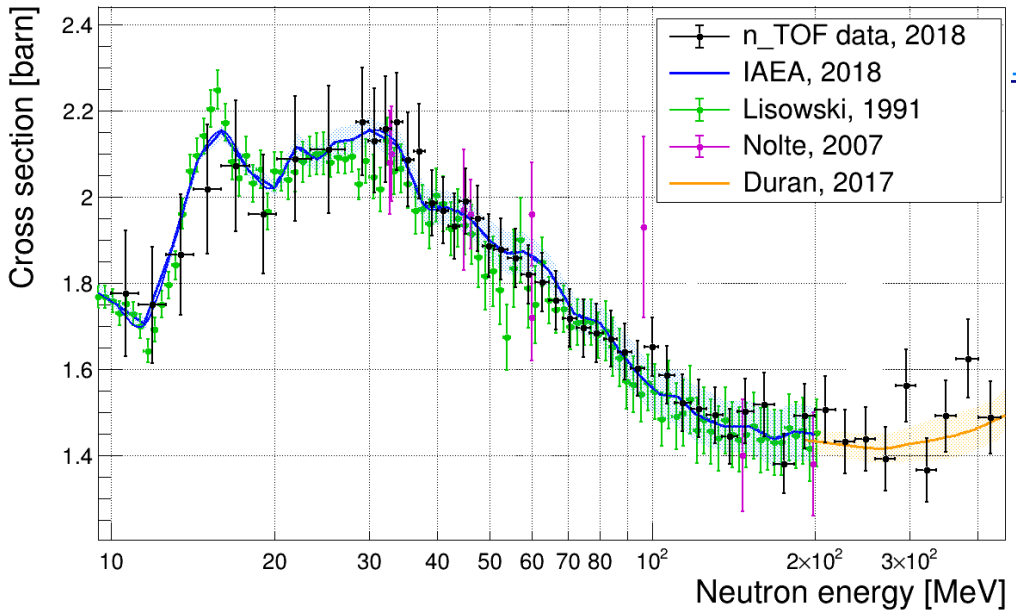
Re-TOF test at EAR1

L. Audouin, A. Manna, M. Marafini, C. Massimi, P. Morfouace,
J. Taieb, L. Tassan-Got, R. Zarrella

Re-TOF detector test



EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

Addendum to the Proposal INTC-P-507 for the ISOLDE and Neutron Time-of-Flight Committee

Measurement of the ^{235}U(n,f) cross section relative to n-p scattering up to 1 GeV

January 7, 2024

L. Audouin[1], N. Colonna[2], L. Cosentino[2], M. Diakaki[3], I. Duran[4], P. Finocchiaro[2], J. Heyse[5], C. Le Naour[1], A. Manna[2,6], C. Massimi[2,6], P.F. Mastinu[2], A. Mengoni[2,7,8], P.M. Milazzo[2], A. Musumarra[2,9], C. Paradela[5], E. Pirovano[10], P. Schillebeeckx[5], L. Tassan-Got[1], G. Vannini[2,6], A. Ventura[2], and the n_TOF Collaboration

A detector able to discriminate:

protons from: $n + p \rightarrow n + p$ $\quad E_{p,el} = E_n cos^2(\theta)$

protons from: $n + p \rightarrow n + p + \pi^0$ $\quad n + p \rightarrow p + p + \pi^-$ $\quad -m(\pi) = 139.6$ MeV/c-

EAR-1 capture collimator
from 9th to 23th October [parasitic to DDX]

Verify:

the elastic and inelastic proton discrimination

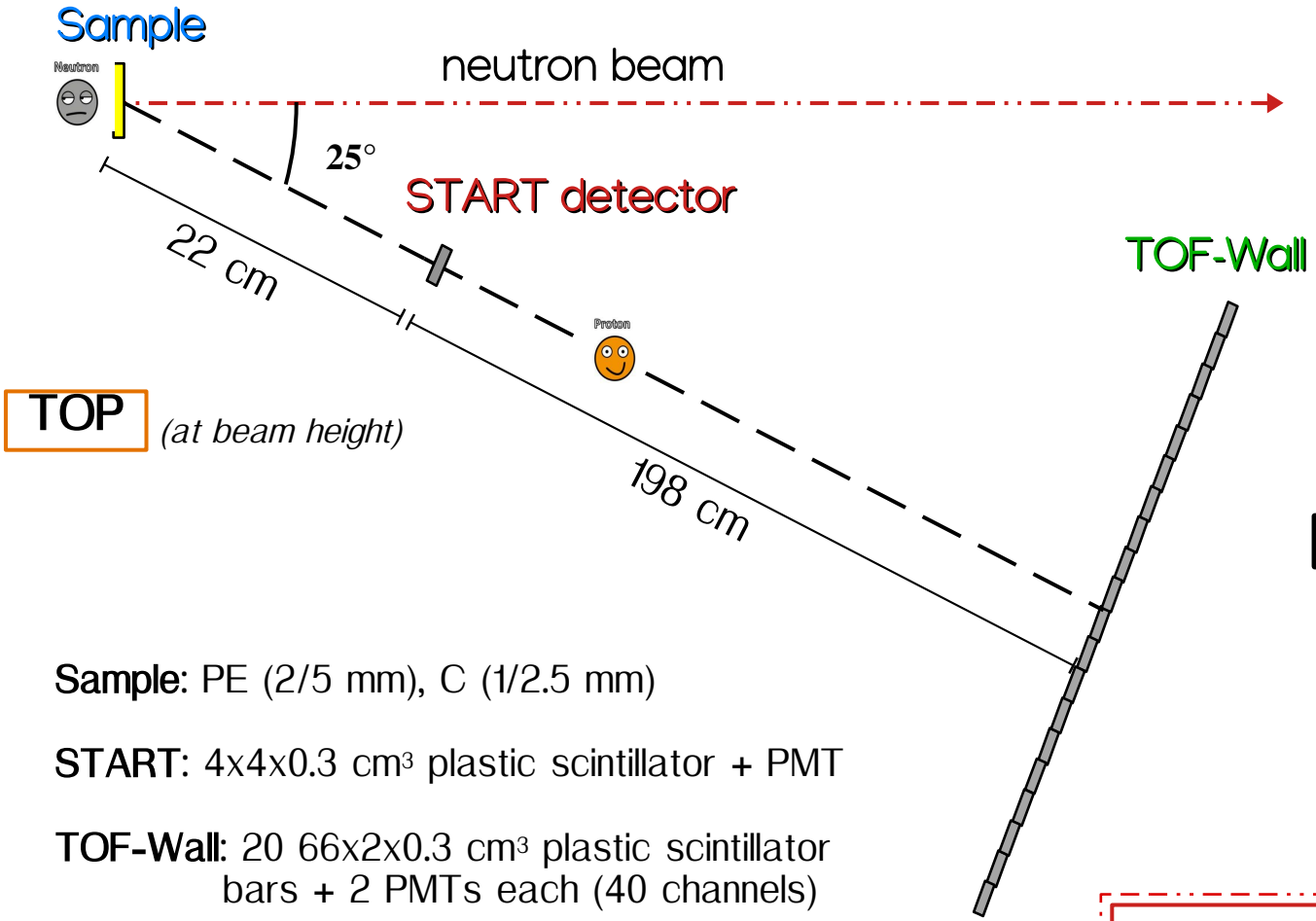
the possibility to discriminate ^{12}C(n,lcp) products

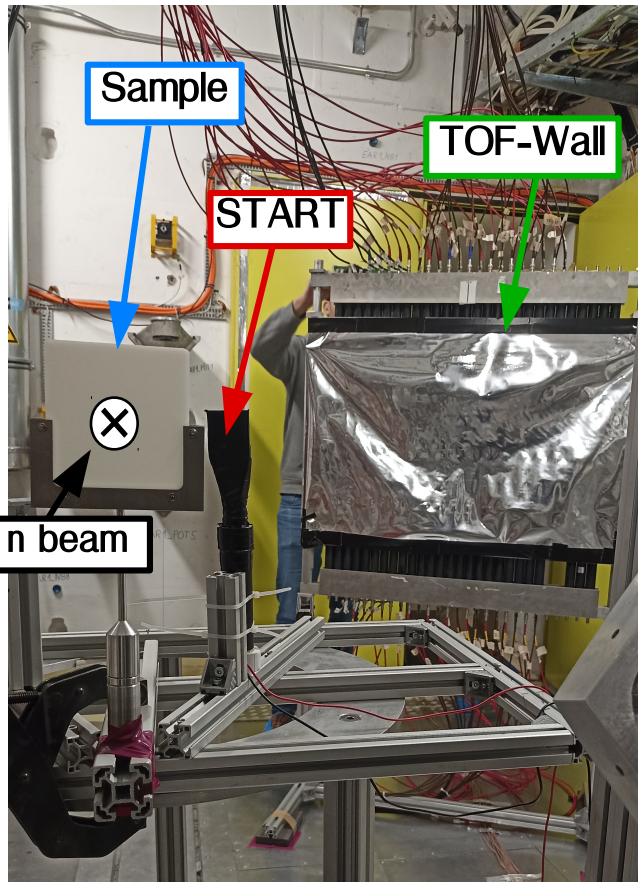
$7 \cdot 10^{17}$ proton on target for the detector test

$4 \cdot 10^{18}$ proton on target for the measurement

Collaboration with CEA
(Julien Taieb and collaborators)

Re-TOF detector test





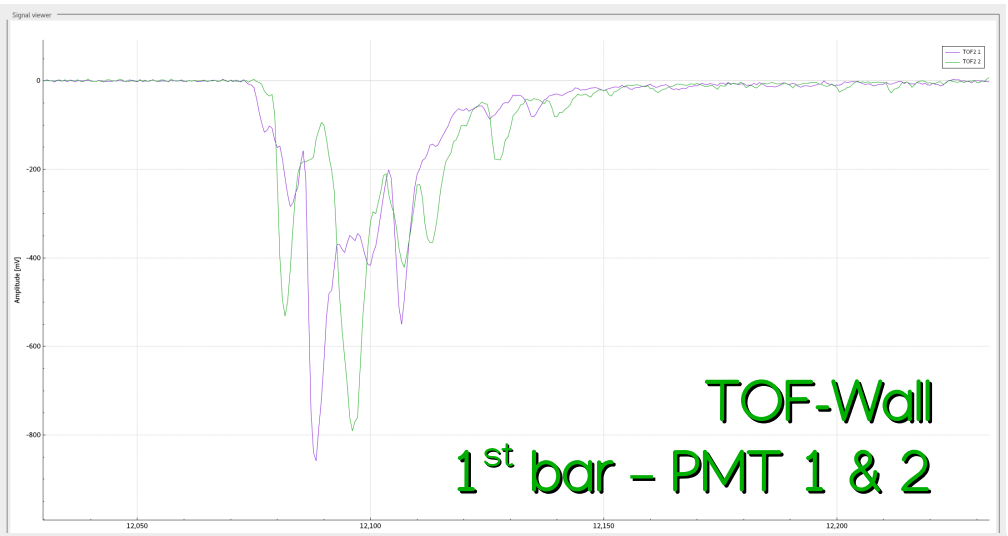
Sample: PE (2/5 mm), C (1/2.5 mm)

