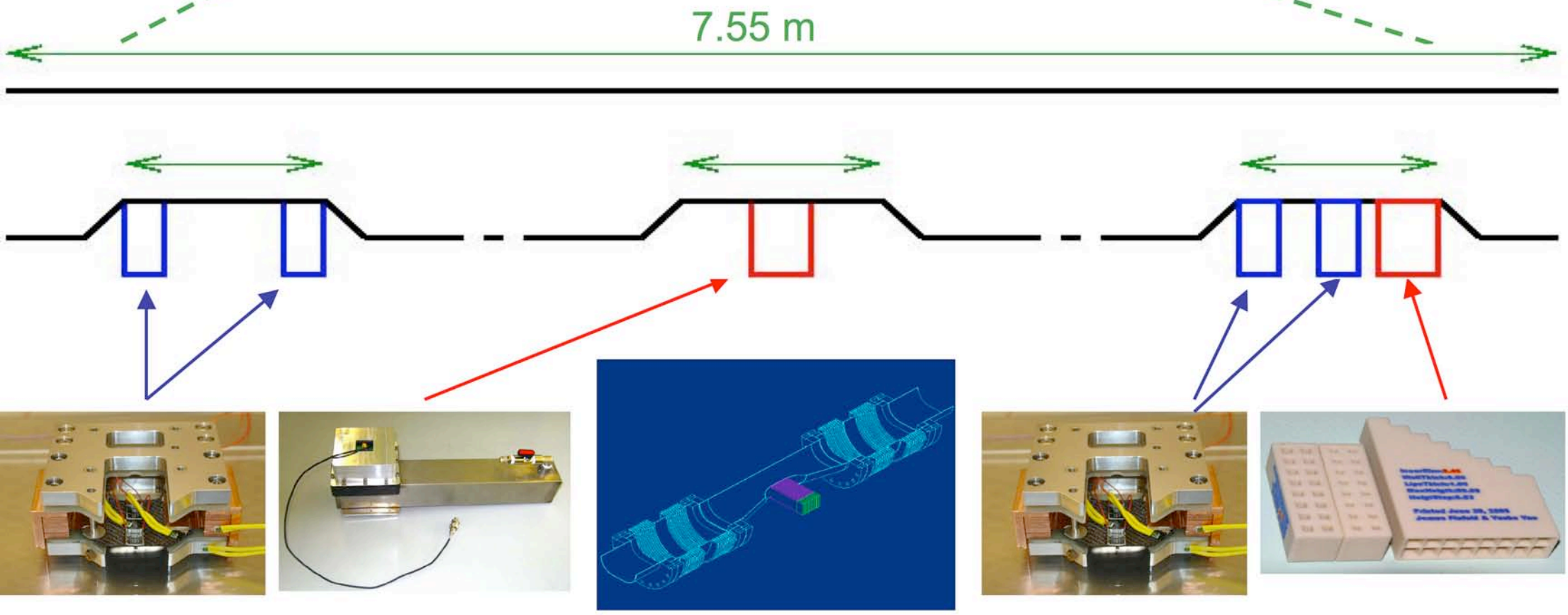


Pocket prototype constructed at Louvain and undergoing simulation and wire-testing at Cockcroft Institute for trapped modes, beam stability etc.

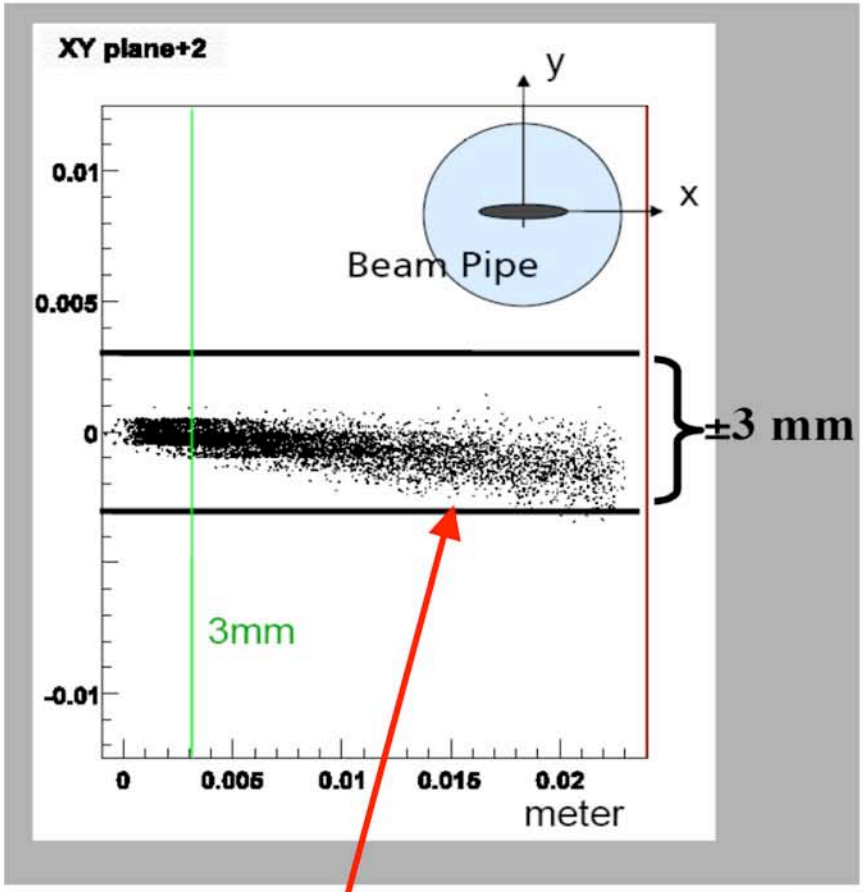
Schematic baseline design

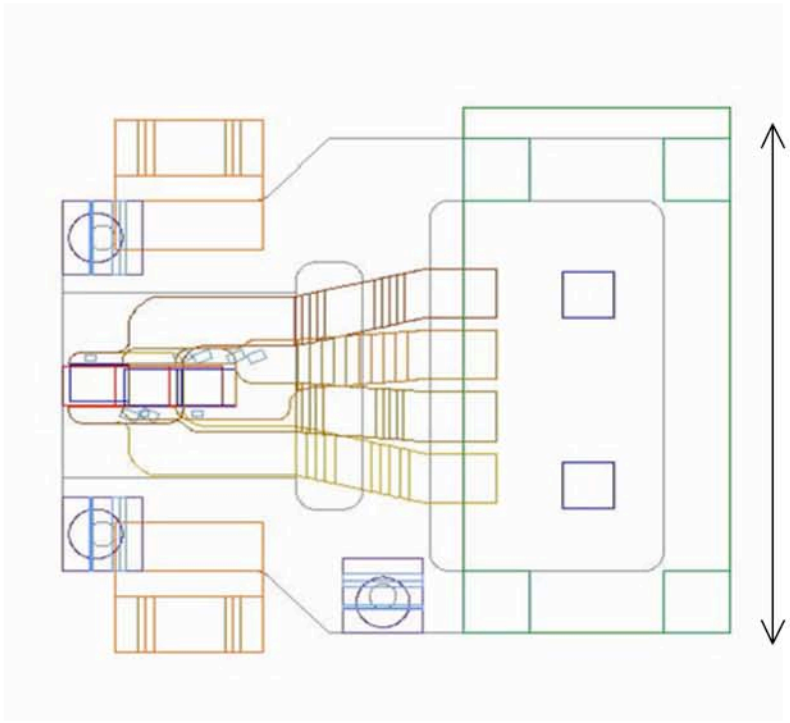
T. Renaglia, EDMS 771549





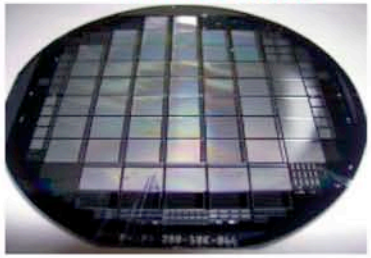
FP420 Silicon Detector Stations

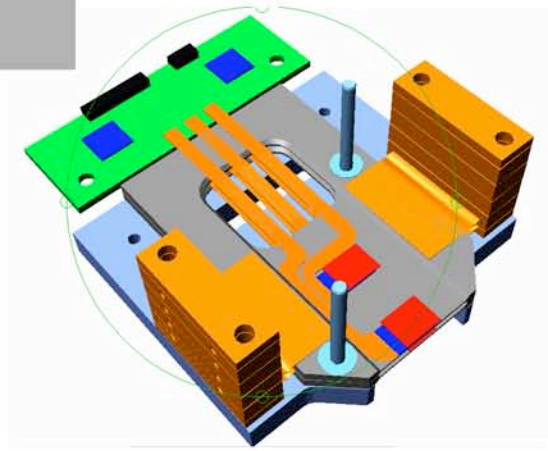


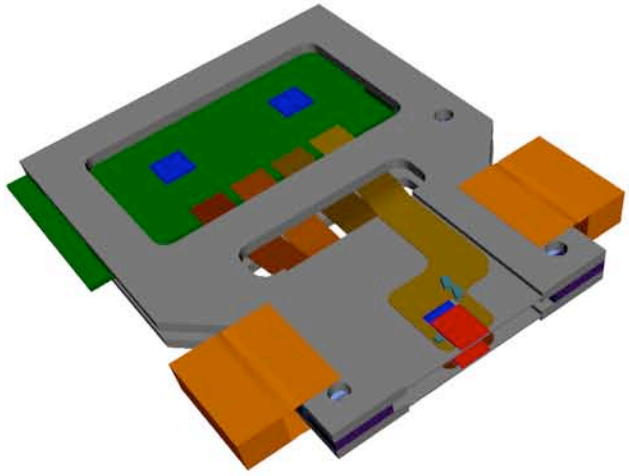


7.2 mm x 24mm (7.2 x 8 mm^2 sensors)

