Implementing Tracking with the ATLAS Diamond Beam Monitor

Miriam Diamond

Supervisor: William Trischuk

University of Toronto

CAP Congress

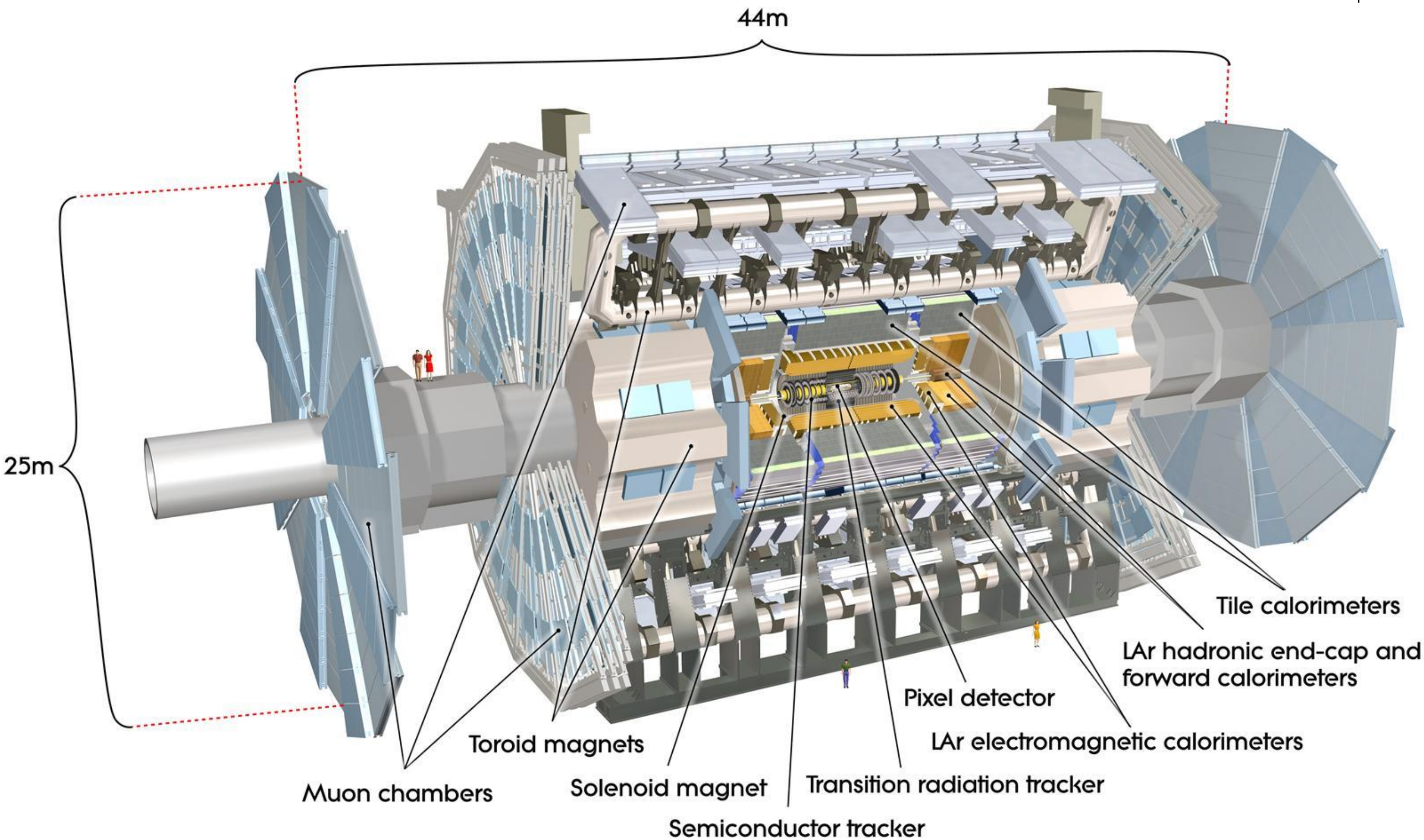
June 18 2014

Outline

- The ATLAS Diamond Beam Monitor
  - Purpose
  - Positioning & Geometry
  - Active Material
- DBM Tracking
  - Goals
  - Challenges
  - Straight Lines vs Helices: Keeping It Simple
- Preliminary Results
  - Track Reconstruction Efficiency
  - Impact Parameter Resolution
- Next Steps

The ATLAS Diamond Beam Monitor

ATLAS Detector:



