The Proton Power Upgrade High-power RF Systems

12th CWRF Workshop

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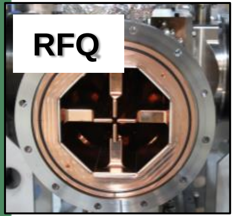
Outline

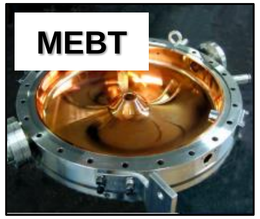
- Background
- Proton Power Upgrade Overview
- PPU Normal Conducting RF Systems
- PPU Superconducting RF Systems
- Summary
- References and Acknowledgements

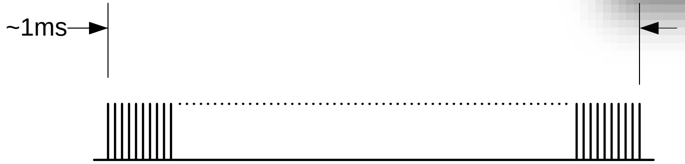
Background - Spallation Neutron Source

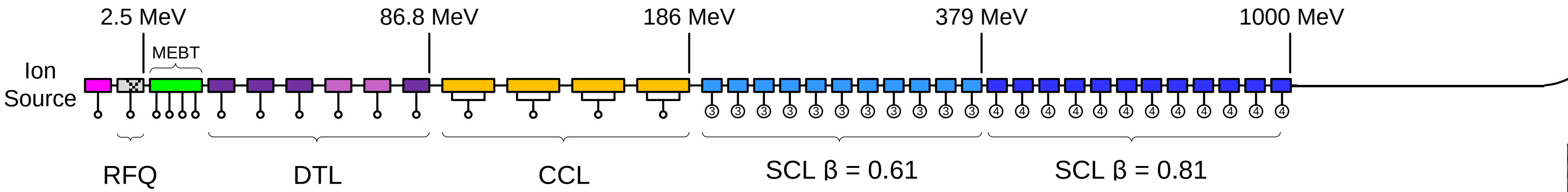
Background – SNS Today

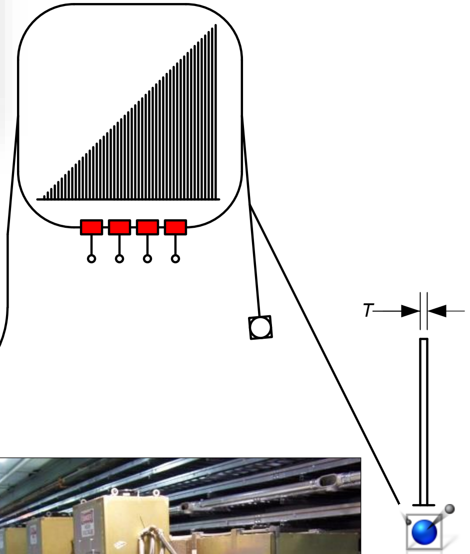
- Over 100 RF systems accelerate and compress 1 GeV proton beam









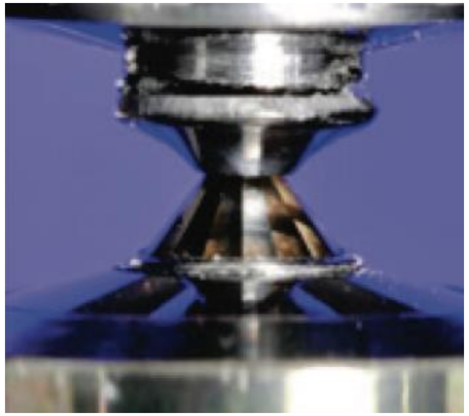


PPU Purpose*

- ORNL operates two neutron sources – the SNS First Target Station (FTS) and the High Flux Isotope Reactor (HFIR)
- PPU will enable the addition of a third – the Second Target Station (STS) while increasing the capability of the FTS

Increase the neutron flux at the existing First Target Station by 40%

- Allow use of smaller samples, and solutions with lower concentrations
- Increase the rate of discovery



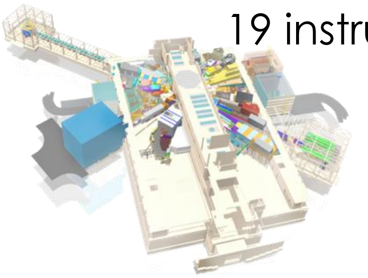
Provide proton beam for the Second Target Station

