The SNS Power Ramp-up Experience

August 25, 2008

42nd ICFA
Advanced Beam Dynamics
Workshop on High-Intensity,
High-Brightness Hadron Beams

Nashville TN, USA

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Managed by UT-Battelle
for the Department of Energy

Oak Ridge National Laboratory

Outline

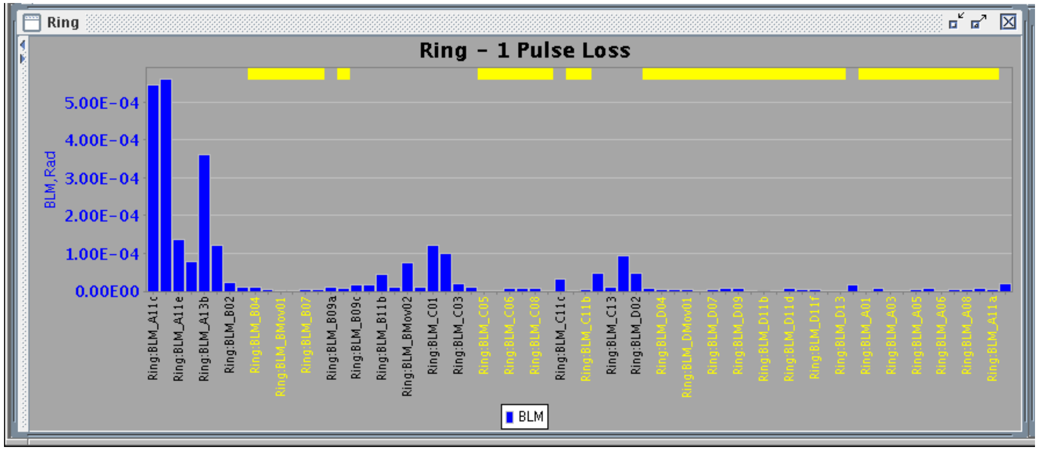
- **Fractional beam loss measurements**
- **Residual Activation levels**
  - **Controlled and uncontrolled**
  - **Predictability**
- **Schedules: beam studies, production, cooldown times**
- **Maintenance worker dose rates**
- **Loss reduction methods: design values vs. empirical tuning**

Fractional SCL Beam Loss Characterization: *(Y. Zhang)*

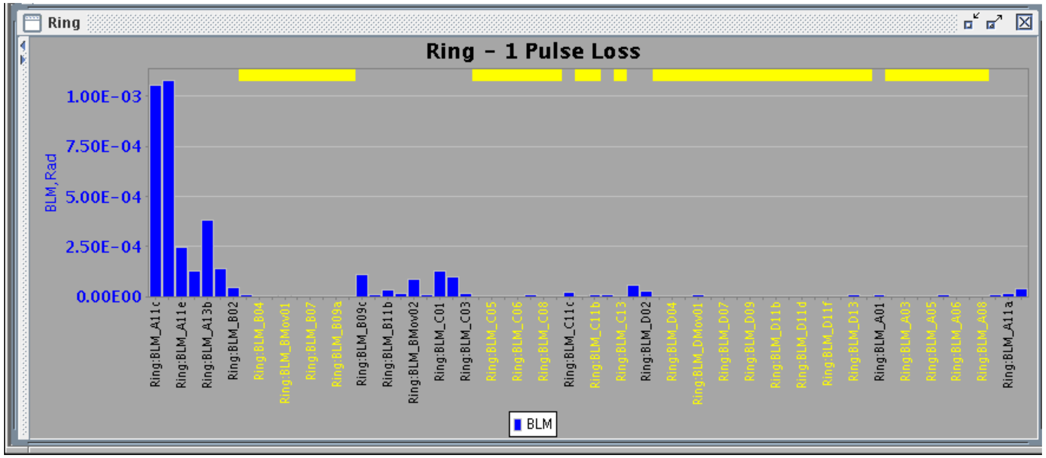
- **Spill an entire (small) single mini-pulse locally in the SCL by purposefully destroying the acceleration: gives nC/Rad calibration**
  - **Medium β: 36 nC/Rad ± factor of 3 variation**
  - **High β: 13 nC/Rad ± factor of 2**
- **Losses during production**
  - **Medium β: < 60 Rad/C,**
  - **High β : < 160 Rad/C**
- **For production conditions we are losing < 2x10^{-6} beam / warm section**
  - **< 10^{-4} total loss in SCL**

	nC/Rad
SCL_Diag:BLM14b	19.6
SCL_Diag:BLM18b	10.4
SCL_Diag:BLM18c	18.8
SCL_Diag:BLM19b	6.4
SCL_Diag:BLM19c	18.7
SCL_Diag:BLM21c	6.8
SCL_Diag:BLM22c	18.3
SCL_Diag:BLM23c	6.2
SCL_Diag:BLM24b	14.6
SCL_Diag:BLM24c	5.8
SCL_Diag:BLM25c	17.3
SCL_Diag:BLM32b	8.3
average	**12.6**

Fractional Beam Loss Charaterization: *Ring Injection – Foil Scattering (2/3/2008)*



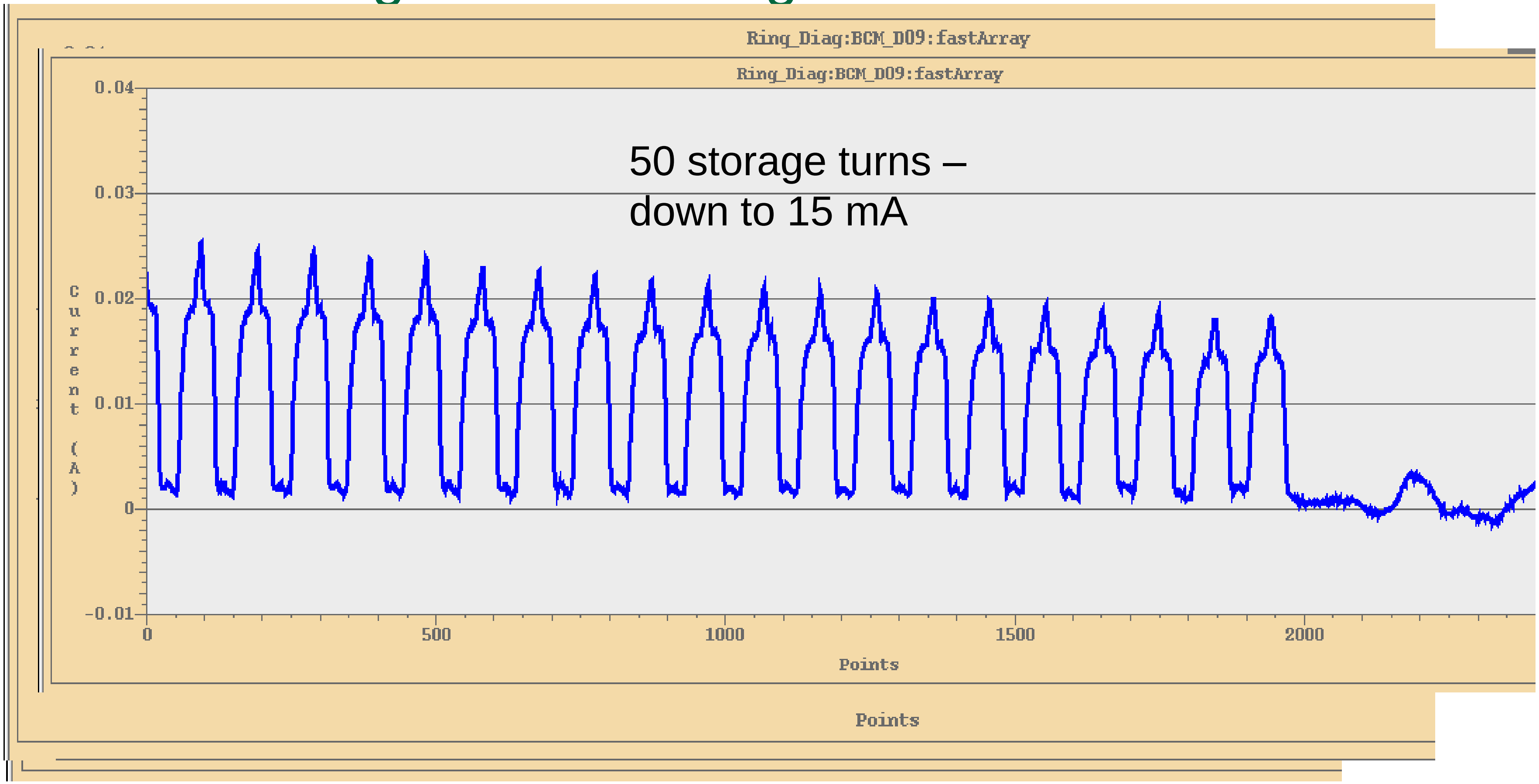
- **1 mini pulse inject, 10 turn storage, with view screen**



