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Sezione di Roma

BEAM SUPERIMPOSITION WITH BENT CRYSTALS

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on behalf of the UA9 Collaboration

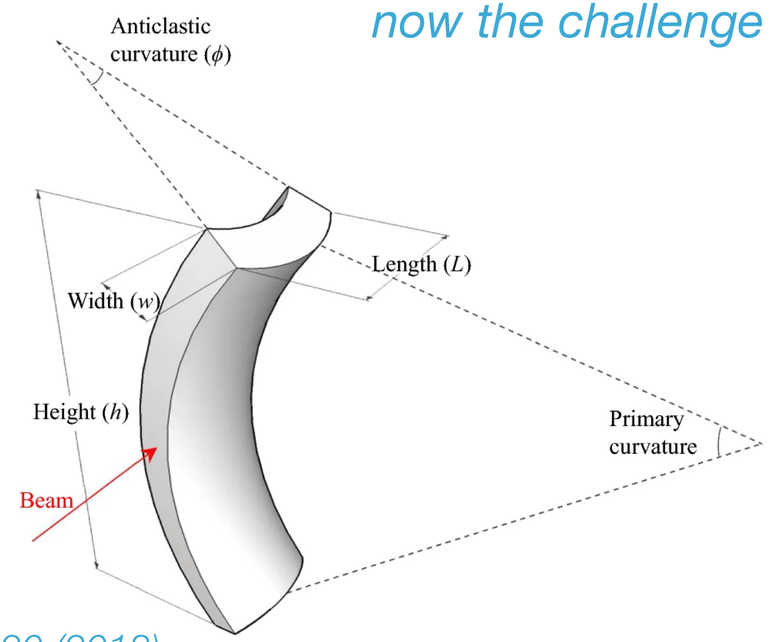
Channeling 2024 - 8-13/9/24 - Riccione, Italy

UA9

Bent Crystals

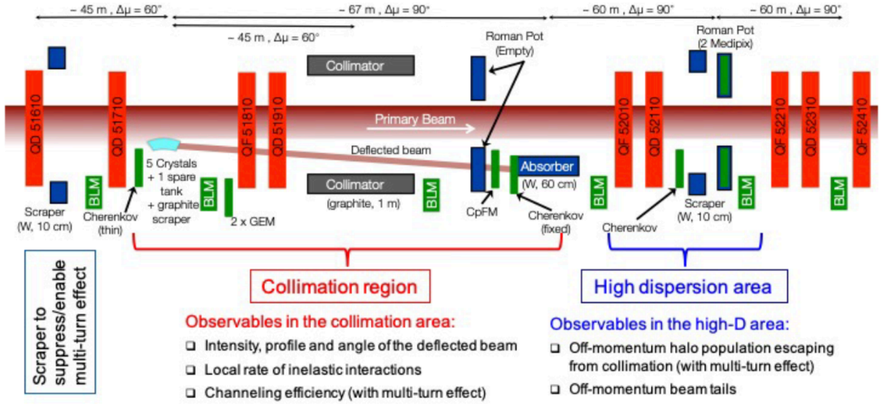
- Channeling phenomena in bent crystal has been investigated in the past decades
- profiting from anticlastic crystal deformation bending up to few *mrad* has been achieved
- Beam steering been experimentally demonstrated for particles ranging from 3 MeV to 1 TeV in energy

now the challenge has changed!

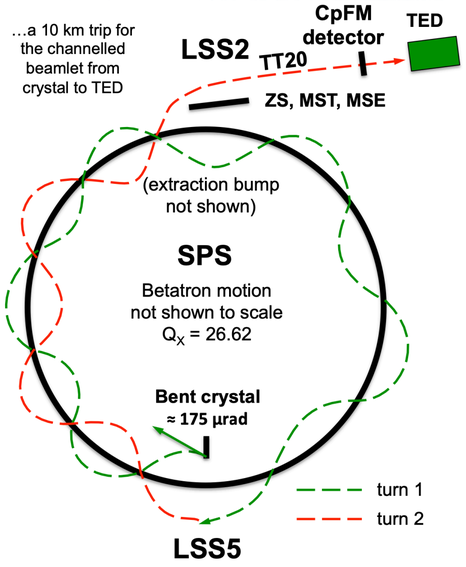


[EPJ C 78, 720 (2018)]

Beam Halo cleaning



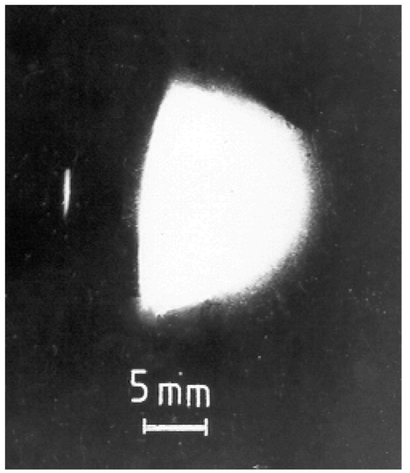
Slow beam extraction



[arXiv:1707.05151]

U-70 beam extraction

[PRL 87, 094802 (2001)]



Beam recombination

- Colliders profit from high instantaneous luminosity, which leads to more data collected by experiments
  (higher sensitivity, higher precision)
- Beam transverse cooling is a crucial aspect to achieve high luminosity
- To overcome single beam production limitations, recombination of multiple beams is a technique to increase the accelerator luminosity
- Optical techniques have intrinsic limitations, can only set beams side-to-side

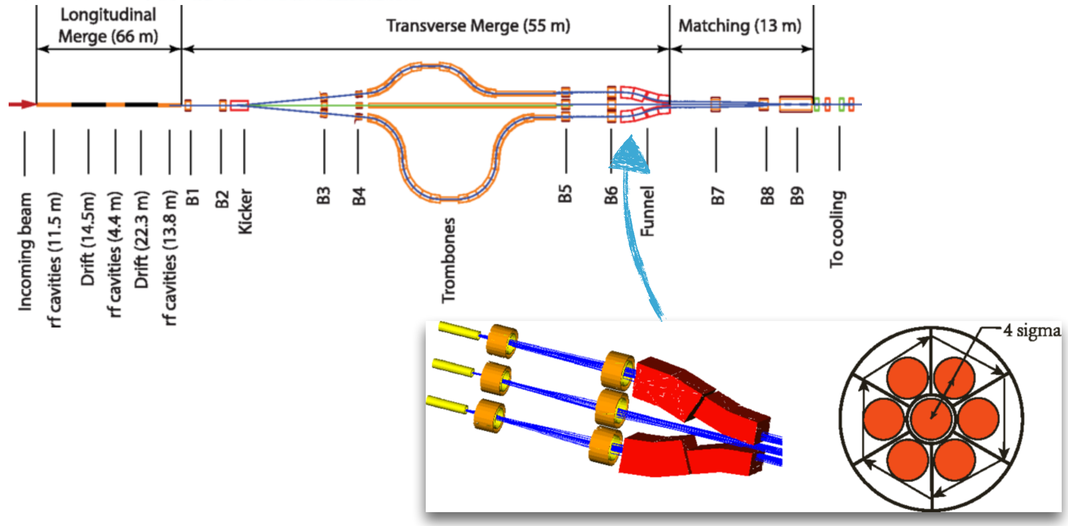
can a bent crystal be an ***angular filter*** *thanks to its* combination of *coherent* and *non-coherent* behaviours?

$$\mathscr{L} = \frac{fN_1N_2}{4\pi\sigma_x^*\sigma_y^*} \Rightarrow \frac{fN^2}{4\pi\sigma^2}$$

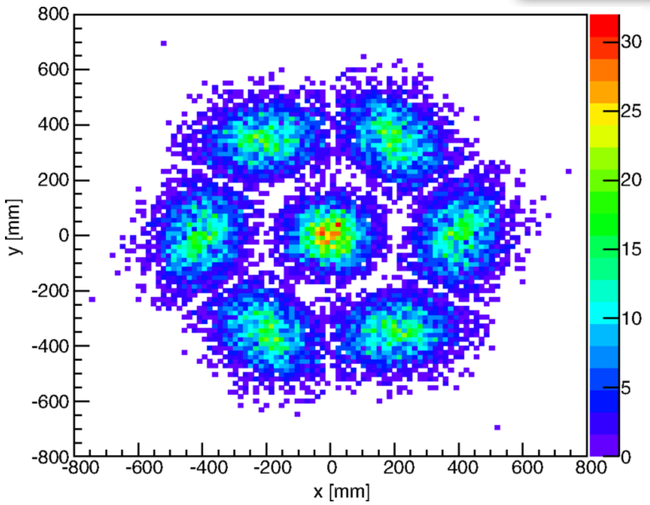
σ depending on beam emittance and accelerator lattice

e.g. Beam merging in MAP

134 m ~ 0.5 μs ~ 0.25 τ_μ



[P.R.A.B. 19, 031001 (2016)]



