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Operation of LANSCE Linear Accelerator with Double Pulse Rate and Low Beam Losses

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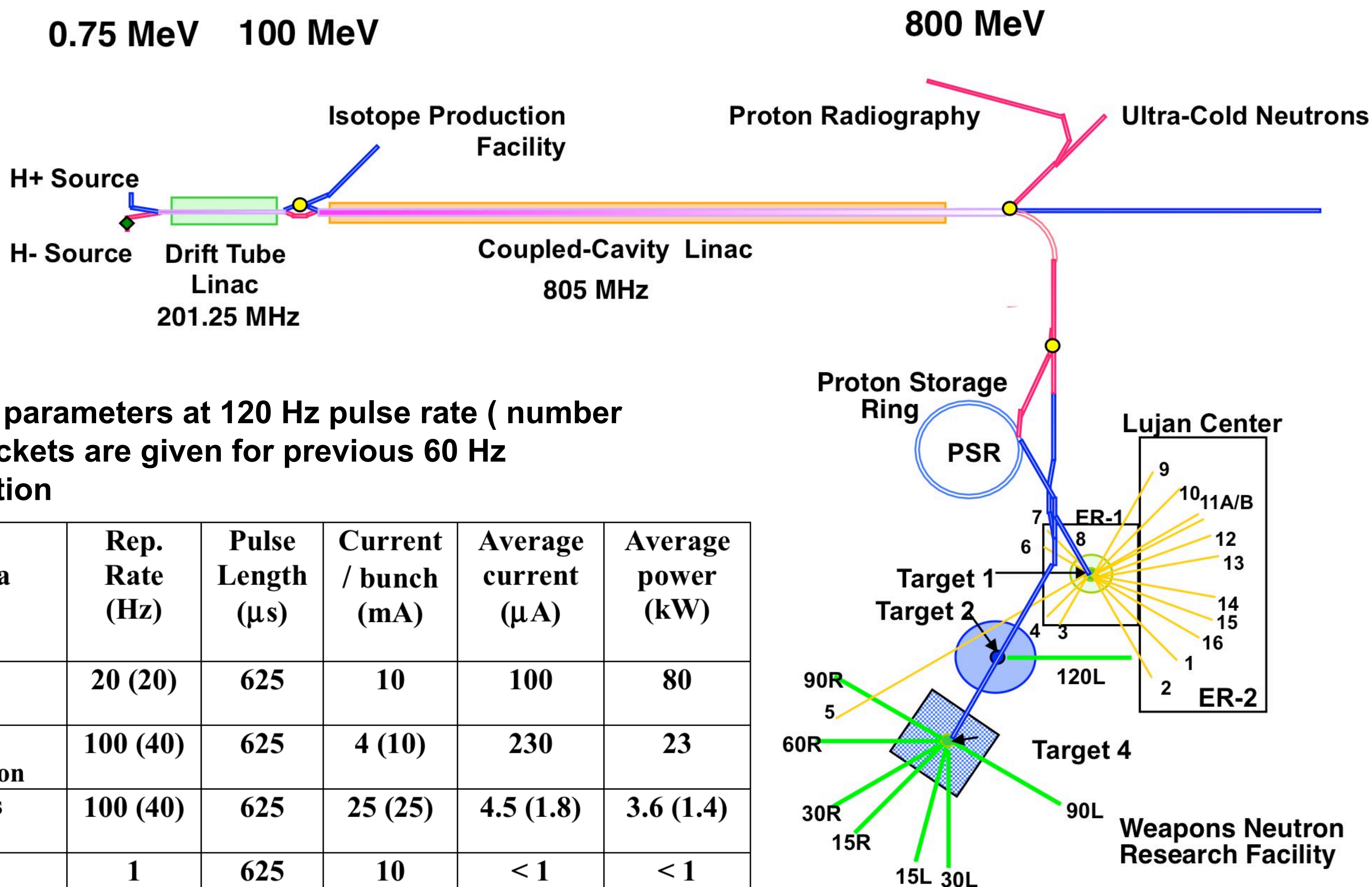
The LANSCE accelerator provides unique flexible time-structured beams from 100 to 800 MeV

