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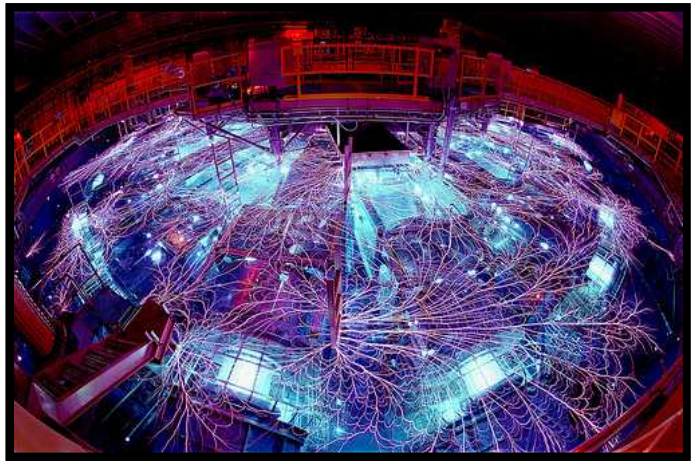

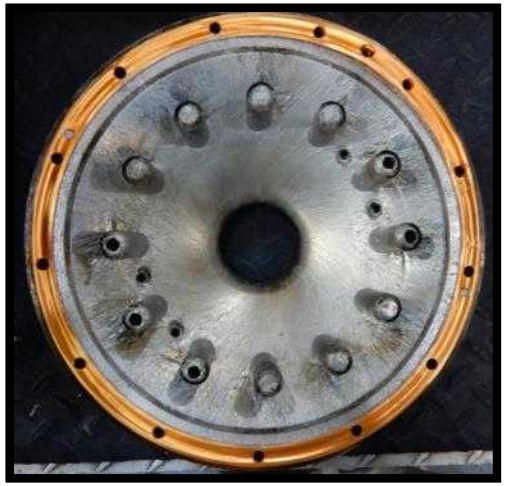

First Measurements of Negative Particles Contributing to Current Loss in Z-Machine Post-Hole Convolute

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*Sandia National Laboratories**

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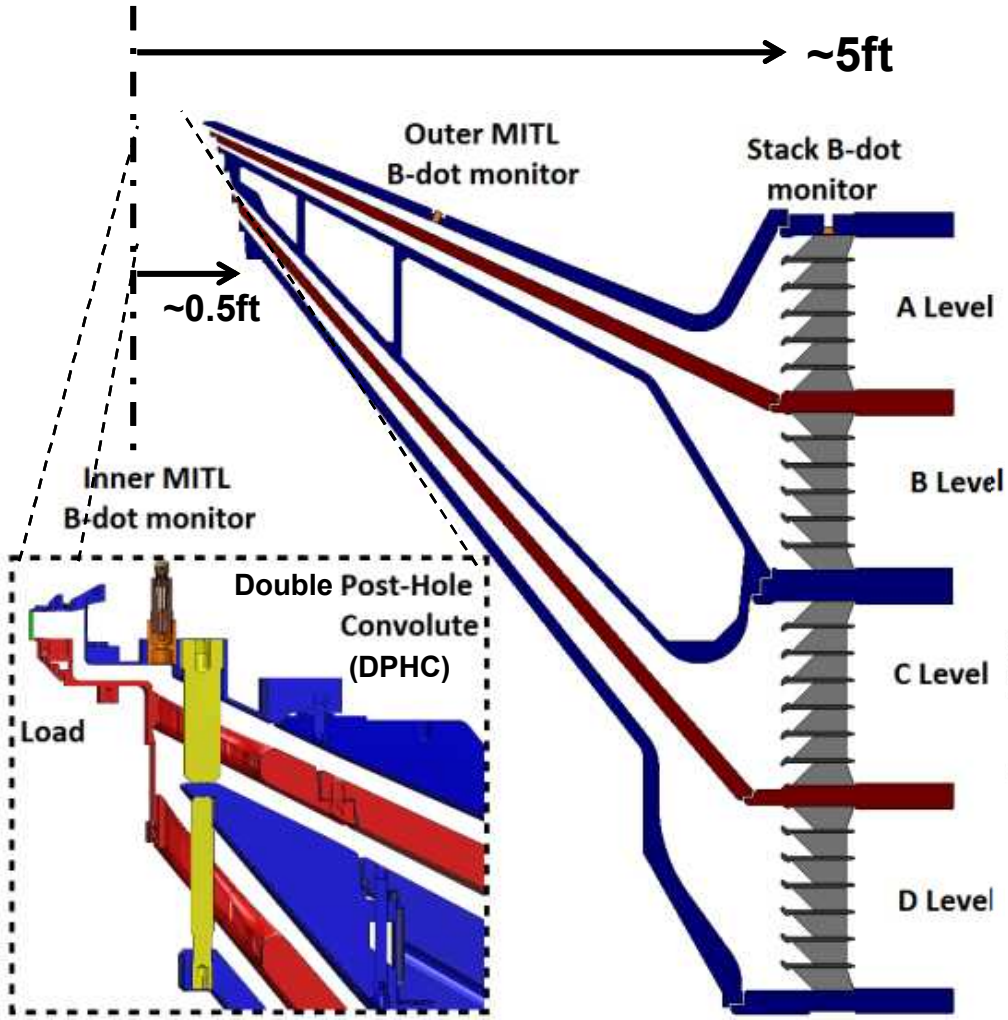
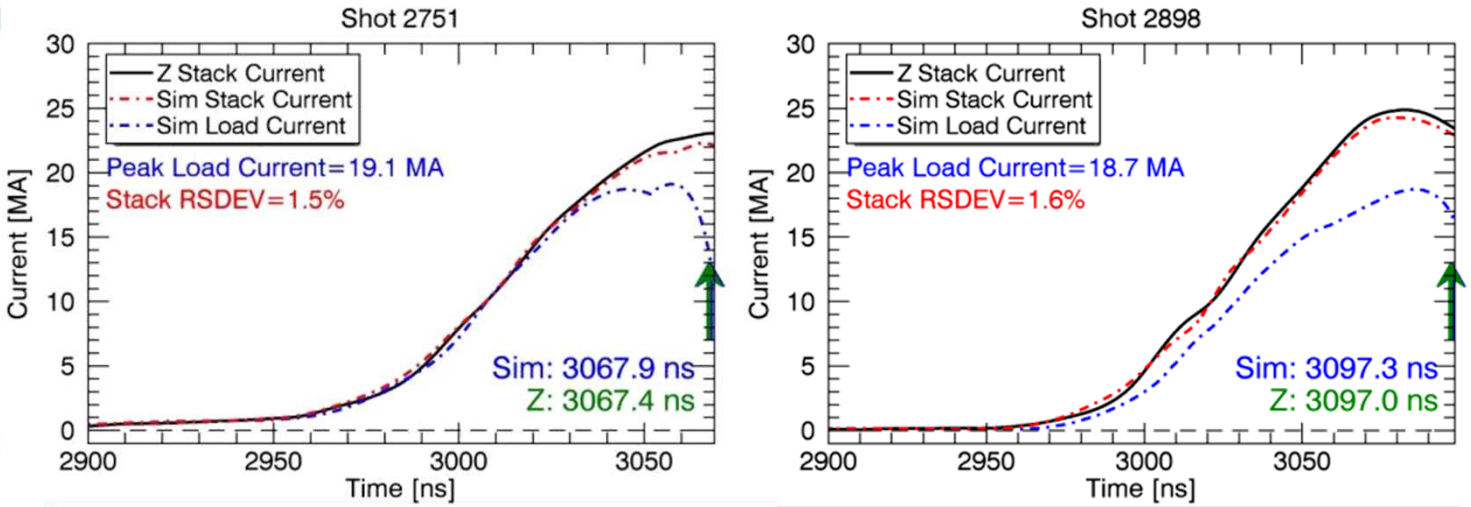
Sandia's Z Machine has delivered up to 27MA in 100ns, but can also lose ~5MA depending on target dynamics



