H8 crystal data analysis

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H8 Crystal test Beam

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.

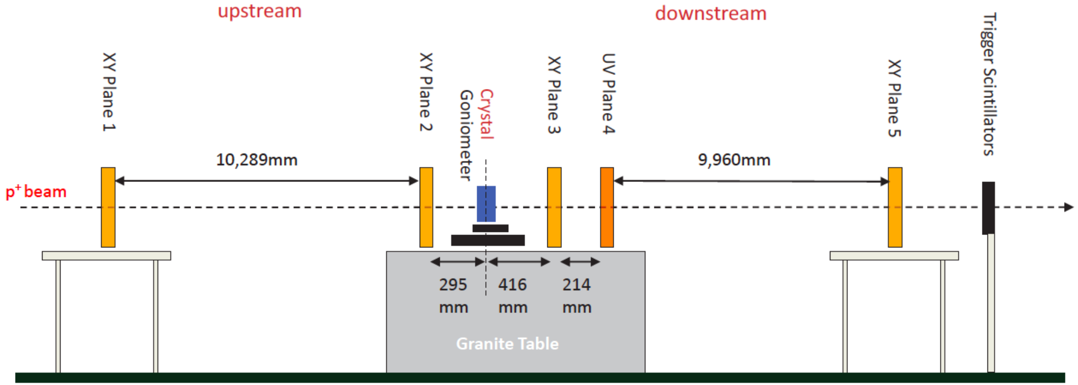
Scope of my master thesis work:
Consistently analyze all the crystals tested in H8 (total of 15 between 2009-2012).

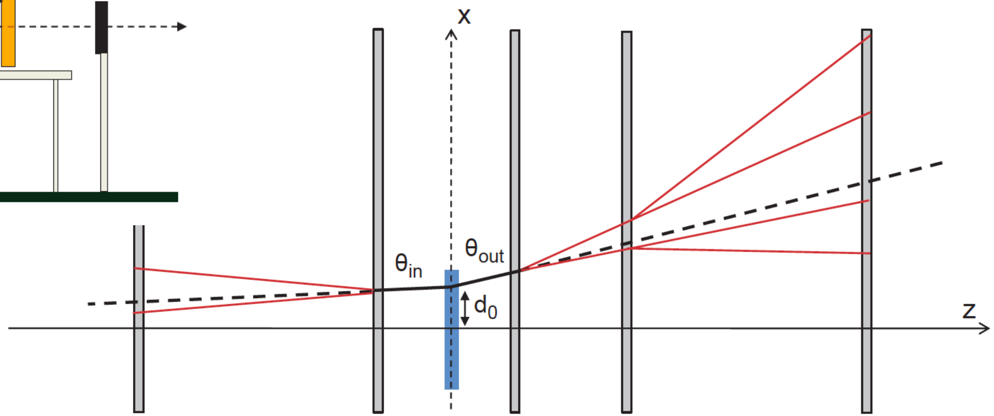
- Compile a comprehensive statistical treatment of different crystals
- Identify “fine” systematic effects (e.g., transitions)
- provide inputs to crystal code developers

Immediate goal: compile list of experimental data for an upcoming workshop on crystal simulations.

H8 experimental Layout

- Five silicon micro-strip sensors (active area 3.8x3.8 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.





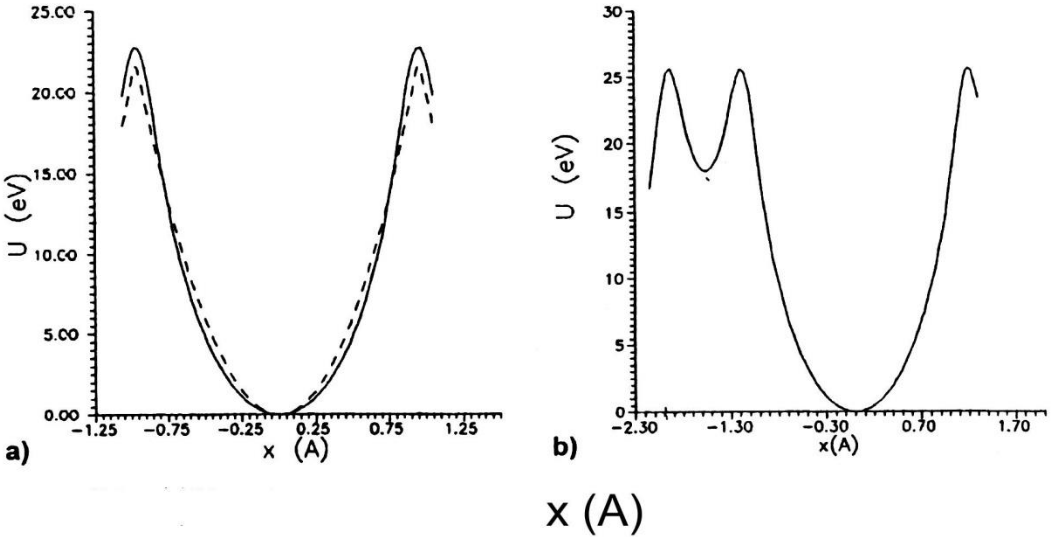
UA9 Crystals

Two kind of crystals were test 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



Run Analysis

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

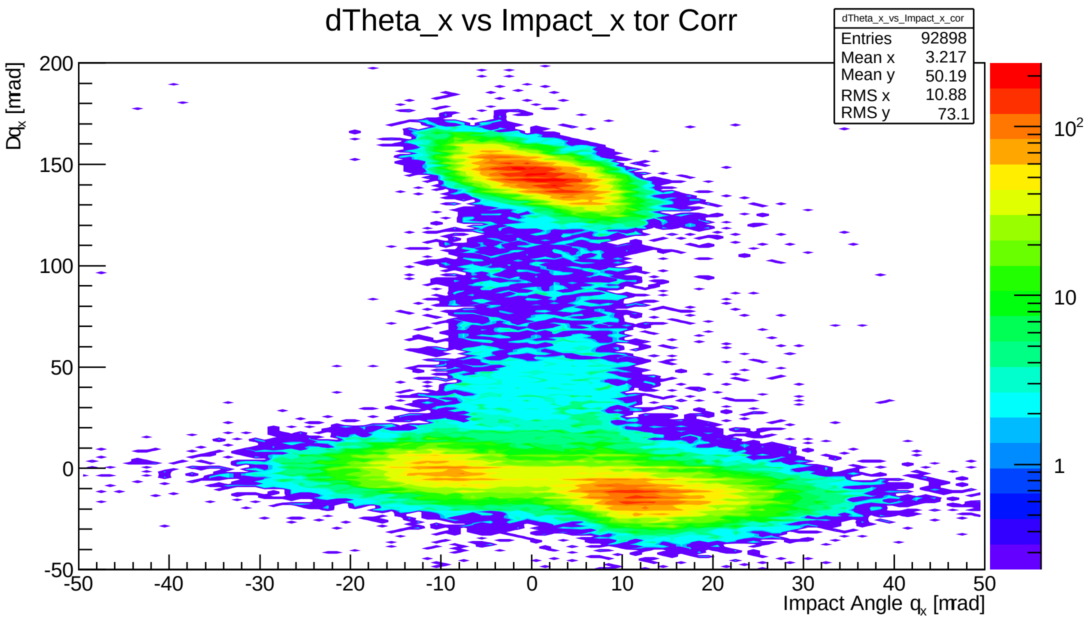
Complete analysis is presented in the previous meeting ColUSM #38

Hi Stat @ Channeling Analysis

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

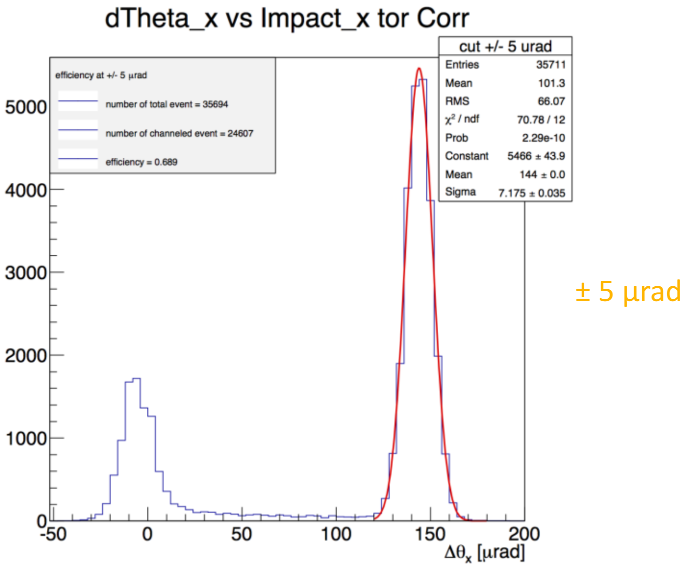
- Channeling, the spot around 150 µrad
- Transition region between the amorphous and the volume reflection zone
- Dechanneling, the region between the first two

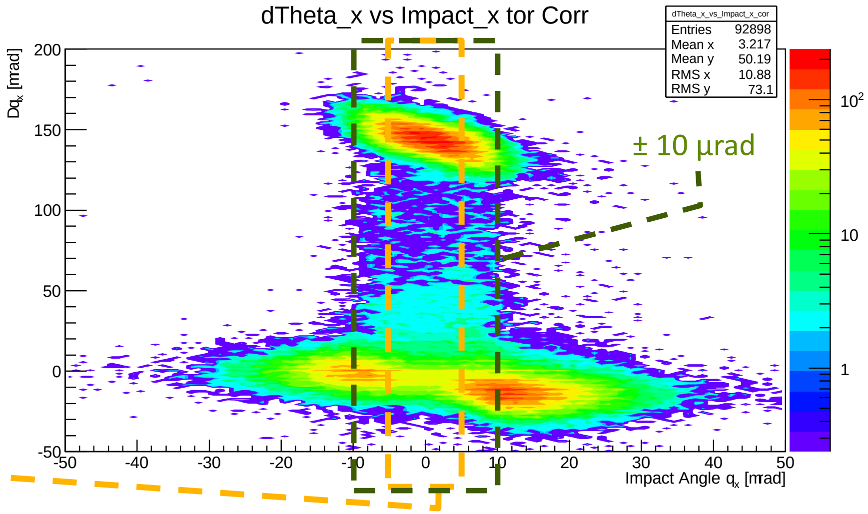


Channeling Efficiency

The channeling efficiency is evaluated at two different angular cuts ± 5 e ± 10 µrad, 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.





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

η = 0,69 @ ± 5 µrad

η = 0,53 @ ± 10 µrad

Dechanneling length

On the same histogram the dechanneling length analysis is also performed

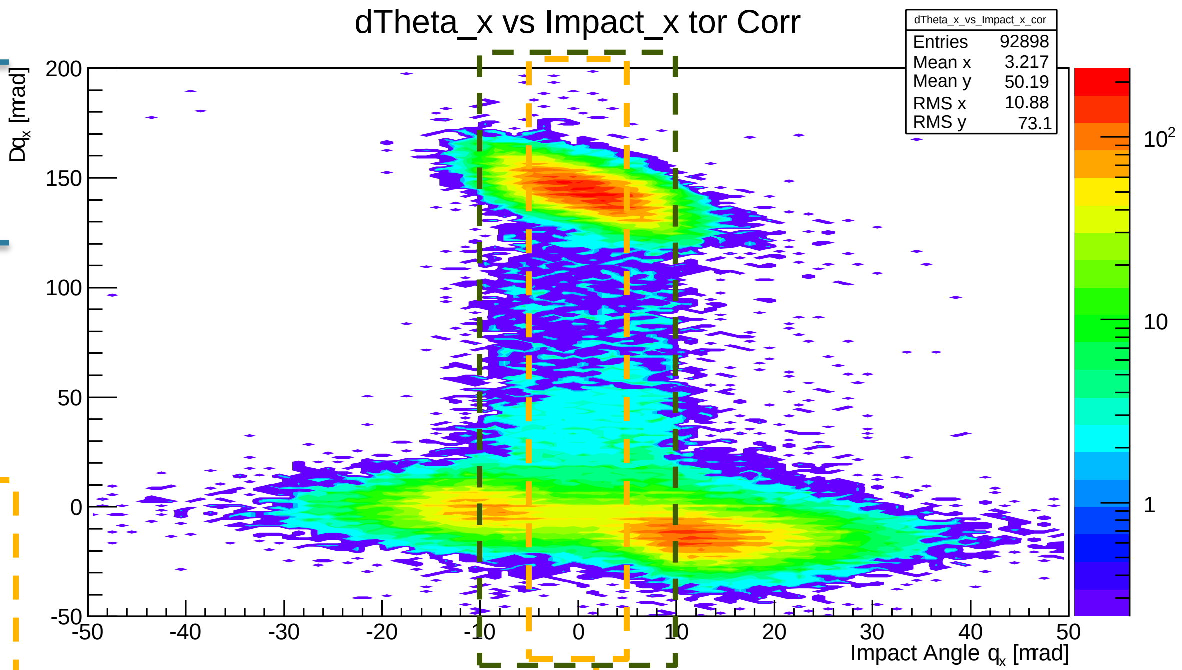
This is a key parameter to improve simulations.

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.

