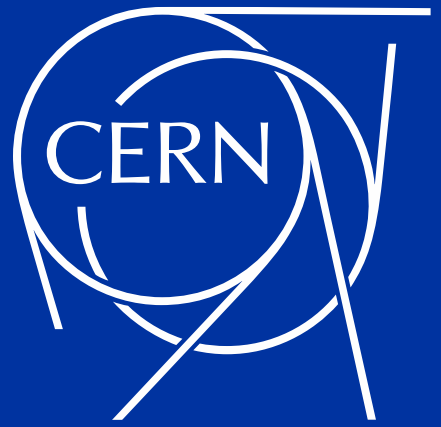


Crystal channelling efficiency: 2023 data from H8 beam test

Presenter: Kay Dewhurst, on behalf of the CERN crystal collimation team.

Thanks to the SELDOM team and all colleagues involved in the measurement!

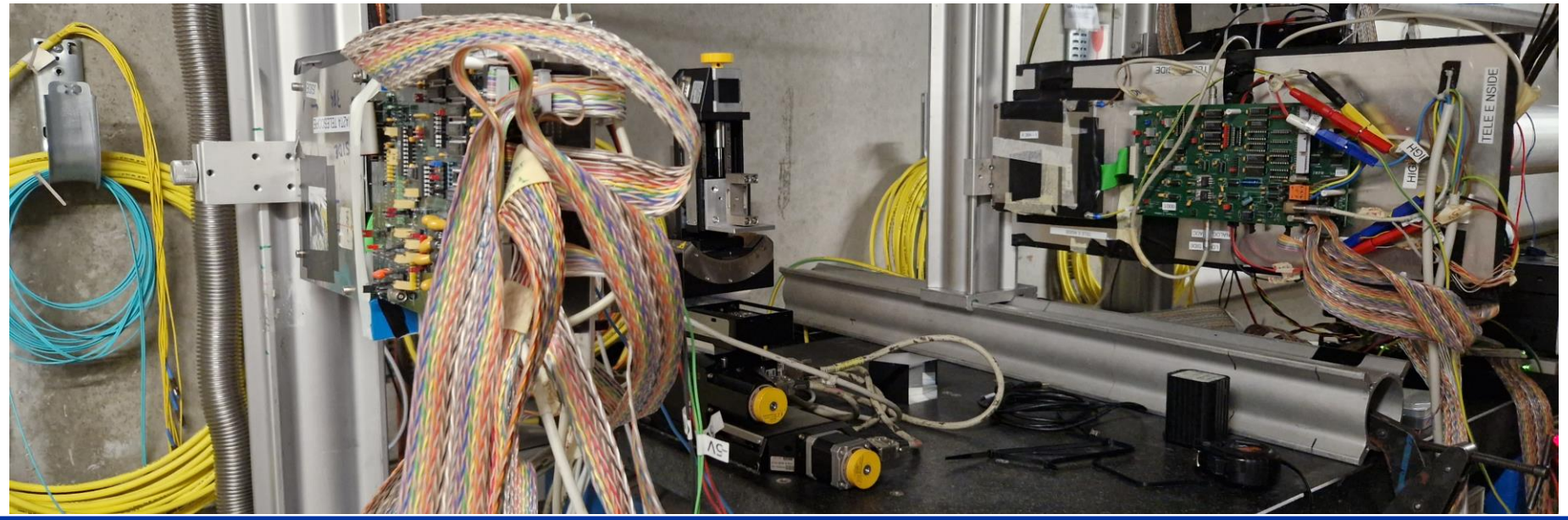
11/12/2023

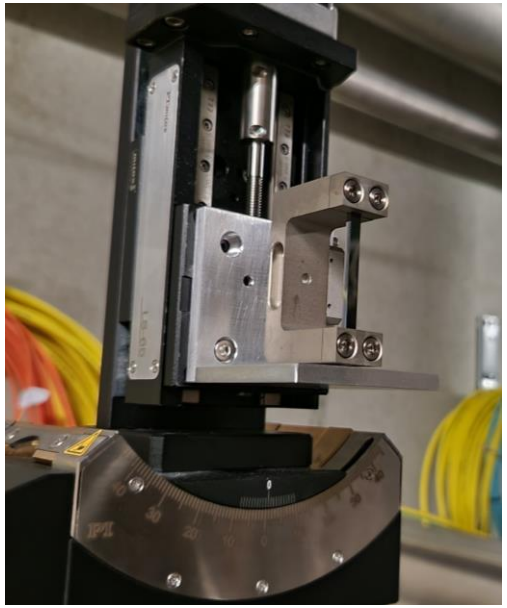
3rd workshop on electromagnetic dipole moments of unstable particles at IJCLab

Many contributions!

