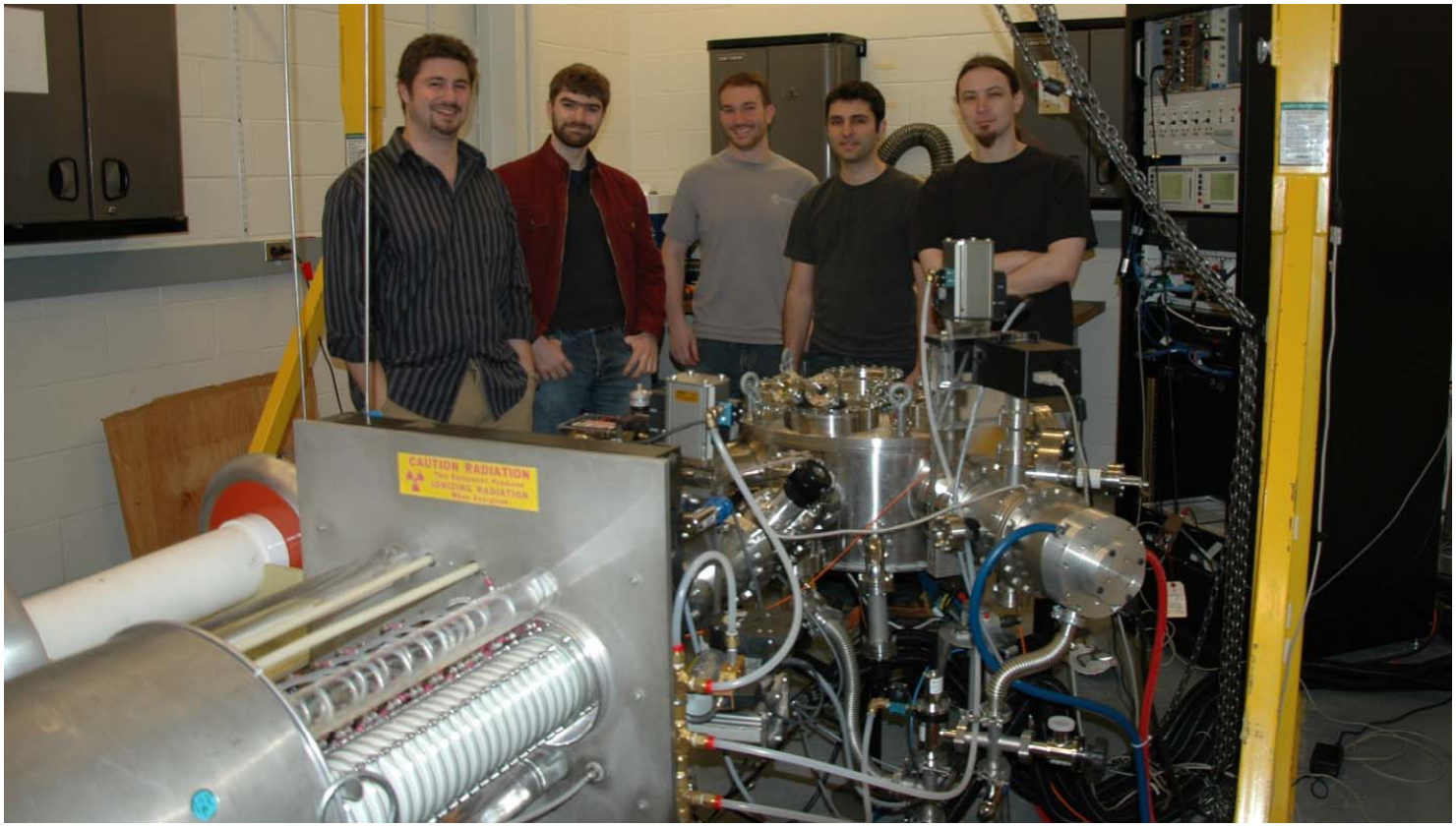
Introduction

The MIT Nuclear Products Generator for development of ICF diagnostics at Omega / Omega EP and the NIF



Present MIT Graduate Students and the MIT Nuclear Products Generator

Omega Laser User's Group
1st Annual Workshop
Wednesday, April 29th, 2009

MIT PSFC UR LLE

Internal and external users and collaborators

Present Graduate students:

N. Sinenian

D.T. Casey

M. Manuel

H.G. Rinderknecht

M.J. Rosenberg

Scientists

J. A. Frenje

C.K. Li

F.H. Seguin

R. D. Petrasso

External Users / Collaborators

V. Tang (LLNL)

M. Akselrod (Landauer Inc.)

J. Sykora (Oklahoma State University)

Past Graduate students:

J. DeCiantis (KAPL)

J.R. Rygg (LLNL)

S. Kurebayashi (Goldman Sachs)

S. Volkmer (Harvard)

C. Chen (LLNL)

Past Undergraduate students:

D. B. Denis (Westinghouse)

M. Canavan (RPI / PPPL)

R. Leiter

S. McDuffee (Columbia)

J. Perez (senior)

S. Virk (senior)

J. Jacox (senior)

Summary

- **The MIT accelerator is capable of producing fusion products and ion beams relevant for Inertial Confinement Fusion (ICF) and Magnetic Confinement Fusion (MCF) applications.**

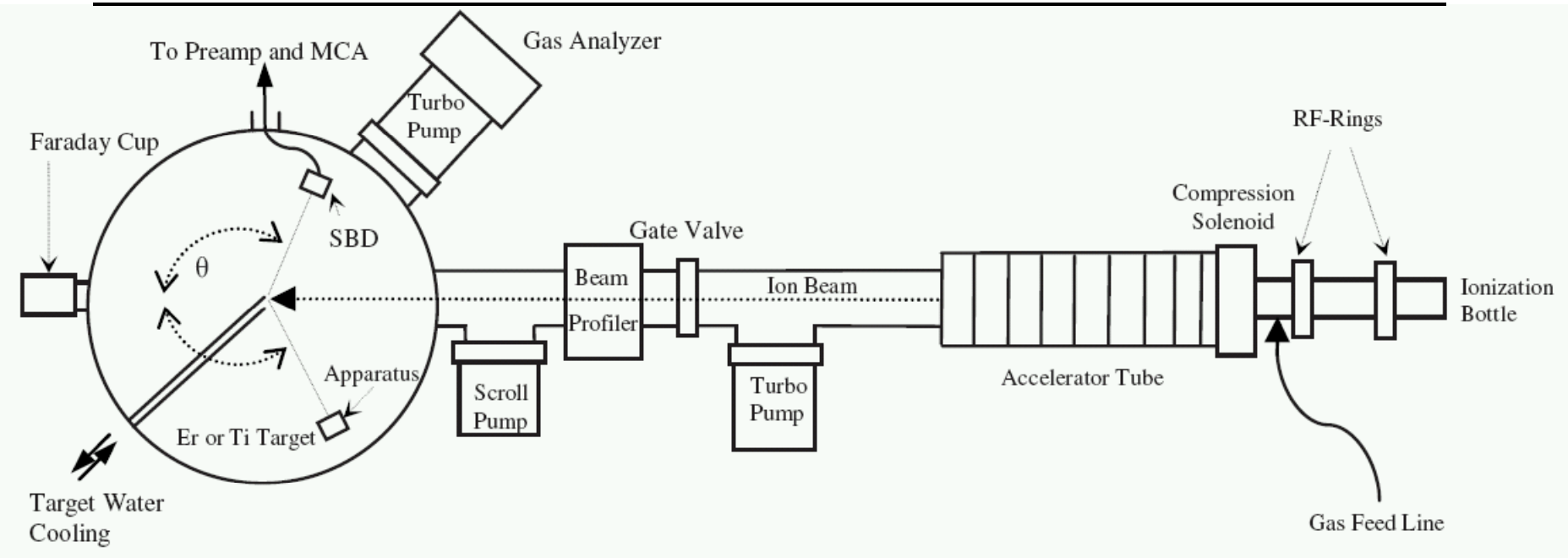
- **The accelerator has been very instrumental in designing, optimizing, characterizing several types of fusion-plasma diagnostics**.**

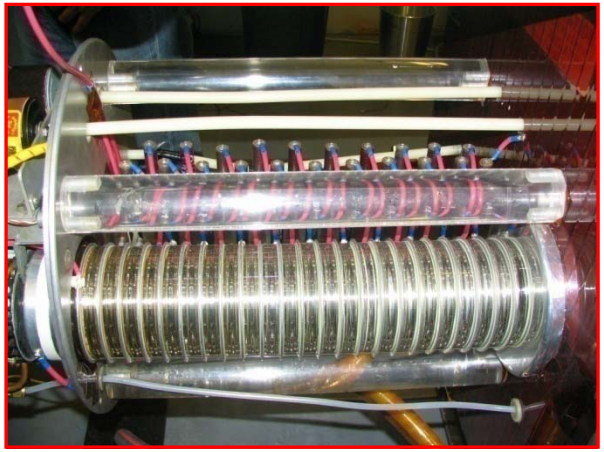
- **It is currently used to support the development and calibration of new and existing diagnostics for use at OMEGA, OMEGA-EP and the NIF.**

