miniBeBe: a TOF trigger for collisions of small systems at MPD-NICA

Maria Elena Tejeda-Yeomans
for the MexNICA Collaboration

Universidad de Colima, México

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Outline

1. Baseline design
   - Mechanical structure
   - Electronics and cell time resolution
2. Simulations
   - Hits and time-of-flight
   - Improvements for small systems
   - Trigger capabilities
3. Closing remarks

miniBeBe baseline design

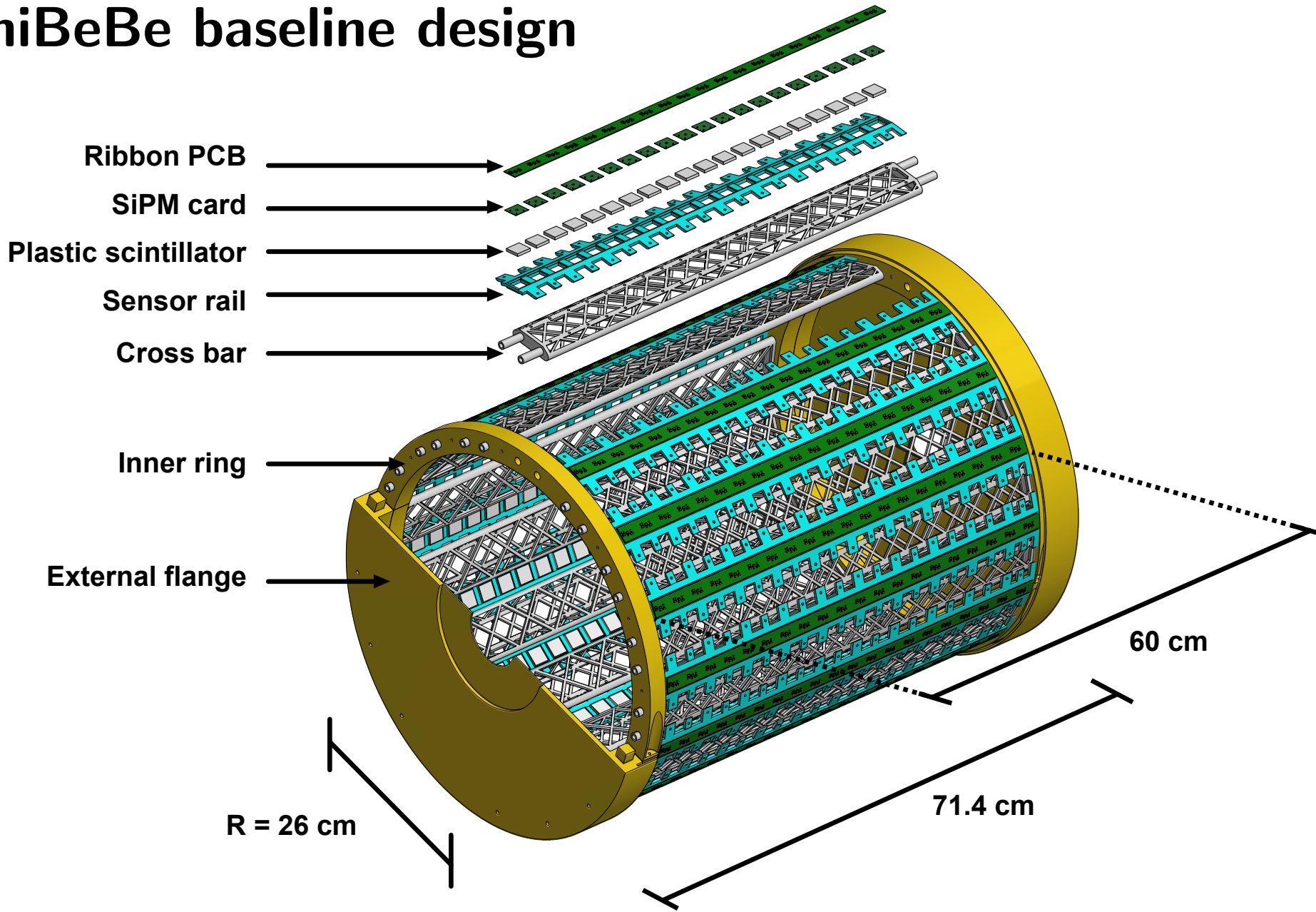
- TOF expected to have overall time resolution $\sim$ 60 ps, to separate π, K and p in wide range of momenta
- In simulations, FFD is efficient for central and semi-central A + A collisions, efficiency decreases below 50% for multiplicity less than 25.
- miniBeBe to improve the trigger