- **Production run: 375 turns injected + 50 turn storage**

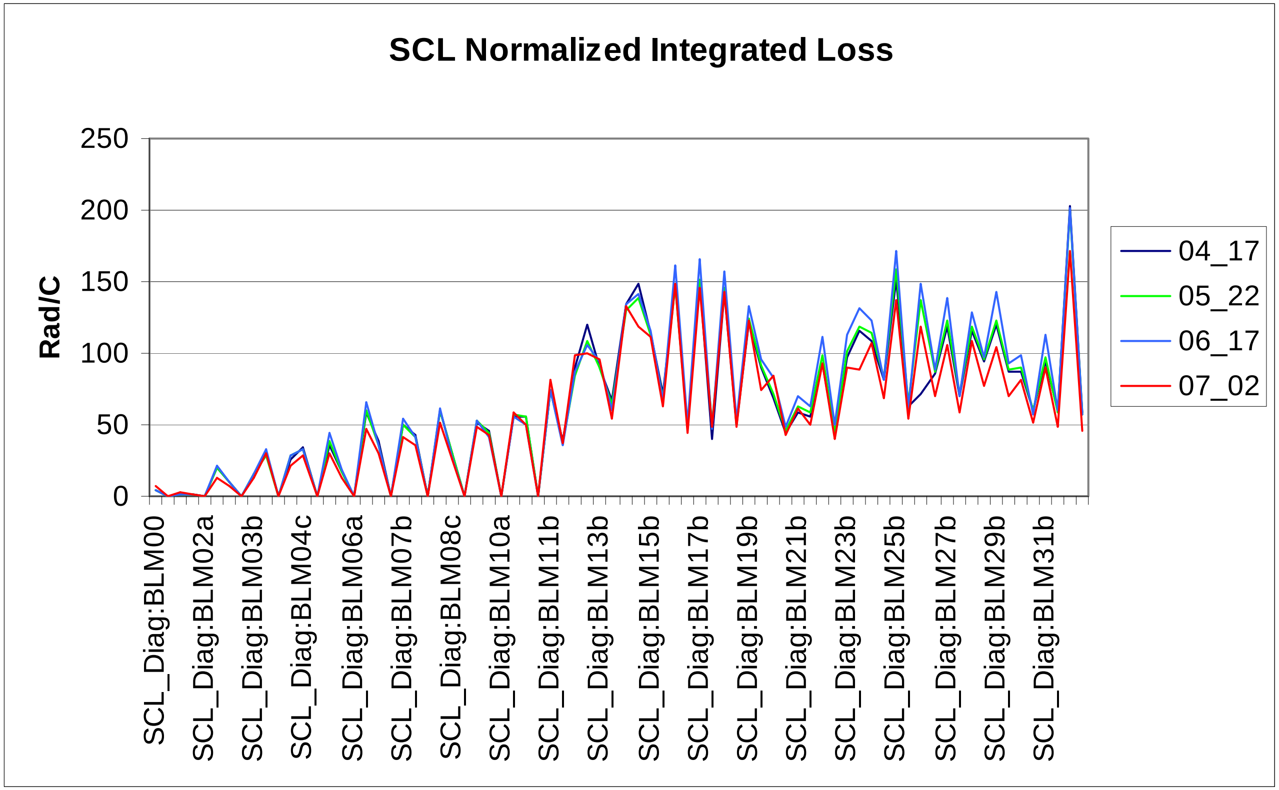
- **Can we learn anything about “foil “scattering losses with the view-screen ???**

Beam Charge vs. Storage with View Screen



- **With 50 turns lose ~ 40% (25 mA decays to 15 mA) of a single mini-pulse (lose ~ .006 μC). Injection BLM is ~ 2.x10^{-3}Rad, or 3.3 x10^{5} Rad/C**
- **For the 7/2/2008 tune-up (1.5x10^{-3} Rad/pulse, 8 uC) this ~ 6x10^{-4} beam loss at the foil**

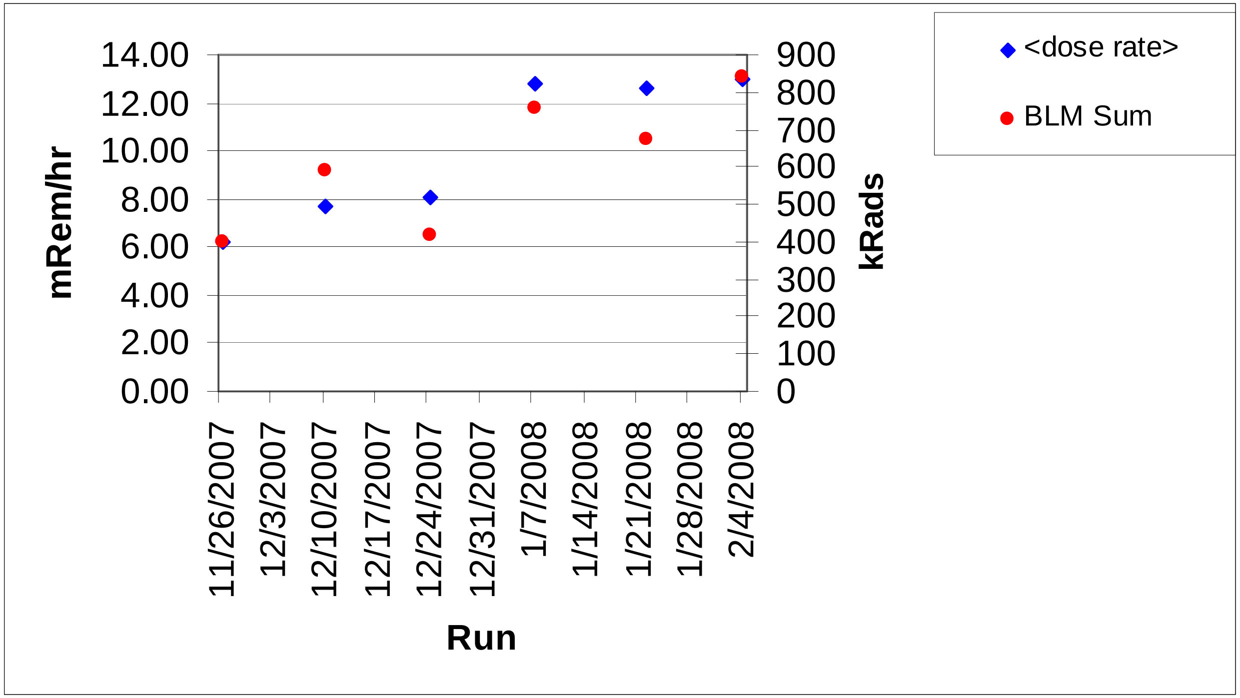
Superconducting Linac Normalized Loss



- **Normalized loss = the integrated BLM signal / integrated charge delivered for a 10 day production run**
- **Well represented by instantaneous BLM signal as well – and can be used to predict residual activation within a factor of ~ 2**
- **Remarkably constant!**
- **Changes that do not reduce beam loss**
  - **Different quad lattices, some RF phase laws, 20 kHz ripple reduction**
  - **Previously looked at gas stripping in CCL**
- **Loss is evenly distributed across the macropulse**

How well do we understand the beam loss / residual activation relationship?

