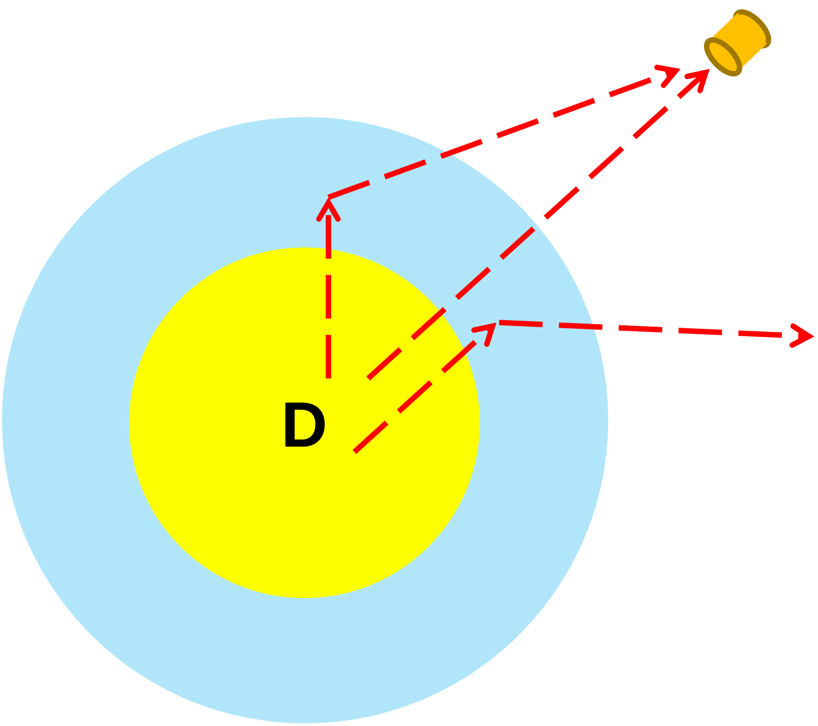
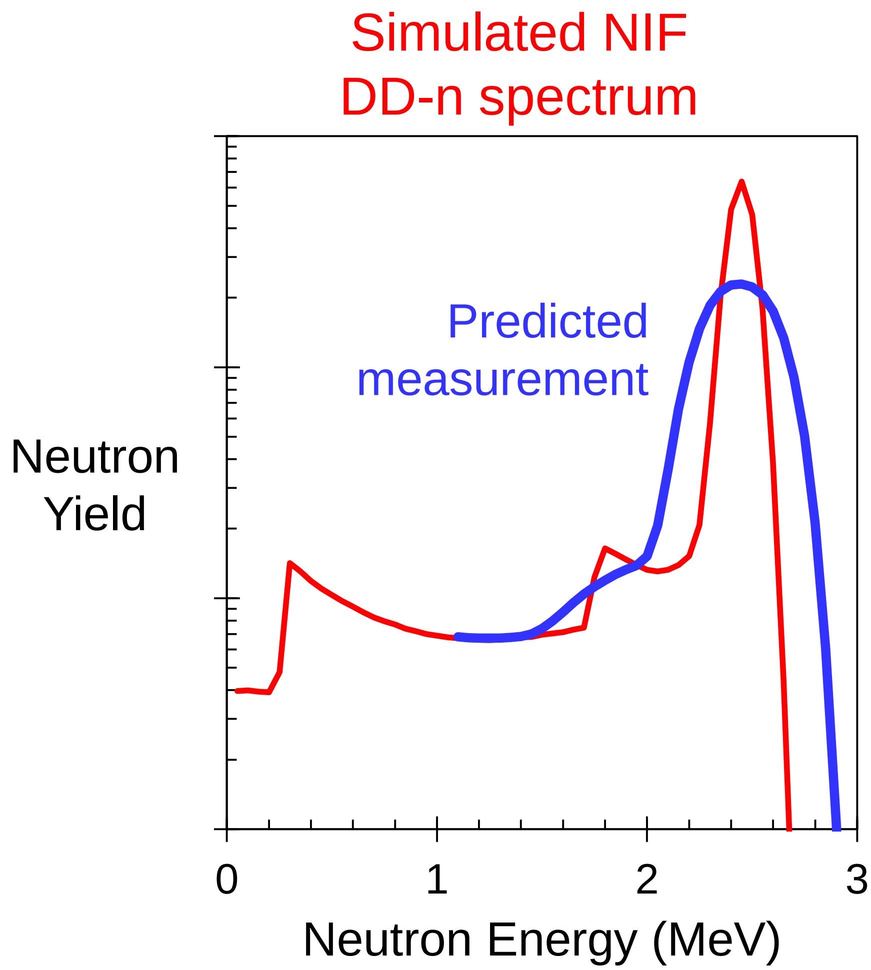
Compact DD-n spectrometer for Yield, T_i , ρR & symmetry at Z, OMEGA, NIF, and for Discovery Science

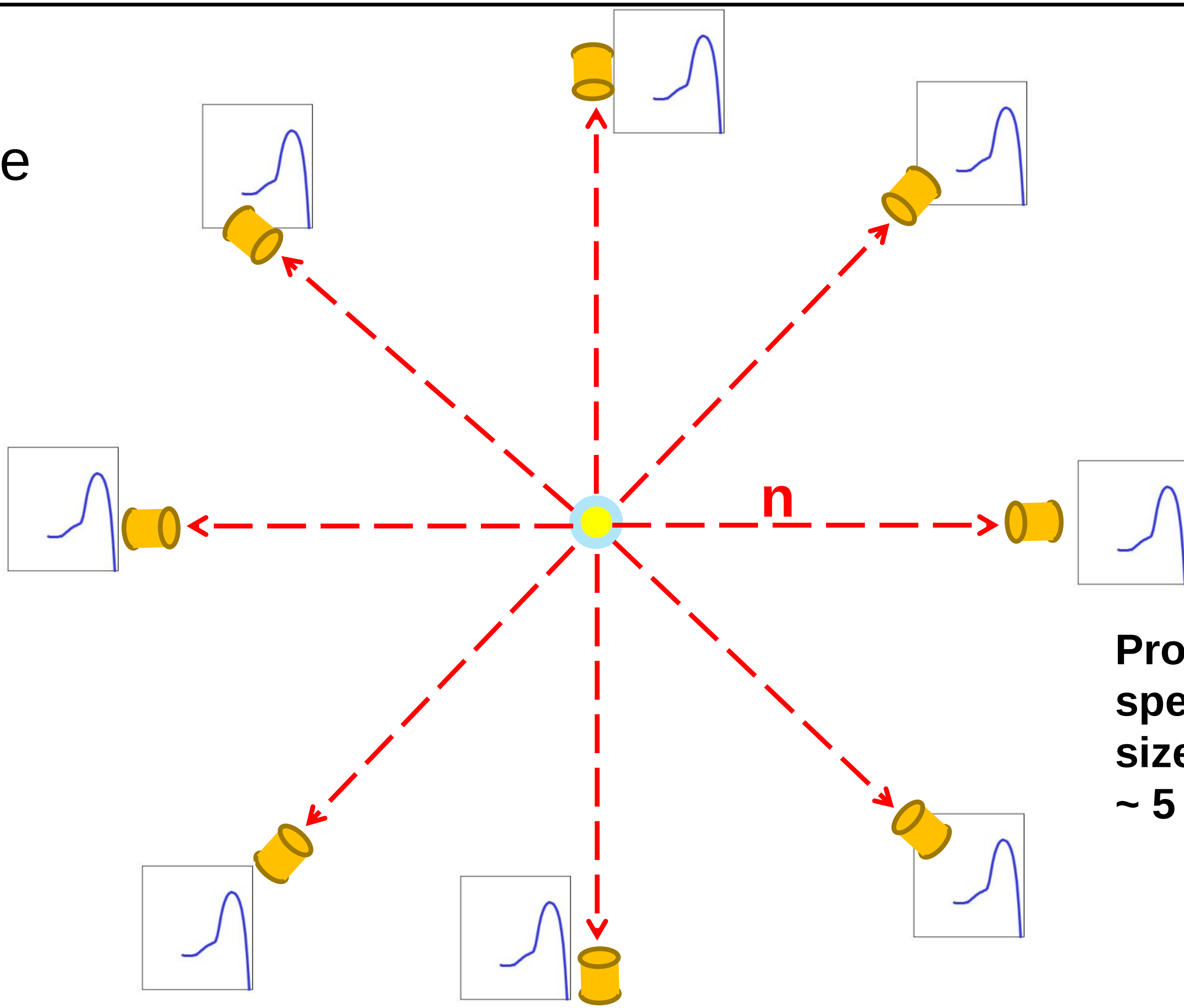
D + D →
^{3}He + **n (2.45 MeV)**





Compact DD-n spectrometers enable multiple views of an implosion for symmetry studies of yield, ρR, …

