Los Alamos NATIONAL LABORATORY

Multi-Beam RFQ Injector for LANSCE Accelerator Facility

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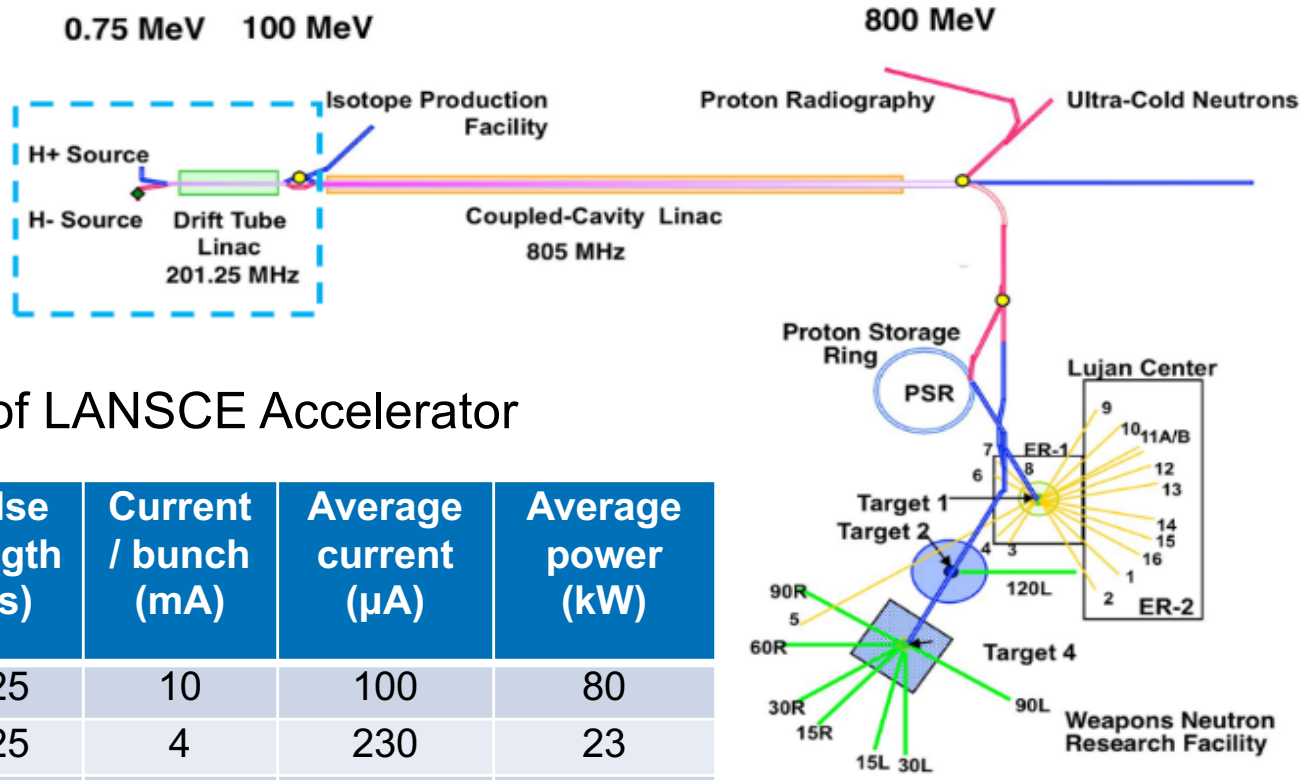
LANSCE Accelerator Facility

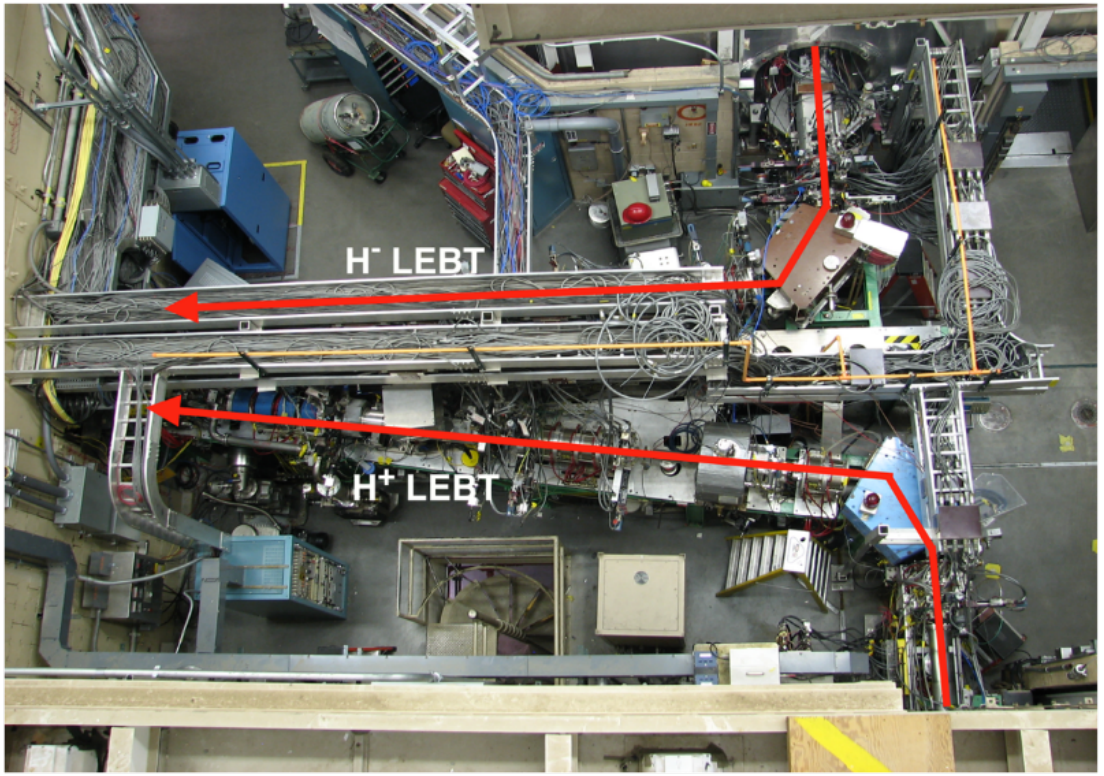


Beam Parameters of LANSCE Accelerator

Area	Rep. Rate (Hz)	Pulse Length (μs)	Current / bunch (mA)	Average current (μA)	Average power (kW)
Lujan	20	625	10	100	80
IPF	100	625	4	230	23
WNR	100	625	25	4.5	3.6
pRad	1	625	10	<1	<1
UCN	20	625	10	10	8

