Recent Operational Experience at the LANSCE Facility

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Abstract

The Los Alamos Neutron Science Center (LANSCE) consists of a pulsed 800-MeV room-temperature linear accelerator and an 800-MeV accumulator ring. It simultaneously provides H^+ and H^- beams to several user facilities that have their own distinctive requirements, e.g. intensity, chopping pattern, duty factor, etc.. This multi-beam operation presents challenges both from the standpoint of meeting the individual requirements but also achieving good overall performance for the integrated operation. This presentation will touch on various aspects of more recent operations including the some of these challenges.

Outline

- **Facility Overview**
- **Schedule and Recent Performance**
- **Beam Losses – Activation**
- **Operational Challenges**
  - Increasing H^- beam current
  - Improving performance under multi-beam operation
  - Maintaining performance for micro-pulse operation at large pulse spacing

Los Alamos Neutron Science Center

- **LANSCE is a multi-user, multi-beam facility that produces intense sources of pulsed, spallation neutrons and proton beams in support of national security and civilian research.**
- **LANSCE is comprised of a high-power 800 MeV proton linear accelerator (linac) and a proton storage ring and has been in operation for over 35 years.**
  - Formerly known as LAMPF, designed to provided 800 kW of beam for meson physics program
- **The LANSCE Experimental User Facilities includes**
  - The Proton Radiography (pRad) Facility, which provides time-sequenced radiographs of dynamic phenomena with billionths-of-a-second time resolution
  - The Weapons Neutron Research (WNR) Facility that provides a source of unmoderated neutrons in the keV to multiple MeV range
  - The Manuel Lujan Jr. Neutron Scattering Center (Lujan Center), which uses a time-compressed proton beam to make a moderated neutron source (meV to keV range)
  - The Isotope Production Facility (IPF) is a source of research and medical radioisotopes for the US
  - The Ultra Cold Neutrons (UCN) which is a source of sub-μeV neutrons for fundamental physics research

A Bird's Eye View of the LANSCE Facility

Ultra Cold Neutron (UCN) Area

RLW plant

Area A (inactive)

Proton Radiography (pRad)

Lujan Center

1L Target

WNR

Cooling Towers

Target 4

Target 2

Side-coupled-cavity accelerator and equipment building (100-800 MeV)

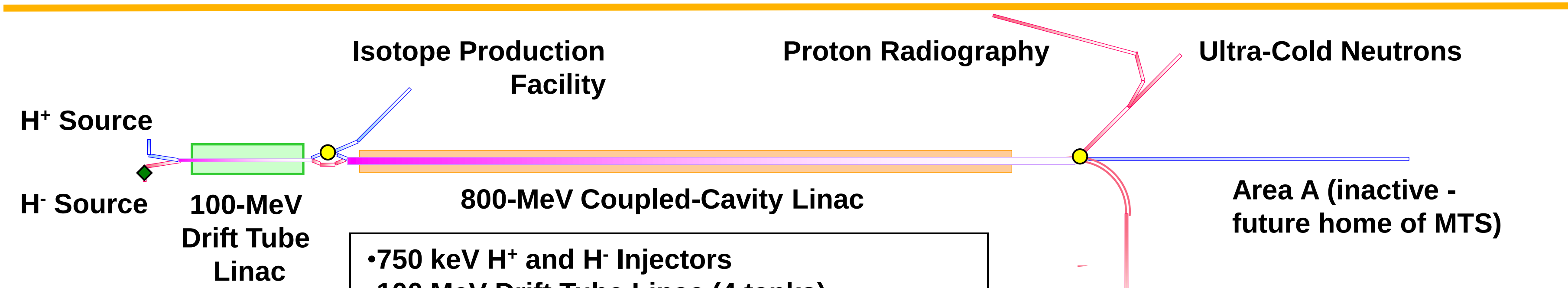
Central Control Room

Isotope Production Facility

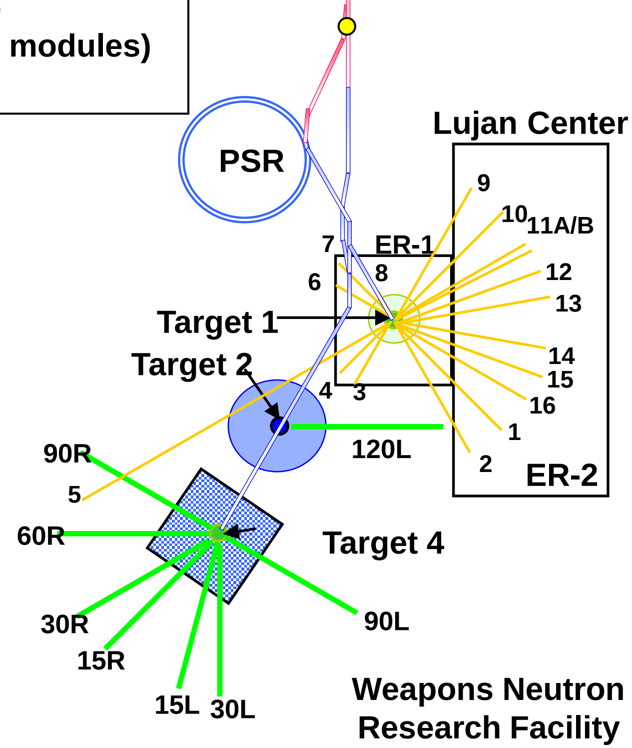
Drift tube accelerator and equipment building (0.75-100 MeV)

Injector (0-0.75 MeV)

