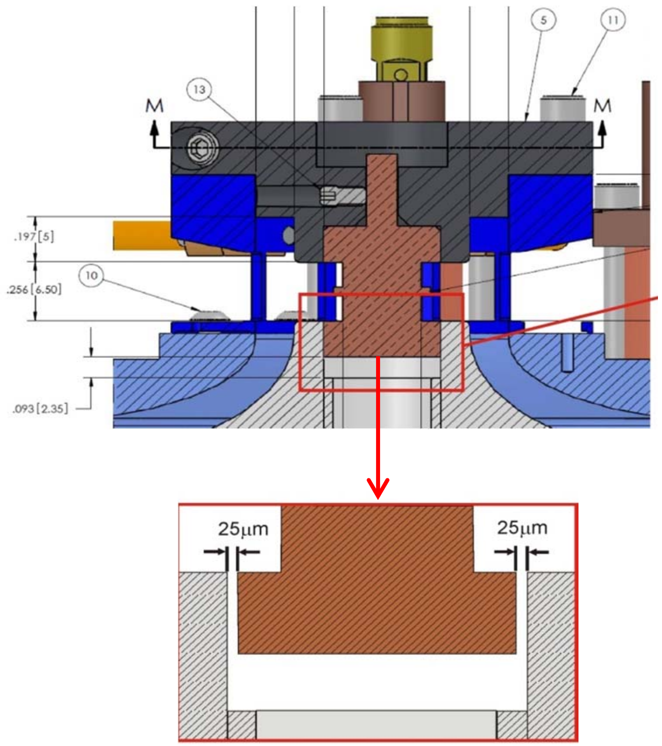
AZIMUTHAL CURRENT DENSITY DISTRIBUTION RESULTING FROM A POWER FEED VACUUM GAP IN METALLIC LINER EXPERIMENTS AT 1 MA

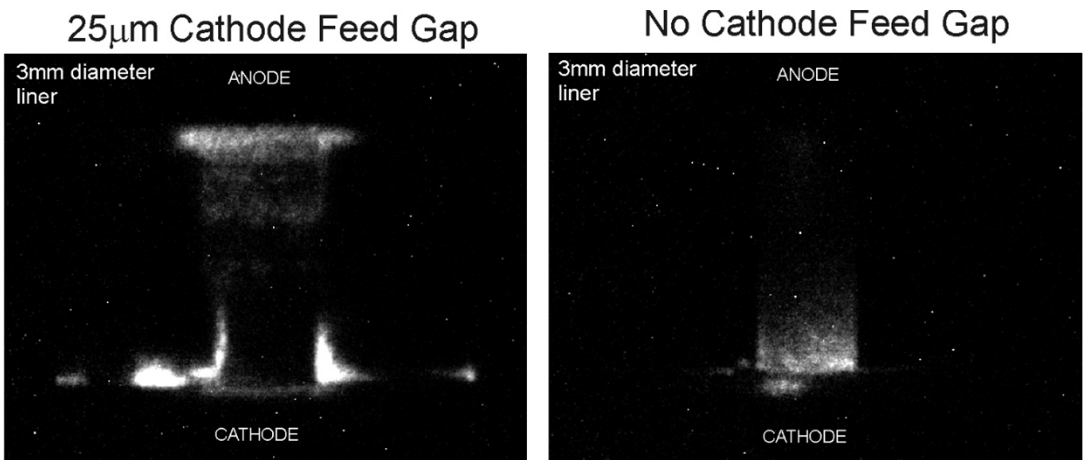
S. C. Bott-Suzuki, S. W. Cordaro, L. S. Caballero Bendixsen,
University of California San Diego, CA, USA

Levon Atoyan, Tom Byvank, William Potter, B.R. Kusse, J.B. Greenly, C. E. Seyler, D. A. Hammer
Cornell University, Ithaca, NY, USA

*Supported by the Center of Excellence in Pulsed Power High Energy Density Plasmas under the NNSA SSAA program through DOE Cooperative Agreement DE-FC03-02NA00057

COBRA liners with Cathode vacuum gap (2011-2013)





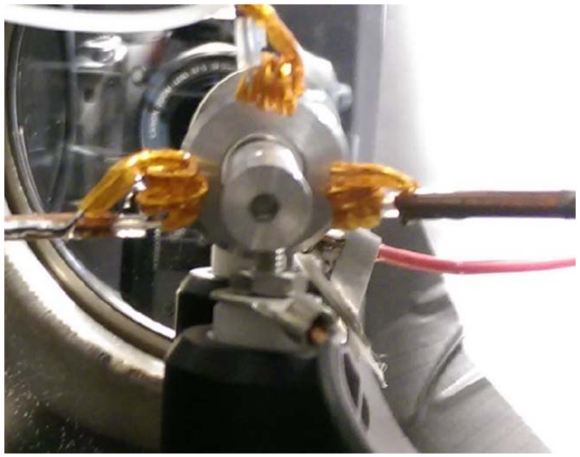
Gated optical images (10ns exposure) of Z-scale liners (300μm thick, 6.3mm OD and 10mm tall)

- The presence of a gap at the cathode clearly has an effect on plasma formation and evolution

S. C .Bott-Suzuki, Phys. Plasmas, 22, 094501 (2015)

High Voltage Vacuum Gap Breakdown Experiment at UC San Diego

- Examines coaxial HV vacuum gap breakdown (15 – 30kV, 100-200 A)