- **Decreased load current through parallel MITLs and current-adding convolute negatively impacts all Z experiments**
  - Achievable pressure profiles in dynamic material properties
  - Radiated power for radiation sources
  - Fuel compression for inertial confinement fusion
- **Losses occur in final 1' of MITL in the dual post-hole convolute**

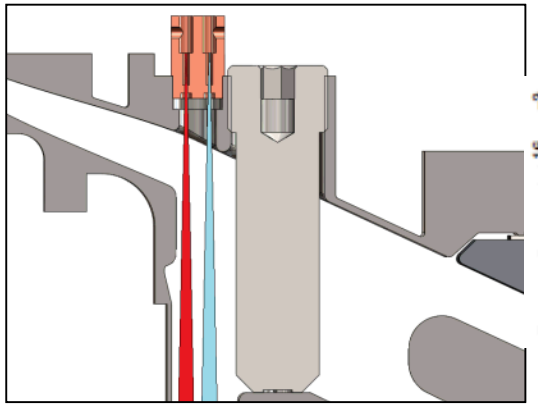


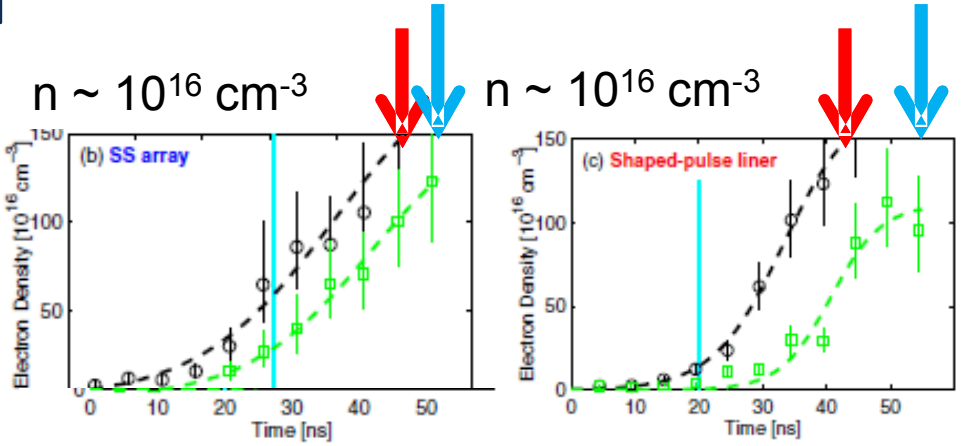
Z Simulations for wire array (left), MagLIF (right) experiments show divergence in Z stack and load current (apparent loss).

See B. T. Hutsel discussion of Z current loss: Poster Session 2!

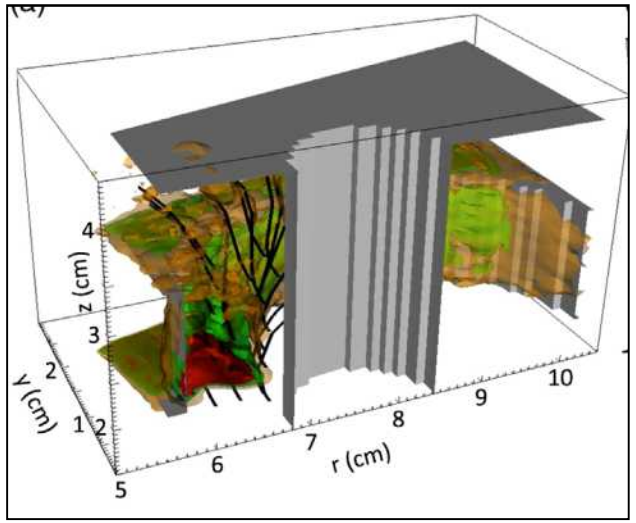
To date, the mechanisms of Z Current Loss are neither fully understood nor diagnosed

- Magnetic pressure from high current drive should insulate all electrons from shunting to anode
  - Loss current is likely ion controlled
  - Anode acts as ion source when heated
  - Uninsulated ions stream across gap
  - Ion enhancement occurs from space charge neutralization by sheath flow
- Collisional sheath electron migration, early deposition of negative ions may quickly increase anode temp
- The DPHC is a complex 3D geometry that defies treatment with classical MITL descriptions





Spectroscopy in DPHC reports apparent closure velocity ~35-50 cm/μs (Gomez et al., Phys. Rev. Accel. Beams 20, 010401 (2017). This value greatly exceeds ~1-2cm/μs in MITL literature.



