




# FaNS
# Spectroscopy Of Cosmic Ray Induced Neutrons

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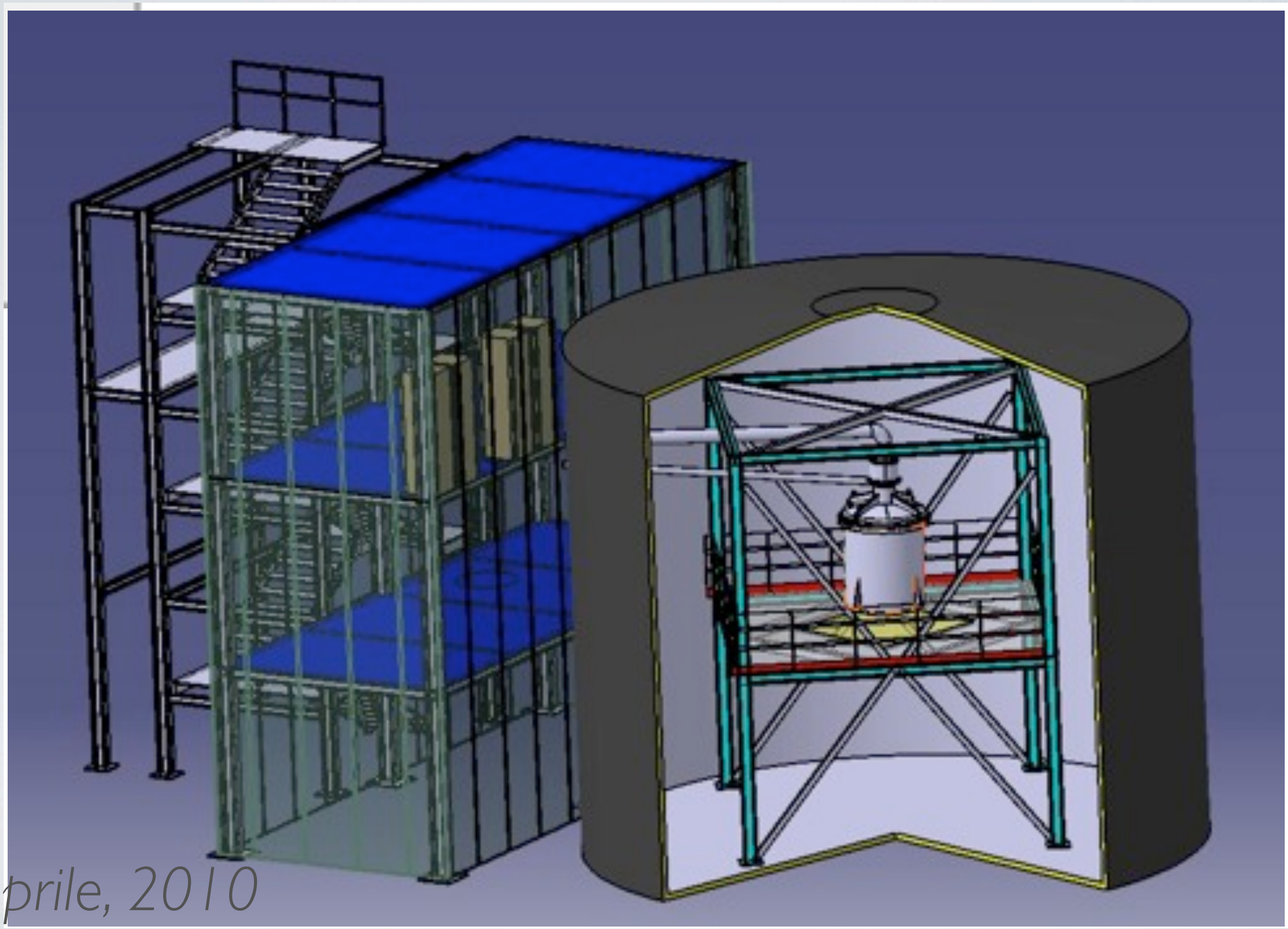
# OUTLINE

- Fast neutrons as backgrounds for underground science
- Detection of fast neutrons with plastic scintillator and helium proportional counters
- The UMD/NIST Fast Neutrons Spectrometers (FaNS)
  - FaNS-1: Measure *in-situ*
  - FaNS-2: Measure and simulate

# Fast Neutron Backgrounds for Underground Science

- Fast neutrons play a particularly problematic role in low background experiments
  - Deeply penetrating
  - Create long lived isotopes (Ge77, Xe137)
  - FNs are indistinguishable from WIMP dark matter interactions
- WIMP searches, Double Beta Decay, and others suffer

# XENON1T DARK MATTER SEARCH



*E. Aprile, 2010*

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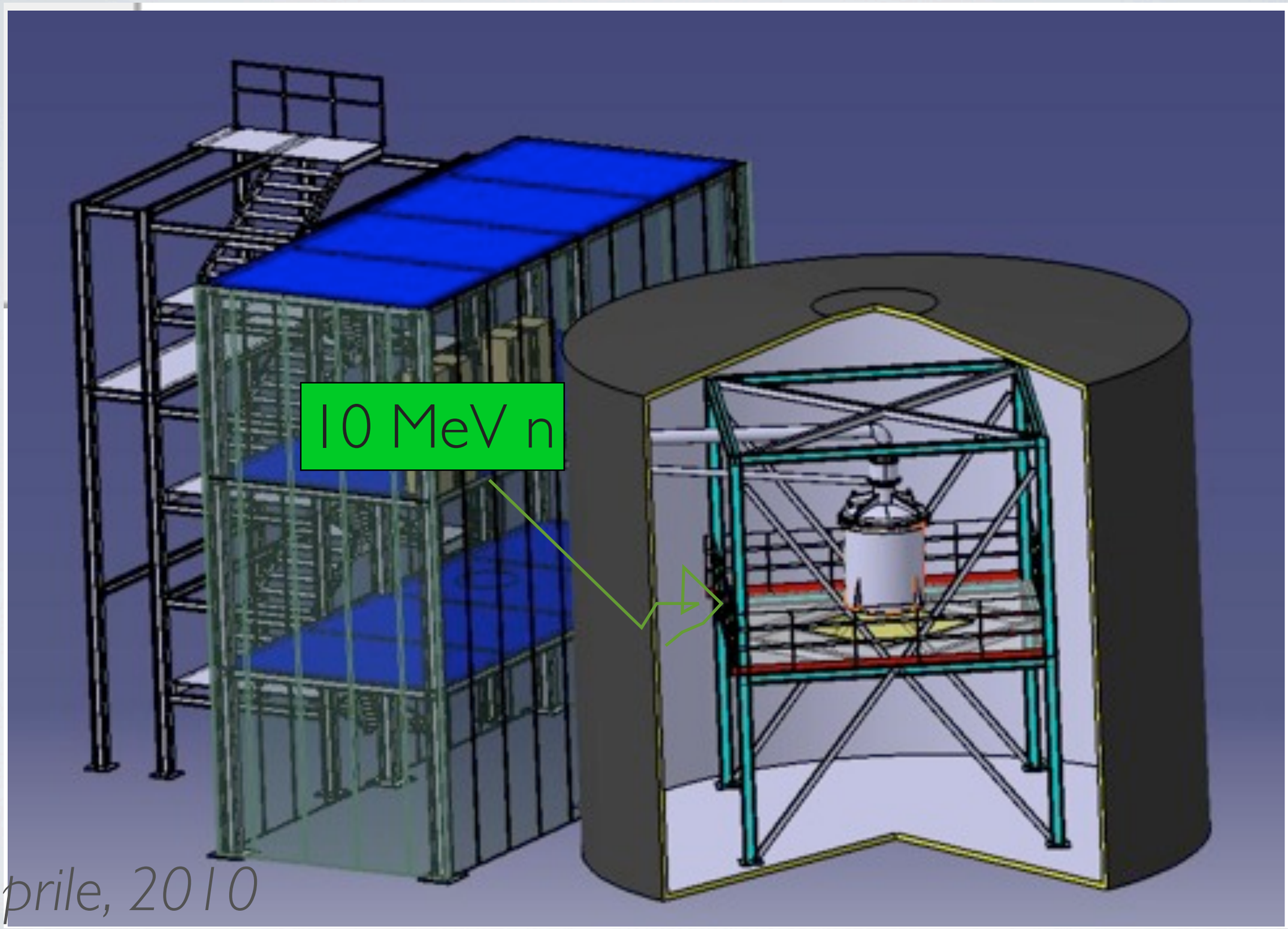

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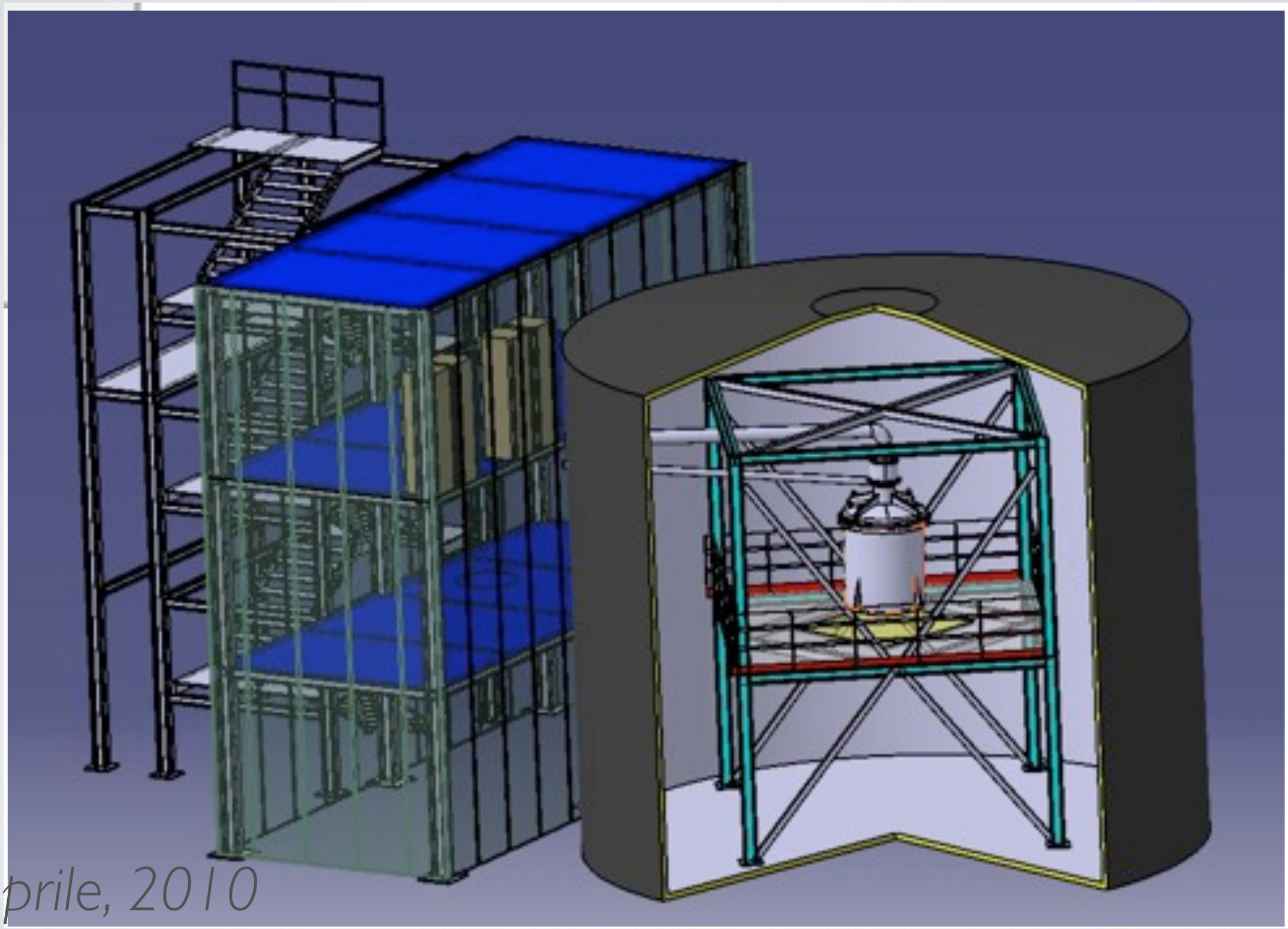

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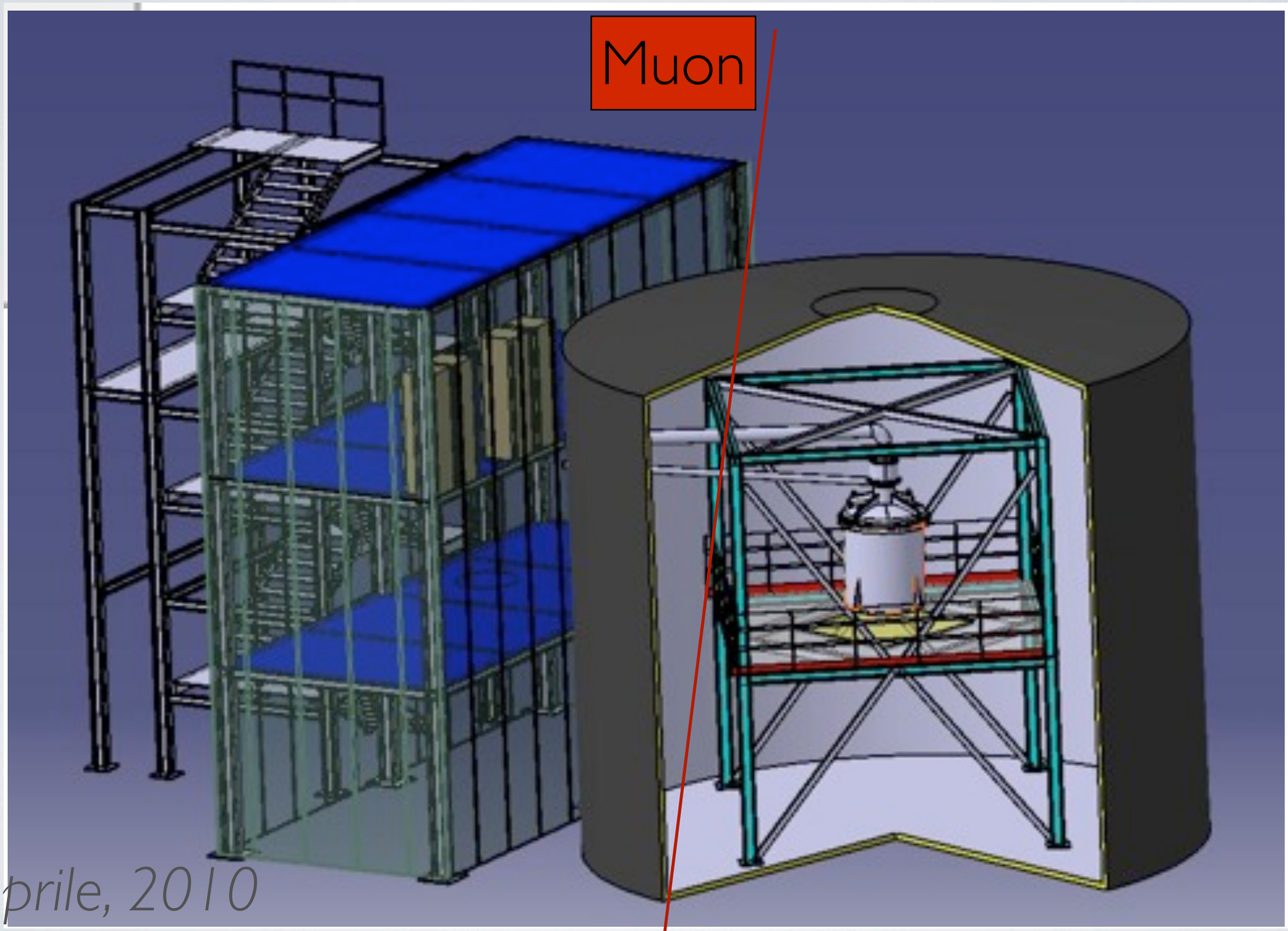

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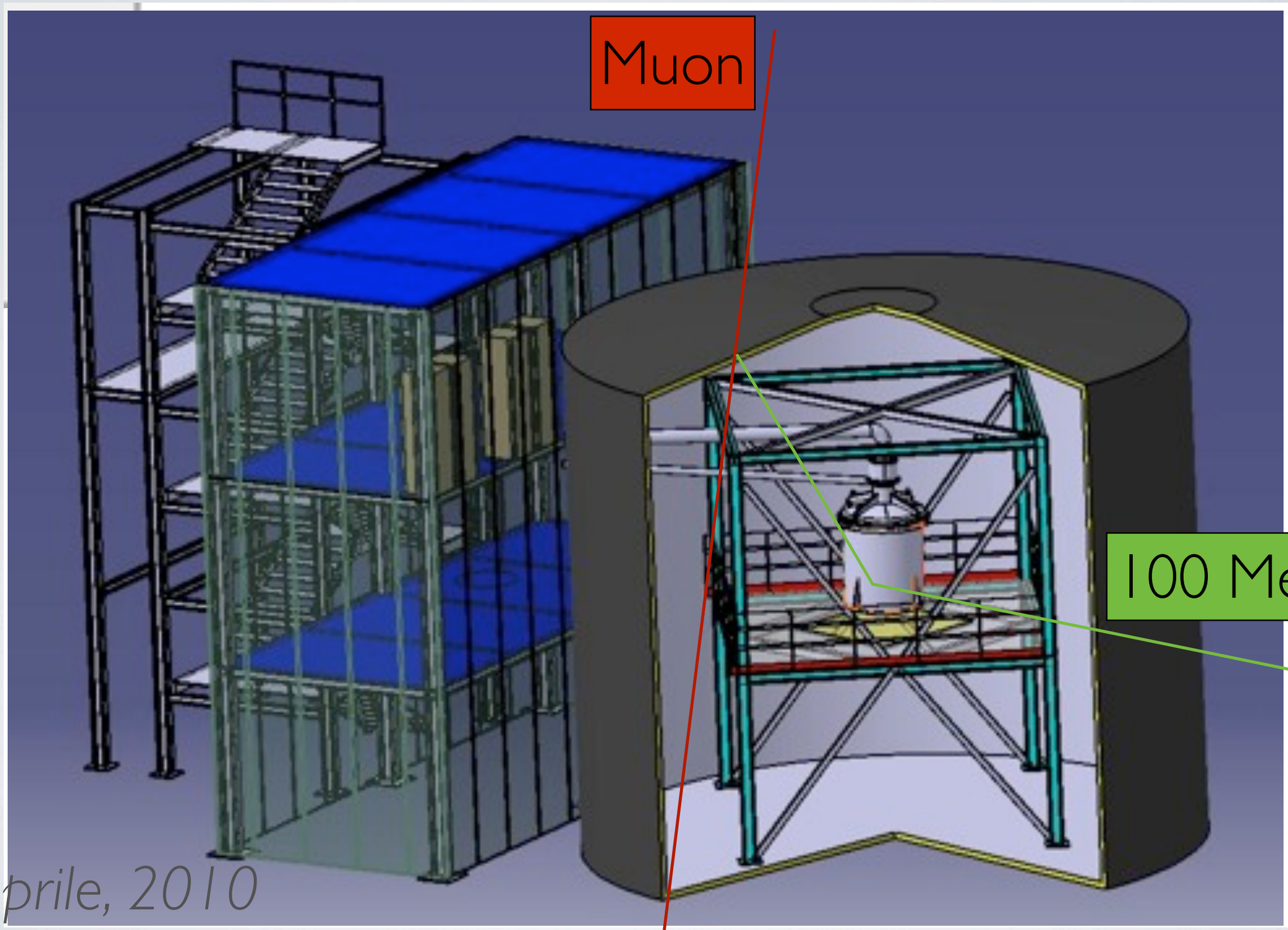

# NEUTRON PRODUCTION

## Simulation vs Data

Data

Simulation

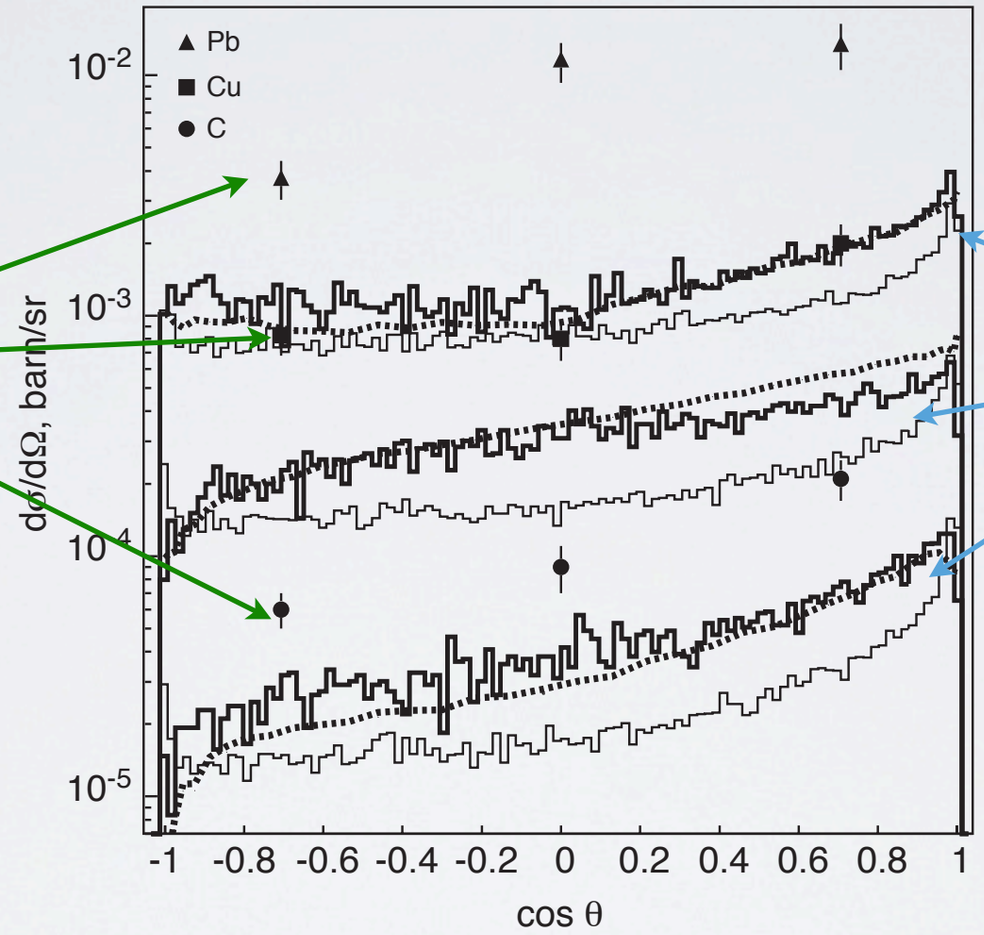


Fig. 7. Differential cross-section of neutron production by 190 GeV muons for a 10 MeV threshold in neutron energy. The data points represent the results of the NA55 experiment. The thin-line histogram shows the GEANT4 simulation considering muon–nucleus interaction only; the thick histogram includes all physics processes. The dashed line represents the FLUKA results for the latter case.

Araújo, et. al. NIM A, 2005

# NEUTRON PRODUCTION

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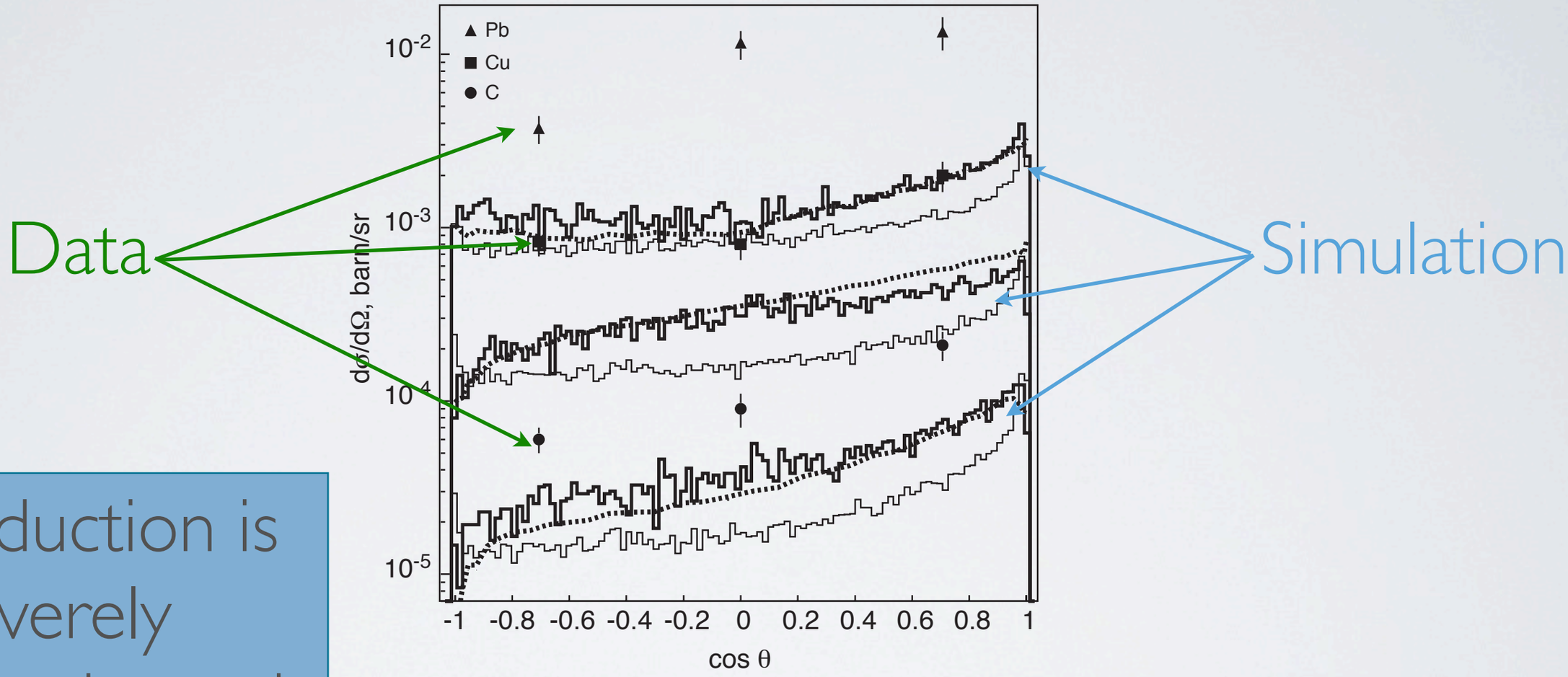


n-production is severely underestimated

Fig. 7. Differential cross-section of neutron production by 190 GeV muons for a 10 MeV threshold in neutron energy. The data points represent the results of the NA55 experiment. The thin-line histogram shows the GEANT4 simulation considering muon–nucleus interaction only; the thick histogram includes all physics processes. The dashed line represents the FLUKA results for the latter case.