LANSCE Facility Overview

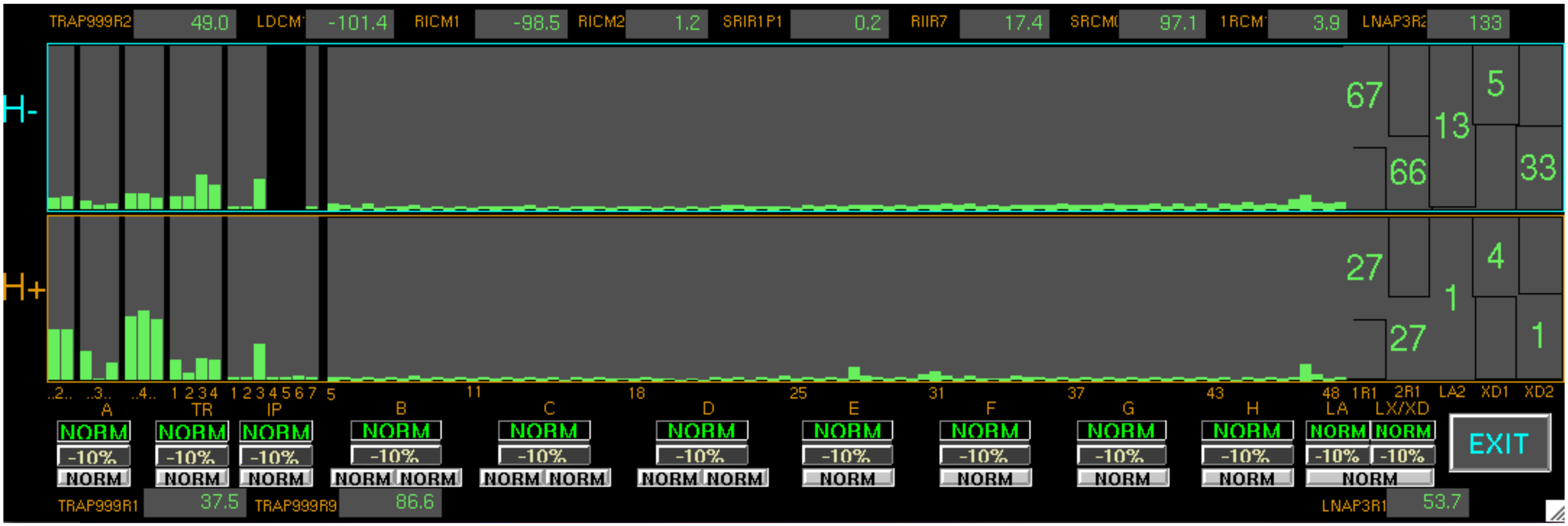


Beam parameters at 120 Hz pulse rate (number in brackets are given for previous 60 Hz operation

Area	Rep. Rate (Hz)	Pulse Length (µs)	Current / bunch (mA)	Average current (µA)	Average power (kW)
Lujan Center	20 (20)	625	10	100	80
Isotope Production	100 (40)	625	4 (10)	230	23
Weapons Neutron	100 (40)	625	25 (25)	4.5 (1.8)	3.6 (1.4)
Proton Radiography	1	625	10	< 1	< 1
Ultra-Cold Neutrons	20 (20)	625	10	10	8

Beam Losses in Linear Accelerator

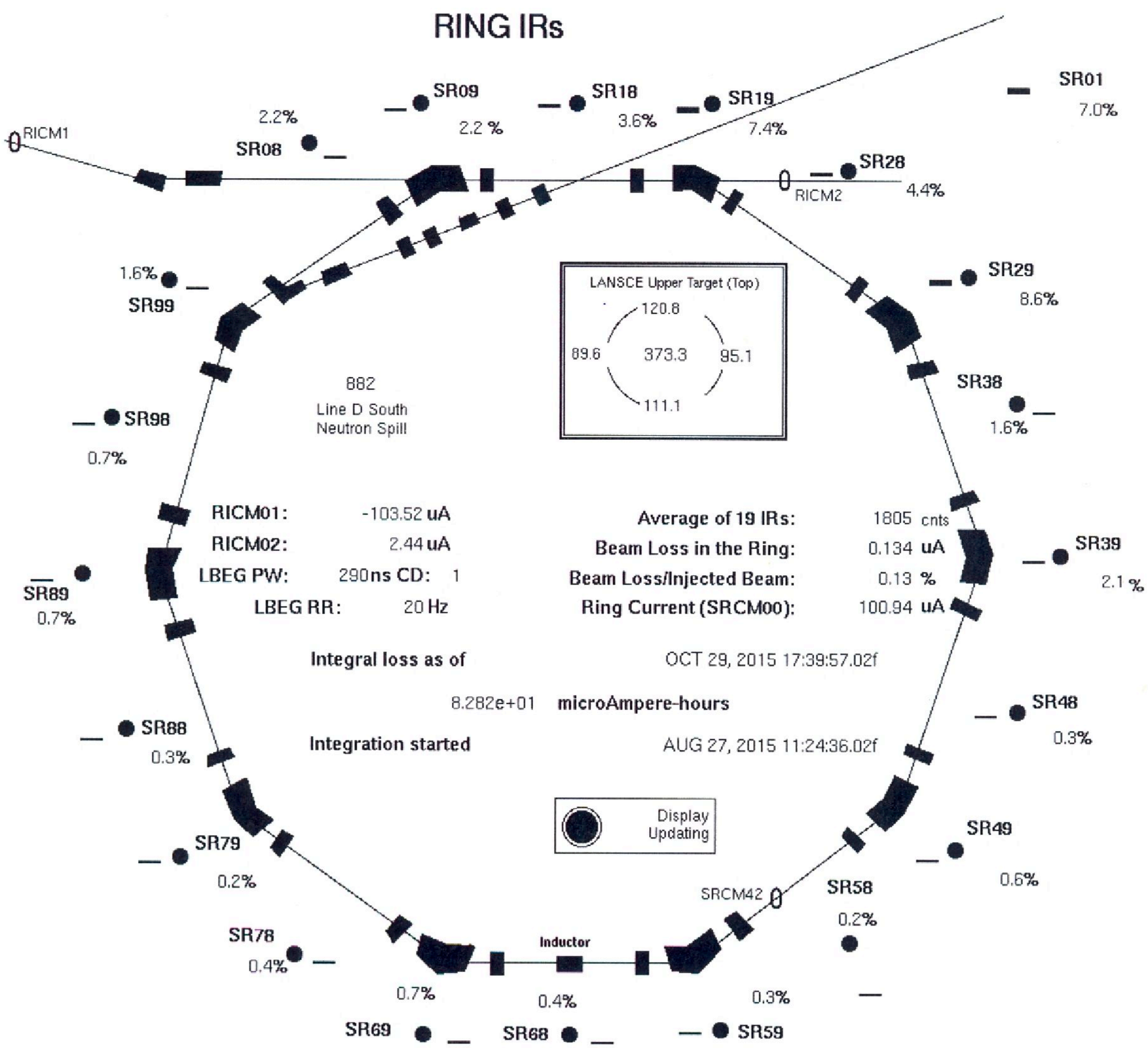
Drift Tube Linac 0.75 – 100 MeV | Transition Region | Coupled- Cavity Linac (100 MeV – 800 MeV)



Linac loss monitors (Activation Protection devices): liquid scintillator and photomultiplier tube, calibrated against 100 nA point spill. Average beam losses are 0.1 – 0.2 W/m.