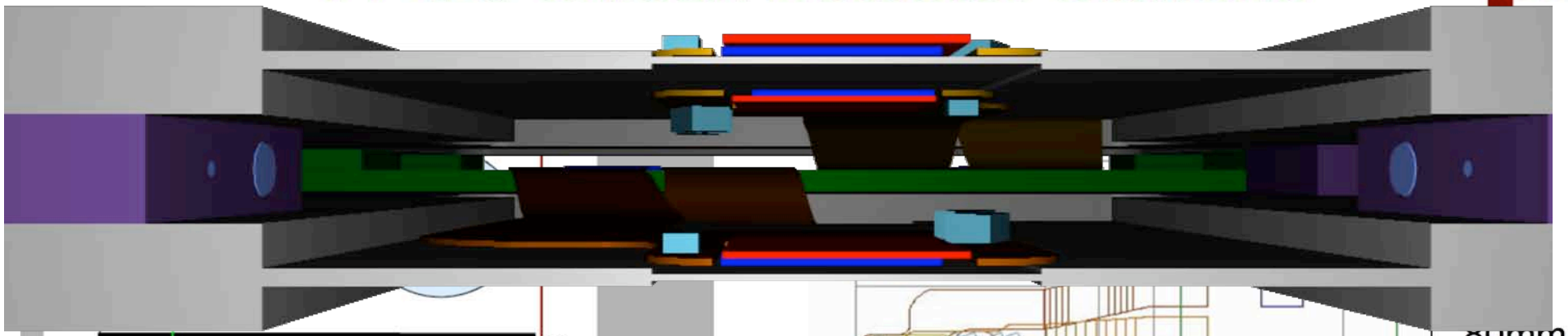
FP420 Mask

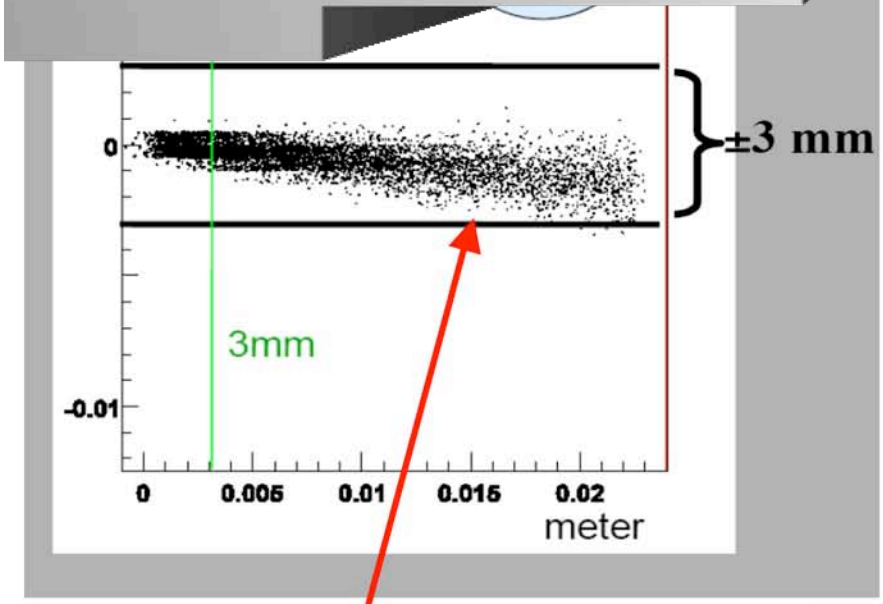






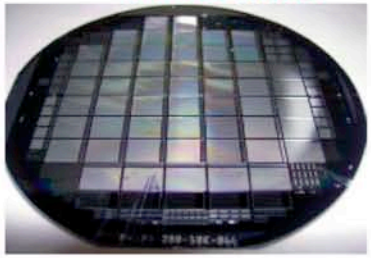
FP420 Silicon Detector Stations

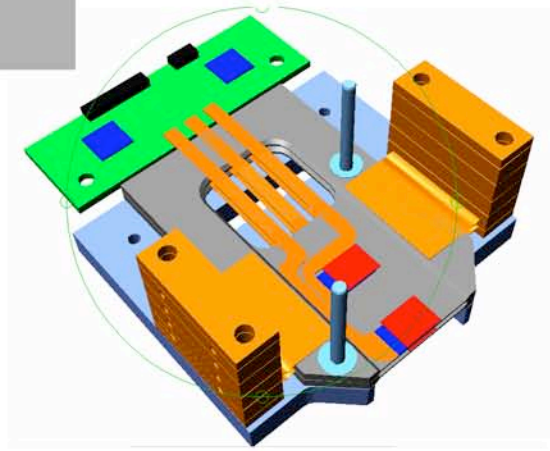


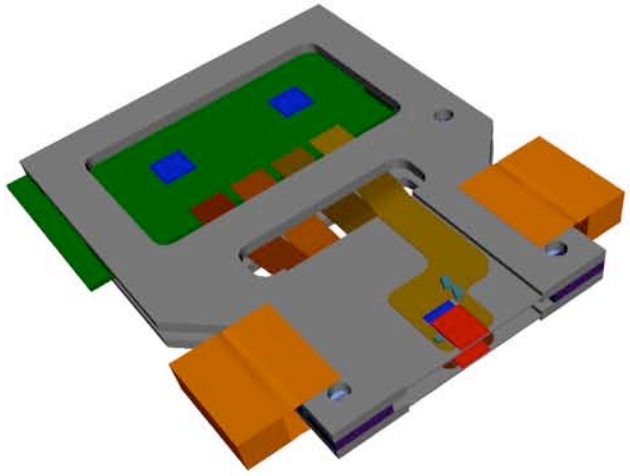


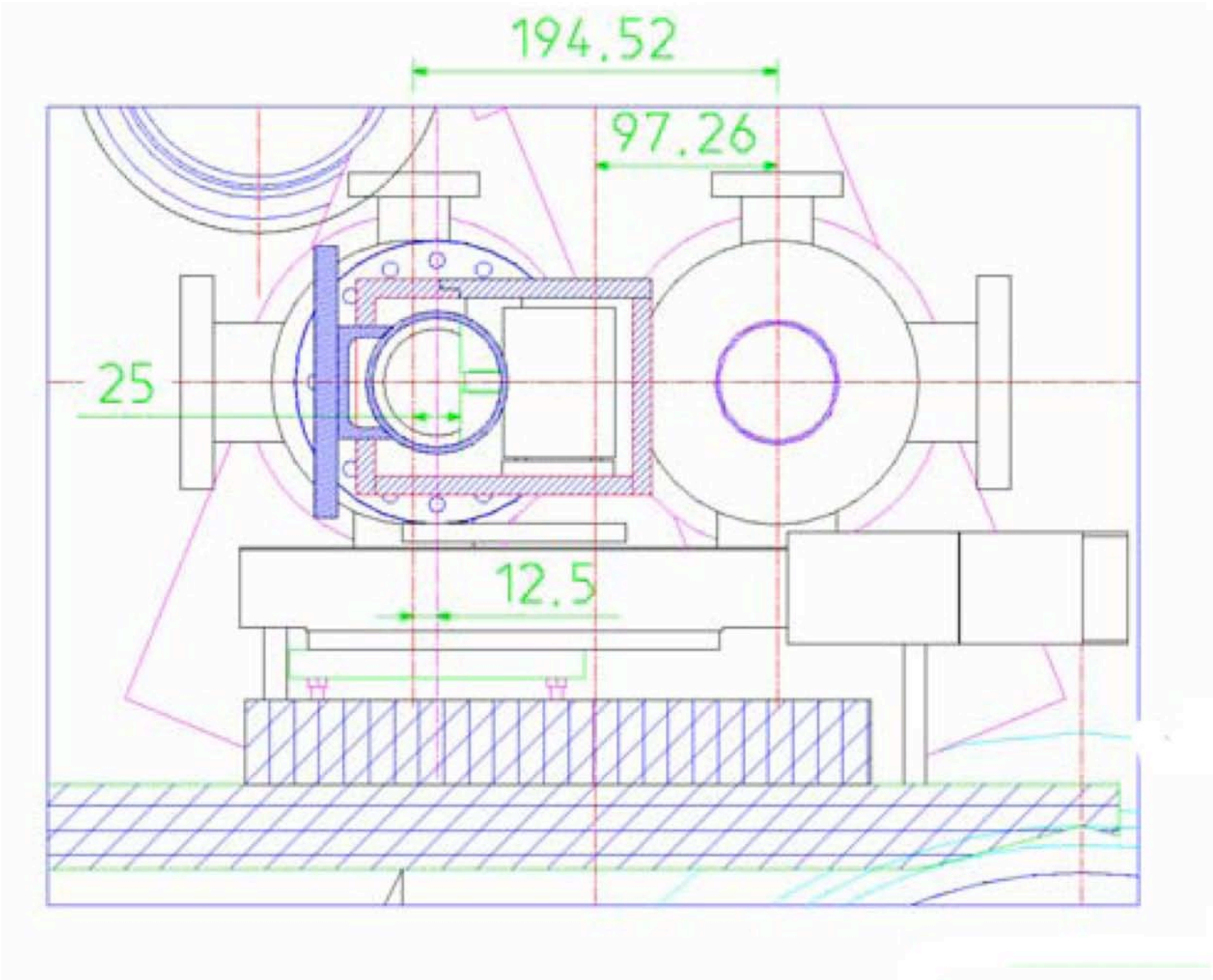
7.2 mm x 24mm (7.2 x 8 mm^2 sensors)

