Workshop on crystal collimation

Fabrication of crystals for channeling at INFN Ferrara

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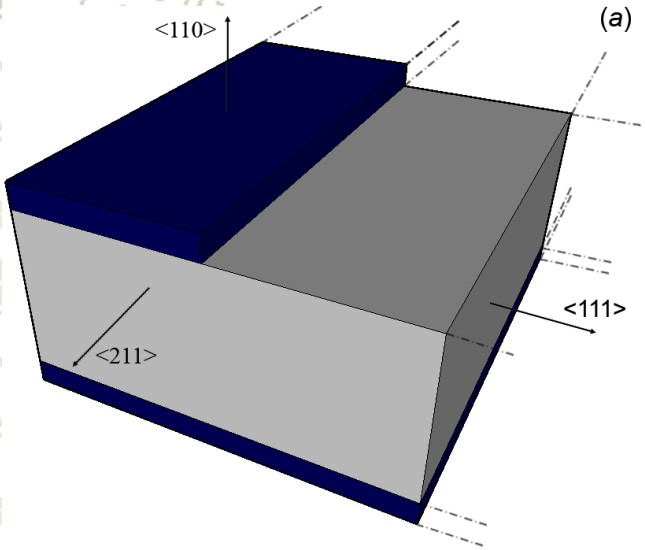
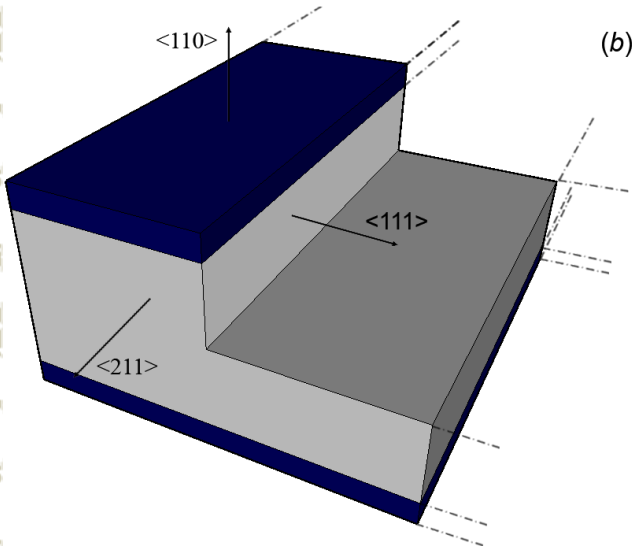
Outlook

- Crystal fabrication and characterization I (anisotropic wet etching)
- Crystal fabrication and characterization II (isotropic wet etching)
- Old and new holders design
- Crystal bending and torsion adjustment
- On-beam characterization
- Conclusions

Crystal fabrication I



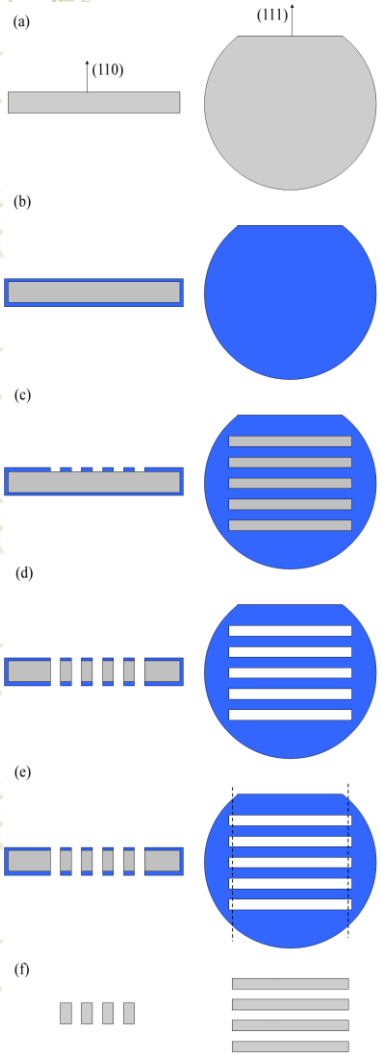


Anistropic etching is a feasible way to realize sub-surface damage free crystals entirely by wet chemical methods

Etch rate on different silicon planes for KOH 20% at 40 °C

(100)	(110)	(111)
7.1 μm/h	10.7 μm/h	Negligible

Crystal fabrication I



a) Starting material: (110) silicon wafer,

Low miscut (certified < 300 µrad),
Double side polished surfaces
TTV < 1 µm
Flatness < 300 nm over 26x9 mm^2