Coherent phenomena in Bent Crystals

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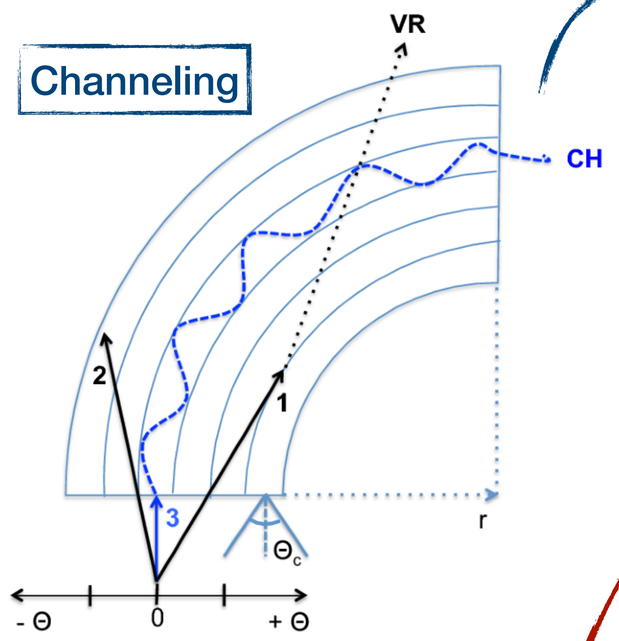
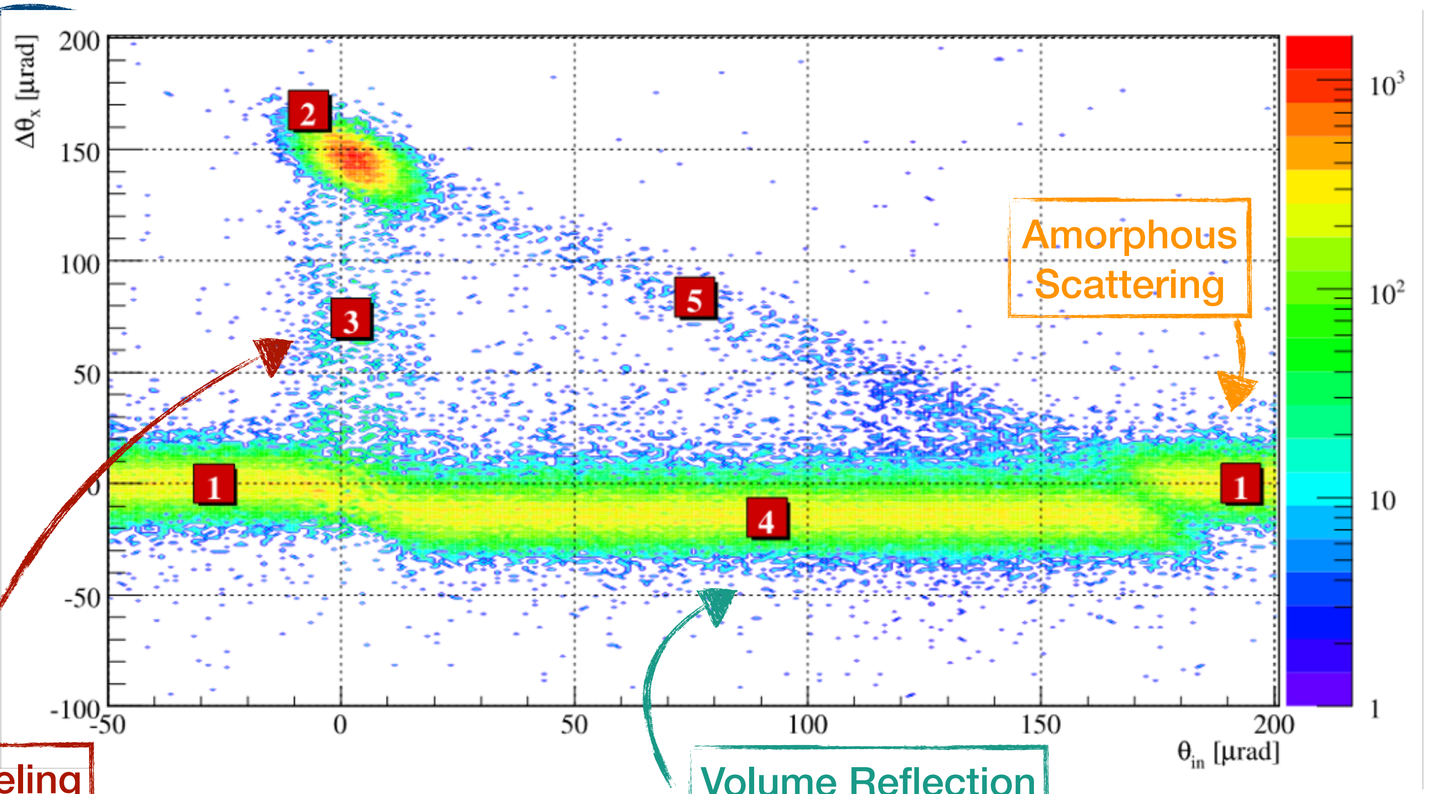
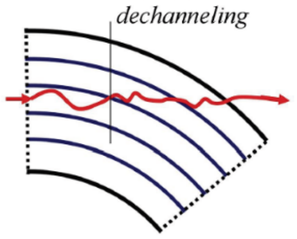
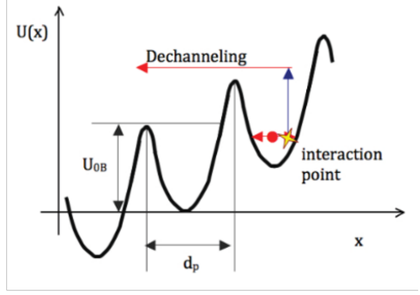


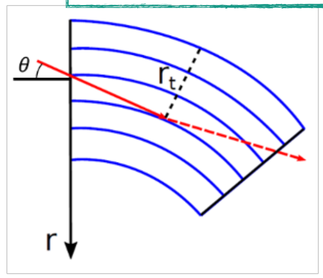


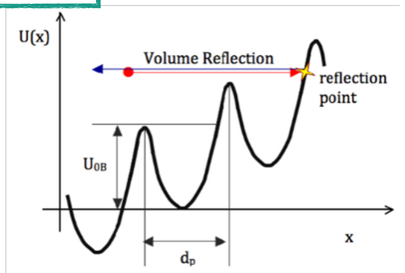
Dechanneling





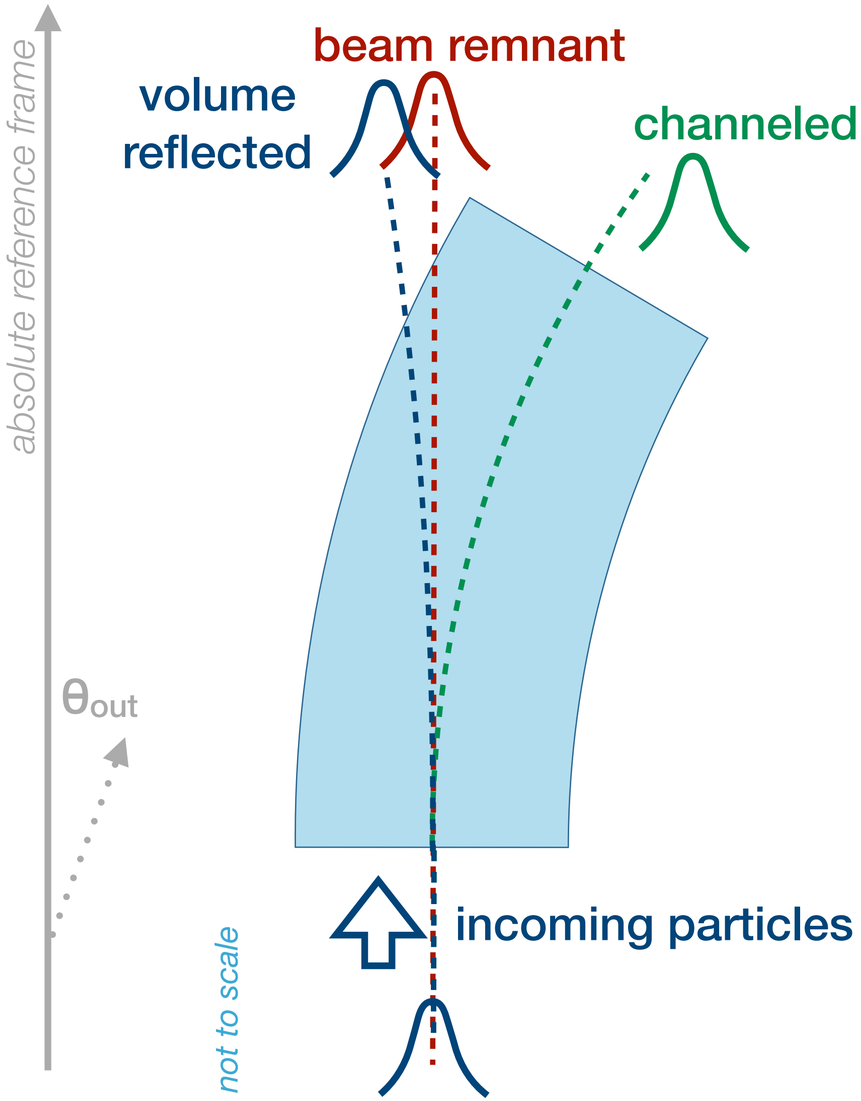
Volume Reflection





The IDEA

looking things from a different perspective



EPJ Plus 138, 981 (2023)

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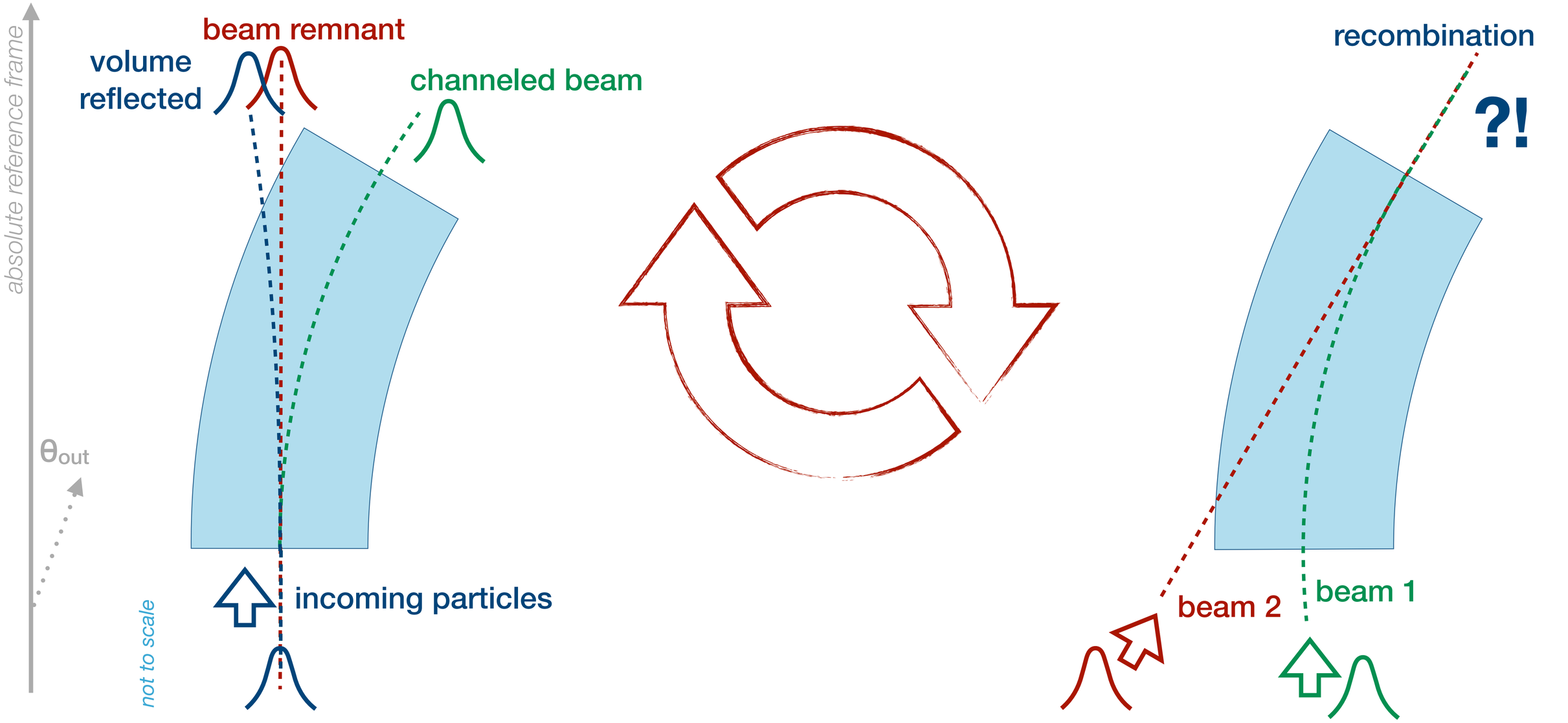