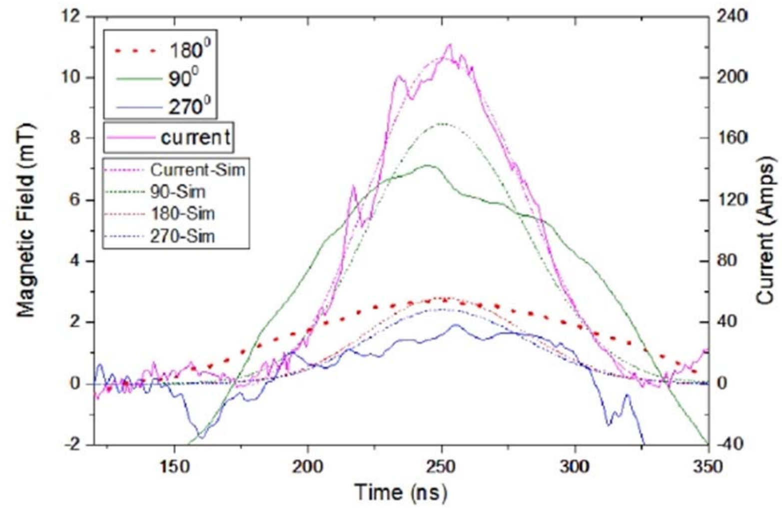
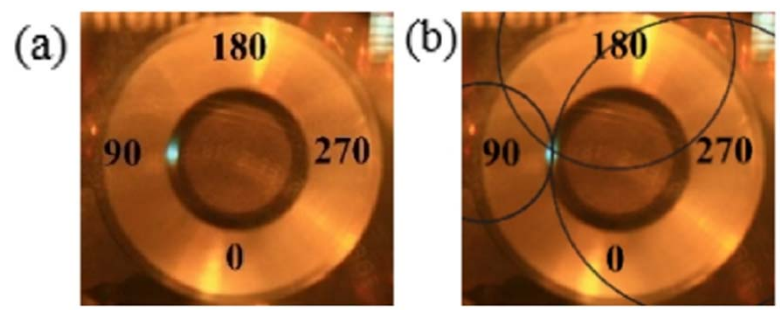


FIG. 7. Experimental vs. analytical magnetic field and current, shot no. 34.

- Use of bdot probes are multiple azimuthal positions allow triangulations of the effective current position



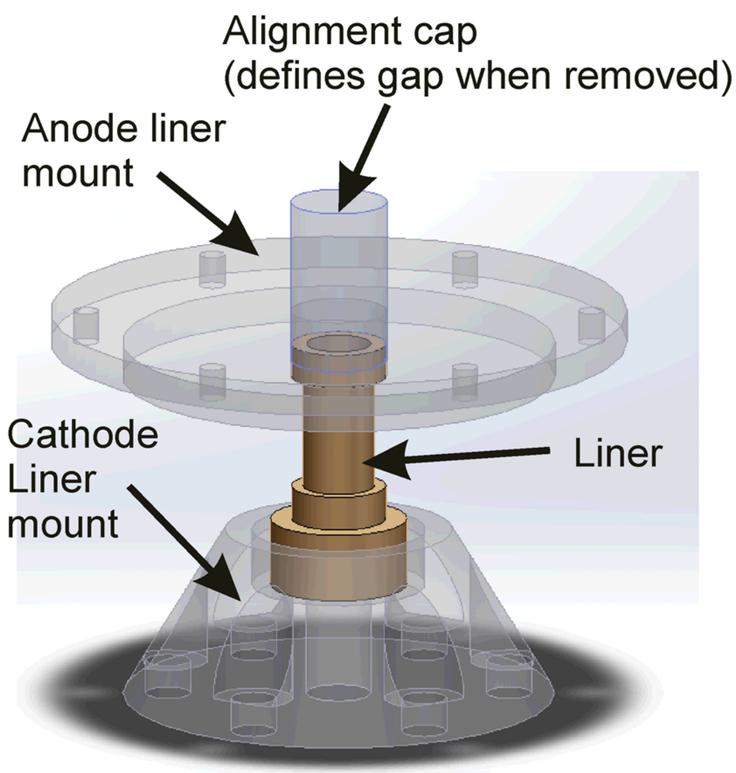
- $R = \frac{\mu I}{2\pi B}$, for each peak B-field value to estimate the corresponding distance from break down. The R value corresponds to the distance the breakdown is from the probe

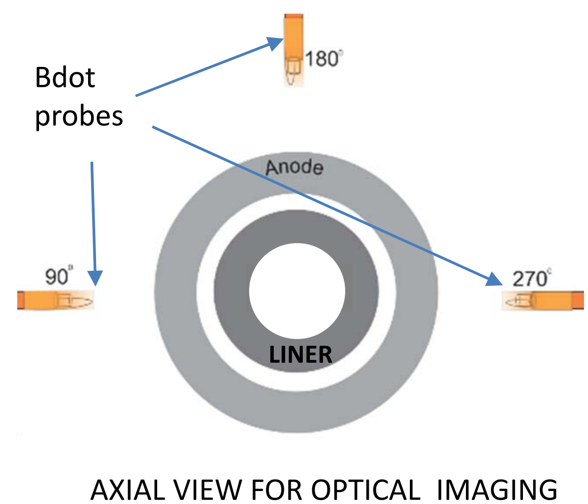
Cordaro *et al, Rev. Sci. Instrumen.*, **86**, 073503 (2015)

COBRA Liner Shots with an Anode vacuum gap

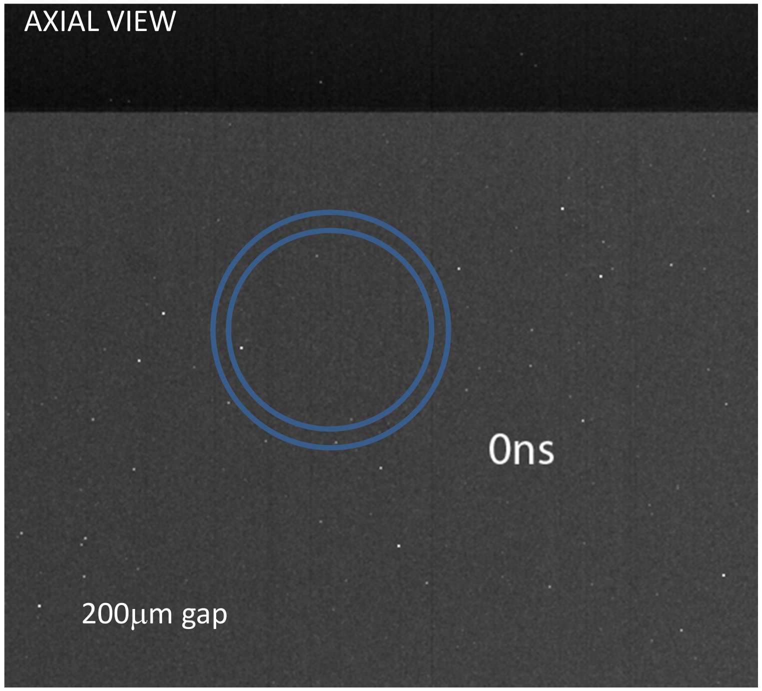
- Gap alignment more accurate and reliable
- Direct imaging access to power feed gap using gated (5ns) multi-frame optical camera
- Bdot array used to enable triangulation method