- Small
- Passive



Prototype spectrometer size ~ 5 cm x 7 cm

Collaborators

MIT

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C. Waugh
H. Sio*
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**Students*
[1]Currently at Imperial College, London

Outline / Summary

- Motivation for absolute spectral DD neutron measurements
- Method: n-p recoil with CR-39 detectors and “coincidence” noise reduction
- Initial tests of concept elements:

  a. Measured spectrum of accelerator-generated neutrons
  without using “coincidence” noise reduction

  b. Collect and evaluate n-p test data on CR-39
  during Z shots of 14-18 Sept 2015

  c. On-going tests of coincidence counting at MIT Accelerator Facility:

    (i) Signal only tests
    (ii) Signal and 2.5 MeV neutron noise background together
    (iii) Monte-Carlo simulations of signal and background
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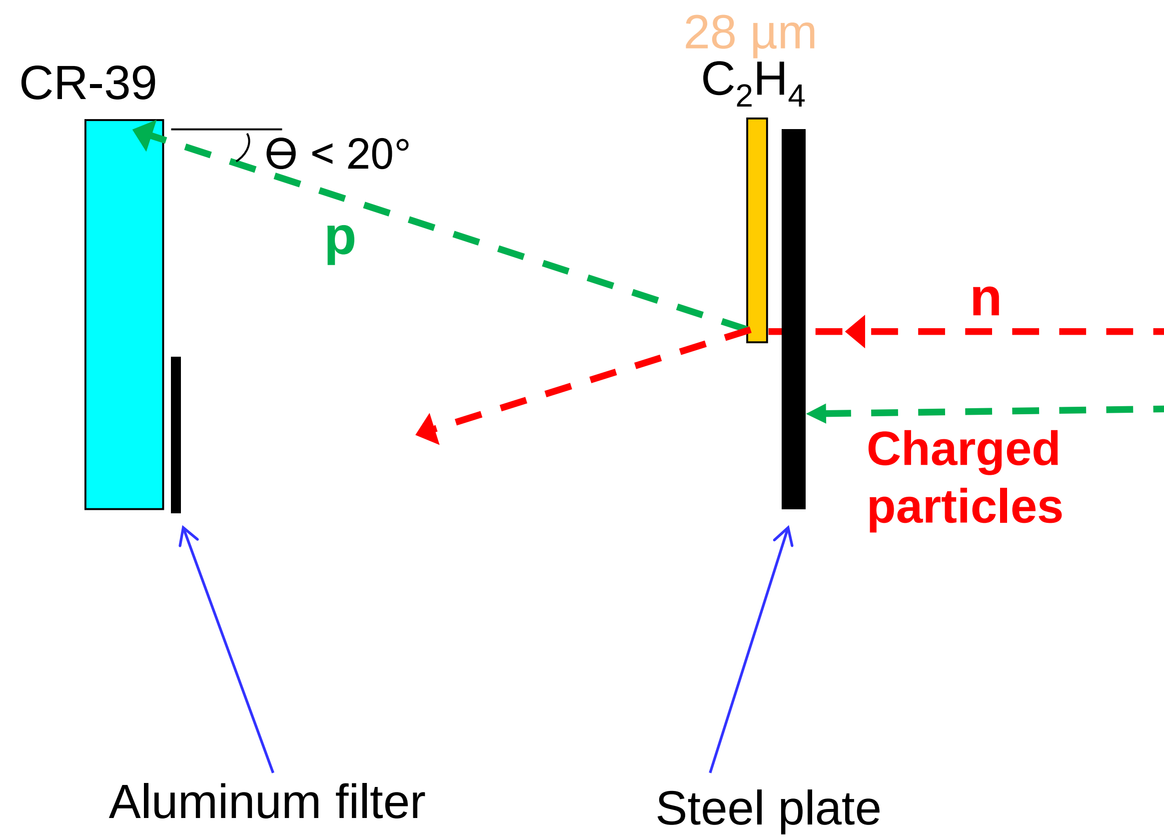
    (v) Fully integrated test of all spectrometer elements

- Future: Field at Z, Omega, and the NIF.

A DD-n recoil spectrometer can be made using a passive CR-39 nuclear track detector

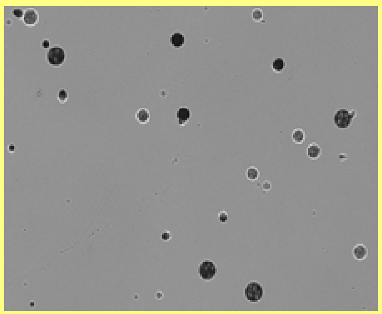
<u>**CR-39 records recoil protons from *n,p* interactions in a CH foil**</u>



A DD-n recoil spectrometer can be made using a passive CR-39 nuclear track detector

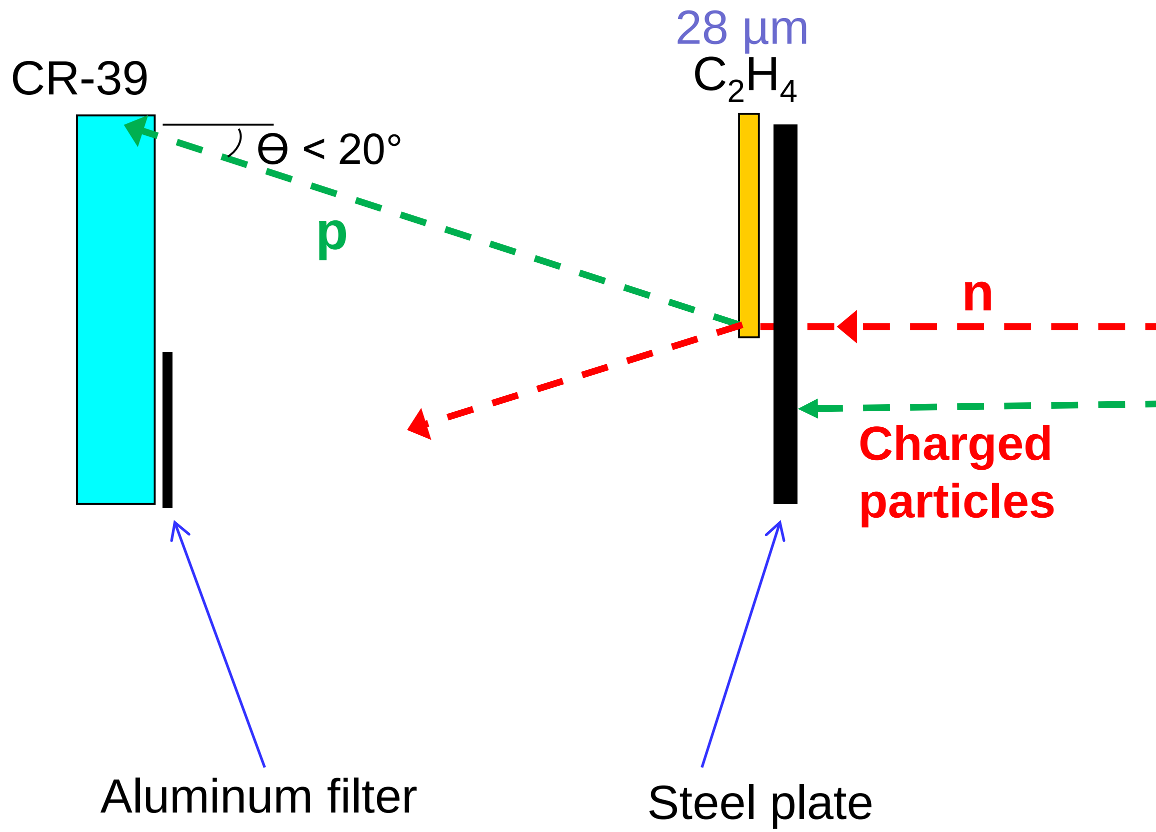
CR-39 records recoil protons from *n,p* interactions in a CH foil

