# Minutes of 44th Collimation Upgrade Specification Meeting

**Participants:** R. Bruce (RB), F. Caspers (FCa), F. Cerutti (FC), B. Dehning (BD), F. Galluccio (FG), M. Garattini (MG), H. Garcia (HG), A. Lechner (AL), D. Mirarchi (DM), S. Montesano (SM), S. Redaelli (SR) (chairman), R. Rossi (RR), P. Schoofs (PS), E. Skordis (ES), G. Valentino (GV) (scientific secretary).
**Remote:** S. Bizzaro (SB), A. Burov (AB), J. Jowett (JJ), M. Kitzmantel (MK), T. Markiewicz (TM), W. Scandale (WS), N. Simos (NS), U. Wienands (UW).

Indico event here.

# 1 Actions

- GV and BS to check loss rates in measured loss maps to compare to simulation results presented by E. Skordis.

# 2 Recap. of crystal simulations for MD configurations (D. Mirarchi)

Slides are available here.

## 2.1 Summary of the presentation

DM mentioned that two crystals in the horizontal and vertical plane were installed in LHC IR7 at the beginning of April. The first beam tests are foreseen after the machine commissioning in the second half of 2015. Several questions should be addressed, including if crystals can improve the existing collimation system, and if they can ensure stable and safe operation in any beam conditions. The beam tests will initially take place at low intensity at injection and top energy, with all secondary collimators (TCSGs) at the nominal positions (TCP retracted), and will then progress to higher intensity with the TCSGs at different settings.

The SixTrack simulations to evaluate the system performance with crystals only provide the density of protons lost per meter, and to determine whether it will be possible to measure beam losses in the BLM detectors during the beam tests, energy deposition simulations are needed. Hence, the SixTrack outputs (available here) were provided to the FLUKA team for this purpose.

DM presented the simulation set up. A perfect machine is assumed, with a 7 TeV beam with nominal collision optics. A strip silicon crystal was used in the horizontal plane, assuming no miscut angle and no amorphous layer. Four systems were simulated for comparison: the present collimation system with nominal and relaxed settings at 7 TeV, and a crystal-assisted collimation system with dedicated TCSG settings and the crystal in the channeling and amorphous orientations.

The predicted cleaning inefficiency in the IR7 DS of the current LHC collimation system with nominal settings at 7 TeV is $1.4 \times 10^{-5}$, while with relaxed settings it increases to $1.8 \times 10^{-5}$. On the other hand, with the crystal in the chanelling orientation, the inefficiency decreases by factor 10 to $1.2 \times 10^{-6}$, while in amorphous, it increases by a factor 4 to $5.9 \times 10^{-5}$. In both cases, only one TCSG was in place. BD asked why the inefficiency was not measured at the maximum loss peak, but from a slightly lower value. DM replied that the inefficiency is averaged over 10 cm bins. ES asked why the losses at the crystal location are so high. DM replied that this is due to the normalization as the crystal is 4 mm long.

DM commented that by the time the simulations were made, the Sixtrack scattering routine was upgraded, however the relative results should not be affected.

# 3 Energy deposition simulations for crystals MDs (E. Skordis)

Slides are available here.

## 3.1 Summary of the presentation

ES presented results from energy deposition simulations for 3 scenarios at 7 TeV, consisting of the reference collimation system with nominal collimator settings and the crystal-assisted collimation in channeling and amorphous states. Three loss rates were considered: 1 bunch of $1 \times 10^{10}$ p with 0.02 h lifetime, 1 bunch of $1 \times 10^{10}$ p with 0.2 h lifetime, and 1 nominal bunch of $1.15 \times 10^{11}$ $p$ with 1 h lifetime. These 3 cases corresponding to loss rates of $1.39 \times 10^{8}$ p/s, $1.39 \times 10^{7}$ p/s and $3.19 \times 10^{7}$ p/s respectively. The first loss rate gives the highest BLM signal above the sensitivity threshold ($3 \times 10^{-7}$ Gy/s), and the coil energy deposition results were normalized to this case.

