1. **Pulse line ion accelerator: recent progress**

2. **How might NDCX-I tests (e.g., what we learn from combined radial and longitudinal compression and focusing) affect the various options for WDM drivers?**

Peter Seidl

Lawrence Berkeley National Laboratory

and the

Heavy Ion Fusion Science Virtual National Laboratory

VNL-PAC

LBNL

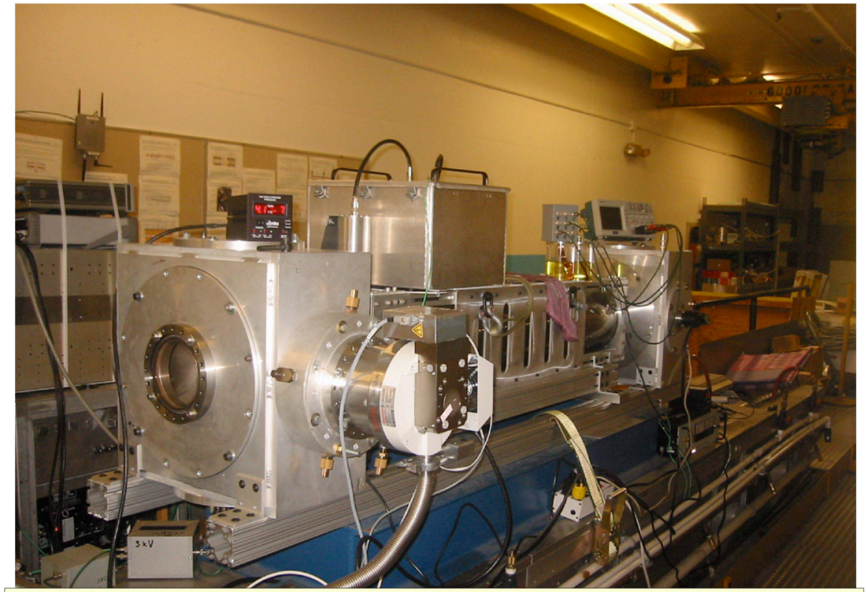
February 22, 2006

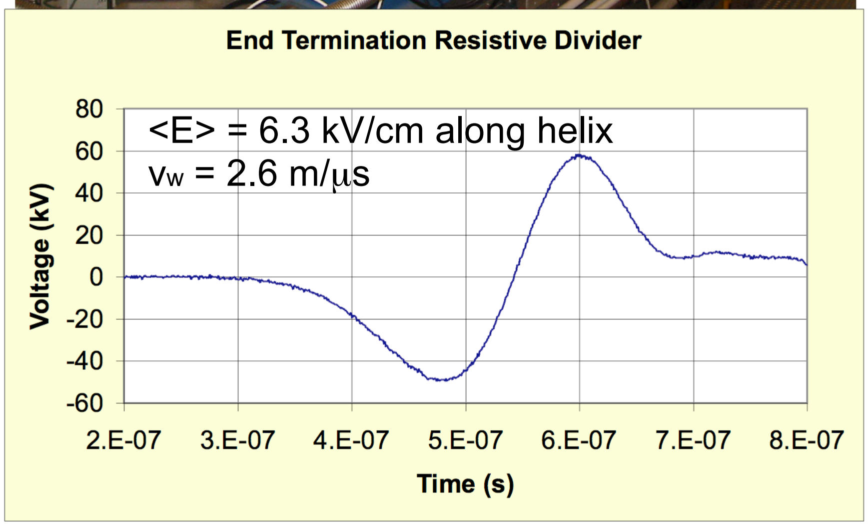
1. PLIA: Progress to date and plan for next 6 months.

1. Since August 2006 (effort level < 0.5 FTE.)
   a) Tests with oil dielectric helix, Pyrex insulator: Pulser filter & damping prevents primary current reversal --> only occasional partial discharges.
   b) Gradient improved to 6 kV/cm and presently limited by pulser.
   c) Mechanism causing "partial discharges" has not been identified.
2. The plan through August 2007 is (effort level ≈ 1 FTE):
   a) Scaled helix assembly: test the partial discharge dependence on various configurations (grading rings, external solenoidal field, direct drive, etc.).
   b) Modifications & testing to demonstrate gradient > 10 kV/cm.
   c) NDCX-2: Physics and cost comparison of using PLIA vs a fully induction acceleration based facility.

