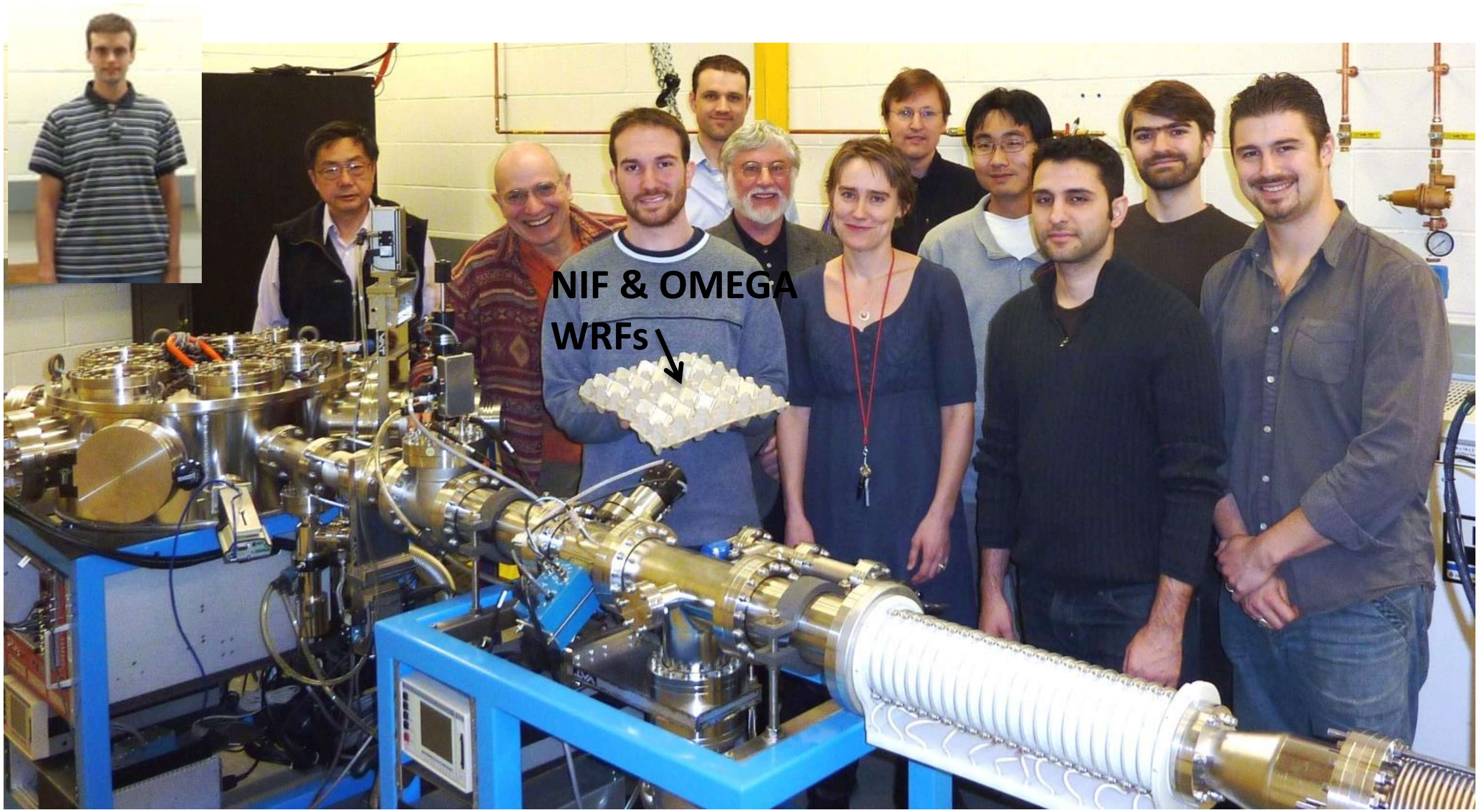
# The MIT HED Accelerator Facility for Diagnostic Development for OMEGA, Z and NIF




**APS DPP**
**New Orleans, LA**
**26-31 October 2014**

# Collaborators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**Plasma Science and Fusion Center, MIT**

**T.C. Sangster**

**Laboratory for Laser Energetics**

**C. L. Ruiz**

**Sandia National Laboratories**

**R. J. Leeper**

**Los Alamos National Laboratories**

*Now at LLNL

**Now at University of Michigan

***Now at Exponent

## Summary

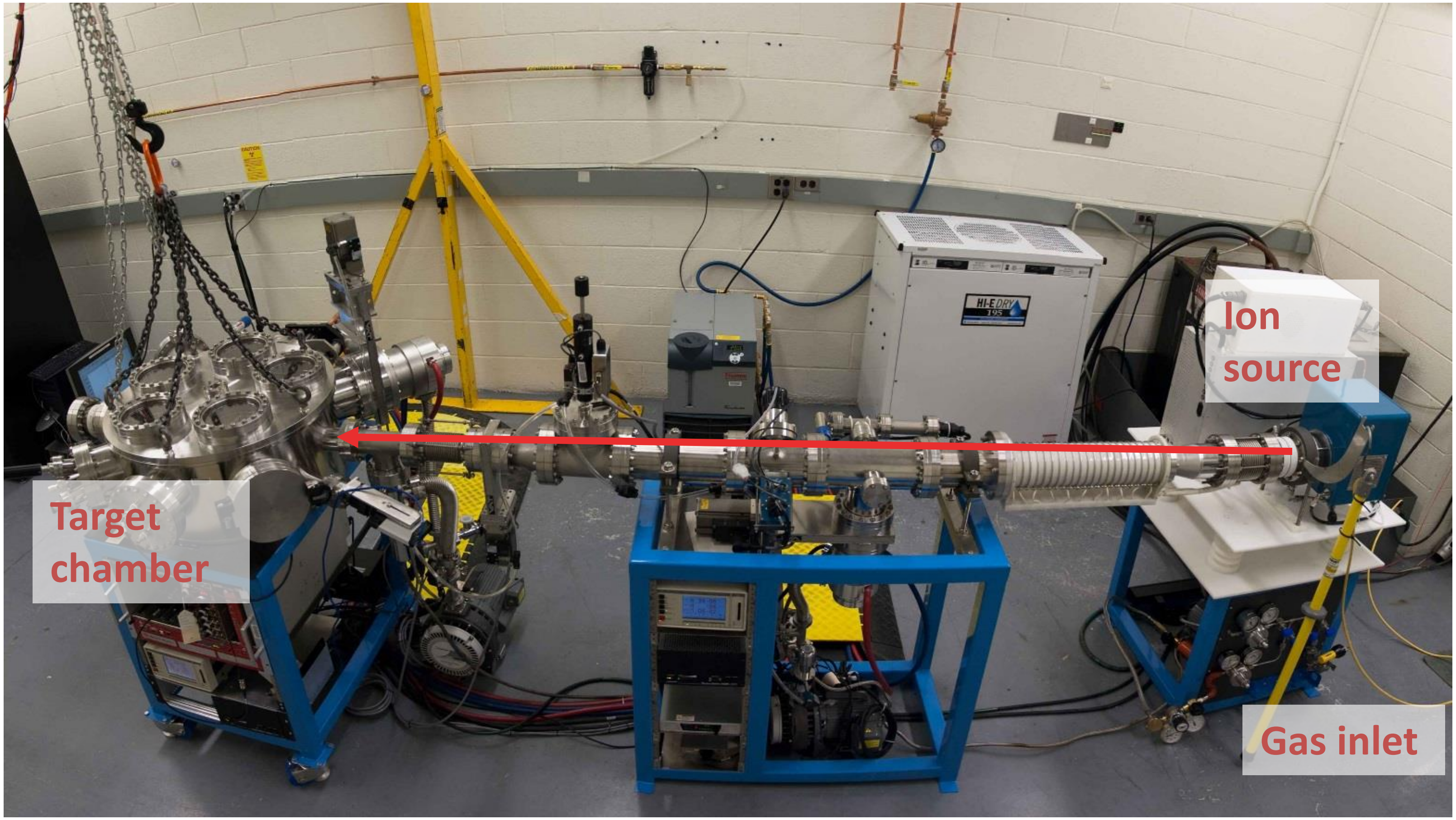
# The MIT Accelerator Facility provides a versatile precision platform for HED Diagnostic Development and student training

