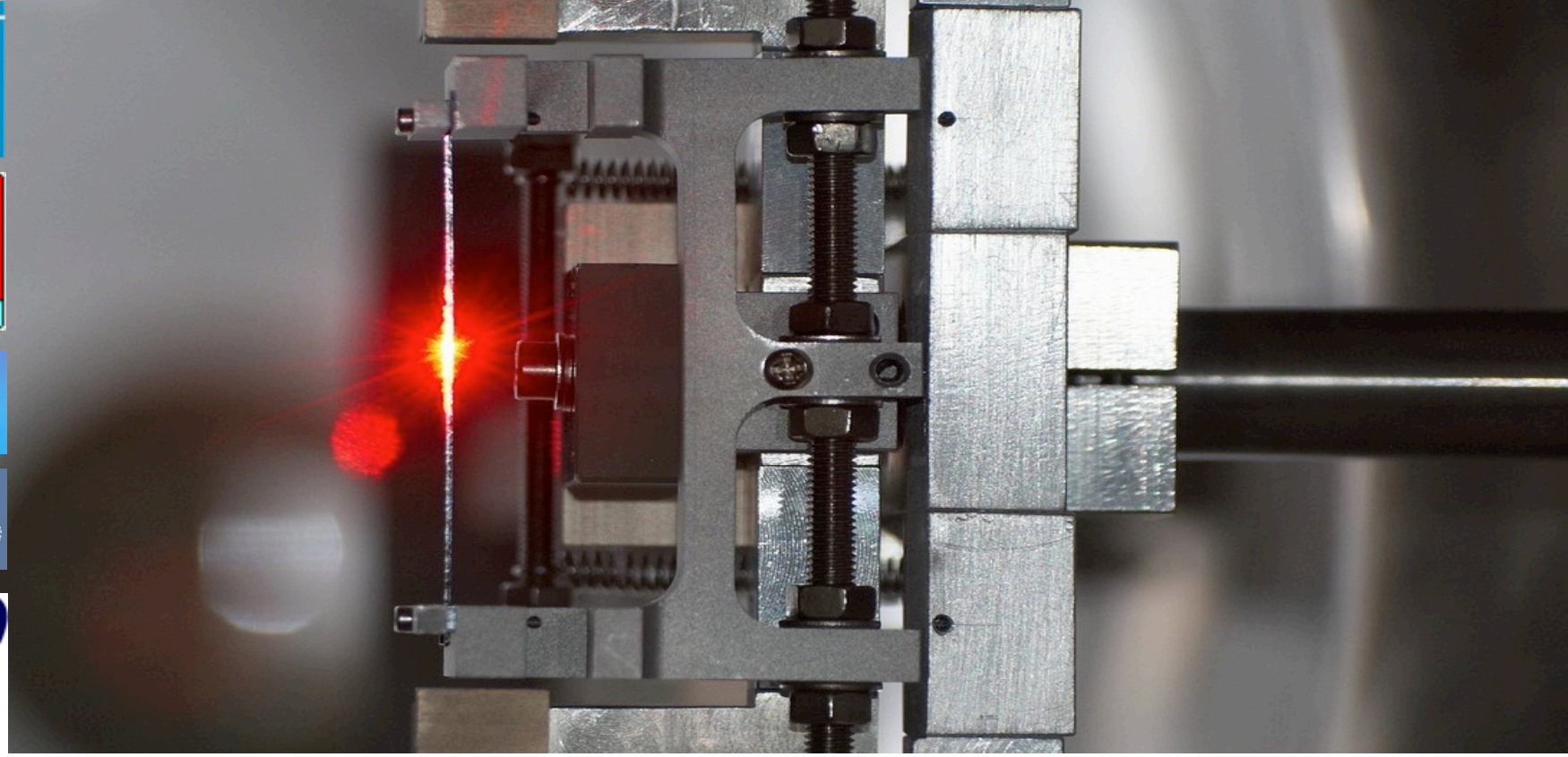


Crystal Collimation for LHC

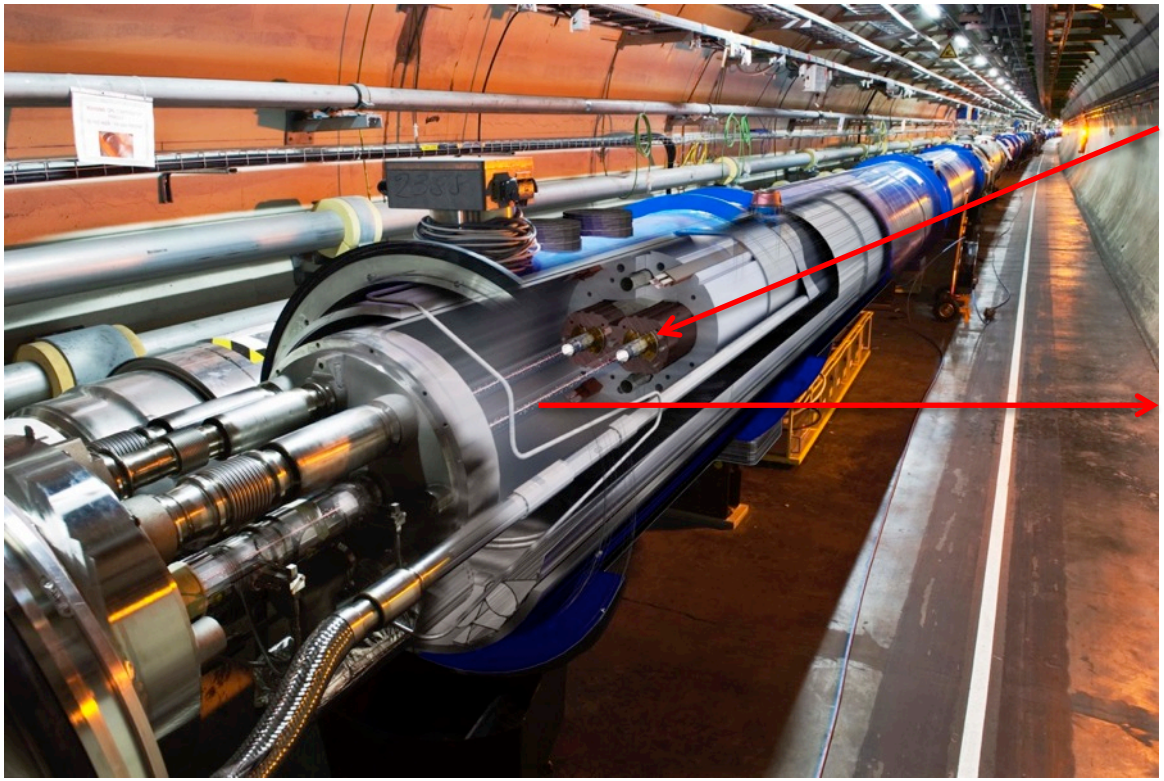
Walter Scandale

(CERN, LAL, INFN)

For UA9 Collaboration and

the LHC Collimation team

Motivations



Superconducting magnets:

