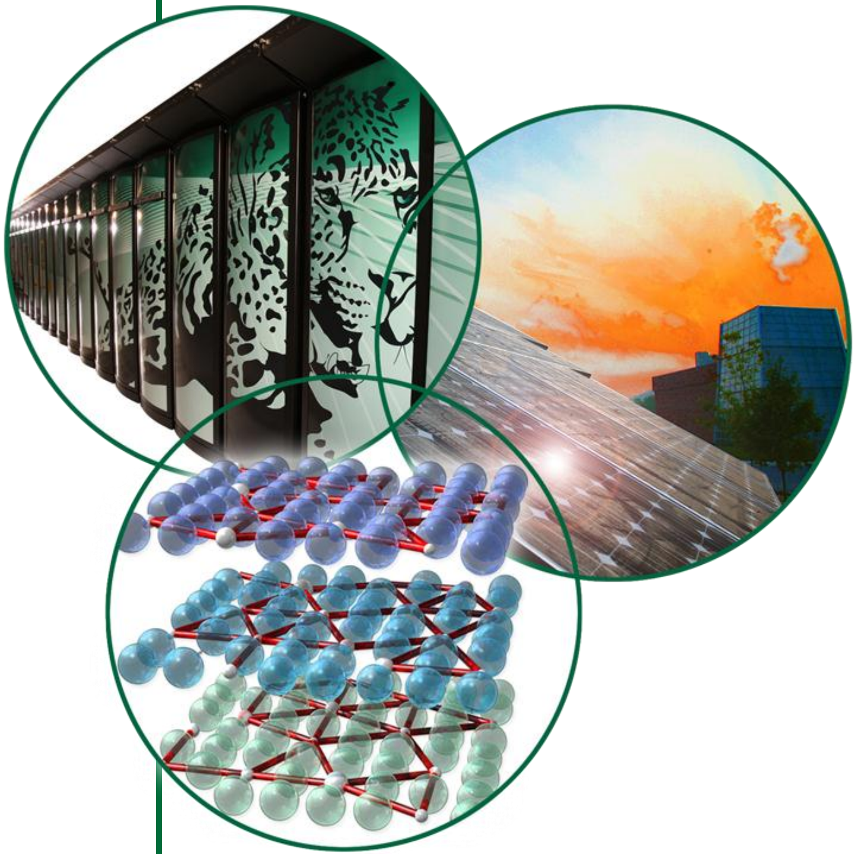
SNS Operational Experience and Upgrades

Proton Accelerators for Science and Innovation Workshop

12-14 January 2012
Fermilab

by Mike Plum,
Ring Area Manager



