MANCHESTER 1824

The University of Manchester

The FP420 Project

The Challenge of Measuring Forward Protons at the LHC

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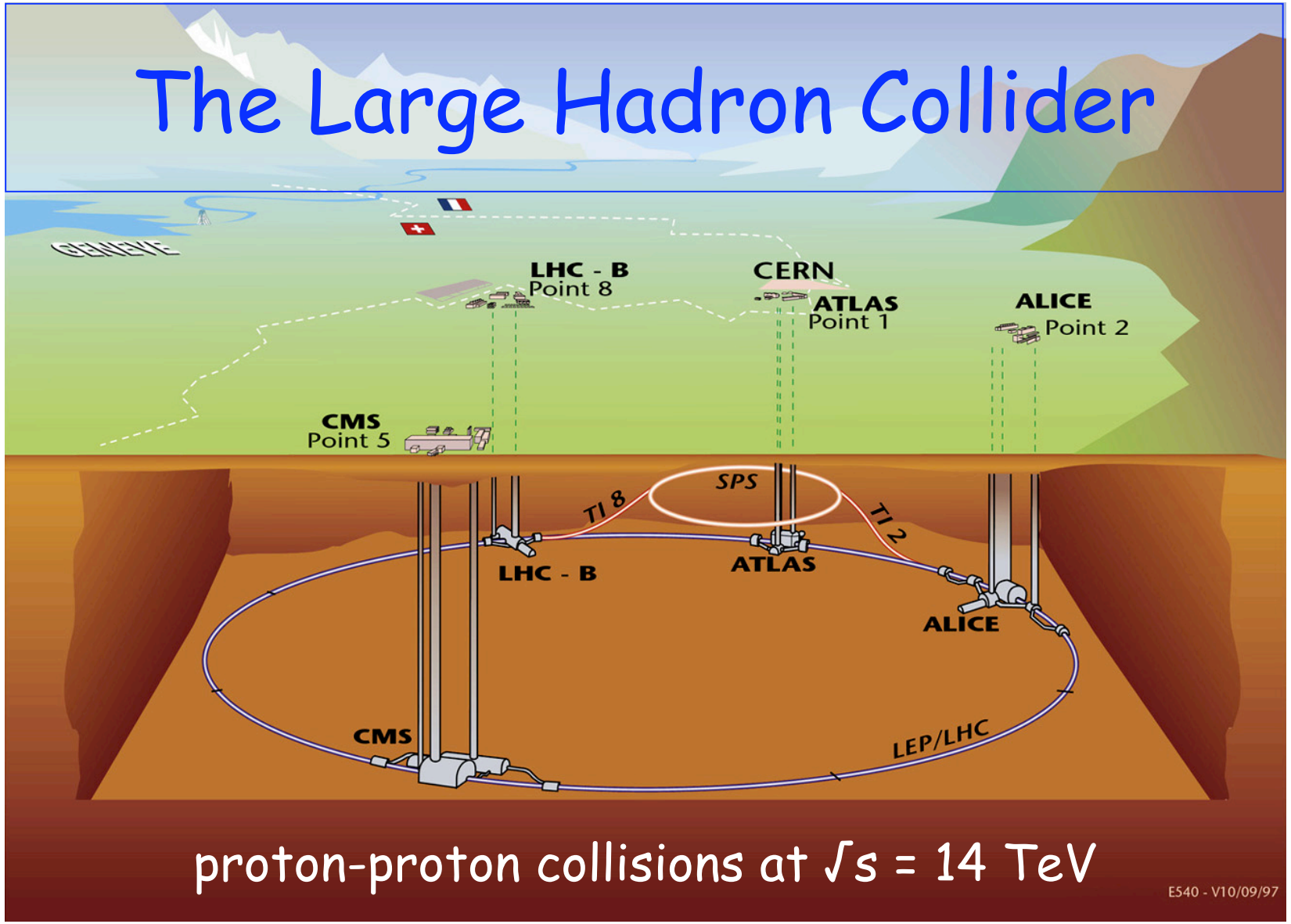
The University of Manchester

