A CHERENKOV MUON VETO DETECTOR

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Topics:

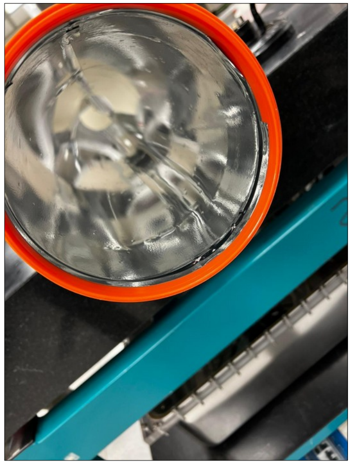
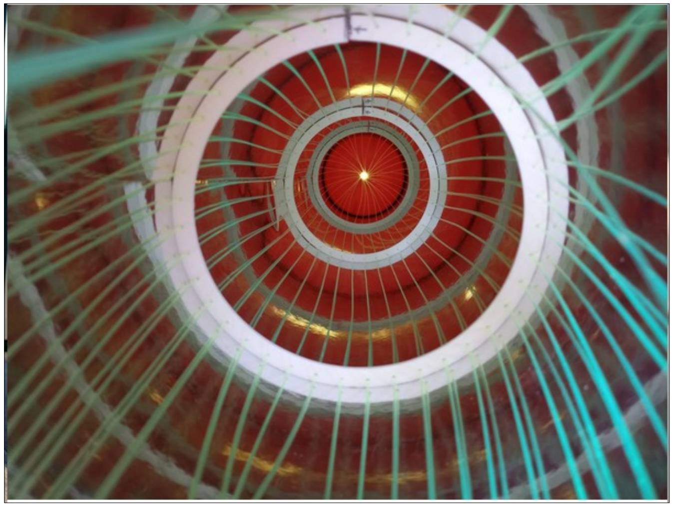
- ✔ Cherenkov muon veto detector
- ✔ Prototypes:
  - ✗ Prototype v0
  - ✗ Prototype v1
- ✔ Test Beam at Frascati National Laboratories
- ✔ Analysis of data
- ✔ Conclusions and next steps

Cherenkov muon veto detector

- At the Frascati National Laboratories (LNF) we are developing a **neutron shield** detector and **muon veto**
- Detector made of pipes filled with demineralized water
- **Water** moderates neutrons and detects muons through the **Cherenkov light**
- Big volumes → low-cost materials
- First prototypes assembled with electronics gathered in the lab and materials available in the market

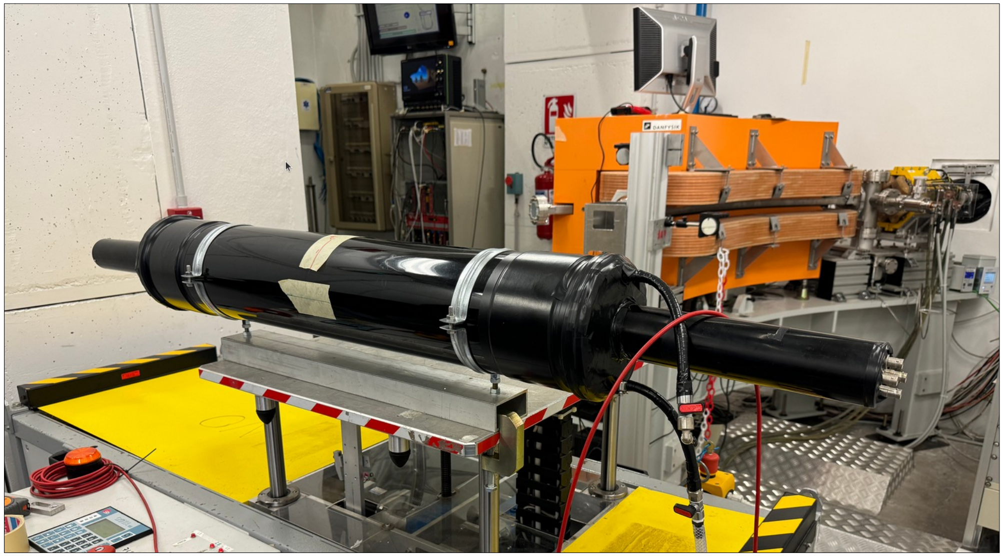
Prototypes

- Two prototypes of the detector:
  - ➔ Prototype v0: **PMTs** readout
  - ➔ Prototype v1: **optical fibers** + **SiPMs** readouts
- Both prototypes internally coated with a **semi-rigid reflective sheet**
- Both prototypes were **15 cm in diameter** and **84 cm in length**

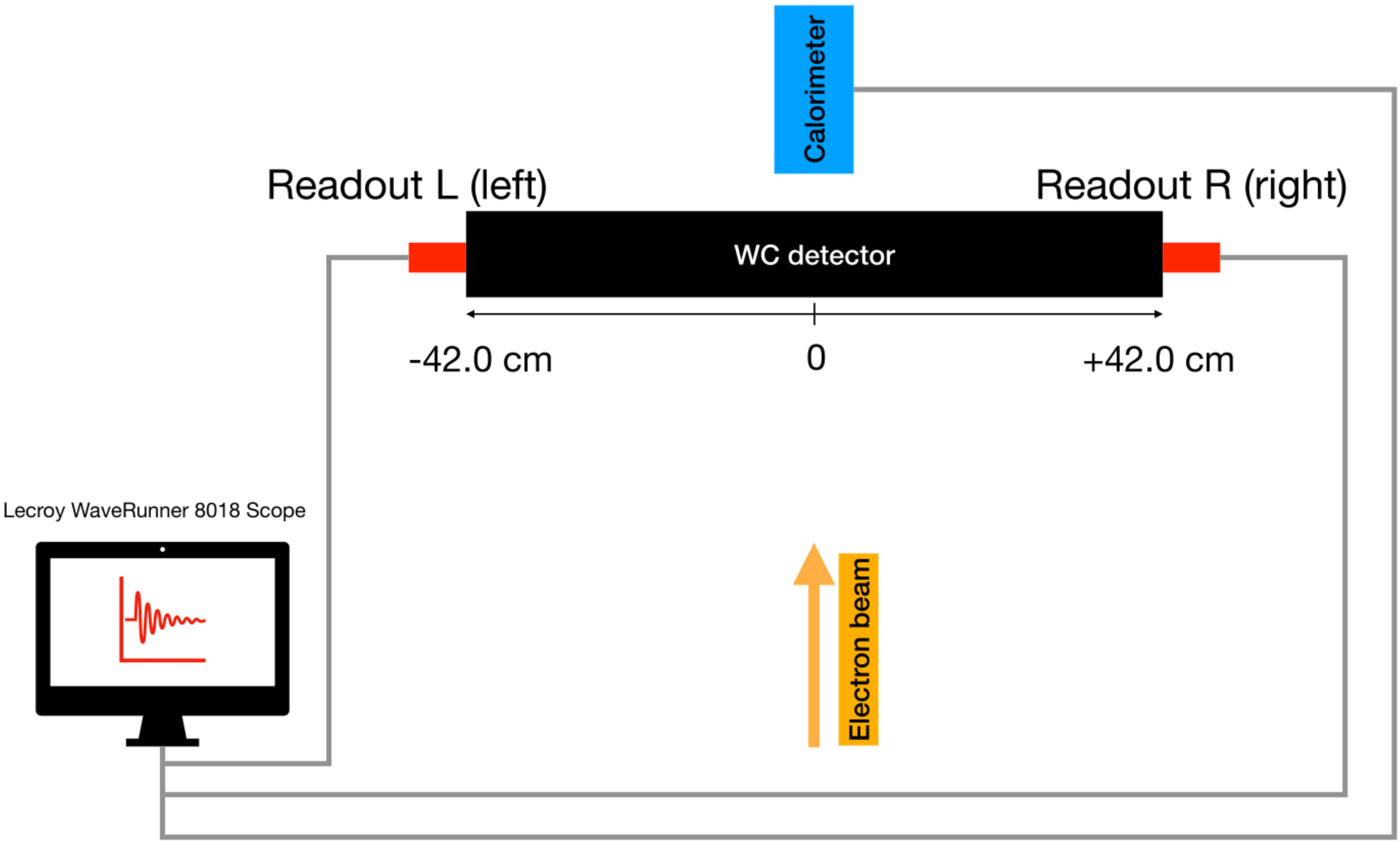





Beam Test

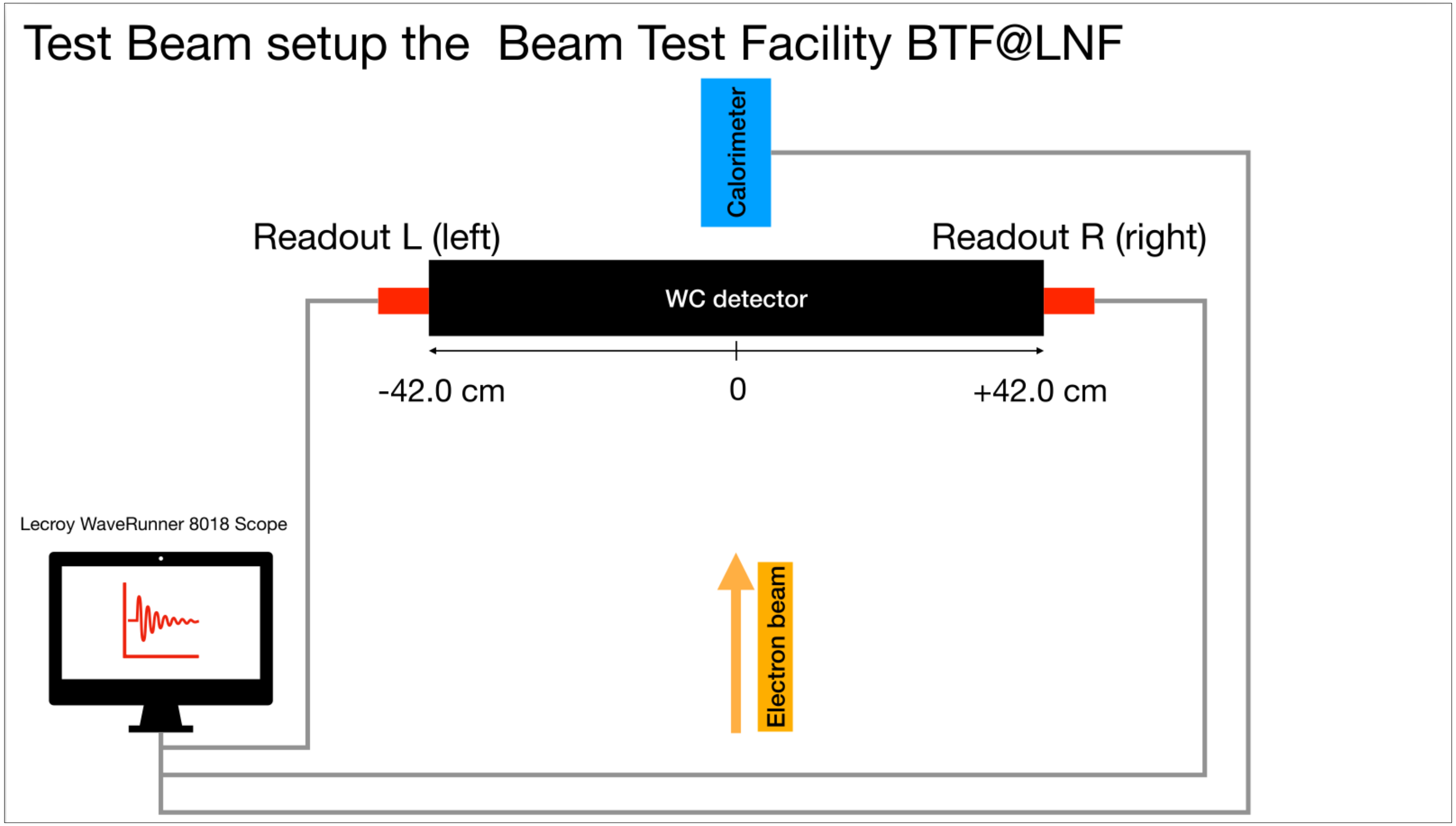
- Performances of the two prototypes characterized during a beam test at the Beam Test Facility (BTF)
- **Electron beam @ 500 MeV** with a beam spot of σ~2 mm
  https://btf.lnf.infn.it/specs/
- Study of the **efficiency** and the **time resolution** of the detector
- Data collected **along both** the detector **diameter** and **length**



