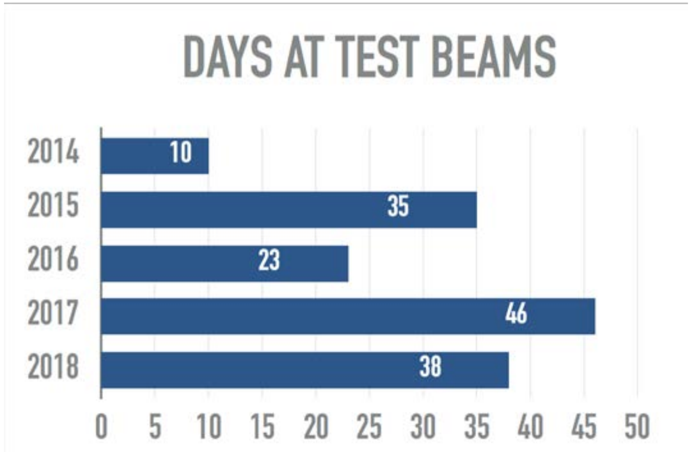
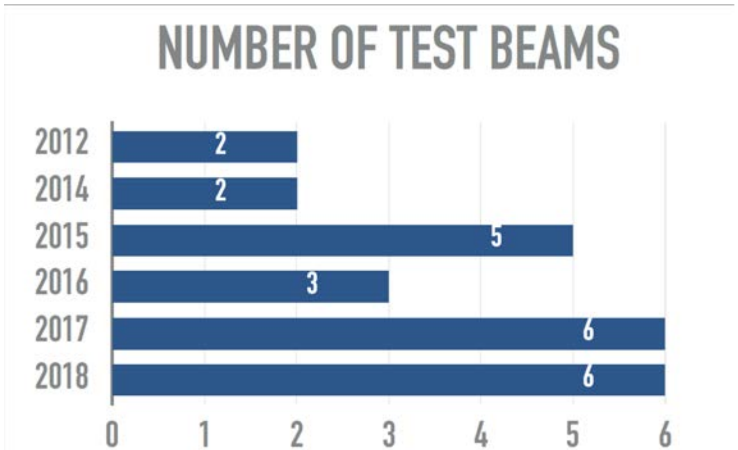
UA9 Collaboration meeting
12.03.19

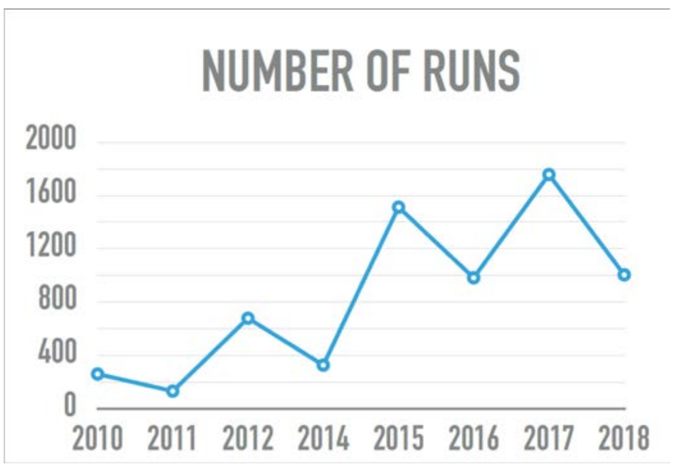
Silicon Strip Beam Telescope at H8

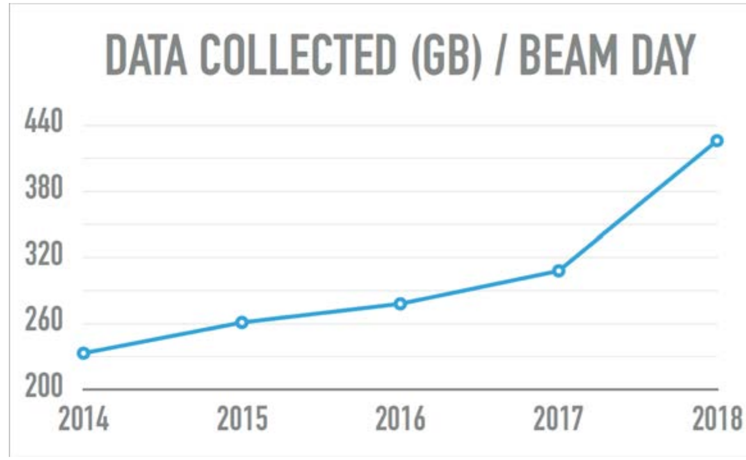
J Borg, G. Hall, G. Iles, T. James, M. Pesaresi

