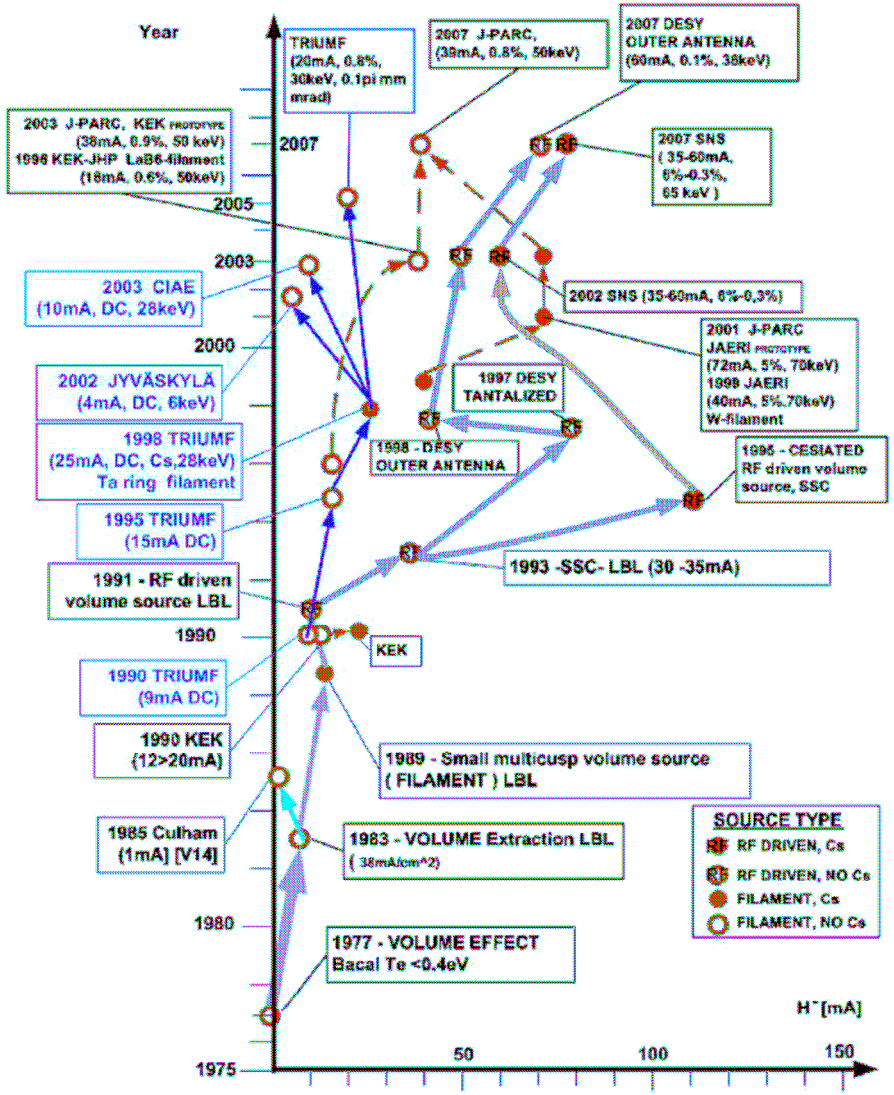
Project X: Ion Source & LEBT R&D plan and Status Report

Qing Ji

July 28, 2010

1. H- Ion Source R&D Plan
2. LEBT R&D Status

History of H⁻ Volume Ion Source



J. Peters, "New developments in multicusp H– ion sources for high energy Accelerators", REVIEW OF SCIENTIFIC INSTRUMENTS 79, 02A515 2008

Filament, no Cs

Filament, with Cs (higher current, lower lifetime)

