A modified accelerator for ICF diagnostic development

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Outline

Accelerator updated to serve as a test-bed for ICF diagnostics

o A Cockroft-Walton accelerator has been modified

- Hardware restored and refurbished
- Special-purpose target chamber has been designed and fabricated

o Accelerator protons will be used to improve the following ICF diagnostics:

- CR-39 solid state nuclear track detectors
- WRF (wedge-range-filter spectrometers)
- PCIS (proton core imaging spectrometer)
- MRS (magnetic recoil spectrometer)

Summary/Abstract

The MIT Cockroft-Walton accelerator has been upgraded with a new diagnostics chamber and new hardware to be used as a highly accurate tool in the development of ICF plasma diagnostics. Detailed studies of CR-39 nuclear track detectors are being performed to support and improve various diagnostics which rely on this detector. In addition, new charged particle spectrometers are being calibrated to greatly enhance our range and accuracy in determining implosion yields and capsule ρR, as well as allowing shock studies. Also being developed is the coincidence counting technique which is integral to the MRS, an instrument that will determine the ρR and T_i of NIF capsules via measurement of the full DT-neutron spectrum. Future extension of this work to the calibration and testing of other diagnostics and diagnostic components using both neutrons and charged particles is likely.

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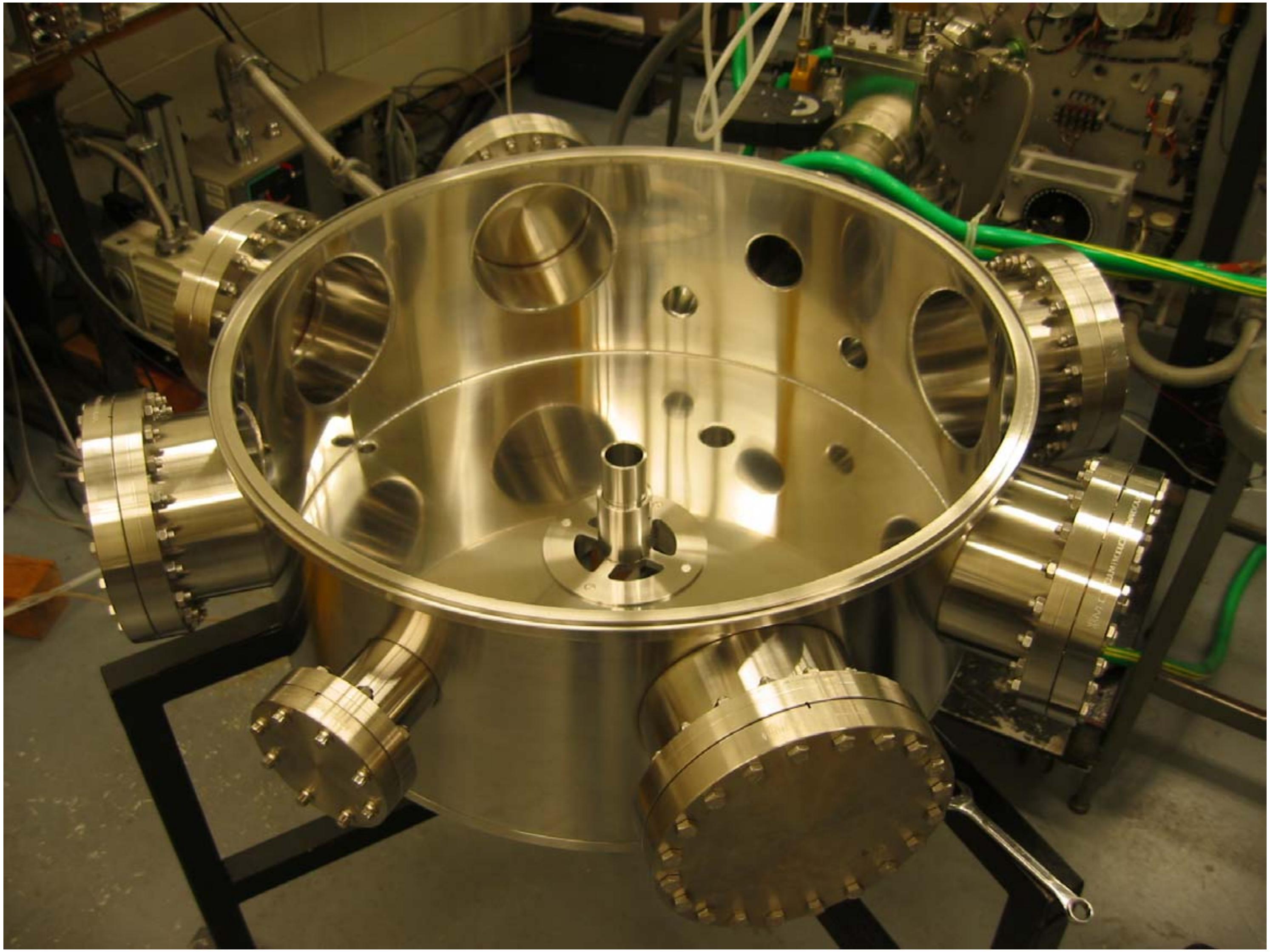
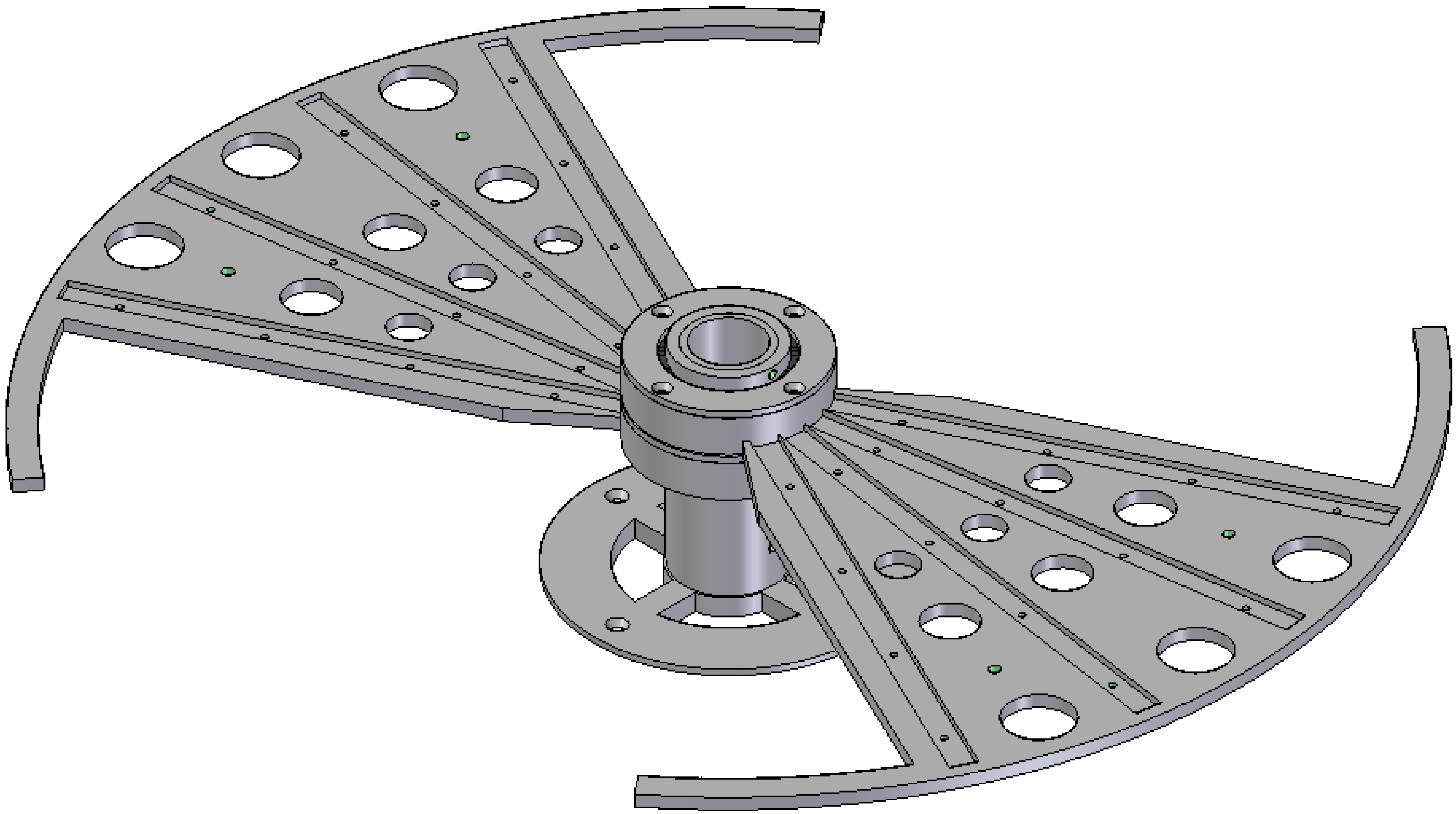
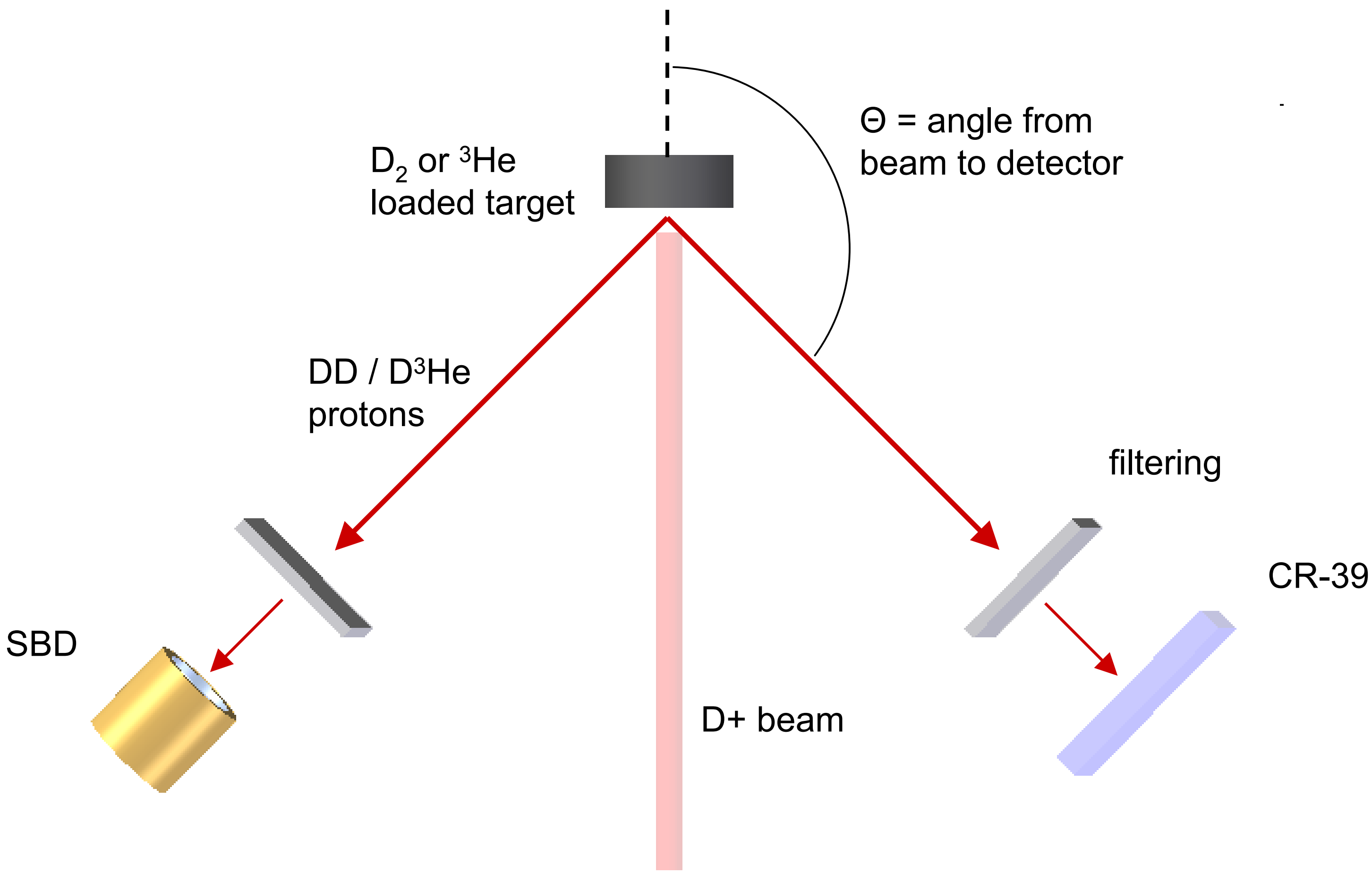
A new diagnostics chamber which provides great flexibility has been designed, built, and installed



