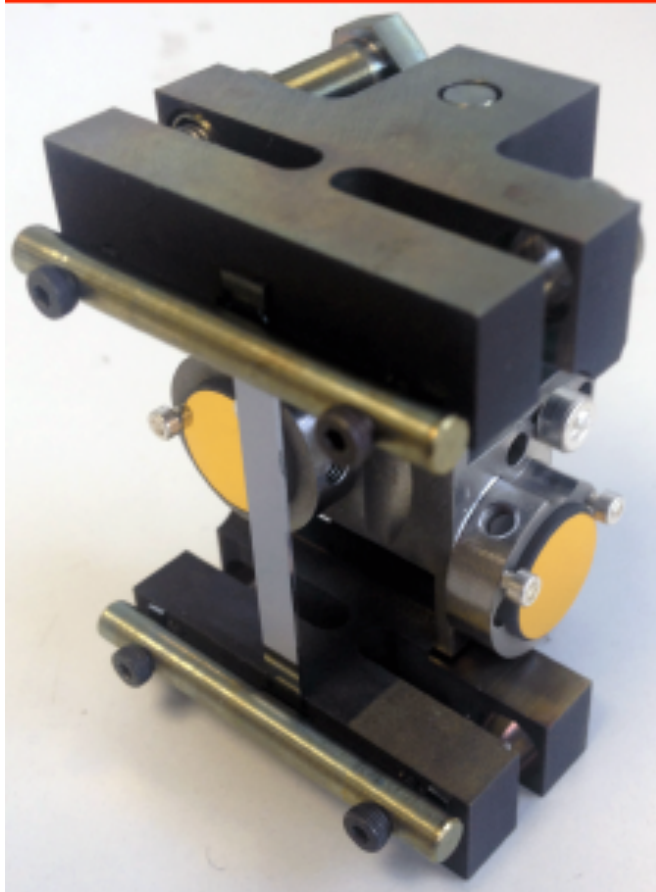




# Collimazione con cristalli, stato.

*Gianluca Cavoto (Sapienza Univ. Roma & INFN)  
Incontro cristalli - Ferrara, 13 feb 2017*

# A bent crystal

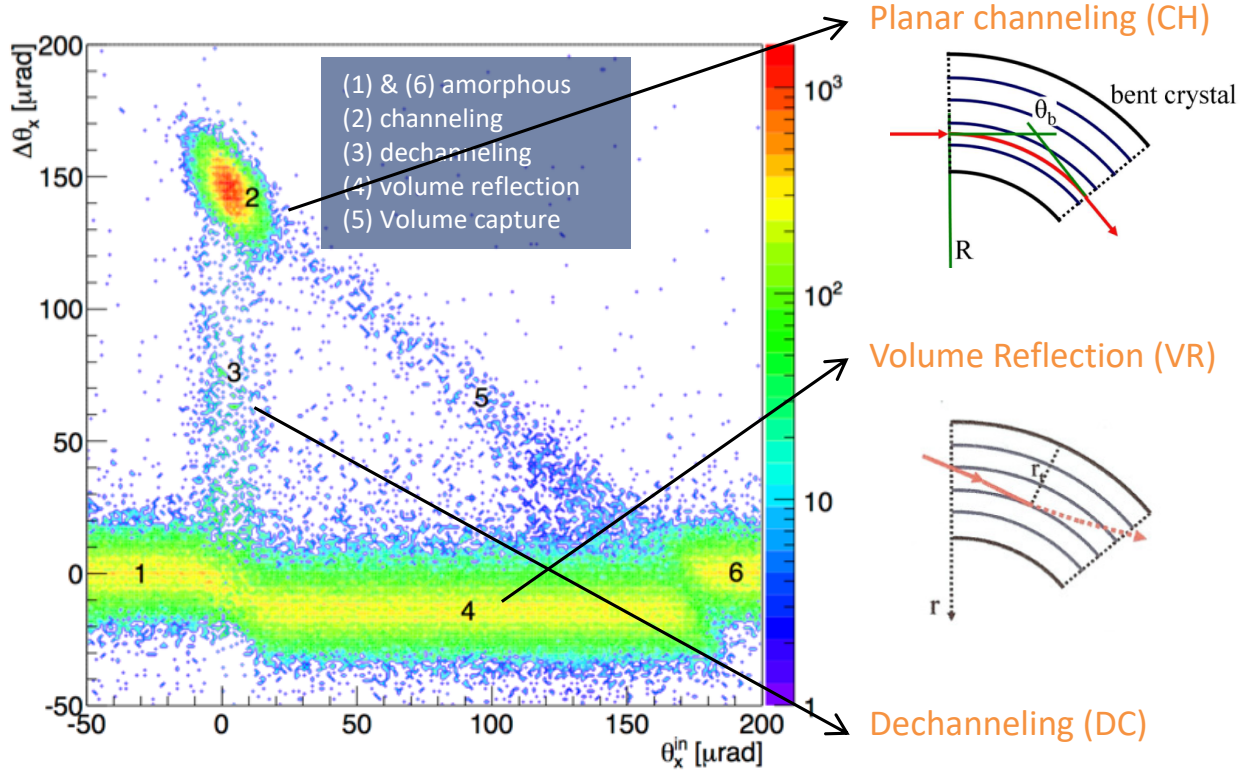


- ▶ We usually refer as **UA9 crystal** for crystal collimation to a high quality manufactured dislocation free (for the LHC low miscut) silicon bent crystal assembled with its mechanical holder (for the LHC, a Ti holder)

