OAK RIDGE National Laboratory

Status of the Spallation Neutron Source Proton Power Upgrade (PPU) project

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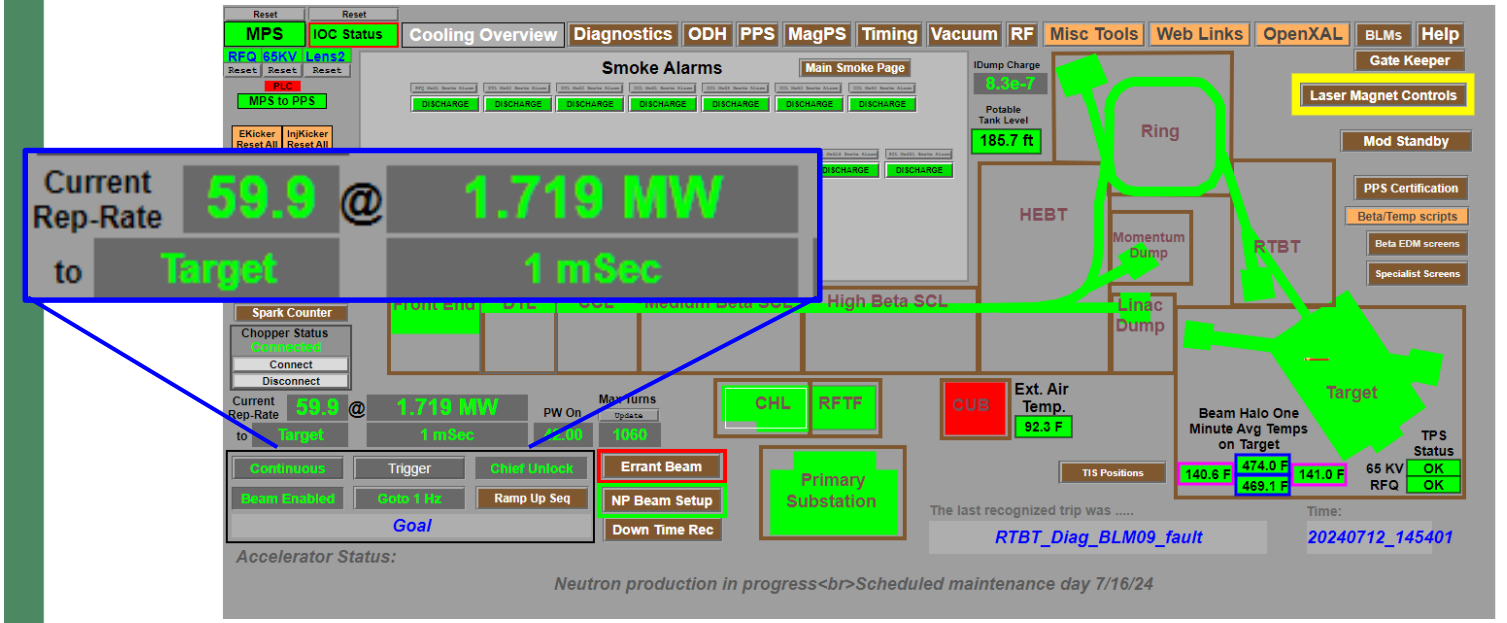
ORNL is managed by UT-Battelle, LLC for the US Department of Energy

