High-Brightness RFQ Injector for LANSCE Multi-Beam Operation

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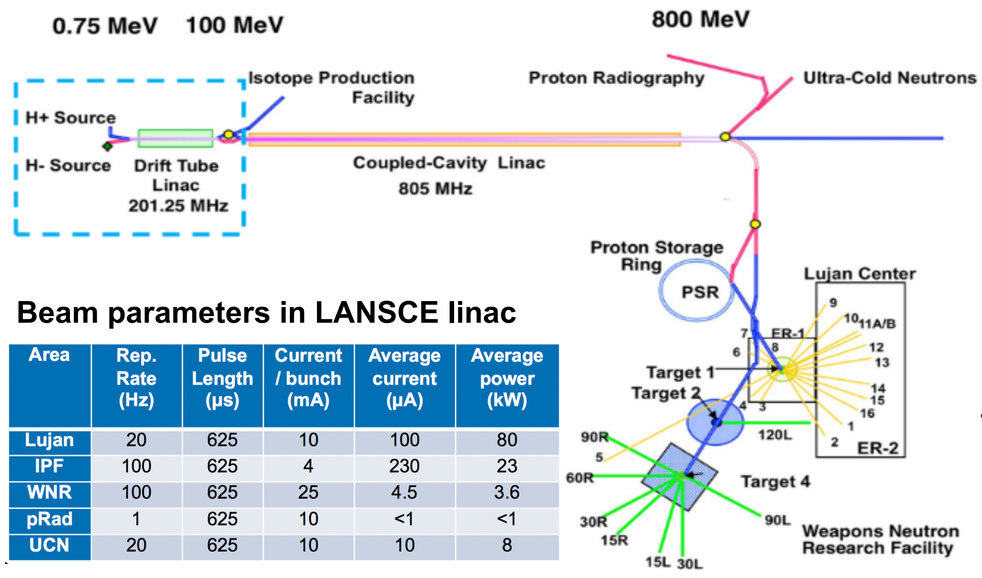
Abstract

The LANSCE accelerator facility has been in operation for 50 years performing important scientific support for national security. The unique feature of the LANSCE accelerator facility is multi-beam operation, delivering beams to five experimental areas. The LANSCE front end is equipped with two independent injectors for H^+ and H^- beams, merging at the entrance of a Drift Tube Linac (DTL). The existing Cockcroft-Walton (CW) – based injector provides high beam brightness before injection into DTL. To reduce long-term operational risks and support beam delivery with high reliability, we designed an RFQ-based front end as a modern injector replacement for the CW injectors. Proposed injector includes two independent low-energy transports merging beams at the entrance of a single RFQ, which accelerates simultaneously both protons and H^- ions with multiple flavors of the beams. The paper discusses details of beam physics design and presents injector parameters.

LANSCE Accelerator Facility



Beam parameters in LANSCE linac

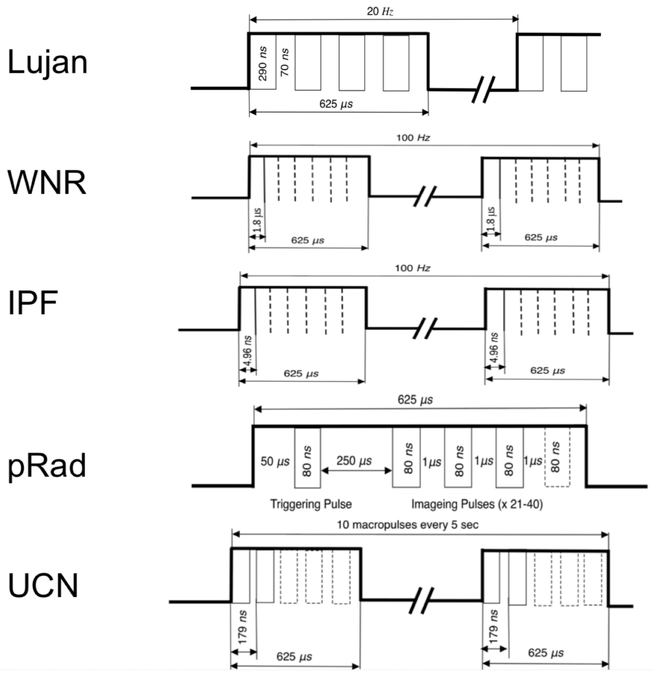
Area	Rep. Rate (Hz)	Pulse Length (μs)	Current / bunch (mA)	Average current (μA)	Average power (kW)
Lujan	20	625	10	100	80
IPF	100	625	4	230	23
WNR	100	625	25	4.5	3.6
pRad	1	625	10	<1	<1
UCN	20	625	10	10	8

