Updates on Project X Ion Source and LEBT R&D

Qing Ji

Lawrence Berkeley National Laboratory

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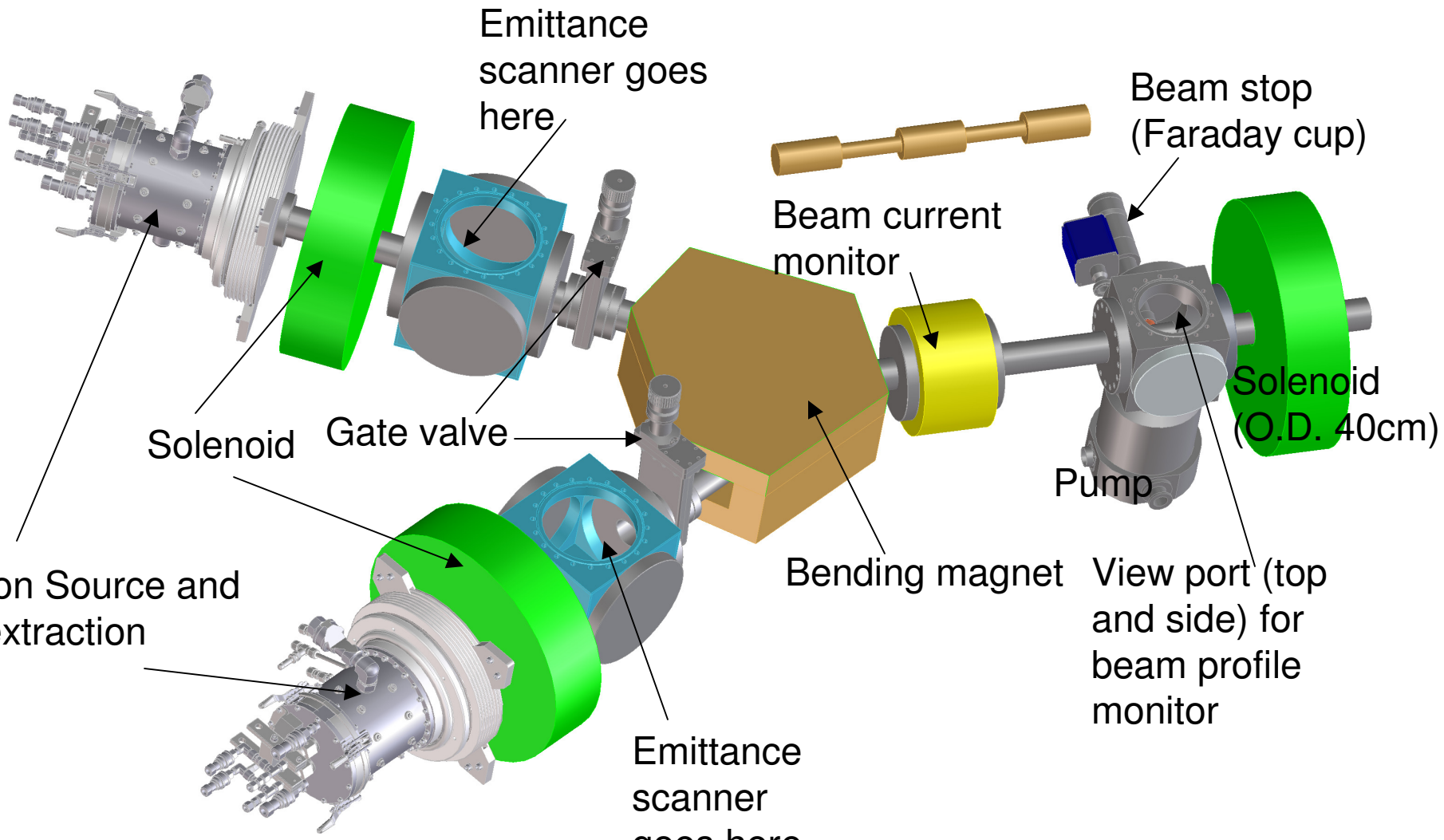
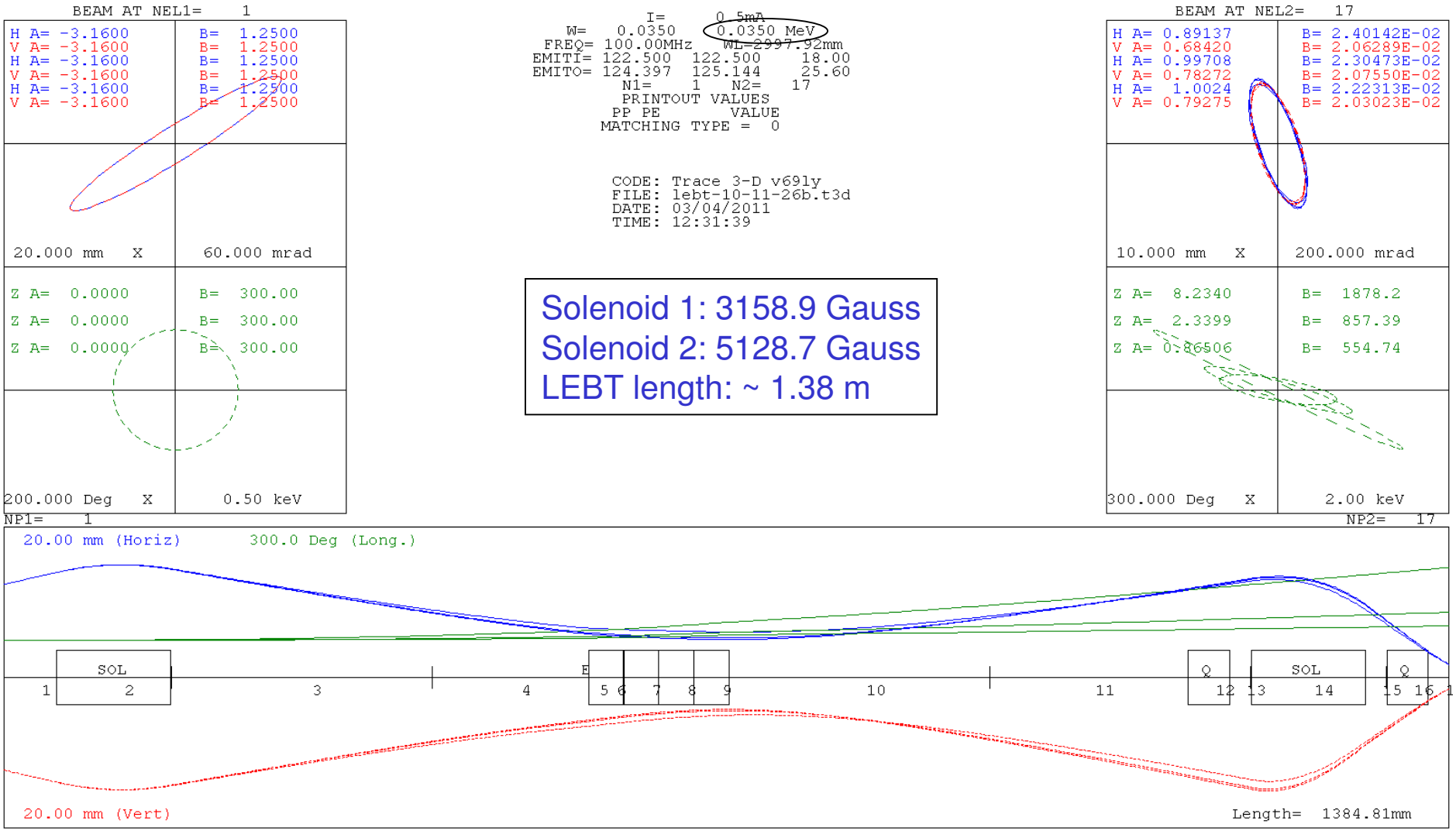
Ion Source and LEBT Beam line and Diagnostics



