

Solenoid-free inductive startup with HHFW pre-ionization

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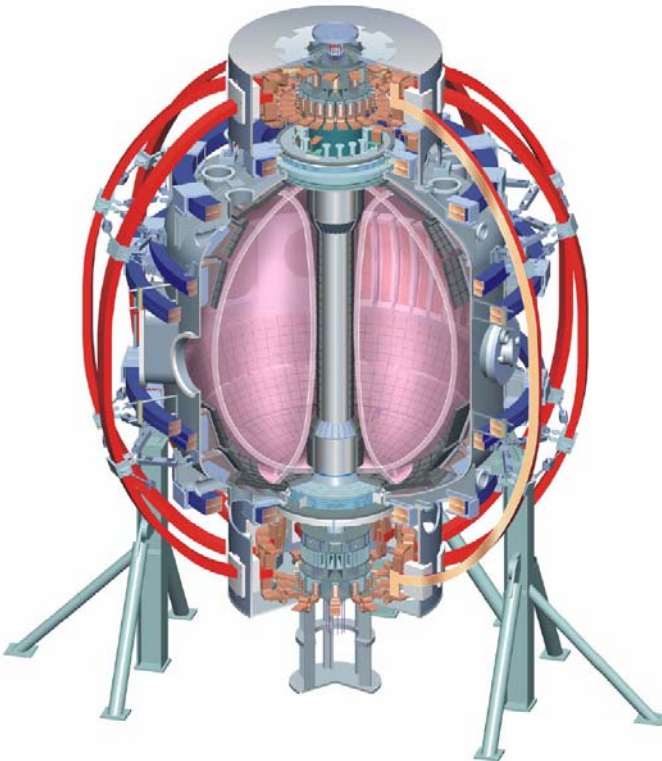
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**NSTX Results Review
for FY2004 Run**

**Princeton Plasma Physics Laboratory
Princeton, NJ
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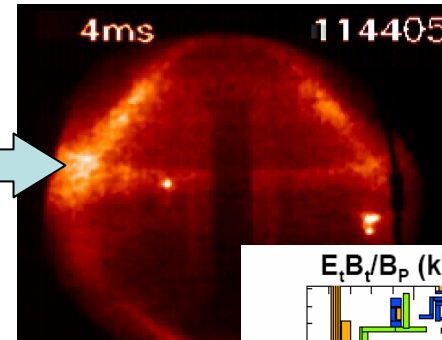
*Columbia U
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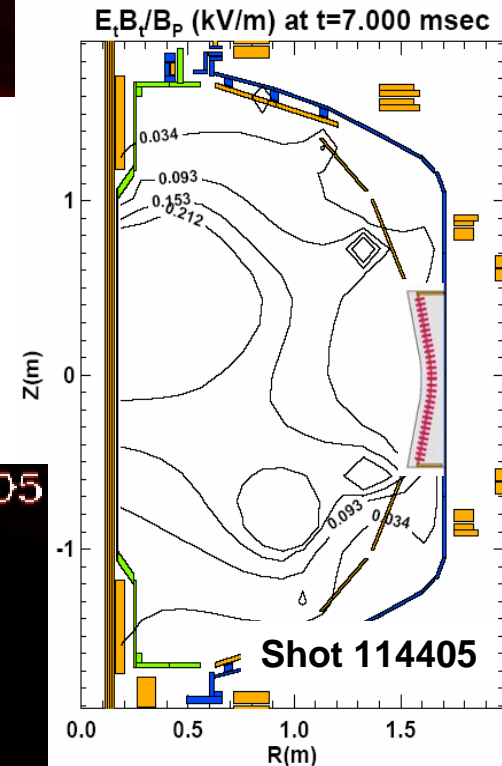
Solenoid-free tokamak formation in NSTX



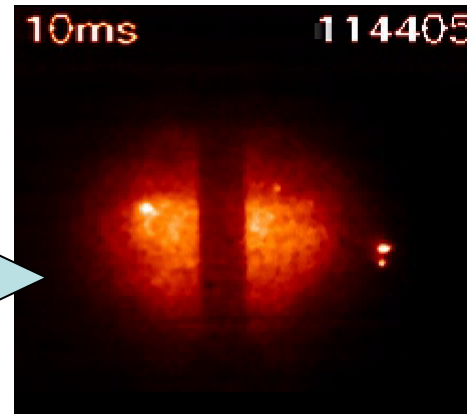
1. Pre-ionize plasma near RF antenna with ECH + 400kW HHFW, $n_{D_2} = 1-2 \times 10^{-5}$ Torr



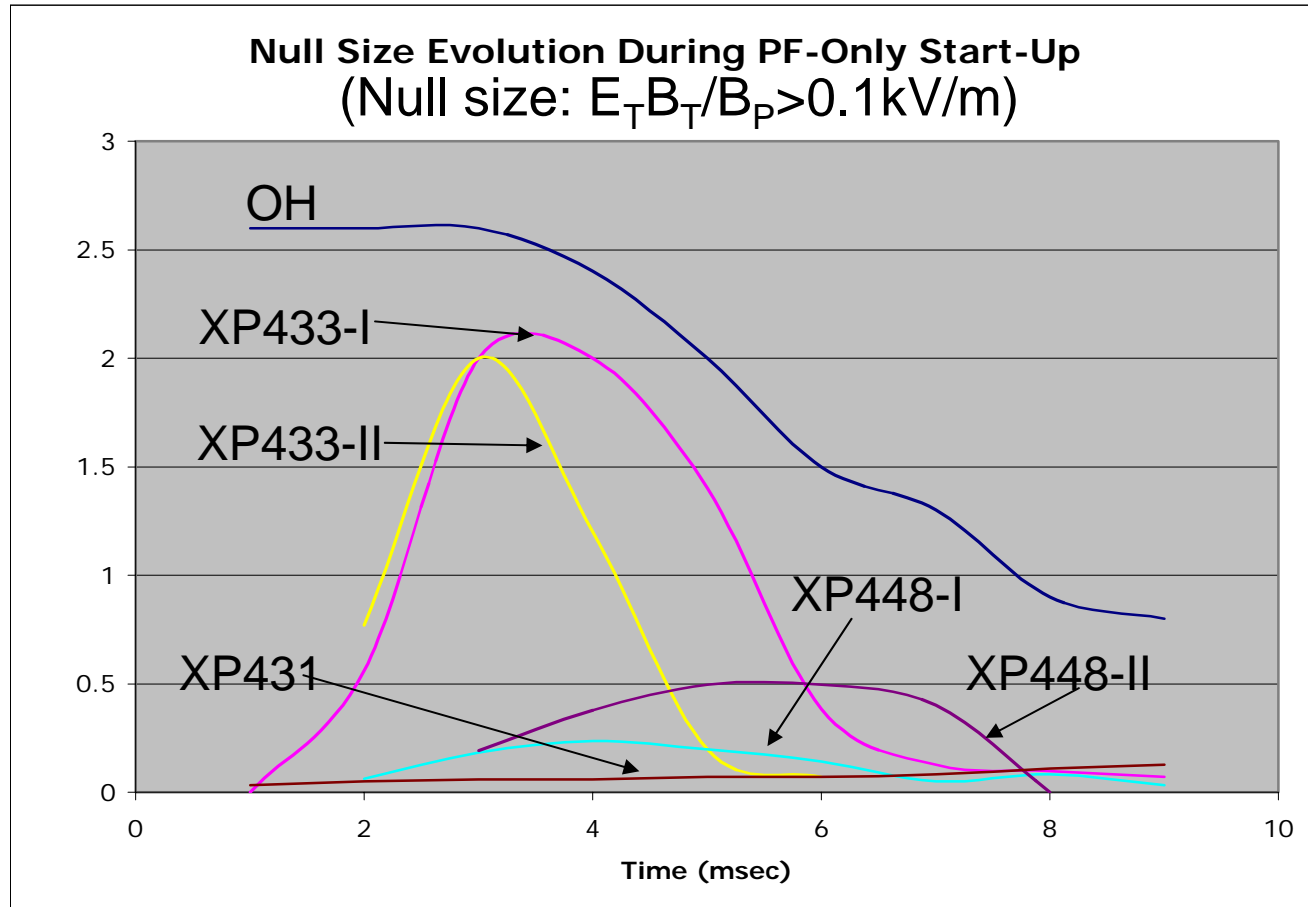
2. Create high-quality field-null with 5-15 loop-volts at antenna - So far, *require* $E_\phi B_\phi / B_p > 0.1 \text{ kV/m}$ over *substantial plasma volume*



