Study of the timing performance and eletronic response of the SBT 4cells prototype

WOM-based liquid-scintillator detector 2 (WP 2.1)

4th High-D Consortium Meeting

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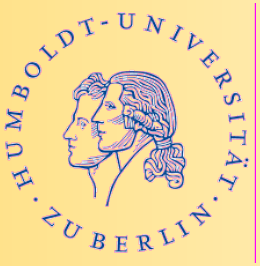
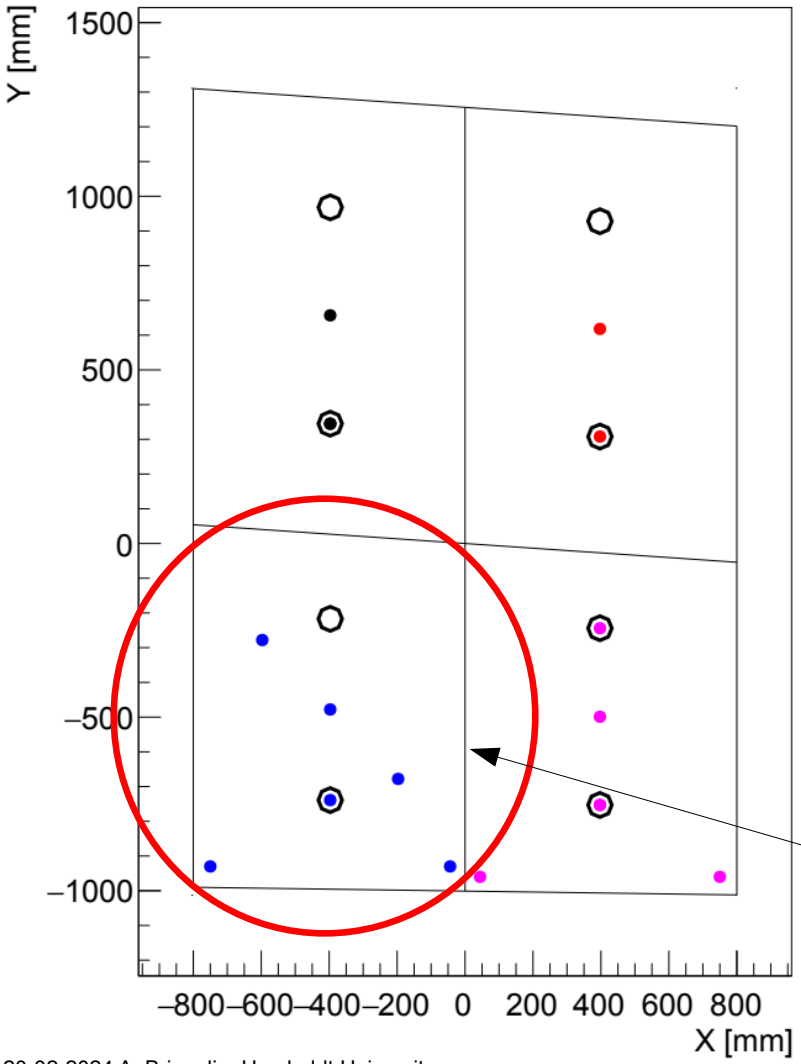
20th February 2024



Test beam measurements



Test beam measurements:

- 5000 events per position

- 5 GeV muon

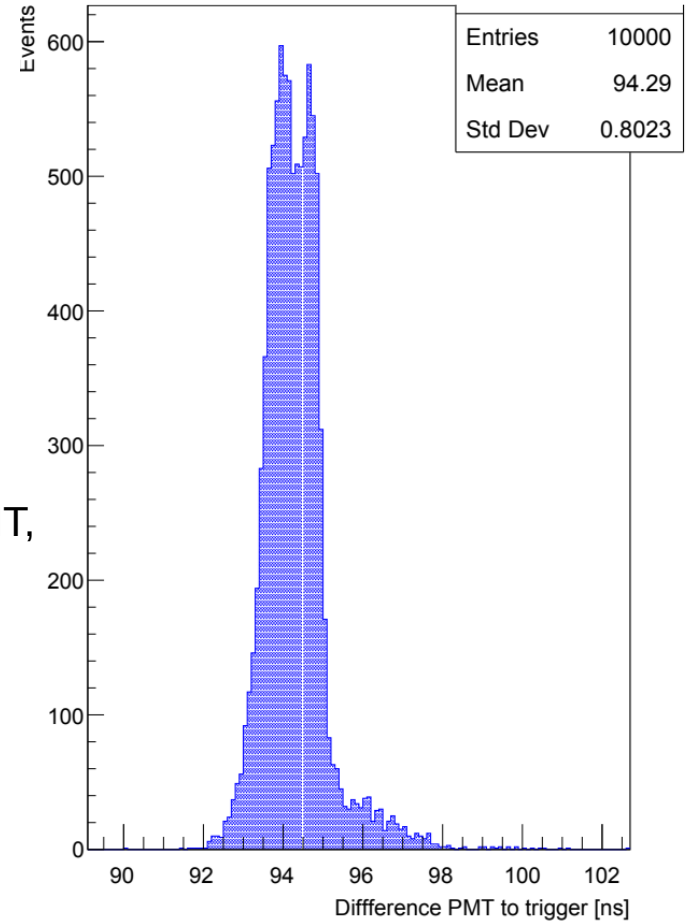
- beam – σ = 13mm

- trigger:
  beam telescope (4PMTs),
  in front of the detector
  +
  additional scintillator with PMT,
  in the back of the detector

  resolution O(0.8 ns)

- 0° - 0° rotation
  For this analysis

Time distribution, beam telescope PMT



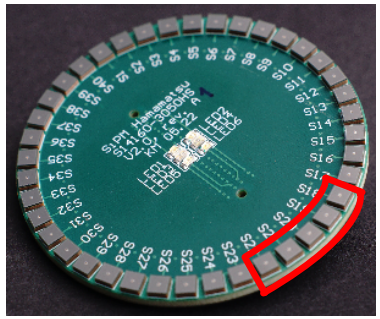
Time response

The time response of the detector has been calculated as the average time response of the two WOMs for each cell:

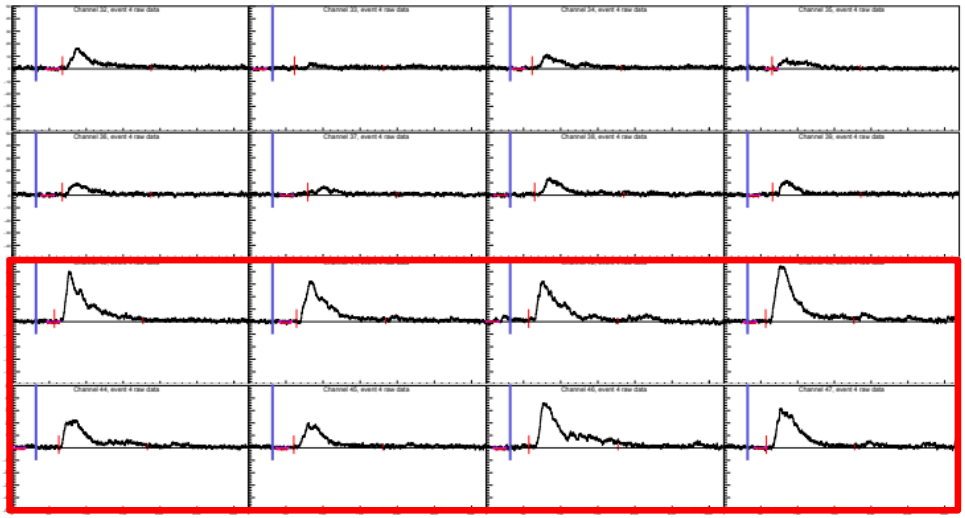
1. Sum of waveforms over each WOM, per event

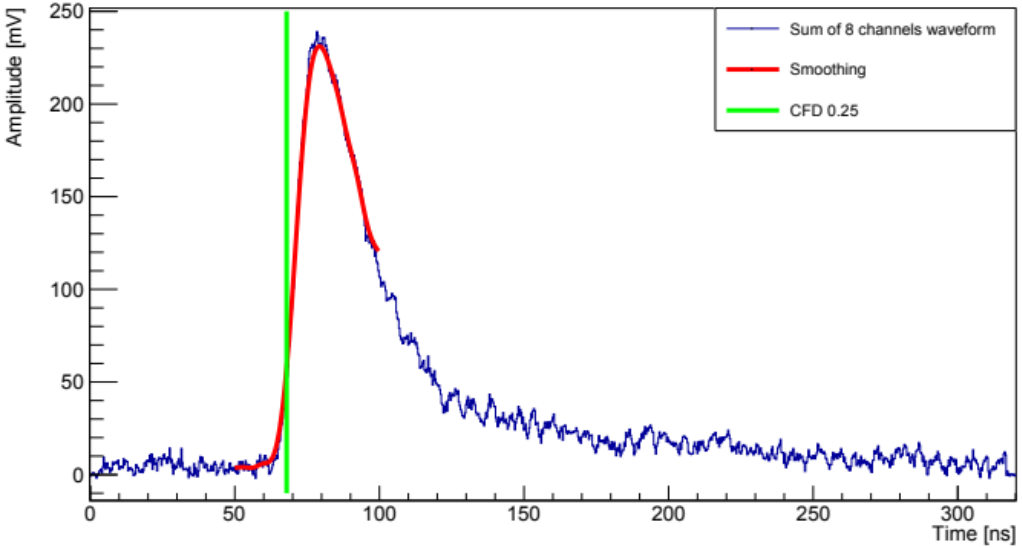
2. Smoothing and Constant Fraction Discrimination (CFD) at 25%

3. Average of the two WOMs, per event j: $T_j = \frac{1}{2}\left(T_{WOM_{up},j} + T_{WOM_{down},j}\right)$

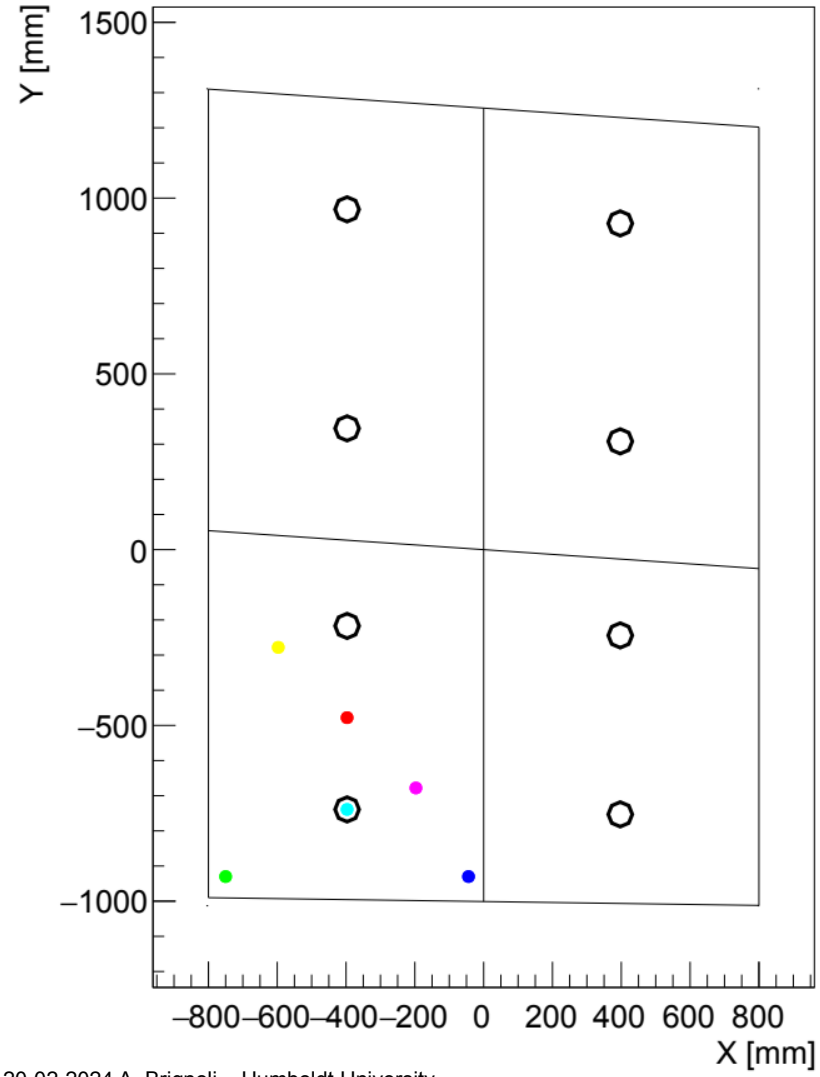


SiPMs grouped in 8 group of 5 SiPMs each (channels)





