What do we want (need) from accelerators?

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CSS2013 Neutrino Working Group Meeting

SLAC

March 2013

New accelerators drive the synergy between experimental frontiers to directly confront theory…

Modified from Hitoshi Murayama , ICFA October 2011

The Intensity Frontier
Mega-Watt Jungle…

Apologies to Jurassic Park and Hitoshi Murayama , ICFA October 2011

A Few High Power Target Challenges…

- Modelling of beam energy deposition
- Modelling of secondary particle production
- Modelling of target material response using FEA codes
- Target cooling or replacement
- Activation and radiation damage everywhere
- Thermal shock
- Target lifetime
- Particle capture, moderation and delivery
- Beam windows
- Target station design, inc. shielding, RH, licensing, etc
- Diagnostics in high radiation environments
- Demanding environmental and safety requirements

Courtesy Patrick Hurh and the UKHPT/STFC

30 White Papers submitted that want or need accelerators as neutrino drivers

Super beams:

- Precision Studies of Nucleon Structure and Medium Modifications with Neutrino Beams
- Hyper-Kamiokande Physics Opportunities
- Getting the Most Out of the On-Axis NuMI Beam
- Performance of a Low-Luminosity Low Energy Neutrino Factory
- Liquid Argon Near Detector for the BNB – Neutrino Intensity Frontier White Paper
- LAr1: Addressing the short-baseline anomalies
- Opportunities for Precision Neutrino Physics and Constraining Oscillation Systematics with an LBNE Near Detector
- NUMI Running with the LANL LDRD Liquid Argon TPC
- MiniBooNE+: A new investigation of oscillations with improved sensitivity in an enhanced MiniBooNE experiment
- Extending the NOvA Physics Program
- The MiniBooNE-II Proposal: A 5-sigma Test of MiniBooNE's Neutrino Mode Excess
- MINOS+: Using the NuMI Beam as a Precision Tool for Neutrino Physics
- A Second Detector at an Off-axis Location to Enhance the Mass Hierarchy Discovery Potential in LBNE
- Nonstandard Interaction in tau-neutrino nucleon scattering
- SciNOvA: A Measurement of Neutrino-Nucleus Scattering in a Narrow-Band Beam.
- CHerenkov detectors In mine PitS (CHIPS)A White Paper
- Proposal for a neutrino Super Beam using the ESS 5 MW, 2.5 GeV linac as proton driver
- Precision Neutrino Oscillation Measurements using Simultaneous High-Power, Low-Energy Project-X Beams

Decay-at-Rest (DAR) sources:

- Whitepaper on Cyclotrons as Drivers for Precision Neutrino Experiments
- Whitepaper on the DAEδALUS Experiment
- Whitepaper on the IsoDAR experiment
- Measuring Neutrino Cross Sections on Argon for Supernova Neutrino Detection
- OscSNS: A Precision Neutrino Oscillation Experiment at the SNS
- Searches for CENNS at the Spallation Neutron Source
- Opportunities for Neutrino Measurements at the Spallation Neutron Source
- Measuring CENNS in the Low Energy Neutrino Source at Fermilab

Muon storage rings and Neutrino Factories:

- The Neutrino Factory
- Nu-STORM: Neutrinos from STORed Muons
- Cross section measurements at nu-STORM

30 White Papers submitted that want or need accelerators as neutrino drivers

Super beams:

- Concepts based on the 700kW 120 GeV Fermilab NuMI beam
- Concepts based on the 15kW+ 8 GeV Fermilab Booster Neutrino Beam
- Concepts based on the 700kW 120GeV Fermilab LBNE beam
- Concept based on the megawatt+ 30 GeV JPARC T2X beam.
- Concepts based on the 2300kW 60-120GeV Fermilab LBNE beam.
- Concept based on multi-Megawatt ESS beams.
- Concept based on dual multi-Megawatt Project-X beams illuminating LBNE.

Decay-at-Rest (DAR) sources:

- Concepts based on the 1000kW SNS Hg spallation target.
- Concept based on cyclotrons driving a nuclear beta decay target.
- Concept based on high power cyclotrons driving DAR sources.

Muon storage rings and Neutrino Factories:

- NuSTORM
- Low energy Neutrino Factory
- Neutrino Factory.

World-Wide Interest, Competition and Collaboration.

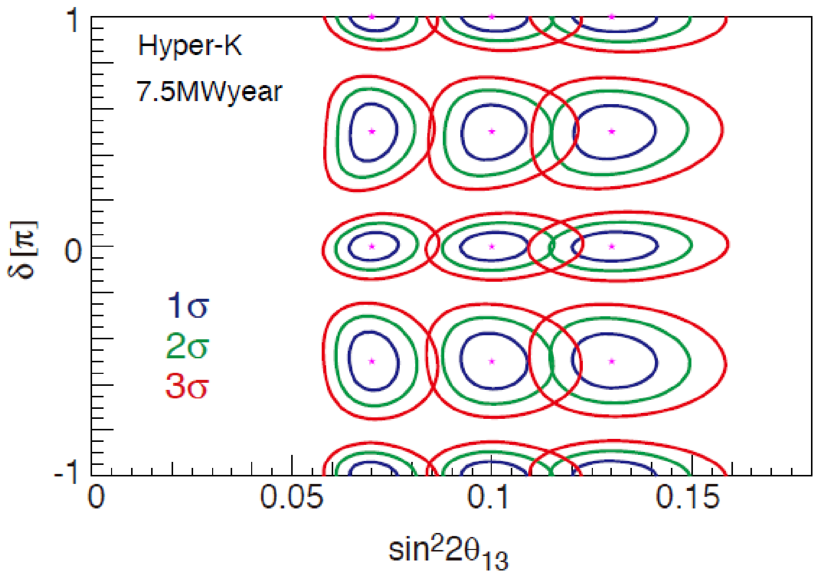


Figure 1: Allowed regions in the space of $\sin^2 2\theta_{13}$ and δ near the known value of $\sin^2 2\theta_{13}$. Blue, green, and red lines represent 1, 2, 3 σ allowed regions in with the hierarchy known to be normal.

