Status of the proposal for a beam-beam counter (BE-BE) for MPD

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2nd. Collaboration meeting of the MPD and BM@N experiment at NICA Facility

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Plan of the talk

- Motivation for a beam–beam counter detector for MPD
- Detector concept
- Simulation and time resolution studies
- Final comments

Motivation for a beam–beam counter detector for MPD

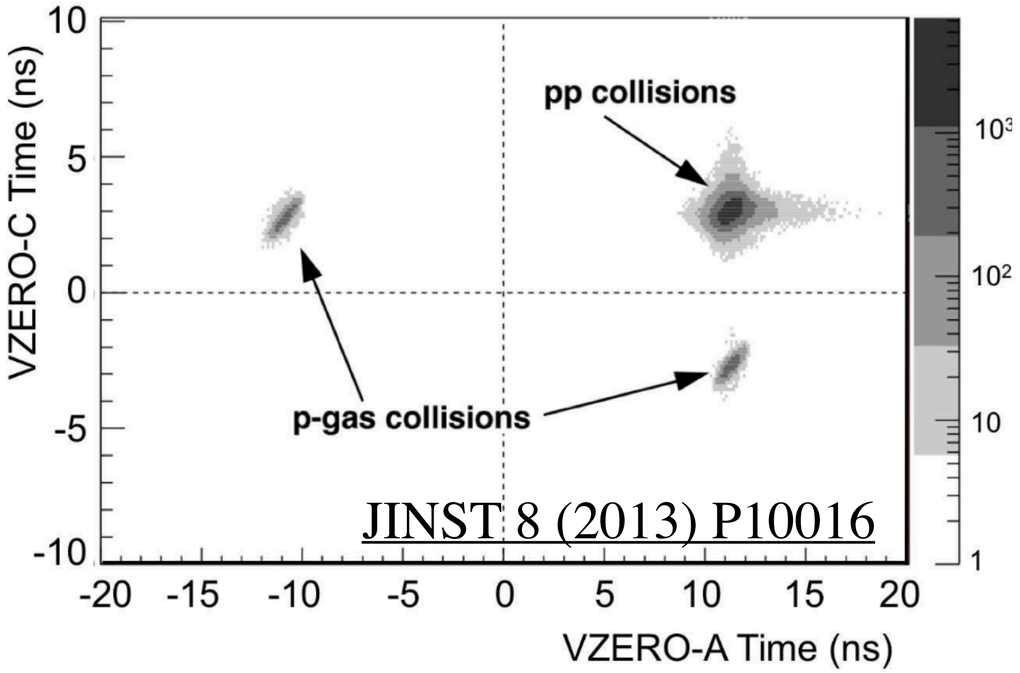
In collider experiments, a beam–beam counter detector is highly desirable.

- **trigger system**: to identify and to discriminate beam–beam minimum bias or centrality events from background and beam–beam interactions.

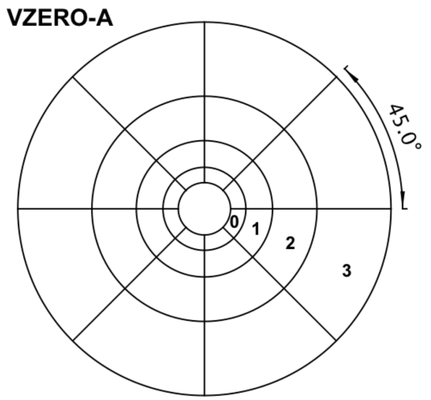
- **bonus, physics studies**:

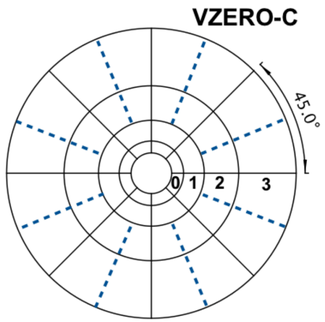
  - luminosity measurements, for the determination of absolute cross sections of reaction processes
  - multiplicity of charged particles, key observable for the determination of the centrality of the collisions events and event plane resolution

Motivation for a beam–beam counter detector for MPD



JINST 8 (2013) P10016





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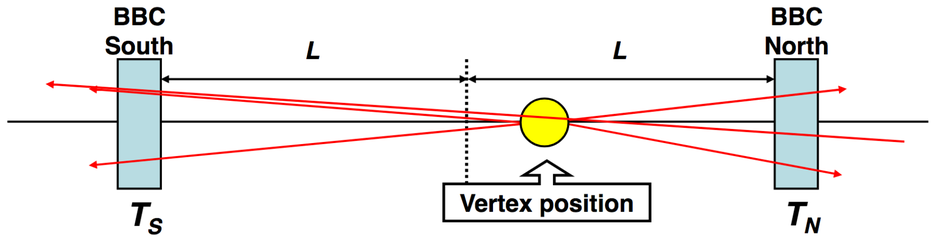
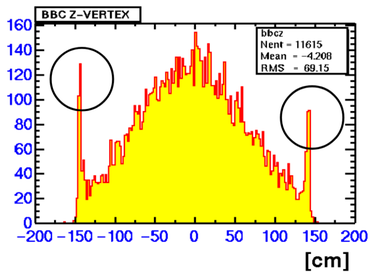
Motivation for a beam–beam counter detector for MPD

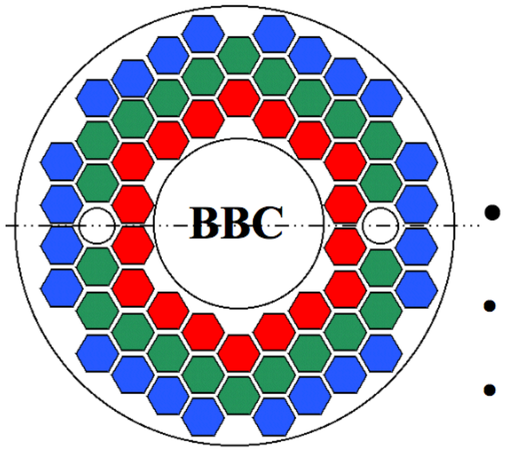
https://www.phenix.bnl.gov/WWW/intro/detectors/focus/focus_bbc.pdf



- ***Z-Vertex*** $= \dfrac{T_S - T_N}{2} \times c$
- **Time zero** $= \dfrac{T_S + T_N - 2L/c}{2}$

