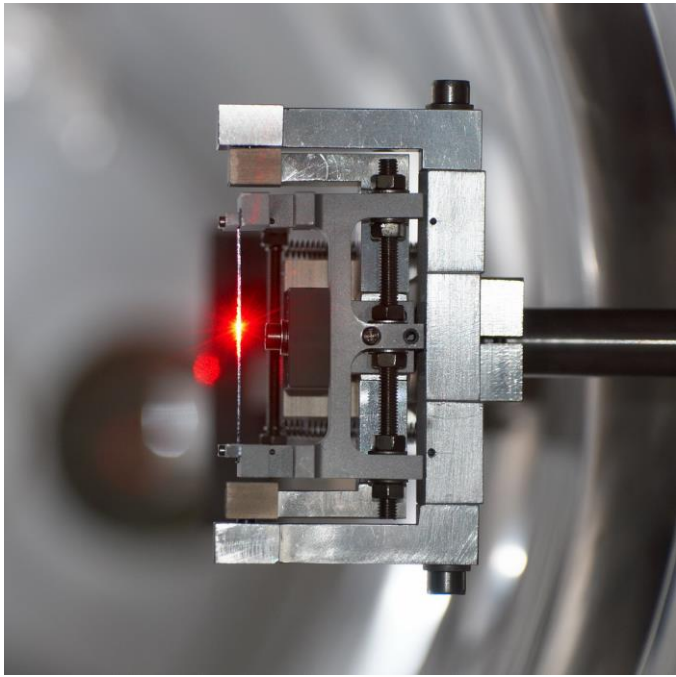
Status of UA9

W. Scandale on behalf of the UA9 Collaboration

- Measurements and tests in the SPS North Area
- Measurements and tests in the SPS
- Test in LHC
- Requests for 2017



SPS-North Area: Oct 2015 - Oct 2016

NA-H8 Test beam

30 days assigned in 4 runs : 22d main user, 8d parasitic

Effective time: ~ 65 % (~35 % lost for machine problems)

2015

Primary Pb Ion Beam (30 AGeV)

Main user

- *November 17nd - 20th*

2016

Secondary Pion beam (180 GeV)

Main user

- *June 29th – July 6th*
- *September 15th – 21st*

Parasitic to TOTEM

- *April 26th – May 4th*

2016

Primary proton beam (400 GeV)

Main User

- *April 22nd – 26th*

SPS North Area: upgrade of the tracker

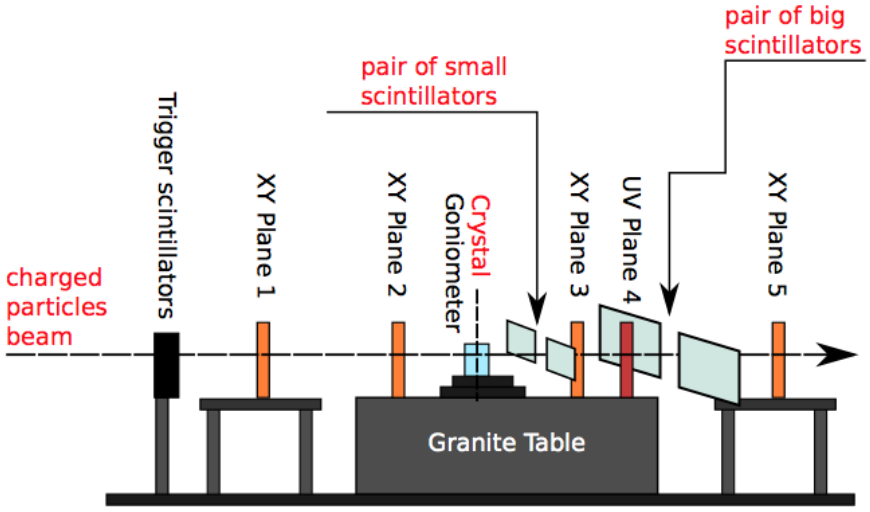


FIG. 1: Experimental layout in the H8 beam line.

- Tracker commissioning with 30 AGeV Pb Ions beam (November 2015)
- New Tracker and DAQ configuration dedicated to test big deflection angle crystals using 4 planes only (November 2015)

SPS North Area: crystals for LHC studies

QuasiMosaic (QM) type

(111) planes, QM bending

Strip type

(110) planes, anticlastic bending

Objective:

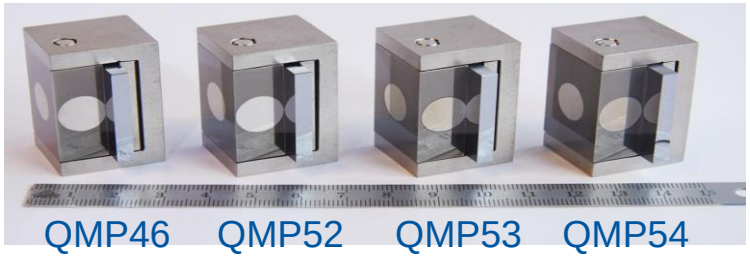
- identify several crystals to be used in LHC in 2017/18:
  - Check that the crystal bending is in the range 50 to 55 μrad
  - Investigate the long-term stability of the holder for repeated thermal cycles

