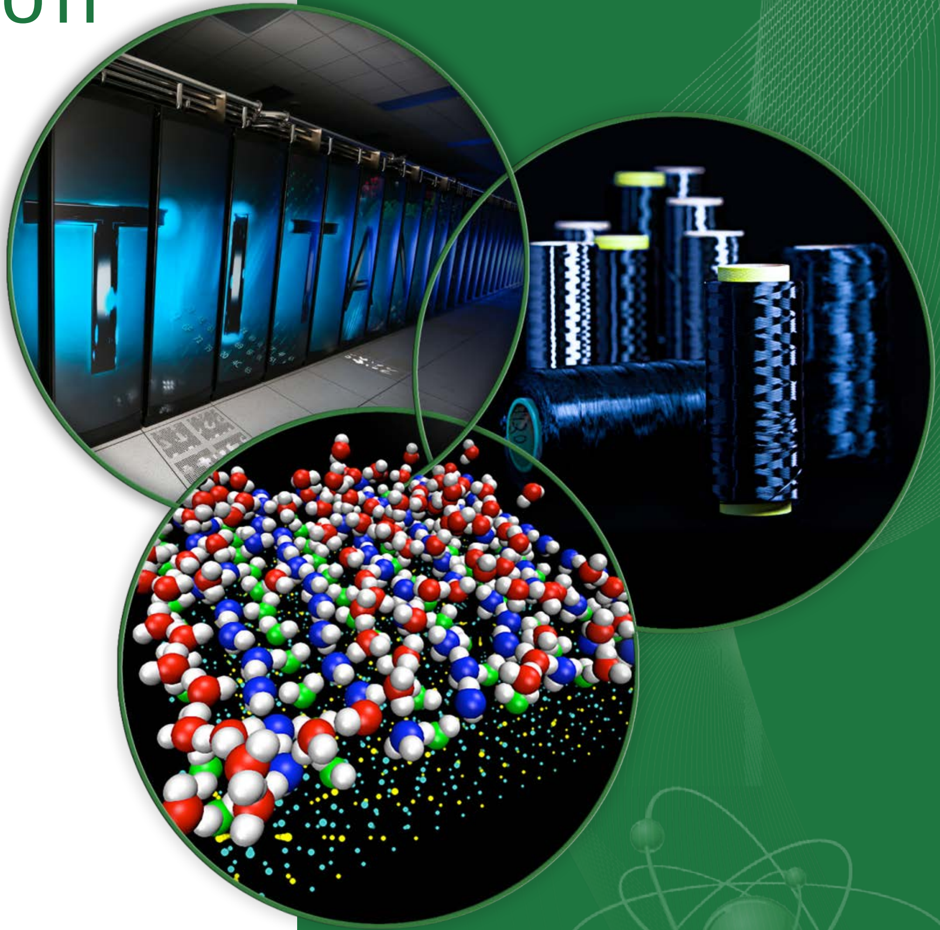
A Short-pulse Second Target Station at the SNS



Presented at
IWSMT-12 – Bregenz, Austria

Bernie Riemer
Instrument and Source Division
Oak Ridge National Laboratory

October 20, 2014

Neutron scattering facilities at Oak Ridge National Laboratory today

High Flux Isotope Reactor (HFIR)
Intense steady-state neutron flux
and a high-brightness cold neutron source

Spallation Neutron Source (SNS)
World's most powerful
accelerator-based neutron source

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Complementarity across 3 ORNL neutron sources provides opportunity for instrument optimization

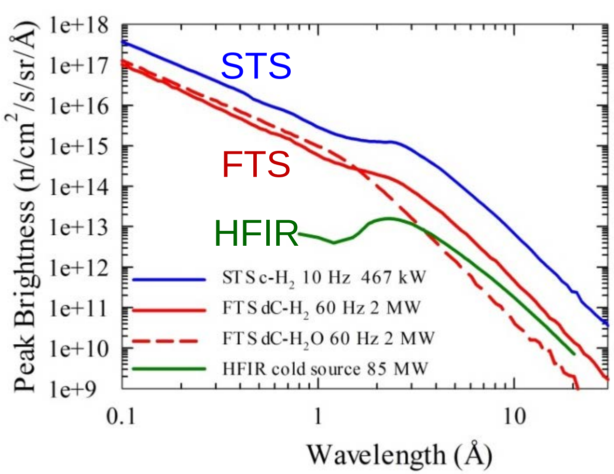
STS: Optimized for cold neutrons with high peak brightness

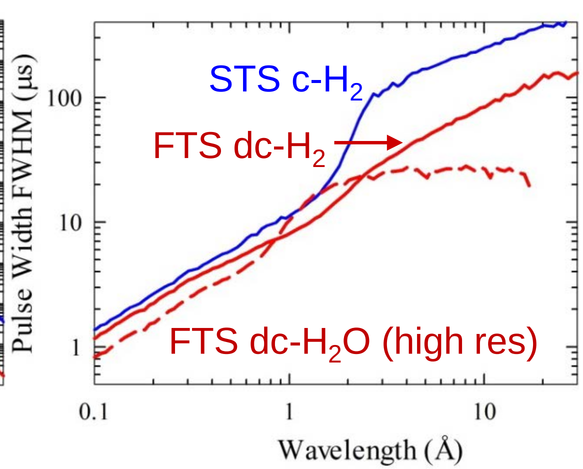
(Coupled moderators, 10 Hz)

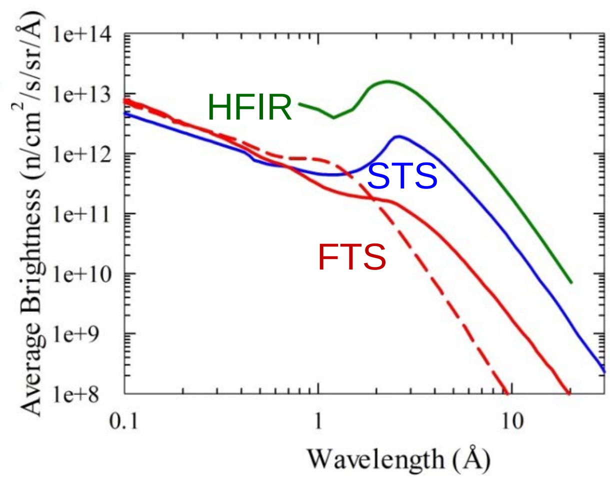
FTS: Optimized for high-wavelength resolution across neutron spectrum

(Decoupled moderators, 60 Hz)

HFIR: Optimized for cold and thermal neutrons with high time-averaged brightness







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SNS accelerator complex was designed to support two target stations

2002
NSF sponsored conceptual study for long-wavelength, **short-pulse** STS, (J. Carpenter)
333 kW, 10 Hz

2009
Department of Energy approved CD-0 mission need for "an additional target station at ORNL optimized for cold neutron beams."

February 2013
BESAC facility prioritization subcommittee: STS is "absolutely central to US leadership in science" and "has scientific and engineering challenges"

1995 | 1998 | 2001 | 2004 | 2007 | 2010 | 2013

1996
BESAC Report (Russell Subpanel Report), SNS should be designed to operate "at a significantly higher power in a later stage" and to include the "capability of additional targets."

