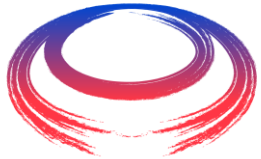

SNS Accelerator: Major Challenges & Mitigation Measures

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SNS and PPU Projects, ORNL, USA
May 20-21,2021

SNS Accelerator Complex

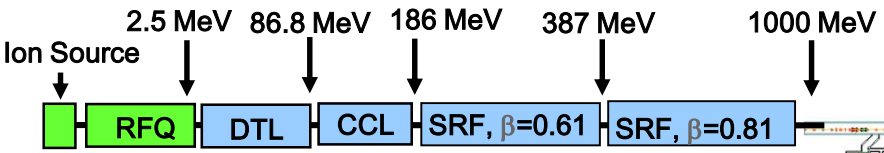
Front-End: Produce a 1-msec long, chopped, low-energy H- beam

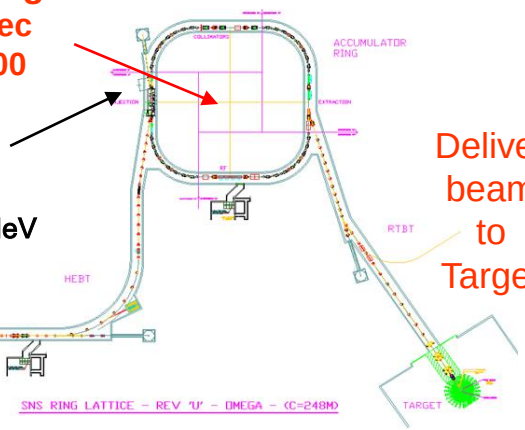
LINAC: Accelerate the beam to 1 GeV

Accumulator Ring: Compress 1 msec long pulse to 700 nsec

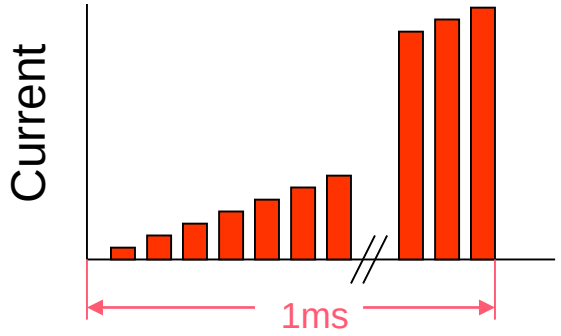
H- stripped to protons

Deliver beam to Target

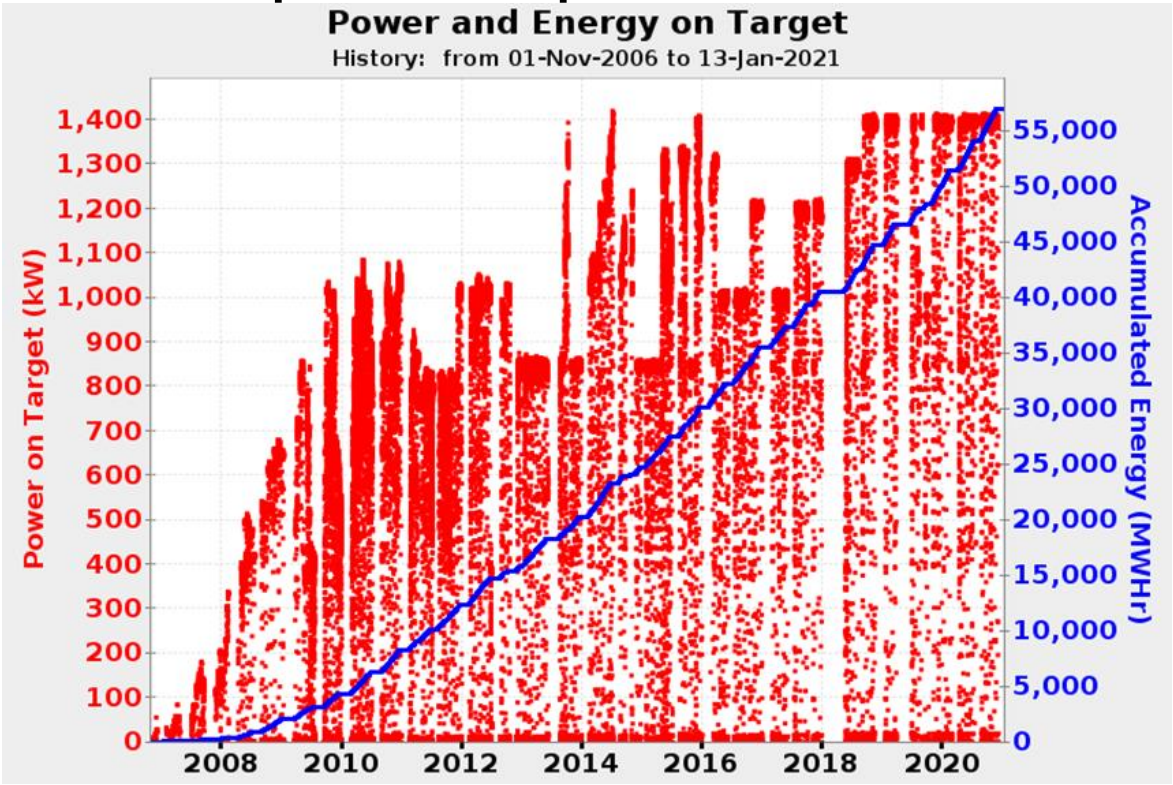




P beam on target :	1.44MW
I beam average:	1.44mA
Maximum Beam energy:	1 GeV
Duty factor:	6%
Rep. rate:	60Hz
Pulse width:	1ms



SNS Operations: April 2006 - Present

