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Summary of some recent Experiments at Sandia:

Ion Beam Generation (Hermes III) and Self-Magnetic Pinch Radiography Experiments (RITS-6)

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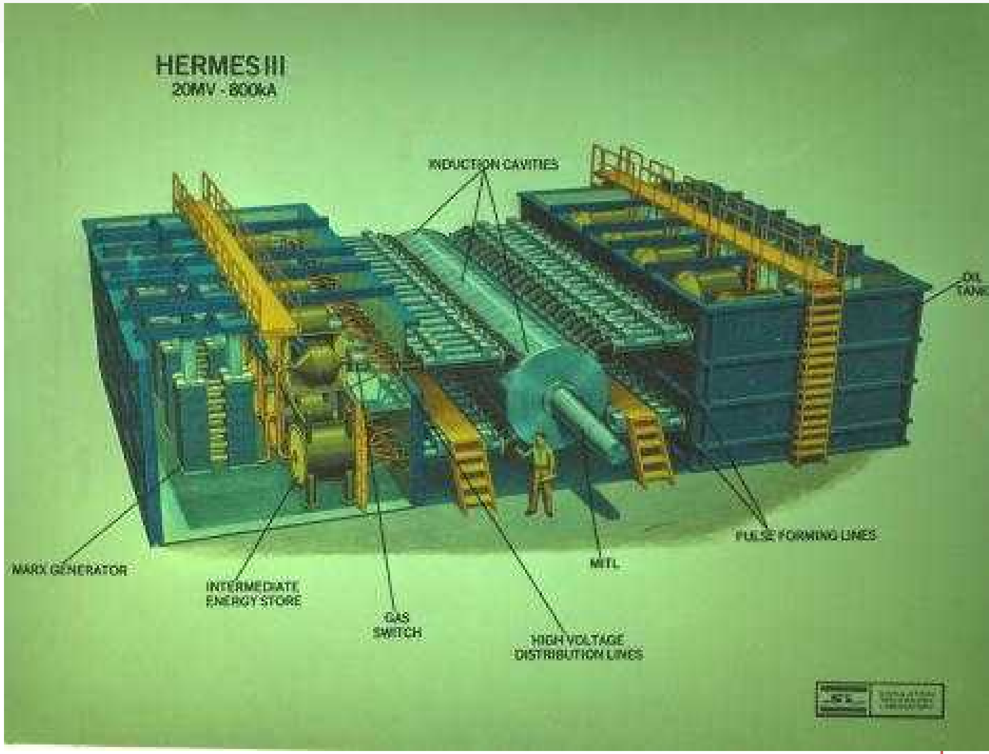
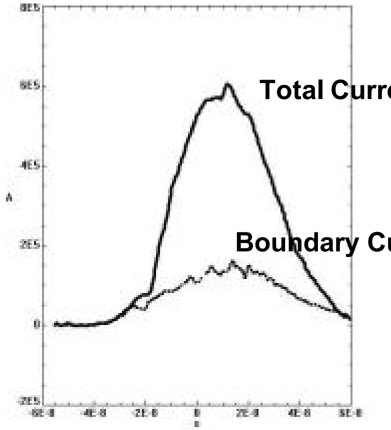
Part One

- Description of Hermes III platform
- Ion Beam source for neutrons
- Radiation Effects applications

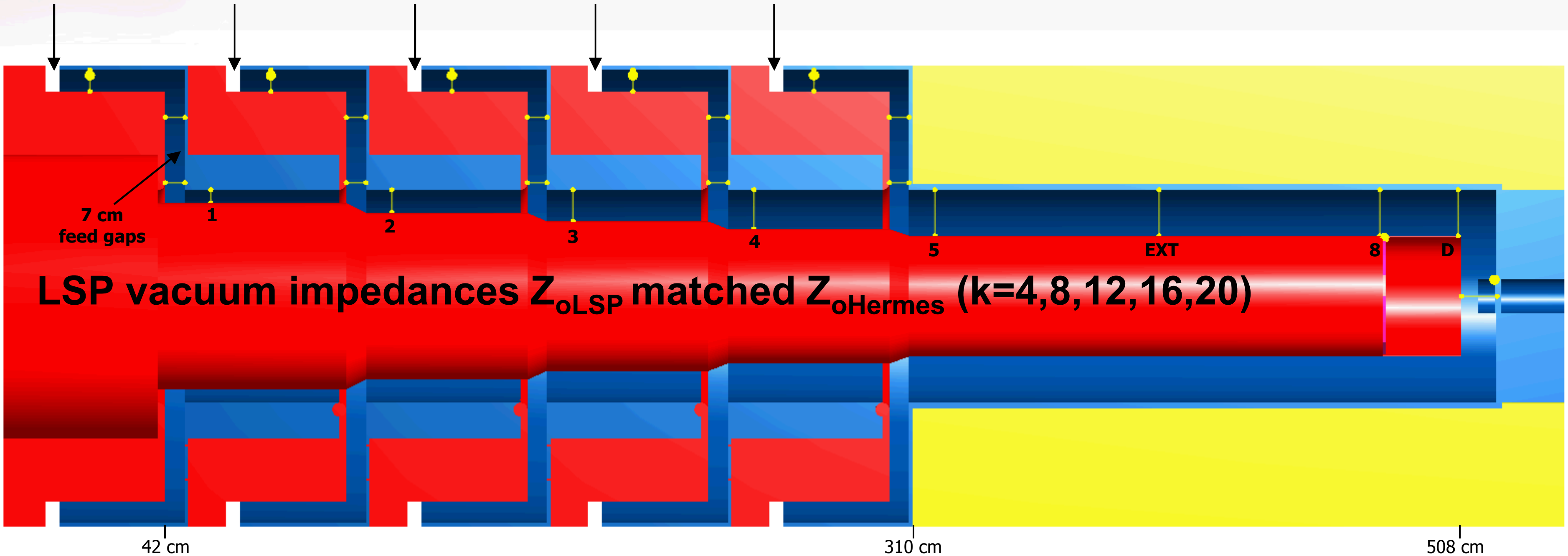
HERMES III is the Test Bed for Pulsed Neutron Generation for Radiation Effects experiments

- HERMES III - Inductive Voltage Adder (IVA) architecture, 19 MV 650 kA 40 ns when operated in negative polarity normal pulse
- 20-stage IVA: significant vacuum current (Below Right) (Total minus Boundary)
- ‘Standard Mode’: electrons flow across 53-cm A-K gap and strike Ta converter
- For ion diode operation, keep Negative Polarity, turn electron flow around, ions propagate into center conductor. This avoids ‘layered flow’
- Modeling tools: LSP for electron trajectories, ITS/MCNPX for neutron characterization
- Beam Diagnostics
  - Faraday Cups, Rogowski, Nuclear Activation
- Neutron diagnostics
  - Bubble detectors, nuclear activation foils, CR-39 counting





This LSP Simulation setup shows 5 IVA cells (instead of the actual 20) to illustrate how the center conductor decreases in diameter as the output voltage rises.



MITL position	R_o [cm]	R_i [cm]	$L_{seqment}$ [cm]	Z_o [Ω]	Z_{flow} (PIC) [Ω]	Z_{flow}/Z_o
1	38.1	33.38	65	7.94		
2	38.1	29.86	65	14.63		
3	38.1	26.78	65	21.15		
4	38.1	24.06	65	27.59		
5	38.1	21.63	65	33.98		
load	38.1	21.63 (17" OD)	198	33.98		

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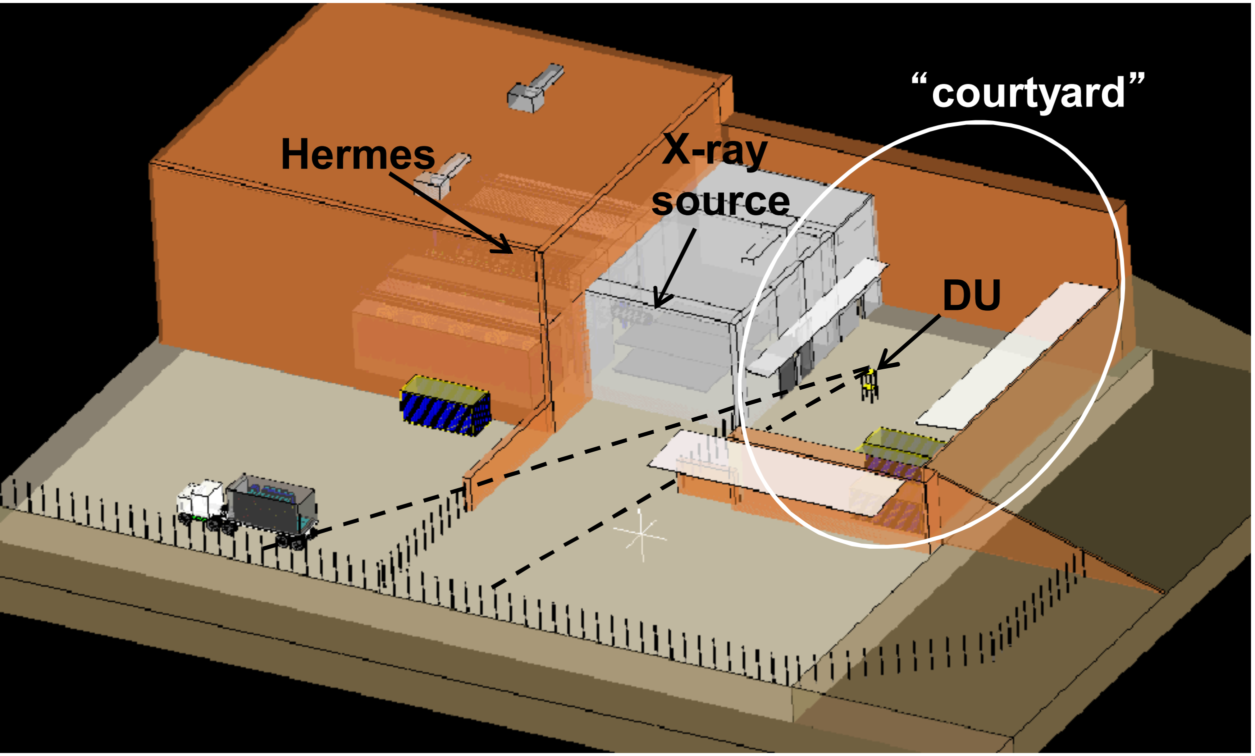
An example of Bremsstrahlung operation: Active Detection experiments from 8 MV to 16 MV output, and detector distances of 10s of meters



- 2 modes of operation
  - Half machine
    8 MV, 300 kA
  - Full machine
    16 MV, 600 kA
- Setup for experiments
  - Photons propagate through door aperture and onto DU target located 18.6m from diode
  - 5 to 45 m neutron detection
  - Measurements also made at 100 m distances

HERMES site active detection in photographs

Target view thru aperture

View from target to detector array

View from 45 m location

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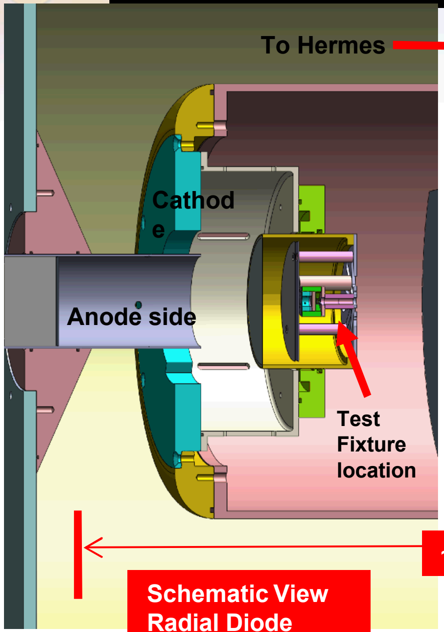
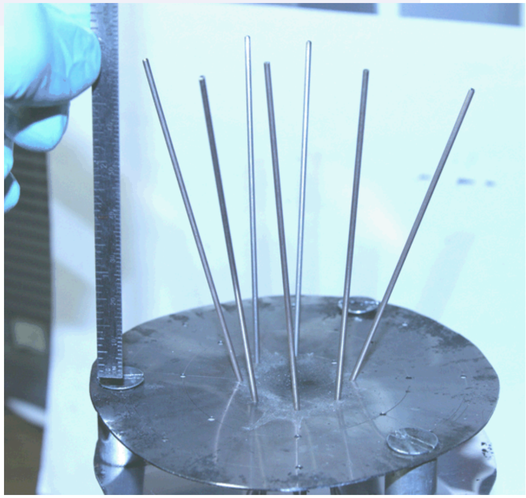
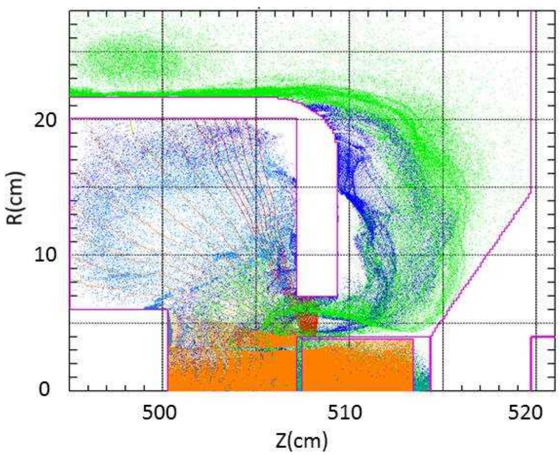
A different Application: The negative-polarity Radial Ion Diode incorporates Flow into diode ion current



Schematic View
Radial Diode
Negative Polarity



Shadowbox with rods
Radial Diode
POSITIVE POLARITY



LSP Particle Plot
Radial Diode
Negative Polarity
REVERSE DIRECTION

- (LEFT) Schematic Drawing, Radial Diode, Negative Polarity. Anode-side cone to grade MITL flow. Anode source: 10-mil polycarbonate. Expect ~ 70% protons, 30% carbon in various charge states.
- (MIDDLE) Shadowbox plate with rods inserted, Radial Diode in POSITIVE POLARITY (weaker beam).
  - Converging beam indicated – propagation distance ~ 10 cm.
  - Shadowbox plate is stainless – can see beam general damage pattern on front.
- (RIGHT) Particle Plot, LSP simulation of Radial Diode at half-machine (Paul Ottinger). Note REVERSED VIEW from LEFT. ORANGE denotes ions, green for electrons.
  - Ions converge, consistent with shadowbox damage.
  - Simulation (and shot data) shows that MITL flow is almost entirely incorporated into diode flow. This is important for matching IVA to ion diode. Key is UNDERMATCHING the load.
  - EXPECTED ION EFFICIENCY: about 20%.