Leading the beam test: M. Prest, E. Vallazza.

Contributions from L. Bandiera, S. Carsi, S. Cesare, K. Dewhurst, M. D'Andrea, C. M. Ferro-Luzzi, P. Hermes, A. Mazzolari, D. Marangotto, A. Merli, M. Monikowska, C. E. Montanari, P. Monti-Guarnieri, L. Perna, S. Redaelli, M. Romagnoni, R. Negrello, N. Neri, A. Selmi, F. Sgarbossa, D. Veres, G. Lezzani, …





Crystal channelling efficiency: 2023 data

1. **Introduction**
2. **Steps in the analysis**
   a) Tracker alignment
   b) Crystal alignment
   c) Channelling efficiency
3. **Results**
   a) Summary from the beam test
4. **Outlook**

1. Introduction

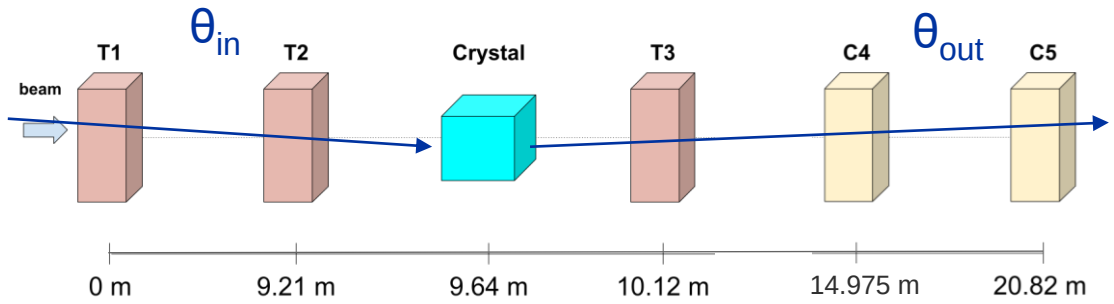
Beam test in Aug 2023

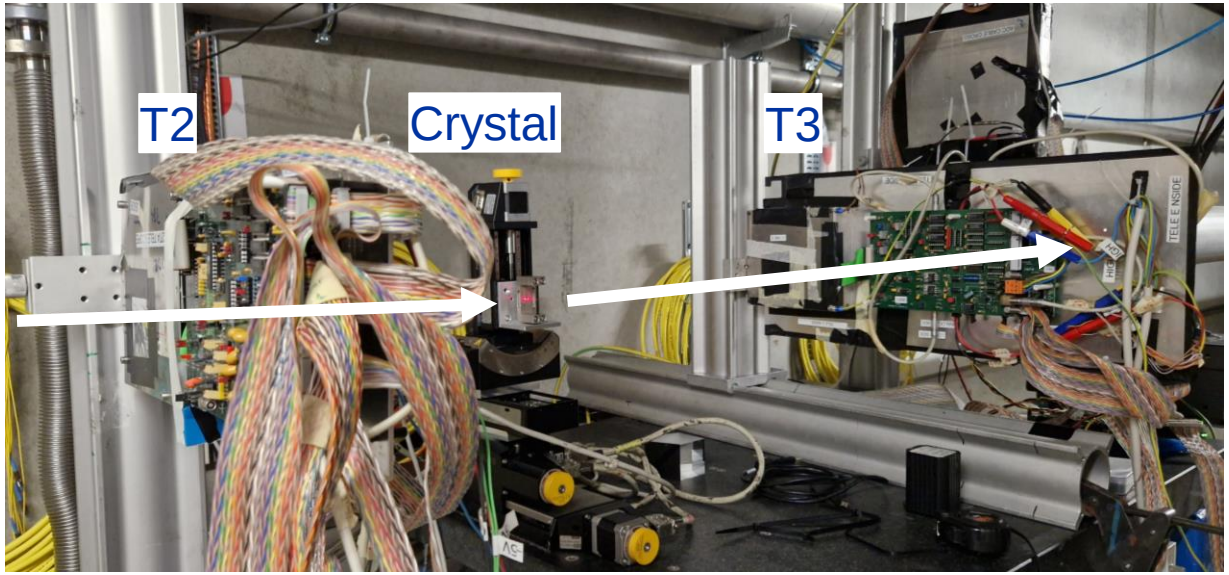
- H8 beam line using 180 GeV/c pions

Three crystals tested

- TCCS – 50 µrad bending
- TCCP – 7 mrad bending
- Anodic bonded crystal

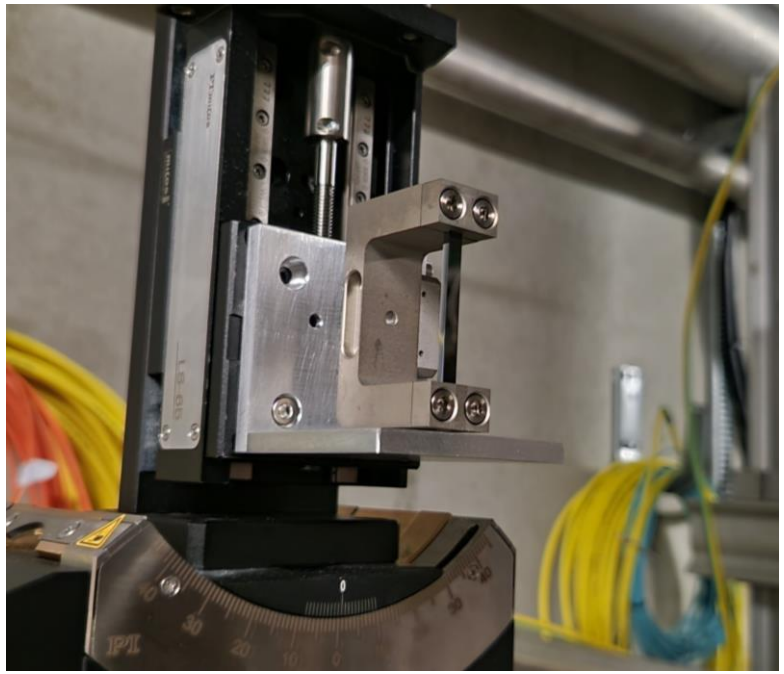
H8 experiment 2023





1. Introduction: crystal parameters

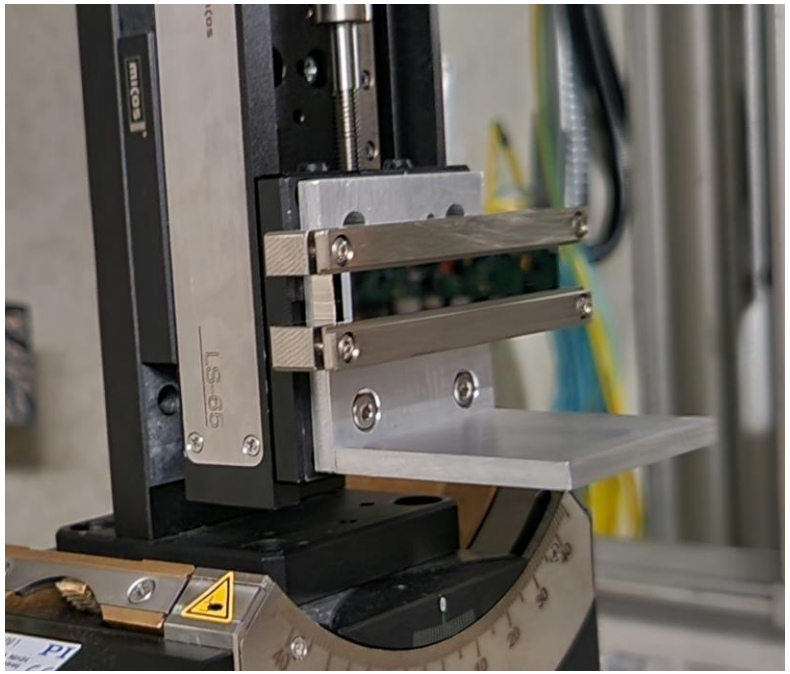
Crystal 1 (short - TCCS)



Crystal properties:

Length	4 mm
Material	Silicon
Bend radius	80.0 m
X dimension	2 mm
Y dimension	35 mm