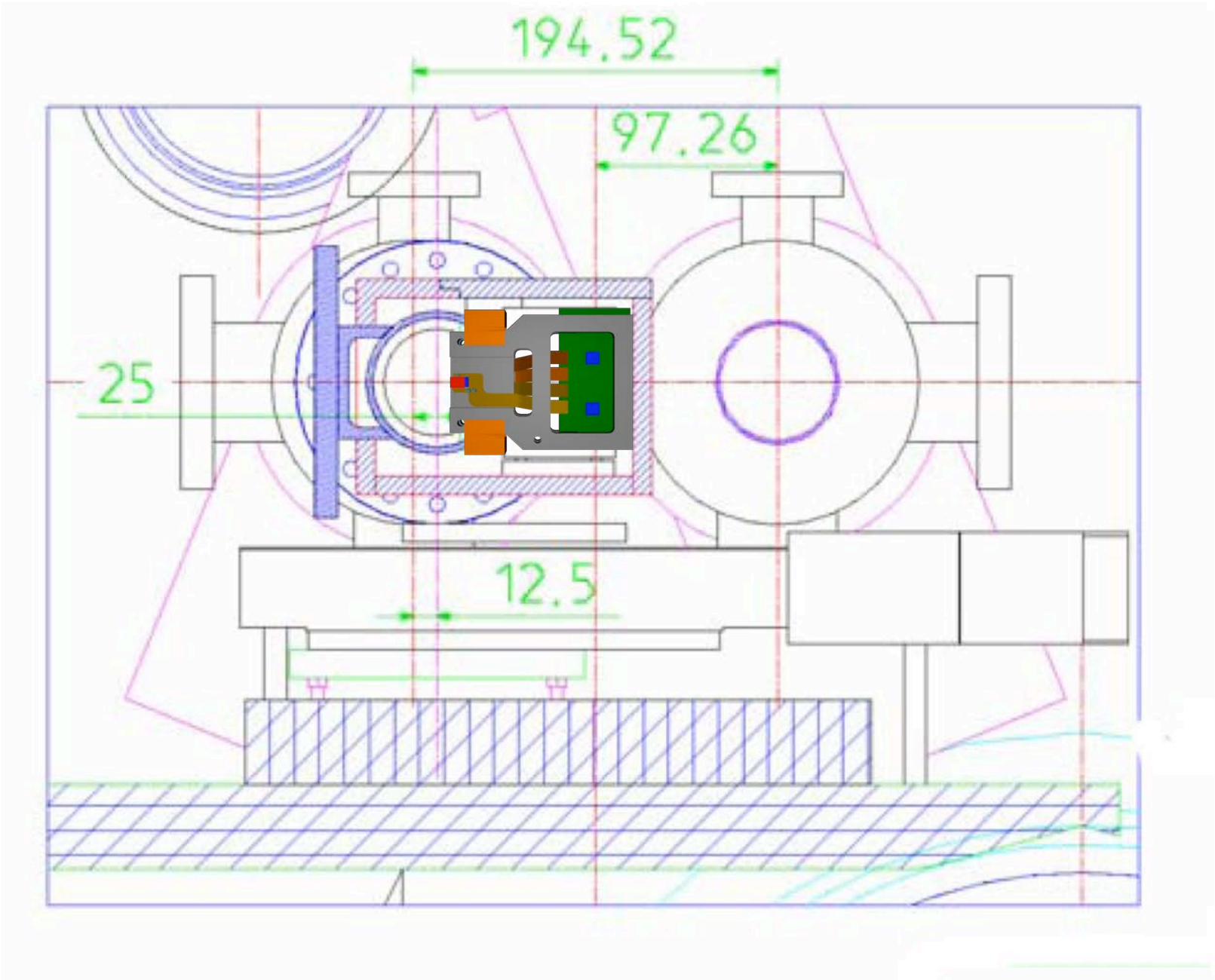
FP420 Mask





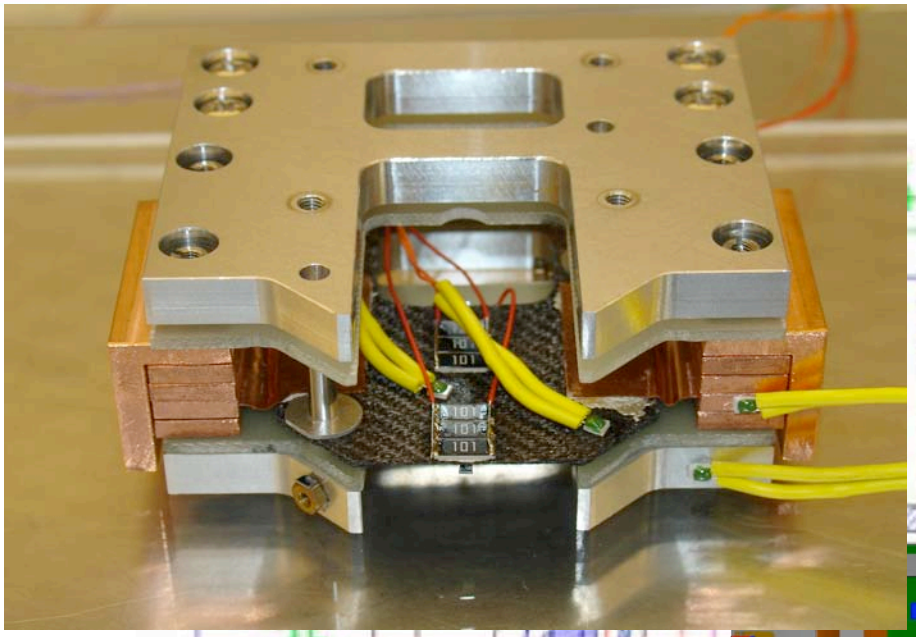






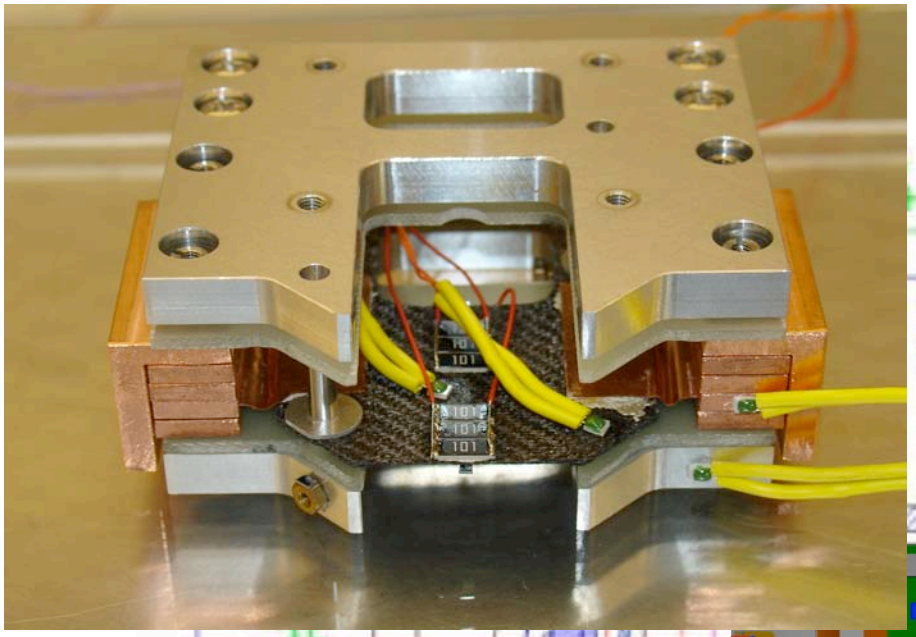
MANCHESTER 1824

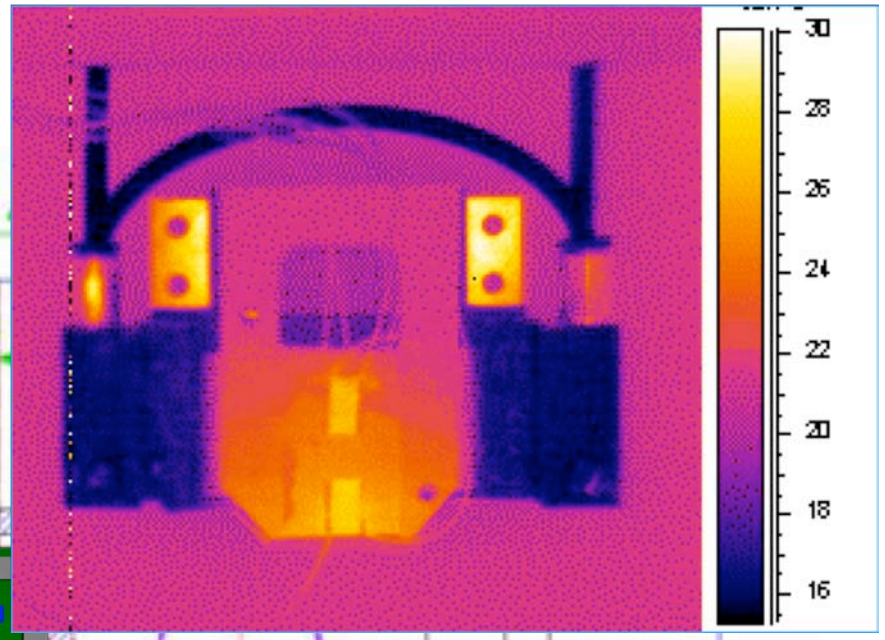
The University of Manchester

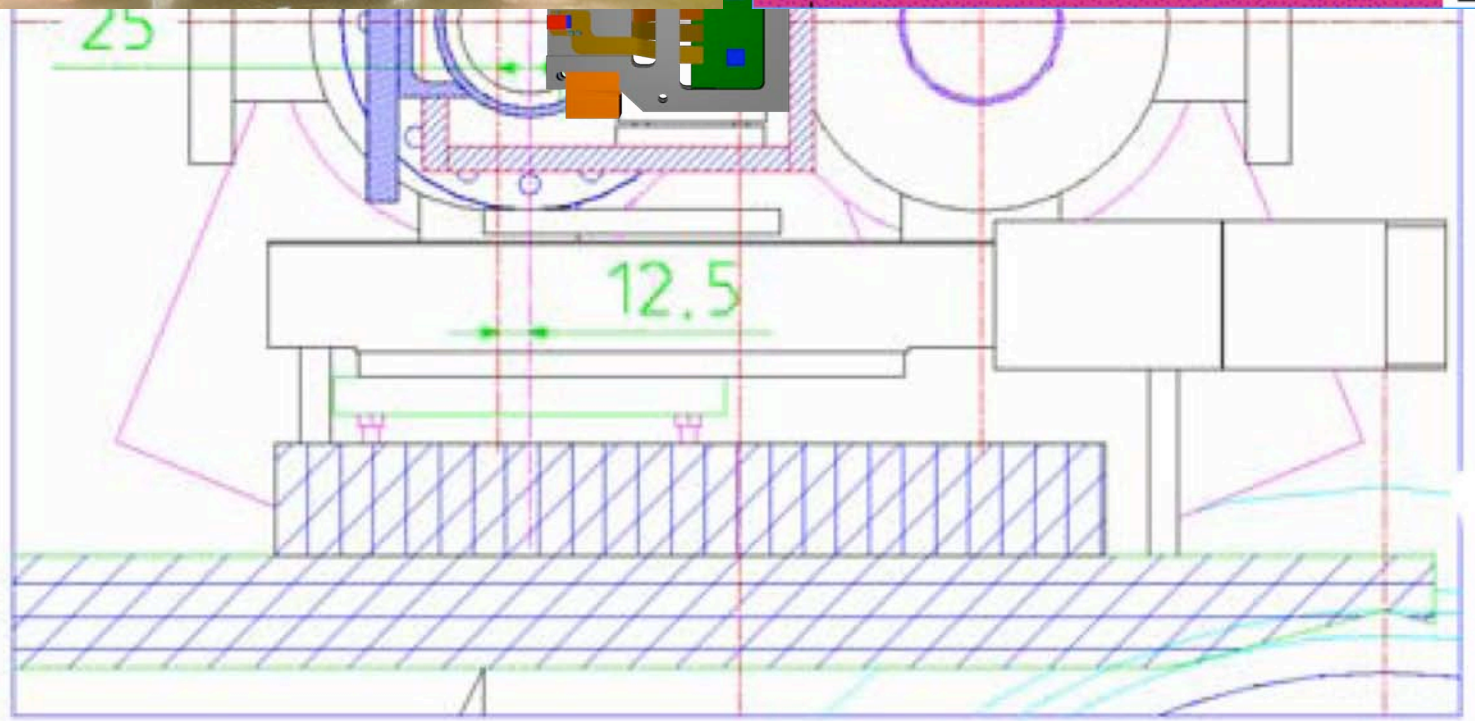


MANCHESTER 1824

The University of Manchester

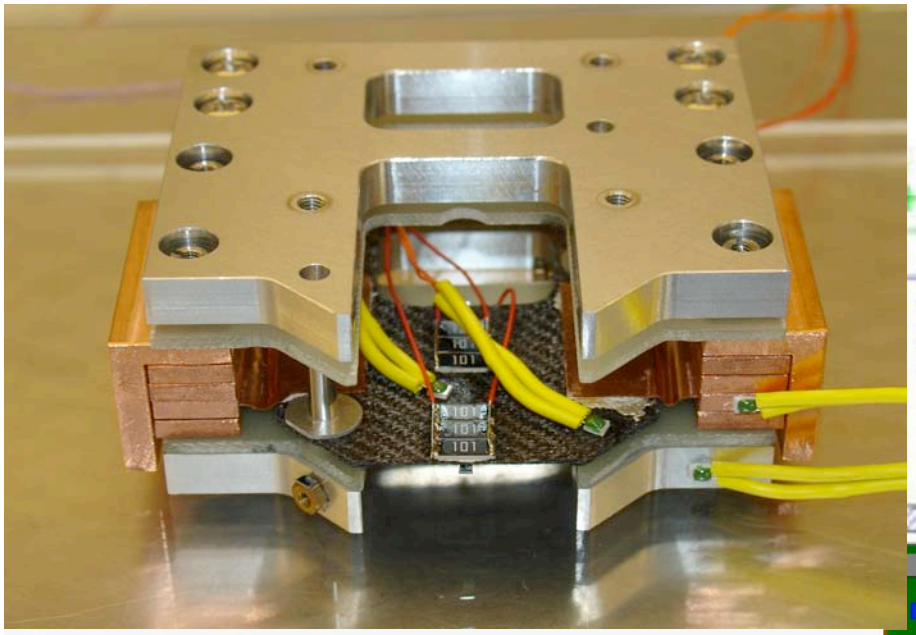


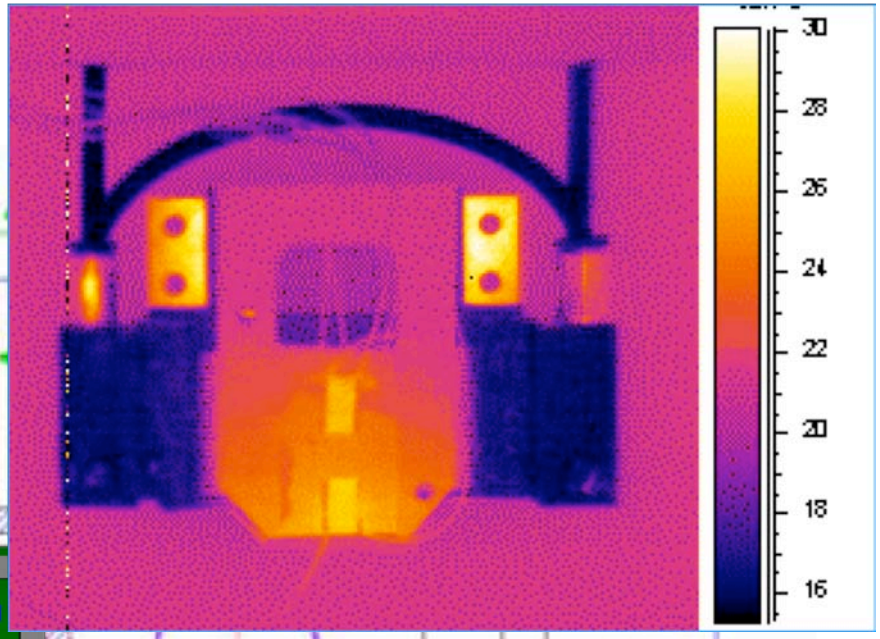




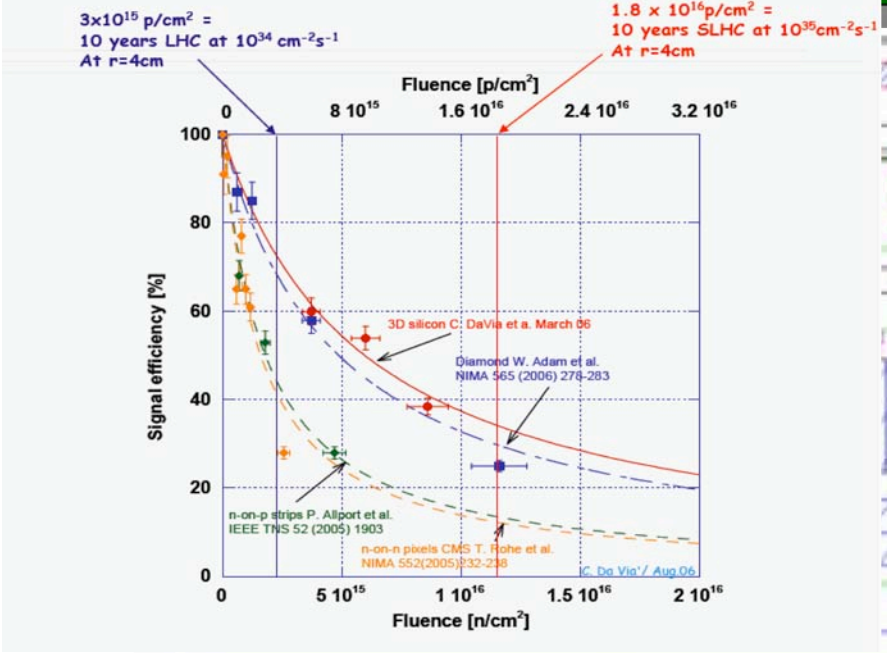
MANCHESTER 1824

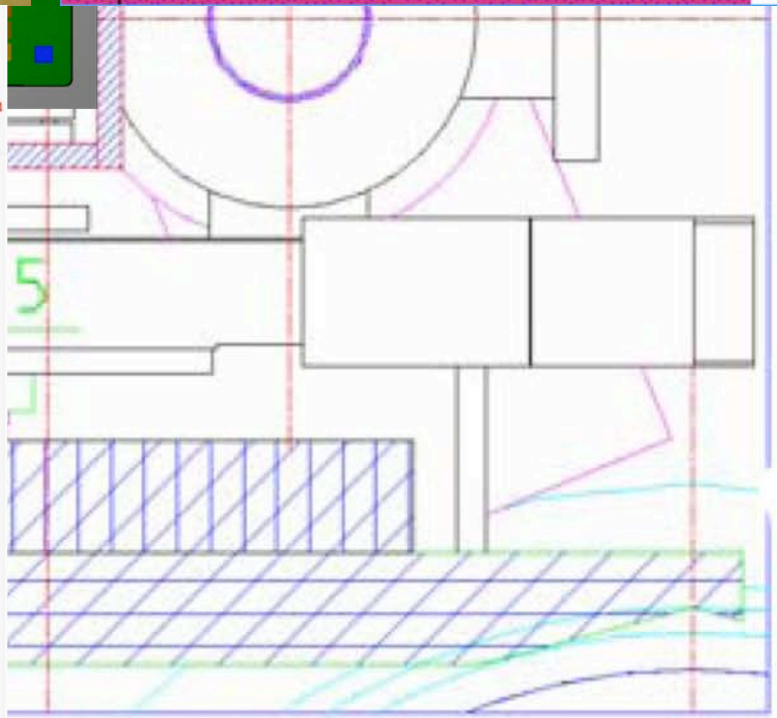
The University of Manchester





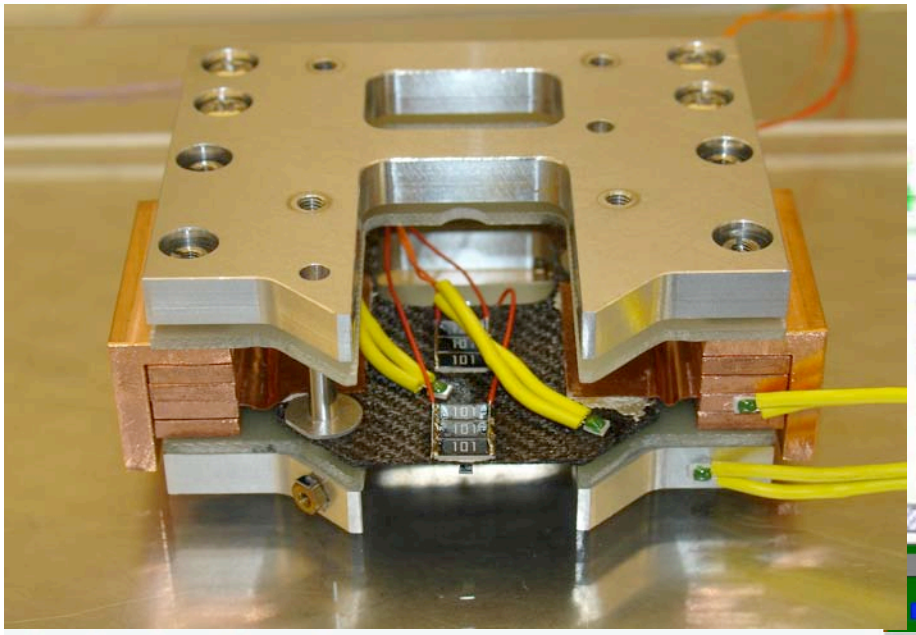
Radiation Hardness

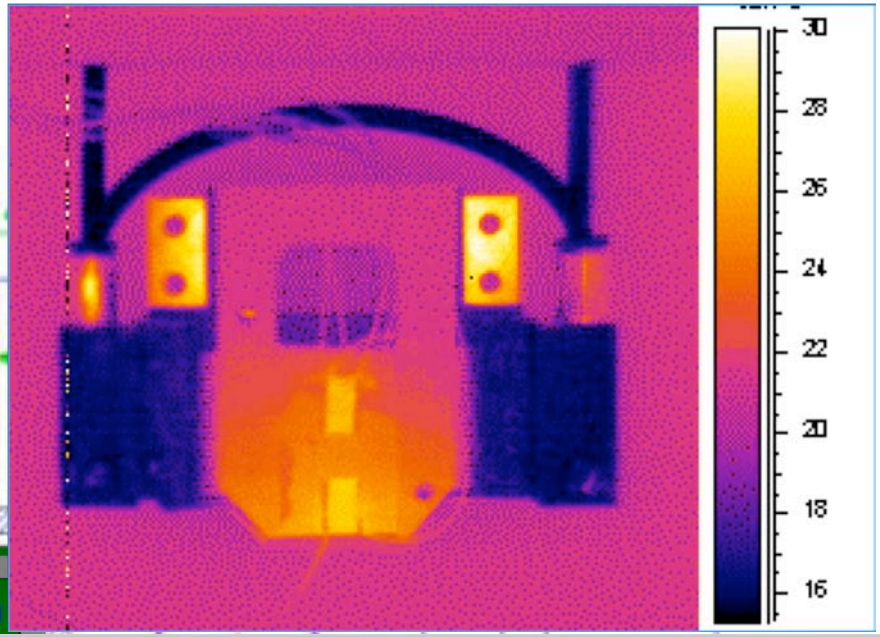




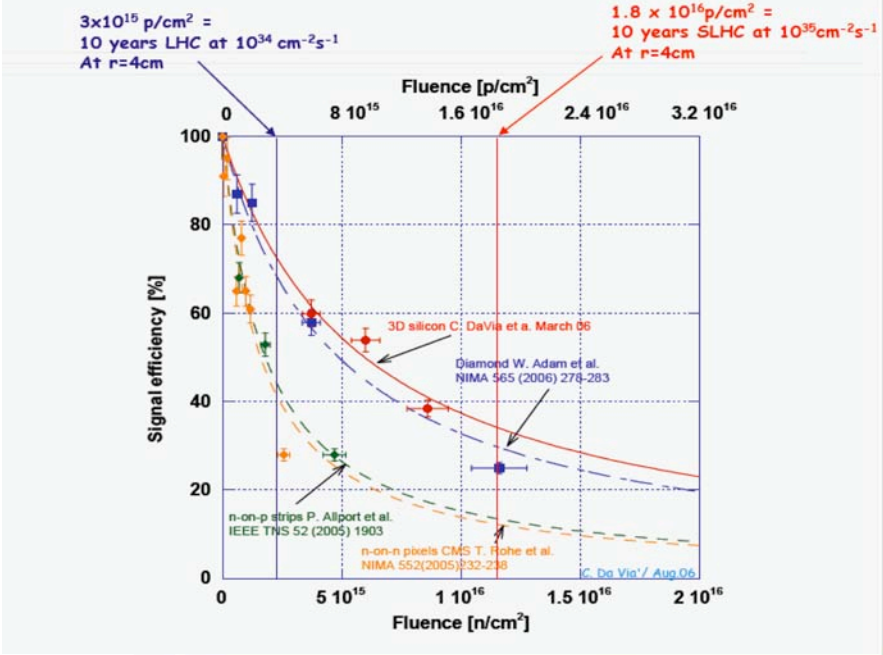
MANCHESTER 1824

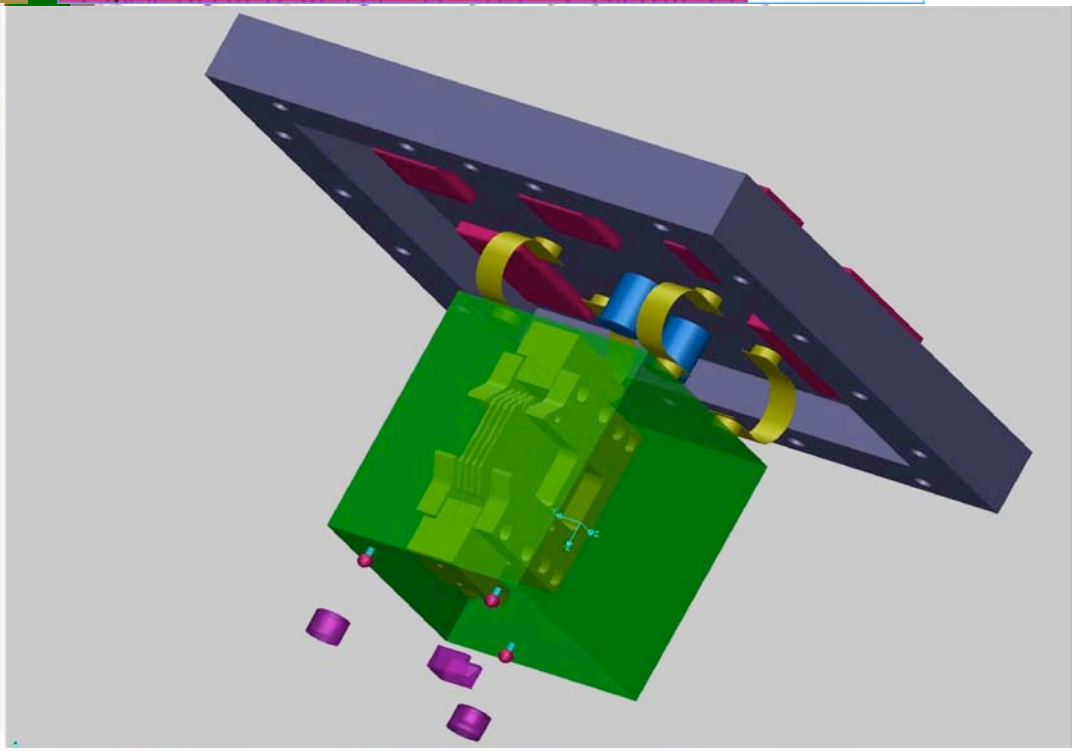
The University of Manchester





Radiation Hardness

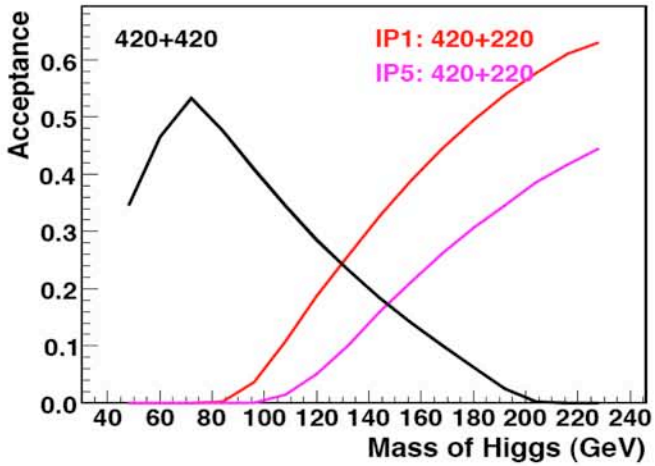




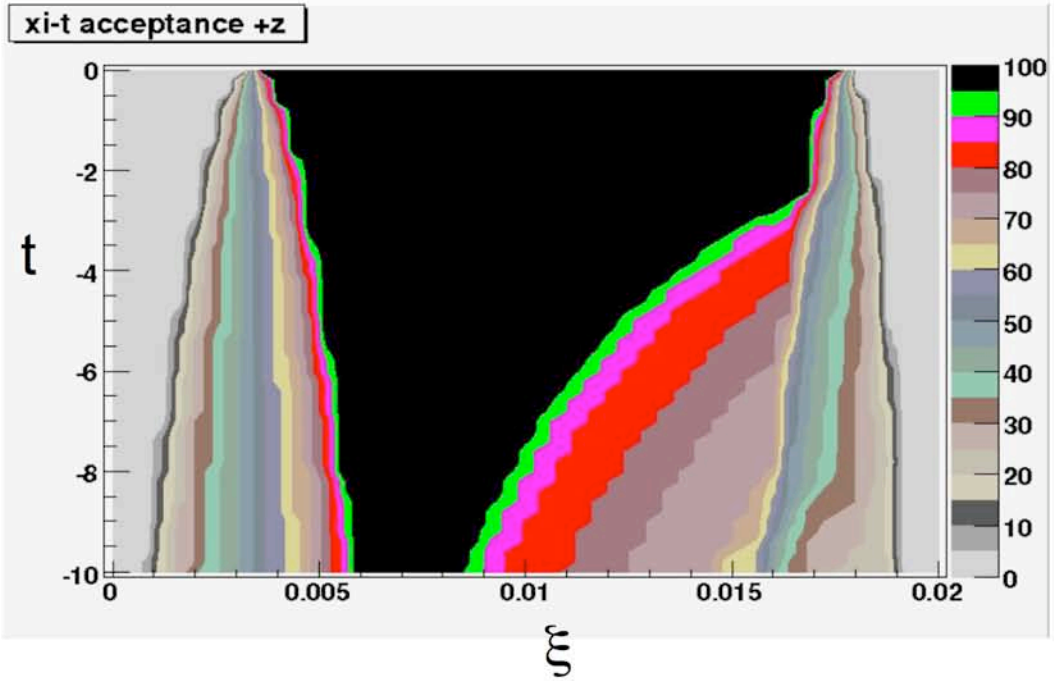
MANCHESTER 1824

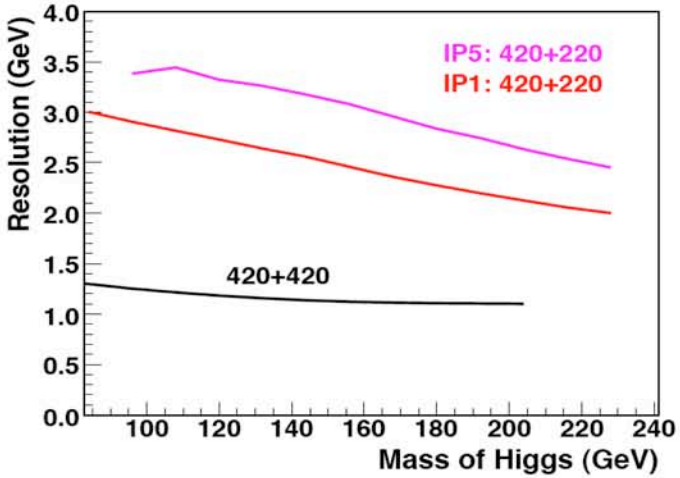
The University of Manchester

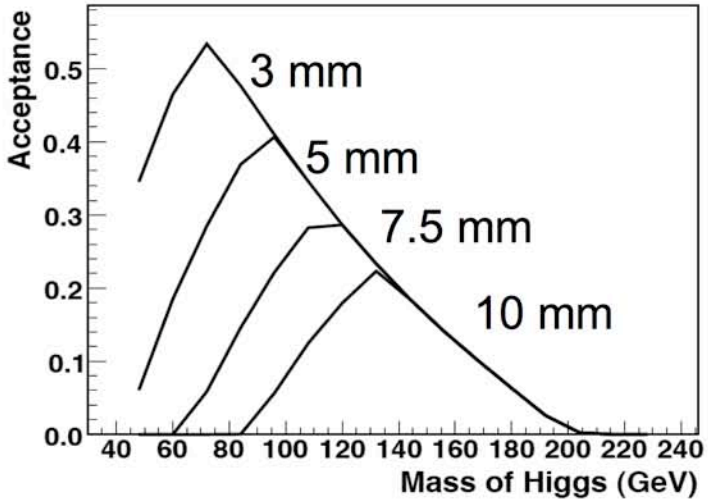