- Compliments FTS and HFIR capability with unprecedented cold neutron brightness
- Simultaneously probe the structure and function of complex materials across broader length and time scales

SNS Upgrade Plans – How PPU Fits in the Bigger Picture

Today

24 instrument positions
19 instruments built



First Target Station

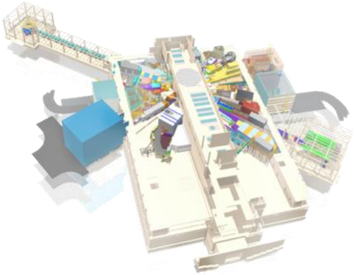
1.4 MW

Accelerator

Now

Future

24 instrument positions
21 instruments built



First Target Station

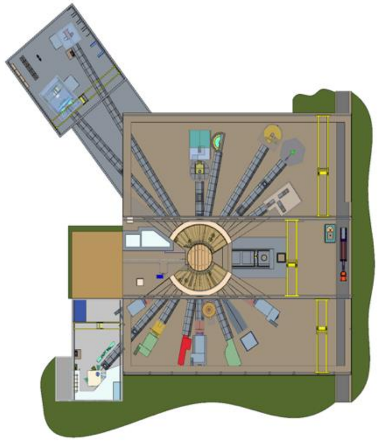
2 MW

Beam energy from 1.0 to 1.3 GeV + Beam current increase from 26mA to 38mA

Accelerator
2.8 MW capable

Proton Power Upgrade (PPU)

Second Target Station (STS)

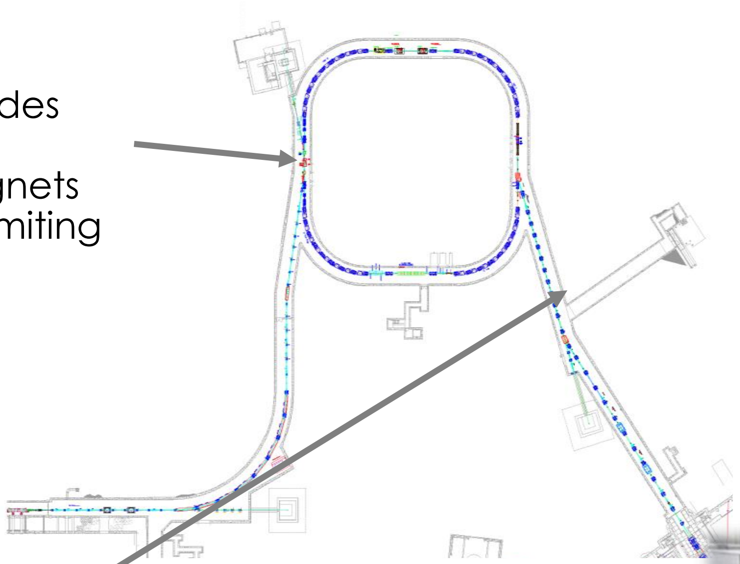


STS Upgrade
22 instrument slots,
8 initial instruments

Proton Power Upgrade Project Scope*

- Includes scope across much of the neutron source

Ring system upgrades
- Injection and extraction magnets
- Beam Power Limiting System

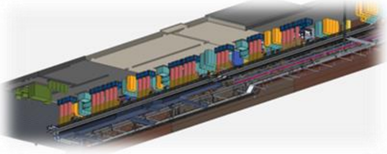


7 new superconducting linac cryomodules, 28 new superconducting cavities

Front-End | LINAC | Upgrade

Radio Frequency (RF) system upgrades
- **New RF stations for new superconducting cavities**
- **Warm Linac upgrades**