- *T = 1.9 K*
- *quench limit ~* ***15-50mJ/cm³***
- *Aperture: r = 17/22 mm*

***Stored energy** in the machine:*

- *LHC 2012:* ***145 MJ***
- *LHC design:* ***360 MJ***

Factor ~ 10^9-10^{10}

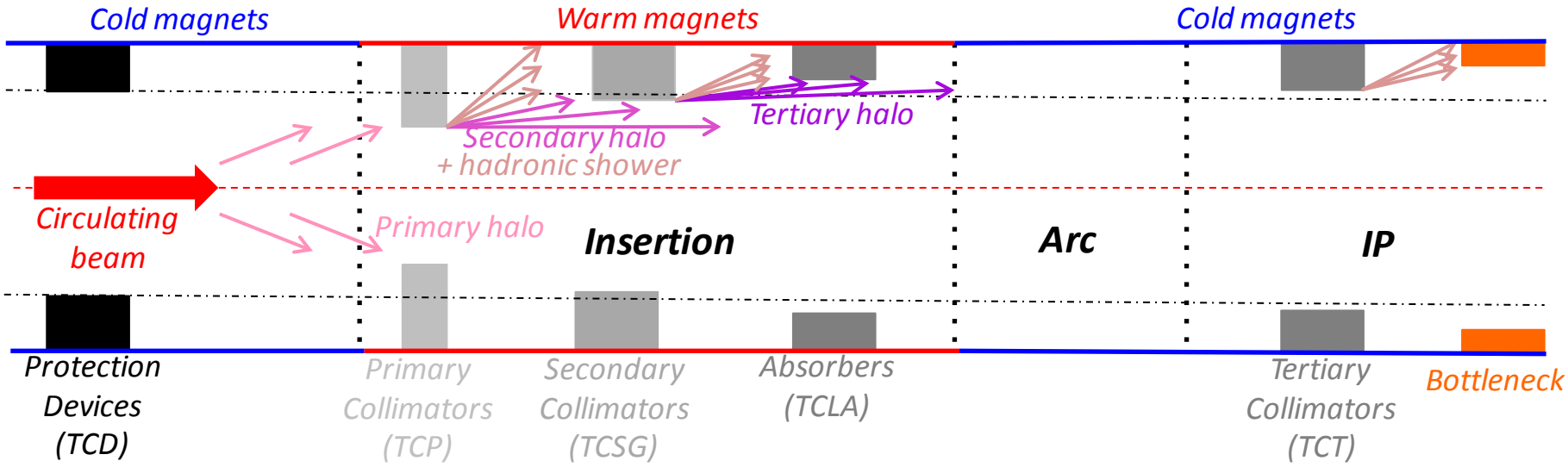
No quench with circulating beam in LHC **Run I** 2010-2013 and **Run II** just started