Enables key decisions regarding PLIA beam experiments & NDCX-2 design

Oil dielectric & Pyrex insulator - added diagnostics, bench test setup for gradient improvements

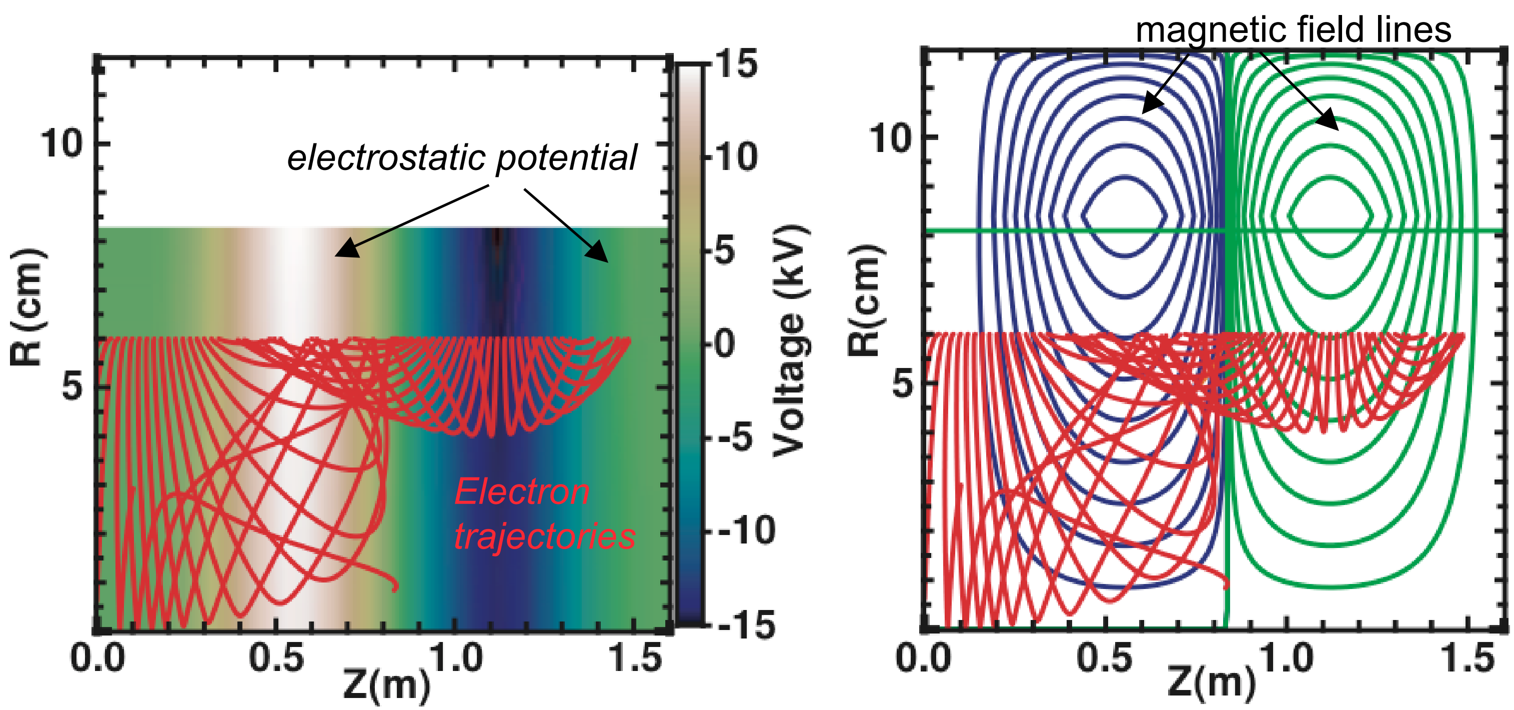




- **Additional diagnostics: E-dots every 10 cm, primary V and I monitors.**
- **New pulser circuit: filter to eliminate high level ringing @ ≈30 MHz (20x fundamental frequency), damping prevents primary current reversal --> occasional discharges.**
- **Gradient improved. Presently @ ≈ 6 kV/cm and limited by pulser.**

Mechanism(s) causing the "partial discharges" in the PLIA have not been identified

Data so far do not show "fundamental limit" on gradient suggested by adverse secondary electron orbits (test particle simulations).



Snapshot of electron traces in wave frame 50.5 ns after launch at 2 cm increments.