Existing 750 keV LANSCE Injector

750- keV Cockcroft-Walton Generator.

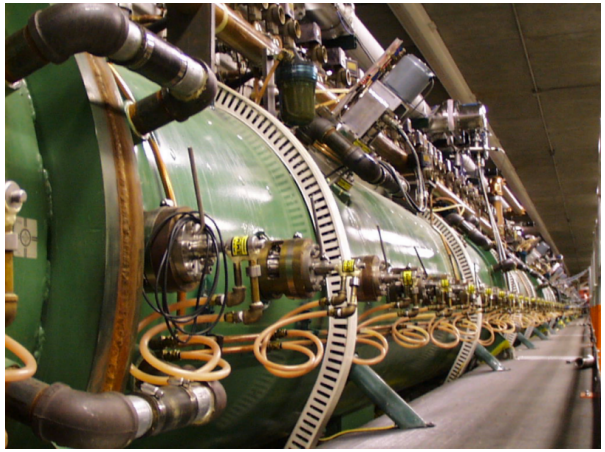


Top view of existing 750 - keV Low Energy Beam Transports (LEBT) of H^+ and H^- beams.

Beam Emittance Growth in Existing LANSCE Accelerator

Beam (Facility)	Ion Source	750 keV	100 MeV	800 MeV	Charge /bunch
H^-(Lujan/pRad/UCN)	0.018	0.022	0.045	0.07	50
H^- (WNR)	0.018	0.024	0.058	0.124	125
H^+ (IPF), DTL only	0.003	0.005	0.026		20

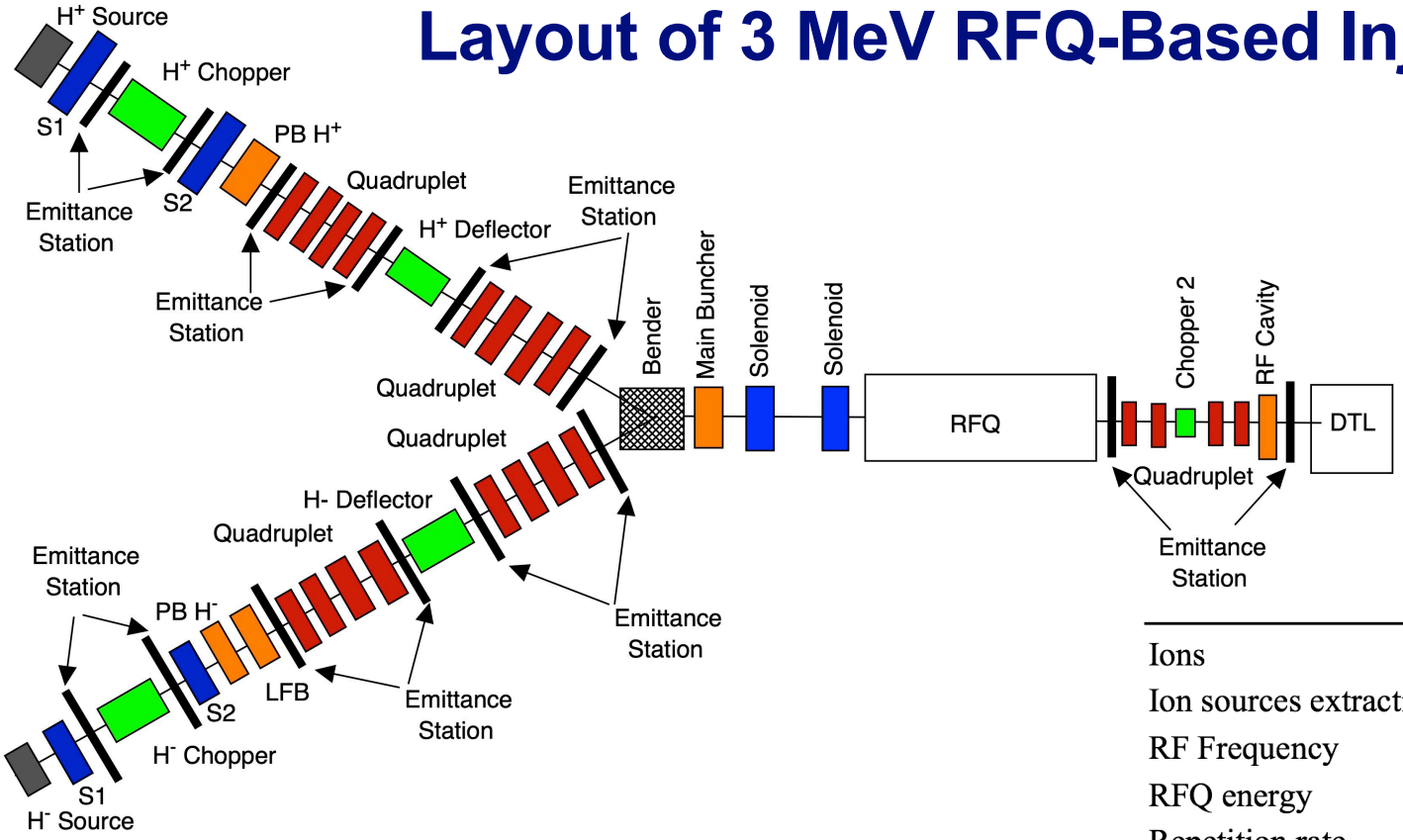
Normalized transverse rms beam emittance (π cm mrad) and charge per bunch (pC) in existing LANSCE accelerator.