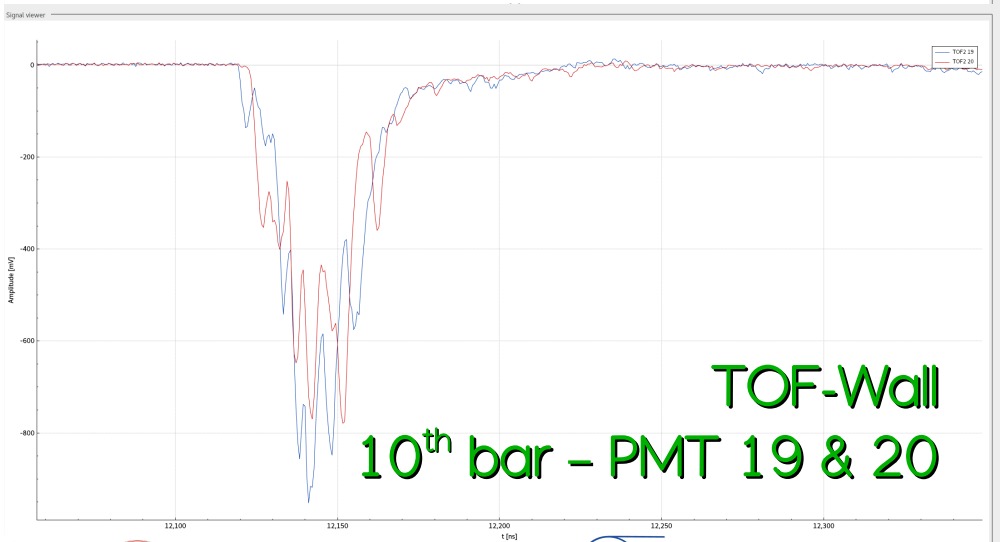
START: 4x4x0.3 cm^3 plastic scintillator + PMT

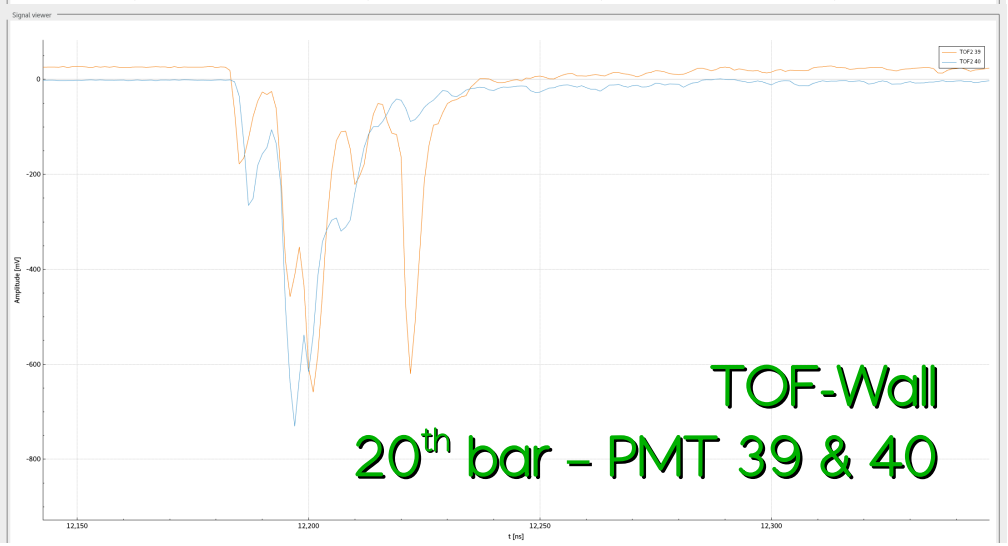
TOF-Wall: 20 66x2x0.3 cm^3 plastic scintillator bars + 2 PMTs each (40 channels)

Exploit the (n,p) elastic scattering to measure neutron flux in the high energy range

γ-flash calibration

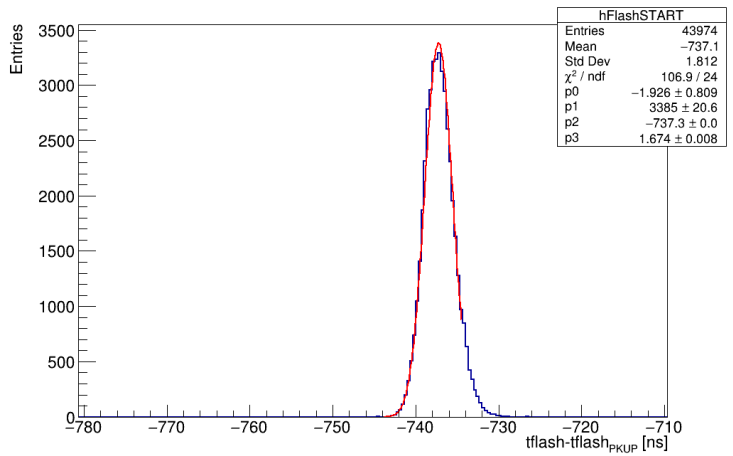


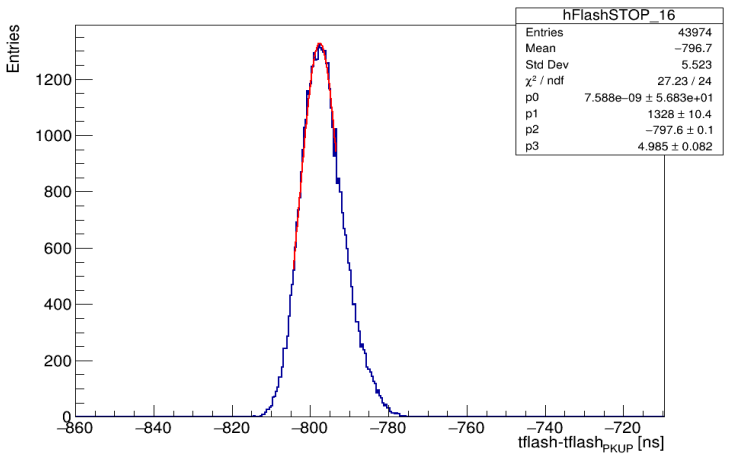




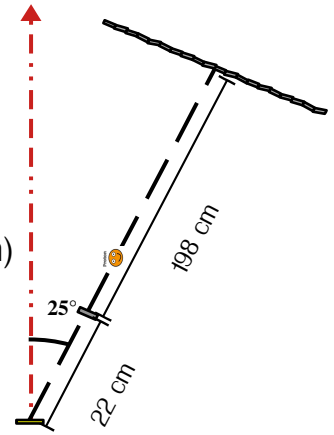
γ-flash calibration

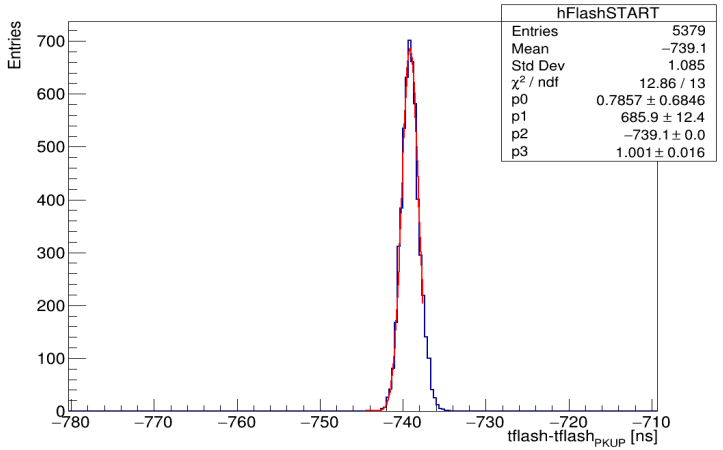
T_{flash} calibration with PKUP for Start and all Tof-Wall channels

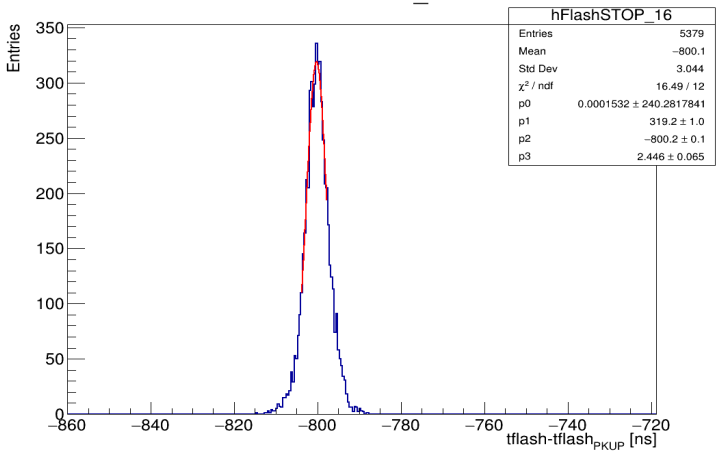




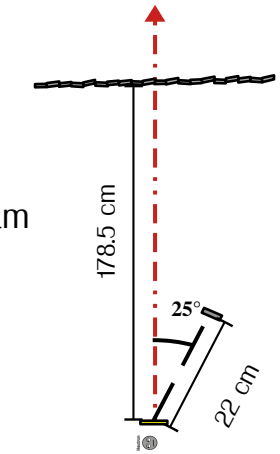
Far from beam line (~1m)