Previous LEBT Design (for 35keV RFQ Injection Energy)

With new input twiss parameters: α=-3.16, β=1.25



Solenoid 1: 3158.9 Gauss
Solenoid 2: 5128.7 Gauss
LEBT length: ~ 1.38 m

Changes in RFQ design

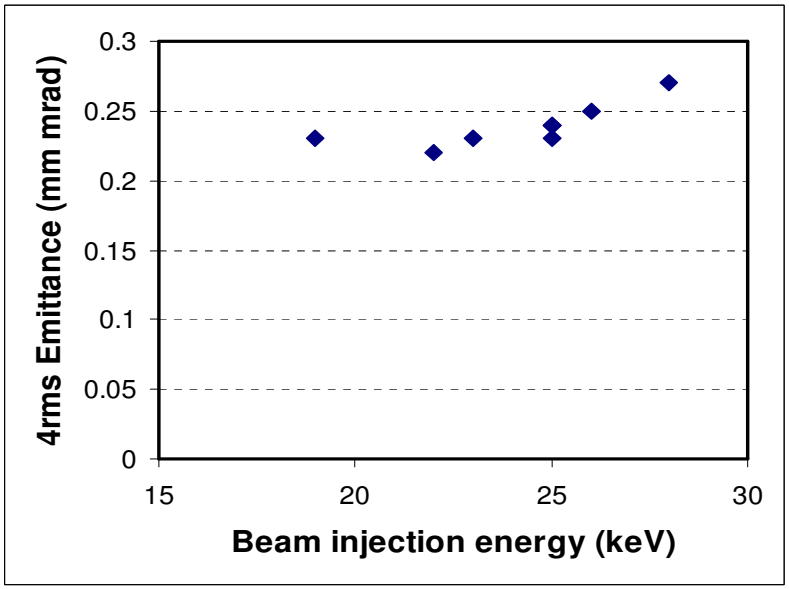
	Previous RFQ	Current RFQ
Freqency (MHz)	325	162.5
Injection Energy (keV)	35	20
Twiss parameter	α=0.9	α=2
	β=0.02 m/rad	β=0.06 m/rad