FP420 Acceptance and Resolution

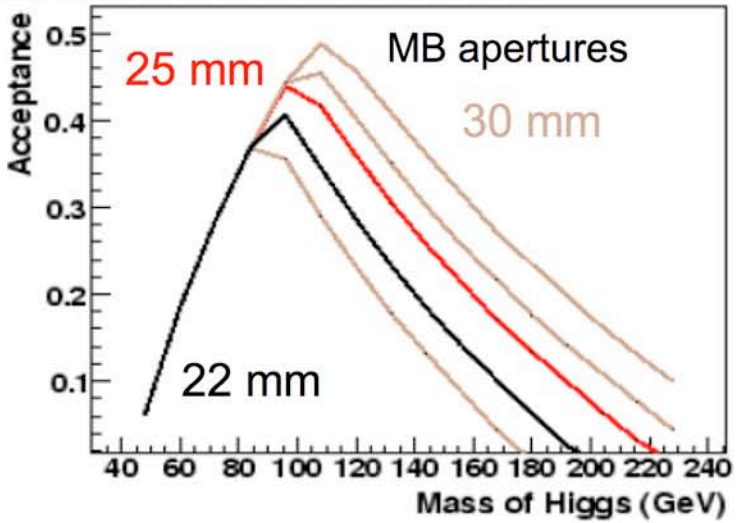


3 mm + 3 mm









Plots : P. Bussey / W. Plano using ExHuME / FPTrack / FPTrack++

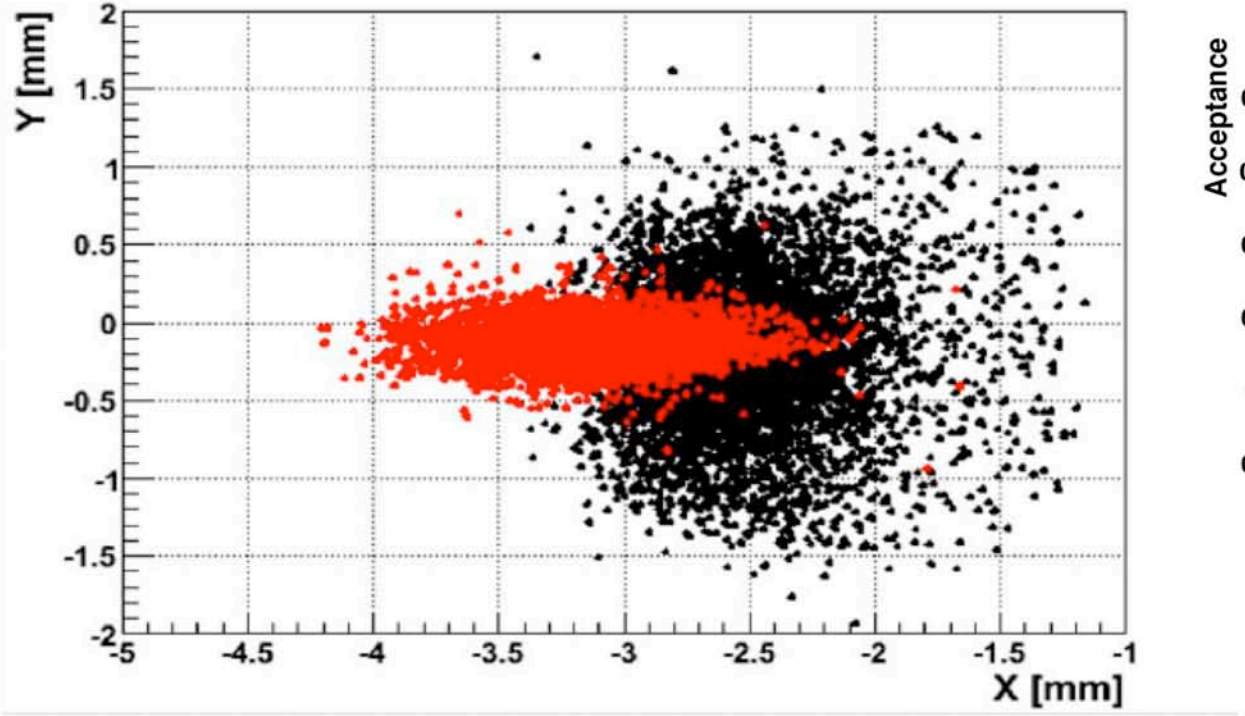
I Baishev, F. Roncarolo, K. Potter

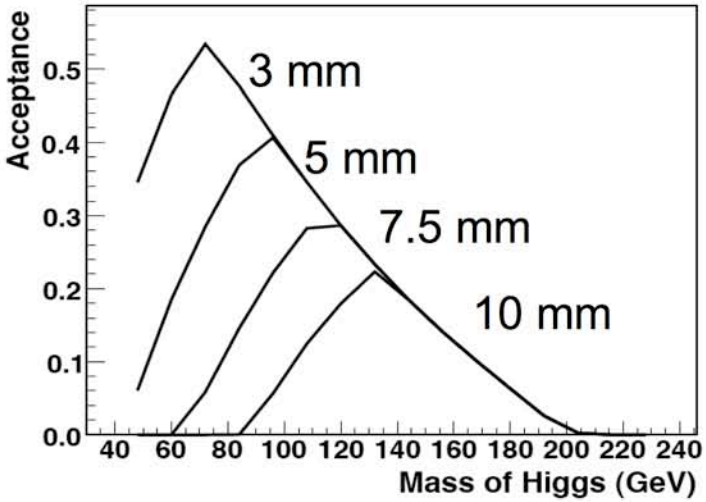
MANCHESTER 1824

The University of Manchester

Machine Induced Backgrounds

- 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

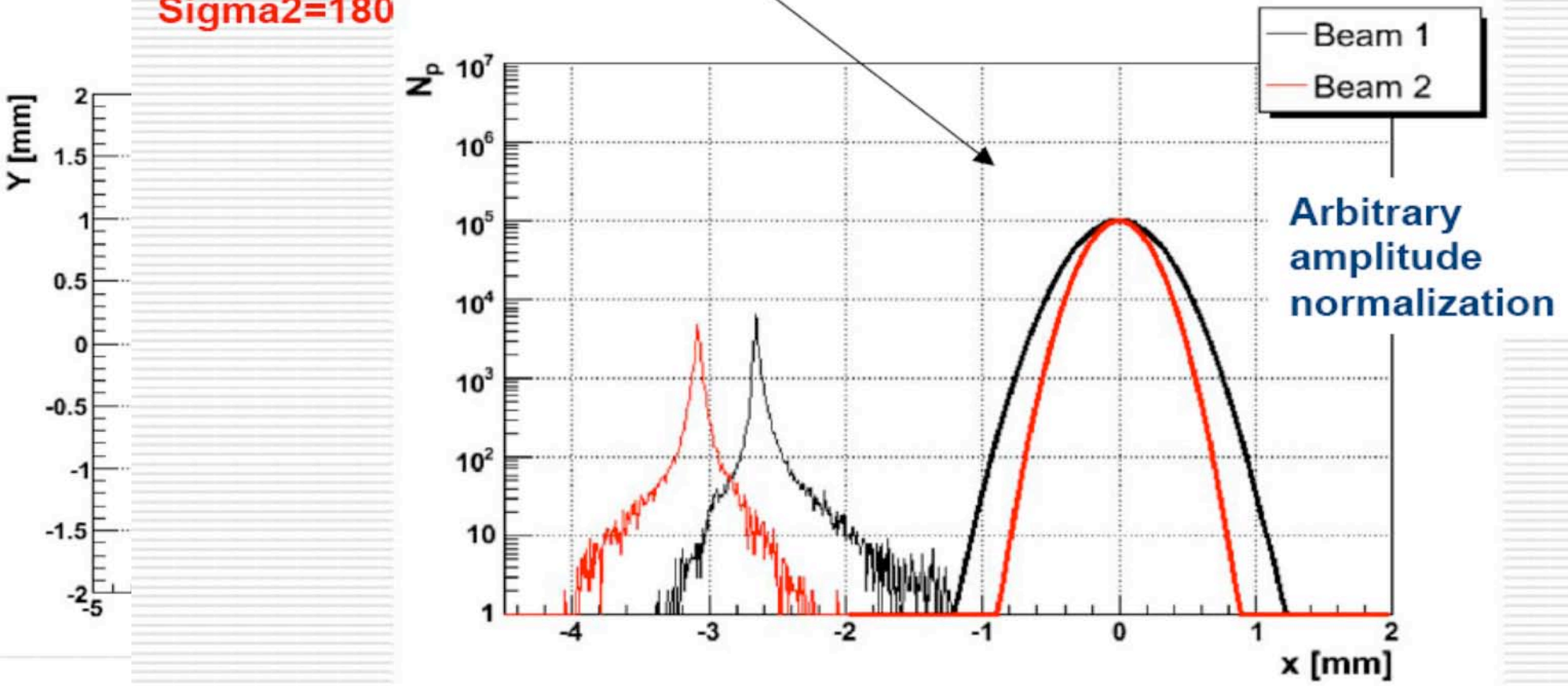
Machine Induced Backgrounds

Hor beam profiles with nominal optics and momentum spread

Physical beam sizes:

Sigma1=250um

Sigma2=180



MANCHESTER 1824

The University of Manchester

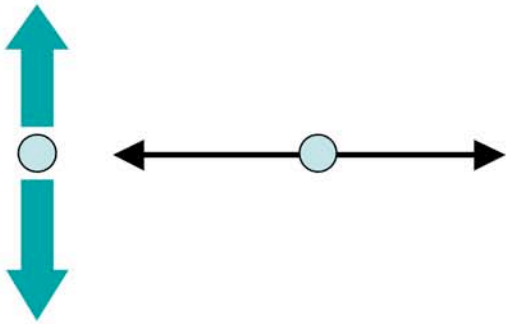
Slides from A. Brandt Dec 2006

Fast Timing Detectors for FP420

UTA (**Brandt**), Alberta (Pinfold), Louvain (K.P.), FNAL (Albrow)

WHY? Pileup Background Rejection

E.g., Two protons from SD interactions, and two b-jets from another



How?

Compare z-vertex for SVX with TOF

$z=c(TR-TL)/2$

How Fast?