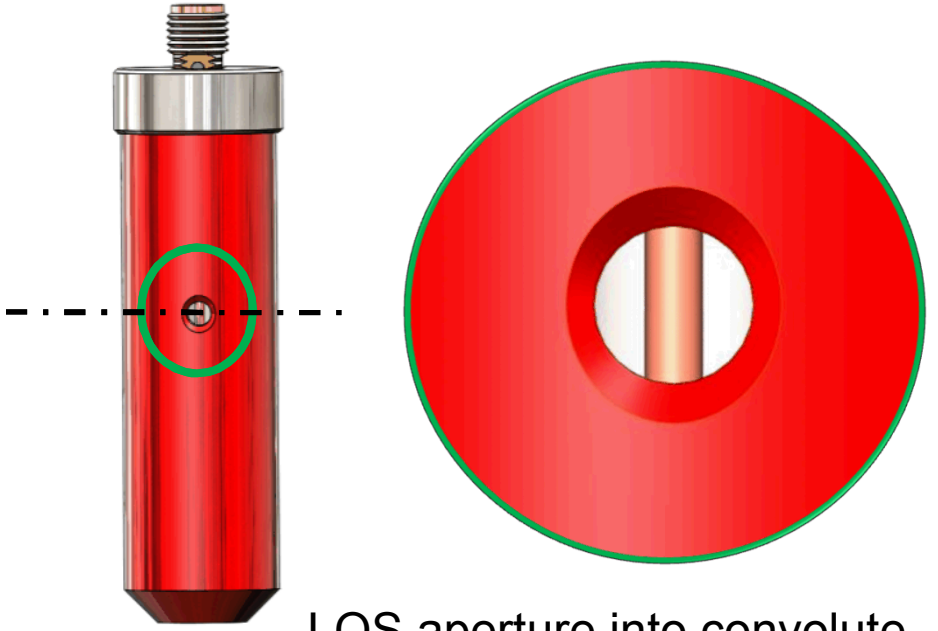
Particle-in-cell calculations of DPHC show plasma flowing along streamlines into post-hole region observed by spectroscopy above

D. Rose, et al.*, Phys. Rev. Accel. Beams *18, 030402 (2015)

See A. Fierro presentation on Current Loss Physics – Poster Session 3!

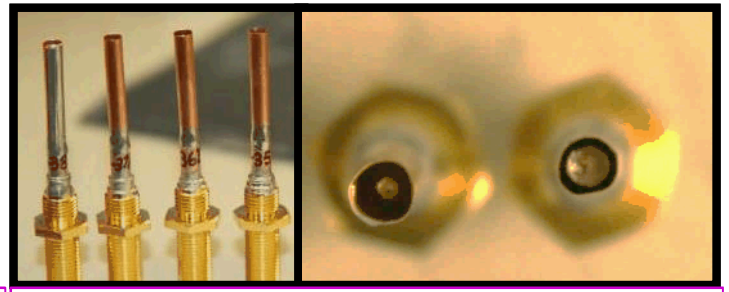
We have fielded a new diagnostic to sample charged particle fluence incident on anode posts

- We have embedded electrodes inside convolute posts to measure charged particle species shunted to anode
  - *Faraday Cup in an Anode Post – an FCAP is born!*
- Unfiltered probes collect all species (e^-, negative ions)
- Filtered electrodes provide opportunity to isolate ion species and low-energy electrons
- We can design custom anode posts with apertures to sample different areas of the convolute