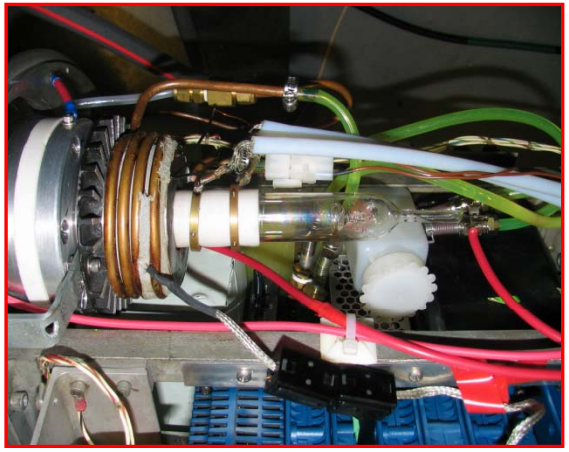
** F.H. Séguin *et al.*, Rev. Sci Instrum 74, 975 (2003).
V. Tang *et al.*, Rev. Sci Instrum 77, 083501 (2006)
S. McDuffee et al., Rev. Sci Instrum 79, 043302 (2008)

MIT PSFC UR LLE

The MIT nuclear products generator is capable of producing fusion products and beam ions relevant for ICF/MCF diagnostics development







Fusion products produced by the accelerator

The accelerator is capable of producing several fusion products and beam ions

Primary products (kinematics not included):

$D + D \rightarrow T\ (1.01\ MeV) + p\ (3.02\ MeV)$

$D + D \rightarrow n\ (2.45\ MeV) + {}^3He\ (0.82\ MeV)$

$D + {}^3He \rightarrow \alpha\ (3.6\ MeV) + p\ (14.7\ MeV)$

Secondary products:

${}^3He\ (<0.82\ MeV) + D \rightarrow a\ (6.6 - 1.7\ MeV) + p\ (11.9 - 17.2\ MeV)$

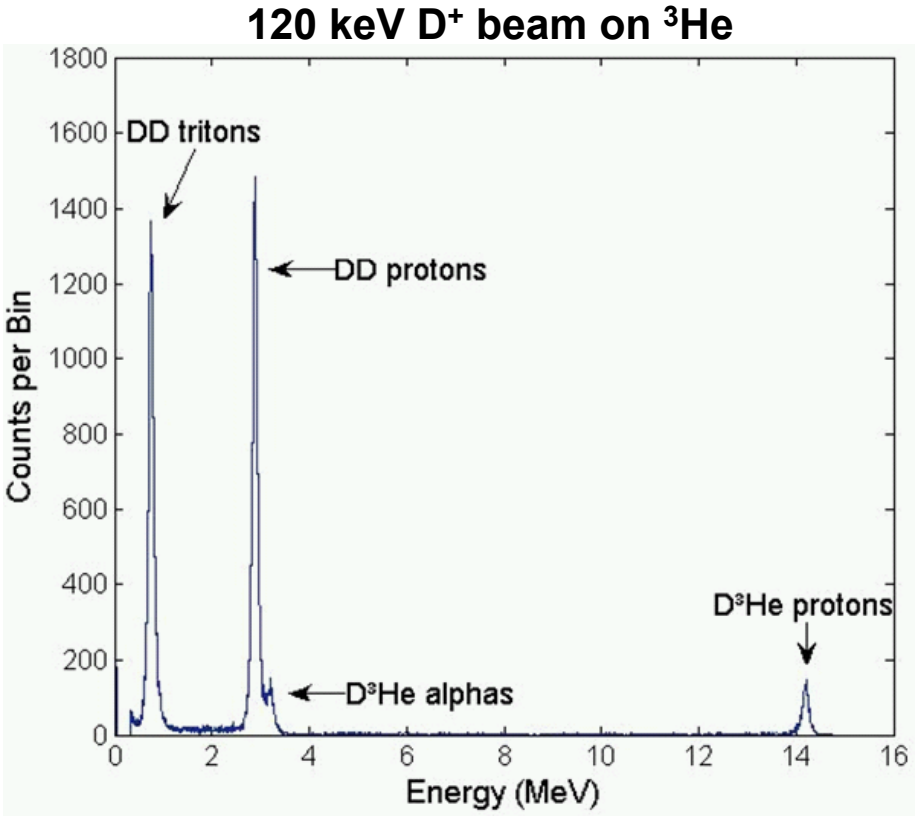
Beam ions:

$D^+\ (<150\ keV)$

${}^3He^+\ (<150\ keV)$

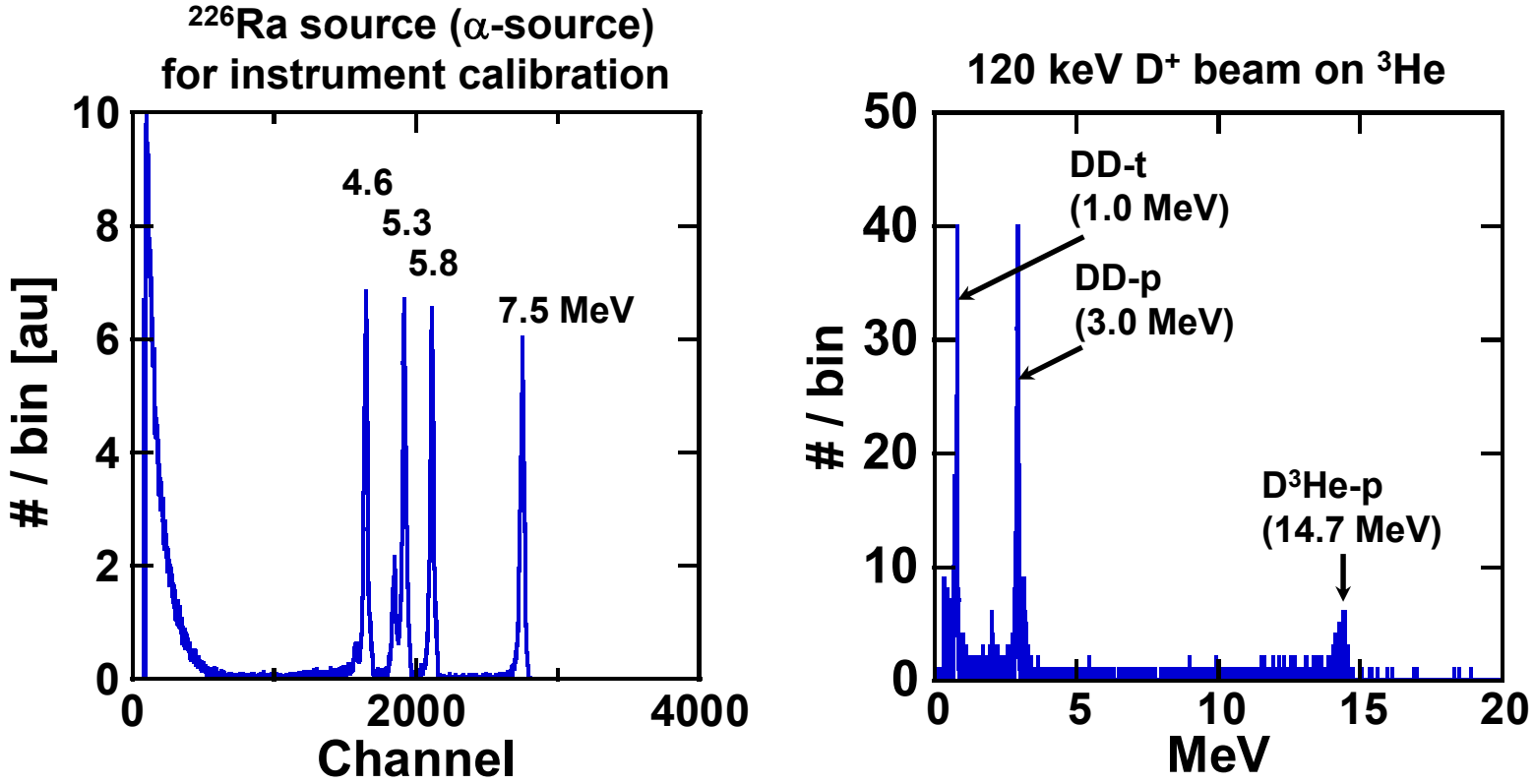
${}^3He^{2+}\ (<300\ keV)$

Fusion products can be produced by running a D^+ beam on ^3He

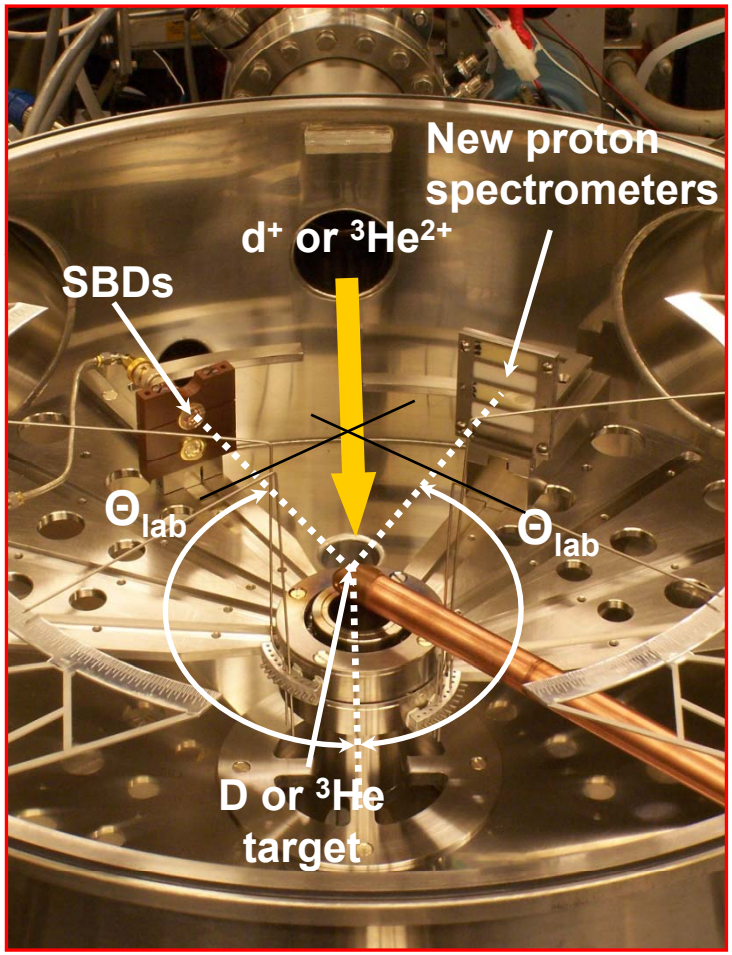


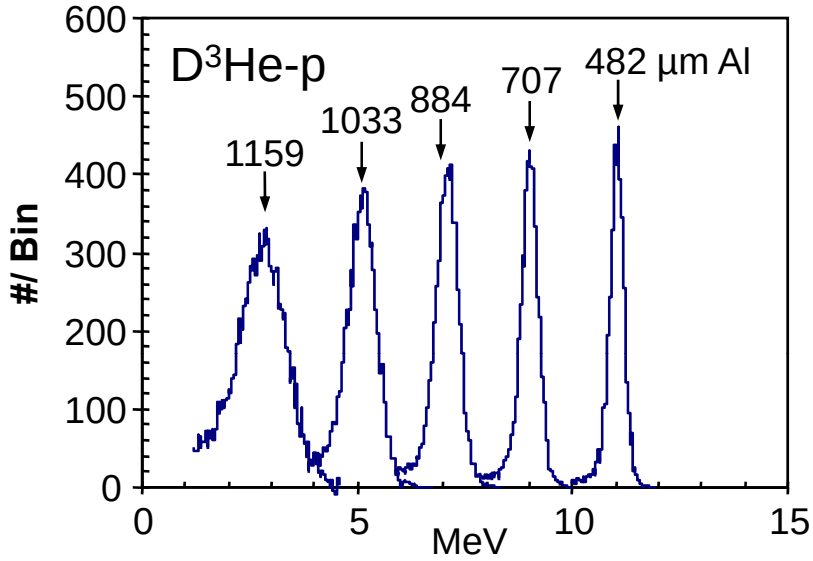
Fusion product rates up to ~10^7/s are readily achieved

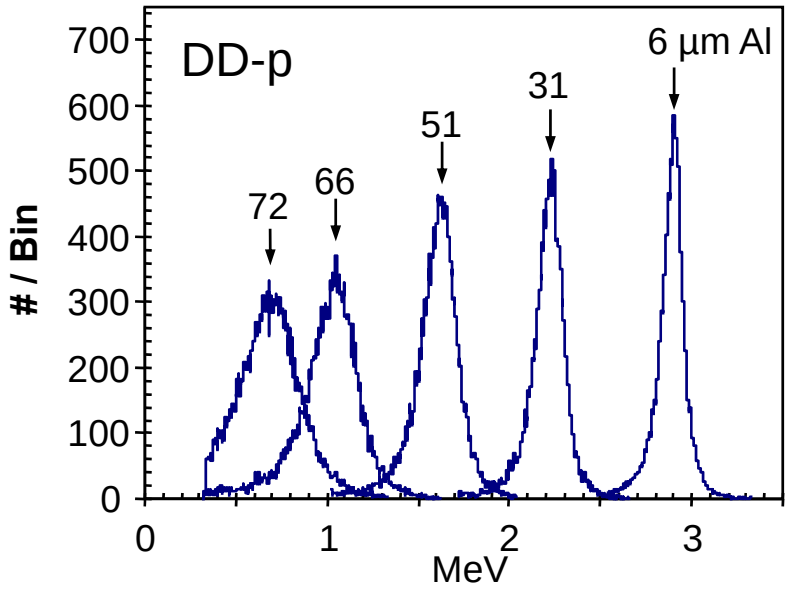
Radioactive sources and kinematic calculations are used to characterize the energy of the fusion products



Kinematic effects and ranging filters are exploited to provide fusion products with a large range of energies

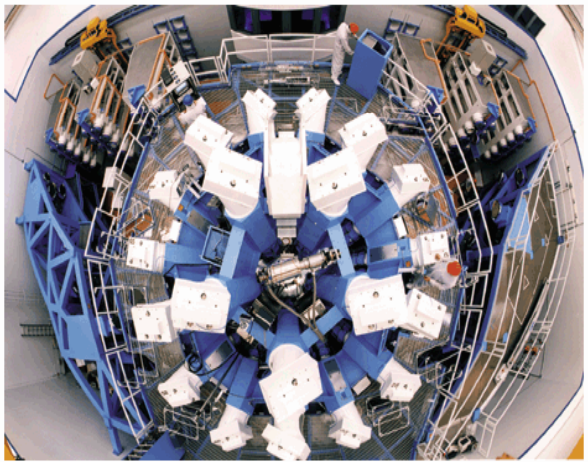


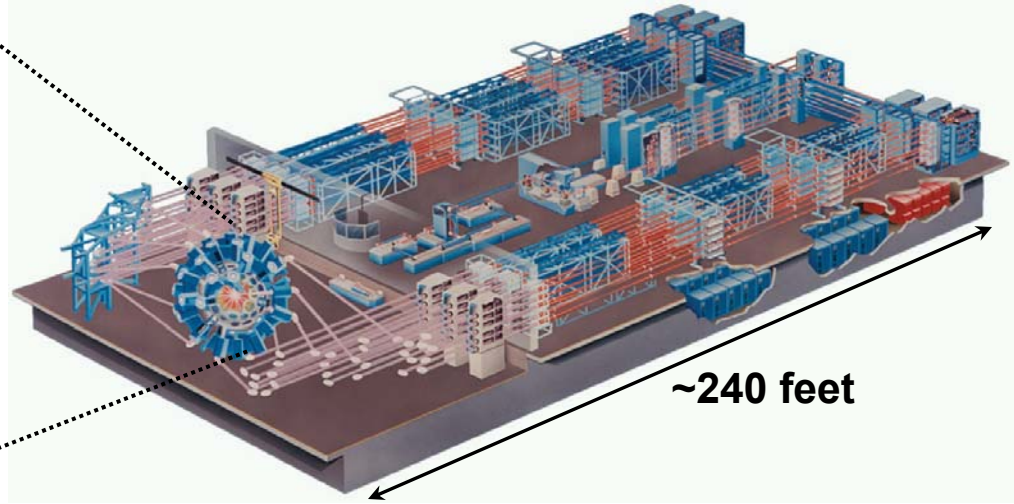


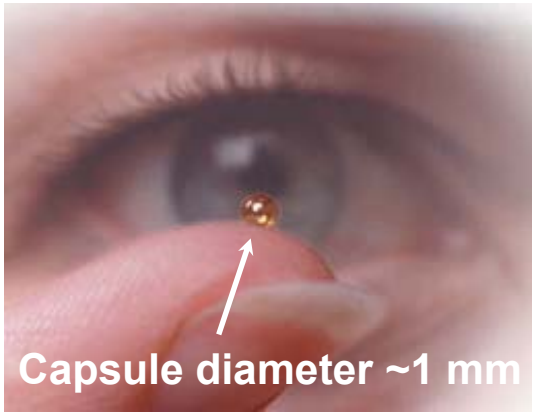


Primary Objectives…

The objective with the accelerator is to design and characterize instruments for diagnosing ICF plasmas at OMEGA, OMEGA-EP…