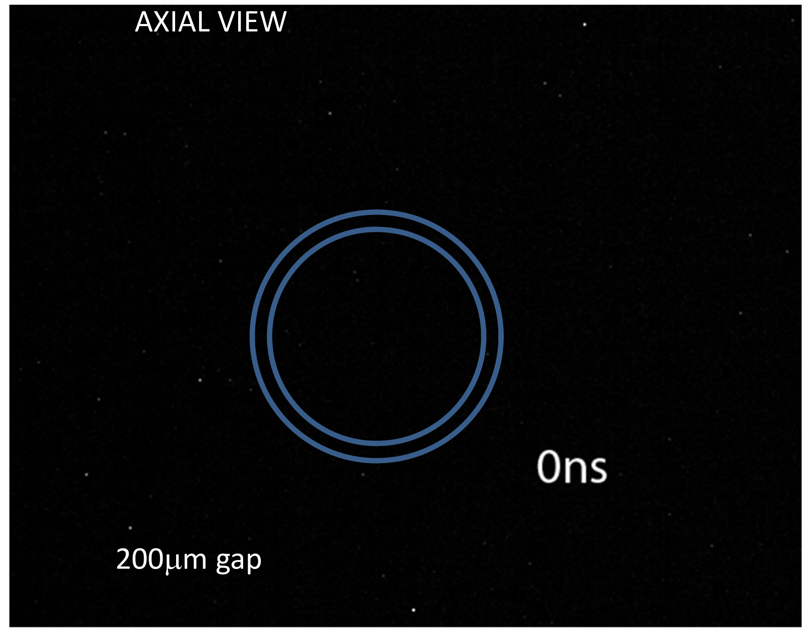
Z-scale liners, aluminum
(150μm thick, 3mm OD and 10mm tall)





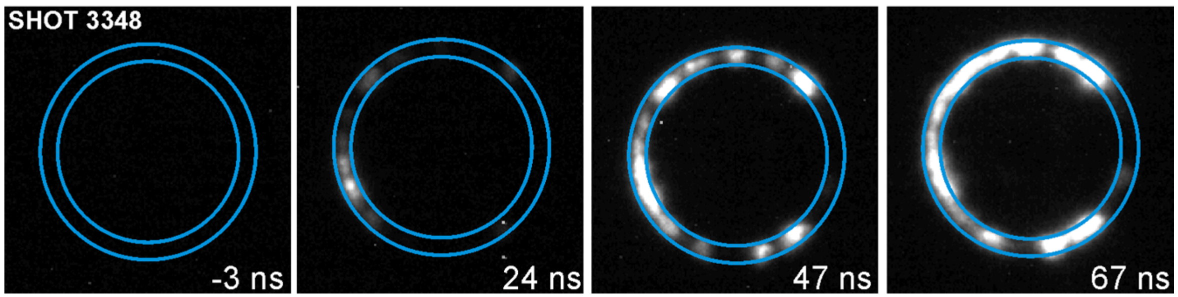
Multi-frame optical camera is ideal for following plasma evolution



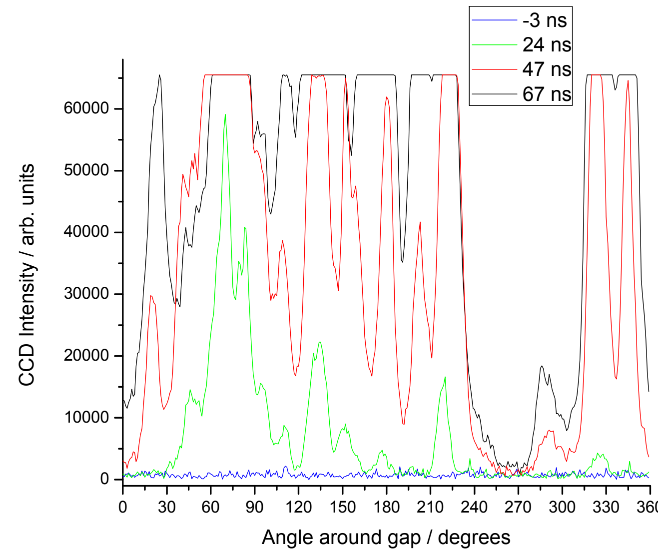


- Identical shots show similar behavior
- Initial breakdowns form multiple hotspots which evolve relatively slowly
- Alignment of gap seems excellent

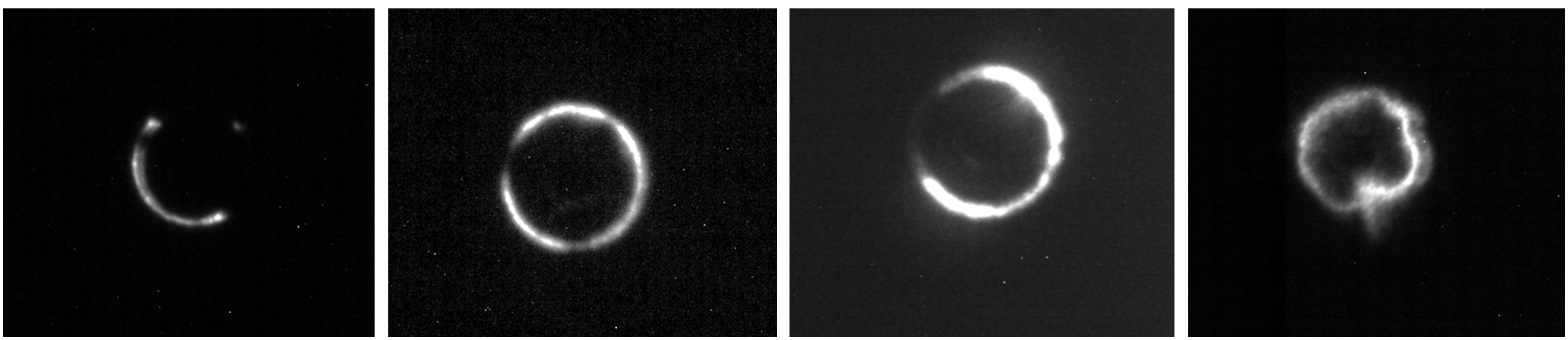
Anode gap is not uniformly closed in any shot at any time