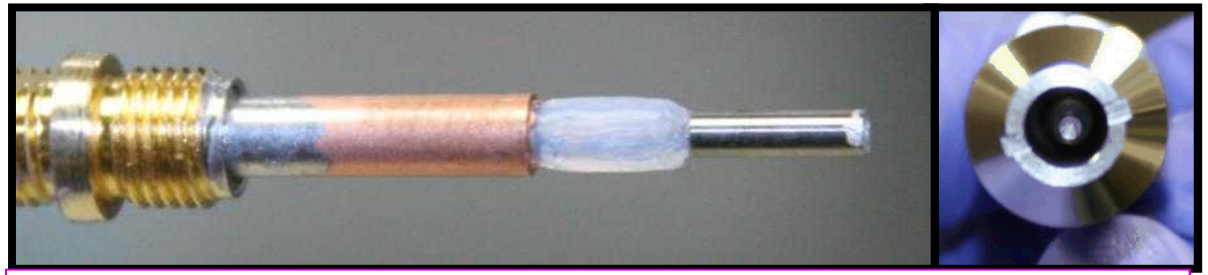


LOS aperture into convolute
ϕ2.5mm – 3mm

**4.75mm electrode (left)
2.03mm electrode (right)**

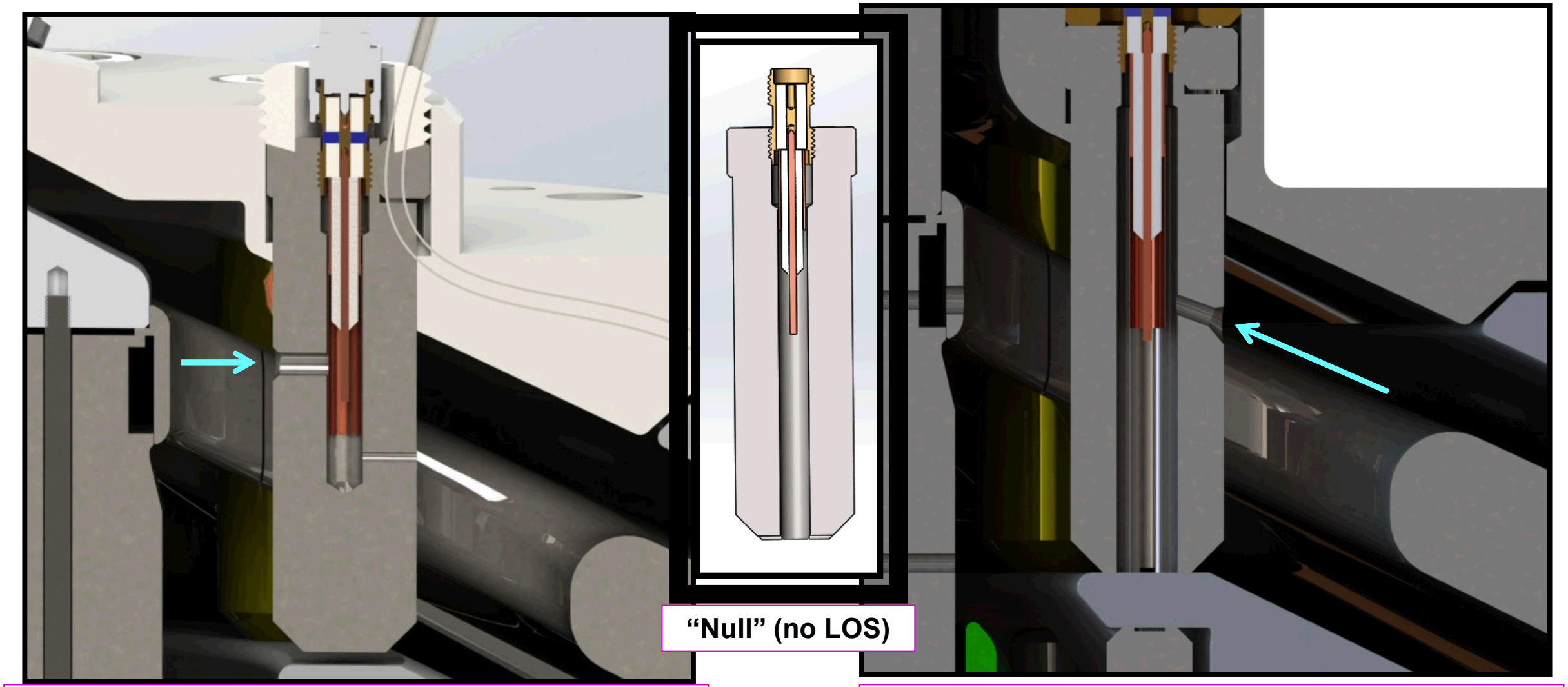


Filtered FCAPs (left), top-view of electrodes within (right)



2.03mm tungsten electrode (left), view from bottom as installed in anode post (right)

FCAPs use apertures to spatially collimate particle fluence in different areas of convolute

