

Overview of University of Wisconsin IEC Research

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* Now at DOE-NNSA

October 19, 2010
12th U.S.-Japan IEC Workshop





Overview



- Progress since the Madison-09 meeting
- Specific Highlights
- Conclusions & Future Work



Other UW-IEC Papers at the 2010 U. S./Japan Workshop



(Lead Author/Title/Time)

- Rich Bonomo, **“UW-Madison IEC Group 2010: Laboratory: Further Infrastructure Improvement and Preparations for 300 kV Operation”**, 1:10 PM, Wednesday
- David Donovan, **“Spatial and Energy Profiling of D-D Fusion Reactions in an IEC Fusion Device”**, 1:55 PM, Wednesday
- Gil Emmert , **“Integral Transport Modeling of Spherically Symmetric Gridded Devices”** , 9:00 AM, Thursday
- Eric Alderson , **“Theoretical and Experimental Studies of Negative Ions in IEC Devices at the UW-Madison”**, 10:15 AM, Thursday
- John Santarius , **“Approaches to Optimizing Gridded IEC Devices”**, 2:40 PM, Thursday

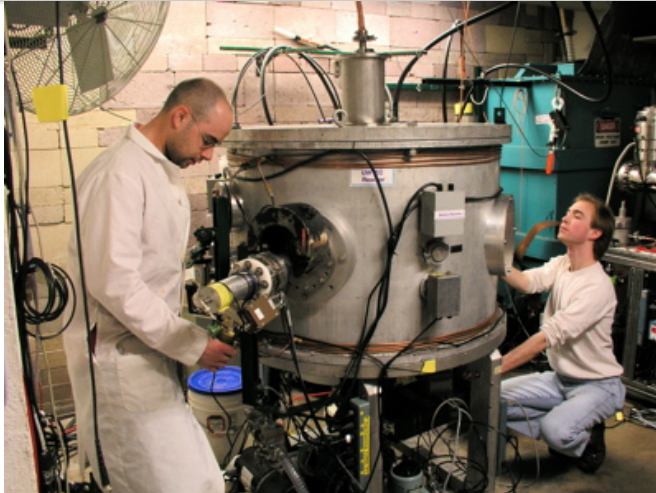


Wisconsin IEC Staff

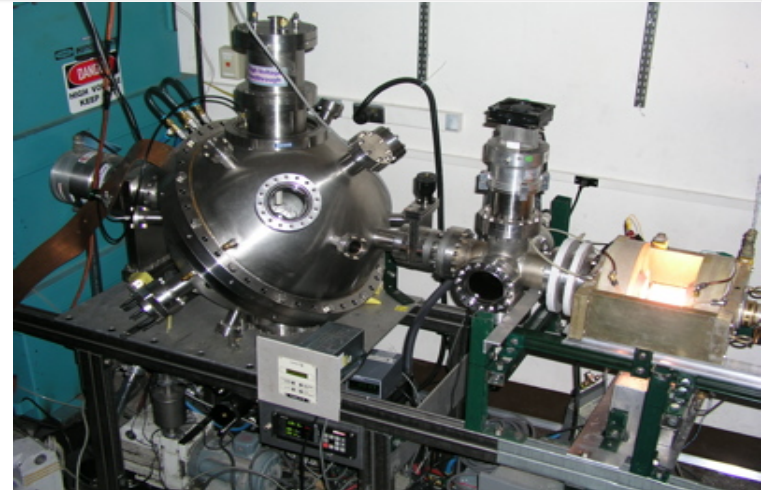




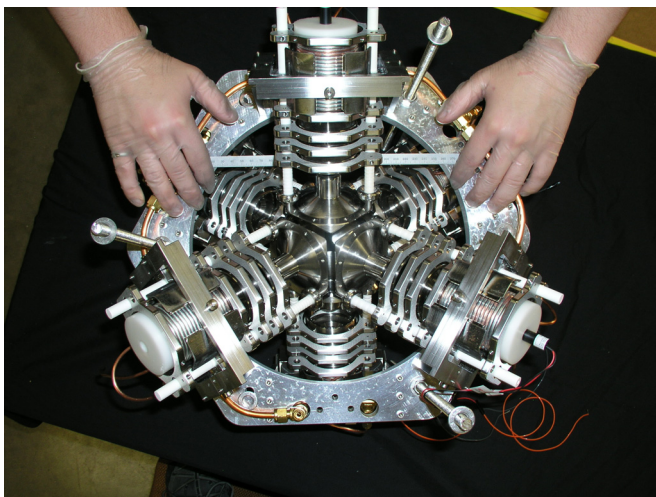
There are Currently Four Different IEC Chambers in Operation at the University of Wisconsin



