

# Update on FOOT neutron detector characterization at n\_TOF

C. D'Orazio, A. Manna, C. Massimi, R. Zarrella

# Neutron detectors



Phoswich: BGO crystals + EJ232

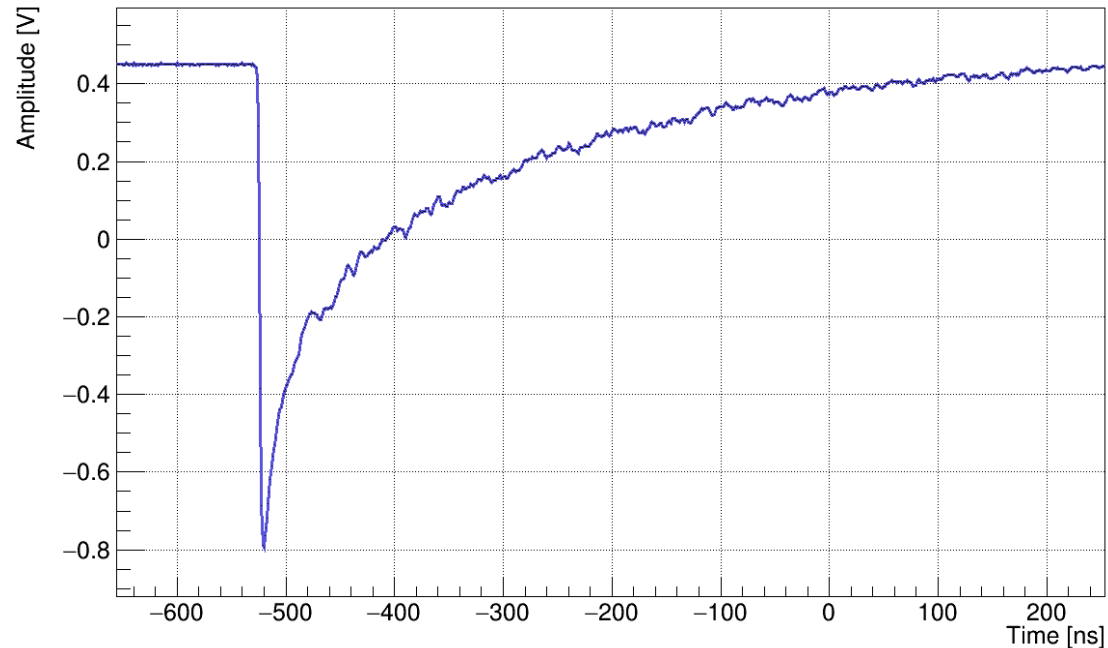
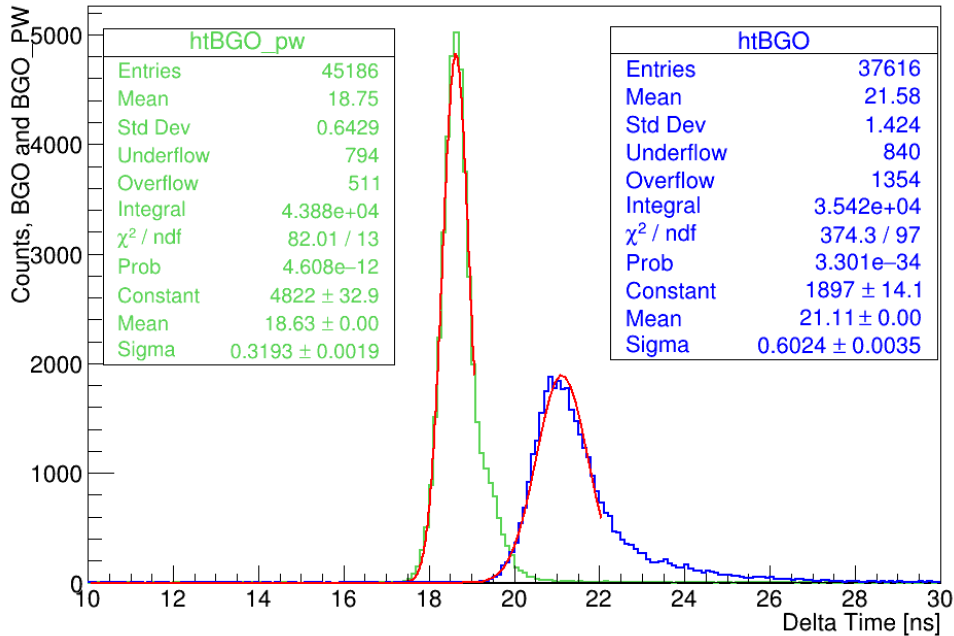
A1: 2.4x2.4 cm<sup>2</sup>

- Particle identification

A2: 3.3 x 3.3 cm<sup>2</sup>

- Possible Calorimeter upgrade

h: 24 cm



# Neutron detectors



Phoswich: BGO crystals + EJ232

A1: 2.4x2.4 cm<sup>2</sup>

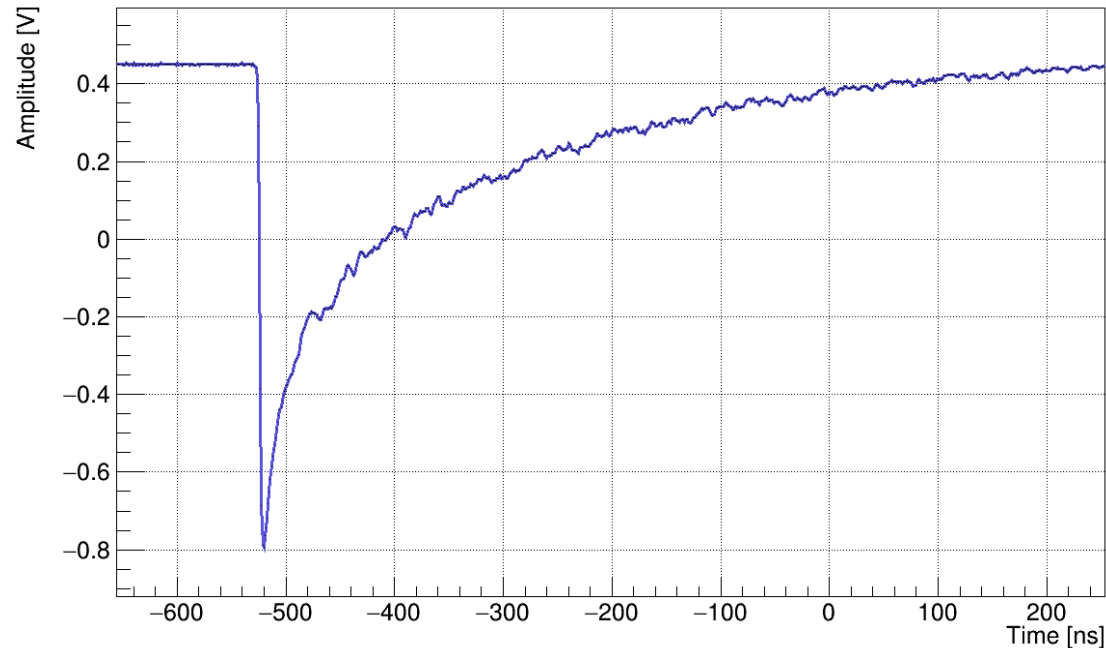
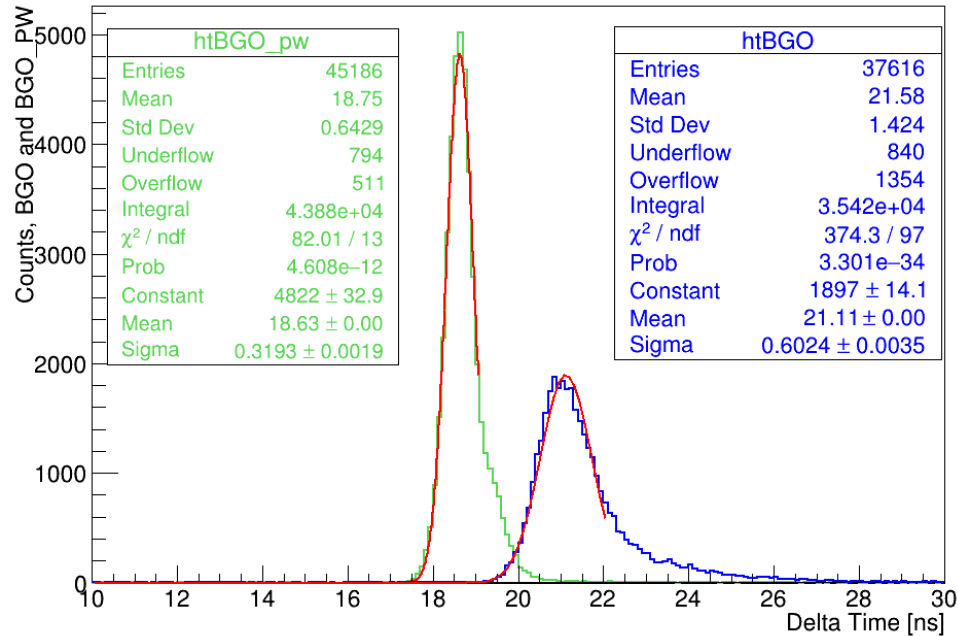
A2: 3.3 x 3.3 cm<sup>2</sup>

h: 24 cm

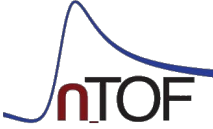
- Particle identification

- Possible Calorimeter upgrade

+ VETO (EJ-204) readout w/ PMT



# Neutron detectors



Nike - NE213/BC-501A → liquid scintillator:

