4th ICFA Mini-Workshop on Space Charge
November 4th – 6th, 2019
CERN (Geneva, Switzerland)

Minutes of Q & A: Wednesday, November 6th, 2019 - morning session

reported by Elisabeth Renner

1) Session: Special topics - Part II

Michaelangelo L. Mangano (CERN, TH Department): Why we need the HL-LHC

- **Yannis** and **Elias** ask, what the advantage of a center of mass energy of 100 TeV is, compared to e.g. 30 TeV or 80-90 TeV.
  - **M:** A center of mass energy of 100 TeV allows to give conclusive 'yes/no' answers to some questions. This exclusion and confirmation of some theories would not be possible for e.g. 50 TeV. It is not the case, that physicists would search for a particle at 90 TeV. However, by colliding with 100 TeV the production rate at 2 TeV is increased significantly. That means, for the stated example of a 2 TeV event (e.g. WIMPs), an operation at 80-90 TeV would hence require higher luminosity to achieve the same statistics due to the reduced production rate compared to 100 TeV.

- **Giuliano** refers to critical comments about FCC, which state disproportionally high costs, criticize the fact that for LHC many things were promised but only the Higgs delivered and mention wrong results due to detector malfunction.
  - **M**: It must be corrected, that it was not a detector malfunction but statistical fluctuations. To address the issue of the Higgs being the 'only' discovery, the answer is that the key lies not in detecting but in understanding the Higgs (e.g. is it composite?) and this exploration may lead to surprises. A comparison can be drawn to gravitational waves: with the measurement of gravitational waves physicist have a new tool of studying the universe. Similarly, by studying the properties of the Higgs one has new ways to study the standard model and beyond. This exploration needs to be appreciated.

- **Ilias** asks about the larger systematic errors for Z-photon events (slide 20).
  - **M:** This plot should be considered more as an example. The error bars in the plot on slide 20 are based on today's analysis and he assumes the corrections to be conservative. On the one hand, extra luminosity results in improved statistics, which is displayed in the plot. However, the numbers in this plot e.g. do not consider that based on this higher statistic also the analysis methodology could be changed.

2) Session: Machine Modeling Part I

Alexander Huschauer: Modelling Main PS Magnets

- **Giuliano** asks whether the presented field measurements were conducted on a separate magnet and implies that there is no knowledge about the differences to the magnets in the machine.
    - **Alexander** confirms this. The measurements were conducted on the measurement magnet, a separate magnet used for measurements (not a reference magnet). Alignment error studies were conducted for this one magnet, a distribution created and assumed that it is similar for the magnets in the machine.

- **Vladimir** suggests conducting measurements on chromaticity to find the sextupole by assuming that all the magnets are similar.
    - **Alexander** confirms that this is what has been done, but that the sextupole in the magnets could not be retrieved.

- **William** asks about the confidence of the settings for the pole face windings used to adjust tunes and chromaticity.
    - **Alexander** points out the complexity of the circuit and explains, that the pole shape has a narrow and a wide air gap. The obtained field characteristics depend on how the pole face correcting coils are powered. If operated close to the bare machine without large excitation, one is in the linear regime. When operating with different working points, one can get a pronounced wave in the nonlinear chromaticity. This could lead to a change from positive to negative chromaticity within the dp/p of the beam.

- **Hannes** asks about the impact of remnant fields and on how the chromaticity behaves as a function of energy.
    - **Alexander** shows recent measurements of the dipole and quadrupole components of the PS combined function magnet as a function of energy (upper left plot in appendix slide 27), which – due to remnant fields - exhibit a discrepancy between measured and simulated data at low energy (up to 2000 A). He furthermore mentioned that measurements of the sextupolar component as a function of energy are currently not available.

- **Giuliano** refers to the simulations regarding the beta beating for different configurations and asks whether related measurements are planned.
    - **Alexander** confirms that repeating measurements to explore the whole tune space and benchmark simulations would be interesting.

- **Shinji** asks about the reason for the interest of the optics around the integer tune.
    - **Alexander** explains that there are certain beams, for which the best working point is a low working point (e.g. horizonal around .15). In the presentation by Haroon Rafique, an emittance blow-up at .15 could already be seen due to the control with the low energy quadrupoles. Increasing the intensity further might lead to beam loss at injection.