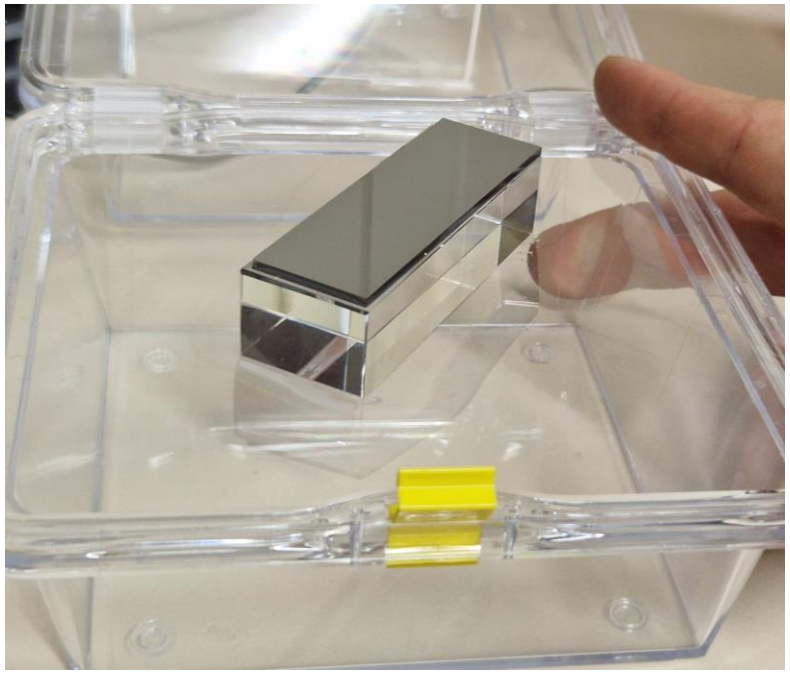
Crystal 2 (long - TCCP)



Crystal properties:

Length	70 mm
Material	Silicon
Bend radius	10.0 m
X dimension	2 mm
Y dimension	8 mm

Anodic-bonded crystal



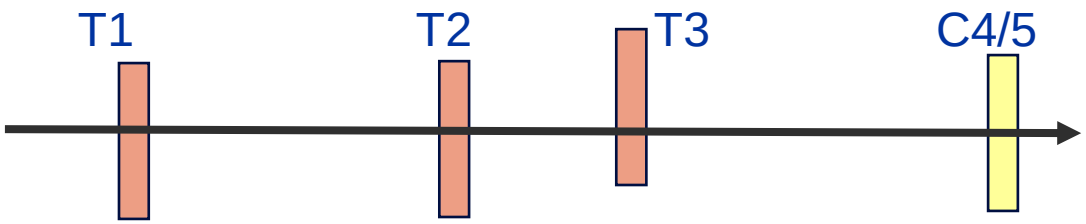
Crystal properties:

Length	70.5 mm
Material	Silicon
Bend radius	5.3 m
X dimension	2 mm
Y dimension	22.5 mm

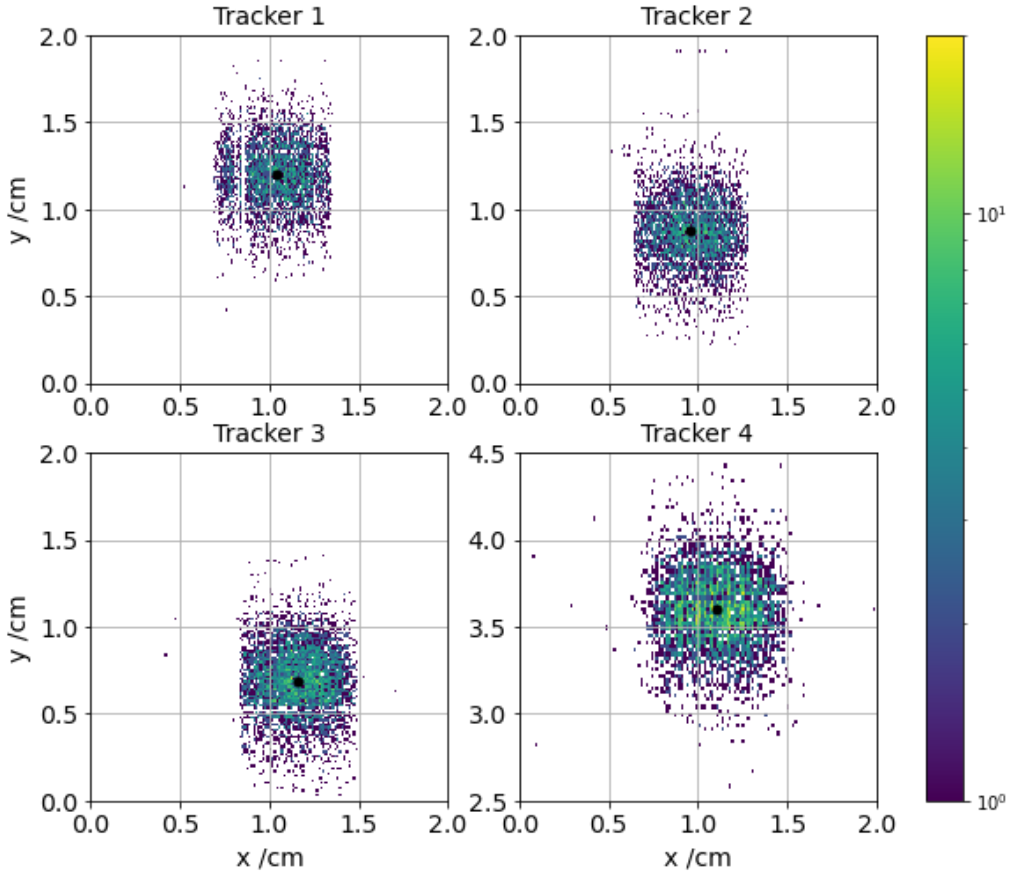
2. Steps in the analysis: tracker alignment