- **A linear ion accelerator generates DD, $D^3He$ and DT fusion products relevant for developing and testing NIF and OMEGA nuclear diagnostics**
- **A new x-ray source will replace the existing one and enhance the capabilities for diagnostic development and CR-39 response testing**
- **A pulsed DT neutron source will be implemented in the next year**
- **An etch/scan lab allows for precision on-site CR-39 processing**
- **Work done at the facility includes: WRF and Indium calibration, pTOF and CR-39 testing, development of the MRS Coincidence Counting Technique**

**This highly accurate development platform allows for refined work which has resulted in many student papers based on lab data**

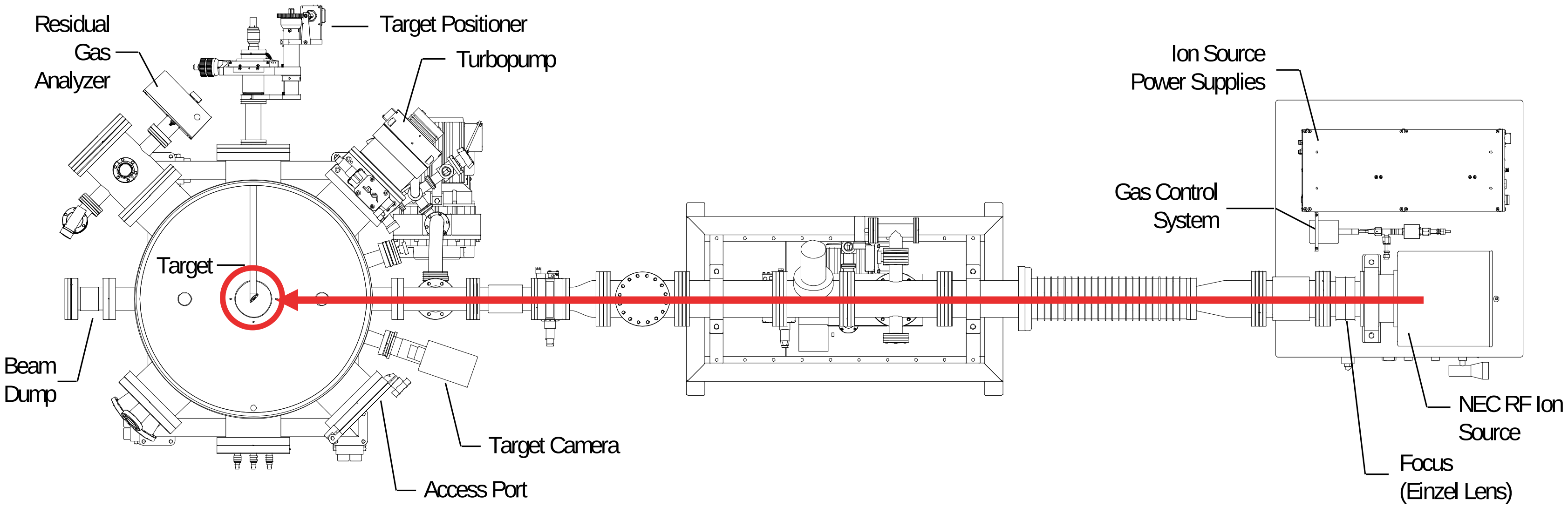
# Capabilities

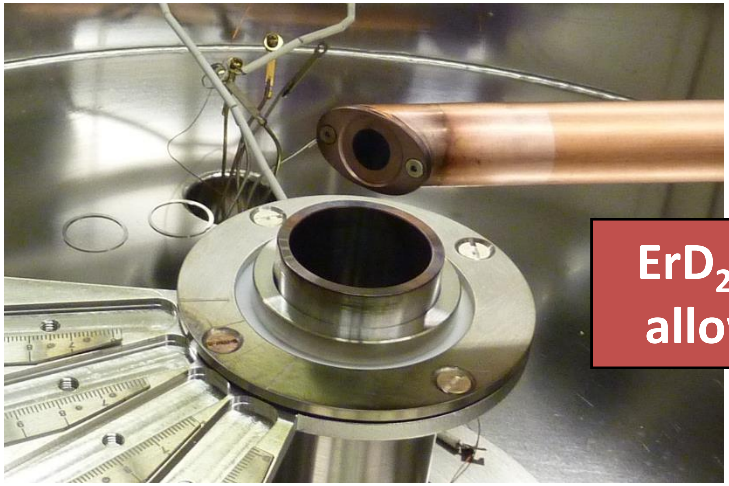
# The 150-keV linear ion accelerator runs with $D^+$ or $^3He^+$ ion beams, generated with a new ion source




**Beam currents around 10 μA are routinely achieved**

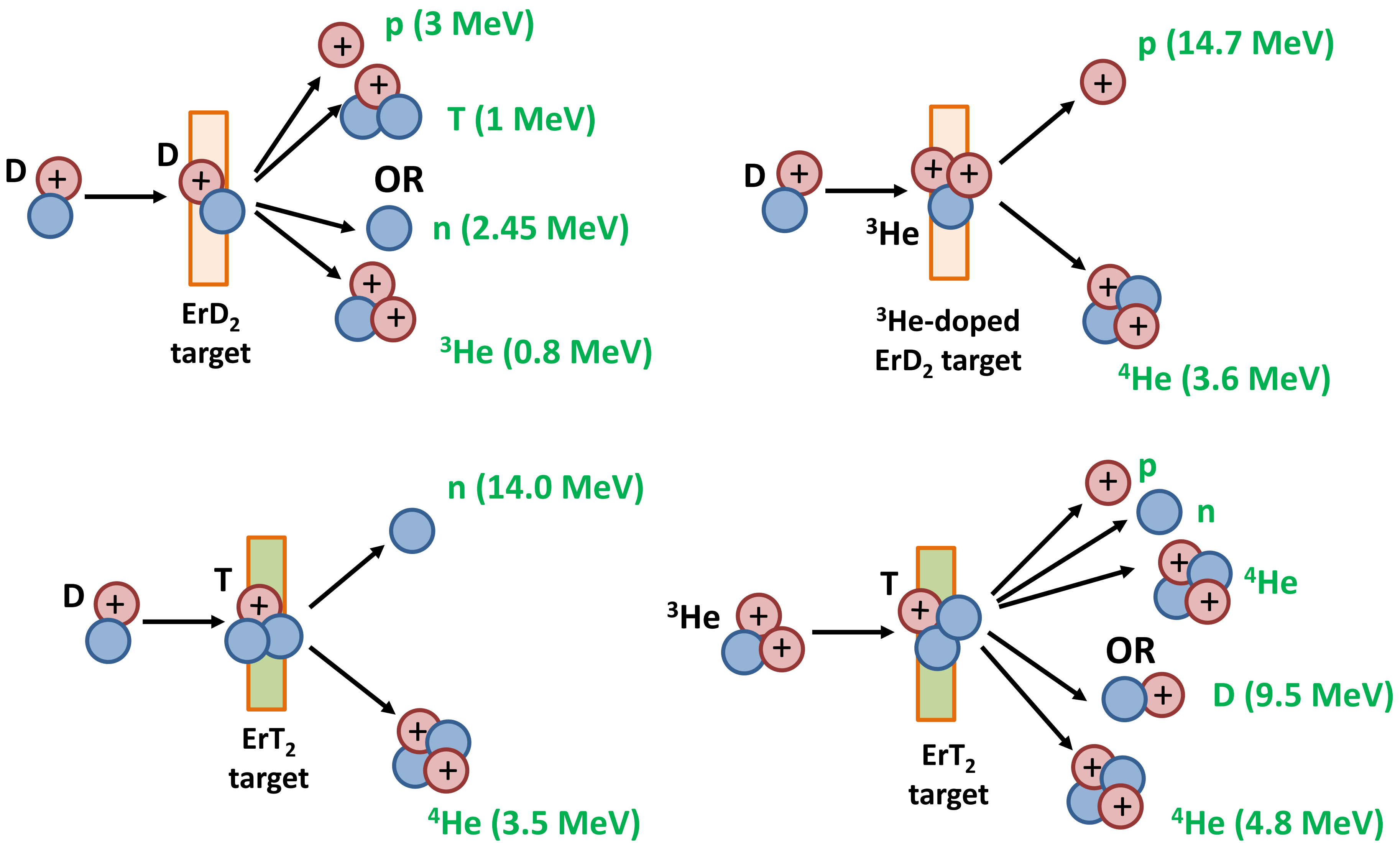
# Beam ions strike $ErD_2$ or $ErT_2$ targets, provided by Sandia