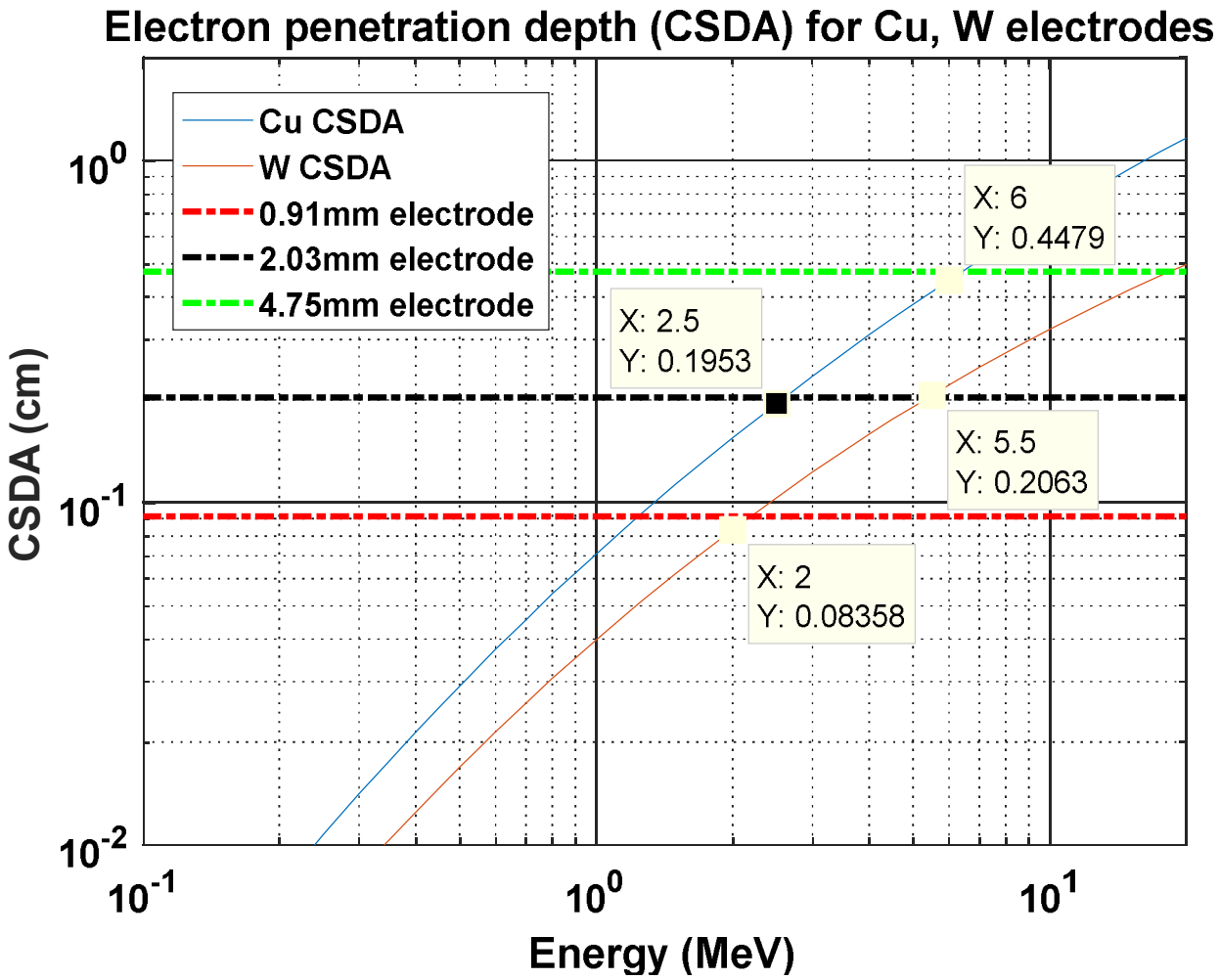


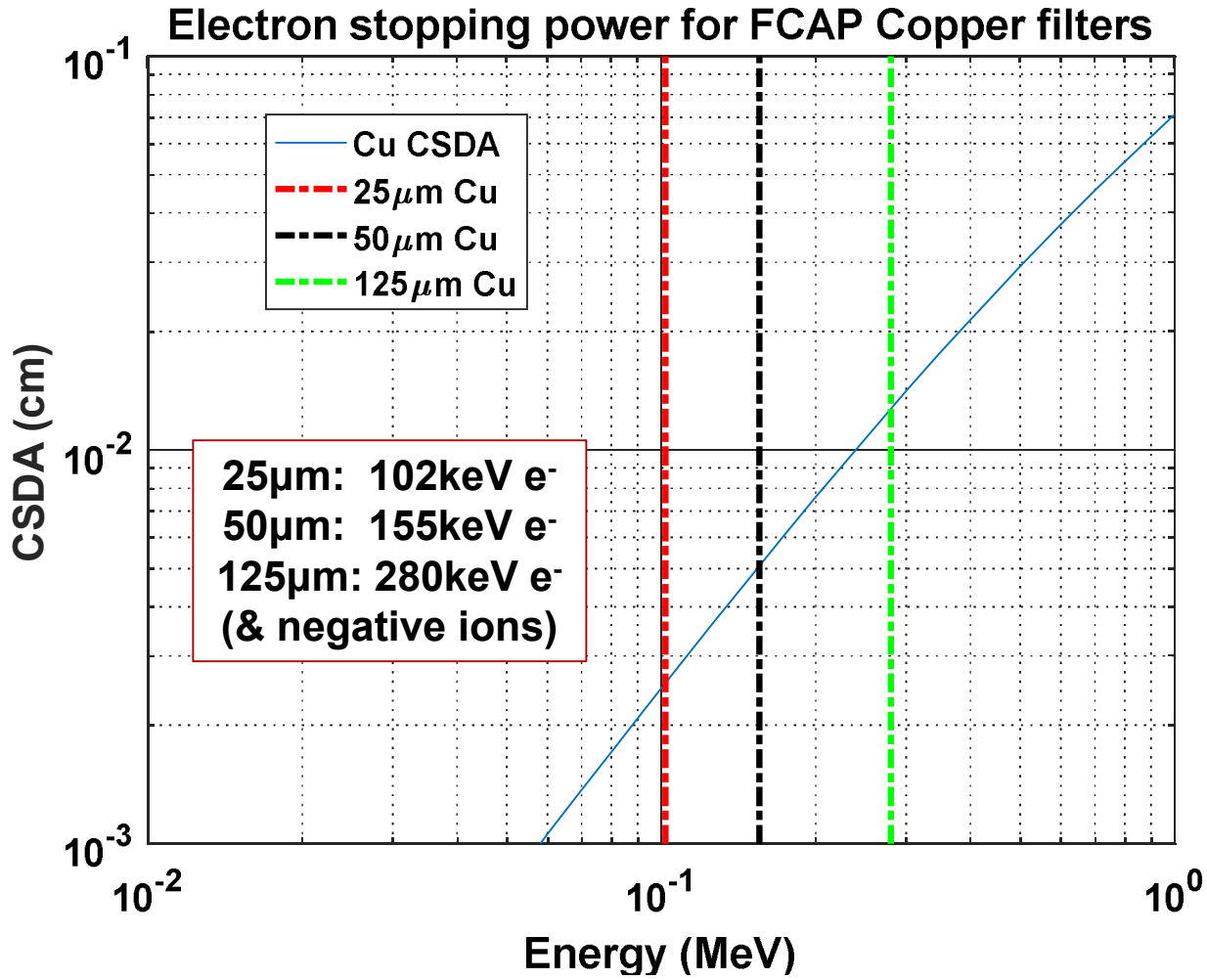
"Null" (no LOS)

"Downstream" FCAP observes same region in post-hole convolute as previous SVS work

"Upstream" FCAP is nominally aligned to measure non-insulated current in magnetic null

Copper and Tungsten electrodes collect electrons; copper shim filters negative ions, low-E electrons

