Study of Muon-induced Neutron Production Using Accelerator Muon Beam at CERN

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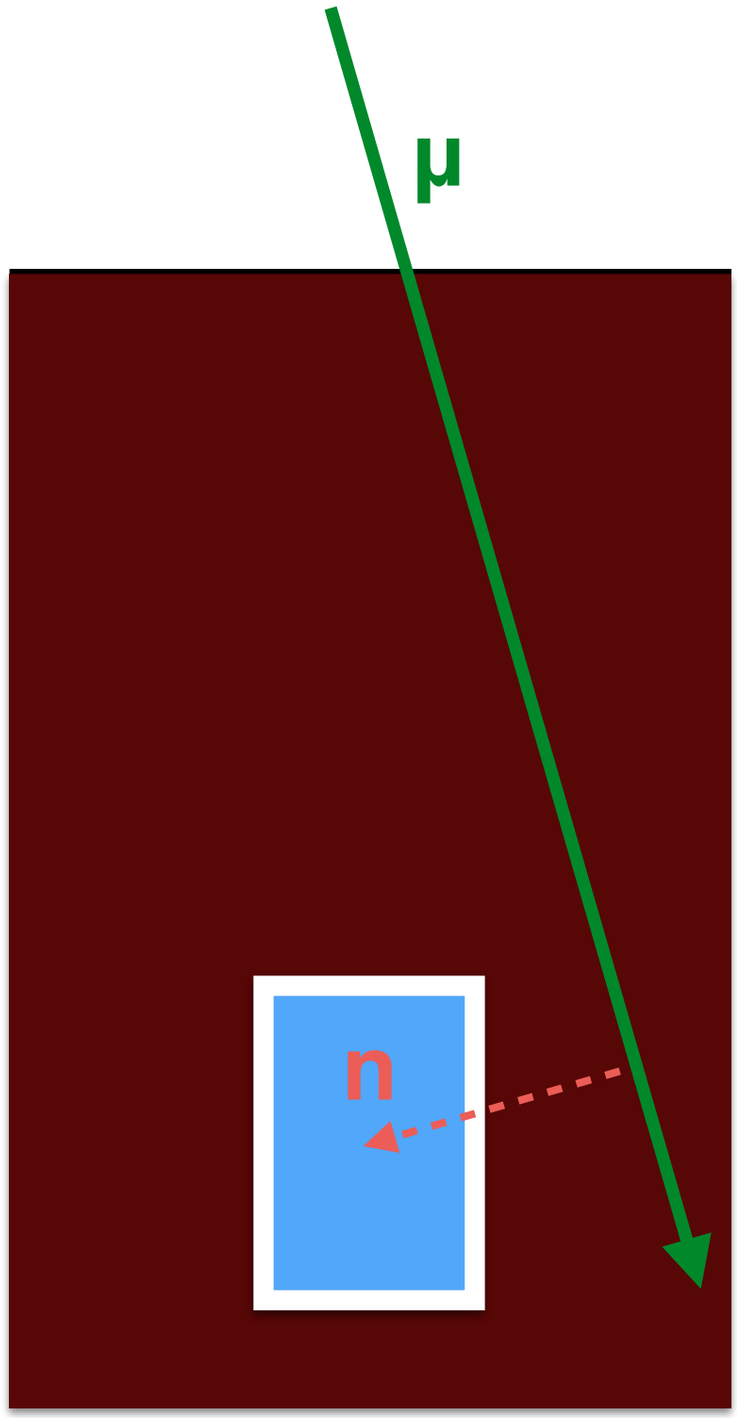
Outline

- Cosmogenic muon-induced backgrunds
- Test experiment with accelerator muon beam at CERN
- Preliminary results

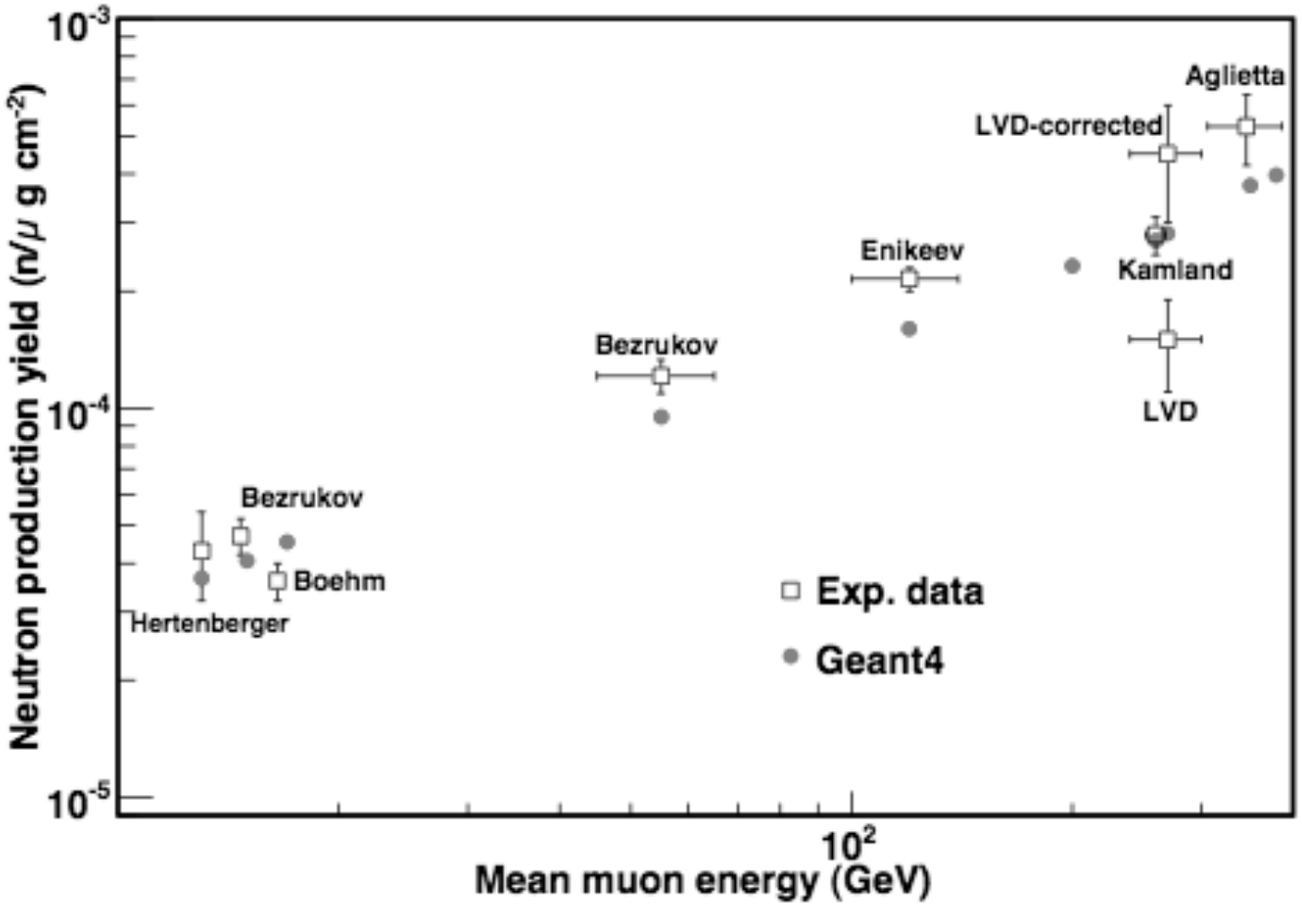
Muon-induced backgrounds

- "Problematic" backgrounds for WIMP dark-matter or double beta-decay searches: cosmogenic muon-induced backgrounds
  - Fast-neutrons
    - Radioactive isotopes, such as ^{9}Li, ^{8}He, ^{11}C, ^{7}Be, etc. (Linked to neutron production)
- Rare searches need to go deep underground
  - Cosmogenic backgrounds are produced by relatively high-energy muons (O(100 GeV)).
  - Interactions with those muons are poorly understood.



