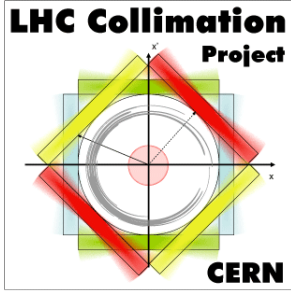

Studies and improvements on SixTrack simulations for crystal assisted collimation in the LHC

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Valentina Previtali, Stefano Redaelli, Walter Scandale

Introduction

Main steps of the reported studies:

Performed a particle by particle analysis of complete loss-map simulation to investigate what experienced by each particle

No losses coming from the crystal were present!
(particles lost only after an interaction with a "standard" collimator)

Started two parallels set of studies:

1. Comparative studies of SixTrack scattering routine and Crystal scattering routine (crystal in amorphous orientation)

2. Made several tests to check the crystal routine itself
   - coherent effects (Channeling, Volume Reflection…) well treated for this stage of simulations, maybe further improvements needed
   - studies focused on the scattering routine (in which are present the "dangerous" interactions)

Found the bug!

New results with the debugged code

Debugging

Main changes applied to SixTrack for debugging and interaction studies

Added output files to SixTrack:

- "cr_interaction.dat" which contains:

1=ipart 2=nturn 3=icoll 4=previous interaction 5=interaction 6=kick_x 7=kick_y 8=E_in 9=E_out
(interaction flags: 1=MCS, 2=VR, 3=CH&VC, 5="absorbed", 6=DC, 7=NES, 8=DIFF)

- "FLUKA_impacts_dan.dat" which contains:

same structure of "FLUKA_impacts.dat" but containing the events in which the particle is not absorbed in the jaw, and added 11=Dp/p got (interaction flags: 0="not absorbed", 4=DIFF)

Added output file to the crystal routine:

- "cry_energy_loss.dat"

1=E_in 2=E_out 3=interaction

"Main" bugs fixed (not influencing the SixTrack functionalities):

- association of the right interaction experienced in the crystal by the hitting particle (due to the rescaling of the particle index while particles are absorbed)
- calculation of the kick given by the crystal when it is placed in the V plane (due to a wrong association of in-coming and out-coming x': x'_in assigned after the rotation in the collimators reference frame, x'_out assigned after the anti-rotation in the accelerator reference frame)

Comparative studies

Performed two complete simulations with identical boundary conditions, only one difference:

Case 1:

- 3mm long Si crystal in amorphous orientation as primary restriction of aperture (treated by the crystal routine)

Case 2:

- 3mm long Al as primary restriction of aperture (treated by standard SixTrack)

Both are placed at TCP.A6L7 location, using as secondary only the TCSG-6R7
(rest of the collimators in the machine placed as 7TeV design)

Choose the Al for comparison since is the closest material to the Si treated in SixTrack
(Z_{Al}=13 , Z_{Si}=14)

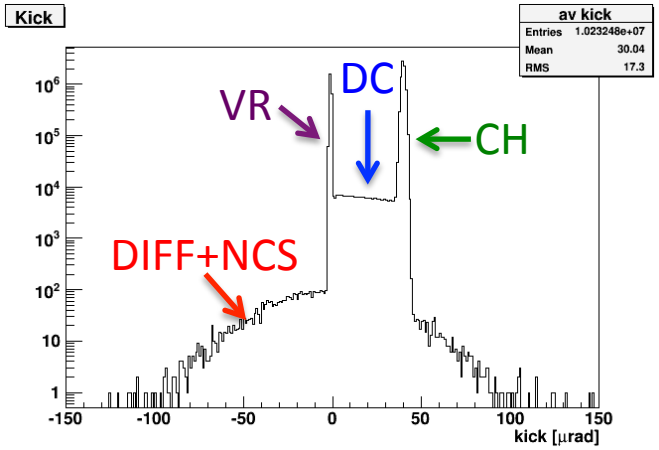
Results:

- No dispersive losses in DS from the primary collimation stage in the Case 1
- Most of the losses in the Dispersion Suppressor coming from diffractive events at the primary collimator in the Case 2

Crystal routine tests

Coherent effects

Total kick given to the particles (no distinction on the interaction):



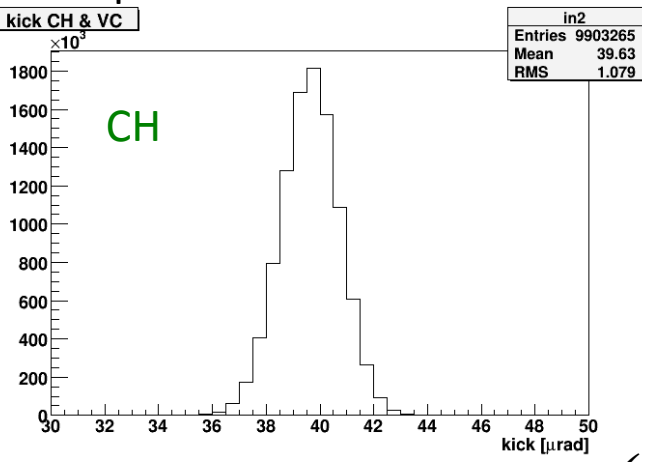
Distribution made using the FirstImpacts.dat

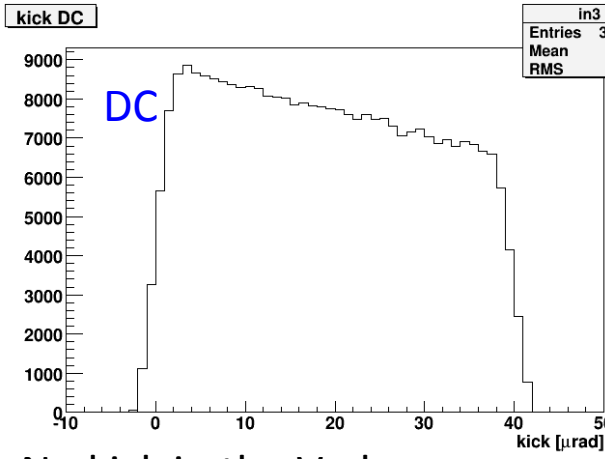
Can be compared to the North Area test beam

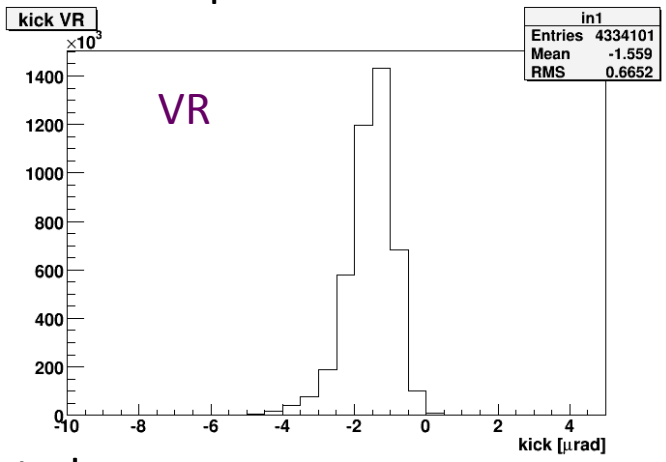
$$CH_{Eff} = \frac{\int CH}{\int TOT} \sim 70\%$$