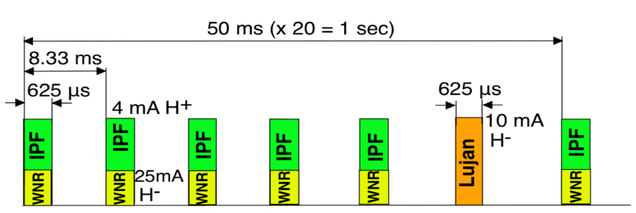
Beam Emittance Growth

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

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

Time Structure of LANSCE Beams

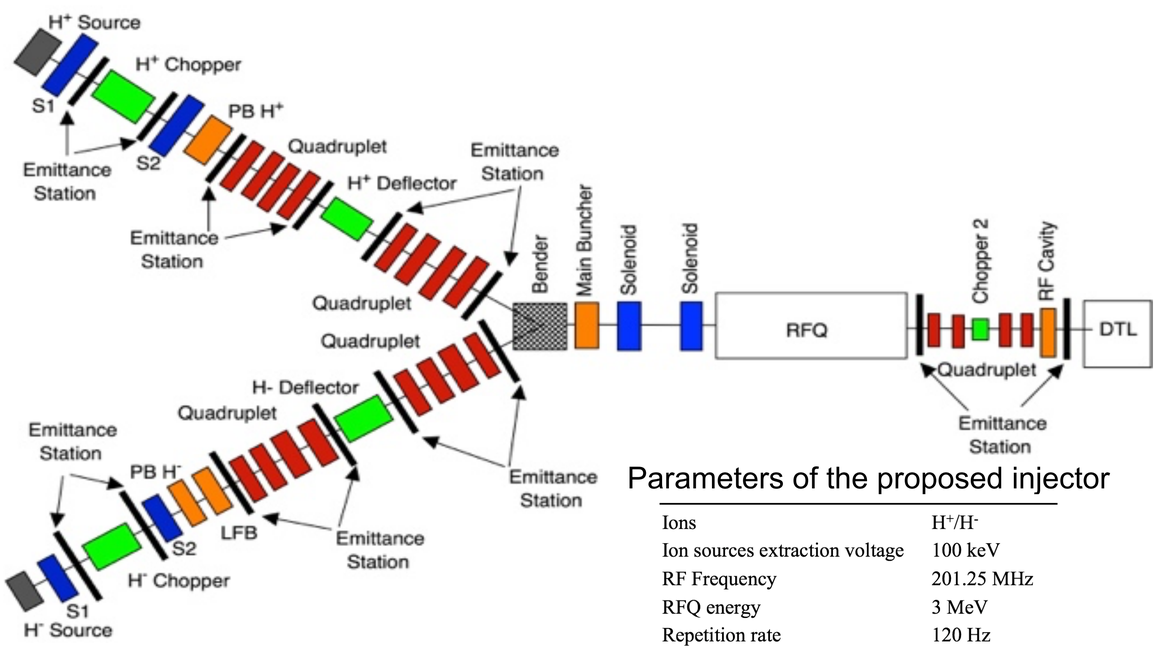




Layout of Lujan/WNR/IPF beams. Beams delivered to pRad or UCN facilities, "steal" their time cycles from WNR beam.