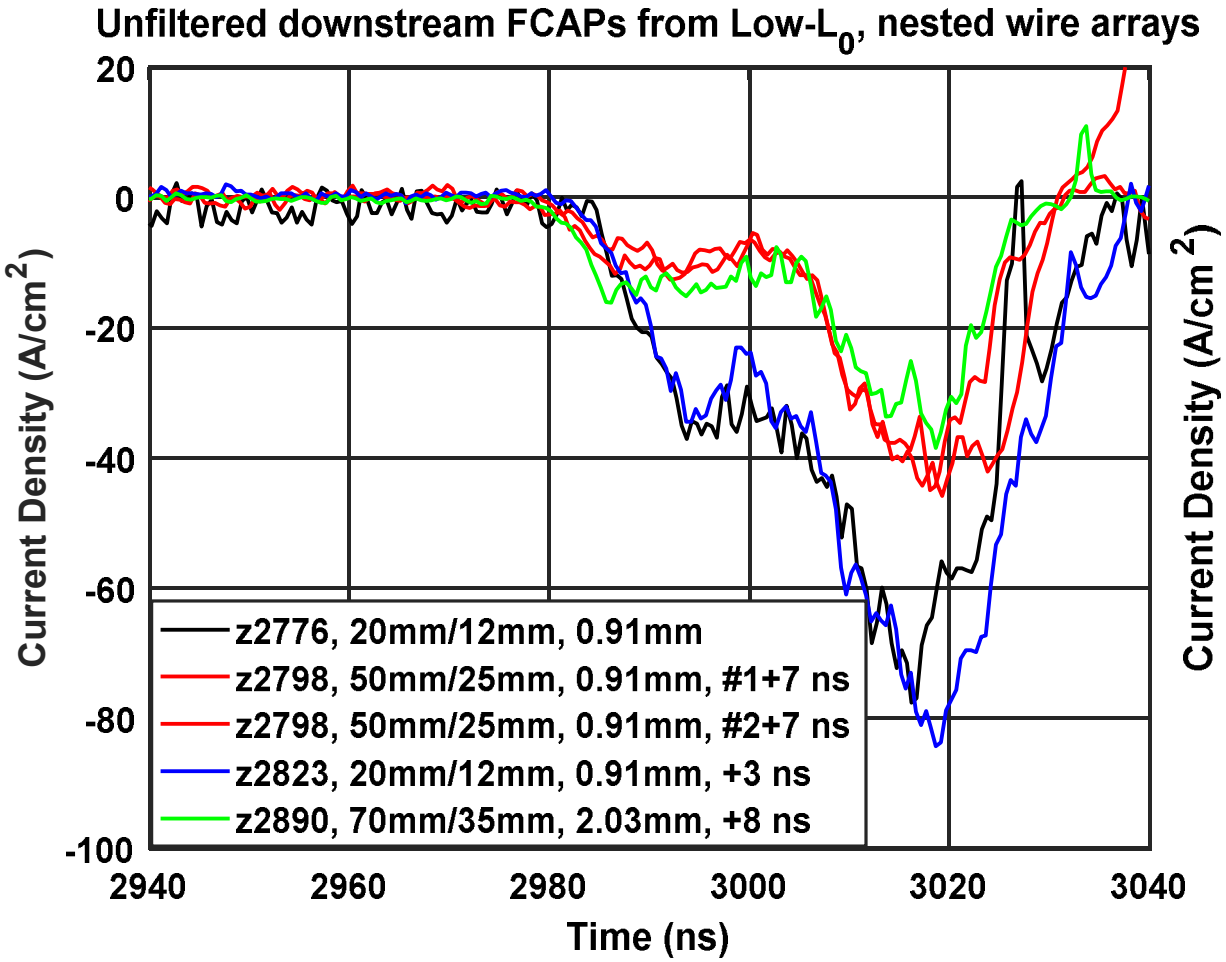


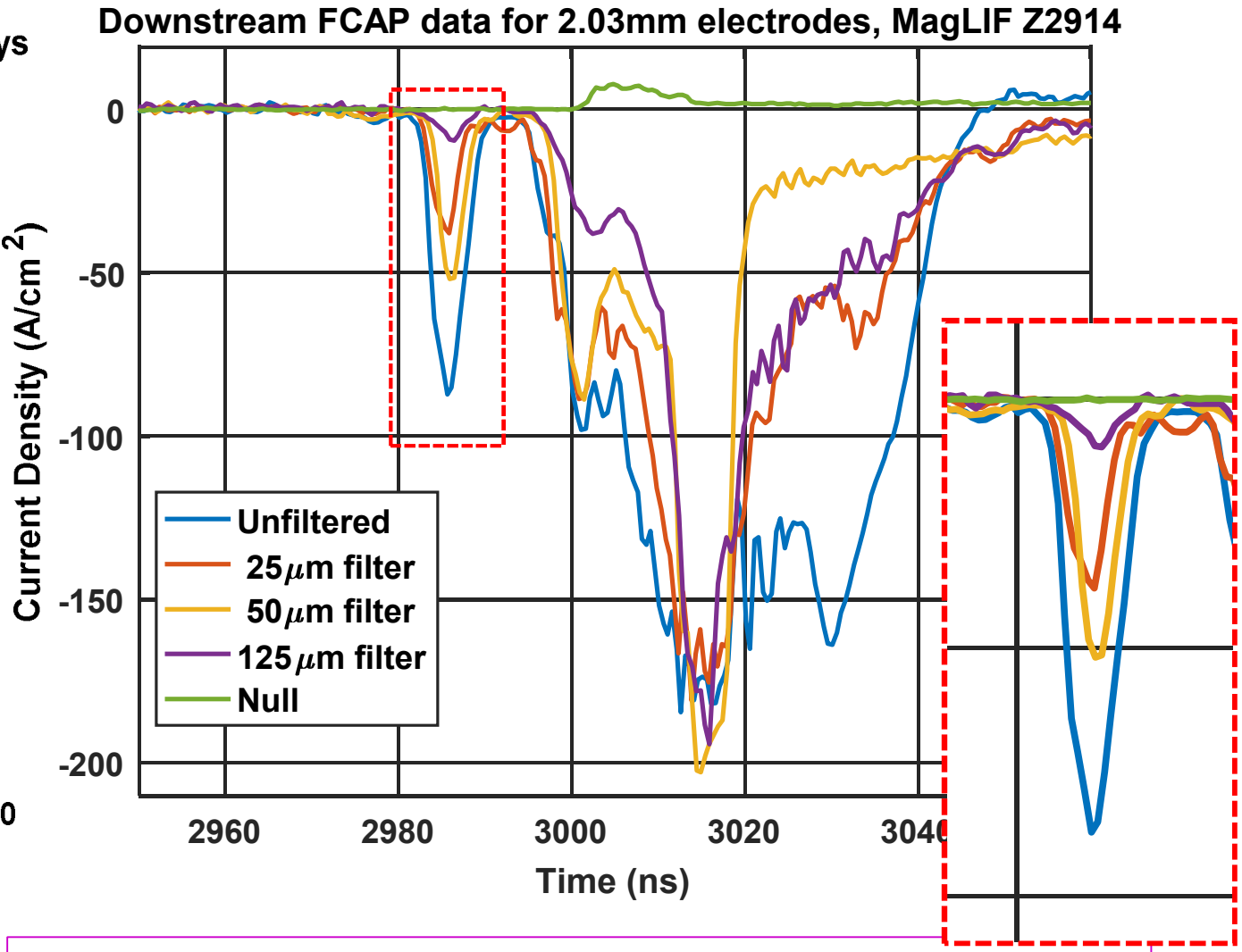


http://physics.nist.gov/PhysRefData/Star/Text/ESTAR.html

25μm Cu sufficient to stop ~2MeV H^- ions (PSTAR)

Downstream post-hole measurements highlight plasma dynamics that vary with initial load inductance

