Time resolution analysis of trigger detectors based on plastic scintillators coupled to silicon photomultipliers

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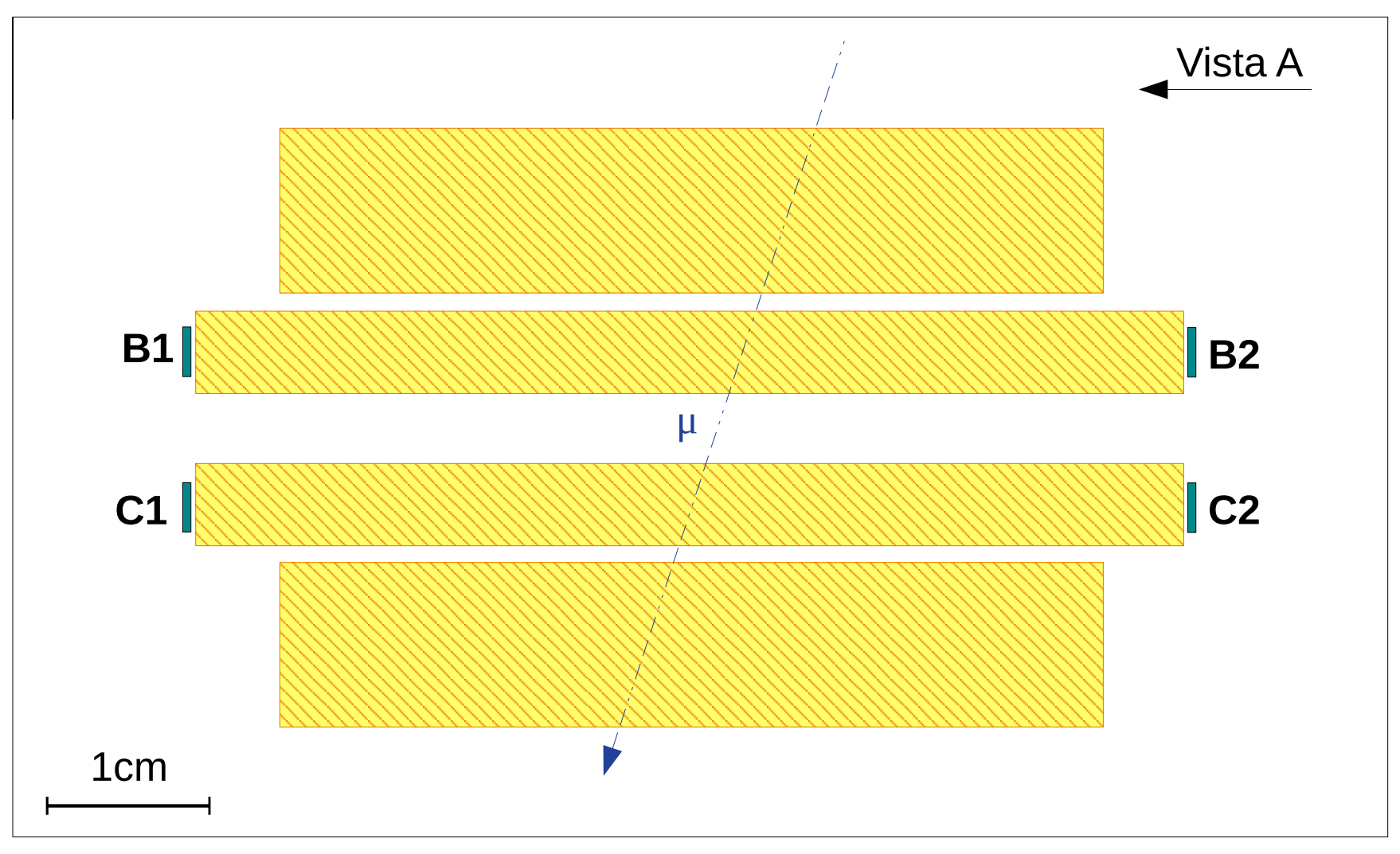
Abstract

