Time response and efficiency of the 1-cell SBT detector

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3rd High-D consortium meeting

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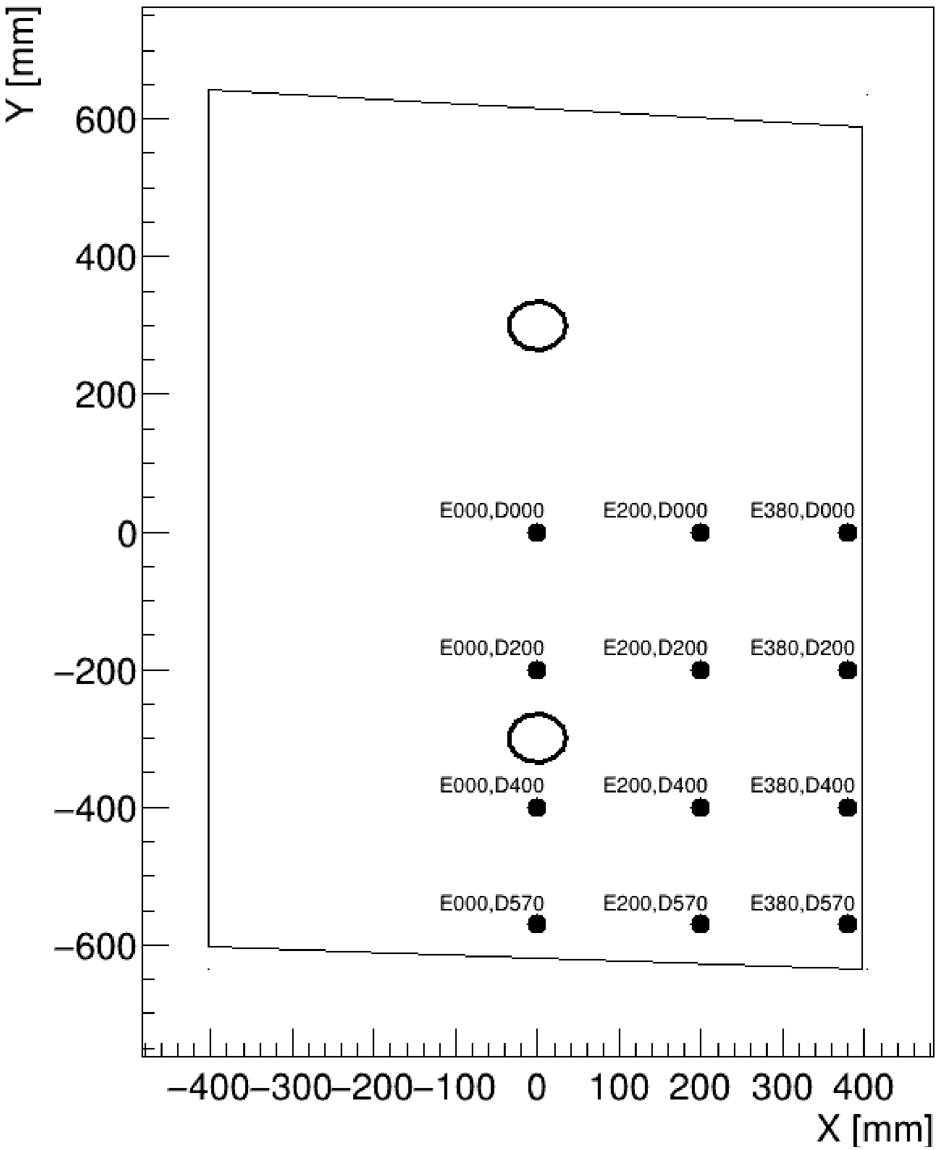
Test beam

Test beam October 2022 – DESY (Hamburg)

Measurements:

- different positions



Test beam

Test beam October 2022 – DESY (Hamburg)

Measurements:

- different positions

- different rotation angles

Test beam

Test beam October 2022 – DESY (Hamburg)

Measurements:

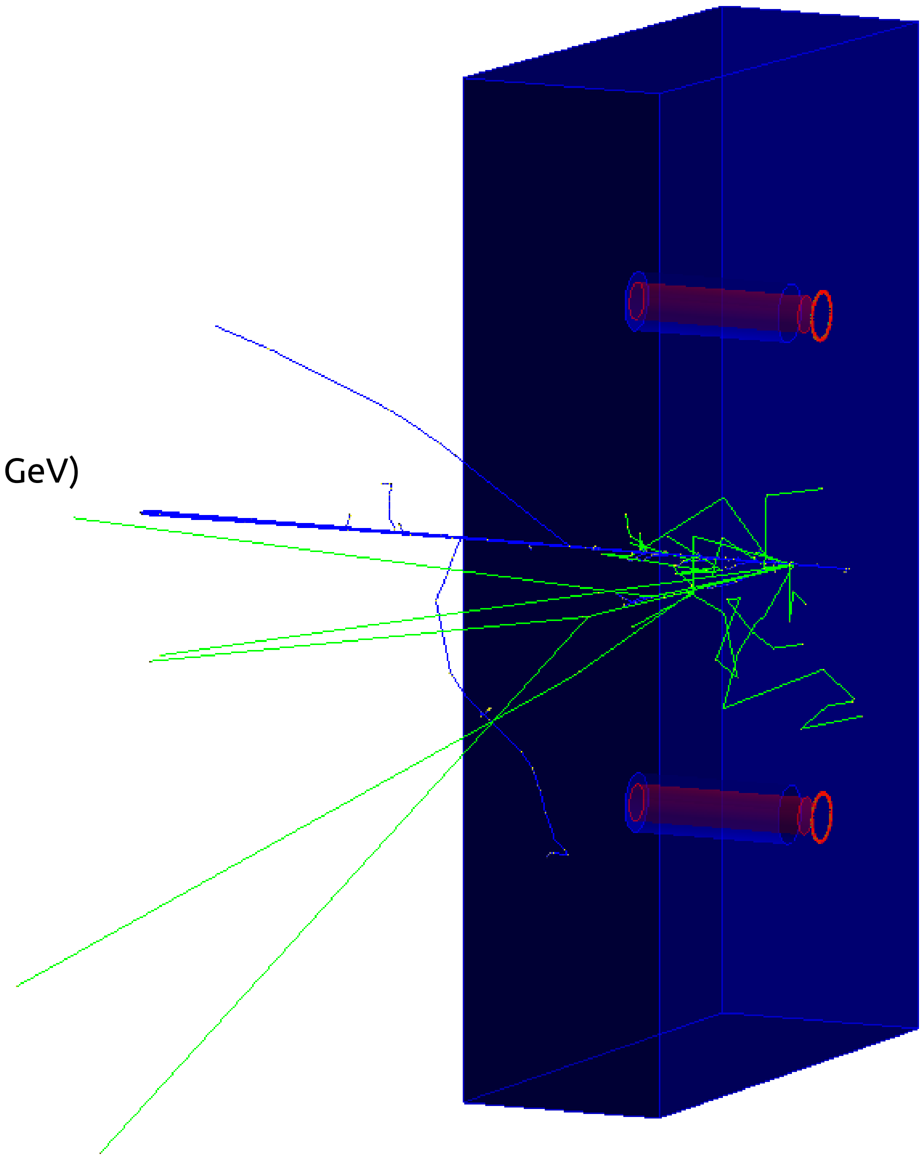
- different positions
- different rotation angles
- different beam energies (1.4 GeV, 2.4 GeV, 3.4 GeV, 4.4 GeV, 5.4 GeV)
- with and without an additional 1cm steel plate

Current results:

- calculation of the detector effiency

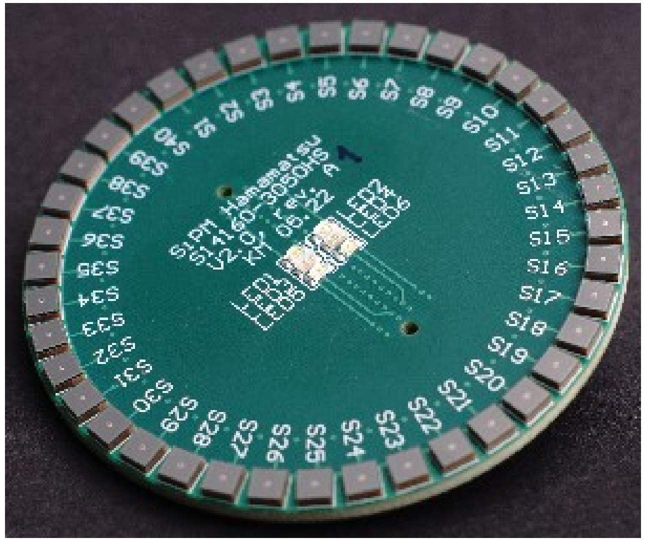
(0° rotation – 5 energies: 1.4 GeV, 2.4 GeV, 3.4 GeV, 4.4 GeV, 5.4 GeV)