3. Have created 20kA plasmas that terminate near center-stack



Successful initiation thus far requires a large null region



Successful initiation:

OH:112152, 4.5 kG

XP433-I: 113612, 3.5 kG

XP433-II:114405, 3 kG

Unsuccessful initiation:

XP431: H:11293, 4.5 kG

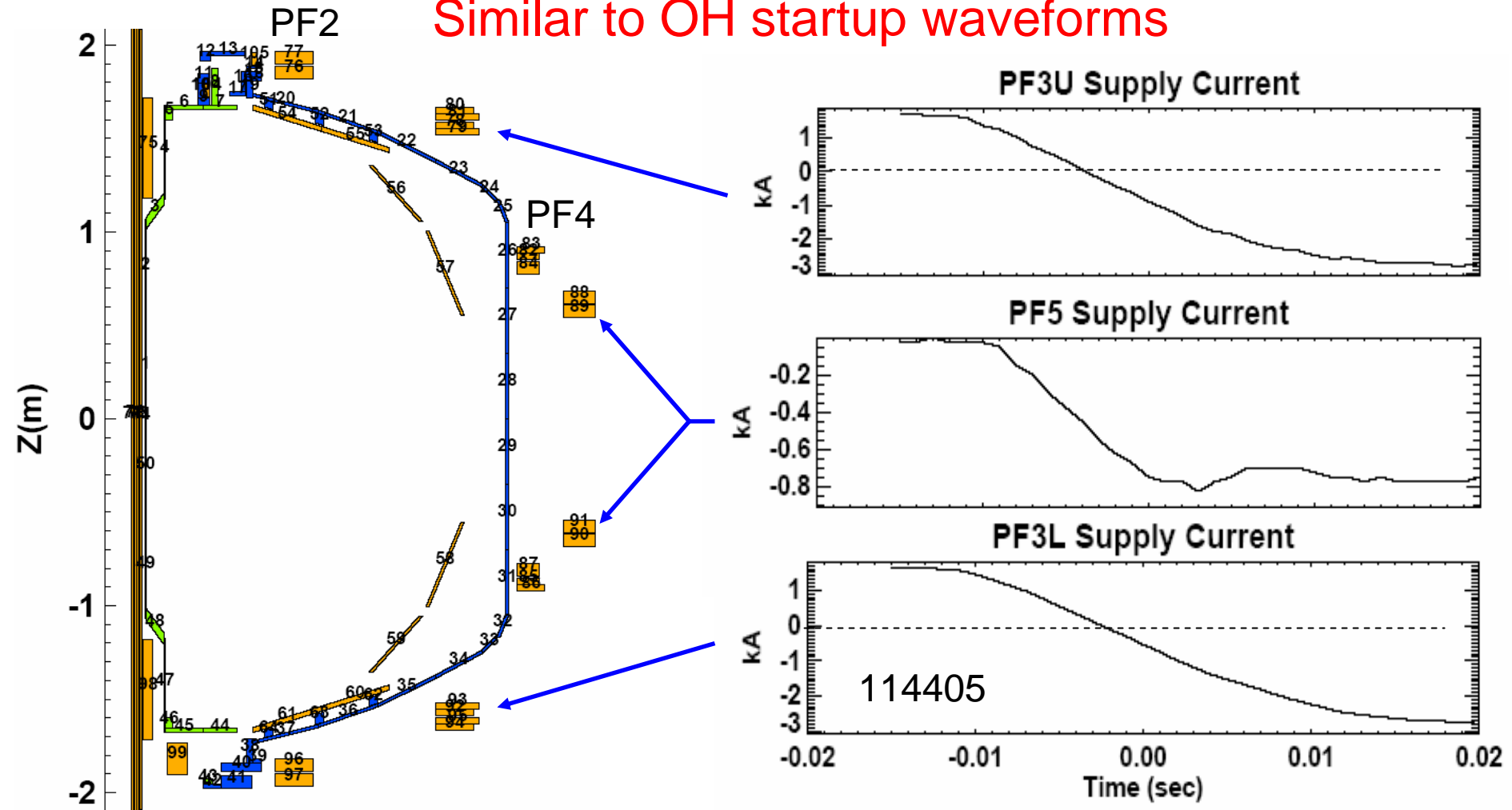
XP448-I: 113609, 3.5 kG

XP448-II:114484, 3 kG

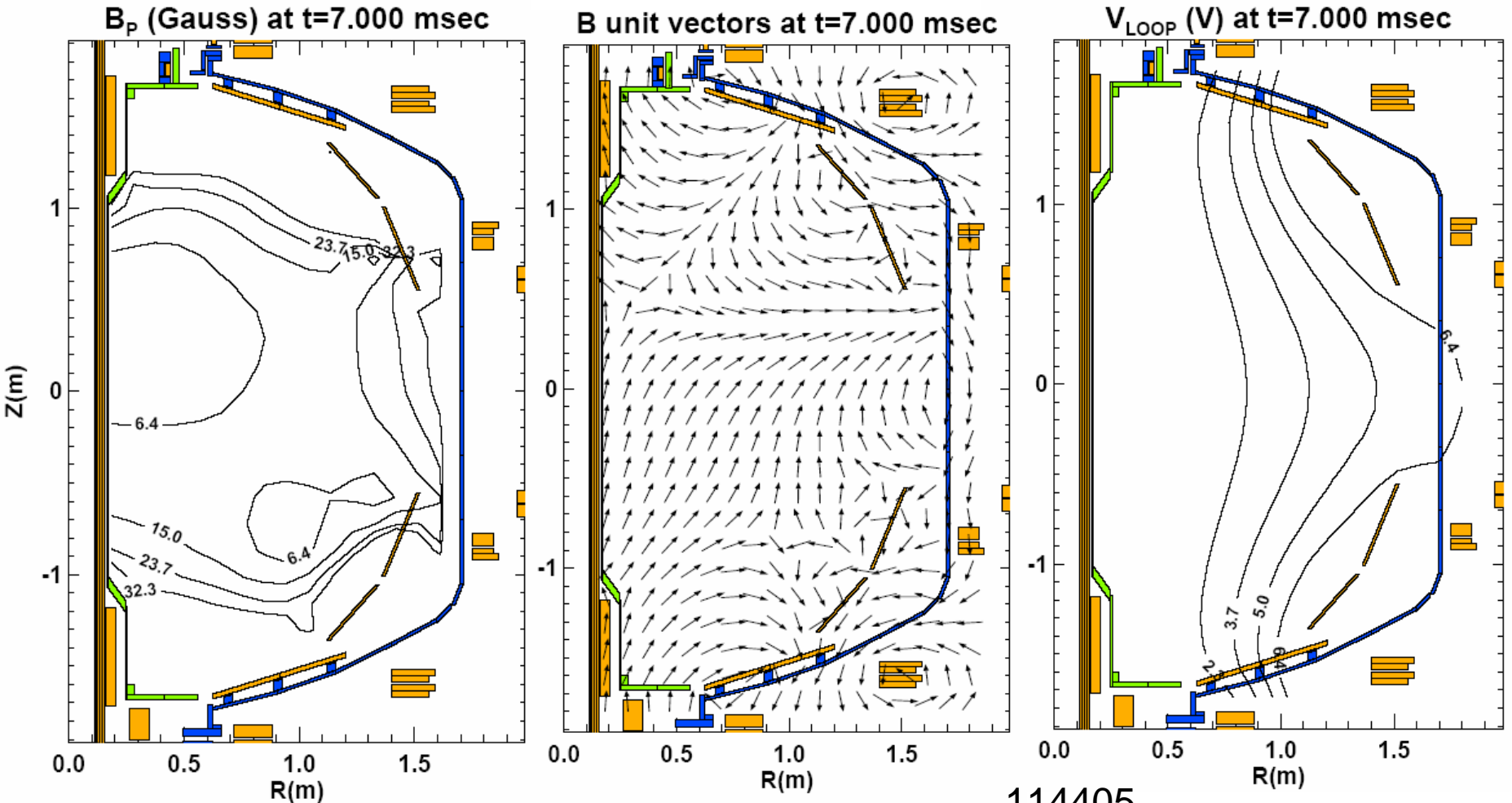
