Supplement to the UA9 report for 2017

The activity of the UA9 Collaboration from 17 October 2017 onwards is presented hereafter, in view of supplementing the UA9 report for 2017. Two new items are shortly reported: 1) the progress of the so-called "double-crystal experiment", aiming at the measurement of the electric and magnetic dipole moments (EDM and MDM respectively) of the heavy baryons in LHC and 2) the first double-crystal test in the SPS in view of demonstrating the feasibility of such a sophisticated beam manipulation in more relaxed conditions than in LHC. The new results strongly support the UA9 request of beam time in the SPS and in H8 for 2018 and represent a relevant step towards a sound formulation of a double-crystal experiment in LHC.

1) The double crystal experiment in LHC.

The UA9 Collaboration presented the conceptual layout of a double-crystal experiment in LHC in the LHC-FT working group of the Physics Beyond Collider (PBC) programme, together with the layout and the scientific and technical considerations motivating test runs in the SPS. The discovery potential and the possible scenarios of such an experiment were discussed in details at the 2nd PBC workshop held at CERN on 21 – 22 November 2017.

In the talk *Measuring Magnetic and Electric Moments of charm baryons with bended crystal*, A. Stocchi presented the conceptual design of the experiment based on the exploitation of the LHCb detector and the road-map to implement it. Four crucial steps were indicated:

- Intensive simulation to optimize the LHC setup.
- Optimization of the detection efficiency of the LHCb setup.
- Procurement and test in the H8 beam line of 15mrad bent crystals.
- Validation of the double channelled crystal scheme in the SPS.

The two latter points also imply to push further the test of the UA9 Collaboration in view of

- Improving the matching of the two crystals using the SPS installation.
- Measuring the efficiencies and the background in the SPS installation.
- Procuring and testing in H8 various long crystals of increasingly large bending in view of obtaining a 15 mrad bent crystal with a sufficiently large channeling efficiency.

CERN-SPSC-2017-044 / SPSC-SR-225
05/12/2017

In the talk LHC fixed target, M. Ferro-Luzzi discussed the operational constraints on the efficiency of the double-crystal setup based on the LHCb detector. Finally, in the talk Search for new physics via EDM of heavy and strange baryons at the LHC, F. Martinez Vidal recalled that the LHCb Collaboration can extract key parameters of the Λ_c production at the LHC energy, useful for the double-crystal experiment, from the data collected in the present LHC runs. In particular, the p-gas SMOG data can be used to record the polarization and the p-p collision data @ 14 TeV to evaluate the parity violation parameter α of the Λ_c and other baryon production. Furthermore, the optimal position and size of the production target and of the long crystal are being investigated with simulations based on different codes, such as GEANT4, EPOS and PYTHIA8, by which the expected flux of useful events and of the background should be evaluated in the full LHCb model. The initial results of these simulation studies were shown at the workshop to describe the sensitivity reach of the double-crystal setup for the EDM and MDM of the known baryons.

2) The double-crystal test in the SPS.

The double-crystal setup for the SPS was obtained by shifting one of the two existing goniometers by one cell upstream of the original position in the UA9 setup. This rearrangement, implemented during 2017, allowed using two crystals separated by 90 ° phase advance for the double-channeling of a fraction of the beam halo. The nominal beam trajectories are shown in Figure 1: the envelope of the circulating beam is confined in between the two red curves whilst the deflected halo trajectories are represented by the light green curves for single-deflected particles and by the dark green curves for double-deflected ones. In the reported test, carried out on October 17th, single- and double-crystal configurations where repeatedly established. Loss rates induced by the LHC-type collimator were recorded during a linear scan from the garage to the beam peripheral positions. Two examples of the loss profiles are shown in Figure 2. The orange curve shows a case where only the first crystal is active and the second one is retracted: only single-deflected particles are detected rather close to the circulating beam. The blue curve shows a case where also the second crystal is active: the resulting loss profile is more complex because of the insufficient thickness of the second crystal. Indeed, only a small fraction of the halo particles experiences a double-channeling deflection whilst the particles passing aside and not encountering the second crystal only experience a single-deflection. Double-deflected particles follow trajectories more distant from the circulating beam, giving rise to a first loss increase at a larger aperture of the collimator, whilst particles that only have a single-deflection follow more internal trajectories thus producing the second loss increase closer to the circulating beam. When the two crystals are active, the image collected by the Medipix detector is even more explicit, as shown in the example of Figure 3. The spot to the left, closer to the circulating beam, is created by the single-deflected particles. Such a spot is split in two slices passing on each side of the second crystal, showing well the shadow of the second crystal. At the same time, a second spot appears to the right of the Medipix frame, due to the particles undergoing double-channeling deflection. The intensity profile to the right of Figure 3 shows that the single-deflected halo spot is partly depleted and a second spot appears due to the double-channeled halo.