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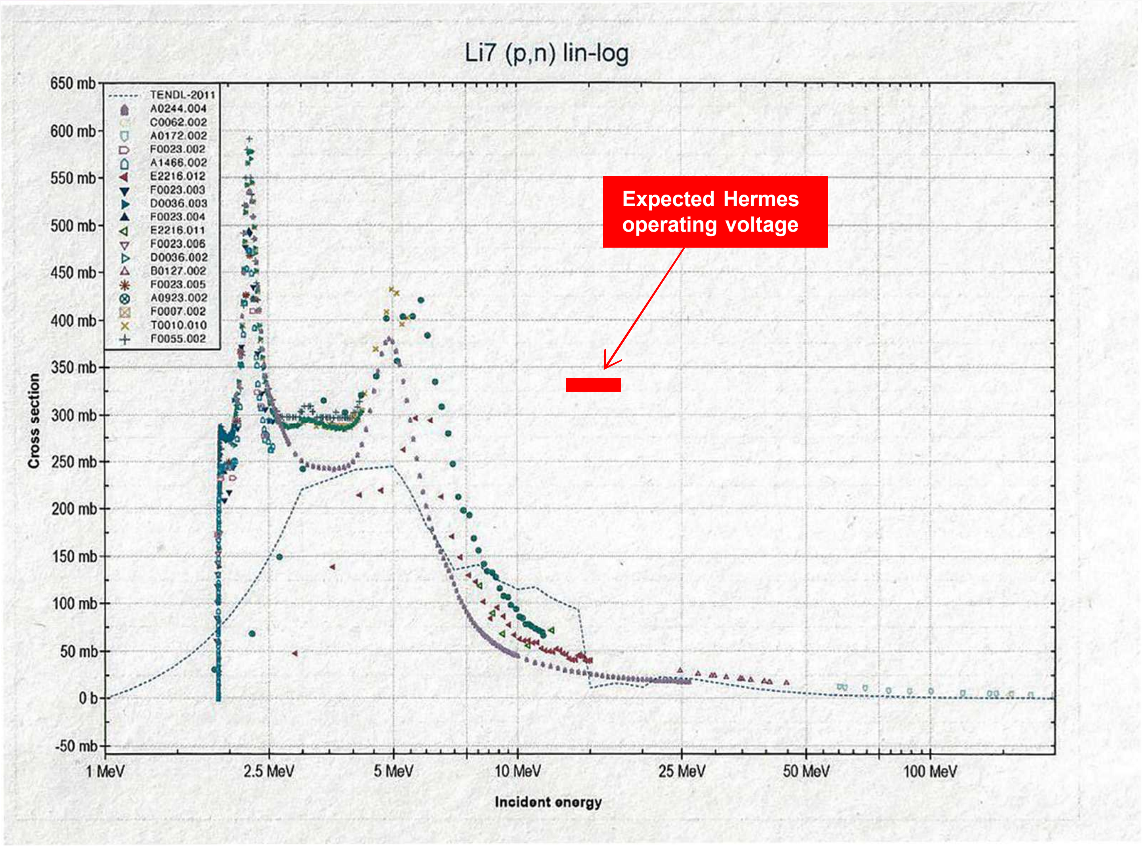
Beam-Target Interaction is the neutron generation method. D-D, D-T, and L7(p,n)Be7 are NOT the neutron reactions of choice for this.



Source:
JANIS Book of proton-induced cross-sections, OECD NEA Data Bank

- **Cross section peak occurs well below expected Hermes Power Pulse voltage (RED)**
- **Except for narrow bands, total cross section is ~ 350 mb, not that high**
- **Reaction product (Be7) decays with 53-day half-life. Since ion diode is single-shot, such long-lived activation interferes with turn-around for next shot.**
- **D-D and D-T both require deuteron beam. T requires Tritium Facility – not possible.**

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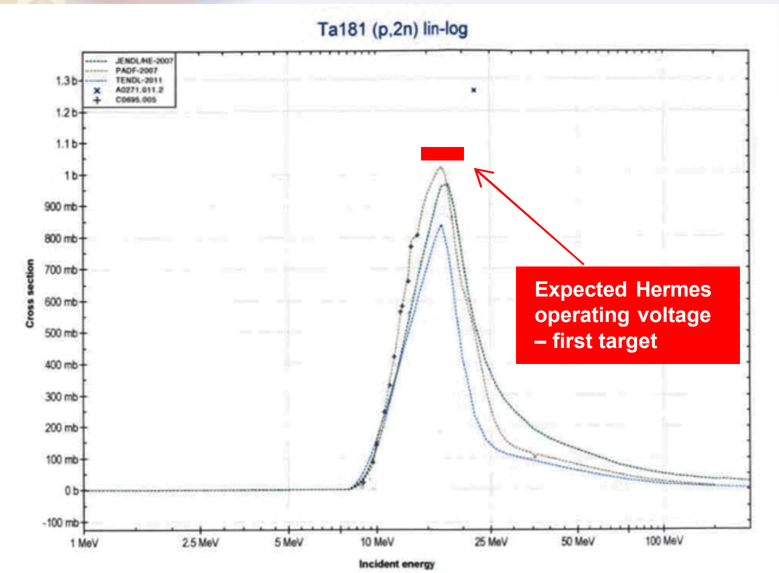
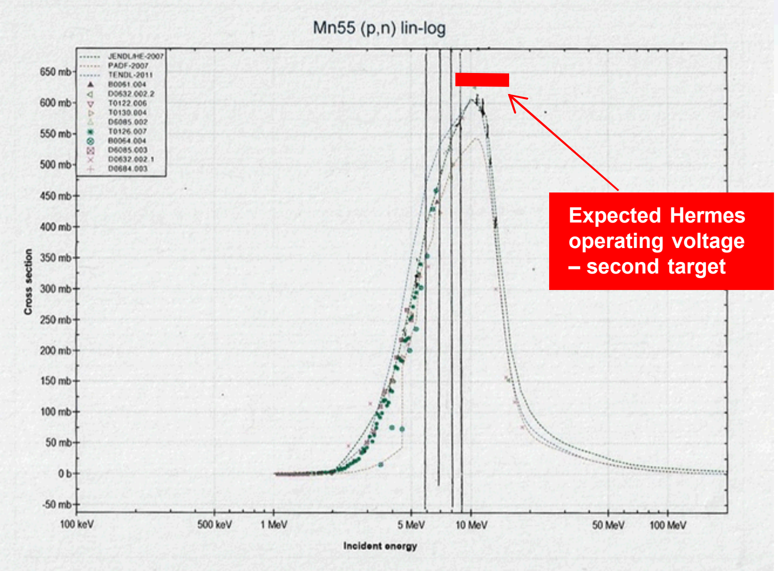
Our approach: Sequential sub-range thin metal plates





- (LEFT) Ta target (~0.3 mm). Cross section, Ta181(p,2n)W180. Peaks at 1 barn (!)* at ~ 17 MeV. But threshold is at ~ 7-8 MeV. So the last 7-8 MeV of a thick-target would yield no neutrons. So add
- (RIGHT) Mn target. Cross section, Mn55(p,n)Fe55. Peaks at 600 mb 11 MeV, threshold at 2 MeV. TWO sub-range targets extract maximum neutron yield.
  - Both targets available in thin plate form, both are 100% single isotope.
  - Activation products:
    - Ta(p,2n) yields W180 with 1.8e18 yr half-life e.g. no activity
    - Ta (p,n) yields W181 with 121 day half-life, but peaks at only 100 mb
    - Mn(p,n) yields Fe55 with 2.7 yr half-life. All decays are EC with secondaries in keV range, no gammas.
  - Other (p,n) reactions could be utilized (JANIS has 800 pages).

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How many neutrons can we expect?

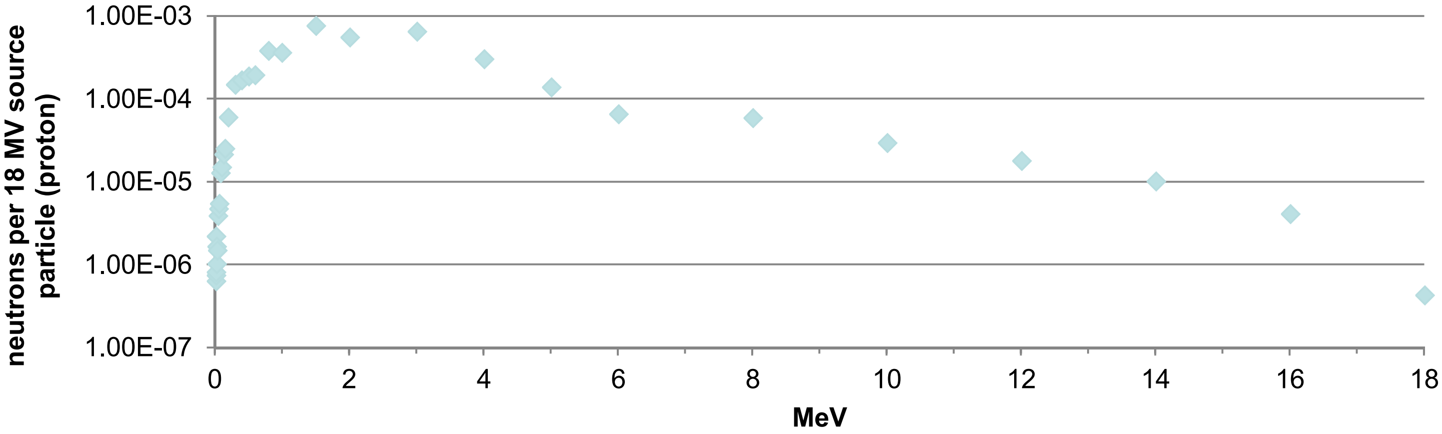
1. Assume 16 MeV peak diode voltage. At 20% efficiency, expect ~ 125 kA total ion current, of which 70% are protons ~ 90 kA. Calculations below assume 75 kA.

2. Peak Beam Power ~ 1.2 TW into ~ 5-6 cm spot size, or ~ 50 GW/cm^2. For 40 ns pulse, deposited energy ~ kJ/cm^2.

3. Using this beam input, a hand-calculation using total cross-sections for the Ta/Mn target yields 3.7e13 neutrons/pulse/4pi. MCNP calculations give 4.5e13. Expect at least factor ~2-3 forward bias.

Neutron Spectrum is Broad-spectrum

Preliminary modeling (MCNP) Spectrum below (neutrons/incoming proton:



- (SHOWN) MCNP output: neutron spectrum, fixed-energy 18 MeV incoming PROTON
  - Spectrum is Broad, extends from 18 MeV to 100 keV (99% of neutrons > 100 keV)
  - ≥ 2 MeV: 33% in backward direction, 41% in forward. ≥ 5 MeV: 2.5% in 180 direction, rising to 11% in 25-18° direction (protons angled at 15%). So definite forward-bias for high-energy neutrons.
  - At 10 cm distance to board, across ~ 6 cm distance, looks like ~ 3e10 neutrons/cm^2.
  - (from PoP paper): clear evidence of SEPARATE POPULATION of protons propagating BACKWARDS e.g. out of machine. If targets are placed there, expect even more neutron dose.

This work intended to support Radiation Effects Sciences at SNL

Radiation Effects Sciences studies the response of engineered systems to radiation environments relevant to stockpile systems

- **Neutron, x-ray, gamma-ray, and EMP**

Goal – Develop a scientific understanding needed to design, certify, and deploy non-nuclear components such that they will operate as intended.