ES explained the simulation procedure. This involves obtaining the SixTrack distributions of the proton inelastic interactions in the collimators, and then loading them in the FLUKA geometry to generate the distribution of particles impacting the TCLA and DS aperture. This distribution is then used to simulate the energy deposition in the magnet coils and the BLM signals per inelastic interaction in the collimators.

The loss distributions (SixTrack output) show that the highest losses are at the TCPs, followed by the TCSGs and the TCLAs for the reference case (as expected), while for the crystal in amorphous, the losses are higher on the TCLAs. ES then presented plots for the peak power deposition in the coils of DS magnets for the three scenarios. The losses decrease by almost factor 10 with the crystal in channeling mode with respect to the reference collimator settings. With the crystal in amorphous mode, the losses in increase by a factor 4-5.

The simulated BLM signal in units of Gy/s for the highest loss rate of $1.39 \times 10^{8}$ p/s rises above the BLM sensitivity of $3 \times 10^{-7}$ Gy/s only in cell 8. ES commented that if the BLM sensitivity is decreased to $3 \times 10^{-9}$ Gy/s as planned, then the BLM signal will be visible up to cell 11. ES commented that usually, the predicted BLM signal is a factor 3 lower than reality. SR commented that when loss maps are produced for the reference collimation system, the measured losses are higher than those shown. At a higher energy, for the same number of protons lost, one would expect to see a higher BLM signal. SR suggested that GV and BS could look at the loss rates and lifetime during loss maps in Run 1 to check whether the loss rates and lifetimes are the same as in the simulations.

# 4 Summary of H8 data analysis (R. Rossi)

Slides are available here.

## 4.1 Summary of the presentation

RR presented results from the H8 crystal data analysis. Measurements of crystal properties are done in the SPS extraction line (H8) with 400 GeV protons before beam tests with circulating beams. The work was done as part of a Master's thesis, which had the goal of analyzing all 15 crystals tested in H8 between 2009 and 2012 to compile a comprehensive statistical treatment of the crystals, identify "fine" systematic effects and provide inputs to crystal code developers.

RR reminded the H8 experimental layout. Five silicon micro-strip sensors are used to track the particles in the plane orthogonal to the beam direction before and after passing through the crystal. A high-precision goniometer is used to modify the crystal plane orientation with respect to the beam direction. Ten crystals were tested in H8: 7 strip crystals and 3 quasi-mosaic crystals.

Tools in Root were developed for the analyses, which include the check of beam parameters, crystal channeling efficiency, transition region and population studies. The analysis for the STF45 crystal is used as a reference case for comparison with the crystal simulation routines. The complete analysis was already presented in ColUSM 38.

After the geometrical and torsion corrections, RR presented the deflection of the particle as a function of the impact angle. The three regions of channeling, transition region and dechanneling can then be distinguished. The channeling efficiency was evaluated to be 69% and 53% at two different angular cuts of $\pm5$ and $\pm10$ $\mu$rad respectively. The dechanneling length is a key parameter to improve the simulations, and decays exponentially as a function of the kick angle. By selecting different impact angles, a deflection analysis can be performed to obtain the channeling deflection angle, volume reflection angle and amorphous angle.

The transition zone, which describes how the amorphous region is transformed to the volume reflection region after the channeling region, was also analysed. RR mentioned that the trend of the peak plotted would be useful for a comparison with the crystal simulation routines. RR also analysed the population of the three different regions, as a function of the incoming impact angle, which show that the channeling length is larger in the centre of the crystal and shorter on the edges.

A webpage will soon be available online with all the necessary inputs to reproduce the experimental data of the reference case. RR mentioned that the comparison results will be discussed in an upcoming crystal channeling workshop. PS asked whether all data for the 10 crystals tested in H8 will be put online. RR and FG replied that the inputs for 10 crystals will be put online, but only the comparison will only be made for the crystal with the most statistics.