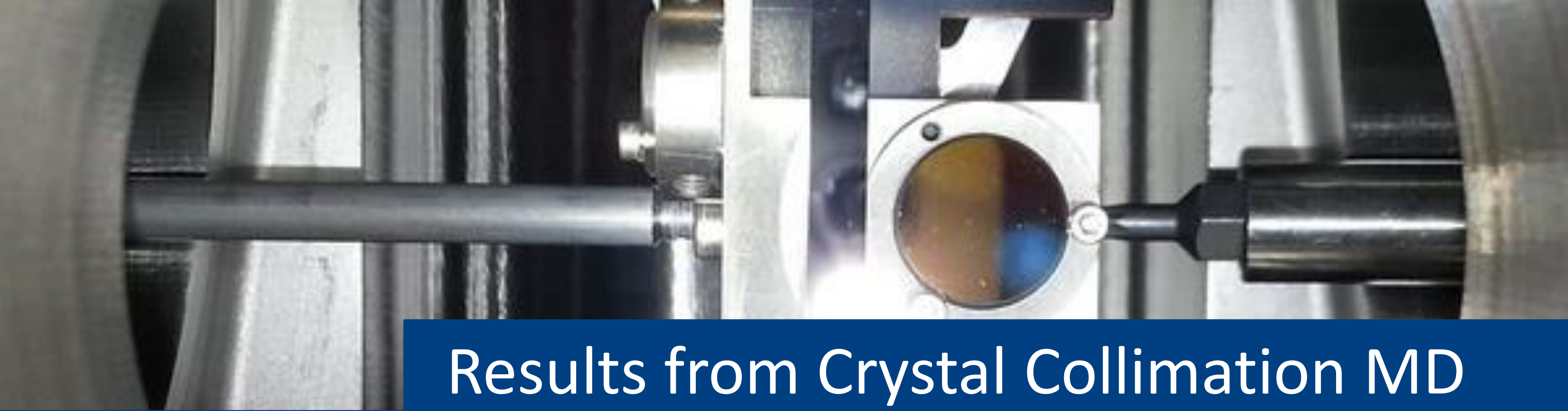


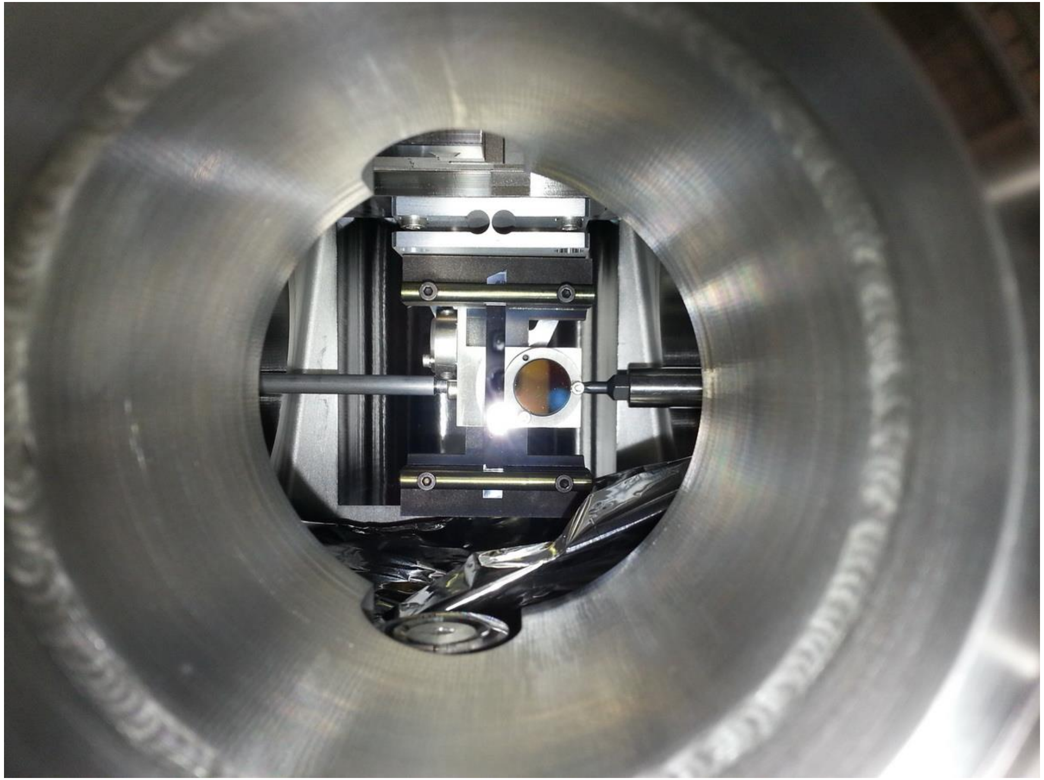
Results from Crystal Collimation MD with Xenon ions in LHC

24/11/2017 – Collimation Upgrade Specification Meeting

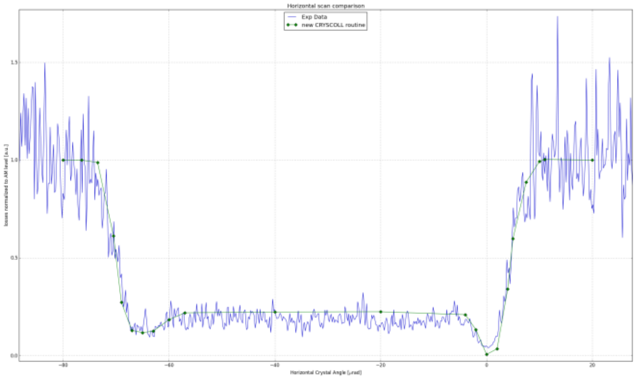
Roberto Rossi, Daniele Mirarchi, Stefano Redaelli, N. Fuster Martinez, M. D’Andrea, W. Scandale, S. Montesano, F. Galluccio, A. Masi, G. Valentino, M. Butcher, C. Barreto, P. Serrano Galvez

Outline

- Introduction
- MD plans
- MD results
  - Channeling Measurements
  - Cleaning Measurements
- B1-H crystal discussion



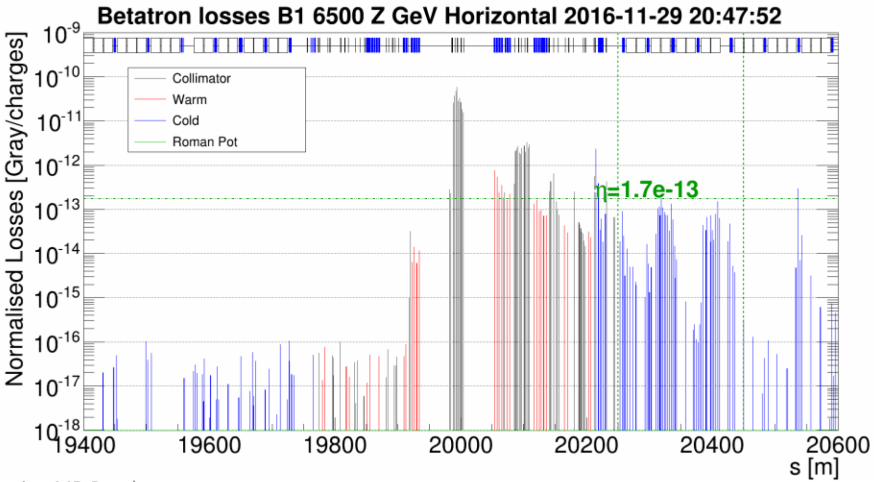
Introduction



During 2015-2017 MD blocks crystal collimation devices on B1 & B2 have been successfully tested.

