UA9 Proposal for SPS Tests in Run 3

R. Rossi on behalf of UA9 Collaboration

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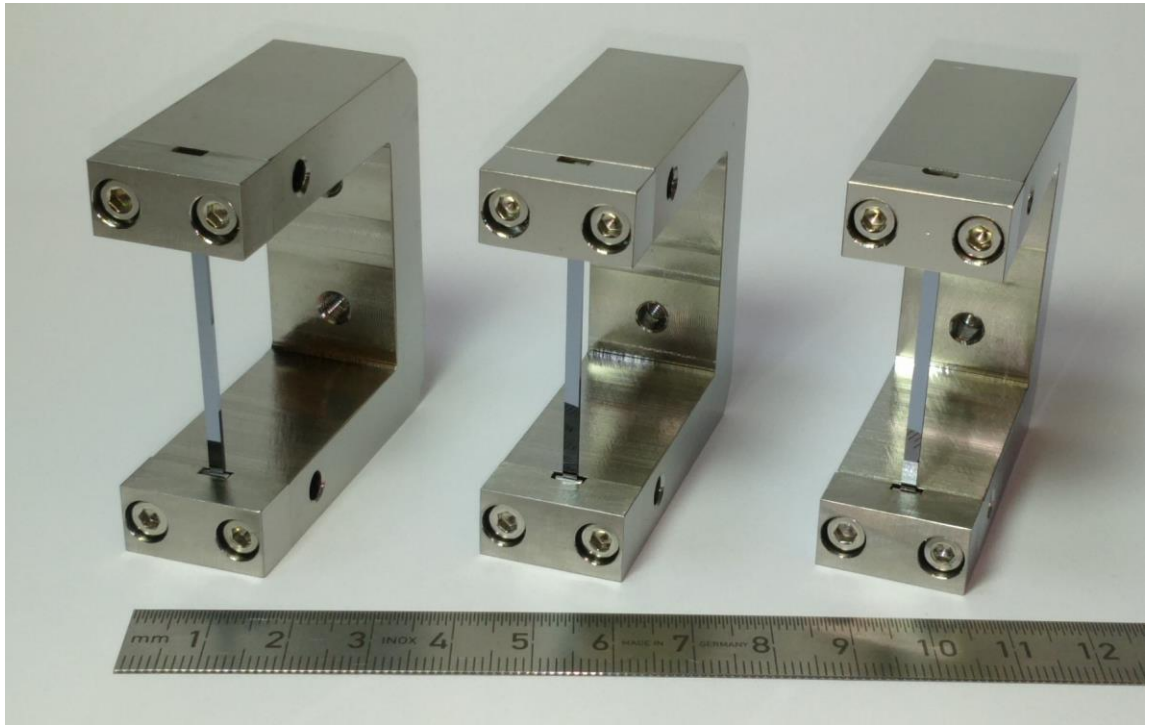
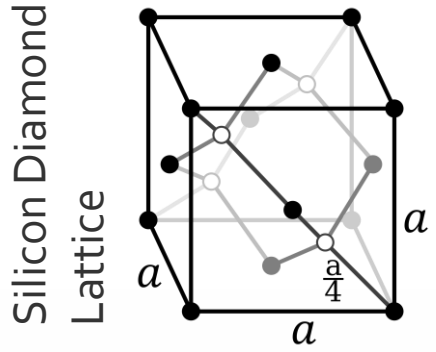


Crystal Channeling



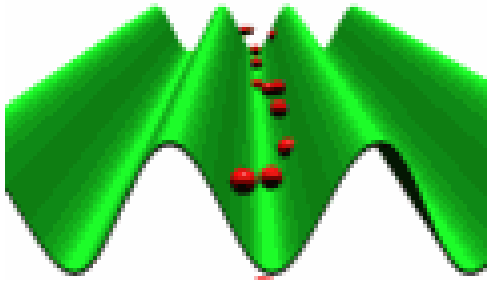
Lindhard: "In the hypothesis of low impact angle, the potential generated by the crystalline plane can be approximated by a continuous potential."

Channeling : Transverse momenta < potential well

The channeling condition can be defined as

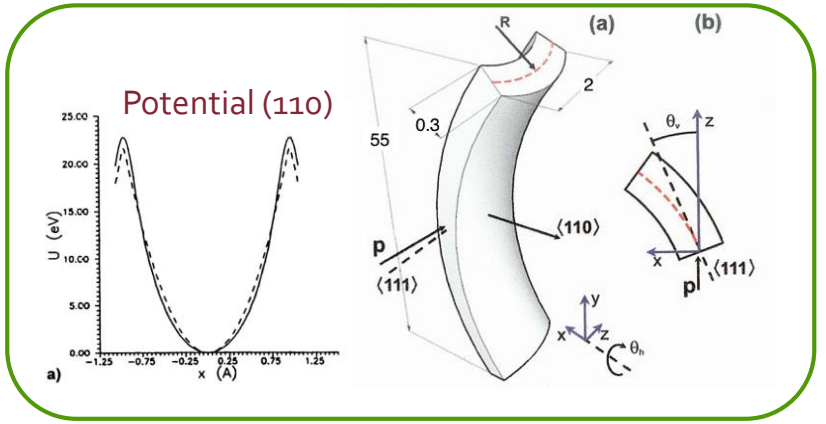
$$\frac{p^2 c^2}{2E}\theta^2 + U(x) \leq U_{max}$$

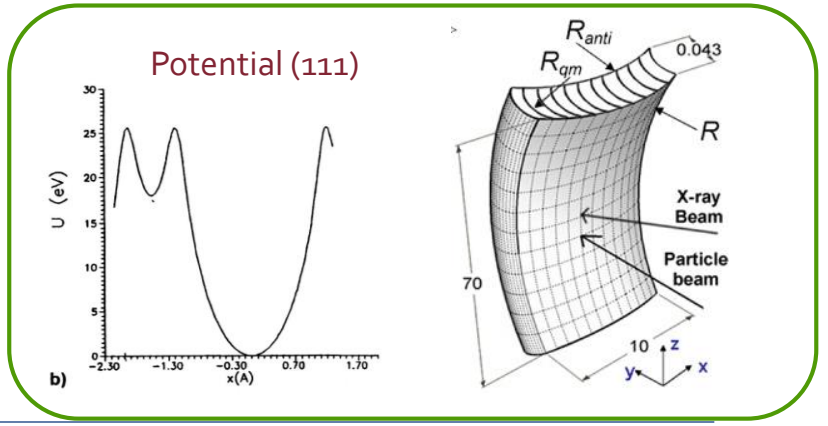
Case	Energy [GeV]	θ_c $[\mu rad]$
SPS coast	120	18.3
SPS coast	270	12.2
H8	400	10.0
LHC inj.	450	9.4
LHC top	6500	2.5
LHC top	7000	2.4



Critical angle

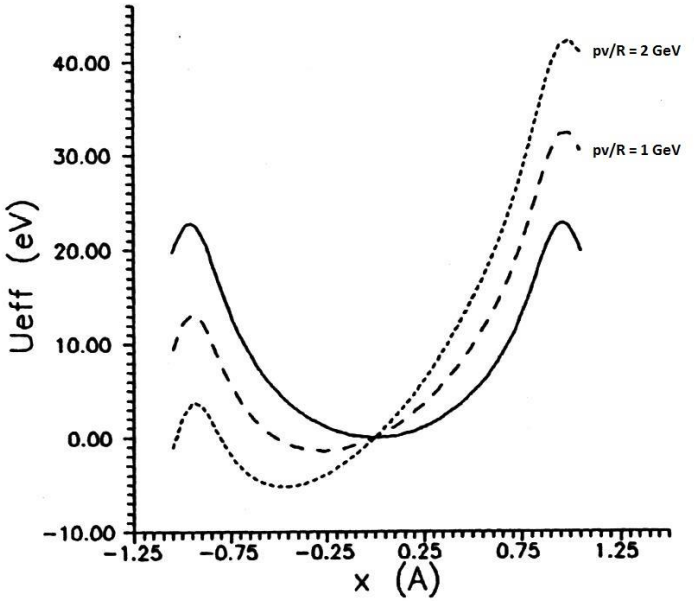
$$\theta_c = \sqrt{\frac{2U_{max}}{pv}}$$





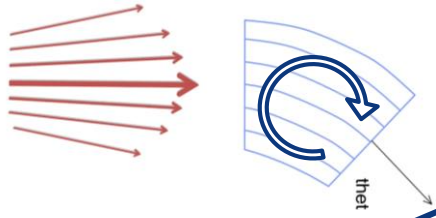
Coherent effects in bent crystals

The particles are trapped in the channel, hence if a curvature is given to the lattice the particles direction will be modified by $\theta_b = l/R$