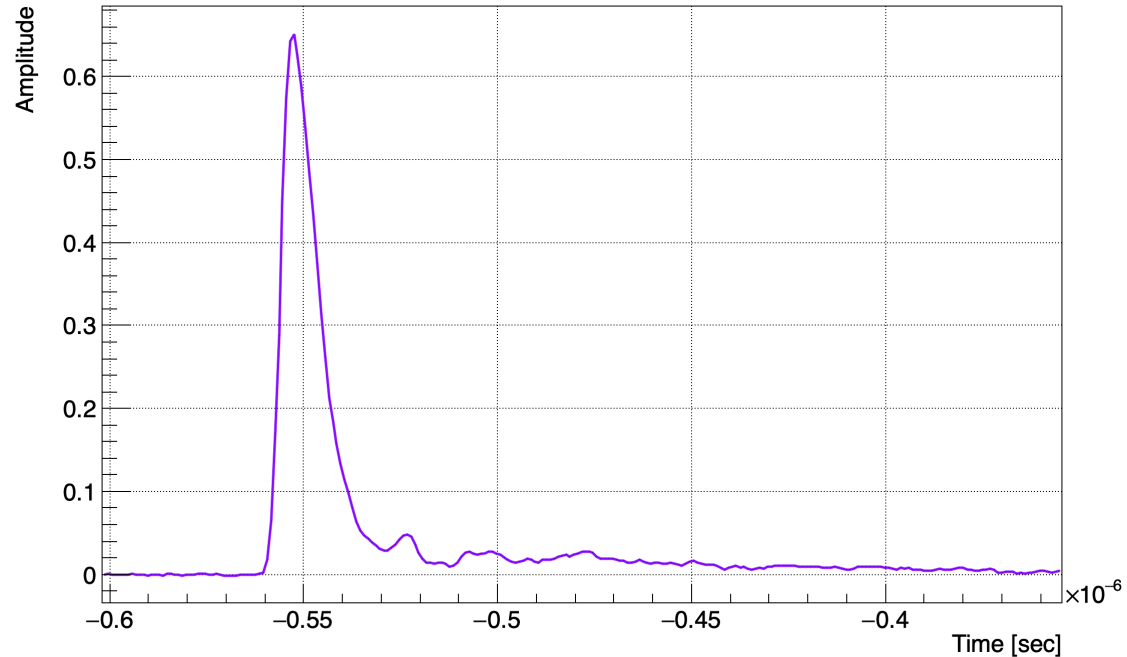
- Good time resolution ( $\sim 3$  ns RT)
- n/ $\gamma$  discrimination
- Decay Time components 3.16, 32.3 & 270 ns



h = 3"  
7.62 cm



diametro=3"  
7.62 cm

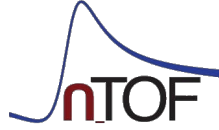


# Neutron detectors



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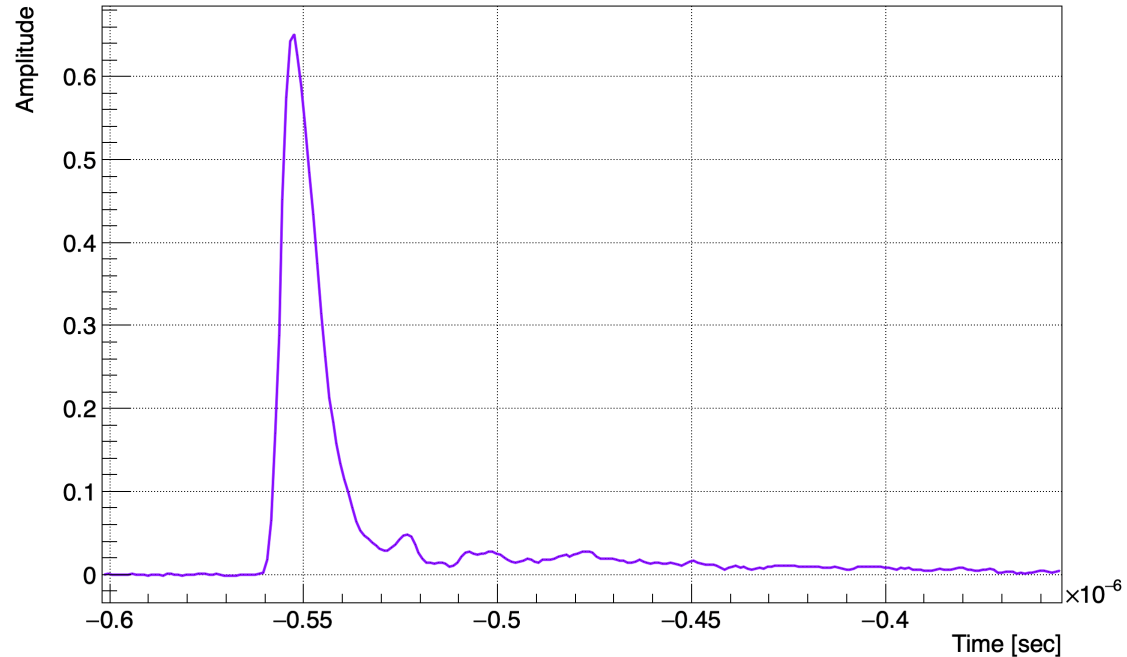


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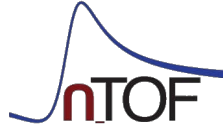