Coil current waveforms used in XP-443



Similar to OH startup waveforms



Field and voltage at plasma breakdown



114405

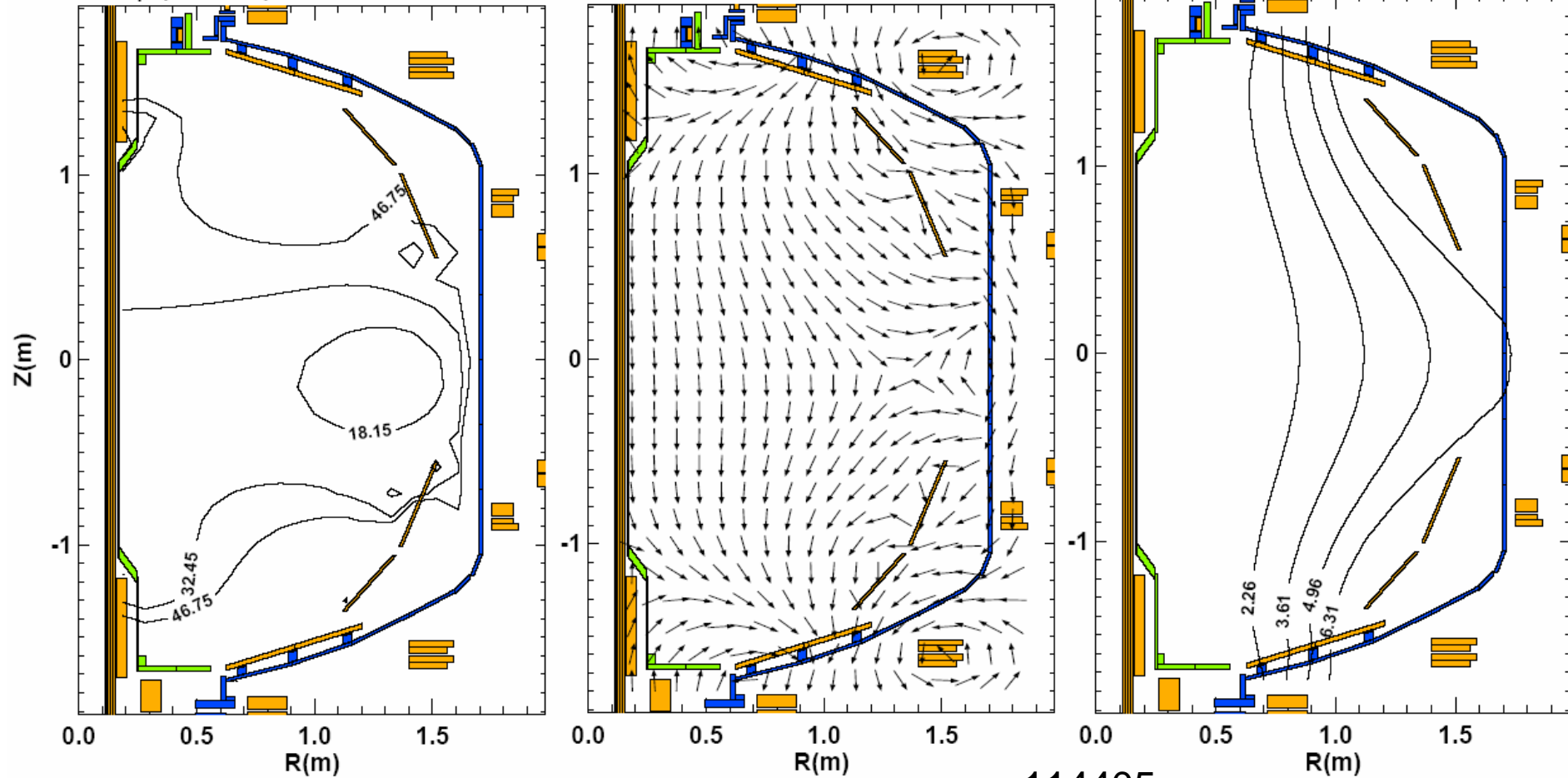
Field and voltage near max. plasma current



B_p (Gauss) at $t=10.00$ msec

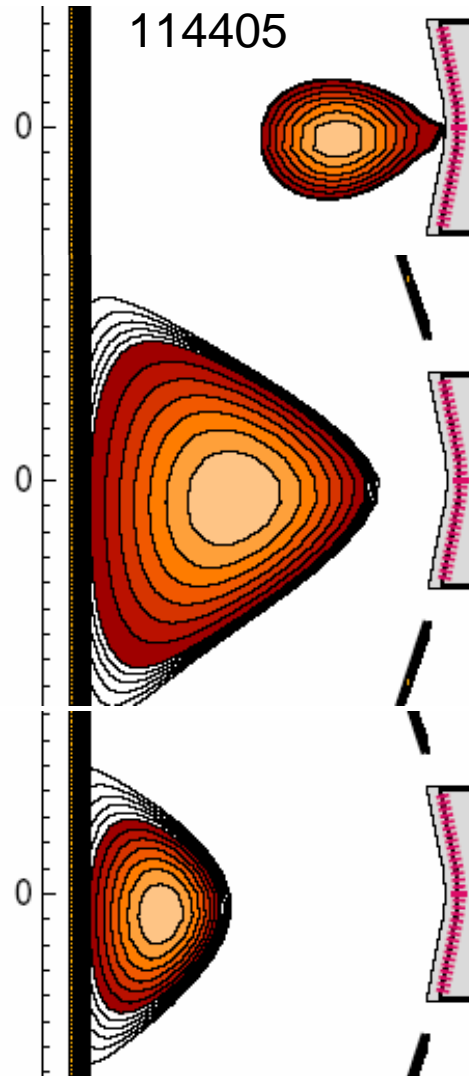
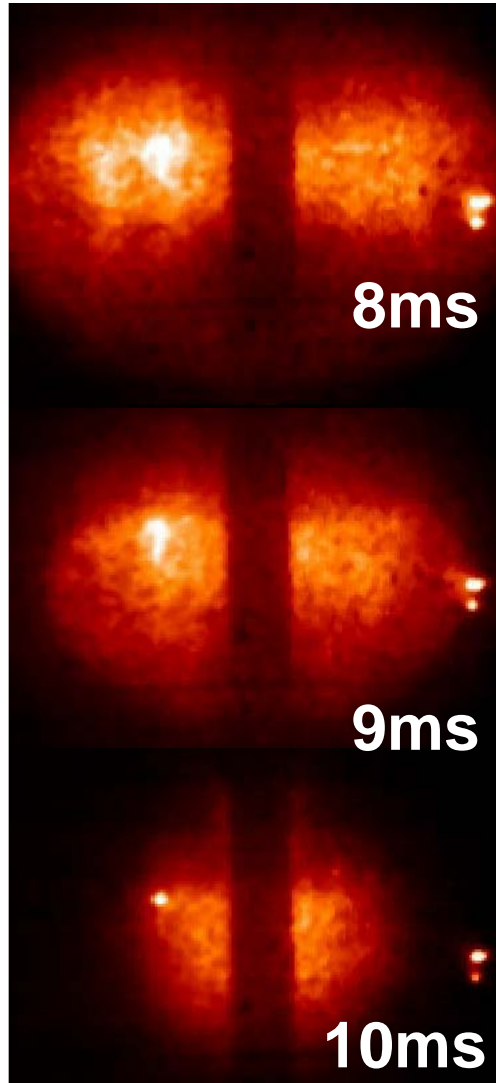
B unit vectors at $t=10.00$ msec