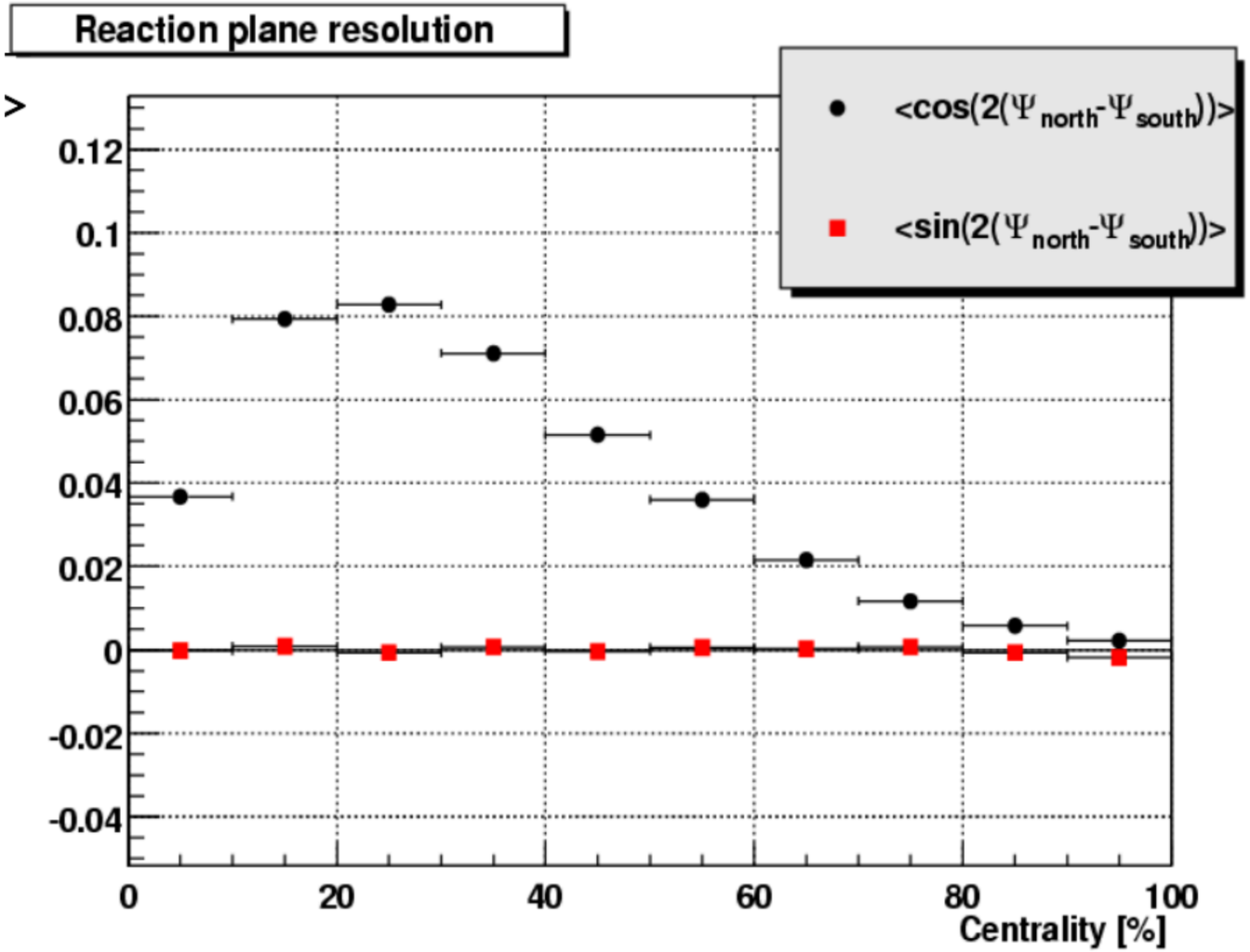


$T_{N/S}$: average hit time, c : light velocity, L : 144.35 cm



RING ID

- **inner ring**
- **middle ring**
- **outer ring**



Detector concept

Main role of MPD beam–beam counter detector (BE–BE): to produce a signal for the MPD Level–0 trigger.

Requirements for BE–BE detector:

- radiation hard
- need to work in high magnetic field environment
- time resolution of 30 ps (see Slava's slides from last collaboration meeting: https://indico.jinr.ru/getFile.py/access?contribId=6&resId=0&materialId=slides&confId=385)

Detector concept

Geometry of BE–BE detector

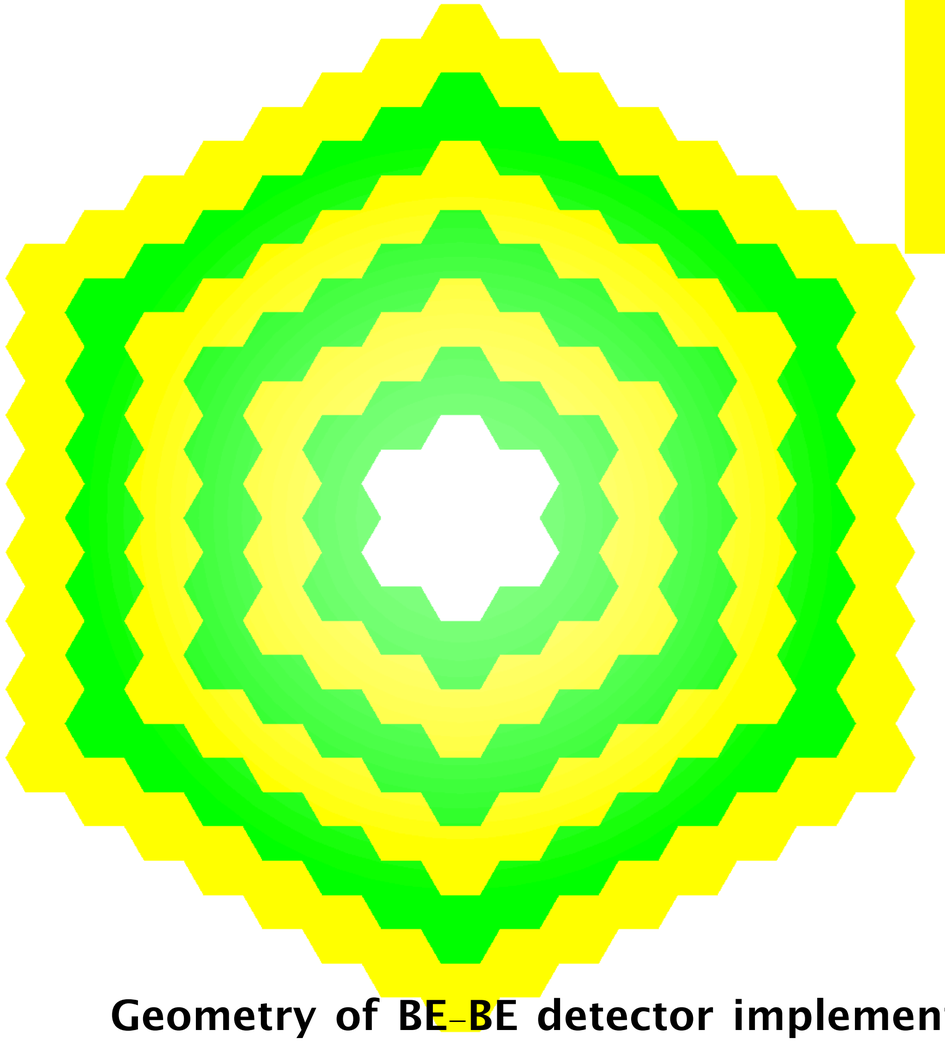
- two hodoscope detectors located, each located 2 m. away from interaction point at opposite sides.

- each hodoscope consists of 162 hexagonal plastic scintillator cells arranged in six concentric rings.

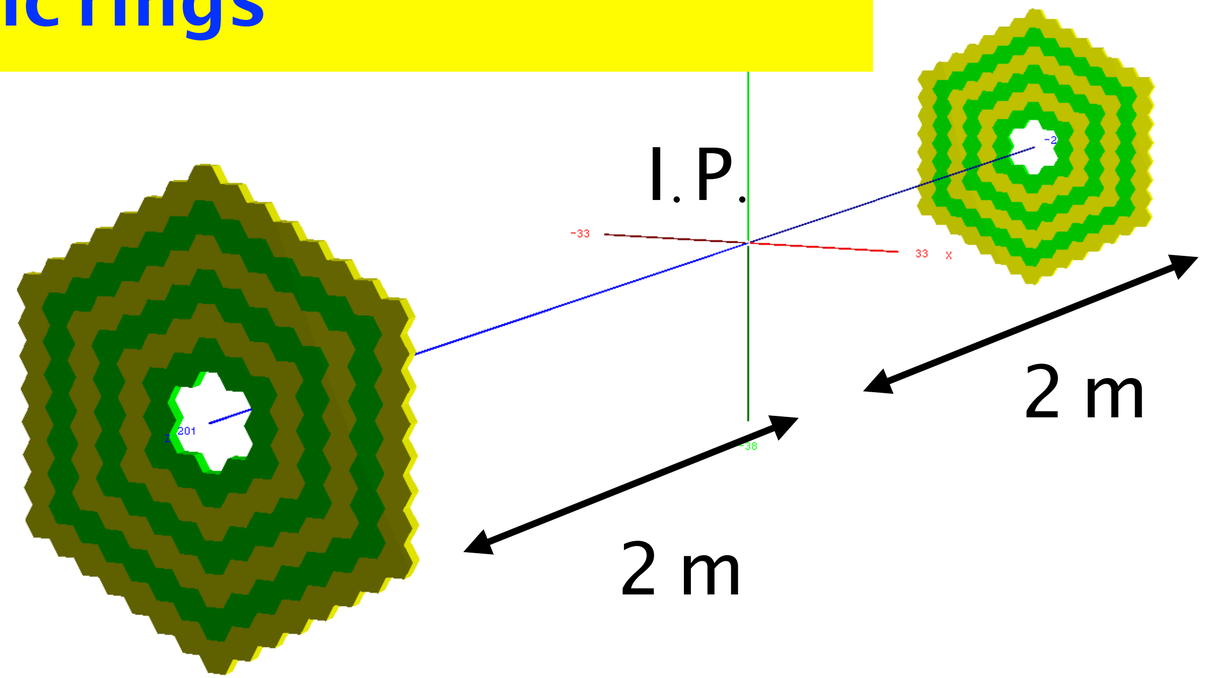
- pseudorapidity range $1.9 < |\eta| < 3.97$