Etching the CR-39 reveals proton tracks on the surface

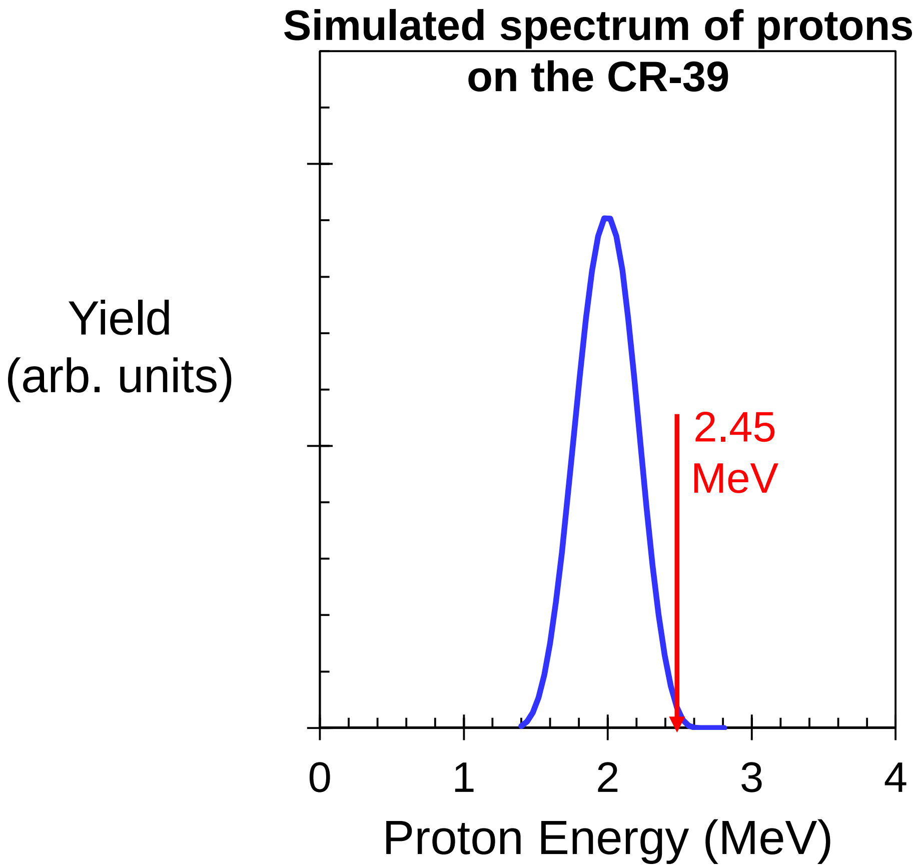


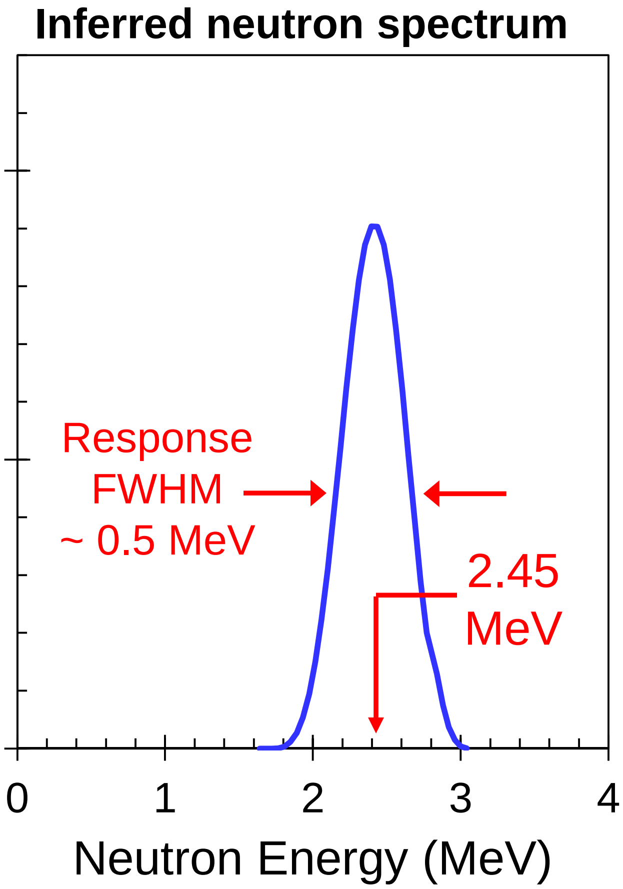
Proton energy will be determined based on track size on the CR-39

Neutron background will be reduced with coincidence counting



Using this geometry, an estimated response to monoenergetic 2.45-MeV neutrons is calculated





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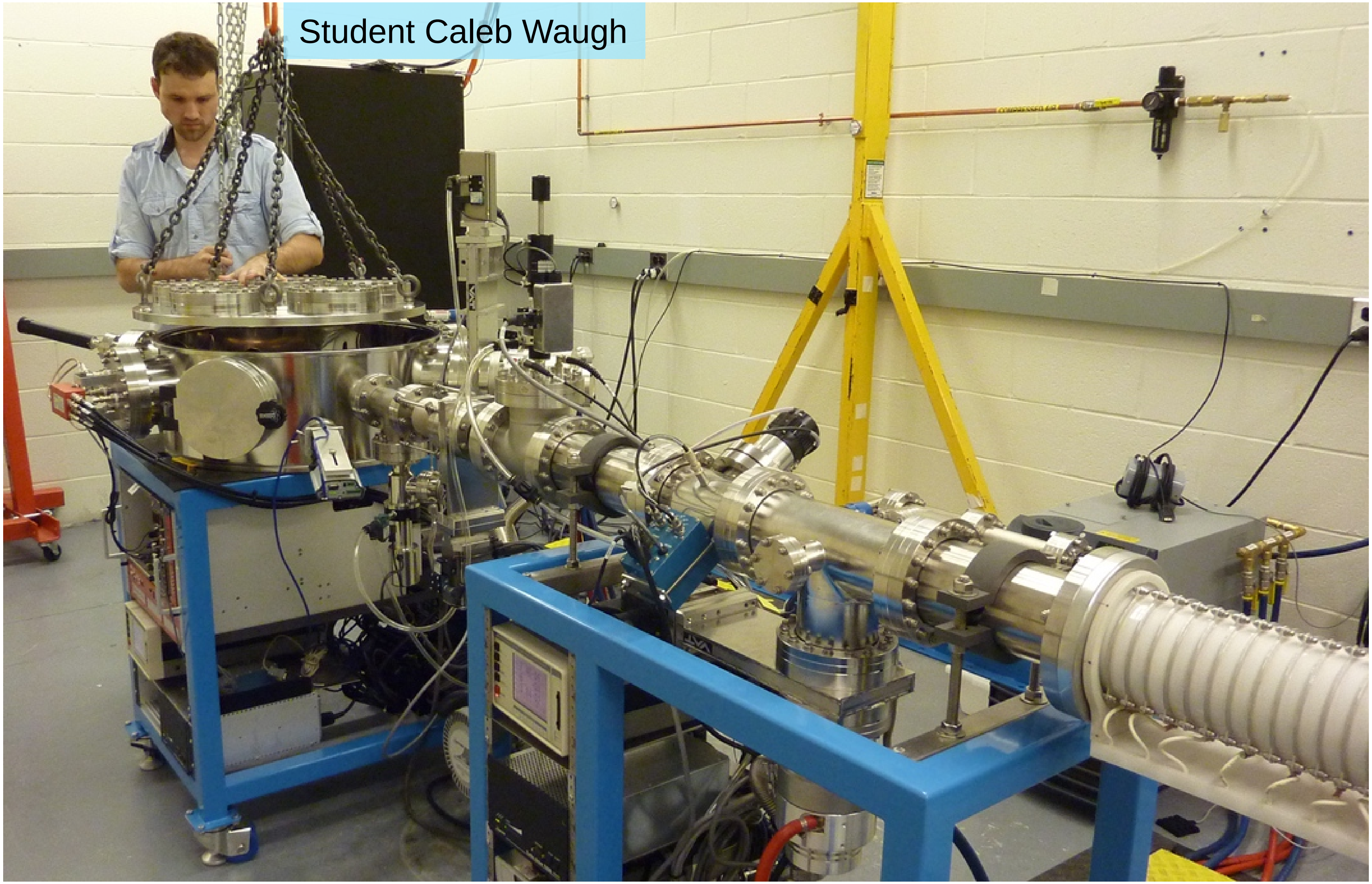
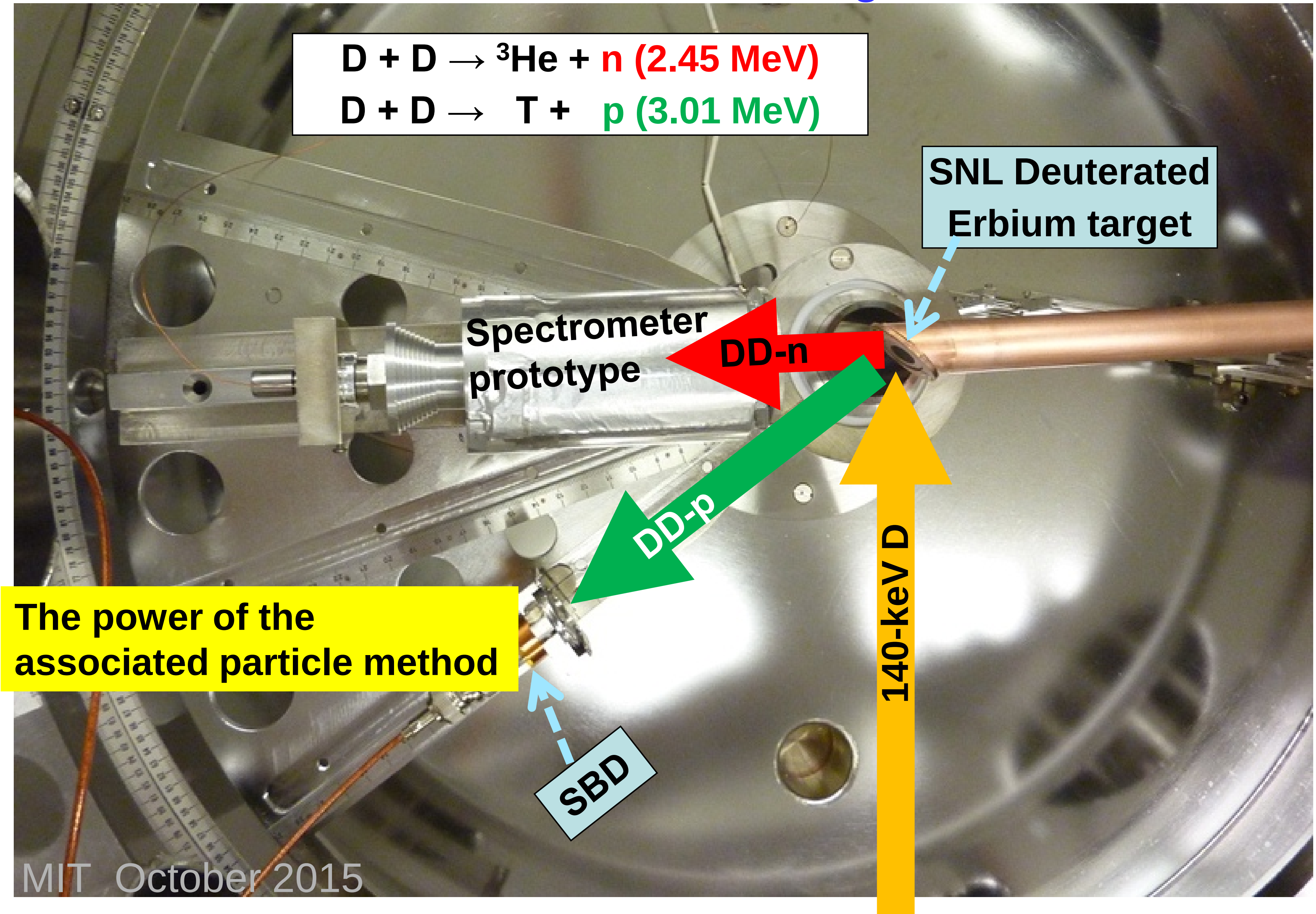
A proof-of-principle test of a prototype was carried out on the MIT accelerator without using coincidence noise reduction*