V_{LOOP} (V) at $t=10.00$ msec



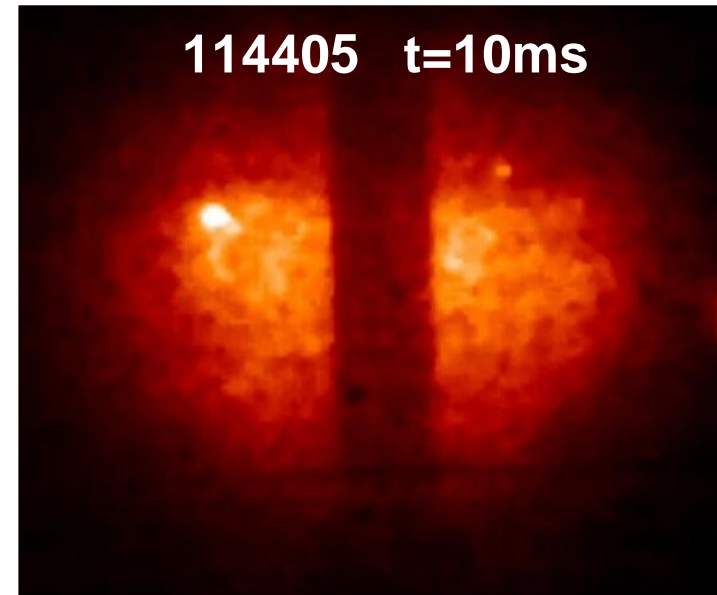
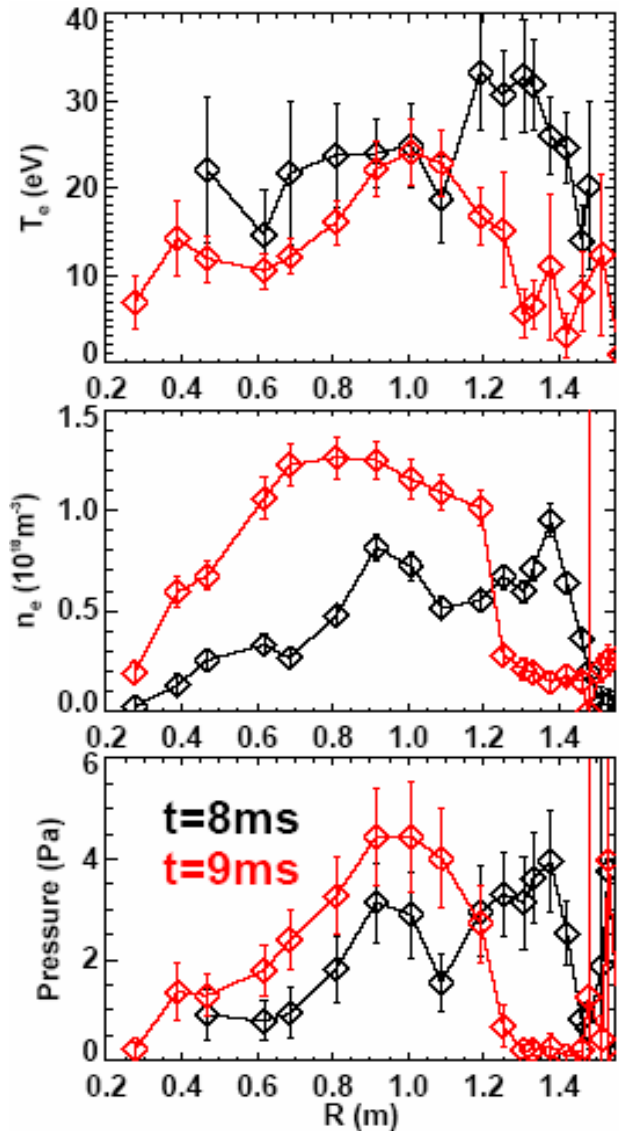
114405

Camera images and reconstructions show plasmas are born on LFS and have an inward radial trajectory



- LRDFIT code used for reconstructions
 - $I_{\text{Vessel}} \approx 10 \times I_p$
- Careful control of B_z after breakdown helped raise I_p from 10kA to 20kA
- More B_z evolution optimization possible

Thomson measurements consistent with plasma motion and peaked p_e profiles



Thomson $T_e < 35\text{eV}$ and camera images consistent with lack of burn-through →

need more plasma heating power:

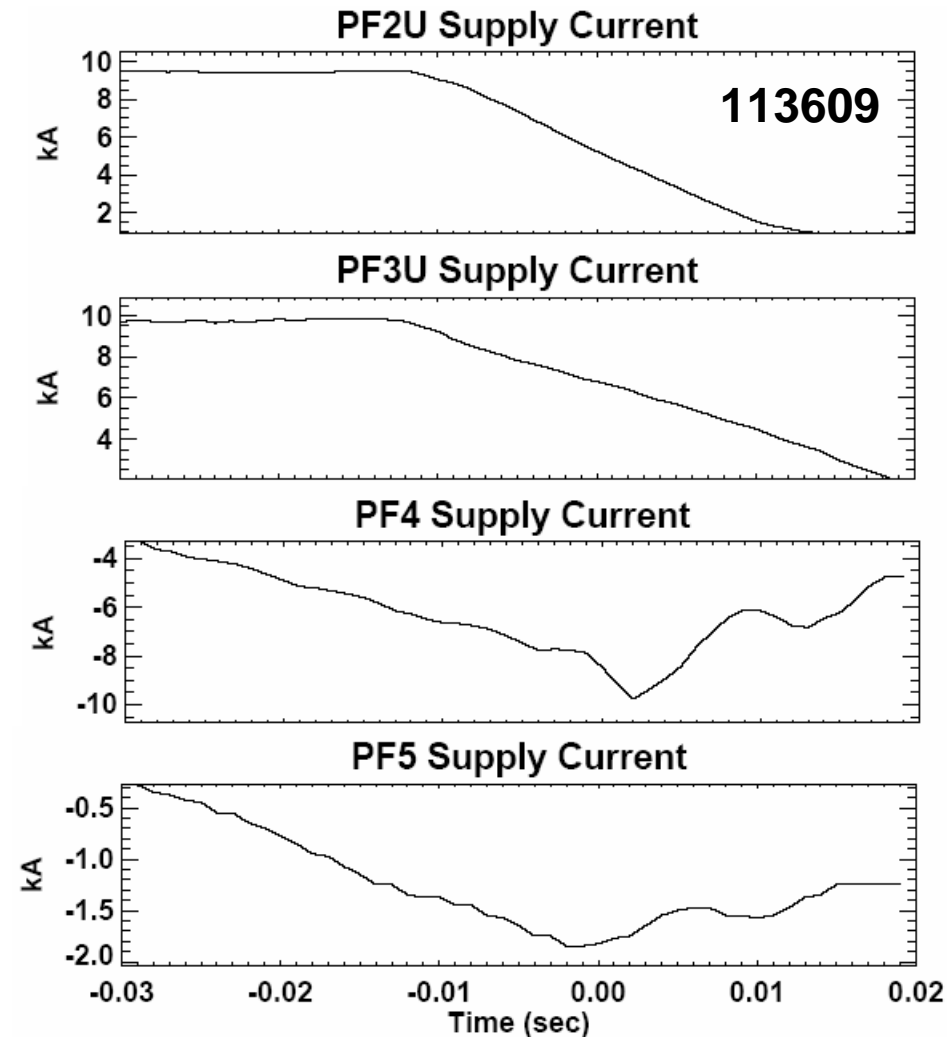
- More HHFW power during breakdown
- Higher V_{LOOP} – keep plasma outboard
- EBW power could be very helpful

Overview of XP448 (M. Ono & W. Choe)