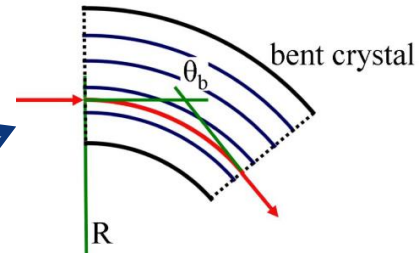


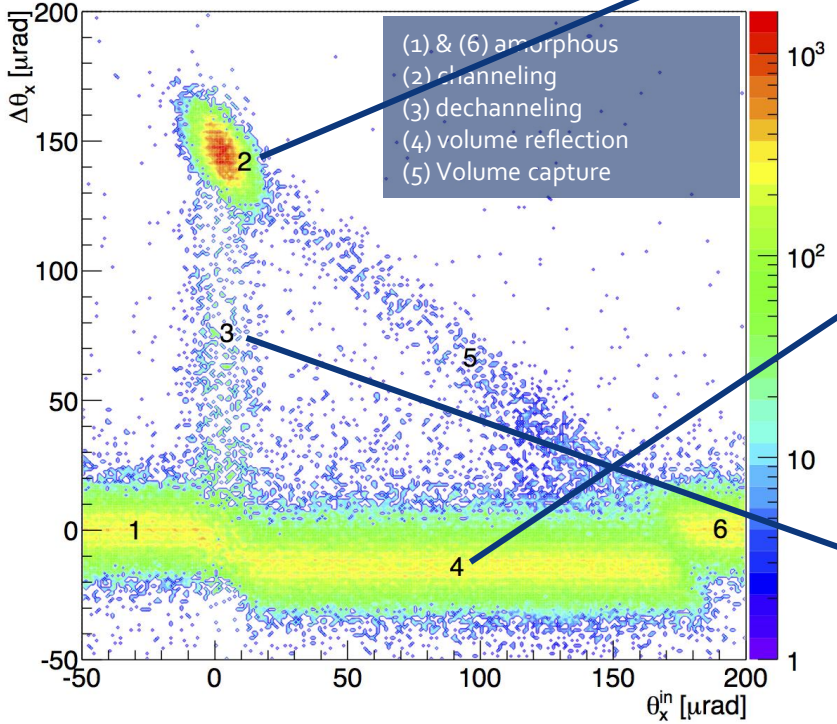
$$R_c = \frac{pvx_{\max}}{2U_{\max}} \Rightarrow \theta_c^b = \theta_c\left(1 - \frac{R_c}{R}\right)$$

Single pass measurements with 400 GeV protons. Strip crystal (110) with a bending of 144 µrad.

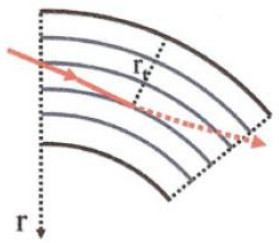


Planar channeling (CH)

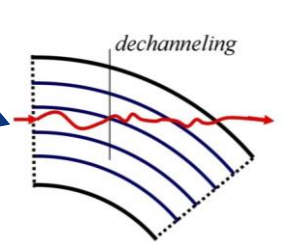




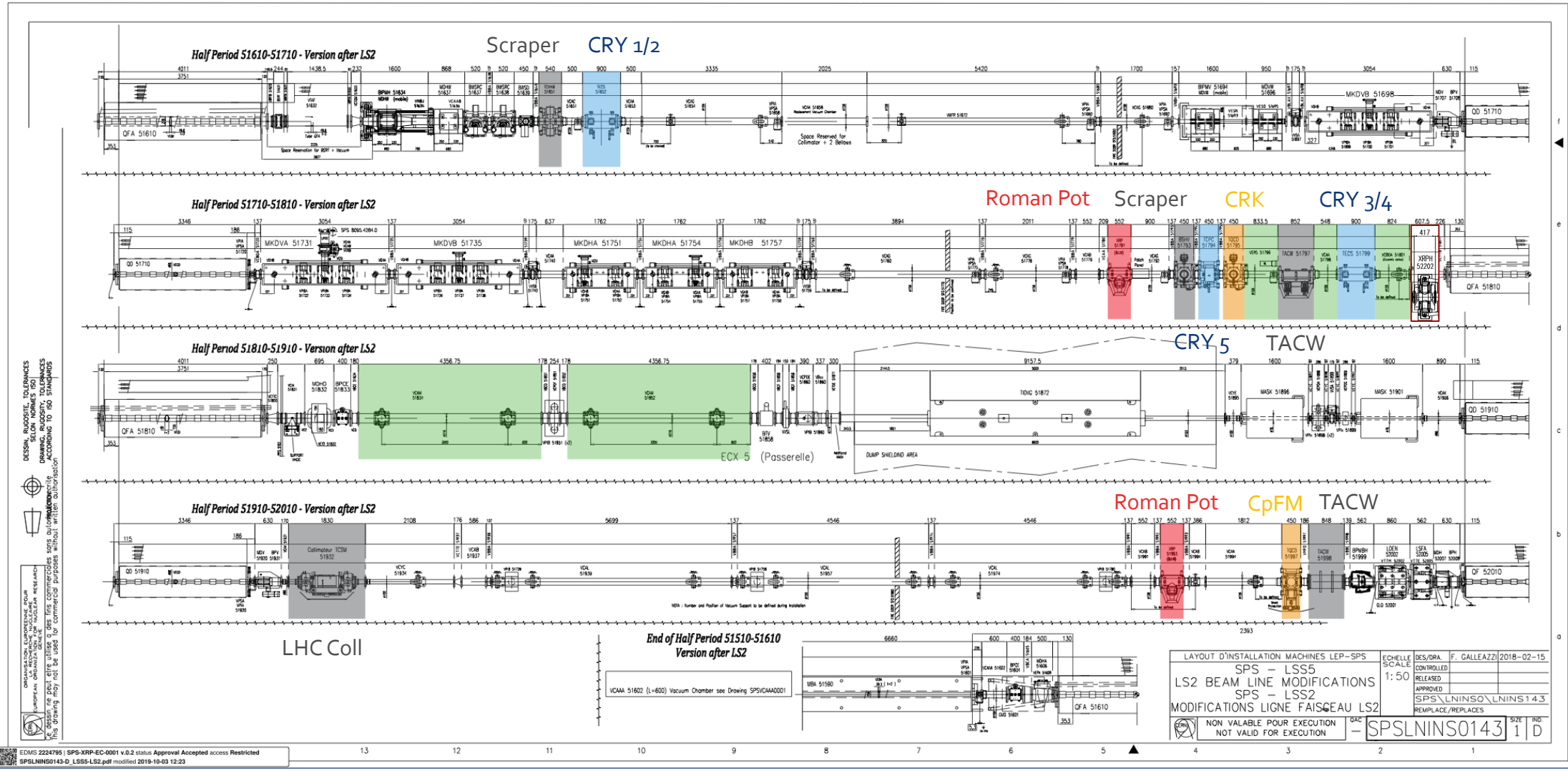
Volume Reflection (VR)



Dechanneling (DC)

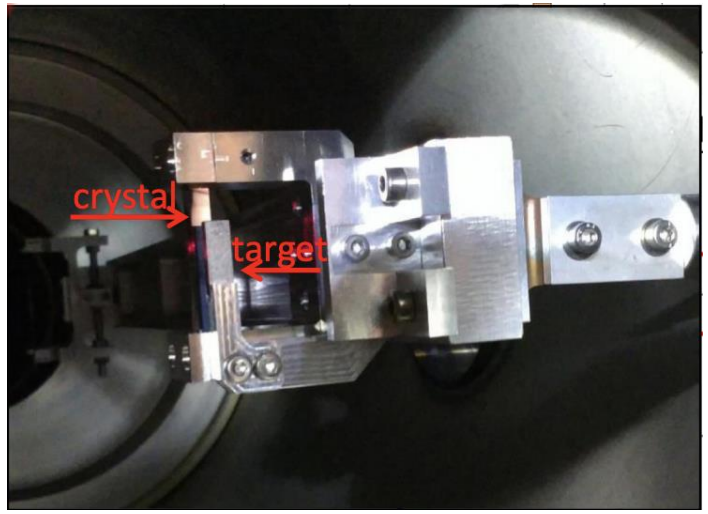


UA9 Instrumentation Layout



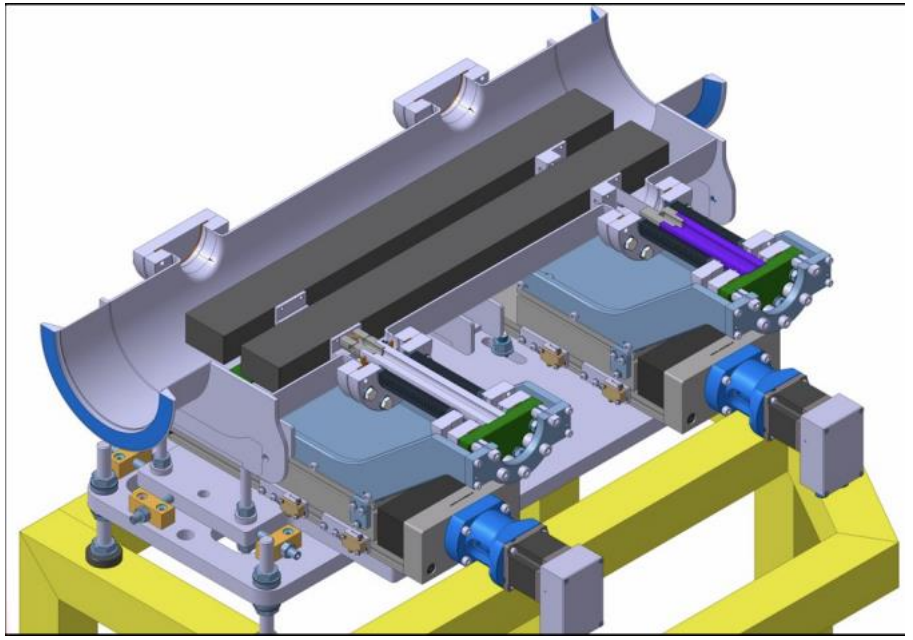
Crystals

- 5 crystals can be installed in the experimental layout:
  - 1 upstream tank with mechanical goniometer (can house 2 crystals)
  - 1 downstream tank with piezo goniometer (1 crystal)
  - 1 downstream tank with mechanical goniometer (2 crystals)