diametro=3"  
7.62 cm

+ VETO (EJ-200)  
readout by SiPMs



# n\_TOF @ CERN

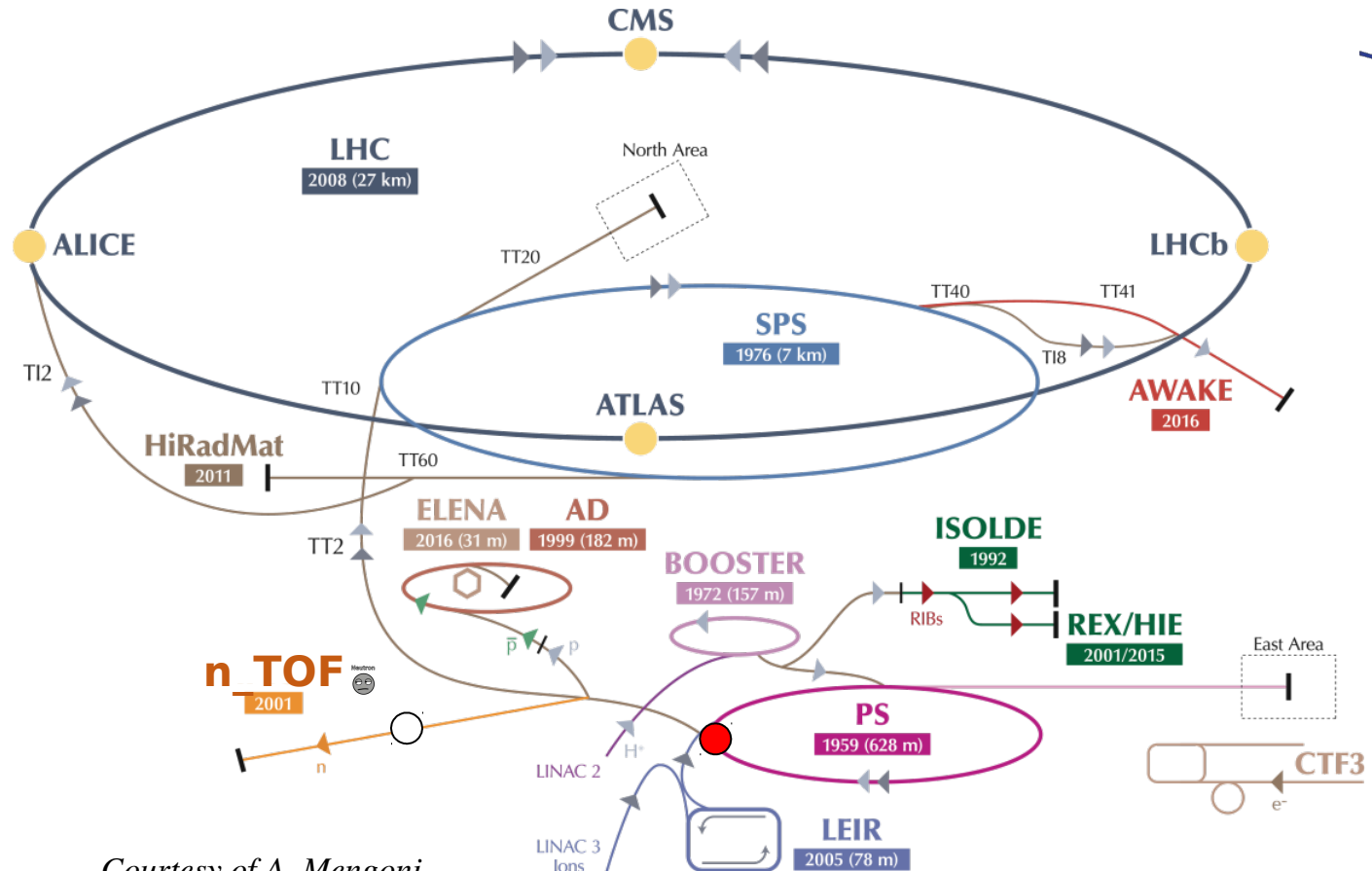


## Proton beam

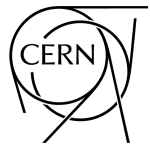
20 GeV/c p from PS

7 ns bunch length

Min. 1.2s btw bunches



Courtesy of A. Mengoni



# Neutron flux @ n\_TOF



## High neutron flux

$7 \times 10^{12} \text{ p} \rightarrow 10^{15} \text{ n}$

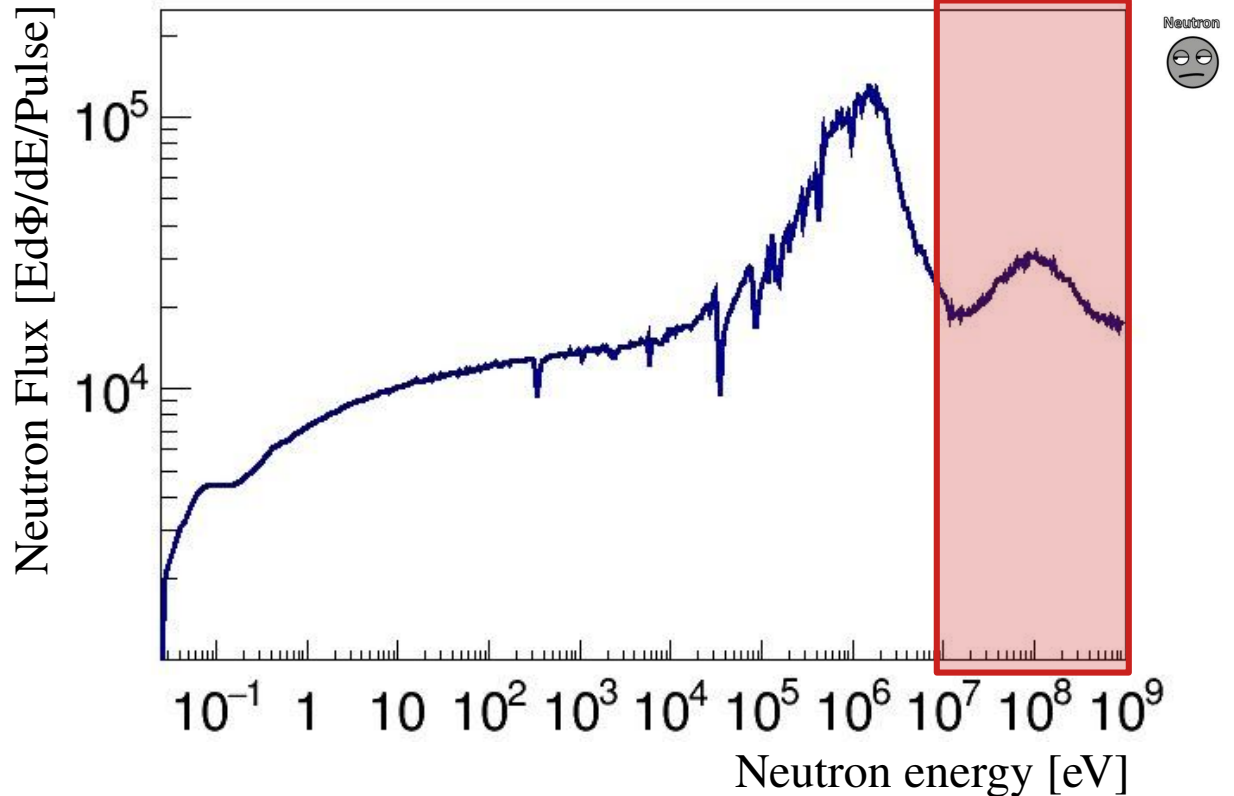
## Wide energy range

Thermal – up to 1 GeV

## High energy resolution $\rightarrow$ TOF

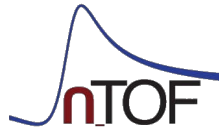
EAR1  $\rightarrow$  185 m flight path

$\Delta E/E \ 10^{-5} - 10^{-3}$

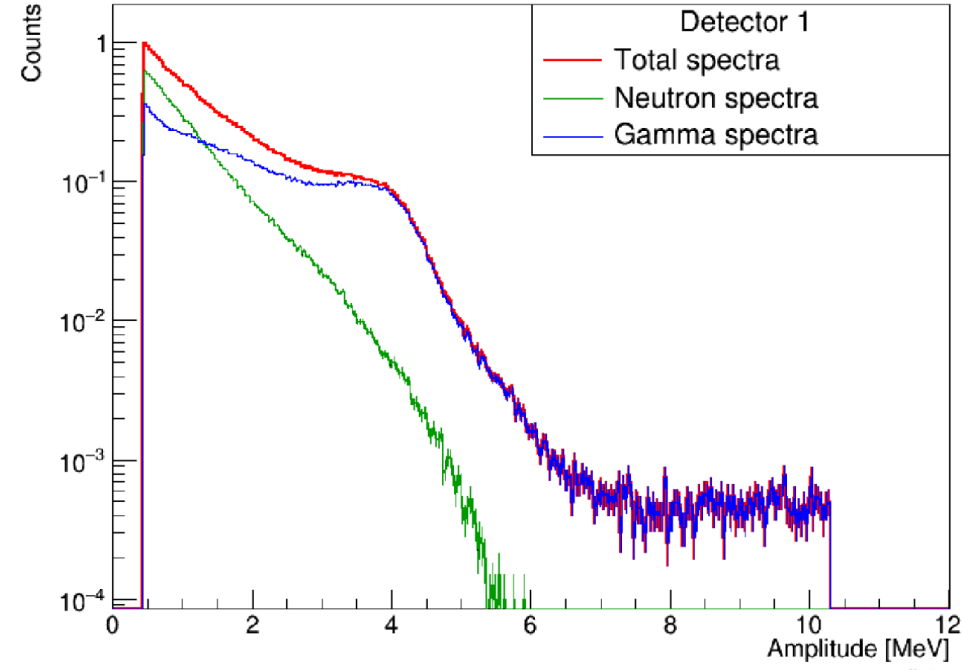
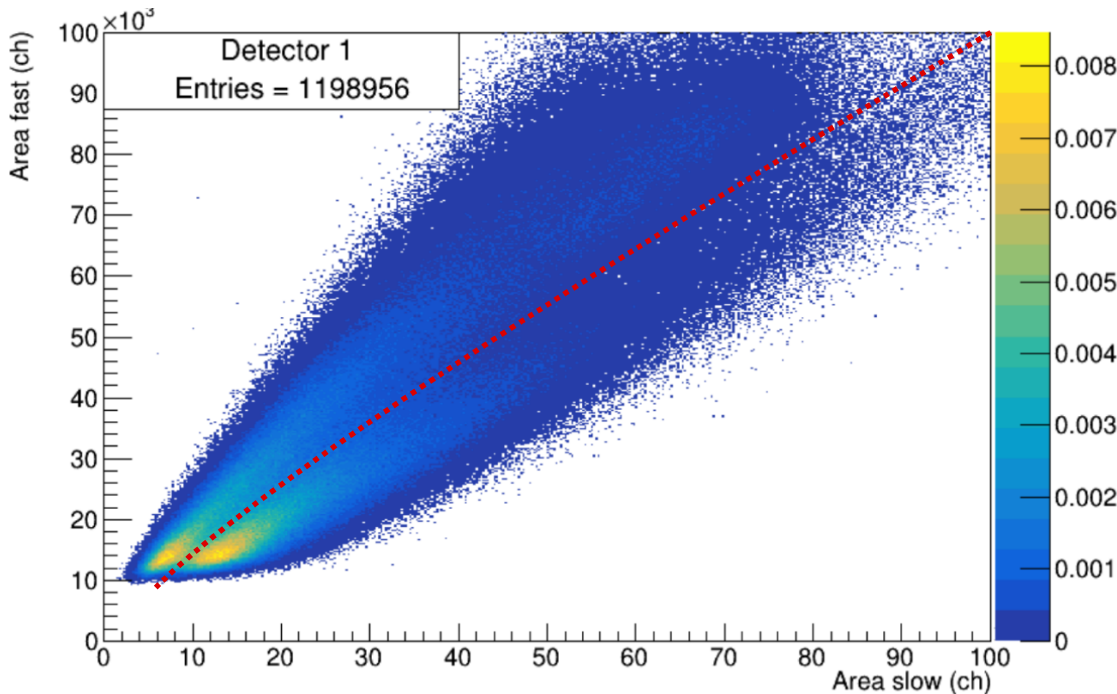


# Detector characterization

- Am-Be/ $^{88}\text{Y}$  source for BC501-A particle identification (n- $\gamma$ ) studies
- Area fast/slow extraction added to PSA