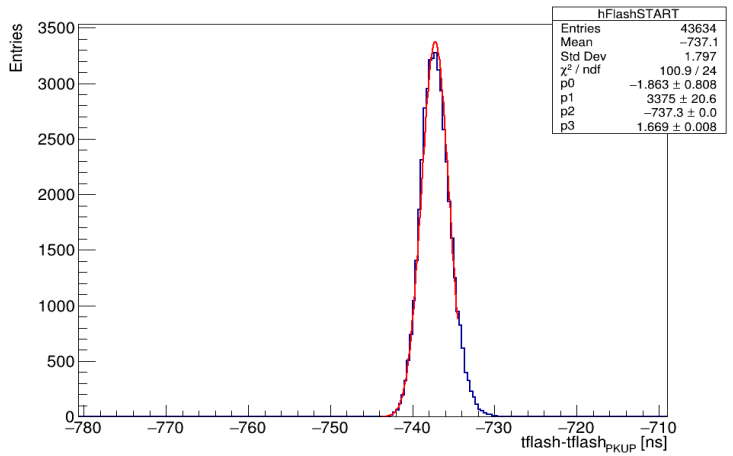
In beam

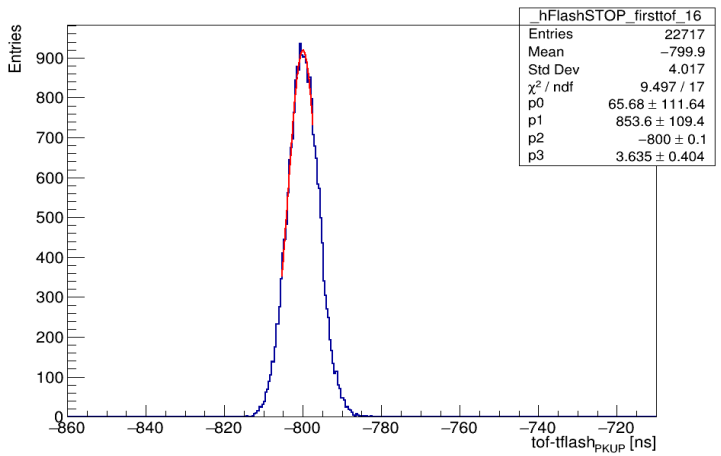


Request:
$|\gamma\text{-flash} - \text{tof}_{\text{first signal}}| < 1.5$ ns

γ-flash calibration

T_{flash} calibration with PKUP for Start and all Tof-Wall channels





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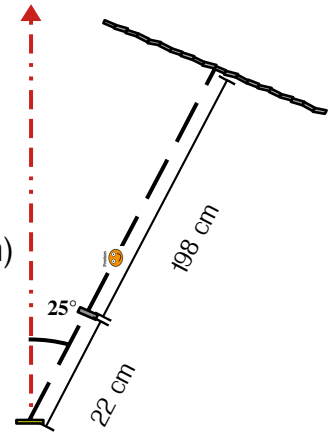
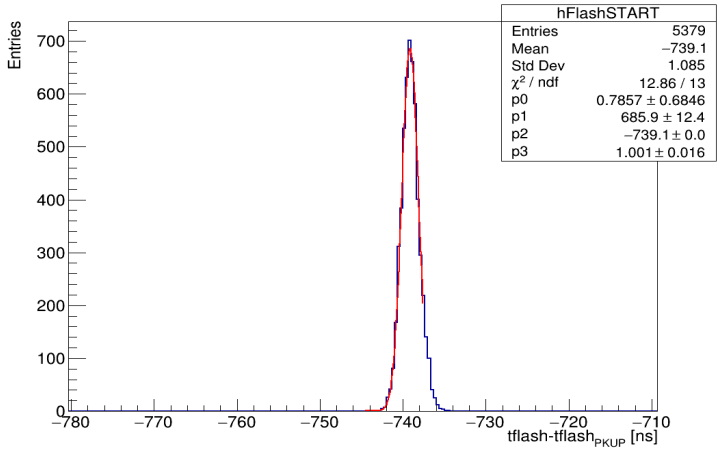
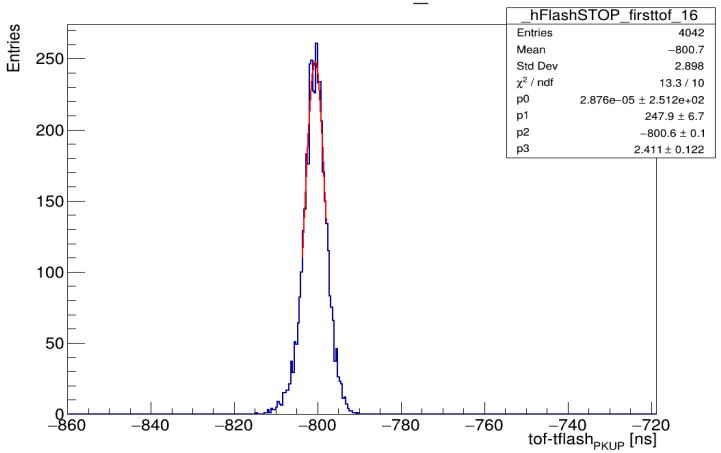
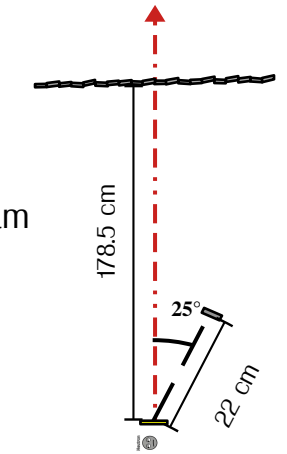






In beam



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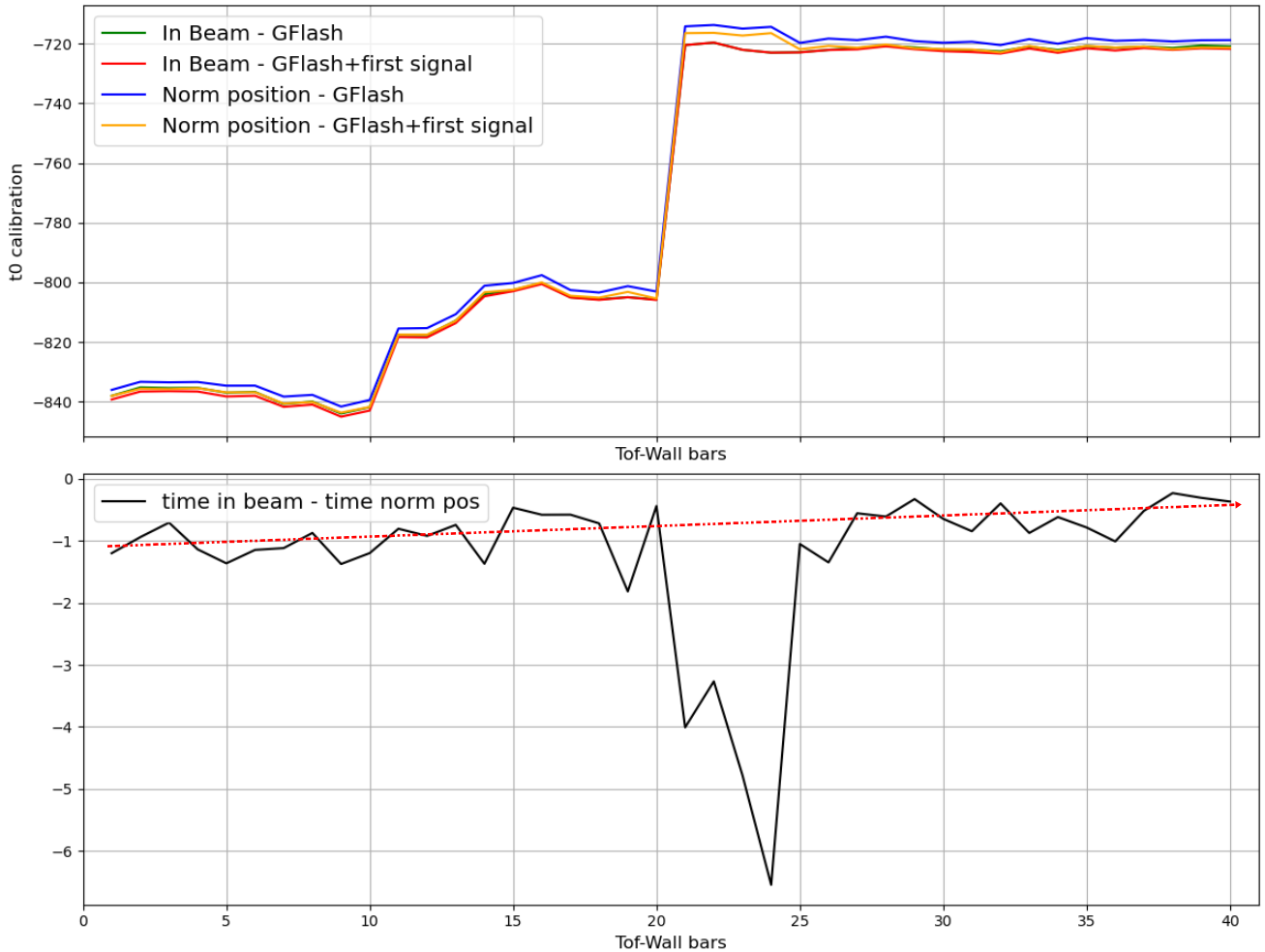
T_{flash} calibration with PKUP for Start and all Tof-Wall channels



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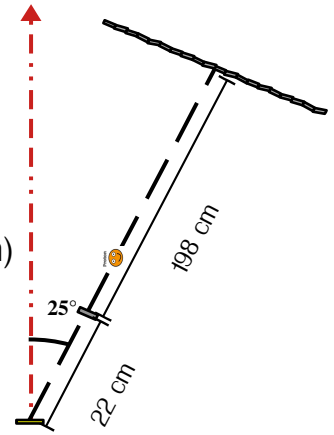
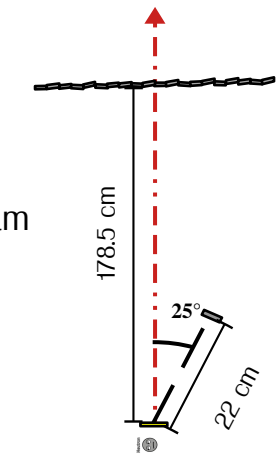


