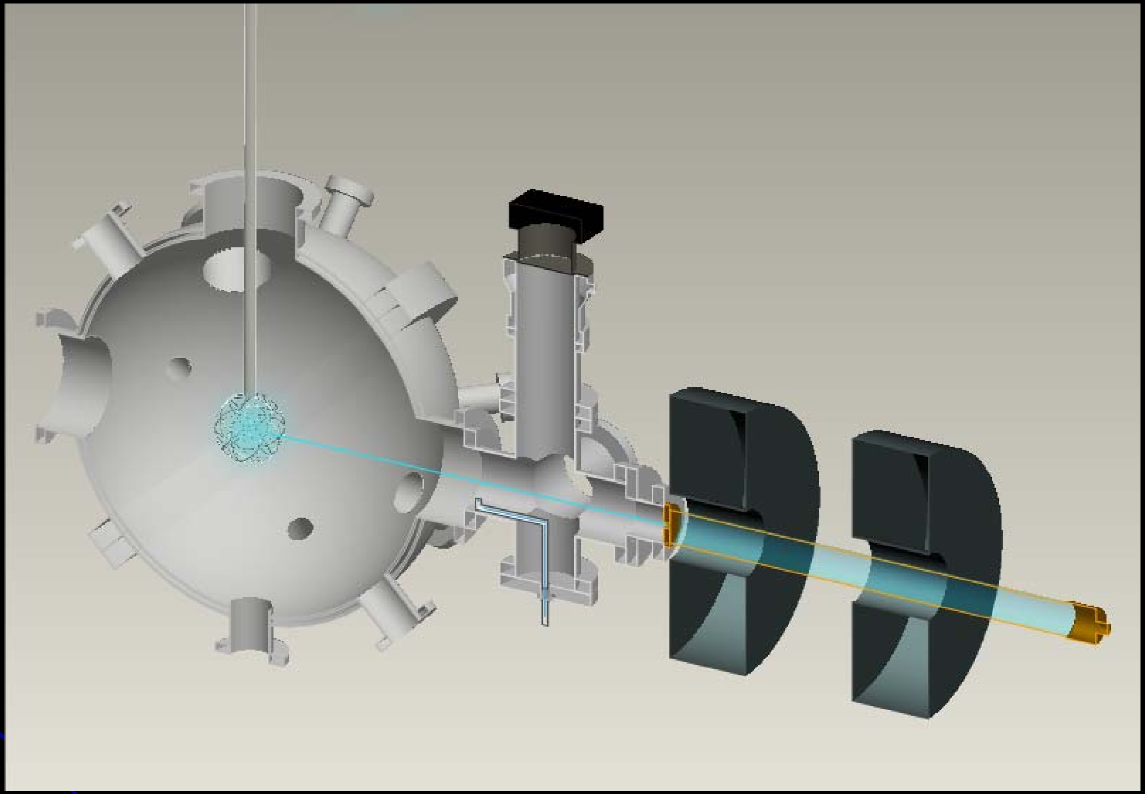
Progress in the Development of a ^{3}He Ion Source for IEC Fusion



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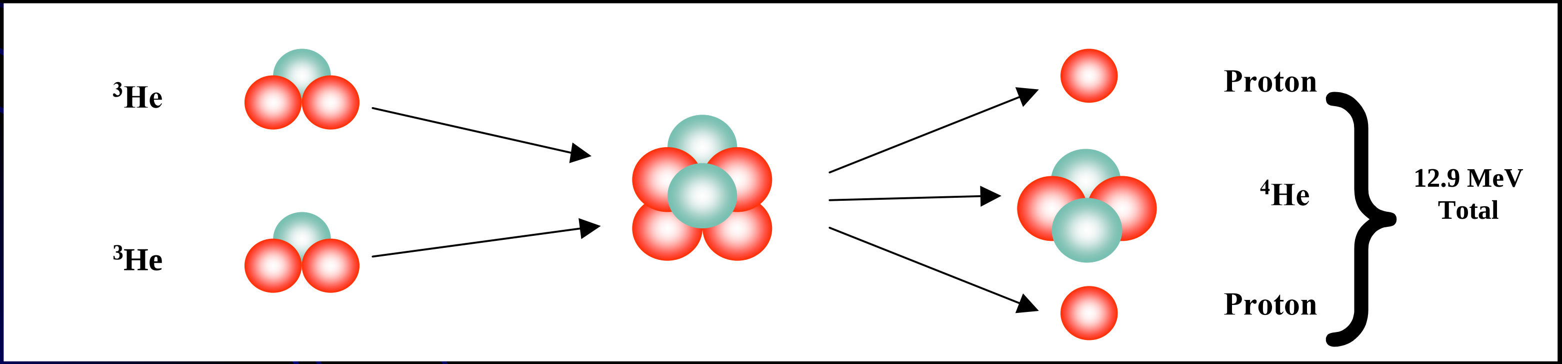
US-Japan Workshop on IEC Devices
March 14-16, 2005 Los Alamos National Lab
Los Alamos, New Mexico

Outline

- ^3He-^3He Fusion
  - Rationale for experiments
  - Reaction physics
  - IEC beam-background reaction rate estimate
  - Detectability
- Ion source development
  - Status as of the last meeting
  - Progress since the last meeting
  - Summary

Purpose of ^{3}He-^{3}He Fusion in an IEC

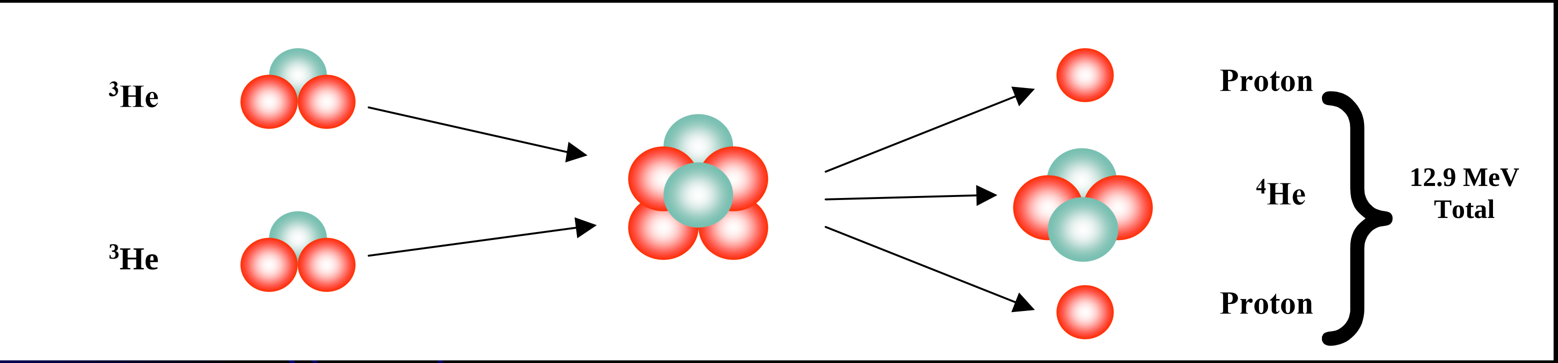
- Benefits of ^{3}He-^{3}He Fusion
  - No Radioactive fuels or products
  - Possibility of direct energy conversion
  - Minimal or no activation of reactor vessel