Comparable with the UA9 test beam in H8

✓ expected kick and width for CH ✓ "reasonable" DC distr. ✓ expected kick for VR







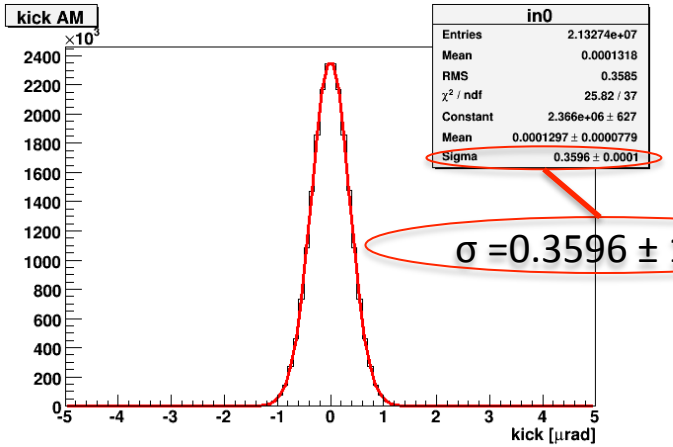
✓ No kick in the V plane as expected

Still work to do to optimize the coherent effects in the crystal routine, but reasonable level of accuracy for the present studies

Crystal routine tests

Scattering routine

Distribution of kicks due to MCS in the H plane



σ =0.3596 ± 1e-4

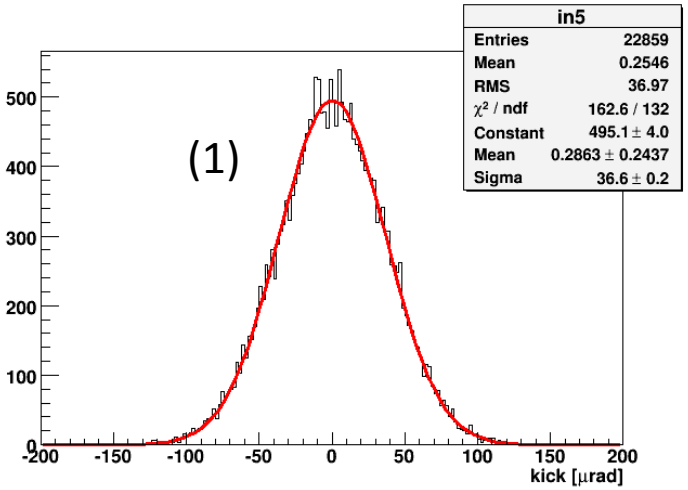
Comparable with:

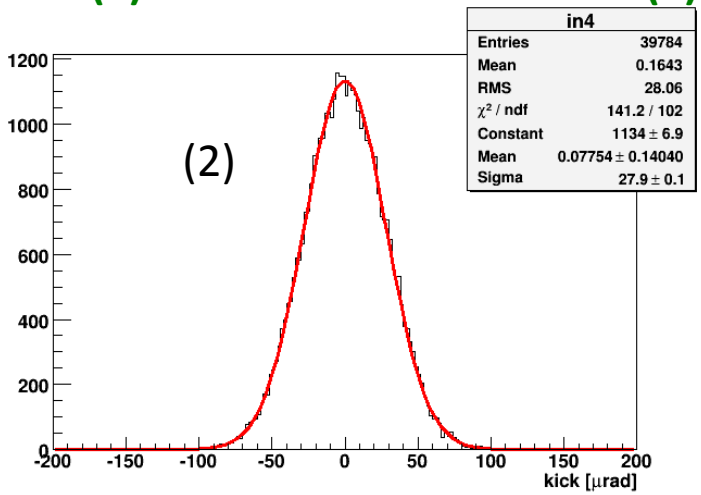
$$\theta_0 = \frac{13.6\ \mathrm{MeV}}{\beta cp}\, z\, \sqrt{x/X_0}$$

~0.348μrad

for 3mm long Si @ 7TeV
in amorphous orientation

Distribution of kicks due to Diffractive events (1) & Nuclear Elastic events (2)



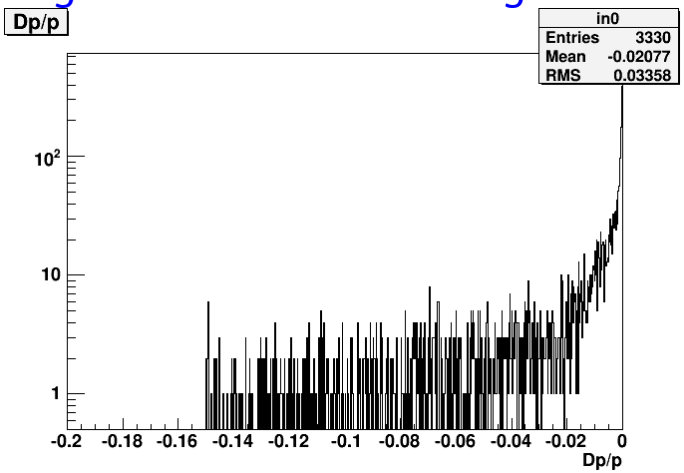


Shown only the H plane, coherent results for the V plane

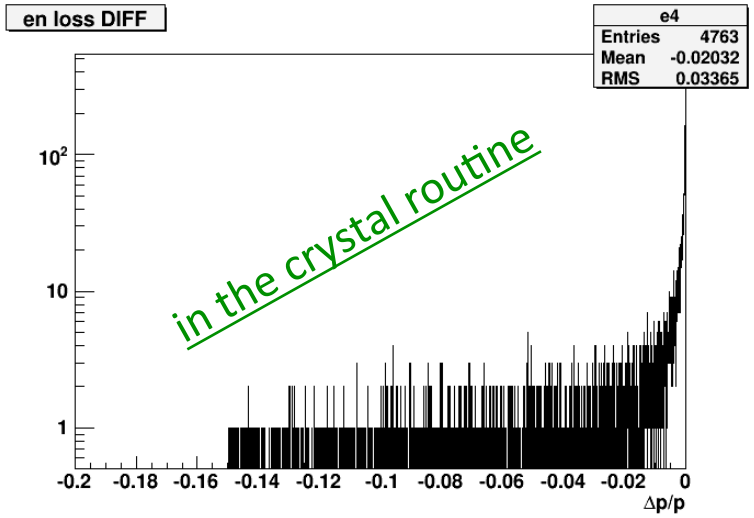
Started FLUKA simulations to check the Diff. and NES kick distribution