U.S. DEPARTMENT OF ENERGY

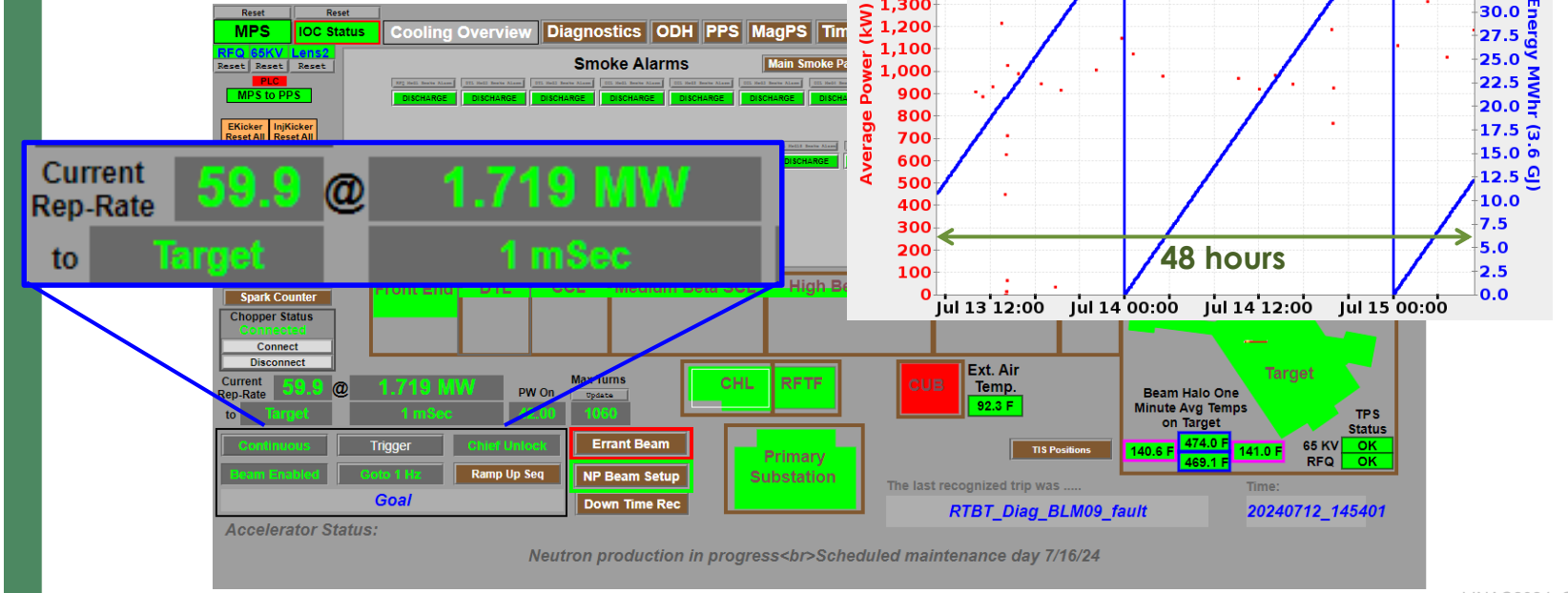
SNS 1.7 MW at 1.3 GeV !!!