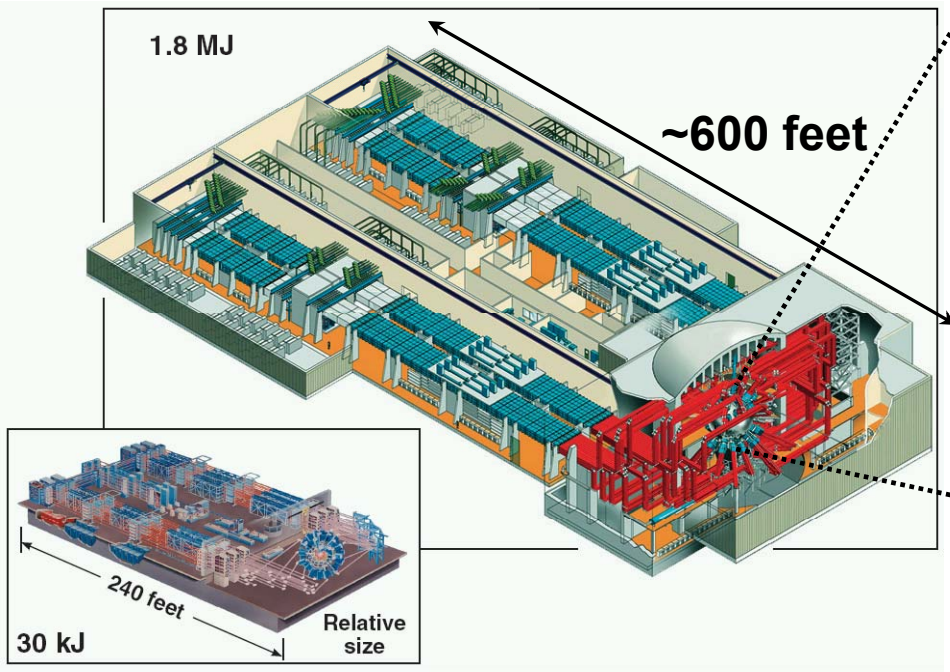


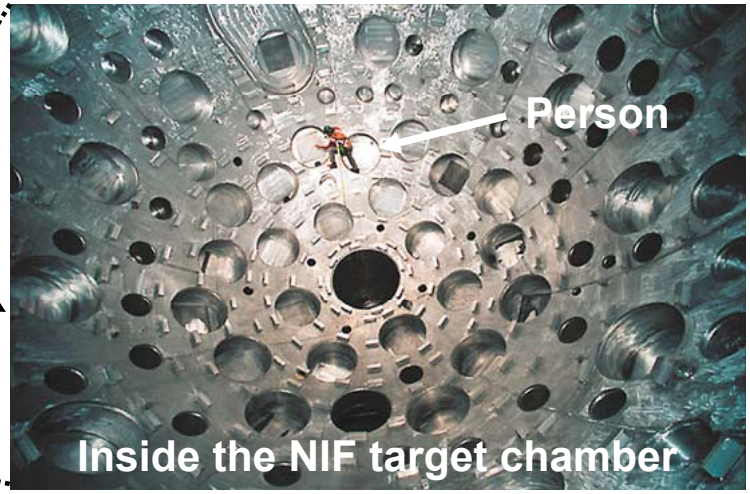




- 60 laser beams delivering 30 kJ on capsule in ~1 ns
- Direct or indirect drive

…and the National Ignition Facility (NIF) at LLNL

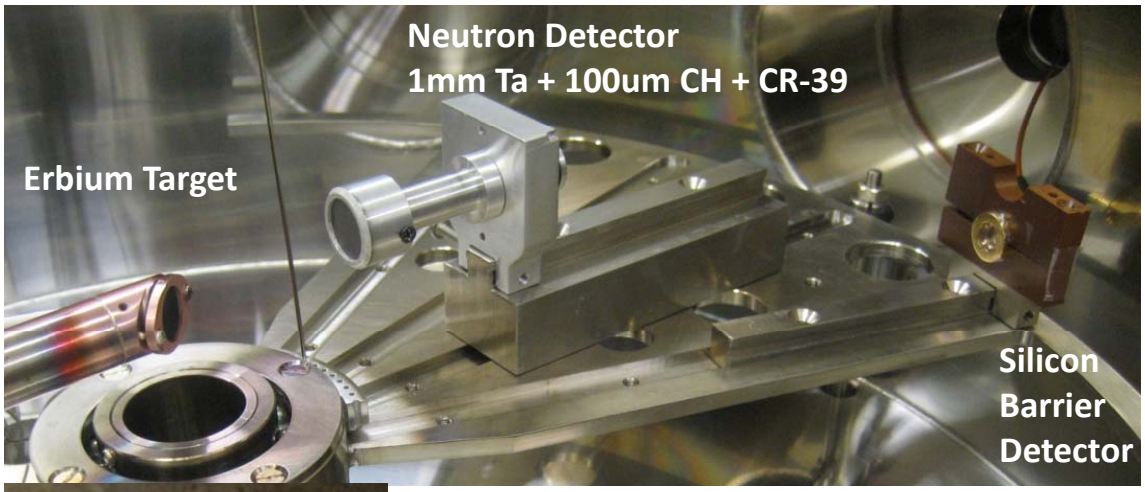




- 192 Laser Beams delivering 1.8 MJ on capsule
- Indirect drive or direct drive
- First credible ignition experiments ~2010

Projects on Accelerator

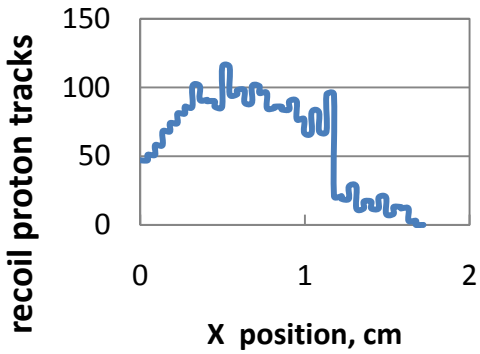
a) Calibration and optimization of an X-ray/EMP immune, CR-39 based detector for the measurement of neutron yields



The fusion products generator is being used to characterize and optimize the efficiency of the neutron detector for sensitive measurements of neutron yield at OMEGA/OMEGA-EP and the NIF

Experimental Setup

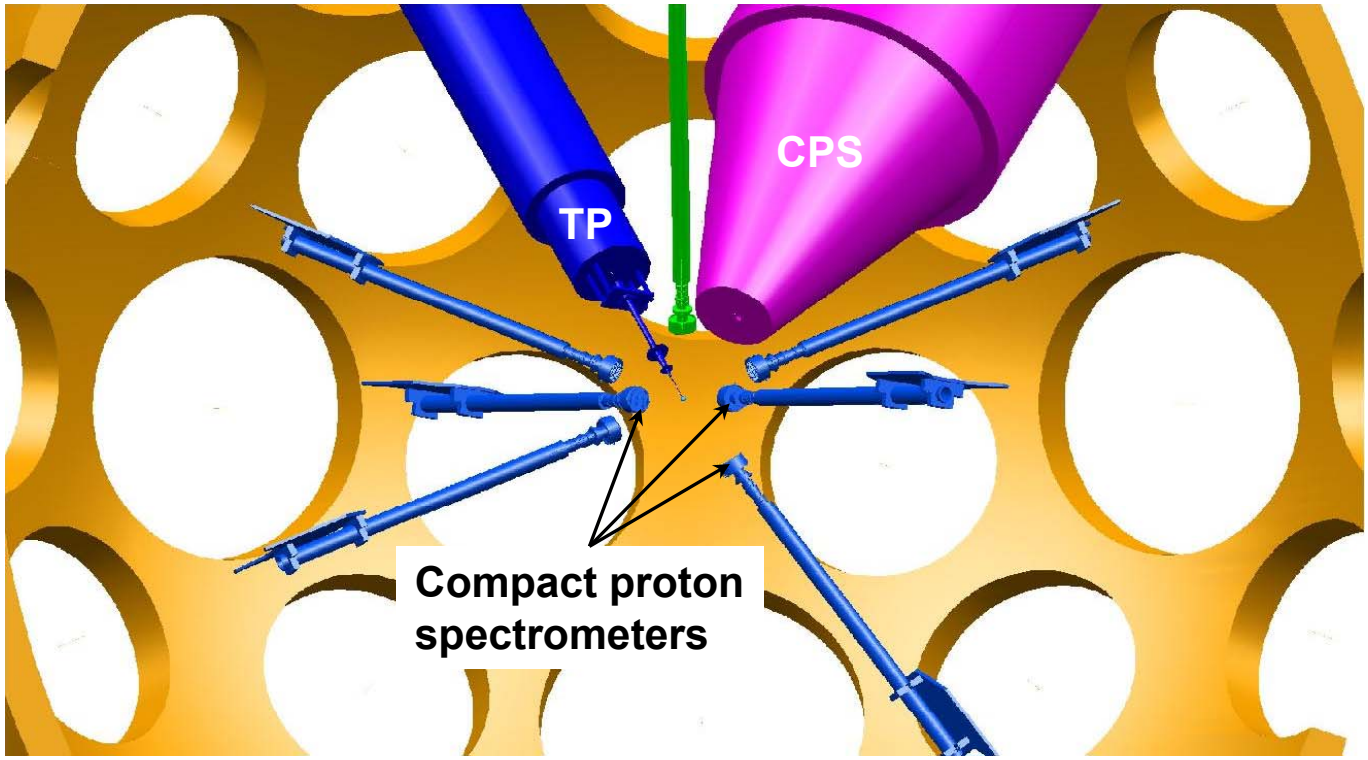
Scanned image of CR-39



Number of tracks vs. position

[1] J.A. Frenje et al., Rev. Sci. Instrum. 73 (2002).
[2] The Optimization of an EMP/X-Ray Immune CR-39 based detector for Sensitive Measurements of Neutron Yields at Omega & the NIF OLUG Workshop, April 29th – May 1st, 2009

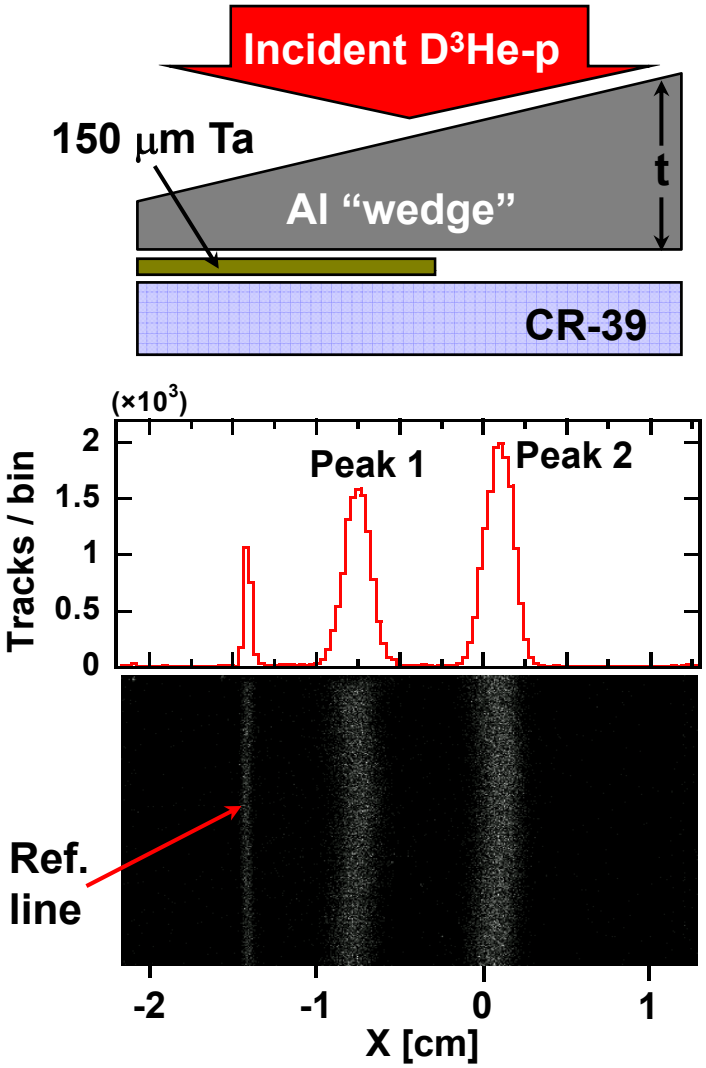
b) Calibration of the compact proton spectrometers** currently used on OMEGA