Michele Carla: Non-linear model of the SPS main dipoles

- **Alexander** asked about **Michele's** experience with the impact of the slicing on long-term tracking times. He mentions his own experience of removing the slicing for the PS simulations due to the additional integration time.
  - **Michele** answered that he had never tried tracking, but already e.g. simulating chromaticity results in significantly slower computation times (E.g. calculating the response matrix for three optics versions took approx. two days.)

- **Shinji** asks, if fringe fields are considered (i.e. if all slices are similar).
  - **Michele** is not able to distinguish from his chromaticity measurements between the impact of the fringe fields and the rest of the dipole. He further mentions that the dipoles in the SPS were corrected before installation to have the same integrated field by installing a shim at one end of the dipole. Hence, the field is asymmetric, but this is not distinguished in the model. It is assumed that all slices are the same.

- **Vladimir** asked about measurements regarding the impact of the skew component, mentioning a feedback from skew to normal and vice versa in case of a vertical offset.
  - **Michele** had not tried it so far. New measurements would need to be conducted to address this.

3) Session: Space charge and interplay with other effects

Eric G. Stern: Simulation of Space Charge Compensation with Electron Lenses

- **Elias** refers to slide 16/17 and asks, whether the factor of .73 is the compensation for all the 6 space charge kicks.
  - **Eric** confirms this.

- **Elias** asks about the meaning of full compensation (tune spread = 0?) and the mechanism of the shown emittance growth in that at case?
  - **Eric** refers to a presentation of Olivier Boine-Frankenheim in last year's workshop, showing that electron lenses act as a perturbing kick (essentially lattice error) and therefore drive a resonance itself. **Vladimir** and **Shinji** add, that whereas only one lens could compensate space charge, it would introduce strong beta beating. Therefore, many electron lenses are required.

- **Stephen** asks to specify lattice / error settings for the presented tune footprints on slide 25.
  - **Left:** Lattice without error. Tune footprint crosses all resonance lines but no detrimental emittance growth due to the perfect lattice. **Right:** Compensation of lattice with errors.

- **Stephen** asks if the space charge compensation compensates a linear error (like a corrector quadrupole) or space charge.
  - **Eric** thinks of it as if the lattice error creates a bump on a smooth surface and the compensation smooths it out. However, it is difficult to give an answer as a theoretical explanation is missing.

- **Yannis** asks about specifications of the electron lens (e.g. integrated current).
  - **Eric** points out, that it is a toy lens. In this example, for chosen lattice and beam current, the full compensation would be for around 10 Am (to be rechecked if per lens or for all).

- **Giuliano** asks about the impact of any closed orbit distortion, referring to a resulting feed-down effect of non-linear components of the lens in such a case (see Malte Titze's presentation).
  - **Eric** states, that in this example, the closed orbit is set to zero.
  - **Angela** mentions that correctors can be set to make sure beam passes electron lens on-axis and compares it to the electron cooling in LEIR.
  - **Eric** refers to talk on Tuesday in which hydrogen jet was used to compensate space charge, which is self-centering.

- **Shinji** asks about the possibility to make a matched beam distribution with space charge with Synergia.
  - **Eric** states that he can make a matched distribution with compensation elements, but there is currently no way of matching with space charge. It has been planned for a while, but it is not clear whether there is a matched solution with high space charge.

Angela Saa Hernandez: Space charge and intra-beam scattering effects in LEIR

- **Yannis** refers to the presented emittance dependence on intensity (slide 17, lower plot), in which a difference of approx. 30 % between measured and predicted vertical emittance can be observed. He asks, if beta beating can explain this discrepancy and comments, that it cannot explain the evolution, but a static effect.
    - **Angela:** Beta beating has not been considered so far. It can be included in the model.

- **Michele** asks about the impact of an off-axis passage of the IPM on the obtained IBSIMU results (slide 25)
    - **Angela:** This has not been considered yet.

M. Zampeakis: Modelling of IBS

No questions