→ Why do we study a **collimation upgrade?**

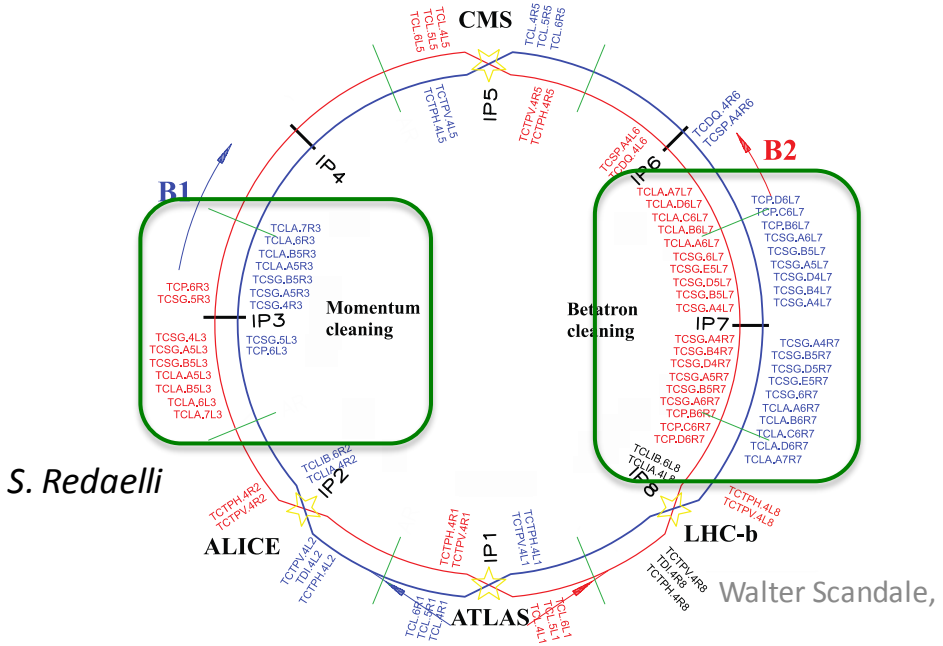
→ *HL-LHC:* ***700MJ!***

→ **Crystal collimation** promising approach

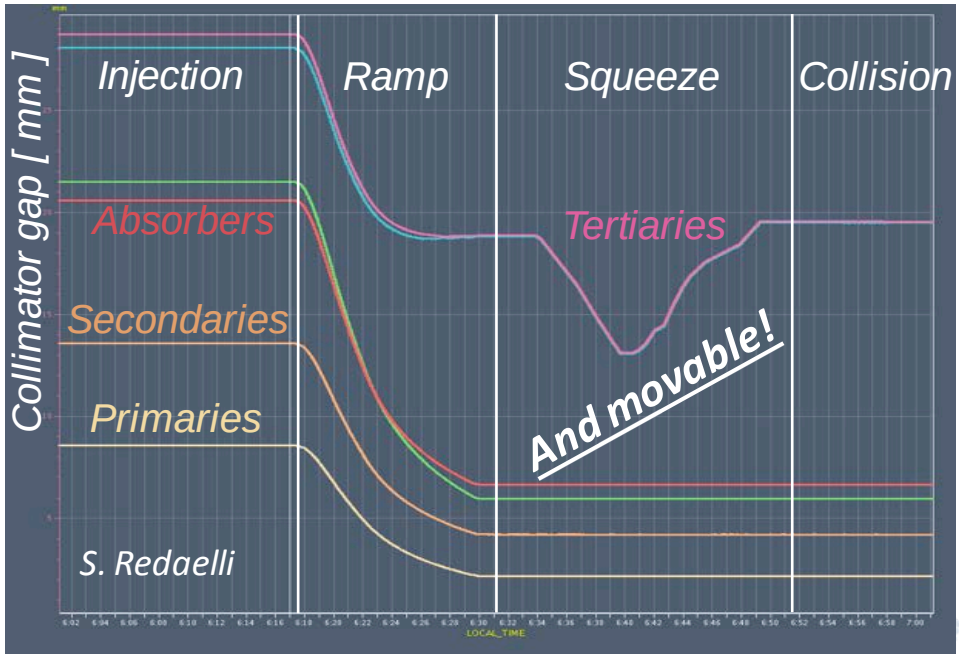
Present Collimation



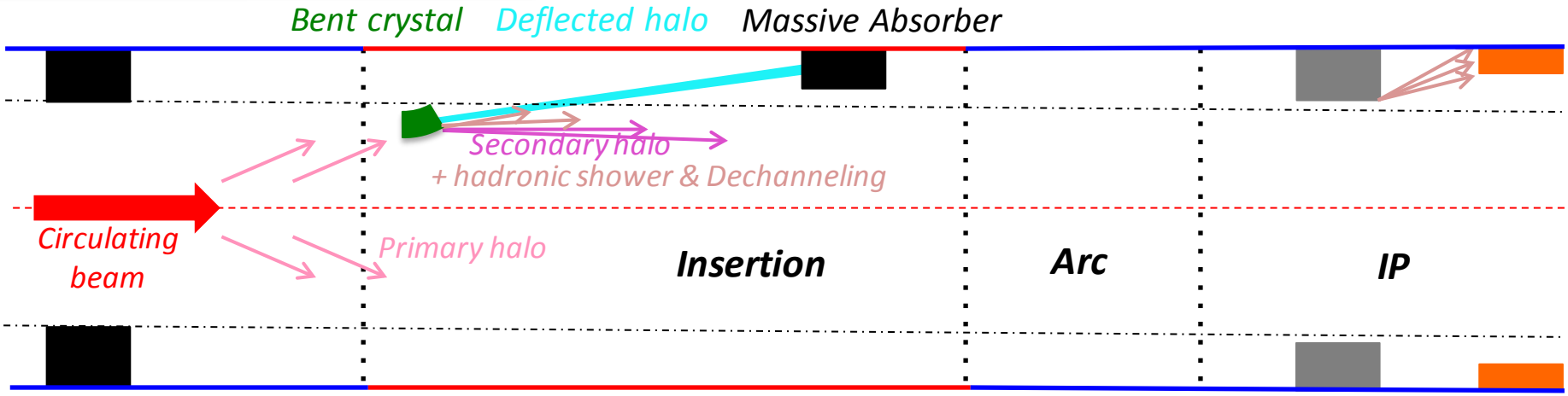
Multi-stage cleaning with about 50 collimators per beam, two dedicated insertions