2007
K. Crawford led a conceptual study for a long-wavelength, **long-pulse** STS
1 MW, 20 Hz

2011-2012
ORNL LDRD study on optimizing neutron scattering at 3 ORNL facilities compared long and short pulse performance

April 2013
NScD Neutron Advisory Board: endorsed low repetition rate, short-pulse STS

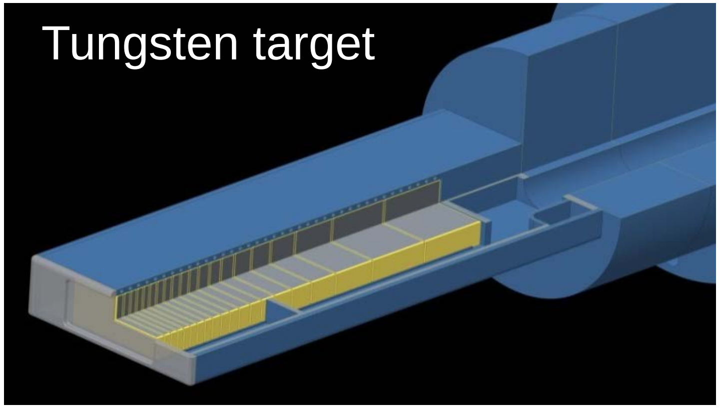
Rotating solid target

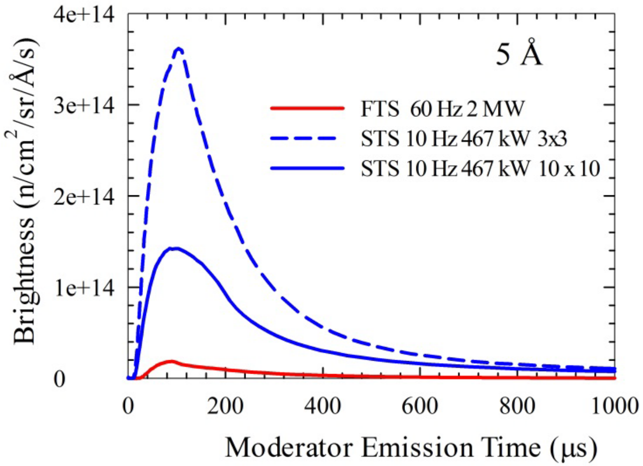
Fixed solid target

STS concept

Optimized for highest neutron peak brightness at long wavelengths

2.8 MW accelerator complex, 1.3 GeV protons, 60 Hz, pulse-stealing mode	Compact, high-performing target	Compact, high-brightness moderators	22 instrument end stations
FTS: 2+ MW (5/6 pulses) STS: 467 kW (1/6 pulses)	30 cm^2 proton beam cross section (FTS: 140 cm^2) Solid tungsten for better neutron production	Gains of 2–3 compared to large moderators	≈11 deg beam separation Instrument length: 15 m ≤ L ≤ 120 m

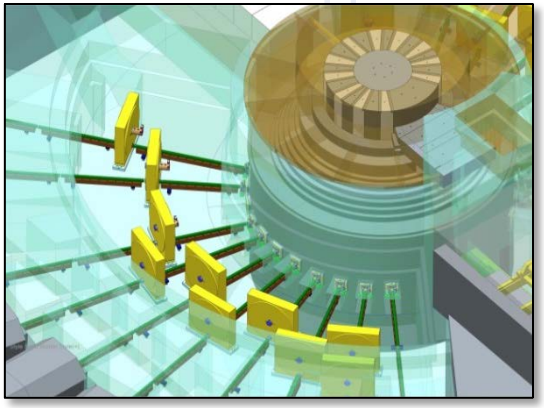


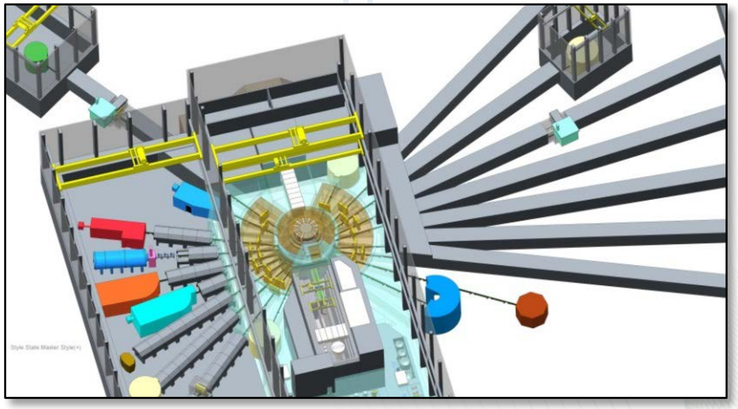


TDR activities, FY14
(Technical Design Report)

Core team of engaged individuals

Establish initial design concepts	Define Work Breakdown Structure to level 3	Engage A/E for site layout and definition of conventional facilities
• Instrument suite plan • 3 moderators (FY13 LDRD) • Compact tungsten target • Proton beamline lattice to STS	• Major subsystems (e.g., individual instruments, accelerator RF systems) • Top-down cost estimates	• ORNL estimators will generate initial cost estimate





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We have engaged the U.S. scientific community

Quantum Materials

Quantum Condensed Matter
Lawrence Berkeley National Laboratory
December 2013
Bob Birgeneau

Biosciences

Structural Biology, Bio-materials, and Bioengineering
UC San Diego
January 2014
Susan Taylor

Soft Molecular Matter

Soft Matter
Santa Barbara
May 2014
Fyl Pincus
and Matt Tirrell

Materials Synthesis and Performance

Energy Materials
Chicago
August 2014
George Crabtree

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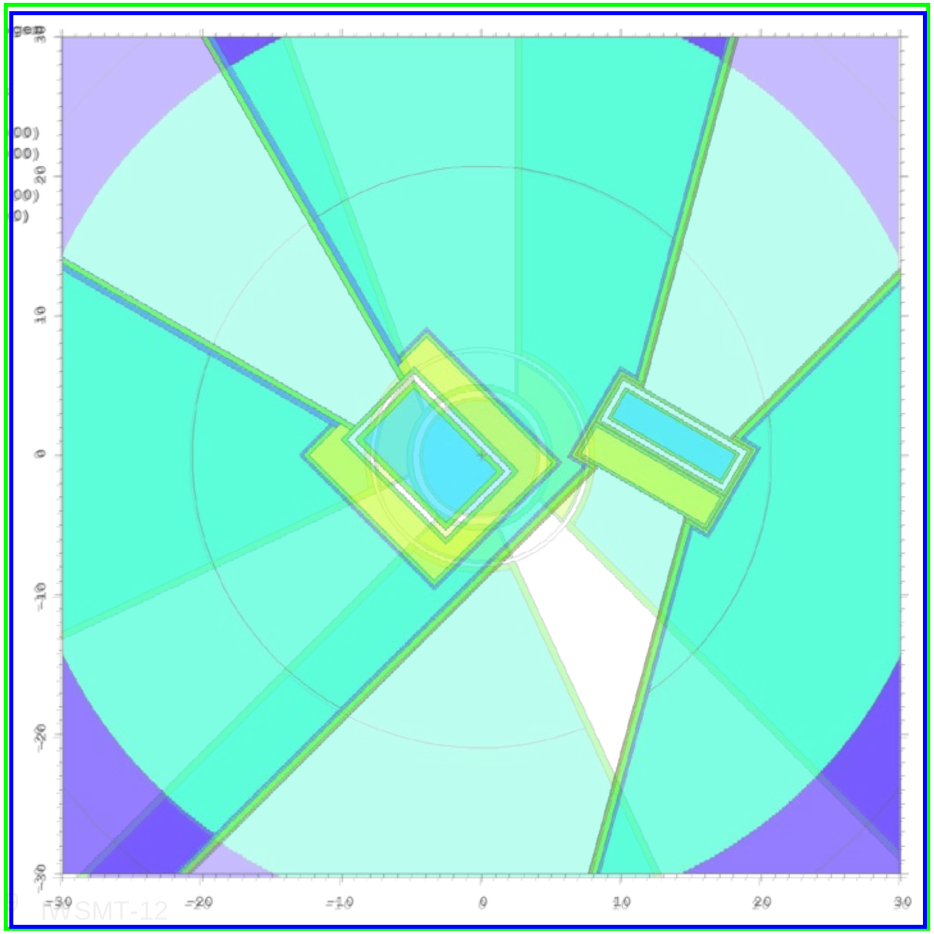
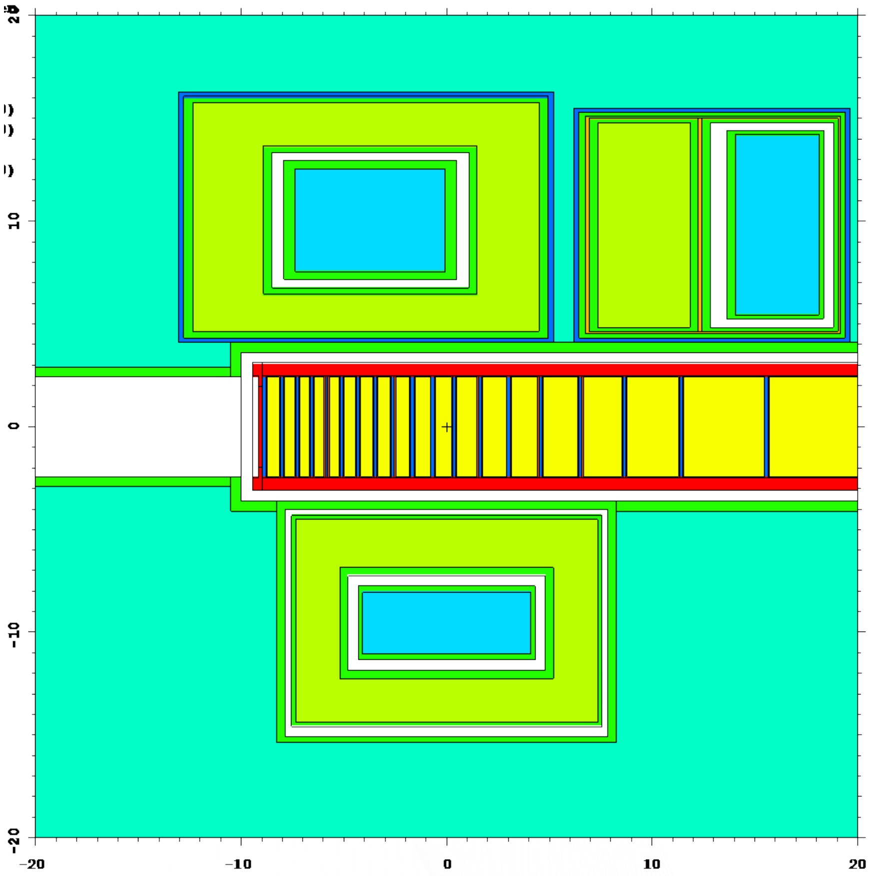
19 STS instruments in planning suite