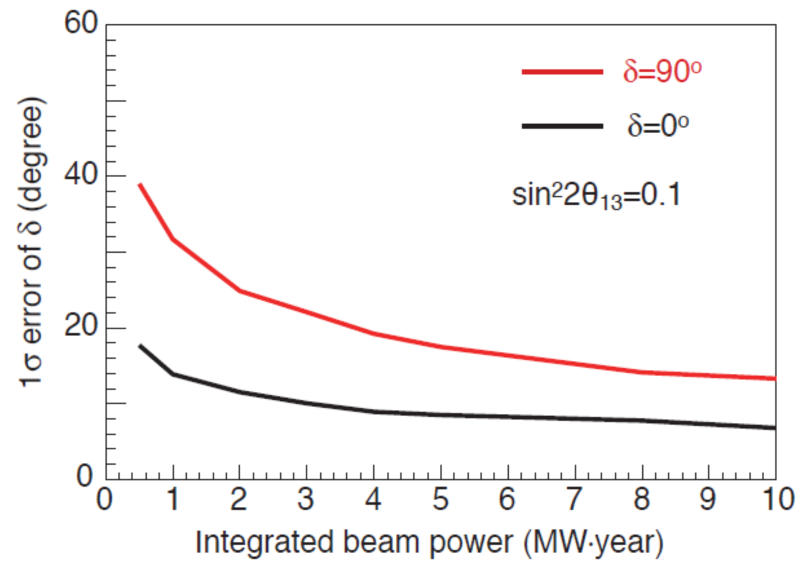
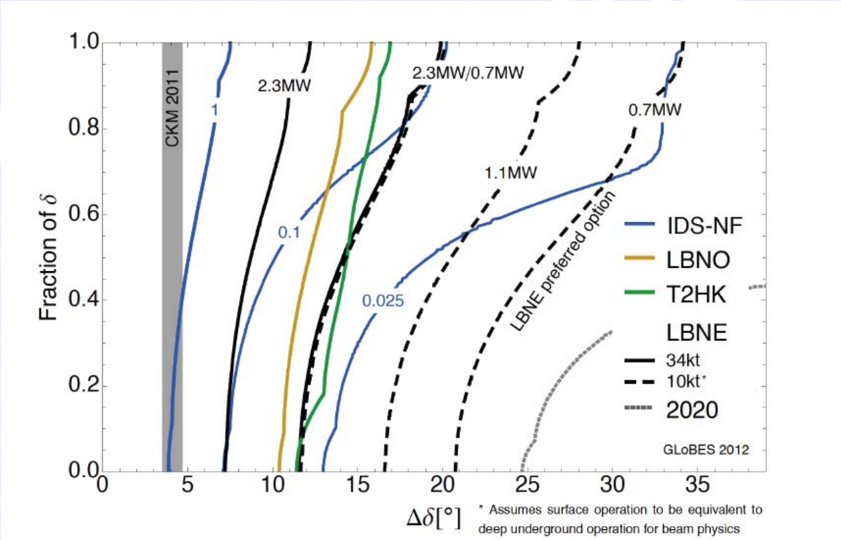


Figure 2: 1σ uncertainty of δ as a function of integrated beam power. The ratio of ν and $\bar{\nu}$ running time is fixed to 3:7.

T2HK Whitepaper Submitted

A 5°(σ) goal in CP violating phase δ: How do we get there with accelerators?



K. Long, NF whitepaper

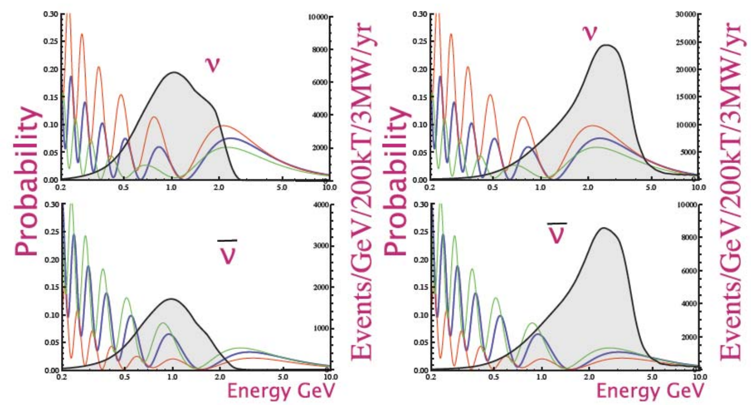
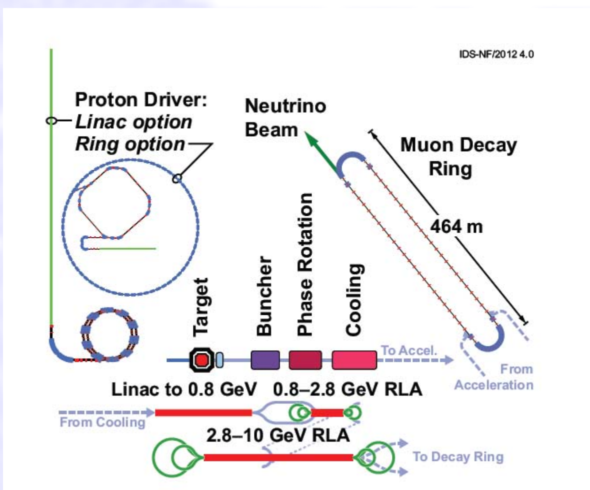


FIG. 5: Spectra of event rates as a function of energy for 8 GeV (left) and 60 GeV (right) proton beams from Fermilab. The spectra are superimposed on the expected oscillation probability for normal hierarchy. Spectra are for the total charged current cross-section for muon neutrino (top) and antineutrinos (bottom). The beam is from Fermilab to Homestake over a distance of 1300 km; the intensity for the 8 GeV beam is assumed to be 3 MW and for 60 GeV it is 2 MW. The detector size is 200 kTon fiducial mass.

