LANSCE Modernization Project (LAMP): Overview and Update

N. Moody
M. Furlanetto, John Tapia, S. Mosby

November 10, 2021

LA-UR-21-31201

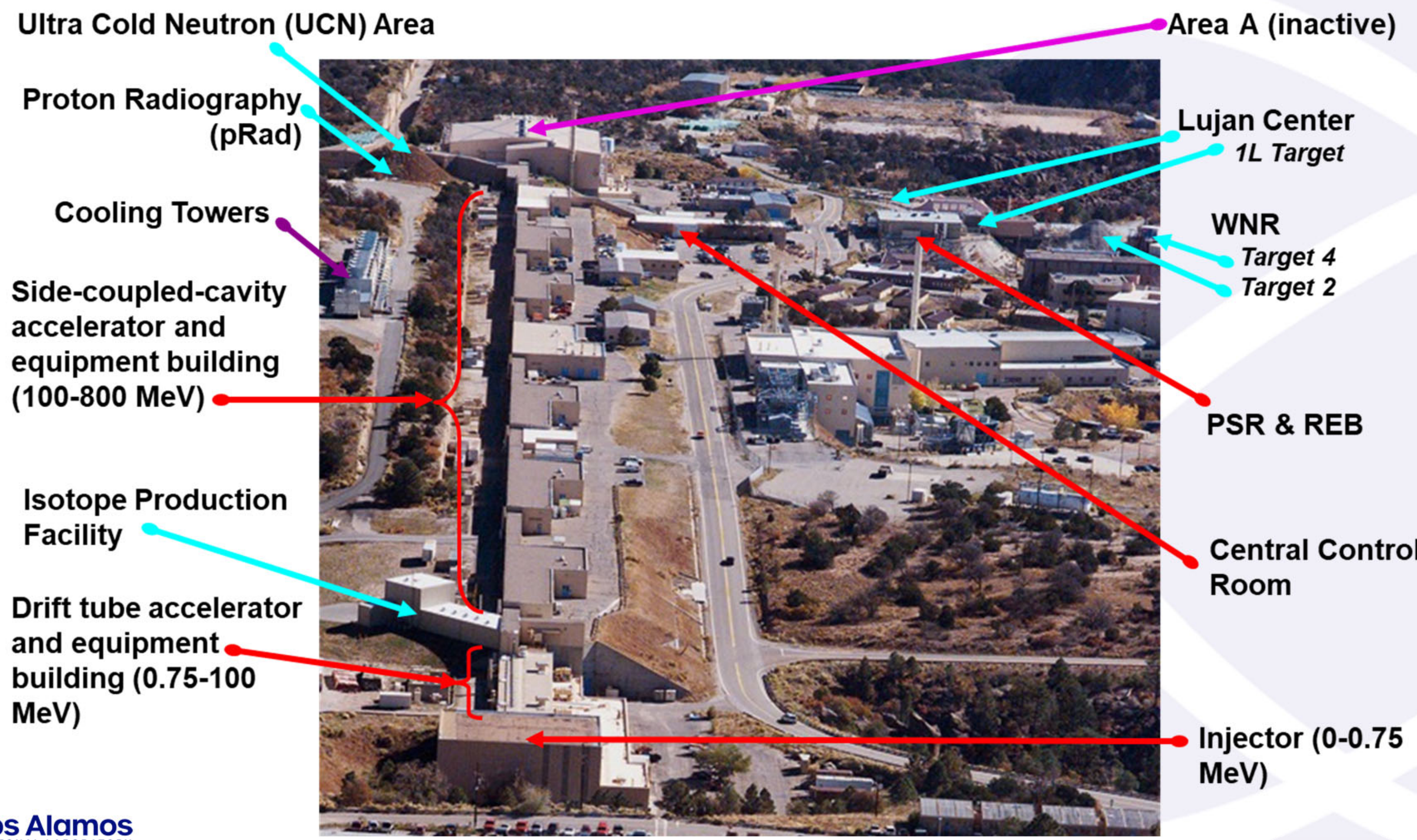
Talk Outline

- **LANSCE Overview**
  - ❑ Review of the accelerator system that provides beam to users
  - ❑ Facility configuration impacts potential upgrade paths
- **Failure Modes and Motivation**
  - ❑ Trends and risk analysis
- **LAMP Work Scope and Impact**
  - ❑ Process to date and anticipated timeline
  - ❑ Pre-conceptual proposal and progress

Accelerator facility consists of integrated sub-systems that sequentially condition and accelerate proton beams

- 750-keV proton (H+) and H- Sources and Injectors
- 201.25 MHz, 100-MeV Drift Tube Linac (DTL)
- 805 MHz, 800-MeV Side-Coupled Cavity Linac (SCCL)
- 800-MeV Proton Storage Ring (PSR)
- Beam Switchyard, Line-D (south side), Line-X (north side), Line-A (straight ahead, inactive), … beam transport lines