Year	Pulse Rate (Hz)	Summed Loss Monitor Reading (A.U.)
2015	120	135
2014	60	211
2013	60	190
2012	60	183
2011	60	167

Beam Losses in Proton Storage Ring (PSR)



Year	PSR Pulse Rate (Hz)	PSR Beam Losses (%)
2015	20	0.13
2014	20	0.24
2013	20	0.23
2012	20	0.26
2011	20	0.24

Main Sources of Beam Losses

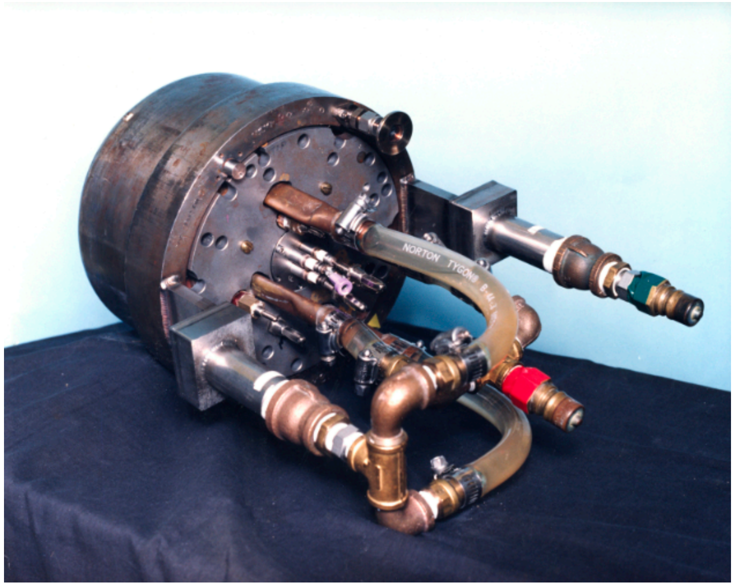
1. Misalignments of accelerator channel components
2. Transverse-longitudinal coupling in RF field
3. Particle scattering on residual gas, intra-beam stripping
4. Nonlinearities of focusing and accelerating elements
5. Non-linear space-charge forces of the beam

6. Mismatch of the beam with accelerator structure
7. Instabilities of accelerating and focusing field
8. Beam energy tails from un-captured particles
9. Dark currents from un-chopped beam

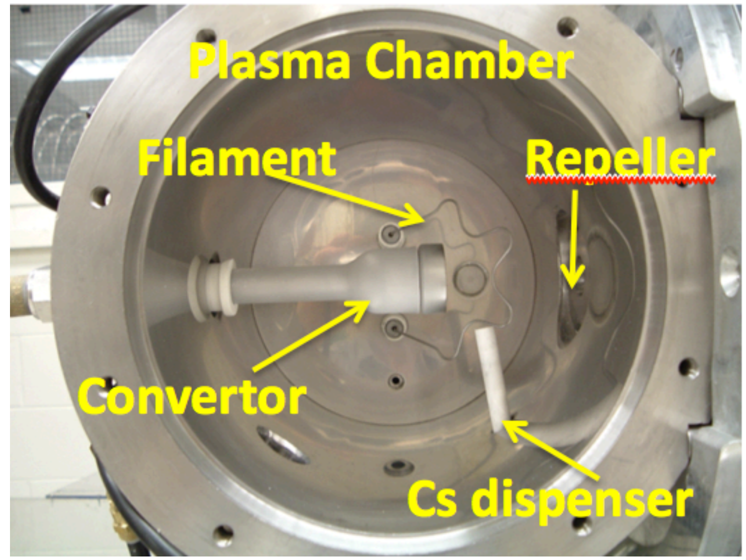
Tuning Procedures Used in Accelerator Facility

Energy (MeV)	Transverse (steering, matching)	Longitudinal (RF Amplitude and Phase Set Points)
0 – 0.75	Emittance Scans	
0.75 – 100	Emittance Scans, Wire Scans, Harps, Beam Position Monitors	Phase Scans
100 – 800	Emittance Scans, Wire Scans	Phase Scans, Delta-t
800	Wire Scans, Beam Position Monitors, Phosphor Screens	Wire Scan at High Dispersion Point