b) LPCVD deposition of silicon nitride thin layer

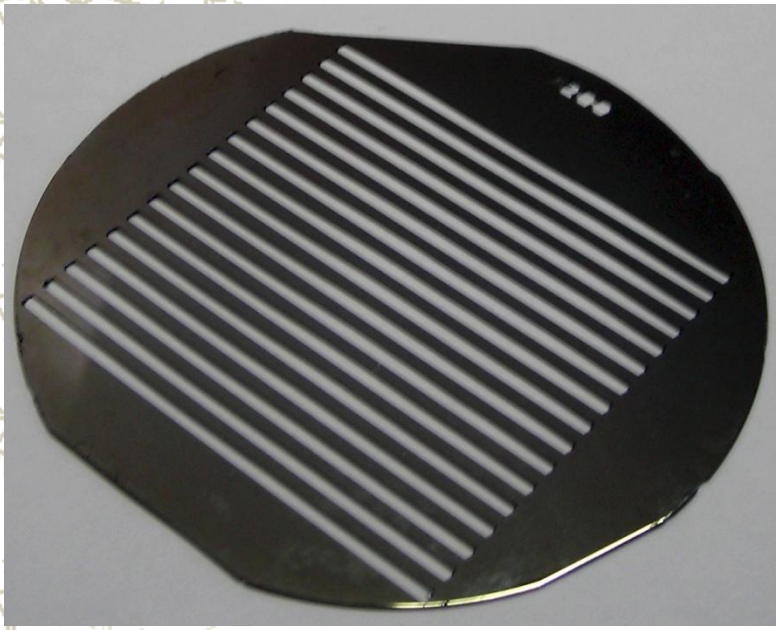
c) Silicon nitride patterning

d) Etching of Si in TMAH solution, silicon nitride acts as masking layer

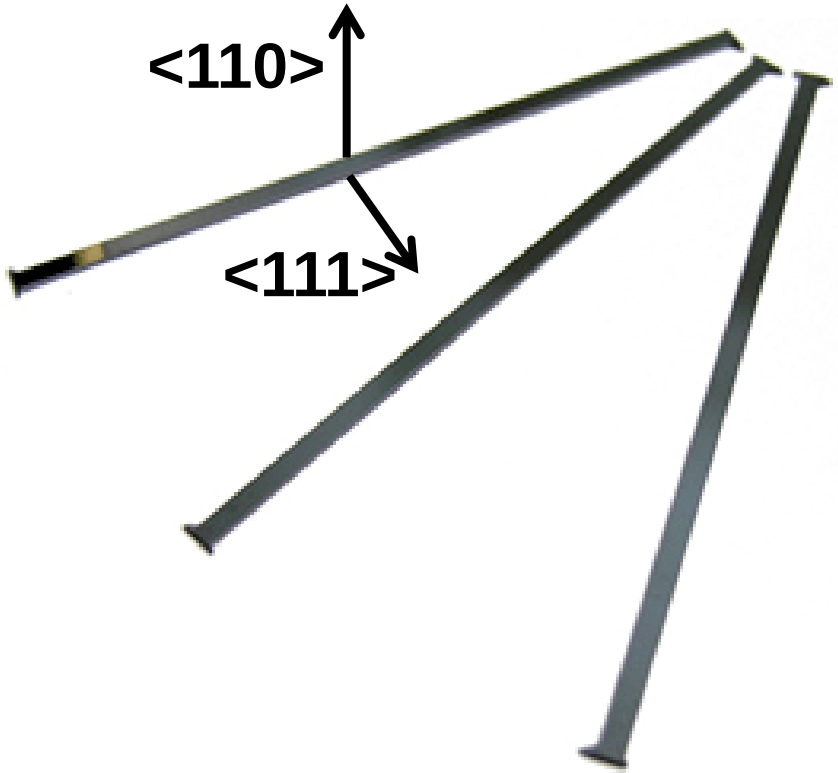
e) Silicon strips release

f) Removal of silicon nitride

Crystal fabrication I



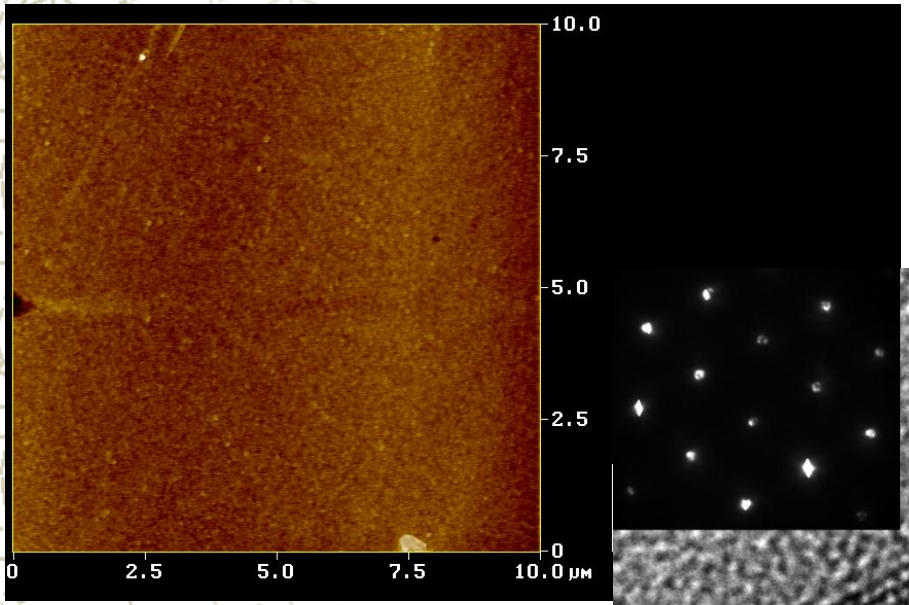
Fabrication of a batch of strips is possible through wet chemical methods



V. Guidi et al. *JPD 41, 24 (2008)*

Crystal characterization I

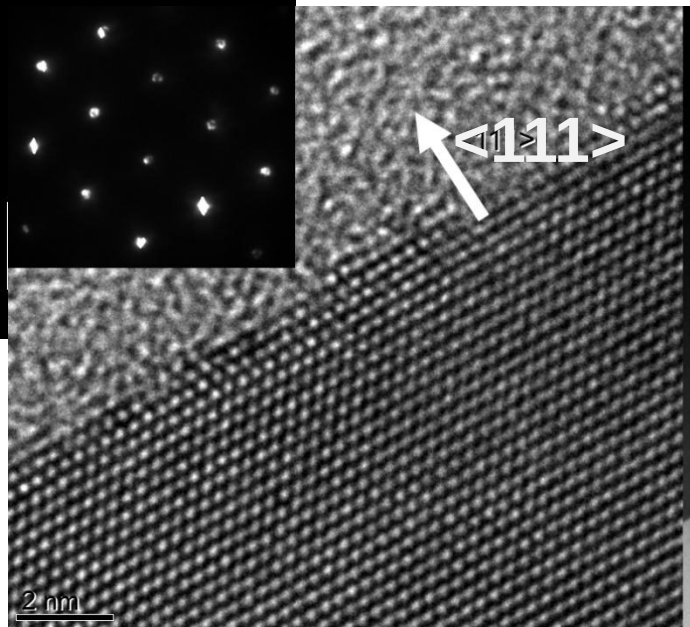
Lateral surface (AFM)

