BaPSF: A flexible user facility for experiments at the frontier of fundamental plasma science

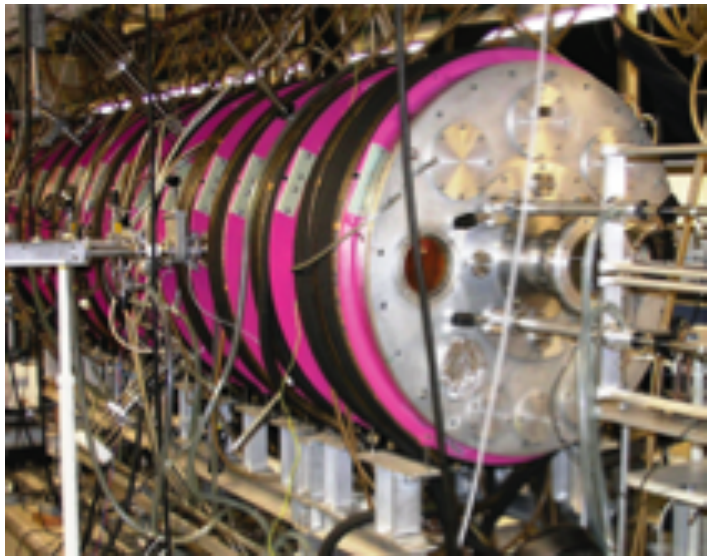
- The purpose of BaPSF is to provide the plasma science community access to frontier-level research devices (principally the LAPD) that permit the exploration of plasma processes which can not be studied in smaller devices or are difficult to diagnose in large fusion facilities.
- Example processes:
  - Alfvén waves, Alfvénic turbulence/instabilities
  - Magnetized collisionless shocks
  - Turbulent transport
  - Interaction of energetic particles with waves
  - Magnetic Reconnection/Flux rope interactions

The LArge Plasma Device (LAPD)

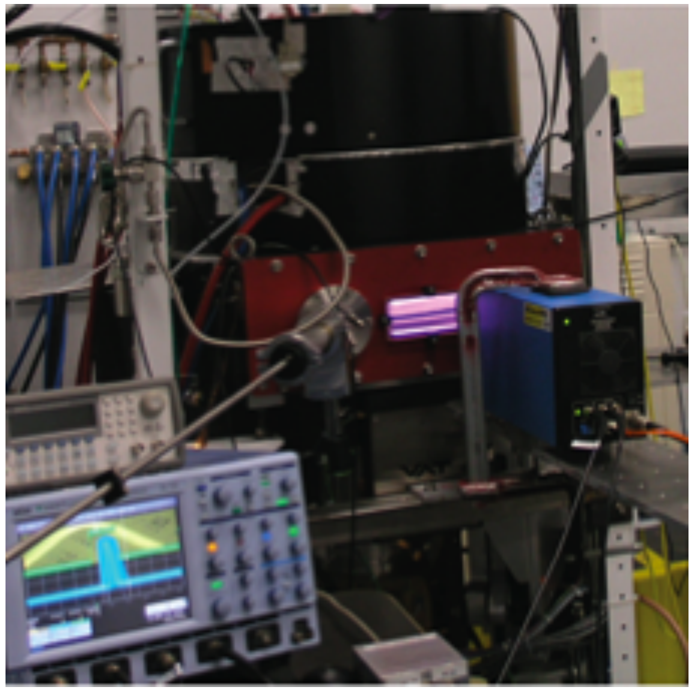
- Solenoidal magnetic field, cathode discharge plasma (BaO and LaB_6)
- BaO Cathode: n ~ 10^{12} cm^{-3}, T_e ~ 5-10 eV, $T_i \lesssim 1$ eV
- LaB_6 Cathode: n ~ 5×10^{13} cm^{-3}, T_e ~ 10-15 eV, T_i ~ 6-10 eV
- B up to 2.5kG (with control of axial field profile)
- BaO: Large plasma size, 17m long, D~60cm (1kG: ~300 ρ_i, ~100 ρ_s)
- High repetition rate: 1 Hz

