SAND2018-14003PE

MARS update

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2018/12/11

COHERENT collaboration meeting

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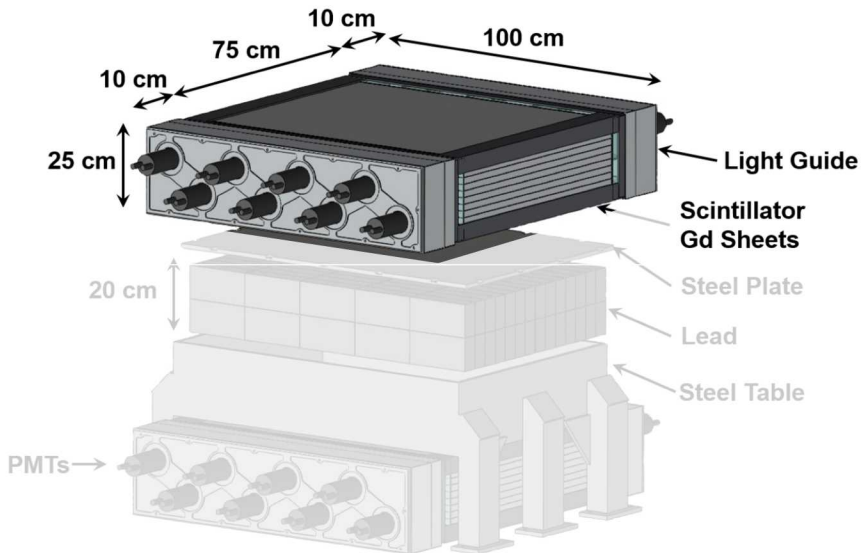
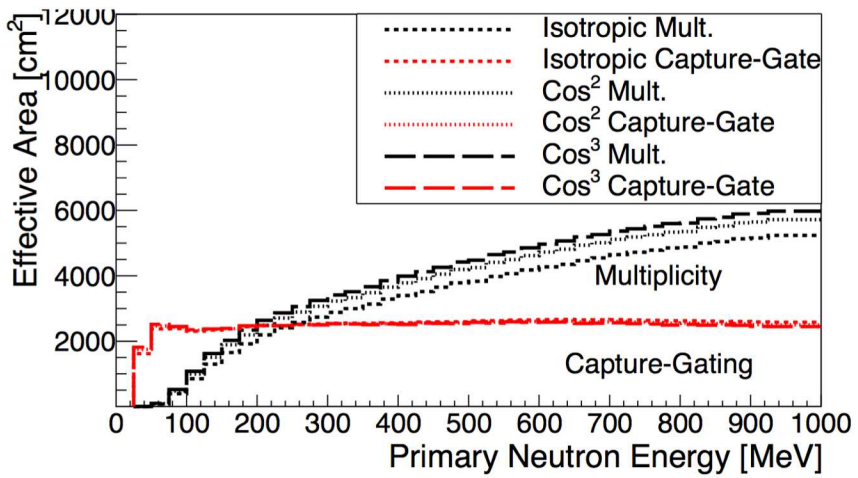
SAND2018-0718 PE

MARS detector for neutron background monitoring

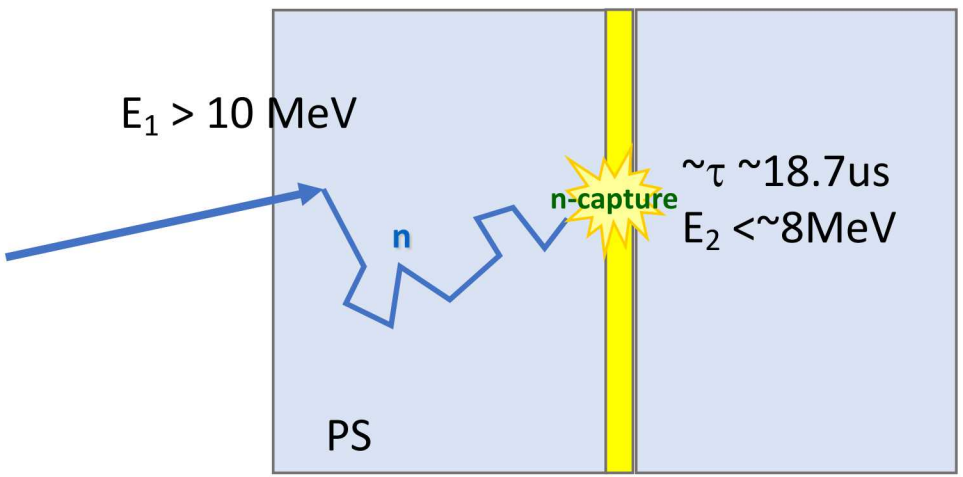




From Roecker et al. NIM A 826 (2016) 21-30

- **M**ultiplicity **A**nd **R**ecoil **S**pectrometer
  - Sandwiched plastic scintillator and Gd sheets
  - Originally created for measuring neutron multiplicity from high-energy neutron interactions on lead

- A single module (without the lead) can provide uniform response to intermediate to high energy neutrons through capture-gating techniques:
  - rate estimate: 1 event/day @ 10^{-6} n/m^2/spill

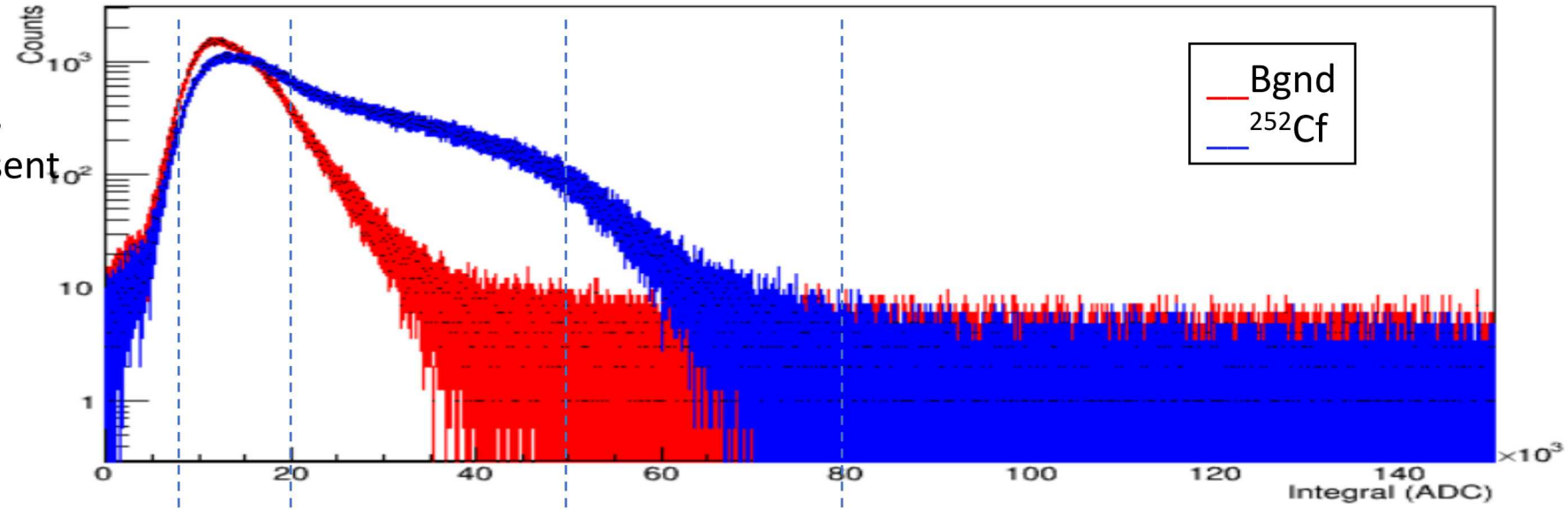


The problem

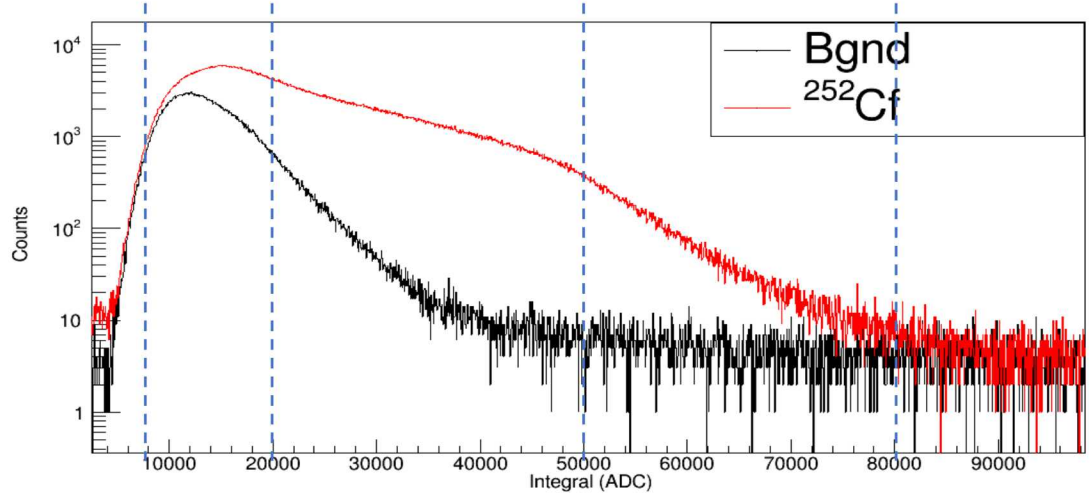
- Arrived to ORNL in June, 2017. Placed in neutrino alley next to CsI. Without shielding.
- MARS data analysis so far has not identified beam-related neutrons: **no capture signal from beam neutrons**.
- Concerns with HOG background being too high.
- Any other MARS n capture signal?