SPS North Area: QM crystals for LHC

4 QM crystals prepared at PNPI:

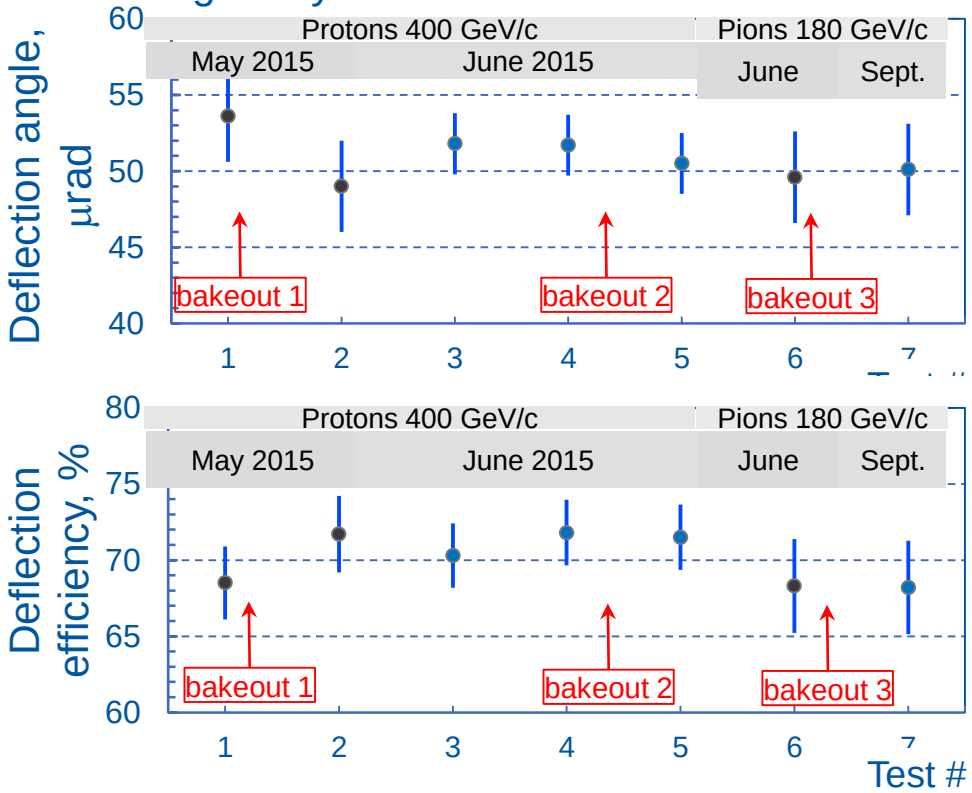
Crystal	Defl. Angle µrad	Efficiency * %
QMP46	**50** ± 2	71 ± 2
QMP52	**55** ± 2	69 ± 2
QMP53	**55** ± 2	71 ± 2
QMP54	**55** ± 2	70 ± 2

* for protons 400 GeV/c and beam divergence ± 5 µrad



Dimentions HxWxL, mm	40 x 30 x 25
Weight, g	96 ± 1
Holder material	Titanium alloy grade V

QMP46 Deflection and Efficiency measured during 1.5 year after 3 bakeouts at 250°C



SPS North Area: strip LHC crystals

STF Crystals (INFN-Fe): Tests with a new titanium holder

STF105 has the perfect angle of 50 μrad for LHC

One thermal cycle in June/July 2016, stable holder

	Time	Deflection Angle
400 GeV/c protons	June 2015	49±1 μrad
	April 2016	50.6±1.4 μrad
180 GeV/c pions	30 June 2016 – pre-heating	52.2±2.2 μrad
	5 July 2016 – after-heating	48.3 ±2.3 μrad
	September 2016	51.4 ±1.7 μrad

STF106 has an angle of 40 μrad too low for LHC

One thermal cycle in June/July 2016, stable holder

	Time	Deflection Angle
400 GeV/c protons	June 2015	41.5±1.5 μrad
	May 2016	41.9±1.8 μrad
180 GeV/c pions	30 June 2016 – pre-heating	41.0±2.3 μrad
	5 July 2016 – after-heating	36.5 ±2.5 μrad

STF107 has an angle of 56 μrad for LHC

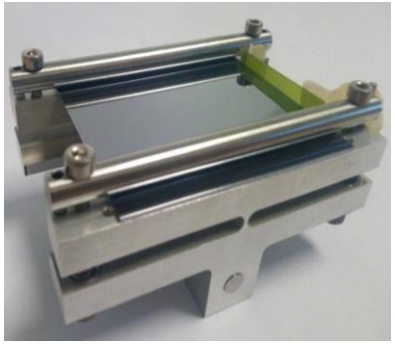
No thermal cycle,
One accidental holder instability
Angle slightly out of the LHC range

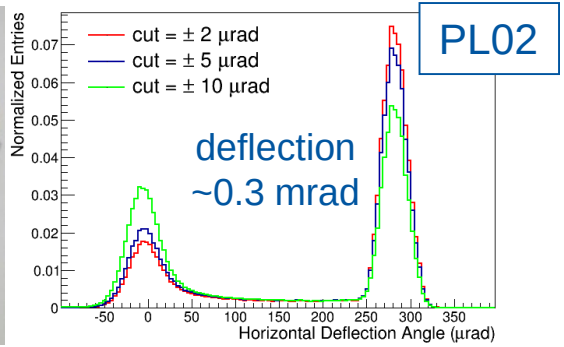
	Time	Deflection Angle
180 GeV/c pions	June/July 2016	55.7±2.1 μrad

SPS North Area: new crystals

Large angle long crystals (INFN-FE)

Anticlastic deformation



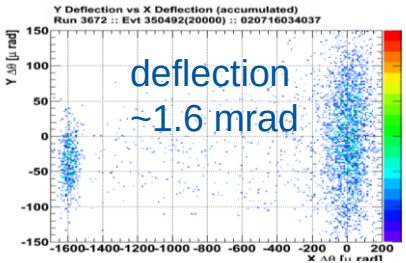


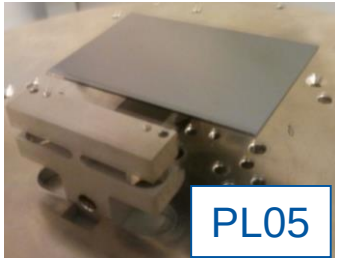
PL02

Self-standing deformation

PL04

Crystal surface is patterned with a silicon nitride film 100 nm thick





PL05

Crystal deformation occurs as a consequence of plasticization of one of its surfaces