Present Day LANSCE Facility Overview



- •750 keV H+ and H- Injectors
- •100 MeV Drift Tube Linac (4 tanks)
- •800 MeV Coupled Cavity Linac (44 modules)
- •800 MeV Accumulator Ring (PSR)



Area	Typical Repetition Rate [Hz]	Typical Pulse Length [µs]	Linac Beam Species	Typical Chopping Pattern	Average Beam Current [µA]	Nominal Energy [MeV]	Avg Beam Power [kW]
Lujan	20	625	H-	290 ns/358 ns	100 -125	800	80 - 100
WNR Tgt4	≤40	625	H-	1 µpulse every ~1.8 µs	≤ 2	800	< 1.6
UCN	20	625	H-	Lujan-beam like to unchopped	< 5	800	< 4
pRad	~1	625	H-	60 ns bursts every ~1 µs	< 1	≤800	< 1
IPF	≤30 in Pulsed mode	625	H+	NA	≤ 250	100	≤ 25
AreaA inactive	≤100	625	H+	NA	1000	800	~ 800

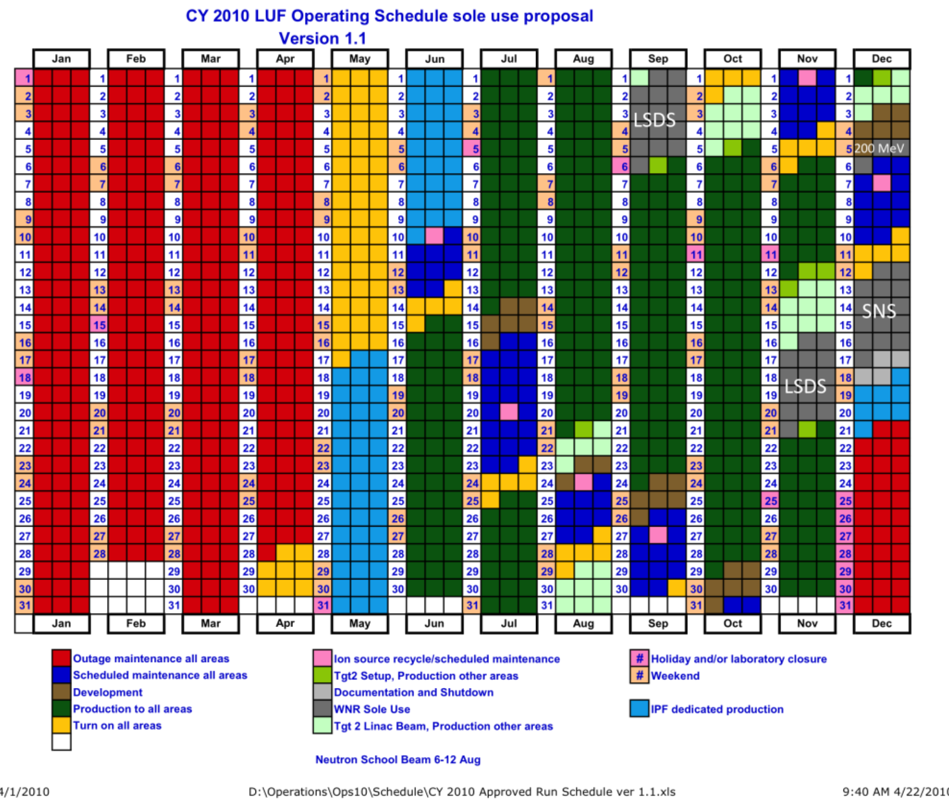
○ kicker
◆ chopper

Linac Performance – Present, Historical & Demonstrated

- **Present Performance**
  - 60 Hz x 625 µs Operation (limited by 7835 in DTL 201 MHz RF System)
  - RF duty factor ~5%
  - Peak beam current: ~13 mA (H- ion source limit, H+ set to match)
- **Historical Performance**
  - 120 Hz x 625 µs beam gates -> 7.5% duty factor
  - Combined and simultaneous H^+ & H^- operation (limited by peak RF power)
  - Typical peak beam current: 16.5 mA, avg. beam power: 800 kW
  - RF duty factor: ~10%
- **Demonstrated Performance (non-coincident)**
  - RF duty factor: ~12%
  - Beam gates: 1225 µs
  - Peak beam current: 21 mA (800 MeV with I_{avg}= 320 µA)
  - 1 MW beam operation

2010 Operating Schedule is Typical of Recent Years

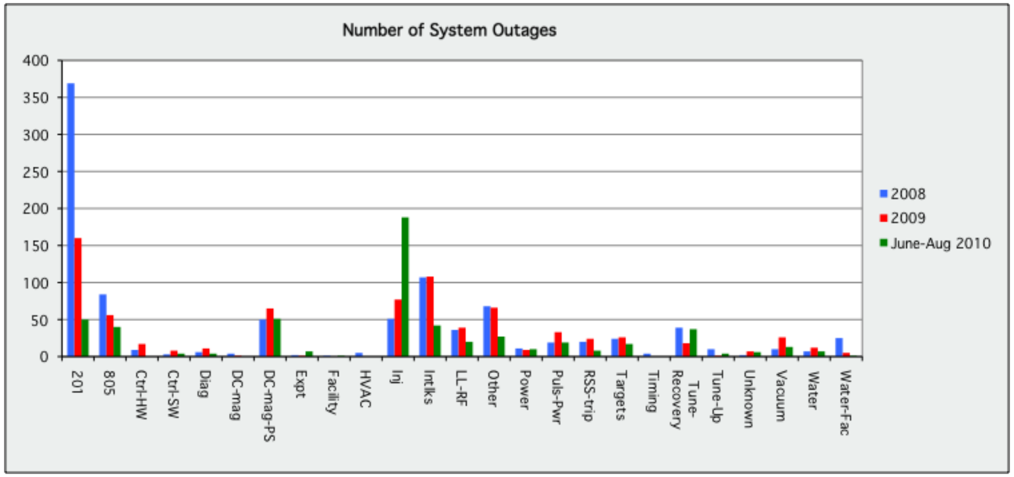
- **Extended Maintenance January 1 thru April 28**
  - Lujan target-moderator system replaced
  - MW-class magnet power supplies replaced
- **Annual Start-up/Turn-on**
  - Personnel safety/machine protection interlock checks & tuning
  - First 19 days to 100 MeV
  - Next 24 days
    - Dedicated production to IPF
    - 800 MeV turn-on completed
- **5½ blocks of "production beam" over next 6 months**
  - 24-29 days of user beam per cycle, including sole use
  - ~1-2 days of machine development per cycle
  - Separated by maintenance activities and H^- source recycle
- **Extended Maintenance begins Dec 21**