± 5 μrad

± 10 μrad

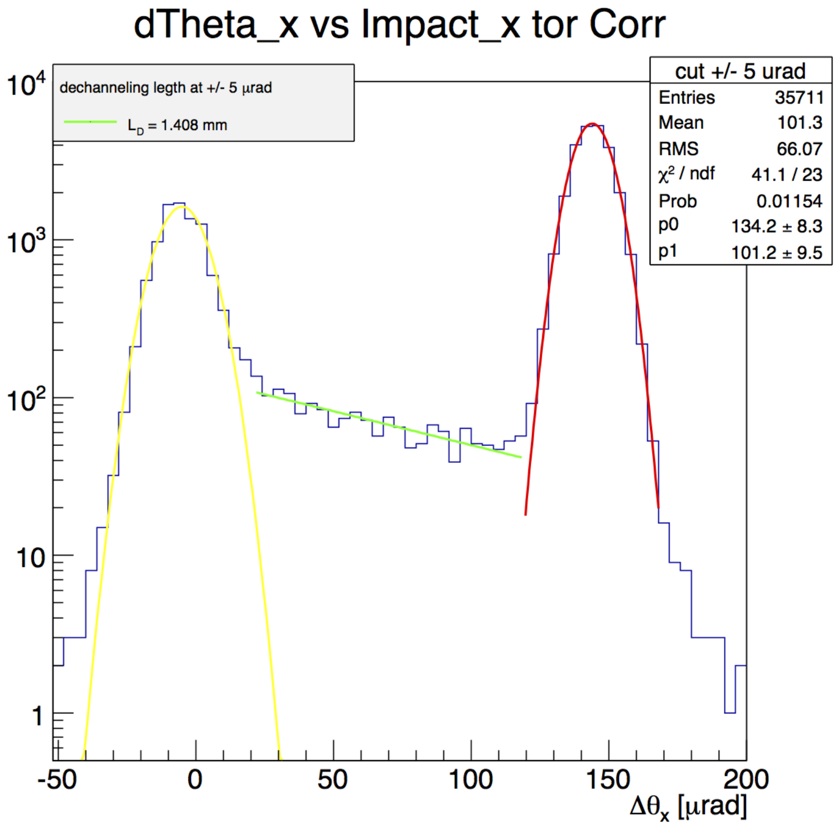


Dechanneling length

Dechanneling Length

± 5 µrad

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 ~ 1,4 mm



Deflection analysis

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

- Channeling deflection angle
- Volume reflection angle
- Amourphous angle

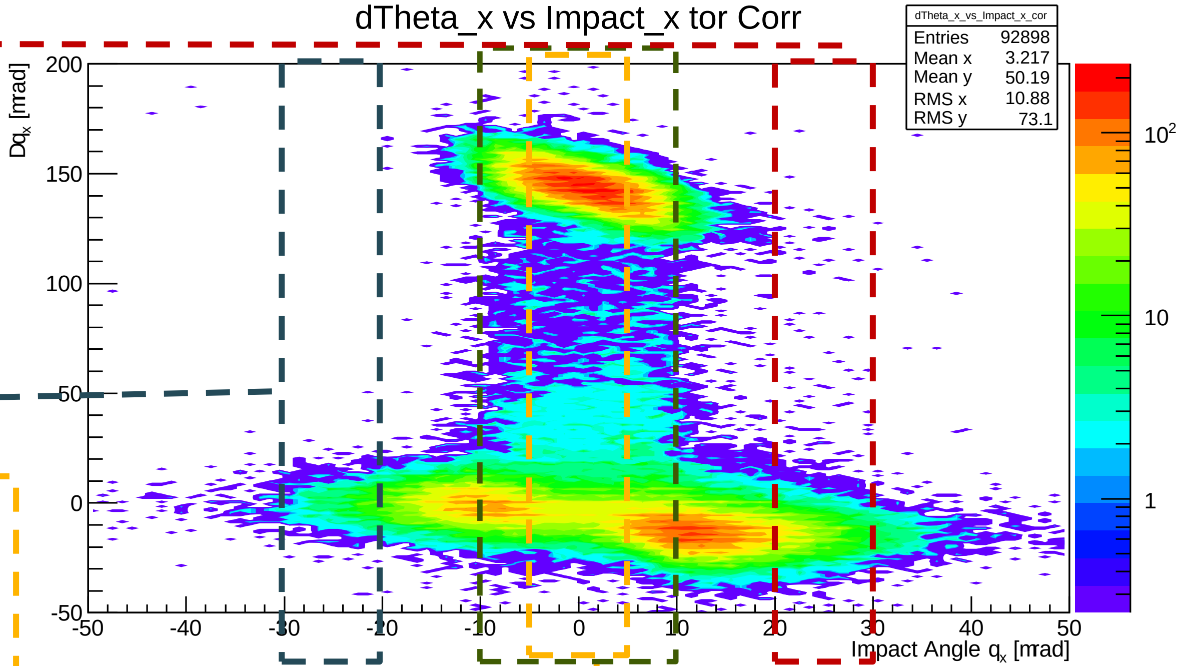
The same gaussian fit gives also t

VR – [20,30] μrad

AM – [-30,-20] μrad

± 5 μrad

± 10 μrad

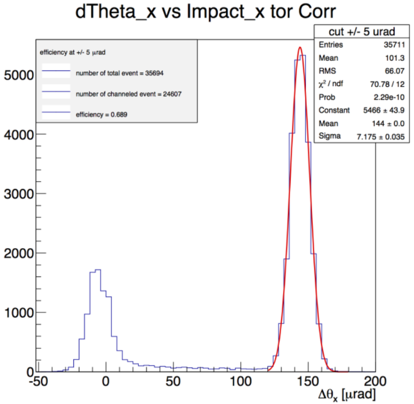


Deflection analysis

The same gaussian fit gives also the sigma distribution value

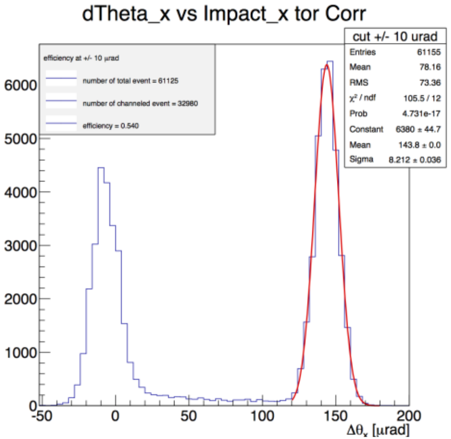
CH - ± 5 μrad

Mean 144.0 ± 0.1 μrad
Sigma 7.18 ± 0.04 μrad



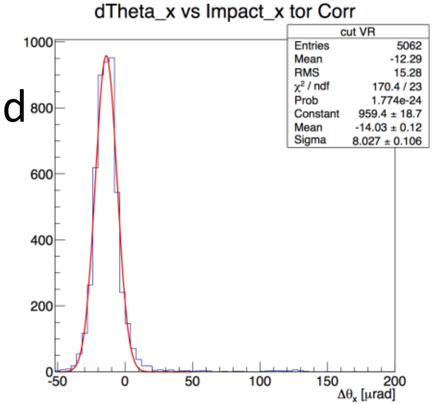
CH - ± 10 μrad

Mean 143.08± 0.1 μrad
Sigma 8.21 ± 0.04 μrad



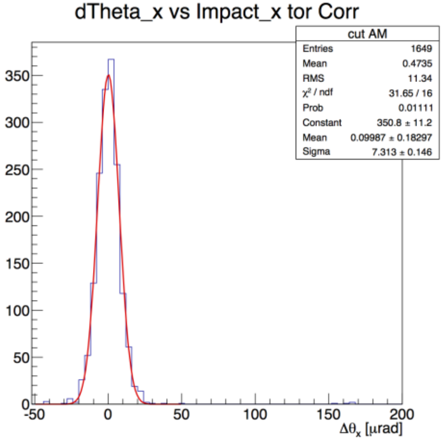
VR – [20,30] μrad

Mean -14.03 ± 0.12 μrad
Sigma 8.03 ± 0.11 μrad



AM – [-30,-20] μrad

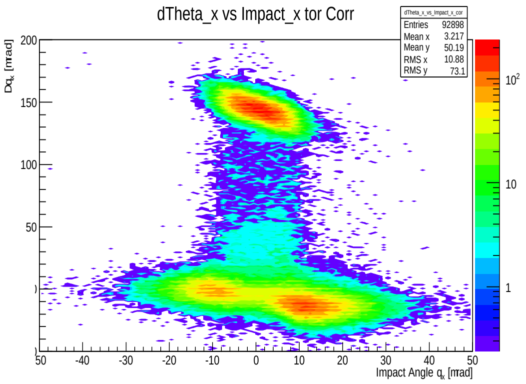
Mean 0.01 ± 0.18 μrad
Sigma 7.31 ± 0.15 μrad

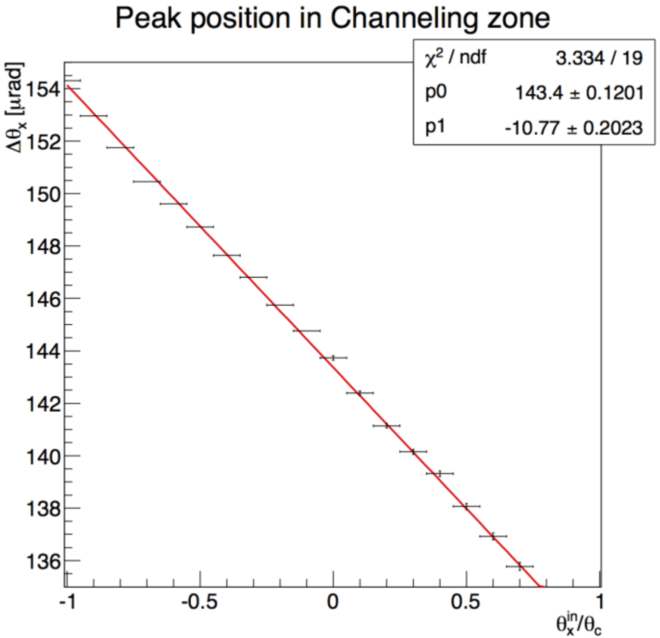


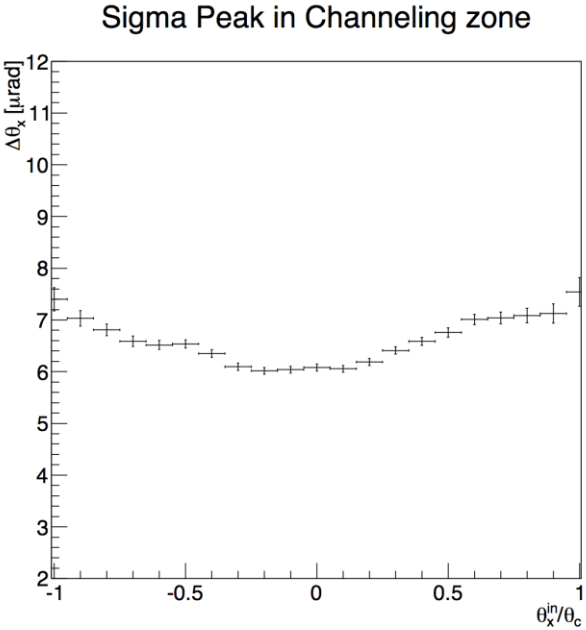
Channeling zone

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

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



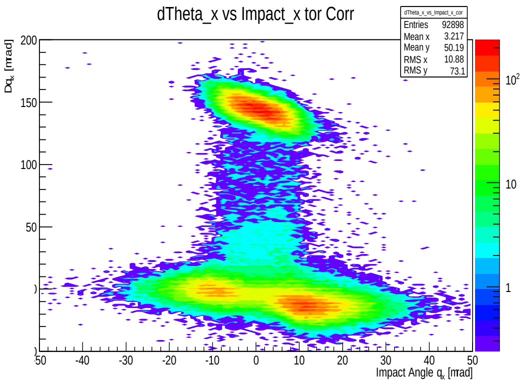




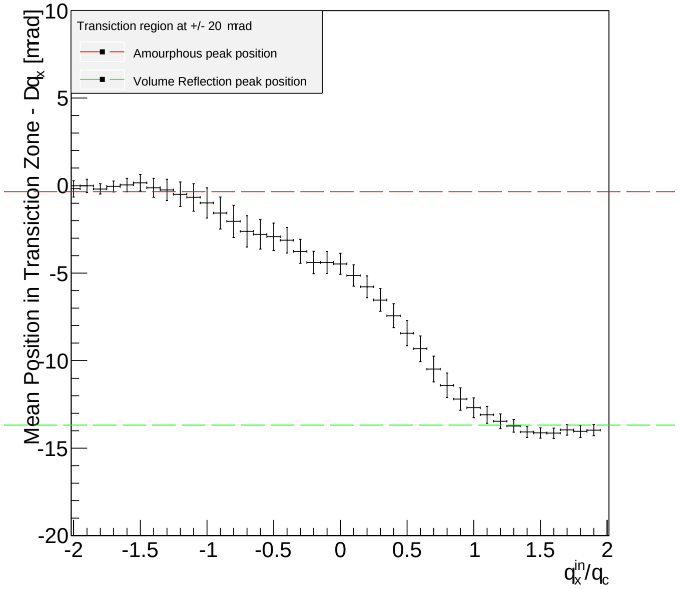
Transition zone

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

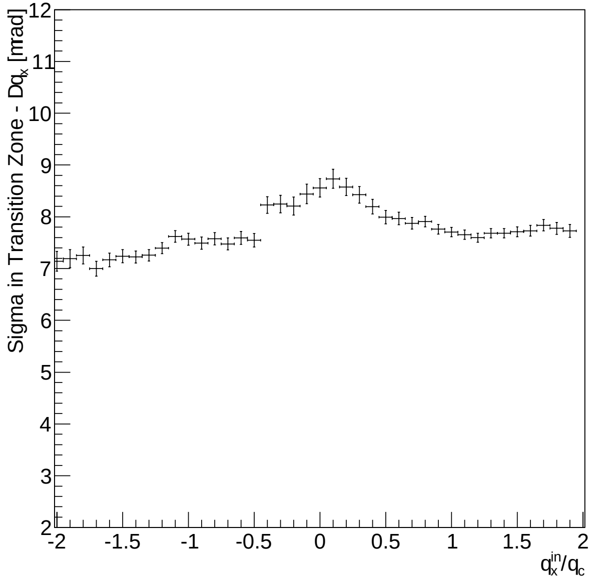
The trend of the peak plotted would be useful for a confrontation with the crystal simulation routines.



Peak position in transiction zone



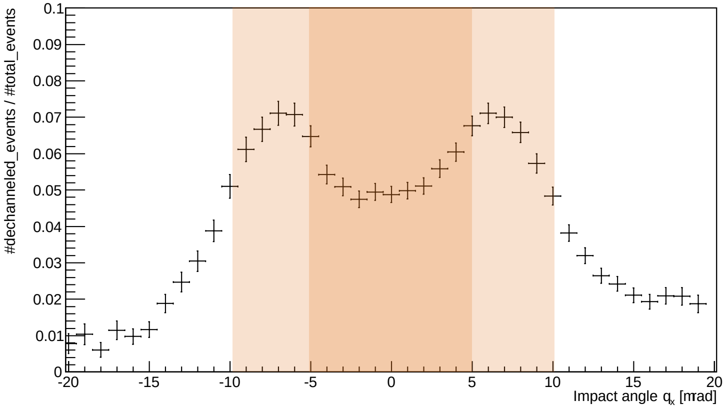
Sigma peak in transition zone



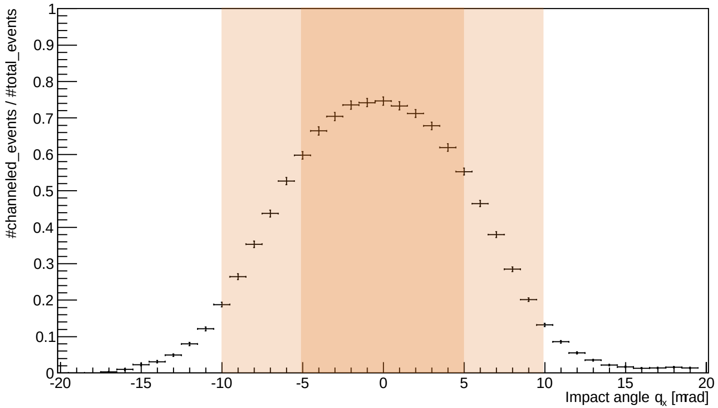
Population

The Population of the three different region are evaluated as a function of the impact incoming angle.

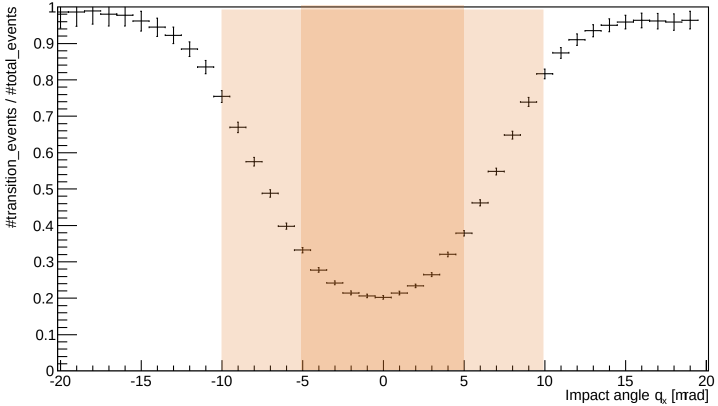
Dechanneling Population (normalized to total events)



Channeling Population (normalized to total events)



Transition Region Population (normalized to total events)



$2 * \theta_c$

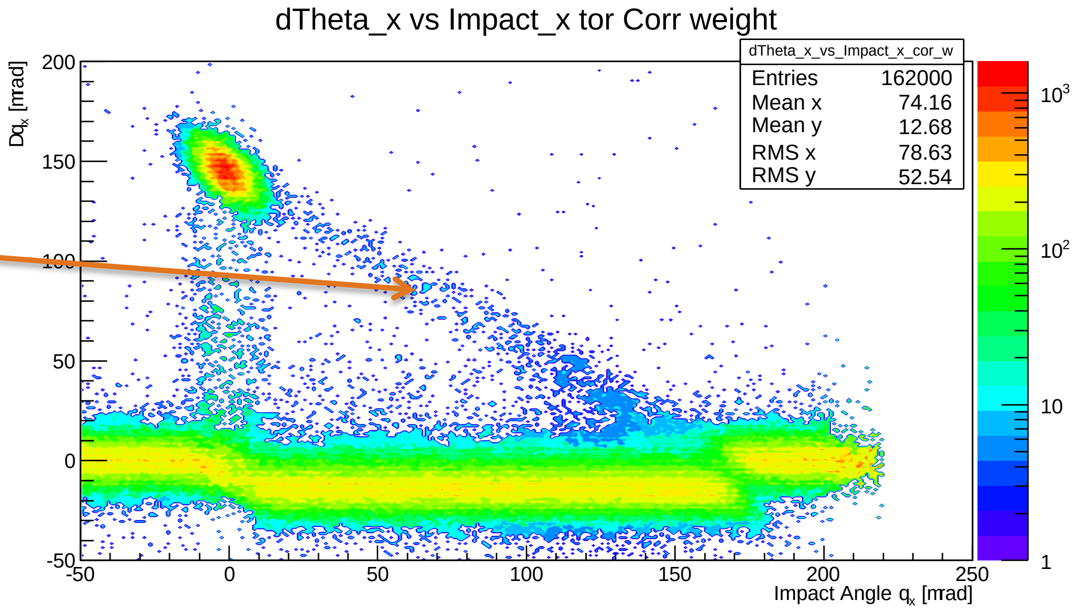
θ_c

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.

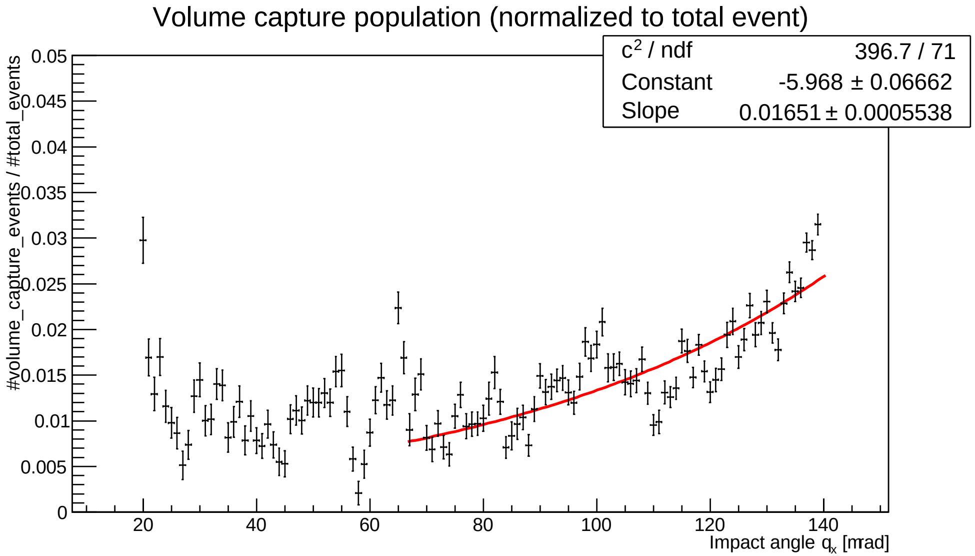


Volume capture analysis

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 ~ 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*. Spinger, 1997.

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
- Requirments 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 measurment 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 adeguate with statistics allowing the relevant parameters to be calculated with small error.