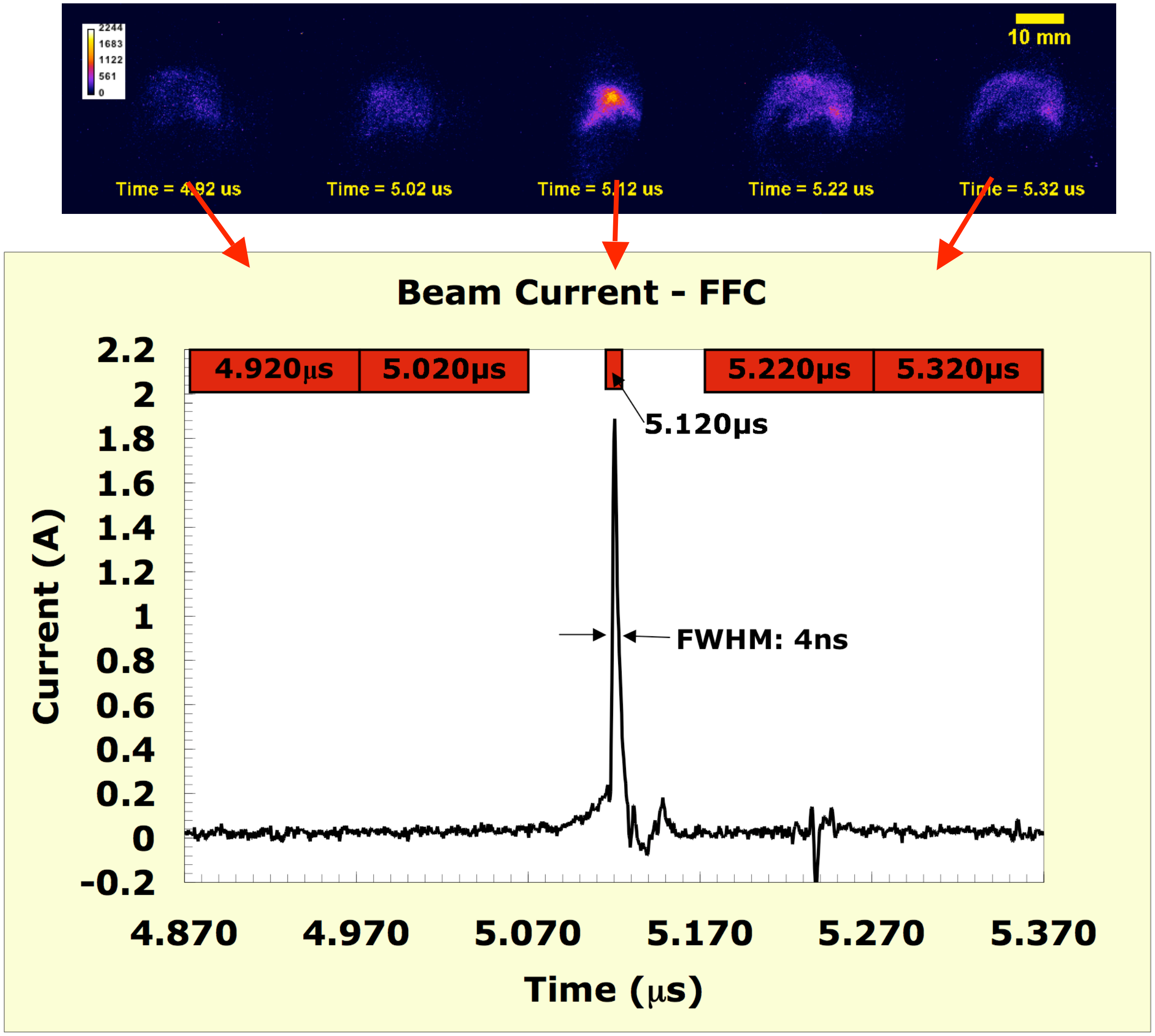
Likely that high level ~ 30 MHz ringing in the previous pulser had deleterious effects.

2. Recent, near term NDCX: test beam manipulations common to all three WDM designs.

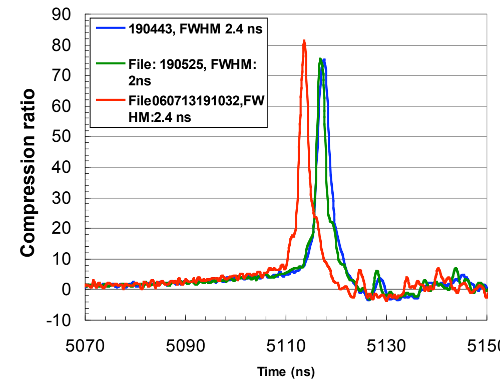
1. Simultaneous longitudinal bunching and transverse focusing
   a) 2-4 ns FWHM, 2x reduction in transverse spot size (now 4-mm FWHM). Consistent with model predictions.
2. High field final focusing solenoid
   a) Sub-mm spot size (from 4-mm above).
   b) How to inject high-density plasma near target and in solenoid field?
3. Bunching module waveform upgrades
   a) 100 - 250 bunching ratio suggested by simulations.
   b) HV holding, waveform fidelity.