HOMER



HELIOS

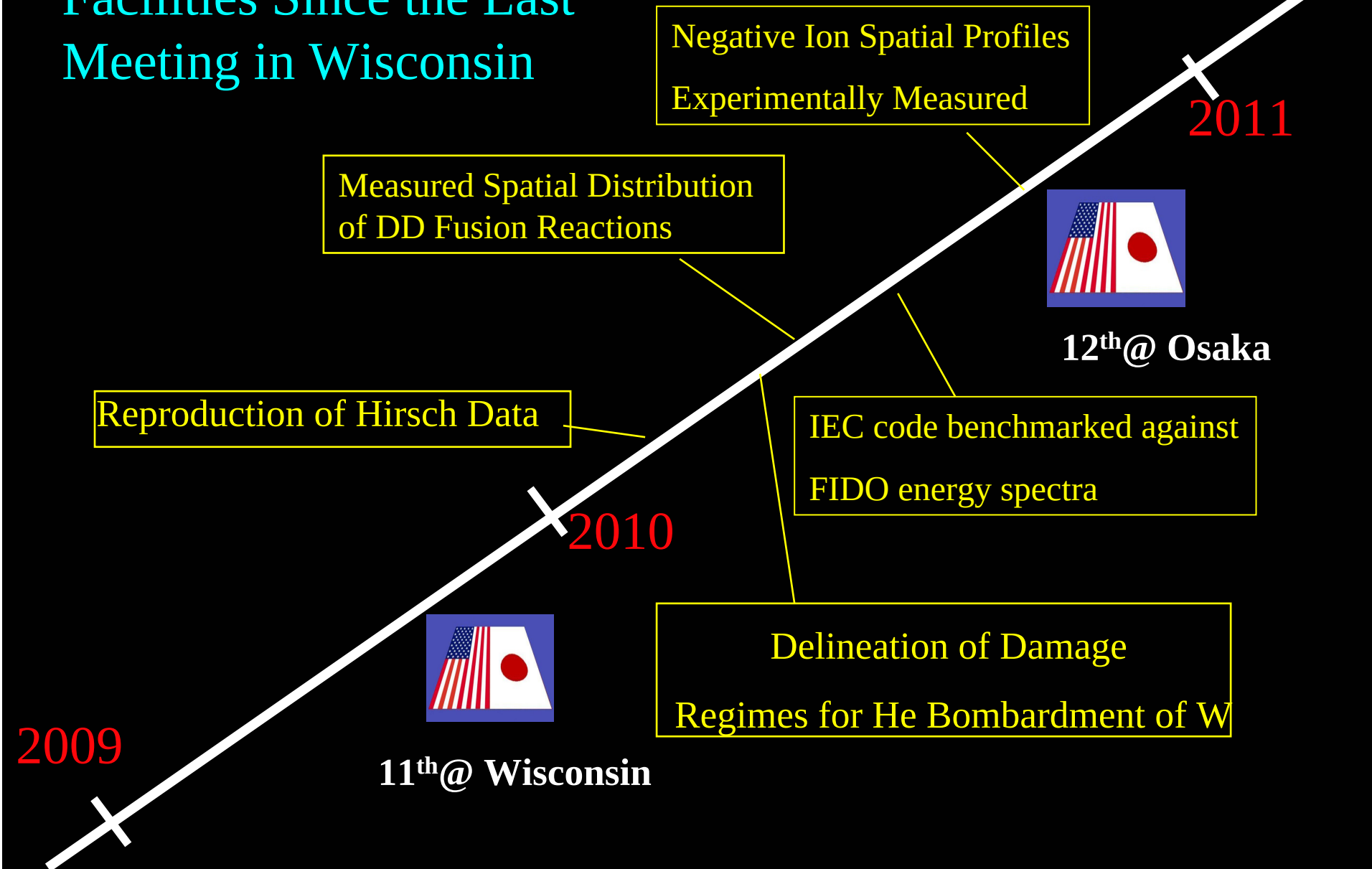


SIGFE



MITE-E

Progress at UW IEC Facilities Since the Last Meeting in Wisconsin

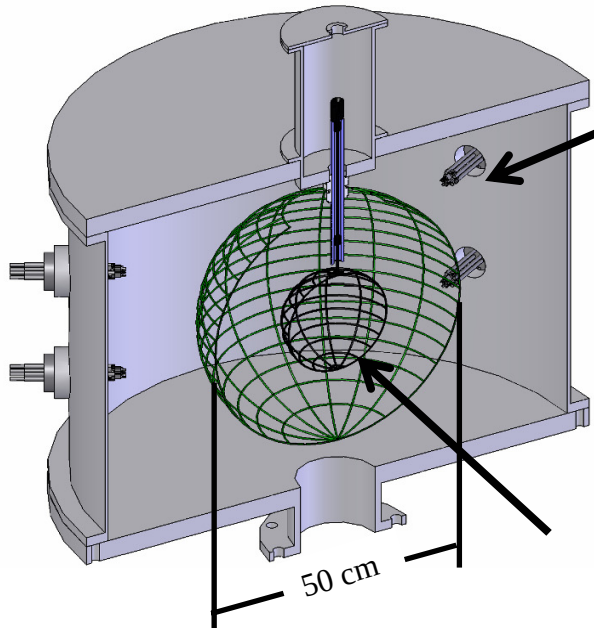




Hirsch Device Unique in Several Ways



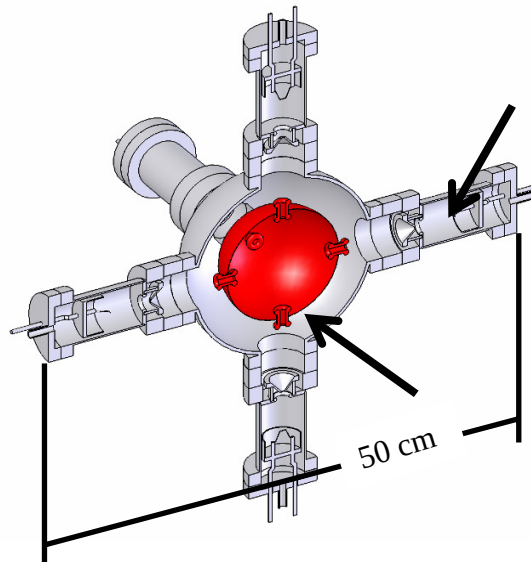
UW Gridded IEC Device



UW IEC Gridded device

- Filament assisted DC discharge in main chamber
- Greater than 90% transparent wire grids
- 0.07 to 1.3 Pa (0.5 to 10 mTorr) D and/or ^3He gas