δz (mm) $=0.21\ \delta t$ (psec)
(2.1 mm for $\delta t=10$ psec)

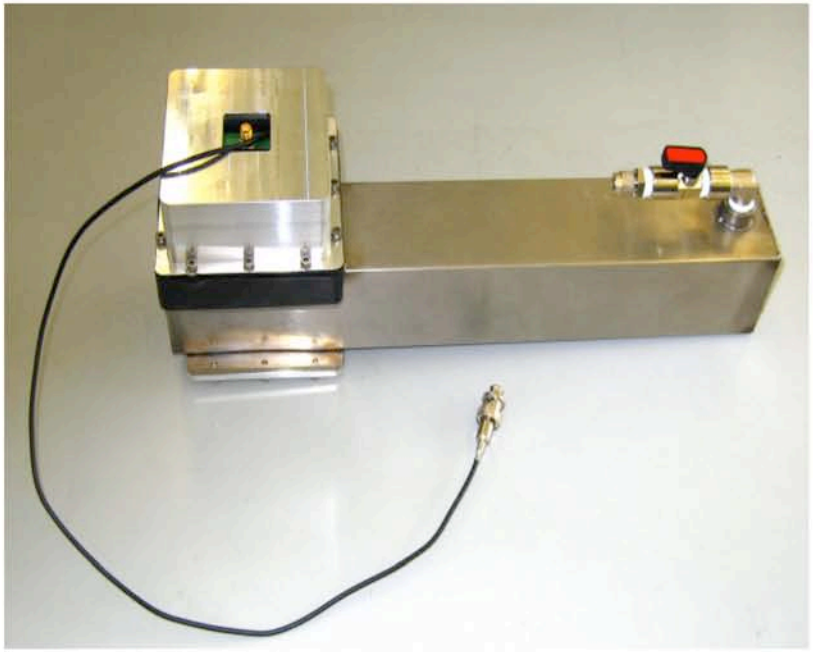
10 psec -> x40 to x30 rejection

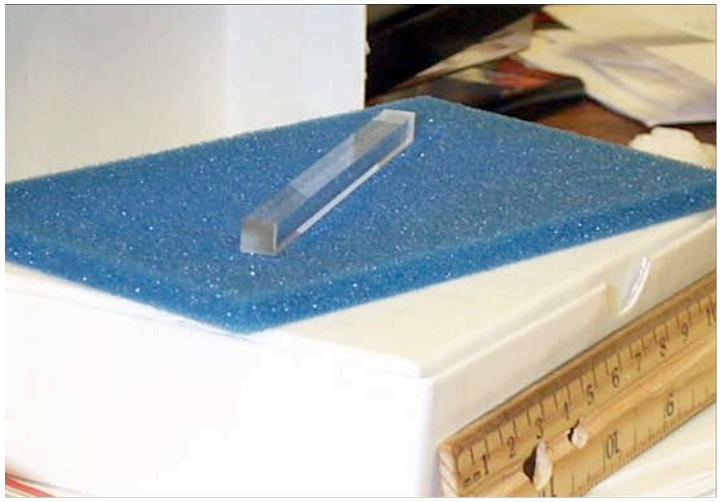
MANCHESTER 1824

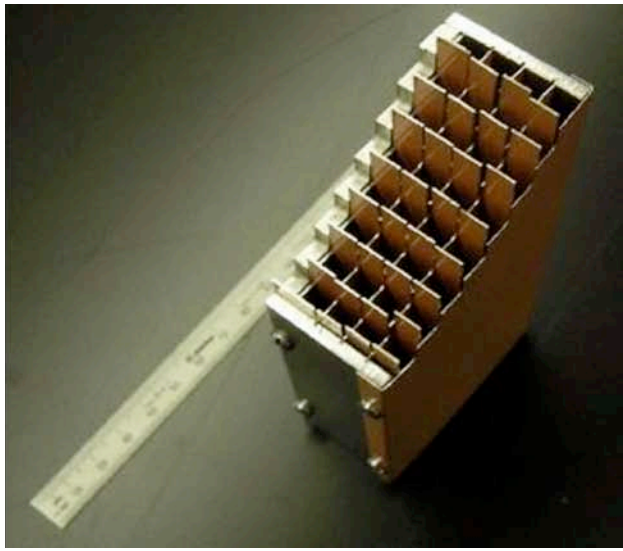
The University of Manchester

UTA / Alberta / FNAL / Louvain

FP420 Fast timing Detectors





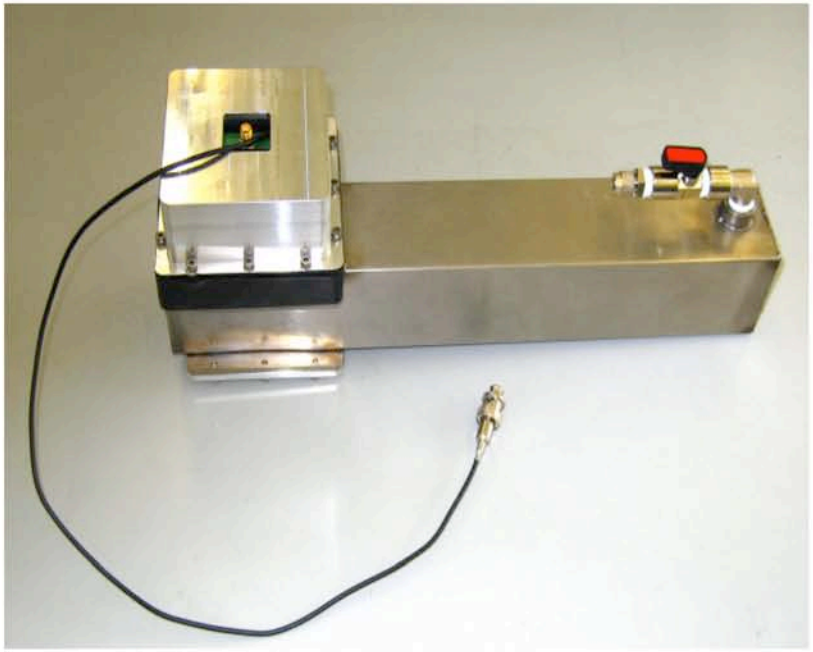


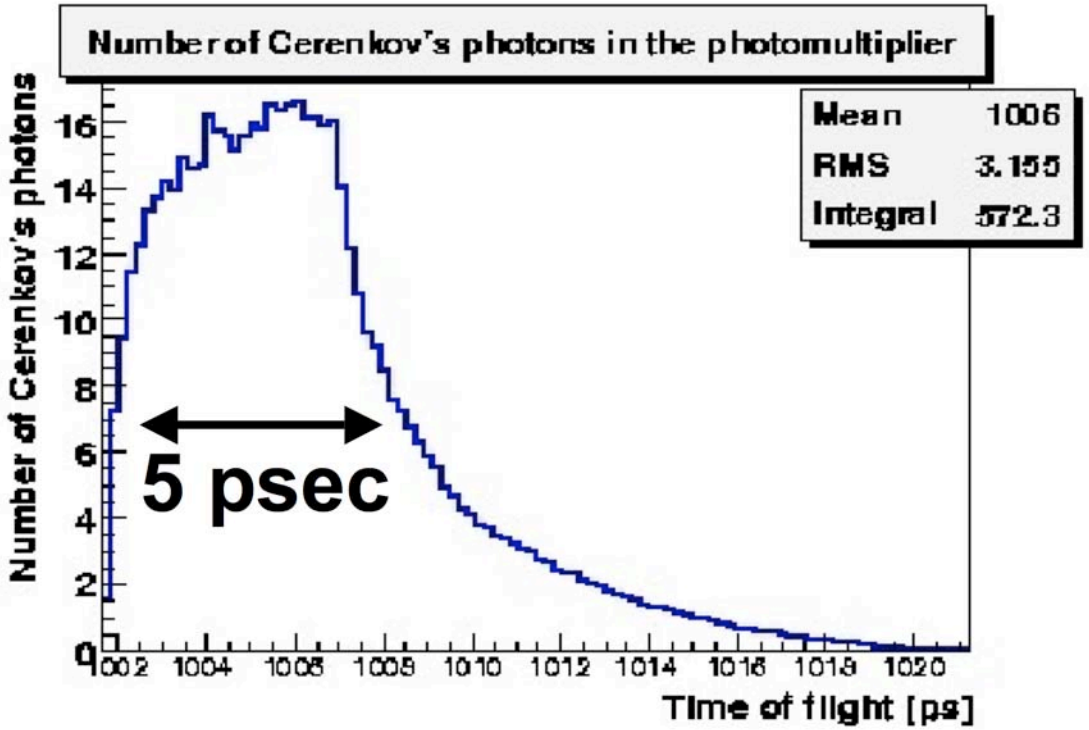
MANCHESTER 1824

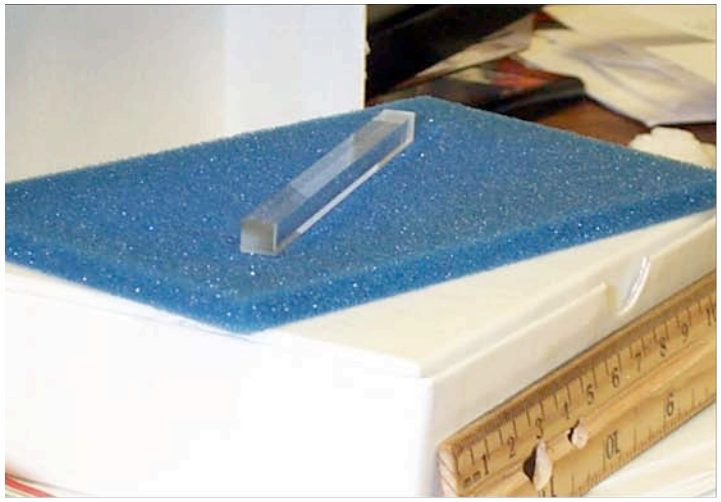
The University of Manchester

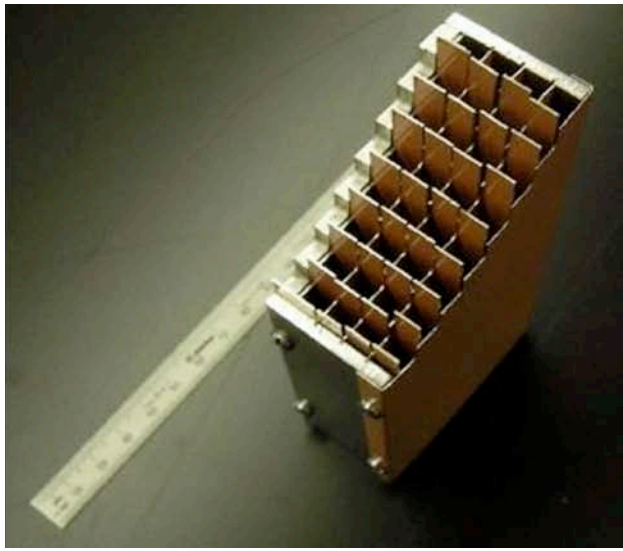
UTA / Alberta / FNAL / Louvain

FP420 Fast timing Detectors







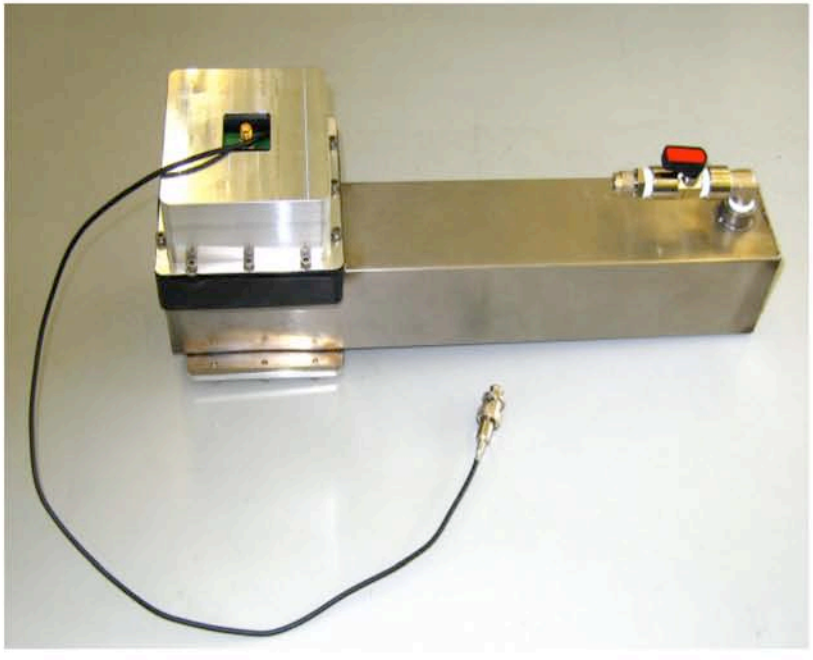


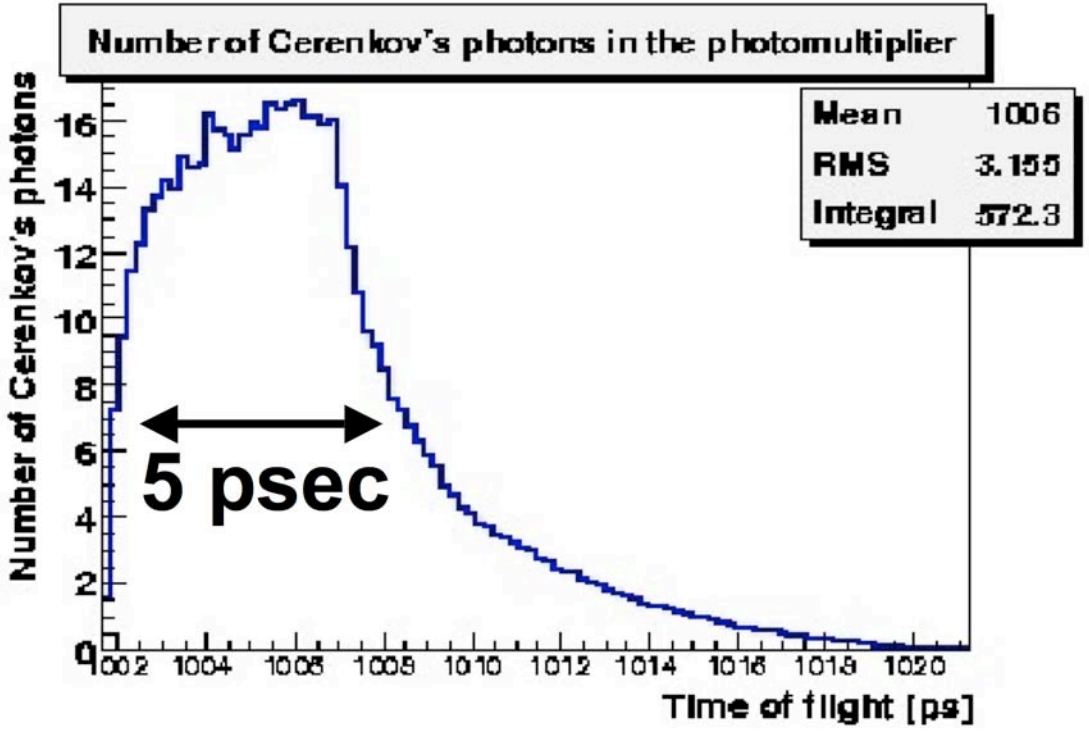
MANCHESTER 1824

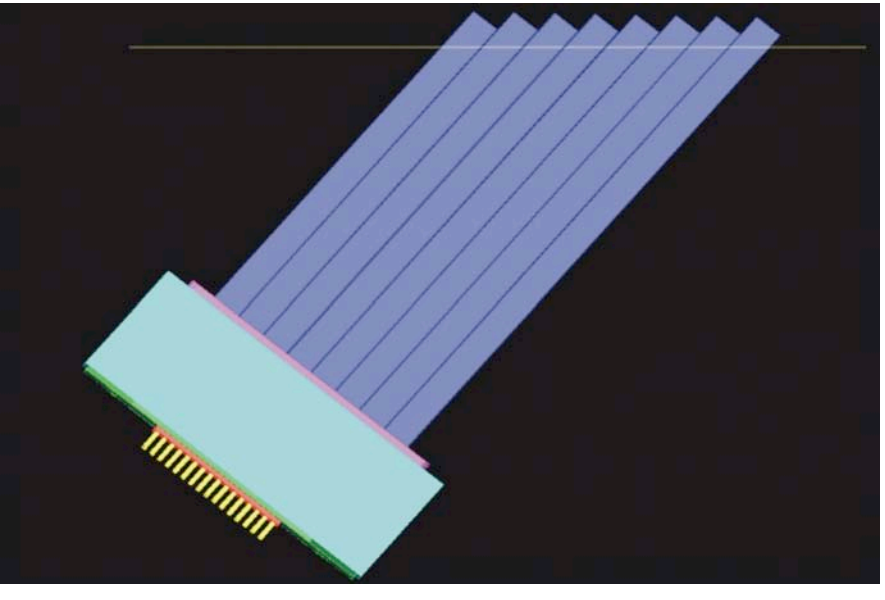
The University of Manchester

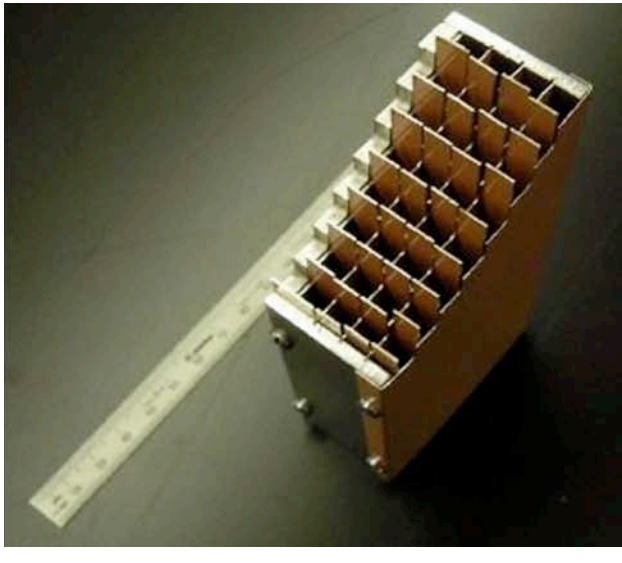
UTA / Alberta / FNAL / Louvain

FP420 Fast timing Detectors







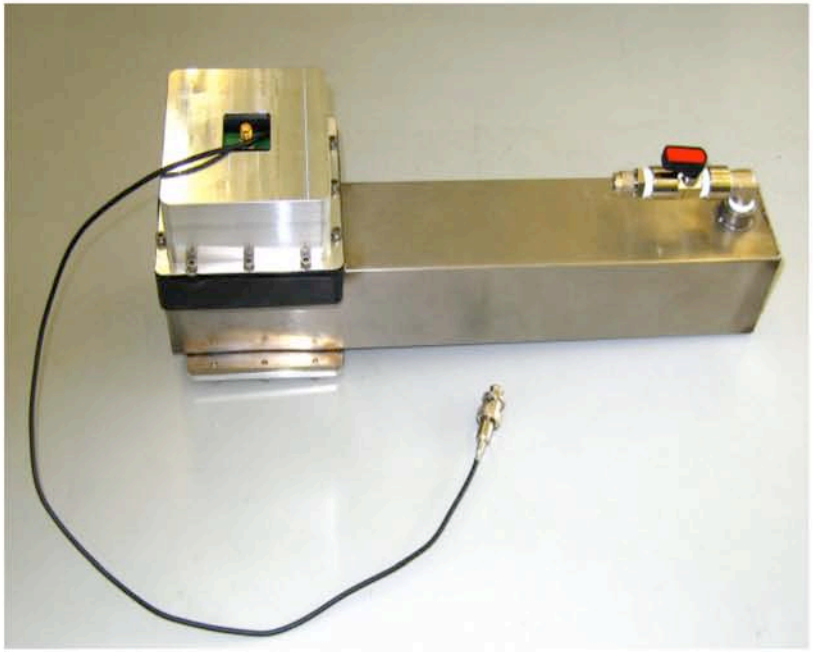


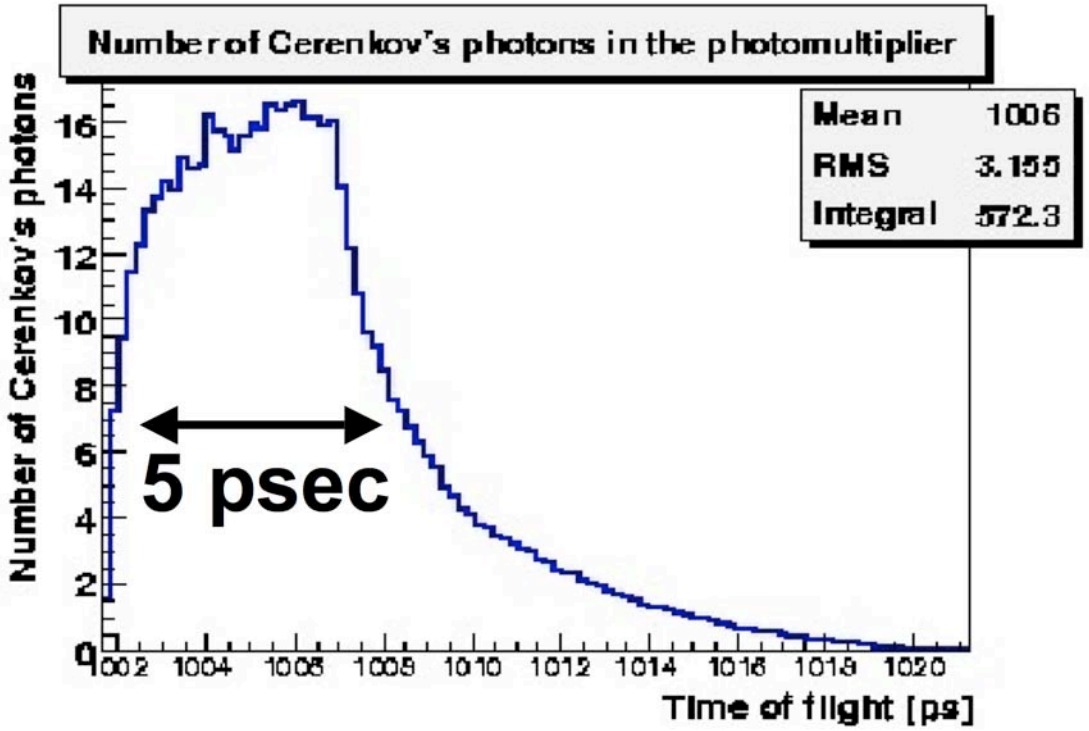
MANCHESTER 1824

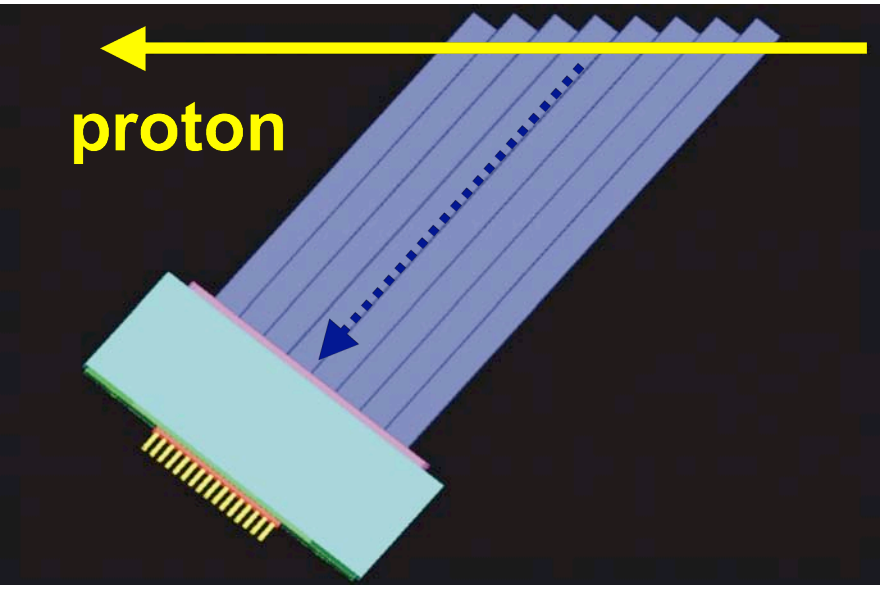
The University of Manchester

