SNS Operational Experience at the MW Level

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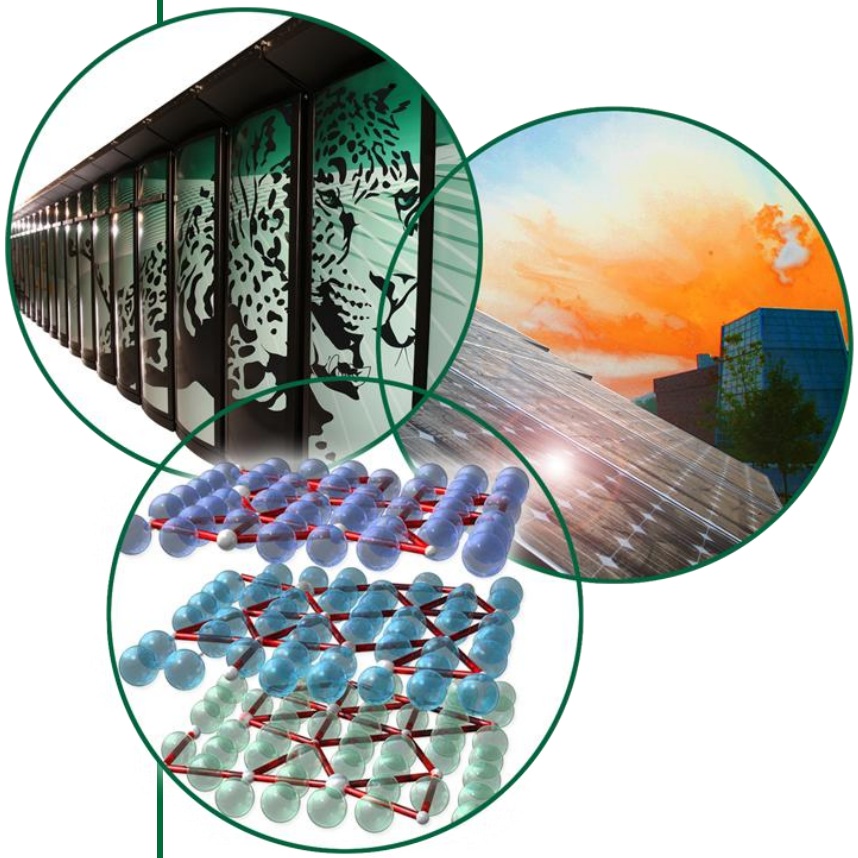
Sept. 27, 2010

46th ICFA Advanced Beam Dynamics Workshop on High-Intensity and High-Brightness Hadron Beams

Morschach Switzerland



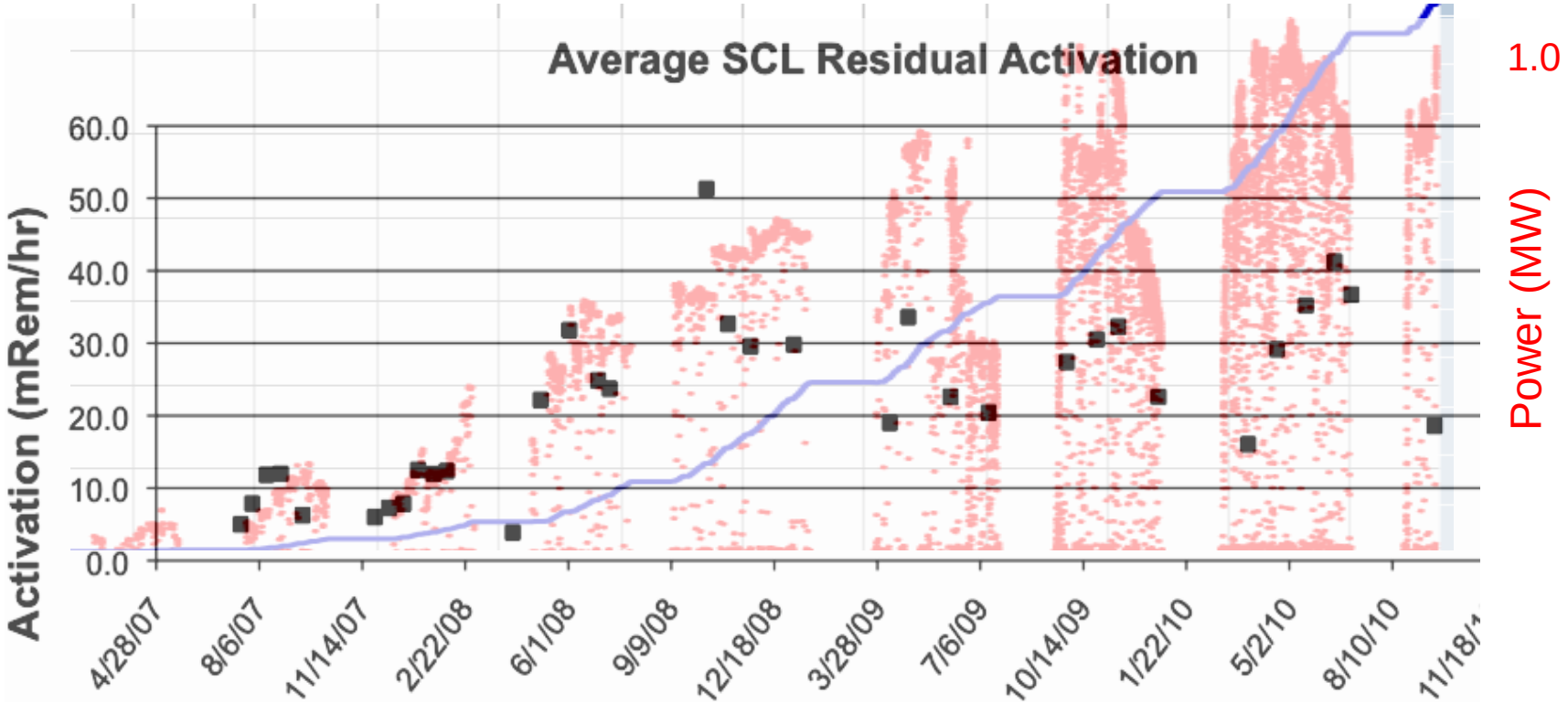
U.S. DEPARTMENT OF ENERGY

OAK RIDGE NATIONAL LABORATORY
MANAGED BY UT-BATTELLE FOR THE DEPARTMENT OF ENERGY

SNS Operational Experience

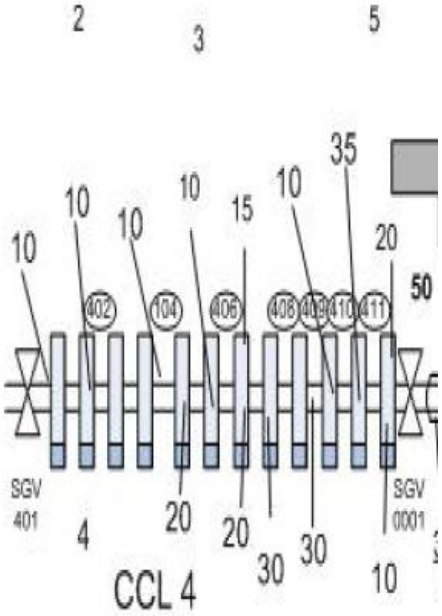
- Beam loss, worker dose
- Machine Protection
- Reliability/ Availability

SCL Activation: How are we doing?