Simultaneous transverse and longitudinal compression experiments

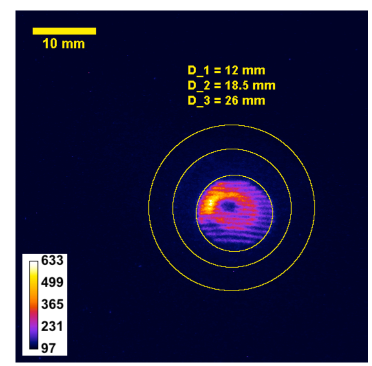
Filtered cathodic-arc plasma source



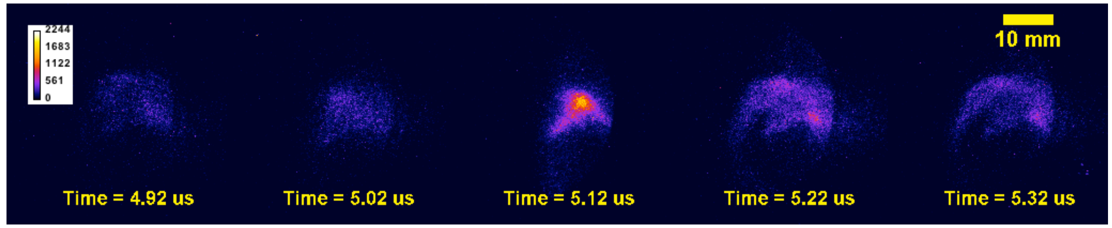
Ferro-electric plasma source