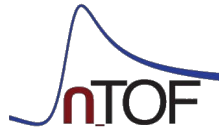


Am-Be

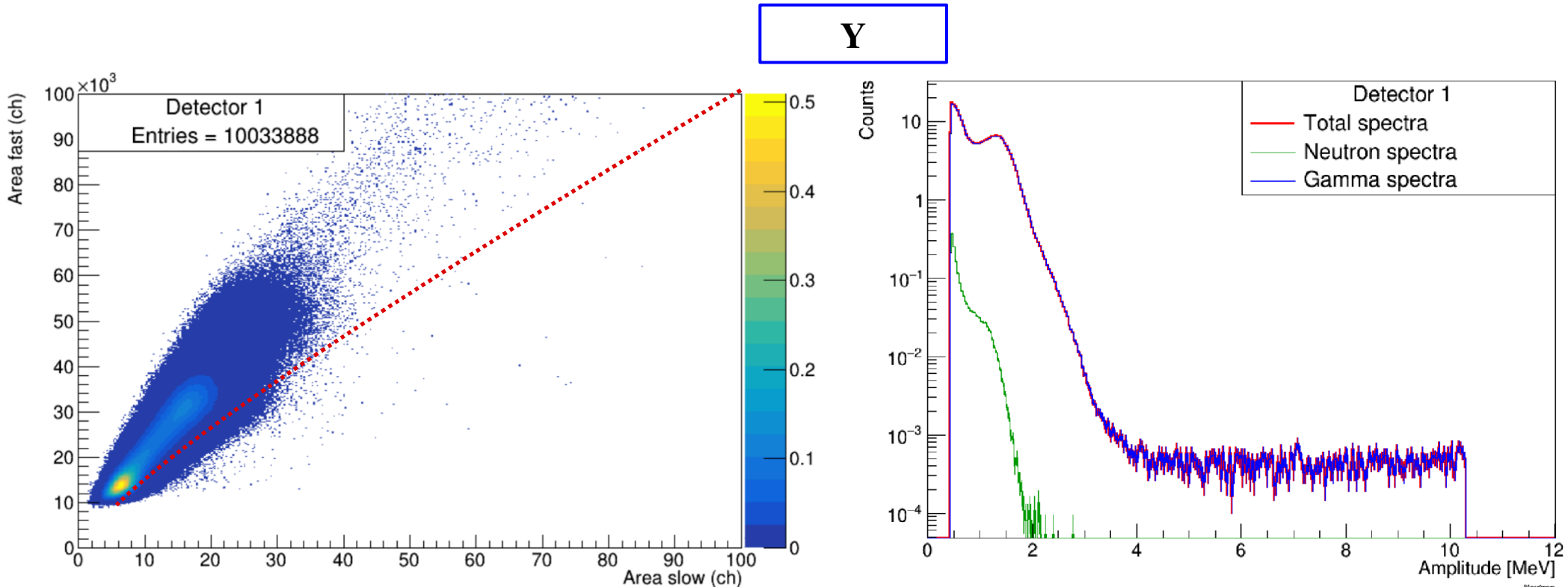




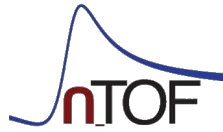
# Detector characterization



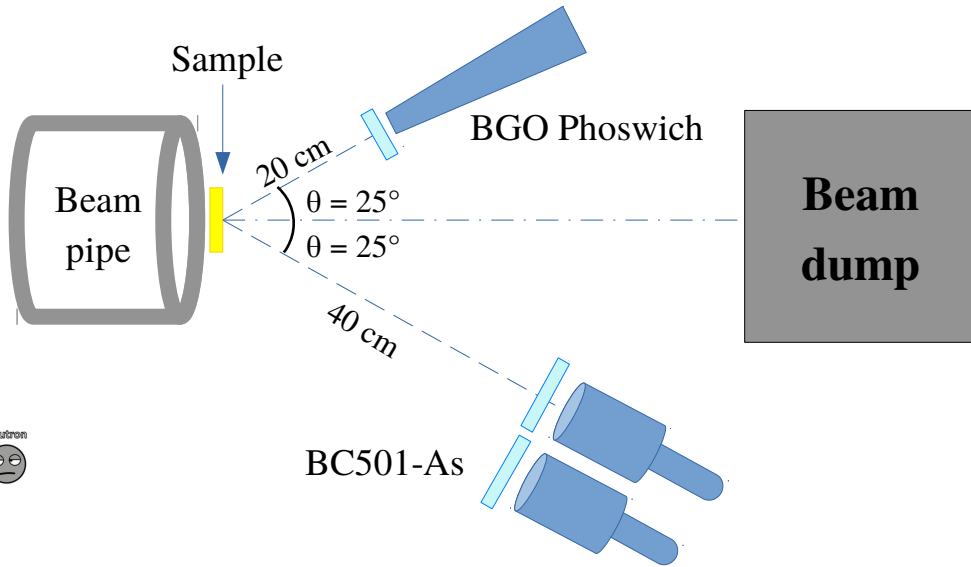
- Am-Be/ $^{88}\text{Y}$  source for BC501-A particle identification (n- $\gamma$ ) studies
- Area fast/slow extraction added to PSA



# Detector characterization in NEL of EAR1

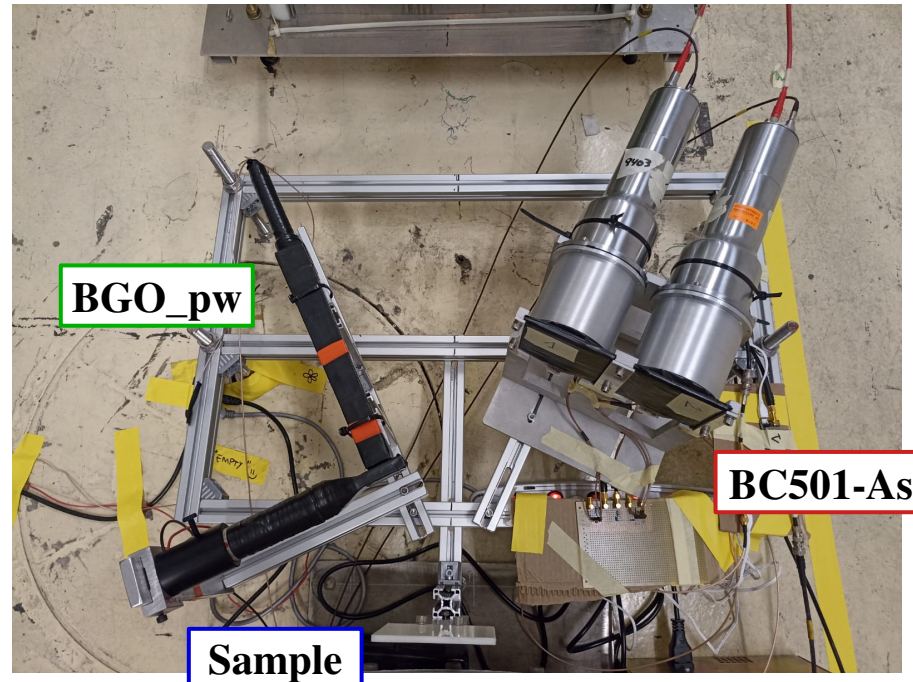


Detection efficiency for high energy neutrons (> 1 MeV)



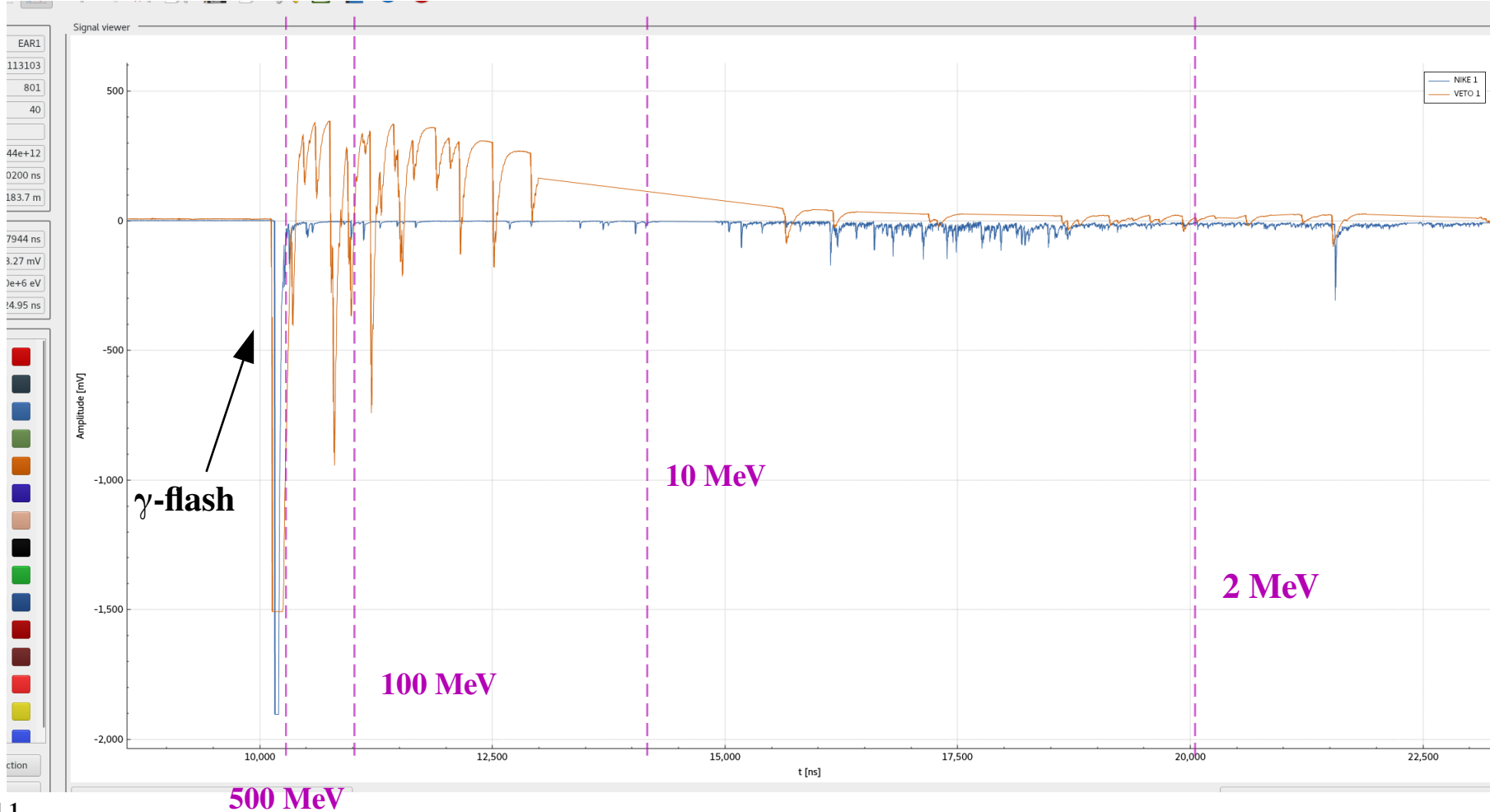
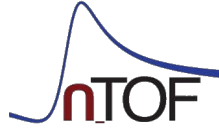
$$E_n = E'_n \cos^2(\theta)$$