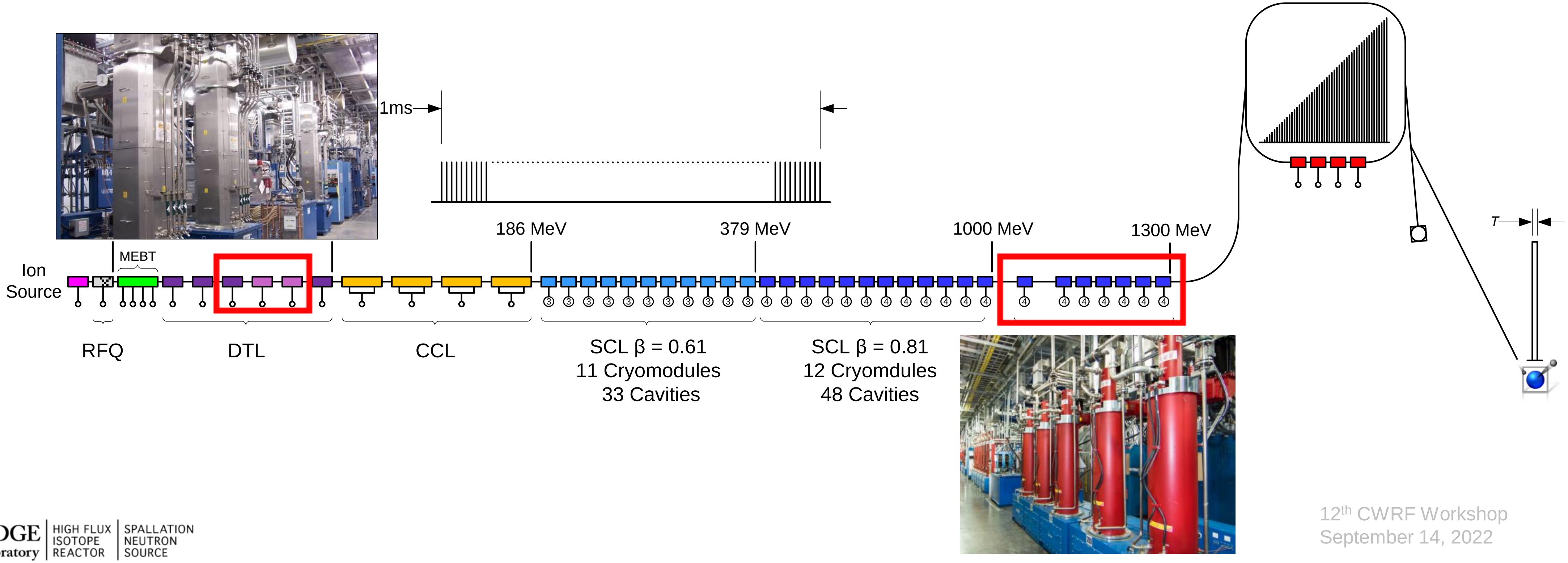
Conventional facility upgrades include klystron gallery buildout and tunnel stun



Target system upgrades for 2MW capability

PPU High-Power RF Systems Overview

- Normal Conducting High-Power RF (HPRF)
  - Upgrade 3 existing Drift-tube Linac (DTL) HPRF stations from 2.5 to 3.0 MW peak power capability
- Superconducting HPRF
  - Install 28 new HPRF stations with 700 kW peak power capability