- **Expectation: Modeling during the design stage indicated no beam loss in the SCL**
- **30-40 mRem/hr at 1 MW operation is typical**
- **SNS operations has not been limited by beam loss – but 10 MW is a problem**

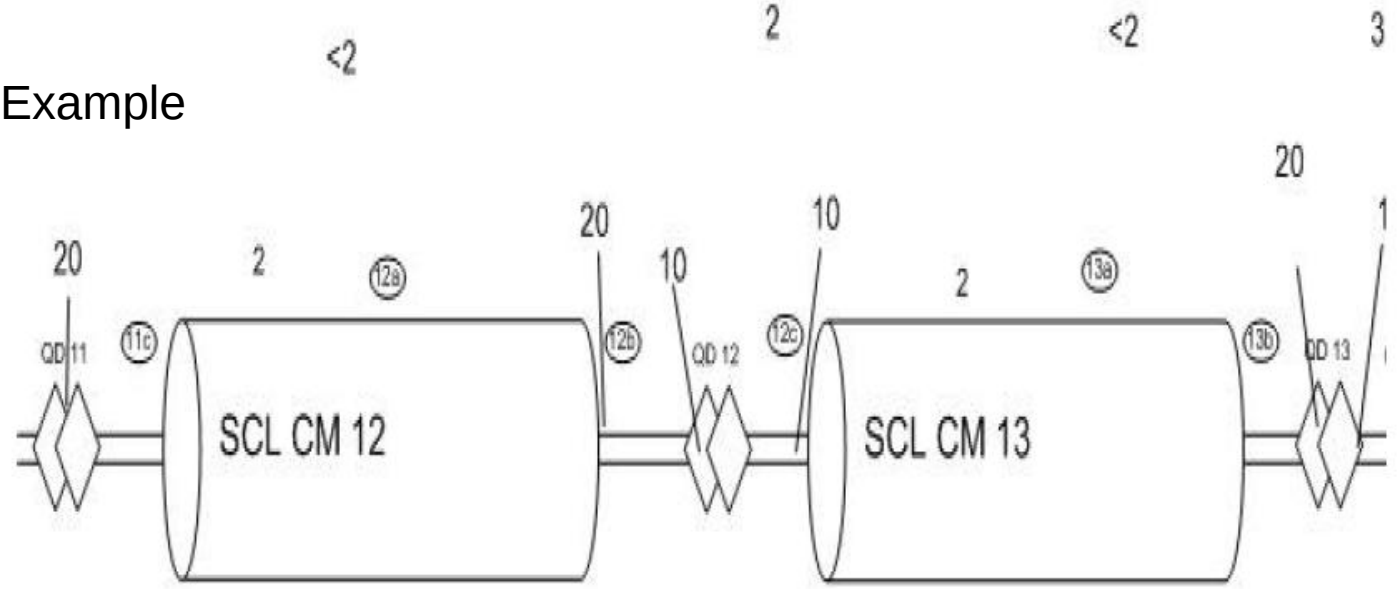
Example SNS Cyro-module Activation (9/20/2010 Survey)