Obstacles

- Massive obstacles to intercept/absorb the particle beam
  - 1 double sided collimator (60 cm graphite, LHC-type), used to align crystals and other devices
  - 2 single sided absorber (60 cm tungsten), used to stop the channeled beam; one for the upstream crystals, and the other for the downstream ones.
  - 1 double sided scraper (10 cm tungsten)
  - 1 single sided scraper (10 cm graphite) -> to be changed with a tungsten target

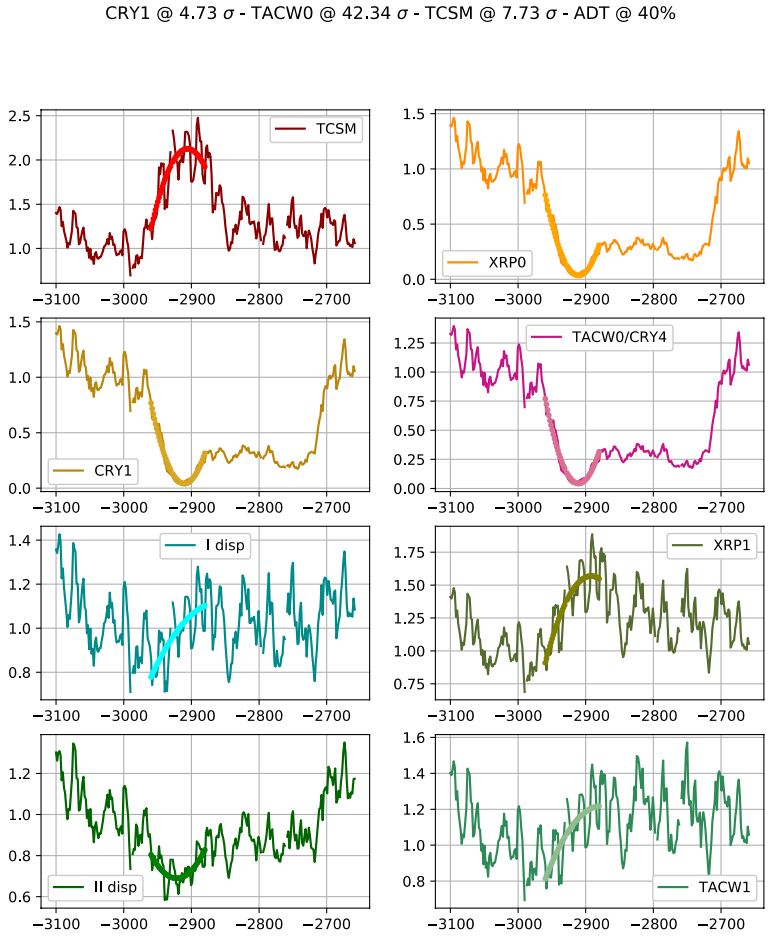


BLM

- Beam Loss Monitor of the LHC-type are installed close to each device in the experimental area.

  Used to investigate beam losses at given locations

  Similar electronics and readout to LHC BLMs

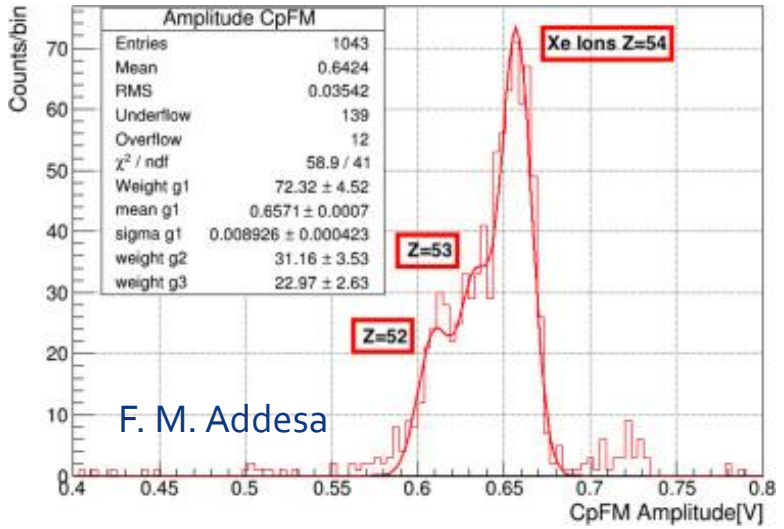


Cherenkov Radiators

- In-vacuum Cherenkov radiators are available in the layout
  - 1 old detector is close to the 3 downstream crystals
  - 1 so called "CpFM" is installed at very end of the experimental line, just upstream to the last absorber

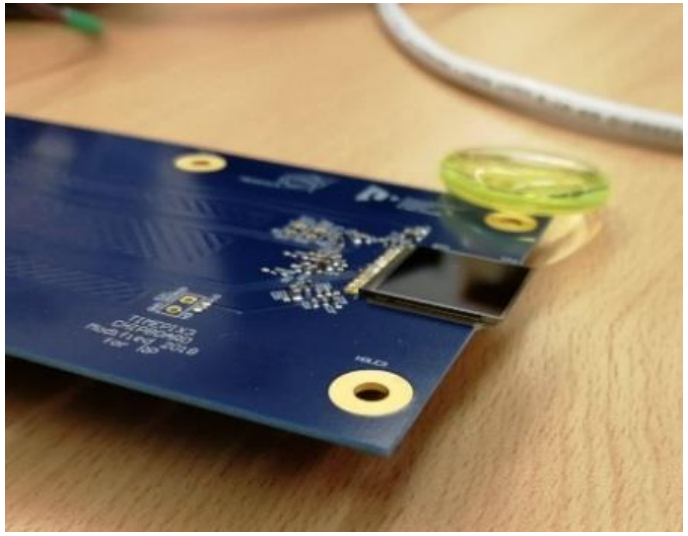
Both need further improvements to be considered operational

CpFM has been successfully calibrated with Xe beams [1]

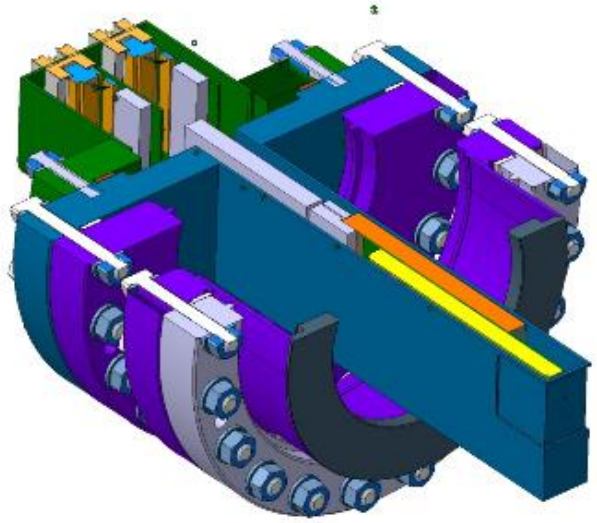


Medipix

- New design for a compact single sided Roman Pot (1 Medipix each) is under development for Run3
  - New Timepix3 sensors to be installed in these new Roman Pots
  - New locations of interest for measurement scenarios have already been selected



F. Murtas



R. Seidenbinder

NB. 3 Roman Pots are still available and can be equipped with 6 Medipix in a secondary vacuum chambers, which can be inserted in the beam line to have an 2D online monitor of the beam