^{252}Cf calibrations show n capture signal

Beam-ON September 2018,
With HOG background present

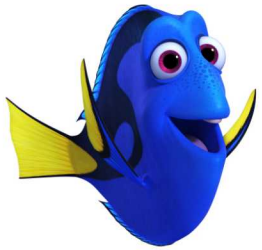


Beam-OFF February 2018

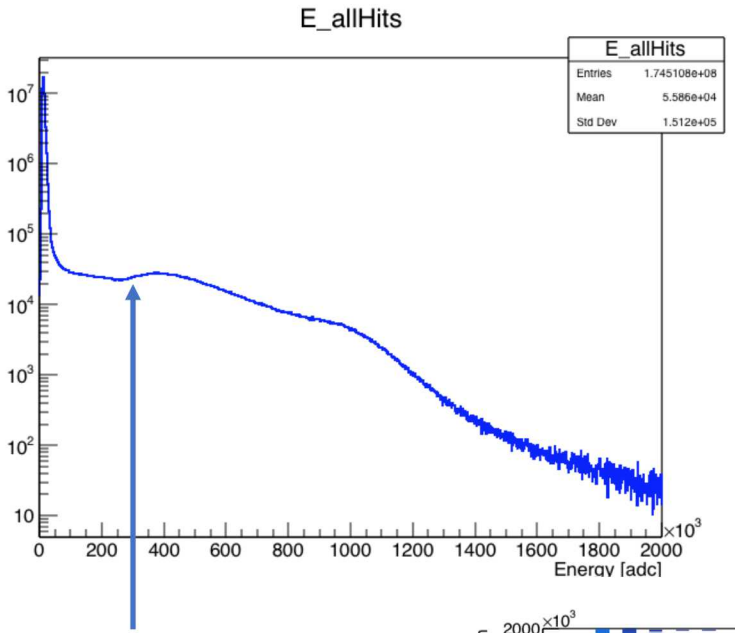


The HOF background apparently not having a significant effect on the energy range for the Gd gamma shower signal from n capture.

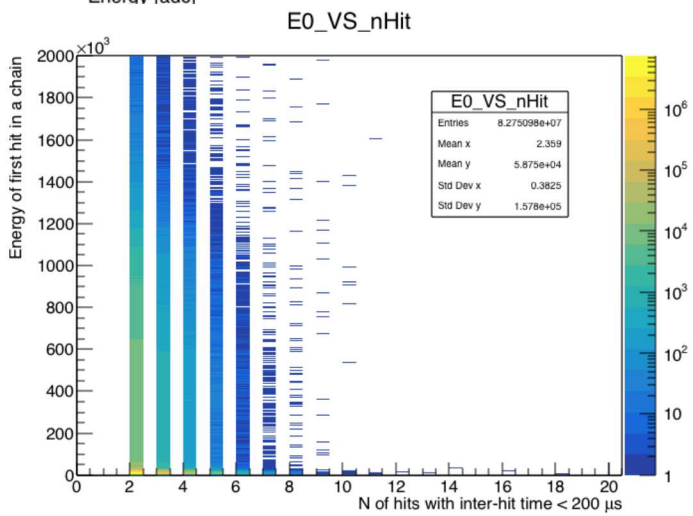
FINDING muon-induced neutrons



- Muons will spallate neutrons in MARS surrounding materials.
- **Strategy:**
  - In Beam-off data, look for “neutron cascade” accompanying MARS muon events (E_μ ~>300 K adc),
  - Use bean-off data to set neutron-selection cuts,
  - Repeat analysis with Beam-on data to verify how HOG background affect the neutron cuts.
  - Look for beam-related neutrons! (though maybe not so simple)
- **Look for pairs (E_1,E_2) = (E_μ, E_{Gd})** where
  - E_μ ~>300 K adc is a muon followed by
  - E_{Gd}, the neutron-capture Gd gamma shower.



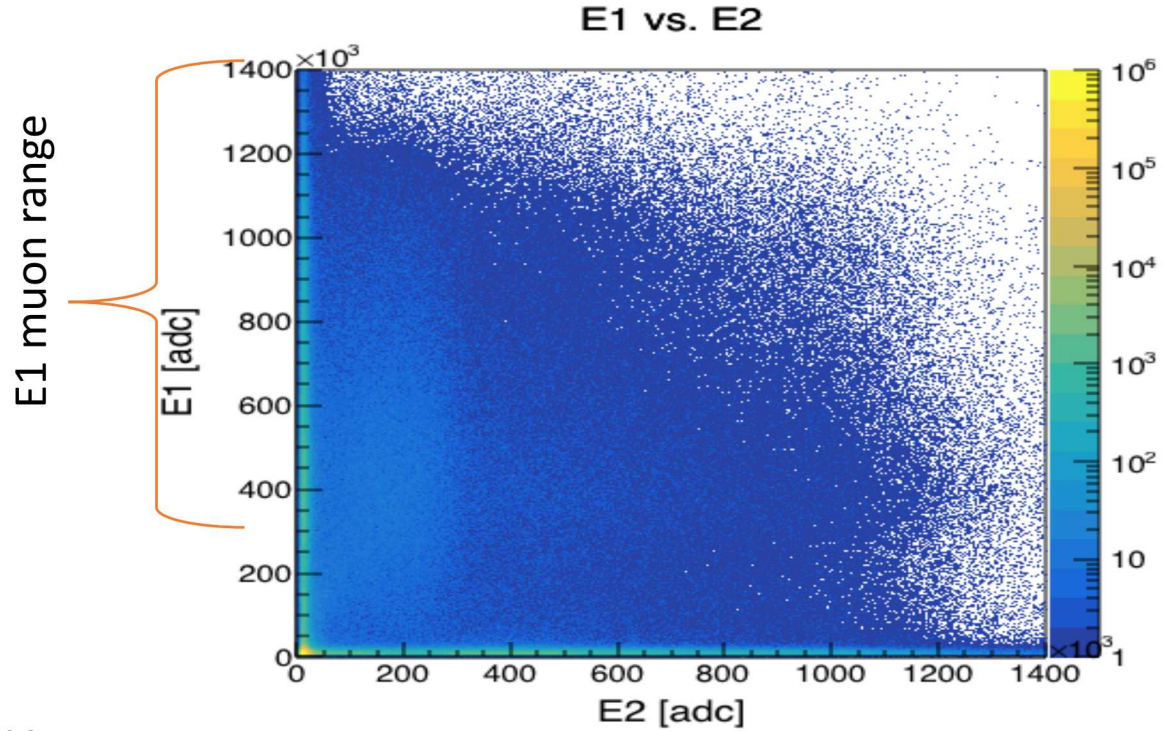
Muons of about 30 MeV



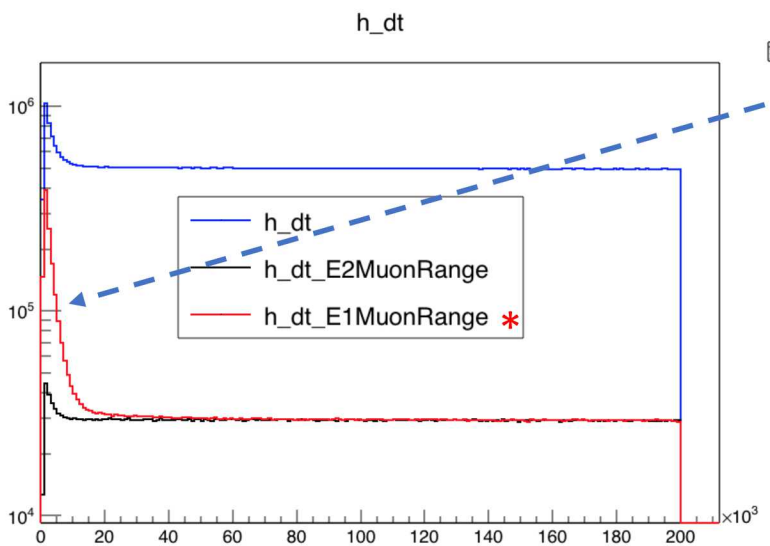
Using data organized in hit pairs with < 200 μs time separation.

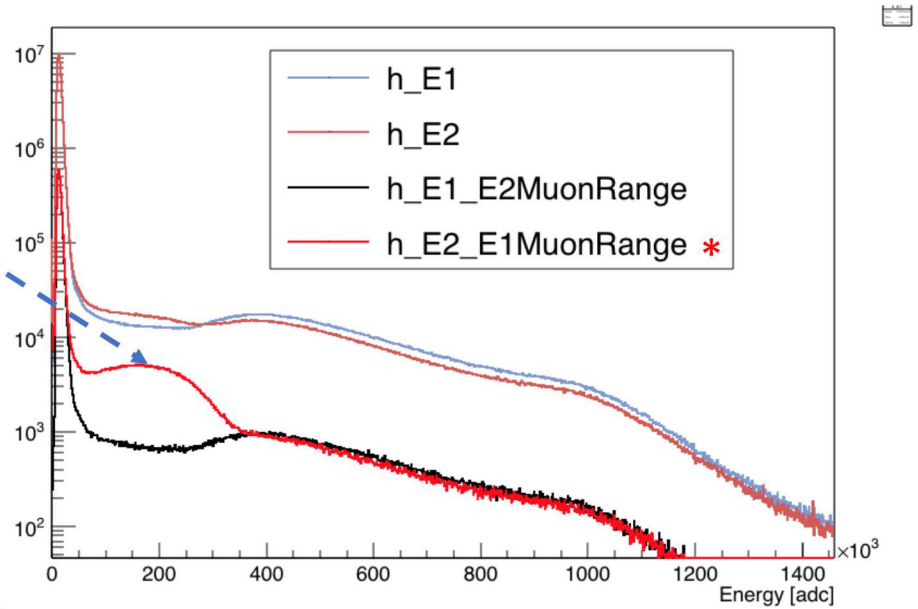
Beam-off April 2018: Restrict E_1 to be "muon"

- When restricting E1 to be in the selected Muon Range > 3E5 adc:
- E2 reveals the Michel electron spectrum (broad peak around 20 MeV) and timing structure (τ ~ 2.2 μs).