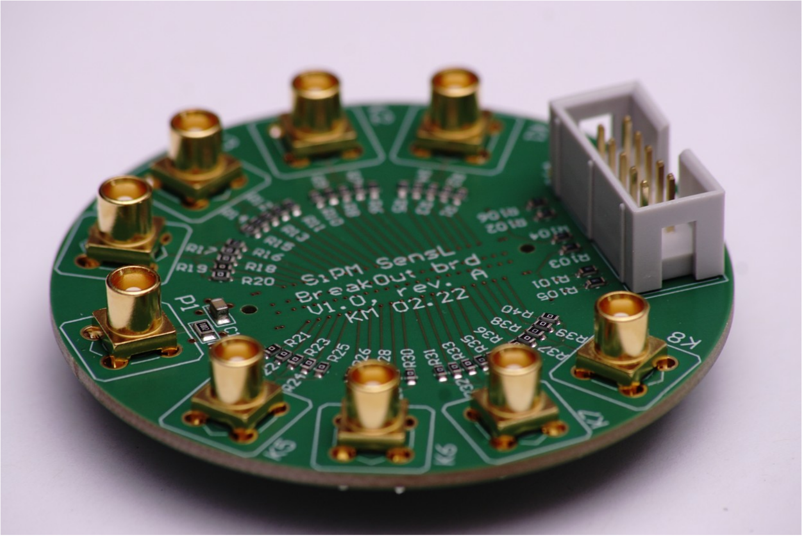
- timing performance study (0° rotation - 1.4 GeV)

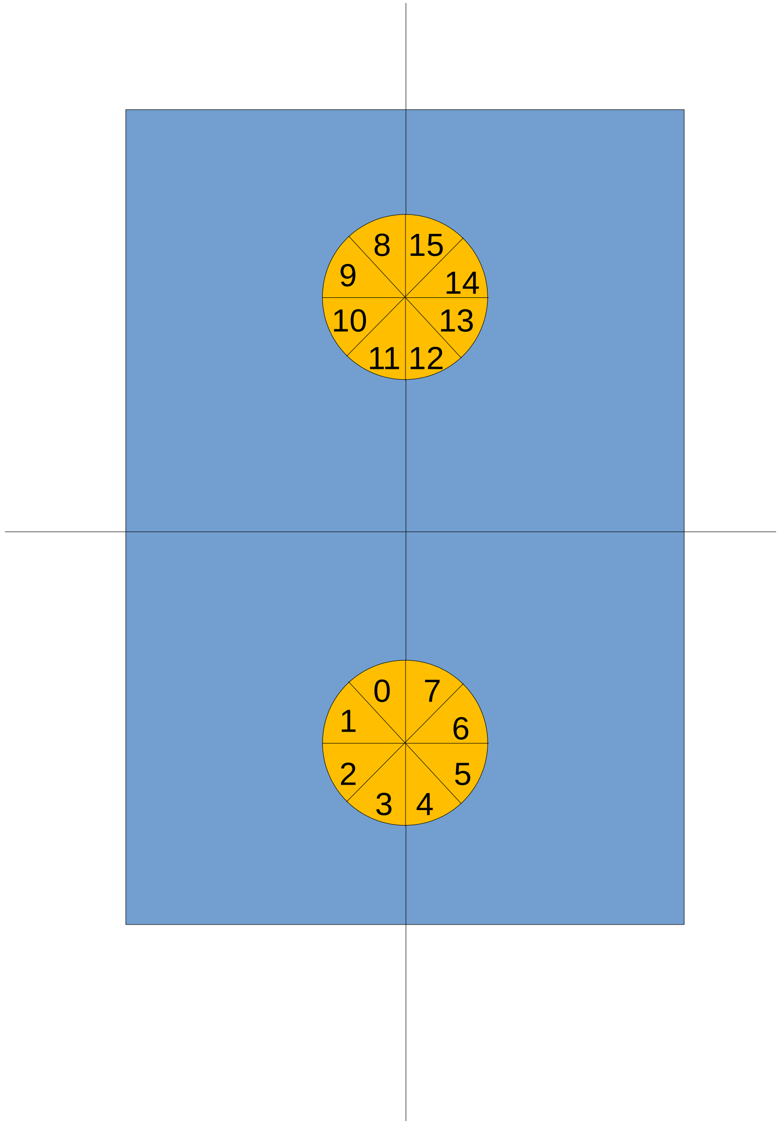


Data

- 40 SiPMs are grouped in 8 groups of 5 SiPMs each (channel)
- each channel records a waveform





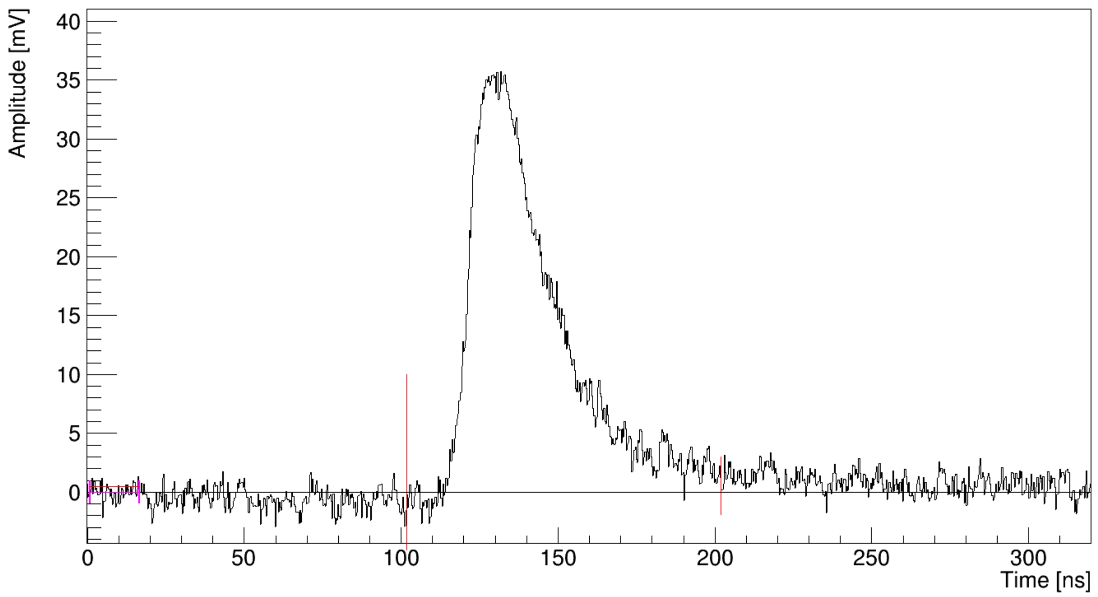


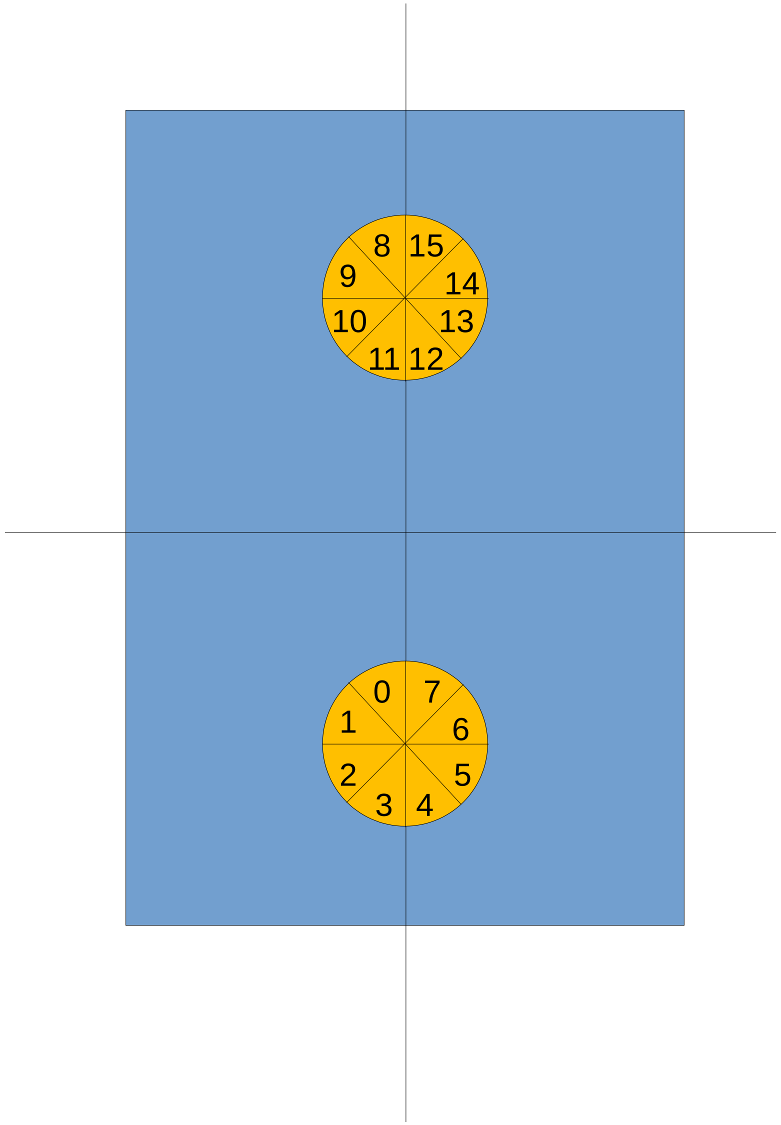
- 40 SiPMs are grouped in 8 groups of 5 SiPMs each (channel)
- each channel records a waveform