The ATLAS Diamond Beam Monitor

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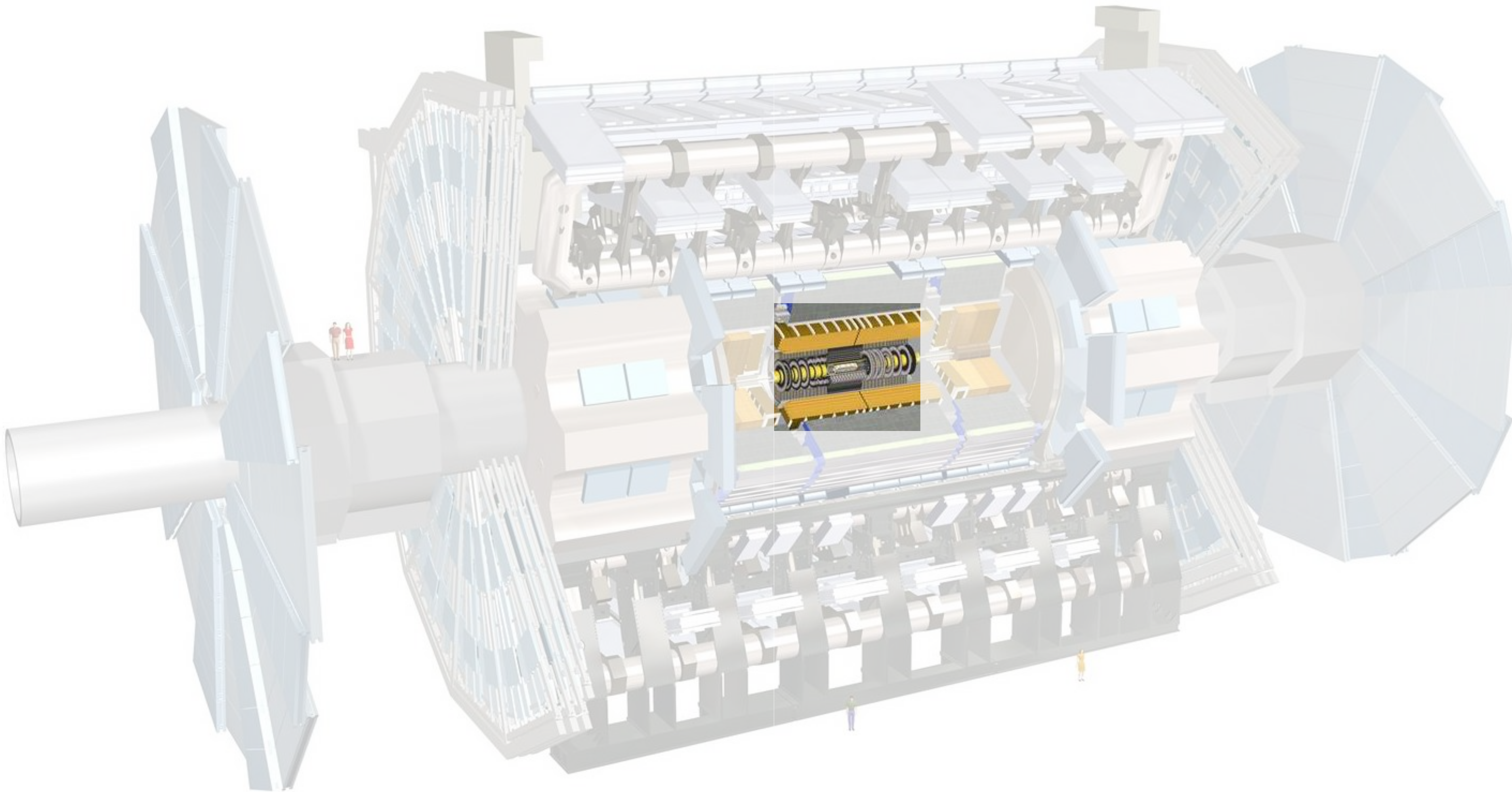
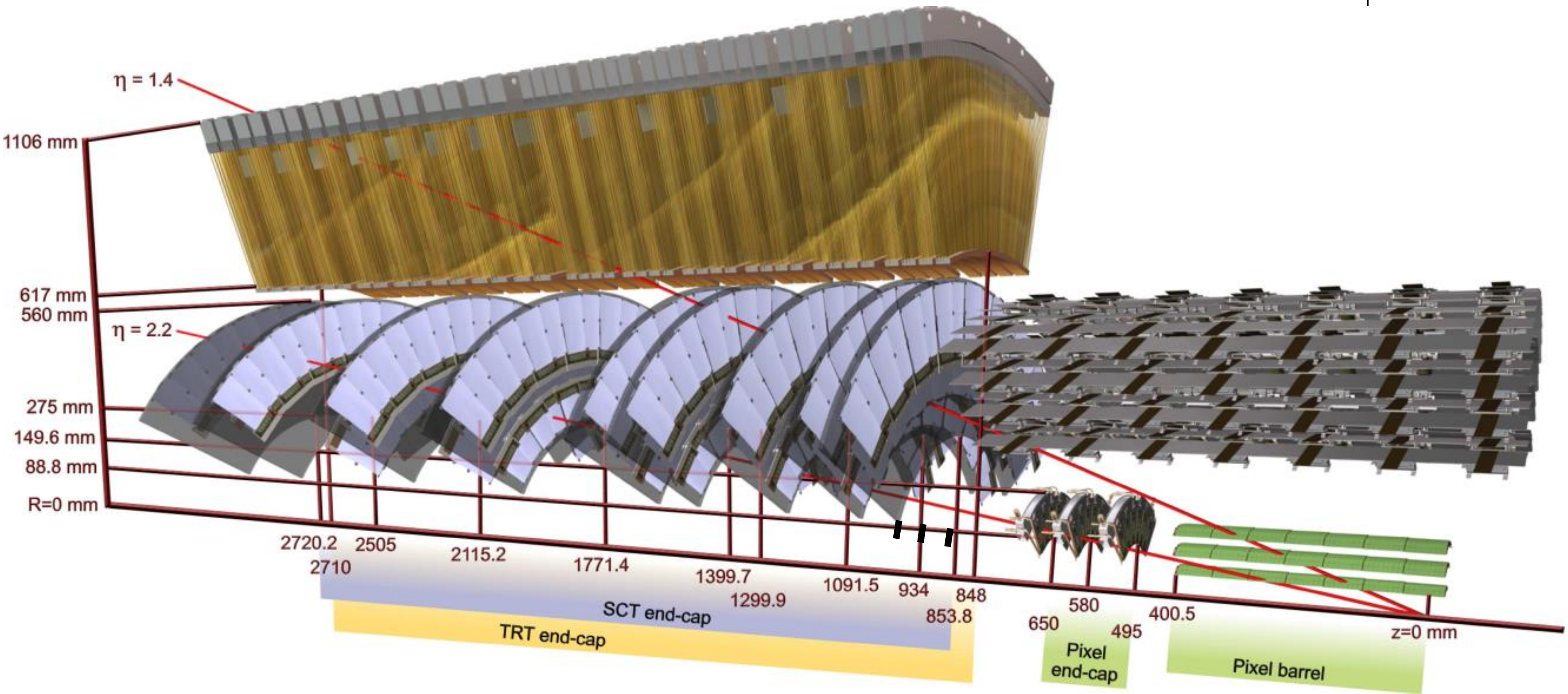