U.S. DEPARTMENT OF ENERGY

OAK RIDGE NATIONAL LABORATORY
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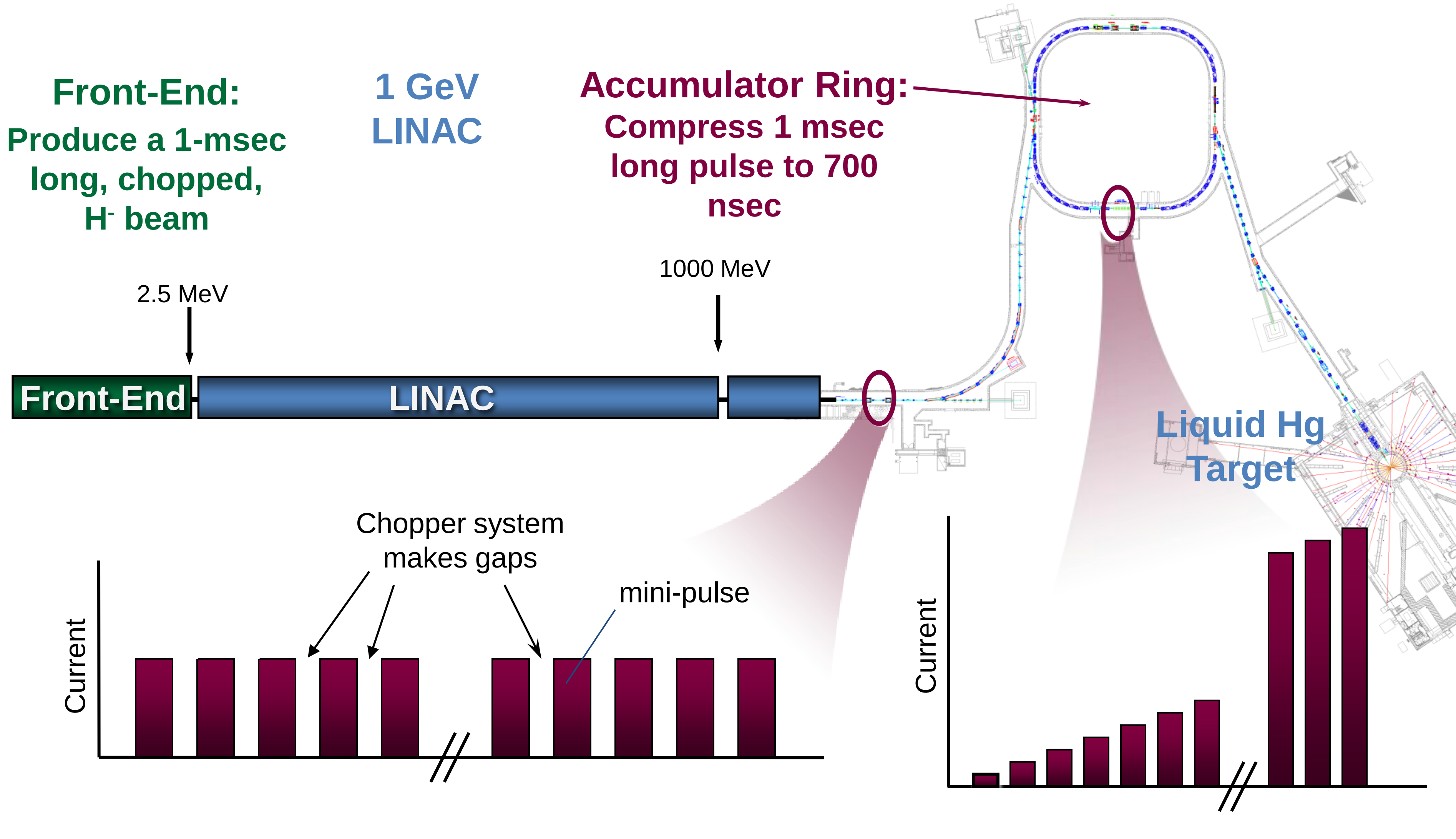
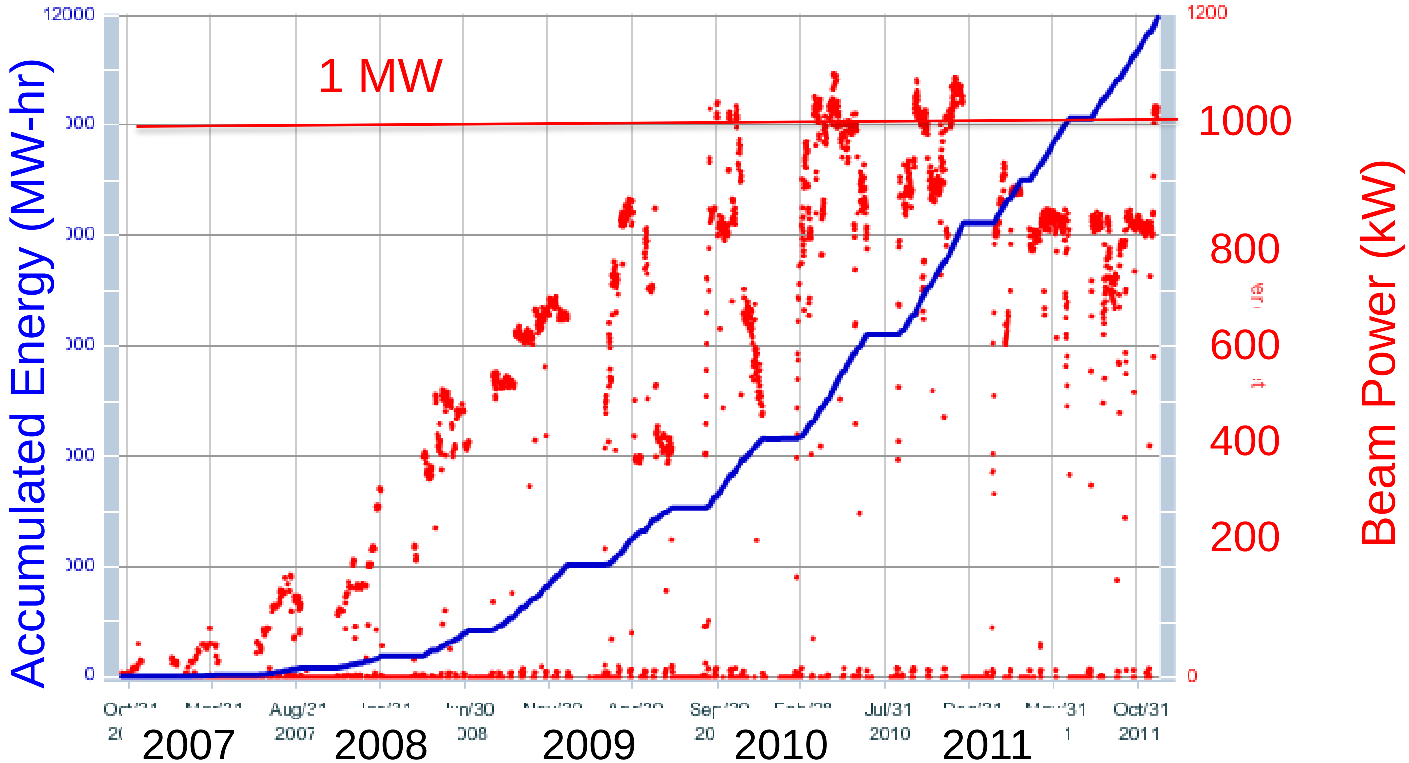
What is SNS ???


