

High
Luminosity
LHC



H8 crystal data analysis

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The UA9 collaboration is studying techniques to steer ultra-relativistic beams with bent crystals to improve the collimation of proton and heavy ion beams at the LHC.

Measurements of key crystals properties ([bending angle](#), [channeling efficiency](#), etc..) are performed on the SPS extraction line (H8) with 400 GeV/c protons before testing crystals with circulating beams.

Data analysis main goal:

Consistently analyze all the crystals tested in H8 (total of 15 between 2010-2012).

- Compile a comprehensive statistical treatment of different crystals
- Identify “fine” systematic effects (e.g., transitions)
- provide inputs to crystal code developers

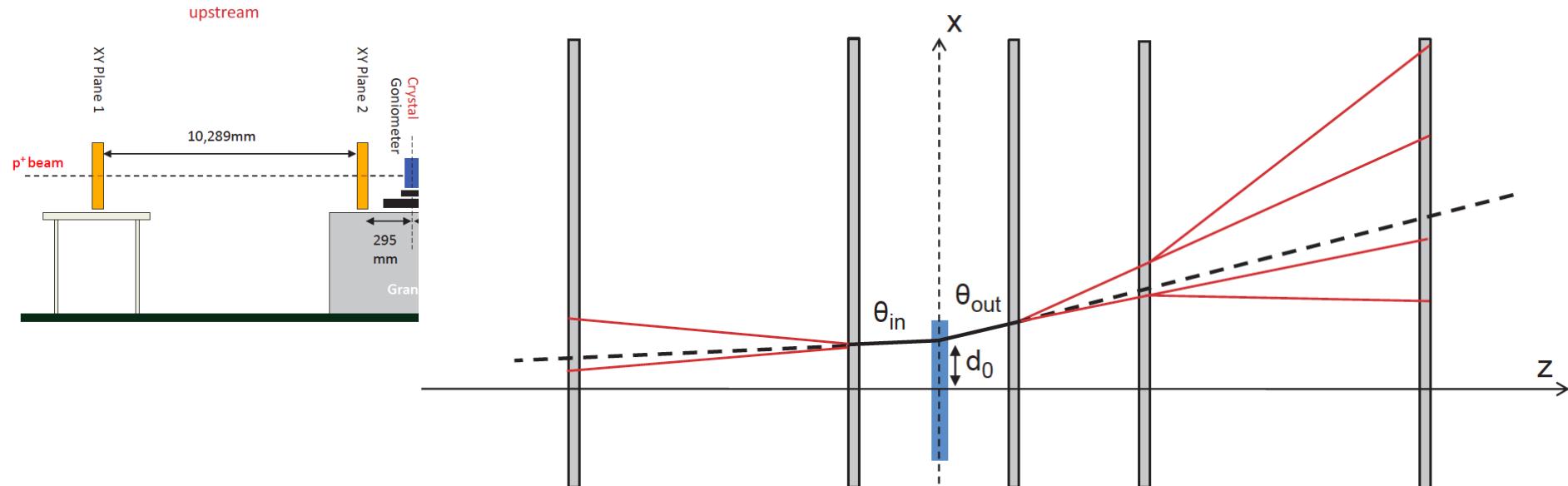
Immediate goal: compile list of experimental data for comparison with crystal simulations.



http://lhc-collimation-upgrade-spec.web.cern.ch/LHC-Collimation-Upgrade-Spec/H8_input.php

H8 experimental Layout

- Five silicon micro-strip sensors (active area $3.8 \times 3.8 \text{ cm}^2$ in the x-y plane) are used to track the particles **in the plane orthogonal to the beam direction** before and after passing through the crystal.
- High precision goniometer is used to modify the **crystal plane orientation with respect to the beam direction**.



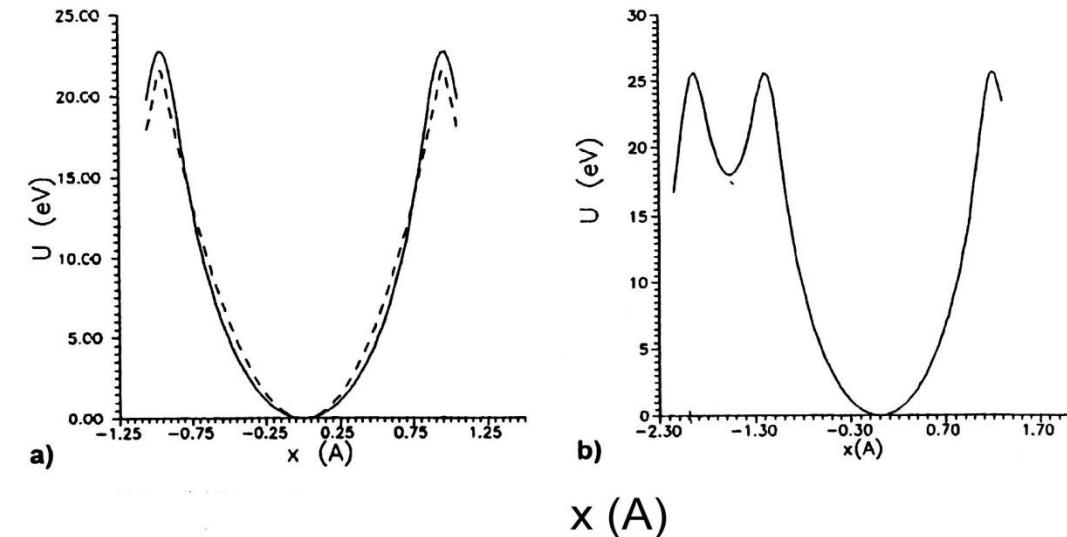
UA9 Crystals

Two kind of crystals were tested in H8

- **Strip crystal** : the anticlastic bending is induced on the planes (110)
- **Quasi-mosaic crystal** : the anticlastic bending is induced on the planes (111)

The main difference is that the strip channels have all the same width, while the QM have a main channel and a smaller secondary (1/3).

A total of 10 crystals were analyzed,
7 strip and 3 quasi-mosaic



We developed analysis tools in Root to get from the raw data (details in next slides):

- Alignment run ->
 - check of beam parameters (e.g. input distributions on crystal)
 - telescope resolution
- Hi stat CH ->
 - Geometrical cut (different strategy between ST and QM)
 - Torsion correction
 - Crystal channeling efficiency
 - Dechanneling length
 - First look to transition region
 - Population studies (Future paper)
- Angular scan run ->
 - Volume capture features

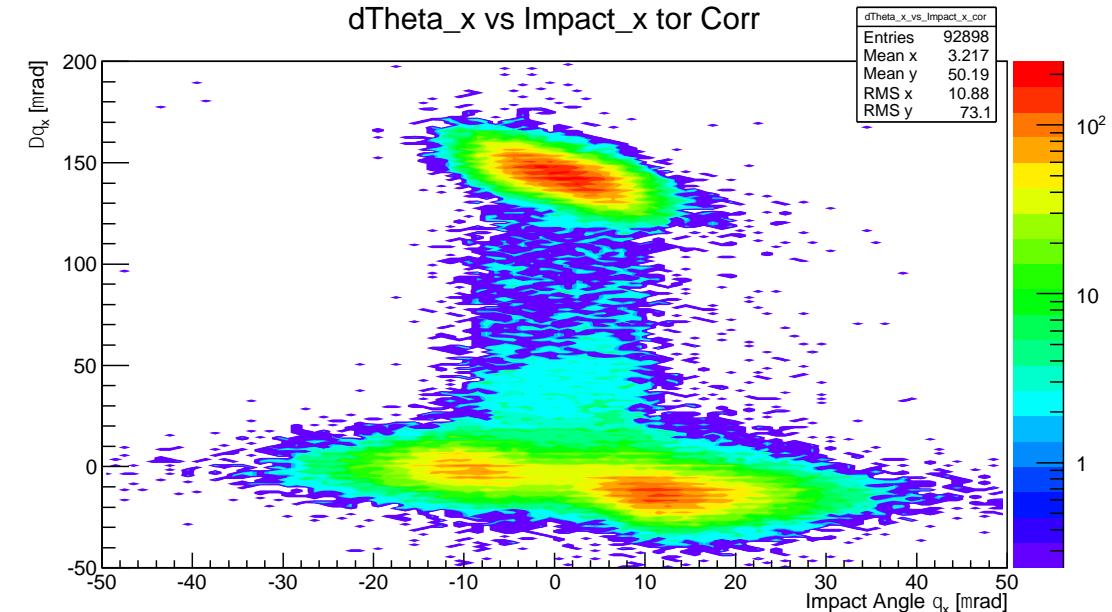
The analysis for the **STF45** crystal is used as reference case for comparison with crystal simulation routines

The optimum channeling condition is the one studies in more detail

All the analysis are performed by studying the deflection x angle as a function of the impact x angle. We can then distinguish three regions with respect to the x deflection

- **Channeling**, the spot around $150 \mu\text{rad}$
 - **Transition region** between the amorphous and the volume reflection zone
 - **Dechanneling**, the region between the first two

The plot is produced after a series of selection and correction consistent with the analysis of the interesting phenomena



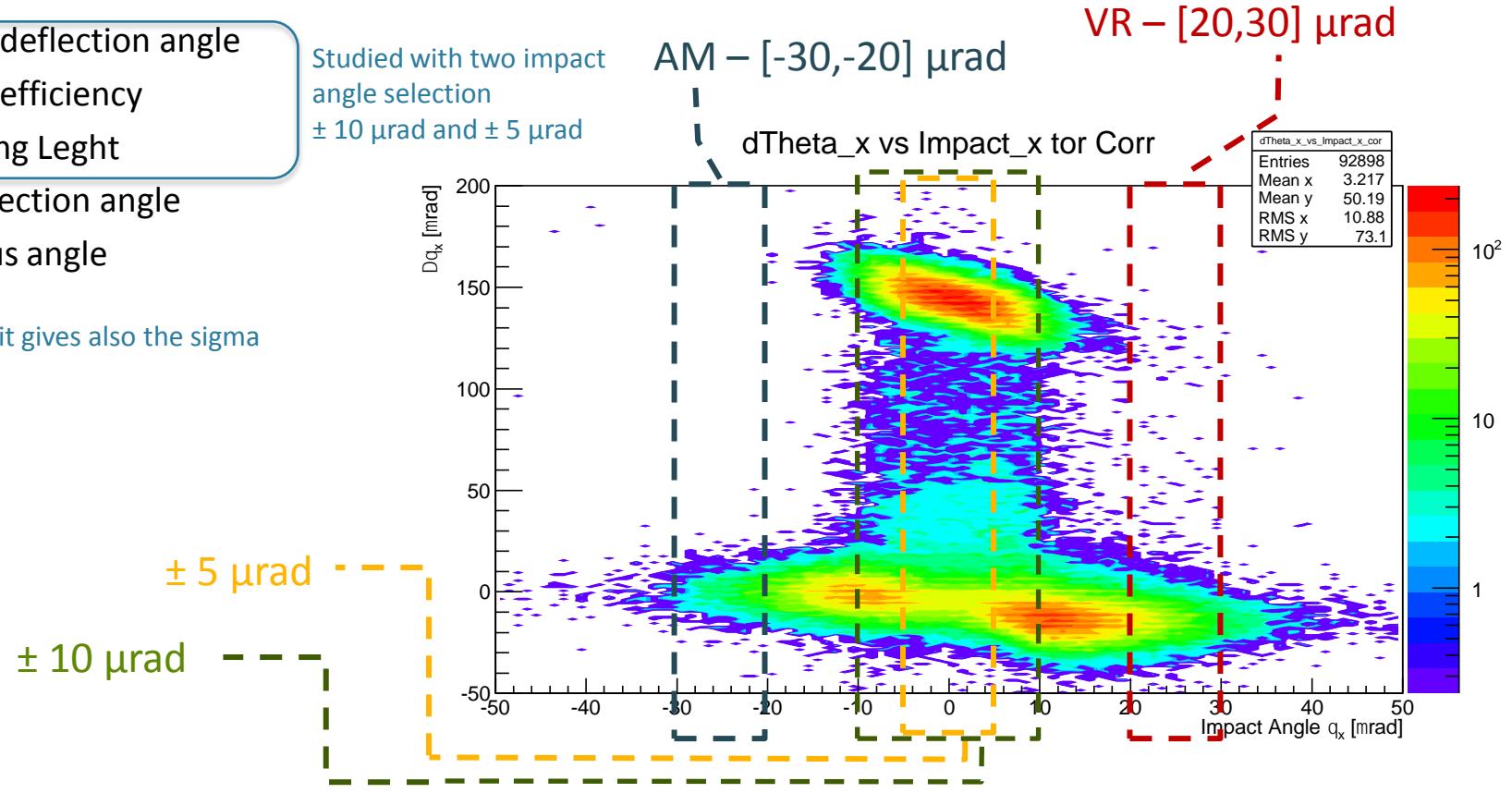
Deflection analysis

With different selection of impact angle we are able to study the different kind of interaction of particle with a bent crystal.

- Channeling deflection angle
- Channeling efficiency
- Dechanneling Length
- Volume reflection angle
- Amorphous angle

The same gaussian fit gives also the sigma distribution value

Studied with two impact angle selection
 $\pm 10 \mu\text{rad}$ and $\pm 5 \mu\text{rad}$



Deflection distribution

The same gaussian fit gives also the sigma distribution value

dTheta_x vs Impact_x tor Corr

CF

MF

VF

MF

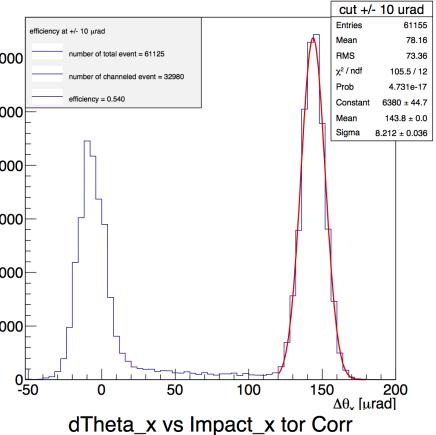
cut AM	
Entries	1649
Mean	0.4735
RMS	11.34
χ^2 / ndf	31.65 / 16
Prob	0.01111
Constant	350.8 ± 11.2
Mean	0.09987 ± 0.18297
Sigma	7.313 ± 0.146

Impact_x tor Corr

cut VR	
Entries	5062
Mean	-12.29
RMS	15.28
χ^2 / ndf	170.4 / 23
Prob	1.774e-24
Constant	959.4 ± 18.7
Mean	-14.03 ± 0.12
Sigma	8.027 ± 0.106

rad
radrad
rad

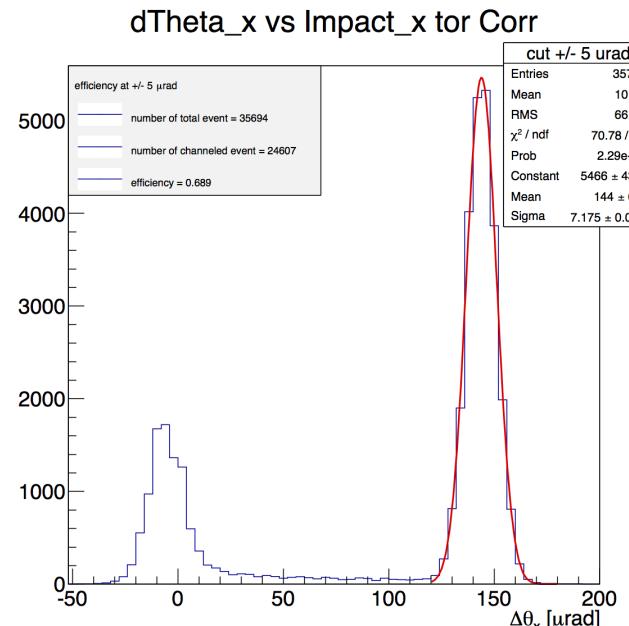
dTheta_x vs Impact_x tor Corr



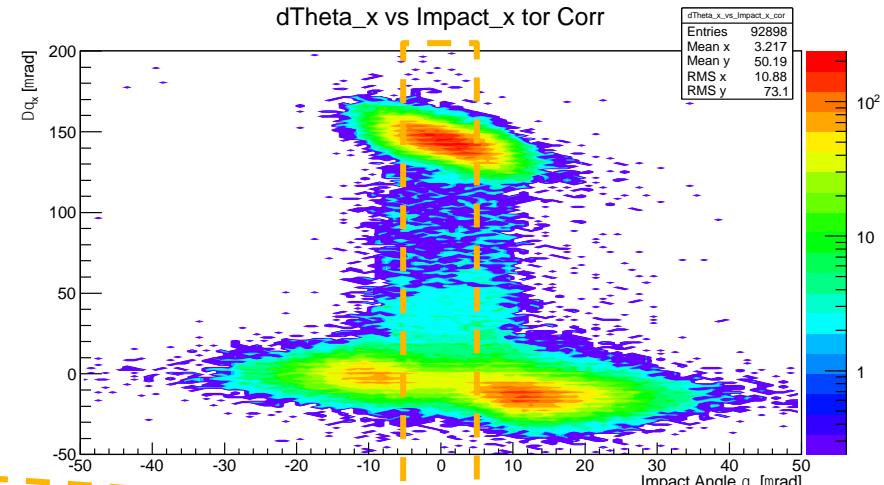
Channeling Efficiency

The channeling efficiency is evaluated at two different angular cuts $\pm 5 \mu\text{rad}$ and $\pm 10 \mu\text{rad}$, that for 400 GeV/c protons represent the critical angle for channeling and two times the critical angle, respectively.

Projecting on the y axis the kick, with the cut described, are obtained.



$\pm 5 \mu\text{rad}$



$$\eta_{ch}^{\theta_x^{\text{cut}}} = \frac{N_{ch}^{-\theta_x^{\text{cut}} < \theta_x^{\text{in}} < \theta_x^{\text{cut}}}}{N^{-\theta_x^{\text{cut}} < \theta_x^{\text{in}} < \theta_x^{\text{cut}}}}$$

$$\eta = 0.69 @ \pm 5 \mu\text{rad}$$

$$\eta = 0.53 @ \pm 10 \mu\text{rad}$$

Dechanneling length

On the same histogram the dechanneling length analysis is also performed

This is a key parameter to improve simulations.