CHARGE:

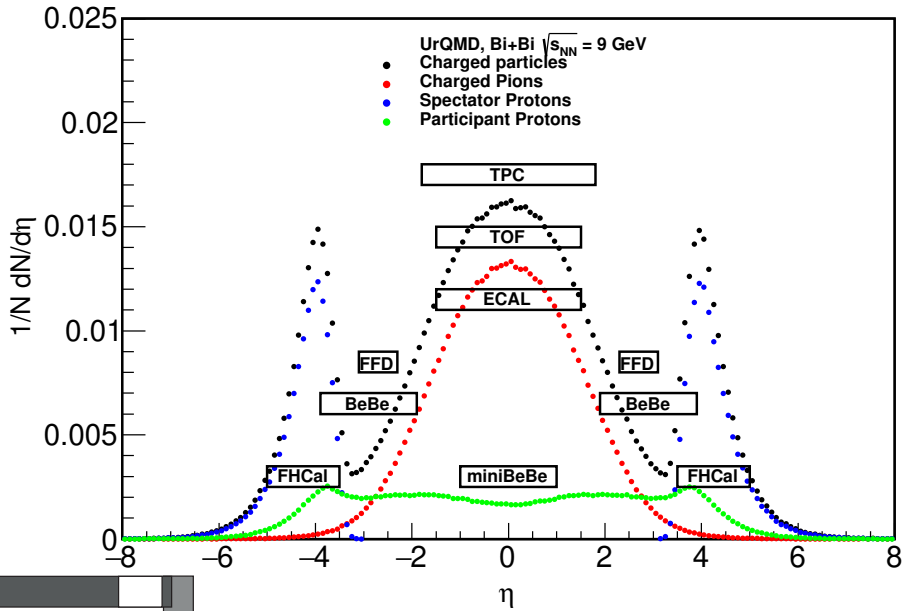
$\rightarrow$ miniBeBe to provide a (fast response) wake-up trigger signal for the TOF.

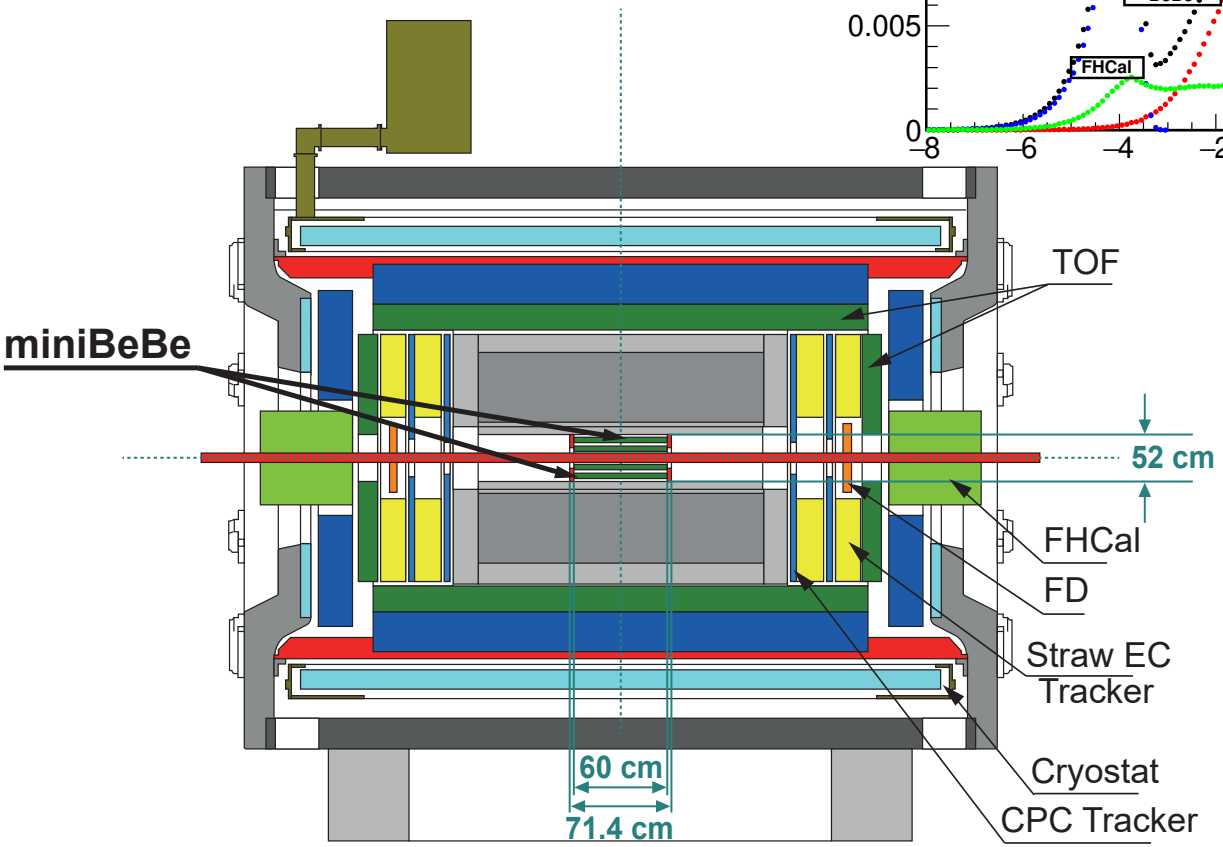
$\rightarrow$ miniBeBe must be efficient for low multiplicity p + p, p + A and A + A collisions.