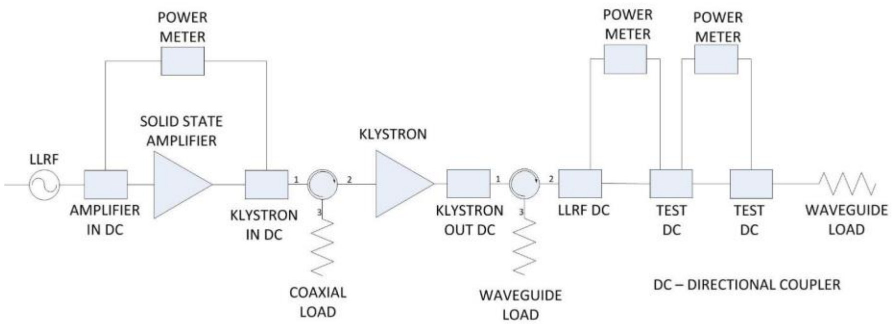


PPU Normal Conducting HPRF Systems – Design Criteria

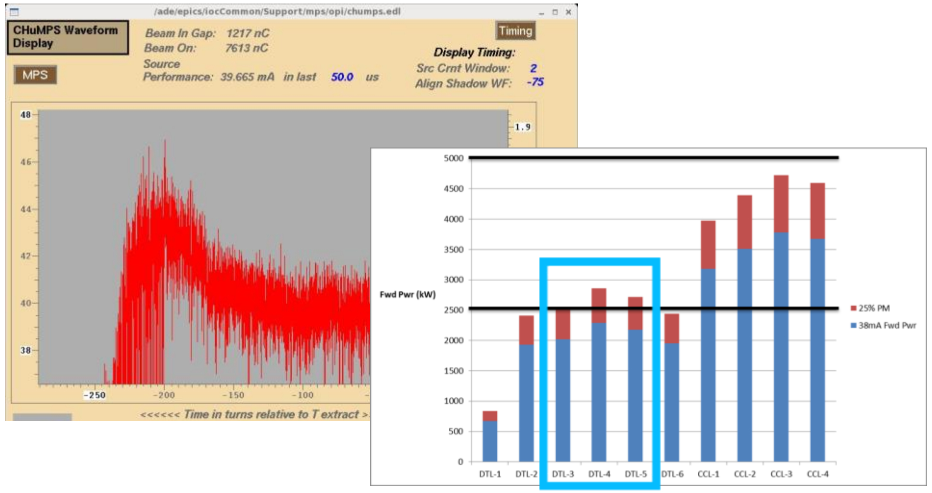
- Capable of accelerating 38 mA proton beam with 25% power margin (PM) [1,3]
  - Matches original SNS design requirement
  - Maximizes operational flexibility – see "PM Budget"
- Ran series of high-current tests in 2017 [2]
  - DTL stations 3, 4, and 5 did not meet requirements

Description	Percent
Prevent operation in highly non-linear region (full saturation)	10
HVCM Voltage (Operational adjustments)	5
Variation in Klystron Output	5
Operation of detuned cavities (DTL – 8.5kHz BW)	5
Increased power required for AFF learning	3
Total	**28**

Power Margin Budget



RF Power Margin Measurement Set-up

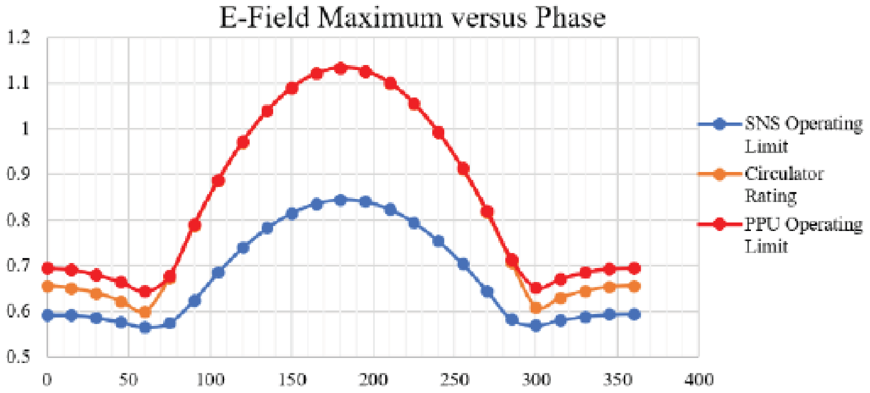


Demonstration of 38 mA beam in Linac and results

PPU Normal Conducting HPRF Systems – Final Design

- Final design includes a klystron upgrade - 3 MW peak power capable
  - Increased perveance to allow operation with existing klystrons
  - Nearly "plug compatible" with existing infrastructure – spares for operations!
- What about other components?
  - No 38mA test measurement exceeded 2.5 MW
  - Circulator (highest concern), WR2100 full-height load, and coupling iris are all adequate for normal post-PPU operation
  - Further simulation of the circulator indicated 3 MW operation is permissible** [4]

New 3 MW klystron first article in SNS Radiofrequency Test Facility (RFTF)



Circulator E-field maximum (3MV/m limit)