Front-End:
Produce a 1-msec long, chopped, H^- beam
1 GeV LINAC
Accumulator Ring:
Compress 1 msec long pulse to 700 nsec
2.5 MeV
1000 MeV
Front-End
LINAC
Liquid Hg Target
Chopper system makes gaps
mini-pulse
Current
Current

SNS Operates at ~ 1 MW

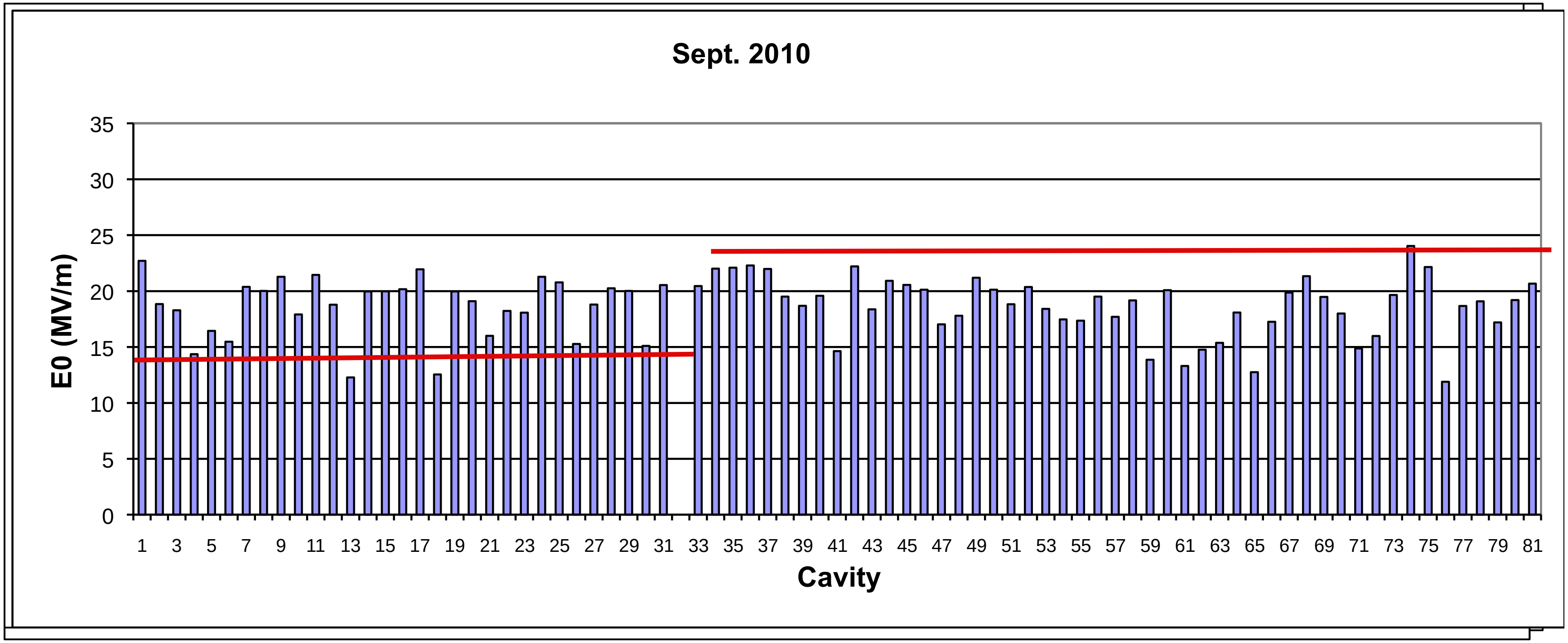


- **1 MW reached within 3 years of operation**
- **2 years of experience at MW level**

SNS Beam Parameters

	Design	Operational Value	Best Ever (not together)
Power (MW)	1.4	1	1.08
Energy (MeV)	1000	925	1000
Repetition rate (Hz)	60	60	60
Pulse length (ms)	1	0.8	1
<macro-pulse current> (mA)	26	23	26
Beam duty factor (%)	6	4.8	4.8
Stored beam intensity (ppp)	1.5×10^{14}	1.1×10^{14}	1.5×10^{14}

Superconducting RF Linacs are Flexible



- **SCL can run with a wide range of cavity performance**
- **But they are flexible, and can accommodate different "gradient profiles"**

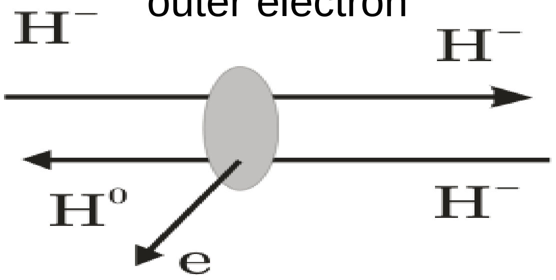
Operating Gradients (E_0T MV/m)	Medium Beta	High Beta
Design	10.2	15.6
Production (now)	11.9	12.8