miniBeBe baseline design

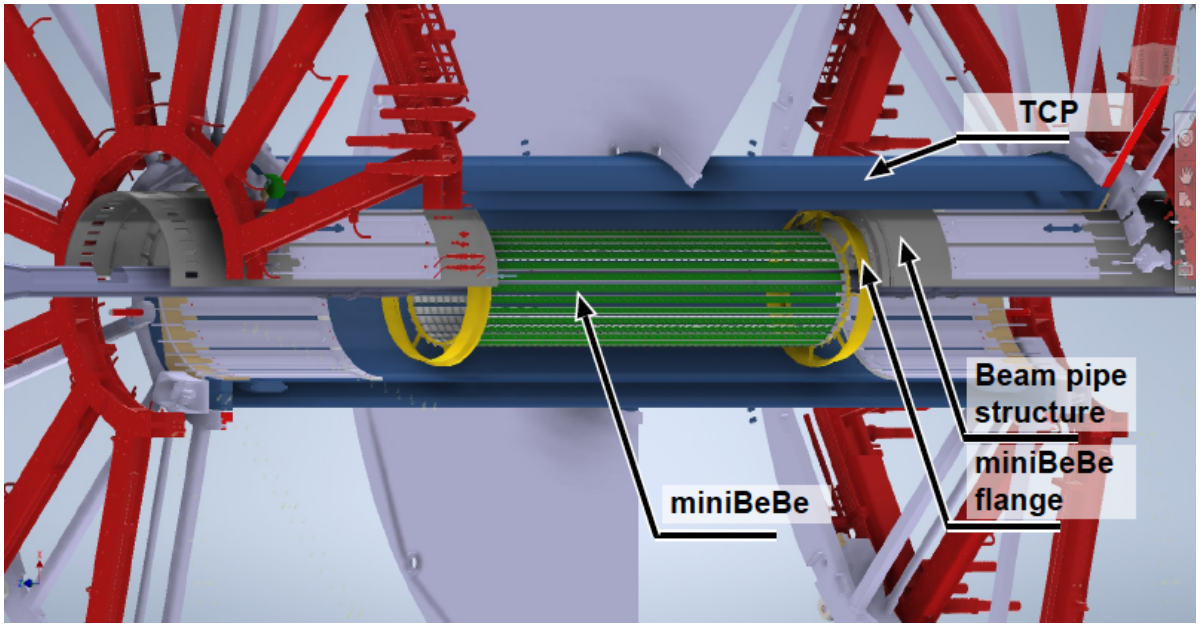


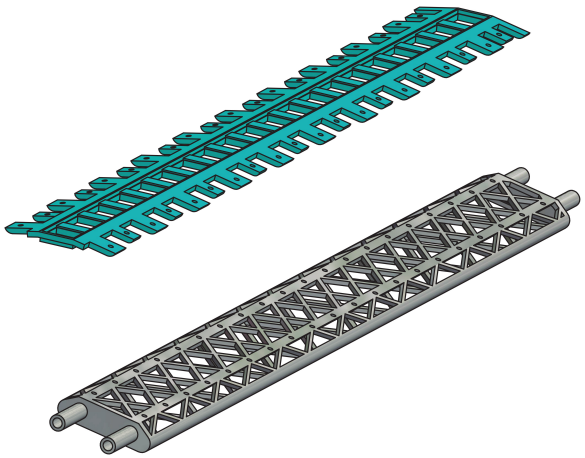
miniBeBe @ MPD

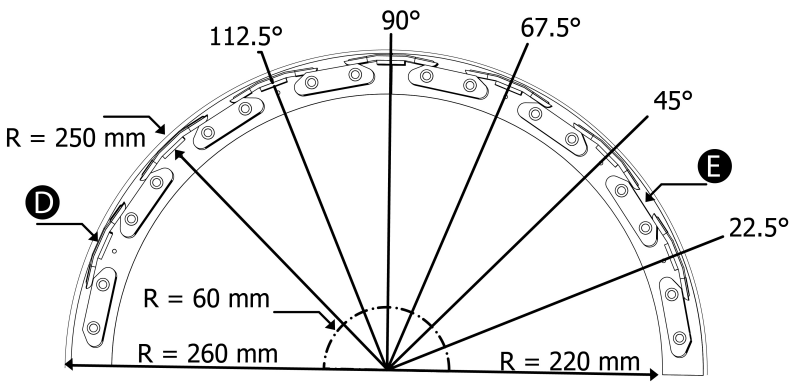




Integration with beam pipe support

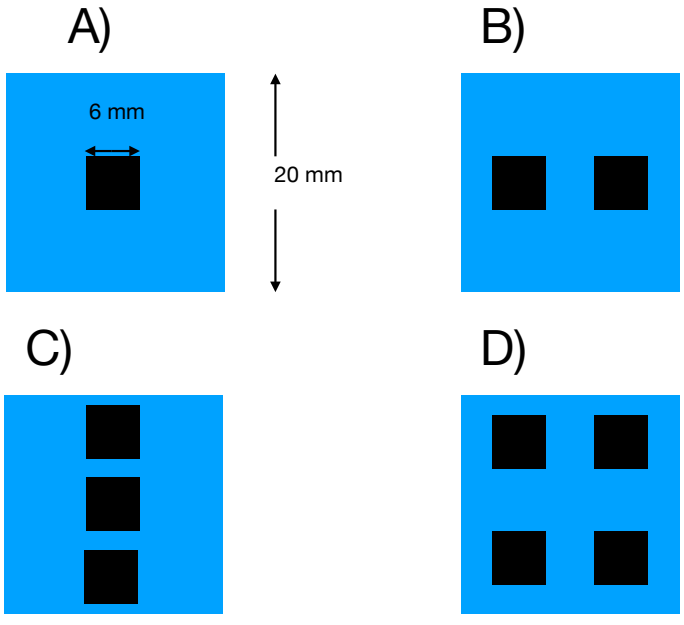


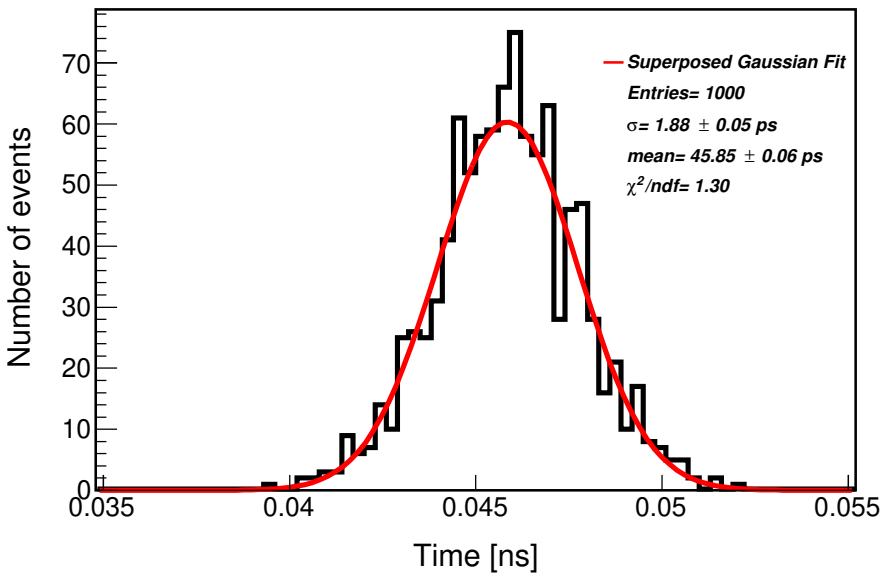




Plastic cell & SiPM intrinsic time resolution

