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Measurements of the back-streaming ions in the SMP diode

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SANDIA NATIONAL LABORATORY
Albuquerque NM

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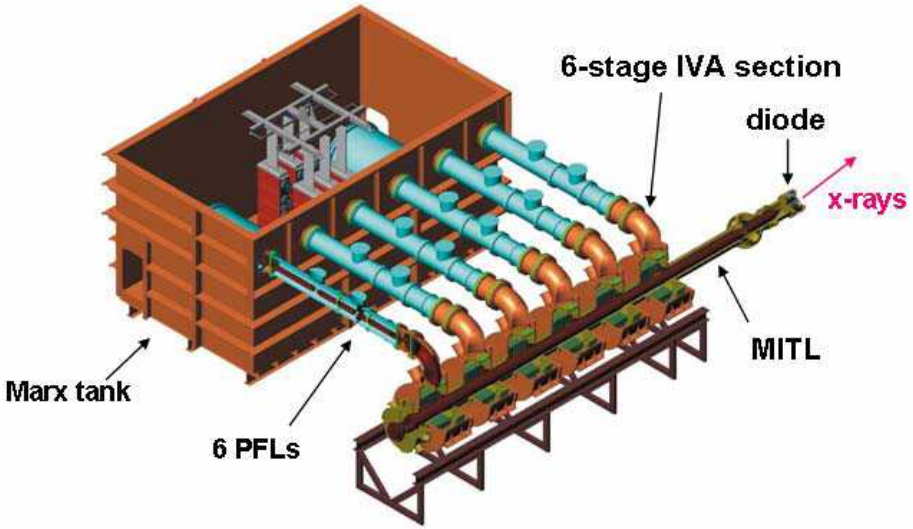
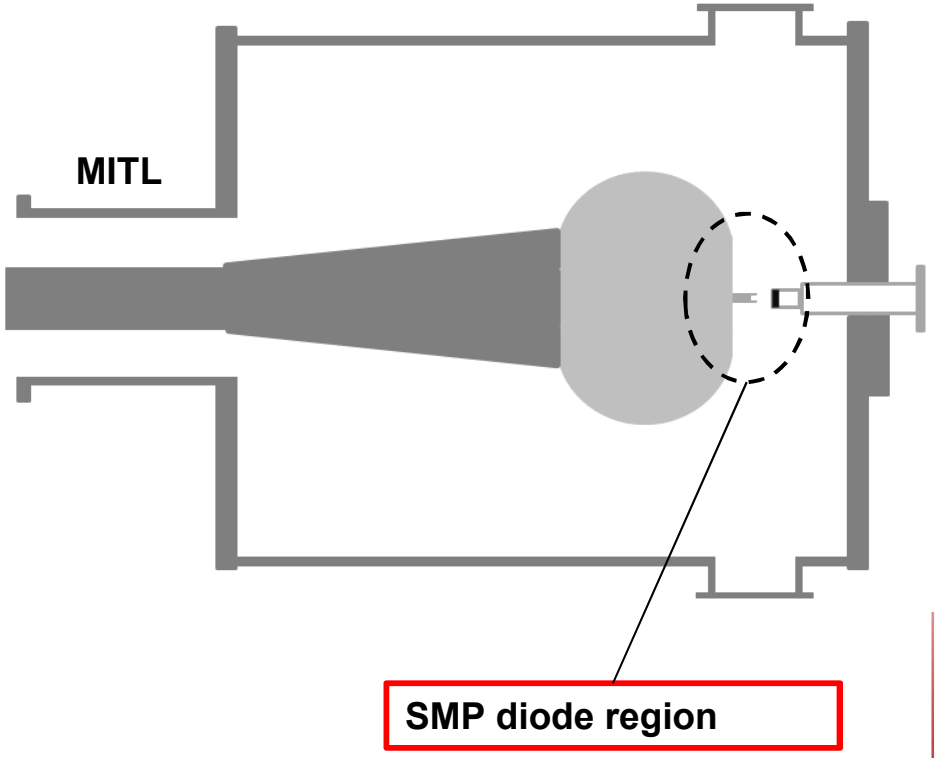
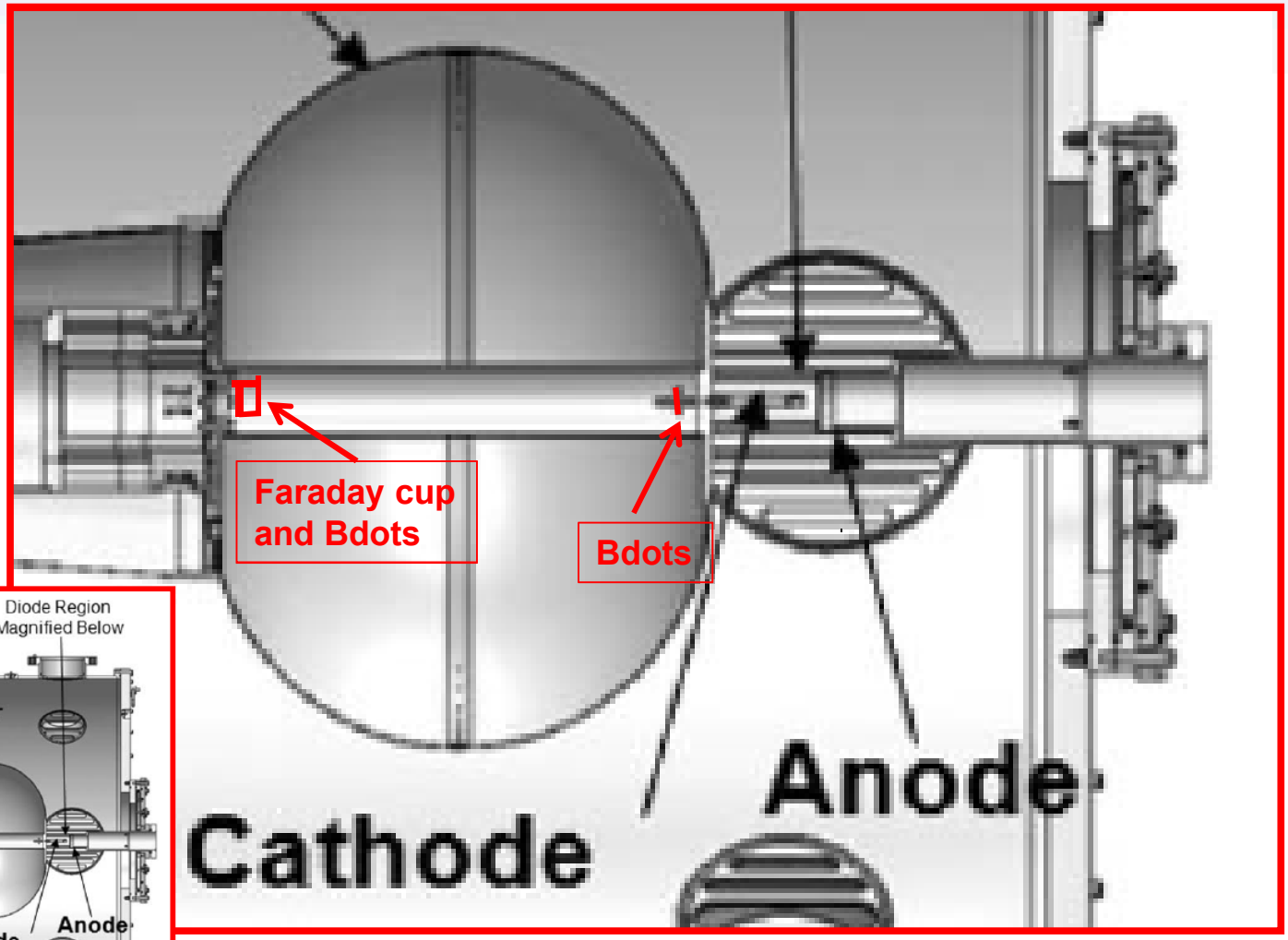
Radiographic Integrated Test Stand: RITS-6