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

Requirments for comparison

Measurement vs. Simulation

The inputs should be used to simulate the interaction of 400 GeV protons with a bent crystal (θ_c–10 μrad).
In particular, at the least for the reference crystal, STF45, the following experimental results should be reproduced by simulations tools with a minimum statistics of 10^6 :

- Distribution of deflection angle vs. impact angle
- Distribution of deflection angle for impact angle selection of ± 5 and ± 10 μrad, with caluclation of:
  - Channeling angle and its distribution sigma
  - Channeling efficiency
  - Dechanneling length
- Volume reflection angle and its sigma from distribution of deflection angle for an impact angle selection in the range ($+2\theta_c$,$+3\theta_c$)
- Amorphous angle and its sigma from distribution of deflection angle for impact angol selection in the range ($-3\theta_c$,$-2\theta_c$)
- Channeling angle and its sigma as a function of impact angle
- Transition region peak and its sigma as a function of the impact angle
- Channeling and dechanneling 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
Requirments 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

Conclusion

Achieved goals :

- ✓ A complete analysis of the crystal tested in the H8 line has been done.
- ✓ The results of the present analysis fit the results in literature.
- ✓ Many fine systematic effect were analyzed for the first time.
- ✓ A complete list of experimental data and inputs are ready for crystal code developers.

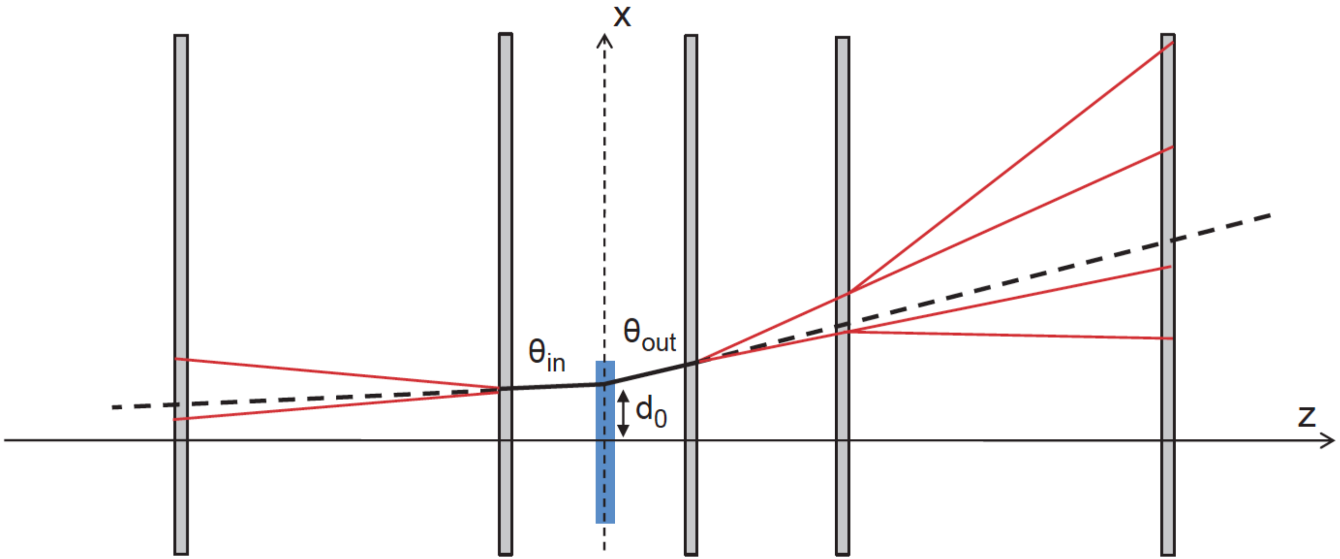
Future goals :

- ❑ understanding and development of an analytical model of the “fine” effects observed.
- ❑ implementation of the analytical models to improve the crystal simulation routines.

BACKUP

Track reconstruction

- <u>Only one track per event is reconstructed.</u>
- 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.

Alignment Run Analysis

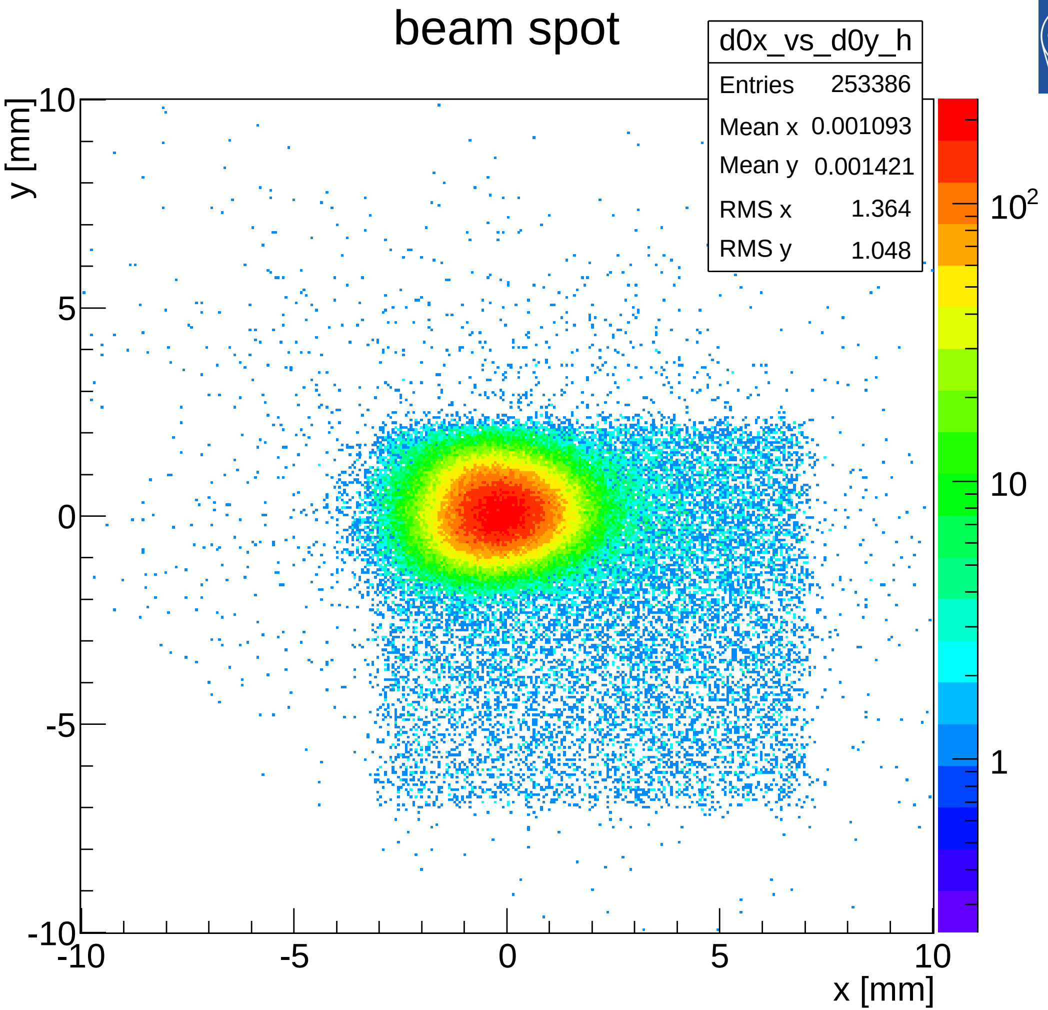
– With the crystal removed from the line is possible to measure the key parameters :
  - Beam divergence
  - Beam distribution
  - Telescope resolution

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

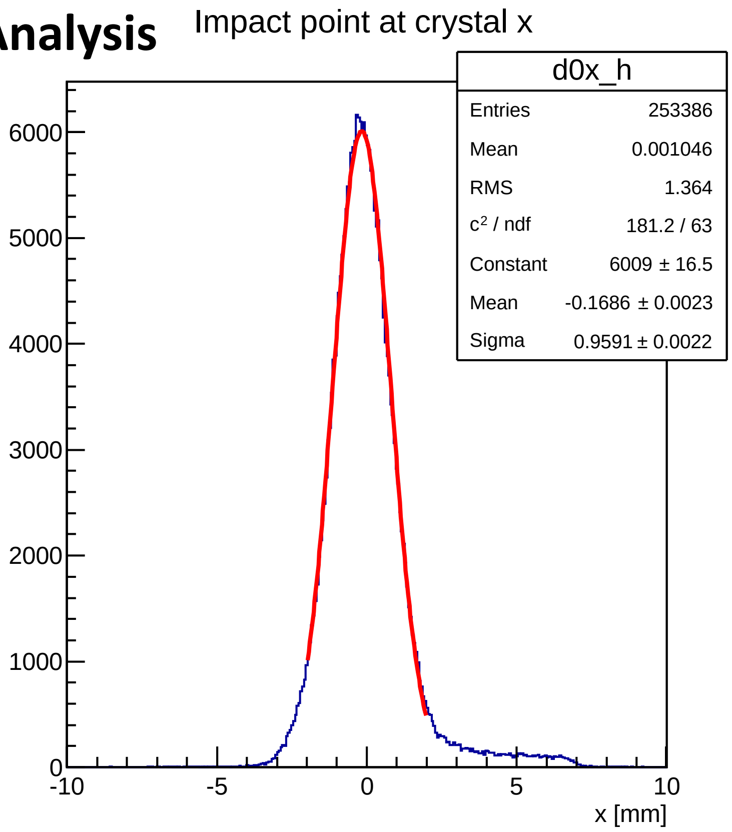
Here we can see the beam profile in the orthogonal plane.

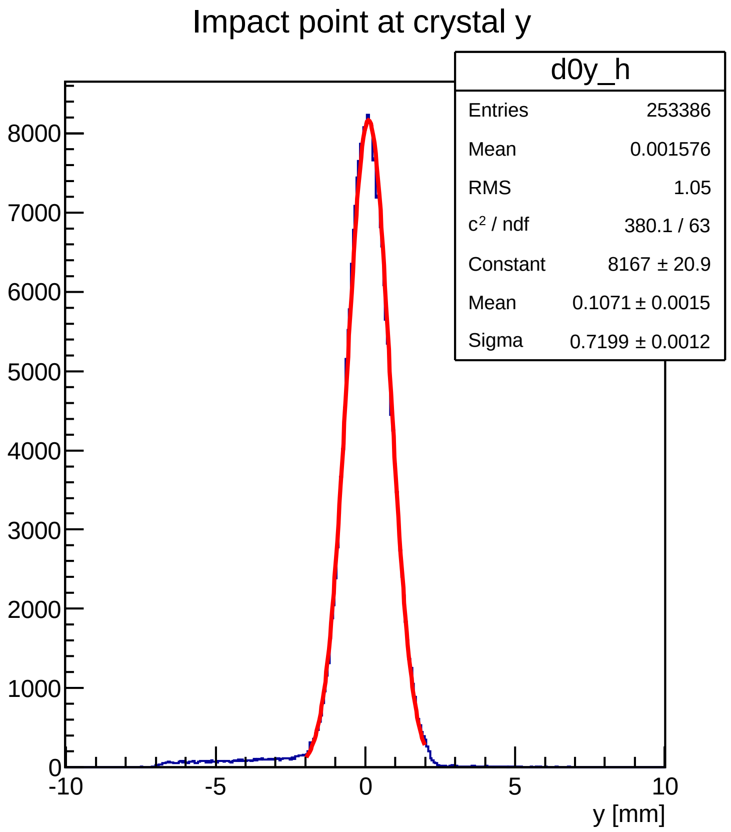
Double Gaussian shape of the beam core

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.





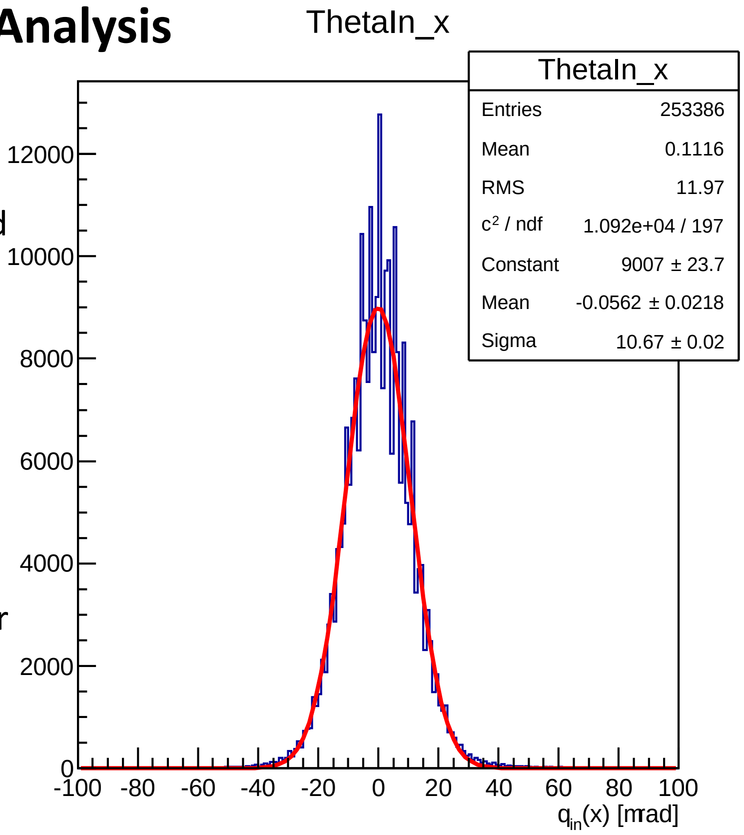
Alignment Run Analysis

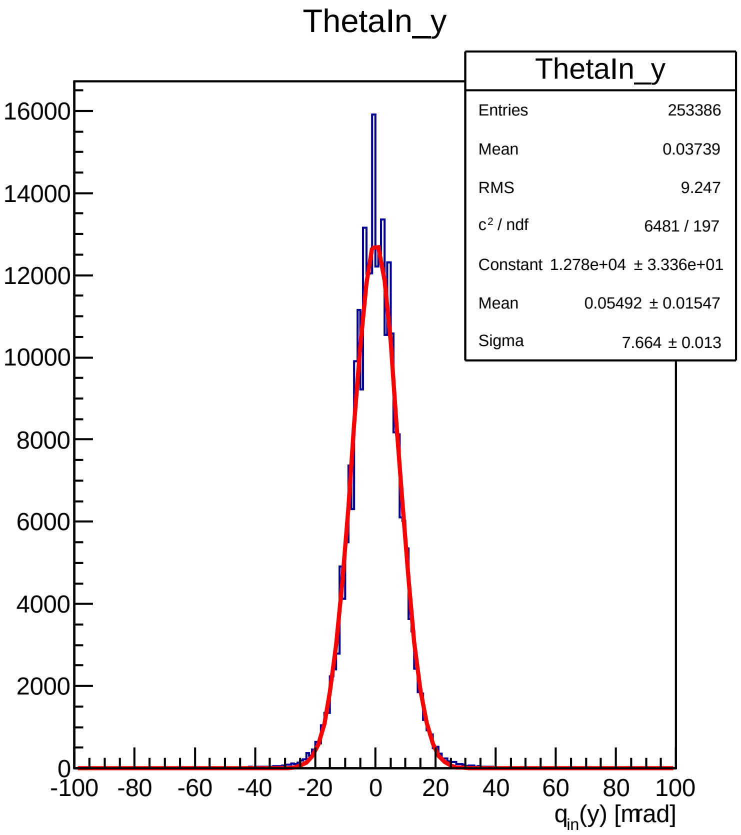
The beam divergence is found to be 10.67 µrad in x and 7.66 µrad in y.

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.





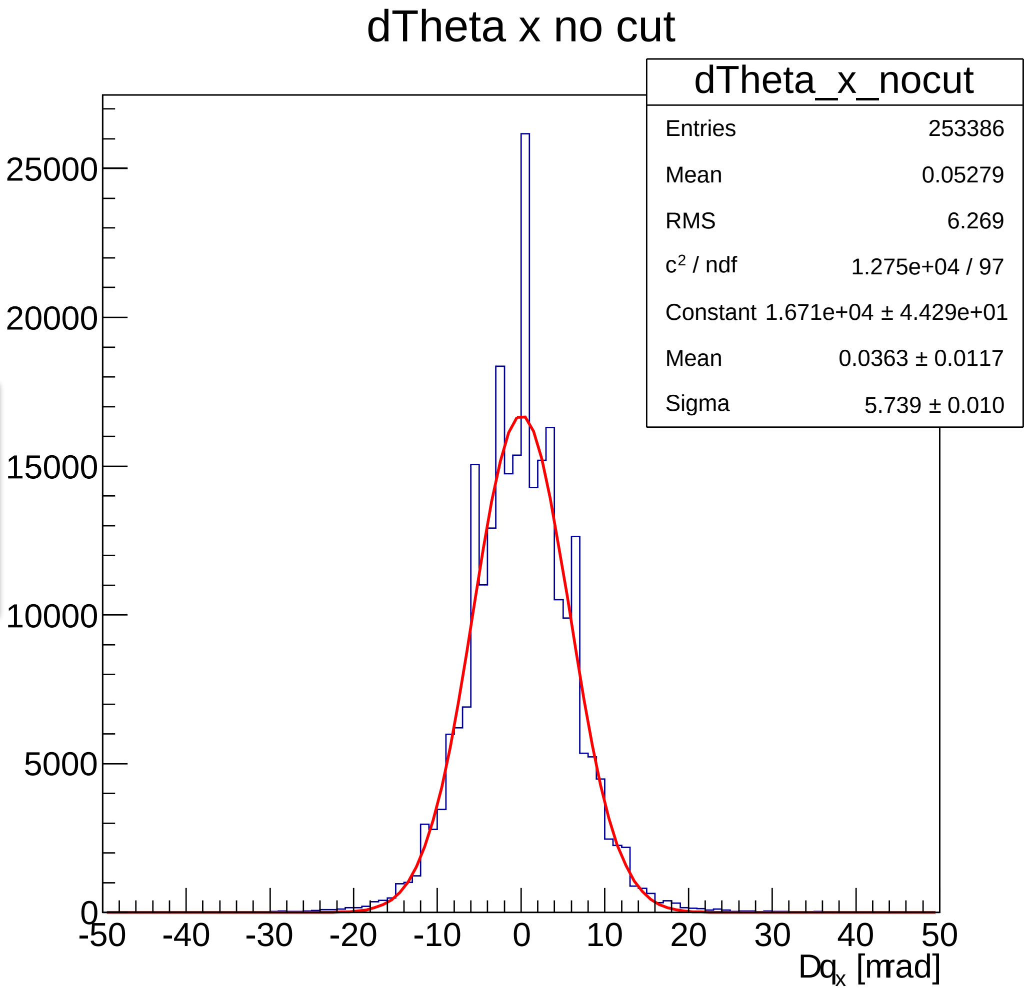
Alignment Run Analysis

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 μrad

in good agreement with the resolution estimated in [1].