100 MeV Drift Tube Linac

800 MeV Coupled Cavity Linac

Layout of 3 MeV RFQ-Based Injector



Parameters of the proposed injector

Ions	H^+/H^-
Ion sources extraction voltage	100 keV
RF Frequency	201.25 MHz
RFQ energy	3 MeV
Repetition rate	120 Hz
Max beam peak current	32 mA
Average current	1 mA
Beam pulse	625-1000 μs
Number of RFQ cells	187
RFQ Length	4.2 m

Time Structure of LANSCE Beams

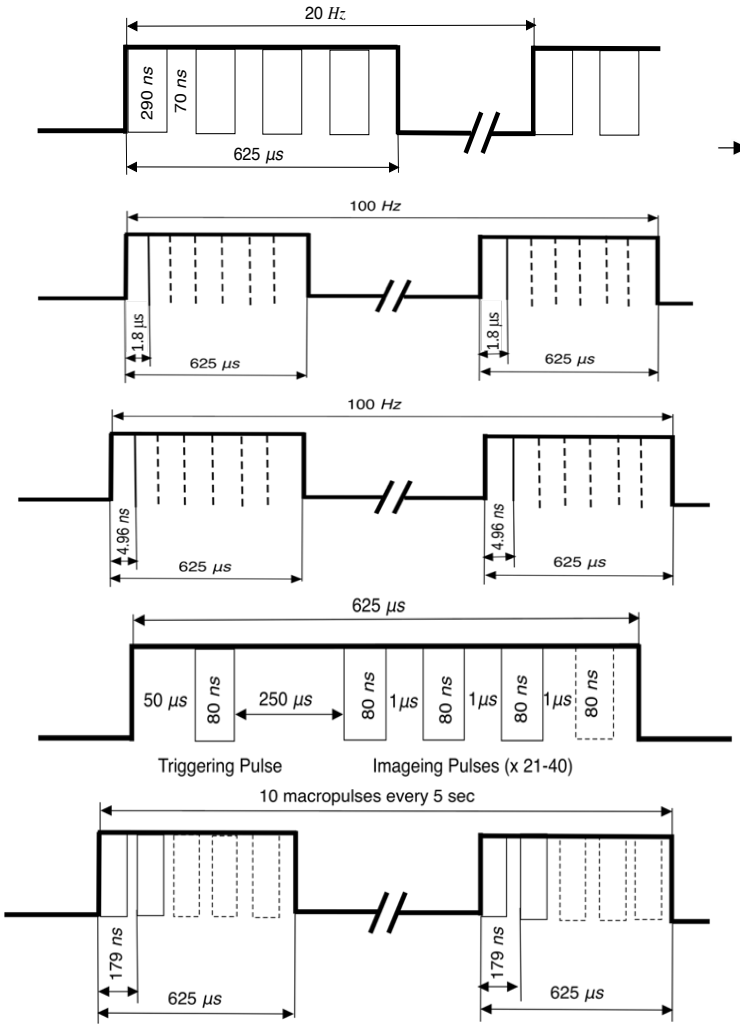
Lujan

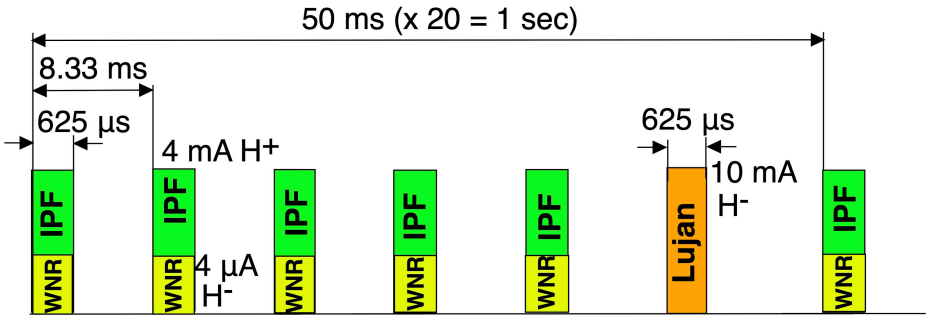
WNR