Bird's eye view of LANSCE Facility

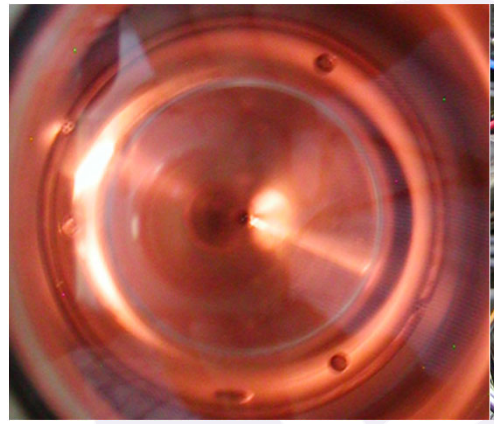


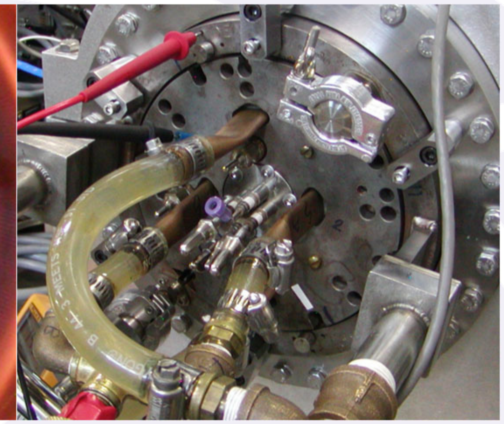
Beam propagates west to east on mesa

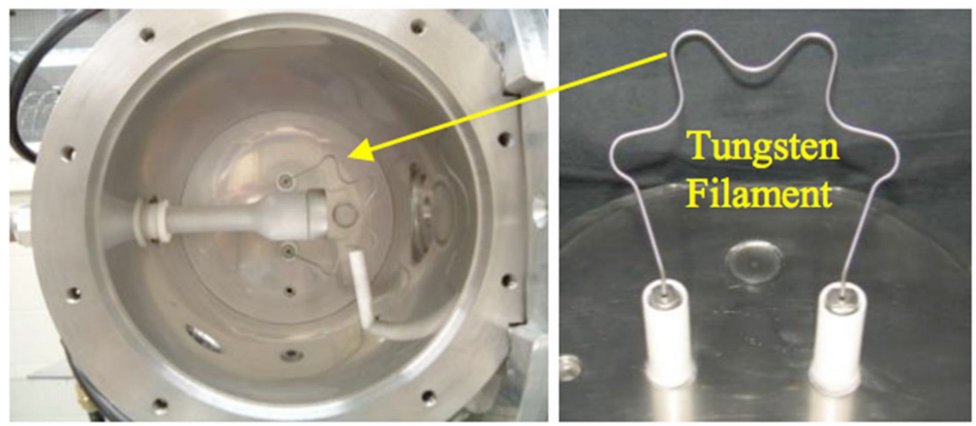
Beam originates in Sector J from H+ and H- ion sources

- H+ Duoplasmatron
  - Operational parameters
    - 10% duty factor
    - 10 mA_p (more available)
    - $\varepsilon^{rms,n} \approx 0.002\ \pi.cm.mr$
    - Lifetime ≈ very robust, years

- H- Multicusp field, cesiated, surface converter
  - Operational parameters
    - 10% duty factor
    - 14-16 mA_p typical
    - $\varepsilon^{rms,n} \approx 0.02\ \pi.cm.mr$
    - Lifetime ≈ 4 weeks



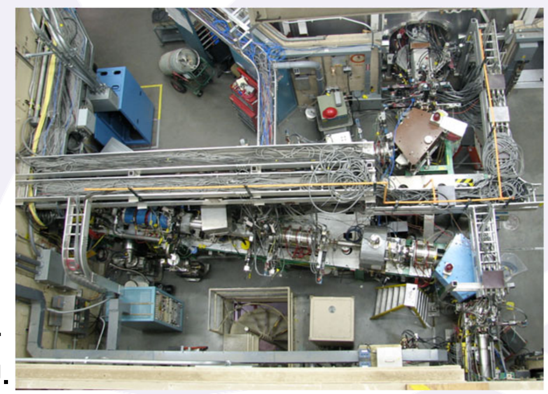




First-stage acceleration occurs in Cockcroft-Walton (CW) injectors

- Components
  - H- ion source, 80-keV LEBT & 670-kV Cockcroft-Walton (CW)
  - Proton ion source & 750-kV CW
  - Separate and combined 750-keV LEBTs
- Functions
  - Provide proper intensity beam that is correctly chopped, bunched and transversely matched beams to DTL
  - Initial acceleration, delivery, and control of beams into DTL

H+ Cockcroft Walton Injector



Top view of750 keV H+ LEBT (lower) and H- LEBT (top) merging to right before DTL located in Sec J.

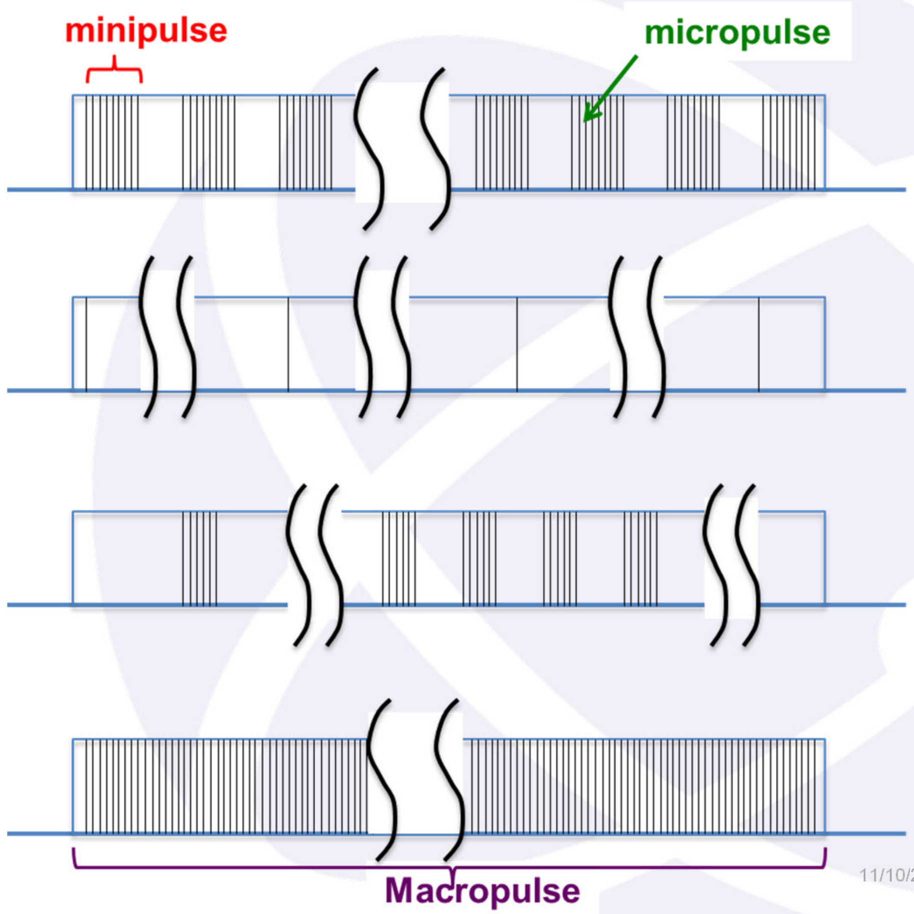
Beam chopper produces requisite formats for H- beams