Michel electrons

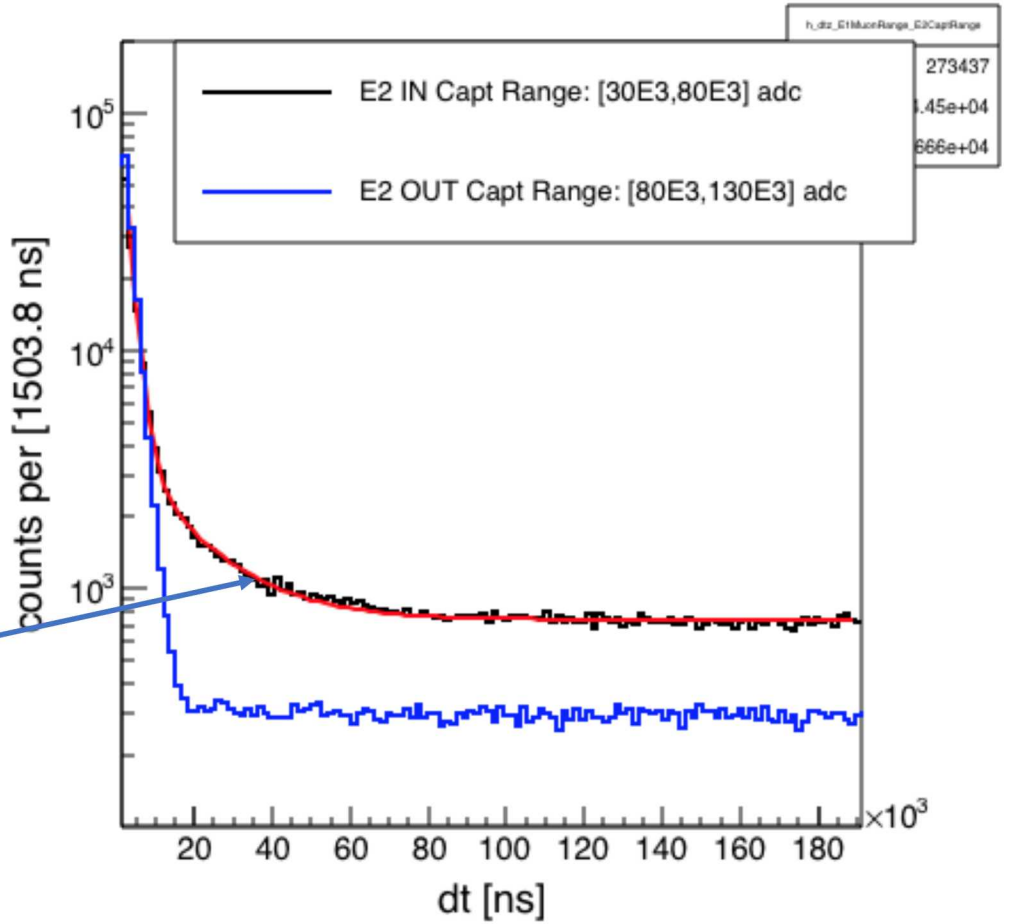




* These are the histograms that contain the signal **(E_μ, E_{Gd})** we care about.

Beam-off, April 2018: Restrict E_2 to be a "Gd nCapture"

- Using the Cf252 calibration, we restrict E_2 to be in the the neutron-capture Gd gamma shower range [30,80] x10^3 adc
- The "dt = t_2-t_1" histogram shows longer time decay when E_2 is in an energy window coincident wit the "Capture Range", compared to when E_2 is another equal window [80,130] x10^3 adc outside the "Capture Range".

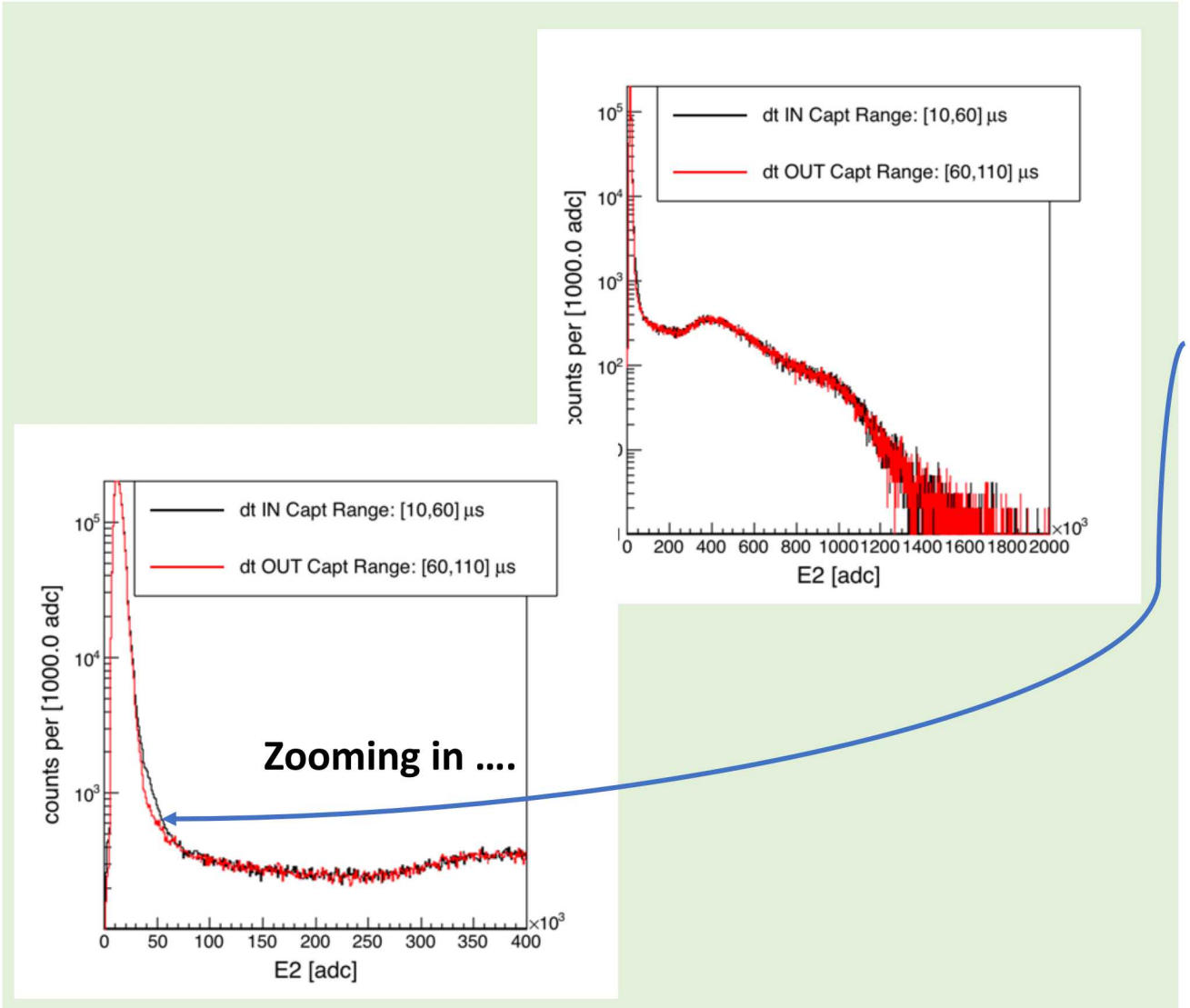


Double exponential fit with

τ_1 = 2.0902 us : ~ muon capture

τ_2 = 16.2574 us: Gd n-capture

Beam-off April 2018: Restrict dt to be a “Capture”



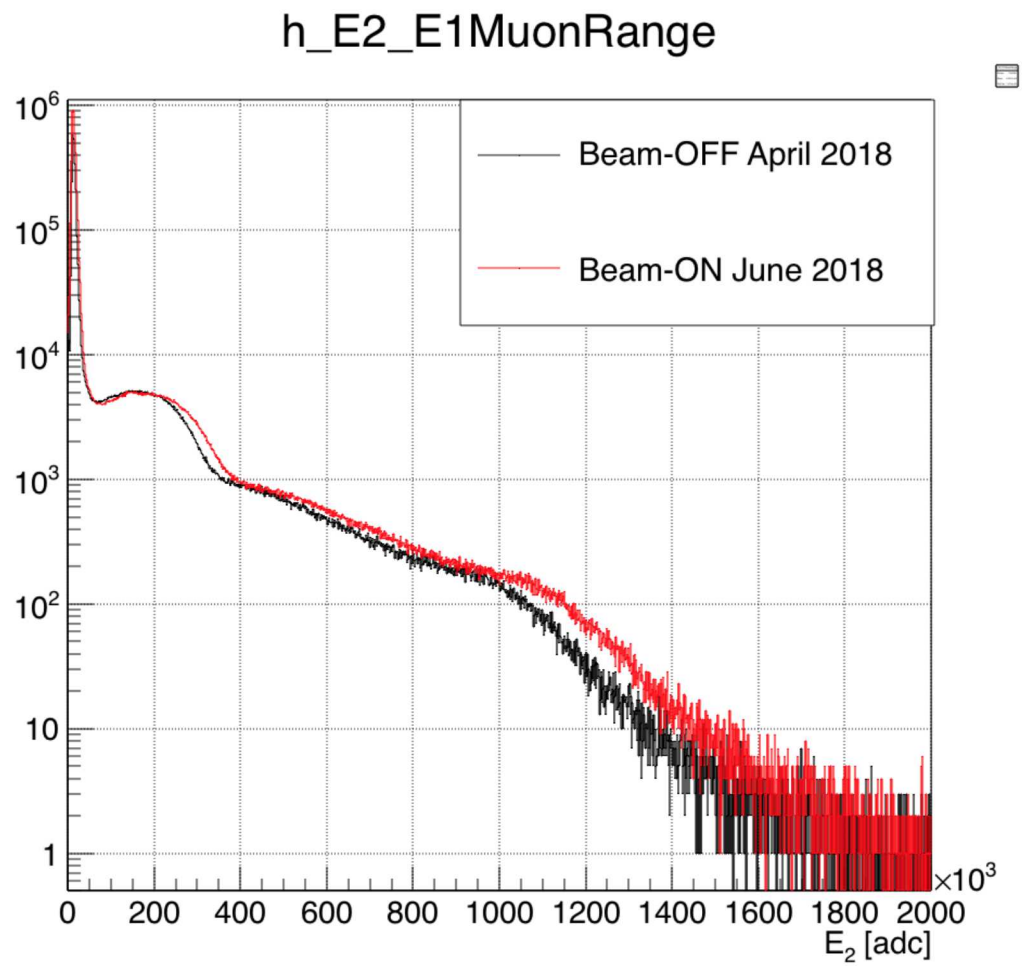
- Restrict dt to [20,100] μs:

  (from ~10x τ_1 to ~5x τ_2)
- An excess of events in the Gd gamma shower range [30,80] x10^3 adc is observed.