E. Worcester et al, LBNE/PX whitepaper



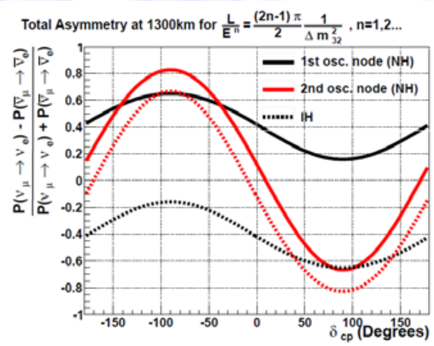
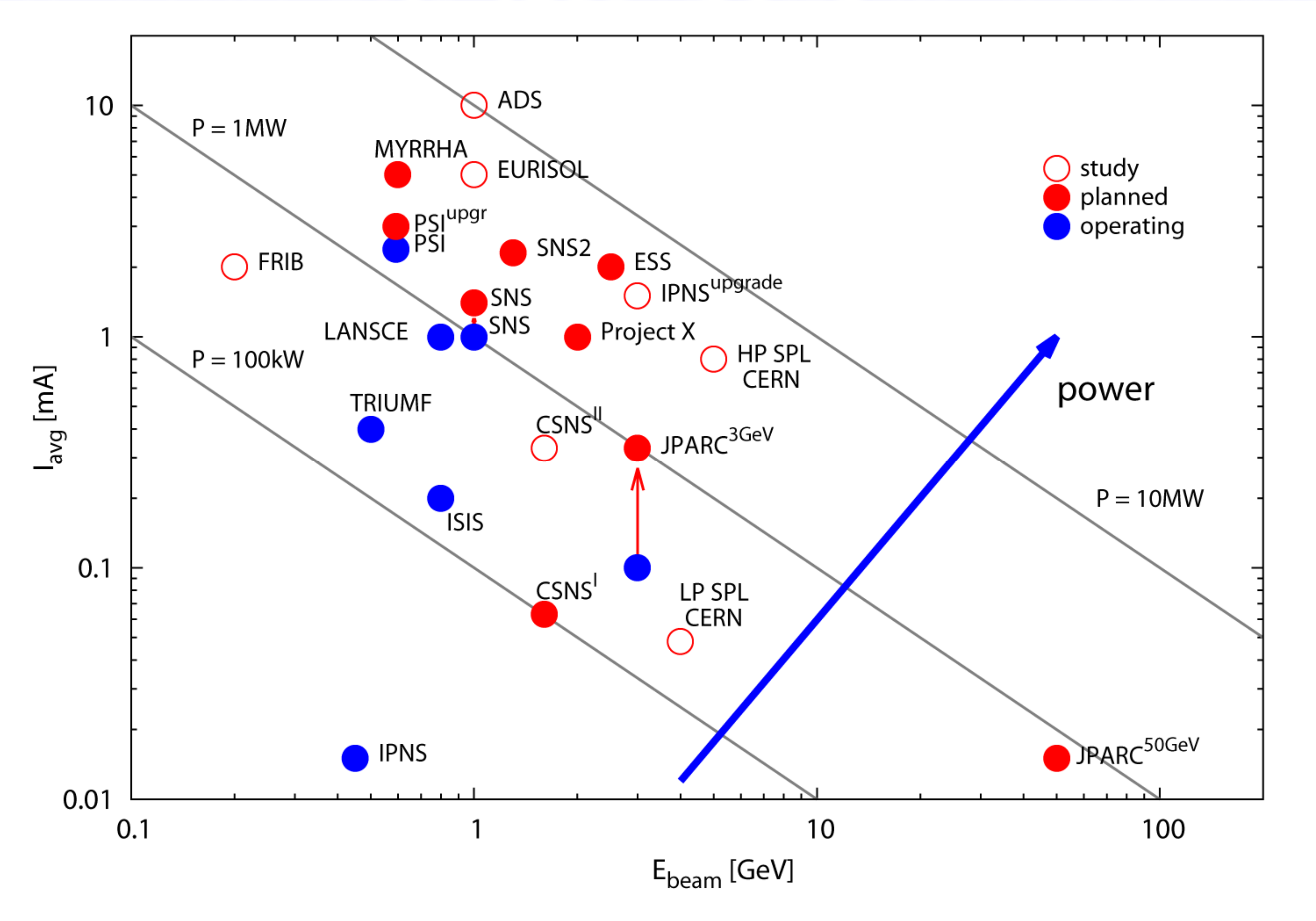


Figure 1: Total neutrino-antineutrino asymmetry in the probability of $\nu_\mu \to \nu_e$ appearance at 1300 km, at the first and second oscillation maxima, for normal and inverted hierarchy, as a function of the true value of δ_{CP}.

Dual-beam technique, separate tagged low-E, high-E ν_μ.

$\sigma(\delta)$ 5-10 degrees

High Power Proton Source Landscape



The Fermilab Project-X Research Program

- ***Neutrino experiments***

A high-power proton source with proton energies between 1 and 120 GeV would produce intense neutrino sources and beams illuminating near detectors on the Fermilab site and massive detectors at distant underground laboratories.

- ***Kaon, muon, nuclei & nucleon precision experiments***

These could include world leading experiments searching for lepton flavor violation in muons, atomic, muon, nuclear and nucleon electron dipole moments (edms), precision measurement of neutron properties (e.g. n,nbar oscillations) and world-leading precision measurements of ultra-rare kaon decays.