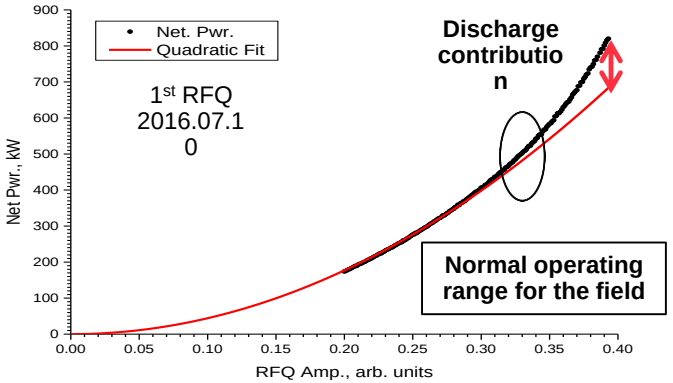


Despite all challenges, SNS operates at 1.4 MW with > 90% availability

RFQ: 1st (2002-2017) and 2nd (2017-Present)

- 1st RFQ is very robust machine, capable to take some abuse
- Transmission is major figure of merit, it declined with time (reason is not clear)
- Excessive heat generation at higher amplitudes and with beam presence
- Resonance Control is instable (too slow) for “Beam On/Off” transitions
- Stabilization with fast model-controlled addition/removal RF power solved this problem

- 2nd RFQ does not show this behavior (yet)



Warm Linac: DTL + CCL

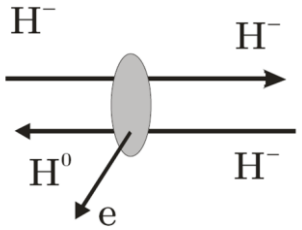
- High rate of vacuum trips inside cavities in the past
- Ion pumps were replaced with turbo-pumps