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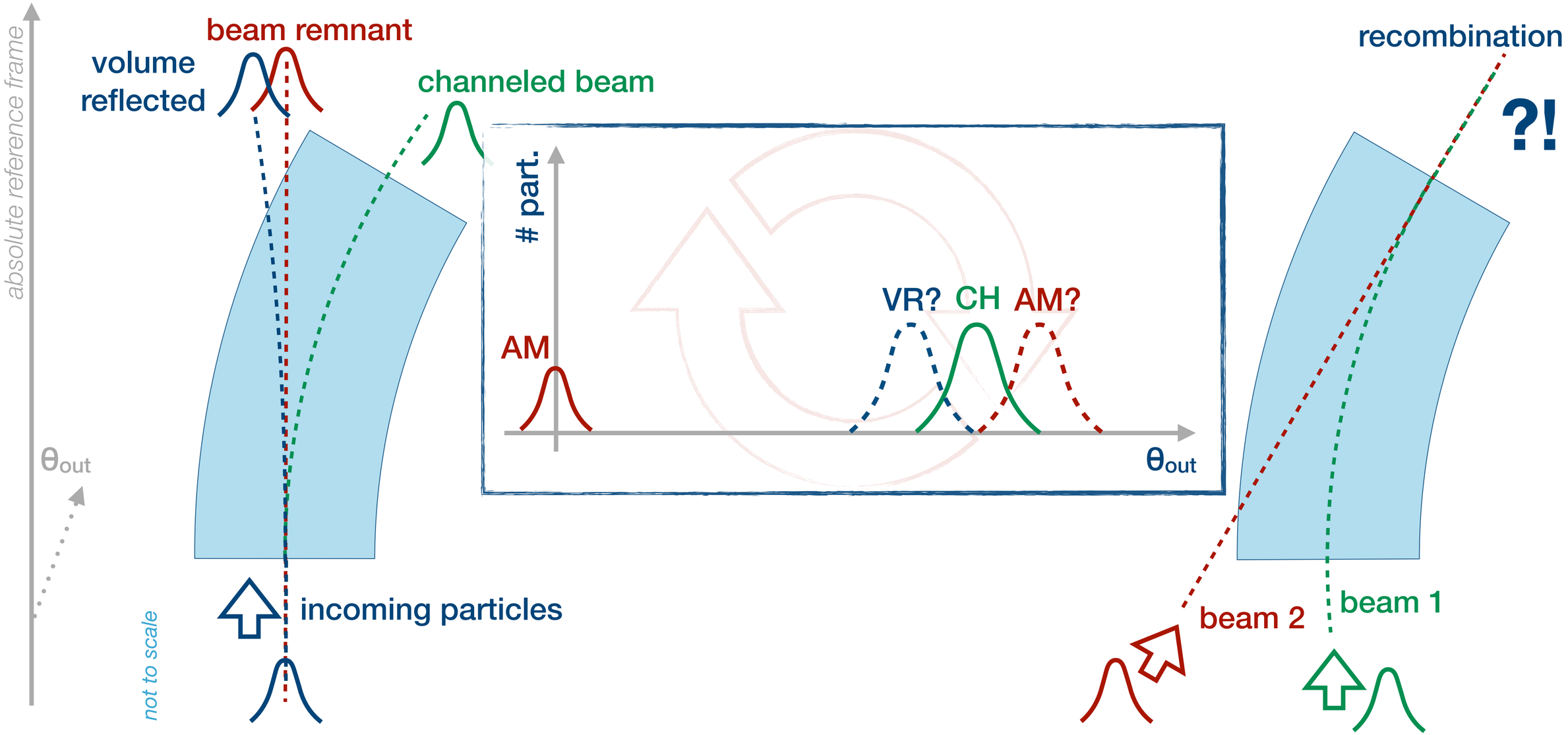

Recast available data

UA9 has recorded already data studying properties of bent crystal:

can we profit from them?

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ACP80 crystal (110)

size : 3.0x50.0x4.0 mm^3
θ_b : 60.9 ± 0.5 μrad
R : 65.7 ± 1 m
Ty: 0.28 ± 0.25 μrad/mm

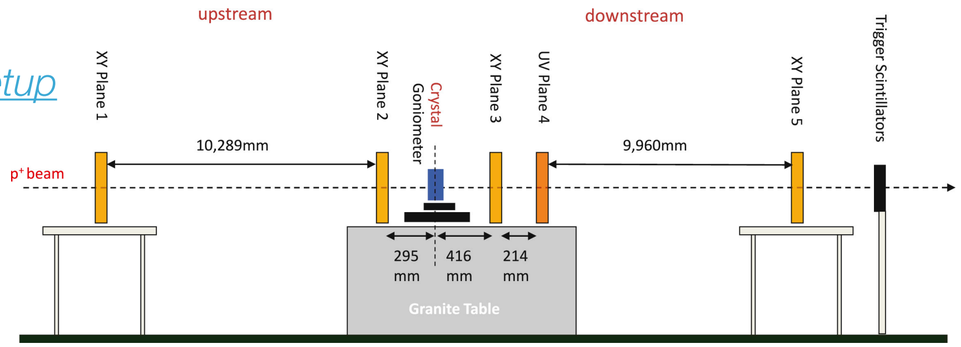
SPS beam

E : 180 GeV
70% p - 30% π

Performances

$\varepsilon_{CH}(<\theta_c)$: 52.1 ± 0.4 %
$\varepsilon_{CH}(<\theta_{c/2})$: 65.6 ± 0.9 %
$\varepsilon_{VR}(2\theta_c\text{-}3\theta_c)$: 83.9 ± 0.6 %
$\sigma(\theta_{out})/\sigma(\theta_{in})_{AM}$: 3.26 ± 0.05
$\sigma(\theta_{out})/\sigma(\theta_{in})_{VR}$: 3.39 ± 0.07

UA9 experimental setup
σ_θ = 12.3 μrad



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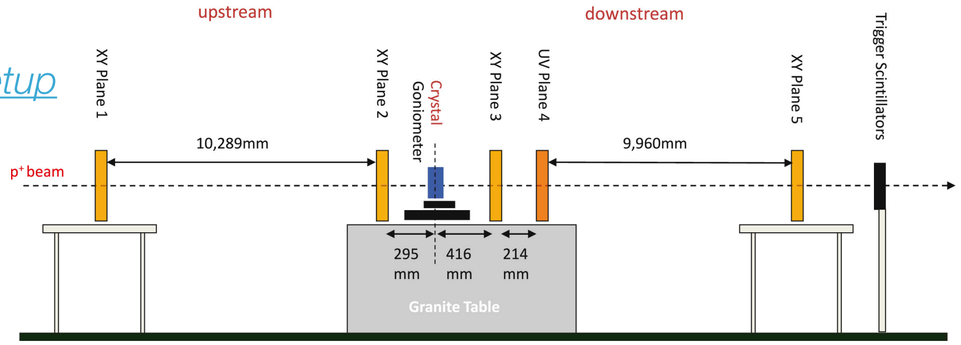