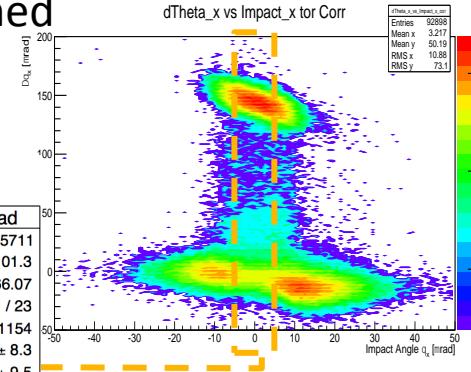
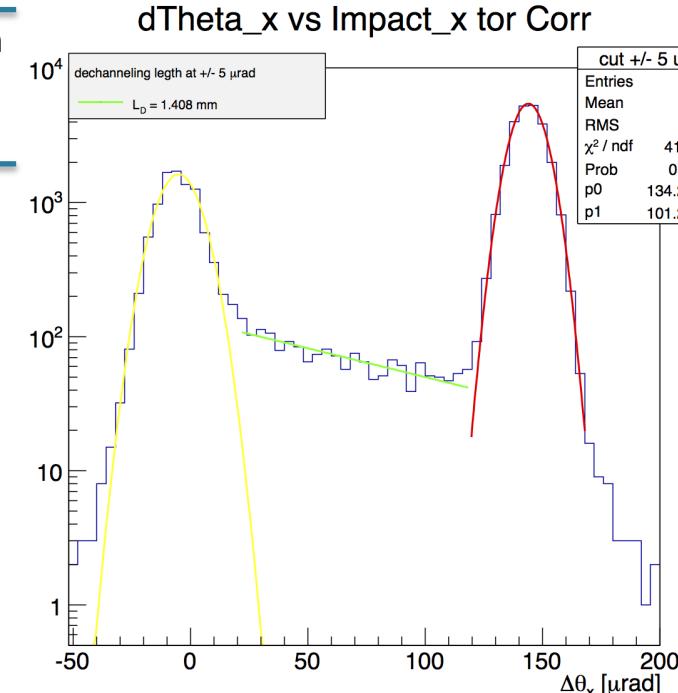
The dechanneling probability is described as an exponential decay as a function of the kick angle



the characteristic dechanneling length is calculated from an exponential fit in the dechanneling region.

$$L_d = 1.41 @ \pm 5 \mu\text{rad}$$

$$L_d = 1.23 @ \pm 10 \mu\text{rad}$$



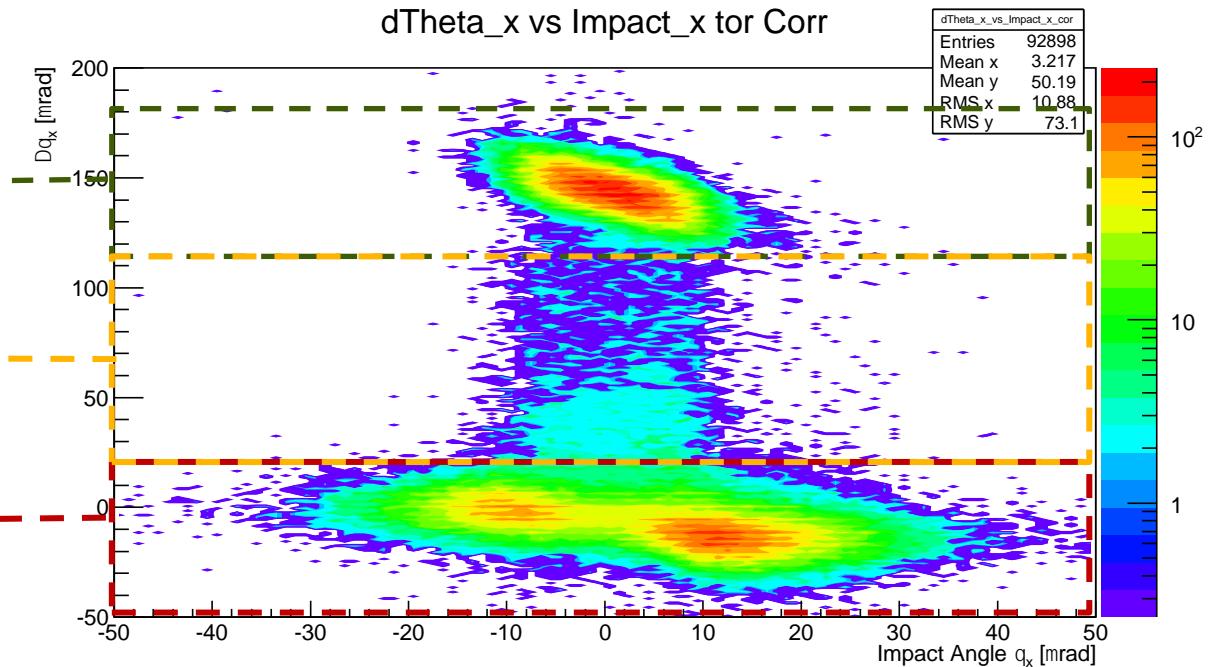
Deflection region definition

The three regions identified in the deflection distribution are selected and studied in detail.
This studies are perfo

Channeling –
 $[\mu_c - 3\sigma_c, \mu_c + 3\sigma_c]$ μrad

Dechanneling –
 $[\mu_t + 3\sigma_t, \mu_c - 3\sigma_c]$ μrad

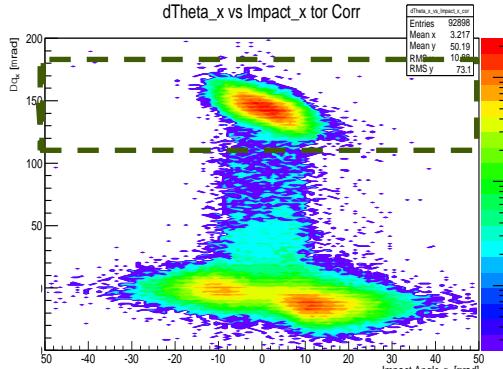
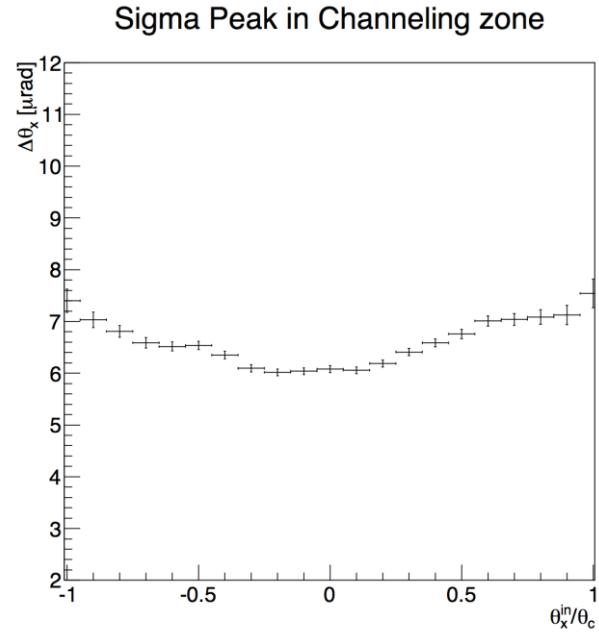
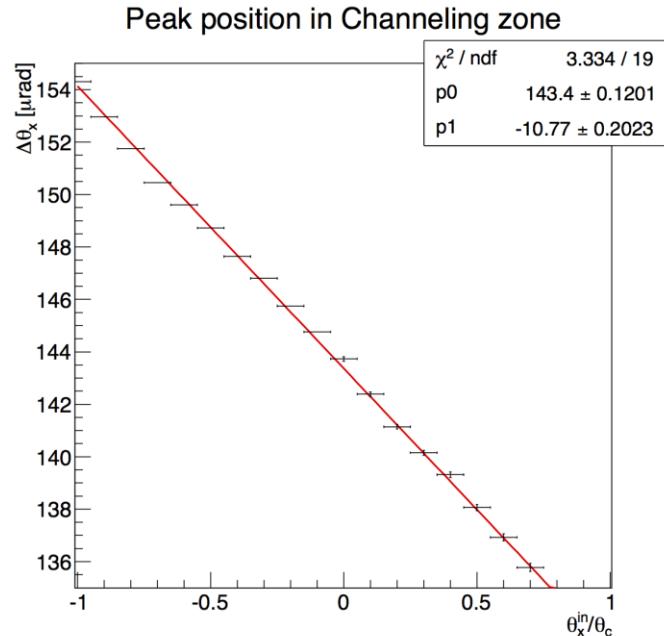
Transition –
 $[-50, 20]$ μrad



Channeling zone

The channeling peak position are studied as a function of impact angle

Also the distribution sigma is plotted as a function of impact angle

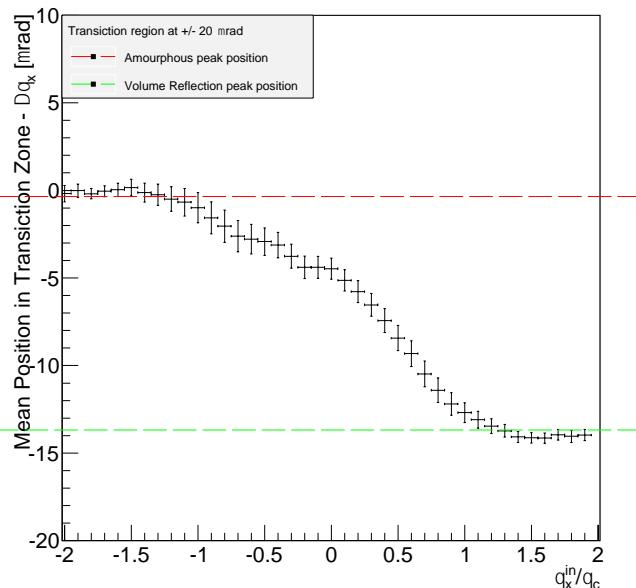


Transition zone

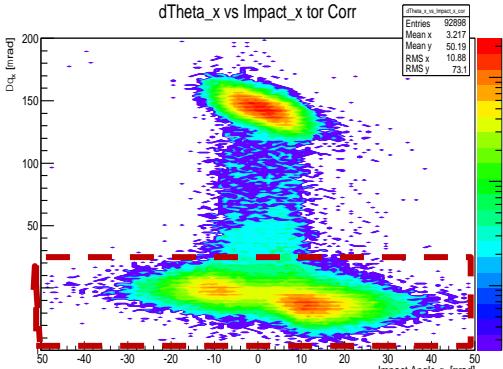
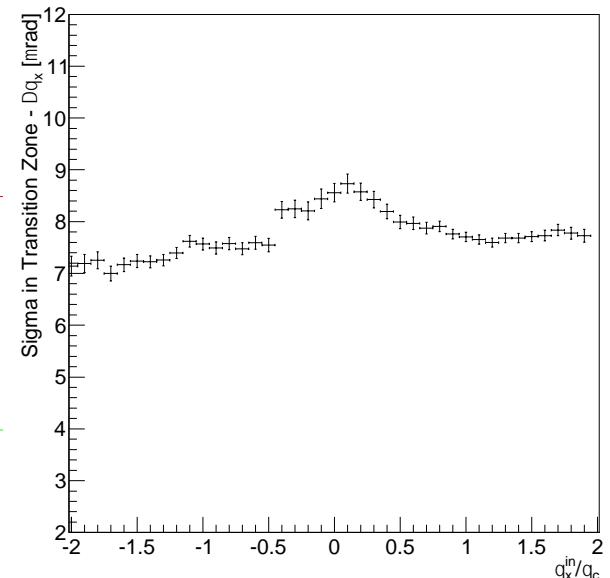
The **transition zone** describes how the amorphous region is transformed to the volume reflection region after the channeling region

The trend of the peak plotted would be useful for a confrontation with the crystal simulation routines.

Peak position in transition zone

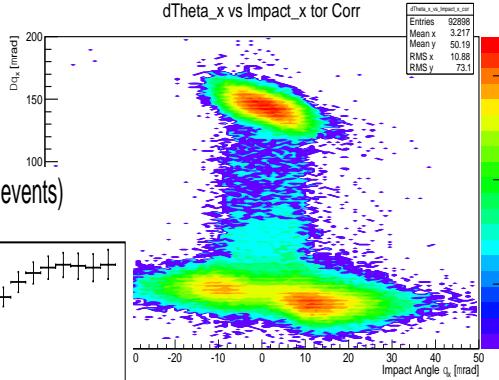
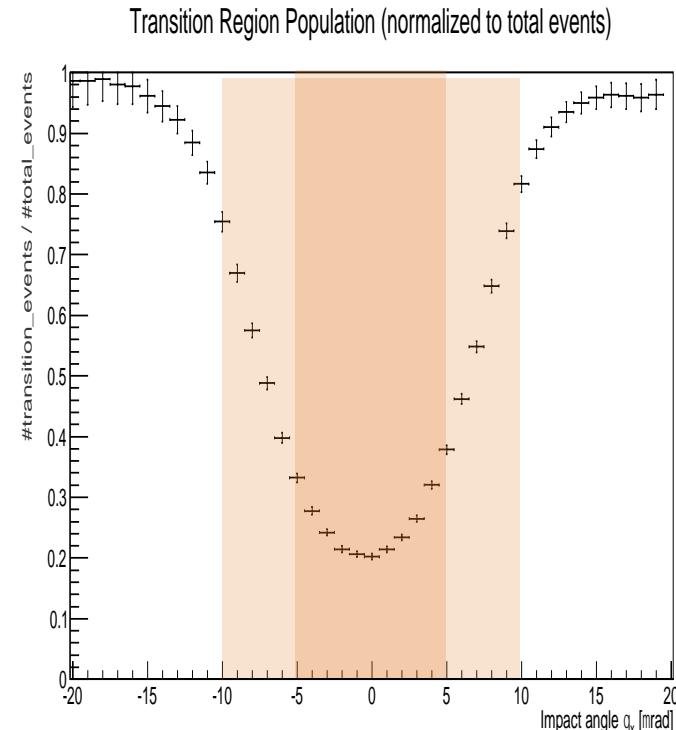
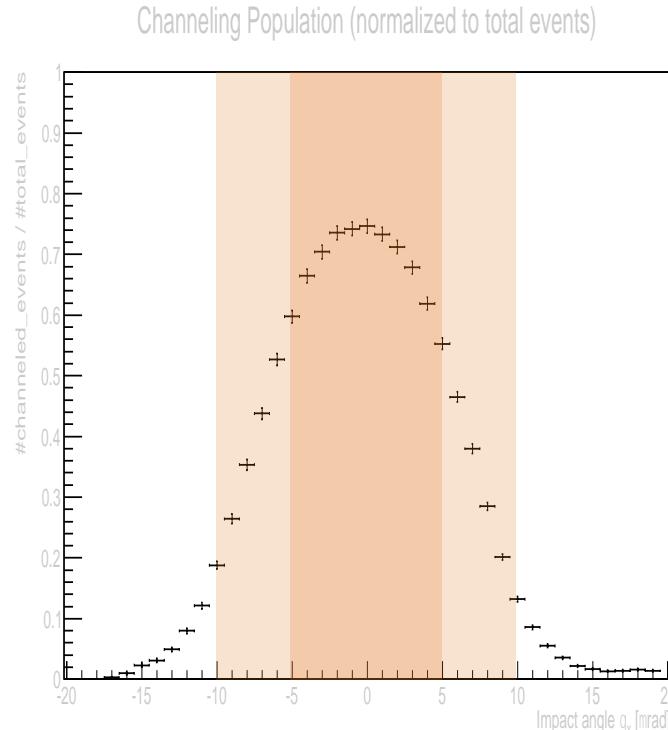


Sigma peak in transition zone



Population

The population of the channeling and transition region are evaluated as a function of the impact incoming angle.



Conclusion

Achieved goals :

- ✓ A complete analysis of the crystal tested in the H8 line (2010-2012) has been done.
- ✓ The results of the present analysis fit the results in literature.
- ✓ Many fine systematic effects were analyzed for the first time (dechanneling length).
- ✓ A complete list of experimental data and inputs has been provided for crystal code developers.

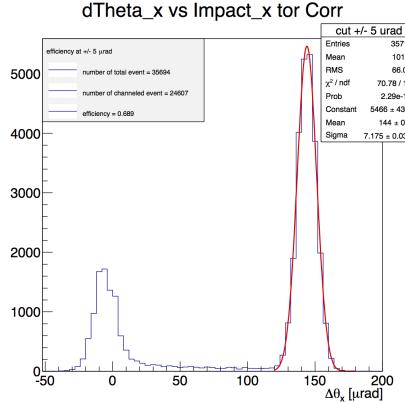
BACKUP

Deflection distribution

The same gaussian fit gives also the sigma distribution value

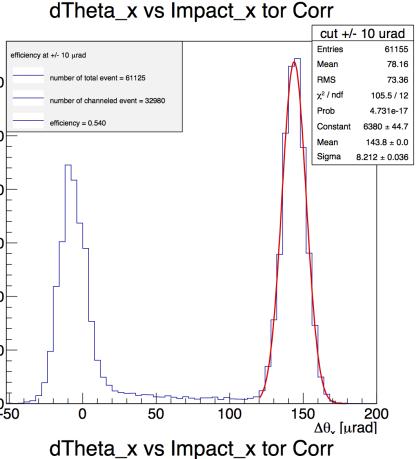
CH - $\pm 5 \mu\text{rad}$

Mean $144.0 \pm 0.1 \mu\text{rad}$
Sigma $7.18 \pm 0.04 \mu\text{rad}$



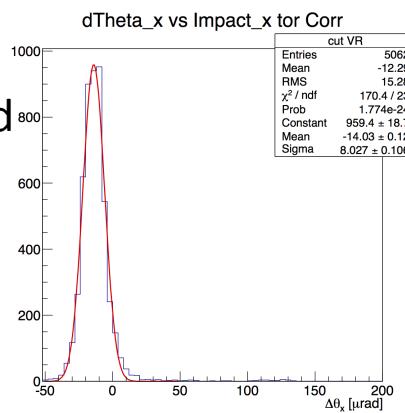
CH - $\pm 10 \mu\text{rad}$

Mean $143.08 \pm 0.1 \mu\text{rad}$
Sigma $8.21 \pm 0.04 \mu\text{rad}$



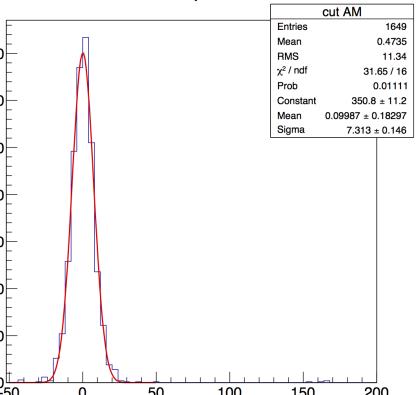
VR – [20,30] μrad

Mean $-14.03 \pm 0.12 \mu\text{rad}$
Sigma $8.03 \pm 0.11 \mu\text{rad}$



AM – [-30,-20] μrad

Mean $0.01 \pm 0.18 \mu\text{rad}$
Sigma $7.31 \pm 0.15 \mu\text{rad}$

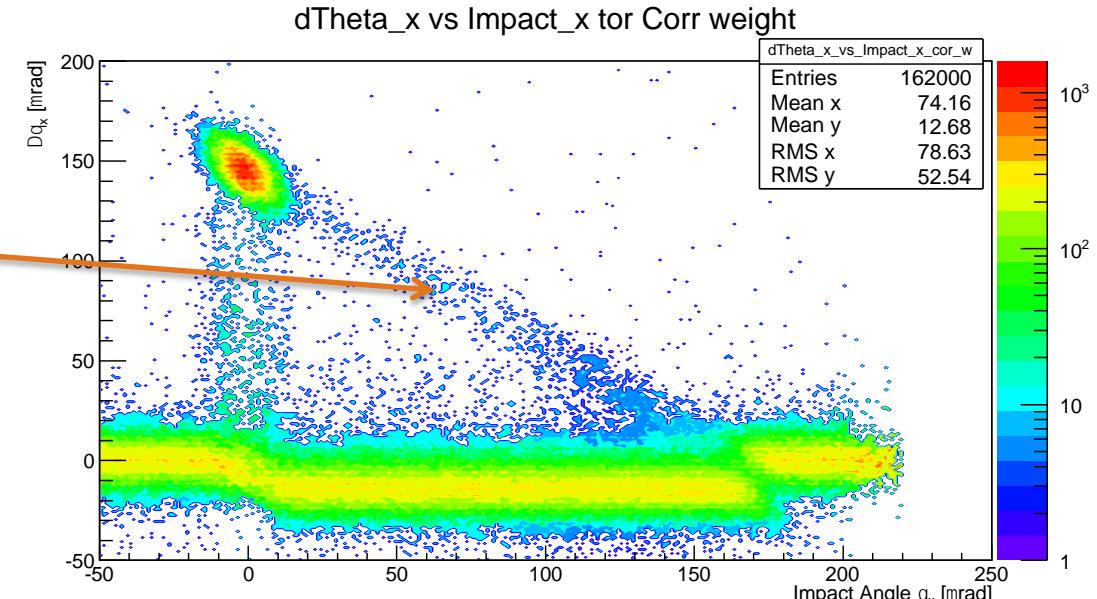


Angular Scan Analysis

The angular scan has the same geometrical cuts and torsion correction.