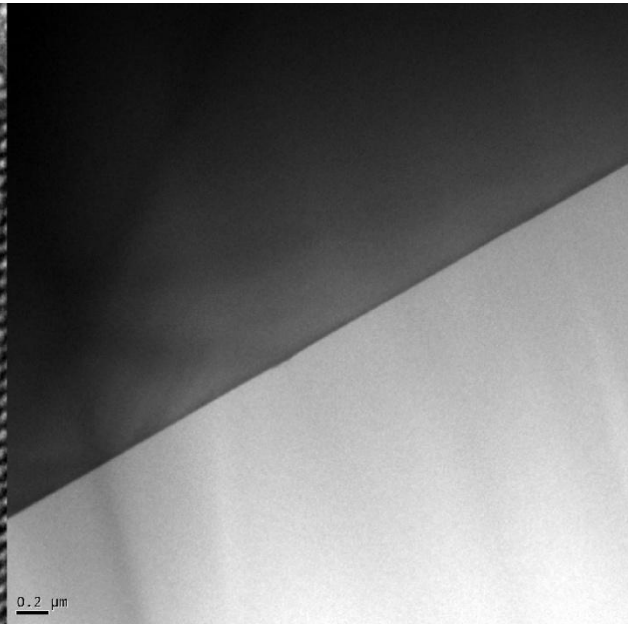


Sub-nm roughness was achieved

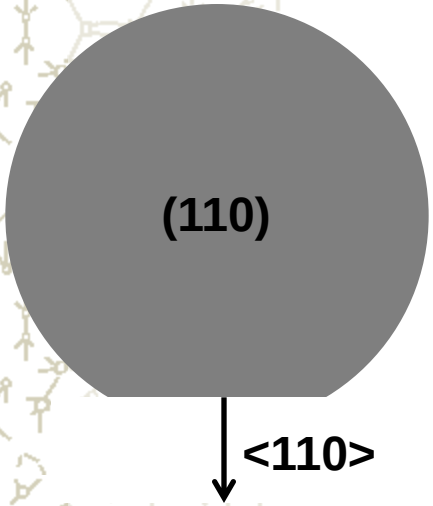
High-quality surfaces achieved via ACE

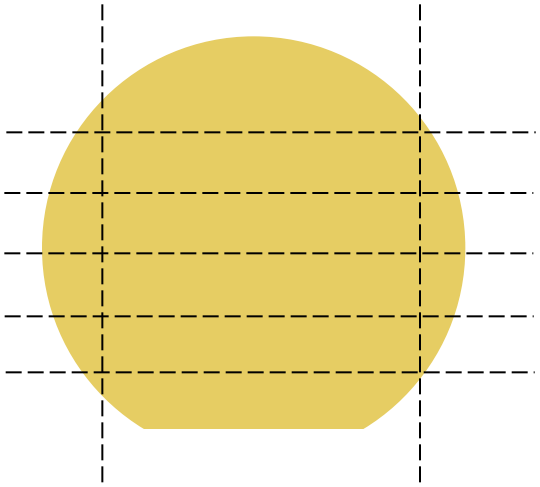
Entry surface (HRTEM)





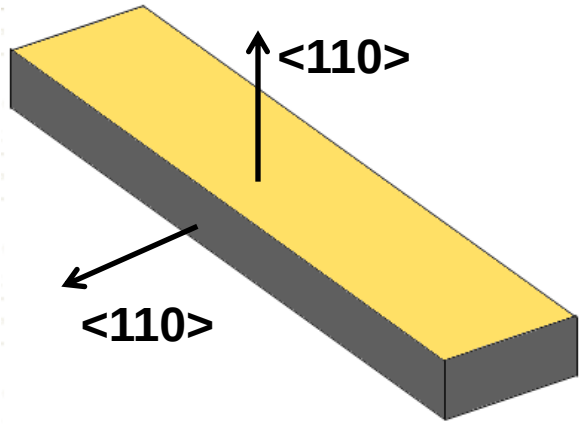
Crystal fabrication II



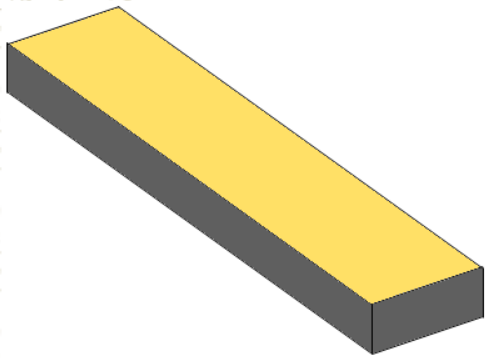


Starting material

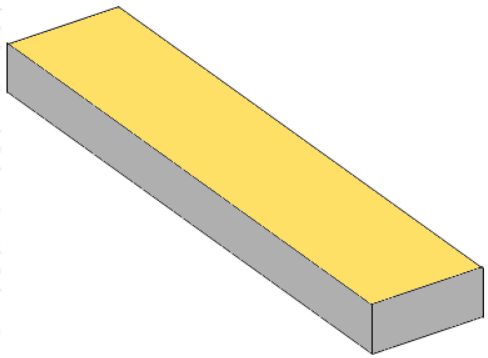
- 4” silicon wafers
- Low miscut (certified < 300 µrad)
- Double side polished surfaces
- TTV < 1 µm
- Flatness < 300 nm over 26x9 mm^2



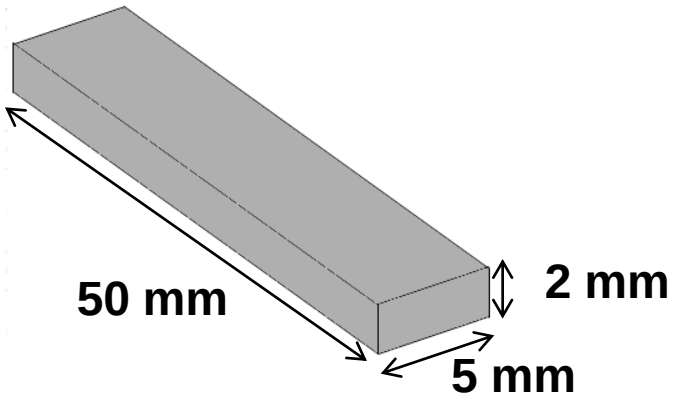
Crystal fabrication II



Starting silicon strip



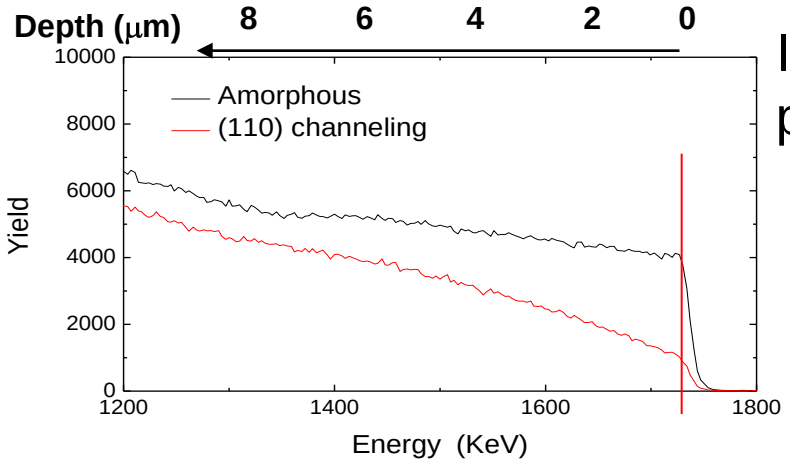
Lattice damage is removed thorugh isotropic wet etch



Cr/Au mask is removed through wet etch

- Surface parallel to the beam is not affected by etchant, so it mantains low rougness and high flatness

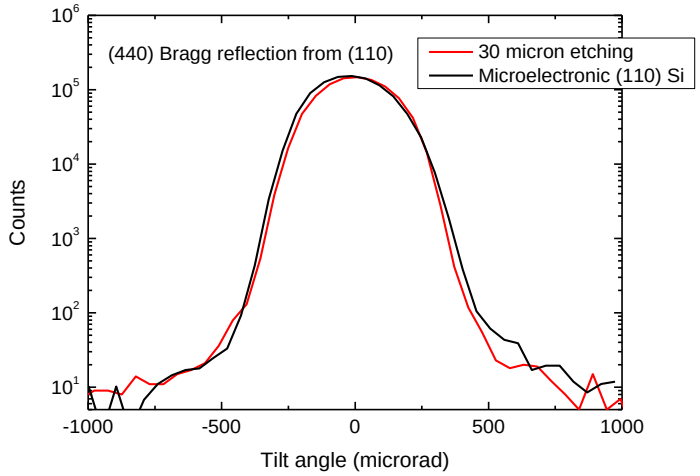
Crystal characterization II



In channeling condition only the non-channeled particles undergo backscattering (LNL-INFN)