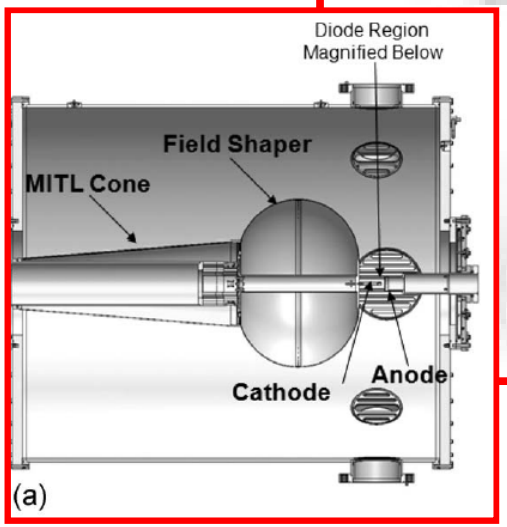




RITS-6 is a 5-11 MV Marx driven six-stage Inductive Voltage Adder (IVA) capable of driving a variety of flash x-ray radiography diode configurations

The idea was originally to use filtered Faraday cups and /or time of flight techniques along the bin axis to measure the ion currents and energy.





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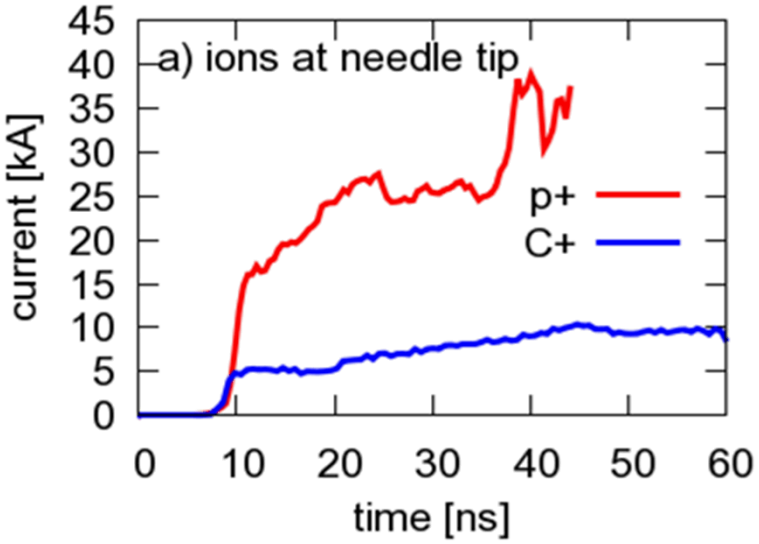
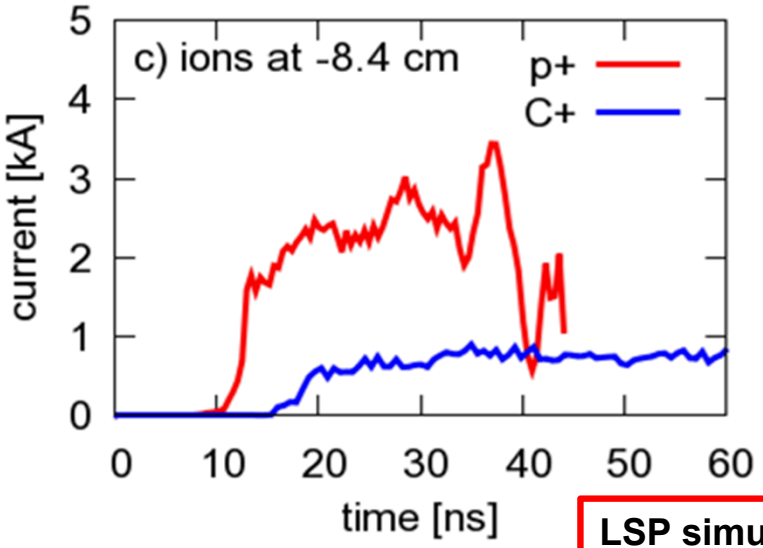
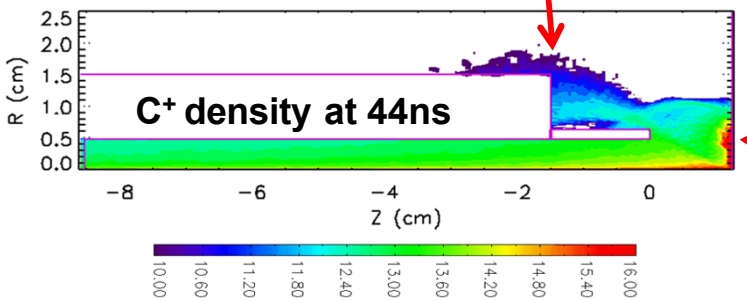
Ion propagation simulation results