The deflection x as a function of the impact x angle is shown

In this case we can see all **the volume reflection region**, and the halo that have the same trend of the channeling spot is the **volume capture region**.

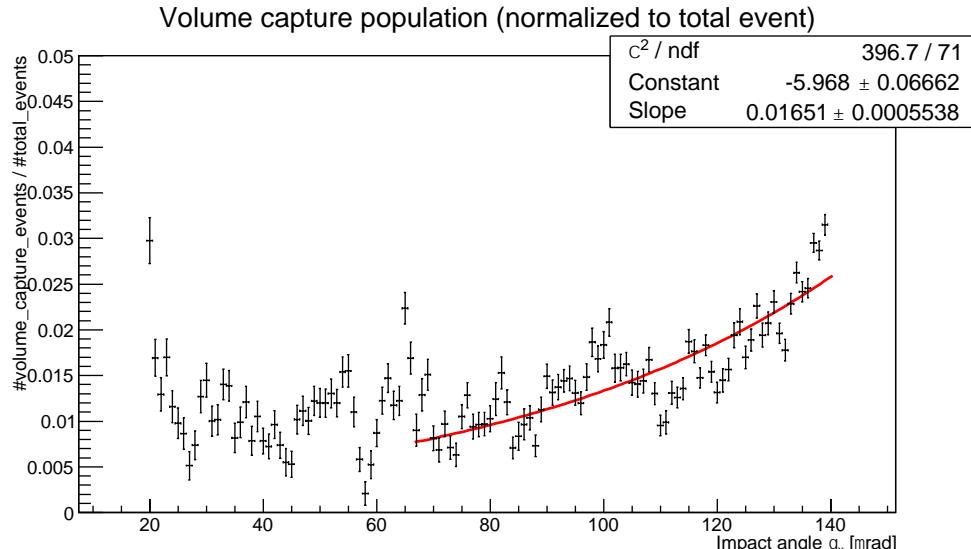


Volume capture analysis

A first try for a description is under investigation : in this region are present both volume capture and dechanneling.

As described in [2] the fraction of channeled particle is $f(z) \propto Cost * \exp(-z/L_D)$

So, if we perform an exponential fit in the rising zone we can obtain a characteristic length which should be proportional to L_D .



This length can be obtained as

$$L_C = R * (\alpha_{bend} - \theta^*)$$

where θ^* is the fit parameter.

This length is estimated to be $\sim 1,1$ mm

The same analysis on the STF50 and on STF38 give nearly the same results.

[2] V. M. Biryukov , Y. A. Chesnokov, and V. I. Kotov., *Crystal channeling and its application at high-energy accelerators*. Springer, 1997.

Dechanneling length

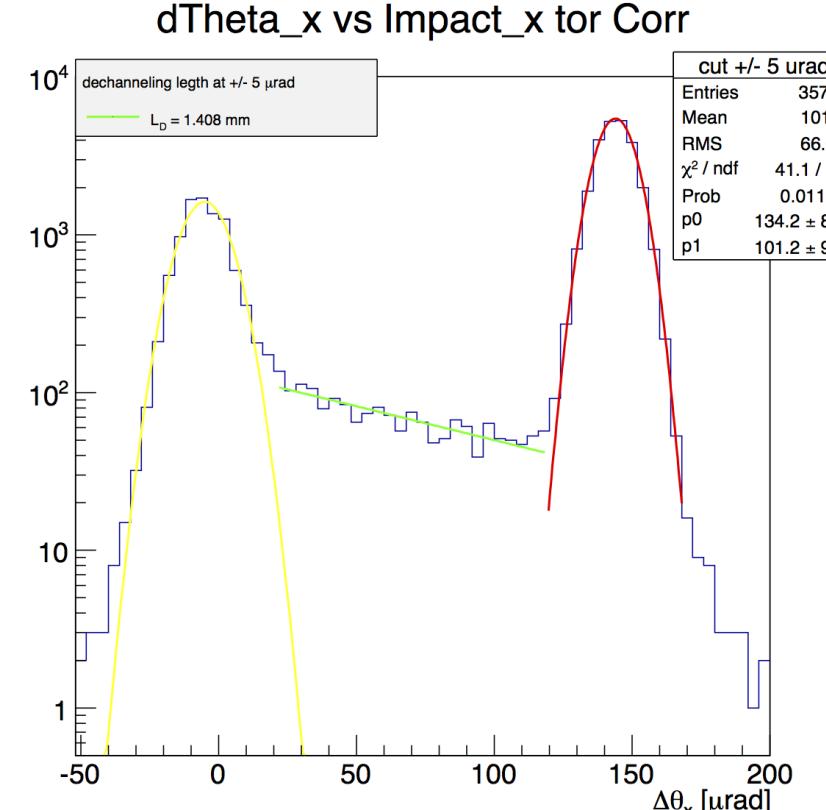
Dechanneling Length

$\pm 5 \mu\text{rad}$

The exponential fit gives the dechanneling angle.

To get the dechanneling length we have to multiply the parameter by the bending radius of the crystal.

Variation on the fit range don't show significant changes of the dech length, that is estimated to be $\sim 1.4 \text{ mm}$



Webpage

A webpage is ready, and will be soon on line.

It contains the necessary input to reproduce the experimental data of the reference case.

Crystal Collimation

H8 Single Pass Test Data Analysis

Inputs for Simulation Routines

[Scope](#)
[Requirements for comparison](#)
[Inputs](#)
[Reference case, STF45](#)
[Complete list of crystal and beam parameters](#)

Scope

The analysis of data from the H8 beam tests for bent crystals has been performed. All crystals tested in the runs 2010-2012 have been consistently analyzed with the same analysis tools.

This provides inputs for crystal simulation routines for comparison against experimental data. In particular, in view of the upcoming [Crystal Channeling Workshop](#), the relevant parameters for each crystal are made available.

The case of a reference crystal with the inputs and the minimum required analysis for the comparison of the measurement of interaction of a 400 GeV proton beam with a bent crystal with the results from simulation routines is also presented.

This crystal has been selected because the experimental data were taken in well controlled conditions and with adequate statistics allowing the relevant parameters to be calculated with small error.

The characteristics of LHC crystals are also provided in order to allow the comparison of the different routines in the simulations of the interaction of a crystal with a 7 TeV proton beam.

Requirements for comparison

Measurement vs. Simulation

The inputs should be used to simulate the interaction of 400 GeV protons with a bent crystal ($\Theta_c=10 \mu\text{rad}$). In particular, at least for the reference crystal, STF45, the following experimental results should be reproduced by simulation tools with a minimum statistics of 10^5 :

- [Distribution of deflection angle vs. impact angle](#)
- [Distribution of deflection angle for impact angle selection of \$\pm 5\$ and \$\pm 10 \mu\text{rad}\$, with calculation of:](#)
 - [Channelling angle and its distribution sigma](#)
 - [Channelling length](#)
- [Volume reflection angle and its sigma](#) from distribution of deflection angle for an impact angle selection in the range $(+2\theta_c, +3\theta_c)$
- [Anomalous angle and its sigma](#) from distribution of deflection angle for impact angle selection in the range $(-3\theta_c, -2\theta_c)$
- [Channelling angle and its sigma](#) as a function of impact angle
- [Transition region peak and its sigma](#) as a function of the impact angle
- [Channelling and dechannelling population](#) (normalized to total number of particle) as a function of the impact angle

We also present all the characteristic for all the analyzed crystals.

Crystal Collimation

H8 Single Pass Test Data Analysis

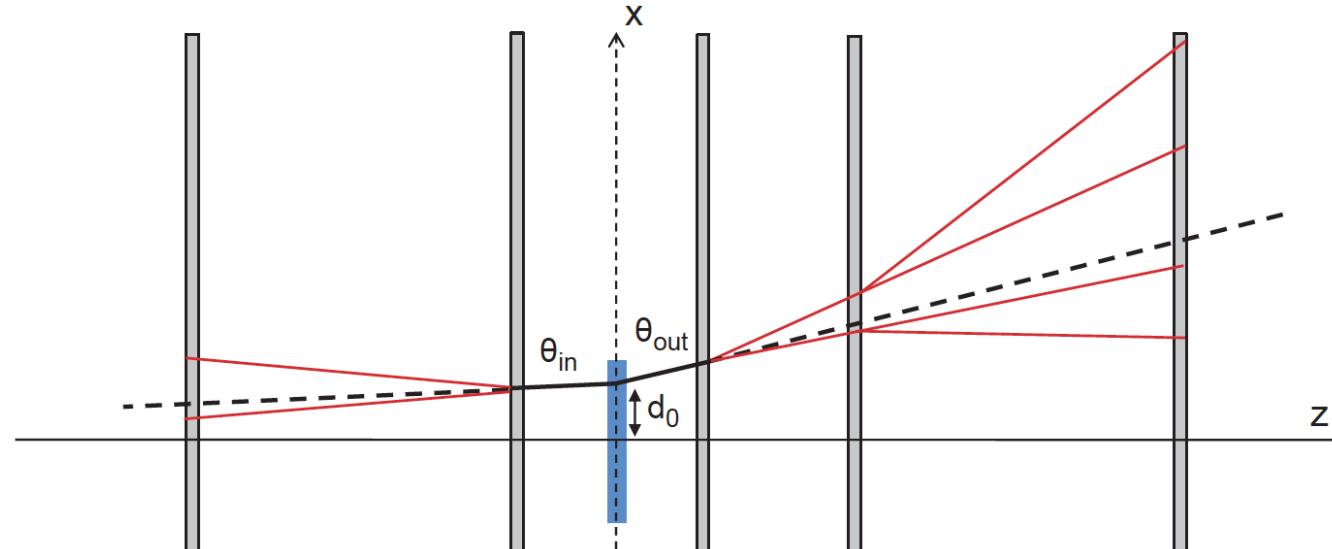
Inputs for Simulation Routines

[Scope](#)
[Requirements for comparison](#)
[Inputs](#)
[Reference case, STF45](#)
[Complete list of crystal and beam parameters](#)

The results of the comparison will be discussed in the upcoming [Crystal Channeling Workshop](#)

Track reconstruction

- Only one track per event is reconstructed.
- The event reconstruction uses the first two and the last two detectors to measure the **incoming** and the **outgoing angle** of the tracks, respectively.
- The **impact point at the crystal position** is given by the interpolation of the incoming and the outgoing tracks.



Experimental data structure

A complete experimental characterization of a crystal consists of different acquisition runs

- “Alignment” run: used to validate the telescope performance without crystals on the beam line
- Transverse position scan: used to find the crystal, when it crosses the beam
- Crystal angular scan: used to identify the interesting angular regions - amorphous, channeling and volume reflection orientations.
- High statistic acquisitions: performed in the region where we want fully analyze a given effect. Typically, done in the optimum channeling orientation.

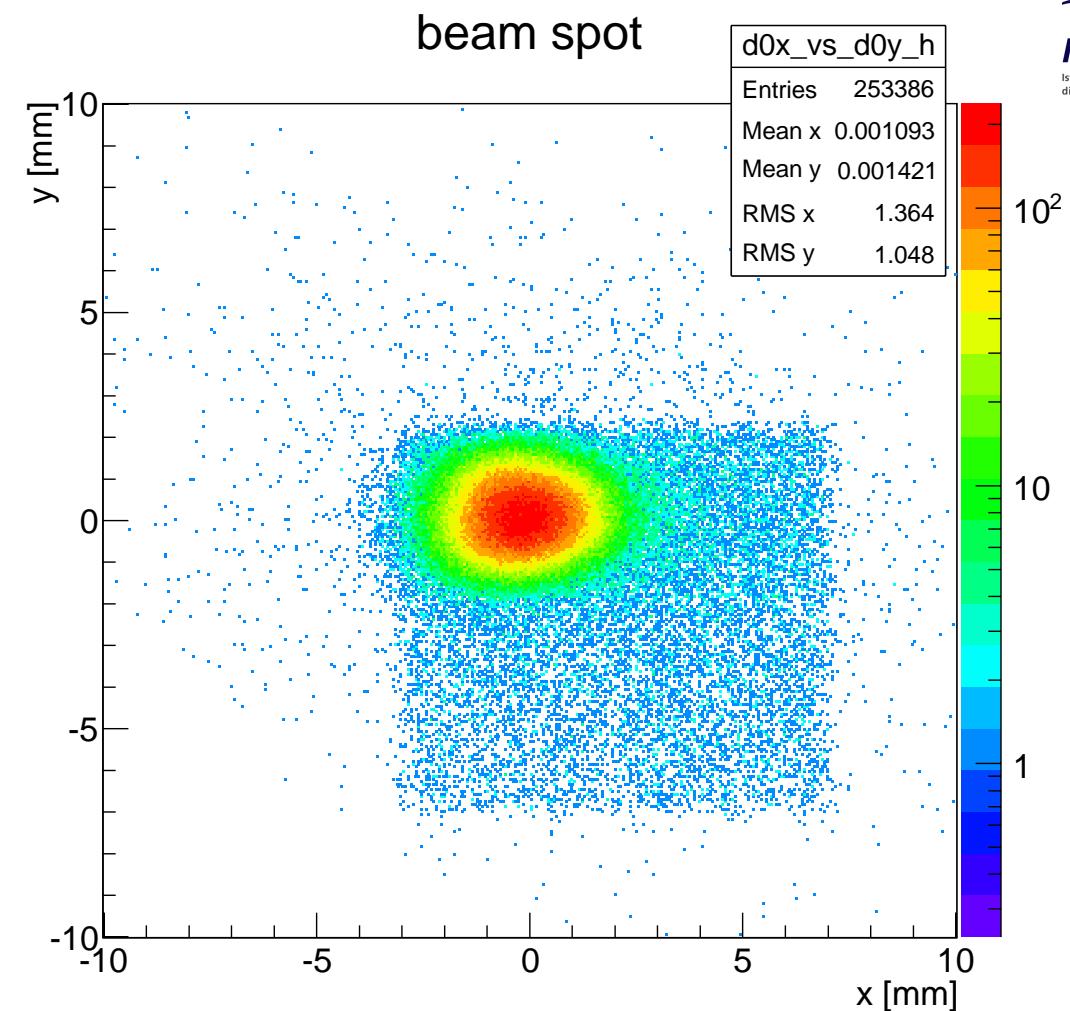
- With the crystal removed from the line is possible to measure the key parameters :
 - Beam divergence
 - Beam distribution
 - Telescope resolution

Alignment Run Analysis

The incoming beam spot can be well approximated by a **double Gaussian** (see next slide).

The surrounding background (square area in light blue) is given by the interaction of the beam particle with the micro collimators placed at the beginning of the line;

When the micro collimators are moved the shape of the background change.



Alignment Run Analysis

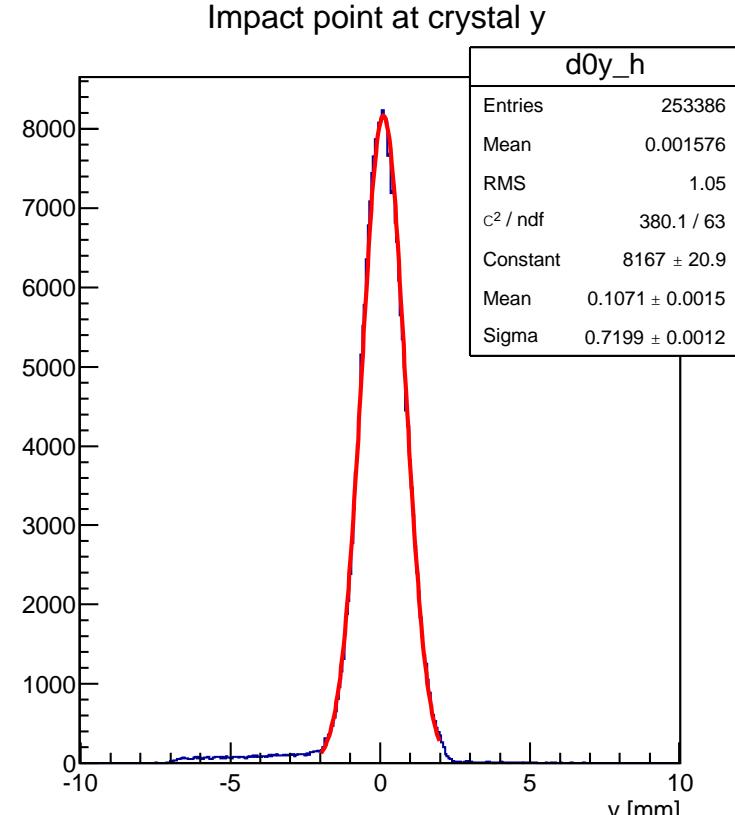
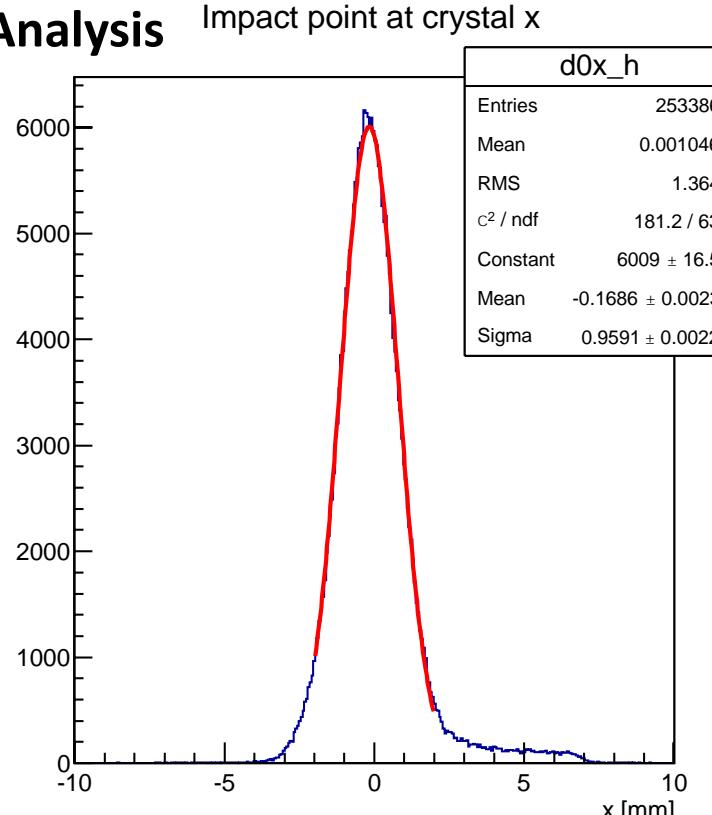
Here we can see the beam profile in the orthogonal plane.