Detector concept

of 162 hexagonal plastic scintillator cells arranged in six concentric rings

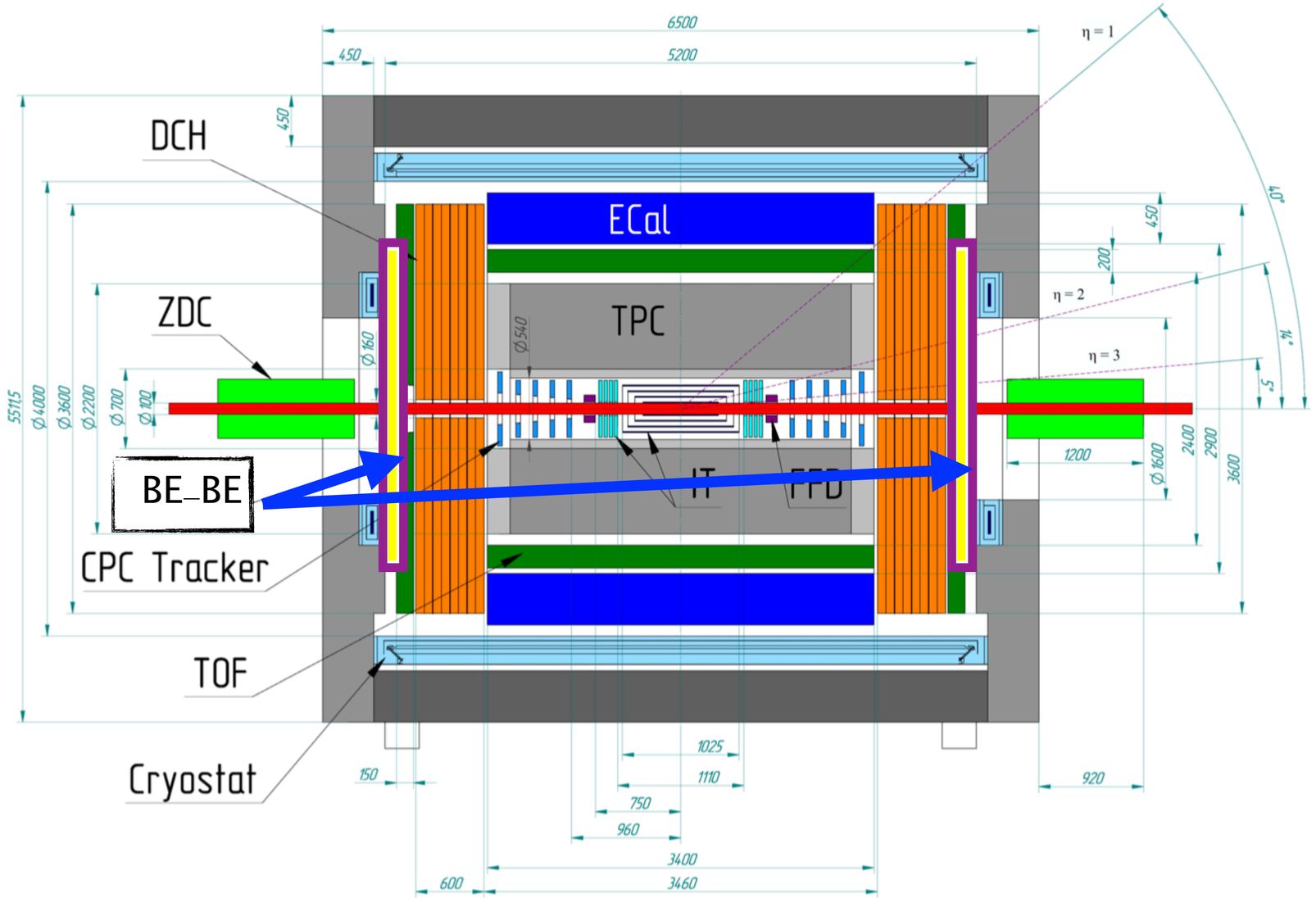


Geometry of BE–BE detector implemented in MPD–ROOT



located 2 m away in opposite sides from the I.P.

Detector concept



Simulation and time resolution studies

To study the BE–BE capabilities,

- we performed simulation studies to evaluate the event plane resolution

- we built a prototype evaluated with a beam test

From here, all the details can be found in:

https://arxiv.org/abs/1809.10553

Simulation and time resolution studies

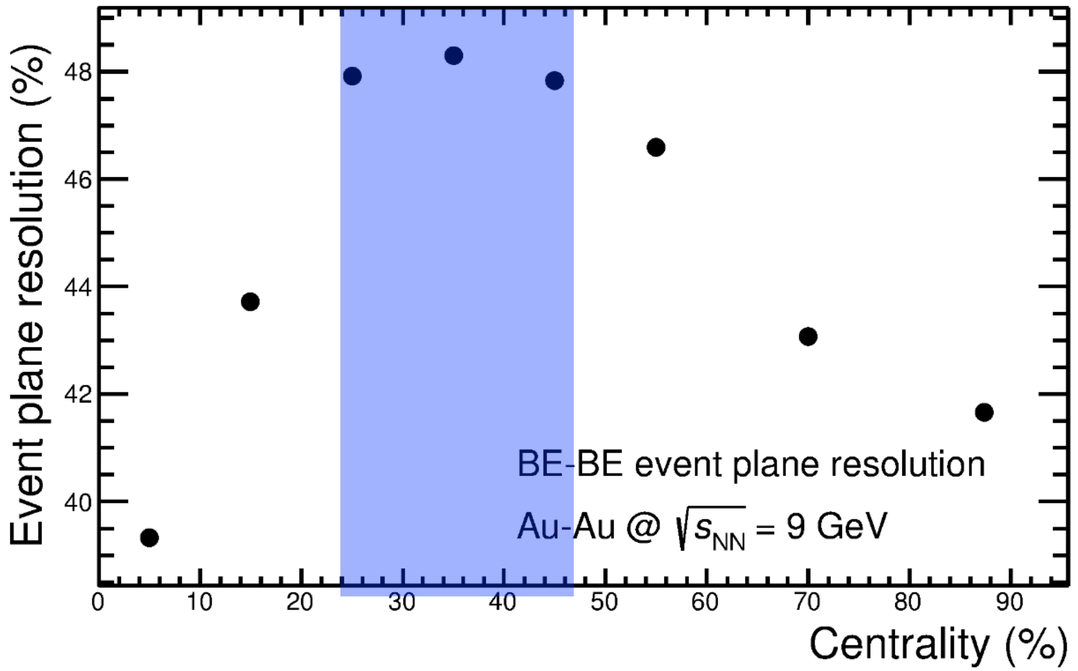
To estimate the event plane resolution with the proposed BE–BE detector geometry, we simulated 95,000 MB Au+Au collisions events at 9 GeV energy of the center of mass in a centrality range between 0 % and 90%. The simulations were performed with UrQMD (n=1).

$$\Psi_n^{BB} = \frac{1}{n} \tan^{-1}\left[\sum_{i=1}^{m} w_i \sin(n\varphi_i) \Big/ \sum_{i=1}^{m} w_i \cos(n\varphi_i)\right] \longrightarrow$$ estimated with BE–BE

$$\left\langle \cos\left(n \times (\Psi_n^{BB} - \Psi_n^{MC})\right)\right\rangle \longrightarrow$$ comparison with truth Monte Carlo

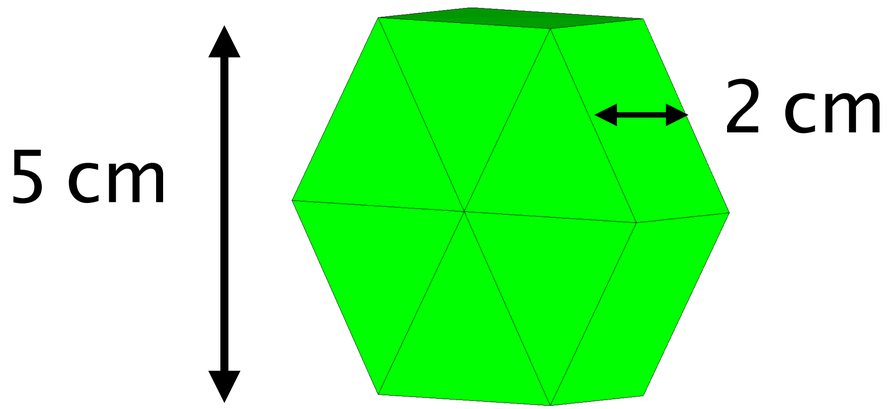
Simulation and time resolution studies

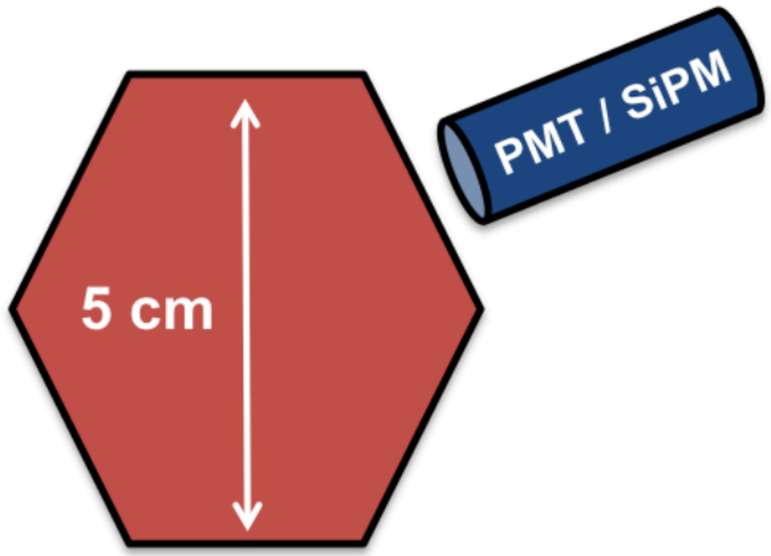
To estimate the event plane resolution with the proposed BE–BE detector geometry, we simulated 95,000 MB Au+Au collisions events at 9 GeV energy of the center of mass in a centrality range between 0 % and 90%. The simulations were performed with UrQMD (n=1).