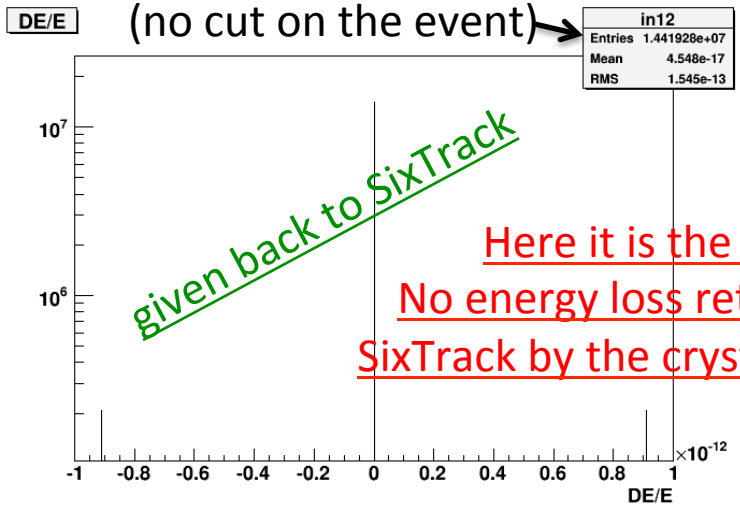
Crystal routine VS SixTrack

Δp/p of a particle which has experienced Diffractive event in 3mm Al using the SixTrack scattering routine



Δp/p of a particle which has experienced Diffractive event in 3mm Si using crystal routine



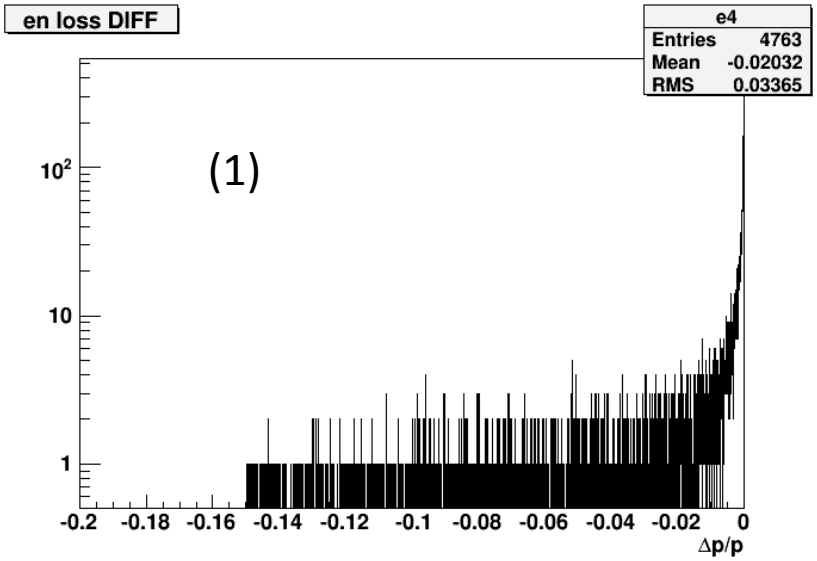


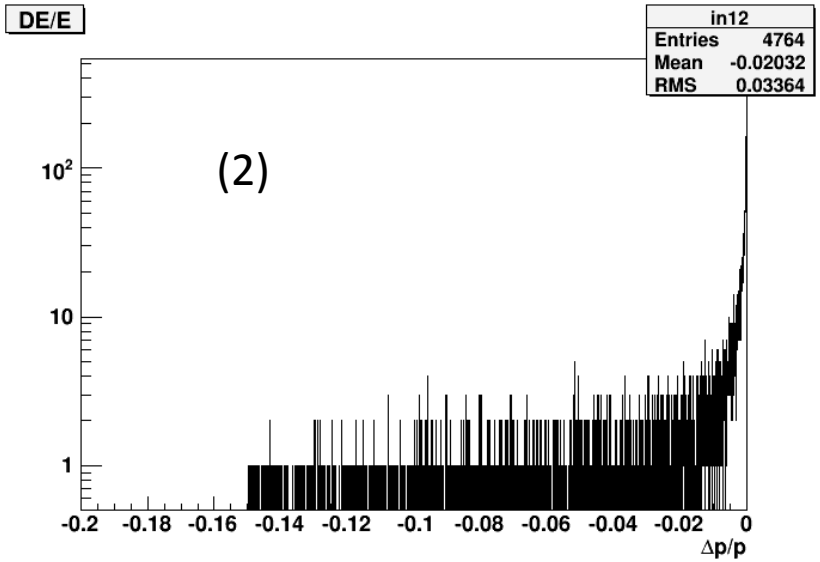
Here it is the bug!
No energy loss returned to SixTrack by the crystal routine!

Crystal routine tests

After the debugging!

Δp/p of a particle has experienced Diffractive event:
in the crystal routine (1) and returned to SixTrack (2)





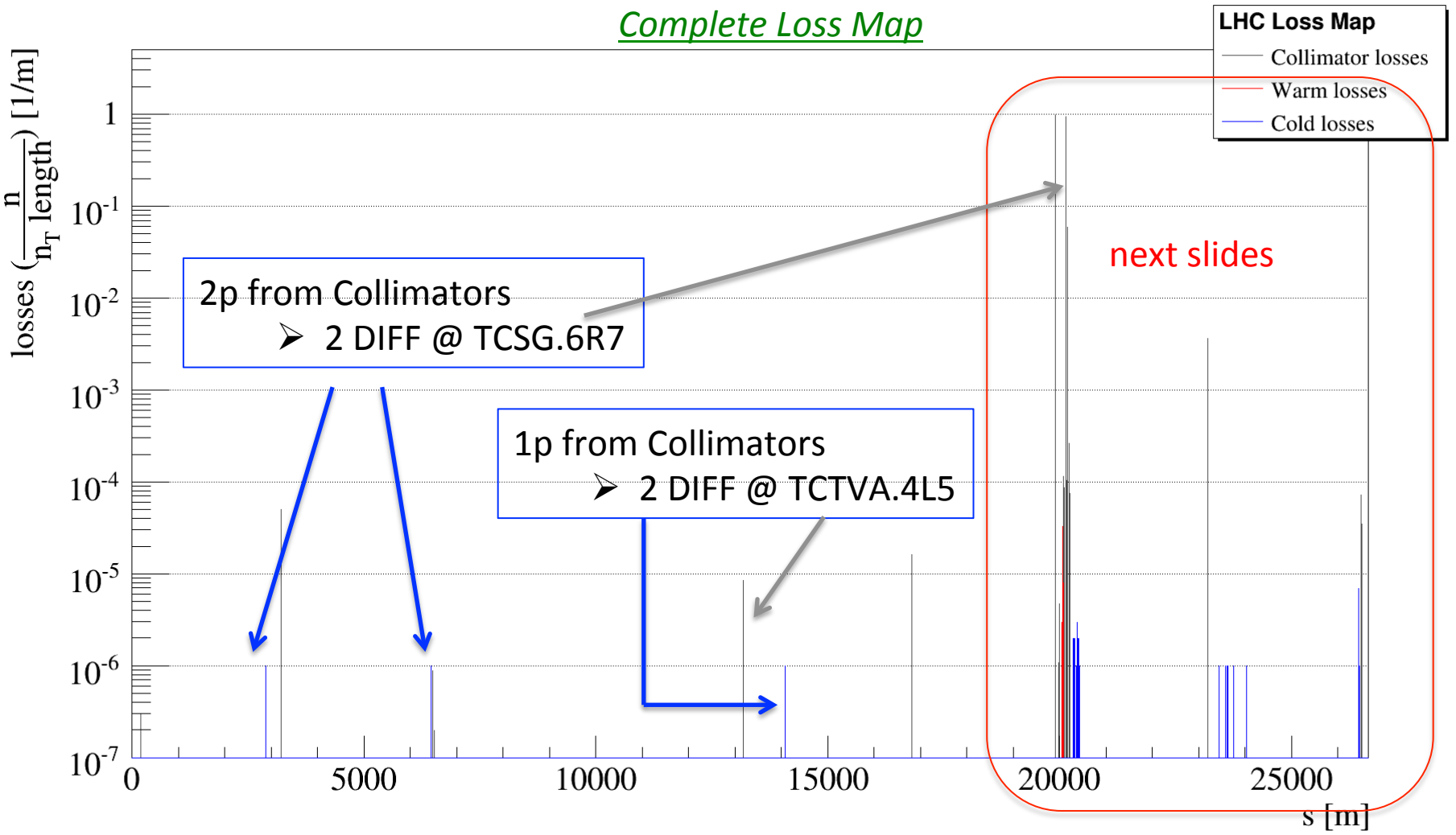
Detailed studies started in collaboration with the FLUKA team in order to check (for each interaction type):