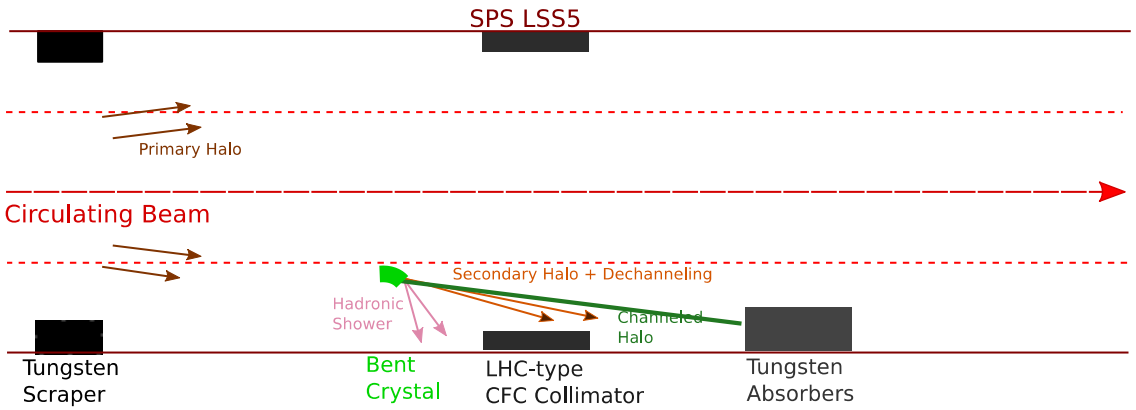
Achievements

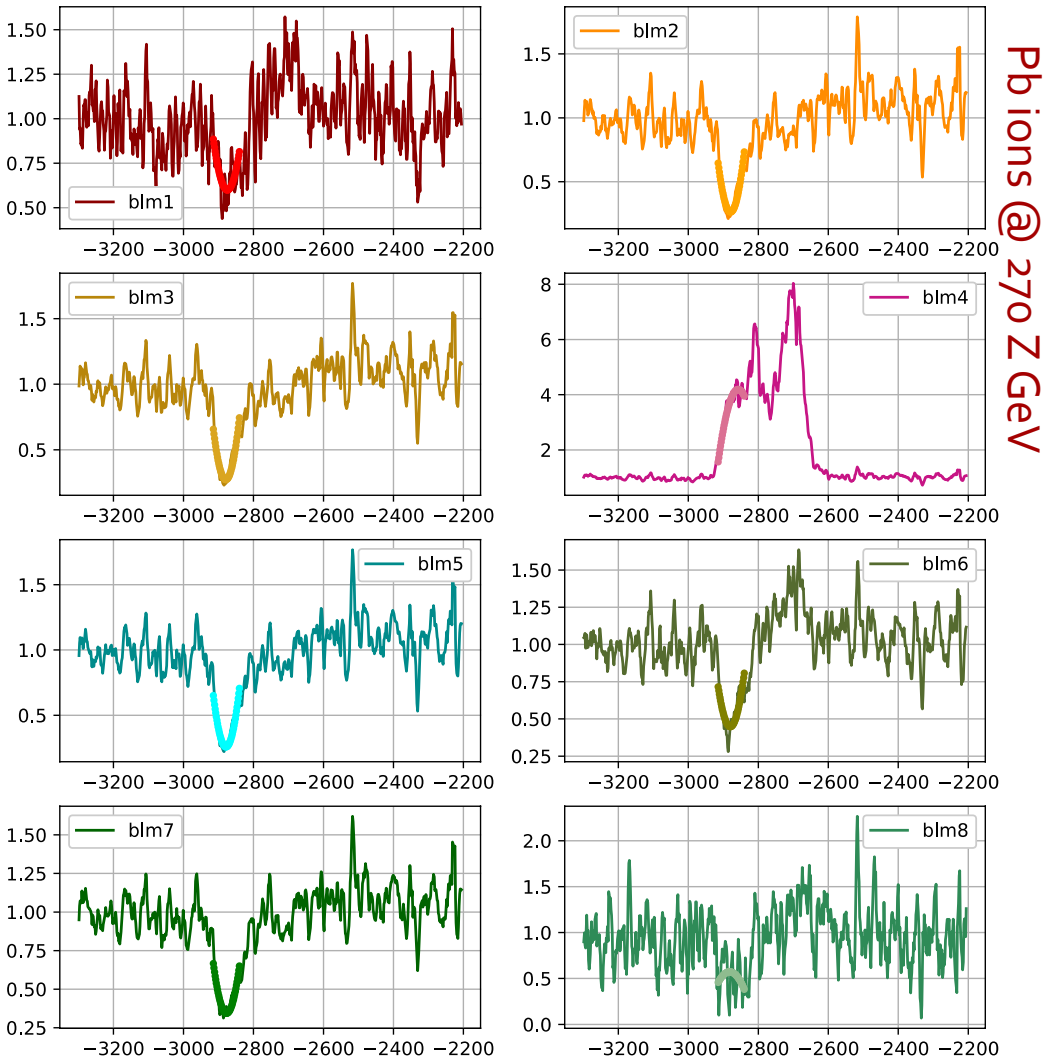
- Channeling and crystal collimation setup achieved in 2012
- Crystal collimation studies carried in several configurations
  - Upstream collimators effect
  - Absorber materials study
  - Analysis of losses in dispersive area
- Channeled beam extracted from LSS5 to the NA extraction line in LSS2 in 2017
- Double channeling achieved w/ and w/o target in 2017-18

Also with Pb and Xe ions

Achievements - Channeling

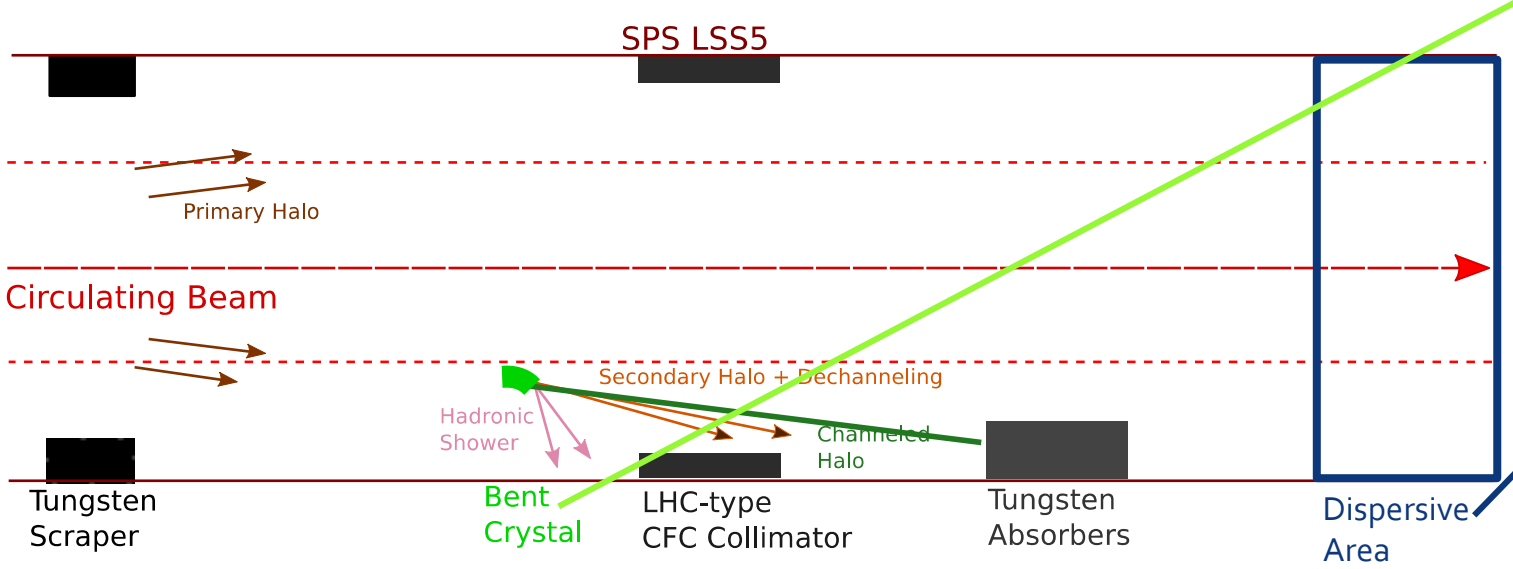
Channeling has been observed as a reduction of local losses when crystal is well oriented with respect to beam direction.

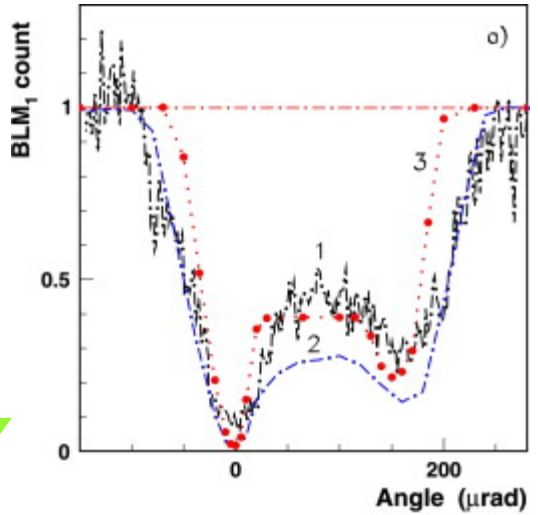


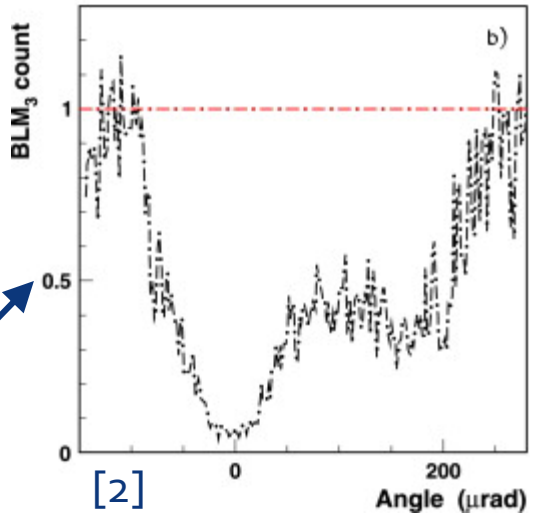


Achievements – Crystal Collimation

Demonstration of crystal collimation efficiency in the dispersive area downstream the crystal





