*This project has received funding from the European Union's Horizon 2020 research and innovation programme.*

# Status of the crystal based ALICE fixed target layout

Marcin Patecki

Warsaw University of Technology

Acknowledgments: D. Kikoła, S. Redaelli, C. Hadjidakis, A. Fomin, D. Mirarchi

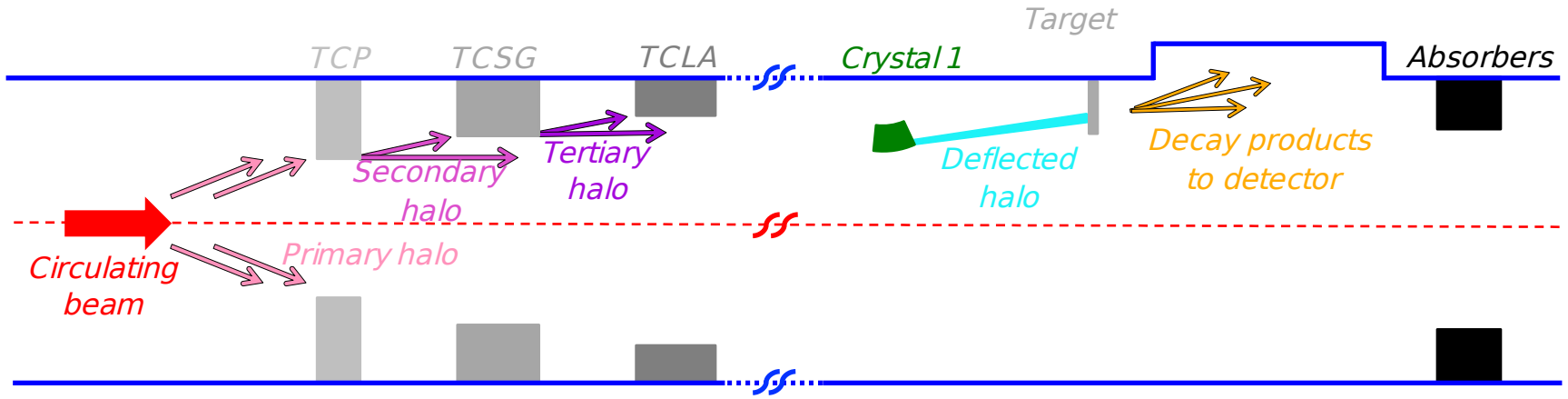
Joint workshop GDR-QCD/QCD@short distances and STRONG2020/PARTONS/FTE@LHC/NLOAccess

# Context

- Publications:
  - A fixed-target programme at the LHC: Physics case and projected performances for heavy-ion, hadron, spin and astroparticle studies https://doi.org/10.1016/j.physrep.2021.01.002
  - LHC fixed target experiments: Report from the LHC Fixed Target Working Group of the CERN Physics Beyond Colliders Forum https://doi.org/10.23731/CYRM-2020-004
  - Physics opportunities for a fixed-target programme in the ALICE experiment https://cds.cern.ch/record/2671944
  - Layouts for fixed-target experiments and dipole moment measurements of short-lived baryons using bent crystals at the LHC https://doi.org/10.1140/epjc/s10052-020-08466-x

- Presentations
  - F. Galluccio, W. Scandale Proposal for beam splitting in LHC IR2 https://indico.cern.ch/event/853688/contributions/3620725/
  - A. Fomin Updates on IP2 FT layouts https://indico.cern.ch/event/981210/contributions/4132813
  - D. Kikoła A fixed-target program in the ALICE experiment https://indico.cern.ch/event/1002356/contributions/4229546/

# Layout for crystal based fixed-target experiments




Graphics: D. Mirarchi

- Halo particles are intercepted and disposed by the collimation system.
- Part of the secondary halo is intercepted by the crystal and deflected towards the target.
- Additional absorbers (not currently present within the collimation system) capture additional losses coming from crystal+target assembly.
- Parasitic operation of fixed target experiment is possible only if new loss spikes stay within acceptable limits (e.g. not larger than usual losses).
- Experiment requires high enough flux of protons on target (PoT). Exact number to be defined by the detector experts.

# Layout at IR2

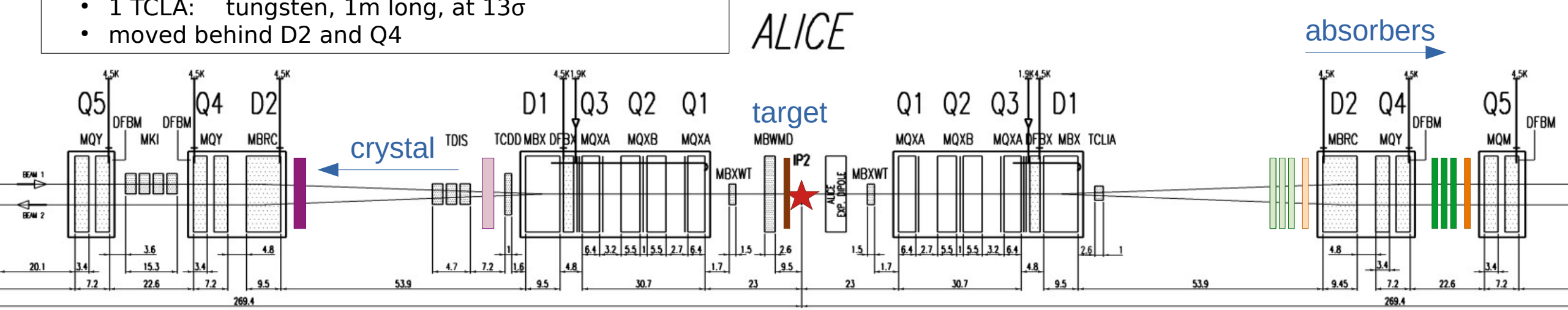
Layout:
- Based on studies of F. Galluccio and A. Fomin
- Last update on the layout (slide 9):
  https://indico.cern.ch/event/1002356/contributions/4229610/

Gaps:
- Primary coll. (TCP@IR7): 5σ
- Crystal: 5.5σ

Crystal:
- bending radius: 80m
- bending angle: 150 urad → 125 urad
- length: 12mm → 10mm

Target:
- 5mm long, tungsten
- 4.8m upstream from the IP2

Absorbers:
- 3 TCSGs: graphite, 1m long, at 10σ
- 1 TCLA: tungsten, 1m long, at 13σ
- moved behind D2 and Q4



# Layout at IR2

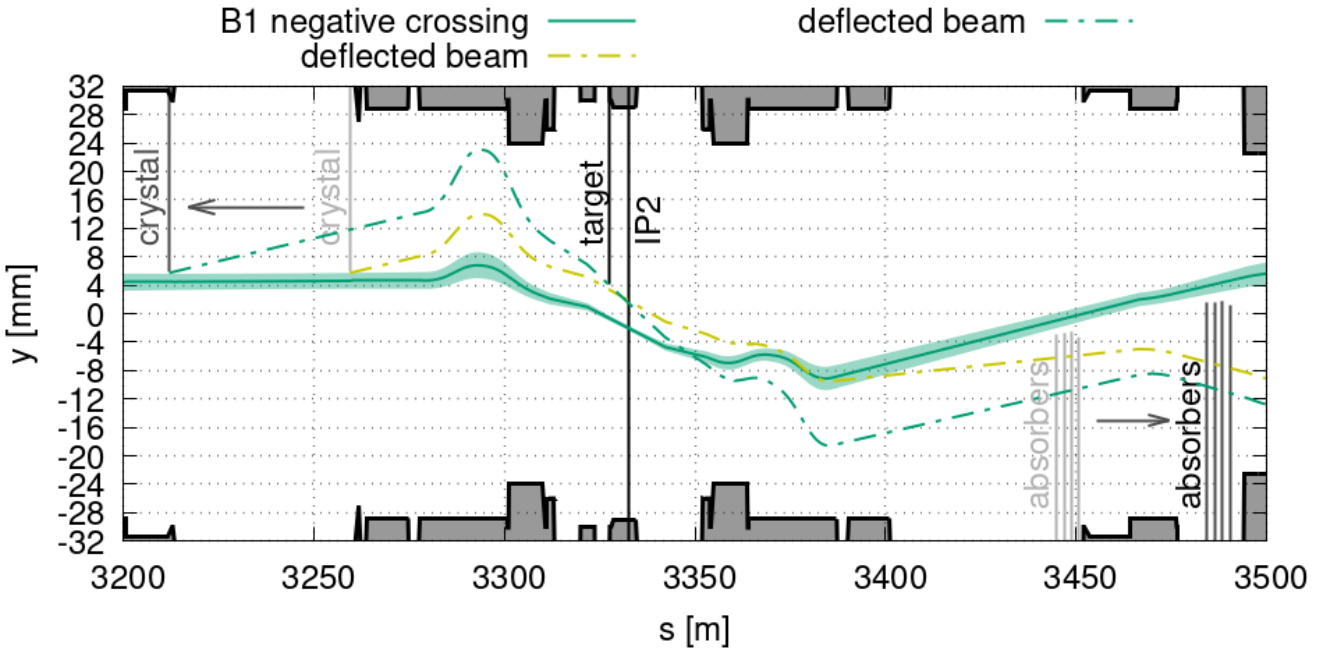
Layout:
- Based on studies of F. Galluccio and A. Fomin
- Last update on the layout (slide 9):
  https://indico.cern.ch/event/1002356/contributions/4229610/