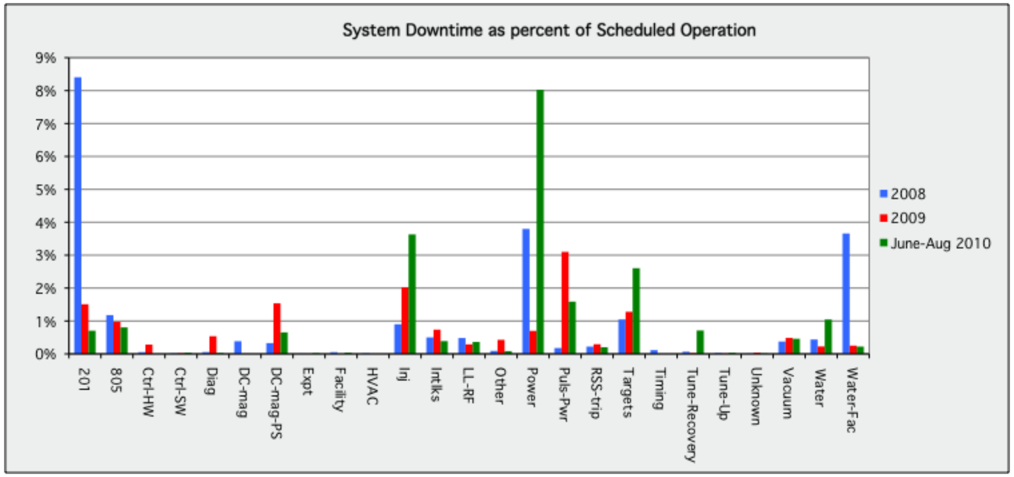


Recent Unscheduled Downtime Associated with Accelerator and Facility Systems (Lujan beam statistics '08-'10)

Items of note based upon performance data

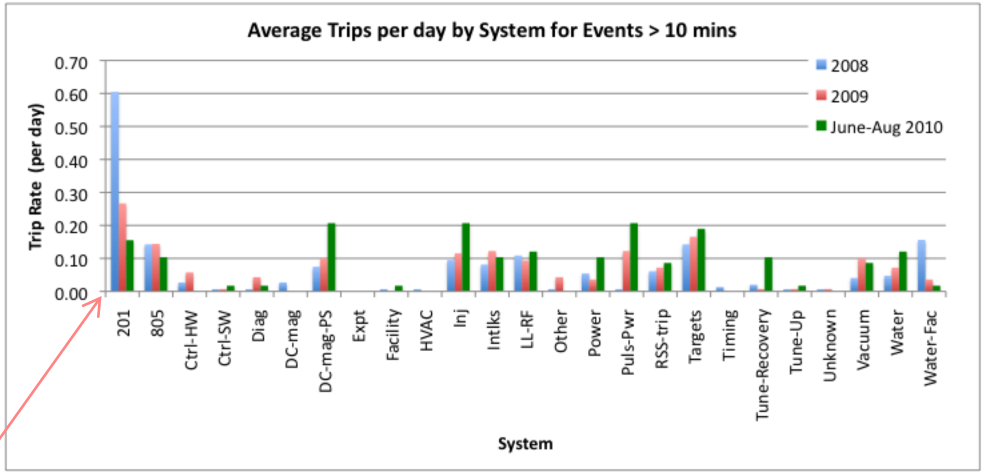
- **2008**
  - 7835 & Ignitron failures
  - AC Power interruption – lightning, substation switchgear
  - Facility water – chemistry, resin bottles
- **2009**
  - 7835 failure
  - PSR kickers
- **2010 (thru August)**
  - AC power interruptions
  - LEBT chopper
  - Lujan-target moderator gas