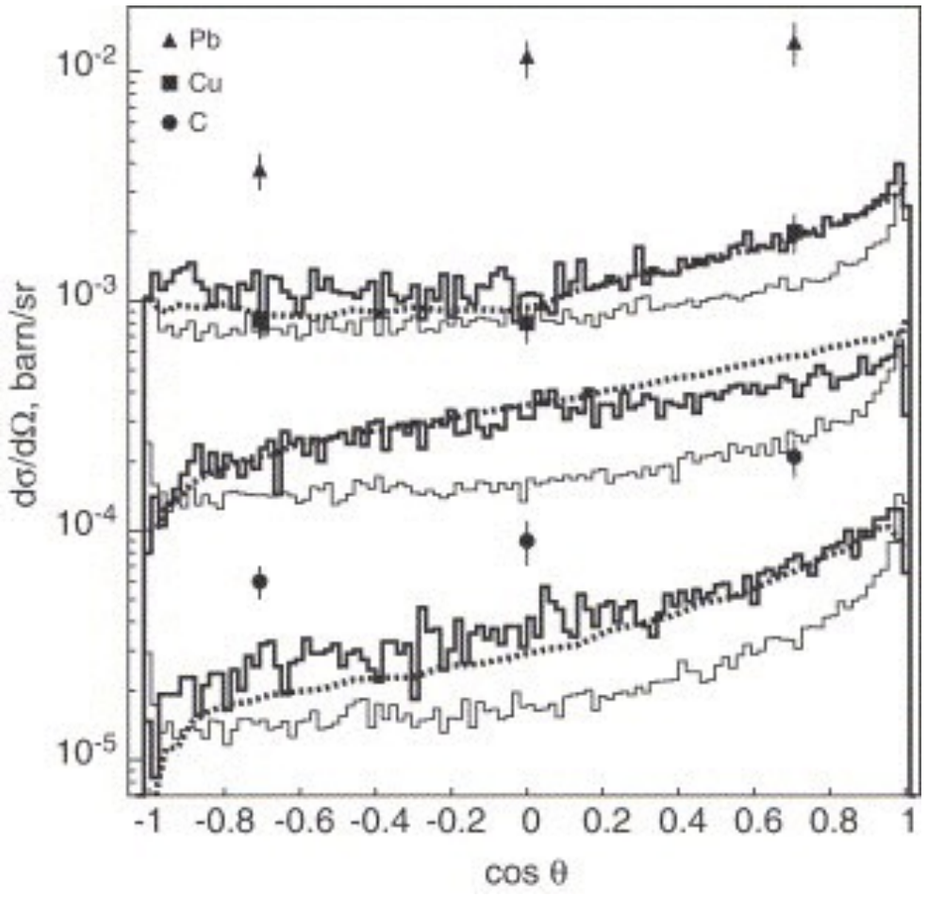
Why we need external data?

In-situ neutron production measurements



Phys.Rev., D64:013012, June 2001

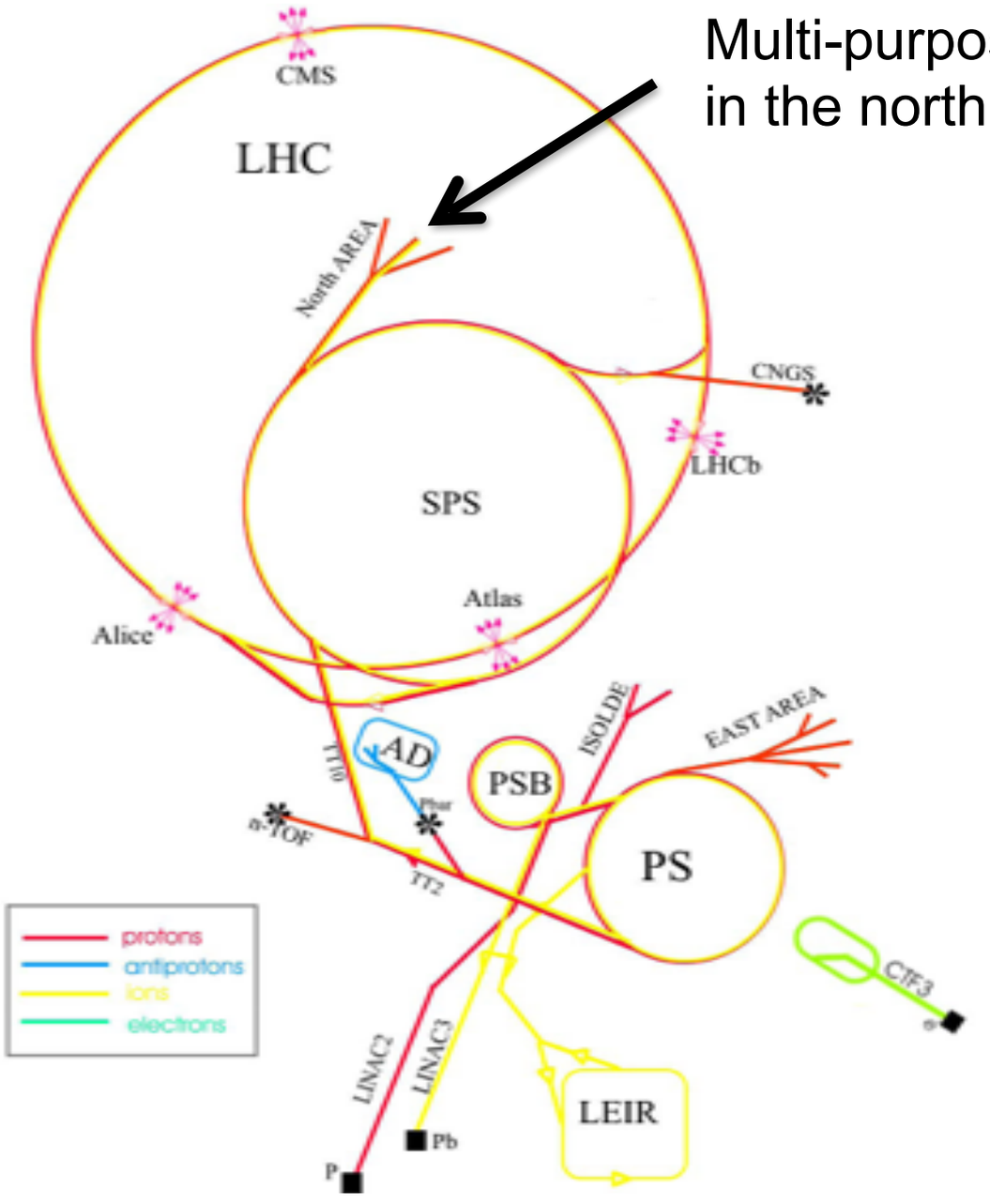
"Latest" data with accelerator muon beam



Nuclear Instruments and Methods in Physics Research A, 545:398-411, June 2005

- In-situ measurements at underground sites are difficult, due to low muon rate
- "Recent" measurement using accelerator muon beam a big discrepancy with simulations
- More comprehensive data desired for better understanding of muon-induced backgrounds

CERN accelerator complex



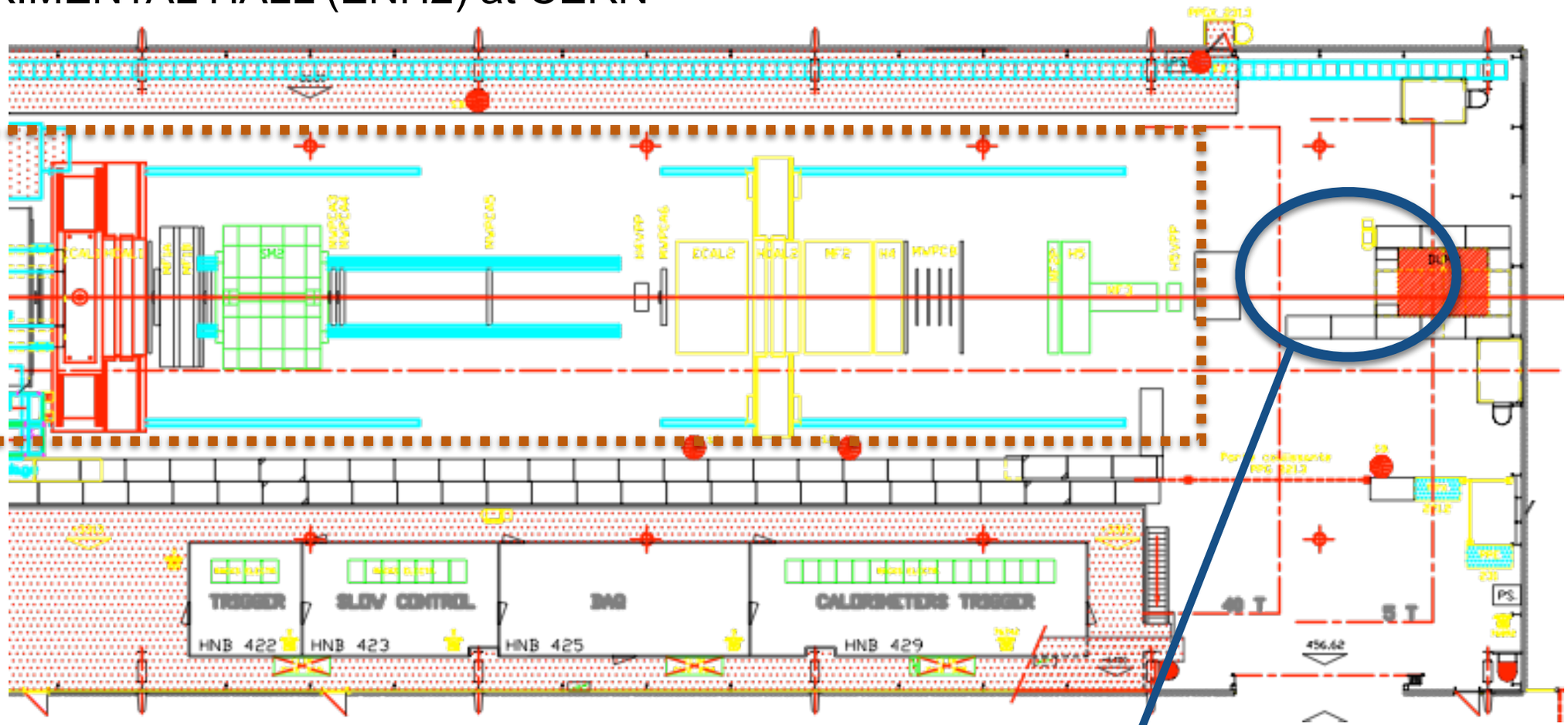
Multi-purpose beamlines in the north area