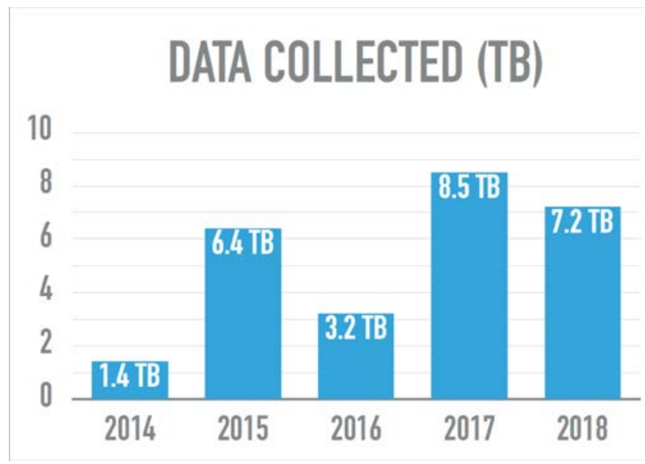
Some statistics





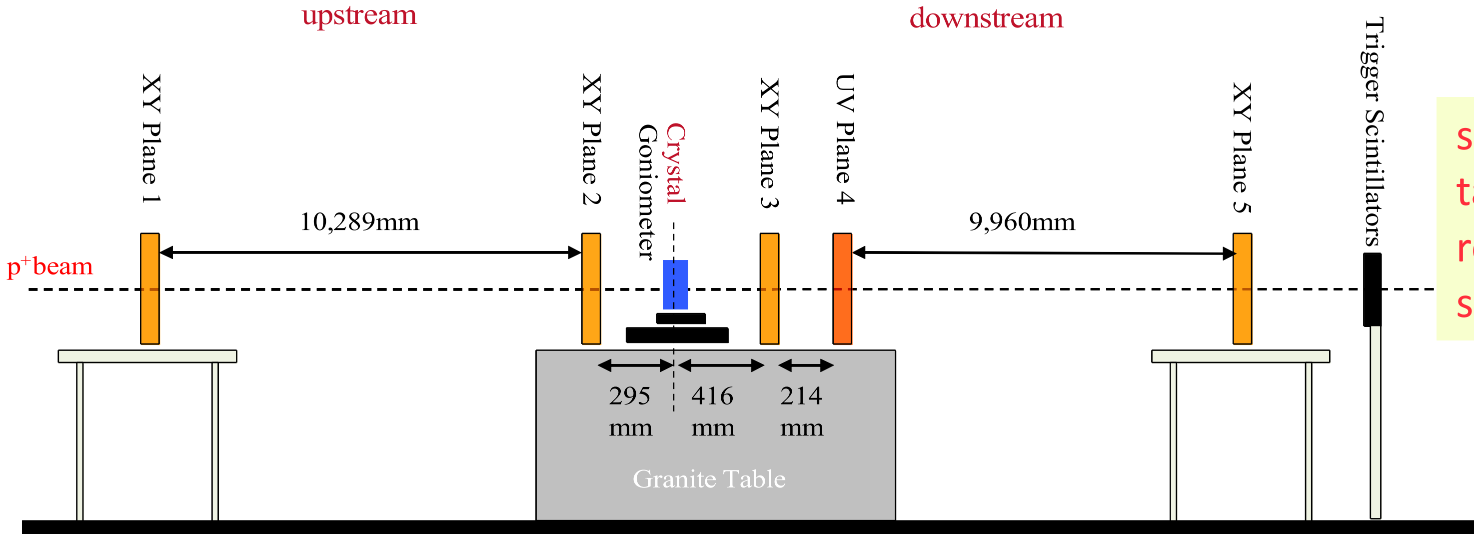






Reminder: “standard” layout

Performance, in several beam species, analysed and reported in a couple of conference presentations

