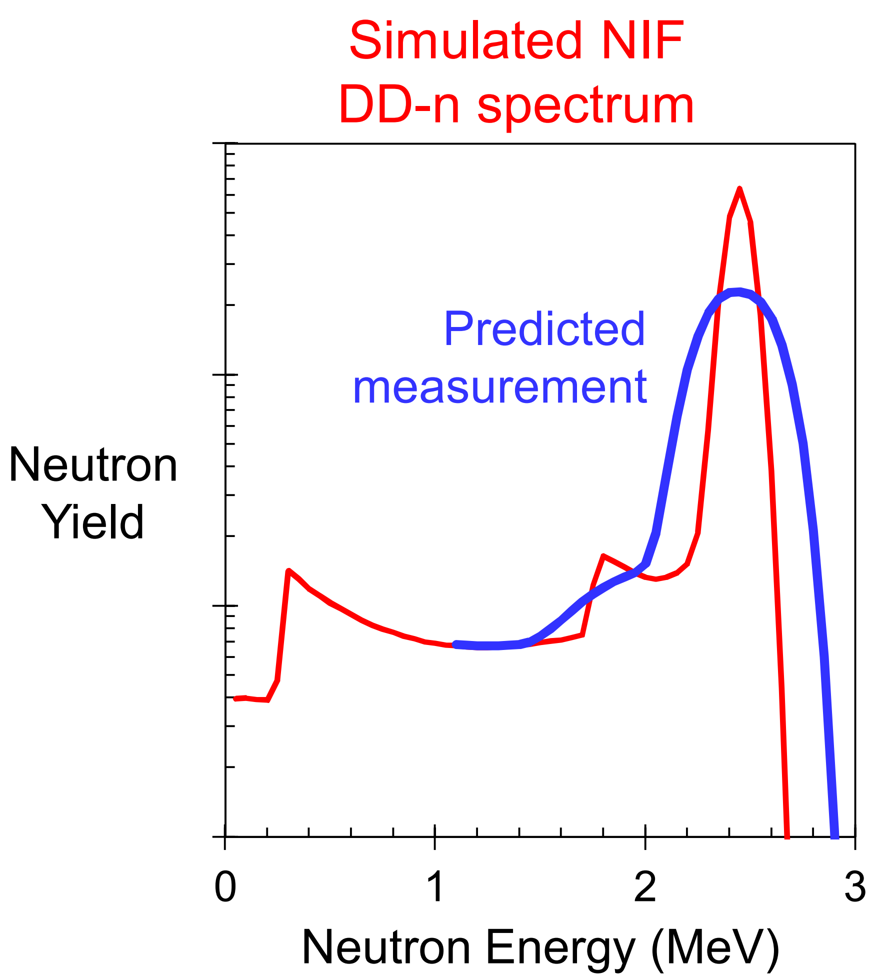
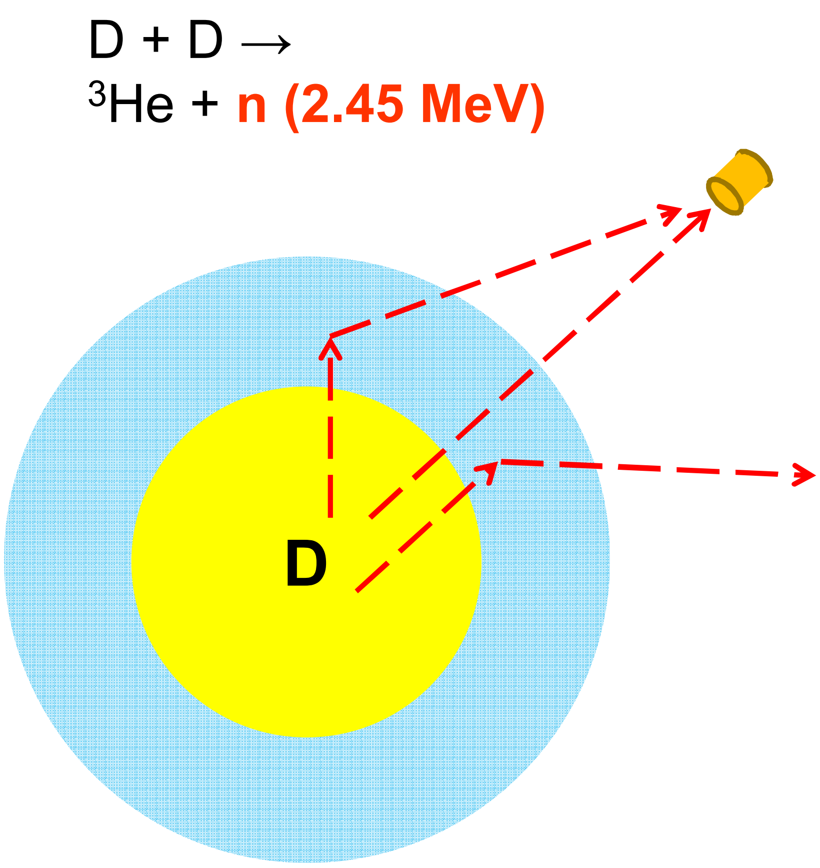
# Compact DD-n spectrometer for Yield, $T_i$, ρR & symmetry at Z, OMEGA, NIF, and for Discovery Science

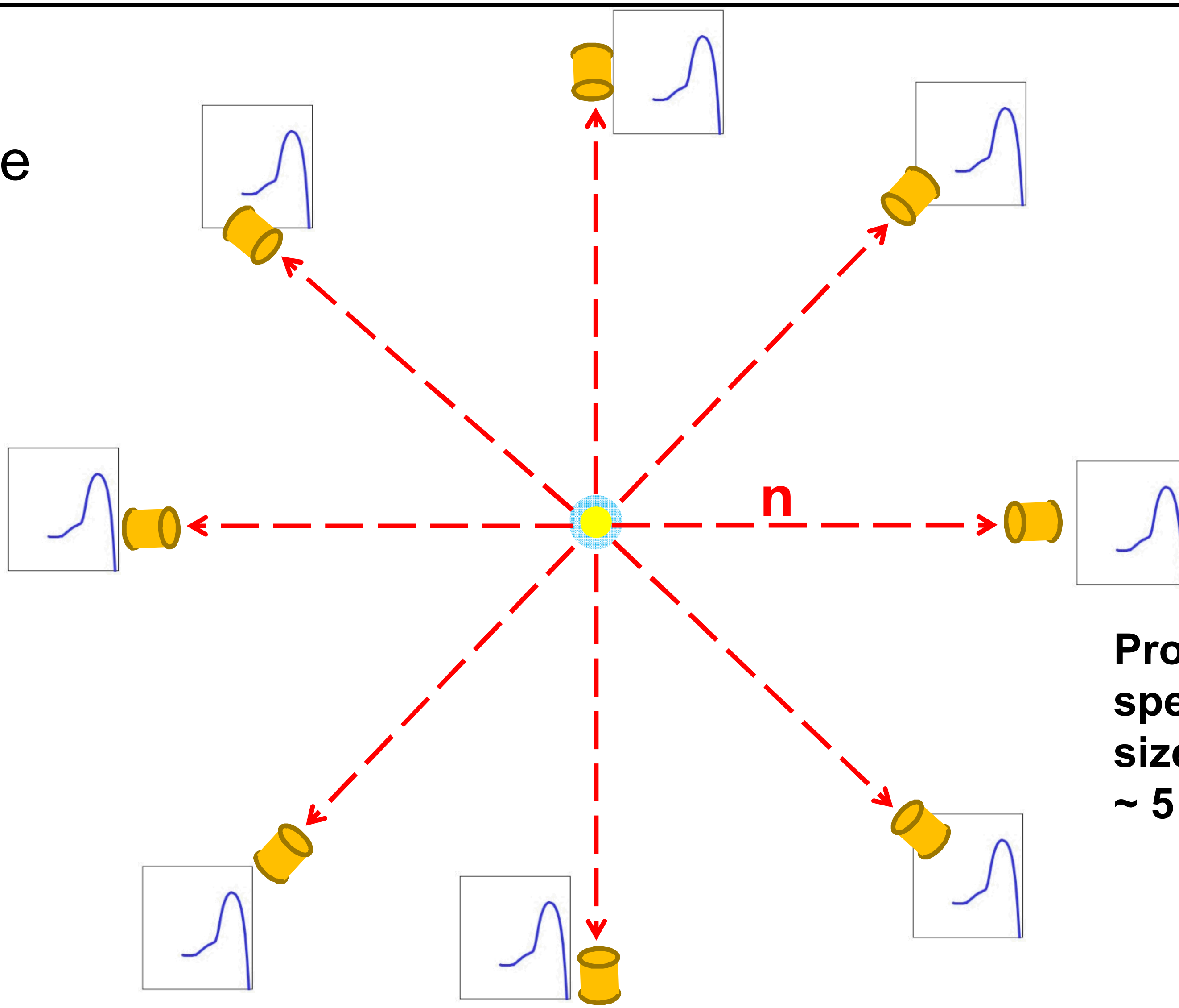
SAND2015-8625C



# 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

W. Han*
L. Milanese*,[1]
F. Seguin
B. Lahmann*
M. Gatu Johnson
C. Waugh
H. Sio*
N. Kabadi*
C. Wink*
G. Sutcliffe*
J. Rojas-Herrera*
A. Birkel
J. Frenje
C.K. Li
R. Petrasso