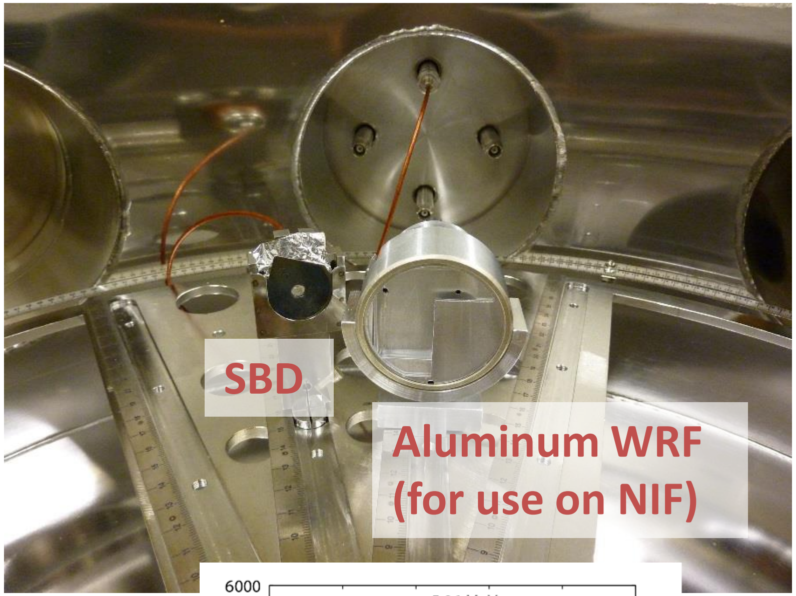



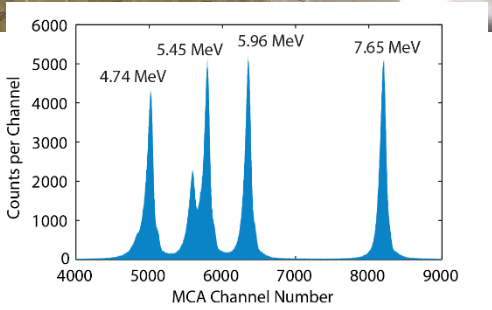
$ErD_2$ targets are frequently doped with $^3He$ to allow for generation of $D^3He$ fusion products

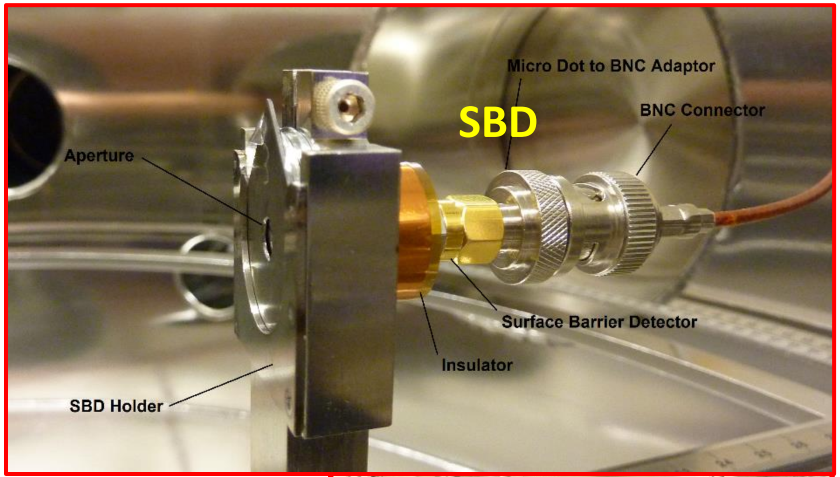
# DD, D$^3$He, DT and T$^3$He fusion products are generated when D$^+$ or $^3$He$^+$ ions strike the target



# SBDs and an MCA provide real-time monitoring of fusion rates, and fusion product energies





$^{226}$Ra alphas are used to calibrate the system to within ± 50 keV. Precise calibration is important for charged-particle diagnostics development

# A new X-ray source will allow extended studies of diagnostic x-ray response and sensitivity

- Peak energy: 35 keV
- Max dose rate: ~ 0.5 Gy/min


- Peak energy: 225 keV
- Max dose rate: > 12 Gy/min

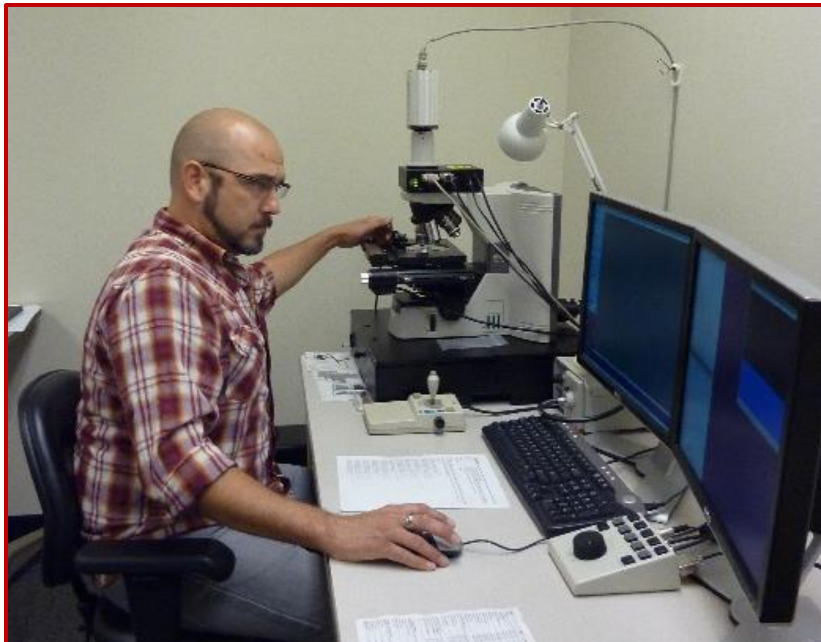
**The new system provides > 10x larger and more uniform irradiation area**

# A pulsed DT source generating $3\times10^8$ neutron/s in ~5 μs pulses is being added to the lab

**Source will be used to:**

- **Characterize CR-39 DT-neutron background**
- **Improve calibration of recently developed neutron Wedge-Range-Filter (nWRF) spectrometers**
- **Test components for the MRS-t neutron spectrometer**

# The CR-39 etch/scan lab has served as model for similar facilities at OMEGA and NIF



Research specialist Ernie Doeg scanning WRF CR-39

# Applications

# The foundation for many diagnostics at OMEGA and NIF is laid at the MIT HED accelerator facility

Recent work includes:

- Calibration (and re-calibration) of WRF spectrometers
- Indium calibration (Sandia)
- Assembly and testing of pTOF CVD diamond detectors
- CR-39 response and sensitivity testing and development of new processing techniques
- Development of the Coincidence Counting Technique (CCT) used in MRS analysis
- Development of a Step-Range-Filter for DD proton spectrum measurements
- Development of a scattering pinhole for proton and alpha yield measurements in high-fluence applications

