Ramp-up Progress: Challenges, Beam-loss overview, AP Topics

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**Action Items (Summary) / Outline**

- Understand the origin of observed beam loss
  - Model + measurements
  - Linac + ring

- Continue “R&D” efforts
  - Laser stripping + high intensity

- Misc.
  - Fix collimator
  - Calibrate beam loss

+ beam loss and progress related to action items
• The upward climb continues (with some backslides)
  – Still had new tune-up settings with power increases
  – But some periods of simple setting restorations
Power Increase During 2009

- Beam Energy (design = 1000 MeV):
  - Last run in 2008: 865 MeV with 76 cavities
  - In 2009: 928 MeV with 80 cavities (out of 81)

- Pulse length (maximum beam flattop, design = 1000 µs):
  - End of 2008: 625 µs
  - Spring 2009: 700 µs
  - Fall 2009: 825 µs

- For 1 MW operation, parameters were
  - 928 MeV, 60 Hz, 800 µs, 38 (23) mA peak (Av)
Warm Linac Beam Loss
(see A. Shishlo’s talk)

- Some modest improvement in CCL4 this past year
- MEBT collimation helps
  - Simplifies the production setup

\[
\text{Beam Loss} = \int \frac{\text{beam loss signal}}{\text{beam power on target}} \, dt
\]
SCL Beam Loss – Historical Base

- Insensitive to transverse matching
- Degrades with slight RF (longitudinal) imperfections (hence we suspected longitudinal origin to the loss)
~ 50% reduction in losses with initial model based quads (Y. Zhang, resonance avoidance)

Another ~25% reduction with machine specialist empirical quad reduction
  – Maybe more to be gained????
SCL Activation History

*NOT Loss limited*

- Over the last year the SCL activation is not increasing, even though the accelerated charge increased
  - Reduced beam loss helps
Linac Modeling: 60-deg. Resonance
Y. Zhang

- Identified a 60-degree resonance with quadrupole duodecapole errors as a possible loss generation mechanism

- Max. beam emittance in simulation, for an ideal transport line, except with SNS duodecapole errors

See Yan Zhang’s talk
Linac Modeling: Beam Based Comparisons (A. Shishlo)

- Use beam based measurement information to move towards having the right physics in the models
- X-Y coupling from the RF — Preliminary

(See Y. Zhang’s talk)

Orbit different SCL example:

Apply horizontal Kick and compare model and measured differences

Red = model
Blue = BPMs
**Linac Modeling: Code Benchmark**

- **Code benchmark**
  - First gather a good understanding of how the codes compare with each other with simplest modeling
  - Then add increasing order of modeling complexity (space charge, 3-D RF fields, … etc.)
  - Still preliminary stage

Differences between codes for RMS size still exist at 1% level
Linac Profile Measurements (Preliminary)
D. Jeon

- Starting to measure halo using the HEBT scrapers (direct measurement of intercepted charge – thanks to BIG group)
- Promise of $> 10^4$ dynamic range profile measurements
Laser measurements indicate some dependence of profiles (Y. Zhang’s talk)

Bunch Shape Monitor:
• Ongoing efforts measuring the longitudinal bunch length.
• More recent measurements are closer to the design value than one year ago—see A. Shishlo’s talk
Calibrating SCL Loss Using Laser Profile System
Small Fraction of Beam Intercepted by Laser

- Temporal fraction is $\sim 1.2 \times 10^{-5}$ of the $\text{H}^-$ macro-pulse

  $\text{H}^-$ beam

- Spatial fraction is $< 0.05$ of the $\text{H}^-$ macro-pulse

- Total fraction of the beam intercepted by the laser is $< 10^{-6}$
Calibration of SCL beam Loss
Using the laser profile system

- Conditions for 11/23/2009, 14:00
  - 640 kW
  - 600 μs pulse
  - 12 μC/pulse in the linac

- Maximized BLM response to laser
  - Local bump at laser interaction (~20% impact)
  - Increase laser power to max. safe level (~50% effect)
Calibration of Operational Beam Loss

- < $10^{-6}$ of the beam is intercepted by the laser
- Stripped H$^-$ (i.e. H$^0$) produces a BLM response corresponding to $\sim 10\%$ of nominal BLM response during 640 kW operation
- $\Rightarrow 10^{-5}$ beam lost in the SCL ($\sim 4$ W, or 0.15 W/warm-section)

- Could be off by a factor of 10
  - Activation measurements indicate 0.1 to 1 W/warm-section at 1 MW
Ring Efforts