Hirsch: Six Focused Ion Guns

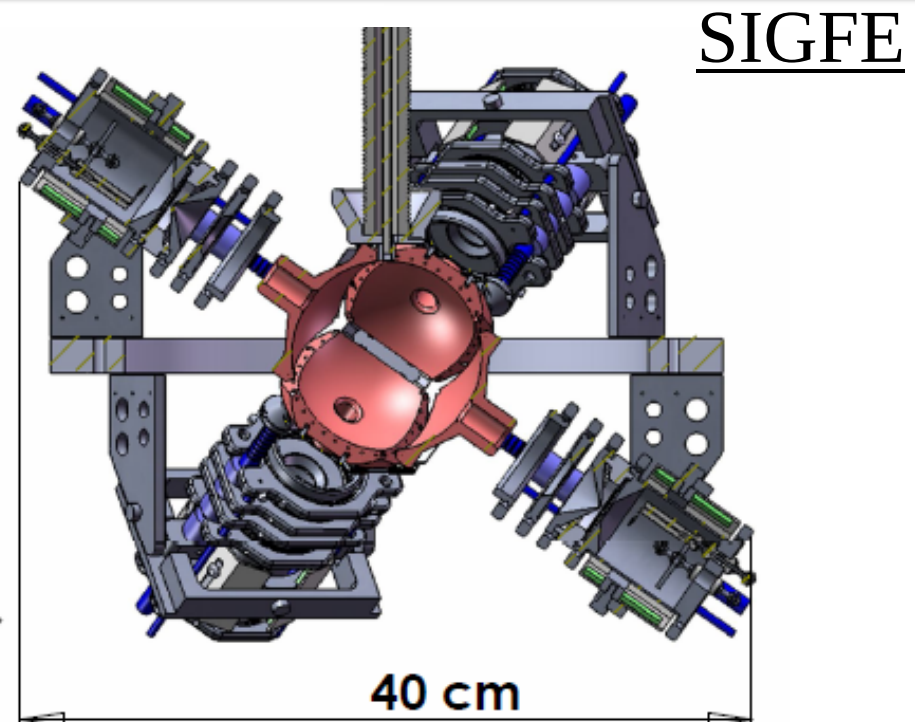
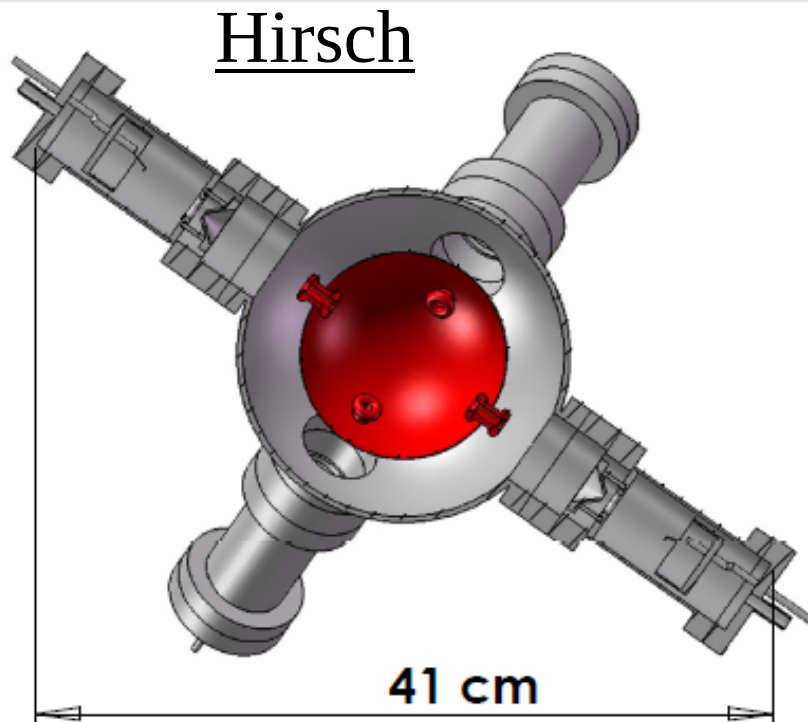


Hirsch-1967 IEC device

- Six ions guns with:
 - Ion optics to implicitly focus ions at center
 - High-pressure plasma region with filaments and gas flow restricted from main chamber
- Opaque cathode
- 0.01 to 1 Pa (0.1 to 7.8 mTorr) of D and/or T gas



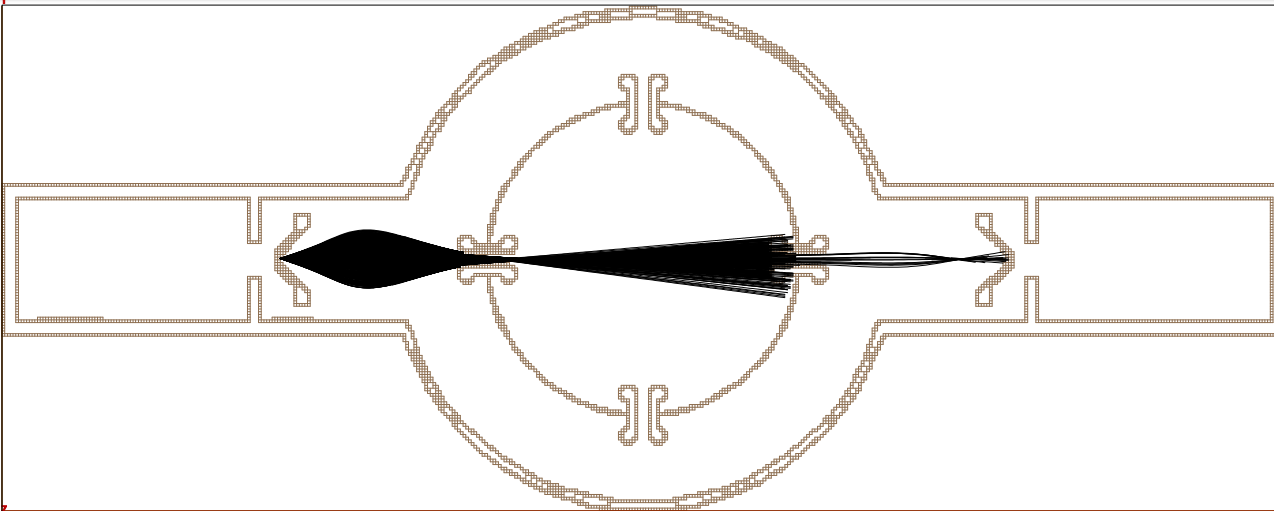
Comparison of SIGFE to Hirsch Geometry



- SIGFE's design attempted to replicate the geometry of Hirsch-1967 as close as possible
- Major difference that may effect electric fields include:
 - Grounded ring in SIGFE replicates chamber wall as anode
 - Addition of focusing lens
 - Electron suppression on cathode



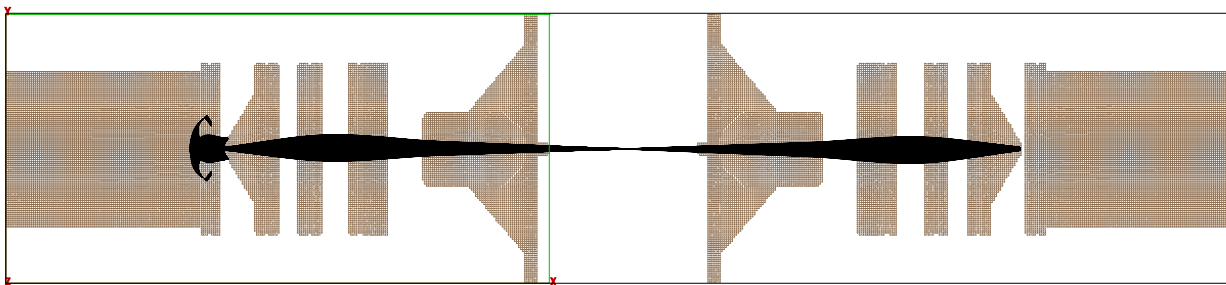
Ion Beam Focusing Changes Ion Impact Profile and Fusion Rate in the Cathodes