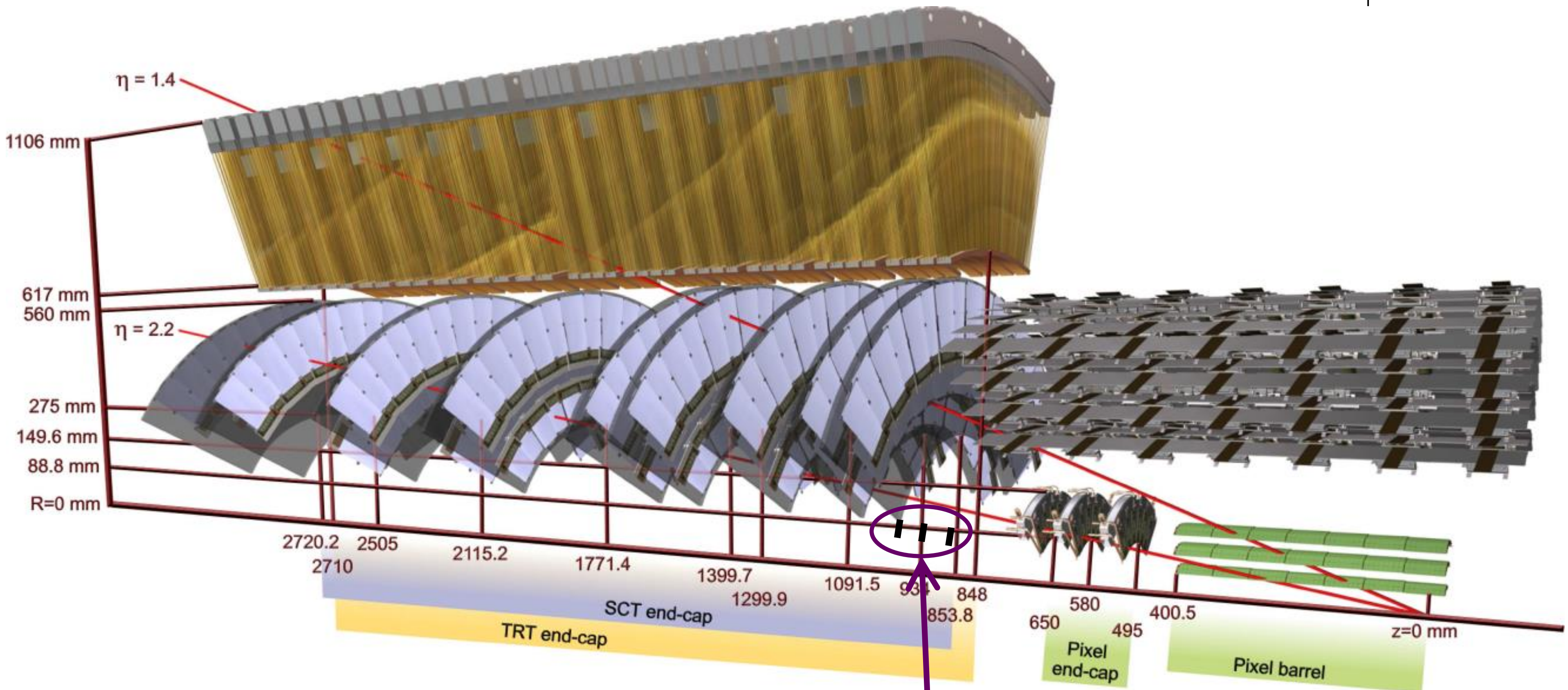
The ATLAS Diamond Beam Monitor

ATLAS Inner Detector:



The ATLAS Diamond Beam Monitor

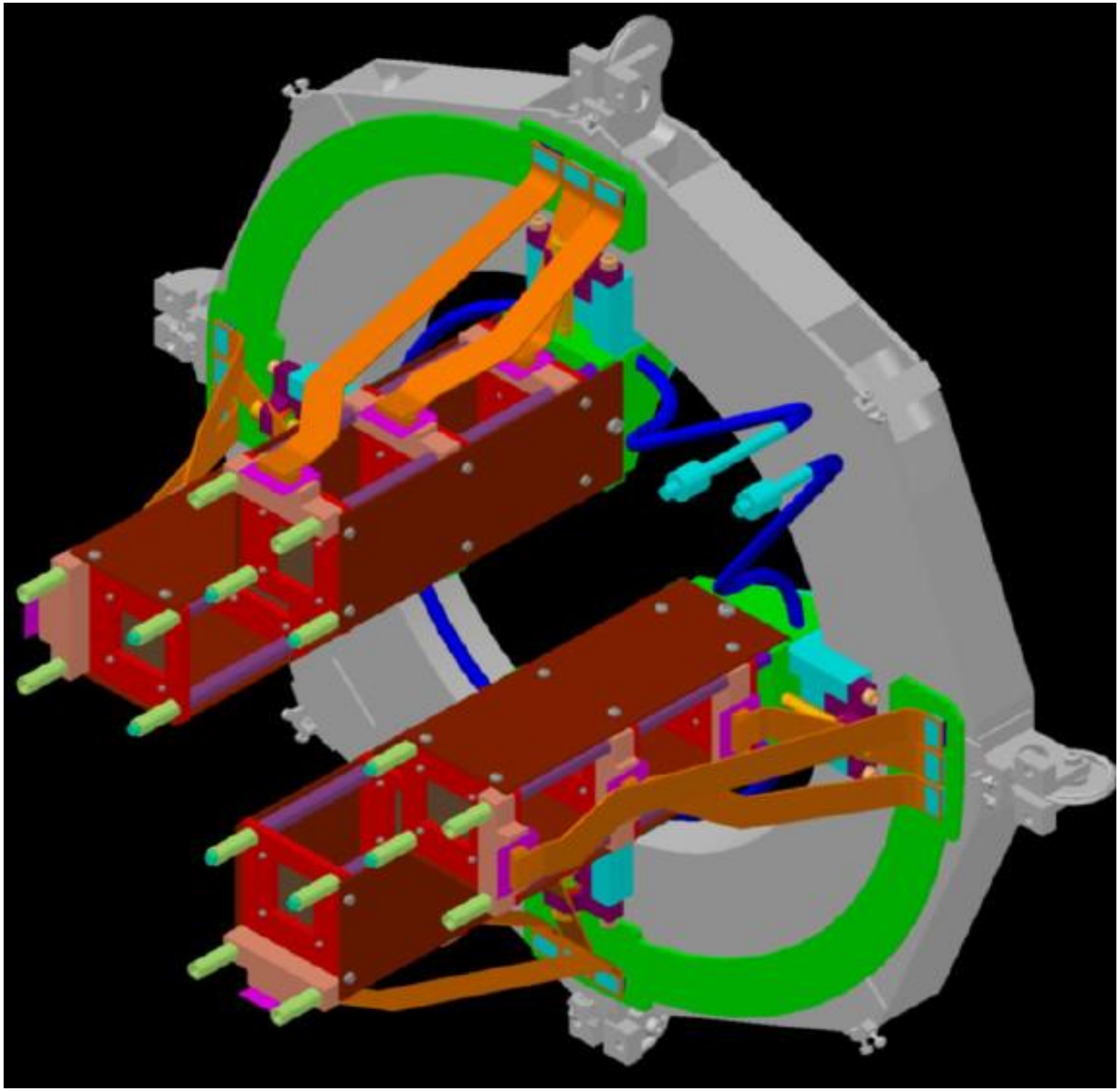
ATLAS Inner Detector:



DBM: $3.2 \leq \eta \leq 3.5$

90-100 cm from vertex

The ATLAS Diamond Beam Monitor



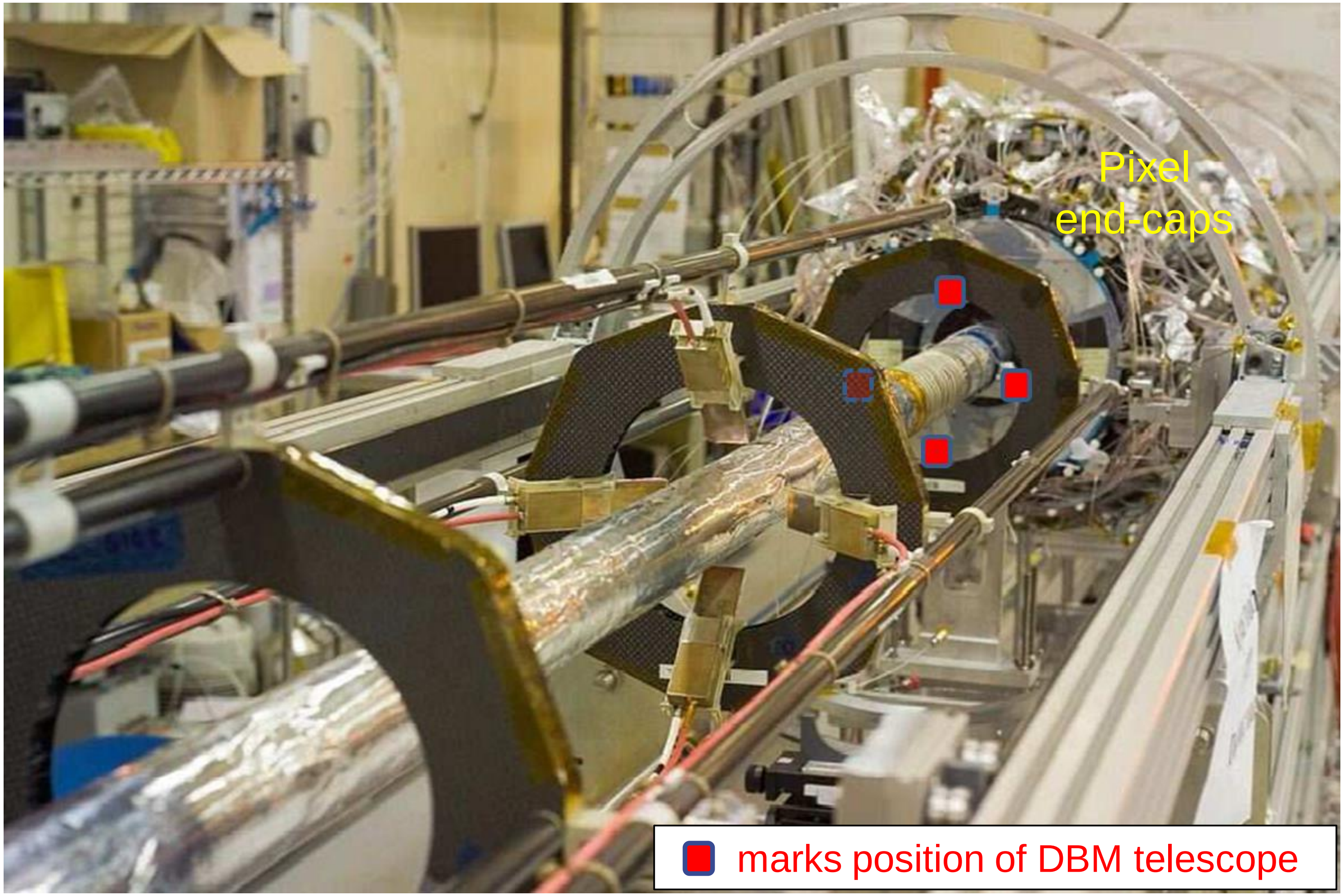
Highly spatially-segmented pixel device

Four 3-module telescopes on each side of IP

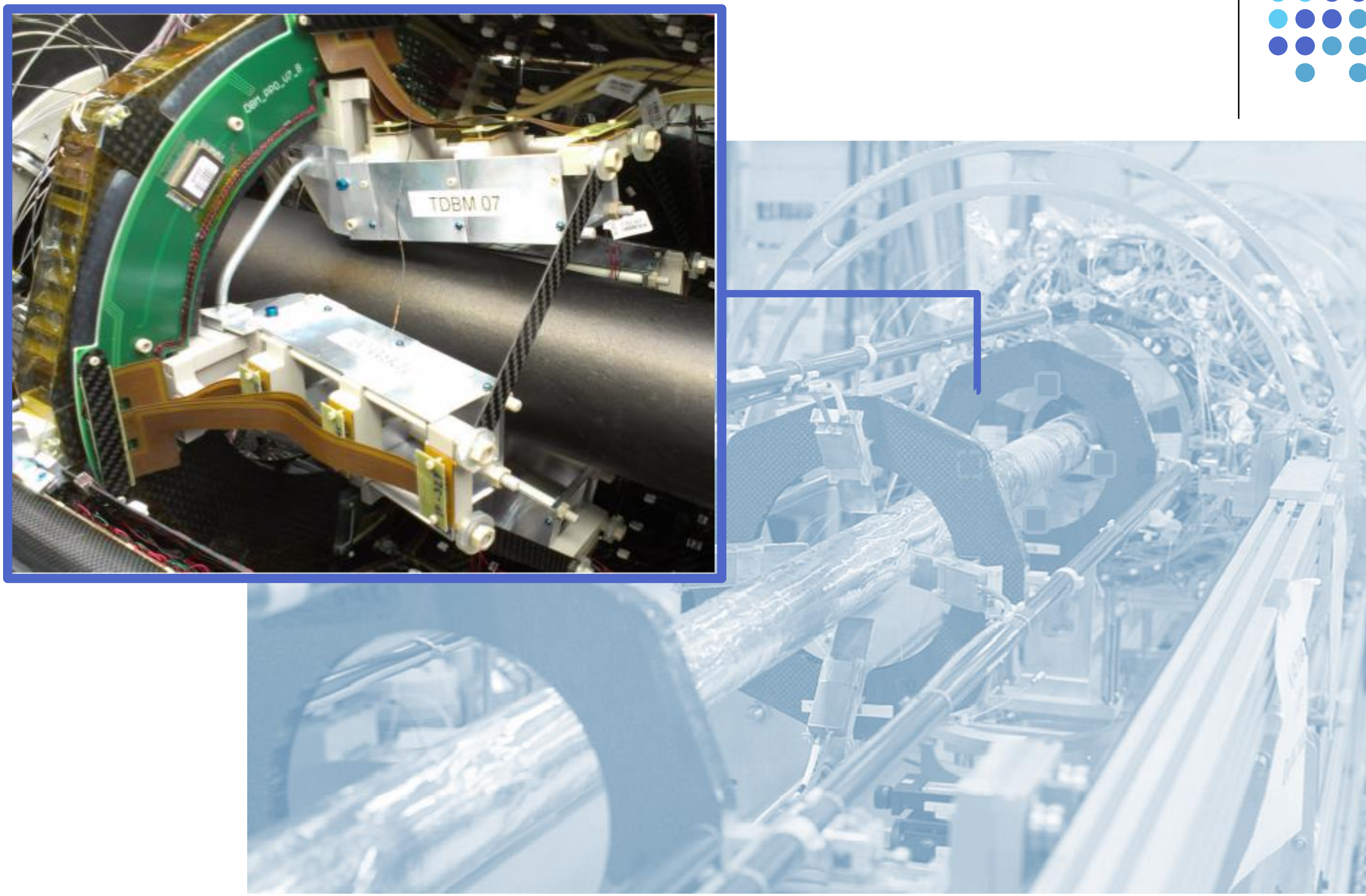
Each module has

- 20.0 x 16.8 mm active area
- 26880 pixels
- 250 x 50 µm pitch

The ATLAS Diamond Beam Monitor



The ATLAS Diamond Beam Monitor

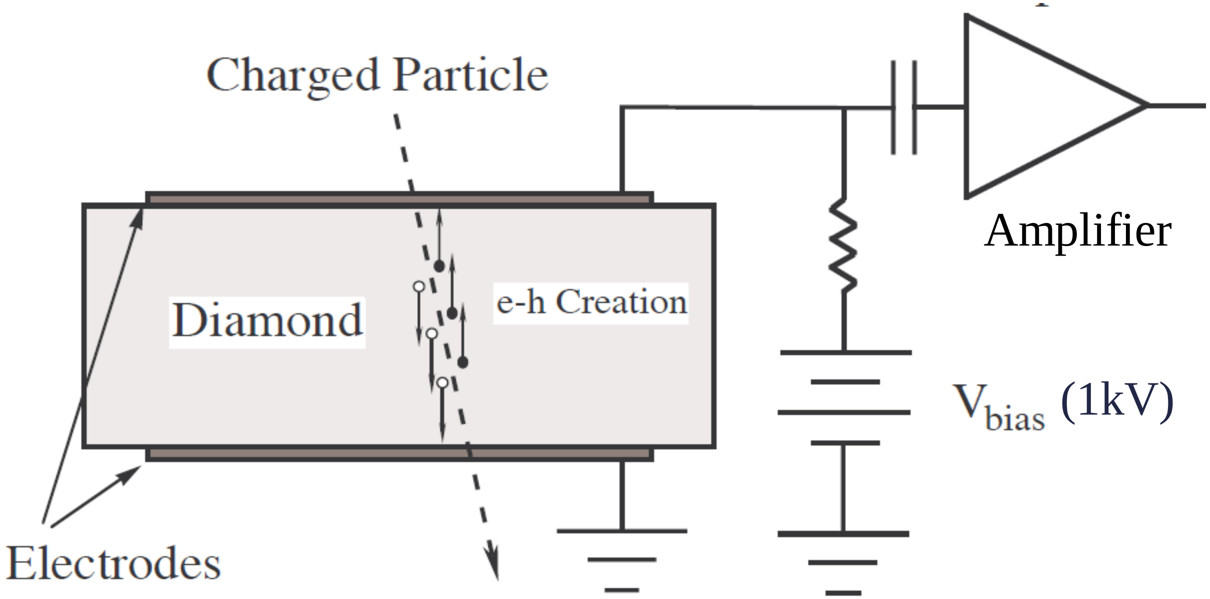


The ATLAS Diamond Beam Monitor

- Main purposes:
  1) Bunch-by-bunch luminosity measurements
  2) Bunch-by-bunch beamspot monitoring
  3) Background determinations
- New for Run II
  - Installation in ATLAS completed Oct 2013 (during current long shutdown)
- Run I ATLAS luminosity monitors may saturate in Run II, but DBM won't (highly spatially-segmented)
  - Saturation: all detector segments have high hit probability in every bunch crossing