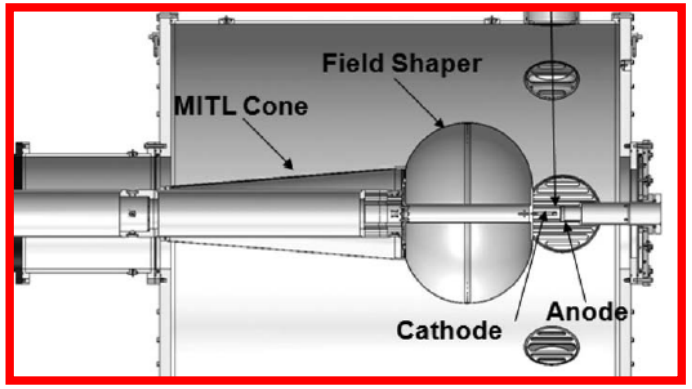


Counter-streaming ions



anode plasma

density scale ($\log_{10}$)



LSP simulations by Nichelle (Nicky) Bennett

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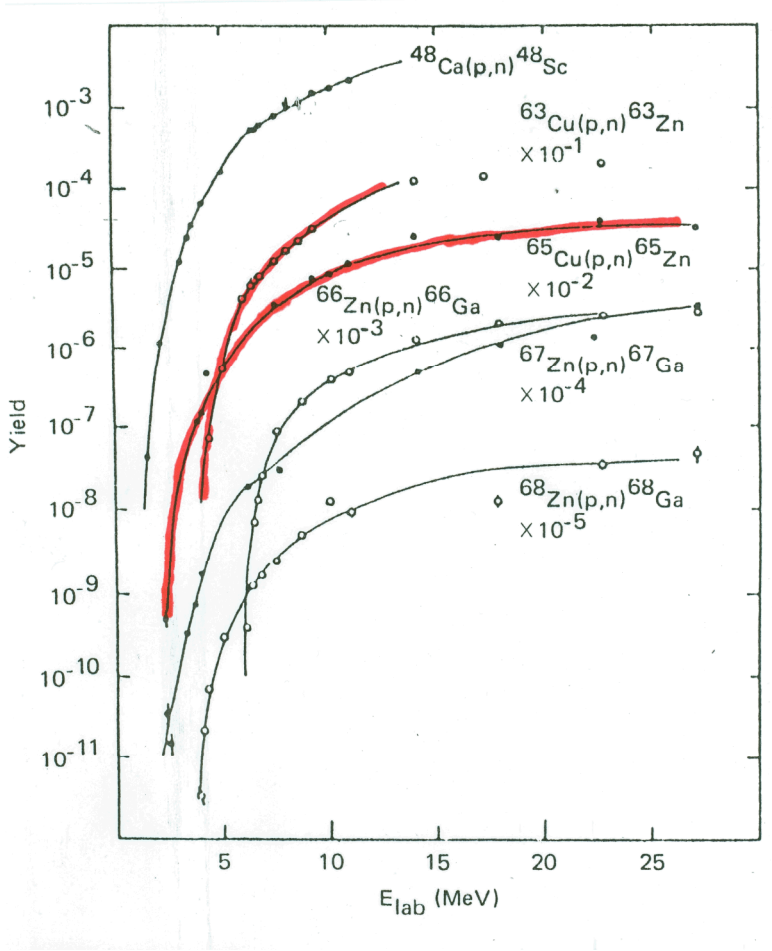
We use copper-proton activation channels.

$Cu^{65} + p = Zn^{65} + n$. The Zn^{65} has a 244 day halflife and decay by emitting γ of 1.115MeV.

$Cu^{63} + p = Zn^{63} + n$ The Zn^{63} has a 39.5 minutes halflife. The Z^{63} is in an excited state and decays as follows:

$Zn^{63} = Cu^{63} + \beta^{+} + \gamma$.

Because of high level of activation we cannot retrieve and γ spec. the copper coupon before the next morning. Hence only the Zn^{65} remains radioactive at γ spec. times. However, because of the low yield of the reaction at 8-10MeV, we have to count the coupon for 60,000 seconds, and still the statistics of the measurements is low.



