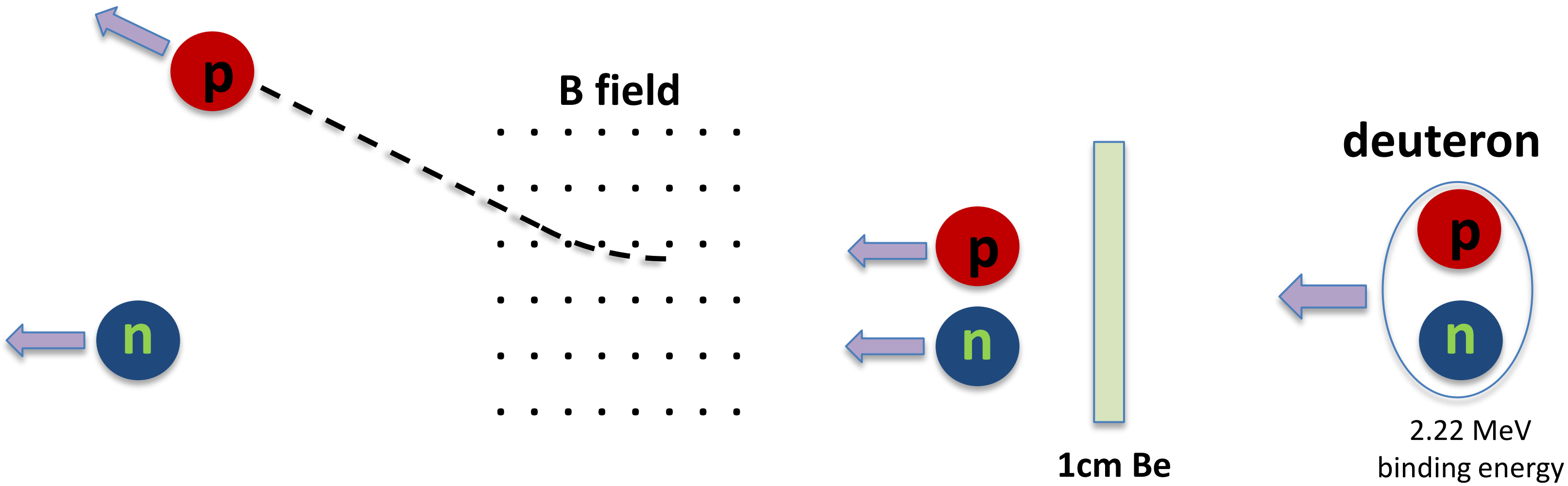
Xiaodong Jiang

LDRD-C 25-043 project update

Tunable Neutron Beam through Deuteron Disassociation



Method: (1947) disassociation reaction strips the loosely bounded deuteron into p + n with similar energies, with a ~2% possibility for 100 MeV/n deuteron on a 1 cm Be target. This work focused on deuteron 100 MeV/u.

Goal: once "mono-energetic" neutron is demonstrated, a tunable neutron beam (15MeV - 200MeV) is achievable with existing technology, could reach up to 10^{10} neutrons/cm^2/sec.

Approved for FY2025 (LDRD-C $75k, covers 8hr beam time at NSRL, engineer time, etc.).

- Results of a beam test (Sept. 3rd, 2025), with deuteron and proton beams 100 MeV/u.
- Next steps.

Why Fast Neutron (E_{kin} = 15MeV - 200MeV) ?

Applications of neutron technology are limited by the available neutron sources:

- Reactors neutrons (thermal): E_{kin} << 1 MeV.
- Fusion neutrons (Deuteron-Deuteron, Deuteron-Tritium): E_{kin} =2.5 MeV, 14.1 MeV.
- Accelerator based proton-spallation neutrons: a wide energy spectrum not easily selectable.

Fast neutron beam (E_{kin} = 15MeV - 200MeV) with selectable energy is not currently available to satisfy the needs of:

- Aviation Industry: neutron induced radiation damages in electronics.
- National Security:
  - fast-neutron cross-sections for weapons design and simulation.
  - imaging of subcritical nuclear material in high-energy and high-density states.

It's well-known since 1940s that deuteron disassociation on a light nuclear target produces mono-energetic neutrons, a practical fast-neutron beam with tunable energies has never been demonstrated.

R. Serber, *Phys. Rev.* 72, 1008 (1947)

PHYSICAL REVIEW VOLUME 72, NUMBER 11 DECEMBER 1, 1947

The Production of High Energy Neutrons by Stripping*

R. SERBER
Radiation Laboratory, Department of Physics, University of California, Berkeley, California

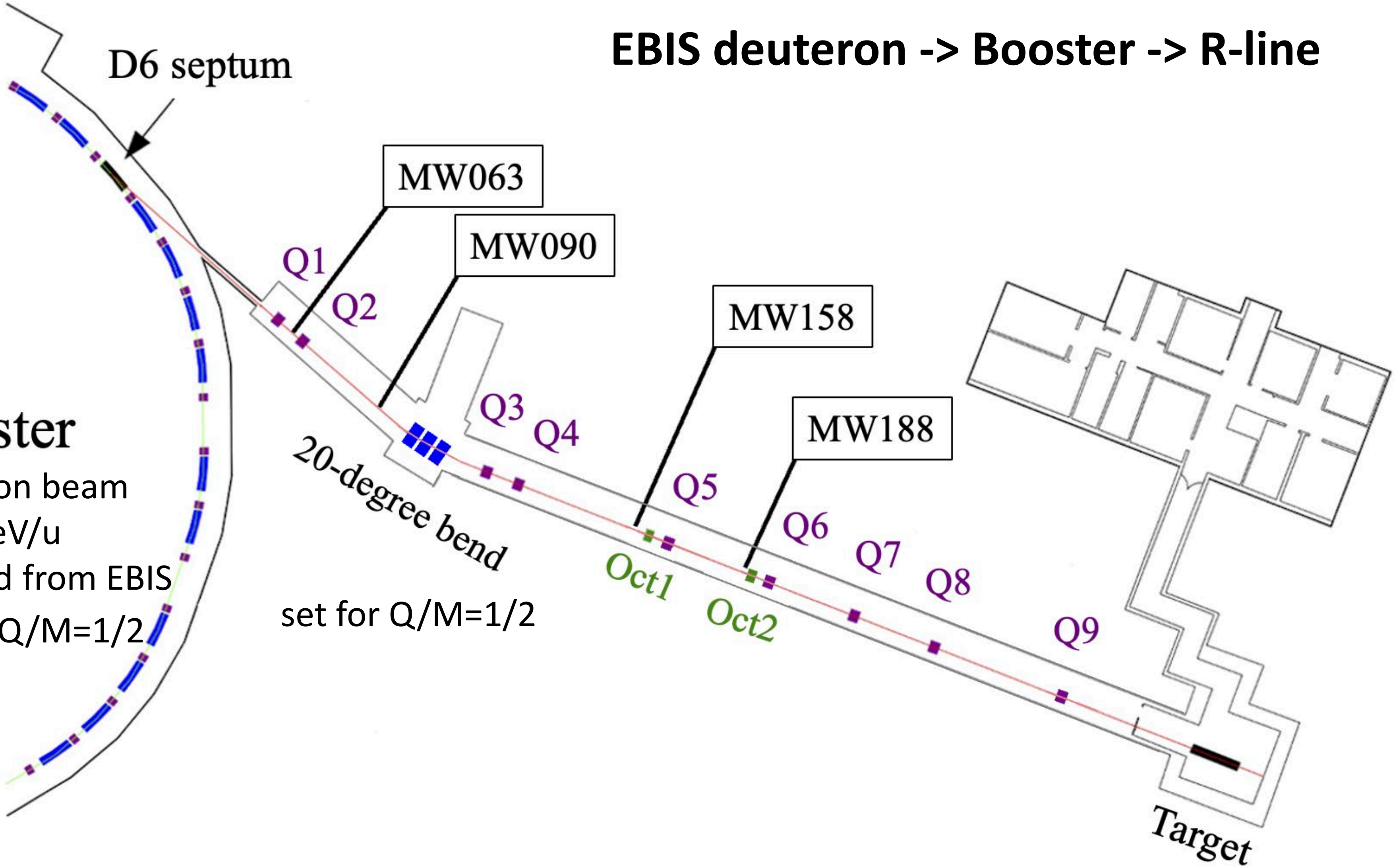
(Received August 28, 1947)

The yield of neutrons from a ½-in. Be target (in which the energy loss for 190-Mev deuterons is 20 Mev) is nearly 2 percent.