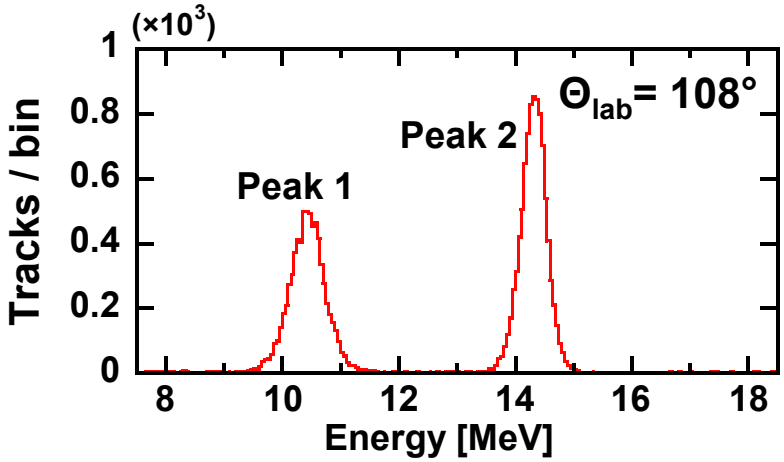


These spectrometers are used extensively at OMEGA for measurements of either primary or secondary protons, from which *rR* and *rR* asymmetries can be determined for a large range of capsule implosions

** F.H. Séguin *et al.*, Rev. Sci Instrum 74, 975 (2003).

The old spectrometers were recalibrated on the accelerator to account for any changes from extensive use at OMEGA

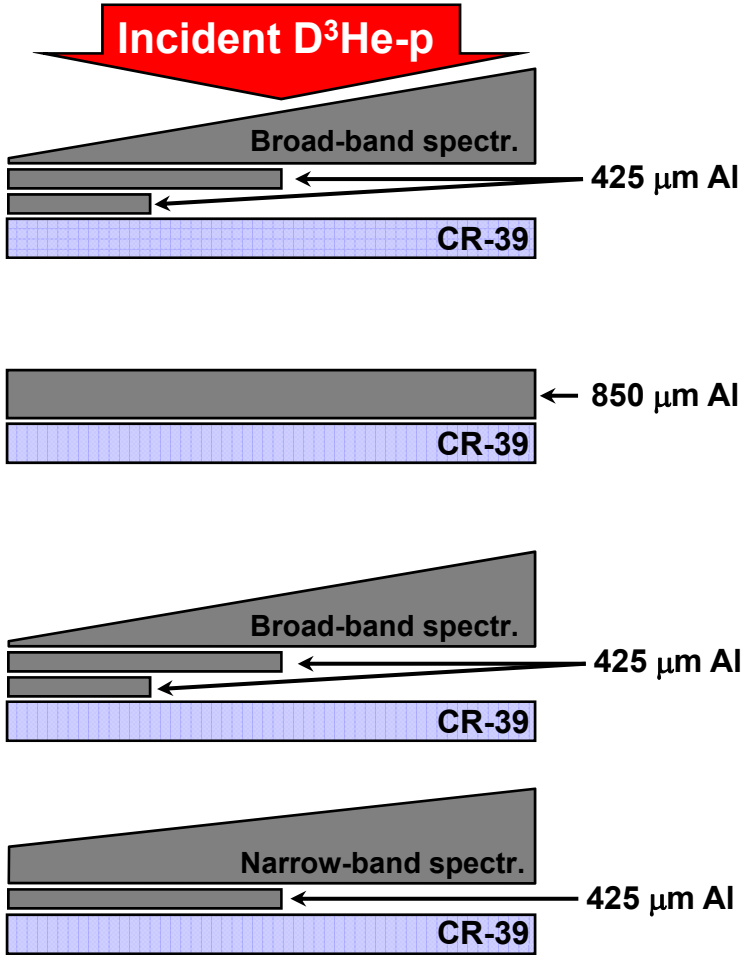


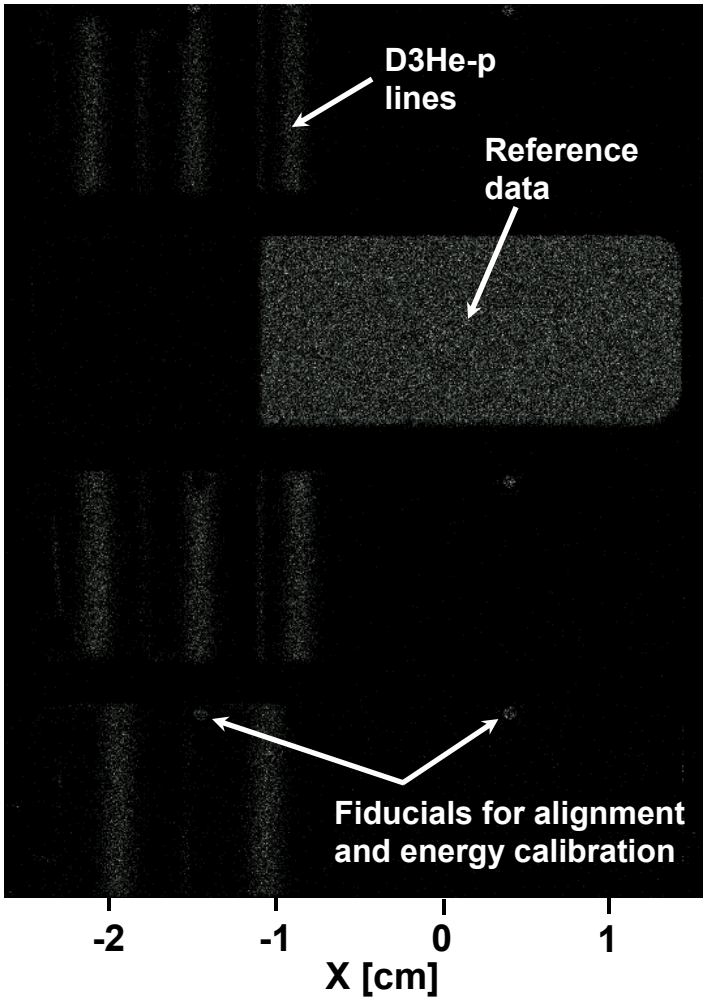


Peak:	1	2
Measured (MeV):	10.32	14.35
Anticipated (MeV):	10.3	14.4

No significant changes have occurred during several years of operation at OMEGA

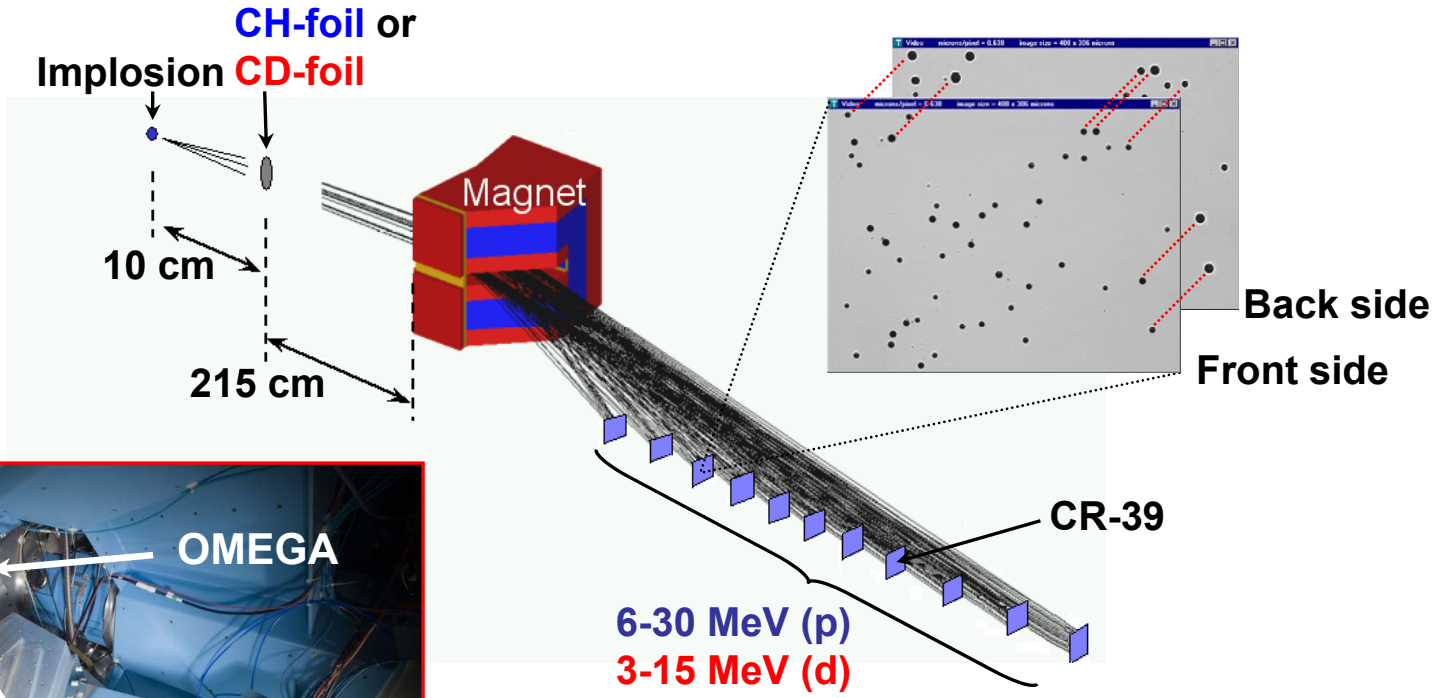
The new proton spectrometers were absolutely calibrated on the accelerator using D^3He-protons