Ion Sources



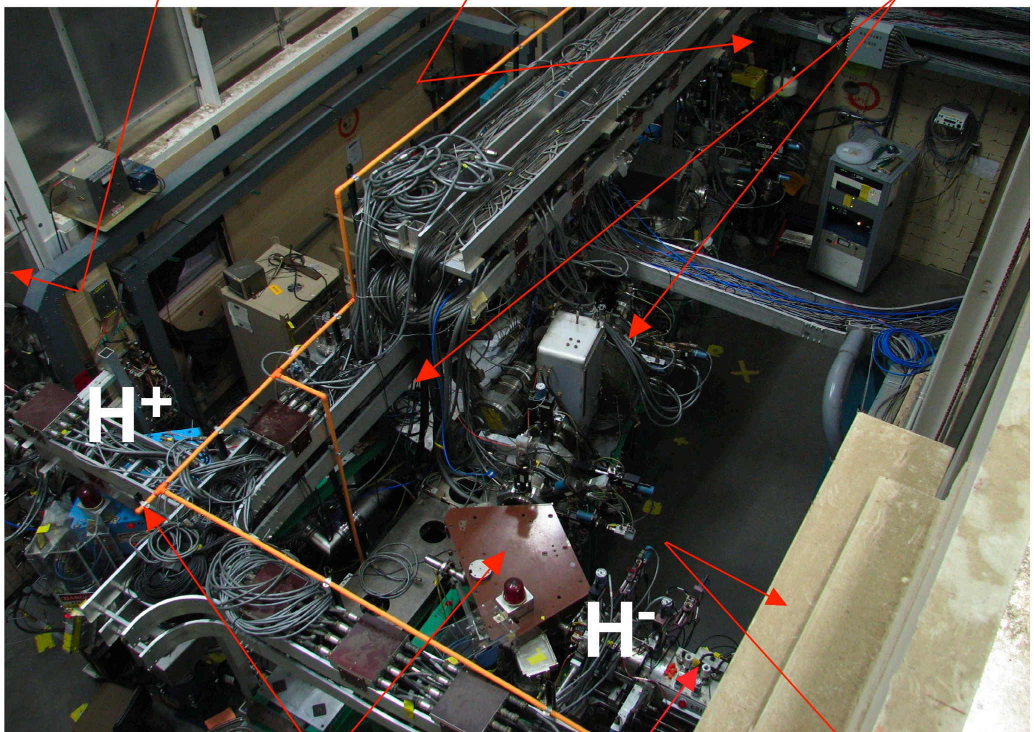
Duoplasmatron proton ion source.



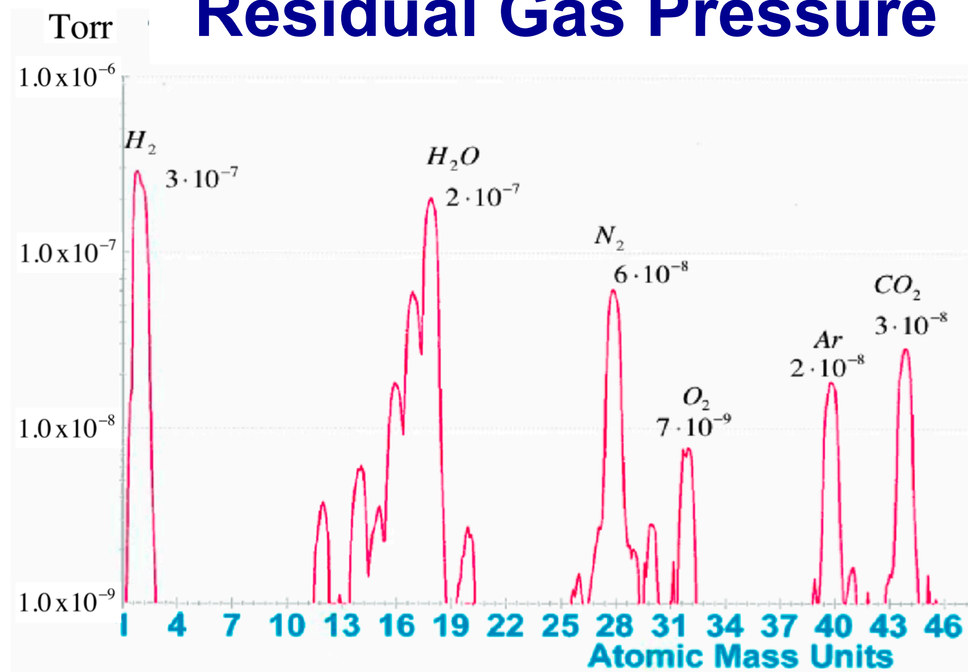
Cesiated, multicusp-field, surface-production H^- ion source

Source	Pulse Rate (Hz)	Pulse Length (μs)	Beam Current (mA)	Normalized rms emitttance (π mm mrad)
H^+	100	830	5	0.04
H^-	120	830	15	0.2

750 keV H+/H- Low Energy Beam Transports



Residual Gas Pressure



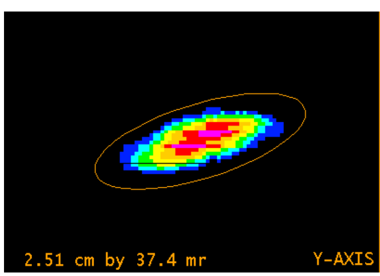
	H+ Transport	H- Transport	Common H+ / H- Transport
Length, m	10.2	9.8	2.5
Number of Quadrupoles	18	18	4
Vacuum, Torr	10^{-6}	10^{-6}	10^{-6}
Space Charge Neutralization, %	< 20	50 - 100	0 - 50
Peak Current , mA	5	15	4.5/14.5
Beam Loss, mA	0.4	0.4	0.1