Alignment run

- Exp. - Remove the crystal from the beam.
- Remove outliers from the data (any positions recorded beyond the edge of each tracker).
- Use the beam centre to define (0,0) position on each tracker.



H8 experiment 2023: Alignment run TCCS

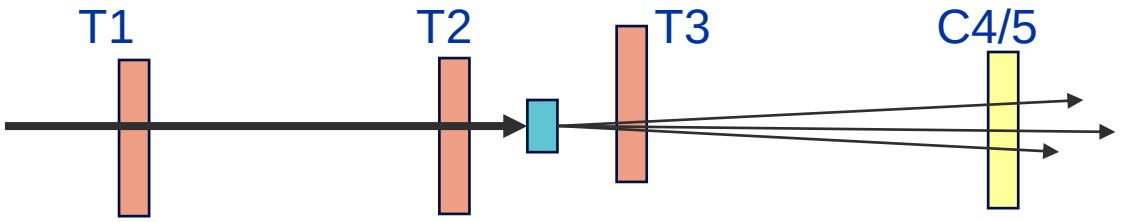


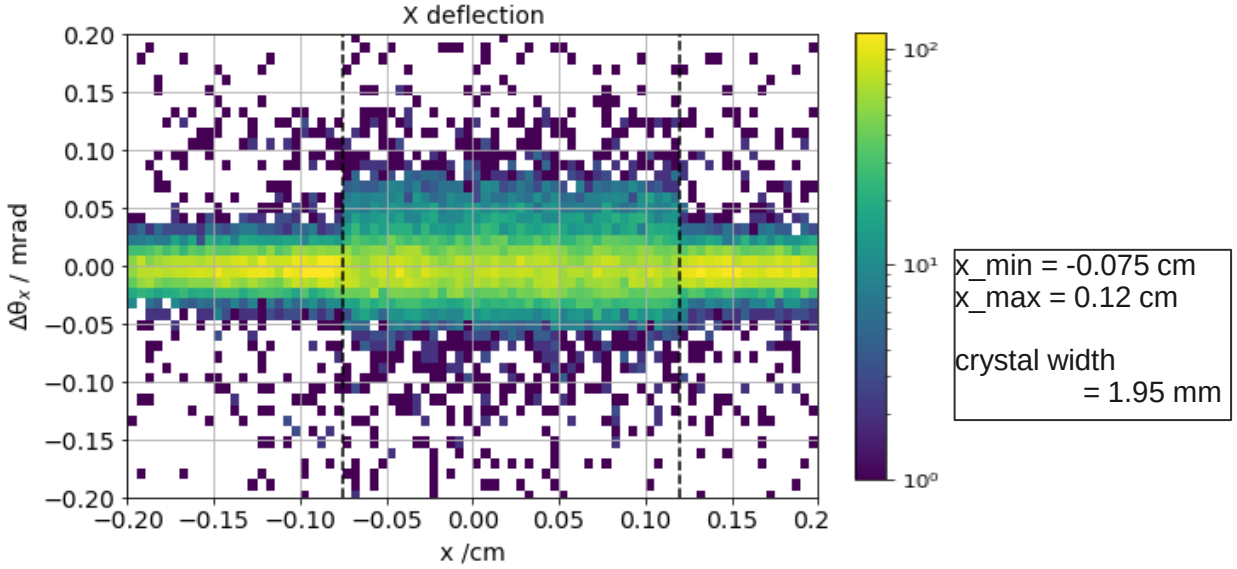
2. Steps in the analysis: crystal alignment

Amorphous run

- Exp. - Position the crystal in the beam. Angle the crystal so it is not in a channelling orientation.
- Particles undergo amorphous scattering.
- Trace back scattered tracks to give coordinates on the crystal entrance.
- Use the edge of the scattering region to define the edges of the crystal in x.
- Use the known crystal dimension to define the edges of the crystal in y. Particles that do not impact the crystal can be removed from further analysis.