Ongoing/upcoming work includes:

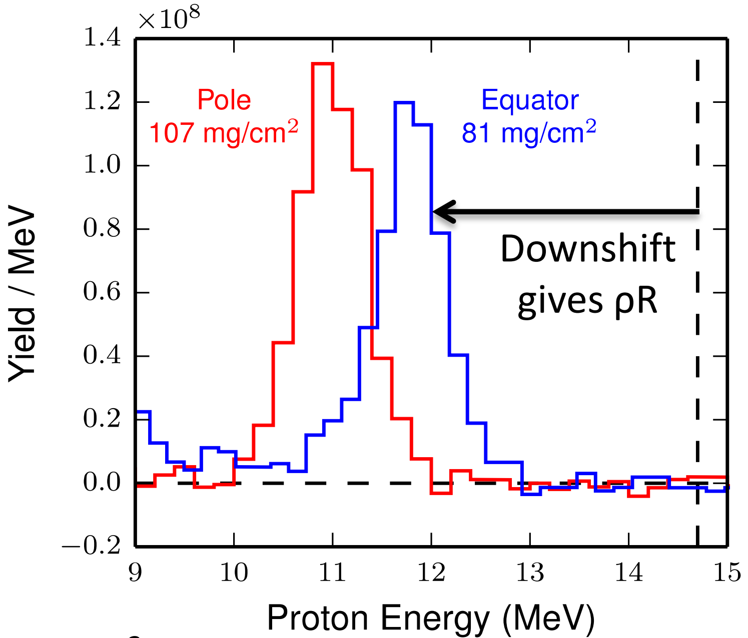
- Calibration of the magnet for the planned MagPTOF detector
- Development of an orange spectrometer for low-yield, low-energy proton and alpha spectrum measurements
- MRS-t component testing

WRF calibration

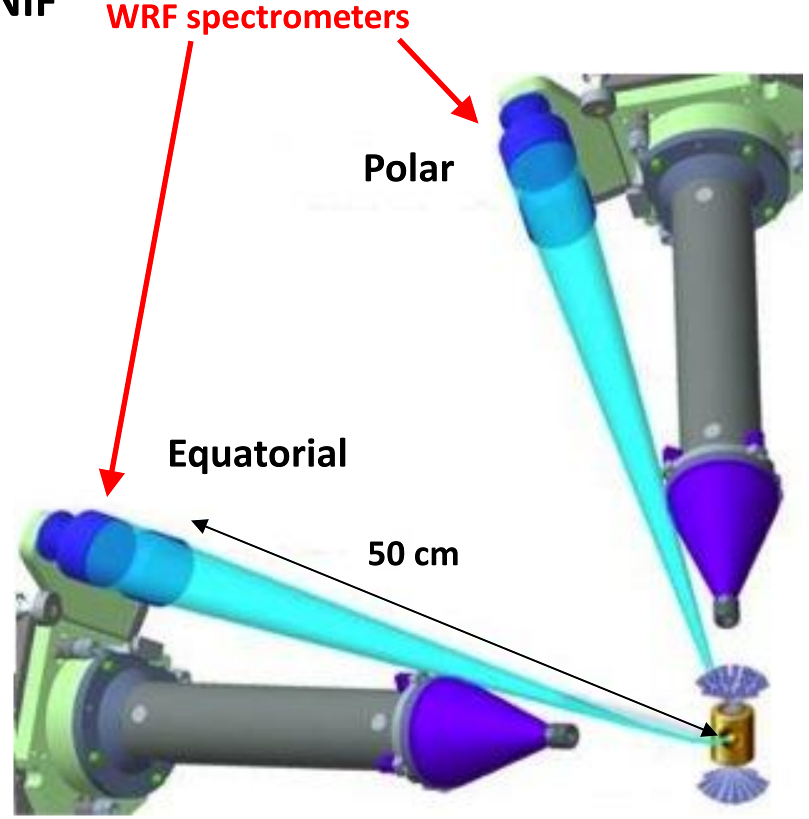
# WRF spectrometers calibrated at MIT are used at OMEGA and the NIF for diagnosing ρR

Graduate project: Alex

## Example: Diagnosing ρR asymmetries on NIF




N101218 $D^3He$
Proton Spectra





A. Zylstra *et al.*, submitted to Phys. Rev. E and Phys. Plasmas (2014)
F.H. Séguin *et al.*, Rev. Sci Instrum 83, 10D908 (2012)
P.B. Radha *et al.*, Phys. Plasmas 18, 012705 (2011)
H.F. Robey *et al.*, Phys. Plasmas 17, 056313 (2010)

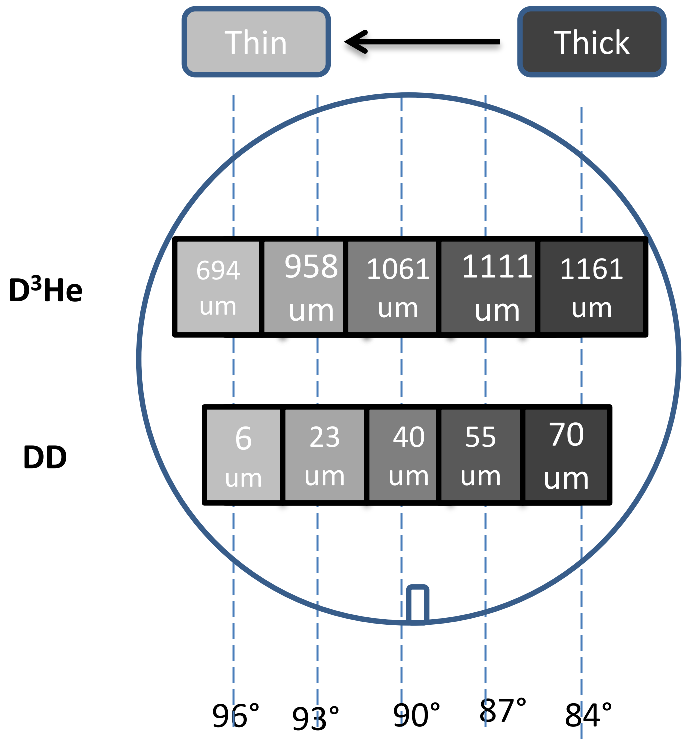
# Sandia Indium activation diagnostics were calibrated using the facility DD-neutron capability