For this analysis:

- charge calculated as the signal integral in a choosen time window

- light yield calculated as the integral in a choosen time window
- first photon arrival time





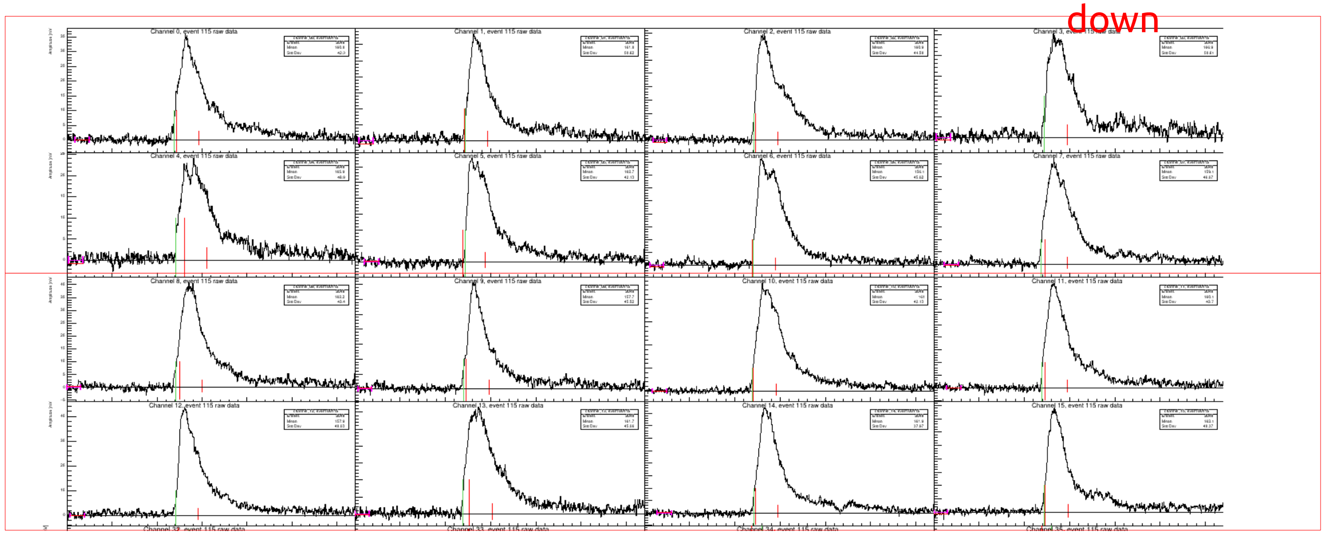
Efficiency

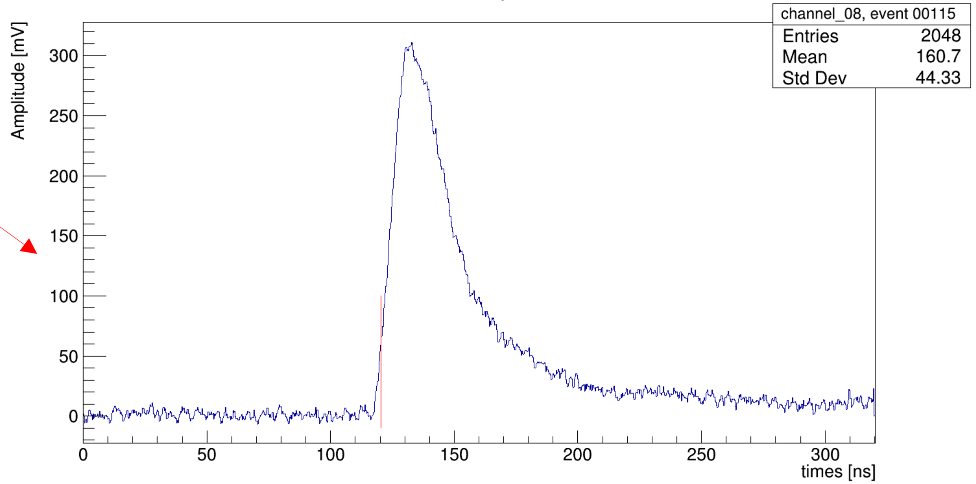
Efficiency

To calculate the charge over a WOM tube, for each event:

- sum of waveforms

WOM down





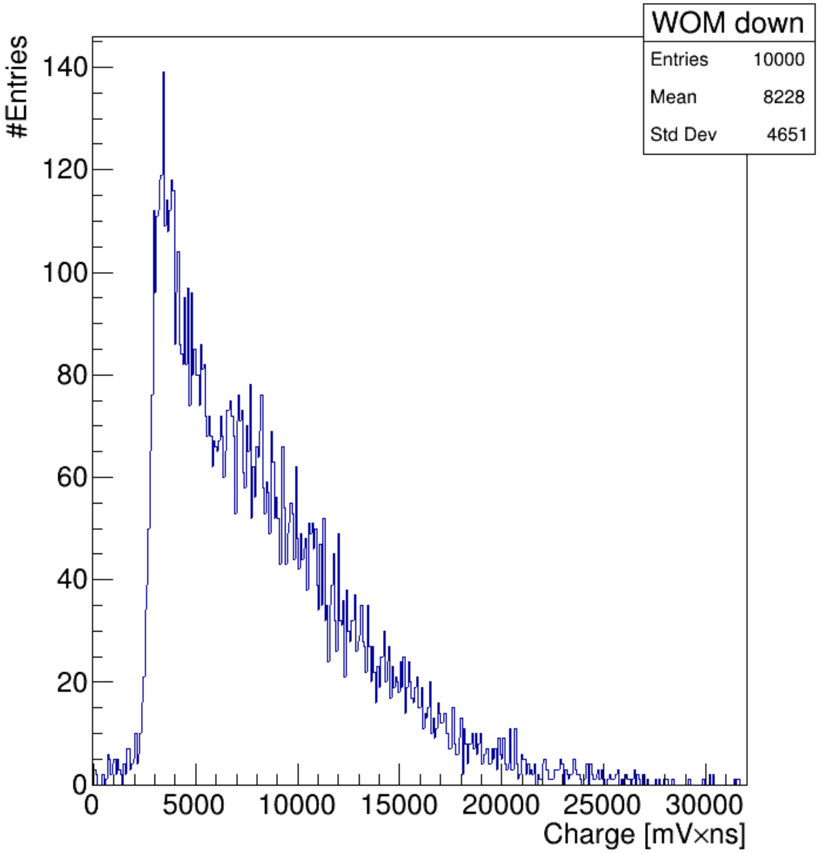
WOM up

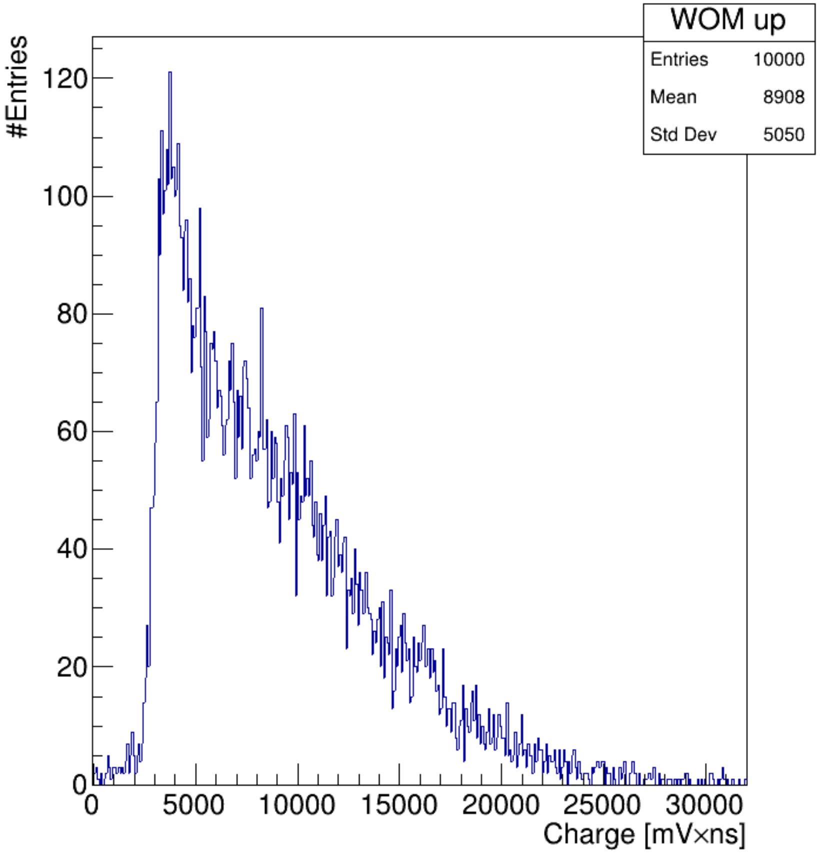
Efficiency

To calculate the charge over a WOM tube, for each event:

- sum of waveforms

- integral over 20 ns





Efficiency

To calculate the efficiency:

$$\frac{N_{triggered} - N_{rejected}}{N_{triggered}}$$

With 68% confidence interval quoted using the ClopperPearson method

The rejected events are dark count events

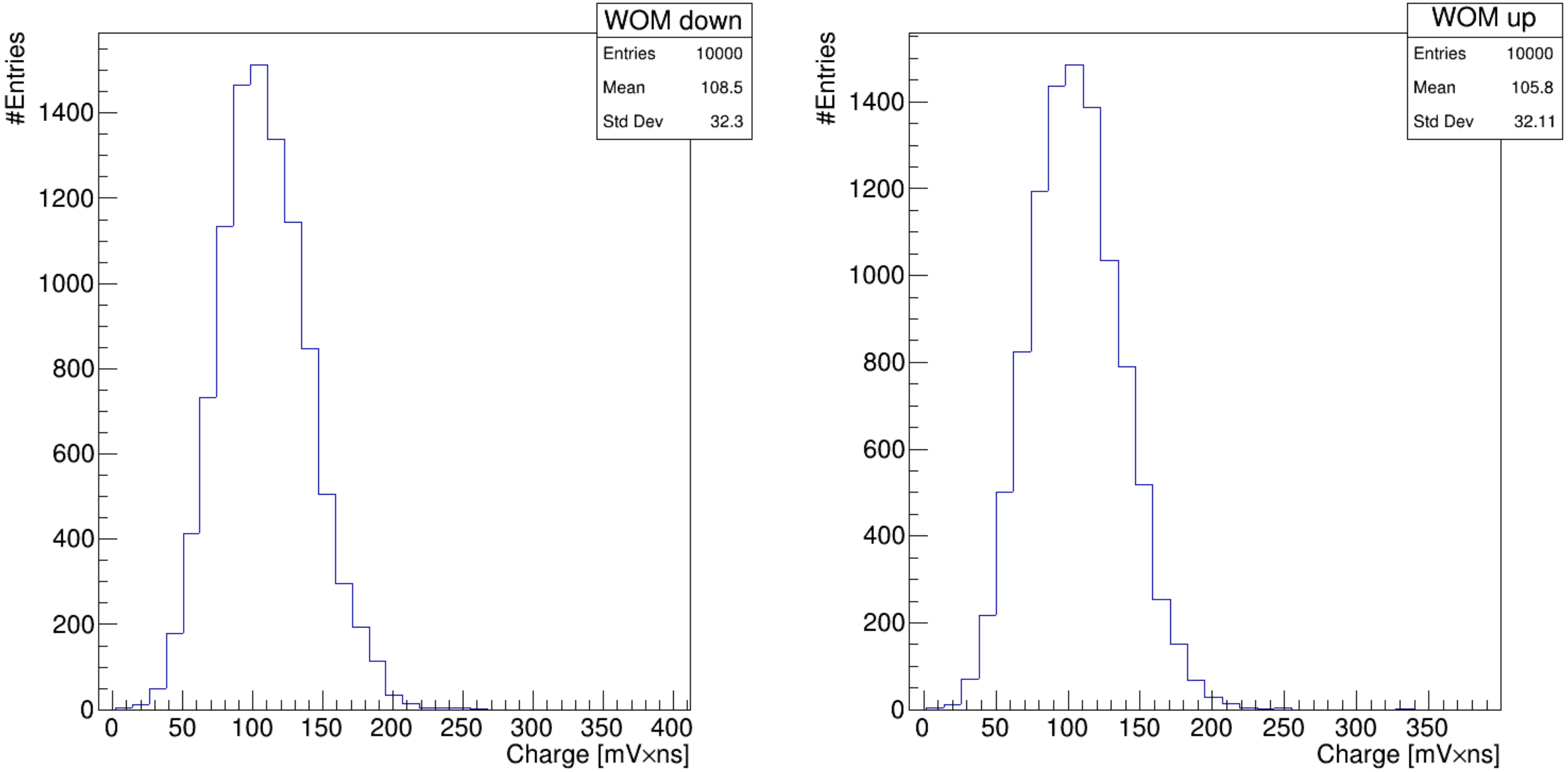
To decide where to apply the rejected cut a dark counts measurement was used

Dark count measurements

The dark counts measurement was performed:

- triggering on one of the beam telescope PMTs

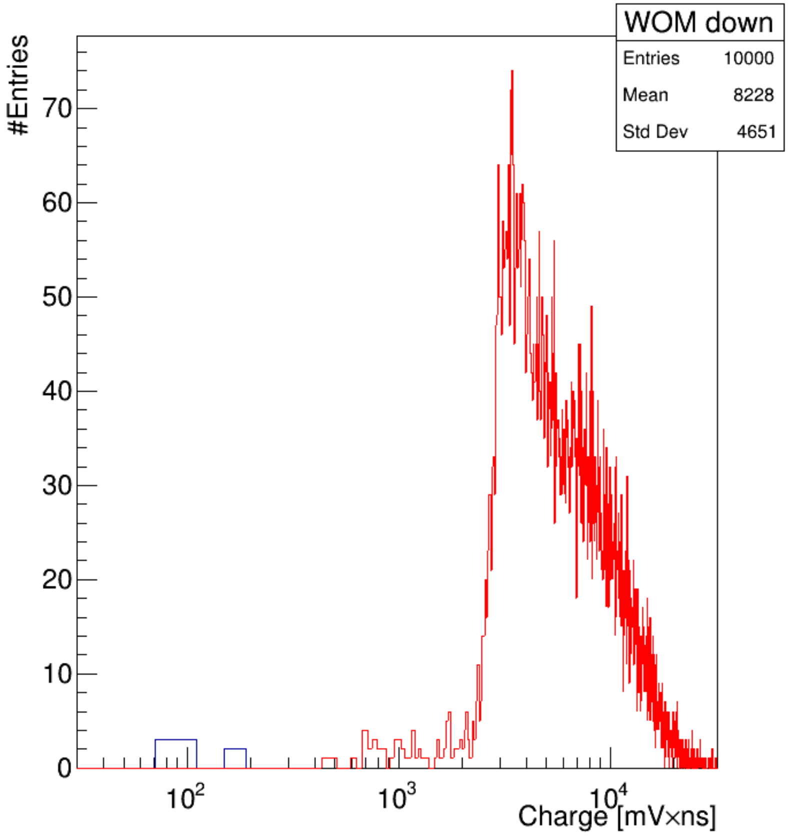
- without the positron beam

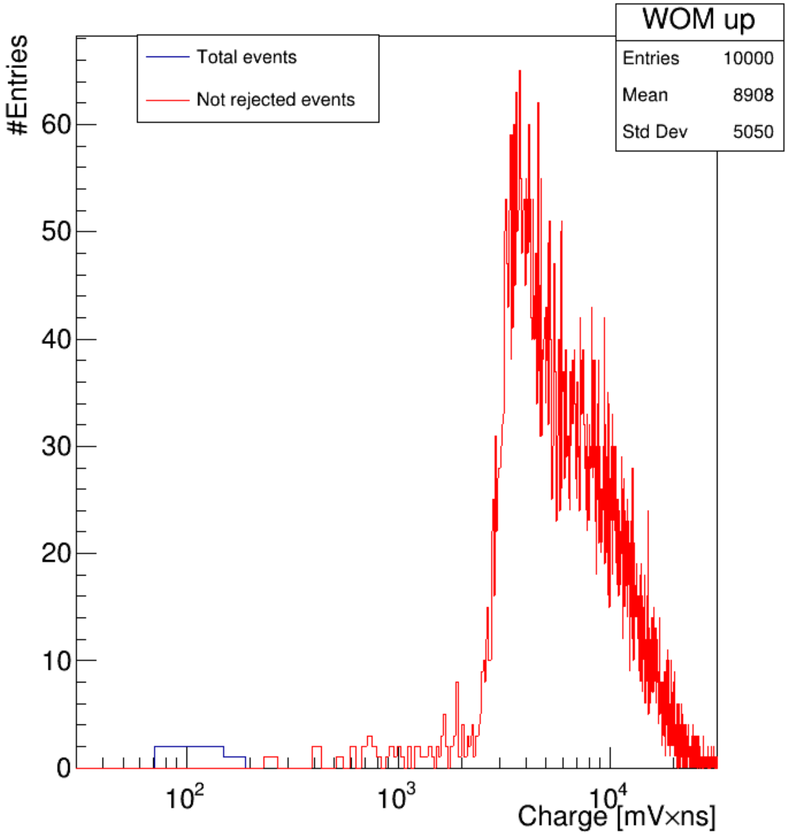


Efficiency

The dark counts measurement was performed:

- triggering on one of the PMT → $$\frac{N_{c>200}}{N_{triggered}}$$
- without the positron beam



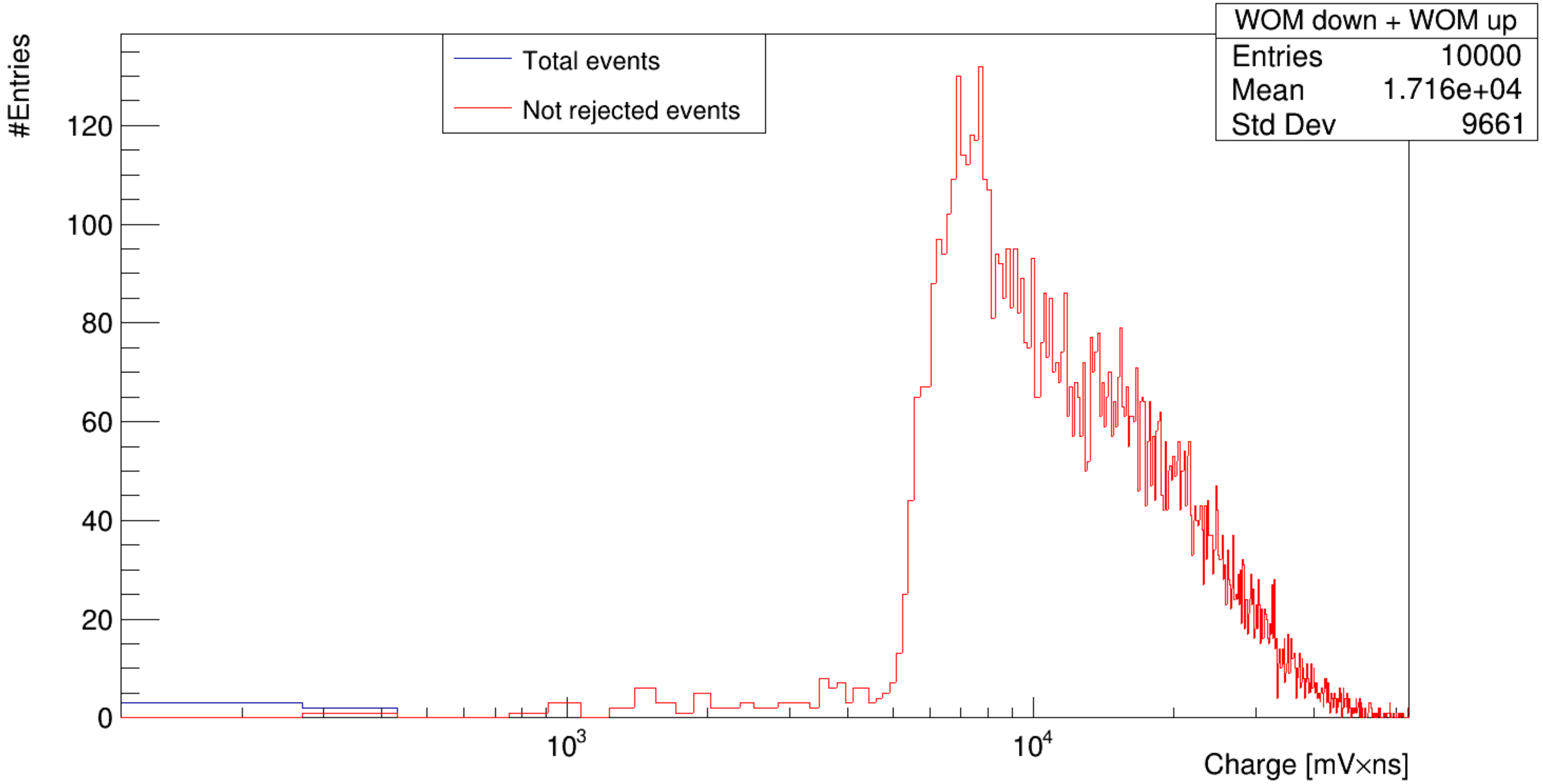


Efficiency

Condition to calculate the efficiency of the entire detector:

$$\frac{N_{(c_{down}>200 \vee c_{up}>200)}}{N_{triggered}}$$

cut performed on the histogram of the total charge, calculated summing the waveforms of every SiPMs, event per event

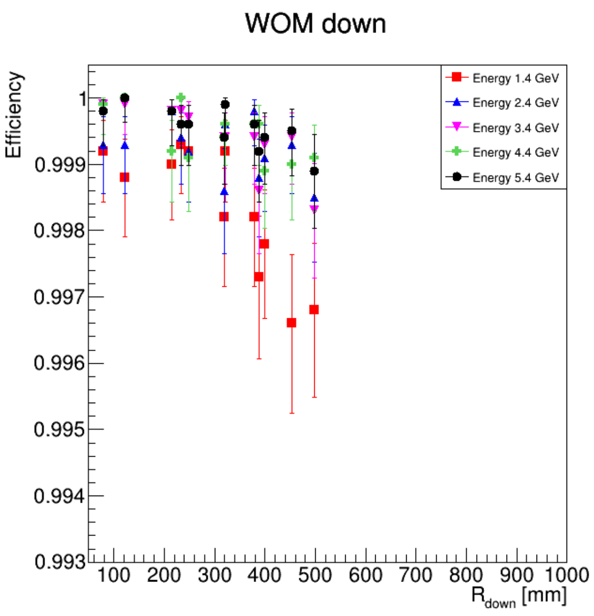


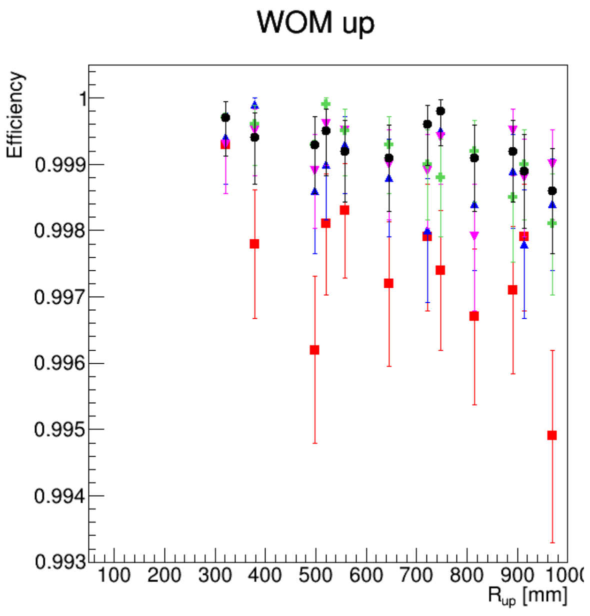
Efficiency results

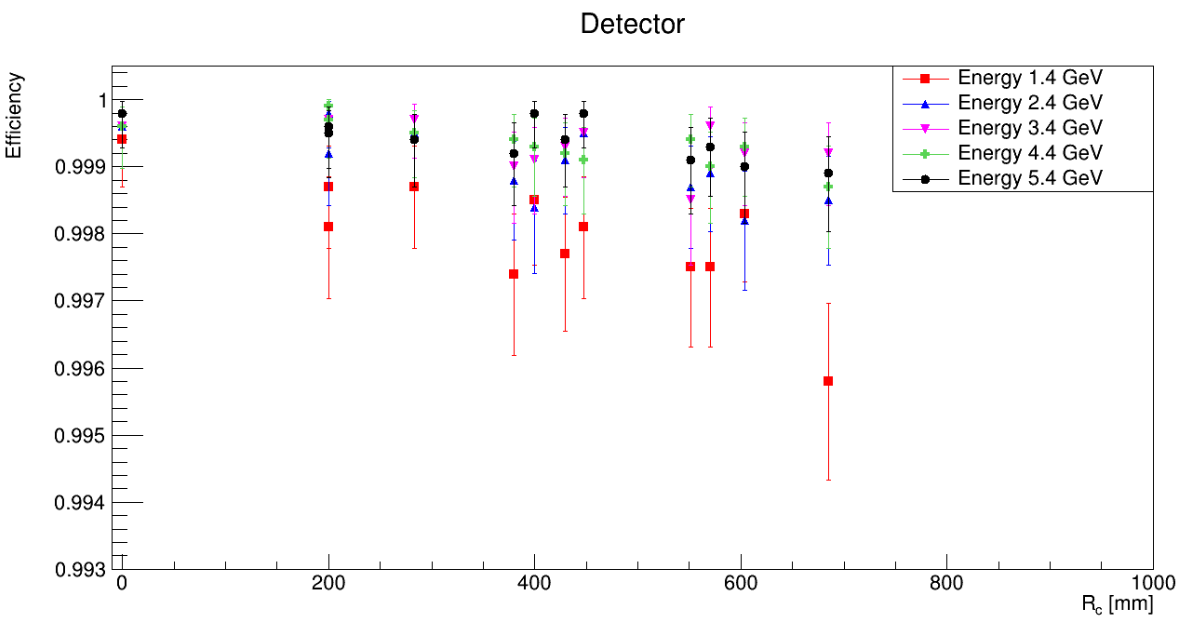
- Slight decrease of efficiency with decreasing distance from WOM (as expected)