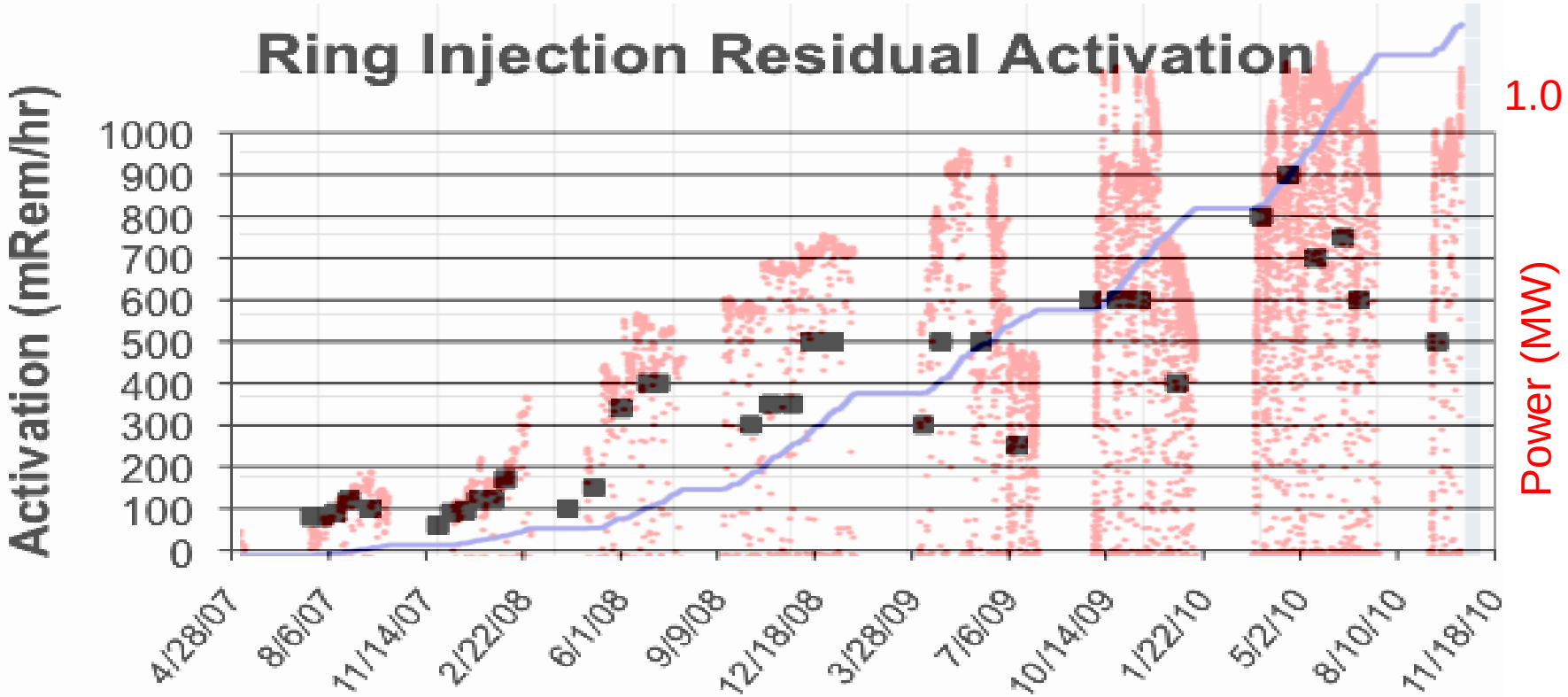
- **End of CCL has hot spots**

30 cm readings, 2 days after neutron production, 3 hours after beam studies

SCL Example

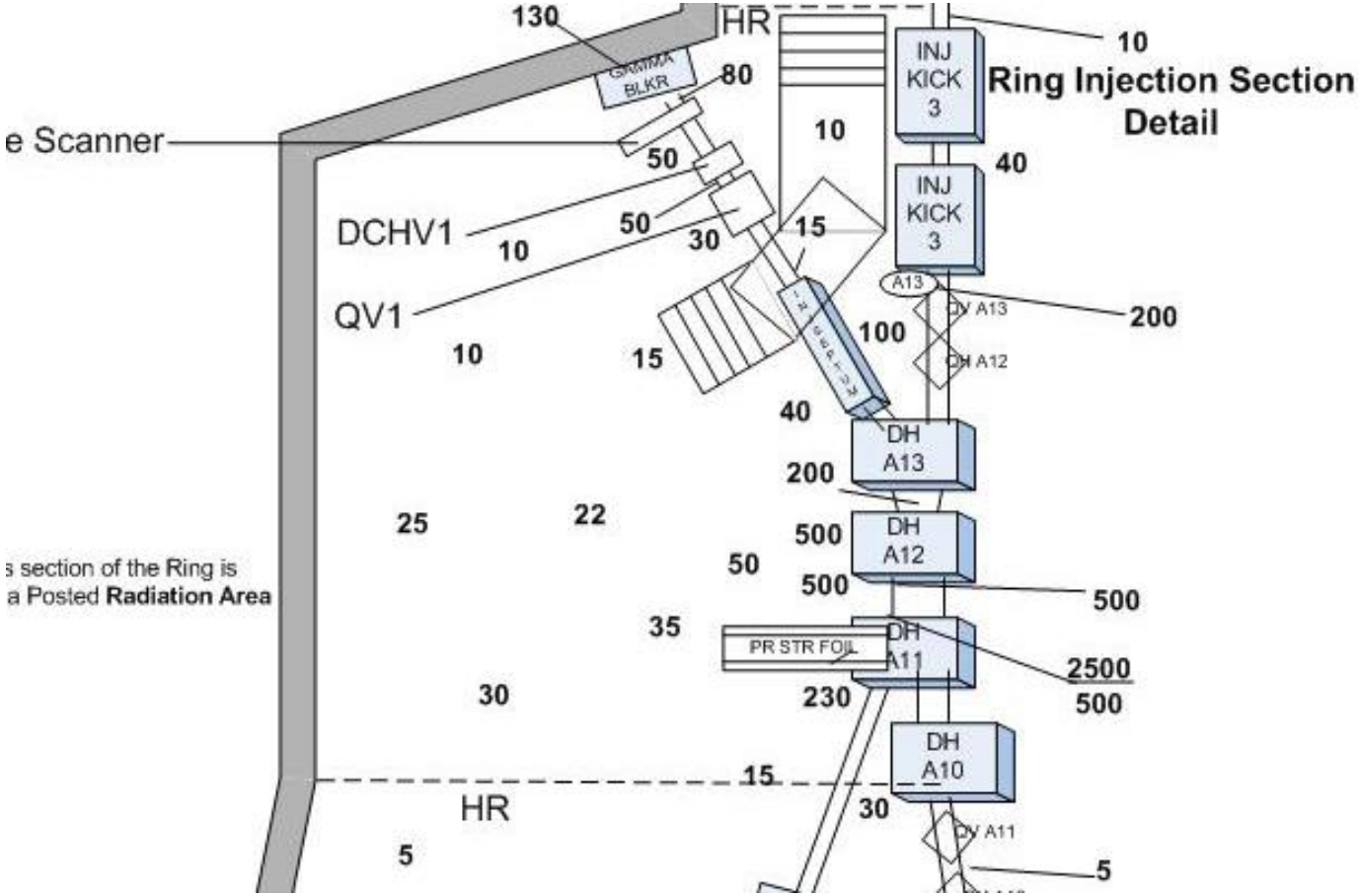


Ring Activation History



- **Activation by the injection stripper foil is the highest in the SNS accelerator**
- **Close to activation expectations**
- **~ Monotonic increase with beam power**

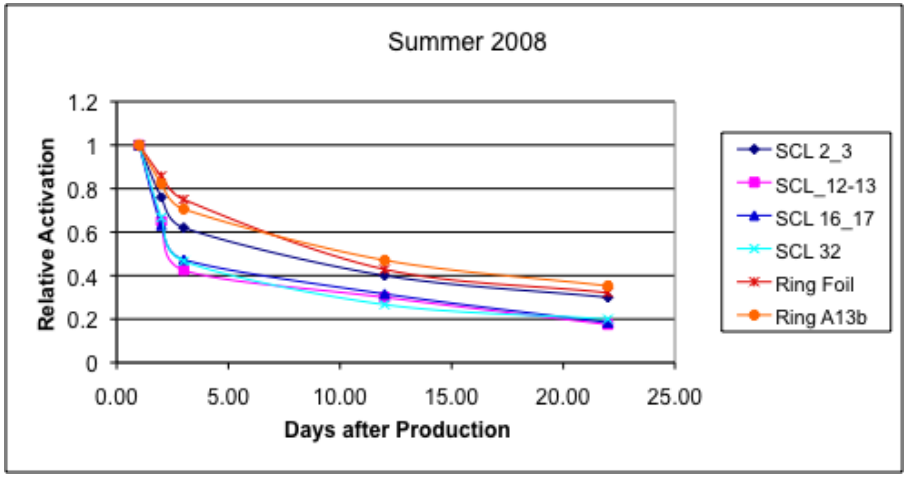
Example Ring Injection Survey (9/20/2010)

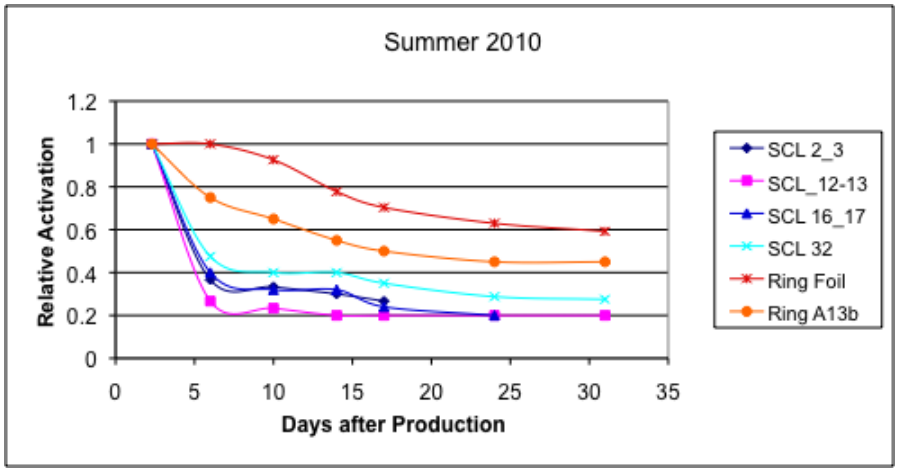


- 30 hr reading / contact reading
- 2 days after production, 3 hours after beam studies