Beam Emittance Growth in Low Energy Beam Transport

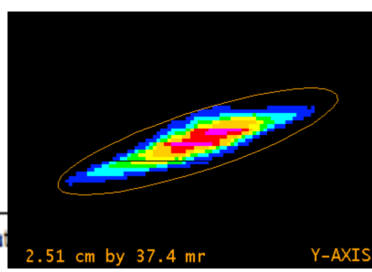
RF Bunching

Beam	Emittance Growth $\varepsilon_{RF}/\varepsilon$
H^-	1.1 – 1.2
H^+	1.9 – 2.2

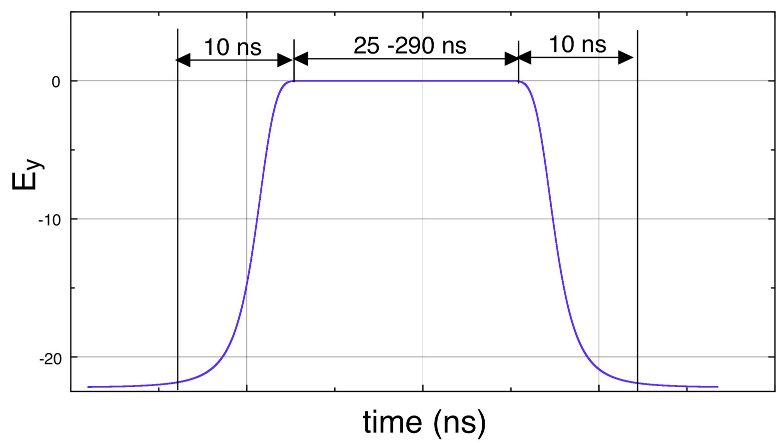
Bunchers Off



Bunchers On

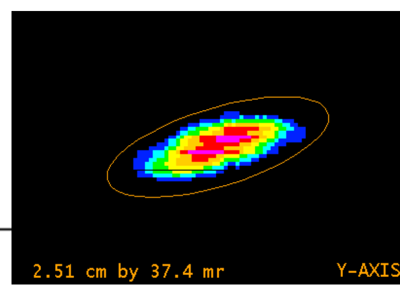


H^- Beam Chopping

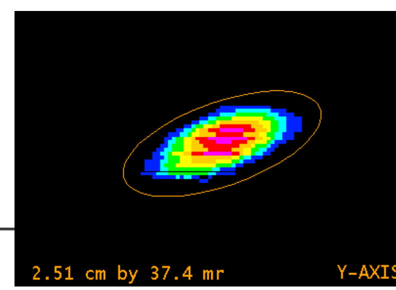


H^- Chopper Pulse	Emittance Growth $\varepsilon_{Ch}/\varepsilon$
290 ns	1.1
36 ns	1.3