New hardware has been fabricated to allow for easy and precise positioning of various detectors

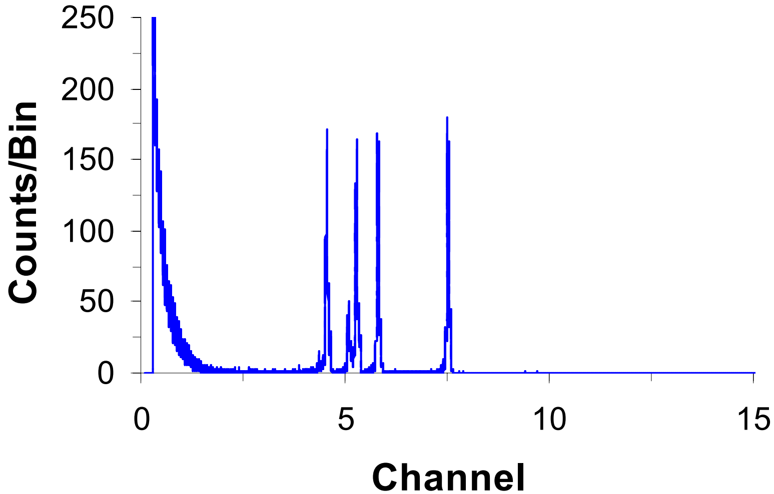


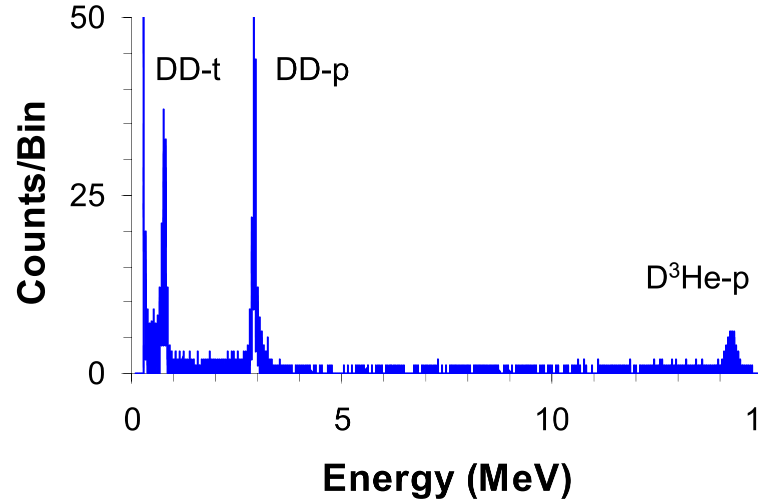
D^{3}He and DD reactions are being used to accurately characterize CR-39 proton response

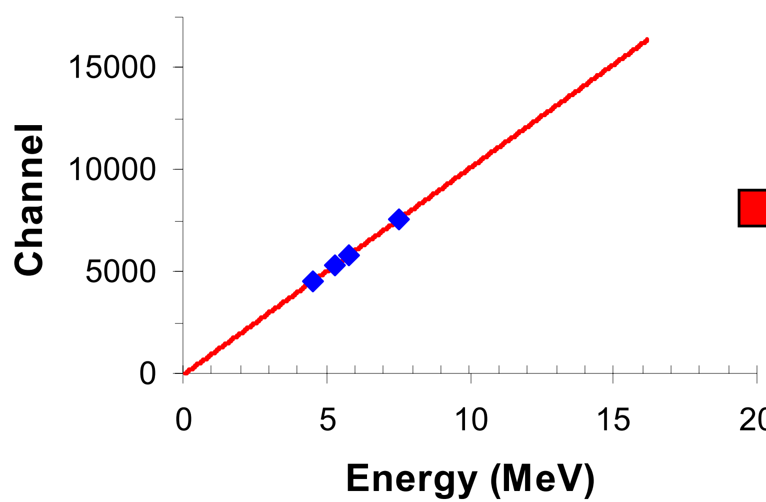


Particles at the same Θ and therefore the same energy are simultaneously monitored by a calibrated electronic system and CR-39 detectors.

Well-calibrated electronic detectors allow precise measurement of resultant fusion particles' energies





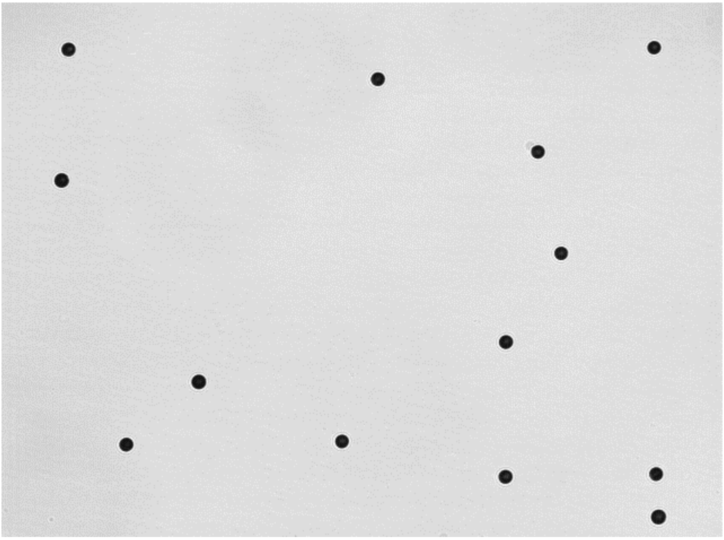


Four nearly monoenergetic alpha lines from a ^{226}Ra source provide a very good mapping between MCA channel and particle energy.

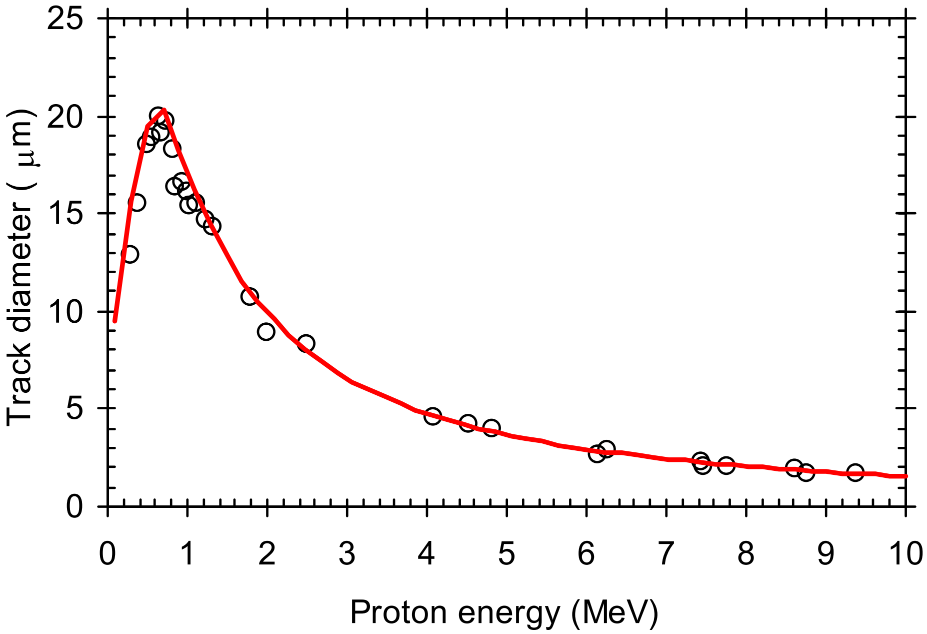
This mapping allows very accurate determinations of incident charged particles' energies

Calibrated protons will be used to calibrate the CR-39 response

Etched CR-39 has holes where particles entered which are analyzed under a microscope.