- Increasing of the effieciency with increasing beam energy (as expected)

- The total efficiency is higher than the one for the single WOM tube





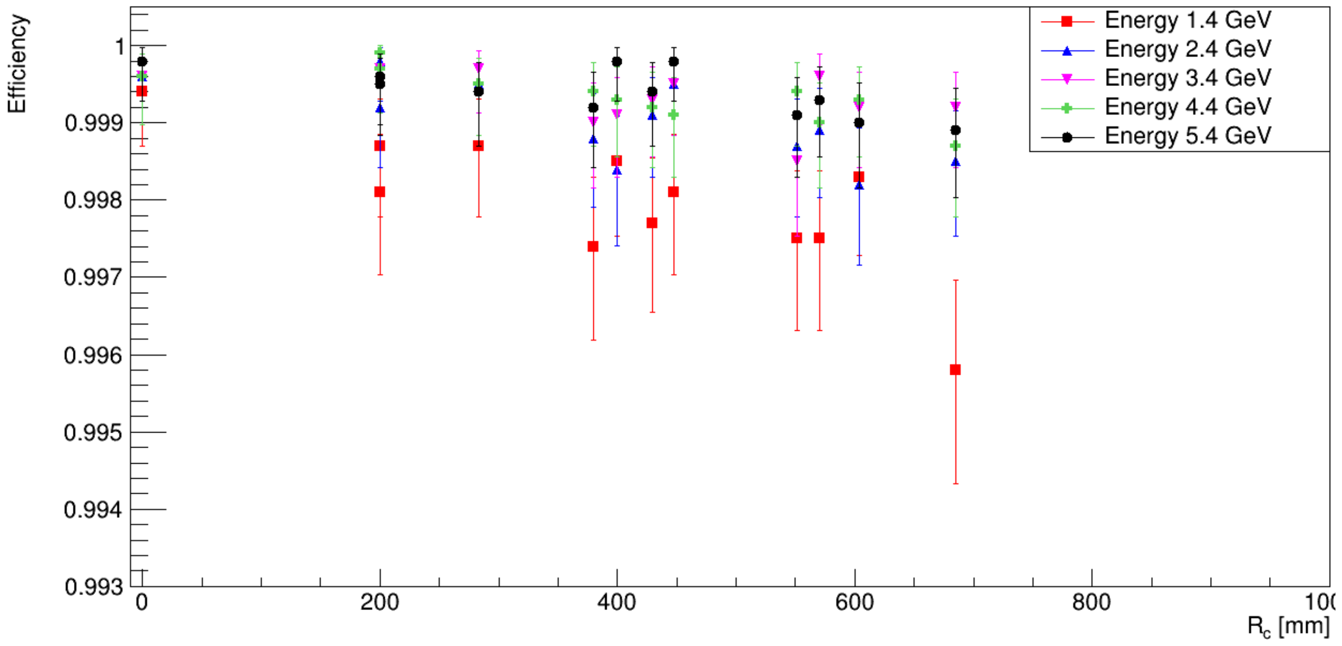


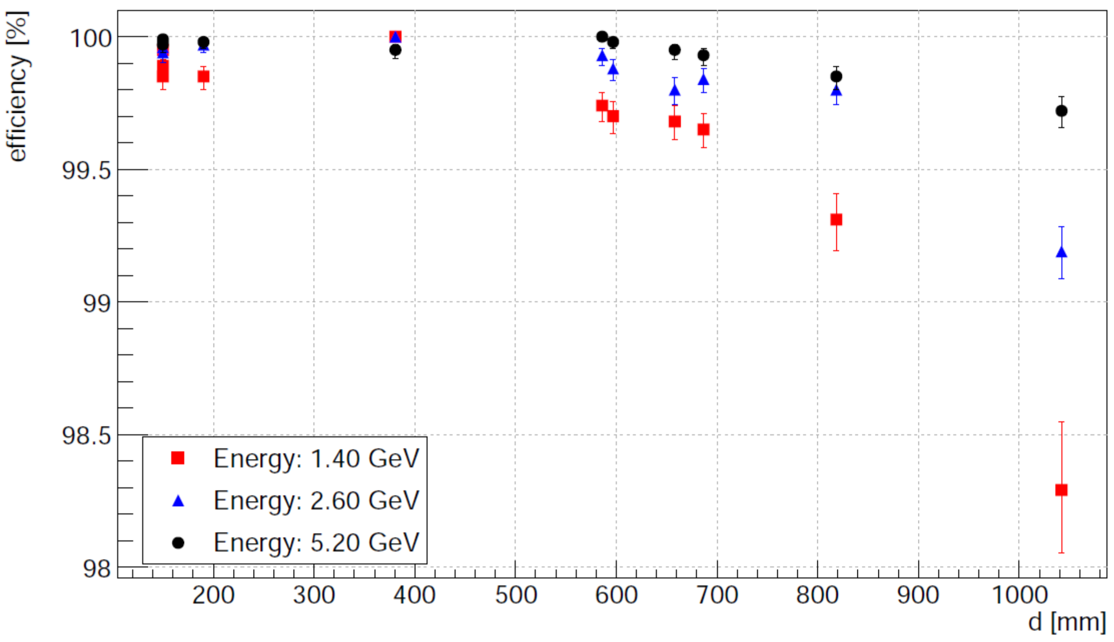
Comparison with previous results

Last test beam (2022) results:

Previous test beam (2020) results:

[Efficiency studies of a liquid-scintillator detector based on Wavelength-shifting Optical Modules – J. Zimmermann (10 2020)]





Timing performance

Timing performance

Goals:

Determine time and position of a particle crossing the detector

Calculation of the average time of the first arrival photon for the 4 trigger PMTs $\overline{T_{PMT}}$

Calculation of the average time of the first arrival photon for each WOM tube (T_{up} , T_{down}) , subtracting $\overline{T_{PMT}}$ for each event

Calculation of the light yield for each WOM tube for each event (LY_{up}, LY_{down})