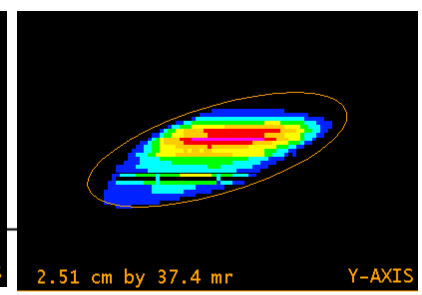
Chopper Off



Chopper pulse 290 ns

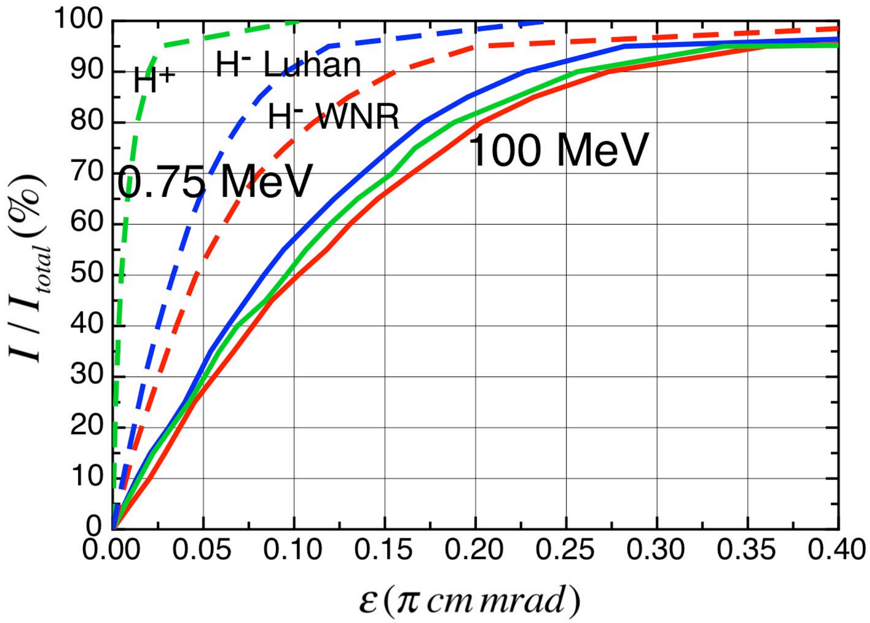


Chopper pulse 36 ns

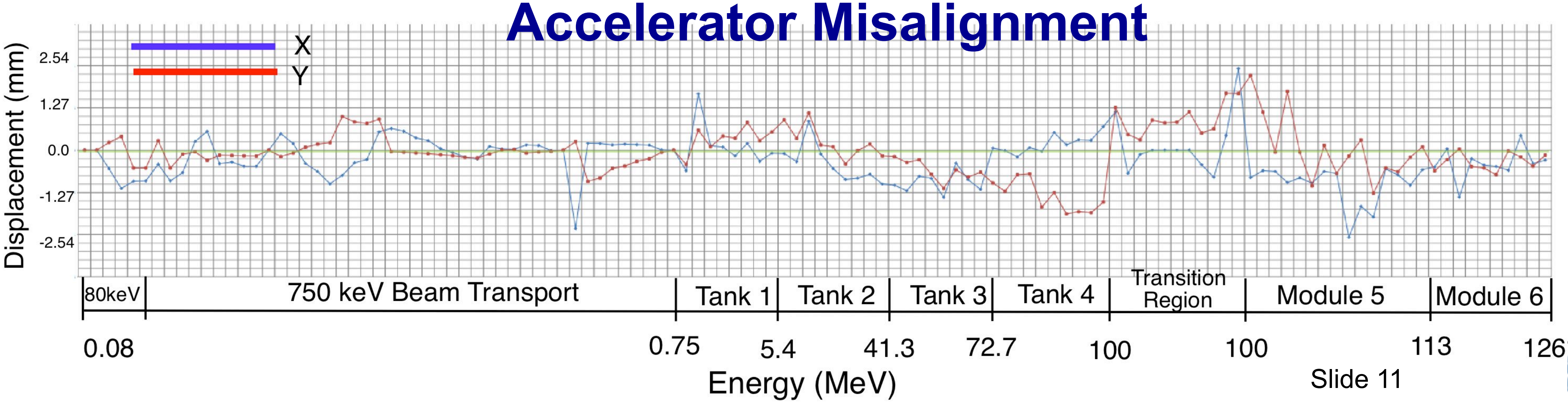


Emittance Growth in Drift Tube Linac (0.75 MeV – 100 MeV)

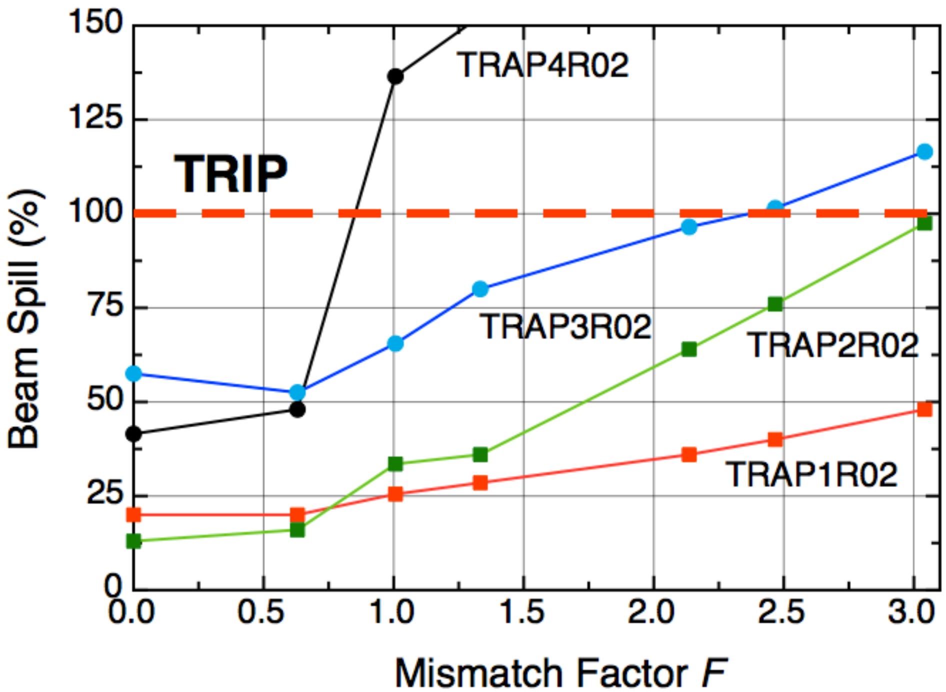
Beam Capture in DTL 75% - 80%
Additional losses 0.1% -1%

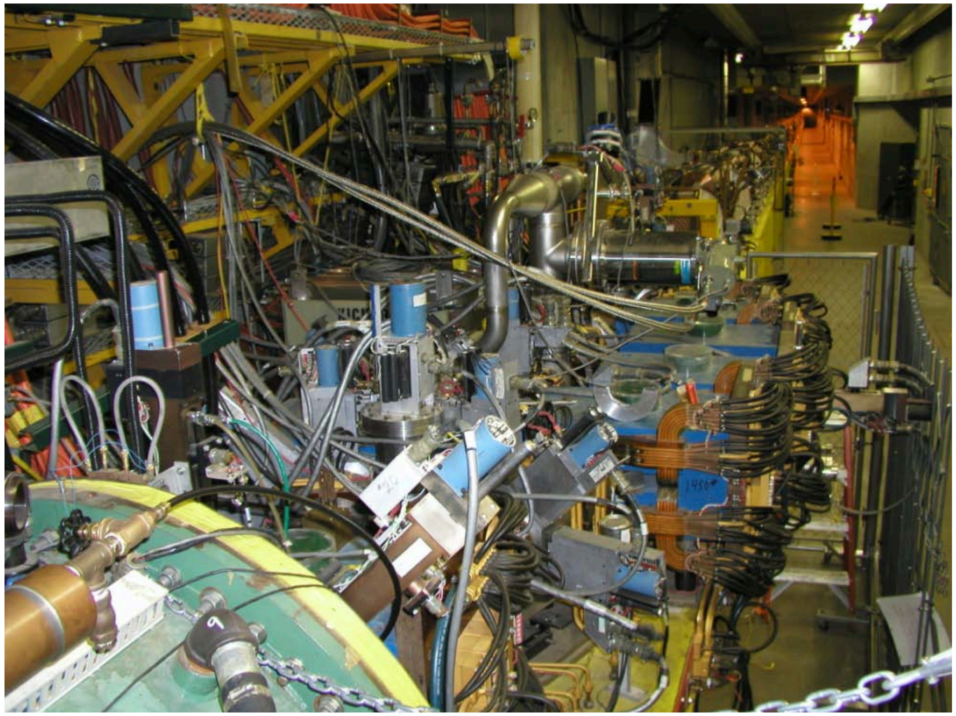


Accelerator Misalignment



Effect of Beam Mismatch at the Entrance of DTL on Beam Loss in Transition Region (100 MeV)