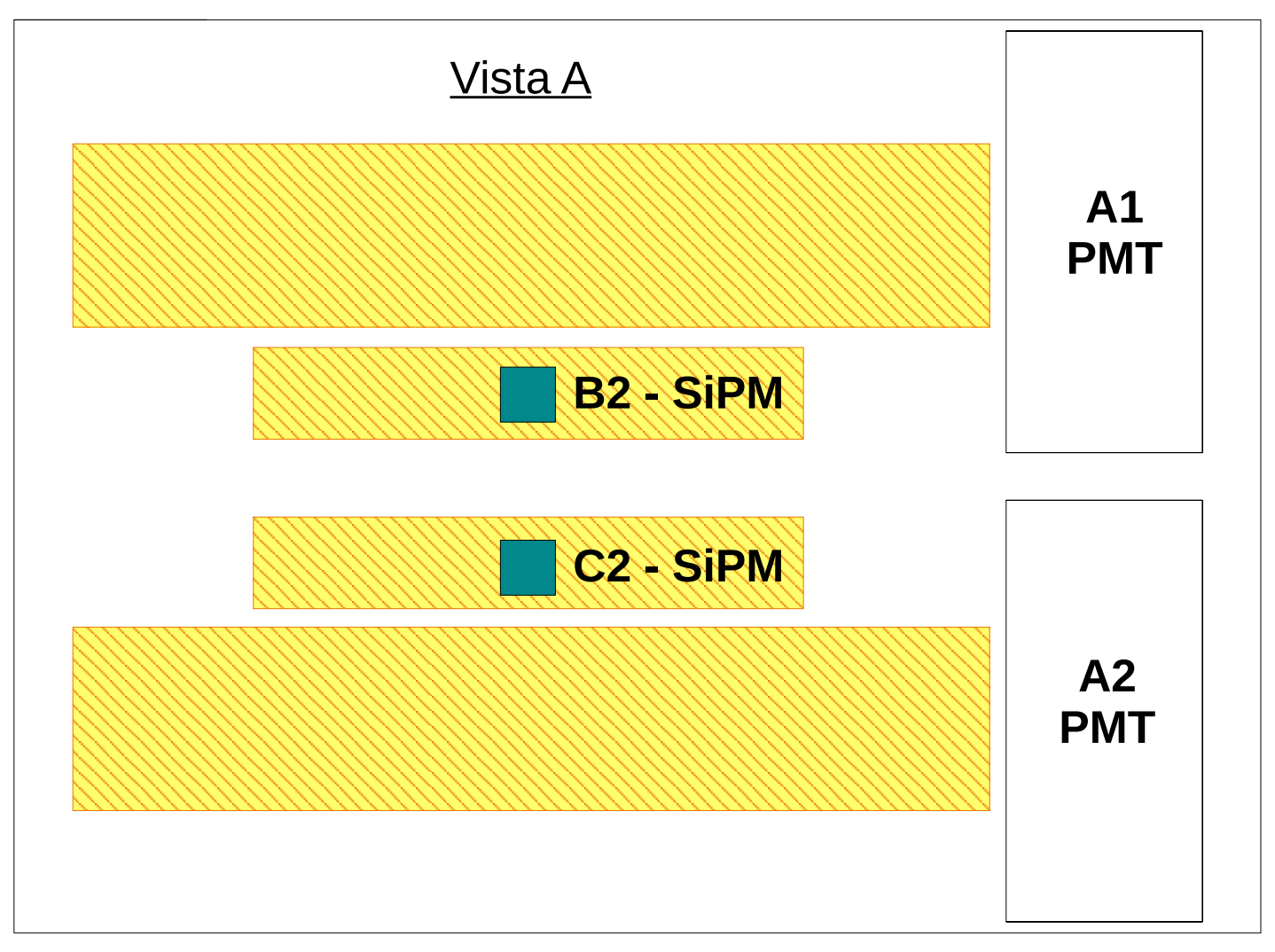
The performance of several trigger counters based on plastic scintillators with silicon photomultiplier readout is investigated with cosmic rays. Efficiency and time resolution are measured using digital waveform analysis. The obtained results are relevant for trigger subsystems of **B**aryonic **M**atter **at** the **N**uclotron (BM@N) and **M**ulti-**P**urpose **D**etector (MPD) at the NICA heavy-ion collider. The results show very high efficiency and good timing performance of the counters.

Introduction

In modern high energy physic experiments Silicon Photomultipliers (SiPMs) have a potential to replace traditional Photomultiplier Tubes (PMTs) in many applications, such as trigger detectors, time-of-flight hodoscopes, and calorimetry. Because the event rate in many high energy physics experiments is very high, trigger detectors are typically based on either fast plastic scintillators or Cherenkov radiators coupled to PMTs or SiPMs. Basic requirements for such trigger detectors are high efficiency of particle detection and very good time resolution.