The ^{3}He-^{3}He fusion reaction

Purpose of ^{3}He-^{3}He Fusion in an IEC

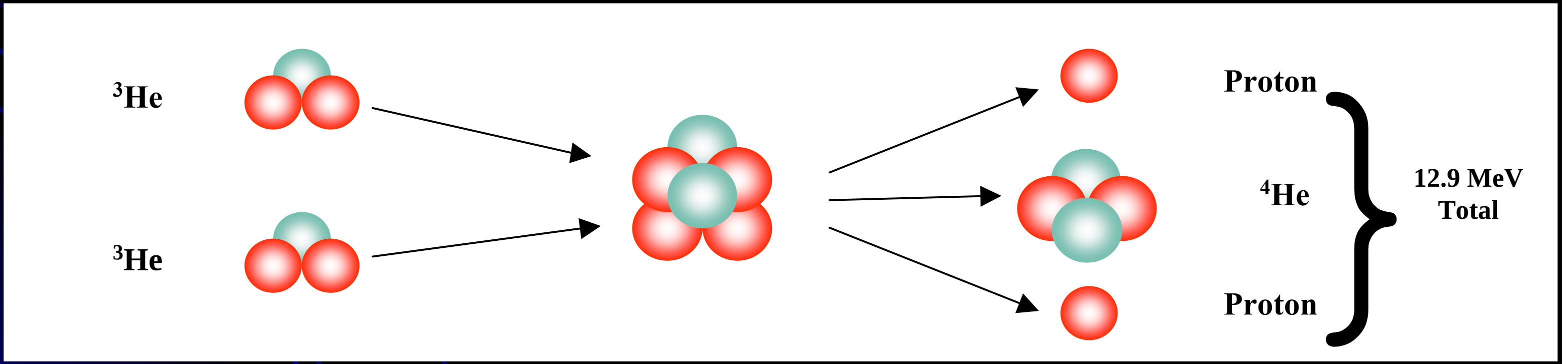
- IEC offers some advantages over other research experiments
  - Higher energy capability than MFE or ICF devices
  - Higher current capability than accelerators
  - *Allows for study of cross sections where counting statistics are currently poor*



The ^{3}He-^{3}He fusion reaction

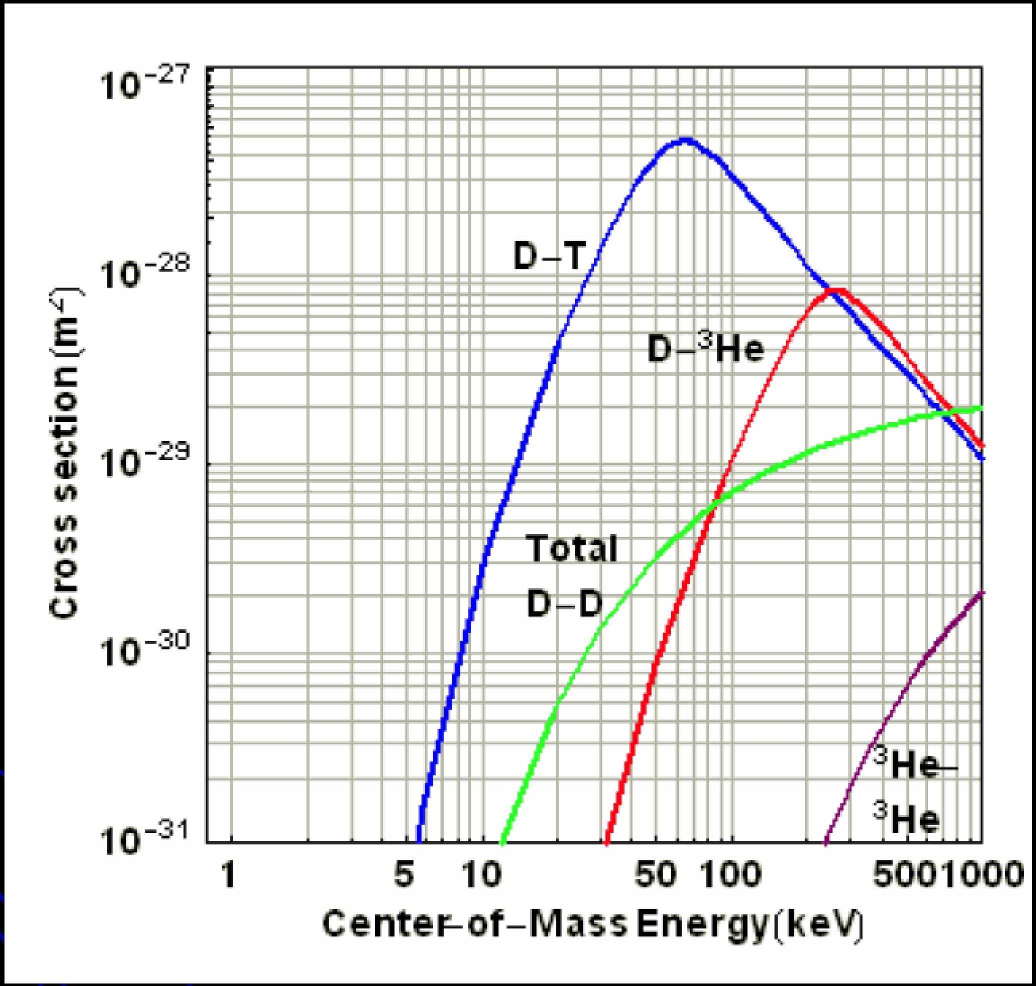
Purpose of ^{3}He-^{3}He Fusion in an IEC

- ^{3}He-^{3}He fusion has some significant disadvantages
  - Very small cross section at low voltages
  - Relatively difficult to obtain fuel in large quantities