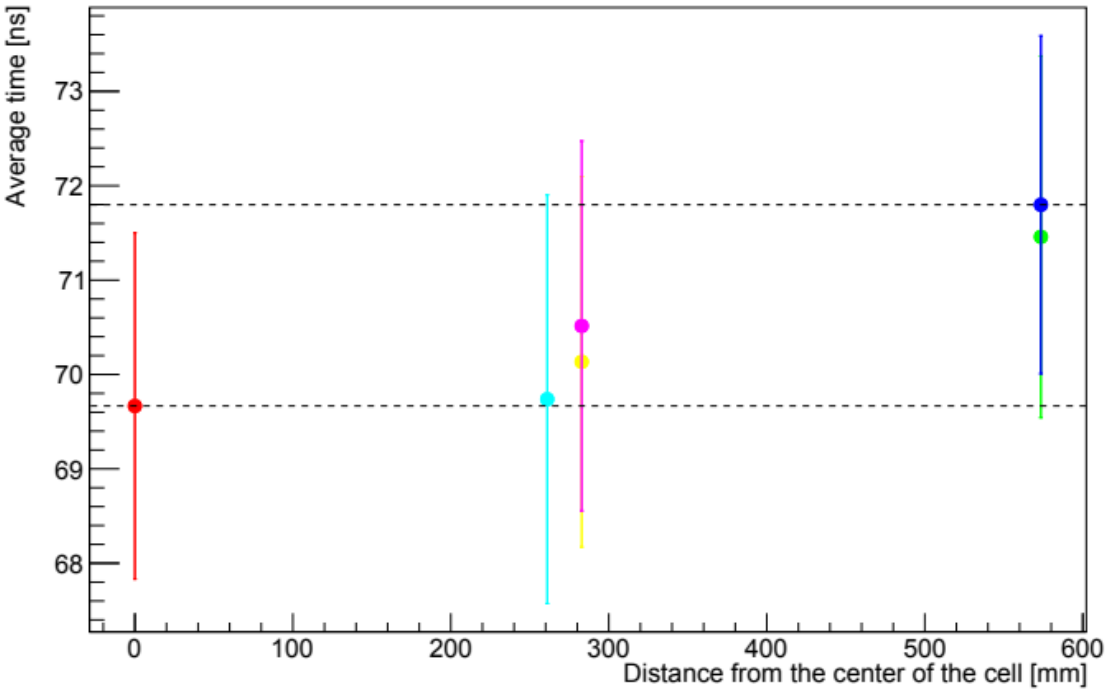
Time response



The shown results are mean and standard deviation of the average time distribution

Time variation over a cell of the detector: $\pm$ 2ns

→ Reducible with likehood method



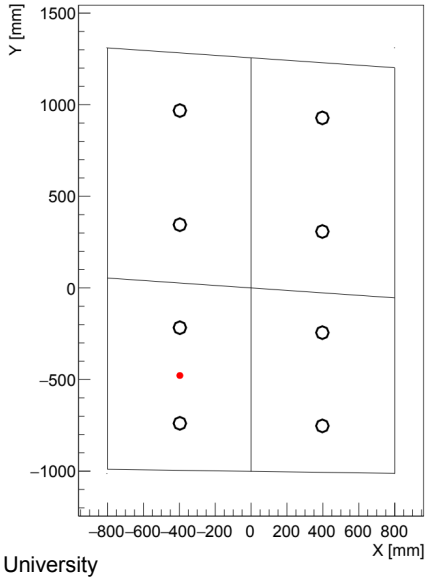
Time response

In order to get the time resolution for a fixed position, calculation of the time difference in the central position of the box:

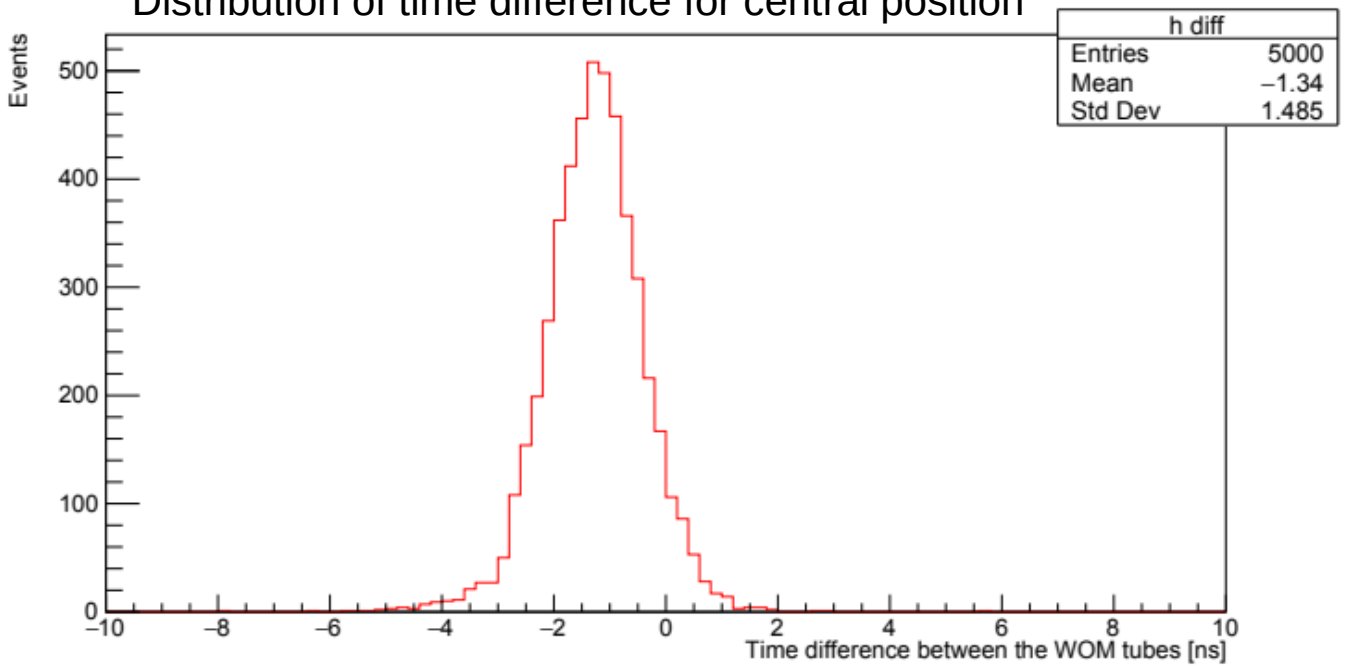
From the distribution, the error is 1.49 ns