Double Gaussian shape of the beam core



x sigma of 0.96 mm
y sigma 0.72 mm

The asymmetric tail are not fitted, because are the background due to the micro collimators.



Alignment Run Analysis

The beam divergence is found to be $10.67 \mu\text{rad}$ in x and $7.66 \mu\text{rad}$ in y.

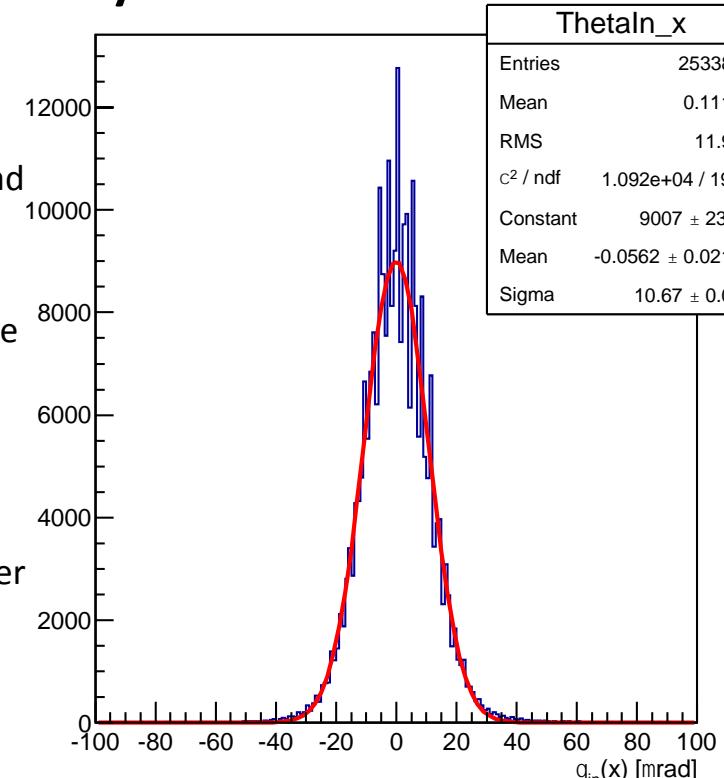
This characteristics are crucial for the key measurements.

The input angular distributions are bigger than θ_c

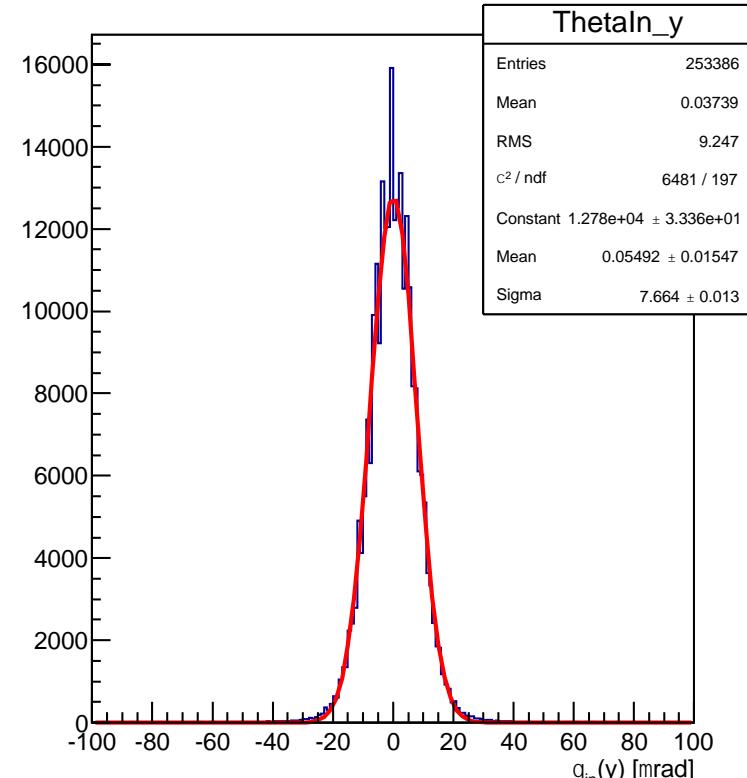


we need to apply a selection to analyze the different effects.

Thetain_x



Thetain_y



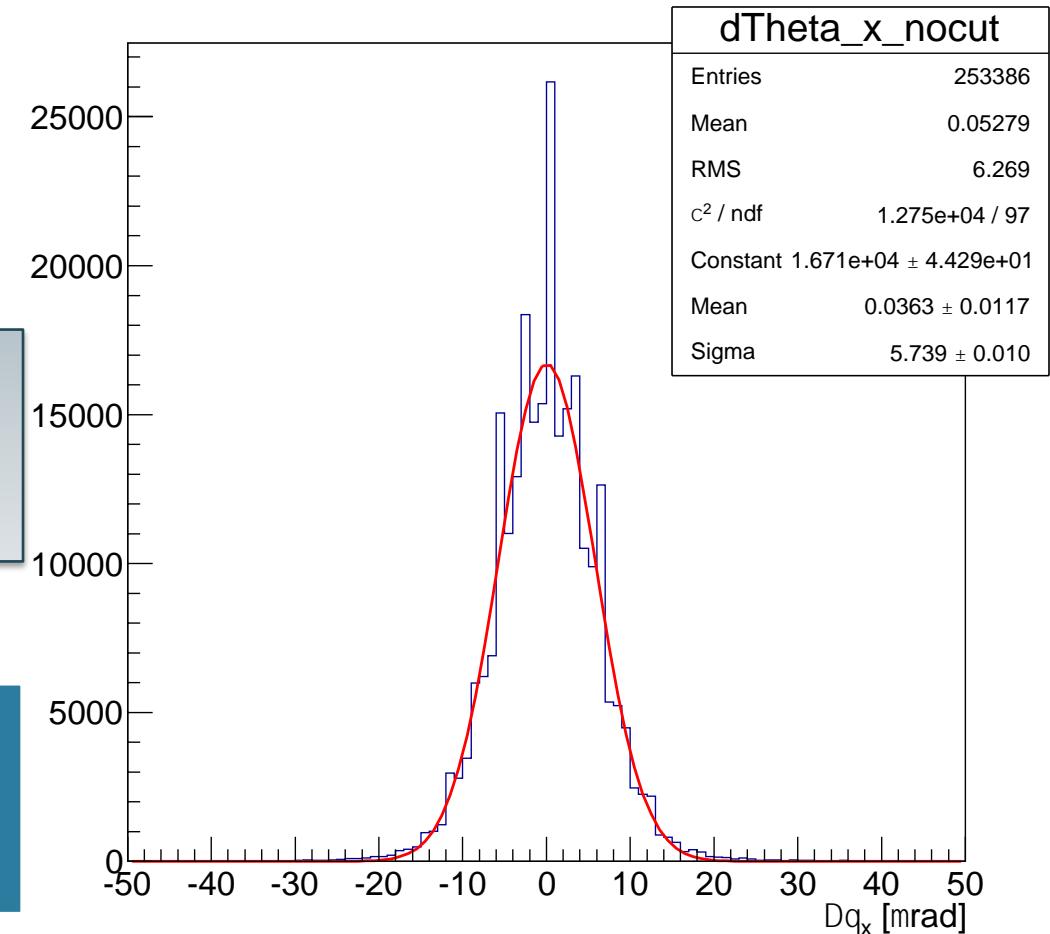
Alignment Run Analysis

This plot shows the difference between the outgoing and the incoming angle of the tracks without any object on the beam line.

The sigma of this distribution gives us the telescope resolution taking into account a variety of systematic effects, including scattering in air.

The resolution of the telescope is $5.7 \mu\text{rad}$
in good agreement with the resolution estimated in [1].

dTheta x no cut



[1] M. Pesaresi et al., *Design and performance of a high rate, high angular resolution beam telescope used for crystal channeling studies*, 2011 JINST 6 P04006

Alignment Run Recap

Each crystal has a good alignment run
If a run is missing, the closer one is used.

2010

2011

2012

Xtal	X Profile [mm]	Y Profile [mm]	X Divergence [μrad]	Y Divergence [μrad]	Resolution [μrad]
STF38	1,014	0,721	10,670	7,658	5,619
STF40	1,017	0,724	10,680	7,697	5,756
STF45	1,001	0,725	10,650	7,684	5,762
QMP27	1,017	0,724	10,680	7,697	5,731
STF47	1,063	0,949	11,730	8,964	5,283
STF48	1,055	0,960	11,880	8,982	5,302
STF49	1,075	0,979	12,170	8,973	5,259
QMP32	1,059	0,944	11,830	8,949	5,286
STF50	1,294	0,861	10,900	8,049	5,494
STF51	1,290	0,825	10,880	8,022	5,496
STF70	1,239	0,827	9,216	5,748	5,284
STF71	1,215	0,825	9,111	5,731	5,311
QMP26	1,269	0,821	9,134	5,774	5,421
QMP28	1,287	0,822	9,153	5,770	5,408
QMP29	1,239	0,827	9,216	5,748	5,284

Two kinds of cuts are performed on the initial distributions

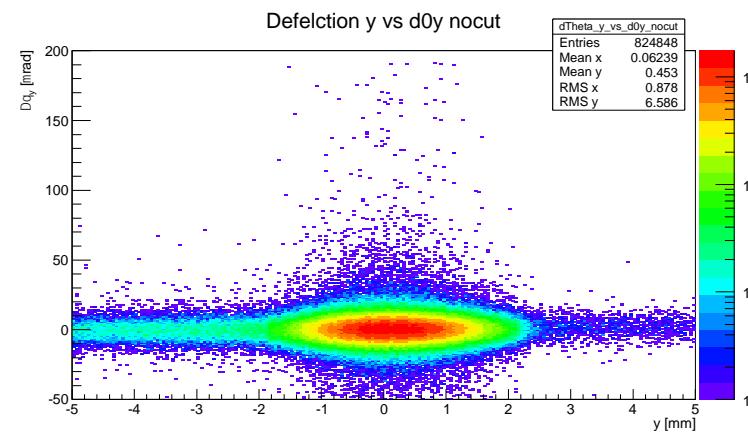
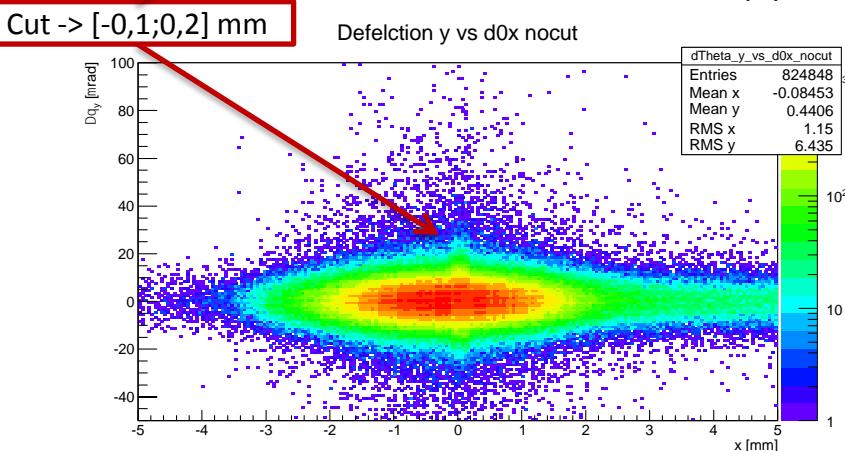
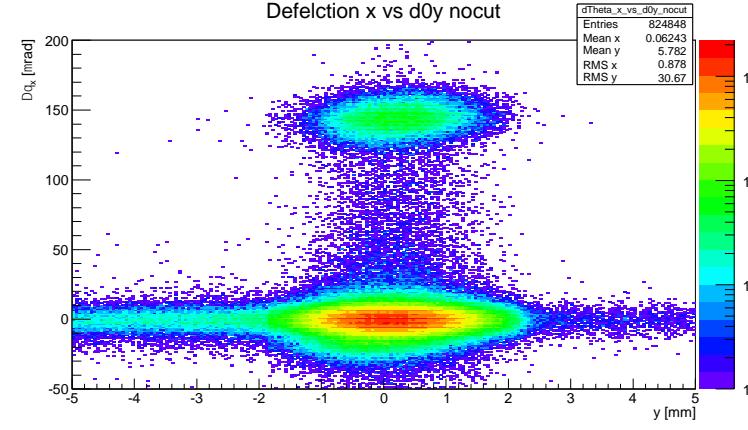
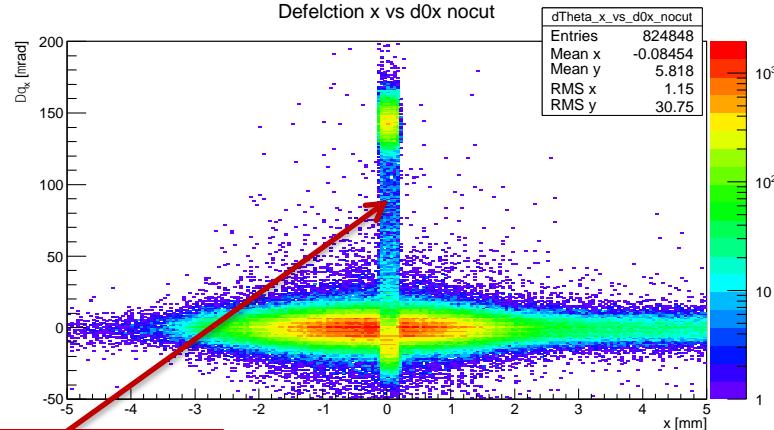
Geometrical cut

- The geometrical cuts are used to select particle impinging on the crystals and can be established by looking at the spread given by the multiple coulomb scattering.

Angular cut

- The angular cuts are performed to study the coherent interactions in crystals.

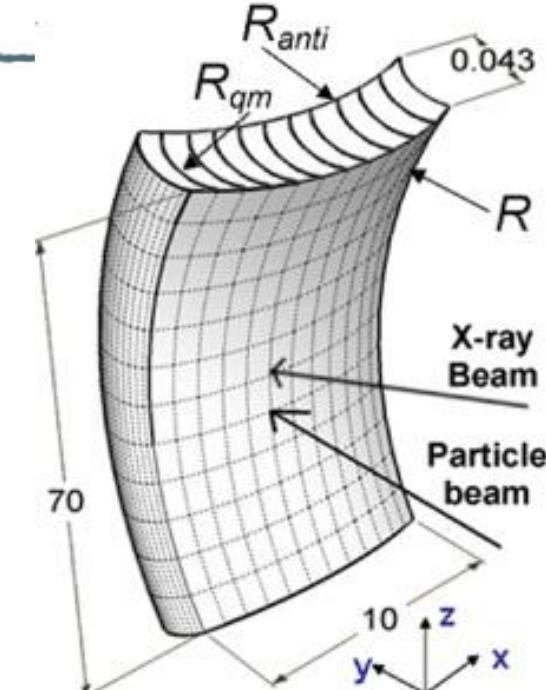
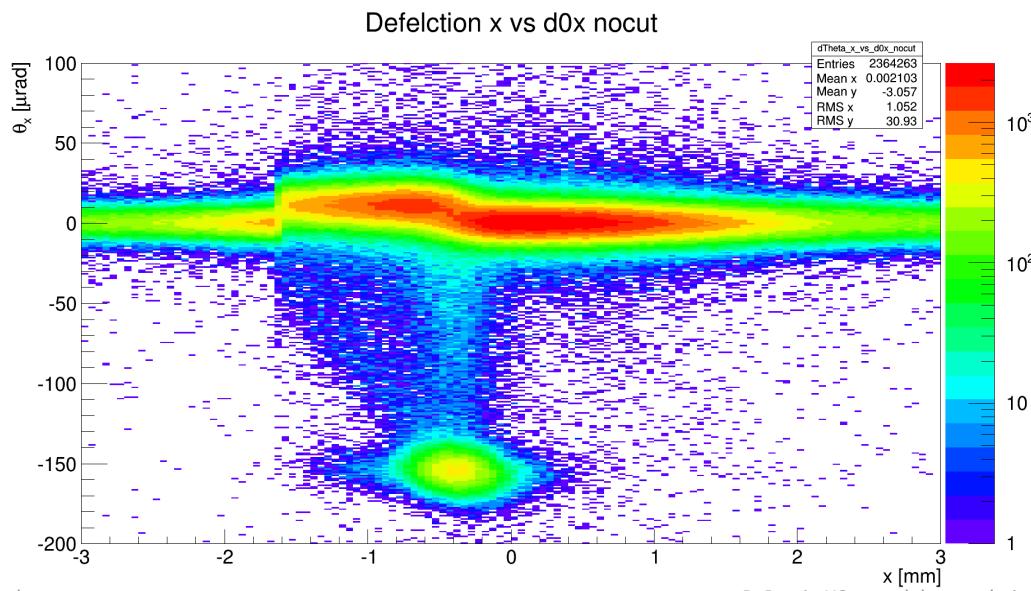
Geometrical cut



Example of QM

The crystal face xy is not flat, because of a characteristic additional bending on the QM crystal

- the kick as a function of the impact position (on a fixed crystal) shows a behavior similar to an angular scan.



We have to find a region where this curvature is negligible.

Cut recap

The table summarize the geometrical cuts made

2010

2011

2012

Xtal	X min [mm]	X max [mm]	Y min [mm]	Y max [mm]	Initial gonio angle [μrad]
STF38	-1,05	-0,05	-2,033	2,29	4712400
STF45	-0,10	0,20	-2,07	2,28	4714800
QMP27	-0,40	0,00	-1,50	1,50	
STF47	-0,90	1,10	-2,83	2,86	
STF48	-0,70	0,30	-2,87	2,89	4712947
STF49	-0,15	0,40	-2,91	2,96	4714776
QMP32	-0,25	-0,35	-1,50	1,50	
STF50	-0,70	0,30	-2,59	2,57	3143940
STF51	-1,10	0,90	-2,49	2,46	3146760
STF70	-0,525	0,425	-2,48	2,49	4744150
STF71	-0,40	0,60	-2,46	2,49	4746650
QMP26	-0,25	0,45	-1,50	1,50	
QMP29	-1,50	-0,20	-1,50	1,50	4749570

Torsion Analysis

For particles with the same impact angle, the torque applied to the crystals causes **different relative angles** with respect to the crystal planes. The difference is proportional to the y impact location.