Walter Scandale,



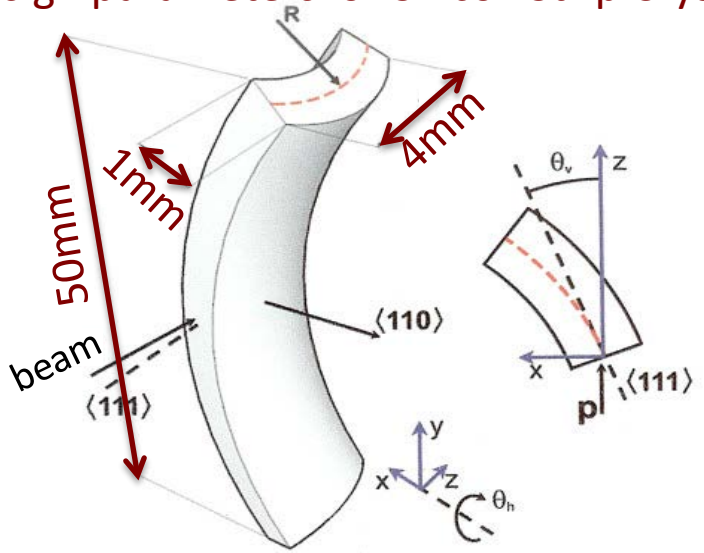
Crystal Collimation



Main gains:

- ✓ Reduction of **inelastic interactions**
  - *Reduced off-momentum losses in DS*
- ✓ **Less collimators** and with larger gaps
  - *Impedance reduction*
- ✓ **Similar performance with both p and Pb**
  - *Significant improvement of w.r.t. present*

LHC design parameters for Silicon Strip Crystals



Bending 50µrad ≡ B ≈ 300 T @ 7 TeV!

Main goals

Two crystals installed in the LHC for crystal collimation tests with main goals:

- ✓ Demonstrate that **required performance** of crystal channeling can be established
  - ↳ Uncertainties in the extrapolations to unknown energy territories
- ✓ Demonstrate that that crystal collimation can **improve** the **present cleaning efficiency**
  - ↳ For both protons and ions (mainly)
- ✓ Demonstrate that **stable crystal channeling** can be established
  - ↳ Crystal alignment w.r.t. beam envelope within required angular tollerances
- ✓ Demonstrate **that crystal collimation** can ensure required collimation efficiency during all **operational phase** of the LHC

↓

*First **experimental tests** with low beam intensity **started***

Observation of channeling for 6500 GeV/c protons in the crystal assisted collimation setup for LHC

by W. Scandale on behalf of UA9 collaboration

For the first time channeling of 6500 GeV/*c* protons was observed in the LHC

Strong reduction of beam losses in the aligned crystal
due to channeling was detected

