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Participants: L. Blondel, M. Carlà, L. Giacomel, M. Himmerlich, G. Iadarola, K. Li, L. Mether, E. Metral, N. Mounet, Y. Papaphilippuou, L. Sabato, K. Skoufaris, G. Skripka, M. Taborelli, F. Van Der Veken, E. Wulff.

Symplectic kicks from an e-cloud pinch (K. Paraschou)

Konstantinos presented his investigation on how to model incoherent effects from e-cloud.

- The goal is to modify the kicks on the beam particles as implemented in PyECLOUD-PyHEADTAIL, in order to support long term tracking. This requires the applied map to be symplectic.
- In the case of a static 2D interaction (electrons do not move), the symplecticity condition is verified if the electric field is irrotational.
- This condition is not automatically verified by the PyECLOUD linear interpolation scheme.
- Instead, it is possible to show that the map is symplectic if the fields are computed analytically from a C^1-continuos approximation of the electric potential. This approach can be generalized to time dependent potentials by ensuring the C^1-continuity with respect to space and time.
- The C^1-continuity can be obtained following the "Tricubic interpolation" approach proposed by Lekien and Marsden to find a locally defined polynomial interpolation that yields first derivatives that are continuous globally. A polynomial of the third order is required to have enough degrees of freedom to verify these conditions.
- This tricubic interpolation has been implemented in a Python package:
    - It can use exact derivatives if provided, or use finite differences to estimate them.
    - It has been thoroughly tested to check that it can exactly reconstruct any "tricubic" polynomial when using exact derivatives.
- It can be found in https://github.com/kparasch/TricubicInterpolation/.
- The algorithm has been tested on a realistic electron cloud pinch:
    - The interpolation of the potential looks flawless, the derivative on the other hand can be very noisy due to macroparticle noise.
    - The noise can be effectively mitigated by averaging many pinches.
    - When looking at the transverse plane one can notice that the field changes very sharply. This leads to "wiggles" in between cells. Through undersampling, the bumps get worse. We need to find a way to quantify and control these artifacts.
- Next steps of the studies will be:
    - Check whether the interpolation can be improved or whether the "wiggles" can be quantified.
    - Begin some preliminary tracking in PySixtrack and then move to efficient tracking with SixTrackLib.

- These approach could be generalized for the simulation of other phenomena (e.g. space charge and beam-beam).

Investigation of e-/ion dynamics for very high gas densities: 16L2 regime (L. Mether)

Lotta presented a study investigating the e-/ion dynamics in the presence of very high gas densities (16L2 regime):

- The simulation model considers only beam-induced ionization, but additional electrons and ions may be produced by the interaction of the gas with the e-cloud itself.
  - Electrons in the energy range of 50 – 500 eV have a 50 – 100 times larger ionization cross section than the beam particles.
  - The development of ionization driven by electrons is ongoing.
  - The option to record energy histograms of all particles in the chamber that was recently implemented by L. Giacomel allows to better investigate this effect.
- It is possible to see that the electron energy distribution changes when the gas density increases:
  - For low gas density the energy distribution coincides with the one obtained from the single-species simulation.
  - For higher gas densities the multi-species simulation gives energy spectra that are significantly different from the single-species case (mainly above 10^{20} N_2/m^3). In particular in the multi-species case the electrons have significantly larger energies. This means that a significant fraction of the electrons have energies corresponding to high electron-induced ionization cross-section.
- Also the ion energy distribution changes significantly when the gas density increases. As for the electrons, a significant effect on the spectrum is seen above10^{20} N_2/m^3.
- Comparing the average electron energies at every time step, it is possible to see that for high gas density the energy of the electrons is larger than for the single-species case, especially in between bunch passages.
- These observations can be understood by comparing the electric fields of the beam, electron and ions during a 25 ns interval. It is possible to show that, for high bunch densities, the ion electric field is stronger than the beam field, accelerating the electrons to energies in the keV range.

A study on the e-cloud saturation mechanism (L. Giacomel)

Lorenzo investigated the mechanism behind the saturation of the e-cloud buildup using PyECLOUD simulations.

- At a first glance, it might seem that the electrons space charge field could be able to shield the bunch field. This is not the case. In fact, even at saturation, the bunch field is still two orders of magnitude higher than the electrons space charge field.

- By observing the behavior of the electrons in between bunch passages, it is possible to notice that during the exponential growth the number of emitted electrons exceeds the number of absorbed electrons.
- The saturation takes place because the number of absorbed electrons increases, becoming equal to the number of emitted electrons.
- When the number of electrons increases, the electric potential in the chamber increases. Electrons which are emitted with low energies don't manage to "climb" the potential and impinge back on the wall before the new bunch passage. Because of the high potential, at saturation the electrons concentrate close to the chamber wall. This happens because the initial kinetic energy of the electrons is not high enough for them to reach the center of the chamber.
- The effect of this mechanism can be observed also on the time-of-flight of the electrons (from the moment they are emitted to when they are absorbed). A dedicated feature has been implemented in PyECLOUD to keep track of this quantity. At saturation the average time of flight of the electrons decreases significantly.
- Based on these results it would be interesting to build a simplified model to predict the saturation level → to be investigated in the future.