- Production run is ongoing

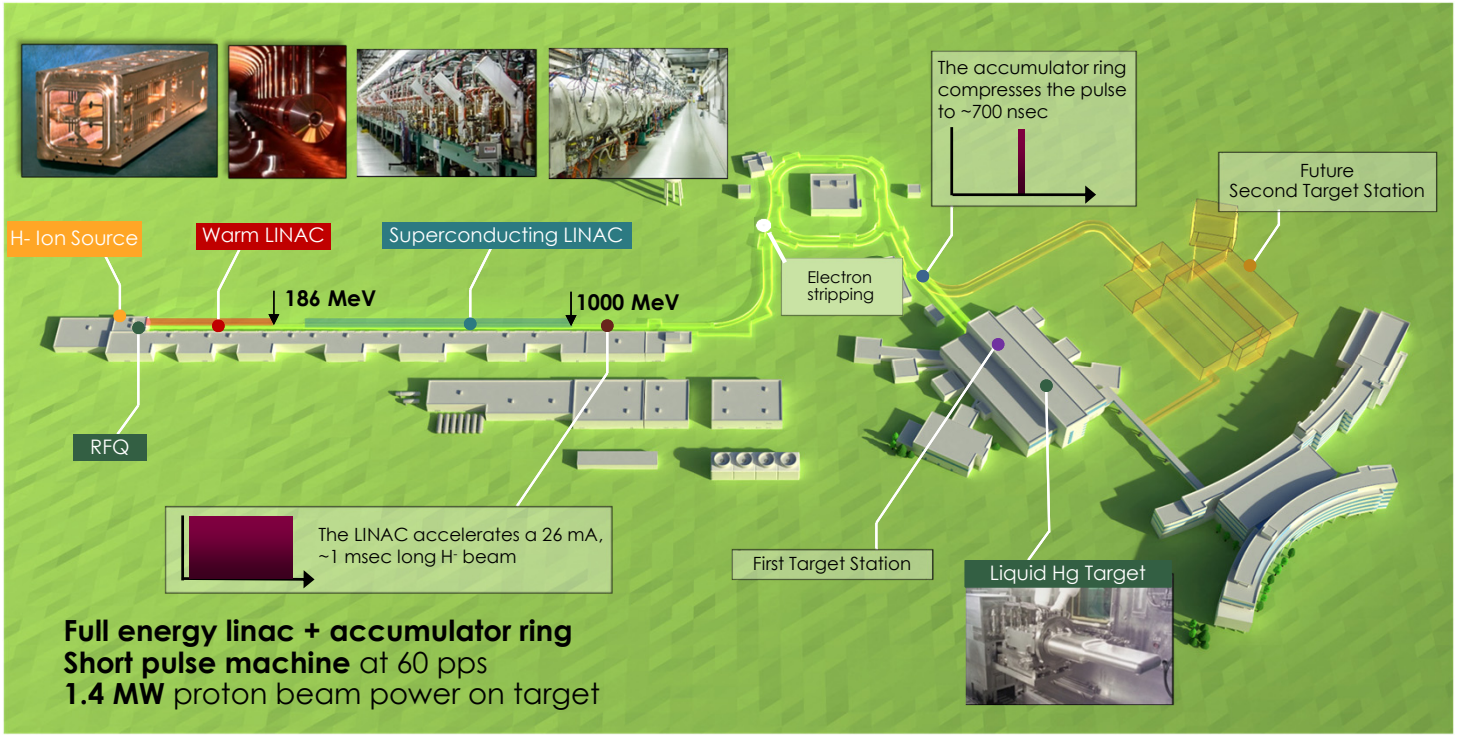


SNS 1.7 MW at 1.3 GeV !!!

- Production run is ongoing
- Very reliable operation

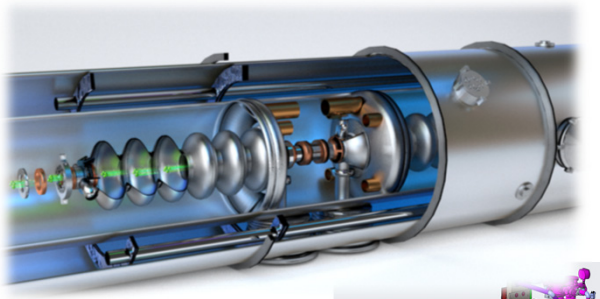


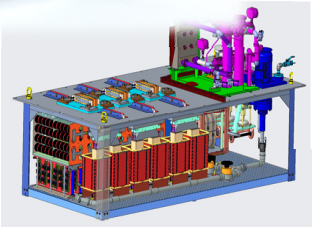
SNS machine overview

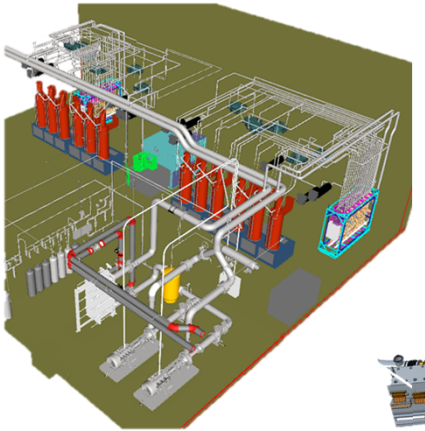


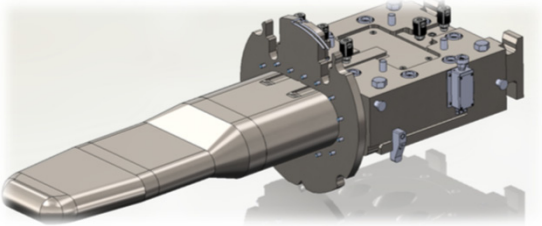
High level goals of Proton Power Upgrade (PPU) project

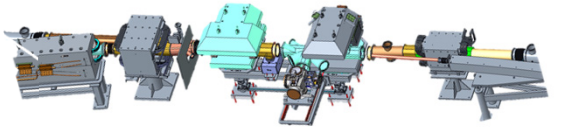
- Optimization between Built-in upgrade provisions, Cost effectiveness and Technical aspects to achieve;
  - Accelerator: upgrade or replace components to enable 2.8 MW beam
  - First Target station: upgrade for 2-MW beam at 1.3 GeV, 60 pps
  - 700 kW for Second Target Station (STS) in the future





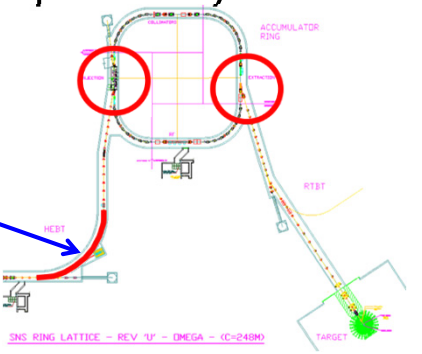




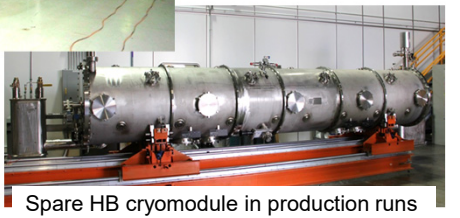


PPU approach for 2.8-MW accelerator capability

- Beam energy upgrade to 1.3 GeV
  - At H- beam >1.3 GeV, Lorentz Stripping will cause increased beam loss at HEBT arc
  - Most of existing magnets in HEBT and ring are capable for 1.3 GeV except injection and extraction regions
  - By adding 7 PPU cryomodules and associated RF/HVCM systems to reach 1.3 GeV with margin
    - PPU cryomodule design based on in-house built spare high beta cryomodule
- Beam current increase by 50%
  - Most of existing systems are capable
    - Front end system can support 2.8 MW operation with a significant margin
    - Except three DTL high-power RF systems and associated HVCM (out of ~100 existing RF systems)