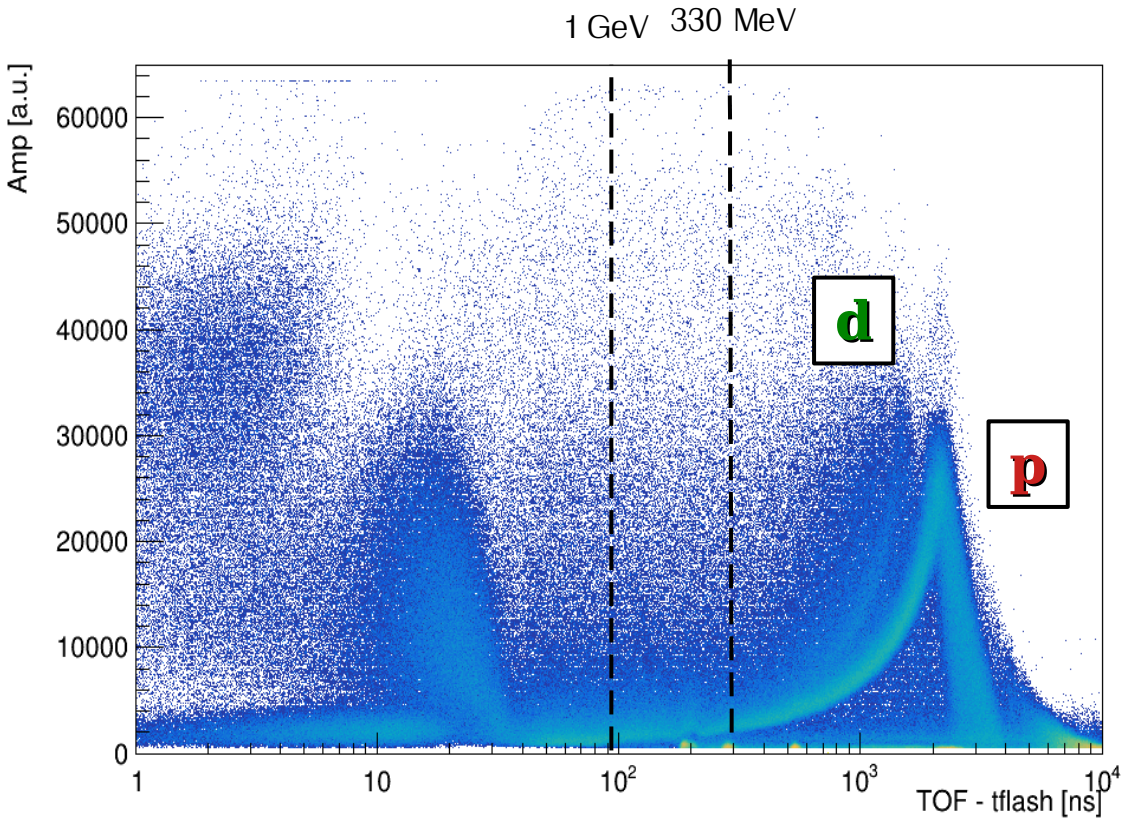
Spallation target

In beam



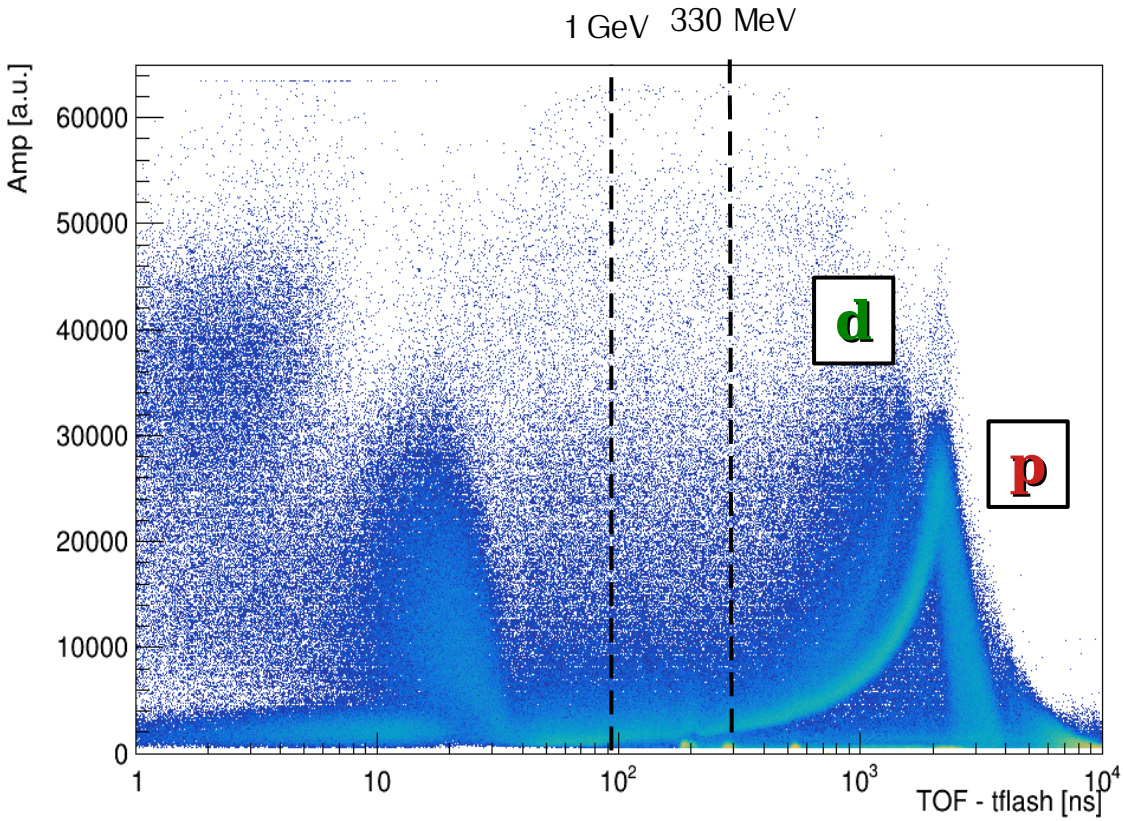
Spallation target

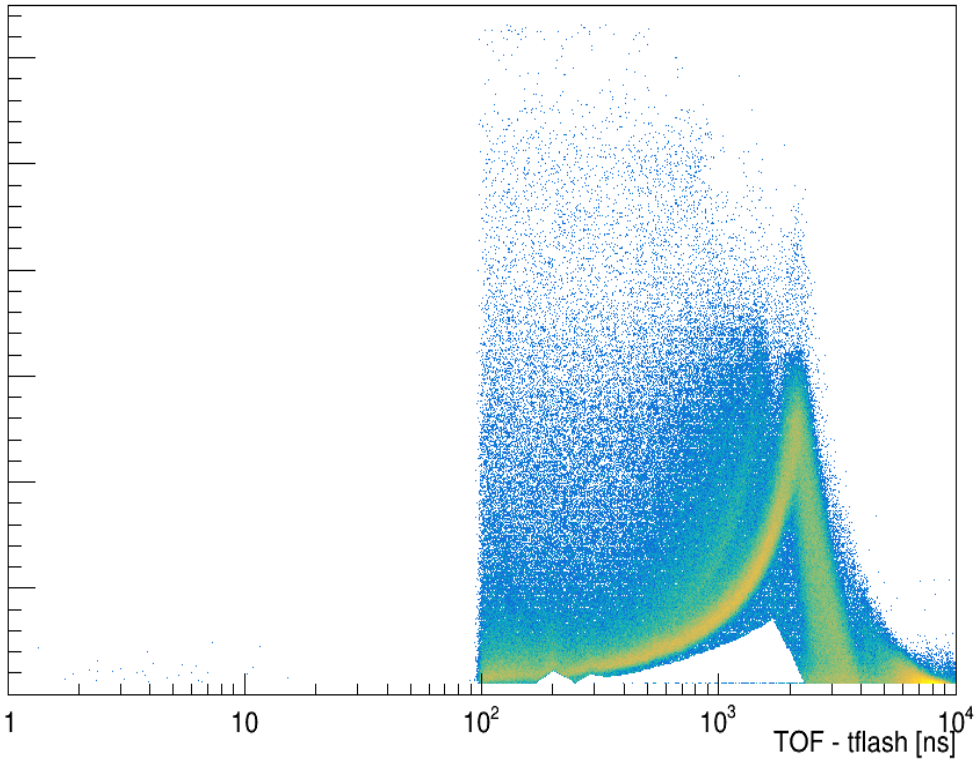
Start detector



protons punch-through at
neutron Energy ~ 20 MeV

Start detector





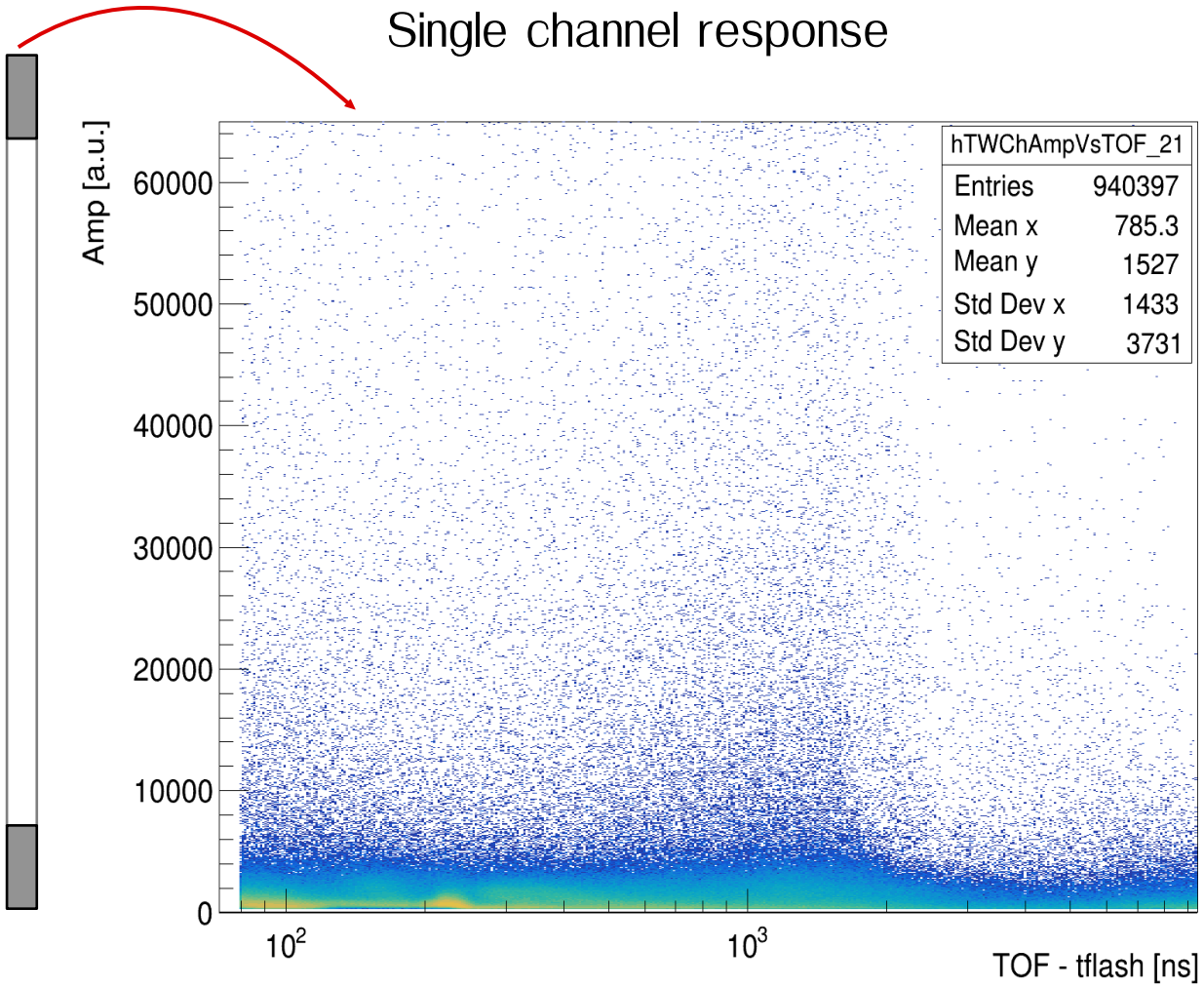
protons punch-through at
neutron Energy ~ 20 MeV

