UW IEC Group 2010: Further Infrastructure Improvements and Preparations for 300 kV Operation

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University of Wisconsin – Madison IEC Group

U.S. -- Japan 2010 IEC Workshop

Osaka, Japan

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University of Wisconsin -- Madison

Fusion Technology Institute

Inertial Electrostatic Confinement Group

Presentation Outline

1. Current Status
2. Laboratory configuration and basic operation
3. Preparations for 300 kV operation
4. Other infrastructure improvements

Prof. Gerald Kulcinski provided an overview of experiments in progress this morning.

Current Status of Laboratory

- Personnel:
  - 7 graduate students
  - 1 staff engineer/researcher/laboratory manager
  - 1 undergraduate technician/researcher
  - 4 faculty

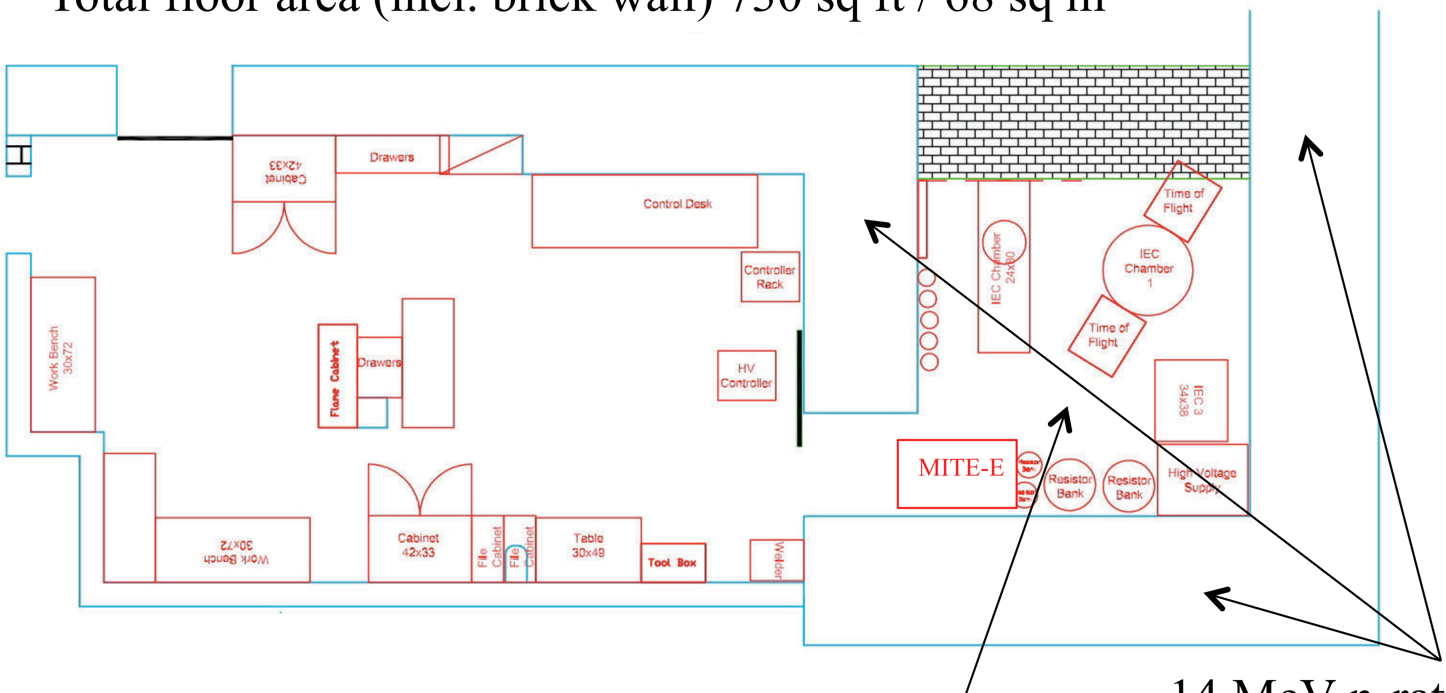
Current Status of Laboratory (as of October 2010)

- Apparatus
  - 3 operating IEC devices
  - 1 operating materials testing device
  - 1 pulsed device under construction
  - 300 kVDC power supply
  - 2-channel low-ripple filament-heating-and-bias power supply

Laboratory Layout

FTI Primary Laboratory
B151 ERB

Total floor area (incl. brick wall) 730 sq ft / 68 sq m



Experiment cell (12 X 12 ft) / (3.7 X 3.7 m)

14 MeV-n-rated walls
52 in / 132 cm thick

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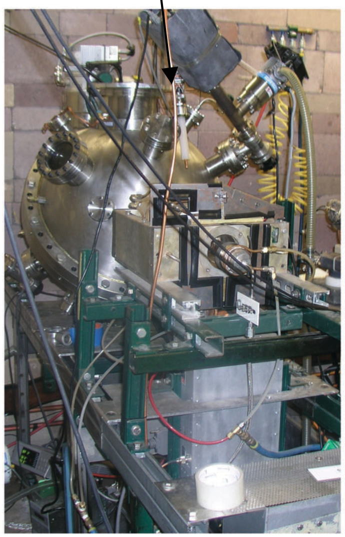
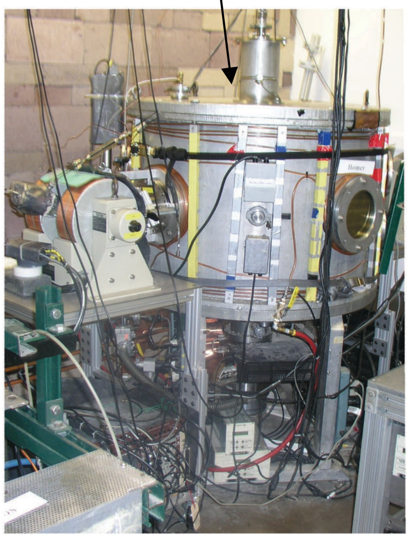
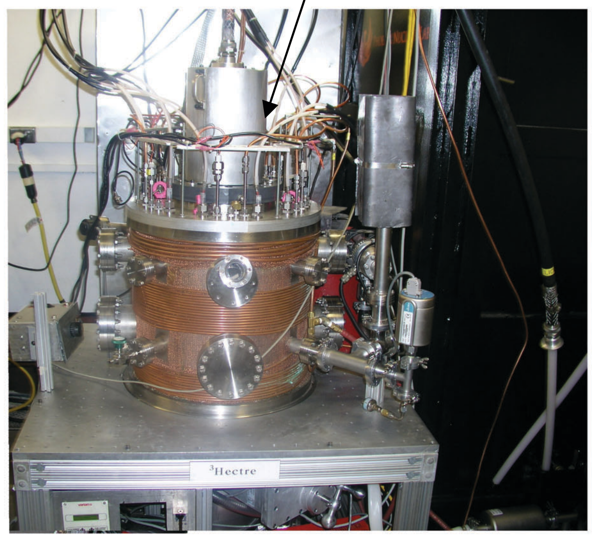
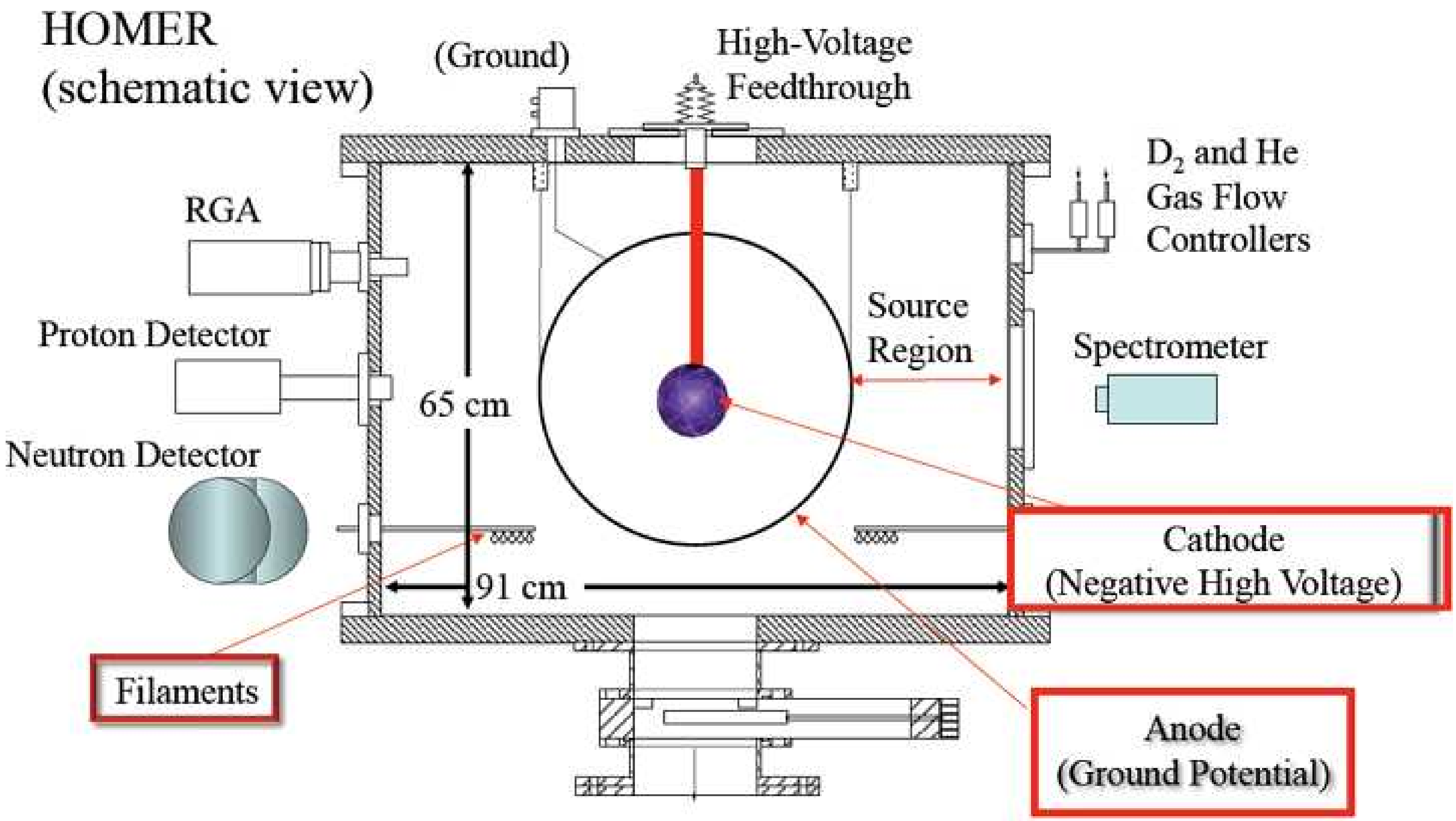
Laboratory Apparatus