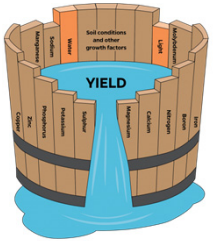



Empty slots at the end of linac tunnel


Spare HB cryomodule in production runs since 2012 demonstrates PPU gradient

Reflect on lessons learned from SNS operational issues and successes in the past

- Many of sub-systems were the first attempts: All these challenges required significant R&D
- All challenges were overcome to achieve balanced performances ("law of minimum")



- Achieved stable/reliable operation at 1.4 MW operation with up to 95 % availability against planned beam time for users

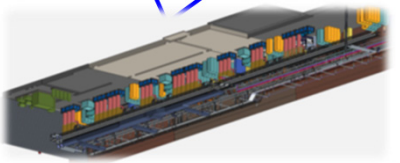
PPU scope

Superconducting Linac upgrades
- Add 7 new cryomodules

Ring system upgrades
- Primarily injection and extraction

Radio Frequency (RF) system upgrades
- Additions for new cryomodules
- Upgrades for existing systems

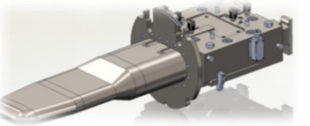
FE | DTL | CCL | SRF, β=0.61 | SRF, β=0.81 | upgrade



Conventional facility upgrades
- Klystron gallery extension
- RTBT stub

Liquid Hg Target

First Target Station upgrades
- 2 MW, at 1.3 GeV, 60 pps



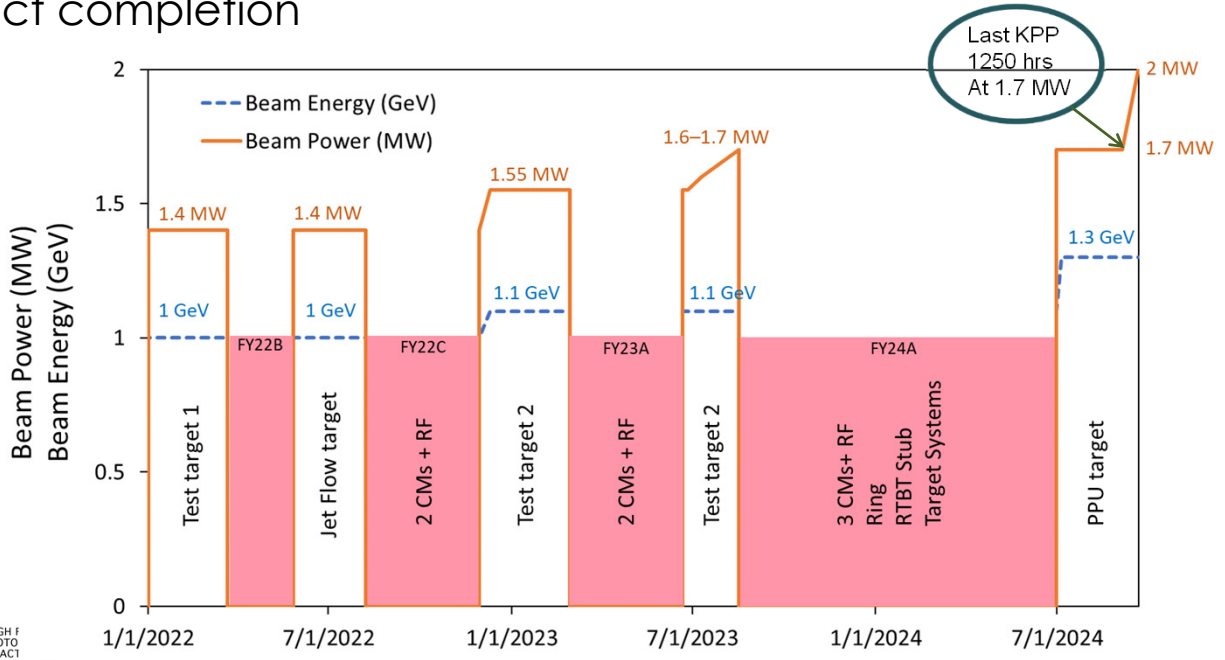
PPU Key Performance Parameters

Key Performance Parameter	Threshold	Objective
Beam power on target (MW)	1.7 at 1.25 GeV	2.0 at 1.3 GeV
Beam energy (GeV)	1.25	1.3
Target operation without failure (hours)	1250 at 1.7 MW	1250 at 2.0 MW
Stored beam intensity in ring (protons per pulse, ppp)	1.60×10^{14} at 1.25 GeV	2.24×10^{14} at 1.3 GeV