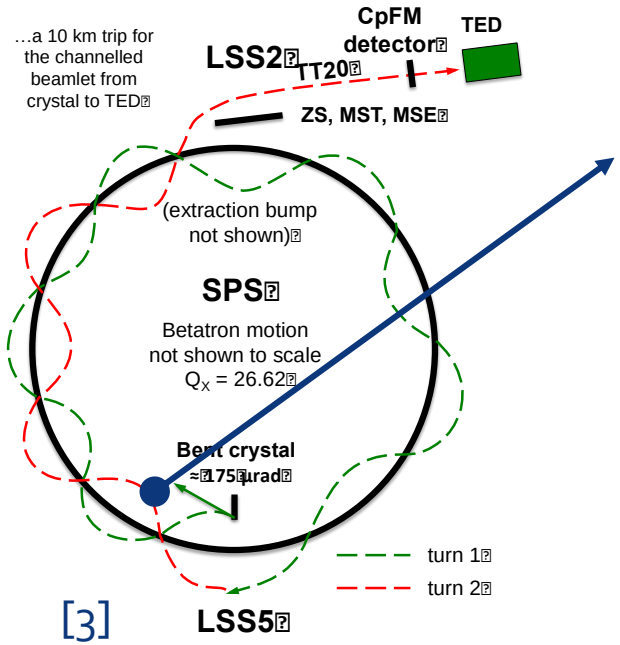


[2]

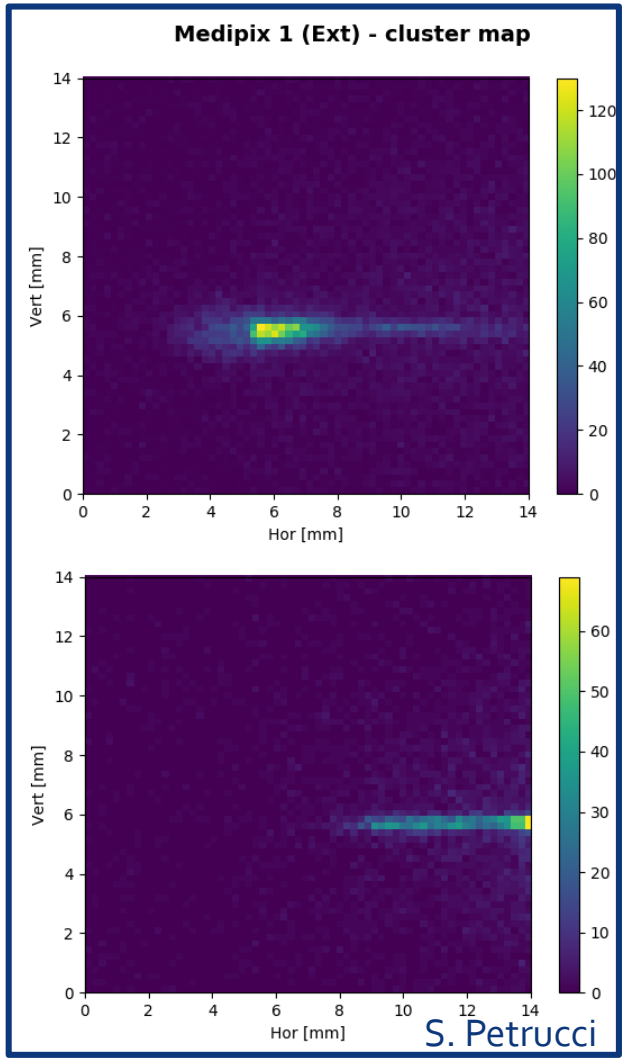
Achievements – Crystal for Extraction

In 2017 also extraction for SPS was achieved with a crystal deflecting the circulating beam in LSS5.

After one turn and a half in the machine the beam was extracted when a closed orbit bump was activated at extraction septum location in LSS2.



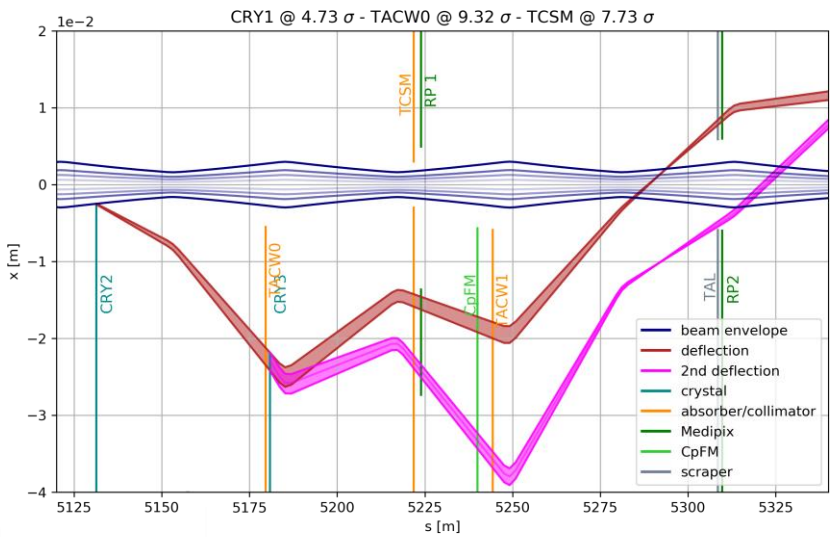
[3]

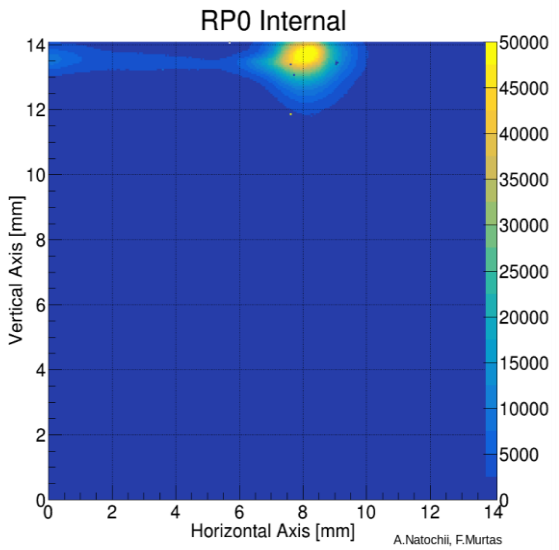


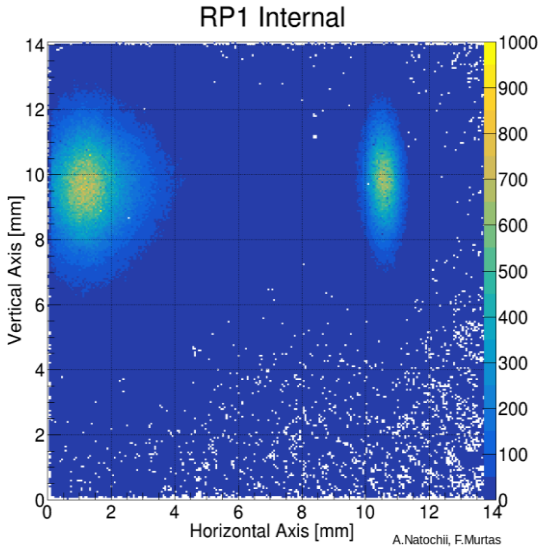
S. Petrucci

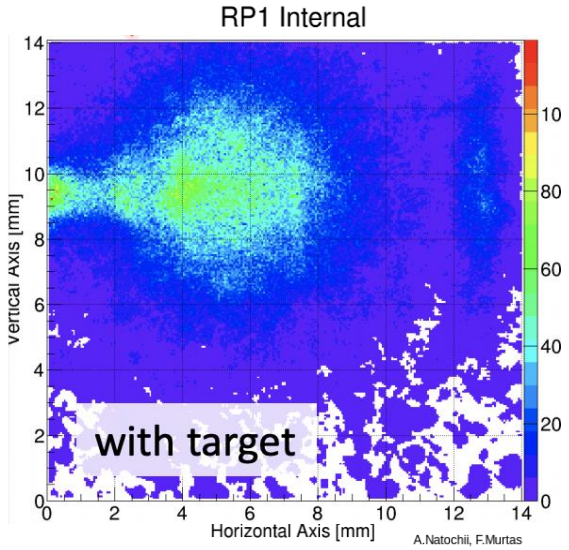
Achievements – Double Channeling

Double channeling of beam halo was achieved in 2017 [4].
Measurement with new crystals, and new configuration with target in front of second crystal achieved in 2018.