  - In Run II, ~3x higher luminosity (will be ~10^{34} $cm^{-2}s^{-1}$), half the bunch spacing (will be 25 ns)
- Chemical Vapour Deposition diamond as active material: largest diamond tracking detector ever deployed in HEP

The ATLAS Diamond Beam Monitor

Charged particle ionizes atoms in crystal lattice sites, charge carriers drift in response to applied voltage

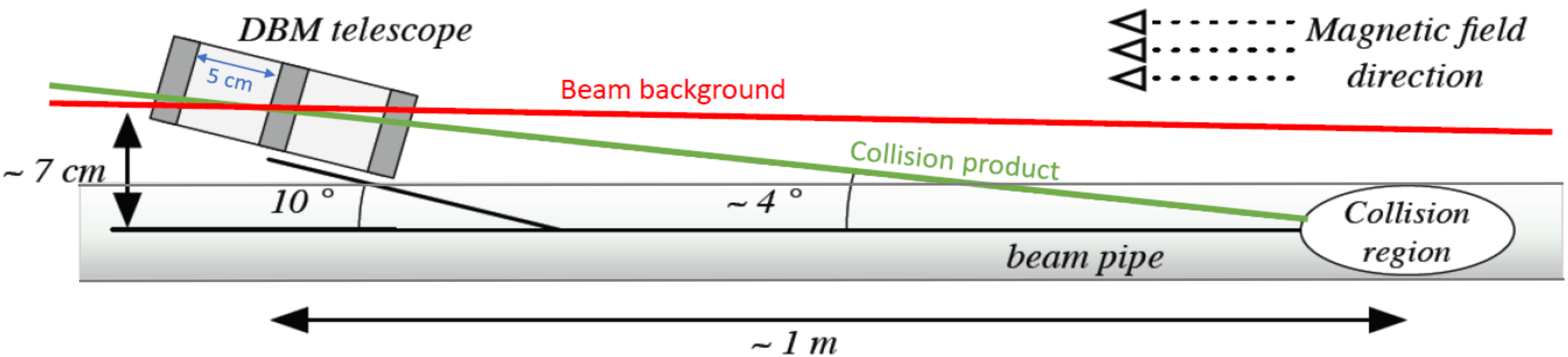


Advantages of CVD diamond as solid-state ionization chamber:

- Inherently radiation tolerant
- Room-temperature operation
- Low leakage current, low pixel capacitance, low noise
- Fast signal collection

DBM Tracking

Basic goal: Eliminate background for the luminosity determinations, based on whether track points back to Interaction Point



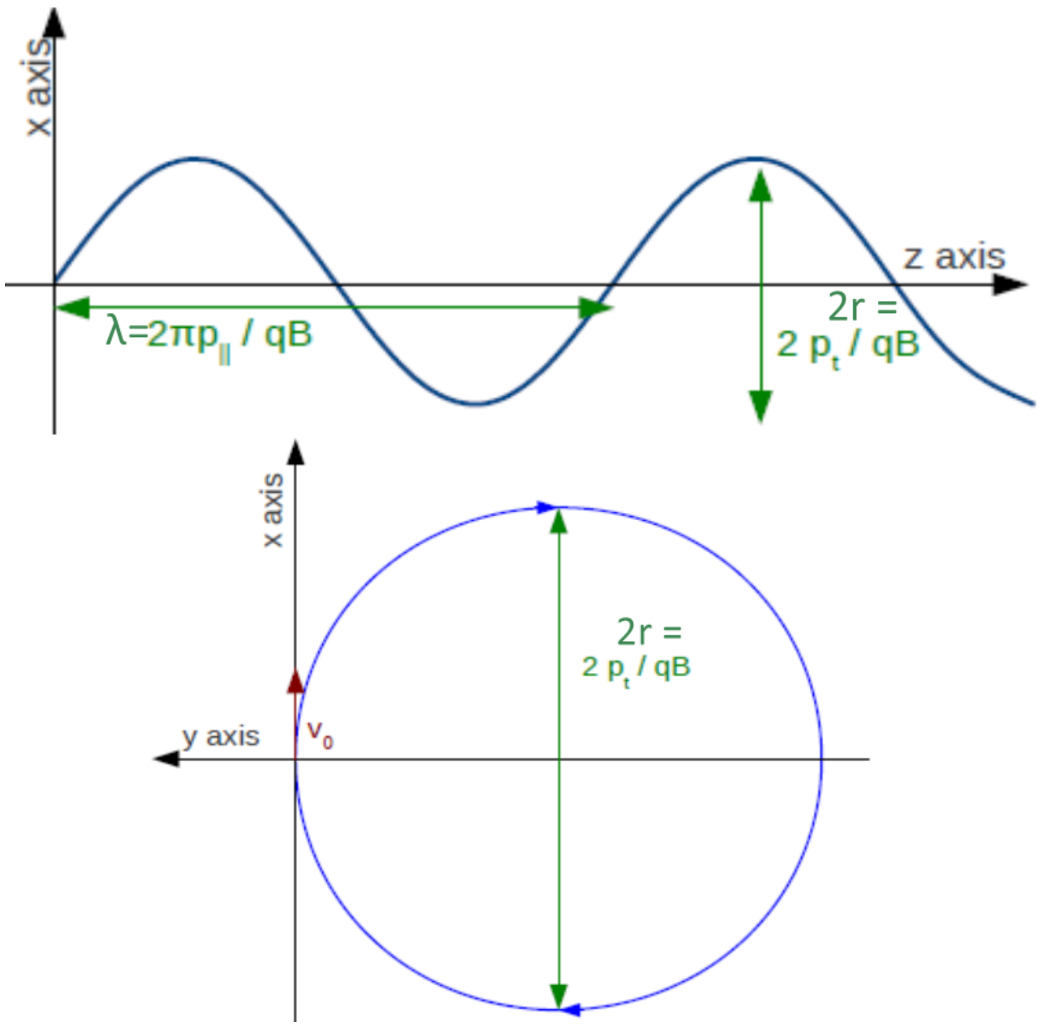
Ambitious goal: Pinpoint spatial locations of prominent background sources, and use DBM as background monitoring tool