IPF

pRad

UCN

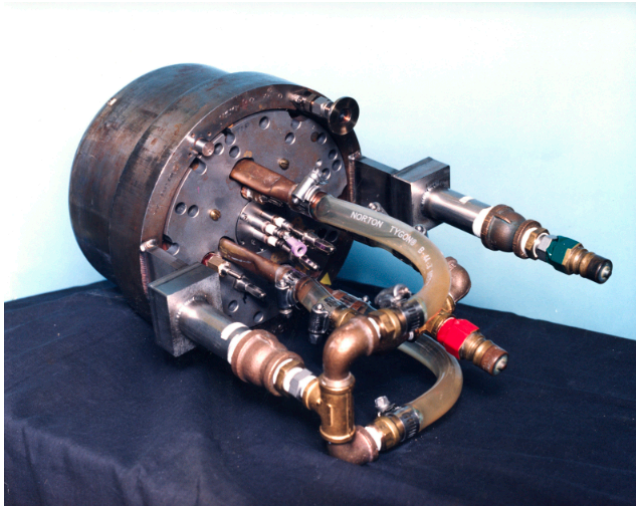




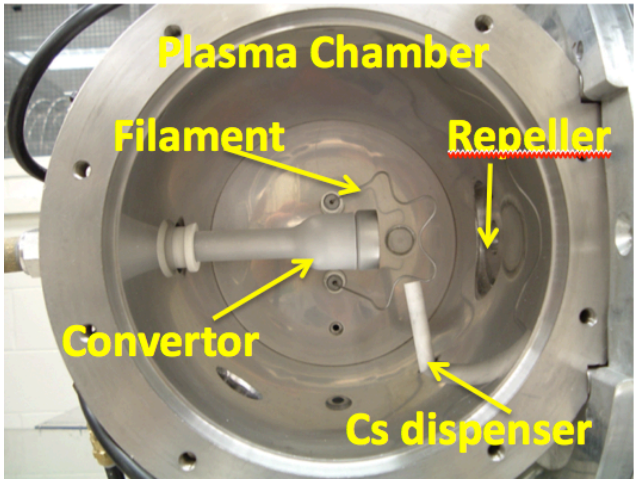
Layout of Lujan/WNR/IPF beams. Beams delivered to pRad or UCN facilities “steal” their time cycles from WNR beam.

LANSCE slow-wave chopper

High-Brightness Ion Sources



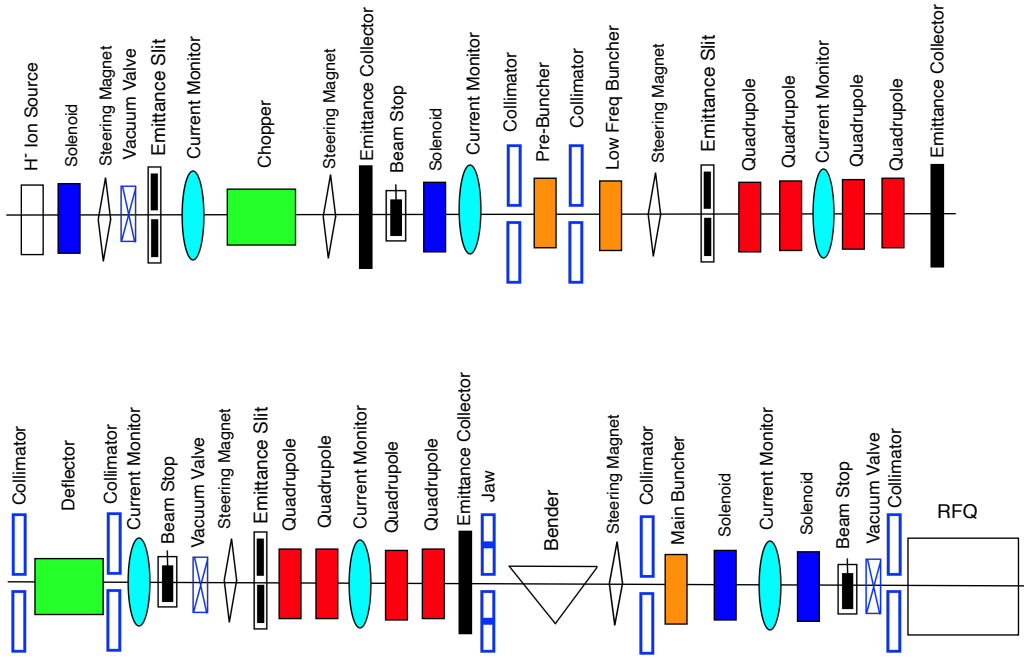
Side view of assembled LANSCE duoplasmatron proton ion source.



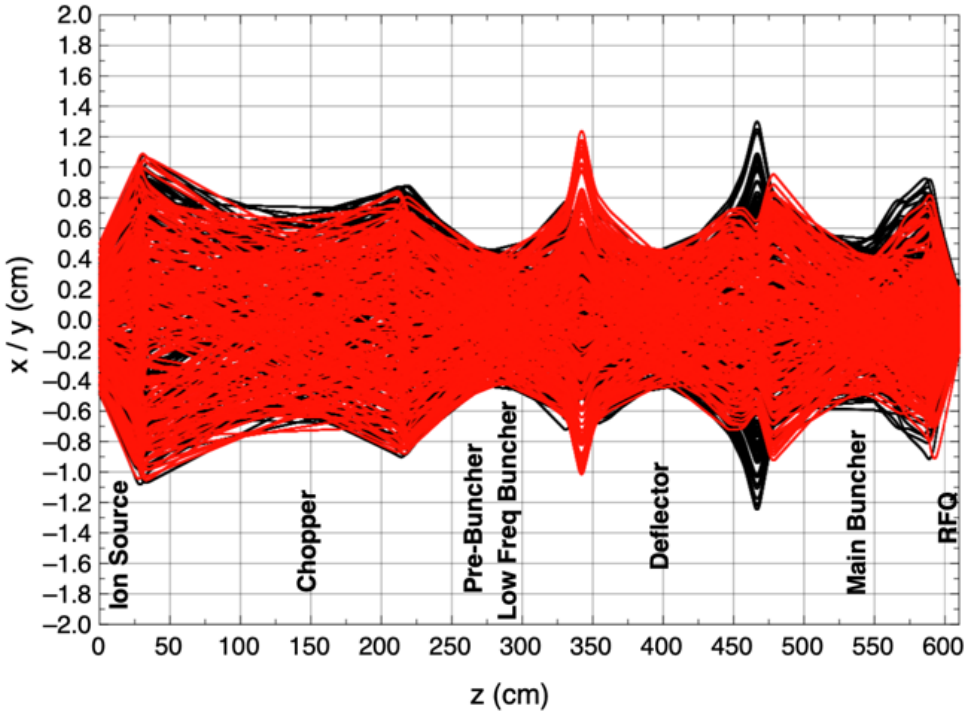
Cesiated, multicusp-field, surface-production H^- ion source