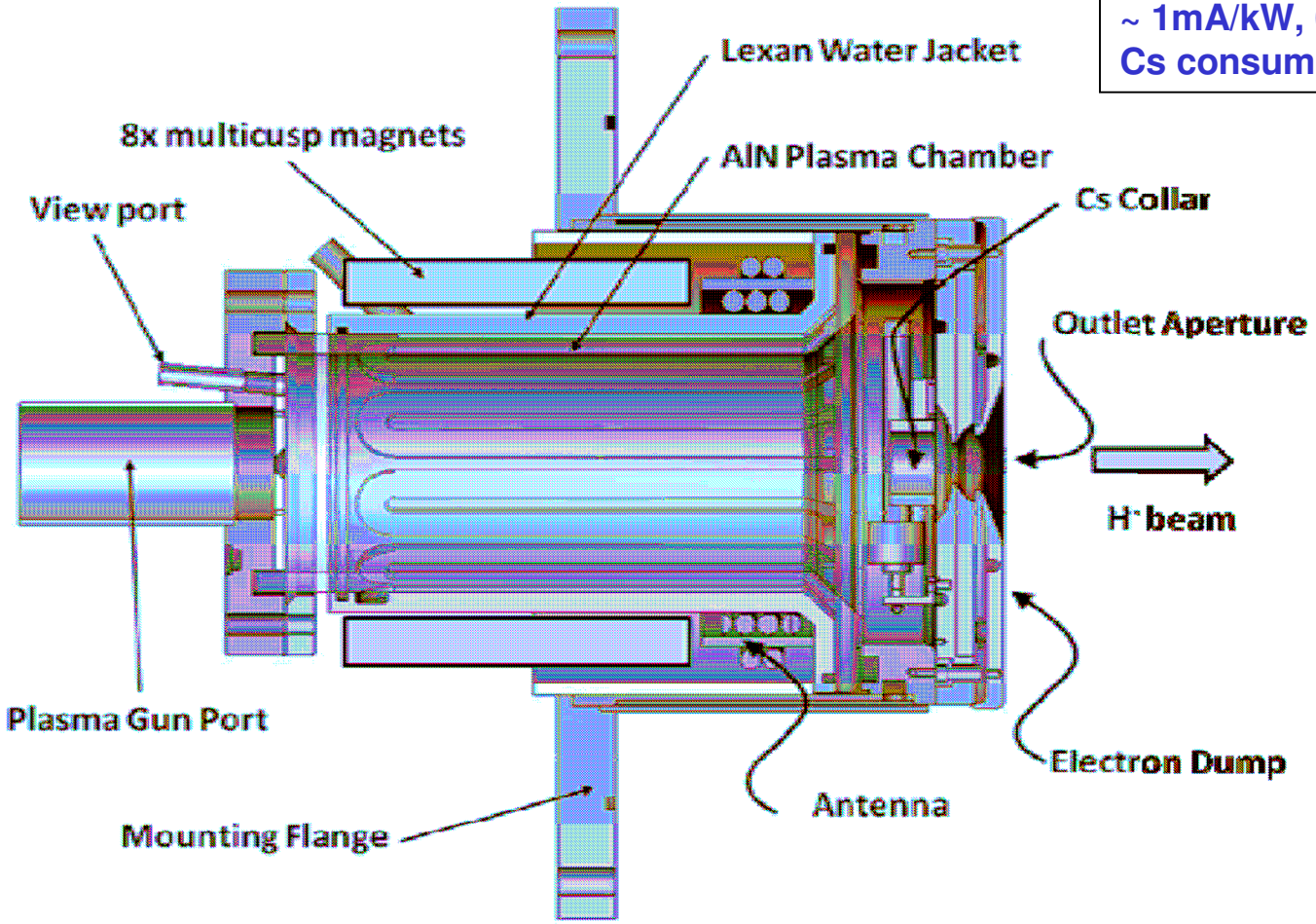
RF driven w. internal antenna, no Cs (higher lifetime)

RF driven, w. internal antenna, with Cs (higher current)

Current R&D: RF driven, external antenna, with Cs (higher current)

