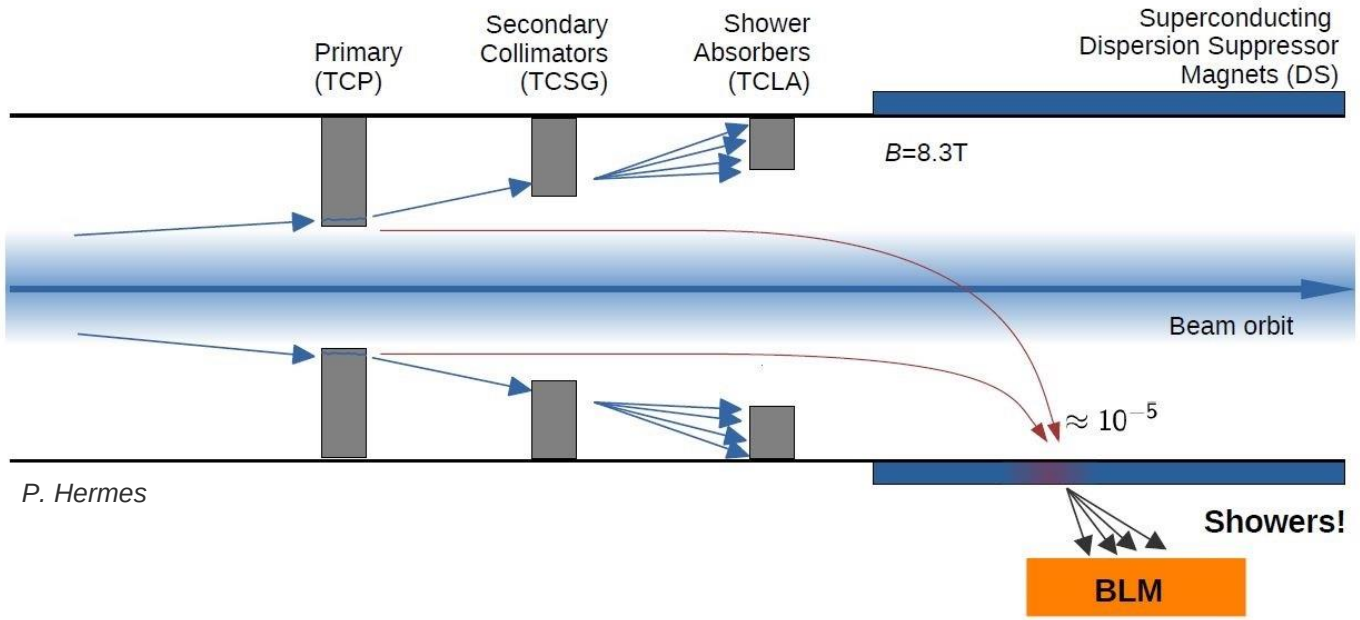
Overview of TWOCRYST MD Studies

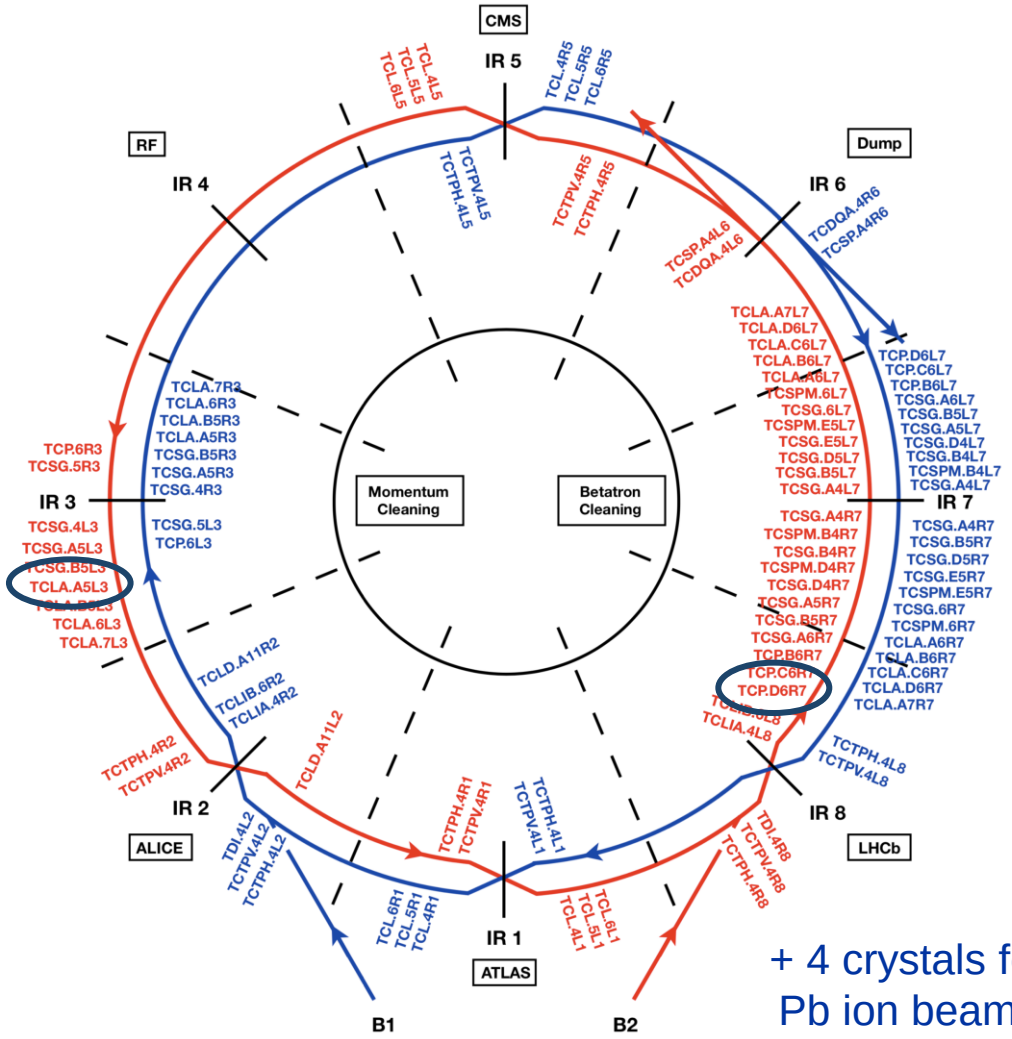
Chiara Maccani

CERN BE-ABP-NDC

19/09/2024

Collimation System





TWOCRYST collimators:

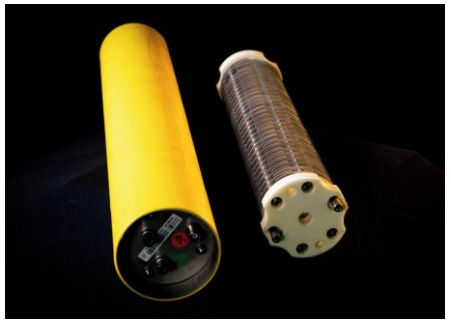
- TCP.D6R7: vertical collimator in IR7 ➜ defines beam size
- TCCS.5R3: new 4mm crystal
- TCCP.4L3: new 7cm crystal
- TCLA.A5L3: absorber in IR3 ➜ catch channeled halo

+ 4 crystals for Pb ion beams collimation

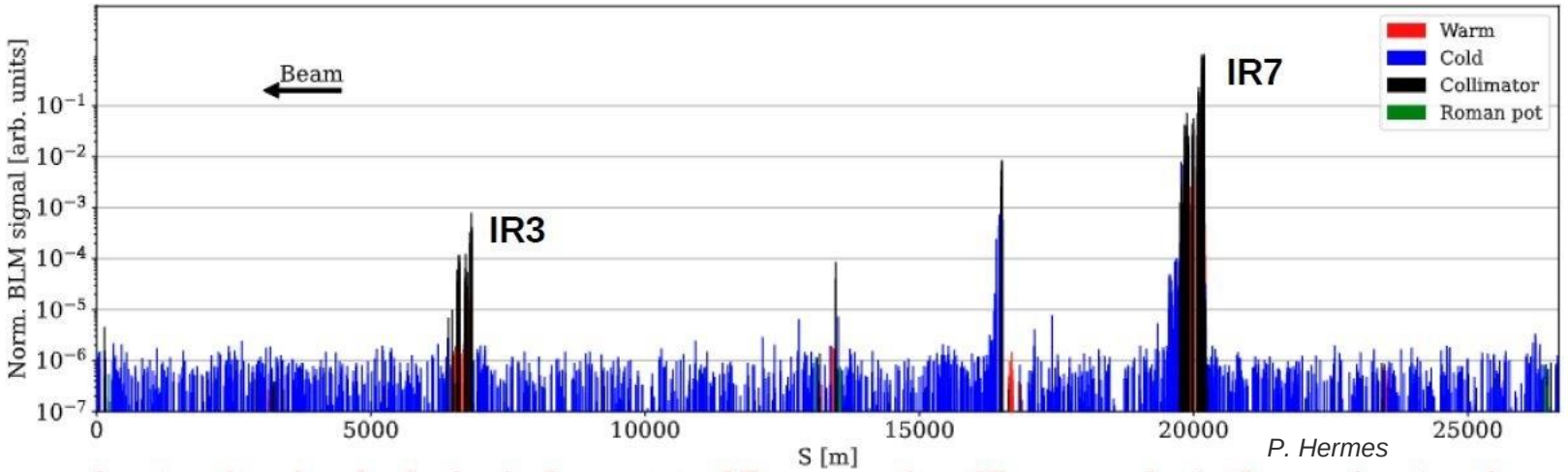
Beam Losses

❖ Measure beam losses

Beam Loss Monitors (BLMs)