Not just LAPD: Infrastructure for Plasma Research and Education at BaPSF

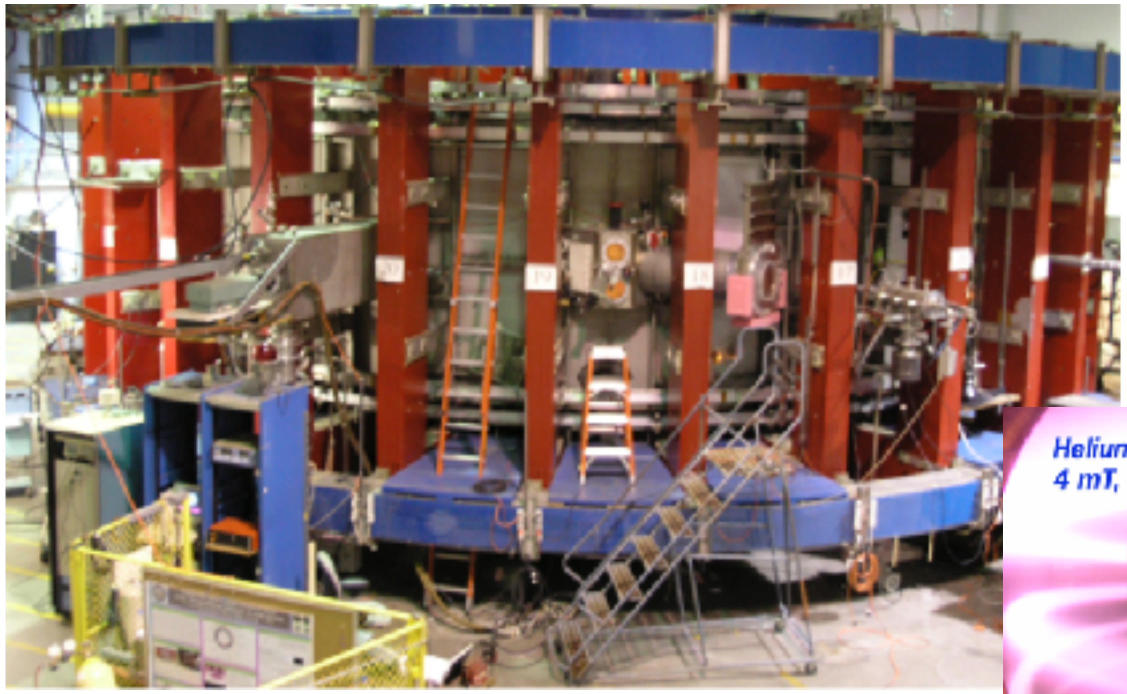
LAPD

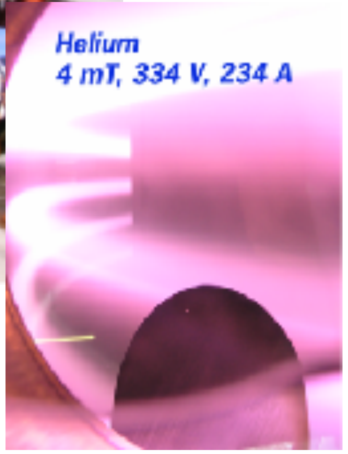


SMPD

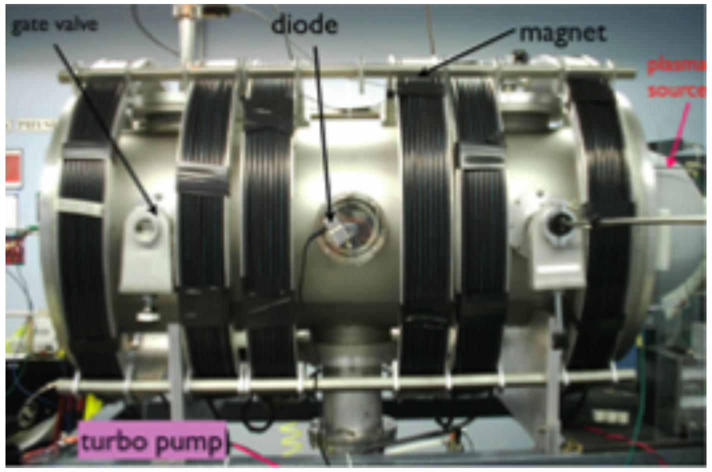


Industrial Etch Tool



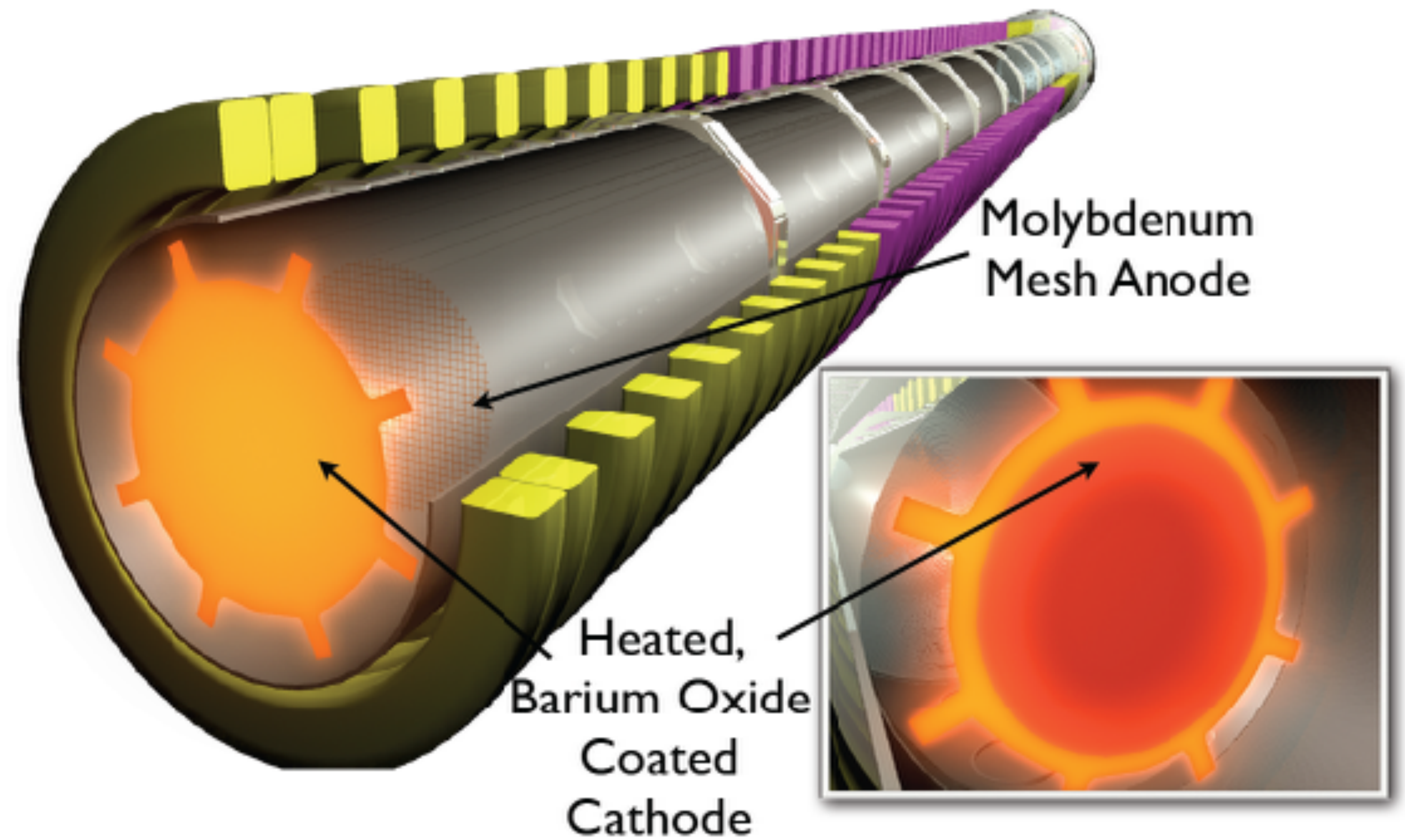


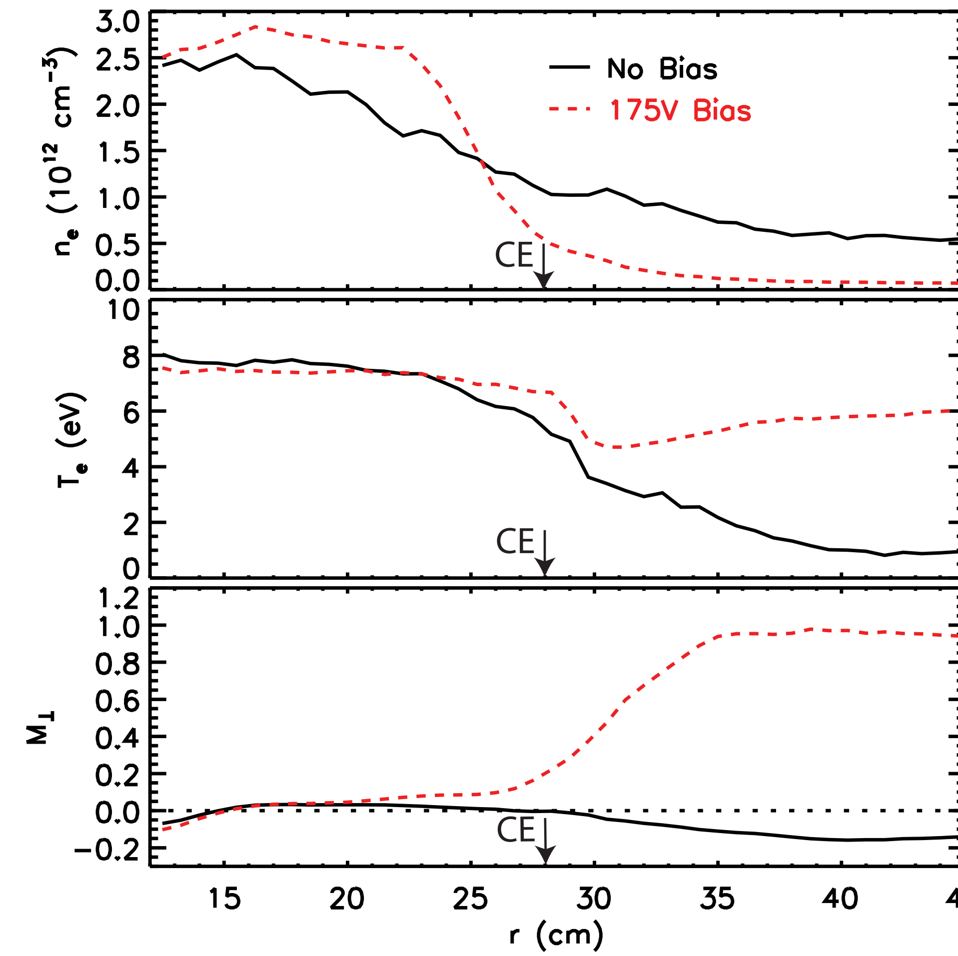
ETPD



High School Outreach Device