This work focused on deuteron@100 MeV/u

Deuteron Beam in the NSRL beam line (Booster R-line)

EBIS deuteron -> Booster -> R-line



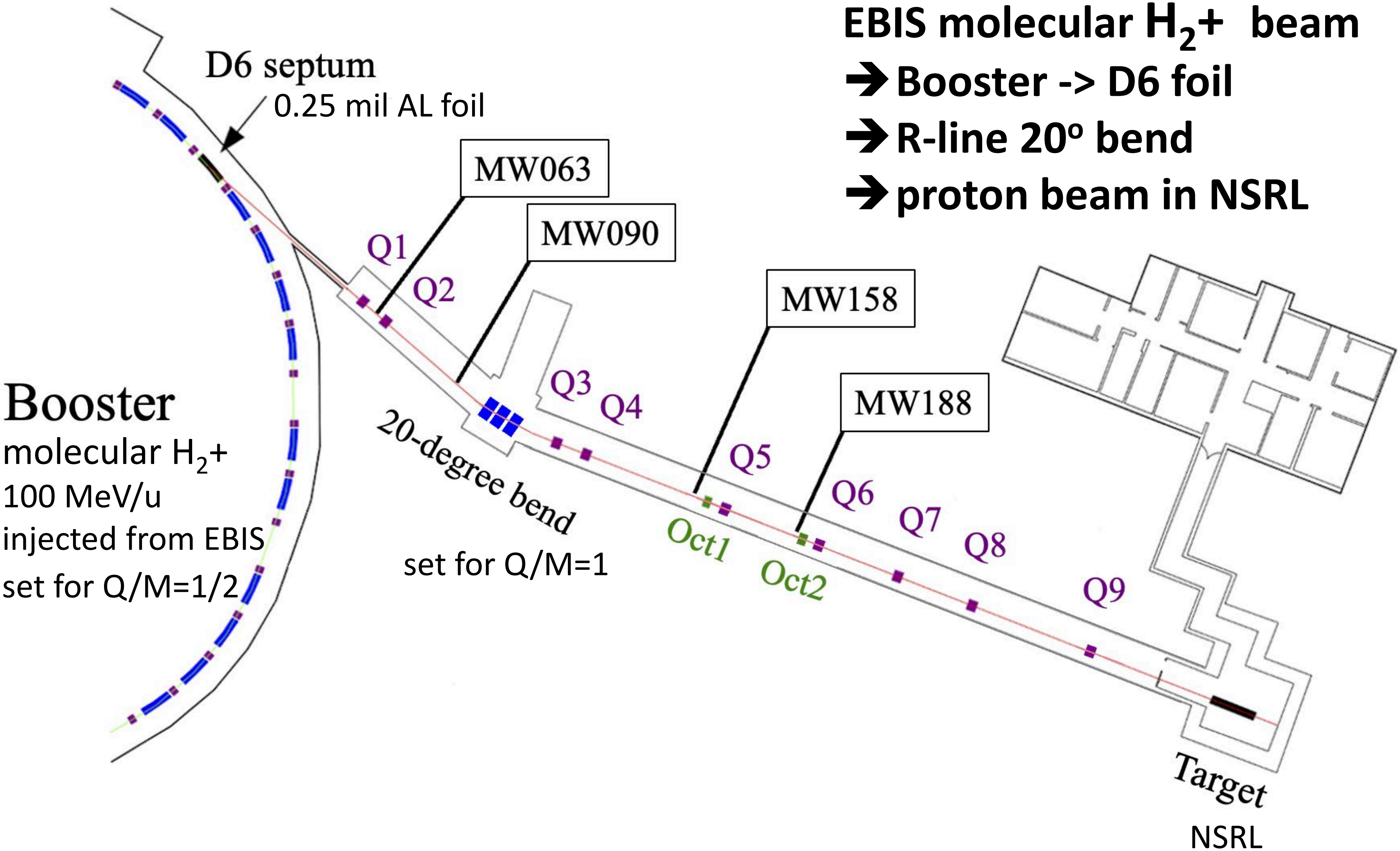
Booster
deuteron beam
100 MeV/u
injected from EBIS
set for Q/M=1/2

set for Q/M=1/2

This work focused on deuteron@100 MeV/u

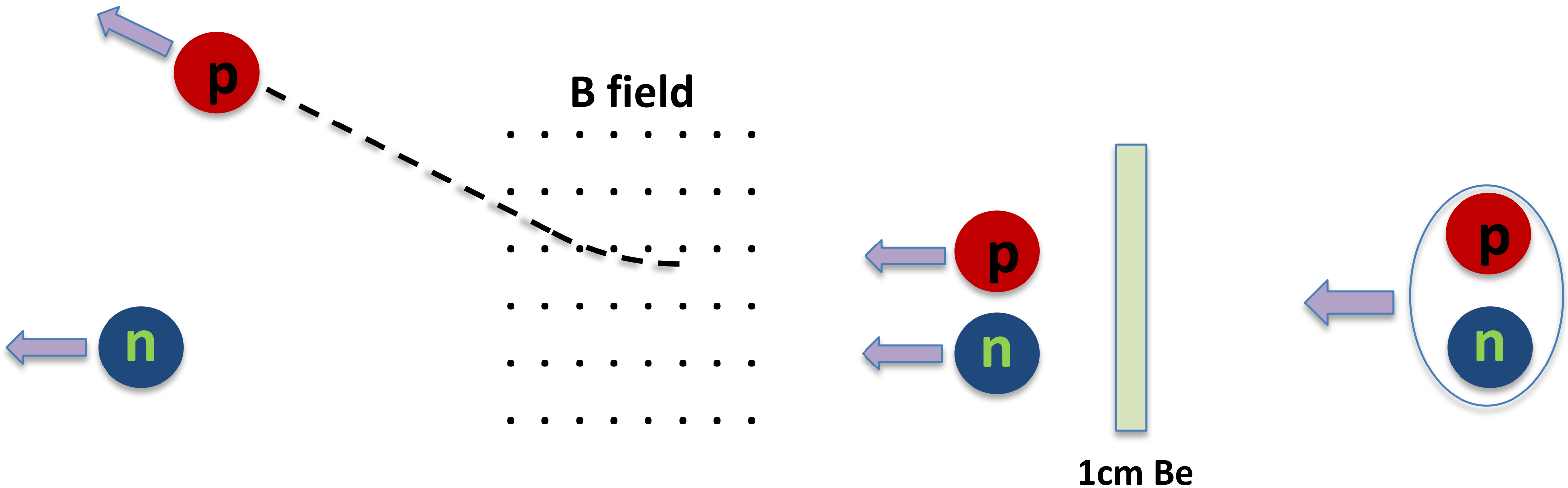
Proton beam in the NSRL beam line (Booster R-line)

EBIS molecular H_2+ beam
- ➔ **Booster -> D6 foil**
- ➔ **R-line 20° bend**
- ➔ **proton beam in NSRL**