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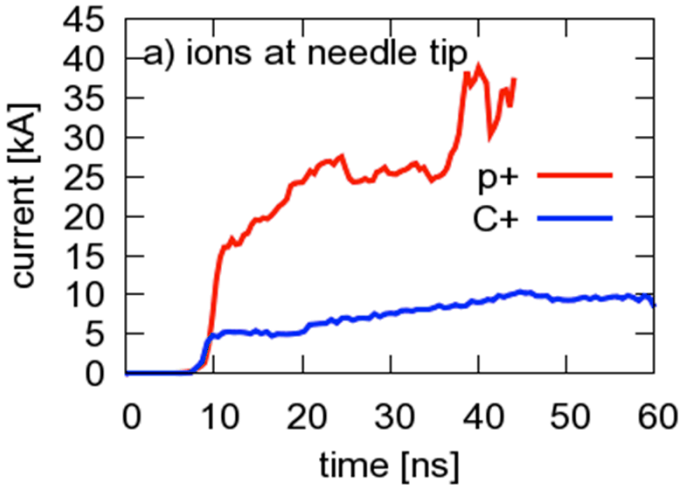
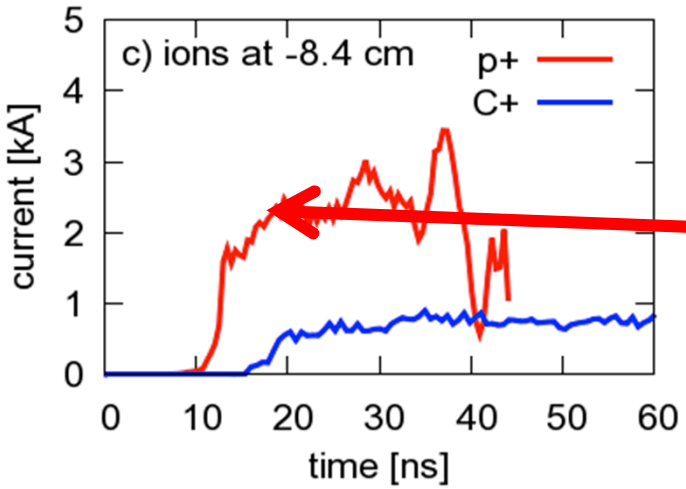
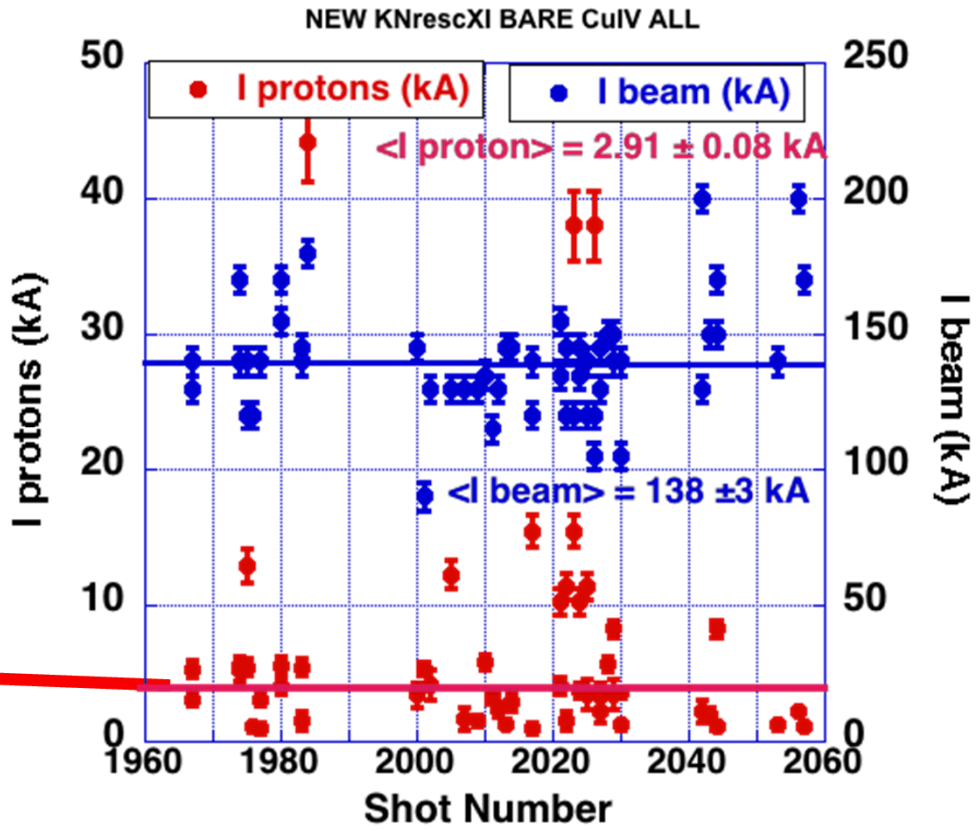
Nuclear reaction yield per incident Proton

- The copper coupons are many times proton range thick (1/4”), so all protons are stopped in the target.
- The abundance percentage of Cu^{65} is 30.6% as compared with the Cu^{63} which is 69.1% . This is taken into account in the data analysis.
- In order to estimate the proton current, an average reaction yield of 4.4×10^{-8} (reaction /proton) in the range of 5-8 MeV proton was taken. For lower energies the yield drops rapidly down to zero since the threshold for the reaction is 2.12 MeV.

The measured average proton current is in good agreement with LSP simulation.