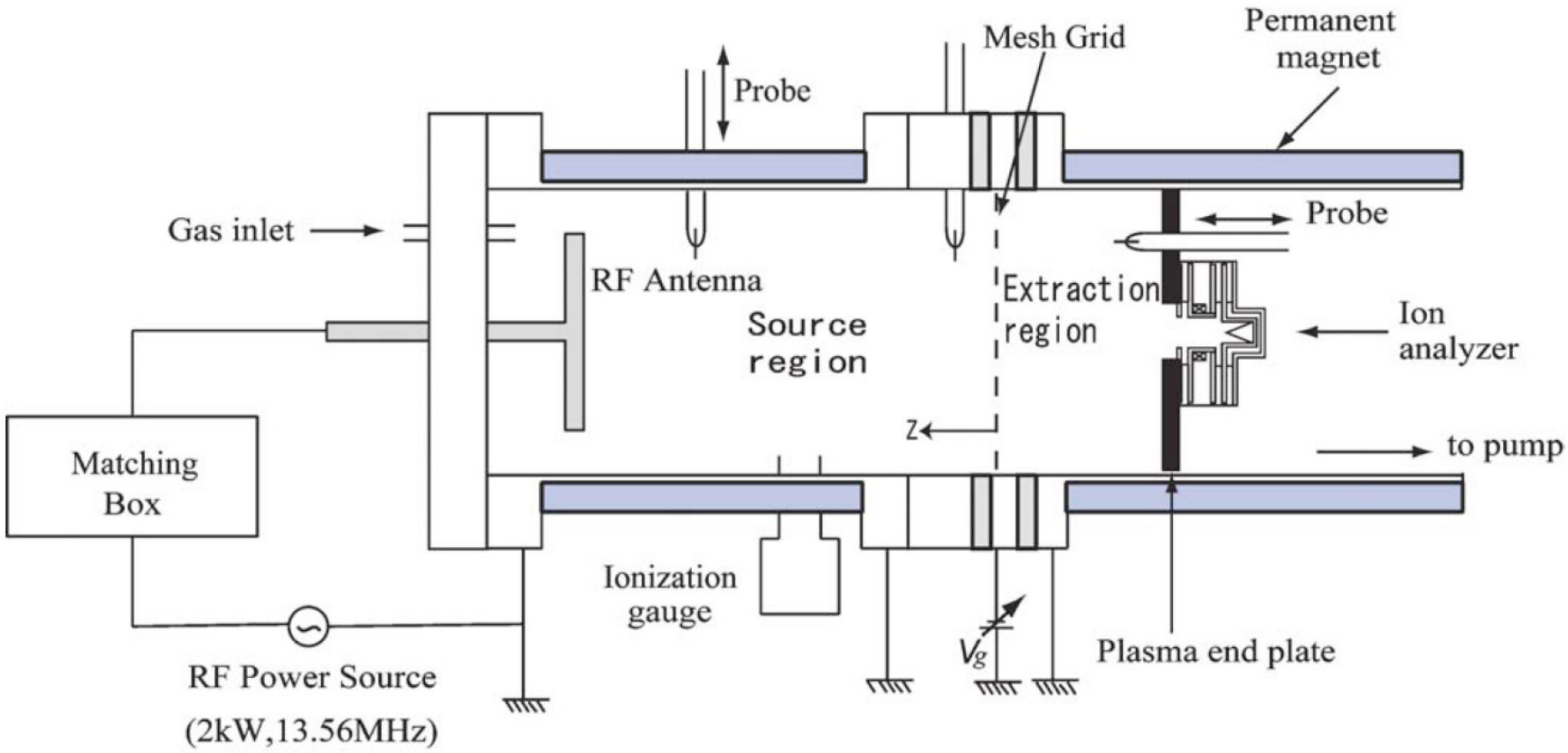
RF with External Antenna and Cs Collar

~ 1mA/kW, 6% duty factor
Cs consumption: 0 mg/day



R. F. Welton et al, "The Continued Development of the SNS External Antenna H⁻ Ion Source", REVIEW OF SCIENTIFIC INSTRUMENTS **81**, 02A727 2010