Beam
CAUTION
THIS DEVICE MAY OPERATE REMOTELY
NSRL Target Room

Test Setup



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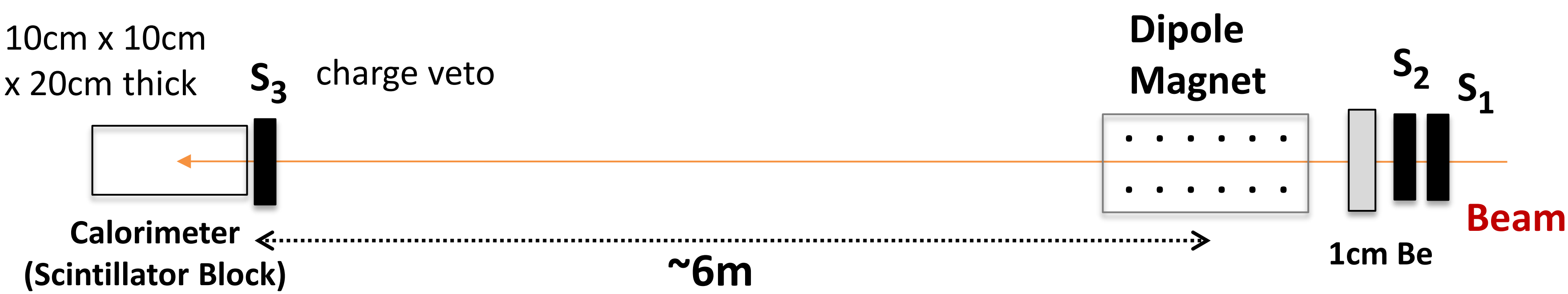
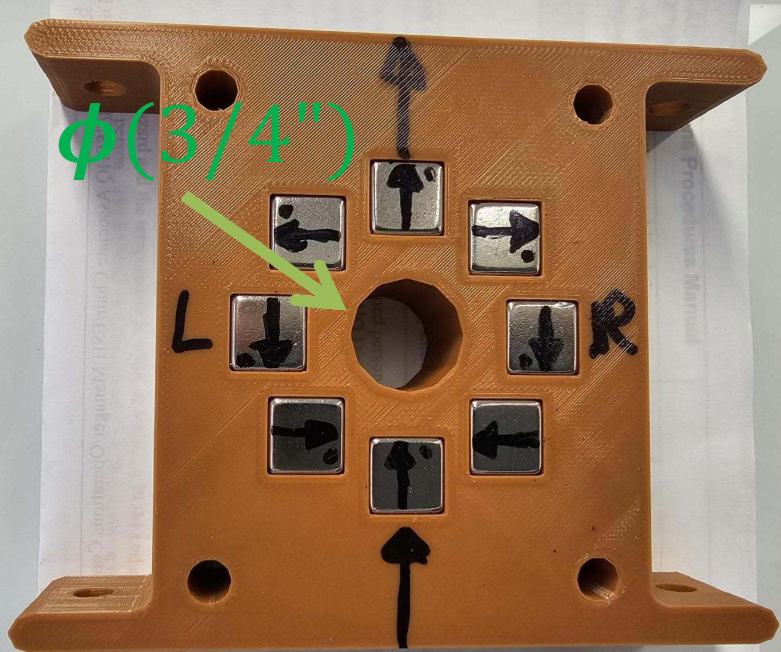
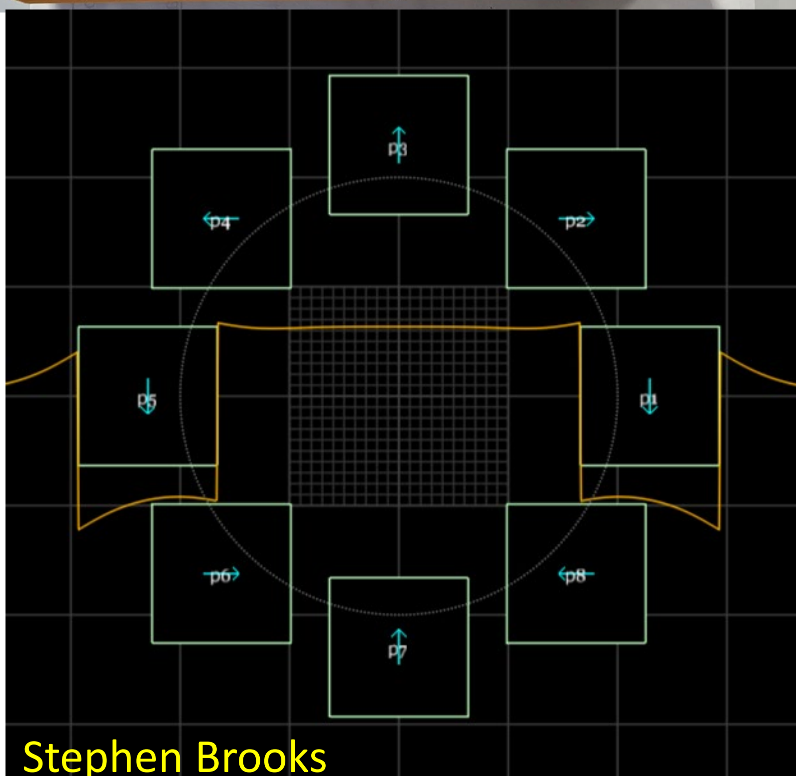


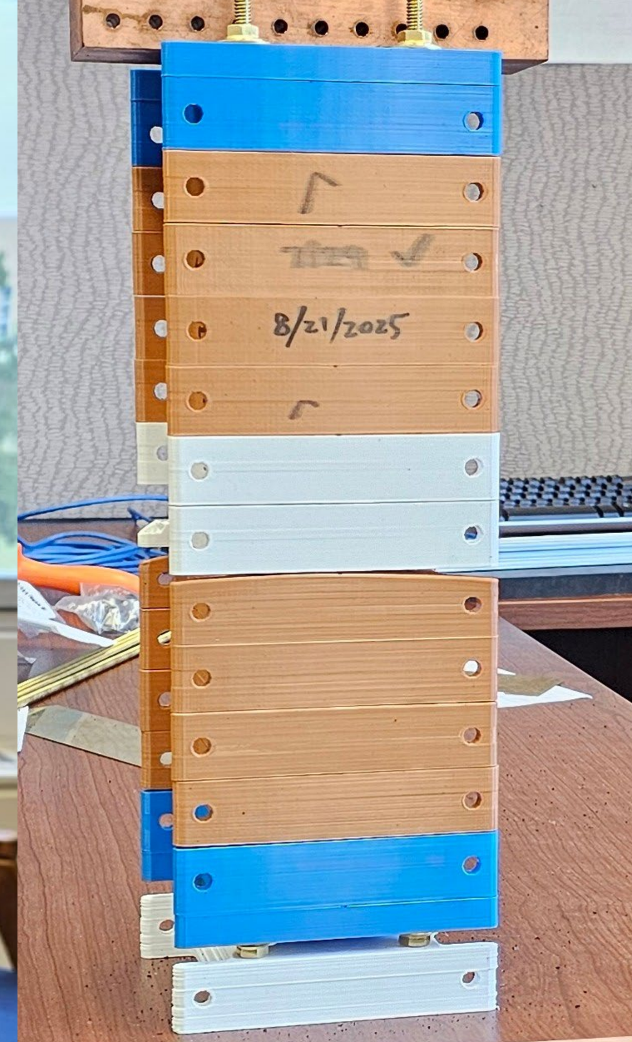
neutron detection through (n,p) interactions.

Trigger: (S_1+S_2)+Calo

scintillator S1, S2, S3: 5”x5”x1/4”