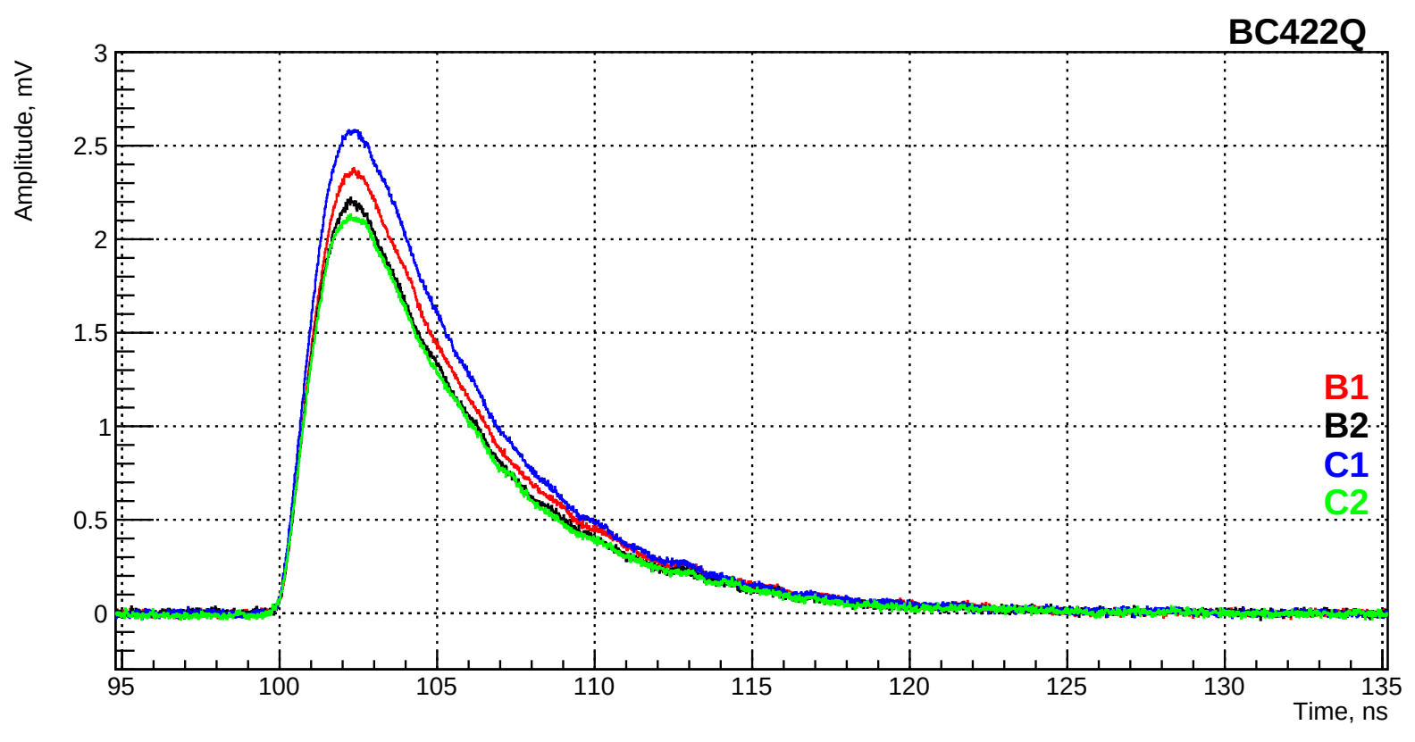
Setup 1



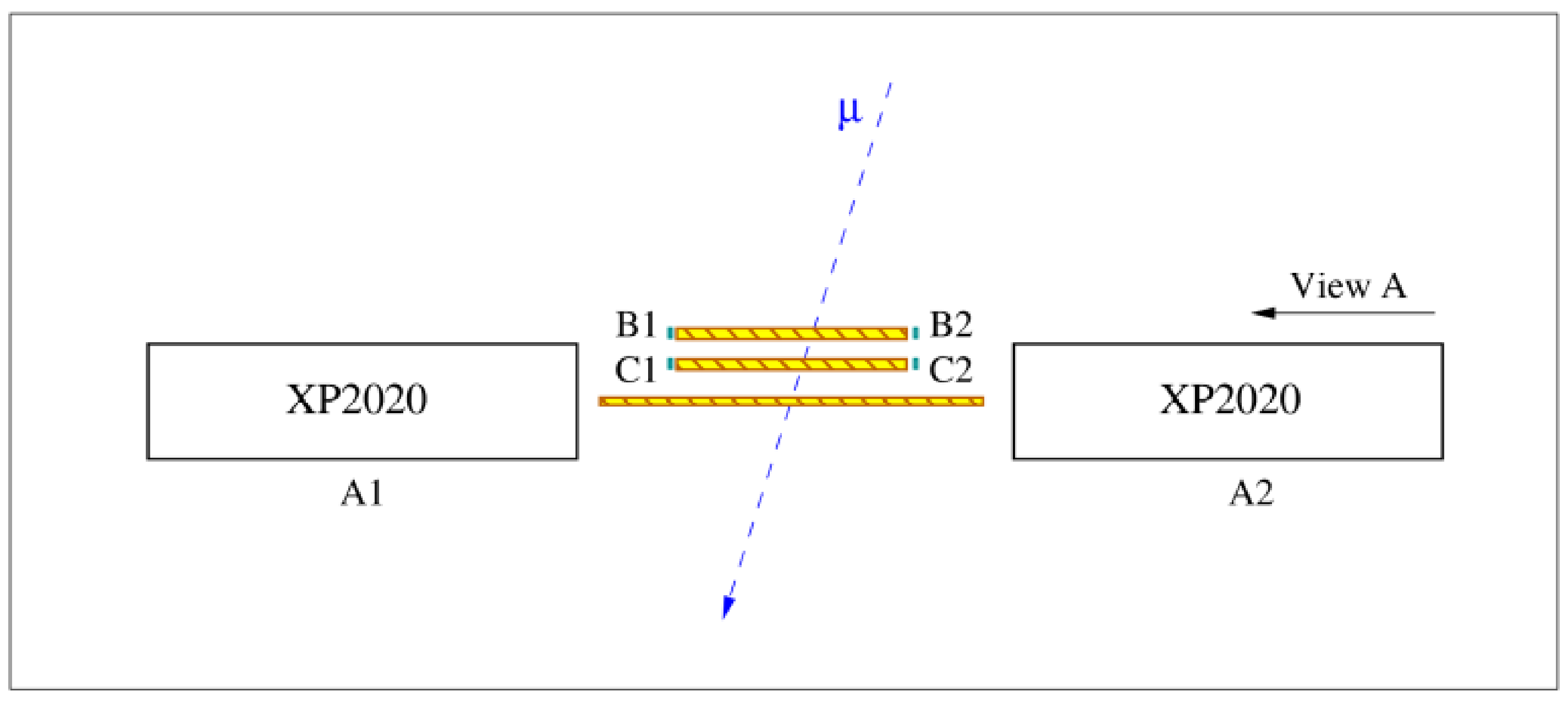


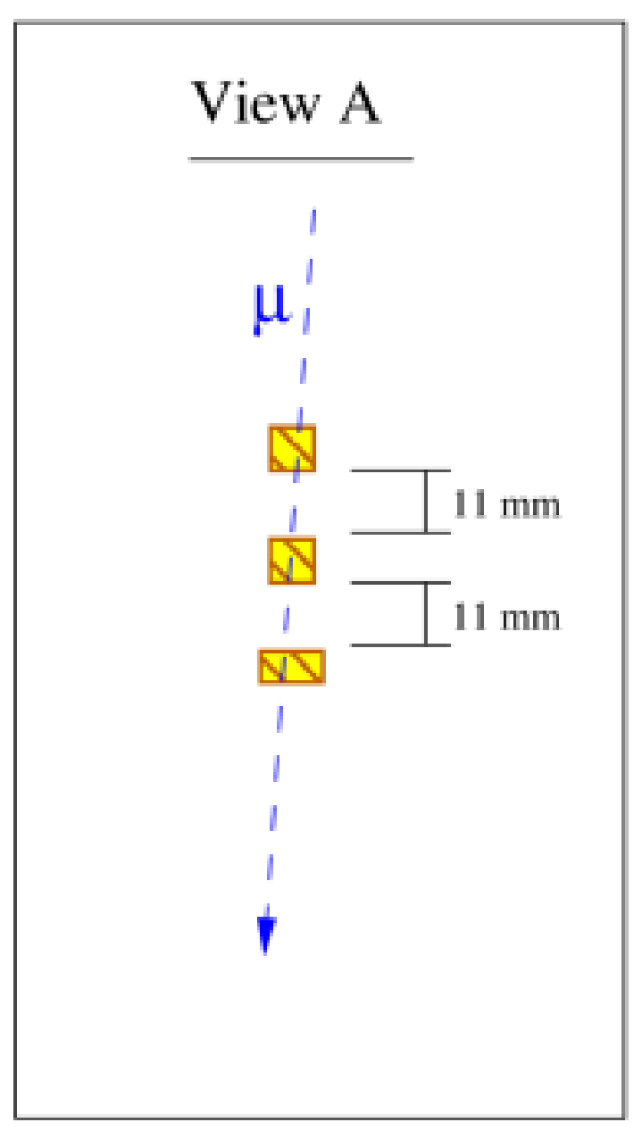
Characteristics:

- Trigger: PMTs Ham H5783 coupled to BC-404 wrapped in Al-mylar of $50 \times 50 \times 10mm^3$.
- SiPMs Ham S13360-3050CS $3 \times 3mm^2$ coupled to BC-404/BC-422Q wrapped in Al-mylar of $60 \times 30 \times 5mm^3$.