Beam	Current, I (mA)	Normalized rms Emittance, ε_{rms} (π cm mrad)	Normalized Beam Brightness, $B = I / (8\,\pi^2\varepsilon^2_{rms})$ A/(π m mrad)^2
H^+	10 - 30	0.003 - 0.004	20
H^-	14 - 20	0.016 - 0.018	0.6

Low Energy Beam Transport

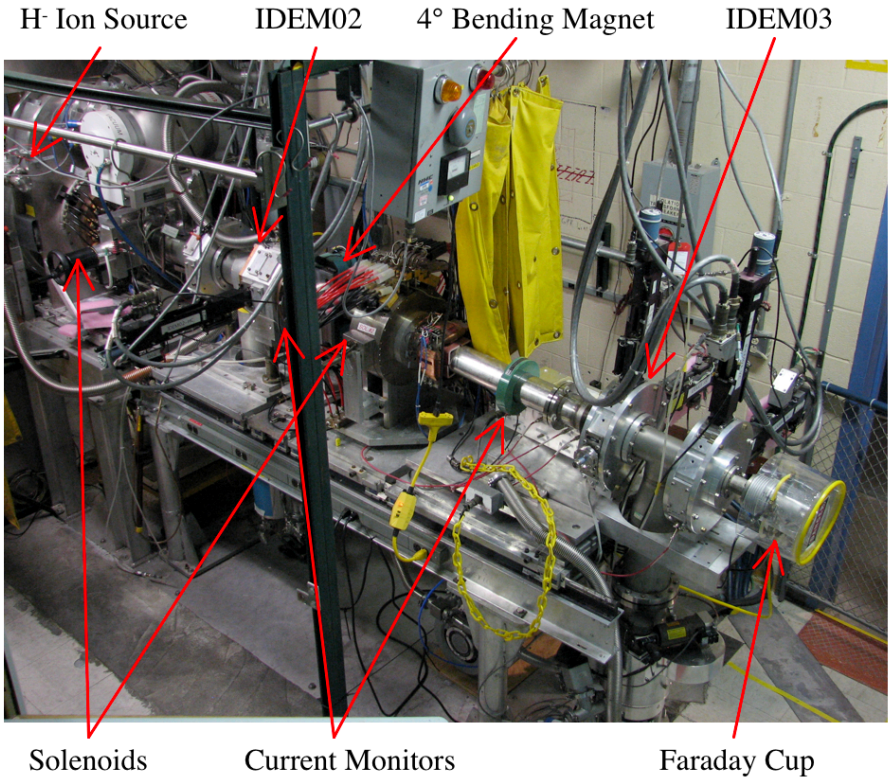


Layout of H^- leg of injector part with additional beamline elements.

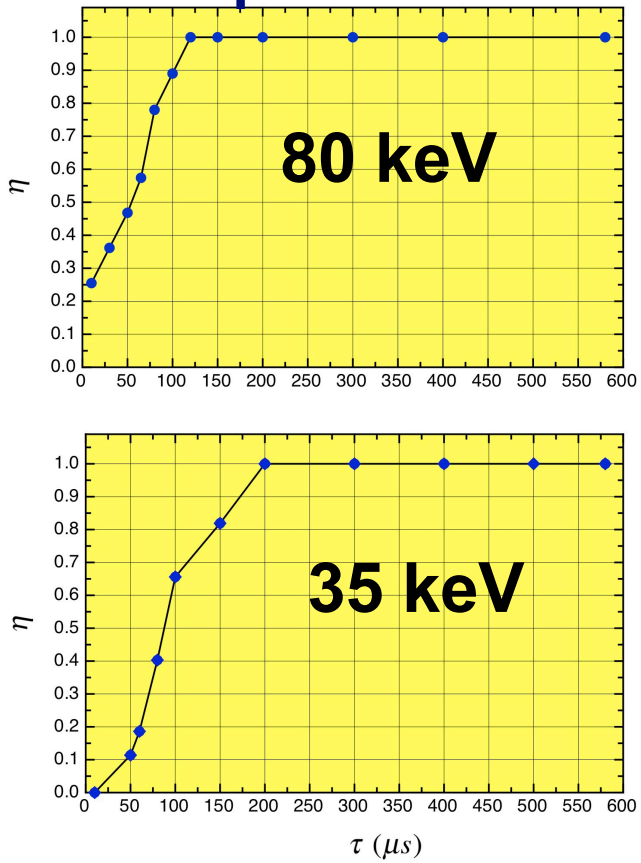


Particle trajectories in the Low-Energy Beam Transport: (red) horizontal, (black) vertical.