- Beam Loss experience
- Foil Issues
- Understanding Ring Beam properties
- High Intensity Beam Studies
Great strides in loss reduction early on
• Losses are fairly constant, but:
  – Injection / storage times have been increasing (~ 600 to 850 us)
  – Collective effects are higher (10 to 18 uC/pulse this past year)

• Injection losses are estimated to be < ~ 3x10^-4
  – Using controlled spills of small amounts of beam to calibrate
Ring Activation

- Generally the injection losses are increasing with beam power as expected.
  - Activation is also in line with expectations
- A13b is holding steady, despite power increases (J. Holmes will discuss)
Worker Dose History

**Doses for the extended maintenance periods**

- Dose is not increasing over the past year
Ring Foil
(See M. Plum’s talk)

- May 2009 Experienced Foil Failures
  - Had observed foil “fluttering” before

- Formed a task force, headed by Mike Plum
  - Identified and addressed several issues
    - Maintaining a clear path for stripped electrons
    - Use high temperature material for foil holder frames
    - Good contact (electrical & thermal) between foil and frame

- Fall 2009 run used 1 foil, no failures

- Still an area of concern
• ORBIT simulation comparison of measured beam profiles is progressing
  – Compares well for unpainted beam
  – Useful for identifying equipment issues

See J. Holmes’ talk
High Intensity Studies

- Still dedicate beam study time for full pulse length, high intensity studies
  - July 2009 had outside experts participate in a ~ 2 day high intensity effort
  - Now able to do get high intensities with production setup

- Concentrating on understanding the role of the bunch shape on the e-p instability
  - Use of the 2\textsuperscript{nd} harmonic cavity to control the trailing edge shape is an effective way to inhibit the e-p

See J. Holmes talk
The linac delivered the full pulse length. For the first time we verified the Ring can stably store and extract the design intensity of $1.5 \times 10^{14}$ ppp.

- The Linac Beam waveform:
  - produces the design intensity
- The Beam Pulse Extracted from the Ring:
  - Full baseline design intensity stored and extracted
  - No gross instability observed

Current (mA) vs. Time relative to Ring Extraction (turns):

- Losses at 24 uC (1.44 MW) are not terrible
Other AP Group Activities

- Code support
  - ORBT / XAL
- Laser Stripping
ORBIT Code Support
(J. Holmes talk)

- ORBIT is an in-house multi-particle beam tracking code developed in house
  - Used for Ring Beam Dynamics
  - Open Source
  - Used at many institutes (FNAL, CERN, CSNS, J-Parc, ....)

- Many modules (e-P, H0 excited state, 3-D fields)
  - Users develop their own modules

- Developing a modern easier to use/install version (Python-ORBIT)
XAL – Application Programming Infrastructure (Tom Pelaia et. al.)

- XAL has been a key to the successful commissioning and rapid power ramp up progress
  - Open Source
  - Integral part of beam studies
- Envelope beam model, user friendly layer on top of EPICS, …
- Continual improvement / upgrades
- Workshop is planned in May
  - BNL(ESS), TRIUMF, SLAC, FRIB, GANIL
Laser Stripping Effort
S. Danilov, T. Gorlov

- Ongoing support of laser stripping studies

- Planning a next step experiment with an intermediate pulse length
  - 10 µs (vs 10 ns for the initial POP experiment)
  - Believe it may be possible without the use of a Fabry-Perot resonator

- Supporting laser stripping modeling for FNL and CERN upgrade studies

- Hosted a laser stripping workshop at SNS in March 2009
  - Experts from CERN, LBNL, FNL, KEK and industry
Can use the last few SCL cavities to provide a smaller bunch at the proposed laser stripping location in our HEBT.
Operational Experiences

- Scraping and chopping
- Design vs. production
MEBT Scraping

- MEBT scrapers are effective at reducing loss in the CCL, HEBT and Injection dump
- Typically we scrape a few % of the beam
- The MEBT scraper effectiveness varies from tune-up to tune-up (source change)

See A. Shishlo’s talk
MEBT Chopping helps clean the Ring extraction gap
- Depends on the LEBT Chopper quality
- Depends on the source and fraction of the mini-pulse we are chopping

See A. Shishlo’s talk
HEBT Scraping

- Different combinations of scrapers help at different times
  - MEBT scraping dependent
  - Source dependent

- Vertical scrapers work better

See M. Plum’s talk
Production Setup vs. Design Setup

- Beam trajectories are not always flattened
  - Minimum loss is the final arbiter
- Do not always run with matched beams (see Y. Zhang’s talk)
Summary

- **Beam Loss**
  - SCL: Significant improvement compared to last year
  - Not loss limited (yet)
  - Ring is holding steady – manageable losses at injection

- **We are trying to understand what we observe using models**
  - Rate of gaining new understanding < rate of new empirical observations