Instrument	Description	Length (m)	Sample size (cm)	Moderator Type	Moderator Size HxV (cm^2)	Beamline
		DIFFRACTION				
NeSCRY	Magnetic diffraction for small crystal and epitaxial materials	90	2	Cold, coupled p-H2	5x5	14
		40	2	Cold, decoupled p-H2	5x5	
VERDICT	Long-wavelength neutron diffractometer for magnetic structure determination similar to ISIS-TS2 WISH	40	2	Cold, coupled p-H2	5x5 → 3x3	13
HiRes	High resolution powder diffractometer	100 - 120	3	Cold, decoupled p-H2	7x7	20
EWALD	Macromolecule single crystal diffractometer (1 mg samples)	90	<0.1	Cold, coupled p-H2	3x3	16
DYPOL	Macromolecule dynamically polarized single crystal diffraction	90	<0.1	Cold, coupled p-H2	5X5 → 3x3	12
		REFLECTOMETRY				
TLR	Kinetics liquids reflectometer	15-20	2	Cold, coupled p-H2	5x5 → 3x6	2
mmLR	Small sample liquids reflectometer	30-40	1	Cold, coupled p-H2	3x3	4
M-STAR	Polarized neutron reflectometer	20-30	2	Cold, coupled p-H2	3X3	7
M-WASABI	Polarized reflectometer combined with GISANS	20-30	2	Cold, coupled p-H2	3x3	6
		SANS				
SWANS	High-resolution small and wide-angle neutron scattering. (Molecular ordering to nanostructures)	20	1	Cold, coupled p-H2	3x3	15
FLOODS	Flux Optimized Order-Disorder SANS. Fast kinetics and out-of-equilibrium behavior	20-30	1	Cold, coupled p-H2	3x3	5
		INELASTIC/QUASI-ELASTIC				
superCNCS (SBIS)	Cold neutron chopper spectrometer optimized for high flux on small samples (10 mg) and polarization	60 – 120	1	Cold, coupled p-H2	3x3	17
superLET	Cold neutron chopper spectrometer optimized for large single crystals and polarization	25	5	Cold, coupled p-H2	10x10 → 5x5 guide at 75 cm	11
MiBARS	Mica-based very high resolution backscattering spectrometer	60	3	Cold, decoupled p-H2	7x7	19
WAVESS	Very broad dynamic range using wide-angle velocity selector as analyzer	15-17	3	Cold, decoupled p-H2	7x7	18
JANUS	Hybrid spectrometer (low-Q chopper spectrometer, backscattering analyzer spectrometer)	50	3	Thermal-Cold, decoupled	7x7	10
CAMEA-type	Extreme environment/inverse geometry	40-50	1	Thermal-Cold, decoupled	3x3	8
SPHIINX	SPHerical Indirect Inelastic Xtal spectrometer (70 meV elastic, 1% dw/w)	35-40	3	Thermal-Cold, decoupled	7x7	9
		EXTREME CONDITIONS				
Zeemans	Versatile instrument designed for studies at the highest magnetic fields	60	2	Cold, coupled p-H2	5x5 → 3x6	1

STS source baseline configuration

Coupled para-hydrogen moderators in the upstream positions





Decoupled para-hydrogen and water moderators at top downstream position

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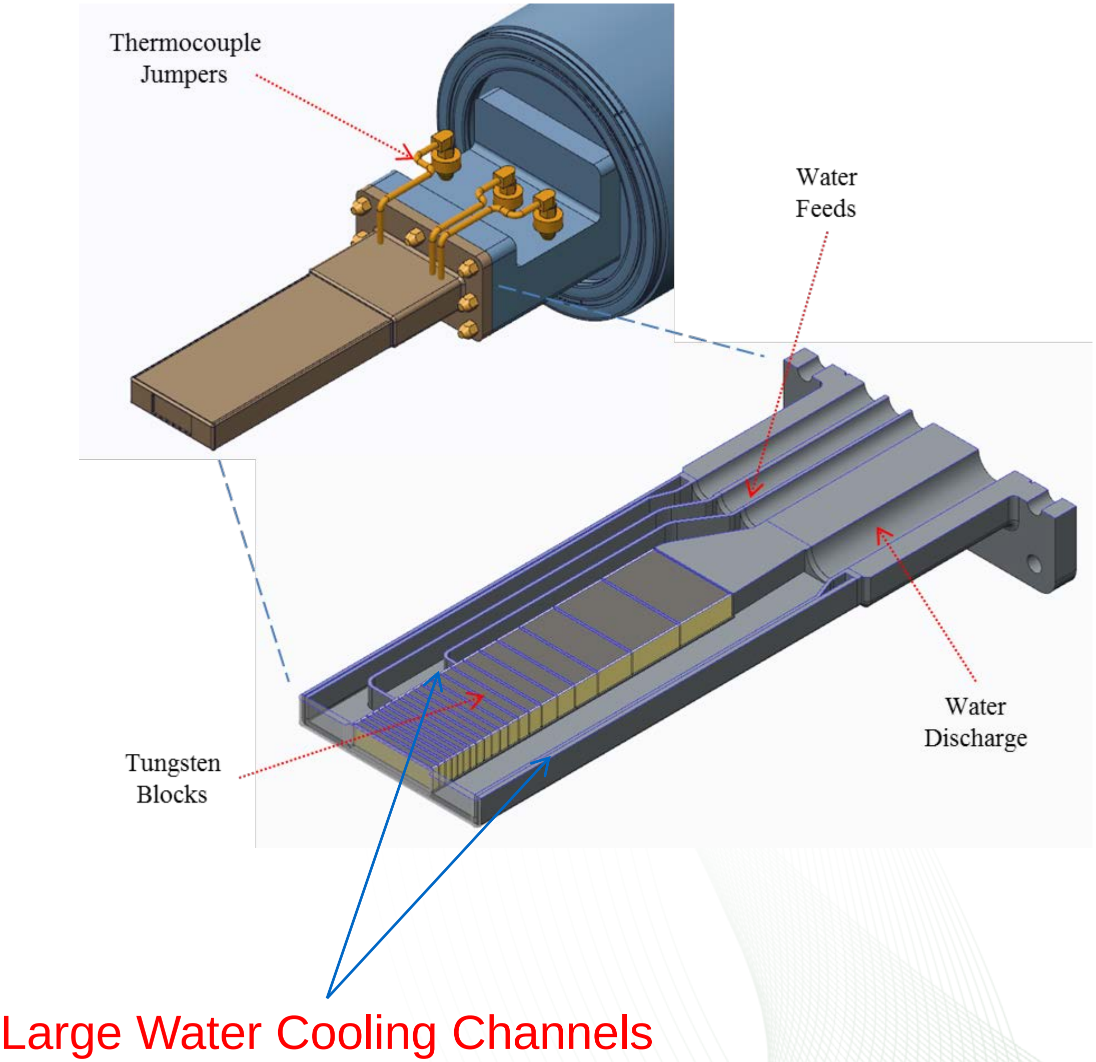
Stationary solid target uses stacked plates