Maximum resolution between 25–45 % of centrality.

Simulation and time resolution studies

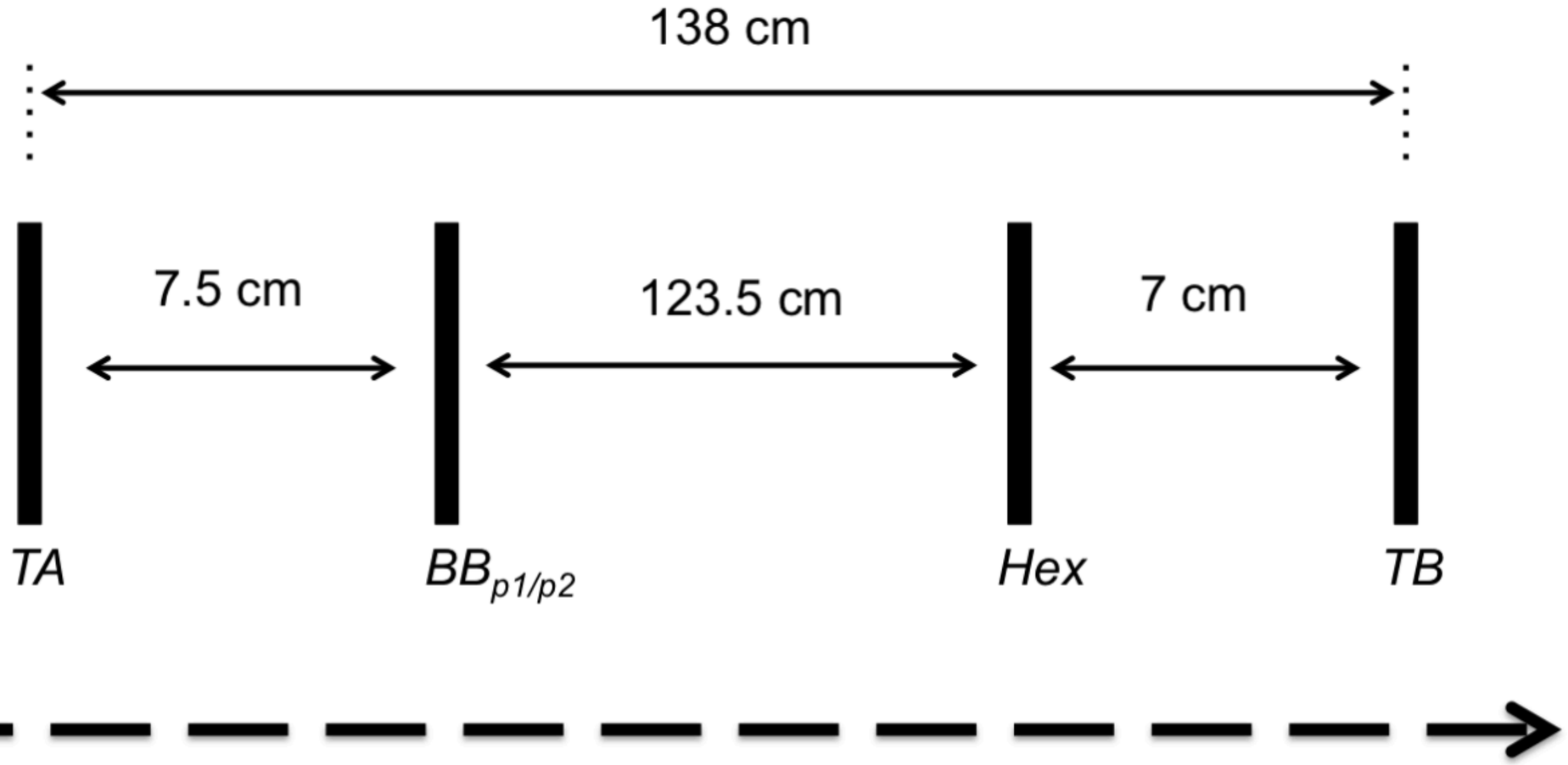




BE–BE prototype:

- hexagonal cell of 5 cm. heigh and 2 cm. width.
- BC–404 plastic scintillator
- sensor light PMT (BBp1) and SiPM (BBp2)
- evaluated in T10–CERN beam facilities
- DAQ provided by AD/VZERO ALICE groups. Same FEE as used in ALICE data taking.