200μm gap



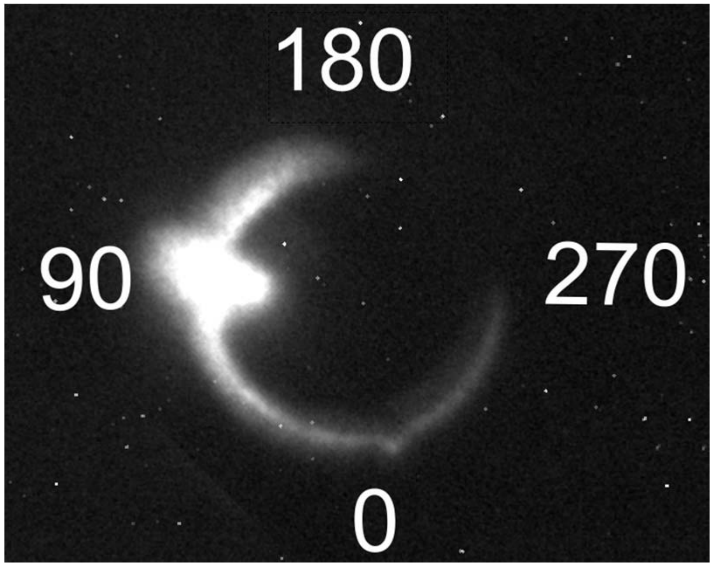
- No clear trend with gap size (electric field strength)

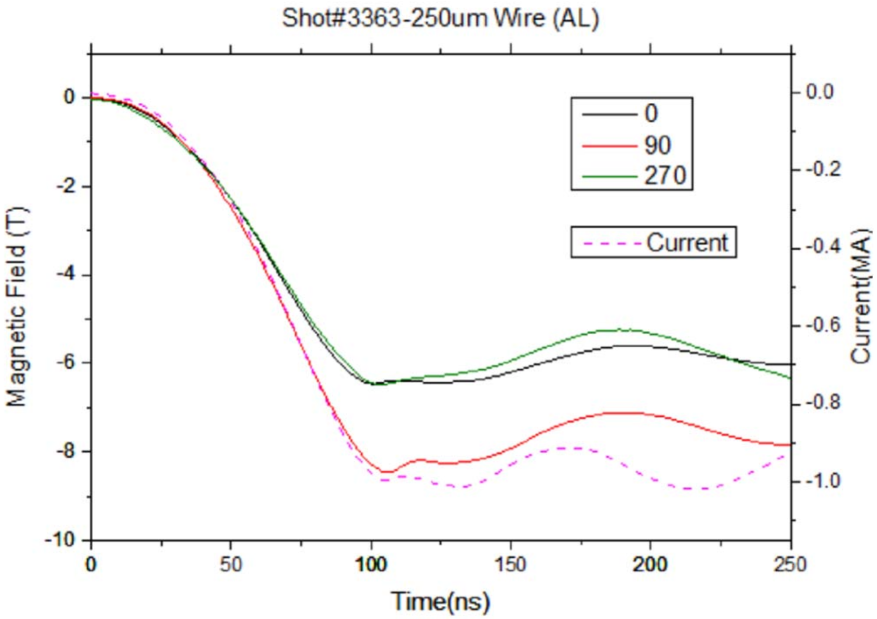


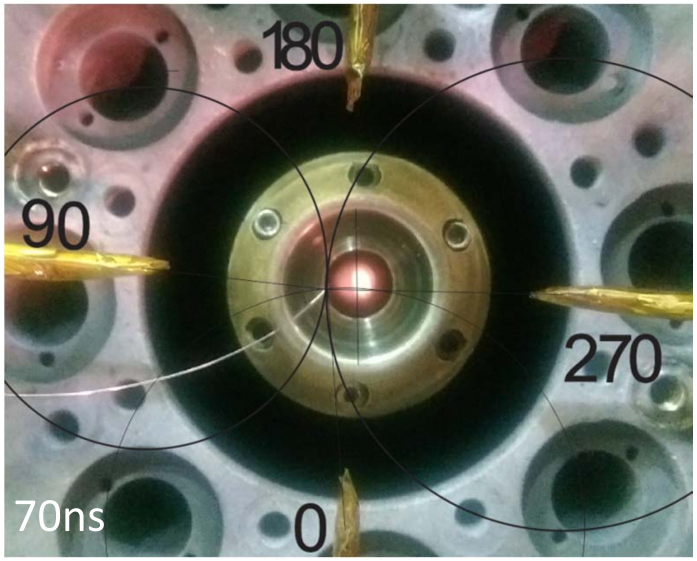
100um 200um 400um 600um

Testing of Bdot triangulation method on COBRA

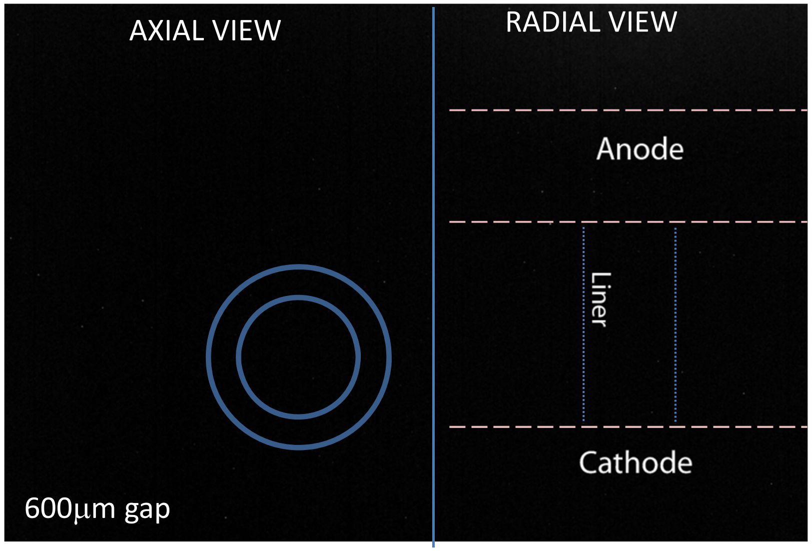
- “Sanity check” of triangulation method uses a single Al wire offset to one side
- Provides a single and stationary current path
- Triangulation at peak current gives excellent correlation to wire location