Design concept proven in other facilities (LANSCE->3 years; ISIS->13 years).

- Tantalum clad tungsten plates
- Heavy water cooled
- Significant TC monitoring
- Independent cooling of shroud

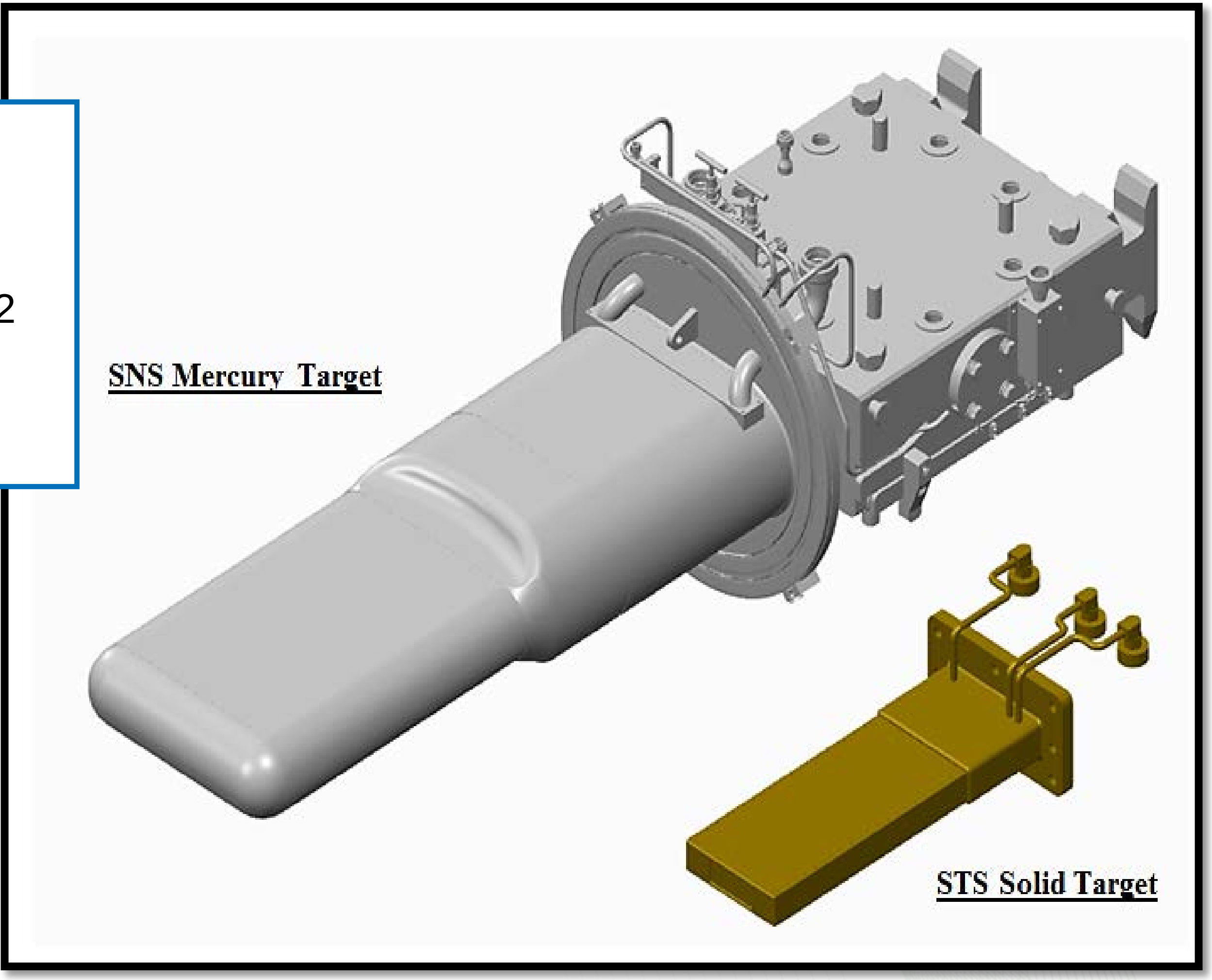
- Preliminary thermal and neutronic calculations based on a flat beam profile indicate that a stack of 18 tantalum clad tungsten plates with 240 GPM water cooling will perform well.
- FY15 design will incorporate more accurate beam profile



Compact STS target for high n intensity

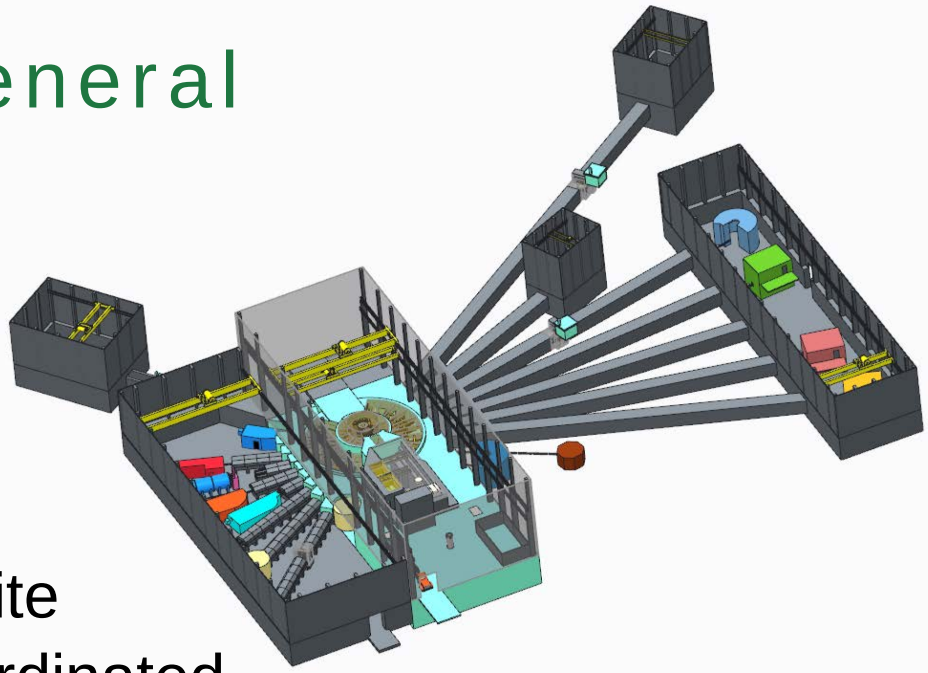
Incident proton beam areas:

- FTS ~140 cm^2
- STS ~30 cm^2



Expect ~similar radiation damage lifetime with FTS
Limit on target vessel / water shroud
Even with 1/4 power ratio