Courtesy S. Kim

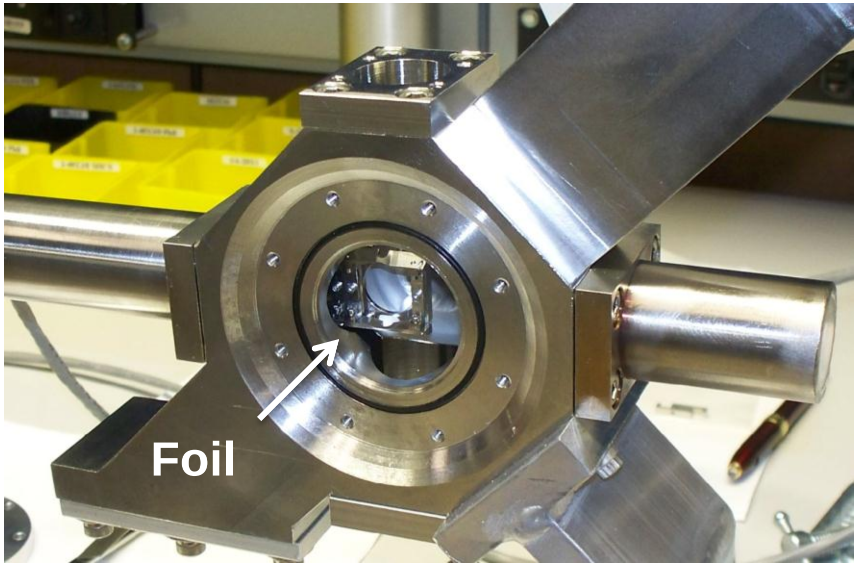
Proton Beam Experiment at SNS

- SNS beam loss explanation: related to H^- stripping by self collisions
  - V. Lebedev, FNAL

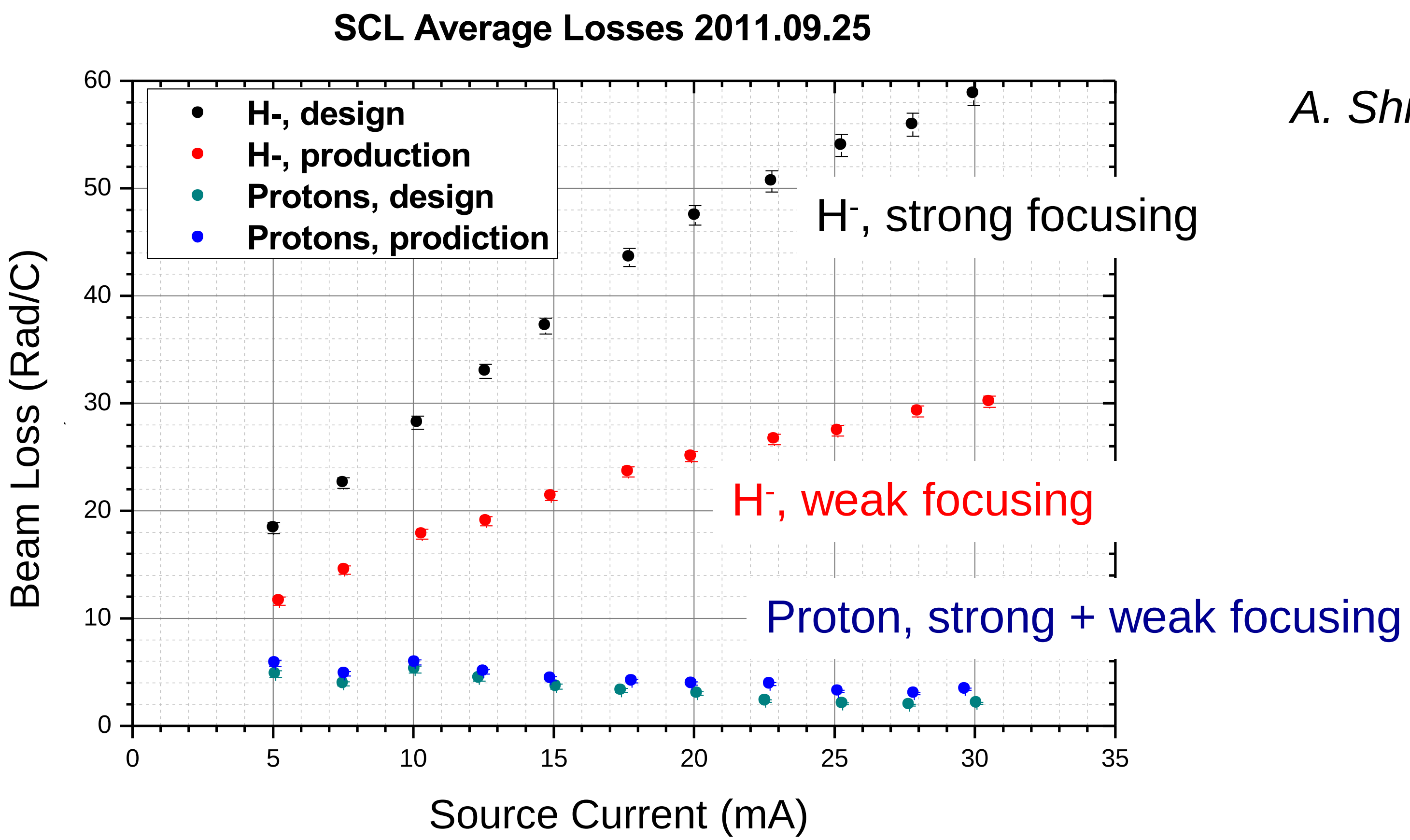
Collisions between H^- in the accelerated bunch can strip the outer electron