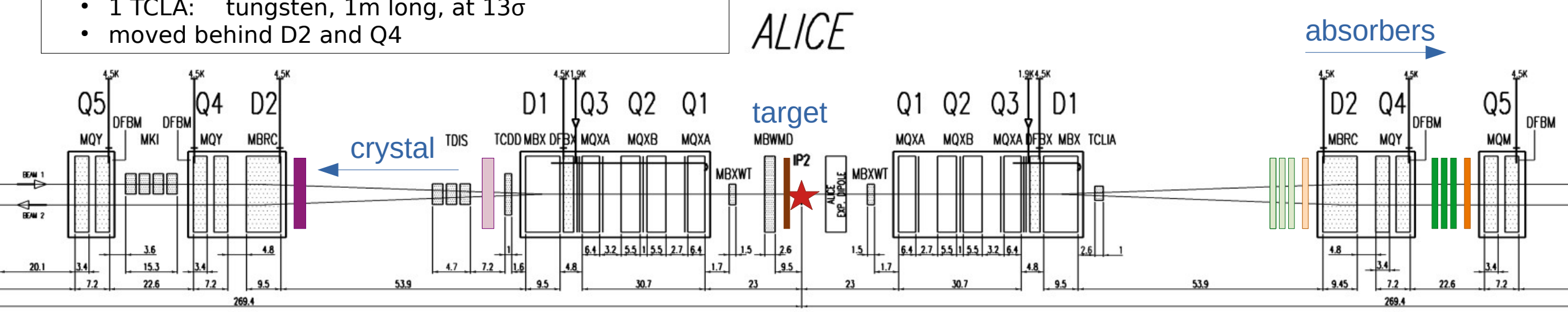
Gaps:
- Primary coll. (TCP@IR7): 5σ
- Crystal: 5.5σ

Crystal:
- bending radius: 80m
- bending angle: 150 urad → 125 urad
- length: 12mm → 10mm

Target:
- 5mm long, tungsten
- 4.8m upstream from the IP2

Absorbers:
- 3 TCSGs: graphite, 1m long, at 10σ
- 1 TCLA: tungsten, 1m long, at 13σ
- moved behind D2 and Q4



# Layout at IR2

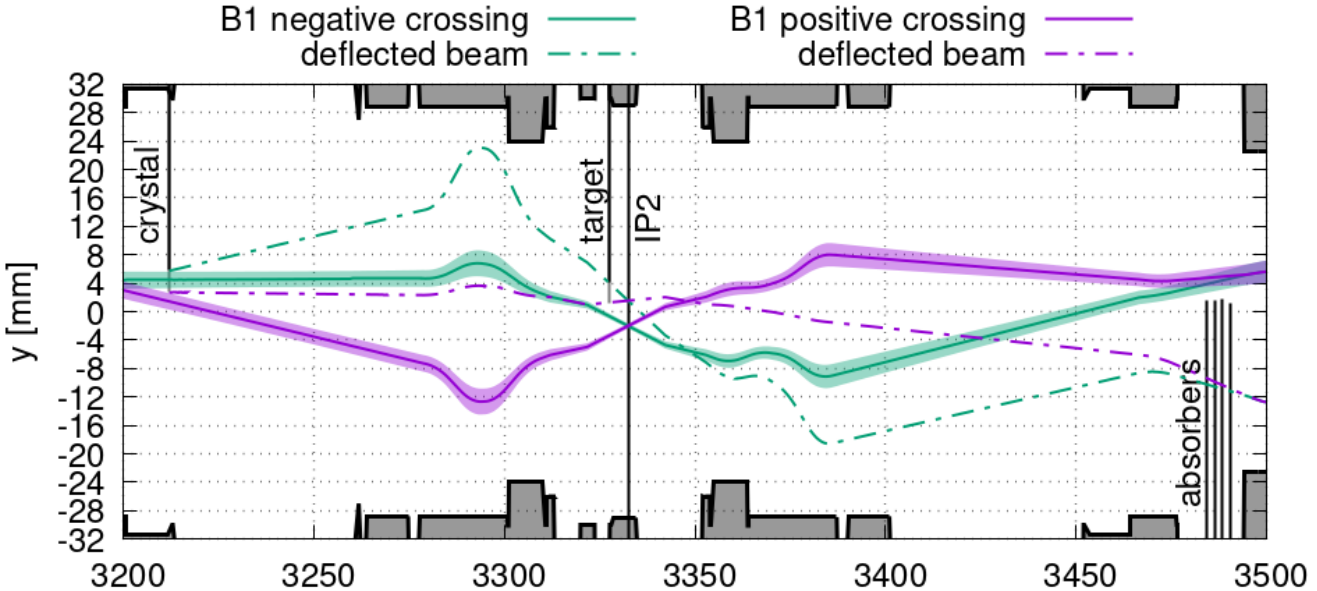
Layout:
- Based on studies of F. Galluccio and A. Fomin
- Last update on the layout (slide 9):
  https://indico.cern.ch/event/1002356/contributions/4229610/

Gaps:
- Primary coll. (TCP@IR7): 5σ
- Crystal: 5.5σ

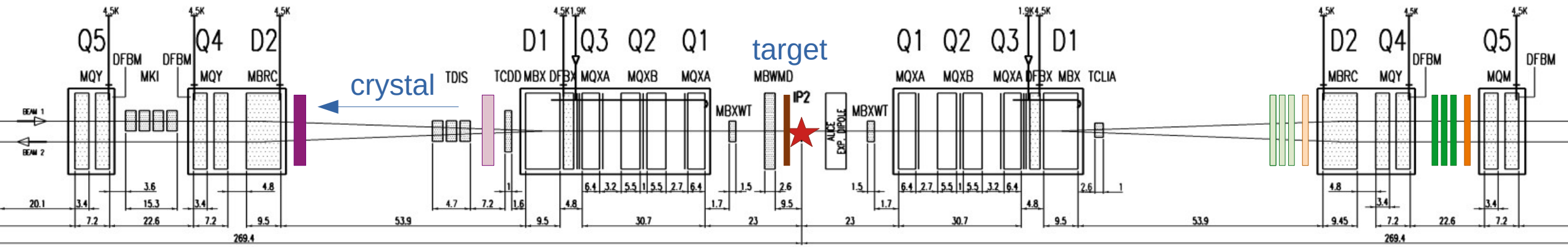
Crystal:
- bending radius: 80m
- bending angle: 150 urad → 125 urad
- length: 12mm → 10mm

Target:
- 5mm long, tungsten
- 4.8m upstream from the IP2

Absorbers:
- 3 TCSGs: graphite, 1m long, at 10σ
- 1 TCLA: tungsten, 1m long, at 13σ
- moved behind D2 and Q4




