Stefano Redaelli, 04-07-2007

88th Meeting of the LHC Collimation Working Group, July 4th, 2007

Present: Ralph Assmann (chairman), Giulia Bellodi, Chiara Bracco, Roderik Bruce, Francesco Cerutti, Valentina Previtali, Stefano Redaelli (scientific secretary), George Smirnov, Thomas Weiler. Igor Yazynin.

1 A.O.B.

R. Assmann informed the DG approved the proposed *White Paper*, which among others included a proposal for the Phase 2 collimation project. A detailed program has been sent to the DG for the final approval.

2 Possibilities of using the crystalline targets for beam collimation in the LHC (I. Yazynin)

2.1 Scope

Igor Yazynin for the Protvino Institute of High Energy Physics has spend one month at CERN to work with the collimation team - in particular with Valentina Previtali - on investigating the possibility of using crystals to improve the cleaning performance of the LHC collimation system. Igor's routines are now available for the collimation team and V. Previtali will continue these studies and include crystals in our simulation tools. I. Yazynin presented the studies that he has performed in this period at CERN and preliminary results on the performance of crystal based collimation at the LHC.

2.2 Simulation results

First I. Yazynin showed his simulations of cleaning efficiency for the Phase I collimation system, which is based on amorphous primary collimators. Igor showed the definition of cleaning efficiency that he uses in his simulations and his modelling of the LHC beam cleaning system. Igor distinguishes the contribution to the overall cleaning from the various collimator families (primary, secondary and tertiary collimators). Igor also showed the distribution of beam protons at the primary collimators as calculated for different number of tracked turns (see page 8). In addition, he performed parameter scans for assessing the dependence of cleaning performance on (1) number of tracking turn; (2) impact parameter on the primary collimators; (3) available machine aperture (simplified model for the arc aperture is used); (4) retraction between primary and secondary collimators. Details can be found in Igor's transparencies. Even though more detailed comparisons will have to be performed, it was noted that the simulation results are in basic agreement with the results from the ABP collimation team. In particular, Igor also finds that at 7 TeV the losses in the machine are dominated by the protons that leak out of the primary collimators.

I. Yazynin also showed that in some range of beam impact parameters, the inefficiency can become worst for increasing impact amplitudes. This occurs for impacts of about 10 μm at injection and 0.5 mm at 7 TeV. This effect can be explained by taking into account the proton distribution after the interaction with the TCP's and the phase difference between TCP's and TCSG's collimators for the various TCSG locations (slide 9). R. Assmann commented that he did not find this effect in his simulations. However, he did not explore large impact parameter values as Igor did. It will be interesting to see if we reproduce this effect with our tools.

Next I. Yazynin focused on the simulations with crystals. First he reviewed the relevant phenomena that have to be taken into account: (1) crystal channeling; (2) crystal reflection and (3) volume capture. S. Redaelli asked if the scattering is also taken into account and Igor replied that this is the case. He then showed example of simulations that show the contributions of the effects quoted above. Simulations reproduce nicely the experimental results achieved last year with extracted beams in H8 (experiment lead by W. Scandale).

Simulations were performed to investigate the possible usage of (1) **crystal channeling** and (2) **volume reflection** at the LHC. Preliminary results show that by using channeling the inefficiency can be improved by up to a factor 20 with respect to what is achieved with amorphous TCP's. The bending angle of the crystal must be at least **50 micro radiants**. The angular accuracy for crystal alignment is of the order of a few micro radiants. Outside of the range where channeling is effective, the cleaning improvement is reduced to zero and one obtains the same performance that is achieved with amorphous scatters. On the other hand, the angular acceptance could be significantly improved by using **multi-crystal channeling**, which would also have the effect of increasing the angular distribution of the channeled beam. This could improve the heating of the absorbers used to stop the channeled beams.

By using volume reflection, the achieved deflection angles will be smaller and the improvement of cleaning efficiency is limited. The system could be improved by opening two secondary collimators, which otherwise would absorb too much load, but nevertheless further investigations are required for a detailed system optimization. However, the volume reflection would greatly relax the angular alignment requirements: an acceptance of about 40 milliradiants can be achieved.

I. Yazynin also gave preliminary estimates of **crystal heating**. Assuming volume reflection as a worst scenarios, it is expected that crystals can withstand up to 15×10^{14}p per second. Details are shown in the table at page 23 of Igor's slides.

2.3 Discussion

R. Assmann warned that the preliminary conclusions on cleaning improvement should be validated by more detailed simulations including error models. V. Previtali will use the routines provided by I. Yazynin to start further studies. The goal is to review in autumn the estimates and assess the estimates of the improvement that can realistically be achieved.

R. Assmann also commented that the possible usage of volume reflection from several consecutive crystals, which has been experimentally demonstrated last year in W. Scandale's experiment, might not work for circulating beams. Ralph's argument is that, in order to add-up the kicks from consecutive reflections, the crystals further downstream should be close to the beam core (which obviously is not needed if channeling towards the outside of the beam is used). However, in this case they will intercept first the primary beam protons. It is therefore not clear how one could take profit of the multi-reflection. In any case, R. Assmann suggested that I. Yazynin should provide the detailed technical drawing of the multi-crystal layout for a detailed implementation into our simulation codes.

S. Redaelli asked about the plot of cleaning efficiency versus crystal angle (page 18). The efficiency for large angular alignment errors (crystal working as an amorphous material) seems to be too good considering that the crystal if only a few millimeters long. I. Yazynin replied that in this case the particles go through the crystal many times before being lost.

G. Smirnov suggested to review more systematically the comparison between the inefficiency calculation of I. Yazynin and the ones done so far within the collimation people. In some cases it was not clear that the agreement is very good.

R. Bruce asked if the plans of crystal studies for the LHC include calculations for ion beams. I. Yazynin replied that his simulation routines are only for protons for the moment however this year's experimental program at the SPS also include ion crystal studies.