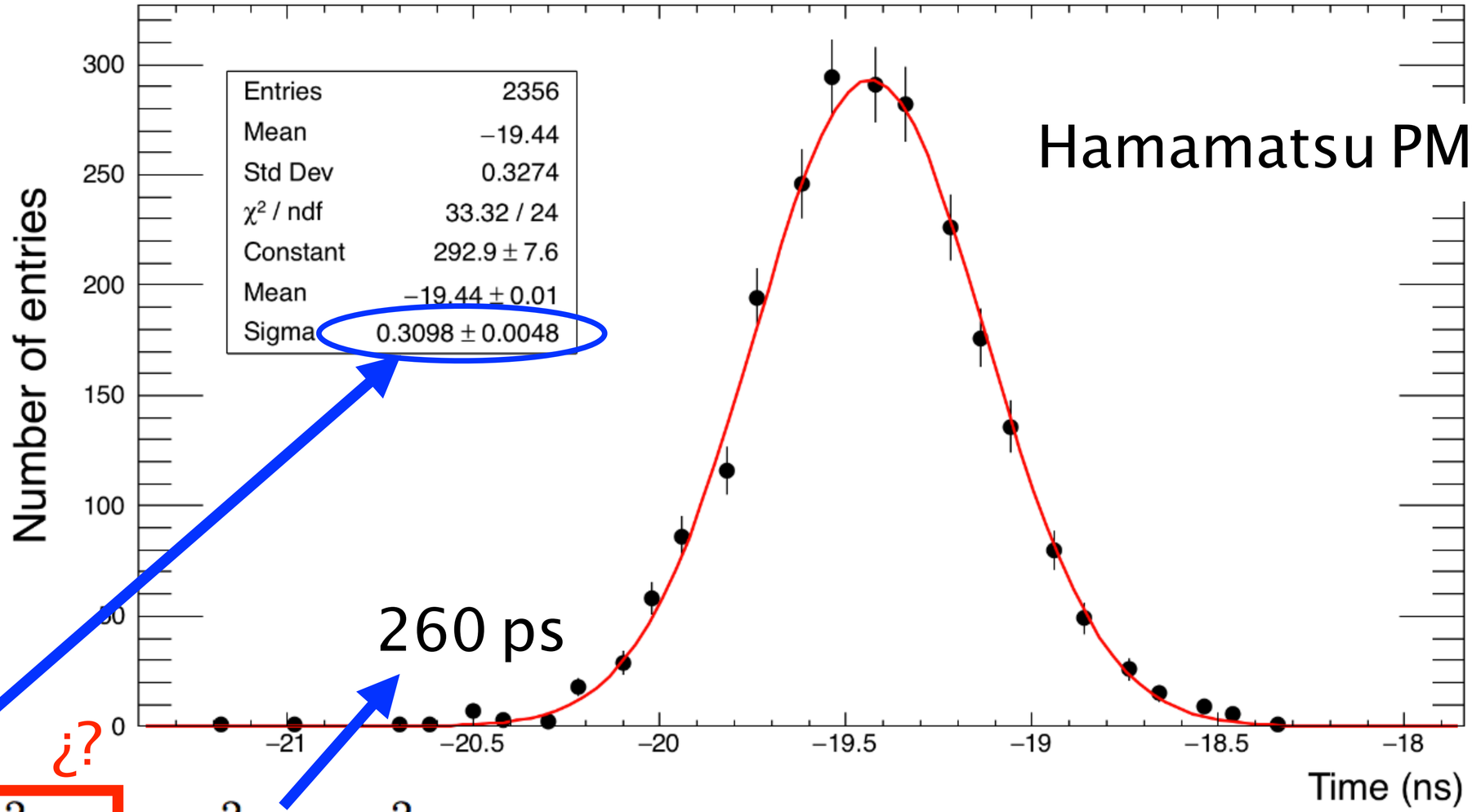
Simulation and time resolution studies



$$\sigma_{p1}^2 = \sigma_{BB_{p1}}^2 + \sigma_{TA}^2 + \sigma_{FEE}^2$$

Simulation and time resolution studies

Time difference between the TDC value from TA and BB_{p1}



Hamamatsu PMT R6249

260 ps

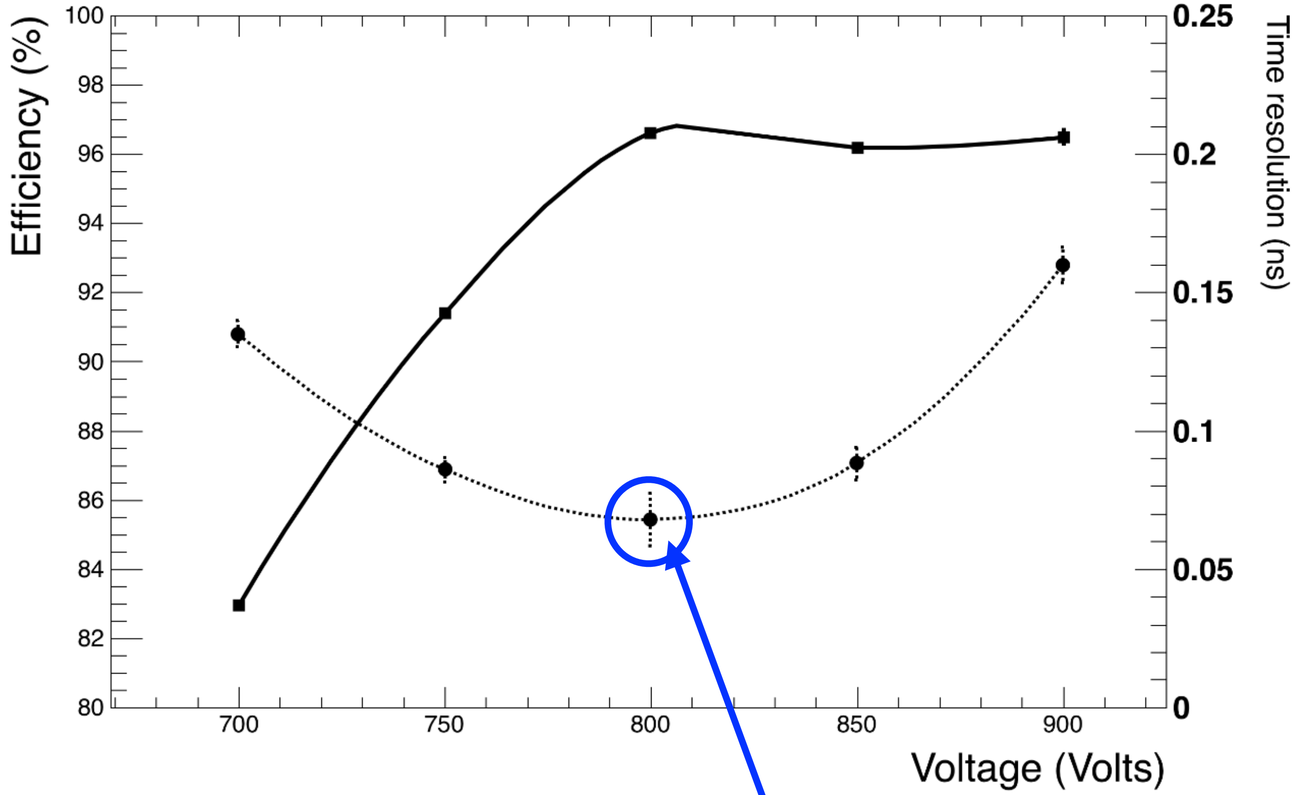
¿?

$$\sigma_{p1}^2 = \sigma_{BB_{p1}}^2 + \sigma_{TA}^2 + \sigma_{FEE}^2$$

100 ps (Nucl. Instrum. Methods Phys. Res. A 626–627 (2011) 90–96)

Simulation and time resolution studies

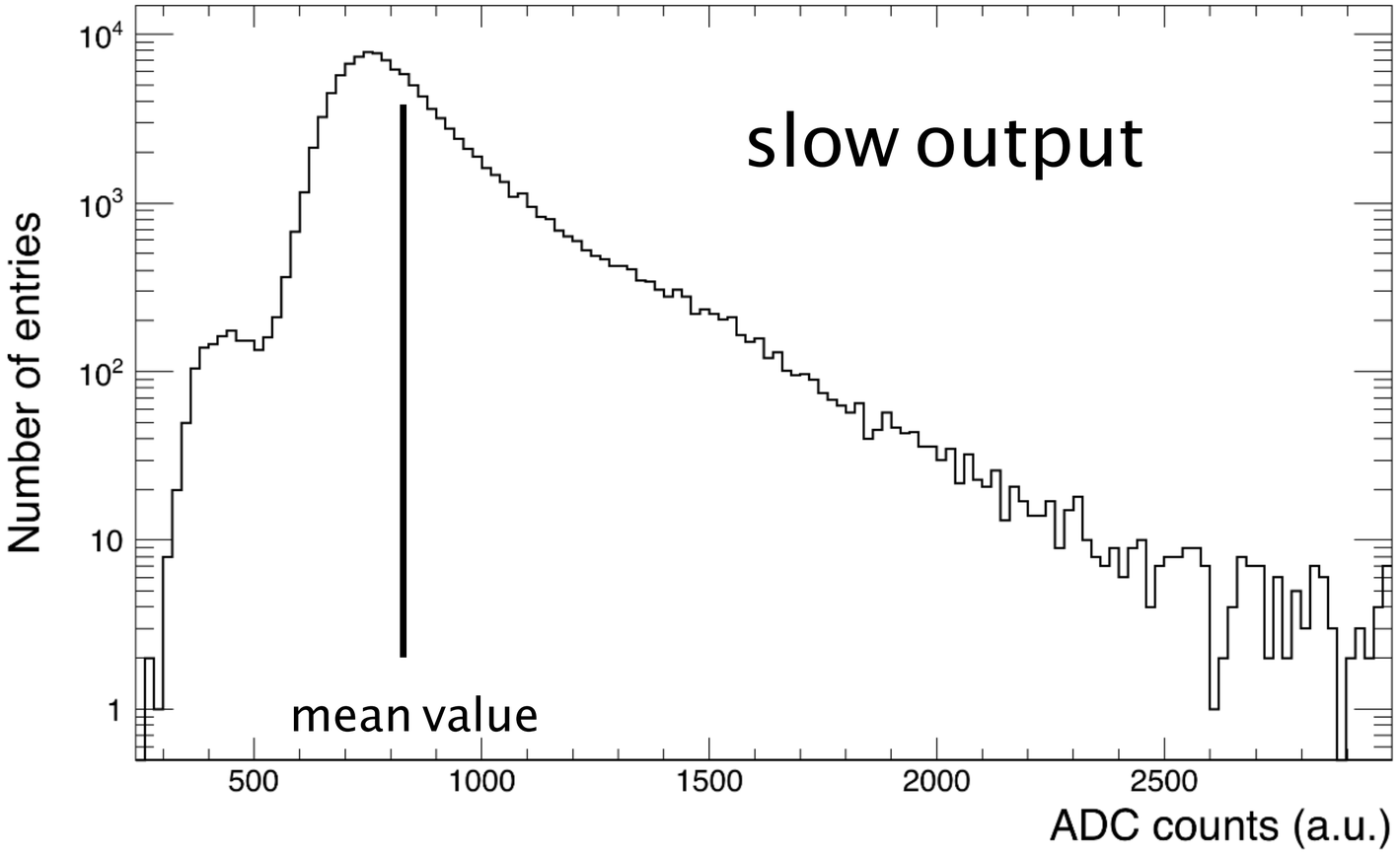
Time resolution of BE–BE prototype coupled to Hamamatsu PMT R6249



Voltage (V)	700	750	800	850	900
Time resolution (ps)	135 ± 5	86 ± 4	68 ± 5	88 ± 6	160 ± 7
χ^2/ndf	33.32/24	13.42/19	23.26/19	19.82/19	27.68/23

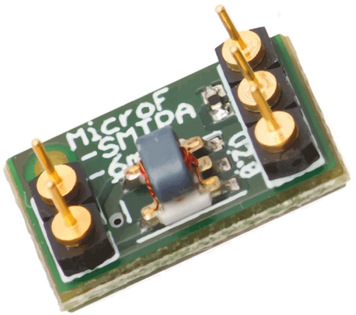
Simulation and time resolution studies

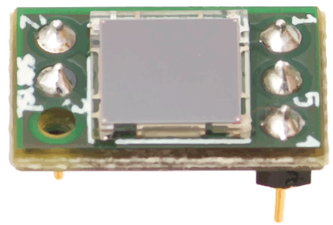
SensL (C-60035-4P-EVB) SiPM



Several ADC ranges, for slow (charge) output, were considered to compute the time resolution of BB_{p2}