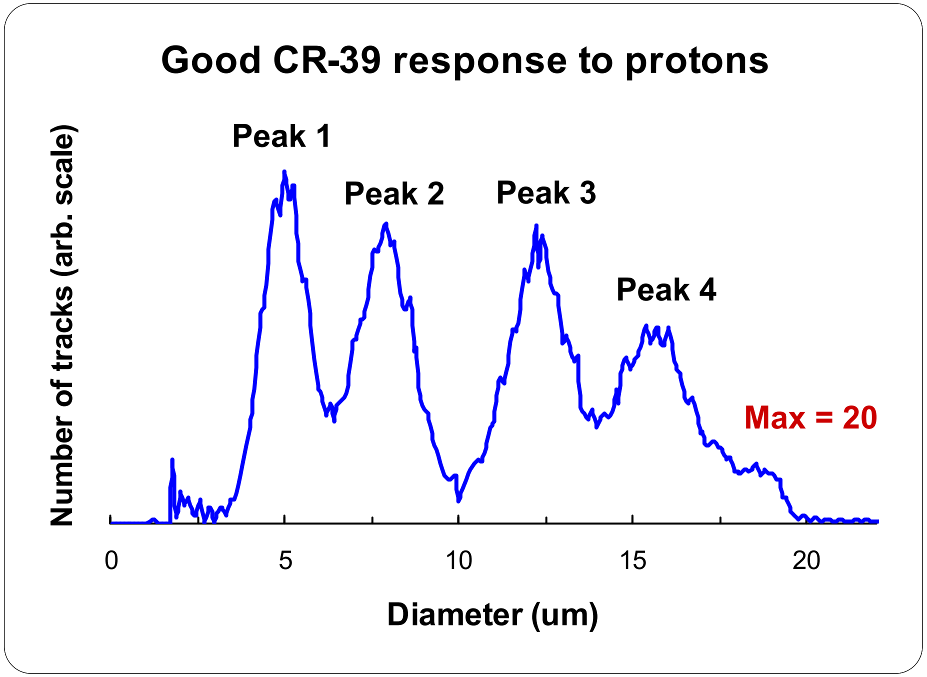
The hole diameter is proportional to dE/dx, therefore a calibrated mapping between proton energy and hole diameter can be obtained.

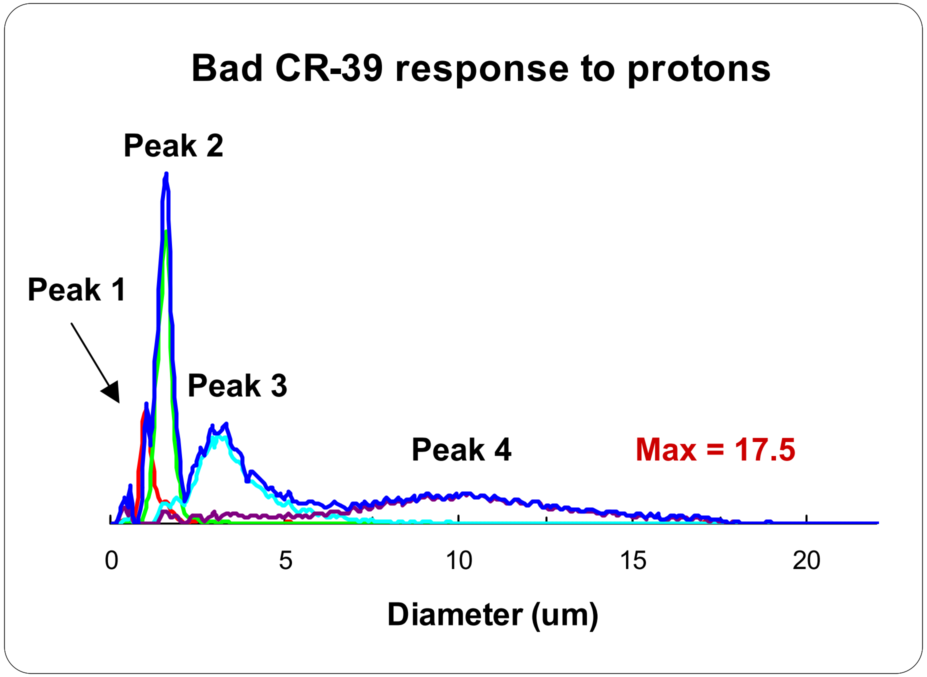


This diameter versus energy mapping can also be obtained for various etch times to compensate for any nonlinearities in the etch

Identifying and characterizing anomalous CR-39 proton response is an important capability

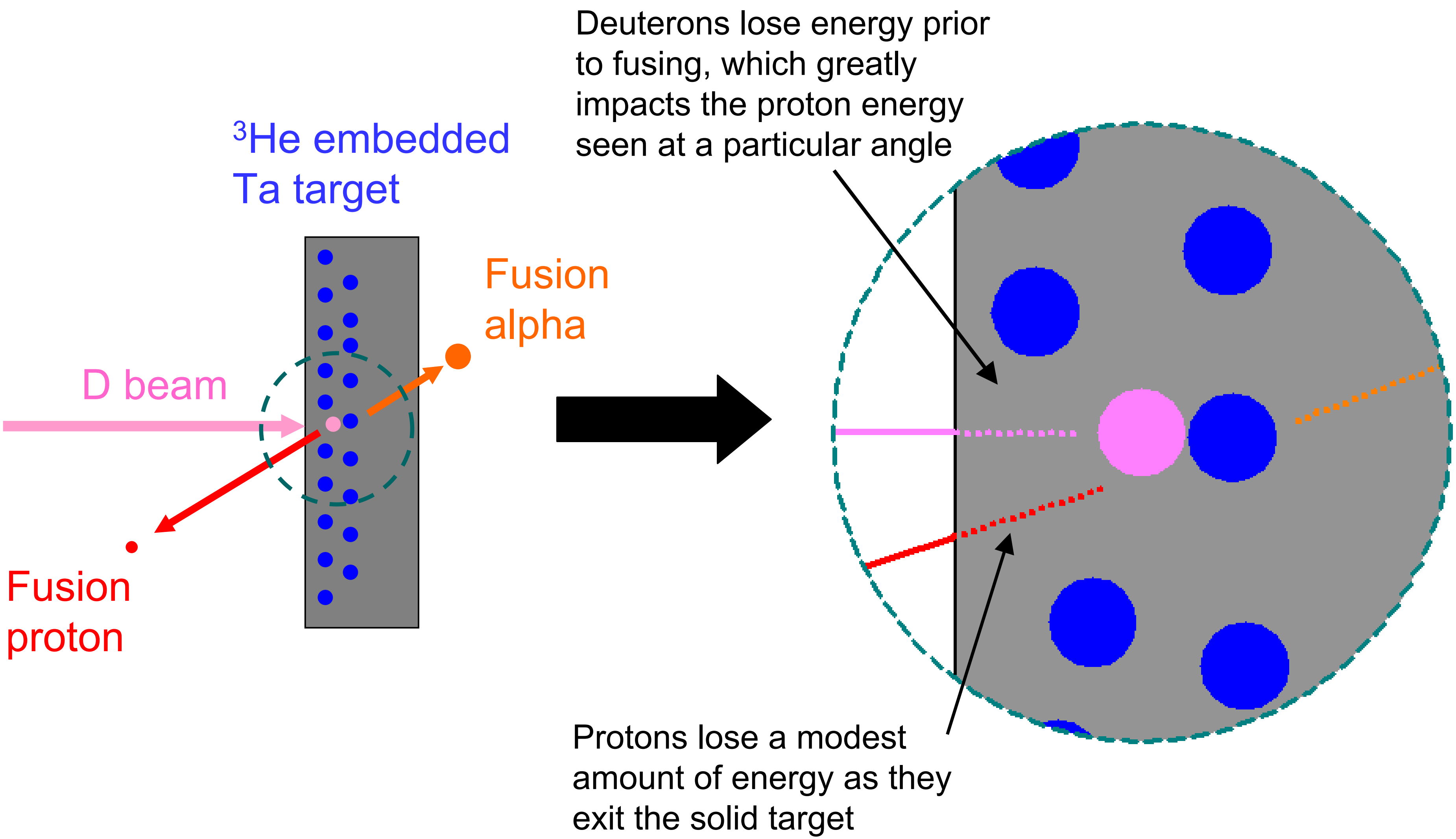
Sometimes, anomalous proton response is seen in certain sheets of CR-39. By using accelerator generated protons, we have the capability to identify the problem before these sheets are used for diagnosing an ICF capsule on OMEGA