Compare Beam-Off and Beam-On

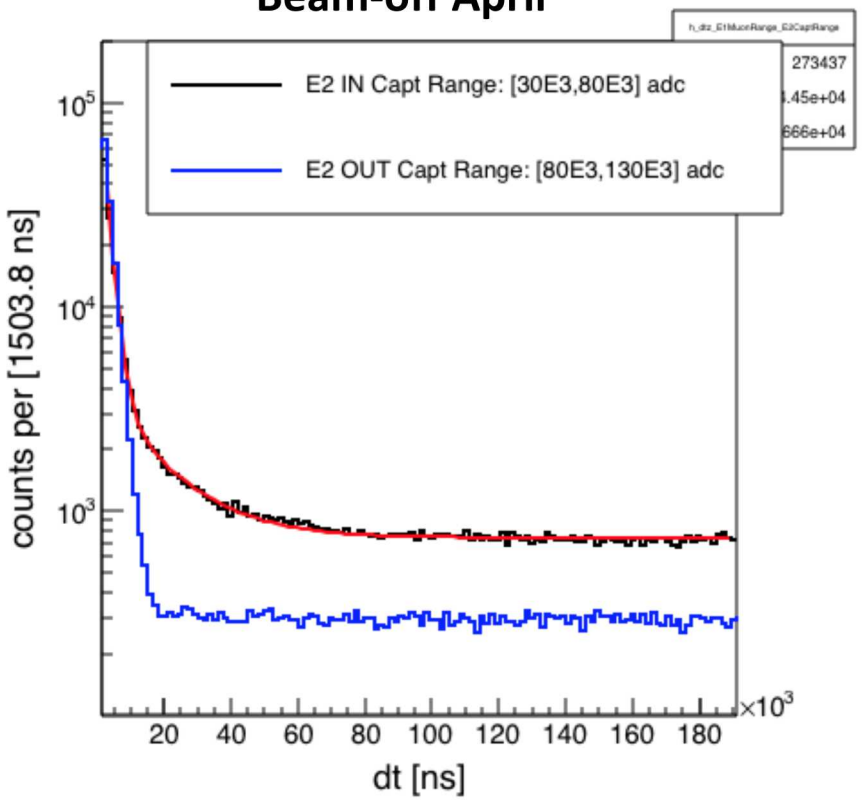
Beam-ON energy shift

- These are the same previous histograms of E_2 with E_1 in the "muon range".
- Beam-ON spectra shifted by ~ 2-3 MeV
- Likely due to high HOG background not present during Beam-OFF



Compare Beam-Off and Beam-On: dt histograms constraining E_2

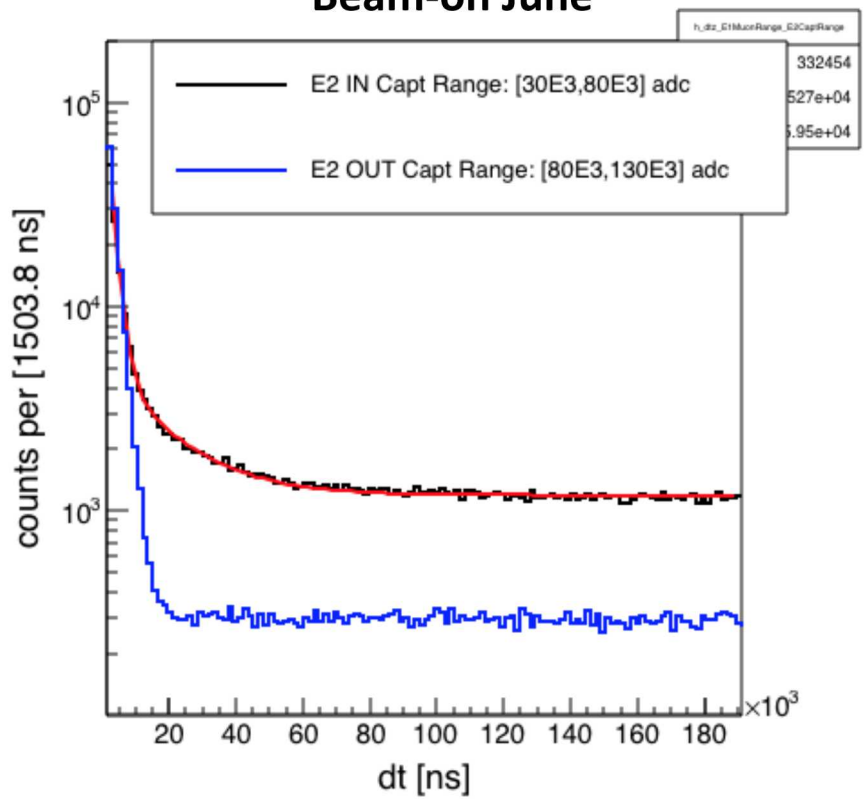
Beam-off April



τ_1 = 2.0902 us

τ_2 = 16.2574 us

Beam-on June

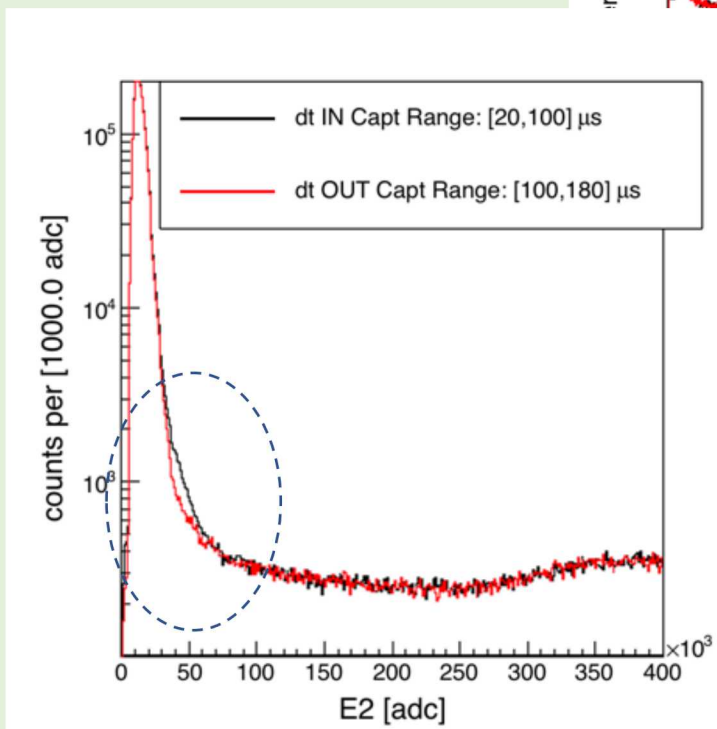


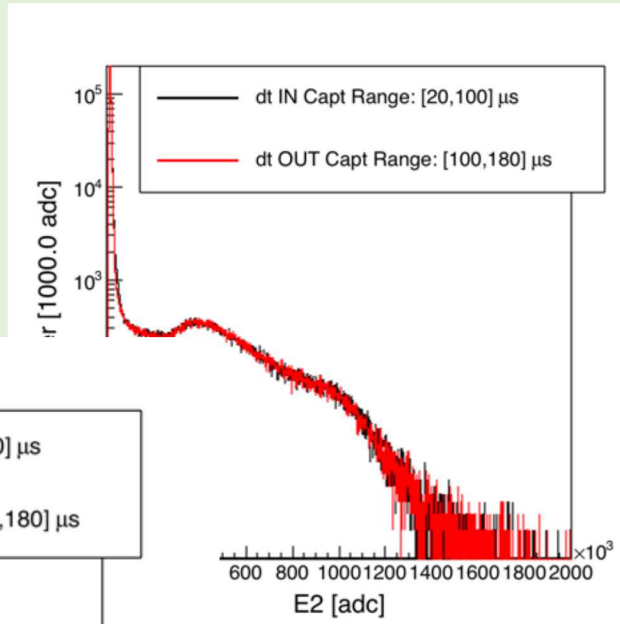
τ_1 = 2.08262 us

τ_2 = 17.0747 us

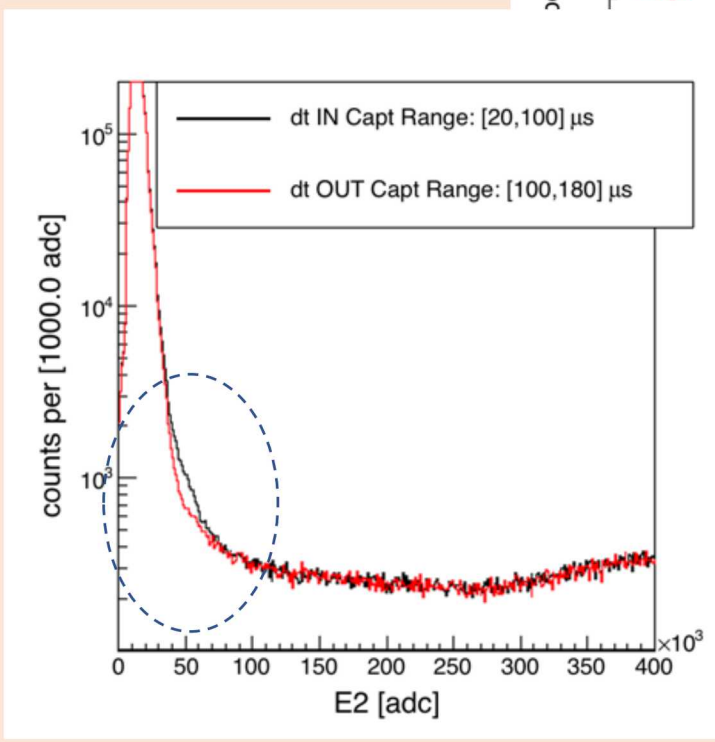
Compare Beam-Off and Beam-On: E_2 histos constraining dt