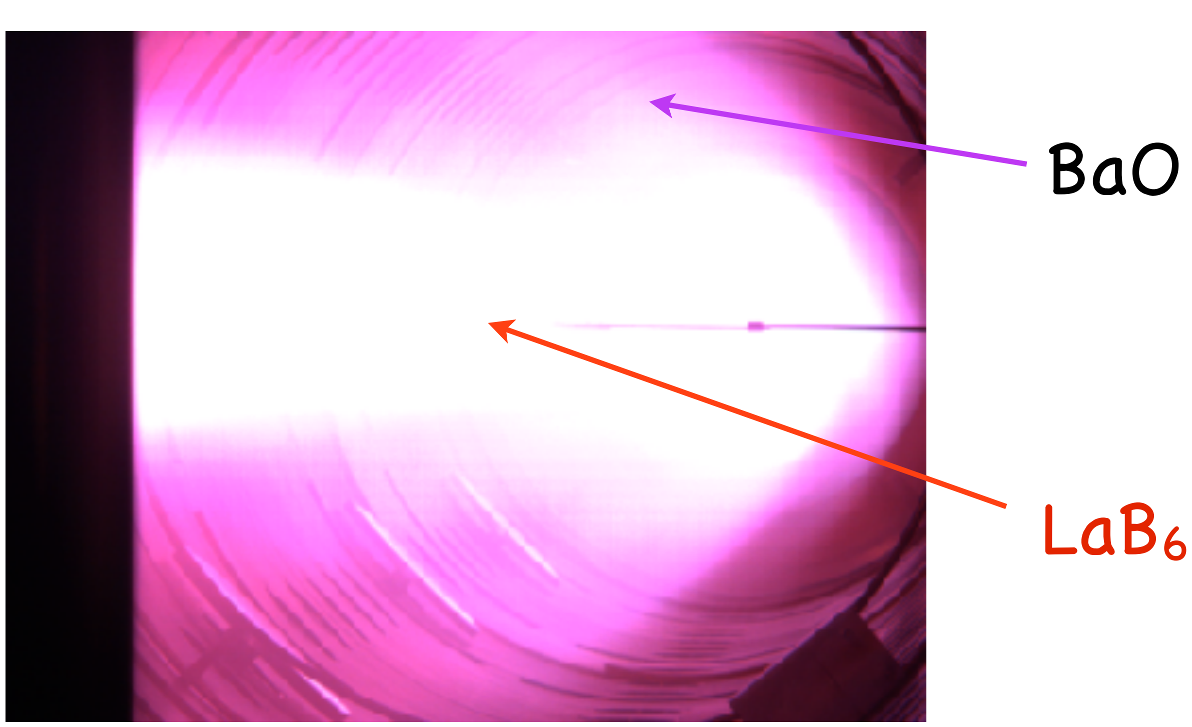
LAPD BaO Plasma source

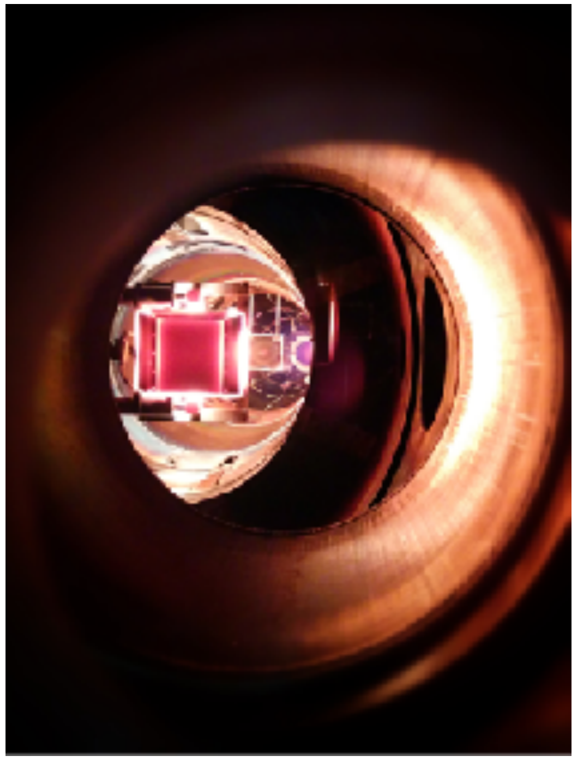




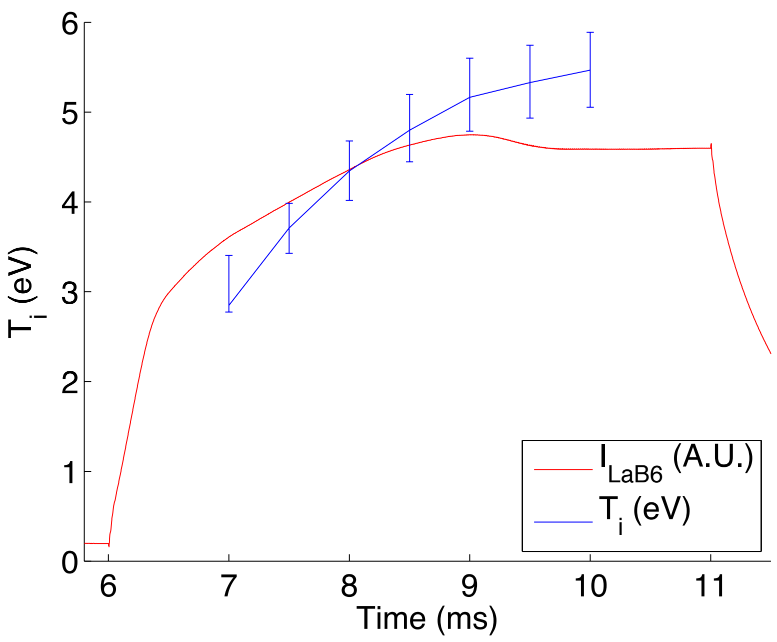
- Produces plasmas with 10-20 ms duration at 1 Hz rep rate
- $n \sim 10^{12}$ cm^{-3}, $T_e \sim$ 5-10 eV, $T_i \lesssim$ 1 eV
- Large quiescent core plasma (~60 cm diameter) for study of plasma waves, injection of ion/electron beams, etc.