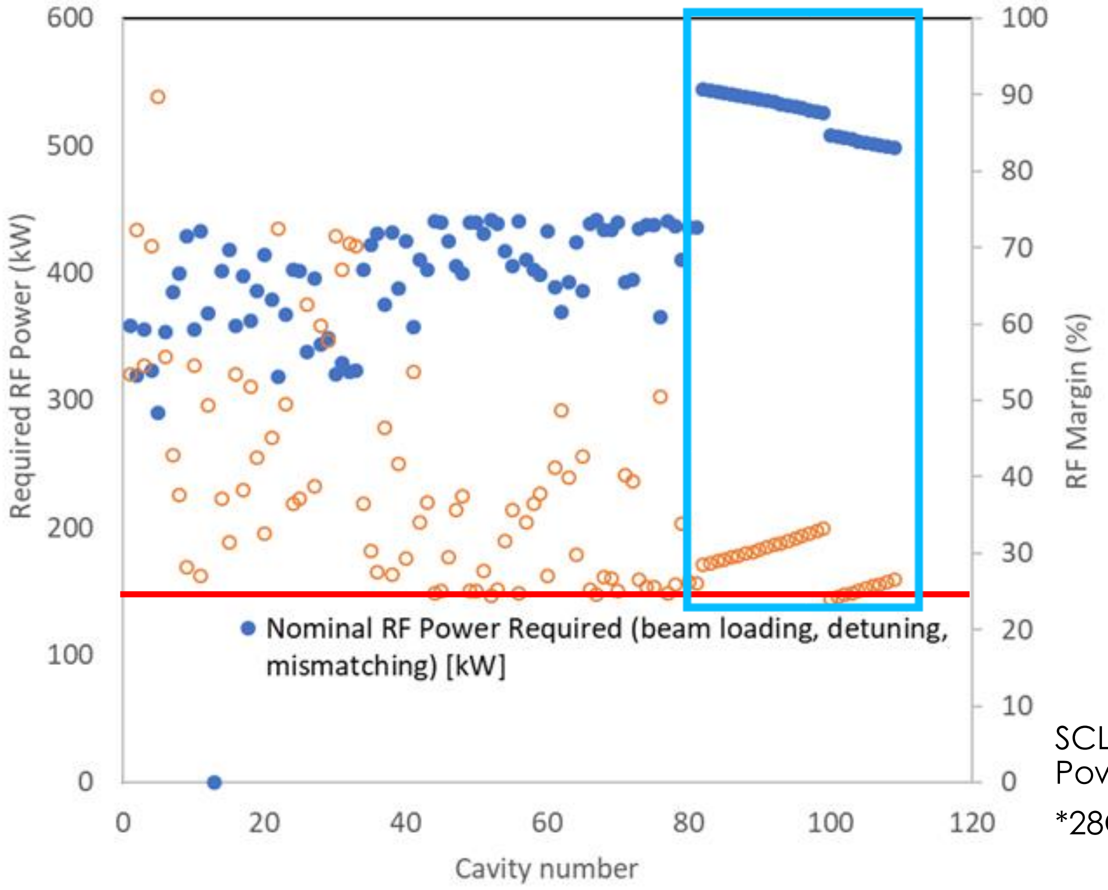
Blue – 2.5 MW forward (fwd) with 600 kW reflected (rfl).

Orange – 2.5 MW fwd with 2.5 MW rfl.

Red – 3MW fwd with 2.05 MW rfl

PPU Superconducting HPRF Systems – Design Criteria

- Increase the proton beam energy from 1.0 to 1.3 GeV
  - Provide HPRF generation for 28 new superconducting cavities
  - Apply the same 25% power margin requirement*