DBM Tracking

- My task: software to build tracks using only DBM hits, such that DBM tracking runs "standalone" wrt rest of ATLAS
- DBM tracking challenges:
  - Only 3 points (at best) per track, one point from each layer
  - Small magnetic field integral, which entails poor p_T resolution
  - High η, high dz/dR
- Standard ATLAS tracking algorithms won't even try to construct such tracks
- So... run DBM tracking separately (in parallel), disregarding data from all other ATLAS components

DBM Tracking

Standard ATLAS algorithms construct helical tracks (radius r, pitch λ) :



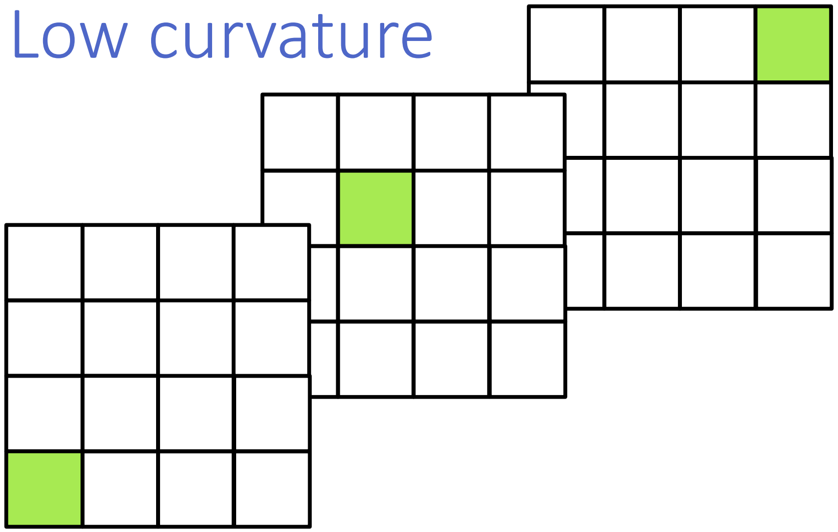
For any 3 points, there exists a helix that goes through all of them

- But -1 dof for direction of helix axis (determined by direction of magnetic field)

For 3 points close together, with one out-of-place wrt others: very high curvature assigned!

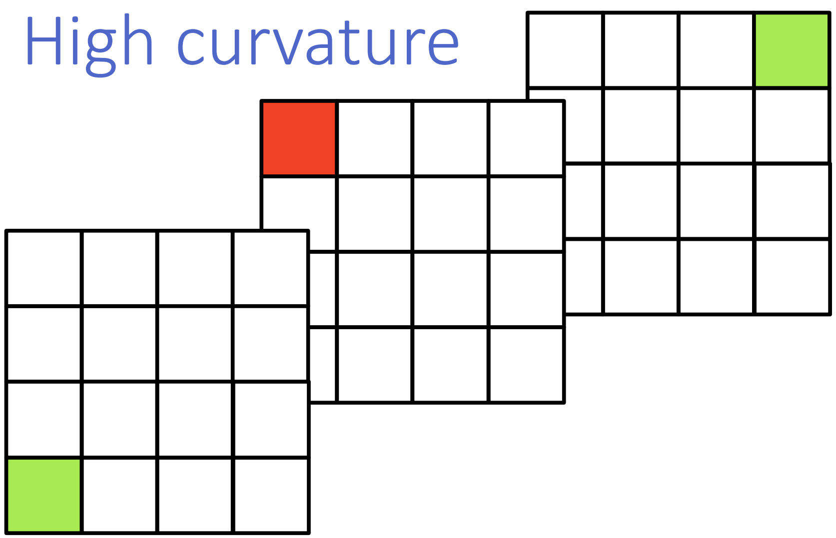
DBM Tracking

Low curvature



For 3 points close together, with one out-of-place wrt others: very high curvature assigned!

High curvature



This often occurs in DBM tracks, due to:

- Charge-sharing and uncertainties for pixel clusters
- Misalignments (in real data, not simulations)