- cross sections
- kick distributions
- energy loss

“Undebugged” results

Particle by particle analysis before the bug correction

Crystal @ 6σ, placed between TCSG.D4L7 & TCSG.B4L7. TCSG used in IR7: 6R7 @ 7σ (stat ~10e6 p)



“Undebugged” results

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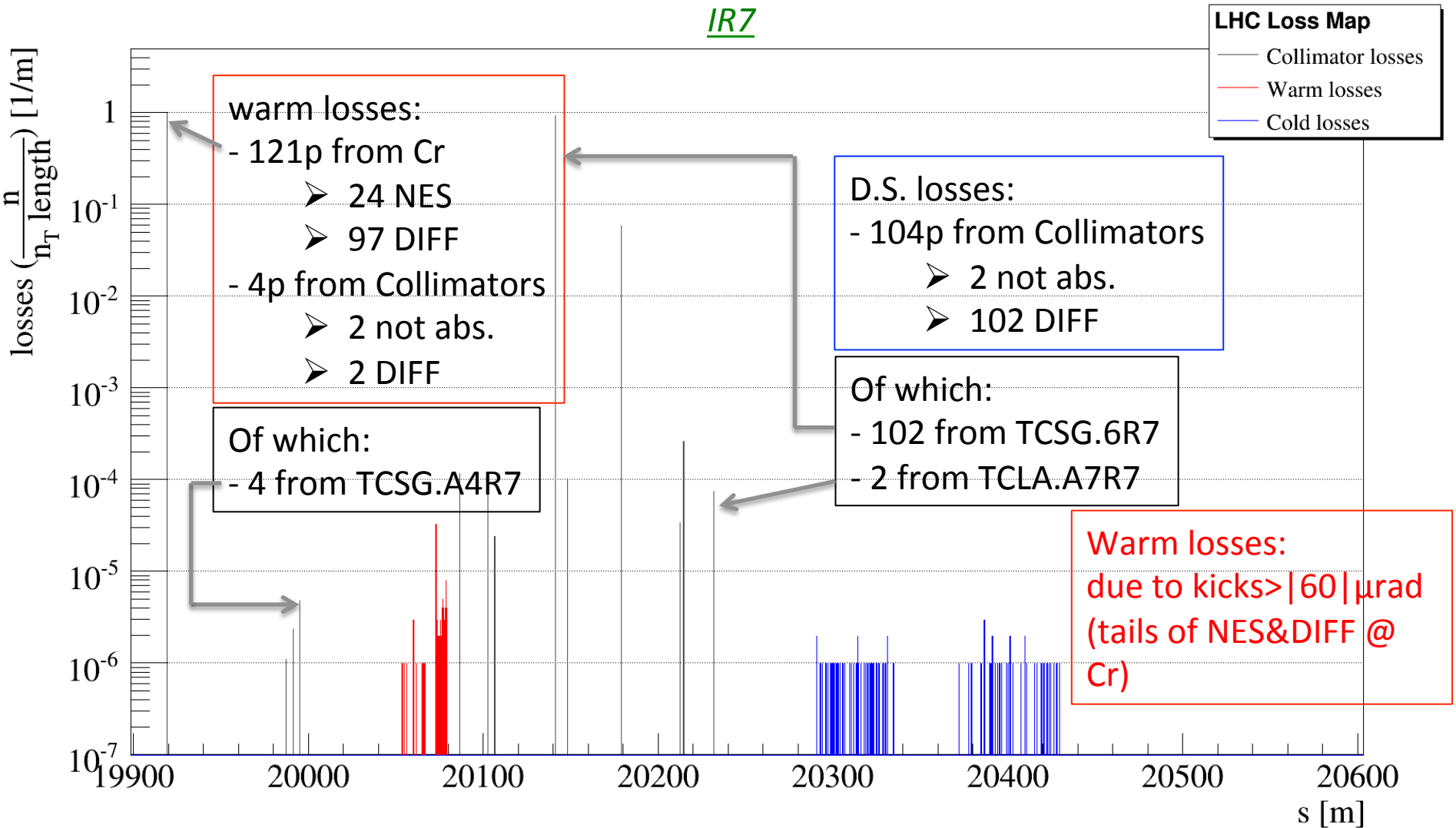