## SNL

K. Hahn
B. Jones
G. Rochau

## U of R – LLE

V.Yu. Glebov
J. Knauer
T.C. Sangster
C. Stoeckl

## LLNL

R. Bionta
D. Casey
C. Yeamans

*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

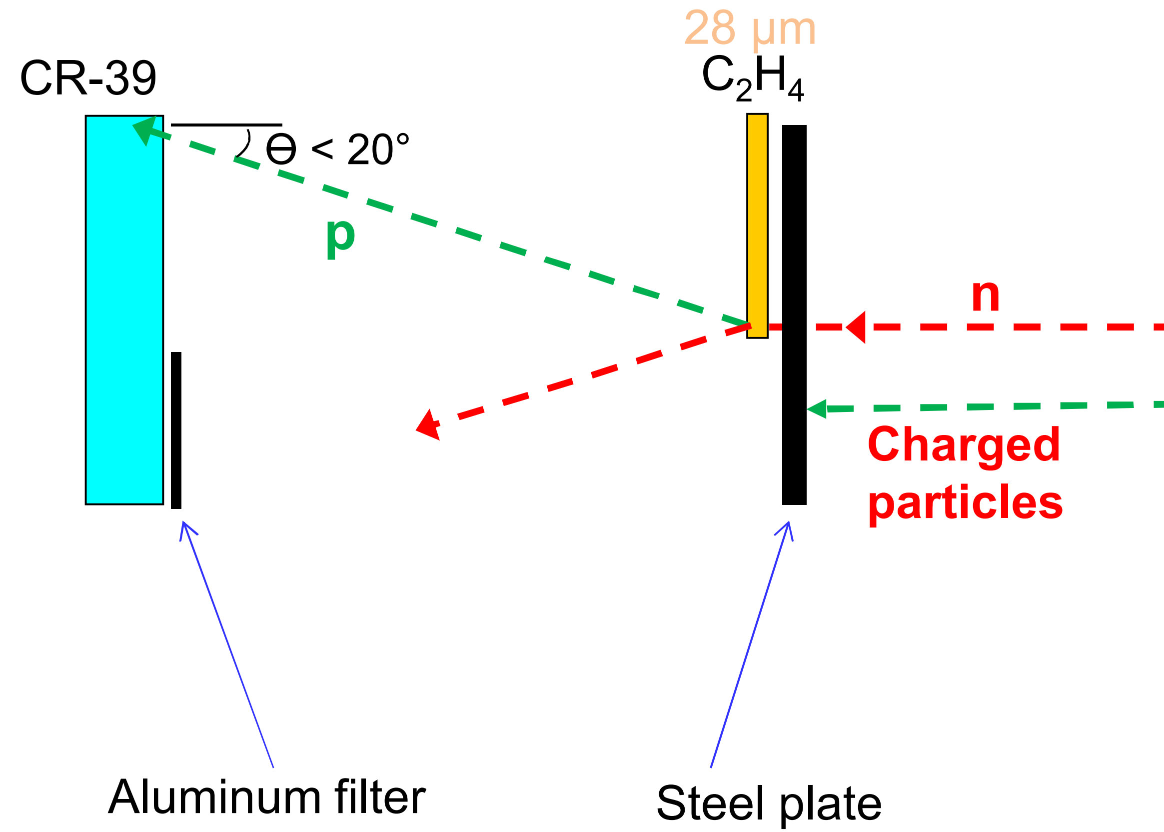
  c. On-going tests of coincidence counting at MIT Accelerator Facility:

     (i) Signal only tests
     (ii) Signal and 2.5 MeV neutron noise background together
     (iii) Monte-Carlo simulations of signal and background
     (iv) Determination of spectrometer sensitivity, characteristics
     (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

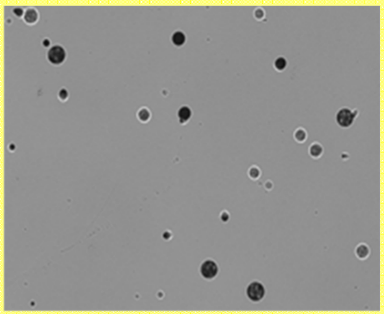
## CR-39 records recoil protons from *n,p* interactions in a CH foil



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

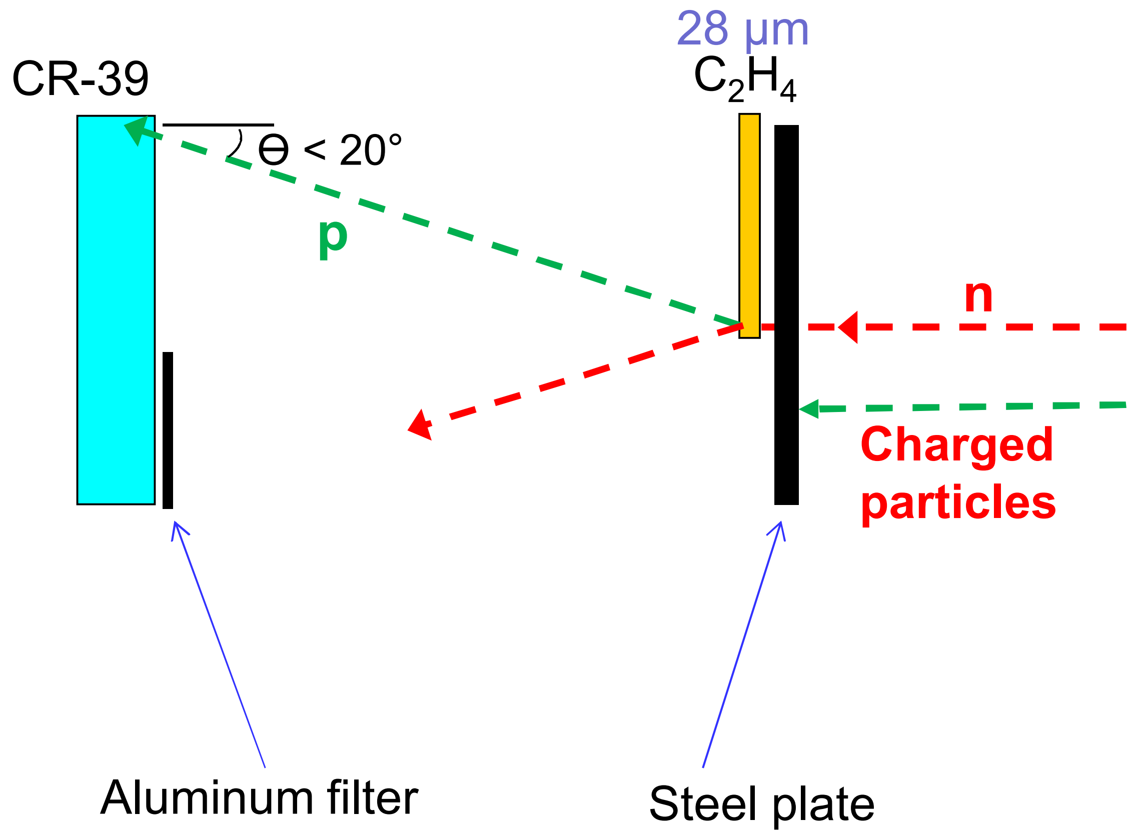
## CR-39 records recoil protons from *n,p* interactions in a CH foil