Channeling inefficiency can be measured

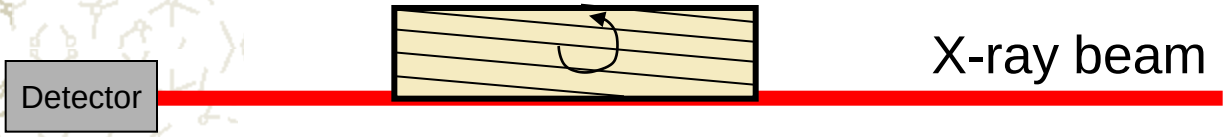
Treated sample	Reference
21.5±0.8%	22.7±0.9%



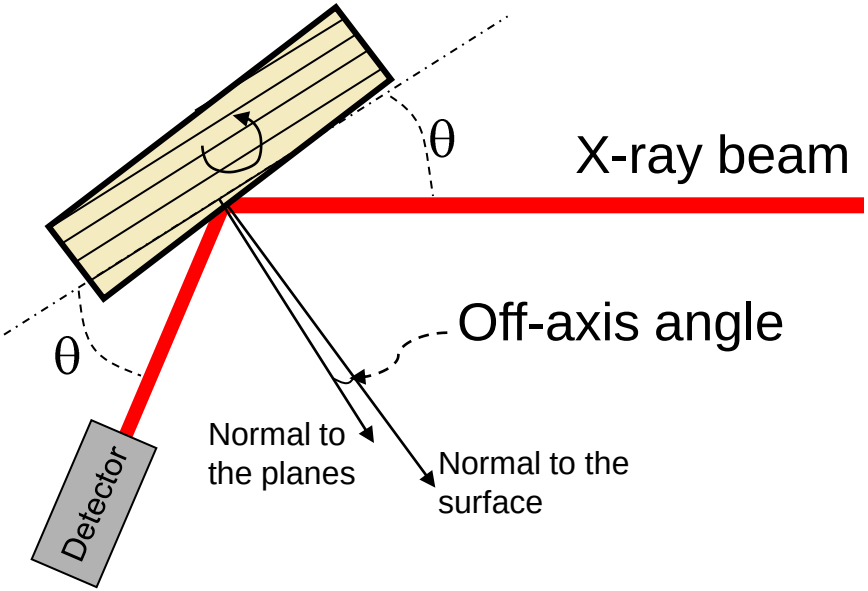
- HRXRD comparison between treated sample and a reference (Padova Physics department)
- HRXRD and RBS-c shows that crystals are lattice damage free

Miscut characterization

Maximum signal when the surface is parallel to the beam

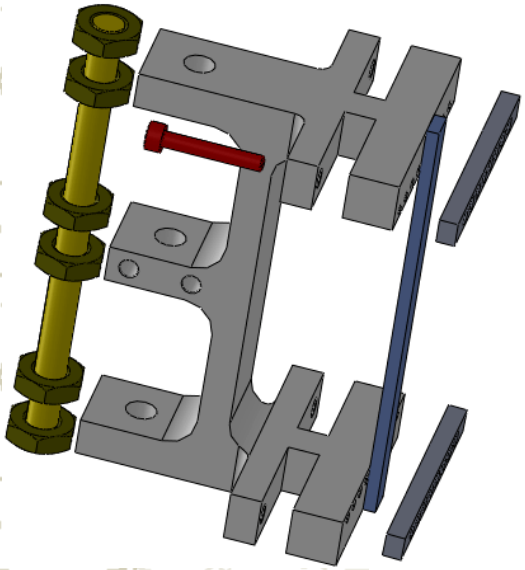


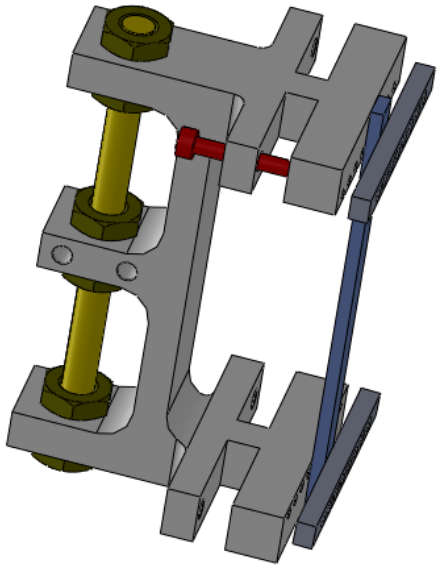
Bragg reflection: Signal from a bragg plane reflection occurs only when the sample is rotated by the miscut angle

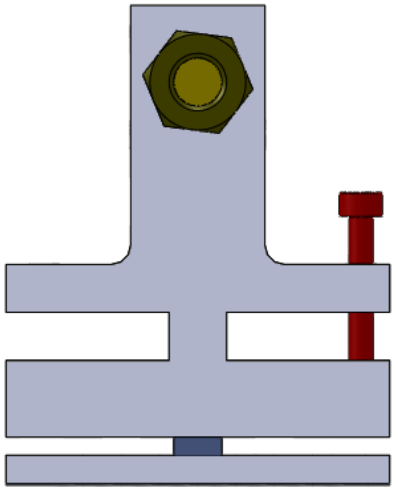


Old holders design

Torsion arises as a consequence of mechanical imperfections in the bending device







Torsion adjustment

- Based on controlled deformation of holder surfaces
- Raw possibilities for torsion adjustment