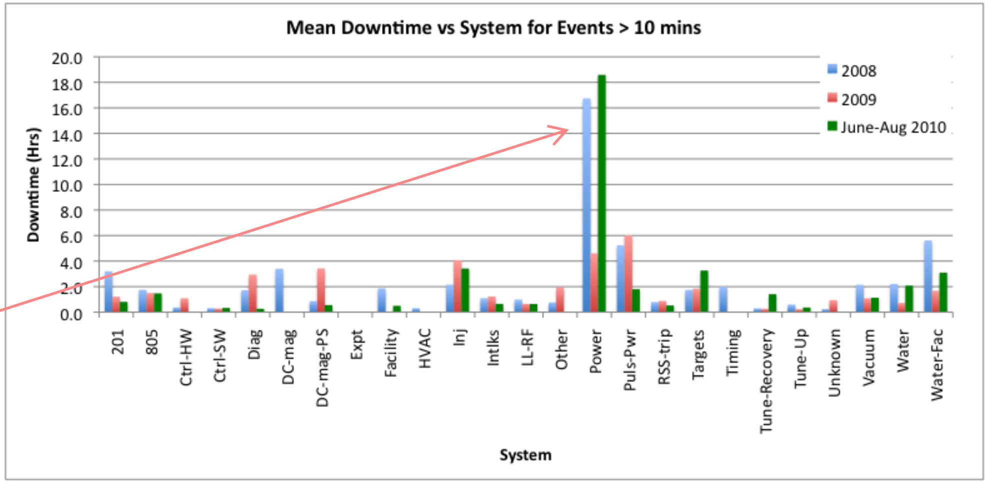




Nuisance and Significant System Trips

- **Separating system trips into two class**
  - Nuisance <=10 mins vs. Significant >10 mins
  - Nuisance trips can be readily corrected by operator or system expert in short order
  - Significant trips almost always require system expert
  - Separation can help to better understand those trips which result in significant downtime
- **Trends in performance**
- **Type and severity of event**



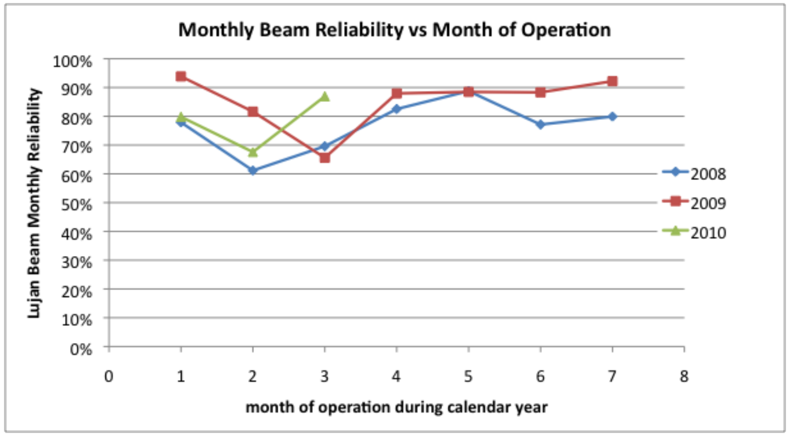


Recent Lujan Beam Reliability Statistics

- **Statistics are similar from year to year**
  - Exception was better linac reliability in 2009
- **Beginning months more troublesome in production year**

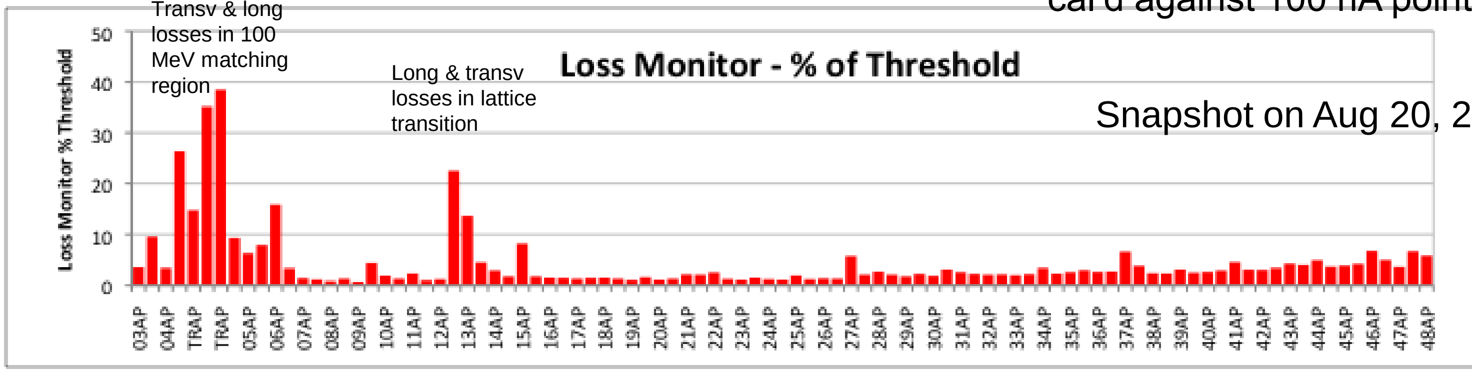
Lujan beam	2008	2009	2010 thru Aug
Scheduled time (hours)	3532	3330	1392 (3072)
Beam Reliability (%)	77.6	85.3	78.3
LINAC Reliability (%)	83.9	93.4	84.2

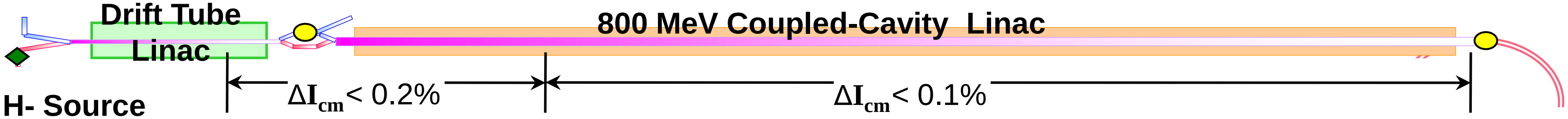
Average number of trips per day for Lujan beam with beam off time …	2008	2009	2010 thru Aug
from 1s to 1 min	No data	No data	No data
from 1 min to 1 hr	1.0	1.0	1.6
from 1 hr to 3 hr	0.46	0.48	0.41
greater than 3 hour	0.35	0.24	0.31