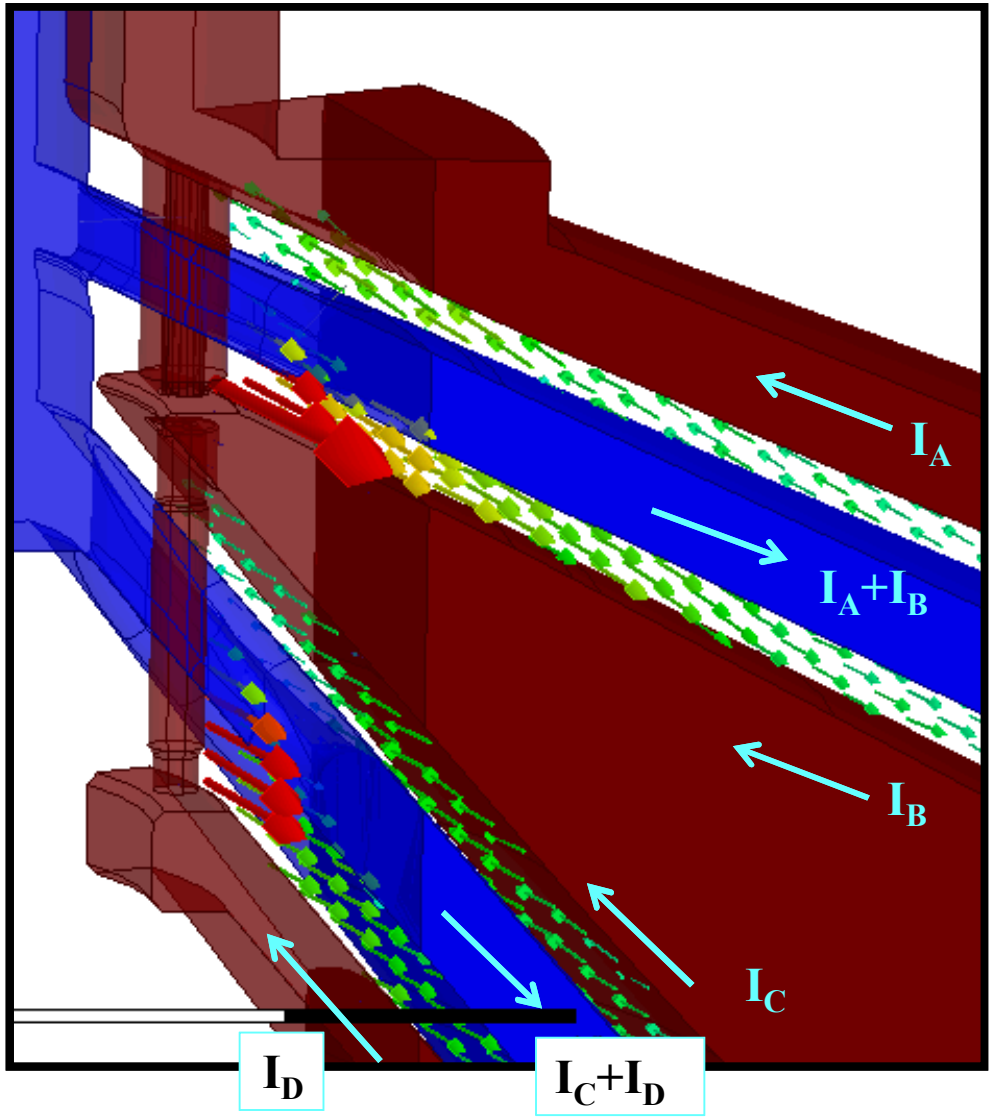


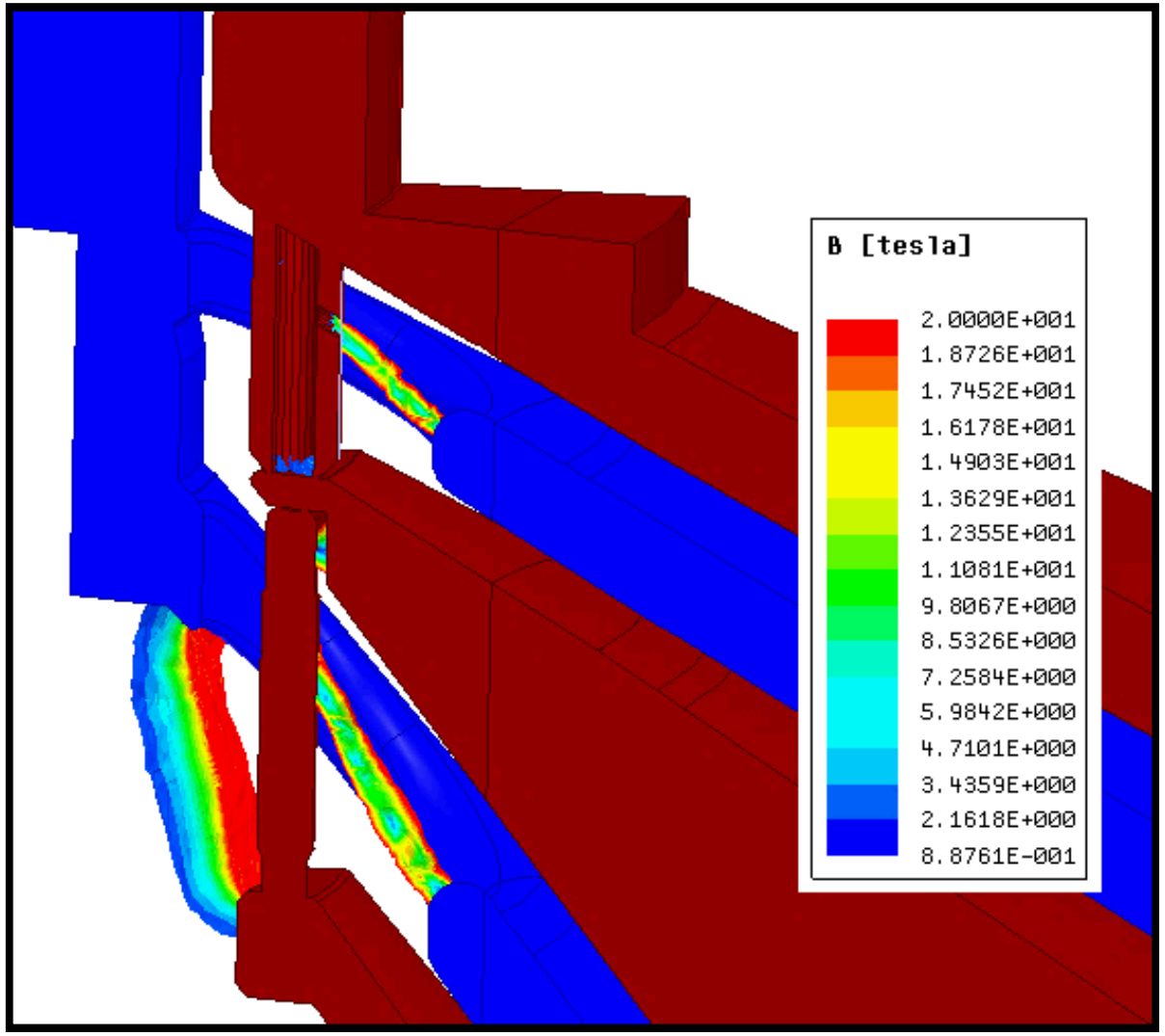


FCAPs on nested (OD/ID) wire-array experiments suggest repeatable plasma dynamics in convolute

High-L_0 load shows unexpected energy discrimination with varying filter thickness, possible azimuthal asymmetry

DPHC magnetic field topology introduces magnetic nulls that provide non-insulated electron flow to posts