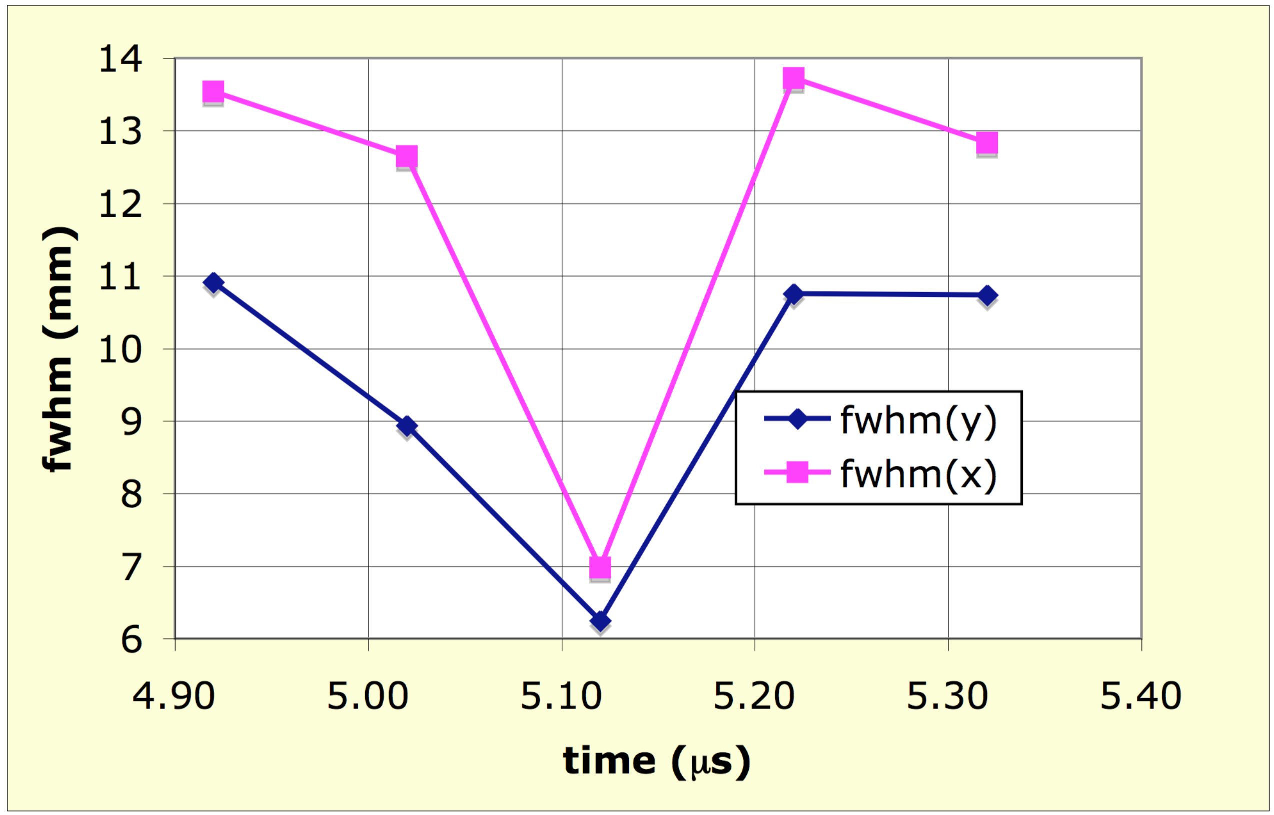


non-uniformity? Might be partly caused by non-ideal beam upstream of IBM



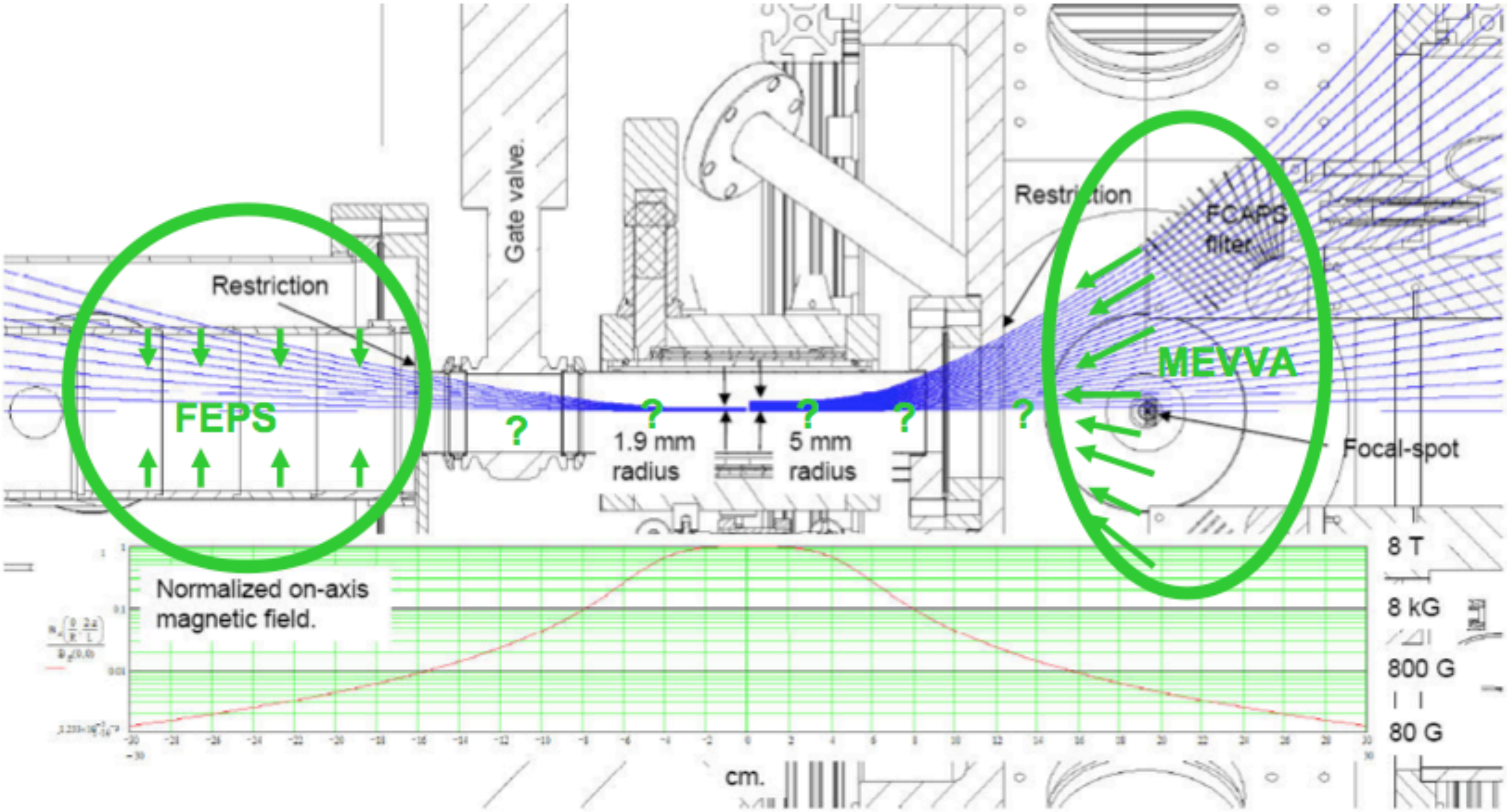
Minimum spot size @ same time as peak compression