- Challenges
  - Target longevity demonstration
  - Production run with high availability immediately after completion of final installation of new equipment

Power ramp-up plan as equipment installed

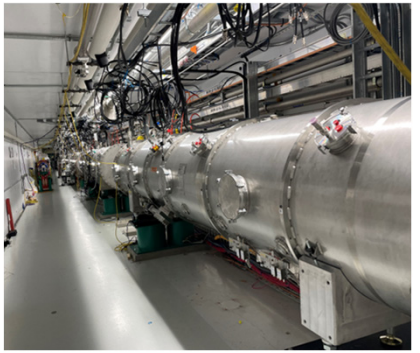
- Performance verification of new equipment as they are installed
  - Including existing equipment for higher power operation
- Increases neutron flux to users more quickly compared with waiting until project completion



Technical highlights (I)

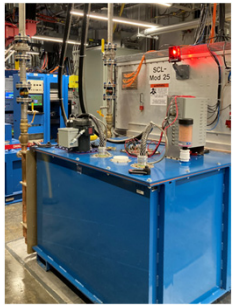
In linac tunnel

- All seven cryomodules installed
- All SRF cavities exceeded the design specification
  - One cryomodule for energy reserve



RF systems

- Similar with the existing systems
- With 700-kW klystrons to support 2.8 MW beam loading
- With new AT-HVCMs
- New LLRF system



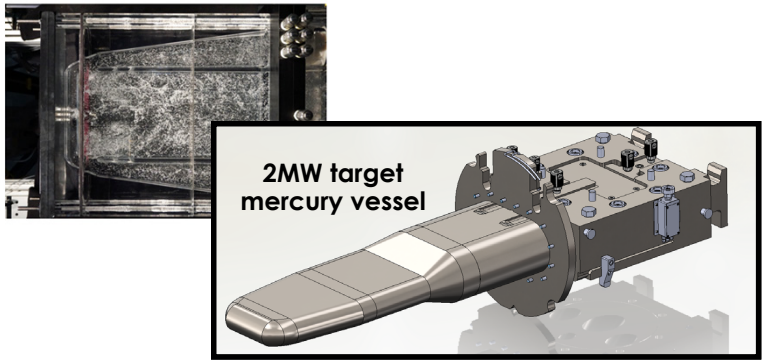
In ring tunnel

- New injection region
- New power supplies for extraction kickers for 1.3 GeV beam
- New injection dump imagining system
- All worked as designed!

Technical highlights (II)

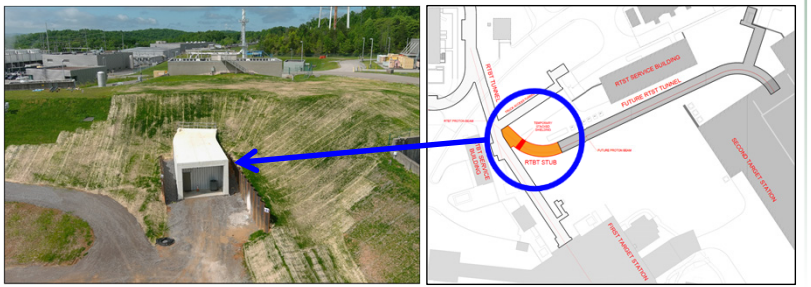
First target station

- All available means of leverage are sought
- Successful R&D for high-rate gas injection
- Successful test runs with PPU test target 1 & 2