LANSCE slow-wave chopper

Proposed RFQ Based Injector

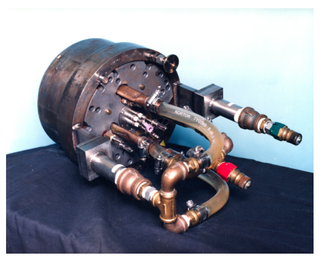


Parameters of the proposed injector

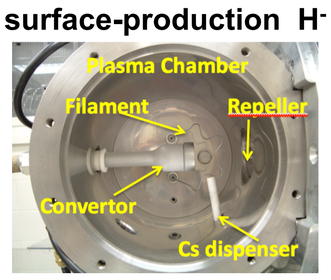
Ions	H^+/H^-
Ion sources extraction voltage	100 keV
RF Frequency	201.25 MHz
RFQ energy	3 MeV
Repetition rate	120 Hz
Max beam peak current	32 mA
Average current	1 mA
Beam pulse	625-1000 μs
Number of RFQ cells	187
RFQ Length	4.2 m

High-Brightness Particle Sources

Duoplasmatron H^+ source

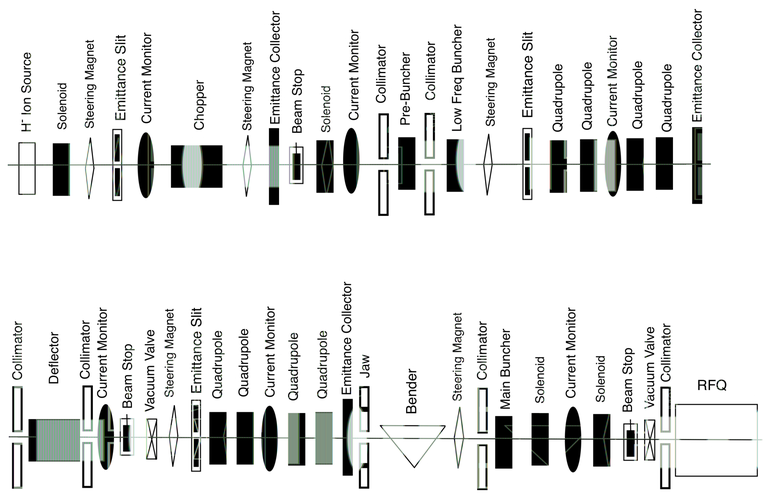


Cesiated, multicusp-field, surface-production H^- source

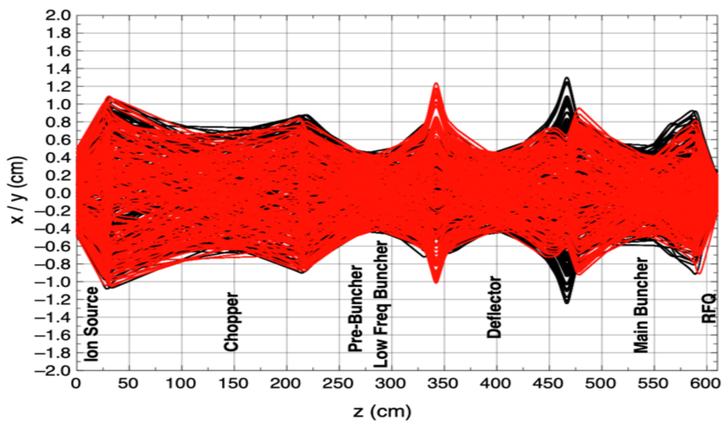


Beam	Source Type	Beam Current (mA)	Normalized rms Emitttance, ε_{rms} (π cm mrad)	Normalized Beam Brightness, $B=\frac{I}{8\pi^2\varepsilon_{x\_rms}\varepsilon_{y\_rms}}$ A/(π cm mrad)^2
H^+	Duoplasmatron	10-30	0.003 - 0.004	20
H^-	Multicusp	14-20	0.016 - 0.018	0.6