Hirsch Geometry

Cathode: -100 kV

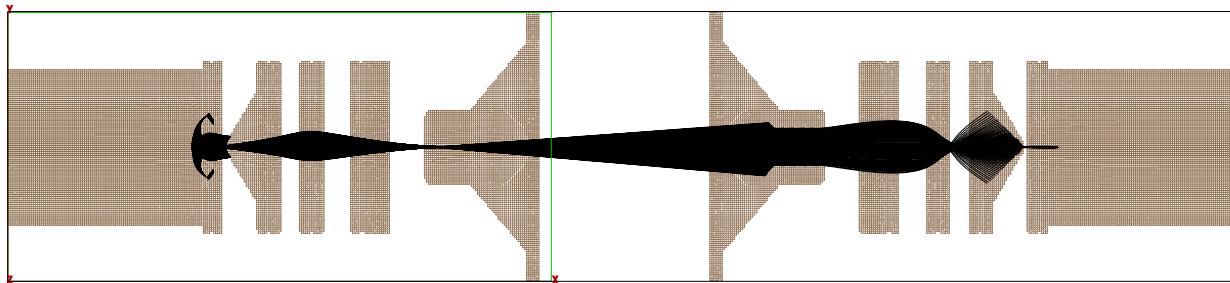
Focus: 0 kV



SIGFE Geometry

Cathode: -100 kV

Focus: -5 kV

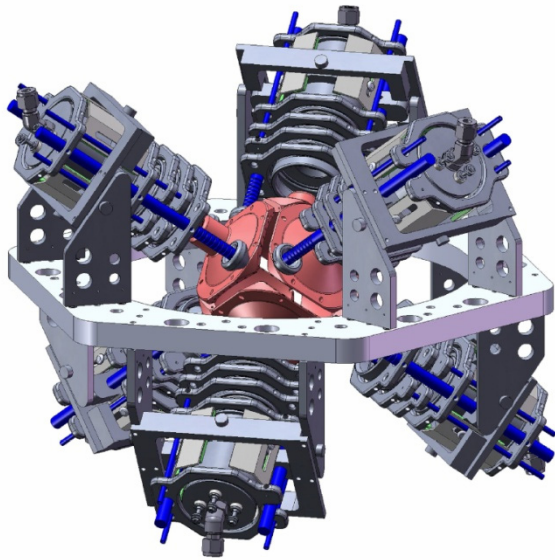


Cathode: -100 kV

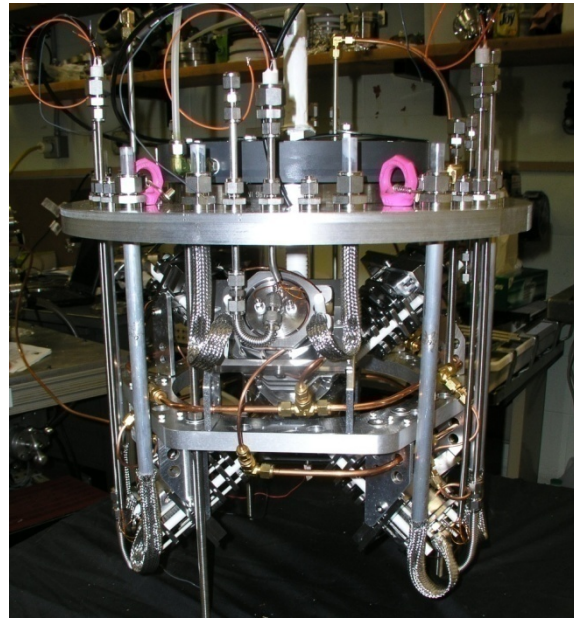
Focus: 0 kV



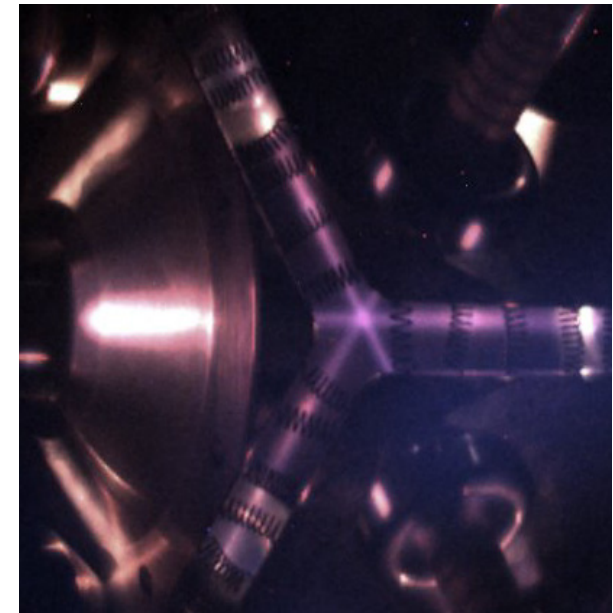
Six Ion Gun Fusion Experiment (SIGFE)- Brian Egle-Matt Michalak