- Recently added an insert-able thin foil upstream in the SNS linac (A. Shishlo)
  - Converts H^- to protons
  - Adjust a few quadrupoles and flip all RF by 180 degrees:
    - A proton linac!!!



Proton Beam Loss is much lower than H^-

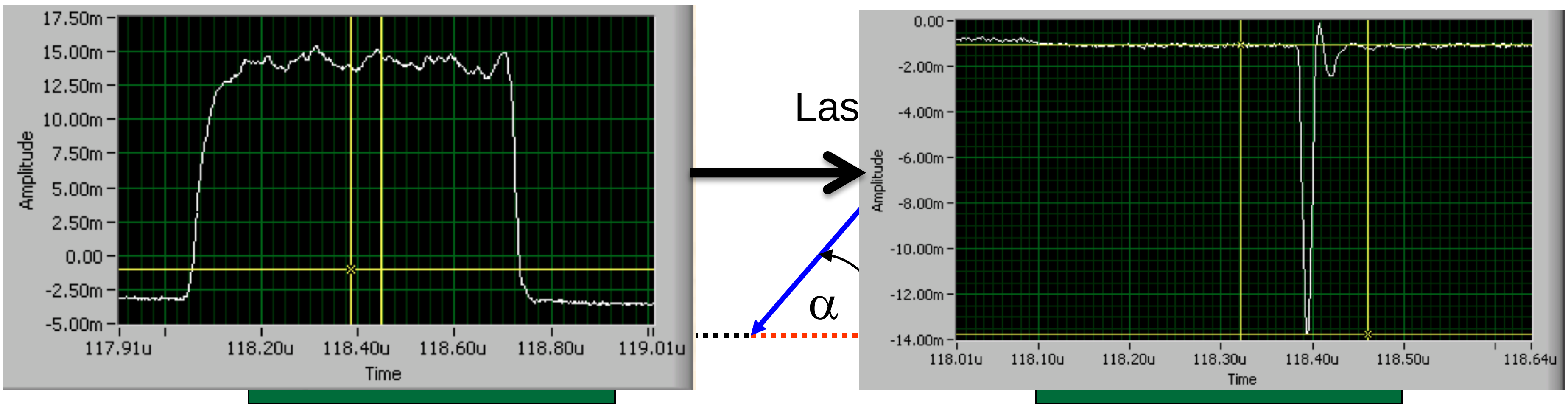


A. Shishlo et al.

- **Measured beam loss in the SNS linac is much lower for protons than for H^-**
  - **Trends are consistent with “Intra-beam stripping”**
  - **Good news for future high intensity proton linacs**

Laser Assisted H^- Beam Stripping

- Our team has developed a novel approach of “foil-less” stripping for charge-exchange injection in high intensity proton facilities
- The approach uses a three-step method employing a narrowband laser beam
- Proof-of-principle experiment demonstrated a stripping efficiency of 90% for ~10 ns