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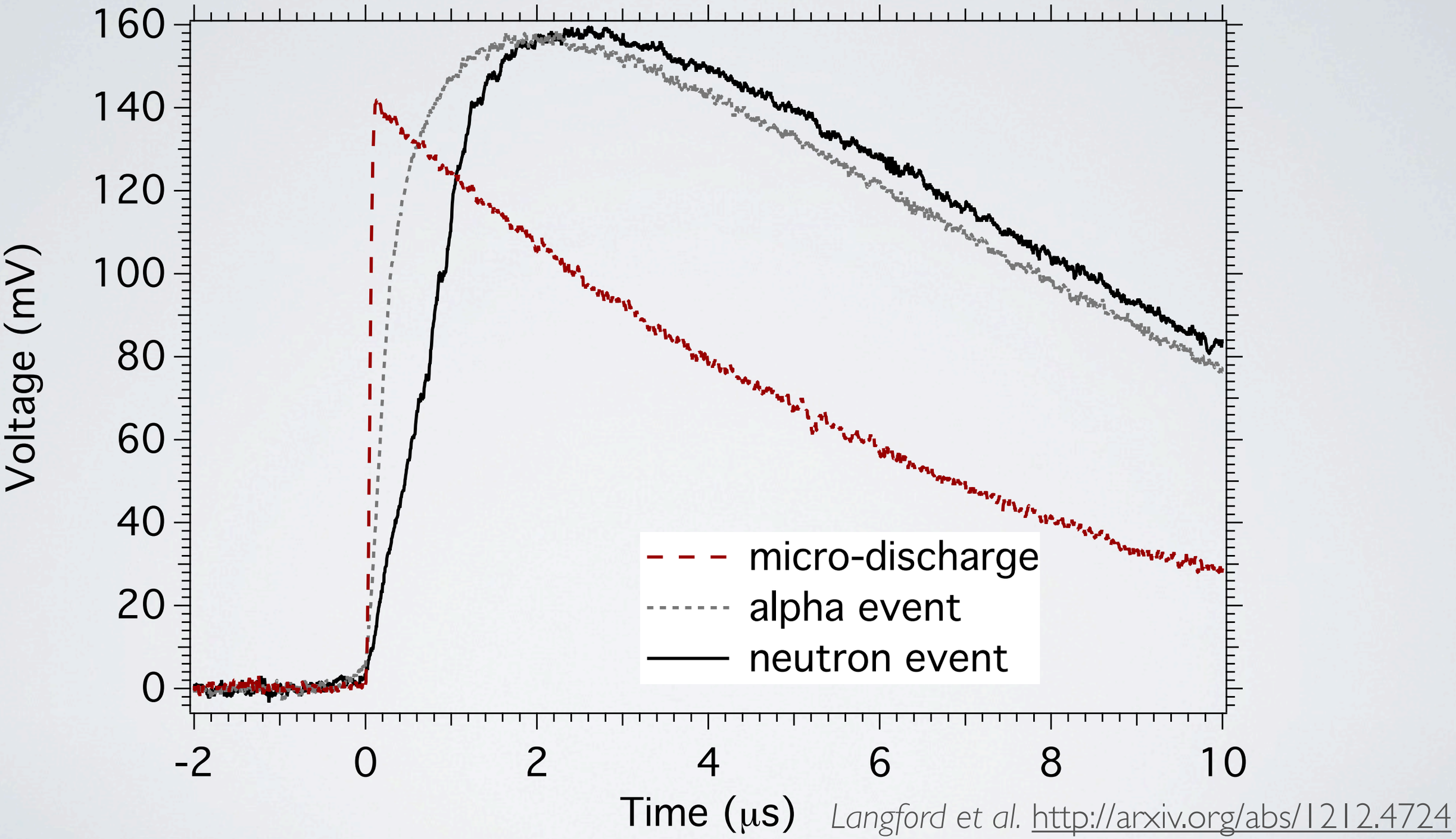
# UMD NIST FAST NEUTRON SPECTROMETERS

# THE FaNS DETECTORS

- Arrays of plastic scintillator and helium-3 proportional counters
- Risetime of helium tubes gives a powerful handle on rejecting alpha backgrounds in detectors
- Use Capture-gated Spectroscopy for particle identification and energy information
- Calibrated at NIST with Cf, DD, and DT neutrons
- Measure the surface and underground neutron spectra
  - FaNS-1: operated at Kimballton Underground Research Facility
  - FaNS-2: to be operated at shallow location at NIST

# RISETIME OF HELIUM SIGNALS




*Langford et al.* http://arxiv.org/abs/1212.4724

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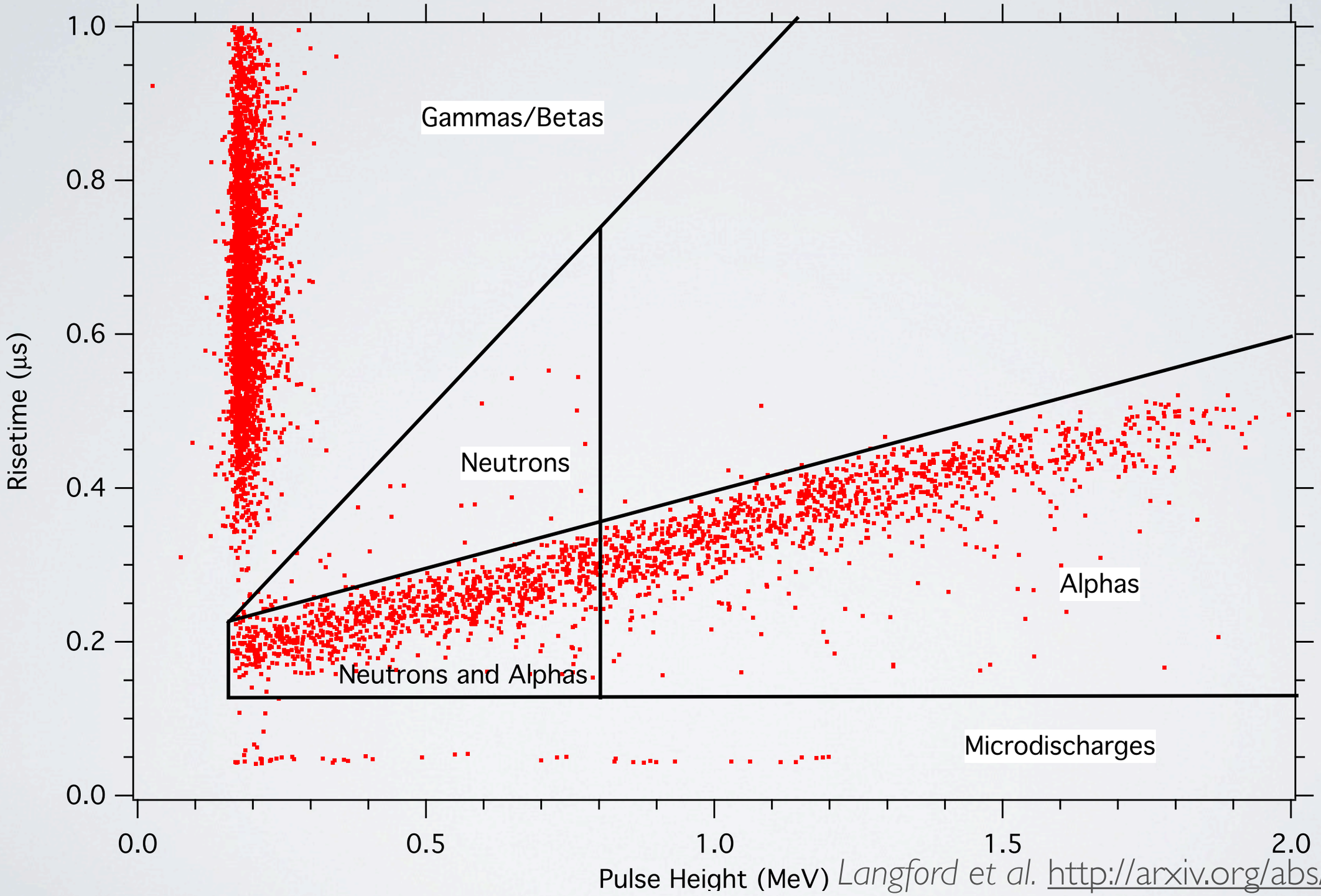


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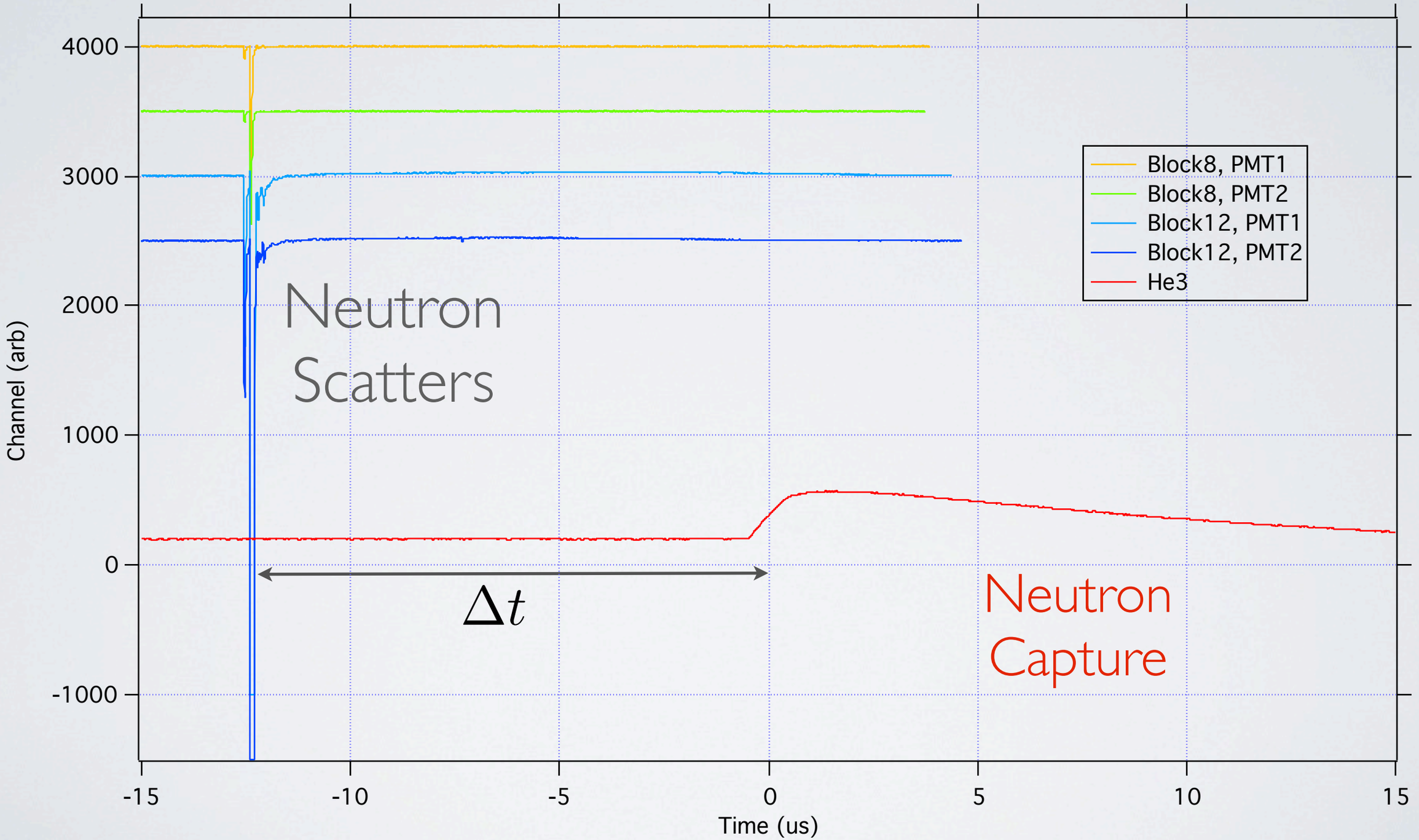
# CAPTURE GATED SPECTROSCOPY



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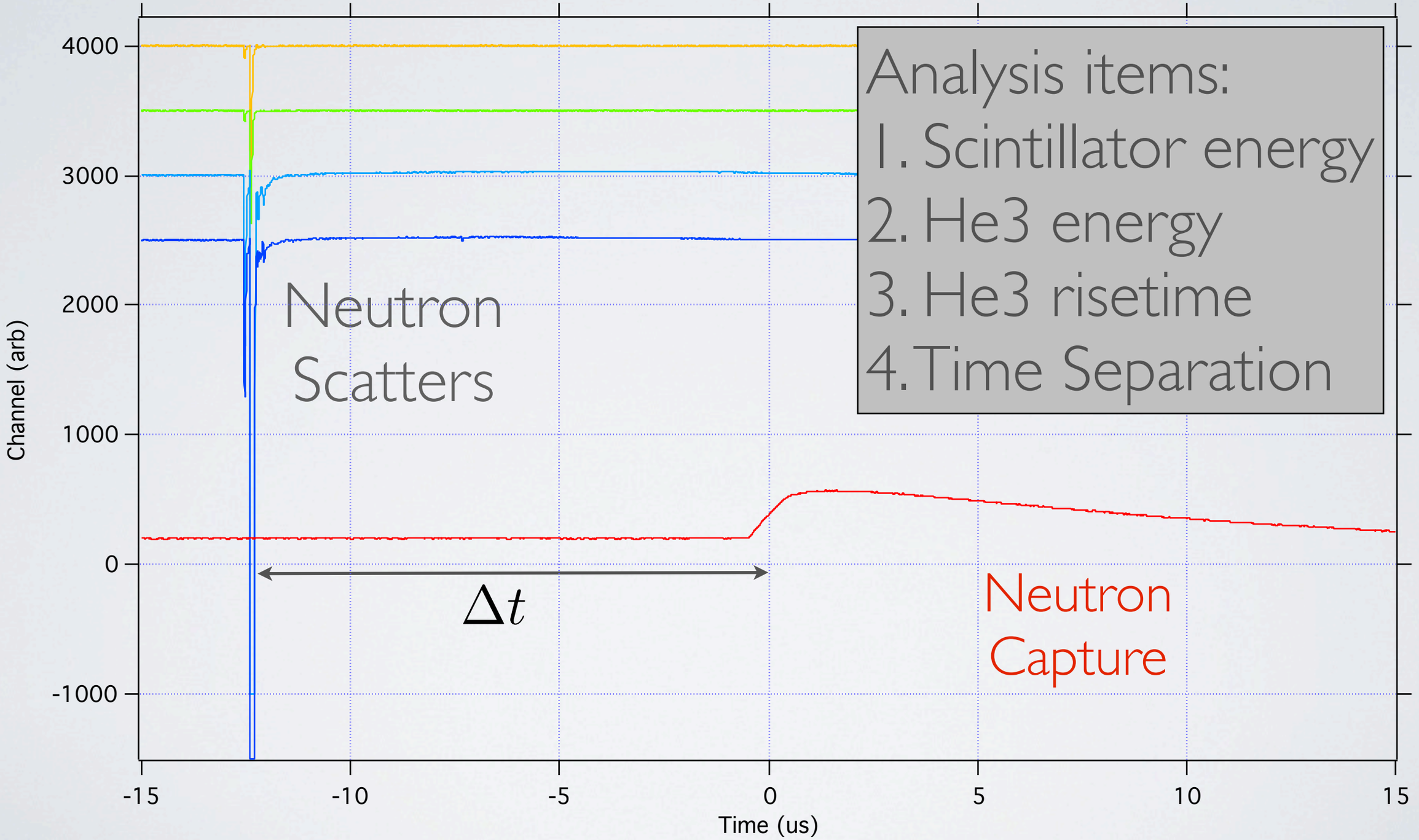

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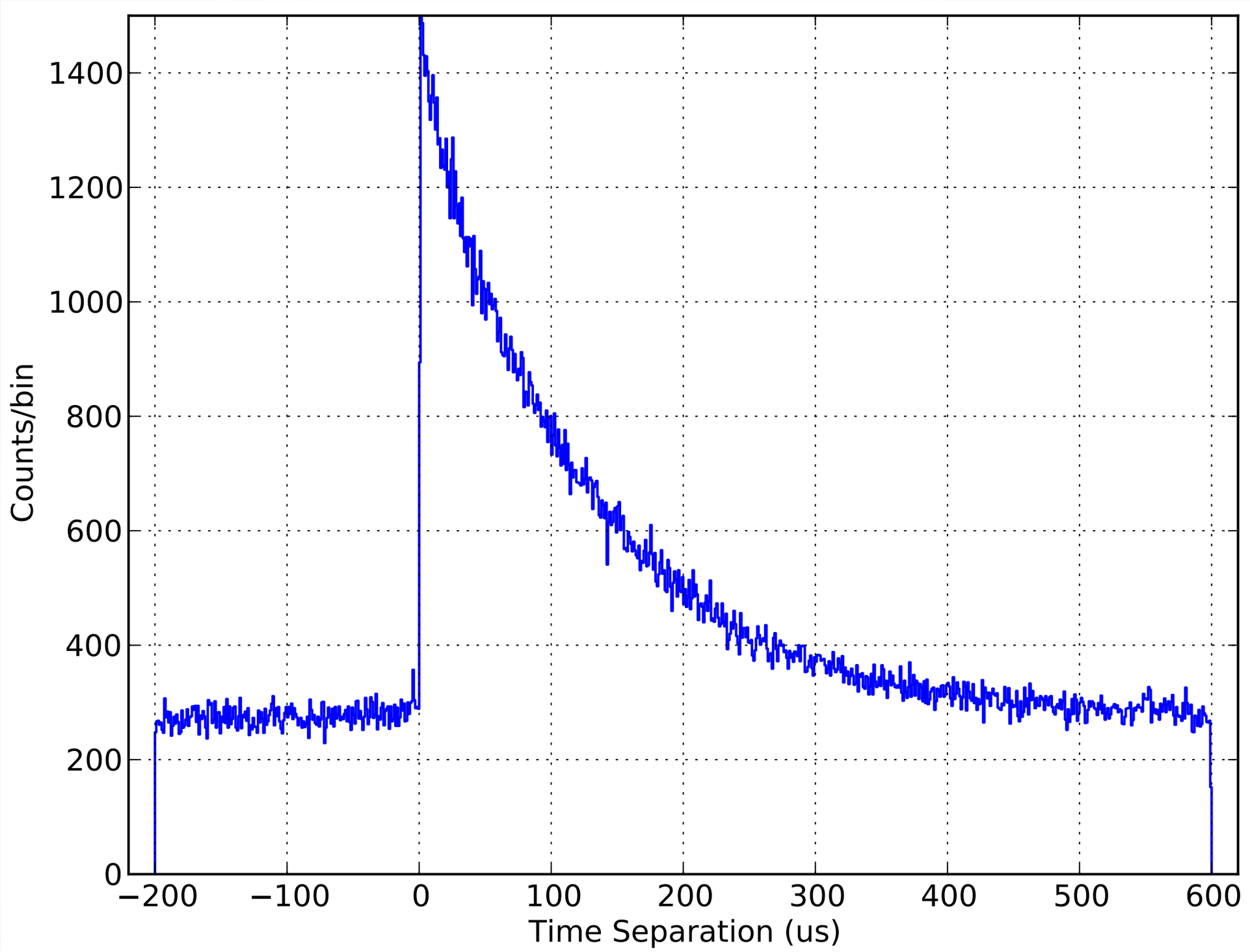

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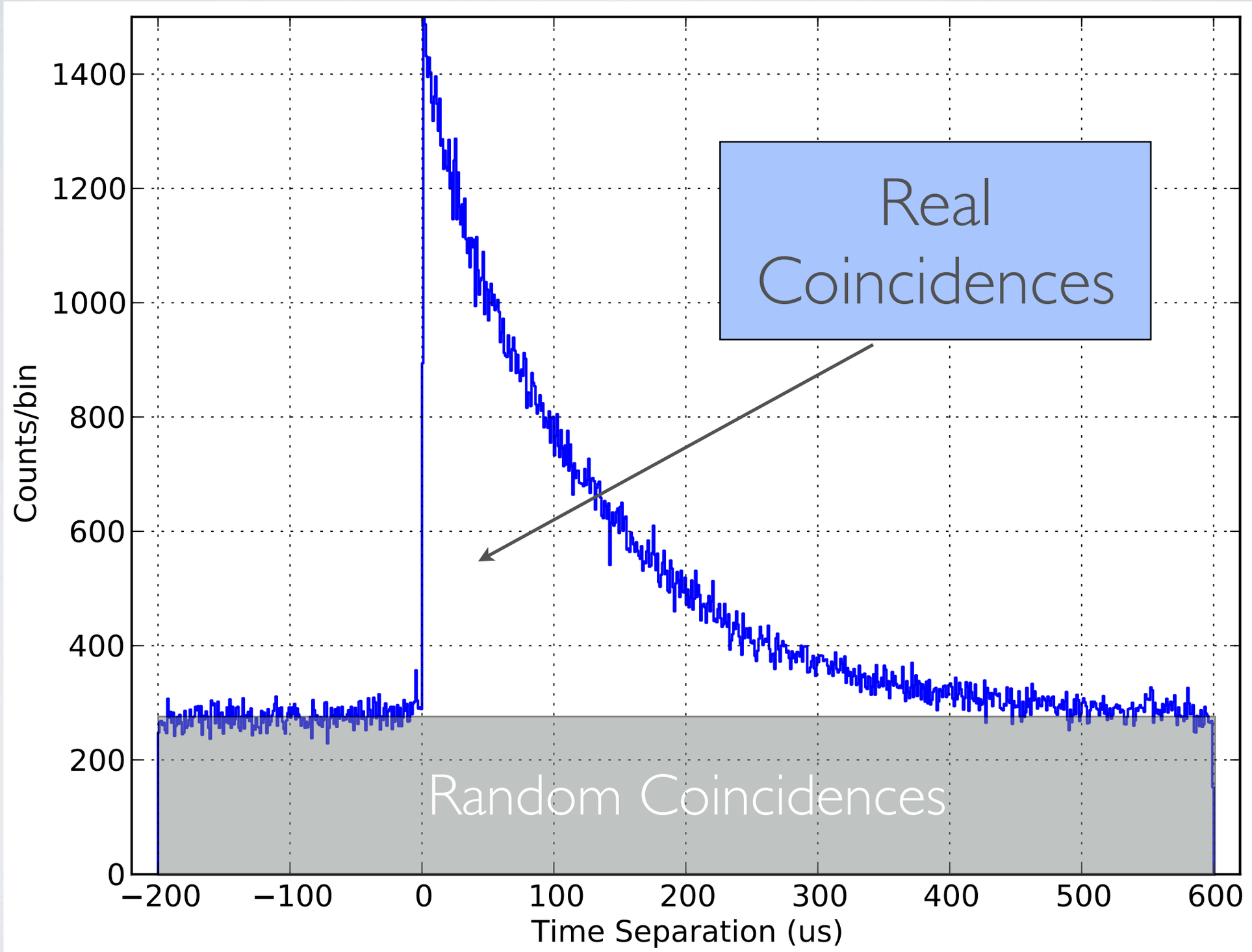
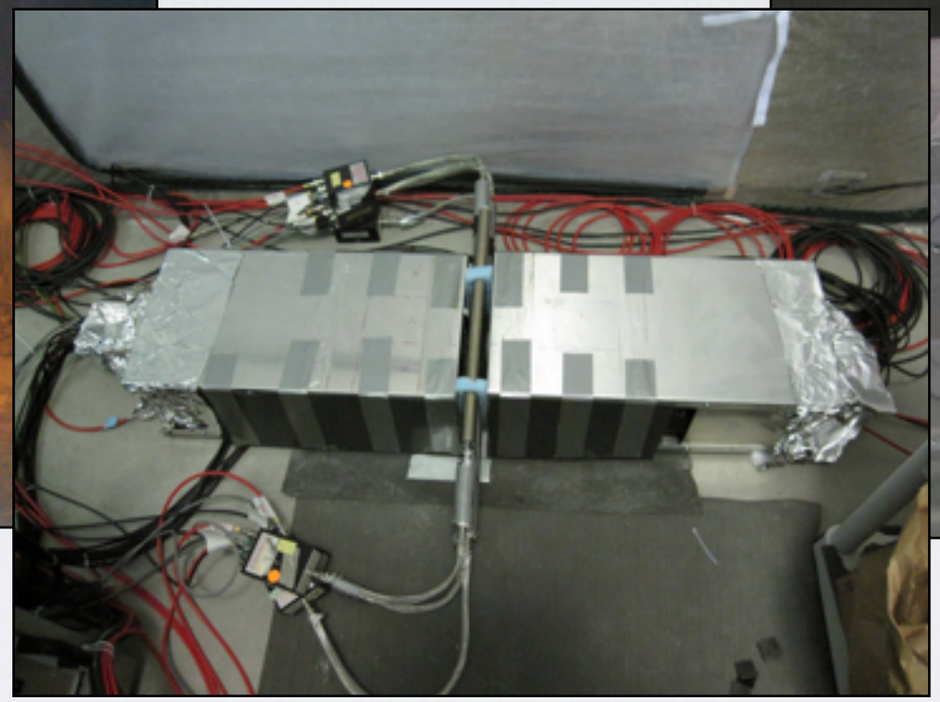
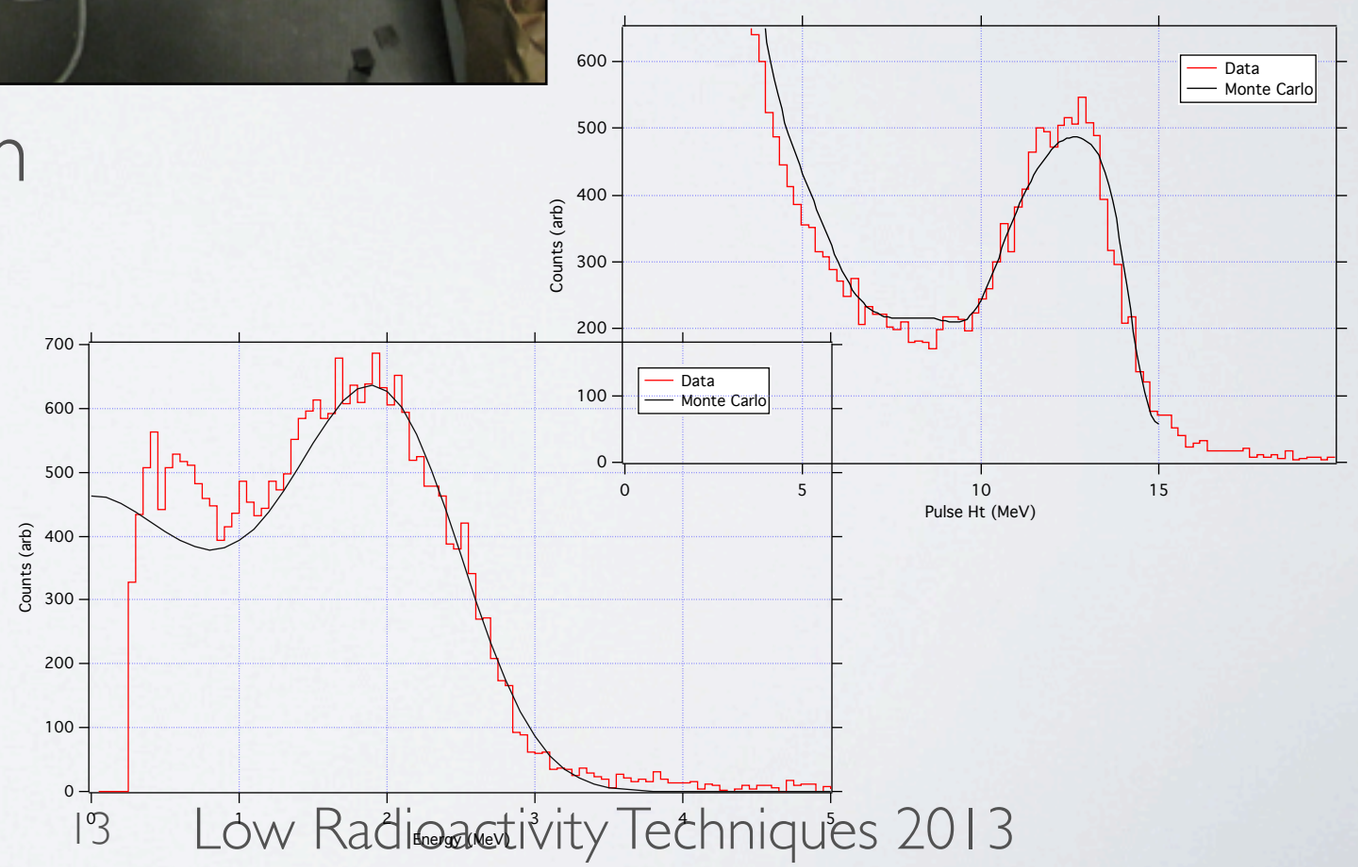