Test Beam setup the Beam Test Facility BTF@LNF

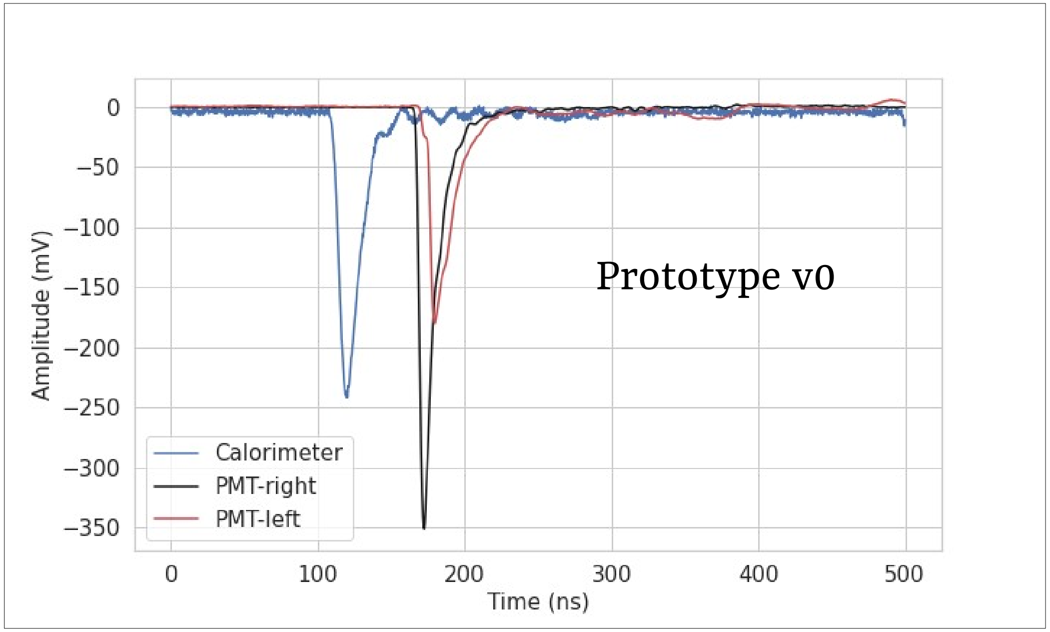


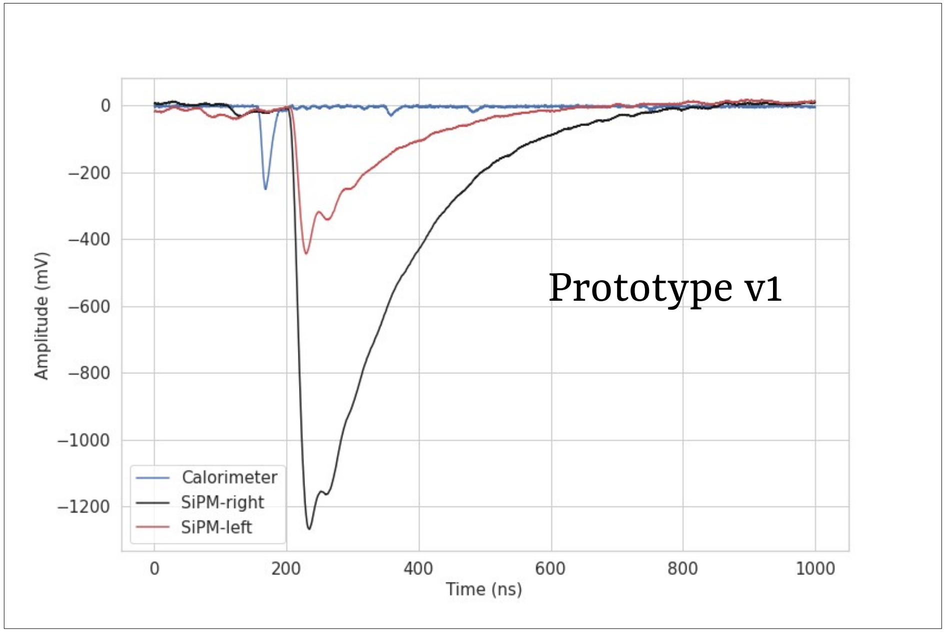
- Along the diameter:
  - Point-1 → @ -5 cm
  - Point-2 → @ 0 cm
  - Point-3 → @ +5 cm
- Along the length:
  - Point-A -> @ -20 cm
  - Point-B → @ 0 cm
  - Point-C → @ 41 cm
- Lead-glass Calorimeter:
  - Length: 37 cm



Signal waveforms

- Each run → **1000 events**
- Each event → **3 signals**: calorimeter, right readout and left readout

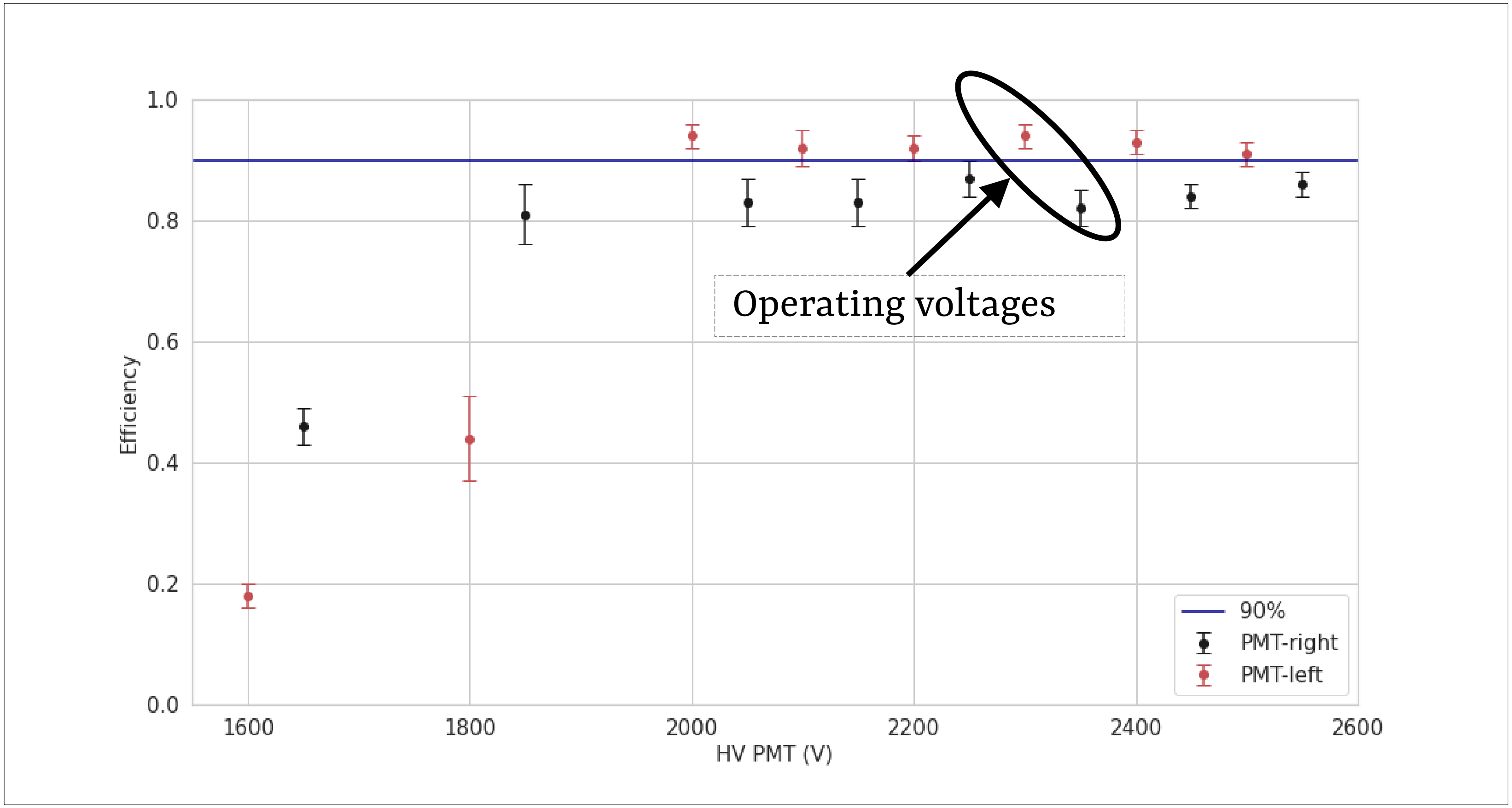




- SiPMs signals inverted to use the same analysis of PMTs
- First, data of prototype v0 were analyzed

High Voltage (HV) scan

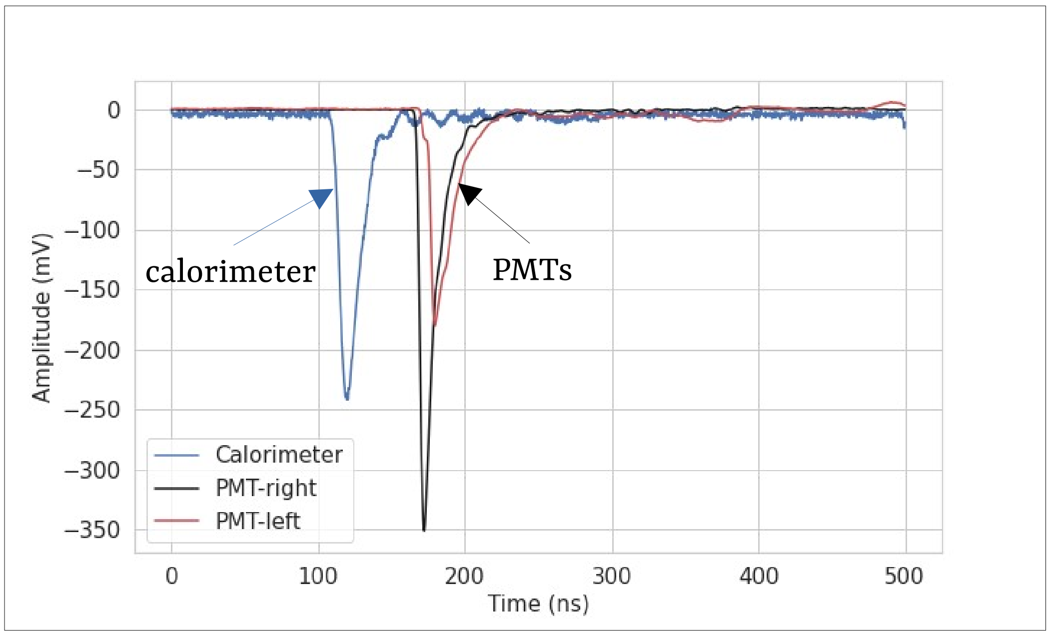
- Study of optimal **operating voltages** with the beam at the center of the detector (x=0,y=0)
- Efficiency estimated respect to the signals of calorimeter
- Operating voltages: 2300 V for left PMT and 2350 V for right PMT

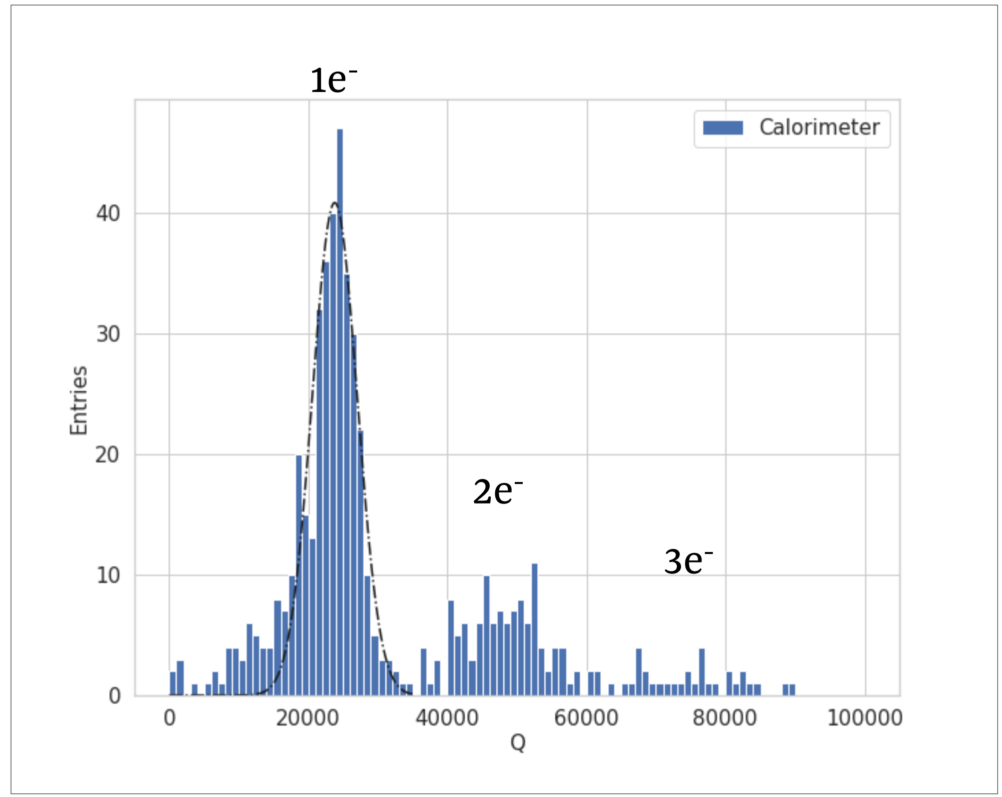


Efficiency study - PMTs

Events selection

- We focused our attention on events where **calorimeter signals** were **present**
- We selected events where a **single electron** crossed the calorimeter

