CEI section meeting 08-08-2024

Present: Chiara Antuono, Xavier Buffat, Elena de la Fuente Garcia, Lorenzo Giacomel, Dora Gibellieri, Miguel Gonzalez Torre, Fredrik Grønvold, Gianni Iadarola, Christophe Lannoy, Szymon Lopaciuk, Elena Macchia, Elias Métral, Konstantinos Paraschou, Josephine Potdevin, Giovanni Rumolo, Luca Sabato, Carlo Zannini

Online:

Excused: David Amorim, Lotta Mether, Nicolas Mounet, Leonardo Sito, Roxana Soos

Scientific secretary: Chiara Antuono

General information (G. Rumolo)

Communications and Arising matters

- New arrival and departures from CEI
    - Bernardo Abreu Figueiredo as a doctoral student with Gianni
      He will work on Xsuite, in particular “Development of computing techniques for accelerator physics in the Xsuite framework’’
    - Josephine will leave on 15th of August and will move to a new phase of her career evolution
- CERN Announcements for the Locks and Keys service and the Main Reception (email from Stéphanie)
    - The Locks and Keys service is moving to Building 73 (link)
    - The new CERN Community Support Centre (link):first line of support for all CERN services and activities that were previously housed in Building 55. These services will all be centralised on the ground floor of Building 33
- IPP meeting on 2nd August
    - SPS recovery after magnet exchange (Kostas)
        - Scrubbing and performance recovery has been analysed by Kostas for

the cases of magnet exchange in the SPS (4 times in 2024)
    - Dynamic pressure rise is higher in the region of the exchanged magnet when it is an MBA (non coated spare) than when it is an MBB (coated spare). However, we know that MBA scrubs faster (higher SEY threshold for e-cloud build-up)
    - In all cases, pressure and beam conditions can be efficiently recovered in about half a day, especially if pressure interlock thresholds are temporarily relaxed around the region of the exchanged magnet to allow for faster scrubbing
  - BCMS beams (Foteini and Sofia)
    - Low emittance
      - BCMS beam highly optimized along the injector chain to produce the lowest possible emittance at a given intensity, space charge in the SPS is important for this beam – as expected
      - 20% decrease of emittance at LHC injection when comparing to standard and BCMS variants (as expected). 10% by the end of injection process and 10% at the beginning of stable beams. It results in 5% gain of integrated luminosity
      - The emittance growth on the injection plateau has a part with clear e-cloud shape and a part that equally affects all bunches (consistent with IBS globally, but the model would expect only in H while it is observed shared in H and V)
    - Low tail
      - Low tails version has been used for LHC physics productions: tails made more gaussian by using scaping in the PSB (tails come also from Linac4) and optimizing PS transition crossing
      - Lower q-values are measurable at LHC injection
      - The impact of tails on losses at collision seems to be evident both in MDs and in operation
  - **Elias** asks which one we are using now. Giovanni answers that is the BCMS-low tail.
- Injectors schedule v2.1
  - No dedicated nor long parallel SPS MDs for three weeks due to HIRadMat

run and then LHC MDs
    - Vacuum problem in sectors 1and 4 appeared when no FT beam in the SPS supercycle
    - **Gianni** asks when it happened in the cycle and **Carlo** and **Giovanni** answer that it was at flat bottom and **Carlo** adds that it was there and was very strong also with operational cycle. **Giovanni** adds that the vacuum spikes look like sparking.
    - **Gianni** suggests that the first attempt could be to change the orbit, make it on purpose worse and see what happens. **Carlo** says that they tried some corrections but it did not help.
    - **Kostas** and **Gianni** remind that in 2022 during the scrubbing they had something similar.
    - **Elena** adds that the same happened during her night MD (the night before IPP) with operational beam.
    - **Gianni** asks if it happens also if you dump the fixed target beam right after the injection, so if you have the cycle with everything pulsed but no beam. **Kostas** says that it happens anyhow.
    - **Giovanni** suggests that it is important to understand and investigate that in more detail.

- High intensity beams in the SPS

    - 938 MHz HOM coupler breakage in cavity 3 of the 200 MHz system in the SPS lead to a limit to 2e11 p/b for LHC beams in the SPS
    - Following LMC of last week, it was decided that:
        - Beams for LHC MDs are much below the LIU specs and can be considered safe. They will be therefore prepared in the injectors
        - HiRadMat has accepted to run with 1.9-2.0e11 p/b this week and the next one, therefore stays within the current limit o LIU MDs can take place at the end of August with the full LIU beam (4x 72b with 2.6e11 p/b injected) but without acceleration to 450 GeV
        - Full-blown LIU MDs including acceleration will gently resume after the week of the Jeûne Genovois, when it is expected that more information on the post-mortem analysis and miscellaneous inspections will be available and the RF team will be also available in case of further failures of this type
        - LIU ramp up might benefit from the possible Run 3 extension into 2026,

for which a decision will be taken in September.

- 2024 LHC schedule v2.0
    - Physics production with very good availability
- LHC Lumi
    - LHC integrated lumi finally back on target following good production with high availability and large fraction in stable beams (>60%)
    - Nice emittance at the beginning of stable beams (~1.7 um) and now great agreement between BSRT and lumi form experiments after BSRT calibration
    - **Giovanni** asks highlights from the first MD schedule. **Gianni** answers that next week they should publish the final version and from the section there will be:
        - Tune shift of Kostas
        - Stability MD
        - E-cloud behaviour with negative octupole polarity at injection

Modeling of coasting beams in X suite (G. Iadarola)

Gianni presents the modeling of coasting beams in Xsuite which was mostly triggered by Hannes and his team for space charge studies for the PSB.
Elias asks if it is similar to the coasting beam analysis in PyHeadtail. **Gianni** does not think it is the same, essentially because Xsuite mainly thinks in terms of particles than bunches.