- ✓ Channeling observed with both ion and proton beams at top energy
- ✓ Cleaning measurements performed
- ✓ Channeling maintained during the proton energy ramp
- ✓ New installation on B2 tested – with understanding of new installation features

With lead ion beams no improvement indication of beam cleaning observed in the 2016 tests.
Xe beams tests crucial to understand if crystal collimation can work with heavy ions.



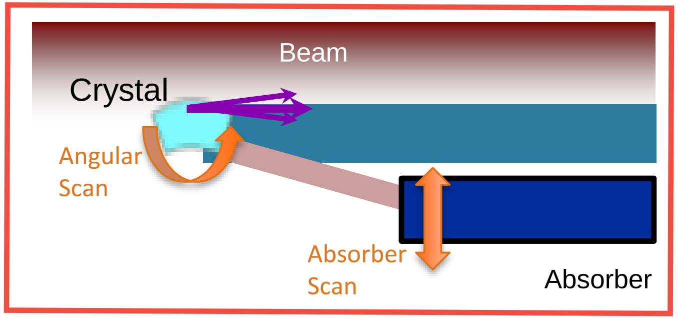
MD Plan

The main goals is to assess the performances of the new hardware

- ❑ Crystal aligned and set as primary collimator

  downstream system at nominal settings

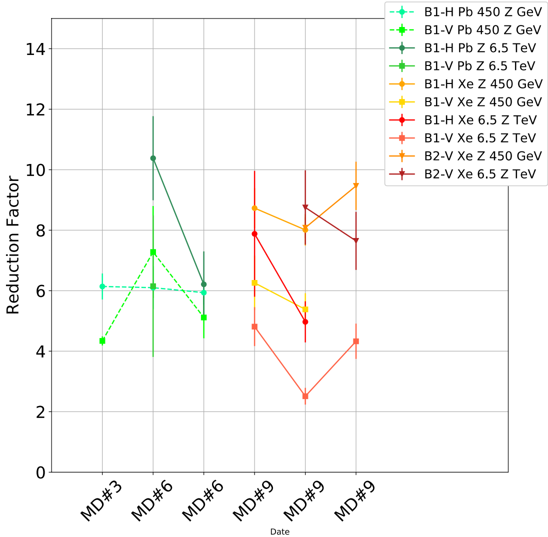
- ❑ Fast angular scan to find channeling orientation
- ❑ Characterization measurements
  - Injection
    - Angular scan to find optimal channeling orientation
    - Linear scan with absorber to characterize the channeled beam
  - Flat Top
    - Angular scan to find optimal channeling orientation
    - Linear scan with absorber to characterize the channeled beam
- ❑ Cleaning measurements of crystal collimation (Loss Maps)
- ❑ Perform in parallel same tests on B2

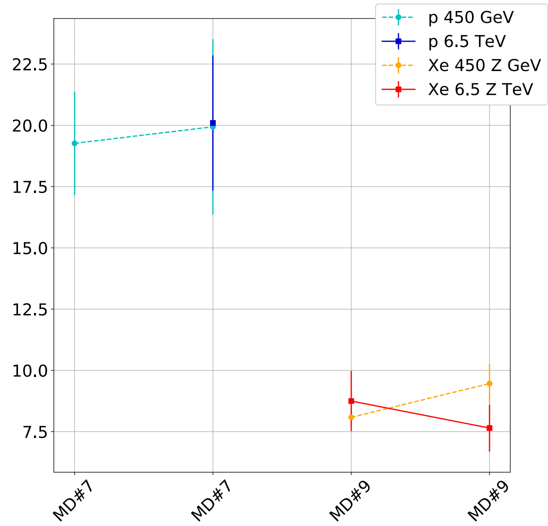


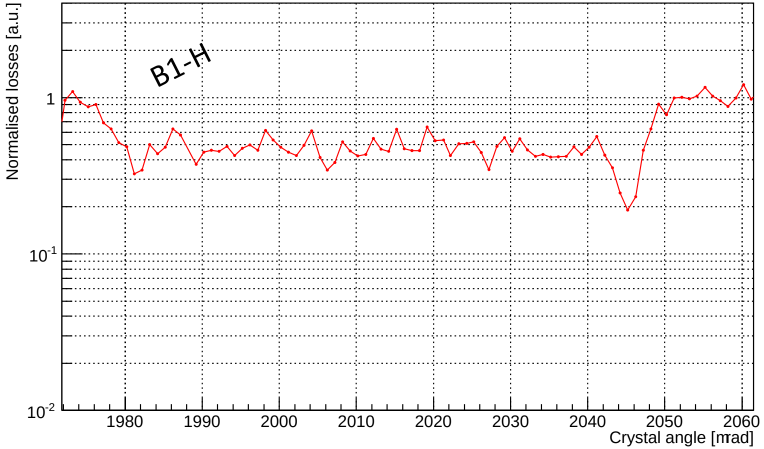
Crystal Channeling Measurements

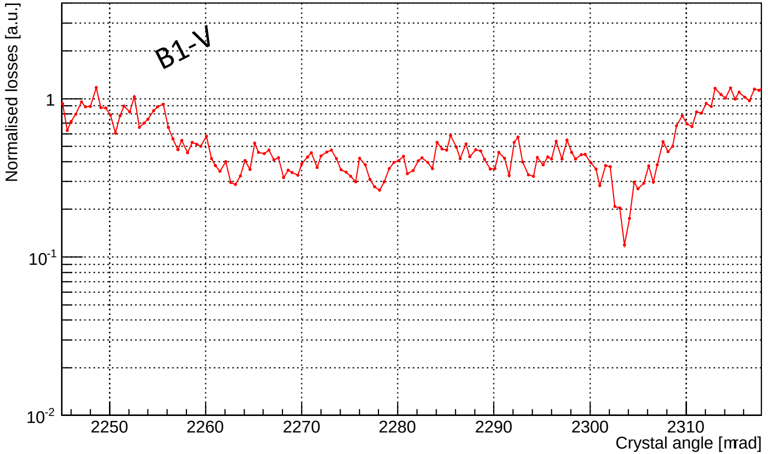
Crystal Channeling with Xe

Channeling measurements in agreement with lead ions observation.
In comparison with protons, the reduction factor is about a factor 2 lower.