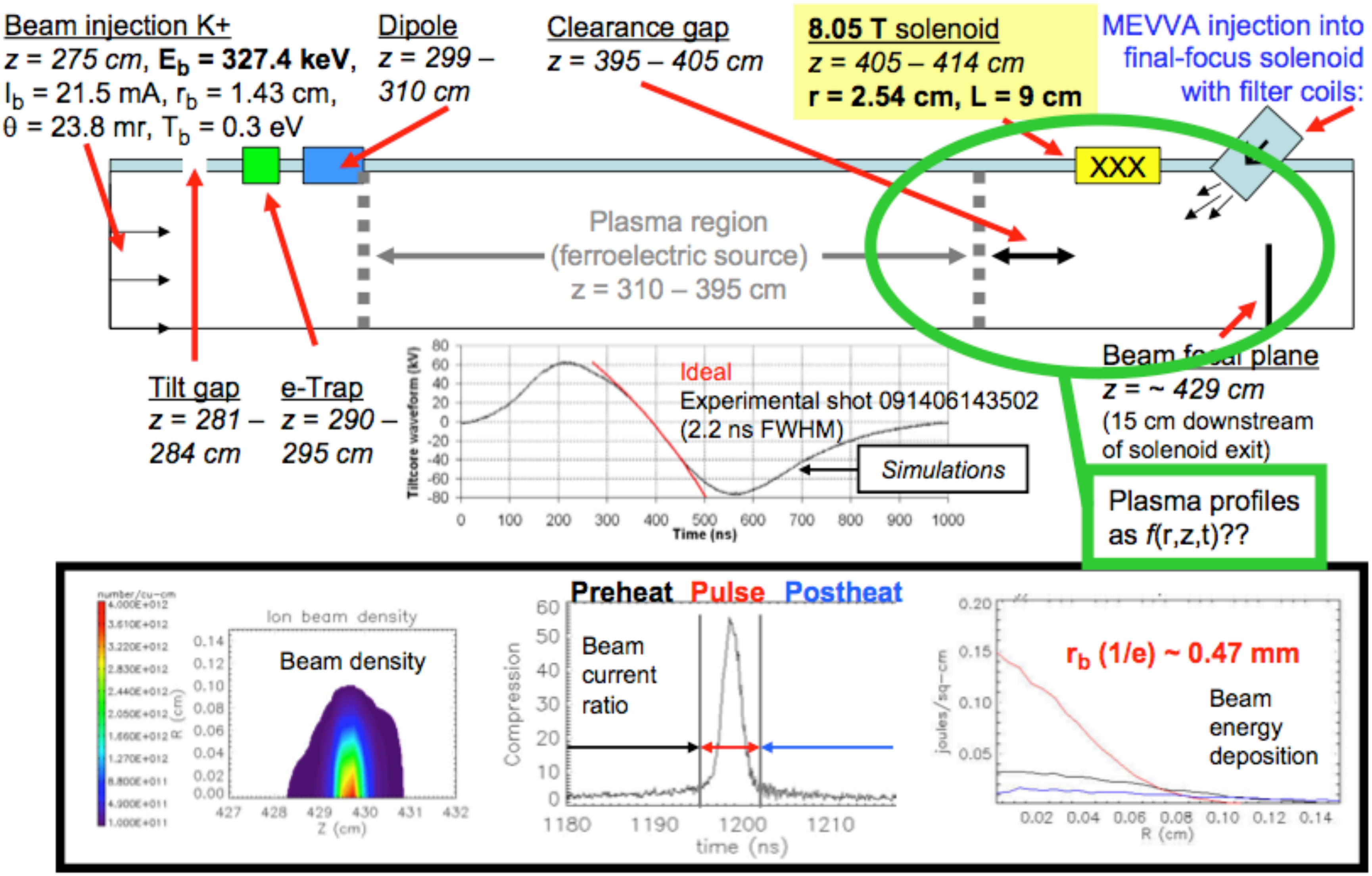
2X reduction in the spot size (4X increase in beam intensity) brings the peak beam density to the range $n_b \approx 10^{11}$ - 10^{12} cm^{-3}.