Lujan Beam Losses and Residual Activation along Linac

- Typical Lujan Operation, I_{avg}=110 uA , DF=1.25%, chop=290ns/358ns
- Linac loss monitors - liquid scintillator & PMT (integrating (shown here) and instantaneous modes) cal'd against 100 nA point spill

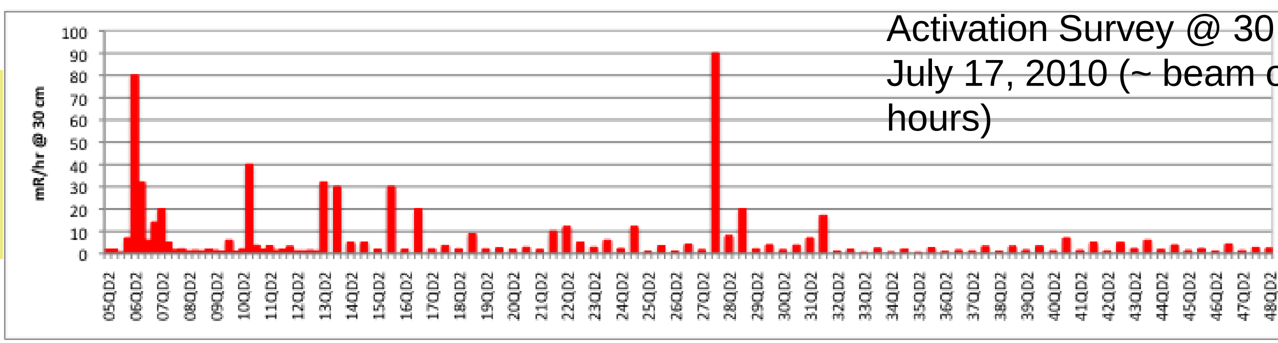




Linac Activation Levels (mR/hr @ 30 cm)

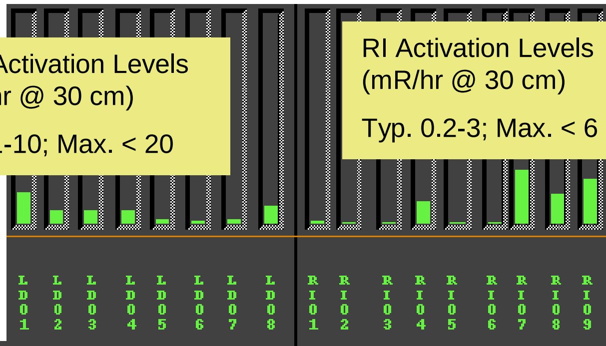
Typ. 1-10; Max. < 90

Isolate spots ~ few 10's



Lujan Beam Losses and Residual Activation – 800 MeV

- Line-D, PSR and 1L loss monitors - N_2-filled ion chambers

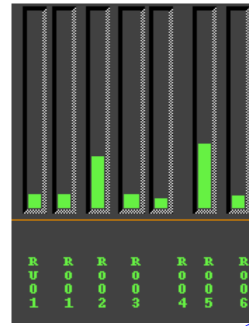


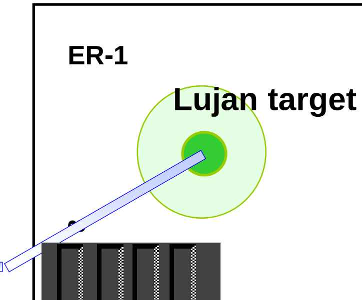
LDN Activation Levels
(mR/hr @ 30 cm)

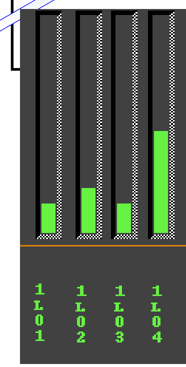
Typ. 1-10; Max. < 20

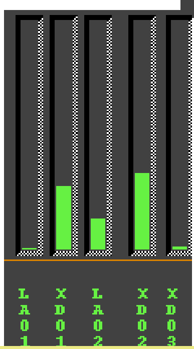
RI Activation Levels
(mR/hr @ 30 cm)

Typ. 0.2-3; Max. < 6







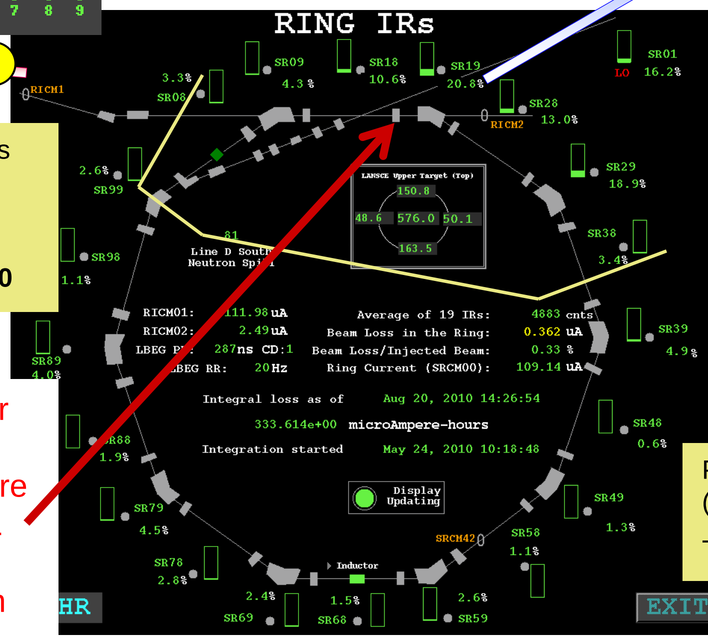


PSR (2) Activation Levels

(Inj, Foil Area)
(mR/hr @ 30 cm)