STS target station general configuration



- The basics:
  - Neutron beam lines coordinated with planning suite
  - Moderators and reflector coordinated with neutronics analysis team
  - Buildings coordinated with conventional facilities
  - Target building
    - Based on existing facilities
    - Target operations separated from instrument operations

Many features adopted from FTS

- Inner reflector plug & tooling & storage vessel
- Moderators and hydrogen / helium system
- Proton beam window & tooling
- Water utility system & layout
- Core vessel configuration
- Target module & maintenance system
- Waste handling system and casks

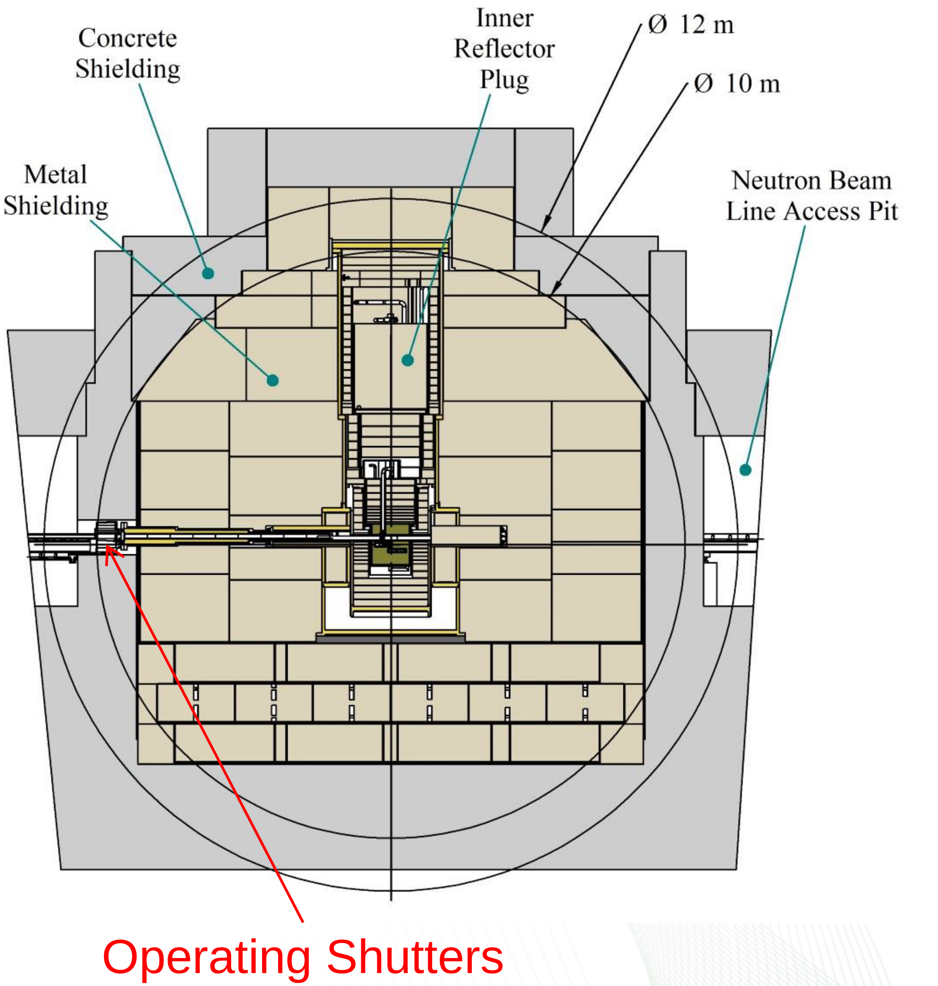
But …

New features requiring development

- Neutron beam line tunnels (below grade beam lines)
- Shutters *outside* monolith
- Extended monolith guide inserts
- Larger choppers ($\phi \sim 1.7$ m)
- Precision neutron beam guides (narrow and long)
- Increased power density on solid target, energy density per pulse
- SAFETY

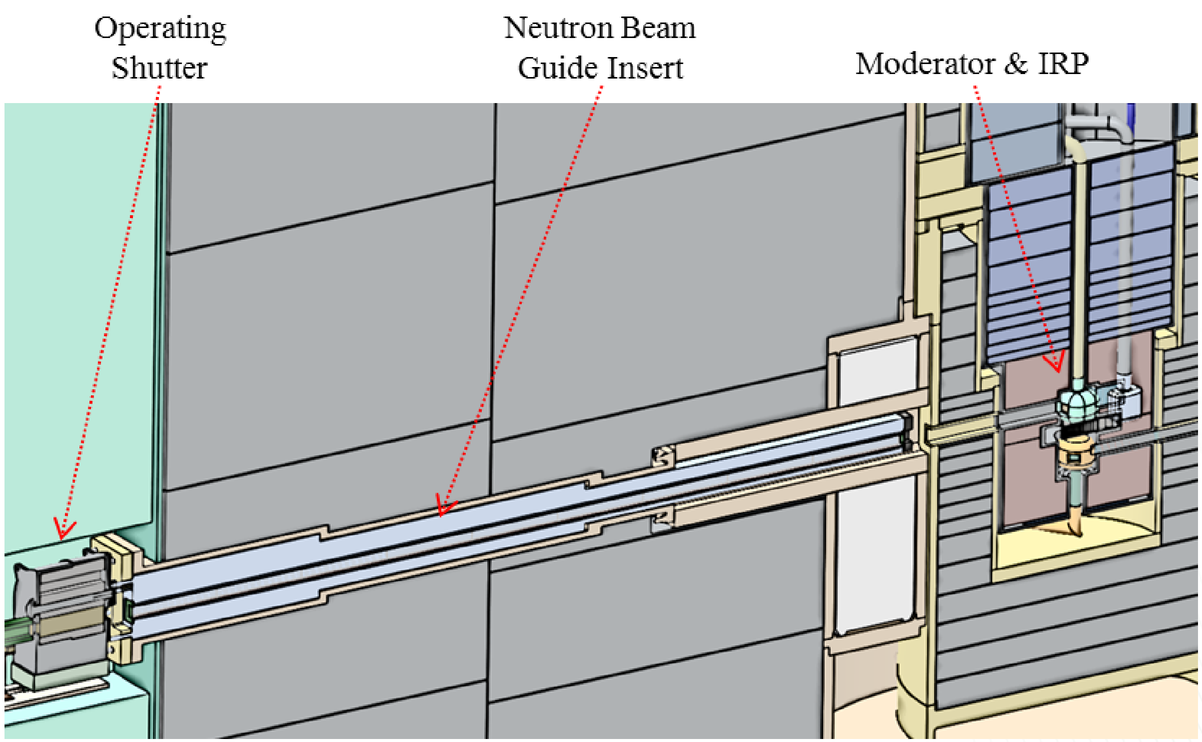
Shutters will not be Installed in the monolith

- Advantages include cost savings, simplified beam-on operations and reduced maintenance
- Issues:
  - Operating shutters in pits must be sized and configured
  - Maintenance scenario and tooling must be developed
  - Design for additional shutters on some beam lines must be developed