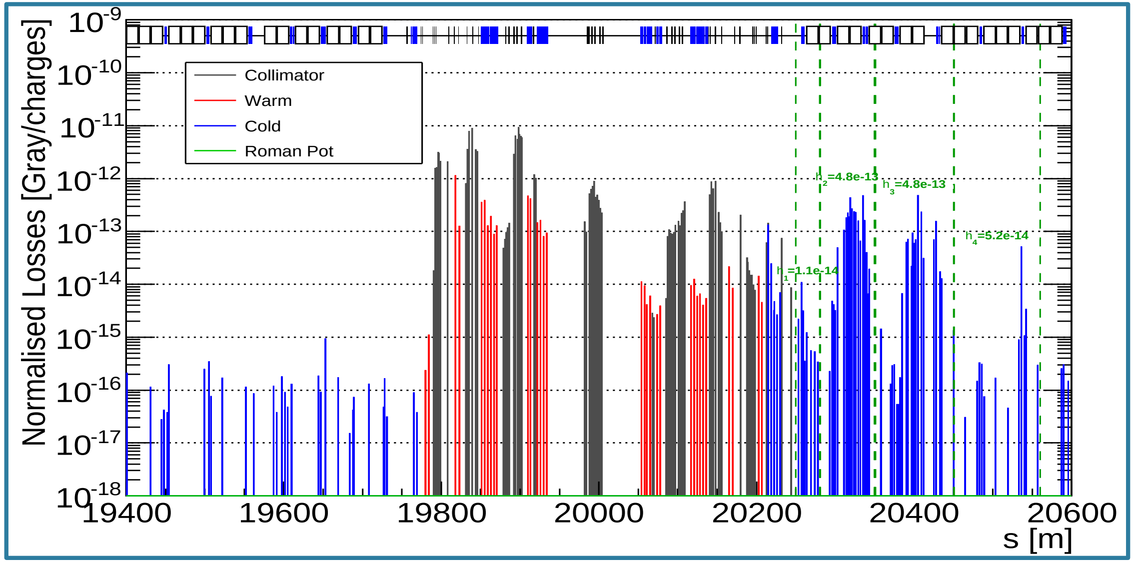


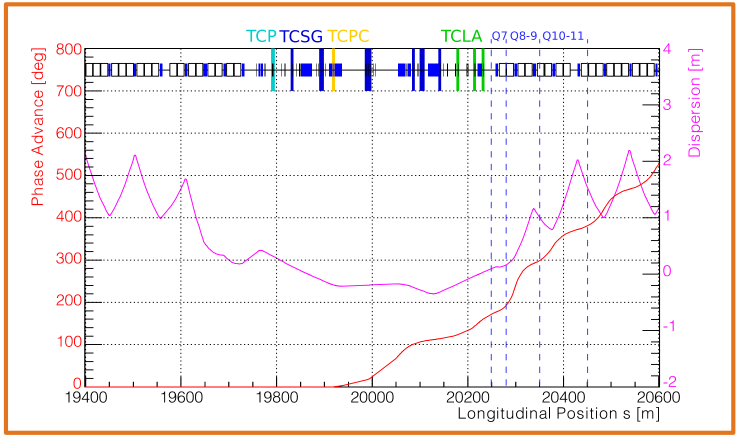


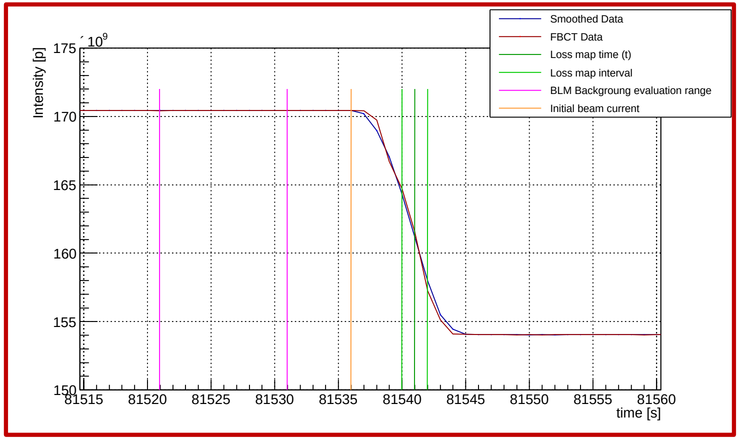
Crystal Collimation Measurements

Methods

Usual normalization to TCP losses does not allow direct comparison





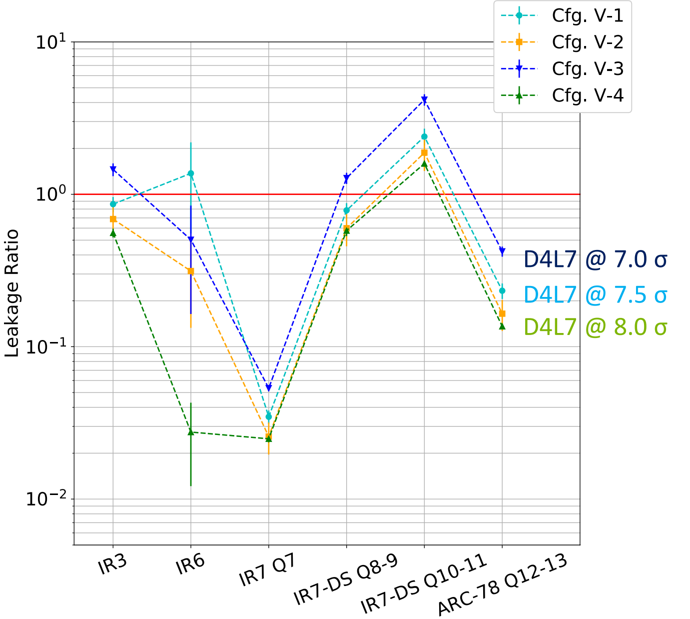


To compare the crystal collimation to the standard collimation the leakage of particles in specific region near to the IR7-DS is evaluated by normalizing losses to the beam flux.

Collimation cleaning setup

In lead ion test of last year a small improvement were observed when the first secondary collimator was moved to tighter apertures.

Collimator / Configuration	Standard Reference [σ] Nominal	Tight	Horizontal Crystal [σ] 1	2	3	4	5	6	7	8
TCPs	5.0	5.0	Out	Out	Out	Out	Out	Out	Out	Out
TCSG Upstream	6.5	6.0	Out	Out	Out	Out	Out	Out	Out	Out
TCPCH.A4L7	Out	Out	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
TCSG Downstream	6.5	6.0	Out	6.0	7.0	8.0	9.0	6.5	6.5	6.5
TCLAs	10.0	6.0	6.0	6.0	7.0	8.0	9.0	7.0	8.0	10.0



Lead ion leakage ratio to standard coll

With Xe was decided to explore different settings, using also TCLAs to different apertures. Because of the tighter settings used, also the standard system was tested with such TCSGs & TCLAs positions: no significant difference were observed.