Typ. **20-300**; Max. < **1500**

kicker



SY Activation Levels
(mR/hr @ 30 cm)

Typ. 0.1-3; Max. < 30

Higher integrated spill over recent operations likely resulted in premature failure of water hose on SRQU01 during recent accelerator development, Cancellation of 2 experiments & ~0.5 man-Rem of dose to repair

PSR (1) Activation Levels
(mR/hr @ 30 cm)

Typ. **10-100**; Max. < **200**

1 mR/hr = 10μSv/hr

Worker Dose Statistics for CY2009

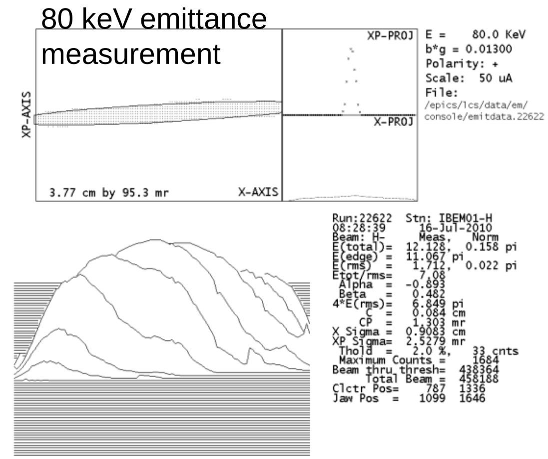
- **Annual radiation worker whole-body dose limit**
  - DOE: 5 Rem
  - LANL: 2 Rem (based upon ICRP recommendation < 10 Rem/5 yr)
  - AOT goal: < 0.5 Rem/yr
- **LANL Dose management**
  - ALARA – Time, distance and shielding
  - Action levels
    - 1 Rem – notify worker, RLM, and RP Div Ldr
    - 2 Rem – requires approval by Inst. RSC to exceed

- **Collective Dose AOT Groups/Teams with largest**

Year	Annual Dose (Rem)	Uncommon Activities that year
2007	8.2	PSR BM coil, bldg vent mods
2008	5.7	TWS resin anomaly
2009	4.1	
2010 thru June	5.6	Lujan target-moderator & IPF window change out

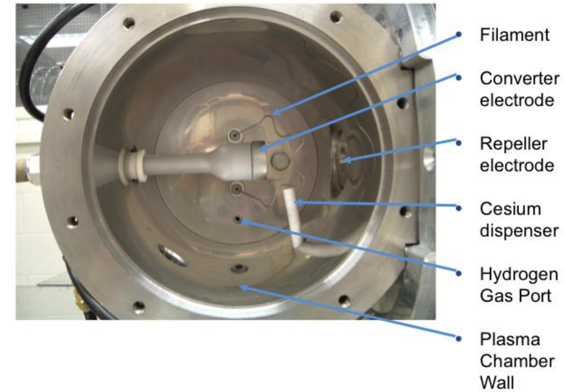
Operational Challenges (1) – Increasing H$^-$ Beam Current

- **All experimental programs would benefit from more H$^-$ beam current**
  - For some, increased throughput for experiment programs
  - For others, better signal to noise
- **Long term approach - increase source peak current**
  - More economical than increasing duty factor or operating days
- **Present H$^-$ Ion Source performance**
  - 16 mA$_p$ H- @ 60 Hz, 5% DF (>10%@120 Hz)
  - Tungsten Filament (Kamis Inc.) lifetime of 35 days
  - e/H$^-$ ratio ~ 4
  - ε^n_{rms} ~ 0.022 π cm mrad



LANSCE H$^-$ Ion Source

Elements of the multi-cusp filament driven cesiated surface converter H- ion source are shown in the interior view of source. Not shown are the cusp magnets imbedded in plasma chamber wall.

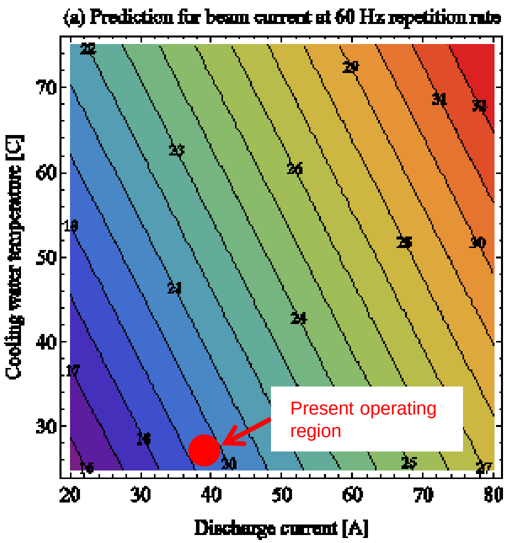


High Priority H$^-$ Ion Source Development Activities Aimed at Increasing Performance

AOT-ABS Injector Team & O. Tarvainen (U.of Jyvaskyla)

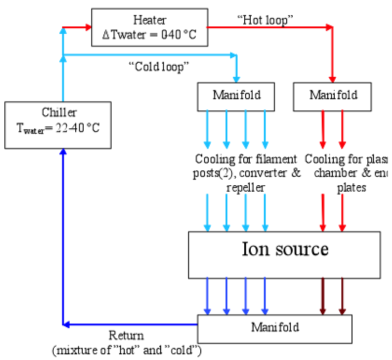
Hot plasma chamber walls

Increased Cesium vapor pressure at elevated wall temperatures should result in enhanced sputtering of *H*$^-$ ions from the converter.