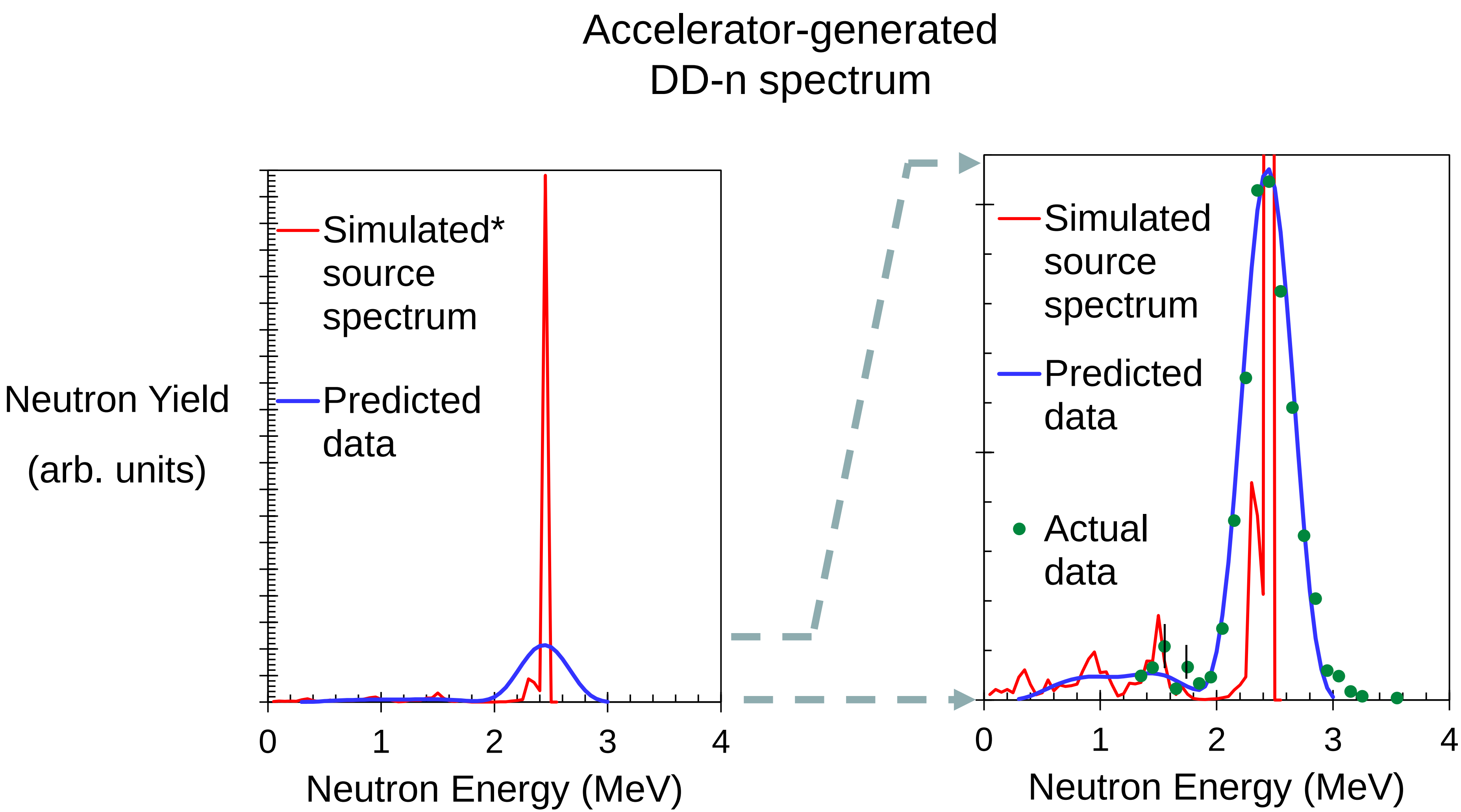


*Seguin *et al*., Bull. Am. Phys. Soc. (2012)

Tests utilized DD-n from fusion reactions in the accelerator target

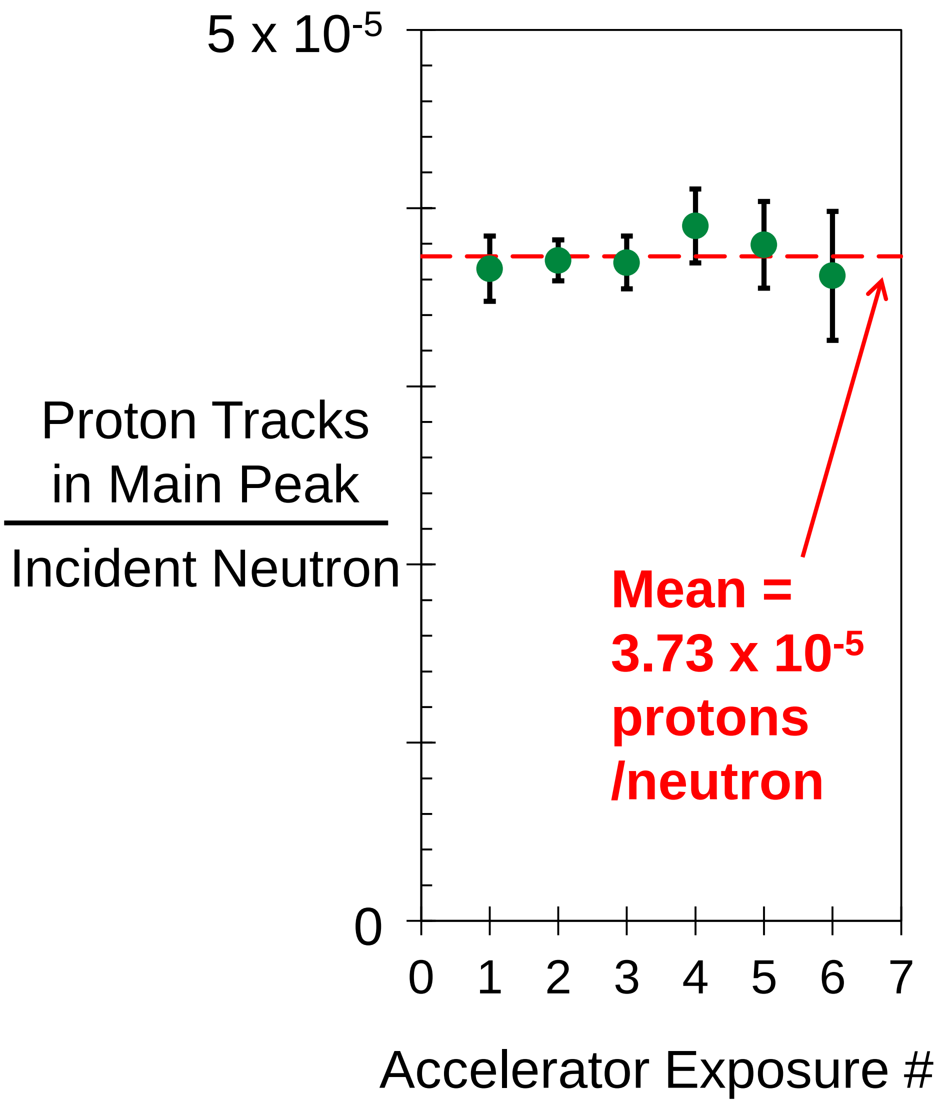


The measured spectrum shape agrees well with expectations



*Simulated with MCNP by D. Casey

The measured detection efficiency provides a well-defined quantitative sensitivity