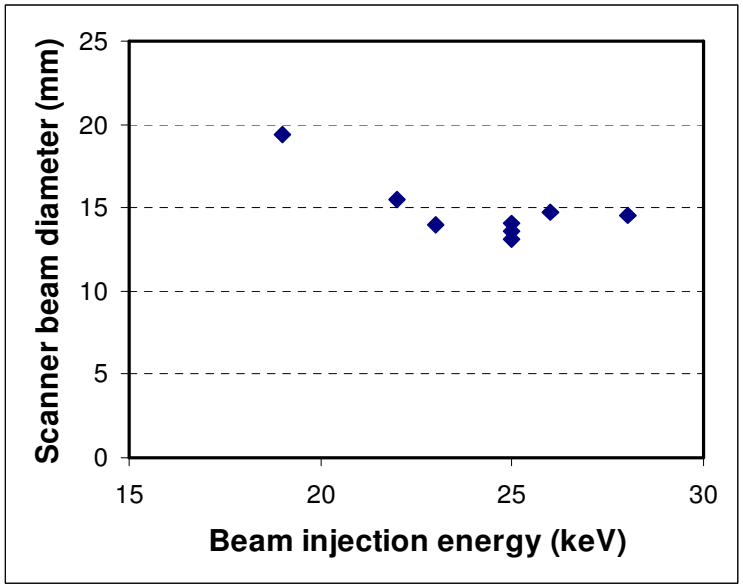
Emittance vs. Beam Injection Energy

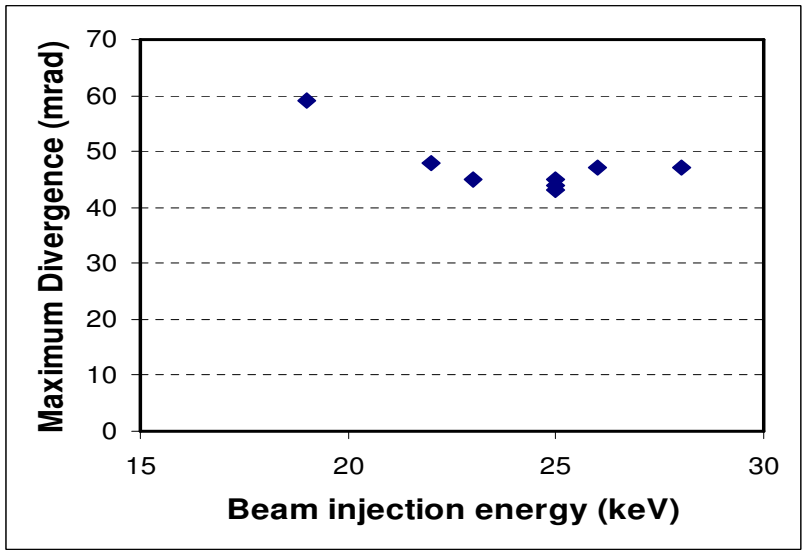
Beam injection Energy (keV)	Normalized 4rms emittance (mm mrad)	unnormalized 4rms emittance (mm mrad)	Maximum Divergence (mrad)	Scanner beam diameter (mm)	Output beam current (mA)
28	0.27	34.94	47	14.5	1.897
26	0.25	33.58	47	14.7	1.897
25	0.24	32.87	45	14.1	1.86
25	0.23	31.50	43	13.1	1.907
25	0.24	32.87	44	13.6	1.916
23	0.23	32.84	45	14	1.897
22	0.22	32.12	48	15.5	1.785
19	0.23	36.14	59	19.4	1.766

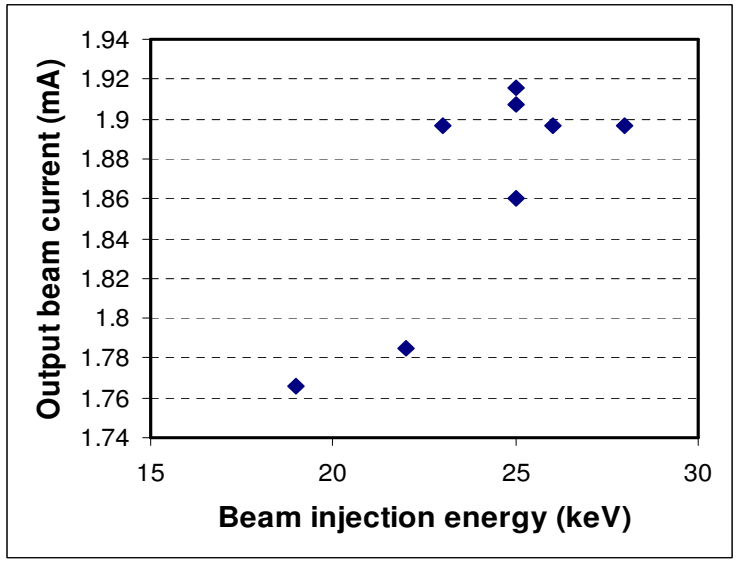
Morgan Dehnel's PhD thesis. Data was taken on a low current filament-discharge H- ion source, which the current D- Pace source is based on.