[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 P040006

Alignment Run Recap

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

Year	Xtal	X Profile [mm]	Y Profile [mm]	X Divergence [µrad]	Y Divergence [µrad]	Resolution [µrad]
2010	STF38	*1,014*	*0,721*	*10,670*	*7,658*	*5,619*
2010	STF40	*1,017*	*0,724*	*10,680*	*7,697*	*5,756*
2010	STF45	*1,001*	*0,725*	*10,650*	*7,684*	*5,762*
2010	QMP27	*1,017*	*0,724*	*10,680*	*7,697*	*5,731*
2011	**STF47**	1,063	0,949	11,730	8,964	5,283
2011	**STF48**	1,055	0,960	11,880	8,982	5,302
2011	**STF49**	1,075	0,979	12,170	8,973	5,259
2011	**QMP32**	1,059	0,944	11,830	8,949	5,286
2012	**STF50**	*1,294*	*0,861*	*10,900*	*8,049*	*5,494*
2012	**STF51**	*1,290*	*0,825*	*10,880*	*8,022*	*5,496*
2012	**STF70**	*1,239*	*0,827*	*9,216*	*5,748*	*5,284*
2012	**STF71**	*1,215*	*0,825*	*9,111*	*5,731*	*5,311*
2012	**QMP26**	*1,269*	*0,821*	*9,134*	*5,774*	*5,421*
2012	**QMP28**	*1,287*	*0,822*	*9,153*	*5,770*	*5,408*
2012	**QMP29**	*1,239*	*0,827*	*9,216*	*5,748*	*5,284*

Two kinds of cuts are performed on the initial distributions

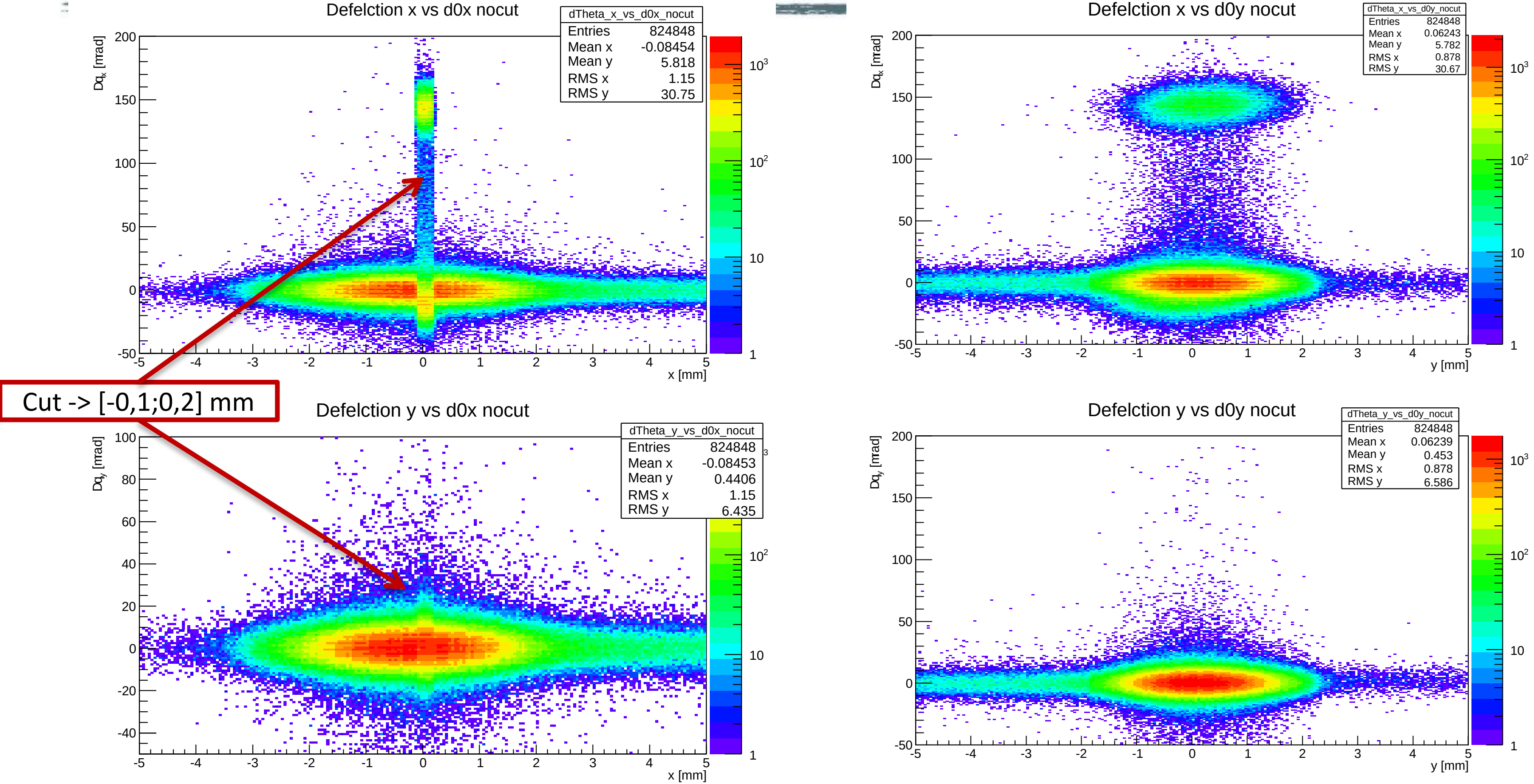
Geometrical cut

- 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.

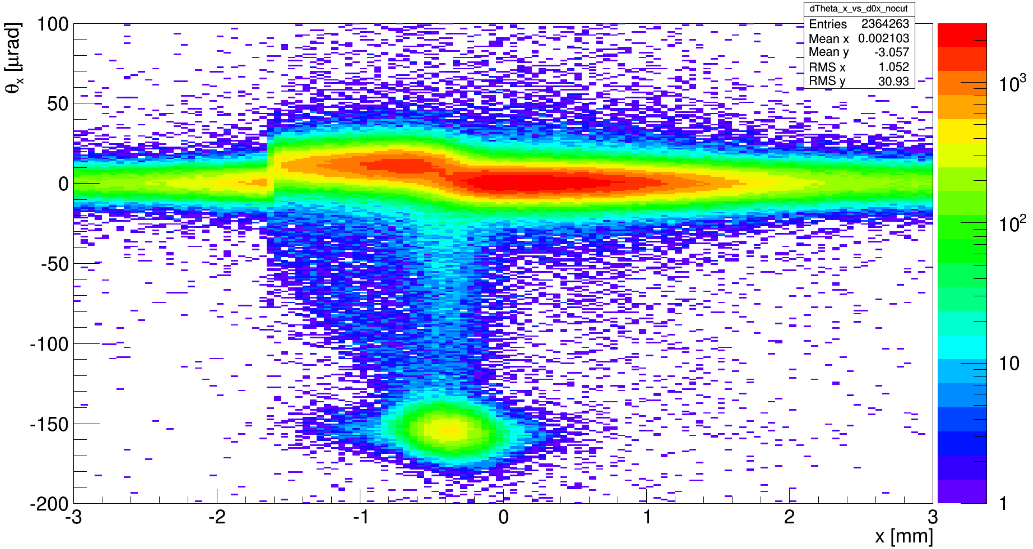
Geometrical cut

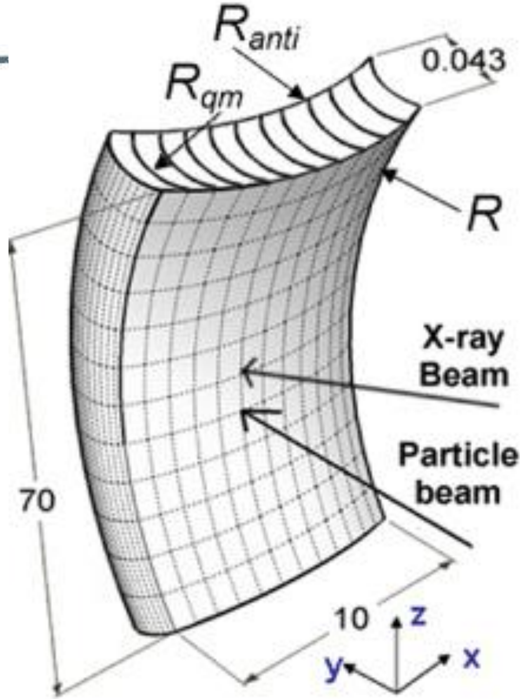


Example of QM

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

	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*
2010	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*
2011	**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*
2012	**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 if proportional to the y impact location.

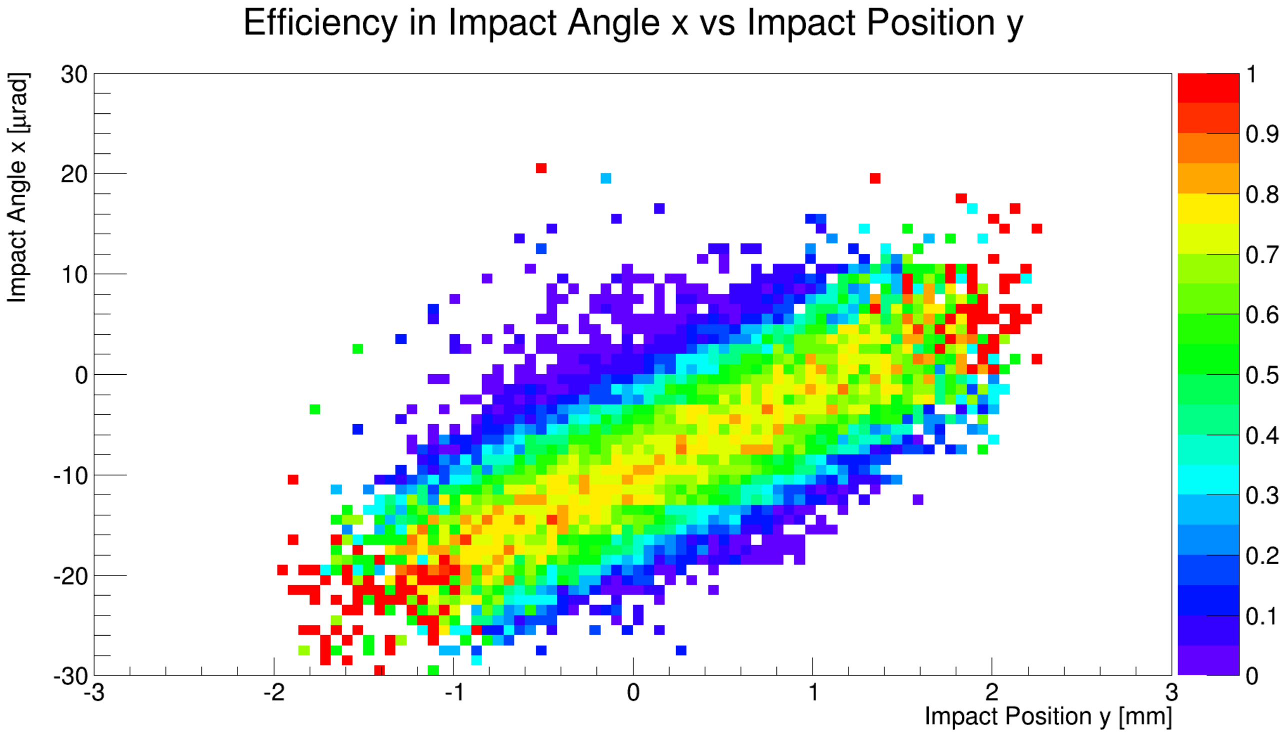
This effect is defined as torsion. As a result, the channeling efficiency varies with both the horizontal impact angle and the vertical impact position.

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

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

Channeled events are calculated from the deflection profile

Efficiency vs. Impact angle x vs. Impact y

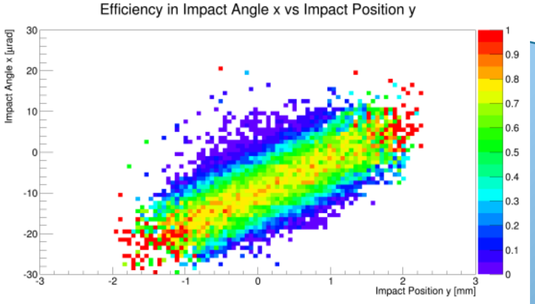


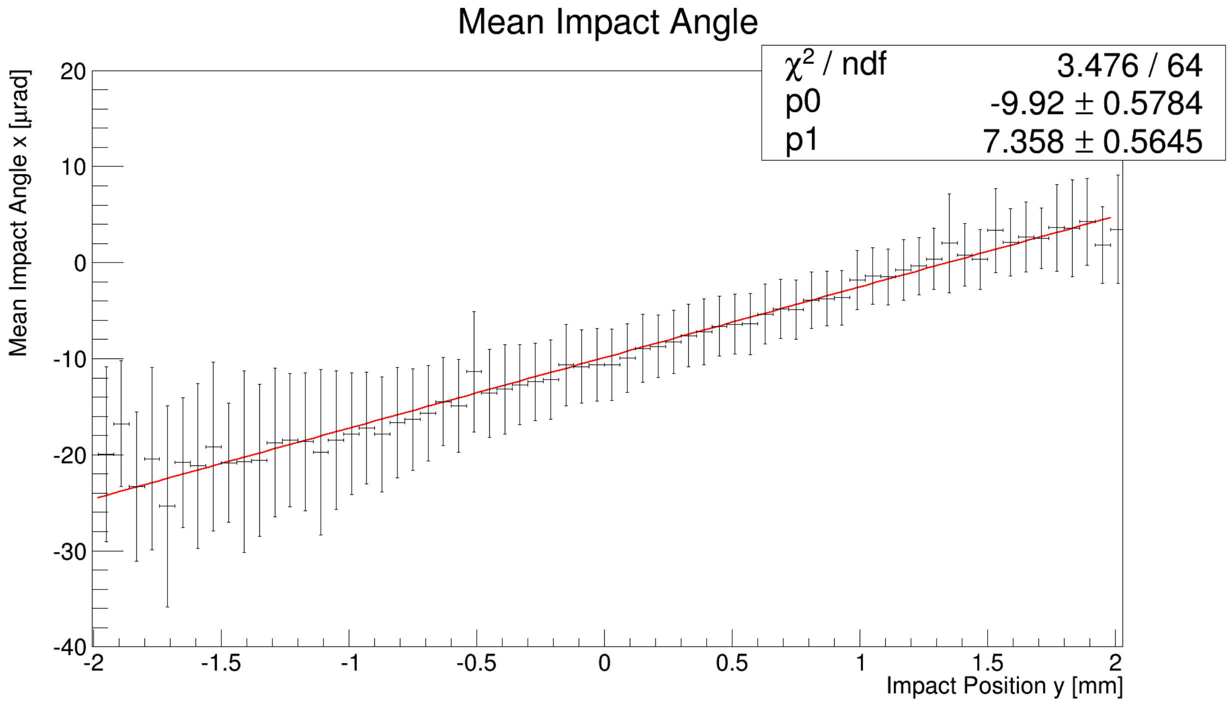
2-dimensional efficiency plot as a function of impact x angle and impact y points is obtained.