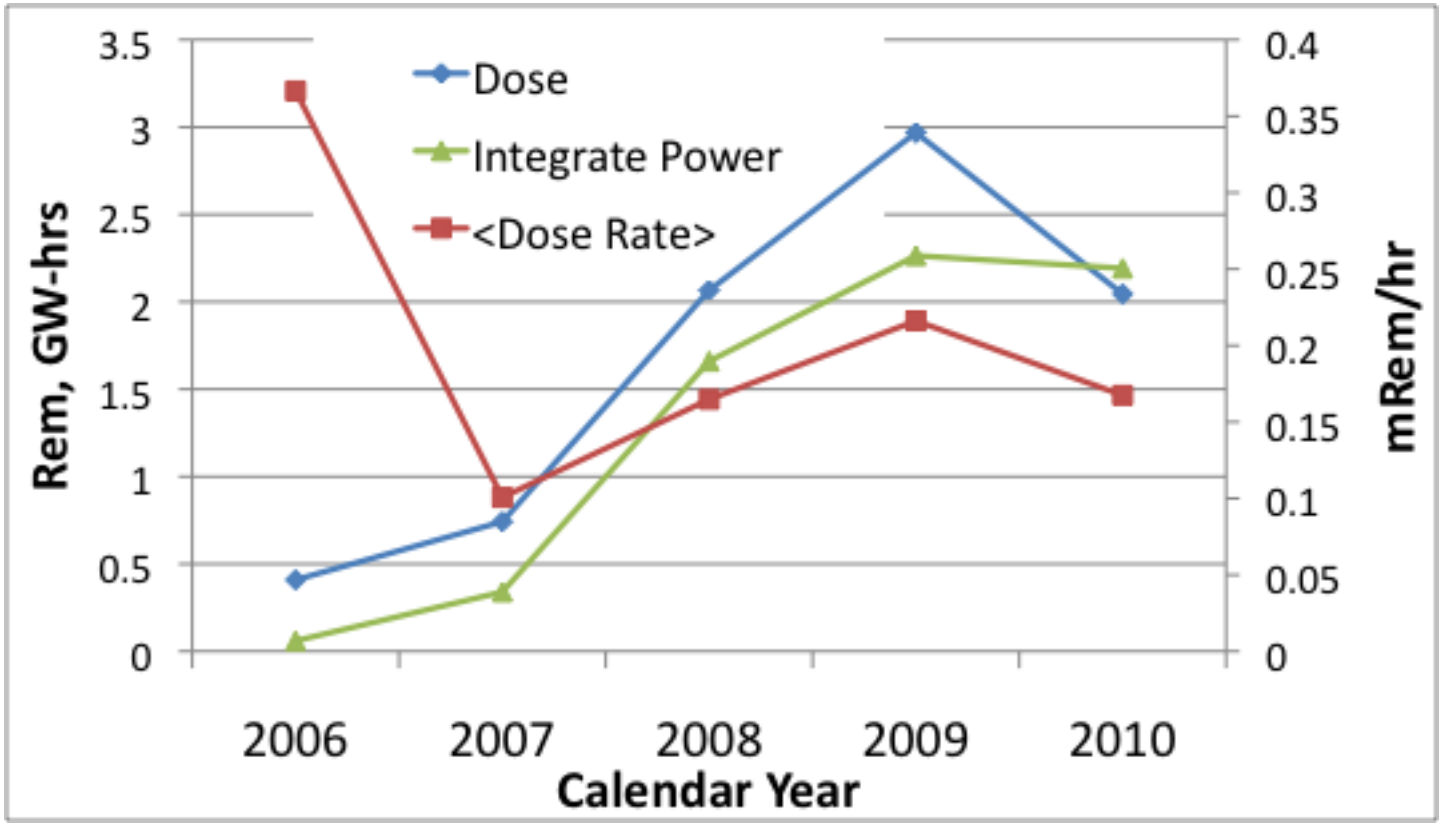
Beam Loss Residual Activation Decay

- Why does the SCL cool off faster than the Ring???
- Beam energy, material constituents???





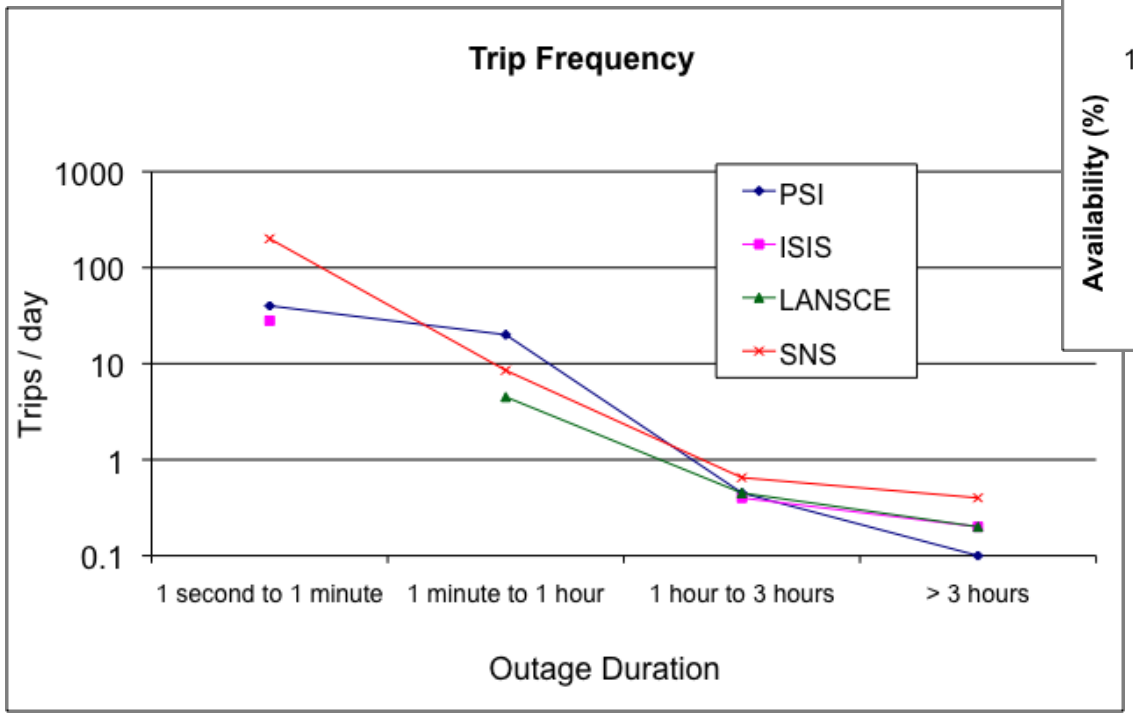
Worker Dose (Accelerator + Target)

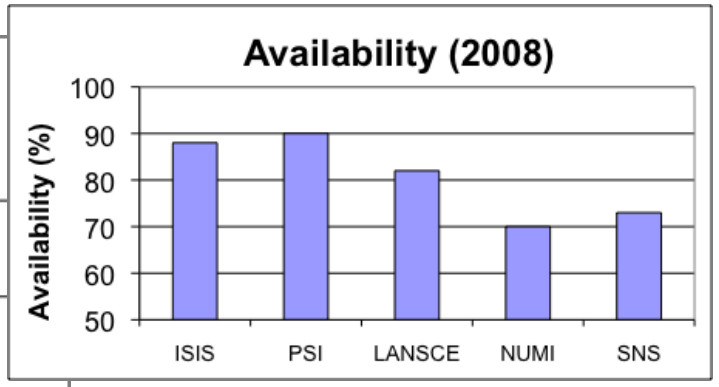


- Dose and dose rate are not increasing over the last 2 years
  - 2010 YTD:
    - Max dose = 103 mRem
    - 5 people with > 50 mRem