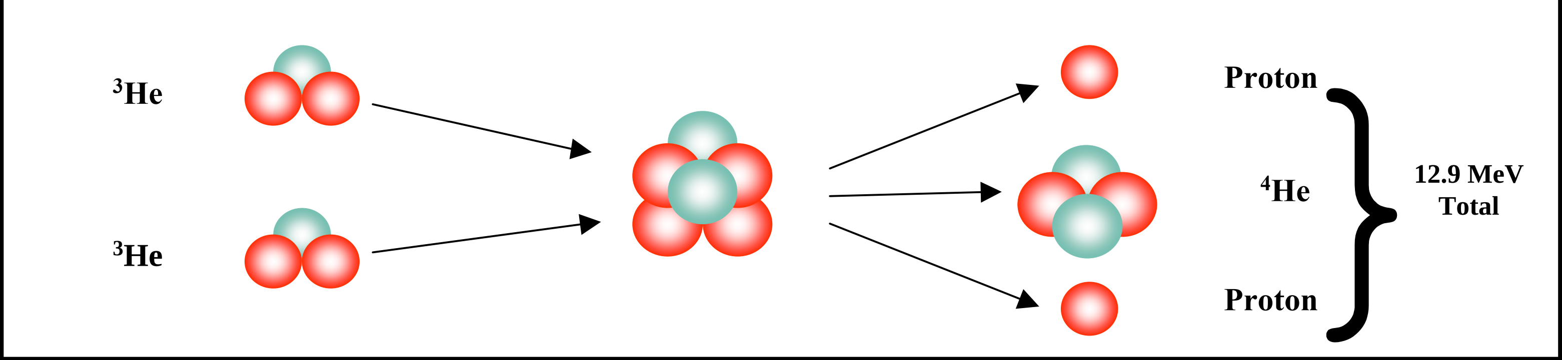


The ^{3}He-^{3}He fusion reaction

^3He-^3He Fusion Cross Section is Substantially Lower than D-D

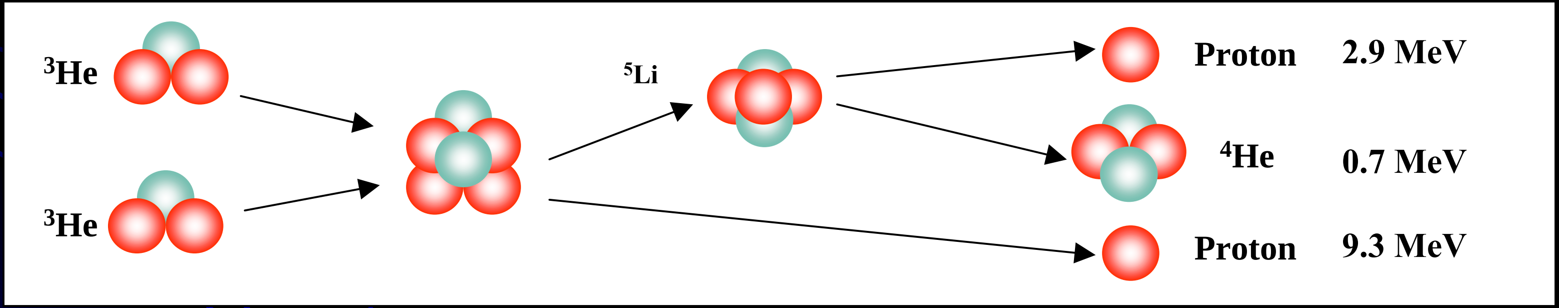


^{3}He-^{3}He Reaction has Two Possible Reaction Sequences



The 3-body ^{3}He-^{3}He reaction (~90% of reactions at 190keV CM energy)

- The three body reaction gives a relatively flat continuum of proton energies, which will be difficult to separate from noise



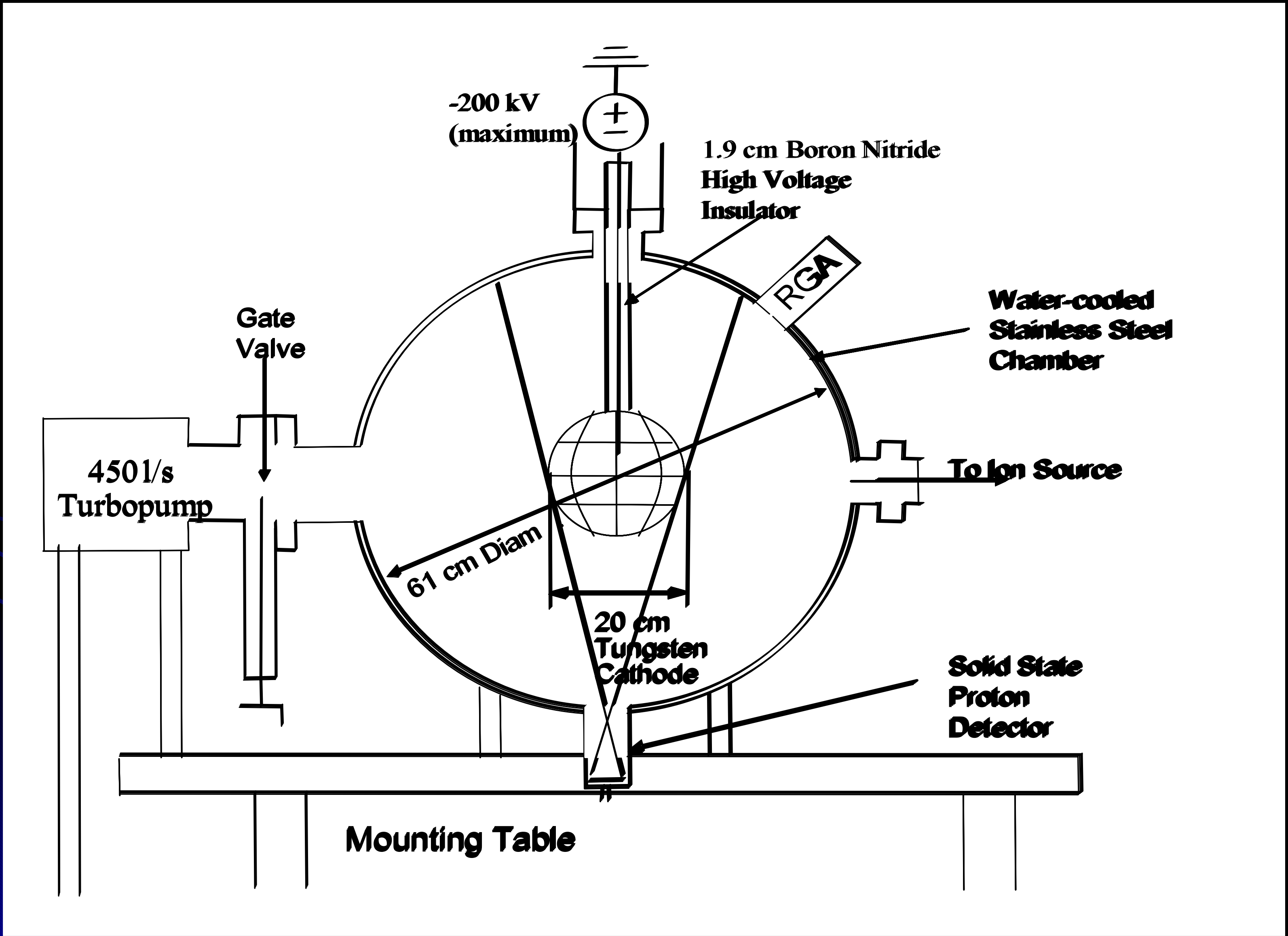
The two 2-body 3He-3He reaction (~10% of reactions at 190keV CM energy)

- The 2-body reaction however, gives discrete proton energies, which will appear as a peak on top of the continuum at 9.3 MeV