Conventional facility

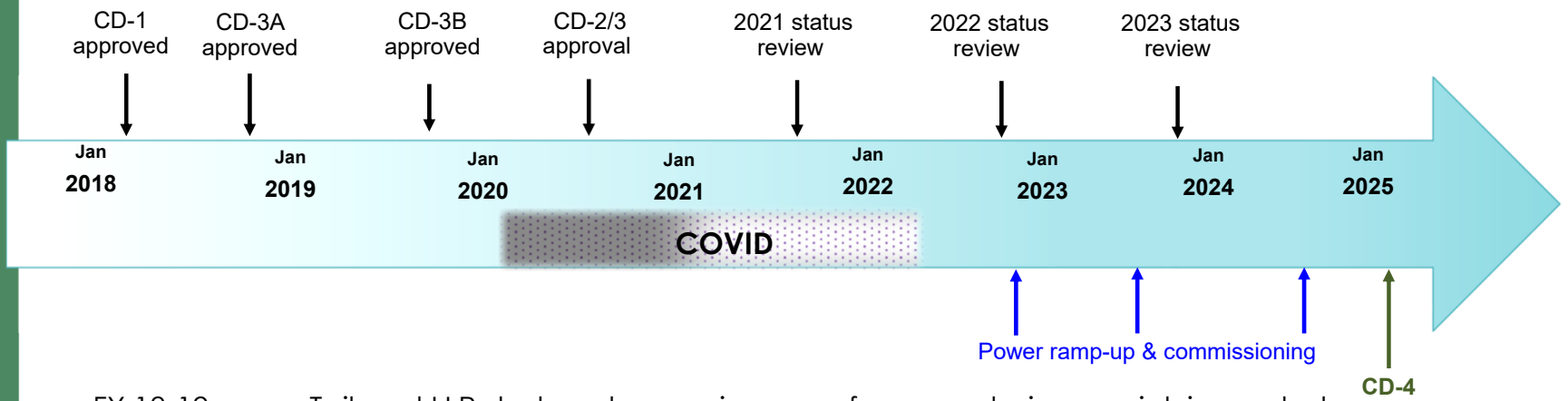
- Stub-out from 'Ring to target beam transport' to future beam transport line to the second target station
  - To minimize SNS operational impact during Second target station construction



Thanks for Excellent Partnerships !

- LLRF firmware development with LBNL
- Cryomodule Production with JLab
- Ring injection region magnet production with FNAL

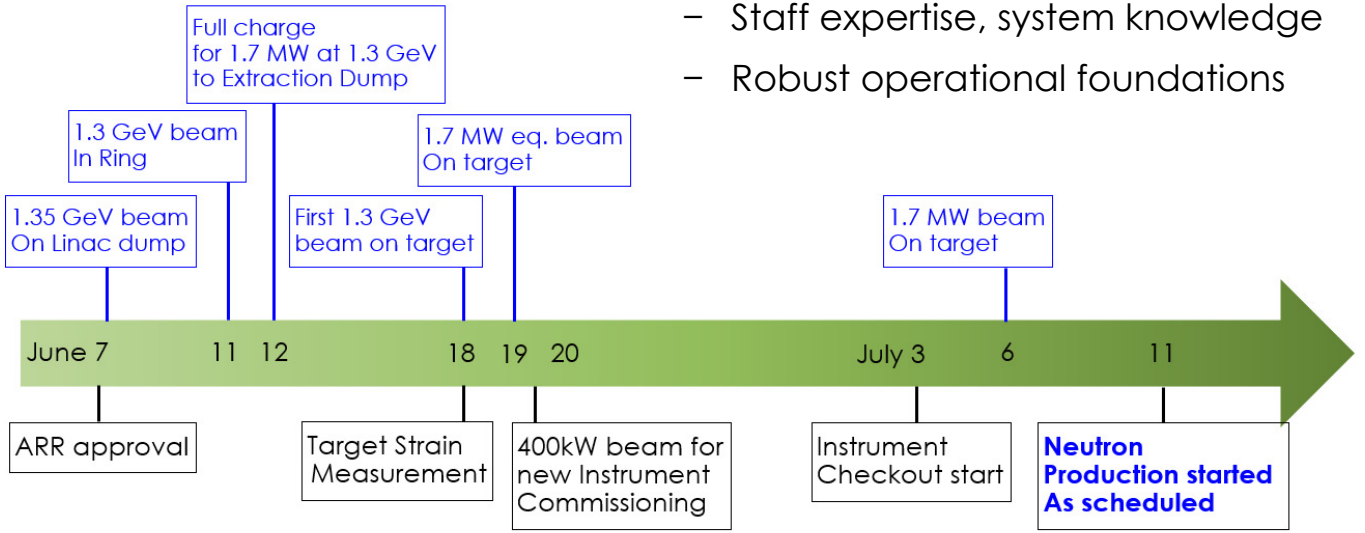
Project timeline was stable from the beginning



- FY 18-19 : Tailored LLP strategy leveraging use of proven designs: quick jump start
- FY 20 : Baselining combined CD-2/3 review
- FY 21-22 : Execute CD-3, 3a, 3b scope
- FY23 : Start power ramp-up
- FY24 : Long outage & final commissioning & demonstration of KPPs
- **Early FY25 : CD-4 (no change from the start of the project) and financially very healthy**