Some environments can be physically simulated with high fidelity using existing radiation facilities.

Complex temporal and combined radiation environments can only be approximated, or not physically simulated at all today.

The development of a high intensity, short pulse width, low gamma-ray, low noise environment would greatly enhance the simulation capabilities for the RES program.

Capability development:

Test passive and active electronic devices and active board level circuits

Relevant parameters:

- Fast neutron fluence (> 10^{12} n/cm^2)
- Pulse width (~ µs)
- Exposure size and area (> 5 cm x 5 cm)
- Spatial uniformity (< 20%)
- Signal-to-noise (~0.1 mV)
- Signal output (3 coax per active transistor)

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Part Two

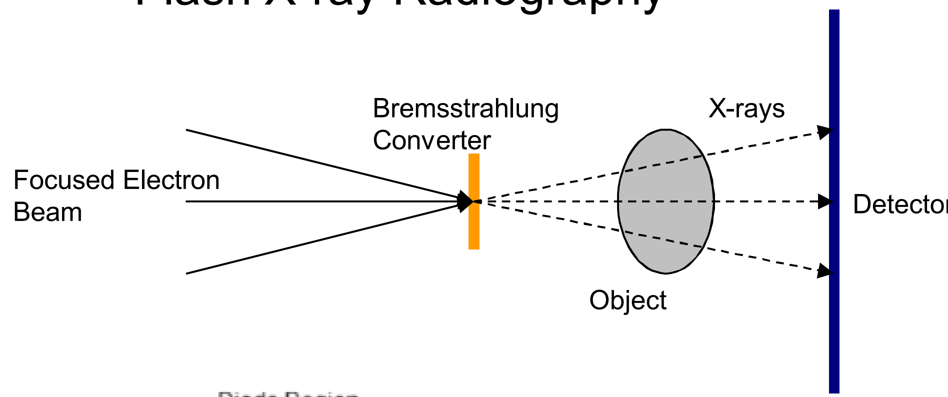
- Description of RITS-6 platform
- Electron beam source for radiography photons
- Sub-Theme: how does a Diode Load interact with a IVA?*
- Collaborators: Sean Simpson, Timothy J. Webb, Mark D. Johnston, Josh Leckbee, Michael G. Mazarakis, Sonal Patel, Mark L. Kiefer, and Nickie Bennett
- * a tale of Unintended Consequences

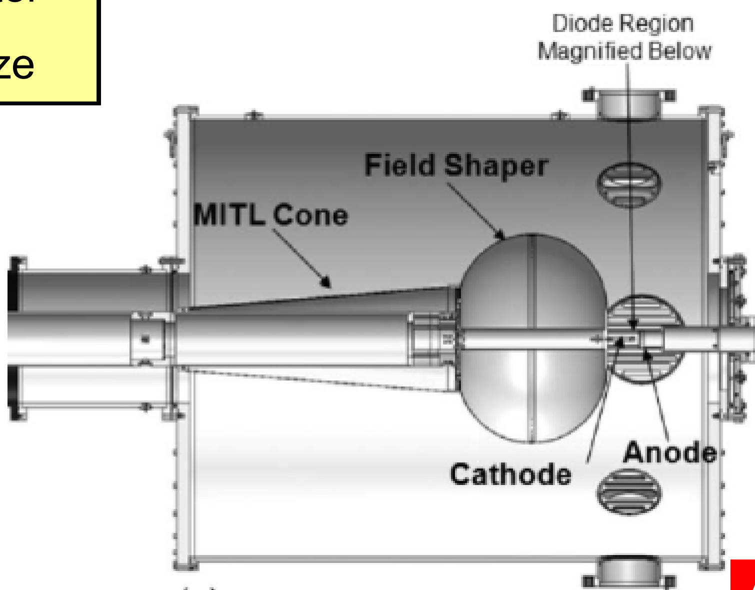
Schematic view: RITS-6 front end

SMP Diode Parameters[2]

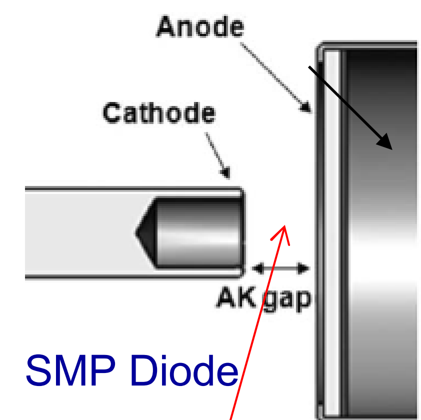
- 3.5-7+ MV
- 150 kA (~15% ions)
- 80-50 ohms Impedance
- 45ns Radiation Pulse
- > 350 Rads @ 1 meter
- < 3 mm focal spot size

Flash X-ray Radiography





(a)



Aspect Ratio:
Cathode diameter to A- K gap in mm. Example: 12.5-12

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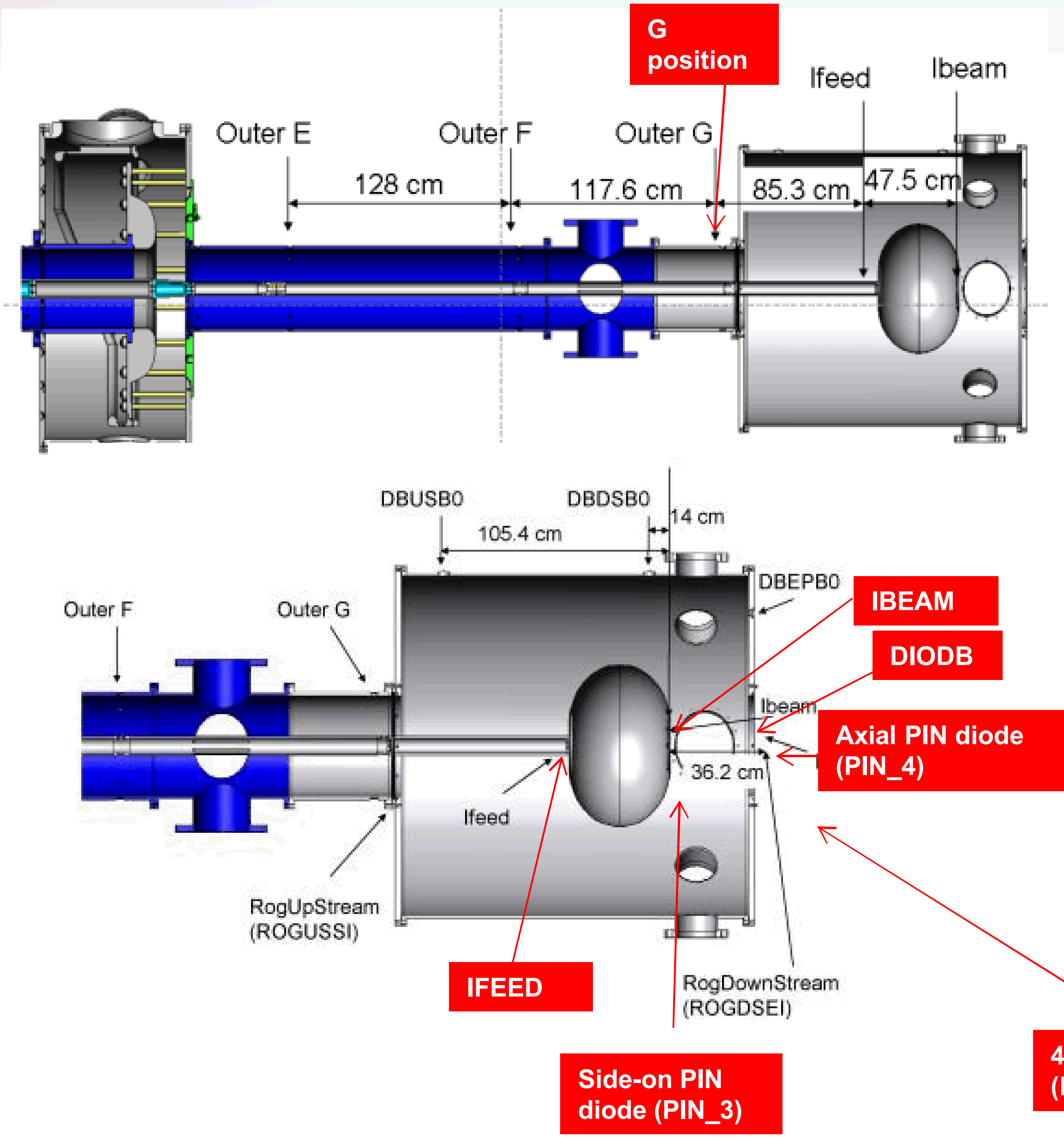
[2] K. Hahn, et. al., *IEEE TRANSACTIONS ON PLASMA SCIENCE*, VOL. 38, NO. 10, OCTOBER 2010, pp.2652-62.

Location of RITS Bdots, P-I-Ns



- Inner-outer Bdots at locations E, F, G (shown). Voltage (e.g. V at E) calculated from Mendel. On typical full-pulse shot, waveforms ~ identical.
- In Dustbin:
  - (4) IFEED (upstream of Knob)
  - (4) IBEAM, outside of cathode position
  - (4) DiodB, on downstream wall outside of anode plate
- Three P-I-N diodes, axial (PIN_4), 45° (PIN_6), 95° (PIN_3, PIN_5)
- 'DERIVED' SIGNALS:
  - VCORR_G: V at G is moved ~ +10ns, Lidot-corrected with IBEAMdot
  - ZDIODE: VCORR / IBEAM
  - V from Radiographer's Eq inverts: 20mono, 30mono, etc (CYLTRAN)

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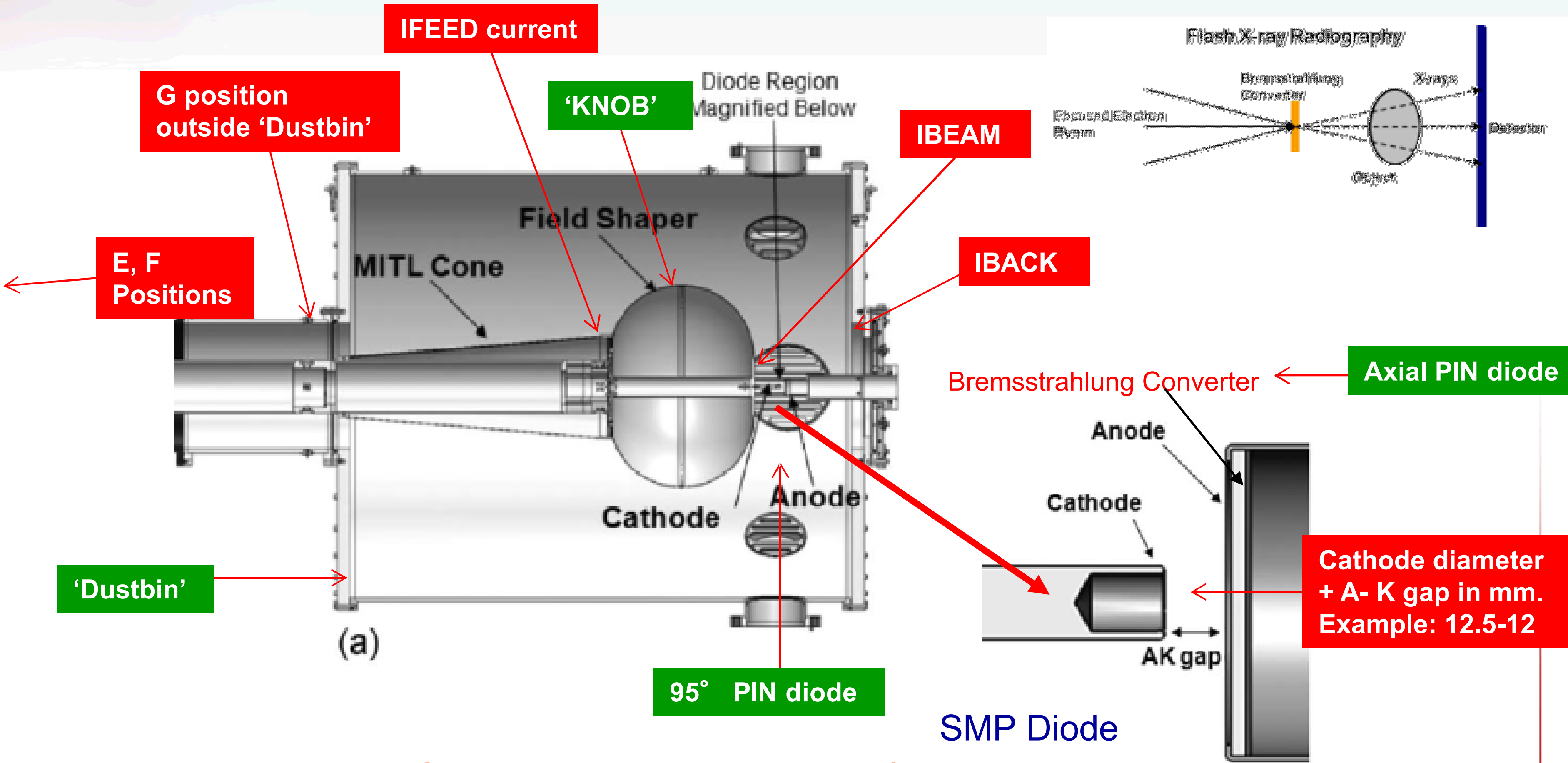
RITS-6 (Radiography Application) front end with current monitor locations. Desire small spot size for beam at converter.