Solenoid-free current-start-up scenario including PF4

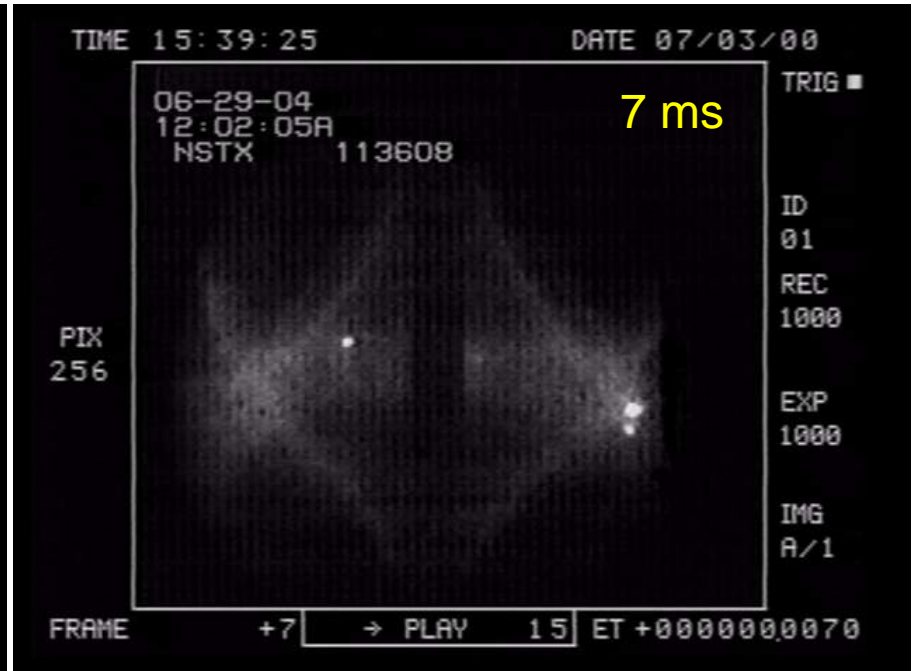
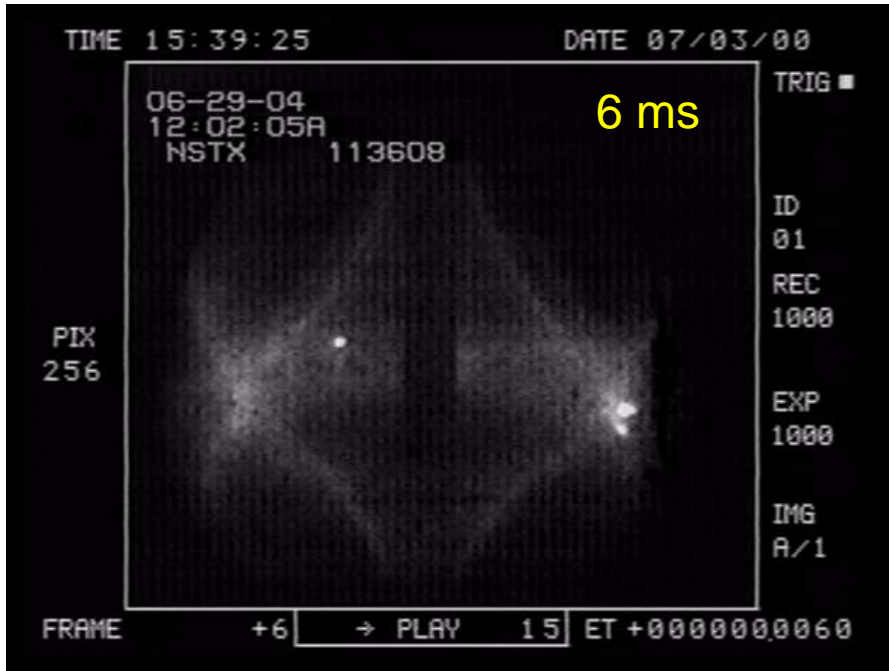
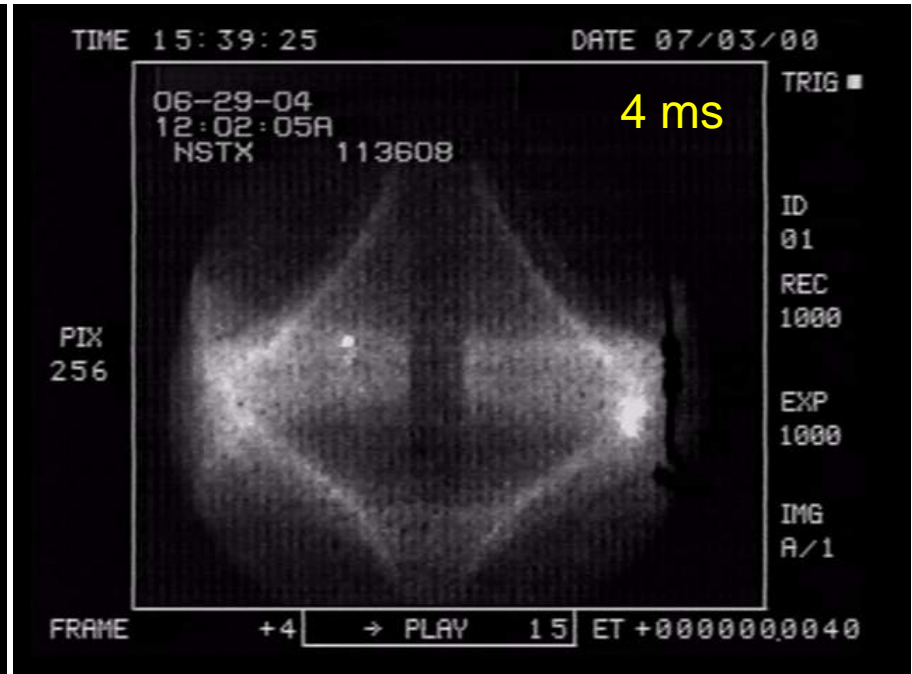
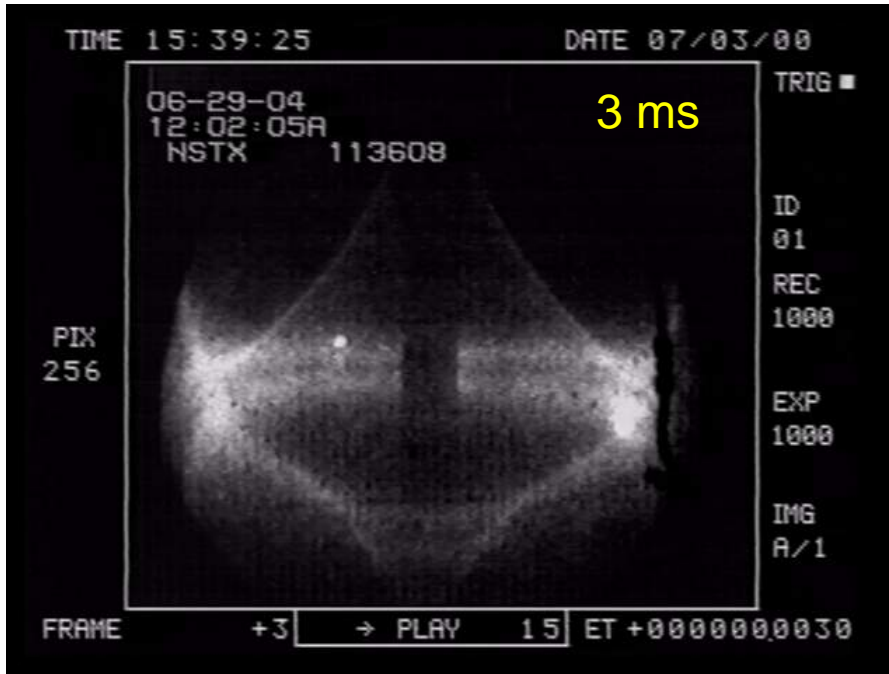


- Try to store more poloidal flux at null region for I_p ramp
- Start PF2 & 3 coils with large positive bias
 - Balanced by negative PF4
 - Store 50-100mWb at null
 - Null size 1/3 of XP448
- Null formation very sensitive to coil current time-history and vessel current model