Expected signal level at 20 cm on Z:

Yield	Signal
1e9	~100
1e12	~100,000

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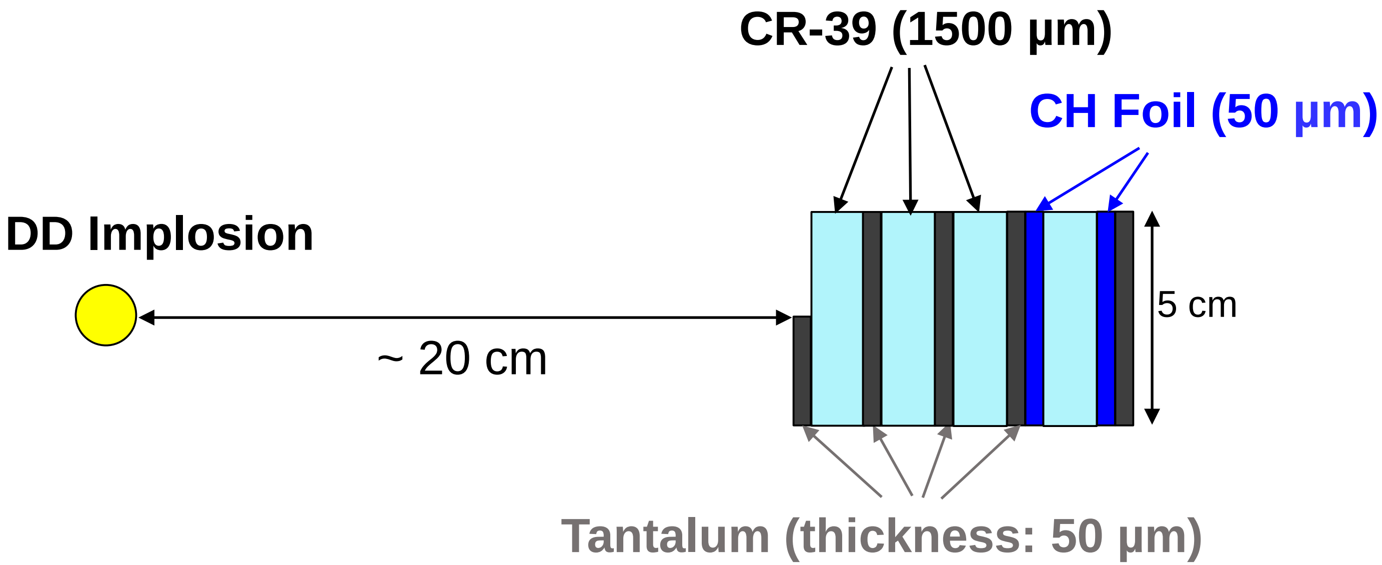
Test data with simple CR-39 packages were acquired on 14-18 September 2015 during MagLIF shots 2849-52 (DD-n yields ~ $3x10^{10}$ – $2x10^{12}$)



Data about to be analyzed

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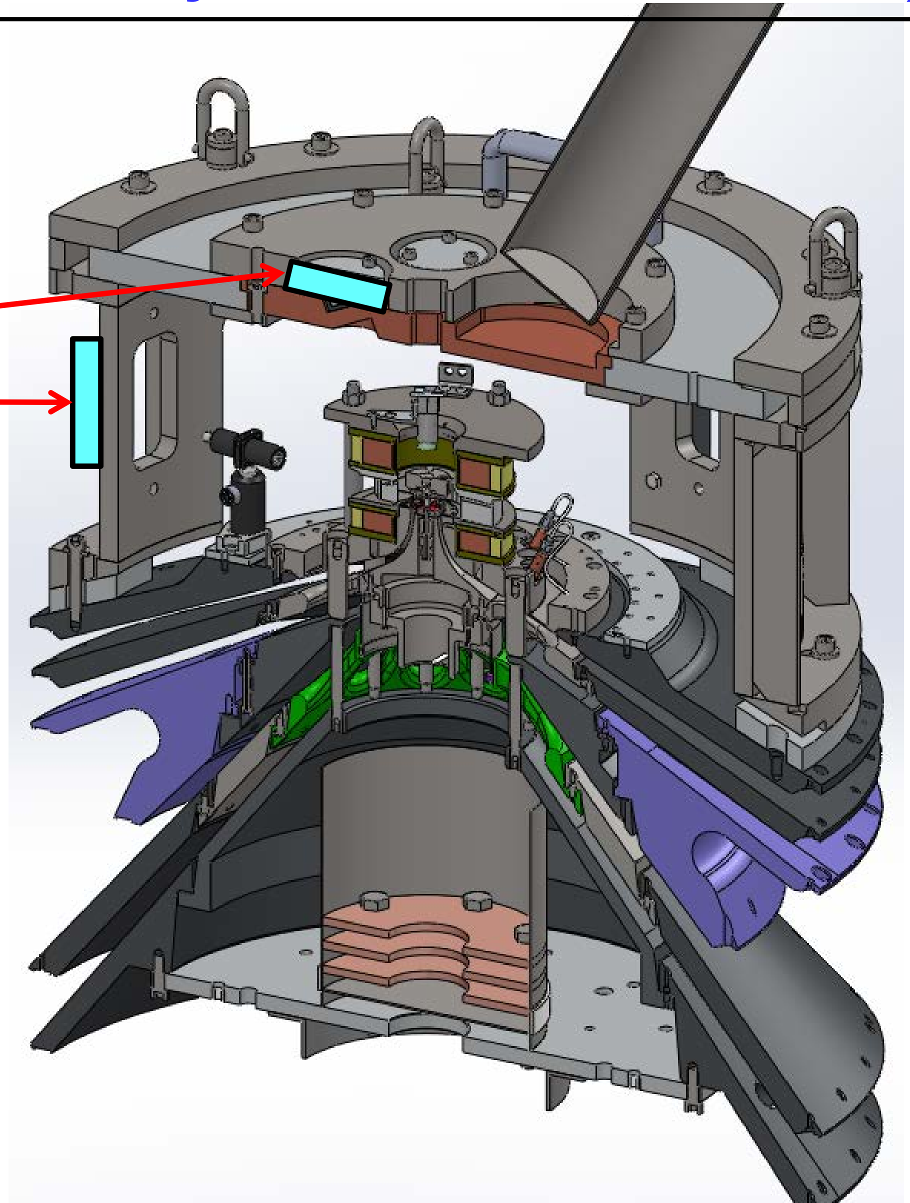
CR-39 test packages