Compatible for both crossing scenarios



# Layout at IR2

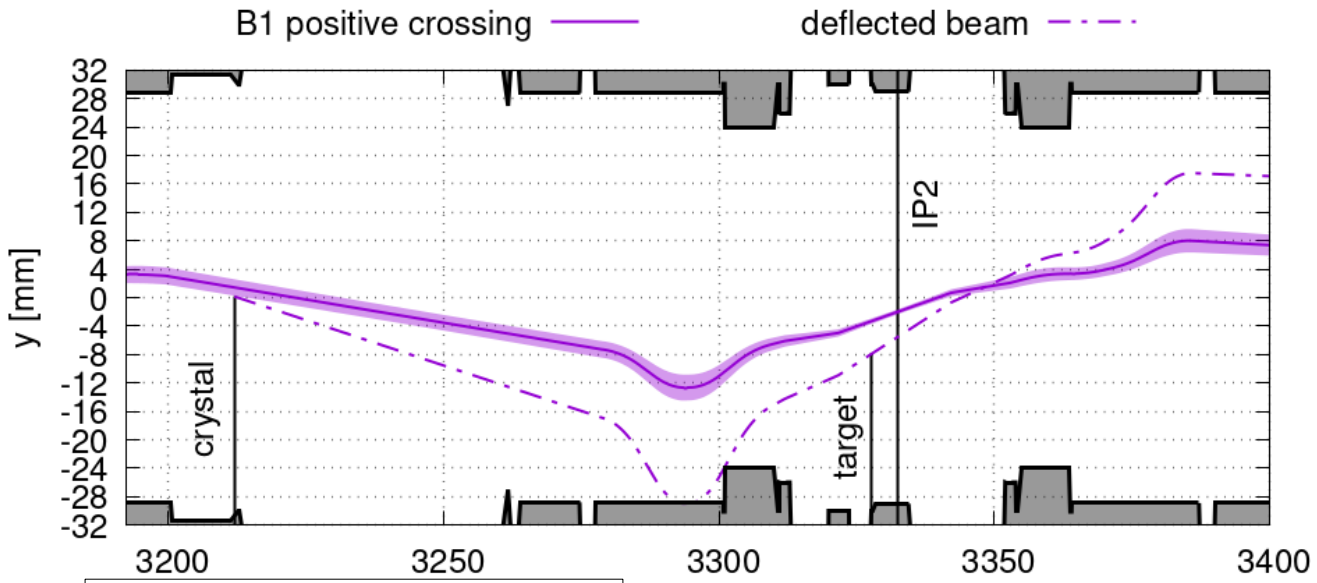
Layout:
- Based on studies of F. Galluccio and A. Fomin
- Last update on the layout (slide 9):
  https://indico.cern.ch/event/1002356/contributions/4229610/

Gaps:
- Primary coll. (TCP@IR7): 5σ
- Crystal: 5.5σ

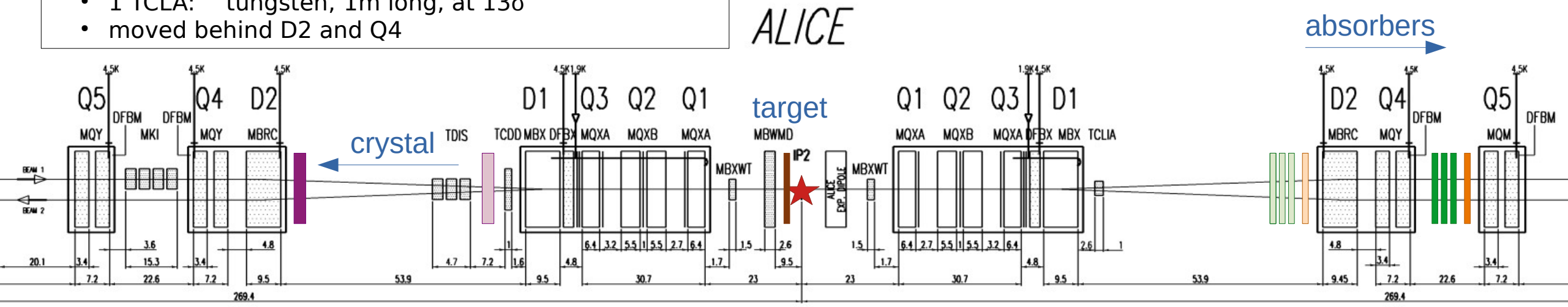
Crystal:
- bending radius: 80m
- bending angle: 150 urad → 125 urad
- length: 12mm → 10mm

Target:
- 5mm long, tungsten
- 4.8m upstream from the IP2

Absorbers:
- 3 TCSGs: graphite, 1m long, at 10σ
- 1 TCLA: tungsten, 1m long, at 13σ
- moved behind D2 and Q4




Not compatible with crystal installed from the bottom



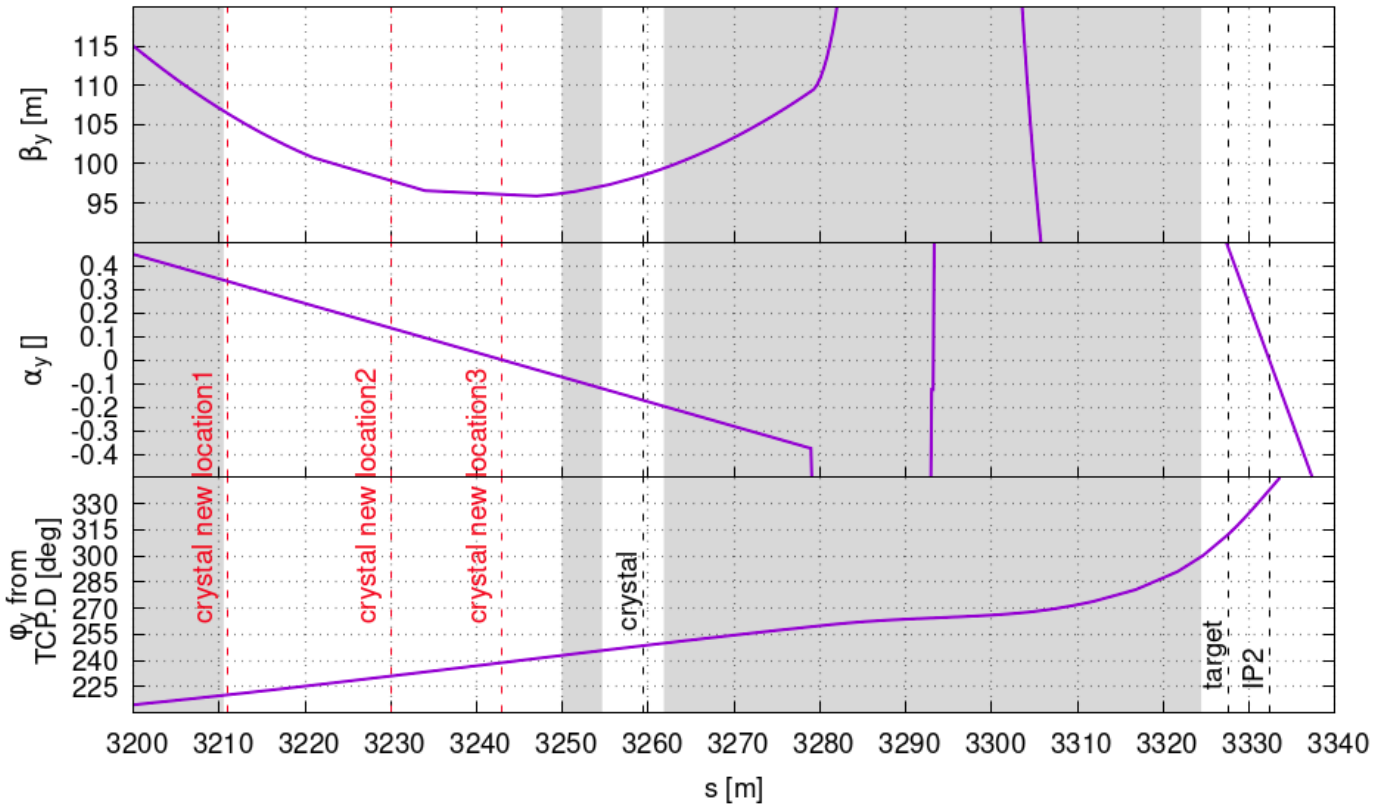
# Simulation setup

- SixTrack 5
- Run II optics (2018), Stable Beams, IP2-β* = 10m
- Negative crossing angle of B1 at IP2
- 2M protons
- Annular halo distribution at 5σ
- Standard collimation settings

| Coll. family | IR | Settings ($\sigma$) |
|---|---|---|
| TCP/TCSG/TCLA | 7 | 5.0/6.5/10 |
| TCP/TCSG/TCLA | 3 | 15/18/20 |
| TCTP | 1/2/5/8 | 8.5/37/8.5/15 |
| TCL | 1/5 | OUT |
| TCSP/TCDQ | 6 | 7.4/7.4 |