Lujan(-)
Macropulse: 20 Hz x 625 μs
Minipulse: 290 ns / 358 ns
Micropulse spacing: 5 ns (201 MHz)

WNR(-)
Macropulse: 100 Hz x 625 μs
Minipulse: NA
Micropulse: every 1.8 μs

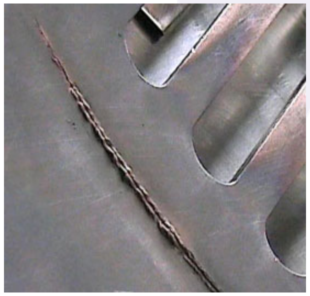
pRad(-)
Macropulse: 1 Hz/SS x 625 μs
Minipulse: 10’s of 60 ns wide every ~us
Micropulse spacing: 5 ns

UCN(-)
Macropulse: burst of 20 at 1 Hz x 625 μs
Minipulse: NA
Micropulse spacing: 5 ns



Acceleration to 100-MeV via 201.25-MHz Drift Tube Linac

- Makeup
  - Four separate accelerating tanks (modules 1-4): 5, 41, 72 and 100 MeV
  - Total Length = 61.7 m
  - Separate HPRF and LLRF systems for each tank/module
  - FODO lattice: EMQ's insides DT's for transverse focusing
  - E0: 1.6-2.3 MV/m (T1), 2.4 MV/m (T2-4); $\varphi_s = -26^\circ$
  - Duty Factor: ~10%
- Concerns
  - Beyond expected end-of-life, exhibiting failures

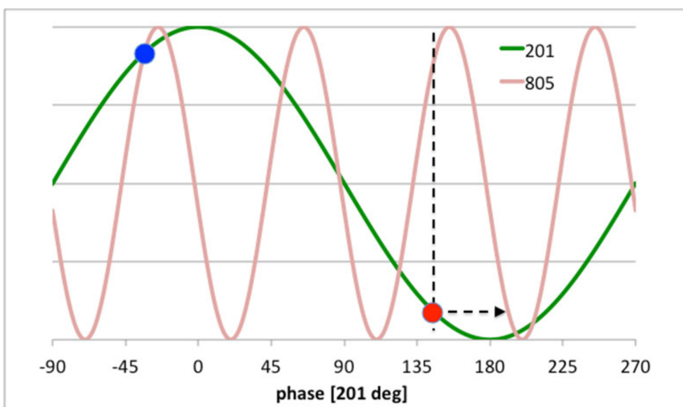


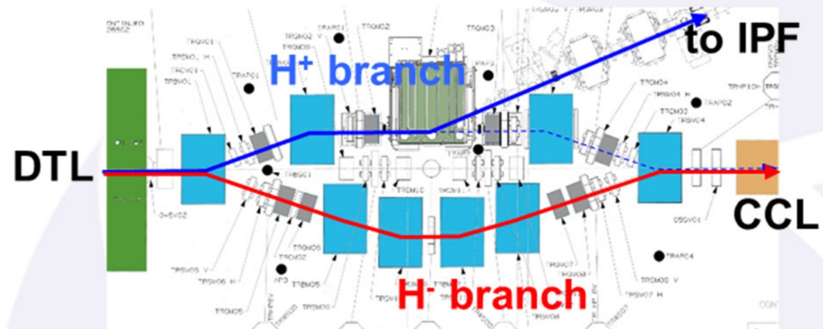
100 MeV Drift Tube Linac

Inside of DTL tank 4

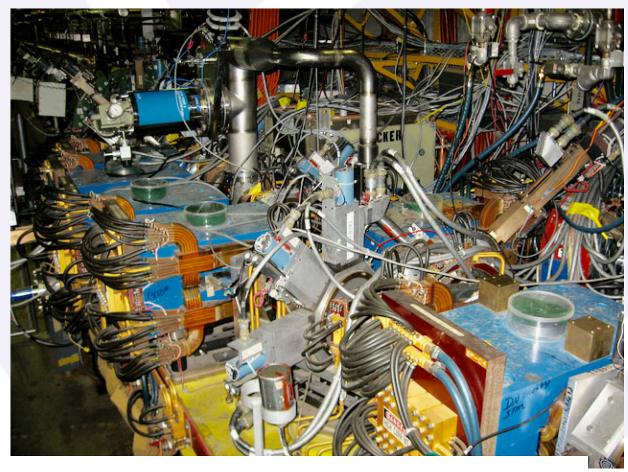
100 MeV Beam Transport (Transition Region - TR)

- **Function**
  - Independently match, steer and phase H^+ and H^- beams into CCL
  - Extraction point for 100 MeV IPF(H^+) beam
  - Independent phasing necessary for dual species operation with frequency jump from 201 to 805 MHz





Top View of 100 MeV TR transport

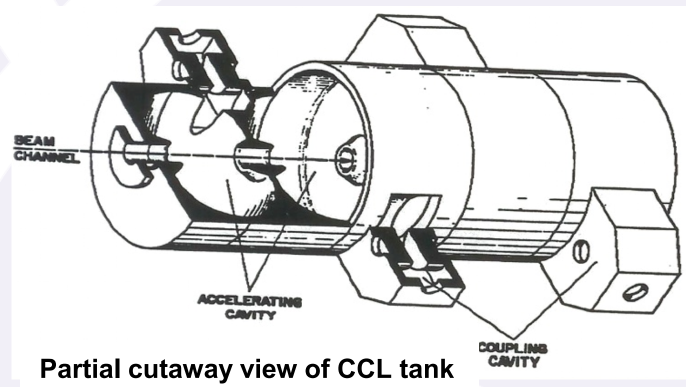


View of TR next to H- branch, aka Sidetrack

Acceleration to 800 MeV via Coupled Cavity Linac (CCL)