1. 850_870
2. 840_880
3. 830_880
4. 830_890
5. 800_920
6. 700_900

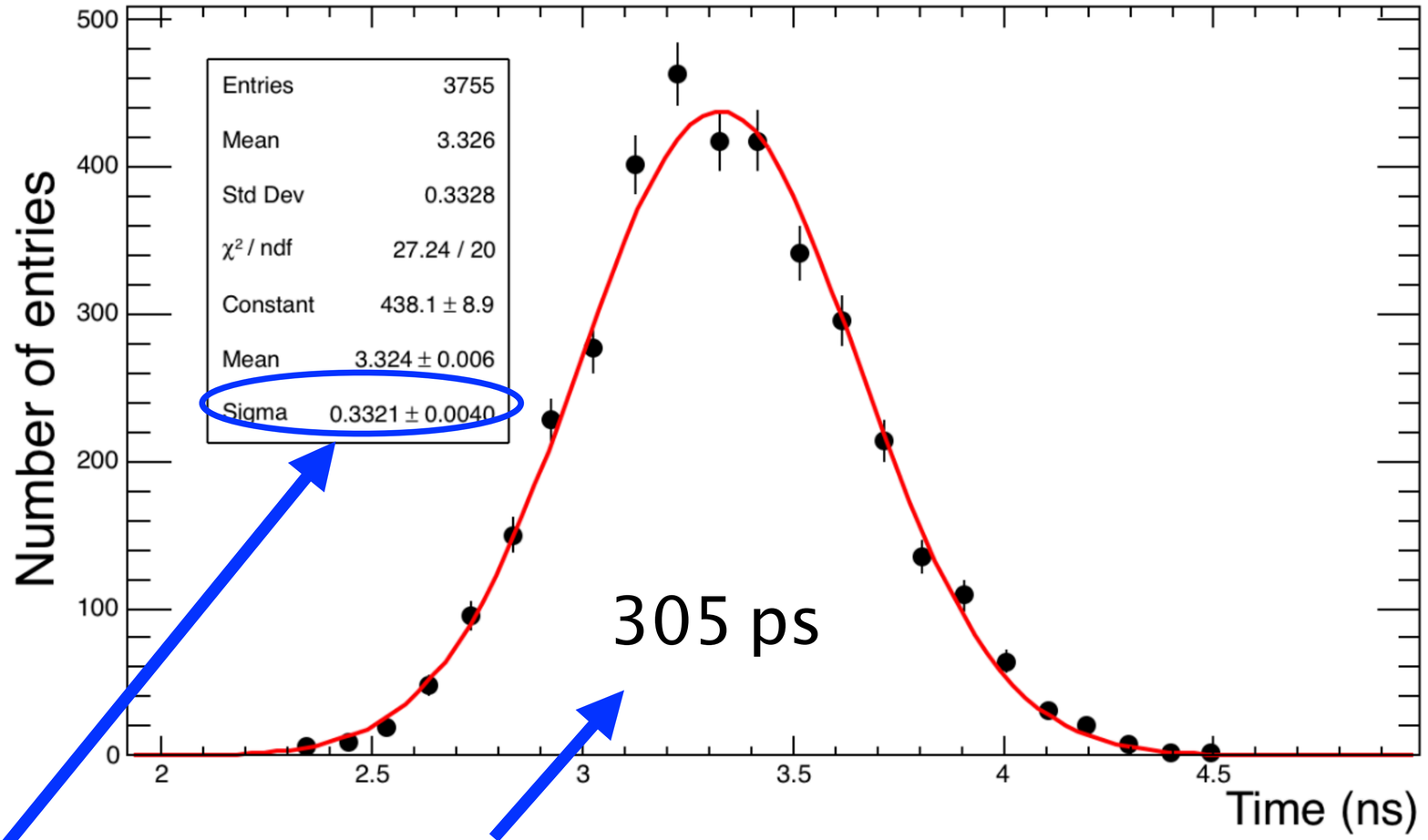


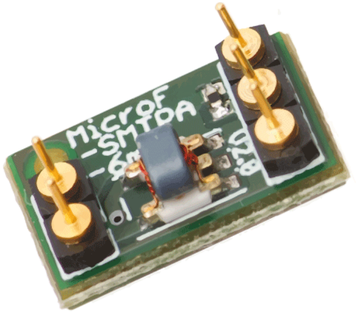


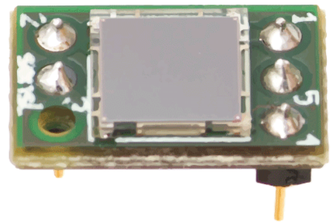
Two outputs: fast (timing) and slow (charge)

Simulation and time resolution studies

SensL (C-60035-4P-EVB) SiPM



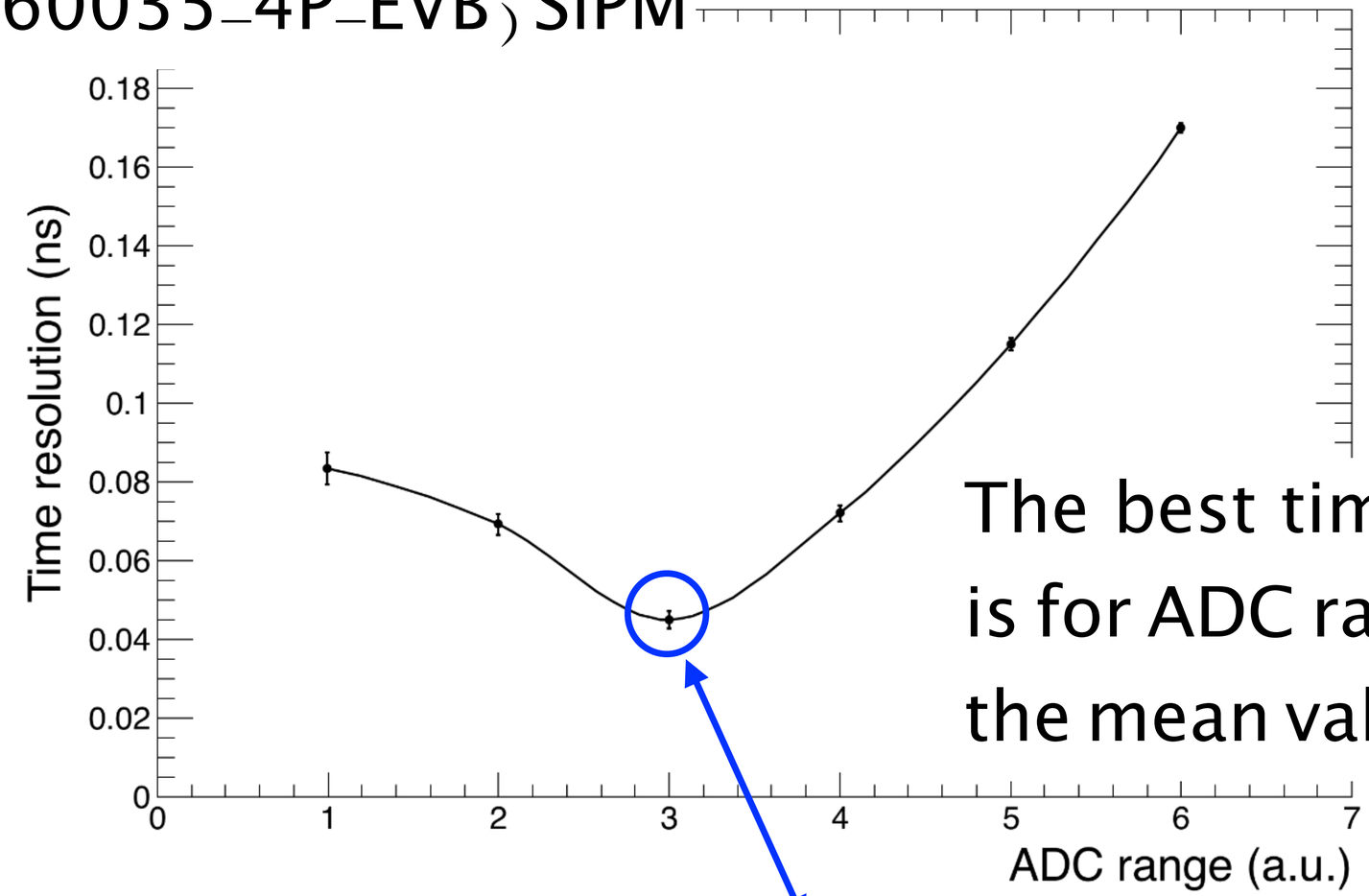


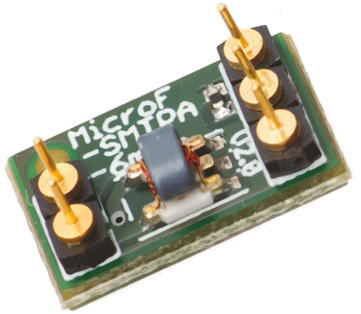


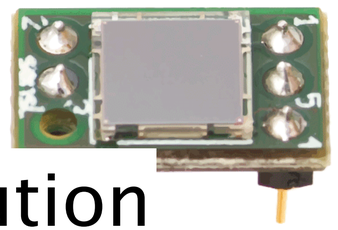
$$\sigma_{p2}^2 = \sigma_{BB_{p2}}^2 + \sigma_{TA}^2 + \sigma_{FEE}^2 \rightarrow 100 \text{ ps}$$ (Nucl. Instrum. Methods Phys. Res. A 626-627 (2011) 90-96)