- M2 beamline in the North Area provides high intensity muons
- Muon energy up to 280 GeV
- ~10^8 muons per spill @160 GeV (45 sec duty cycle)
- Currently being used by the COMPASS experiment

Experimental site

EXPERIMENTAL HALL (ENH2) at CERN

Muon Beam
(100 GeV – 280 GeV)

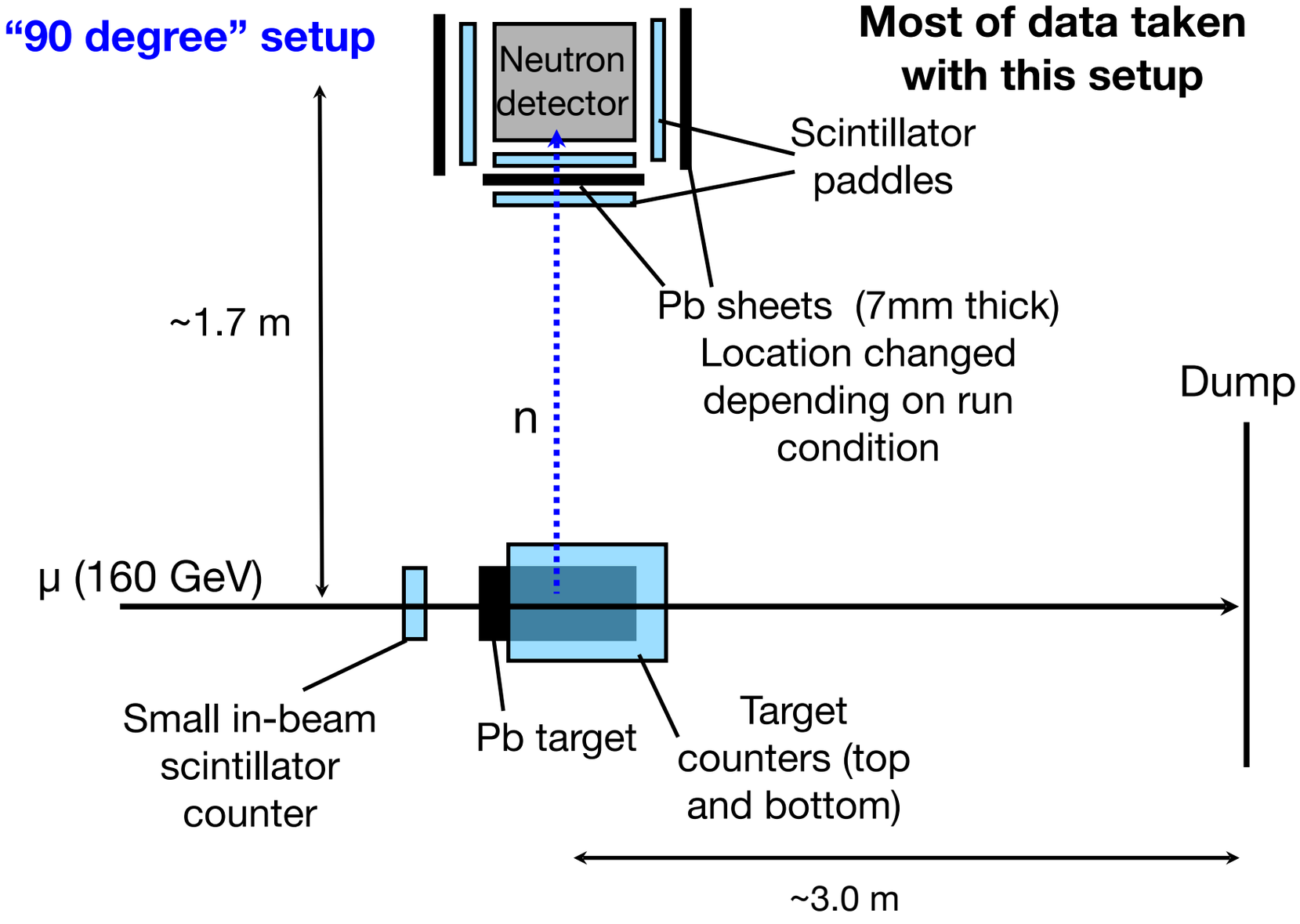


COMPASS detector

Neutron production measurement (2012)
+ possible larger scale experiment?

We thank Lau Gatignon and the COMPASS collaboration for their generous helps

Beam test setup



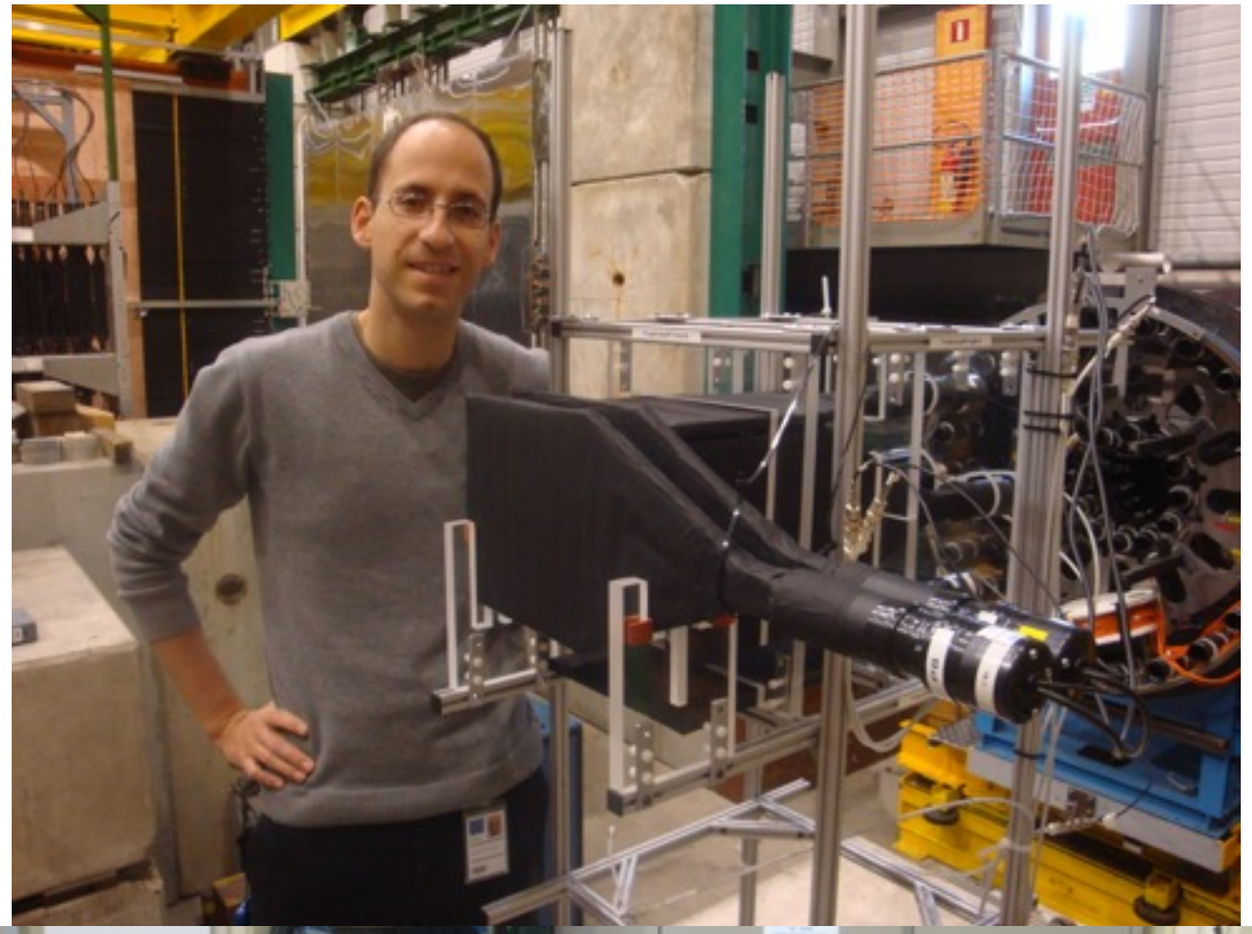
- Pulse-shape discrimination at the neutron detector.
- Use Time-of-Flight to measure neutron kinetic energy.