Dipole Magnet

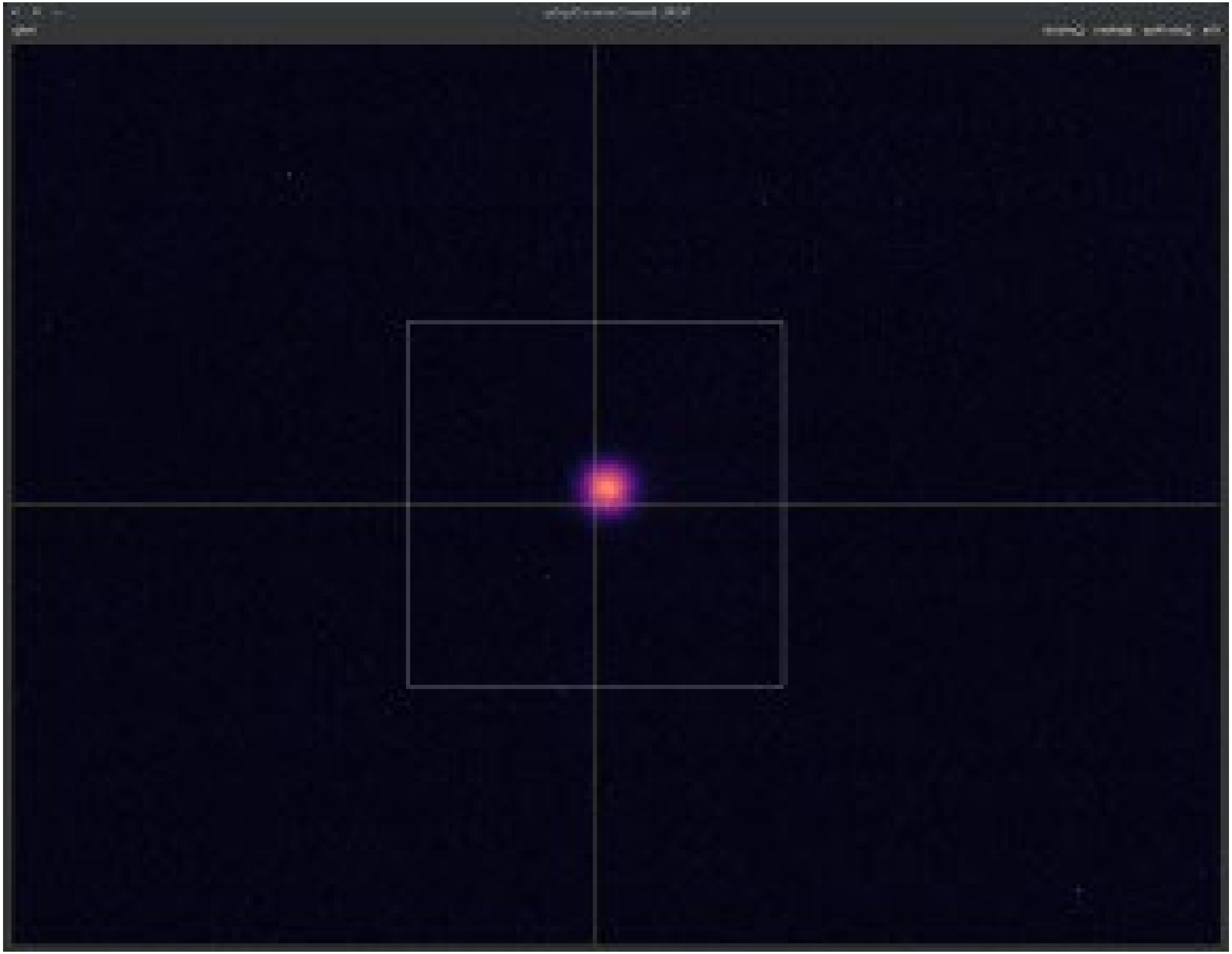
B=0.475 tesla, L=12”

BdL ~ 0.145 Tesla.meter

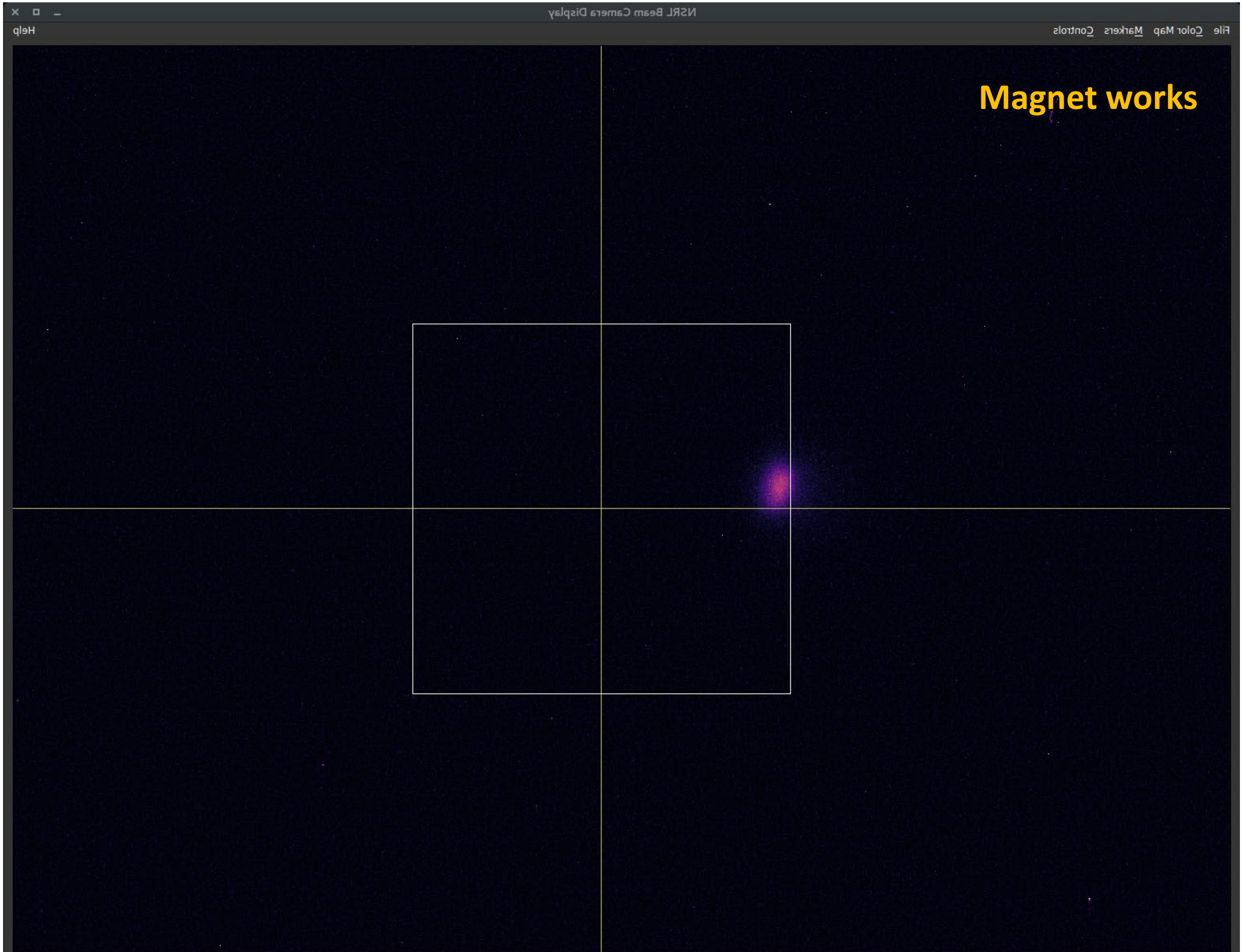
center clearance:0.75”