Experimental Study of Space Charge Neutralization in 80 keV H^- Beam Transport

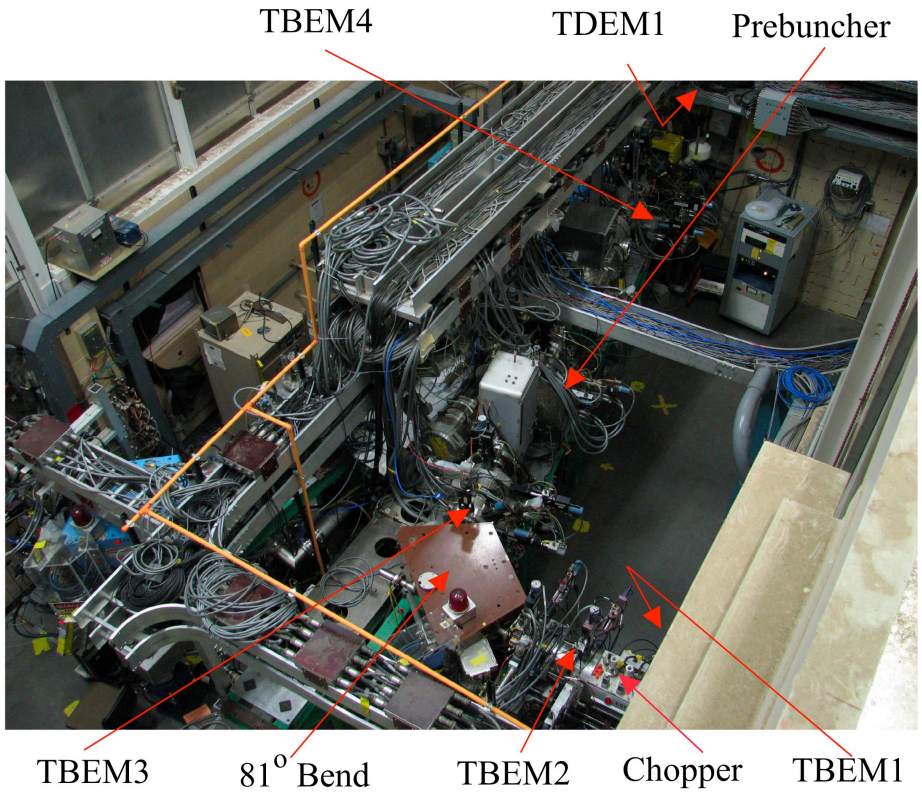


LANSCE H^- Ion Source Test Stand

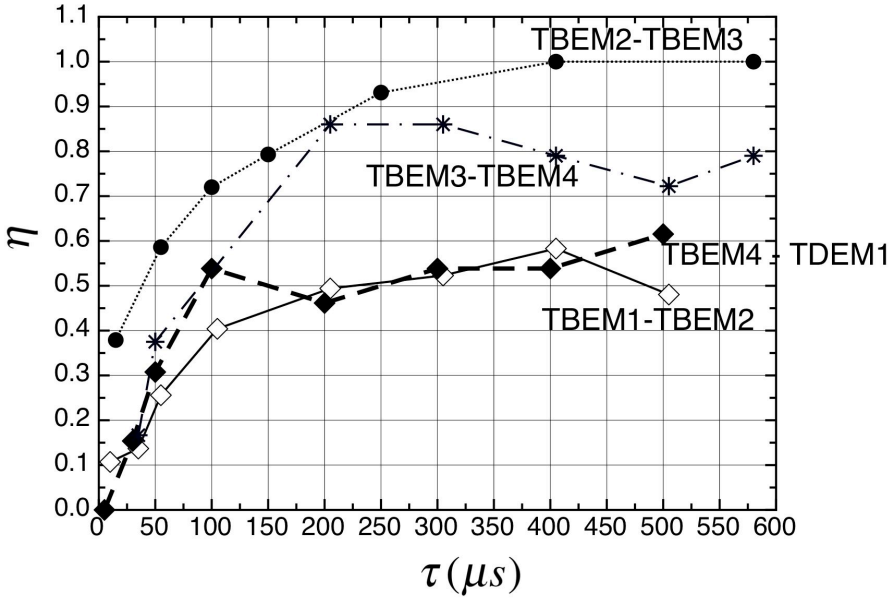


Space charge neutralization of H^- beam as a function of beam pulse length (Y.B. et al, IPAC13, TUPWA066).

Experimental Study of Space Charge Neutralization in 750 keV H^- Beam Transport

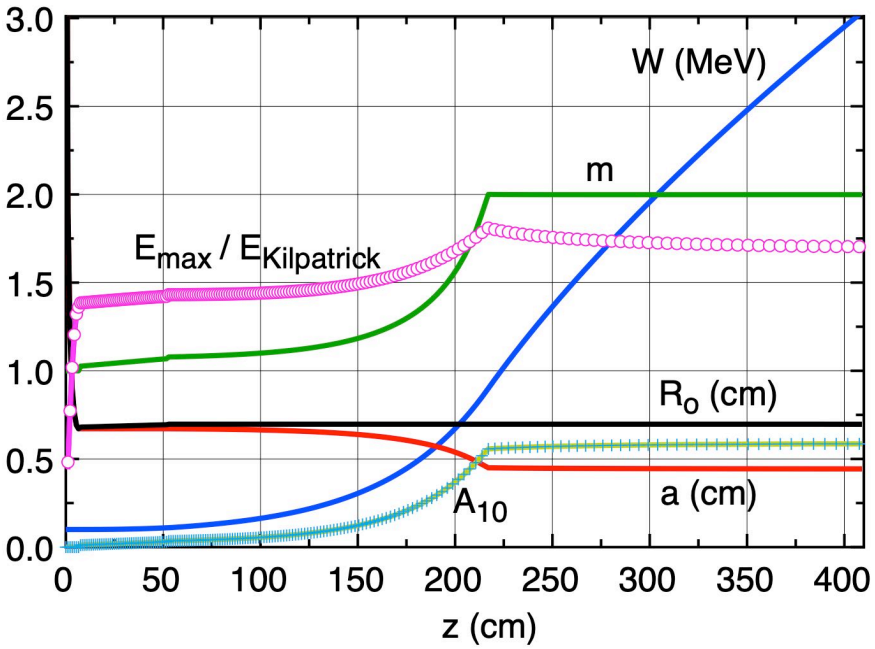


LANSCE H^- 750 keV Beam Transport



Space charge neutralization of H^- beam as a function of beam pulse length (Y.B., NIM-A 904 (2018) 64-73).