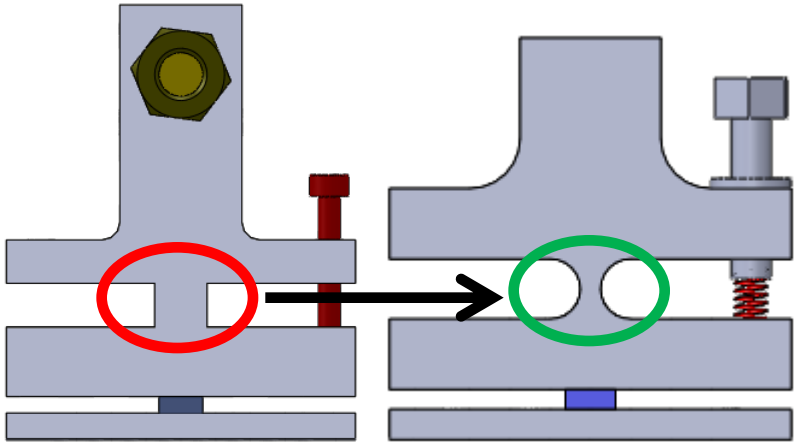
Crystal bending

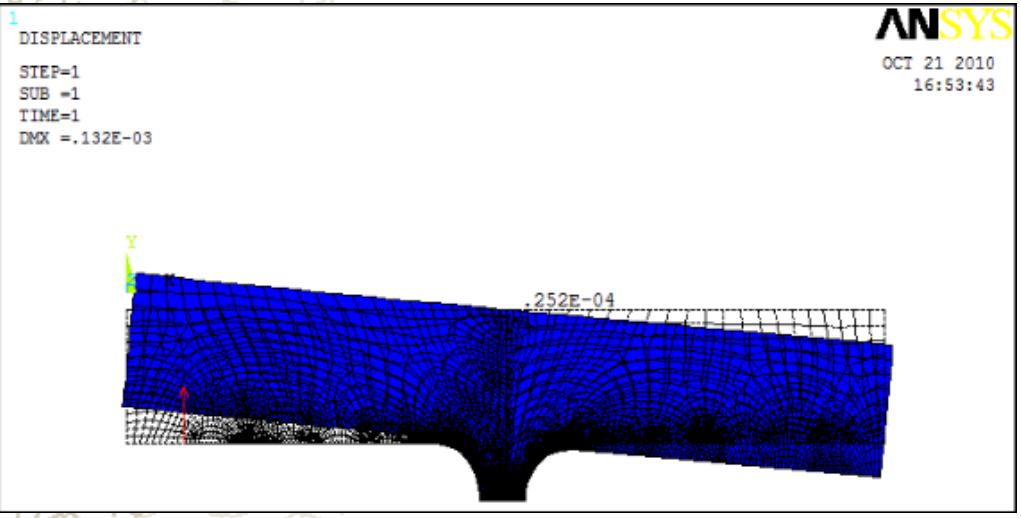
- Adjusted acting on a thread bar fixed by nuts

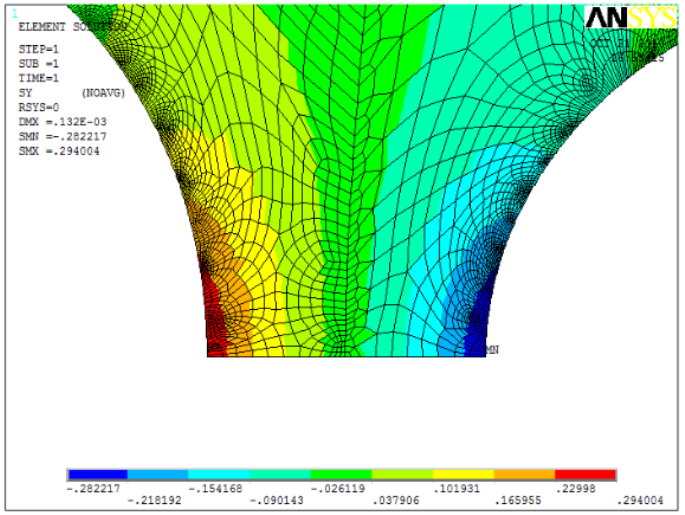
New holders design

FEM assisted holder design

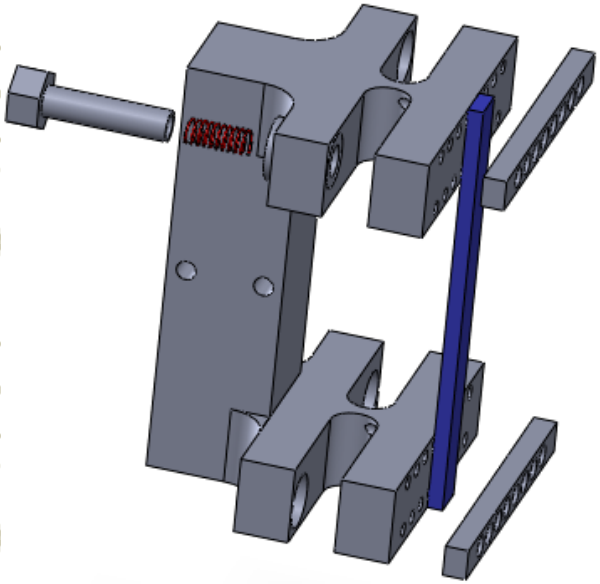
- 90° joint replaced with a rounded joint
- Better deformation control