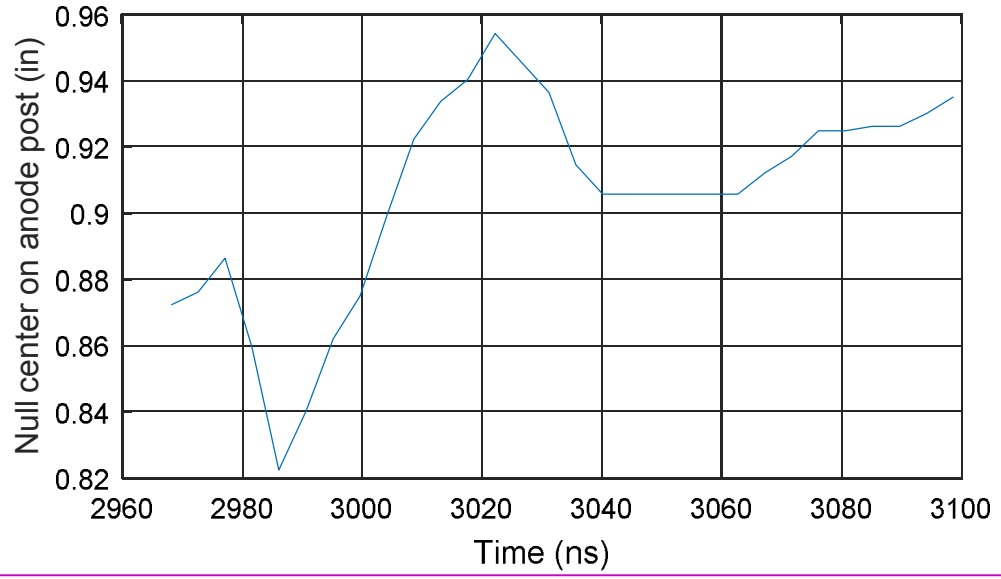




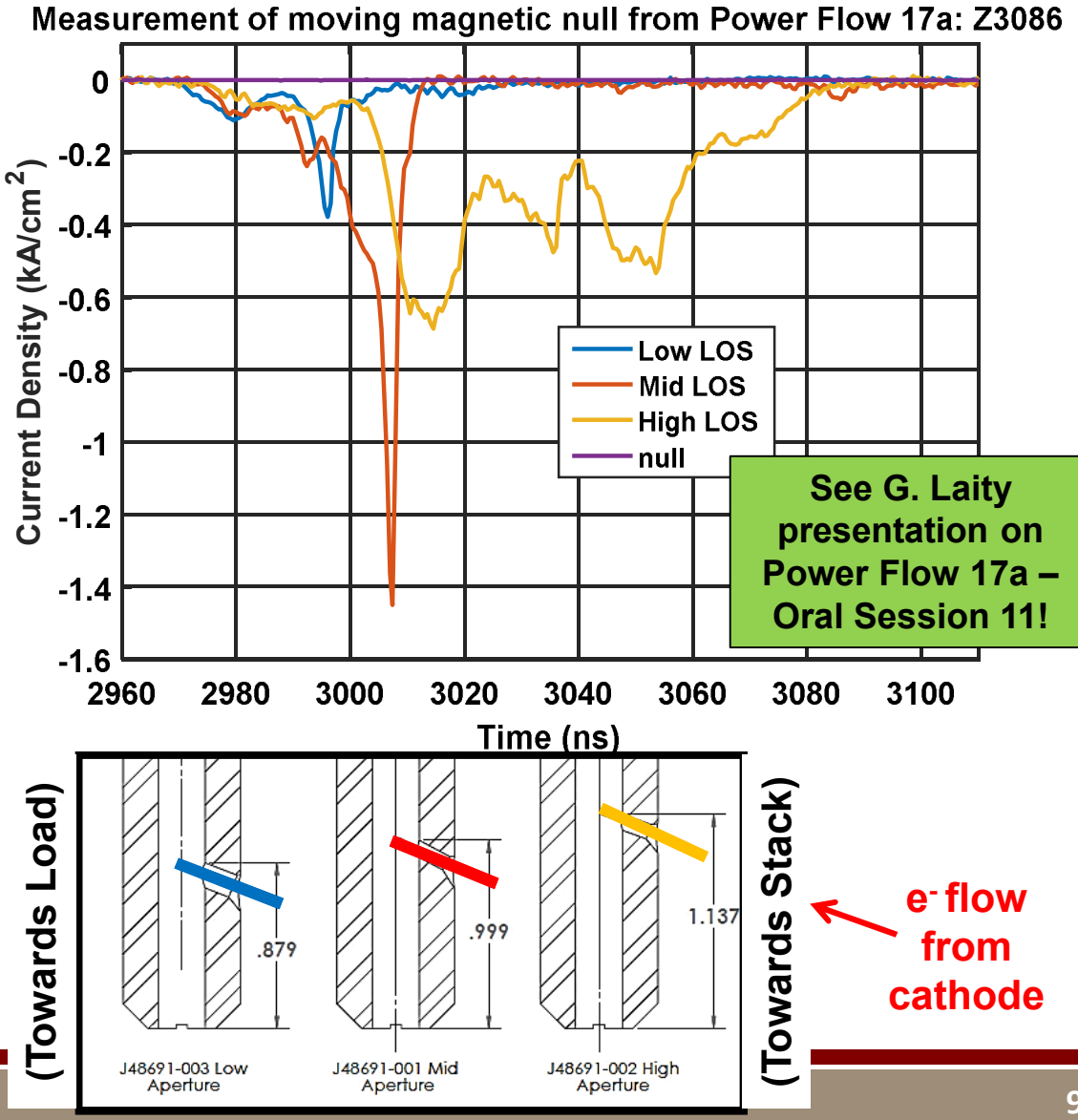
ANSYS Maxwell time harmonic solution (f = 2.5MHz) for convolute hardware shows magnetic null location at 3060ns for Z3086

Experimental data supports a narrow magnetic null that does not carry majority of lost current

- Tungsten electrodes reduced collection area, increased measurable current density > 1kA/cm^2
- Fielded on same shot upstream posts with narrow LOS at three axial heights.
- Probe response follows trend of cold calculations



Location of magnetic null centerpoint calculated using translated stack measurements for Z3086.



Ambiguities in interpretation exist, and must be addressed to build confidence in results

- Loss of signal / signal cutoff may be attributable to several phenomena
  - Bending out of aperture due to onset of magnetic insulation (or movement of magnetic null)
  - Ion beam current ablates filter or probe material; shorts measurement locally
  - High energy electrons are ranging through detector
  - Probe voltage exceeds 1-2kV on highest current density shots! Flashover problems?
- Blackbody radiation from cathode generates photoelectric emission
  - Emitted photocurrent partially cancels negative particle currents
  - Recent data with biased FCAP-like diagnostic suggest bright blackbody radiation in final power feeds
  - Positive perturbations have been observed on unfiltered FCAPs following loss of signal
- Need to expand dataset to account for other variables
  - Azimuthal asymmetry in post-hole plasma dynamic behavior
  - Probe alignment to aperture
  - Alignment of incident current to aperture

Future Work and next steps

- Design experiments to remove sources of ambiguity in data interpretation
  - Fielding the diagnostic on subscale experiments at other accelerators
- Independently confirm presence and magnitude of negative ion beam current with additional diagnostic
  - In-post passive magnetic spectrometer has been designed and is ready for testing!
- Resolve electron energy distribution using multi-conductor FCAP configurations and compare to expectations from MITL literature
  - Calculate energy deposition into anode surfaces and estimate turn-on time ($\Delta T > 400K$)
- Correlate observed plasma behavior to target and convolute electrical dynamics
  - System L_0 and dL/dt certainly affect convolute voltage. What will FCAPs see?

Questions?