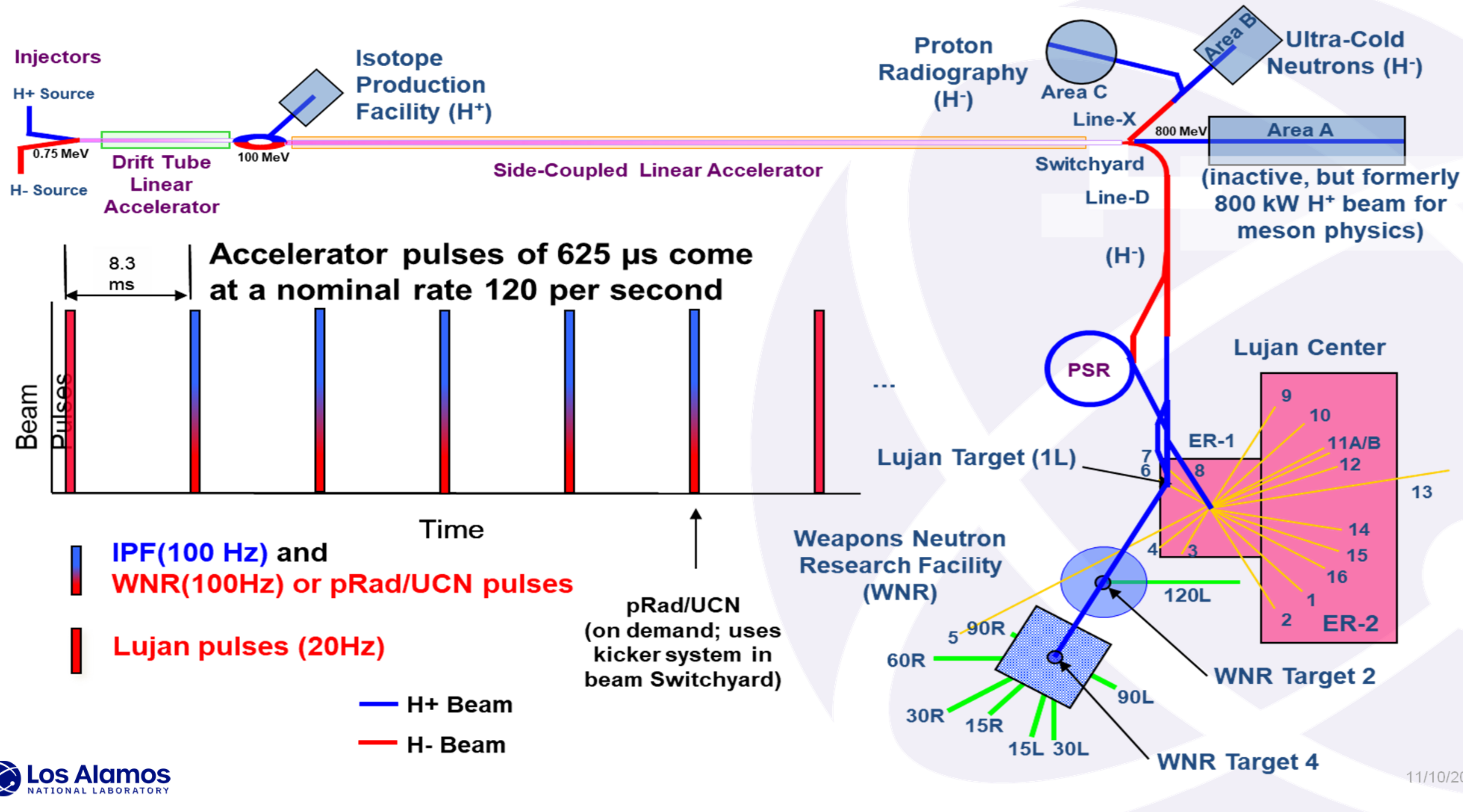
- Design
  - Side coupled structure developed at LANL
  - 44 Modules (5 to 48) – L_{tot}: 727 m
    - M5-12: 4 tanks per module
    - M13-48: 2 tanks per module
  - 100 – 800 MeV
  - Frequency: 805 MHz
  - E0T: ~ 1.4 – 1.2 MV/m, 10% Duty Factor
  - Design phase: -36˚ to -30˚
  - FDO Quad lattice
    - M5-12 FDO, 4 doublets per module (gradient profile: ramped)
    - M13-48: FDO, 2 doublets per module (gradient profile: constant)