Geant4: π^+, $E = 500$ MeV $\rightarrow$ lowest mean of Landau ToF dist
Intrinsic time res. : 1-4 scorers $\rightarrow$ 7.76 $\pm$ 0.87 ps - 9.29 $\pm$ 0.67 ps



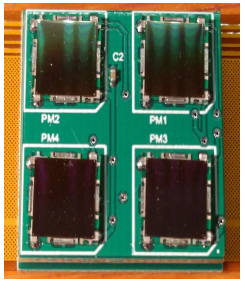


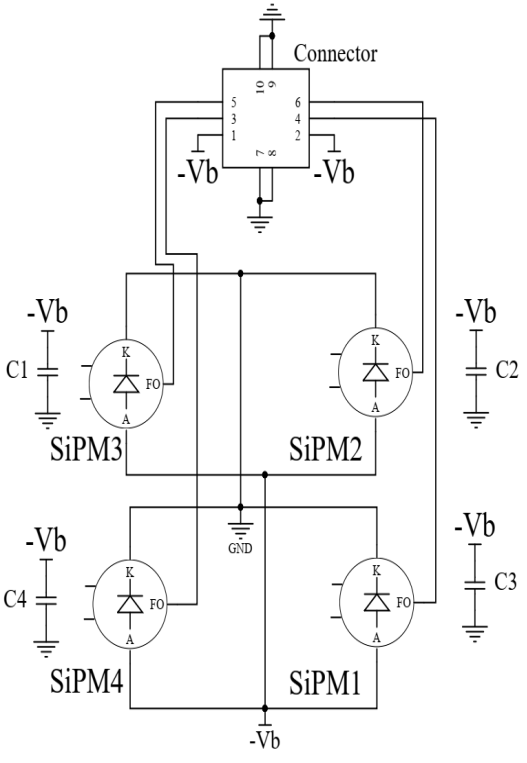
Photon ToF dist., beam hits the top