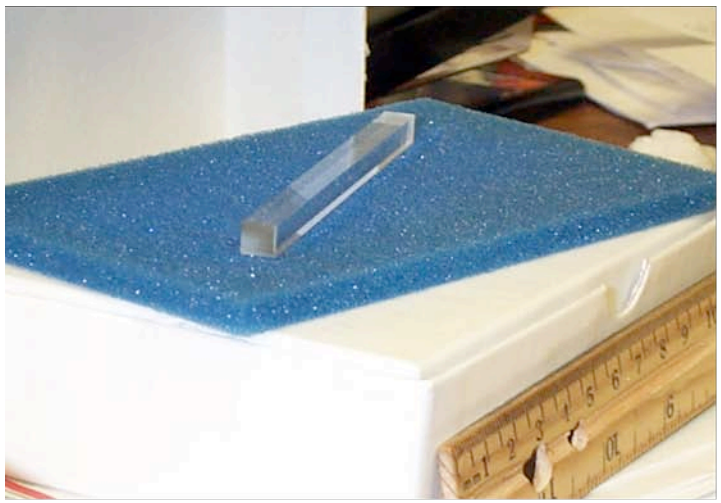
UTA / Alberta / FNAL / Louvain

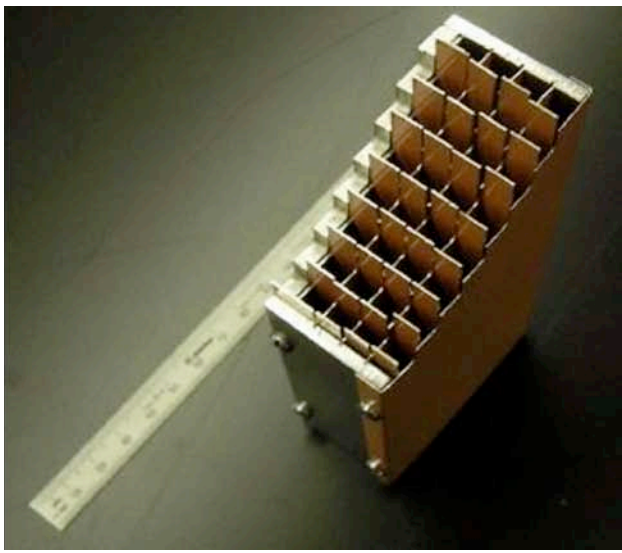
FP420 Fast timing Detectors





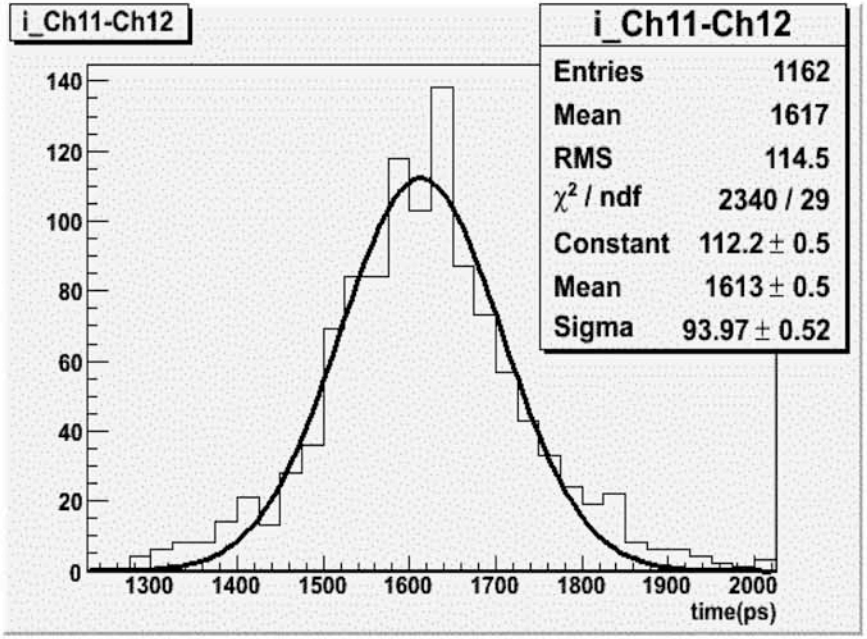






T958

- Fermilab Test beam experiment to study fast timing counters for FP420 (Brandt spokesman)
- Used prototype/preprototype detector with expensive or Louvain-made amplifiers and NIM/CAMAC discriminator/TDC to test concept
- Sporadic mostly parasitic running Aug 12- Sep 14 (primary user Sep 7-10, 14)



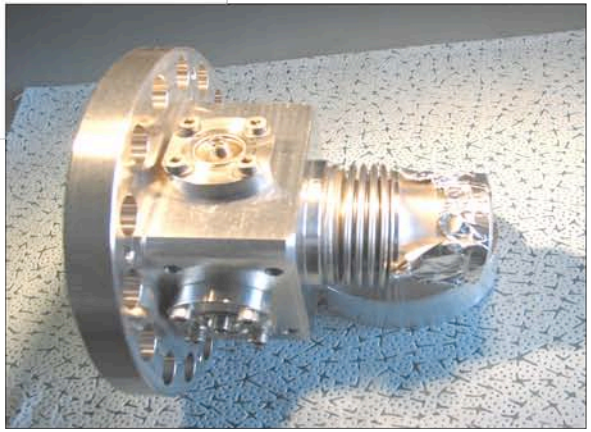
For events with a few bars on see anticipated √N dependence

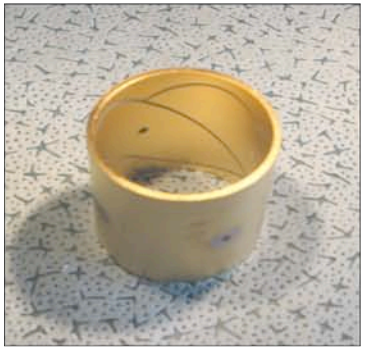
Upgrade for T958 Phase II

Planned for March 7-20

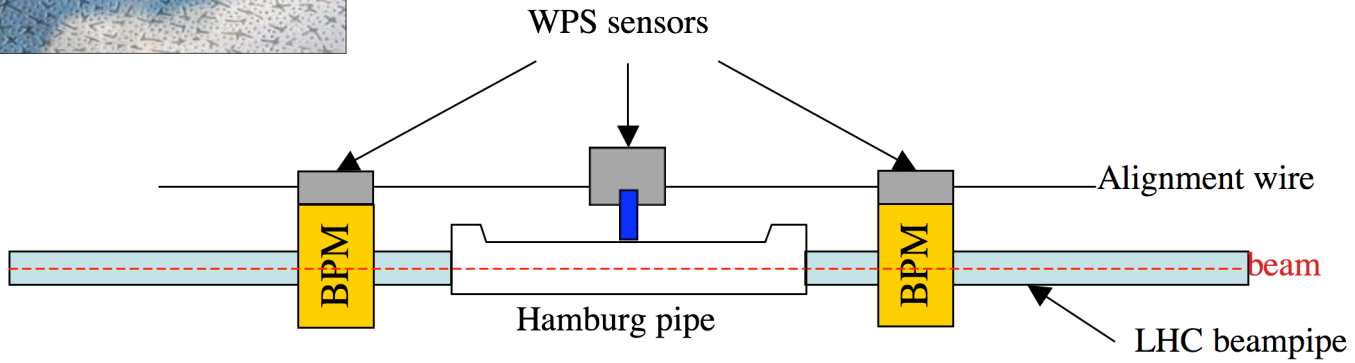
- New detector prototypes
- New electronics
- Improved DAQ
- Improved alignment
- Automated analysis and database routines, to allow instant and easier analysis
- Improved tracking
- At present, full QUARTIC + GASTOF would give 40ps. Upgrade expected to give ~ 20ps. Ultimately, with phase 3 improvements expect 11ps. Increase to 2 x QUARTICS would give < 10ps.