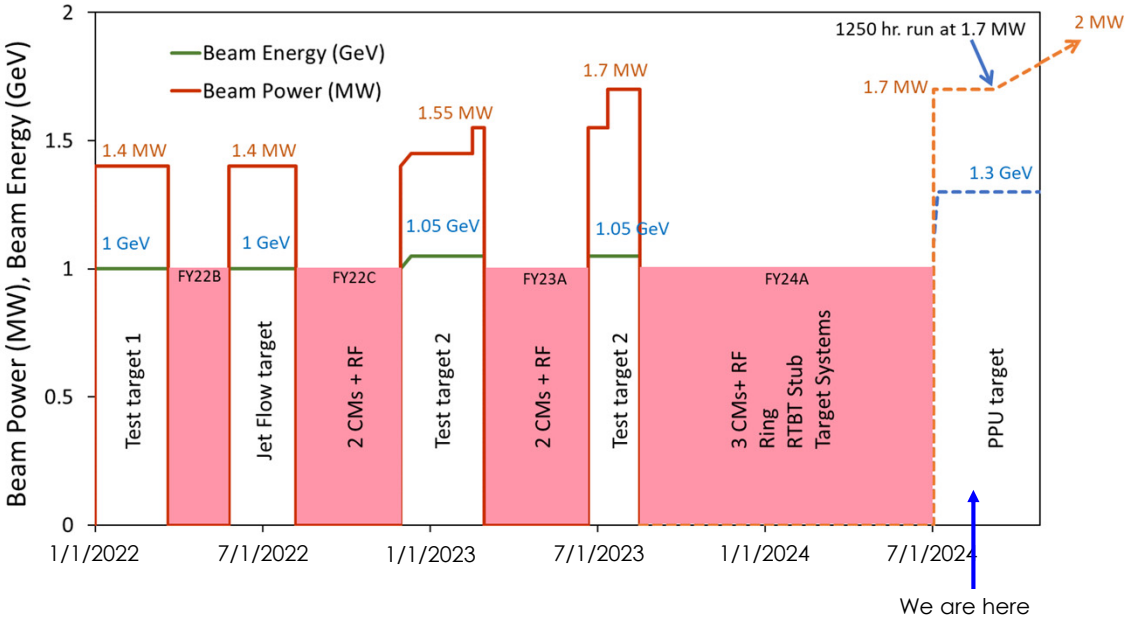
Beam commissioning has gone very well, and neutron production started as planned

- Actual commissioning except low-loss beam tuning only took several days
  - Staff expertise, system knowledge
  - Robust operational foundations

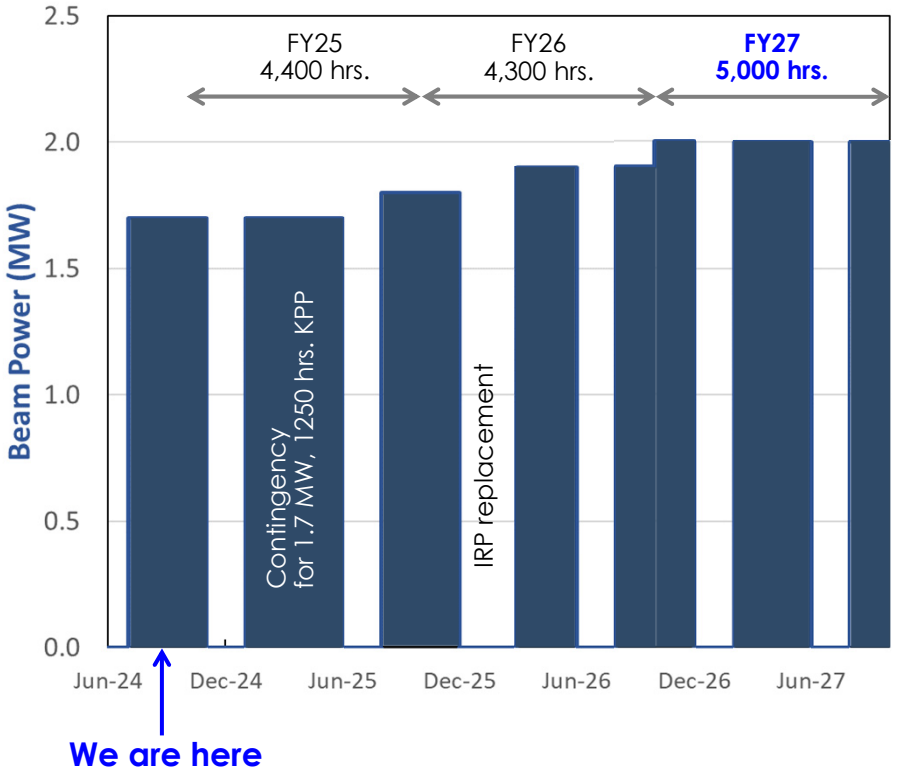


Actual power ramp-up history

- Successful power ramp-up
  - Phased approach is invaluable!
  - Demonstrated all KPPs except the KPP for target longevity