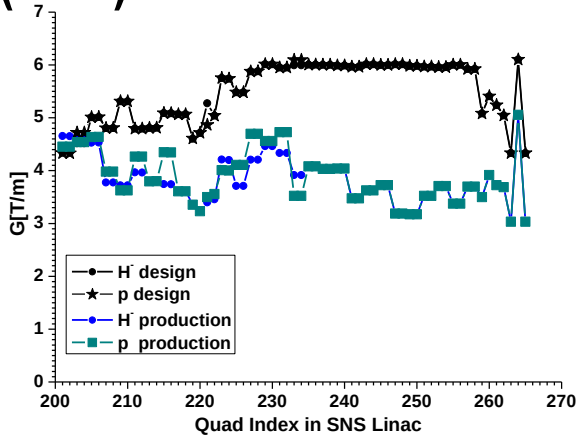
- Trips in Warm Linac/ RFQ/Ion Source are possible source of damage to SCL cavities due to beam loss
- “Errant Beam Control” implemented. Comparing macro-pulse waveform with previous one allows to shut beam faster than using Beam Loss Monitor signals

- Trip rate and beam loss in SCL were reduced further by empirical tuning Warm Linac cavities slightly (significantly) away from design parameters

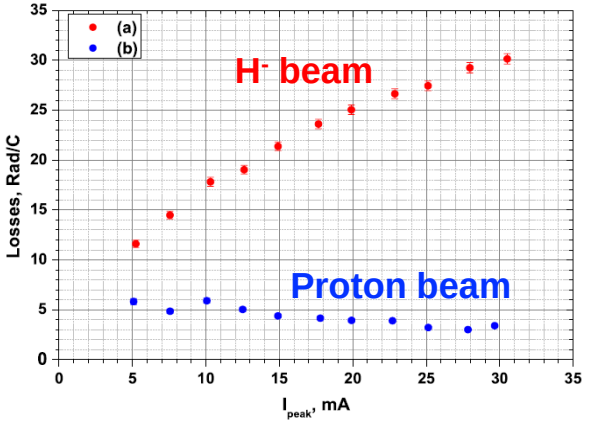
Cavity	Design φ_{synch}, deg	Real φ_{synch}, deg	To Design A_{RF}, %
CCL 1	**-30.9**	**-16.7**	93
CCL 2	**-30.8**	**-21.6**	95
CCL 3	**-30.7**	**-23.9**	98
CCL 4	**-29.3**	**-18.3**	93

SCL: Intra-Beam Stripping (IBSt)