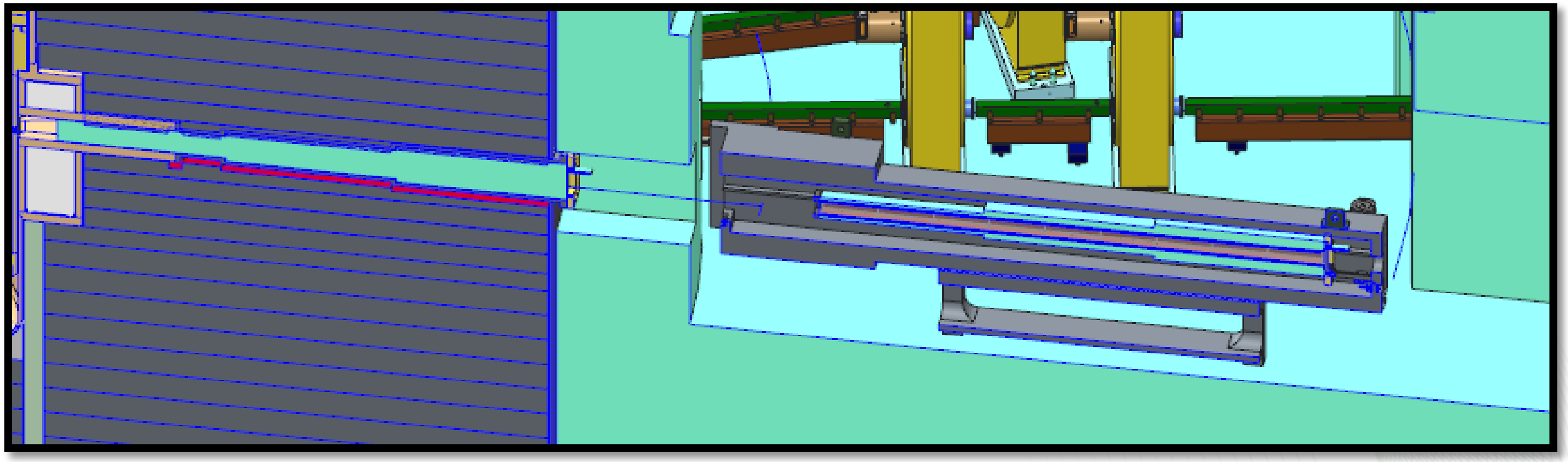
Extended monolith beam line inserts

- Advantages: minimum number of beam line windows; simplified maintenance access (compared to FTS)
- Issues
  - Length (3.7 m) incompatible with mirror guide lengths
  - Precision alignment will be a challenge



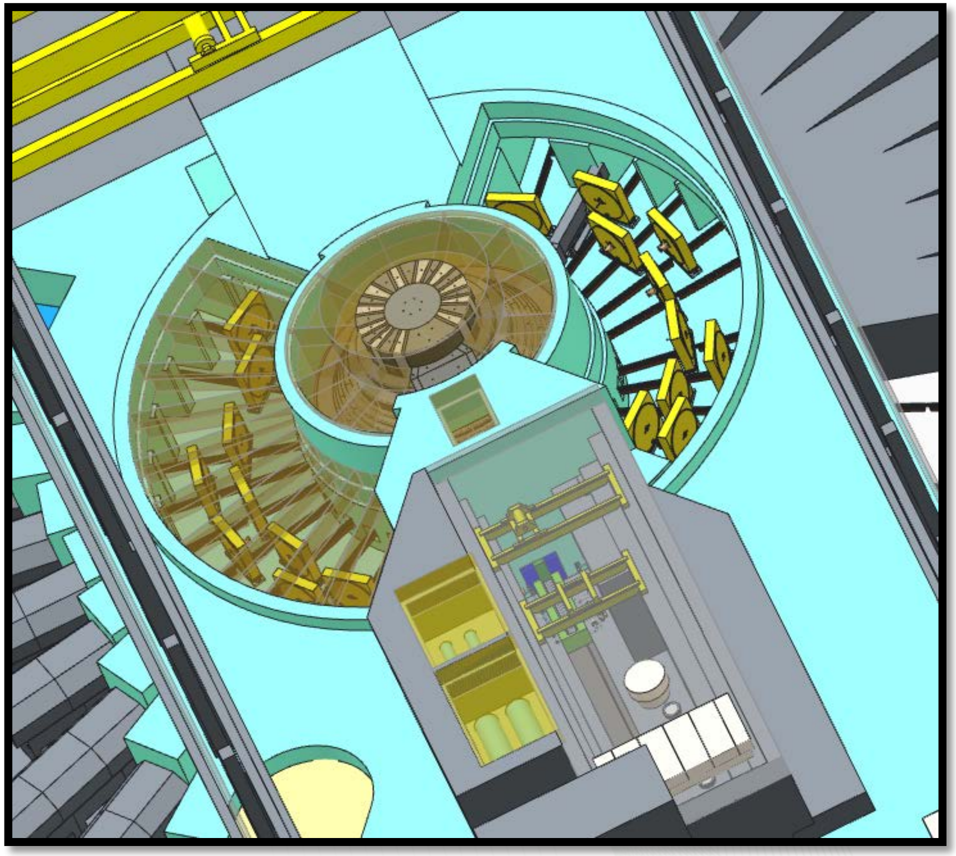
Neutron guide remote tooling will be complex

- Activated inserts retracted into shielded container for handling and temporary storage
- New inserts inserted with same machine.
- Beam line components in pit must be removed to make room for machine
- Neighboring choppers may also require removal
- Streaming radiation will be significant during change-out



Choppers in neutron beam pits

- Pits primarily designed to accommodate choppers and insert removal tooling
- The width of the pits is determined by the length of the insert removal equipment.
- The height of the pits is determined by the choppers.
- The pit cover blocks with individual mass ~36 tonne and stack to a thickness of ~2 m
- THE PITS WILL BE VERY CROWDED



Precision neutron beam lines

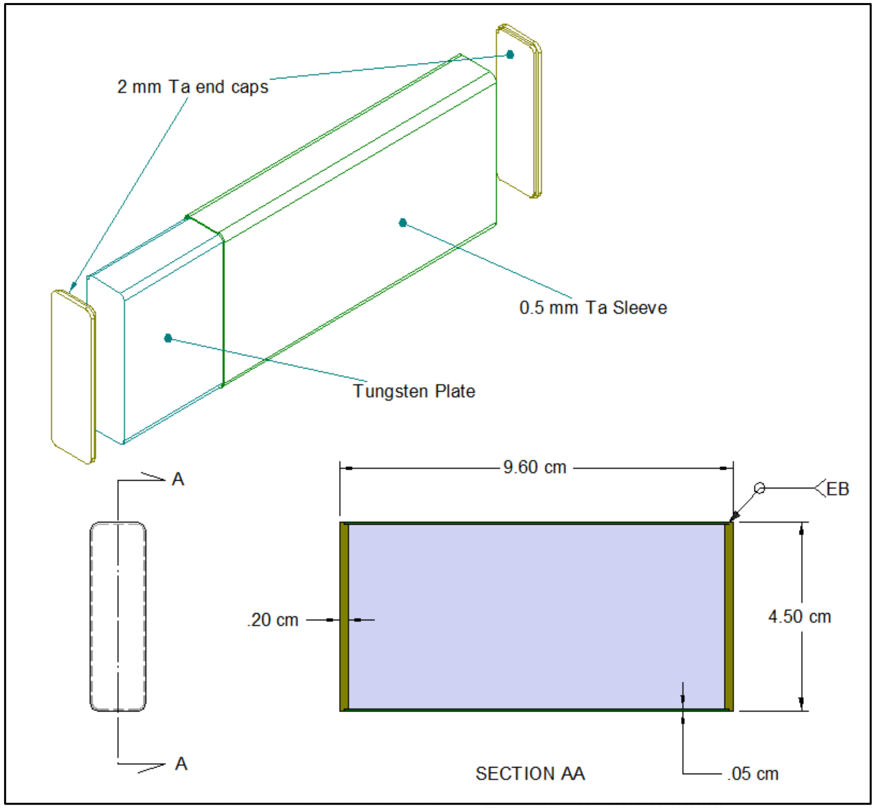
- STS relies on precisely focused, small, bright beams to achieve superior instrument performance
- For many beam lines this will require:
  - Active guide alignment
  - Elliptical, mirrored guides
  - Precise alignment of core components (moderator-inserts)
- Structural stability
- Beam line design will be one of the primary design focus areas in FY15

Loss-of-coolant accidents (LOCA) are a concern

- Loss of coolant could result in tungstic acid vapor (WO_3*H_20) being produced as a result of tungsten vaporization at an elevated temperature (> 800 ^{o}C) in the presence of steam
  - This reaction also produces hydrogen which can burn or detonate creating elevated pressures for discharges
- Highly activated powder generated by the condensing acid vapor dispersed to the site boundary is an unacceptable condition if a large fraction of the tungsten is involved
  - Must prove it can’t happen or incorporate credited controls
- The LOCA failure mode has been studied and documented at LANSCE
  - has never occurred there or at ISIS
- Understanding this failure in STS and incorporating controls into the system will be one of the primary focus areas of the STS FY15 design effort
- Experiments to quantify the mitigation of tungsten vapor release by virtue of the cladding under LOCA scenarios are planned