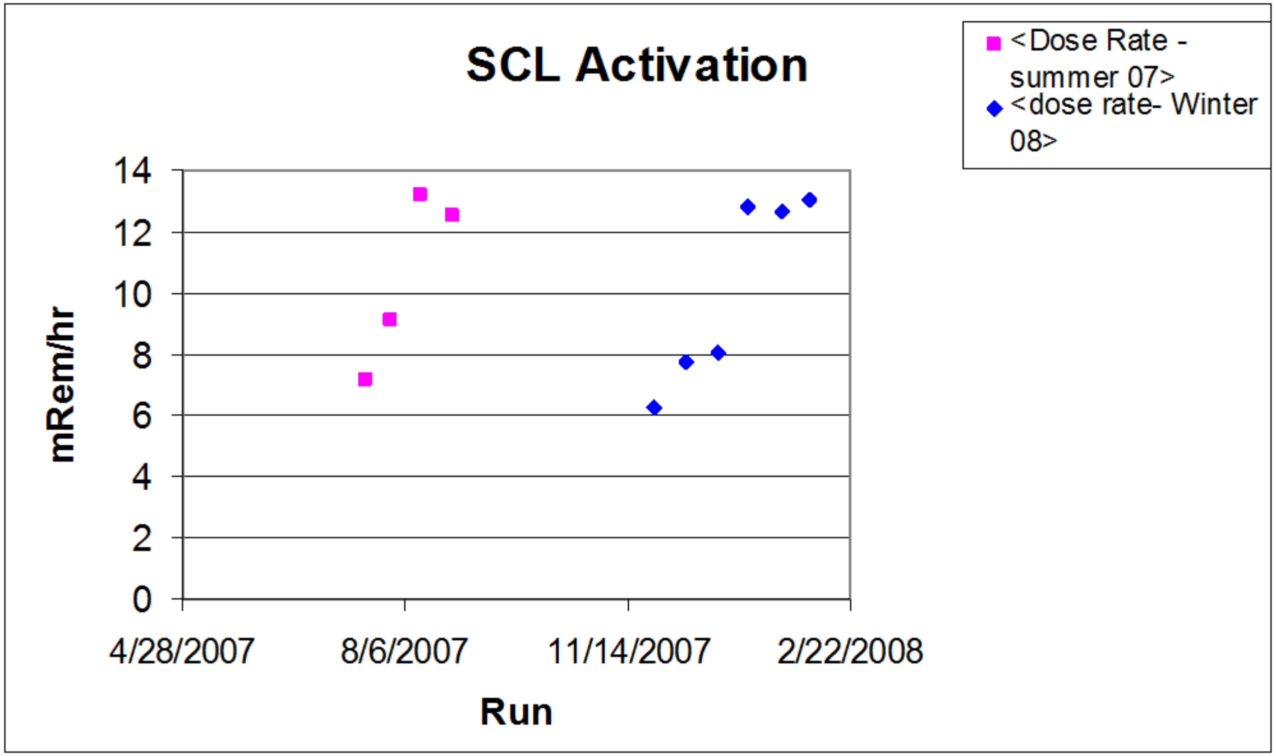
Compare the average activation over the entire SCL with the integrated beam loss over the entire SCL for each of the 6 runs from Nov 07 – Jan 08



- **Overall beam loss went up and dose rate went up**
- **From one run to the next – not always a good correlation**

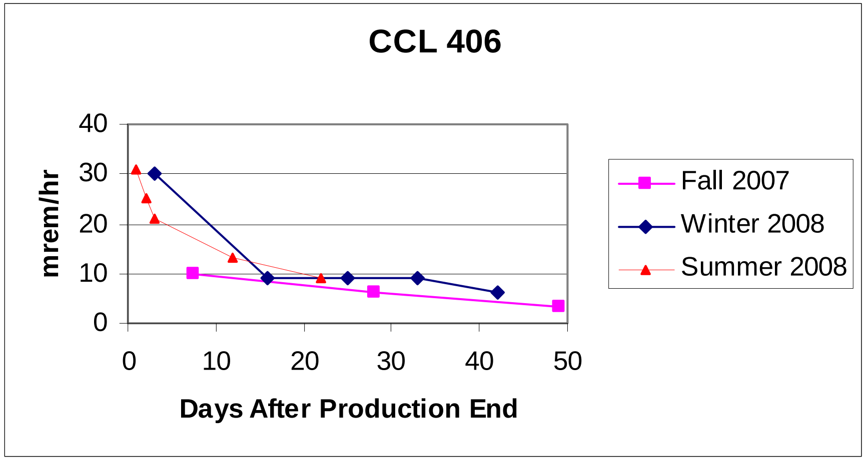
Look at SCL Activation History

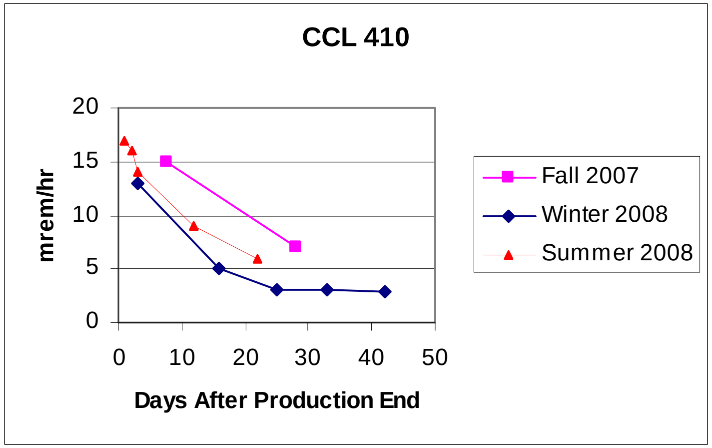
Consider the average residual activation for the surveys after the production runs for summer 07 and winter 08:

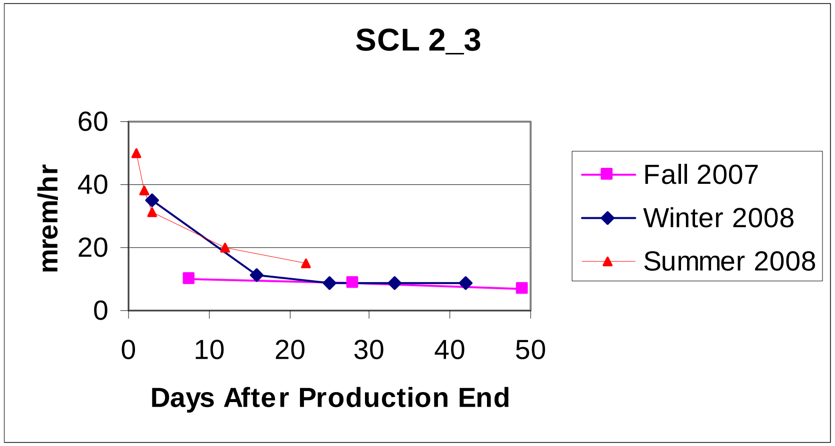


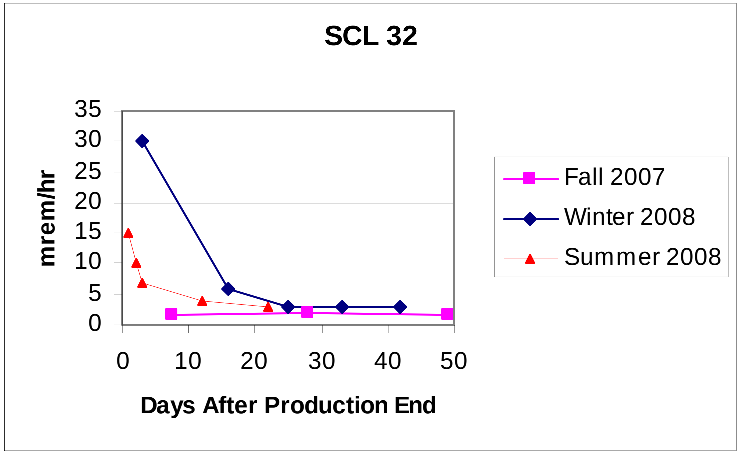
- **Pattern seems to be 2-3 runs with low activation, jump to higher activation – and then stays the same.**