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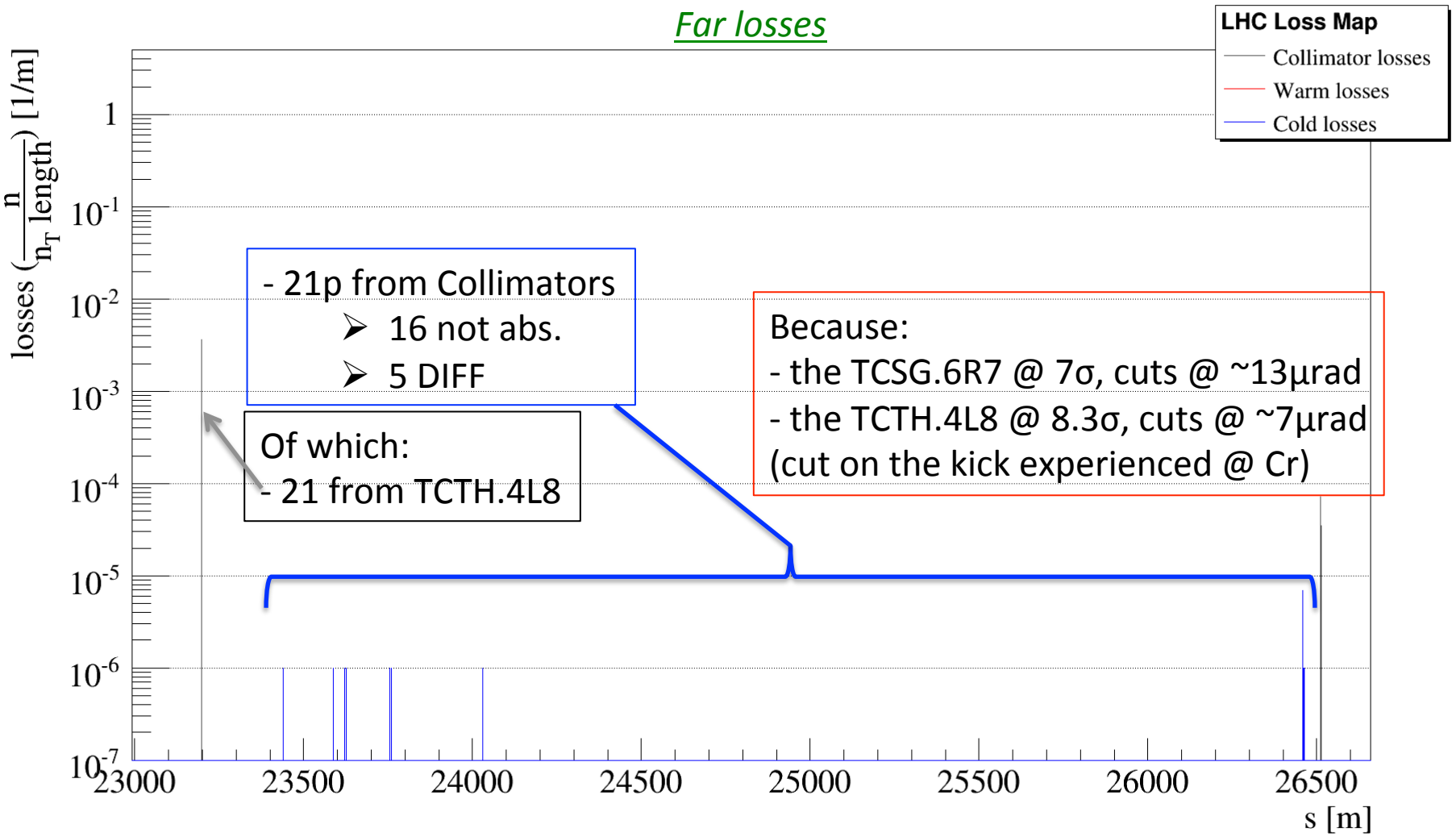
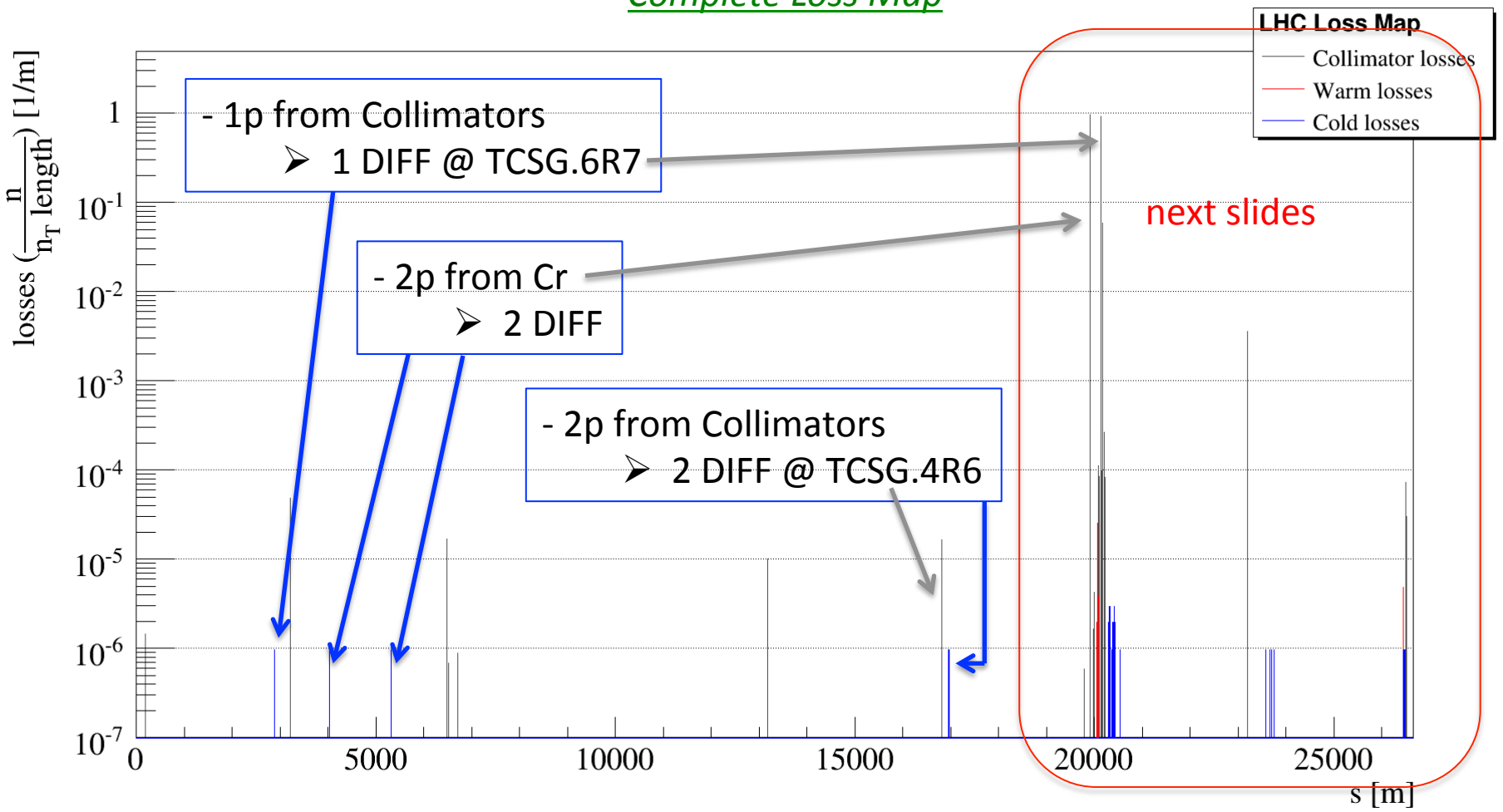


“Debugged” results

Particle by particle analysis after the bug correction

Same boundary condition with respect to the previous slides
(stat ~10e6 p)