HELIOS HOMER ^{3}HeCTRE / SIGFE MITE-E

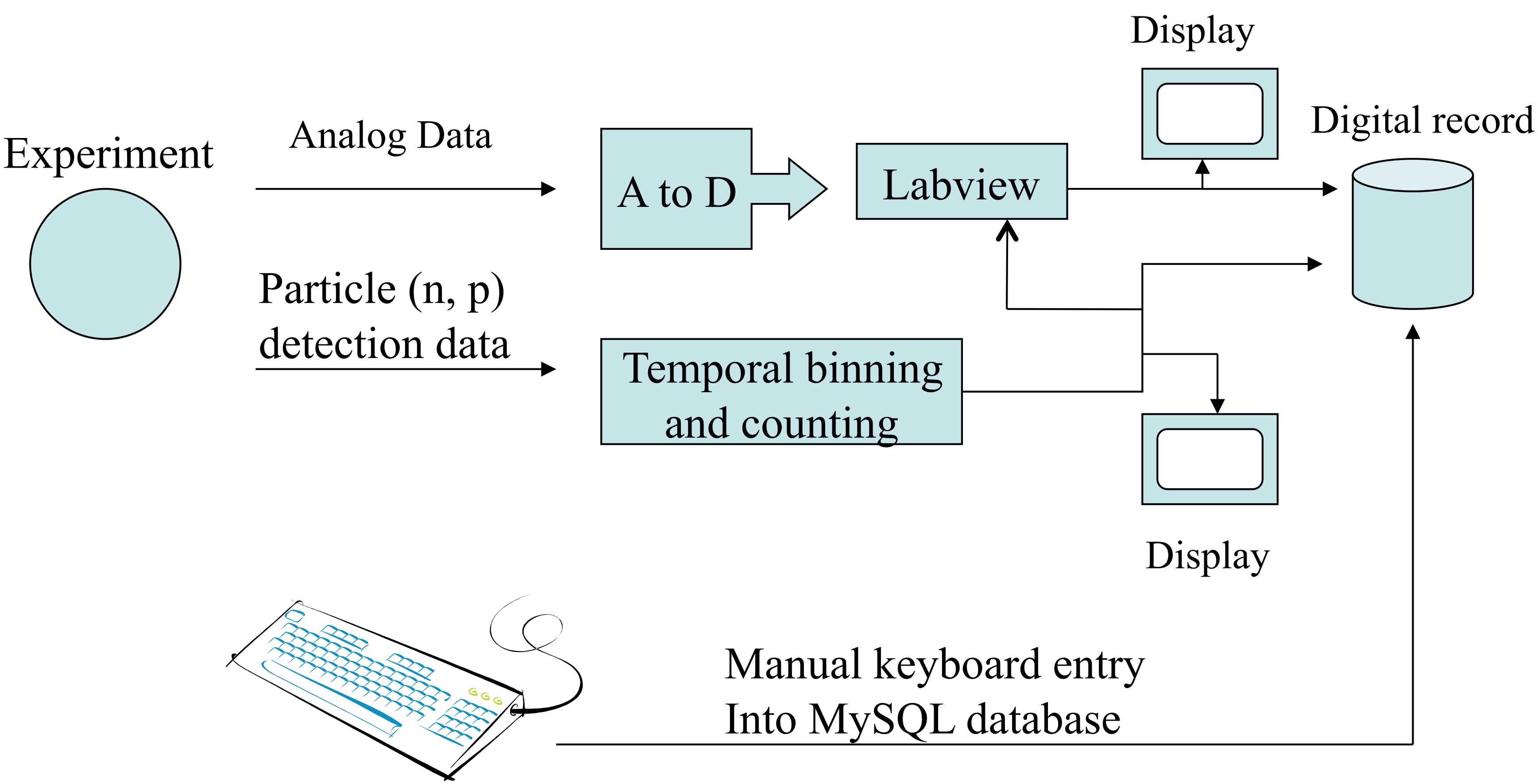







HOMER
(schematic view)
(Ground)
High-Voltage
Feedthrough
D2 and He
Gas Flow
Controllers
RGA
Proton Detector
Source
Region
Spectrometer
65 cm
Neutron Detector
Cathode
(Negative High Voltage)
91 cm
Filaments
Anode
(Ground Potential)

Data Flow (typical)



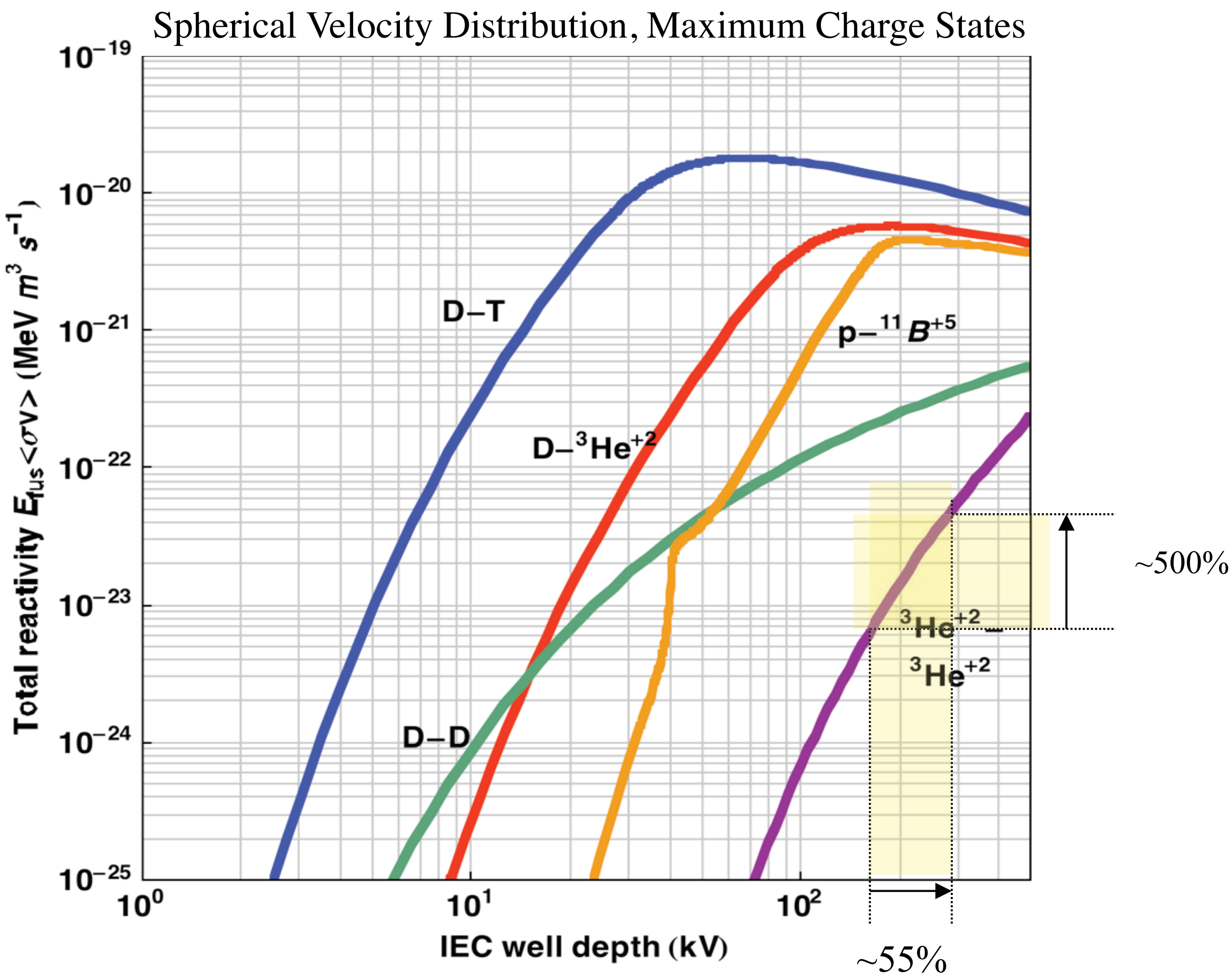
Data are analyzed using a number of software packages available in the laboratory and at the college computing facility