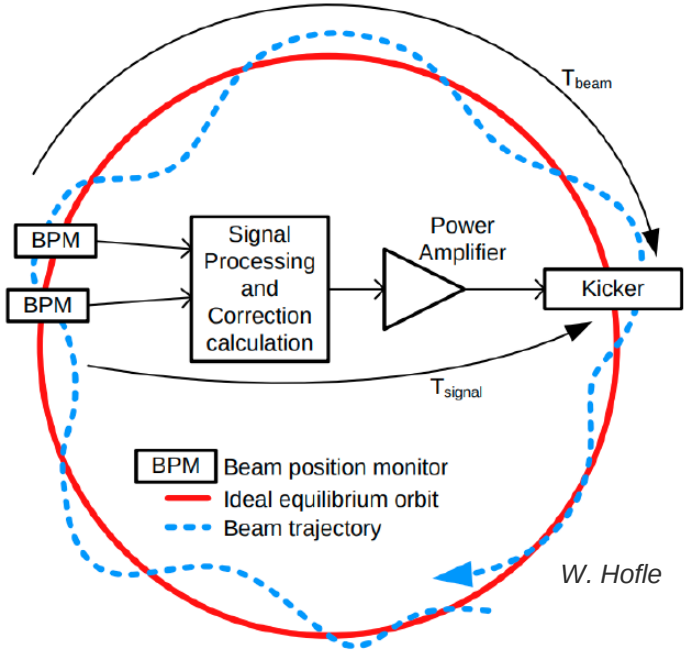
Lossmaps



P. Hermes

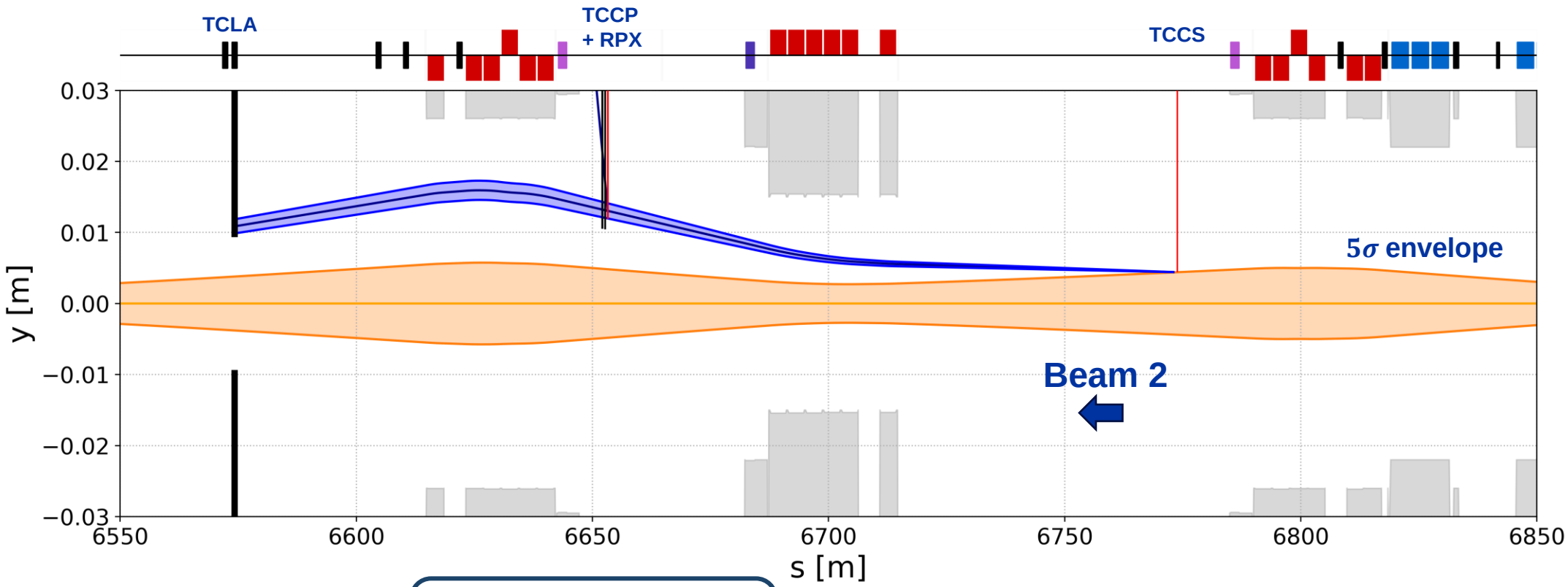
❖ Induce beam losses

LHC Transverse Damper (ADT)
➜ beam blow-up



W. Hofle

TWOCRYST beam dynamics



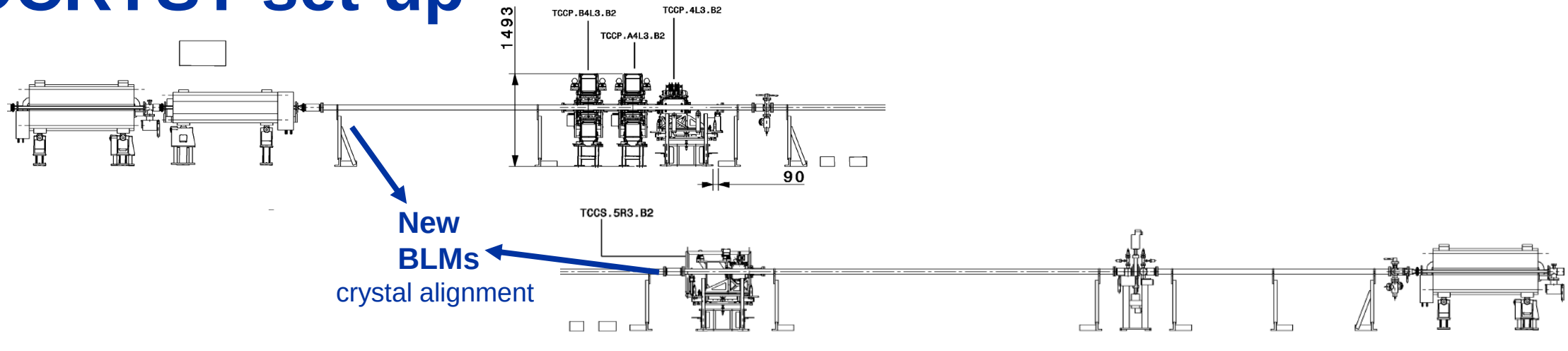
Beam envelope

$$\sigma = \sqrt{\frac{\varepsilon_N}{\beta_{rel}\,\gamma} \cdot \beta_y(s)}$$

→ defined by TCP in IR7

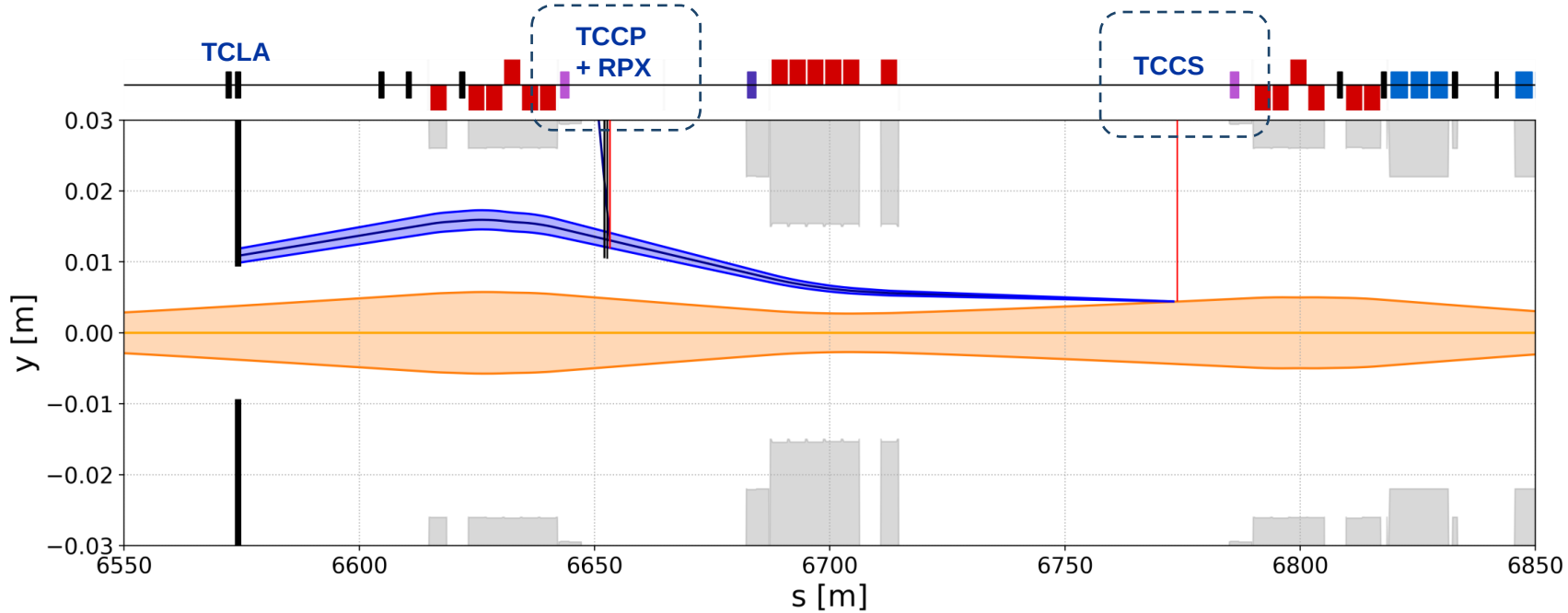
$\varepsilon_{N,\,LHC} = 3.5\ \mu m\ rad$