Prediction for *H*$^-$ beam current (contours) at 60 Hz pulse repetition rate as a function of discharge current and cooling water temperature.

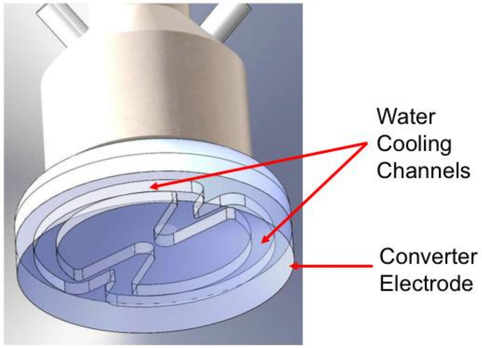
Arrangement of the ion source water cooling at test stand.



Experimental results for the hot plasma chamber walls test showed elevating the chamber wall cooling loop temperature by up to 30°C increased the H$^-$ beam current by ~ 3 mA with no emittance increase.

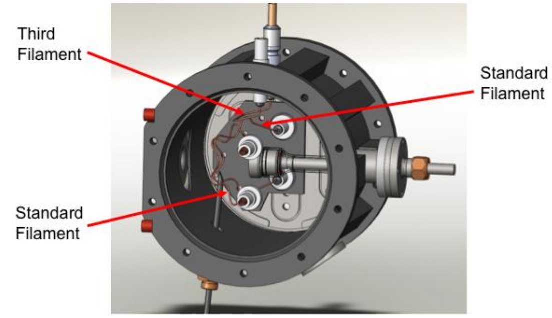
Improved Converter Temperature Control

Even small temperature deviations on the converter surface may cause variations of hydrogen coverage, which affects the H$^-$ yield. Better cooling arrangements, could establish control over these mechanisms.



Insertion of Third Filament

Increasing the emission area of electrons would cause the discharge current and plasma density to increase followed by enhanced production of H- beam current.



Operational Challenges (2) – Improving Performance under Multi-beam Operations

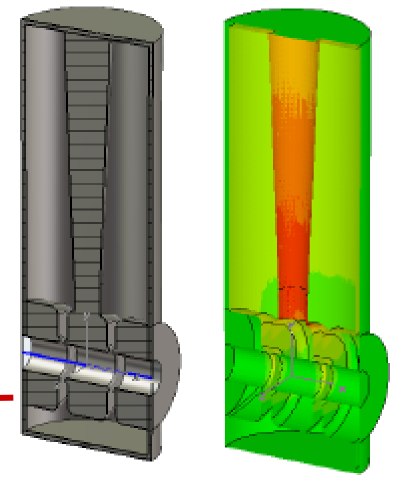
- **Dual species, multi-beam operations employs shared linac macropulses to improve operating efficiency, i.e. second beam almost free!**
- **However, the operation of the common transport upstream of linac may compromise the quality/intensity of one or both beams!**
- **This is the case for IPF (H^+) and WNR (H^-), which are distinctively different beams**
  - IPF
    - I_{pk}=10-12 mA (plenty in reserve) H^+; I_{avg}= 250 μA; unchopped
    - Optimal DTL capture (I_{Acc}/I_{Inj}) of ~80% achieved with two LEBT **201-MHz** bunchers
    - Optimal performance with high amplitude (~12-15 kV) setting for common-LEBT buncher
    - With ~best WNR performance, IPF capture reduced to 28% and 4-5X higher losses in T4
  - WNR
    - I_{pk}=12 mA H^- (no reserve); I_{avg}= 1.8 μA; chopped to single-micropulses with 1.8 μs
    - 20-25 ns of charge bunched @ **16.7 MHz** to increase charge per pulse; ~50% capture
    - Optimal performance with very low amplitude (~2-7 kV) setting for common-LEBT buncher
    - With ~best IPF performance, WNR capture reduced to 30-35% and current by 40%
    - WNR most severely impacted!

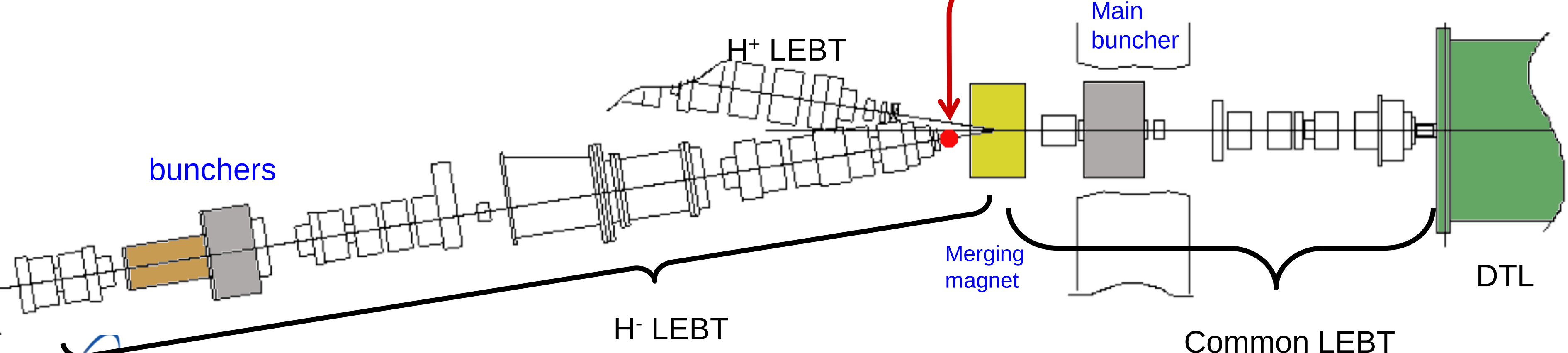
Investigating Use of Debuncher Cavity to Mitigate this Situation