Data with 45 degree (forward) and 135 degree (backward) were also taken

Beam Test Installation and Commissioning Photos

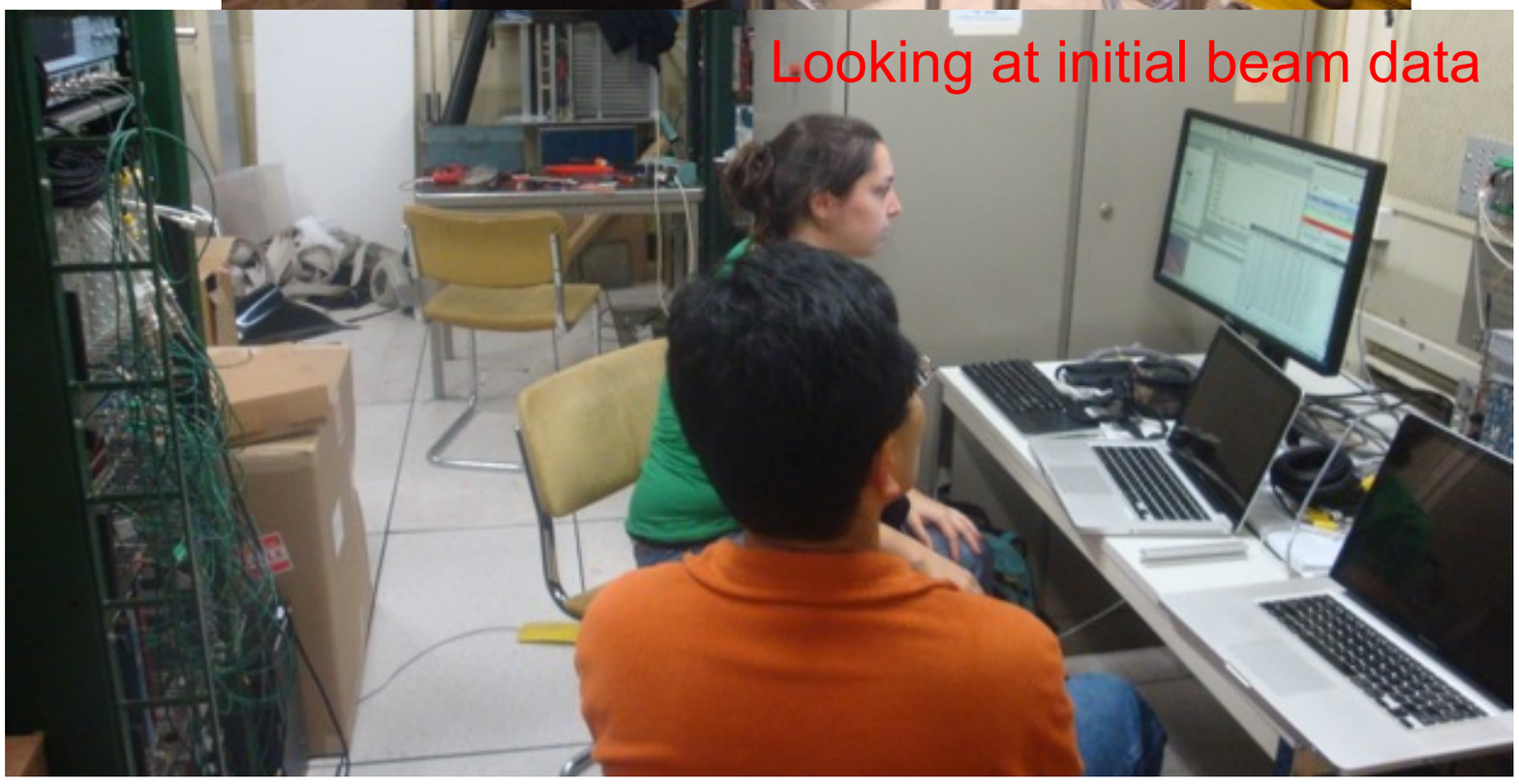
Installing the Neutron Detector Assembly