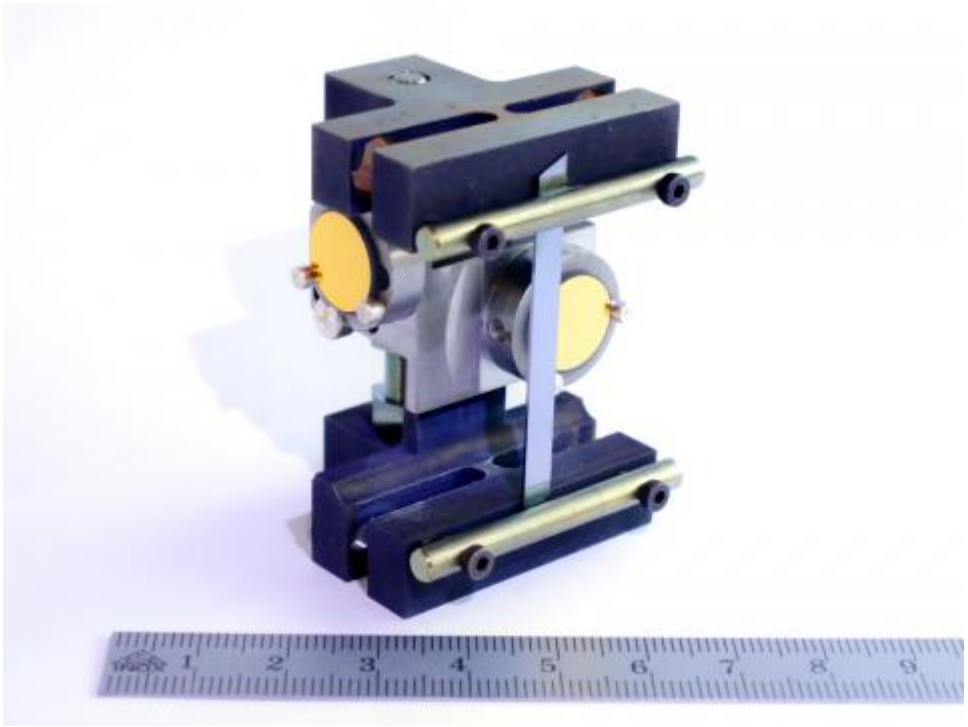
Critical angle for channeling in (110) Si - θ_c=2.6 μrad
Critical radius – R_c=11 m