Tungsten plate design, manufacturing & cladding

- Manufacturing tantalum clad tungsten plates with high reliability is a significant challenge
- ISIS has been directly involved in the manufacturing process for more than 15 years and is now fabricating the plates in-house
- During FY15 ORNL plans to begin a formal, cooperative R&D effort with ISIS to better understand and improve the manufacturing process



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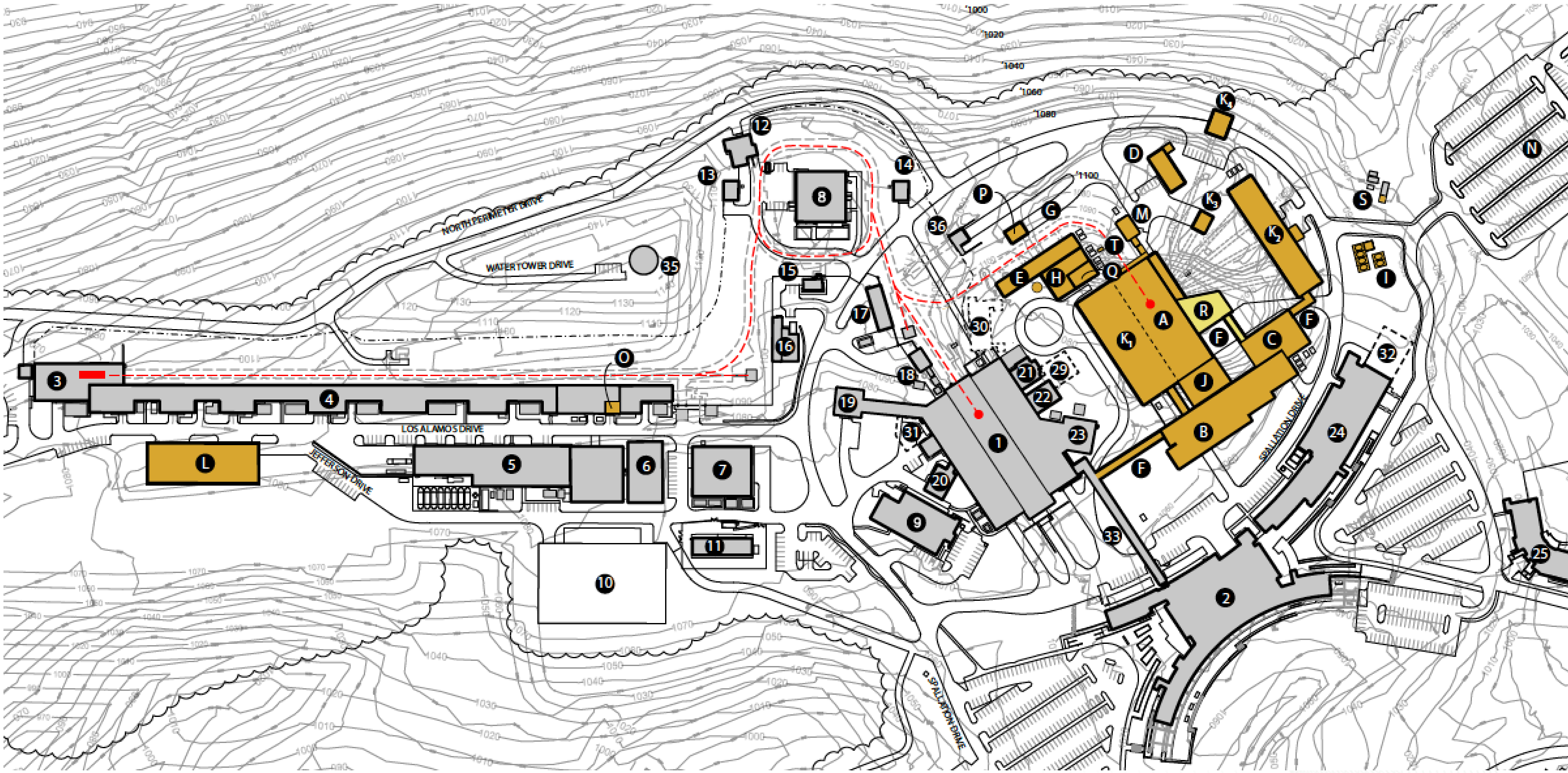
Conceptual Site Layout



Conceptual Site Layout – 3D

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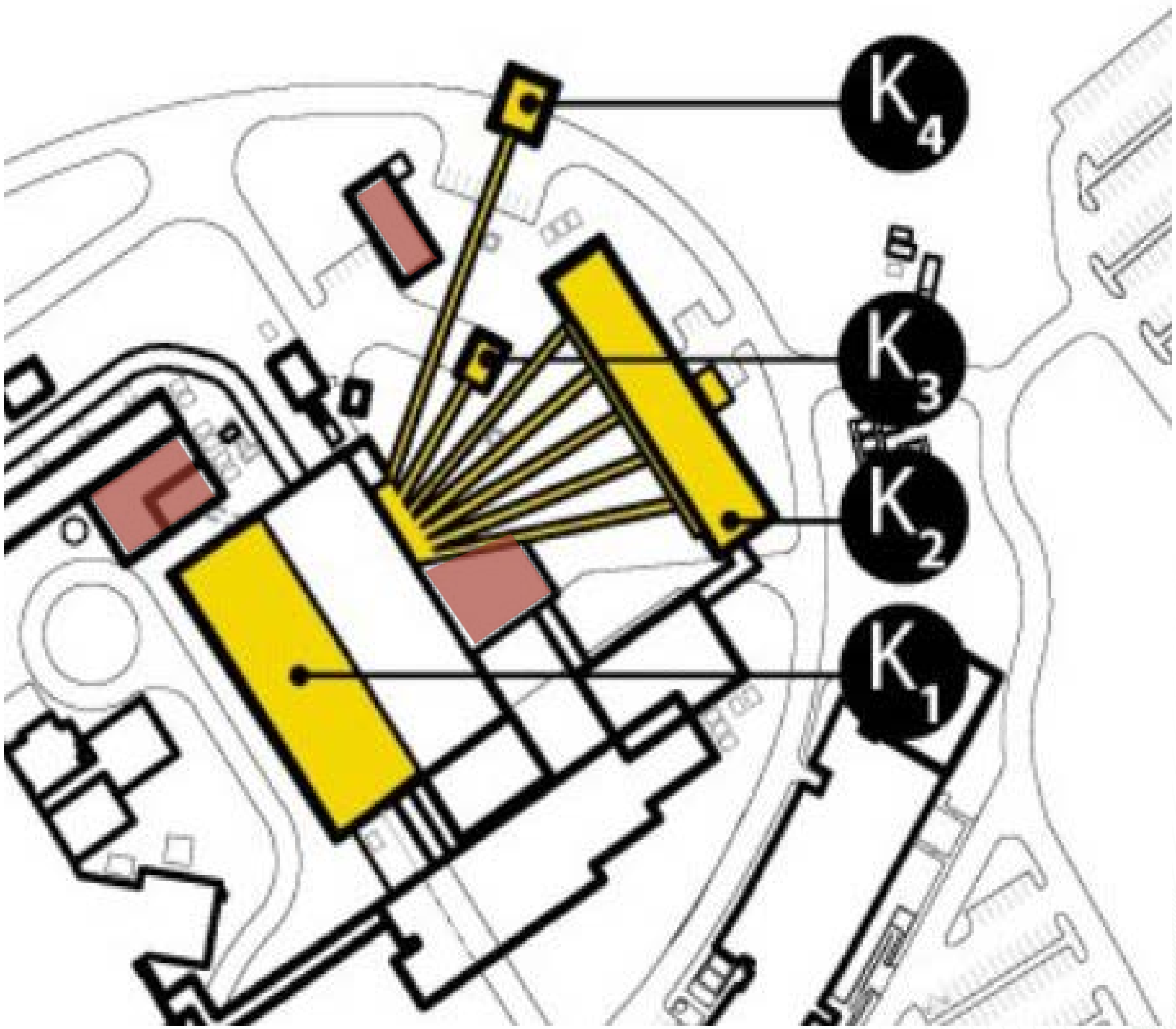
Conceptual Site Layout – 3D

Instrument Buildings



Doubling the Accelerator Intensity
- *use operational lessons*

	1.4 MW Operation	STS Upgrade	Original STS Upgrade
Energy (GeV)	0.94	1.3	1.3
Macro-pulse length (ms)	0.97	0.97	1
RFQ output beam current (mA)	35	45	55
Macro-pulse un-chopped fraction	0.81	0.85	0.7

- New approach significantly eases the ion source requirements

Where are we right now?