- Each location: E, F, G, IFEED, IBEAM, and IBACK has 4 monitors.
  - E and F locations at left of drawing, G just before the dustbin opening. EACH as both inside (bound) and Outside (total) current monitors.
- Voltage at E, F, G calculated from Mendel formula.
  - Voltage at G LiDot-corrected to diode (Corrected Diode Voltage).
  - Abbreviation: 12.5 – 12 refers to 12.5 mm Cathode diameter + 12mm A-K gap.

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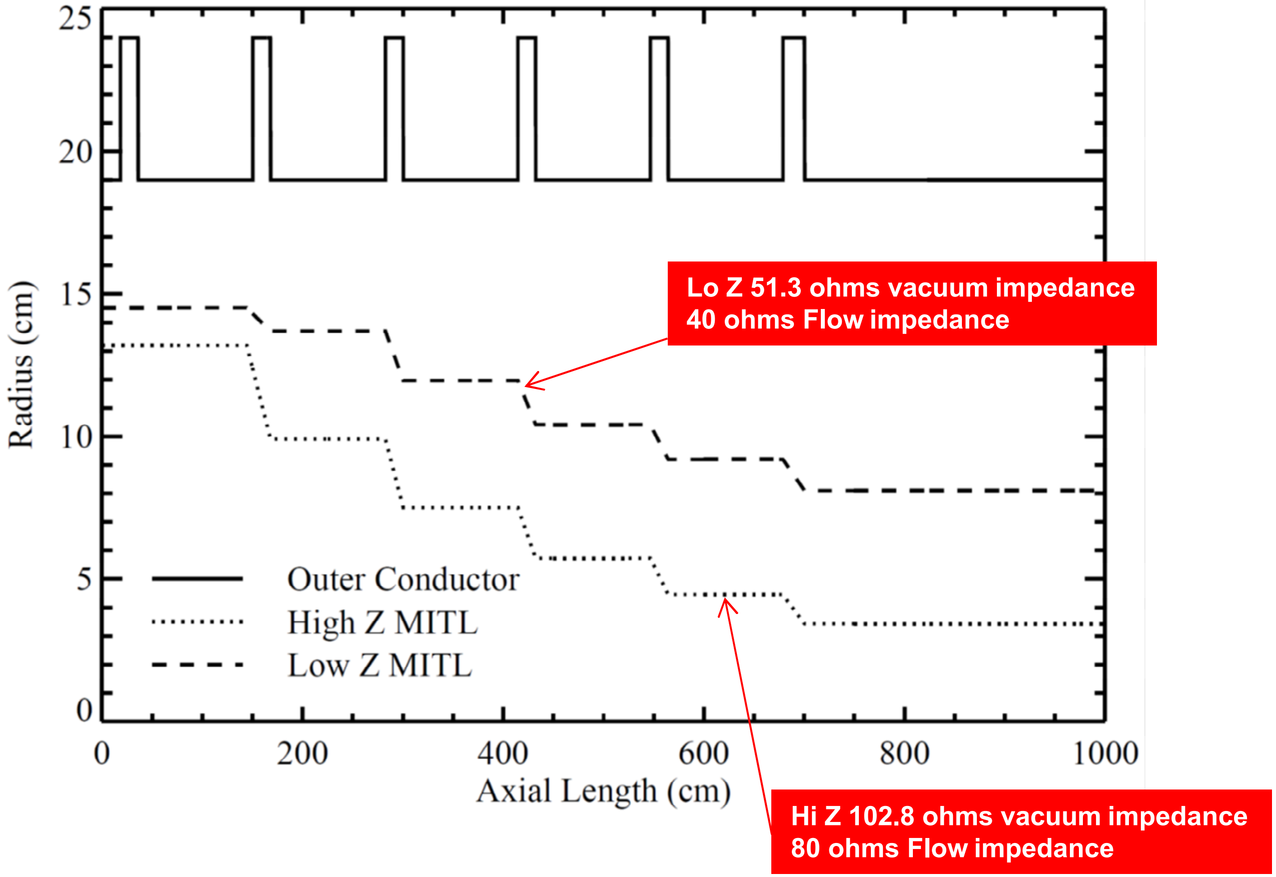
Schematic comparison of HiZ vs LoZ on RITS



- **HiZ MITL is smaller-diameter Cathode stalk**
  - **Same Knob AND same SMP diode configuration used for both LoZ and HiZ.**

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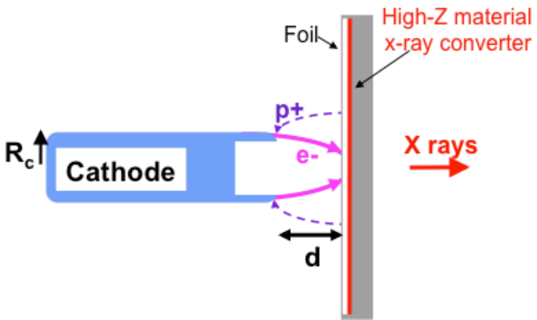
Premise: in-situ heating to extend radiation pulsewidth

- Reducing Cathode size leads to reduced spot size
  - (also *raising* operating voltage reduces spot size)

- 12.5 mm Cathode diameter + 12 mm A-K gap (12.5-12) is 'standard' SMP diode (40 ohm MITL)
  - Good: Stable operation, full radiation pulse. Desire: smaller spot size
  - 8.5 – 8.3 SMP produces smaller spot size. Downside: FWHM can be reduced
  - Premature impedance (Z) collapse on 50% of 8.5 - 8.3 shots.
  - One hypothesis: cause is electrode plasma-induced gap closure
    - N. Bennett et al, Phys. Plasmas **22**, 033113 (2015)

- Proposed Mitigation: In-situ DC heating and/or glow discharge cleaning to reduce adsorbates, interstitial hydrogen (Ta anode) in as - provided parts
  - Cleaner diode should result in full-pulse operation
  - Key metric: increased diode impedance
  - For 'stable' 12.5 – 12 diode operation (at 7-8 MV): heating should have little impact
  - For 'unstable' 8.5 – 8.3 operation, greatest impact expected here



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Question:

- PREMISE relies on the assumption that Diode Impedance is an independent variable.
- What if this is not true?

- Addressing THIS question changes the Storyline of this Talk:
  - from Heating
  - to a Systems Study of IVA-Diode Interaction

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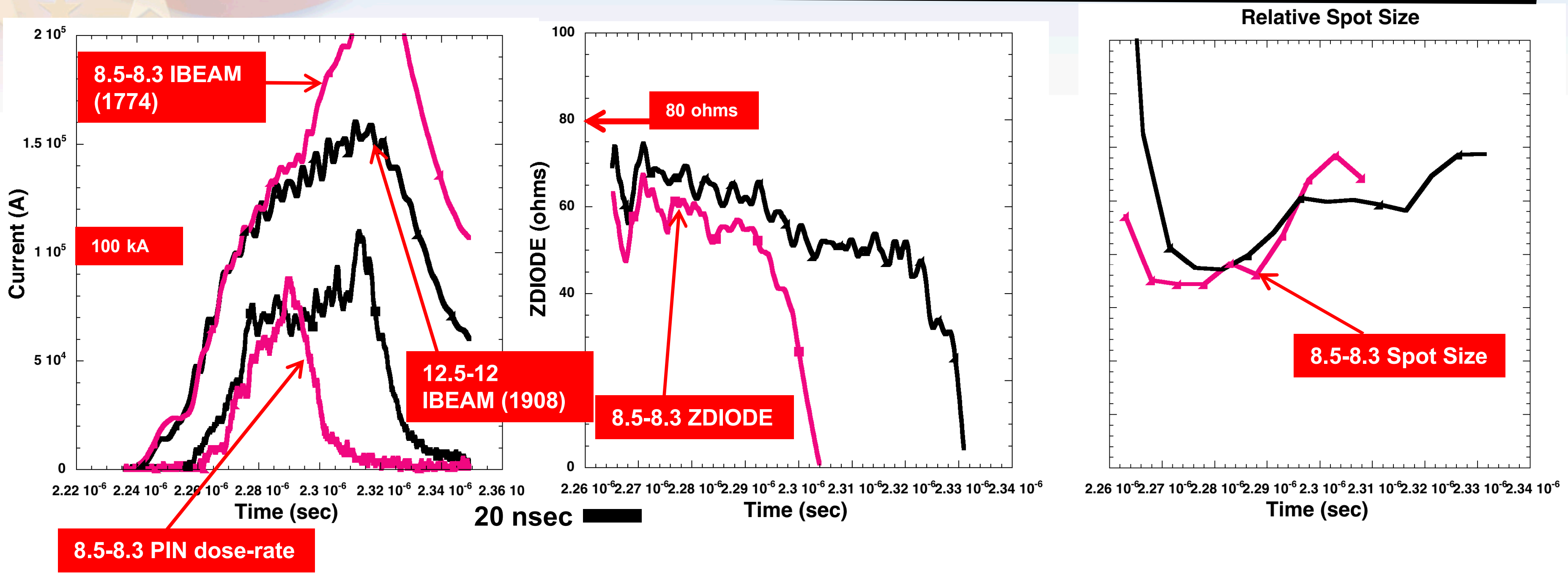
An example of Standard Foil 12.5 – 12 vs 8.5 - 8.3 diode operation (1908 vs 1774)



- **(LEFT)** Beam current (IBEAM) for 8.5 – 8.3 (**RED**) increases faster then 'runs away'. 8.5 – 8.3 radiation dose-rate (**RED**) almost equals 12.5-12, then collapses.
- **(MIDDLE)** 8.5 – 8.3 Corrected Diode Impedance (ZDIODE) less than 12.5-12, then collapses.
- **(RIGHT)** 8.5 – 8.3 pinch Spot Size (**RED**) initially smaller than 12.5 – 12, then increases as voltage collapses.

- **TWO PARTS** to question of in-situ heating success:
- 1) Does the heating remove adsorbates and interstitials?: Light Lab measurements (Simpson) confirm YES. Activation measurements on heated shots (Mazarakis) confirm protons removed.
- 2) Does the removal of contaminants improve shot performance? Let's address this.

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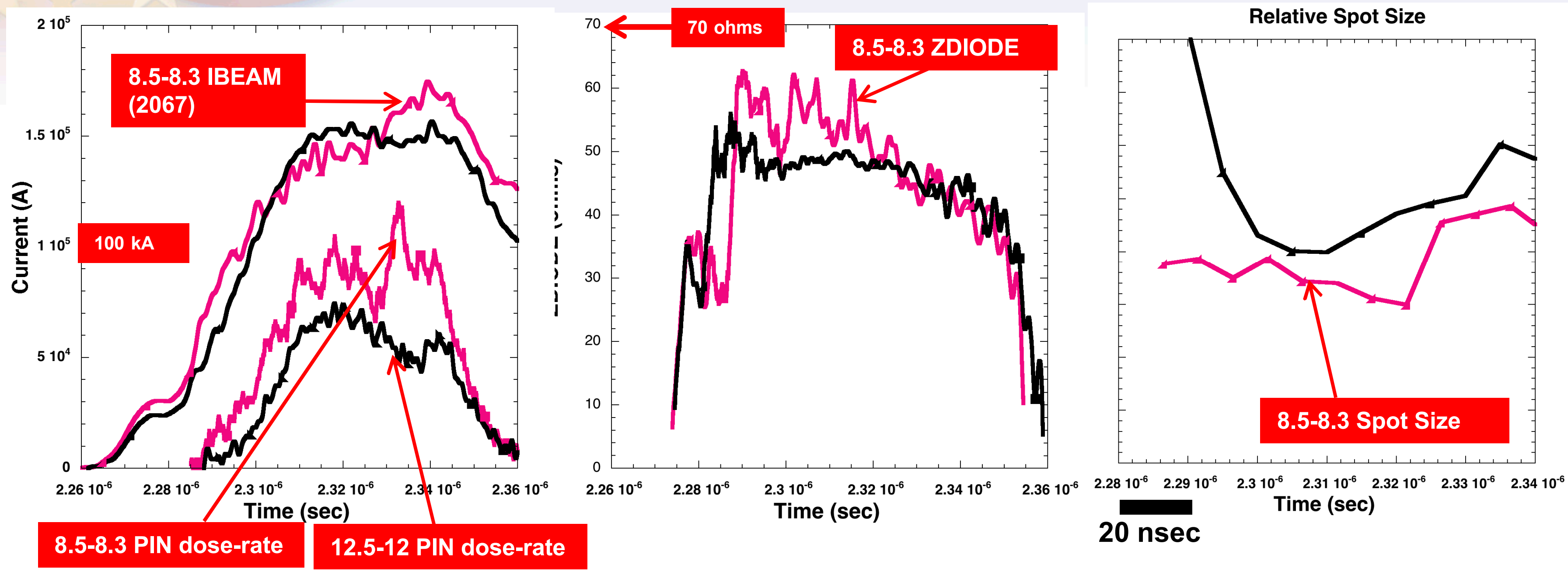
Now compare two heated shots: Bare Ta 12.5 – 12 vs 8.5 - 8.3 (1986 vs 2067)



- **(LEFT)** Beam current (IBEAM) for 8.5 – 8.3 (**RED**) does not 'run away'. 8.5 – 8.3 radiation dose-rate (**RED**) exceeds 12.5-12 by significant amount.
- **(MIDDLE)** 8.5 – 8.3 Corrected Diode Impedance (**ZDIODE**) runs **HIGHER** than 12.5–12.
- **(RIGHT)** 8.5 – 8.3 pinch Spot Size (**RED**) stays significantly smaller than 12.5–12 for entire pulse.