TWOCRYST set-up



New BLMs
crystal alignment

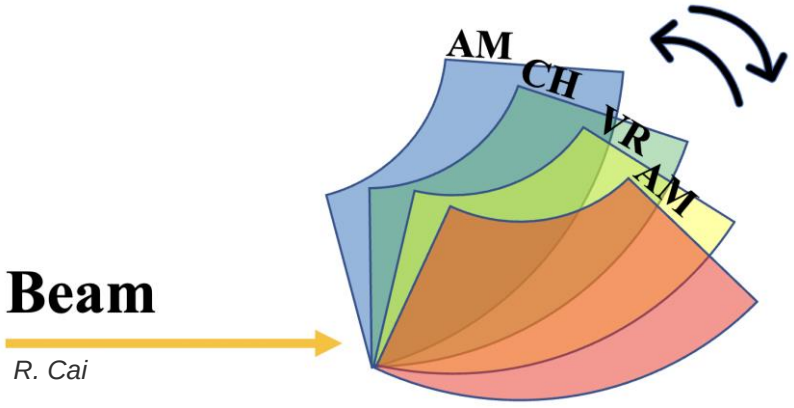
J.P. Corso



Angular scan with circulating beam

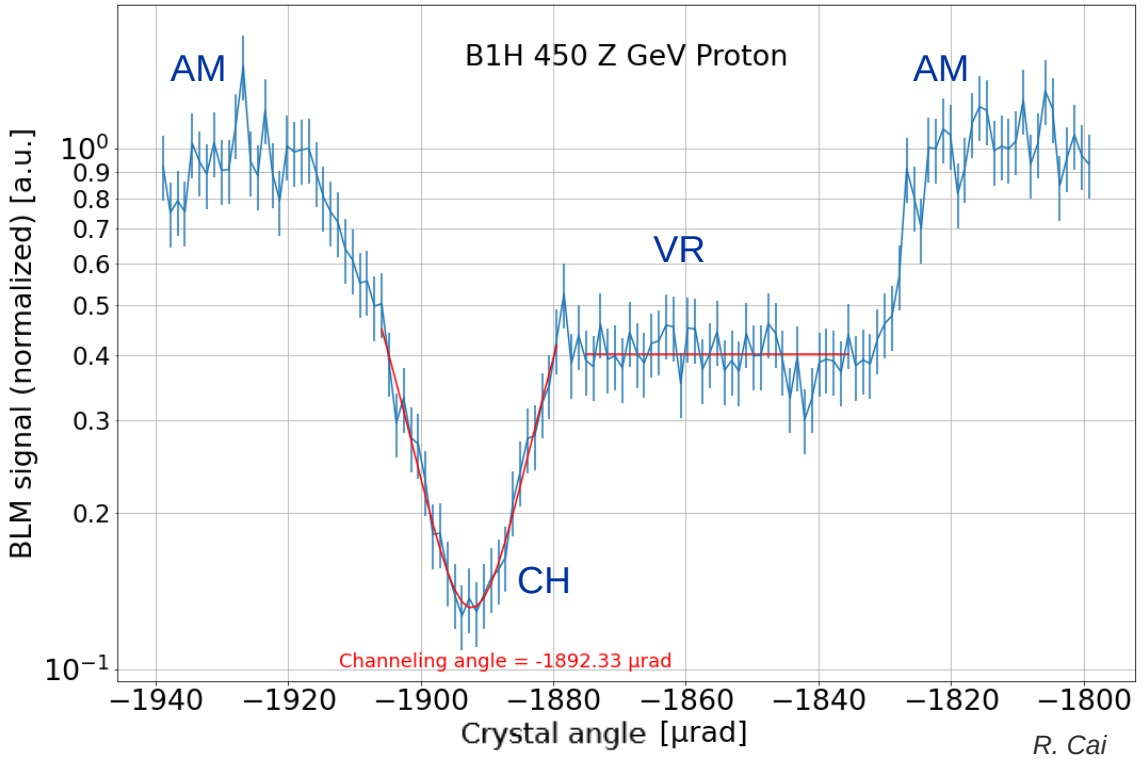
Find channeling orientation

- Induce losses with ADT
- Observe BLM signal
- Slow crystal rotation



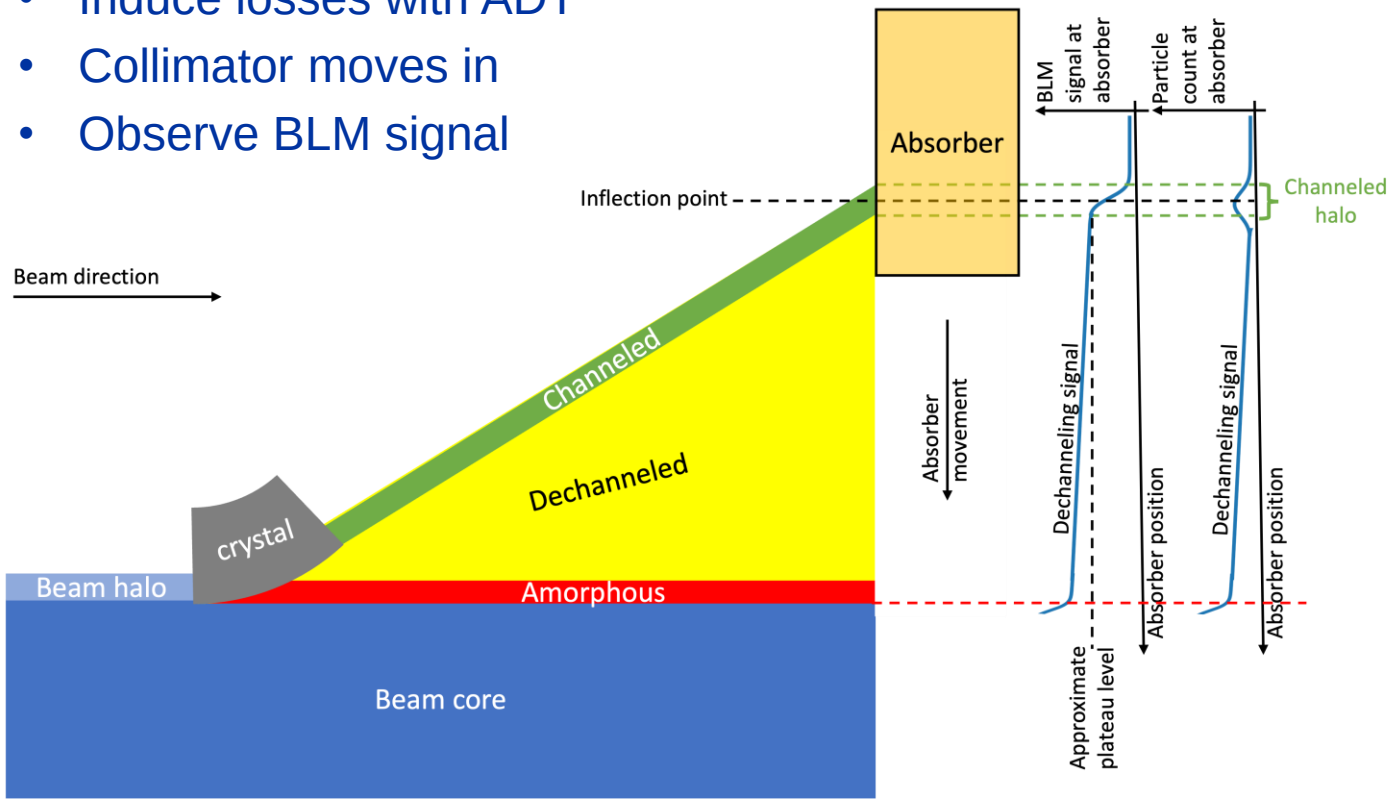
Measures:

- Channeling angle
- Reduction factor (crystal quality)
- Bending angle (rough estimate)