Etching the CR-39 reveals proton tracks on the surface

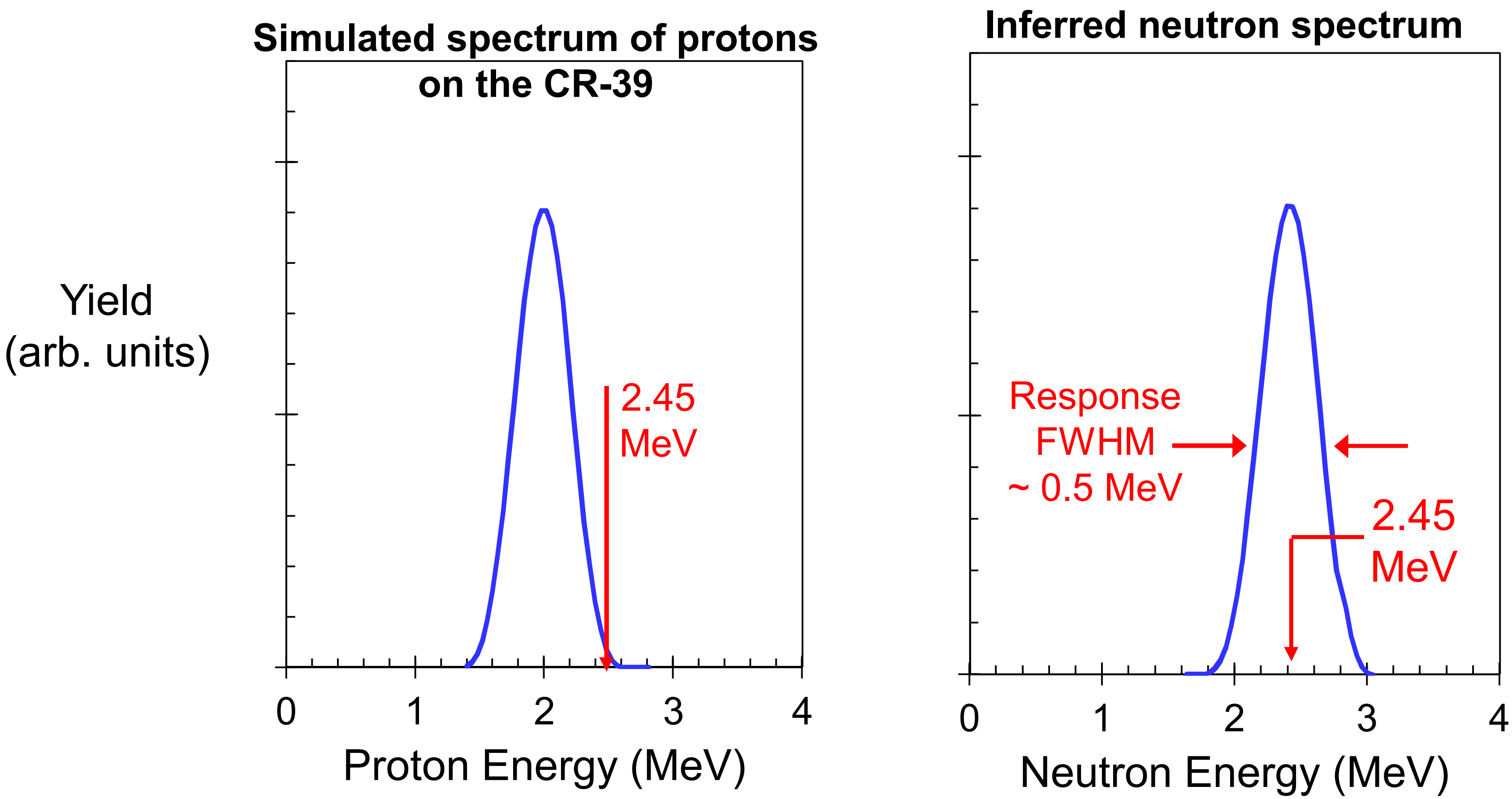


Proton energy will be determined based on track size on the CR-39

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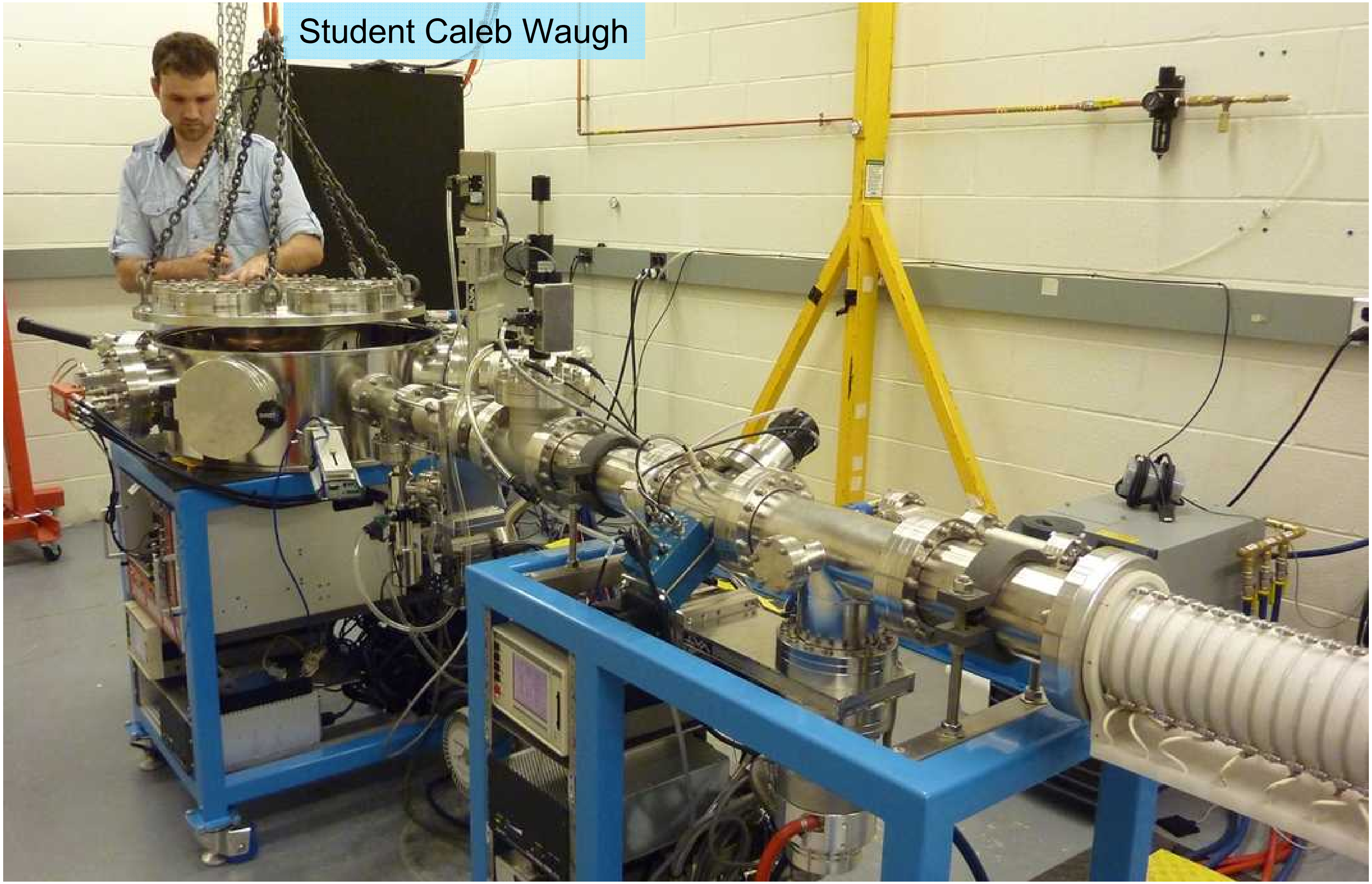
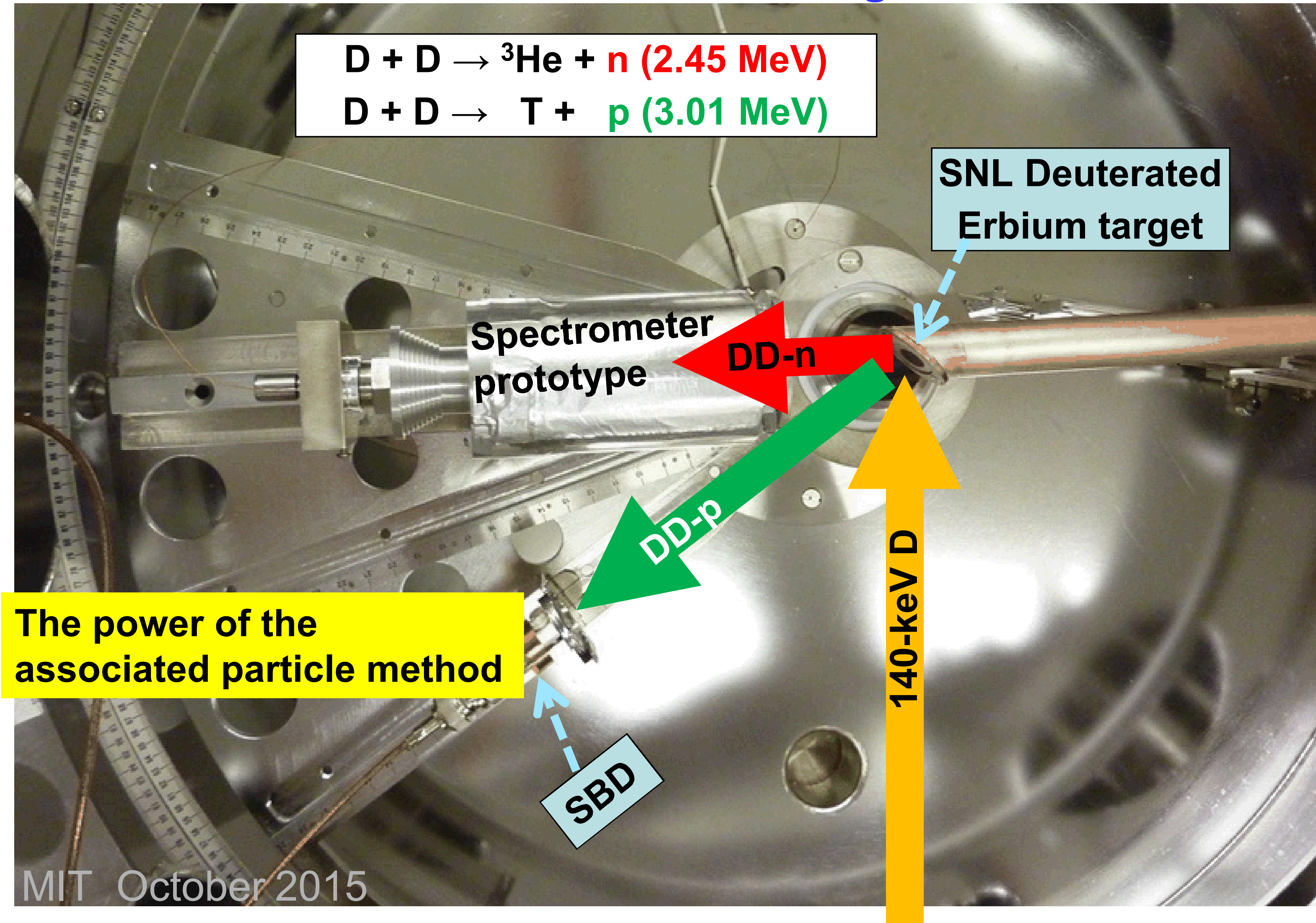
# A proof-of-principle test of a prototype was carried out on the MIT accelerator without using coincidence noise reduction*