Layout Overview

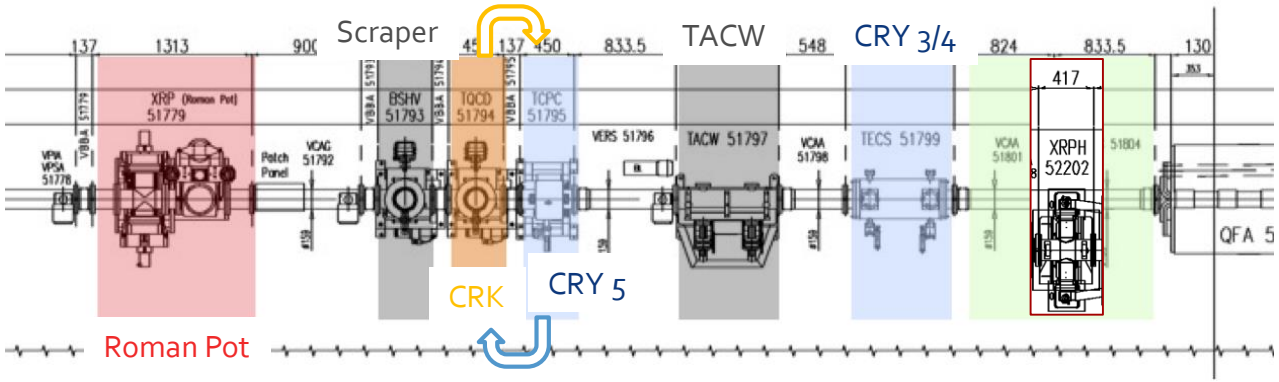
- The UA9 SPS experimental setup is present in the Long Straight Section 5 (LSS5) since 2012
  - It involves a large number of devices, both beam obstacles and diagnostic instruments
- During this Long Shutdown (LS2) a new Dump facility is being built in the LSS5 pit
  - For this reason all the devices and instrumentations had to be dismounted and stored outside the beam line
  - Still, it gave UA9 the opportunity to rearrange the instrumentation layout in order to be more flexible for a larger number of measurements

Layout modifications

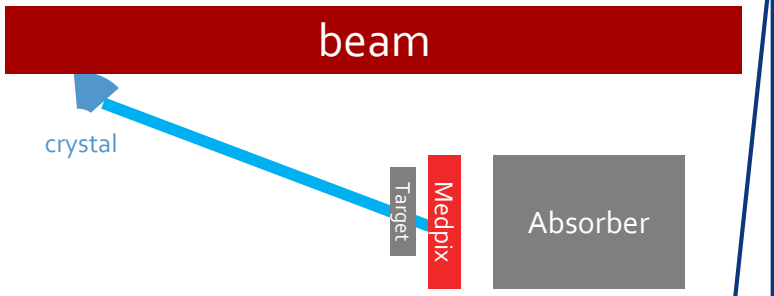
1. First proposal is to swap crystal 5 (TCPC.51795) with Russian Cherenkov (TQCD.51794)
   This will allow to install a new independent target (BSHV.51793) + crystal configuration, and an extra Cherenkov radiator behind the crystal
2. New XRP to replace the XRP0 (upstream the scraper/target) and XRP1, will reduce the space occupancy.
3. The available space downstream of CRY3/4 (TECS.51799) could be equipped with one of the new RP

Crystals bending angles can be adapted to the experimental scenario

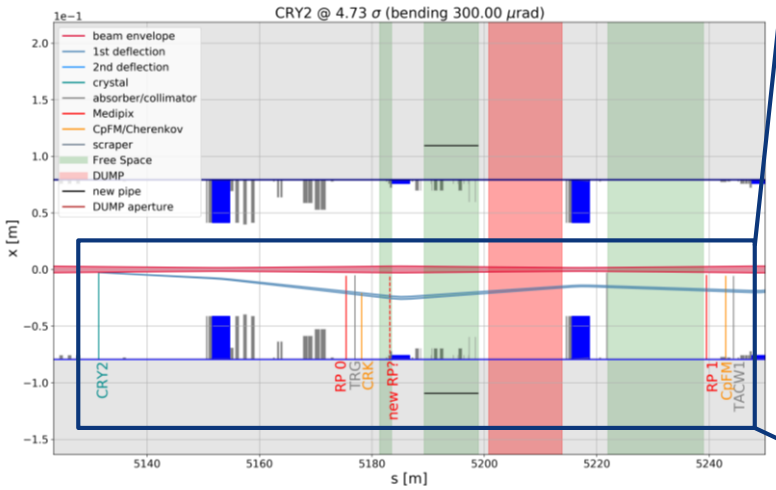
NB. Piezo-Gonio TCPC.51795 has a limit for the crystal weight (as for LHC crystals)

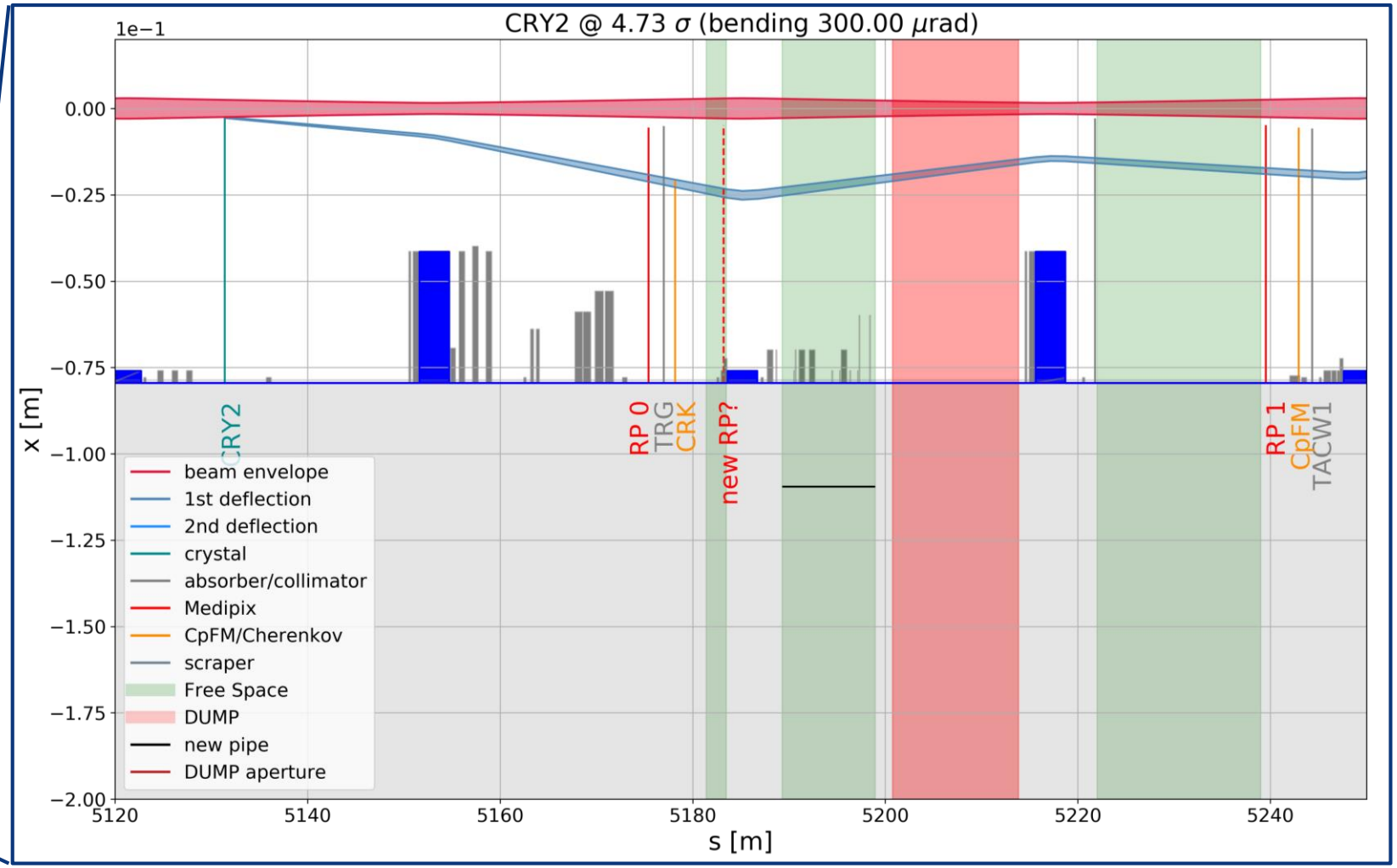


Scenario for ALICE studies



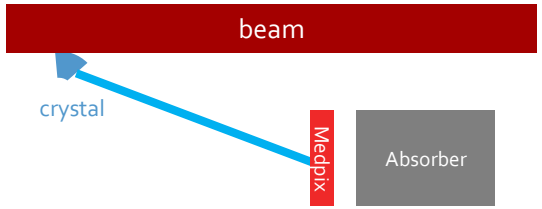
New RP, after TECS.51799 (CRY3/4), can be useful for the measurement