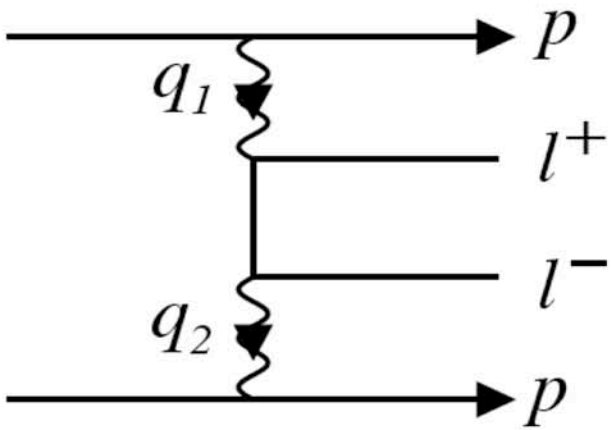
FP420 Alignment





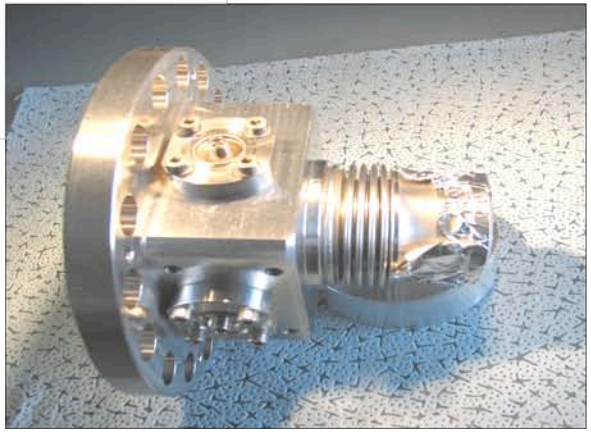
CLIC BPMs + wire positioning system : aim for 10 microns relative to beam

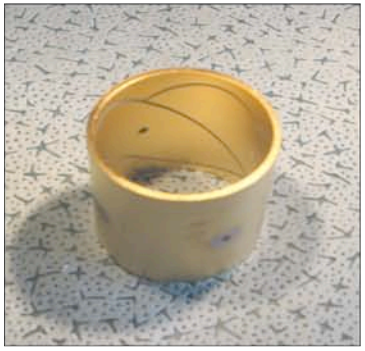




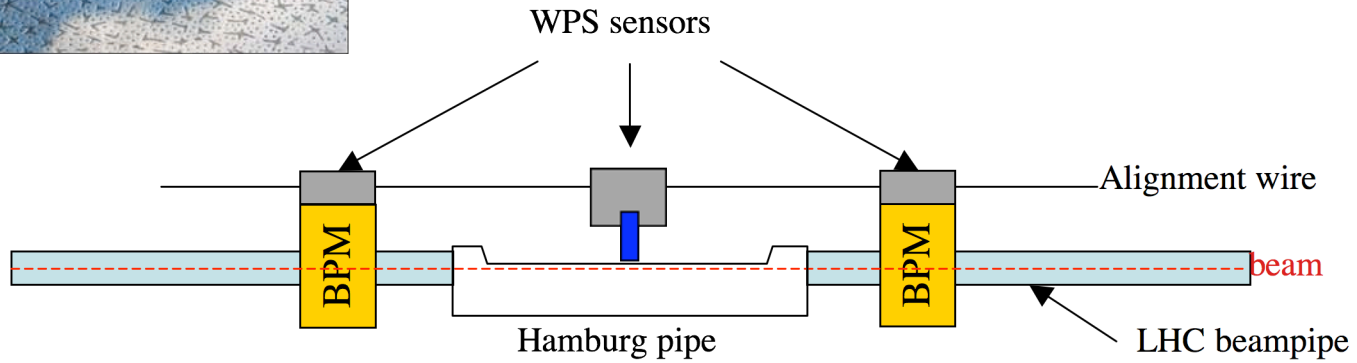
@ 10^{33} $cm^{-2}s^{-1}$ with standard ATLAS triggers, have ~ 30 di-muon events / fill in FP420 acceptance

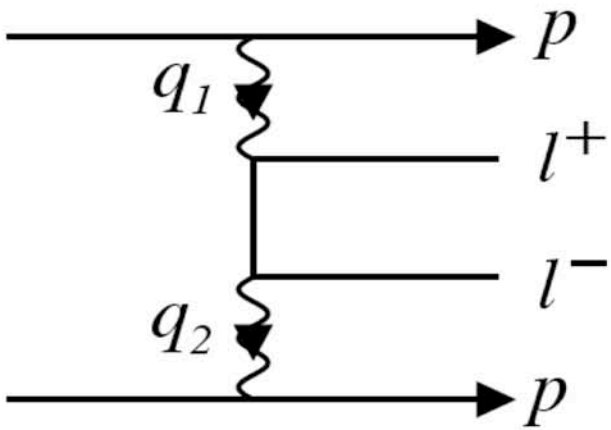
FP420 Alignment





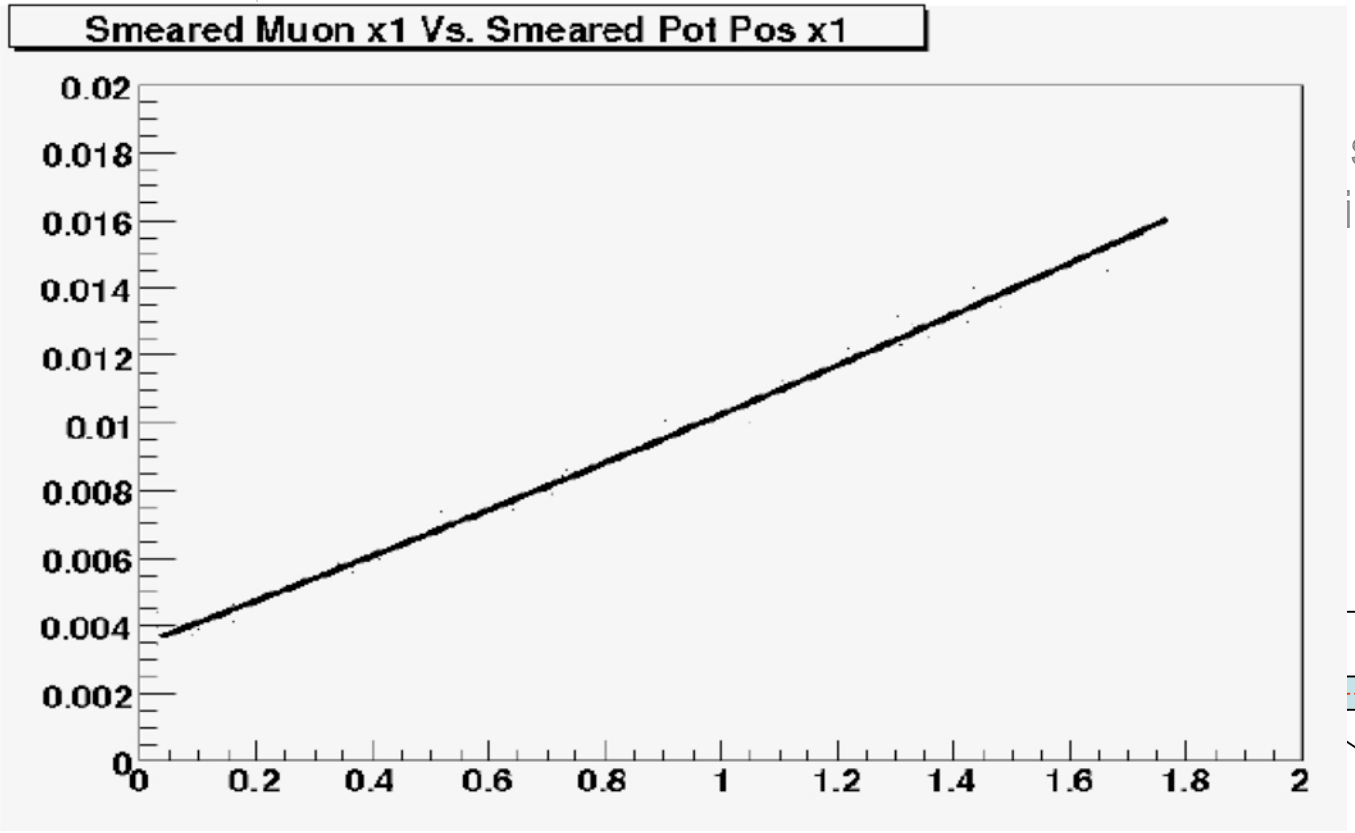
CLIC BPMs + wire positioning system : aim for 10 microns relative to beam



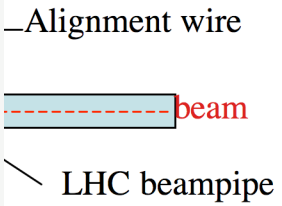


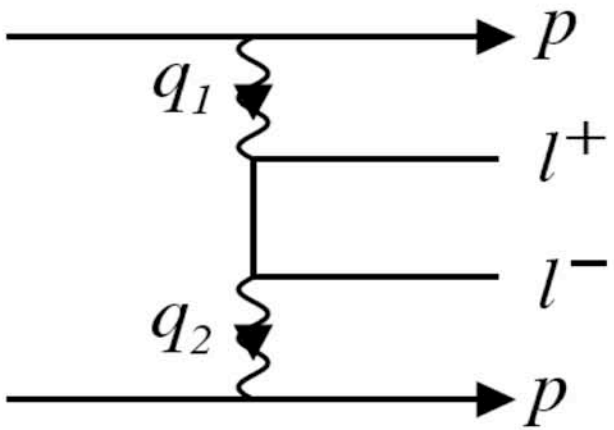
@ 10^{33} $cm^{-2}s^{-1}$ with standard ATLAS triggers, have ~ 30 di-muon events / fill in FP420 acceptance

FP420 Alignment



s + wire positioning
im for 10 microns relative





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

MANCHESTER 1824

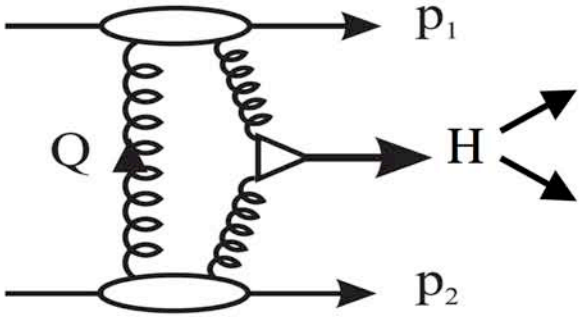
The University of Manchester

The benchmark : Standard Model Higgs Production

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 jets : M_H = 120 GeV σ = 2 fb

M_H = 140 GeV σ = 0.7 fb

0^{++} Selection rule

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

Also, since resolution of taggers > Higgs width:

$$S/B \propto \Gamma(H \rightarrow gg)/\Delta M \propto G_F M_H^3/\Delta M$$

- The WW* channel is extremely promising : no trigger problems, better mass resolution at higher masses (even in leptonic / semi-leptonic channel)
- If we see Higgs + tags - the quantum numbers are 0^{++}

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

FP420 Discovery scenarios

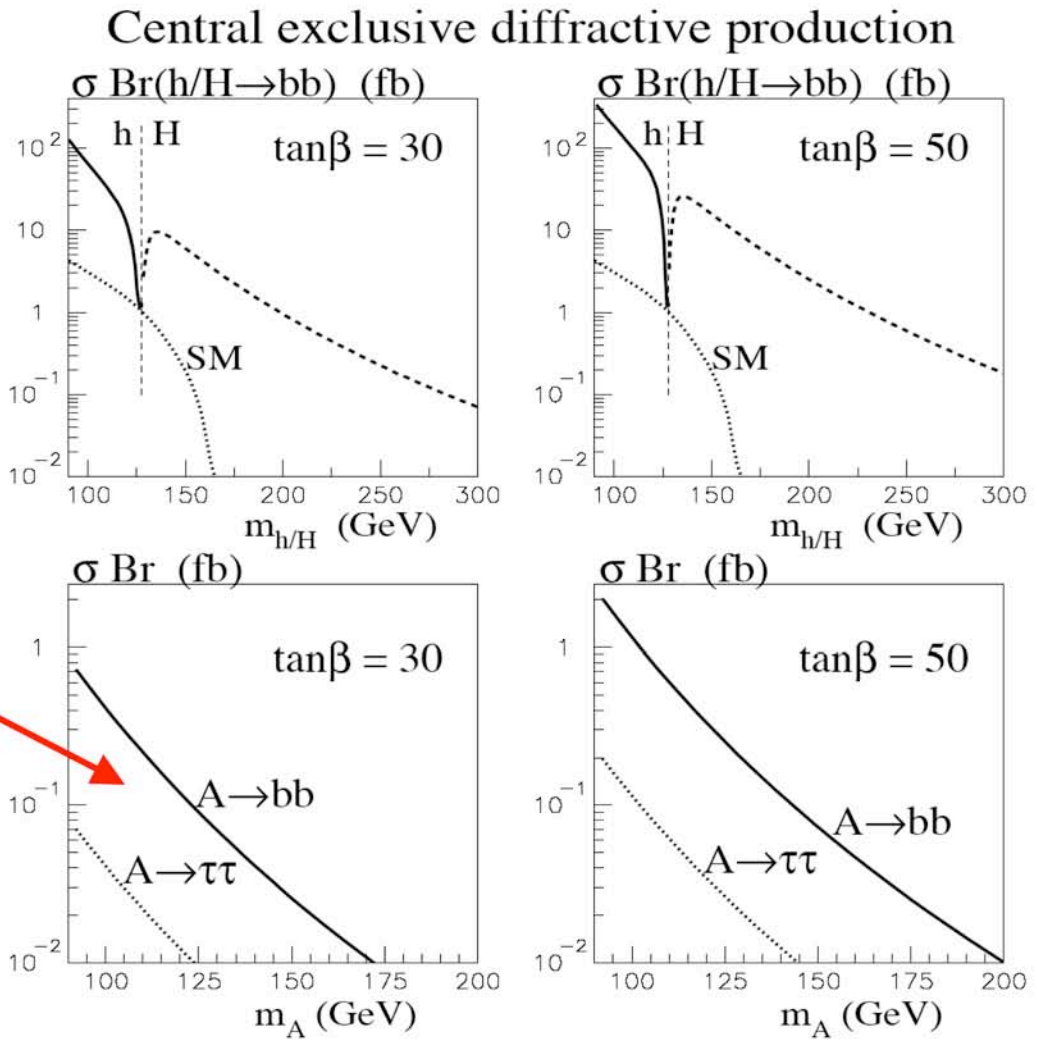
The intense coupling regime is where the masses of the 3 neutral Higgs bosons are close to each other and tan β is large

$\gamma\gamma, WW^\star, ZZ^\star$ suppressed

$gg \longrightarrow \phi$ enhanced

0^{++} selection rule suppresses A production:

CEDP 'filters out' pseudoscalar production, leaving pure H sample for study



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}

Well known difficult region for conventional channels, tagged channel may well be the discovery channel, and is certainly a powerful spin/parity filter

Backgrounds 1: CEP

- Backgrounds are:
  - **pp→p + bb + p** and
  - **pp→p + gg + p** (where both gluons are mis-identified as b quarks).