RFQ Design and Beam Parameters



Design parameters of RFQ

Beam (Facility)	Charge/ bunch (pC)	Transv space charge depress σ_t/σ_{to}	Longit space charge depress σ_z/σ_{zo}
H^- (Lujan/pRad/UCN)	50	0.81	0.65
H^- (WNR)	240	0.58	0.45
H^+ (IPF)	50	0.42	0.58

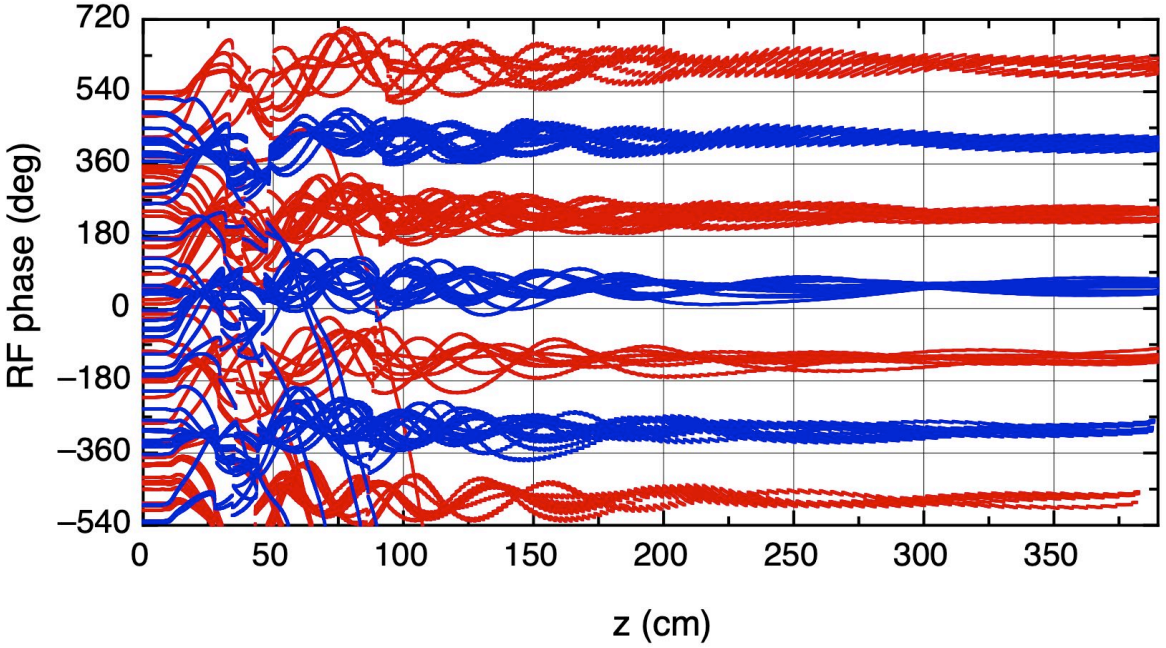
Space charge tune depression and charge per bunch for LANSCE beams.

Beam Parameters

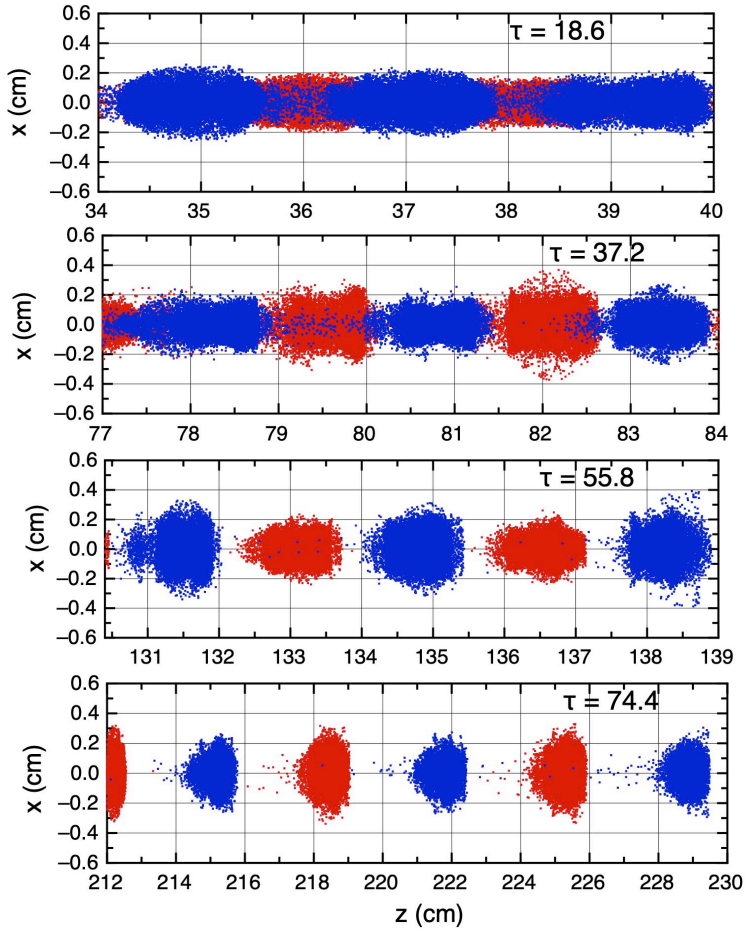
Beam (Facility)	Ion Source	100 keV	3 MeV	Charge /bunch
H^- (Lujan/pRad/UCN) unbunched	0.02	0.021	0.022 (0.84)	50
H^- (Lujan/pRad/UCN) bunched	0.02	0.021	0.022 (0.96)	50
H^- (WNR) bunched	0.02	0.024	0.028 (0.96)	240
H^+ (IPF) unbunched	0.003	0.004	0.006 (0.84)	50
H^+ (IPF) bunched	0.003	0.004	0.008 (0.96)	50

Normalized rms emittance (π cm mrad), beam capture (in parenthesis), and charge per bunch (pC).