Linear scan with circulating beam

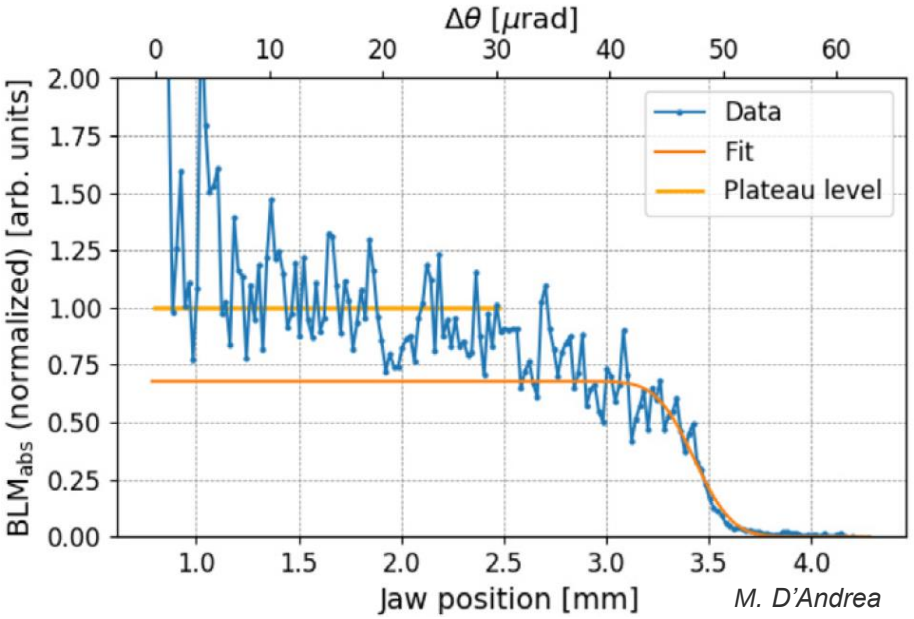
- Crystal in channeling
- Retract a collimator downstream crystal
- Induce losses with ADT
- Collimator moves in
- Observe BLM signal



R. Cai

Measures:

- Bending angle
- Multiturn channeling efficiency (see next slide)

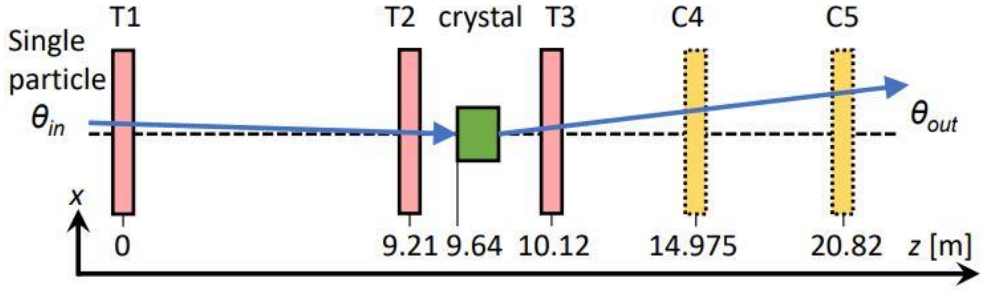


M. D'Andrea

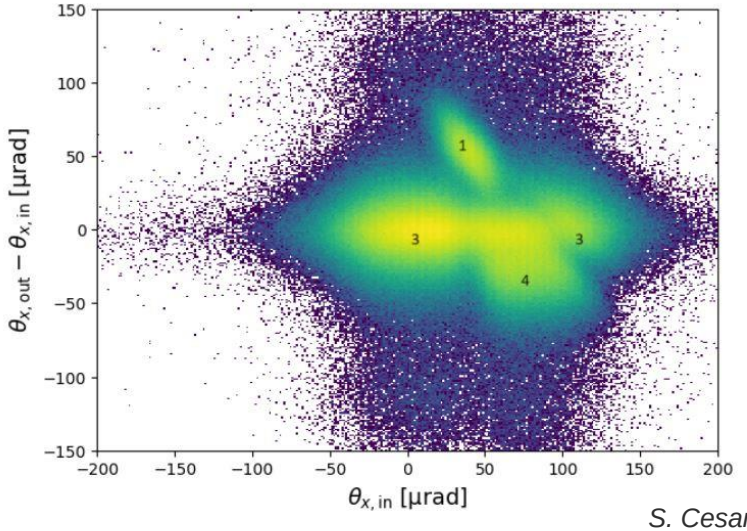
Channeling Efficiency

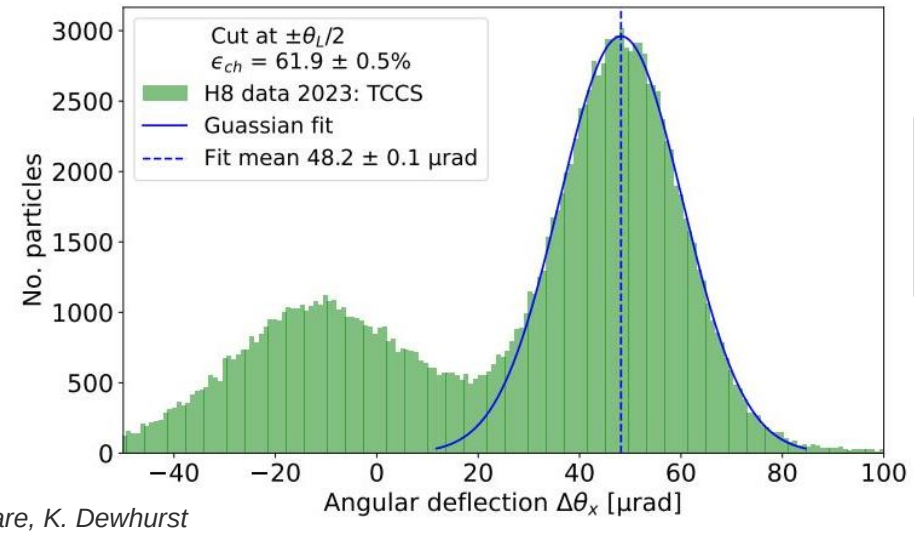
❖ Single pass efficiency

- **Number of particles that can be channelled is known** (detectors before crystal to measure θ_{in})
- Measure deflection angle $\Delta\theta_x$ with detectors after crystal
- Estimate n° channeled particles via Gaussian fit



→ **H8 Test:** *see S. Cesare talk*





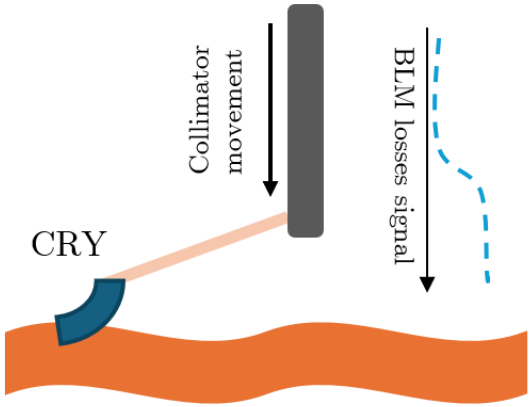
S. Cesare, K. Dewhurst

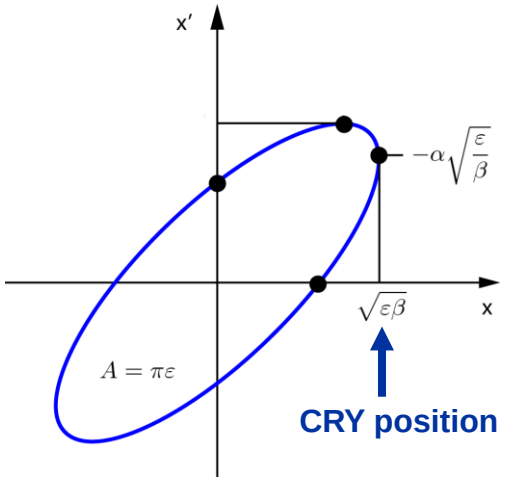
$$\varepsilon_{CH} = \frac{n^\circ\, part.channeled}{n^\circ\, part.in\left[-\frac{1}{2}\theta_c < \theta_{in} < \frac{1}{2}\theta_c\right]}$$

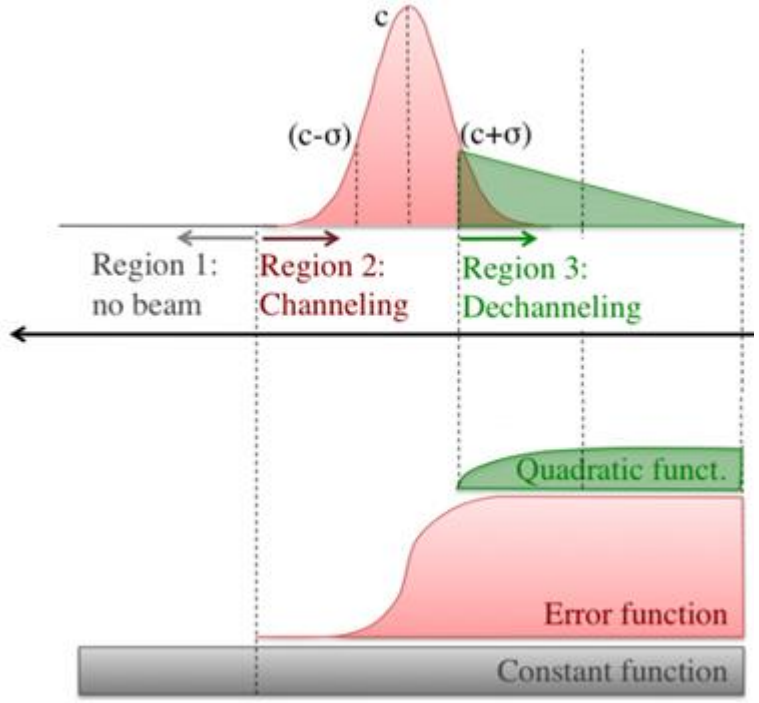
Channeling Efficiency

❖ Multiturn efficiency

- Only way to measure ε_{CH} in the machine
- Number of particles that can be channelled **not** known
- Known incoming angle from beam optics