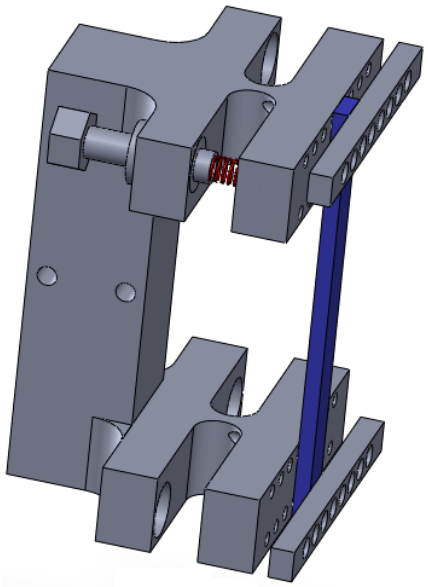


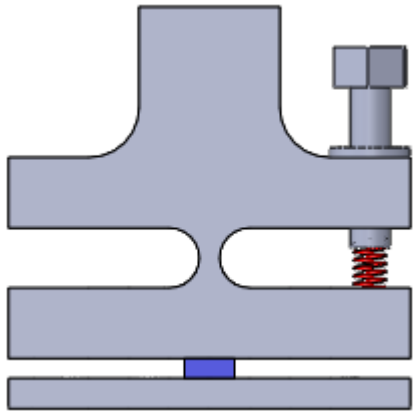




New holders design







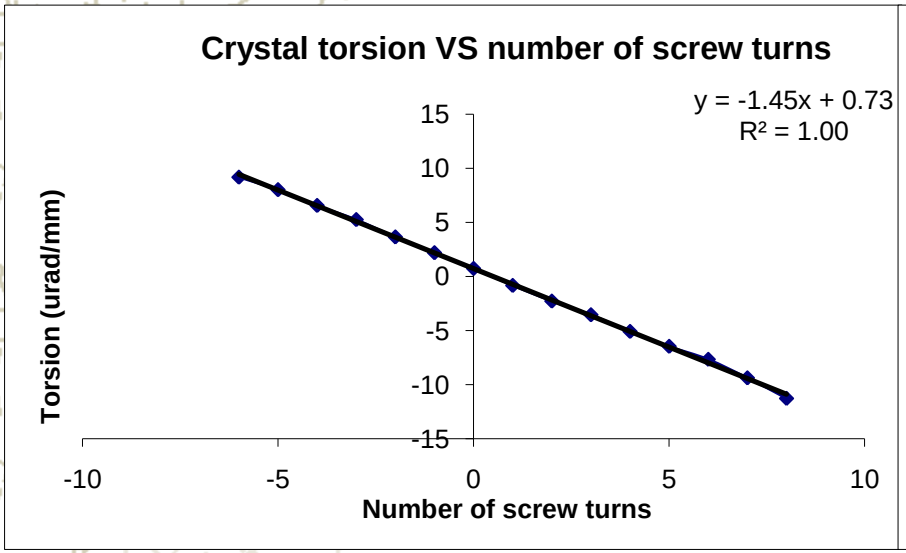
Torsion adjustment

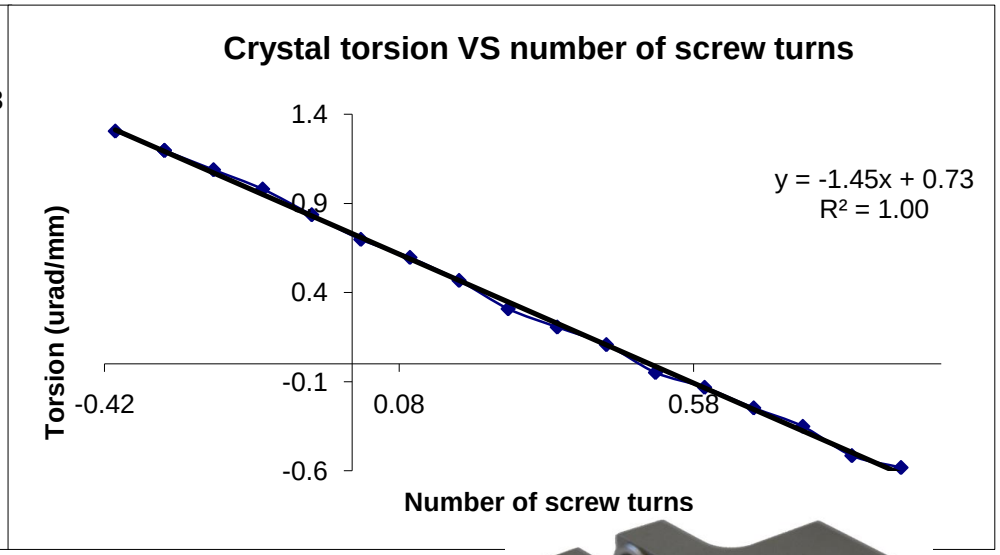
- Spring demultiplicate the action of the force imparted by the screw
- Higher resolution in torsion adjustment