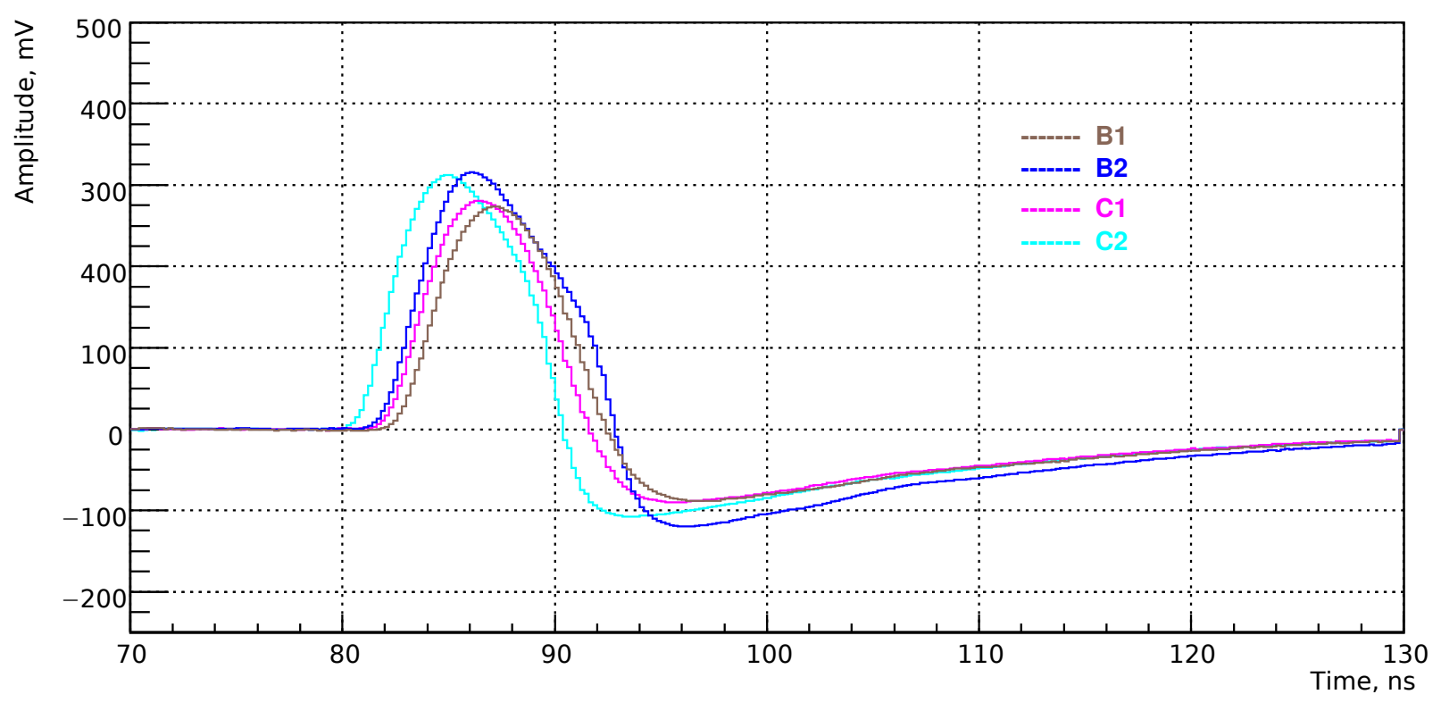
Setup 2





Characteristics:

- Trigger: PMTs Ham XP2020 coupled to BC-418 wrapped in Al-mylar of $240 \times 10 \times 5mm^3$
- SiPMs (SensLMicro FC-60035-SMT $6 \times 6mm^2$) coupled to BC-418 wrapped in Al-mylar of $150 \times 7 \times 7mm^3$. The BM@N **B**arrel **D**etector (BD) consists of 40 of this type strips.



Acknowledgements

I would like to express my thanks to the FFD group of the Laboratory of the High Energy Physics at the **J**oint **I**nstitute for **N**uclear **R**esearch (JINR), and in particular to my superb supervisor Sergey Sedykh, for his continuous support during and after my Summer Student program. Also, special thanks to Victor Rogov for helping with the experimental setup and SiPM electronics.
To the JINR, for all expenses that I received to can work and be part of the SSP2018.

References

[1] Vinke, R. (2011). Time-of-flight PET with SiPM sensors on monolithic scintillation crystals. s.n.
[2] H. Kumawat. (2012). Time Resolution Study of the Range Counter for $K^{-}pp$ Bound State Searches at J-PARC
[3] Search 'Marco Alberto Ayala Torres' in the list http://students.jinr.ru/en/jinr2018-participants