# p on crystal (PoC) and p on target (PoT)

## move crystal to a new location



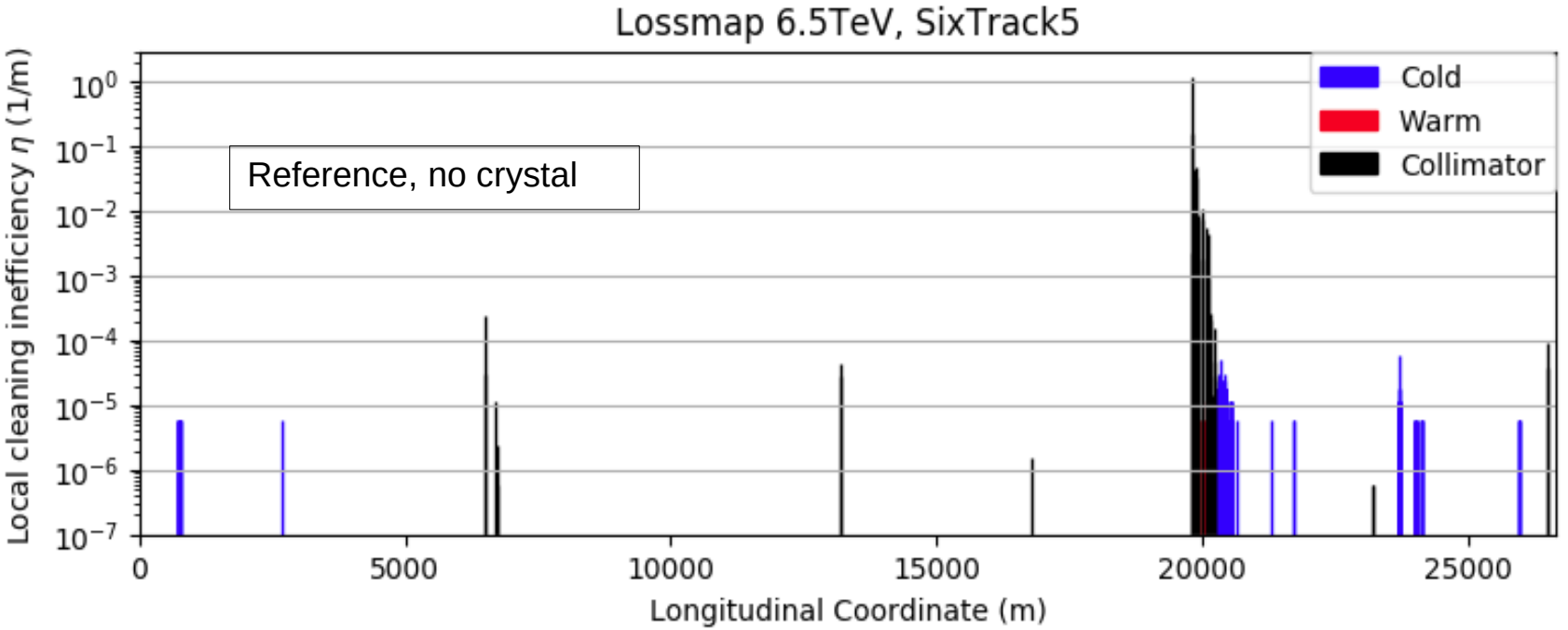

Optimised for crystal angular orientation

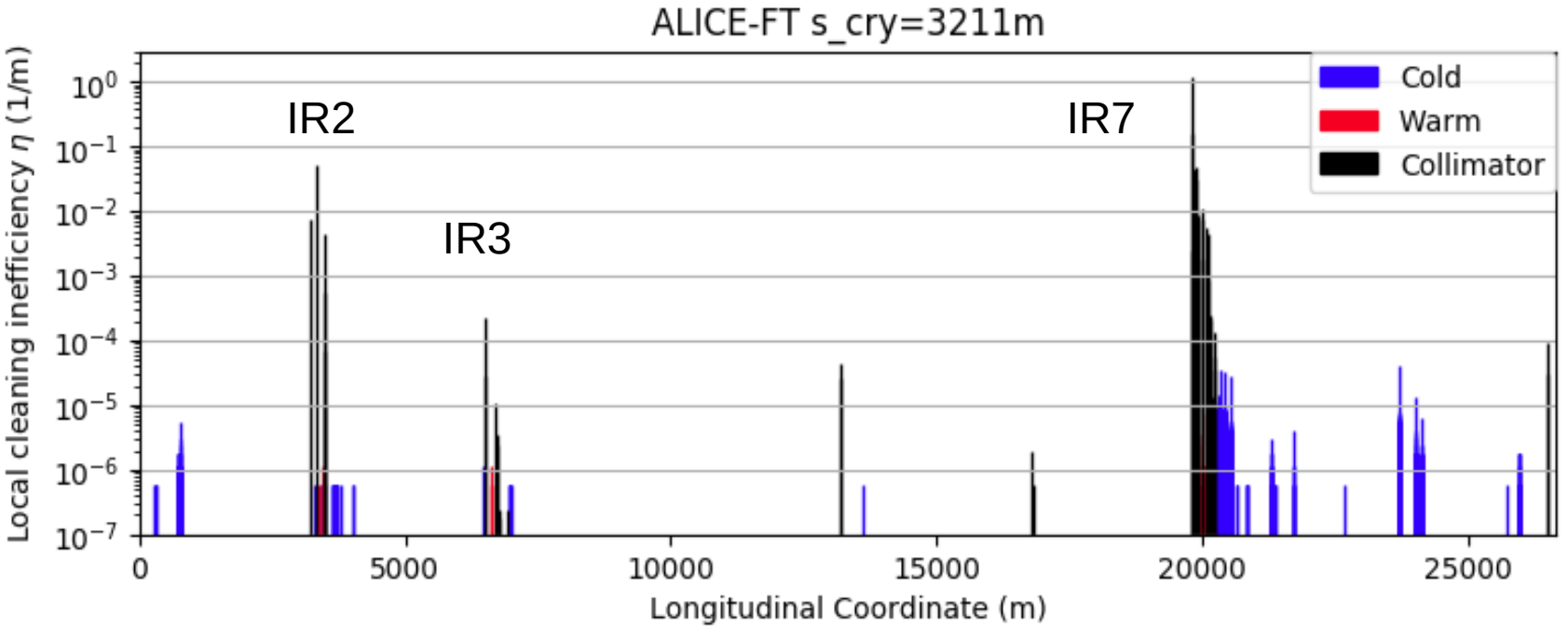
| | PoC [1e-3] N_cry/N_sim | PoT [1e-3] N_tar/N_sim |
|---|---|---|
| IR2 3259m | < 1.3 | < 0.2 |
| IR2 3243m | < 2.1 | < 1.0 |
| IR2 3230m | < 4.3 | < 2.5 |
| IR2 3212m | 6.7 | **4.2** |
| IR3 | 11 | 5.5 |
| IR8 | 14 | 8 |