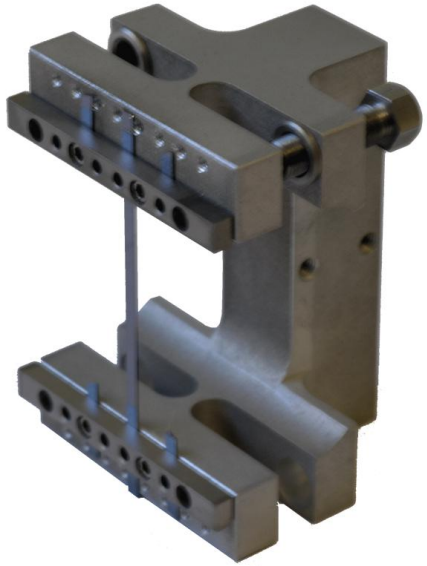
Crystal bending

- Determined by surfaces inclination
- Removed screws →increased stability

Torsion adjustment



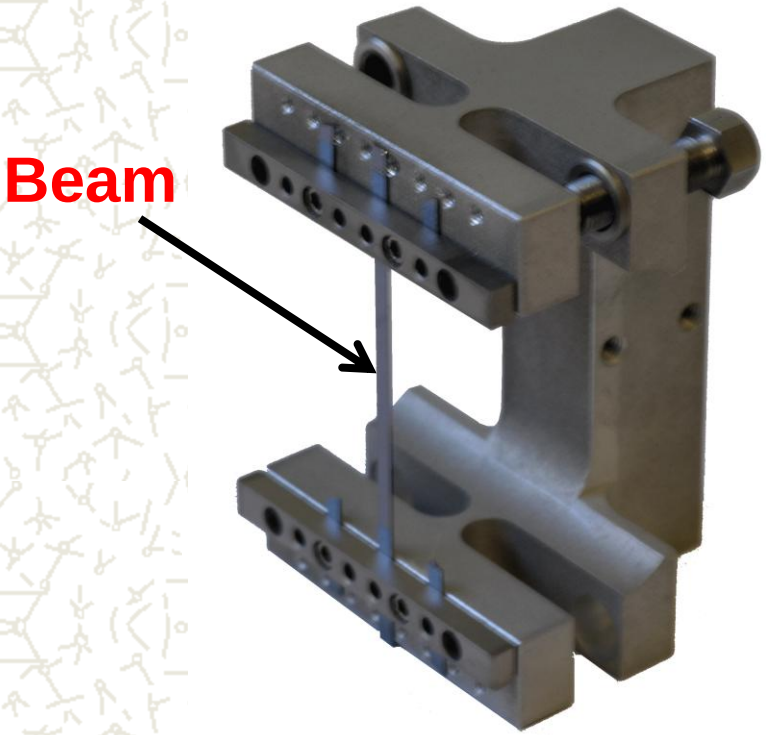


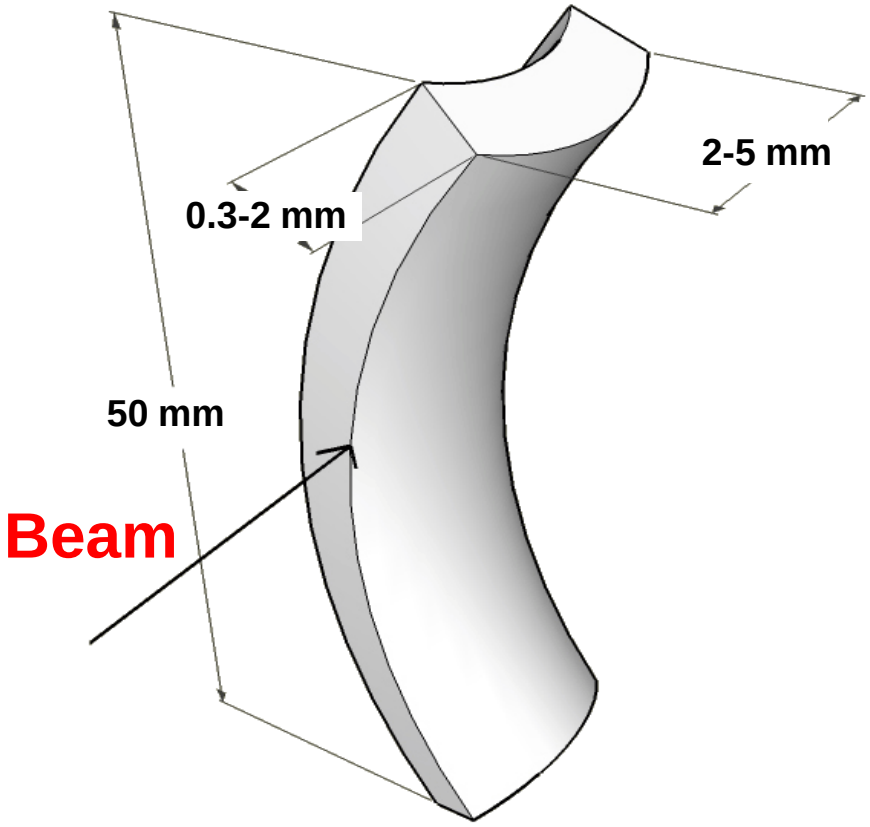


Torsion adjustment

- 1 screw turn → 1.4 µrad/mm torsion adjustment!!
- High linearity
- Reproducibility< 0.2 µrad/mm

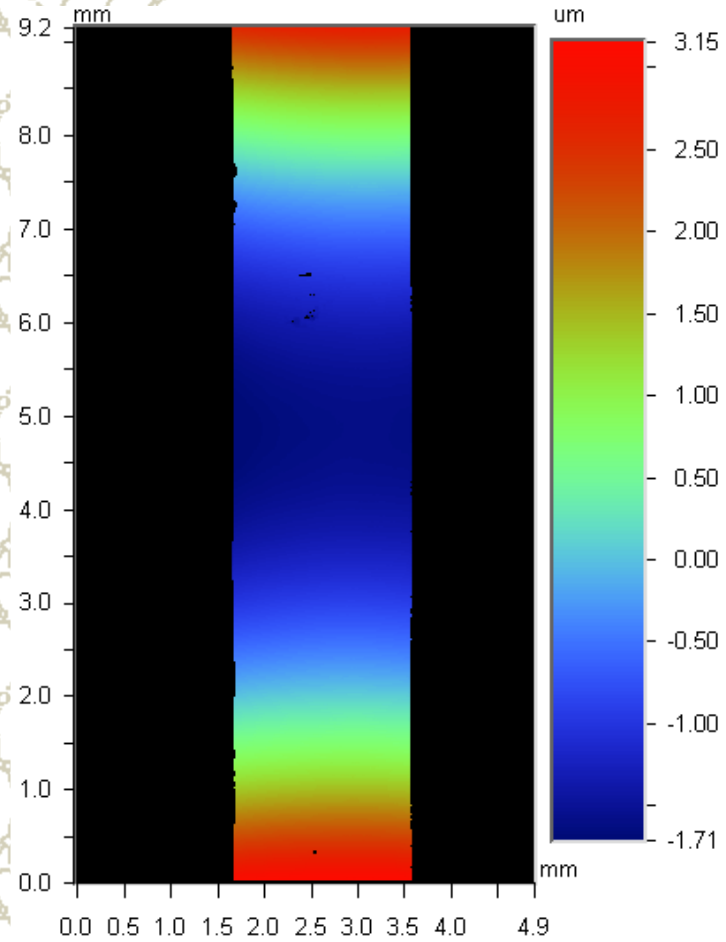
Crystal bending





A primary curvature is imparted by mechanical external forces, which result in a secondary (anticlastic) curvature.

Crystal bending



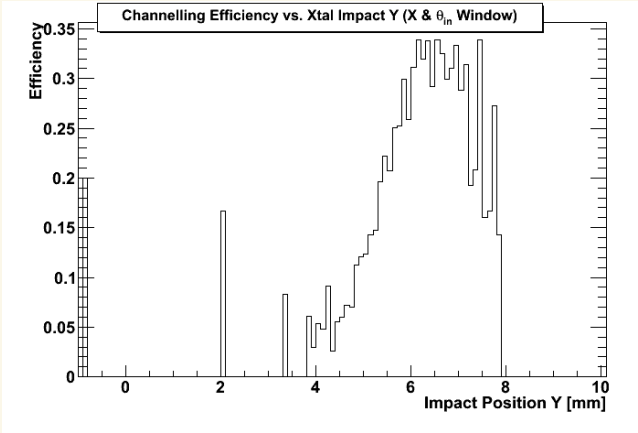
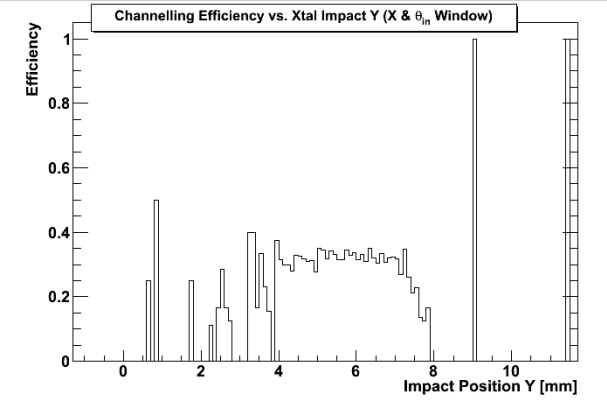
White light interferometry

- Vertical resolution < 0.8 nm
- Lateral resolution ~ 2 μm

Precise measurement of

- Bending angle: 152 μrad
- Torsion < 5 rad
- Crystal thickness: 1.93 mm

On-beam characterization

Torsion value	Deflection as function of vertical direction
-3.3 µrad/mm	
-0.7 µrad/mm	

ST-45-A

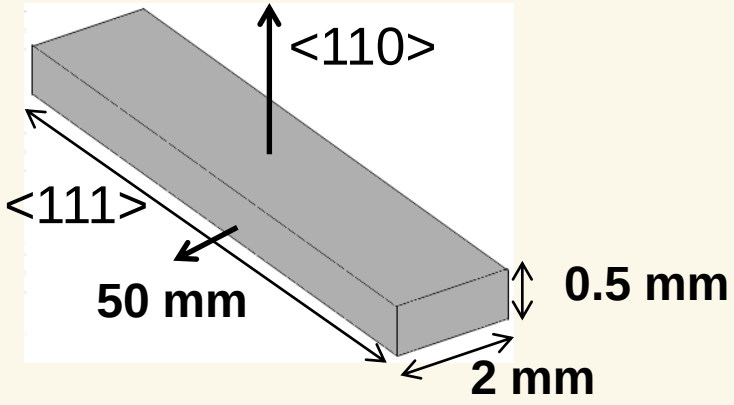
- Off-axis: 70 µrad
- Thickness: 2mm
- Bending angle: 150 µrad
- Torsion < 1 µrad/mm