On behalf of the FP420 Collaboration*

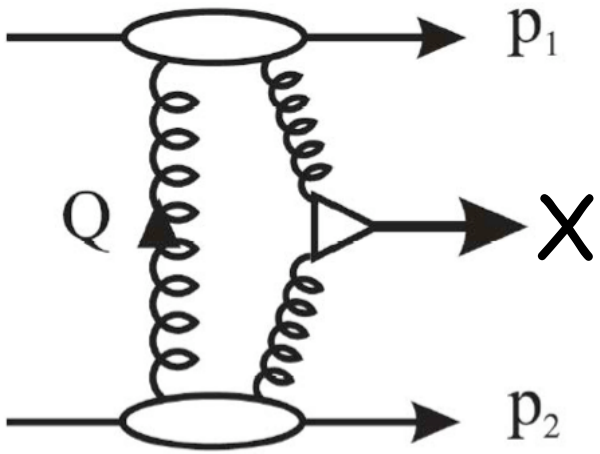
*~30 institutes from Europe and North America

The Large Hadron Collider



FP420: Physics Motivation I

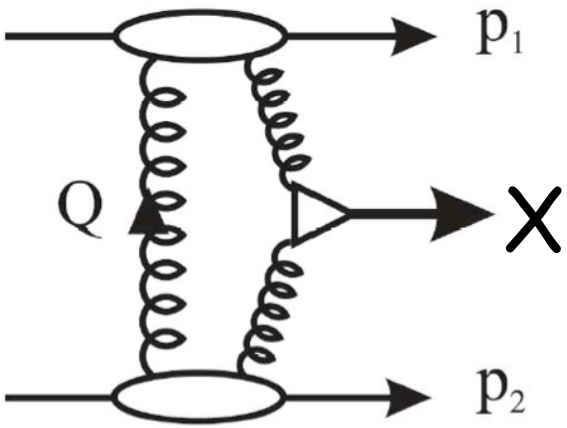
- Detect off-momentum protons at 420m from the interaction point, due to e.g. diffractive events in ATLAS/CMS
  - "X" can be for example a Higgs boson
- How far p1 and p2 are from the beam tells us how much momentum they lost, i.e. the mass of the central system.
  - The better we can measure distance (proton-beam), the better we can measure X's mass



"X" is reconstructed in central detector (ATLAS or CMS)