Plan to reach 2-MW and 5000 hours for users

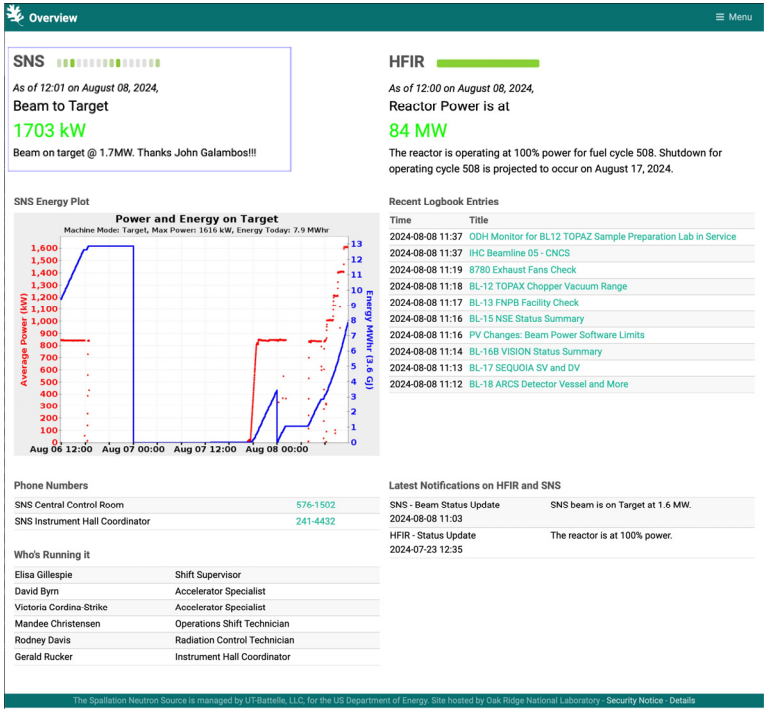


- Beam power ramp from 1.7 MW to 2.0 MW over 2 ~ 3 years
  - It is deliberately conservative
  - Already ran 2.1 MW equivalent beam loading during the previous run (1.7 MW at 1.05 GeV)
- But still, there's challenges
  - Obsolescence, aging systems
  - Unknown unknowns
- We will start 2.8-MW beam power demonstration

Summary

- PPU is nearing completion
  - Demonstration of the last KKP is ongoing
    - 1250 Hours with one target at 1.7 MW
- Operation plan for Power ramp-up is in place
  - 2 MW routine operation on the first target station
- SNS starts a new journey toward 2.8 MW or beyond
  - Verify/test capacities/performances of components/equipment
  - Find 'Unknown unknowns' asap
  - Demonstrate capability/reliability as a whole

Thanks for your attention and Thanks to SNS/PPU Team &



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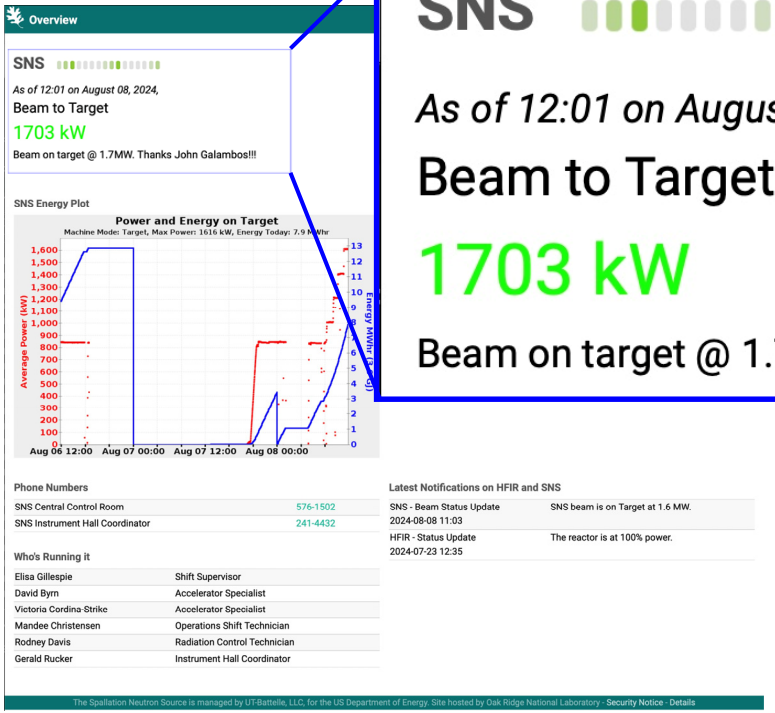

SNS

As of 12:01 on August 08, 2024,

Beam to Target

1703 kW

Beam on target @ 1.7MW. Thanks John Galambos!!!