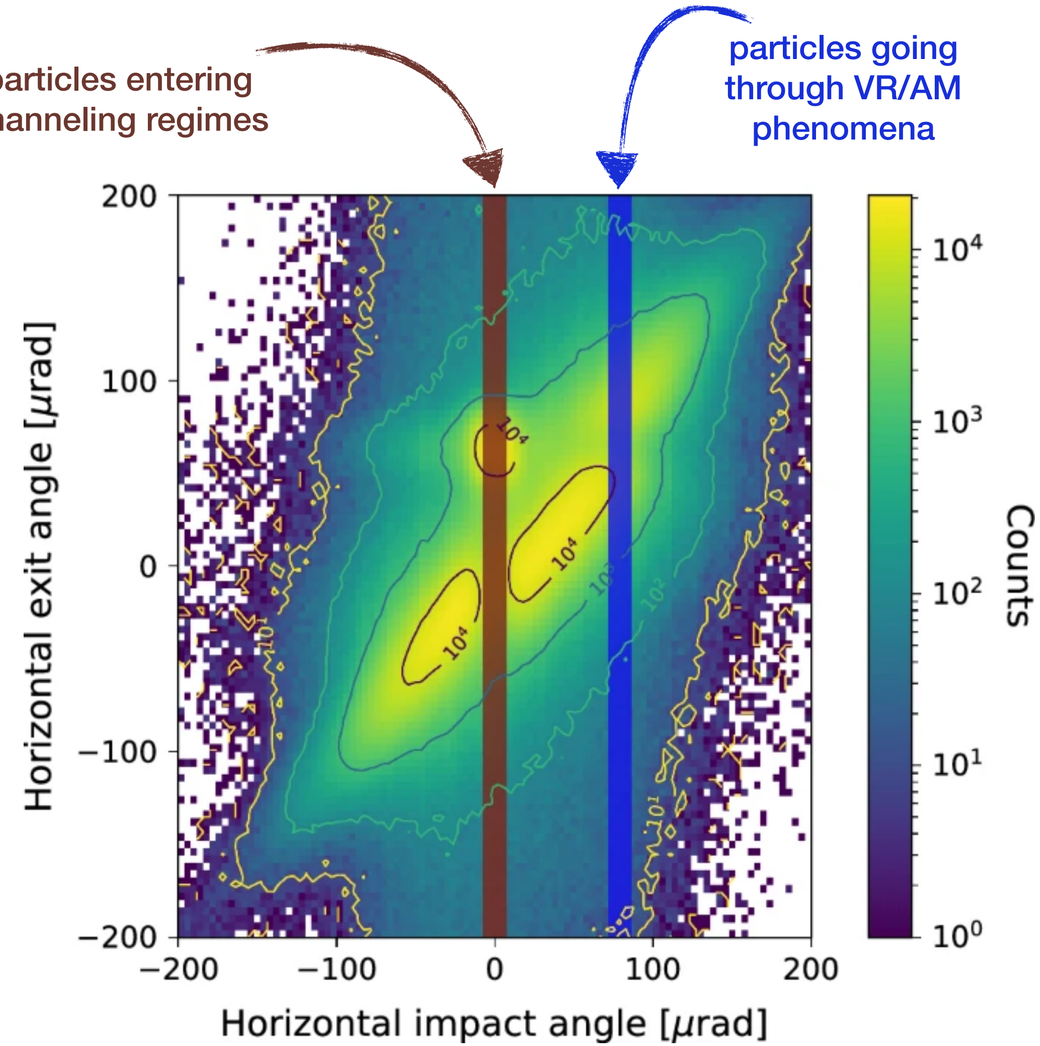

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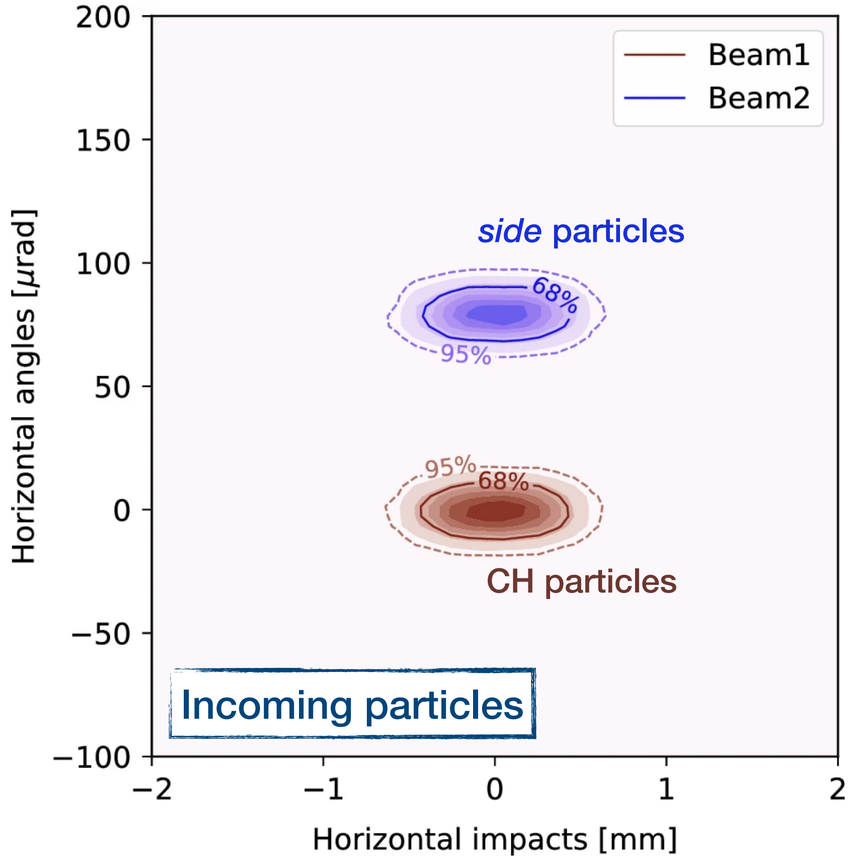
UA9 Data Analysis

P.D.F. applied to selected tracks:

σ_x = 0.2 mm - $\sigma_{x'}$ = 8 μrad (~$\theta_C/2$)



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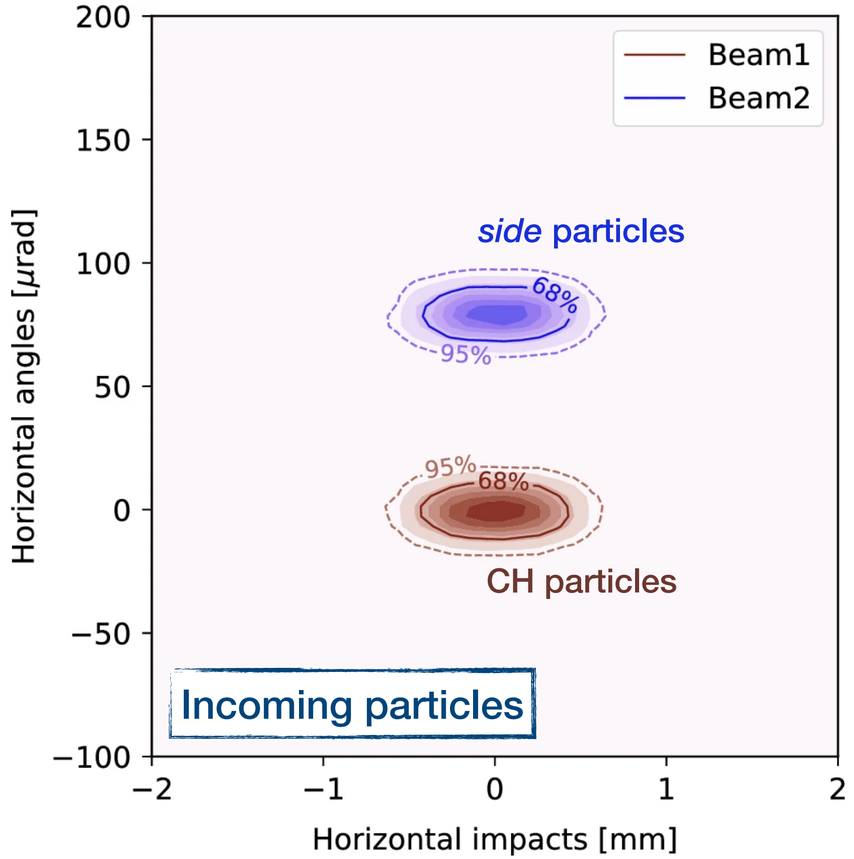
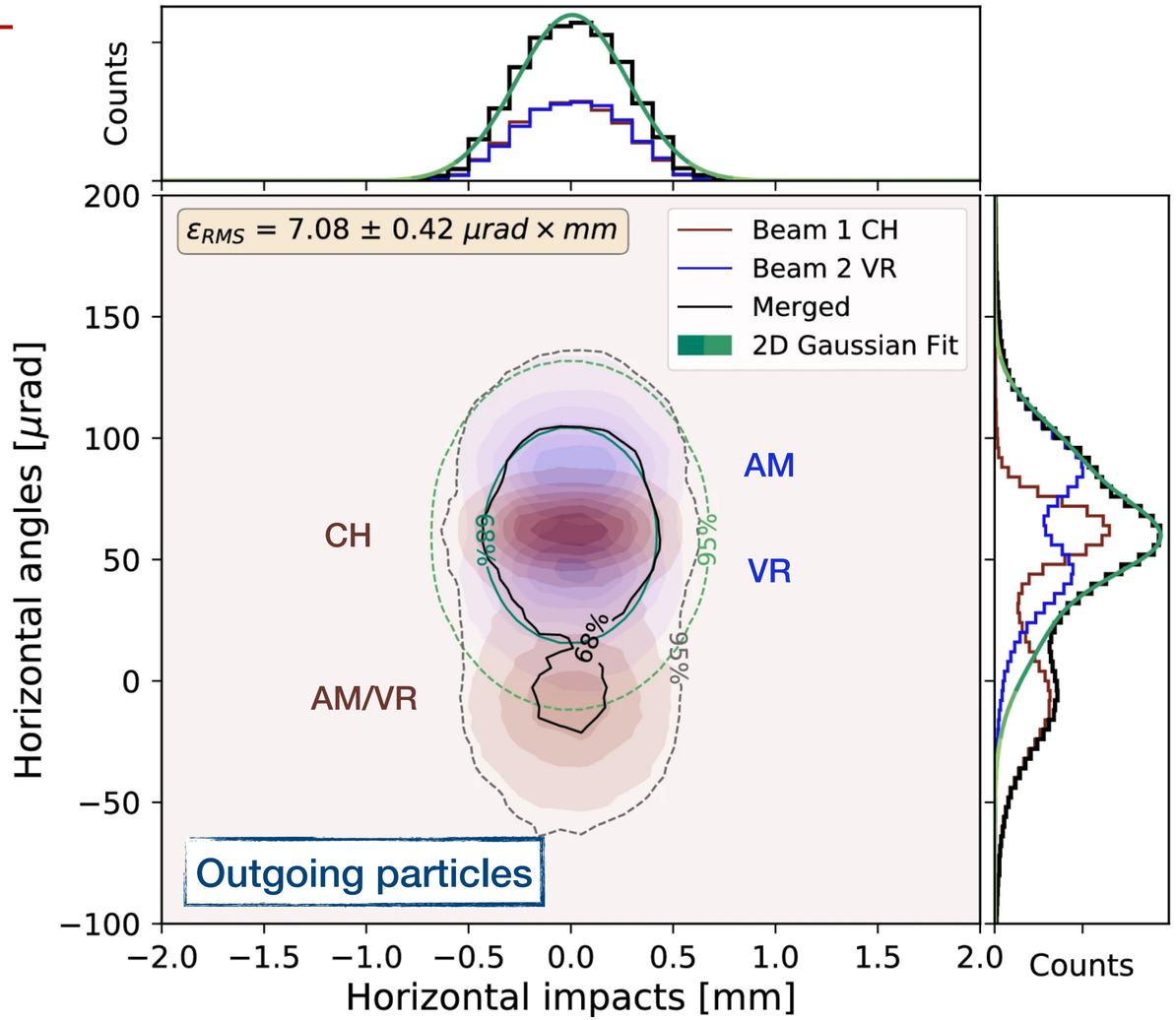
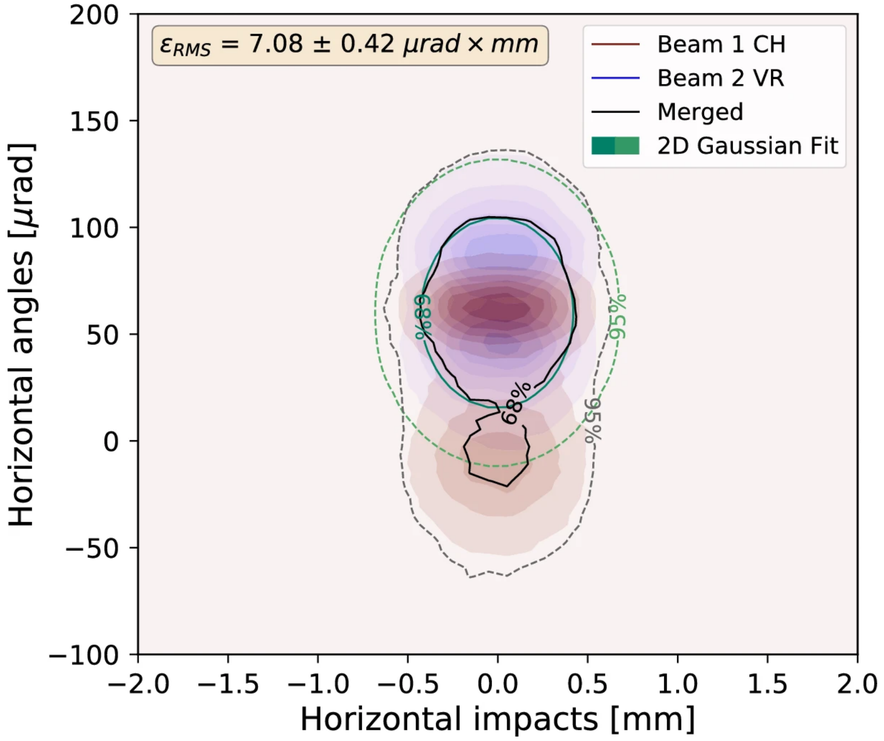