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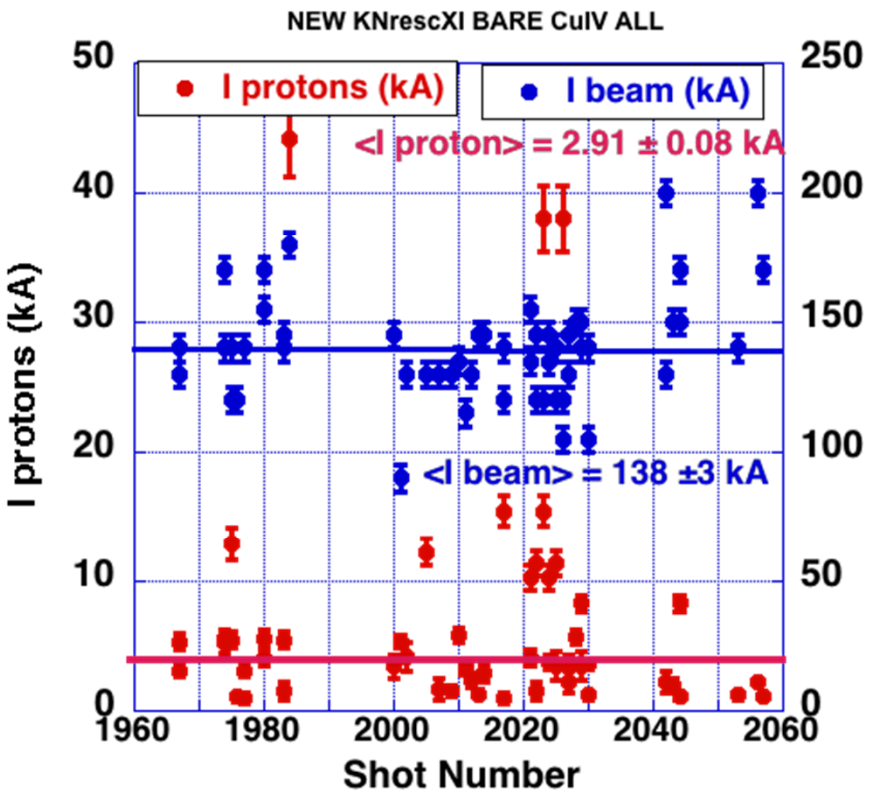
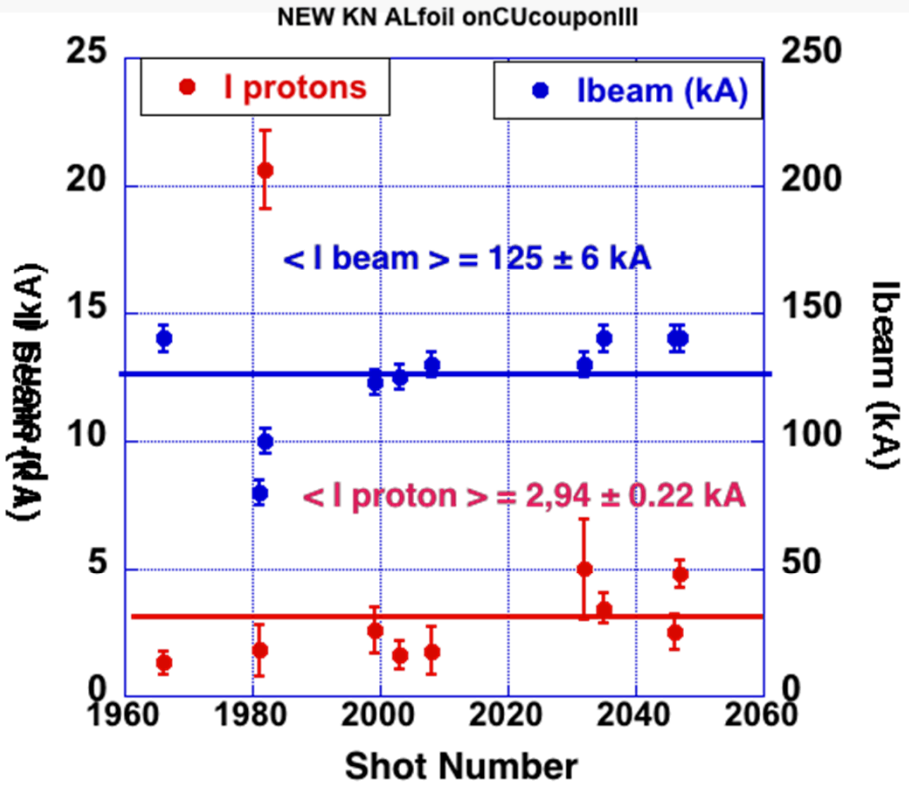
Comparison of shots without (left) and with (right) 100 micron Al foil filter in front of the Cu coupon





The very good proton yield agreement of shots without and with Al foil .suggests an average beam energy of ~ 7.5 MeV which is in good agreement with the estimated diode voltage.

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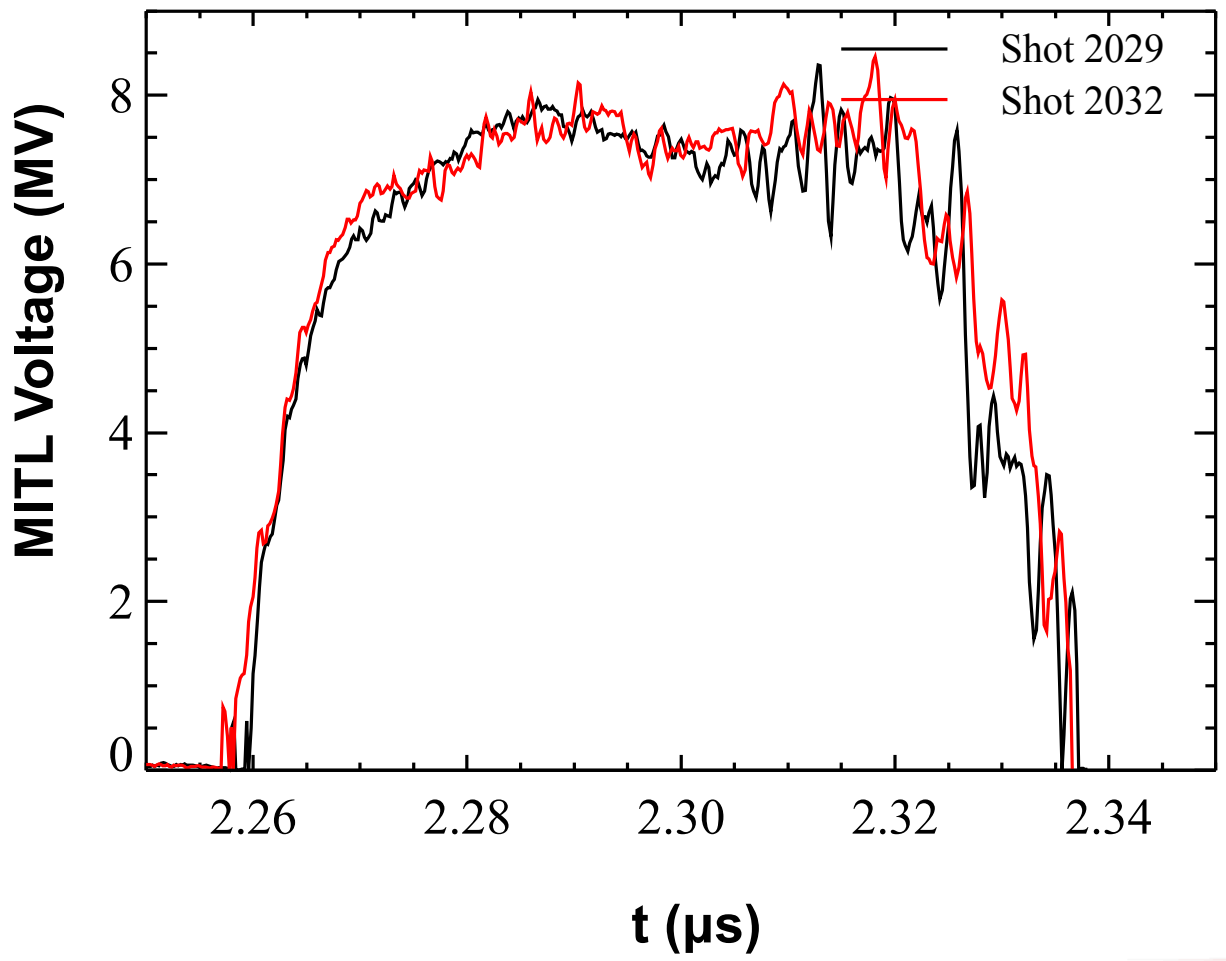
Typical MITL voltage traces estimated with the para-potential method technique (low impedance 51.3 Ω MITL)