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

Efficiency vs. Impact angle x vs. Impact y

STF48





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

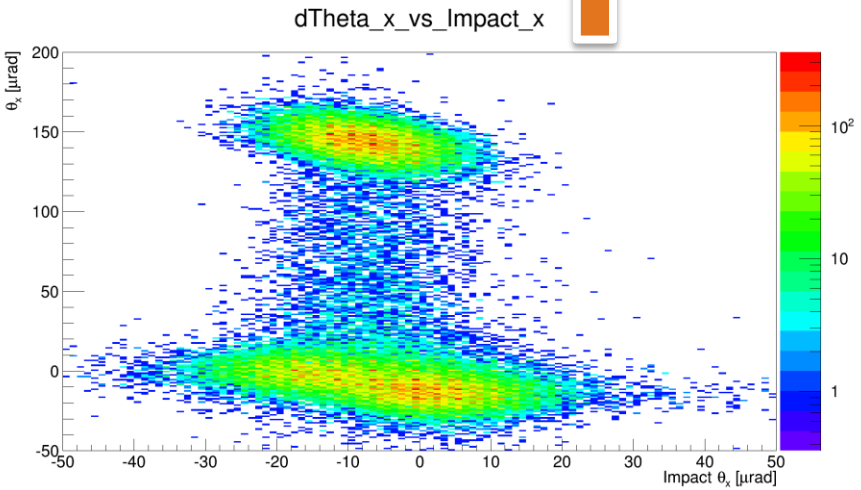
Torsion correction

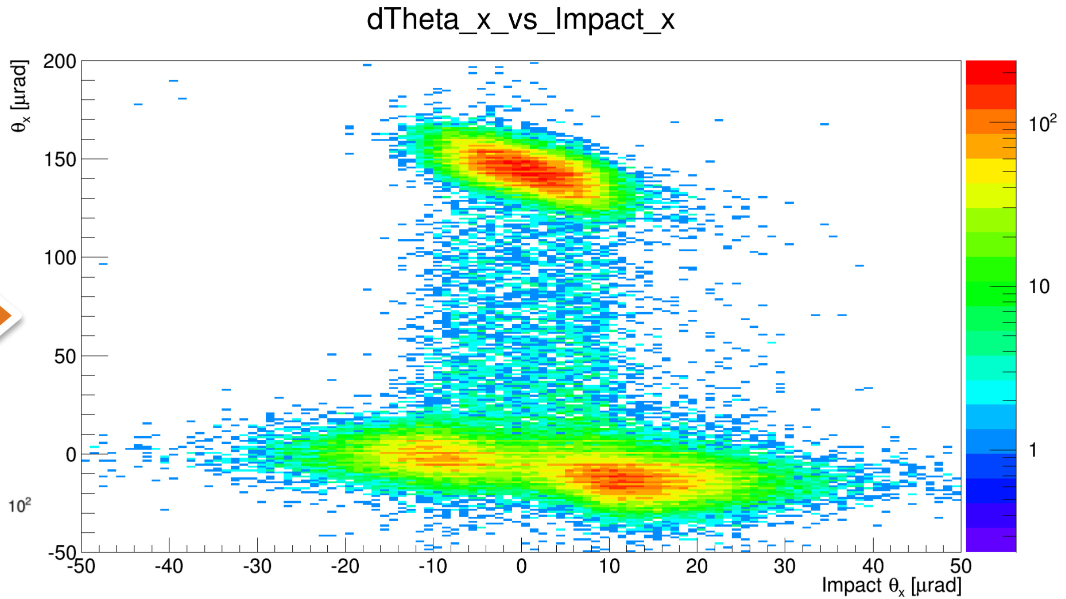
If we define the impact x angle as

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

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

	Xtal	Initial gonio angle [μrad]	Initial gonio angle [μrad]
2010	STF38	*-5,032*	*-5,515*
	STF45	*7,358*	*-9,920*
	QMP27	1,381	-0,351
2011	**STF47**	*-2,521*	*1,753*
	STF48	*6,942*	*7,285*
	STF49	*5,310*	*5,285*
	QMP32	*-0,25*	*-0,35*
2012	**STF50**	*4,998*	*-4,654*
	STF51	*1,075*	*-2,193*
	QMP26	*6,888*	*2,217*
	QMP29	*-0,343*	*-0,873*

The calculated torsions are summerized in this table

Channeling efficiency recap

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

2010

Xtal	± 5 µrad	± 10 µrad
STF45	0,69	0,54
QMP27	0,589	0,50

2011

Xtal	± 5 µrad	± 10 µrad
STF47	0,56	0,48
STF48	0,55	0,43
STF49	0,47	0,35
QMP32	0,51	0,41

2012

Xtal	± 5 µrad	± 10 µrad
STF50	0,56	0,46
STF51	0,52	0,47
QMP29	0,66	0,56

Dechanneling length recap

That is the recap of the dechanneling length

2010

Xtal	± 5 μrad	± 10 μrad
STF45	1,43	1,25
QMP27	1,15	1,35

2011

Xtal	± 5 μrad	± 10 μrad
STF48	1,525	1,414
STF49	0,19	0,17
QMP32	0,42	0,37

2012

Xtal	± 5 μrad	± 10 μrad
STF50	1,52	1,37

recoData caratteristic

dfs/Experiment/UA9/Data-Test_beams

- 2010 data [/2010_09_16,_H8_re-recodata]
  - reconstruction problem
    - » Each variable is in the array “thetaIn_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 Propiety							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	384
											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

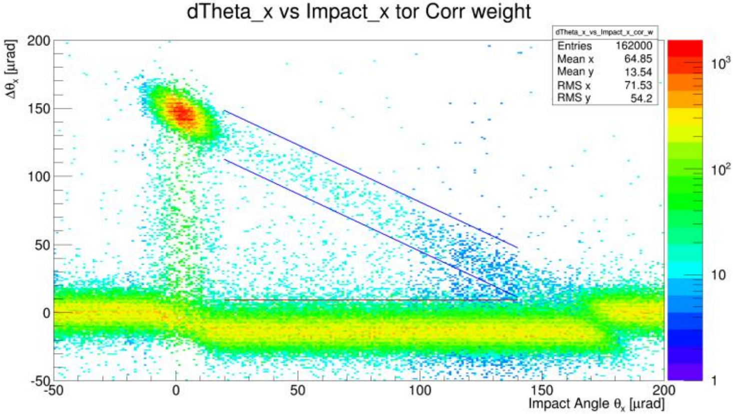
Missing Hi stat ch

Xtla code	Year	Nominal Propiety							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

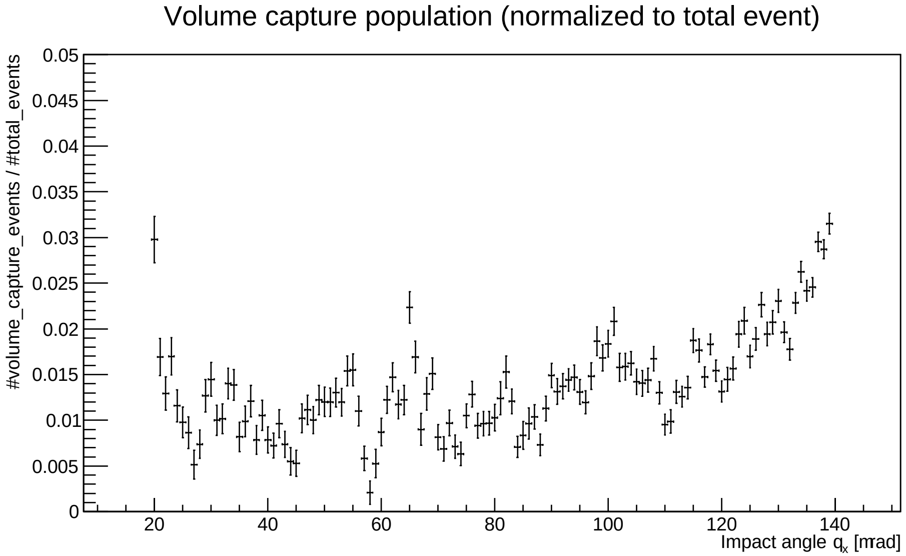
Bad Angular Scan
Moving backward

Volume capture analysis

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



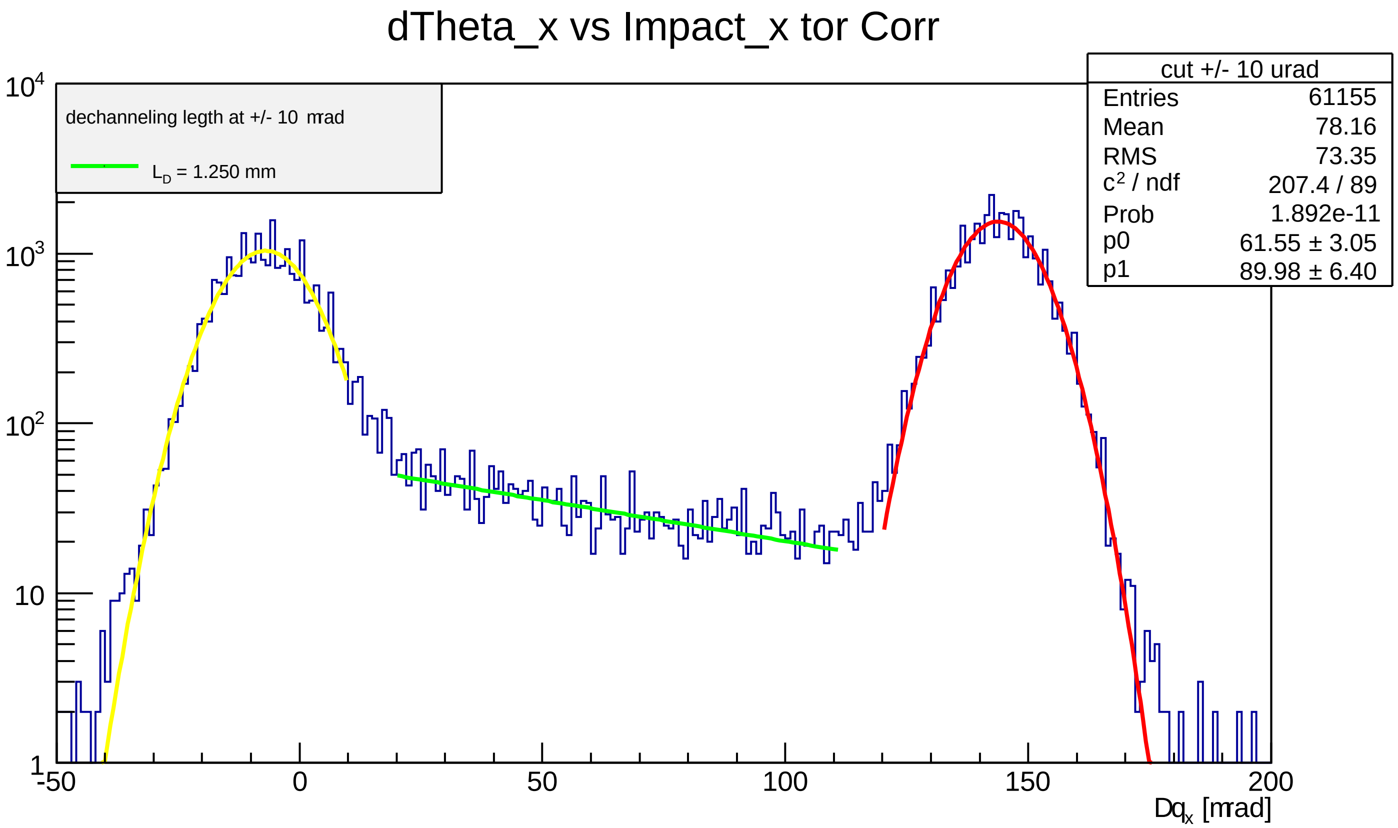
The captured population is plotted as a function of the impact x angle. The rise in the end of reflection region is a well-known behavior.

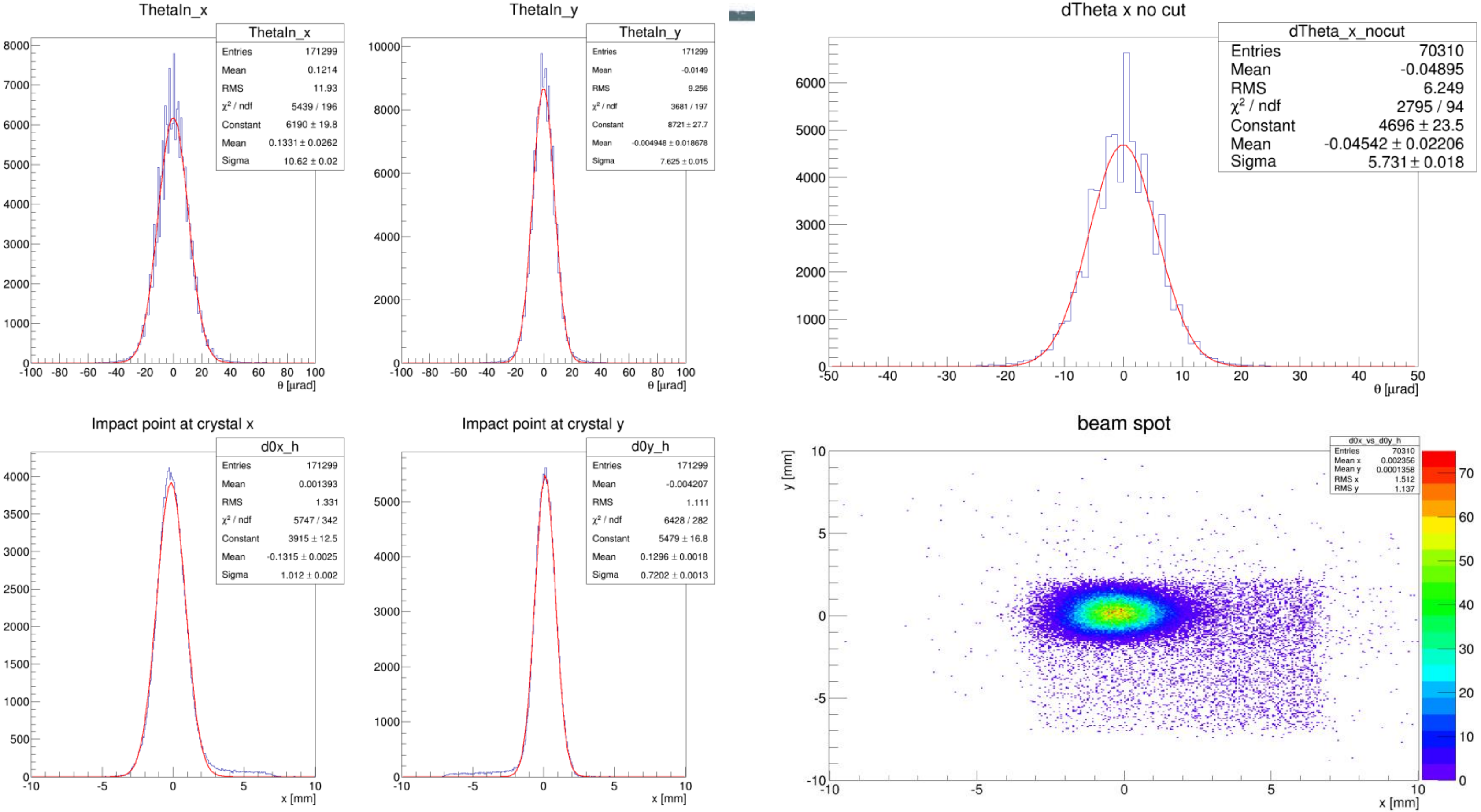


This analysis is performed for the first time, we are looking for a model that describes the trends observed.

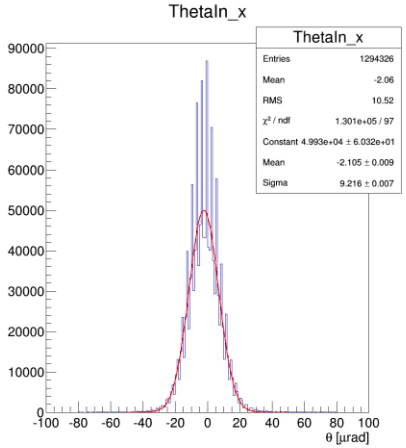
Dechanneling Lengt

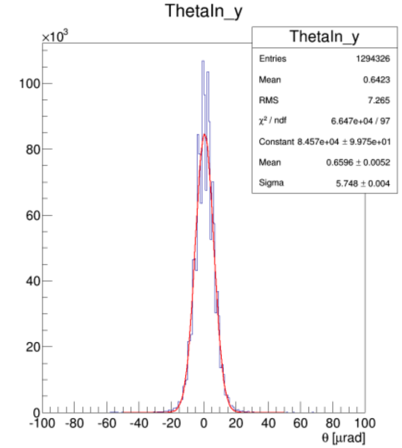
± 10 μrad

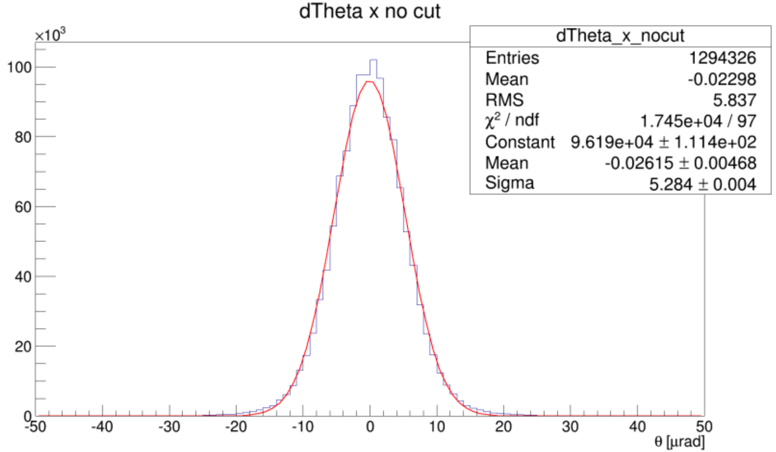


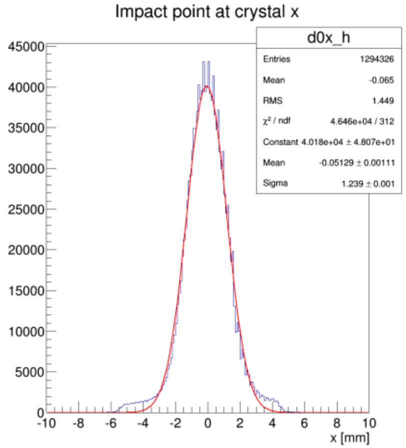

ThetaIn_x
ThetaIn_x
Entries 171299
Mean 0.1214
RMS 11.93
χ² / ndf 5439 / 196
Constant 6190 ± 19.8
Mean 0.1331 ± 0.0262
Sigma 10.62 ± 0.02
θ [µrad]
ThetaIn_y
ThetaIn_y
Entries 171299
Mean -0.0149
RMS 9.256
χ² / ndf 3681 / 197
Constant 8721 ± 27.7
Mean -0.004948 ± 0.018678
Sigma 7.625 ± 0.015
θ [µrad]
dTheta x no cut
dTheta_x_nocut
Entries 70310
Mean -0.04895
RMS 6.249
χ² / ndf 2795 / 94
Constant 4696 ± 23.5
Mean -0.04542 ± 0.02206
Sigma 5.731 ± 0.018
θ [µrad]
Impact point at crystal x
d0x_h
Entries 171299
Mean 0.001393
RMS 1.331
χ² / ndf 5747 / 342
Constant 3915 ± 12.5
Mean -0.1315 ± 0.0025
Sigma 1.012 ± 0.002
x [mm]
Impact point at crystal y
d0y_h
Entries 171299
Mean -0.004207
RMS 1.111
χ² / ndf 6428 / 282
Constant 5479 ± 16.8
Mean 0.1296 ± 0.0018
Sigma 0.7202 ± 0.0013
x [mm]
beam spot
d0x_vs_d0y_h
Entries 70310
Mean x 0.002356
Mean y 0.0001358
RMS x 1.512
RMS y 1.137
y [mm]
x [mm]