LaB_6 Plasma Source: Hotter and denser plasmas in LAPD

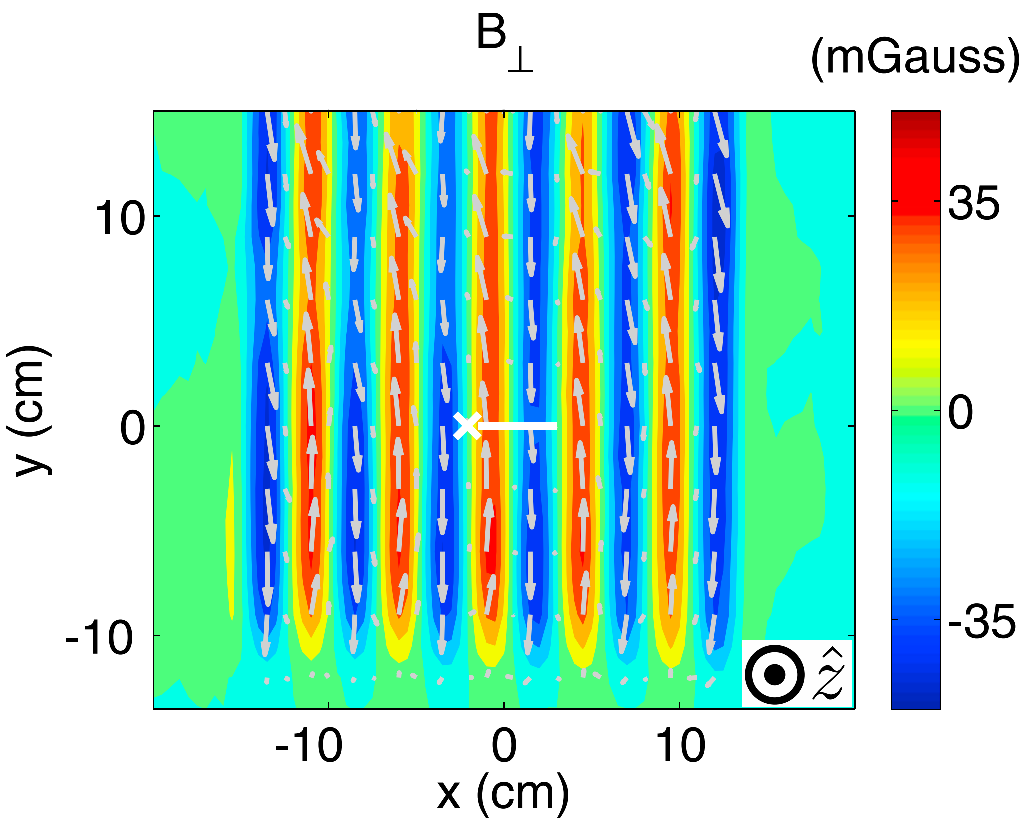


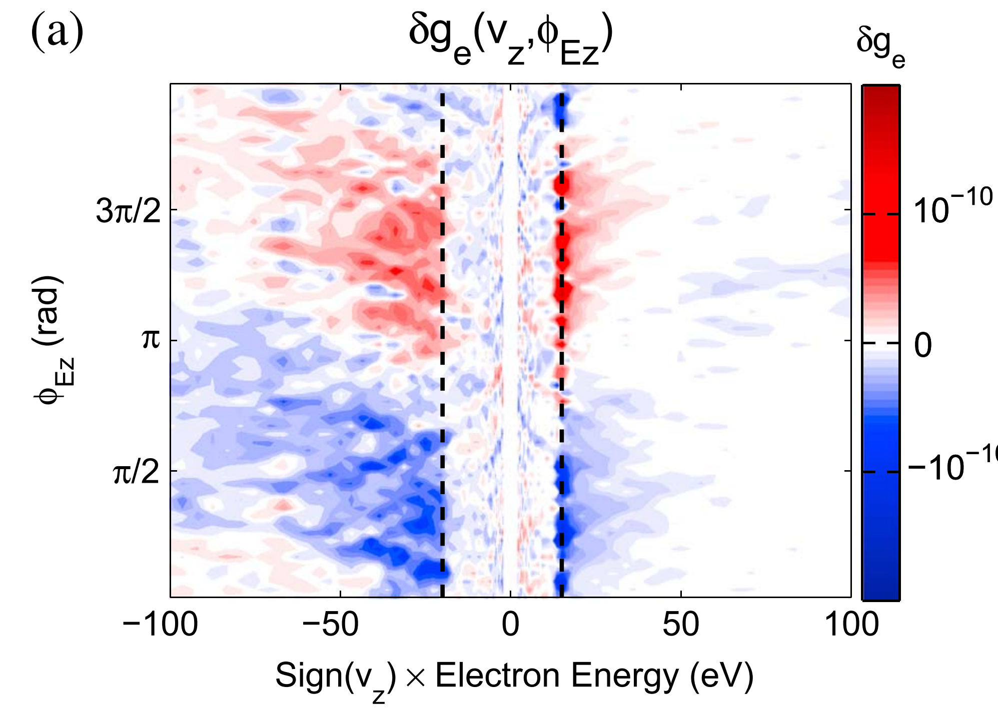


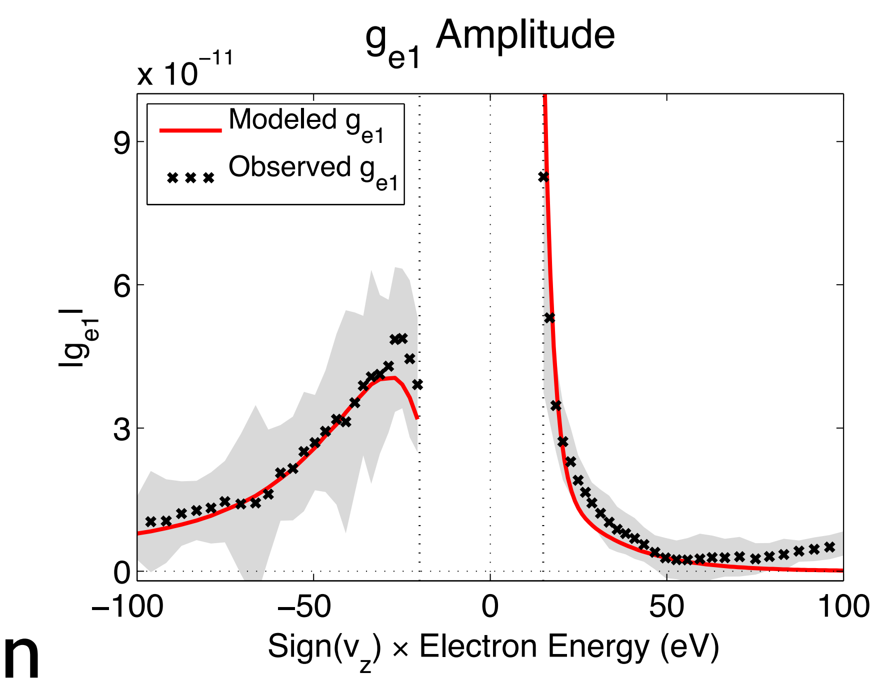
- Prototype LaB_6 source developed, installed in 2014 (small 20cm square at opposite end)
- Order of magnitude increase in density, hotter electrons and ions (through collisional coupling)
- **With lowered field, can get magnetized plasmas with $\beta \sim 1$.**
- **Major upgrade to LAPD in process: replace BaO cathode with large LaB_6**