↓ Detected neutron    
 ↓ Incident neutron    
 ↓ Scattering angle

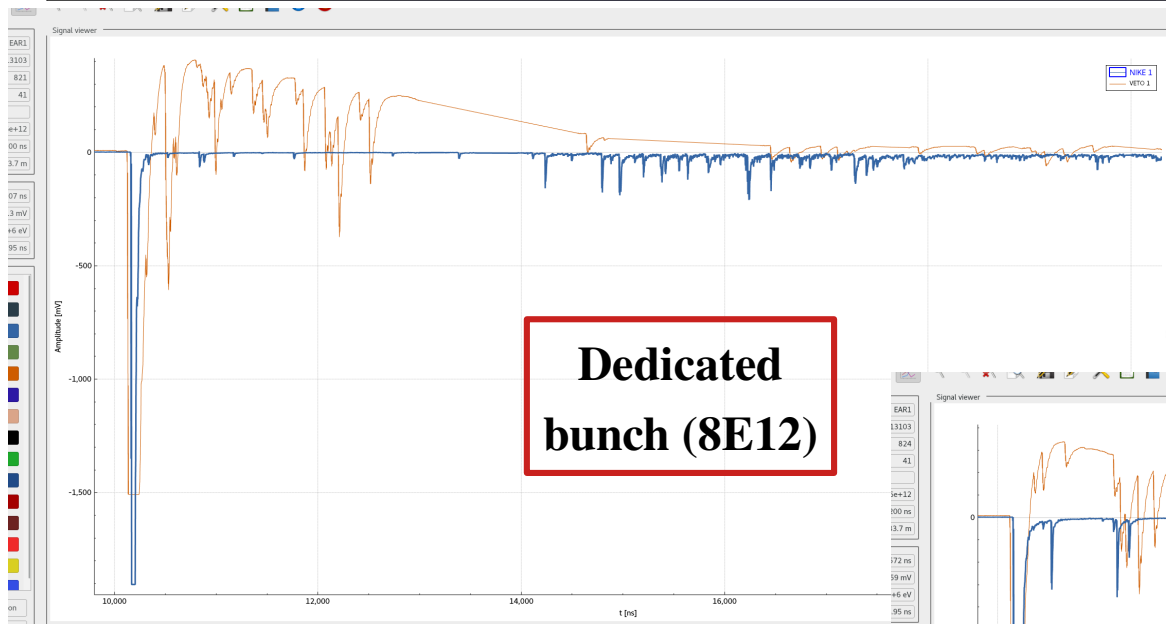
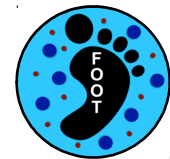


<i>Sample</i>	None	C <sub>2</sub> H <sub>4</sub> 2 mm	C <sub>2</sub> H <sub>4</sub> 5 mm	C 1 mm	C 2 mm
<i>Protons</i> [x10 <sup>18</sup> ]	1.50	1.83	3.33	3.16	1.42

# Signals: BC-501A system



# Signals: BC-501A gain issue



**Dedicated  
bunch (8E12)**

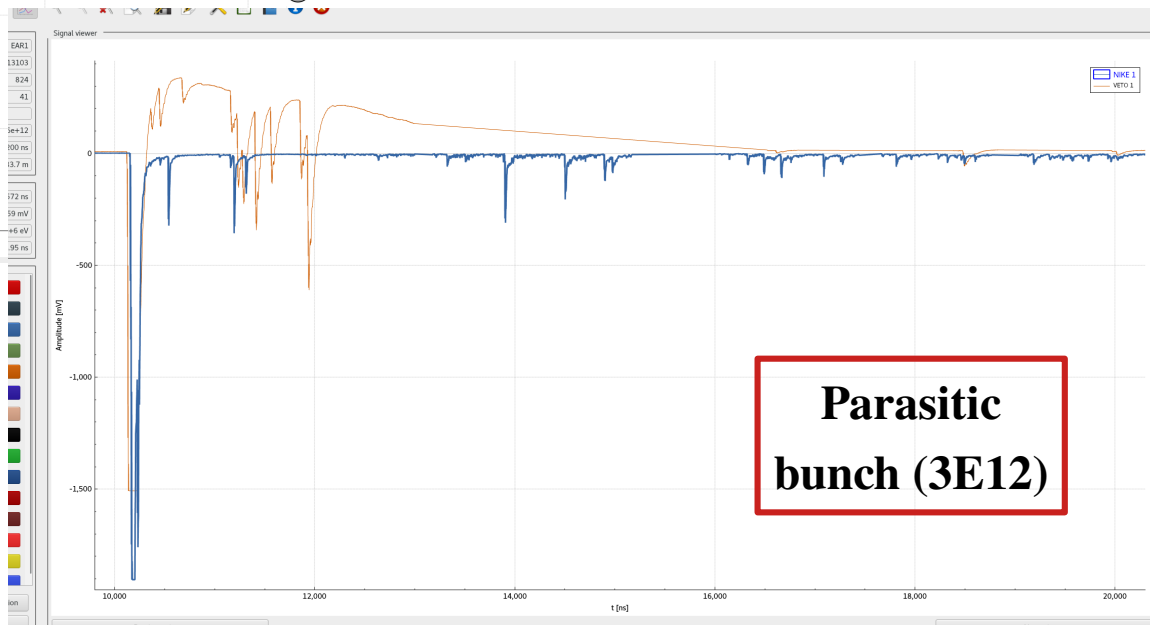
BC-501A gain loss  
near the  $\gamma$ -flash



n/ $\gamma$  discrimination  
challenging

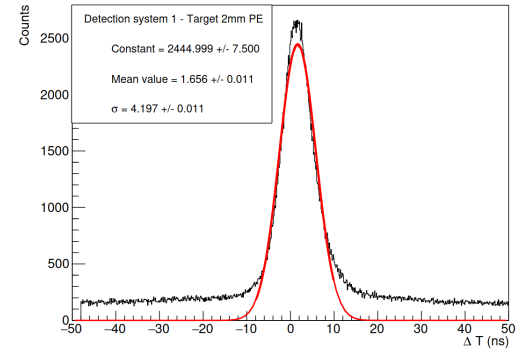
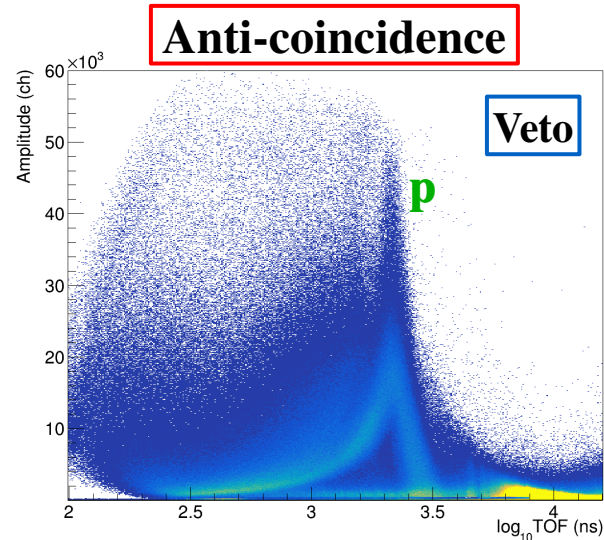
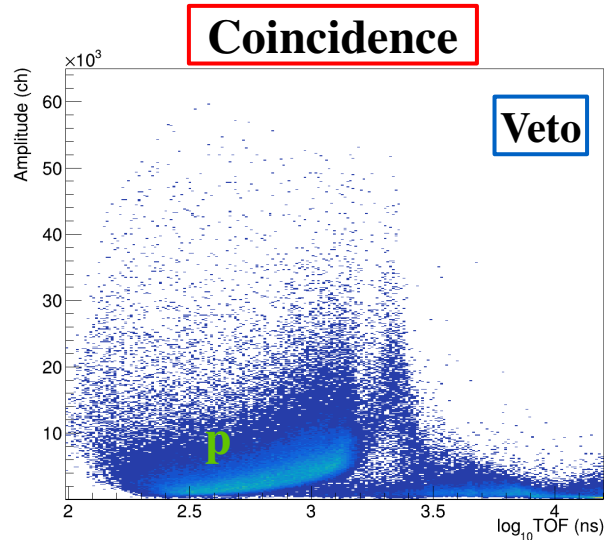
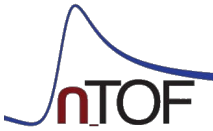
Need to investigate