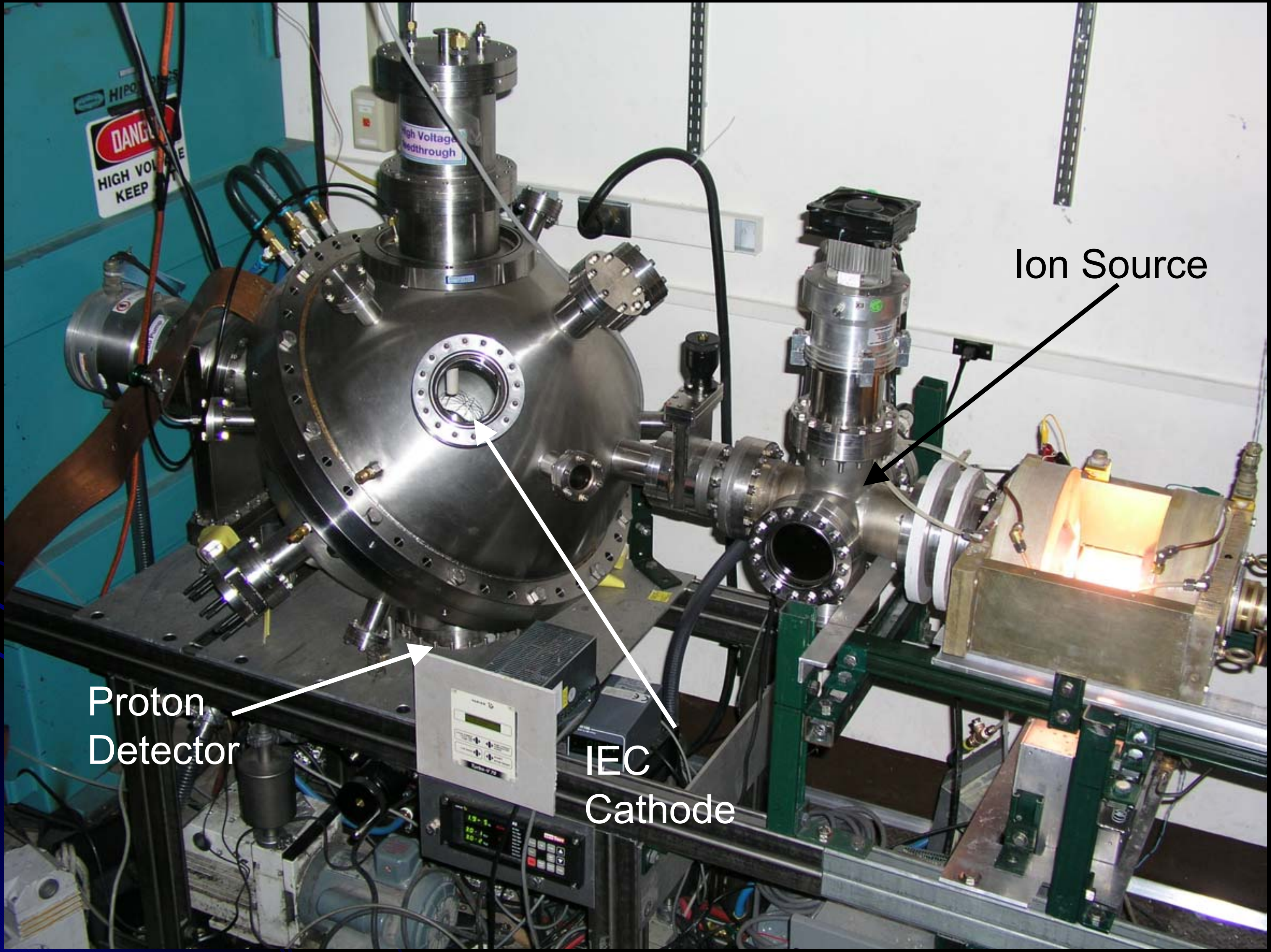
Reactivity in IEC will be Modeled as a Monoenergetic Beam-Background Source

- Beam currents low enough so that converged-core reactions are assumed to be insignificant
- Background gas pressure kept low enough such that ion charge exchange time is long compared to ion lifetime
- Model assumes proton detector observes reactions only inside of the cathode

Setup for ^3He-^3He Experiments



Setup for ^3He-^3He Experiments



Assumptions for Rate Calculation

- Cathode current ~ 10 mA
- Cathode voltage = 200 kV
  - ^{3}He singly ionized -> Center of mass energy = 200 keV
- Cathode Transparency = 99%
- Average secondary emission coefficient = 2
- Background gas pressure = 0.2 mtorr (27 mPa)
- Cathode/anode radius ratio sufficiently small such that full ion current can be drawn

Fusion Rate can be Calculated from Assumed Parameters

- The fusion rate for a beam-background mono-energetic system can be calculated by the following equation:

$$F = n_b * \frac{I_{cath} * 2R_{cath}}{e(1-\gamma)(1+\sigma_{se})} * \sigma(E)$$

n_b is the background gas density, I_{cath} is the measured cathode current, R_{cath} is the cathode radius, $\sigma(E)$ is the fusion cross section, e is electron charge, γ is the grid transparency, and σ_{se} is the average secondary emission coefficient

Fusion Rate can be Calculated from Assumed Parameters

- The fusion rate for a beam-background mono-energetic system can be calculated by the following equation:

$$F = n_b * \frac{I_{cath} * 2R_{cath}}{e(1-\gamma)(1+\sigma_{se})} * \sigma(E)$$

- Using existing data for ^3He-^3He cross sections, this gives a fusion rate of $2*10^5$ fusions/second

Detection Rate Should be Observable

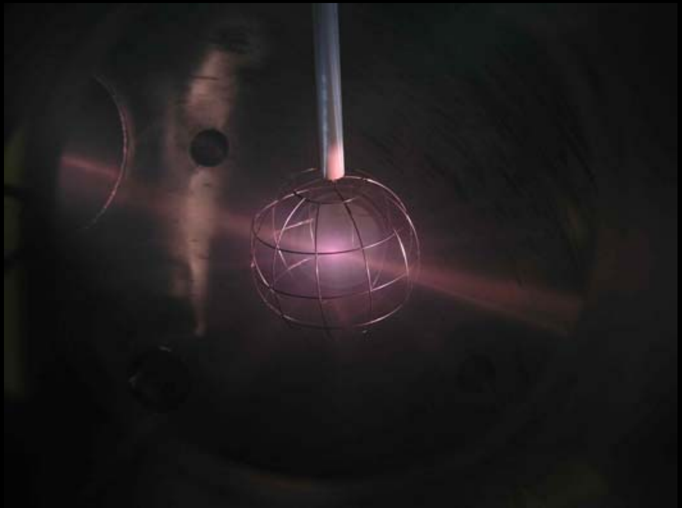
- Detector is ~ 50 cm from center of device
- Detector area = 1200 mm^2
- The number of detected counts can be expressed as:

$$D = \frac{F}{4\pi R_{\mathrm{det}}{}^{2}} A_{\mathrm{det}}$$

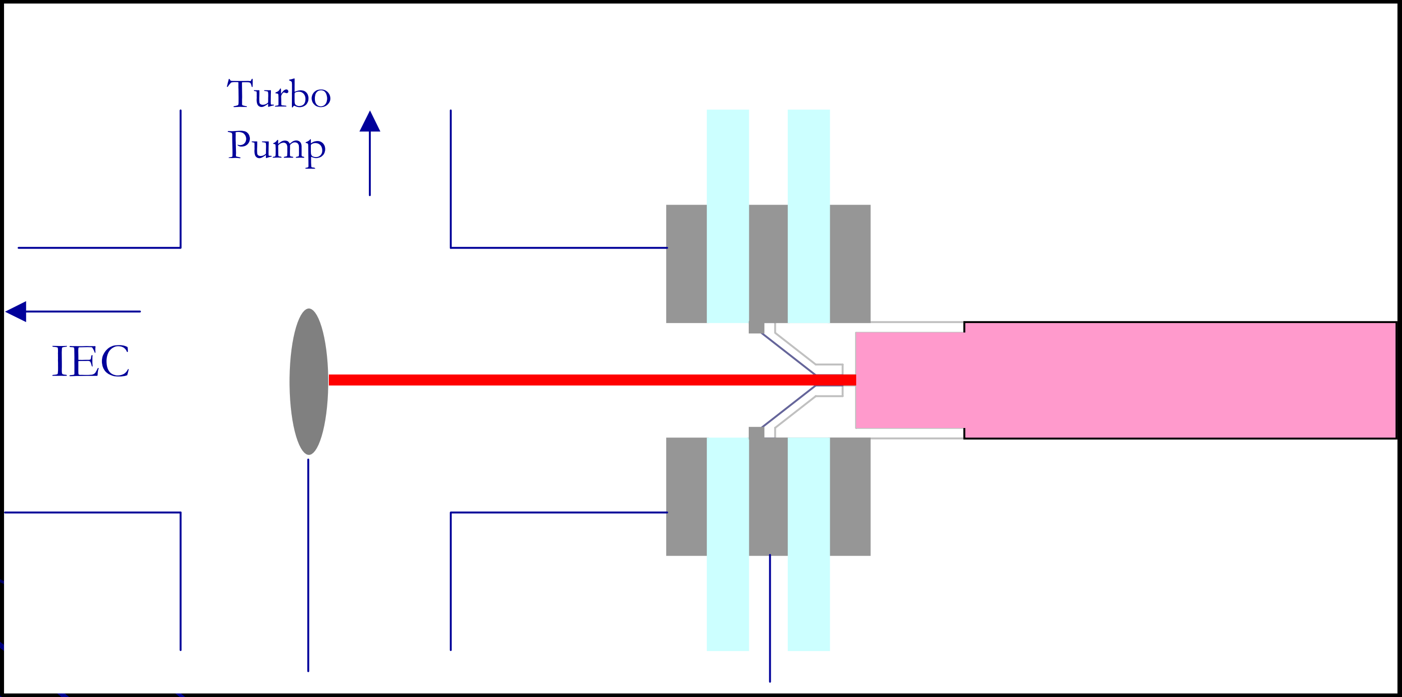
- Detection rate ~ 76 counts/sec
- If 10% of these are 2-body reactions, the 9.3 MeV peak will have 7.6 counts/sec

Ion Source Status as of Last Workshop—October 2003, Tokyo, Japan

- Helicon source on-line with ^{4}He
- 2 mA cathode current observed in main system at modest voltage (~35 kV)
- Extraction system not yet constructed
- Ion current difficult to control
- Helicon fringing fields affected extracted beam