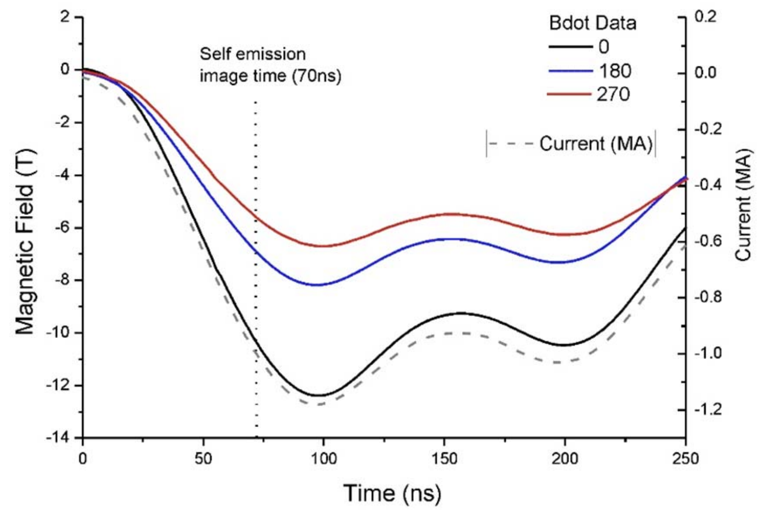


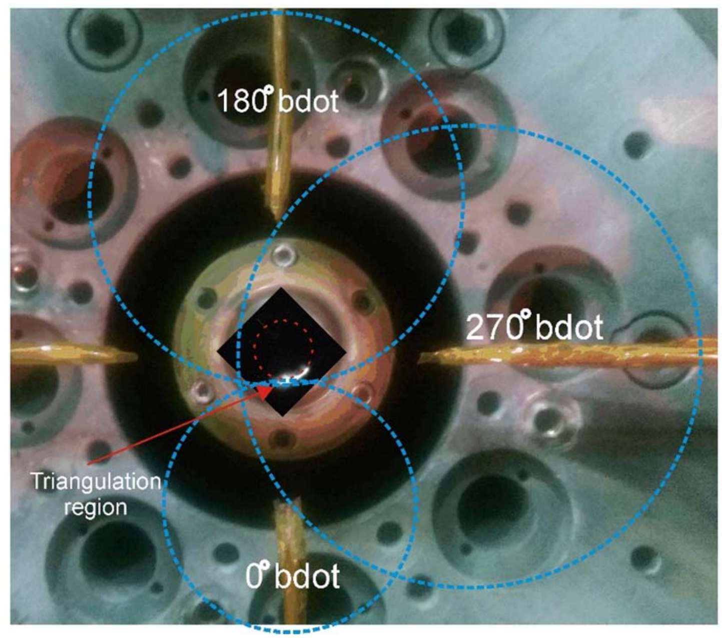


Bdot triangulation method correlated to imaging for COBRA liners



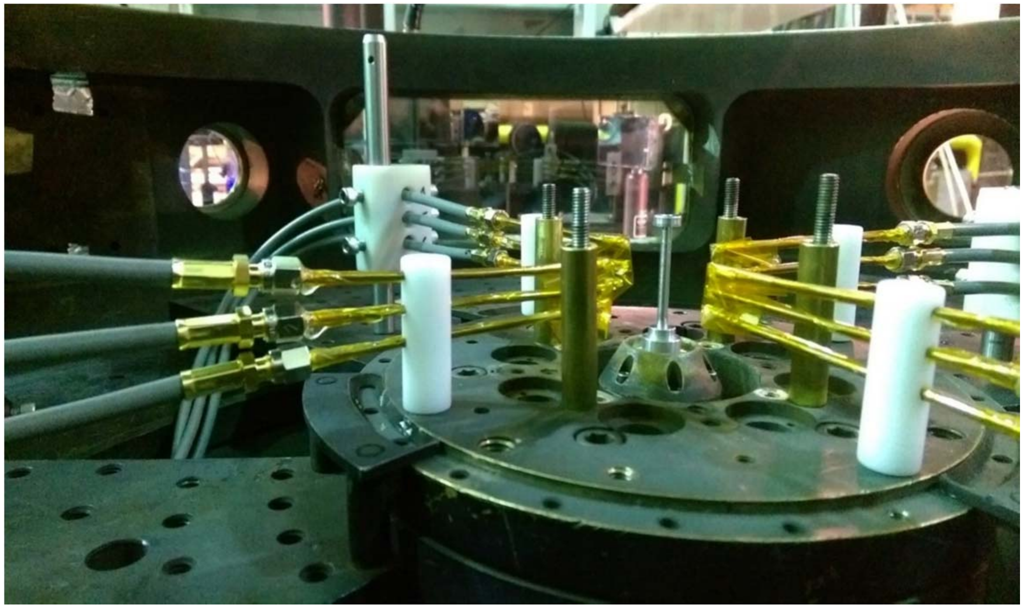
Optical emission frames (10ns)

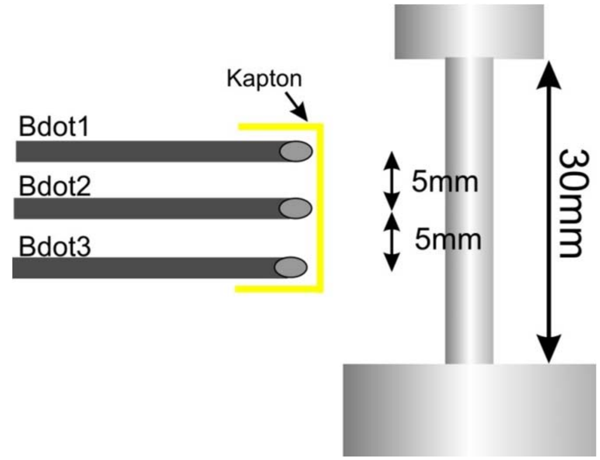




- In some shots, plasma one azimuthal position appears to dominate the profile for much of the current drive
- Effectiveness of the bdot triangulation links emission to current density
- This assumes all current at a single point