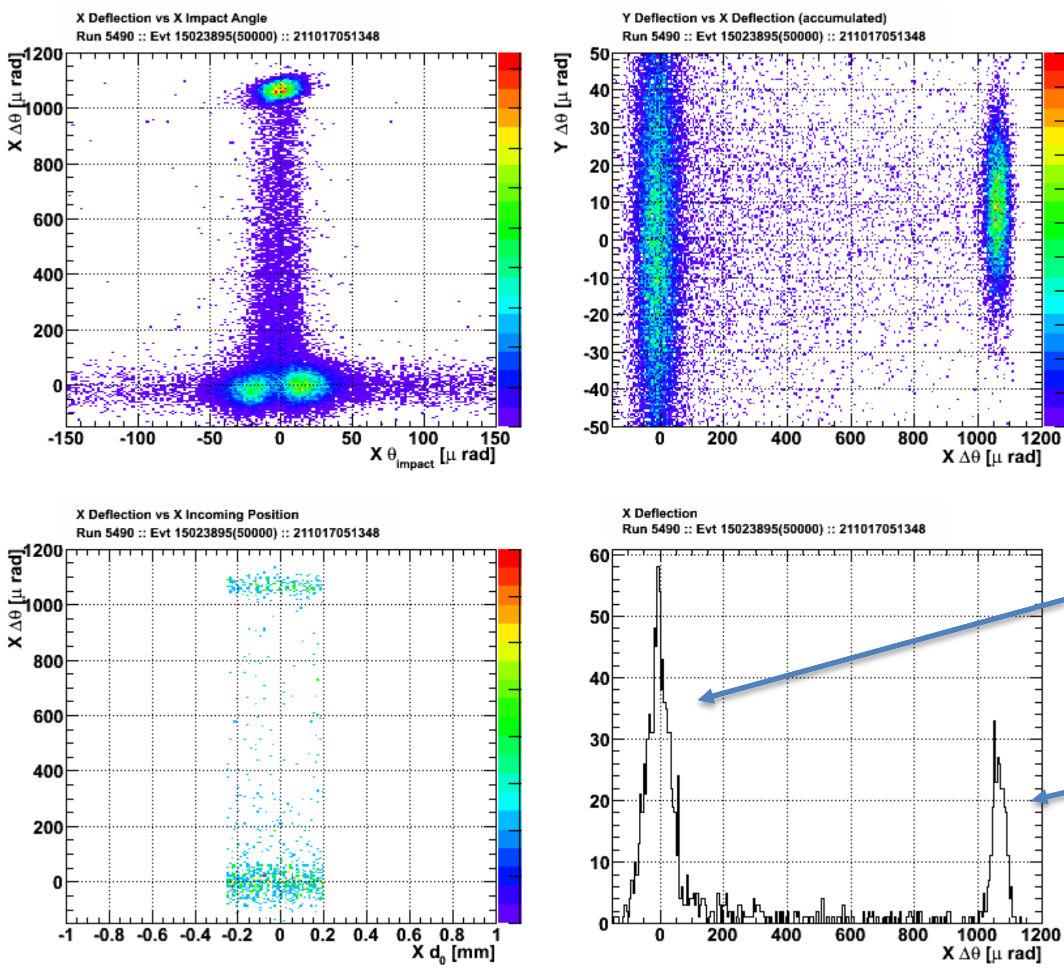


silicon crystal target on precise rotation stage to study channeling

[8] M. Pesaresi, W. Ferguson, J. Fulcher, G. Hall, M. Raymond, M. Ryan, and O. Zorba, Design and performance of a high rate, high angular resolution beam telescope used for crystal channeling studies, J. Instrum. 6, P04006 (2011).
[9] G. Hall, G. Auzinger, J. Borg, T. James, M. Pesaresi, M. Raymond A high angular resolution silicon microstrip telescope for crystal channeling studies Nucl. Instrum. Meth. A https://doi.org/10.1016/j.nima.2018.08.060
[10] M.A. Gordeeva, M.P. Gurev, A.S. Denisov, et al., JETP Lett. 54 (1991) 487-490