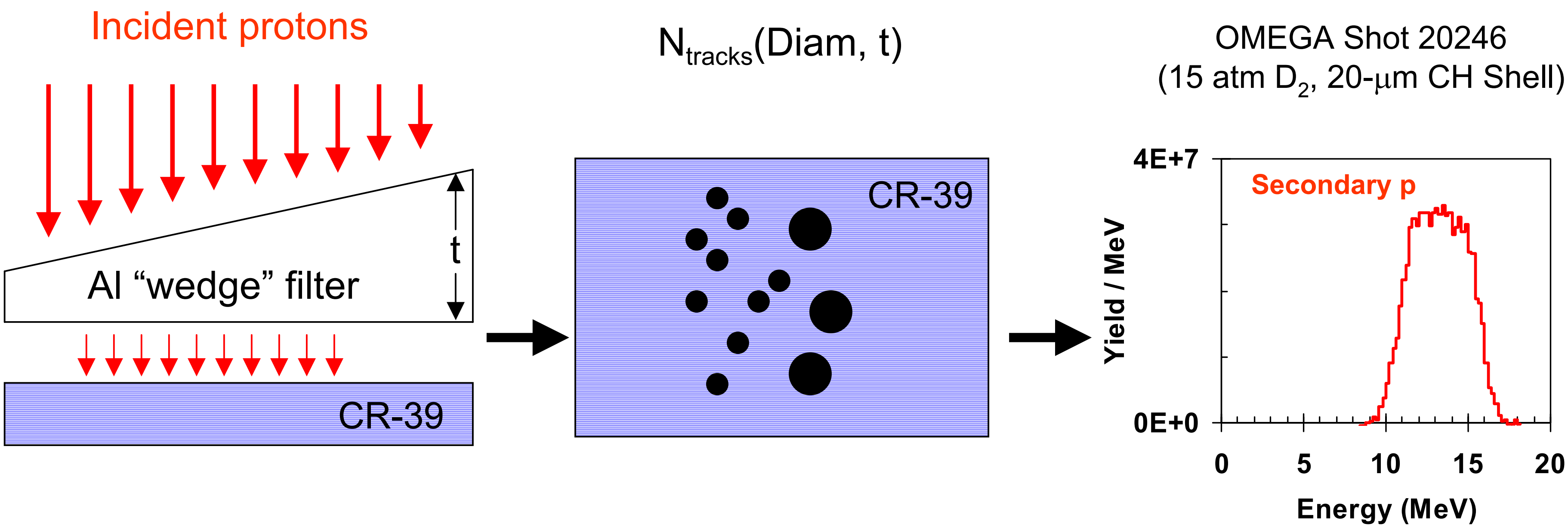


For this test, ‘good’ and ‘bad’ CR-39 were exposed to protons of four discrete energies at separate locations. On anomalous sheets, the tracks almost always appear significantly smaller than anticipated

Modeling and testing must be performed to more accurately characterize fusion production



WRF (wedge range filter) modules include a wedge shaped filter and CR-39 to measure proton spectra



Top view
of WRF

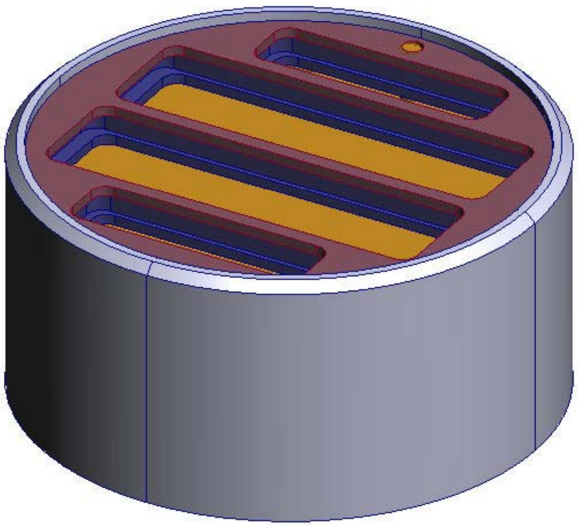
Front view
of etched CR-39

Reconstructed
spectrum

These current wedges will be re-calibrated, to account for any changes from use on OMEGA

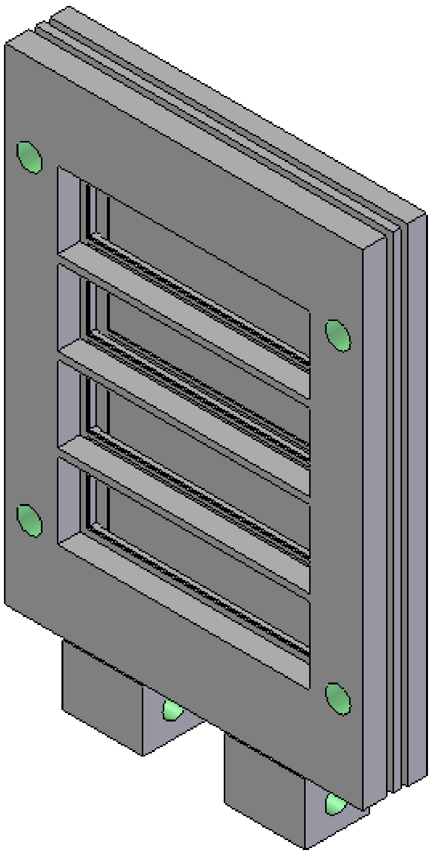
Precise calibrations of next-generation wedge spectrometers are to be performed