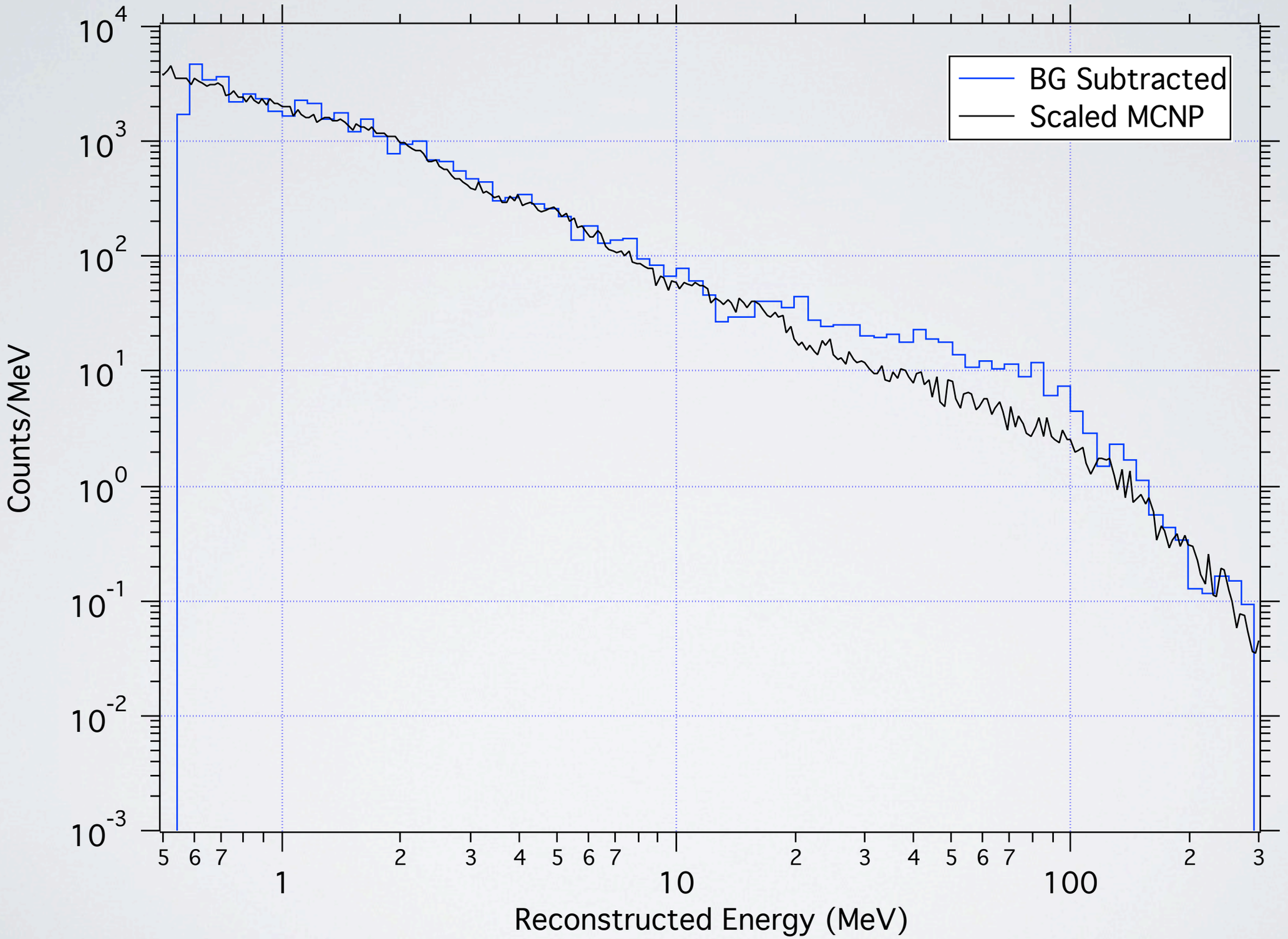
# FaNS-1 SUMMARY



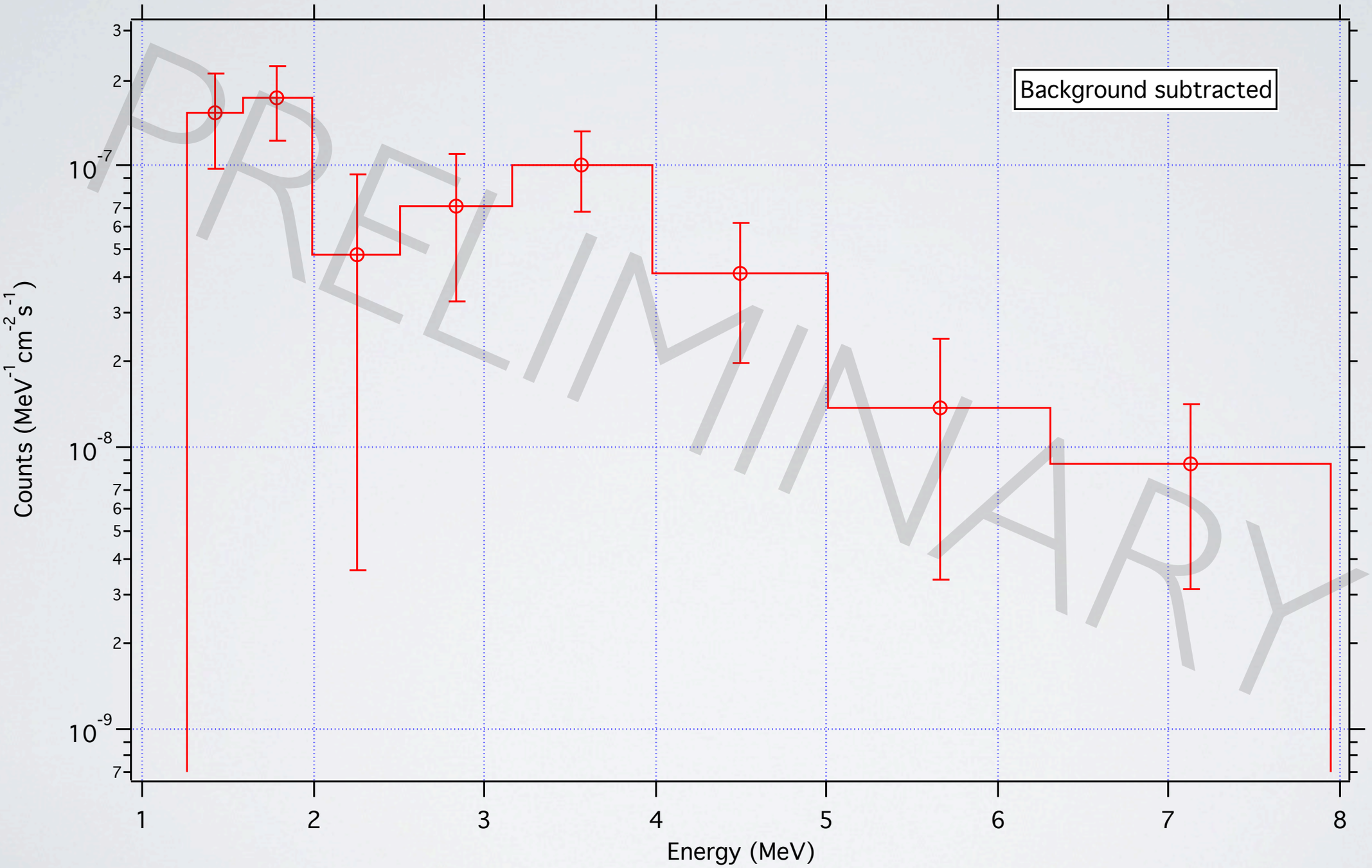
- Calibrated at NIST
- Measured the surface spectrum to ~150 MeV
- Operated for 2 years at KURF
- Measured the fission neutron spectrum and flux at KURF
- To be submitted to PRC



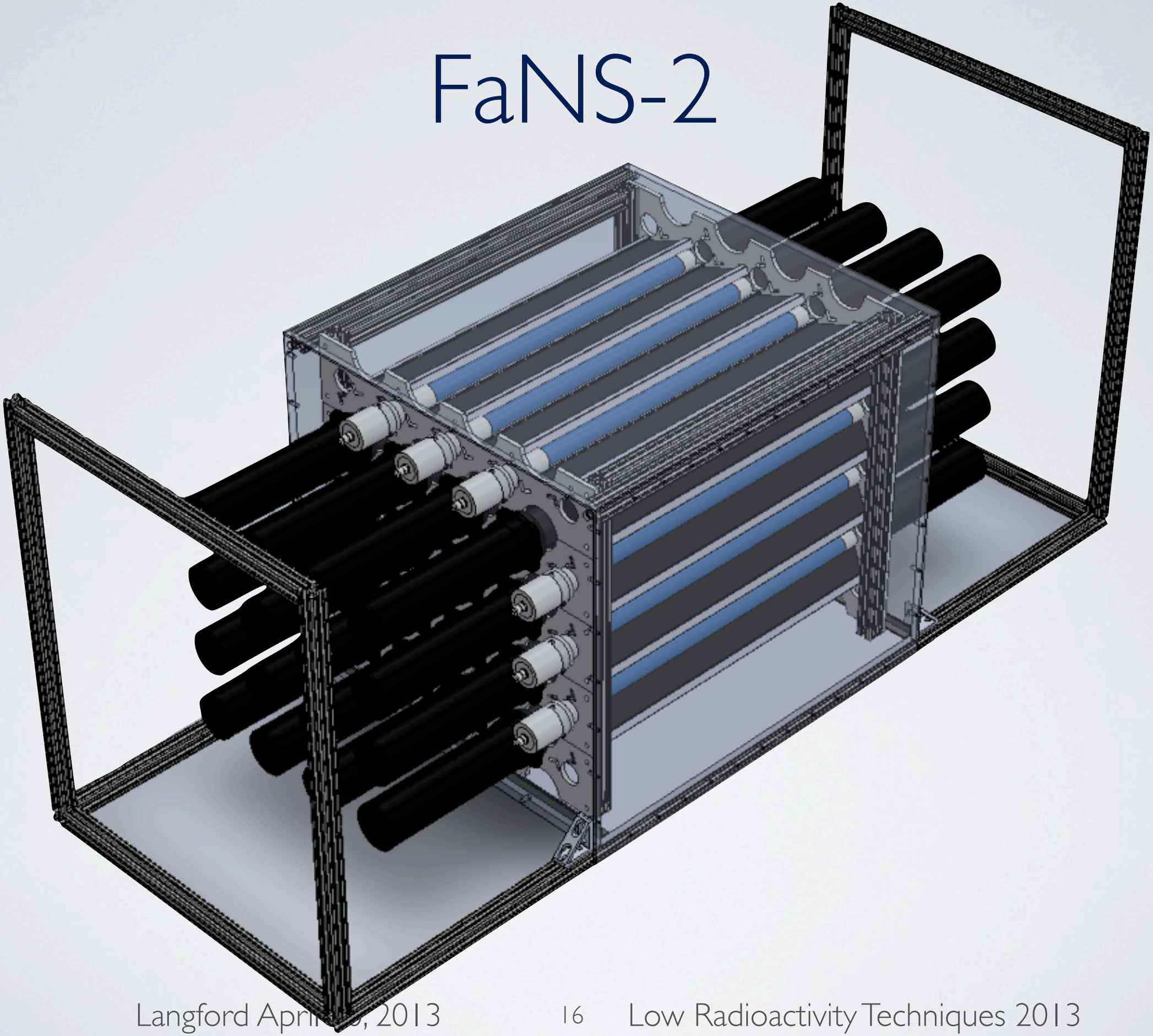
# FaNS-1 SURFACE NEUTRONS



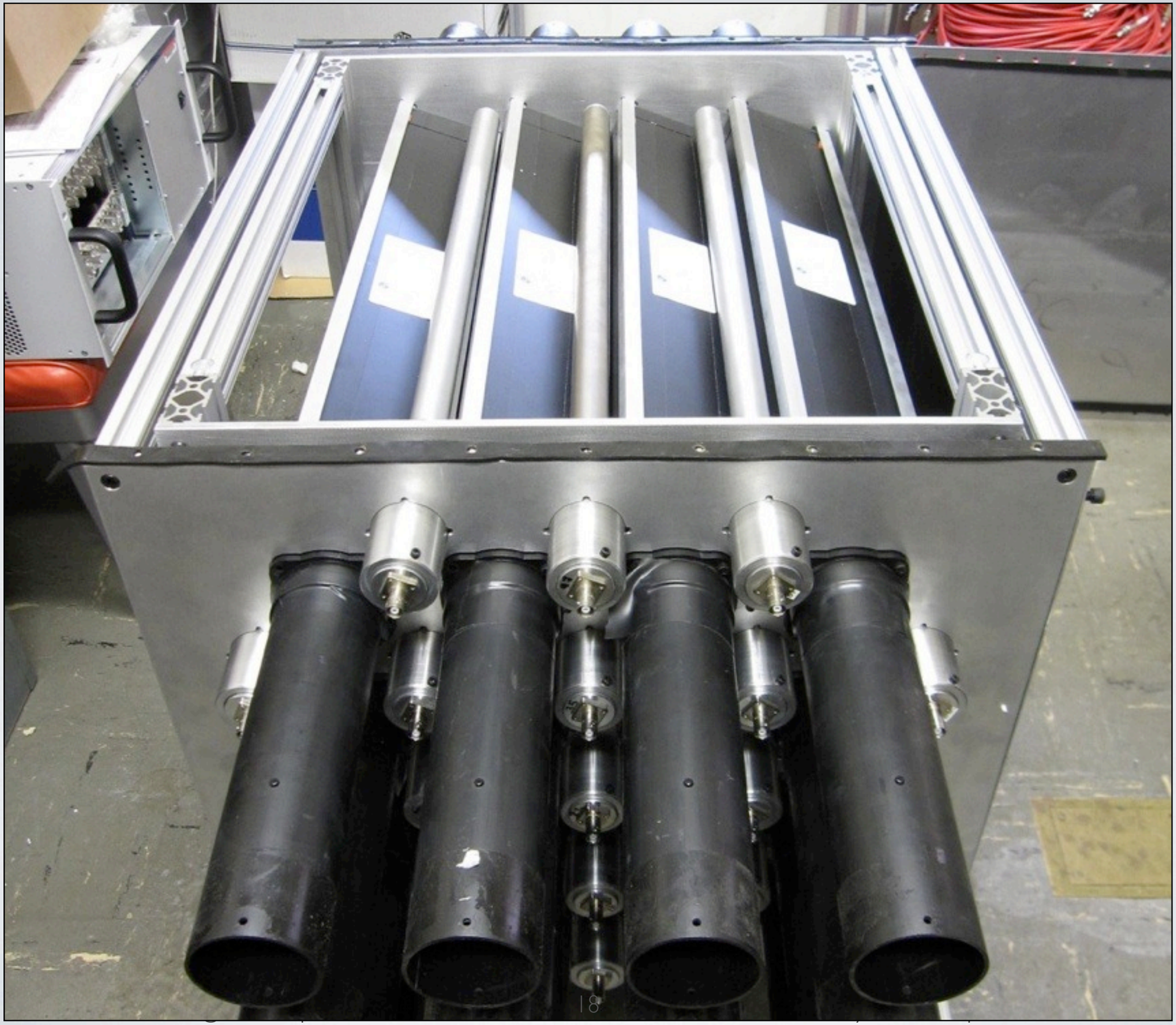
# FaNS-1 AT KURF - 1450mwe



# FaNS-2




KIMTECH



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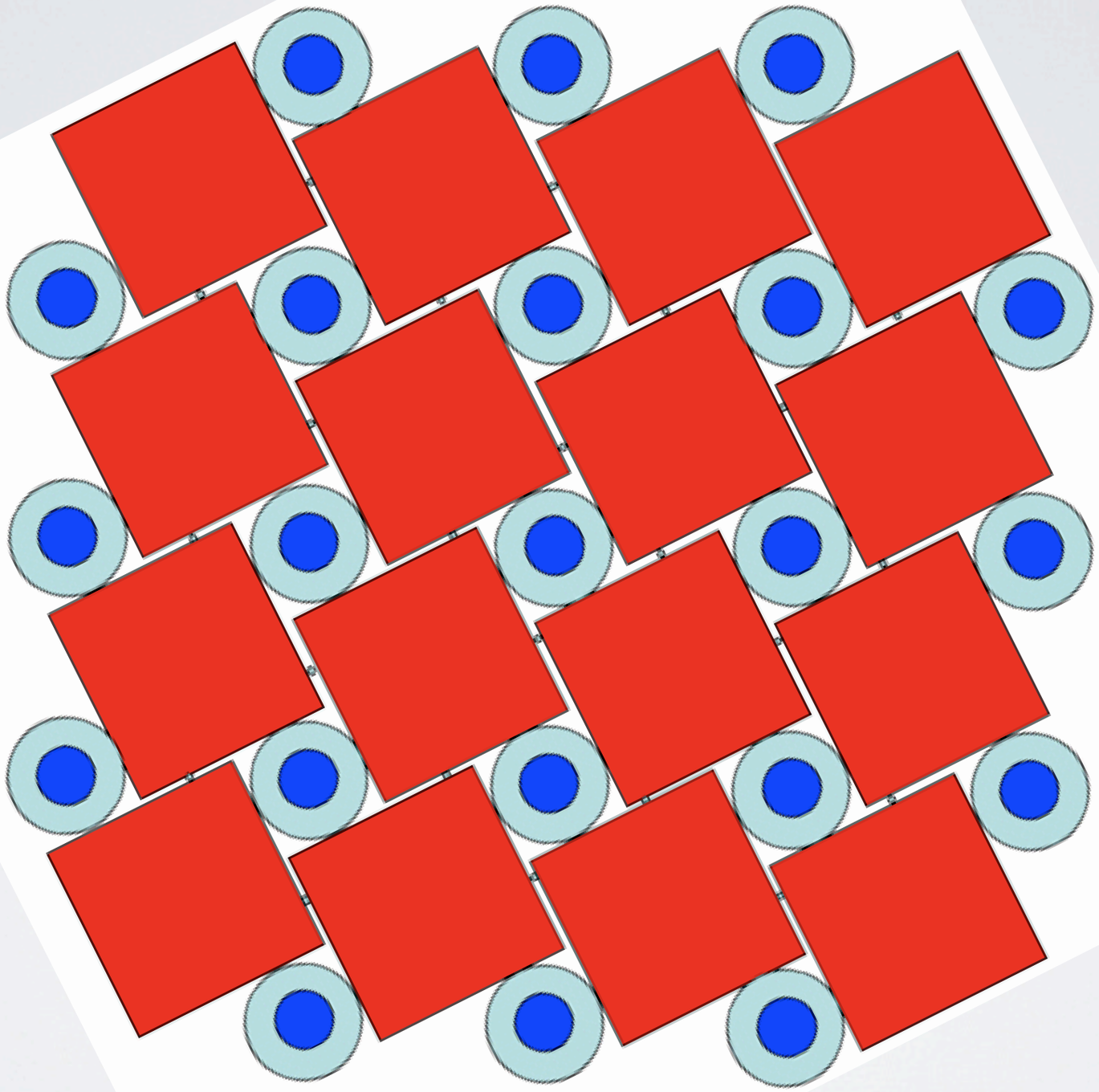

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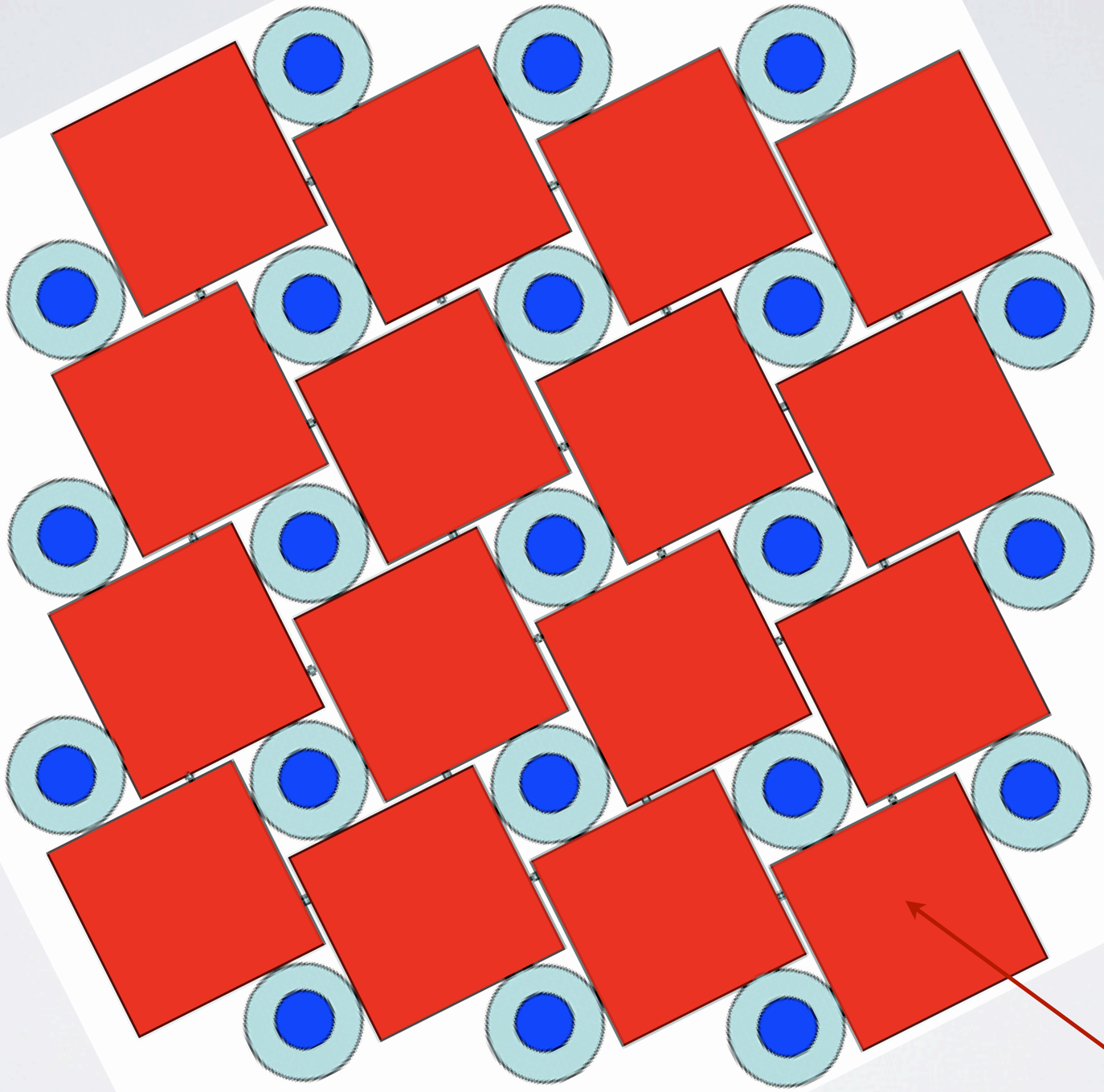
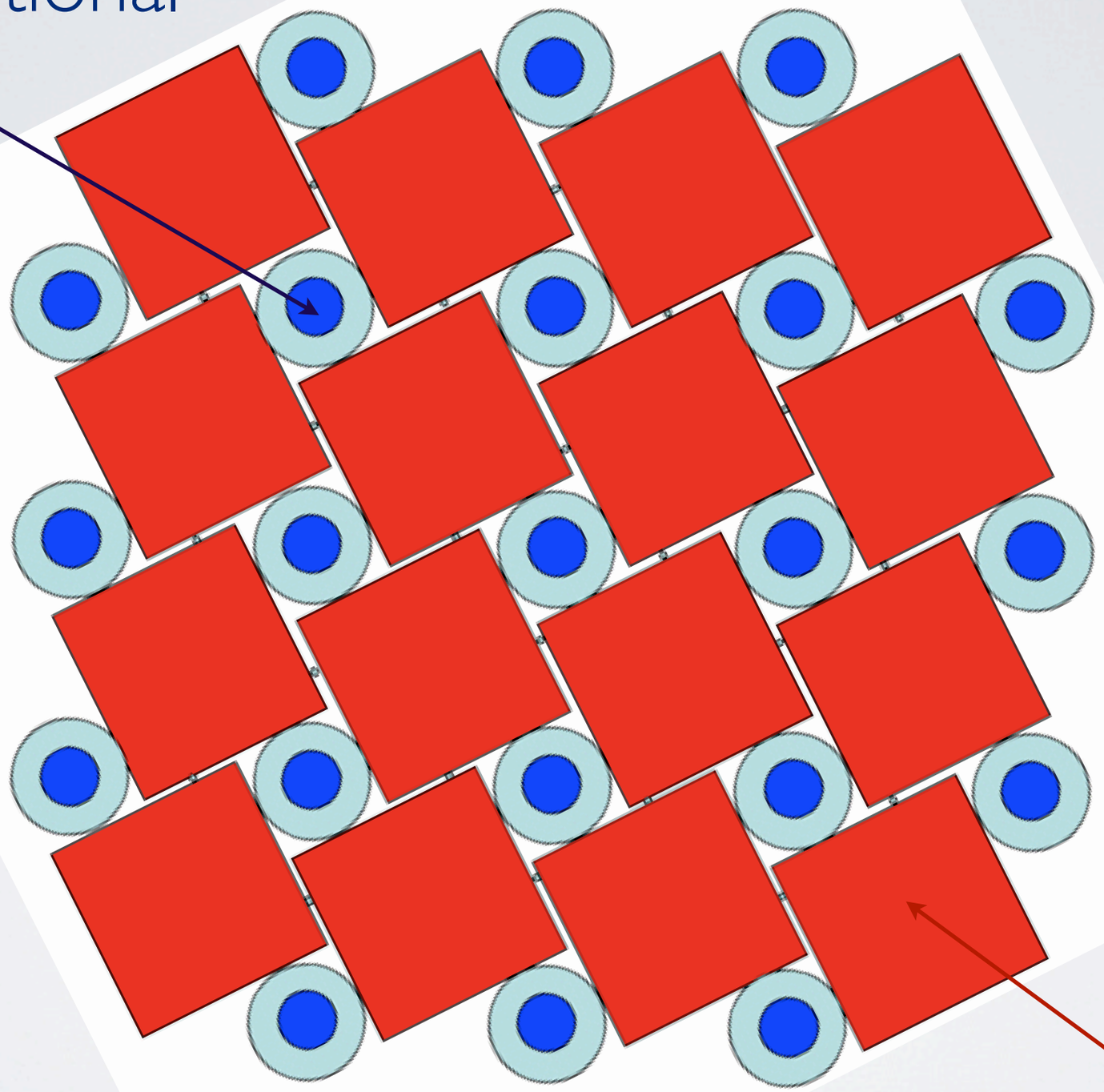