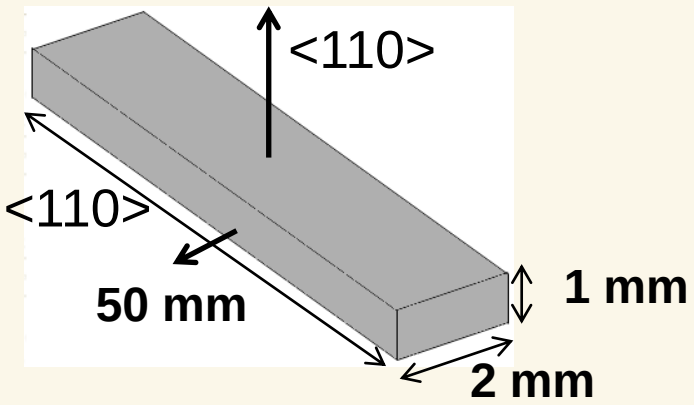
- Agreement with interferometric characterization

- crystal ready for SPS

Crystals for the SPS

ST45A (SPS)	ST38A (SPS)
• Channeling planes (110) • Miscut 70 μrad • Channeling axis <111> • Thickness along the beam 2 mm • Transversal thickness 0.5 mm • Bending angle 150 μrad • Torsion 0.7 μrad/mm	• Channeling planes (110) • Miscut 100 μrad • Channeling axis <111> • Thickness along the beam 2 mm • Transversal thickness 1 mm • Bending angle ~ 200 μrad • Torsion data analysis to be performed

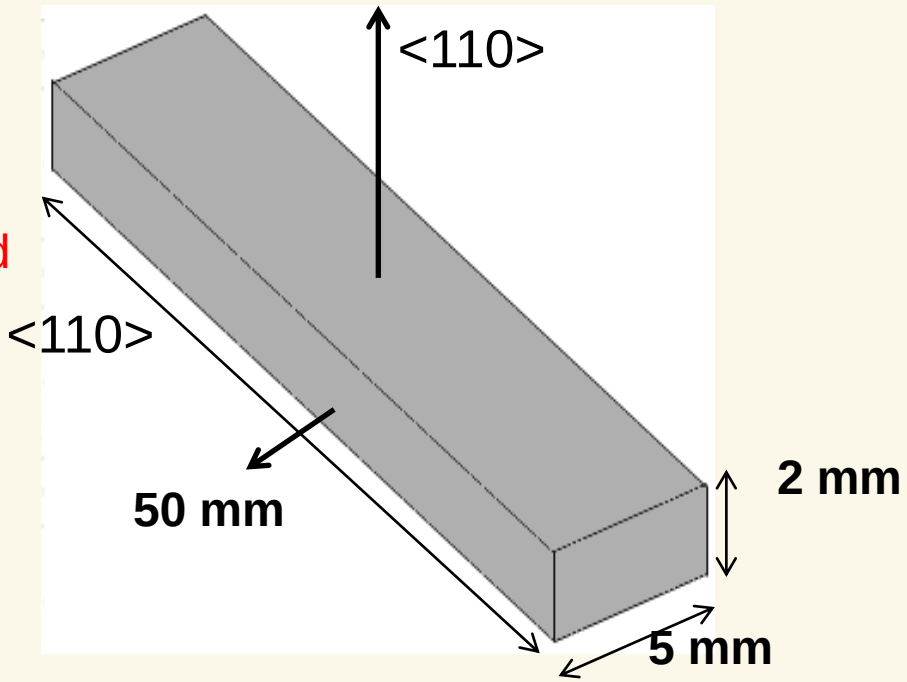




Crystal for LHC

ST40A (prototype for the LHC)

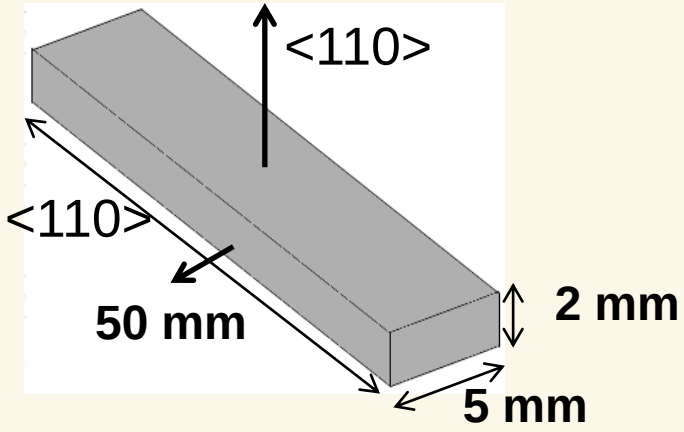
- Channeling planes (110)
- Miscut 220 μrad
- Channeling axis <110>
- Thickness along the beam 5 mm
- Transversal thickness 2 mm
- Bending angle ~ 60 μrad
- Torsion data analysis to be performed

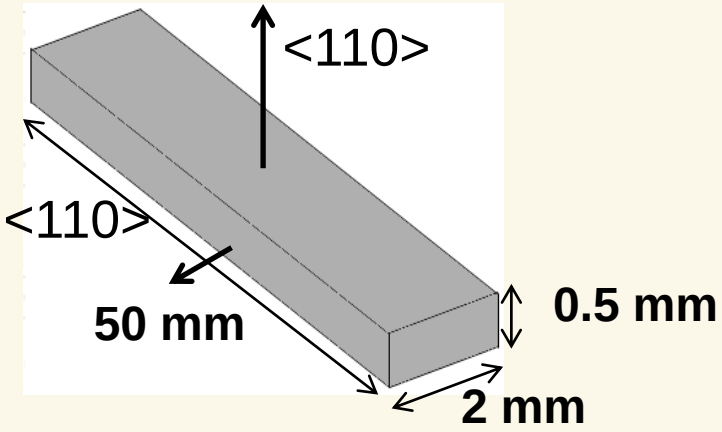


Proposals for LHC and SPS

LHC (under construction)	SPS (under construction)

• Realization of a strip crystal with the following features
  • Channeling planes (110)
  • Miscut: as low as possible
  • Torsion < 1 μrad/mm
	• Realization of a strip crystal with the following features
	  • Channeling planes (110)
	  • Miscut: as low as possible
	  • Torsion < 1 μrad/mm





Conclusions

- Fully estabilished two metodologies to prepare crystals free of lattice damage
- Established protocols to characterize crystals quality (miscut and crystalline quality)
- Improved holders easily allows torsion adjustment to less than 1 μrad/mm
- On beam characterization highlights agreement with previously made characterizations