- ***Platform for evolution to a Neutrino Factory and Muon Collider***

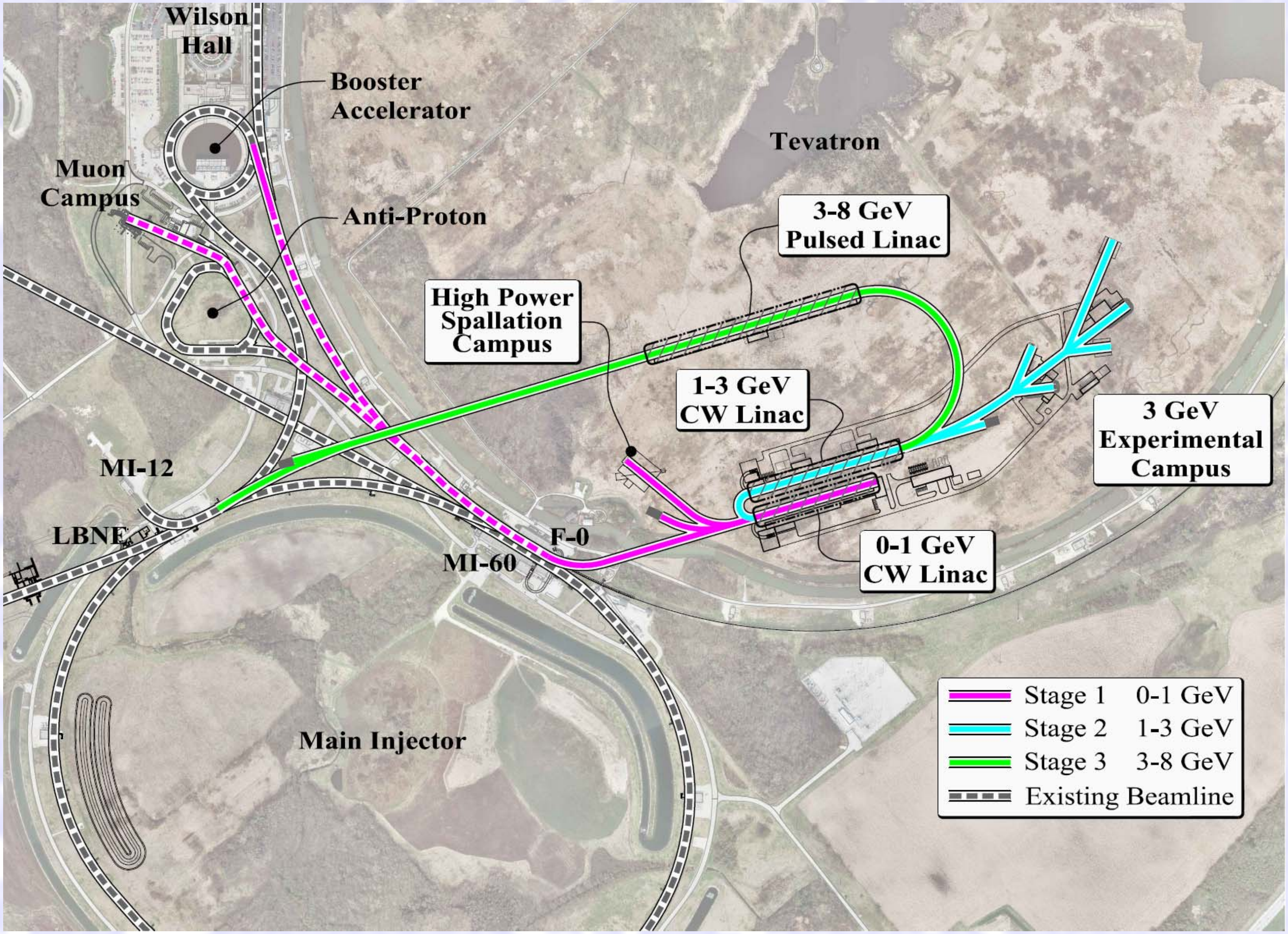
Neutrino Factory and Muon-Collider concepts depend critically on developing high intensity proton source technologies.

- ***Material Science and Nuclear Energy Applications***

Accelerator, spallation, target and transmutation technology demonstrations which could investigate and develop accelerator technologies important to the design of future nuclear waste transmutation systems and future thorium fuel-cycle power systems. Possible applications of muon Spin Resonance techniques (muSR). as a sensitive probes of the magnetic structure of materials .

Detailed discussion on Project X website

Project X Campus



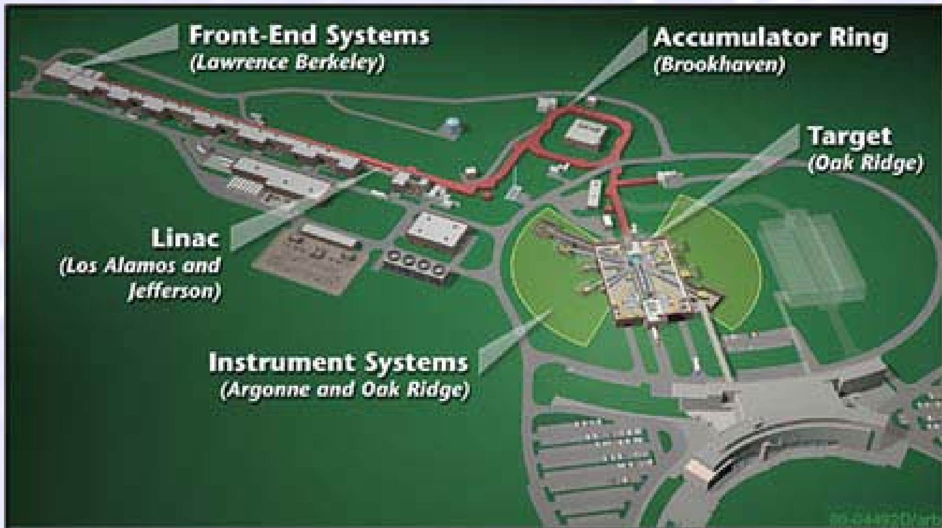
Project X: Evolution of the Fermilab Accelerator Complex