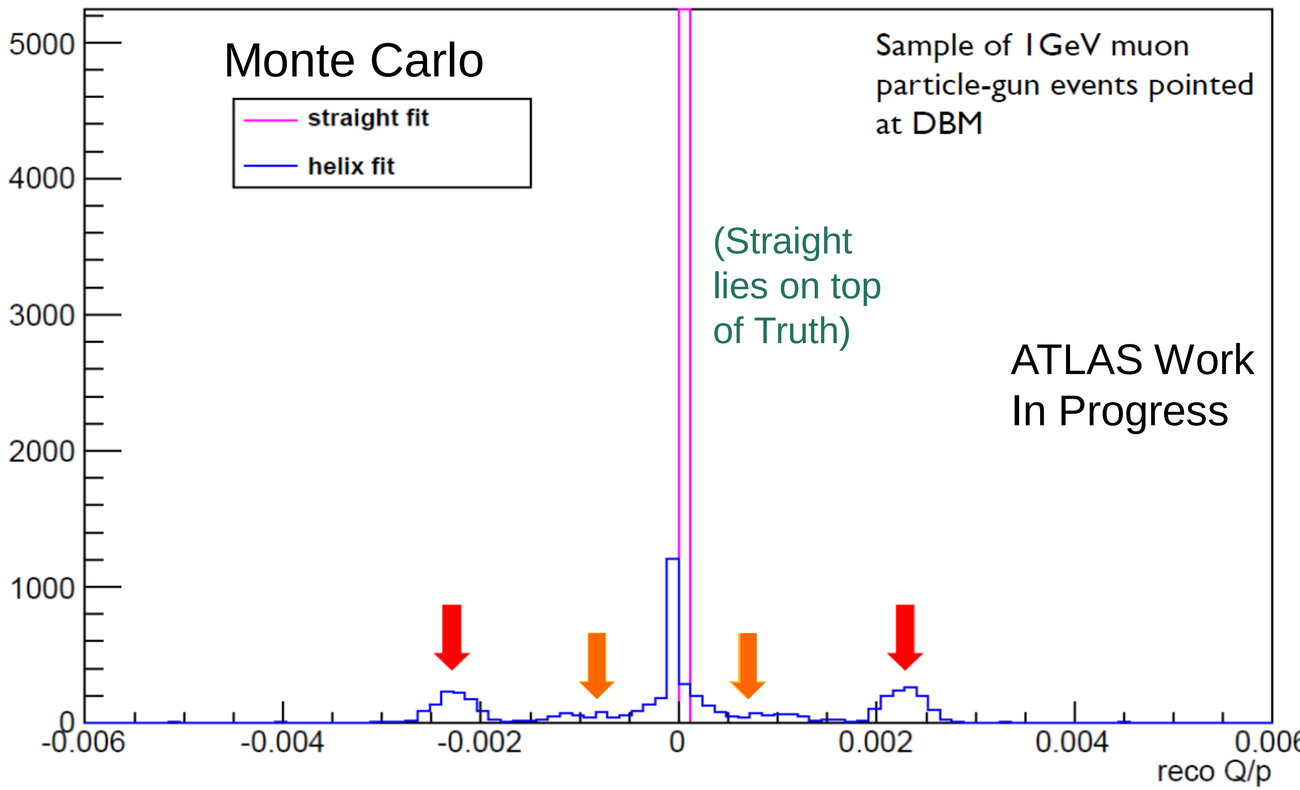
DBM Tracking

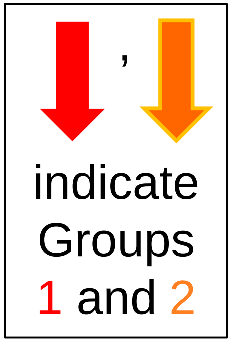
Helical fitting for DBM tracks → groups of poorly-reconstructed tracks (Groups 1, 2), even in simulations

- Obvious in Q/p, d_0, z_0 distributions of reconstructed tracks

Solution: straight-line fit

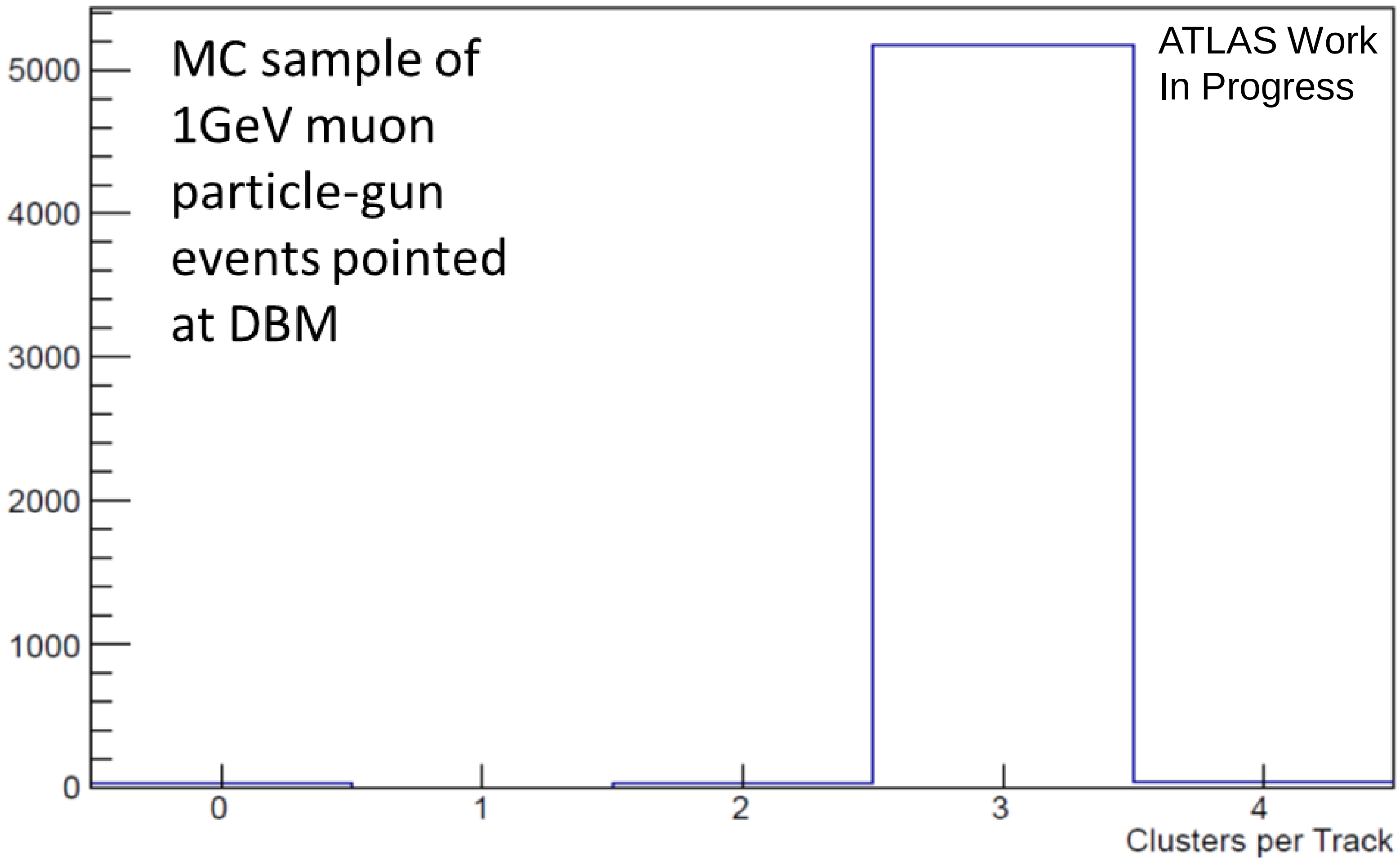
- Works because magnetic field integral within DBM is very small