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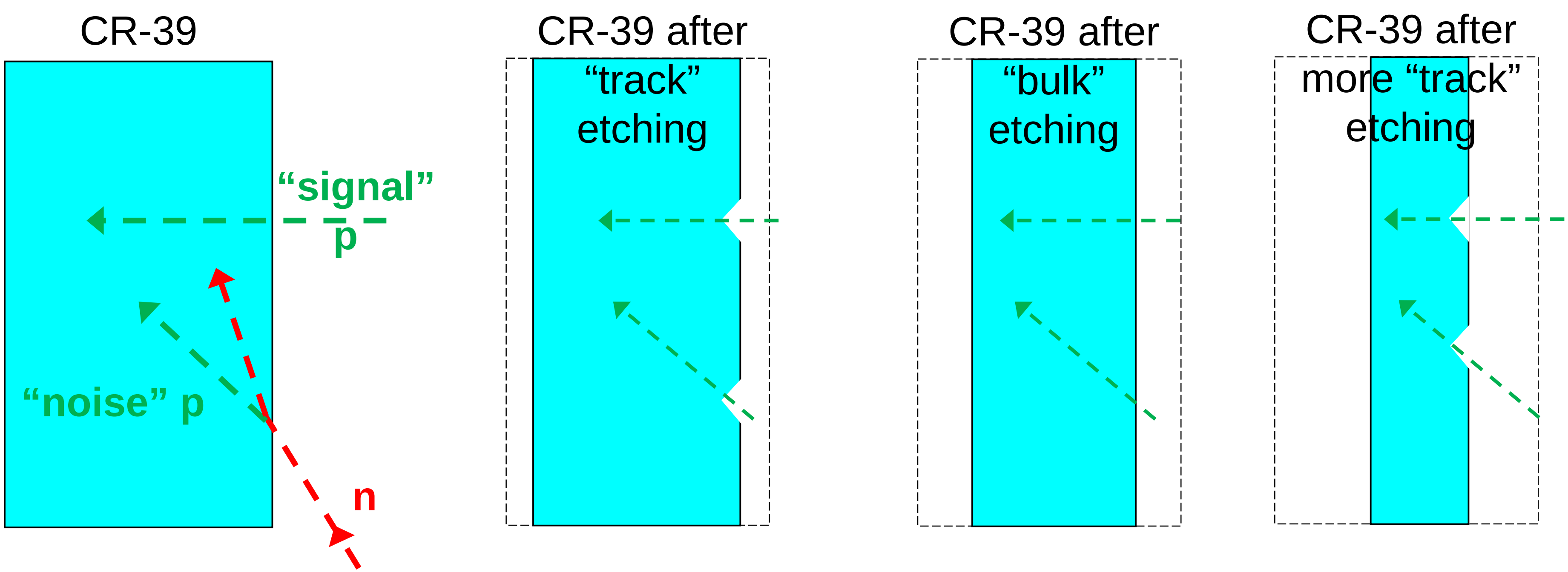
The Coincidence Counting Technique (CCT)* is used to eliminate neutron-induced noise (and "intrinsic" noise) in CR-39 track data



*D. T. Casey *et al.*, ***RSI*** (2011)

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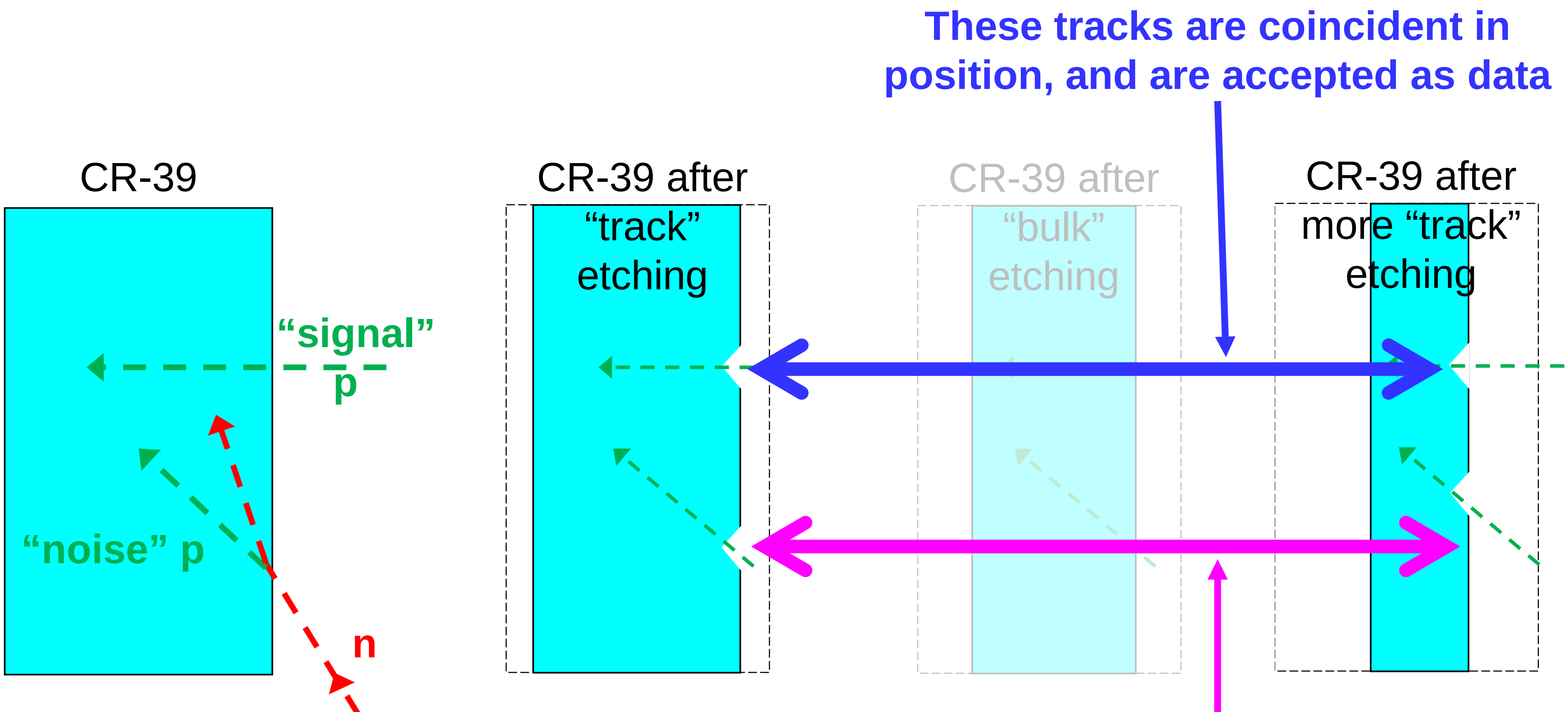

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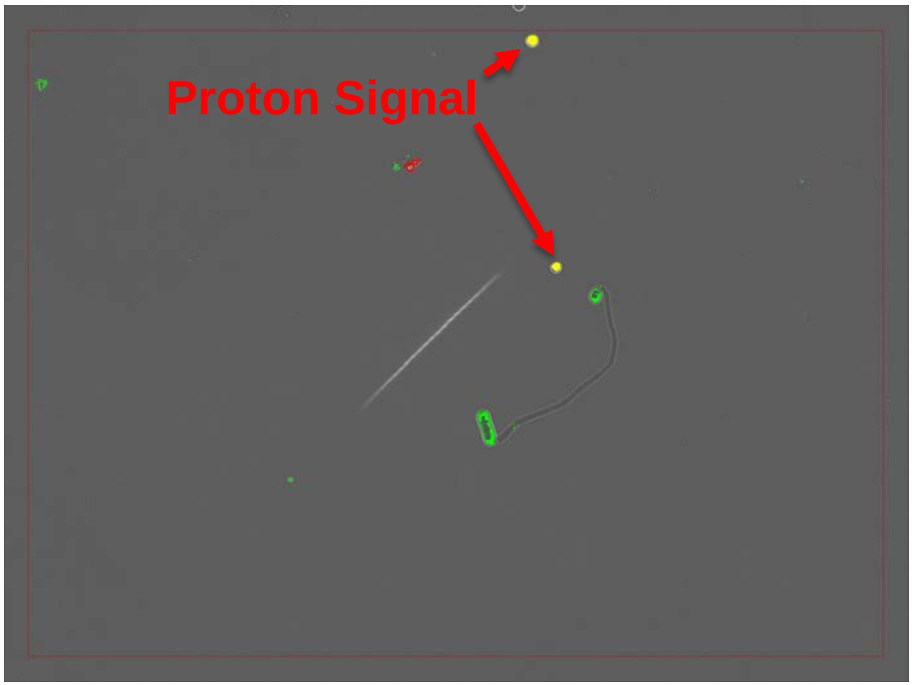
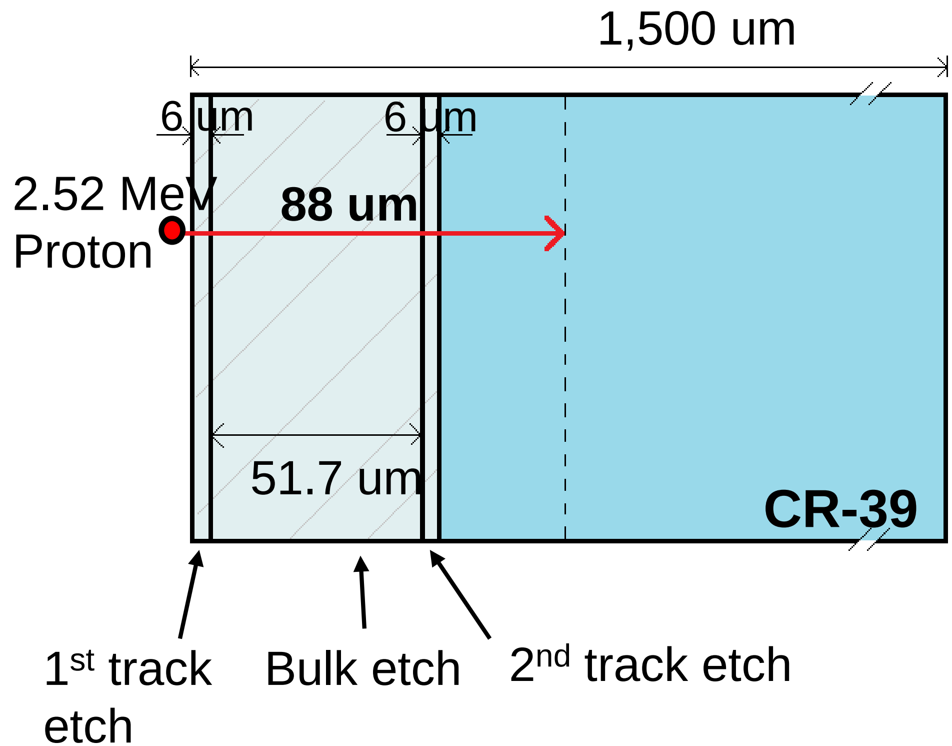
Tests of coincidence counting are being conducted at the MIT Accelerator Facility