Close-up of detector assembly

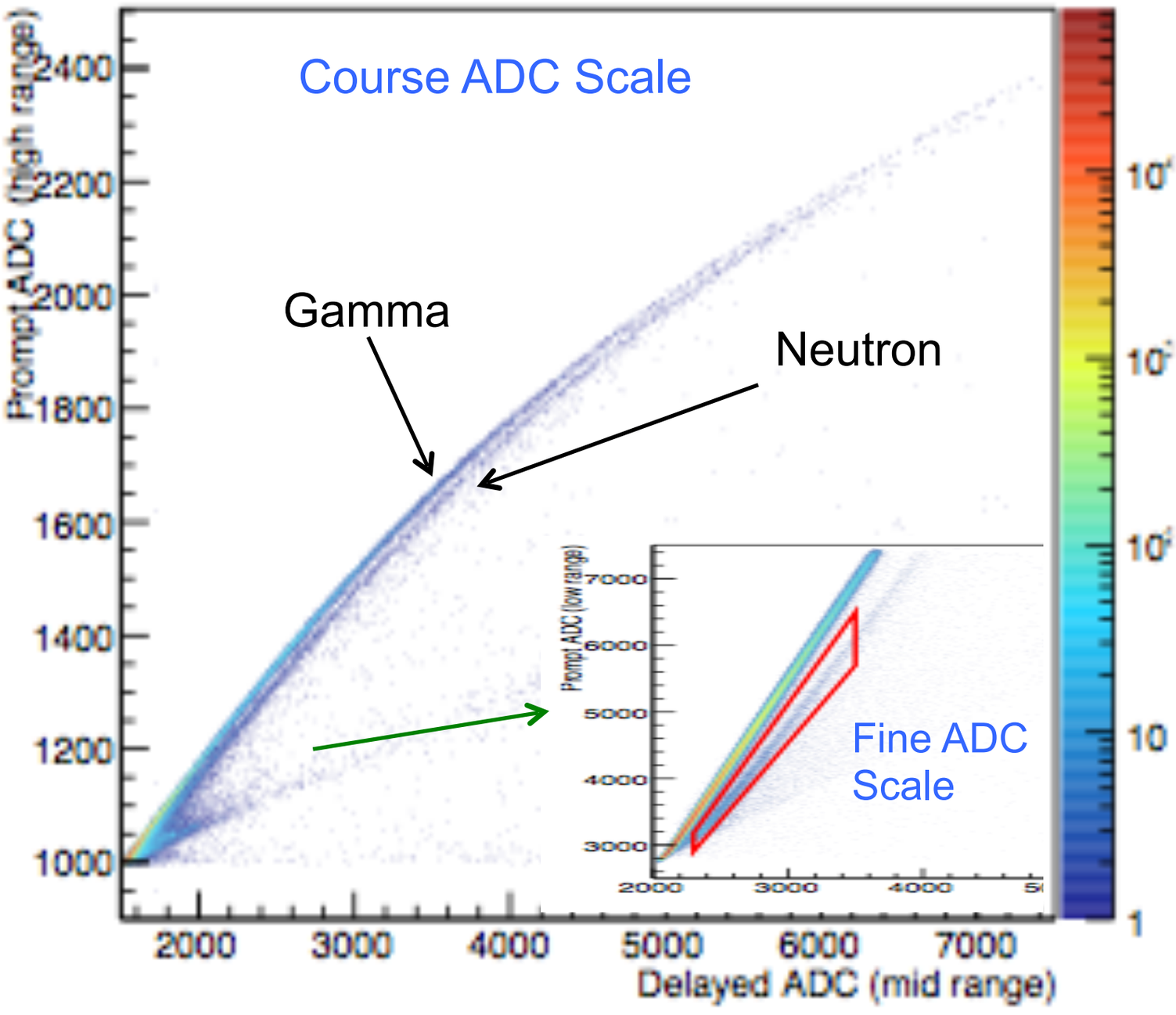


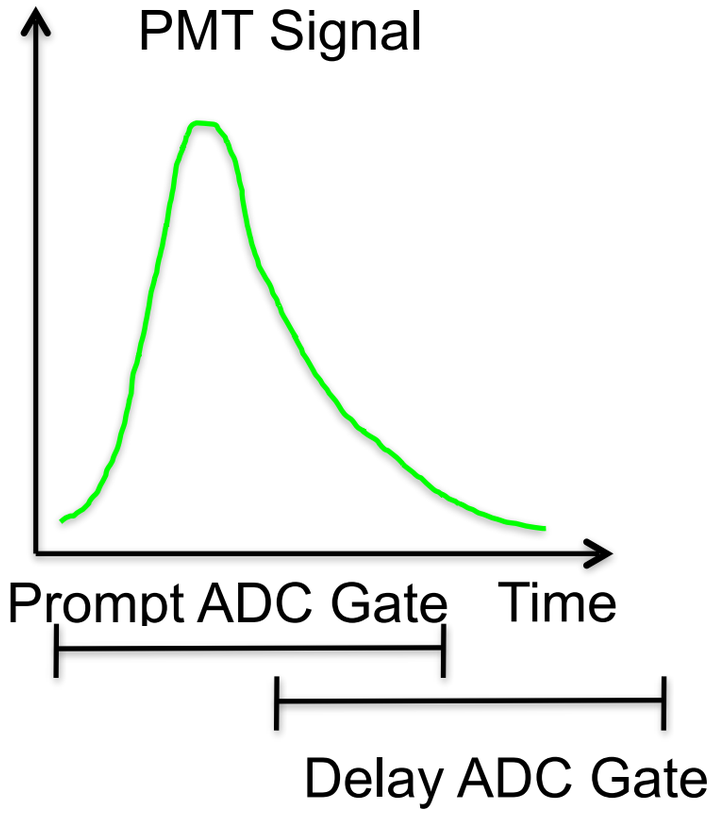
DAQ rack

Looking at initial beam data



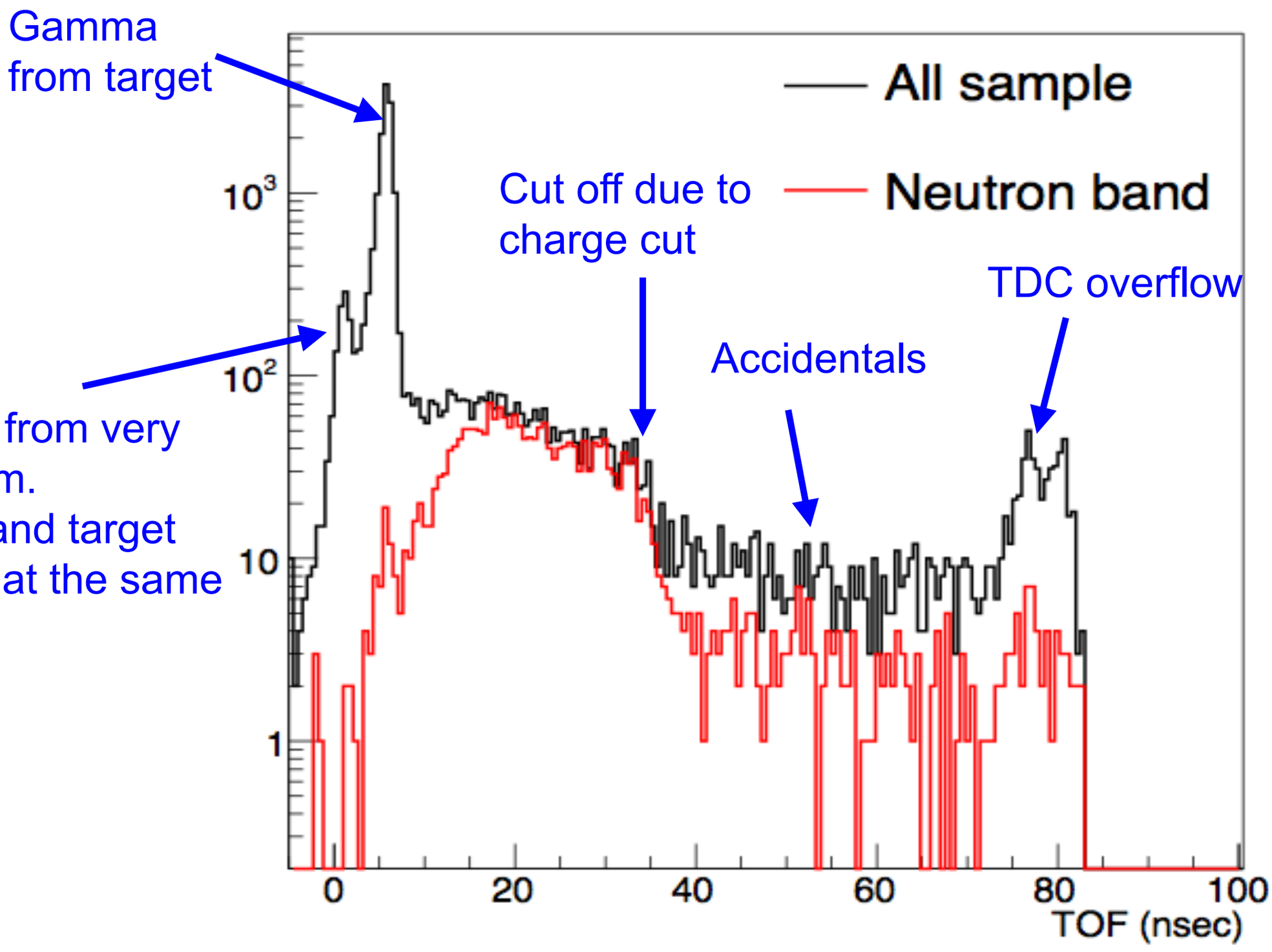
Pulse-shape discrimination



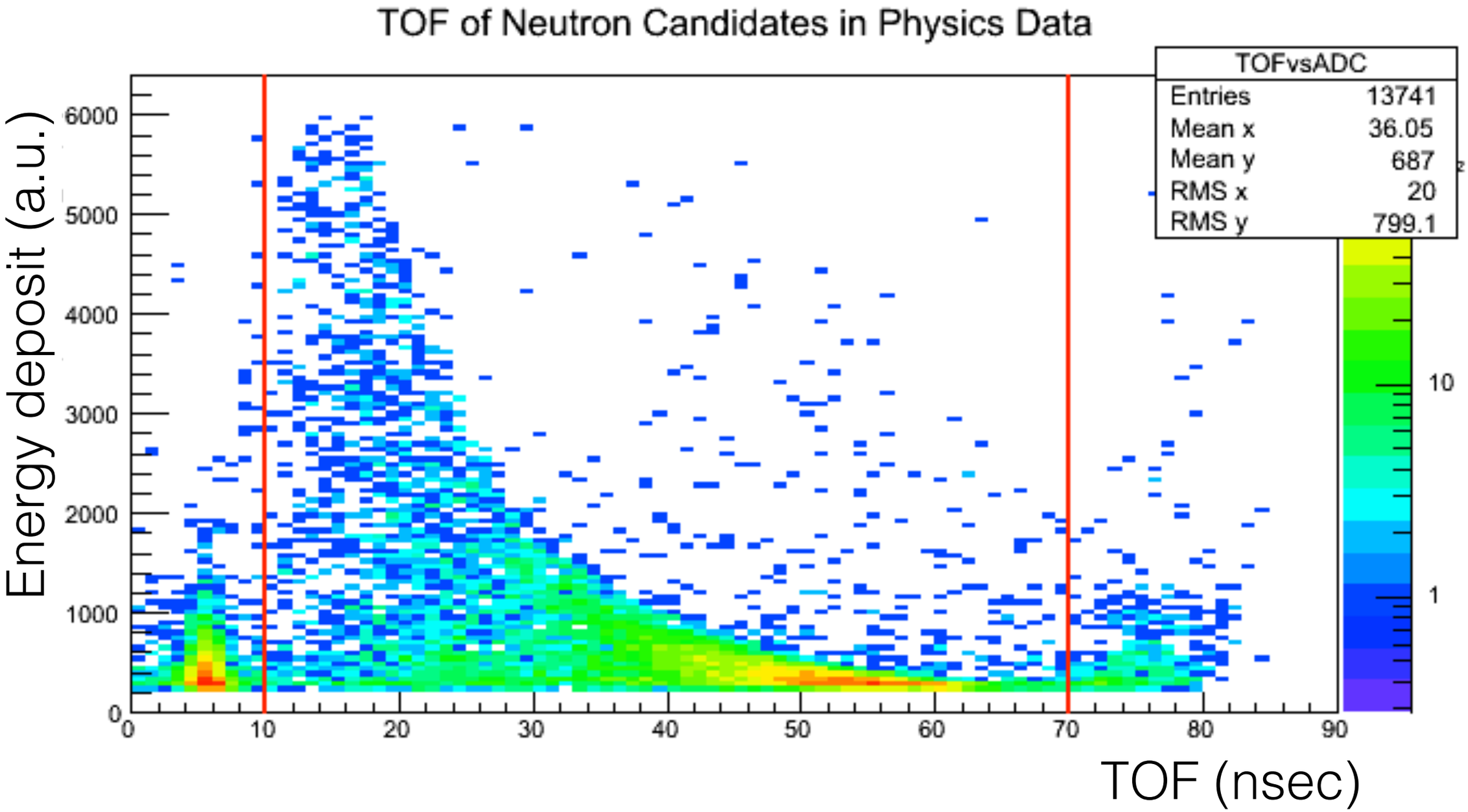