High Power Accelerator Reliability Experience

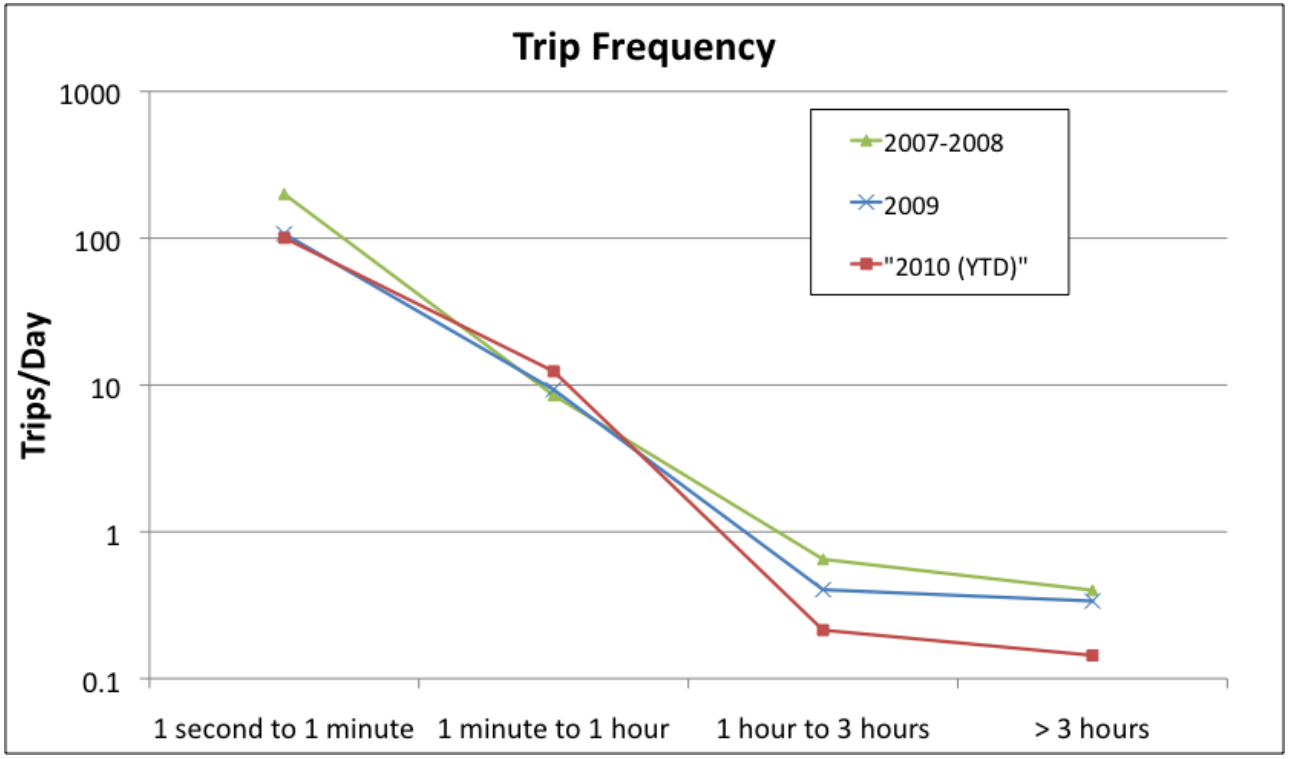
Data compiled at the 2008 ICFA High Brightness workshop, Nashville TN





- **Similar performance across several facilities**
- **Facilities with the fewest long outages have the highest availability**

SNS Availability Experience (2007-2010)



- **Progress in reducing the longer trips**
  - **Big outages are largest "bang-for-the-buck" on availability**

Availability =(hours beam is provided over the year) / (hours promised to provide at the start of the year) - calulated over a year

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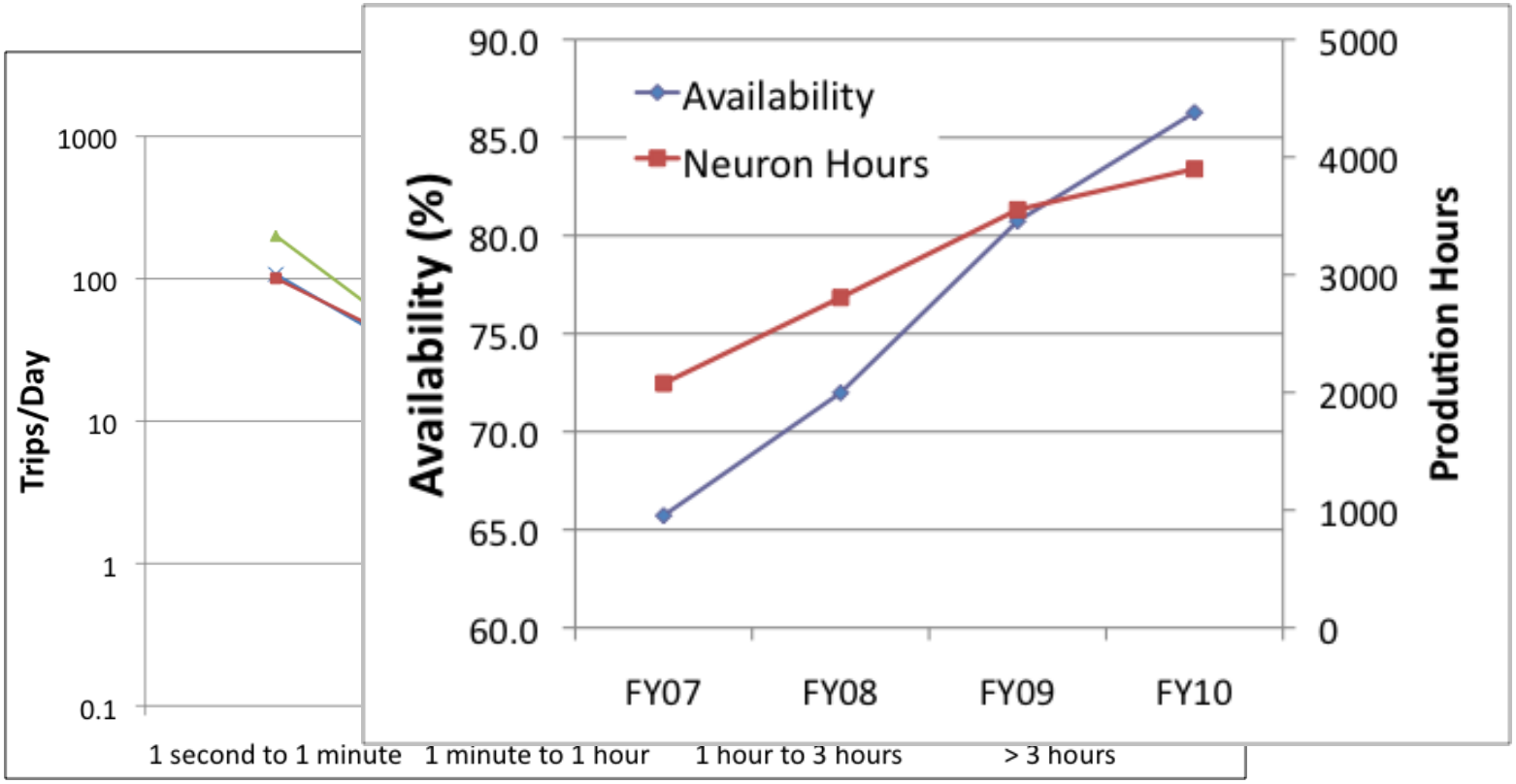