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Summary of the activation technique back-streaming ion measurements (8 MeV results)

- The experimental results on the average are in good agreement with LSP simulations.
- Comparing the measurements with LSP simulations we find that the total proton current could be as high as 30 kA and equal to 23% of the total beam current.
- The C^+ ions estimate based on the simulations again should not be more than 7.5 kA: about 10% of the total beam current.
- Hence the total beam current could be composed of 33 % of ionic current.
- We have evaluated the voltage on the A-K gap by positioning 100 μ thickness Al foils in front of the Cu coupons. The A-K voltage obtained is of the order of 7.5 MV and in good agreement with the parapotential flow estimates.
- When we plasma discharge cleaned or heated the anode target to 900^0C and up to $3{,}000^0$C (pulsed) no proton activation was detected.

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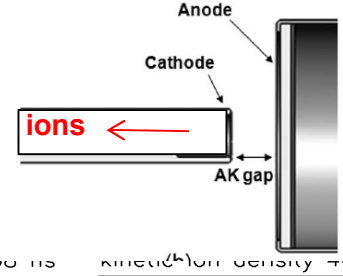
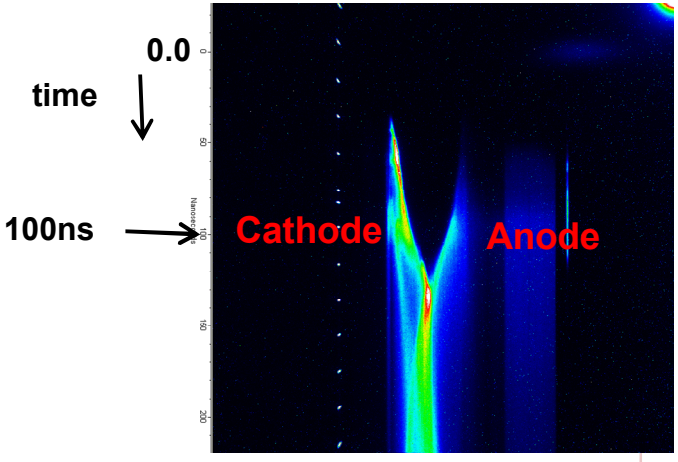
Back-up Slides

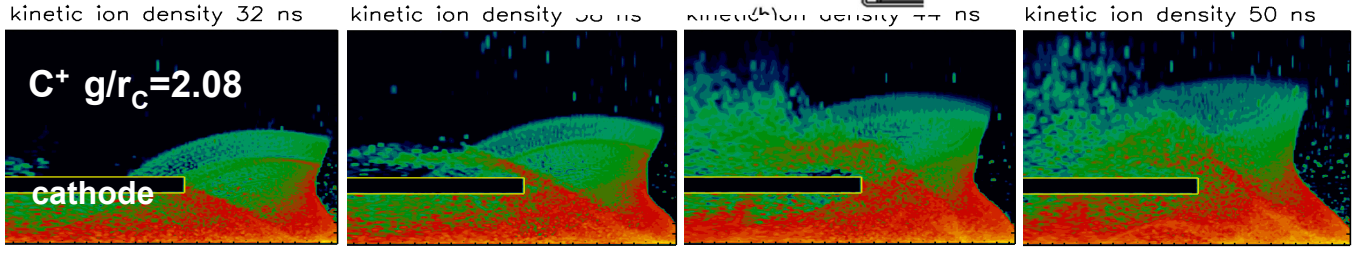
We are measuring the current and the energy of the ions that pass through the cathode hole.

The fast kinetic ions that traverse the A-K gap (bipolar current) before the merging of the anode and cathode plasmas are substantial contributors to the diode current. The densities of those ions cannot be evaluated by optical techniques.