Recent highlights: Electron response to inertial Alfvén wave





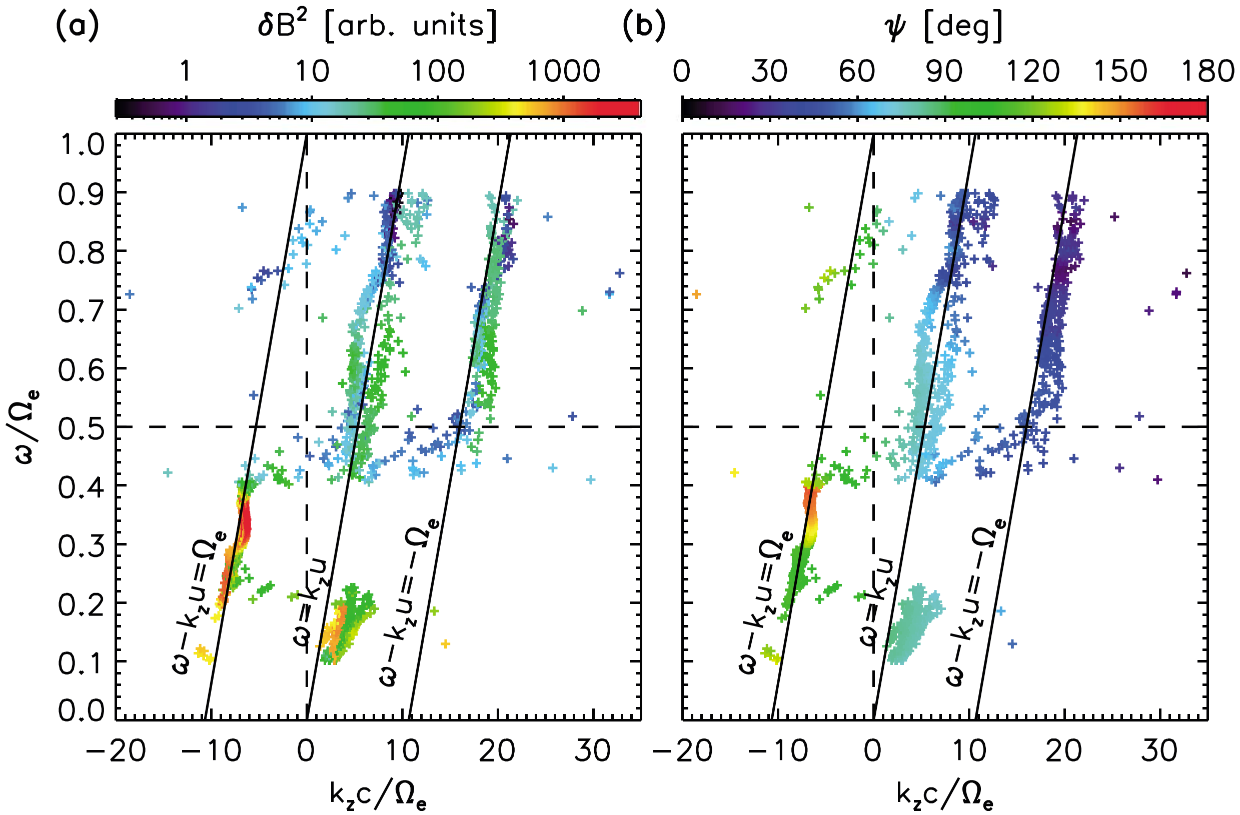


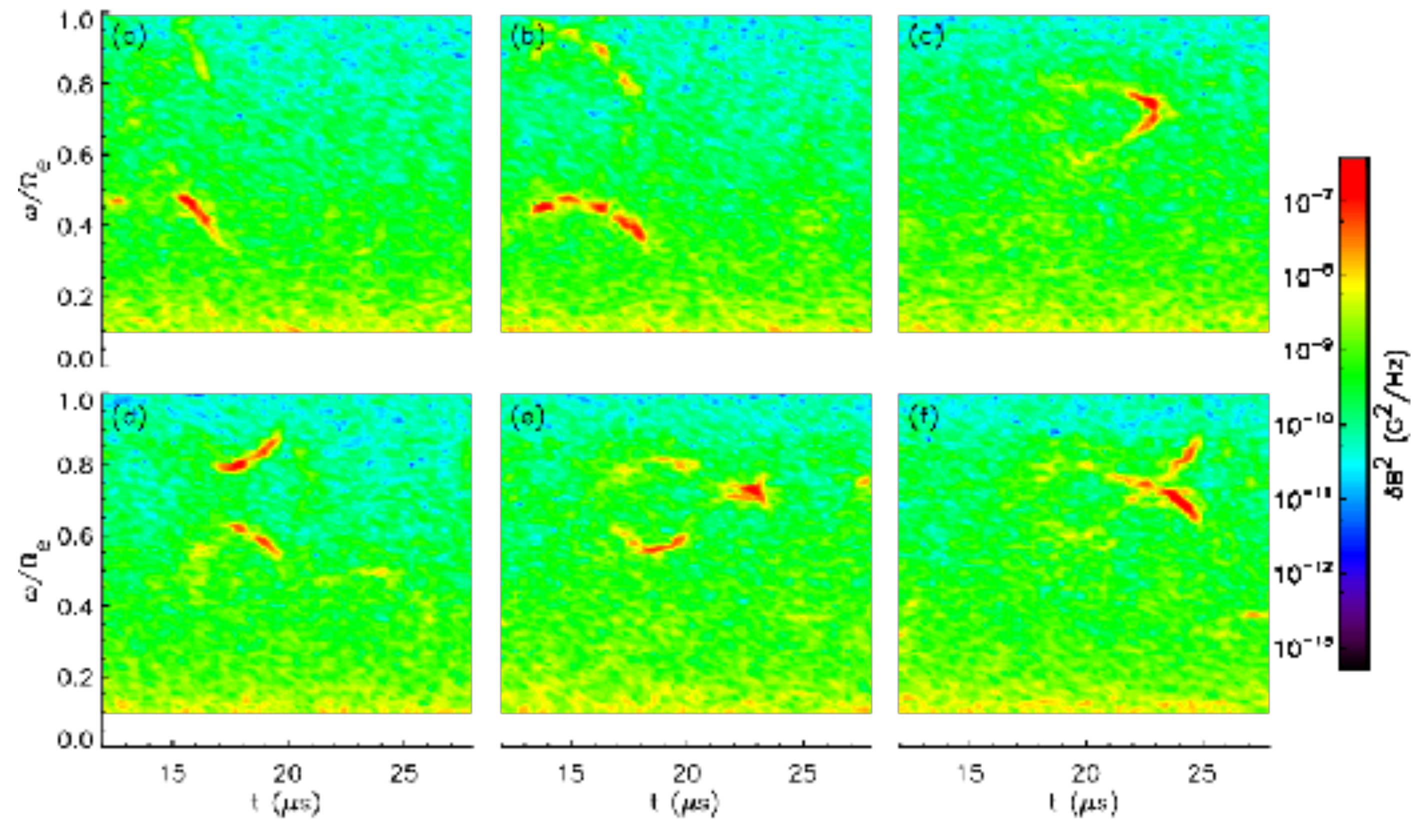
- U. Iowa group: interest in understanding electron acceleration by Alfvén waves; relevance to generation of Aurora

- Used novel electron distribution diagnostic (whistler wave absorption) to study oscillation in electron distribution function in presence of inertial AW

Schroeder, et al., Geophys. Res. Lett. 43, 4701 (2016)

Recent highlights: Whistler modes excited by energetic electrons

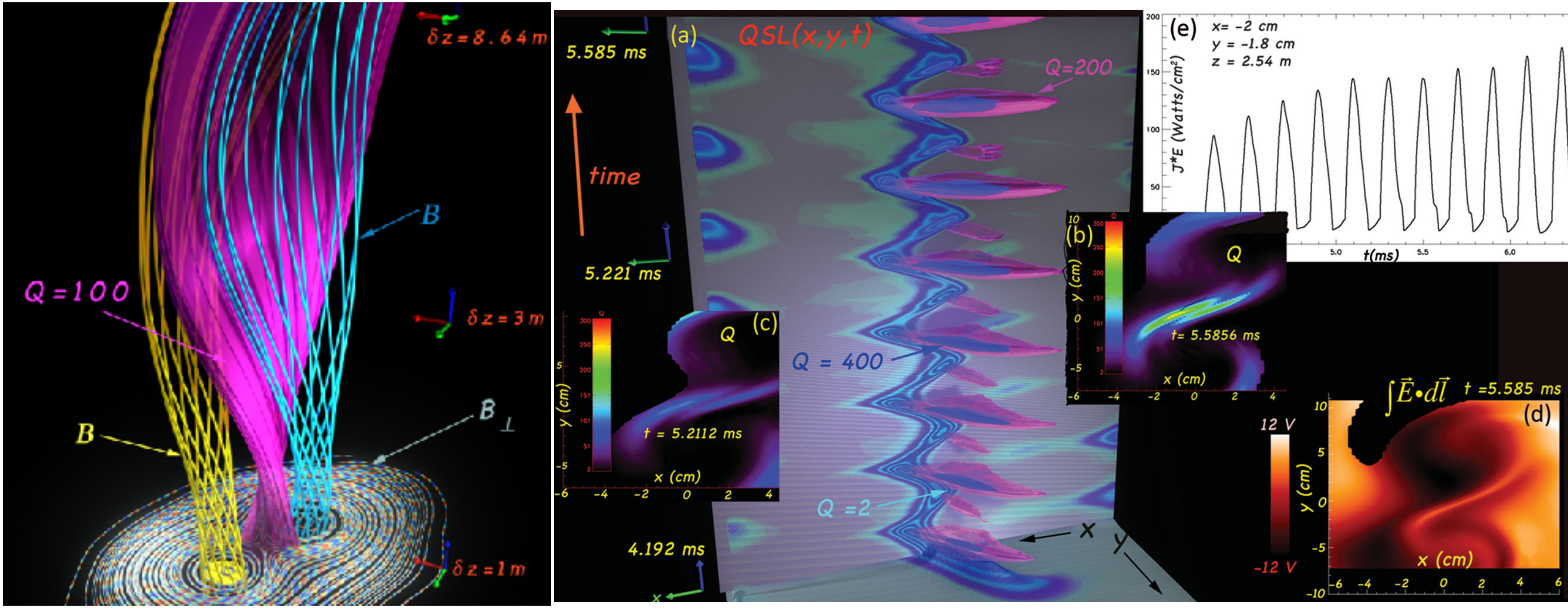




- Excitation of whistler waves by energetic electron beam (project led by J. Bortnik, R. Thorne)
- See “chirping” emission, similar to whistler chorus in magnetosphere (tied to transport/loss of radiation belt electrons)

X. An, et al., Geophys. Res. Lett., 43 (2016)

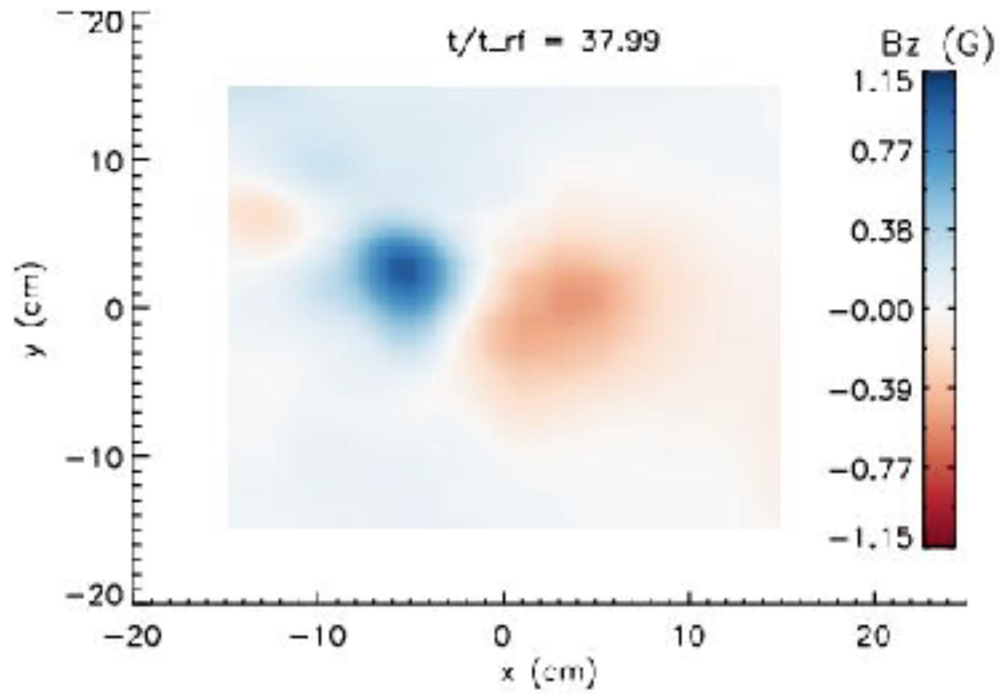
Recent highlights: Three-dimensional reconnection in flux ropes

