Questions for the discussion of the 4th ICFA Mini-Workshop at CERN 4th – 6th of November 2019

Thanks to F. Asvesta, E. Renner, M. Titze, M. Zampetakis,

LINACs

- **SC Issues at LINACs**
  - **Critical Issue: Space Charge Neutralization and Rise Time: phenomenon noticeable at low energy, the time for the build-up of the neutralization is measured on the beam pulse. Effect of fast switching elements on the neutralization.**
  - **Less critical but discussion starter: Beam Matching: at 45 KeV and 3 MeV, change of transverse phase advance to accommodate diagnostics, effects on emittance and beam losses.**

Noise

- **Noise Issues with SC Codes**
  - **PIC codes are suffering intrinsically from Grid Noise. How bad is that really?**
  - **In the Frozen, but Adaptive mode, Noise has also been seen caused by the renormalization of the Beam Sigmas. Remedies other than more macro particles?**
- **Symplectic PIC Solvers – Progress and Outlook**
  - **Will this solve the Noise Issue or only part of it?**
  - **What is the progress presently?**
  - **What is the penalty in terms of speed?**

Noise

From **Steve's talk**:

- Problems **Symplectic Space Charge solves**: **Grid heating** — existence of a conserved pseudo-Hamiltonian means no spurious energy growth
- Problems **Symplectic PIC does not solve**: **Particle noise*** — still need many macro particles
- Challenges**: Poor scaling** with number of modes, ~ Nmodes × Nmacro, **parallel performance** tied to AllReduce(), **Force Interpolation** scales with number of modes
- **Gridded Poisson solvers** suffer none of these, but do have the same challenges as a conventional Poisson solver

From **Ji's talk**

- Symplectic integration in long-term space-charge simulation can be achieved by using **gridless** or PIC symplectic space-charge integrator.
- Self-consistent space-charge effects can be included and extracted in **Taylor map by** integrating a DA particle the multi-particle tracking code.
- From the **discussion**: Symplectification of this map could be used for tracking and used as the "frozen" adaptive integrator

Noise

From **Frank's talk**:

- The **3D symplectic SC kick** and the **SigmaMatrix** have been successfully installed into a special MAD-X version.
- Fully **self-consistent adaption** of the effective Beam Sigmas, ("Free" mode), leads to unacceptable high transverse **emittance blow-up** due to **noise** from limited number of macro particles. **"Periodic" mode** reduces noise this
- Attack the **noise problem** as one of the serious limiting issue in all modes.
- Allow for **distributions different** from **Gaussian**.
- Include the 3D symplectic SC kick into **PTC** and **NormalForm**.
- From the **discussion**: Validity of **"Periodic" mode:** Yuri said that if the distribution is matched (non-linearly!) it should be quasi-stationary and can take into account slow emittance growth

From **Adrian's talk**:

- GPU-accelerated beam dynamics suite based on SixTrackLib and PyHEADTAIL allows > 400× speed-up for single-particle physics, non-linear single-particle and SC physics benchmarked
- Allows beam loss: resonance diagrams for SIS100 + magnet errors +SC (SIS100 see **Vera's** talk)

General Issues II

- **SC Compensation**
  - **Recent developments, feasibility**
    - From **Eric's** talk:
      - **Demonstrated** for the first time in detailed simulations that placement of a **sufficient number of electron lenses** can **compensate** space charge effects.
      - Plans for e-lens **experiments** at **IOTA**
      - From the discussion: Issue with **beta-beating** with limited number of lenses
- **Limits of resonance compensation with space charge**
  - **Limited by tune spread itself?**
  - **Experimental experience?**

General Issues II

- **Interplay of space charge with other Effects**
  - **E.G. IBS, electron cooling**
    - From **Angela's talk:**
      - **MAD-X** module **extended** (for low-energy ions, coasting beam) and **debugged**
        - » **Comment**: What is the correct Log factor to put into the IBS theories?
      - **IBS** has a **strong effect** on **emittance growth** in **LEIR**
      - Analytical **IBS calculations reproduce measured horizontal** but **not vertical emittance growth.**
      - **Ongoing** investigations on the instrumental **effects** of the **IPMs**
    - From **Michalis' talk**:
      - Understand the **Kinetic theory** to implement it into an efficient tracking code.