V. Previtali

$$\varepsilon_{CH} = \frac{BLM\,|_{plateau}}{BLM\,|_{before\ beam}} \propto \frac{n^{\circ}\ part.channeled}{n^{\circ}\ part.chann + dechann}$$

$$\varepsilon_{CH,\,mutiturn} > \varepsilon_{CH,\,single\ pass}$$

- Multiple crystal passage
- Not all AM and VR particles are detectable

Plan for 2025 MDs

P. Hermes - ICHEP 2024

Preparatory

- Ramp in steps (1 / 3 / 5 TeV): performed 15 May 2024
- Detector commissioning + TCCS and TCCP alignment on main beam at injection energy (450 GeV) + full characterization of both crystals

TCCP Crystal Characterization

- TCCP angular scan in the beam at 1 / 3 / 5 TeV
- TCCP multiturn channeling efficiency measurement
- Double channeling observation at 450 GeV (and potentially at 1 / 3 / 5 TeV) and estimation of TCCP single pass channeling efficiency

Performance estimate:

- Protons on target at top energy

Plan for 2025 MDs

P. Hermes - ICHEP 2024

Preparatory

- **Ramp in steps (1 / 3 / 5 TeV): performed 15 May 2024**
- Detector commissioning + TCCS and TCCP alignment on main beam at injection energy (450 GeV) + full characterization of both crystals

TCCP Crystal Characterization

- TCCP angular scan in the beam at 1 / 3 / 5 TeV
- TCCP multiturn channeling efficiency measurement
- Double channeling observation at 450 GeV (and potentially at 1 / 3 / 5 TeV) and estimation of TCCP single pass channeling efficiency

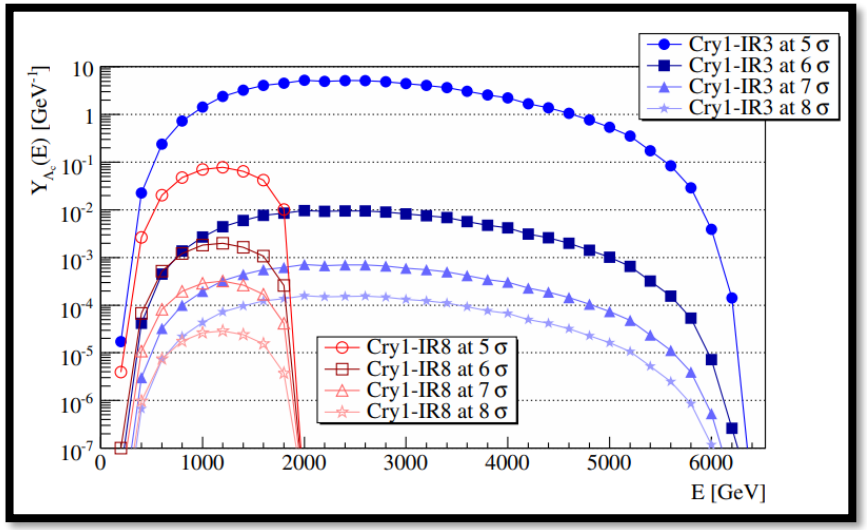
Performance estimate:

- Protons on target at top energy

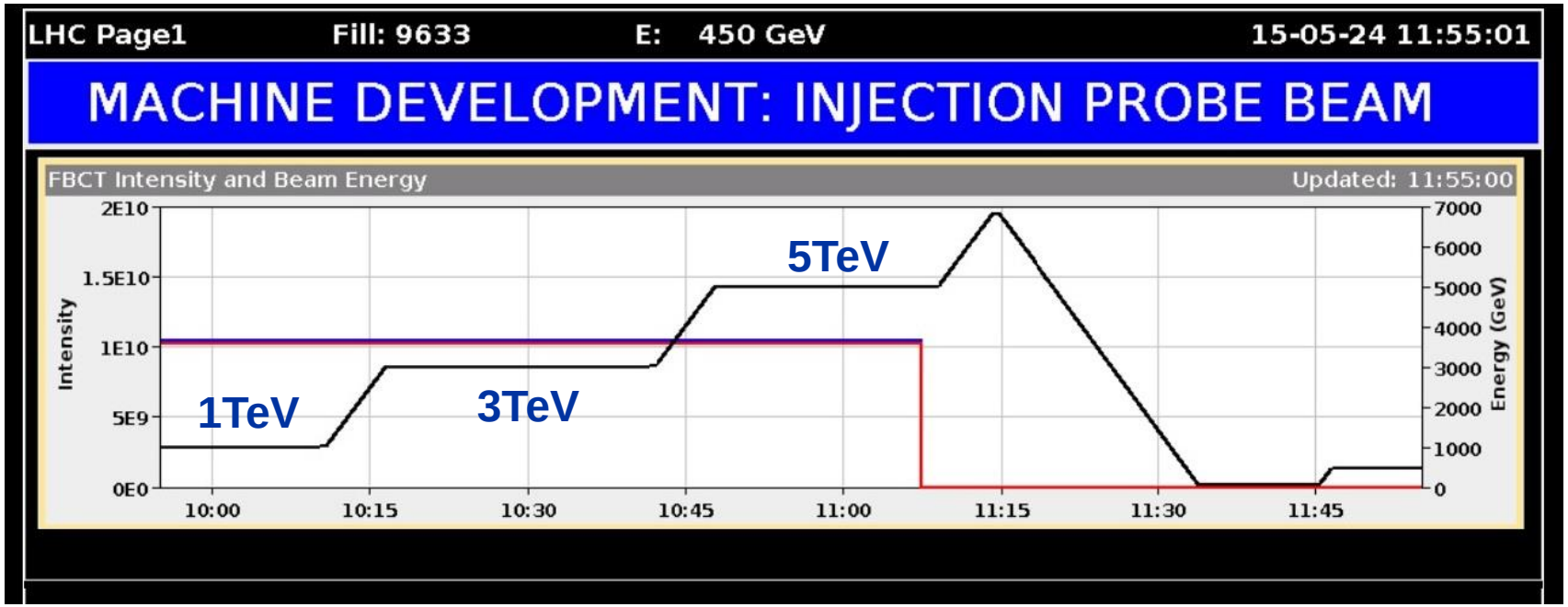
Ramp at intermediate energies

- **Λ_c^+ yield is maximum in 1-5 TeV energy range**
  - ➜ TCCP needs to be tested at those energies
- **A lot of MD time can be saved if ramp can stop at intermediate energies and continued**

Successful ramp in steps operational test of in 2024!