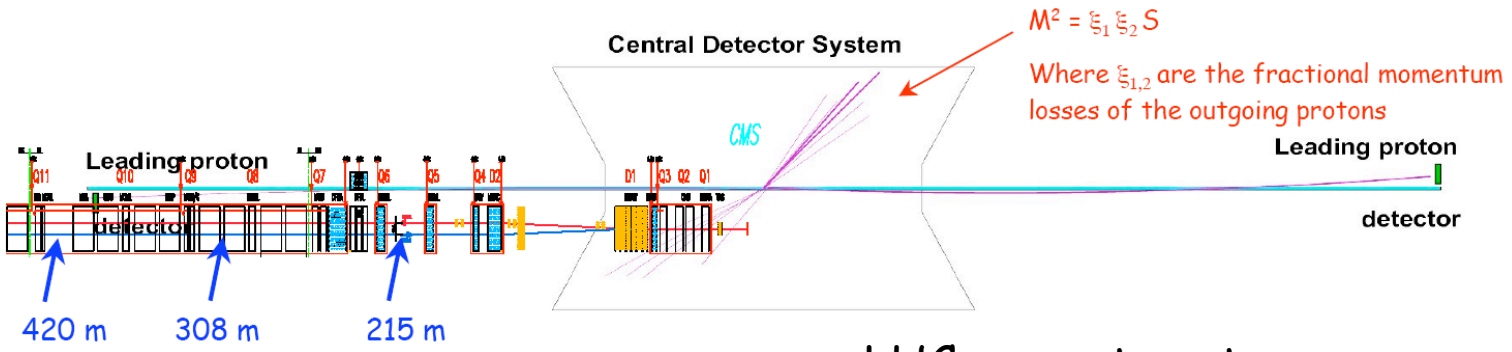
p_1 and p_2 are tagged by FP420

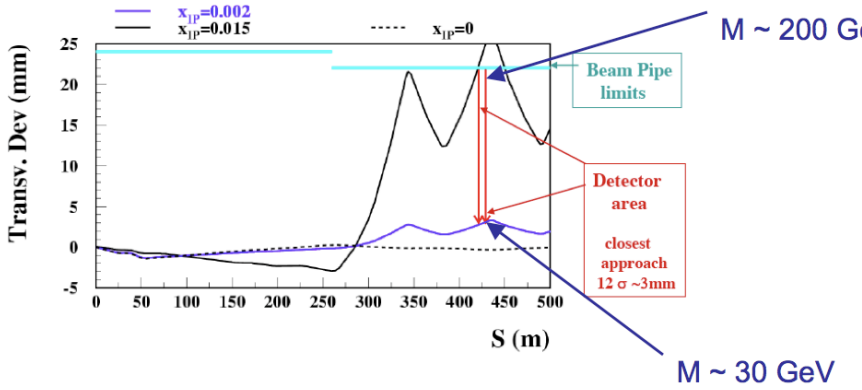
FP420: Physics Motivation II



- Selection rules mean that the central system is (to a good approximation) 0^{++}
  - → If you see a new particle produced exclusively with proton tags, you know its quantum numbers.
- Proton tagging can significantly improve signal/background ratios
  - → may be the discovery channel in certain regions of the MSSM
- Tagging the protons means excellent mass resolution (~GeV) irrespective of the decay products of the central system.

Schematic Layout for FP420





LHC magnets act as a spectrometer, bending protons with small momentum loss out of the beam

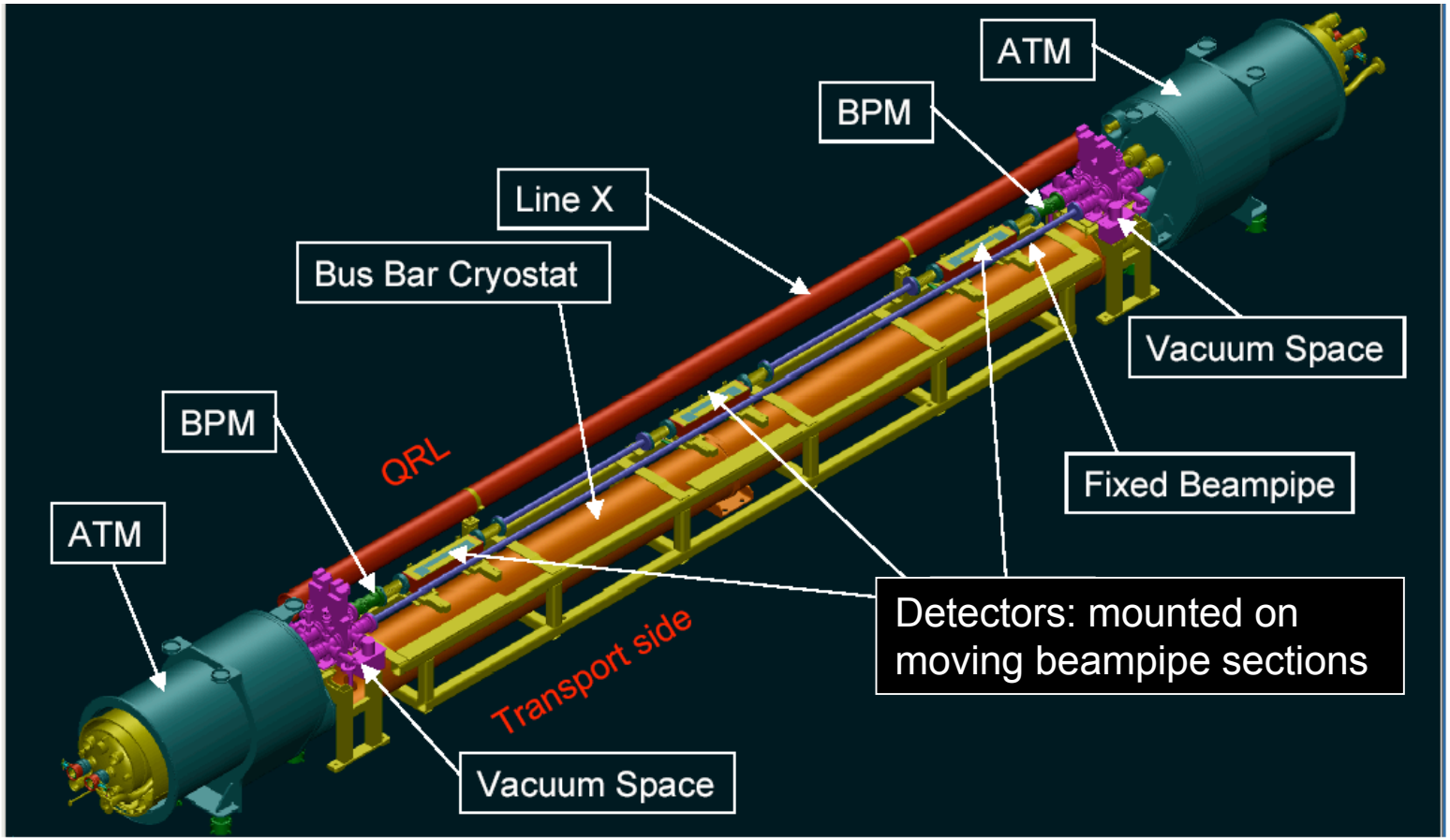
At 420m, can tag protons that have lost 15-100 GeV