Step 1: Lorentz Stripping

$H^- \rightarrow H^0 + e^-$

Step 2: Laser Excitation

$H^0\ (n=1) + \gamma \rightarrow H^{0*}\ (n=3)$

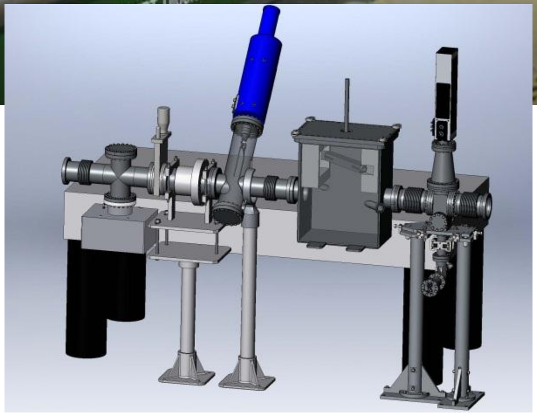
Step 3: Lorentz Stripping

$H^{0*} \rightarrow p + e^-$

Courtesy V. Danilov

Intermediate Stage Laser Stripping

New experiment site

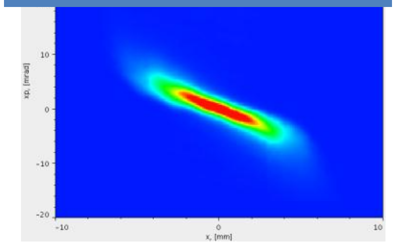


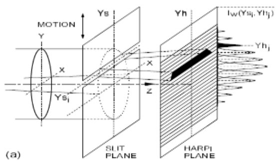
Macro-pulse laser system

- Optimization of beam parameters has been investigated to minimize the laser power requirement
- Macro-pulse laser system has been designed, fabricated and tuned
- The laser can deliver 1 MW / 50 ps / 402.5 MHz micro-pulses at 355 nm. Micro-pulses are bunched to 10 us macro-pulses at 10 Hz.
- Laser is ready for experiment on actual SNS H^- beam