- Lower energies
- Parasitic bunches

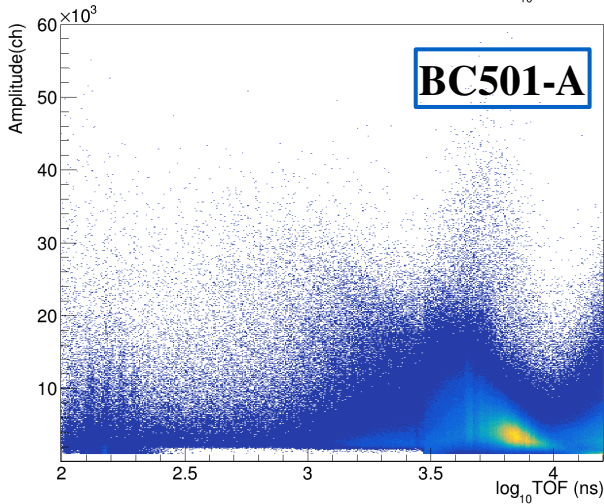
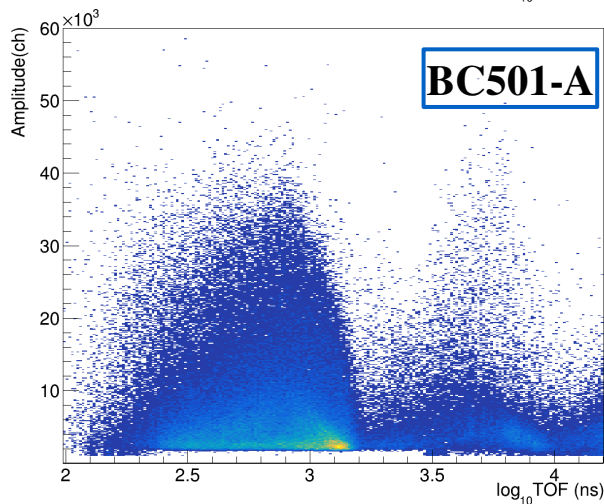


**Parasitic  
bunch (3E12)**

# BC-501A coincidence analysis

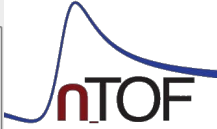


Coincidence analysis routine  
→ divide signals from charged  
and neutral particles

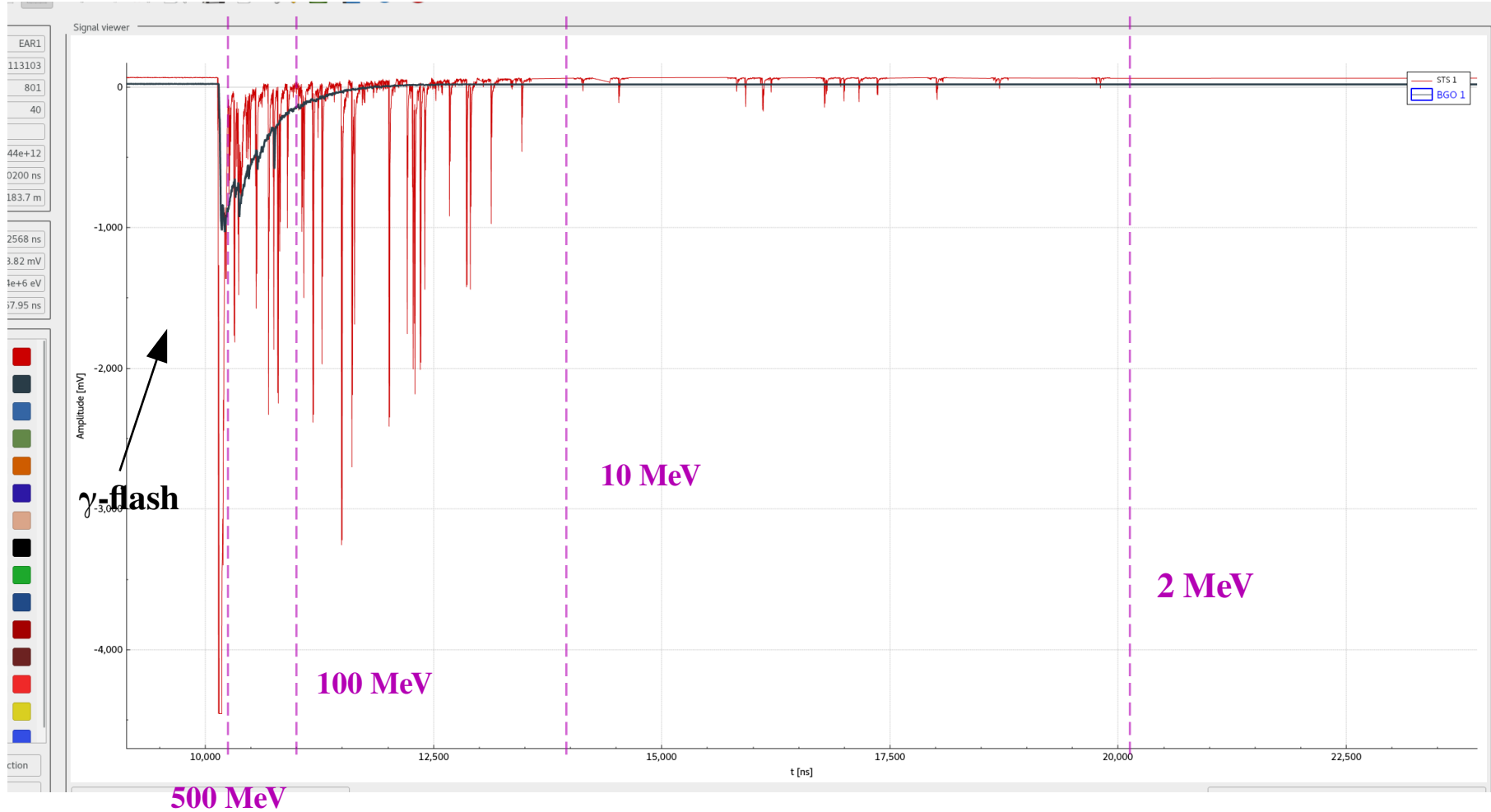


- Time coincidence window  $\pm 10$  ns
- Energy loss branches from charged particles clearly visible in the veto
- Anticoincidence events to be studied in further detail

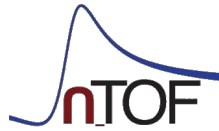
# Signals: BGO system



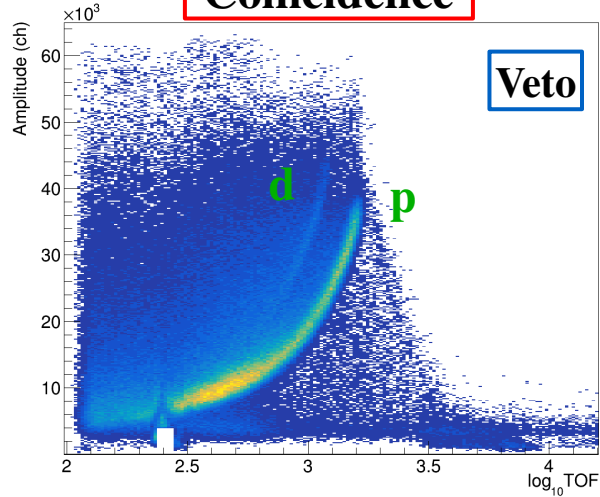
Neutronron



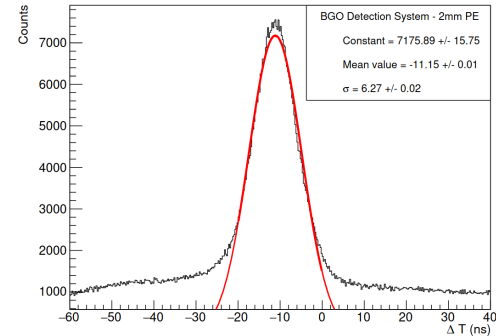
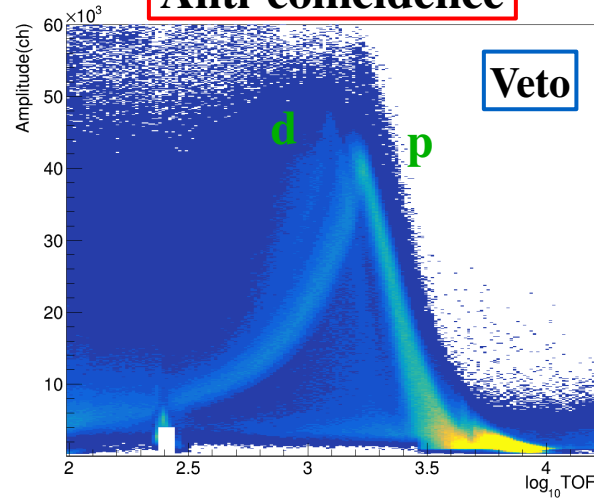
# BGO coincidence analysis



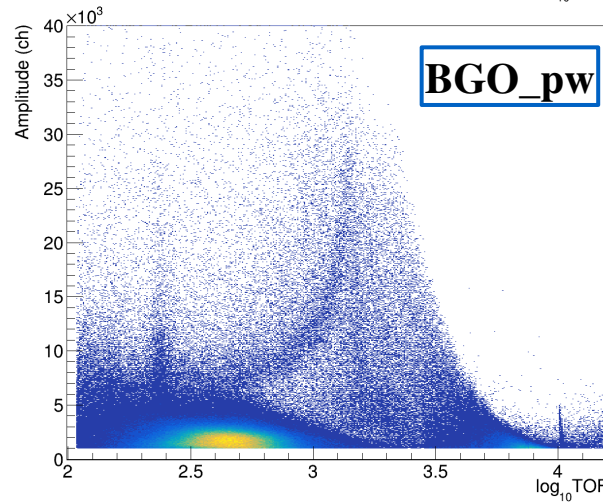
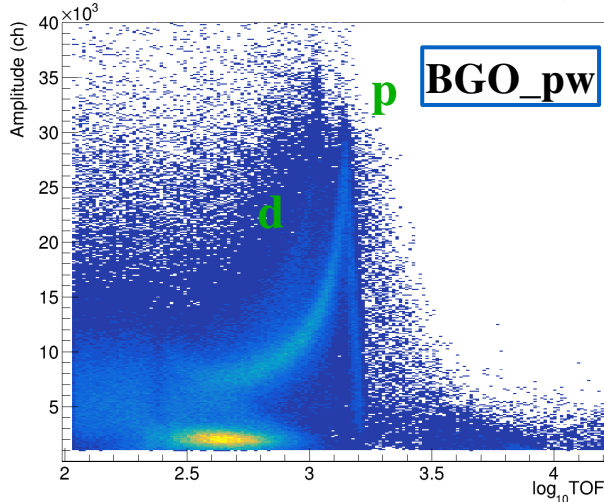
**Coincidence**