View of CCL near upstream end



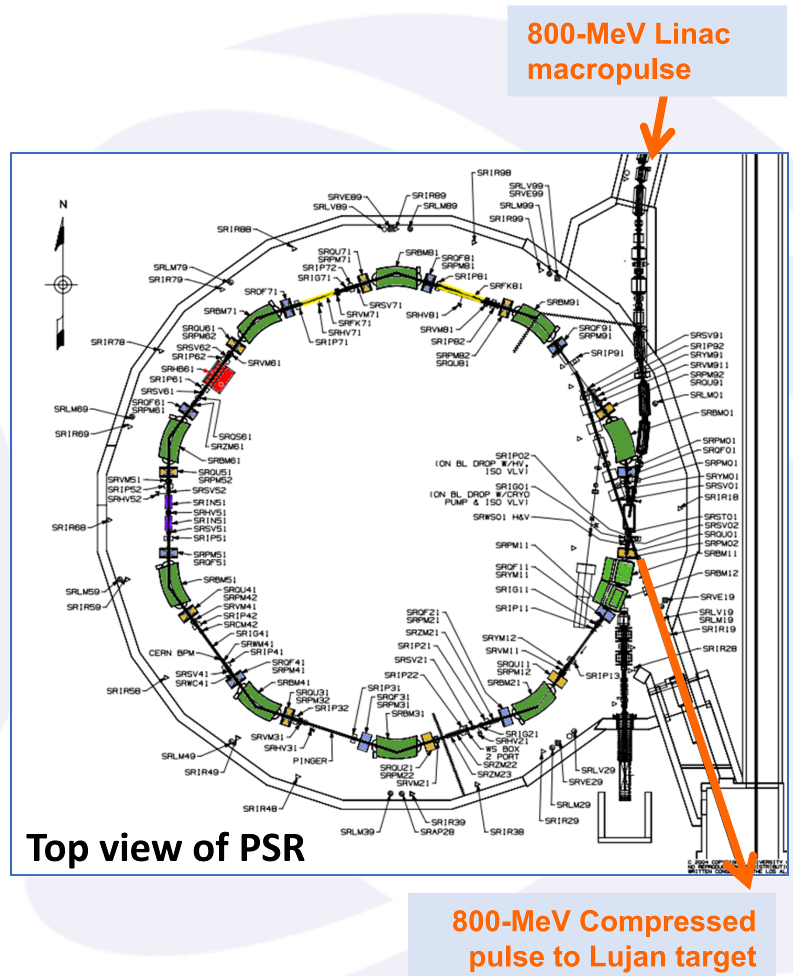
Partial cutaway view of CCL tank

LANSCE Linac Delivers Beam to Five Experimental Facilities



Proton Storage Ring (PSR)

- Design & Operational parameters
  - Layout:
    - FODO lattice – 10 cell
    - Circumference: 90.23 m
    - Rev freq/period: 2.795 MHz / 357.8 ns
    - Direct H- injection, 400 µg/cm2 C/B foil
    - Buncher cavity (2.8 MHz, 0-18 kV)
    - Inductive inserts (s.c. compensation)
    - Stripline extraction kickers
  - Input beam: 799 MeV; macropulse width: 625µs pulse; minipulse width: 290 ns, 70 ns extraction gap
  - Output beam: 799 MeV; 150 ns FWHM
  - Beam current/charge:
    - 100 uA average @ 20 Hz, 5 µC/pulse, 6.2×10^{12} ppp



Top view of PSR

Talk Outline

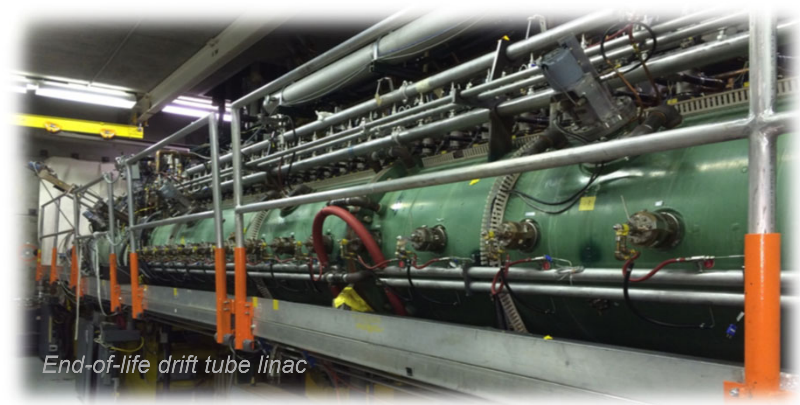
- **LANSCE Overview**
  - ❑ Review of the accelerator system that provides beam to users
  - ❑ Facility configuration impacts potential upgrade paths
- **Failure Modes and Motivation**
  - ❑ Trends and risk analysis
- **LAMP Work Scope and Impact**
  - ❑ Process to date and anticipated timeline
  - ❑ Pre-conceptual proposal and progress

The LANSCE Modernization Project (LAMP) is a critical upgrade required to ensure LANSCE readiness and reliability

The timeline for LAMP is driven by four factors:

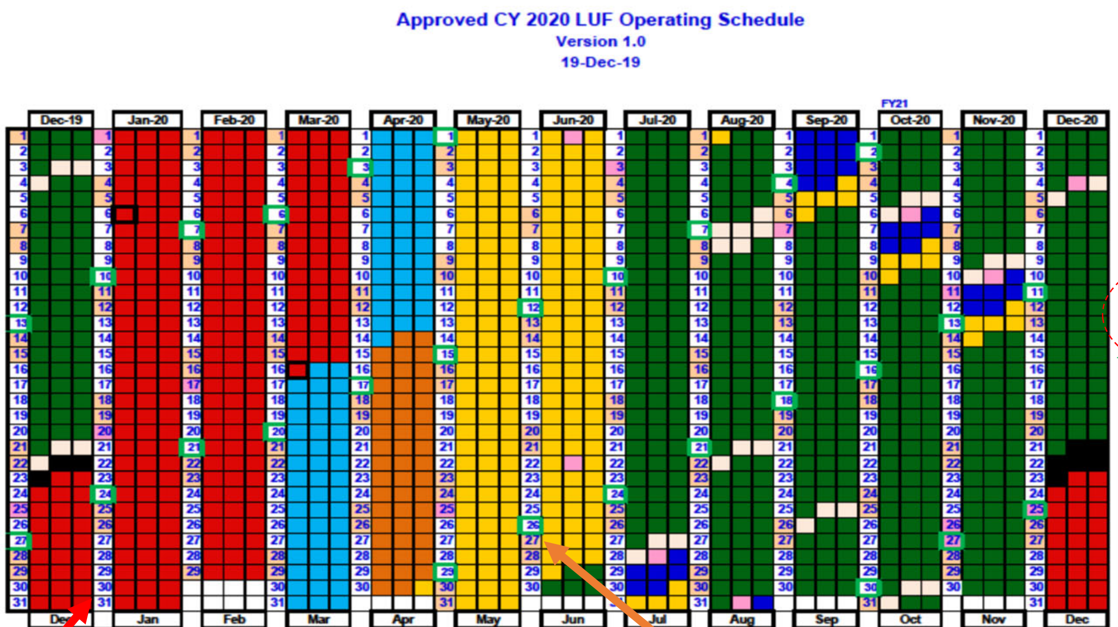
- Data from LANSCE will be required to support assessment and certification at least **through 2050**
- We have already started to experience **end-of-life failures** that have reduced beam availability
- We have developed a **high-TRL pre-conceptual upgrade design** which would take ~7 years to complete. It would replace everything from the ion sources through the drift-tube linacs
- We are investigating alternatives involving multiple projects, potentially with a raised GPP limit, to allow **more options** for completion of this work.