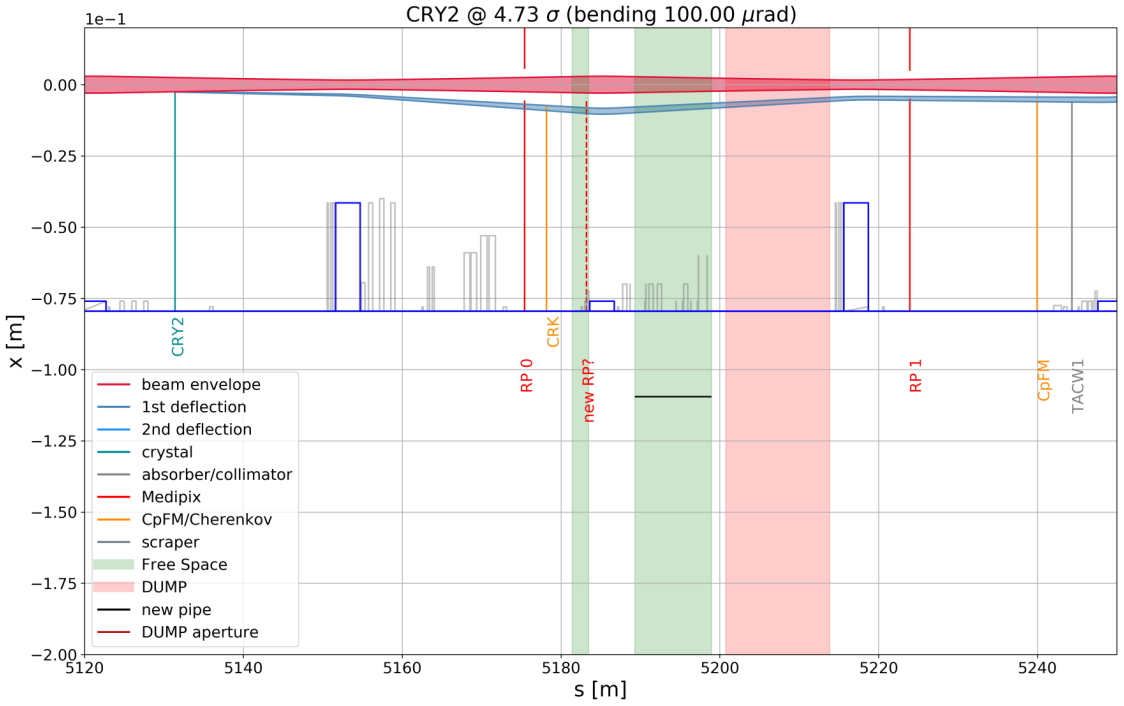


Additional scenarios

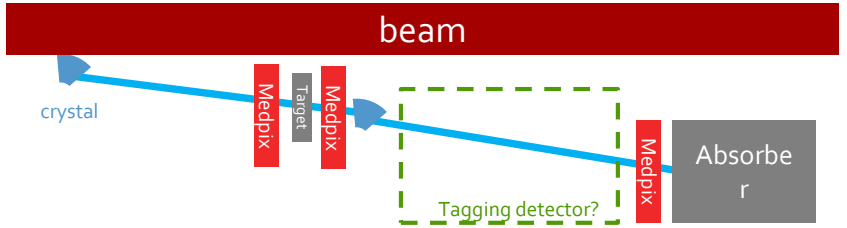
Scenario for extraction studies

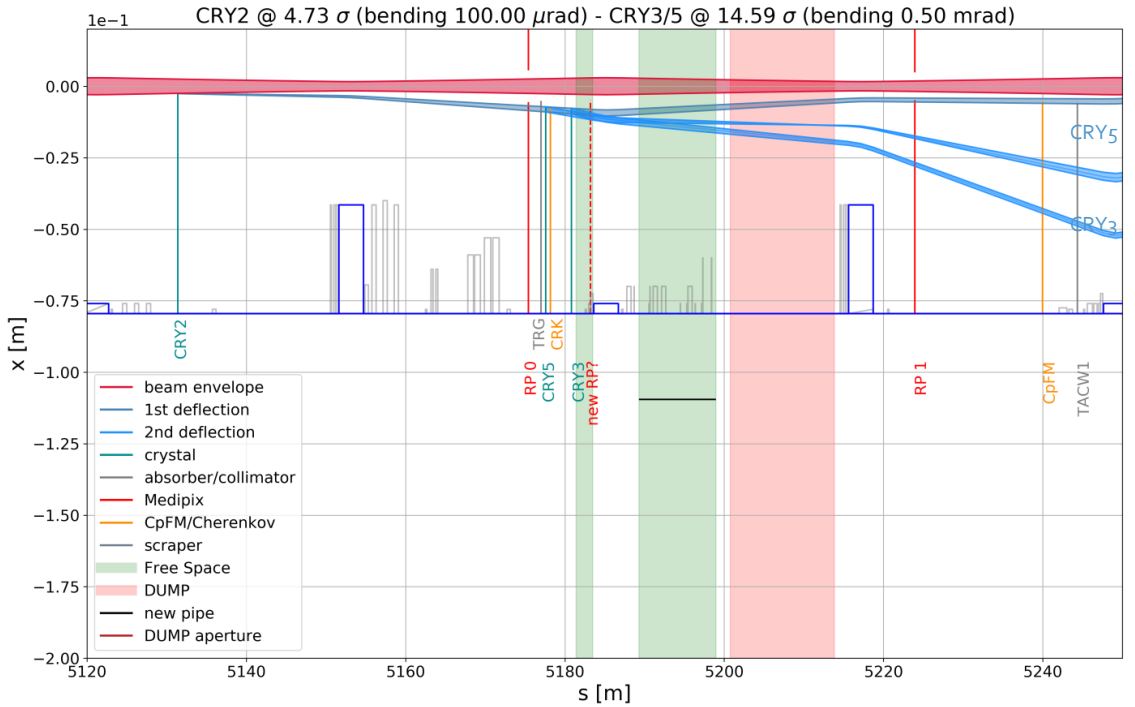


Also CRY3/4 and CRY5 can be used in single channeling, using RP1 for the measurements



Scenario for Double Channeling w/ Tagging





Conclusion and Outlook

- UA9 setup in SPS is ready for the Run 3
  - The layout has been modified in order to allow investigations on different experimental scenarios

Open points:

- ❑Participation of IPN to the SPS tests in '21/'22
- ❑Identification of the observables of interest
- ❑Evaluation of the existing detectors and their possible upgrade
- ❑Selection of the target
- ❑Estimate of the yield
- ❑Construction and implementation in the SPS pipe of the pneumatic motorization of the target

References

[1] F.M. Addesa et al., "Commissioning and operation of the Cherenkov detector for proton Flux Measurement of the UA9 experiment", NIM A (946), 2019

[2] W. Scandale et al., "Observation of strong leakage reduction in crystal assisted collimation of the SPS beam", Physics Letters B (748), pp. 451-454, 2015

[3] M. Fraser et al., "Experimental results of crystal-assisted slow extraction at the SPS", in proceedings International Particle Accelerator Conference (IPAC) 2017 in Copenhagen, Denmark

[4] S. Montesano et al., "Testing the double-crystal setup for physics beyond colliders experiments in the ua9-sps experiment", in proceedings International Particle Accelerator Conference (IPAC) 2018, Vancouver, BC, Canada

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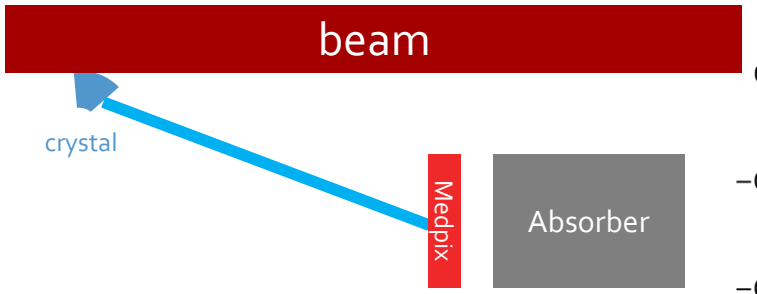
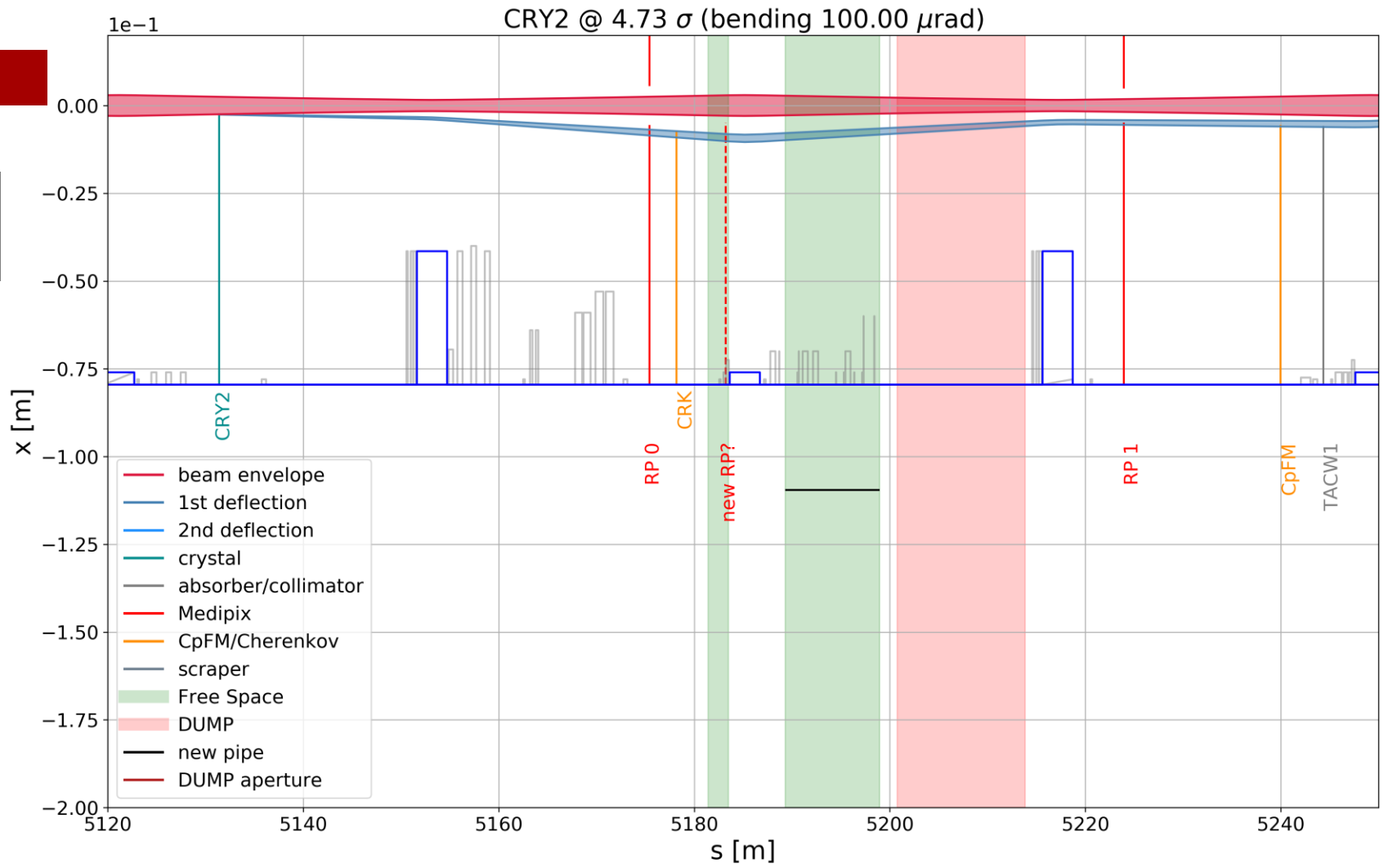
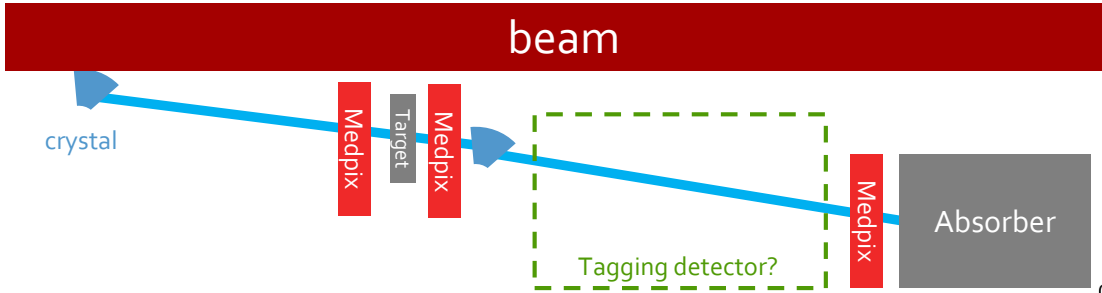
Scenarios - Extraction