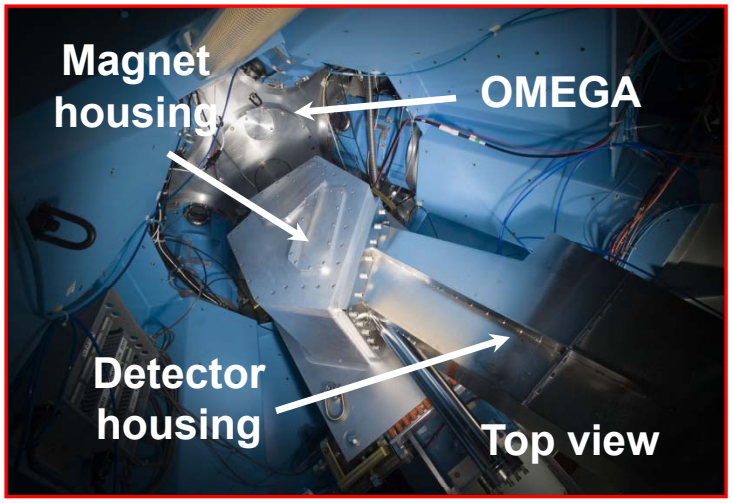




Projects… (continued)

c) Optimization of the Coincidence Counting Technique (CCT) for the Magnetic Recoil Spectrometer (MRS)**

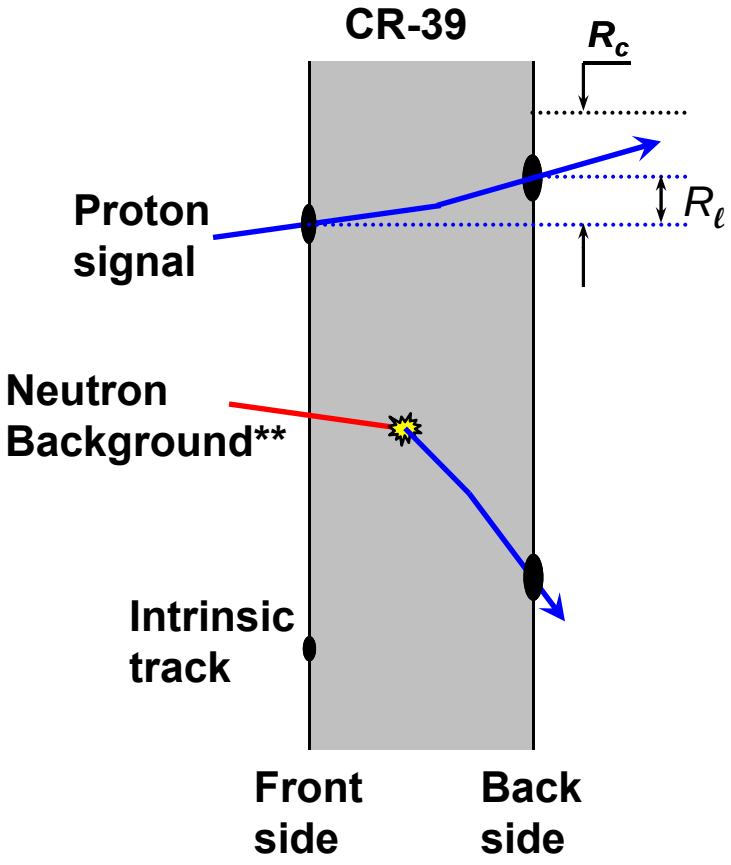


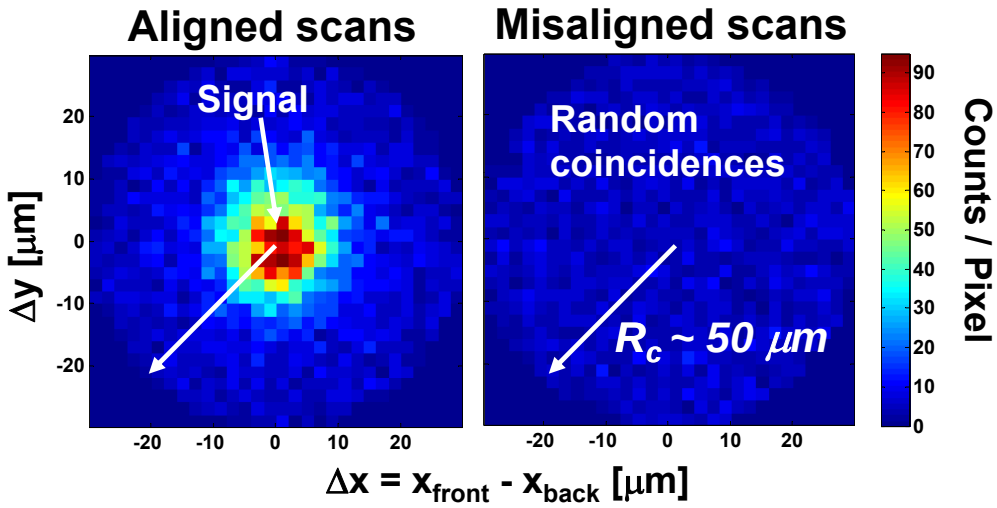


This spectrometer measures the absolute neutron spectrum (6-30 MeV) from which rR, T_i and Y_n can be determined for a large range of implosions.

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

The CCT for the MRS at OMEGA was developed and optimized using the accelerator



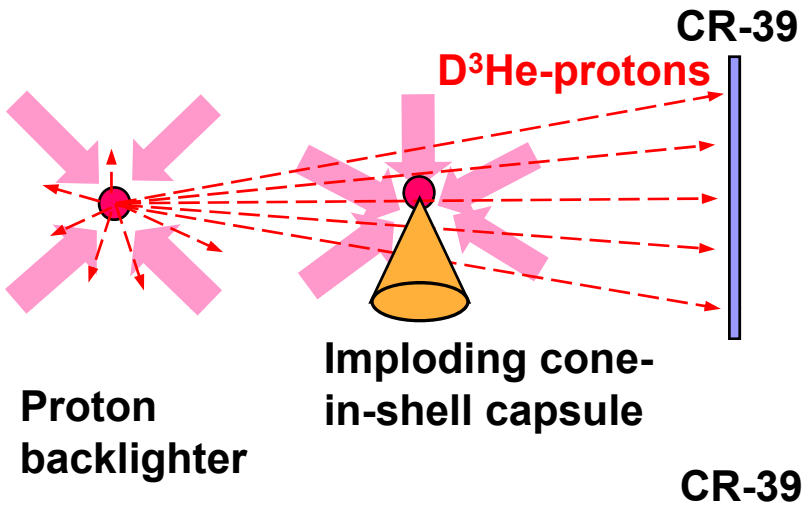


By applying the CCT, *S/B* is enhanced orders of magnitude*

* D.T. Casey *et al.* , to be submitted to Rev. Sci. Instrum. (2008).

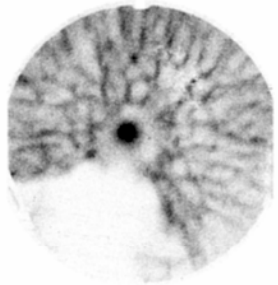
** J.A. Frenje *et al.* , Rev. Sci. Instrum. 72, 2597 (2002).

d) Characterization of new sensitive CR-39 planned to be used in proton radiography applications at OMEGA