H8 experiment 2023: Amorphous run TCCS



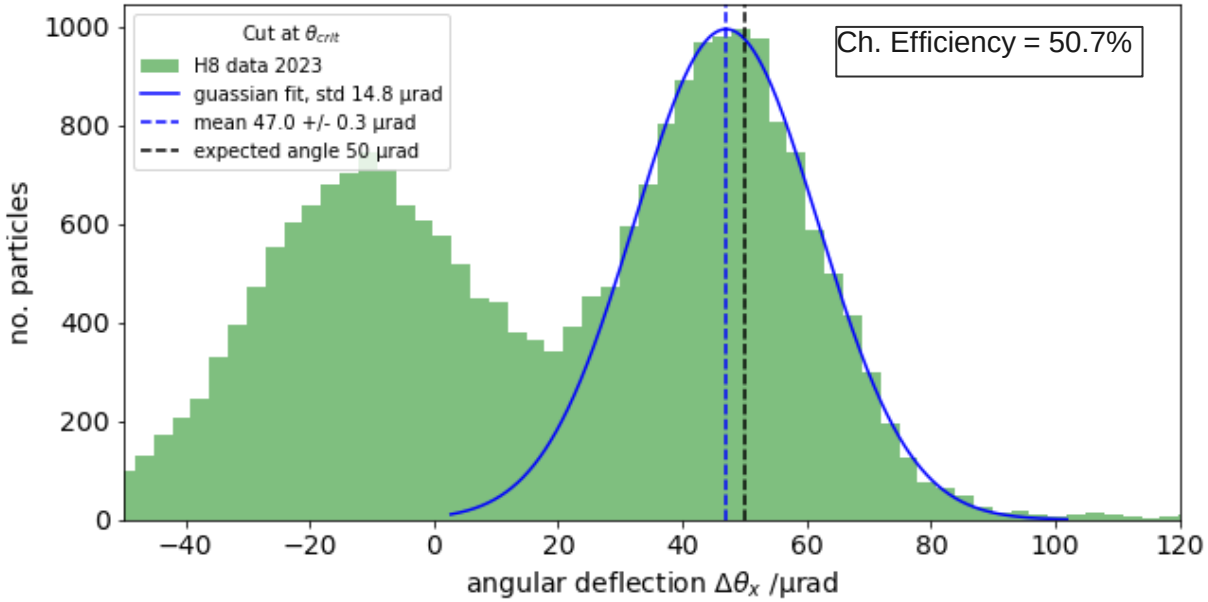


2. Steps in the analysis: channelling efficiency

Channelling run

- Exp. - Position the crystal in channelling orientation.
- Cut data in x & y; limits from the previous step.
- Cut data in angle; remove particles with an incoming angle outside of the critical angle. The critical angle is different for each crystal.
- Plot a histogram of the change in angle of the particles. Fit a Gaussian curve to the right side of the channelled peak. The area under the curve gives the number of channelled particles.
- *Ch. Efficiency* = $\frac{\text{No. of channelled particles}}{\text{Total no. of impacting particles}}$

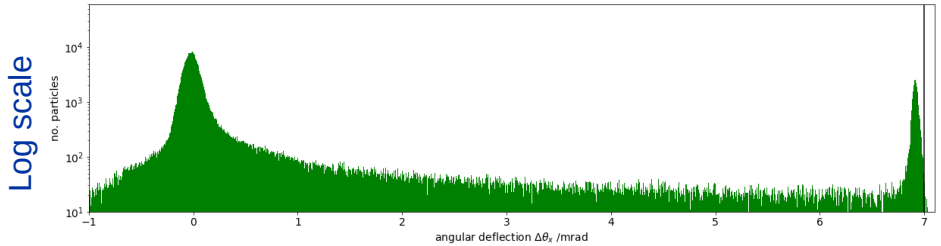
H8 experiment 2023: Channelling run TCCS