Two silicon crystals were installed for LHC beam collimation

Length is 4 mm and proposed bend angle is 50 µrad

Record crystal parameters: torsion < 1 µrad/mm, miscut < 6 µrad

Strip (110) crystal

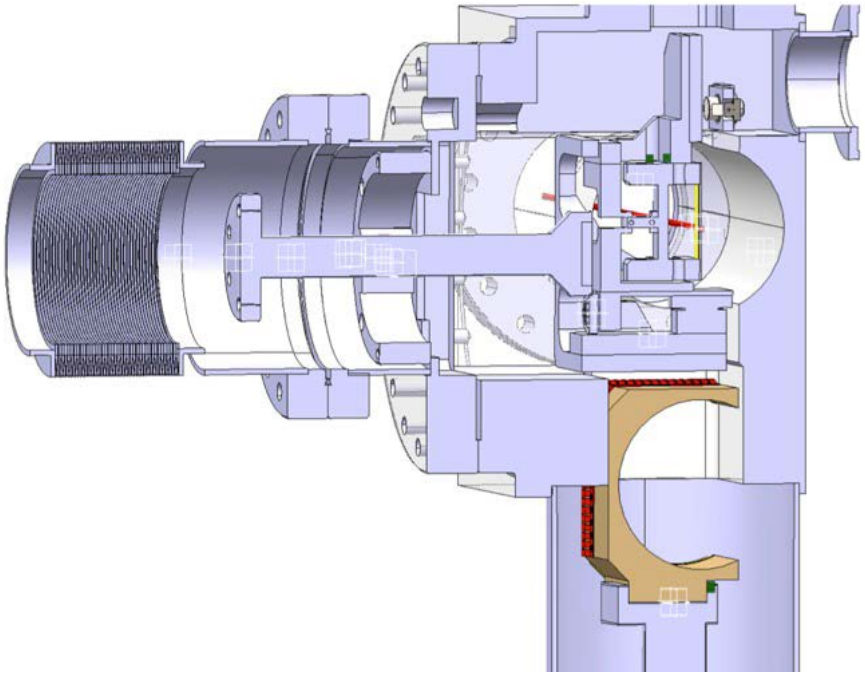


Horizontal collimation

Quasi-mosaic (111) crystal

Vertical collimation

Two high-accuracy piezoelectric goniometers



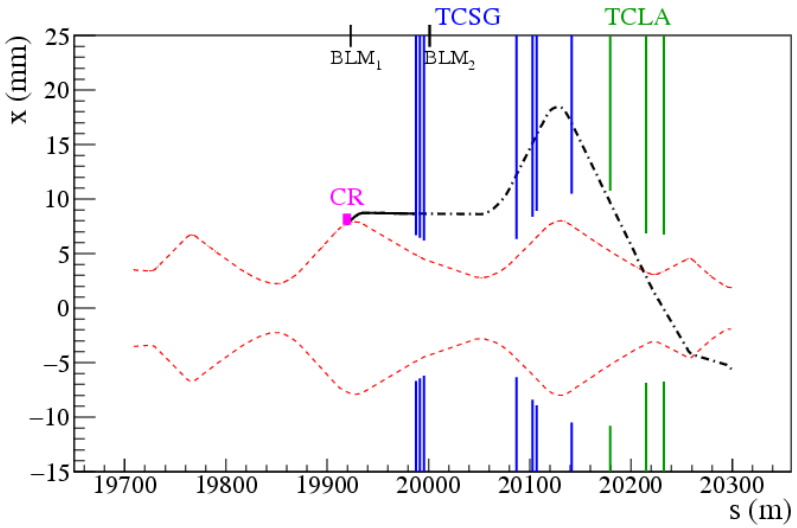
Goniometer has a complete transparency for the normal LHC operations

Goniometer with crystal is remotely retracted only during the special collimation tests

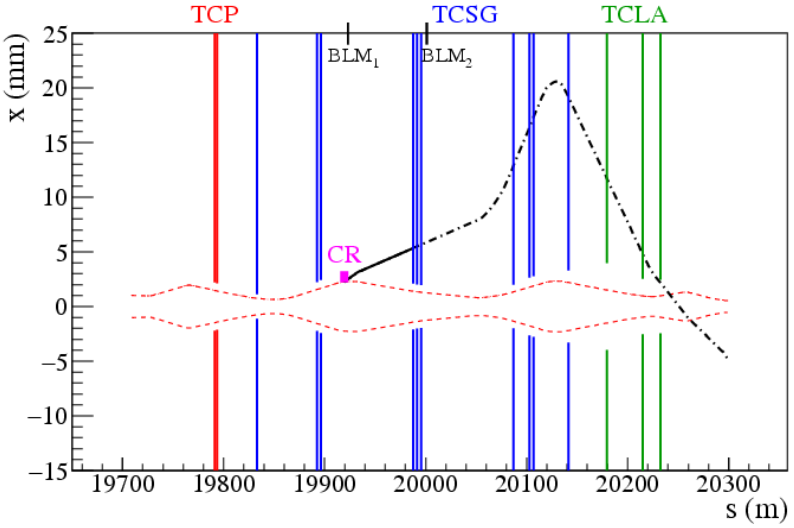
Angular range (mrad)	Angular resolution (µrad)	Linear range (mm)	Linear resolution (µm)
10	0.1	40	5

