WG-A SUMMARY

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Abstract

WG-A took three main themes this year, short term beam loss, instability and space charge and long term beam loss. In the following, three conveners will summarise each theme.

BACKGROUND

At this workshop, working groups were asked to consider the following general questions:

- Is it possible to understand the beam losses in detail and to predict them?
- What really has to be provided by simulation and diagnostics to make this possible?
- What seems actually feasible/has been delivered?
- If a detailed understanding of losses would be possible, how would it affect operation/tuning/hardware improvements?
- How important is a detailed understanding for decreasing/limiting the beam losses?

Working Group A was tasked with the topics of Beam Dynamics in Rings. We broke the discussion for rings down into three specific areas:

- Short-tem beam loss – Beam loss in short cycling rings.
- Instability and space charge.
- Long-term beam loss – Beam loss in long cycling rings.

Our consideration of the general questions led us to pose specific questions for each of the three areas:

Beam loss in fast cycling rings

- Are single particle resonances important? If so, to what order do these need to be taken into account?
- Is the beam loss due to coherent (excluding instability) or incoherent phenomena?
- What techniques can be used to mitigate beam loss mechanisms that are independent of intensity? How will such losses be detected?

Instability and space charge

- Do we have a reasonable model of instability including space charge effects? What are the concerns – Emittance growth? Beam loss? Other?
- Can we separate pure space charge problems from impedance related instabilities (incl. electron clouds) in observation?
- How important is it to include space charge effects when we design mitigation methods?

Beam loss in long cycling rings

- Can we define dynamic aperture concept with space charge? Is it a right way to understand long-term beam loss?
- Is it possible to identify the source of beam loss; instability with slow growth rate or resonance coupled with space charge?
- To what energy range must we consider direct space charge effects?

BEAM LOSS IN SHORT CYCLING RINGS BY J. HOLMES

Presentations included:

- R. Macek, LANL, “Understanding Beam Losses in High Intensity Proton Accumulator Rings”.
- K. Seiya, FNAL, “The Status of the Proton Improvement Plan (PIP) at Fermilab Booster”.
- C. Warsop, RAL, “High Intensity Loss Mechanisms on the ISI Rapid Cycling Synchrotron”.

Presentations included from other sessions that had a direct bearing on this topic included:

- H. Hotchi, JAEA/J-PARC, “Lessons from 1 MW Proton RCS Beam Tuning”, Plenary session.
- I. Hofmann, GSI, “Grid Noise and Entropy Growth in PIC Codes”, WG-B with A/C.
- M. Blaskiewicz, BNL, “Instabilities and Space Charge”, WG-A – instabilities.
- V. Kornilov, GSI, “Instability Thresholds of the Head-Tail Modes in Bumches with Space Charge”, WG-A–instabilities.
- S. Cousineau, ORNL, “Status of Preparations for a 10 us H-Laser-Assisted Stripping Experiment”, WG-D.

Response to questions

Question 1: Are single particle resonances important? If so, to what order do these need to be taken into account?

Even in fast cycling rings, low order single particle resonances must be avoided. In addition to integer and half-integer resonances, low (certainly second, third, and fourth) order coupling resonances, and especially sum resonances, should be avoided in choosing operating scenarios. It is important to include the effect of space charge on the tune distribution in choice of operating point. In addition to avoiding low order resonances, correction of the driving terms may be important in certain situations.

Question 2:

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Is the beam loss due to coherent (excluding instability) or incoherent phenomena?

Beam loss in rapid cycling rings can be caused both by coherent and incoherent phenomena. Coherent phenomena, such as space charge forces, must be incorporated when considering beam loss due to resonances, a traditionally incoherent process. However, for a well-tuned rapid cycling ring in which instabilities are avoided or mitigated, effects such as stripper foil scattering or collimation provide the dominant losses. Such losses, due to the interaction of beam with materials, are statistical and incoherent in nature. Other losses in rapid cycling rings involve beam capture and extraction. Such losses can also be regarded as incoherent, although for high intensity beams it may be necessary to include space charge effects in a quantitative description.

Question 3:
What techniques can be used to mitigate beam loss mechanisms that are independent of intensity? How will such losses be detected?

We assume that, in the statement of question 3, mechanisms that are independent of intensity means losses that vary linearly with intensity. We expect such losses to be caused incoherent processes, such as foil scattering or collimation. In the case of foil scattering, beam loss monitors show clearly the sections of the accelerator in which the losses occur, and radiation surveys during maintenance confirm the BLM readings. The best strategy for the minimization of beam loss due to foil stripping is choice of a painting scheme that minimizes foil hits by the circulation beam. Laser stripping is now under study as a long range alternative to beam stripper foils, but the practical use of this techniques is still likely to be decades away.

Other Thoughts and Observations Regarding Beam Loss in Short Cycling Rings

These are issues that arose during the discussion.