December 2007



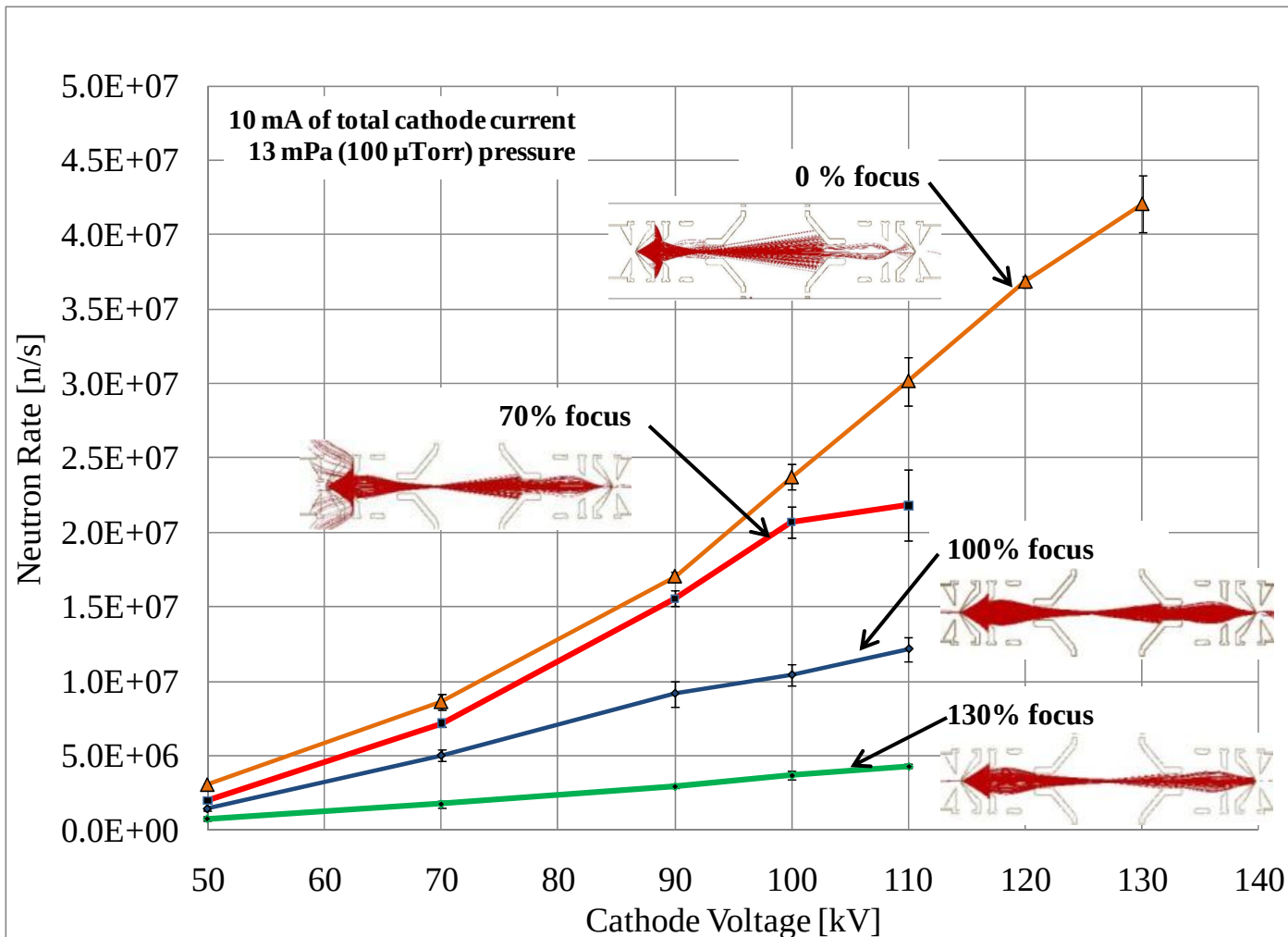
December 2008



September 2009



D-D neutron rate scaling with cathode voltage depends on focus



- Best fusion rates with defocused ion beams

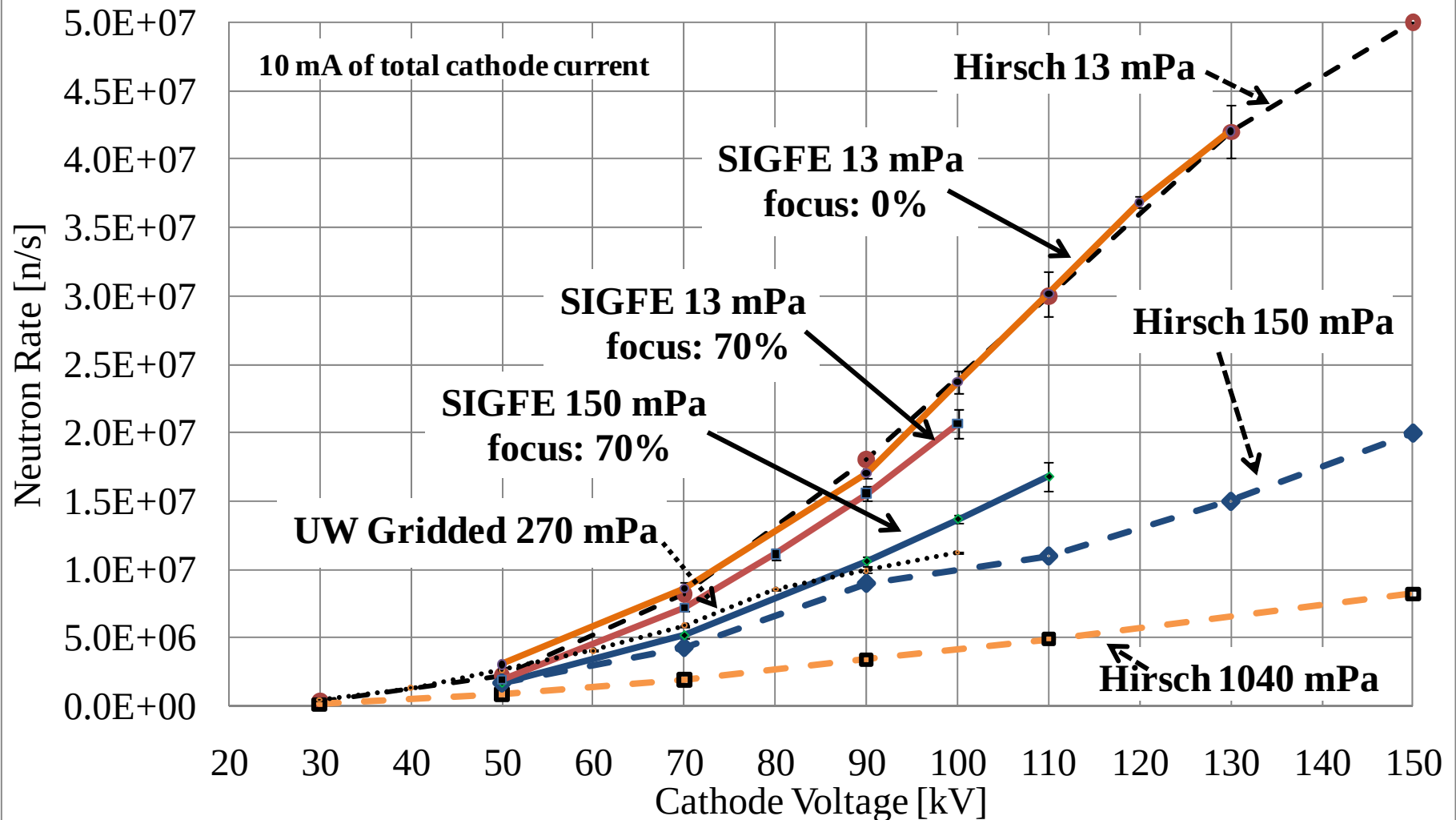
- Best D-D rate:

$$4.3 \times 10^7 \text{ n/s}$$

at -130 kV, 10 mA, 13 mPa

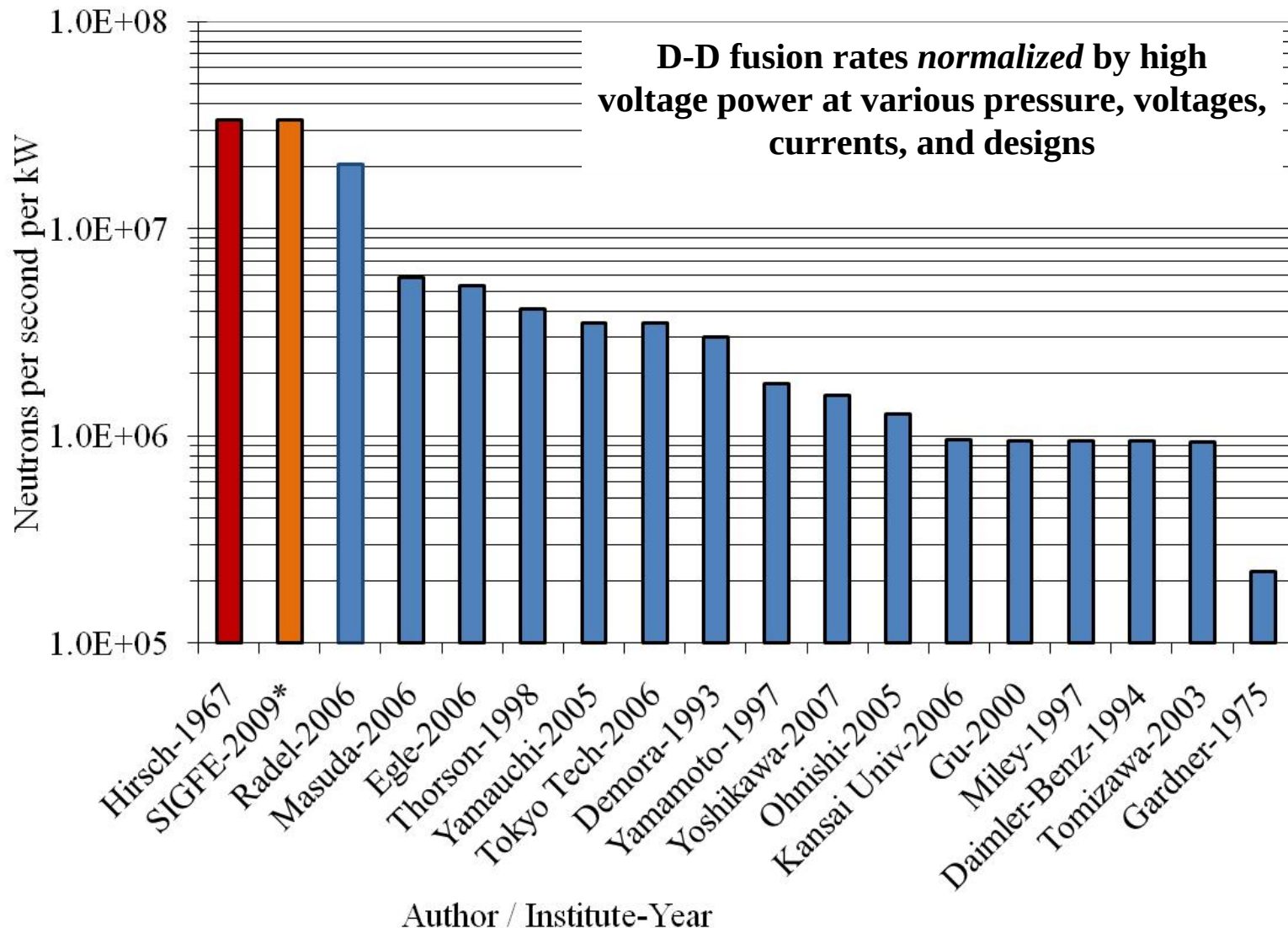


Defocused SIGFE matches Hirsch D-D neutron rates





Defocused SIGFE matched fusion rates and efficiency of Hirsch device

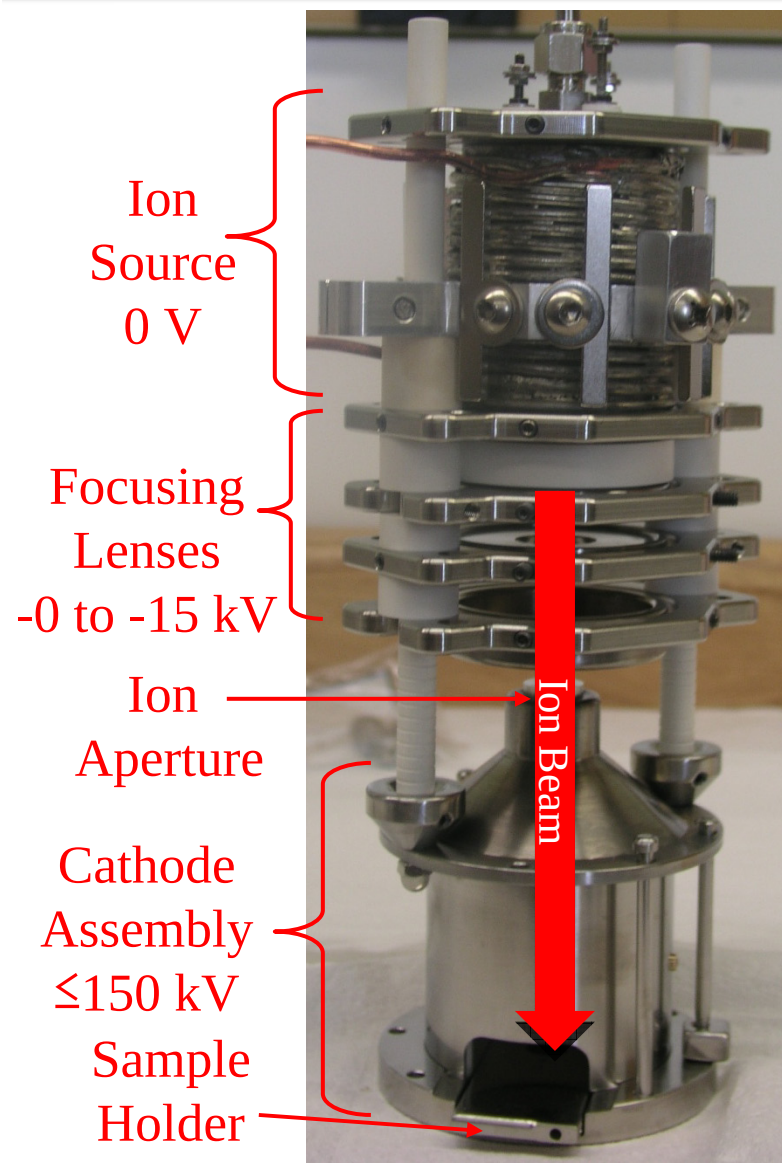




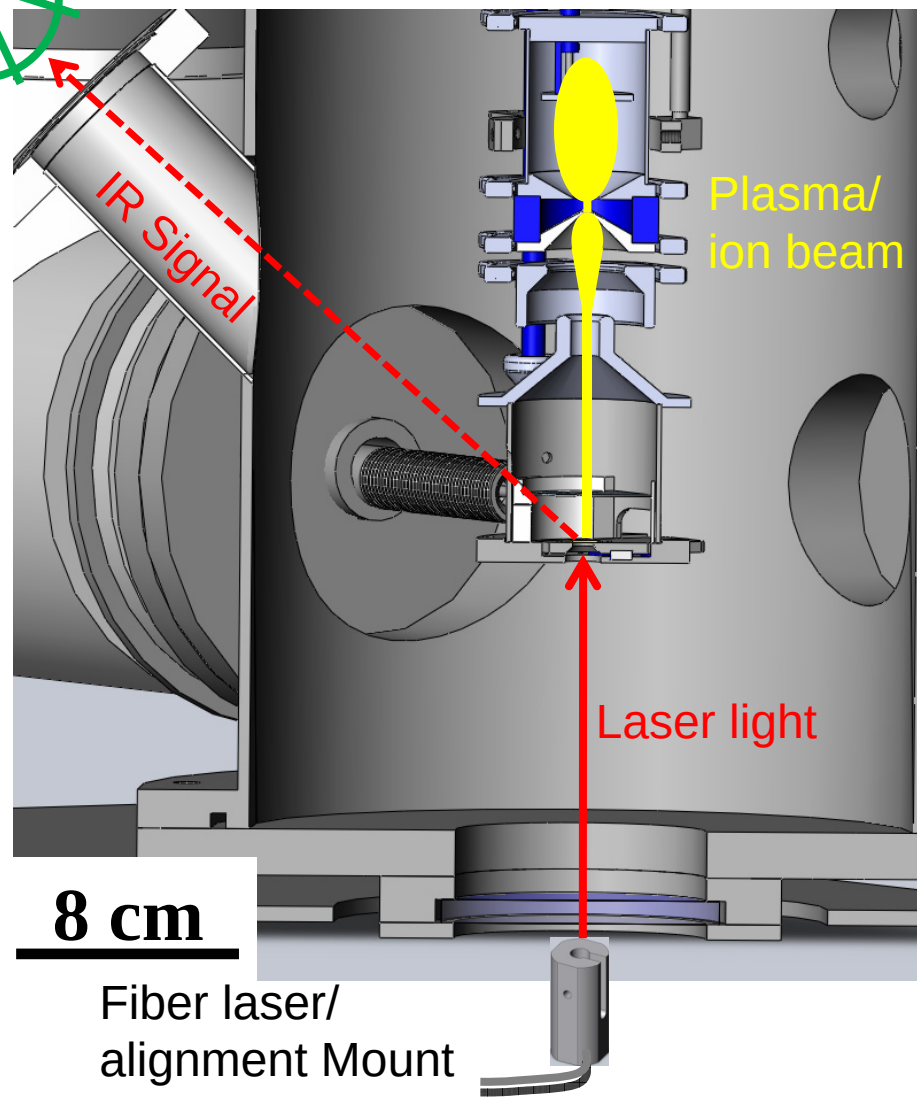
The *MITE-E*'s Ion Gun Module



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Pyrometer

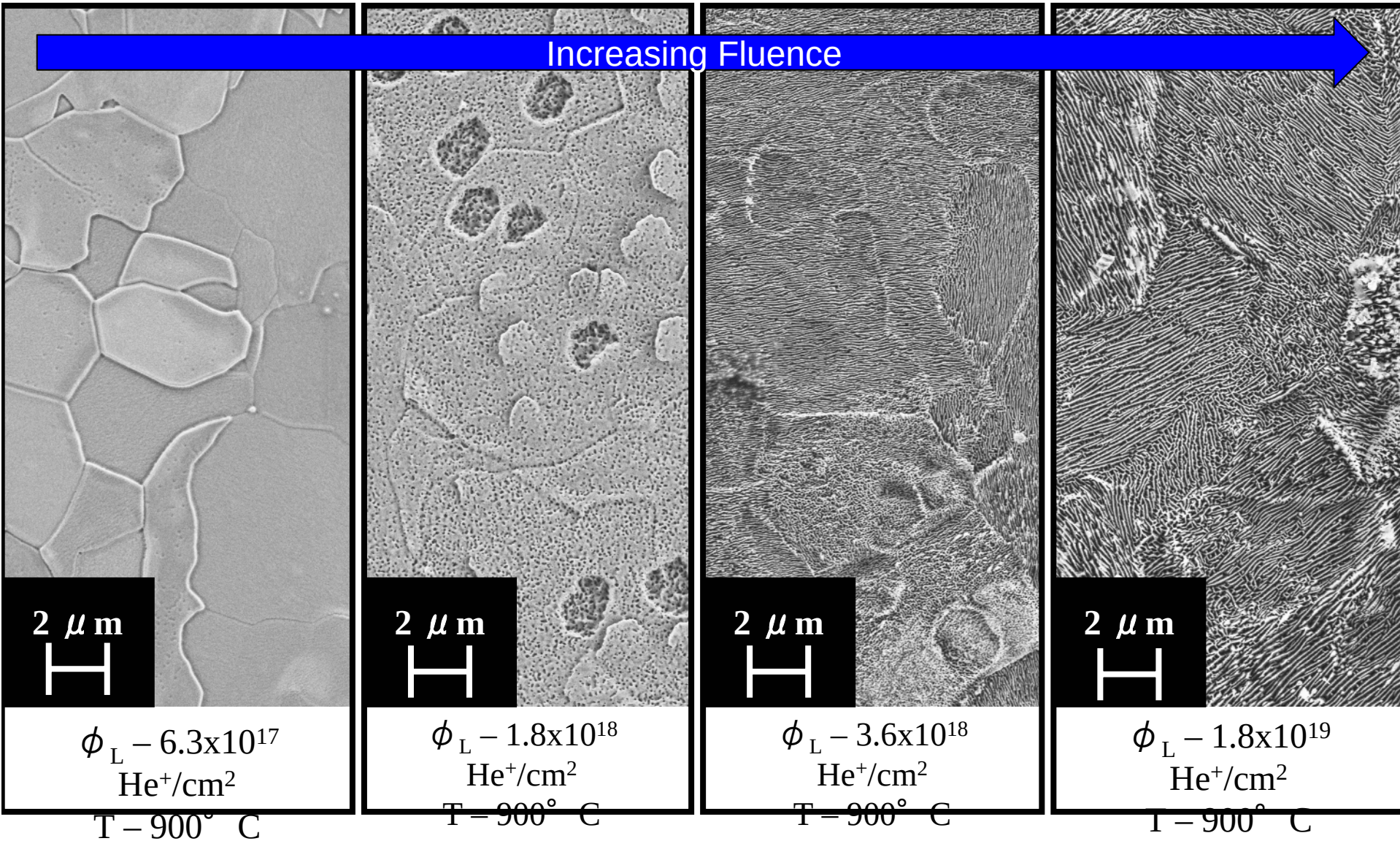




The Formation of Blisters at High Temperatures (900° C)-30 keV

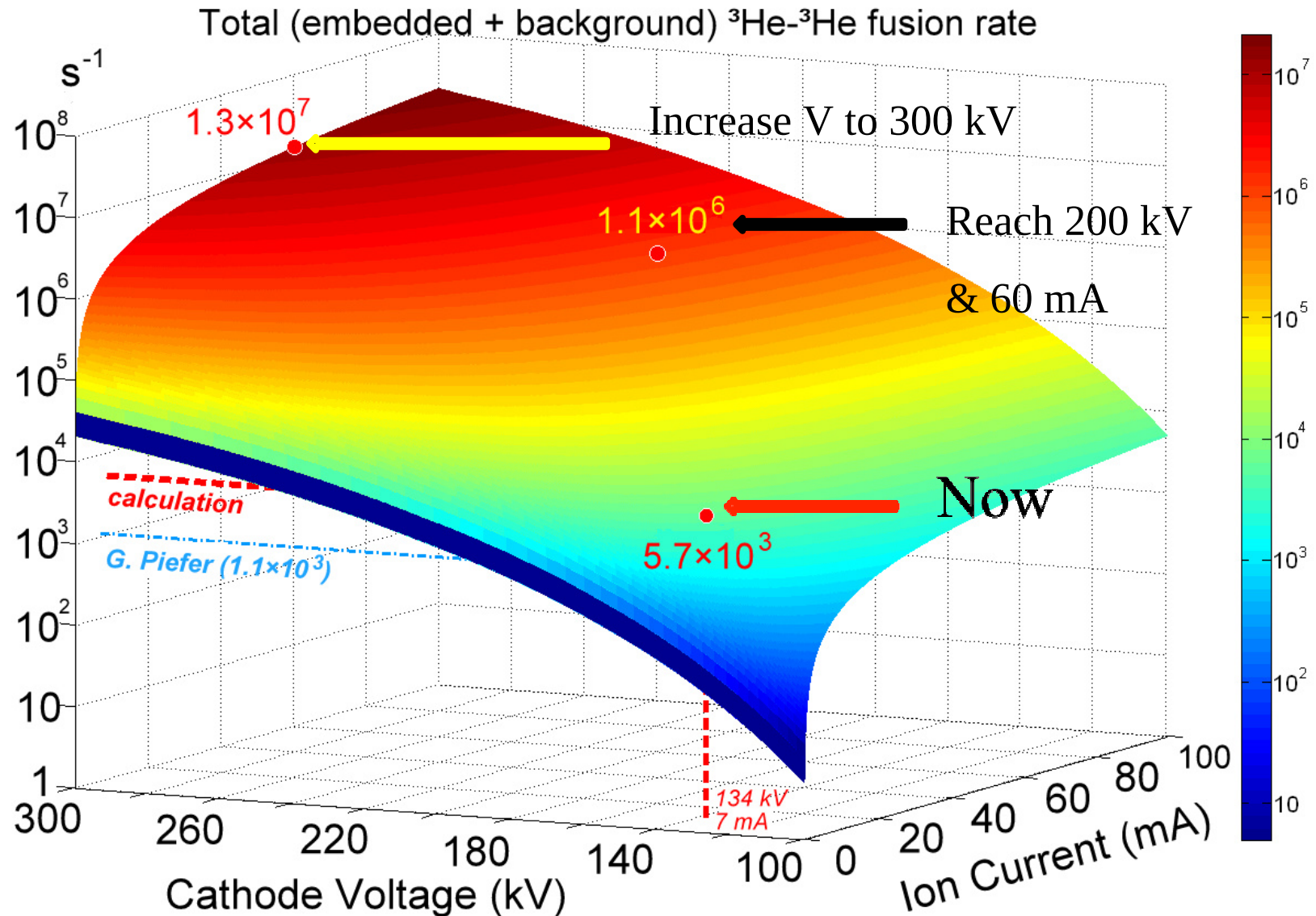


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Efforts Continue to Increase the ^3He ^3He Fusion Rates in HELIOS-Becerra





Conclusions



- Experiments on SIGFE have successfully reproduced the record DD fusion rates measured by Hirsch in 1967