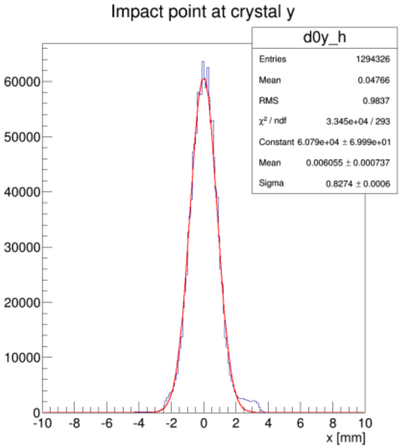
2012

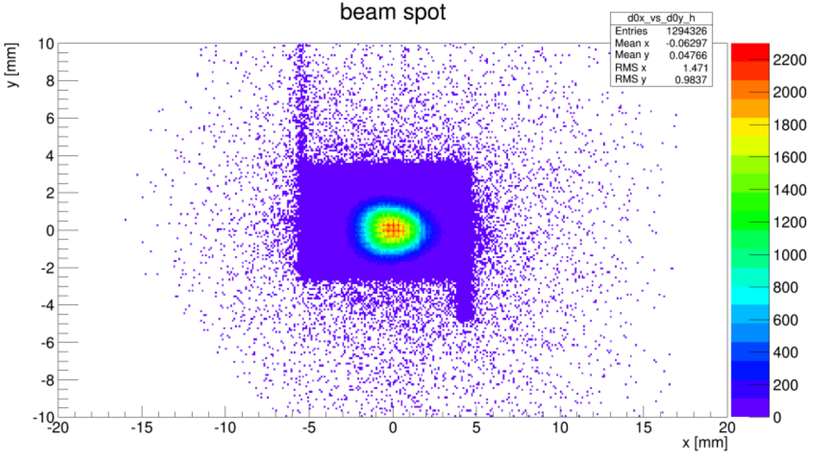

ThetaIn_x
ThetaIn_x
Entries 1294326
Mean -2.06
RMS 10.52
χ² / ndf 1.301e+05 / 97
Constant 4.993e+04 ± 6.032e+01
Mean -2.105 ± 0.009
Sigma 9.216 ± 0.007
θ [μrad]


ThetaIn_y
ThetaIn_y
Entries 1294326
Mean 0.6423
RMS 7.265
χ² / ndf 6.647e+04 / 97
Constant 8.457e+04 ± 9.975e+01
Mean 0.6596 ± 0.0052
Sigma 5.748 ± 0.004
×10³
θ [μrad]


dTheta x no cut
dTheta_x_nocut
Entries 1294326
Mean -0.02298
RMS 5.837
χ² / ndf 1.745e+04 / 97
Constant 9.619e+04 ± 1.114e+02
Mean -0.02615 ± 0.00468
Sigma 5.284 ± 0.004
×10³
θ [μrad]


Impact point at crystal x
d0x_h
Entries 1294326
Mean -0.065
RMS 1.449
χ² / ndf 4.646e+04 / 312
Constant 4.018e+04 ± 4.807e+01
Mean -0.05129 ± 0.00111
Sigma 1.239 ± 0.001
x [mm]

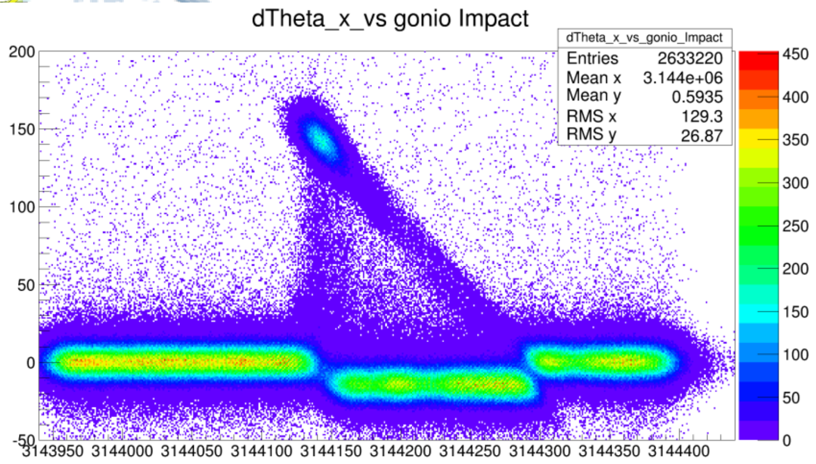

Impact point at crystal y
d0y_h
Entries 1294326
Mean 0.04766
RMS 0.9837
χ² / ndf 3.345e+04 / 293
Constant 6.079e+04 ± 6.999e+01
Mean 0.006055 ± 0.000737
Sigma 0.8274 ± 0.0006
x [mm]


beam spot
d0x_vs_d0y_h
Entries 1294326
Mean x -0.06297
Mean y 0.04766
RMS x 1.471
RMS y 0.9837
y [mm]
x [mm]

Angle Scan Run Analysis

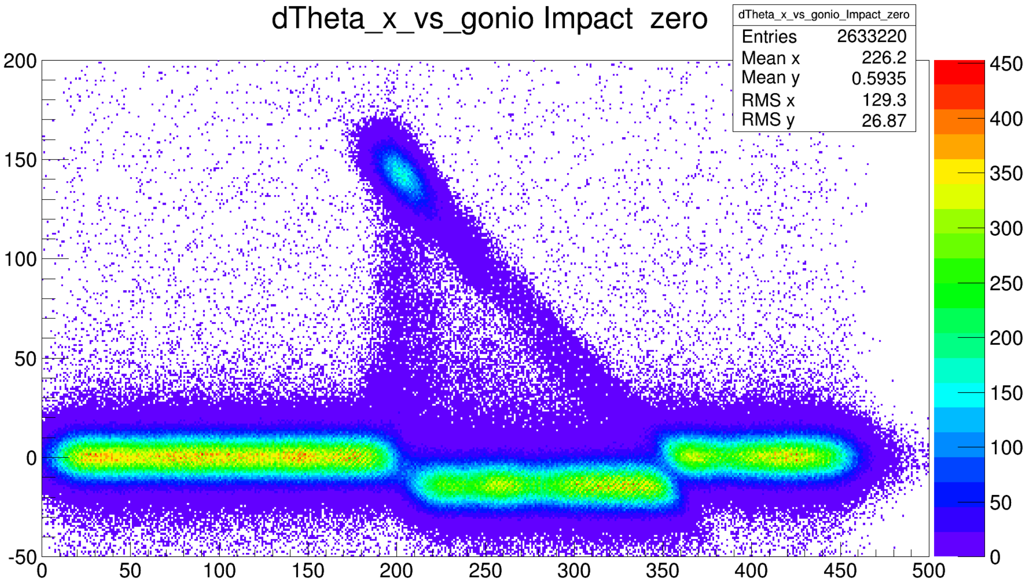
- Angular scan of the crystal, moving the goniometer on the horizontal plane respect to the beam
- We obtain both the scan of the angular kick with respect to the impact x angle and the goniometer position

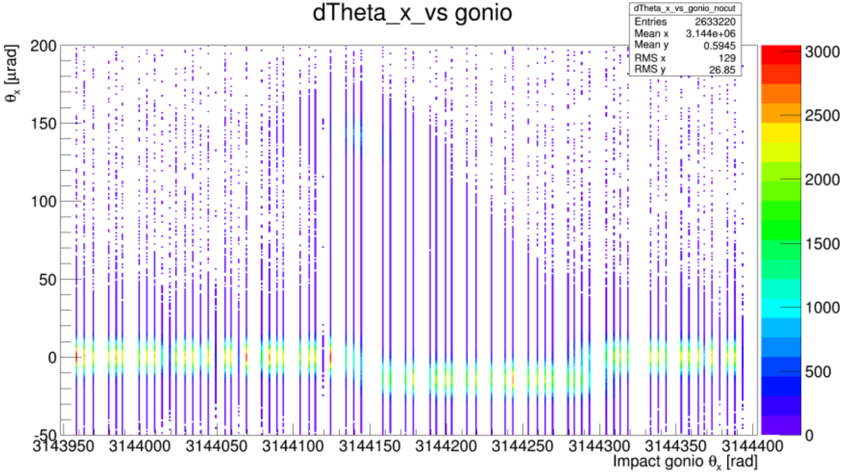
  - From the second one we get three stripes in which each effect is quite evident, and we analyze the peak of AM, CH and VR
    - NB : That's only a check, befor torsion correction, so we don't know jet what is the impact angle respect the crystallographic plane. So for each stripes all the beam divergence is accepted.



x deflection vs. impact angle x

Down here is subtracted the initial angle scan of the goniometer

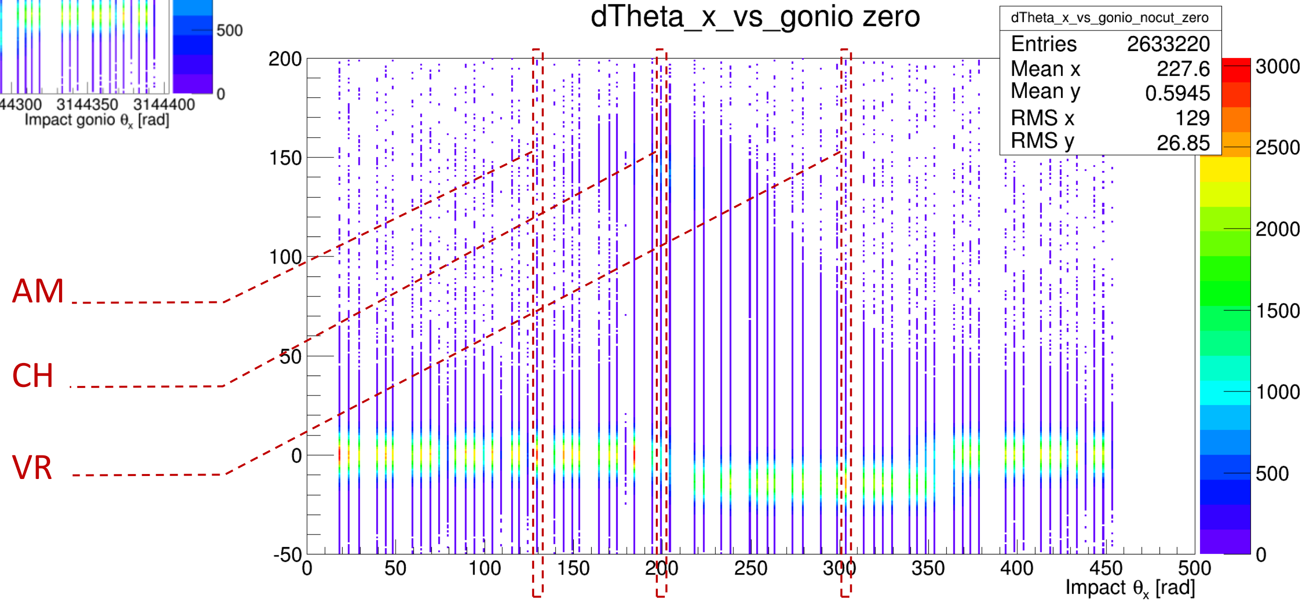




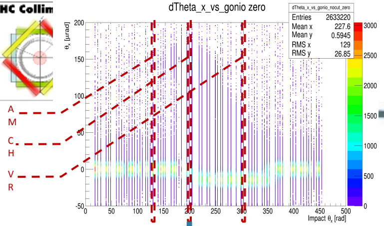
x deflection vs. the goniometer position on the horizontal plane.

Down here is subtracted the initial angle scan of the goniometer

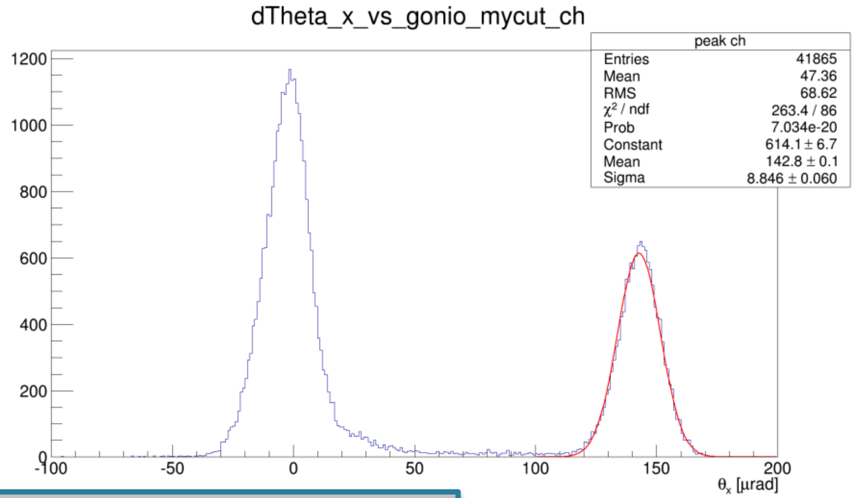
Slice selected for the analysis



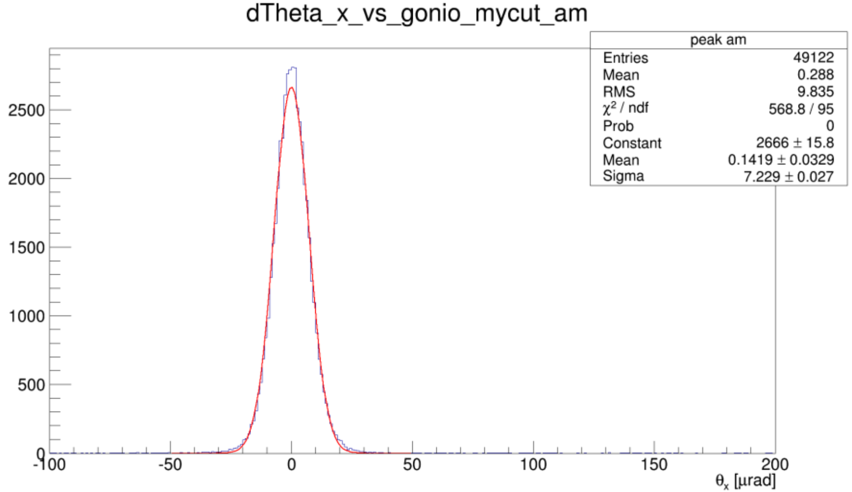
Peak



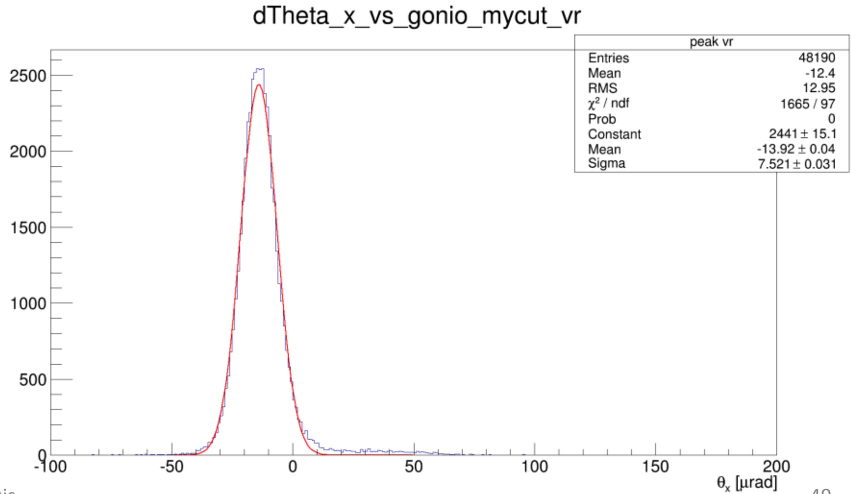
dTheta_x_vs_gonio zero
Entries 2633220
Mean x 227.6
Mean y 0.5945
RMS x 129
RMS y 26.85
A
M
C
H
V
R
Impact θ_x [rad]



dTheta_x_vs_gonio_mycut_ch
peak ch
Entries 41865
Mean 47.36
RMS 68.62
χ² / ndf 263.4 / 86
Prob 7.034e-20
Constant 614.1 ± 6.7
Mean 142.8 ± 0.1
Sigma 8.846 ± 0.060
θx [µrad]



dTheta_x_vs_gonio_mycut_am
peak am
Entries 49122
Mean 0.288
RMS 9.835
χ² / ndf 568.8 / 95
Prob 0
Constant 2666 ± 15.8
Mean 0.1419 ± 0.0329
Sigma 7.229 ± 0.027
θx [µrad]



dTheta_x_vs_gonio_mycut_vr
peak vr
Entries 48190
Mean -12.4
RMS 12.95
χ² / ndf 1665 / 97
Prob 0
Constant 2441 ± 15.1
Mean -13.92 ± 0.04
Sigma 7.521 ± 0.031
θx [µrad]

Agnle Scan Analysis Recap

Xtla code	Year	Measurements		
		ch peak [µrad]	vr peak [µrad]	am peak [µrad]
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 [µrad]	vr peak [µrad]	am peak [µrad]
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

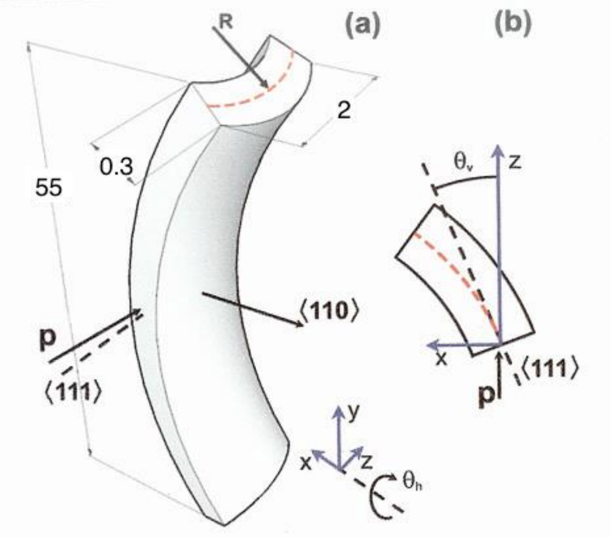
Note – VR sigma should be 1,387 µrad, which have to be added to the AM spread.