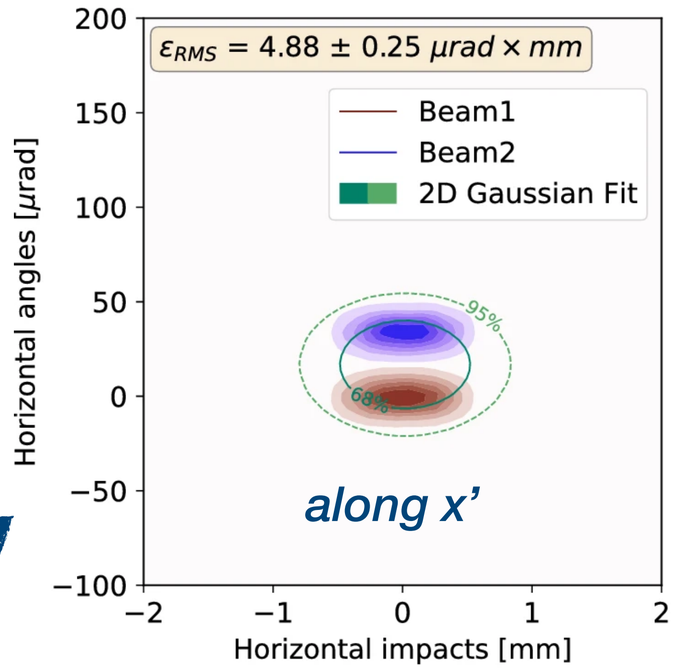


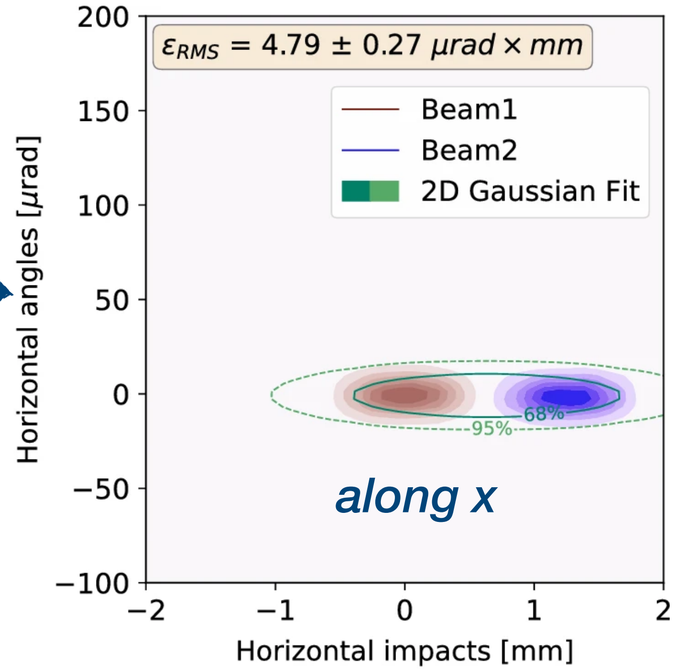
Crystal vs. Magnetic Stacking

An indication of the crystal-assisted merging can be obtained comparing it with magnetic recombination



non-optimized
Magnetic Stacking





The higher ε_{RMS} for the crystal-assisted merging is probably due to the MCS affecting particles crossing 4 mm of crystal and contribution from dechanneled particles.

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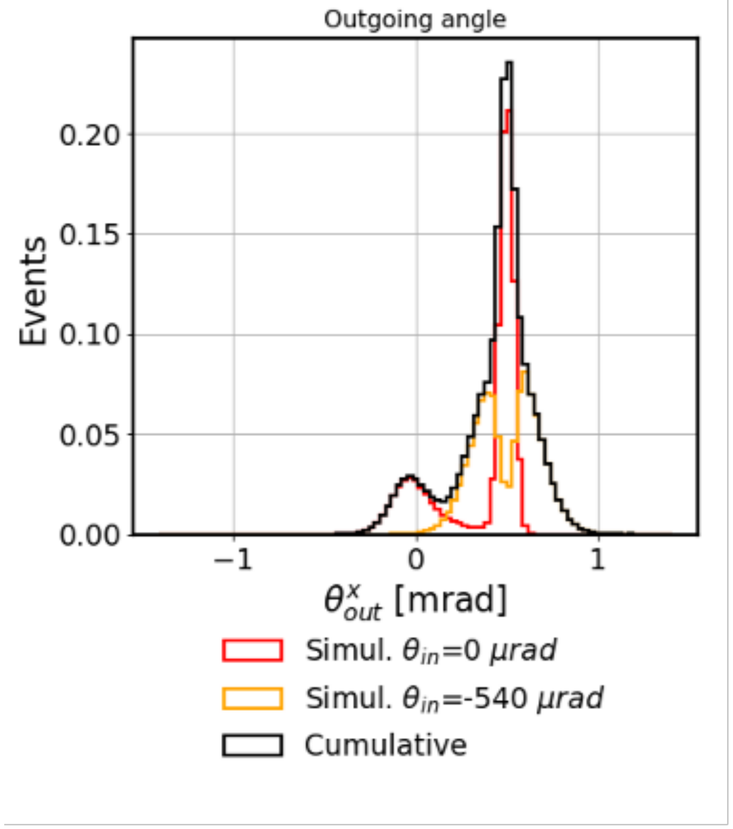
Alternative recombination schemes

Simulations:
beam: 10 GeV μ^+
$L_{x,y,z}$: 3.0x50.0x1.0 mm^2
θ_b : 500 μrad

Channeling + Amorph./Vol.Ref.



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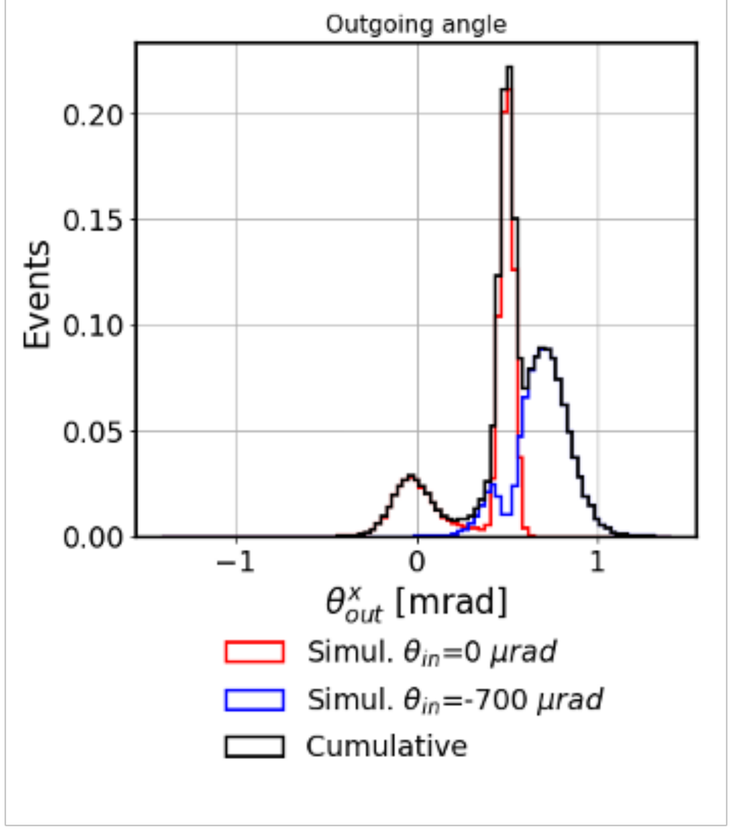
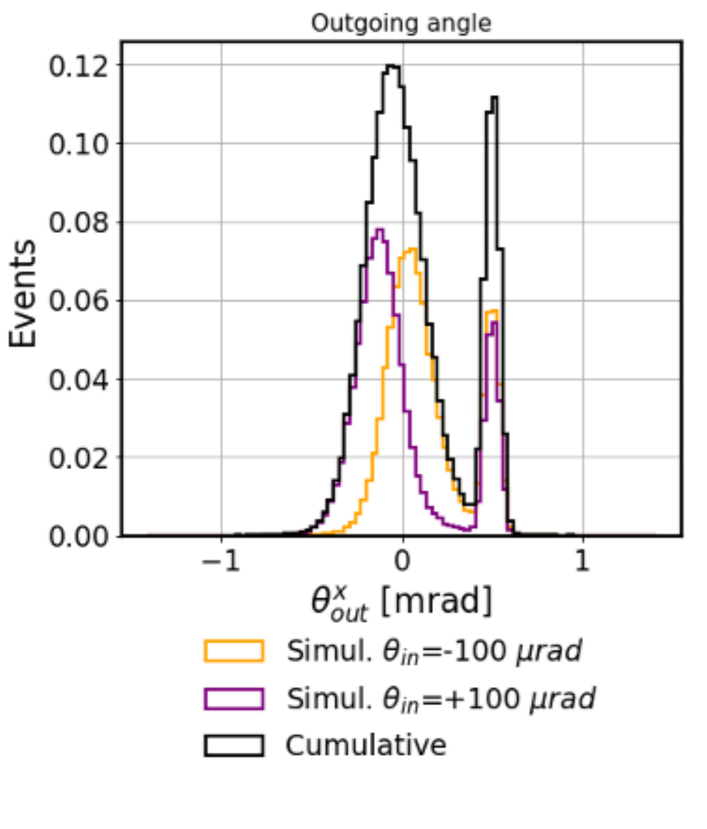