- **Technical Design Report (TDR)**
  - **Almost complete - in final technical editing**
  - **Mainly intended for internal use**
  - **First cut at cost estimate just compiled**
- **Over next ~ 15 months**
  - **Further optimization, development, refine cost estimate**
    - **Instrument suite**
    - **Source design**
    - **Accelerator and facility**
  - **Prepare Conceptual Design Report (CDR)**
    - **Submit to Dept. of Energy in 2016**

Questions?

Additional Material

FY15–FY16 LDRD: Next-generation neutron source and instrumentation

Development and demonstration of Wide-Angle VElocity Selector (chopper used in an indirect geometry)

Eugene Mamontov

Novel approach to resonant spin echo for ultrahigh resolution spectroscopy (HB1)

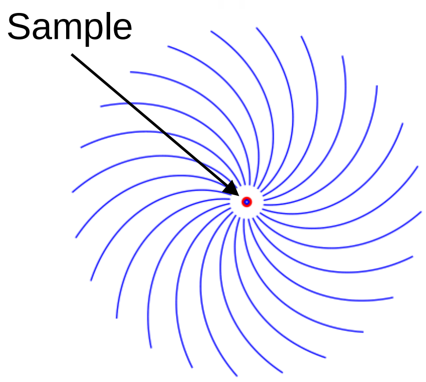
Jaime Fernandez-Baca

Solid-state neutron detectors for STS (new scintillator + silicon PMT)

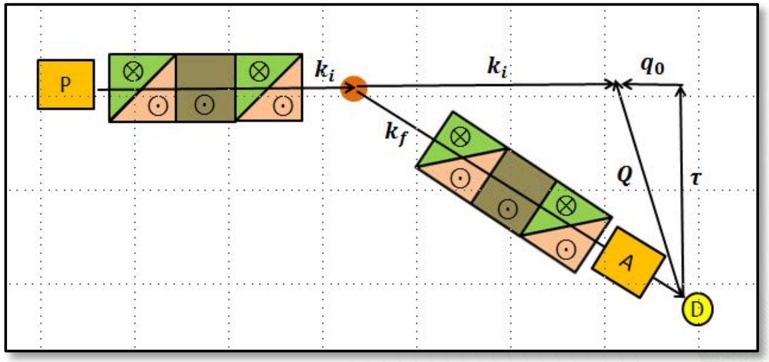
Rick Riedel

Moderator demonstration at Integrated Test Stand Facility: Performance of large volume, high-brightness para-H_2 moderators

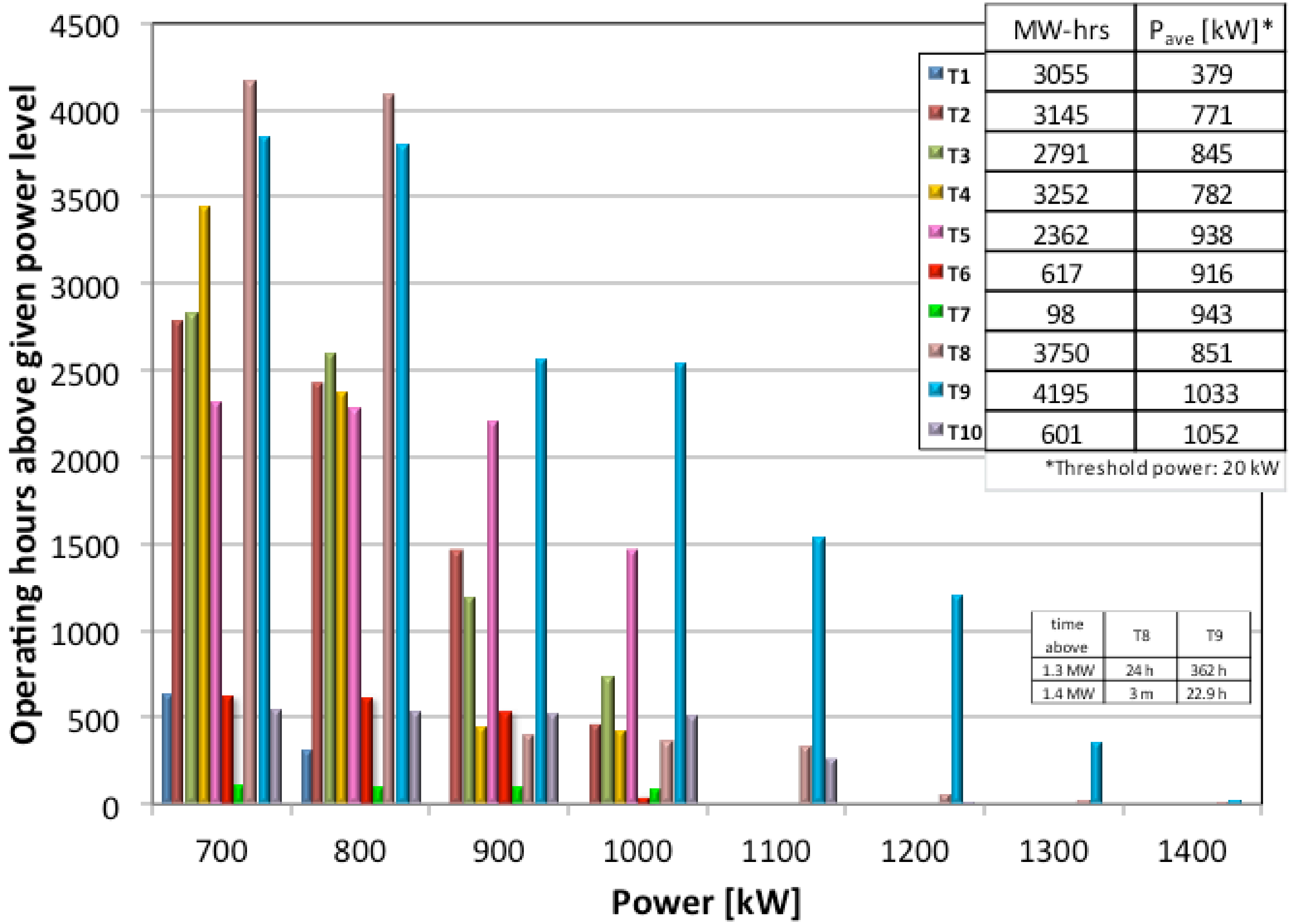
Erik Iverson



WAVES concept



Resonant spin echo using Wollaston prisms



Operating hours above given power level
0
500
1000
1500
2000
2500
3000
3500
4000
4500
700
800
900
1000
1100
1200
1300
1400
Power [kW]
MW-hrs
P ave [kW]*
T1 3055 379
T2 3145 771
T3 2791 845
T4 3252 782
T5 2362 938
T6 617 916
T7 98 943
T8 3750 851
T9 4195 1033
T10 601 1052
*Threshold power: 20 kW
time above
T8
T9
1.3 MW 24 h 362 h
1.4 MW 3 m 22.9 h