300 kVDC Power Supply

installed May 2009

Motivation for Power Supply Upgrade

- Improved access to ^3He-^3He Fusion Regime



Source: J. F. Santarius

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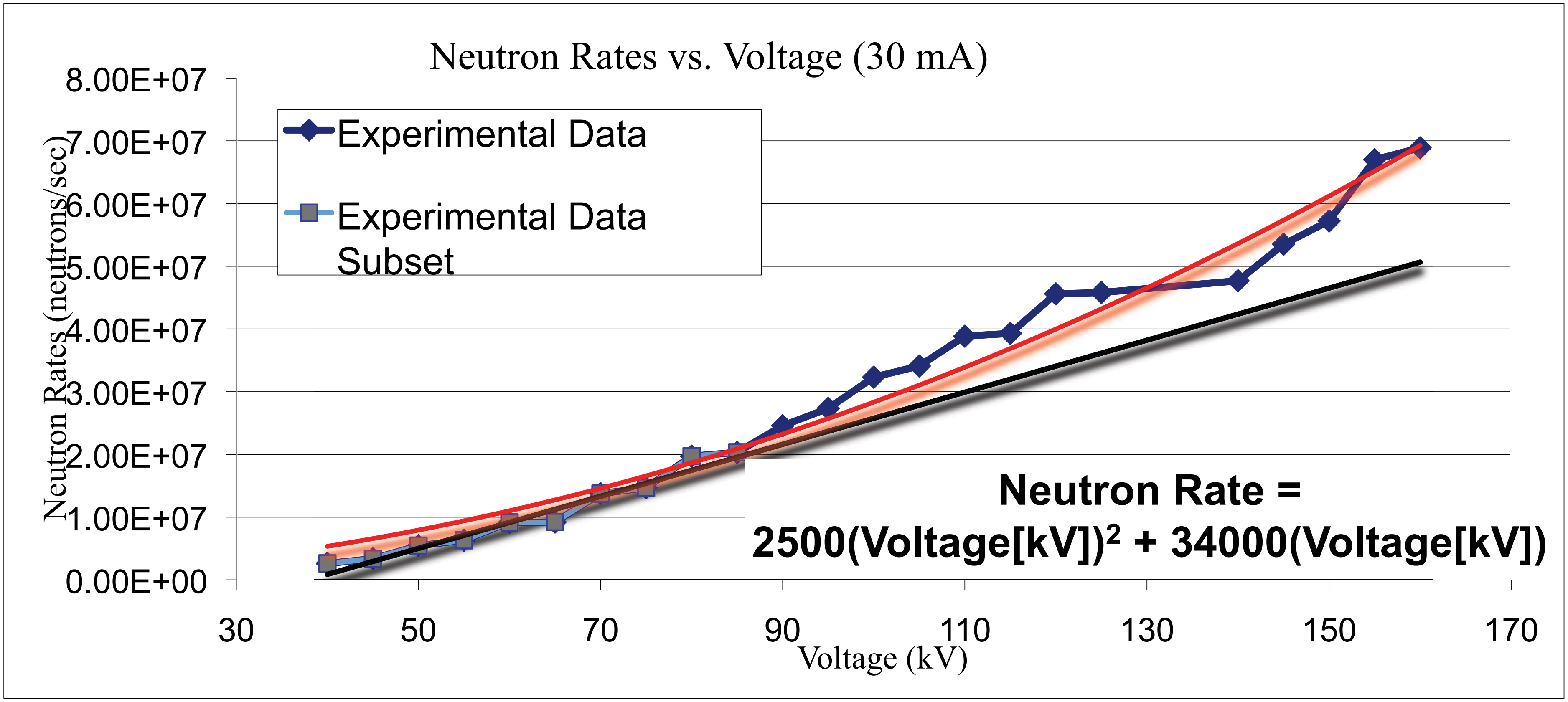
Motivation for Power Supply Upgrade

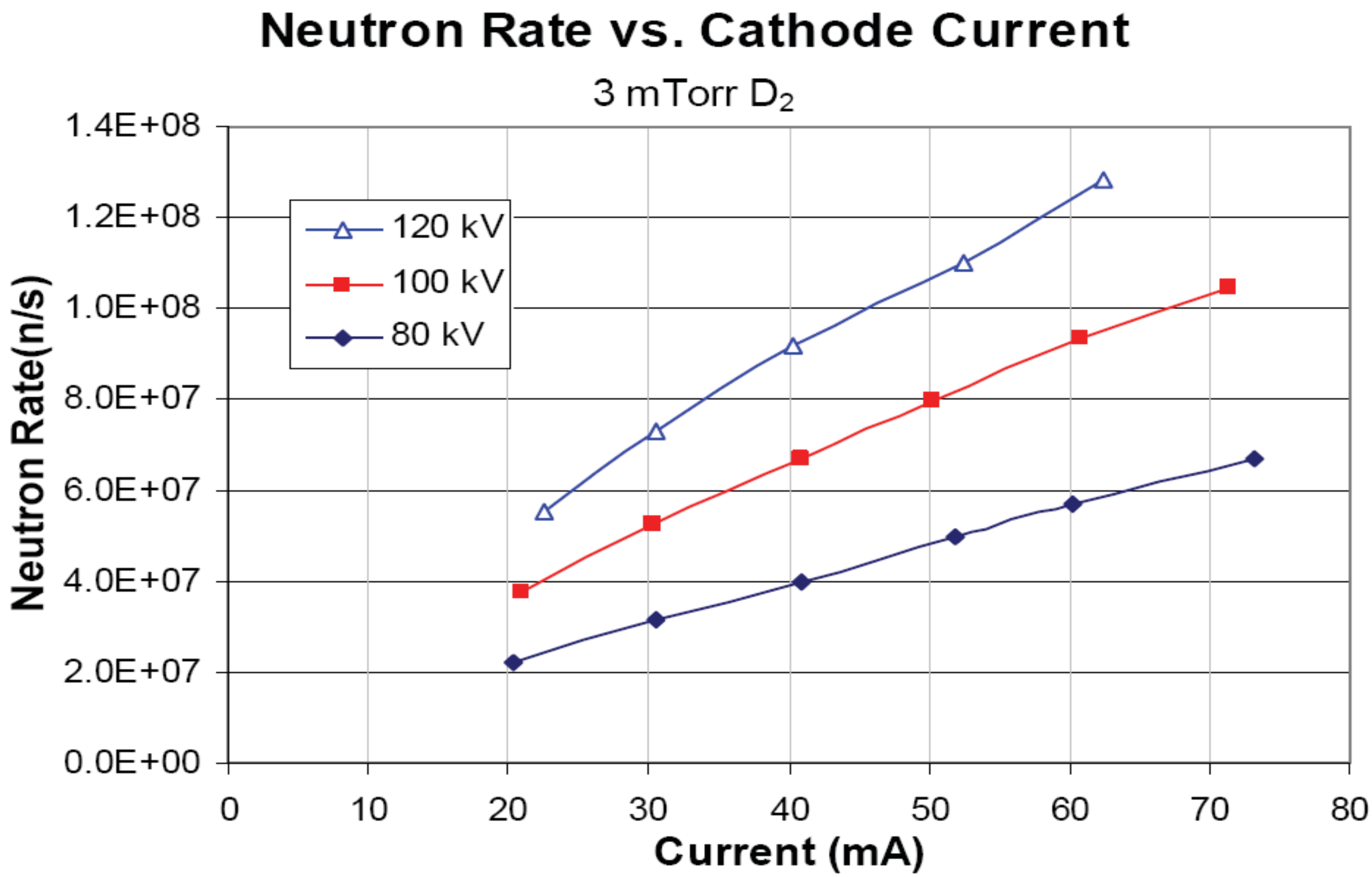
- Neutron flux appears to be monotonically increasing with voltage (greater voltage ==> more neutrons)