→ M_X~30-200 GeV

FP420 Requirements

- Must get as close as possible to the beam
  - 3mm is ~12σ
  - Detectors need to be edgeless
- Severe environment! Detectors must be:
  - very radiation-hard
  - moveable to garage position during beam filling/tuning
- Must know beam-detector distance precisely
  - 50μ position uncertainty at 420m due to energy spread in beam
  - Keep alignment precision around ~10μ to avoid degrading this further
- Precision timing needed to beat pileup

FP420 Integration



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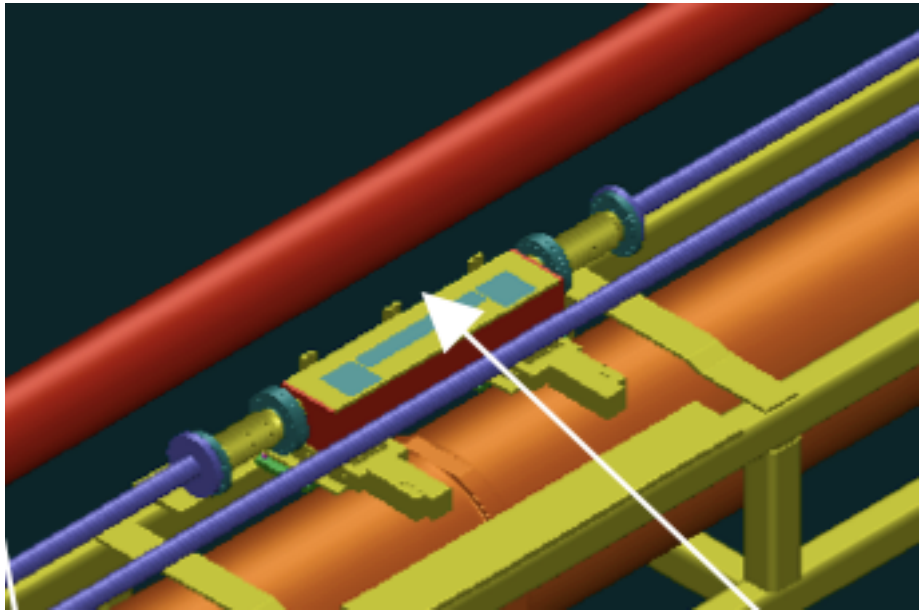
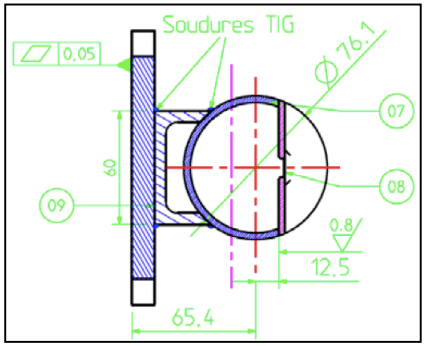
Louvain-la-Neuve