Plastic Scintillator

# FaNS-2

He3 Proportional Counters



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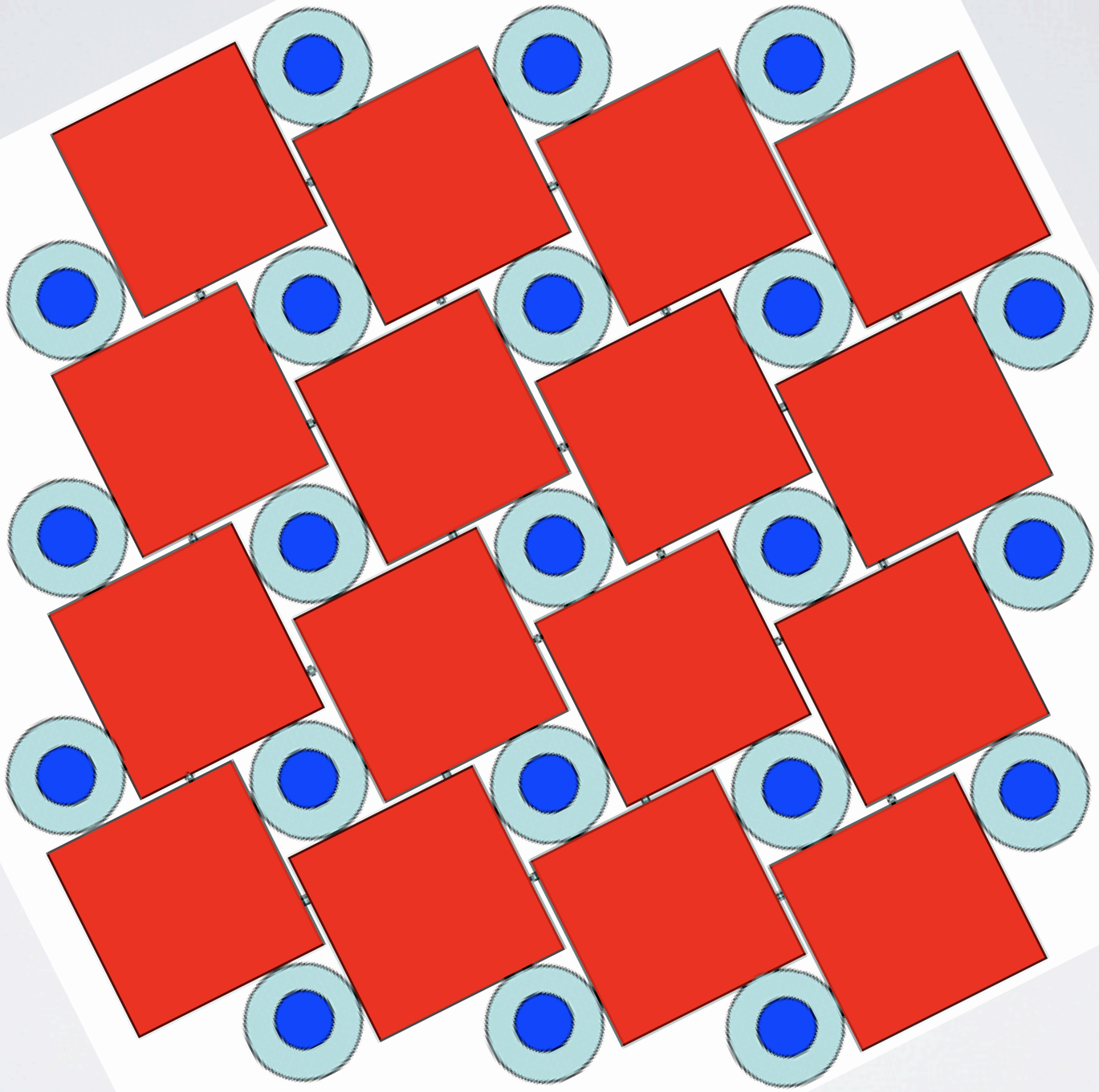

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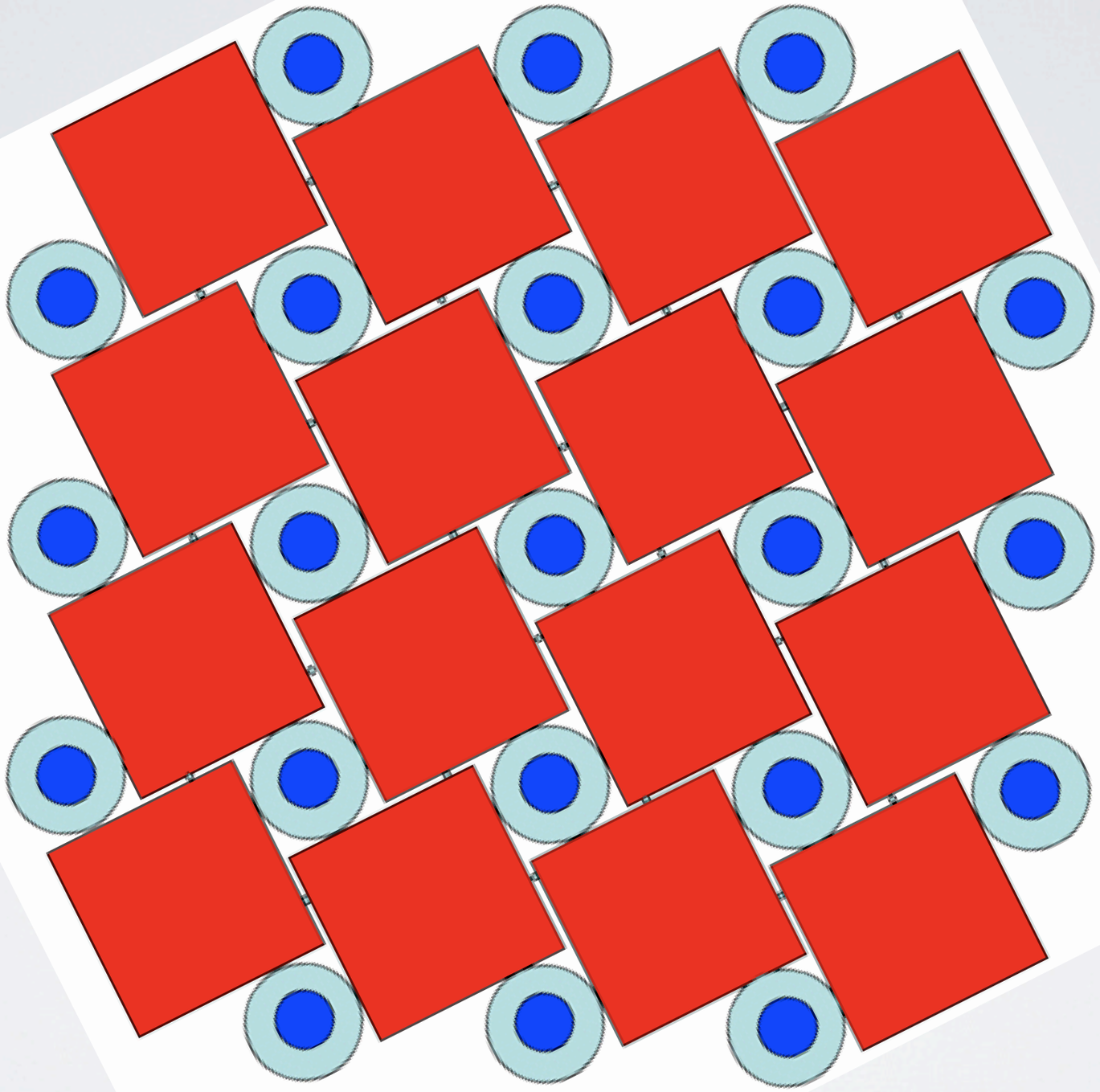

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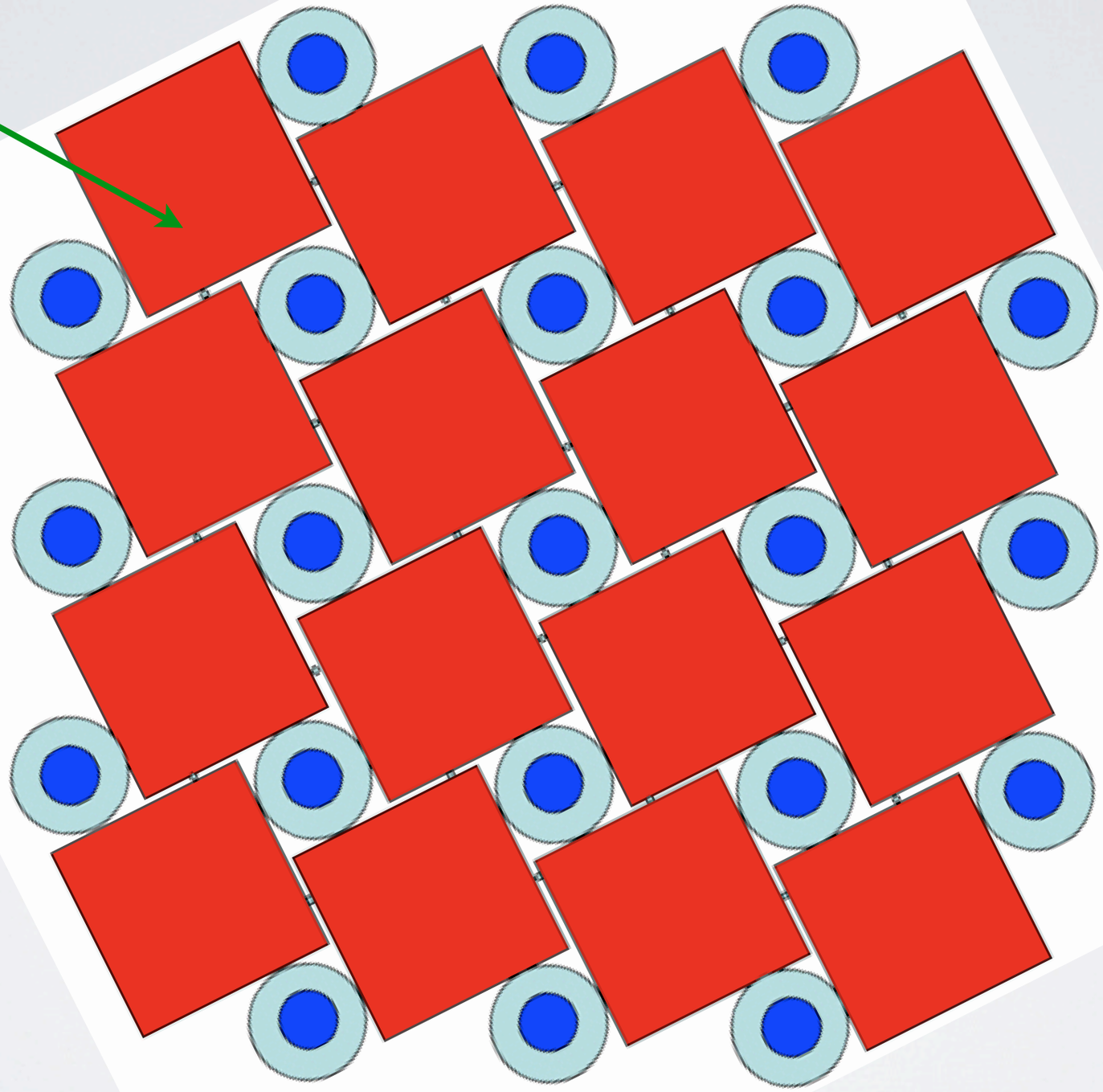

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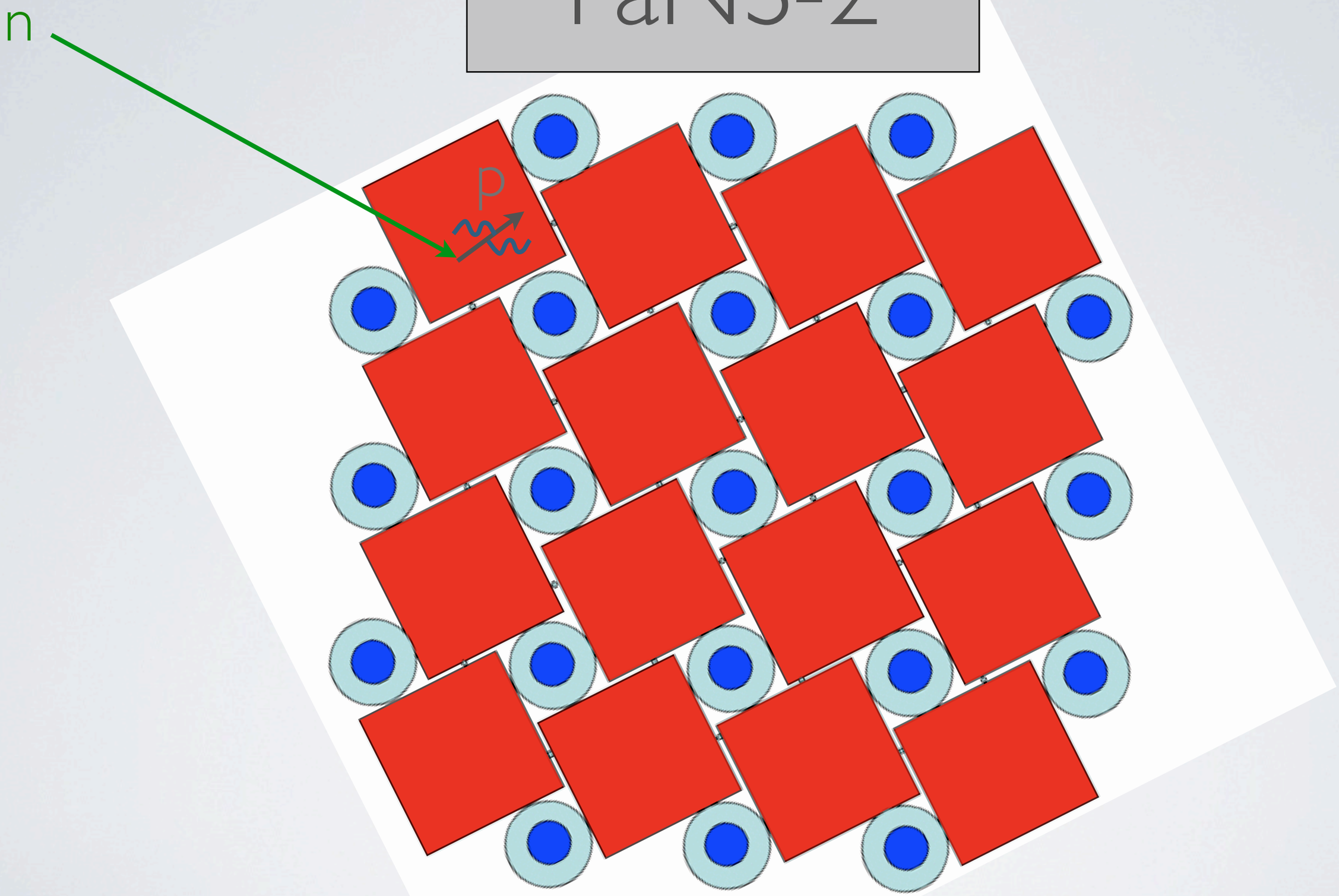

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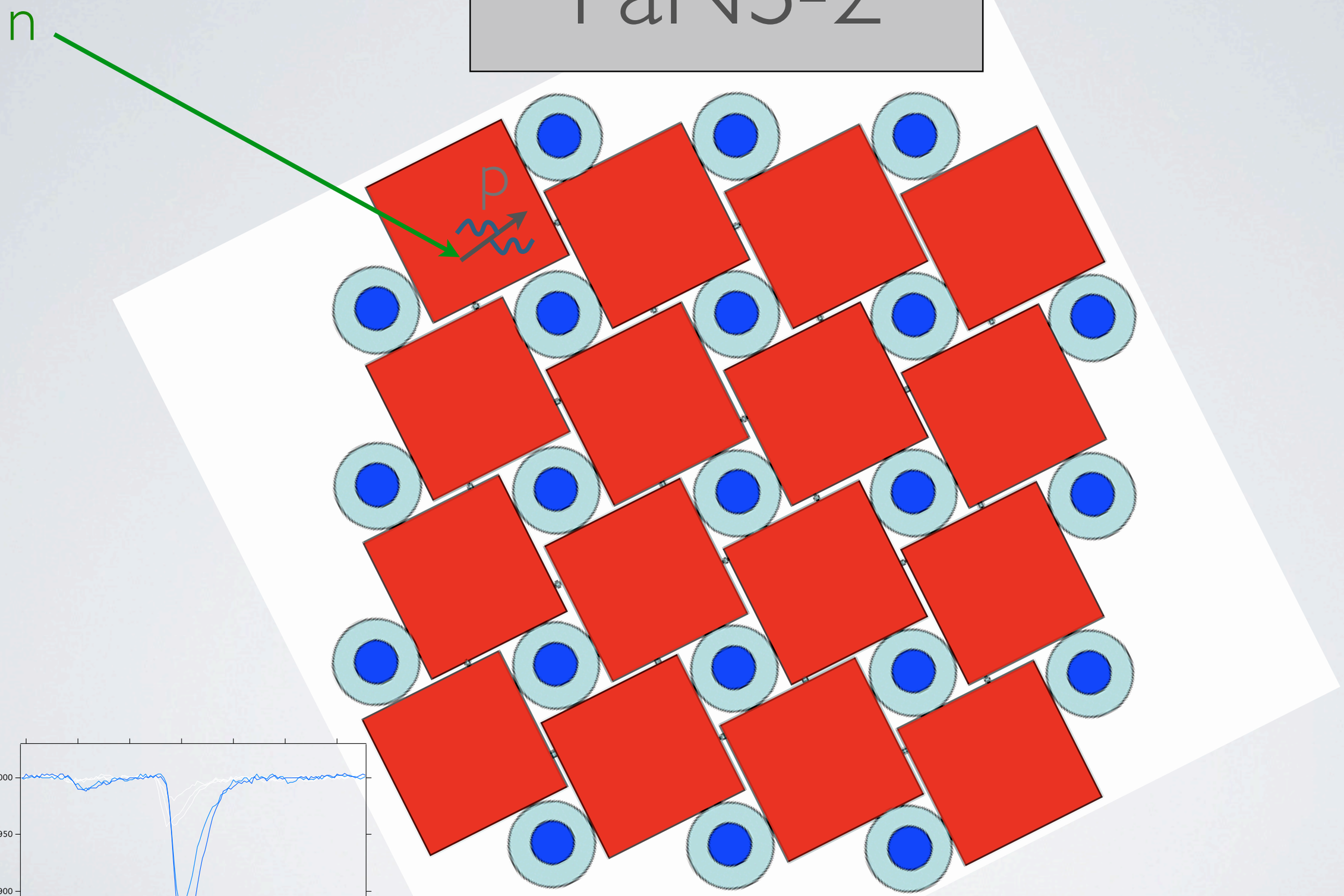
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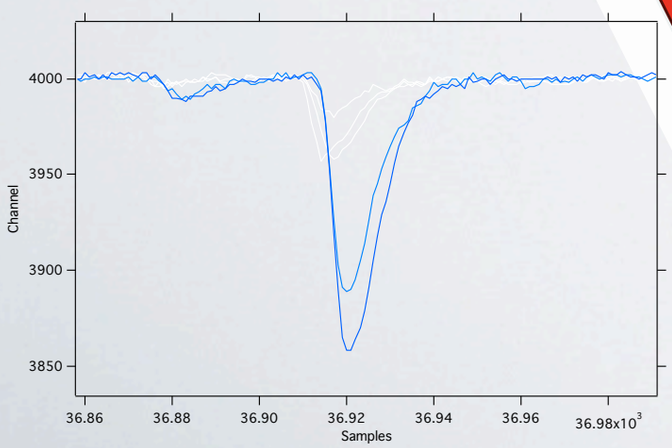
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Samples