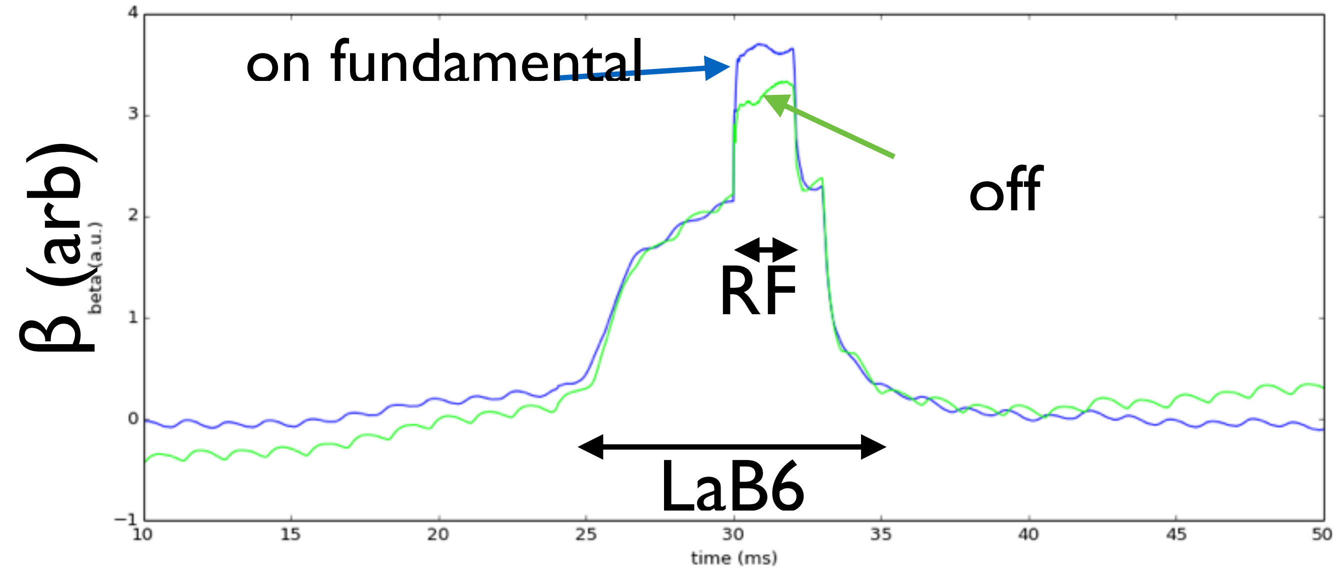


- Pulsating reconnection observed between magnetic flux ropes
- First time "squashing factor"/presence of QSL quantitatively linked to the reconnection rate

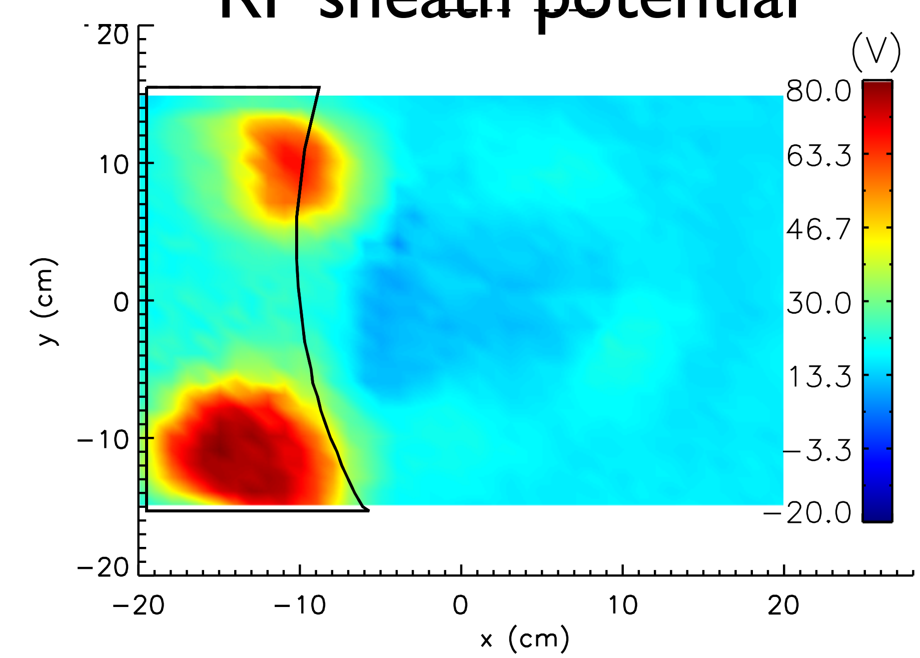
Gekelman, et al., Phys. Rev. Lett. 116, 235101 (2016)

Recent highlights: high-power ICRF experiments





- High power (~200 kW) RF driver and fast wave antenna
- Initial experiments: good coupling (~30G wave amplitude), some evidence of ion heating via fundamental minority resonance (H in He plasma)
- Measurement of RF sheath potential (Mike Martin)
- Ramp up of ICRF campaign, involvement from R. Perkins (PPPL), D.Van Eester, K. Crombe (Laboratory for Plasma Physics, ERM-KMS, Belgium)



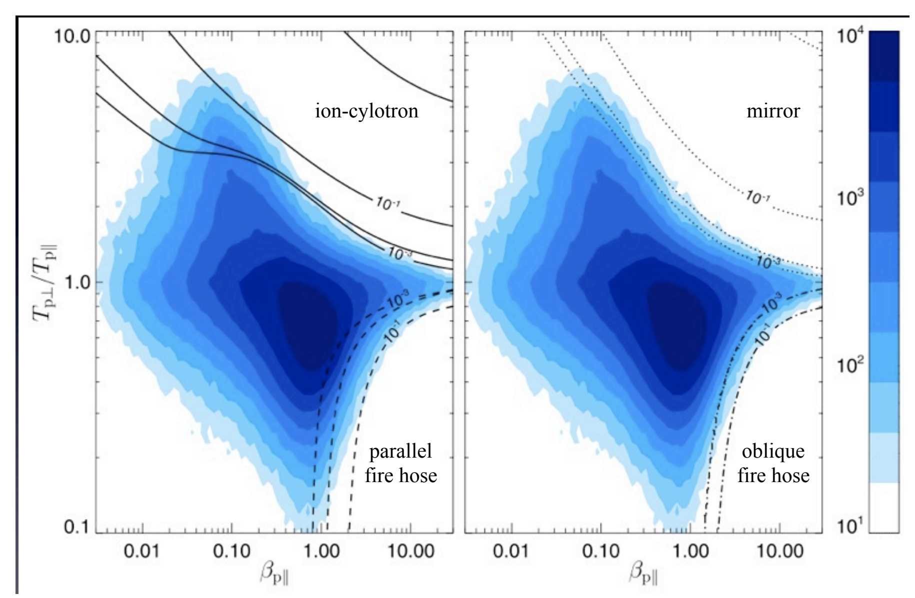
Three distinct categories of BaPSF Projects

- **Individual Users:** Single PIs who propose to use BaPSF to lead an experiment; BaPSF staff in support role.
- **Theory-driven Users:** Theoreticians propose an experiment; BaPSF staff are heavily involved in experimental design and lead execution of the experiment. Theoreticians are directly involved in data analysis and participate in data taking.
- **Campaigns:** Collaborative projects with participation from experimentalists, theoreticians, simulators, usually involving several institutions. **BaPSF resources are provided to support workshops and special hardware for these projects.**

Solar wind campaign: physics of $\beta \sim 1$, warm ion plasmas

- Kinetic instabilities, waves and turbulence at high plasma beta ($v_A \sim v_{th,i}$) with warm ions
- Warm ions provide opportunity to study ion kinetic effects in waves and instabilities: e.g. ion FLR effects on Alfvén wave propagation; ion cyclotron absorption; modification to nonlinear Alfven wave interactions
- With lower field, plasma beta can be increased substantially to study, e.g., modifications to Alfvén wave dispersion and damping (e.g. ion Landau/ Barnes damping). Can temperature anisotropy driven instabilities (mirror and firehose) be observed in these plasmas?