- Intn in cell perimeter: time resolution ∼2.6 ps.
- Intn in cell center: time resolution decreases to ∼26 ps.

Basic cell with four SiPMs & electronics

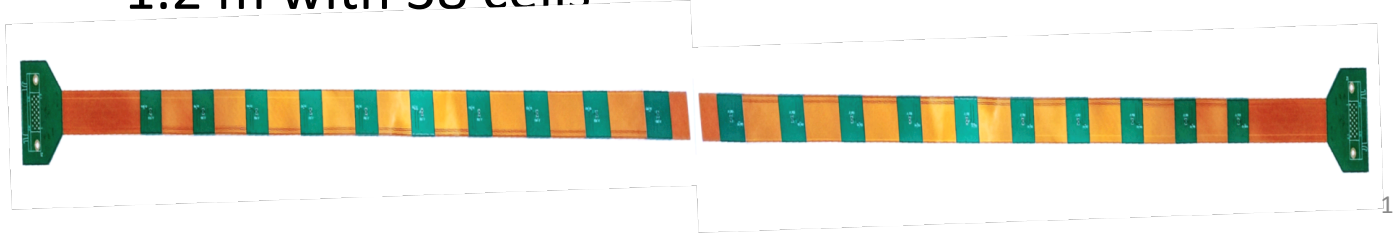
- 20x20 mm^2
- 4 SiPMs card attached to BC404 plastic scintillator
- Fast outputs to "connector" (micro mezzannine)
- DC decoupling capacitors