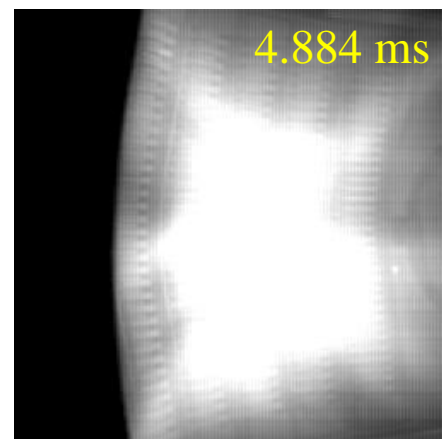
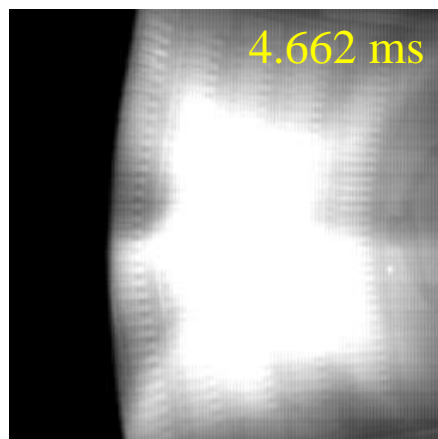
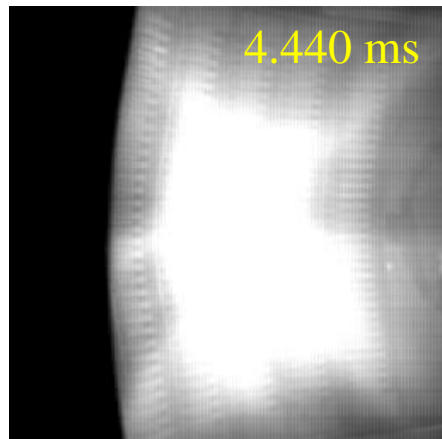
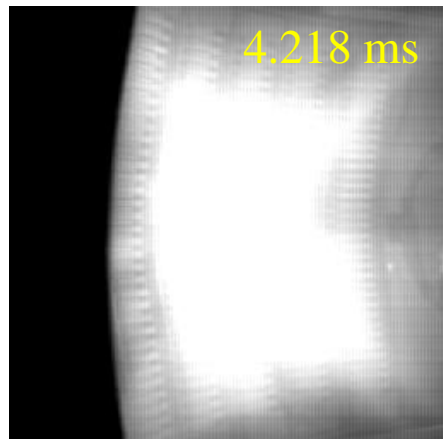
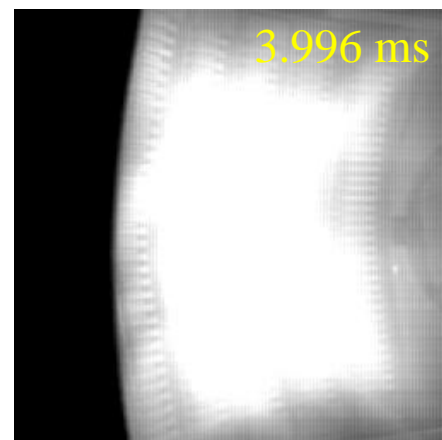
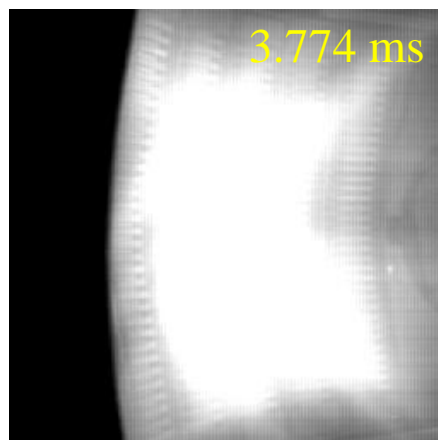
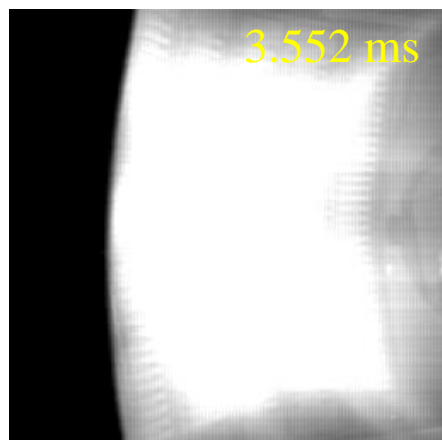
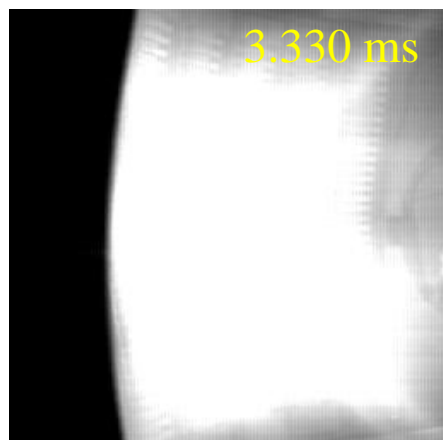
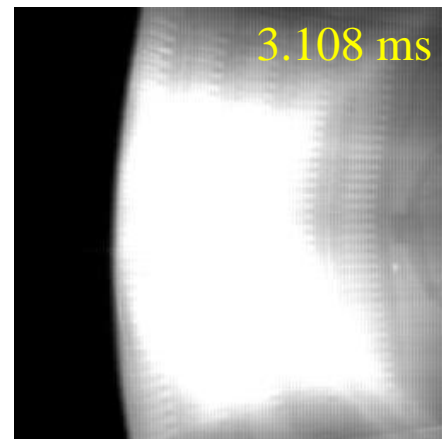
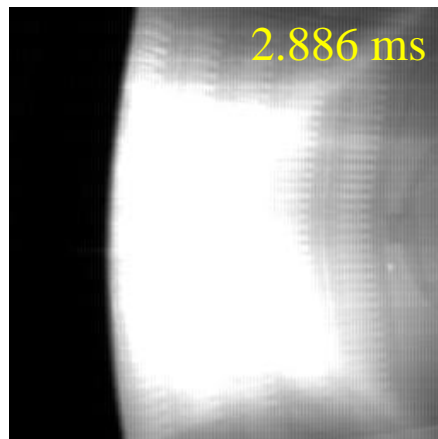
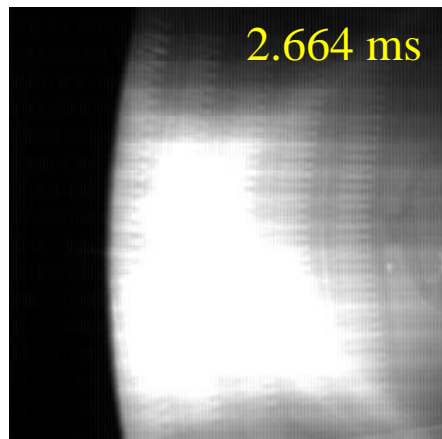
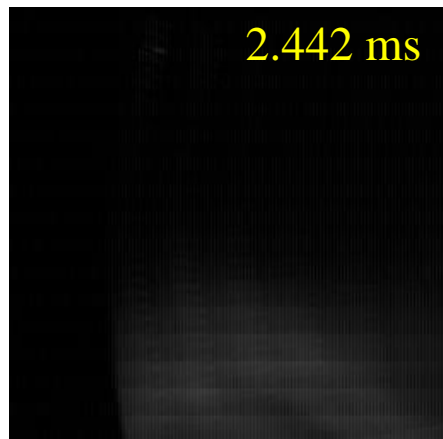