Measurements in H8 beam

- Data taken with range of beam particles
  - 400 GeV/c p, 180 GeV/c π, light and heavy ions, e.g. Pb and Xe
  - Large number of different crystals and types of crystal characterised



180 GeV/c π data

channeling efficiency in H8 beam depends on beam dispersion, i.e. fraction within θ_c

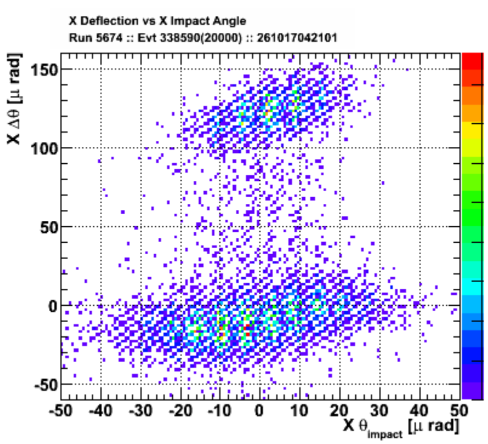
undeflected beam

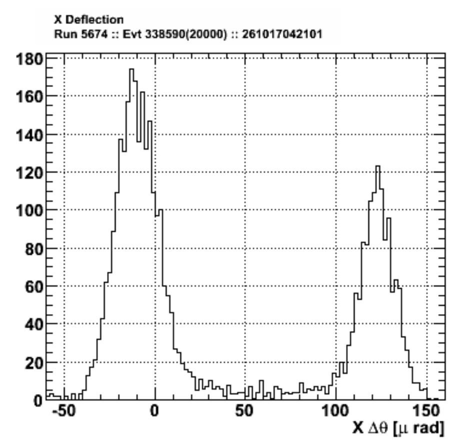
channeled particles

Ion beam measurements

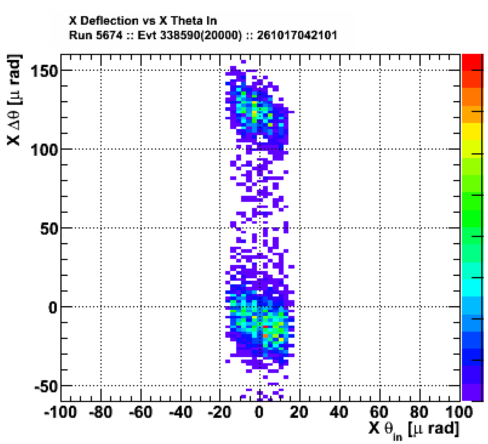
- Special operating conditions needed for ions because of very large dE/dx
  - Signal size = Z^2.MIP => 2916 MIP [Xe] - 6724 MIP [Pb]
  - Amplifier designed for linear operation up to a few MIP signals in 300-500µm silicon

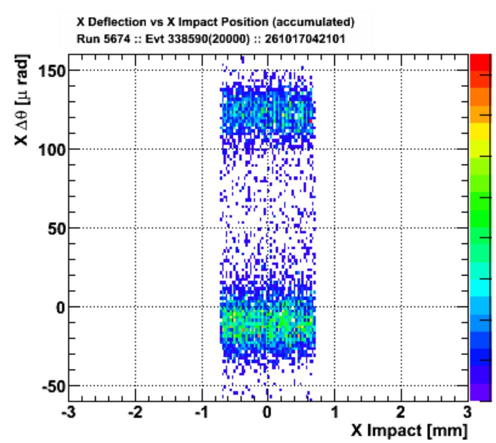
150A GeV/c Xe data

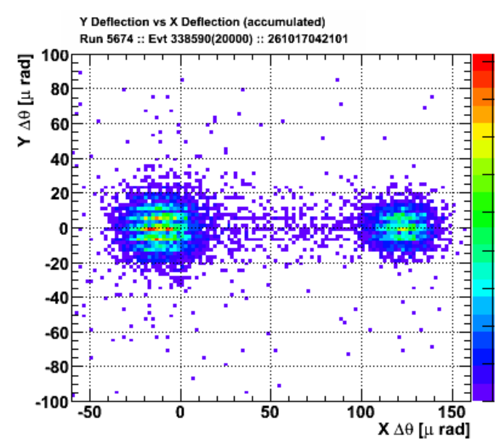




- V_{sensor}= 3.6V (cf. 150V normally)
- include clusters <20 strips (cf. 8)
- peak cluster size ≈ 3 [Xe] (cf. 1-2)
- strip threshold ≈ 5 MIP
- $\sigma(\Delta\theta)$ = 7.7 µrad