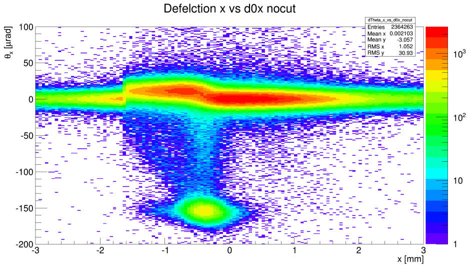
Hi Stat CH analysis

Strip geometrical cut

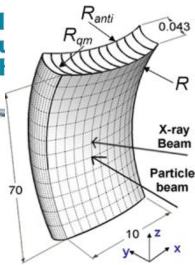
Angular kick as function of x and y impact point is measured

- 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 : ± 3 σ from the mean of the y beam profile





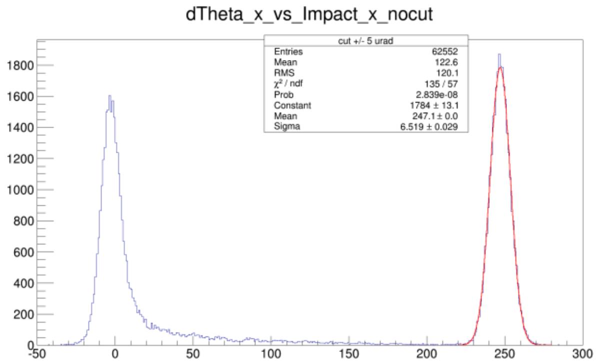
QM cut

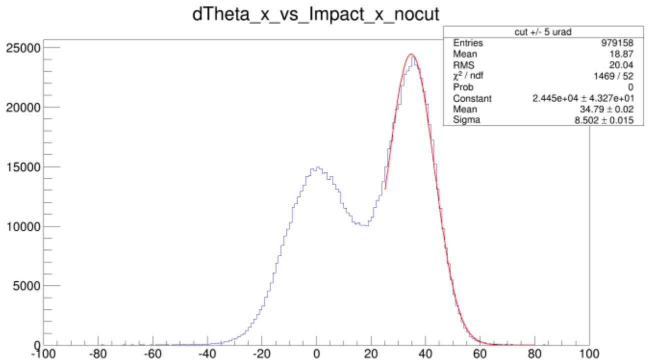


We measure the channeling efficiency (#ch/#tot) versus the impact point on the plane xy

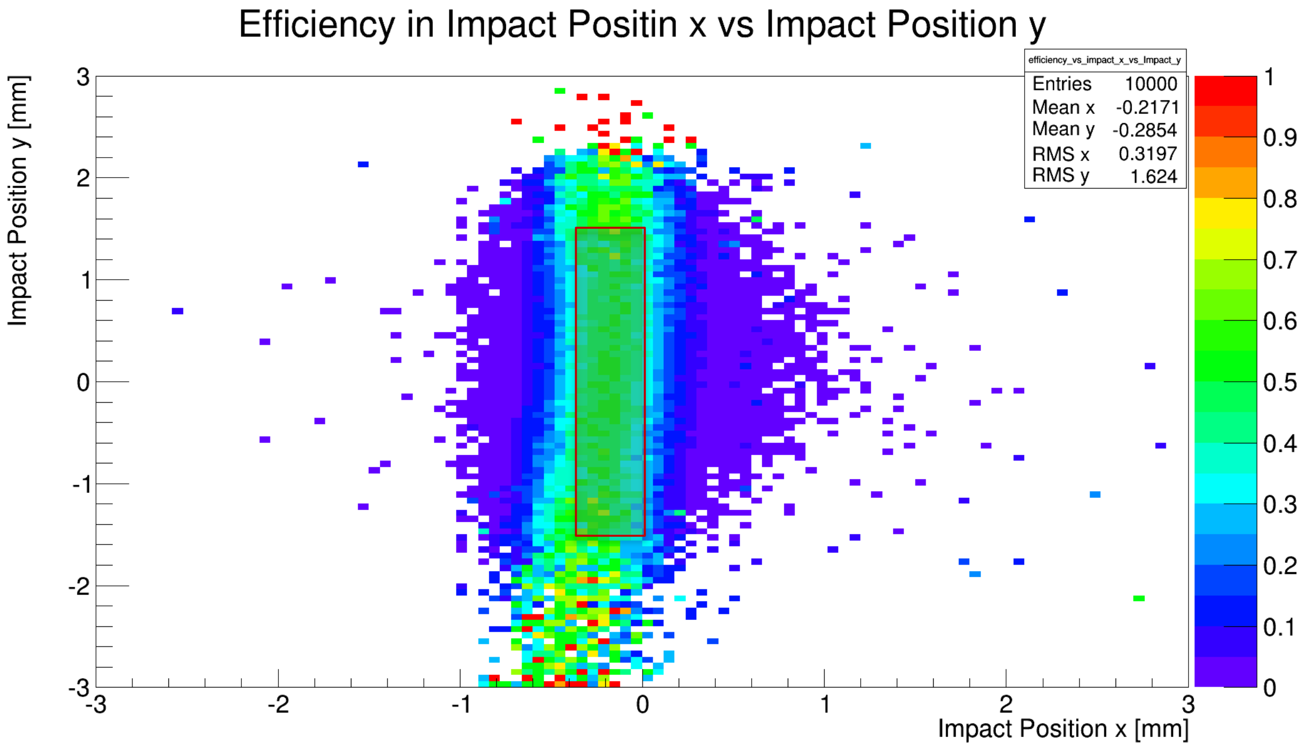
note :

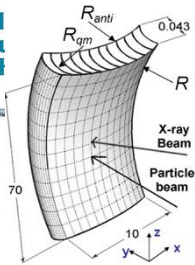
- We get a pixeled map of the xy plane. Each pixel have as dimension the spatial tracker resolution (50/60 μm)
- For each pixel we analize the 1dim histogram of the angular kick inferred to each particle. A gaussian fit is performed around the CH peak
- The channeling event are measured in two different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





QM cut





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

QMP27

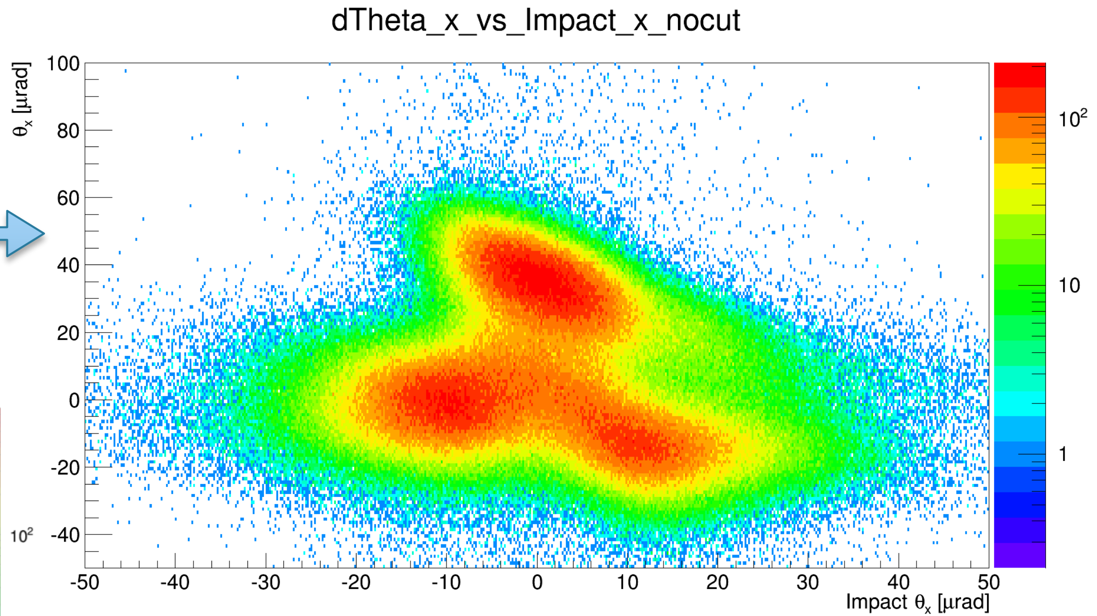
x = [-0,4 ; 0,0]

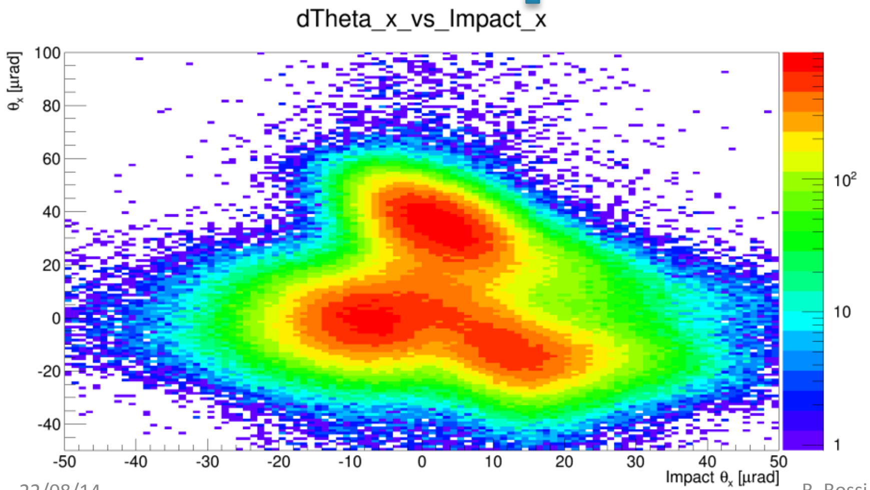
y = [-1,5 ; 1,5]