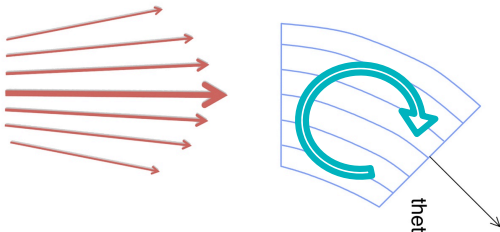
For the crystal collimation application the properties of the UA9 crystals depends on both the silicon crystal (well understood) **and** the Ti holder (less understood)

- ▶ A **new** generation of **crystals** started to be available more than ten years ago.
  - ▶ INFN involved in **H8-RD22** (2007-2010, INFN-NTA):
    - ▶ tests of crystals with a **400 GeV micro-beam**
    - ▶ **single** particle deflection reconstruction
  - ▶ Many papers on **coherent** interactions of charged particles in crystals
- ▶ After 2010, **UA9 (CNS1)**: crystal collimation feasibility at the **SPS** ring
  - ▶ Long(er) term goal: improve the collimation performance for protons and ions at the **LHC**

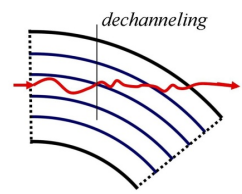
# Coherent interactions



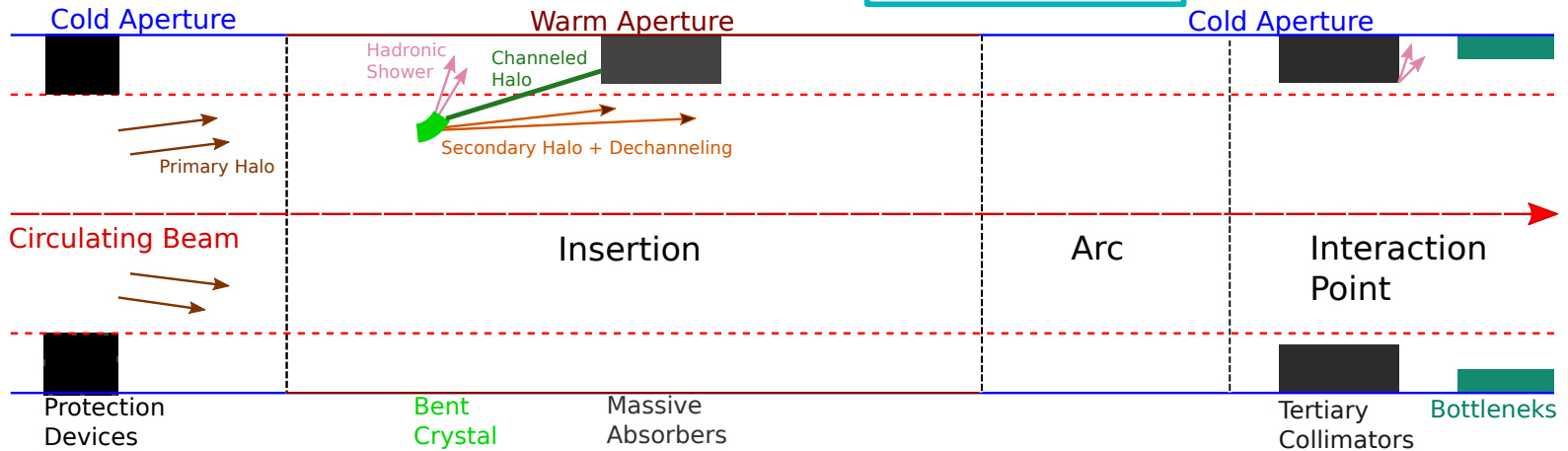
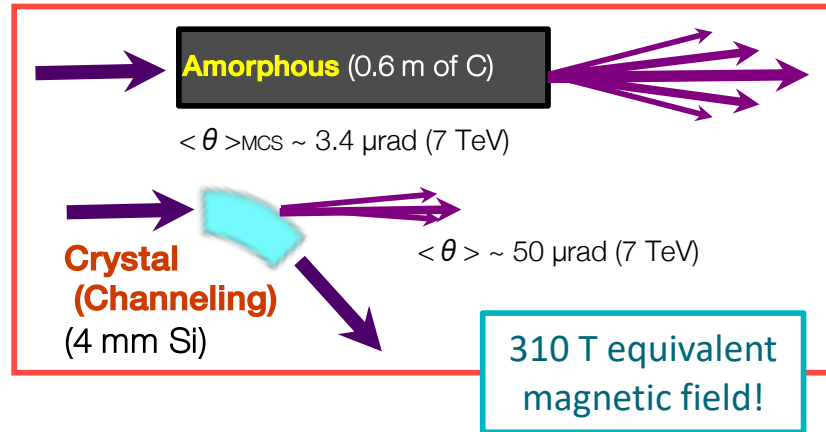
- ▶ A full realm of physics by its own!
- ▶ We observe for the first time several effects at high energy