SCL RF Power Requirements and Calculated Power Margin

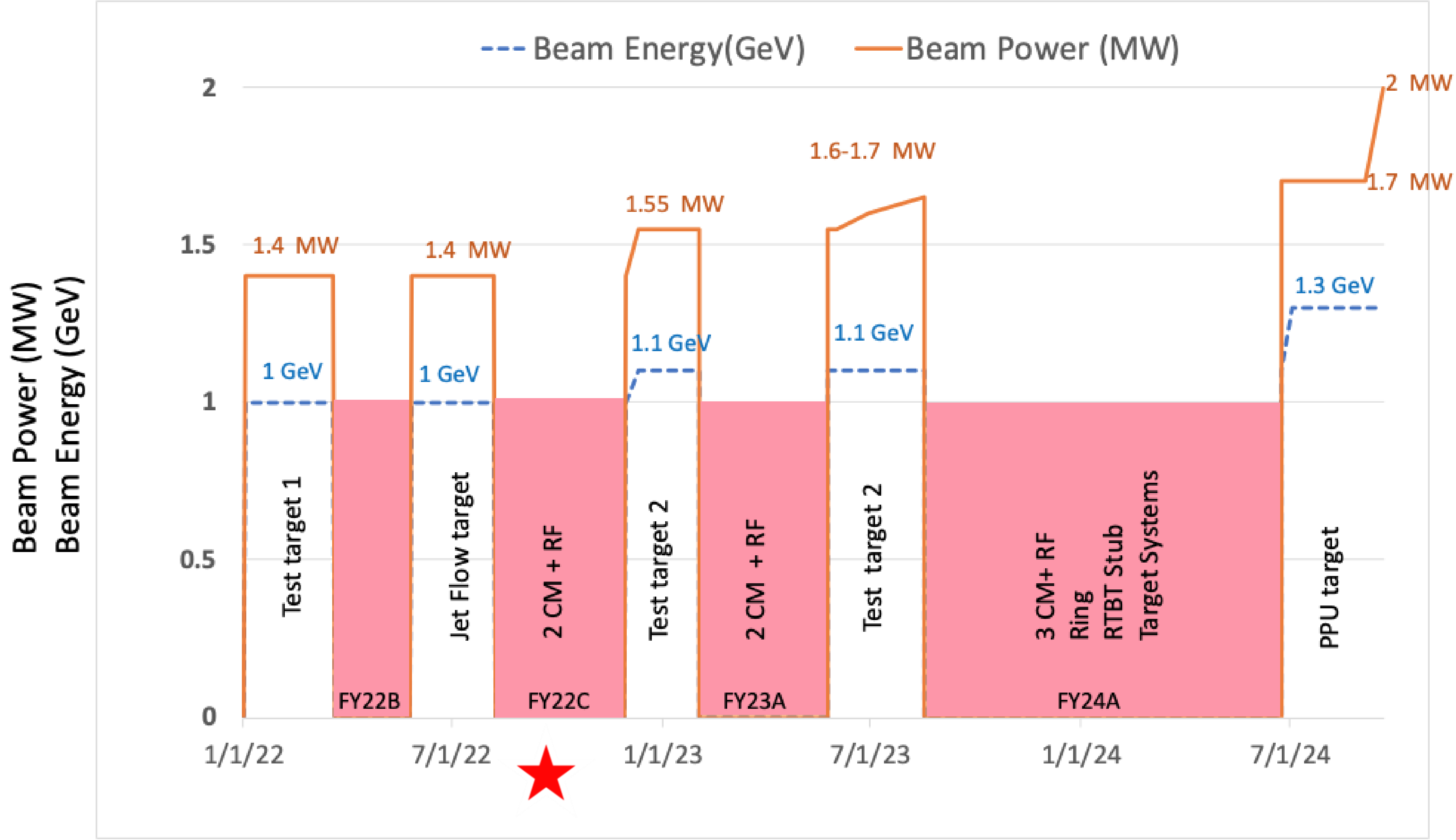
*28C PM is 24%

PPU Superconducting HPRF Systems – Final Design

- Total of 28 new Superconducting RF stations at the high energy end of the Linac
  - 28 700 kW peak power capable klystrons with associated circulators, waveguide, and waveguide components
  - Five transmitter systems that support up to six klystrons per system
    - Provide cooling, solenoid power, filament power, RF pre-amp, monitoring and interlocks
- Installation and testing is ongoing – first HPRF in October


First 12 SCL RF stations; First transmitter system; First transmitter system under test

Power Ramp-up Plan



- First RF to cryomodule in November 2022

Summary

- The PPU will double the proton beam power available at the SNS from 1.4 to 2.8 MW
  - 2.0 MW to the first target station
- The RF scope consists to two main parts
  - Upgrade 3 DTL RF stations to 3 MW peak power capable
    - Value engineering principles were employed to maximize the use of the existing RF equipment
  - Install 28 new 700 kW peak power capable SCL RF stations
    - New equipment is capable of being used throughout the existing SCL RF stations
- First RF generation is scheduled for this October
- Proton beam power will ramp up gradually as new RF stations are brought on-line

References and Acknowledgments

1. SNS-104010000-DC0001-R00, *Design Criteria Document WBS 1.4.1 Linac RF System, Table 2*
2. PPU-P03-TR0001, *Proton Power Upgrade (PPU) Project, Linac RF Power Margin*
3. J. Moss *et al., The Spallation Neutron Source Normal Conducting Linac RF System Design for the Proton Power Upgrade Project,* presented at the 12th Int. Particle Accelerator Conf. (IPAC'21), Campinas, SP, Brazil, May 2021, Paper ID THPAB296
4. G. Toby *et al.*, *SNS Warm Linac Circulator Breakdown Considerations,* presented at the 12th Int. Particle Accelerator Conf. (IPAC'21), Campinas, SP, Brazil, May 2021, Paper ID MOPAB335

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