New wedge module currently being used to diagnose OMEGA implosions

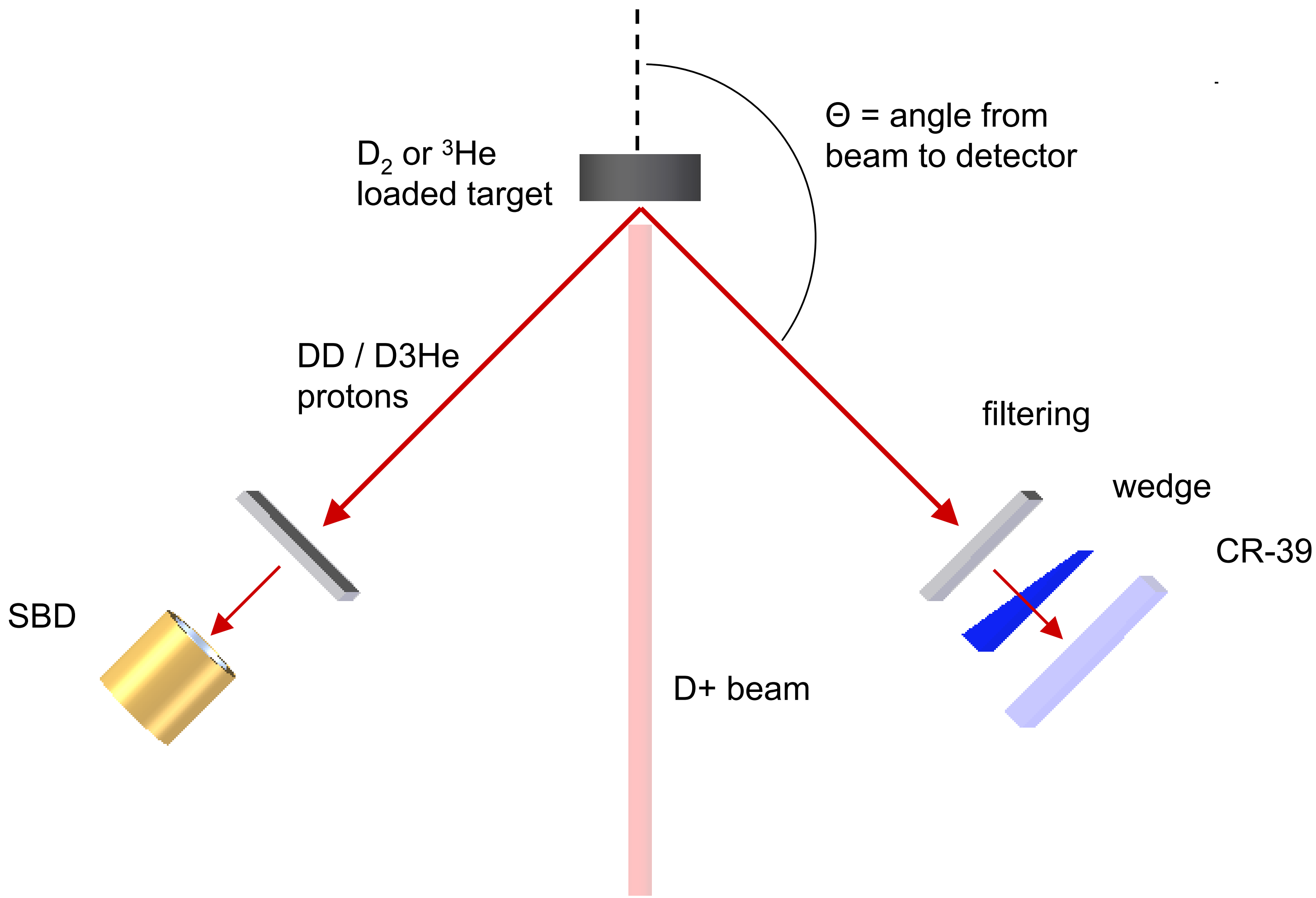


- $E_p \approx 2$ -20 MeV
- ρRs up to 200 mg/cm^2
- Modular & flexible
- Current accuracy ~100 keV
- Expected calibration accuracy < 50 keV

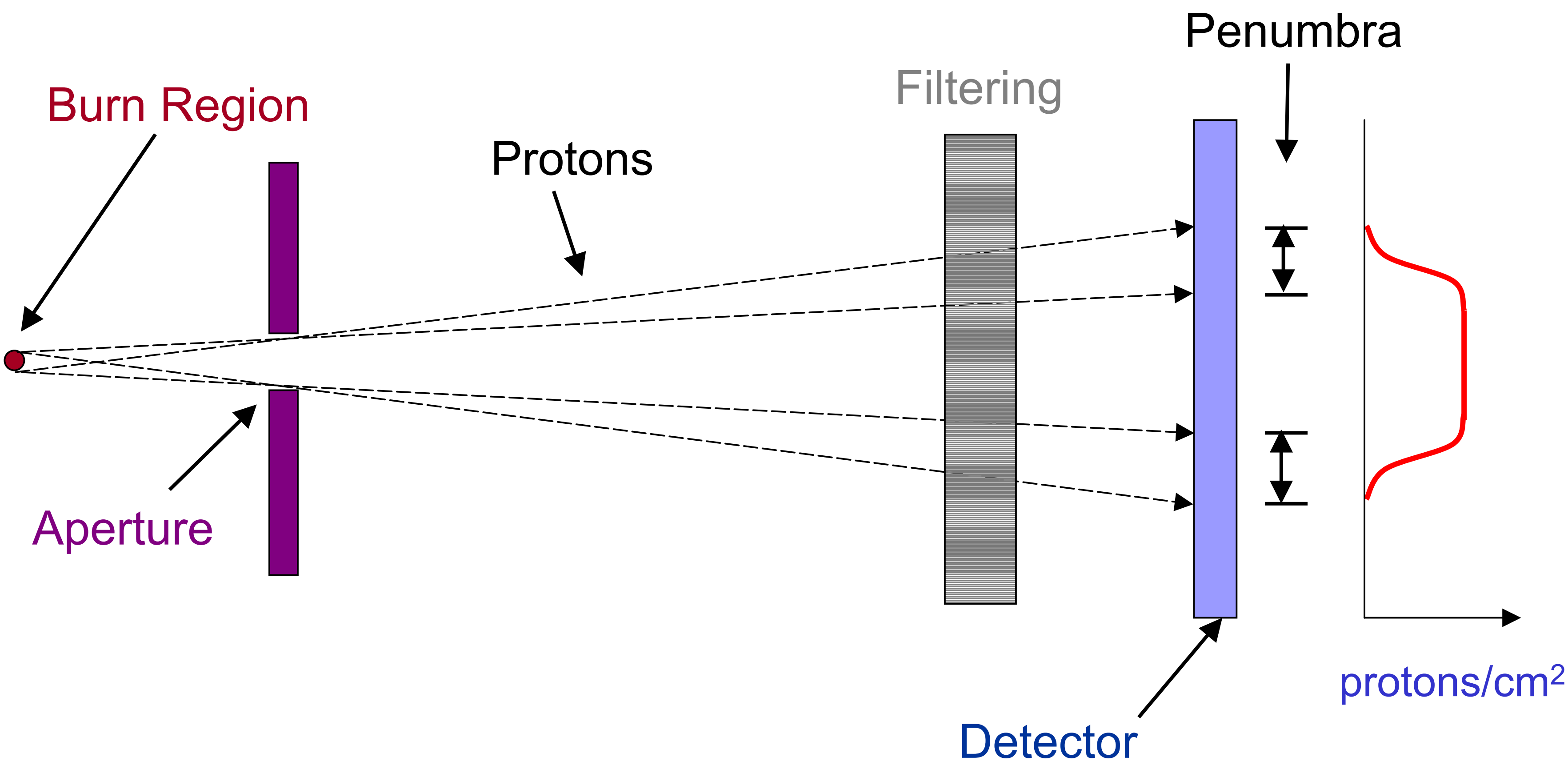
Wedge holder to be used on MIT accelerator to calibrate new wedges