Graph courtesy of David Donovan

Motivation for Power Supply Upgrade

- Neutron flux appears to be monotonically increasing with currrent (greater current ==> more neutrons)

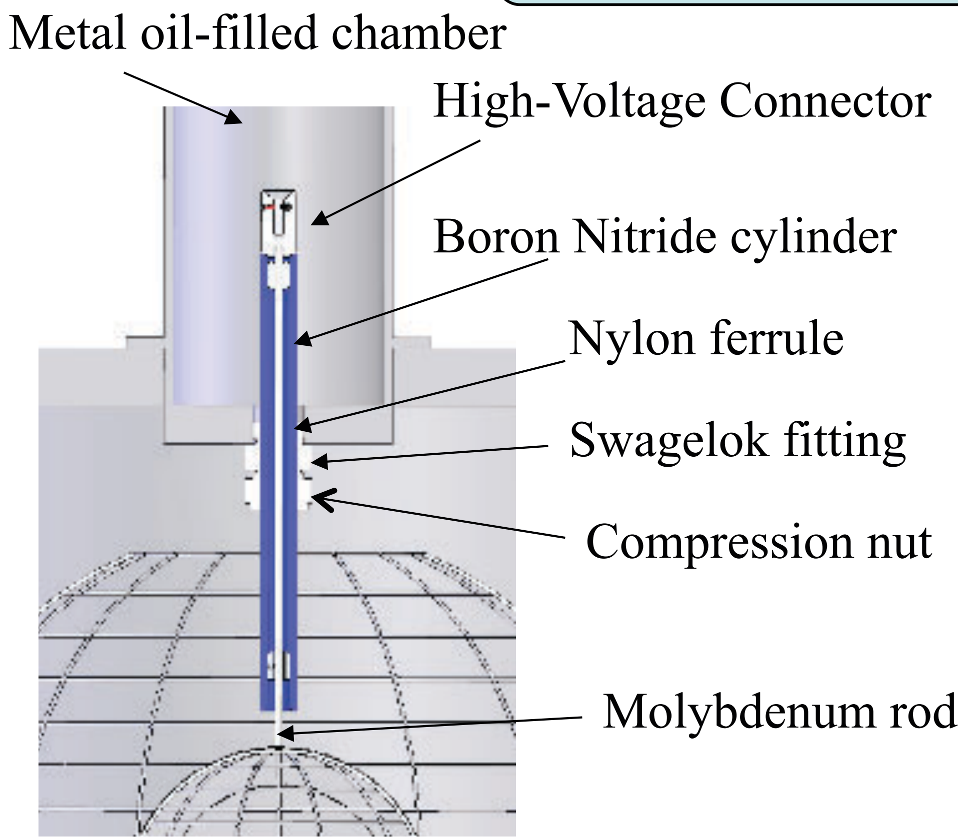


Graph courtesy of David Donovan

Preparations for 300 kV Operation

Replacement of high-voltage electrical vacuum feed-through

Current System



Preparations for 300 kV Operation

Replacement of high-voltage electrical vacuum feed-through

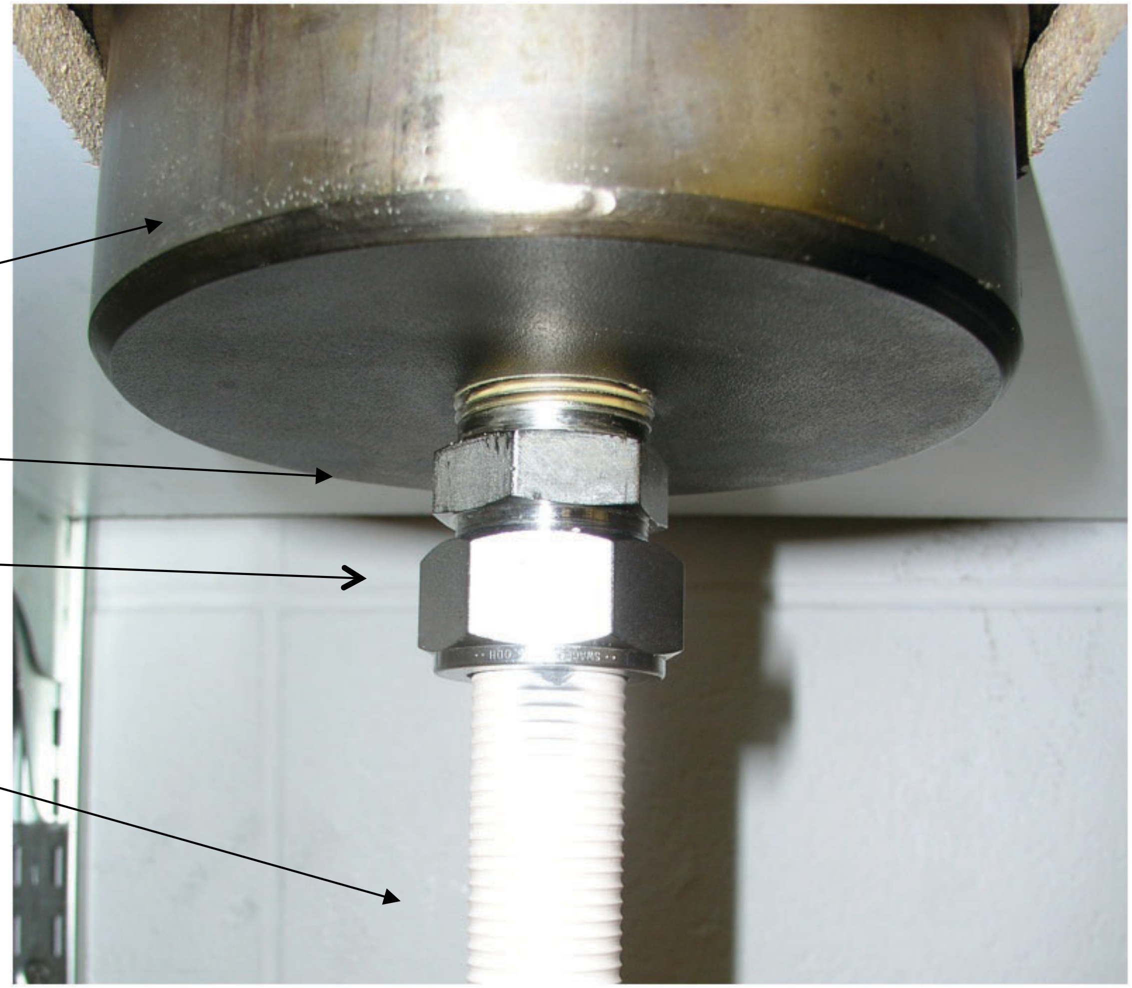
Current System

Metal oil-filled chamber

Swagelok fitting

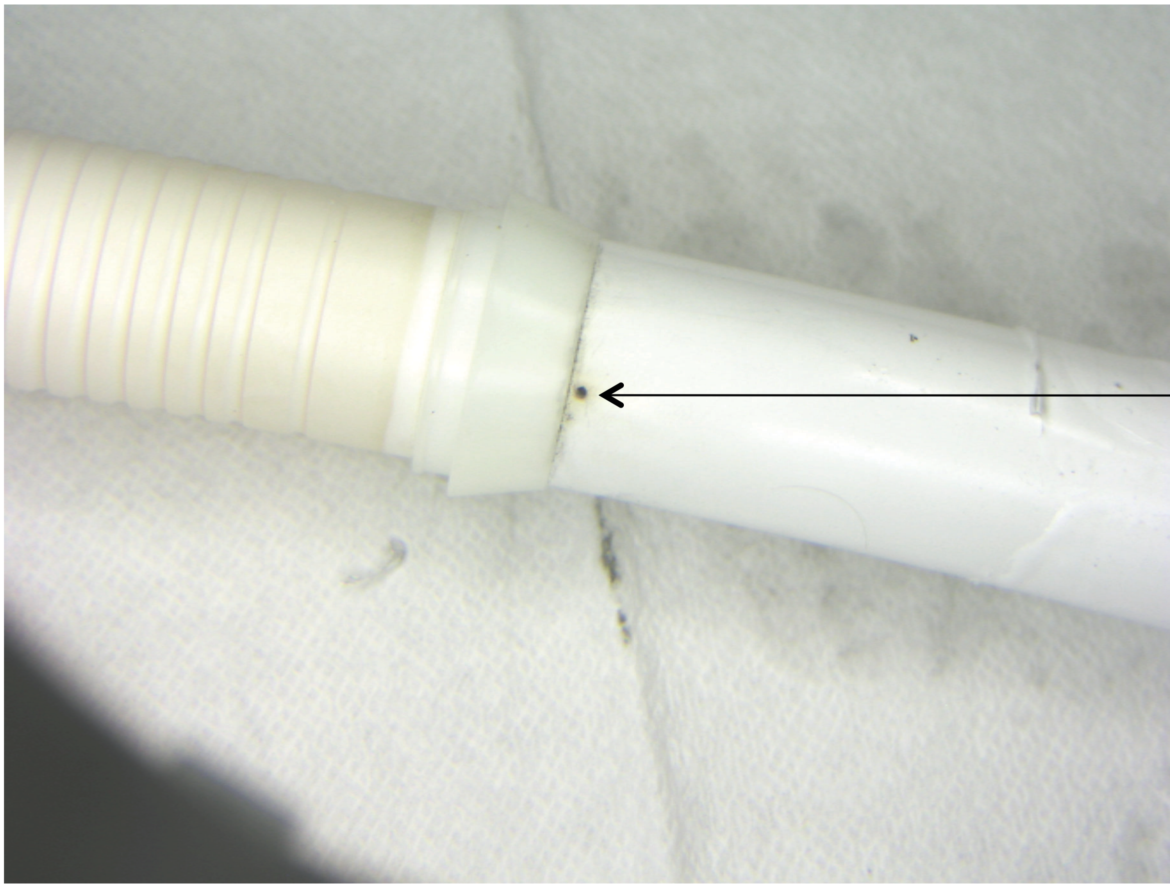
Compression nut

Boron Nitride cylinder