RF H- Ion Source with Mesh Grid

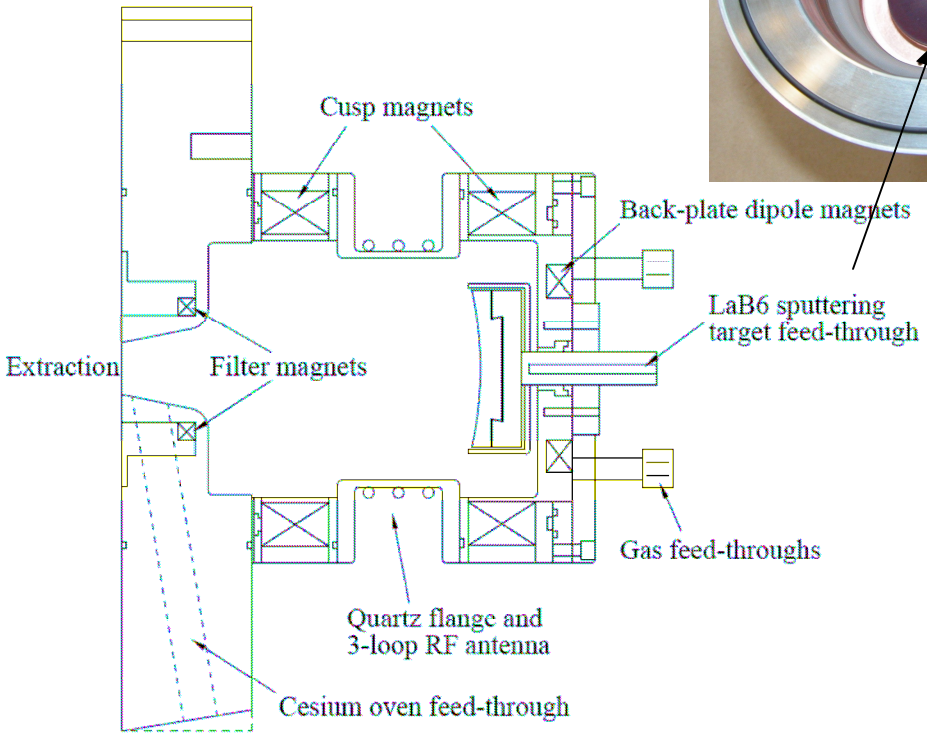


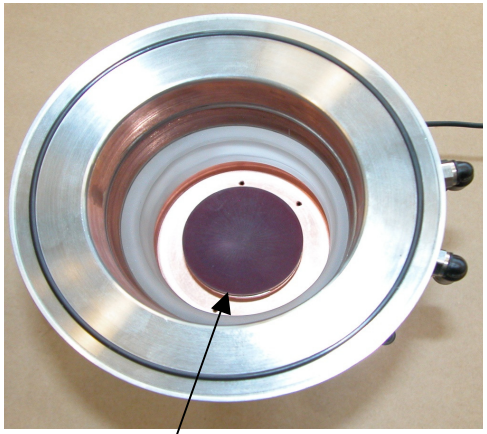
Biased mesh grid helps to:

1. **Improve H- formation by reducing electron temperature in extraction region**
2. **Avoid negative ion destruction by non-absorbed RF signal**

J. Okada et al, 'Efficient negative ion production in rf plasmas using a mesh grid bias method", REVIEW OF SCIENTIFIC INSTRUMENTS 79, 02A502(2008)

LBNL: AIMA H^- source

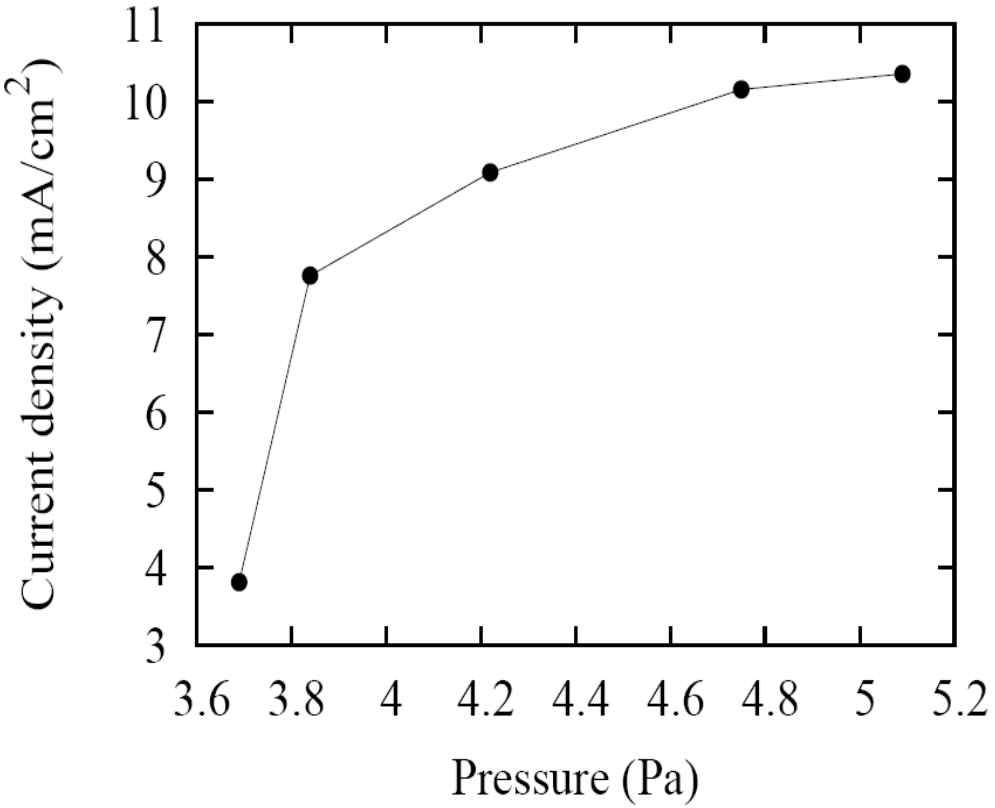




96 mm long, 75mm diameter

T. Kalvas et al, "Multicusp ion source with external RF antenna for production of H^- ions", CP925, *Production and Neutralization of Negative Ions and Beams,11th International Symposium,* edited by M. P. Stockli, American Institute of Physics, 2007.