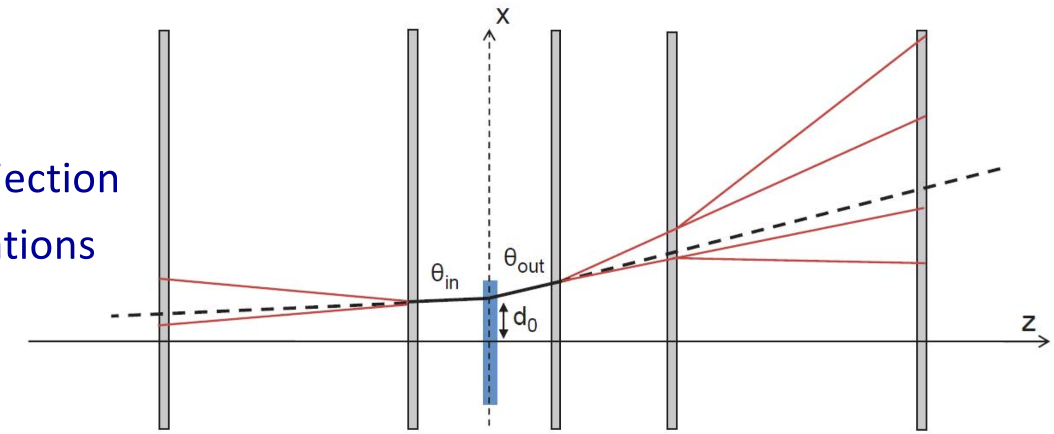




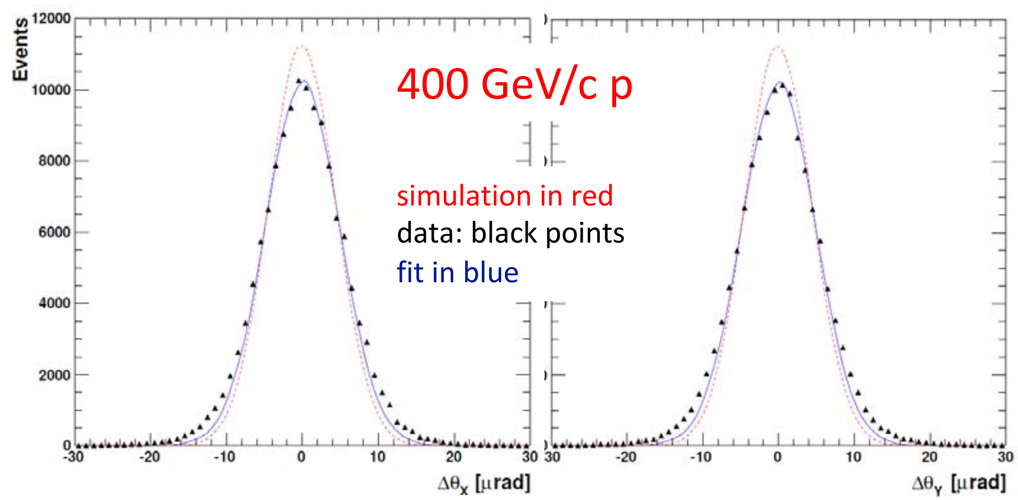


Track reconstruction

- Fitting procedure
  - 2D hit required in each plane
  - Two straight line fits
  - Three parameter fit (θ_{in}, θ_{out}, d_0) per projection
  - includes multiple scattering error correlations
  - χ^2 cut
- Angular resolution
  - alignment run events (no crystal) => $\sigma(\Delta\theta)$ = 5.2μrad in x and y
    - simulation predicts 4.4μrad



beam	Z	A	p [GeV/c]	sigma [μrad]	sigma estimated [μrad]
p	1	1	400	5.4	5.4
Xe	54	131.2	19680	7.8	5.9
Pb	82	207.2	6216	29.6	28.5
pi	-	-	180	12.3	12.0