D. Mirarchi et al.
Eur. Phys. J. C (2020) 80:929

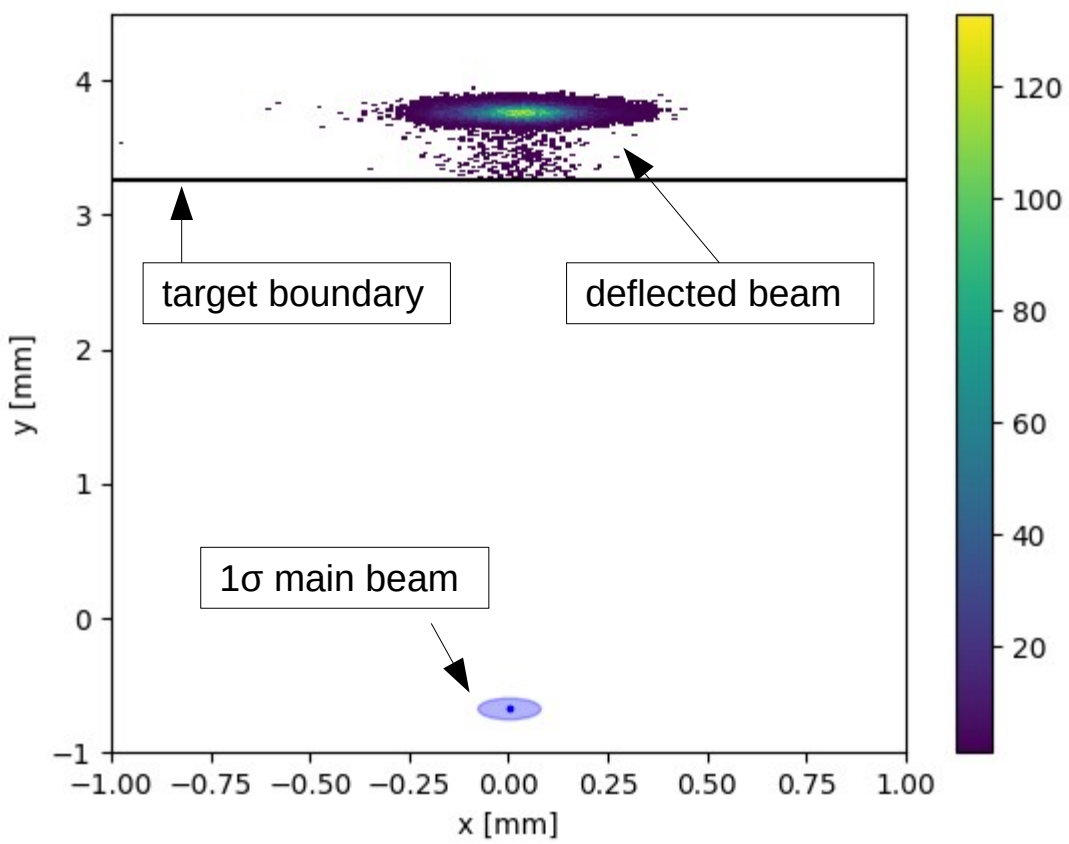
# Loss map comparison

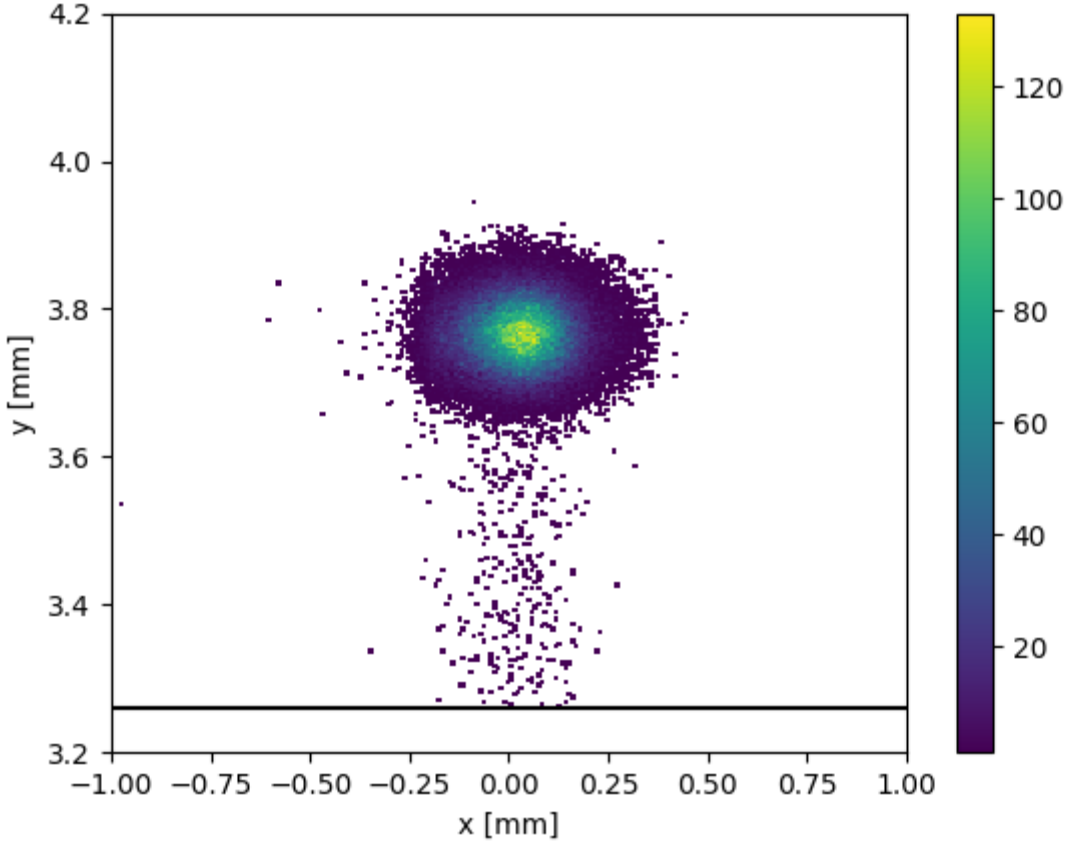
- No issue for cleaning
- IR2 extra absorbers can be potentially optimized for lower number of collimators



# p distribution at the target



# Summary and Outlook

- The current layout profits from initial considerations of Francesca and Alex.
- Number of PoT significantly improved when crystal is moved 50m upstream.
- PoT now comparable with IR3 and IR8 scenarios.
- Trajectory of deflected beam is brought close to the aperture, but >4mm margin is kept.

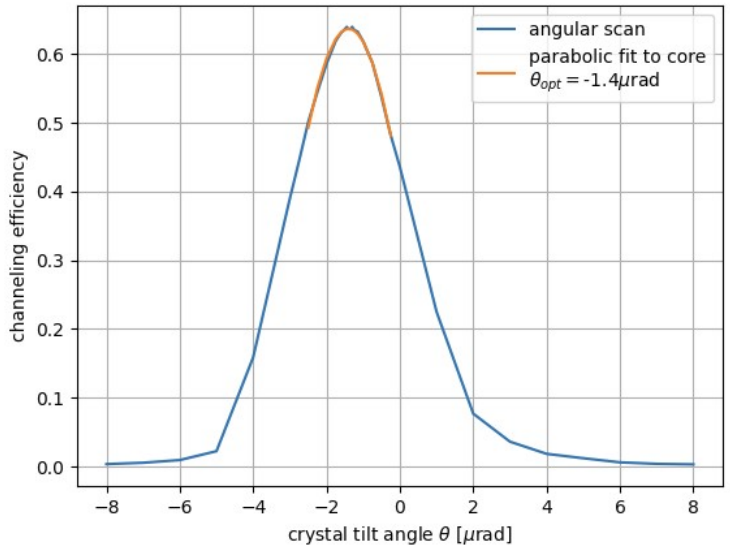
- No issue with ring losses.
- Number of absorbers will be revised and potentially optimized.

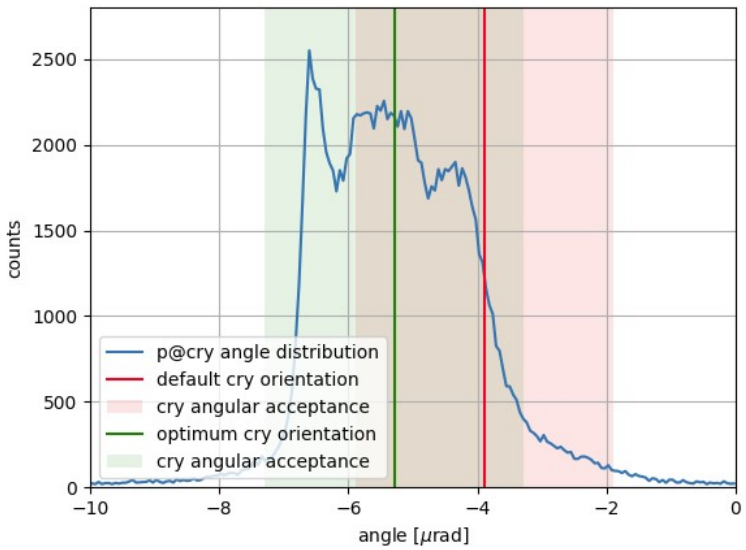
- Impacts distribution on the target is given to detector experts.