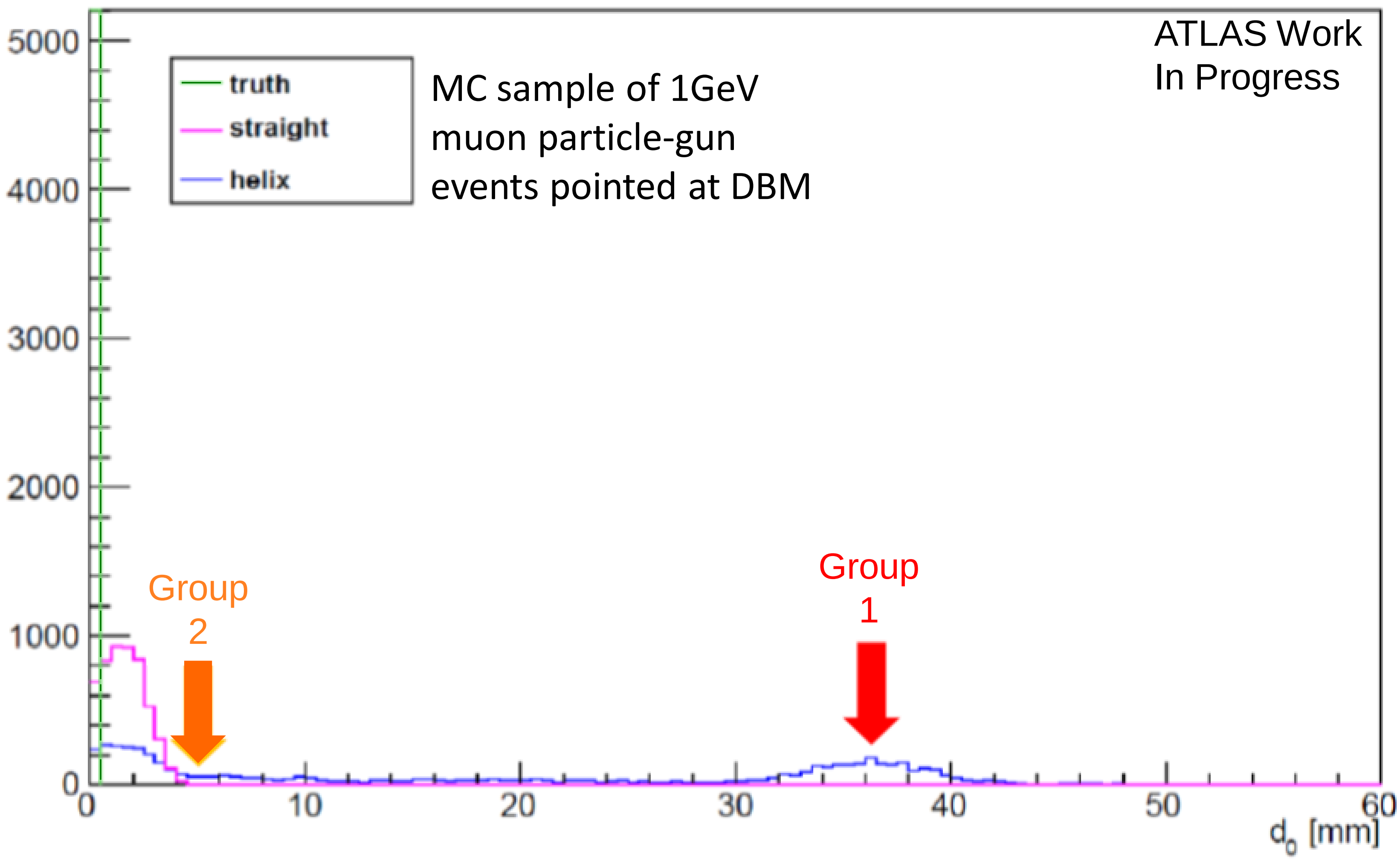
Preliminary Results

Good reconstruction efficiency:



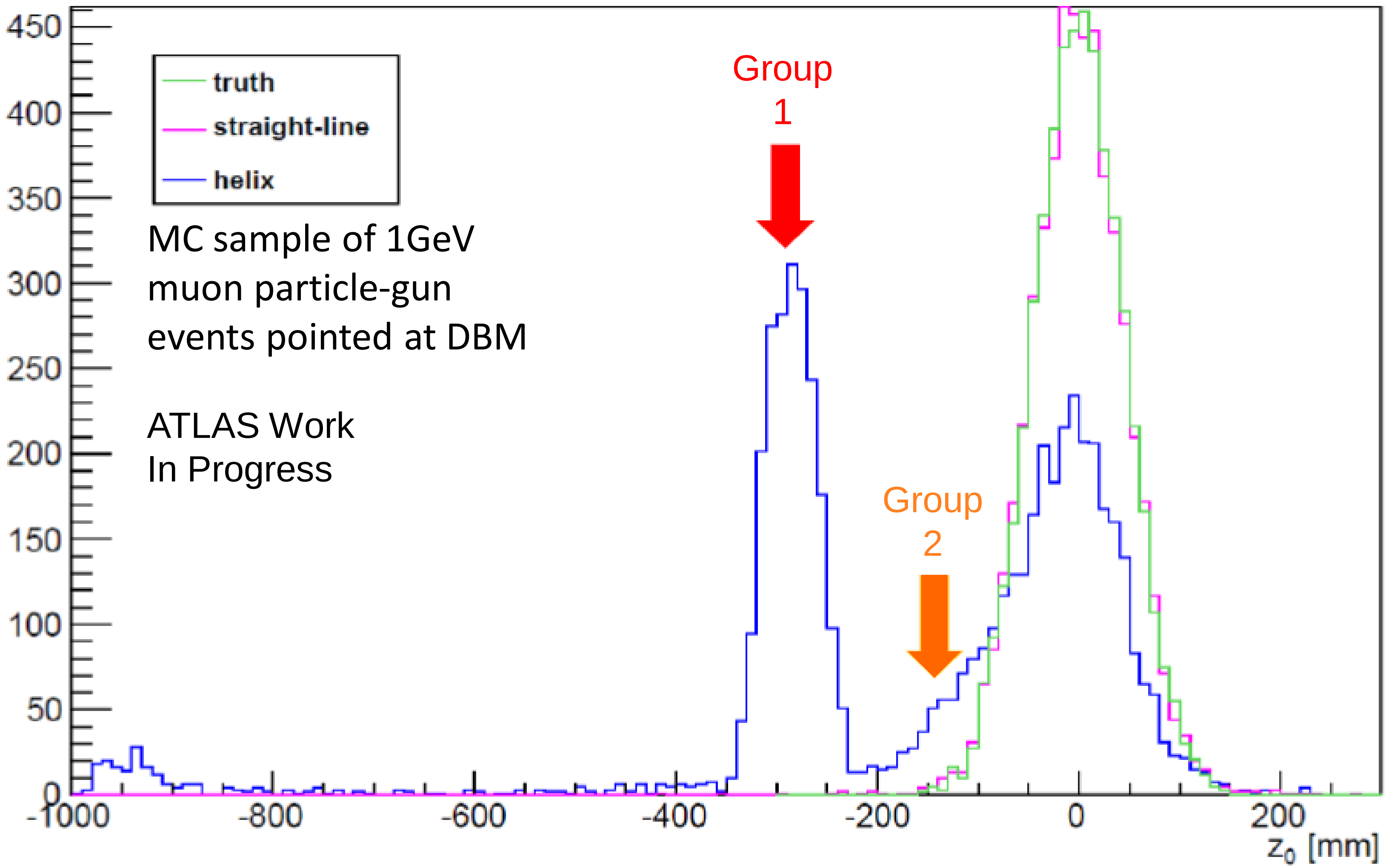
Preliminary Results

Impact parameter resolution:



Preliminary Results

Longitudinal impact parameter resolution:



Next Steps

- Refine pixel cluster uncertainty and charge-sharing models
  - Pixel charge deposition model: must consider charge collection distance, charge trapping, etc.
  - Simulations vs test-beam data
  - Detailed studies of position residuals
- Handle multiple DBM tracks per event
  - Expected average occupancy per collision per module ~ 0.1
  - “Pattern-recognition” algorithm to determine which clusters belong to which tracks
- Luminosity Group is considering track-based (vs. counting-based) luminosity determinations…

Conclusions

- ATLAS Diamond Beam Monitor: highly segmented pixel device, largest-ever HEP diamond pixel detector
- DBM Tracking aims to eliminate background for luminosity determinations, and hopefully spatially pinpoint prominent background sources
- Architecture and positioning of DBM poses tracking challenges
- Helical fitting yields groups of badly-reconstructed tracks
- Straight-line fitting yields promising results: good reconstruction efficiency, impact parameter resolution, etc.
- Several further refinements and extensions to explore