(i) Signal only tests using DD protons from MIT accelerator

First track etch before bulk etch:



Accelerator shot A2015091702



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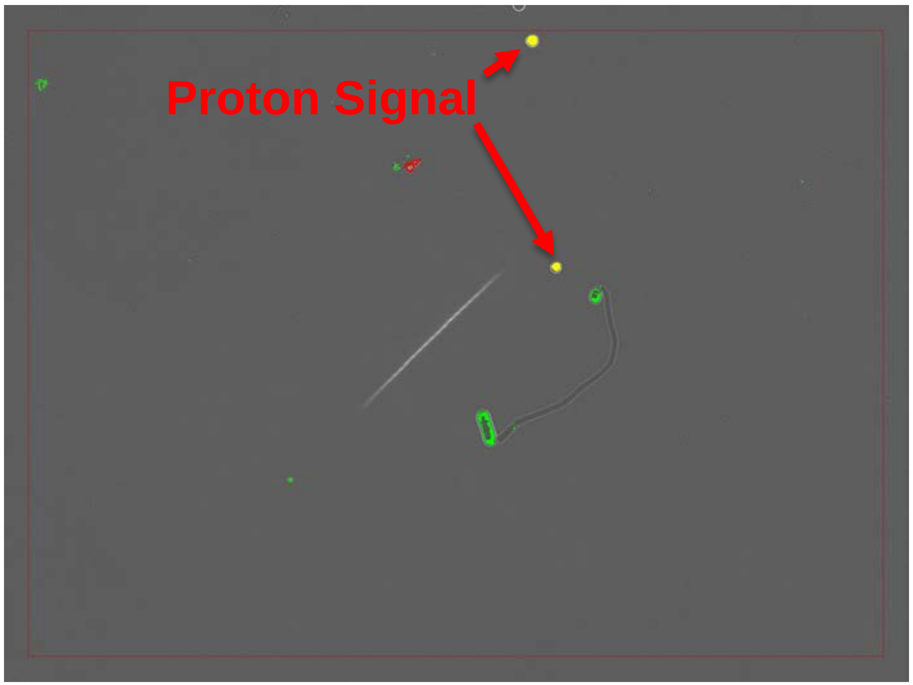
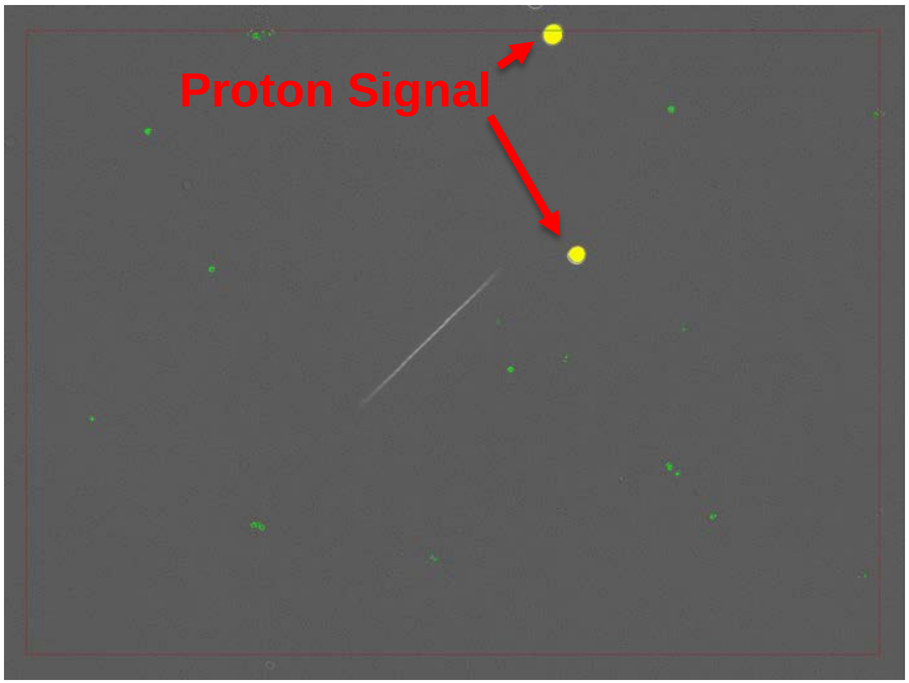


Standard front-side analysis:
8533 protons counted

Second track etch after 52 μm bulk etch:



Standard front-side analysis:
8536 protons counted

CCT analysis:
8540 protons counted

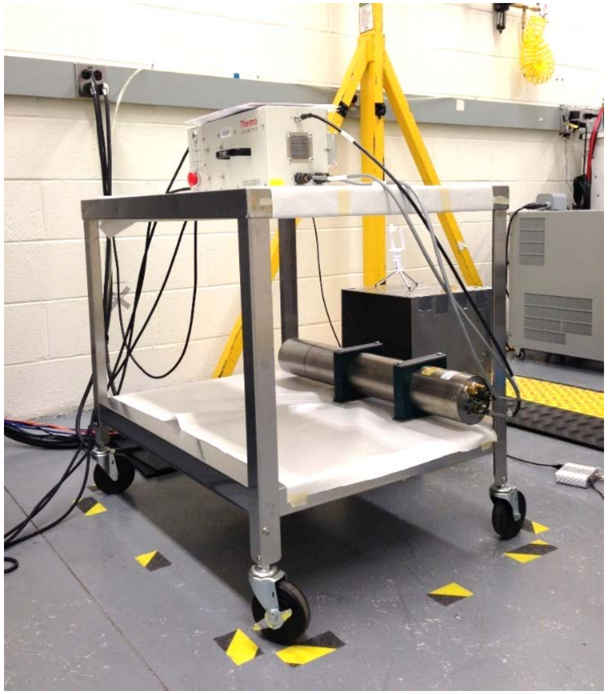
Next steps include noise rejection tests using neutrons from our DD neutron generator

(ii) Signal and 2.5 MeV neutron noise together (noise from DD-n generator)

(iii) Monte-Carlo simulations of signal and background

(iv) Determination of spectrometer sensitivity, characteristics

(v) Fully integrated test of all spectrometer elements



Our DD and DT neutron sources can easily generate neutron fluences replicating conditions at 1e7-1e15 yield applicable to OMEGA, Z and NIF

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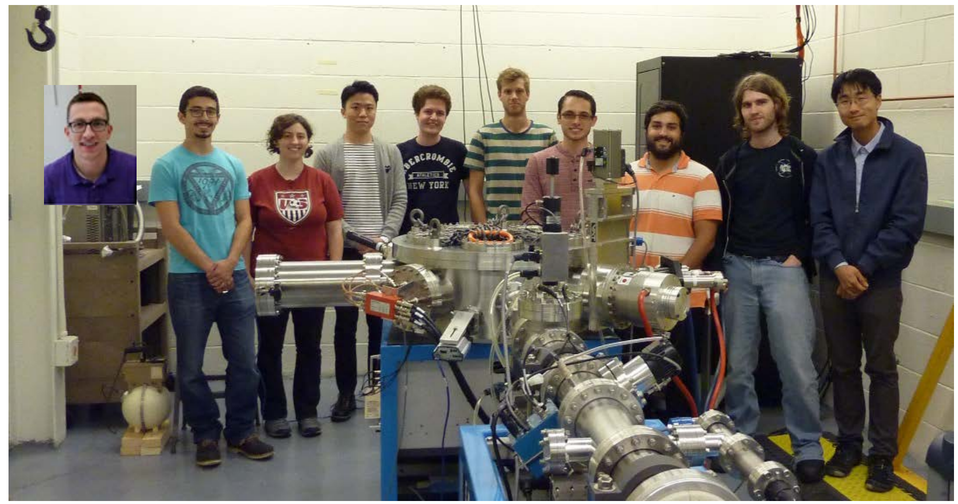
Future