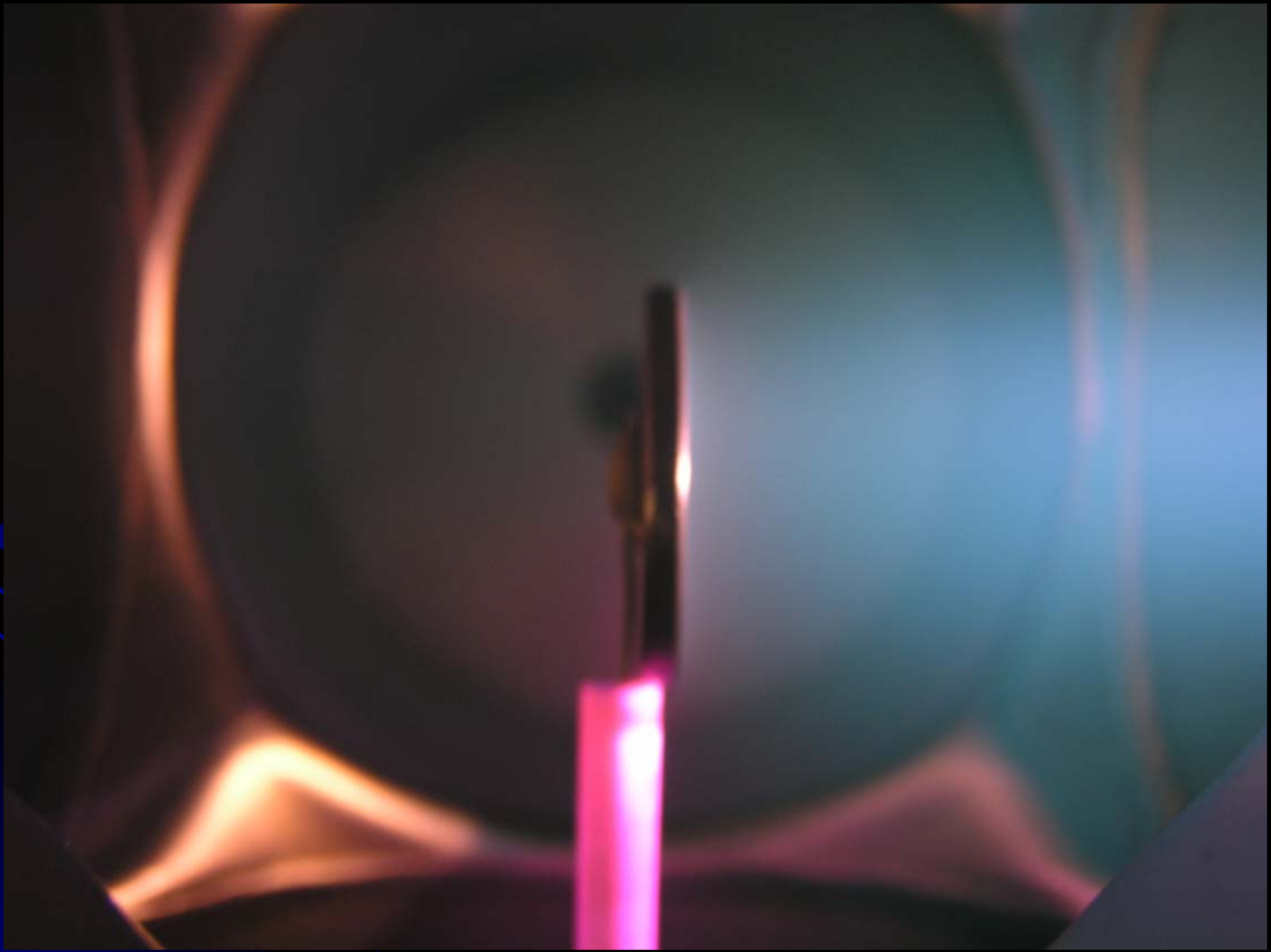


Ion Extraction Region Completed and Operational

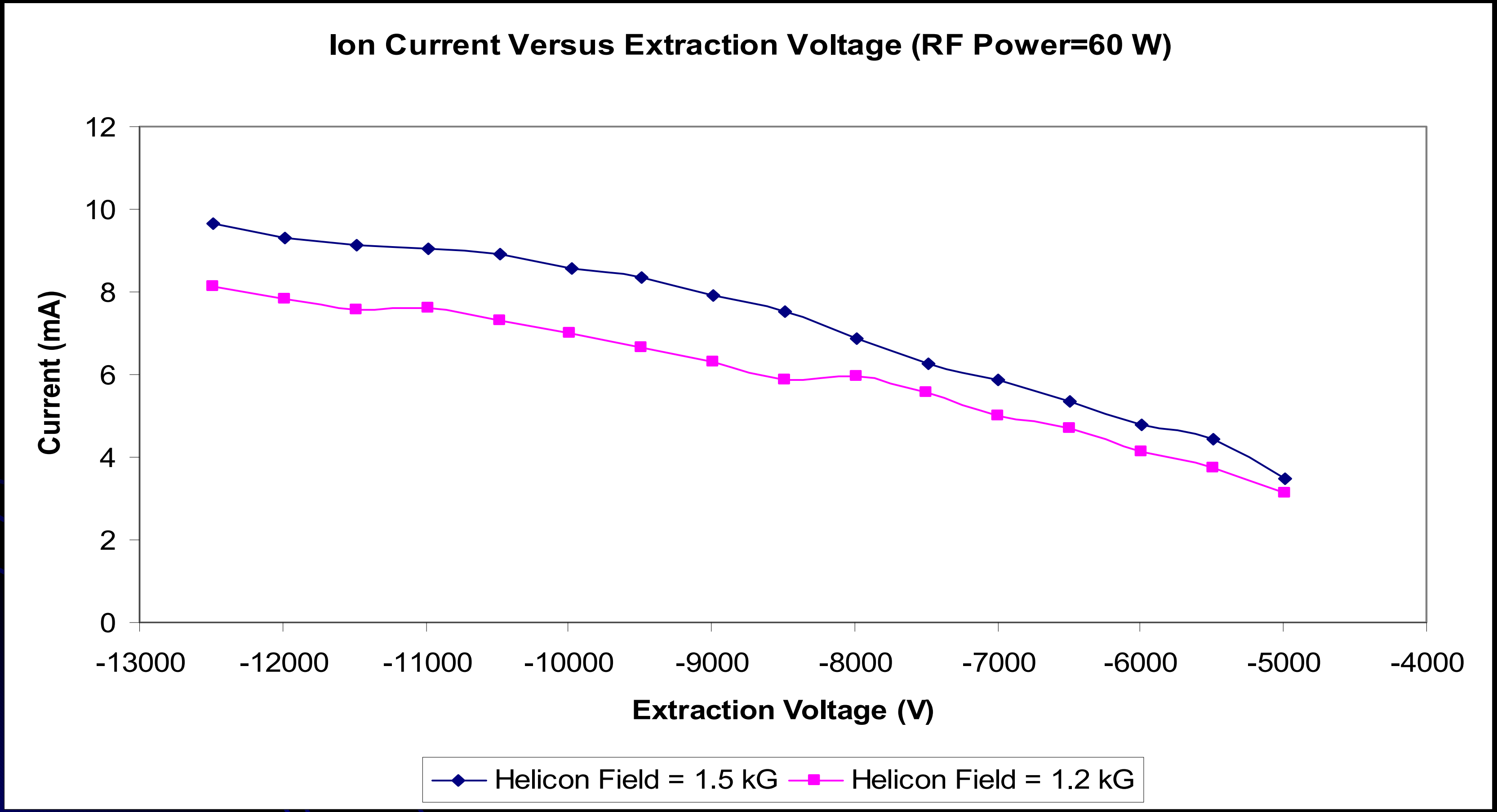


- New electrode designed to minimize erosion
- Beam collection plate diagnostic added

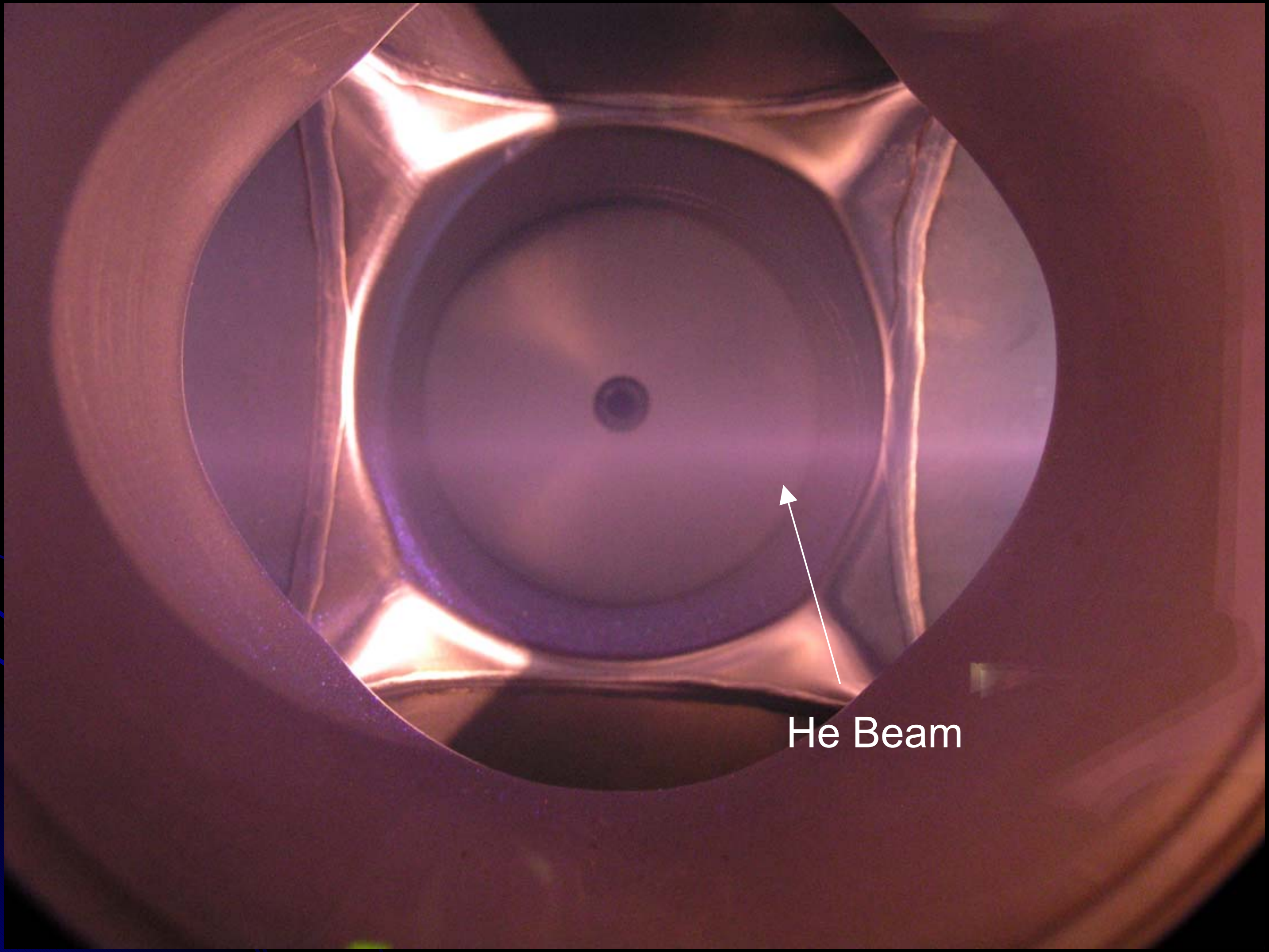
Extraction System Tested in ^{4}He with Collection Plate