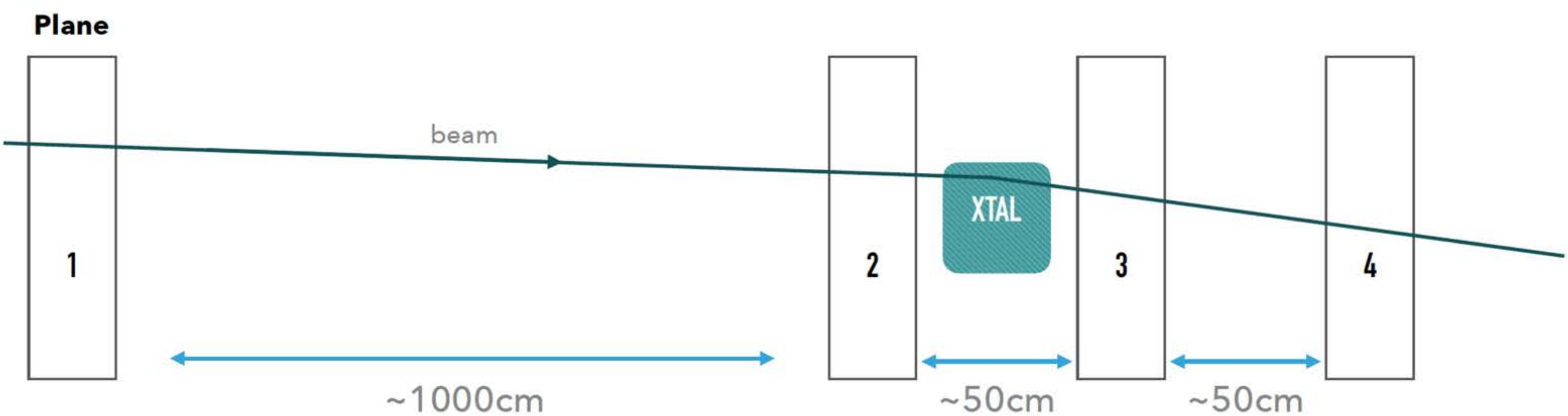
Evaluation of long crystals

- Some new issues

LONG CRYSTAL RECONSTRUCTION

14

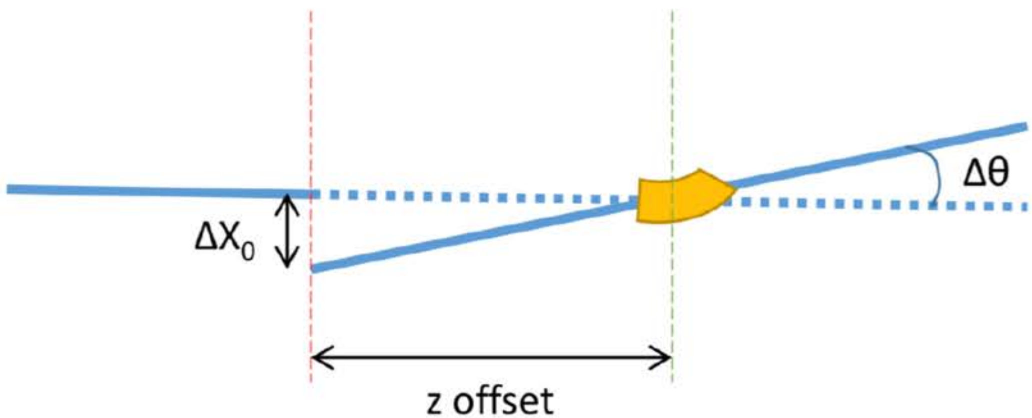
- **Special configuration and reconstruction required for longitudinally 'long' crystals** (> 10 mm), with **large deflection** angles (> 1 mrad)
- **4 plane configuration** (deflection angle too large for particle to be seen in most downstream plane)