Investigations of current density as a function of axial position

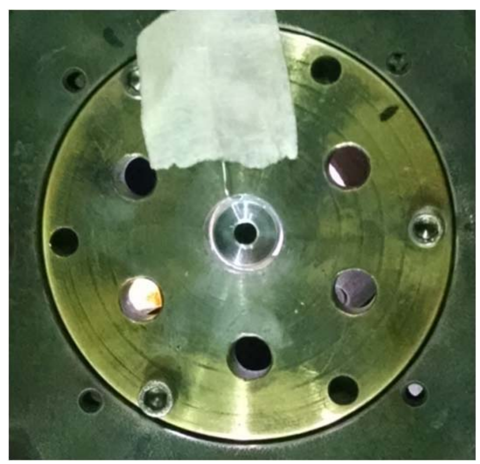




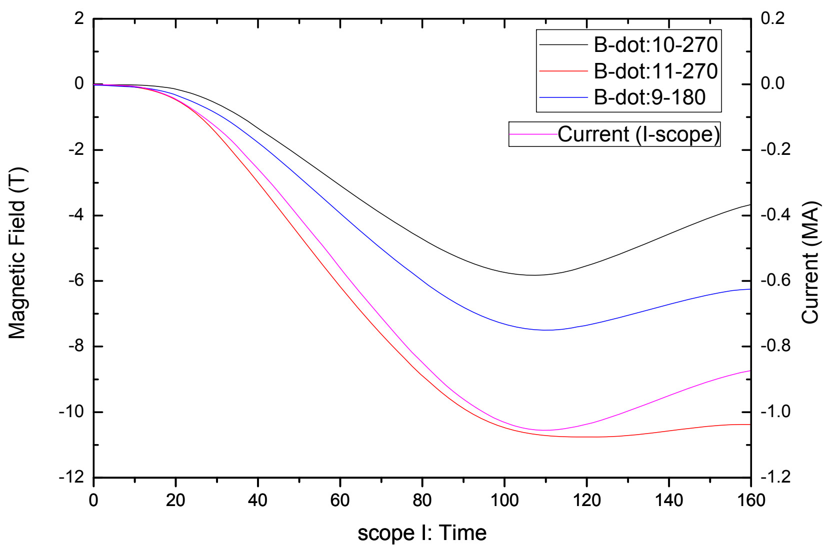
- Probes well-protected and can we used for several shot before repair required

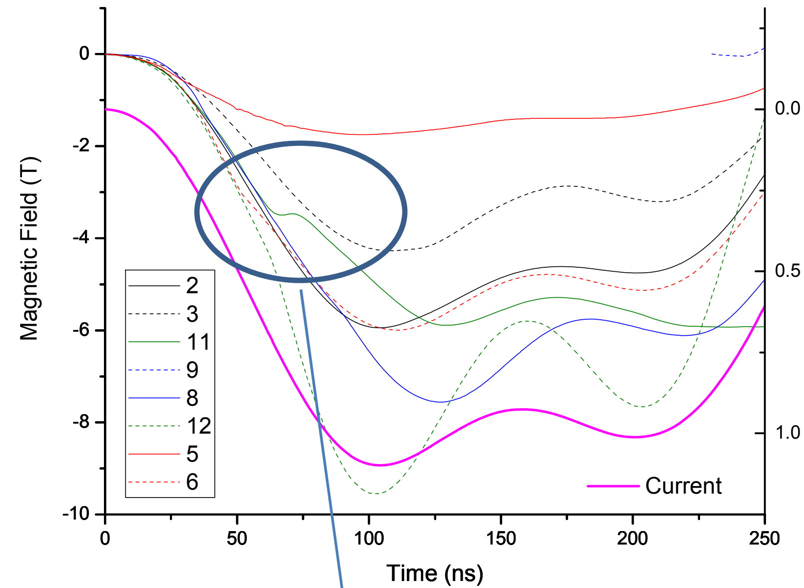
- Pre- and post shot calibration on repaired probes identical

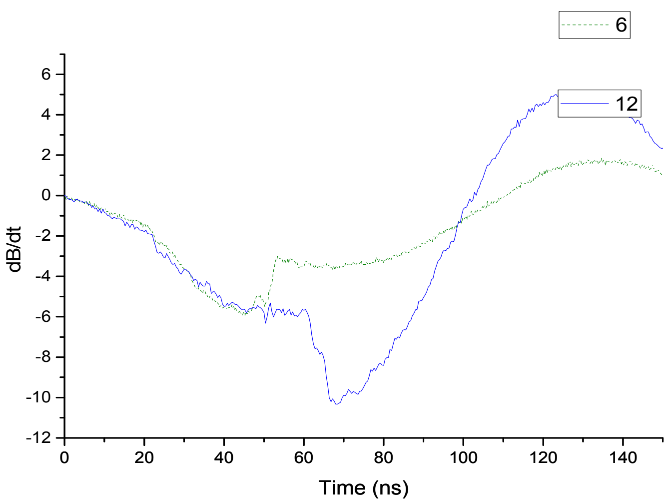
- Using a 'trigger pin' determines initial breakdown position