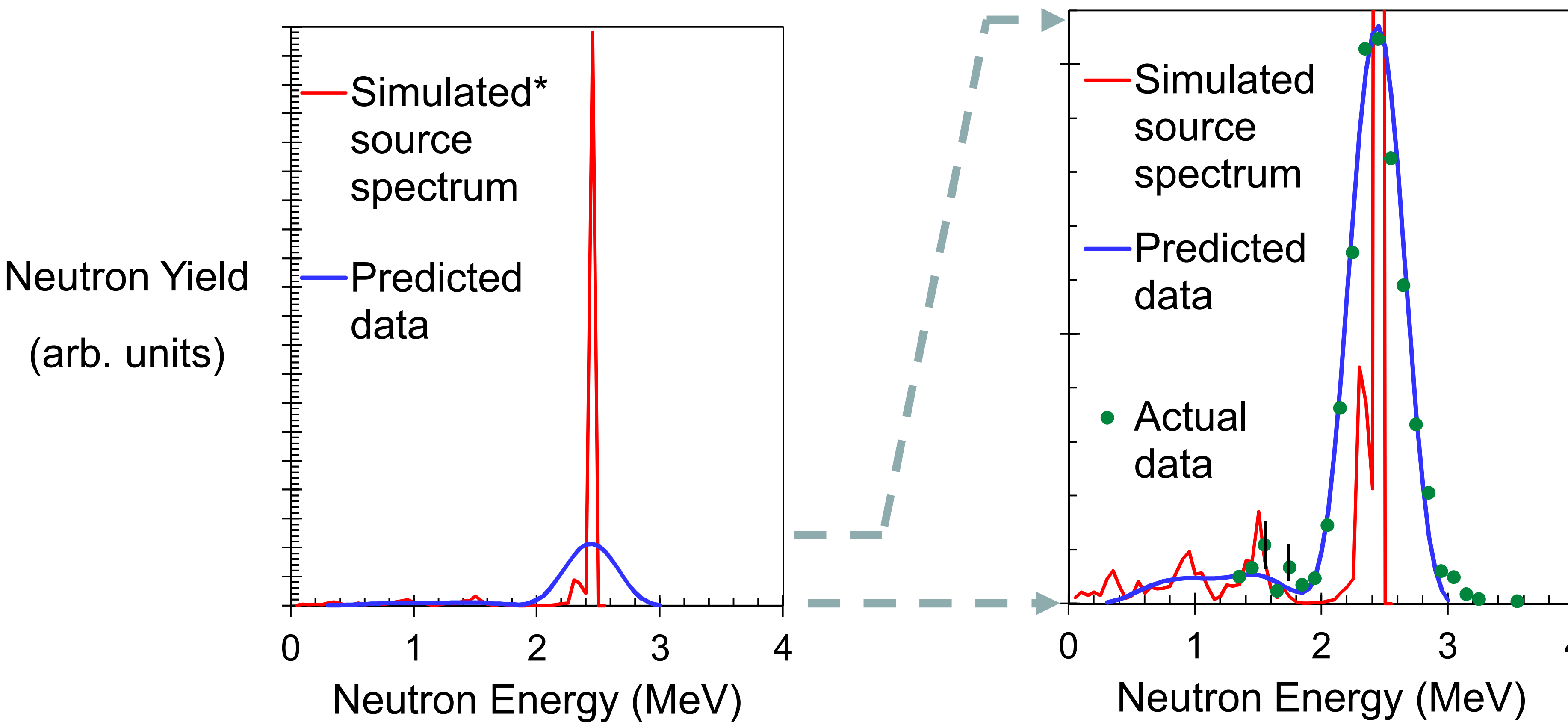

*Seguin *et al*., Bull. Am. Phys. Soc. (2012)