Emittance vs. Beam Injection Energy

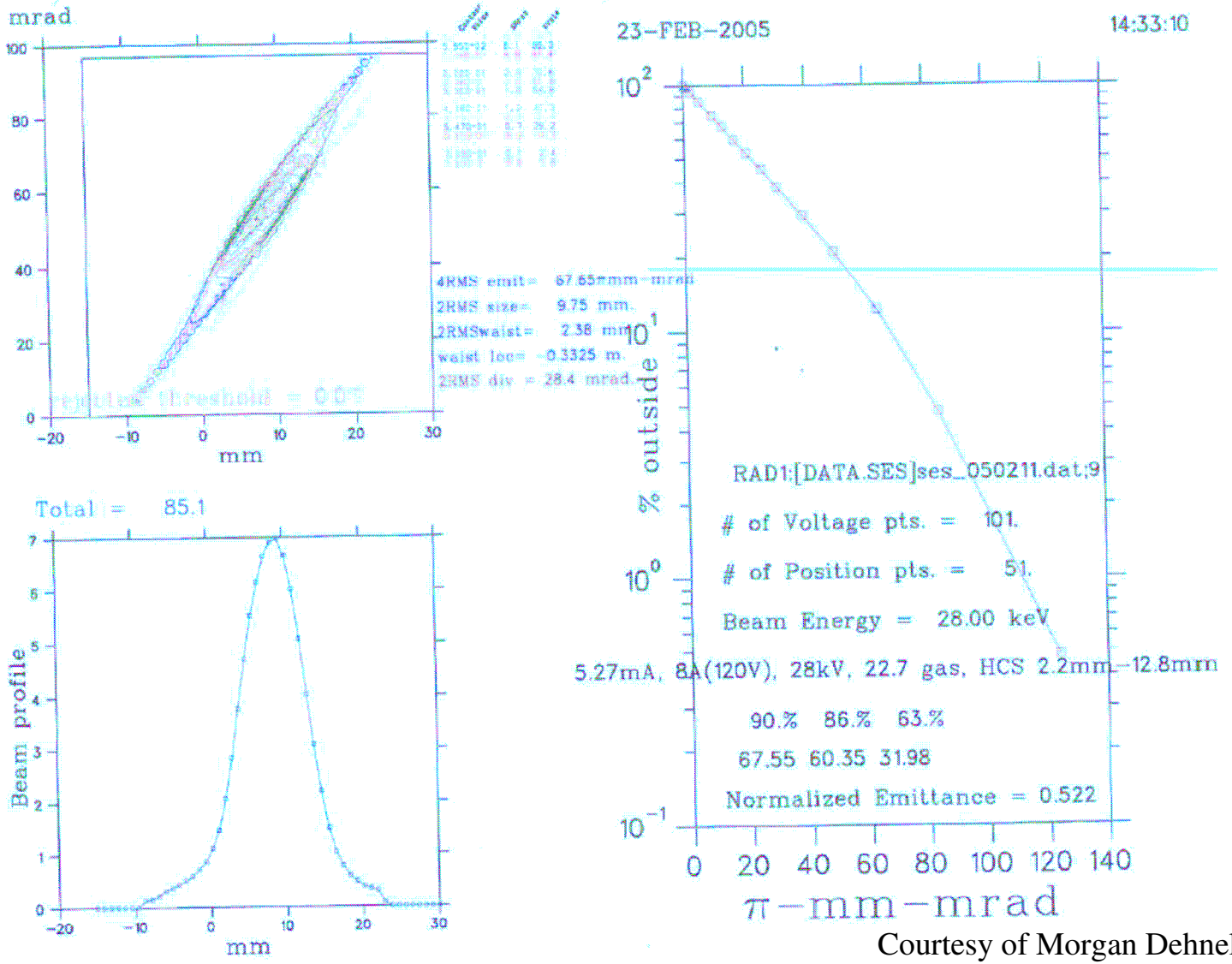








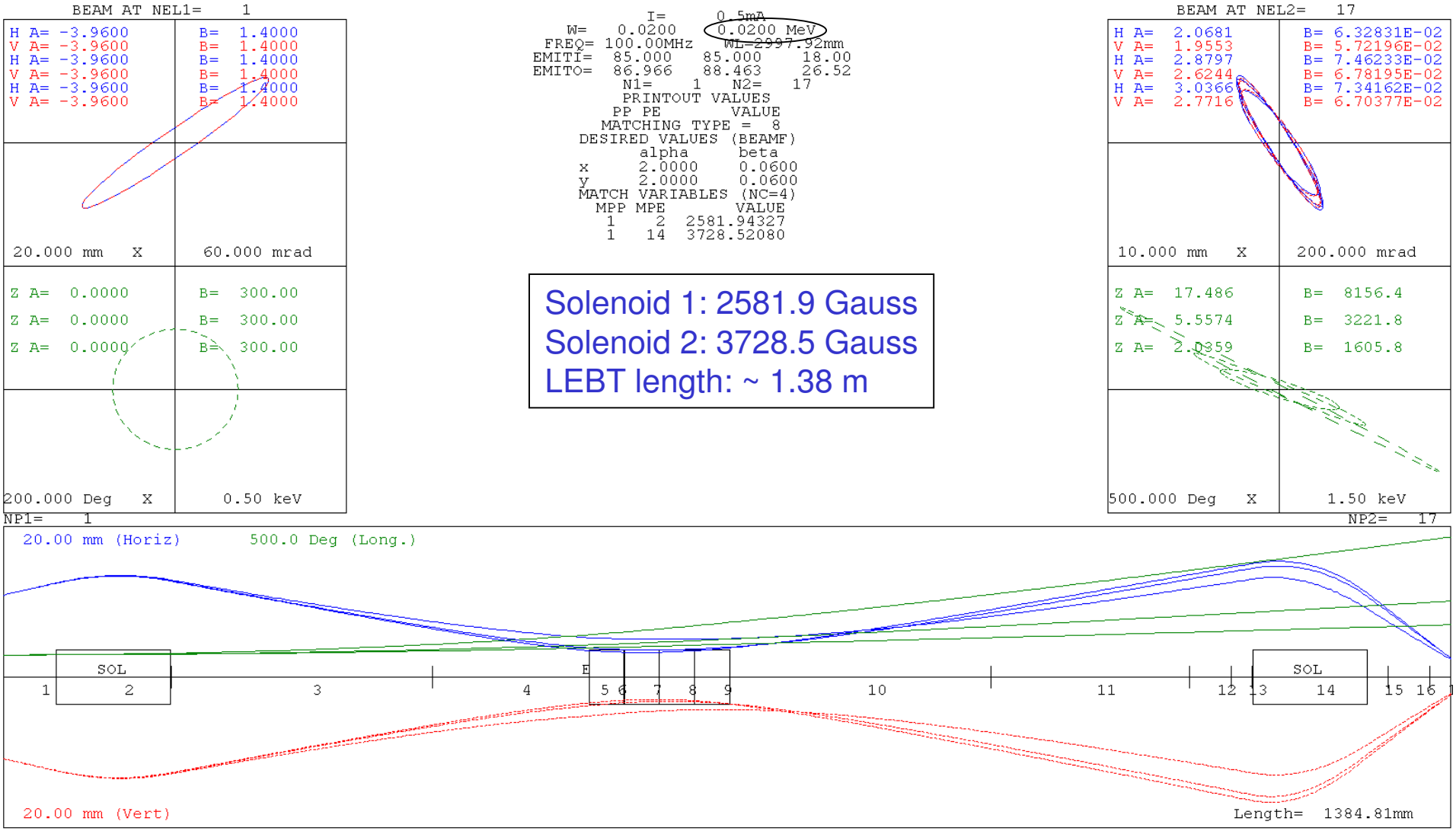
Emittance Measurement (5.27 mA @ 28kV)



Courtesy of Morgan Dehnel, D-Pace, Inc.