Torsion correction

STF47

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

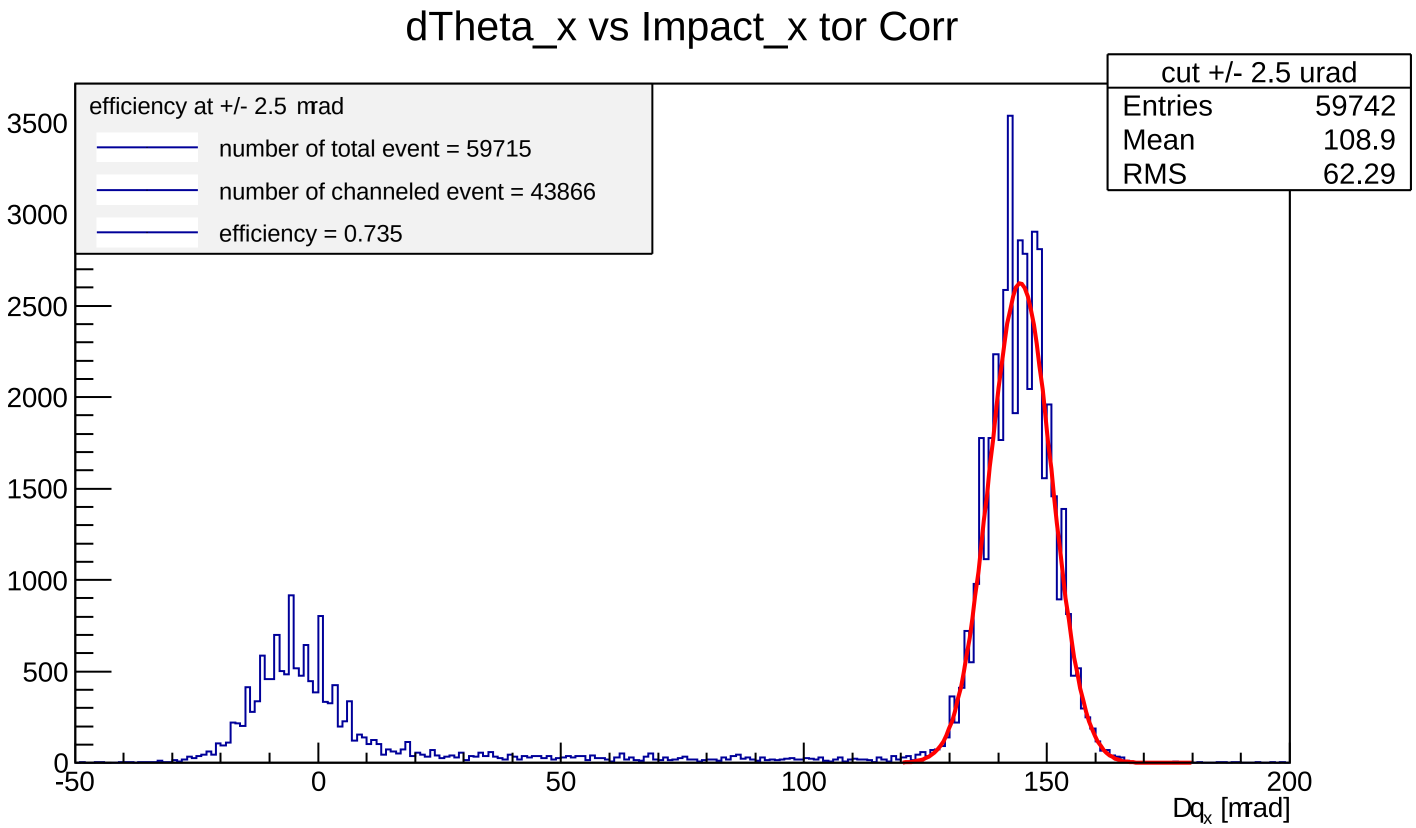




Channeling Efficier

± 2.5 μrad

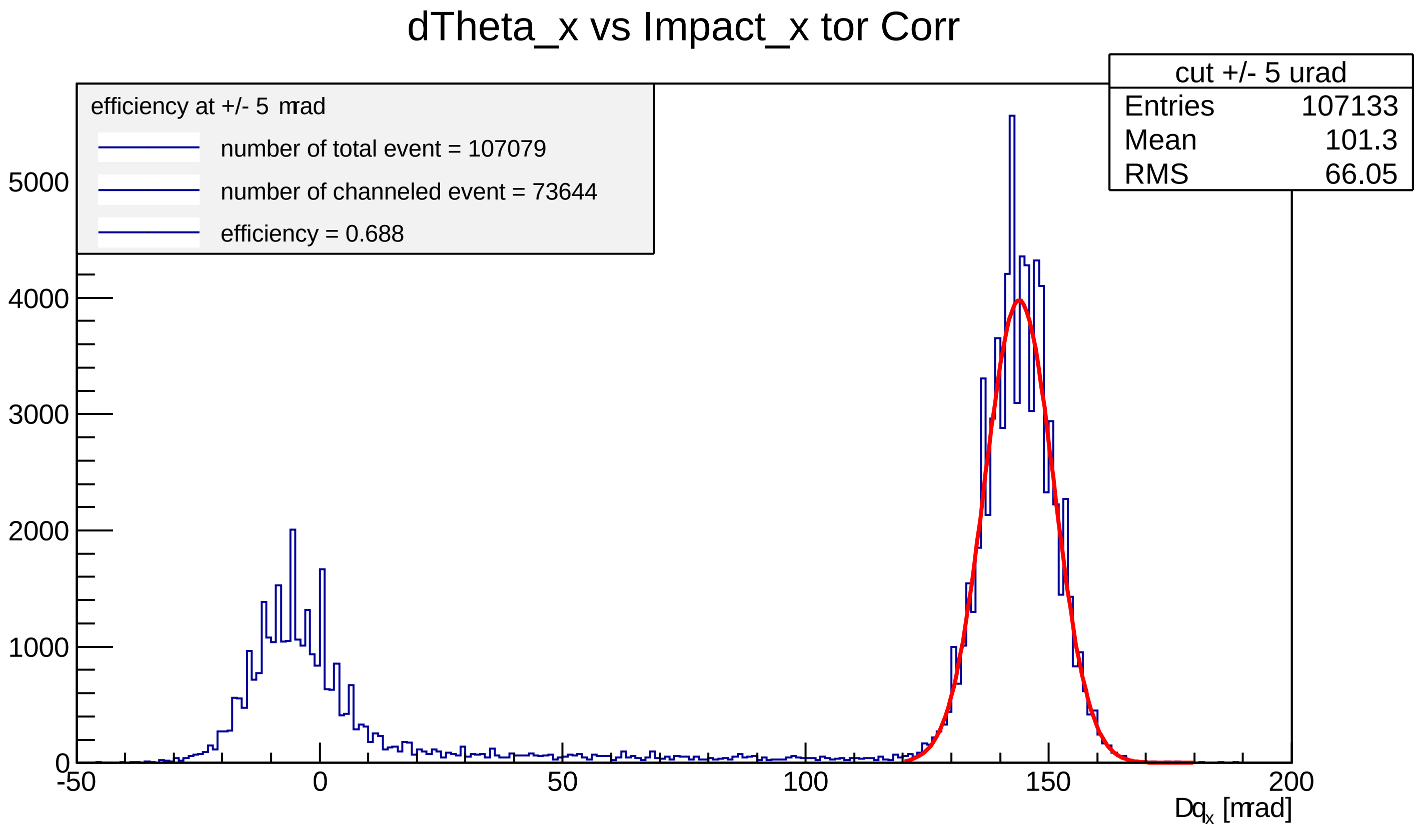
Efficiency = 0,74



Channeling Efficiency

± 5 μrad

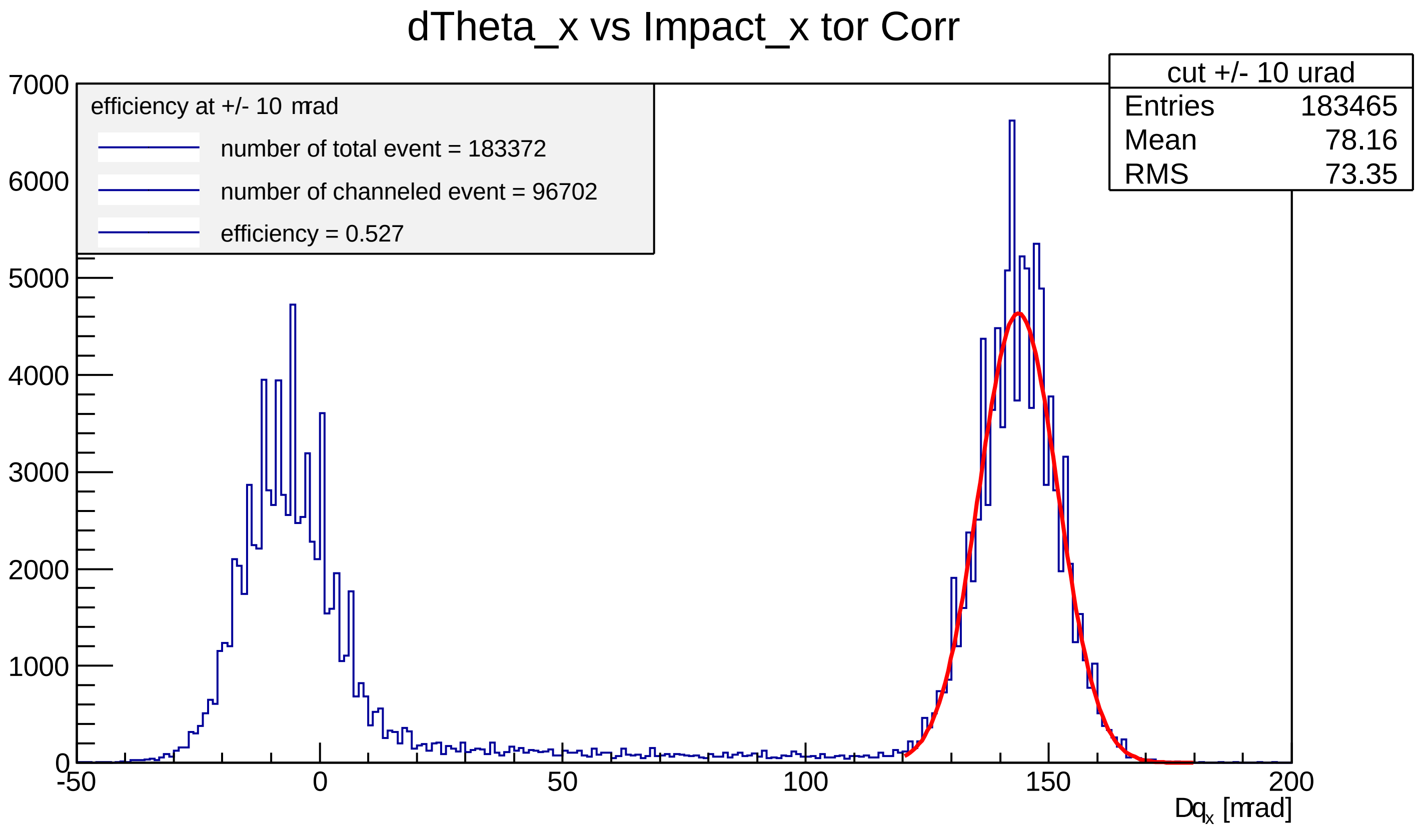
Efficiency = 0,69



Channeling Efficier

± 10 µrad

Efficiency = 0,53



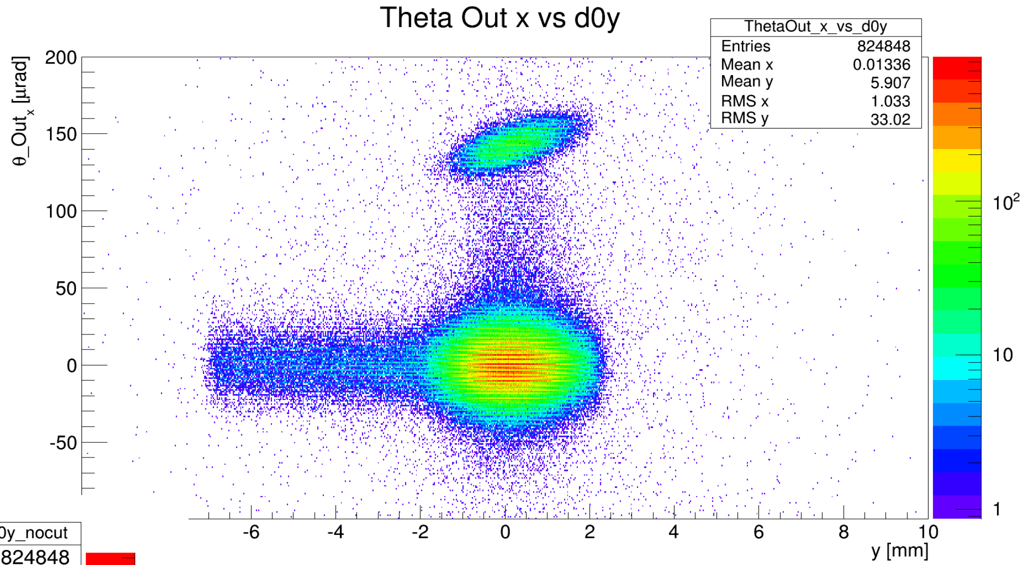
Hi Stat CH Analysis

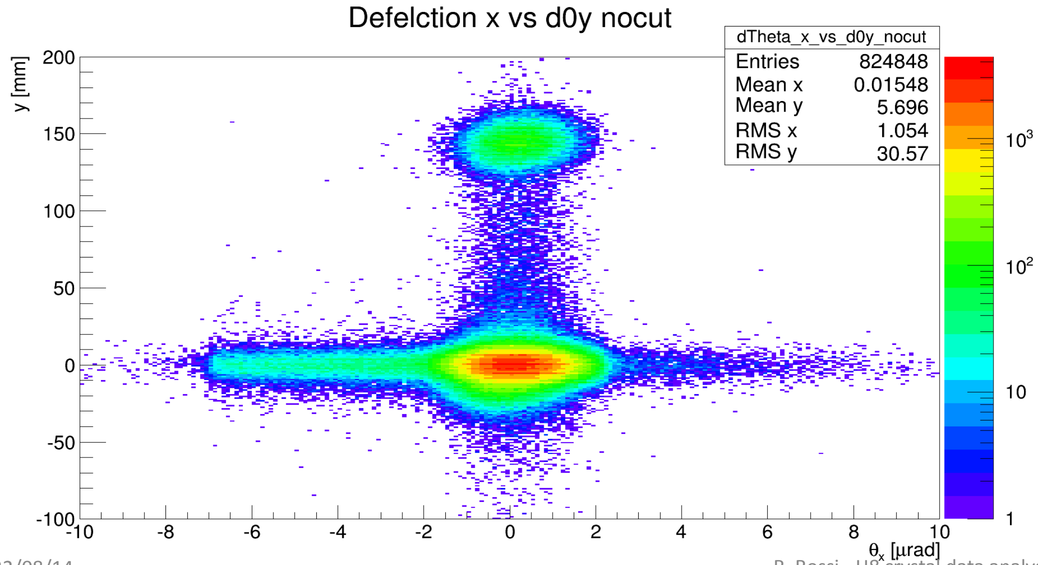
torsion

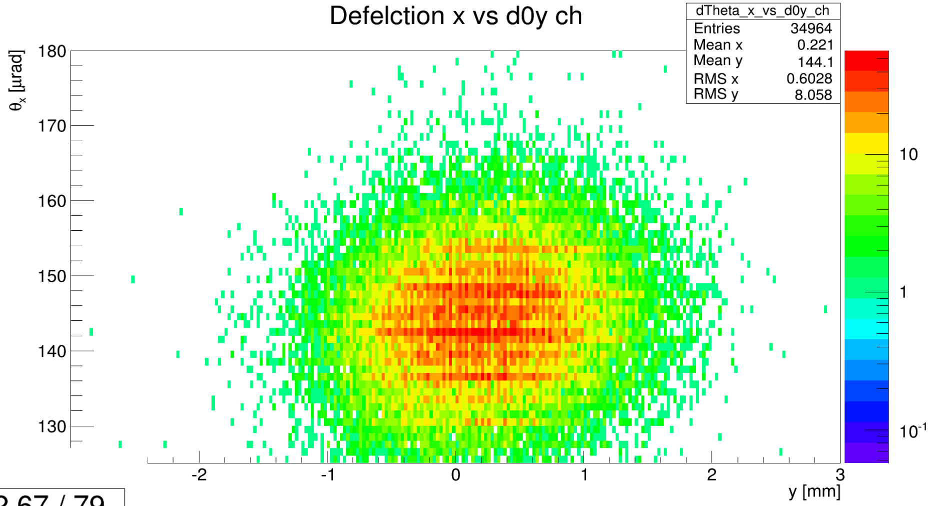
- x kick vs. impact y position is analyzed to measure the bending variation as a function of the vertical impact position

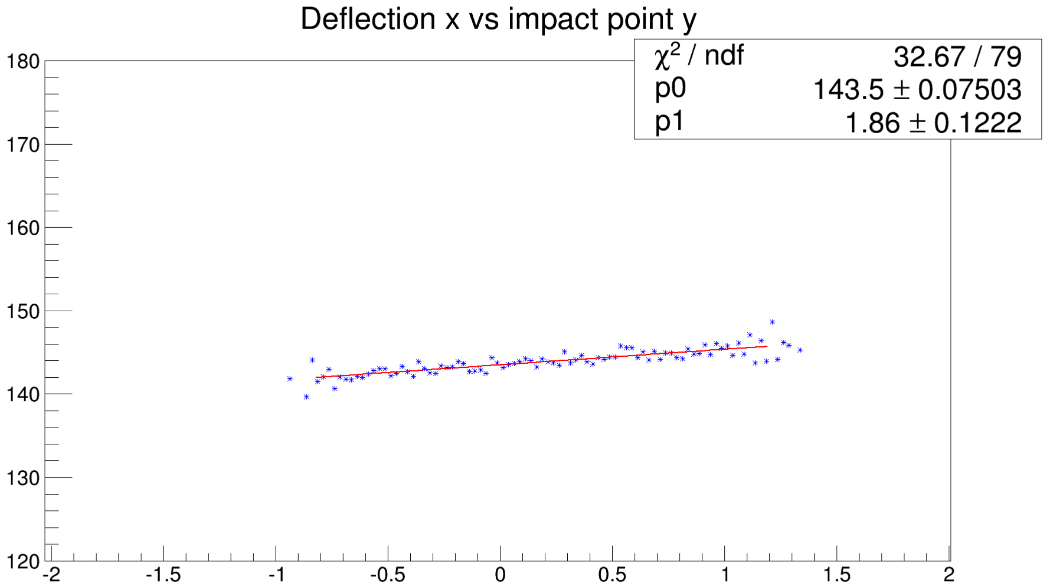
- The outgoing x angle vs. impact y position is also analyzed to measure directly the torsion as the variation of the outgoing angle as a function of vertical impact position

Geometrical cut is used for both the analysis

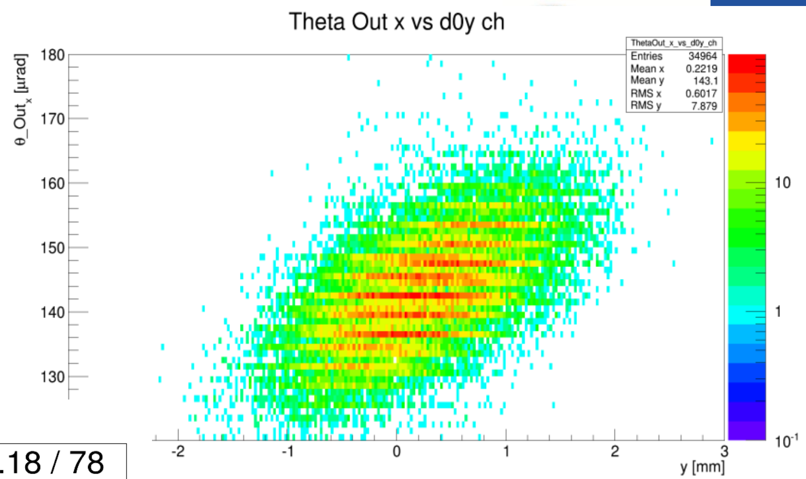

Theta Out x vs d0y
ThetaOut_x_vs_d0y
Entries 824848
Mean x 0.01336
Mean y 5.907
RMS x 1.033
RMS y 33.02
θ_Out_x [μrad]
y [mm]

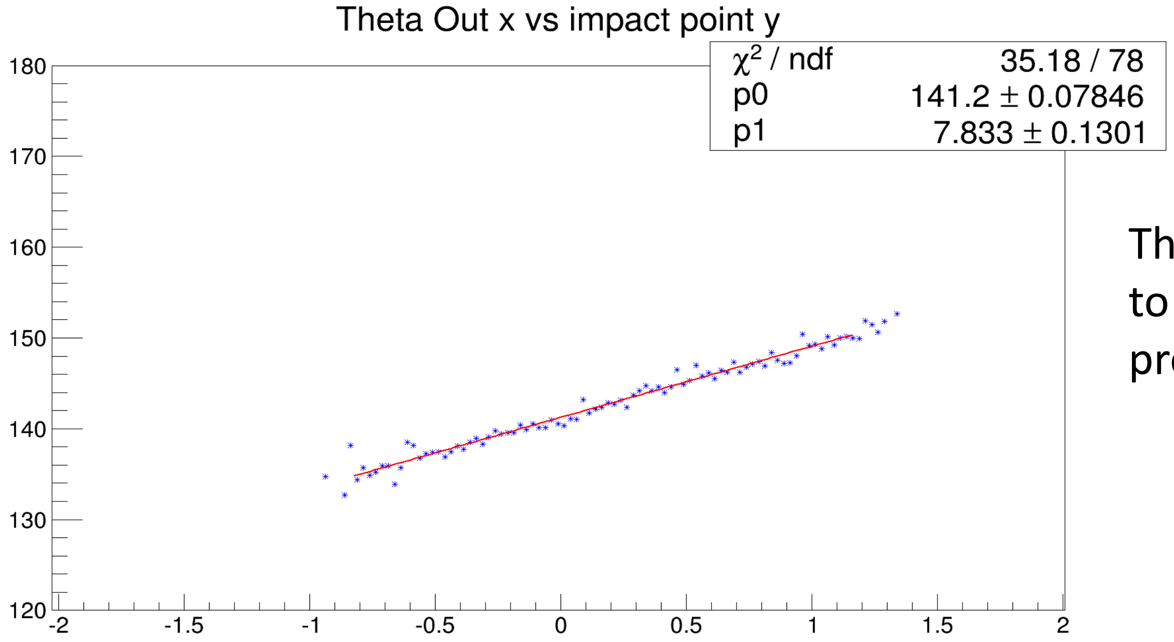

Defelction x vs d0y nocut
dTheta_x_vs_d0y_nocut
Entries 824848
Mean x 0.01548
Mean y 5.696
RMS x 1.054
RMS y 30.57
y [mm]
θx [μrad]





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





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