Linac Activation Decay after Shutdown



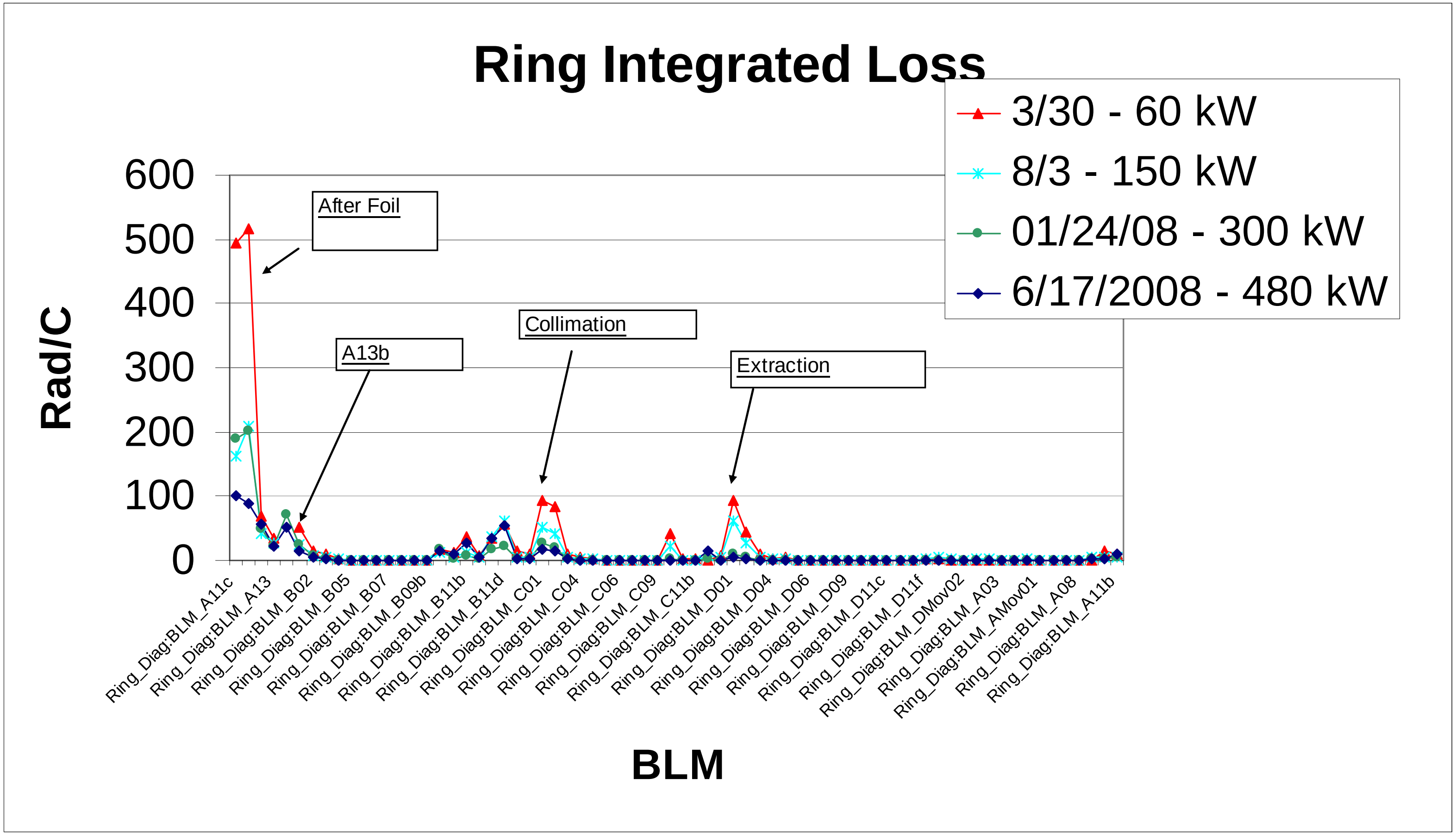






- **Generally we are approaching similar residual dose rates after 1 month as previous run cycles !**
  - **SCL may not decay to previous start level though**
- **SCL shows an initially fast decay**

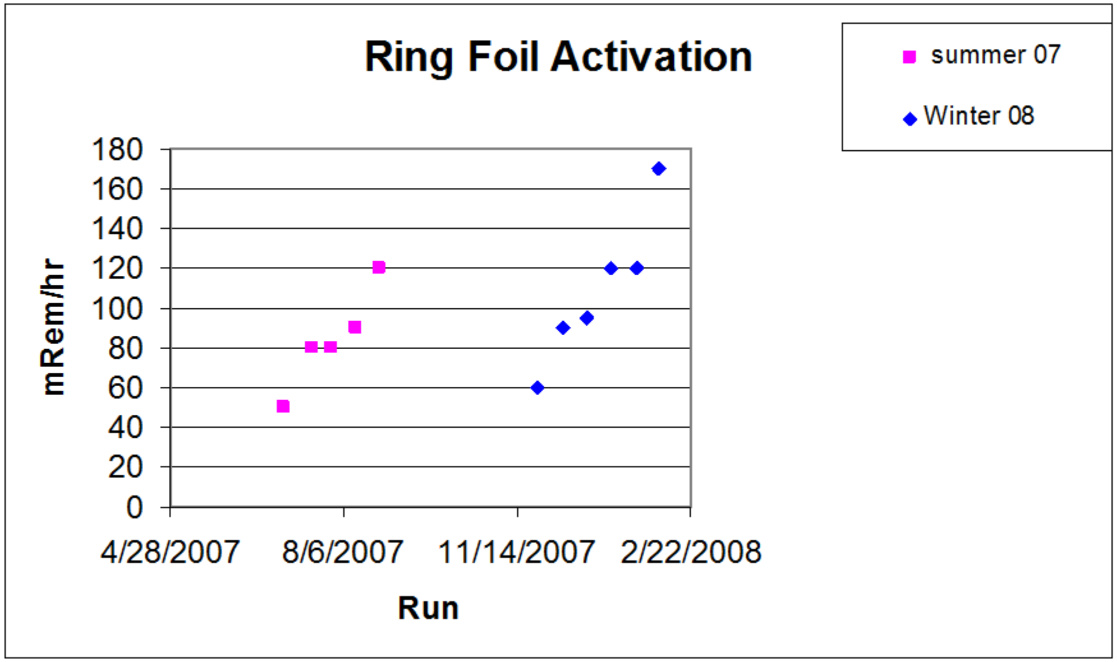
Ring Long Term Loss Trends



- **Ring Injection is the primary beam loss area**
- **Making tuning progress**

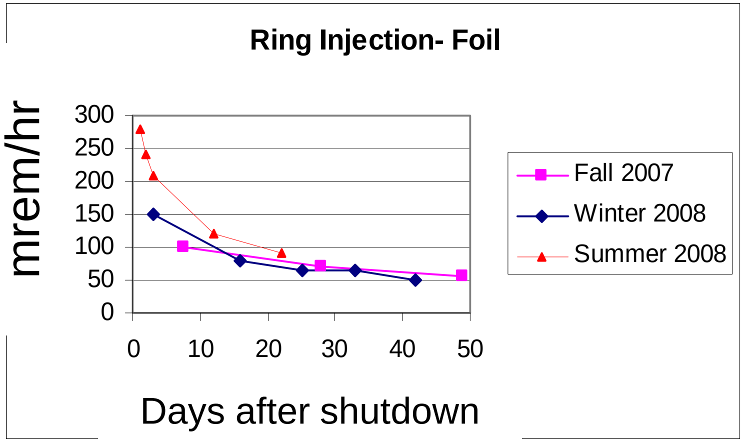
Look at Ring Injection Activation History

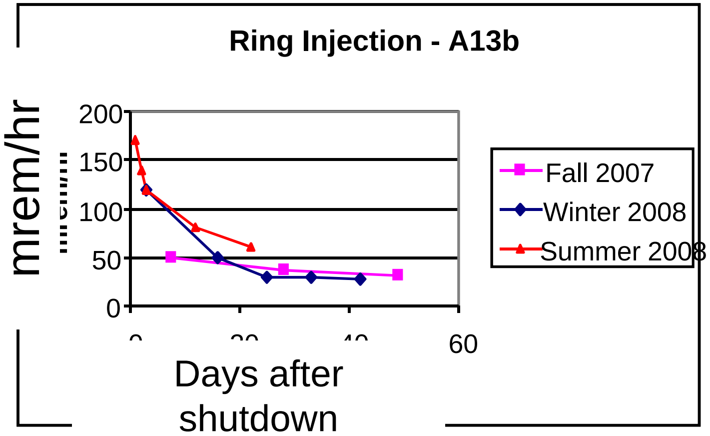
Consider the Activation by the injection foil for the surveys after the production runs for summer 07 and winter 08:

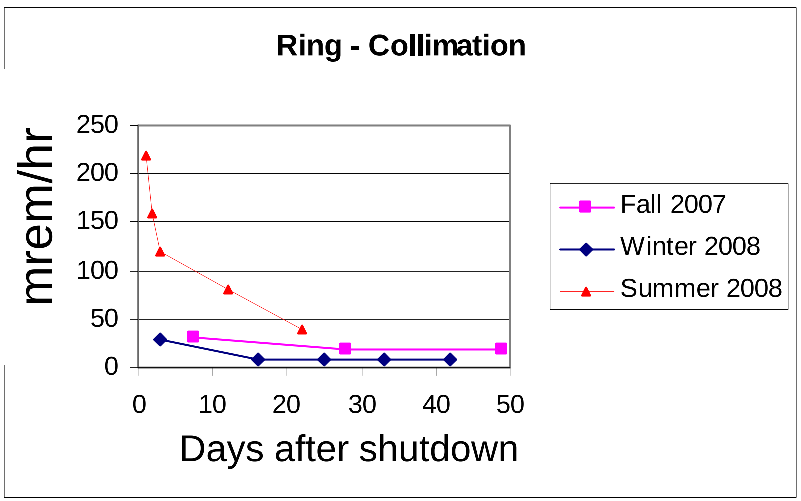


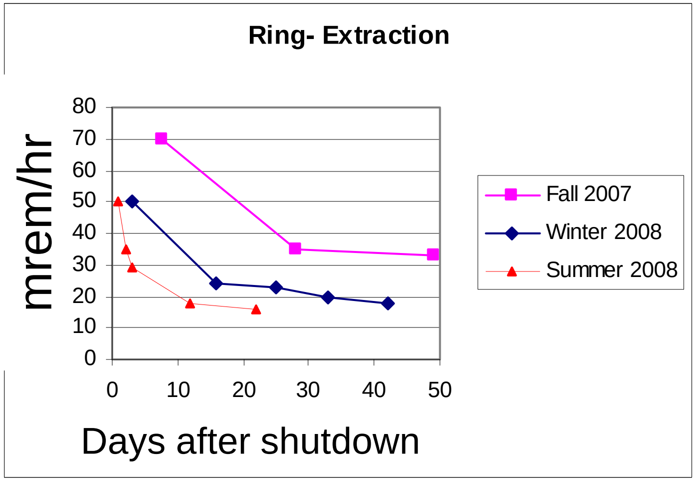
- **Summer run is missing survey data after the last run**
- **Monotonic increase of activation with power**