Current LEBT Design (for 20keV RFQ Injection Energy)

With new input twiss parameters: α=-3.96, β=1.4 (5.27mA/28kV scan)



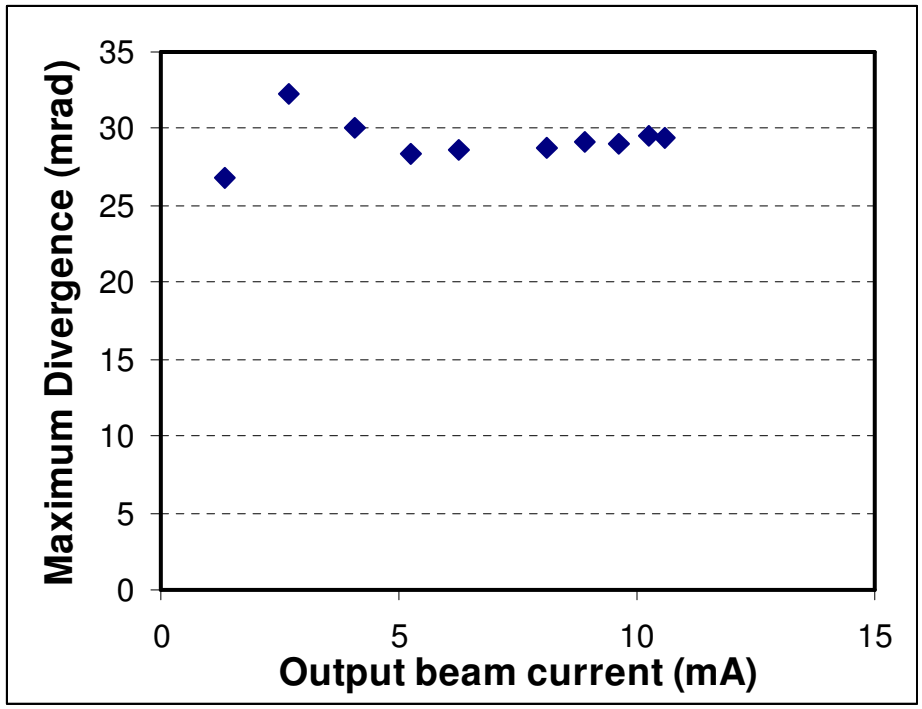
Solenoid 1: 2581.9 Gauss
Solenoid 2: 3728.5 Gauss
LEBT length: ~ 1.38 m

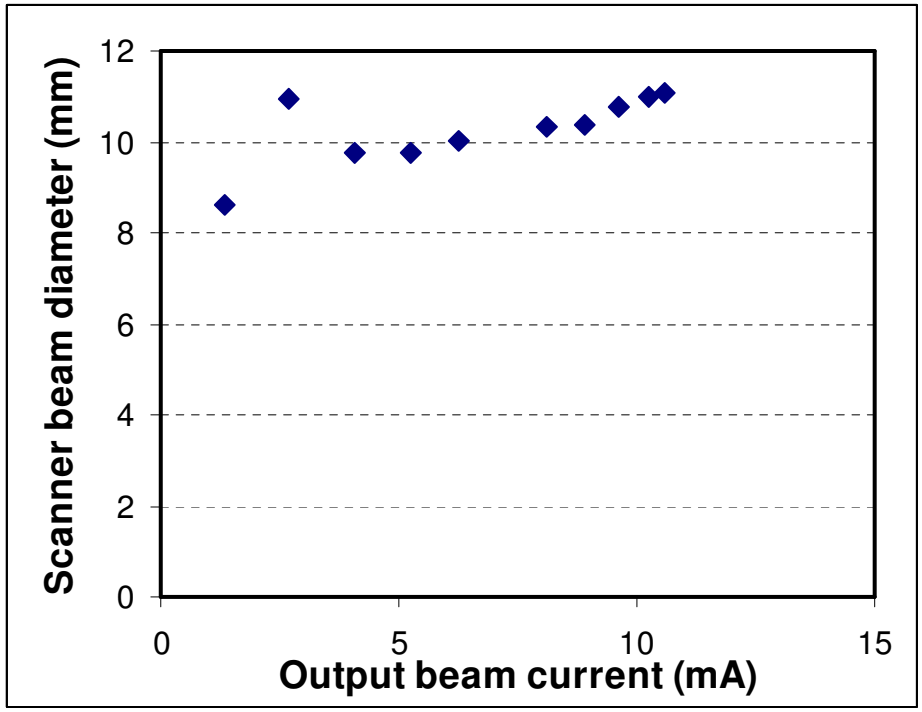
D-Pace Ion Source Performance

Output beam current (mA)	Normalized 4rms emittance (mm mrad)	Maximum Divergence (mrad)	Scanner beam diameter (mm)	Bias voltage (kV)
1.35	0.751	26.8	8.6	28
2.71	0.503	32.3	10.96	28
4.09	0.502	30	9.77	28
5.27	0.523	28.4	9.75	28
6.28	0.569	28.6	10.04	28
8.11	0.658	28.8	10.33	28
8.92	0.701	29.1	10.37	28
9.64	0.712	29	10.77	28
10.27	0.745	29.5	11	28
10.6	0.758	29.4	11.08	28