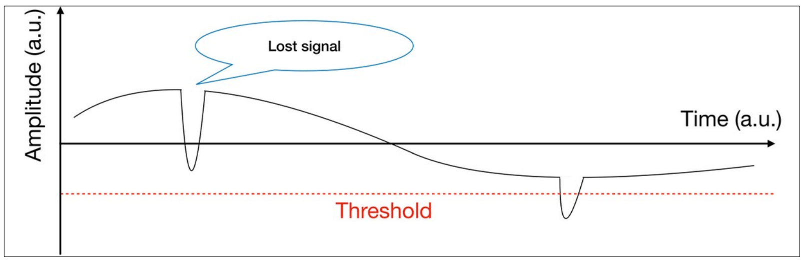


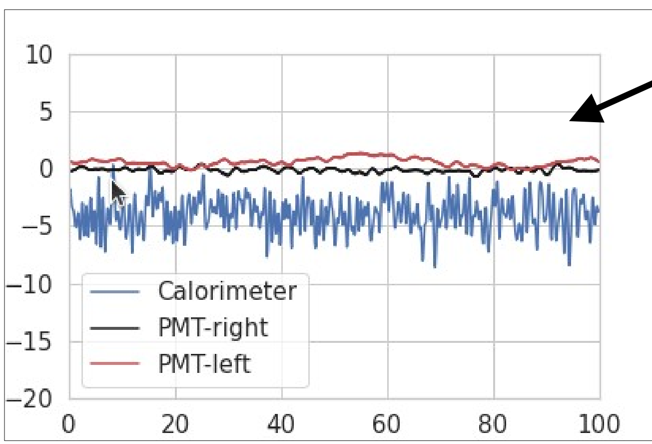


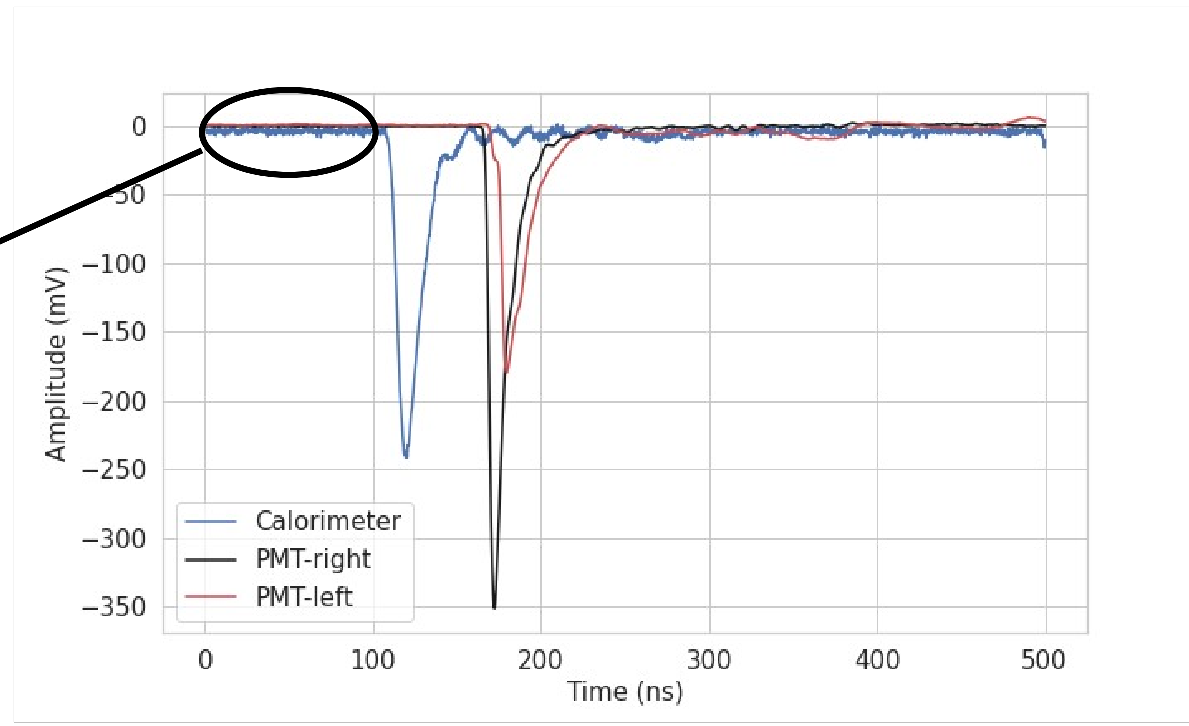
Efficiency study - PMTs

Signal correction

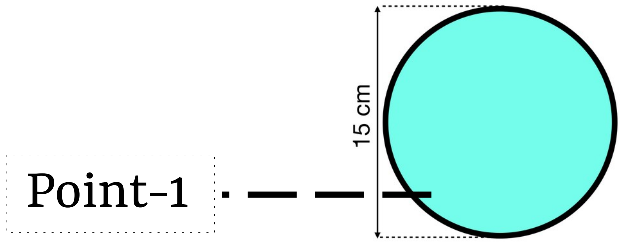
- Possible **offset** of signals was subtracted
- For each signal, we estimated the offset as the mean of the amplitudes distribution in the time window [0,100] ns and we subtracted the offset mean value from the signal