Methods

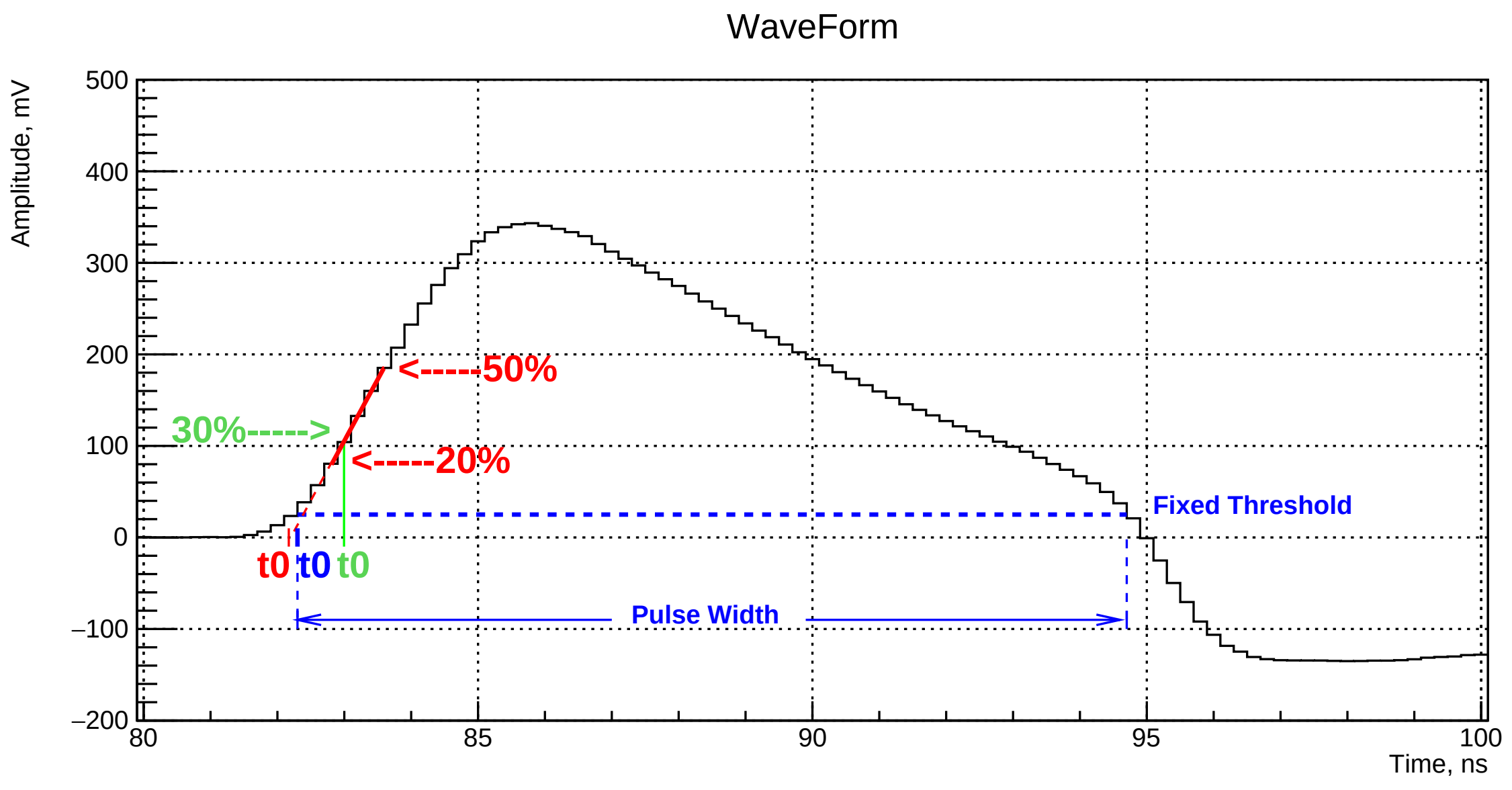
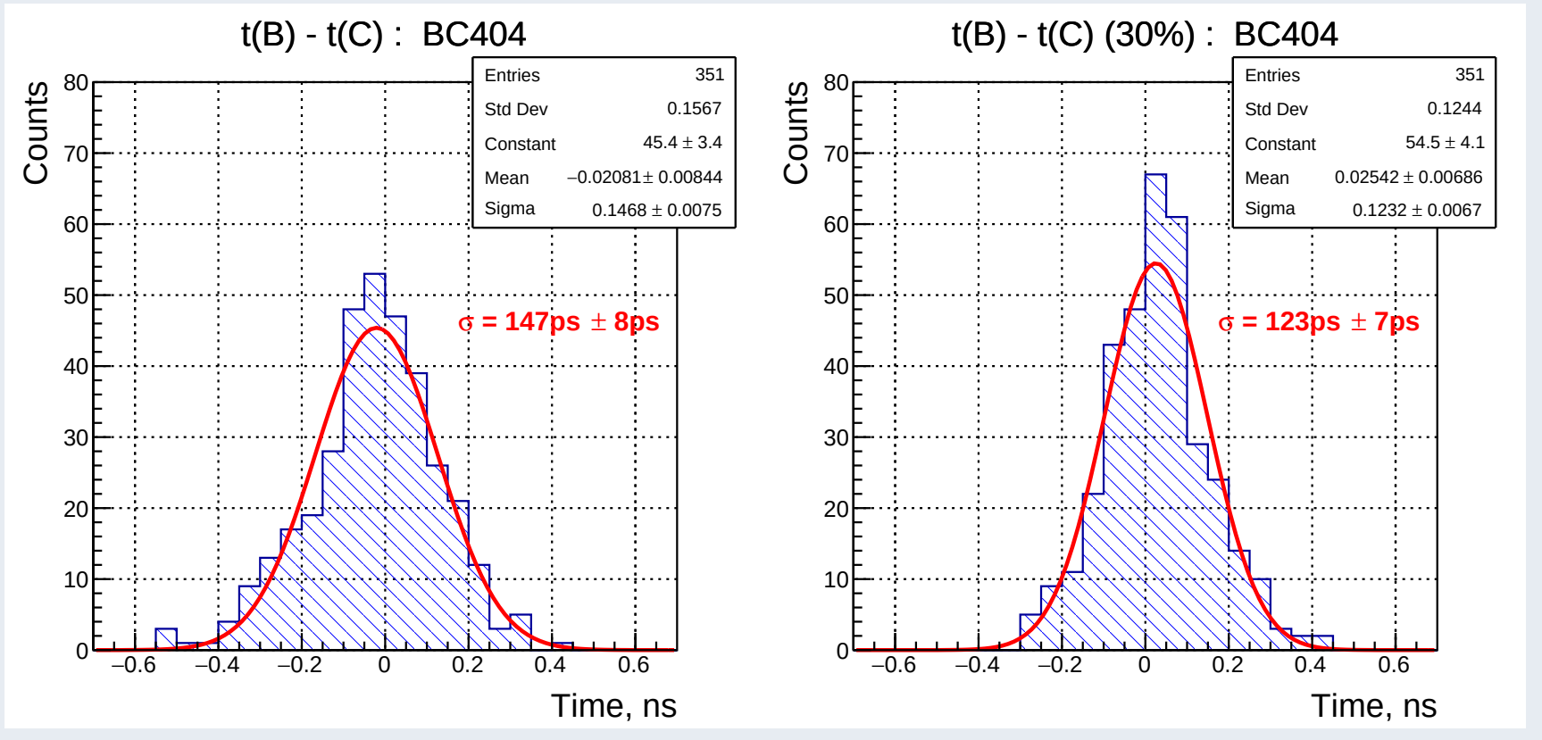