Ring Residual Activation Decay History





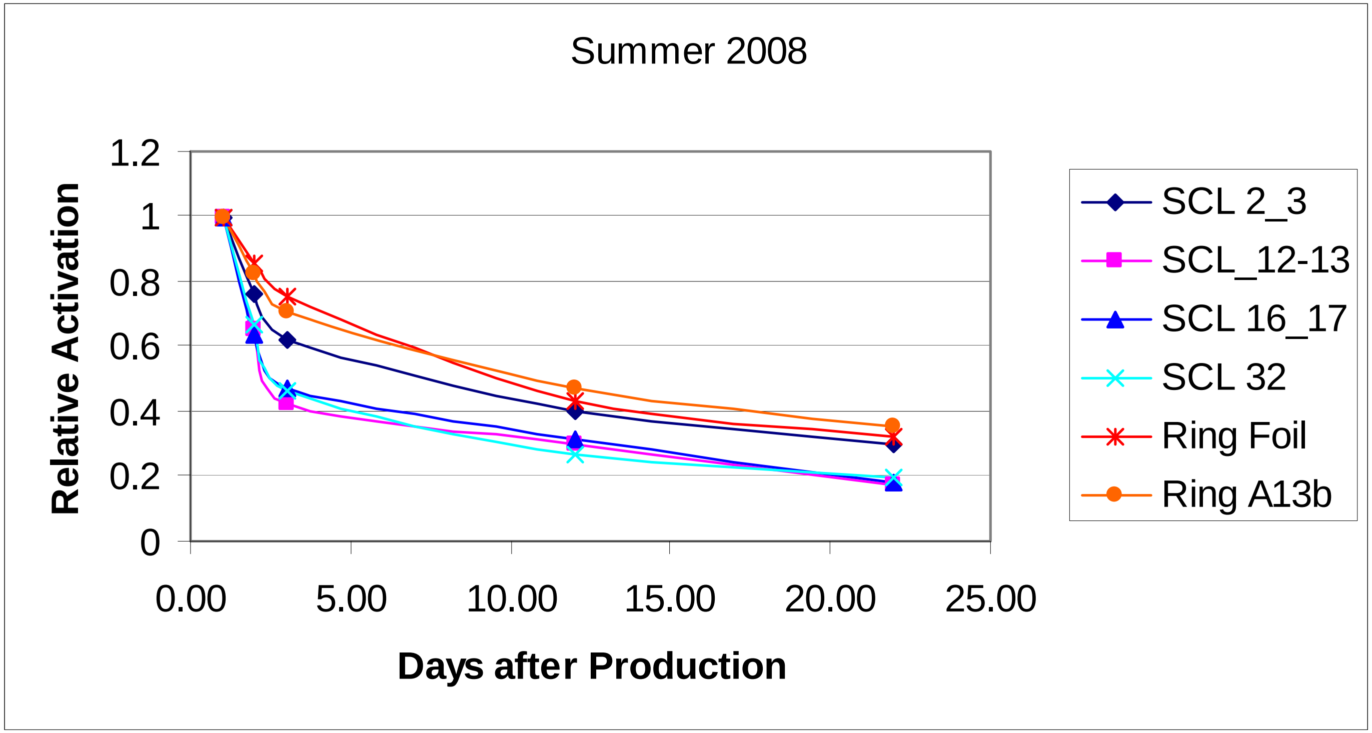




- **Despite increasing the beam power by factor of 2.5, the long term residual activation buildup is not increasing proportionally**

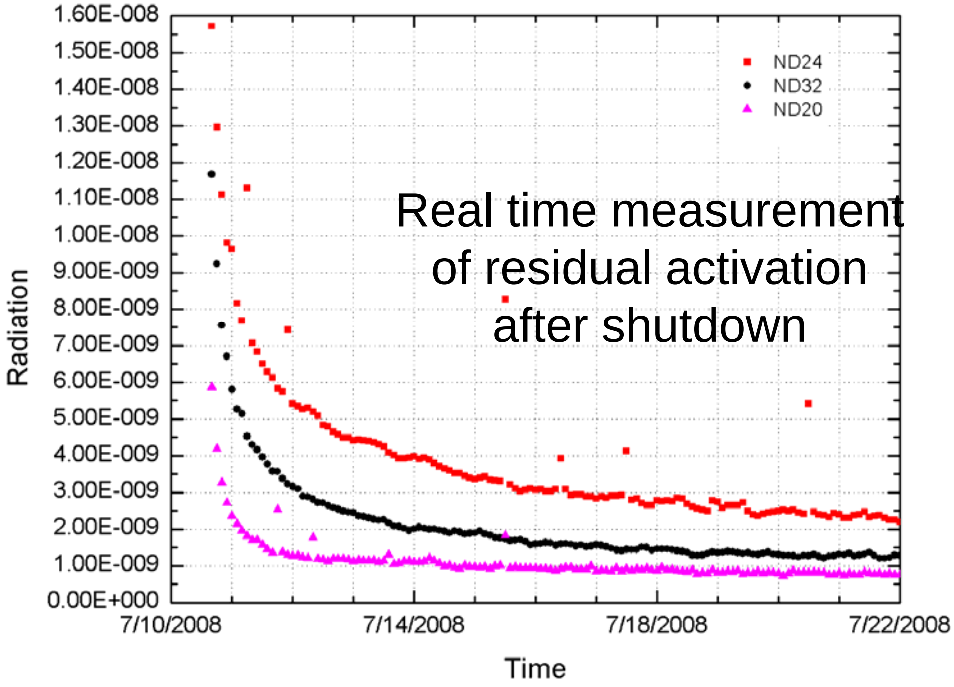
Residual Activation Decay Across the Machine

Beam loss normalized to the initial reading



- **The SCL warm sections decay faster than the rest of the machine**
  - **Except SCL2_3 is intermediate**

Residual Activation Decay
(*Zhukov, Assadi, Popova*)



- **SCL decays quite fast – model comparisons are underway**
- **Possibly useful information for diagnosing nature of the beam loss**
- **Also looking at gamma spectra of residual activation**

Activation levels after latest run cycle (500 kW) *24 hrs after shutdown, at 30 cm (mrem/hr)*

- **Linac: 10-60**
- **HEBT Collimation:100**
- **Ring**
  - **Injection: 100-400**
  - **Injection Dump: 100**
  - **Collimation: 200-250**
  - **Extraction: 50**