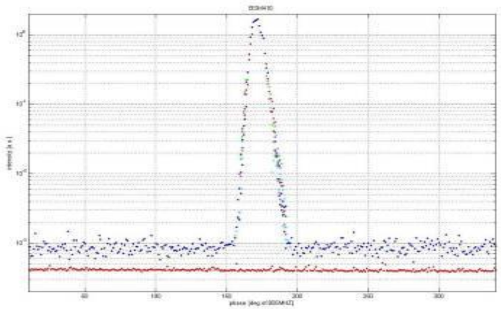
Excellent diagnostics suite in linac

High-resolution transverse emittance

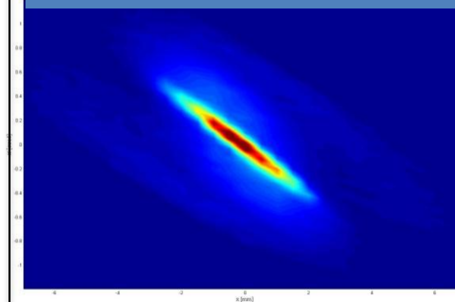


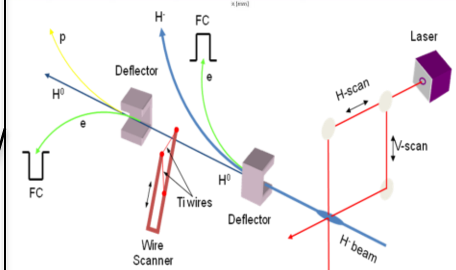


Large dynamic range longitudinal profiles

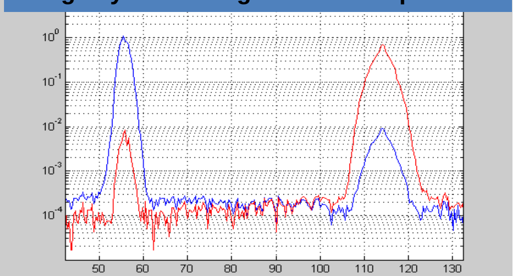


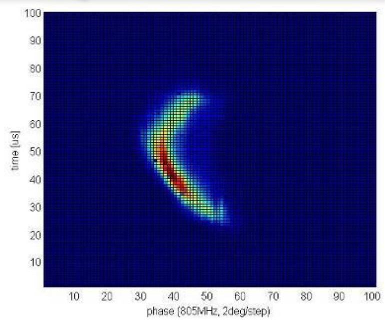
Non-interceptive laser emittance

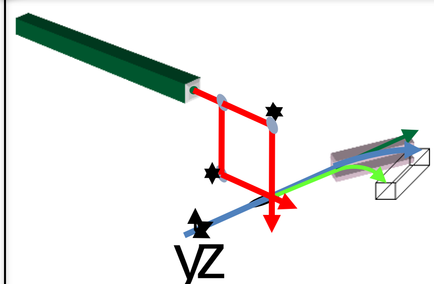




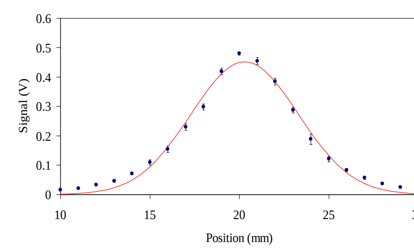
Large dynamic range transverse profiles







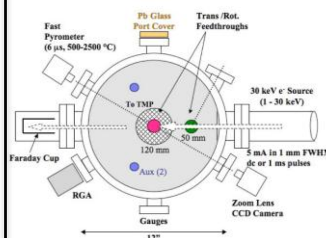
Non-interceptive laser wire

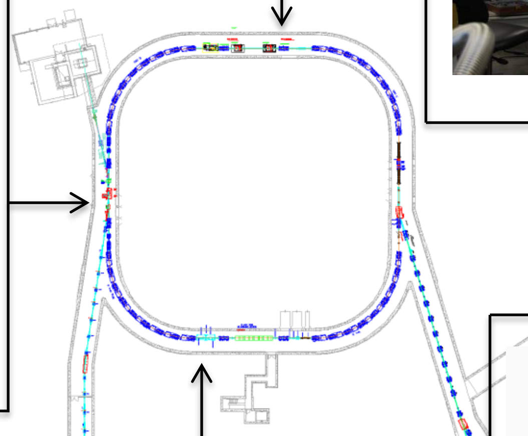


SNS Ring - world record 1.55 x 10^{14} ppp

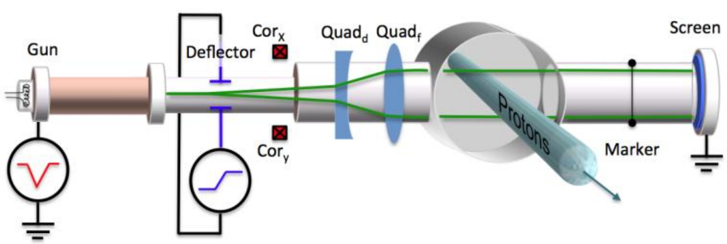
Transverse feedback system
- Both analog and digital LLRF systems

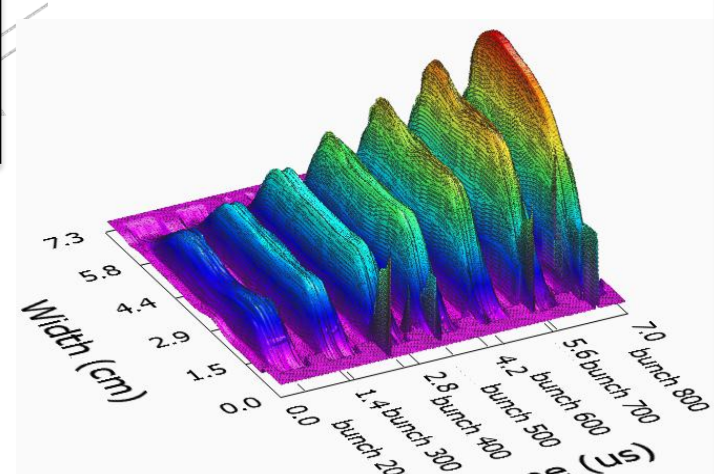
Stripper foil development program
- Nanocrystalline diamond foils
- Developing boron-doped foils





Non-intercepting electron beam profile monitor
- Time-resolved profiles





SNS The Future

- Near term: few years
  - Increase beam power to 1.4 MW

- Longer term: Second Target Station
  - Long pulse neutron source
  - Possible materials irradiation testing
  - Beam power of 2-3 MW