Preparations for 300 kV Operation

Replacement of high-voltage electrical vacuum feed-through

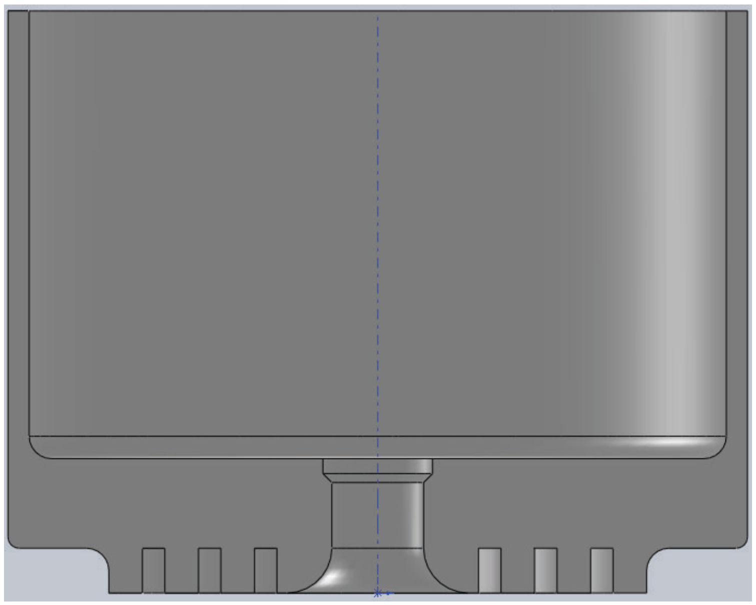


Failed stalk from a previous year, showing burn-through from arcing

Preparations for 300 kV Operation

Replacement of high-voltage electrical vacuum feed-through

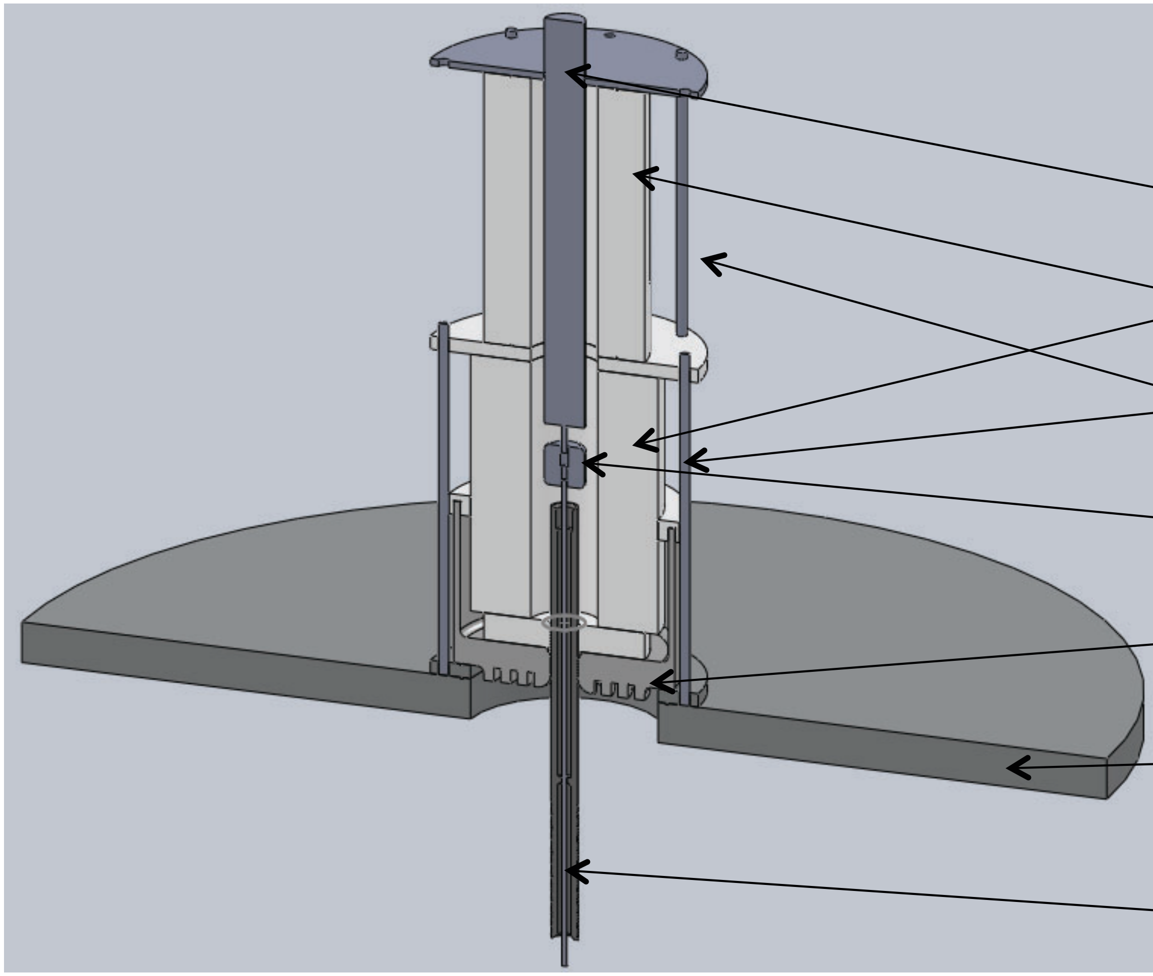
New System: a metal-free feed-through



Quartz chosen for its high purity, tolerance of high temperatures (min 1000C), and high mechanical strength (1000psi tensile strength)

Preparations for 300 kV Operation

Replacement of high-voltage electrical vacuum feed-through



New System

HV cable (coaxial)