Campaign Leader: Greg Howes (U. Iowa)

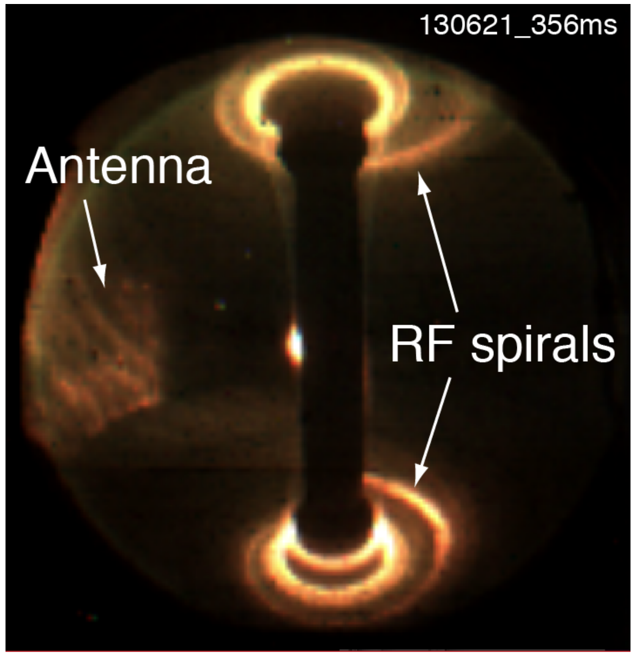


Our goal this workshop: to define this campaign and identify participants

Hellinger, et al., 2006

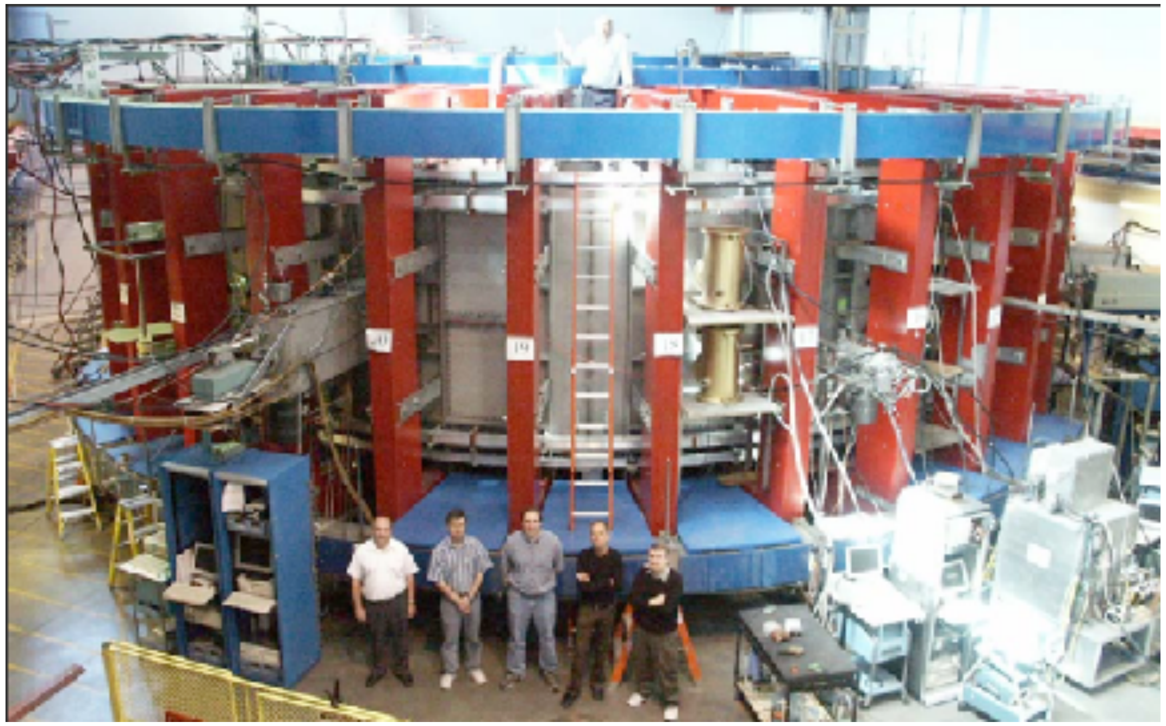
ICRF Campaign: Physics of fast waves

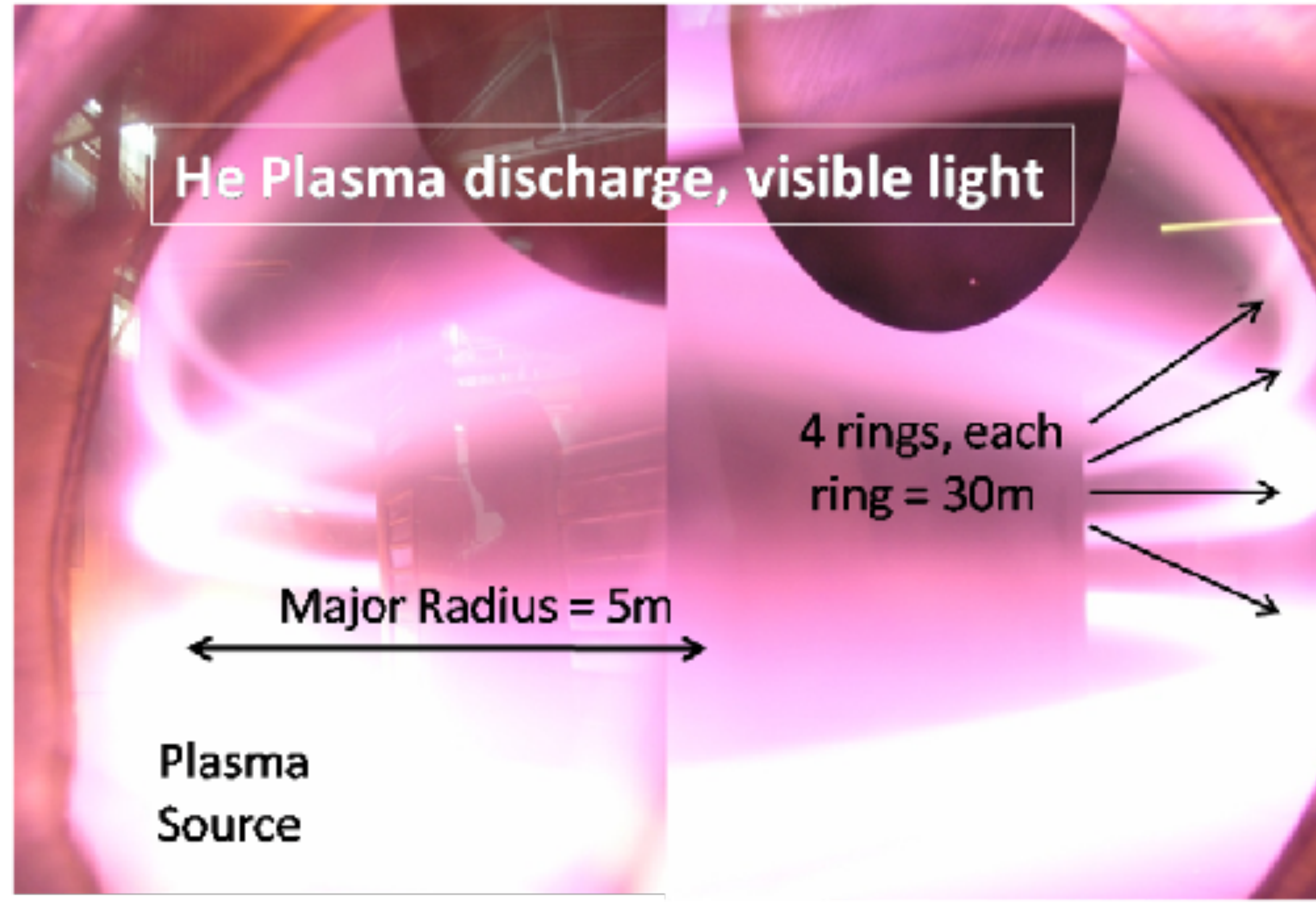
- Physics of RF waves for heating and current drive in laboratory (fusion) plasmas (enabled by higher density plasmas, high power RF drivers)
  - Novel heating schemes (two or three ion species), mode conversion physics, decay instabilities, interaction with drift waves/filamentary structures
  - Interaction with boundary plasma: RF Sheaths, mechanisms for edge losses
  - Helicon Wave Current drive — planned test of GA antenna design using LAPD
  - Validation of fusion RF codes