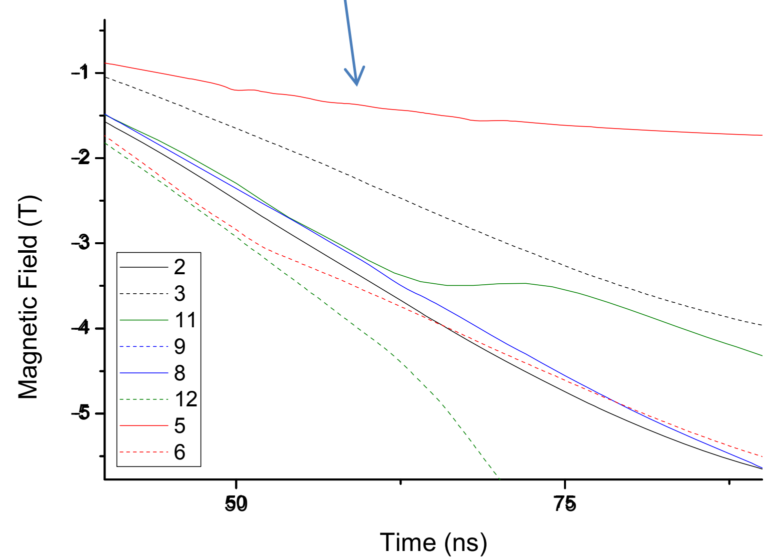


dB/dt and integrated traces show clear changes in azimuthal current distribution





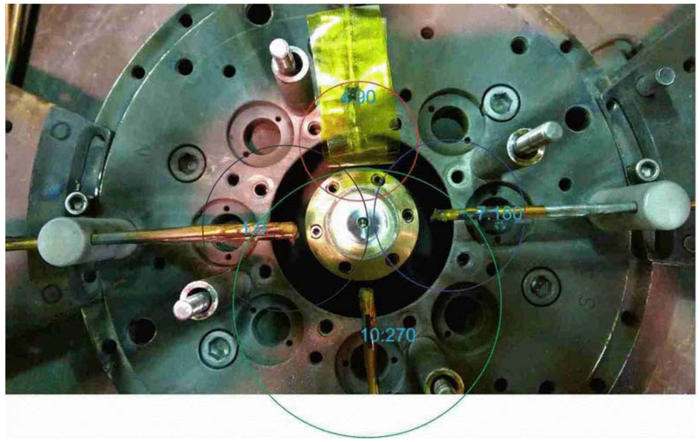


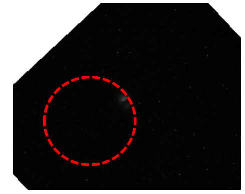


SHOT 3675

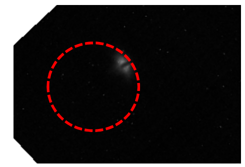
Al liner with trigger pin

Top (1,4,7,10)



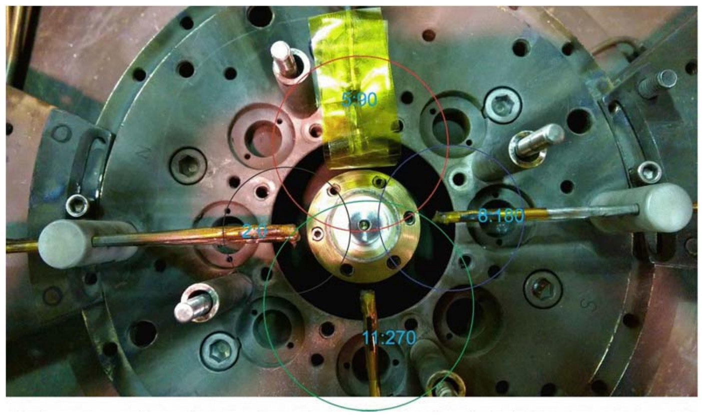


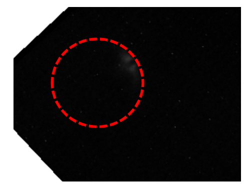
50ns



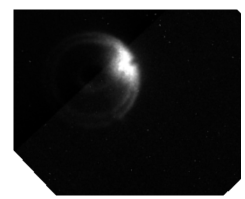
60ns

Middle (2,5,8,11)



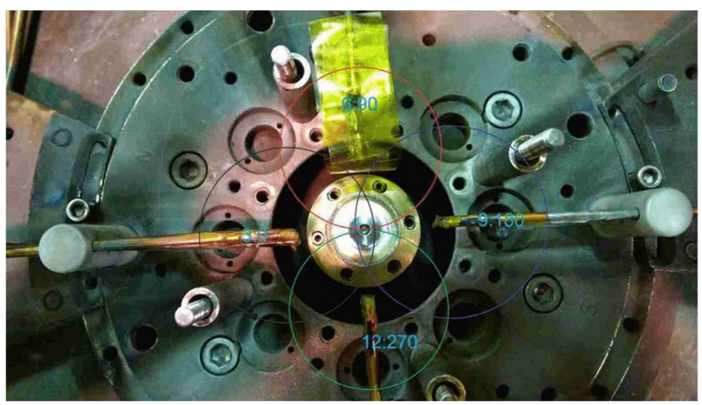


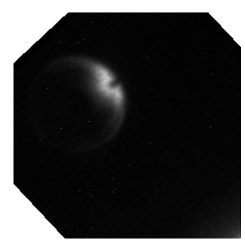
70ns



80ns

Bottom (3,6,9,12)



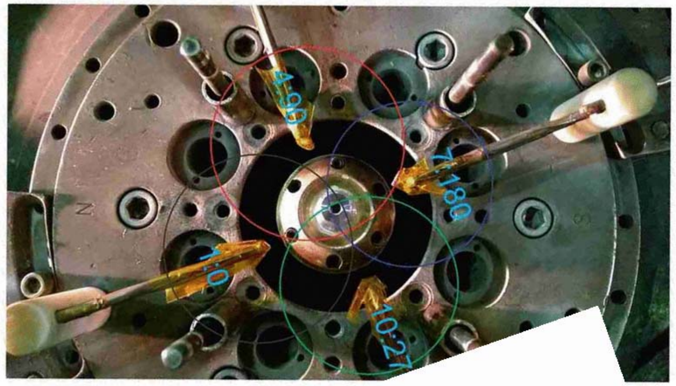


100ns

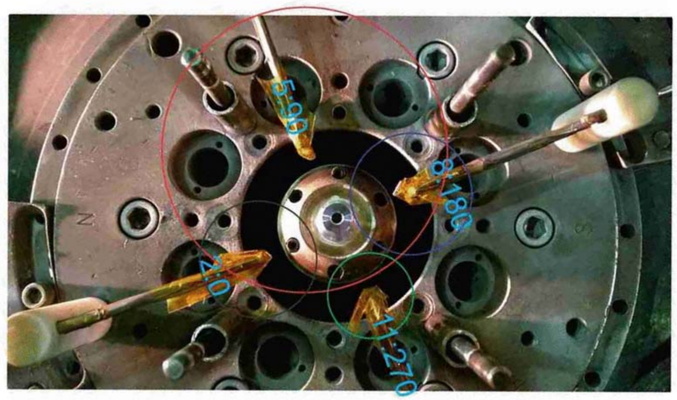
SHOT 3678

Al liner with trigger pin

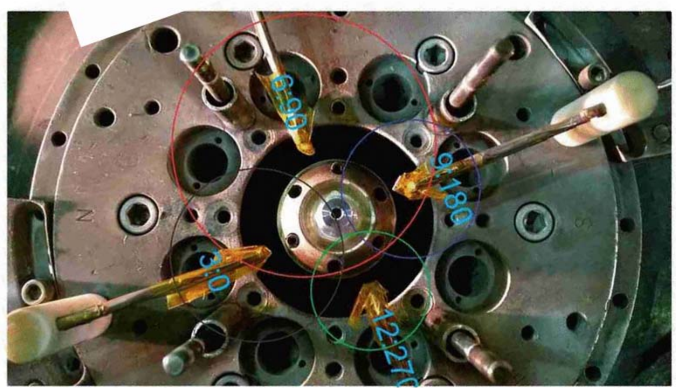
Top (1,4,7,10)