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



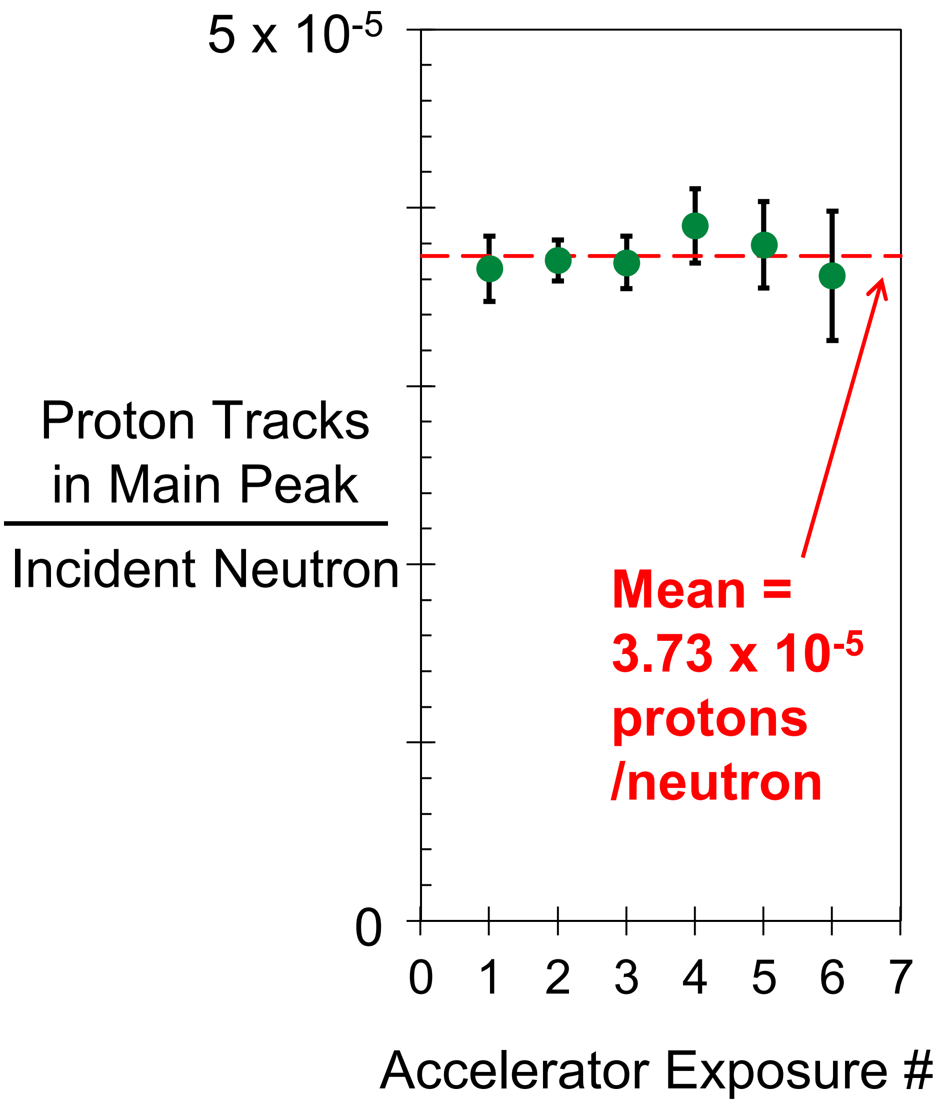
# The measured spectrum shape agrees well with expectations

Accelerator-generated
DD-n spectrum




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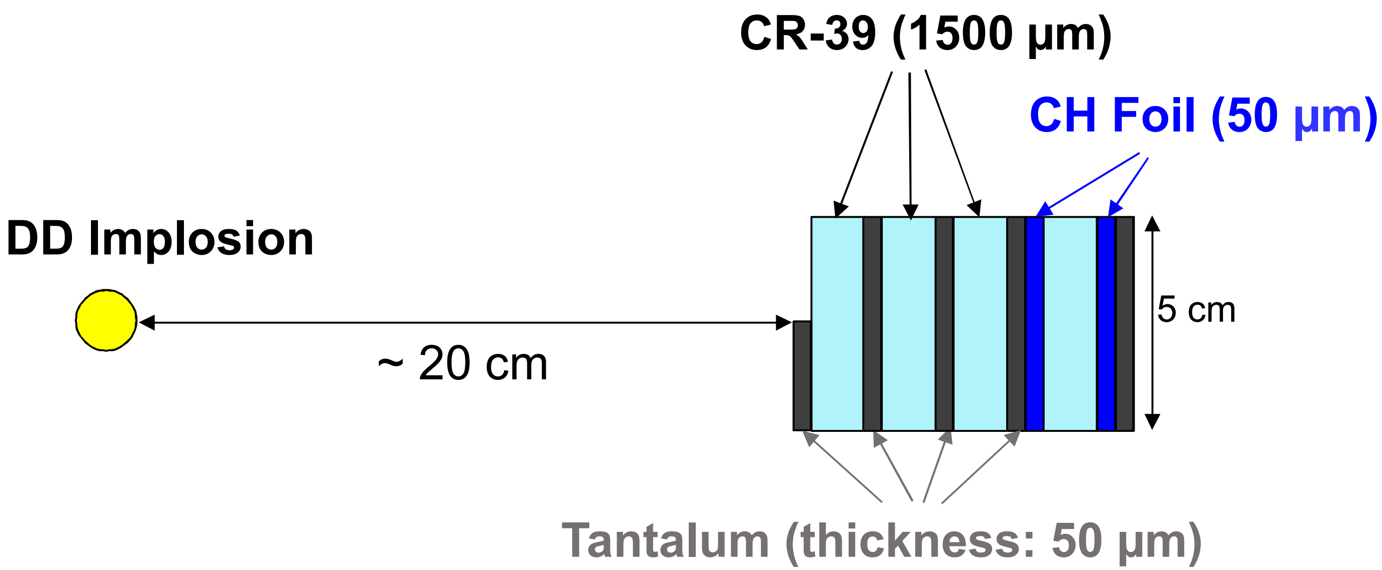
# Test data with simple CR-39 packages were acquired on 14-18 September 2015 during MagLIF shots 2849-52 ( DD-n yields ~ $3x10^{10}$ – $2x10^{12}$ )




Data about to be analyzed

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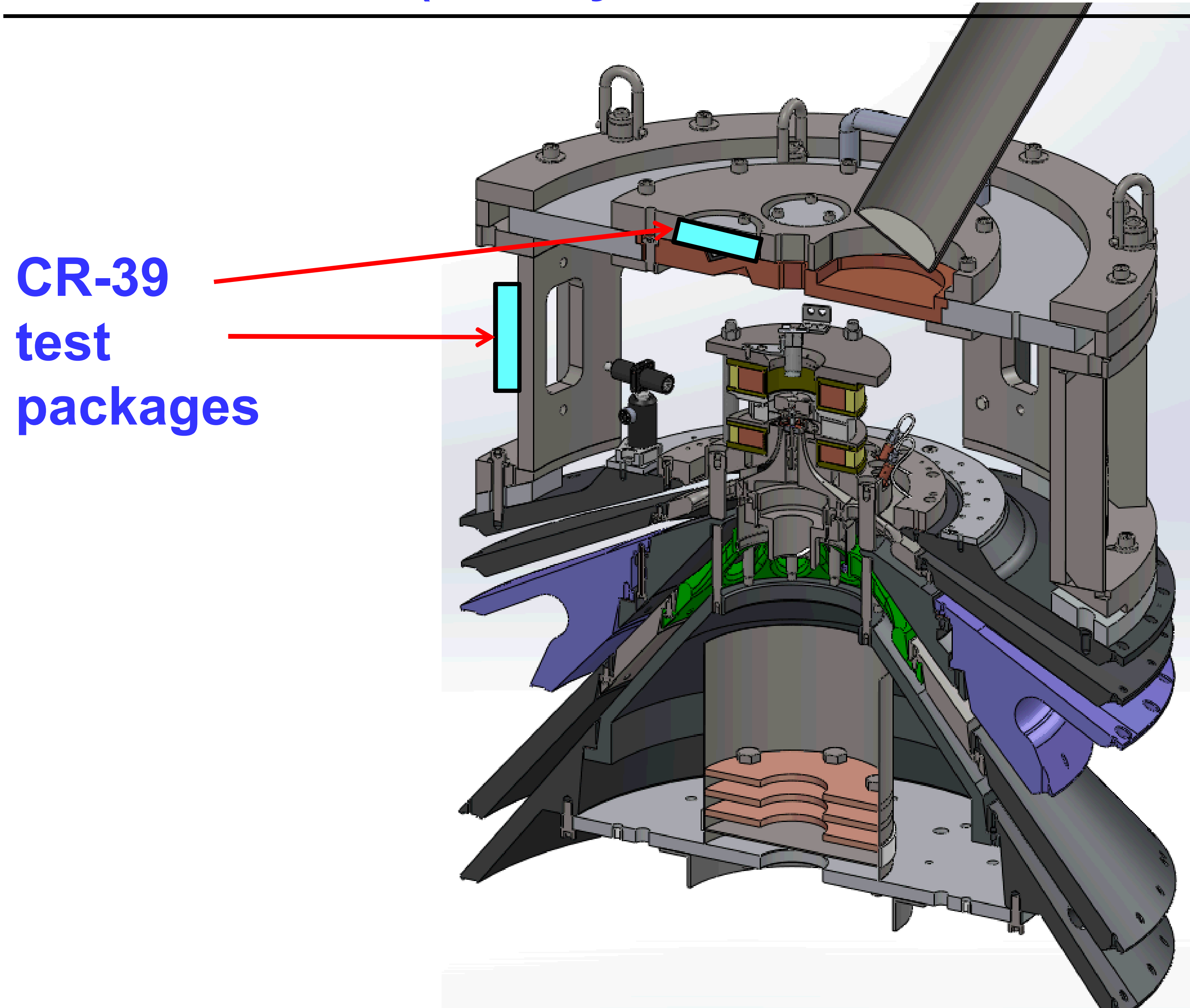