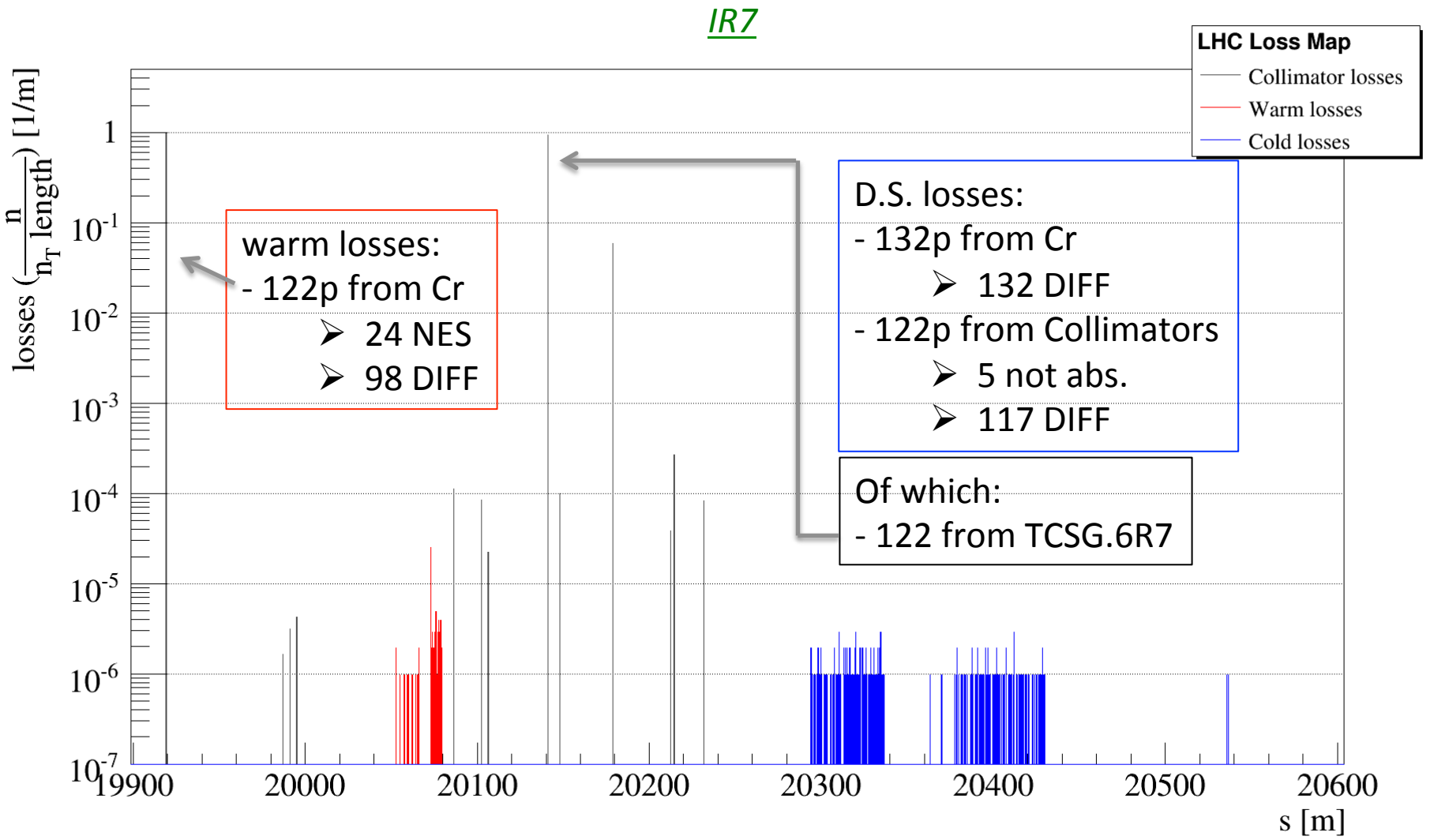
Complete Loss Map



“Debugged” results

Particle by particle analysis after the bug correction

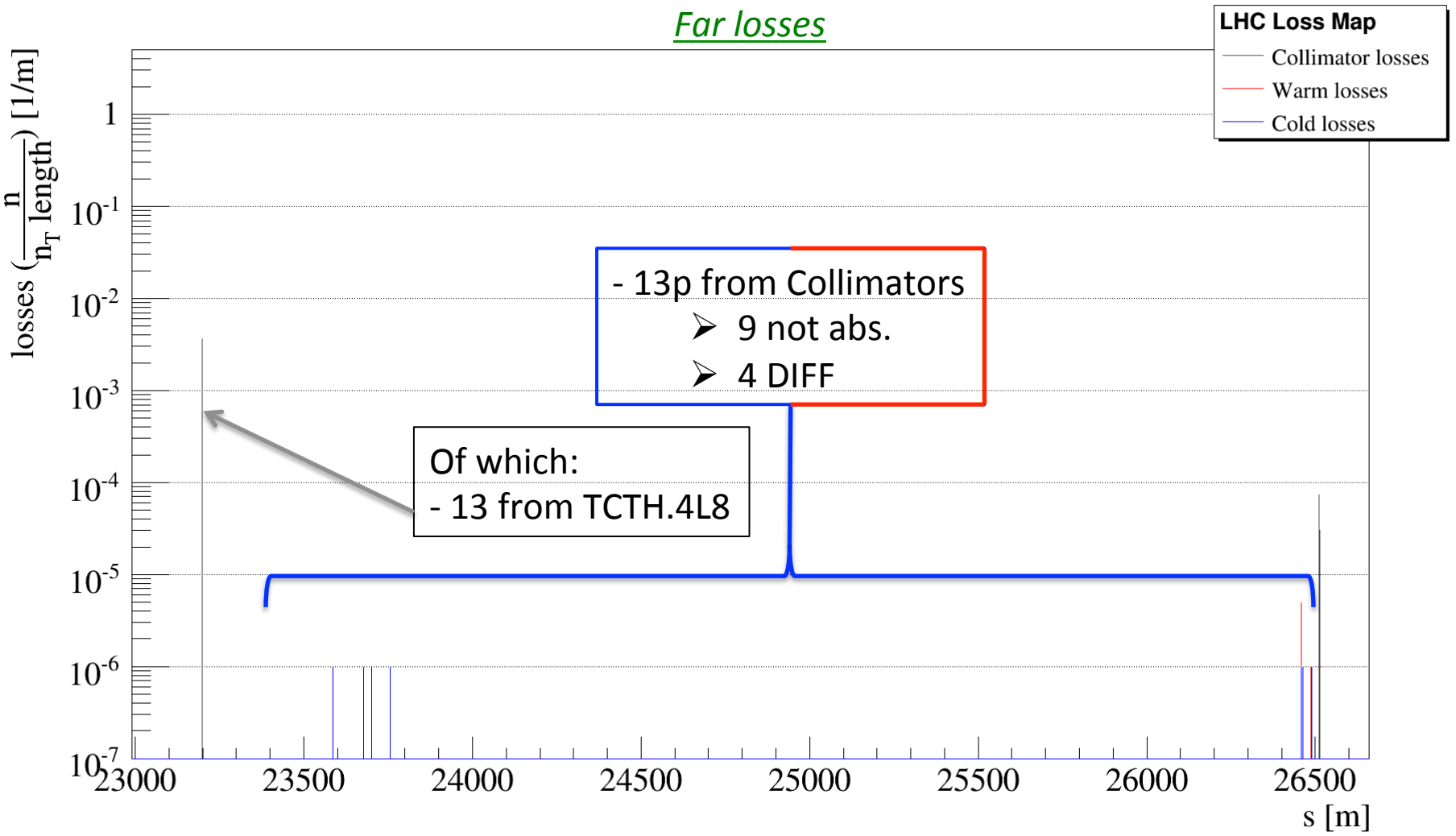
Same boundary condition with respect to the previous slides