Low Energy Beam Transport

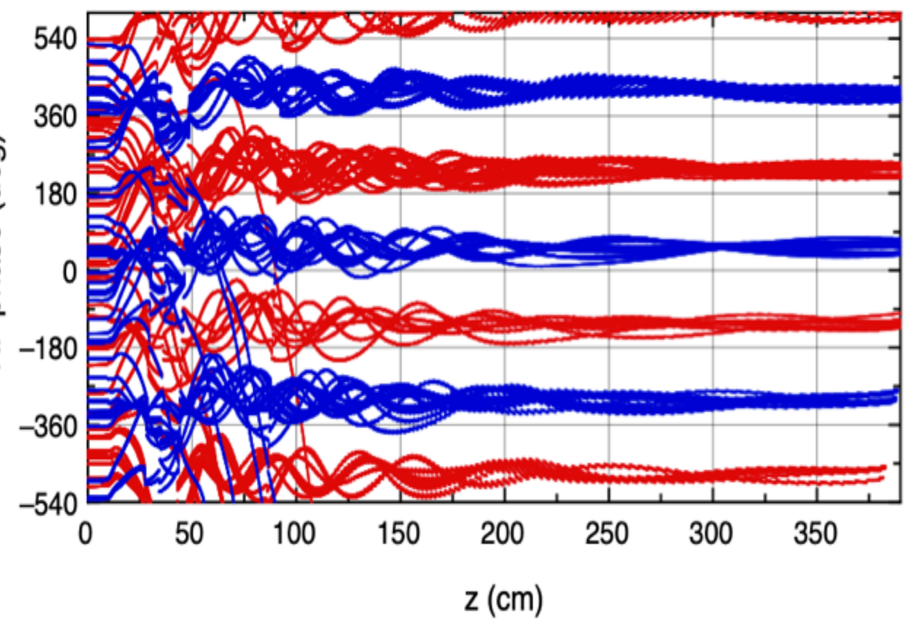


The layout of H^- leg of the injector part with additional beamline elements.

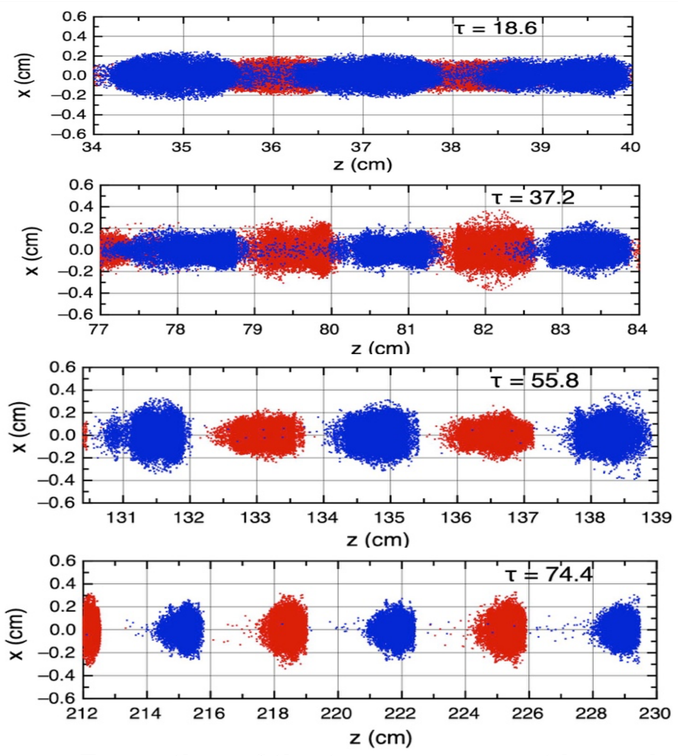


Particle trajectories in the injector beamline: (red) transverse, (black) vertical

Acceleration of Two-Component Beam in RFQ



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



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

Normalized transverse rms emittance (π cm mrad), beam capture in RFQ (in parenthesis), and charge pe bunch (pC) in RFQ injector.

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