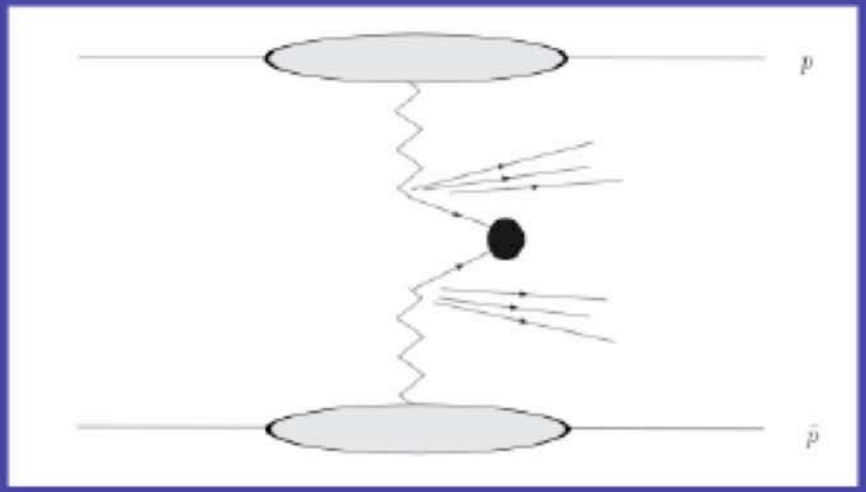
- Quark production is suppressed by m_q^2 / M^2 . This means that bb production is suppressed, but also that light quark backgrounds are negligible.

- These are also produced by ExHuME.

MANCHESTER 1824

The University of Manchester

Backgrounds 2: DPE



This type of background is generated using the POMWIG MC.

pp→ p + A + bb + p
pp→ p + A + jj + p

A = other activity in the central system. i.e pomeron remnants.
j = light quark and gluon jets.

Note: $M \neq M_{bb}$

MANCHESTER 1824

The University of Manchester

Backgrounds 3: Overlap

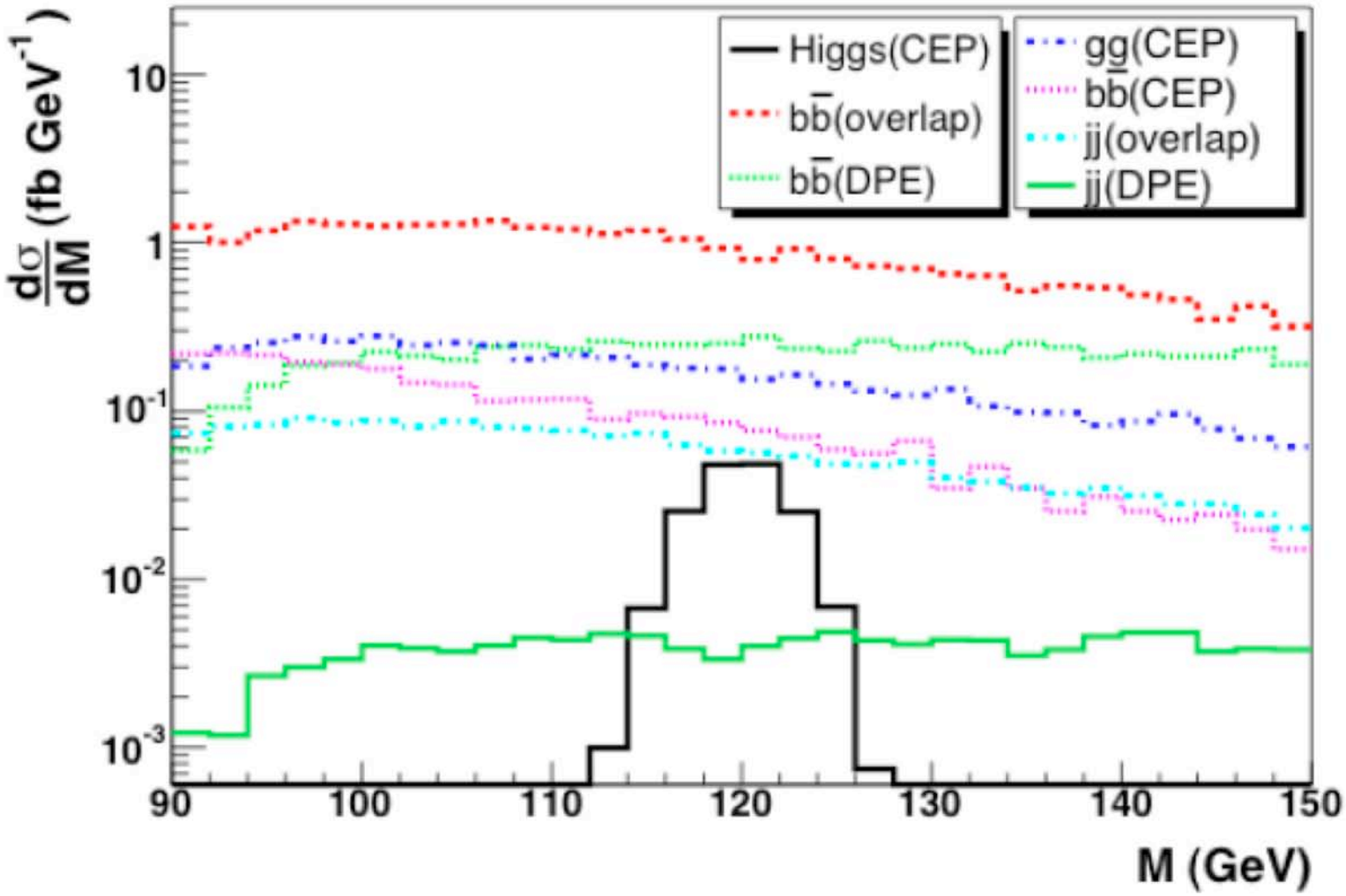
- The overlap background is a normal QCD (bb or jj) event + 2 single diffractive events in the same bunch crossing.

- $\sigma_{new} = (N-1)(N-2)\, P_i^2\, Q\, \sigma$
  - σ_{new}= observed cross section (fb)
  - N = no. of pile up events (luminosity dependent).
  - Q = quartic rejection factor (Q=0.025)
  - P_i = probability of pile up event being single diffractive which produces a proton and causes a hit in FP420 .
  - σ = input cross section for the QCD event.

MANCHESTER 1824

The University of Manchester

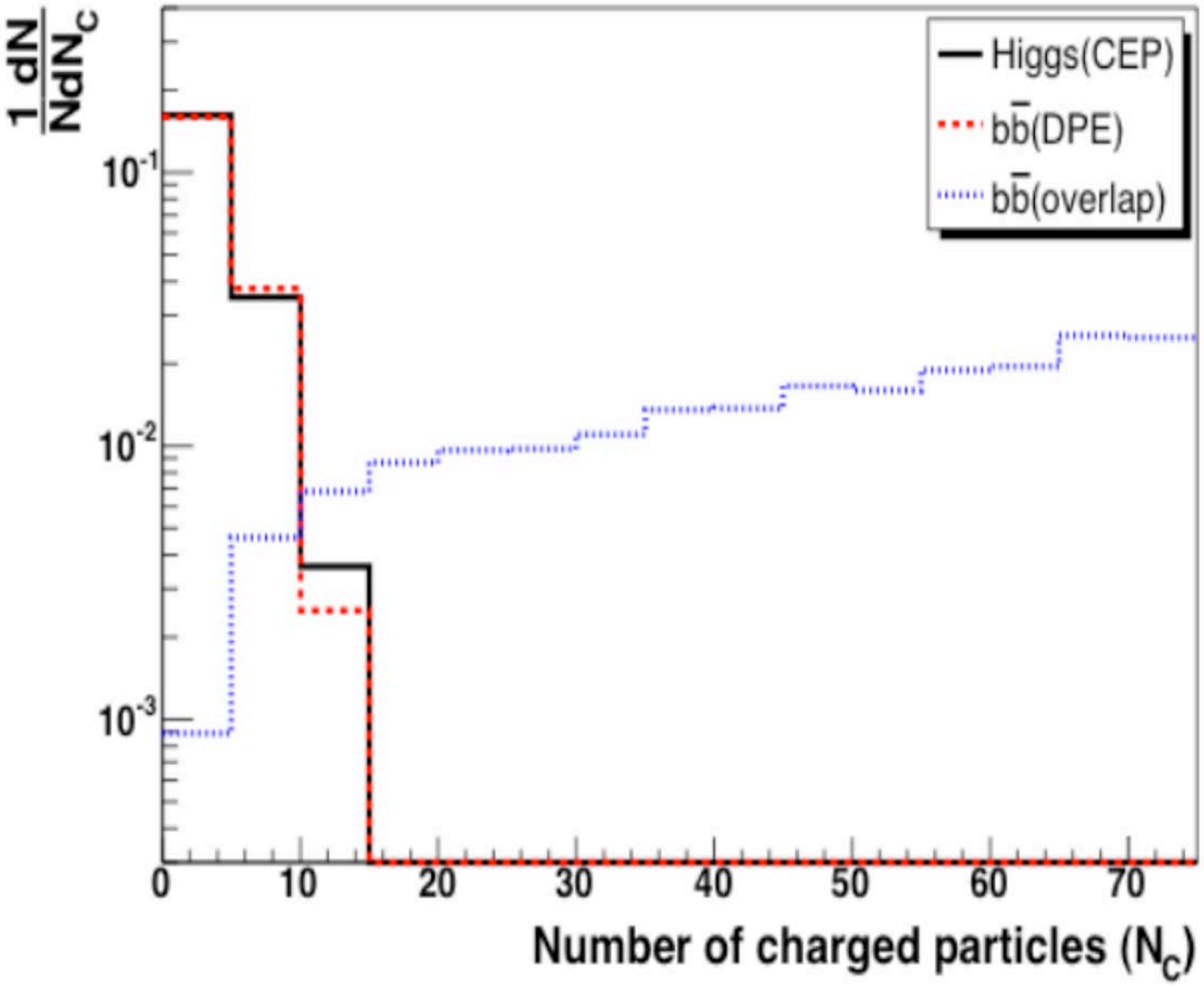
After basic cuts, smearing according to ATLAS TDR and FP420 beam simulation, with overlap calculated at 2 x 10^{33} cm^{-2} s^{-1}



MANCHESTER 1824

The University of Manchester

After basic cuts, smearing according to ATLAS TDR and FP420 beam simulation, with overlap calculated at 2 x 10^{33} cm^{-2} s^{-1}



0

MANCHESTER 1824

The University of Manchester

Preliminary Results for full analysis (ATLFAST)

SM 120 GeV Higgs -> bb after all cuts and acceptances, but excluding trigger

Final Cross Section

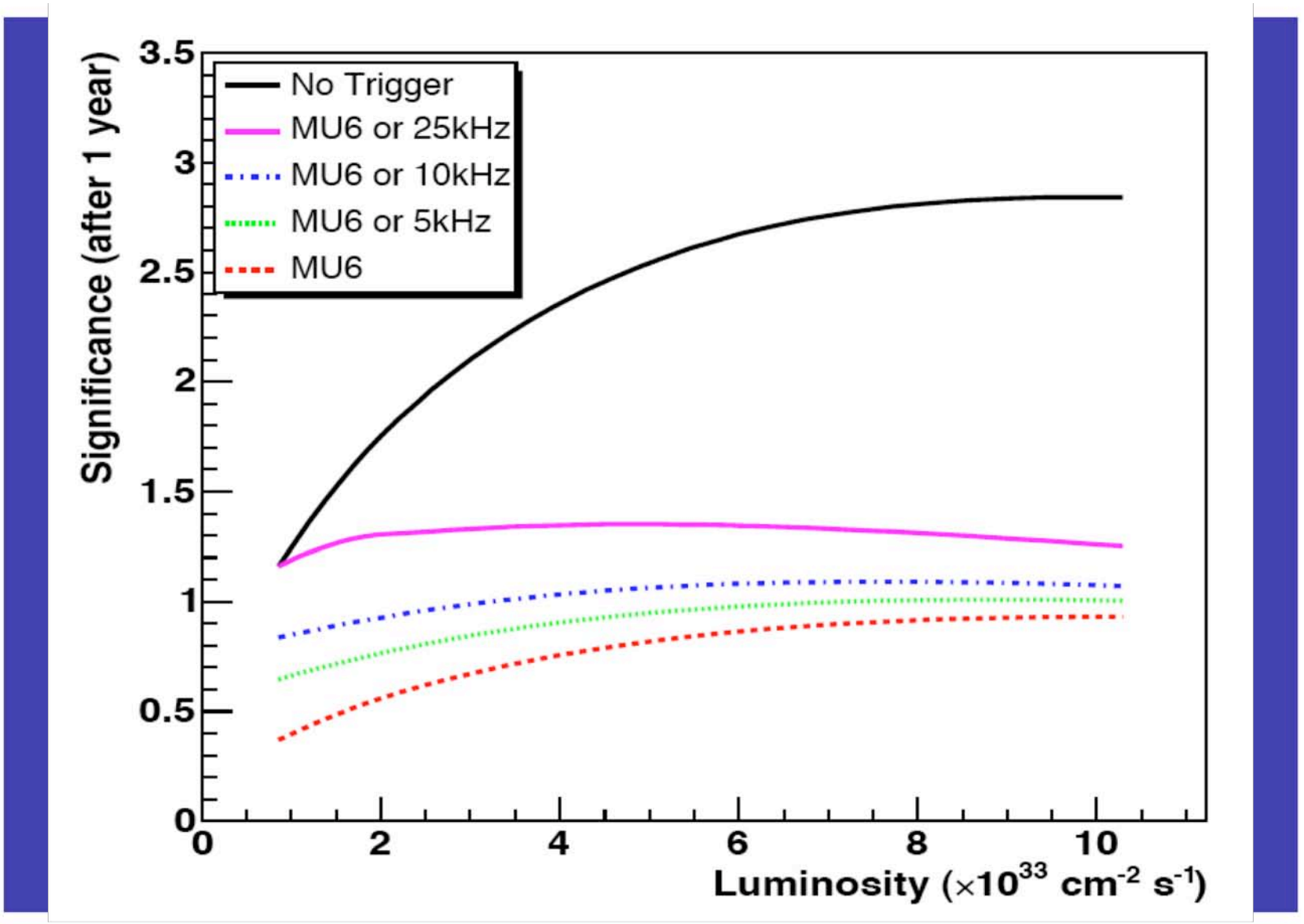
Process	σ_{K_T} (fb)	σ_{cone} (fb)
H→bb (CEP)	0.058	0.054
bb (CEP)	0.12	0.10
gg (CEP)	0.18	0.08
bb (DPE)	0.14	0.08
jj (DPE)	0.002	0.0005
bb (OLAP)	0.032	0.03
jj (OLAP_	0.001	<0.001

MANCHESTER 1824

The University of Manchester

How to keep those events

- Cannot use current jet triggers so…..
- Use low p_T muon triggers (as the b can decay to muon)
  - At ATLAS p_T > 6GeV
  - Retains 11% of events
- New Jet trigger?
  - Possible in principle to have large rate at level 1 and veto at level 2 using FP420. Level 2 rate of 20Hz (1%).
  - Veto on level 2 is 2 proton hits in FP420.
  - Additional veto on vertexing could be possible using QUARTIC TOF.
  - So choose E_T > 40GeV and prescale to a fixed jet rate at level 1. i.e 1kHz, 5kHz or larger?



MSSM tan $\beta = 50$, M_A=130 GeV, $\sigma \sim 7\ \sigma_{SM} \sim 10$ (50?) signal in 30 fb^{-1} @ 2 x 10^{33} cm^{-2}s^{-1}

MANCHESTER 1824

The University of Manchester

FP420 Timetable

- FP420 is an R&D collaboration between ATLAS, CMS and non-affiliated groups
- Aim is to build 420m proton taggers as upgrades to both experiments
- FP420 will produce a design report in Spring 2007
- If accepted by ATLAS and / or CMS, this will lead to TDR from experiments to LHCC in early summer 2007
- There will be no formal FP420 collaboration after this time, although we envisage creating some framework for continued co-operation in construction and installation phase
- The proton taggers will be operated and maintained like any other sub-detector component of ATLAS and CMS