→ time resolution for the two WOMs:
1.04 ns

→ time resolution on the average time:
0.52 ns



Distribution of time difference for central position

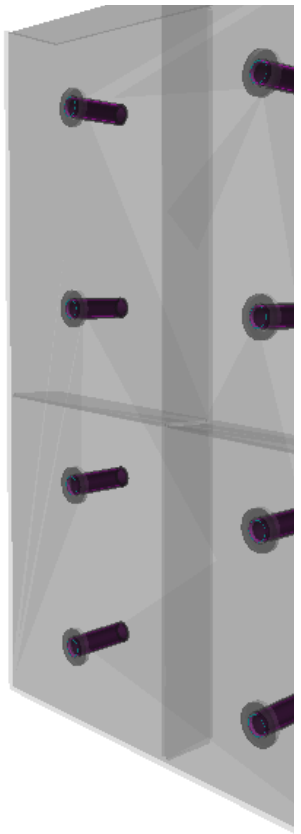


Geant4 simulation

Geant4 simulation of the 4 cells detector
with geometry and materials properties implemented with high precision

Originally, the final output of the simulation was the photons arrival times

To have a better comparison between data and simulation, regarding time response and light yield, implementation of the electronic response of the SiPMs



Simulating the waveform

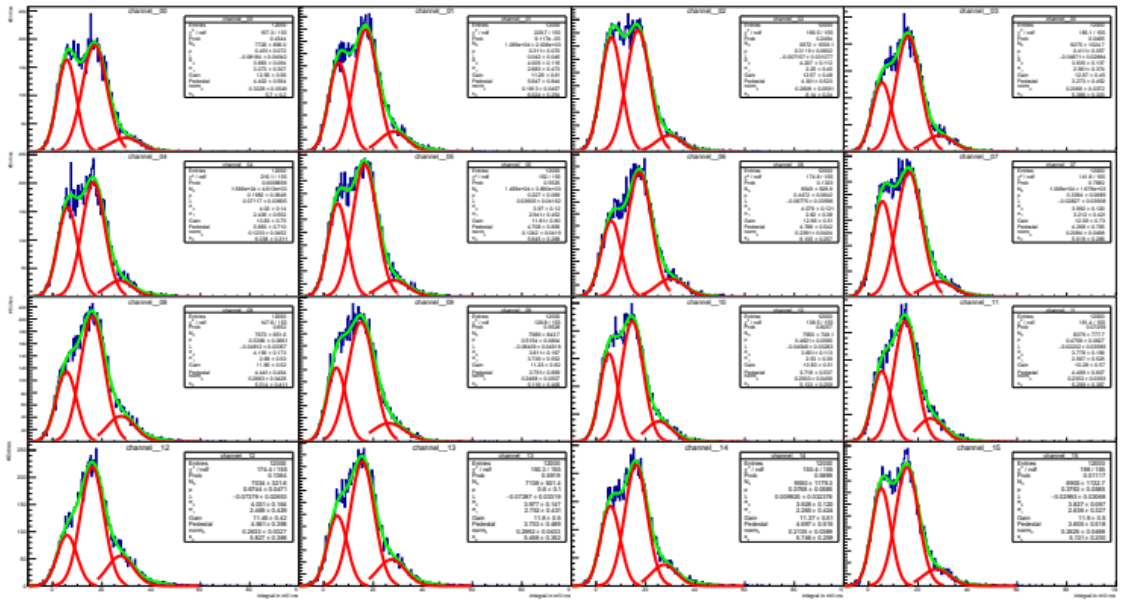
From dark count charge spectrum:

(no beam; trigger on random signal; search for the maximum of amplitude in the whole 320 ns window, per event: integrating 5 ns before maximum and 9 ns after)

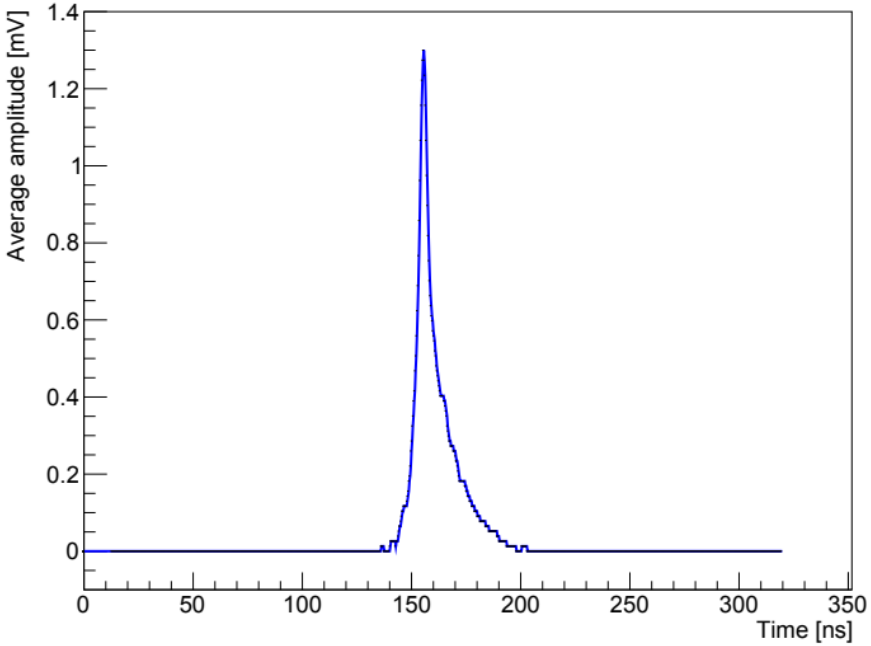
→ 1pe waveform → Dark count probability ~ 75% → Electronic noise ~ 1mV