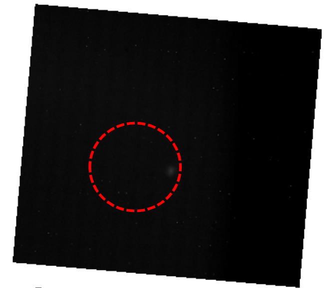


Middle (2,5,8,11)

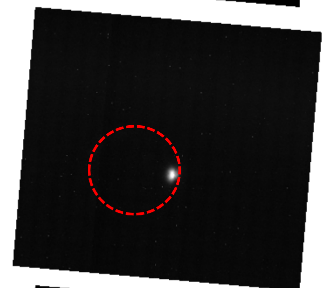


Bottom (3,6,9,12)

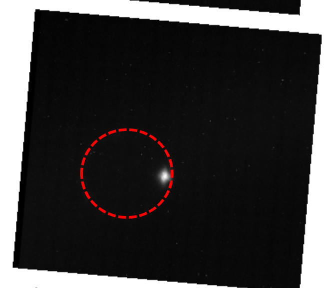




50ns

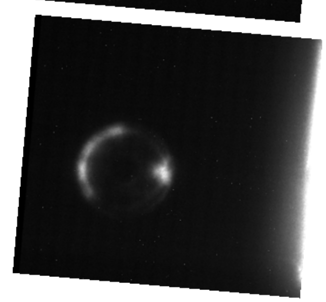


60ns



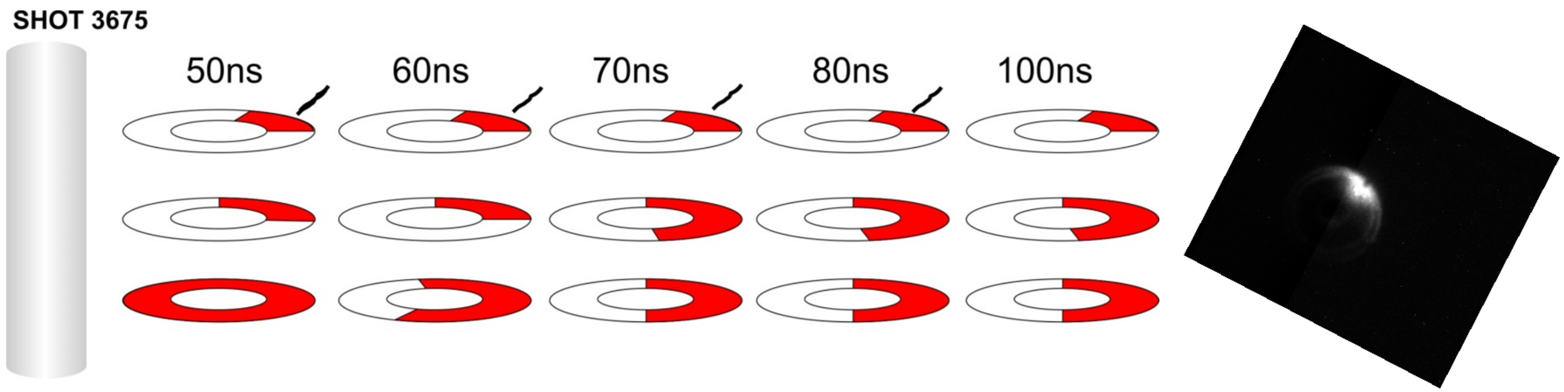
70ns

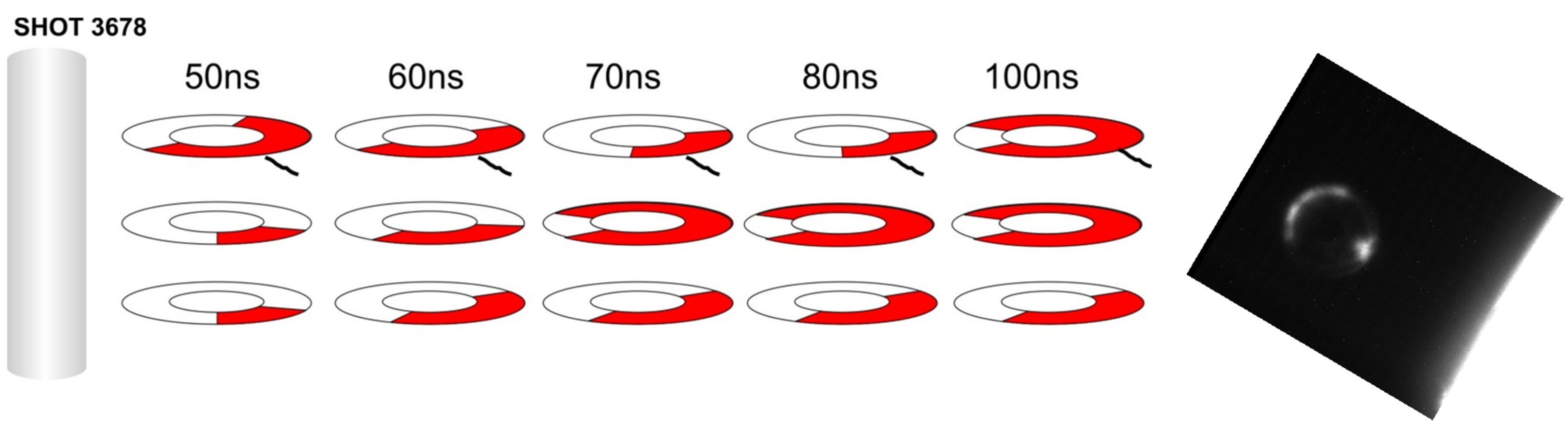
80ns



100ns

“Visualization” of the current density distribution





Summary

- Presence of a vacuum gap in the power feed strongly affects plasma formation

- The azimuthal uniformity of the current distribution is directly affected

- Induced asymmetry at the vacuum gap does not become evolve to uniform current density distribution over >15 mm axially in >100ns.

- Limitations of the triangulation methods
  - Does not have high spatial resolution
  - On-going discussion about current distribution effect

Next Steps

- Simulation work: PERSEUS and GORGON. We have a good test problem with trigger pin loads

- Upgrade UCSD current driver and reduce electrode dimensions on HV breakdown expts to drive up current density. Will highlight driving factors and allow scaling arguments