- It now appears that the neutrons produced in the “6-Gun” experiments were largely the result of beam-solid target DD fusions in the components of the device.
- The use of He fuel ions can result in significant degradation of W cathodes in IEC devices (along with negative implications for MFE and IFE fusion reactors).



Conclusions (cont.)



- Time of Flight (TOF) measurements of DD fusion products (p, T) reveal the influence of energetic neutral particles, positive, **and** negative ions on the spatial distribution of fusion events.
- Faraday Cup measurements confirm the existence of negative ions in “jets”.
- Understanding the origin and energy spectrum of negative ions may help design more efficient IEC devices.



Conclusions (cont.)



- The ability to predict, and measure, the softening of the ion energy spectrum at the cathode in even relatively good vacuums ($\approx 10^{-3}$ torr) gives us a whole new perspective on the operation of IEC devices.
- The discovery of IEC devices as sources of negative ions may lead to new applications for IEC facilities.



Future Goals of UW IEC Program



- Understand & extend performance of the SIGFE 6 ion-gun device.
- Inject D, ^3He into SIGFE at high energies to study D^3He fusion and medical isotope production.
- Begin routine operation at cathode voltage >200 kV
- Increase $^3\text{He}^3\text{He}$ fusion rates in HELIOS.



Future Goals of UW IEC Program (Cont.)



- Compare the experimental results to code predictions of the energy & spatial distribution of DD fusion events in an IEC device.
- Understand the effect of He on the morphology of tungsten IEC cathode grids.
- Measure the current densities & spatial profiles of negative ions emanating from the cathode region in IEC devices.

Questions?