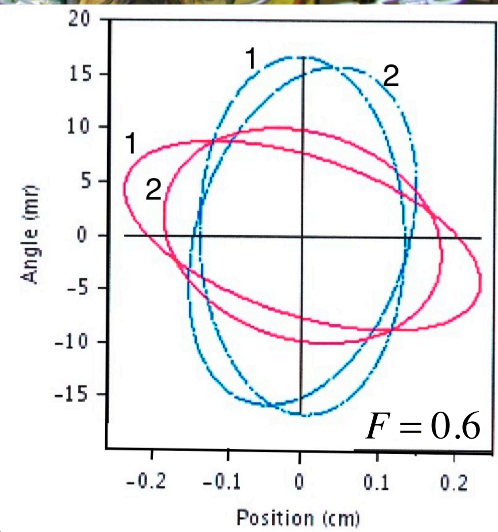


Mismatch Factor:

$$F = \sqrt{\frac{1}{2}\left(R + \sqrt{R^2 - 4}\right)} - 1$$

Ellipse Overlapping Parameter:

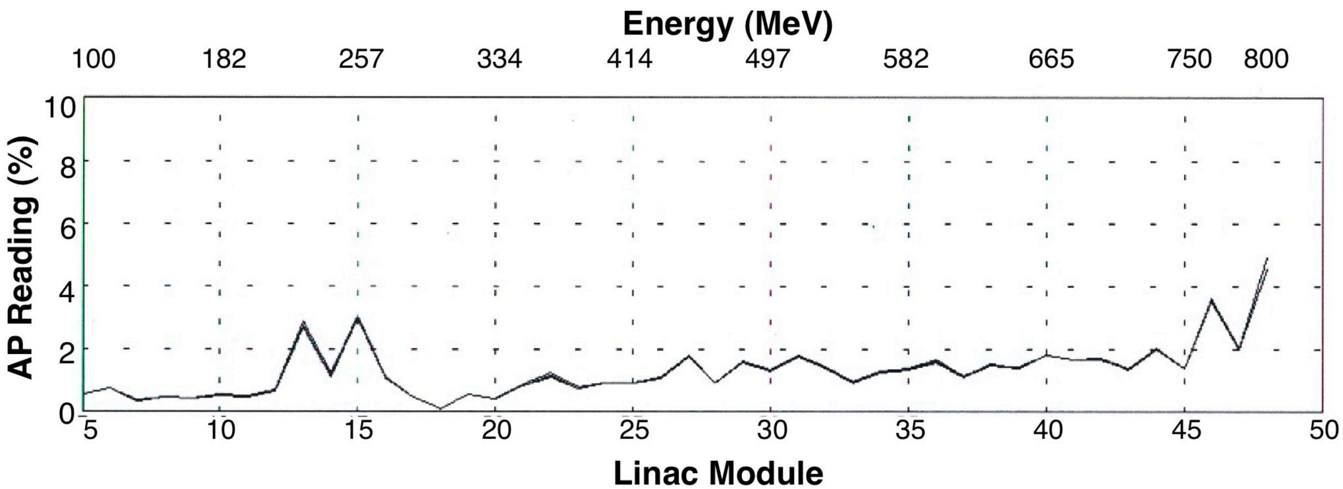
$$R = \beta_1\gamma_2 + \beta_1\gamma_2 - 2\alpha_1\alpha_2$$



H^- Beam Losses in Coupled Cavity Linac (100 MeV-800 MeV)

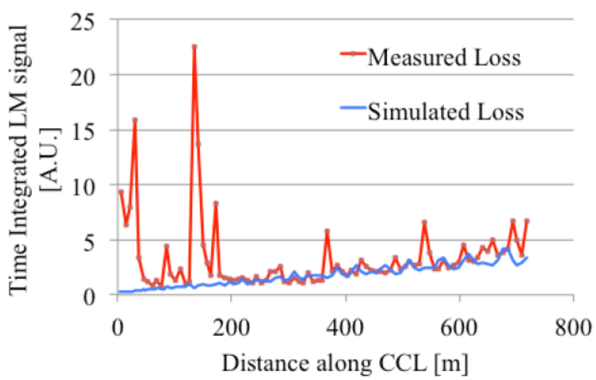
Energy (MeV)	100	800
Normalized rms beam emitttance (π mm mrad)	0.5	0.7