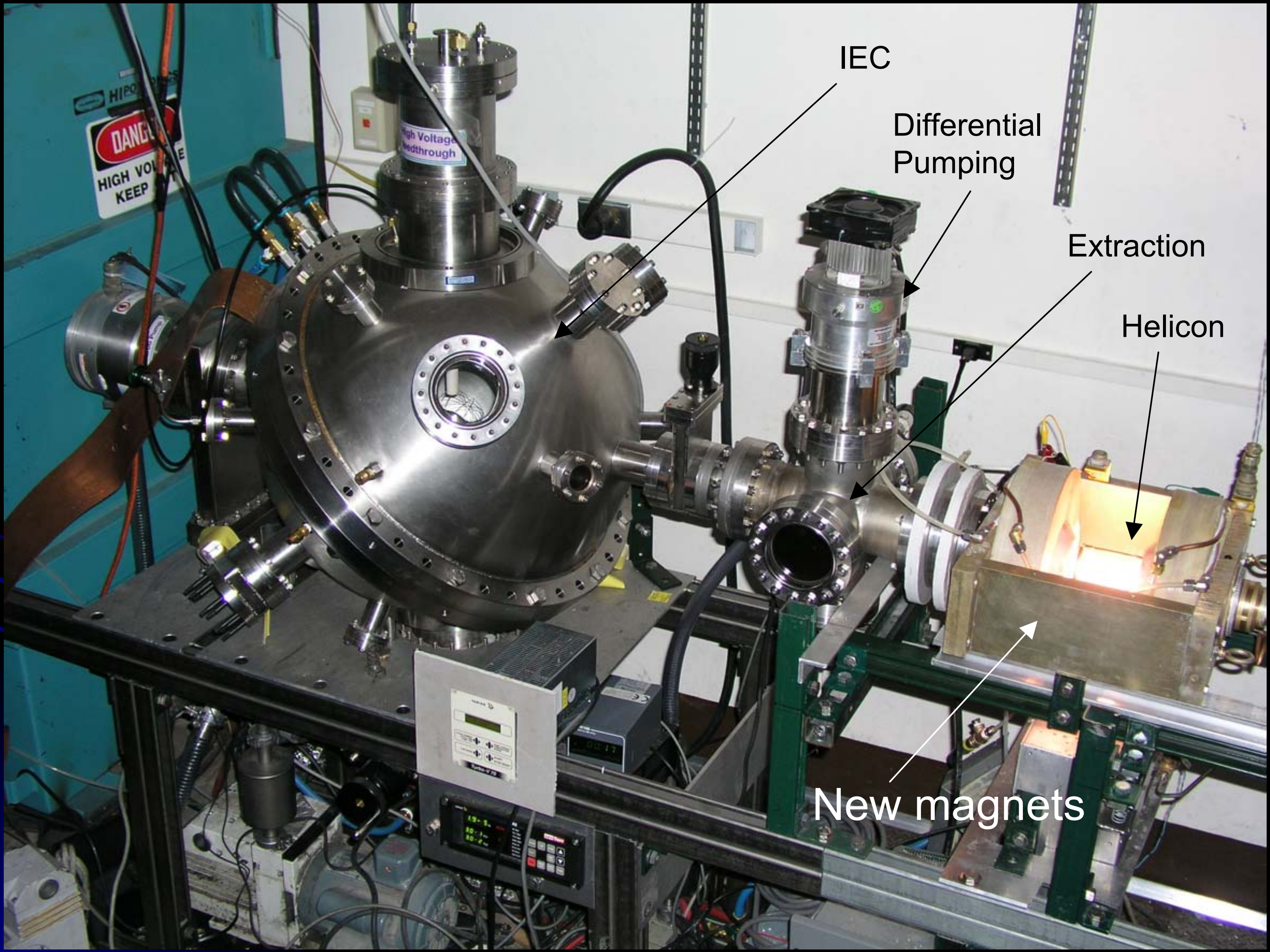
Ion Extraction Current Versus Extraction Voltage Shows Good Current Capability