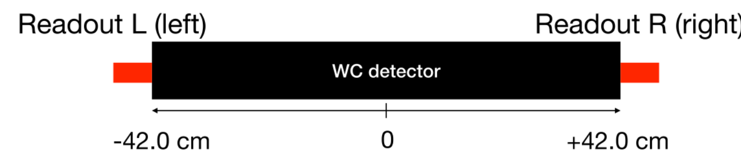


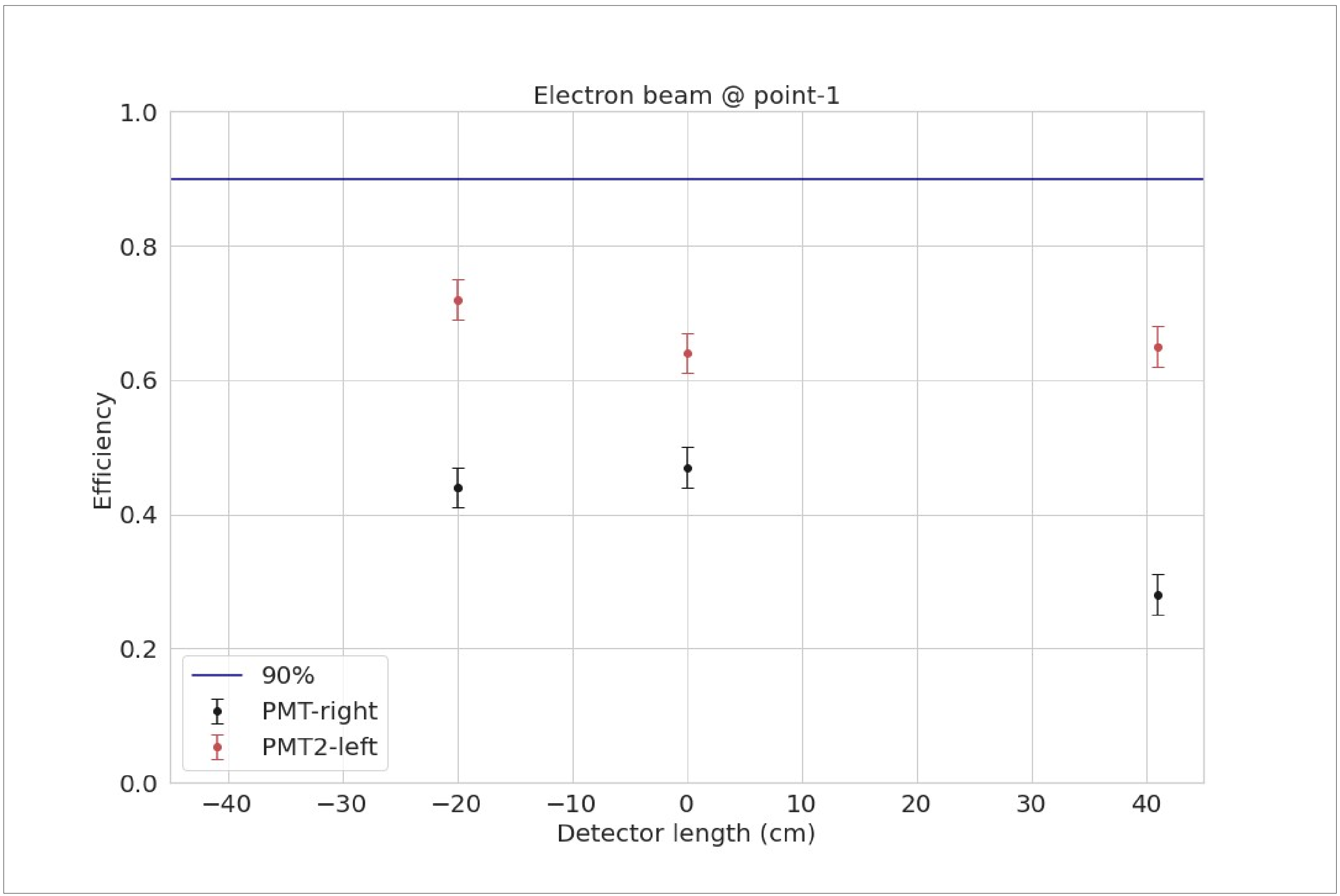




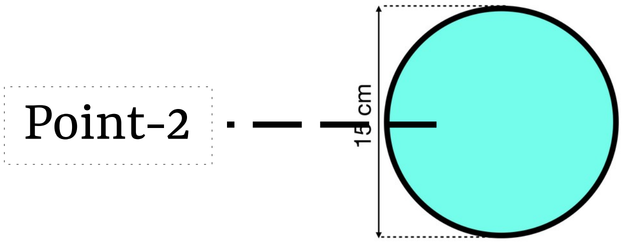
Efficiency study - PMTs

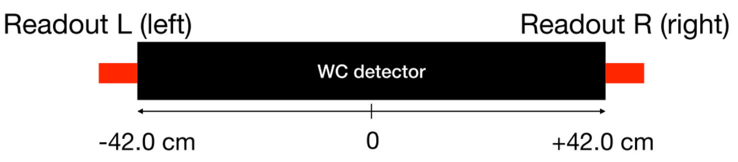


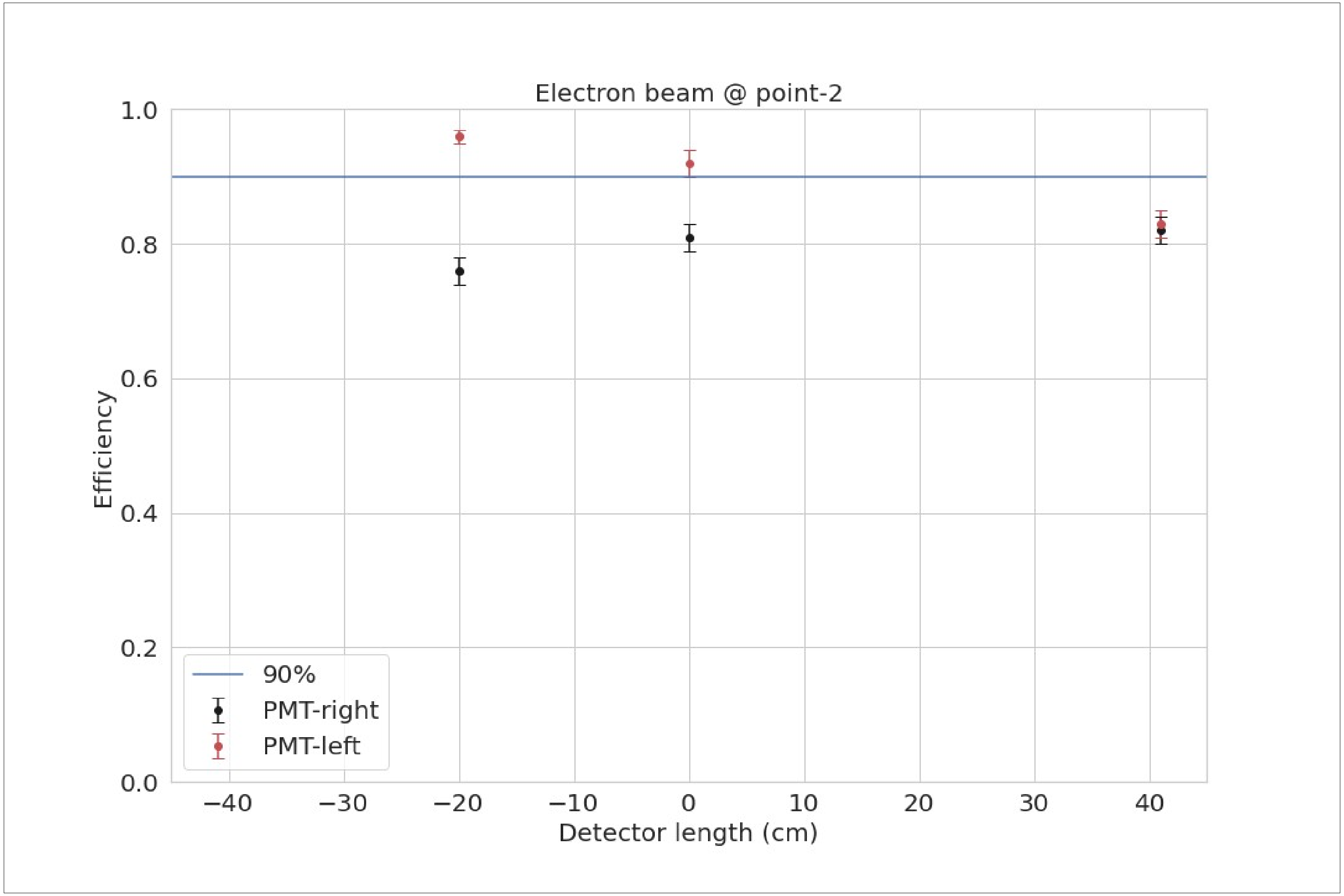




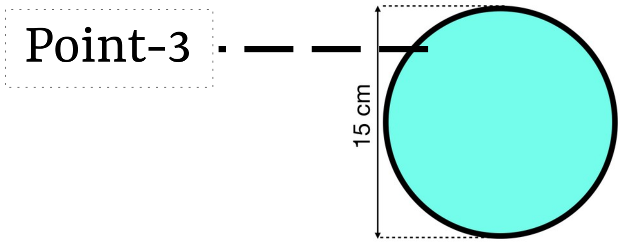
Efficiency study - PMTs

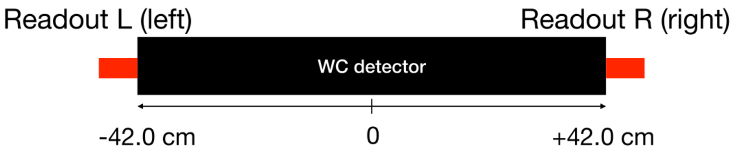


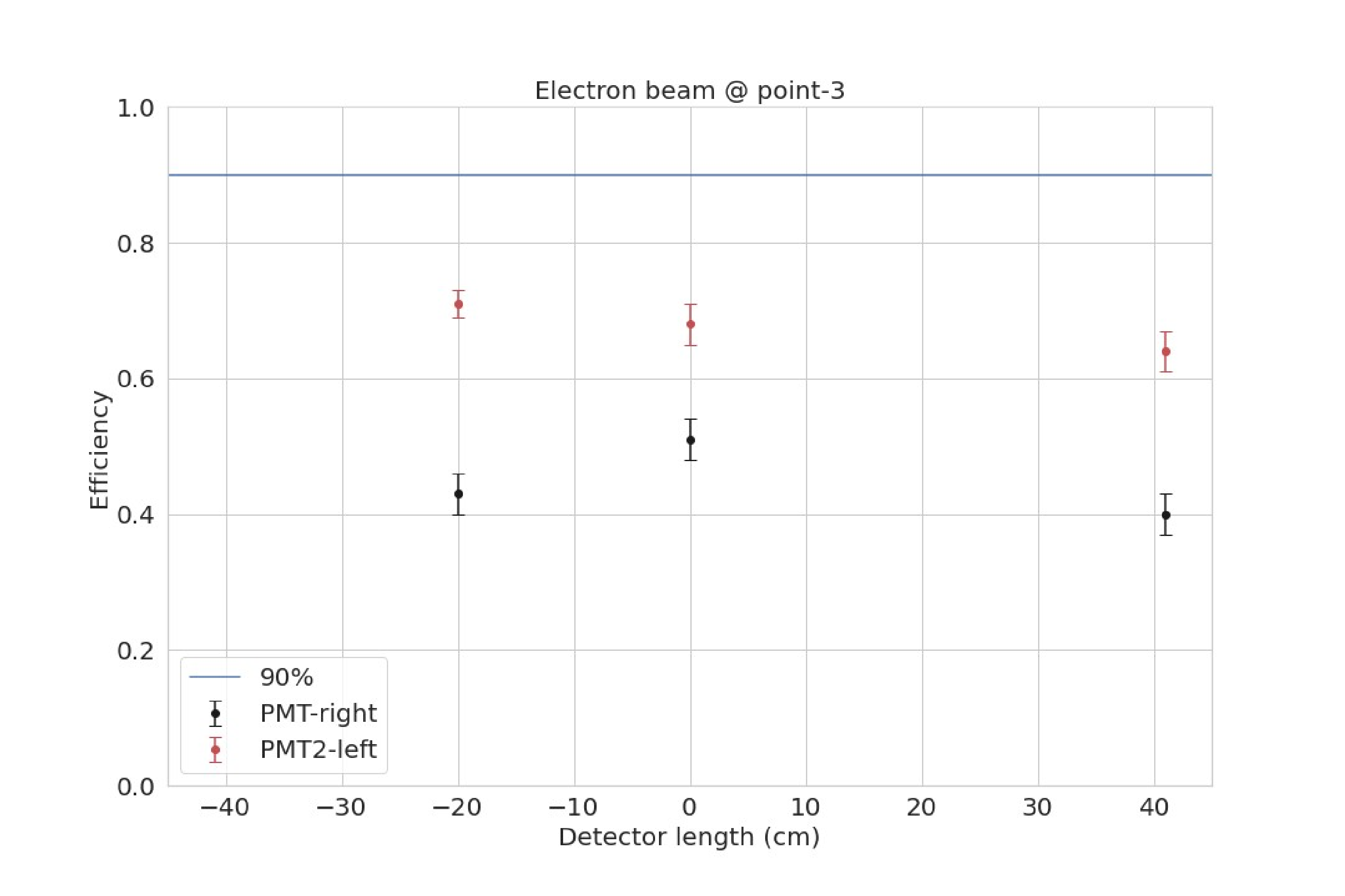




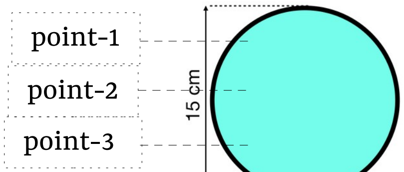
Efficiency study - PMTs

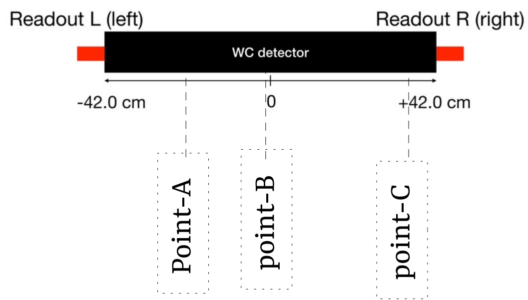


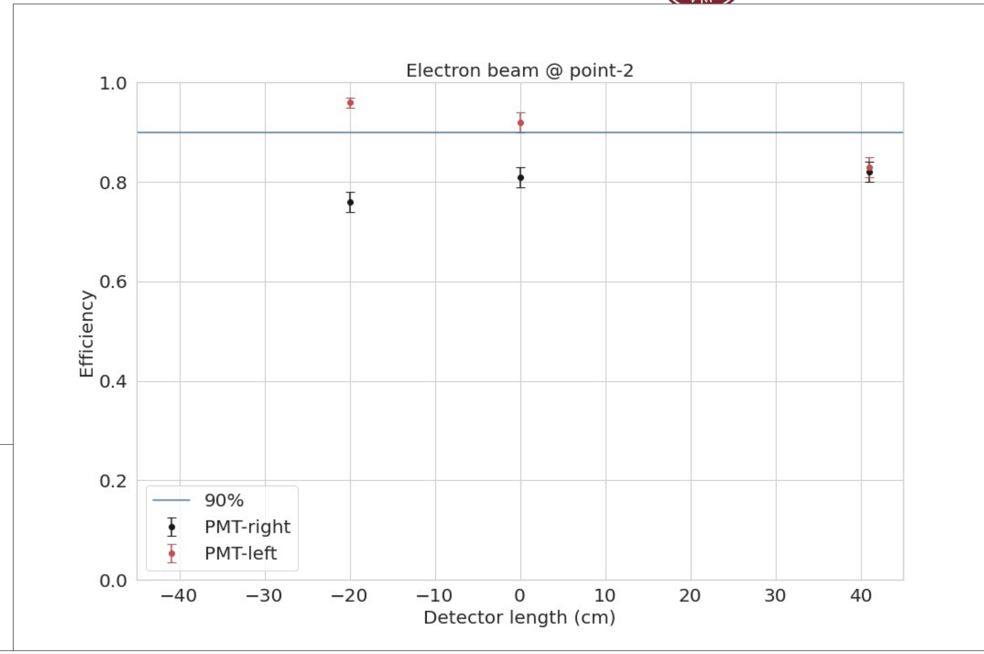


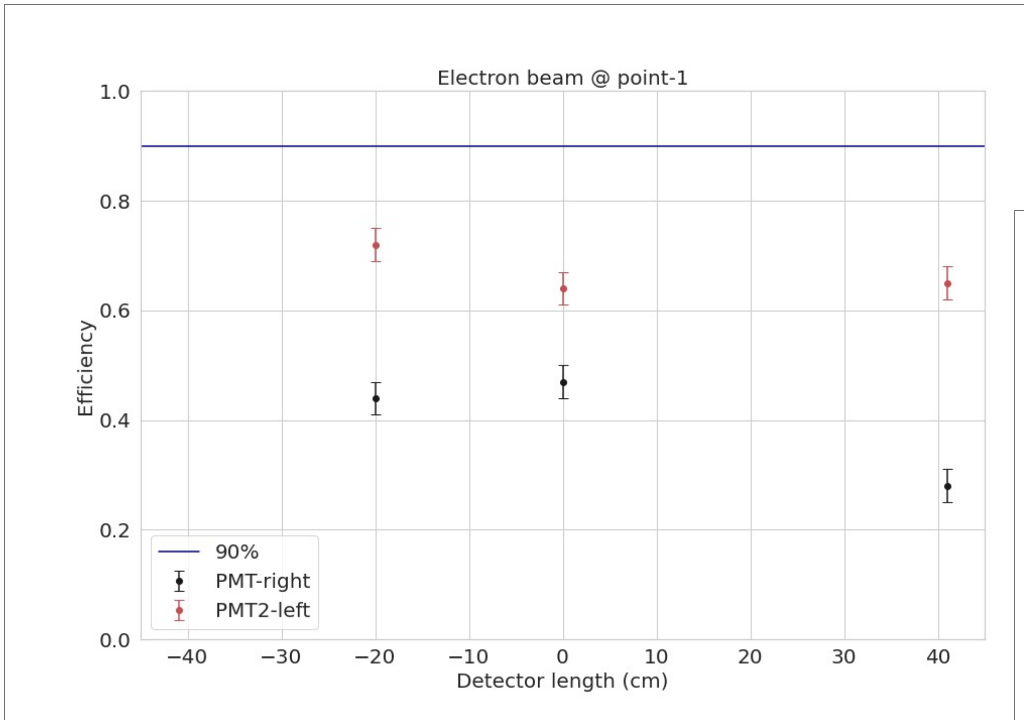


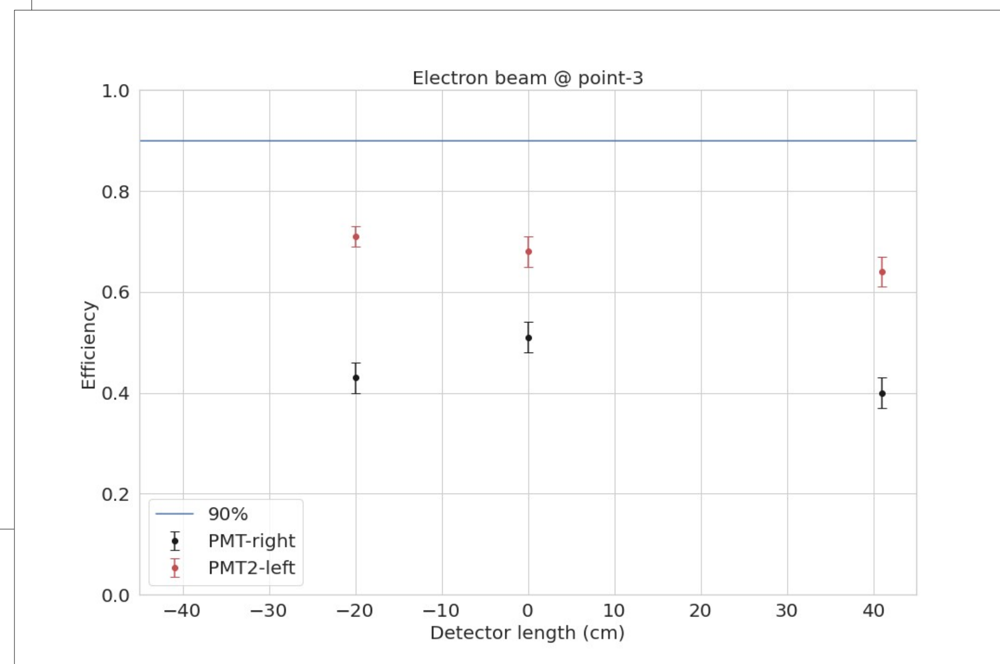
Efficiency study - PMTs







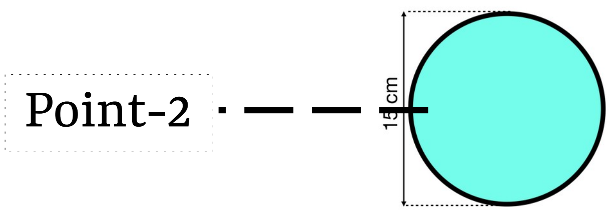


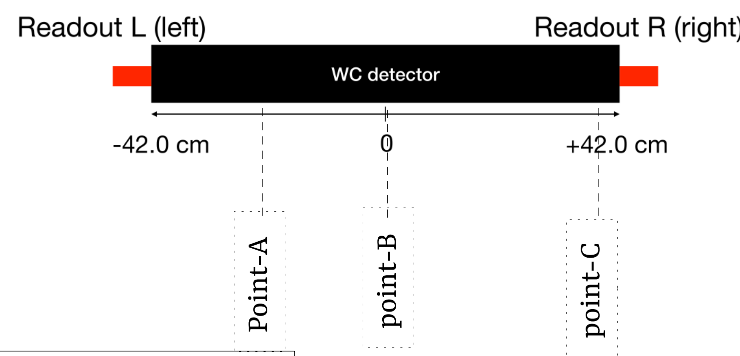