For programmatic and Discovery Science,

DD-n spectrometers will be fielded at:

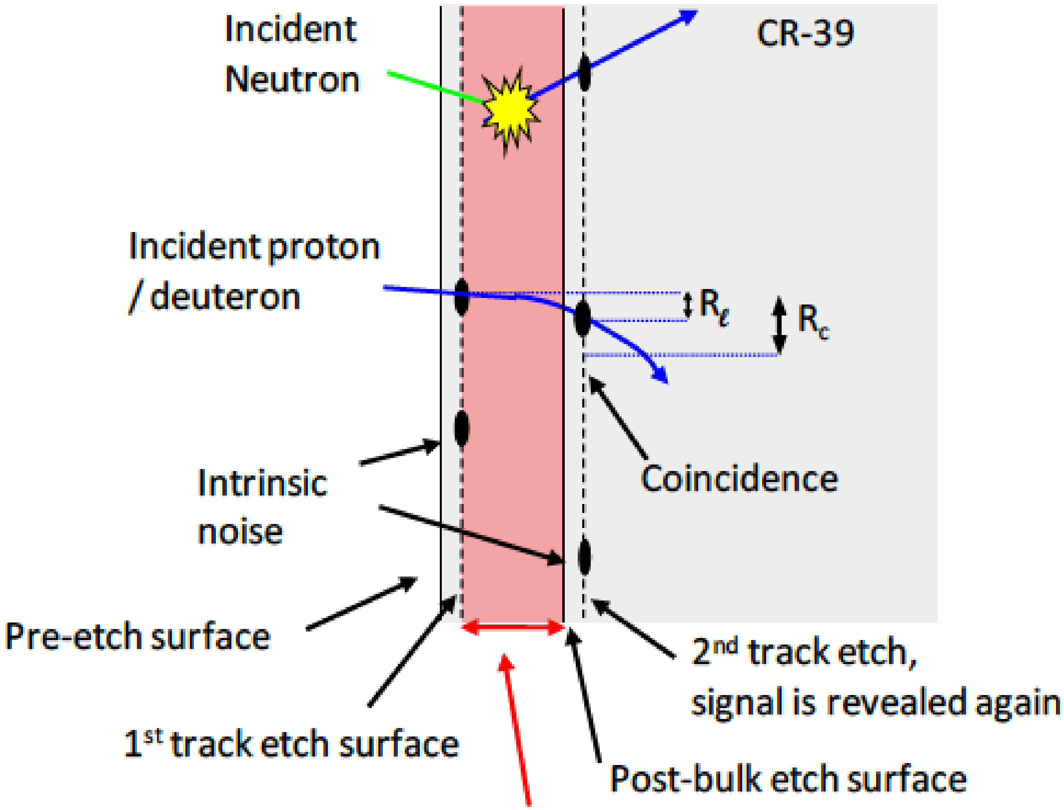
- Z
- OMEGA
- NIF



This will offer a great opportunity for MIT PhD students -- Harry Han, Lucio Milanese, Graeme Sutcliffe, … -- to be directly involved with science on these premier HED facilities

END

The Coincidence Counting Technique (CCT)* for eliminating noise in CR-39 track detectors



Bulk etch: up to 200 μm removed

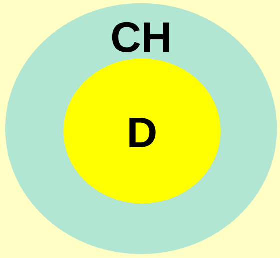
The CCT is used to:

- **discriminate between proton-induced and neutron-induced tracks**
- **reduce the intrinsic and neutron-induced noise by a factor of 100**

*D. T. Casey *et al.*, ***RSI*** (2011)

We can scale the prototype test results to estimate performance with a plausible NIF implosion

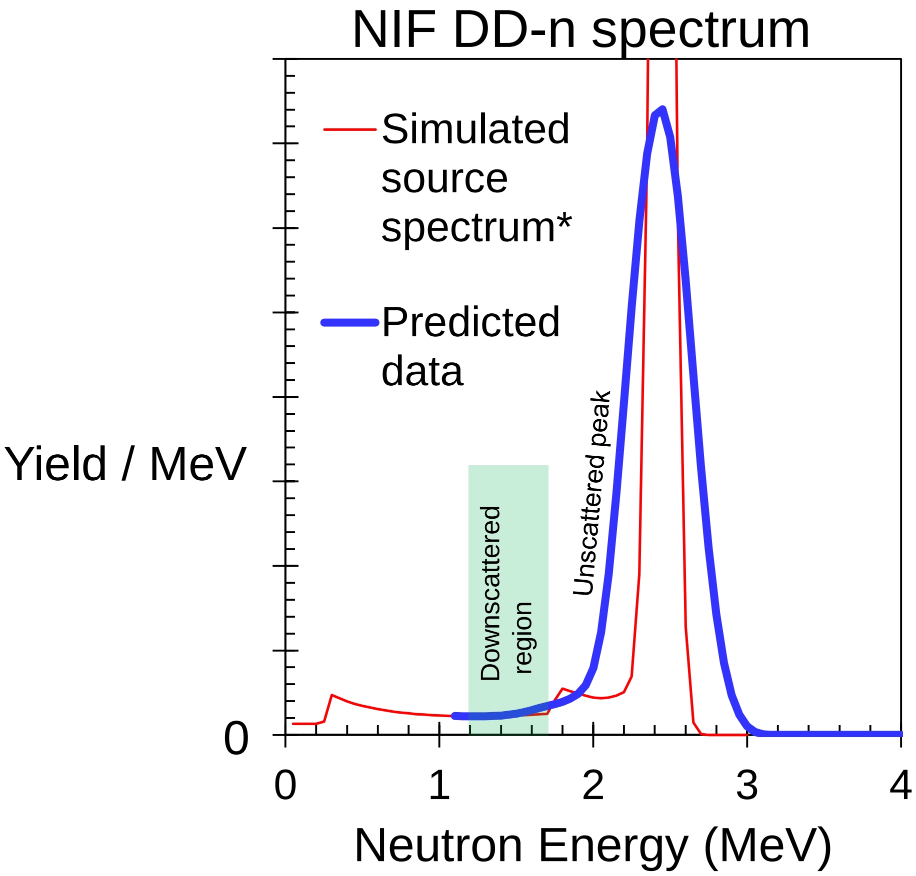
Assumed parameters at bang time



CH shell: ρR ~ 600 mg/cm^2

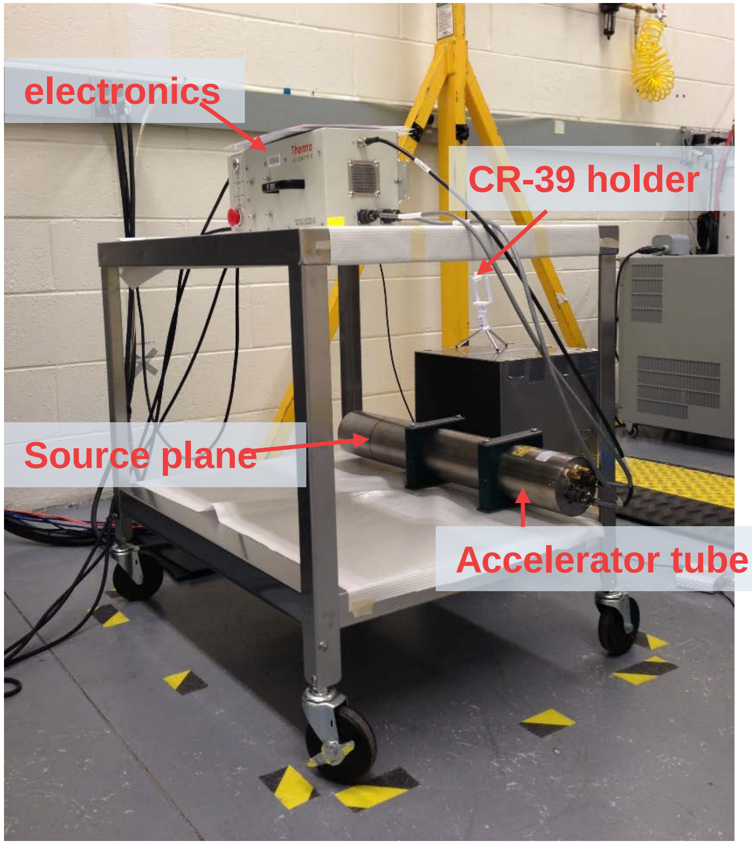
D fuel: ρR ~ 150 mg/cm^2

Ion temperature: T_i ~ 3keV



*Simulated by M. Gatu Johnson using MCNP

A neutron generator will be used to expose CR-39 to the same level of neutron fluence of the Z experiments at SNL



The signal noise coming from the neutrons will be significantly reduced by employing the coincidence counting technique