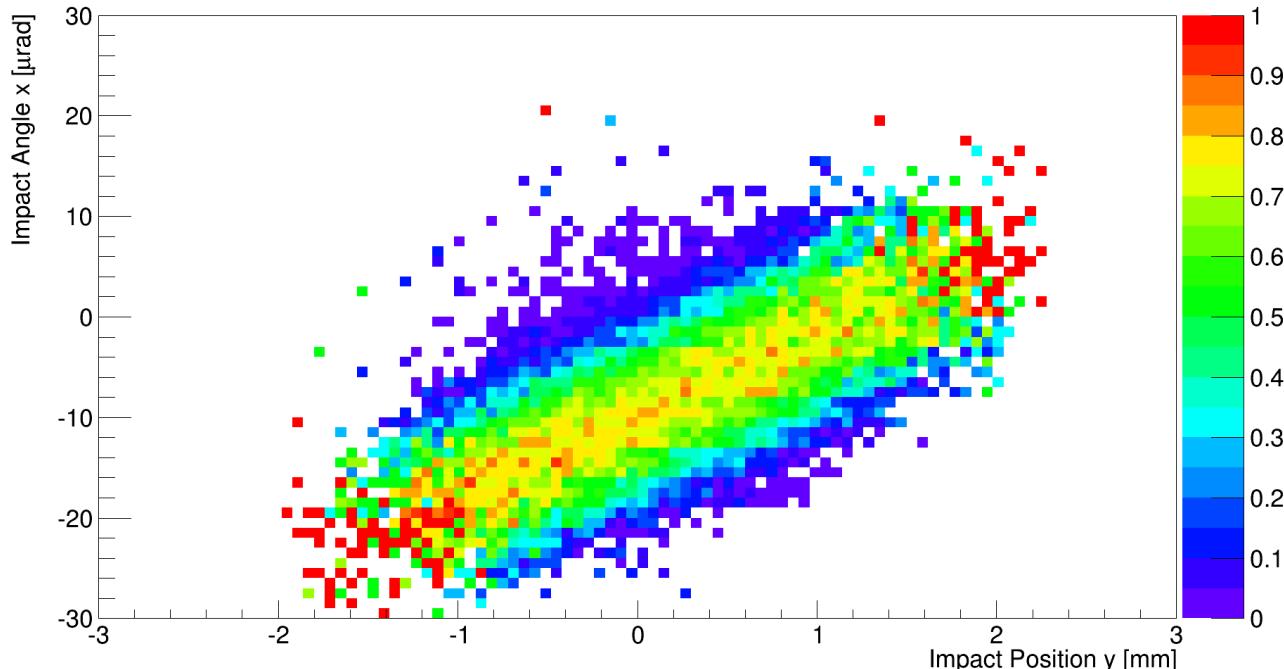
This effect is defined as **torsion**. As a result, the channeling efficiency varies with both the horizontal impact angle and the vertical impact position.

The channeling efficiency is defined as the number of channeled particles normalized to the total number of particles

$$\text{efficiency} = \frac{\text{Channeled Event}}{\text{Total Event}}$$

Channeled events are calculated from the deflection profile

Efficiency in Impact Angle x vs Impact Position y



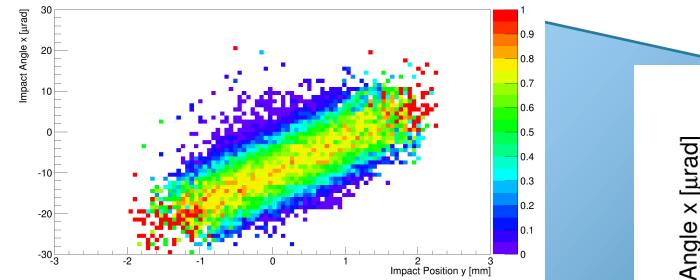
2-dimensional efficiency plot as a function of impact x angle and impact y points is obtained.

The center of gravity of each stripes on the impact y point axis gives the mean impact x angle as a function of vertical impact position

Efficiency vs. Impact angle x vs. Impact y

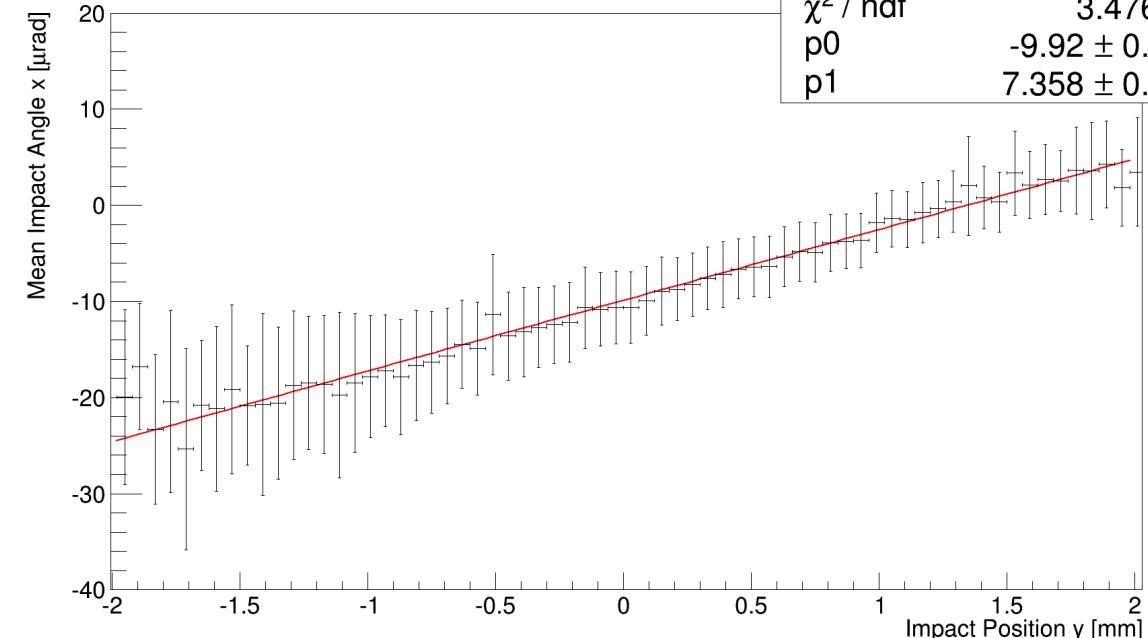
STF48

Efficiency in Impact Angle x vs Impact Position y



Mean Impact Angle

χ^2 / ndf	3.476 / 64
p0	-9.92 ± 0.5784
p1	7.358 ± 0.5645



The linear regression gives the **torsion value** and the initial impact angle offset

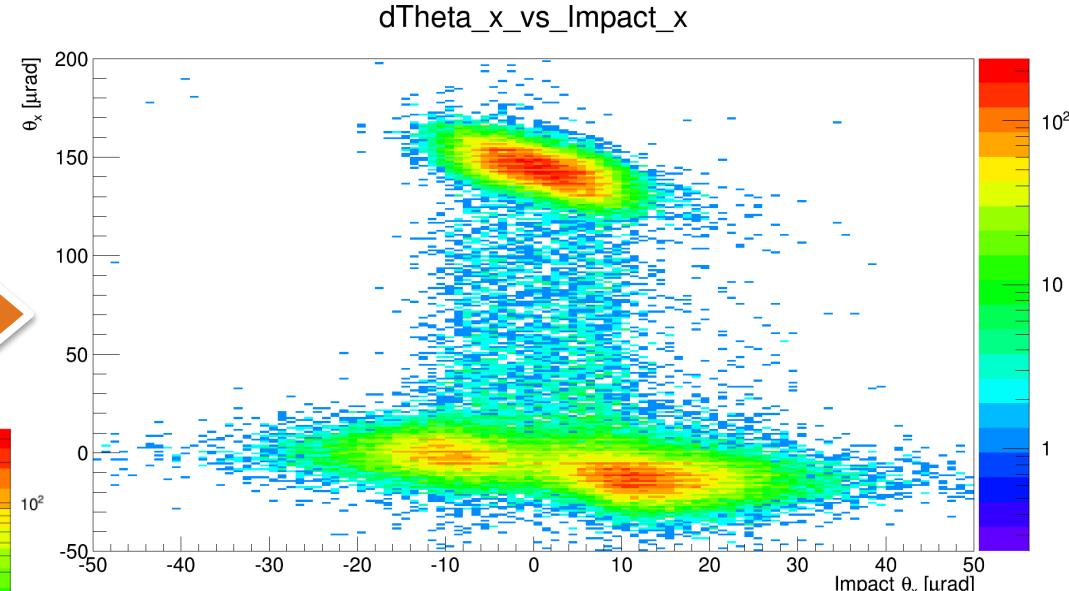
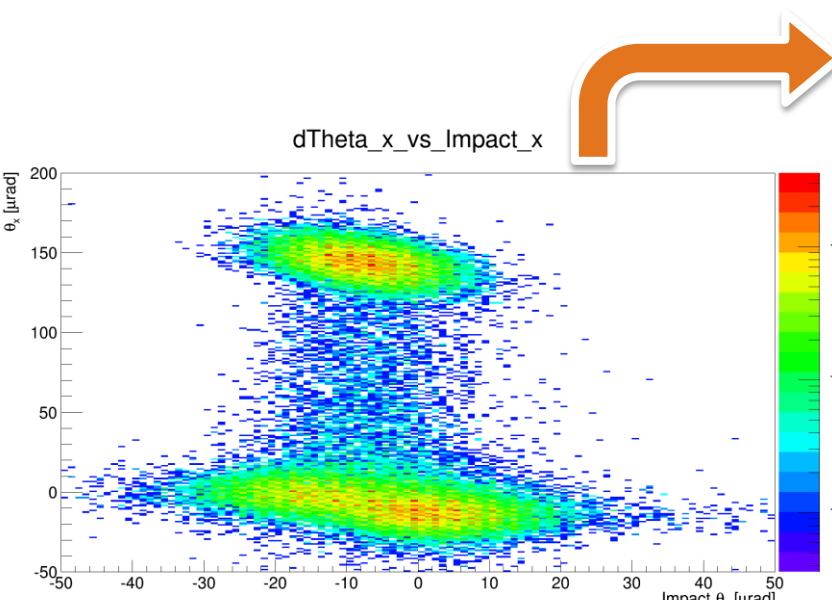
Torsion correction

If we define the impact x angle as

$$\theta_{corr}(x) = g.Pos(x) + \theta_{in}(x) - g.Pos_{init}(x)$$

The torsion correction made is

$$\theta_{corr}(x) - (torsion * Impact(y) + g.Pos_{offset}(x))$$



The plots show the x deflection as a function of the impact x angle before and after the torsion correction

Torsion Recap

2010

Xtal	Initial gonio angle [μrad]	Initial gonio angle [μrad]
STF38	-5,032	-5,515
STF45	7,358	-9,920
QMP27	1,381	-0,351
STF47	-2,521	1,753
STF48	6,942	7,285
STF49	5,310	5,285
QMP32	-0,25	-0,35
STF50	4,998	-4,654
STF51	1,075	-2,193
QMP26	6,888	2,217
QMP29	-0,343	-0,873

2011

2012

The calculated torsions are summarized in this table

Channeling efficiency recap

2010

Xtal	$\pm 5 \mu\text{rad}$	$\pm 10 \mu\text{rad}$
STF45	0,69	0,54
QMP27	0,589	0,50

That is the recap of the channeling efficiency for the analyzed crystals

2012

Xtal	$\pm 5 \mu\text{rad}$	$\pm 10 \mu\text{rad}$
STF50	0,56	0,46
STF51	0,52	0,47
QMP29	0,66	0,56

2011

Xtal	$\pm 5 \mu\text{rad}$	$\pm 10 \mu\text{rad}$
STF47	0,56	0,48
STF48	0,55	0,43
STF49	0,47	0,35
QMP32	0,51	0,41

Dechanneling length recap

2010

Xtal	$\pm 5 \mu\text{rad}$	$\pm 10 \mu\text{rad}$
STF45	1,43	1,25
QMP27	1,15	1,35

That is the recap of the dechanneling length

2012

Xtal	$\pm 5 \mu\text{rad}$	$\pm 10 \mu\text{rad}$
STF50	1,52	1,37

2011

Xtal	$\pm 5 \mu\text{rad}$	$\pm 10 \mu\text{rad}$
STF48	1,525	1,414
STF49	0,19	0,17
QMP32	0,42	0,37

- 2010 data [/2010_09_16,_H8_re-recodata]
 - reconstruction problem
 - » Each variable is in the array “thetaln_x”, inside the “tracks” branch
 - The data was reprocessed because of a bug, but some interesting run is still missing
- 2011 data [/2011_09_07_recodata4]
 - Optimization problem
 - » Each variable in some branch is aa array (100 place), of which only the first spot (0) is the real data (should be reprocessed from CMS)
- 2012 data [/2012_10_12_H8_protons/Data1]
[/2012_10_12_H8_protons/Data2][/TB_22_06_2012_recodata]
 - Tree optimized and “performant”
 - » But run collected in different folder
 - data in [/TB_22_06_2012_recodata] is in a tree 2011 like
- Issue : several run is missing, so some crystals are unanalyzable

Xtla code	Year	Nominal Propety						Analyzed run			
		x [mm]	y [mm]	z [mm]	bending [µrad]	curvature [m]	torsion [µrad/mm]	miscut [µrad]	Alignment	HiStat CH	Angular scan
STF38A	2010	1	55	1,89	100		8,67	<10	545	546	546
STF40A	2010	0,475	55	1	150	6,67		70	347	383	364 386
STF45A	2010	0,3	55	2	150	13,33	3,3	70	406	410	408
STF47	2011	2	55	3,1	45	68,89	0,5	150	616	608	
STF48	2011	1	55	2	~170		0,5	140	628	630	629
STF49	2011	0,5	55	0,8	~270	TBD	<170		643	649	646
STF50	2012	1	2	170	11,76	TBD	70 ± 30		894	889	888
STF51	2012	2	3	45	66,67	TBD			904	899	897
STF70	2012	1	55	3	55		1		1192	1240	1238
STF71	2012	1	55	3	55		1		1174	1191	1188

Missing re-recoData
2010

Missing
angular scan

Missing
Hi stat
ch

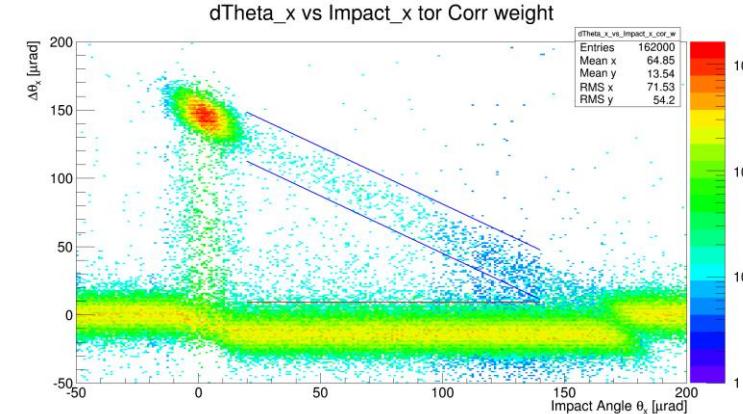
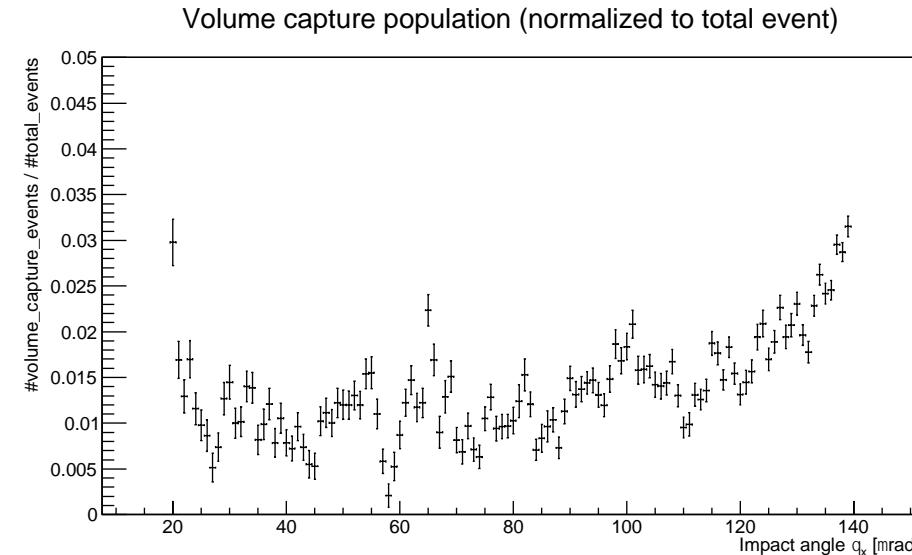
Bad Angular
Scan
Moving backward

Xtla code	Year	Nominal Propety						Analyzed run			
		x [mm]	y [mm]	z [mm]	bending [µrad]	curvature [m]	torsion [µrad/mm]	miscut [µrad]	Alignment	HiStat CH	Angular scan
QMP26	2012	18	13	1,973	50			<100	1000	1012	1011
QMP27	2010			1,77	116	15,26			347	348	321
QMP28	2012			6	~50				1024		1028
QMP29	2012			6	~50				1192	1197	1196
QMP32	2011			0,96	~175				569	572	570

Volume capture analysis

We define the region of captured particle as the area within 3σ of the trend of the channeled spot

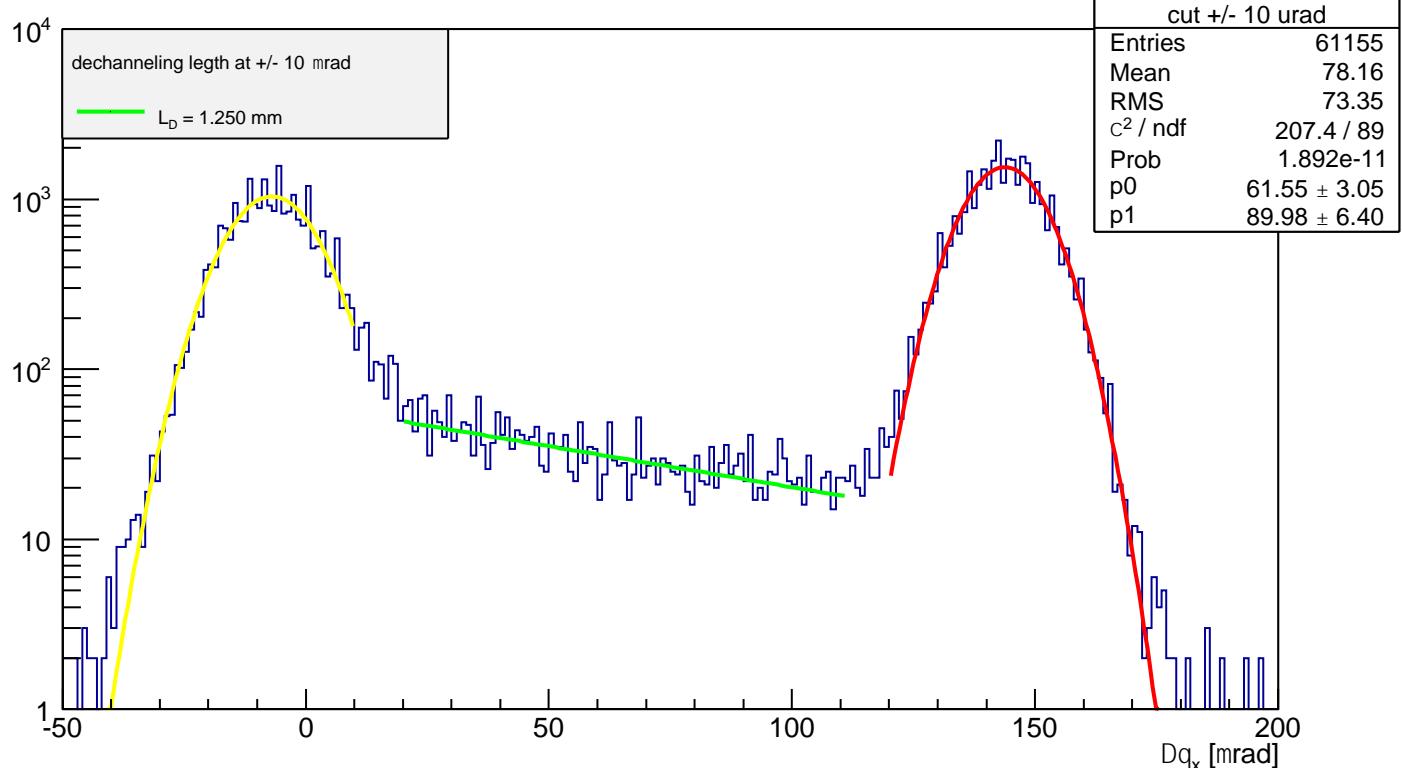
The **captured population** is plotted as a function of the impact x angle. The rise in the end of reflection region is a well-known behavior.