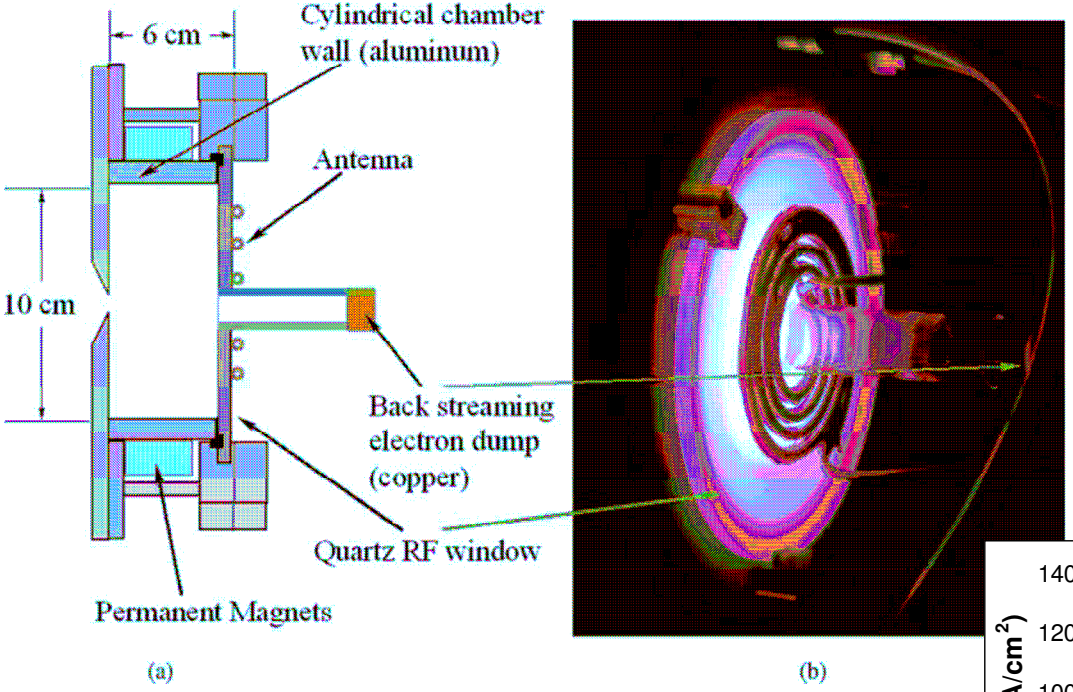
LBNL: AIMA H^- source

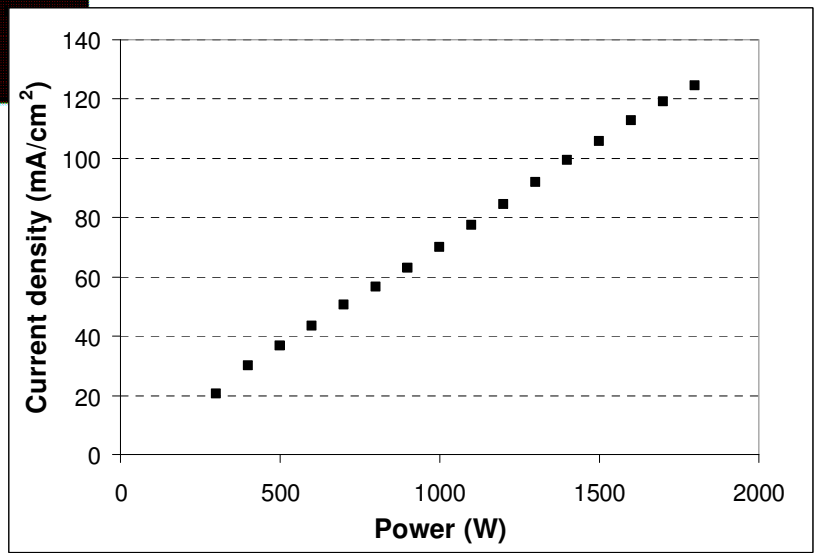


• demonstration of H^- production in 13.5 MHz RF source with external antenna and Cs, extracted currents from small aperture only ~1 mA, not at all fully optimized

T. Kalvas et al, "Multicusp ion source with external RF antenna for production of H^- ions", CP925, *Production and Neutralization of Negative Ions and Beams,11* International Symposium,* edited by M. P. Stockli, American Institute of Physics, 2007.

LBNL: RF (13.56MHz) H+ source with external antenna





Q. Ji and J. W. Kwan, "RF-driven proton source with a back-streaming electron dump", Rev. Sci. Instrum. 81, 02B312 (2010).