# Extra slides

# p on crystal (PoC) and p on target (PoT)

## Optimum angular orientation of the crystal

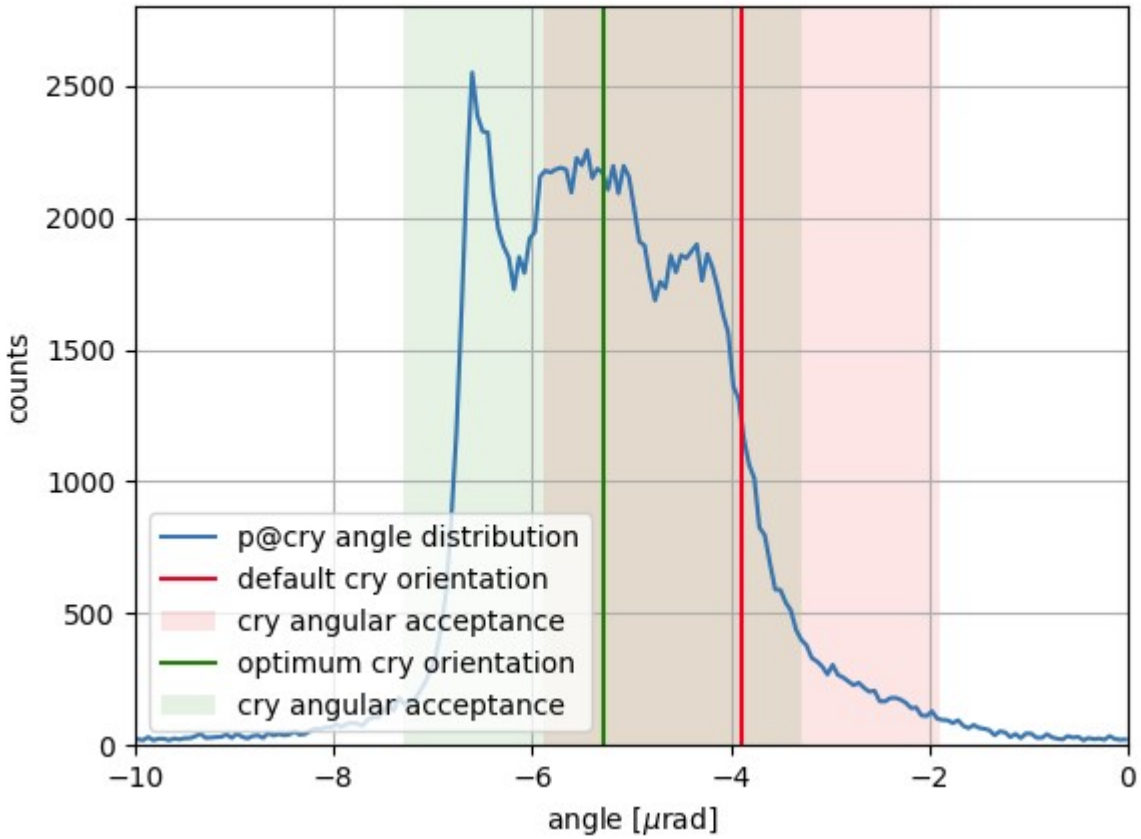


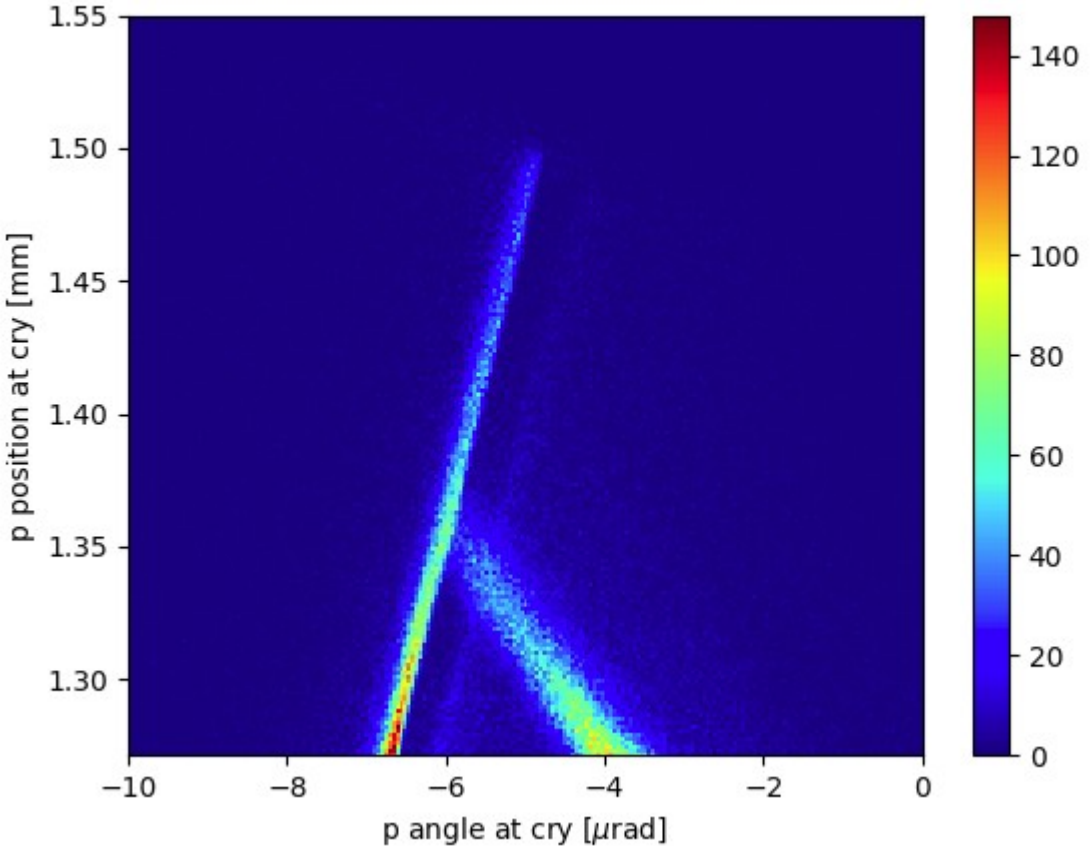




| | PoC [1e-3] N_cry/N_sim | PoT [1e-3] N_tar/N_sim |
|---|---|---|
| IR2 3259m | < 1.3 | < 0.2 |
| IR2 3211m | 6.7 | **2.9 → 4.2** |
| IR3 | 11 | 5.5 |
| IR8 | 14 | 8 |

- Default angular orientation of crystal in SixTrack is set for the primary halo
- Angular distribution of secondary halo is different
- In reality one has to experimentally find an optimum angular orientation