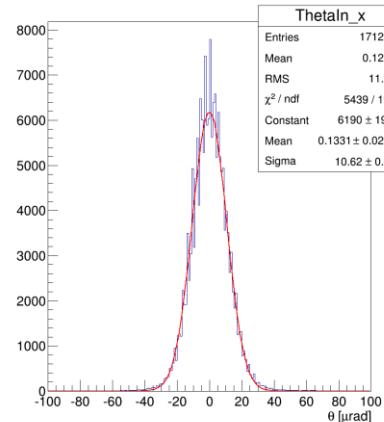
This analysis is performed for the first time, we are looking for a model that describes the trends observed.

dTheta_x vs Impact_x tor Corr

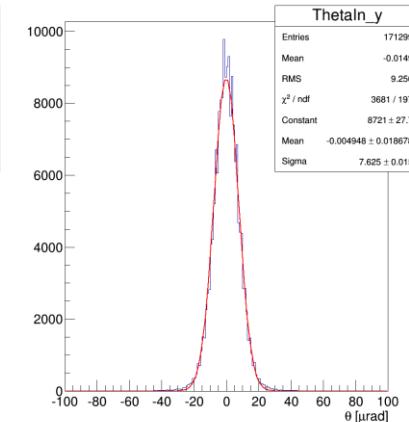
Dechanneling Length
 $\pm 10 \mu\text{rad}$



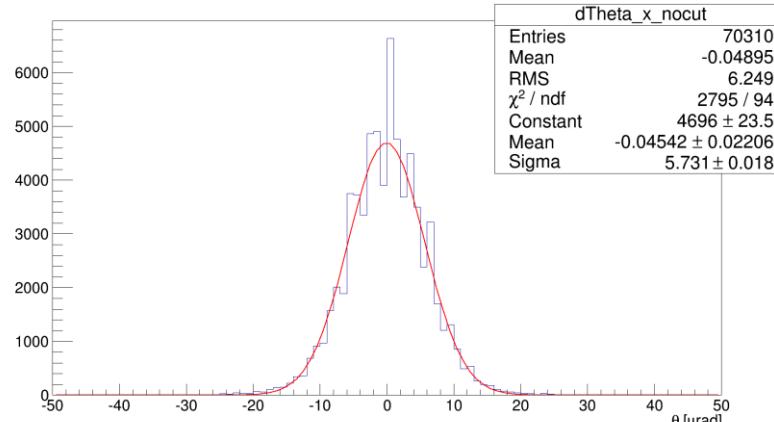
Thetain_x



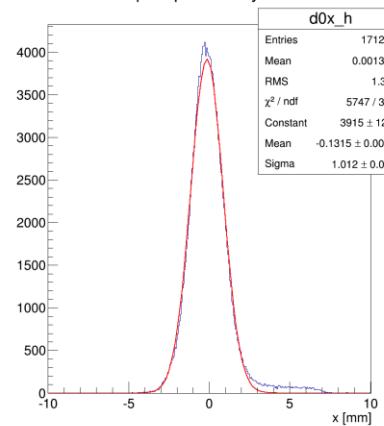
Thetain_y



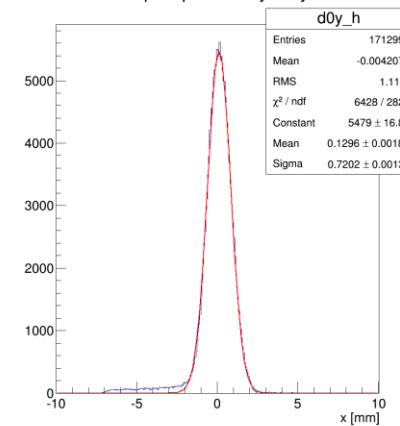
dTheta x no cut



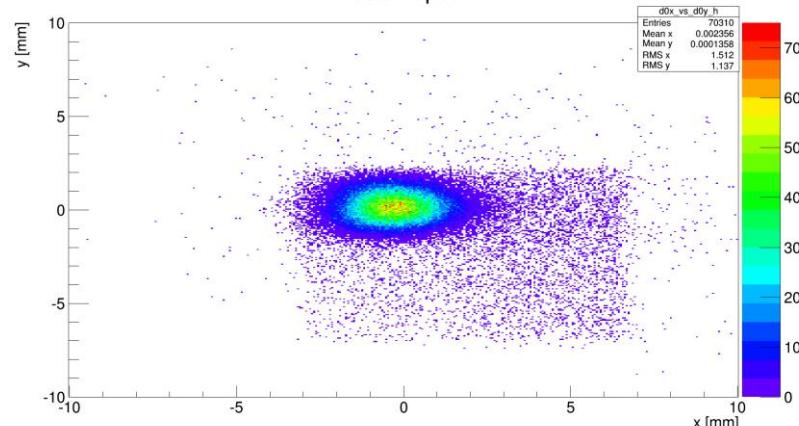
Impact point at crystal x



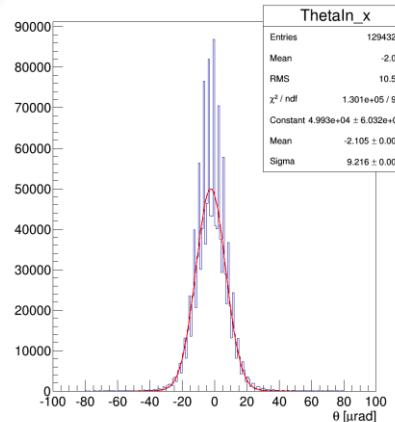
Impact point at crystal y



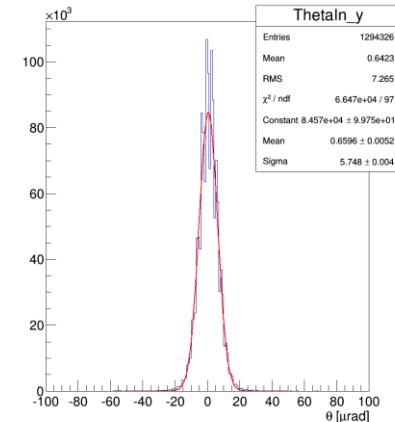
beam spot



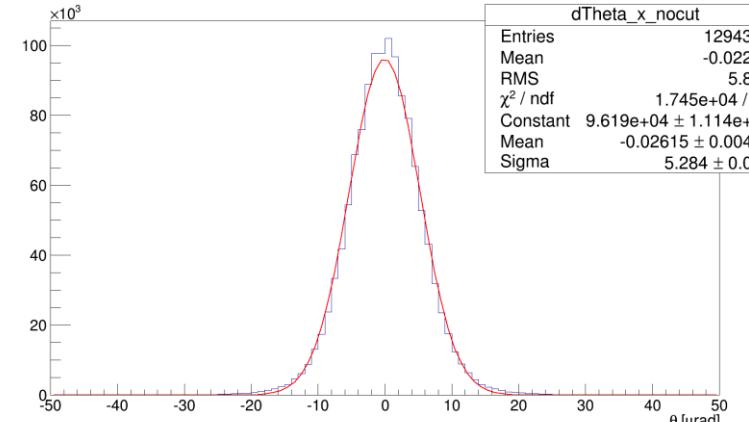
Thetain_x



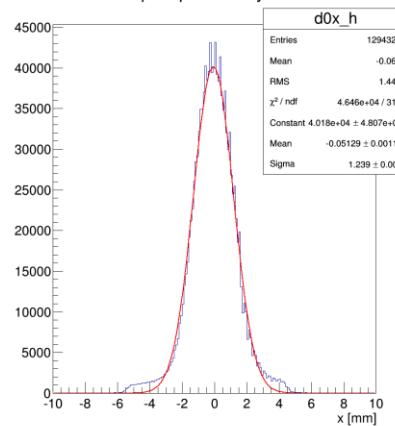
Thetain_y



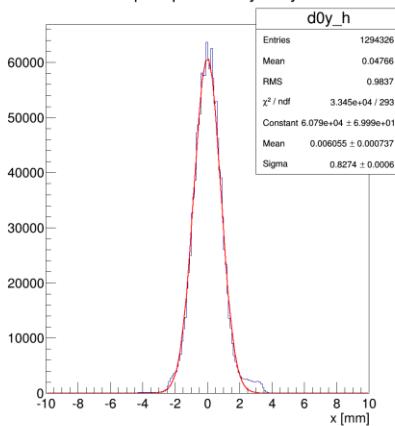
dTheta x no cut



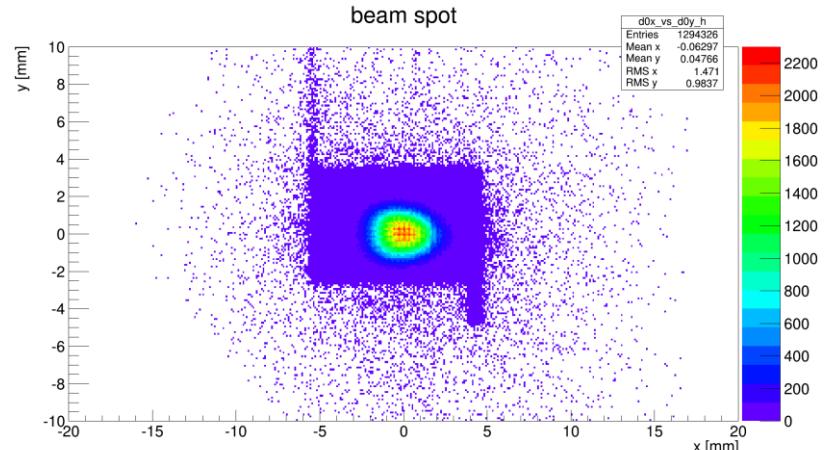
Impact point at crystal x



Impact point at crystal y



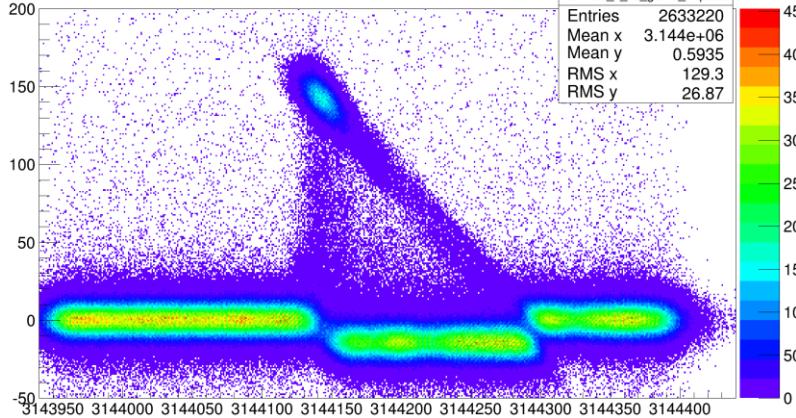
beam spot



Angle Scan Run Analysis

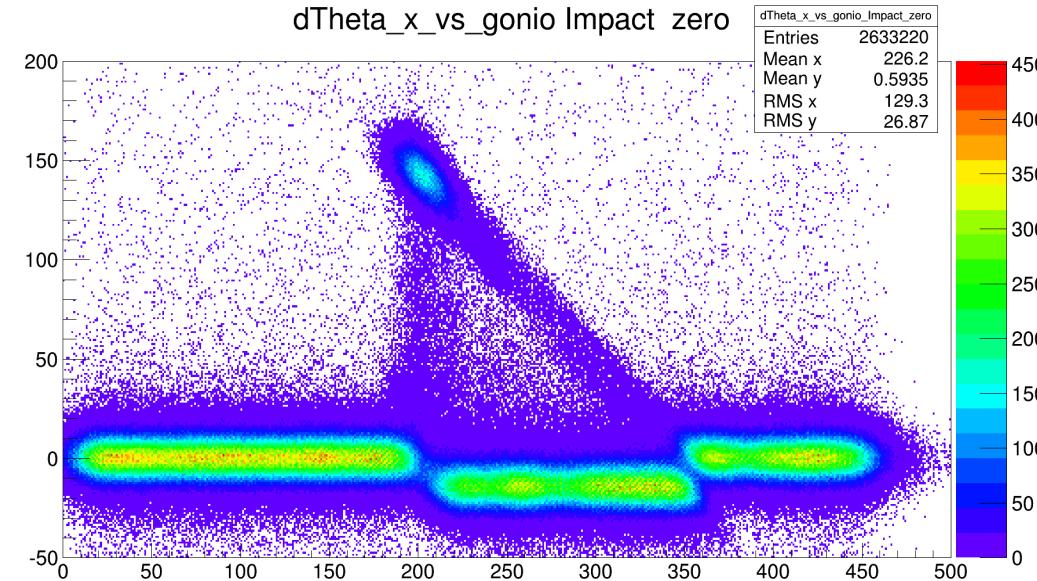
- Angular scan of the crystal, moving the goniometer on the horizontal plane respect to the beam
- We obtain both the scan of the angular kick with respect to the impact x angle and the goniometer position
 - From the second one we get three stripes in which each effect is quite evident, and we analyze the peak of AM, CH and VR
 - NB : That's only a check, before torsion correction, so we don't know yet what is the impact angle respect the crystallographic plane. So for each stripes all the beam divergence is accepted.

dTheta_x_vs_gonio_Impact

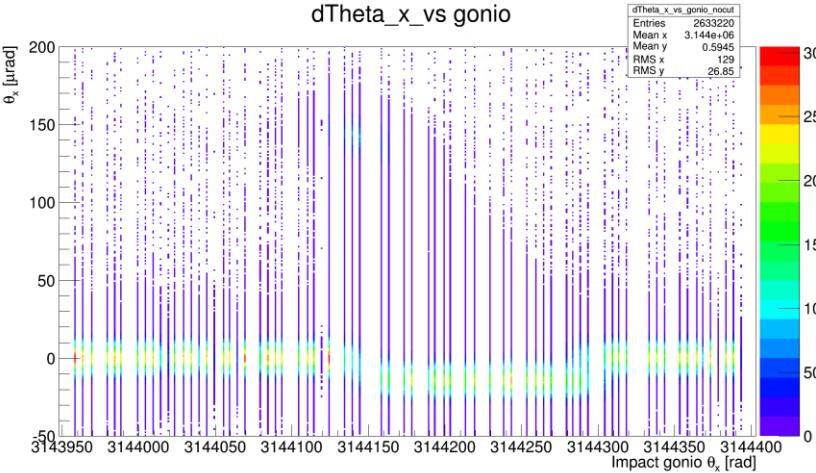


x deflection vs. impact angle x

Down here is subtracted the initial angle scan of the goniometer



dTheta_x_vs_gonio



Slice selected for the analysis

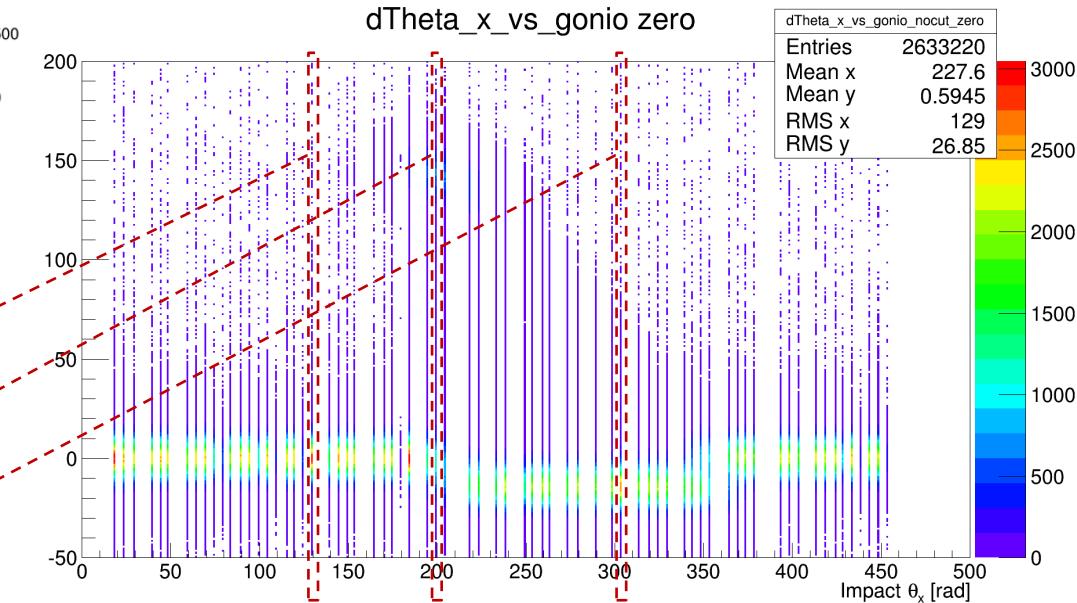
AM

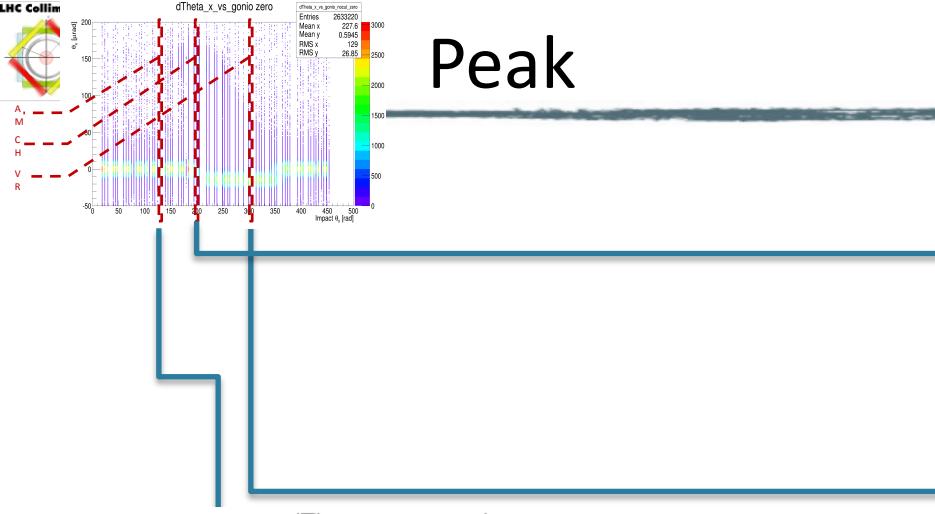
CH

VR

x deflection vs. the goniometer position on the horizontal plane.