Shot 113608

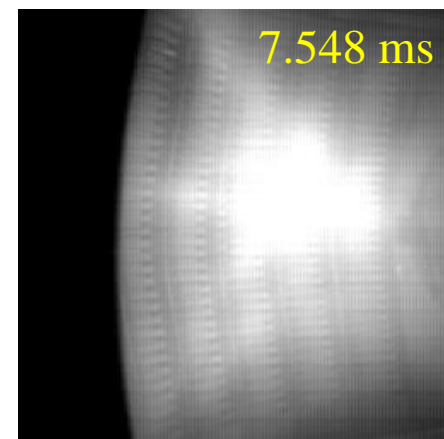
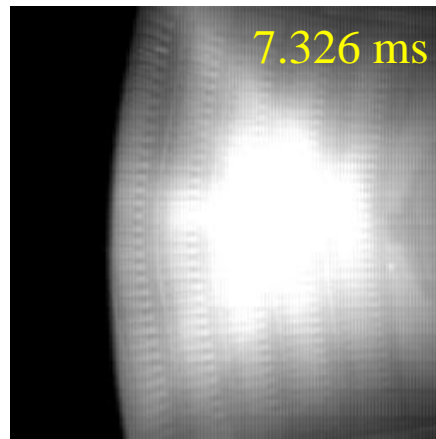
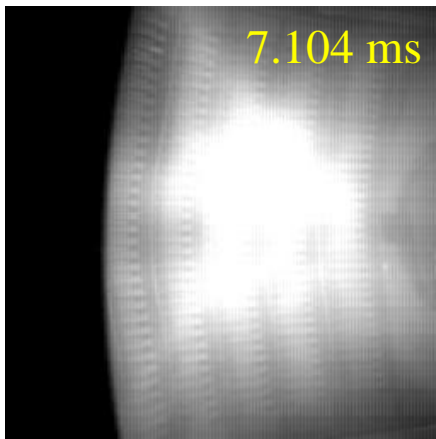
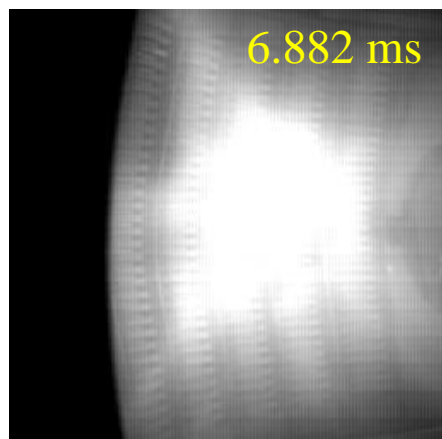
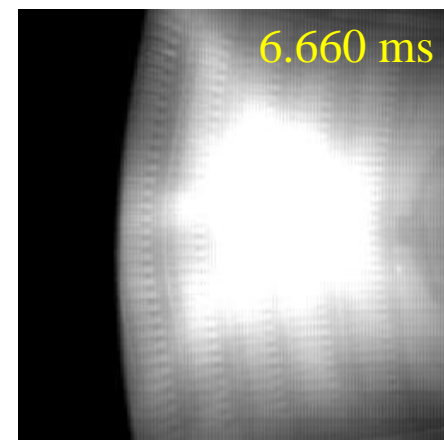
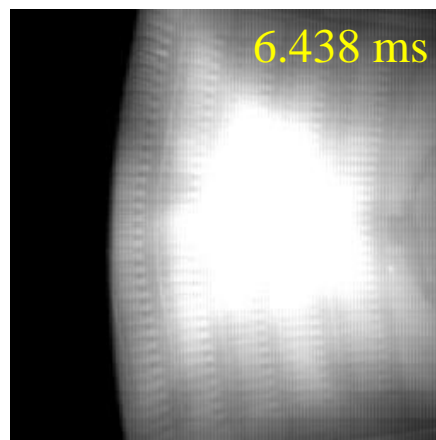
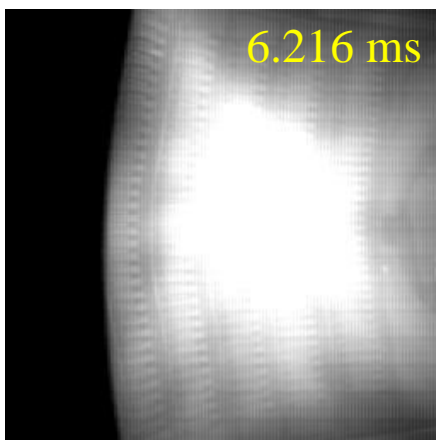
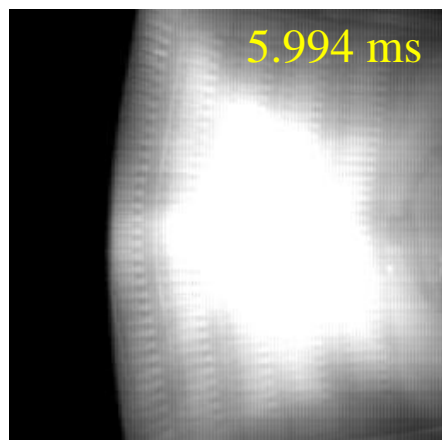
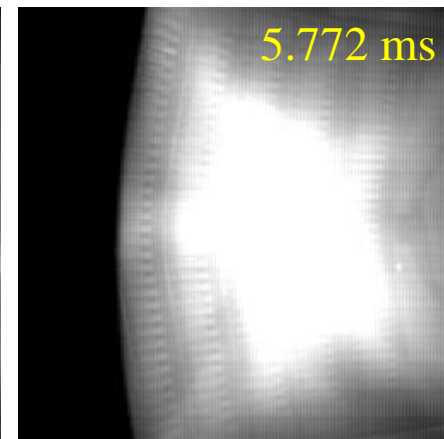
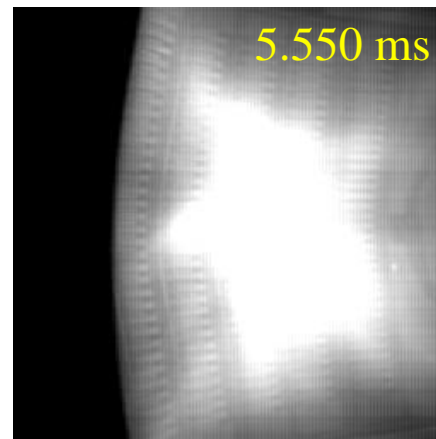
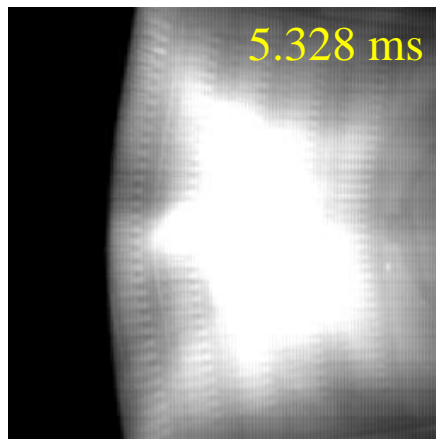
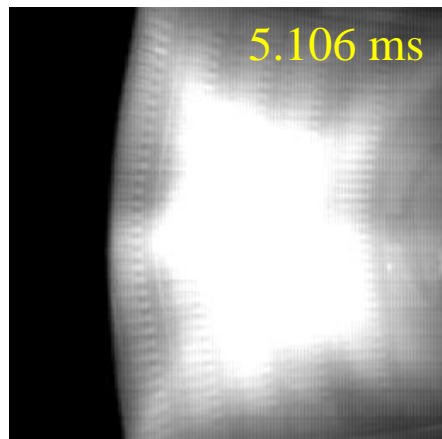
Camera Gain = 95



s113609 (Hiroshima fast camera)



s113609 (Hiroshima fast camera)



Magnetics bound I_p to $< 15\text{kA}$ (probably only few kA)



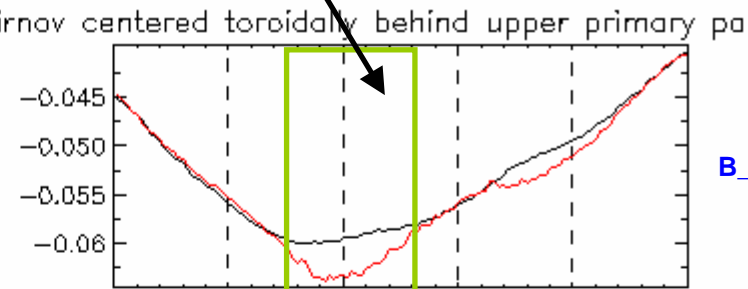
Bright emission (Hiroshima camera) in 2.5 – 8 ms