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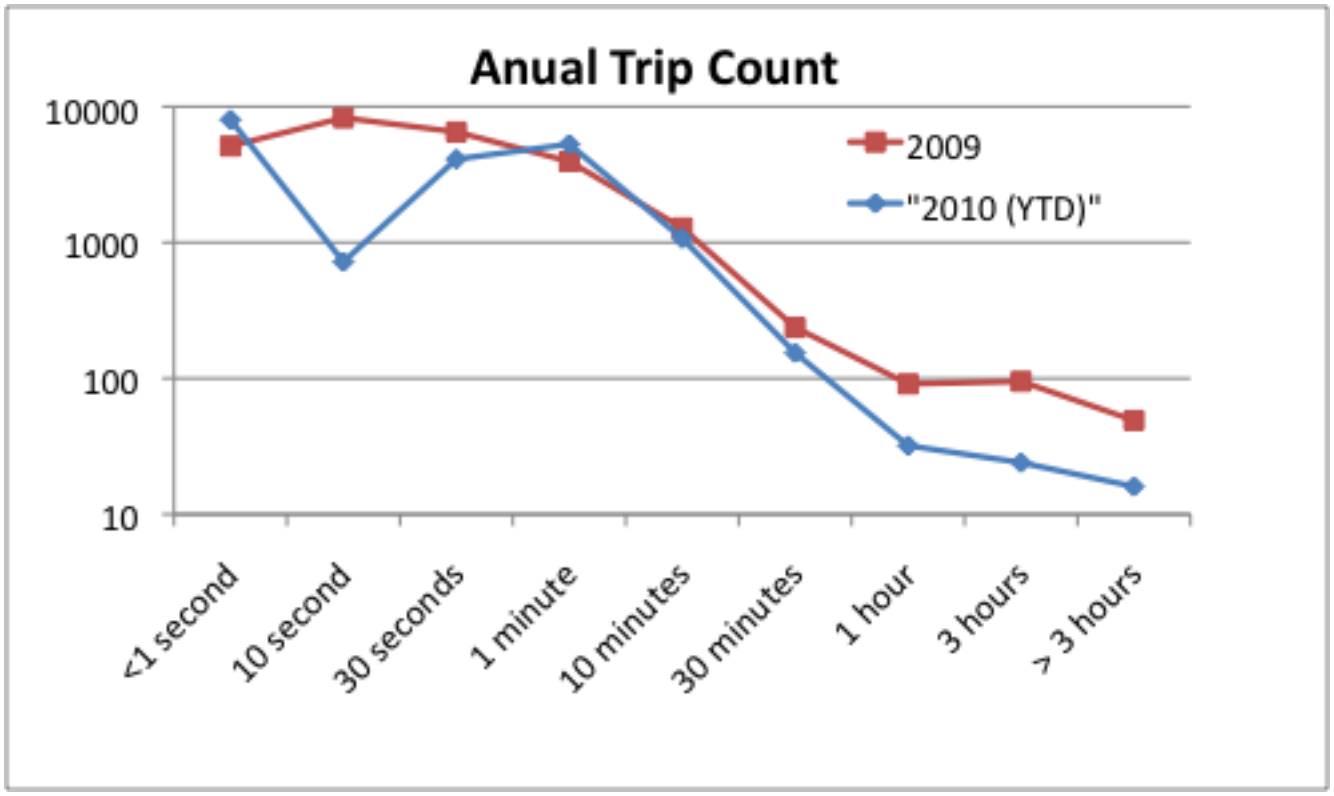
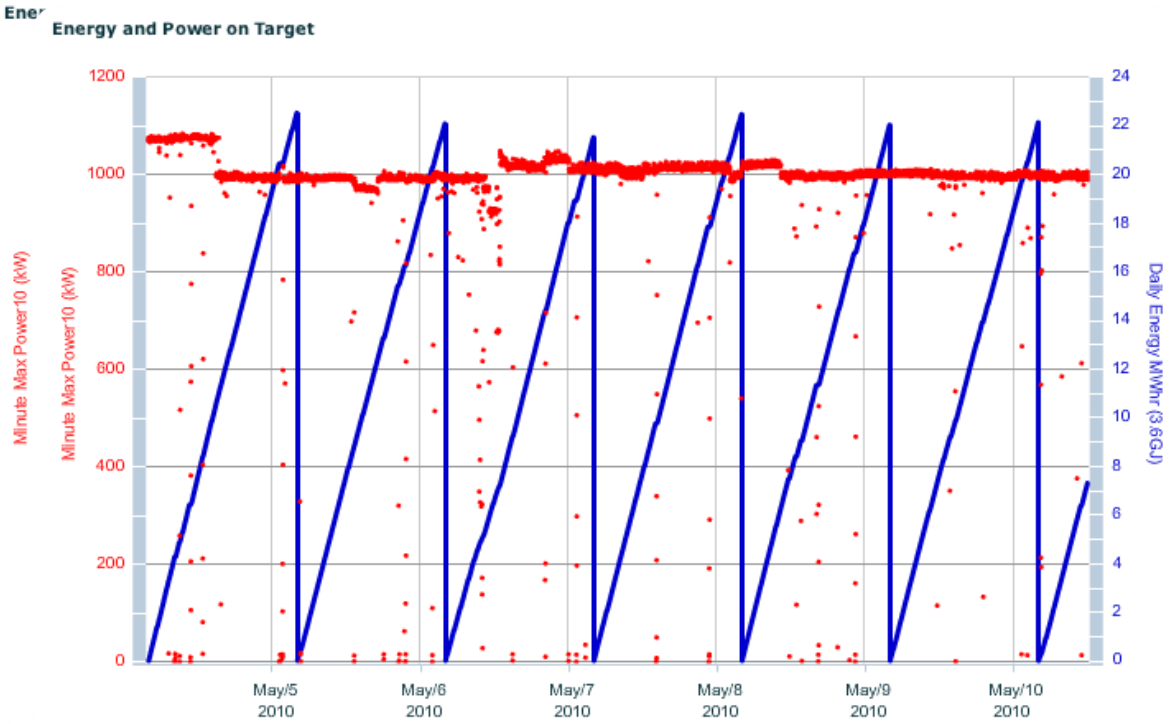
SNS Reliability Experience