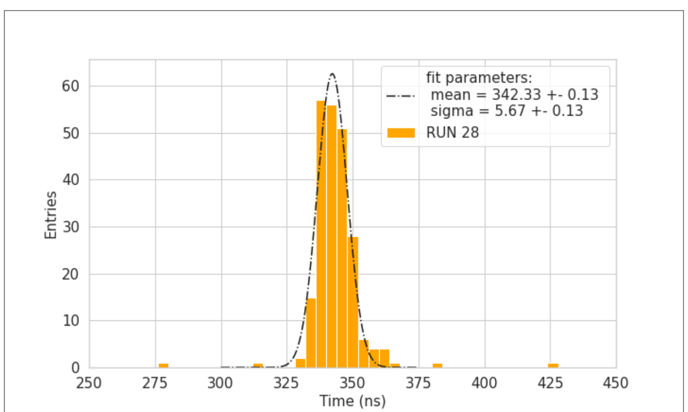
Time resolution - PMTs

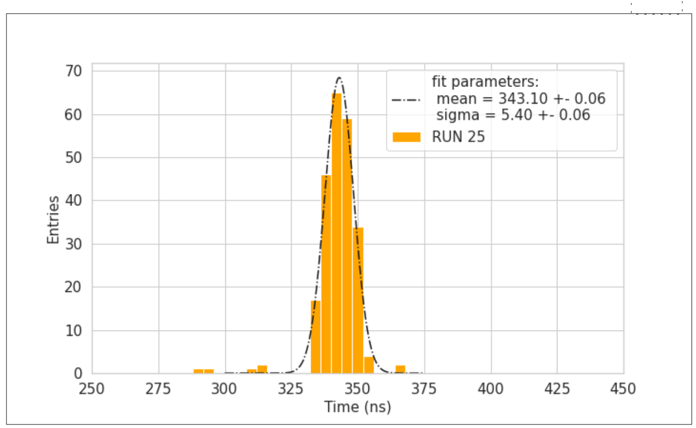
Method A

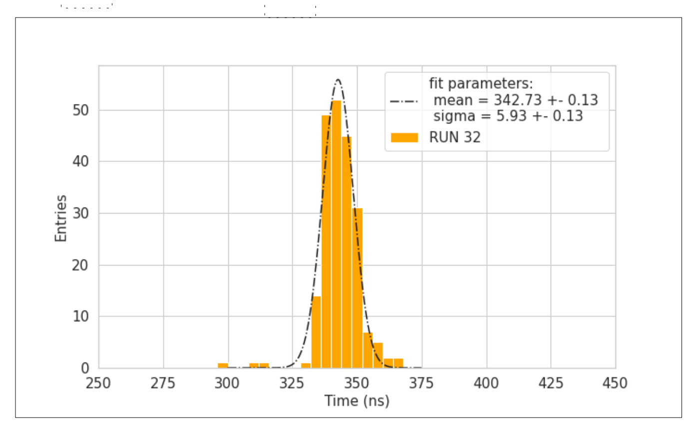
- In order to estimate the **time resolution (σ_t)** of both PMTs, we took the times where the signals passed the threshold
- Times of the signals added and the σ of the time sum distribution was considered
- σ_t estimated along the detector length with the beam at the point-2







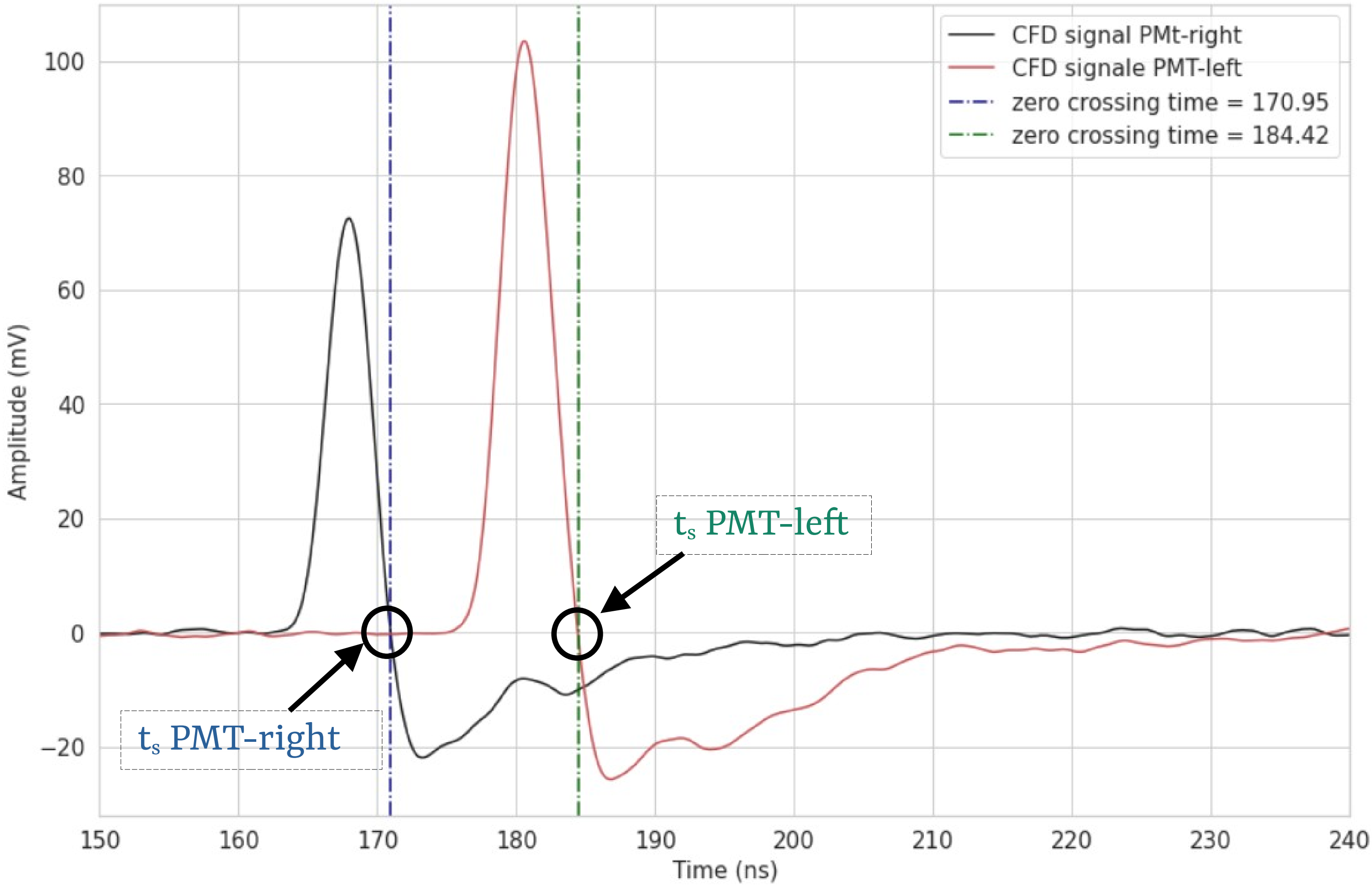




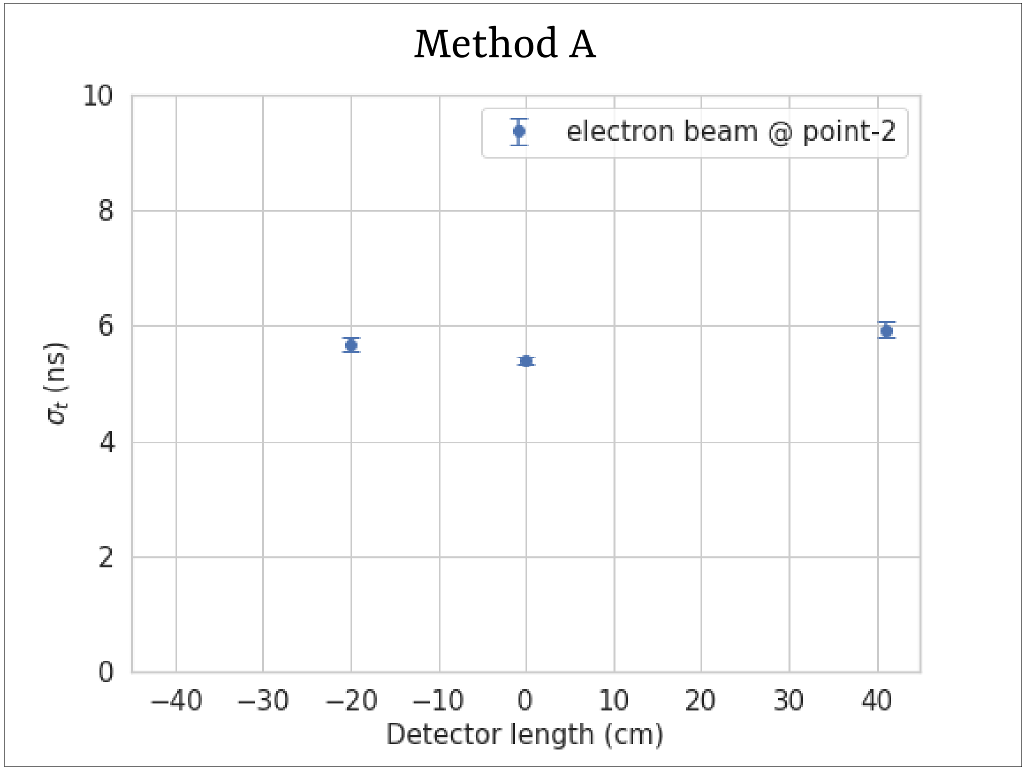
Time resolution - PMTs

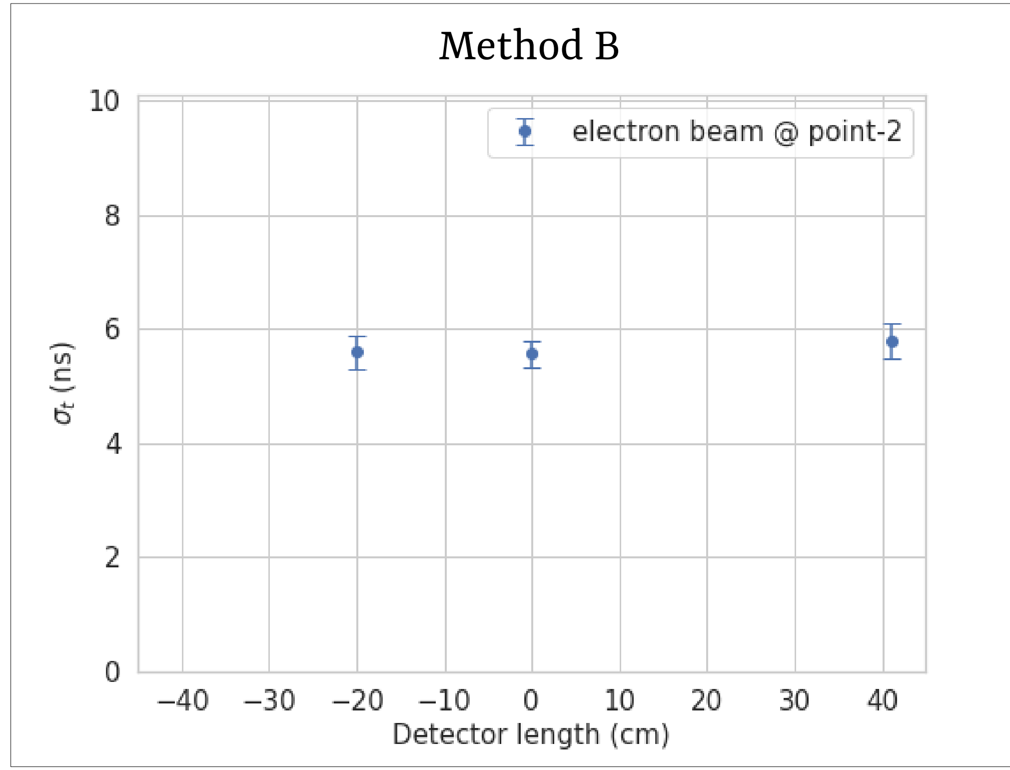
Method B

- In order to **improve** the time resolution (σ_t), we applied the technique of **Costant Fraction Descrimination (CFD)** to take the time of signal (t_s)