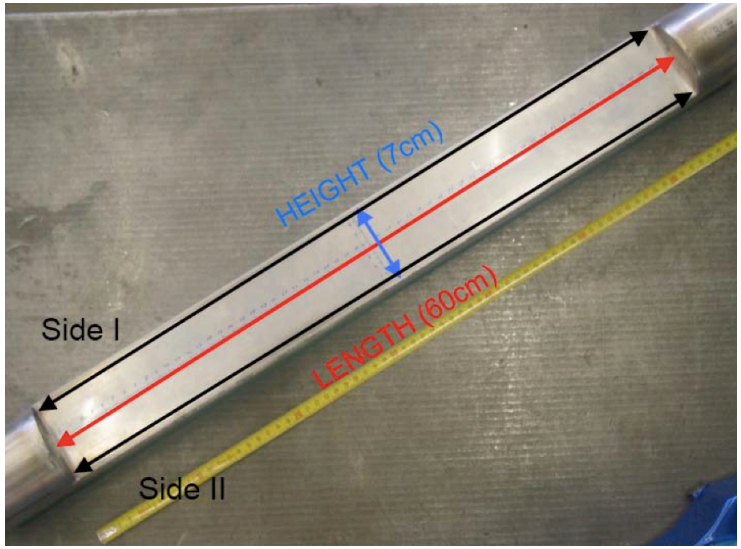
"Hamburg Pipe"