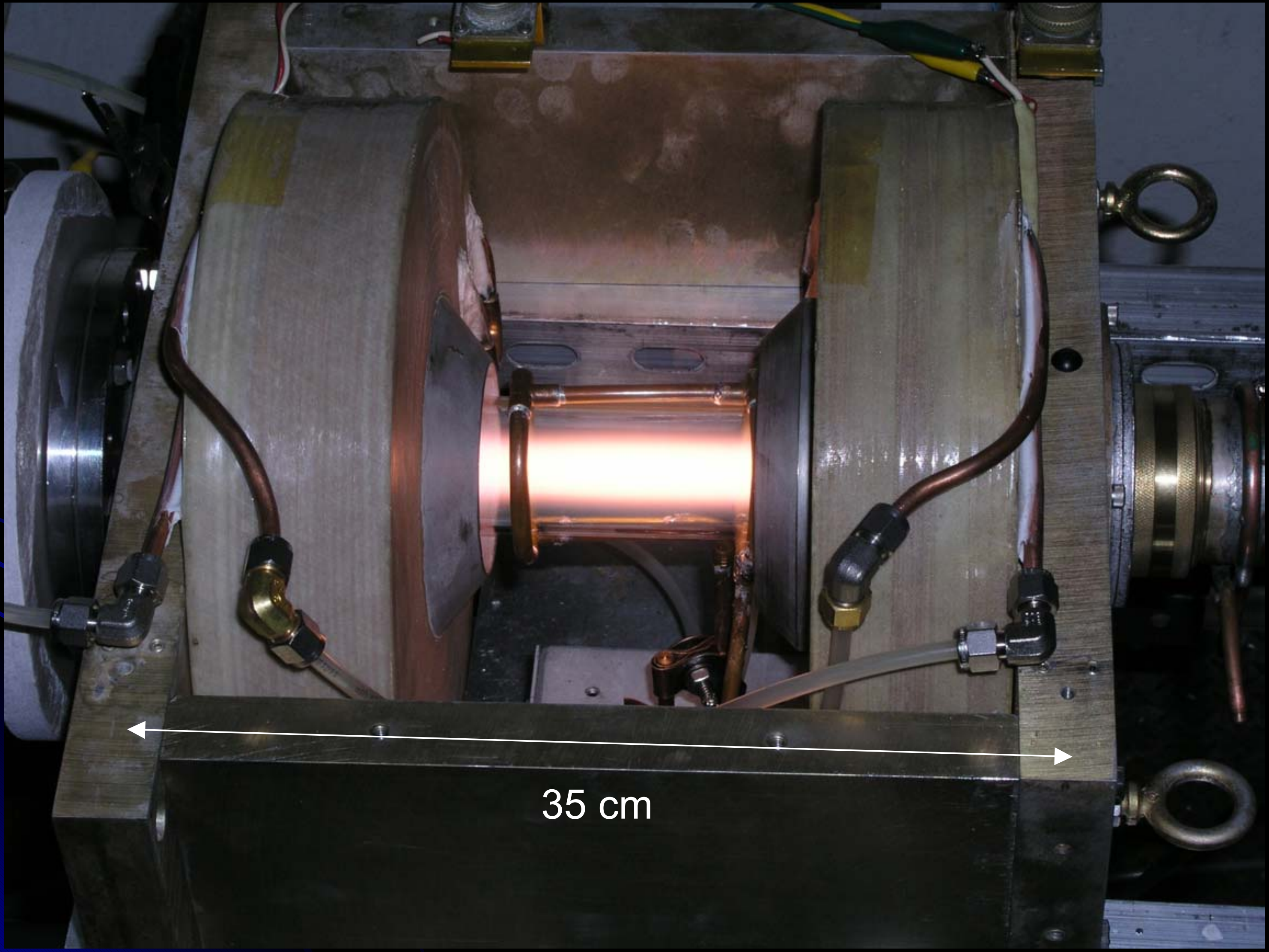
Stray Fields from Helicon Source Appear to Cause Beam Deflection



New Helicon Magnets are Installed and Now Being Tested



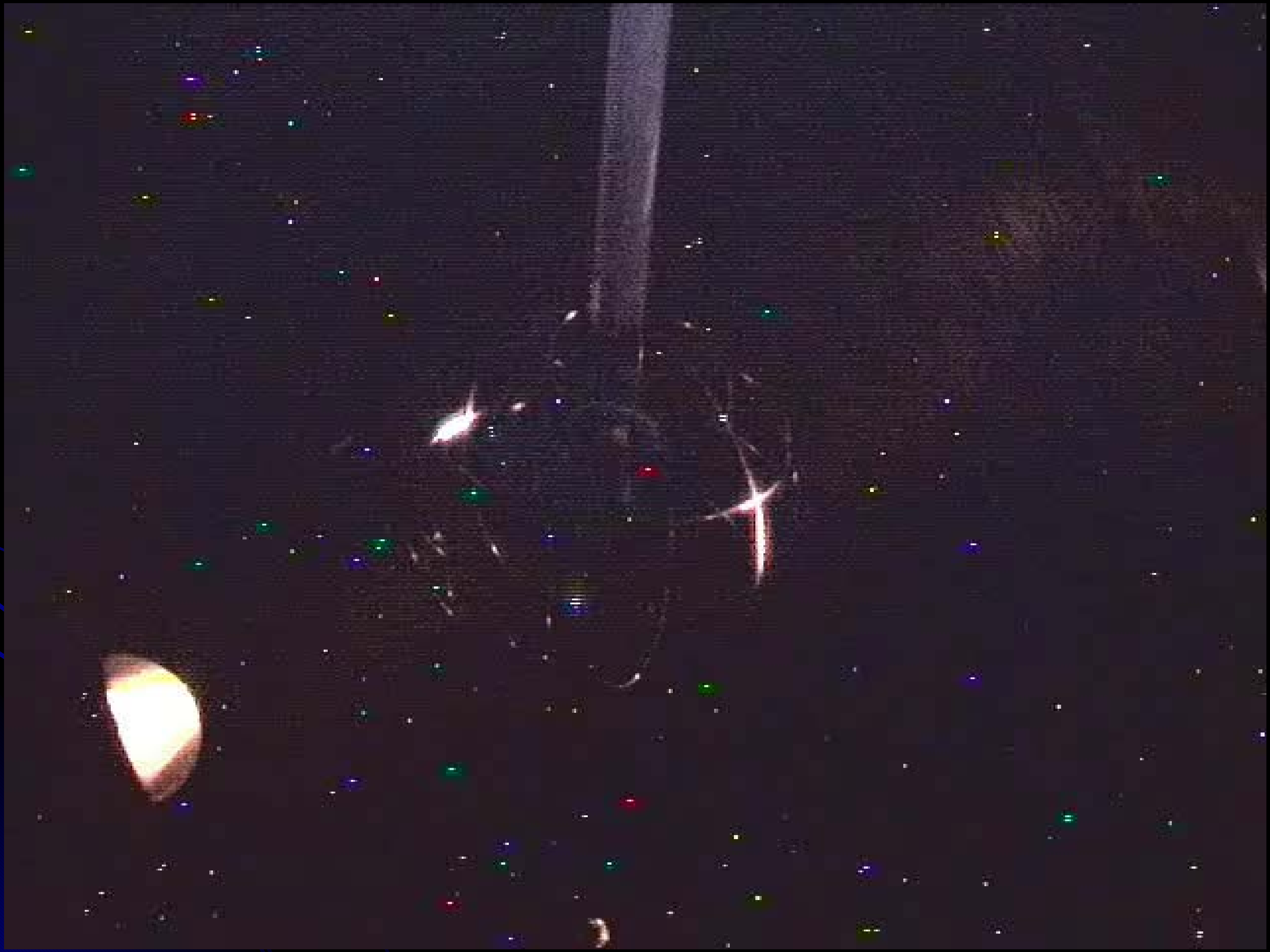
Fringing Fields Shunted Through Magnetic Circuit



IEC Operation with Ion Source is Improving

- Operation at voltages up to 130 kV
- Operation at cathode currents up to 10 mA
- Operation at pressures as low as 50 μtorr, and as high as 0.5 mtorr

Some Instability in High Voltage Discharges



Conclusions

- IEC experiments looking for ^3He-^3He fusion reactions are underway
- Good results so far with ^4He, and some with ^3He
- Ion source and IEC operation with source have improved markedly
  - Extraction region online
  - Helicon fringe fields reduced
  - IEC operating voltage up to 130 kV
- Still some problems to overcome
  - HV breakdown at high cathode voltages
  - He beam deflection

Questions?