Using the known CR-39 proton response calibration, a similar procedure can be used for the wedges



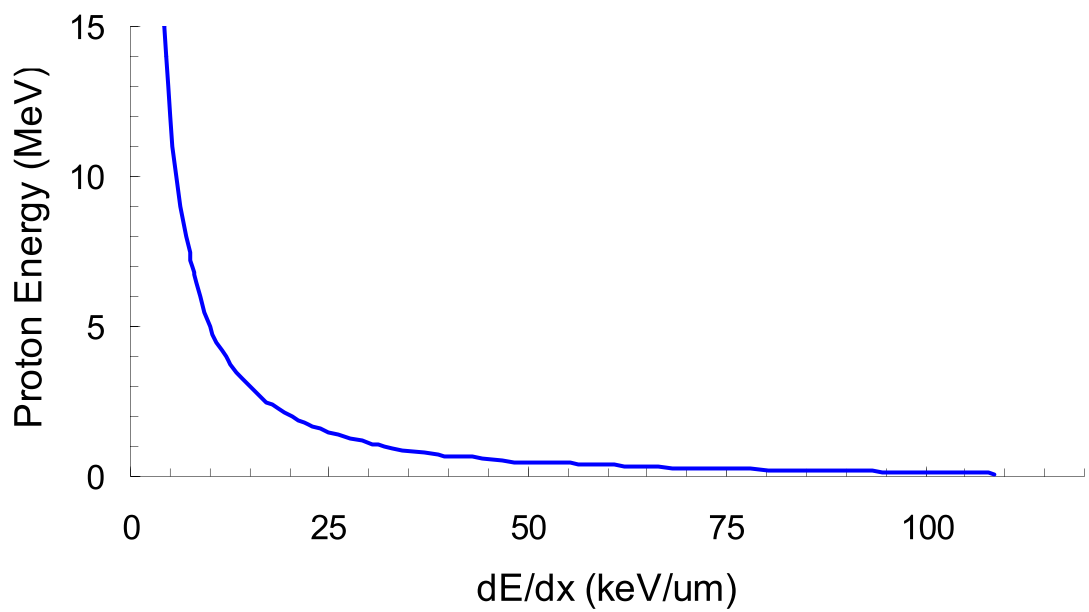
PCIS* uses penumbral imaging to obtain a burn-averaged image of the emission region

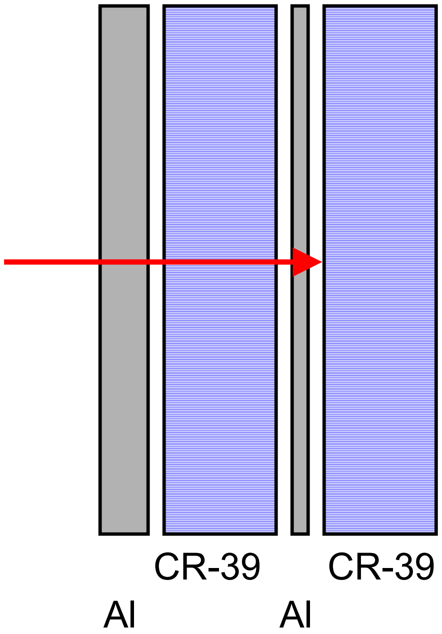


*Joseph DeCiantis CO1.011
Fredrick Seguin CO1.012

Since the PCIS filter pack includes CR-39, it is advantageous to empirically investigate the stopping power of CR-39

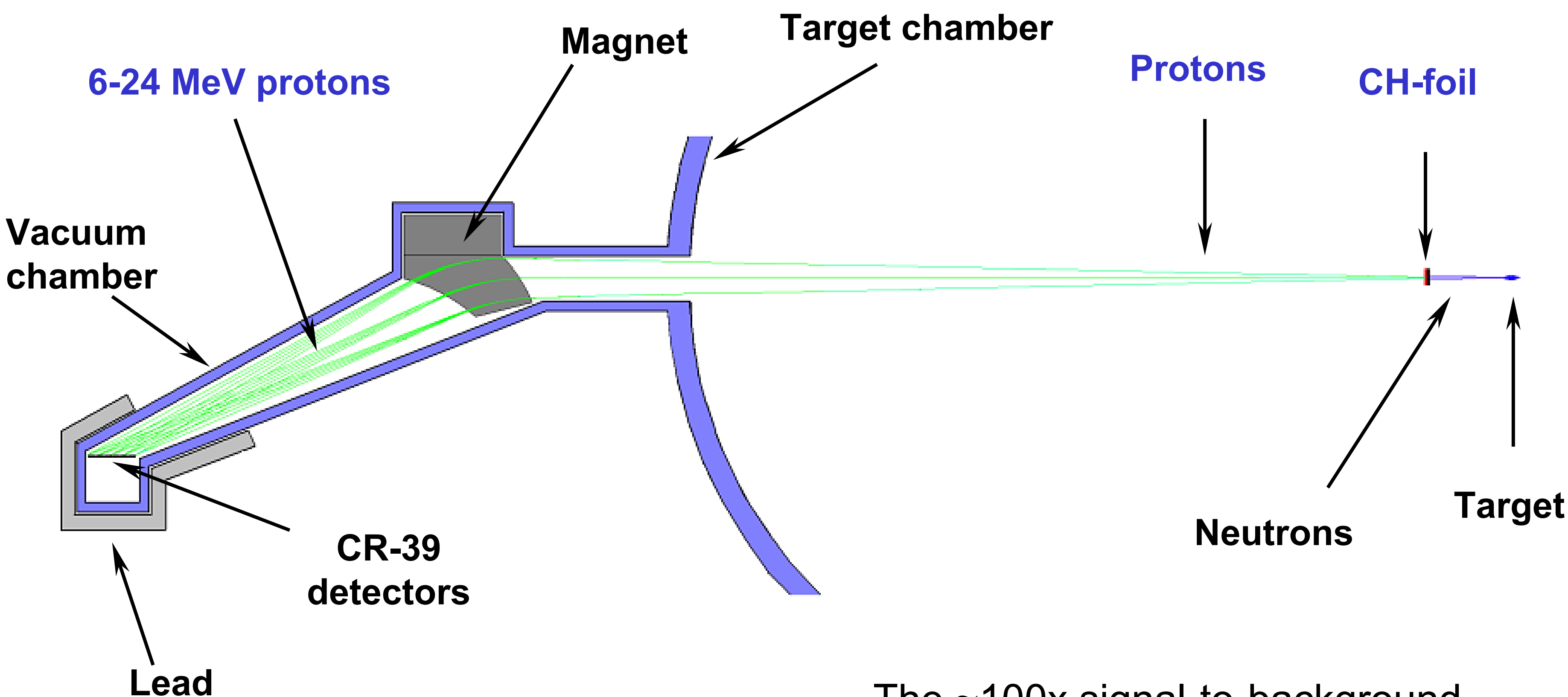
SRIM Stopping power of protons in CR-39





There is evidence that the D_3He protons detected on the front side of the back piece of CR-39, have energies that are slightly different from those calculated using SRIM. The accelerator can help elucidate any discrepancies.