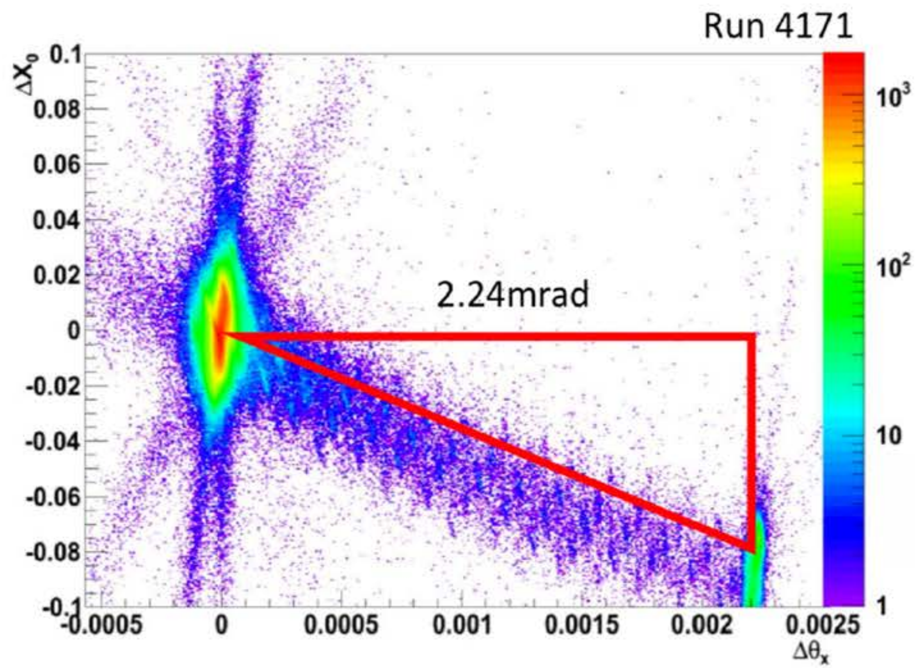


Long crystal analysis

- Has this been sufficiently accurate, or is more attention needed?

- **Additional complication from non-negligible crystal thickness**
- Must calculate, and correct for the true effective deflection vertex
  - Requires special **analysis for each crystal**



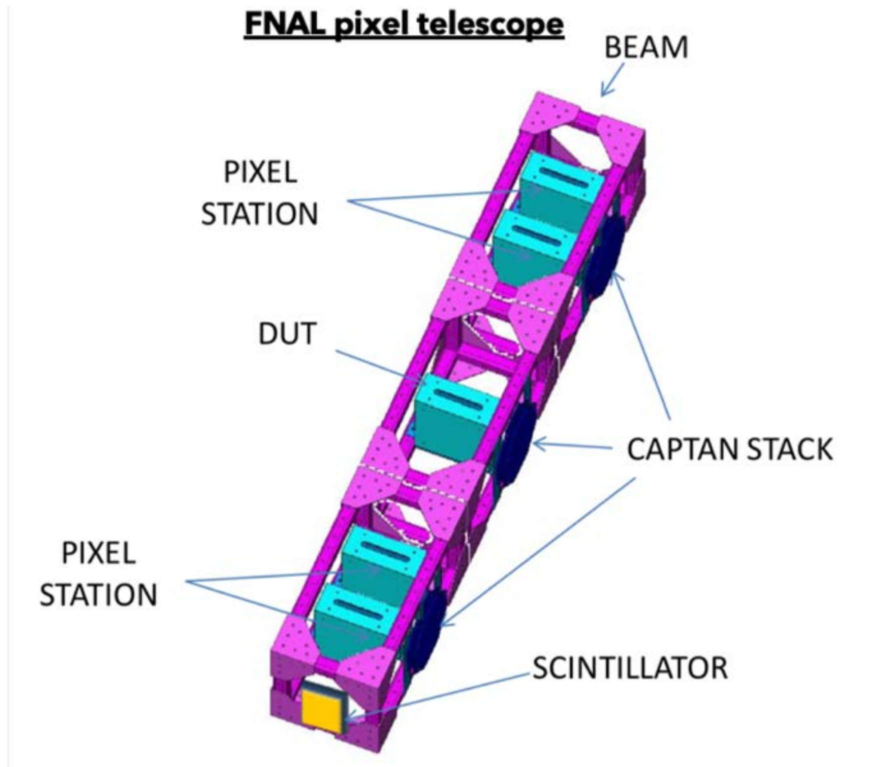


Example: Longitudinal correction 3.3 cm

Future UA9

- In absence of CERN beams, a recent proposal to use FNAL in 2020
  - Some significant practical issues, and seems no longer likely
  - However, it raises questions about what – if anything – should be done next
  - Pixels (at least those available) offer pros and cons