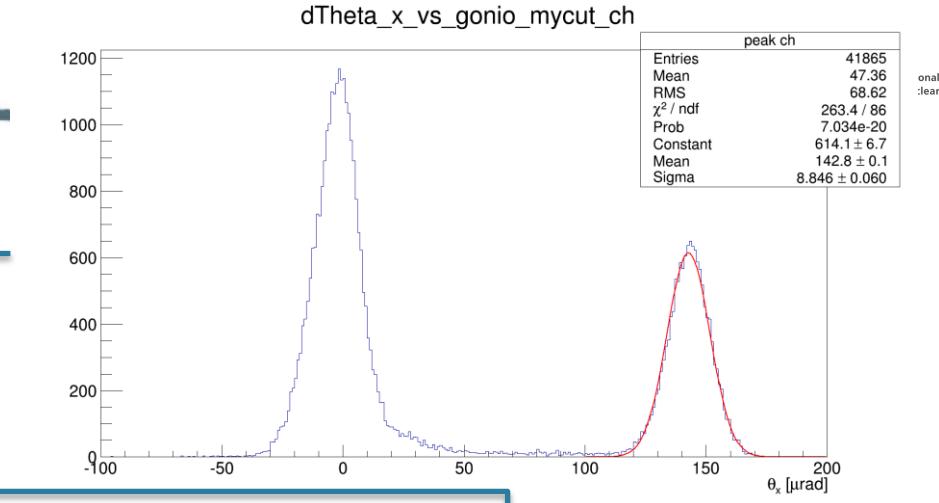
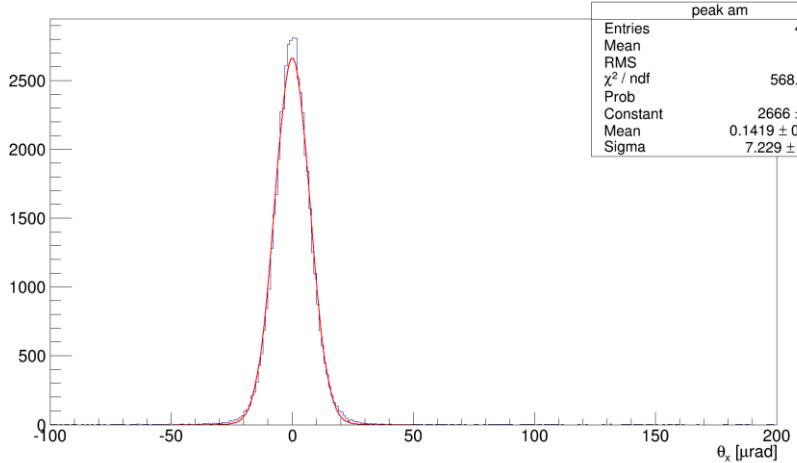
Down here is subtracted the initial angle scan of the goniometer



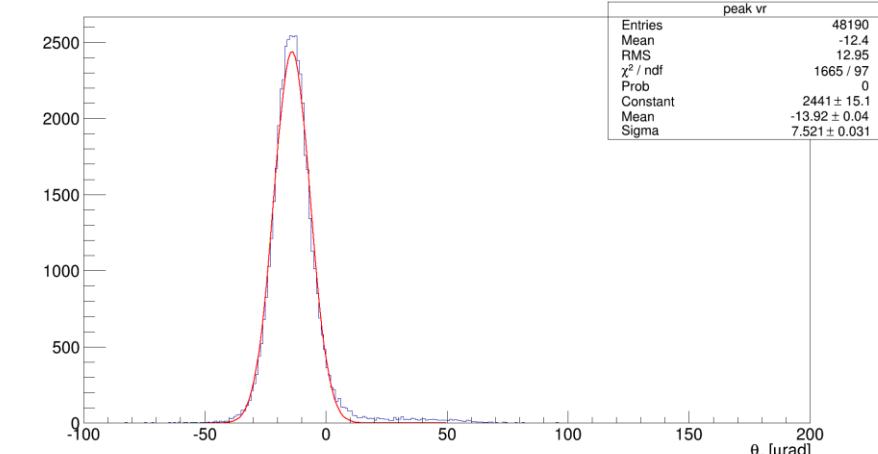


Peak

dTheta_x_vs_gonio_mycut_am



dTheta_x_vs_gonio_mycut_vr



Agnle Scan Analysis Recap

Xtla code	Year	Measurements		
		ch peak [μ rad]	vr peak [μ rad]	am peak [μ rad]
STF38A	2010	220,600 9,781	-13,380 7,873	-0,952 7,377
STF40A	2010			
STF45A	2010	144,500 8,403	-13,380 7,855	-0,184 7,800
STF47	2011	32,140 9,074		
STF48	2011	141,300 9,792	-13,340 7,680	0,000 6,900
STF49	2011	244,900 7,630	-8,185 7,871	0,206 6,008
STF50	2012	142,800 8,864	-13,920 7,521	0,142 7,229
STF51	2012	30,280 11,330	-13,000 9,105	0,466 8,158
STF70	2012	55,020 9,543	-13,450 8,120	0,785 7,074
STF71	2012	61,590 11,320	-14,550 7,883	0,396 7,653

From HiStat CH

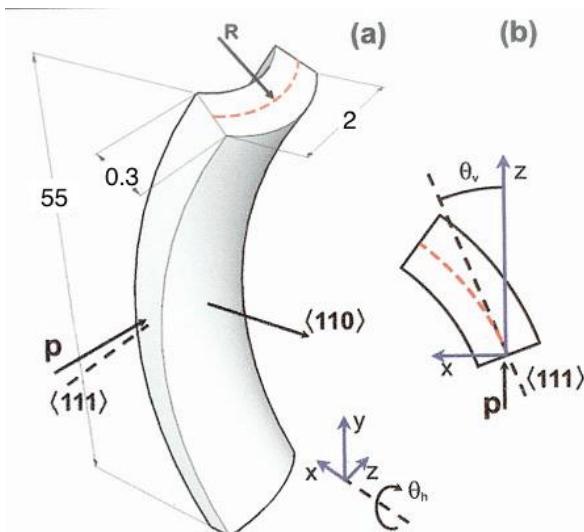
To do

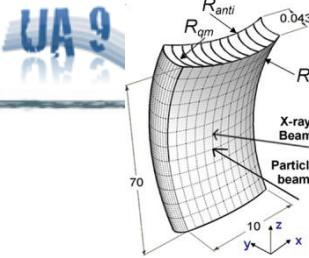
Xtla code	Year	Measurements		
		ch peak [μ rad]	vr peak [μ rad]	am peak [μ rad]
QMP26	2012	42,980 15,750	-13,190 8,164	-0,736 7,738
QMP27	2010		~110	
QMP28	2012			
QMP29	2012	31,600 8,937	-13,840 9,594	-0,164 9,343
QMP32	2011	-155,000 7,506		0,281 6,052

Note – VR sigma should be 1,387 μ rad, which have to be added to the AM spread.

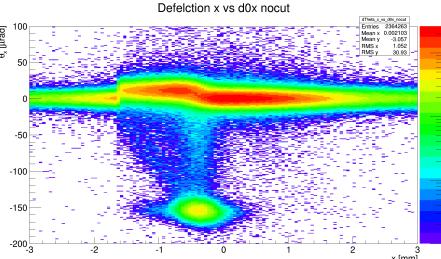
Angular kick as function of x and y impact point is measured

- The x cut is performed where a deflection appear in x deflection and where a spread due to multiple scattering appear in the y deflection plot.
- Most of the case the y height of the crystal contains the y dimension of the beam
 - y cut : $\pm 3 \sigma$ from the mean of the y beam profile



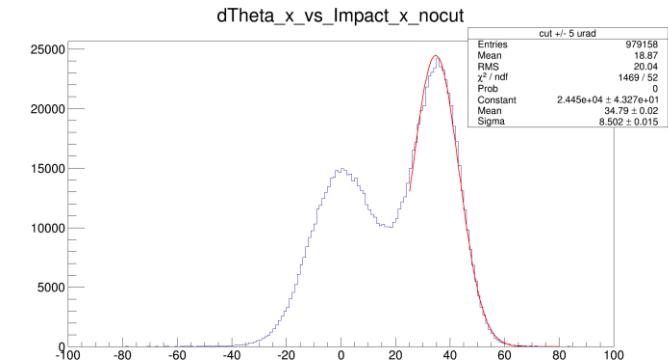
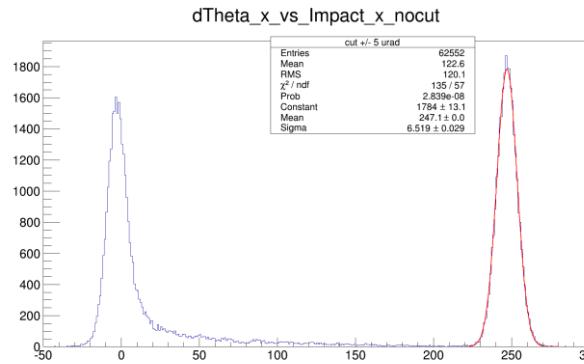


QM cut

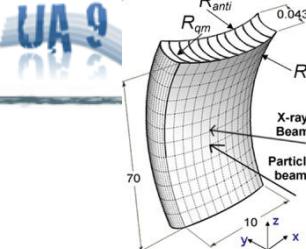


We measure the channeling efficiency (#ch/#tot) versus the impact point on the plane xy
note :

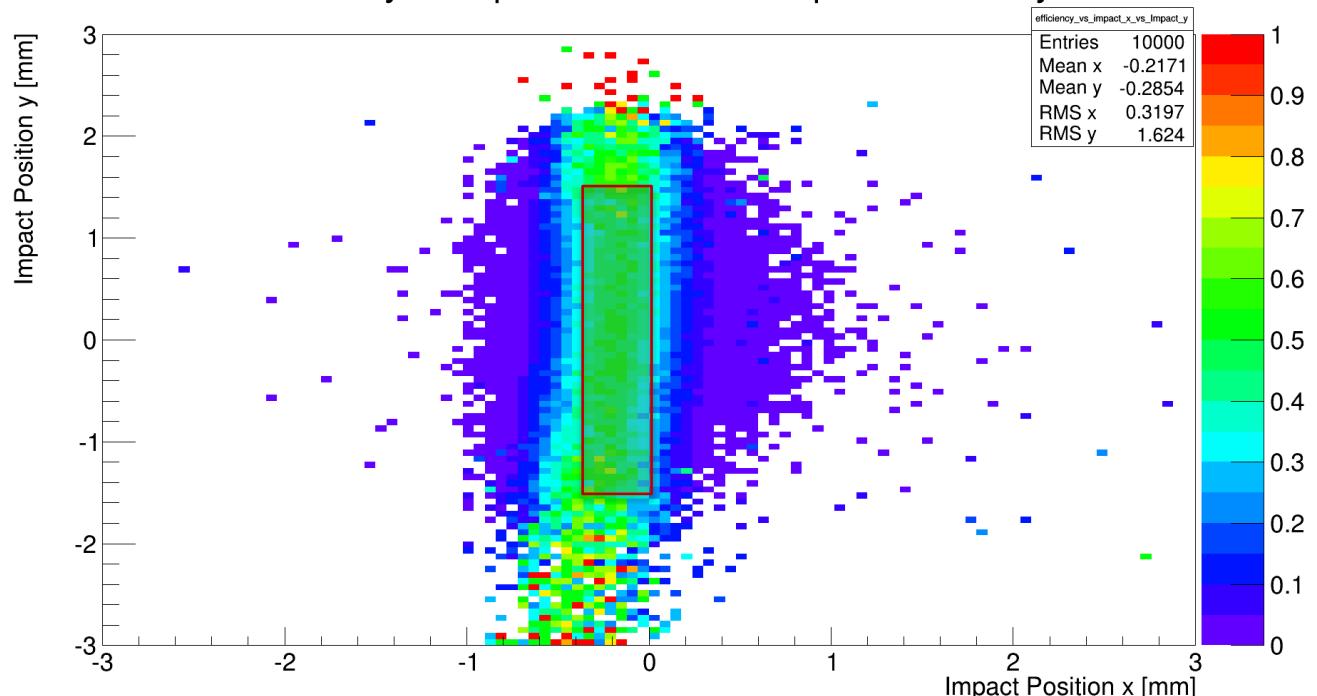
- We get a pixeled map of the xy plane. Each pixel have as dimension the spatial tracker resolution (50/60 μm)
- For each pixel we analize the 1dim histogram of the angular kick inferred to each particle. A gaussian fit is performed around the CH peak
- The channeling event are measured in two different way, depending on the crystal bending
 - Bending > 90 μrad : event counted inside the 3 σ from the mean of the fit
 - Bending $\sim 50 \mu\text{rad}$: gaussian fit integral (because of the overlapped events in the tail)



QM cut



Efficiency in Impact Position x vs Impact Position y

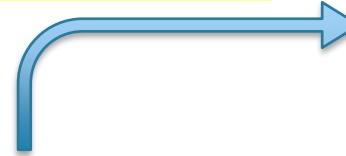


We get a map of the channeling efficiency in each pixel. Then we chose a zone where the efficiency is higher than 0.5 and with a minimal fluctuation

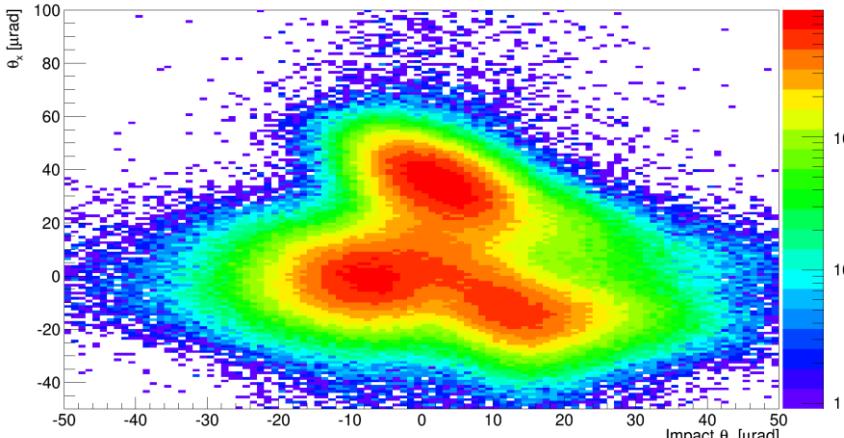
Torsion correction

STF47

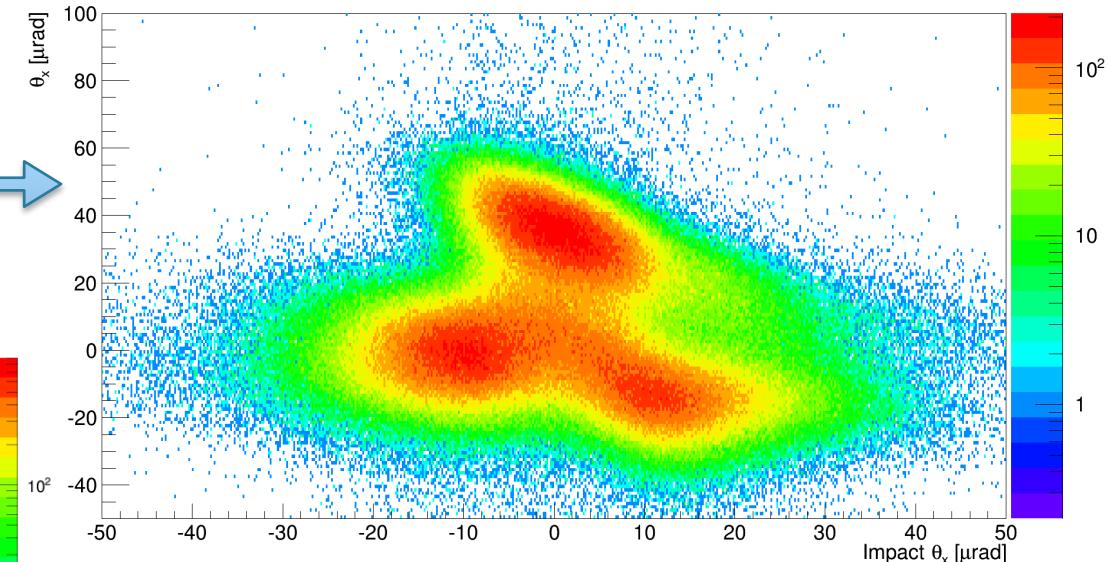
$$\theta_{corr}(x) = g.\text{Pos}(x) + \theta_{in}(x) - g.\text{Pos}_{init}(x) - (\text{torsion} * \text{Impact}(y) + g.\text{Pos}_{offset}(x))$$