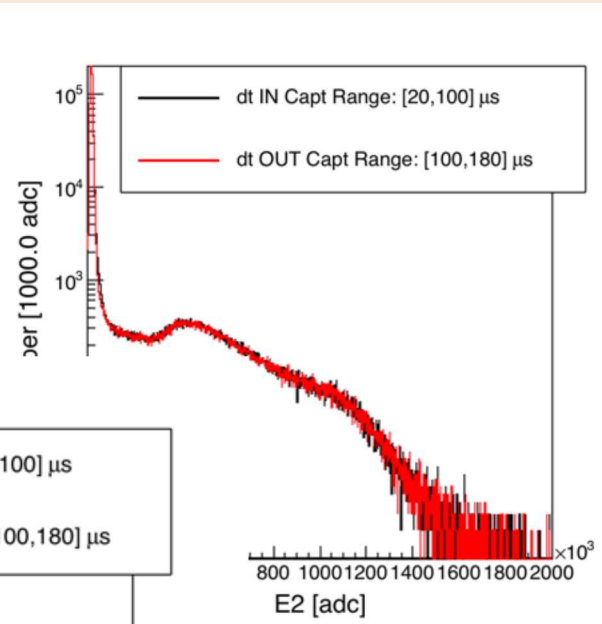
Beam-off April



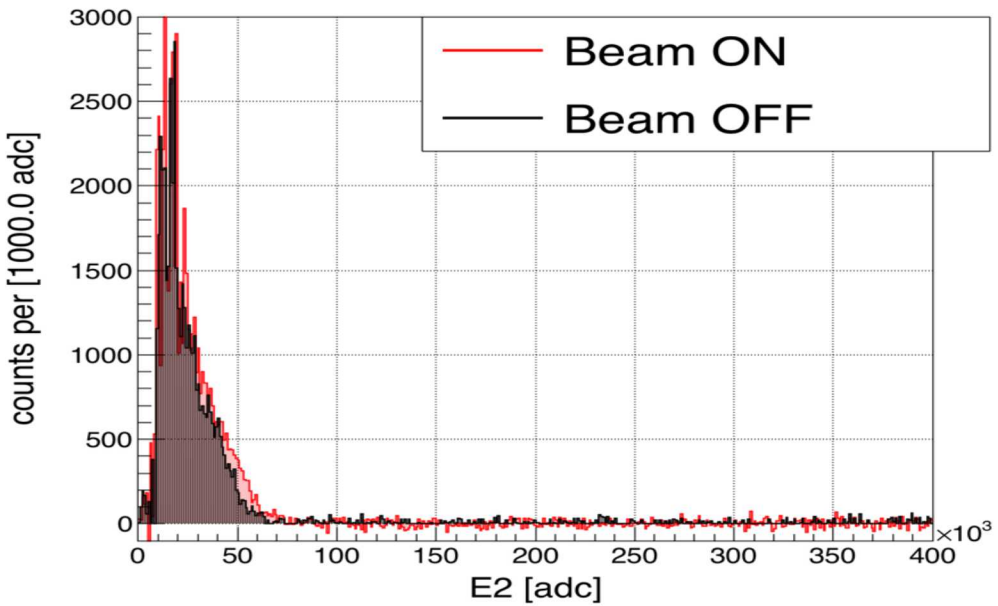


Beam-on June

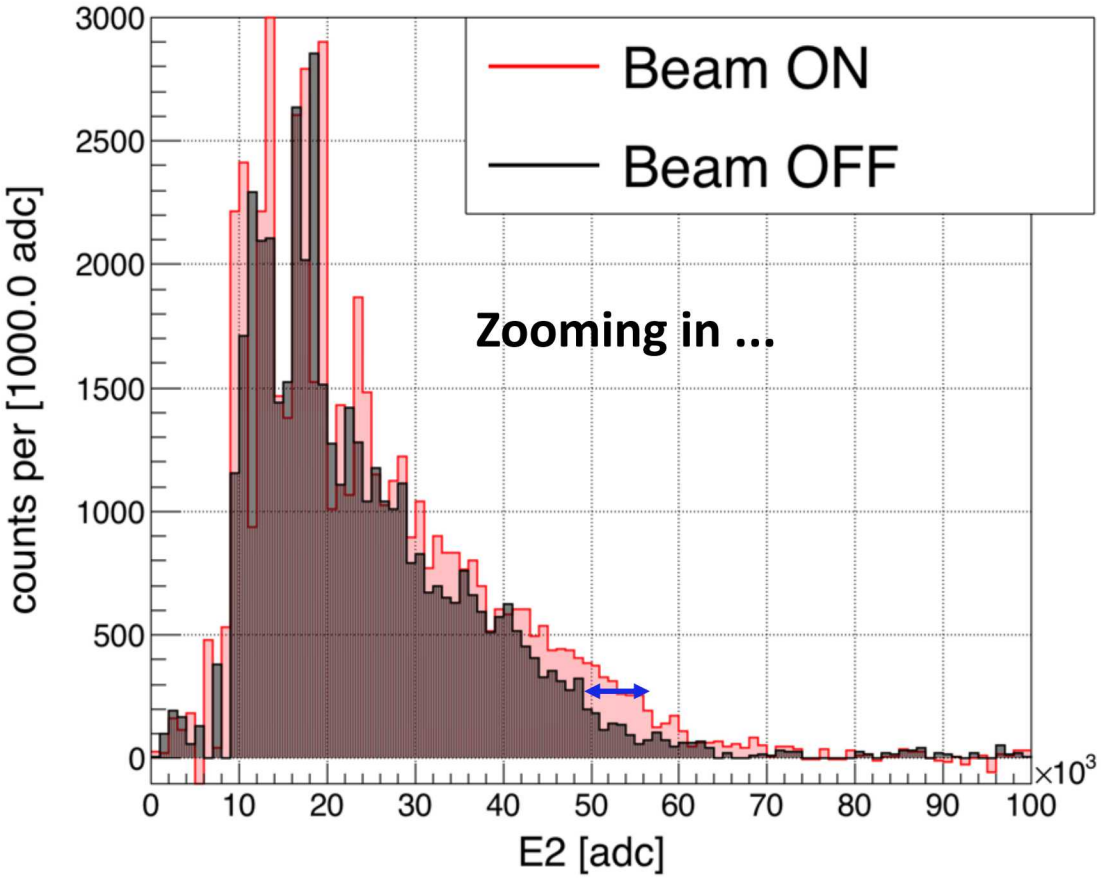




E_2 excess in the capture-COINCIDENT time window over the capture-ANTICOINCIDENT time window:

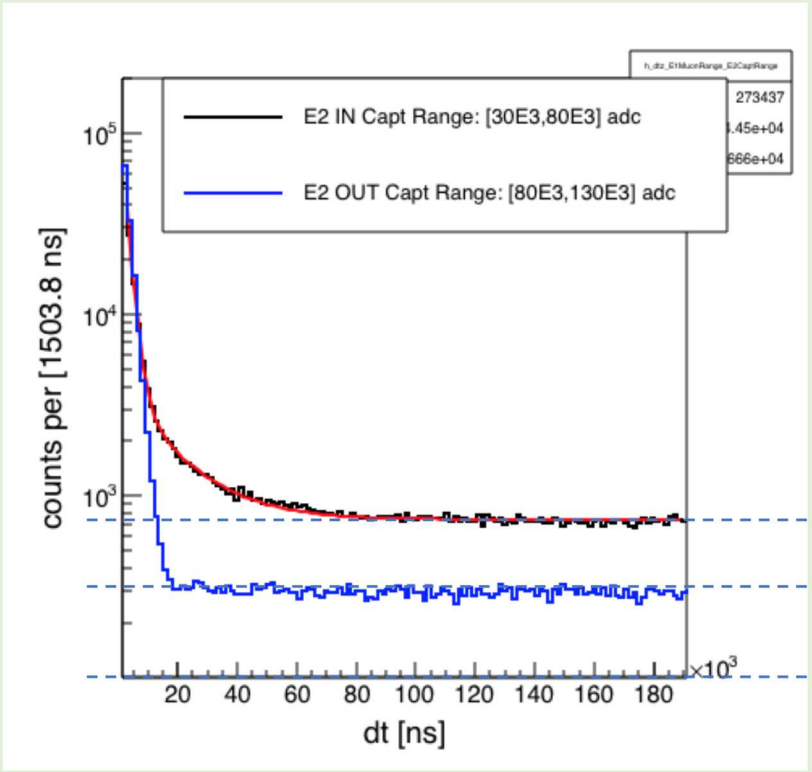


- Suggest a shift in the Beam-On nCapture spectrum of ~5x10^3 adc ~0.5 MeV
- Plots not normalized by runtime: 29 days of Beam-on data and 30 days of Beam-off data



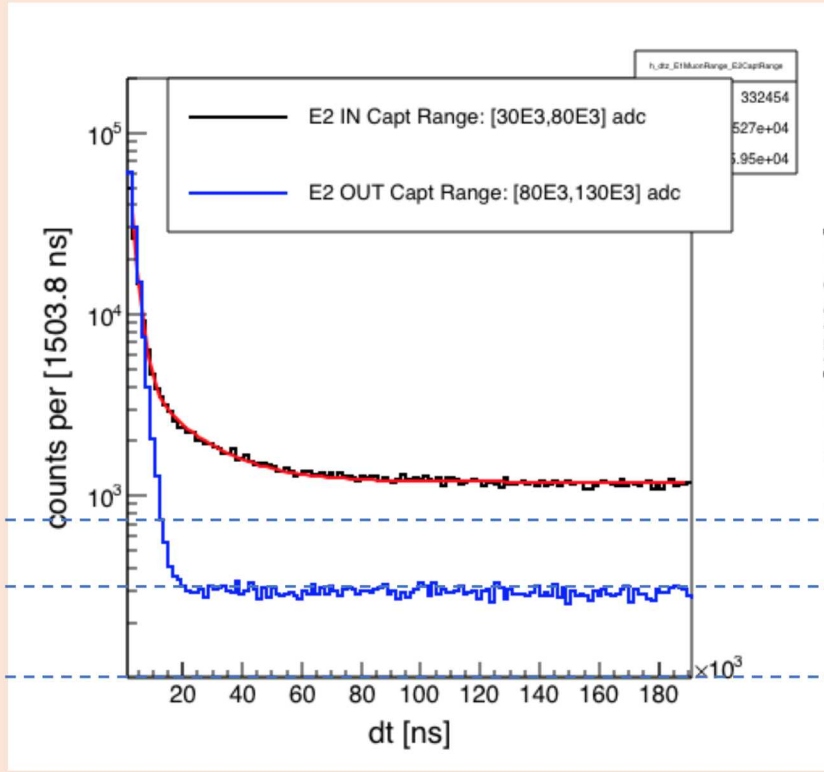
Shifting nCapture range for Beam-On data by “5E3 adc”