- **No beam at SPS until 2021**
- We require a setup to test and characterise crystals in beam
- **Potential solution:**
  - Use beam at FNAL
  - 120 GeV Protons
  - 4.2 second spill every ~60 seconds
  - Order 400k particles per spill possible

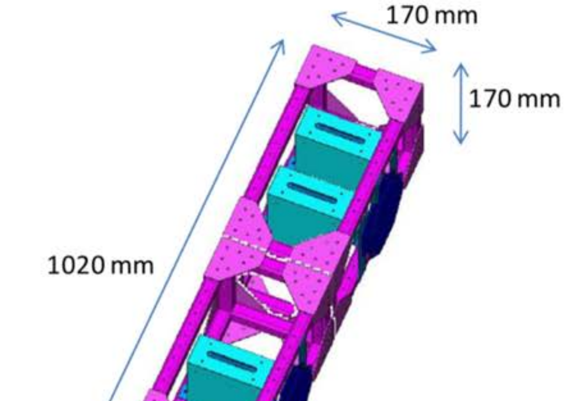


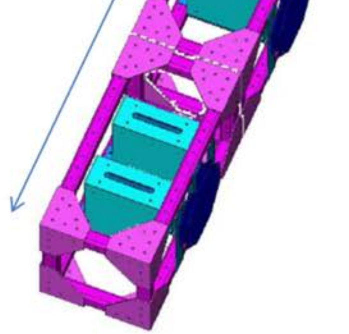
Pixel-based telescope

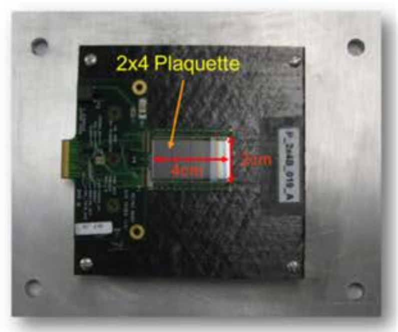
- No detailed analysis, but can offer qualitative remarks
  - Pro - 2D spatial measurements, multi-hit capability
  - Cons - no less material, and perhaps more, per station
  - spatial resolution not optimal, without special efforts
  - Neutral – how to cover larger area, if required

OVERVIEW

- **FNAL telescope specs:**
  - Short arm (default ~1m), but should be able to disassemble
  - Pixel sensors 100 x 150 um
  - 2 sensors per 'station'
  - Outside stations:
    - 2x4 cm area; finer pitch vertically
  - Inside stations:
    - 2x3 cm area; finer pitch horizontal







Other thoughts

- Construct new modules and digital DAQ

A telescope with digitization in the planes

Existing hardware/firmware

- Sensor module interface boards
  - Adapter from mDP to APV hybrid
  - Temperature sensor
  - LDO Voltage regulators
- Digitizer FMC cards
  - Digitizes signals from sensor modules
  - Provides supply voltages for the APVs
  - Peltier driver for temperature control
- FC7 firmware exists, but needs extending:
  - Cluster finding/zero suppresion
  - DAQ integration

Preliminary thoughts

Sensor modules

- 6x APV25+D0 sensor
  - 14 modules exists (12 in planes, 2 at IC)
  - Some sensors show some signs of radiation damage
  - Limited to 142kHz trigger rate due to APVMUX
- Alternative: build new modules without APVMUX
  - Sensors from old modules could probably be reused but some risk that some would be damaged
  - Would allow up to 285kHz trigger rate
  - New PCBs and other hardware needs to be developed

Thoughts on options

- Incremental, or significant, improvement?
  - New measurements, or simply more of similar?
  - Online data reconstruction?

Other possible improvements

- Mounting hardware that allows repeatable positioning
- Tilt planes relative to beam to increase charge sharing
- Spatially/directionally selective silicon sensor trigger using CBC module
- More flexible sensor planes where individual modules can be swapped

- What are long term requirements?
  - Longevity, reliability, increased area, use by ”non-experts”, improved performance, reduced material,…?