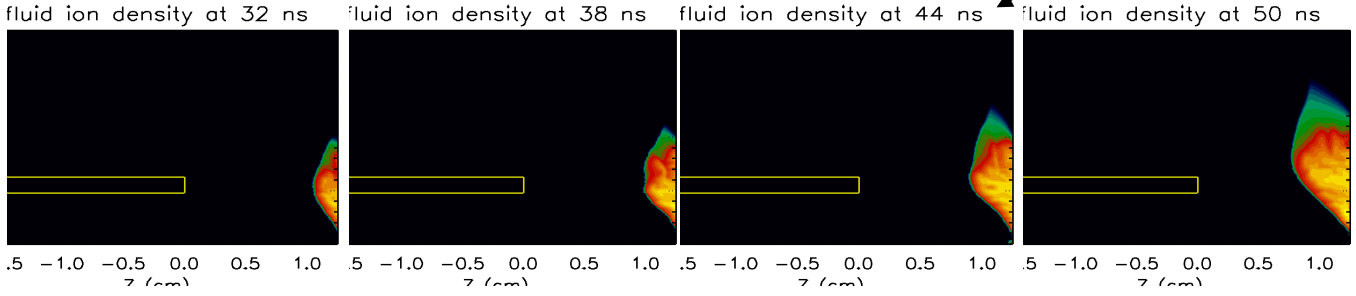
Streak Camera



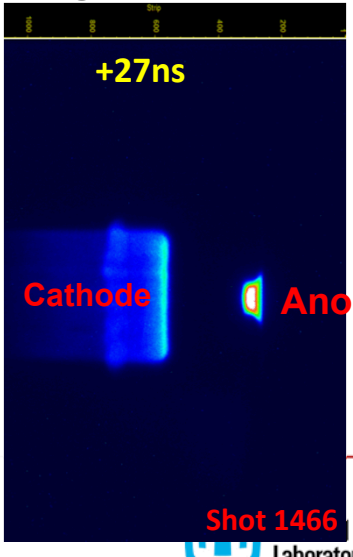


Kinetic Ions

Fluid Species



Framing Camera Image



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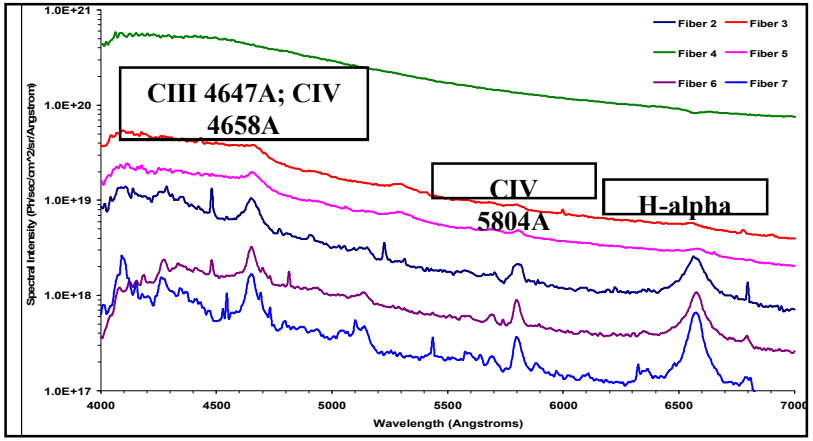
Times of flight for the ion species observed with spectroscopy.

- The plasma formed at the anode electrode during the radiation pulse due to electron beam energy deposition is mainly composed of hydrogen neutrals, protons and carbon ions.
- The times of flight through the bin axis (~44.86 cm length) of the different ionic species for 8 MV diode voltage are as follows:
- t-proton = 11.4 ns
- t- C^{+} (CII) = 39.6 ns
- t- C^{2+} (CIII) = 28 ns
- t- C^{3+} (CIV) =22.9 ns
- It appears that the second group to arrive at the detectors will be the C^{3+} followed by the C^{2+}.



From Mark Johnston at al. IEEE Pulsed Power Conference 2013.

Since the RITS pulse has ~ 50ns flat top,
it would be some overlapping of the various ion arrivals at the detectors.

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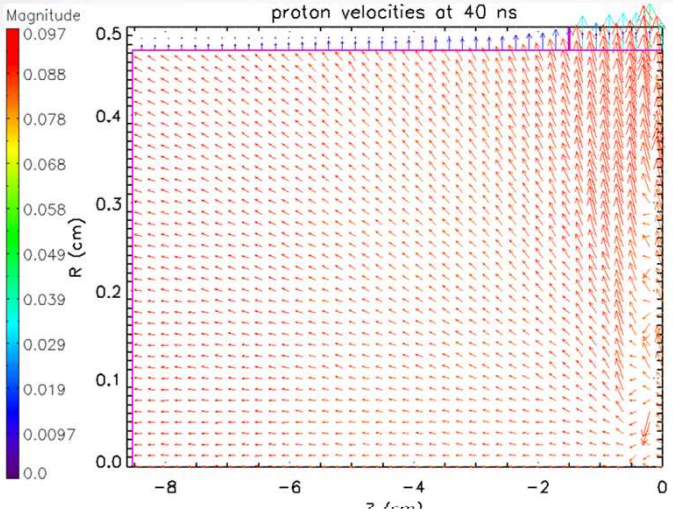
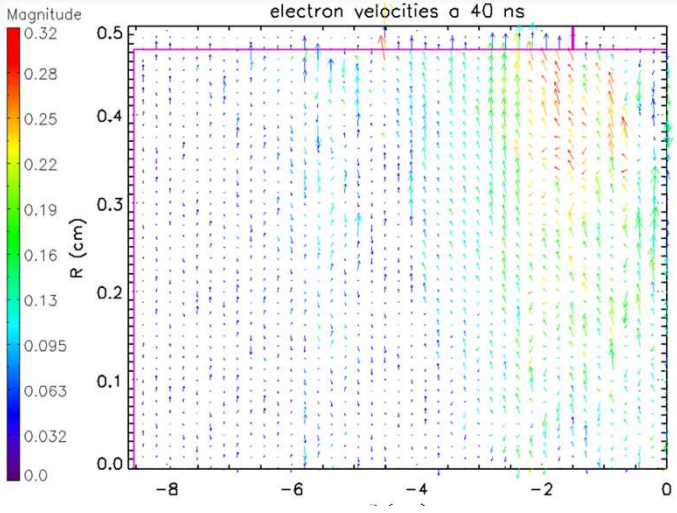
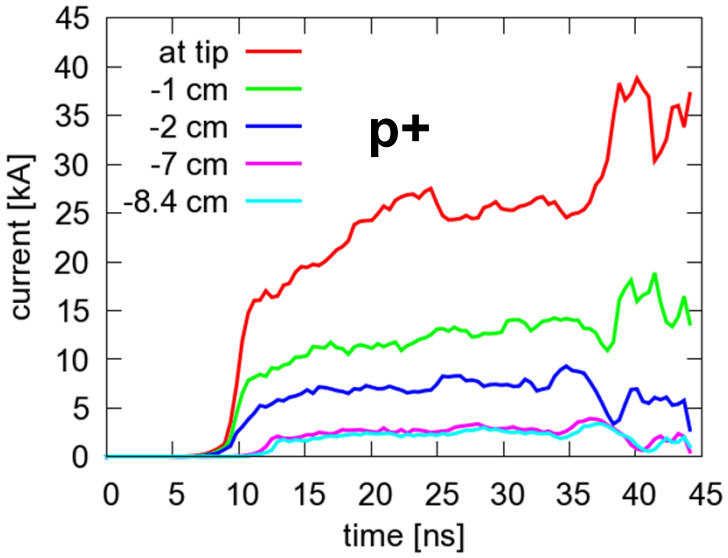
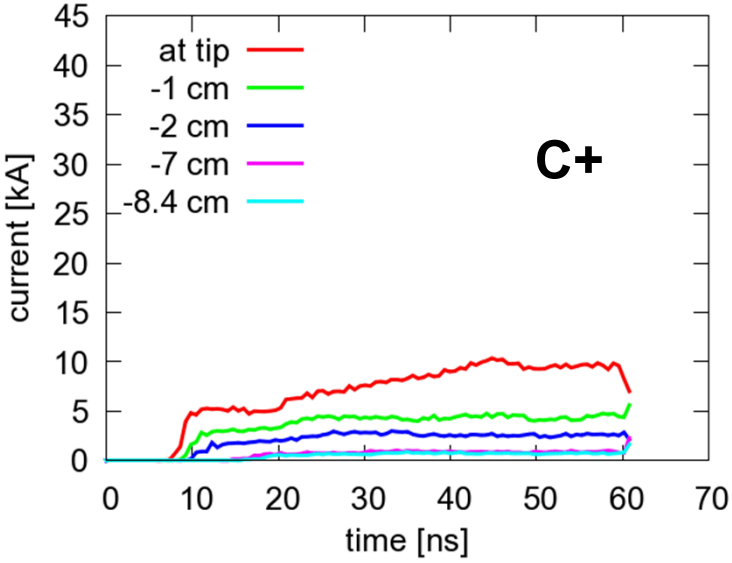
The ion velocities interior to the cathode needle show a collimated beam at the knob.