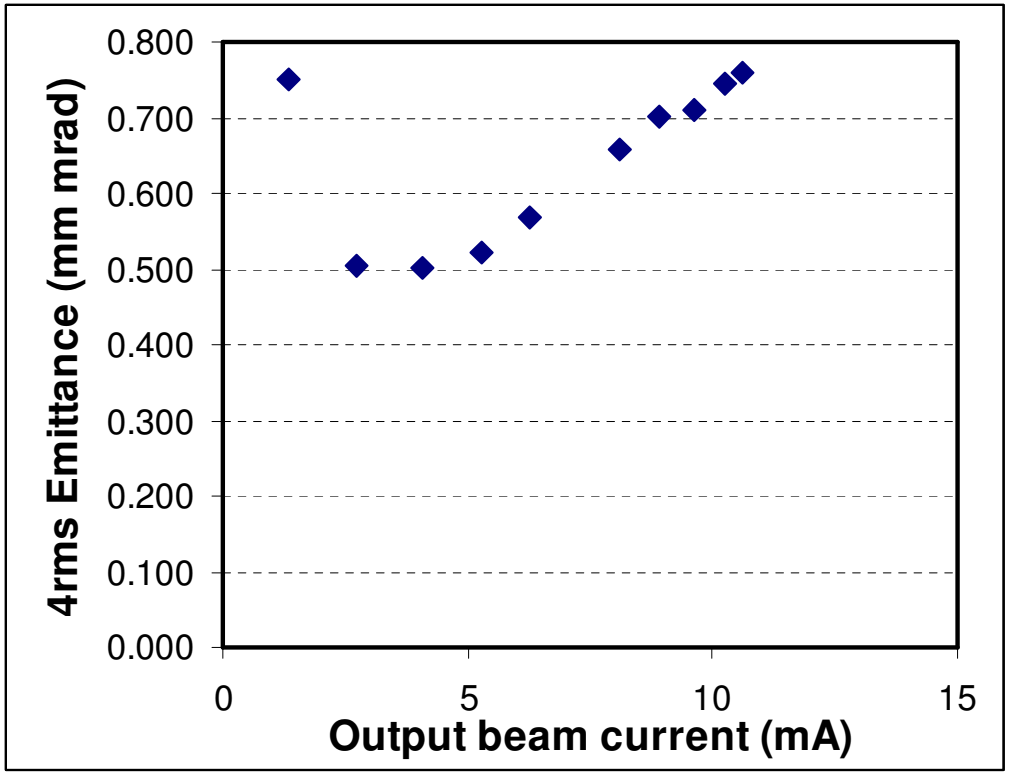
Courtesy of Morgan Dehnel, D-Pace, Inc. Data was taken in 2005 on a delivered D-Pace ion source.

Beam size and divergence angle vs. beam current





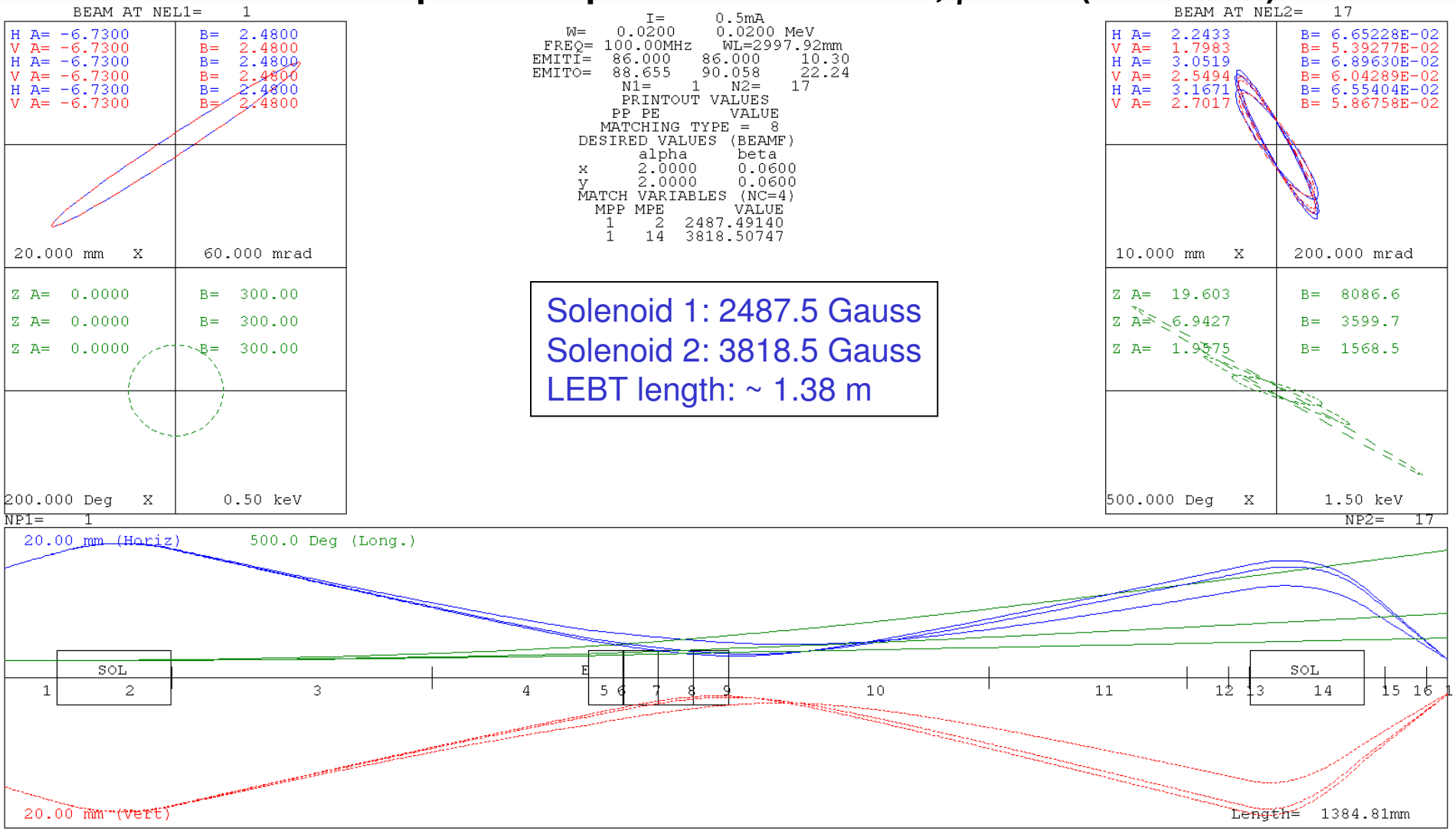
Beam emittance vs. output current



	2mA		5mA	
	19kV	28kV	19kV	28kV
4rms normalized emittance (mm mrad)	0.23	0.27	0.446	0.523
Maximum divergence (mrad)	59	47	35.651	28.4
Beam diameter (mm)	19.4	14.5	13.045	9.75