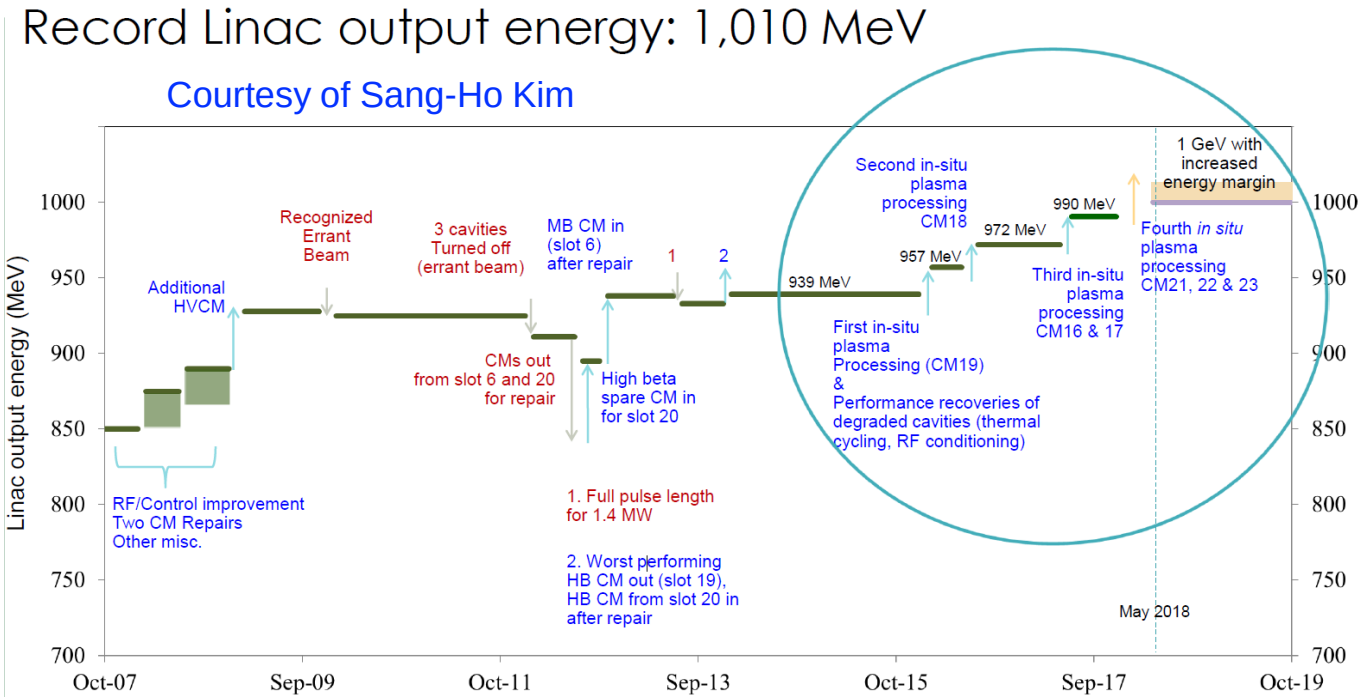


- IBSt was encountered during power ramp-up
- Initially mechanism of beam loss was unknown
- Design showed zero SCL beam loss
- Remedy was developed right away – reduced quad strength in SCL
- IBSt was identified in 2011, experimentally confirmed in 2012
- Since then, we using empirical beam loss tuning in SCL using big apertures



SCL: Superconducting Cavities Degradation

- Problem: SCL cavities reducing gradients and low energy out of SCL
- Solution: Plasma processing of inner surfaces of SCL cavities



Ring Charge-Exchange Injection: Foil Longevity and Max Power

- Nano-crystalline diamond foils (350 $\mu g/cm^2$)
- Typically, 1-2 foils needed for a run (~2500 hrs)
- New foil conditioning time ~40 hours
- It is Ok for now, but what will happen after PPU and STS (2xPower)?
- Benchmarked model was needed
- Optical foil temperature monitoring system was developed + foil test stand studies -> model
- Power limit was calculated as 5 MW
- Temperature control -> alarm -> “beam on foil” size control -> increased longevity

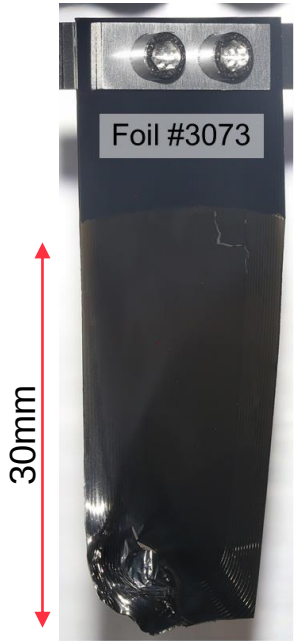


Photo: C. Luck

Notes on Other Technical Peculiarities and Lessons Learned at SNS

- SCL operation is flexible! Much more than anticipated. E.g. run with missing cryomodules, on the fly retune….
- We don’t use SRF piezo tuners nor HOM filters (for our low duty factor application)
- Large aperture is useful for low beam loss if you can afford it
- We don’t use 2 stage ring collimation nor RTBT collimation
- We never used our e-p cloud suppression stuff (e.g. solenoid windings in Ring, transverse instability dumper)
- We never used octupole magnets in ring

Summary

- Technical and physics related challenges are there, but solutions have been found

International MUON Collider Collaboration

CERN

Thank you
for attention