CpFM installation in TT20

fundamental for investigating slow extraction assisted by crystals in the SPS

- The CpFM installed in TT20 in May-June 2016
  - It showed god functionality during the test beam in H8 (89,5% efficiency)
- DAQ electronics *to count particles (and which is able register waveforms over 2.56 us)* is connected
  - not suitable for FFT of the extracted intensity...
- The commissioning of the detector is being planned (delayed for lack of dedicated beam time and man-power)

Preparation of HiRadMat crystal test

Main motivations

Experimental verifications:

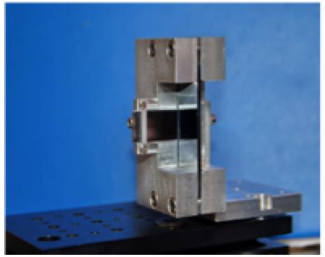
- Crystals robustness (no breakages, no transition to amorphous status)
- Channeling performances under accidental fast irradiation in LHC

Test to be performed with 288 nominal bunch at 440 GeV (May 2017)

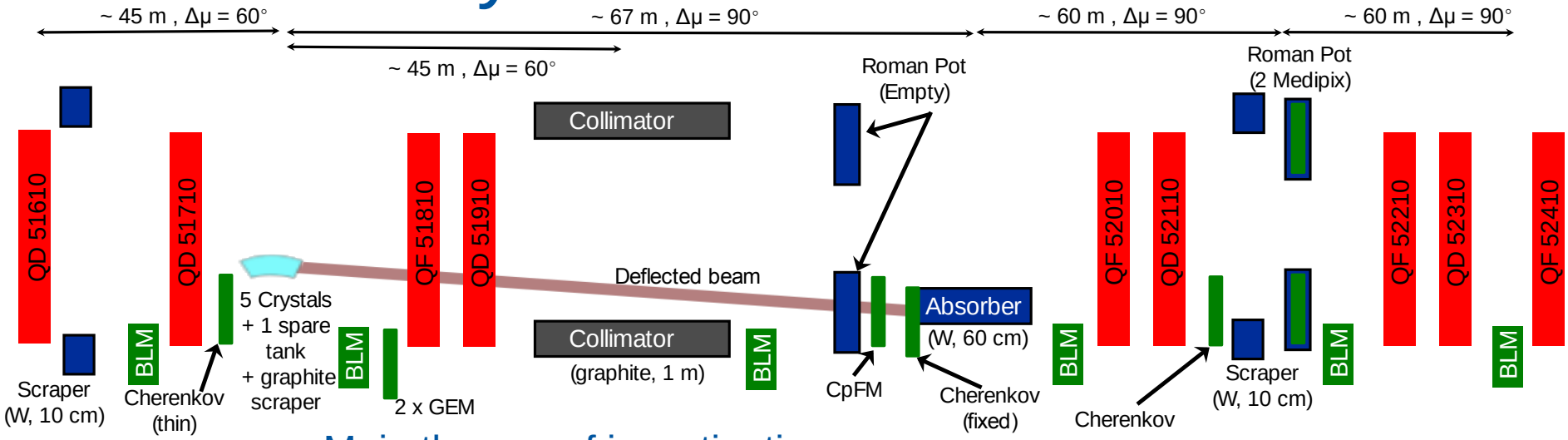
Crystals to be irradiated

STF103:
Silicon Strip Crystal
Bending angle: 55 urad
Width (x): 1.97 mm
Height (y): 55 mm
Length (z): 1.88 mm
Dislocations: < 1 cm^2

QMP25:
Silicon Quasi Mosaic Crystal
Bending angle: 165 urad
Width (x): 30.5 mm
Height (y): 57.5 mm
Length (z): 2.1 mm
Dislocations: < 1 cm^2



SPS: activity from Oct 2015 to Oct 2016



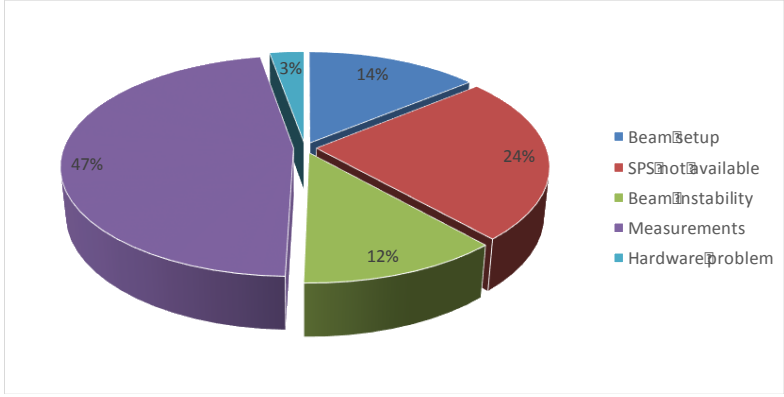
Main themes of investigation:

- Commissioning of LHC-type goniometer (Oct 2015)
- Measurements with CpFM (Oct, Nov, Dec 2015; Jul 2016)
- **Effect of a "protective" upstream collimator (Oct, Dec 2015; Jul 2016)**
- **Crystal with different polishing (July 2016)**
- Collimation efficiency at different apertures (Nov, Dec 2015; Jul 2016)
- Diffusion speed (Dec 2015, Jul 2016)