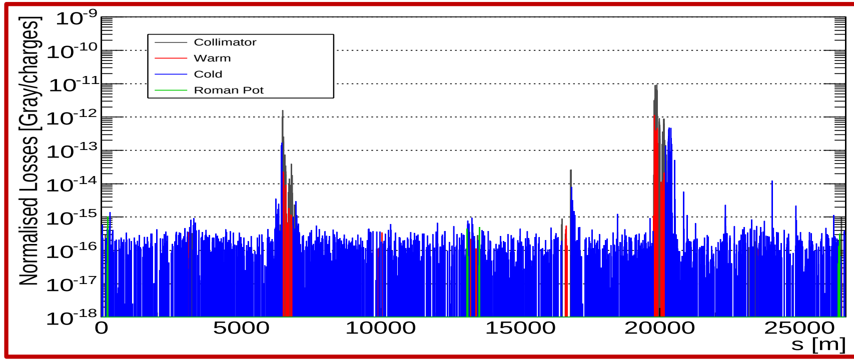
Resume of Results

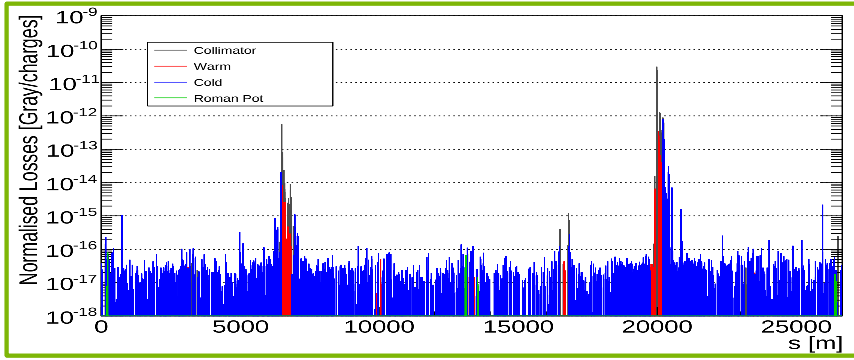
Collimator Configuration	Standard Reference [σ] Nominal	Tight	Horizontal Crystal [σ] 1	2	3	4	5	6	7	8
TCPs	5.0	5.0	Out	Out	Out	Out	Out	Out	Out	Out
TCSG Upstream	6.5	6.0	Out	Out	Out	Out	Out	Out	Out	Out
TCPCH.A4L7	Out	Out	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
TCSG Downstream	6.5	6.0	Out	6.0	7.0	8.0	9.0	6.5	6.5	6.5
TCLAs	10.0	6.0	6.0	6.0	7.0	8.0	9.0	7.0	8.0	10.0

Plane Config.	Leakage Ratio Q7	Q8–9	Q10–11	Q12–13	IR3	IR6
H–1	0.14 ± 0.03	39.07 ± 9.60	4.80 ± 1.07	5.63 ± 1.20	2.10 ± 0.47	0.010 ± 0.003
H–2	0.06 ± 0.01	64.61 ± 13.39	14.98 ± 2.03	7.20 ± 1.22	2.85 ± 0.45	21.32 ± 7.18
H–3	0.18 ± 0.03	38.92 ± 6.18	5.03 ± 0.71	6.12 ± 0.80	2.63 ± 0.37	0.24 ± 0.03
H–4	0.16 ± 0.04	8.95 ± 1.79	3.70 ± 0.79	4.93 ± 1.20	2.12 ± 0.43	0.010 ± 0.001
H–5	0.13 ± 0.05	6.73 ± 2.16	3.31 ± 1.03	4.54 ± 1.36	1.93 ± 0.59	0.004 ± 0.001
H–6	0.18 ± 0.04	30.56 ± 6.00	4.32 ± 0.81	4.80 ± 0.95	2.45 ± 0.56	4.65 ± 0.81
H–7	0.19 ± 0.05	10.80 ± 2.47	4.53 ± 1.10	5.24 ± 1.30	2.43 ± 0.59	5.85 ± 1.44
H–8	0.19 ± 0.03	5.83 ± 0.80	4.39 ± 0.58	5.47 ± 0.71	2.49 ± 0.33	6.20 ± 0.87

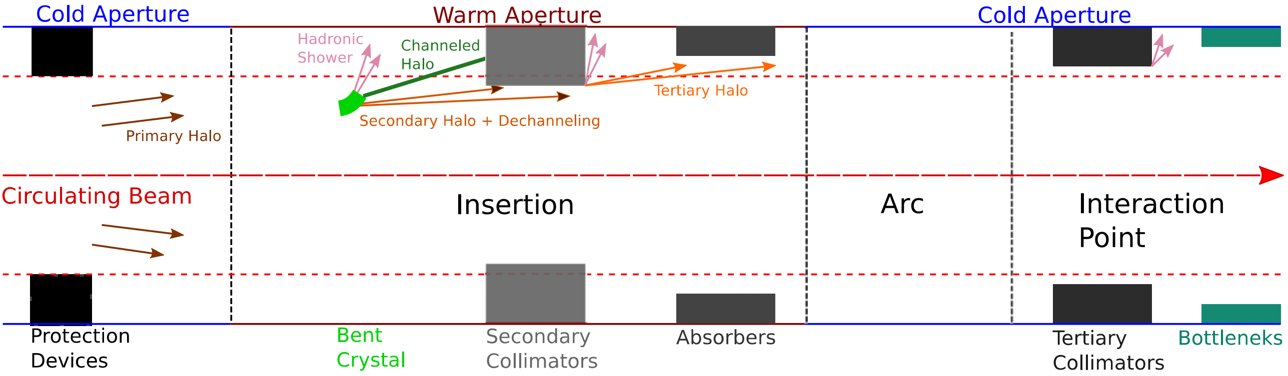
Looking at loss maps along the ring no dangerous peaks with crystal.

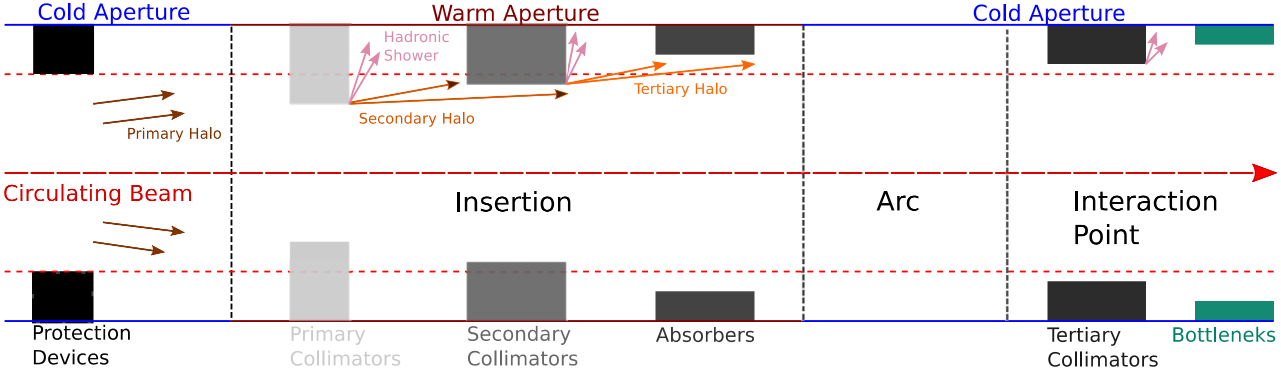
In general, good performance were observed with almost any configuration (except for Q7 region).