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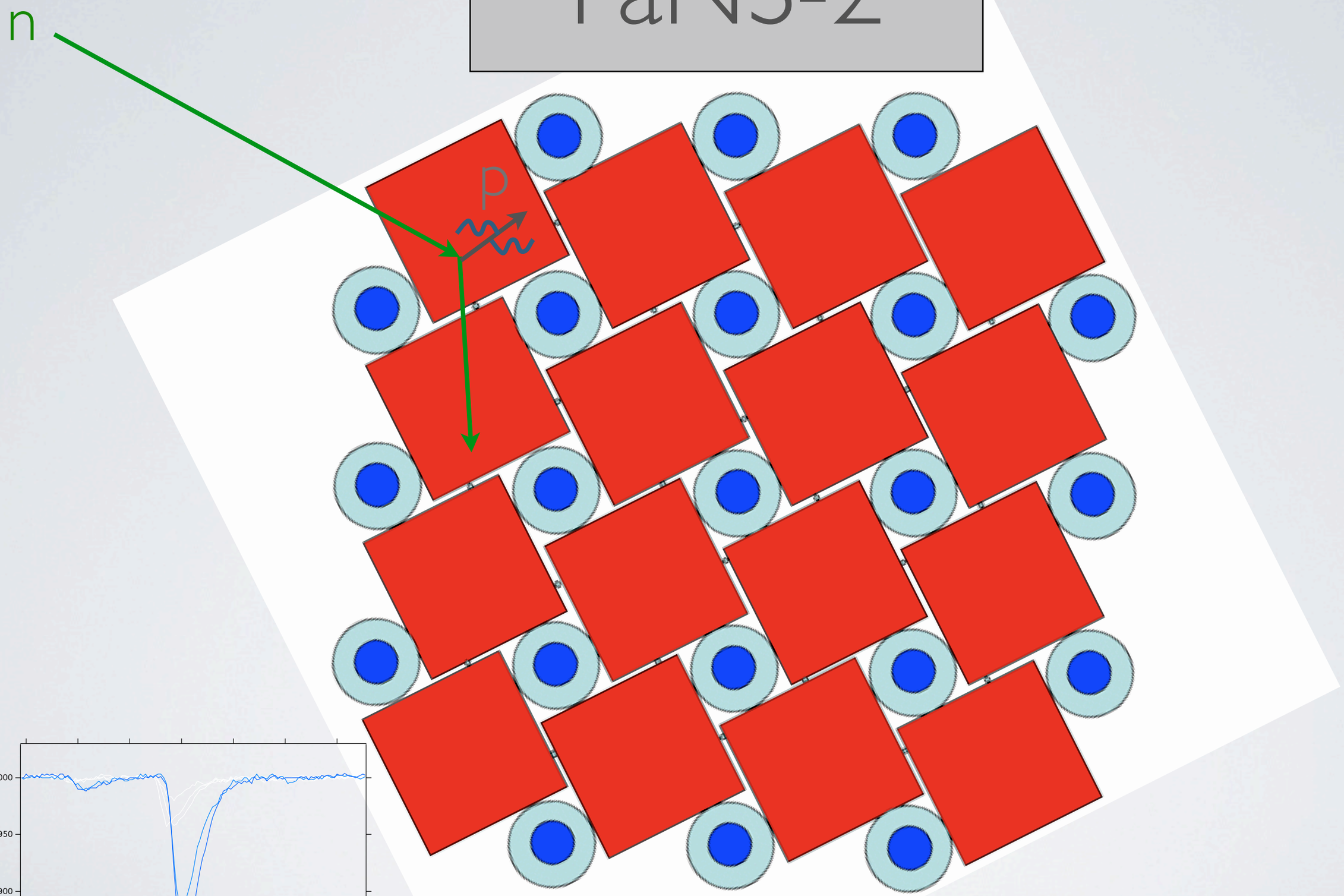
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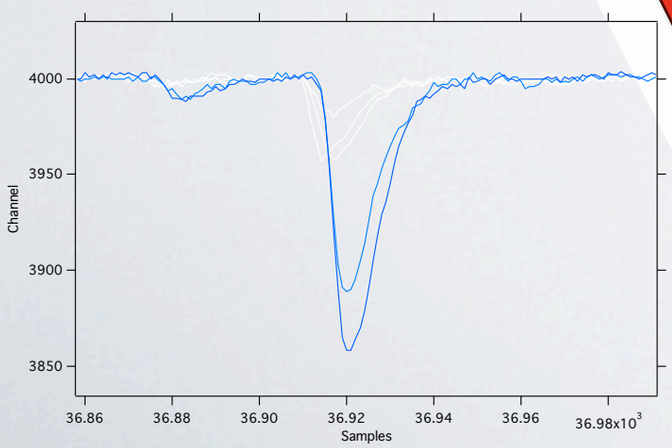
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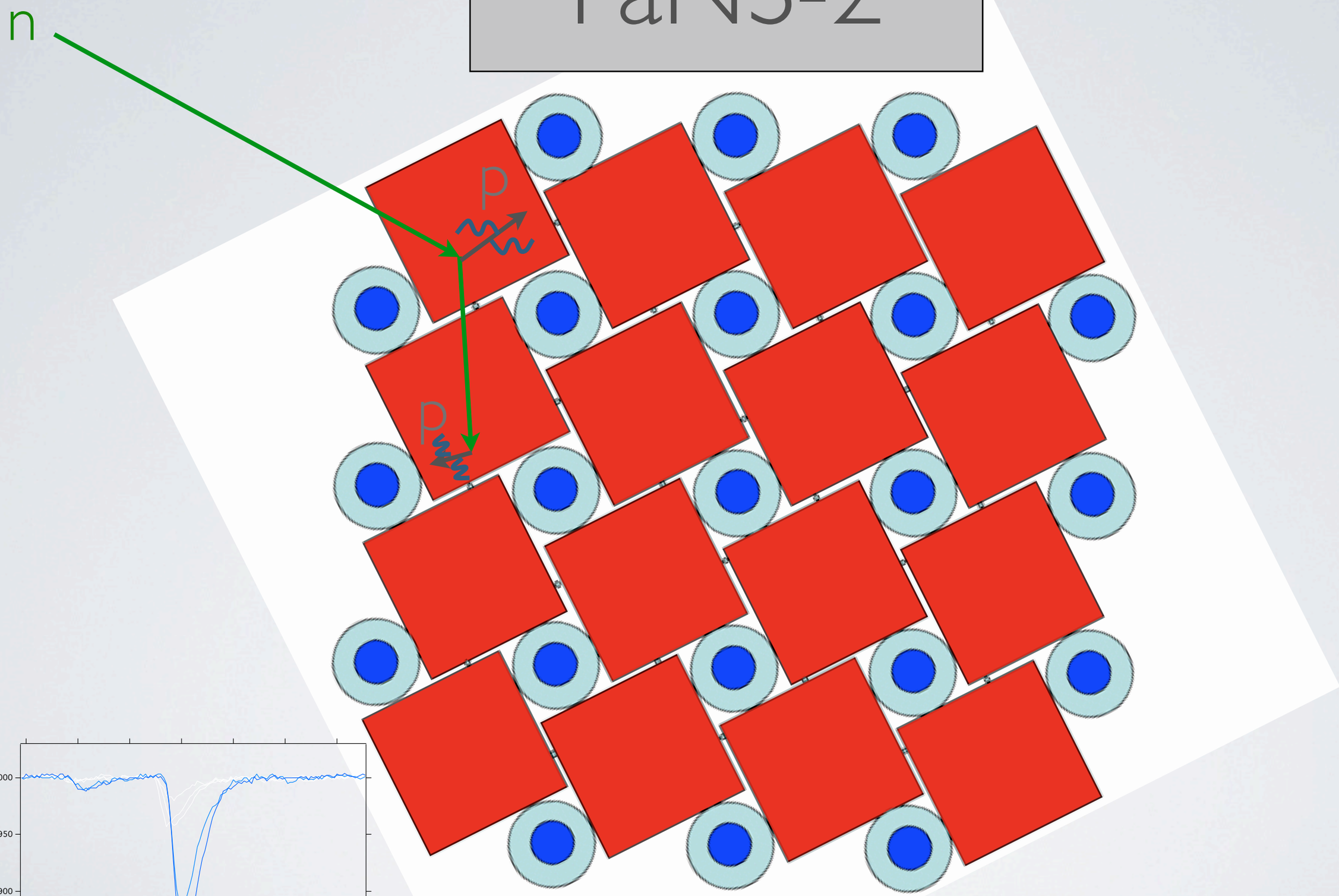
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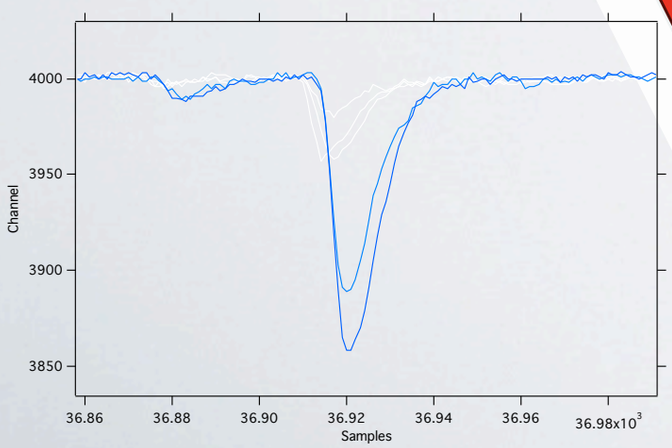
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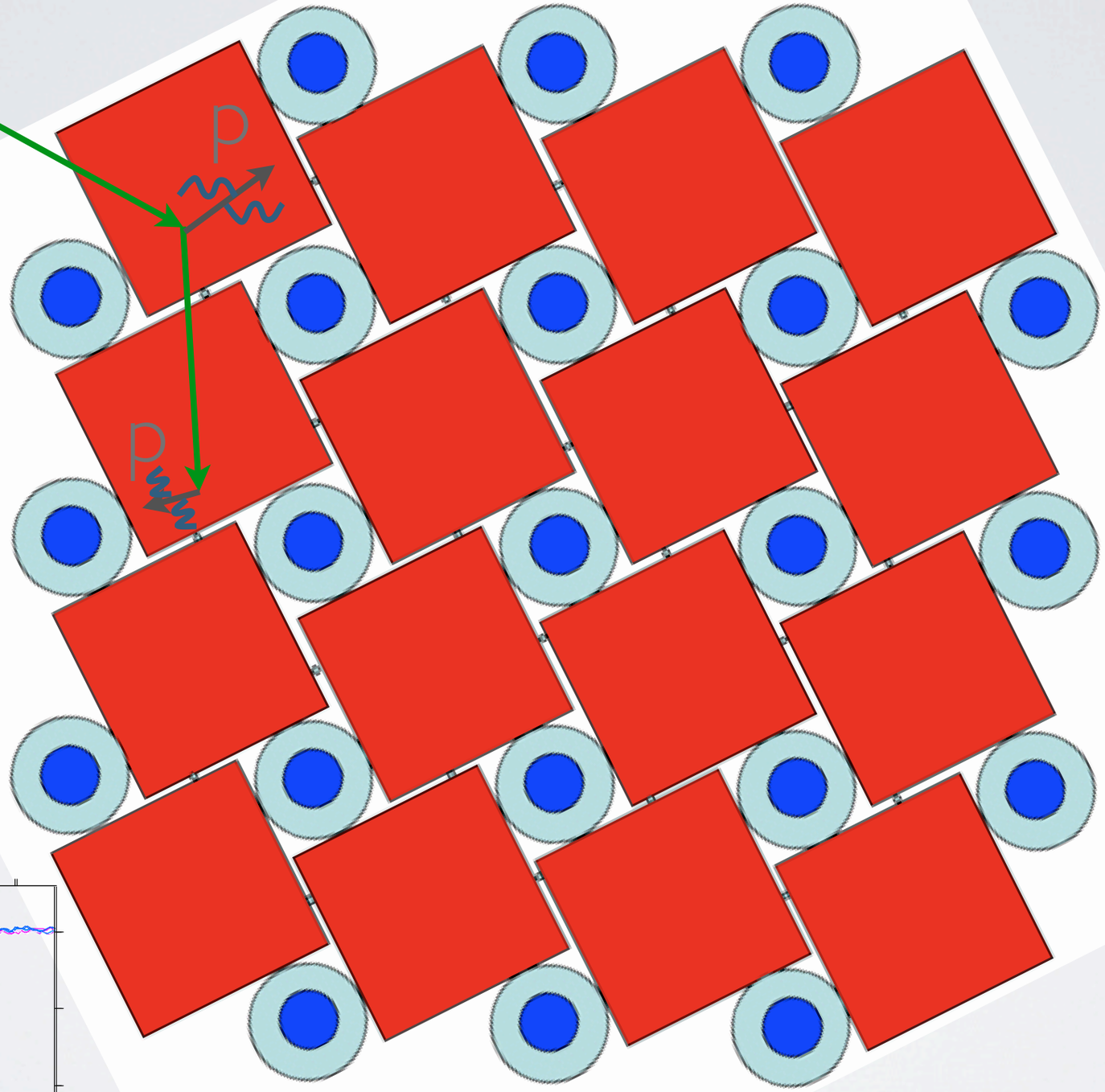
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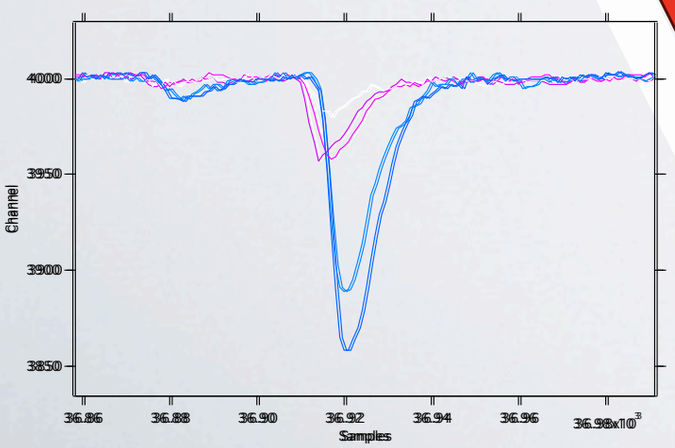
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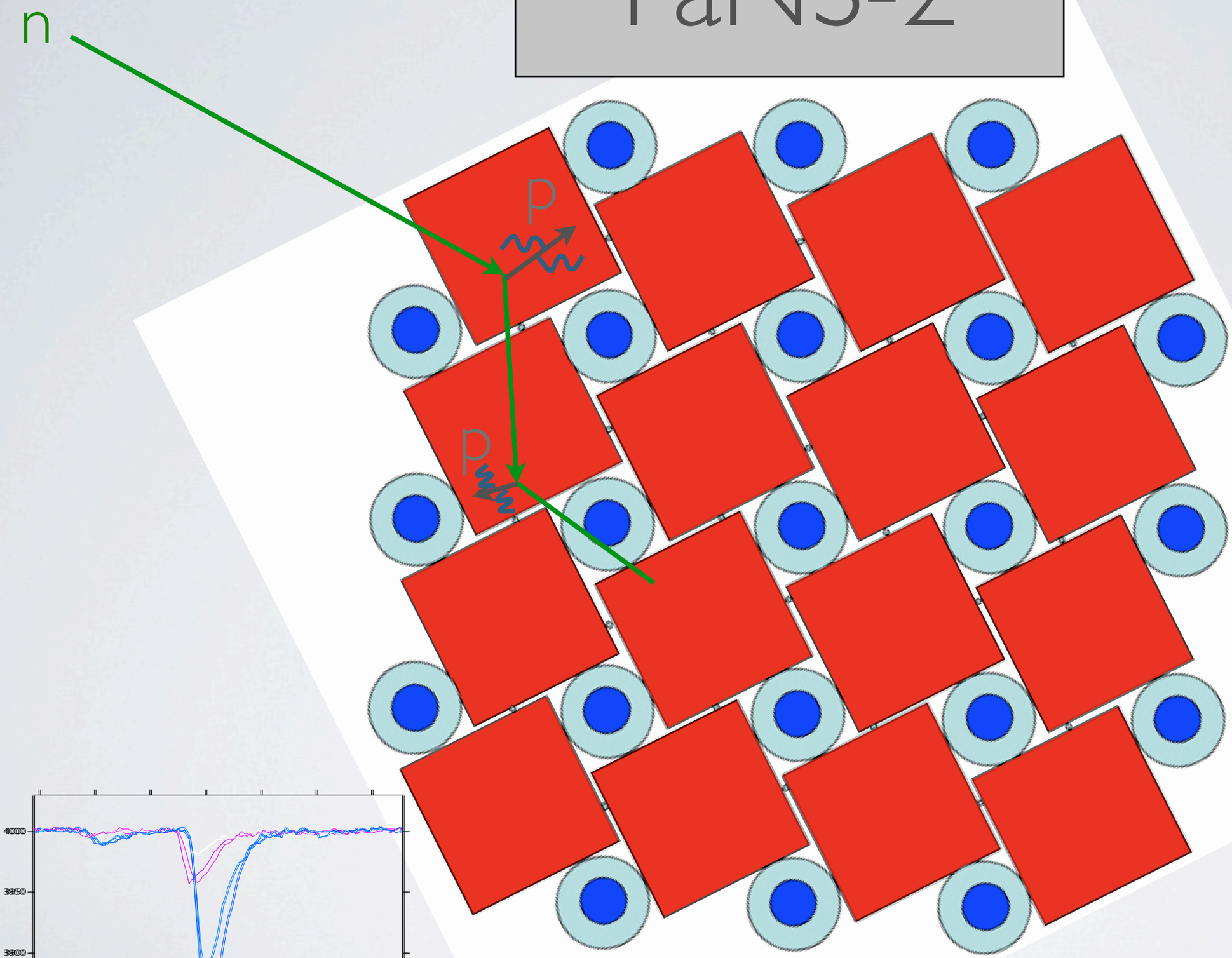
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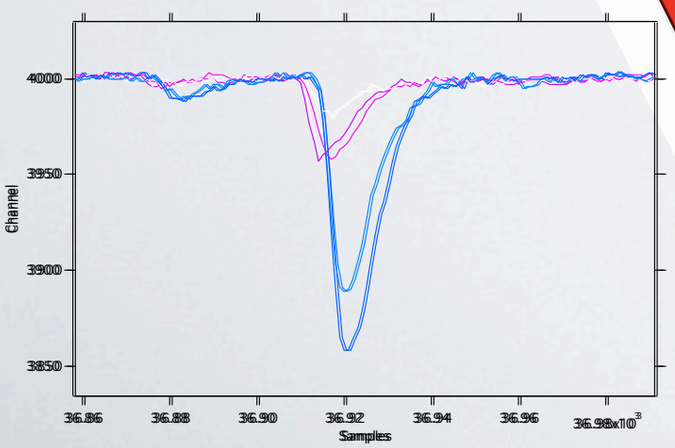
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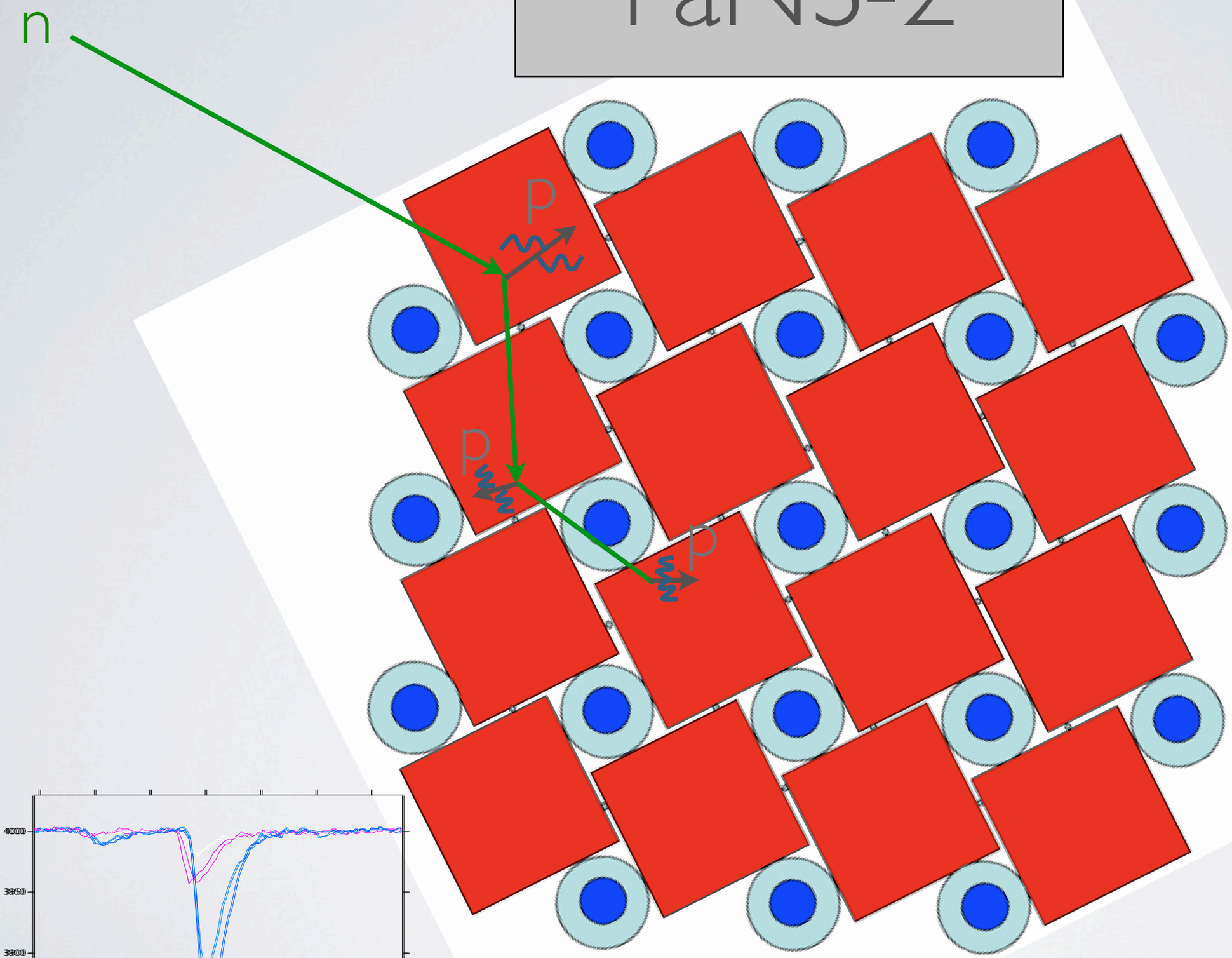
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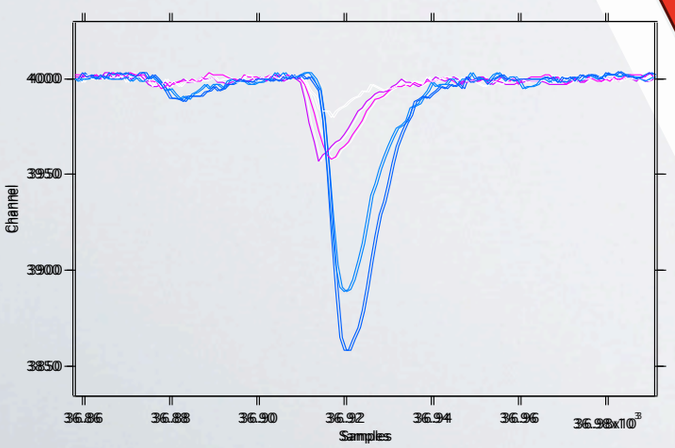
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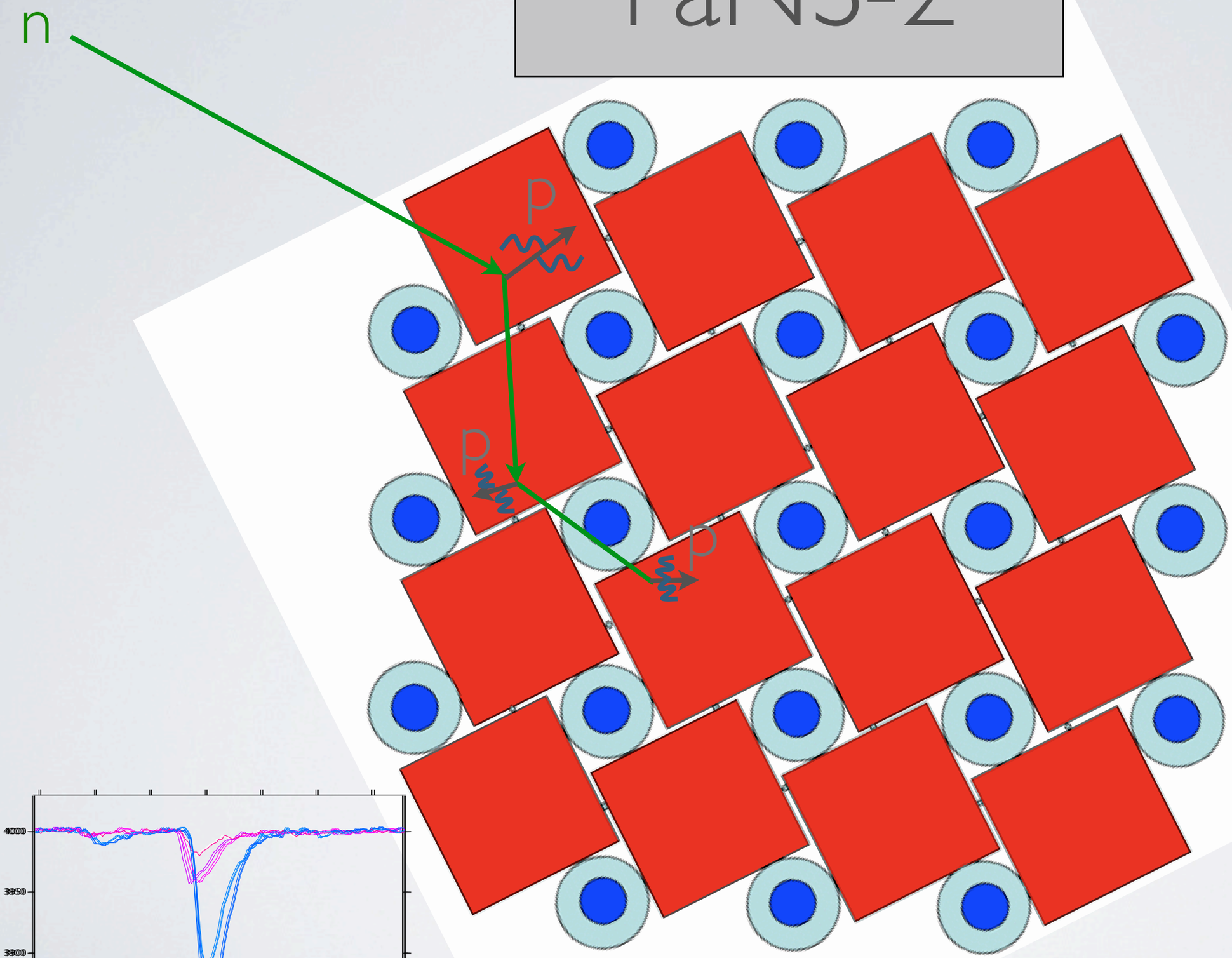
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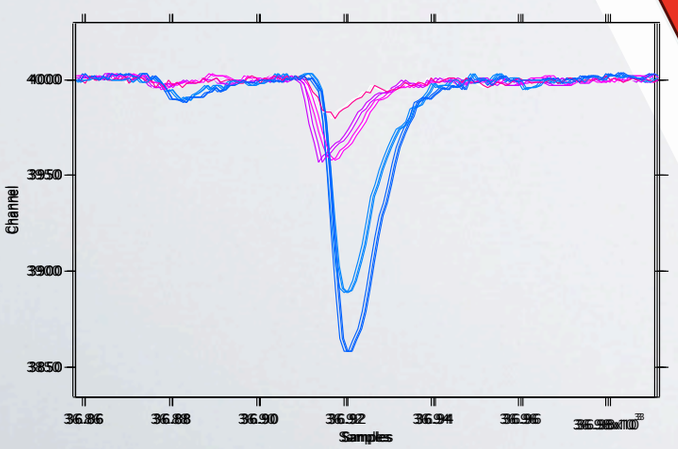
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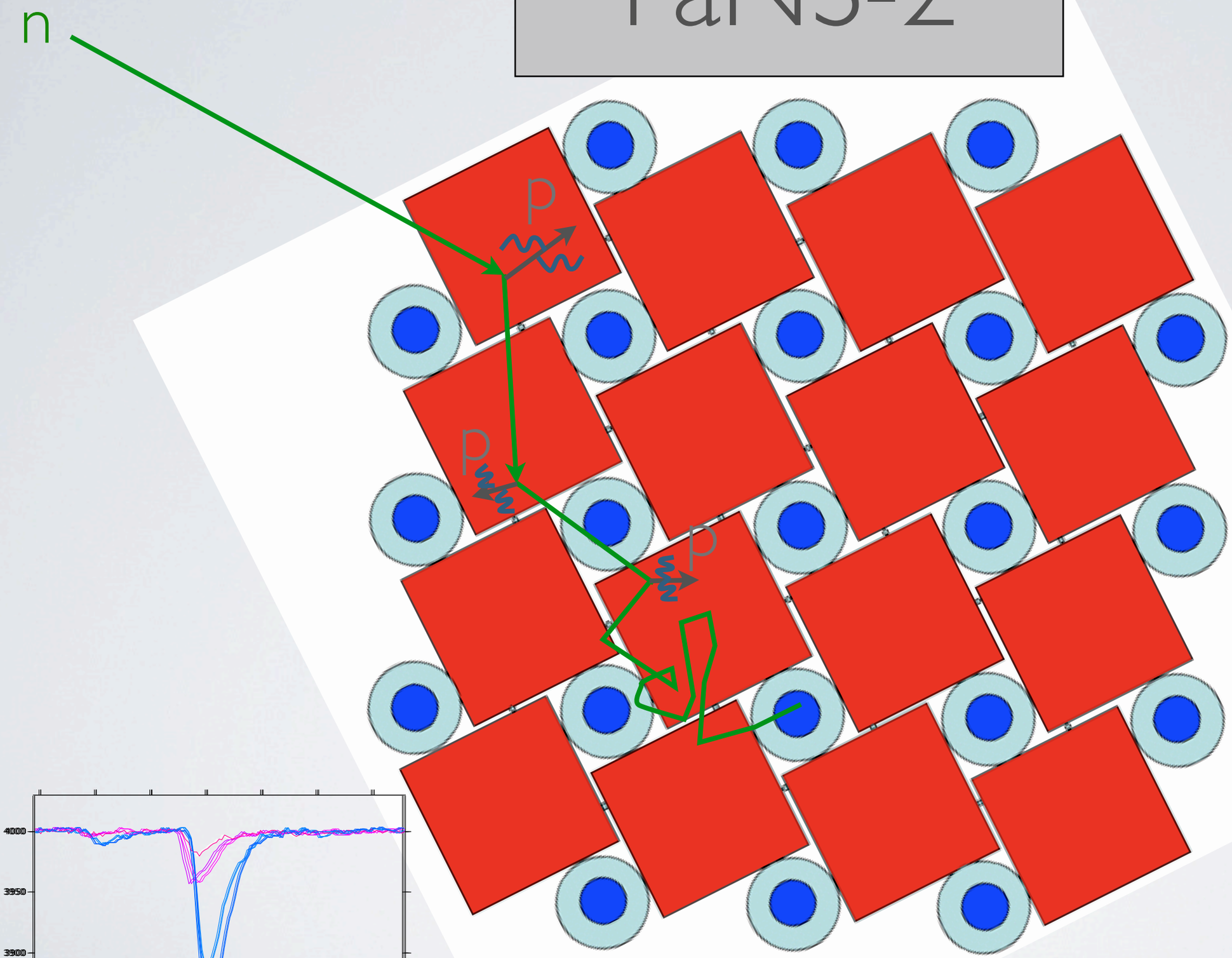
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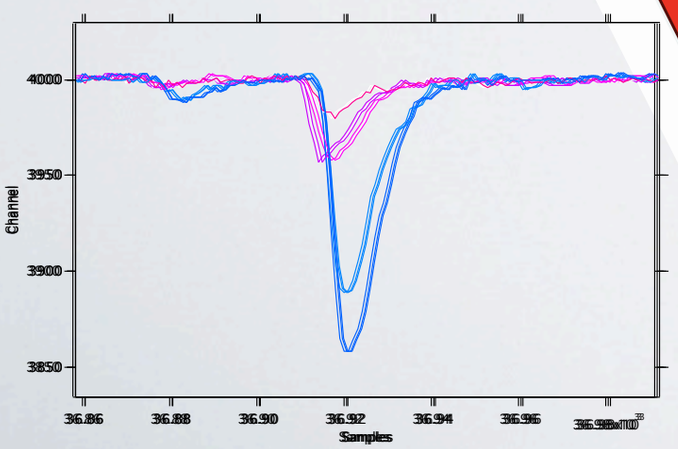
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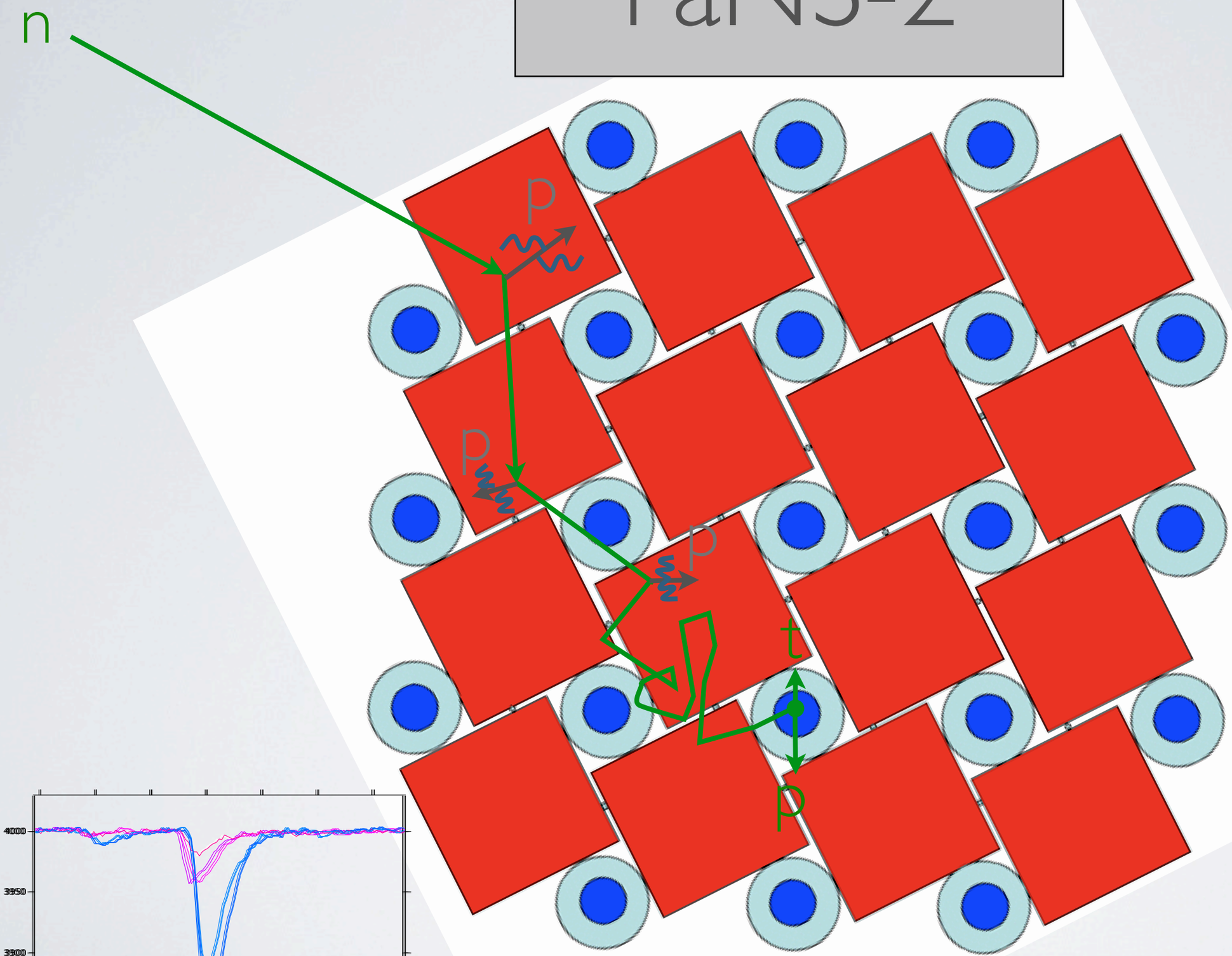
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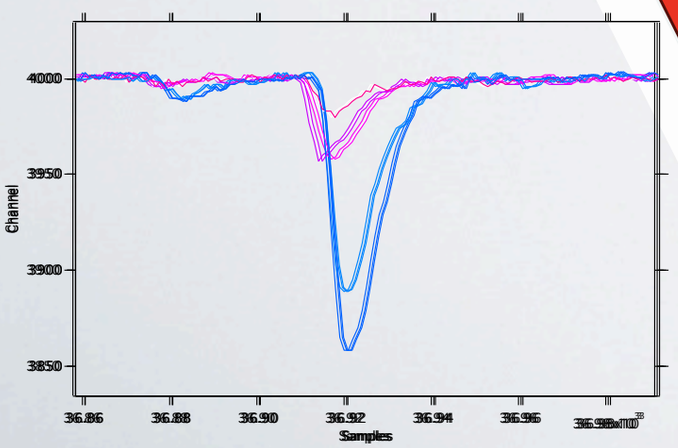
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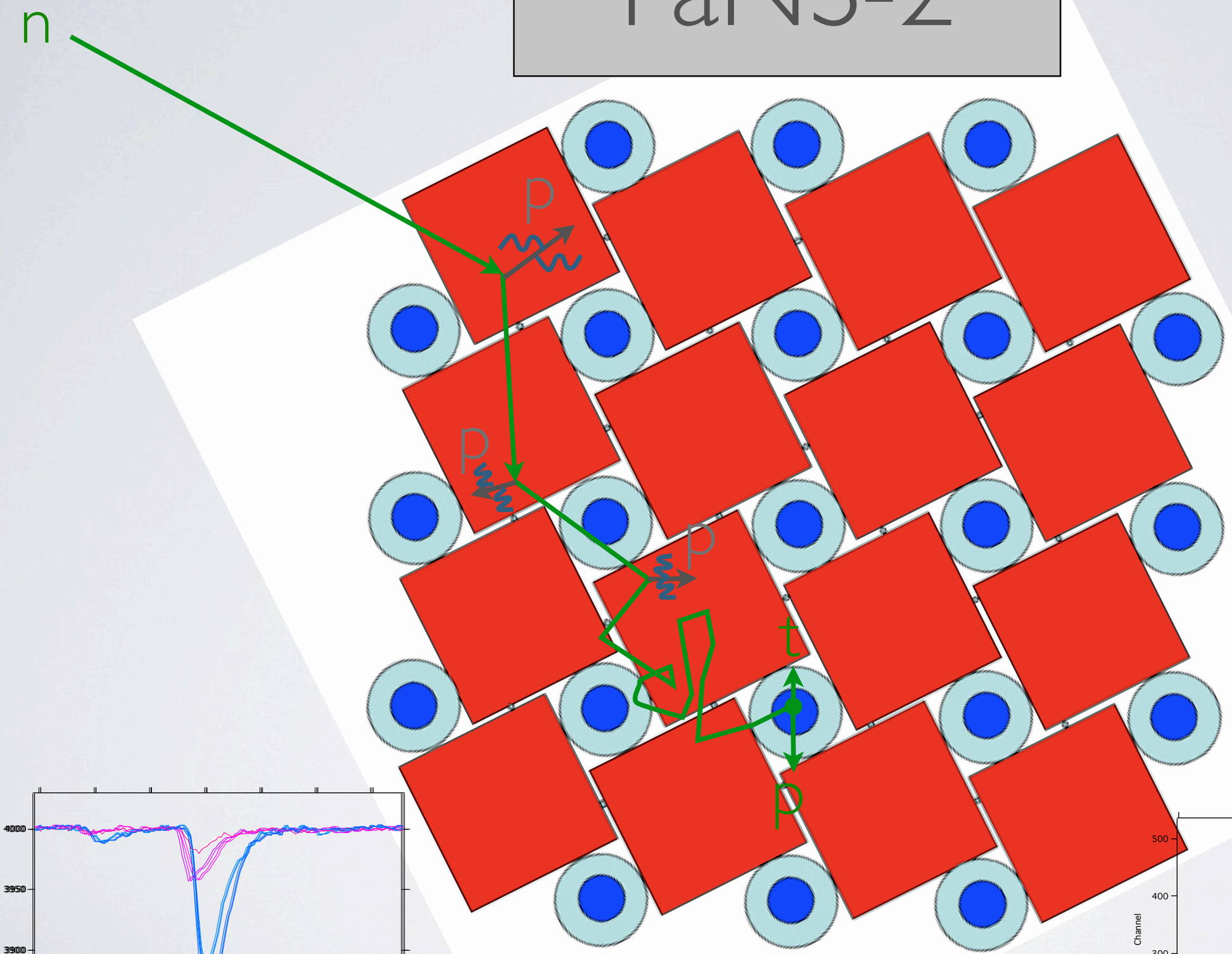
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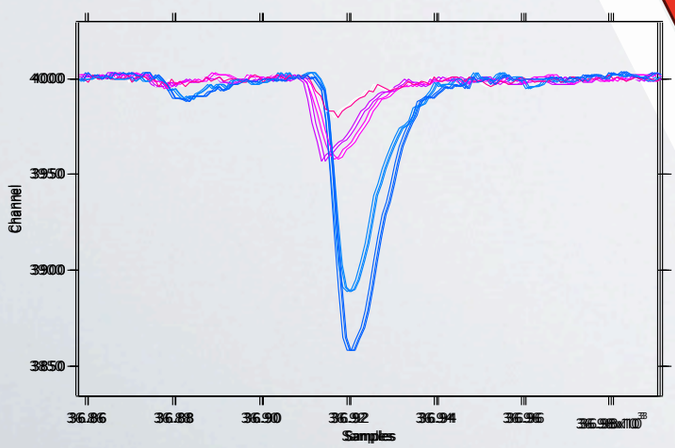
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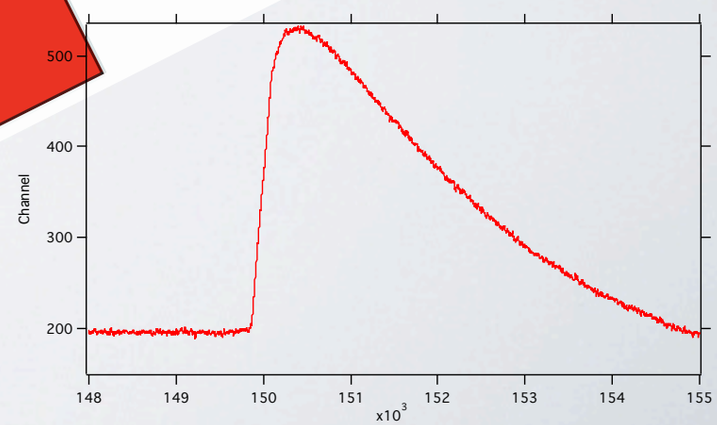
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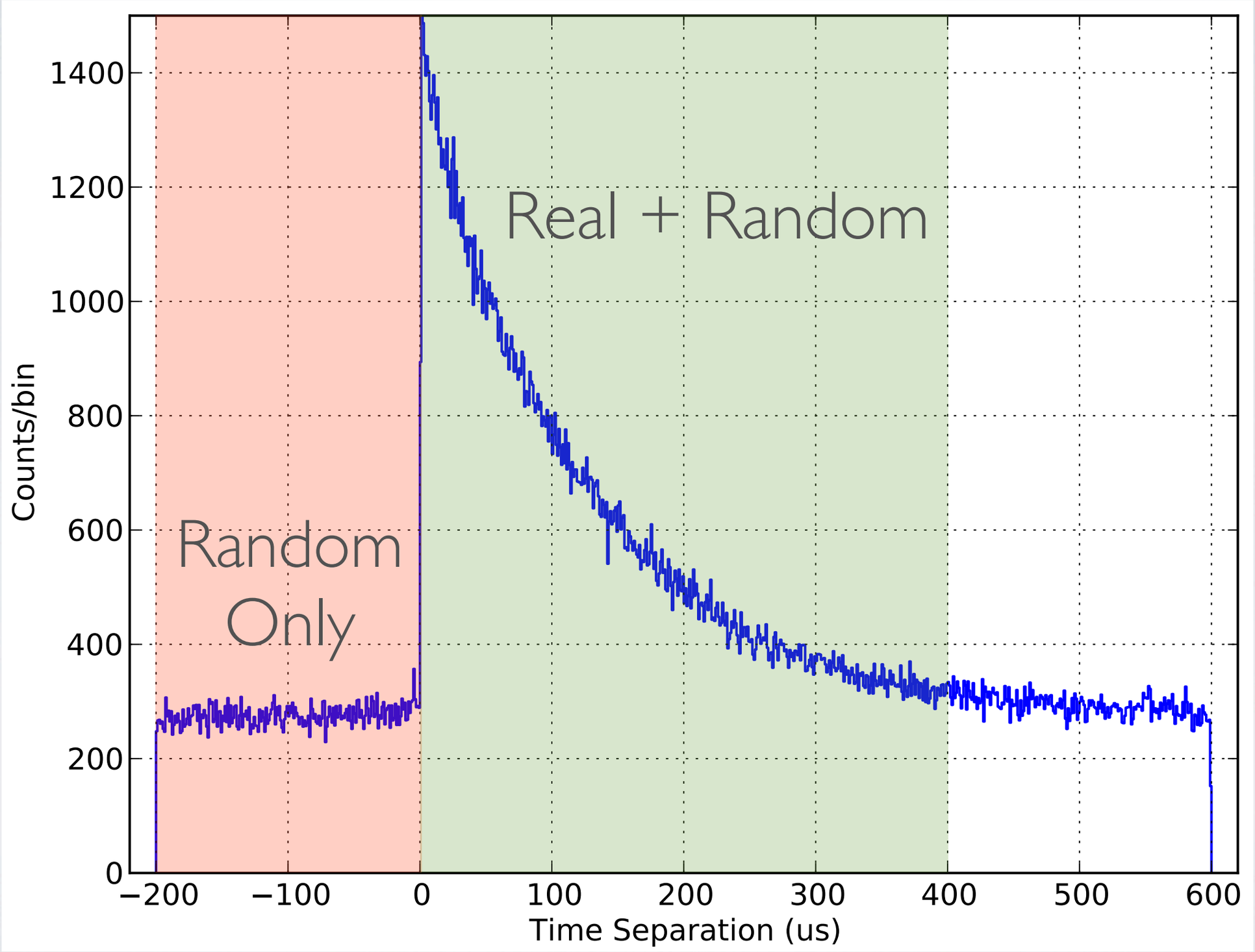