113611 (vac. shot)

113609

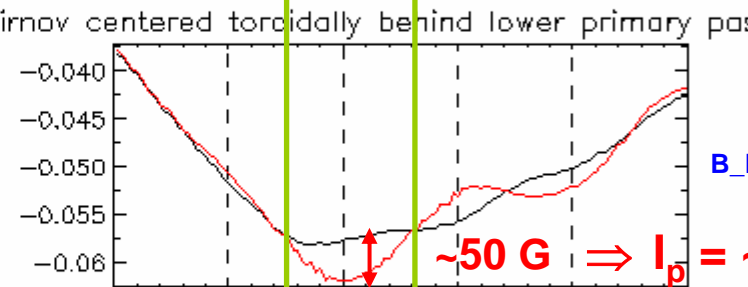
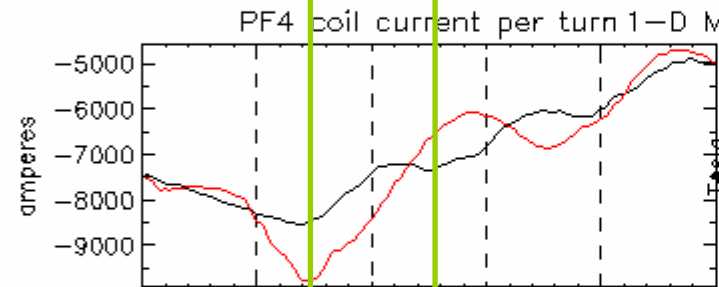
Rogowski

- RF noise
- I_{PF4} diff.



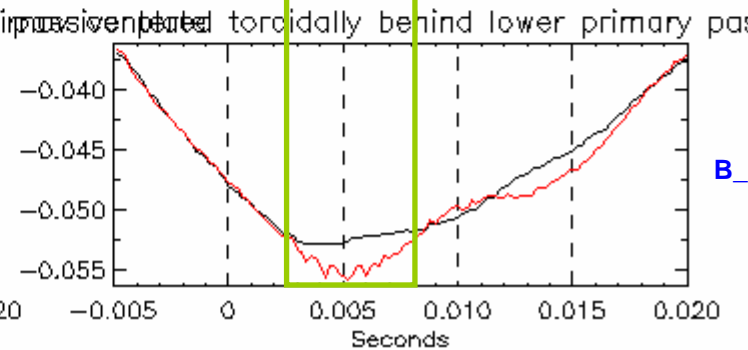
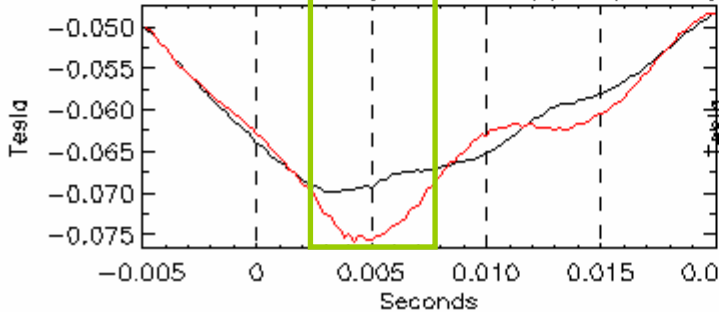
B_L1DMPPGL7

I_{PF4}



B_L1DMPPGU8

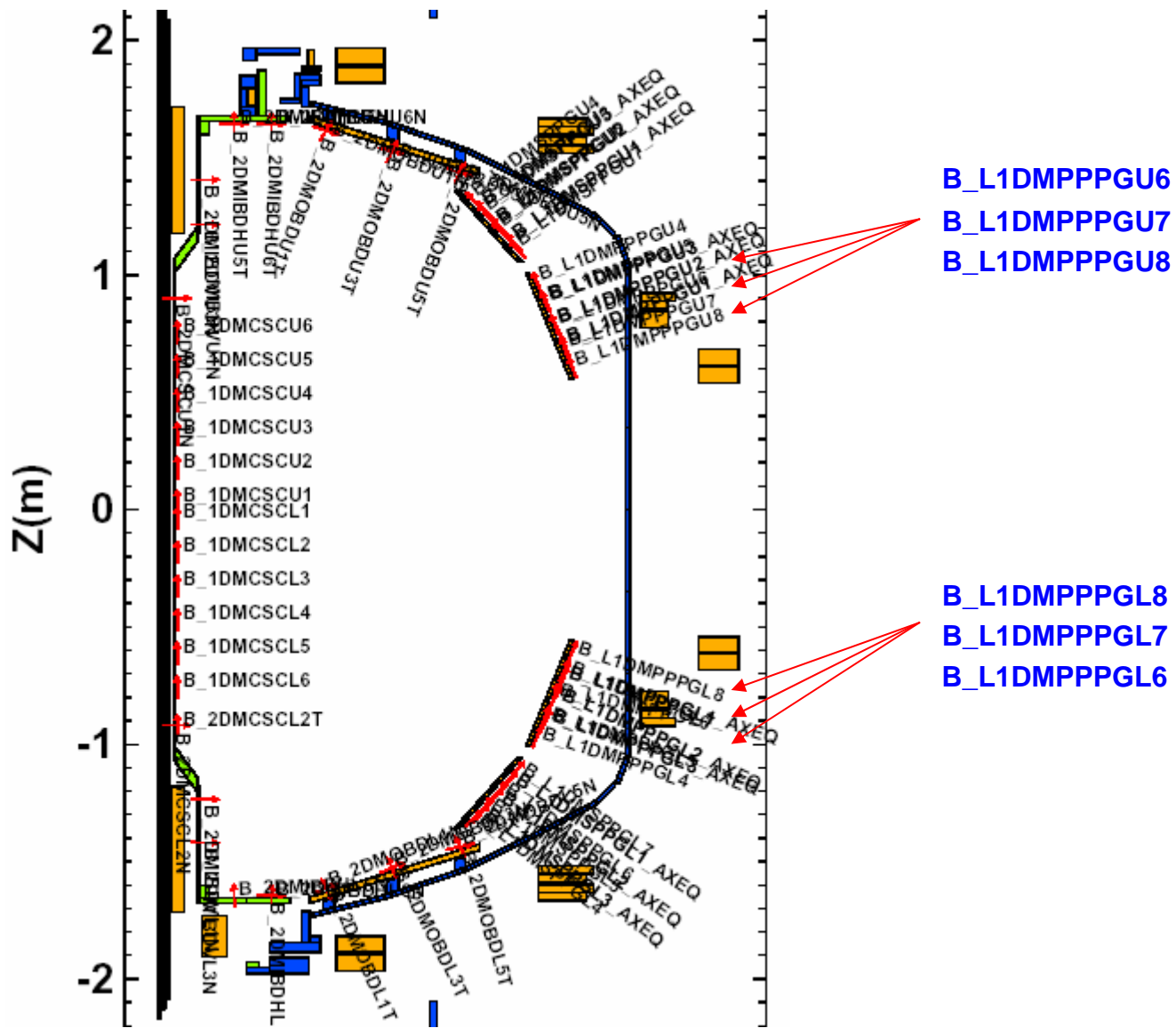
1-D Mirnov centered toroidally behind upper primary pa:



B_L1DMPPGL8

B_L1DMPPGU7

Outboard B-probes in near-field of PF4



Summary of Results



- HHFW pre-ionization necessary
 - Need sufficient neutral density, 0-0 phasing
 - Increase from 0.5MW to > 1 MW w/ more straps
 - EBW could be very helpful (was on TST-2)
- Large null required for I_p initiation thus far
 - Need more work on finding optimal balance of stored flux vs. null size vs. initial plasma shape
- Good plasma position evolution following breakdown crucial to high I_p
 - DINA modeling should be helpful here
 - See talk by M. Walker on Tuesday