Amorphous + Volume Reflection



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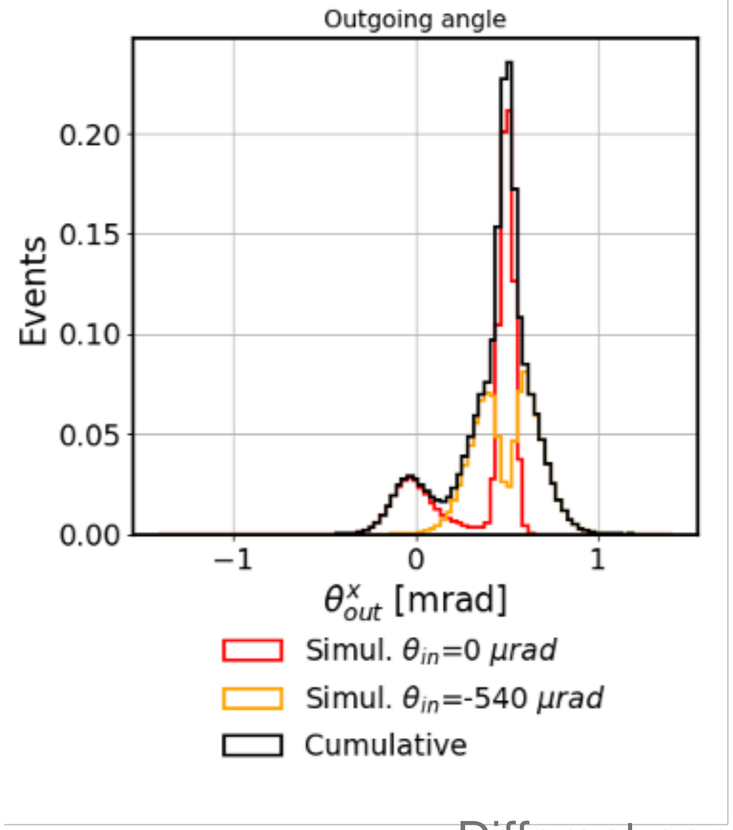

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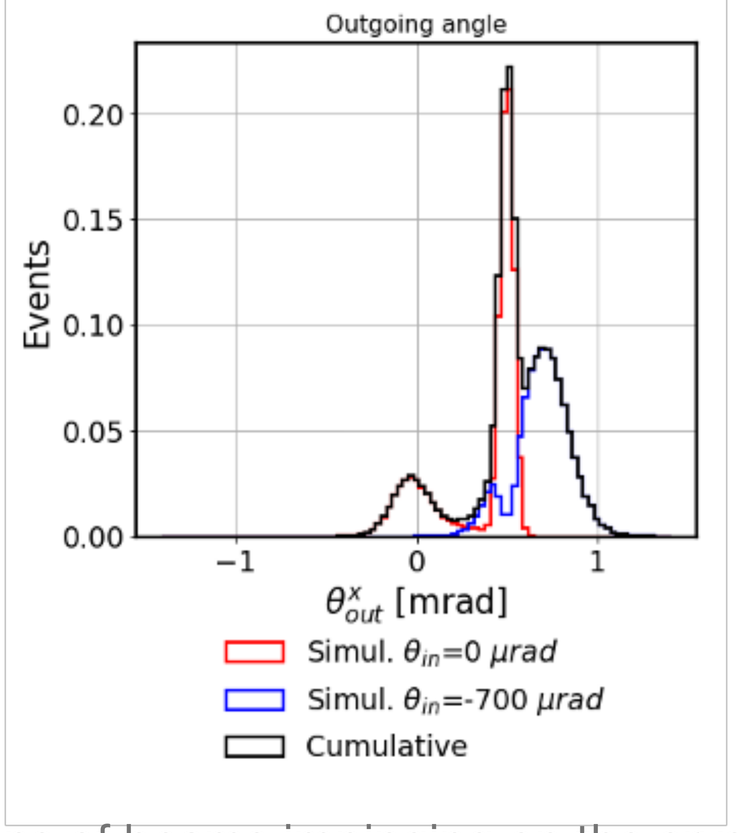

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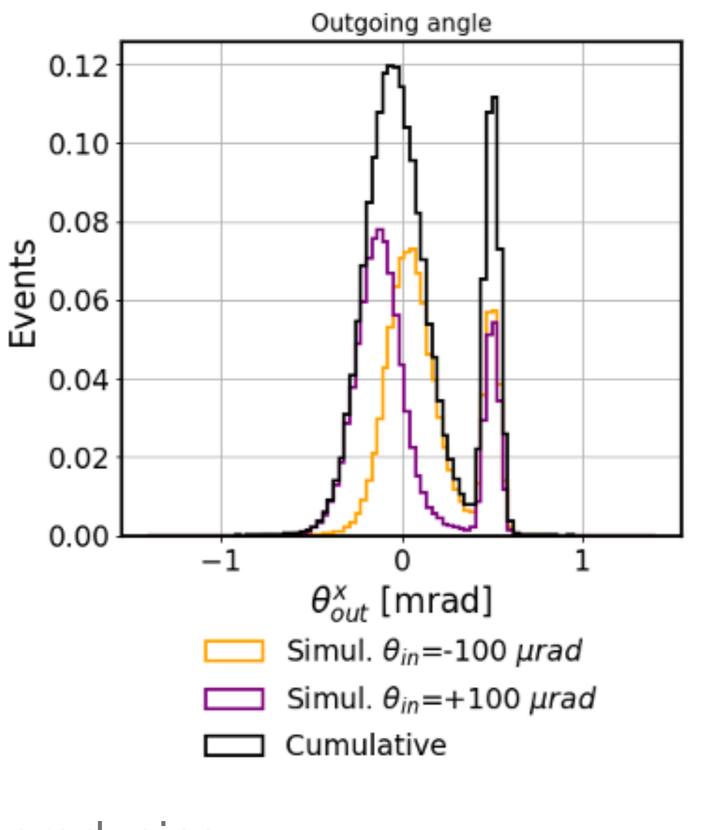

Different combinations of beams impinging on the crystal are producing different recombination structures.

What’s next goal?

To further investigate and evaluate the performance of crystal-assisted merging, an **experimental setup is in preparation**.

This will be taking data profiting from SPS p/π beam in CERN North Area.

p/π

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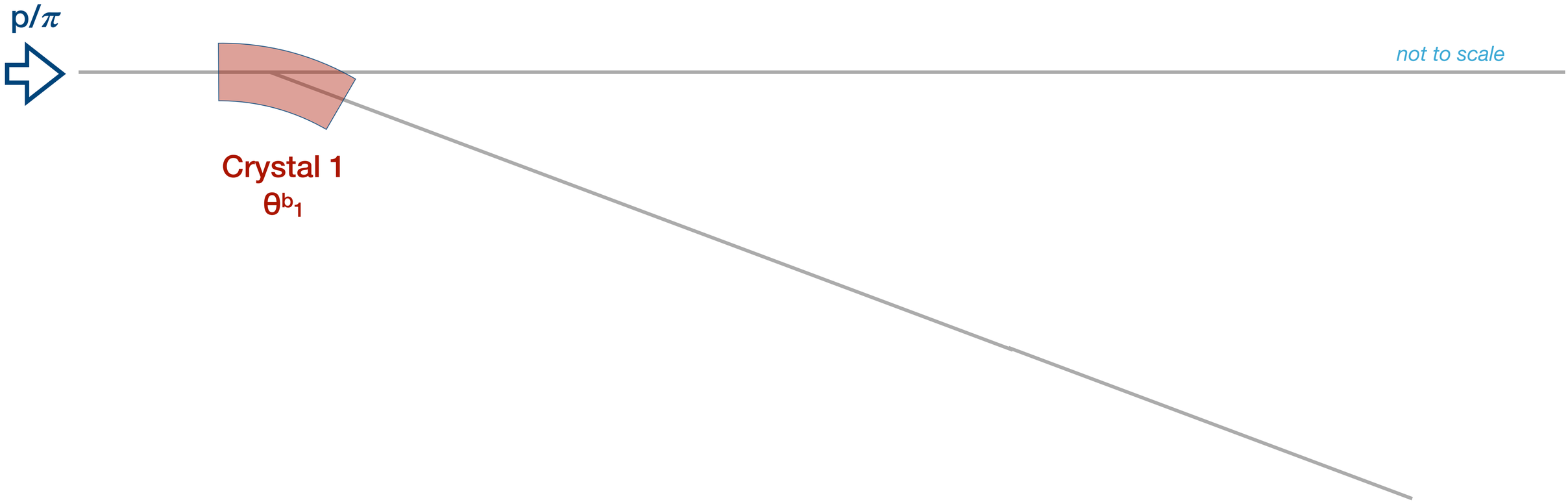