Beam-off April

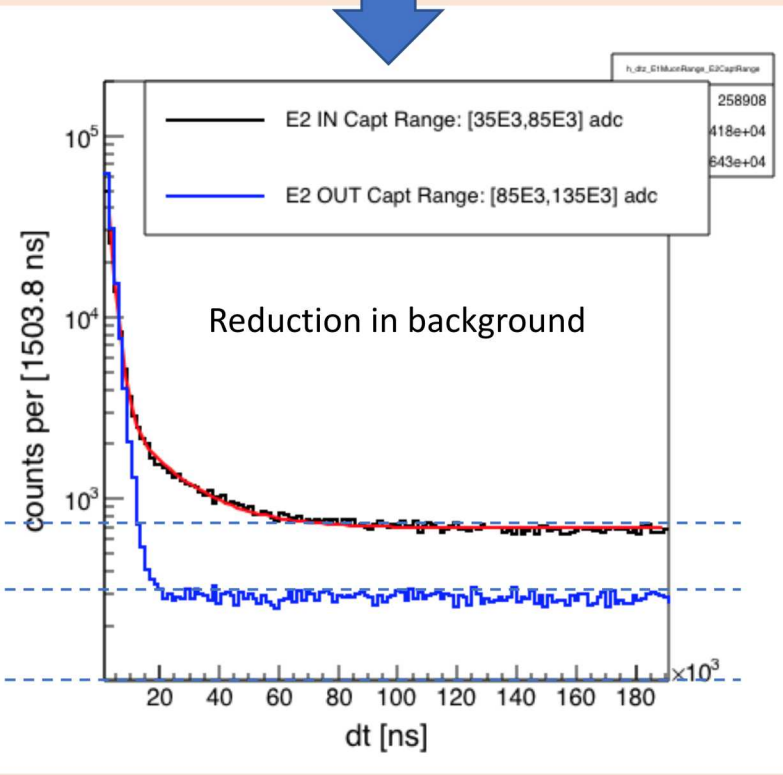


τ_1 = 2.0902 us
τ_2 = 16.2574 us

Beam-on June



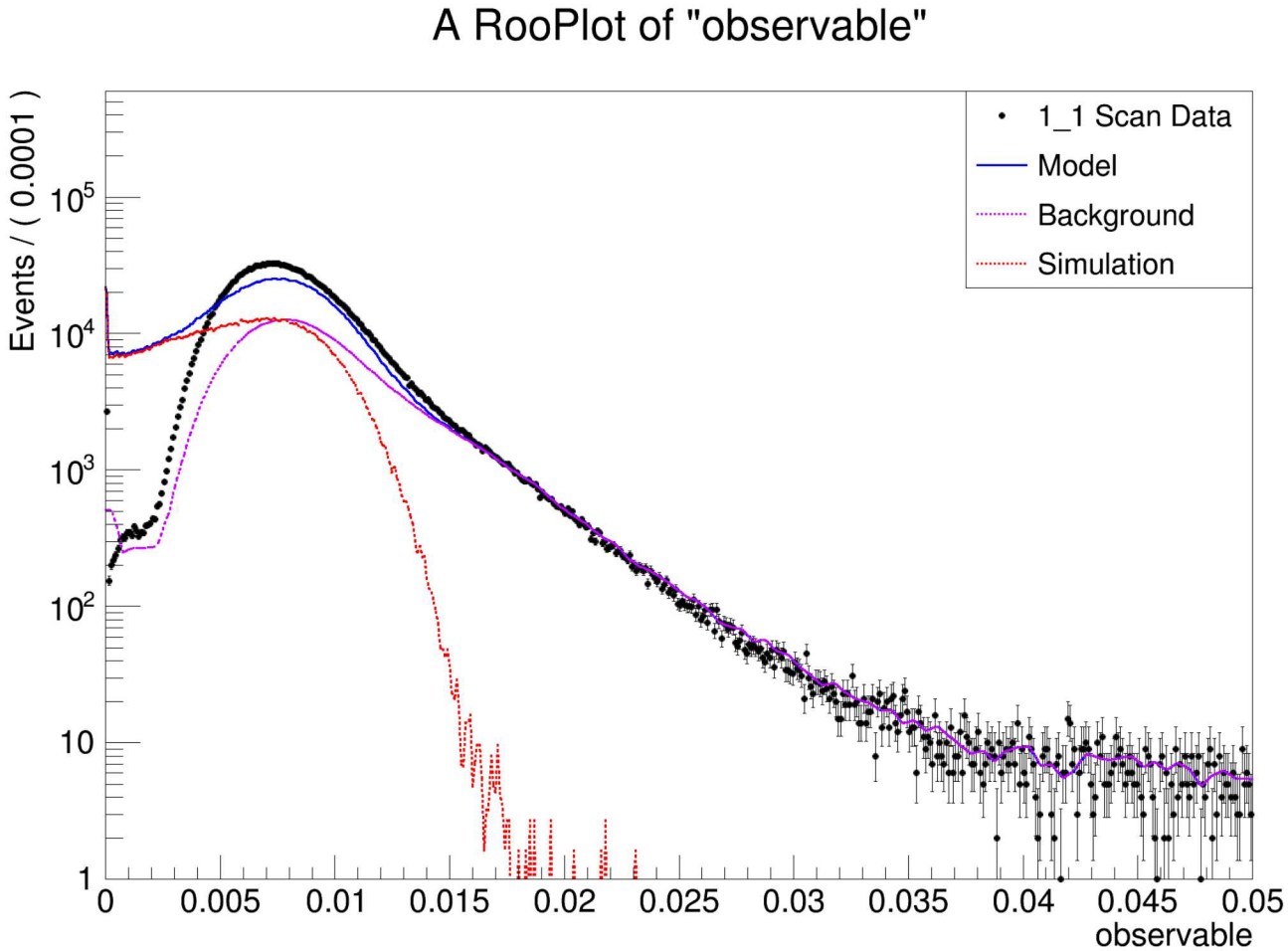
τ_1 = 2.08262 us
τ_2 = 17.0747 us



τ_1= 2.09604 us
τ_2= 17.3504 us

Simulation work update

- Rebecca Rapp spent summer at SNL building the MARS G4 model and ran a ^{60}Co simulation.
- Built RooFit code to calibrate MARS using the Feb 2018 ^{60}Co data. Goal: get energy scale and resolution for each scan position across MARS.
- More work needed: complete ^{60}Co and ^{252}Cf sim. and analysis.

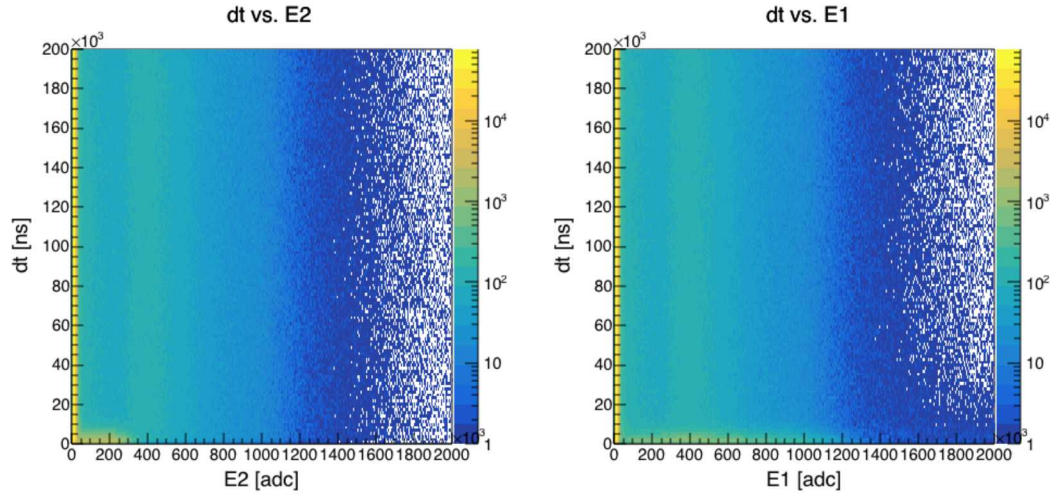


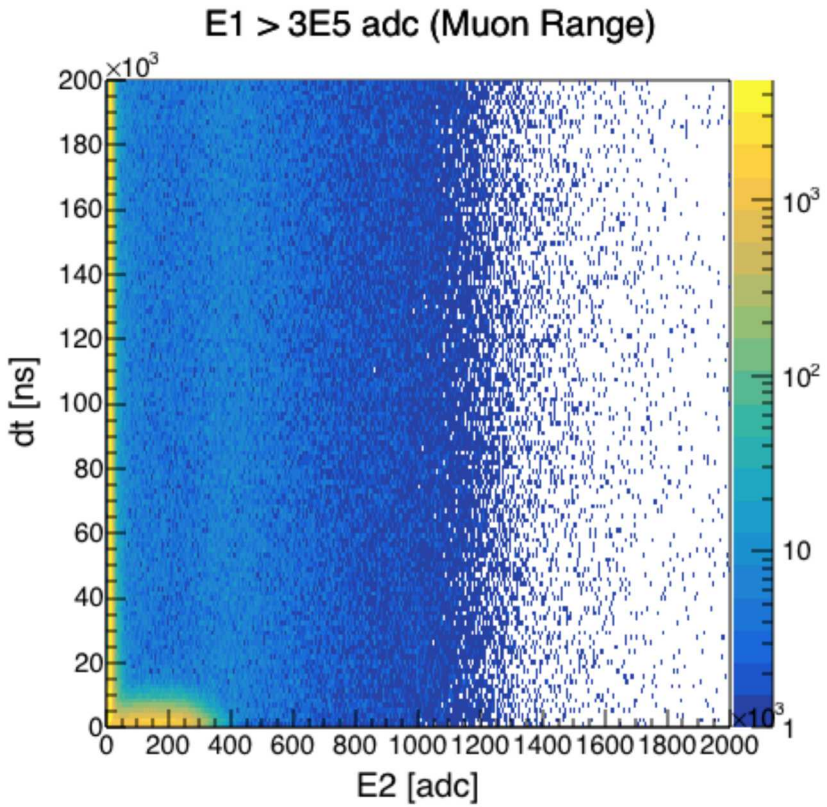
Conclusions

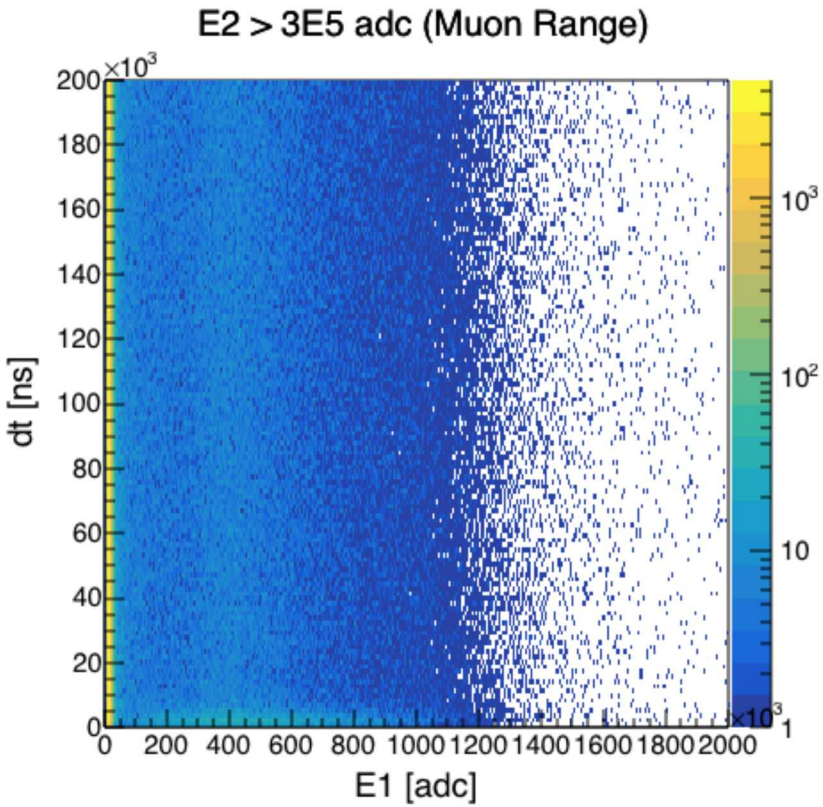
- We identified muon-induced background neutrons by their n capture signal: time and energy cuts are approx. consistent with Cf252 calibration
- HOF background is shifting MARS spectrum.
- n capture signal range seems to be shifted only by ~ 0.5 MeV. While not much compared to MARS poor energy resolution, it could have large S/N effect since the n Capture signal is close to the background low-energy rise.
- Priority: repeat analysis on collected beam-on data.
- If successful, then continue with plan: n rate monitoring analysis, complete simulations for energy calibration, detector status in Grafana, periodic gain calibrations, n-flux unfolding analysis.