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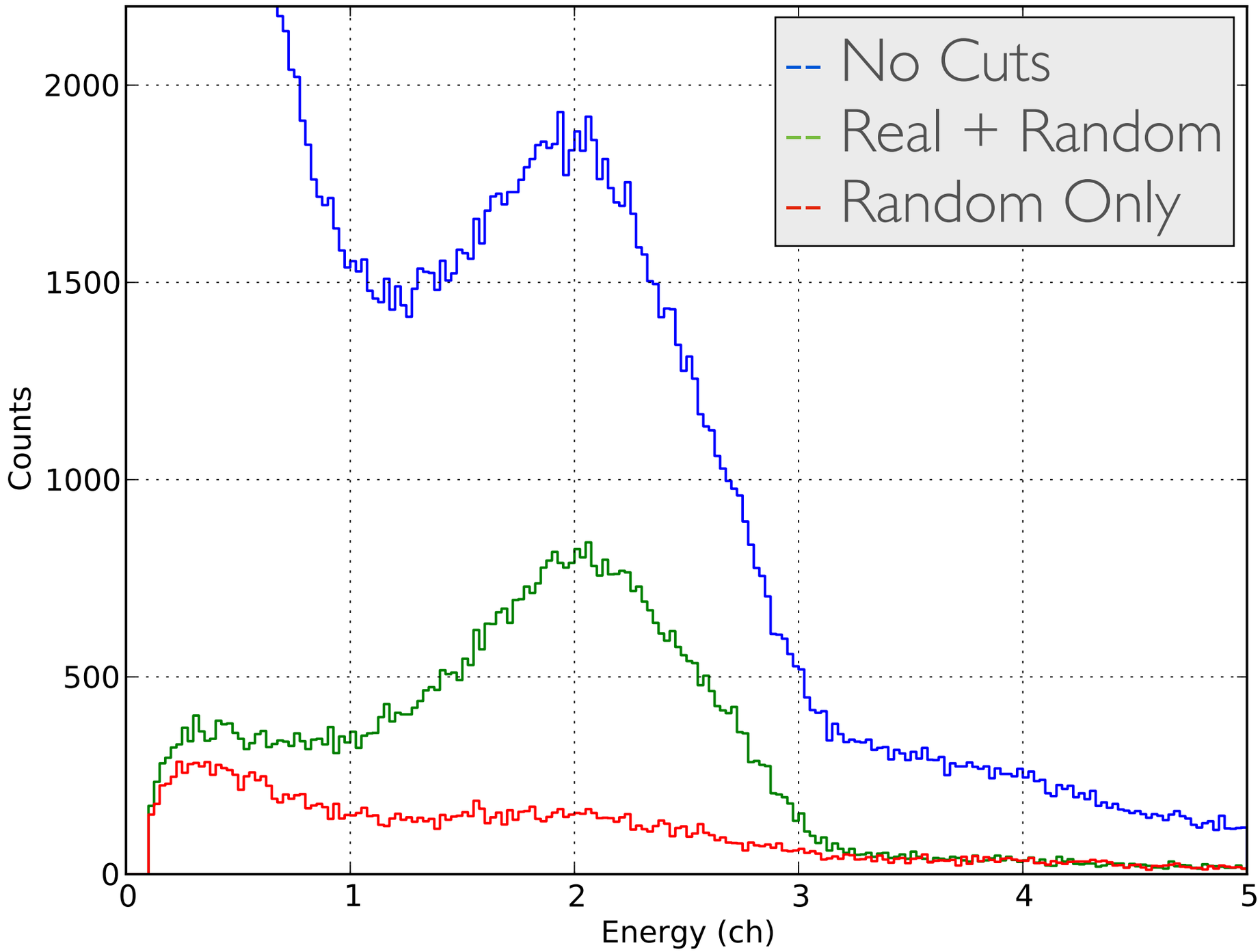
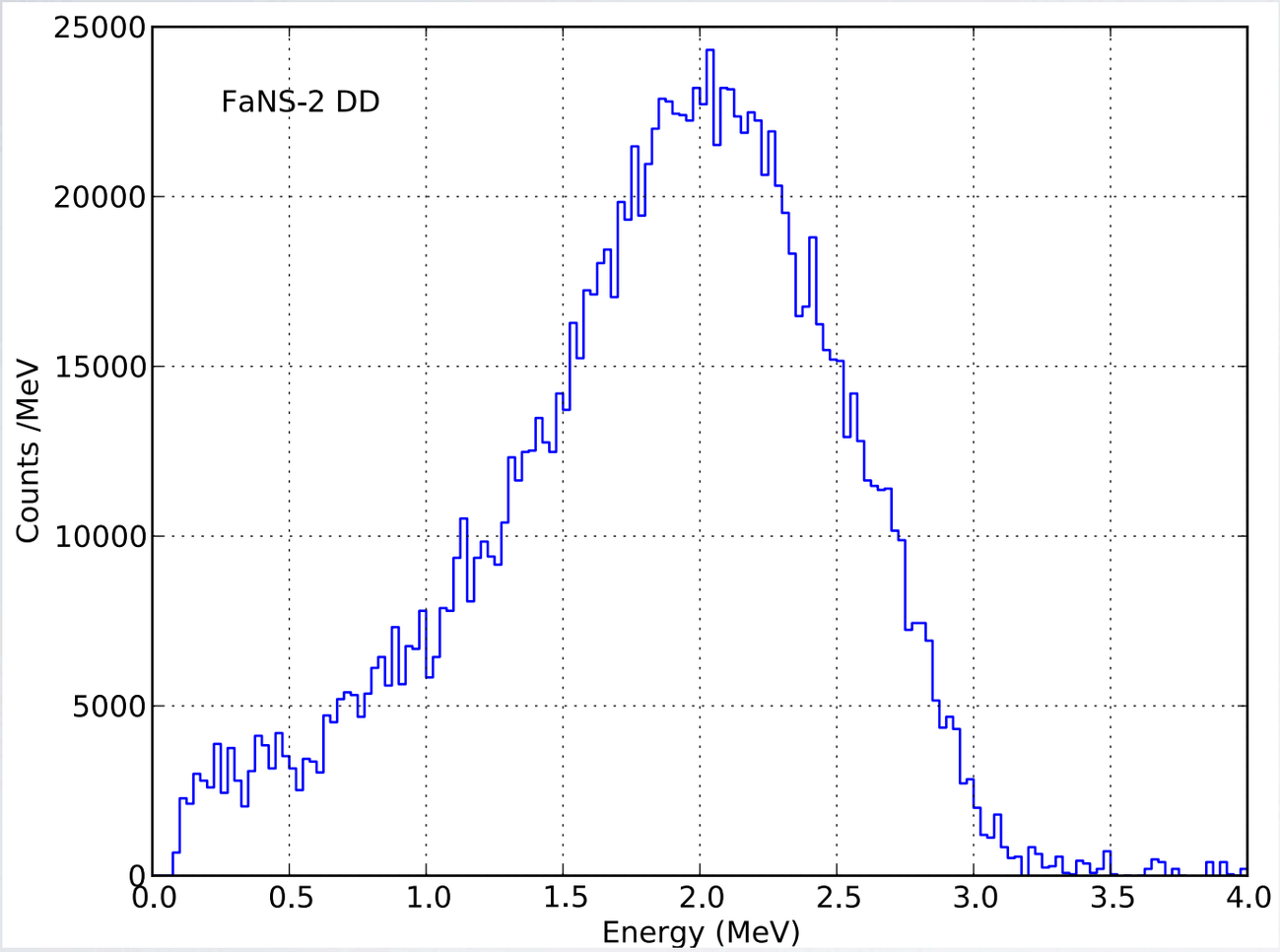
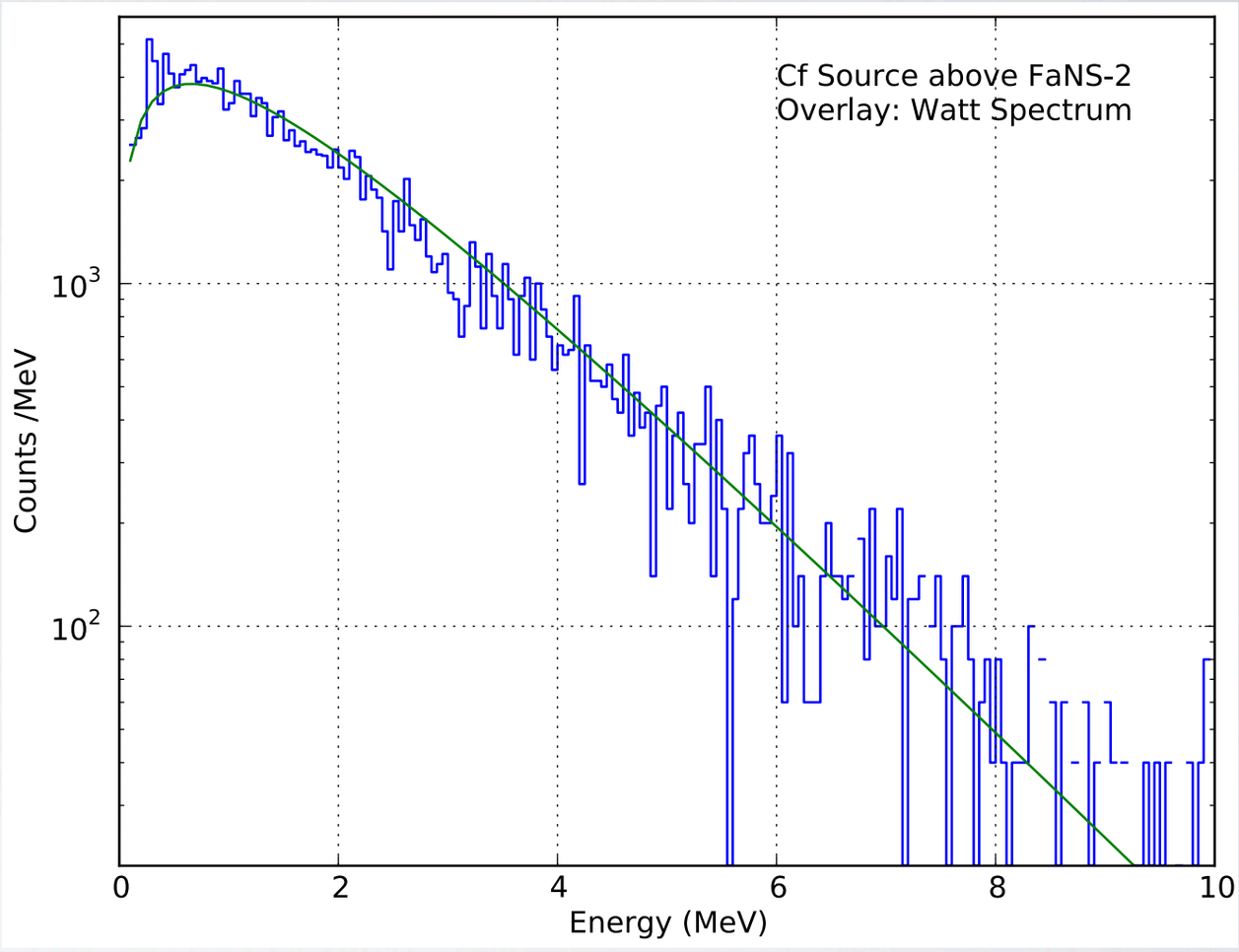


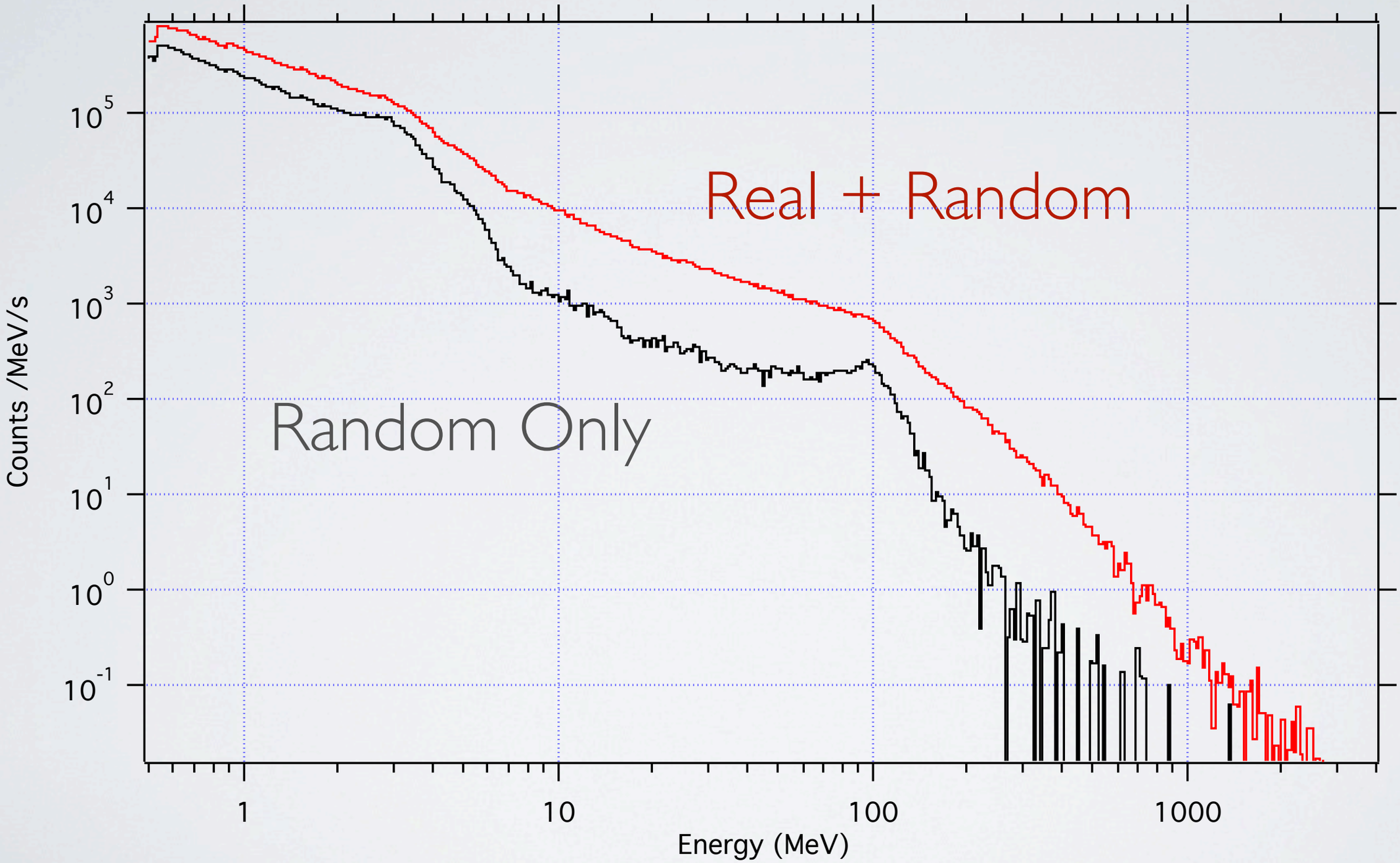
# NEUTRON CALIBRATION




- *DT Generator data to come soon*
- Will measure the absolute efficiency with calibrated Cf source