Program:	Onset of NOvA operations in 2013	Stage-1: 1 GeV CW Linac driving Booster & Muon, n/edm programs	Stage-2: Upgrade to 3 GeV CW Linac	Stage-3: Project X RDR	Stage-4: Beyond RDR: 8 GeV power upgrade to 4MW
MI neutrinos	470-700 kW**	515-1200 kW**	1200 kW	2450 kW	2450-4000 kW
8 GeV Neutrinos	15 kW +0-50kW**	0-42 kW* + 0-90 kW**	0-84 kW*	0-172 kW*	3000 kW
8 GeV Muon program e.g, (g-2), Mu2e-1	20 kW	0-20 kW*	0-20 kW*	0-172 kW*	1000 kW
1-3 GeV Muon program, e.g. Mu2e-2	-----	80 kW	1000 kW	1000 kW	1000 kW
Kaon Program	0-30 kW** (<30% df from MI)	0-75 kW** (<45% df from MI)	1100 kW	1870 kW	1870 kW
Nuclear edm ISOL program	none	0-900 kW	0-900 kW	0-1000 kW	0-1000 kW
Ultra-cold neutron program	none	0-900 kW	0-900 kW	0-1000 kW	0-1000 kW
Nuclear technology applications	none	0-900 kW	0-900 kW	0-1000 kW	0-1000 kW
# Programs:	4	8	8	8	8
Total max power:	735 kW	2222 kW	4284 kW	6492 kW	11870kW

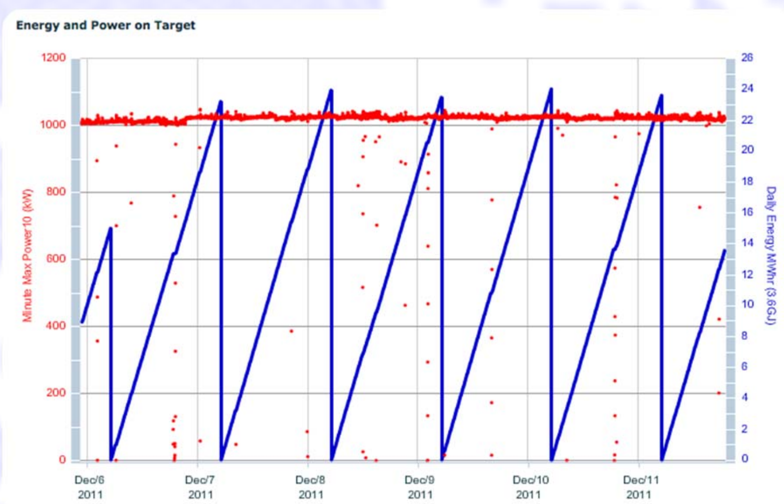
* Operating point in range depends on MI energy for neutrinos.

** Operating point in range depends on MI injector slow-spill duty factor (df) for kaon program.

The Spallation Neutron Source (SNS) at Oak Ridge National Laboratory



- 1000kW pulsed beam (60Hz) driving a spallation target for material sciences.
- Discussion of parasitic use for particle physics.



Cyclotrons as DAR Neutrino Sources

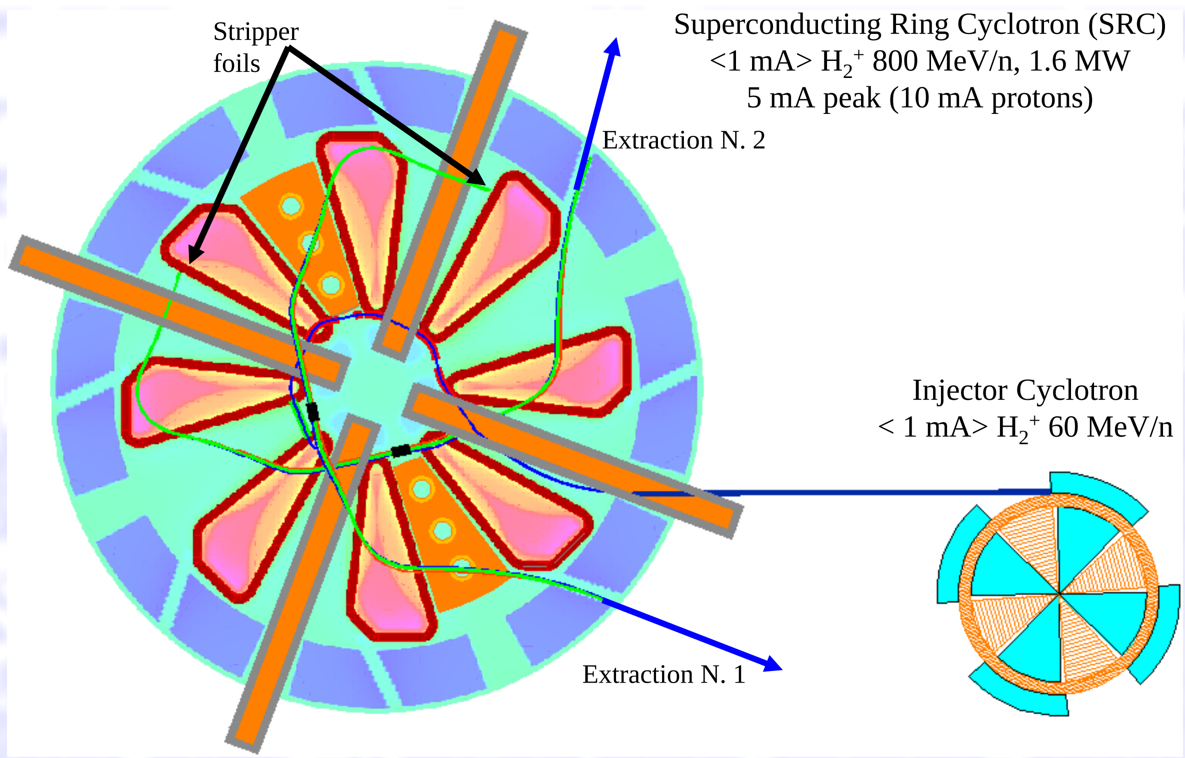
DAEδALUS: Muon decay – CP violation (800 MeV, 10 mA protons)