R&D on cw RF-driven H^- Ion Source

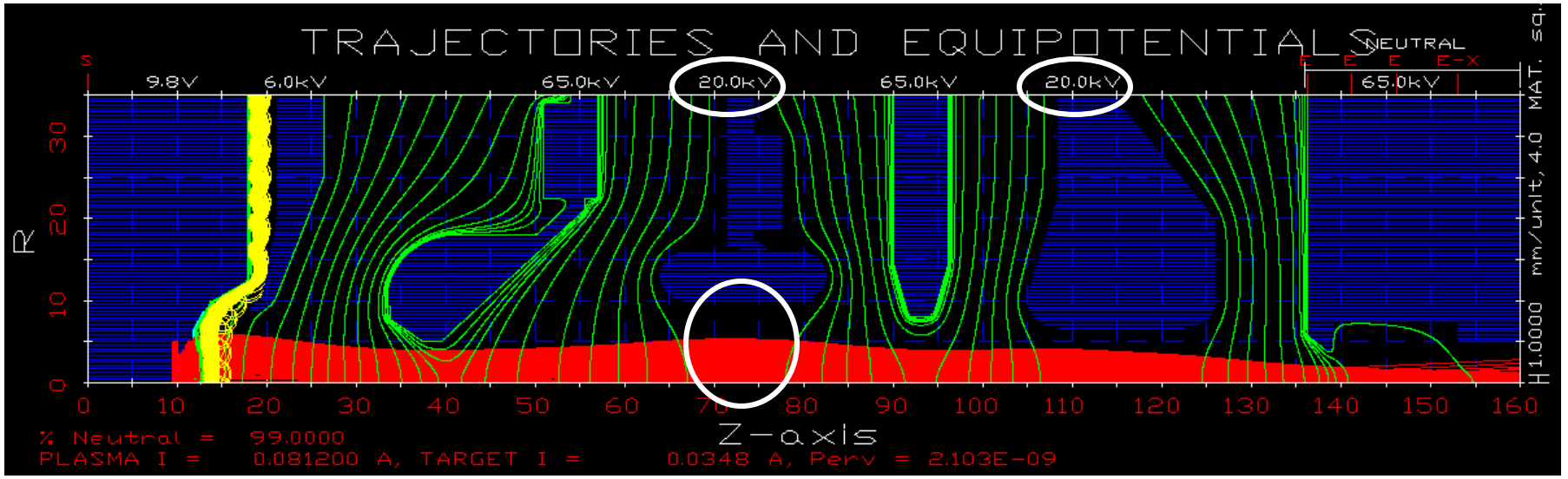
- LBNL will start from the external antenna cw 13.56MHz RF-driven ion sources developed in the past
  - RF ion source technology for both proton and H^- ion source
  - Ion source hardware available in house, need modification and assembly
- Investigate external antenna cw RF-driven H^- ion source for higher brightness and longer lifetime
  - This is the trend in the field
  - With filter magnet or/and biased mesh grid to lower the electron temperature in the extraction region
  - With optimized Cs collar to increase H^- current, increase power efficiency of H^- production beyond 1 mA/kW, and to reduce e/H^- ratio

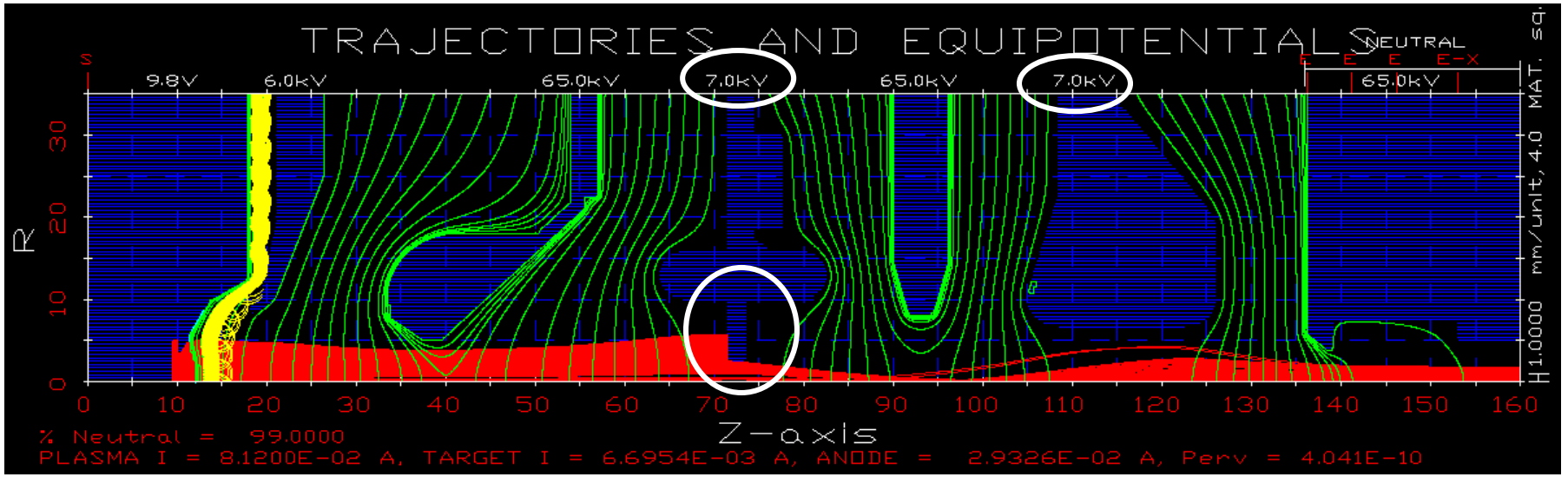
1. H- Ion Source R&D Plan
2. LEBT R&D Status