PVC elements

Threaded rod

Conductor coupling

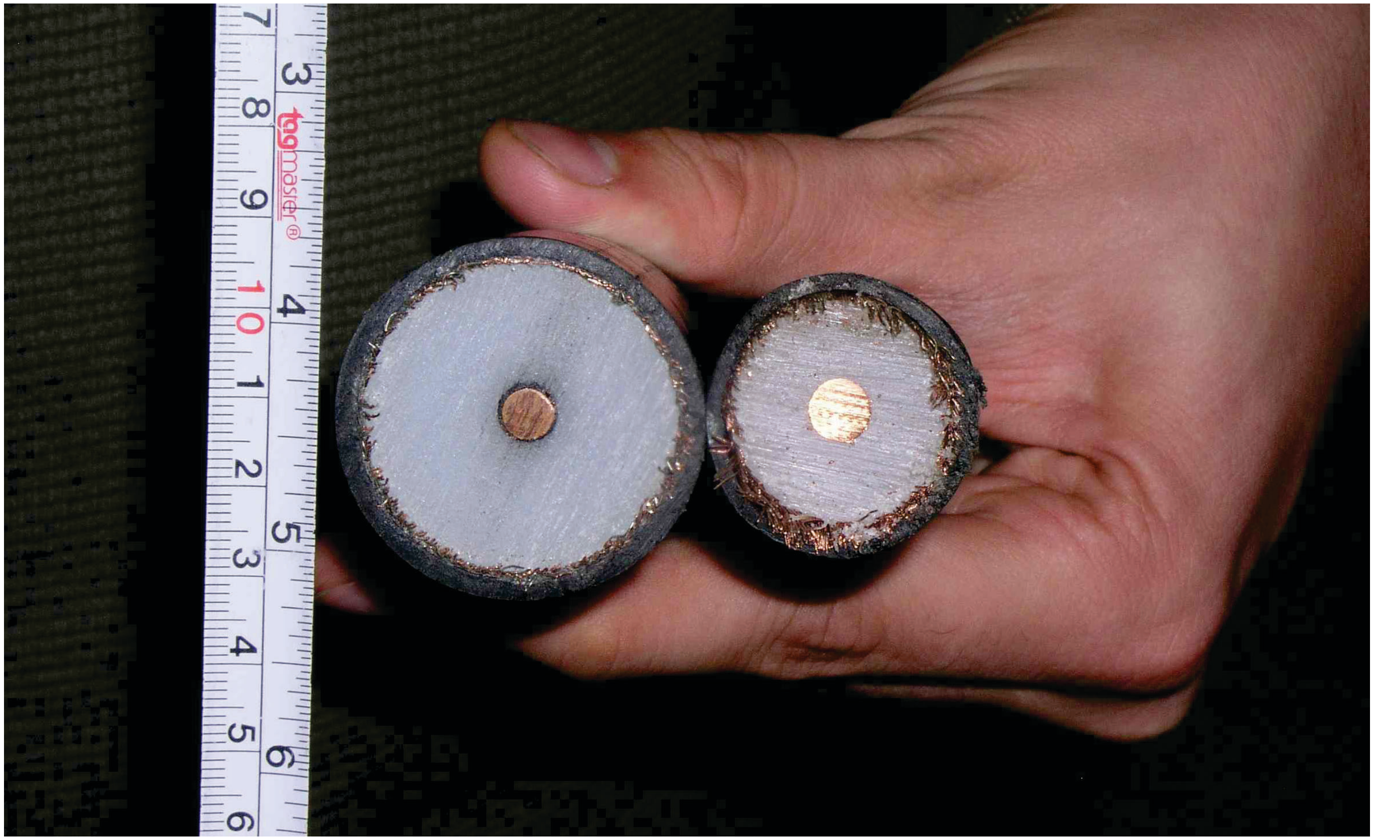
Quartz vessel

Vacuum chamber top cover

Boron nitride stalk and molybdenum rod

Preparations for 300 kV Operation

Device Switching



(New) 300 kVDC cable, left, and (current) 200 ,VDC cable, right

Preparations for 300 kV Operation

Device Switching

•The current practice is to switch the HV power supply between devices by physically detaching and re-attaching a cable from a junction in an oil-filled barrel.

•The larger and much-less flexible cable which will be used at the higher voltages cannot be used in this way for an extended period.

•Space constraints have also made it much more difficult to switch in the resistor-capacitor network needed to operate the devices in pulse mode.

•The group decided to design and construct a high-voltage switch, to allow the HV PS to be switched (while "off") between the various experiments without moving cables, and to incorporate the pulse mode network into the design.

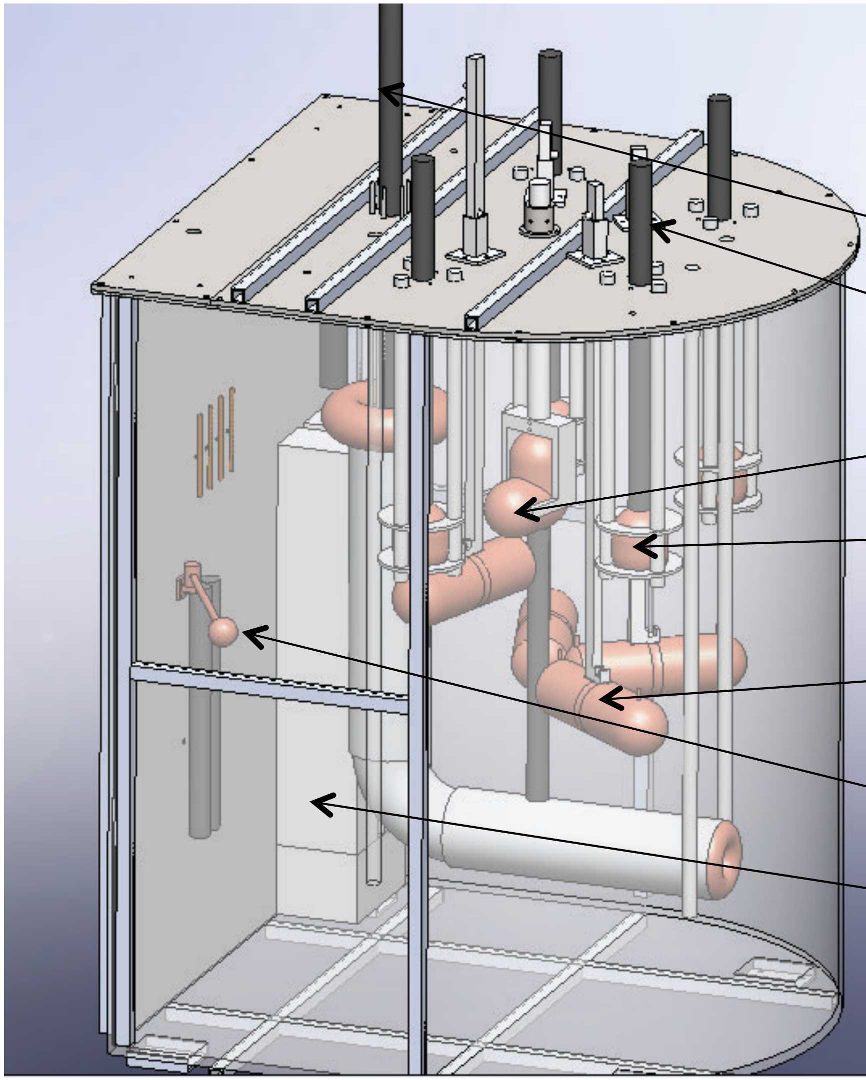
Preparations for 300 kV Operation

Device Switching: Proposed HV Switch

Switch specifications:

- Switching at 0 volts (not “live” switching)
- Able to handle 300 kV DC
- Device terminals not in use must be “safed” (grounded)
- Pulse capacitor and resistors to be internal to the enclosure

Preparations for 300 kV Operation



Device Switching

Proposed High-Voltage Switch

Power input cable

Device power cable (1 of 4)

Rotating device selector (“hot”)

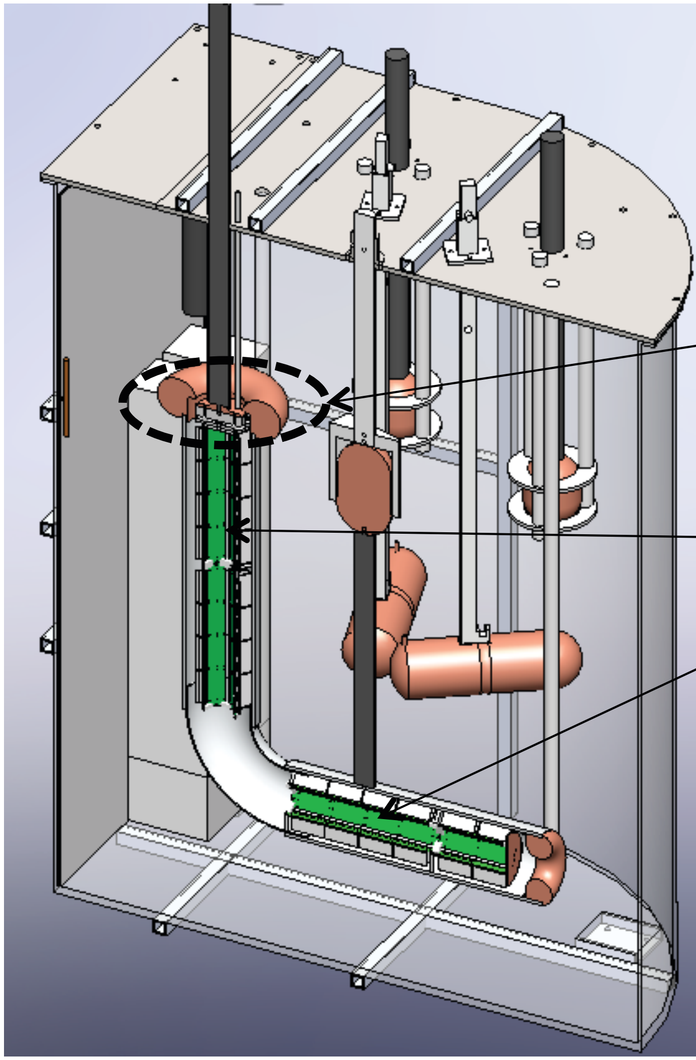
Device terminal (1 of 4)

Raise-able / lower-able
contact bridge (1of 4)