→ Gain → Crosstalk probability ~ 17% → After pulses probability and time (not yet)

Dark count spectra

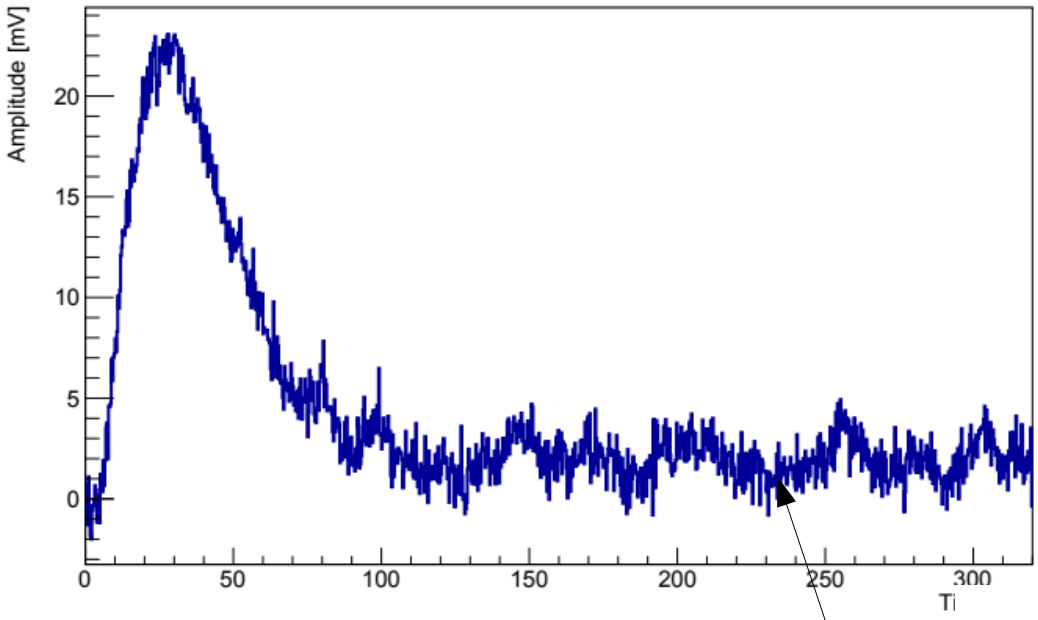


1 photoelectron waveform

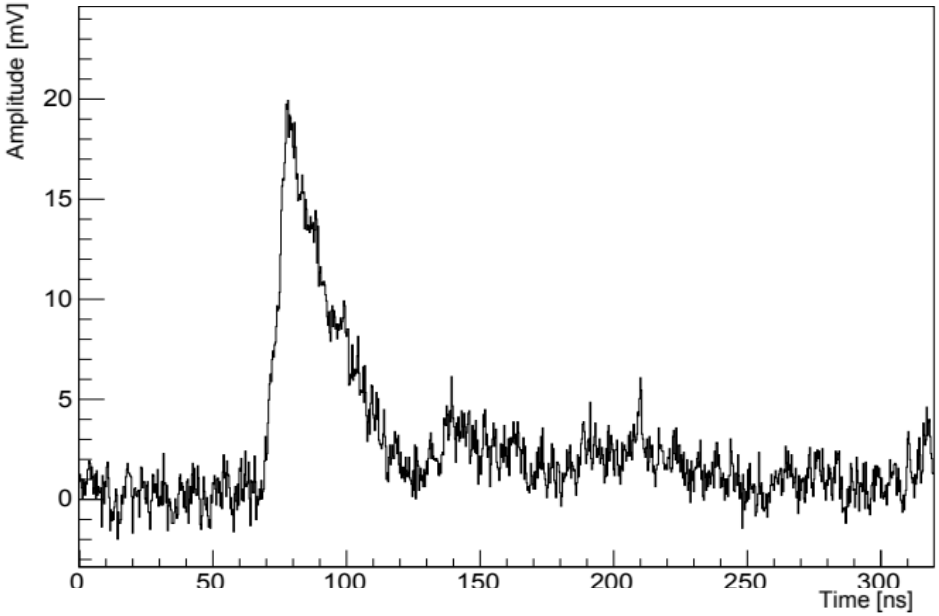


Simulating the waveform

Example of simulated waveform