Accelerator before major 2011-2012 upgrade

CR-39 testing

# Recent experiments address CR-39 sensitivity to x-rays, important for NIF and Sandia applications

**Undergraduate project: Jimmy**



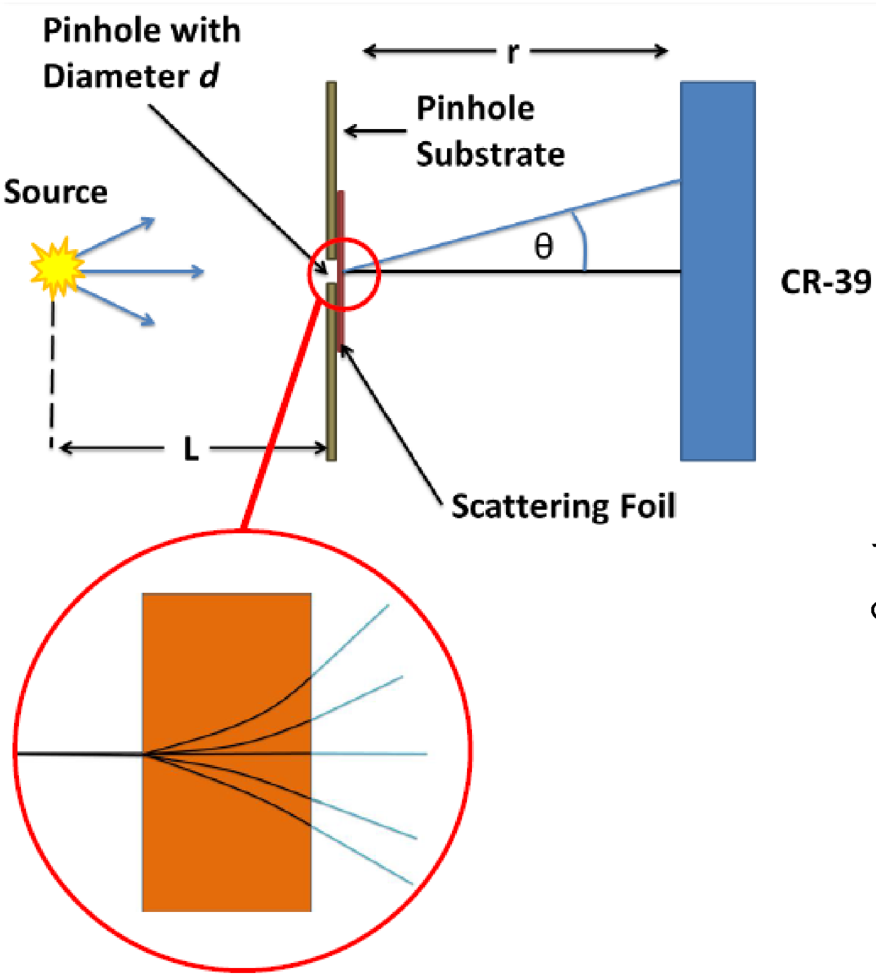

**Each filter results in a different proton energy**

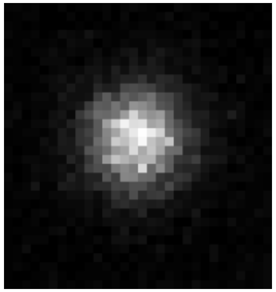

J. Rojas Herrera, **UP8.00120** (this session)

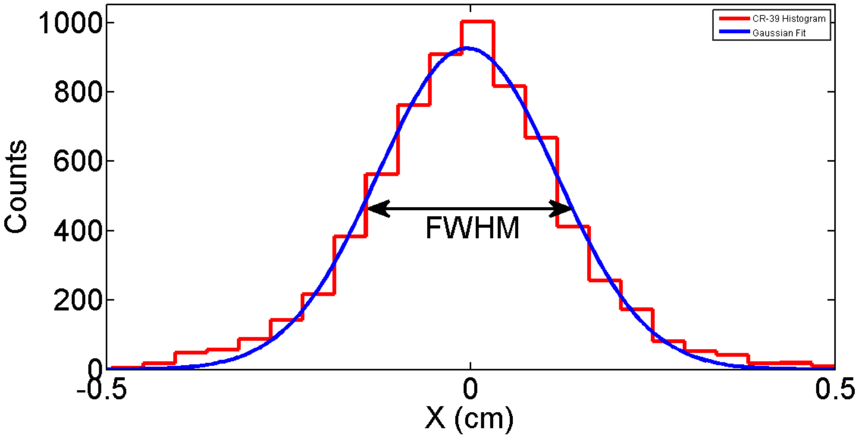
Scattering pinhole

# The Scattering Pinhole measures charged-particle yield and energy in high-fluence conditions

Undergraduate project: David






Total counts → yield

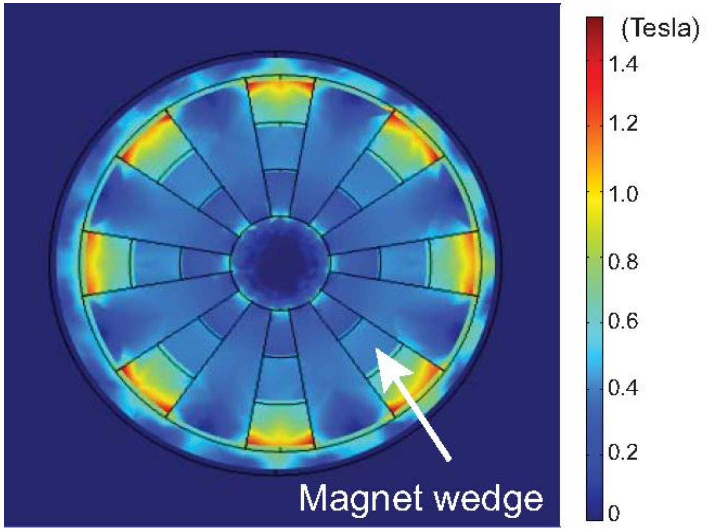
Particle spread (FWHM) → energy

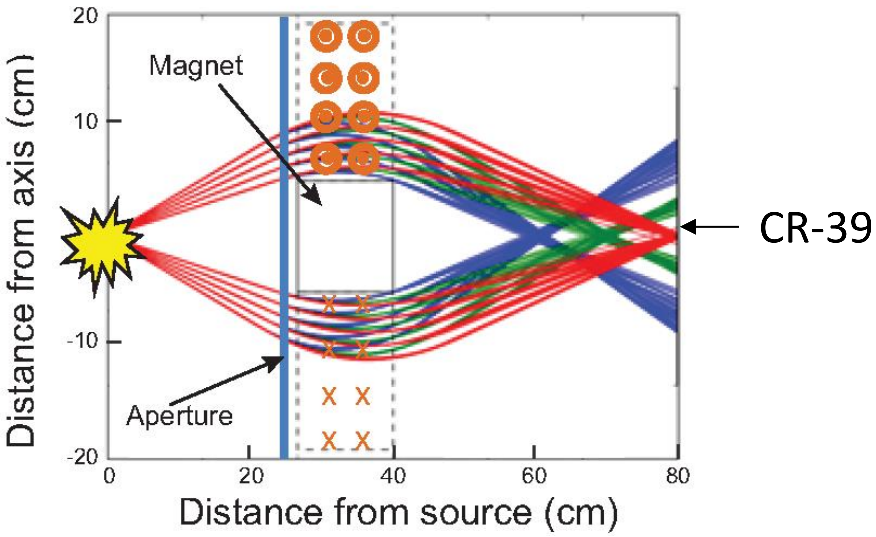
D. Orozco, **UP8.00121** (this session)

## Orange Spectrometer

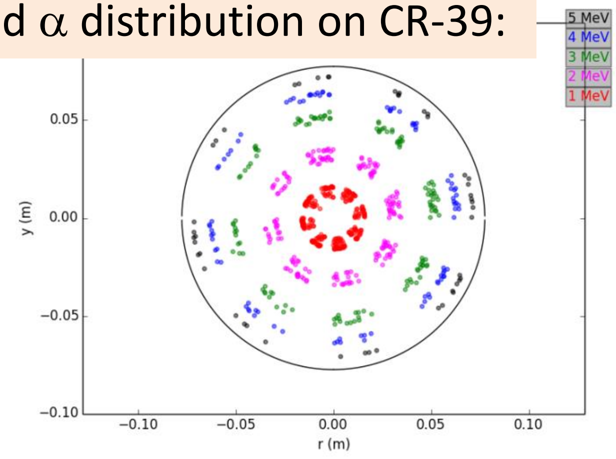
# The Mini Orange Spectrometer will measure charged-particle spectra E<5 MeV at low yield

Undergraduate project: Emily




Simulated $\alpha$ distribution on CR-39:

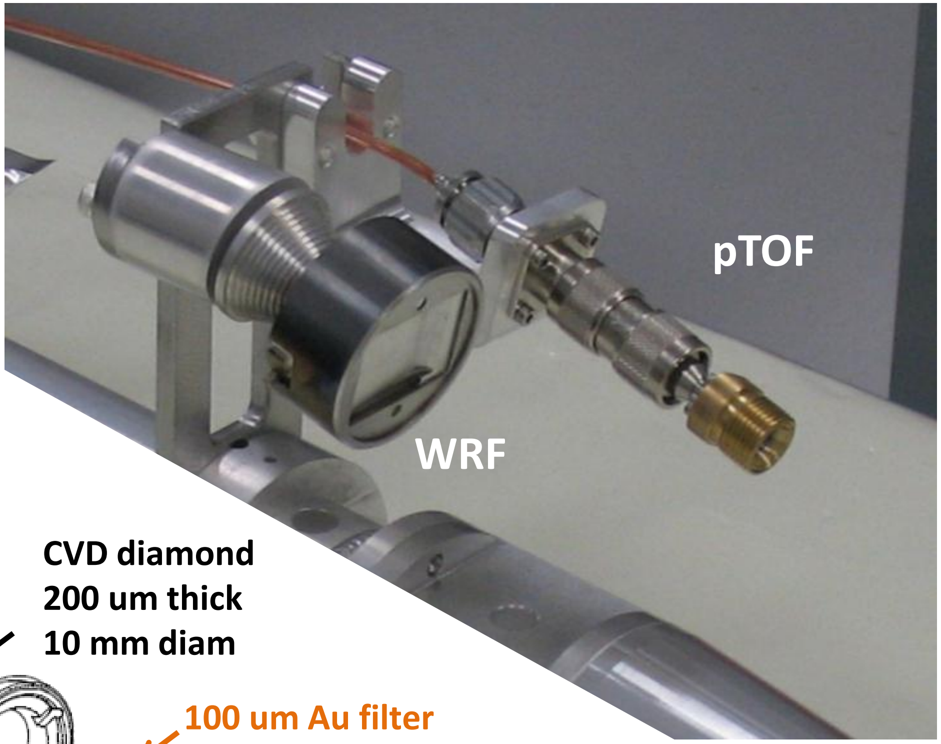


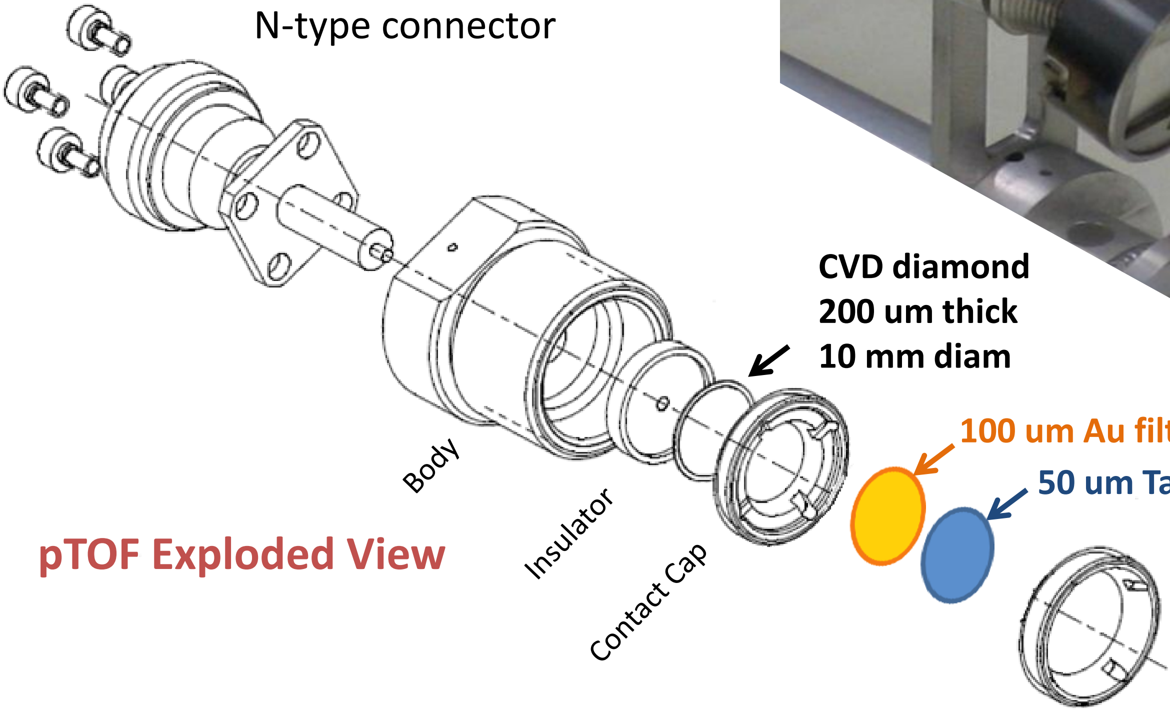

<u>Preliminary design:</u>
Efficiency $5\times10^{-4}$
Resolution ~400 keV

E. Armstrong, **UP8.00119** (this session) pTOF testing

# pTOF* CVD diamond detectors are tested on the x-ray source before fielding at NIF or OMEGA

Graduate project: Hans



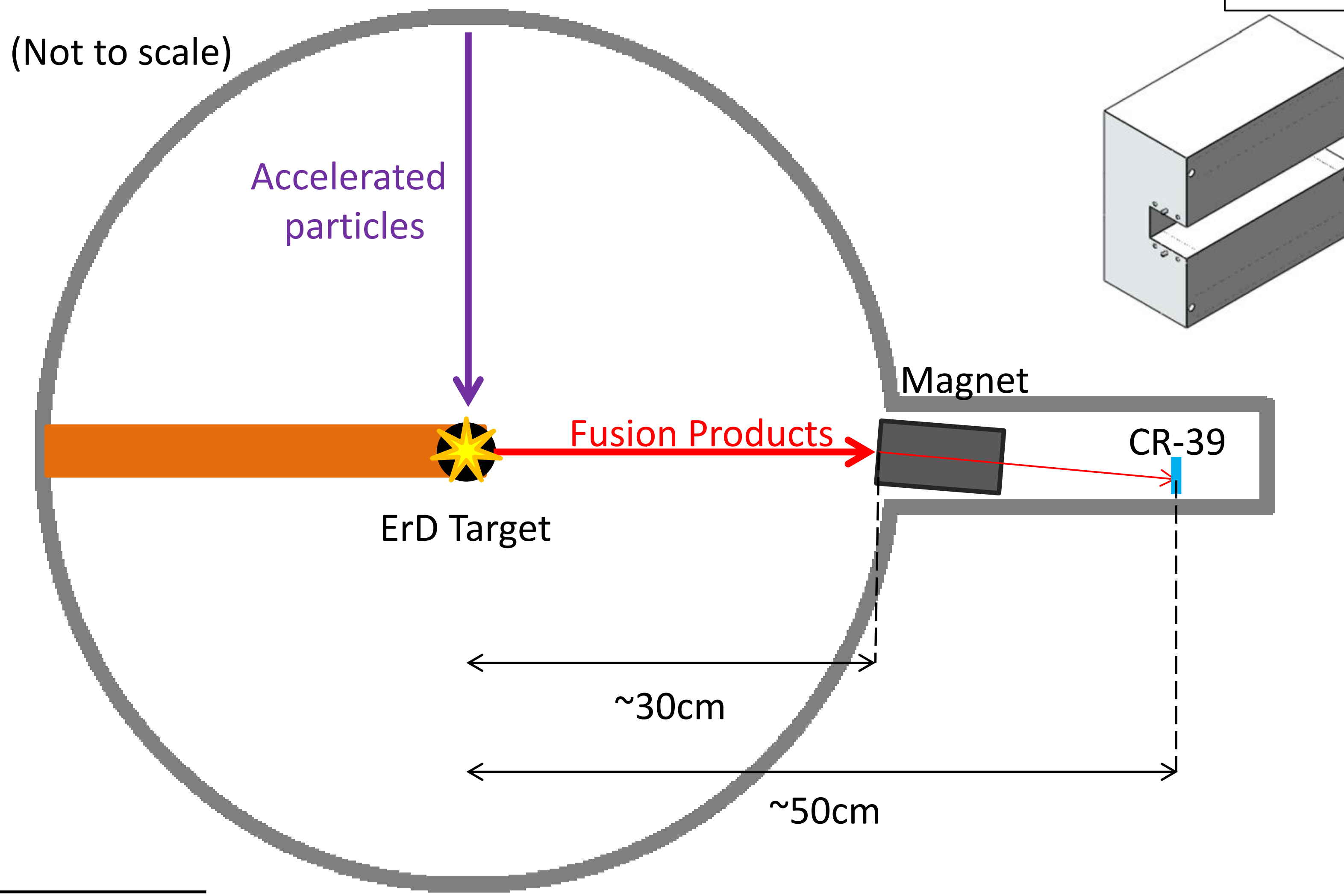




pTOF Exploded View

*H.G. Rinderknecht et al., Rev. Sci. Instrum. 83, 10D902 (2012)