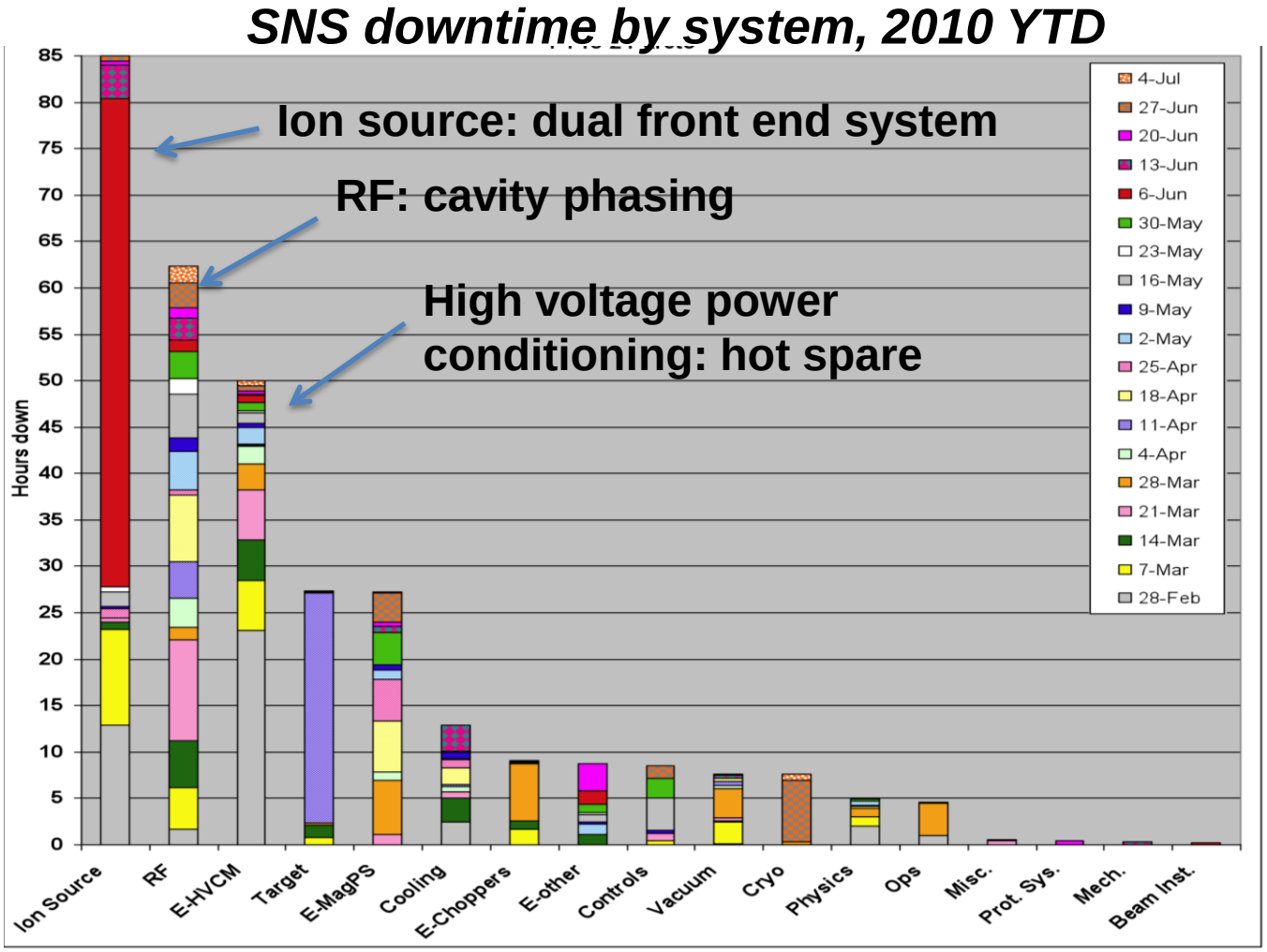
- 2009
  - 185 days production
  - 20,000 trips > 1 sec
- 2010
  - ~ 100 days production
  - 11,000 trips > 1 sec

We Extremely Good Availability Periods



- There are periods of weeks with > 95% availability

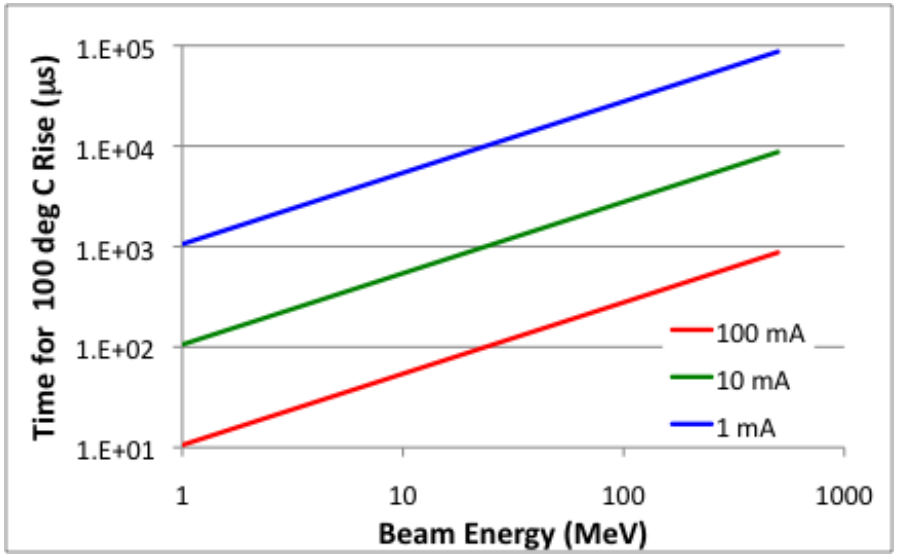
Easy to Identify Primary Reliability Issues for Existing Proton Accelerators



- **Redundant design capability would mitigate much of our downtime**

Machine Protection Systems

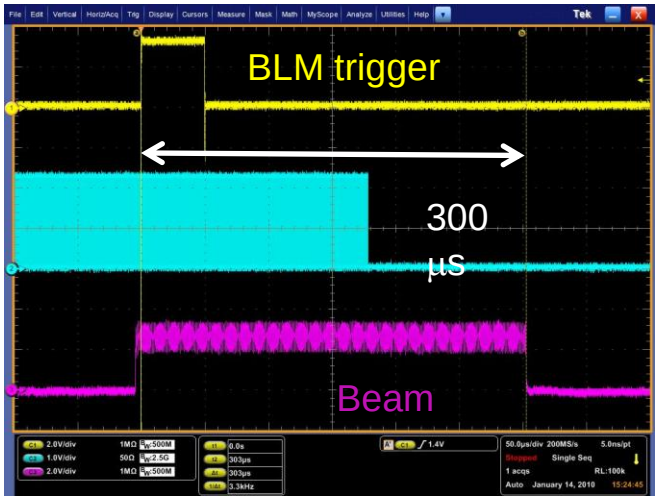
- Fast loss machine protection against equipment damage
  - Hardware system, ~ 20 μs limit
  - Difficult to bypass
  - Loss monitors + RF inputs
  - Some slower magnet inputs