T_{up}

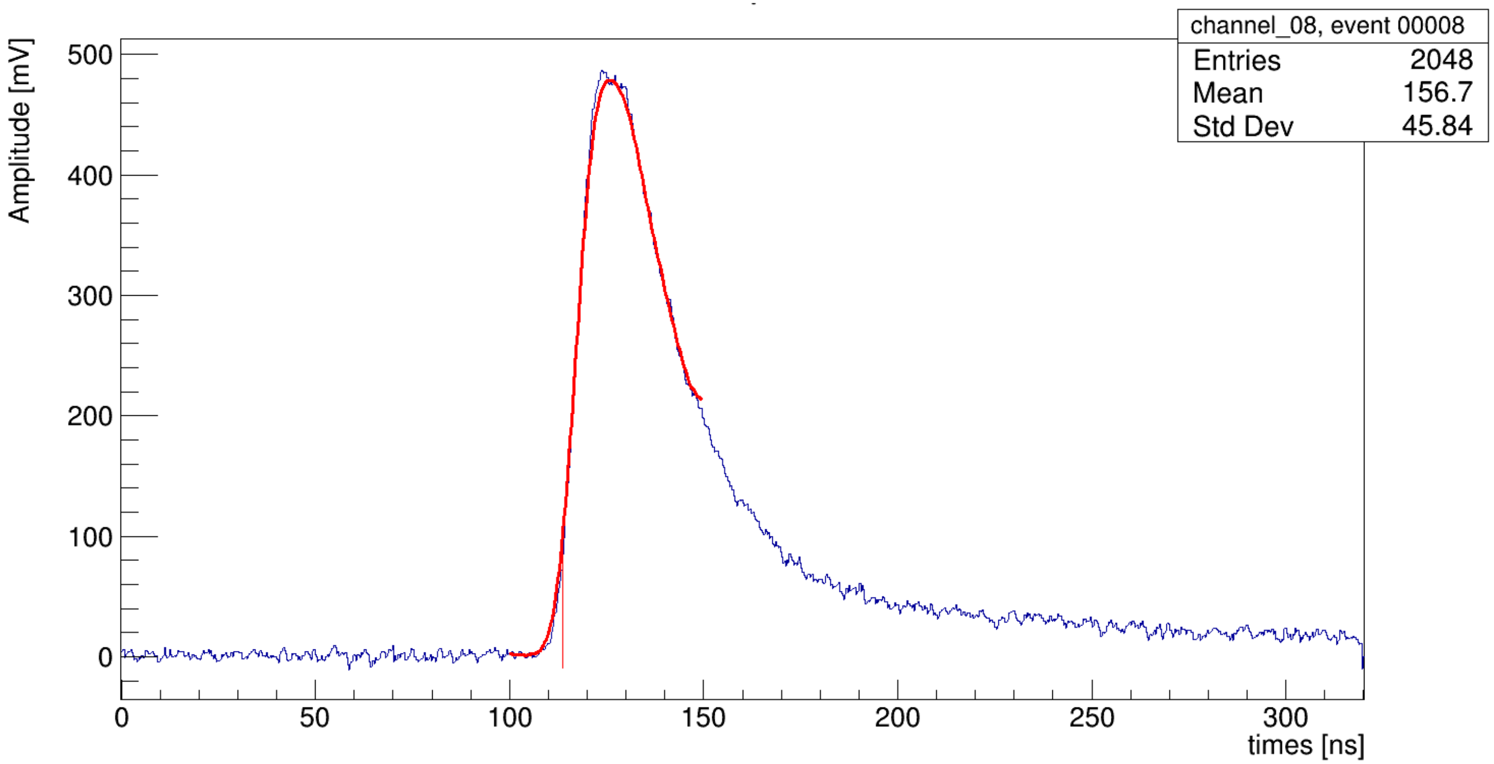
Timing performance

The time from each WOM tube is calculating:

- summing of signal of each SiPMs over WOM tube

- smoothing procedure

- CDF 20% of the maximum of the signal



Results:

$$\overline{T}=\left(T_{up}+T_{down}\right)/2$$

$$\Delta T=T_{up}-T_{down}$$

$$\xi=LY_{down}/LY_{up}$$

$$\xi_{down}=LY_{down}/LY_{tot}$$

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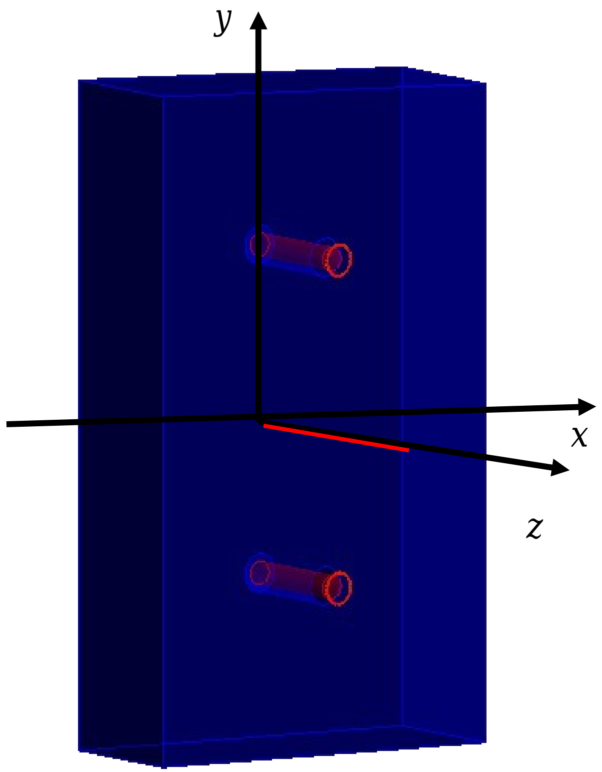


Results:

$$\overline{T} = \left(T_{up} + T_{down}\right)/2$$

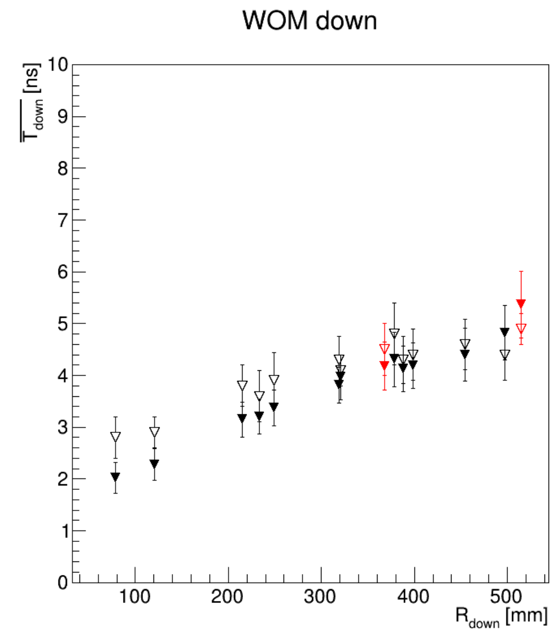
$$\Delta T = T_{up} - T_{down}$$

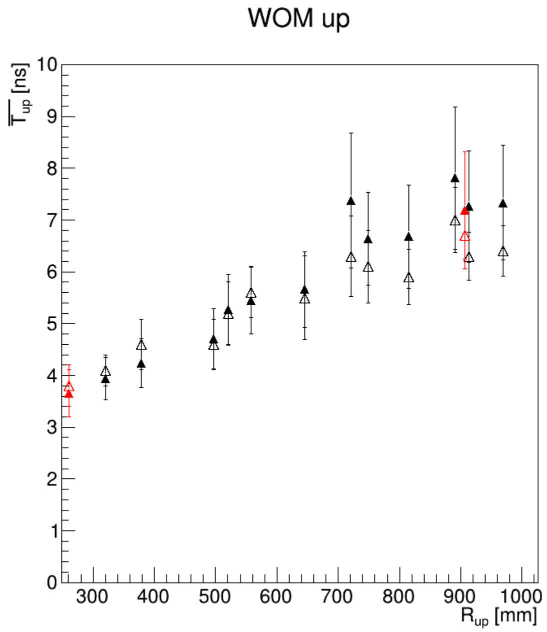
$$\xi = LY_{down}/LY_{up}$$

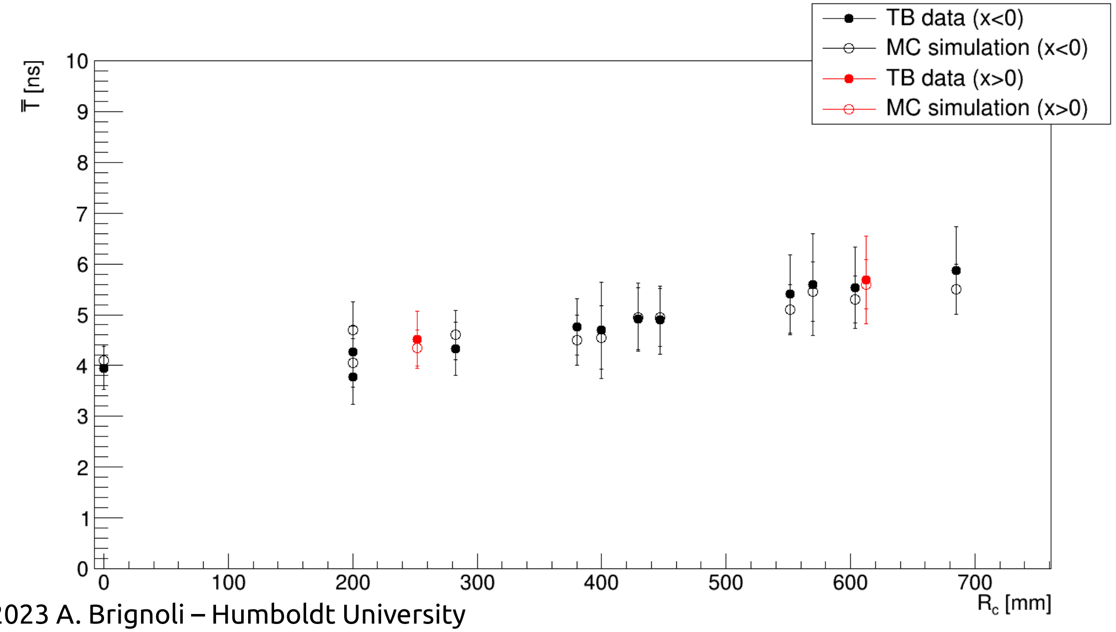
$$\xi_{down} = LY_{down}/LY_{tot}$$

comparison with Monte Carlo simulation
(with 65% of the original reflectivity of the coating)