# COSMOGENIC NEUTRONS AT NIST



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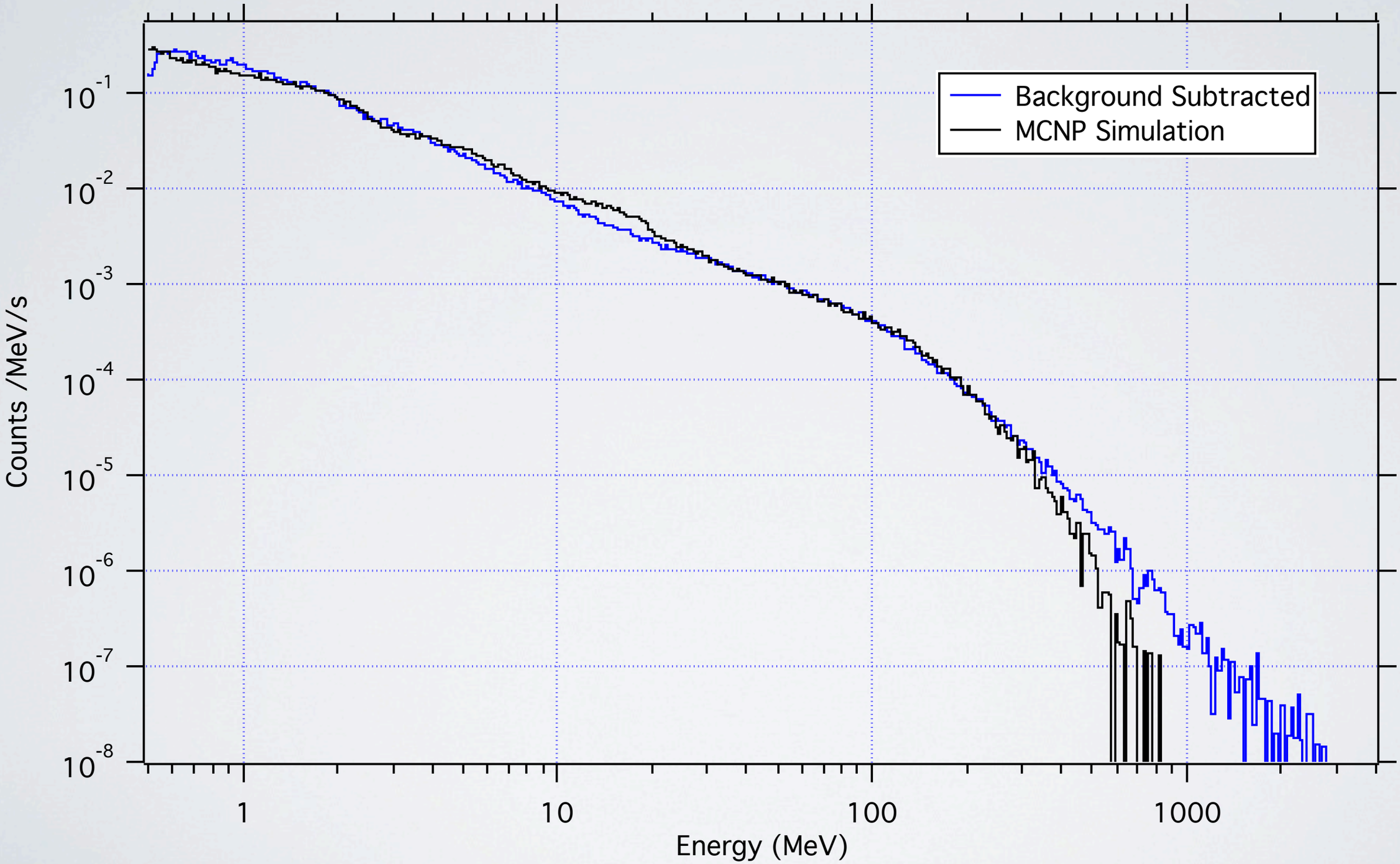


# FaNS-2 OUTLOOK

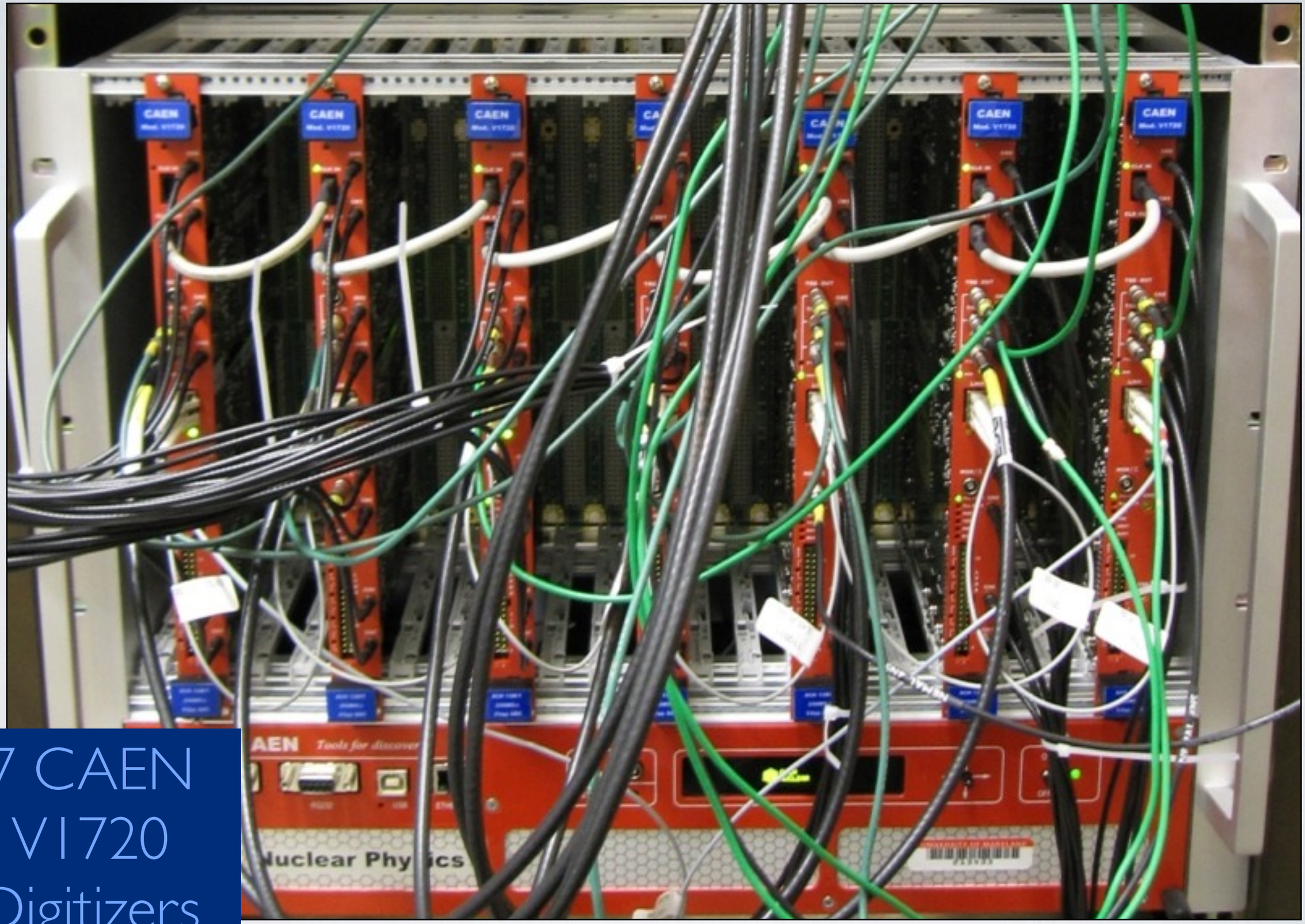
- Absolute calibration up to 10 MeV with $^{252}Cf$
- Measure response to 14 MeV neutrons from DT generator
- Finish measurement of ambient neutron spectrum from 500 keV to > 1GeV
- Install detector in a shallow underground lab to measure muon induced neutrons
- *Simulate the neutron spectrum using Fluka/Geant4/other*

# Backup Slides

# DATA ACQUISITION REQUIREMENTS

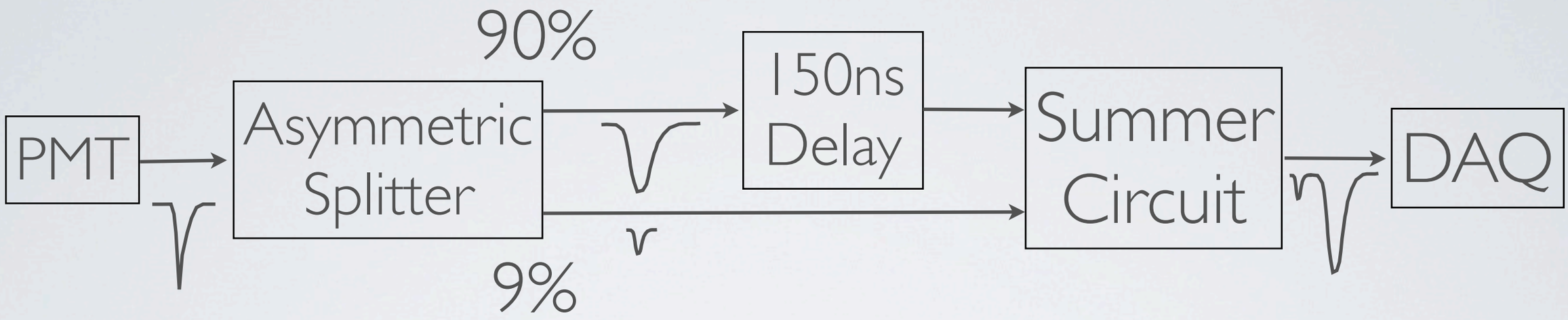
- *Synchronous sampling and triggering of 56 channels*
- Operate in three trigger modes:
  - Gamma calibration: Any PMT triggers all PMTs
  - Muon calibration: Trigger on high multiplicity PMT events
  - Neutron data: Any helium signal triggers all channels
    - ~1ms long traces with ZLE to reduce data size
    - Large dynamic range (30 keV:200 MeV per channel)
- Need to automatically switch between different modes

# DATA ACQUISITION




7 CAEN V1720 Digitizers

# PMT SIGNAL CONDITIONING




- Custom circuit board
- 8ch, NIM form factor
- *Factor of 10 increase in dynamic range*
- Increase of signal width from 10ns to 50ns

  ➡Reduces digitization error

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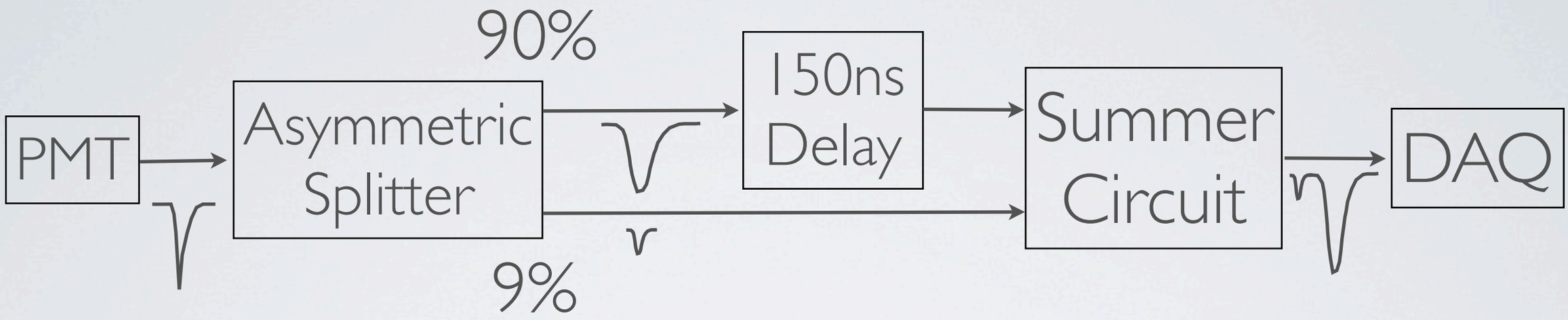


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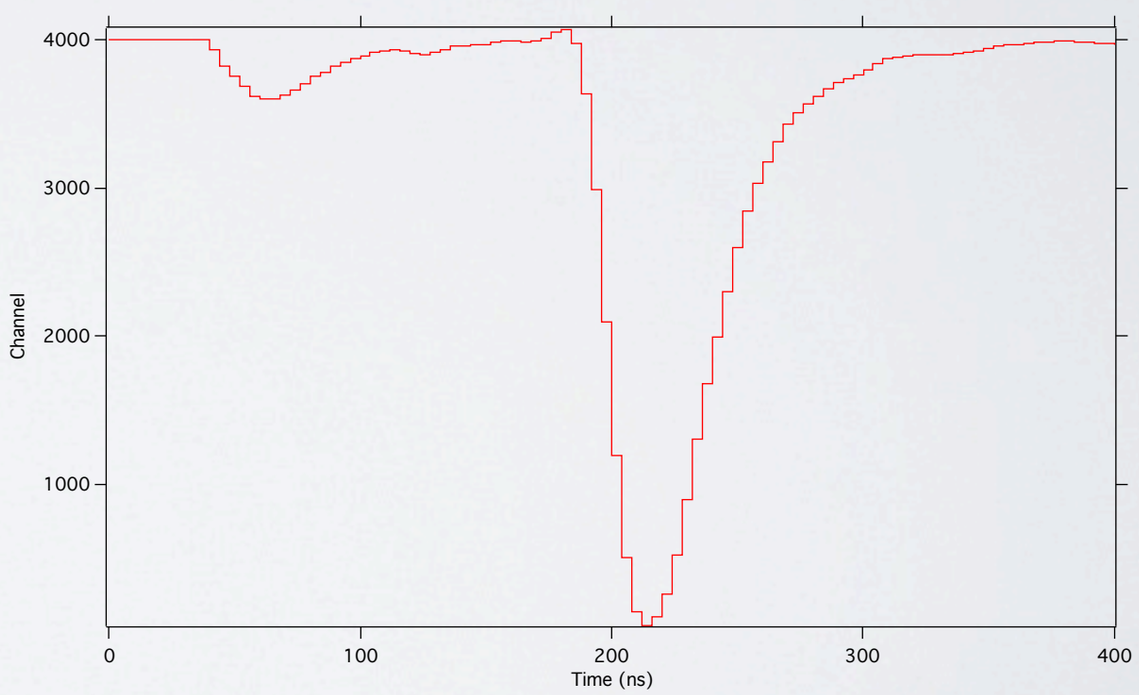

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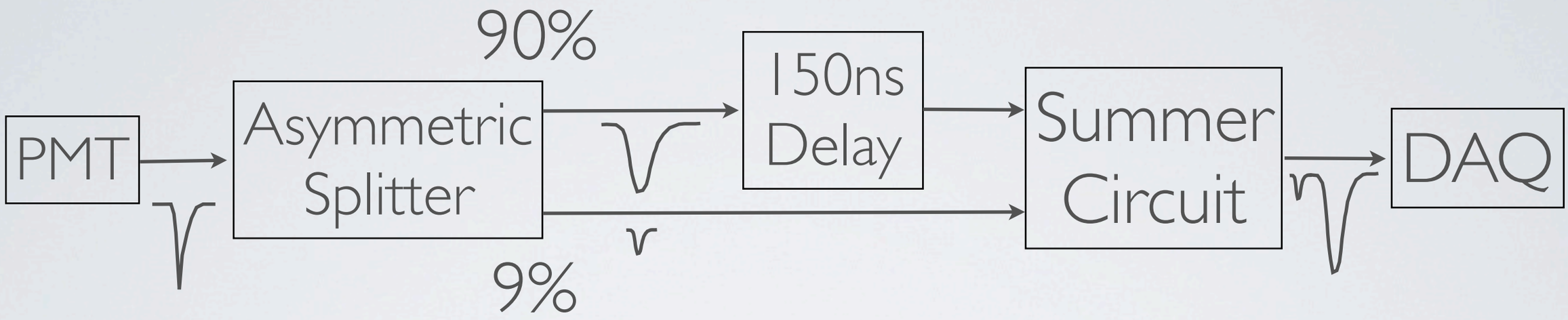


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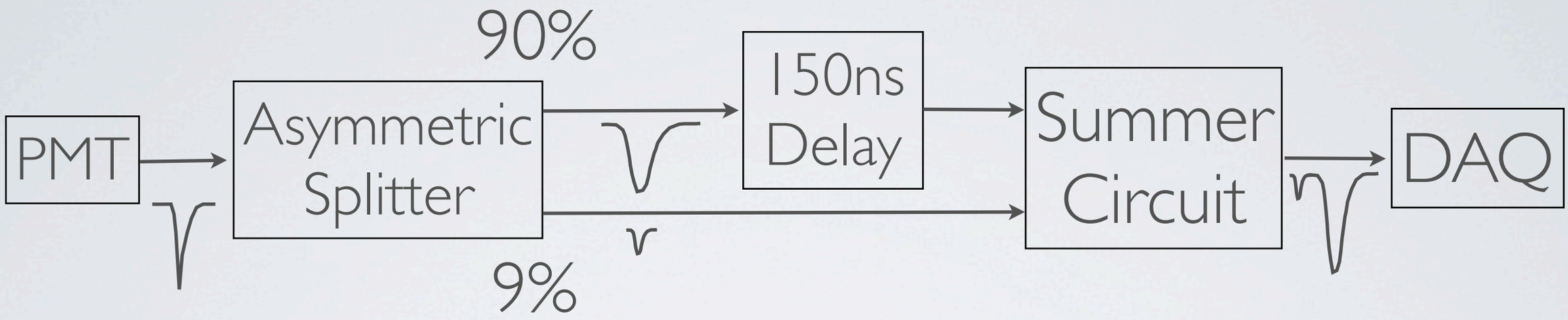


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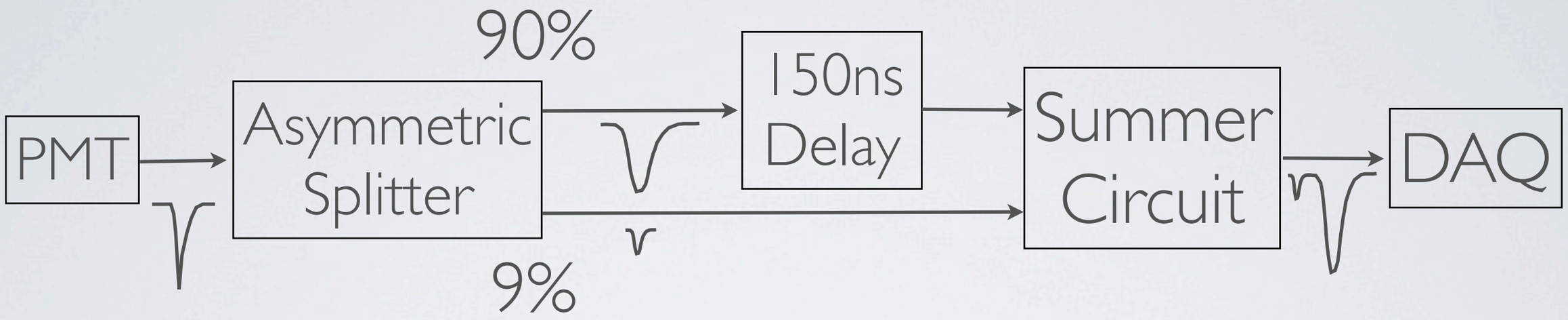


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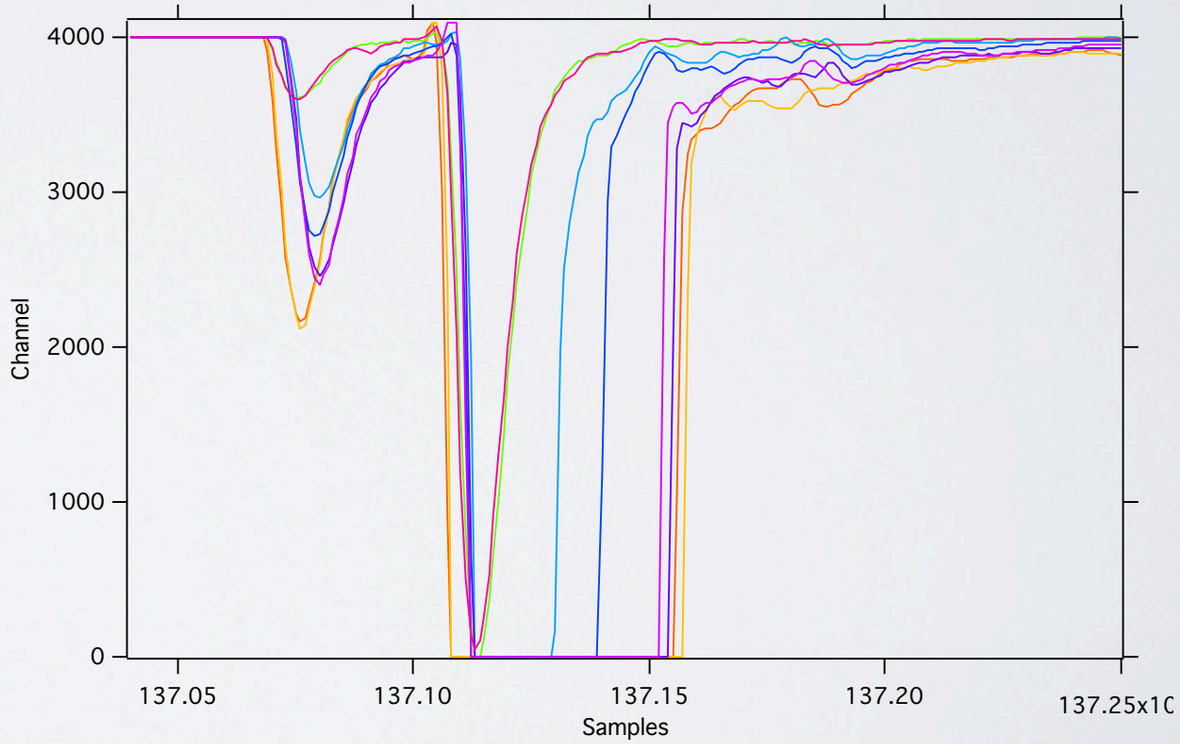
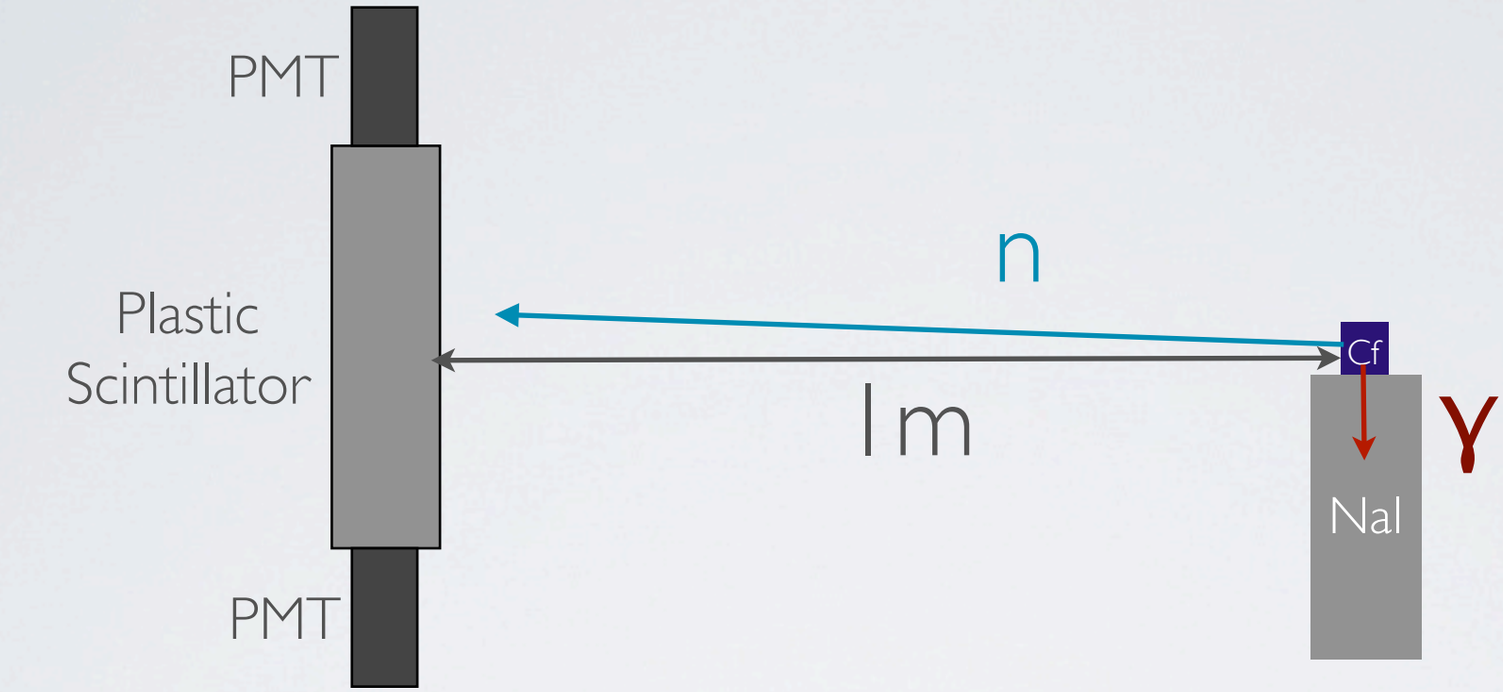
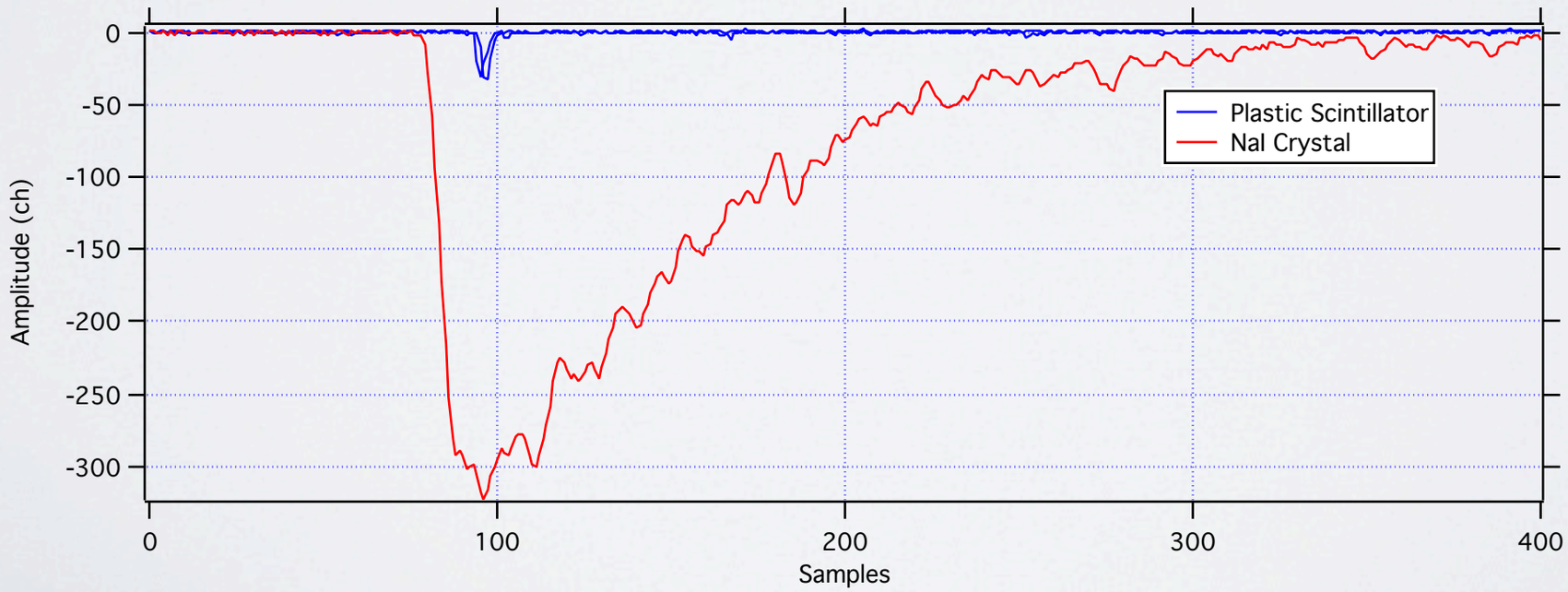
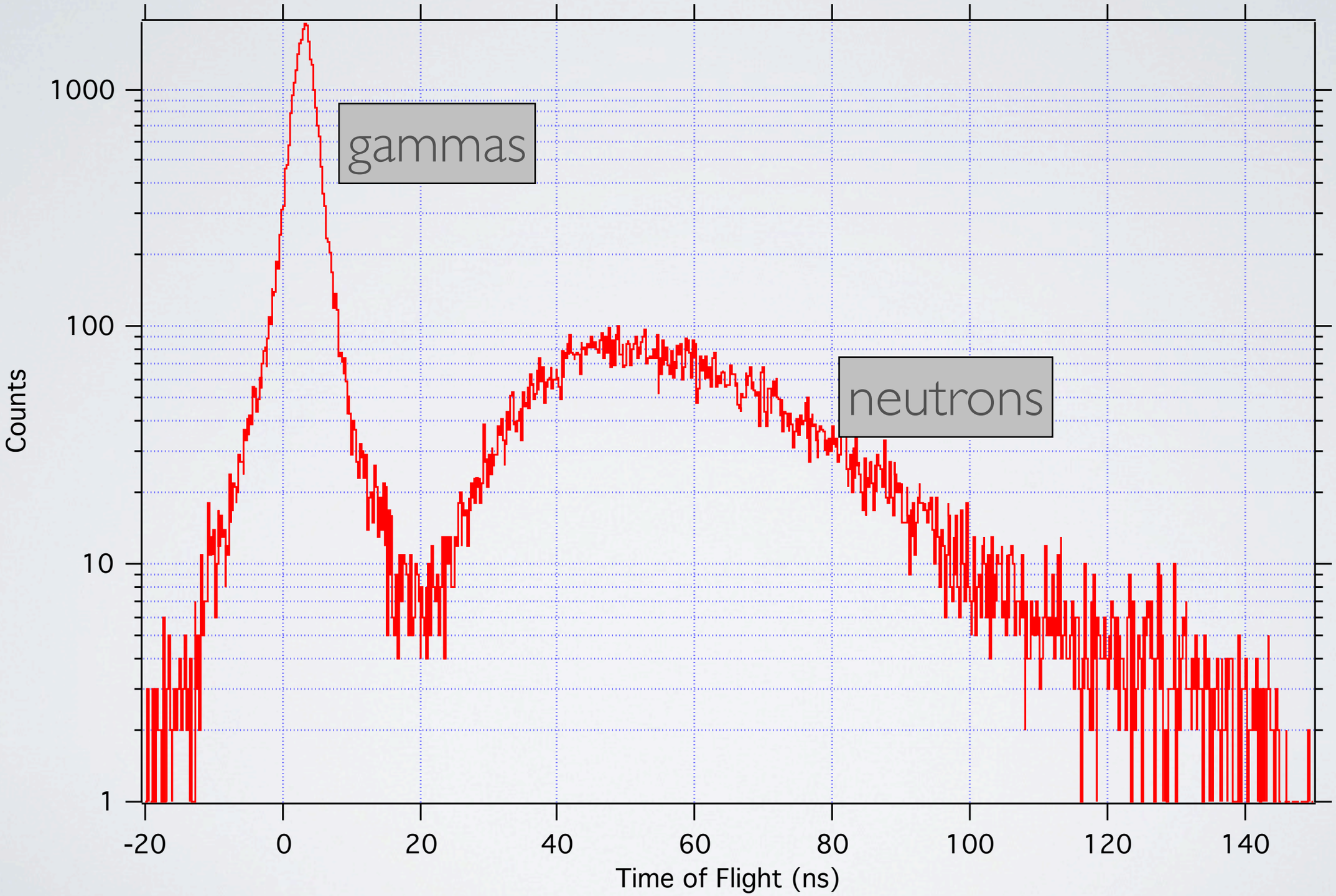