IsoDAR: ^{8}Li beta decay – sterile neutrino (60 MeV, 10 mA protons)
(standalone injector)

Accelerate $H_2^{\pm}$

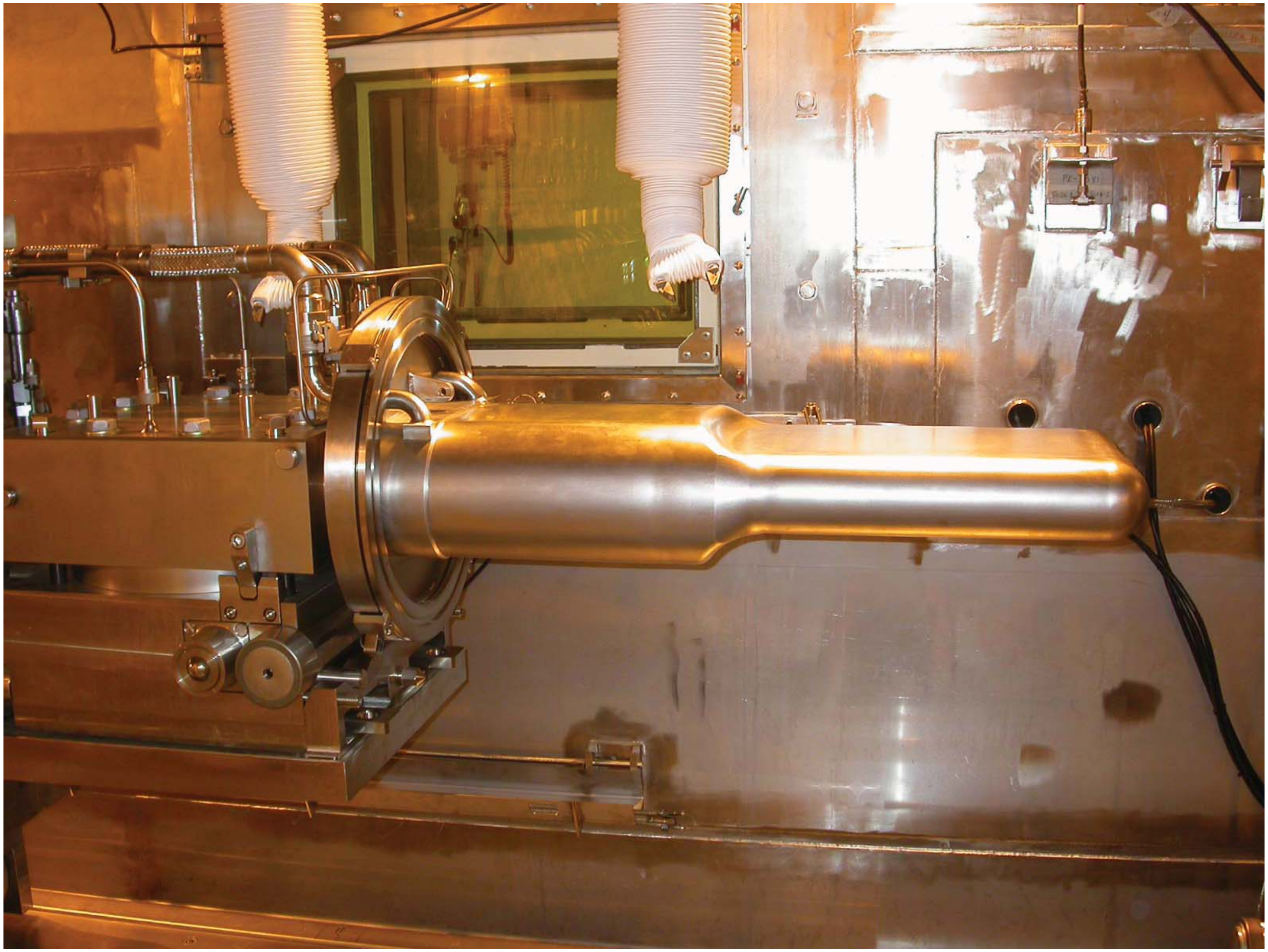
H_2^+ advantages:

- Lower space charge at injection
- Stripping extraction



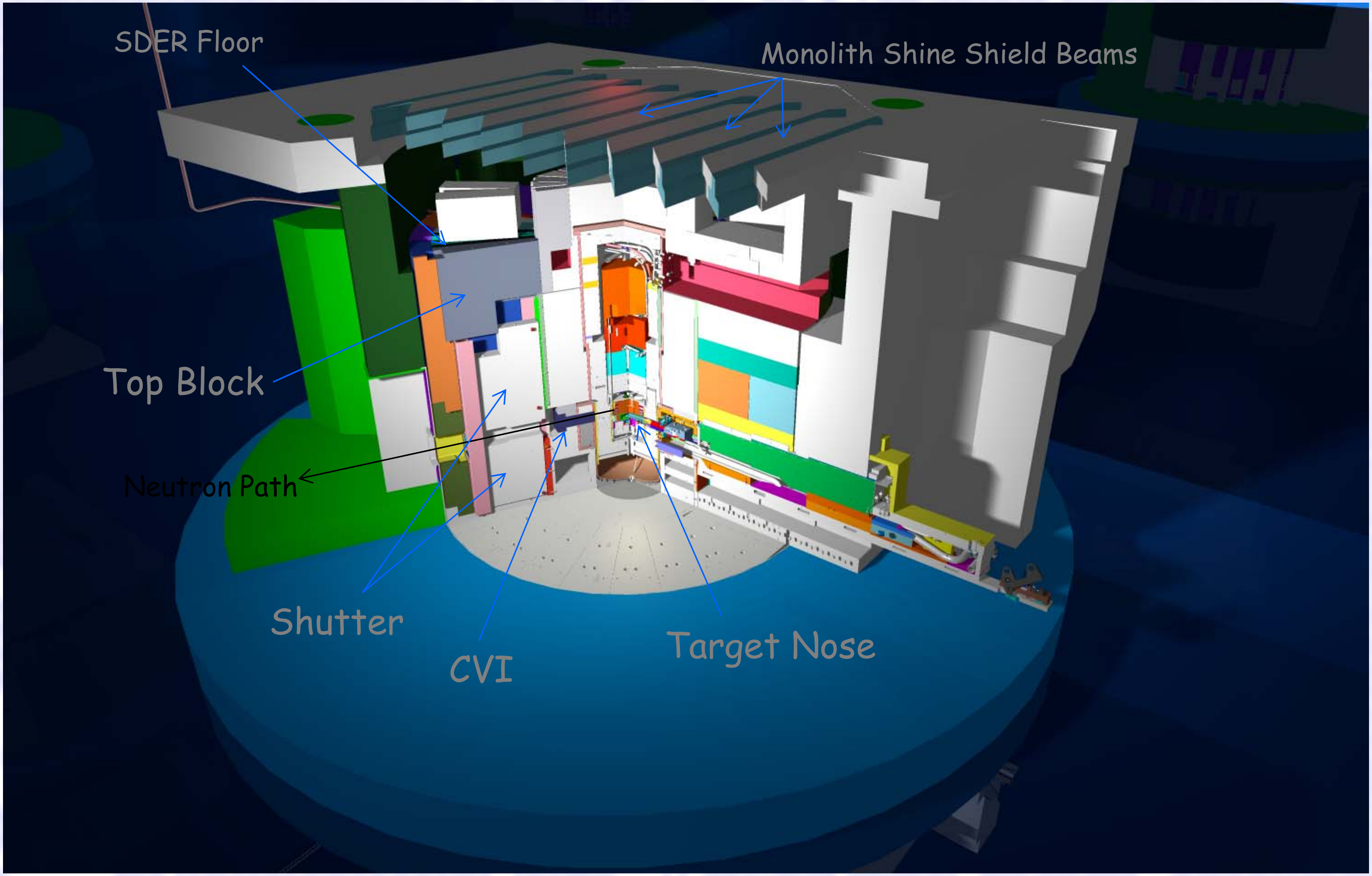
Courtesy Jose Alonso

SNS Mercury Spallation Target



Courtesy Tony Gabriel

Target Monolith Components

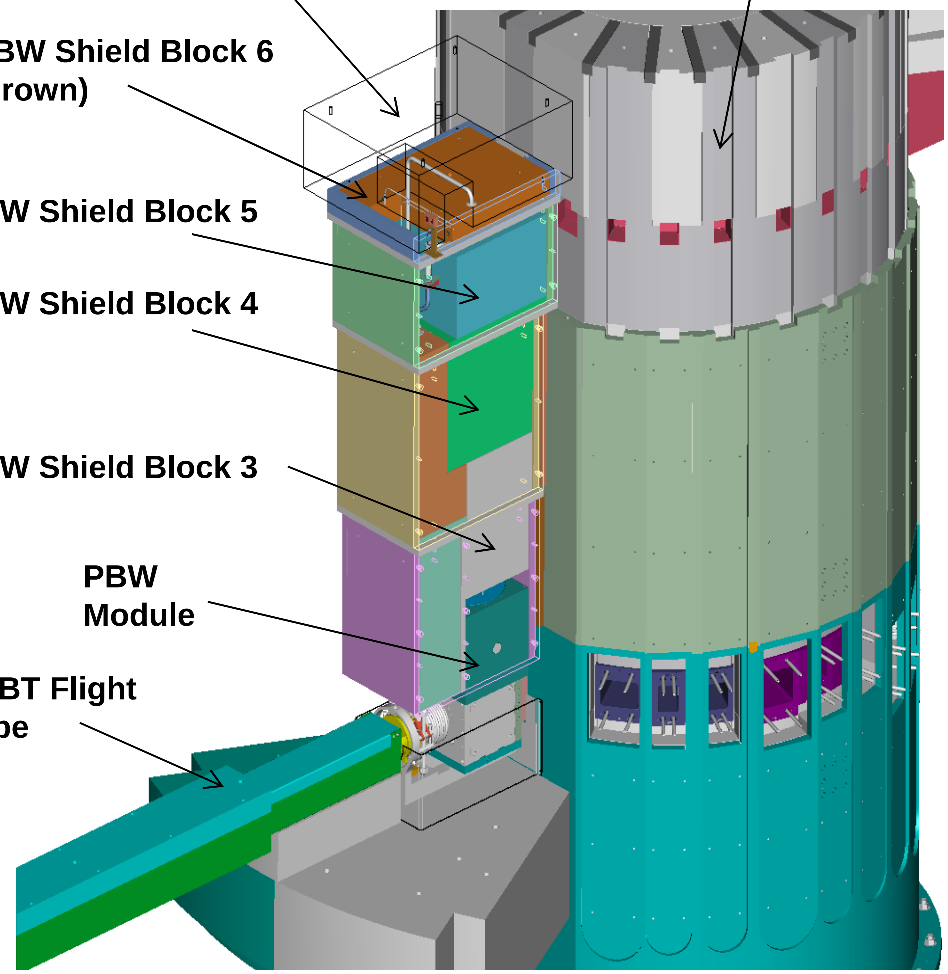


Courtesy Tony Gabriel

Proton Beam Window Replacement

- Replacement of a PBW module involves the following basic operations:
  - Removal of five shield blocks (45 tons of shielding)
  - Drying (water removal) of PBW module
  - Cutting and removal of activated utility piping
  - Withdrawal of PBW module from cavity
  - Installation of new PBW module
  - Connection of utility piping
  - Leak testing of inflatable seals and piping connections
  - Re-installation of shielding