100 MeV/u deuterium beam, a 10x10cm square shown as a reference

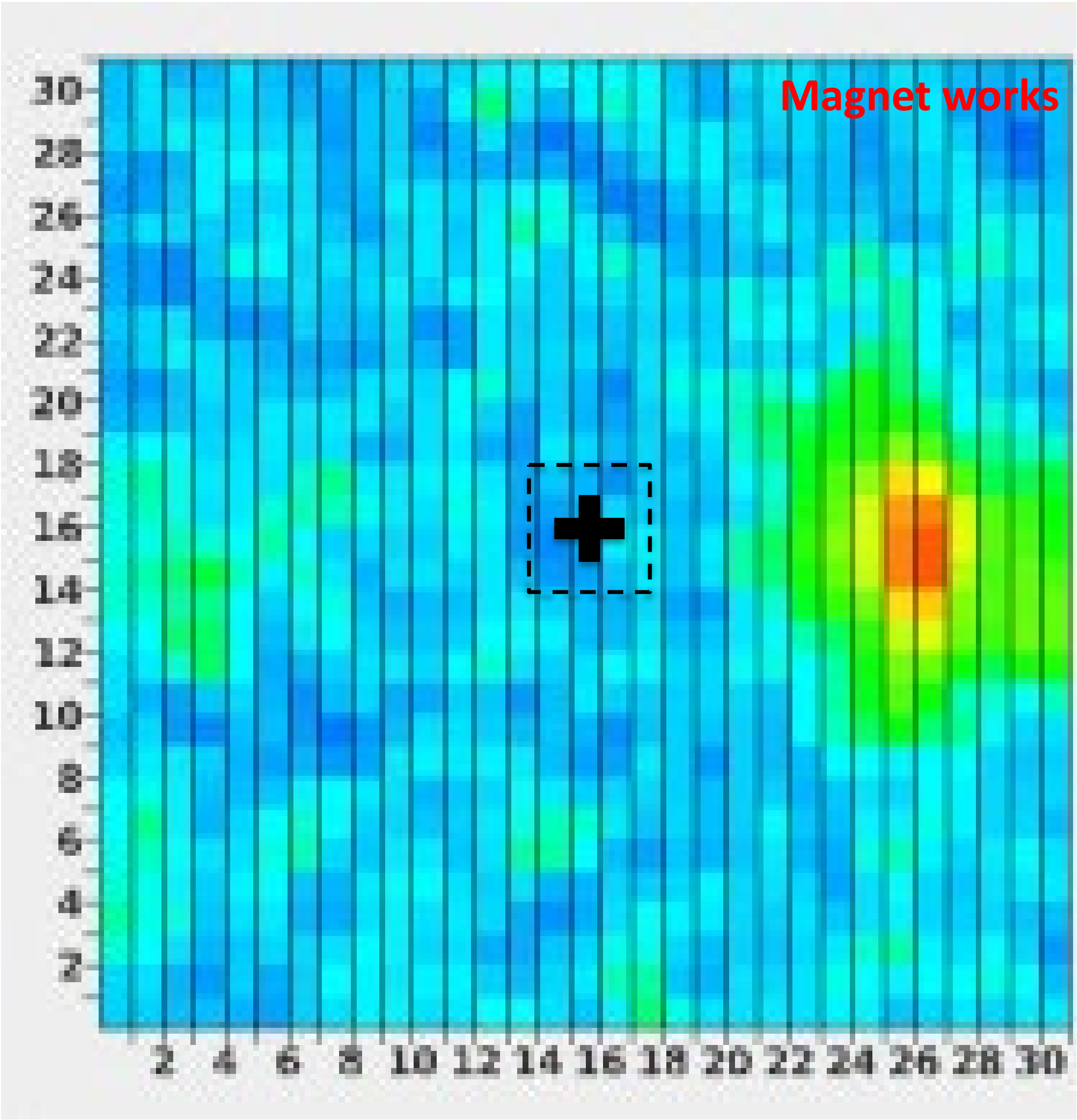
Beam camera screen: ~ 130cm from center of magnet



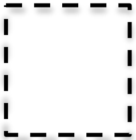
100 MeV/u deuteron beam through the dipole magnet, a 10x10cm square shown as a reference.
Beam camera screen: ~ 130cm from center-of-magnet, primary beam displacement: 5 cm



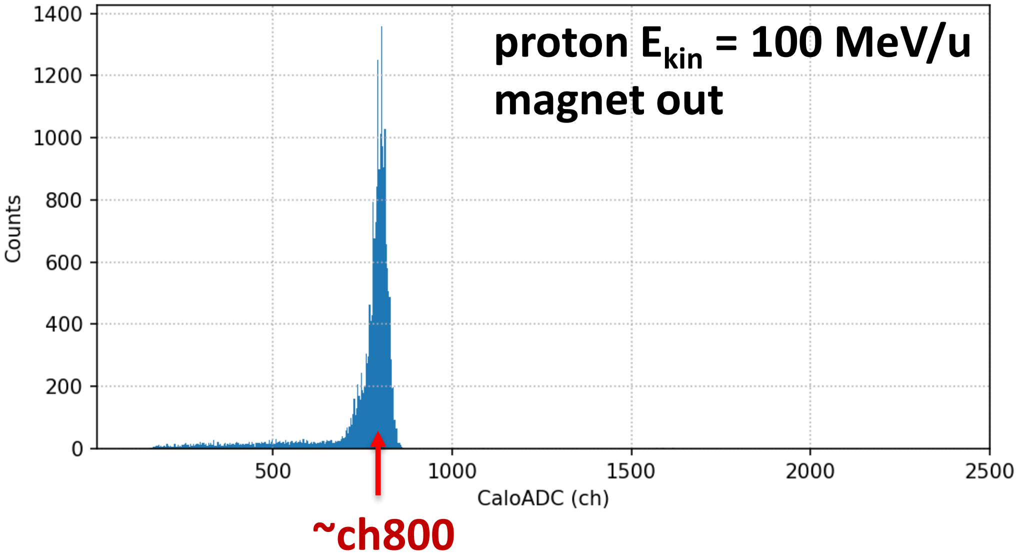
100 MeV/u deuteron beam through the magnet.
At the Strip-Chamber (1" pitch) behind the Calorimeter (~650cm from magnet-center),
Primary deuteron beam displacement: ~10" (25.4cm)