LEBT R&D Plan

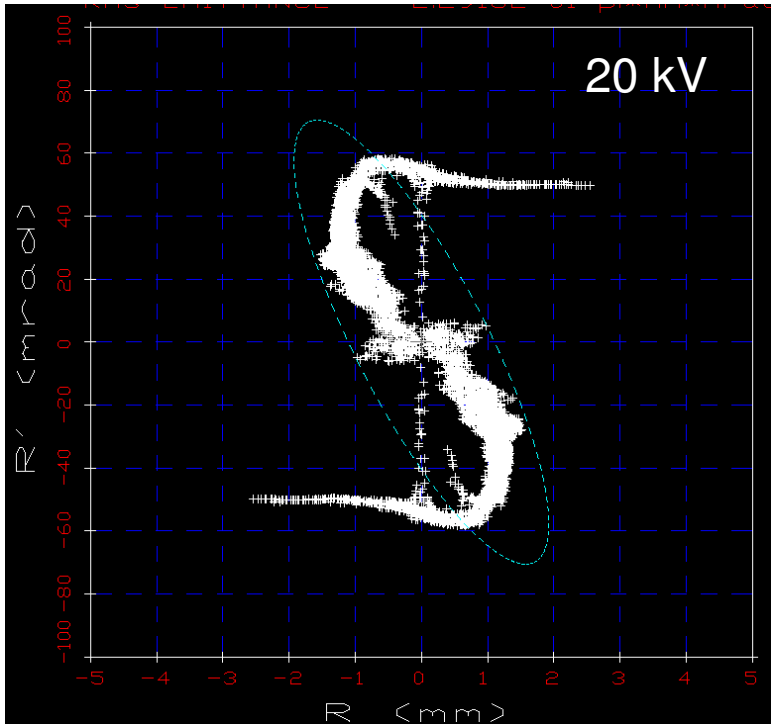
- **Identify a feasible solution for H^- ion source LEBT system that can provide pulsed H^- beam at 10 Hz with 5 ms pulse width, 0.5 ms pulse ramping up and down time, with variable beam intensities of adjacent pulses**
  - Use two ion sources and LEBT systems. One bending magnet is used to select between two beams
    - Low risk
    - Can provide less beam downtime
    - Bending magnet will cause emittance growth, therefore requires higher brightness of the ion source
  - Use one ion source and LEBT system
    - By changing the ion source operation condition (either pulse the RF power level or Arc discharge power supply), the H^- ion beam extracted from the source can be varied.
    - Beam extraction and LEBT operation parameters need to be synchronized with source current level
  - Use one H^- ion source and LEBT with a limiting aperture
    - The H^- ion beam extracted from the ion source stays constant.
    - By varying the setting of the Einzel lens in the LEBT, the H- ion beam current passing through the downstream limiting aperture will change accordingly.