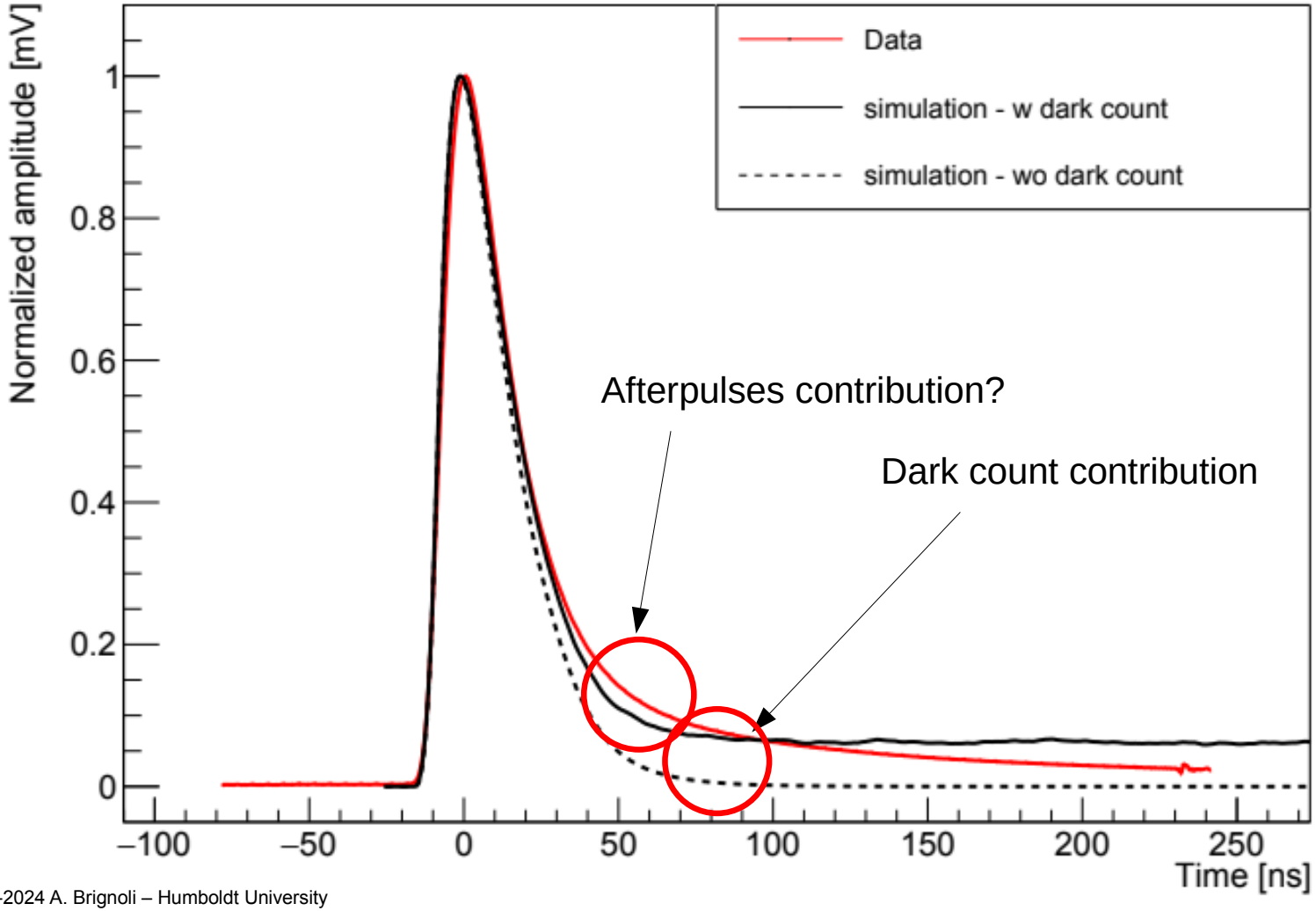
Example of waveform from data

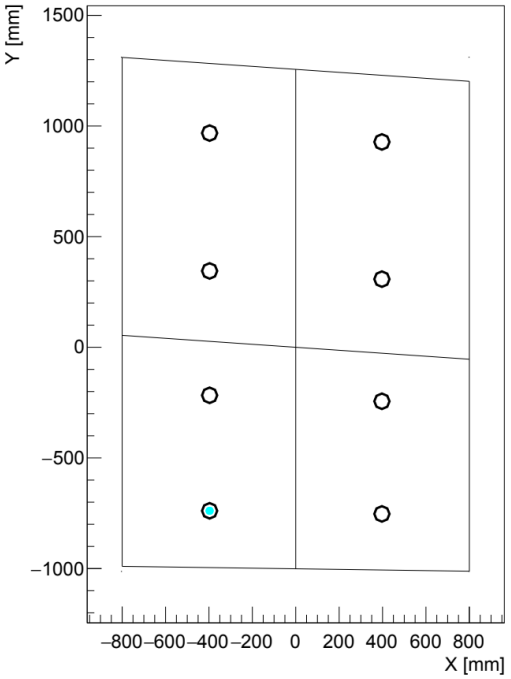


Simulated electronic noise

Shape of the waveform

Average waveform





Comparison with the data

Simulation settings that play important roles in the waveform generation:

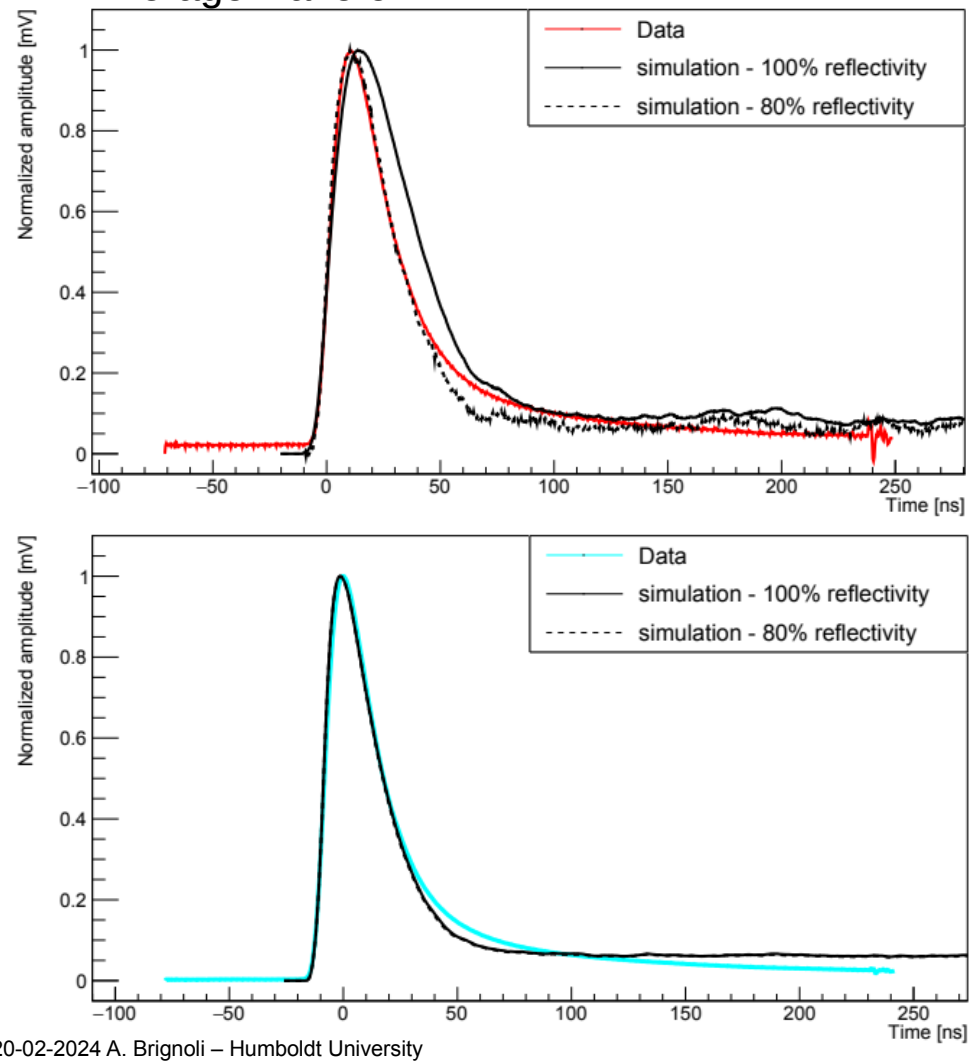
for the amplitude	for the shape
→ LAB-PPO transparency	→ LAB-PPO transparency
→ Cell coating reflectivity	→ Cell coating reflectivity
→ SiPMs Optical coupling	

Other possible sources of discrepancies:

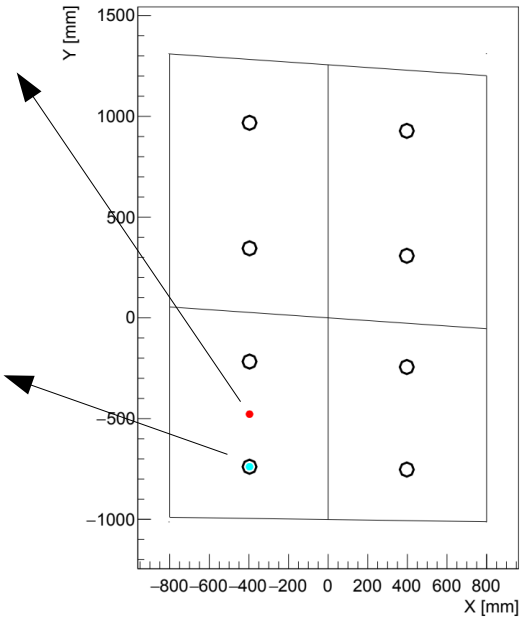
→ PMMA transparency	→ Scintillation decay times
→ WLS coating thickness	
...	

Reflective coating

Average waveform

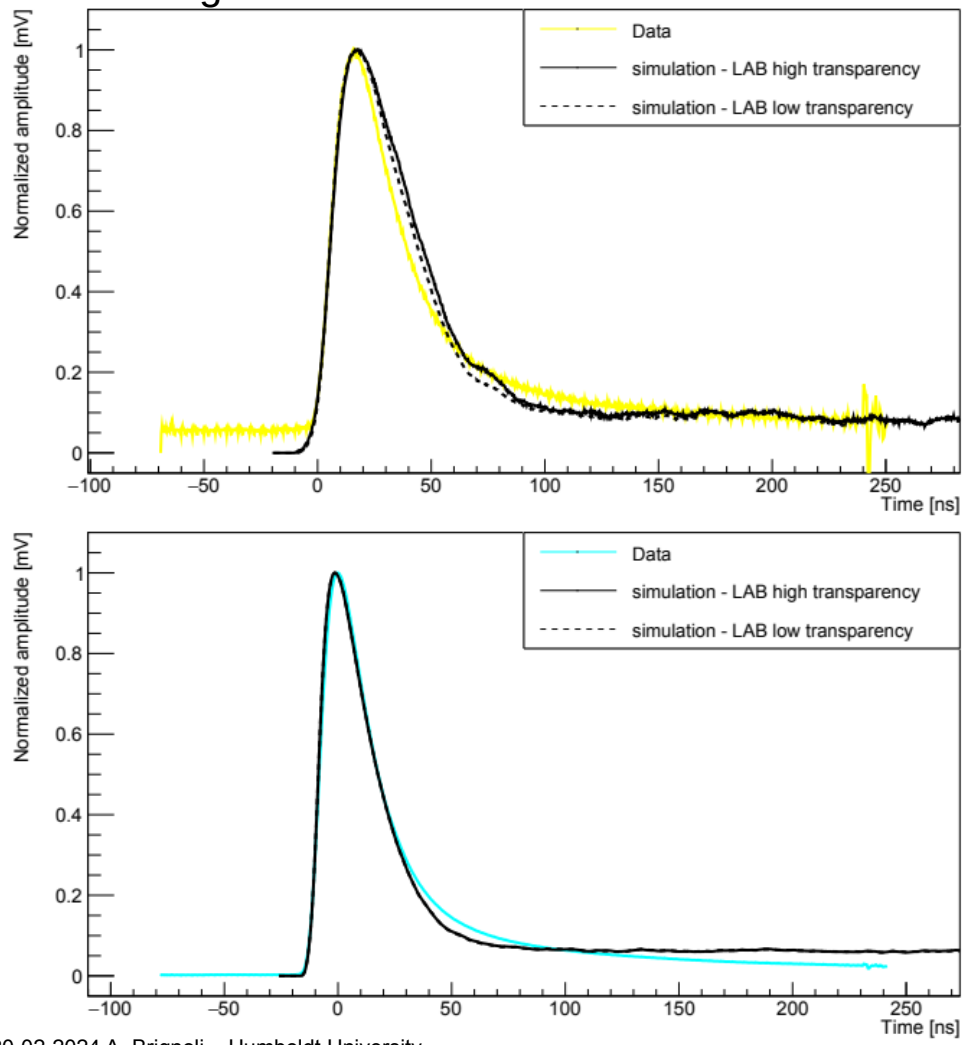


- Depends on the position of the beam
- Effect on the falling edge of the waveform
- Depends on the different cell