Time resolution - PMTs

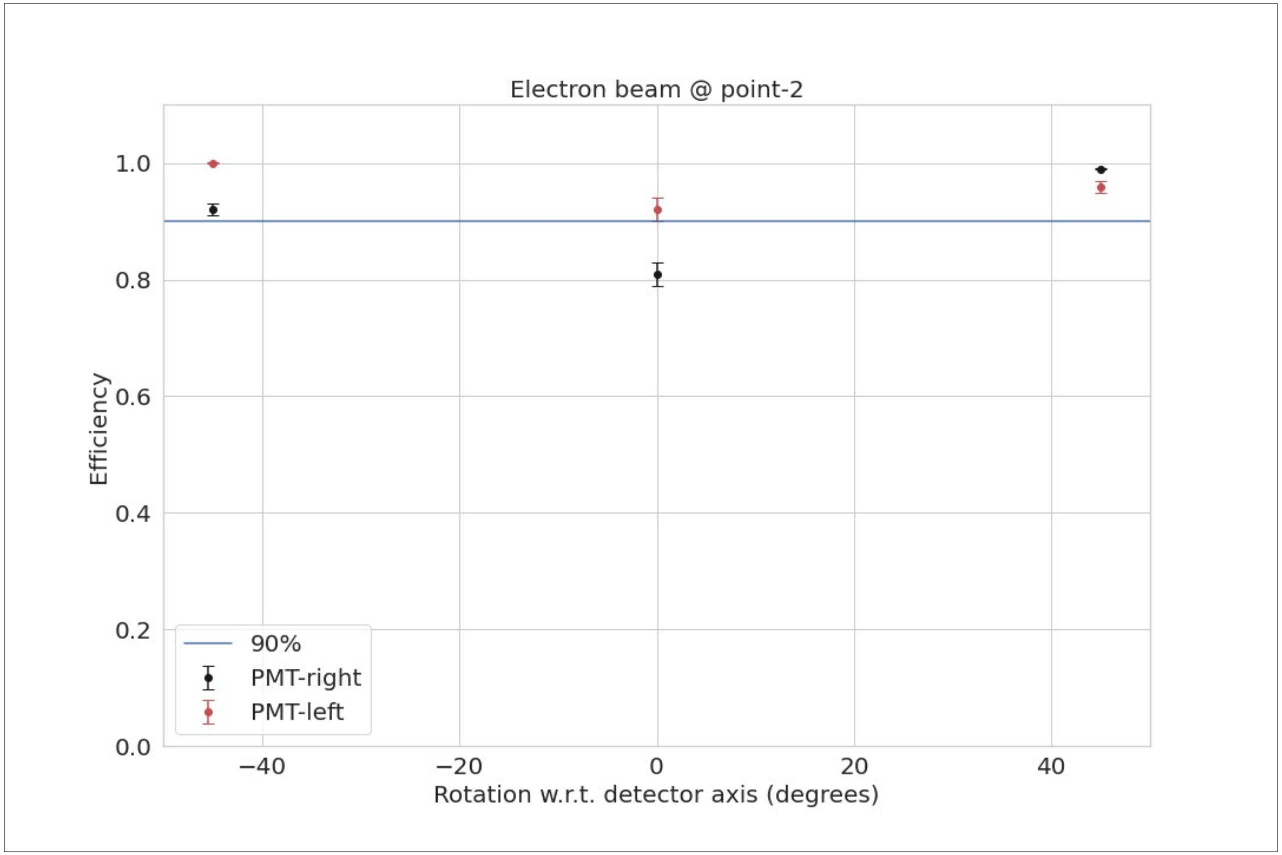




- As we expected for very fast rise time signals, there is not much difference between standard threshold technique (method A) and CFD (method B)

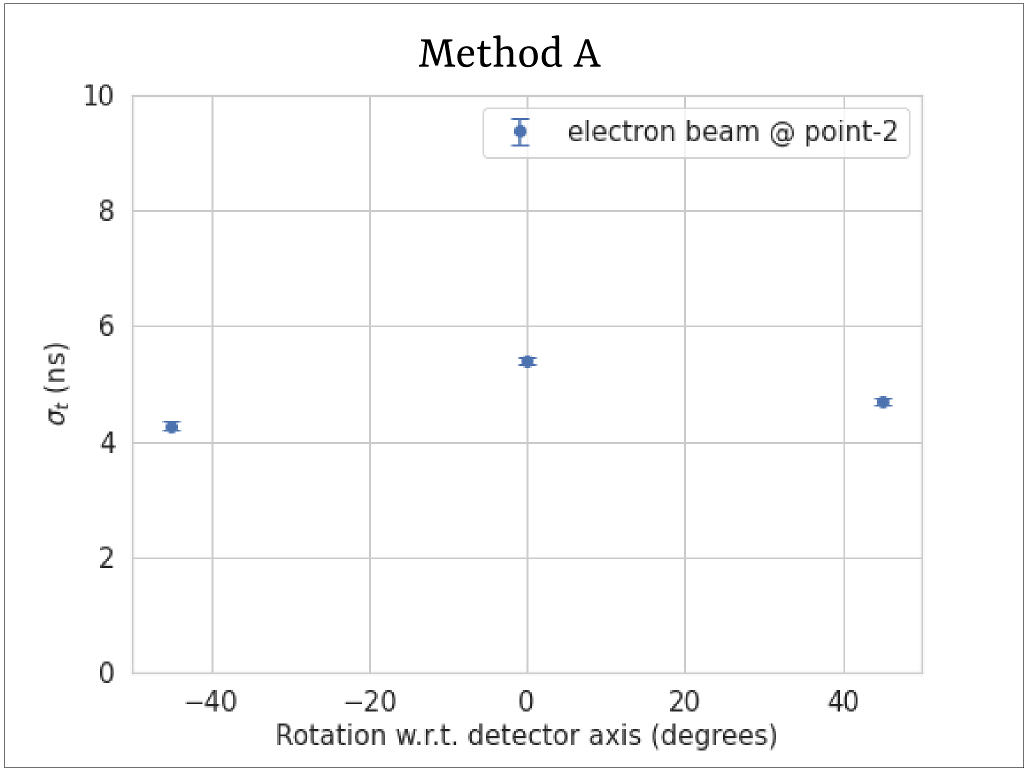
Efficiency study - PMTs

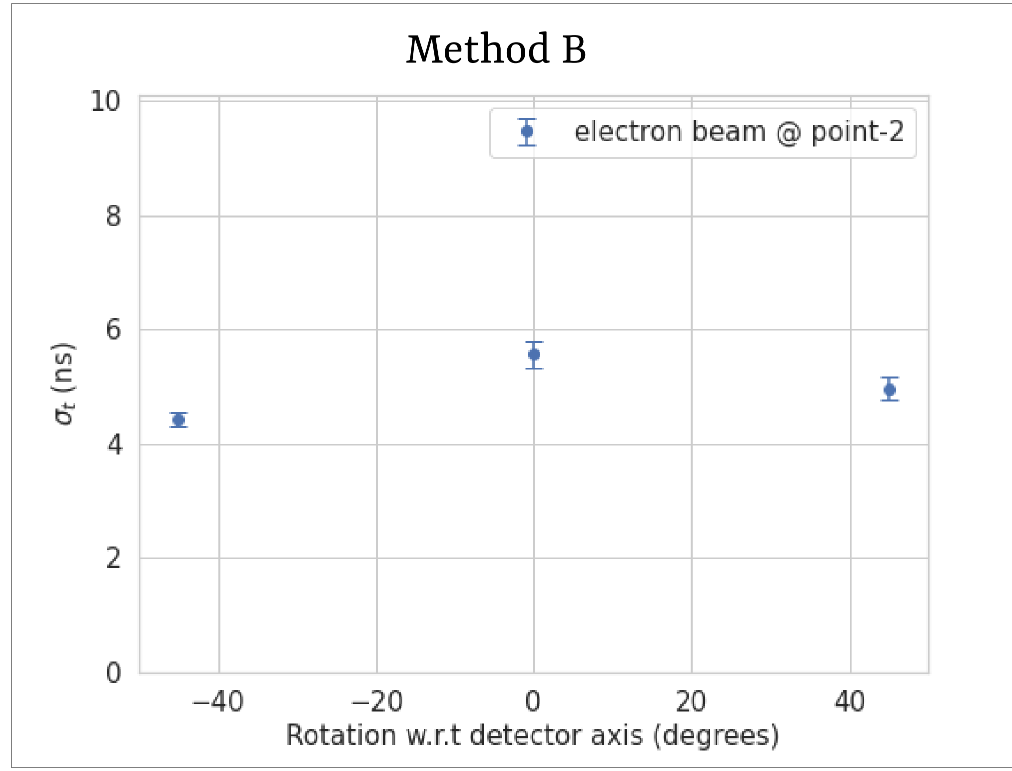
- Data collected with beam spot in the center of detector
- Angle between detector axis and beam → -45°, 0°, 45°



- Inclined tracks give higher efficiency due to the longer travel path → higher signal