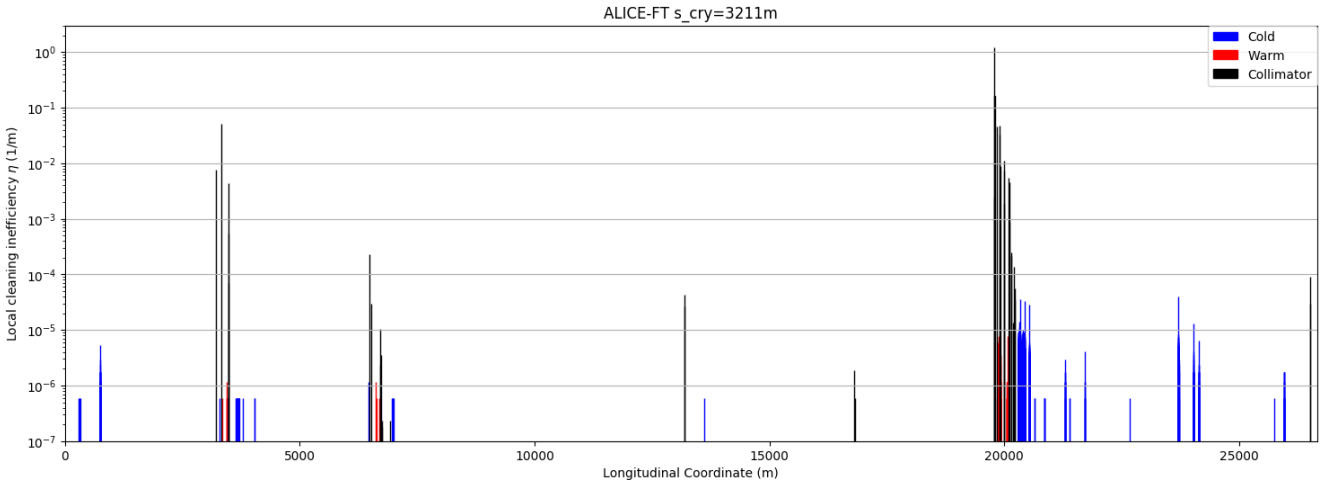
# p distribution at the crystal

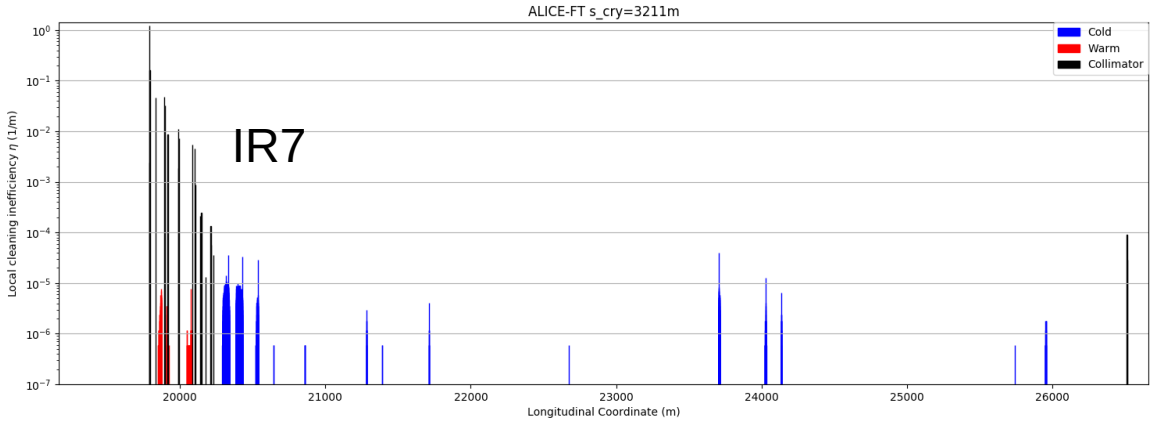


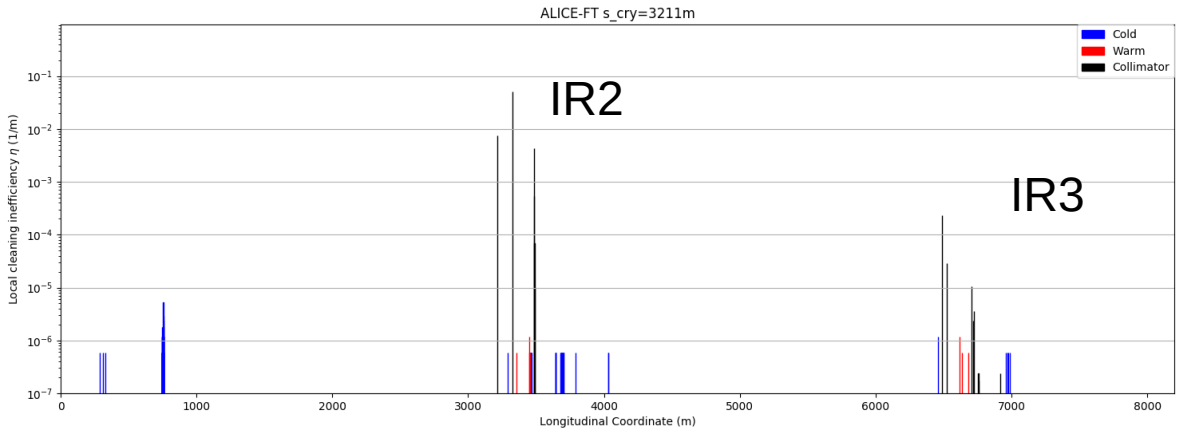



# Loss map

No issue for cleaning

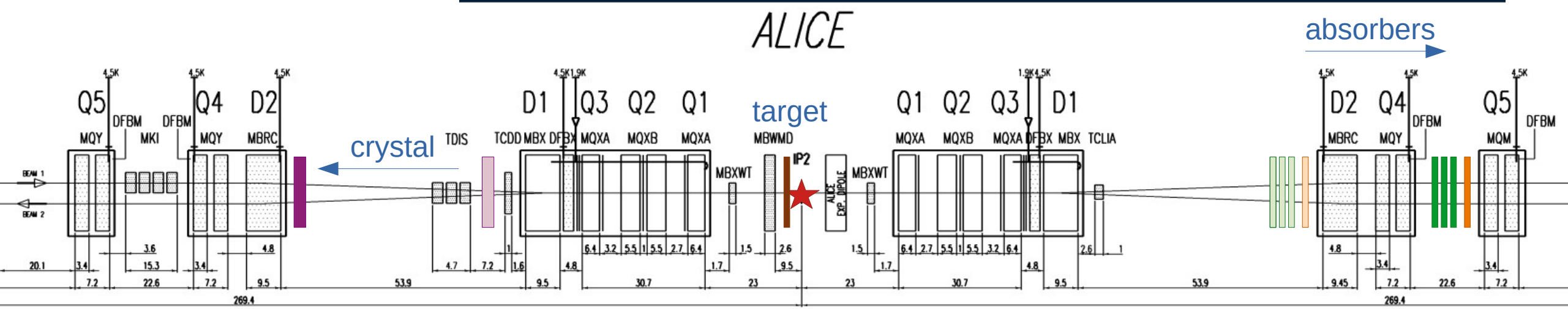


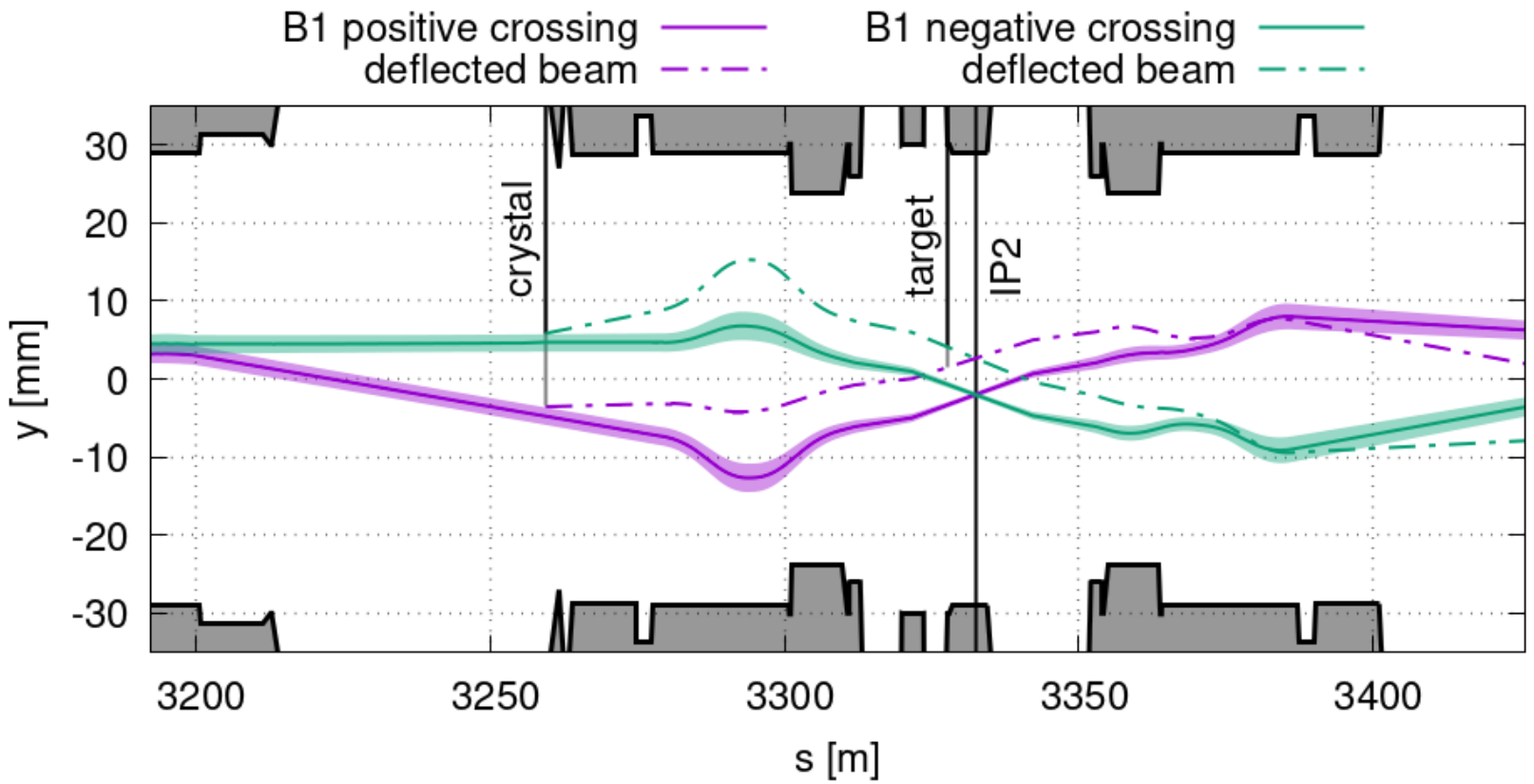



# Space for crystal

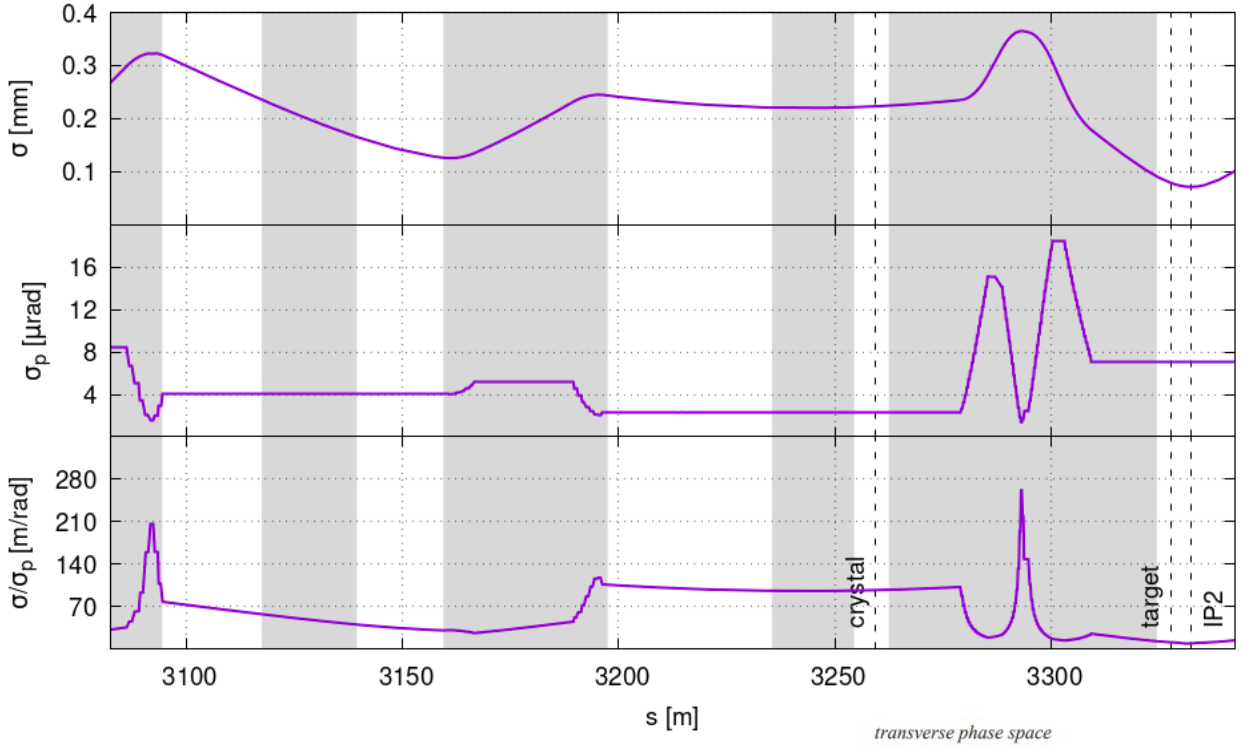
| Type | name | s [m] | L[m] |
|---|---|---|---|
| "MULTIPOLE" | "MBRC.4L2.B1..4" | 3209.813584 | 0 |
| "DRIFT" | "DRIFT_1421" | 3210.906792 | 2.186416378 |
| "RCOLLIMATOR" | "CRY.FIR.B1" | 3212 | 0 |
| "DRIFT" | "DRIFT_1422" | 3212.419542 | 0.8390836218 |
| "MONITOR" | "BPMWI.4L2.B1" | 3212.839084 | 0 |
| "DRIFT" | "DRIFT_1423" | 3213.073834 | 0.4695 |
| "MONITOR" | "BPTUH.A4L2.B1" | 3213.308584 | 0 |
| "DRIFT" | "DRIFT_1424" | 3213.606084 | 0.595 |