**Anti-coincidence**



**Same coincidence analysis routine**



- Time coincidence window  $\pm 12$  ns
- Protons and deuterons branches visible
- No fast component in anticoincidences
- n detection efficiency to be evaluated

$$\varepsilon = \frac{n_n}{n_p}$$

**Independent of  
neutron flux**

# Conclusions

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Possible FOOT neutron detectors studied in the NEL of EAR1

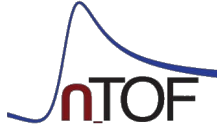
- ✓ Used new PSA feature for area fast/slow
- ✓ Functioning veto/detector coincidence selection routine

**BC-501A:**

- ✓ Particle discrimination with radioactive sources
- ✦ Further studies needed for n detection efficiency evaluation

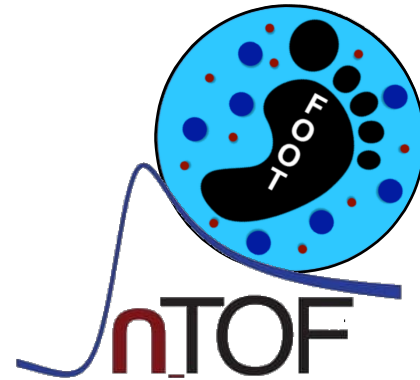
**BGO:**

- ✓ Good reliability of the phoswich system
- ✓ n detection efficiency to be evaluated using proton and neutron flux

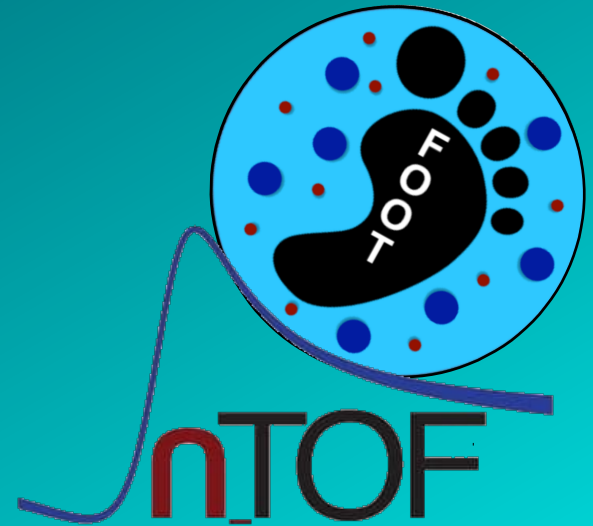




*Thank you for your attention*



*Backup slides*

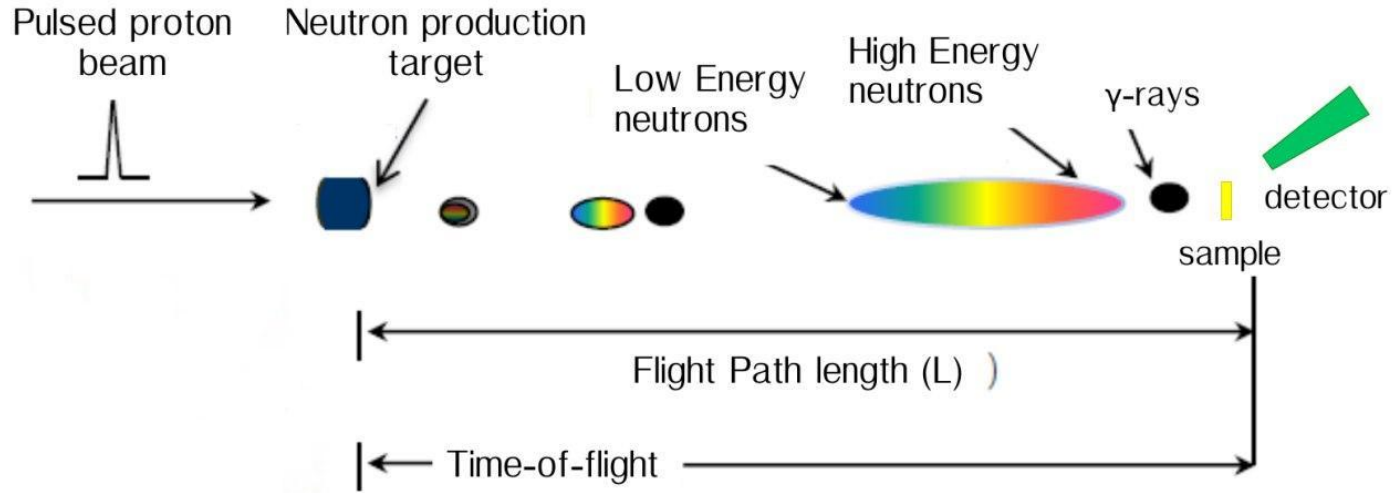


# TOF - Energy conversion

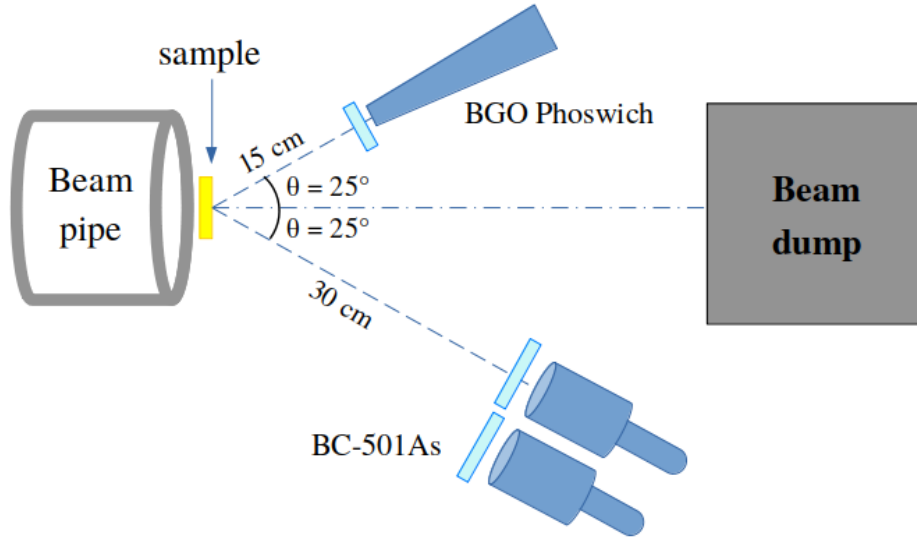
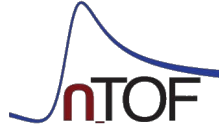


Energy (MeV)      TOF( $\mu$ s)

1	13.8
10	3.94
50	1.46
100	0.89
150	0.65
200	0.51
250	0.42
300	0.36
400	0.27
500	0.21
1000	0.10

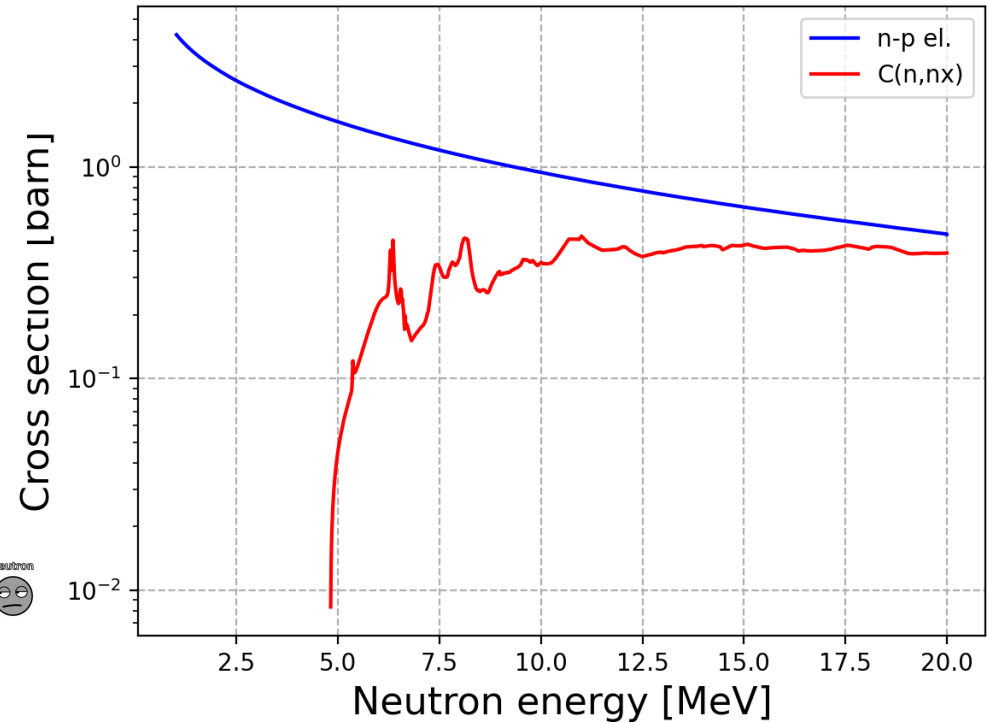


# Detector characterization



**PROBLEM: PE sample**

**Need to subtract the C contribution**

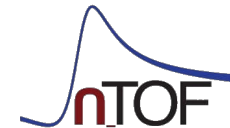


## **OBJECTIVE**

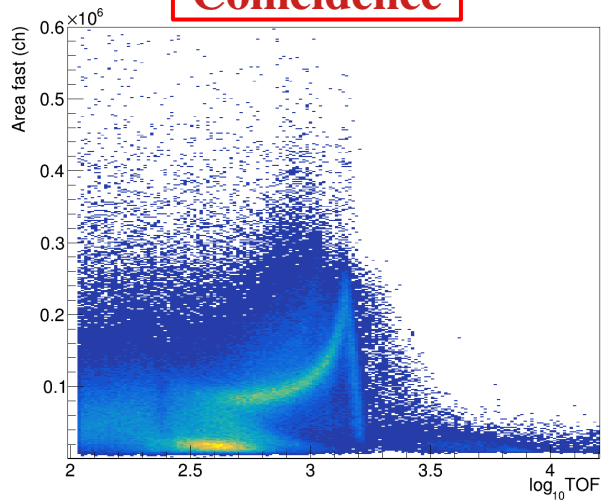
**Neutron detection efficiency with  
maximum statistical uncertainty  
at the level of 5%**