Trajectory of halo particle deflected due to channeling

For injection at 450 GeV/c

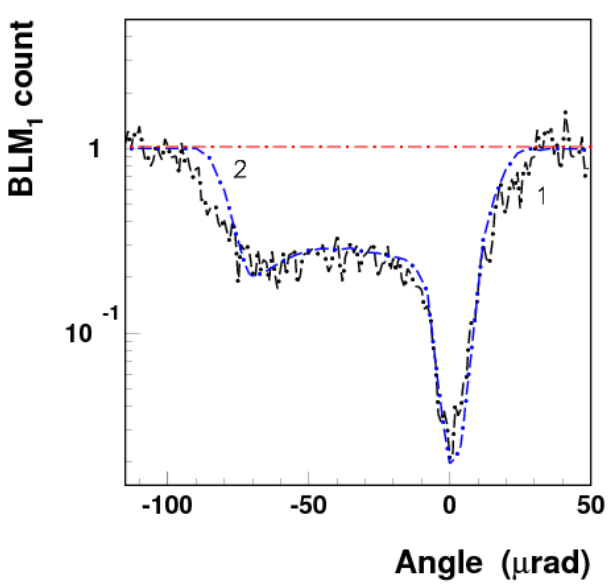


For 6500 GeV/c

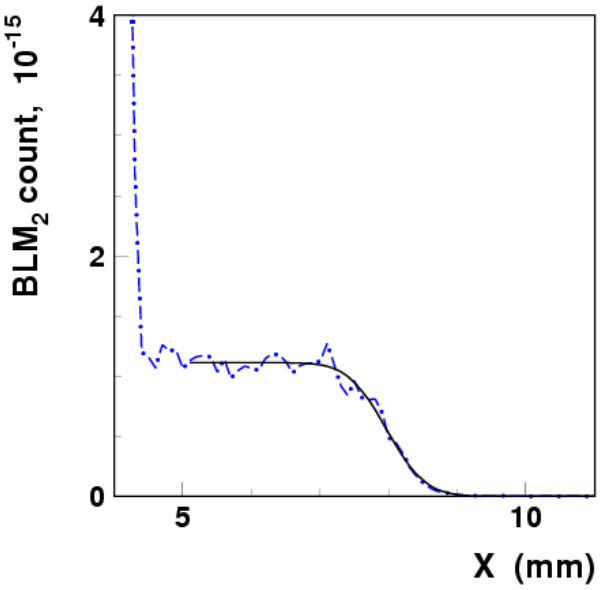


Collimation results for injection case at 450 GeV/c

losses in crystal
Scan of crystal angle



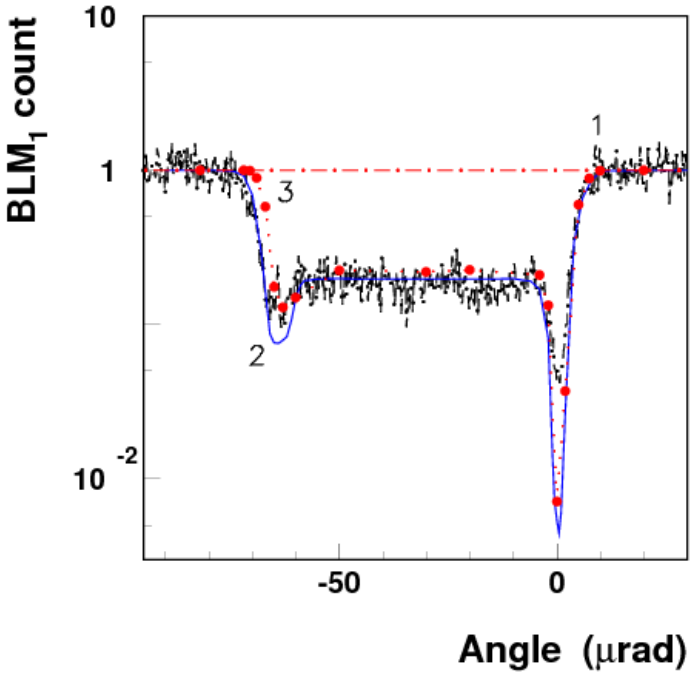
Losses in collimator
Scan of its X position



Loss reduction in crystal due to channeling is about 50

Collimator scan gives the deflected beam distance from the orbit
It corresponds to the crystal bend angle of 65 μrad

Collimation results for collision case at 6500 GeV/c



Loss reduction in crystal due to channeling is about 24

Conclusions

(1) Quality of the crystals and goniometers allows to observe channeling at this record energy in the LHC collider

(2) Good agreement of simulation results with the experiment

(3) LHC beam collimation may be improved with bent crystals
Leakage may be decreased