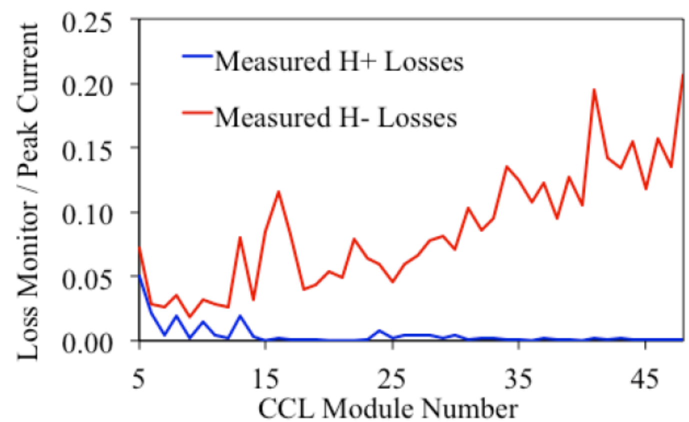
Beam losses in CCL: 0.1% - 0.2%



Previous study indicated significance of Intra Beam Stripping and Residual Gas Stripping on H^- beam losses in Coupled Cavity Linac (L.Rybarcyk, et al, IPAC12, THPPP067):

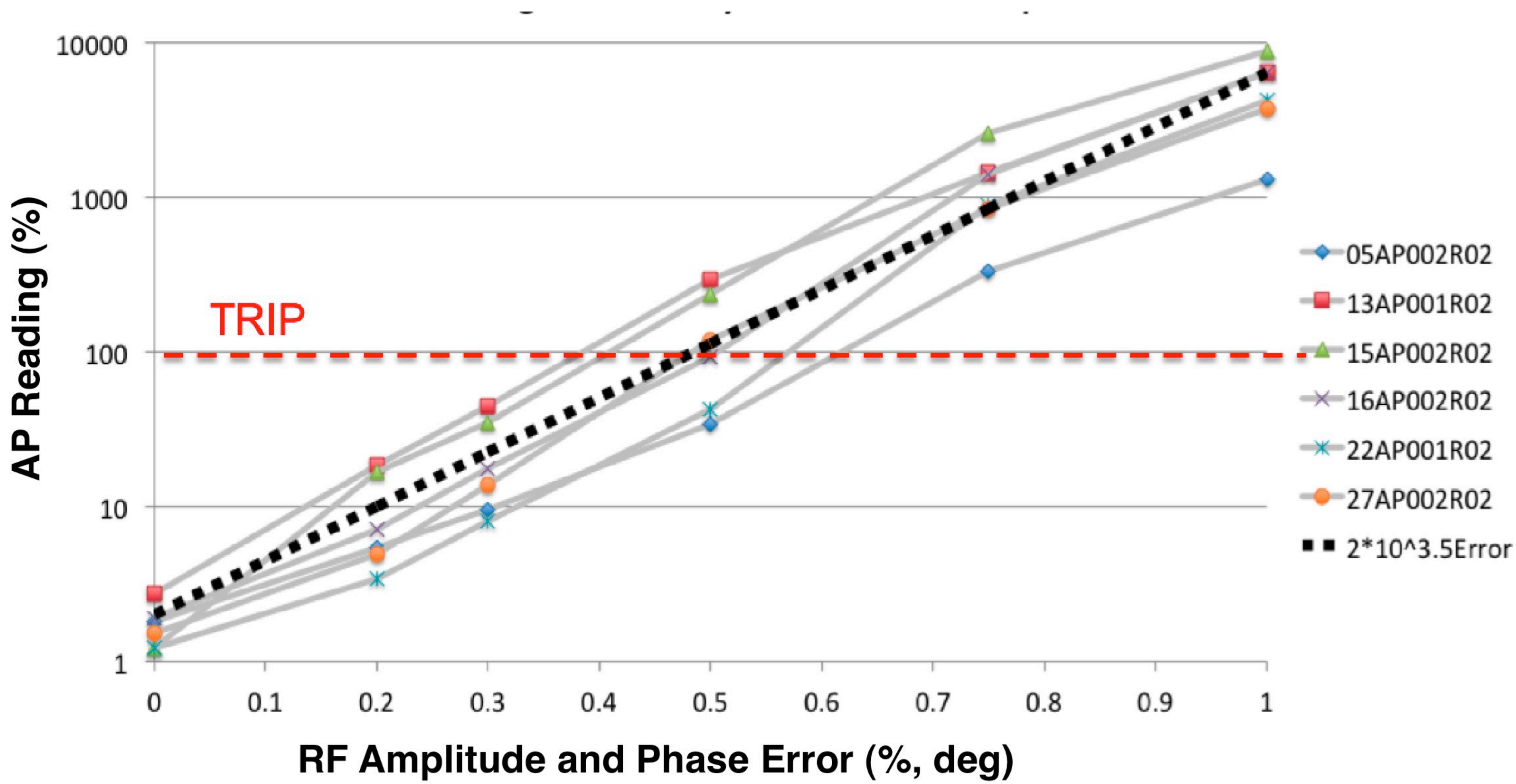
Stripping Mechanism	Beam Fractional Loss
Residual Gas Stripping	2×10^{-4}
Intrabeam Stripping	1.6×10^{-4}
Lorentz Field Stripping	4.5×10^{-11}





Effect of DTL Cavity Field Error on Beam Losses in CCL

Maximum Spill ≈ $10^{n*Error}$ where n = 3 - 4



(L.Rybarcyk et al, LINAC 2016)

Summary

1. The LANSCE accelerator facility successfully transformed operation from 60 Hz to 120 Hz.

2. Beam losses are reduced due to more careful beam matching along the accelerator facility.

3. Beam losses are sensitive to beam mismatch and instability of RF parameters of accelerator cavities.

4. New quantitative criteria for minimizing of beam losses are established for Low Level RF control system of DTL: 0.1% in RF amplitude and 0.1° in RF phase.