LSP simulations by Nichelle (Nicky) Bennett

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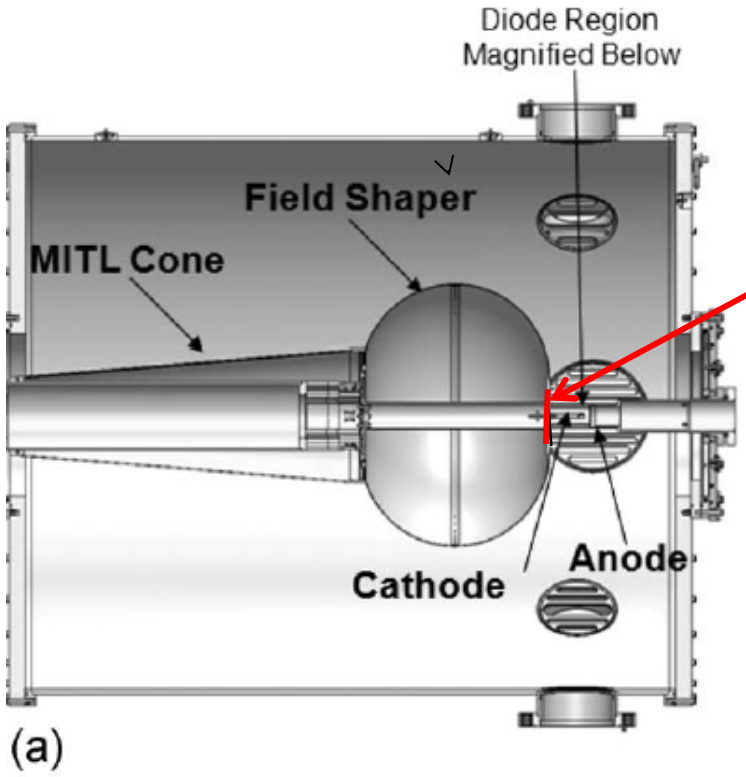
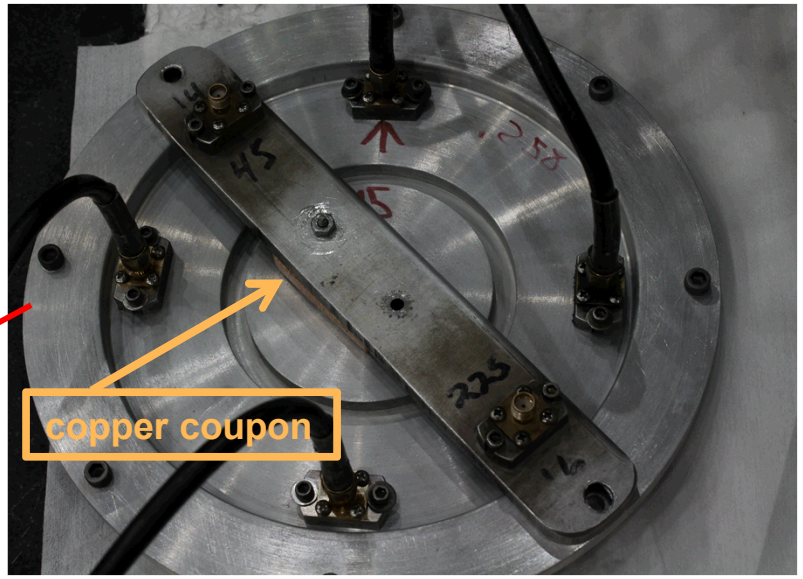
Simplified setup for copper activation (knob front plate)





Back side of the Knob front plate

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