Good gamma-neutron separation over a wide energy range (~1MeV to ~100 MeV)

Time-of-Flight

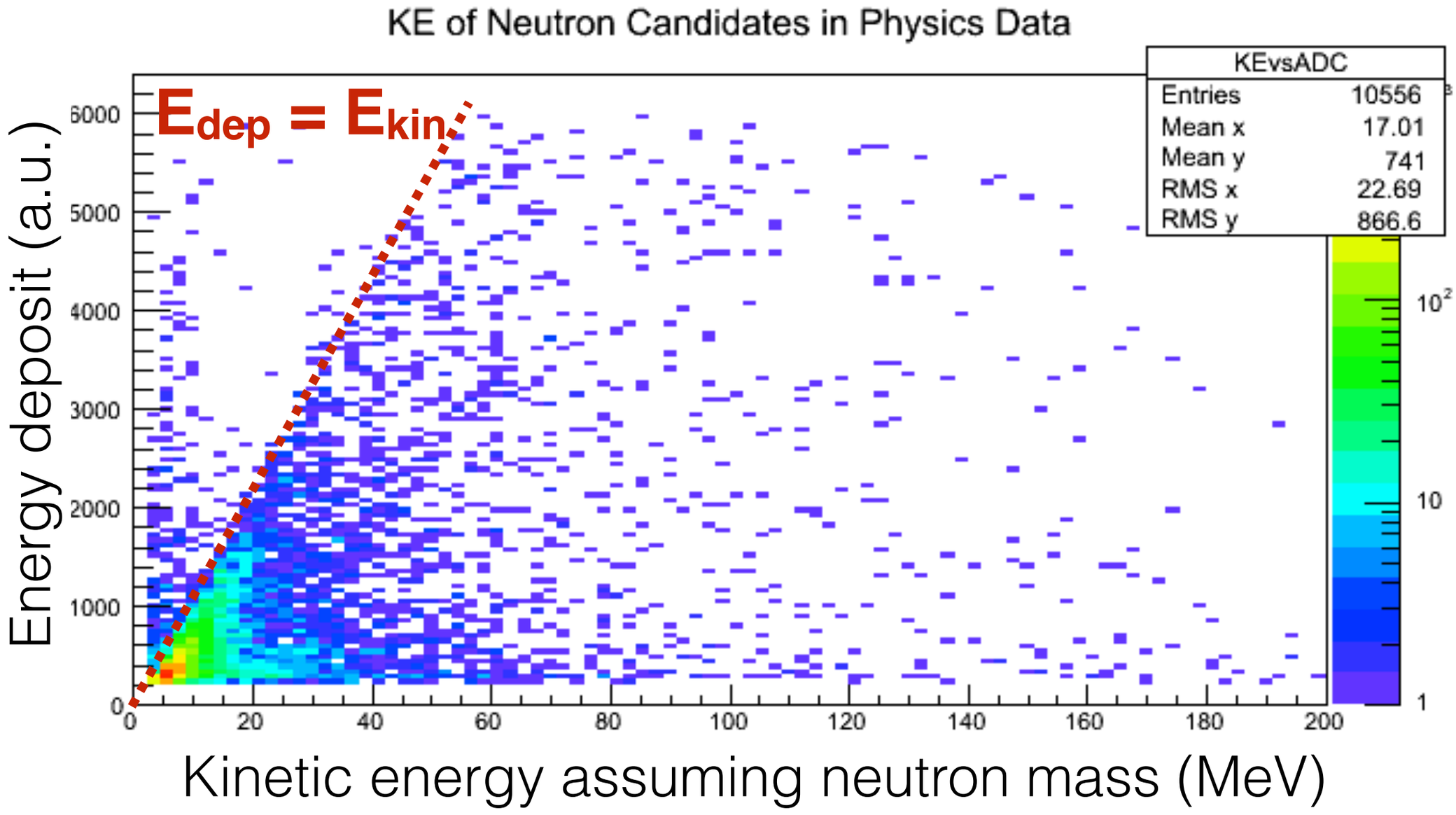


Charge vs TOF



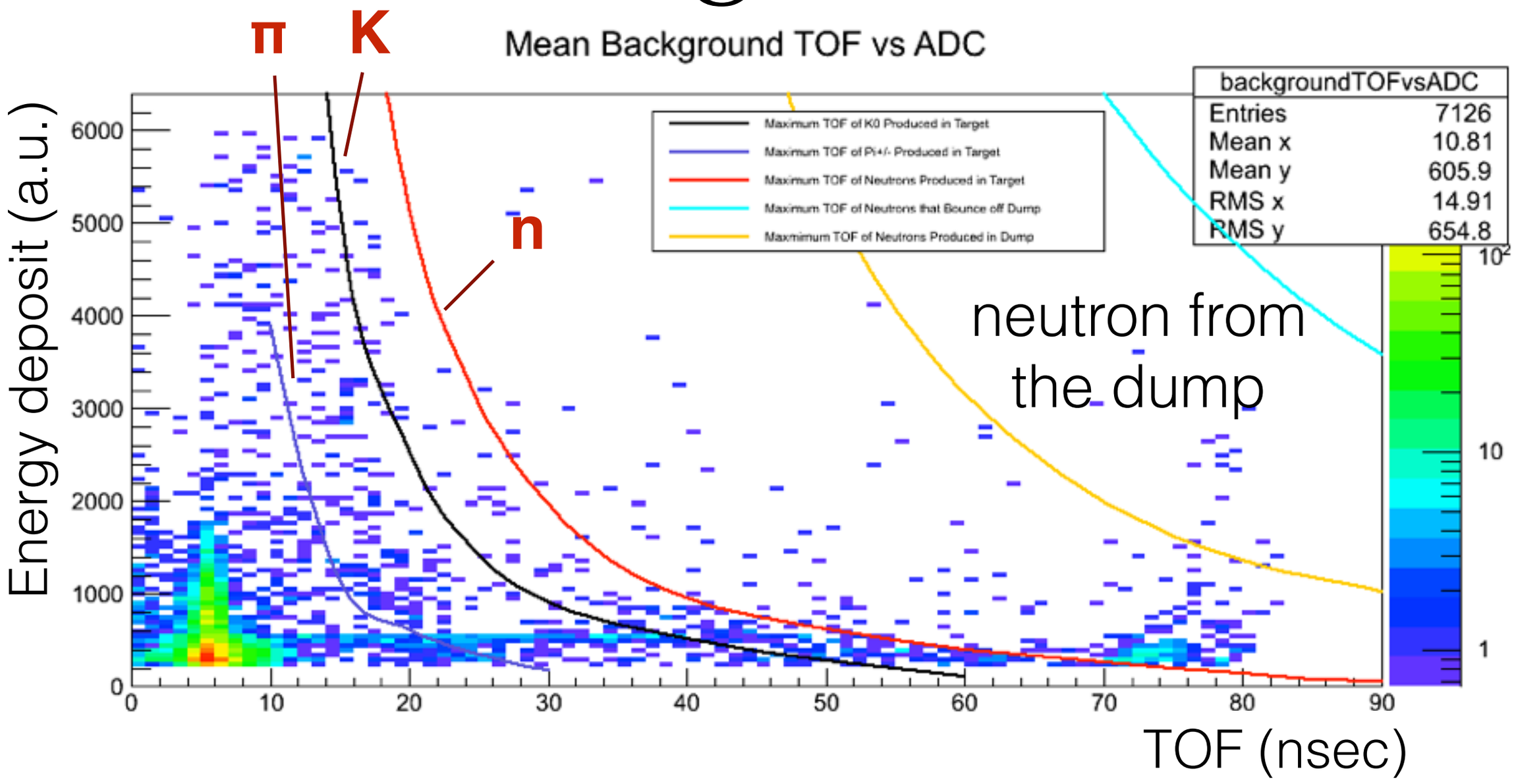
Clear correlation between TOF and energy deposit