Gianni explains the concept of particle slippage and its impact on collective effects in beams. For bunched beams, the momentum of the particles oscillate around an equilibrium momentum, resulting in the same number of turns over a given time interval, allowing the turn index to be used as an independent variable in simulations. In contrast, for coasting beams (such as those in systems like CLEAR, ELENA, or when beams are stored without RF capture) particles keep their momentum deviations indefinitely, leading to varying revolution frequencies and different numbers of turns over the same time interval. He shows an example to make it clearer by comparing three particles having three different revolution frequencies. It shows clearly that over a given time interval, the three particles

perform a different number of revolutions.
Gianni explains that in conventional tracking simulations we use the longitudinal coordinate s and the turn number as independent variables. At a given simulation stage all particles have travelled the same distance. However, with coasting beams it is not the case, and this results in a problem for collective effects, where, it is important to know where particles are at the same time in order to compute the forces.
Gianni, instead of change the simulation approach and use the time as independent variable, decided to devise a method which allows to reuse without changes our conventional simulation modules while achieving the required synchronization for collective effects. The implementation turns out be quite simple, confined in a dedicated module keeping Xsuite extendible and maintainable.
He starts describing the simulation method, starting with the introduction of a reference normalized simulation speed (typo in the slide!). With the convention used for the reference speed β_sim, the particles can be too slow (skip a turn) but not too fast (arrive twice in a turn).
Gianni introduces the concept of “virtual particle” as the particle moving at the “reference speed” β_sim, on the reference trajectory to generalize the concept of turn and introduced the concept of frame. The mid point of each frame depends on the s position and is defined by the passage of the virtual particle at the given s and defines the time frame.
It acts as the turns of the bunched beam case: For each frame we track particles around the ring
We compute forces due to collective effects only for the present frame
We need to ensure that at each collective interaction we pass to the collective elements all particles arriving during the present time frame (independently of their number of performed revolutions)
For this purpose, we install in front of each collective element, a “SyncTime” element
The SyncTime takes care of disabling particles that fall out of the current time frame (arrive too late) and re enabling them at the following frame
Gianni explains the method of simulating the frame, for instance for the frame F0:

- We track particles from the start of the ring to the first SyncTime elements
- Some particles are found to arrive too late, outside F0(s) →these particles are deactivated
- The active particles are taken into account by the collective element
- The active particles are tracked to the next collective location where the same

procedure takes place SyncTime Frame n = 0

- Tracking continues to the end of the ring
- In the following frame F1, at the start of each turn, the ζ coordinate needs to be updated and the articles that arrived too late in F0(s) are now reactivated for F1(s). The same procedure explained for F0 is repeated for F1 and so on.
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Gianni continues with the maths which justifies what illustrated and told him quantitative adjustments that were needed. More details about the maths are in Xsuite Physics Guide.
A central role is played by two propositions on the arrival times and gives a glimps of the proof of the propositions and shows in slides 34 how the proofs justify the simulation procedure (typos are present. Noted by Elias and **Gianni** will update the slides.).
Gianni explains the definition of the ζ coordinate for coasting beam, where the time withing the turn (which is there for bunched beam) is substituted by the time within the frame. From the definition of ζ, one important implications is the need of updating ζ at the start of each turn and indeed he shows the updated equation. Furthermore he shows the proof for the condition on ζ for the arrival time of a particle to be in the current frame Fn(s), and the update equation for ζ when particles arrive out of the current frame.

Gianni shows two numerical tests on:

- The PSB case tracking a beam with an artificially large momentum spread we can clearly see that different particles perform a different number of revolution over the simulated time
- Tracking a beam with no momentum spread, and introducing a perturbation on the beam line density. The perturbation is observed at each turn and the extracted revolution frequency agrees very well with the expectations
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Gianni concludes remarking that:

- A method has been devised to simulate coasting beams with tracking codes that use the reference path length s as independent variable
    - The different revolution frequency among particles is accurately modeled
- The method has been implemented in Xsuite:

  - No modifications in the conventional tracking elements
  - Time synchronization of particles is achieved by installing dedicated SyncTime elements in front of the collective elements (e.g. space charge, impedances)
- Planned applications include:
  - PSB with space charge (benchmark of coasting beam experiments)
  - Fermilab IOTA ring with space charge
  - ISIS-2 stability studies

Comments and discussion
Elias suggests checking the debunching time and using it as a reference for comparison (the time it takes for the bunch to become fully coasting)
Elias asks how many additional turns are needed if simulating coasting beams for 500 turns. **Gianni** answers that you would need 500 turns of the nominal particles plus an additional 10%.
Giovanni asks about the interaction with impedance. **Gianni** answers that the first turn will be unphysical as usual. Either you know that the beam is in steady state at the beginning, and you can precompute yourself and initialize it. However, this is the same even for a bunched beam in a multiturn simulations you will have the same issue.
Elias underlines, for clarification, that with such method the order of the particles is always kept, a particle behind one particles will always stay there and **Gianni** confirms.
Elena summarizes, as a clarification, that the method uses a special synchronization element that you put in front of the collective effects element and you apply the correction to the particles. **Gianni** answers that you actually stop the particle that is going too slow and neglect it at that moment but you remember of it later.

AOB and end of the meeting

The next meeting will take place the 15th August, in which Luca will present the e-cloud studies for FCCee