Setup of NDC with high field solenoid

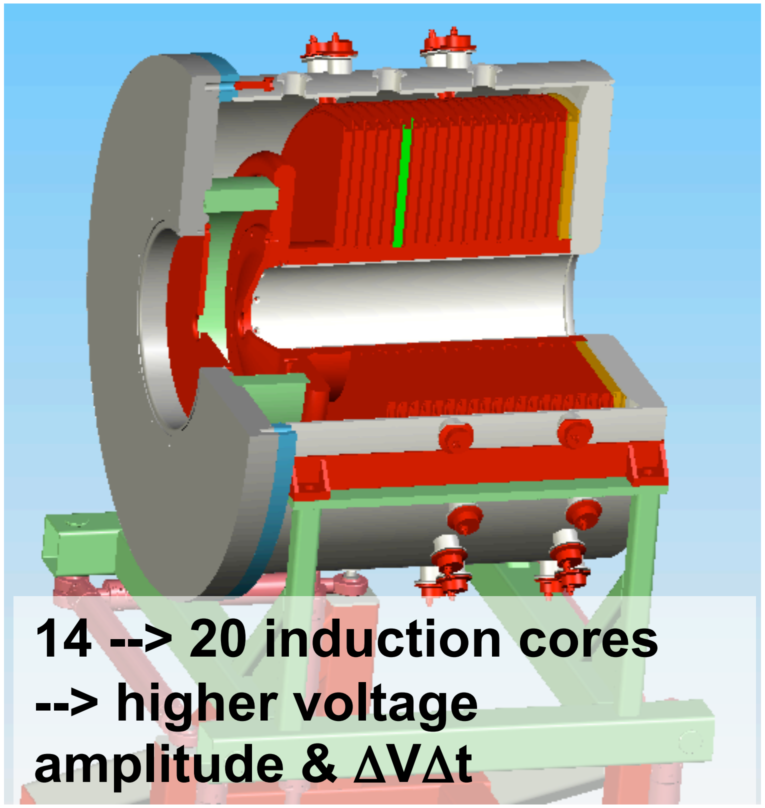


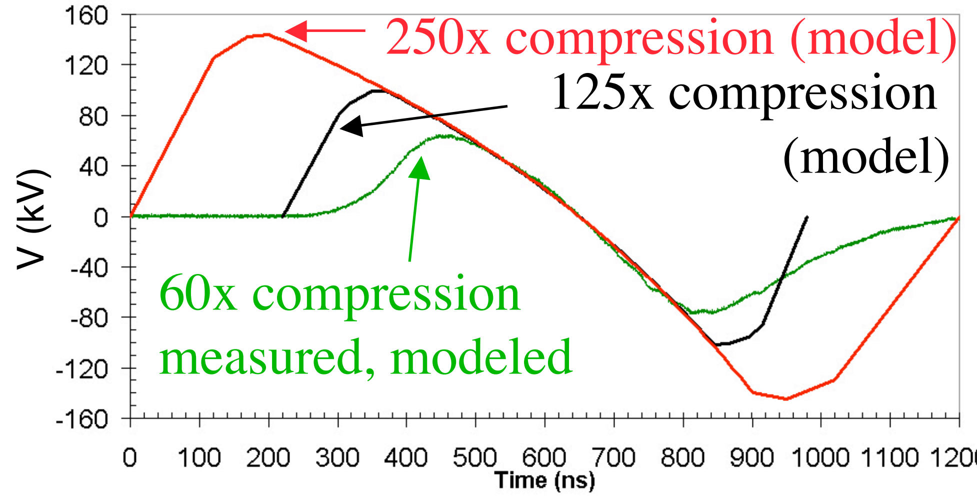
Simulation of both plasma sources operating near the 8.05T final-focus solenoid, using fully kinetic and explicit particles with electromagnetic fields .

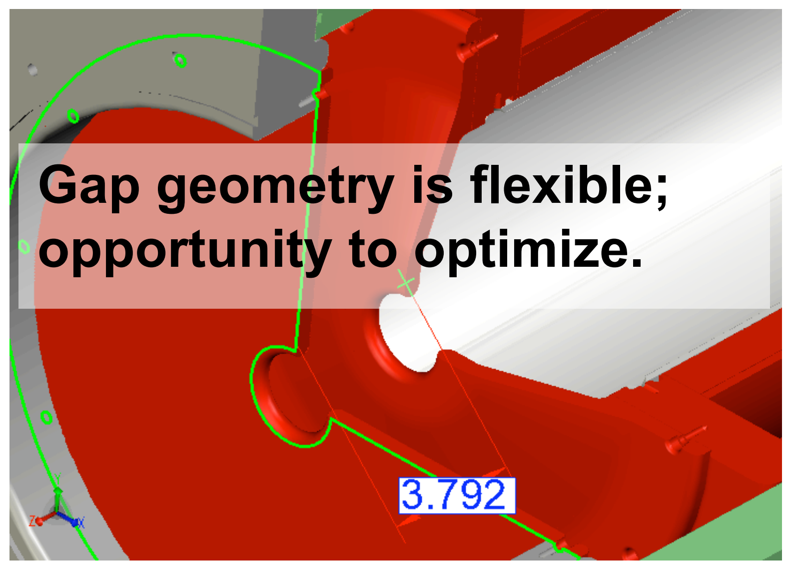
NDC with high field solenoid



A new bunching module will increase the voltage amplitude and voltage ramp duration