Single pass measurements with 400 GeV protons. Strip crystal (110) with a bending of 144  $\mu\text{rad}$ .



# Crystal collimation concept



- ▶ Demonstrated and studied at SPS (up to 270 GeV)
- ▶ Currently being studied at LHC (both protons and ions up to the highest energy)

- ▶ Besides the tests on the LHC (see R.Rossi's slides) that are direct responsibility of the **LHC Collimation group**
- ▶ **INFN: second generation strip crystals**
  - ▶ Titanium holder with *mechanical stress annealing*
  - ▶ Test stability over a long time
- ▶ **PNPI: new** production of quasi-mosaic crystals
- ▶ Standard LHC **bake-out** (250 deg) for the crystal-holder assembly during H8 data-taking
- ▶ **Two new LHC goniometers** (better control system) ready to host one crystal each on beam 2 : optimal deflection angle: **50  $\mu$ rad**
  - ▶ In 2014 two crystals installed on beam 1 had 65 (INFN) and 40  $\mu$ rad (PNPI) respectively.

Characterization (“**efficiency**”) of various “crystal” prototypes for the LHC at **H8** (mainly 180 GeV pions, some protons and ions).  
**Deflection** measured in-house (interferometry, **X-ray diffraction**)

# Strip crystals for LHC collimation studies

- ▶ INFN: three crystal prepared, 1.5 year effort

**STF105** has the perfect angle of 50  $\mu\text{rad}$  for LHC  
*stable holder*



400 GeV/c protons  
180 GeV/c pions

Time	Deflection Angle
June 2015	$49 \pm 1 \mu\text{rad}$
April 2016	$50.6 \pm 1.4 \mu\text{rad}$
30 June 2016 – pre-heating	$52.2 \pm 2.2 \mu\text{rad}$
5 July 2016 – after-heating	$48.3 \pm 2.3 \mu\text{rad}$
September 2016	$51.4 \pm 1.7 \mu\text{rad}$

**STF106** has an angle of 40  $\mu\text{rad}$  too low for LHC  
*stable holder*



400 GeV/c protons  
180 GeV/c pions

Time	Deflection Angle
June 2015	$41.5 \pm 1.5 \mu\text{rad}$
May 2016	$41.9 \pm 1.8 \mu\text{rad}$
30 June 2016 – pre-heating	$41.0 \pm 2.3 \mu\text{rad}$
5 July 2016 – after-heating	$36.5 \pm 2.5 \mu\text{rad}$

**STF107** has an angle of 56  $\mu\text{rad}$  for LHC  
*too short test period*

180 GeV/c pions

Time	Deflection Angle
June/July 2016	$55.7 \pm 2.1 \mu\text{rad}$

- ▶ In Nov 2016 **one** INFN crystal and **one** PNPI crystal were proposed by the collaboration (**50**  $\mu$ rad angle) for installation on the LHC beam 2 during the winter stop.
- ▶ LHC collimation group decided to choose **two PNPI crystals** (one with angle out of spec)
- ▶ Apparently (but no clear official statement) the decision was based on the *number* of bake-out cycles the crystal underwent.
- ▶ At that time there was **no experimental** evidence that the bake-out process is inducing any change to the crystal-holder assembly



- ▶ Apparently CERN is interested in **crystal collimation for operations with ions**
- ▶ During 2017 four goniometers system were equipped with crystals. Comparative tests of 1 INFN strip, 3 PNPI QM
- ▶ **Very promising results for ion collimation**
- ▶ The production of a **crystal pre-series** would have been desirable for the future of this technology
- ▶ This was believed to **beyond** the R&D activity of UA9 (focused on scientific goals rather on technical advances for crystals)
- ▶ Nevertheless, during 2017 INFN produced a record-low miscut crystal

# Crystals at CERN



- Various talks on future crystal applications to accelerators (SPS slow extraction, LHC extraction, split beam in LHC-b)

<https://indico.cern.ch/event/523655/>

This workshop will end up with a report to update the European Strategy by the end of the decade.