Obsolete Cockcroft-Walton generators



End-of-life drift tube linac

LANSCE beam availability significantly lags behind its peers



Key:
Maintenance
Startup
Experimental operations

Beam reliability only 60-85%; LAMP (plus other investments) will bring this to 90% or better

Long maintenance period determined by work required and obsolete designs

Startup ~6 weeks; other accelerators ≤ 2 weeks

Low availability is particularly problematic in light of LANSCE's chronic oversubscription.

Rationale for front end upgrade comes from its risk analysis *and* commonality to all present and future beam availability

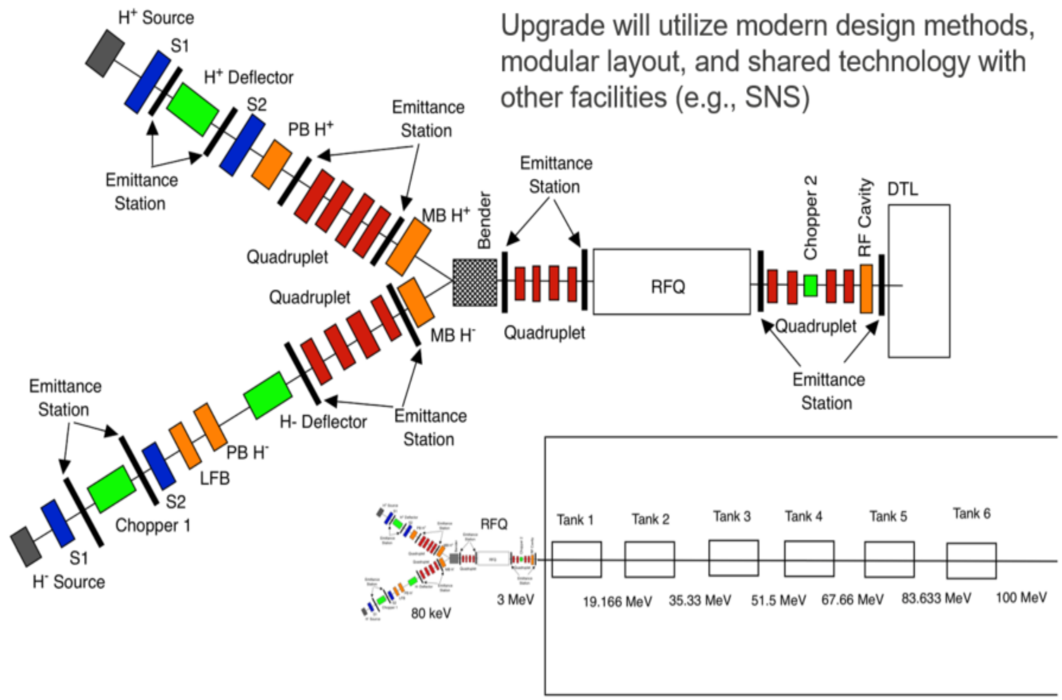
Cockroft-Walton (C-W) injector System						
H+ CW Accelerator	1		Critical	49	Moderate	LAMP Project
H- CW Accelerator	1		Crisis	49	Moderate	LAMP Project
LEBT Lines	2		Critical	49	Moderate	LAMP Project
201.25 MHz Drift Tube Linac System						
Accelerator Tanks	4		Crisis	49	Moderate	LAMP Project
Drift tubes	100s		Critical	49	High	LAMP Project
RF Power system	4		Significant	5	Low	LAMP Project
805 MHz RF System						
Accelerator Structures	44		Crisis	49	Low	None
RF Power system	44		Significant	20	Low	Continuous
Diagnostics	10s		Marginal	49	Moderate	Replace/repair as needed
Magnets	10s		Significant	49	Moderate	Refurbishment in progress
Transfer lines						
Magnets	100s		Critical	49	High	None
Diagnostics	10s		Marginal	49	Moderate	Replace/repair as needed
Vacuum system	10s		Marginal	49	Moderate	Replace/repair as needed
Proton Storage Ring						
Magnets	10s		Crisis	30	High	None
RF Power systems	1		Significant	30	Moderate	None
Diagnostics	10s		Marginal	30	Moderate	Replace/repair as needed
Pulsed Magnets	4		Critical	30	High	Replace/repair as needed
Stripper foil system	1		Significant	30	Moderate	Replace/repair as needed
Target Systems						
1L Target	1		Significant	12	Moderate	Replace every ~10 years
Target 4	1		Significant	1	Low	Replace target every year
Control System						
Linac Control System	1		Significant	30	Moderate	Refurbishment in progress
Timing system	1		Critical	40	Moderate	Refurbishment in progress
Protective Systems						
Radiation Security System (RS	1		Significant	25	Low	Replace/repair as needed
Machine Line-up System (RP)	1		Significant	15	Low	Replace/repair as needed
Machine protection system (F	1		Significant	4	Low	Replace/repair as needed
Facility Interface						
Power distribution	1		Critical	49	Moderate	Replace/repair as needed
Water systems	10s		Significant	49	Moderate	Replace/repair as needed

- Very Poor
- Poor
- Fair
- Good

The LAMP project will modernize obsolete equipment at the front end of the accelerator