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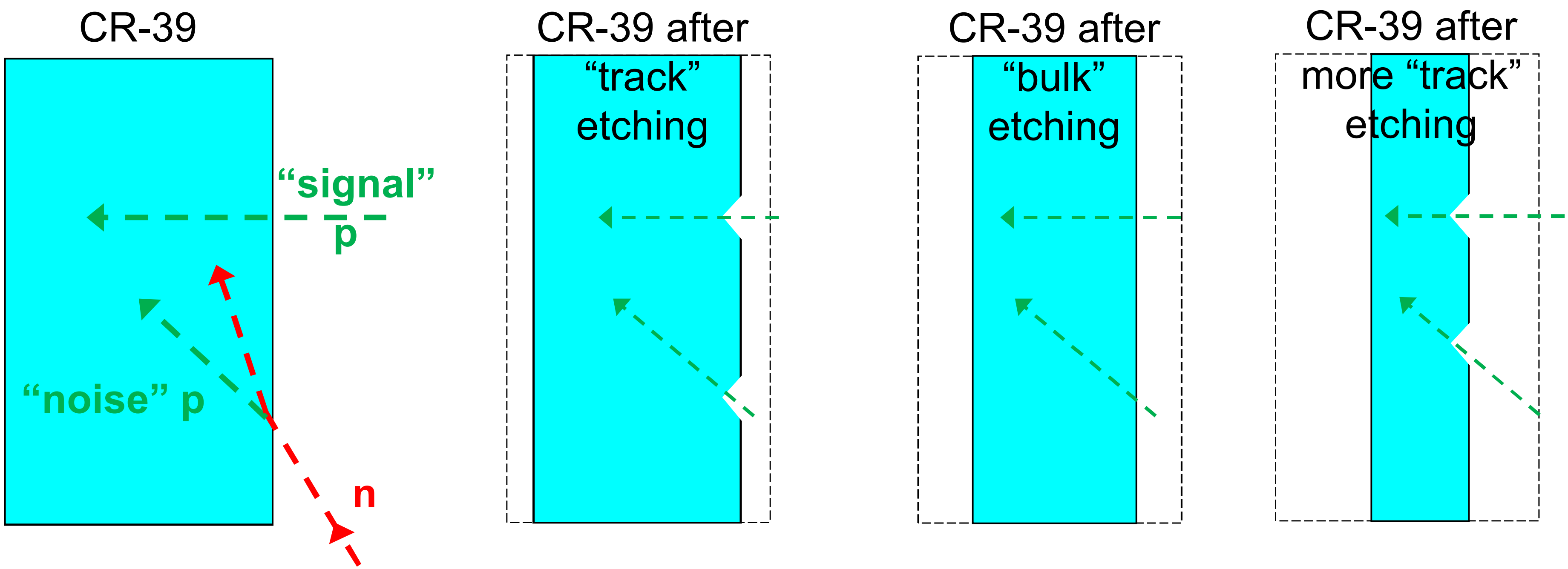
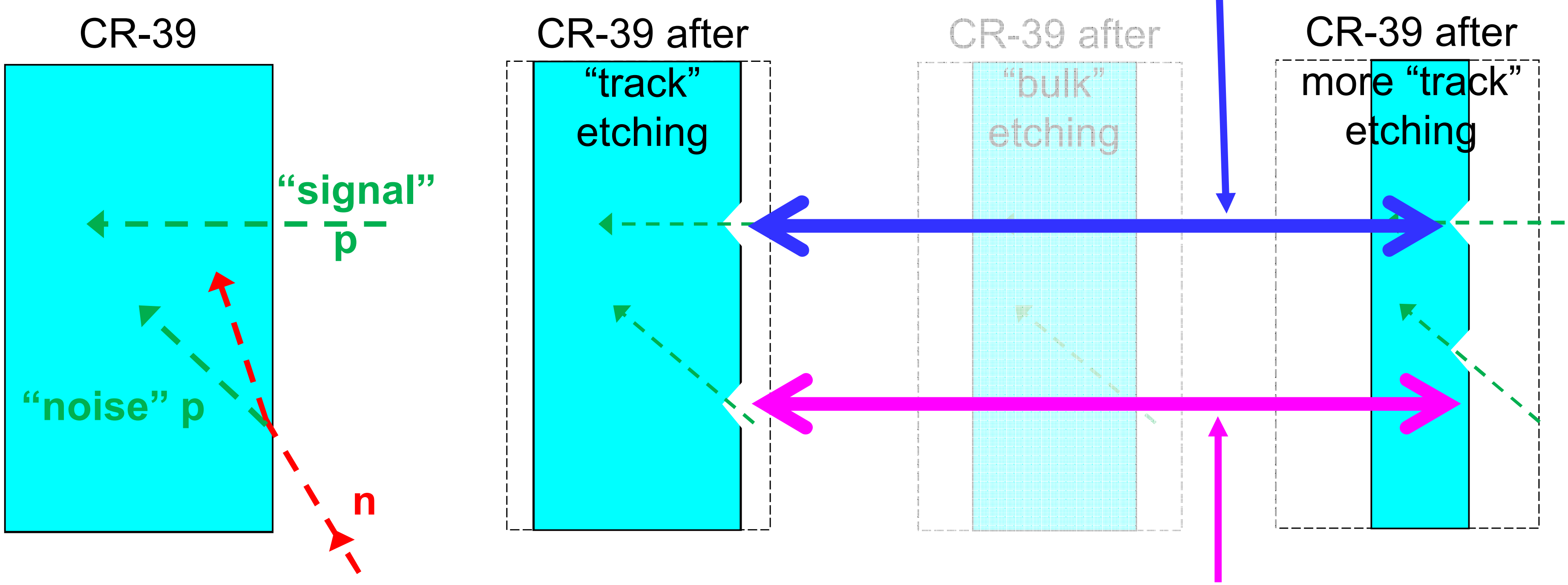
# The Coincidence Counting Technique (CCT)* is used to eliminate neutron-induced noise (and "intrinsic" noise) in CR-39 track data