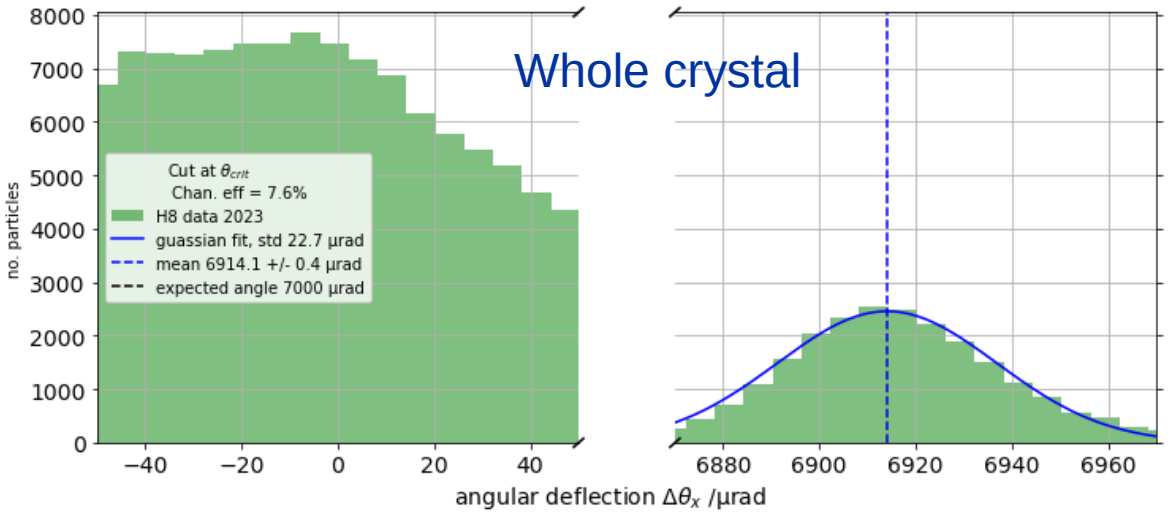


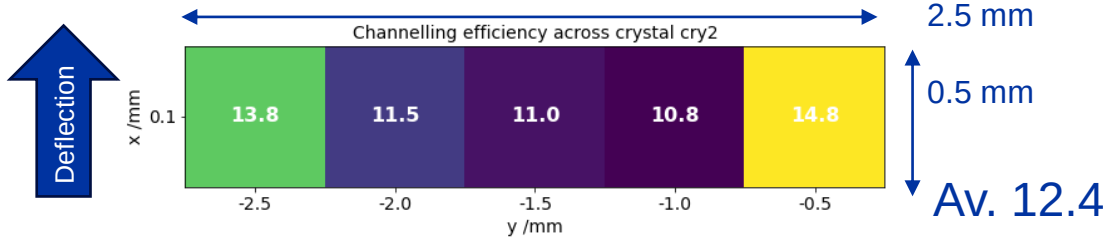
	TCCS	TCCP	Anodic
Critical angle (180 GeV/c pions)	15.3 µrad	14.9 µrad	14.5 µrad