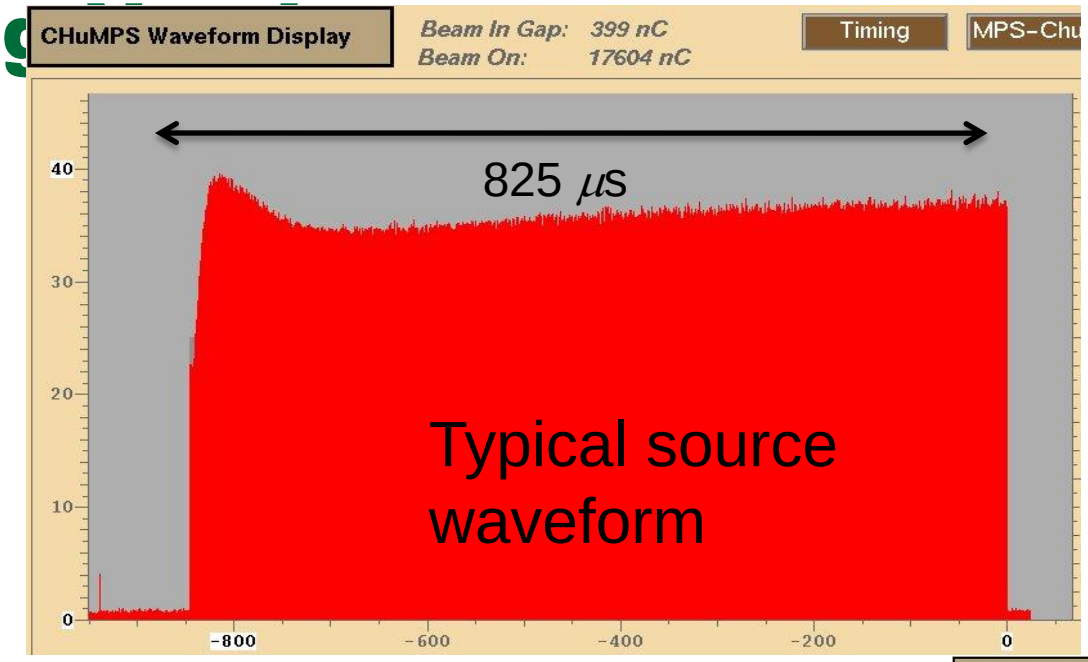
- Also protect against activation buildup
  - "Slow" software integrated beam loss limit (1 sec)
  - Lower loss per pulse than the fast limit

SCL Cavity Damage From Beam Loss

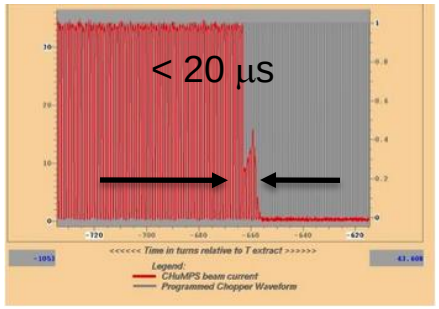
- Machine Protection System (MPS) designed to shut off beam and RF in < 20 μs from generation of a fault condition
  - Some MPS inputs had delays of 100's of μs
  - Can allow RF to overdrive during off-normal conditions
  - Possibly 100's of J deposited in cavities within 2 pulses (32 msec)
  - Can redistribute local gas distribution
  - In Fall 2009, we had to reduce gradients in 2 cavities from errant beam degradation

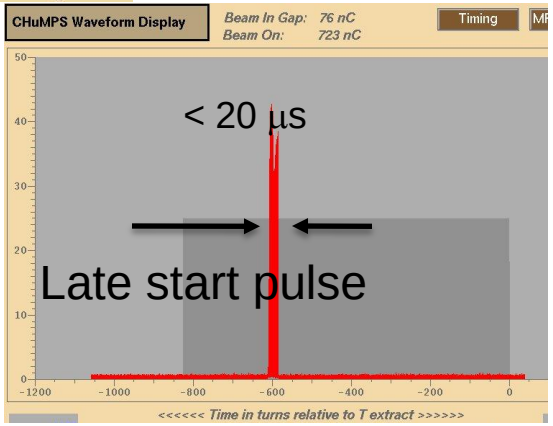


Machine Protection System is Working



Source drop midway through pulse



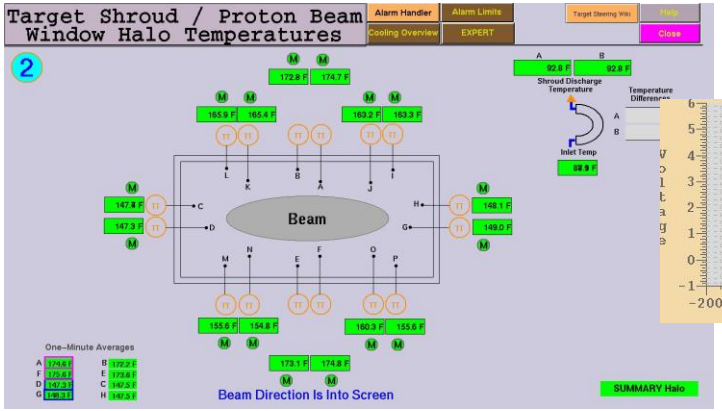


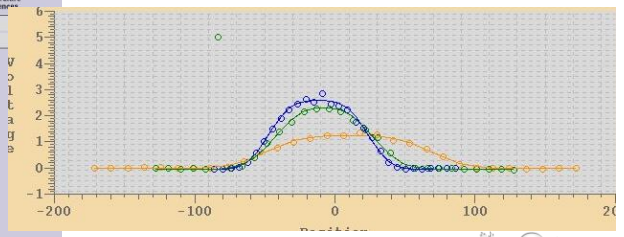
- **Errant source pulses can cause large beam loss and SCL cavity trips**

Target Protection Systems

Beam peak-power density, beam size and centroid position are quantified during tune-up (within limits)

- **Controls include:**
  - **Injection painting kicker and extraction kick wave form monitoring (60 Hz)**
  - **Transport line magnet set-points and loss monitor levels (60 Hz)**
  - **Peak power density (intercepting device - harp)**
  - **Halo thermocouple temperate limits just upstream of the target**
  - **Operator handoff, shift to shift**





Summary

- SNS activation levels are OK for MW operation
- Slow progress in availability increases (~86% this past year)
- MPS is crucial, and requires diligence in verification
  - 2 tier beam loss protection: instantaneous damage and long term activation

Light Sources Have Very Good Accelerator Reliability

Advanced Photon Source (ANL) 2009 Statistics :

Data through Run 2009-2.

FY 2009 Actual	Unavailability Percent	Unavailability Hours	Number of Faults	Mean Time to Beam Loss	Faults Per Day
RF	0.87%	43.43	18	271.3	0.09
Diagnostics	0.19%	9.60	4	1220.8	0.02
PS	0.69%	34.65	20	244.2	0.10
Controls	0.15%	7.25	6	813.9	0.03
Network	0.00%	0.00	0		0.00
Interlocks	0.17%	8.47	5	976.7	0.02
Accelerator	0.03%	1.58	0		0.00
Beamline	0.13%	6.55	4	1220.8	0.02
Radiation	0.02%	1.00	1	4883.3	0.00
MDM	0.08%	3.78	2	2441.7	0.01
S&A	0.00%	0.00	0		0.00
Operations	0.06%	3.03	2	2441.7	0.01
Physics	0.00%	0.00	0		0.00
ID-FE	0.00%	0.00	0		0.00
ID-FE/MD	0.00%	0.00	0		0.00
ID-FE/XFE	0.00%	0.00	0		0.00
Utilities	0.17%	8.35	3	1627.8	0.01
Electrical - APS	0.11%	5.45	1	4883.3	0.00
Electrical - ANL	0.00%	0.00	0		0.00
Cooling - ANL	0.06%	2.90	2	2441.7	0.01
Other	0.01%	0.28	1	4883.3	0.00
Unidentified	0.02%	0.75	2	2441.7	0.01
Total	2.39%	119.50	63	77.5	0.31

User Downtime Hours	116.6
Scheduled Hours	5000
Delivered Hours	4883.3
User Availability	97.7%

~ 98% availability

0.3 trips/day (total)

63 trips/year

- **Inject once per day to once per week**
- **Smaller equipment needed for electrons**
- **Less consequence of beam loss/spill**
- **CW operation**