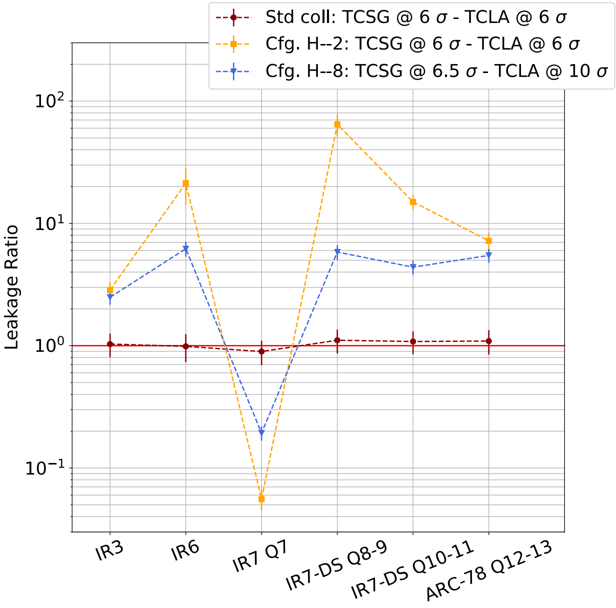




Tight Settings Comparison

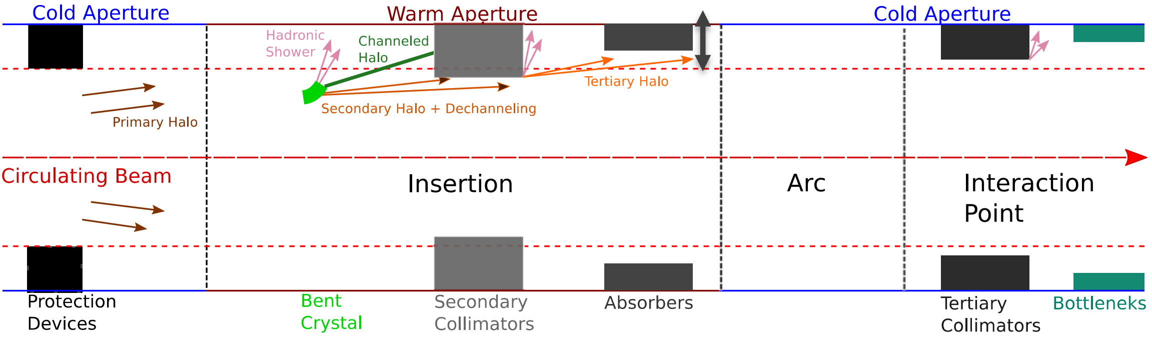






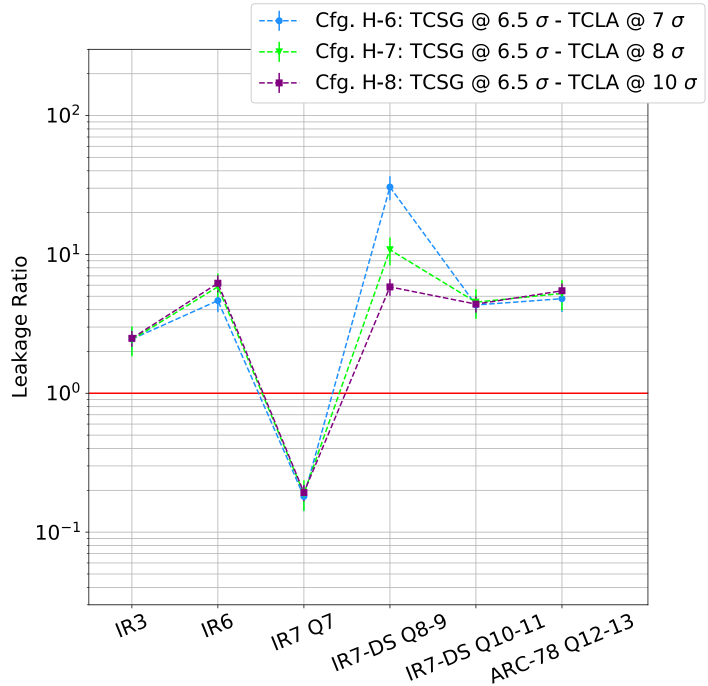
When standard coll is used with tight settings small difference observed in Q7 (more showers), while large difference observed in crystal collimation

Different TCLAs Aperture

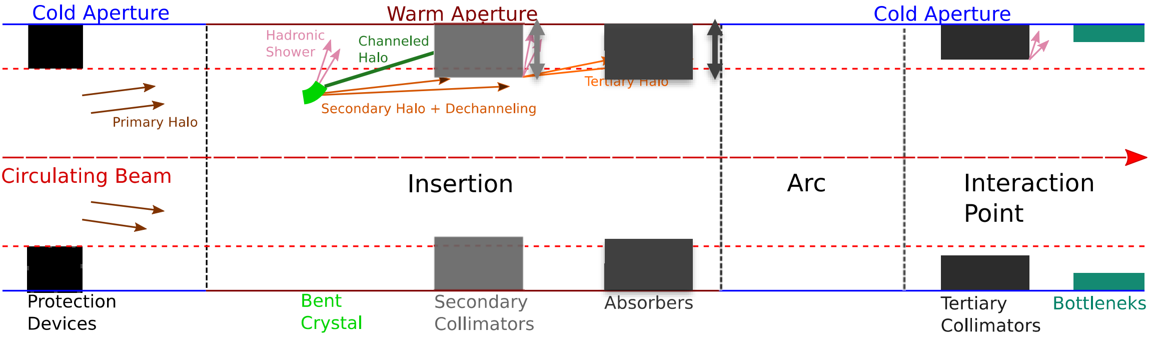


Tighter TCLA's settings correspond to improvement of leakage at first dispersive peak.

May be caused by off-momentum particles produced by TCSGs.