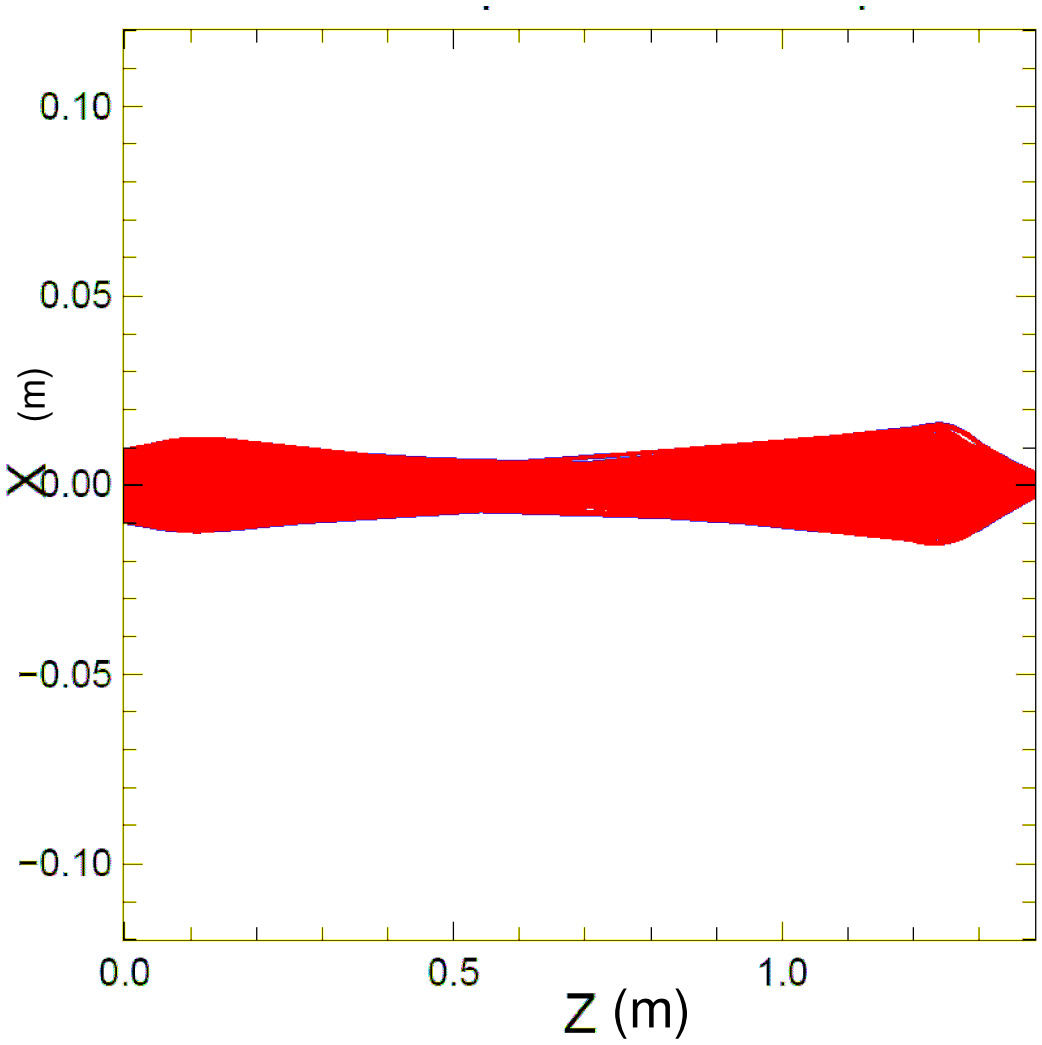
Current LEBT Design (for 20keV RFQ Injection Energy)

With new input twiss parameters: α=-6.73, β=2.48 (5mA/20kV)

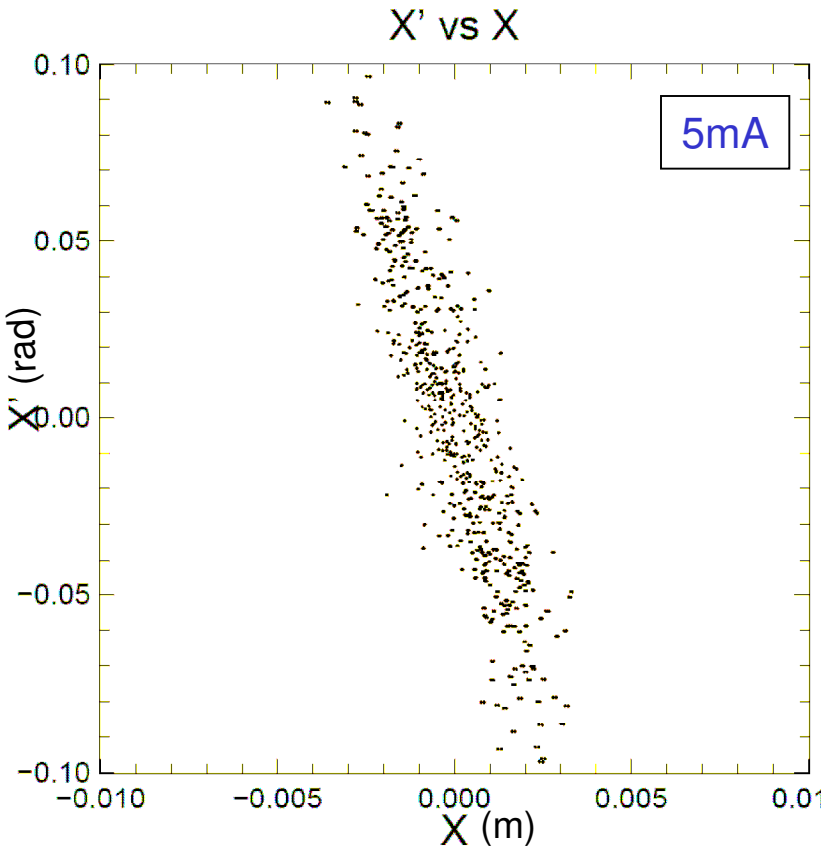


Solenoid 1: 2487.5 Gauss
Solenoid 2: 3818.5 Gauss
LEBT length: ~ 1.38 m

WARP Simulation (Two Solenoids, no bending magnet)