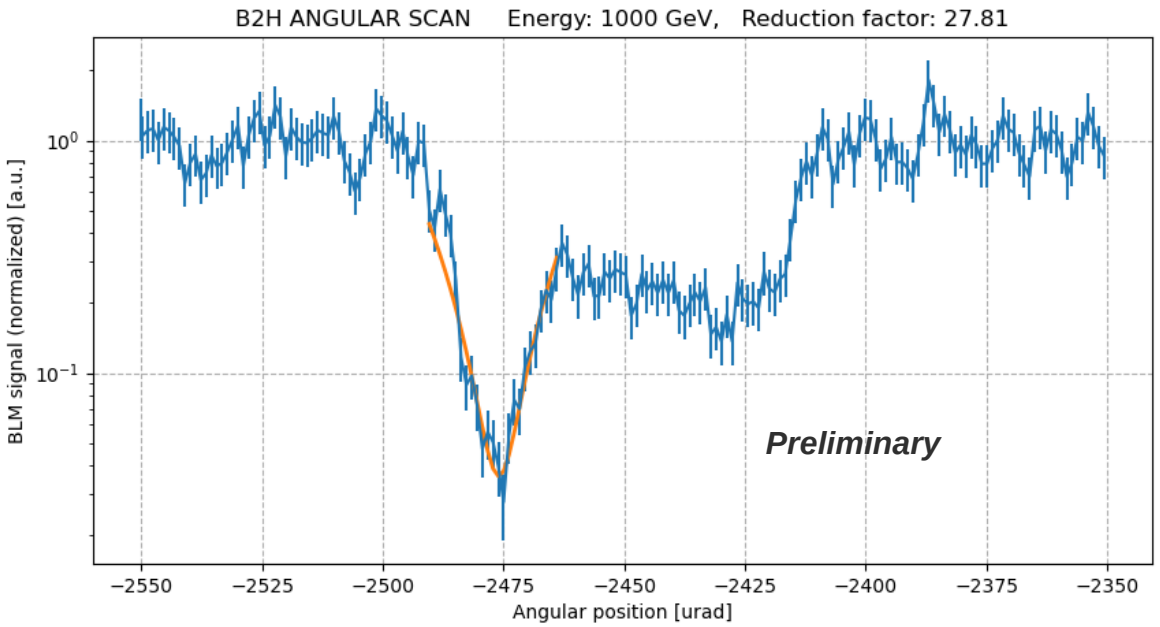


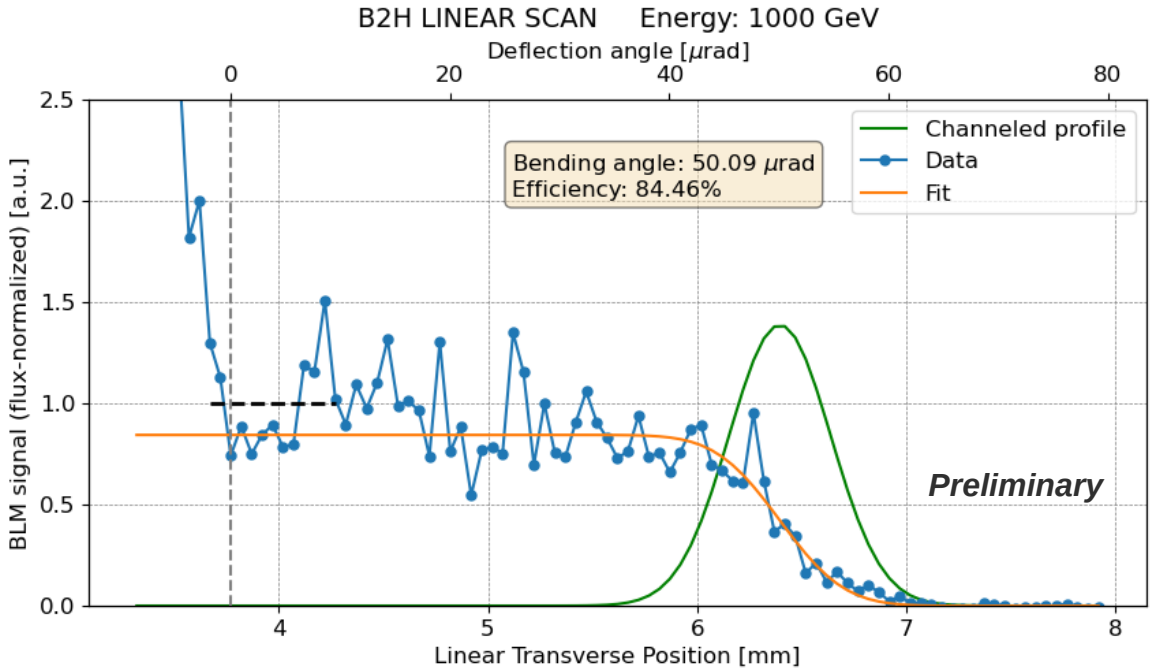
D. Mirarchi



Ramp at intermediate energies

Tested existing $50\ \mu rad$ crystal at 1,3,5 TeV





Ramp at intermediate energies

Plan for 2025 MDs

P. Hermes - ICHEP 2024

Preparatory

- Ramp in steps (1 / 3 / 5 TeV): performed 15 May 2024
- **Detector commissioning + TCCS and TCCP alignment on main beam at injection energy (450 GeV) + full characterization of both crystals**

TCCP Crystal Characterization

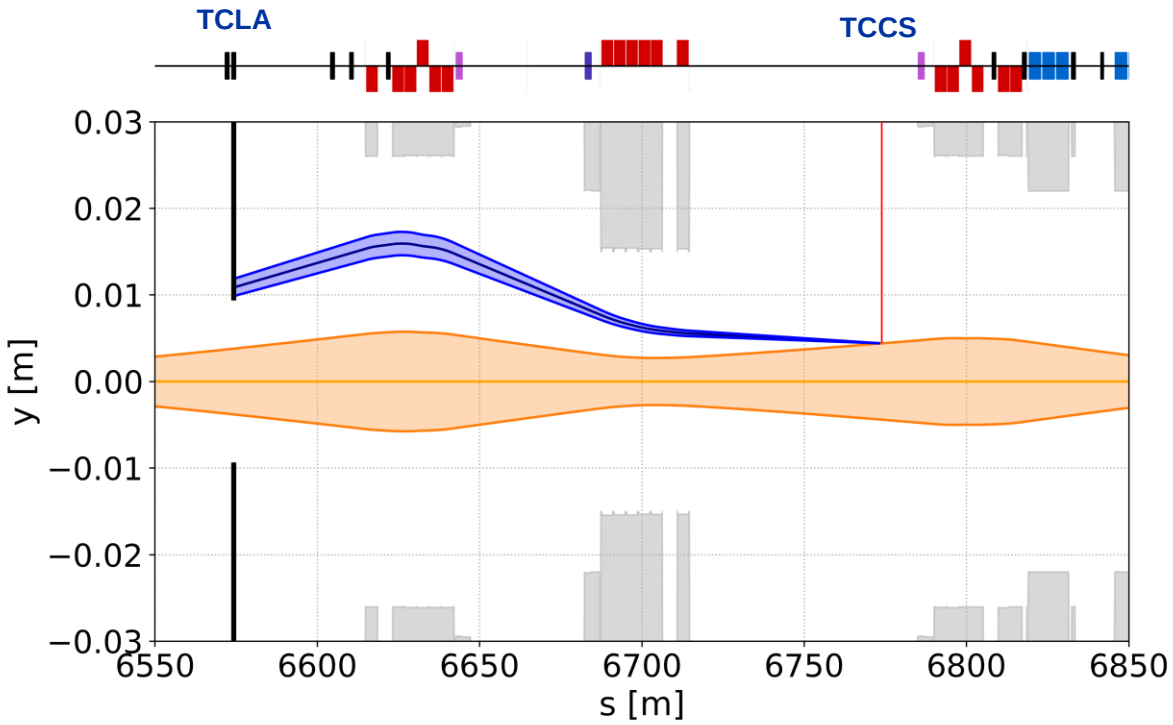
- **TCCP angular scan in the beam at 1 / 3 / 5 TeV**
- **TCCP multiturn channeling efficiency measurement**
- Double channeling observation at 450 GeV (and potentially at 1 / 3 / 5 TeV) and estimation of TCCP single pass channeling efficiency

Performance estimate:

- Protons on target at top energy

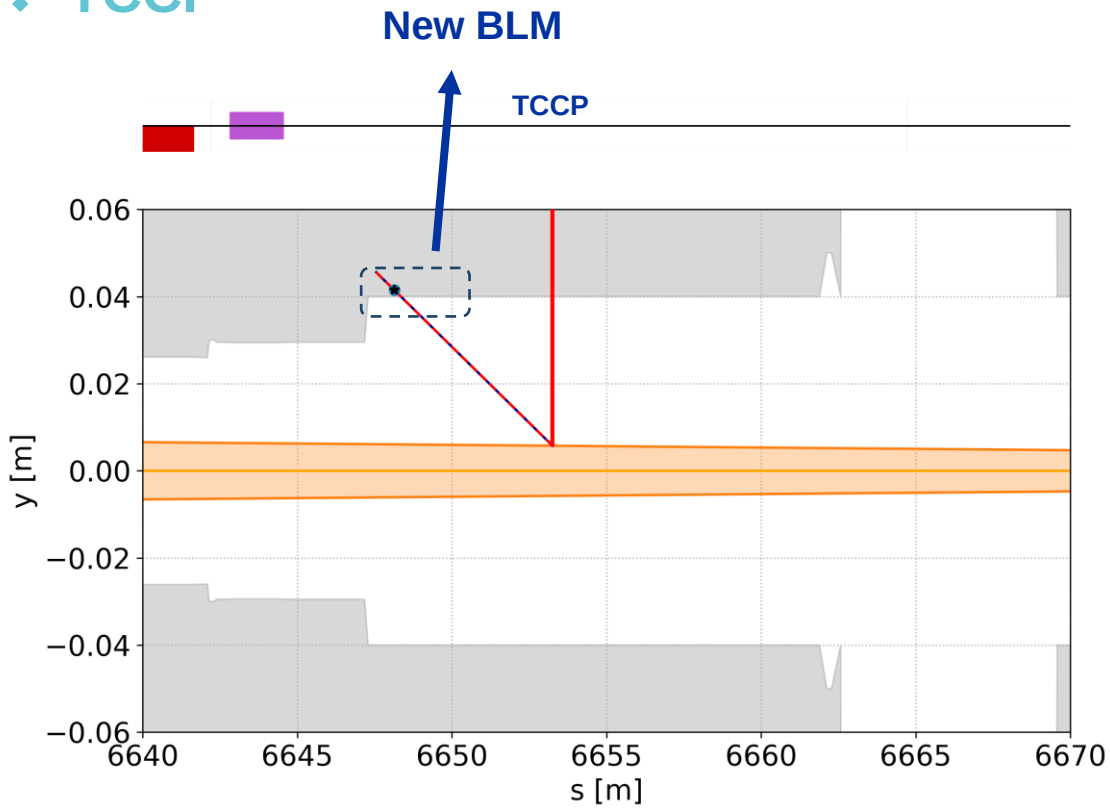
TCCS and TCCP alignment to beam

❖ TCCS



Linear scan with TCLA

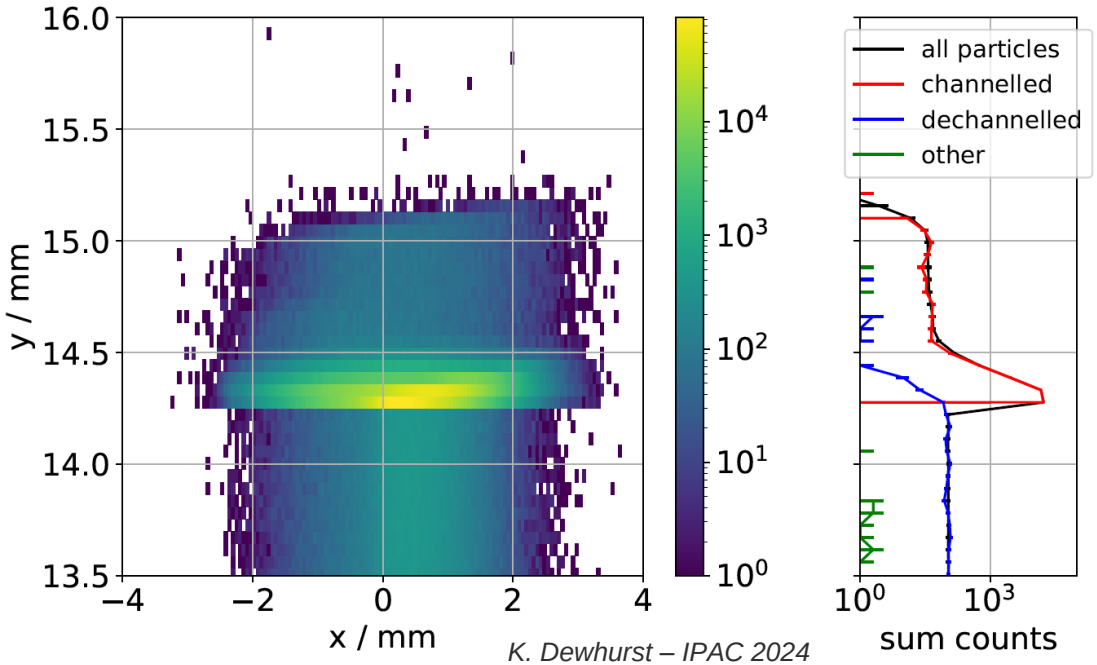
❖ TCCP



TCCP characterization in LHC

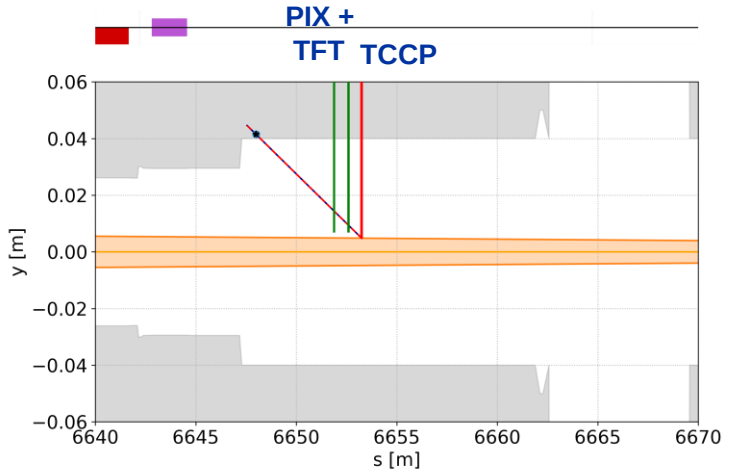
No collimator available for linear scan
➜ Multiturn channeling efficiency estimated with **detectors**

Simulation of channeling distribution in PIX at 1 TeV

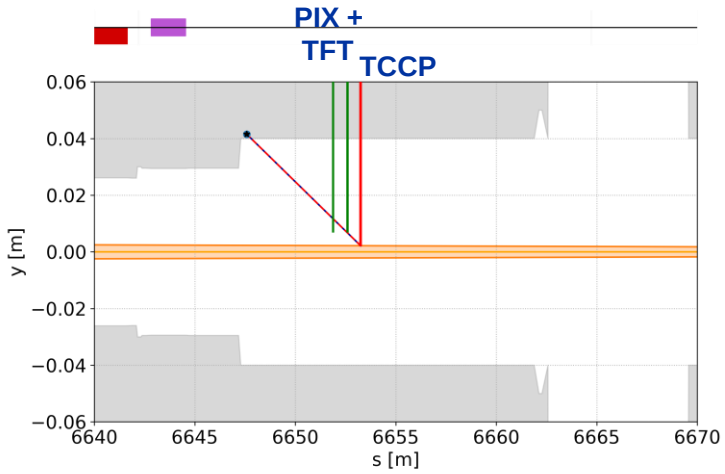


K. Dewhurst – IPAC 2024

❖ 1 TeV (5 σ)



❖ 5 TeV (5 σ)



Plan for 2025 MDs

P. Hermes - ICHEP 2024

Preparatory

- Ramp in steps (1 / 3 / 5 TeV): performed 15 May 2024
- Detector commissioning + TCCS and TCCP alignment on main beam at injection energy (450 GeV) + full characterization of both crystals

TCCP Crystal Characterization

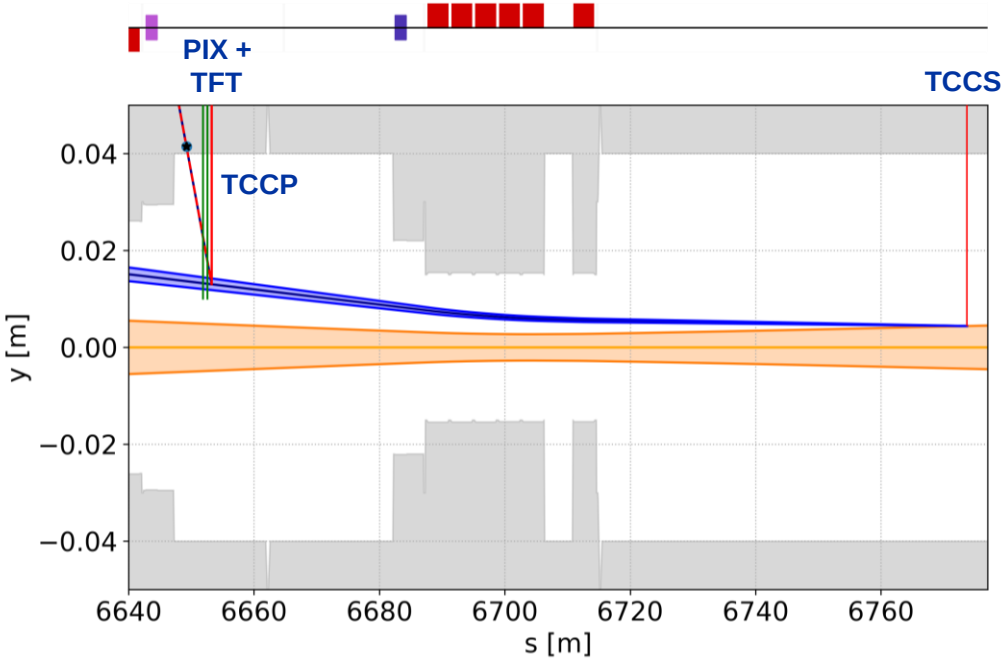
- TCCP angular scan in the beam at 1 / 3 / 5 TeV
- TCCP multiturn channeling efficiency measurement
- **Double channeling observation at 450 GeV (and potentially at 1 / 3 / 5 TeV) and estimation of TCCP single pass channeling efficiency**

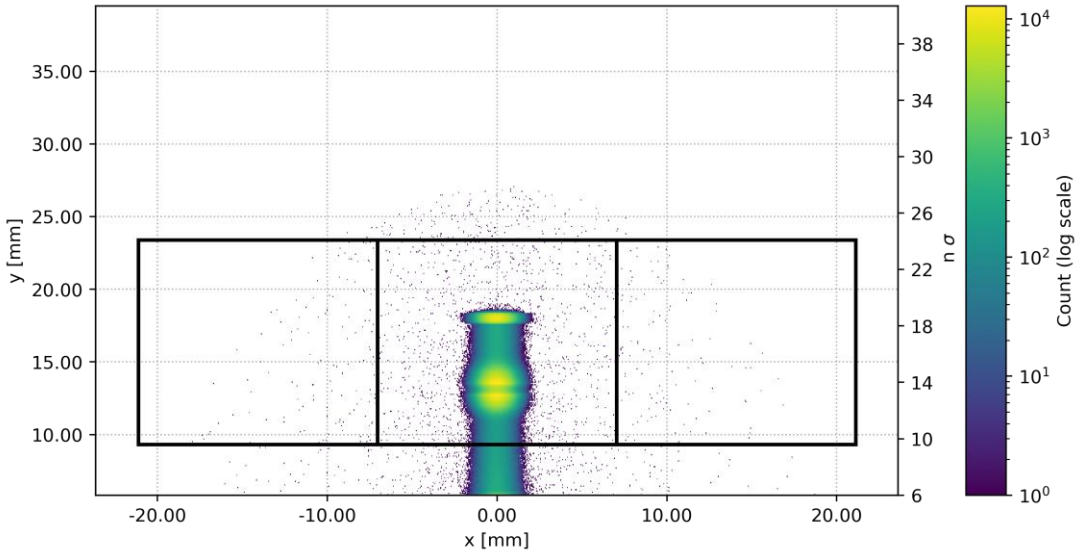
Performance estimate:

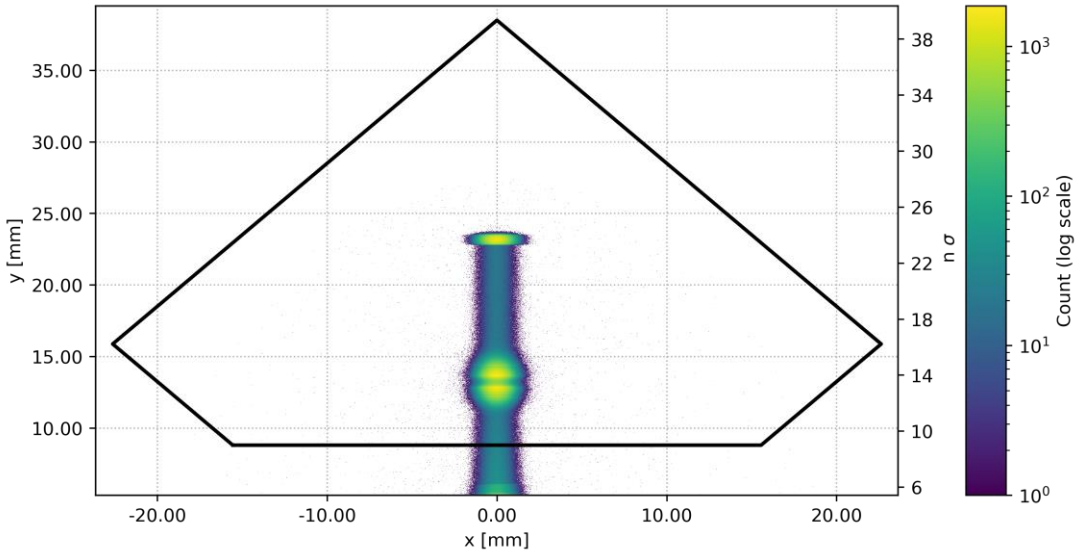
- Protons on target at top energy

Double Channeling observation

- 1 TeV (5 σ)







Reconstruct single pass channeling efficiency by combining information from different detectors

Plan for 2025 MDs

P. Hermes - ICHEP 2024

Preparatory

- Ramp in steps (1 / 3 / 5 TeV): performed 15 May 2024
- Detector commissioning + TCCS and TCCP alignment on main beam at injection energy (450 GeV) + full characterization of both crystals

TCCP Crystal Characterization

- TCCP angular scan in the beam at 1 / 3 / 5 TeV
- TCCP multiturn channeling efficiency measurement
- Double channeling observation at 450 GeV (and potentially at 1 / 3 / 5 TeV) and estimation of TCCP single pass channeling efficiency

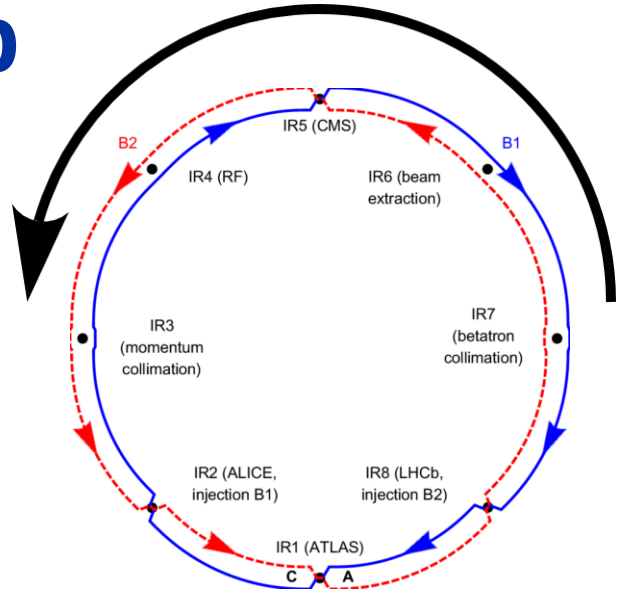
Performance estimate:

- **Protons on target at top energy**

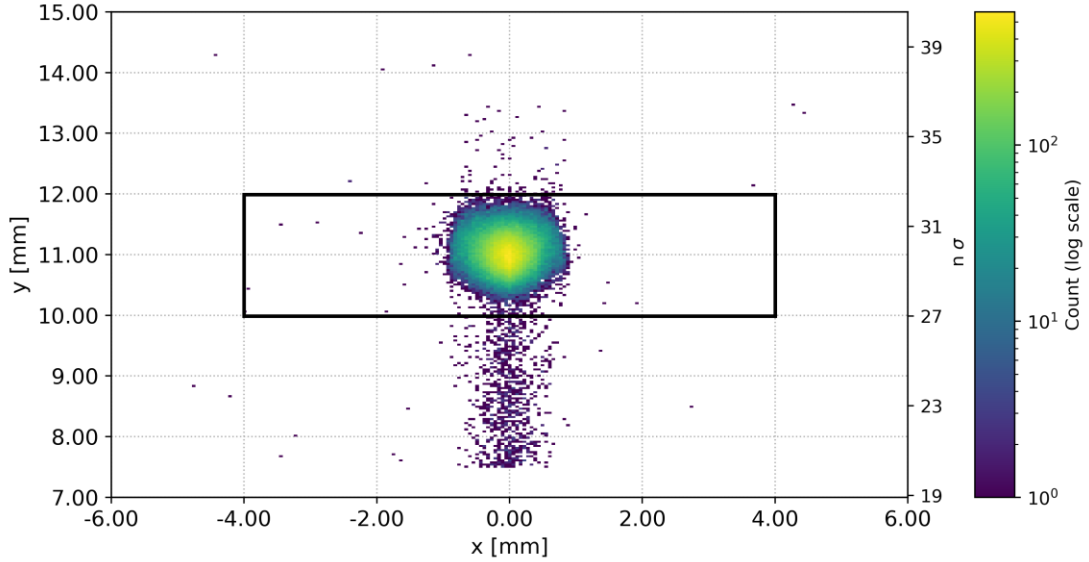
Proton on target (PoT) at flat top

Test proton delivery to target in a **parasitic** mode:

- TCP intercepts beam in IR7
- Secondary halo travels half ring to IR3
- TCCS must be retracted wrt TCP (at least $\mathbf{0.5}\ \boldsymbol{\sigma}$)
- Measure PoT rate of channeled protons



Simulation PoT distribution at 6.8 TeV with $\mathbf{0.5}\ \boldsymbol{\sigma}$ TCCS retraction



Benchmark simulation tools with real observations

→ **Additional study**: PoT optimization changing beam optics

Simulation Framework

collection python packages for **beam dynamics simulation** in accelerators

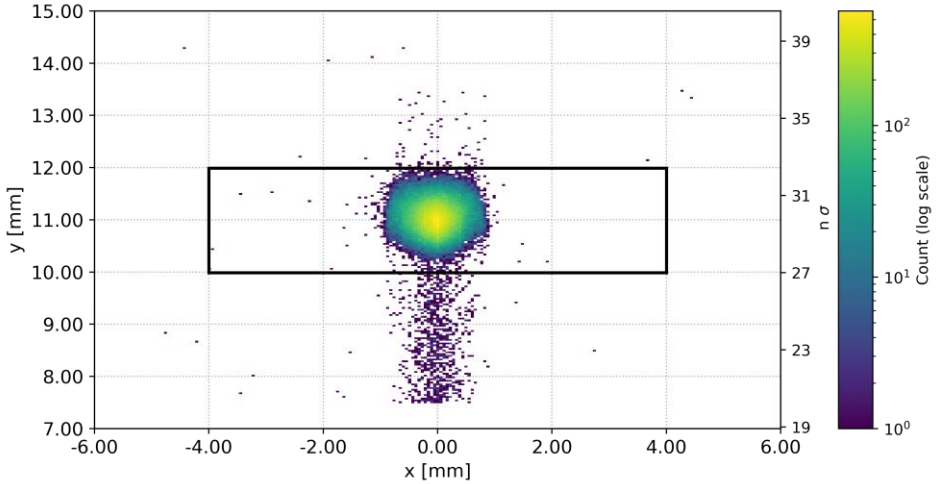
xcoll

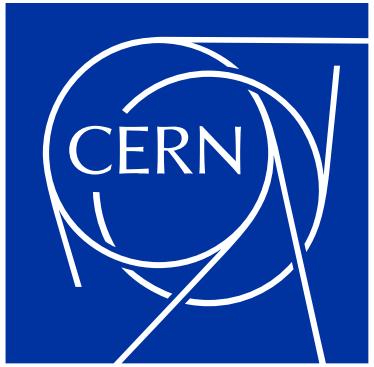
- Particle – matter interactions in collimators
- Crystal physics

→ **multiturn tracking of protons**

→ **beam halo** simulations:

- LHC model + set of collimators settings
- Generate particles of beam edge
- Track for many turns
- Observe channeling distributions
- PoT estimate: normalize by beam intensity and beam life-time





home.cern