**SOLUTION: 1 month PE 5mm + 1 month C 2.5mm**

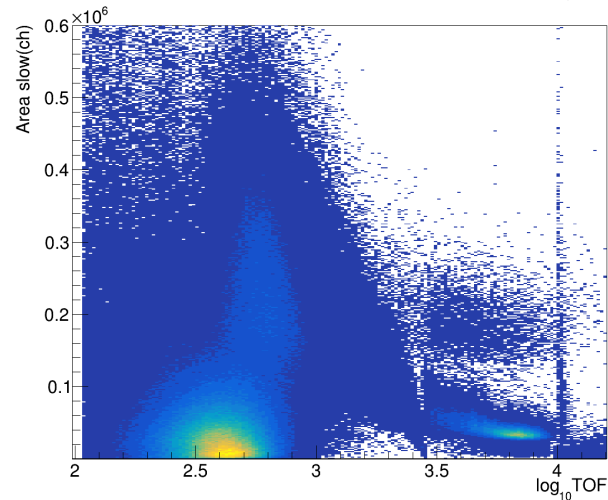
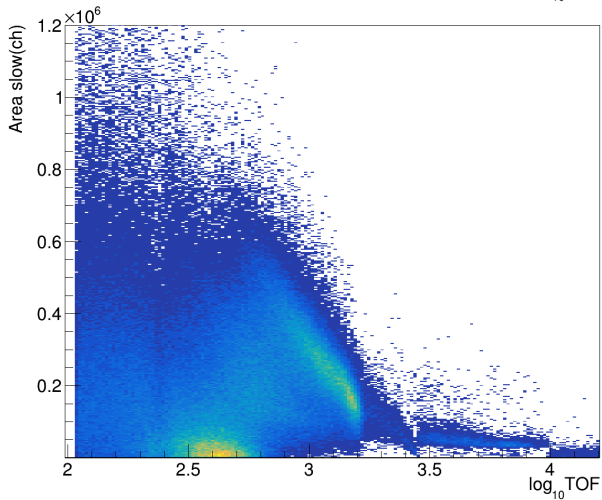
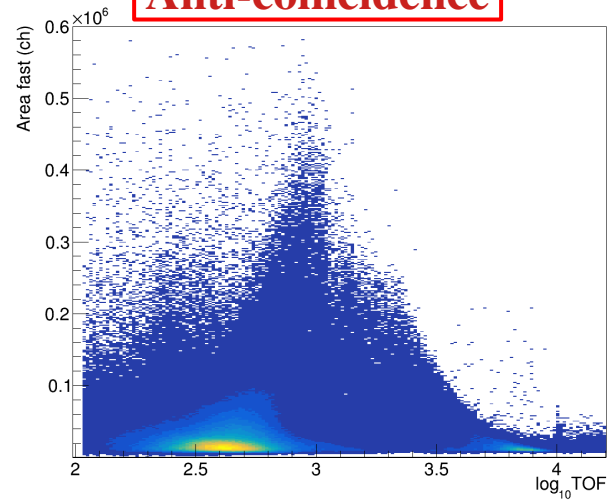
# BGO coincidence analysis



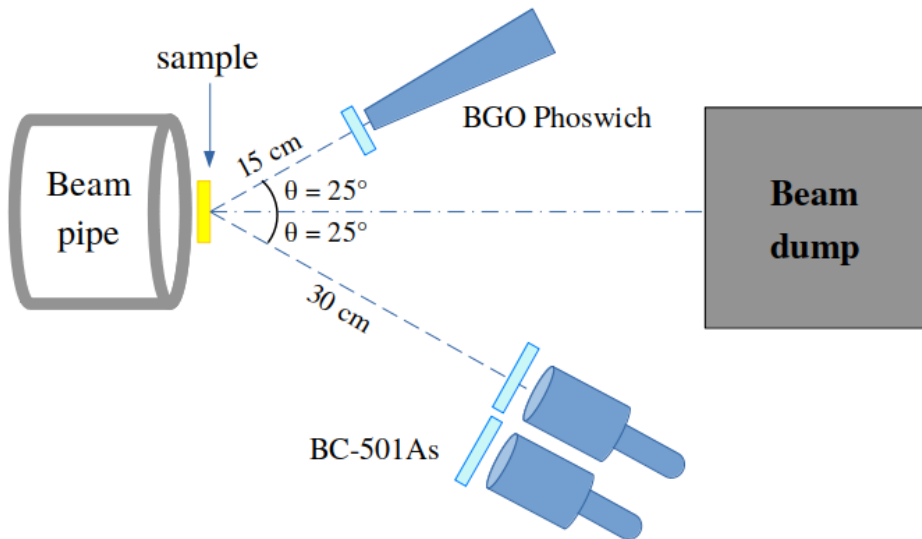
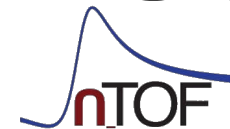
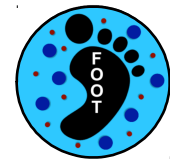
Coincidence



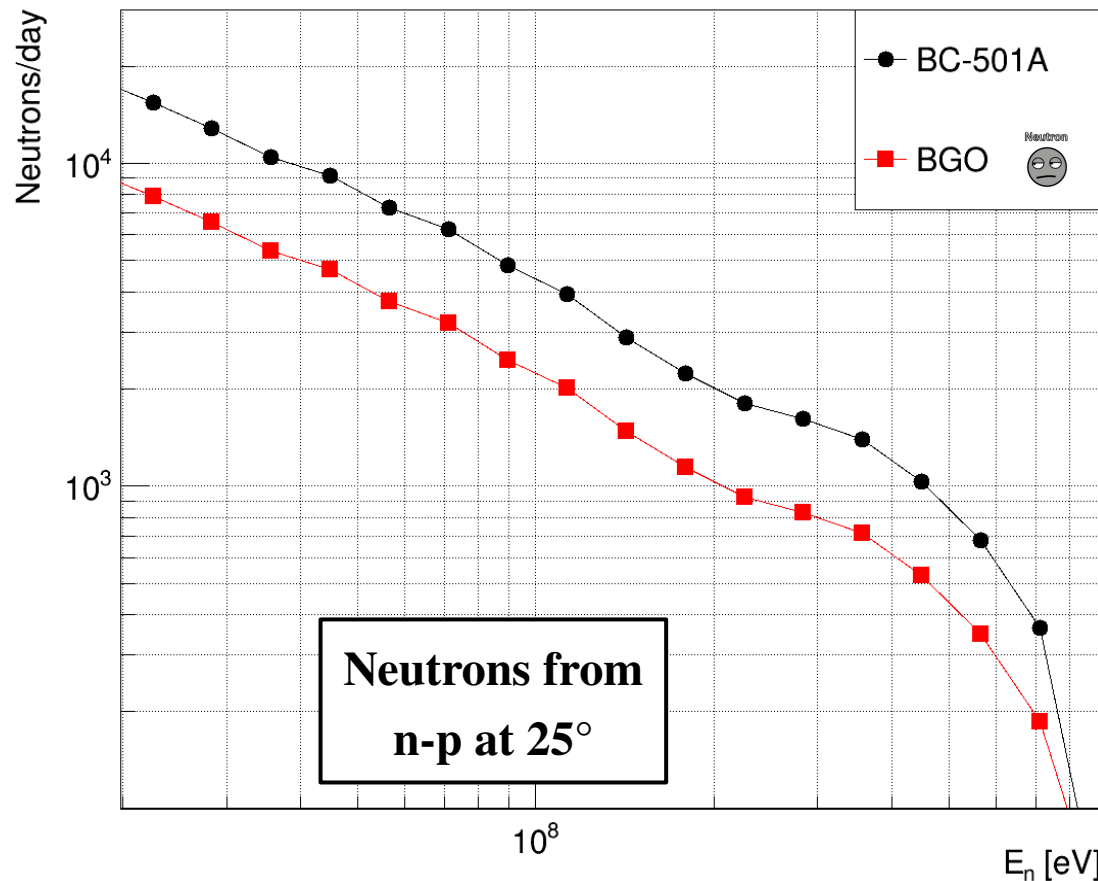
Anti-coincidence



# Detector characterization



$$E_n = E'_n \cos^2(\theta)$$



$n_H \approx 0.04$  at/barn  
1 bunch every 6 s  
10 bins/decade  
8-10% energy bin resolution