Limiting factors of the test in 2017 were the too small cross section of the available crystal in the downstream position, the functionality of the UA9 detectors (CpFM and Medipix) not fully matched for the two-crystal experiment and the impossibility of exploring a case with the target in front of the downstream crystal.

3) Hardware improvements planned for 2018.

Medipix: A drastic improvement is planned during YETS17-18. In all the Roman pots, Medipix 3 should replace Medipix 2 detectors. This action is expected to improve from 0.02 to 1 the duty factor of the data collection and should increase significantly the number of recorded events, thus allowing evaluating in a reliable manner the intensity of single-deflected, double-deflected, dechanneled and randomly scattered particles that may intercept the Medipix sensor during the double-crystal tests.

CpFM: In the coming YETS18 also the Cherenkov Detector for Flux Measurement will be improved. A new radiator should be installed in the coming YETS17-18 to provide higher efficiency and better resolution in the estimation of the deflected intensity. New front-end electronics with higher duty factor is in production and will be provided during 2018. These enhancements should allow evaluating more accurately the double-channeling efficiency.

Crystals: The second crystal will be replaced by a wider one, capable of intercepting the full width of the single-channeled beam, by which a much larger fraction of particles should go through double deflections. Furthermore, during YETS 17-18 or during the first technical stop of 2018 a target will be installed in front of the second crystal to evaluate the modifications of the efficiency and of the signal over background.

Absorber: the first double-crystal test in the SPS was performed by changing the integer part of the horizontal tune from 26 to 20. This precaution made possible to intercept at the same time the deflect halo of crystal 1 and crystal 2 by using the unique absorber of UA9 (the TACW). To recover the standard conditions, a second absorber is being produced and will be possibly installed during YETS 17-18. This precaution should make much easier the setting up of the SPS for the double-crystal test.

4) Plans and perspectives.

The 2018 plans of the UA9 Collaboration will be largely related to investigations of the double-crystal test along three directions.

- SPS: Investigations of the two-crystal layout and operation in the SPS, in view of assessing the efficiency of the process and of evaluating the induced background. The installation of a new absorber downstream of the first crystal, planned for YETS17, will simplify the operation and at the same time provide a diagnostic tool for the optimal alignment of the second crystal with respect to the deflected halo beam. A second crystal with wider transverse size should substantially increase the double-channeled flux. The upgrade of the Medipix and of the CpFM should provide more appropriate tools for a quantitative evaluation of the double-crystal performance. At a later stage, a target should be installed in front of the second crystal and its effect on the background rate should be measured. The potential improvement of the efficiency when using a focusing crystal in the first position to better concentrate the deflected halo into the second crystal should also be studied.

- The activity in H8 will continue in view of selecting and characterizing crystals for double-crystal and in particular the 15 mrad bent crystal requested for LHC.

- The collaboration will continue supporting the effort for the conceptual design of the double-crystal experiment in LHC.

In view of this, the Collaboration would like to request in 2018 to the SPSC:

- 18 days in H8 with proton microbeams at 400 GeV (or as a second choice of pion-beams of 180 GeV).

- 3 dedicated days with proton beam (24 h runs in storage mode) in the SPS to be fully devoted to the double-crystal test.

Studies for the crystal-assisted collimation in LHC and in the SPS will continue to be supported, in particular during the ion runs both in the SPS and in H8. New layout configurations of crystal collimation should be tested in the SPS in view of checking their performance before extrapolating them to LHC. Furthermore, newly developed crystals will be tested and characterized in H8, before their installation in LHC. The participation to the LHC test runs and to the data analysis will continue. To accomplish these tasks, the UA9 Collaboration also would like to request:

- 1 dedicated day with ion beam (24 h runs in storage mode) in the SPS to be fully devoted to collimation tests;
- 7 days with ion beams in H8.

Additional run-time with proton beams for extraction test in the SPS and for crystal-collimation tests in the SPS will be requested separately by the Extraction Group and the Collimation Teams respectively.