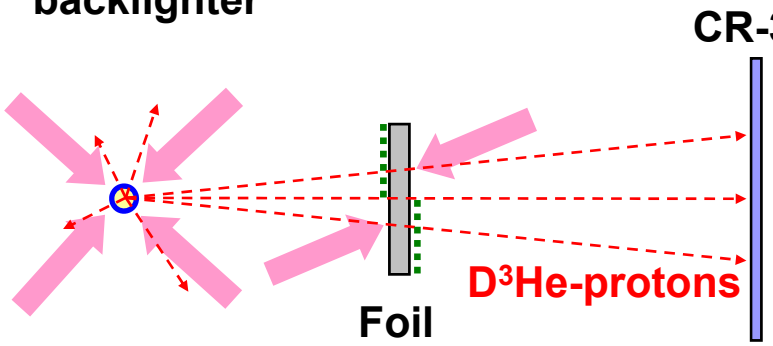


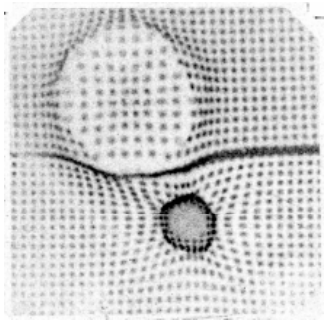
Fluence Images

t = 0 ns



t = 1.5 ns

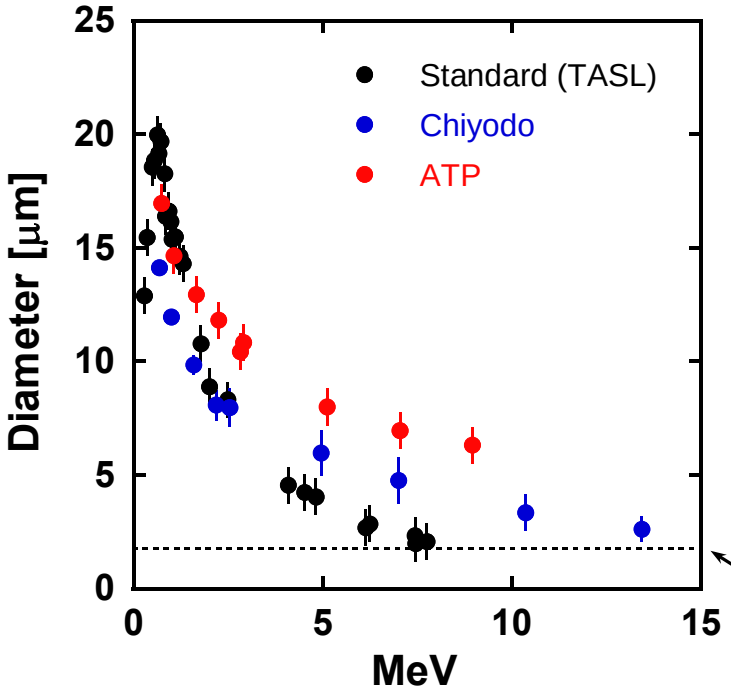


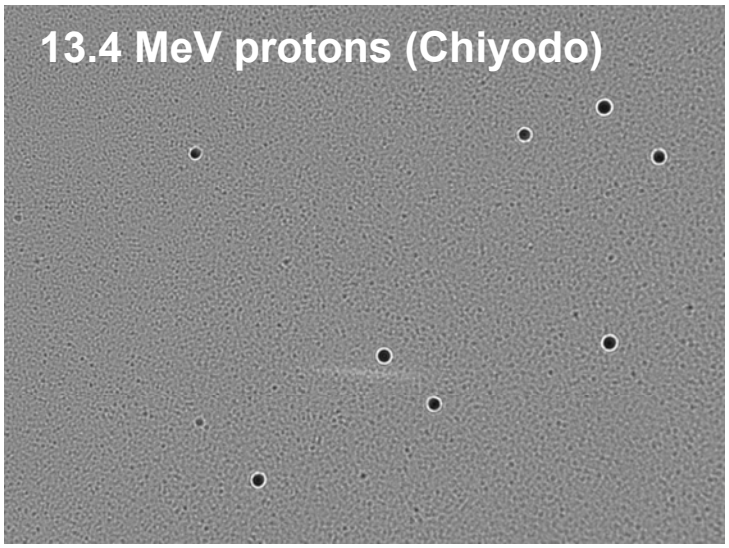


The energy of D³He-protons from the back lighter must be ranged down to the energy window in which the CR-39 detection efficiency is 100%

J.R. Rygg *et al.*, Science 319, 1223 (2008).

DD-p and D^3He-p were used on the accelerator to characterize the response of new sensitive CR-39



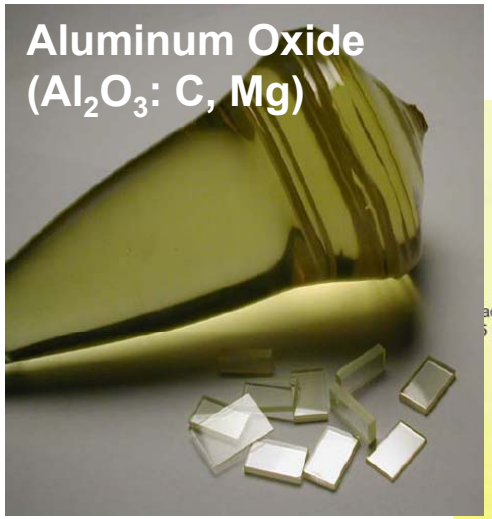


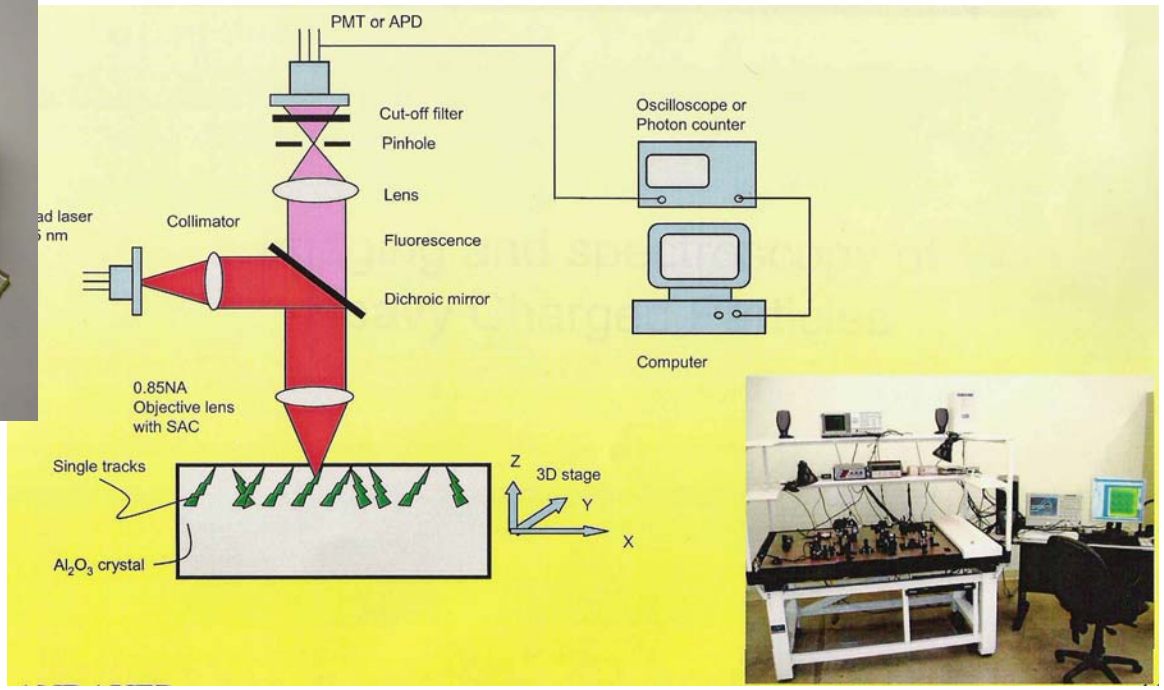
Noise floor

** The tracks are made visible through etching in 6M NaOH. In this case, the CR-39 was etched for 6 hours.

Projects… (continued)

e) Characterization of Fluorescent Nuclear Track Detector (FNTD) response to fusion products

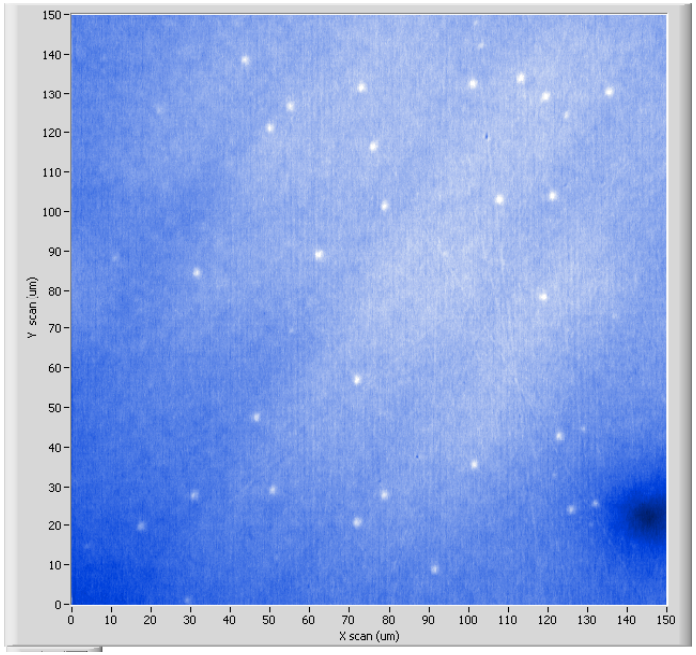


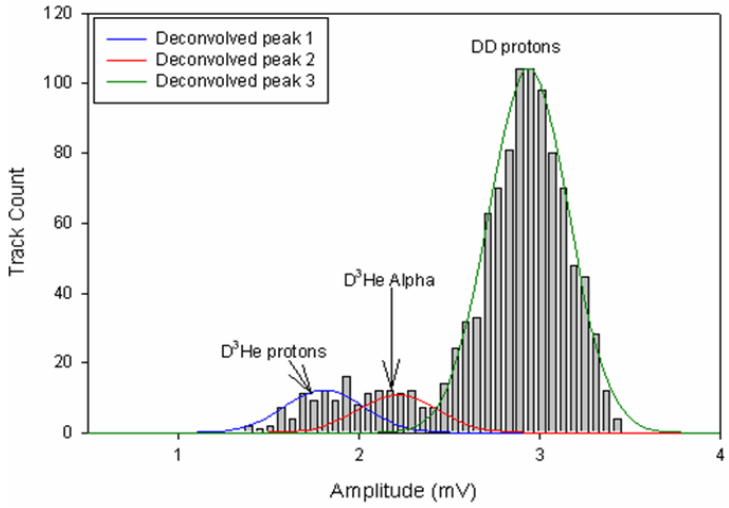


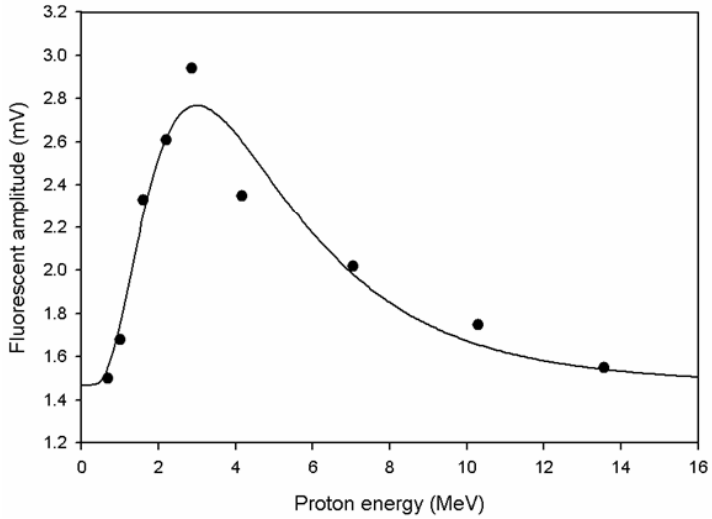
FNTD advantages relative to CR-39:

- **Superior spatial resolution (< 1 mm)**
- **Wider range of LET sensitivity (< 1 keV/mm)**
- **Reusable after annealing**

The FNTD response to D^3He-p, DD-p and D^3He-alpha particles were characterized using the accelerator

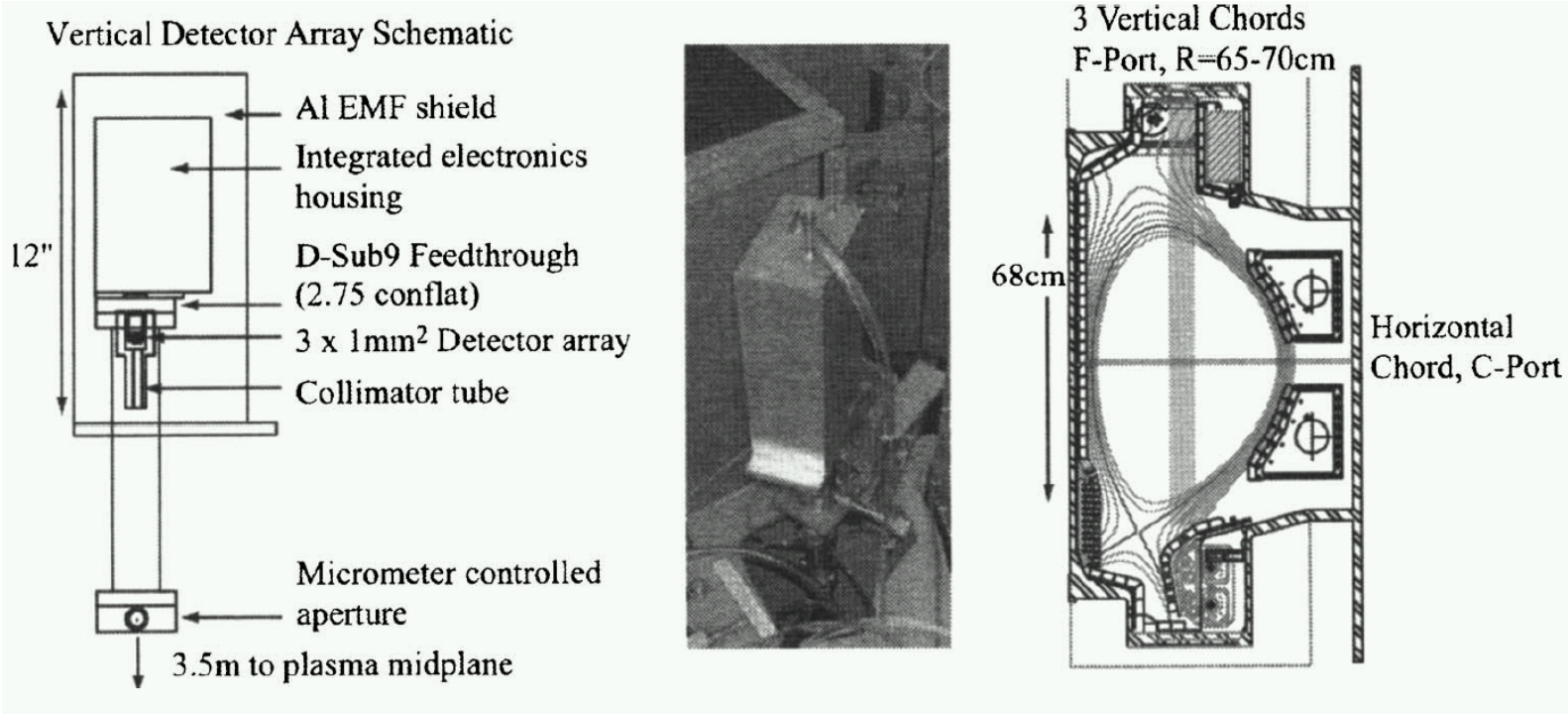






Experiments were performed in collaboration with Landauer Inc. and Oklahoma State University

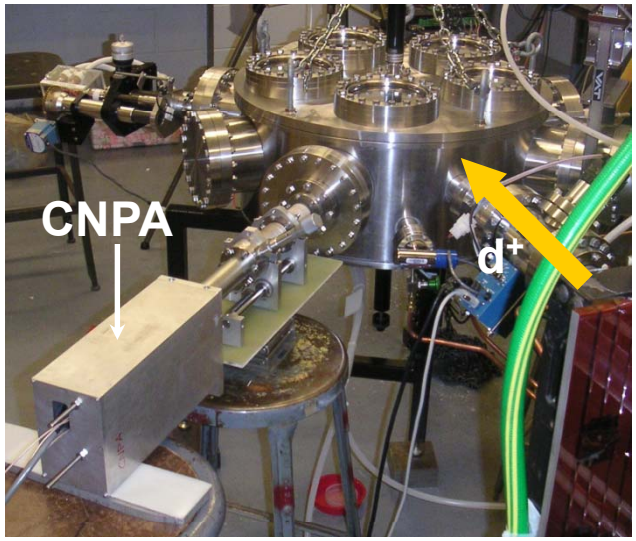
f) Calibration of the Compact Neutral Particle Analyzer (CNPA) for the Alcator C-mod Tokamak

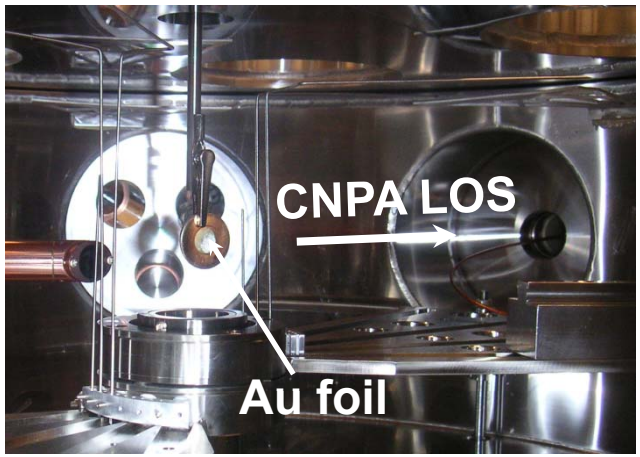


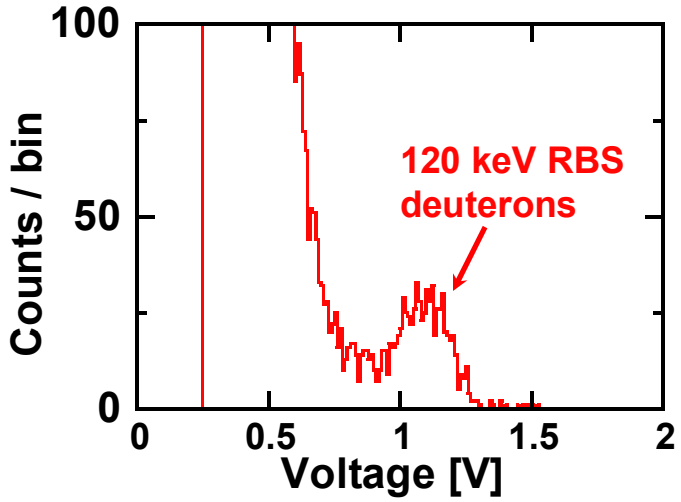
Si-diode detectors in pulse-height mode are used to measure energetic hydrogen minority ions with energies between 40 and 350 keV stemming from ion-cyclotron radio-frequency heated D(H) plasmas.

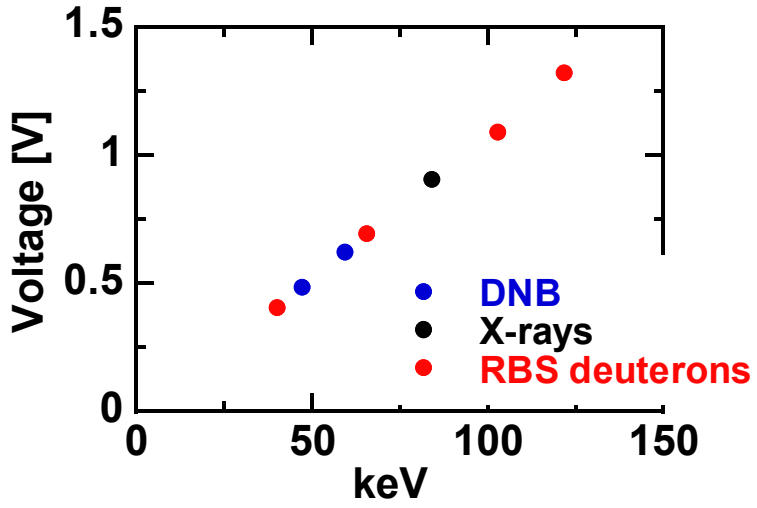
** V. Tang *et al.*, Rev. Sci. Instrum. 77, 083501 (2006).

RBS deuterons (40-140 keV) produced by the accelerator were to used to calibrate the CNPA**









Experiments were performed in collaboration with the Alcator C-mod group