Time resolution - PMTs

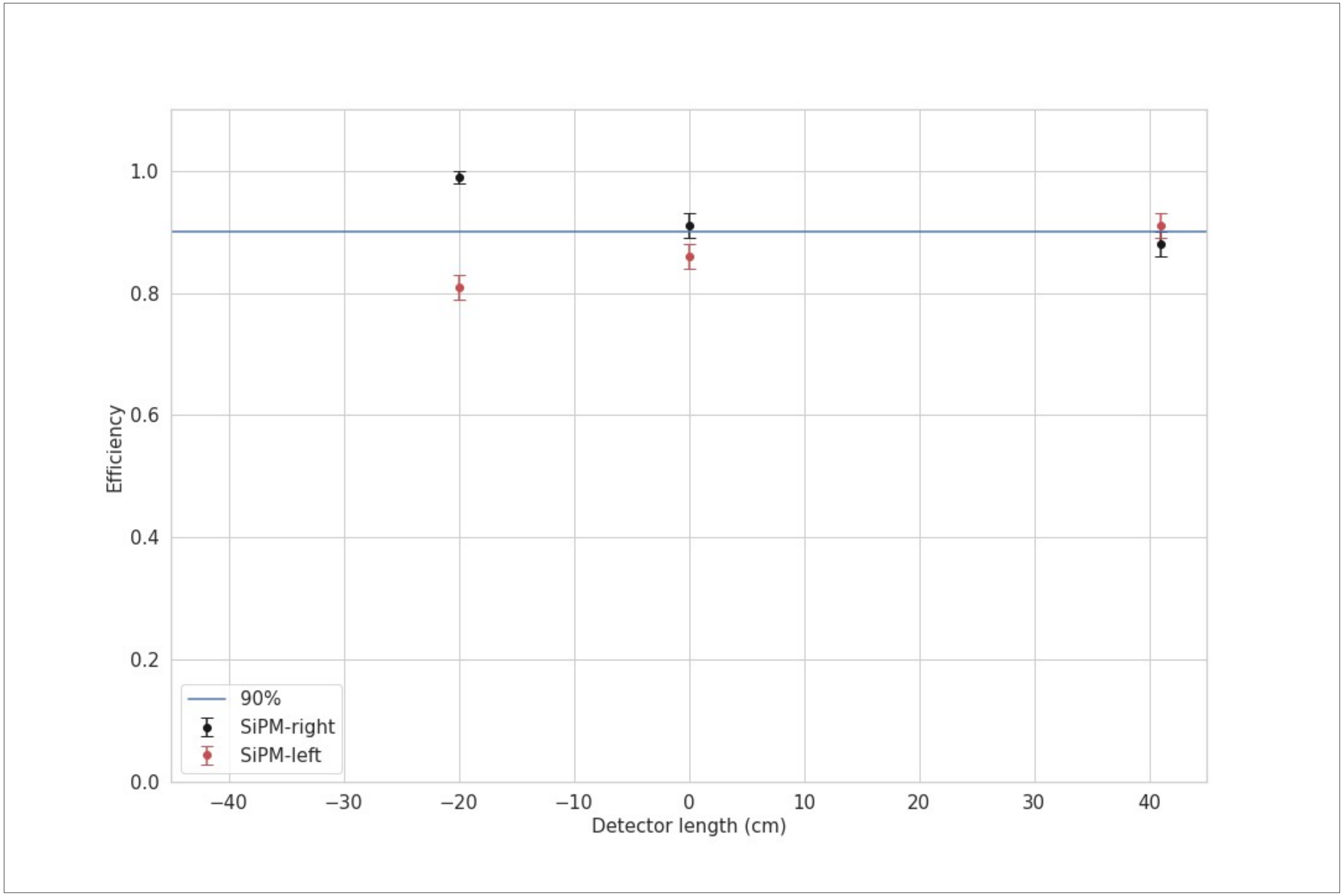




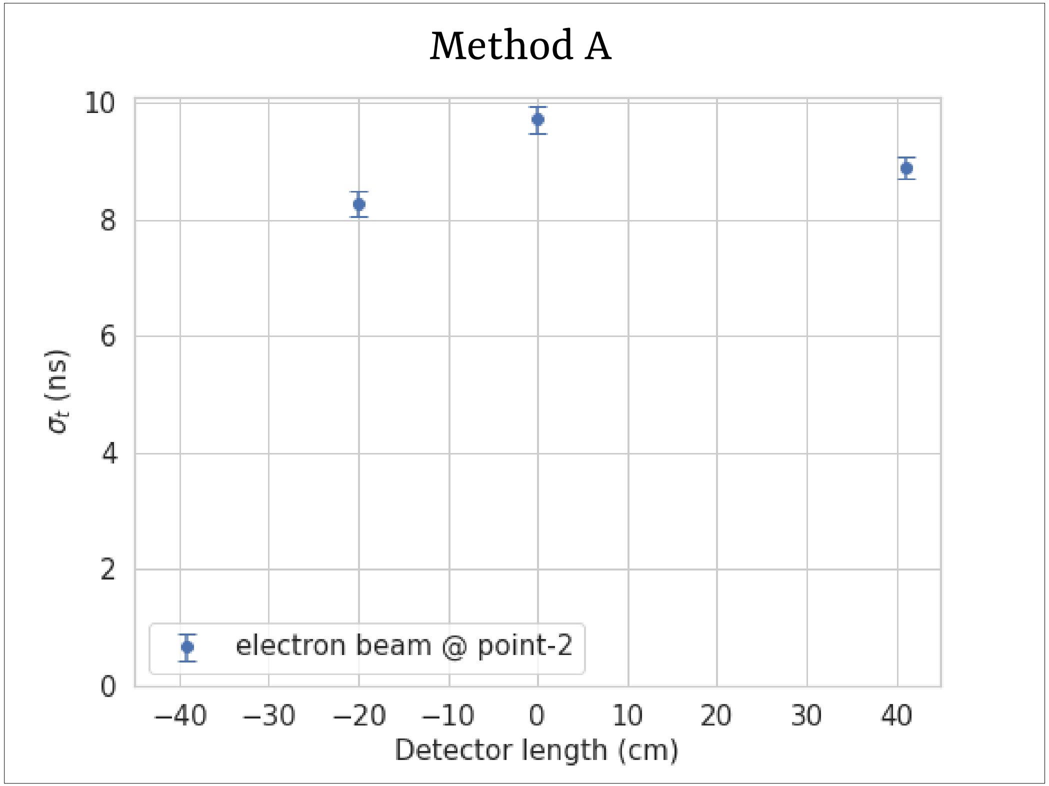
- Inclined tracks give better time resolution due to the longer travel path → higher signal

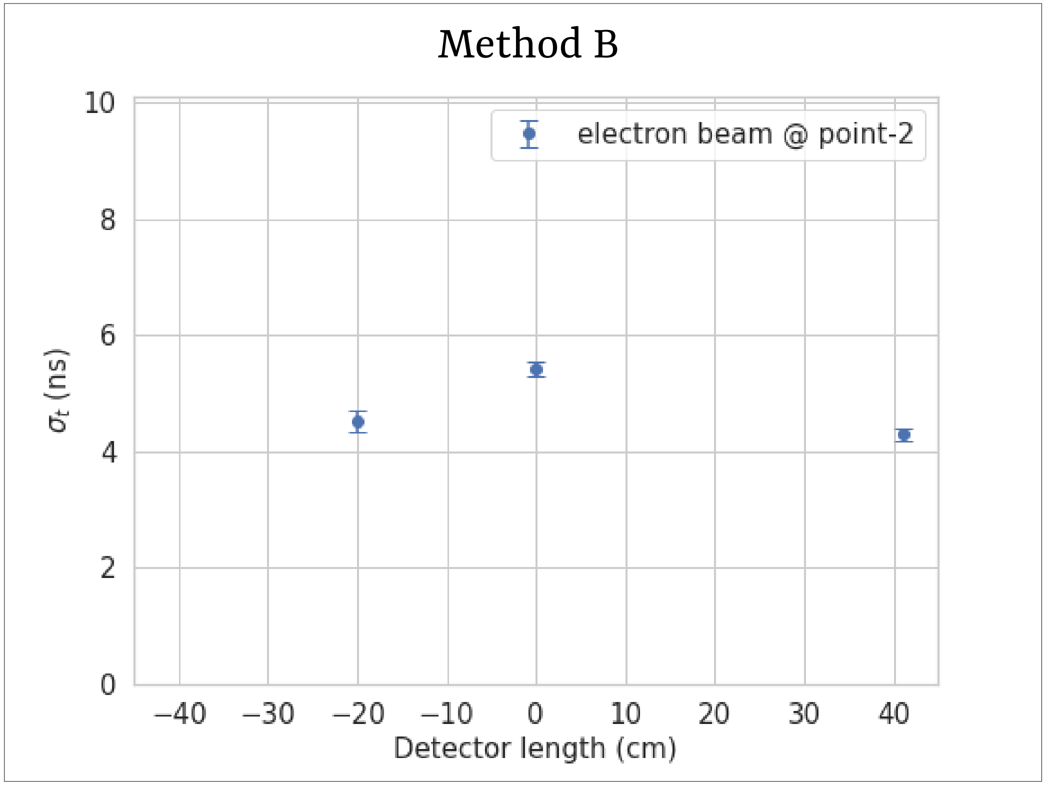
Efficiency study - SiPMs

- In order to estimate both the efficiency and the time resolution of SiPM of the prototype v1, we performed the same analysis
- With SiPM we took data along the detector length with the beam at the point-2



Time resolution - SiPMs





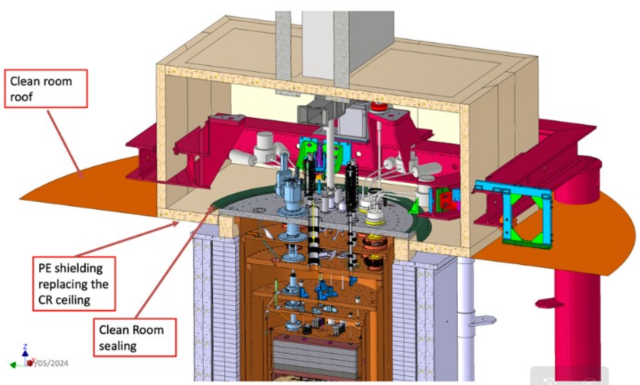
- As we expected for slow rise time signals, CFD technique (method B) improves the time resolution

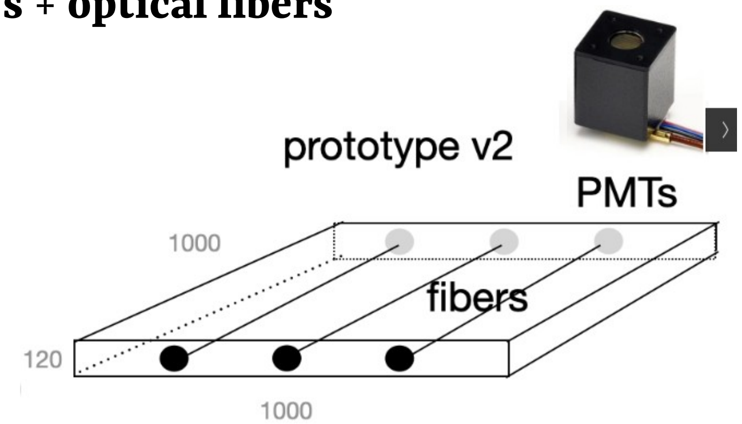
Conclusions and next steps

- These very preliminary results demonstrate that our idea to use this detector on a large scale application is feasible
- The time resolution achieved seems to permit a rough tracking of detected muons
- The preliminary results of the efficiency are also encouraging
- This detector could be used in CUPID experiment as neutron moderator and muon veto (NS&MV)

Next steps:

- Construction and characterization of a third prototype (**prototype v2**) as firts example of a possible CUPID NS&MV
- Next Readout: Hamamatzu compact **PMTs** + **optical fibers**



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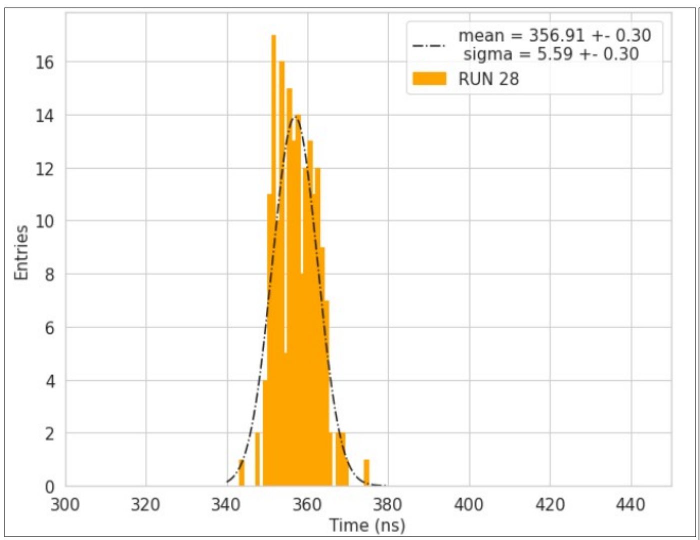
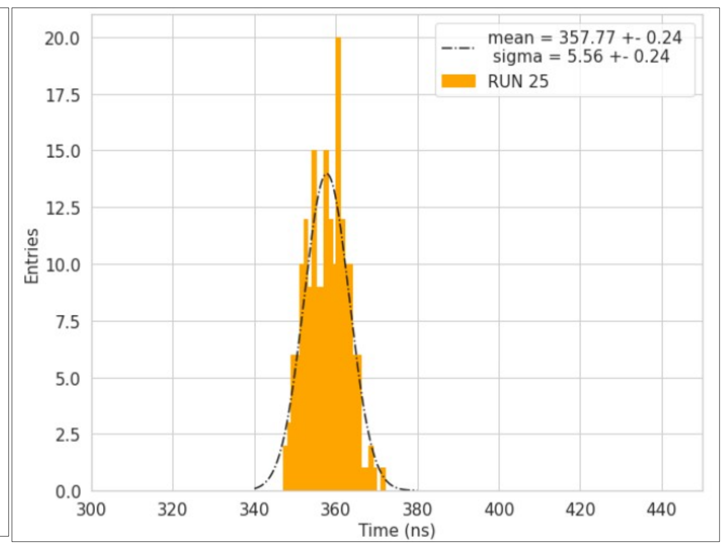
ATTENTION!