Simulation and time resolution studies

SensL (C-60035-4P-EVB) SiPM







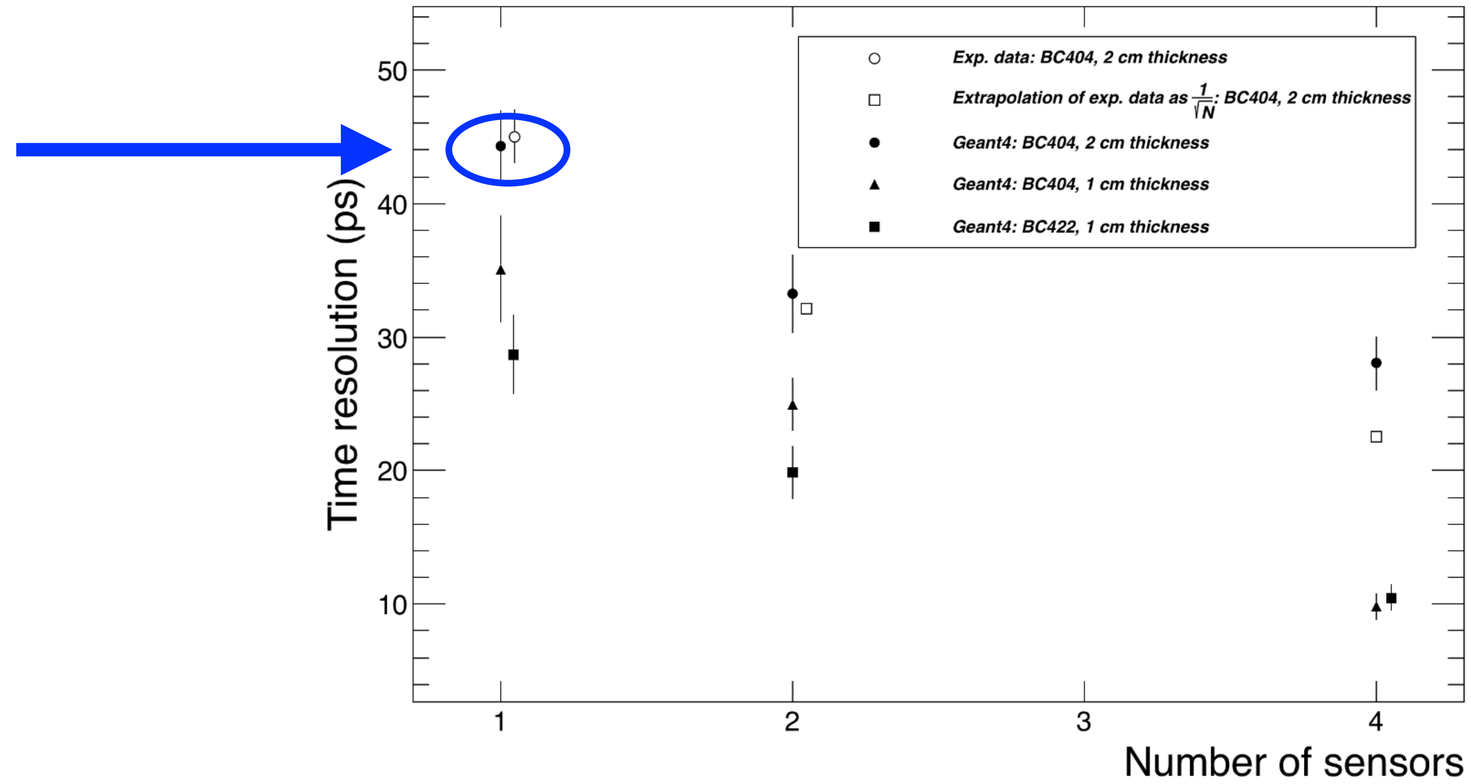
The best time resolution is for ADC ranges around the mean value

ADC range (a.u.)	850-870 (1)	840-880 (2)	830-880 (3)	830-890 (4)	800-920 (5)	700-900 (6)
Time resolution (ps)	83 ± 4	69 ± 3	45 ± 2	72 ± 2	115 ± 2	170 ± 1
χ^2/ndf	27.24/20	60.09/24	82.22/25	65.14/25	150.3/28	140.2/31

Simulation and time resolution studies

To extend the time resolution studies, we simulated the prototype BB_{p2} in Geant_4 interface. Two different plastic scintillator were considered: BC404 and BC422. 2 cm and 1 cm thickness.

good agreement between simulated and measured value for BC_404, 2 cms thickness and 1 SiPM coupled to the hexagonal cell.



Simulation and time resolution studies

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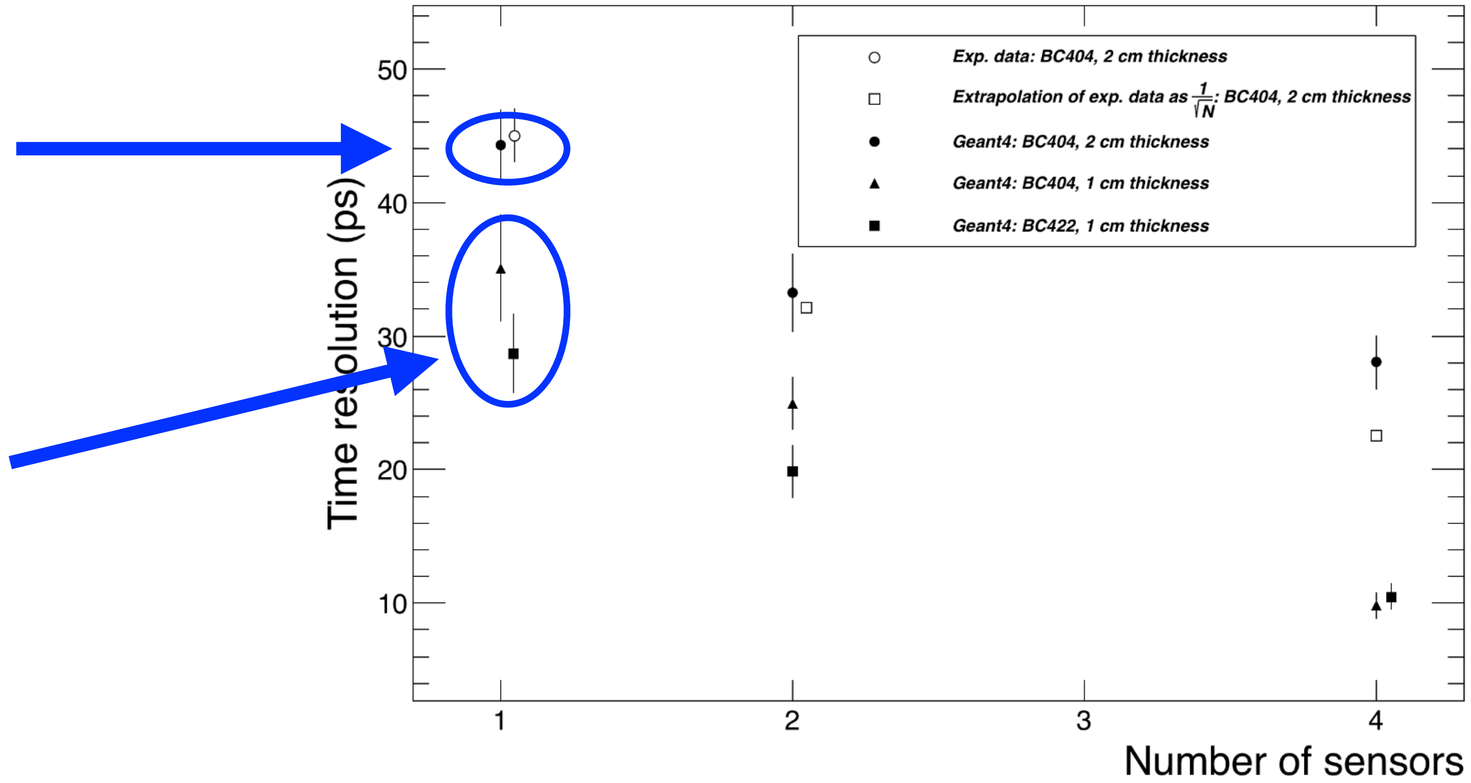
good agreement between simulated and measured value for BC_404, 2 cms thickness and 1 SiPM coupled to the hexagonal cell.