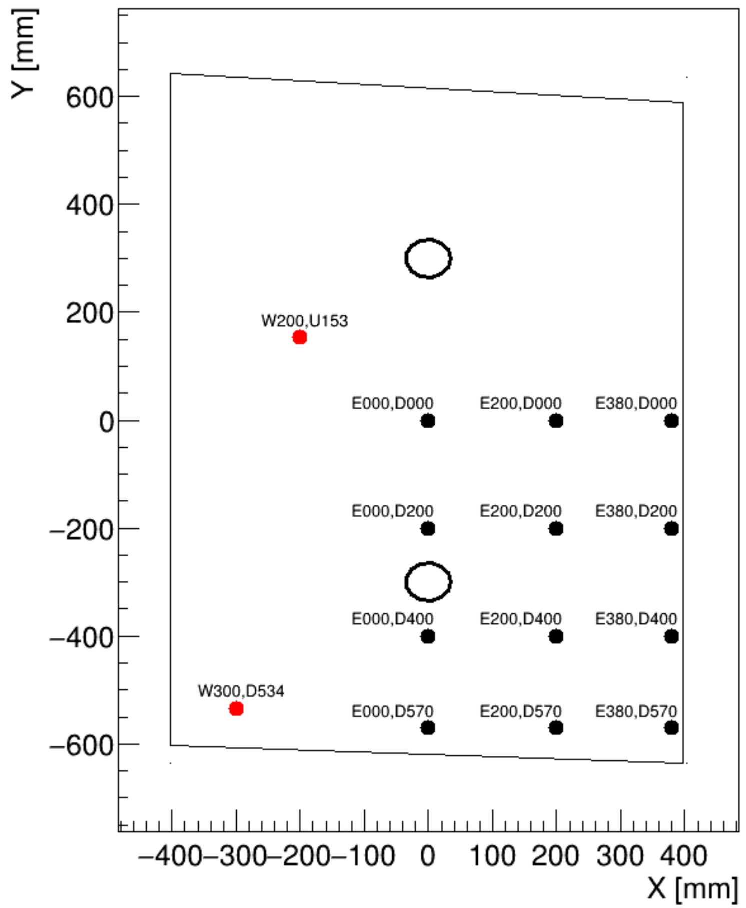
Timing performance results



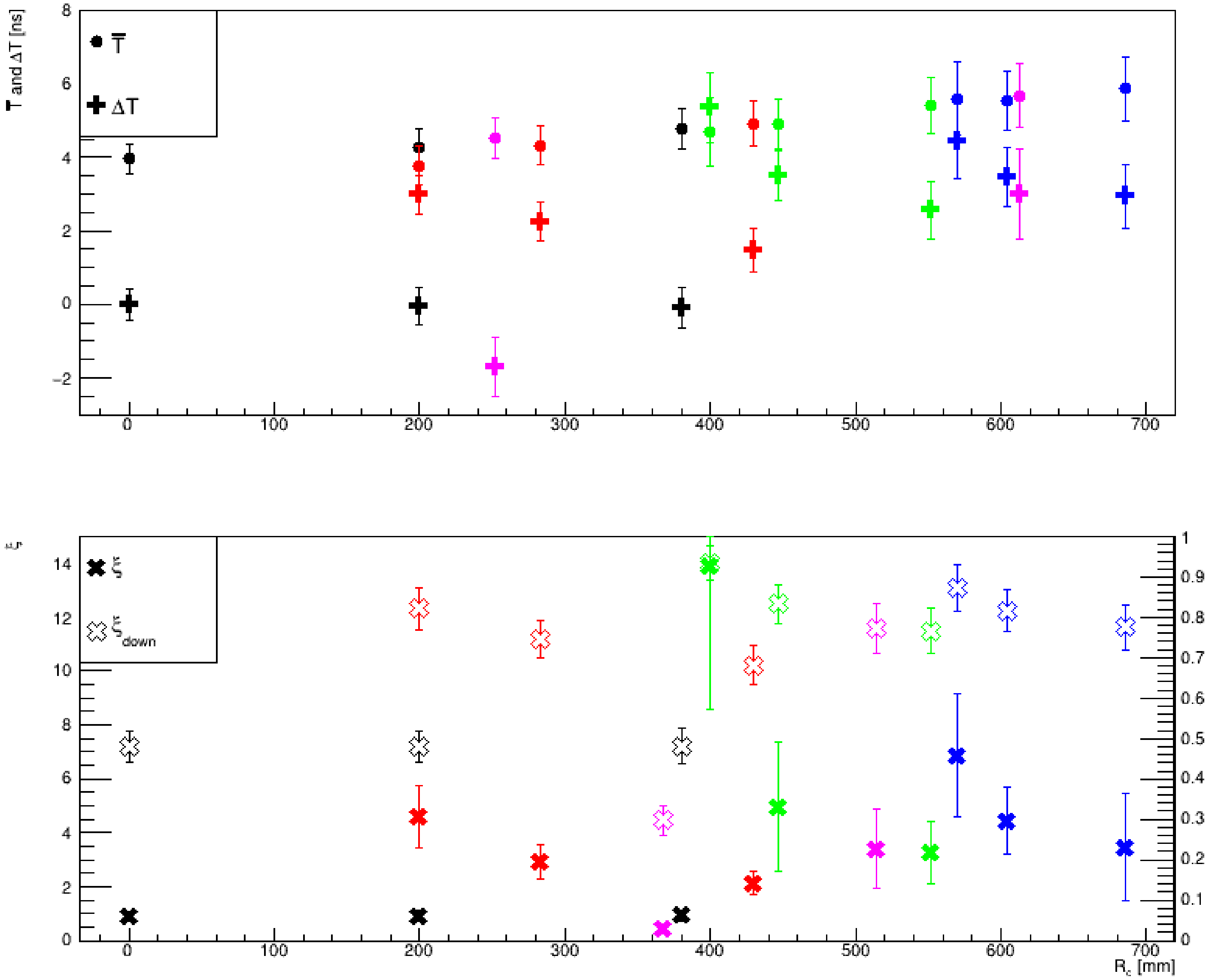




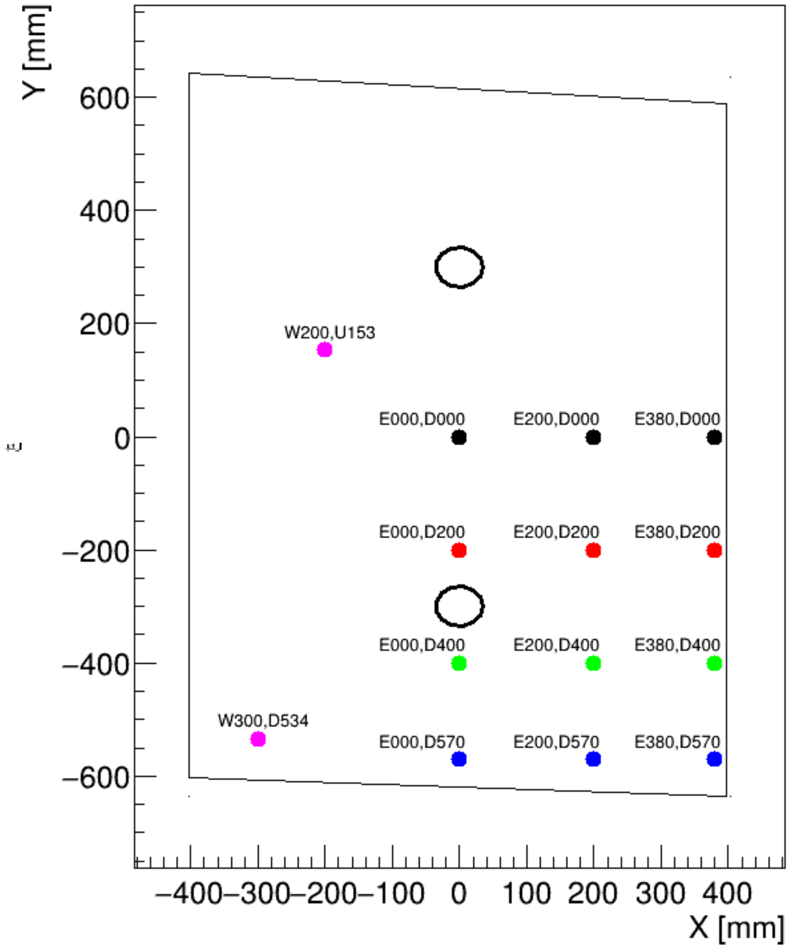
- Uncertanties: standard deviation of the distribution
- Time resolution for a fixed position: < 1 ns
- Timing variation over the size of the detector: $\pm$ 1.8 ns



Timing performance results



We can partially reduced the $\overline{T}$ variation over the detector size using ΔT and LY shared between the two WOM tubes



Conclusions

Results:

- Time resolution for fixed particle position: < 1 ns

- Time variation over detector size: ± 1.8 ns

- Could be partially reduced using:

$$\Delta T = T_{up} - T_{down} \qquad \xi = LY_{down} / LY_{up} \qquad \xi_{down} = LY_{down} / LY_{tot}$$

- These observables also contain info about particle crossing position in y direction

Next steps:

- Analysis with different rotation angles

- Analysis with different energies

- Single channels timing and light yield information

Thank you