3. Results: long crystals

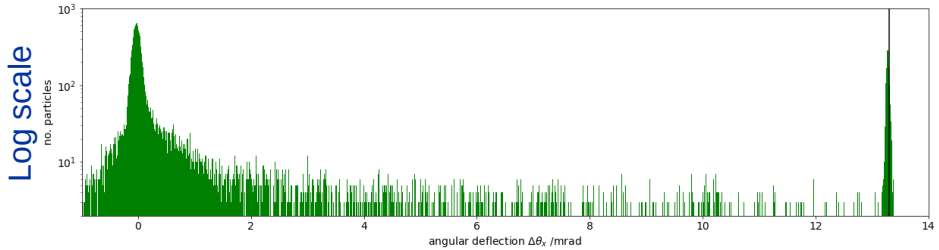
H8 experiment 2023: Channelling TCCP

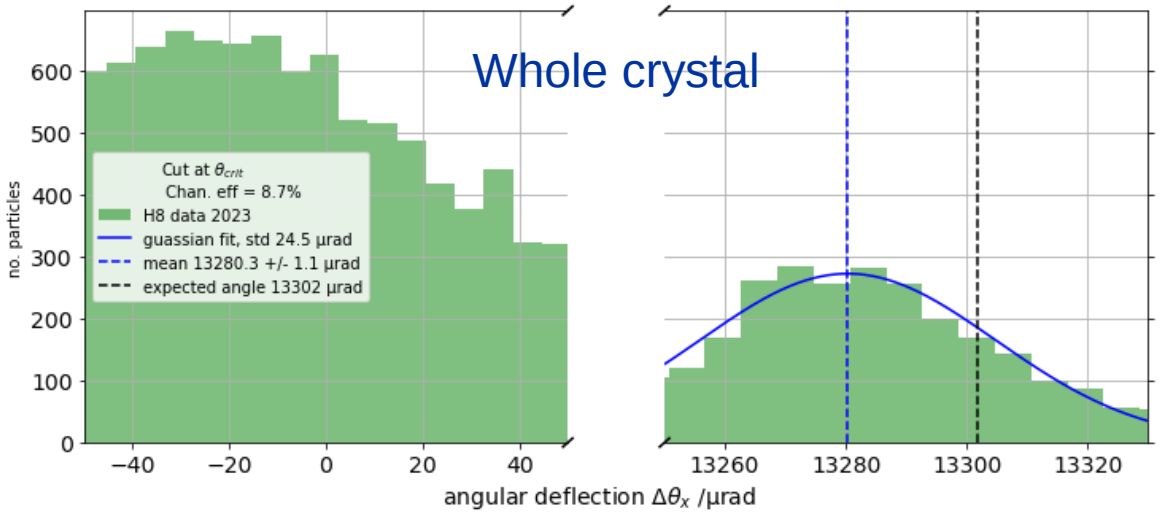


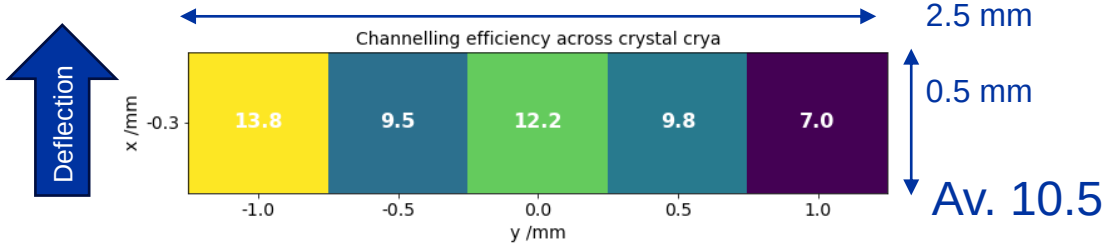




H8 experiment 2023: Anodic-bonded crystal







3. Results summary

In the double-crystal experiment the short crystal will be inserted into a secondary halo of the HL-LHC proton beam: consider the whole crystal efficiency for comparison with previous results of collimation crystals [2].
The long crystal will intercept a channelled beam with expected y-dimension < 2mm so we consider the efficiency of the central ~2mm as relevant for the final experiment.

Cut at the critical angle

Crystal and data cut point	Ch. Eff. expected from simulation	whole crystal Ch. Eff. H8 data	Central 2.5 mm Ch. Eff. H8 data	Bend angle H8 data
Crystal 1 (TCCS) (+/- 15.3 µrad)	~62 %	50.7 %	54.1 %	47 µrad (aim 50)
Crystal 2 (TCCP) (+/- 14.6 µrad)	~28 %	7.6 %	12.4 %	6914 µrad (aim 7000)
Anodic-bonded crystal (+/- 13.9 µrad)	~ 24 %	8.7 %	10.5 %	13280 µrad (expected 13302)

Cut at *half* of the critical angle

Crystal and data cut point	Ch. Eff. expected from simulation	Whole crystal Ch. Eff. H8 data	Central 2.5 mm Ch. Eff. H8 data	Bend angle H8 data
Crystal 1 (TCCS) (+/- 7.7 µrad)	~77 %	59.7 %	63.4 %	48 µrad (aim 50)
Crystal 2 (TCCP) (+/- 7.3 µrad)	~36 %	8.0 %	13.0 %	6915 µrad (aim 7000)
Anodic-bonded crystal (+/- 7.0 µrad)	~ 30 %	10.0 %	12.4%	13280 µrad (expected 13302)

4. Outlook

Further work: expand the analysis to consider efficiency at different x-positions across the crystal, including the crystal edge.

- **Deflection angles of the two crystals within range of the functional specification [1]**
  TCCS: specification 50(±5) μrad, measured 47-48μrad.
  TCCP: specification 6-7.5 mrad, measured 6.9 mrad.
- **Efficiency of TCCS crystal as expected 50-60 %**
  In line with previous measurements of collimation-type crystals in the LHC [2] and simulations.
- **Efficiency in the central region of TCCP is 11-17 %**
  Less than expected from simulation estimates – simulations to be updated for further comparison.
- **Anodic-bonding offers a promising new way to mount bent crystals**

The TCCS and TCCP look promising for the double-crystal experiment

[1] Q. Demassieux *et al.*, '[TCCS/TCCP] Functional and Operational Conditions for the Double-Crystal setup in the LHC IR3'. Oct.12, 2022. Restricted access: https://edms.cern.ch/document/2742008/1.0
[2] https://indico.cern.ch/event/752062/contributions/3114845/

3. Results: short crystal

H8 experiment 2023: Channelling TCCs

Log scale