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

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

These tracks are coincident in position, and are accepted as data



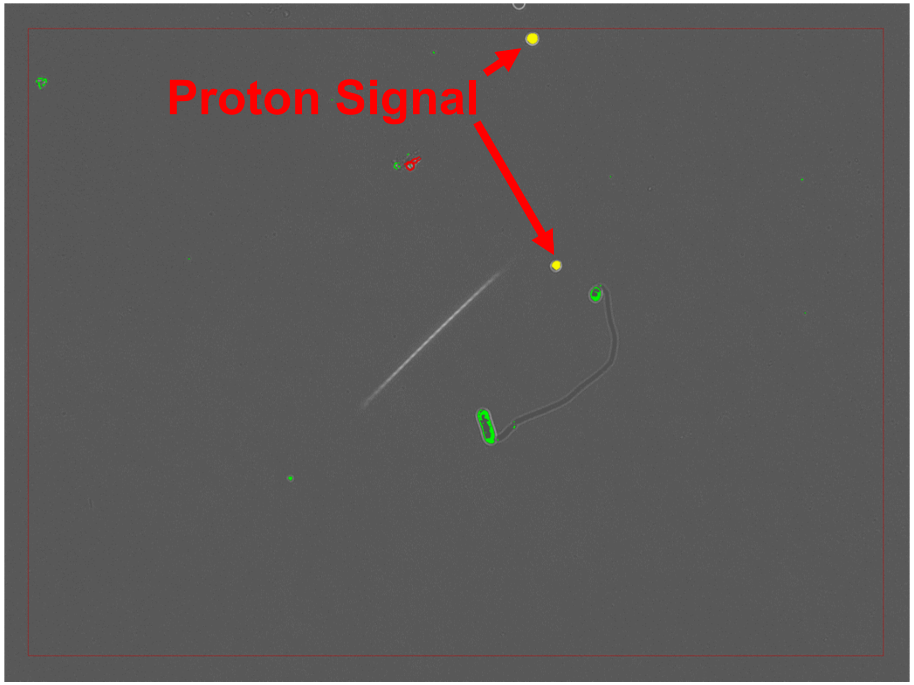

These tracks are NOT coincident in position, and are rejected as noise

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

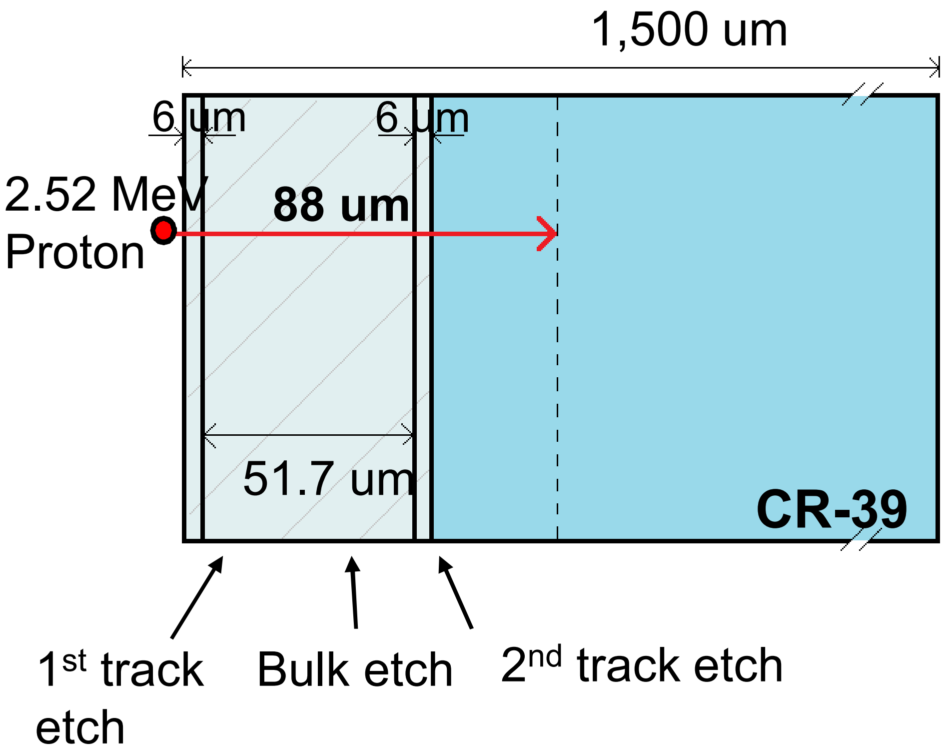
# Tests of coincidence counting are being conducted at the MIT Accelerator Facility

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

**First track etch before bulk etch:**




Accelerator shot A2015091702



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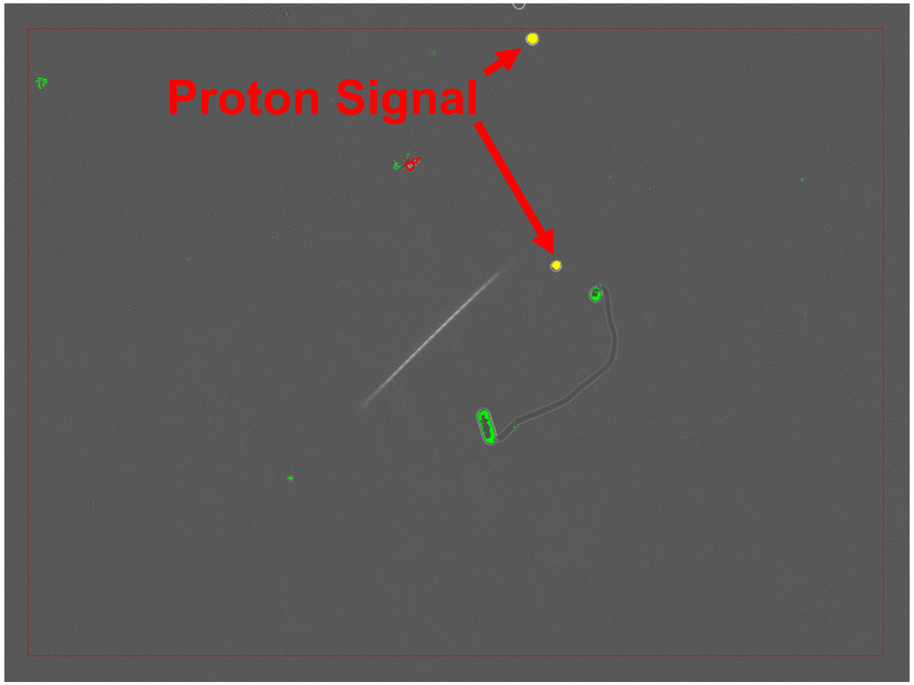
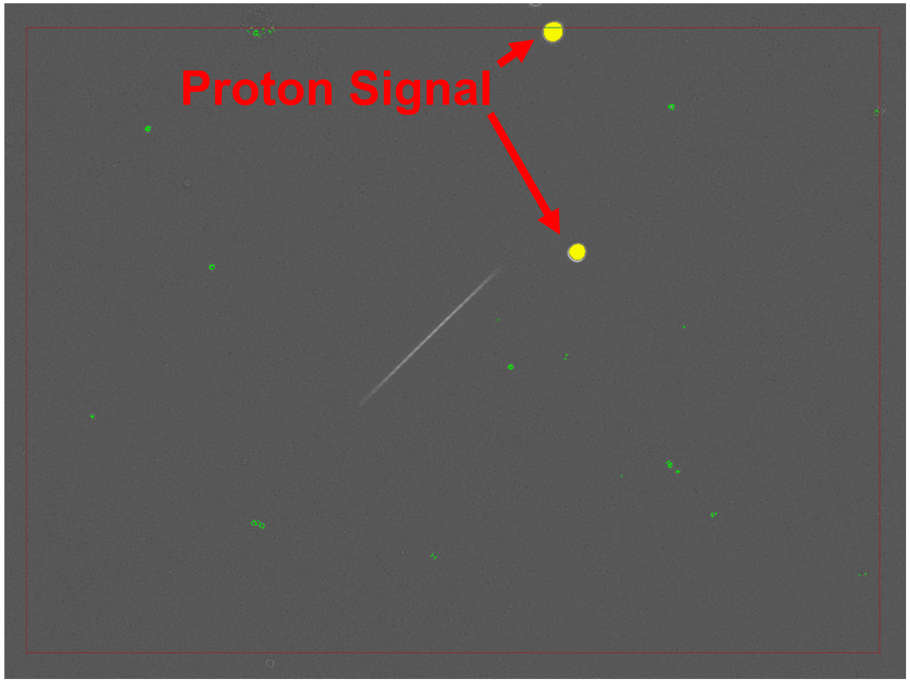



Standard front-side analysis:
8533 protons counted

**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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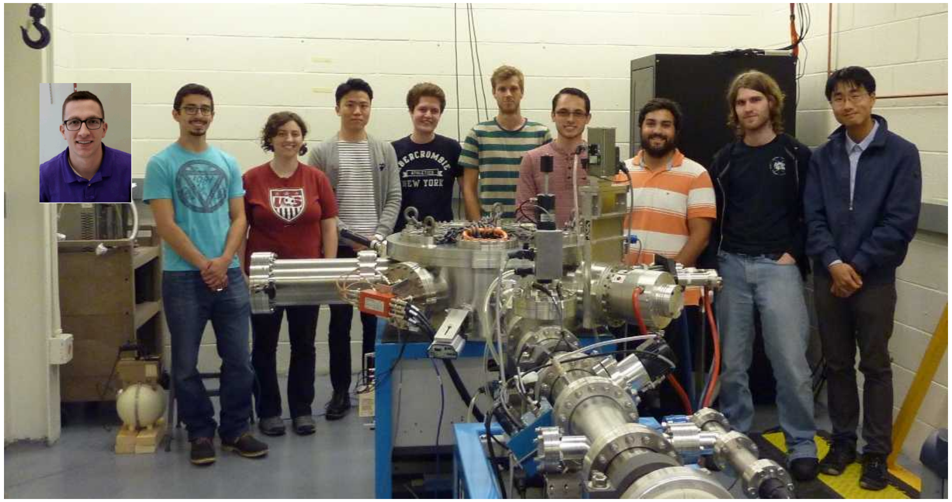
# Future

For programmatic and Discovery Science,

DD-n spectrometers will be fielded at:

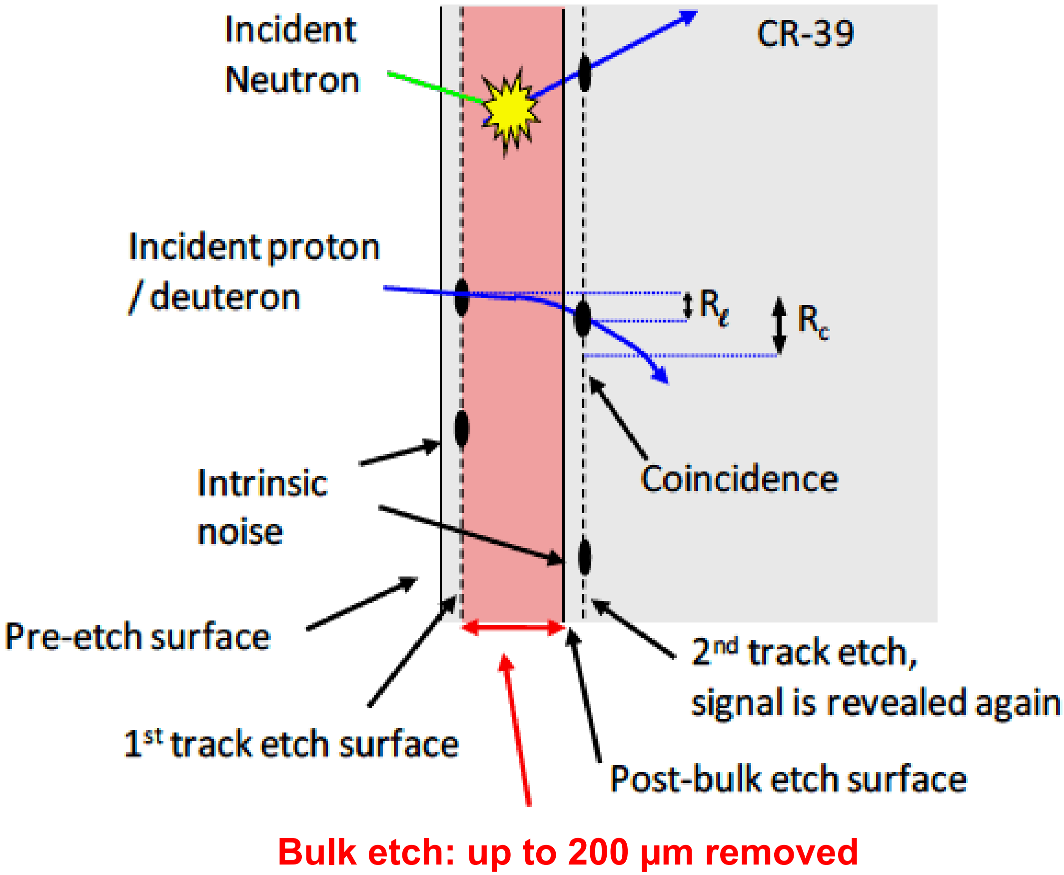
- Z
- OMEGA
- NIF



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




**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**

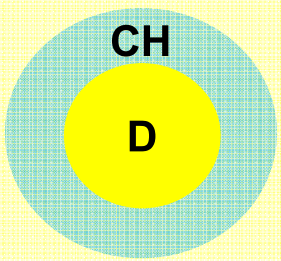
*D. T. Casey *et al.*, ***RSI*** (2011)

# Motivation

- Make a simple, compact spectrometer for ICF DD-n to get
    - Yield
    - Temperature from line width
    - Downscatter component for ρR determination
    - Symmetry
    - ~~Energy symmetry, for plasma flow velocity~~
- For use on
    - Z
    - OMEGA
    - NIF

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

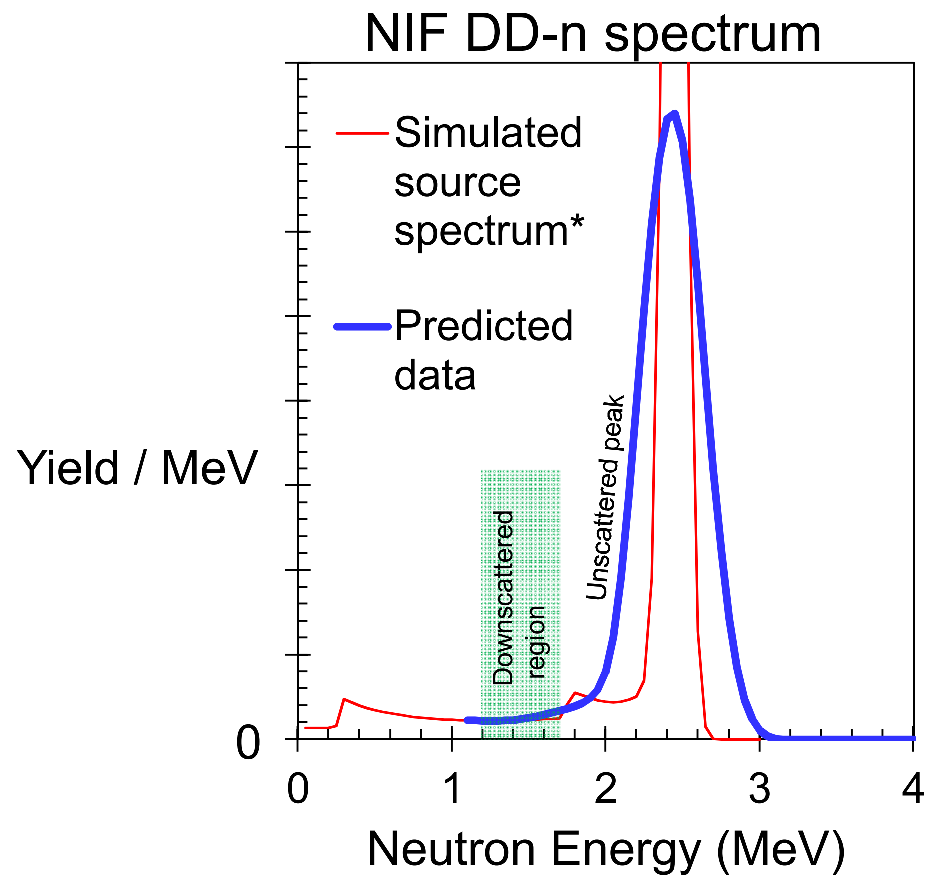
**Assumed parameters at bang time**




CH shell: $\rho R \sim 600\ mg/cm^2$

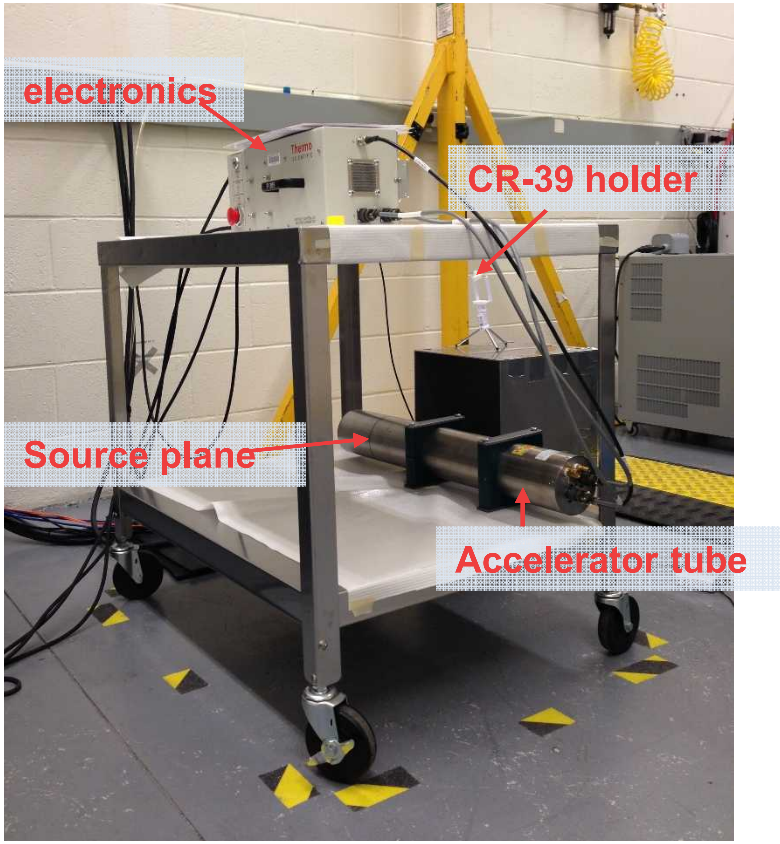
D fuel: $\rho R \sim 150\ mg/cm^2$

Ion temperature: $T_i \sim 3keV$




*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**