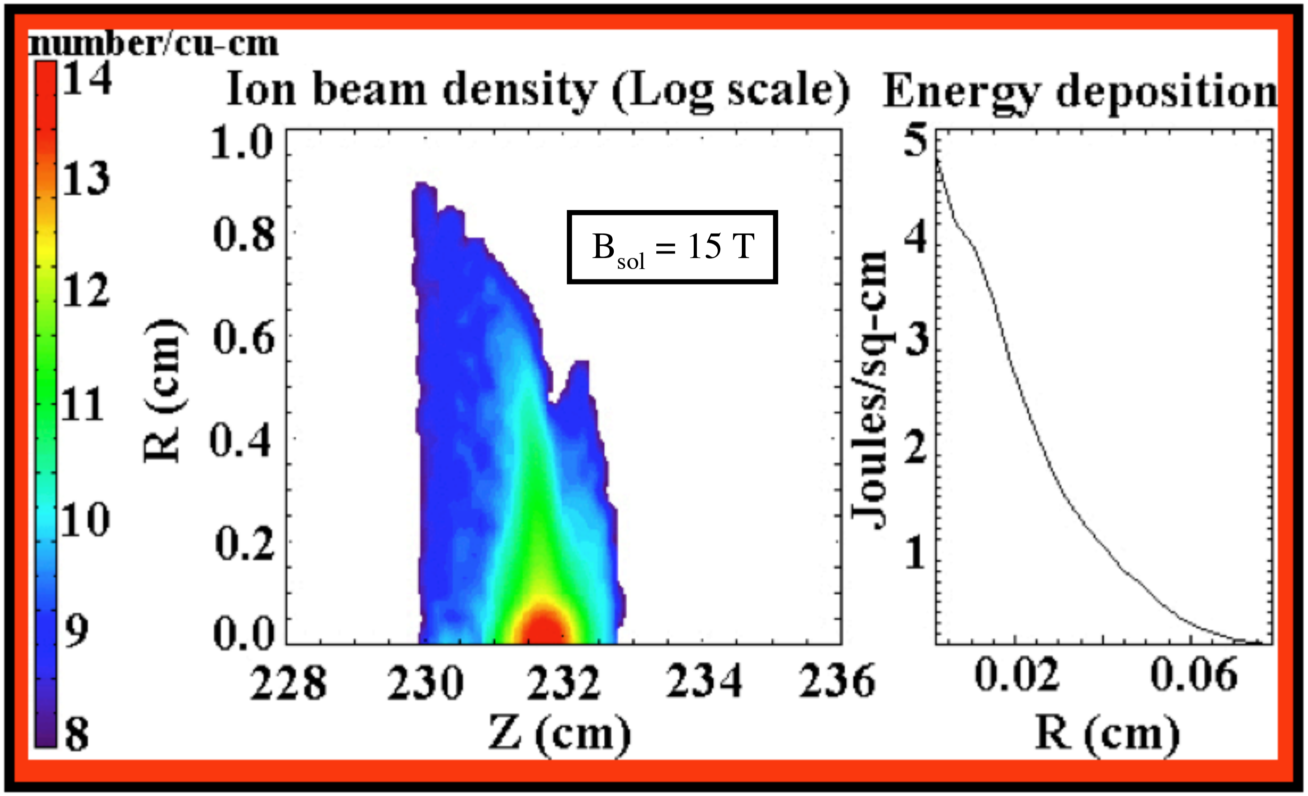






Beam experiments in 2007.

Simulations of compression with new IBM



Simulation above: **400 keV K^+, 80mA --> 20A (250X),FWHM 2.3 ns, f = 2.50 m**

- **Idealized initial transverse and longitudinal temperature ≈ 0.2 eV,**
- **perfect bunching waveform.**

For a final-focus solenoid with B = 8 Tesla: r_b @ focal plane = 0.5 mm
Peak beam density $n_b \approx 7 \times 10^{13}/\ cm^3$. Energy deposition ≈ 2 J /cm^2

Some other critical issues distinguish between the 3 WDM drivers

- Li^+ ion source development is challenging; still a work-in-progress: emitter preparation, current density, emission uniformity & beam quality.

- The required target-heating uniformity for particular WDM experiments needs to be further quantified for beams that are on the peak, and off the peak of dE/dx. Relaxed requirements would allow heavier ions which are easier to fabricate and operate.

- Target preheat tolerances are being quantified for specific target experiments. Ideas for increasing the contrast ratio between the compressed bunch relative to the prepulse have been sketched out, but require further work.

- The modifications to the beam optics for injection of the 1.6 MeV HCX beam into an NDC channel require some study and simulation (eg: matching quadrupoles, beam diagnostics modifications).

Collaborators -

D. Baca,[a] F.M. Bieniosek,[a] J. Coleman,[a,f] R. C. Davidson,[d]
P.C. Efthimion,[d] A. Friedman,[b] E.P. Gilson,[d] D. Grote,[b] I. Haber,[c]
E. Henestroza,[a] I. Kaganovich,[d] M. Kireeff-Covo,[b,f] M. Leitner,[a]
B.G. Logan,[a] A.W. Molvik,[b] P.A. Seidl,[a] D.V. Rose,[e] P.K. Roy,[a]
A.B. Sefkow[a] W.M. Sharp,[b] J.L. Vay,[a] W.L. Waldron,[a] D.R. Welch[e]

[a]Lawrence Berkeley National Laboratory, Berkeley, CA 94720, U.S.A.
[b]Lawrence Livermore National Laboratory, Livermore, CA 94550, U.S.A.
[c]University of Maryland, College Park, MD 20742-3511 CA, U.S.A.
[d]Princeton Plasma Physics Laboratory, Princeton, NJ 08543-0451, U.S.A.
[e]Voss Scientific, Albuquerque, NM 87108, U.S.A.
[f]University of California, Berkeley, CA 94720, U.S.A.
[g]Universite ENS, Paris, France.