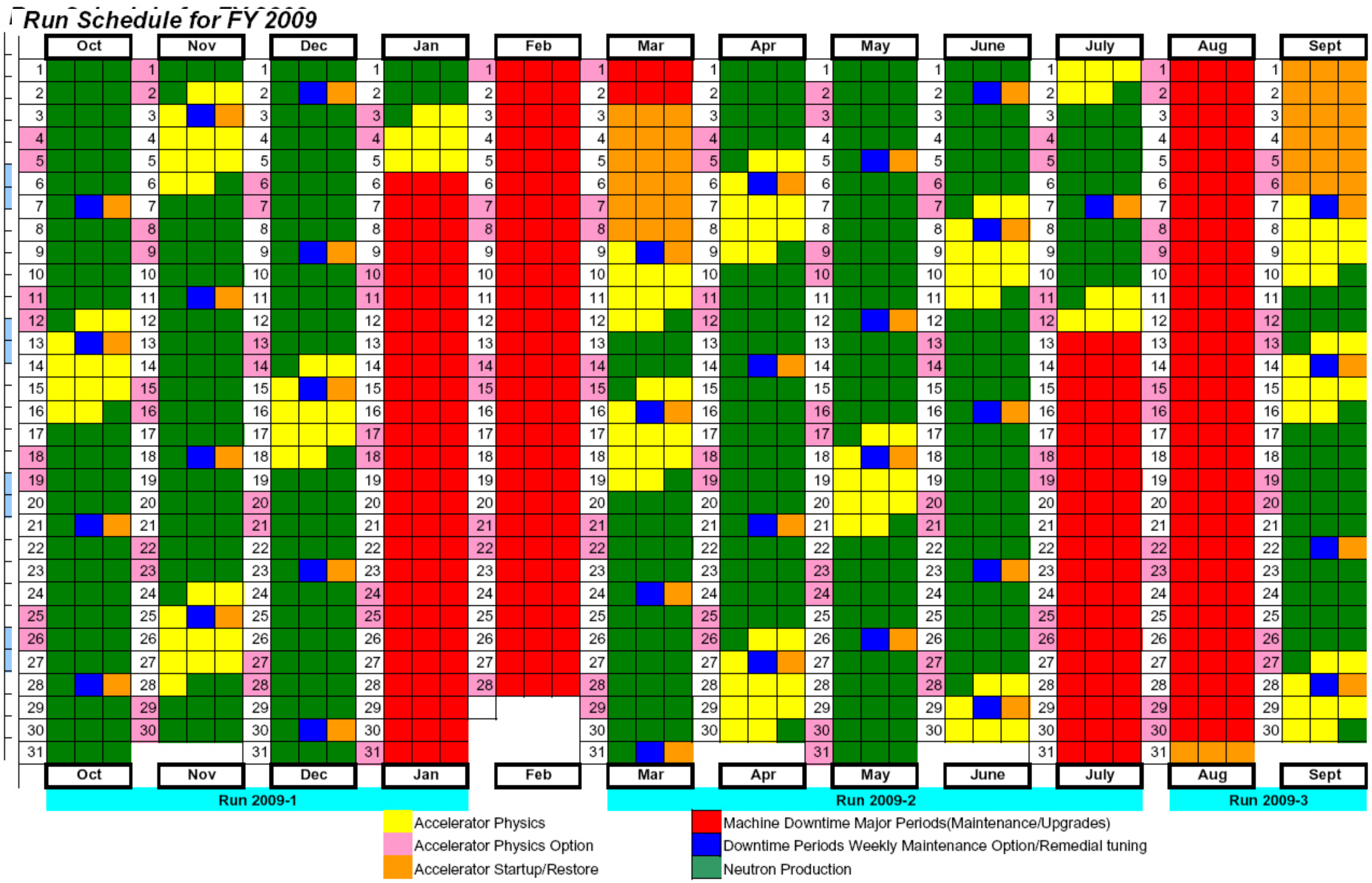
- **Most of transport lines and Ring**

  < 1-2 mrem/hr

Worker Dose Experience

- **2008: collective dose = 1660, max. individual dose = 100 mrem**
  - **1st extended maintenance: 560 mrem collective, 52 mrem individual**
  - **2nd extended maintenance: 700 mrem, highest individual = 60 mrem**
- **Estimate for 2008 was ~ 1500 mrem cumulative**
- **ORNL rad worker individual limits are 600 mrem/year with no exemption, 1000 mrem with an exemption**
- **To date minimal shielding has been utilized during maintenance**
- **The dose rate is not increasing proportional to beam power**

Beam Study / Production Cycles



- Red = extended maintenance
- Yellow = physics
- Green = production

- FY 2009 Cycle: 3 week cycles, 16.5 days production 4.5 days physics

- **~ 1-2 weeks to recover from extended outage (coming out of a "red" period)**
- **Recovery from an 8 hour shift outage takes ~ 1 shift**
- **Moving towards a 3 week rhythm in FY2009 to reduce the number of beam-study to production transitions**

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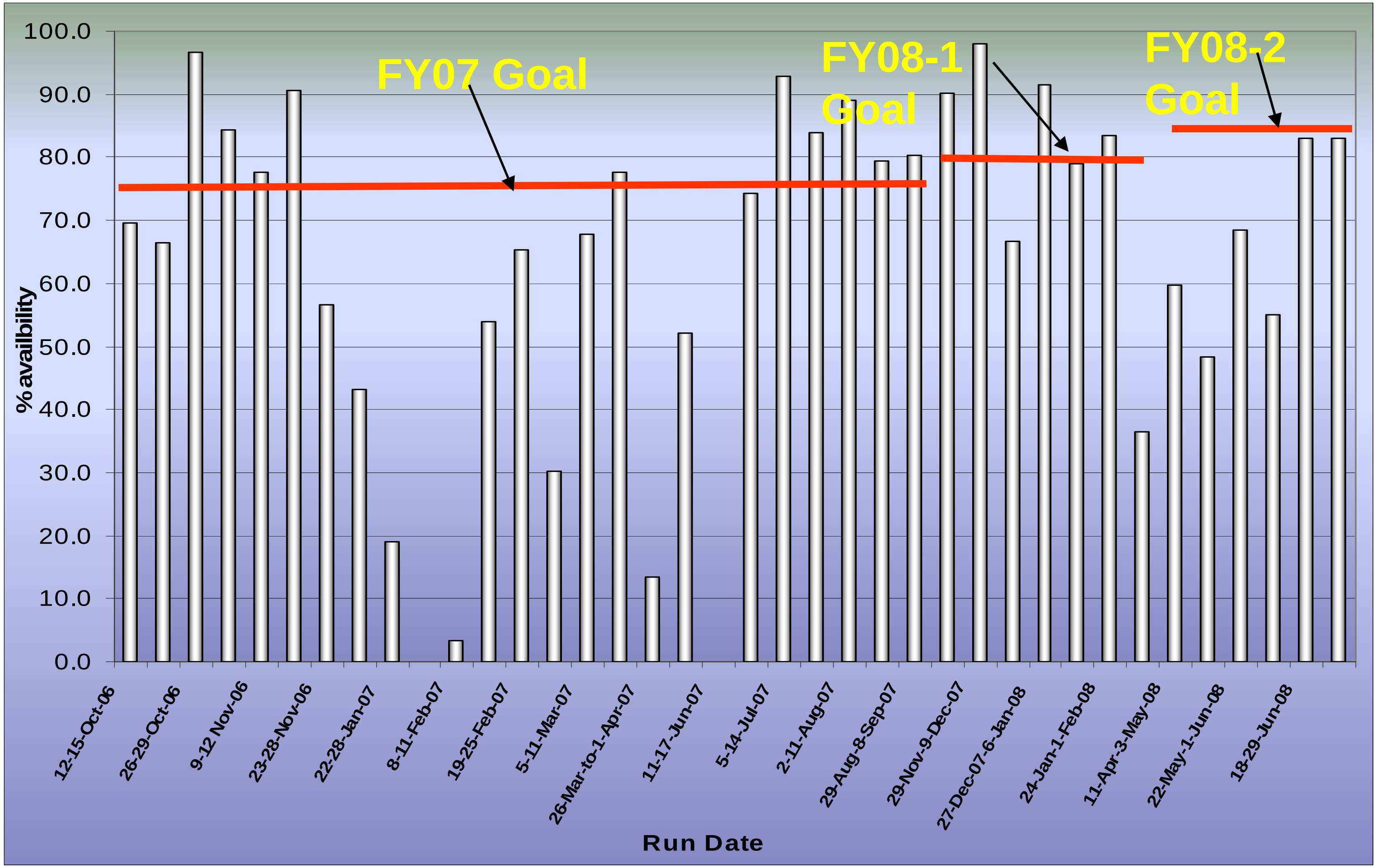
Production Setup Reproducibility

- **If NO equipment is changed, production tune recovery is straightforward**
  - **Good save-compare-restore program**
  - **Magnet cycling is important**
  - **Operators can do this**
- **If an ion source is changed, or any equipment behavior changes it may be difficult to recover a low loss tune**
  - **Had good and bad experiences with ion-source replacements**
- **Subtle changes in equipment performance can be hard to diagnose**

Beam Availability (Hours Delivered/Hours Scheduled for Neutron Production)