PBW replacement requires approximately 9 days



Courtesy Tony Gabriel

Waste Shipment Operations

PBW Waste Preparation

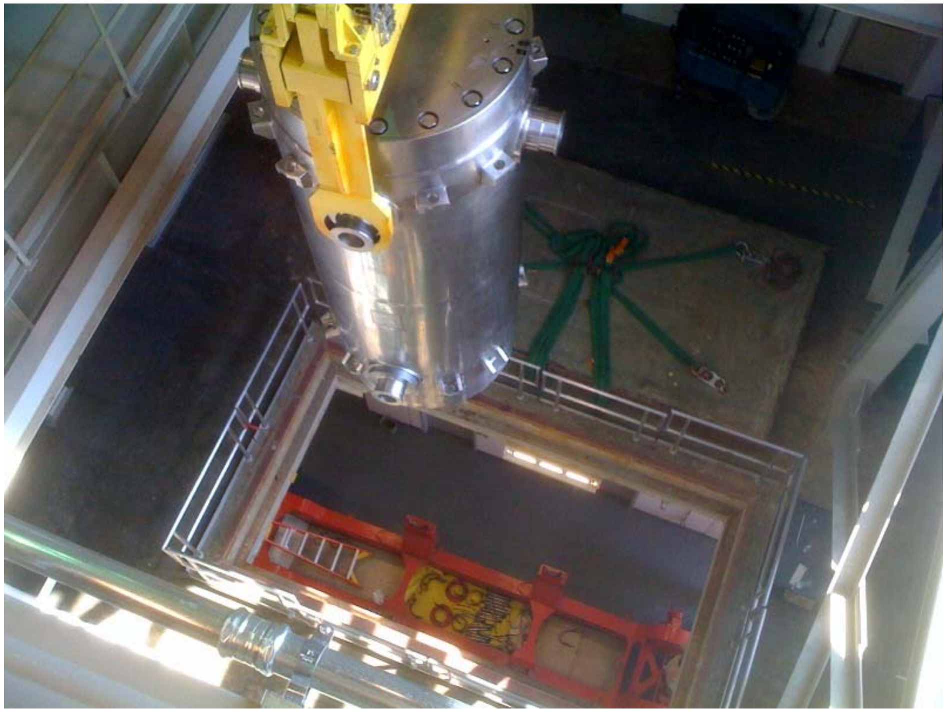
PBW Cask Liner is Loaded into the Service Bay

PBW Cask is positioned over Top Loading Port

PBW is lowered into Service Bay for loading Into Liner

Courtesy Tony Gabriel

Waste Shipment Operations



Cask Lifting from Truck

Translating Cask over for Lowering into Cask Cart

Courtesy Tony Gabriel

Waste Shipment Operations

- Following loading of the Cask, leak testing and radiological surveys are performed to ensure DOT compliance

Courtesy Tony Gabriel

High Level Rollup of Needs

- High Hours/year (e.g. 5000 hours/year operations) and plausible beam-power/neutrino flux doubling roadmaps.
- Timing: Pulsed is preferred, ideally duty factor of 10^{-4} – 10^{-5} .
- Super-beams: Enhance ν_μ fluence at low energy (0.5-2.0 GeV)
- Sign selection of parent pions and muons.
- DAR sources: 1000kW+ for pion DAR, (kaons considered as well).
- Roadmap to a Neutrino Factory, Multi-Megawatt source.
- Roadmap to multi-Megawatt targetry & targetry

Need Your Help in Tabulating neutrino beam requirements for CSS/Capabilities-Frontier meeting April 17th-20th at BNL

Next Generation Requirements for the Frontier Capabilities Working Group 3

Particle beam	Integrated Flux	Purity	Energy	Spatial characteristics	Timing characteristics
Photons					
Muon neutrinos					
Electron neutrinos					
Tau neutrinos					
Anti-muon neutrinos					
Anti-electron neutrinos					
Anti-tau neutrinos					
Positive muons	10^{15}-10^{16}	>95%	As low as possible - 5-70 MeV/c	1-10cm transverse stopping on thin foils.	CW, microstructure > 50 MHz.
Negative muons	10^{21}-10^{22}	>95%	As low as possible - 5-70 MeV/c	1-10cm transverse stopping on thin foils.	0.5-10 MHz of <10-100 nsec pulses.
Positive kaons	10^{16}	>70% at stopping target	400-600 MeV/c	1-10cm transverse incident on stopping target.	CW, microstructure > 50 MHz.
Neutral kaons	10^{16}	$<10^{-4}$ neutrons per beam kaon outside of beam solid angle	300-1000 MeV/c	20-100 μSR neutral beam	20-50 MHz of <50 psec pulses
Neutrons	$(1\text{-}5)\times10^{20}$ n/cm^2/SR	γ, fast neutron, and charged particles < signal neutrons	< 25 meV	Source < 30 cm $(2-10)\times10^{12}$ n/cm^2/s/SR over large solid angle.	Pulsed preferred, CW possible. $(2-10)\times10^{12}$ n/cm^2/s/SR
Inclusive charm					
Inclusive bottom					
Isotopes					
....					

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