- Injection foil scattering/excited H^0: PSR, SNS, ISIS, J-PARC RCS, CERN PSB
  - Understood theoretically and supported by simulations
  - Mitigate by painting to reduce foil hits
- Injected beam capture: FNAL Booster, ISIS, CERN PSB
  - Understood theoretically and supported by simulations
  - Chop beam (inject into bucket), improve RF
- Extraction: FNAL Booster
  - Lose 3 of 84 bunches
  - Cogging to create notch
- Half integer resonance: ISIS, PSR high intensity
  - Understood theoretically and supported by simulations: beam broadening
  - Mitigate by sufficient aperture
- Machine resonances: CERN PSB
  - Understood theoretically including space charge?
  - Mitigate by choice of working point, compensate with multipoles
- Collective instabilities: SNS, J-PARC RCS, ISIS
- ~Equal tune operating point: SNS, J-PARC, CERN PSB option
  - Montague resonance understood theoretically, complicated in practice
  - In SNS, we live with it
- Extraction kicker: SNS, J-PARC
  - Long bunches, coasting bunch not bad model
  - Landau damping from chromaticity, bunching fixes it in SNS
- Head-Tail: ISIS
  - Resistive wall, lack theoretical understanding
  - Correct with feedback damping
- Electron Cloud: PSR, SNS, …
  - Simplified theoretical models and simulations
  - Mitigation: coat beam pipe for low SEY, solenoids, maintain beam gap, bunch shaping

INSTABILITY AND SPACE CHARGE BY Y-H. CHIN

We have been given three questions to discuss on and answer during this session:

Question 1:
Do we have a reasonable model of instability including space charge effects?
What are the concerns - emittance growth? beam loss? other?

Simulation-wise, we have reasonably good models, but still more effects such as magnet non-linearities need to be included. Theory-wise, good progresses have been made, but still more works need to be done for reasonable predictions of instabilities under strong space-charge effects. The beam loss may be more concern than the emittance growth in many cases. Often, instabilities result in sudden large losses of particles and thus may cause intolerable activation of a machine. Unless you stop them immediately, possible emittance growth, another side effect of the instability, may not matter too much.

Question 2:
Can we separate purely space charge problem and impedance related instability (incl. electron clouds) in observation?

If the question is about the resonance creation by the space charge effect in phase space and resulting emittance growth, the impedance related instabilities are generally fast acting (short term) effects, since they may cause sudden losses of large amount of particles. On the other hand, the space-charge related resonance effects are more slowly acting (long term) effects, such as slow growth of

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emittance. In this regard, it may be possible to separate the two effects experimentally.

Question 3:
How important to include space charge effects when we design mitigation methods?

We can somehow expect some benefits from the space charge effect on instability mitigation, in particularly, in low energy rings (anyway, it is already there for free). But, it is hard to predict exactly how much. Setting (or keeping) a large chromaticity is a common way to suppress (or control) head-tail instabilities (e.g., RCS and MR) to some extent. But, it is too risky to give a full rely on them, and it may be better to prepare a transverse feed-back system for case that you suddenly find it indispensable for stable operation of a machine. You can also have a more knob to control beam behavior. In fact, the developments of intra-bunch feedback systems are under way in many rings such as LHC, SPS, PS, MR and others.

Comments by the WG-A convener

At last, but not least, I would like to point out that I was very impressed by a variety of enthusiastic works by young scientists from Europe, US and Asia (China, mostly), in particular, at the last WG-A session on Thursday. Their topics include:

- Microwave instabilities
- Reactive impedance and synchrotron frequency
- Controlled RF noise
- E-p instability
- Emittance preservation
- Intra-bunch feedback system

The time allocated for each talk was modest (15min for each), but it gave them great opportunities to present their beam-dynamics oriented works to experts around the world and to exchange expertise. In my opinion, these beam-dynamic oriented works do not get a fair share of opportunities of oral presentations in large conferences such as IPAC. We should keep this tradition in future HB workshops.

BEAM LOSS IN LONG CYCLING RINGS BY S. MACHIDA

Presentations included:

- S. Gilardoni, CERN, "Long term beam losses in the CERN injector chain".
- Y. Sato, KEK, "Recent commissioning of high intensity proton beams in J-Parc MR".
- G. Franchetti, GSI, "Plan of mitigation on long term beam loss problems at FAIR accelerators".
- E. Benedetto, CERN, "Transverse emittance preservation studies for the CERN PSB upgrade".

Contrary to fast cycling accelerators where intensity is not an issue and power is limited by more fundamental mechanism like foil scattering, we can see that long cycling accelerators still have "conventional problems" although advances for the last decade is enormous and we have much better understanding and cures. We will list some examples of this "conventional problems" below.

- Injection matching: CERN PS, J-Parc MR
  - Vertical injection error is inevitable in CERN PS. It couples with image charge and current.
  - Longitudinal mismatch in J-Parc MR enlarges tune spread after injection.
- Longitudinal bunch manipulation: CERN SPS, J-Parc MR
  - Need control of voltage for either better phase space matching or reduction of beam loss later.
  - Better diagnostics (PS tomography in phase space) in CERN helps a lot.
- Transverse feedback: CERN PSB, PS, J-Parc MR
  - Instability along the cycle in PSB.
  - Headtail instability, injection oscillations in PS.
  - Kicker impedance in J-Parc MR.
  - All can be cured by transverse feedback.
- Better understanding of halo generation: CERN PS, GSI SIS-18
  - Trapping/scattering mechanism coupled with tune modulation was proposed a decade ago.
  - Experimental verification in PS and SIS-18 in 1-D island.
  - Concept is extended to 2-D island around "fixed lines" which agrees experimental observation in PS in 2012.
- Better operating points: CERN PSB, PS, J-Parc MR
  - Better understanding of tune space with space charge theoretically and numerically.
  - Equal emittance removes restriction of Montague resonance.
  - Reconsidering the strength of resonance lines in PS from different view point.
- Resonance correction with space charge: GSI SIS-18
  - Compensation of resonance driving term ($Qx+2Qy=11$) without space charge.
  - Correction works with space charge.
  - Compensation is localised so that it does not affect tune area outside of the resonance.
- Recipe of emittance preservation: CERN PSB, PS
  - Choose bare tune such that beam core will not be suffered from integer resonance.

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