Removed with graphical cut

(not ideal but… good enough for now)

Stop detector - Tof-Wall

Single channel response



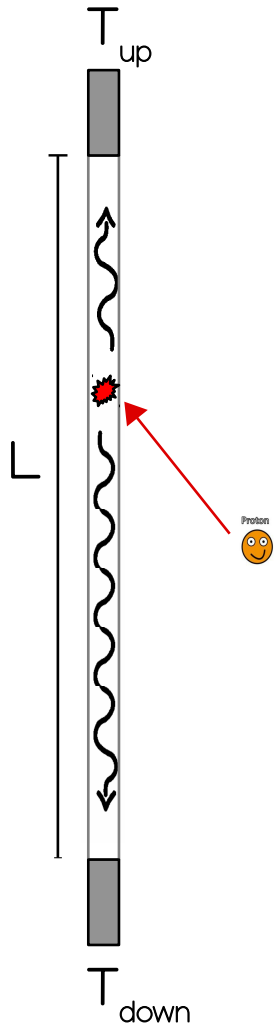
Attenuation along bar

Different gain between PMTs

No structure clearly visible but...

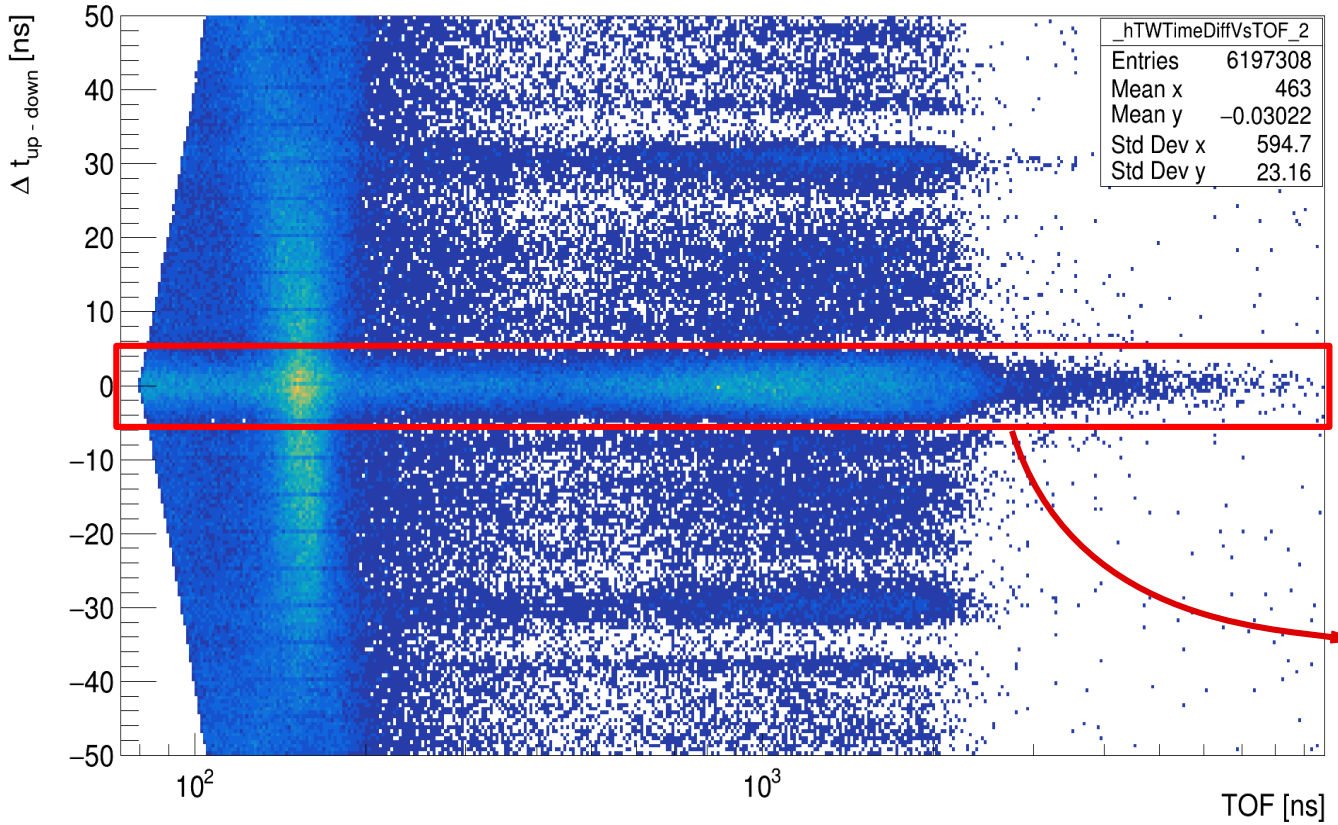
Readout at both ends of the bars
➞ look for internal coincidences!

Stop detector - Tof-Wall



Expected time difference btw channels

$$max\left[\Delta(T_{up} - T_{down})\right] = \frac{2L}{v_{light}} \sim \frac{2 \times 66\ \text{cm}}{13.4\ \text{cm/ns}} \sim 10\ \text{ns}$$



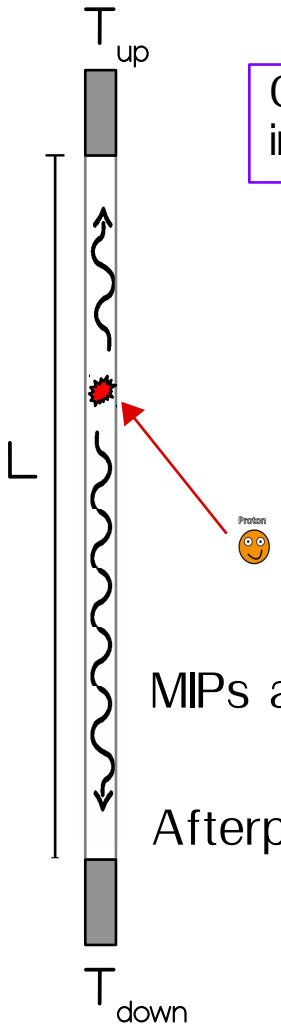
Coincidence window

$\pm$ 5 ns

Start with punch-through in START detector (**> 20 MeV**)

Without imposed coincidence with start detector!!!

Stop detector - Tof-Wall



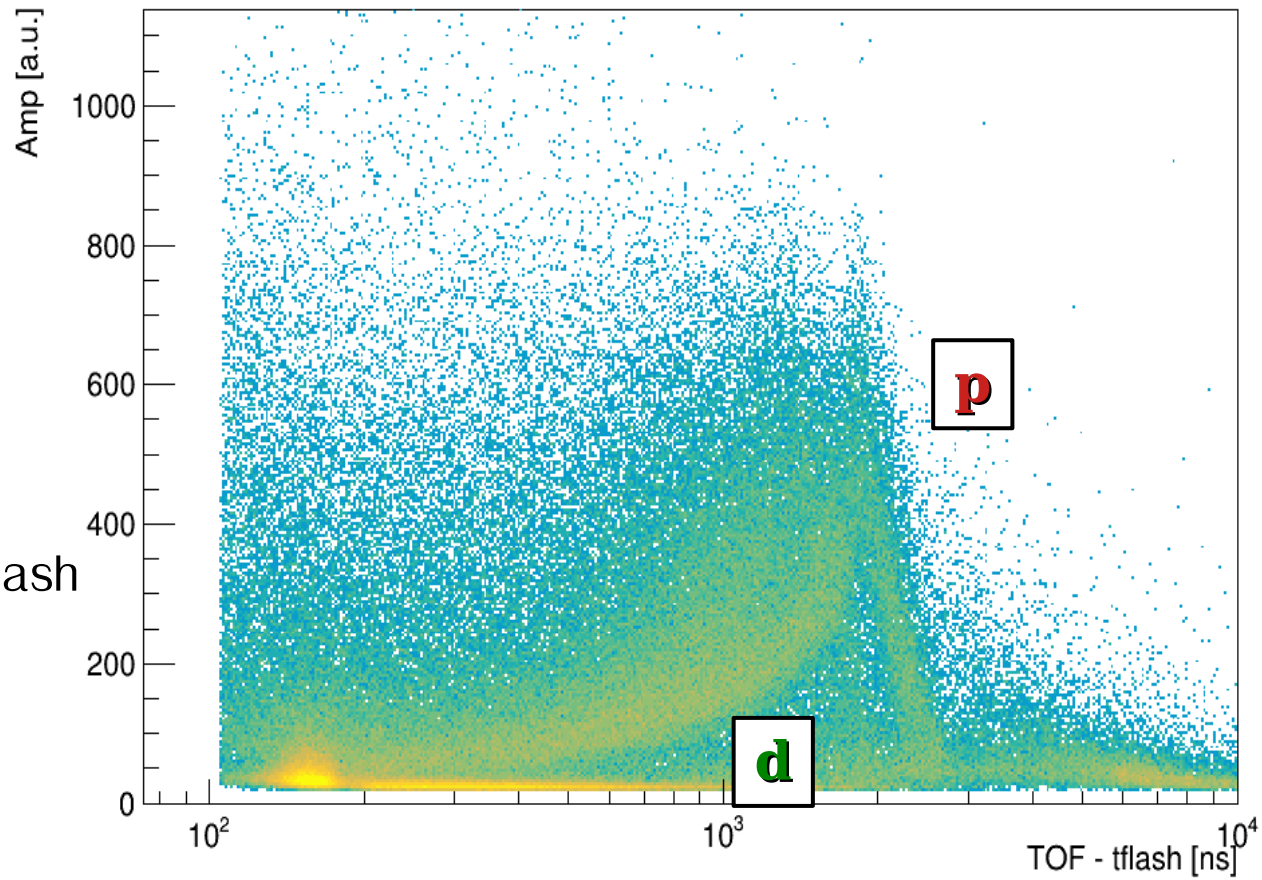
Condition imposed

$$max\left[\Delta(T_{up} - T_{down})\right] \pm 5 \text{ ns}$$ ⇨ Time window coincidence for each bar