# The MagPTOF* magnet will be tested using $D^3He$-p on the accelerator with mocked-up NIF geometry

Graduate project: Hong

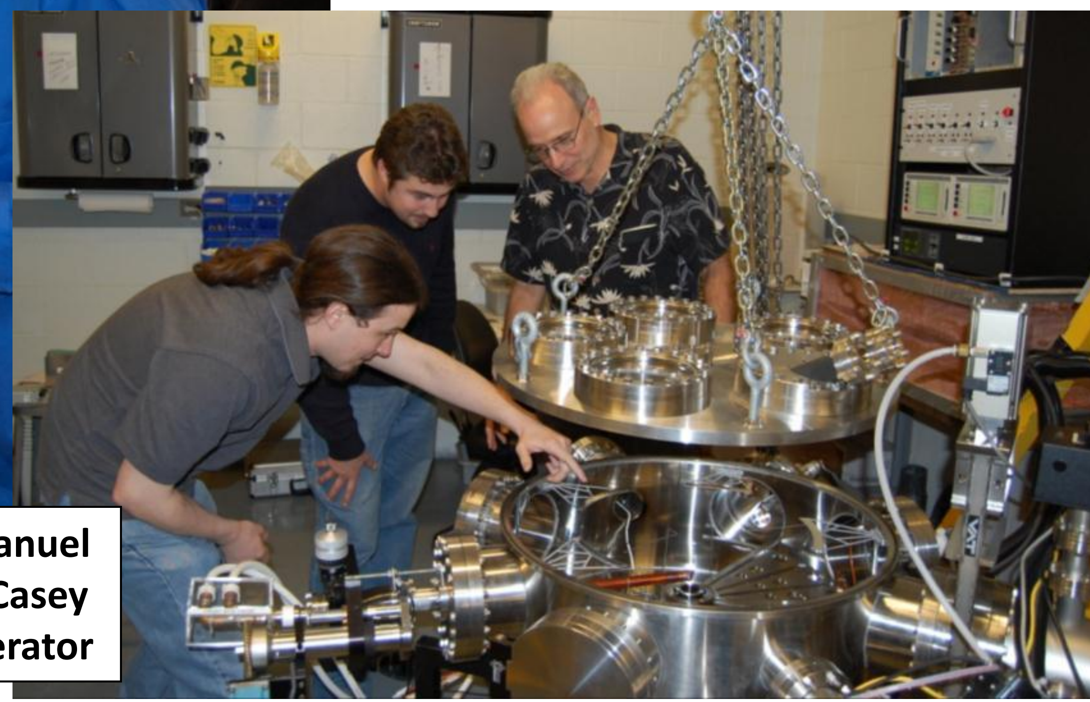



*H.G. Rinderknecht *et al.*, Rev. Sci. Instrum. (2014)

# The MIT HED Accelerator Facility is continuously adapting to serve the needs of the ICF community

NIF Diagnostics Leader Dr. Joe Kilkenny visits MIT

# …while simultaneously allowing students to get real hands-on experience…



Former graduate students Mario Manuel (now at U of Michigan) and Daniel Casey (now at LLNL) working on the accelerator

# …and publishing critical instrumentation papers in peer-reviewed journals

H. Sio et al., "A technique for extending by $10^3$ the dynamic range of compact proton spectrometers for diagnosing ICF implosions on the National Ignition Facility and OMEGA" (RSI 2014)

M. Rosenberg et al., "Empirical assessment of the detection efficiency of CR-39 at high proton fluence and a compact proton detector for high-fluence applications" (RSI 2014)

A. Zylstra et al., "A new model to account for track overlap in CR-39 data" (Nucl. Instrum. Meth. A 2012)

N. Sinenian et al., "Improvements to the MIT Linear Electrostatic Ion Accelerator for advanced diagnostics development for OMEGA, Z and the NIF" (RSI 2012)

D.T. Casey et al., "The Coincidence Counting Technique for orders of magnitude background reduction in data obtained with the Magnetic Recoil Spectrometer at OMEGA and the NIF" (RSI 2011)

N. Sinenian et al., "The response of CR-39 nuclear track detector to 1-10MeV protons" (RSI 2011)

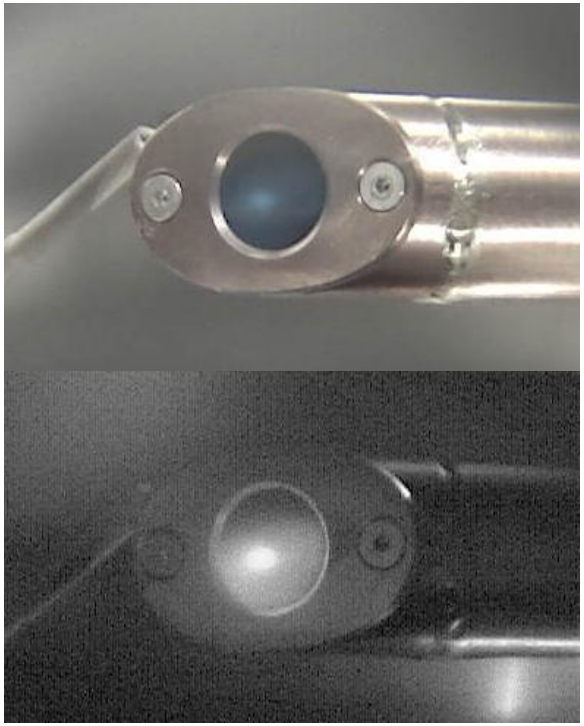
M. Manuel et al., "Observable change in proton response of CR-39 due to prolonged exposure to high vacuum environments" (RSI 2011)

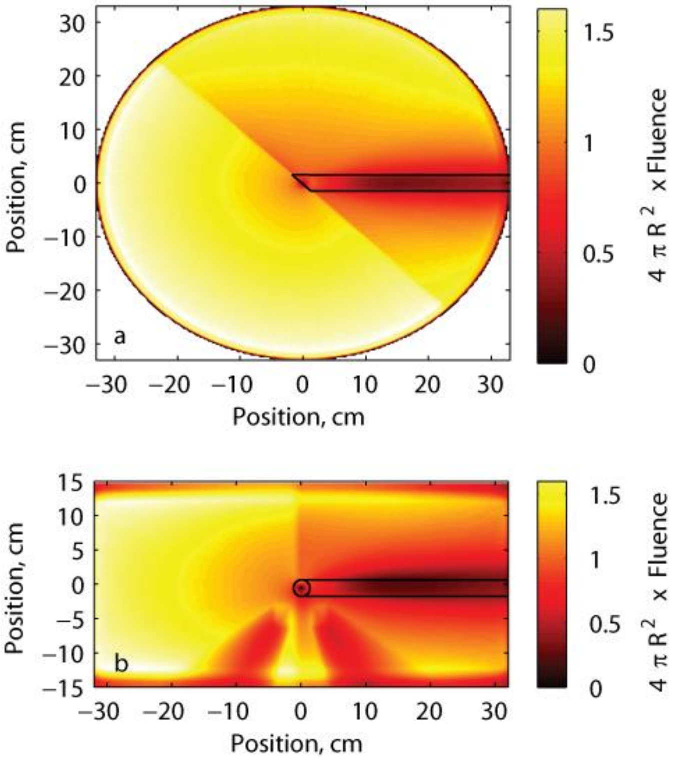
Zylstra et al., "Increasing the energy dynamic range of solid-state nuclear track detectors using multiple surfaces" (RSI 2011)