SPS: Experimental runs

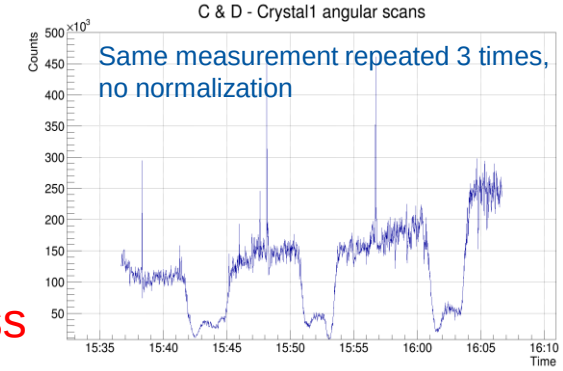
- Six data taking runs in the last year:
  - 4 runs with protons
  - 2 runs with ions
    - 24h for physics + 10 h for machine setting up
    - 12-hours MD for diffusion studies
- Efficiency quite low (< 50%) for beam instabilities:
  - Aging SPS dipole identified and exchanged during the YETS15 (“random beam jitters”)
  - Pulsing equipment powered during COAST cycle (“periodical beam jitters”)
  - Search for the sources and compensation of the instabilities

Date	Beam	Beam setup (h)	SPS not available (h)	Beam instabilities (h)	Measurements (h)	Hardware problem (h)	Total time (h)
14/10/15	Protons, 270 Gev, COAST	3	6	0	15	0	**24**
02/11/15		4	6.5	5	8.5	0	**24**
03/12/15	Pb ions, 270 Z GeV, COAST	2	9.5	1	21.5	0	**24 + 10**
10/12/15		0	5.5	0	6.5	0	**12**
06/06/16	Protons, 270 Gev, COAST	8	2	9	1	4	**24**
20/07/16		3	5	2	14	0	**24**
TOTAL (h, %)		**20 h 14%**	**34.5 h 24%**	**17 h 12%**	**66.5 h 47%**	**4 h 3%**	**142 h**

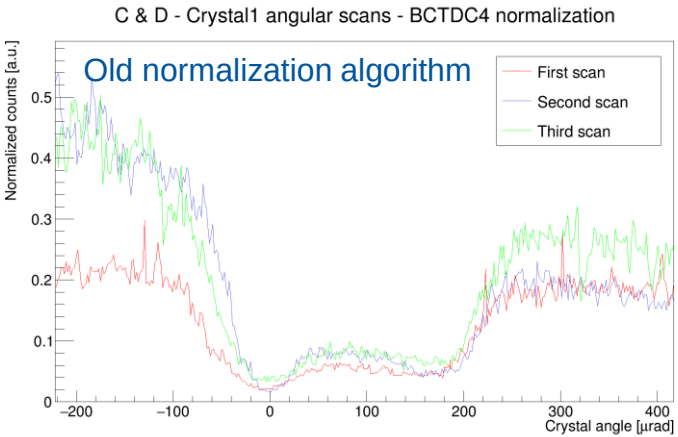


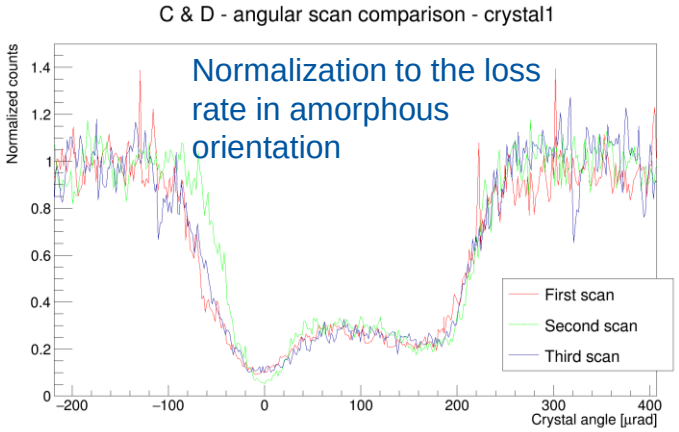
SPS: data normalization issue

- During angular scans beam loss monitors must be normalized to the number of lost protons:
- The normalization factor is normally computed from the derivative of the beam intensity measured in the machine by BCT
- BCT measurements do not correctly normalize the data of the 2016 run



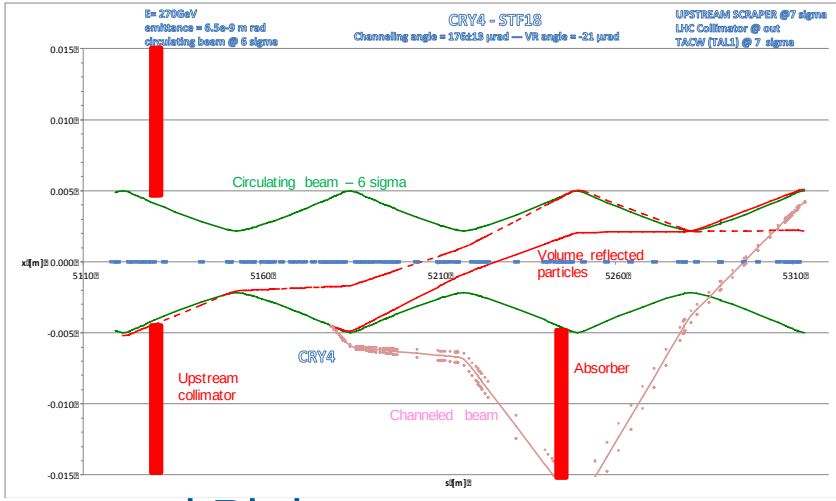
As provisional action for 2016 data, we impose that the loss rate when the crystal in amorphous orientation is constant.