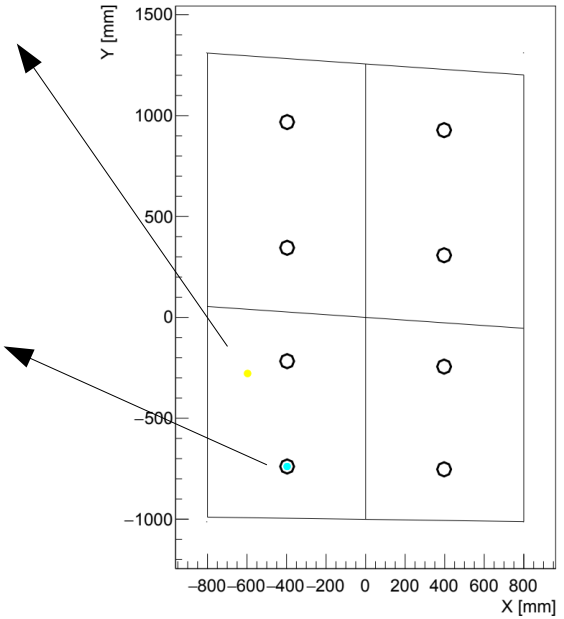
Liquid scintillator LAB

Average waveform



- Depends on the position of the beam, correlated with reflectivity

- Effect on the falling edge of the waveform

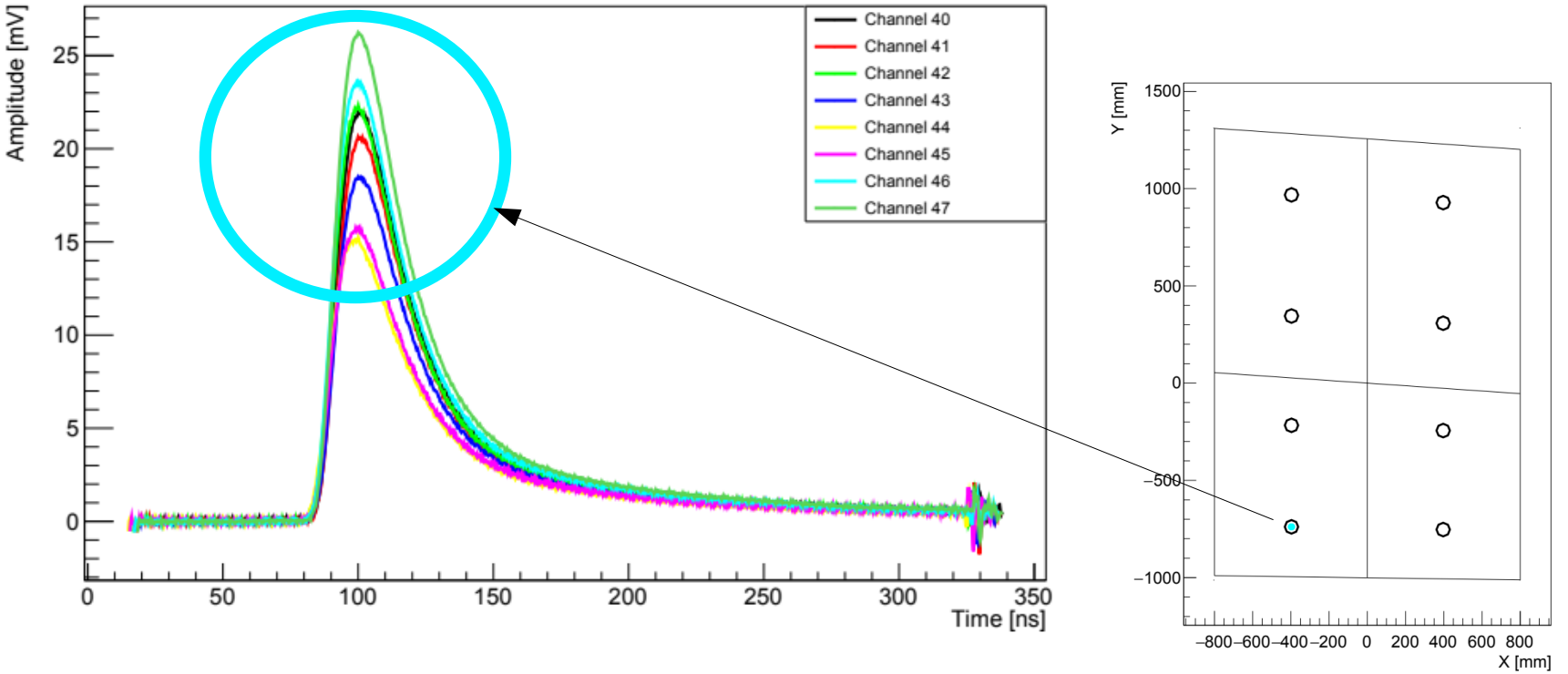


Optical coupling

Difference in channels response, due to:

→ Optical coupling

Analysis and comparison with simulation performed on the sum waveform over 8 channels of the WOM



Conclusion

Regarding the time response:

- Time variance over one cell: ± 2 ns → can be improved with likelihood method
- Time resolution for a fixed position: ± 0.52 ns

Regarding the simulation, it is still a work in progress but:

- Good agreement of the rising edge of the waveform
- Studied how properties of material can affect the waveforms
- Spotted significant differences depending on the channel → Using summed waveform over WOM

Outlook

- Improving of the simulated waveform → implementing afterpulses
  → checking dark counts
  → further investigation over the falling edge

- Calibration of the electronic response for all the WOMs
- Realization of the time and light yield analysis on the simulated waveforms and comparison with the data
- Acquisition of more data/positions during the next testbeam (March 2024)

Thank you