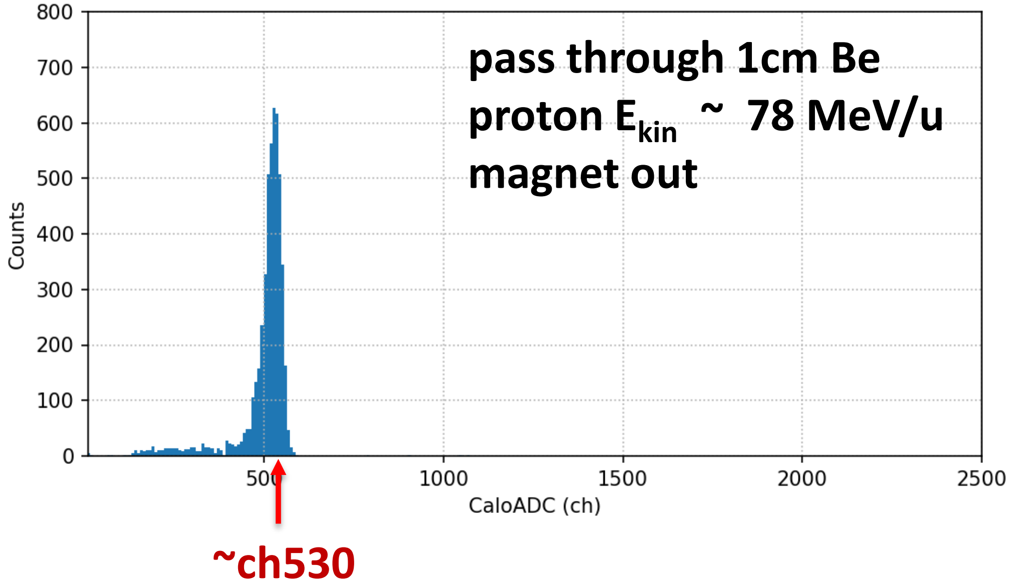


Calorimeter size:
scintillator block
(10cm x 10cm) x 20cm thick

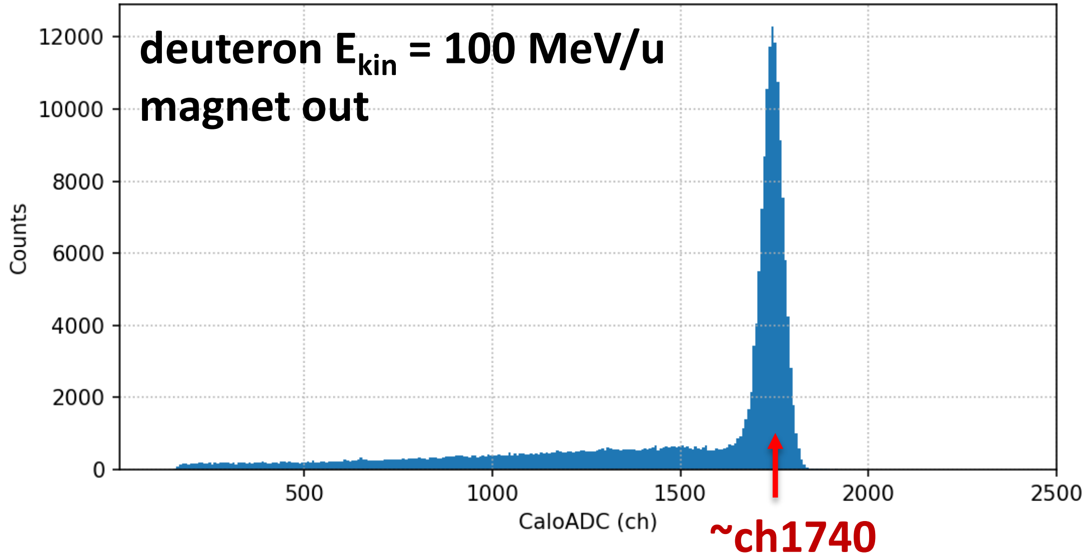


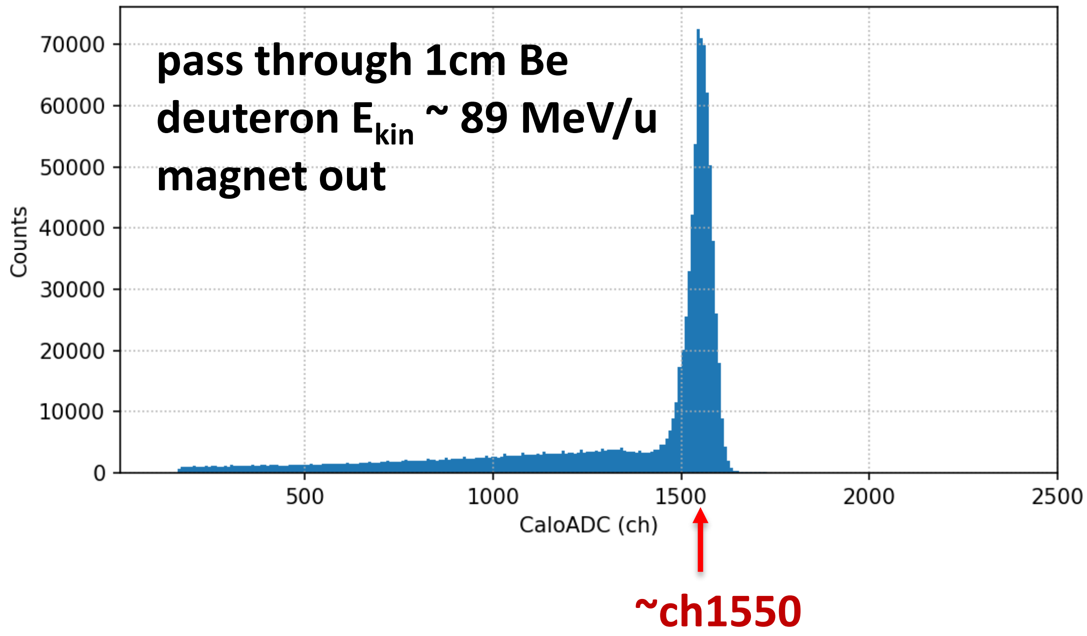
Calorimeter ADC



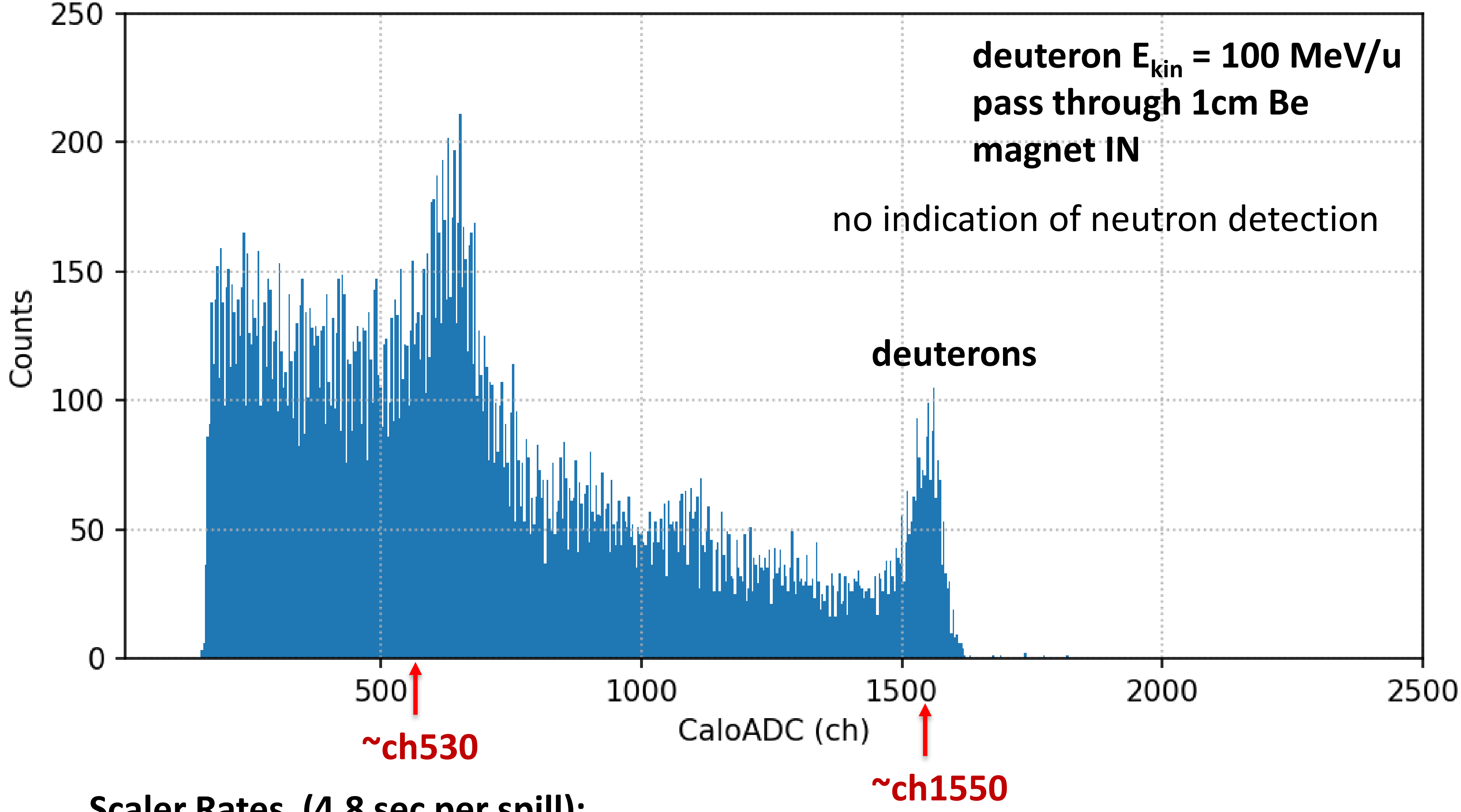


Calorimeter ADC





Calorimeter ADC



Scaler Rates (4.8 sec per spill):