SPS: effect of “protective” collimator

- During LHC tests, primary collimators in front of the crystal were partially closed for machine protection reasons
  - The beam loss profile of the angular scan looked distorted

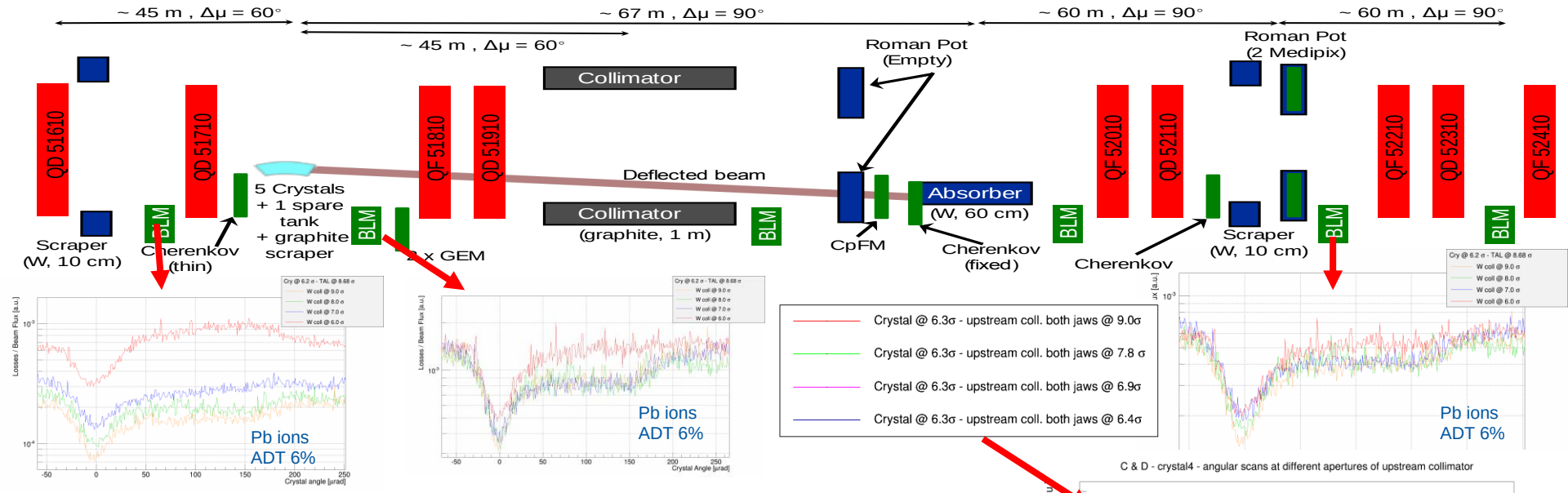


The same effect was studied in SPS with protons and Pb ions:

From tracking studies, the effect of the collimator should be especially visible on particles “volume reflected” by the crystal.

Other effects (i.e. multi-turn halo due to de-channeled or scattered particles) may contribute, accurate simulation ongoing.

SPS: effect of “protective” collimator



- Preliminary analysis shows a clear effect due to the upstream collimator, both for Pb ions and protons
- Reduction of the loss rate in channeling orientation is affected.

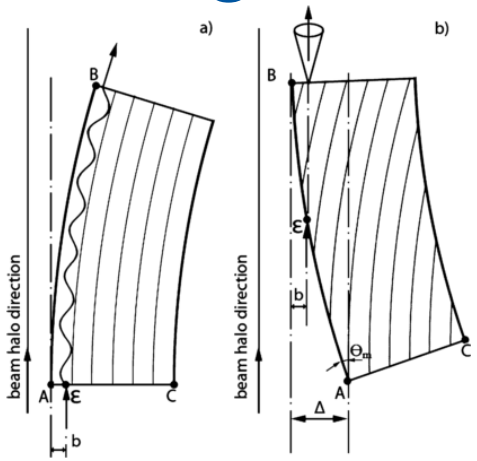
Good qualitative agreement with the observations in LHC

Sca

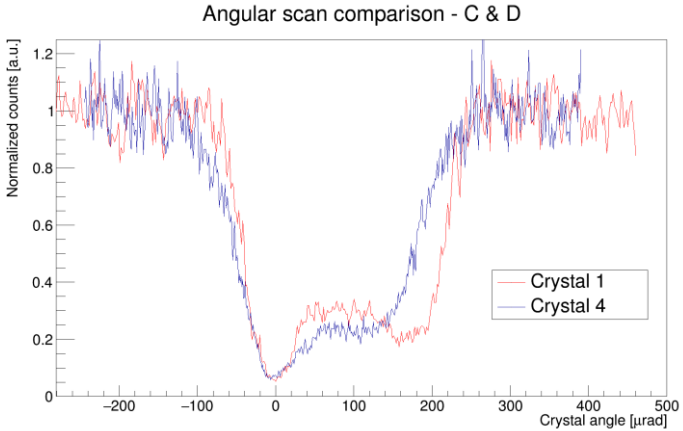
SPS: crystals with different polishing

- The angle between the lattice and the surface of the crystal (mis-cut) can affect collimation performance
- Test with to strip crystals (INFN-FE) with identical geometry

Crystal	Bending angle	Length (z)	Width (x)	Mis-cut angle	Torsion
1	165 µrad	1.87 mm	0.5 mm	6 µrad	< 1 µrad/mm
4	176 µrad	2.00 mm	0.5 mm	200 µrad	< 1 µrad/mm