Charge vs kinetic energy



- Linear correlation between kinetic energy and energy deposit

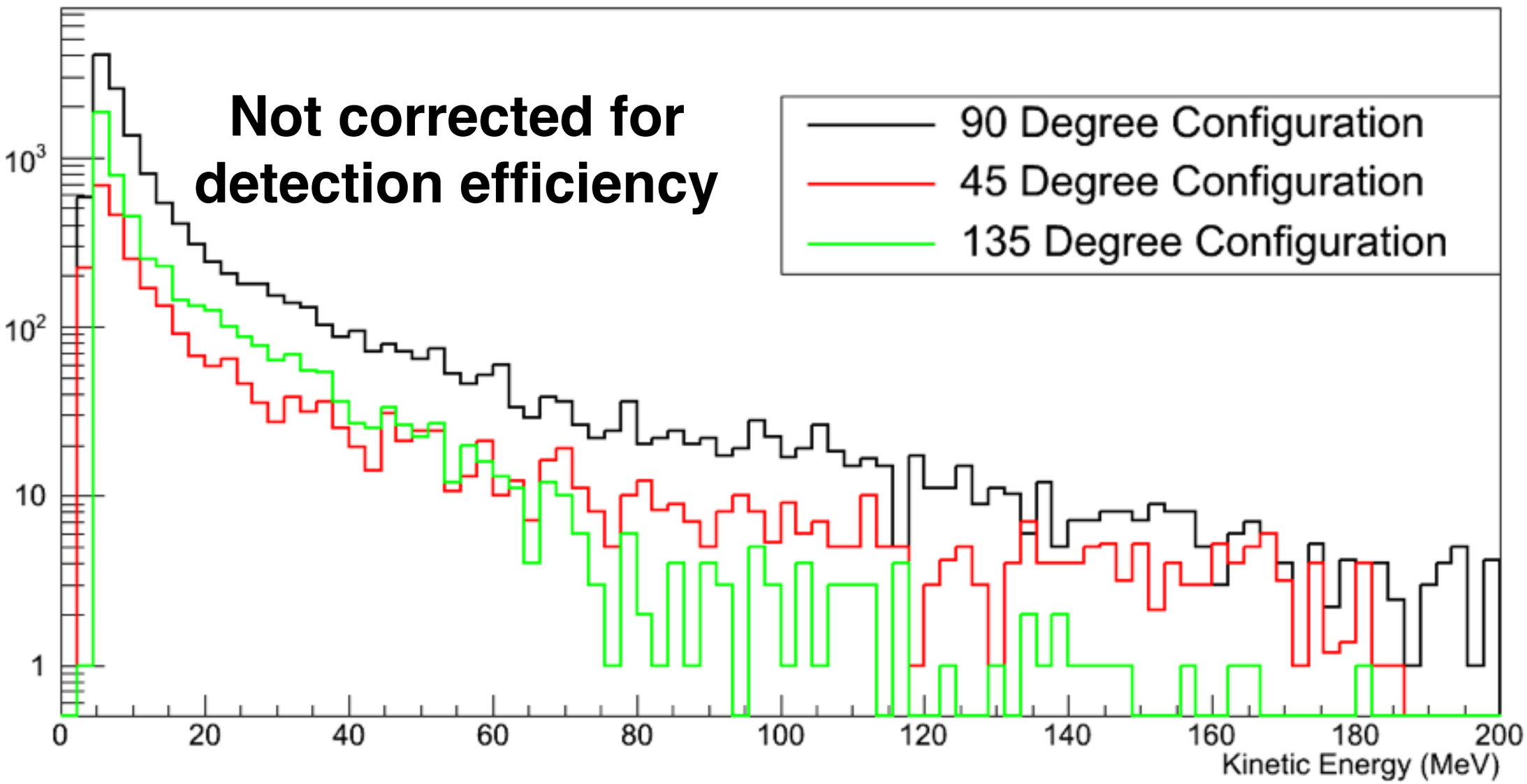
Backgrounds



- Backgrounds estimated using the side-band data of the neutron-band
- B/S ~ 0.05
- Dominated by gammas and accidental
- Also found evidence of lighter meson (π, K) production.

Neutron kinetic energy

E. Dreager



High-quality data of neutron production yield and energy distribution.

Finalizing the analysis.

Summary

- Accelerator muon beam can help understanding the cosmogenic neutron backgrounds

- Measured neutron production yield and energy distribution form 160 GeV/c muons on Pb target.

  - Working on finalizing analysis.

  - Would provide important benchmark for various simulations.

- Setup feasible for possible future large-scale experiments.