“Debugged” results

Particle by particle analysis after the bug correction

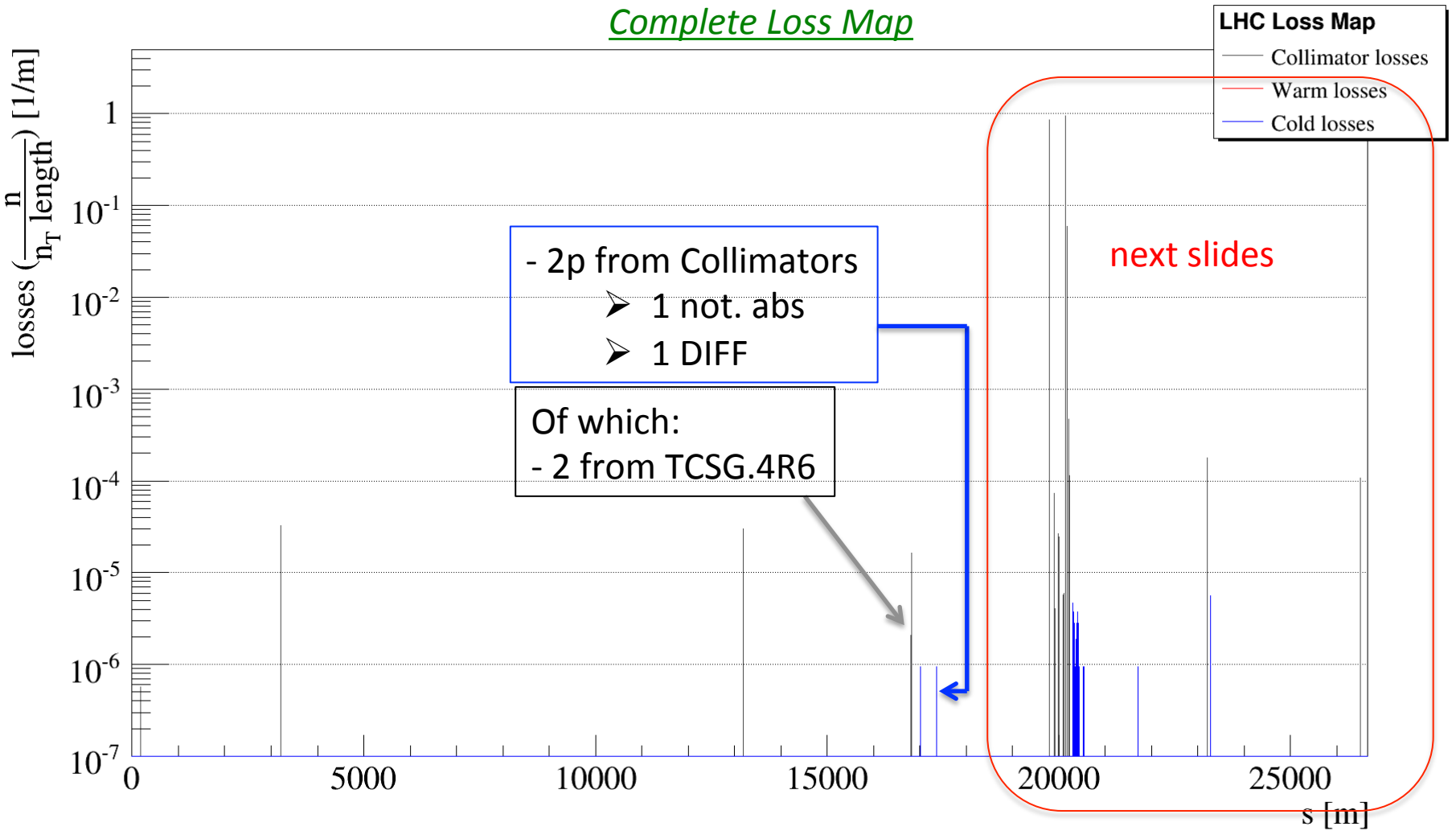
Same boundary condition with respect to the previous slides



“Debugged” results

Particle by particle analysis after the bug correction, second possible location for Cr installation

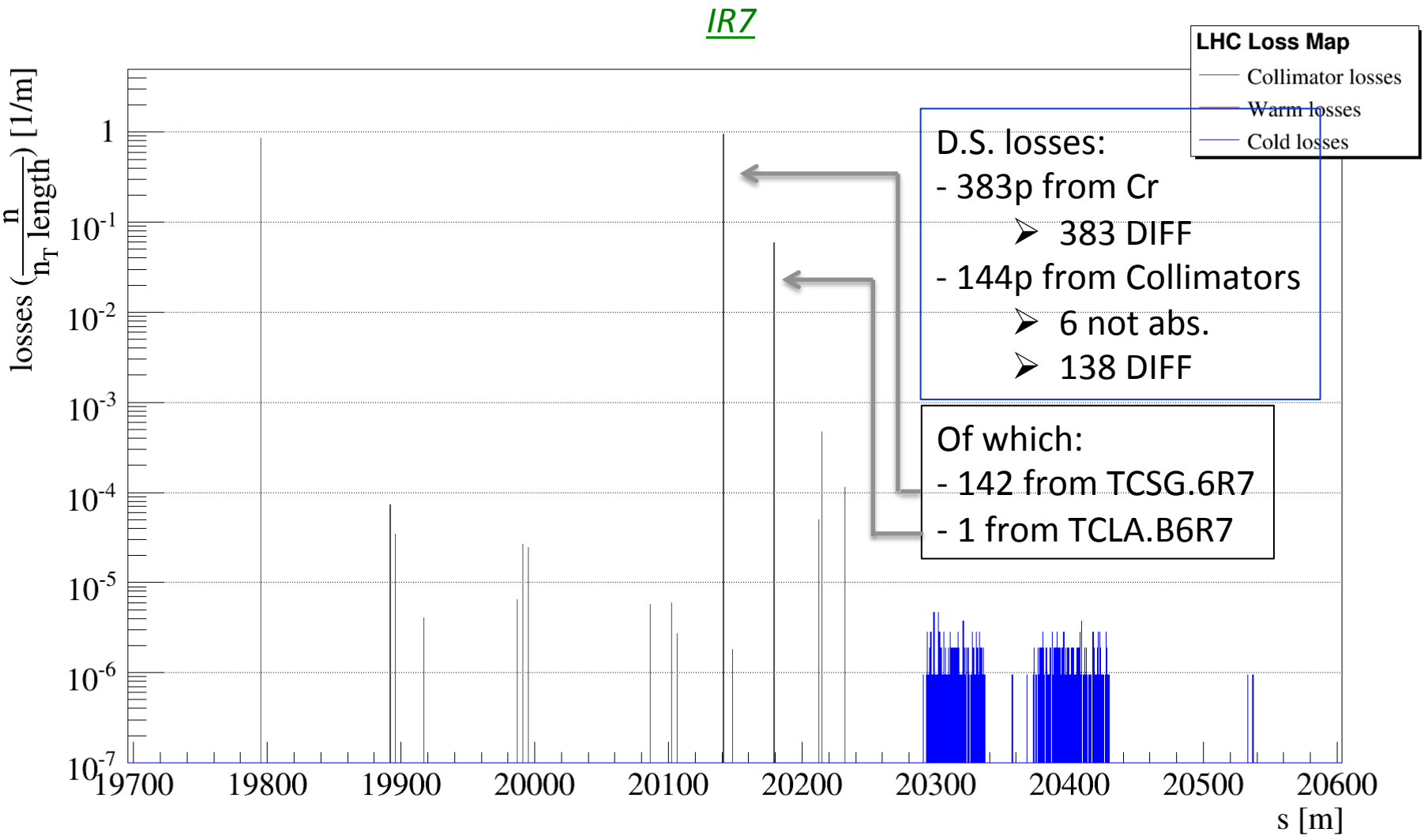
Crystal @ 6σ, placed at TCP.A6L7 location. TCSG used in IR7: 6R7 @ 7σ
(stat ~10e6 p)