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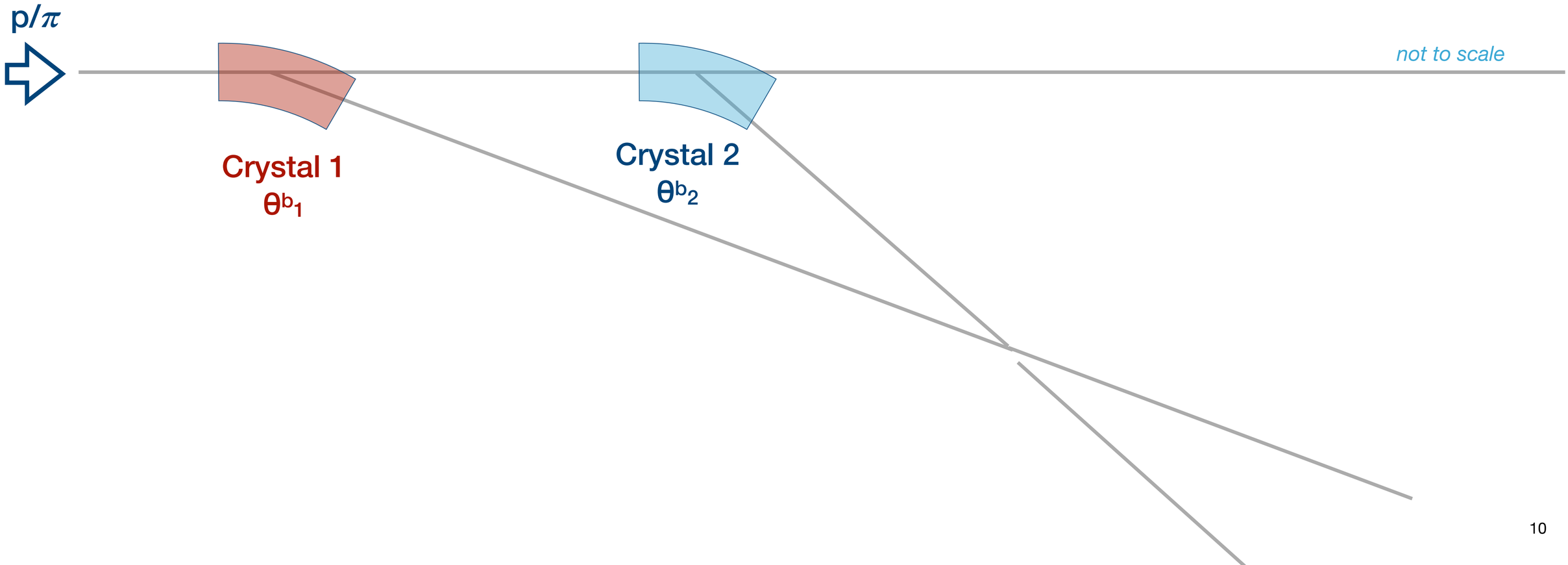

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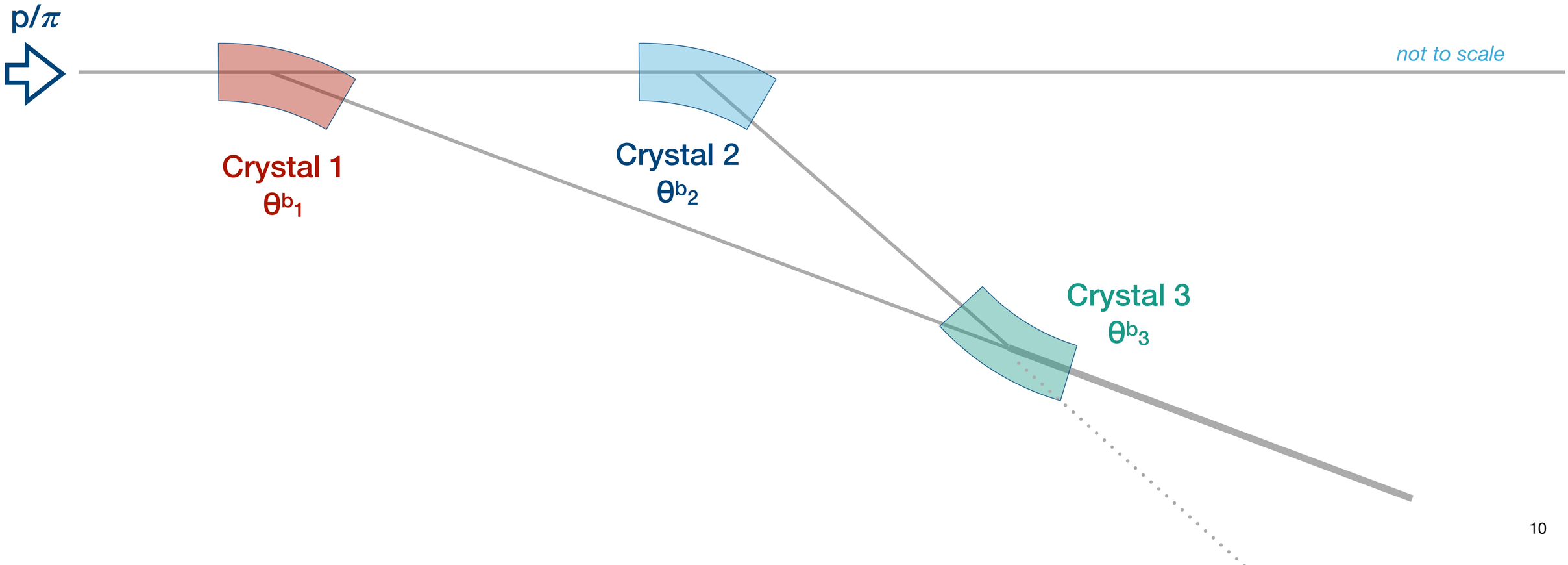

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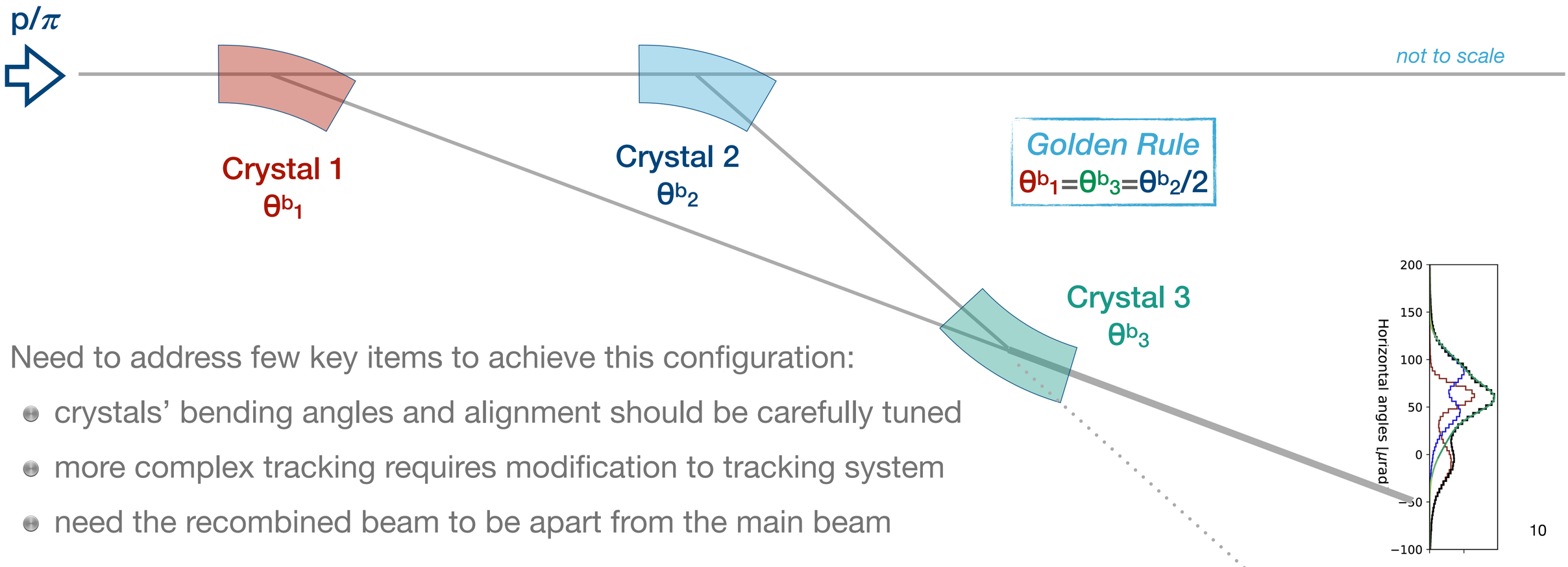


Need to address few key items to achieve this configuration:

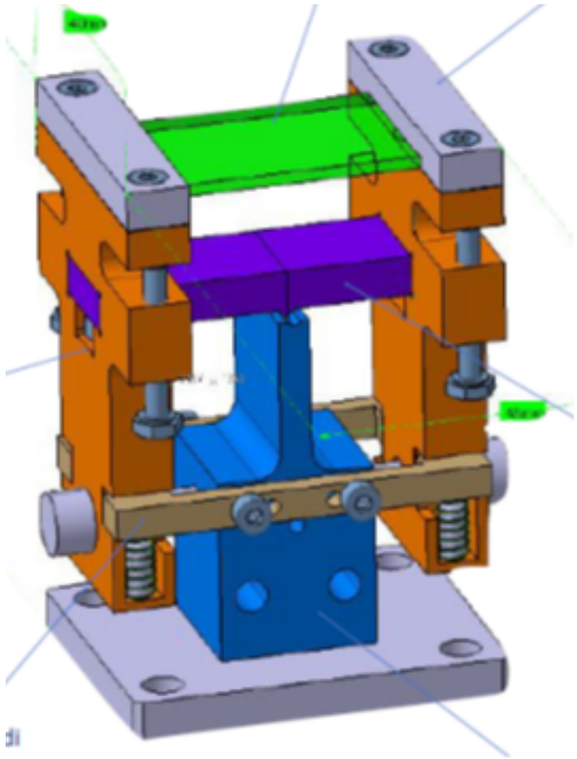
- crystals' bending angles and alignment should be carefully tuned
- more complex tracking requires modification to tracking system
- need the recombined beam to be apart from the main beam