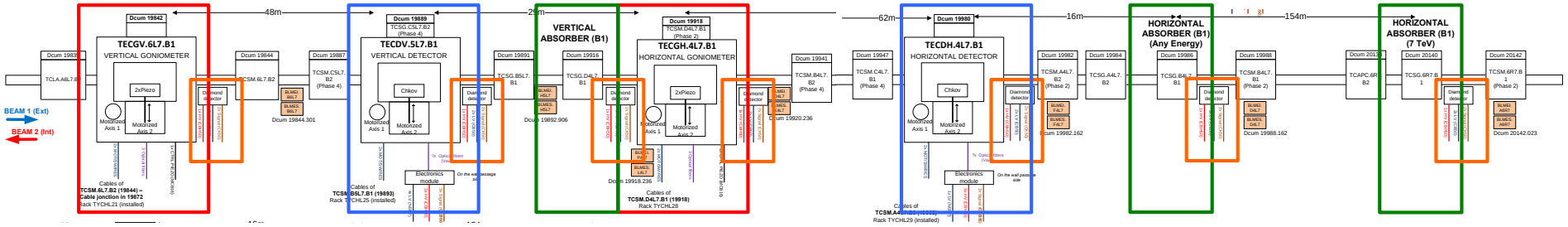


- Similar loss reduction in channeling orientation
- Larger volume reflection region for crystal with low mis-cut
  - Transition regions are sharper
  - Different shape (hump + dip)



The test will be repeated at smaller diffusion speed

LHC: experimental runs



Data taking runs:

- November 6th 2015 with protons
  - crystal channeling in the horizontal plane at 6.5 TeV (record energy).
- December 2nd 2015 with lead ions
  - horizontal and vertical crystals deflecting lead ions at injection energy
- July 29th 2016 with protons
  - characterization and measurements of both crystals at LHC top proton energy.
  - Angular and collimator linear scans performed at both injection and top energies.

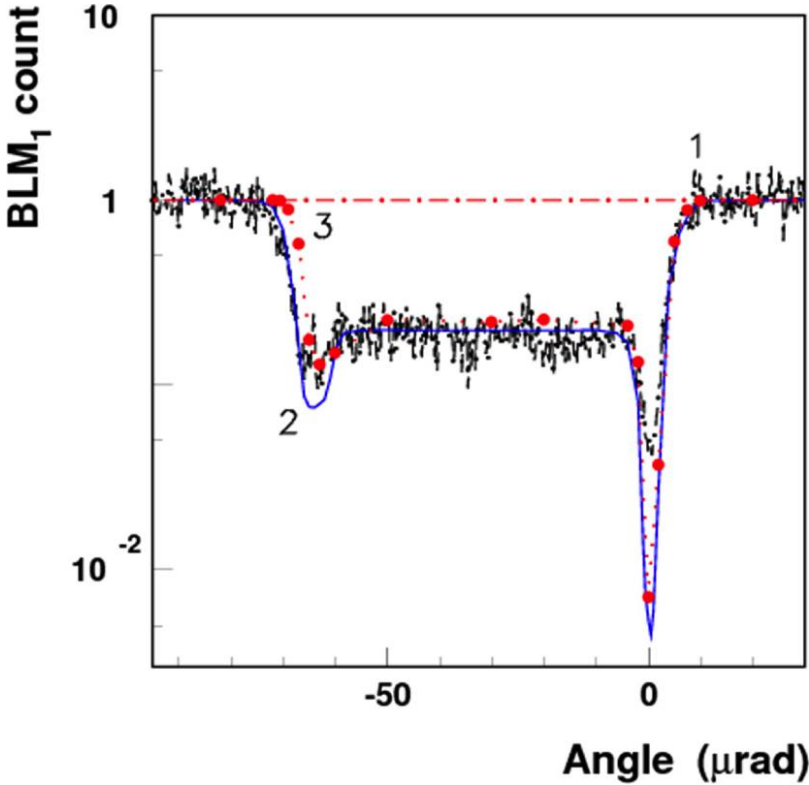
LHC: collimation in the horizontal plane

Angular scan at 6.5 TeV energy. Loss rate as a function of the angle

Curves 2 (solid blue line) and 3 (dotted red line) shows results with two different simulation models.

- Crystal collimation setup:
  - Crystal at ~ 5.6 σ (1 σ = 1.53 mm)
  - Collimators upstream the crystal are retracted
  - TCSGs at 7 σ, TCLAs at 10 σ (nominal position)

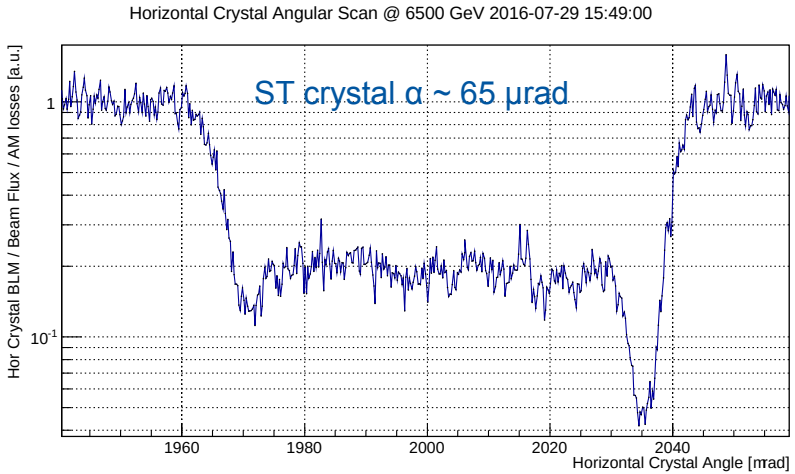
No explanation yet available for the large discrepancy between data and simulation results in channeling orientation