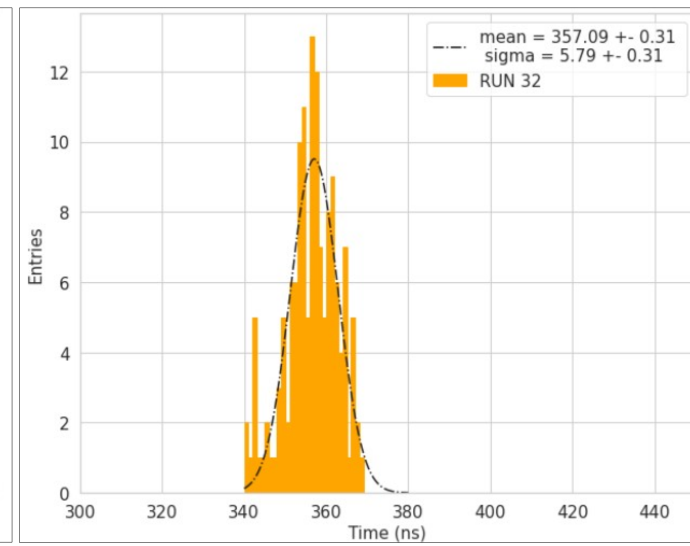
Time resolution - PMTs

Method B

- Then, t_s selected were added and the σ_t was estimated by mean the sum times distribution

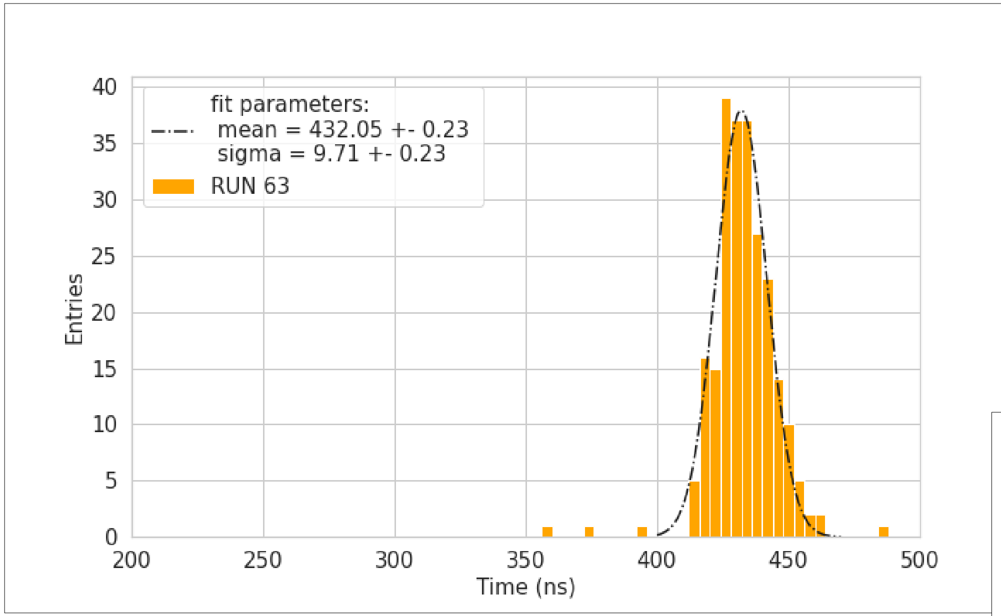


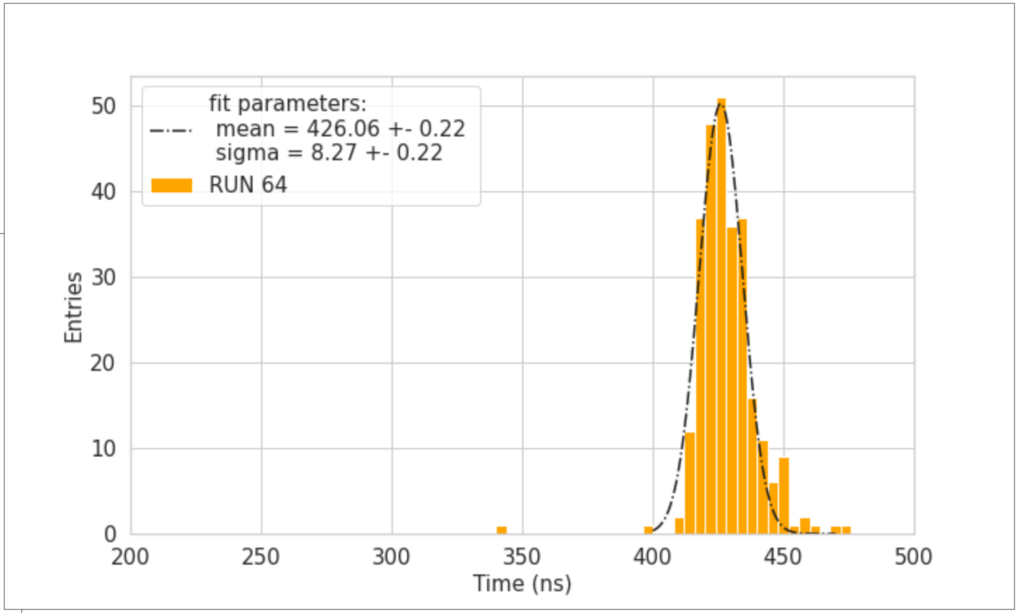


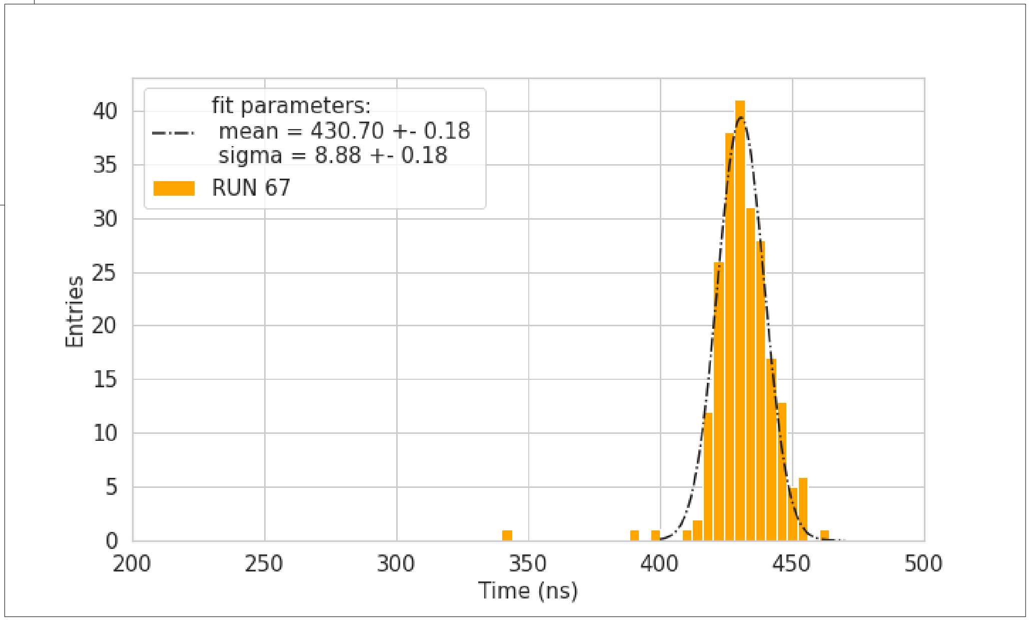


Time resolution - SiPMs

Method A

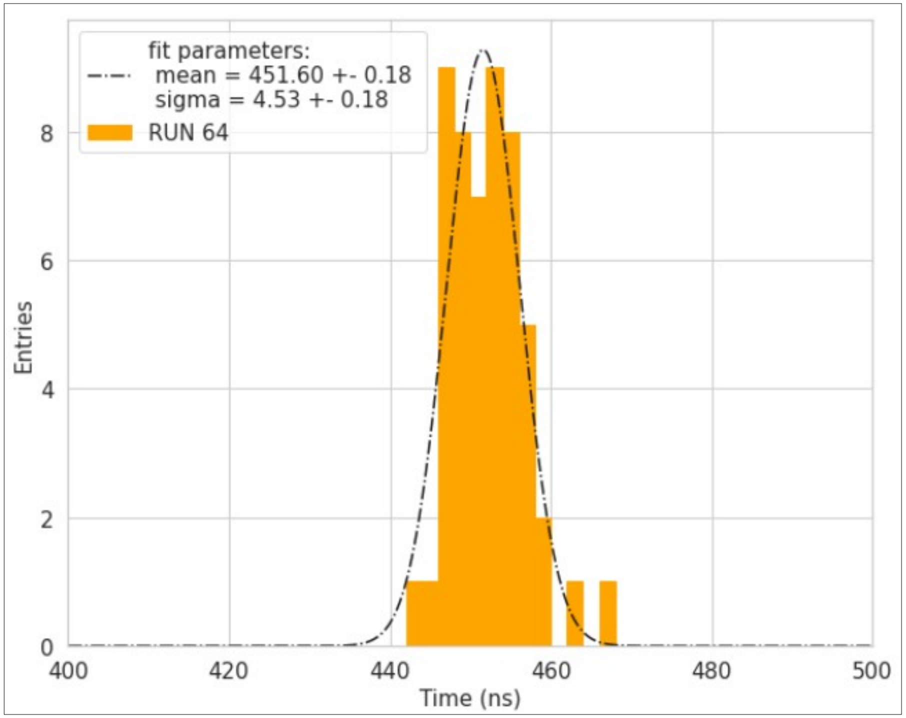


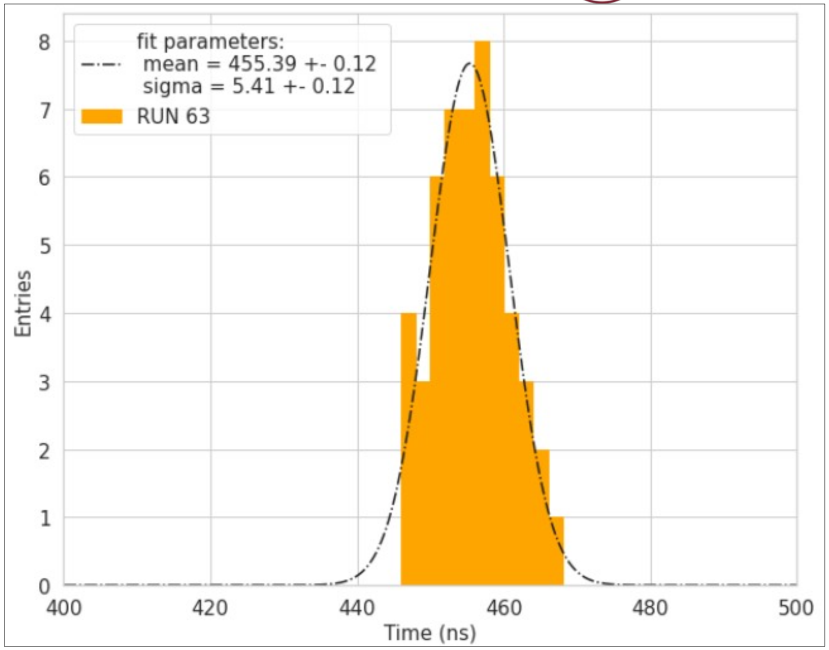


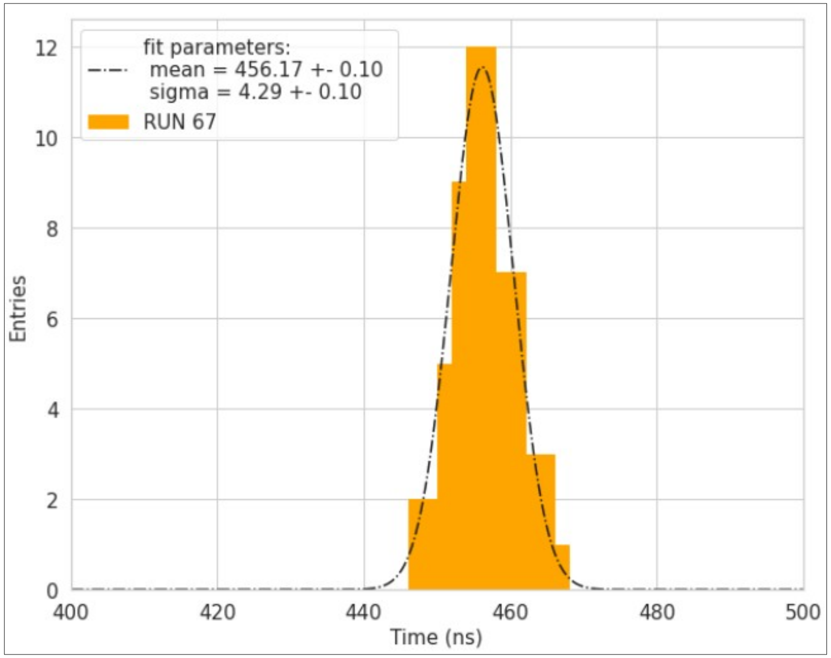


Time resolution - SiPMs

Method B







Conclusions and next steps

Conclusions

Efficiency study:

- **PMTs:**
  - Along radius → it is **higher** at the **center** and **decreases** at the **edges**
  - Along length → it **depends** on the **position** of the PMT w.r.t. the interaction point
- **SiPMs:**
  - SiPM have a **quite similar** efficiency → it does not strongly depend on the interaction position

Time resolution:

- SiPMs have a worse time resolution than PMTs
- It was improved by mean CFD method

- Results demonstrate we can build a **muon veto detector** by using the **Cherenkov light**