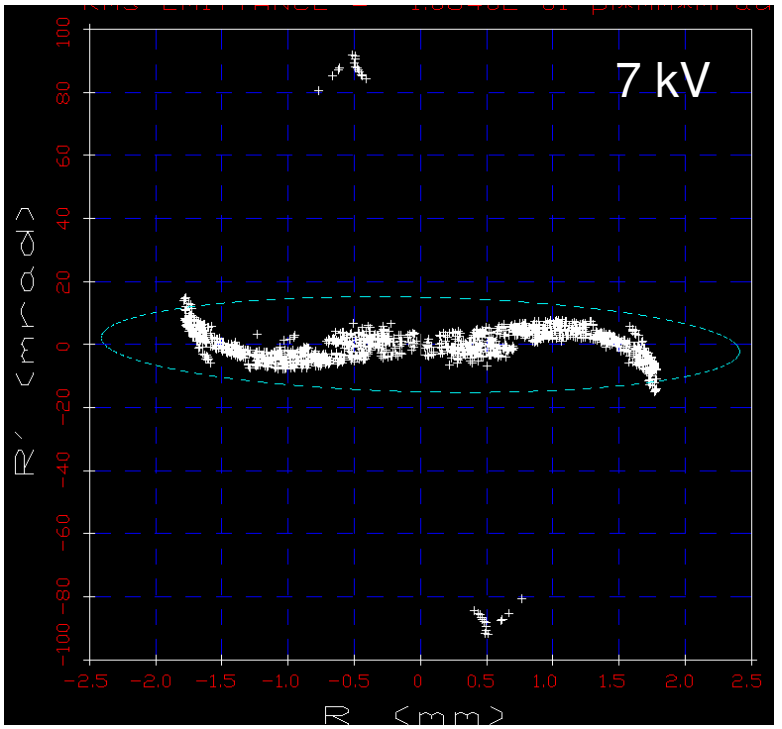
Limiting Aperture Added in Enizel Lens





Comparison between Different Current Level





	20 kV	7 kV
Current (mA)	34.9	6.7
RMS Emittance (π mm mrad)	0.23	0.11
α	1.43	0.14
β	0.047	0.161
γ	63.84	6.35

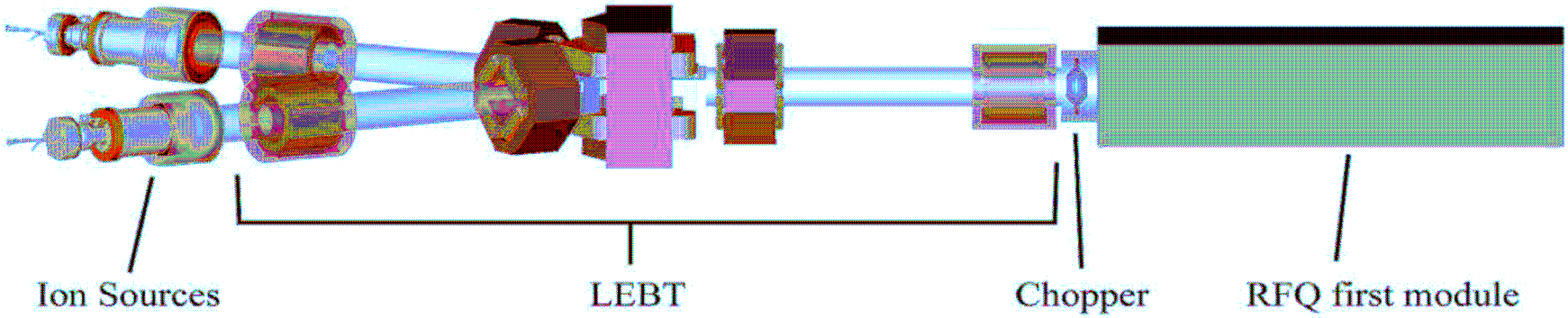
Limiting Aperture: Not an elegant solution

- Use PBGun to simulate the beam modulation
- Case 1: “one H- ion source and LEBT with a limiting aperture”
  - TWISS parameter of the beam varies with different voltage settings
    - Matching with RFQ becomes a problem
  - Sputtering of the limiting aperture
    - Lifetime of the limiting aperture

⇒ Not an elegant solution

Bending Magnets for Switching between Two Beams

B. X. Han and M. P. Stockli, "THE NEW LEBT FOR THE SPALLATION NEUTRON SOURCE POWER UPGRADE PROJECT" Proceedings of PAC07, Albuquerque, New Mexico, USA



- Magnetic LEBT:
  - spark free
  - durable to uncontrolled beam losses
  - Transport high current H- beam with space charge neutralization
- Switching between two beams
  - Field in bending magnets ~ 1000 Gauss

Tasks for Next Month

- Benchmark WARP 3D (in progress)
  - Start with SNS LEBT design
  - Compare WARP 3D simulation with PBGun simulation and SNS experimental results.
- Continue to assess the possibility of modulate beams (0.5 ms pulse ramping) using bending magnet