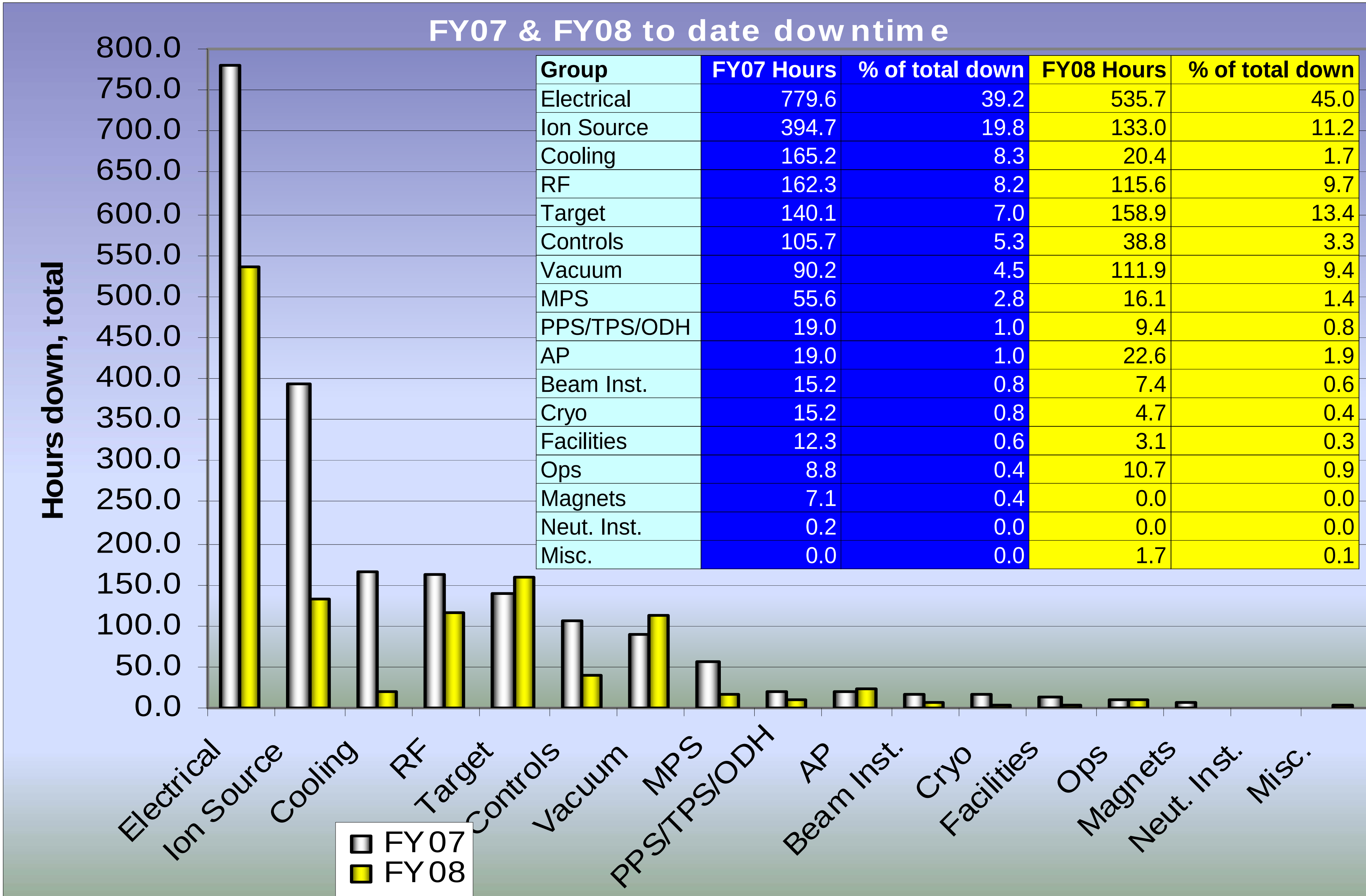
Average annual neutron production availabilities:

FY-2007 = 66%, FY-2008 = 73% (so far)

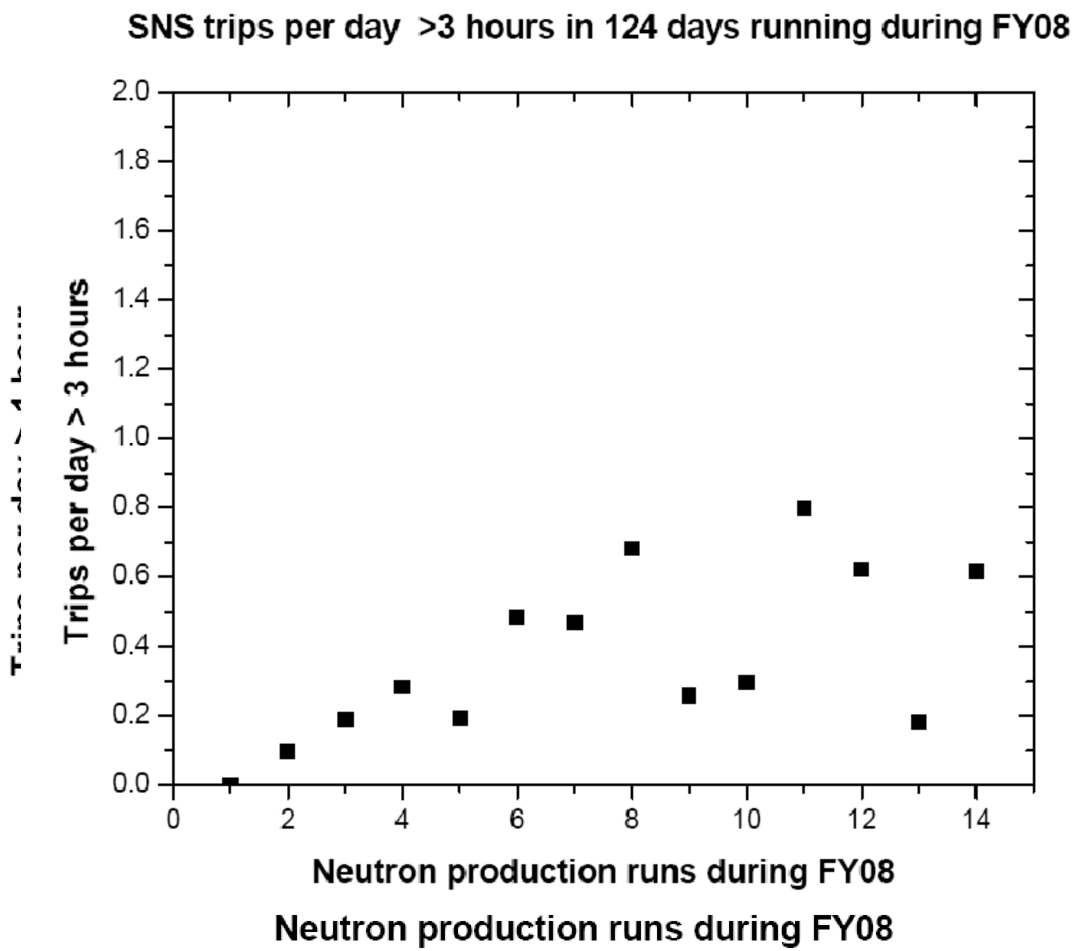
Unscheduled Down Time Summary

FY07 & FY08 to date downtime

Group	FY07 Hours	% of total down	FY08 Hours	% of total down
Electrical	779.6	39.2	535.7	45.0
Ion Source	394.7	19.8	133.0	11.2
Cooling	165.2	8.3	20.4	1.7
RF	162.3	8.2	115.6	9.7
Target	140.1	7.0	158.9	13.4
Controls	105.7	5.3	38.8	3.3
Vacuum	90.2	4.5	111.9	9.4
MPS	55.6	2.8	16.1	1.4
PPS/TPS/ODH	19.0	1.0	9.4	0.8
AP	19.0	1.0	22.6	1.9
Beam Inst.	15.2	0.8	7.4	0.6
Cryo	15.2	0.8	4.7	0.4
Facilities	12.3	0.6	3.1	0.3
Ops	8.8	0.4	10.7	0.9
Magnets	7.1	0.4	0.0	0.0
Neut. Inst.	0.2	0.0	0.0	0.0
Misc.	0.0	0.0	1.7	0.1