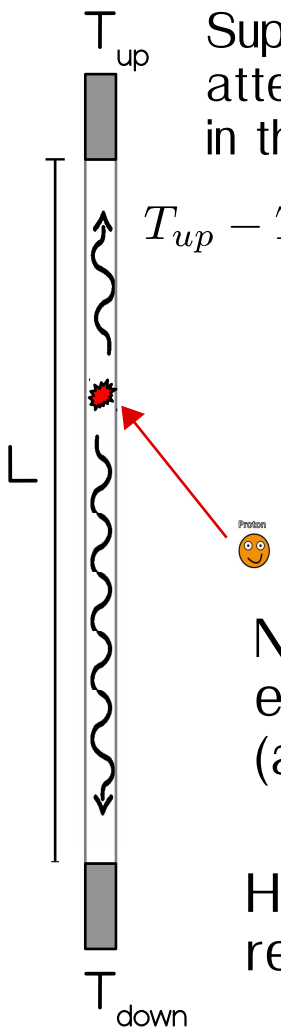
$$A_{bar} = \sqrt{A_{up} \cdot A_{down}}$$ ⇨ Remove dependence on hit position

MIPs at very low amplitude

Afterpulse at ~150 ns from flash



Stop detector - Tof-Wall

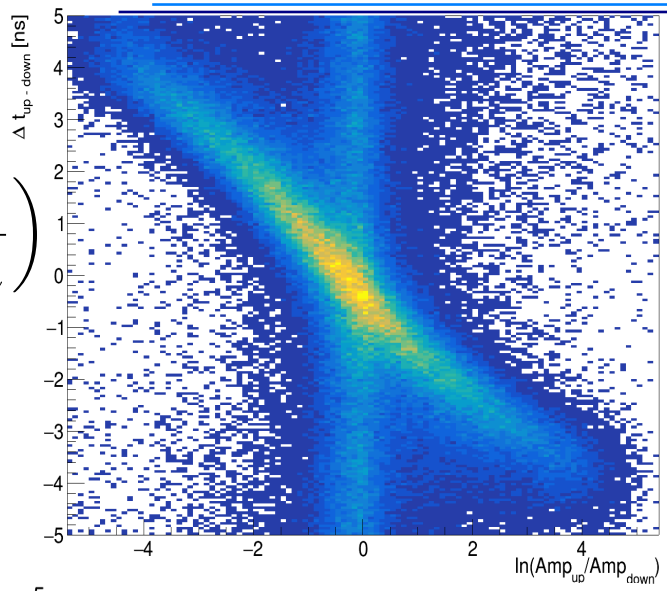


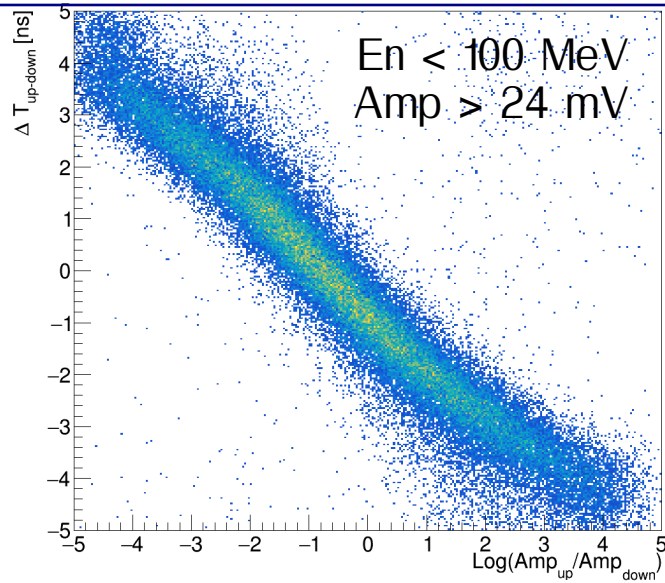
Supposing exponential attenuation of light in the bars

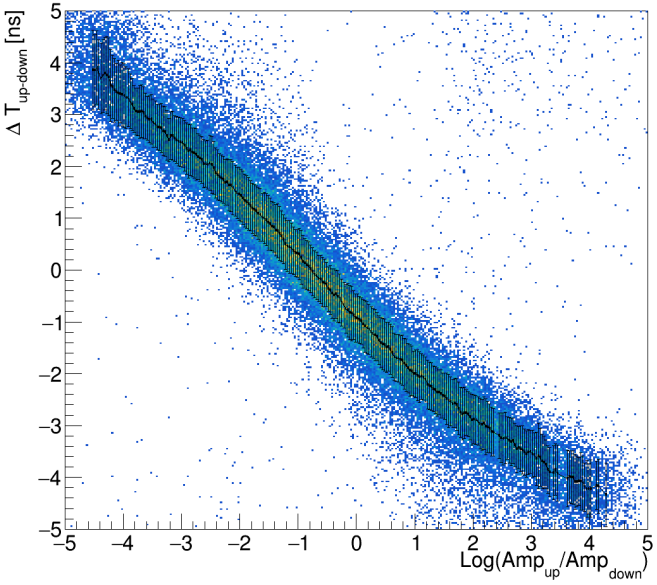
$$T_{up} - T_{down} \propto -\ln\left(\frac{A_{up}}{A_{down}}\right)$$

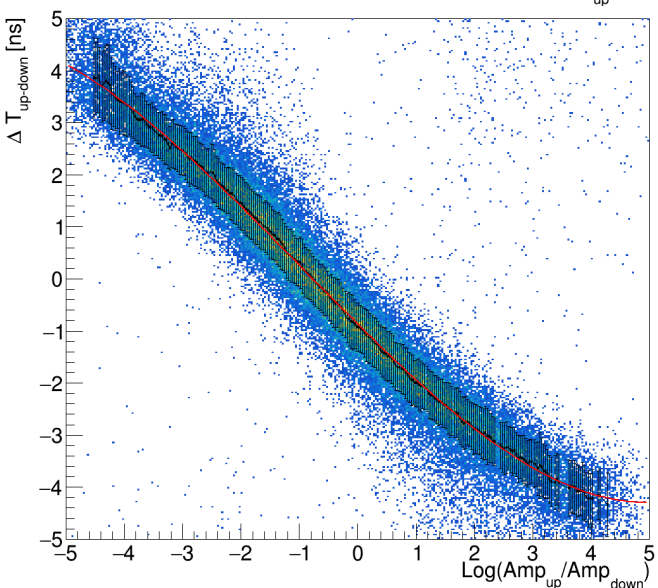
Not exactly exponential (as expected)

Hit position reconstruction









Re-TOF: Start-TofWall coincidences

Expected TOF of elastic scattered protons

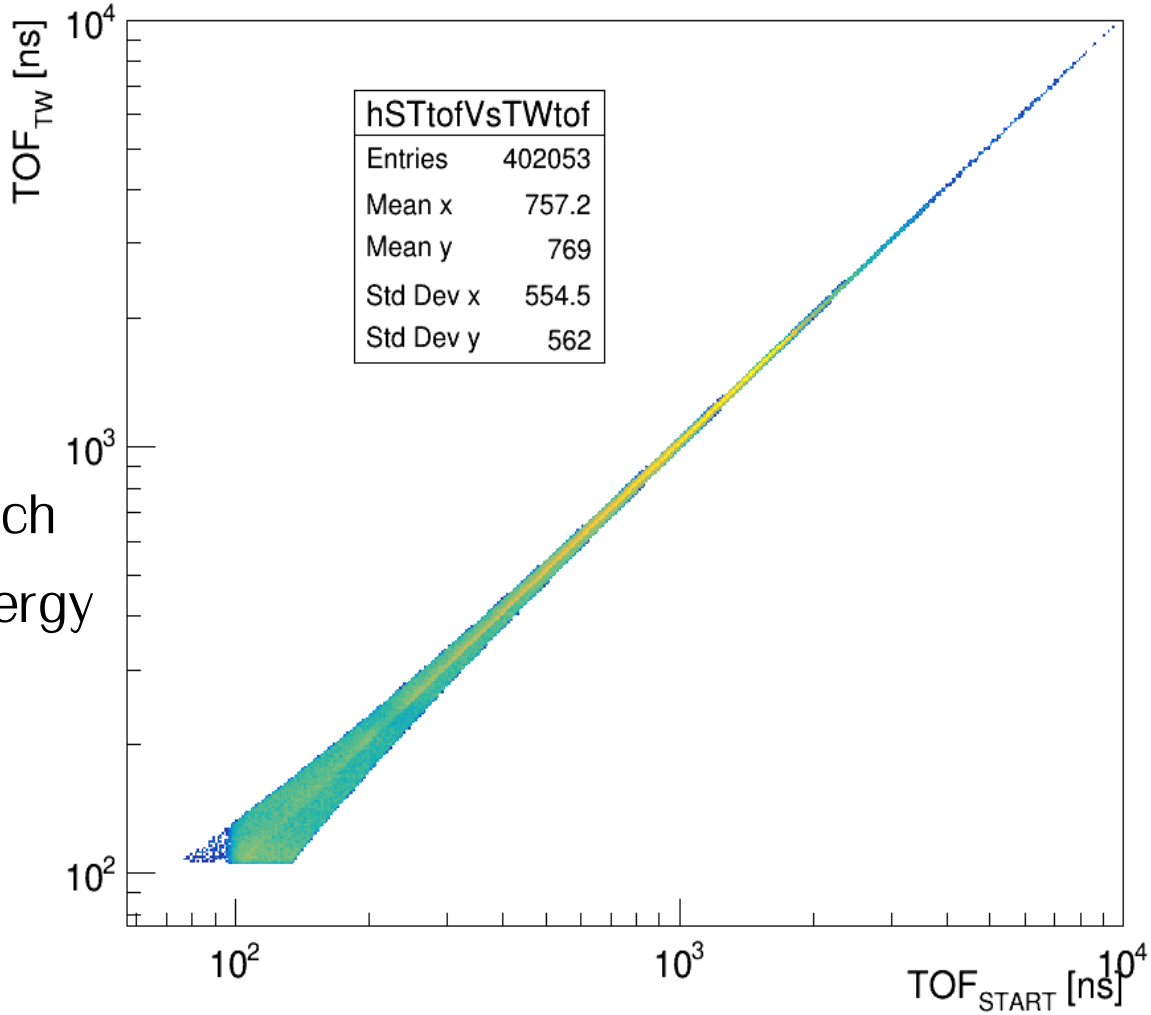
$$(TOF_{TW} - TOF_{ST})_{el} \simeq TOF_{p,el}(E_{p,el})$$

Wide coincidence window (30 ns)