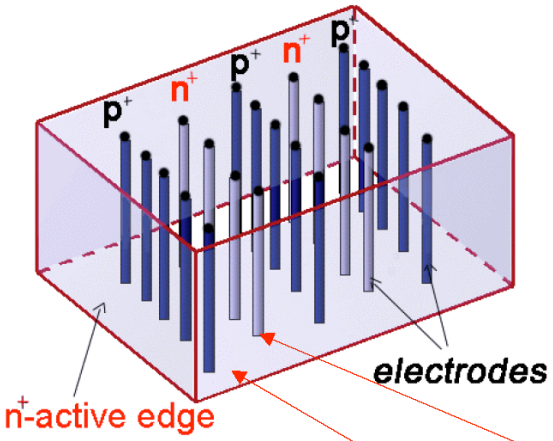


"Hamburg pipes" position detectors

- ~ 3cm from beam during fill/tune
- ~ 5mm from beam during operation



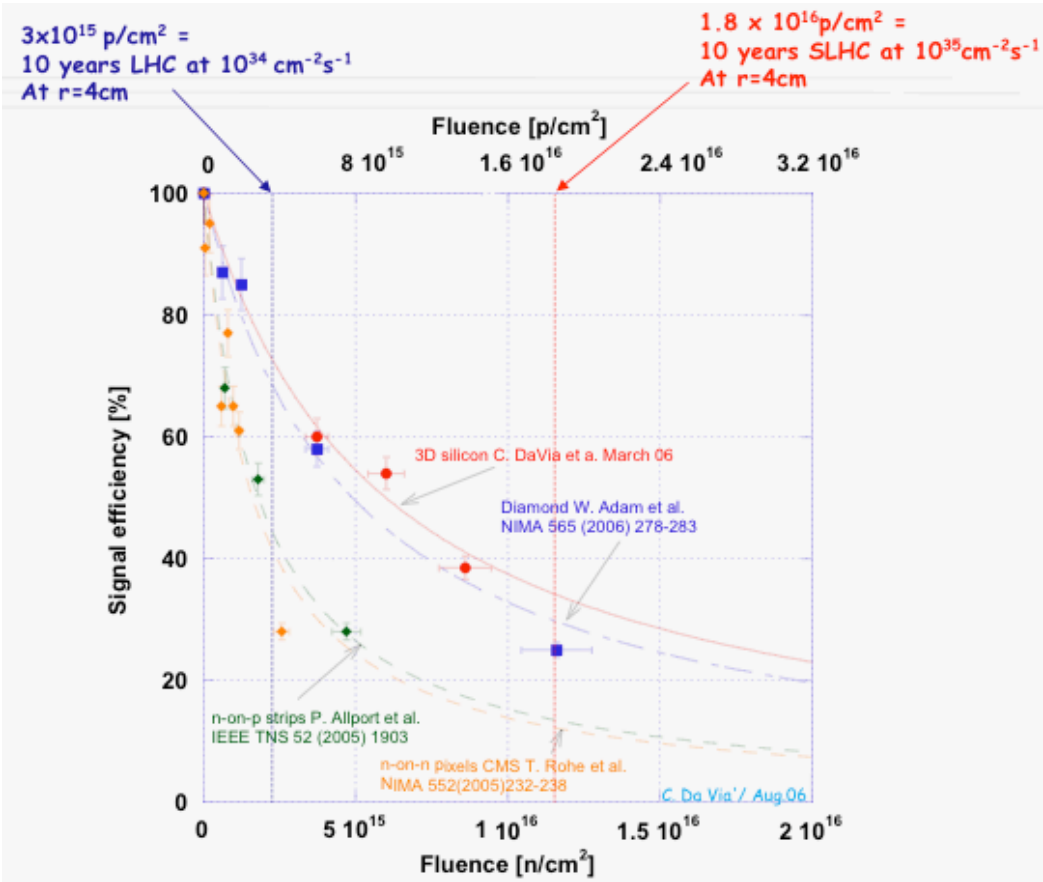
3D Edgeless Silicon



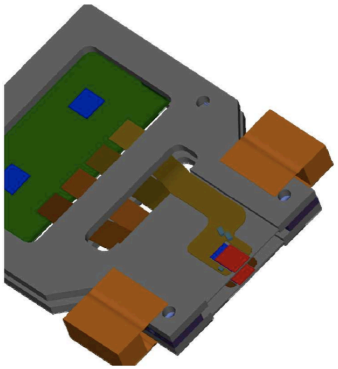
Active edges: the edge is itself an electrode, so dead volume at the edge < 5μ.

Electrodes are processed inside the detector bulk instead of being implanted on the wafer's surface.

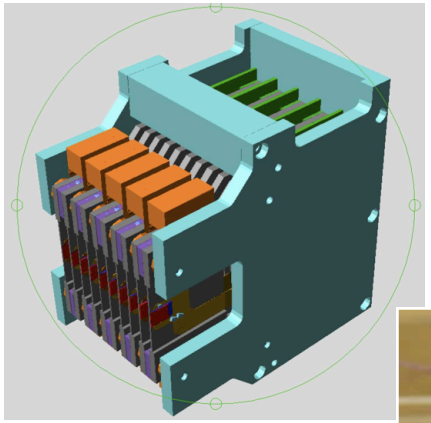
Radiation Hardness

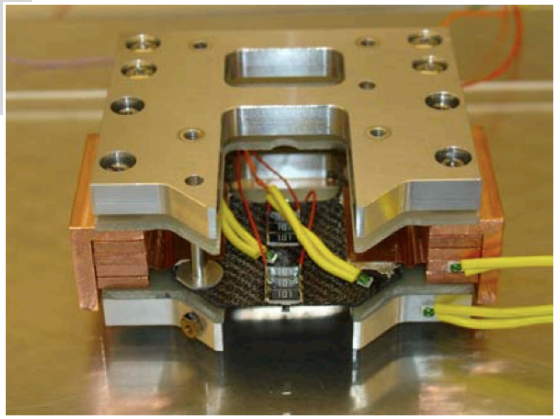


FP420 Detector Stations



x 5 =





Baseline Design:

- 3D Silicon sensors are 7x8 mm^2
  - Electrodes are ganged into 50μ x 400μ groups to fit ATLAS pixel detector readout chip
- Four sensors per superlayer
  - 2 nearest beampipe (offset, for better track resolution at low energy loss), 1 midway, 1 far
- 5 superlayers per detector station
- 2-3 stations each side of ATLAS/CMS

Pileup Background Rejection

~30% of all FP420 events will have an extra track from inelastic collisions

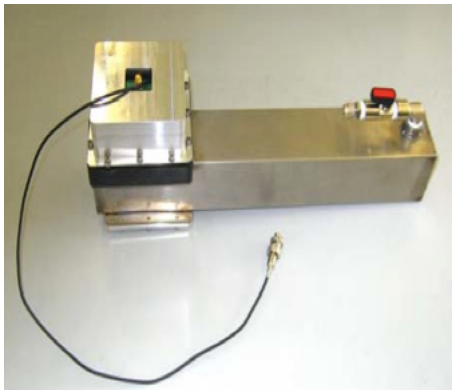
- Some can be removed by kinematic cuts (e.g. matching mass measured in FP420 and central detector)
- Almost all (~97%) of what is left can be rejected by fast (10ps resolution) timing detectors:
  - Measure relative arrival time Δt of protons on the two sides (±420m)