Extra Slides

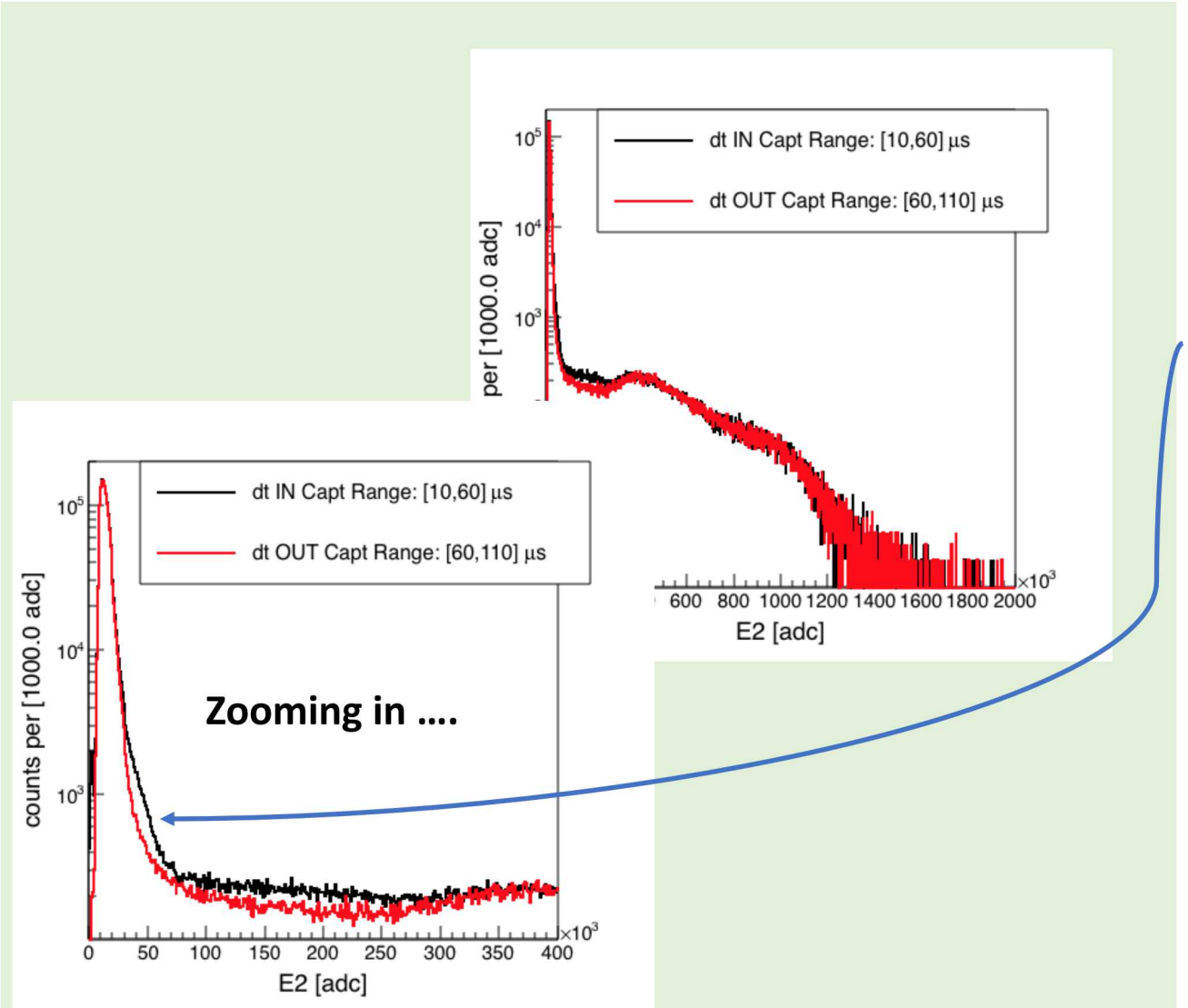
Beam-Off April 2018 dt vs. E_2 and dt vs. E_1







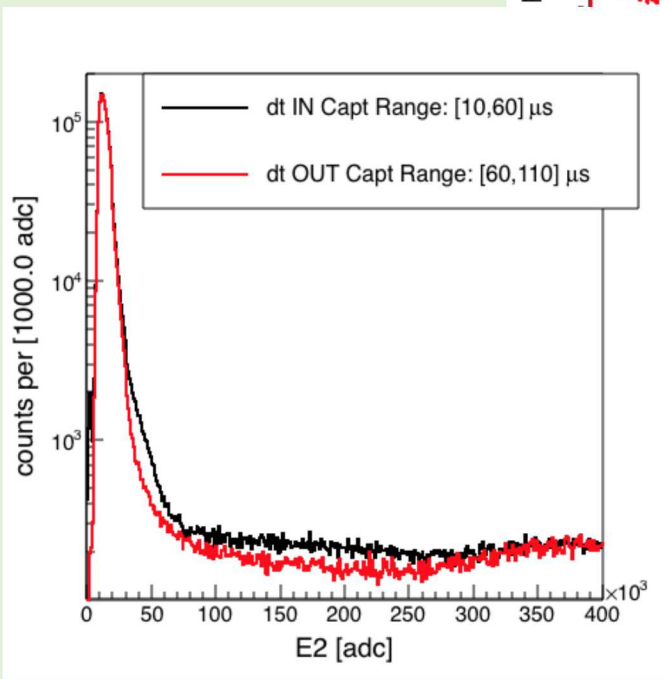
Beam-off April 2018: Restrict dt to be a “Capture”

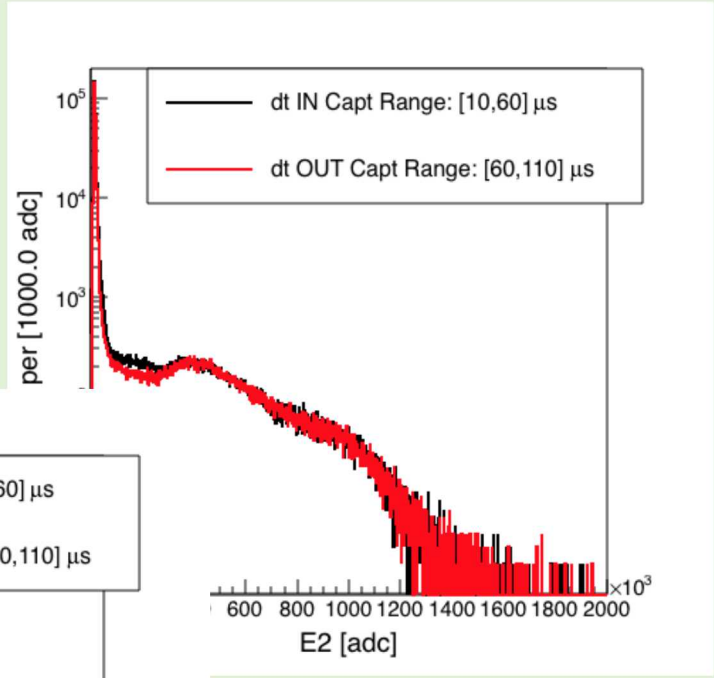


- Restrict dt to [10,60] μs: > ~5x τ_1 and < ~3xτ_2 (this can be improved)
- An excess of events in the Gd gamma shower range [30,80] x10^3 adc is observed.
- We still have some Michel electron contamination in the [10,60] μs window

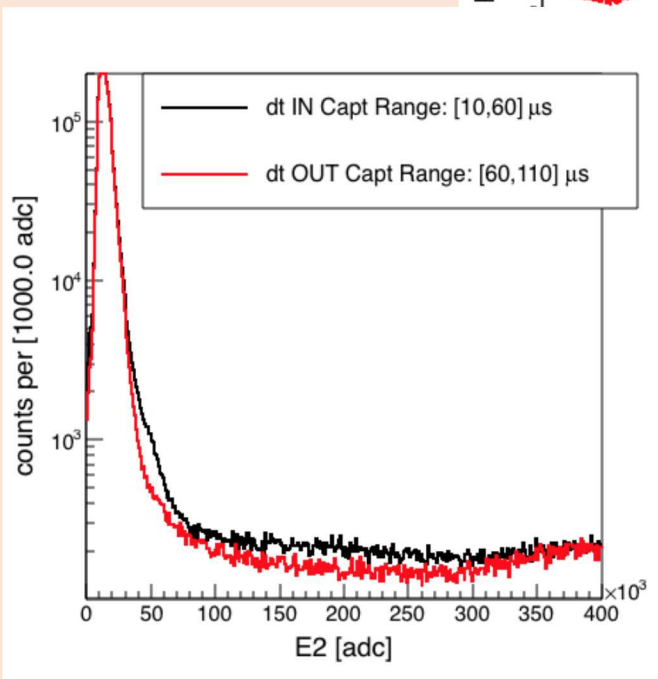
Compare Beam-Off and Beam-On: E_2 histos constraining dt