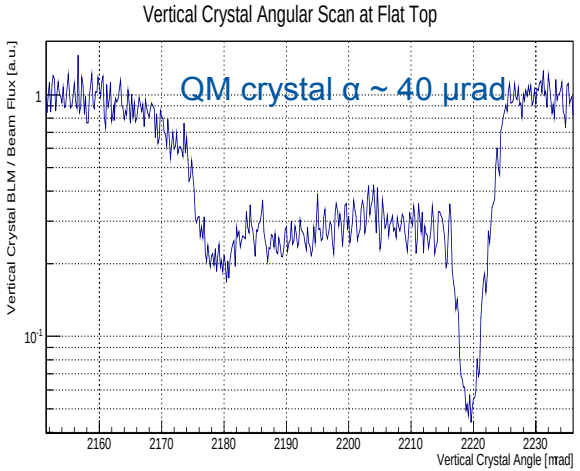


LHC: angular scans at 6.5 TeV

Loss reduction in channeling orientation almost identical

Angular scans of QM and the strip crystals have the same behavior



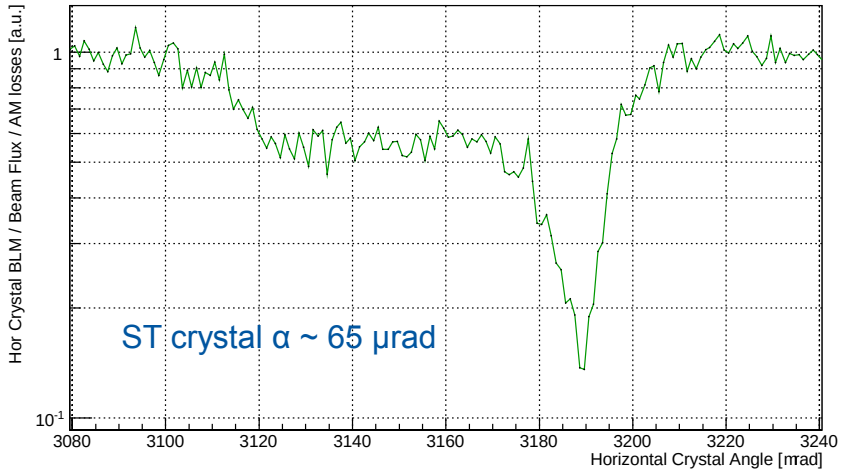


LHC: angular scans at 450 GeV

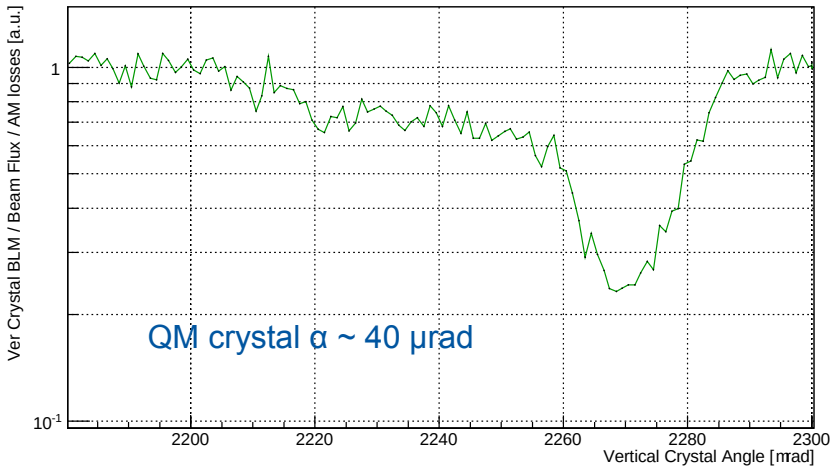
Loss reduction in channeling orientation not the same