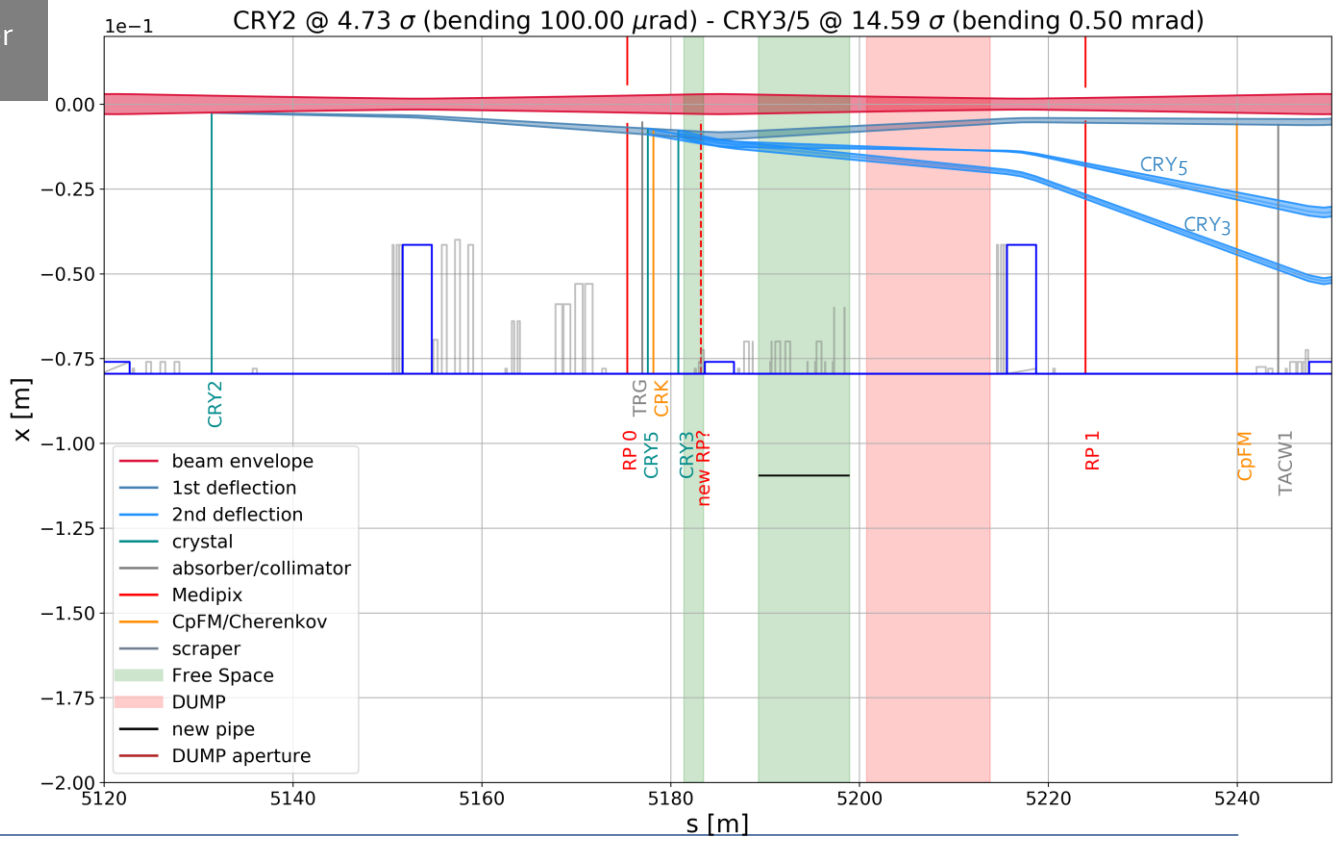




Also CRY3/4 and CRY5 can be used in single channeling, using RP1 for the measurements

Scenarios – Double Channeling w/ Tagging





FLUKA Simulation setup

Beam:

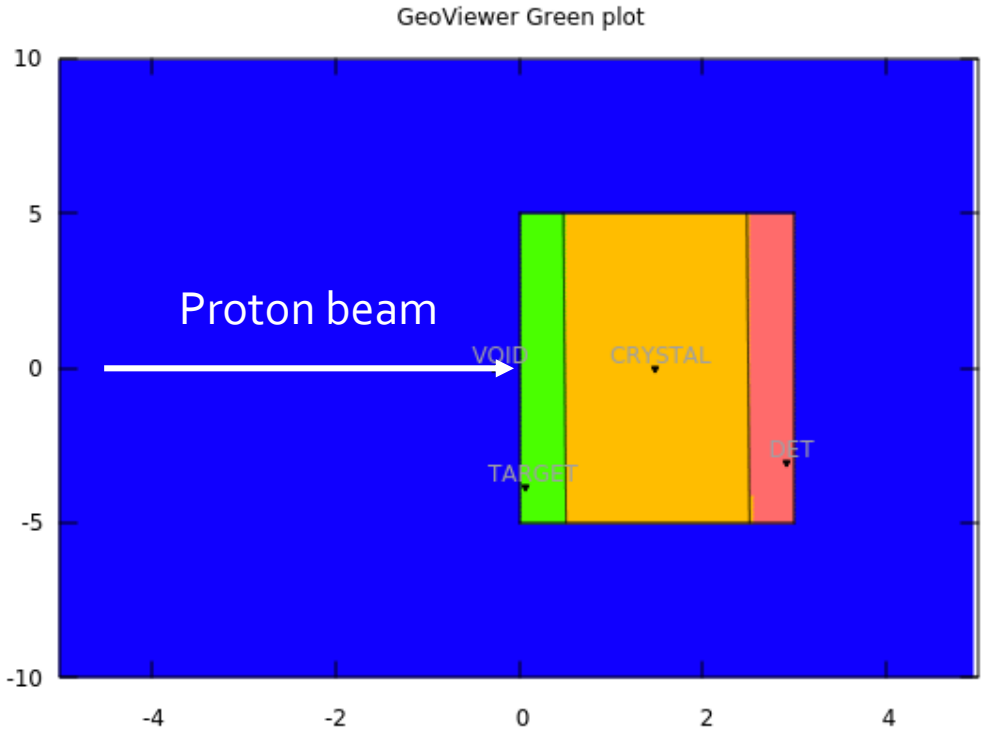
SPS COAST p beams @ 270 GeV

Target:

W – 50 mm and 10 cm*

Cu – 50 mm and 15 cm*

*corresponding to 1 interaction length



Σ^+ Production energy

Highest Σ^+ flux emerging with target 1 interaction length long.