General Issues II

- **Beam loss in simulations**
- **Space charge or multipole error driven resonances**

  How to distinguish experimentally?
- **Importance of non-linear model**

  Remnant fields?

  - From **Foteini's talk:**
    - Simulations including space charge **qualitatively agree** with the measurements,
    - To get better agreement it seems that we are **missing non-linear components** in the lattice
    - From **discussion**: Remnant field of octupoles corrected, contribution? Fringe-fields? 3D PS magnet modelling (talk of **Alex**)
  - From **Elisabeth's talk:**
    - Space charge simulation for post-LS2 operational scenarios ongoing **using py-Orbit. (**ISOLDE beams, chromaticity correction, transverse painting optimization, working point scans, different cycles,…)
    - From **discussion**: Confident about comparative performance of simulations, but need to benchmark with measurements with LIU beams after commissioning.
  - From **Jeff's talk:**
    - Space-charge emittance growth traced to 2Qy resonance, need to improve modeling of Booster optics (signature of other resonances on losses) and correction of the half-integer resonance

General Issues II

- **Beam loss in simulations**
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  - From **Jeff's talk:**
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  - From **Vera's talk:**
    - Tracking with space charge and a SIS100 model including magnet errors and misalignments (+ quadrupoles in the future), for WP optimization studies
    - **From the discussion: sorting** or rely only in **compensation**.

General Issues II

- **Emittance measurements for beams with large dispersive contribution**
  - **Experience, de-convolution**
  - From **Haroon's talk:**
    - Very fast beam blow-up as the beam is brought closer to the **integer tune** (from simulations **50 turns**, evolution not observable with WS, maybe BGI)
    - Agreement between final bunch profiles measured and simulated
  - From **Malte's talk:**
    - **Dispersion amplified due to SC** close to the integer
    - From the **discussion**: Dispersion should be a global quantity not a single-particle one, care should be taken about its definition when SC is included
  - From **Hampus' talk:**
    - Beam Gas Ionisation Profile Monitor (IPM) enables non-destructive beam profile monitoring throughout the full cycle and Turn-by-turn at injection useful for commissioning as matching monitor

General Issues II

- **Coherent vs Incoherent**
  - **regimes, limiting cases**
    - From **Giuliano's talk:** Can distinguish coherent/incoherent regimes based on **"Debye length" analogy** for beams with SC
    - From **Dong-O's talk**: (Mode) Instabilities are instabilities of eigenmodes of Vlasov-Poisson model would better be called **mode parametric resonances** to distinguish them from **single particle parametric resonances**
    - From **Shinji's talk**: Is it 8Qv=50 or 4Qv=25? Check at PS experimentally, synchrotron frequency dependence.
    - **From Elias' talk:** Many mechanisms influencing the TMCI are relatively well understood but still some work needed to understand better the effect of **space charge**, in particular in the **"long-bunch" regime**

SC issues at other accelerators than at CERN

- **Modeling and experimental experience with intrinsic power converter ripple, synchrotron motion and real noise**

  In other accelerators that at CERN?

  - From **Hannes' talk: Different regimes:** Slow synchrotron tune + fast modulation: Trapping can occur on resonance sidebands (at multiples of Qm), resonance sidebands can enhance emittance growth and increase halo size, Fast synchrotron tune + slow modulation:Trapping can occur on resonance sidebands (at multiples of 2 Qs), particle excursions determined by amplitude of external tune modulation, **Fast synchrotron tune + moderate modulation in the SPS:** Scattering can occur on resonance side bands (at multiples of 2 *Qs*), chaotic motion dominates and particles diffuse between sidebands if the external modulation depth is large enough, tail population and emittance growth can be

SC issues at other accelerators than at CERN

- **H- injection chicane experience**

  Operational experience close to half-integer (eddy current induced beta-beating)

  - From **Hideaki's talk:…**