Figure 1: The tested procedures to obtain the arrival time of the signals are illustrated. **M1)** Two points in which the front of the signal crosses thresholds of 20% and 50% relative to the pulse maximum was determined, and the front of the signal in the region between these two points was fitted with a straight line. The intersection of the extrapolation of this line with the baseline of the waveform was accepted as the signal arrival time ($t0$). **M2)** Now, $t0$ is considered equal to the time in which the signal crosses threshold of 30% relative to the pulse maximum [1]. **M3)** A fixed threshold is defined (25 mV) and t0 is the time the signal needs to cross this fixed threshold. Note that t0 moves with the amplitude and it was required to correct by the slewing correction. For this, it was needed to obtain the pulse width (the pulse duration above the fixed threshold) [2]. The impact time in the detector B was calculated as $t_B = \frac{1}{2}(t0_{B1} + t0_{B2})$ and analogous for C.

Results

Comparison between the M1 and M2

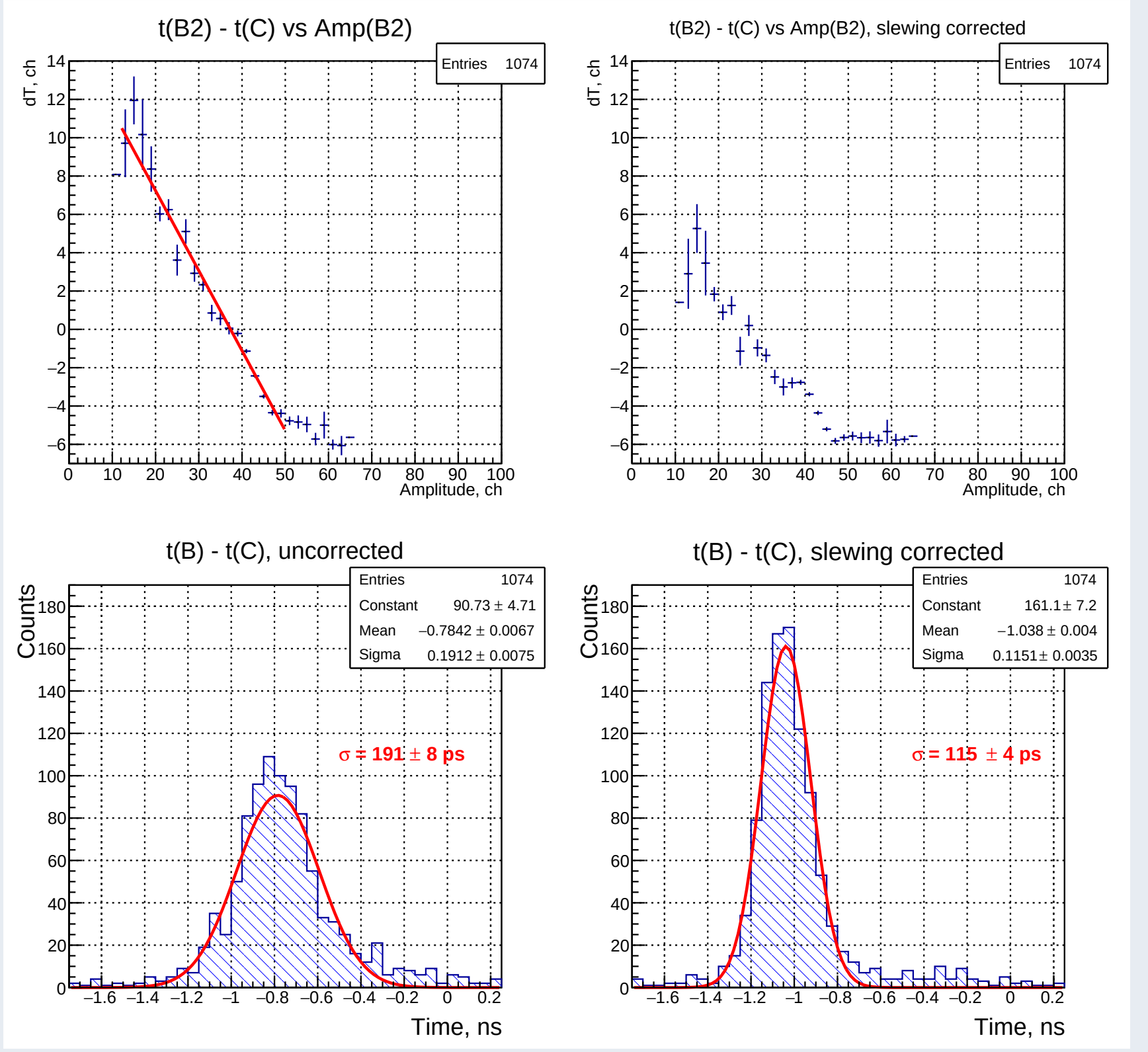


Assuming that the contribution from the detectors B and C is the same $(\sigma_B = \sigma_C = \frac{\sigma_{BC}}{\sqrt{2}})$, it was possible to estimate that the time resolution of the single detector was:

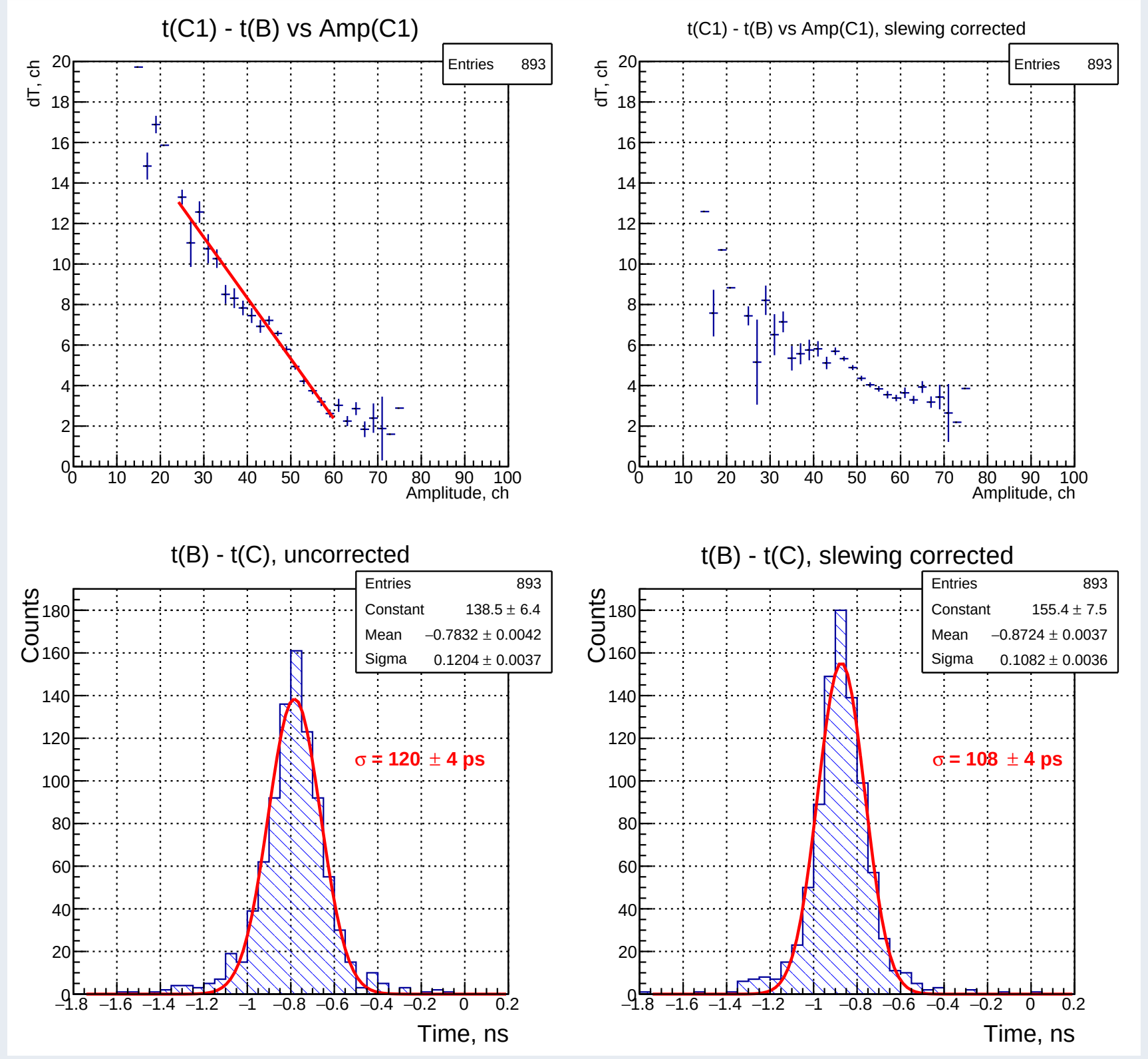
Plastic scintillator	M1	M2
BC404	$104 \pm 6\ ps$	$87 \pm 5\ ps$
BC422Q	$139 \pm 5\ ps$	$125 \pm 5\ ps$

Fixed threshold + slewing correction

Without optical grease



With optical grease



The time resolution of the BC-418 was:

Opt.grease	M1	M3	M3 corrected
without	$95 \pm 3\ ps$	$135 \pm 6\ ps$	$81 \pm 3\ ps$
with	$88 \pm 3\ ps$	$85 \pm 3\ ps$	$76 \pm 3\ ps$

In addition, a test was performed to determine the efficiency of detection of minimum ionizing particles if they completely cross the BD strips and should be close to 100% [3].

In the BM@N run in March-April 2018 the pulse height of the signals from BD was obtained by measuring the time over threshold (ToT). ToT is based on the fact that the larger the amplitude of the pulse, the larger it is the duration. Even if the signal exceeds the maximum level of the digitizer ADC, the saturated amplitude can be obtained by measuring the pulse width.

Conclusion

Scintillation counters with SiPMs can serve as simple and at the same time very efficient trigger detectors with high time resolution. They are being used for testing several sub-detectors of the MPD experiment, and as trigger detectors in the BM@N experiment. In addition, they are considered as possible detectors in the Beam-Beam counter of the MPD.
In the absence of a test beam, cosmic rays provide a good alternative for testing and calibrating particle detectors. Despite relatively low event rate, even small detectors can be efficiently studied with cosmic rays.