S. McDuffee et. al., "An accelerator based fusion-product source for development of inertial confinement fusion nuclear diagnostics" (RSI 2008)

# Appendix

# A target viewing system and MCNP simulations are used to characterize the neutron-fluence field in the target chamber

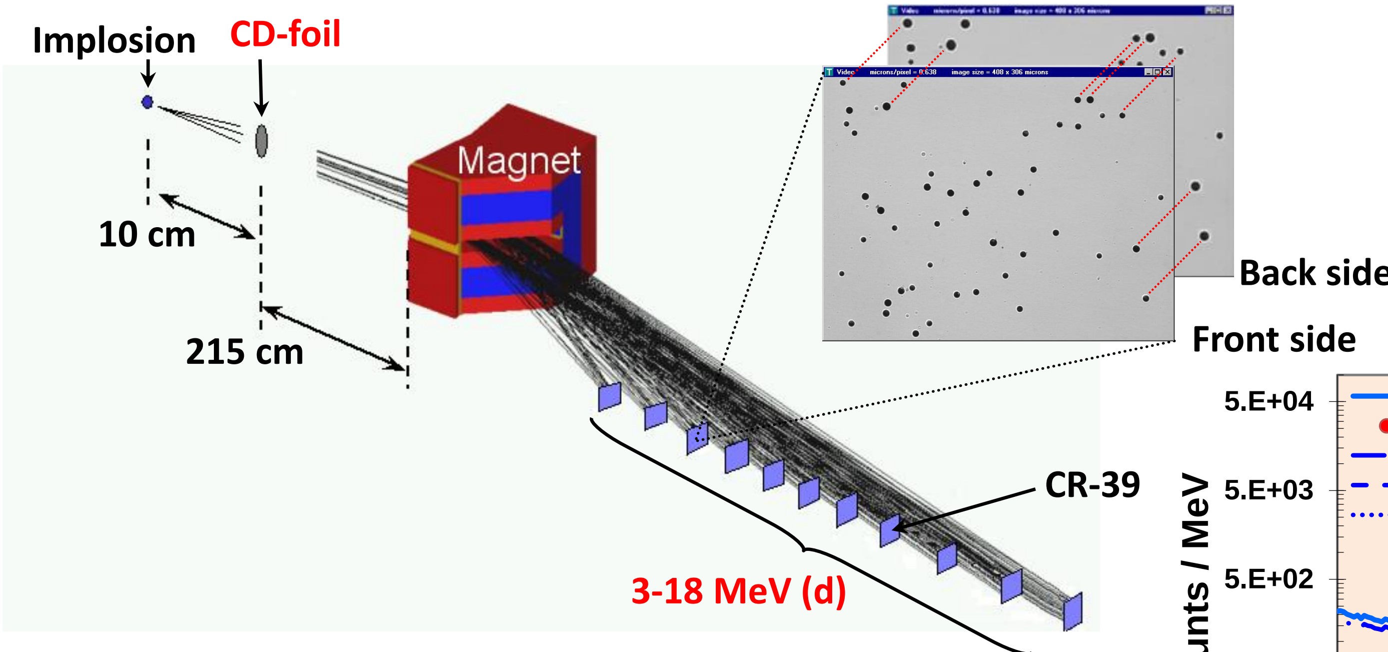


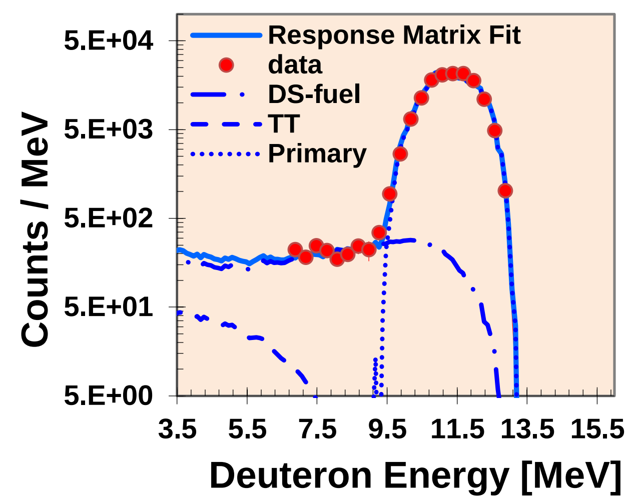



**Source size and scattering of neutrons are important for neutron diagnostics development**

Analysis techniques

# The MRS' on OMEGA and the NIF use CR-39 for detecting recoil deuterons



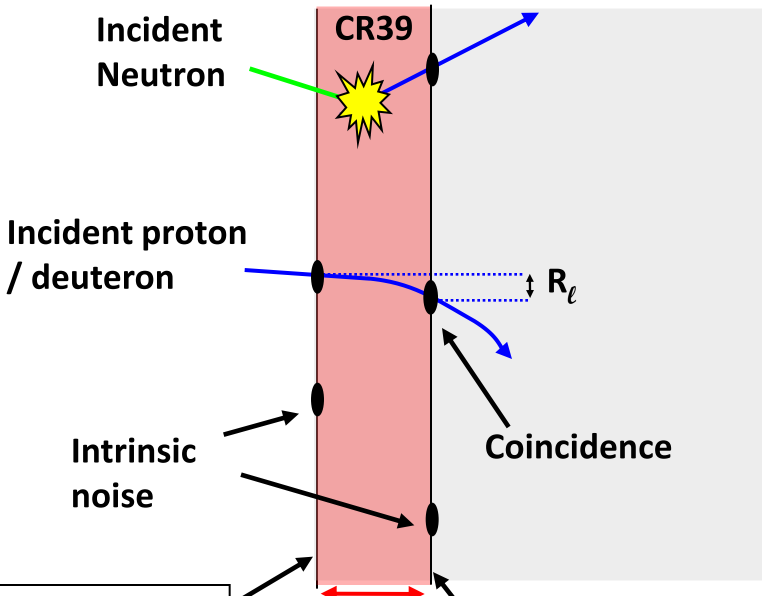

**For low-signal applications, special processing is required to enhance S/B**

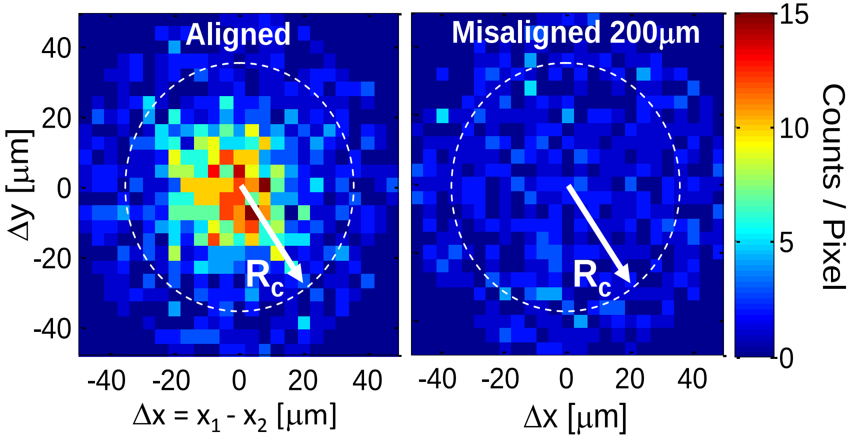

J.A. Frenje *et al.*, Rev. Sci. Instrum. 72, 854 (2001)
J.A. Frenje *et al.*, Rev. Sci. Instrum. (2008)

Analysis techniques

# The coincidence counting technique* (CCT) for the MRS was developed and optimized on LEIA

Graduate project: Dan




1st etch - track etch

3rd etch – track etch – signal is revealed again

2nd etch – bulk etch up - to 200μm removed

**By applying the CCT, *S/B* is enhanced orders of magnitude***

*D.T. Casey *et al.*, Rev. Sci. Instrum. (2011)