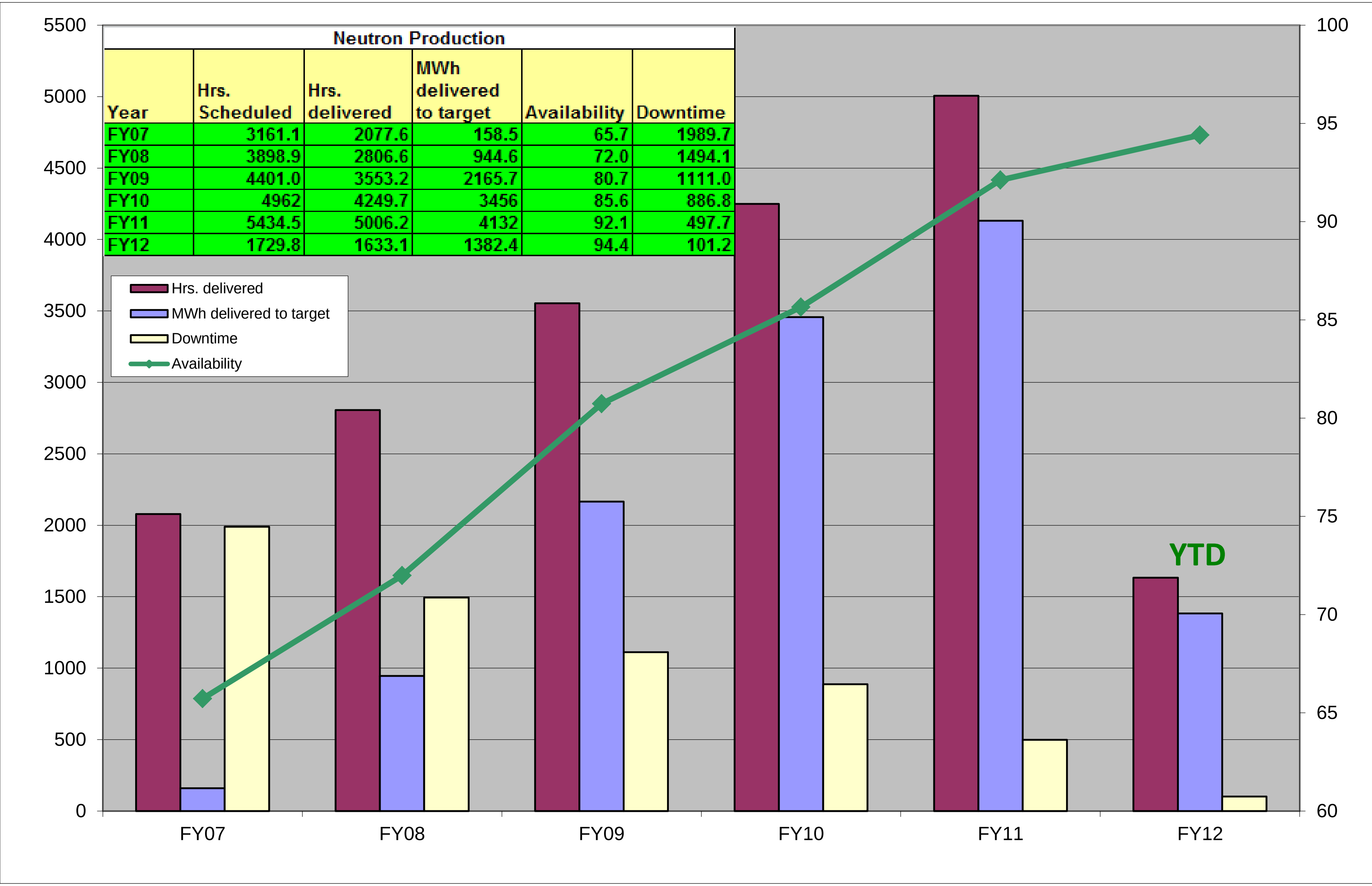
Summary

- SNS is a operational MW class superconducting linac proton accelerator
  - High reliability
  - Well instrumented (longitudinal, transverse, laser-based)
  - Good test bed for H^+ vs. H^- beam dynamics
  - Interesting beam instabilities at high intensities
  - Opportunities to conduct experiments
  - We welcome collaborators from other facilities

Thank you for your attention !

Back up slides

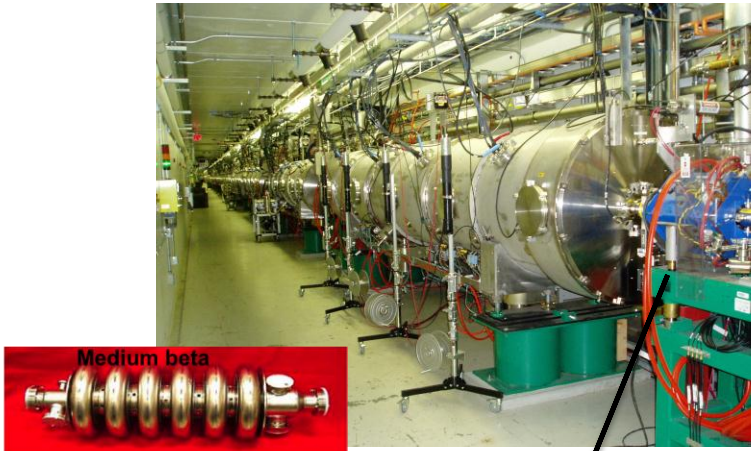
Availability and MWhrs continue to grow each year

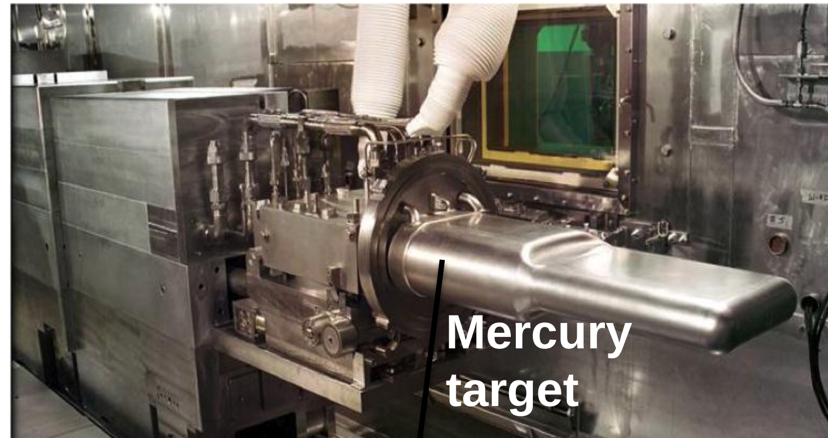


Neutron Production					
Year	Hrs. Scheduled	Hrs. delivered	MWh delivered to target	Availability	Downtime
FY07	3161.1	2077.6	158.5	65.7	1989.7
FY08	3898.9	2806.6	944.6	72.0	1494.1
FY09	4401.0	3553.2	2165.7	80.7	1111.0
FY10	4962	4249.7	3456	85.6	886.8
FY11	5434.5	5006.2	4132	92.1	497.7
FY12	1729.8	1633.1	1382.4	94.4	101.2

SNS Components

SRF Cavities / Cryomodules





High power (MW) proton beam operation