- **Shot 2067 (and one repeat)** show success of heating/discharge cleaning with Bare Ta anode – full pulse. **But Wait.** 2067 (8.5 – 8.3) performance doesn't just match 12.5 – 12, but *really* exceeds it.
- **So what happened, did 8.5–8.3 improve that much, or did 12.5-12 degrade, or both?**

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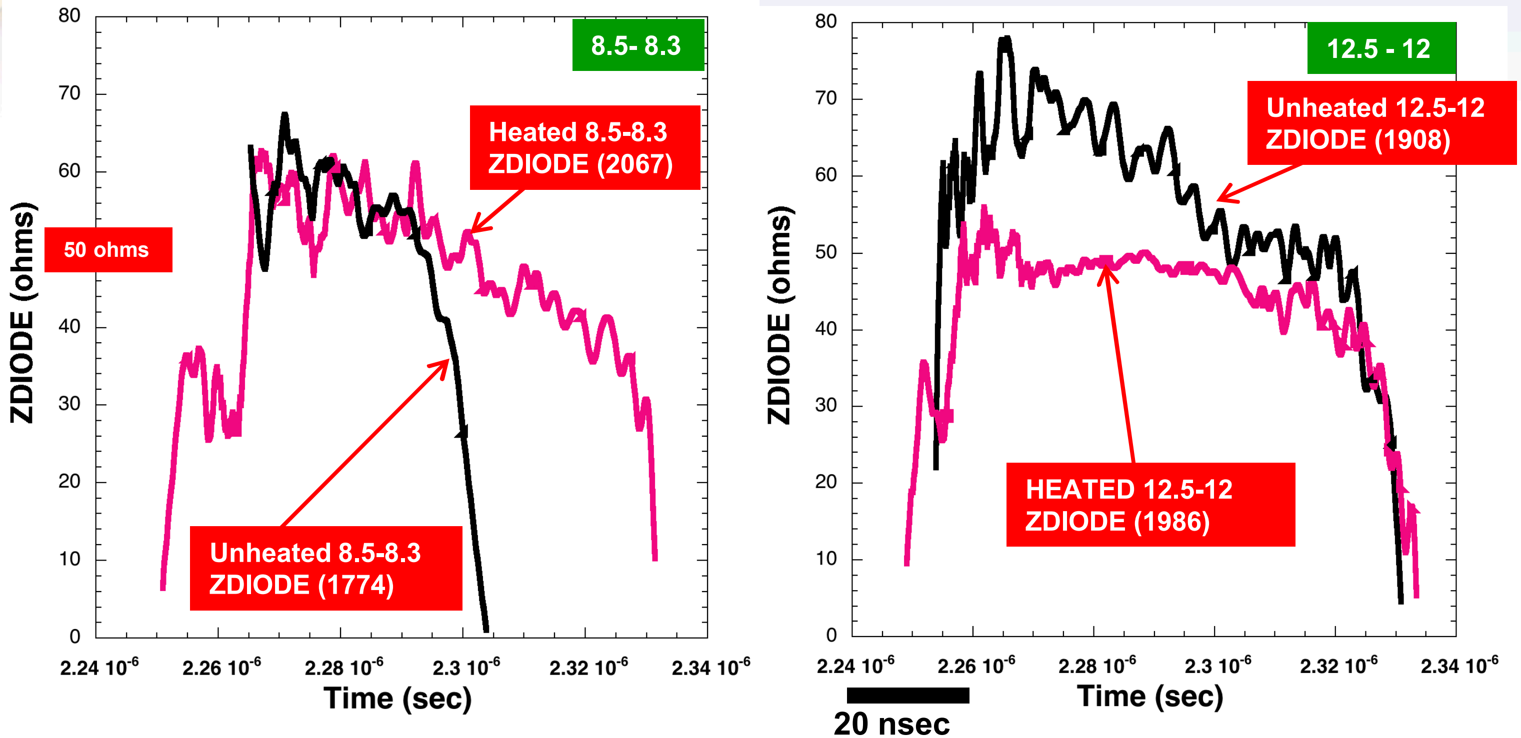
Heated 8.5-8.3 improves FWHM, maintains ZDIODE. Heated 12.5-12 does NOT



- (LEFT) 2067 heated 8.5-8.3 ZDIODE (MAGENTA) = 1774 DIODE (unheated) before 1774ZDIODE collapses.
- (RIGHT) 1986 heated 12.5-12 ZDIODE (MAGENTA) runs WAY below 1908 unheated ZDIODE. Not only that, 1986 ZDIODE stays ~ constant with time, e.g. appears to suffer no ZDIODE decline due to gap closure (heated 2067 ZDIODE *DOES* decline with time)
- How can One explain a flat ZDIODE with time, and reduced in magnitude compared with unheated?

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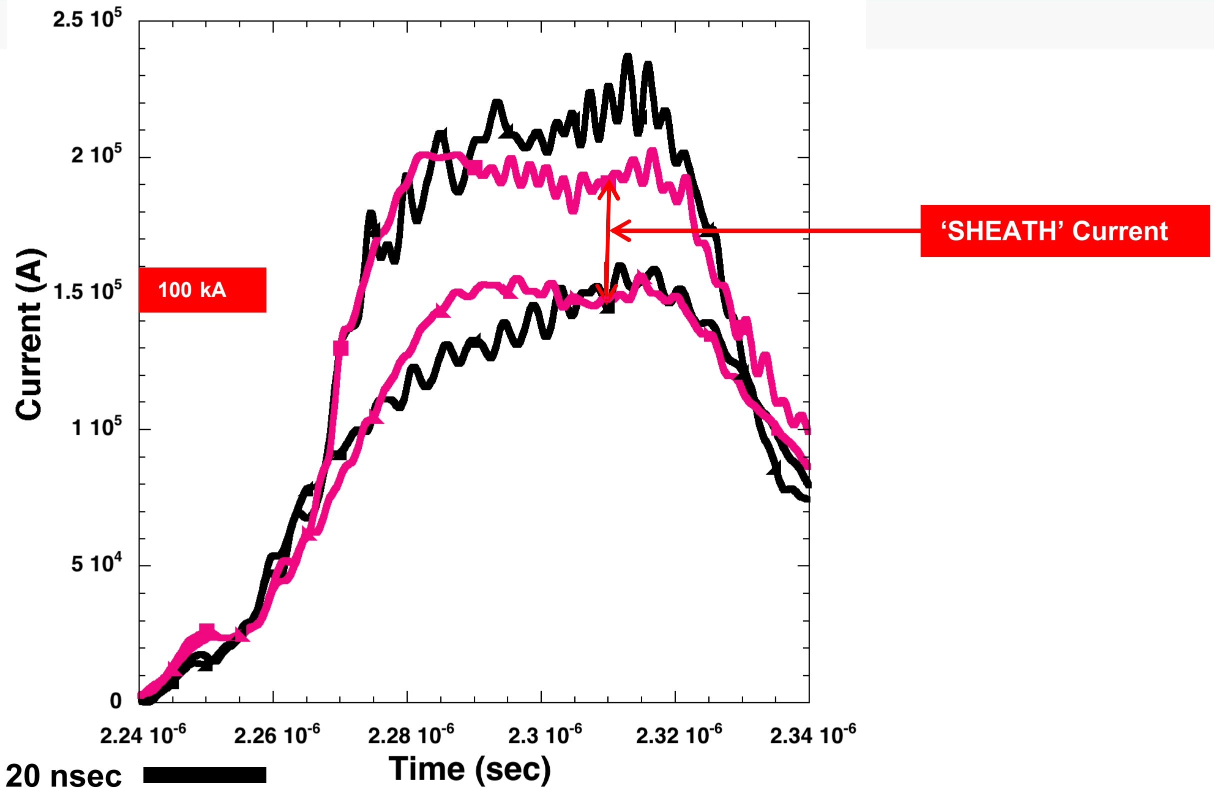
SHEATH current defined

Wait. That's not all. DIODB *decreases* while IBEAM *increases* on the heated 12.5-12 shot.



- 1908 unheated DIODB and IBEAM (BLACK) increase continuously during the power pulse.
- 1986 heated DIODB and IBEAM (MAGENTA) rise but then plateau and actually DROP slightly before the end of the power pulse.
- So for a time in the middle of the power pulse, heated DIODB < unheated DIODB, while heated beam current (IBEAM) > unheated IBEAM. How can this be?
- Answer: IBEAM is NOT the entire current in the diode region. There is a 'Sheath' current (shown) that's the DIFFERENCE between DIODB and IBEAM. That current behaved differently.

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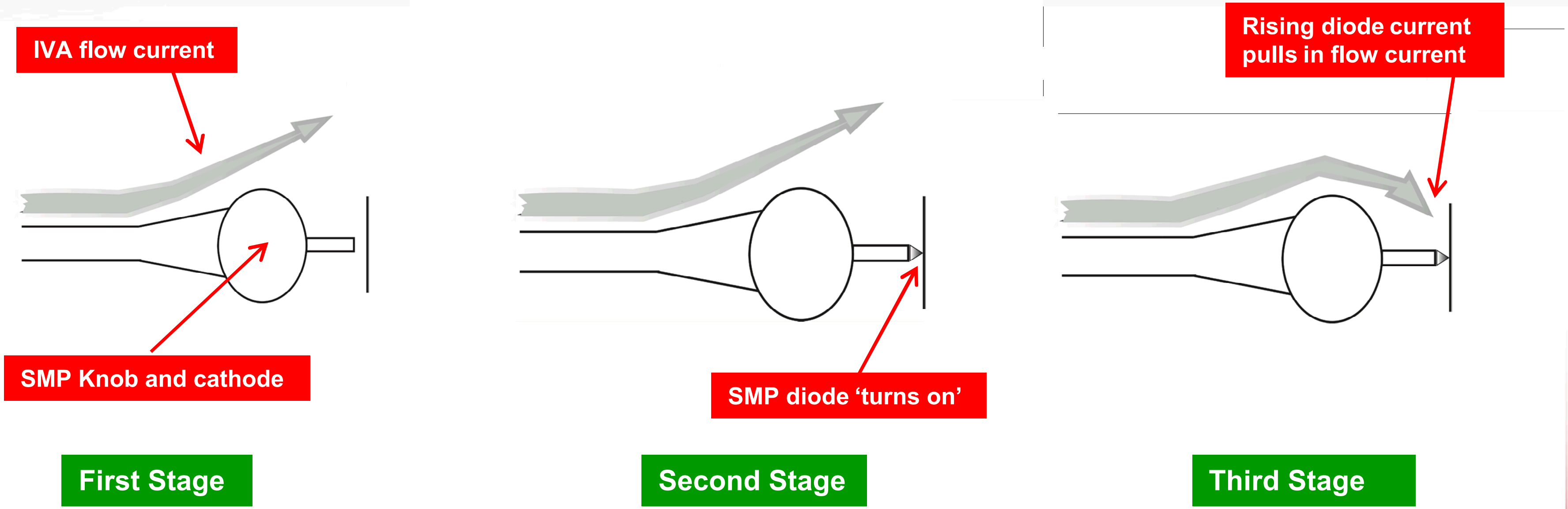
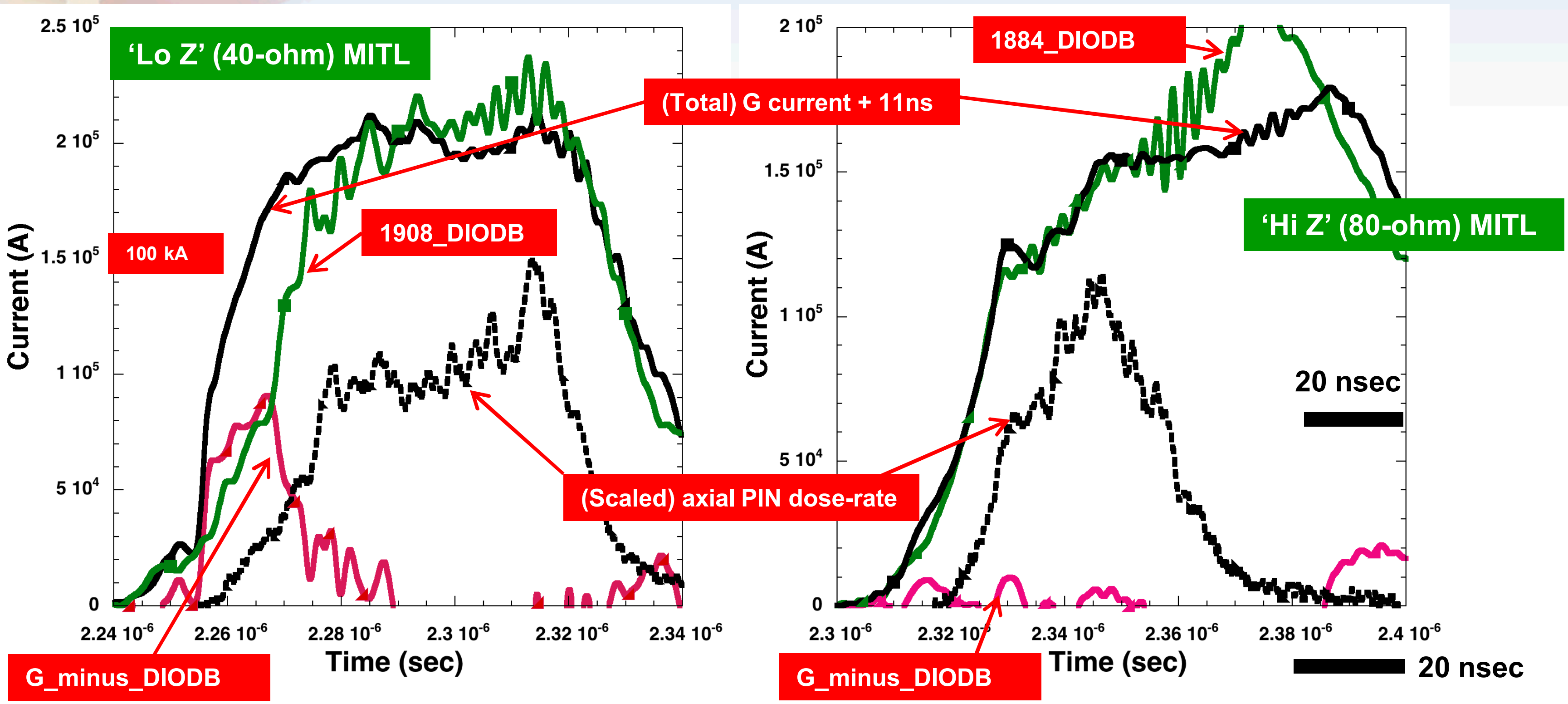
Where does the 'Sheath' Current come from? It happens when IVA Flow interacts with a diode load