90% space charge neutralization



Source operation parameters from prior work

I Injection (μA)	H^2 Flow sccm	Varc V	I arc I	V pull V	I pull mA	V es V	I es A
1011.1	11.0	120.0	4.7	2400.0	3.1	4.7	1.2
1053.0	11.0	120.0	1.9	2200.0	5.2	2.0	0.6
2030.0	11.0	120.0	3.1	2100.0	18.4	1.9	0.9
3026.0	11.0	120.0	4.2	1900.0	5.7	2.7	1.5
4042.7	11.0	120.0	5.6	2100.0	11.1	2.9	2.0
5030.9	11.0	120.0	7.0	2300.0	14.2	3.3	2.5
6066.1	11.0	120.0	8.5	2700.0	17.8	3.7	3.1
7052.0	11.0	120.0	10.1	3000.0	22.8	4.0	3.8
8074.0	11.0	120.0	11.9	3000.0	31.7	4.2	4.4
9028.2	11.0	120.0	13.8	3100.0	40.1	4.6	5.2
100016.0	11.0	120.0	16.2	3200.0	49.3	5.0	6.2
11028.0	11.0	120.0	19.2	3200.0	53.9	5.6	7.7
12013.0	11.0	125.0	23.3	3200.0	95.3	5.8	9.0
13079.0	15.5	125.0	22.5	3400.0	77.2	4.8	7.7
14035.0	15.5	125.0	25.0	3500.0	105.5	4.8	8.3
15000.0	20.6	130.0	30.0	3900.0	120.0	4.7	9.2

Courtesy of Morgan Dehnel, D-Pace, Inc.

D-Pace 15mA H- ion Source Power supplies

- ✓ Arc: 45A, 150V (10A, 150V for 5mA operation)
- • Filament: 375A, 10V
- ✓ Plasma: 30A, 10V (Plasma lens is positively biased relative to the source body)
- ✓ Extraction: 100mA, 5kV(Extraction lens is positively biased relative to the source body)
- ✓ Bias: 40mA, -30kV(Bias supply is negative output)
- ✓ X steering: 6A, 10V
- ✓ Y steering: 6A, 10V

Available Power Supplies at LBNL

Plasma Electrode

Extraction

Arc power supply

Bias

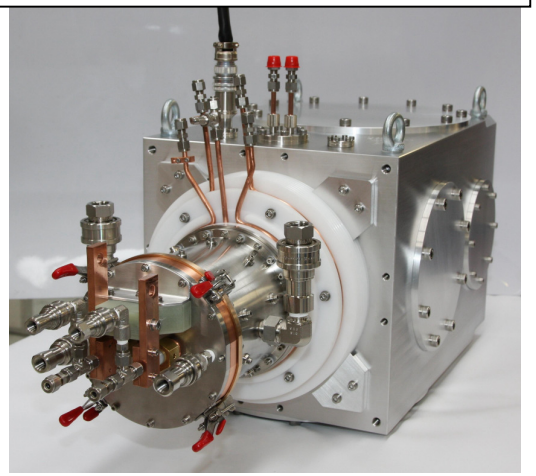
X Steering

Y Steering

Status of D-Pace Ion Source Fabrication

- D-Pace ion source fabrication is on track to have the ion source assembled by the last week of April. Parts that have been received and delivered to the machine shop:
  - All the permanent magnets
  - The grounding strips
  - The quartz tubes
  - The ion source inner housing
  - The wire for the filaments
  - D-Pace specific jigs and tool required to make and assemble certain parts of the ion source
  - D-Pace Ion Source specific vacuum leak test flanges
  - Packing materials for spare Filament sets

Expected Ion Source Assembly



Friction Stir Welded Vacuum Box

H- Ion Source Test Stand @ LBNL

- Two turbo pumps in house: 1000 l/s
  - (suggested)Upstream pump
    - Pfeiffer HiPace 2300
    - Hydrogen pumping speed of 1850l/s,
    - with inlet DN250, outlet DN ISO40-K
  - (suggested)Downstream pump
    - Turbo recommended or Cryo pump with 2500l/s
- Roughing pump
- Isolation transformer
- Faraday cup
- Emittance scanner

D-Pace Ion Source Acceptance Test

- **Factory acceptance tests performed at the machine shop (by D-Pace Inc.)**
  - Vacuum leak testing of entire assembly
  - Electrical isolation test
  - Verification of the magnetic fields in the Ion Source Body, Back Plate and Extraction Lens
  - XY Steering Magnet: electrical isolation, temperature and voltage, magnetic field direction tests and magnet current and magnetic flux densities.
  - Cooling water flow rate test
- **Ion source assembly and installation in TRIUMF (by D-Pace Inc.)**
- **Beam tests at TRIUMF (May 9, 2011 – May 13, 2011)**
  - **Day 1:** Check and make sure Ion Source has pumped down sufficiently. Turn on cooling water, H2 gas, and power supplies. Ramp up the power supplies slowly to "condition" the new filament. Try to get up to max beam current (~10mA due to test stand limitations), tune the beam, record tune and take emittance scan.
  - **Day 2:** Run beam and record tunes in ~1mA increments starting at ~ 1mA up to max capable on Ion Source test stand (~10mA). Take an emittance scan for each tune.
  - **Day 3:** Continue emittance measurement
  - **Day 4:** Beam stability test
  - **Day 5:** Remove Ion Source and extraction lenses from test stand. Reassemble in crate with vacuum box. Repackage for shipping. Reinstall TRIUMF Ion source on test stand. Move Ion Source to shipping department for delivery to client.
- **The results of all the FAT's, the certificate of conformance, and ion source tuning data and emittance scans will be included in the appendices of the final copy of the Ion Source user manual.**

Summary

- A two-solenoids magnetic lens LEBT system has been designed.
- Simulations at beam current of 5 mA have been carried out using different codes.
- Ion source acceptance test has been planned.