Background from combinatorial approach

➔ Selection not optimized for high energy

All bars, PE sample

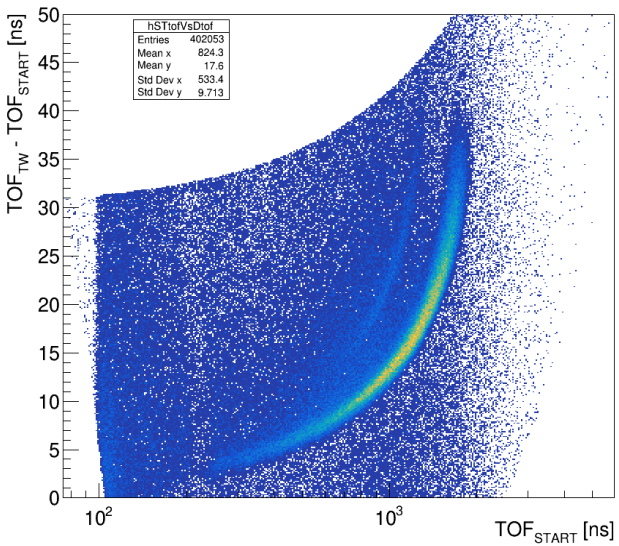


Re-TOF: Start-TofWall coincidences

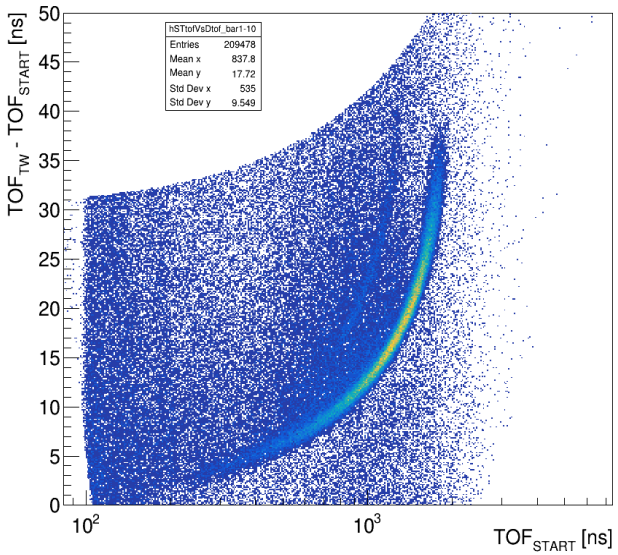
$(n,p)_{el}$ coincidence time request per bar

- TW covers btw 20-30° from beam line ⇨ $0.75 < cos^2(\theta) < 0.88 \rightarrow \Delta\left(E_p|_{E_n}\right) \simeq 15\%$
- Each bar at slightly different angle
  - Angle coverage of 0.5°
  - Much narrower proton energy distribution → TOF coincidence window optimization

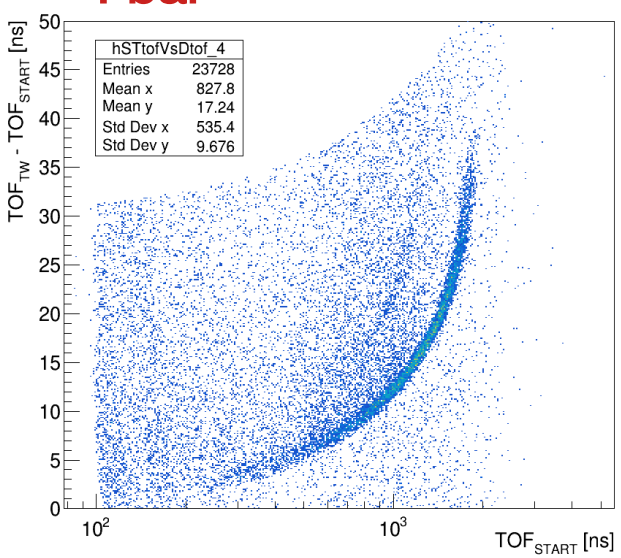
All bars



10 bars

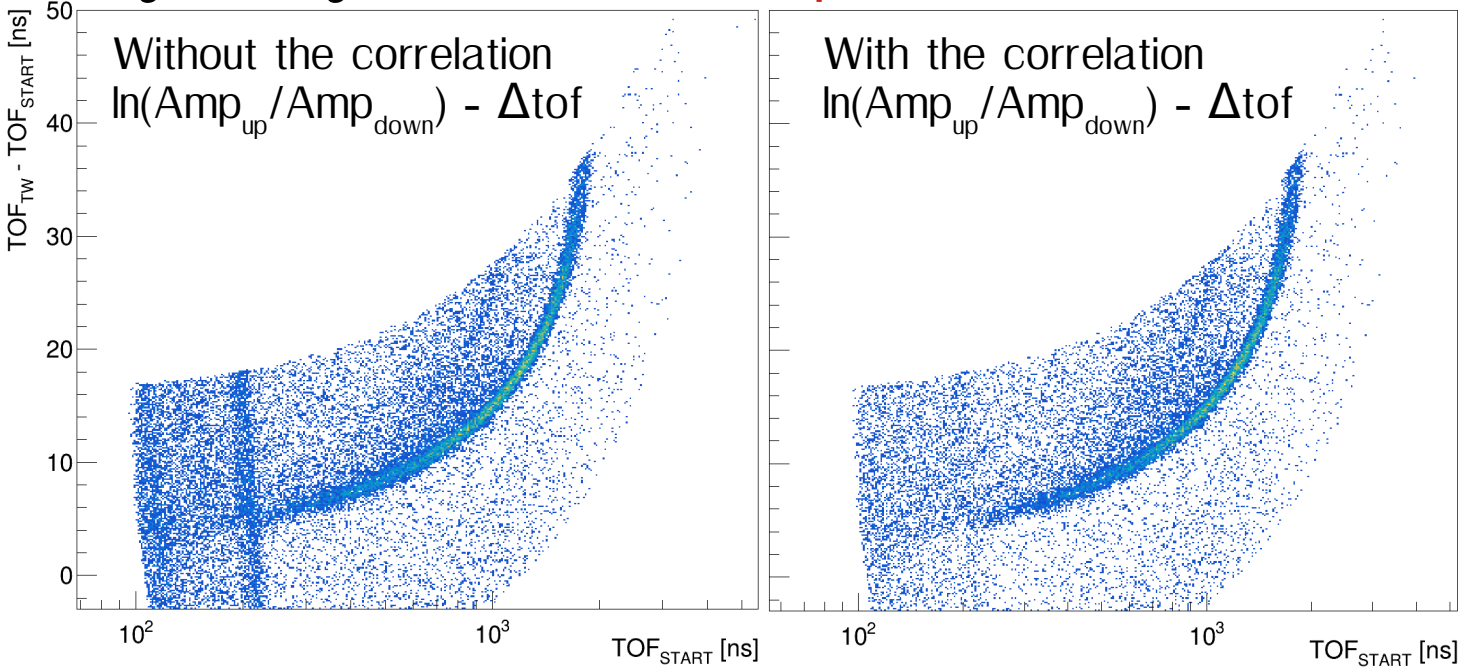


1 bar



Re-TOF: Start-TofWall coincidences

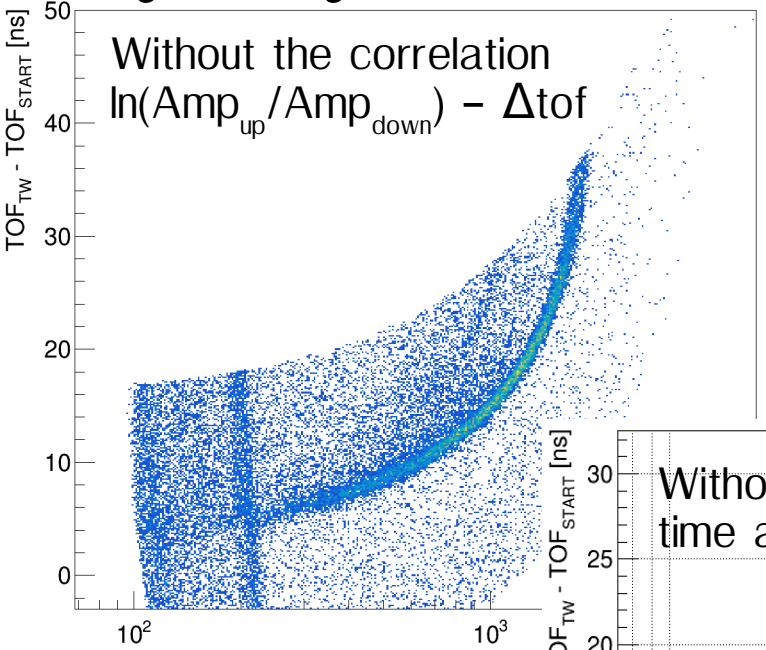
Looking at a single bar... Bar 6, PE sample

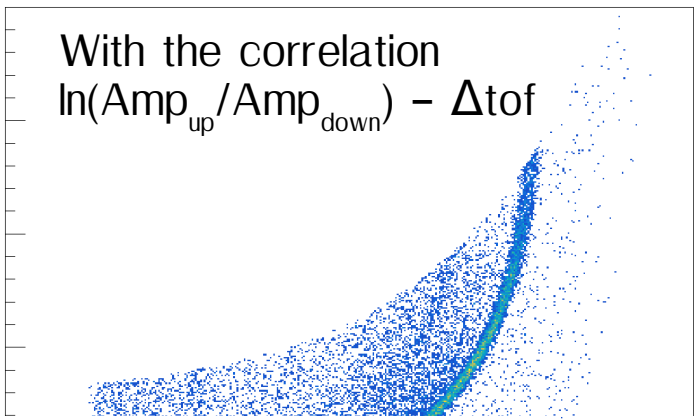


Background from random coincidences and combinatorial: coincidence window ± 15 ns

Re-TOF: Start-TofWall coincidences

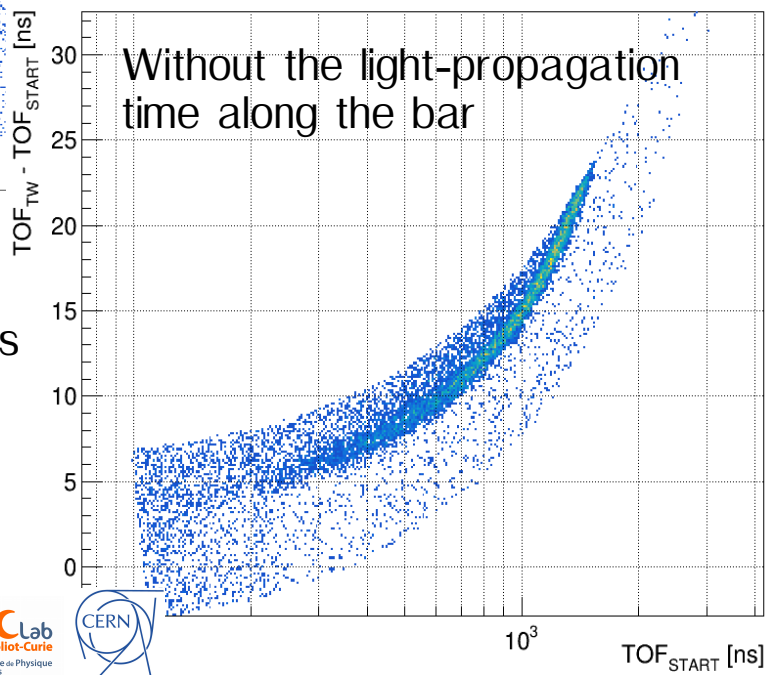
Looking at a single bar... Bar 6, PE sample