“Debugged” results

Particle by particle analysis after the bug correction, second possible location for Cr installation

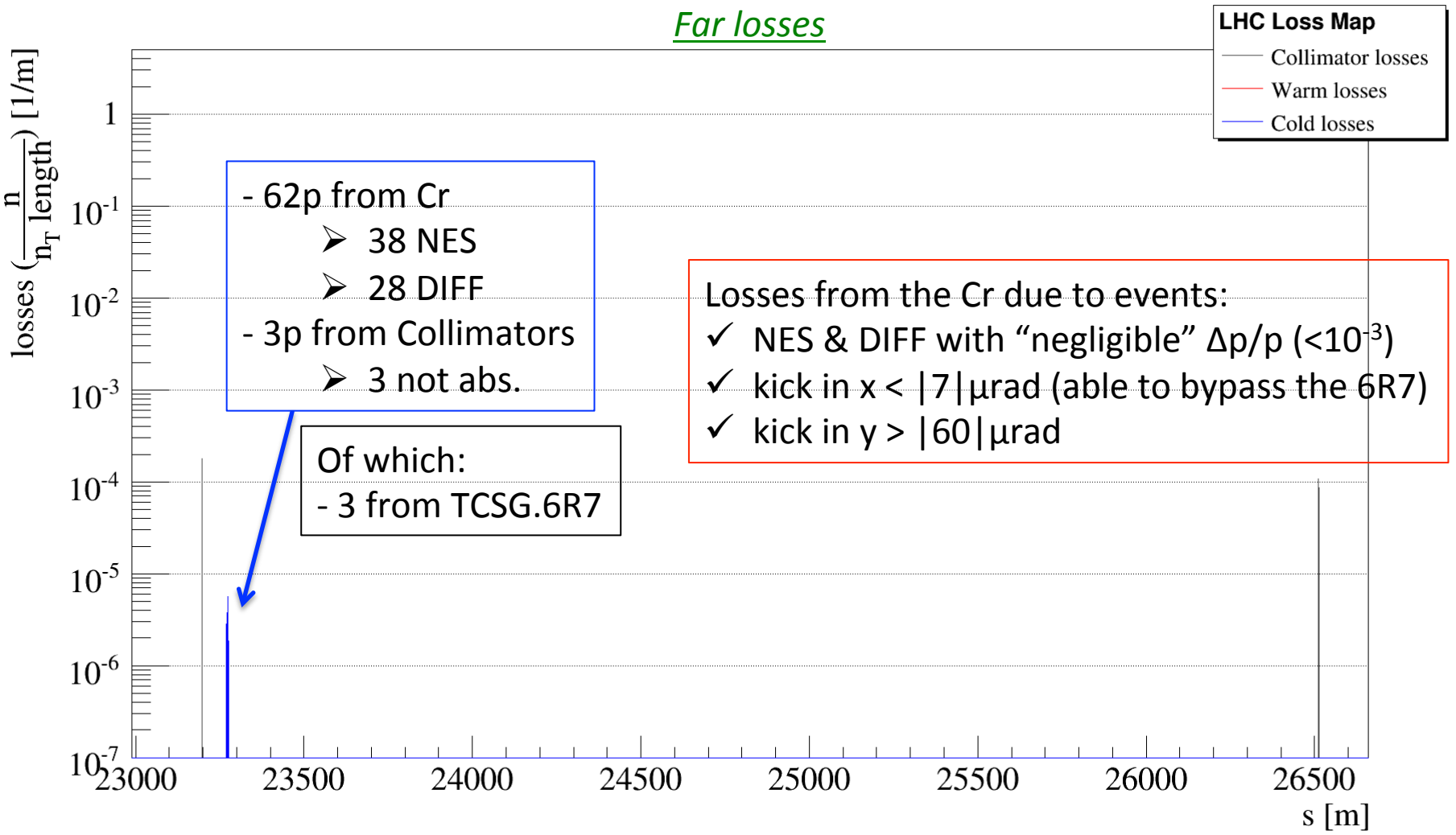
Same boundary condition with respect to the previous slide



“Debugged” results

Particle by particle analysis after the bug correction, second possible location for Cr installation

Same boundary condition with respect to the previous slides



Conclusions

- ✓ *Implemented and debugged new output files:*
  - now possible to make the "history" of each simulated particle with a post analysis (either for crystal assisted or standard collimation)
- ✓ *Checked all the possible interactions type in the crystal:*
  - reasonable level of accuracy for the coherent events for this stage of studies, but further improvements are needed for simulations realistic as much as possible
  - preliminary check of the energy loss due Diffractive events performed doing a comparison with the scattering routine of SixTrack, more detailed studies are needed
- ✓ *Fixed few bugs not relevant for SixTrack functionalities:*
  - crucial to understand what's happening in the crystal (interaction and kick experienced)
- ✓ *Fixed a relevant bug:*
  - energy loss in the crystal given back to SixTrack
- ✓ ***New results with the debugged code much more realistic from a physic point of view***
- ✓ *Next steps:*
  - detailed cross-check of the non coherent events in collaboration with the FLUKA team
  - to preform simulations with crystal in different orientations
  - full comparison of a complete loss-map simulations, between the SixTrack scattering routine (using a "standard" 3mm long Al as primary collimator) and the crystal scattering routine (using a 3mm long Si in amorphous orientation as primary collimator)