QM has a too small deflecting angle for an efficient absorption of the beam halo

Horizontal Crystal Angular Scan @ 450 Z GeV

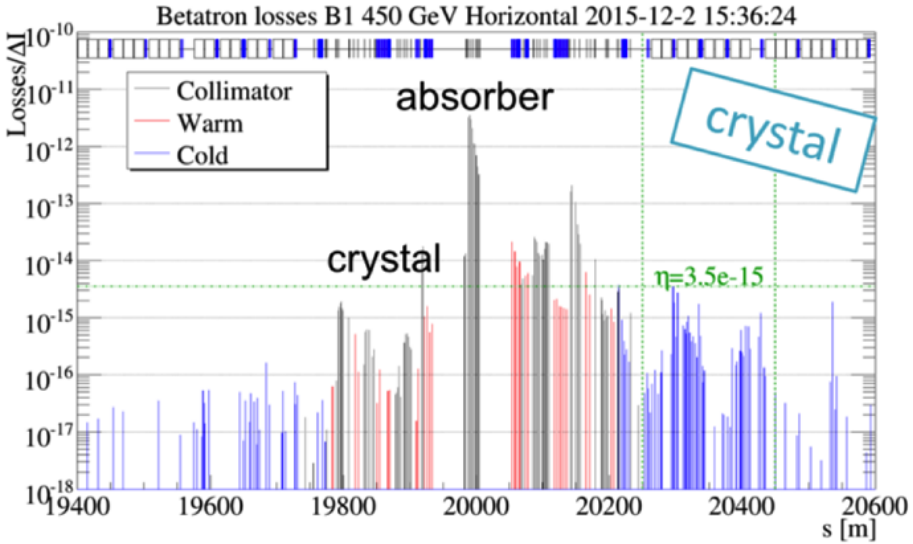


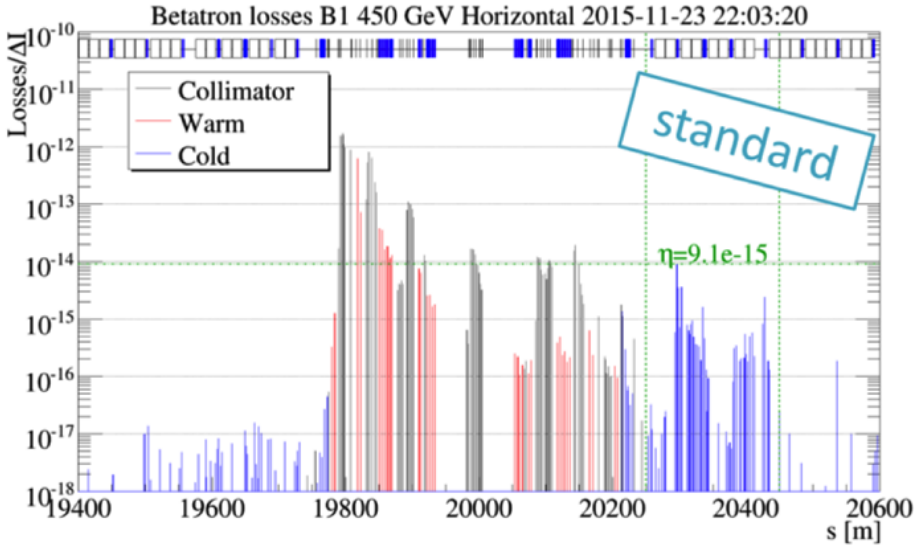
Vertical Crystal Angular Scan @ 450 Z GeV



LHC: loss map at 450 GeV with lead ions

Collimation efficiency improved by a factor 2.6 !!

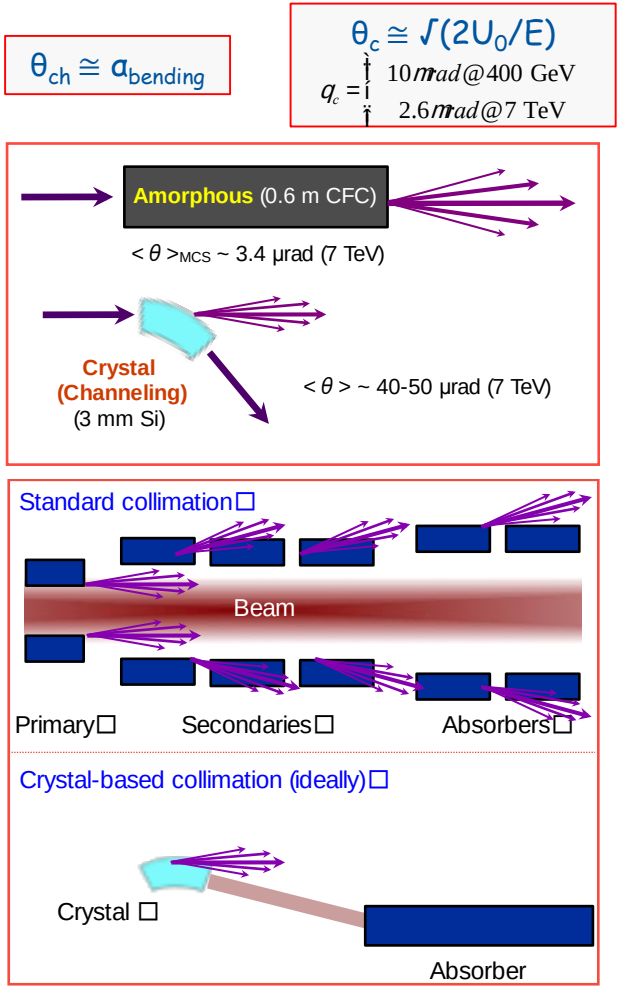




Role of UA9

- Crystal collimation for LHC
  - Demonstration of feasibility completed
  - Detailed studies undergoing with the LHC Collimation team
- Extraction in the SPS
  - Studies started
  - Team to be strengthened for long term results
- Physics with bent crystals
  - Expression of intent independent of UA9 (see SPSC-EOI-012)
  - Team to be defined

Request of beam time to be tuned taking into account the solution of the mentioned issues



Requests for 2017

- Request in H8
- 20 days with 400 GeV protons
- (of which 7 days with ions)

GOAL IN H8

1. Stability of LHC-type holders for strip crystals
2. Calibration of the quartz radiator for LHC
3. Calibration of Timepix for SPS
4. Focusing crystals for SPS
5. New technology crystals

- Request in the SPS
- 3 days with 270 GeV protons
- 1 day with ions

GOAL IN the SPS

1. Complete the studies started in 2016
2. Test collimation in ramping mode changing the store energy
3. Investigate new subject (SPS extraction and more) pending the reorganization of the Collaboration

Acknowledgments

- The Collimation Team for the fruitful collaboration and the support to the UA9 Collaboration
- All the teams and the groups who provide support to the UA9 experimental installations, including: EN/STI, EN/MEF, EN/HE, BE/ABP, TE/VSC, TE/MPE
- All the groups that supports the UA9 Experiment during data taking activities in SPS and in North Area, in particular: BE/OP, BE/RF

Publications and thesis

1) "***High-efficiency deflection of high energy protons due to channeling along the ⟨110⟩ axis of a bent silicon crystal",*** Scandale et al., Physics Letters B, 760 (2016) 826-831

2) ***"Observation of channeling for 6500 GeV/c protons in the crystal assisted collimation setup for LHC"***, W. Scandale et al., Physics Letters B, 758 (2016) 129-133, May 2016.

One master thesis concluded

Two PhD thesis ongoing

Thank you for your attention!