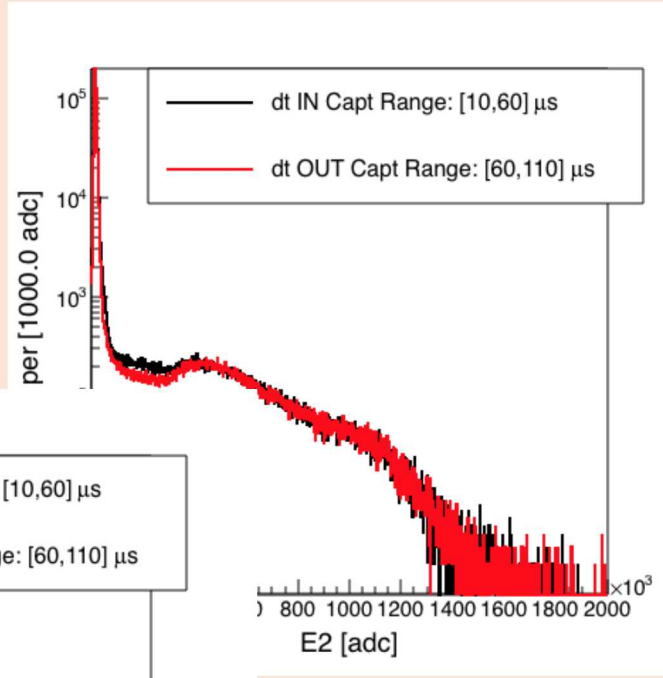
Beam-off April





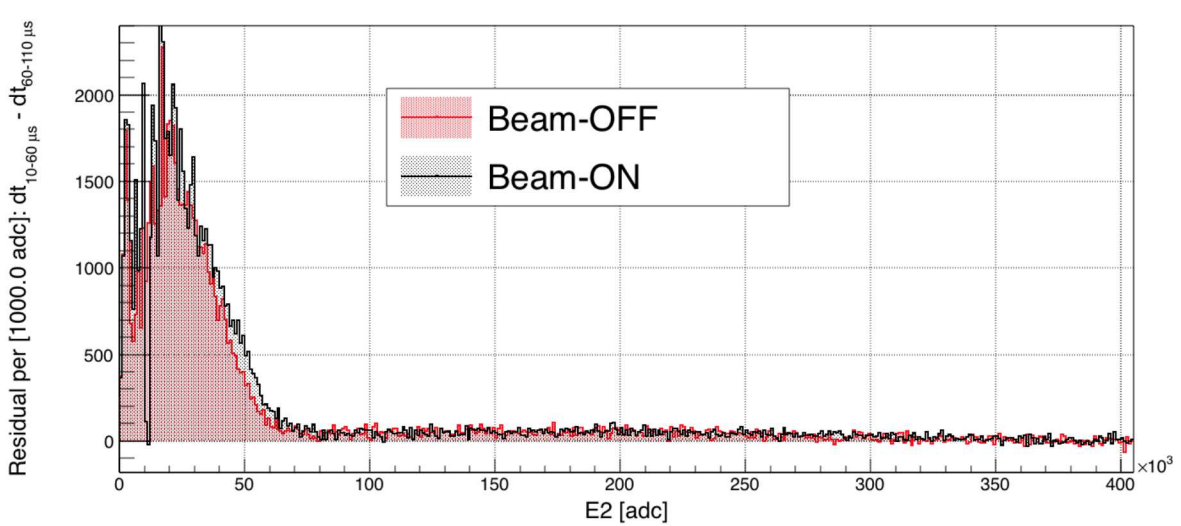
Beam-on June



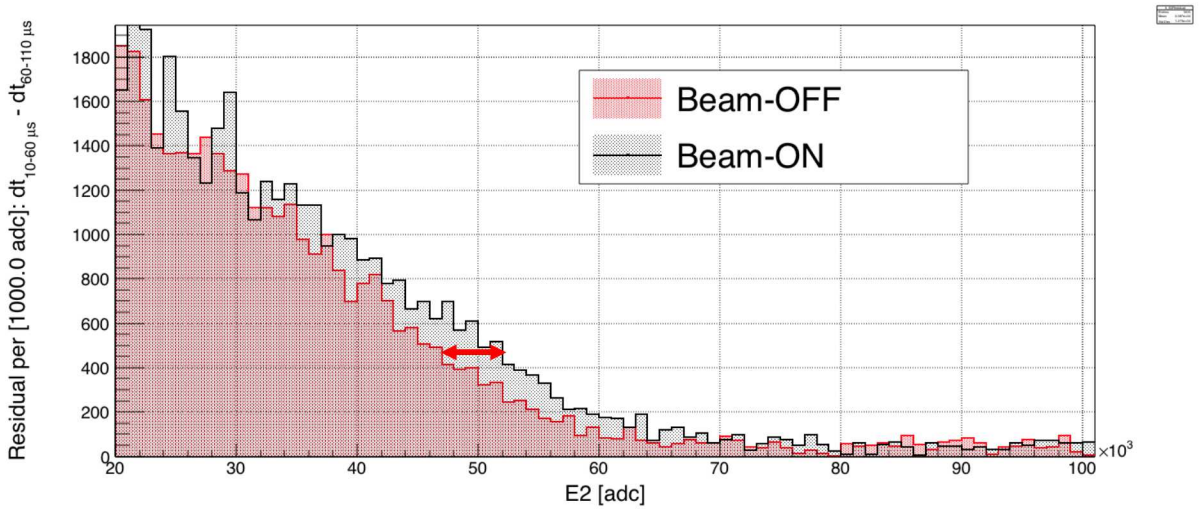


Compare Beam-Off and Beam-On

E_2 residuals between the capture-COINCIDENT time window and the capture-ANTICOINCIDENT time window:

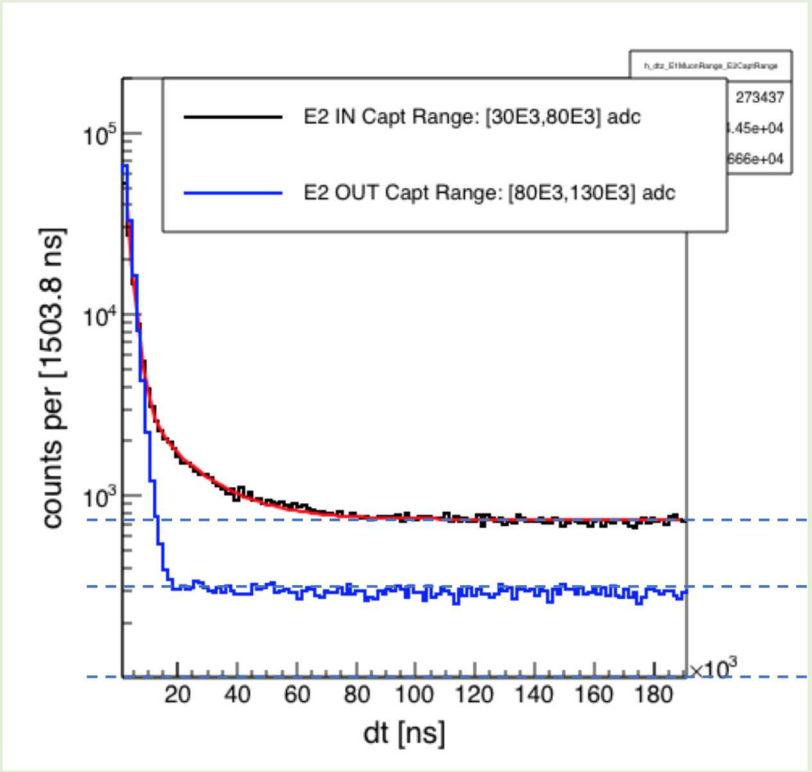


Zooming in….



Suggest a shift of at least 5×10^3 adc ~0.5 MeV

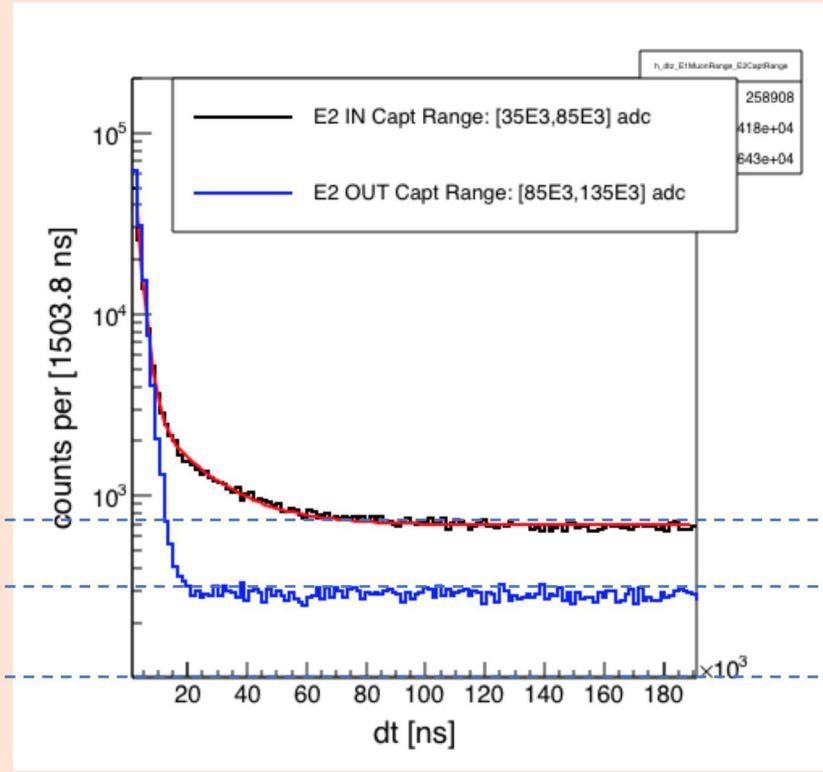
Beam-off April



τ_1 = 2.0902 us

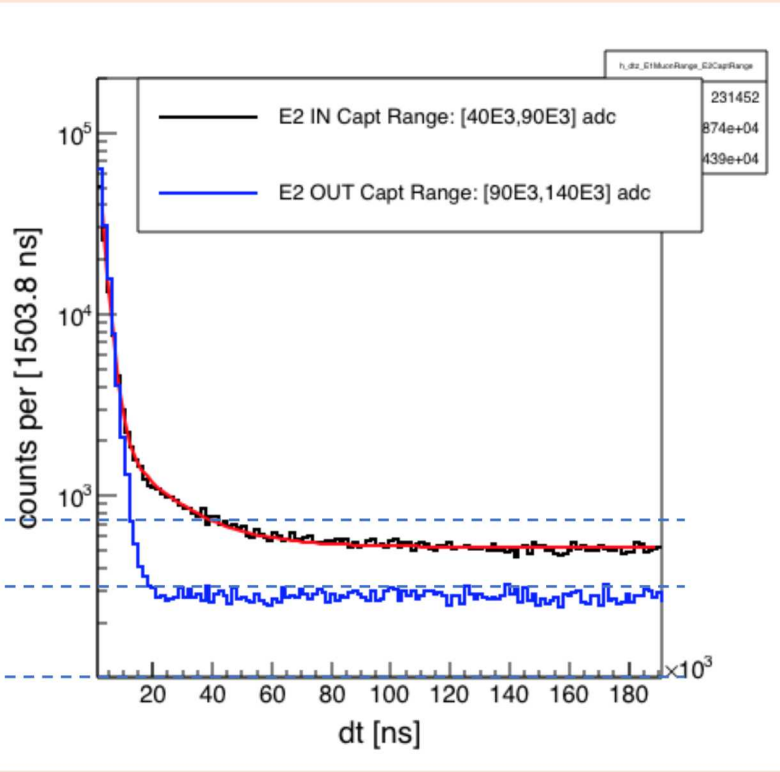
τ_2 = 16.2574 us

Beam-on June



τ_1= 2.09604 us

τ_2= 17.3504 us



τ_1 = 2.09306 us

τ_2 = 17.5183 us