- **(LEFT) First Stage: Flow current enters diode region and is diverted from load.**
- **(MIDDLE) Second Stage: SMP diode (or any diode load) 'turns on' in response to applied voltage. Diode Physics governs load (IBEAM) current generated.**
- **(RIGHT) Third Stage: Rising current B-field can re-direct flow current into load region if knob does not successfully divert flow current. This current (mostly) constitutes 'Sheath Current', which can adversely affect diode (and spot) behavior.**

ZTOTAL defined

The DIODB waveform is (almost) same as upstream *total* current.



- (LEFT) BLACK curve is upstream outer G (total) current coming forward for Shot 1908, timeshifted to DIODB position. G_minus_DIODB is MITL Flow Loss (~ 80 kA peak). After ~ 15-20 ns (and before Axial dose-rate rises substantially), Flow Loss drops to ~ zero. This is typical for a 'Lo Z MITL' shot.
- (RIGHT) same color scheme for Shot 1884, a 'Hi Z MITL' shot. But NOW the Flow Loss is almost = Zero. In other words, for Hi Z MITL operation on RITS, the Knob does not divert MITL flow.
- So in either case, DIODB functions as a Total Current for the diode region. In the Lo Z MITL case, this occurs after a time delay of ~ 15 – 20 ns.
- In that case, we can define ZTOTAL = Corrected Diode Voltage /DIODB.

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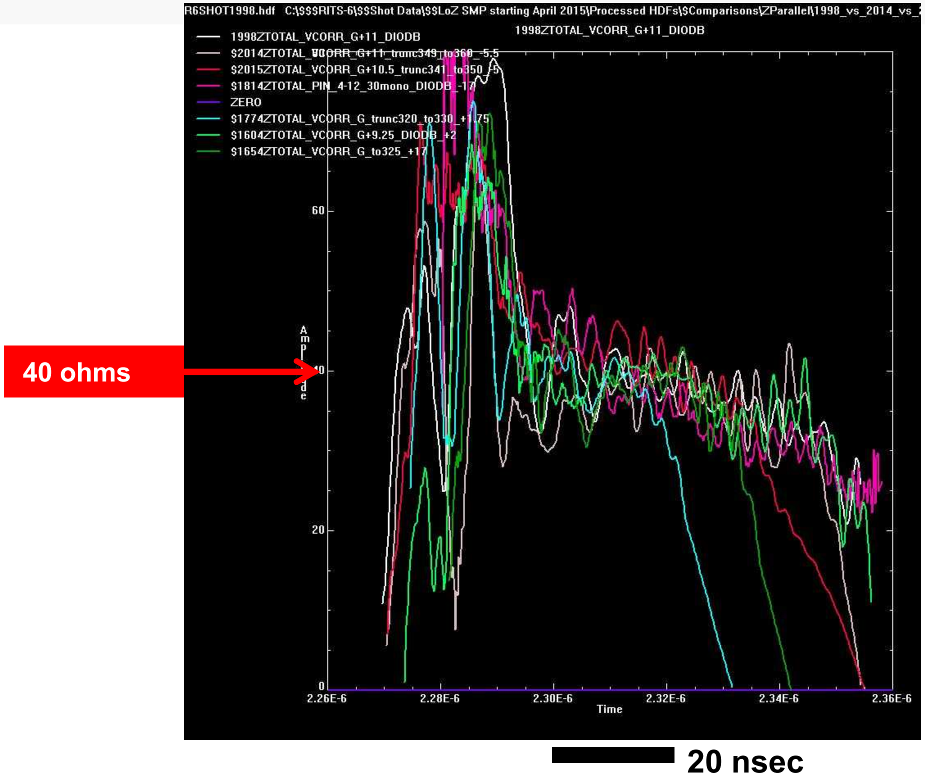
It turns out that after an initial period, all ZTOTALs end up about the same



- **The WHITISH and REDDISH shots are 12.5 – 12, the GREENISH shots are 8.5.**
- **After an initial fluctuation phase, all shots settle in around ~ 40 ohms for ZTOTAL.**
- **Now 40 ohms is the RITS MITL impedance WITH VACUUM FLOW, so this might be expected. A plot of 80 ohm MITL shots would show the same trend, but around 80 ohms flow impedance.**
- **Then suppose we take this as an Operating Principle for IVA-load behavior. What implications are there for Total, Beam, and Sheath current?**

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Sheath current can be characterized by a Sheath impedance. We define then a 'Zsheath' or 'ZParallel', derived from ZTOTAL and ZDIODE

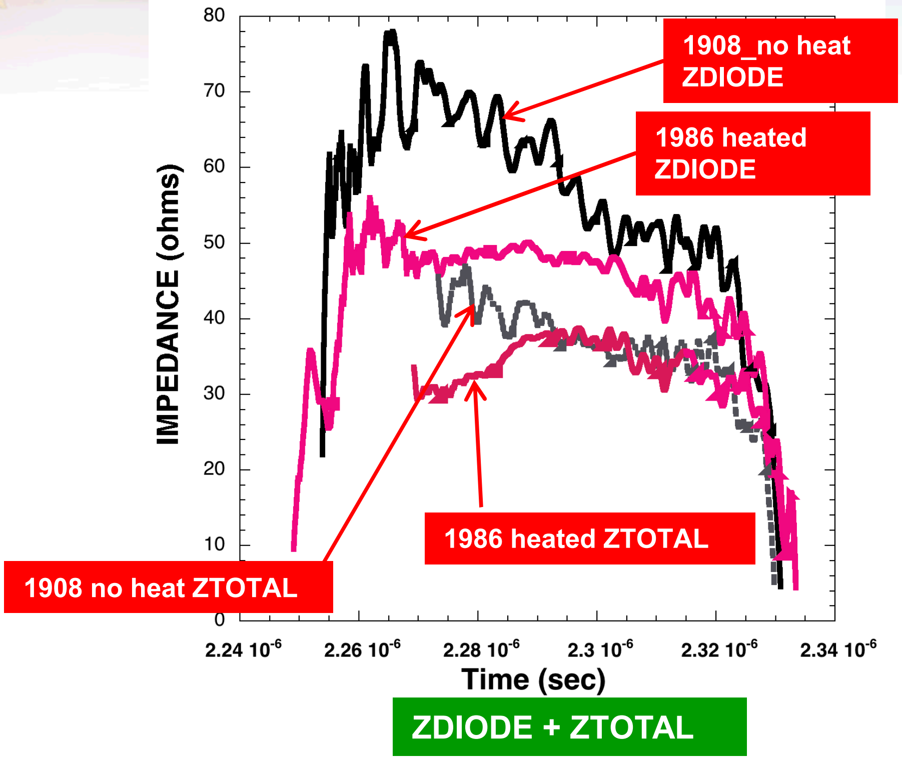
- Assume there is an effective 'ZParallel' in the diode region. The relationship to ZTOTAL and ZDIODE is then

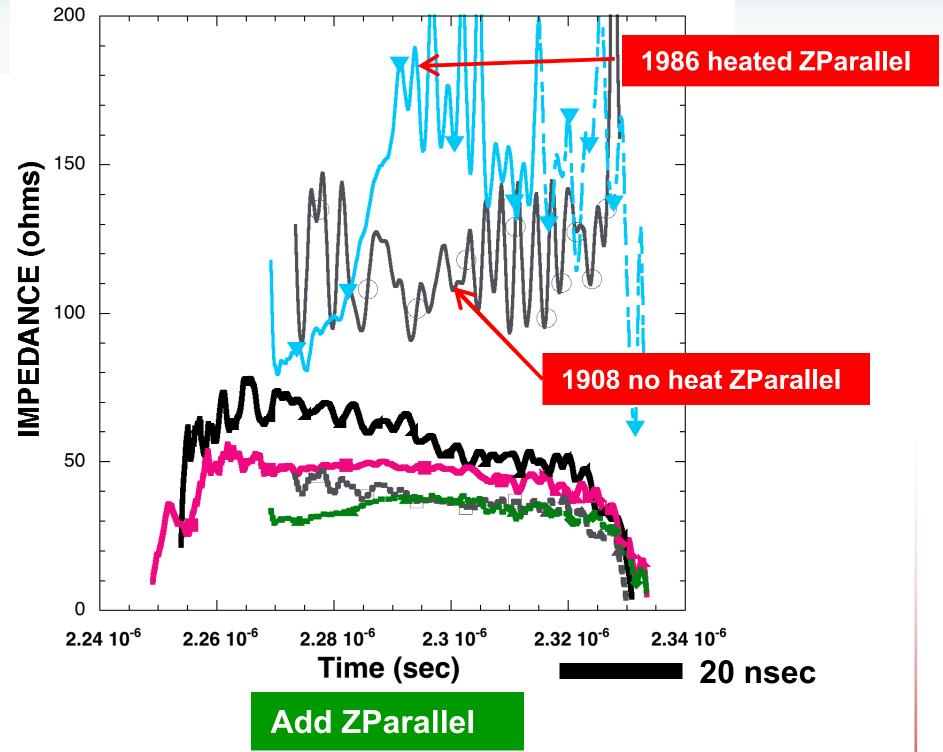
  - 1/ ZParallel = 1/ZTOTAL – 1/ZDIODE

Let's calculate ZParallel for selected 8.5 and 12.5 shots.