| "COLLIMATOR" | "TCTPH.4L2.B1" | 3213.903584 | 0 |
| "DRIFT" | "DRIFT_1425" | 3214.201084 | 0.595 |
| "MONITOR" | "BPTDH.A4L2.B1" | 3214.498584 | 0 |
| "DRIFT" | "DRIFT_1426" | 3214.903584 | 0.81 |
| "MONITOR" | "BPTUV.A4L2.B1" | 3215.308584 | 0 |
| "DRIFT" | "DRIFT_1427" | 3215.606084 | 0.595 |
| "COLLIMATOR" | "TCTPV.4L2.B1" | 3215.903584 | 0 |

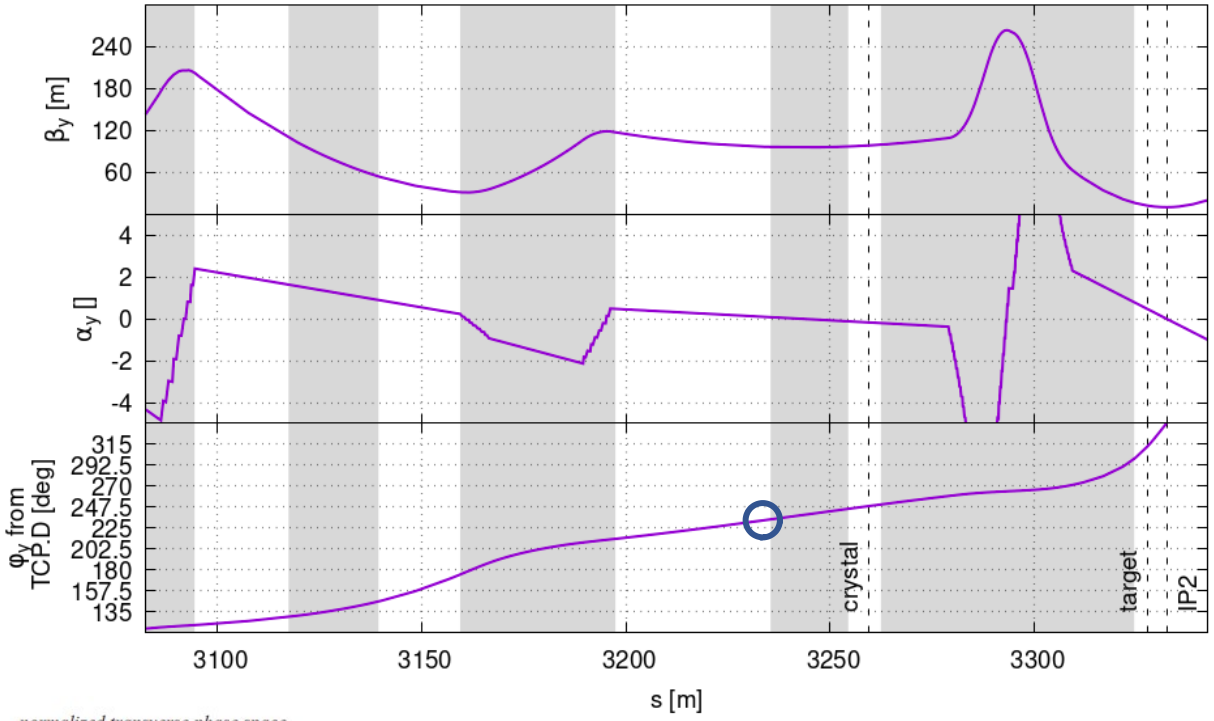


# Positive and negative B1 angle at IP2
# Original layout

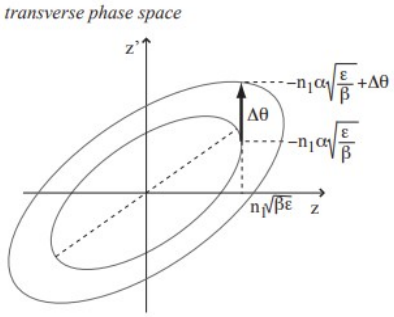


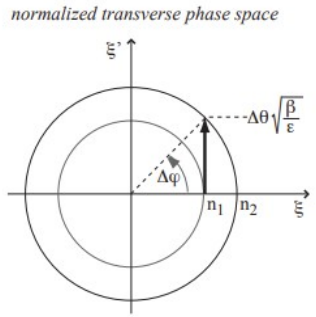
# Optics at the crystal




- Sigma should be maximized
- Sigma_p should be minimized
- Sigma/sigma_p should be maximized




- β should be maximized
- α should be minimized
- Phase advance: (Δphi + kπ)
- Δphi is not a single value but some distribution
- Δphi analysis -> in progress