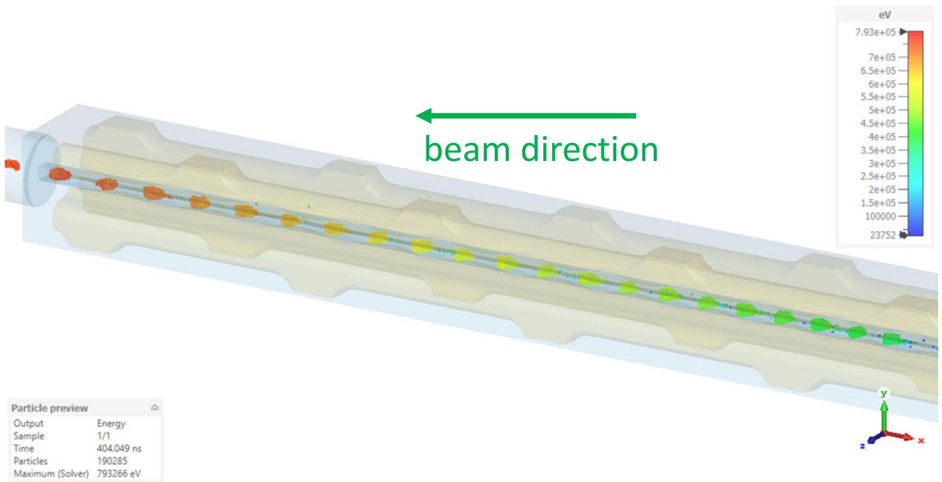
- Upgrade of sources to end of Drift Tube Linac (DTL) at 100 MeV
    - ❑ Utilizes latest advances in accelerator design (e.g., not just like-for-like replacement of components)
- System integration and testing to 20 MeV (sources to end of first DTL)
- System integration and testing up to 100 MeV (sources to end of last DTL)
- Development of controls and new operating procedures
- Operator training on new systems before deployment in LANSCE tunnel

Upgrade will utilize modern design methods, modular layout, and shared technology with other facilities (e.g., SNS)



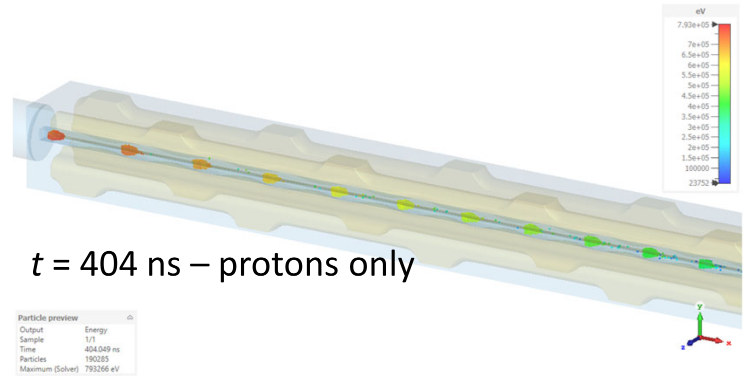
Thanks to FY21 investment, preconceptual efforts in Mod/Sim show LANL RFQ with simultaneous p & H^- beams

Two beams near RFQ exit: all particles (left), p or H^- only (right)

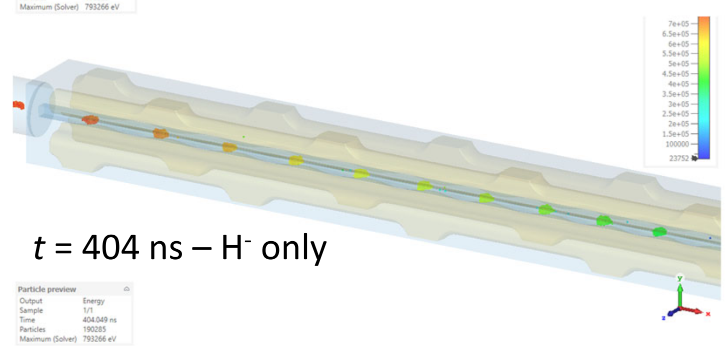


t = 404 ns; 190,285 particles total

Snapshot at *t* = 404 ns; color shows energy



t = 404 ns – protons only



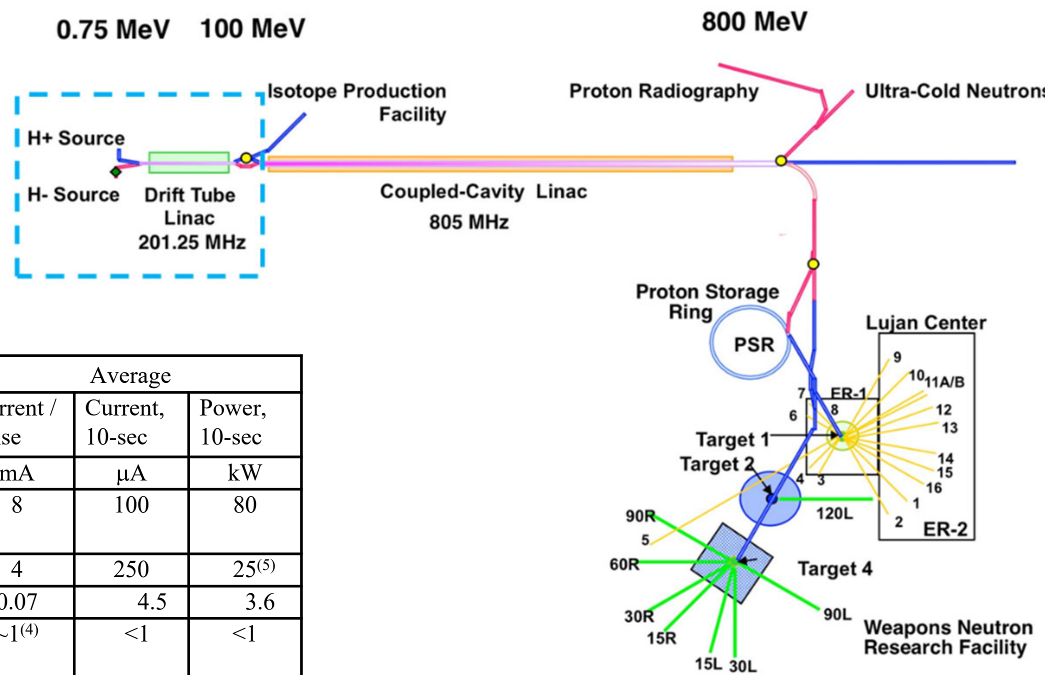
t = 404 ns – H^- only

The use of the same RFQ for accelerating multiple beams (with different species and different current densities), though is novel approach, but looks practical, and allows us both, increase the availability of the whole system (due to simplification, and reduction of number of =the required components), and simplify maintenance, required for supporting of those system.

The upgrade concept will minimize impacts to existing user facilities and off-line testing (possibly in LEDA tunnel) will minimize future outages

The scale of this upgrade will likely cause an interruption of one operational cycle, depending on the project planning and other constraints.