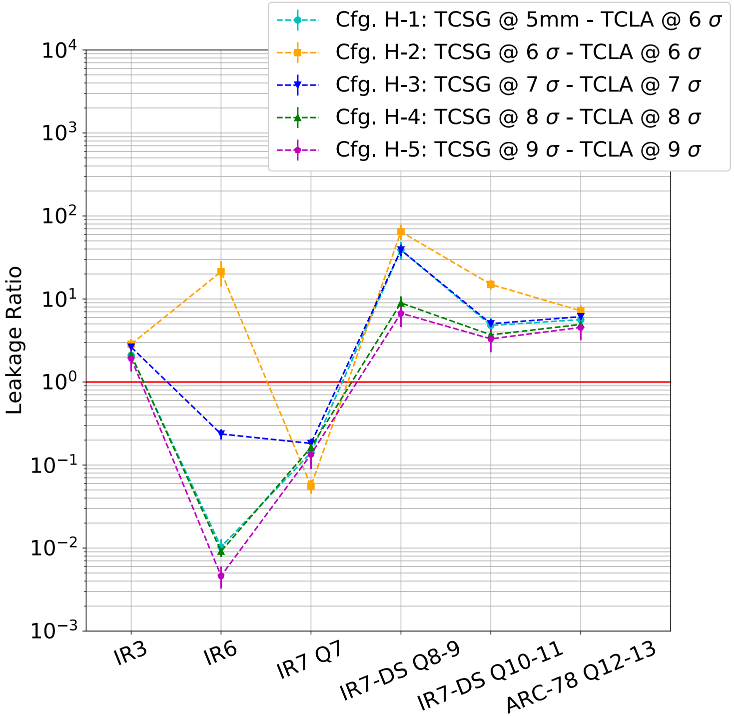


Different Downstream Coll Aperture



Tighter settings of both TCSG and TCLA improves cleaning in all considered regions.

May be caused by particles leaking from crystal.

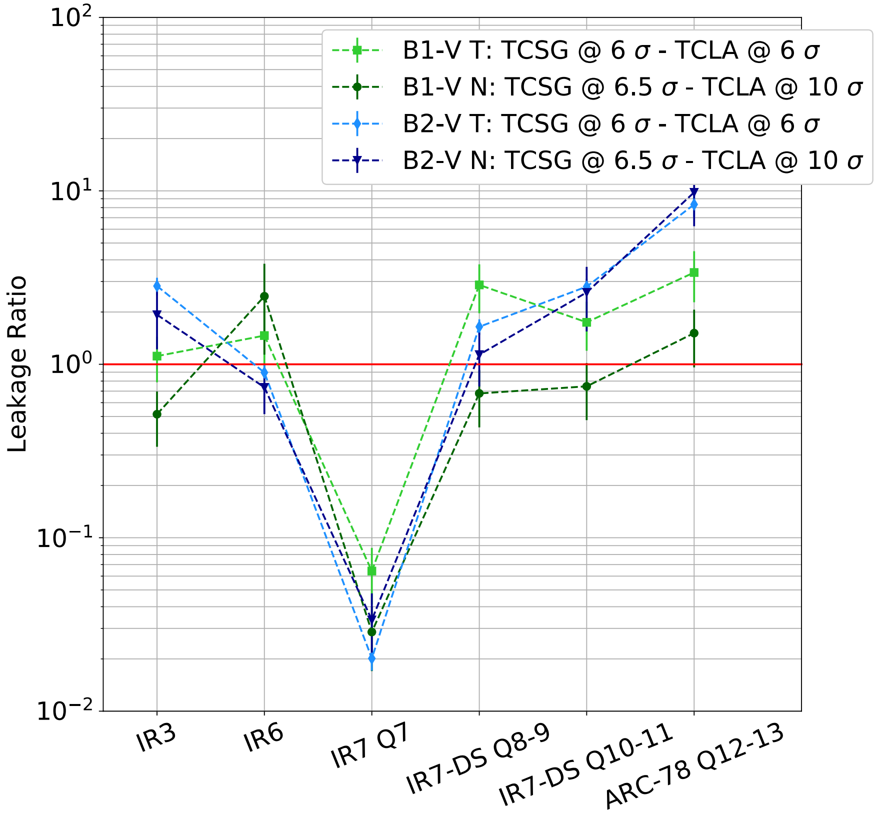


Comparison with QM crystals

With QM crystals, with same tight settings, it is not observed the same magnitude of improvement.

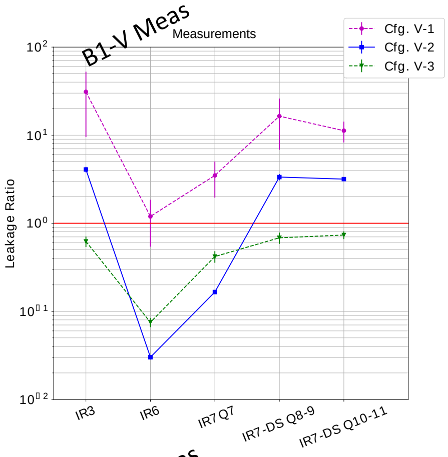
Indication on different behaviour of the two technologies, with heavy ion beams.

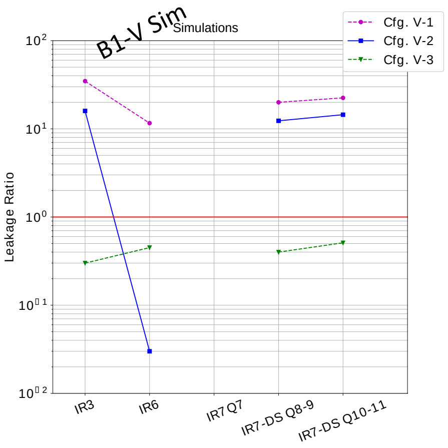
Still, why there it is not observed the huge improvement observed with B1-H with those crystals?

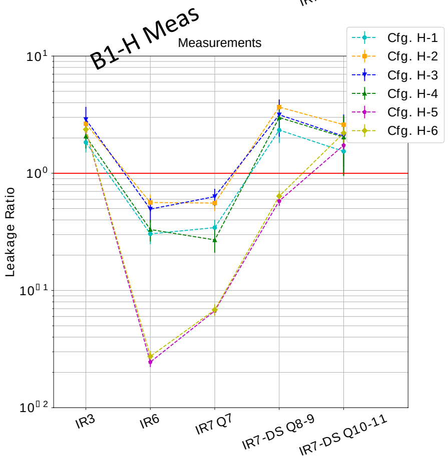


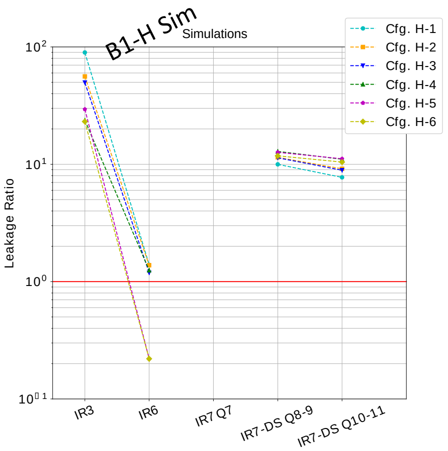
B1-H Characteristics Discussion

Comparison with Proton Simulations









Comparing cleaning simulations, a good agreement with data is found in vertical plane, while an important difference (factor ∼3) is observed in the horizontal plane.