Add ZTOTAL + Zparallel to unheated vs Heated 12.5-12

Return to unheated vs heated12.5 – 12 (1908 vs 1986), add ZTOTAL and ZParallel





- **(LEFT) To 1908 and 1986 ZDIODE (BLACK and MAGENTA, from Slide 8) add 1908_ZTOTAL (no heat) and 1986_ZTOTAL (heat). NOTE: unheated ZTOTAL declines from ~ 40 ohms, but heated ZTOTAL *increases* from ~ 30 ohms to join up with unheated ZTOTAL. Only after the join-up does heated ZTOTAL begin to decline.**
- **(RIGHT) lower part of Plot same as at Left. No Heat ZParallel ~ constant at ~ 120 ohms. But heated ZParallel starts at ~ 80 ohms, then rises to ~ 175 ohms during the time that ZTOTAL is rising.**
- **Since the ZTOTALs become the same, and ZParallel (heated) becomes much greater than unheated, this means heated ZDIODE must be lower than unheated.**
- **Since ZDIODE depends upon ZTOTAL and ZParallel, it does not behave as an independent variable.**

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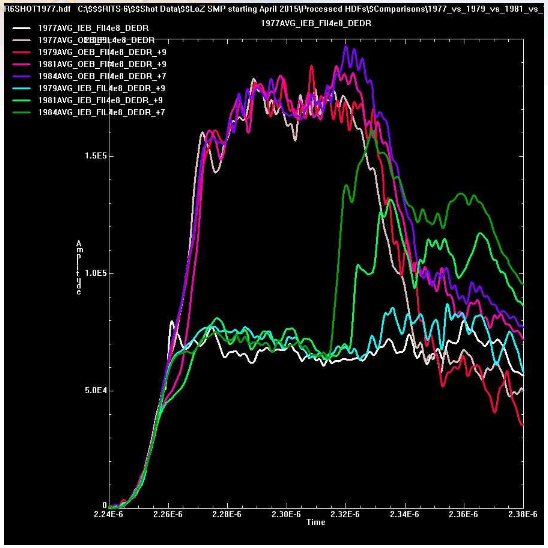
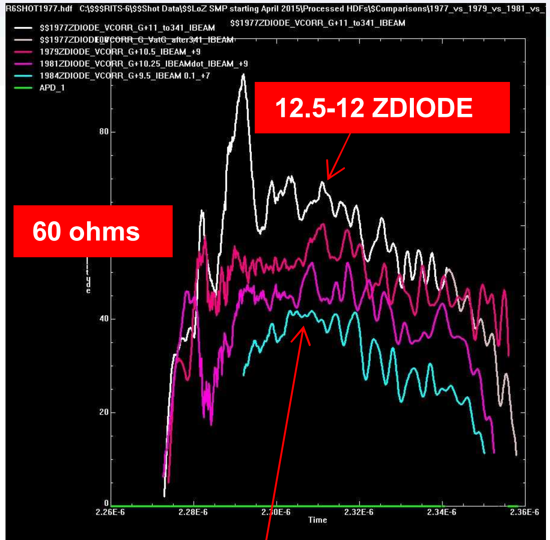
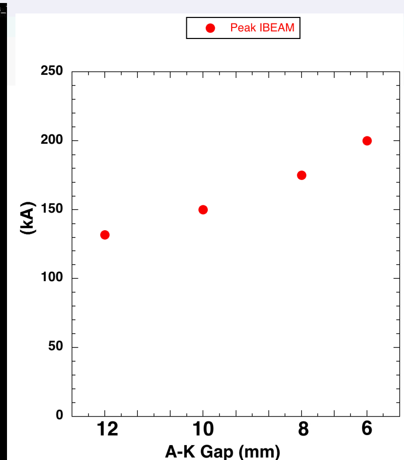
Generally, ZDIODE follows expected trends for Lo Z MITL, as in this A-K gap scan



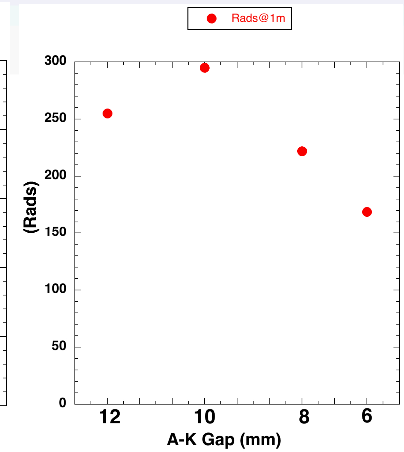
Currents at Position E (upstream)



12.5-6 ZDIODE



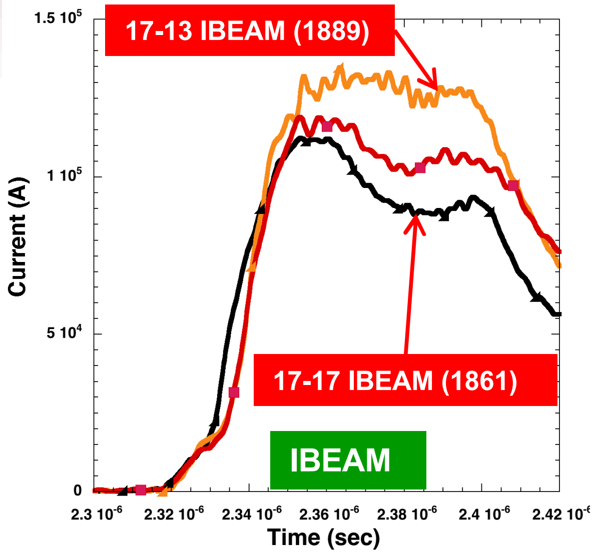
Peak IBEAM

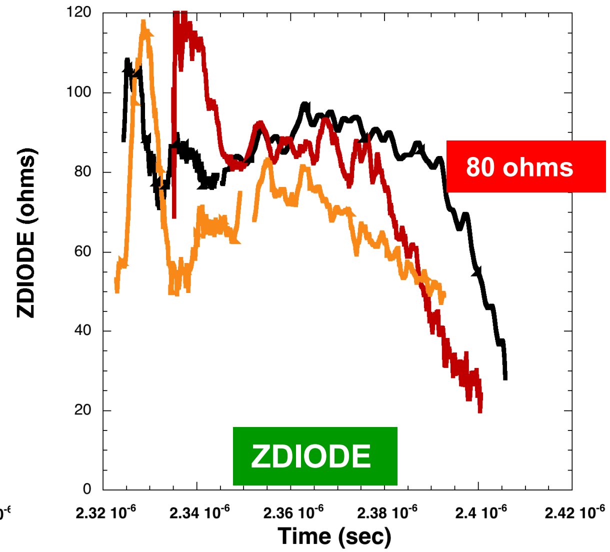


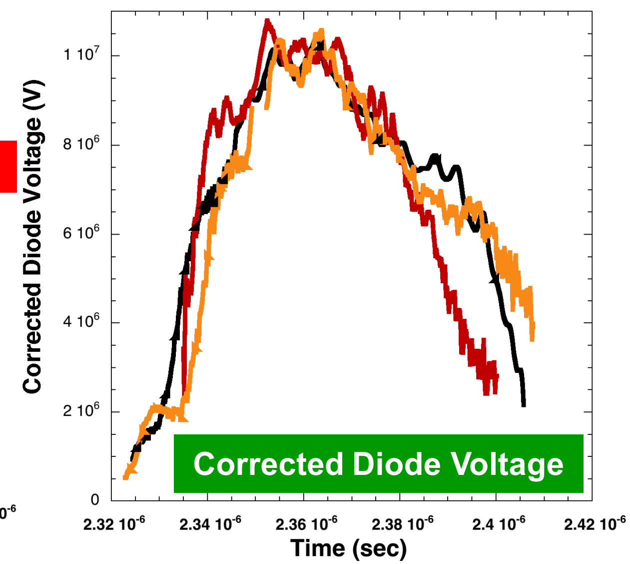
Dose @ 1m

- (LEFT) E currents, 12.5 with AK gaps of 12, 10, 8, and 6mm. Outer (total) at top. At 12 mm A-K gap, retrapping wave (WHITE) is almost non-existent. It then grows to maximum with 6 mm (OLIVE). This implies that ZDIODE / Zflow ~ 1.5 to minimize retrapping wave.
- (LEFT MIDDLE) ZDIODE. WHITE is 12 mm, LT BLUE is 6 mm. As gap drops, so does ZDIODE.
- (RIGHT MIDDLE) Plot of peak IBEAM current. Rises steadily as A-K gap decreases.
- (RIGHT MIDDLE) axial PIN dose @ 1m. As gap decreases, dose drops (12-10 an anomaly).

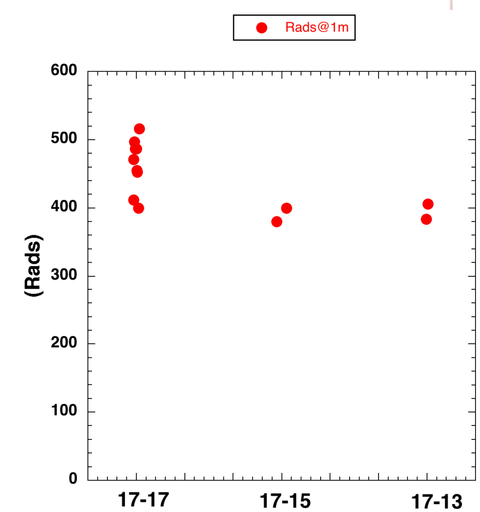
Hi Z MITL operation is totally different, as seen in this 17mm A-K gap scan







- **(LEFT) IBEAM currents, 3 shots with 17-17 (BLACK), 17-15 (RED), and 17-13 (ORANGE). Peak values are not that different, but why the DIPS in two of the shots? (It's not bad power flow.) More later.**
- **(MIDDLE) ZDIODE. 17-17 and 17-15 are almost identical. 17-13 (ORANGE) drops lower.**
- **(RIGHT) Corrected Diode Voltage. Virtually identical shape.**
- **(Near RIGHT) Rads @ 1m vs A-K gap. As with ZDIODE, dose falls, but not as much as with the LoZ MITL scaling.**
- **Diode voltage is virtually unchanged as the gap is lowered. Thus, 'undermatching' the load by lowering the A_K gap is ineffective. Why?**



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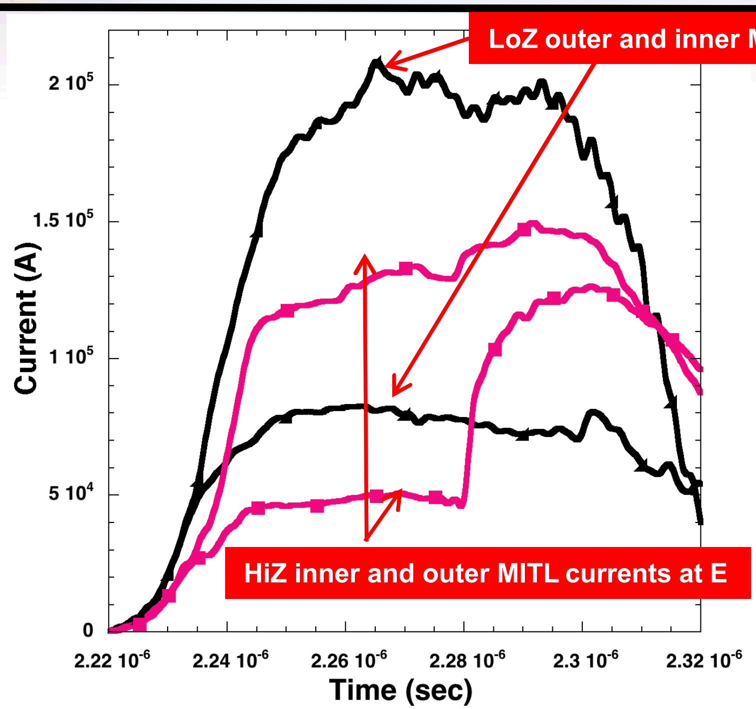
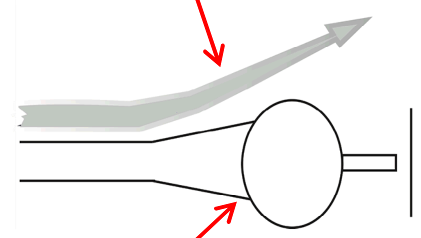
Total Current Inventory defined

I propose the Concept of 'Total Current Inventory'. As calculated, Inventory is LESS for a Hi Z MITL shot. This limits the behavior of IBEAM.





- (LEFT) Comparison, Inner and Outer Currents, LoZ vs HiZ MITL.
  - Outer (total) LoZ current (1908) peaks at ~ 200 kA, inner at ~ 80 kA.
  - Outer HiZ current ~ 130-150 kA peak, inner at ~ 45 kA.
- (RIGHT) (Slide 10): We can QUALITATIVELY* define 'Total Current Inventory' as the combination of MITL Flow plus Electrode current coming forward.
  - Flow current estimate*: Outer_minus_Inner G current, timeshifted to diode location (+10ns).
  - Electrode current estimate: IFEED current shifted to diode location (+2ns).
- * [CAVEAT] Both outer and inner G currents consist of a forward- and backward-wave (Retrapping), so moving BOTH +10 ns is not mathematically correct. But if anything, this *OVERESTIMATES* net flow current.