L. Rybarcyk & S. Kurennoy, AOT-ABS

- **Multiparticle beam dynamics simulation results indicate a debuncher located at end of H^- LEBT could restore H^- micropulse current to ~90% of optimal performance**
- **A compact λ/4 cavity (βλ/2~3cm) could provide required V_{gap} with better TTF but somewhat lower Q (therefore higher power) than TM_{010} cavity and fit in desired location**

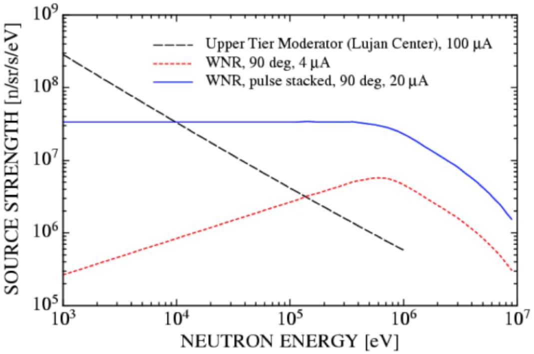
201-MHz λ/4 buncher





Operational Challenges (3) – Maintaining Performance for Micro-pulse Operation at Large Pulse Spacing

- **The nuclear physics program at WNR employs neutron time-of-flight techniques and would like access to a lower energy portion of the neutron energy spectrum, which requires increased spacing between successive beam bunches at the target**
- **These neutron energies are not readily accessible at either Lujan or WNR**
- **Normally achieved by increased spacing with LEBT chopper, but this reduces average current to impractically small values (current drops like 1/pulse-spacing)**
  - 23.4 μs would reduce current by 1/13
  - 1.8 ms would reduce current by 1/1000!

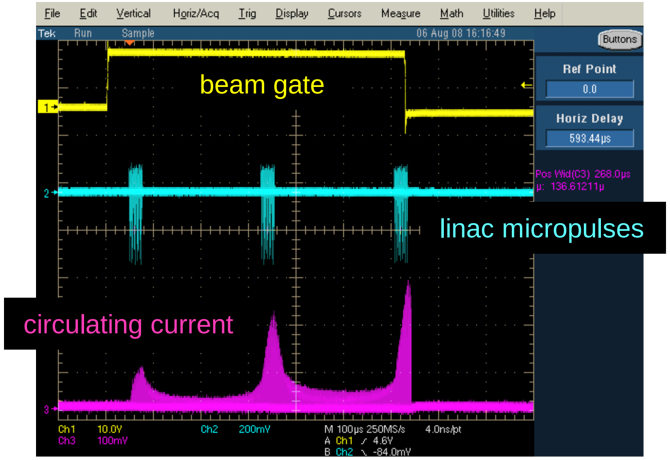


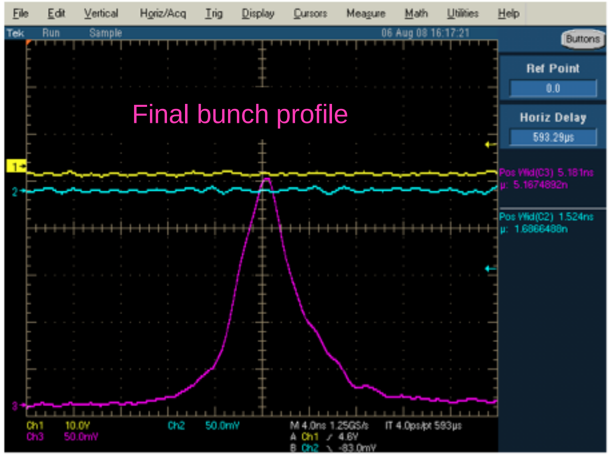
Pulse Stacking Technique Could be the Answer!

- **Pulse stacking approach – Use PSR to "stack" individual linac micropulses and extract on-demand to achieve widely-separated, high-charge, narrow bunches on target**
- **Optimal configuration being considered would upgrade PSR with**
  - Higher harmonic RF cavity to simultaneously provide multiple, high-charge, narrow bunches
  - New solid-state extraction system modulator for on-demand bunch extraction
  - Extraction line kicker for simultaneous Lujan + WNR operation
- **In the mean time, however, pulse stacking demonstration was performed using existing ring hardware**

Results from Pulse Stacking Demonstration

- **Existing PSR hardware**
  - Sole-use mode (i.e. PSR to WNR only)
  - Fast kicker extraction operated at 40 Hz (i.e. once per macropulse)
  - RF (h=1)
- **Took advantage of synchrotron motion in rf bucket to increase charge while maintaining narrow bunch**
- **Results**
  - Rep rate = 40 Hz -> 25 ms spacing!
  - I_{avg} ~ 1 μA (~240 individual micropulses stacked)
  - Extracted bunch FWHM ~ 6 ns





Summary

- LANSCE provides pulsed proton and neutron beams to several user facilities whose missions include defense applications, isotope production and research in basic and applied science
- The H^+ and H^- beams range in power from below 1 to ~ 100 kW with varying pulse formats tailored to meet experiment requirements
- Present day operations include over 3000 hrs/year of scheduled beam to user programs with typical reliability of ~ 80%
- Some of the present Operational Challenges include increasing H^- beam current to user facilities, optimizing dual species operations and improving performance for widely spaced micro-pulse beam

Thank you