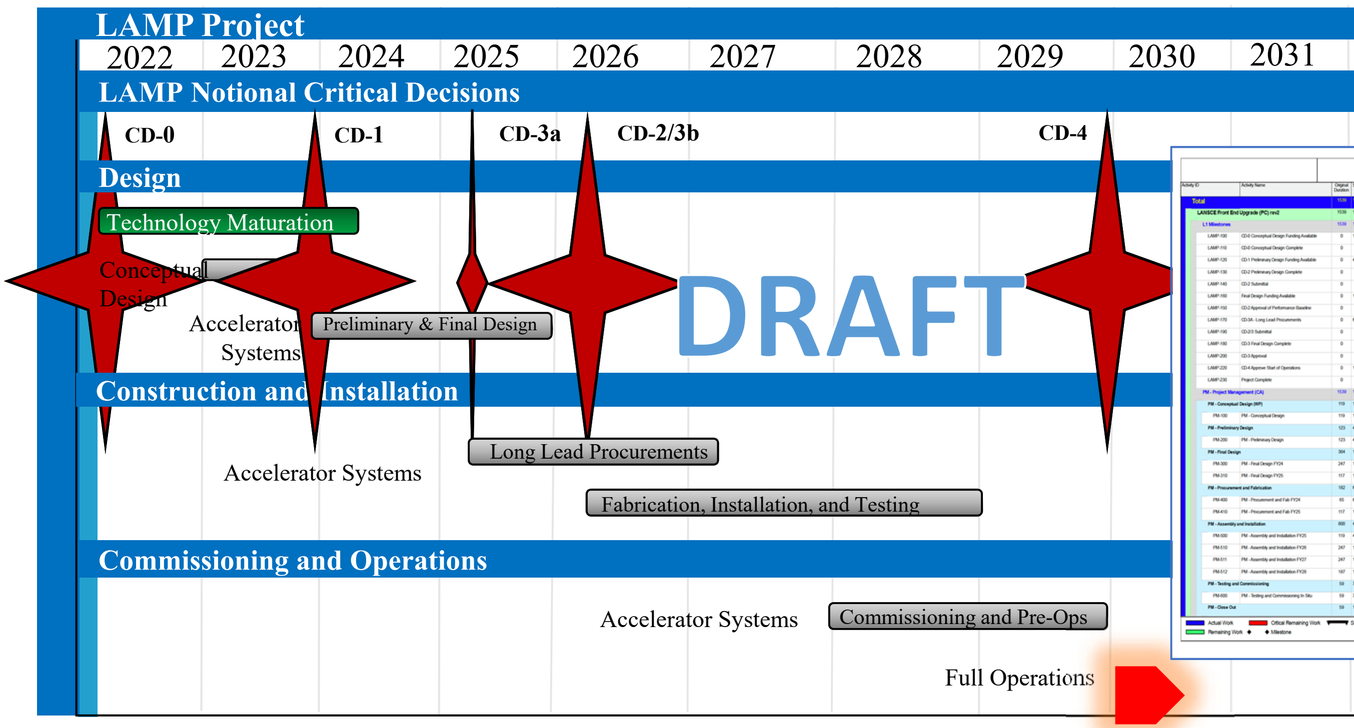
Front End of LANSCE

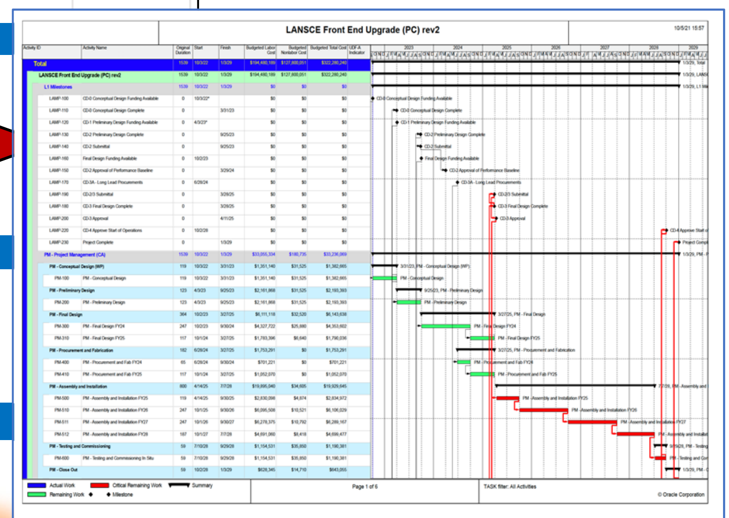


Facility	Species[1]	Pulses / sec	Pulse length[2]	Chopper fraction	Current /µbunch	Average: Current / pulse	Average: Current, 10-sec	Average: Power, 10-sec
			µs		mA	mA	µA	kW
Lujan/PSR	H^-	20	625	0.8	10	8	100	80
IPF	H^+	100	625	1	4	4	250	25[5]
WNR	H^-	100	625	$2.8 \cdot 10^{-3}$	25[3]	0.07	4.5	3.6
pRad	H^-	On demand	<625	-	10	~1[4]	<1	<1
UCN	H^-	10, at 0.2 Hz	625	0.8	10	8	10	8

Lessons from LCLS-II, LCLS-II HE, APS-U, and ALS-U will be applied

A notional schedule is being prepared that reflects our initial assumptions factoring in possible funding constraints at a cost range of $200-$500M





Summary: Next Steps

- LANL to submit LAMP Proposal for consideration by NNSA.
  - Need to agree on planning assumptions that will underpin the project planning and document submittals
  - Need to understand the process and timeline for key HQ briefings / decisions prior to a CD-0 ESAAB and finalizing documents
  - *Note of thanks to contributing members (past and present) to the modeling and simulation efforts*
- Received $2M investment in FY21 and would like to maintain momentum to enable more robust pre-conceptual project planning (modeling / simulation of beam physics, experimental workshops, and CD-0 project documentation)
- ALDPS prepared to formally establish LAMP Project (within ASO) to secure a funding profile beginning in FY23.

To ensure that we can meet the need for LANSCE for decades to come, we need to invest in the facility and its experiments