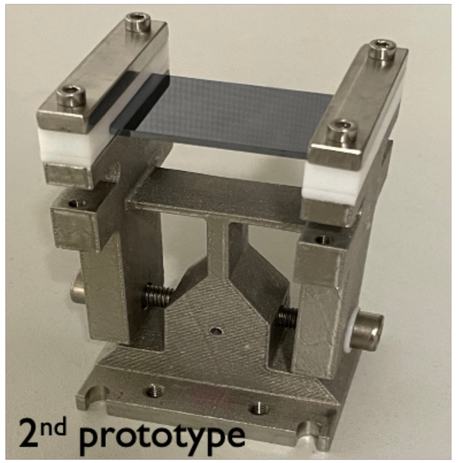
Crystals and Holders

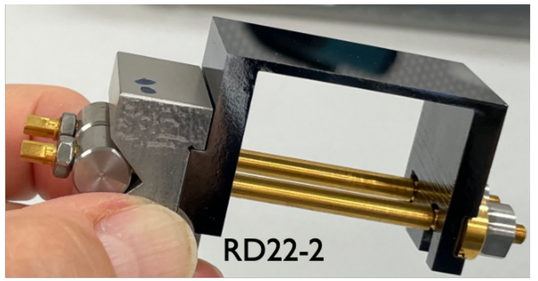
- Dedicated crystals with proper curvature are needed
  - Si(110) Boron doped or Phosphorous doped
- Holder in preparation with fine-tuning adjustement of bending angle
  - aiming at few mrad bending
  - some RD22-2 holder and crystals available, bending in the range 500-800 μrad

Crystal carachterization and bending measurement to be carefully evaluated

1st prototype

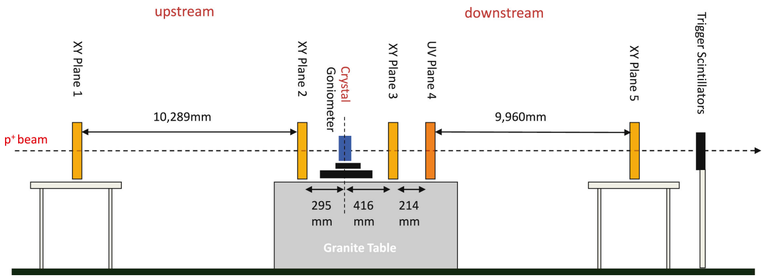






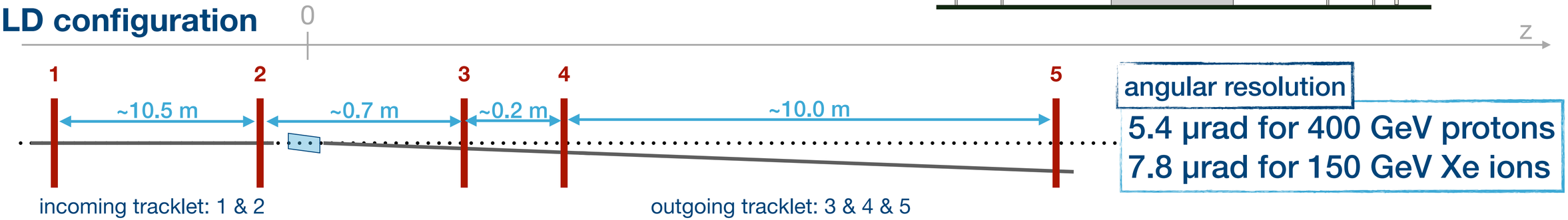
[NIM A 924 (2019) 394]

Upgraded telescope



not to scale

OLD configuration



angular resolution

5.4 μrad for 400 GeV protons

7.8 μrad for 150 GeV Xe ions

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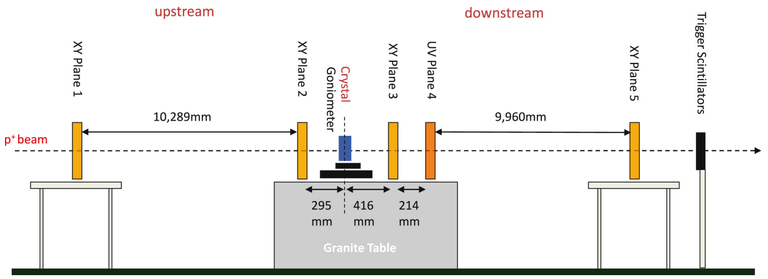

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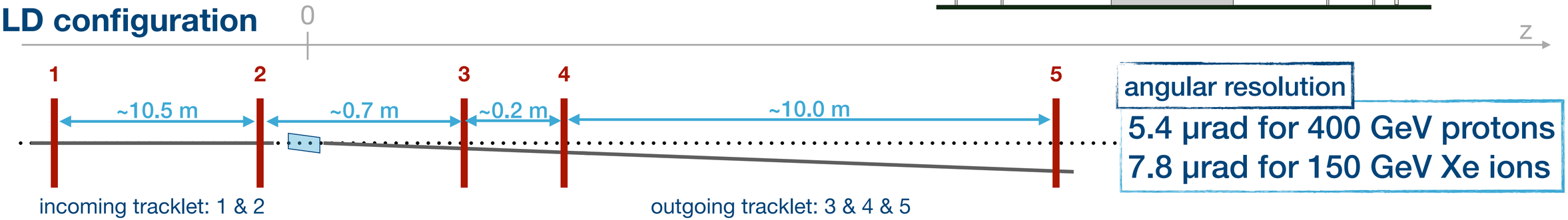

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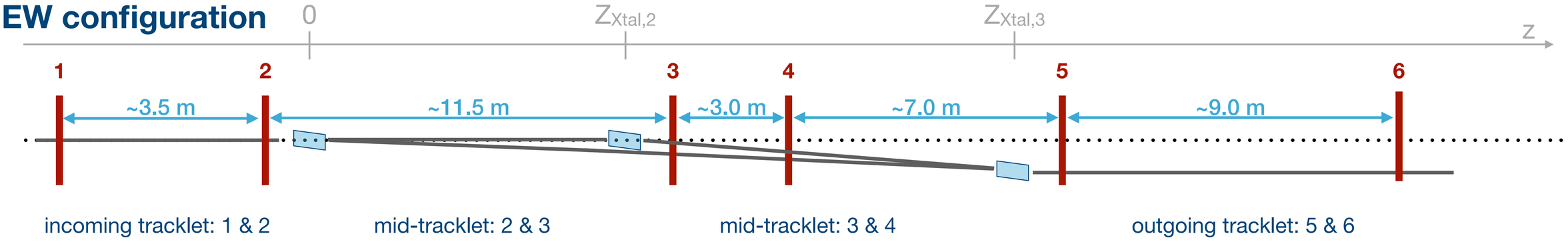

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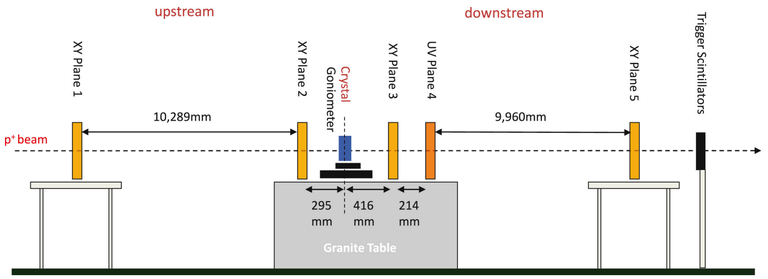

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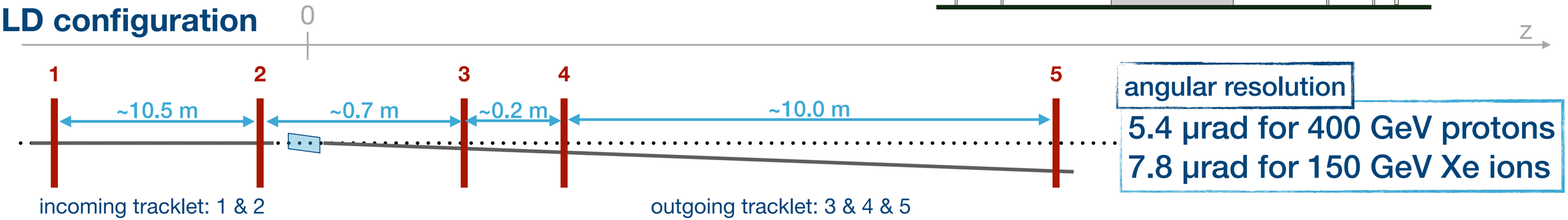

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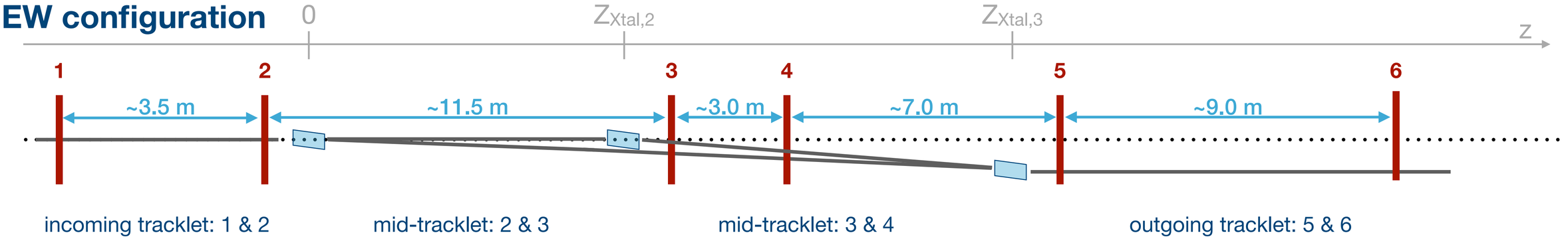

- Additional tracking layer being integrated in the DAQ and Readout system
- 3-crystal alignment procedure defined
- Calibration and evaluation of telescope angular resolution

Conclusions

- The *coherent* and *non-coherent* bent crystal behaviours offer an intriguing scenario for beam superimposition
- Concept proven to be valid on UA9 available data and simulations - *promising preliminary results*
- Experimental setup in preparation at CERN SPS - beam granted to UA9 until end of LHC Run 3
- Technique which can be highly beneficial for future generation of colliders