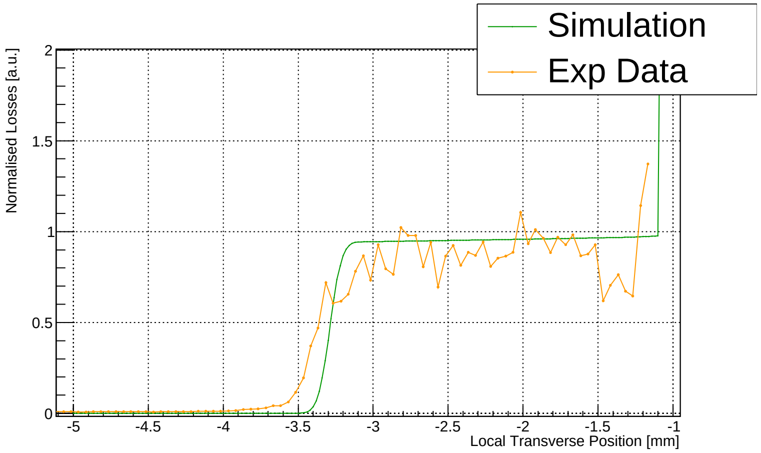
In particular Losses in Q8-9 has a facto >10 of difference, when configuration with only TCSG.6R7 is used.
This collimator has >20 µrad angular cut.

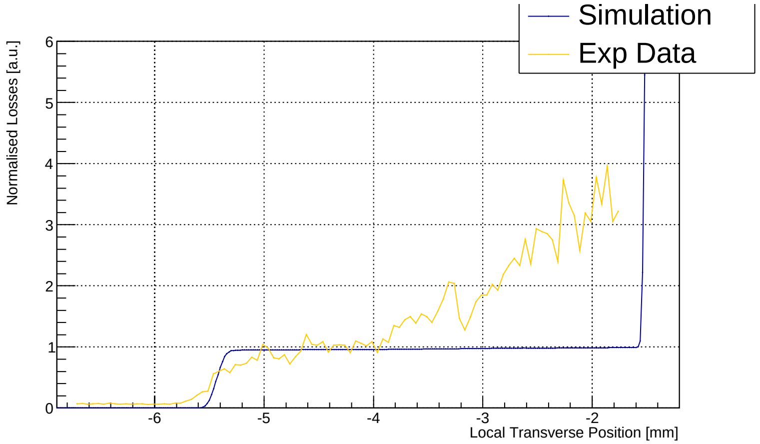
Comparison with Proton Simulations

In collimator scan simulations, it is evident that the dechanneled population at lower deflection angles is higher in B1-H.

The main difference we can found between the two condition is the bending angle of the two crystals

B1-H: θ_b =63 μrad, R = 63 m
B1-V: θ_b =40 μrad, R = 100 m

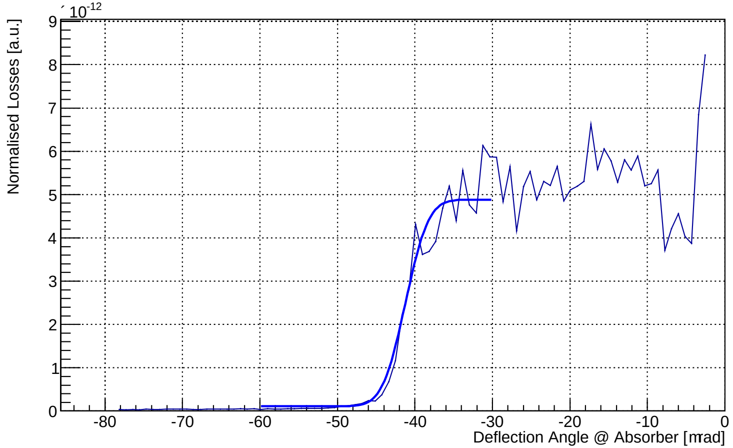


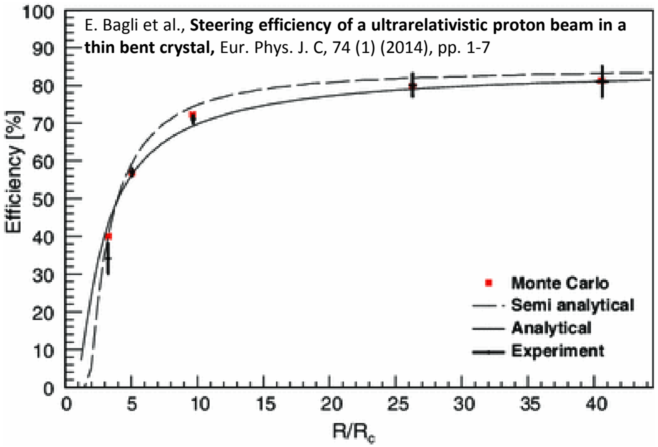


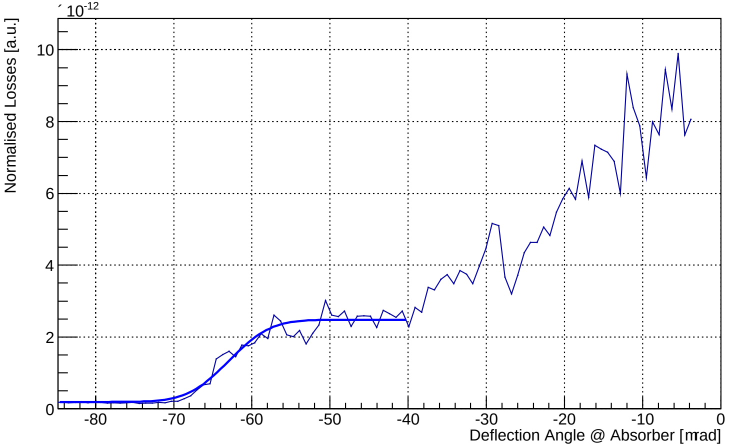
Comparison with Proton Simulations

In measurements is clear how the dechanneled particles increase starting at 30 μrad of deflection.

With 63 μrad deflection and 4 mm of length, the bending radius is 63 m, ~4 critical radius (~15.6 m @6.5 TeV)
In this regime nuclear dechanneling is enhanced and there is no analytical description (simulation discrepancies)





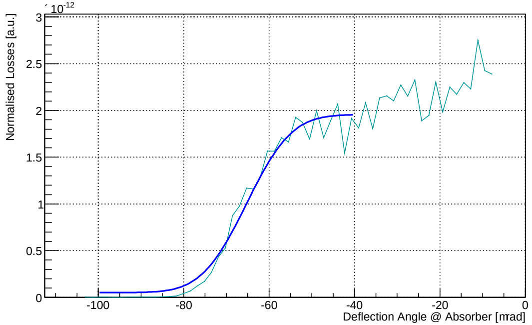


Collimator scan measurements

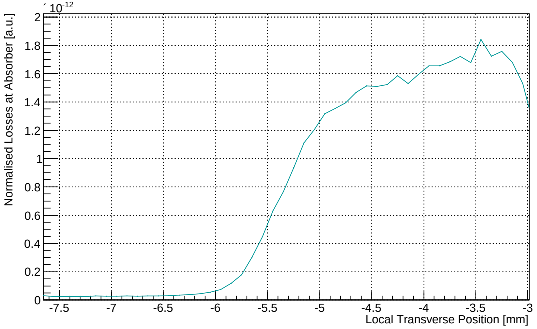
Rc~1.1 m @450 GeV   The crystals are equivalent in injection measurements