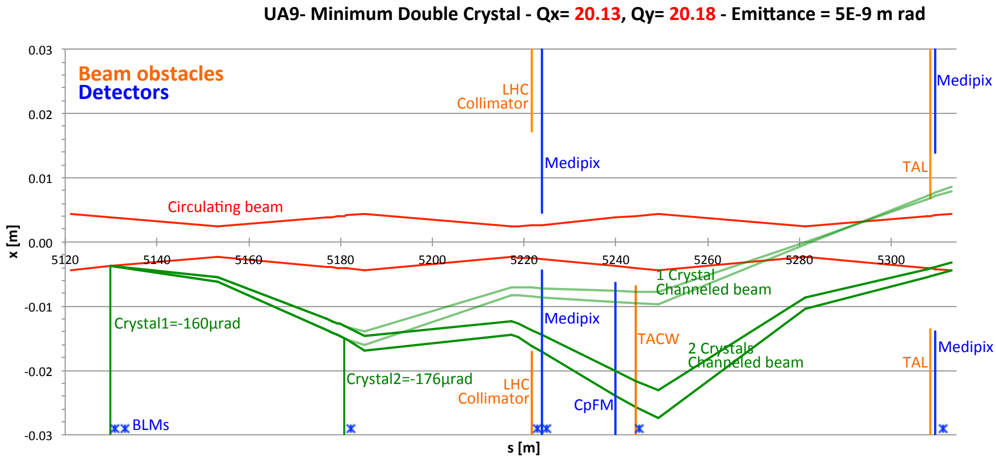

Fig. 1. The UA9 double-crystal optical layout in the SPS showing the circulating beam envelope (red) and the deflected halo trajectories (single deflected beam in light green), (double deflected beam in dark green). The locations of the crystal1 and crystal2 are shown in dark green, the LHC-type collimator and the absorber (TACW) are shown in orange. The beam loss monitors (BLMs), the medipix detectors and the Cherenkov counter (CpFM) are shown in blue.

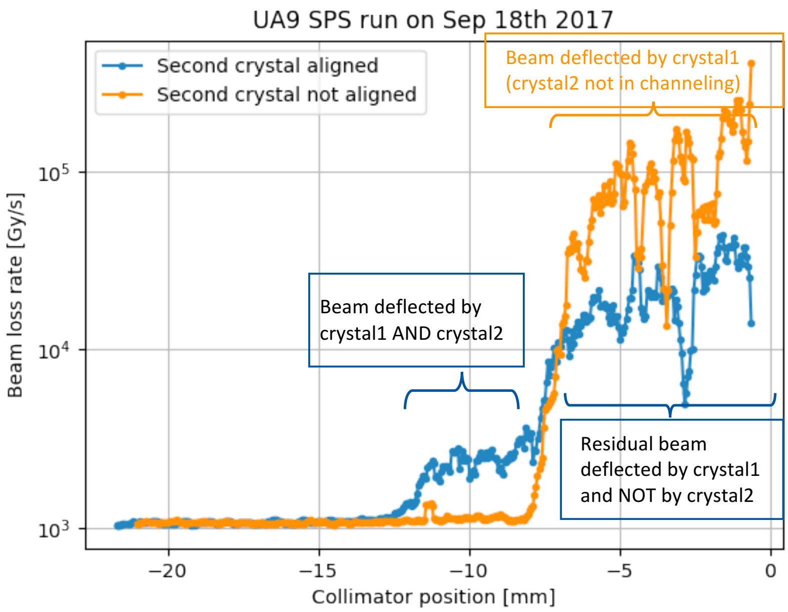

Fig. 2. Beam loss induced by the linear scan of the LHC-type collimator from the garage position to the beam peripheral (at 0 mm). When the crystal 1 only is in channeling orientation the profile in orange is recorded. When crystal 1 and crystal 2 are in channeling orientation the profile in blue is recorded.

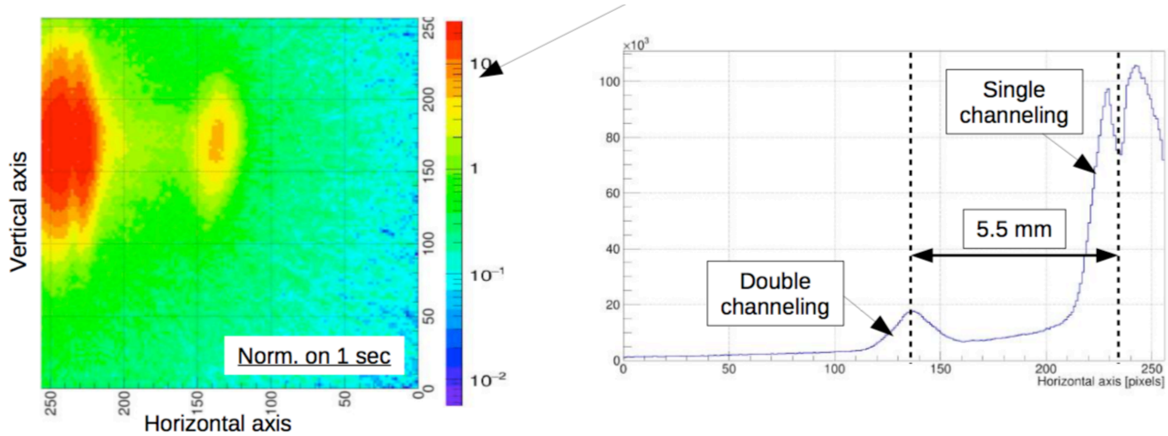

Fig. 3.: left side: 3D image recorded by the Medipix detector during the double-crystal deflection (the spot to the left, spit in two slices, records the halo particle having had a single-channeling deflection and the spot to the right records the particles having had a double channeling deflection); right side: horizontal profile of beam intensity recorded by the Medipix detector (note that the abscissa is reversed with respect to that of the screen plot).