# NIST nTOF APPARATUS

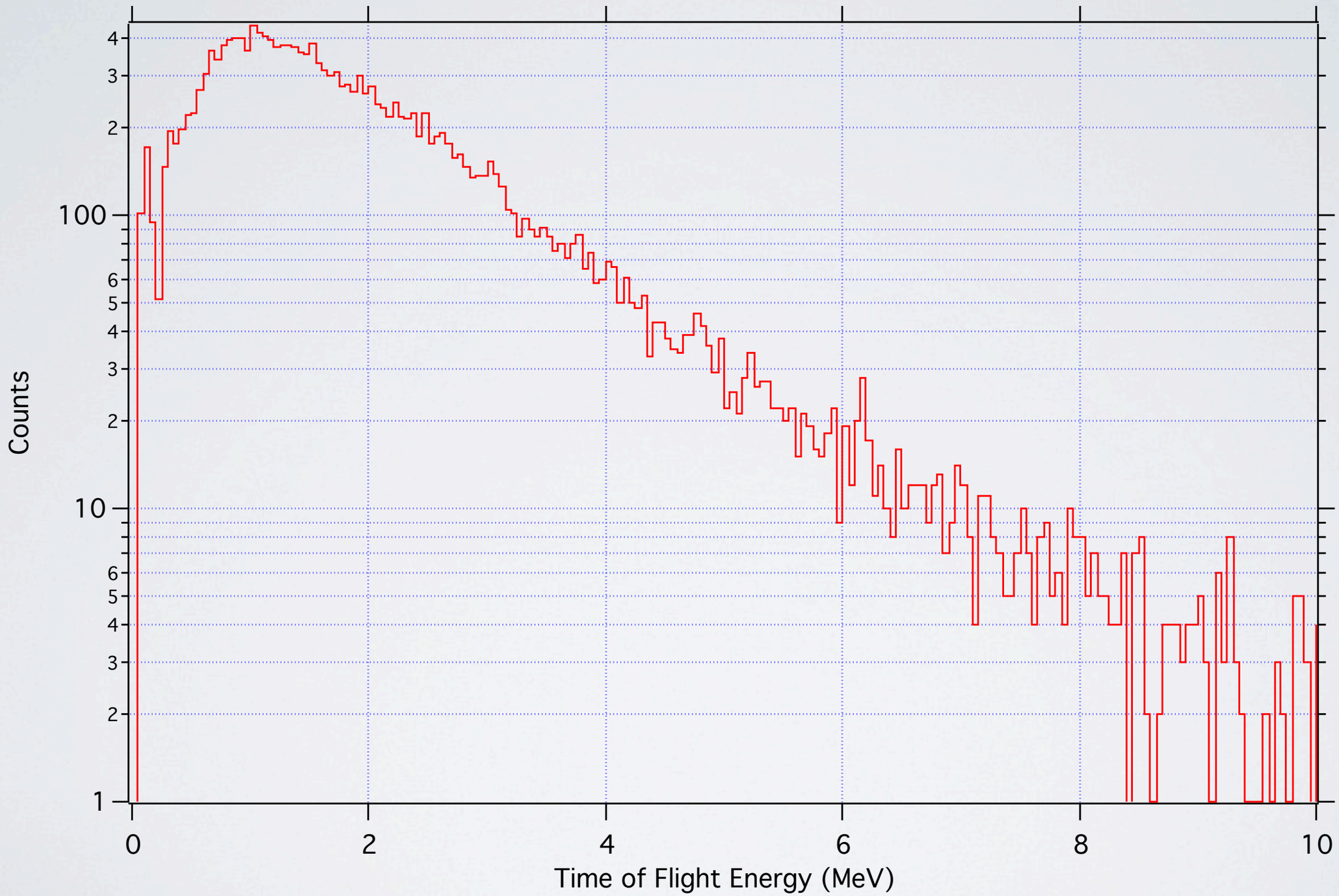


# TIME OF FLIGHT



# TIME OF FLIGHT ENERGY



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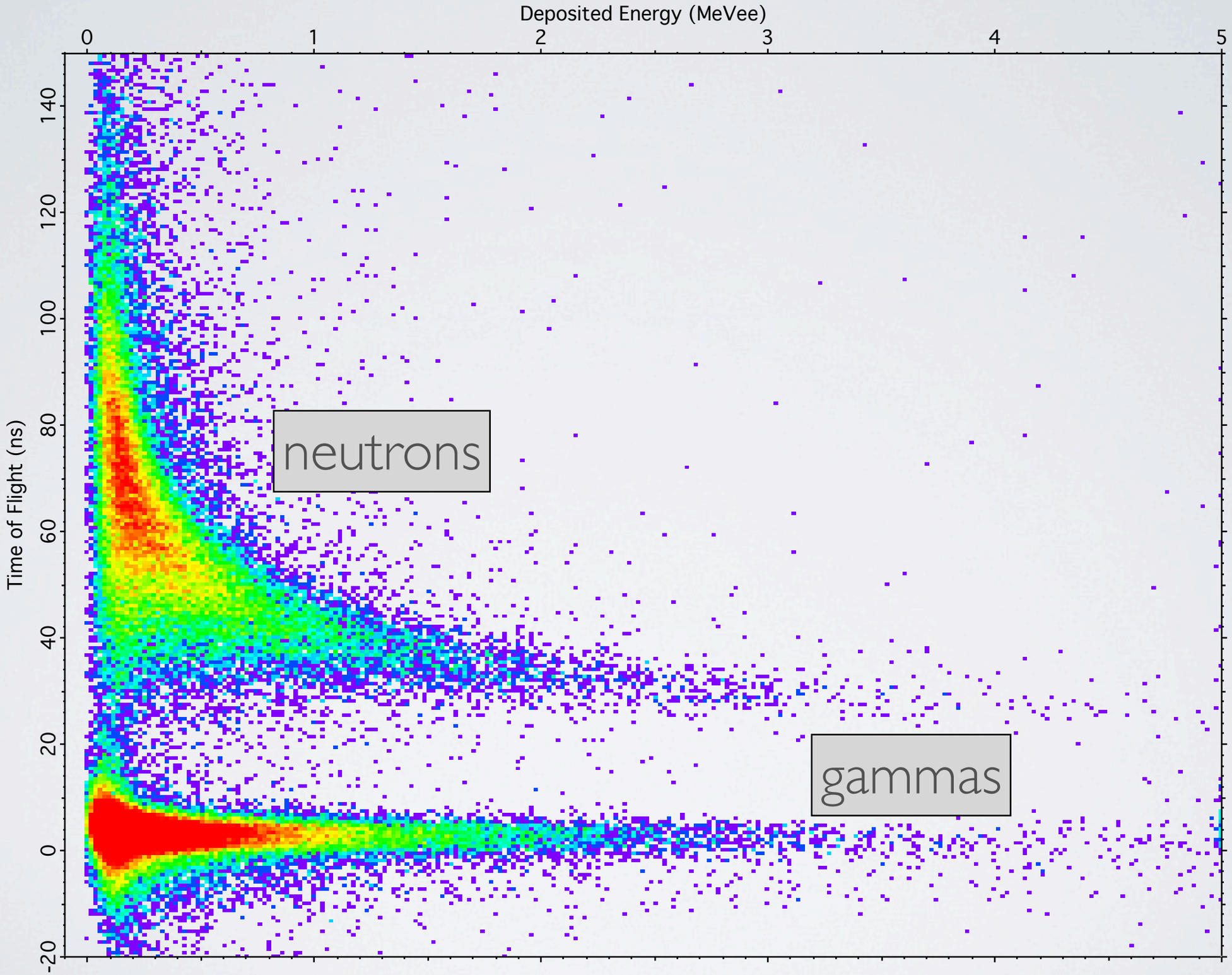
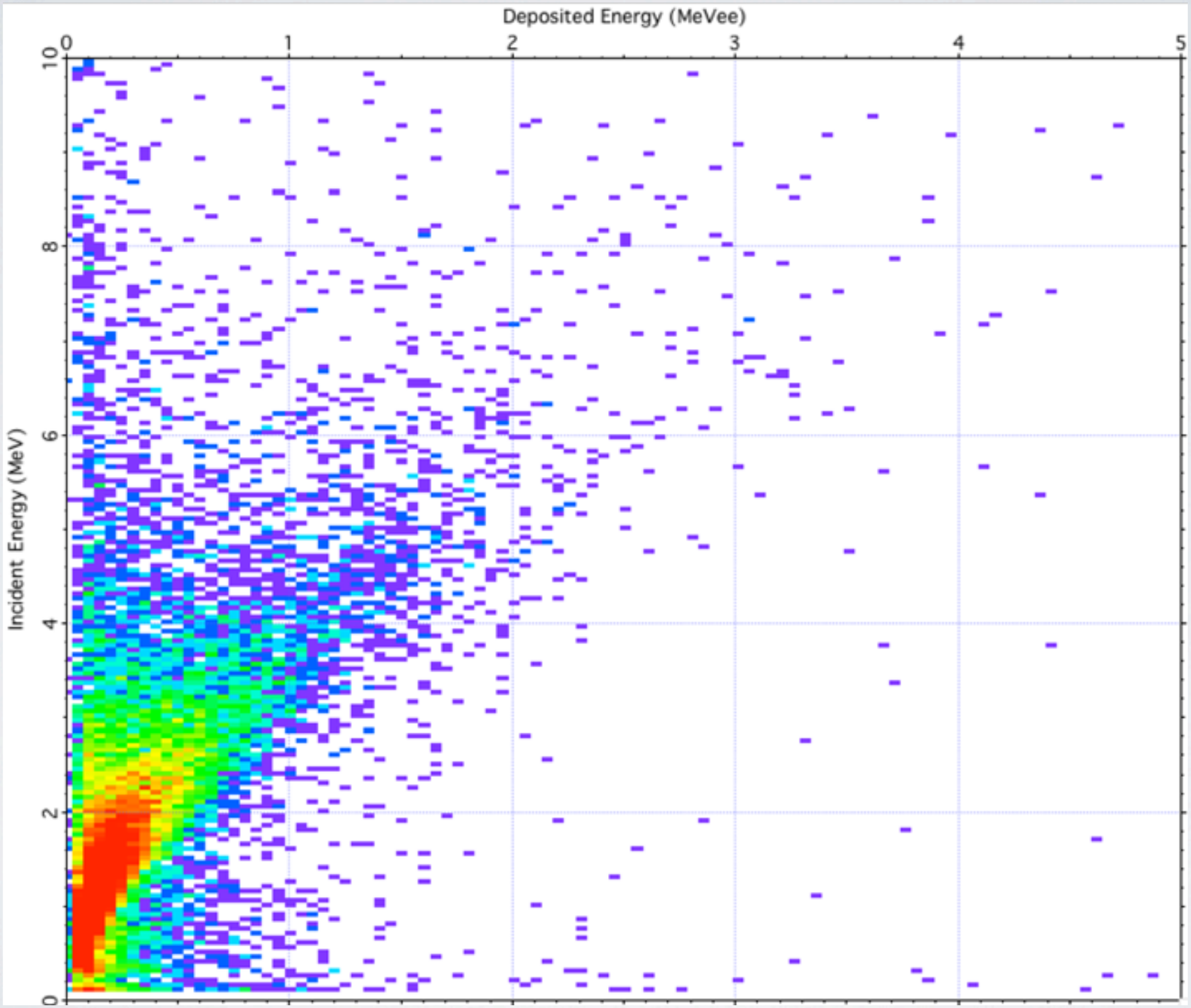
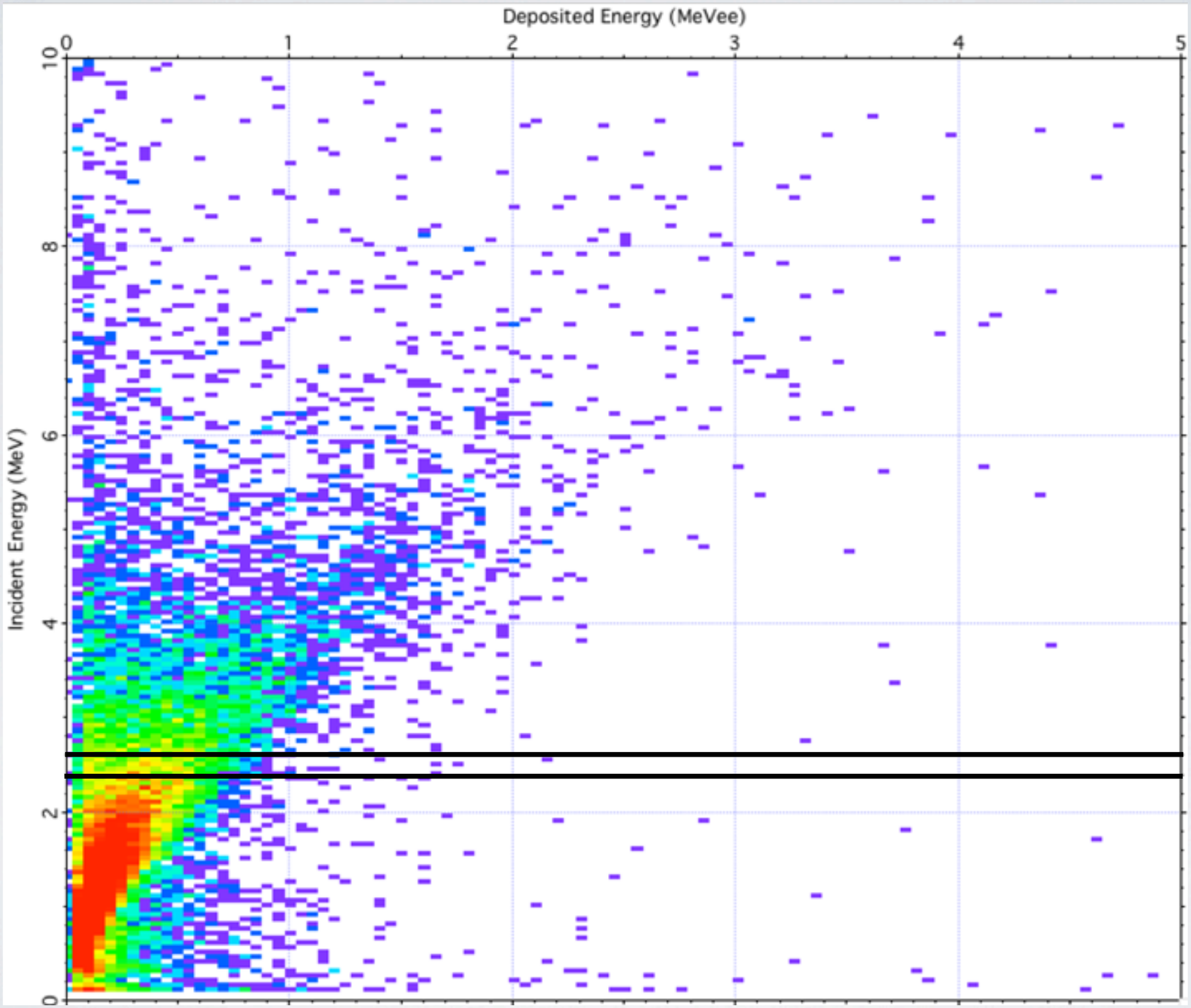


# MeV vs MeVee


Deposited Energy (MeVee)
0
1
2
3
4
5
Incident Energy (MeV)
0
2
4
6
8
10

# MeV vs MeVee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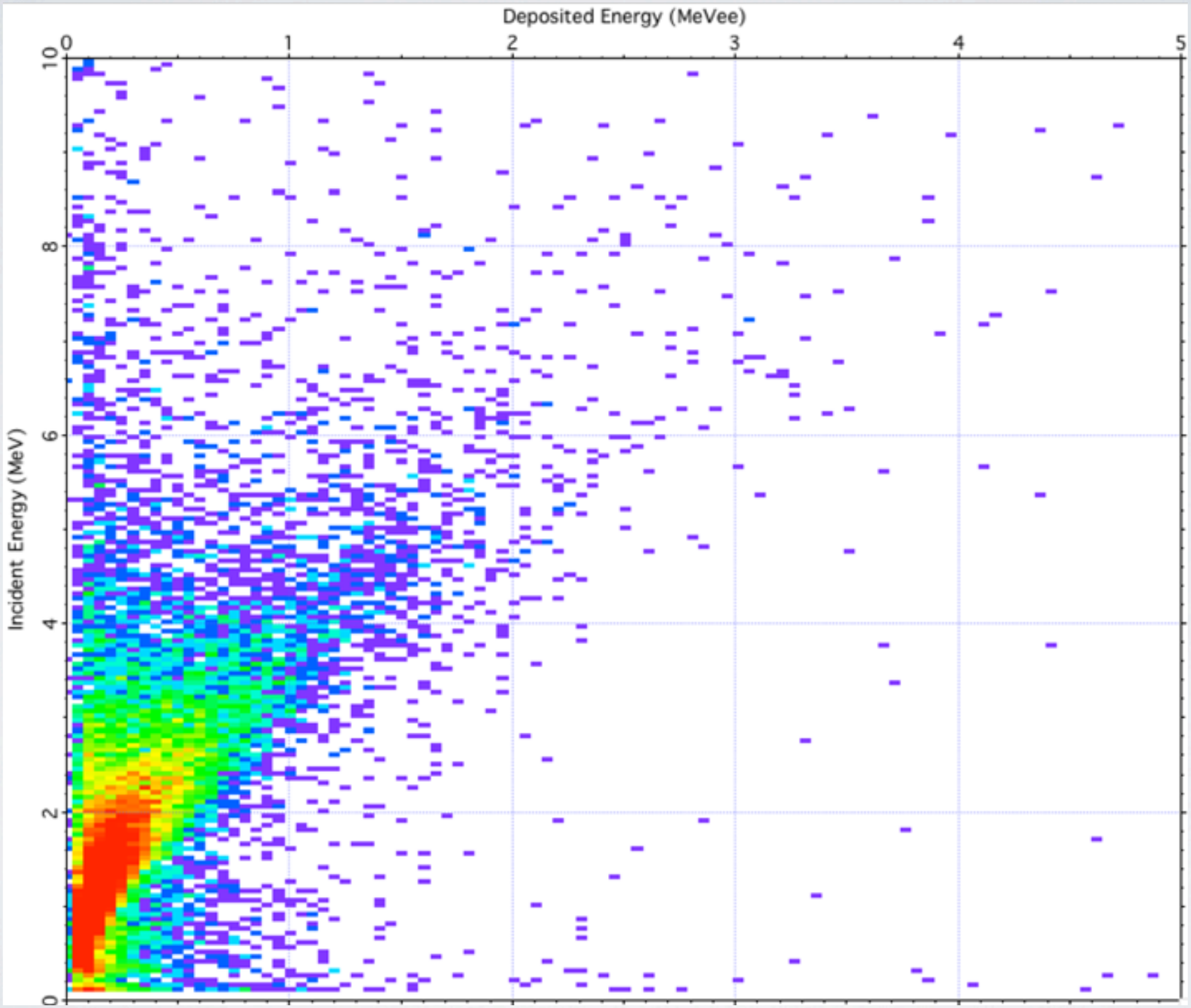
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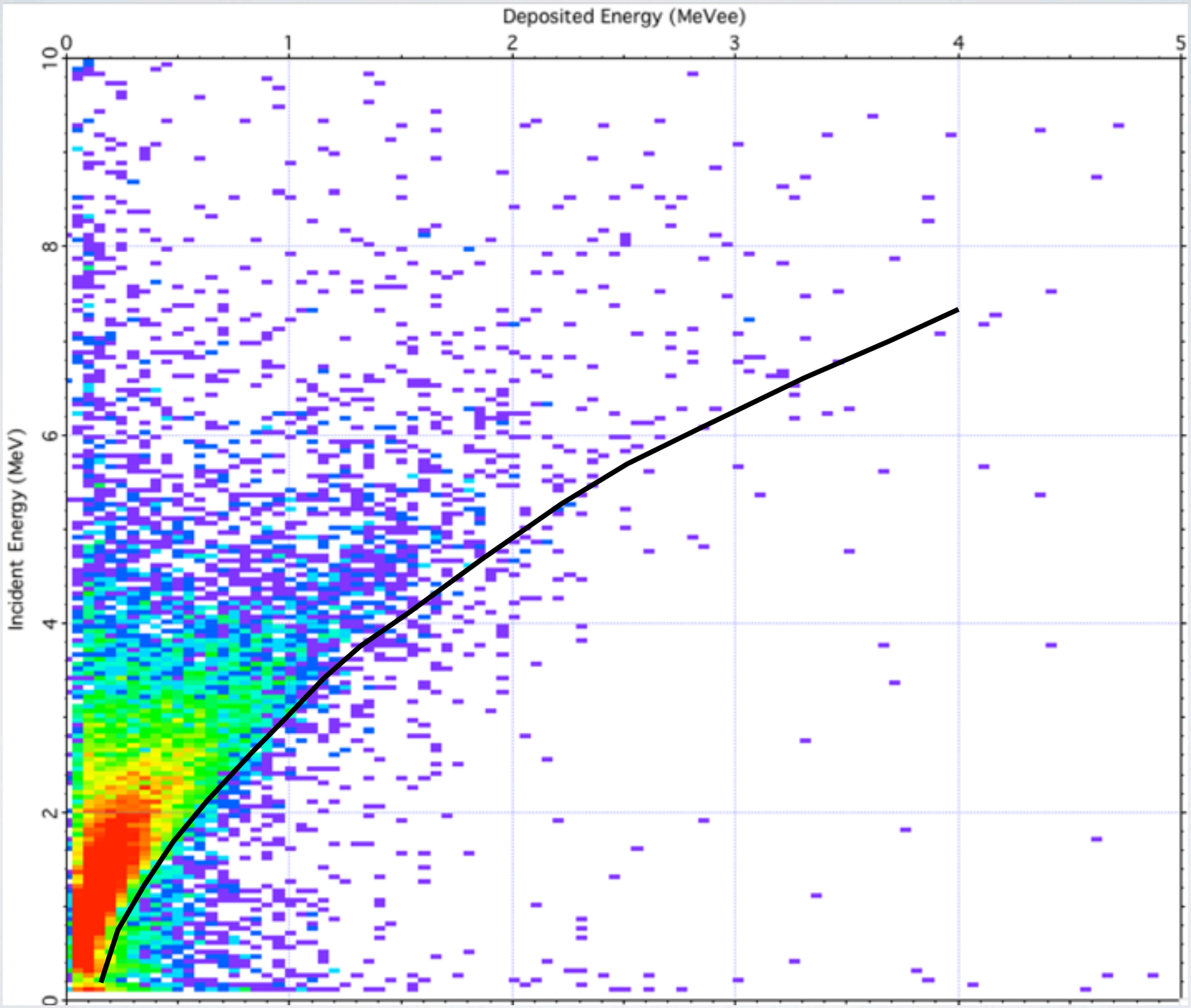
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