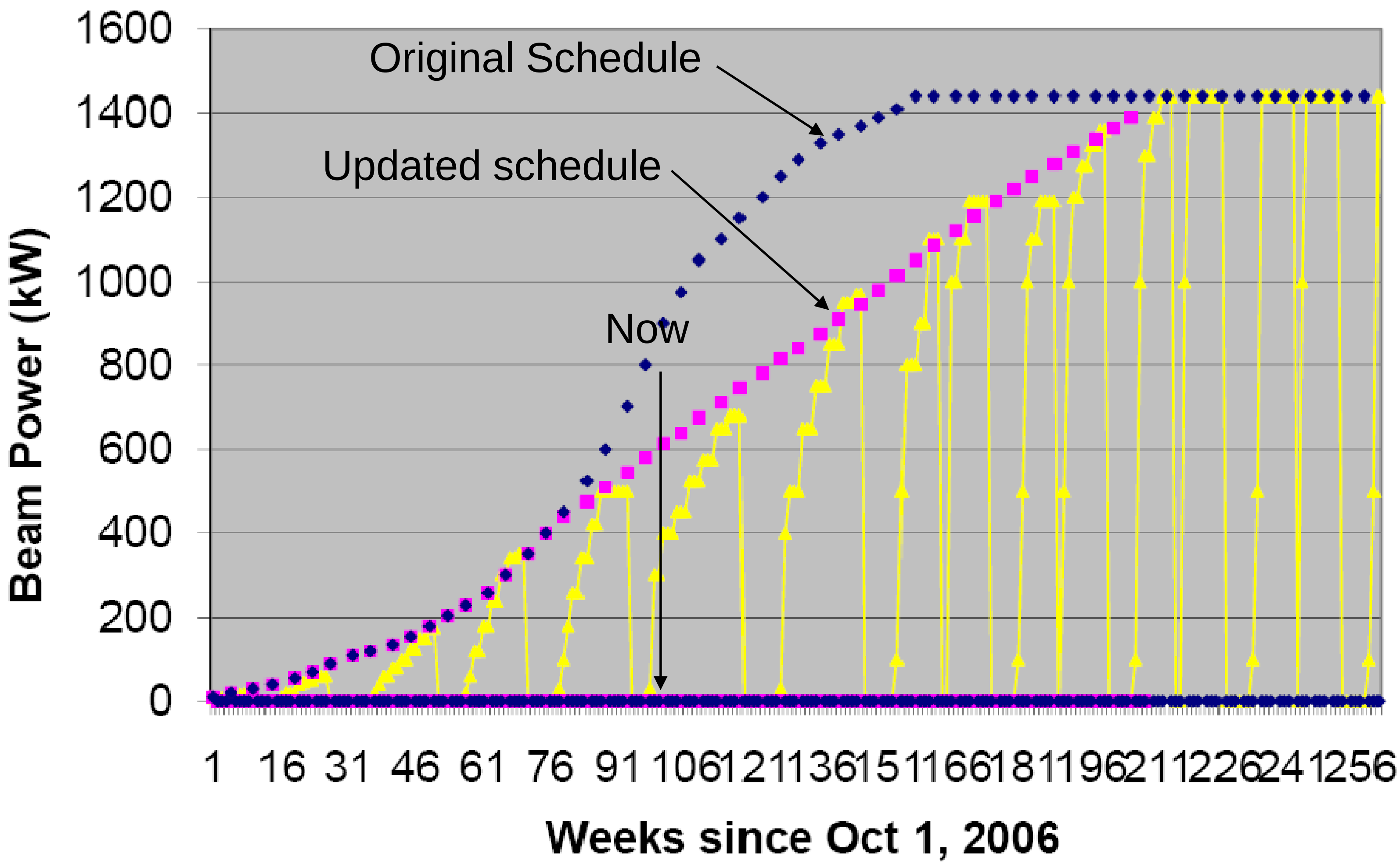


Downtime Statistics for FY08



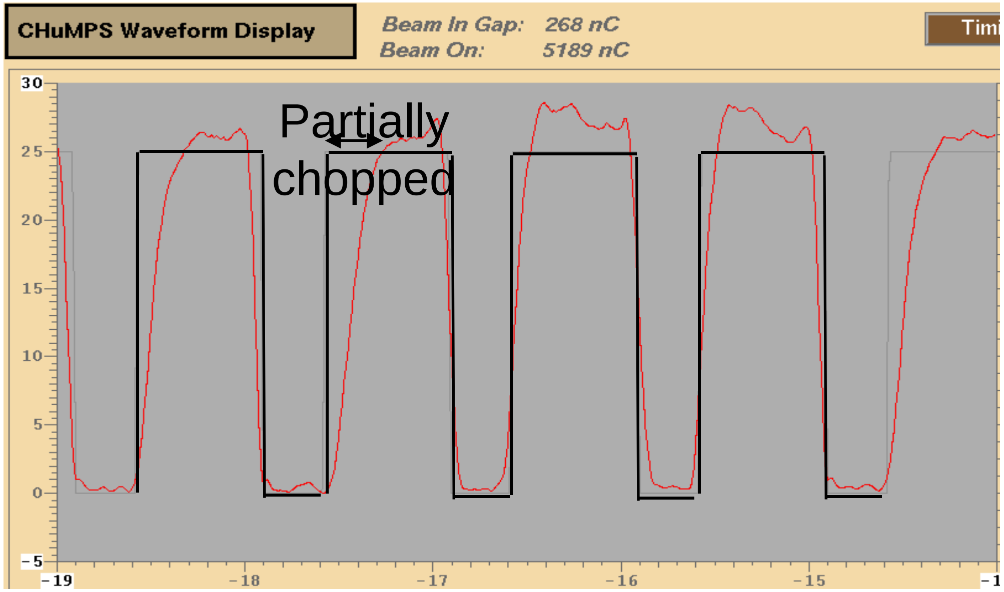
- **Need to improve!!!**

Revised power ramp-up Schedule



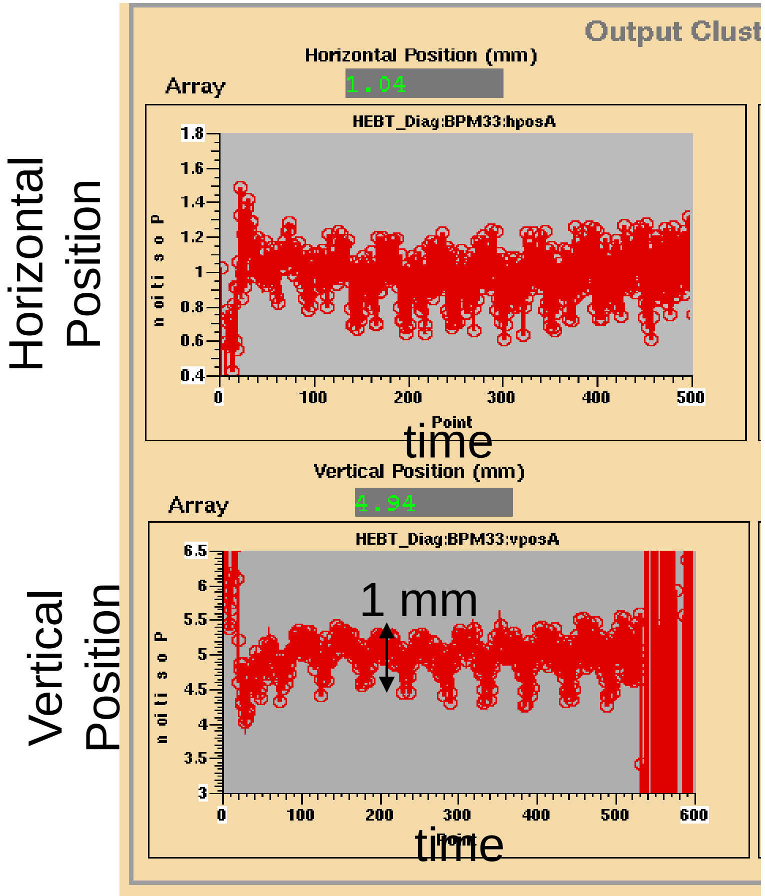
- **Power ramp-up schedule is revised with more emphasis on availability,**

Machine Challenges (I): Chopping



- **Actual chopping is much slower than design due to additional resistance added to circuit to protect from arcs**
  - **Pulse-to-pulse irregularity**
  - **Large fraction of the beam is partially chopped (10-20%)**
- **Original MEBT chopper was not robust enough design (power supplies + structure)**

Machine Challenges II: HVCM



BPM waveform near stripper foil

20 kHz ripple is evident on the beam during the 1 msec macro-pulse

- **Run at lower than expected duty factor (pulse length) to protect against excessive HVCM failure rate**
  - **New components are being developed / tested**
- **20 kHz ripple is evident on RF fields and Beam**

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Machine Challenges III

- **Ring Injection - pay attention to details, 3-D magnet effects, etc. – (M. Plum's talk)**
- **Superconducting Linac:**
  - **Large cavity-to-cavity gradient variation**
    - **OK beam dynamics wise, but there is a net gradient deficit**
  - **Collective cavity effects**
  - **Robust accessories (HOM couplers, CCGs, piezo tuners,…) – keep it simple!**

Summary

- **Over the last two years we have ramped the power up from 0-500 kW**
  - **Worked around technical problems – kept on schedule**
  - **Machine activation is not increasing proportional to beam power**
- **Rapid power ramp-up allowed us to identify technical issues early**
- **Availability is an increasing concern**
- **Further power increases will become more challenging**