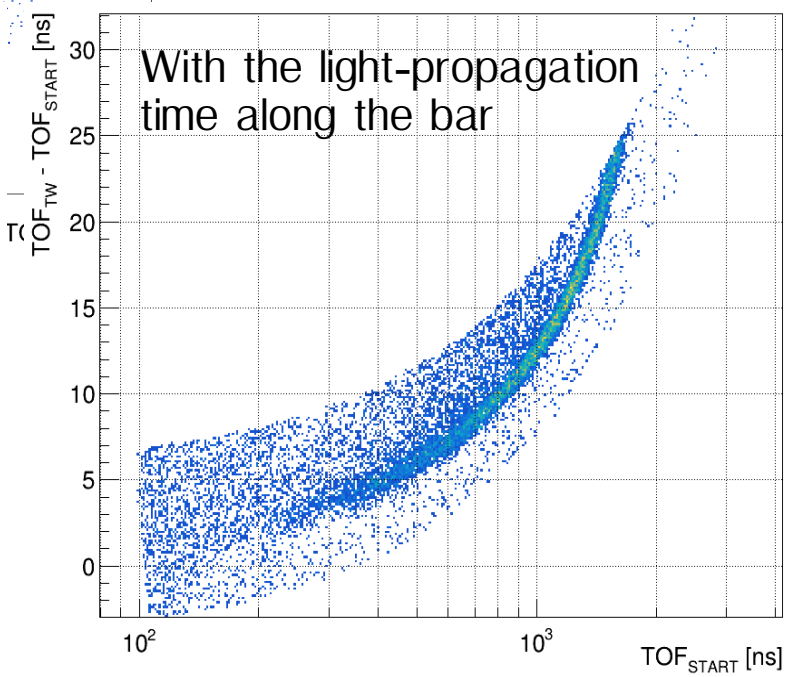




Background from random coincidences and combinatorial: coincidence window ± 15 ns

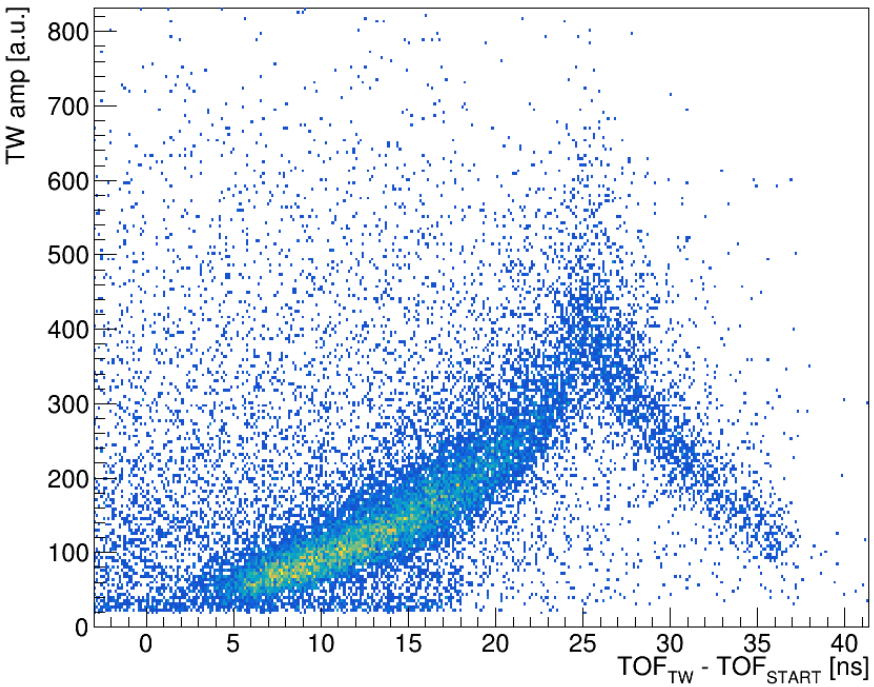
coincidence window ± 3 ns

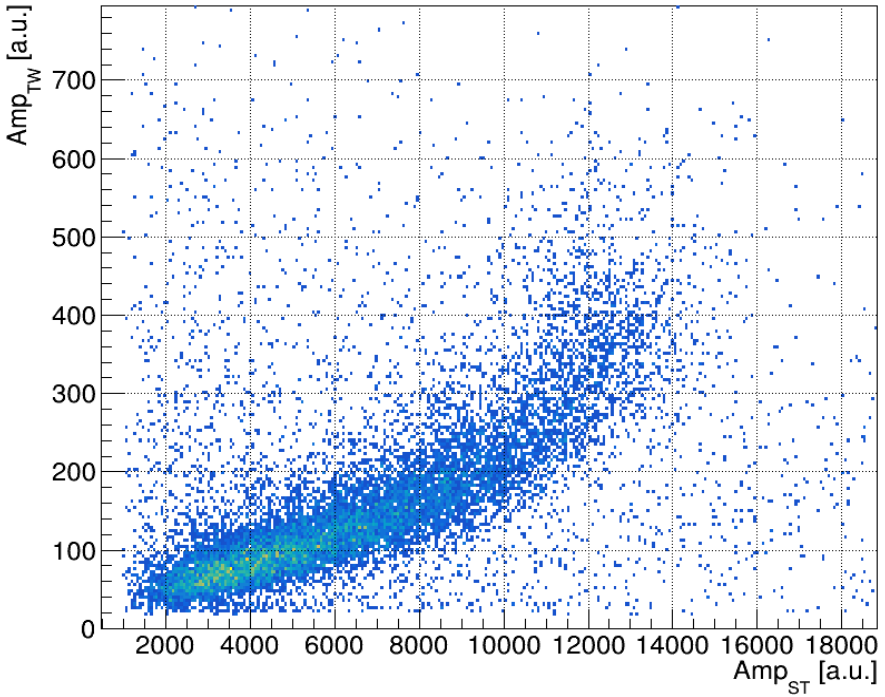




What's next...?

1. Amplitude constrain:





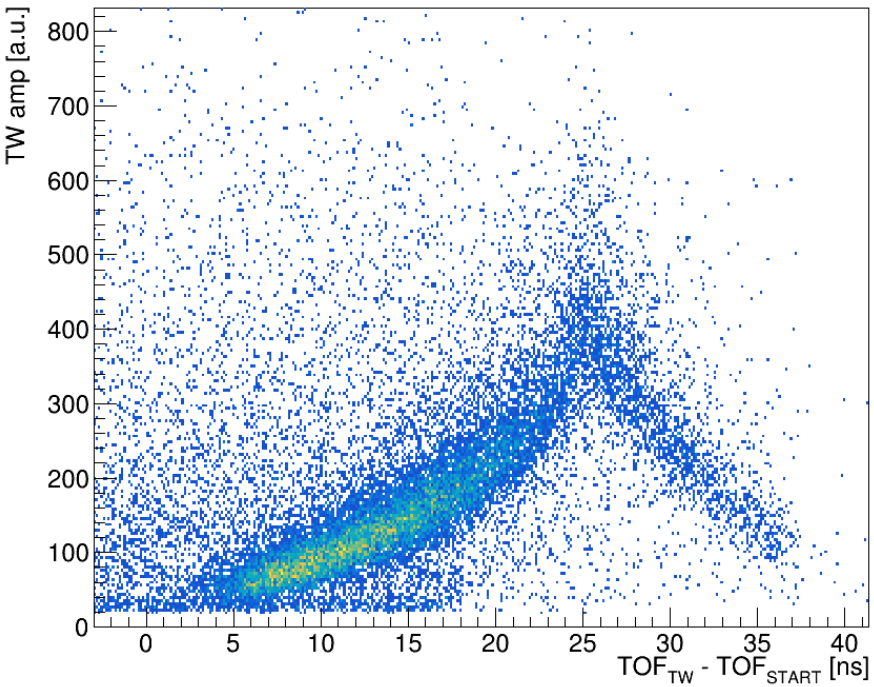
2. Improve PSA for the Tof-Wall detector

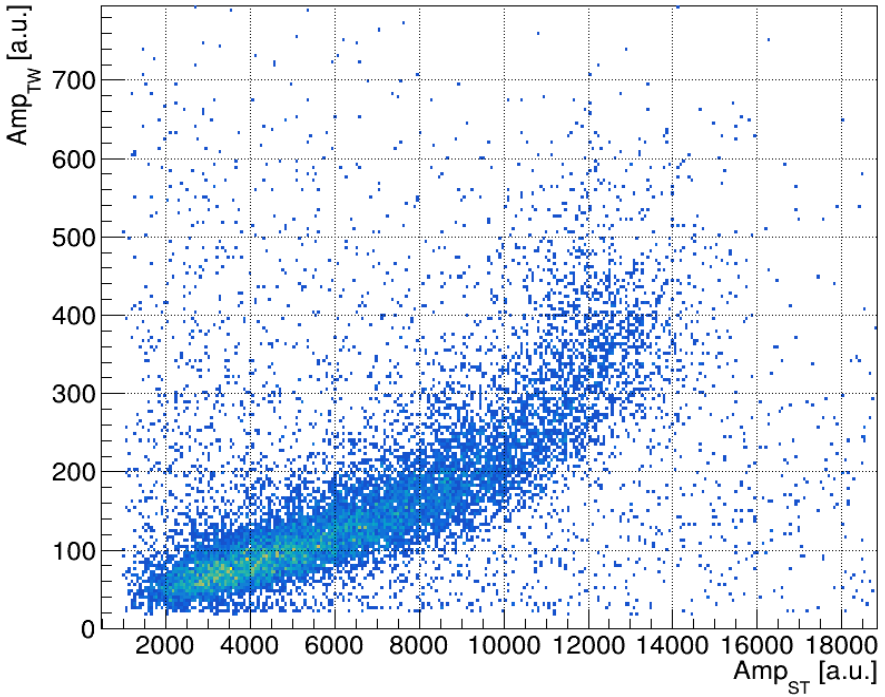
3. Is it possible to not measure C background?

4. Reconstruct the neutron flux

What's next...?

1. Amplitude constrain:





2. Improve PSA for the Tof-Wall detector

3. Is it possible to not measure C background?

4. Reconstruct the neutron flux

Thank you for your attention