Pulse-enabling switch

Pulse-enabling capacitor

Preparations for 300 kV Operation



Device Switching

Proposed High-Voltage Switch

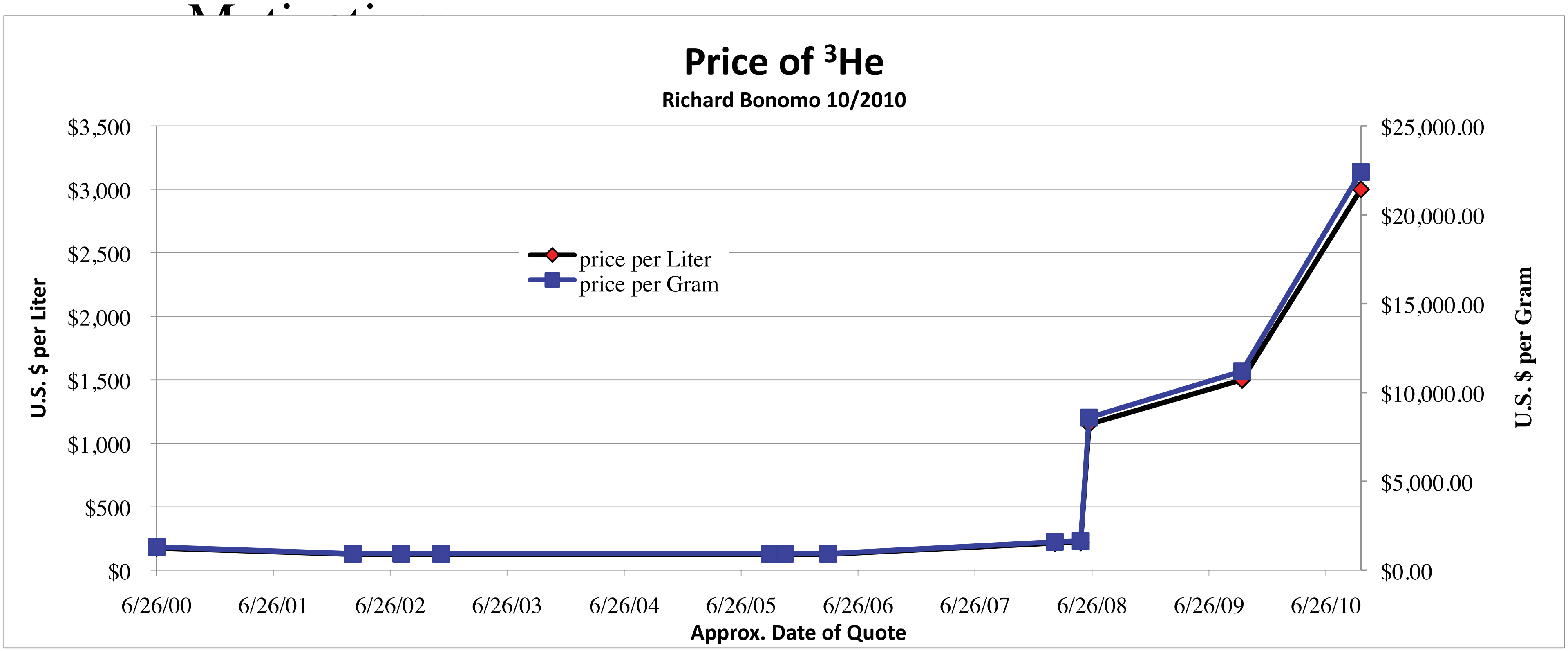
Resistance selector
(0 to 250 kΩ in 50 kΩ increments)

Resistor strings
(5 strings of 250 kΩ each)

Current Status:
- Design studies, including field analysis using Maxwell 3-D complete
- Components and material are being acquired

^{3}He Trapping and Recovery

- Intentions to deploy a trapping system have been advanced.
- Helium-effective turbo-molecular pump, sealed backing pump, and storage cylinder have been obtained.



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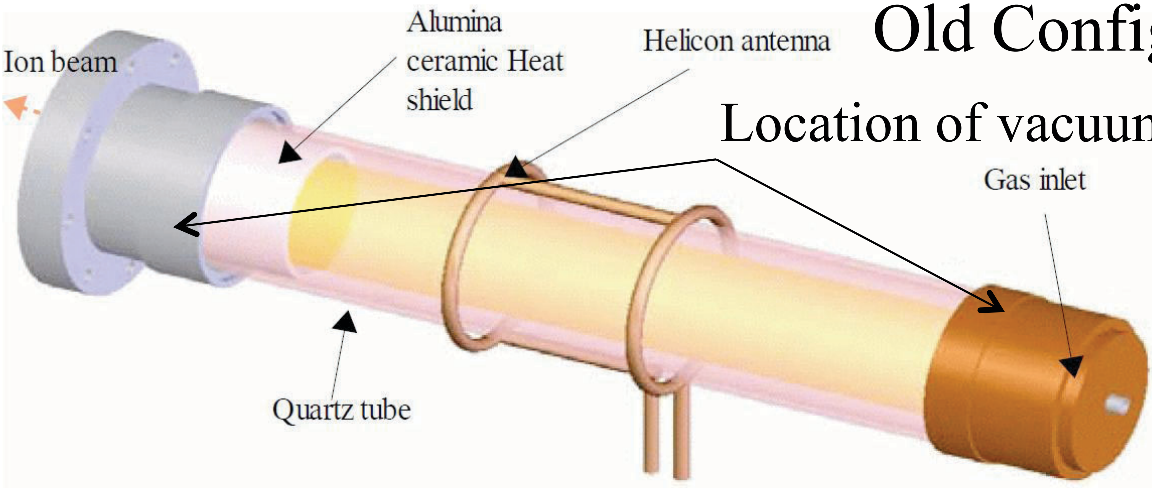
HELIOS Helicon Ion Source

Improved ion source with glass-to metal seal in under construction

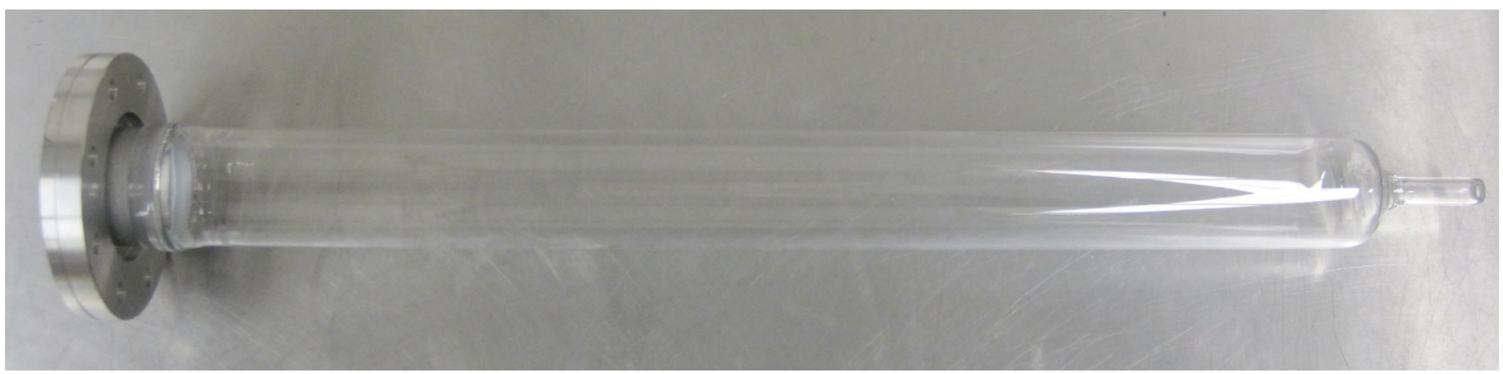


Old Configuration

Location of vacuum O-rings (tend to fail due to heating)

New Configuration

(no O-rings)



Additional Infrastructure Improvements

- Additional steps have been made toward establishing a single ground point for the laboratory, with more steps coming
- Ad-hoc facilities to electroform copper parts for the high-voltage switch are being established