The MRS* neutron spectrometer, a NIF core diagnostic, relies upon CR-39 coincidence detection

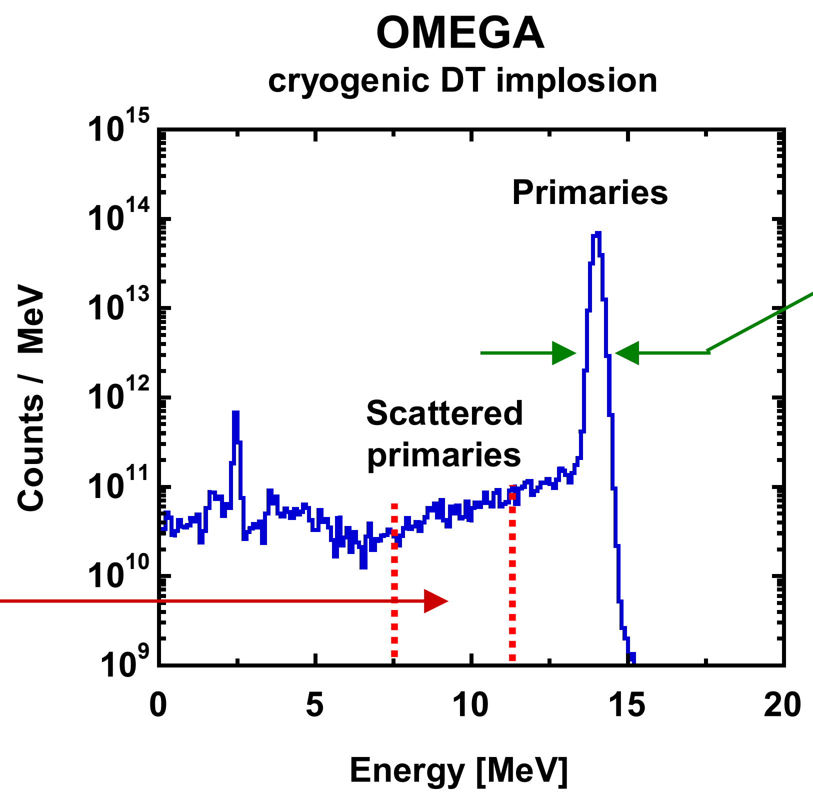


The ~100x signal-to-background improvement will allow measurement of the full DT neutron spectrum

*J. A. Frenje et al. Rev. Sci. Instrum. 73 (2002) 2597

The MRS will reconstruct the DT neutron spectrum, from which the capsule ρR and T_{ion} can be inferred

The yield of scattered DT neutrons will be used to infer the capsule ρR

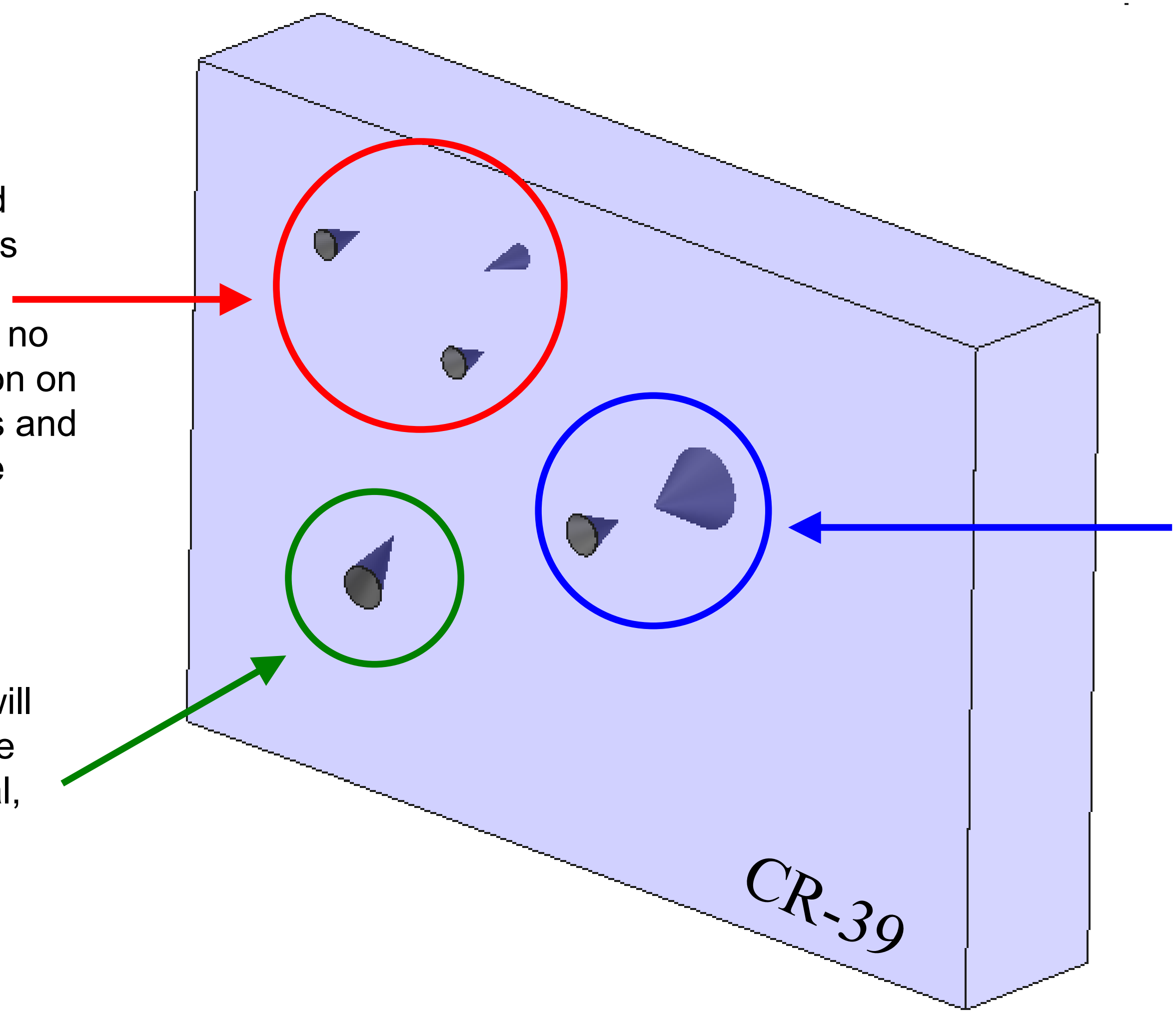


The ion temperature can be inferred from the width of the primary DT-n spectrum

Calculation by
S. Hatchett (LLNL)

The coincidence counting technique is being developed, tested, and improved

Neutron induced tracks, as well as intrinsic noise tracks, will have no spatial correlation on the two surfaces and can therefore be rejected



A fusion proton will leave a hole on the front and back surfaces of the CR-39, at the same (x,y) position, and with different diameters according to the energy of the particle at that surface

Also, many neutron tracks will be rejected since they are elliptical, due to a non-normal angle of incidence