Injection

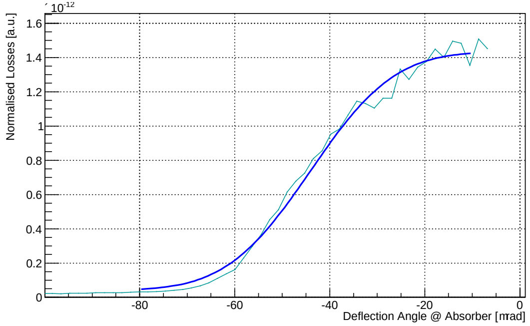
B1-H: θ_b = 63 μrad, R = 63 m



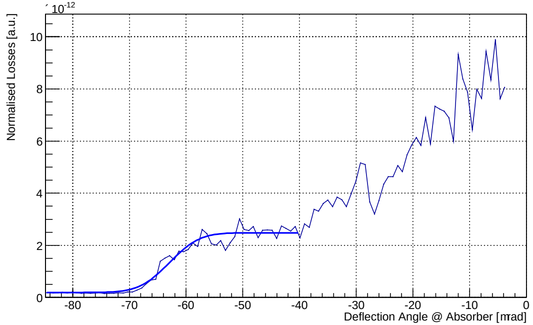
B2-V: θ_b = 56 μrad, R = 71 m

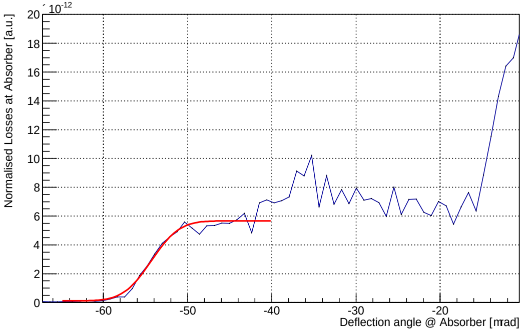


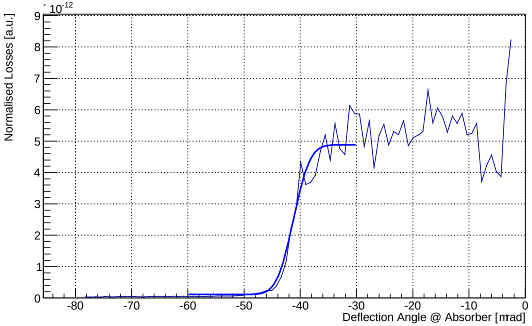
B1-H: θ_b = 40 μrad, R = 100 m



Flat Top

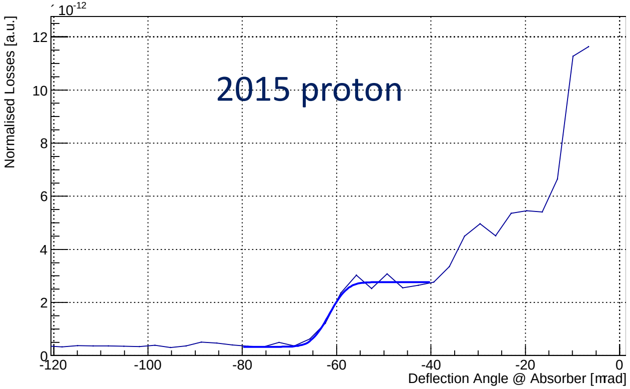


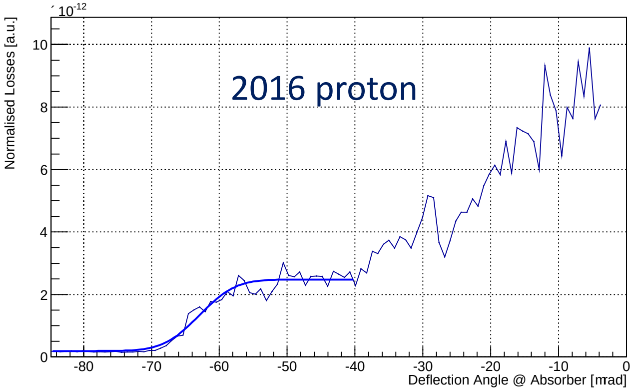


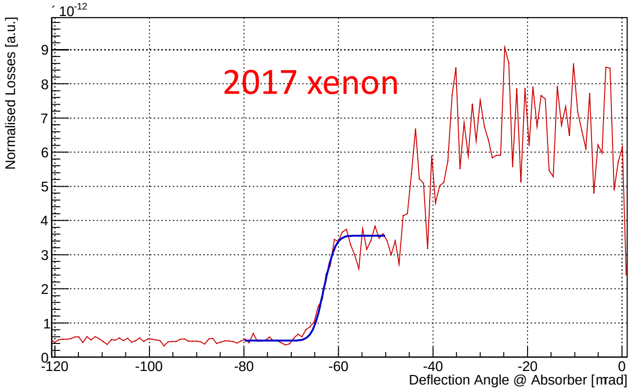


Collimator scan measurements

This observation is confirmed by all flat top collimator scans made with B1-H







Conclusion

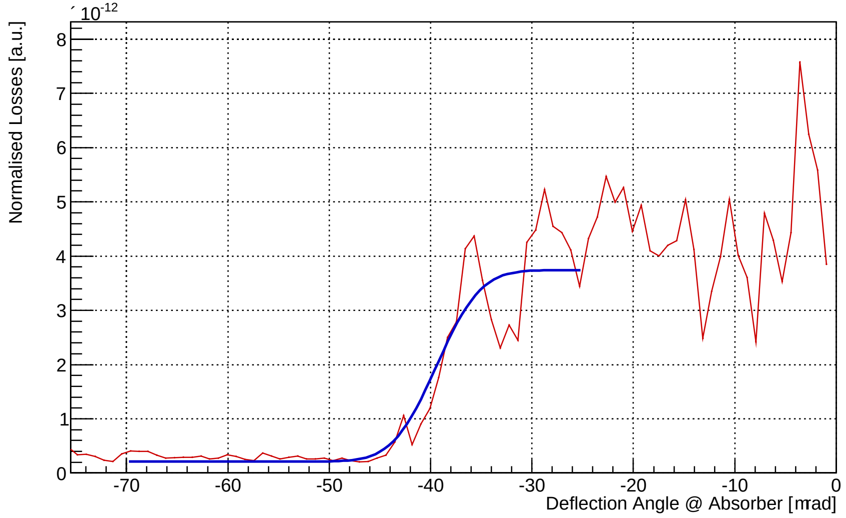
- ✓ Channeling established with both new crystals at injection and top energy for the first time with xenon ions
- ✓ Cleaning measurements performed, tight settings improve the cleaning in the DS and in the machine in general
- ✓ Indication on different efficiency with heavy ions between QM and strip
- ✓ Confirmation that crystals within required specifications provide better results

Goals :

- ❑ Test with Pb ions in 2018 to confirm good results observed with Xe backup

Xenon Measurements

B1- V FT



B1- H INJ