Campaign Leader: Rory Perkins (PPPL)

Enormous Toroidal Plasma Device at UCLA

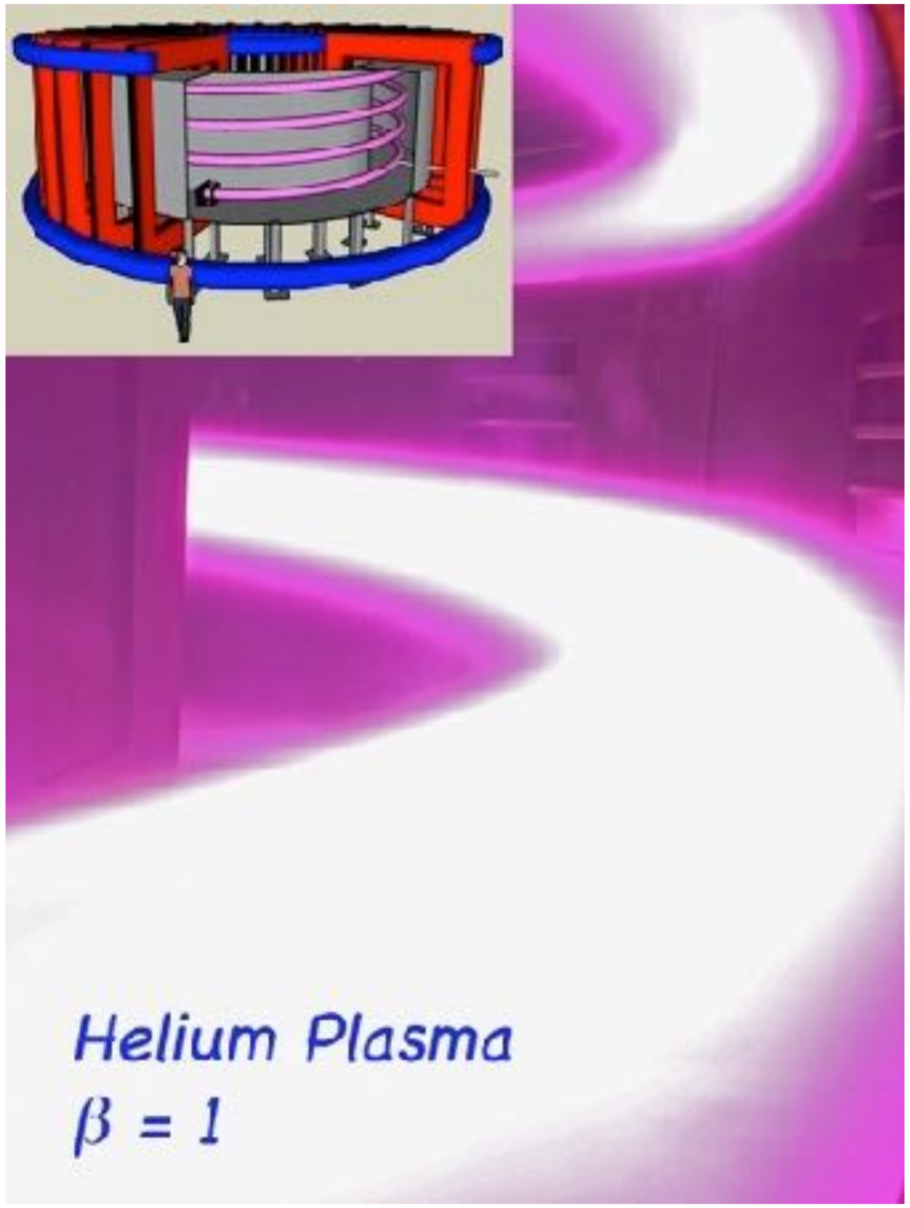


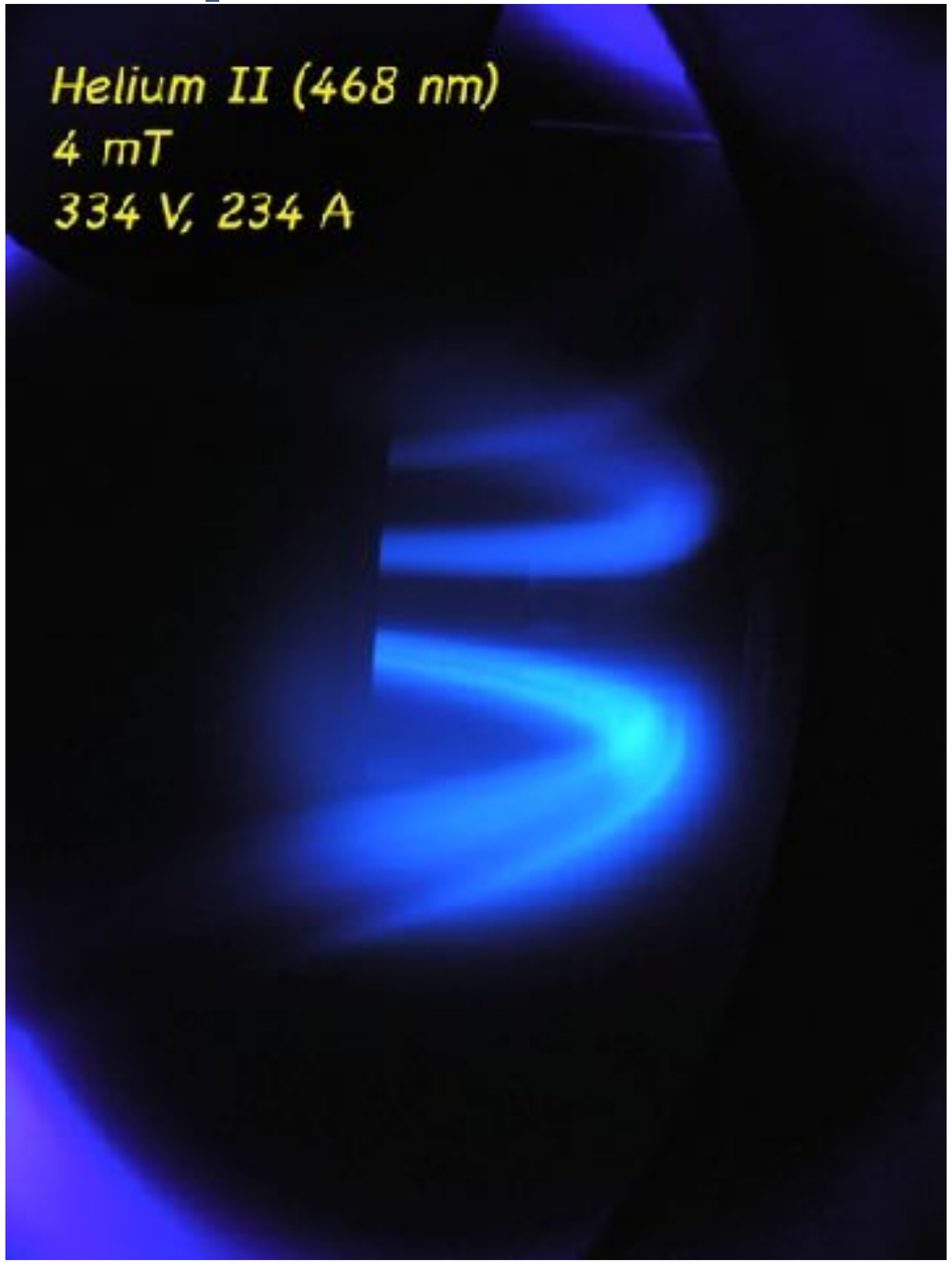


- Former Electric Tokamak, (5m major radius, 1m minor radius) operating now with LaB_6 cathode discharge into toroidal+vertical field

- Produces ~120m long, magnetized, high beta plasma (up to ~5×10^{13} cm^{-3}, Te, Ti ~ 15-30eV, B~200G, β ~ 1).

High beta, hot ion plasmas in ETPD





- $T_e \sim T_i \sim 20$ eV measured (passive spectroscopy of He II 4686 line).
- With lowered field, plasma beta of order unity is achieved with well magnetized ions