Backup slides

Setup

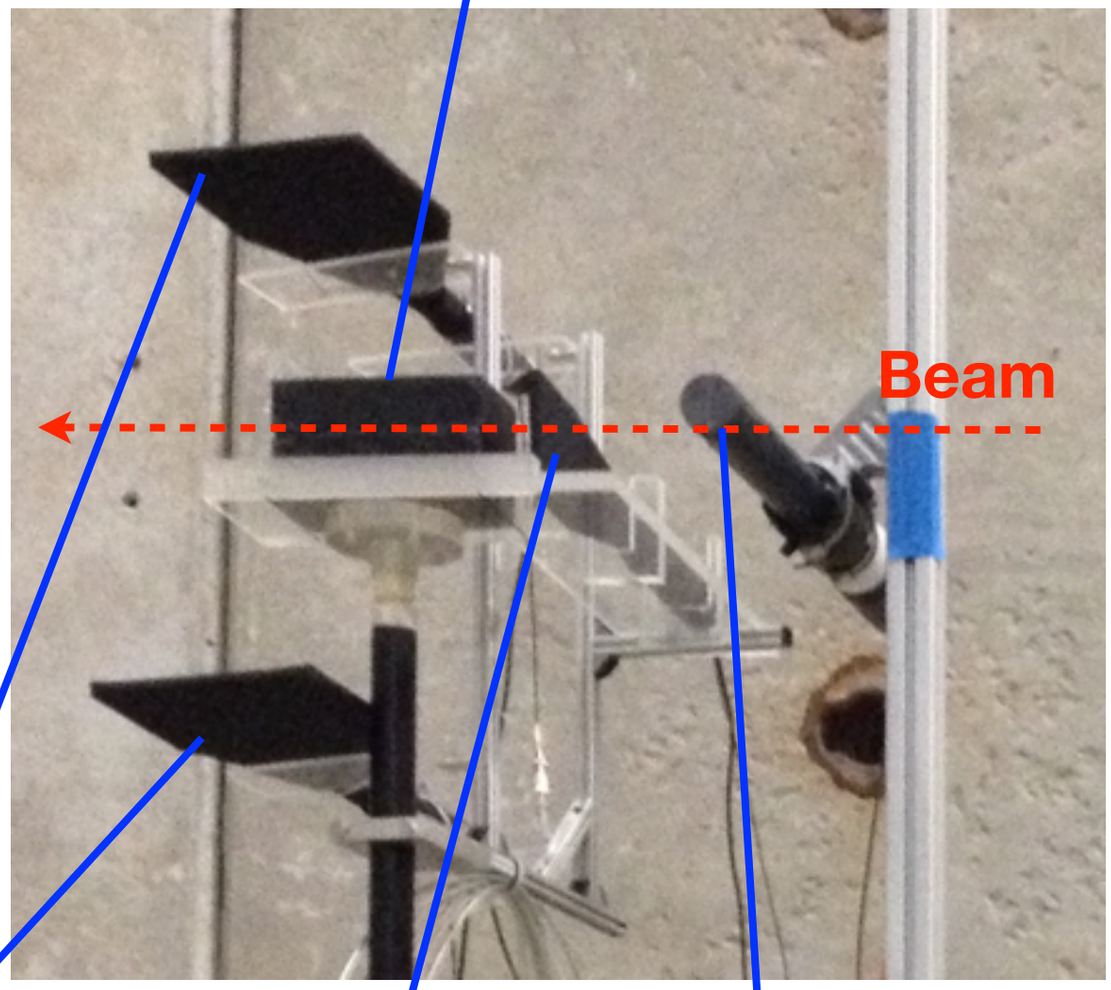
Close-up photos

Neutron detector

Surrounded by Scintillator paddles and lead sheets

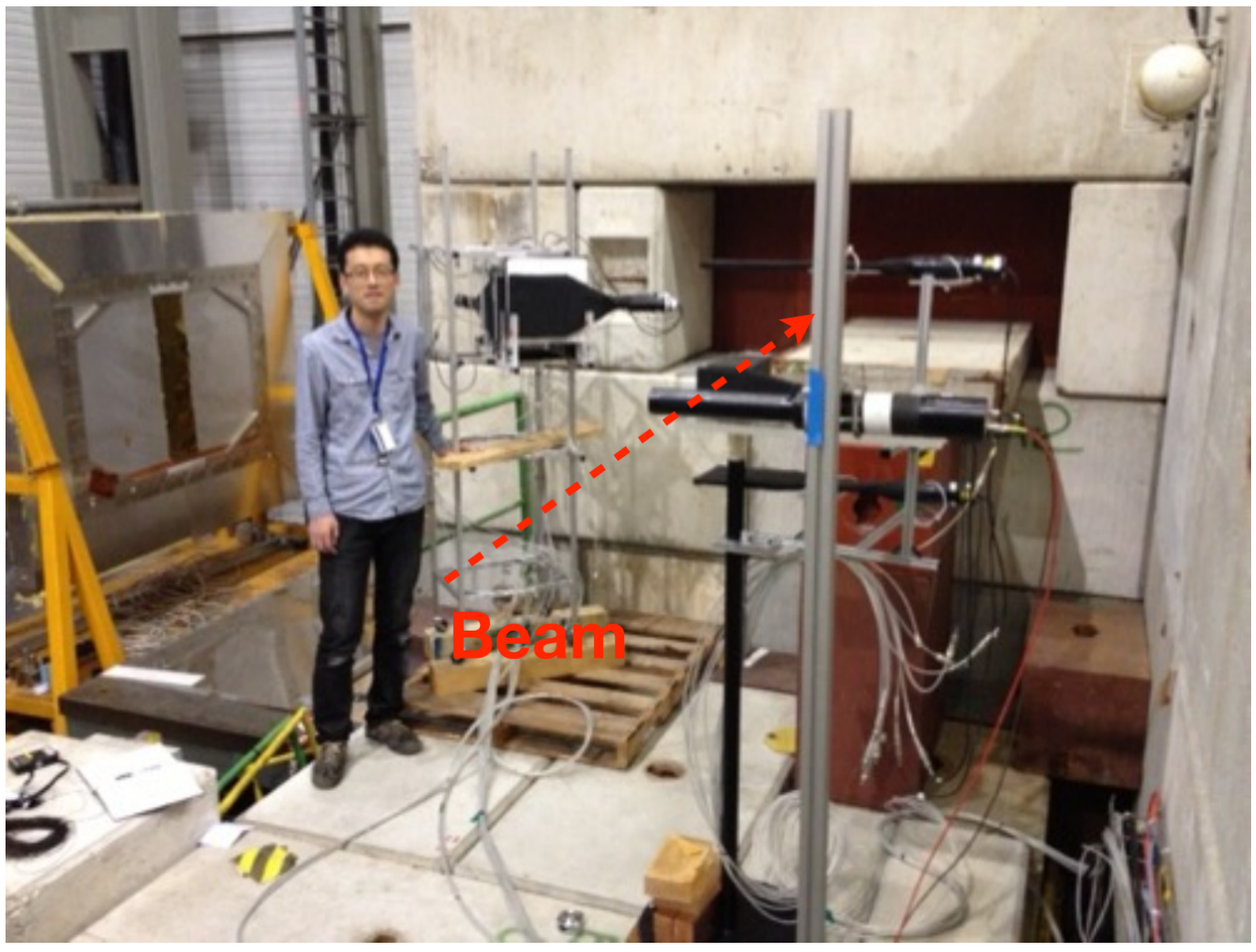
Active volume:
5” diameter and 5” thick liquid scintillator.

Target



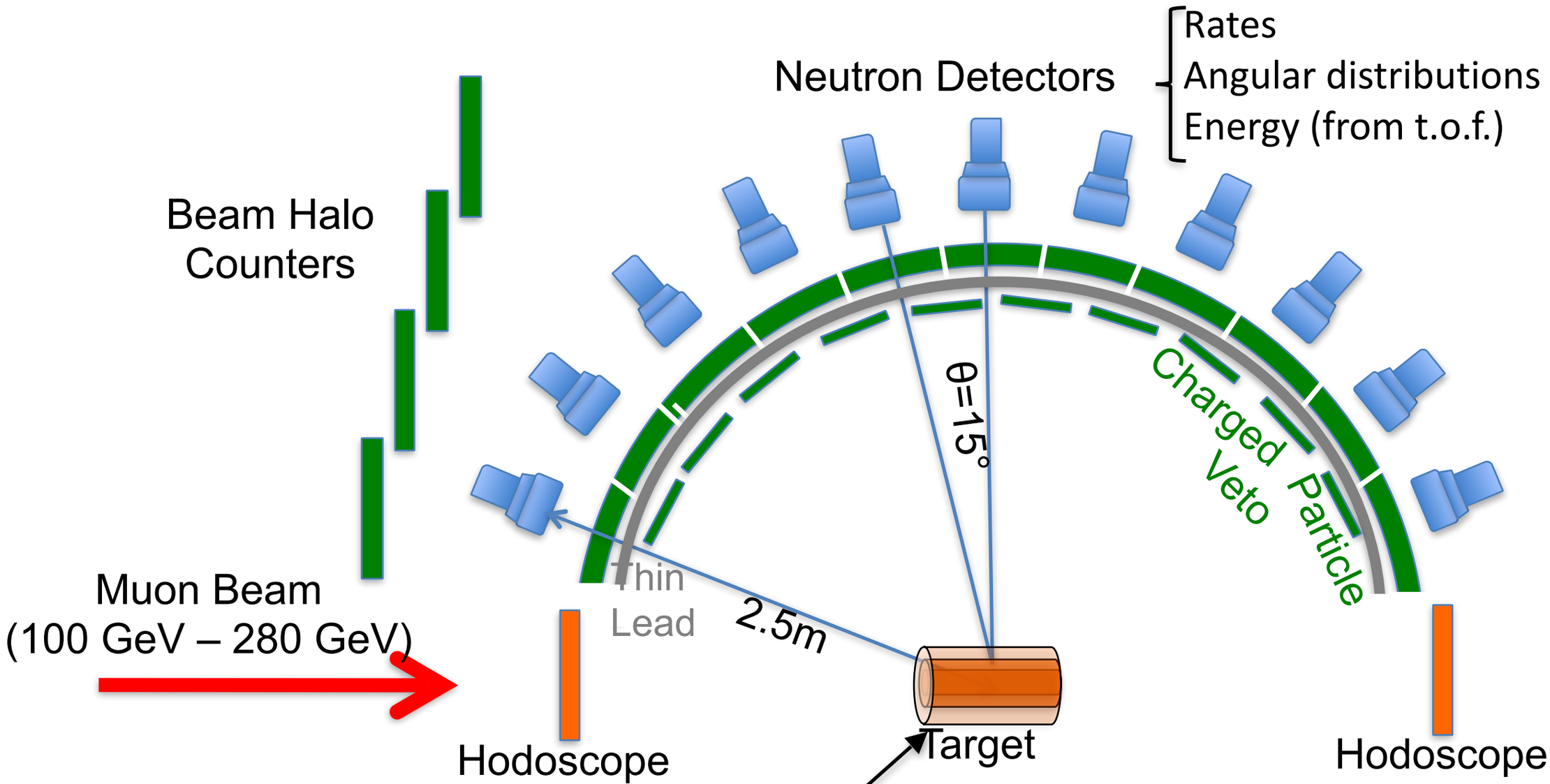
Other setups

"45 degree" setup



"135 degree" setup

Cartoon Sketch of the Neutron Production Experiment



- Target radius is varied to measure neutron production vs. target thickness.
- Potential targets: graphite, copper, lead, H_20, liquid scintillator, etc.