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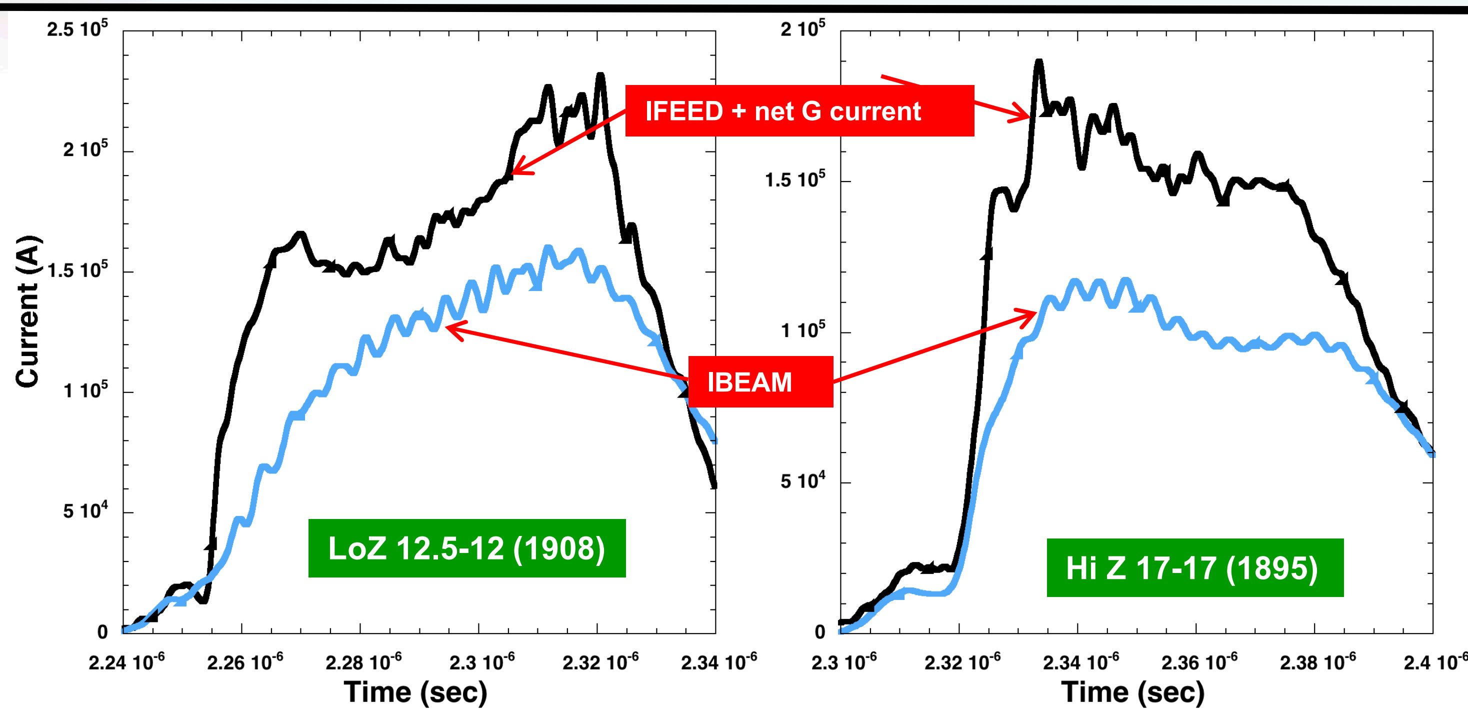
Inventory LoZ vs HiZ

IBEAM current qualitatively follows the shape of the 'Total Current Inventory' for both LoZ and HiZ MITL shots



- (LEFT) IFEED+Net G (IF-G) compared to IBEAM, 1908 LoZ 12.5-12. IF-G rises through the power pulse, as does IBEAM. Load impedance ~ 60-70 ohms is compared to 40 ohms ZFLow of MITL.
  - This implies ratio ZDIODE/Zflow ~ 1.5, to minimize retrapping wave. I believe that this allows for flexibility for adjustment of sheath vs IBEAM current, e.g. so that ZDIODE can operate closer to its 'natural' level.
- (RIGHT and inset) IF-G compared to IBEAM, 1895 Hi-Z 17-17. Now IF-G does NOT rise throughout the pulse, but peaks early and then falls. IBEAM peaks and falls at the same time as IF-G. This is because:
  - 1) There is less net G current coming forward at HiZ.
  - 2) The Very Large Retrapping wave reduces net G current further.

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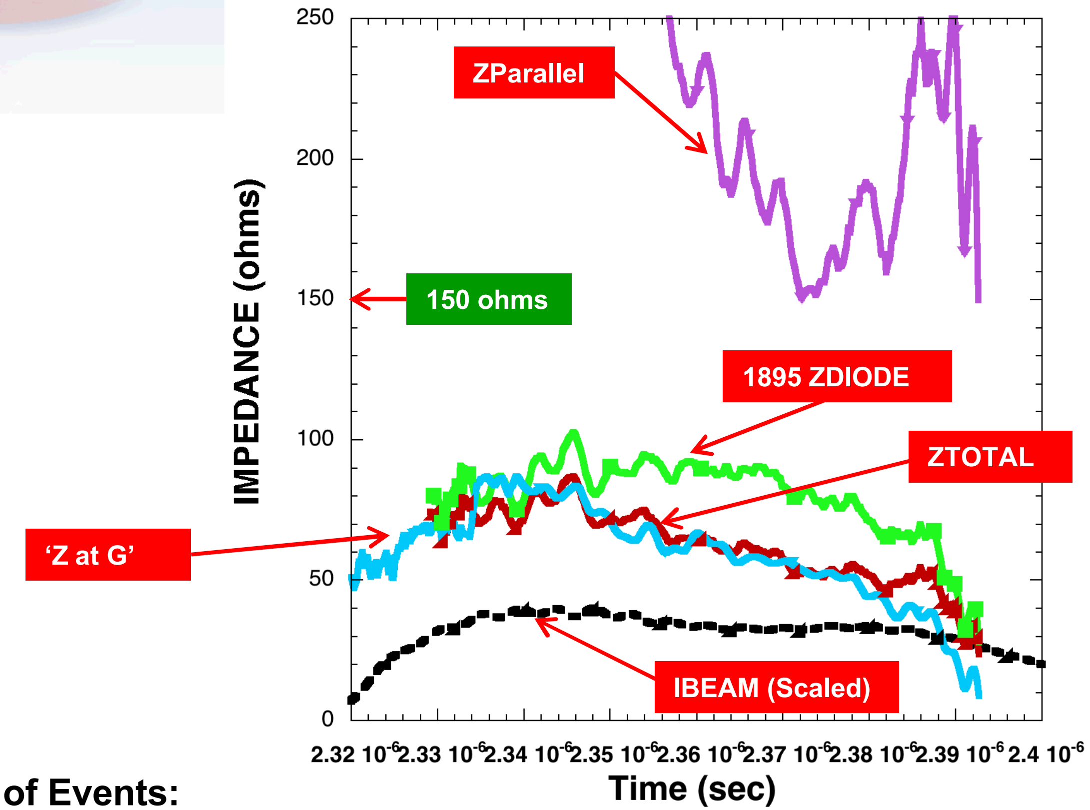
IBEAM dip results in ZDIODE INCREASING to ~ 90 ohms



- **Sequence of Events:**
  - **Diode currents rise, dose-rate increases.**
  - **Z at G – Voltage at G divided by outer G, rises to 80 ohms, then gradually falls.**
  - **Initially, ZDIODE ~ ZTOTAL (ZParallel > 500 ohms). Then IBEAM peaks and falls, ZParallel drops quickly as ZDIODE *rises* to ~ 90 ohms. As ZParallel stabilizes at ~ 160 ohms, ZDIODE begins to fall. ZTOTAL has already begun to track along with Z at G, declining from 90 ohms.**
- **Interpretation: initial IBEAM value is TOO HIGH for a 90 ohm SMP load. As IBEAM decreases, ZDIODE increases to its 'natural' value as an SMP load. Parallel (sheath) current is created out of MITL flow.**

Summary – RITS-6 experiments

- Heating/glow discharging cleaning of a 8.5-8.3 bare Ta anode is successful (2 shots), NOT because reduction of contaminants increased ZDIODE, but because heating appears to stabilize the beam pinch.
- From a Systems Viewpoint, Diode Impedance is dependent upon interactions between the BEAM, Total, and Sheath Currents. It is therefore not a completely independent variable.
- If ZDIODE is not an independent variable, then looking towards changing it by some procedure does not tell the whole picture. A Systems Approach is needed.
- Unlike a Bremsstrahlung diode (basically a terminated MITL), adding a knob structure to an IVA results in separate Diode Physics to initiate the Beam. *If the subsequent beam current is 'incompatible' with the Flow + Beam system, then unexpected results will occur.*
- HiZ MITL operation (increase from 40 to 80 ohms Zflow here), at least as reported here, leads to more restrictive range of operation into a diode load. This occurs because the level of flow current is reduced, and unless the diode load is raised higher (to an estimated 130-150 ohms), the huge retrapping wave removes flow current from the front end region. This can restrict the level of IBEAM and Clamp the load voltage.
  - For SMP diode loads, there has not yet been a successful 130-150 ohm SMP diode demonstrated.

Take-aways

- Working continuously on a Thesis may be the last time in your career that you get to spend so much time on one area of research.
- In many if not most research efforts, sponsor interest does not last long enough to cover Project Completion.
- It helps to maintain an overall viewpoint of research in progress.

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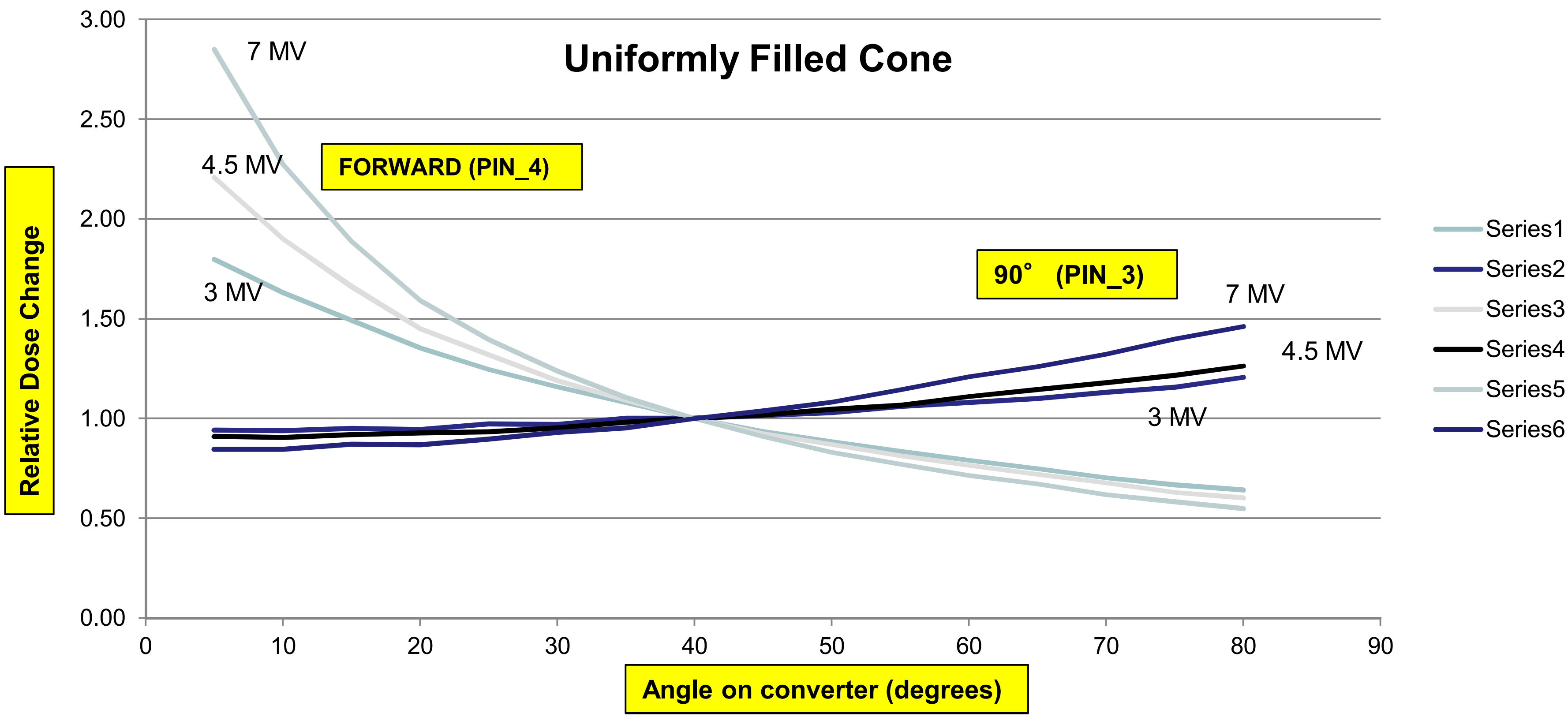
Questions?

Extra Slides

MCNP: Side-on and Head-on P-I-N diode to X-rays scales oppositely as e-beam angle on converter increases



- Relative dose change using mono-angular electrons with angle is even larger
- Both Coefficient and Raise-to-Power (RTP) factor change. We consider only RTP factor changes here.
- As e-beam pinch angle changes, 90˚ PIN goes UP while Forward PIN goes DOWN.
- Therefore, comparing PIN_3 to PIN_4 gives insight on Pinch angle change with time

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