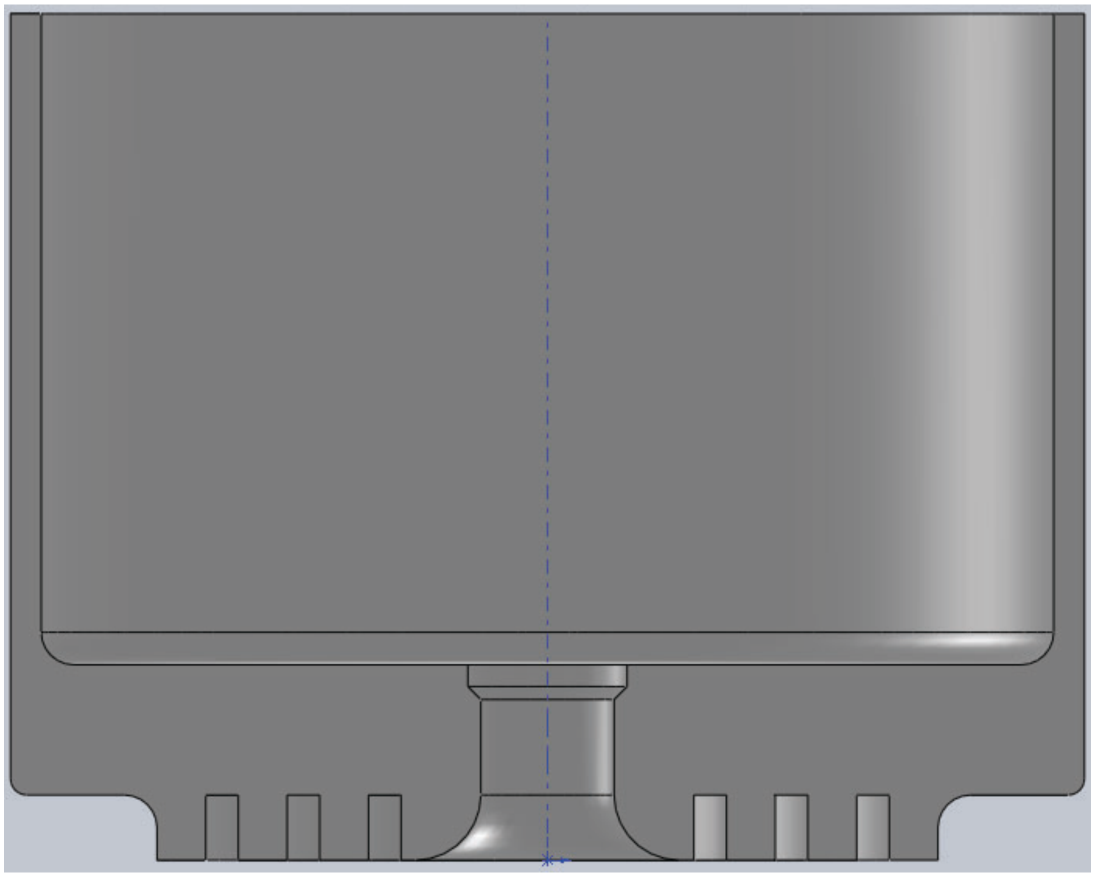
Concluding Remarks

- The laboratory should be able to expand the operating regime (cathode voltage to 300 kV) within the next year

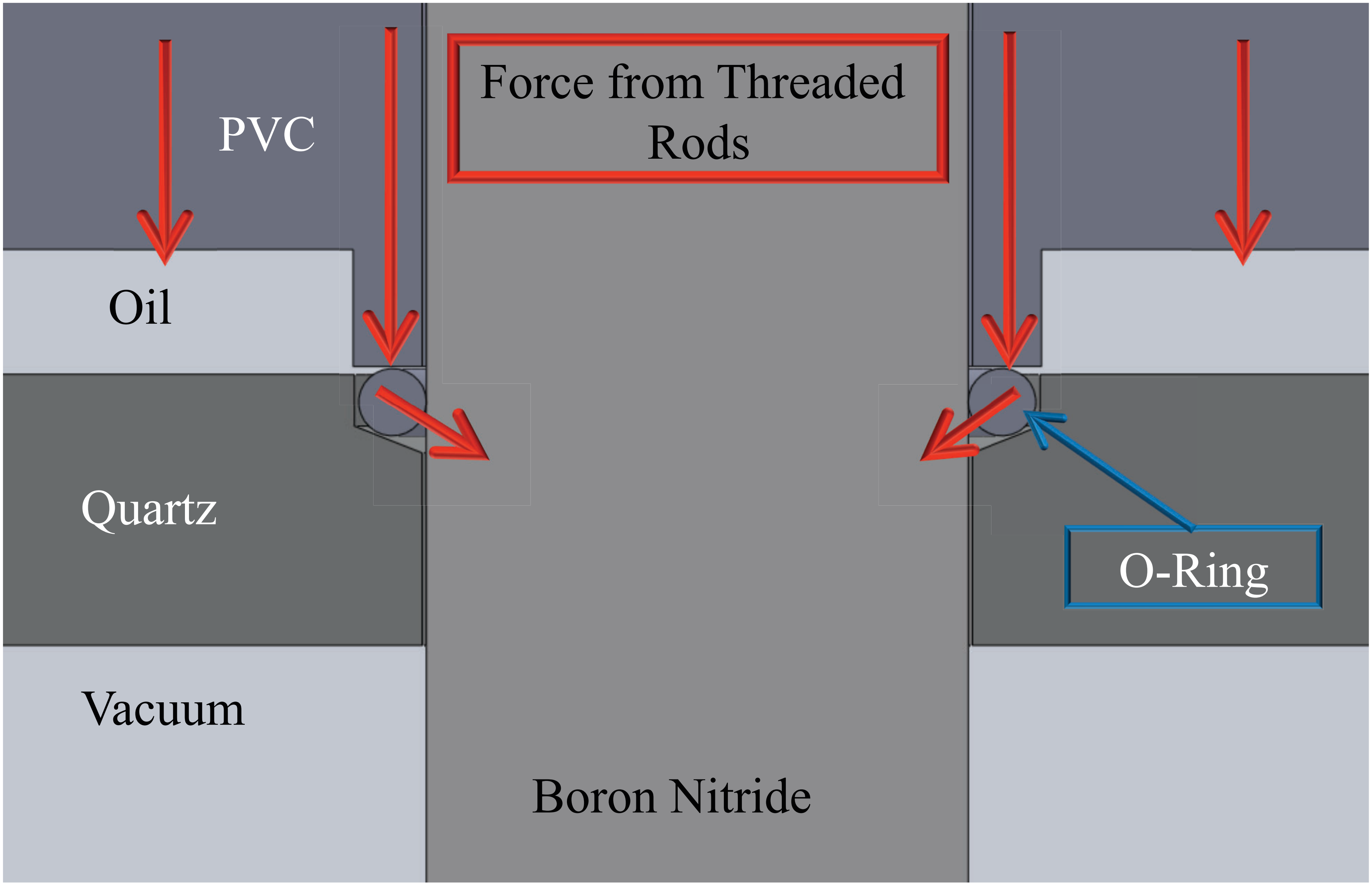
- The improved switching system should permit the continued rapid switching between devices and experiments, and greatly reduce the time and effort required to set up pulsed experiments

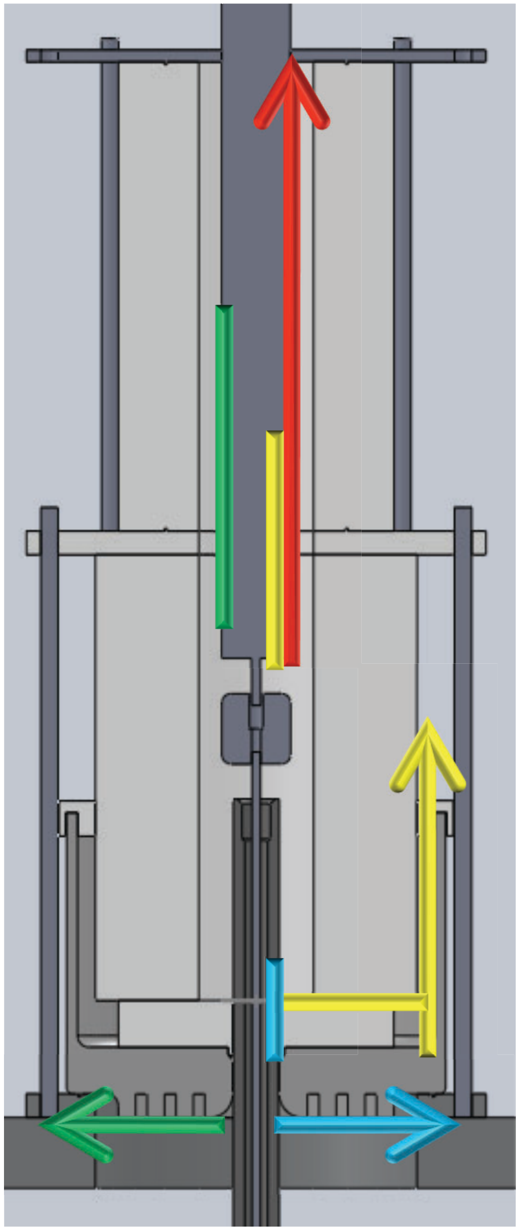
Questions?

Quartz Vessel



- Quartz chosen for its high purity, high heat capacity (min 1000C), and high mechanical strength (1000psi Tensile Strength)
- Base is 1” thick
- Ridges on bottom are 0.5” high, provide additional 3” of path length
- All edges are rounded to minimize sharp points
- Height of cylinder above base is 5”


Force from Threaded Rods
PVC
Oil
Quartz
Vacuum
Boron Nitride
O-Ring



- Primary Breakdown concerns
  - Through materials
  - Along surface
- Minimum 4” radial distance between HV and Ground
  - Minimum 2” PVC, 1”Oil
- At least 4 relevant surface paths
  - Minimum recommended path length for 300kV is 15”, conservatively
  - Minimum achievable in current design is 12.5”
- Two tier design to maximize path length up the HV cable