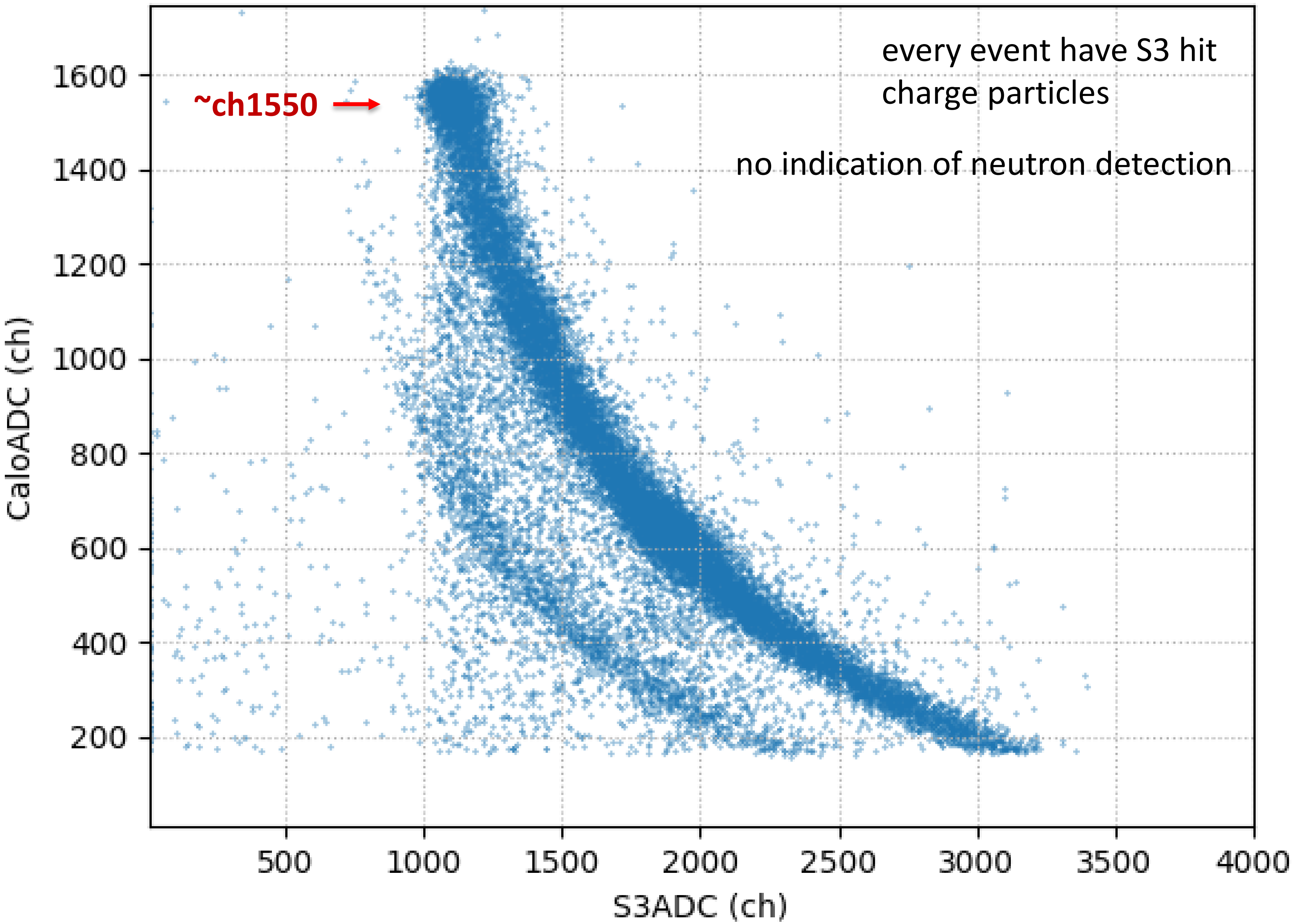
(S_1+S_2): 200k/spill

S_3 : 1200/spill

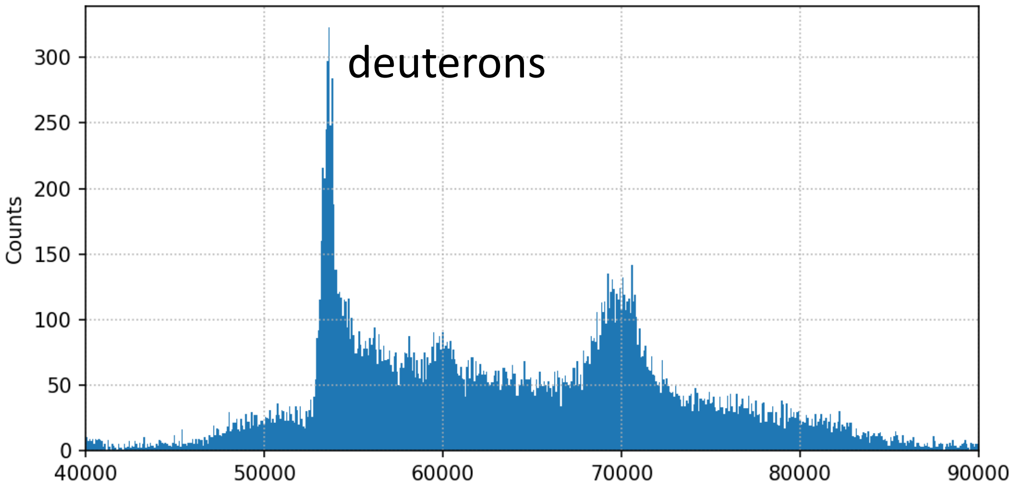
Calorimeter: 270/spill

Trigger (S_1+S_2)+Calorimeter: 90/spill

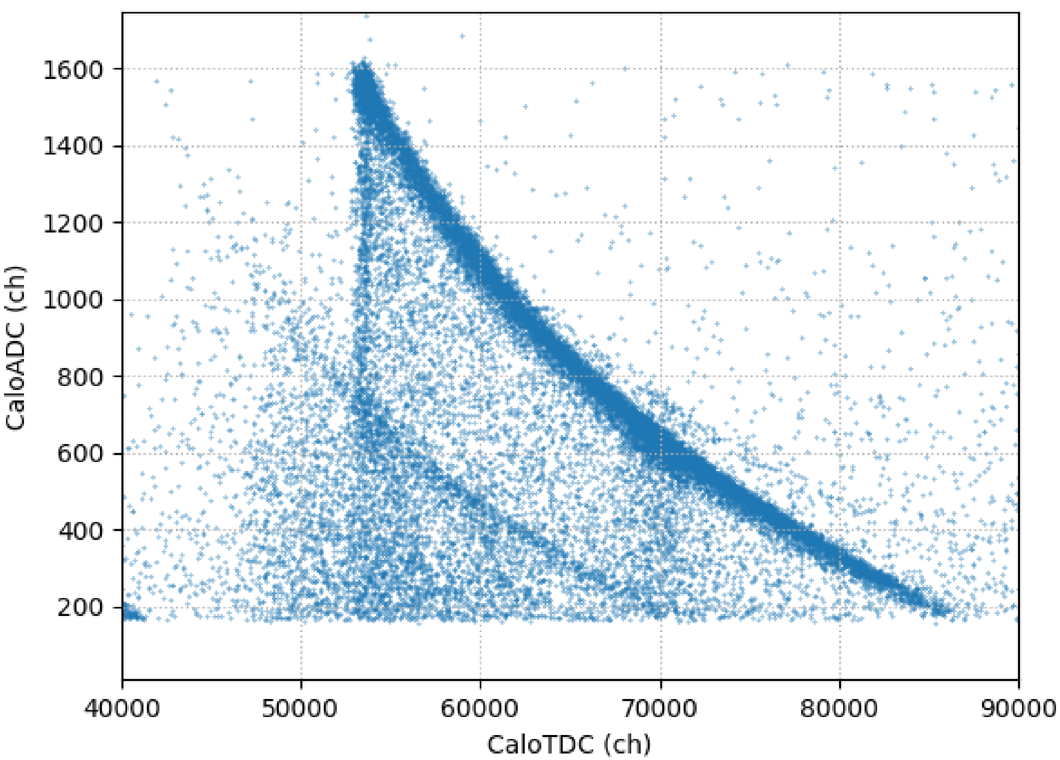
Calorimeter_ADC vs S3_ADC all events



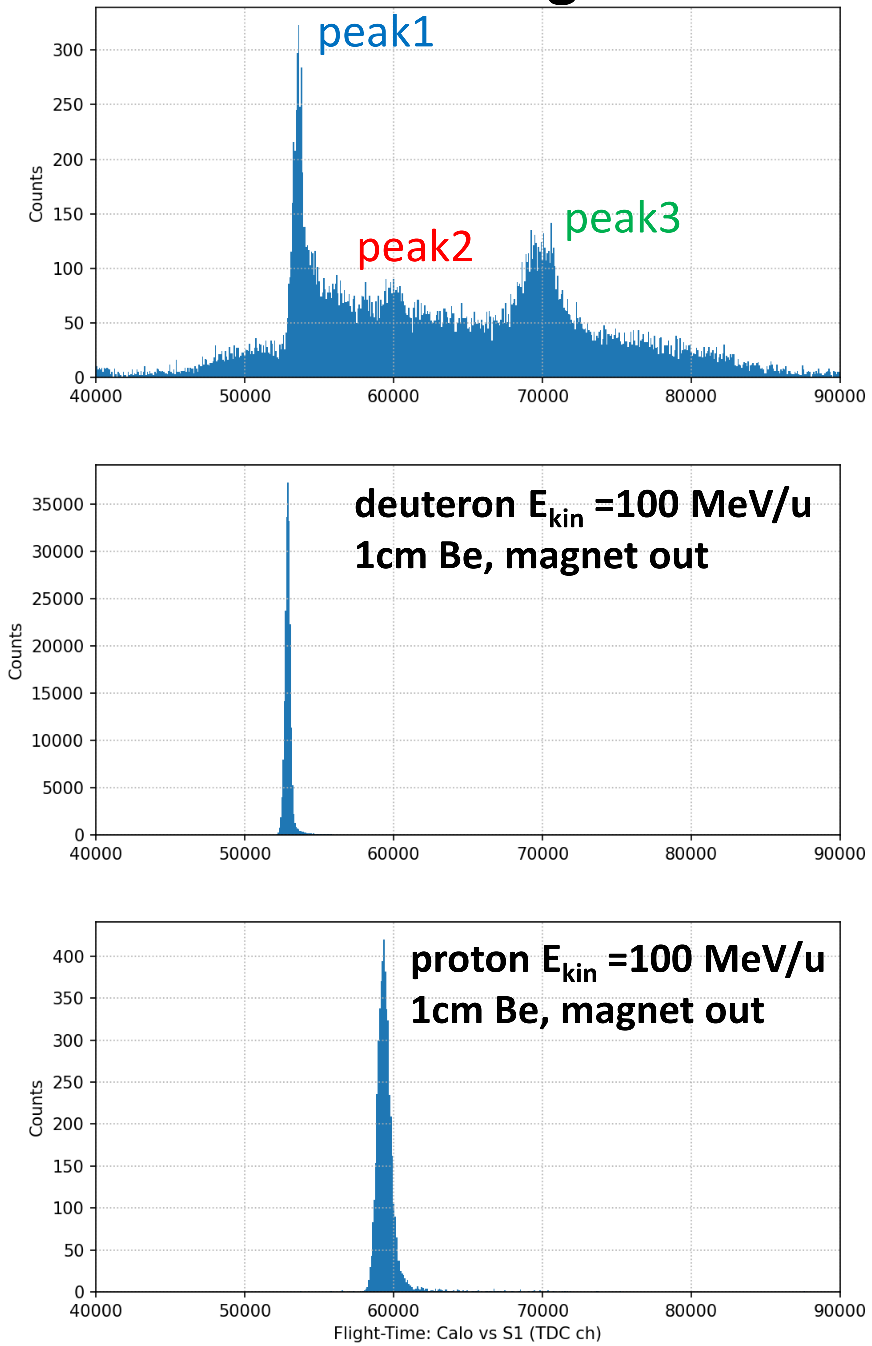
Calorimeter Flight-Time



Calorimeter Flight-Time vs ADC

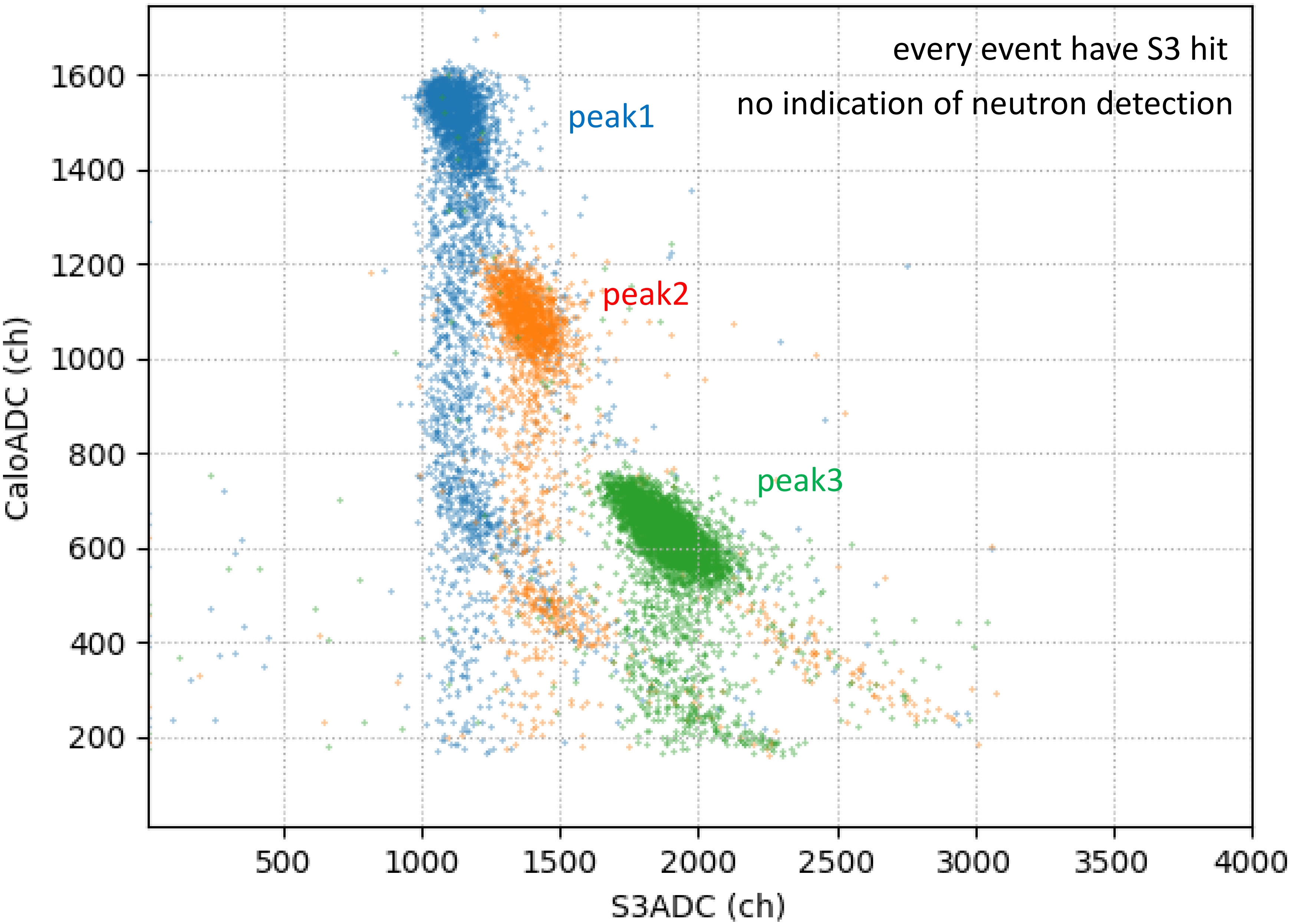


Calorimeter Flight-Time



no indication of neutron detection

Calorimeter_ADC vs S3_ADC with Flight Time Cuts



Summary

It’s well-known since 1940s that deuteron disassociation on a light nuclear target produces mono-energetic neutrons, a practical fast-neutron beam with tunable energies has never been demonstrated.

BNL has all the facilities/technologies to make such a tunable neutron beam possible:

- **EBIS provides deuteron beam (and proton through H_2+).**
- Booster and slow yje extracted beam, for deuterons up to 1000 MeV.
- NSRL beam line and the Target Room.

We took a small step: an effort was made through this LDRD-C project, no clear indication of neutron detection yet.

Improvements Planned (if funded in FY2026):

- A open-slot dipole magnet: to clearly sweep away all primary beam deuterons and the breakup protons.
- Tag the breakup proton with scintillator strip detectors.
- A neutron telescope detector: layers of segmented scintillator blocks (charge-veto combined with range-telescope)
  Design guided by GEANT4 simulations.

Next Step:

Event-by-event tagged neutrons as a clear demonstration.

Backup Slides

R. Serber, *Phys. Rev.* 72, 1008 (1947)

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