dTheta_x_vs_Impact_x



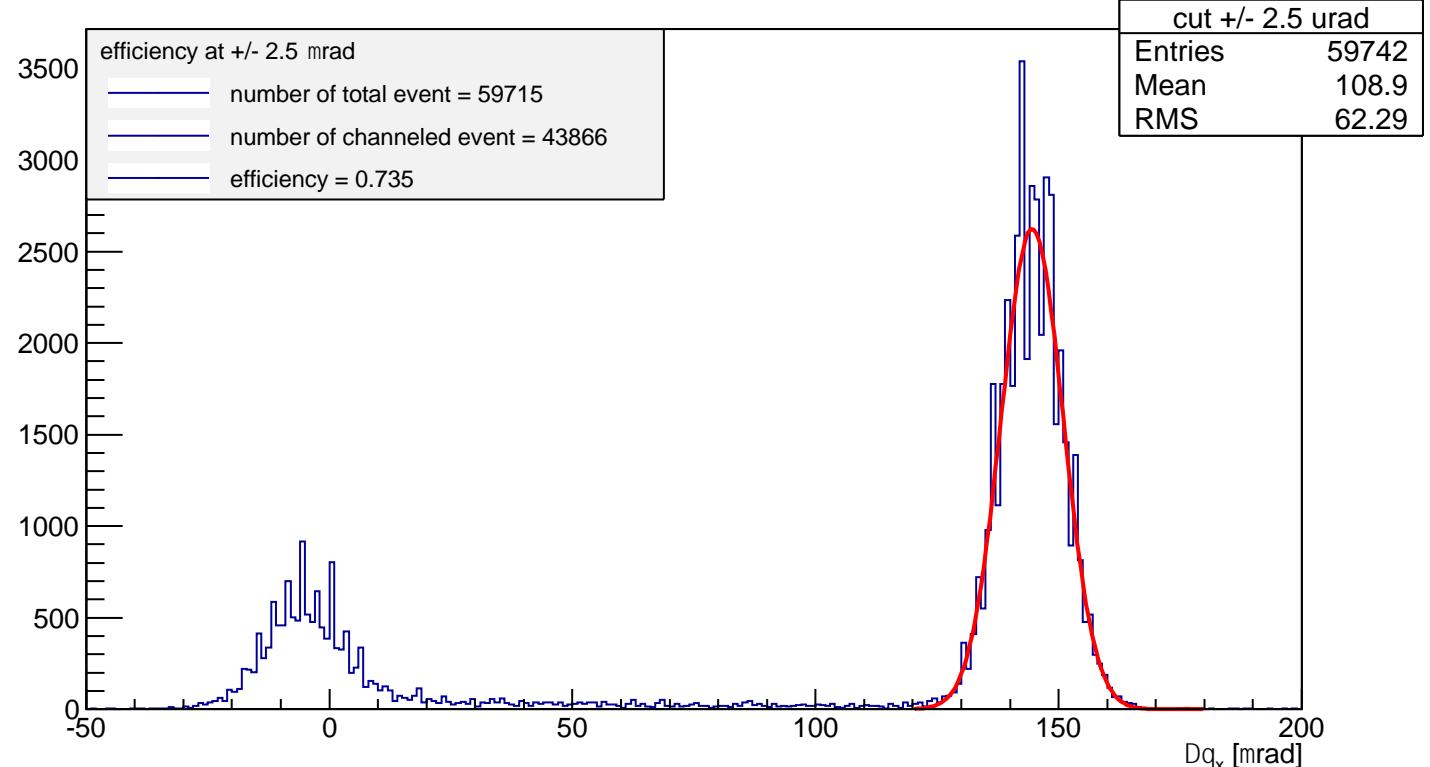
dTheta_x_vs_Impact_x_nocut



dTheta_x vs Impact_x tor Corr

Channeling Efficier
 $\pm 2.5 \mu\text{rad}$

Efficiency = 0,74

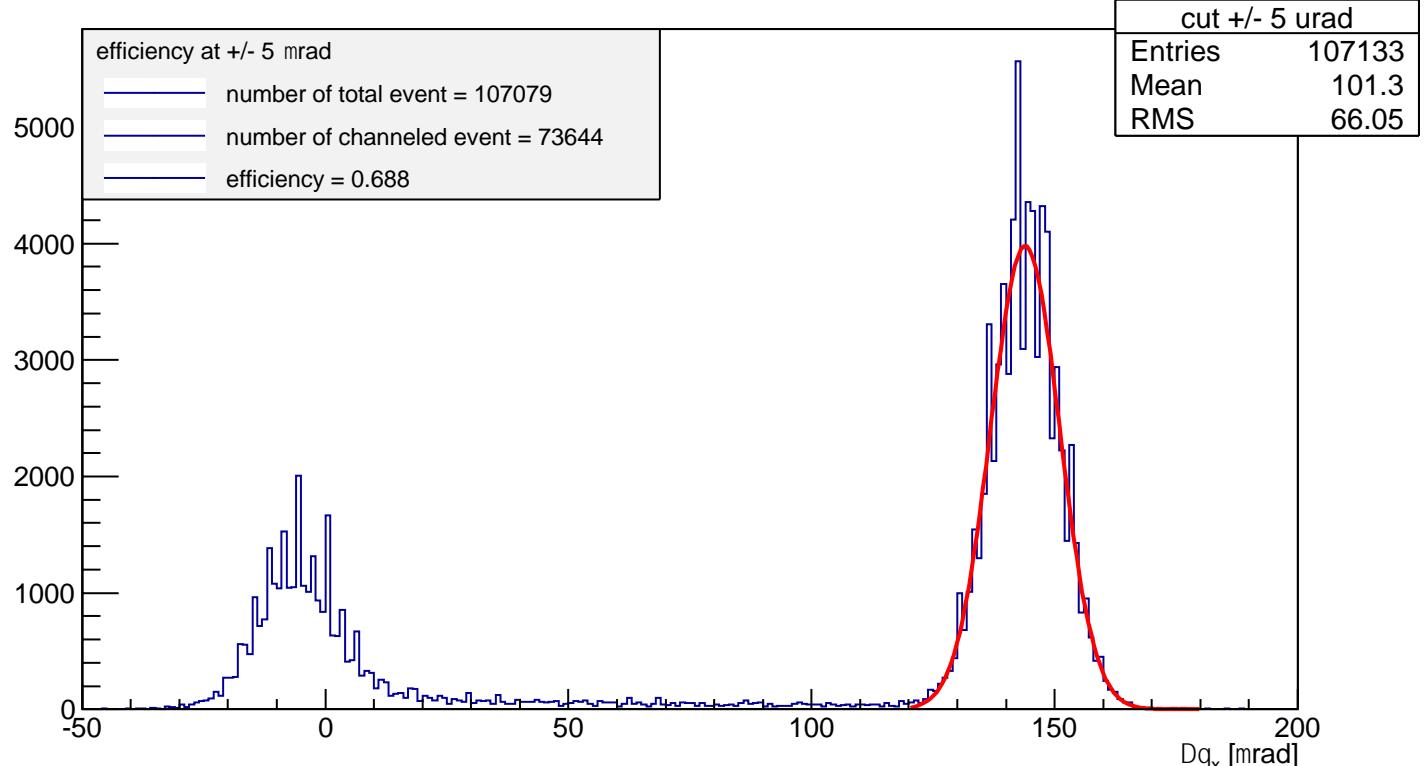


dTheta_x vs Impact_x tor Corr

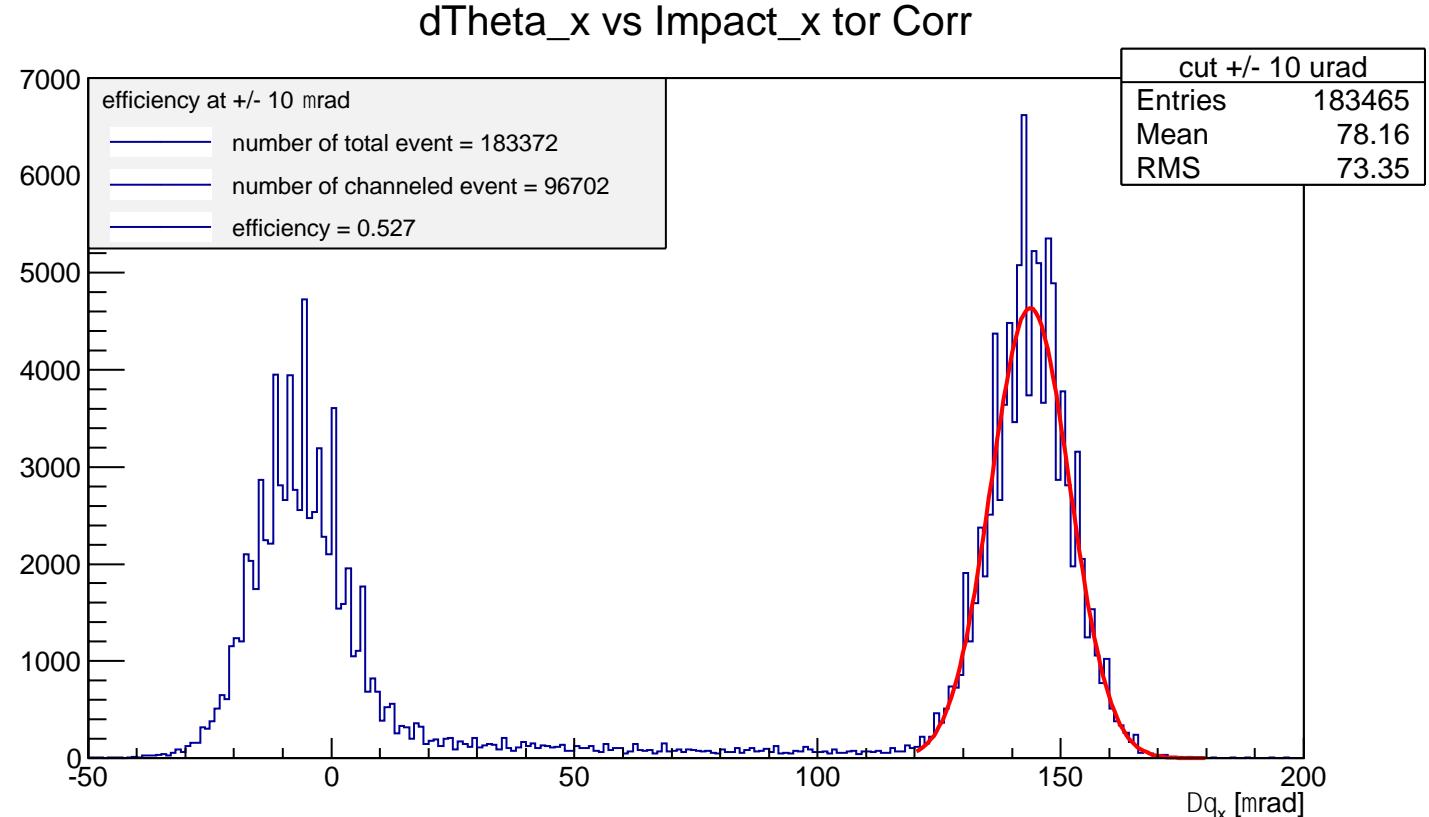
Channeling Efficiency

$\pm 5 \mu\text{rad}$

Efficiency = 0,69



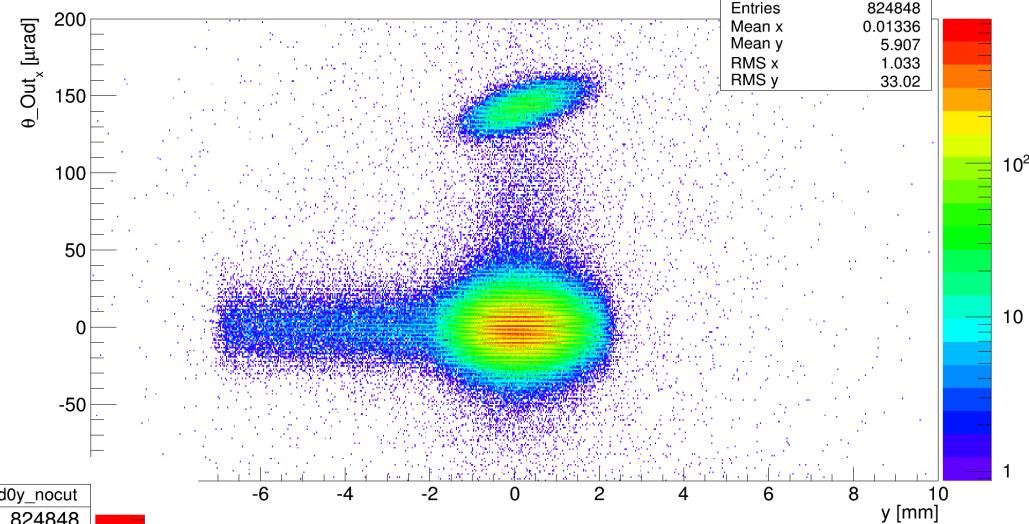
Channeling Efficier
 $\pm 10 \mu\text{rad}$
 Efficiency = 0,53



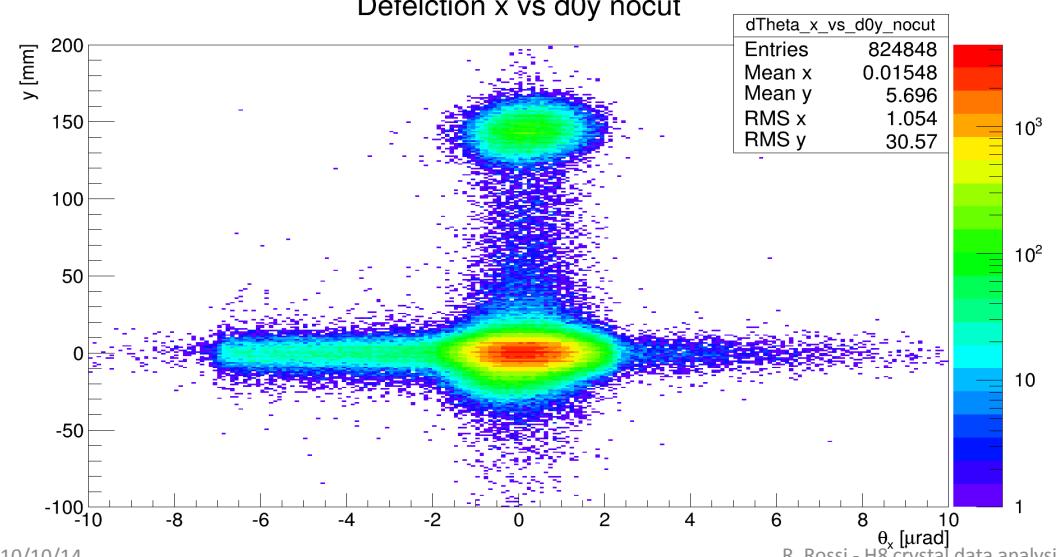
- x kick vs. impact y position is analyzed to measure the bending variation as a function of the vertical impact position
- The outgoing x angle vs. impact y position is also analyzed to measure directly the torsion as the variation of the outgoing angle as a function of vertical impact position

Geometrical cut is used for both the analysis

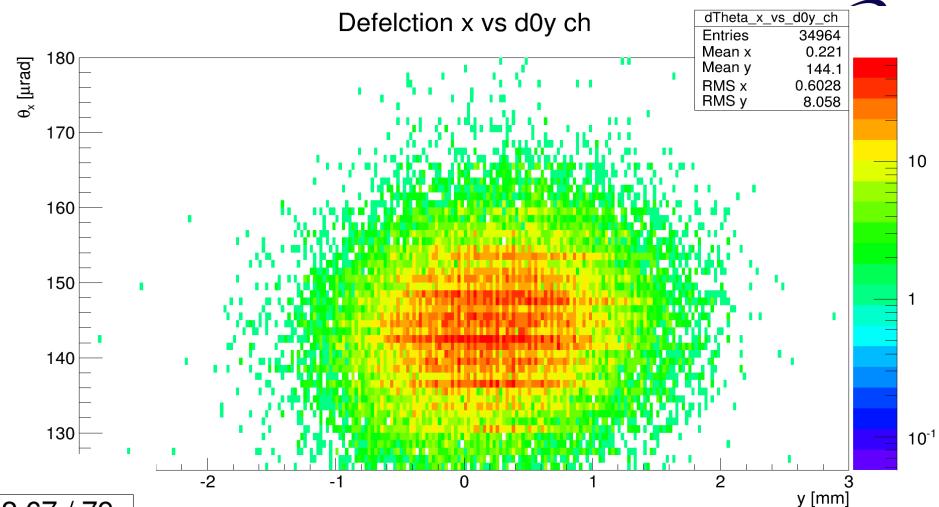
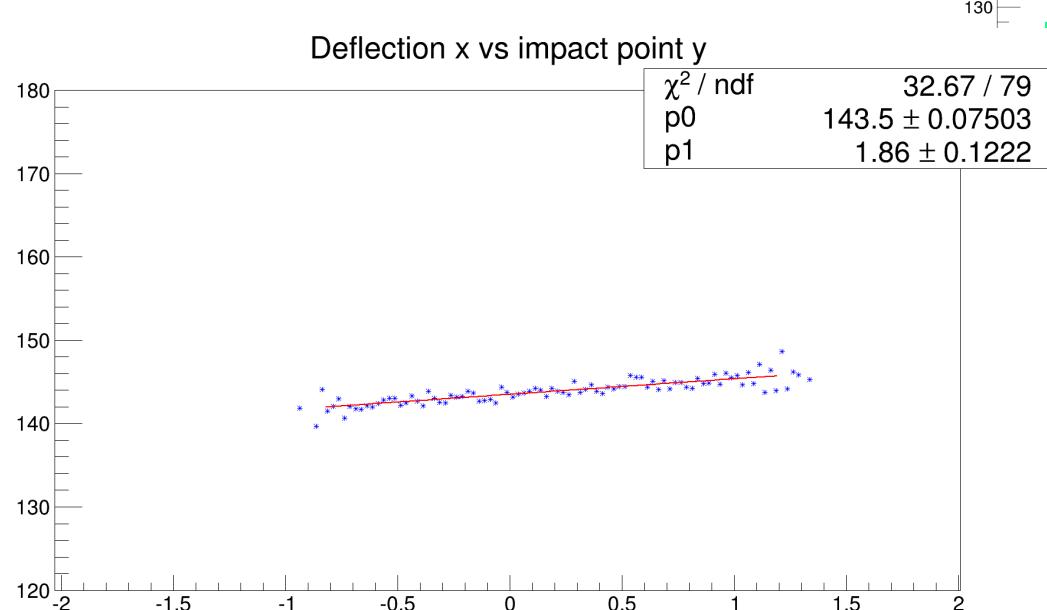
Theta Out x vs d0y



Deflection x vs d0y nocut



STF45

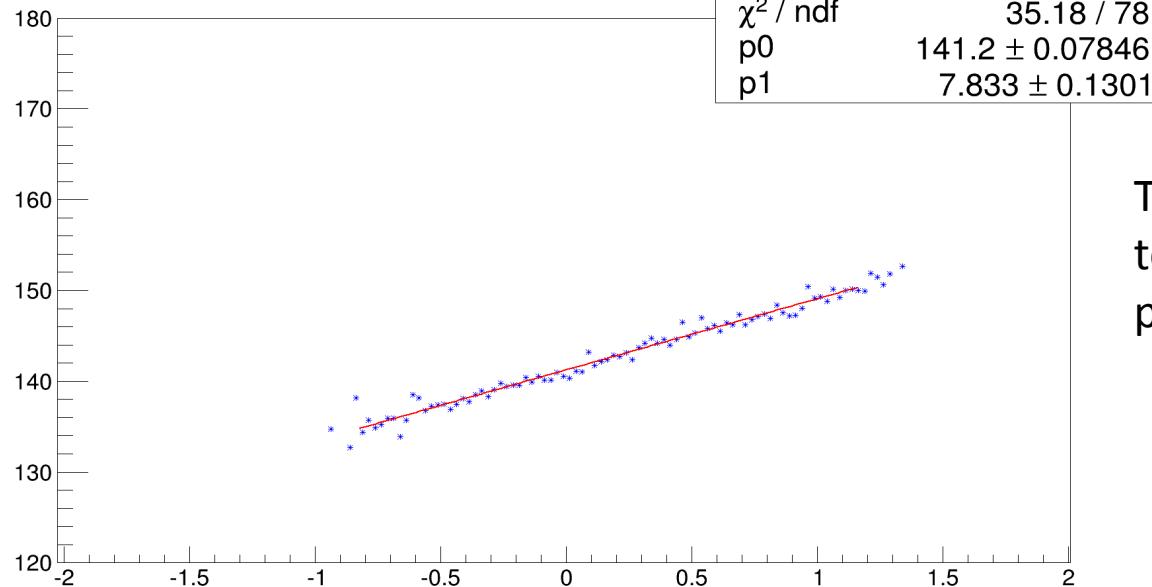


As we can see, a very slight variation of bending is present in this crystal

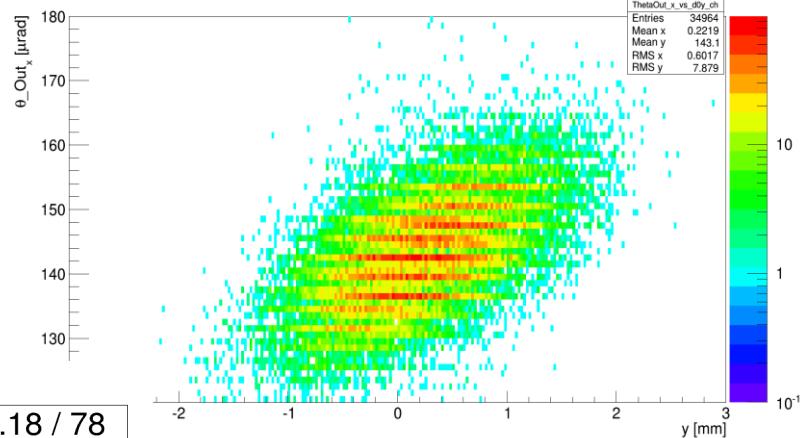
STF45



Theta Out x vs impact point y



Theta Out x vs d0y ch



This torsion value is comparable to the one obtained with the previous method