BEAMPATH Simulation of Two – Component Beam in RFQ

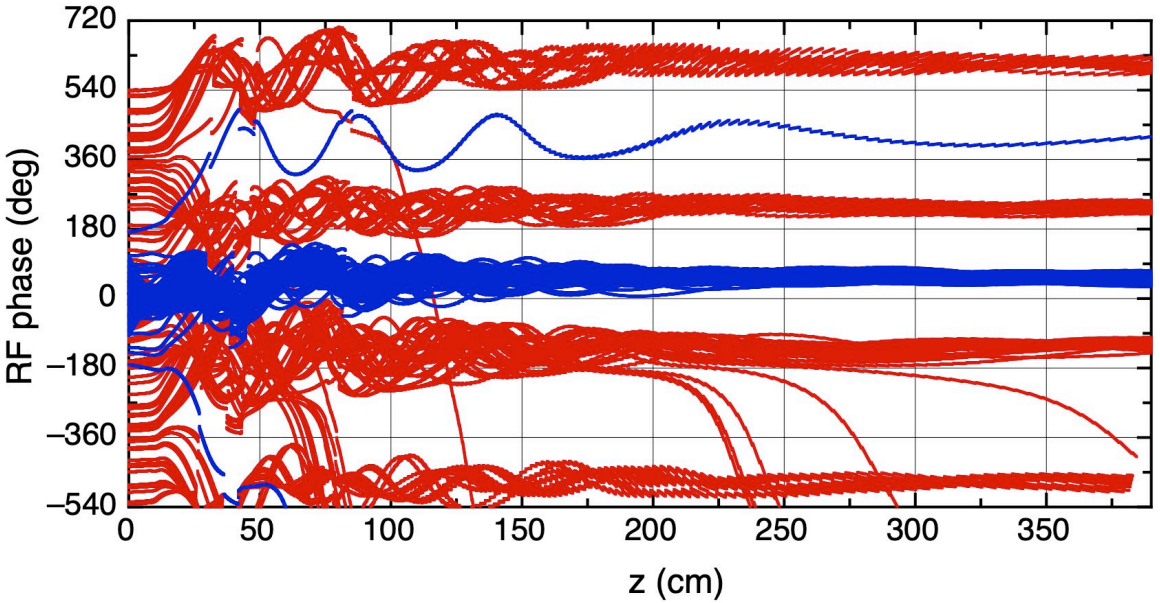


Phase trajectories in RFQ: (red) H^+ beam, (blue) H^- beam.



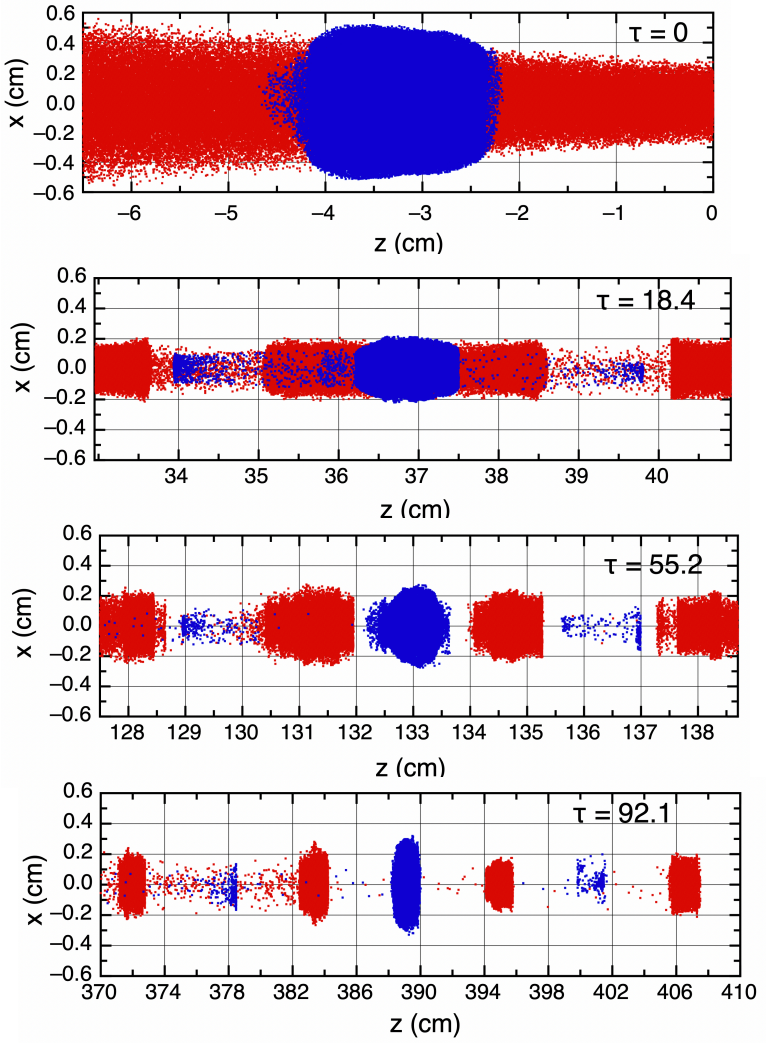
Formation of the two-component beam in RFQ: (red) H^+ beam, (blue) H^- beam.

Acceleration of Single H^- Bunch with the Train of H^+ Bunches



Phase trajectories in RFQ: (red) H^+ beam, (blue) H^- single bunch beam.

Formation of the two-component beam in RFQ: (red) H^+ beam, (blue) H^- single WNR bunch.



Summary

1. The new 3-MeV injector for future LANSCE operation is proposed.

2. The proposed injector will replace the existing LANSCE injector, which is based on old-style 750-keV Cockcroft-Walton accelerating columns.

3. The replacement will use a single Radio Frequency Quadrupole (RFQ) for simultaneous acceleration of protons and H^- ions with multiple flavors of beams.

4. The main space charge issue in the proposed injector is matching of various beams with different charge per bunch, emittances and space charge depression ~ 0.4 ... 0.8.

5. The issue will be resolved by independent matching of proton and H^- (Lujan/pRad/UCN) beams with minimization of mismatch of WNR H^- beam.