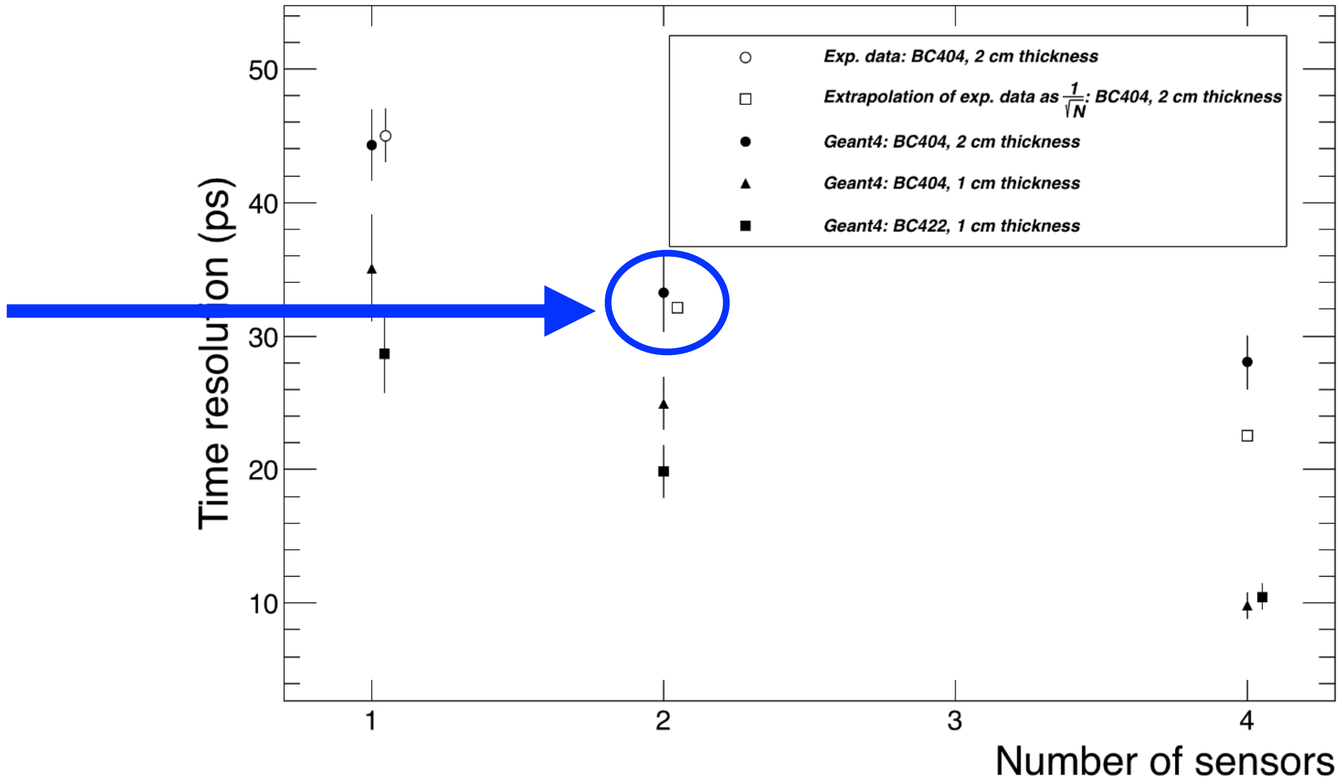
the time resolution may be improved for BC404 and BC422 hexagonal cells of 1 cm thickness.



Simulation and time resolution studies

To extend the time resolution studies, we simulated the prototype BB_{p2} in Geant–4 interface. Two different plastic scintillator were considered: BC404 and BC422. 2 cm and 1 cm thickness.

the time resolution could be improved if we coupled 2 light sensors to the hexagonal cell.



Final comments

We evaluated 2 BE-BE cell prototypes in T10—CERN beam test (May 2018). The size of both cells was 5 cm high and 1 cm width. Our results suggest that the desirable time resolution could be achieved with hexagonal cells with 1 cm thickness coupled to 2 or maybe 3 SiPM. This result is consistent with the Geant-4 simulations. A new beam test was carried out last week at CERN for a BC-404 hexagonal cell of 1 cm thickness and 5 cm high. We will explore the performance of BC-422 with cosmics.

The BE-BE geometry was implemented in MPD-ROOT. We used this geometry to study BE-BE physics performance on event plane resolution studies. It seems that BE-BE could be useful for such kind of studies.

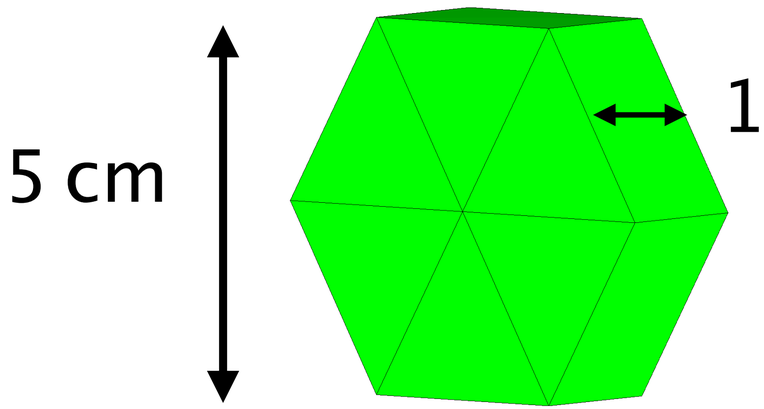
Final comments

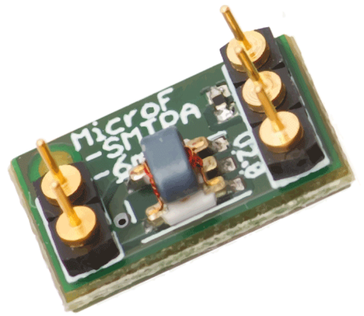
The best time resolution that we found with beam test data was 45 +/2 ps for the hexagonal cell coupled to SiPM. For Hamamatsu PMT, the best time resolution we found was 68 +/– 5 ps. In both cases for MPD, the design of an FEE capable of handlings the signals coming from either the PMT or SiPM is challenging.

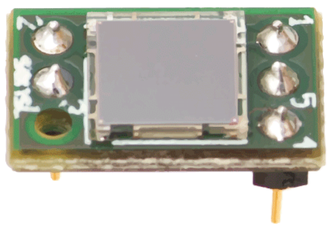
Final comments

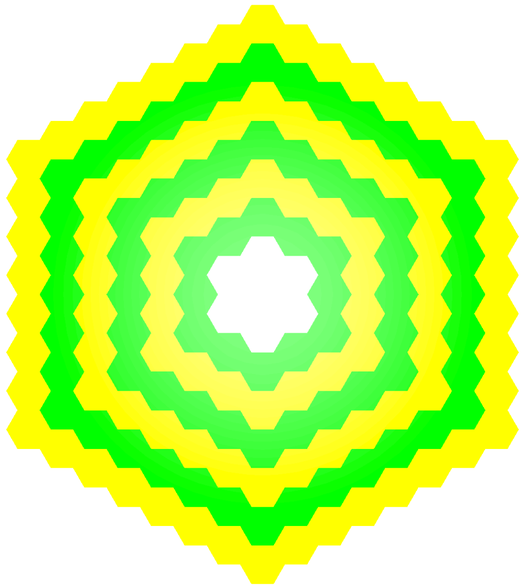
Proposed geometry of BE–BE

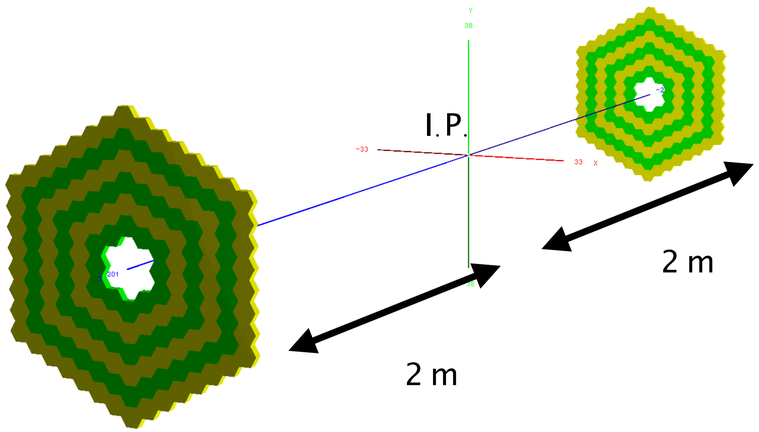
- two hodoscope detectors, each located 2 m. away from interaction point at opposite sides.
- each hodoscope consists of 162 hexagonal plastic scintillator cells arranged in six concentric rings.
- pseudorapidity range $1.9 < |\eta| < 3.97$
- size of hexagonal cell: 5 cm high and 1 cm width coupled to 2 or 3 SiPM











MexNICA group

A beam-beam monitoring detector for the MPD experiment at NICA

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