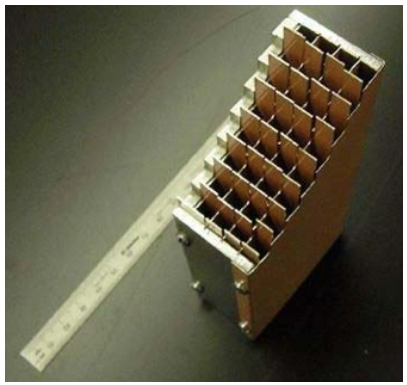
    → z position of interaction point = $(c\Delta t)/2$
  - Match this with measured vertex position from central detector.

Fast Timing Detectors

Two types being considered for FP420:

- GASTOF:
  - Gas-filled tube as radiator
  - Low mass → to be placed in front of FP420

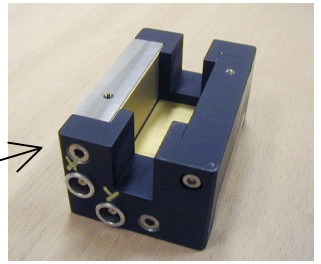


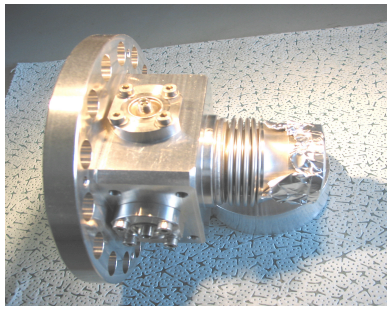


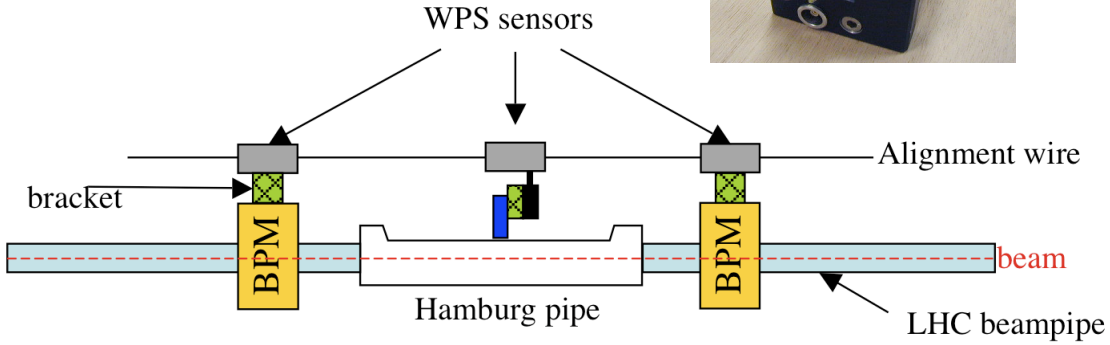
- QUARTIC
  - Fused silica bars as radiators
  - Higher mass → to be placed behind FP420

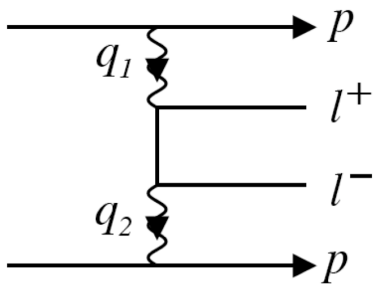
Alignment

Online: Beam-Position Monitors plus a wire-positioning system: aiming for 10 micron precision on beam-detector separation.









Offline: will have ~30 di-muon events per fill in FP420 acceptance: can be used for alignment.

Summary and Schedule

- FP420 is an R&D collaboration between ATLAS, CMS and non-affiliated groups.
- R&D conclusions will be submitted soon to the experiments for consideration as an upgrade/extension.
- If accepted, a Technical Design Report will be submitted later this year.
- On track for installation 2009/2010.