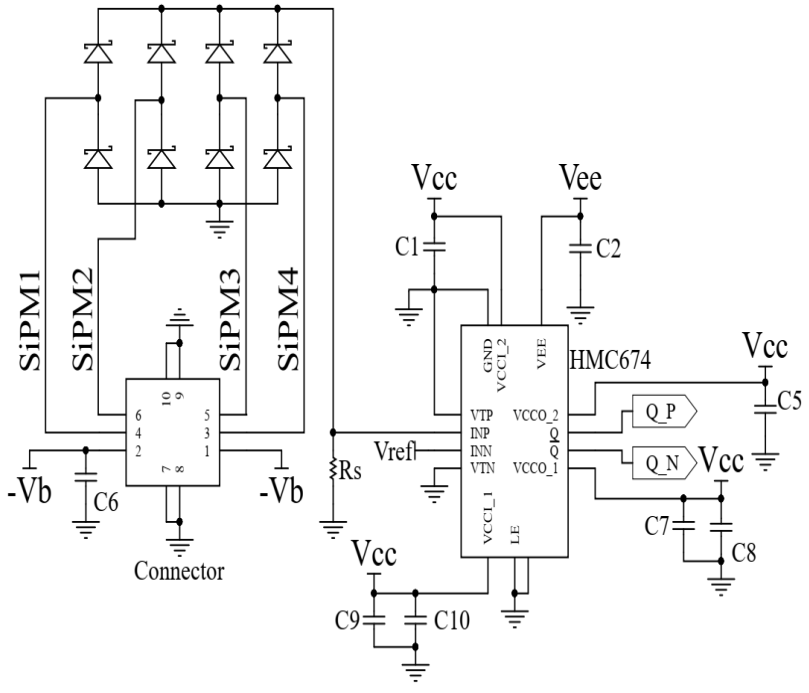
Ribbon card to collect signal from sensor cells

- First prototype length: 0.6 m
- Number of cells: 20
- RSP-ECL differential outputs
- Rigid-Flex design
- Possible improvements:
  - 1.5 m with 48 cells (under development)
  - 1.2 m with 38 cells

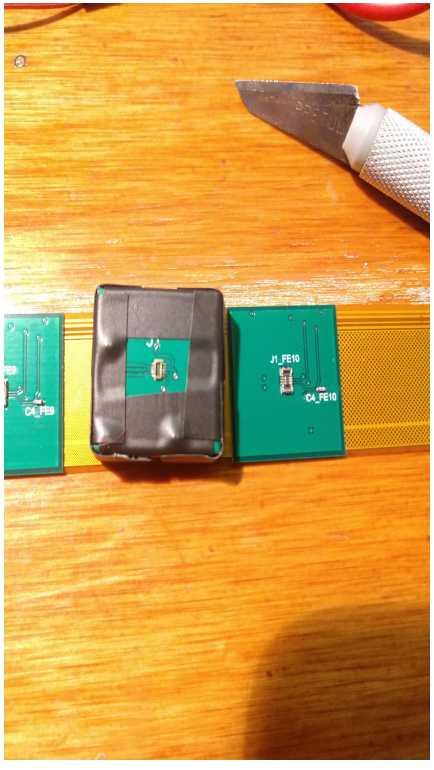


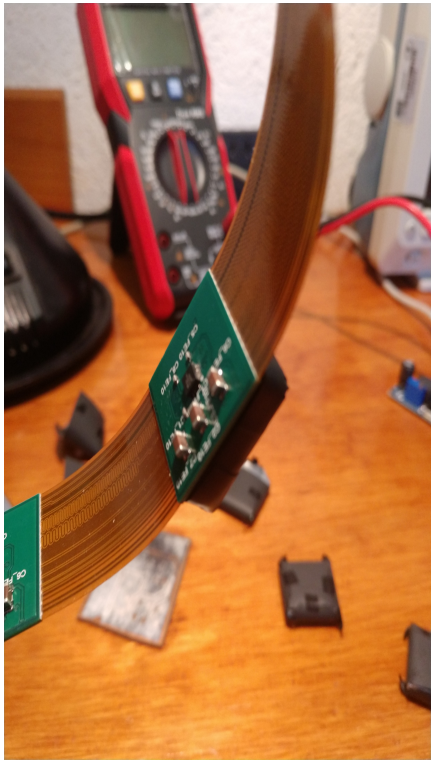
Ribbon card electronics

- Single channel design.
- Micro mezzannine connector to SiPMs.
- Parallel SiPM interconects (Schottky diodes).
- Ultrafast comparator (9.3GHz bandwith)
- RSP-ECL differential output



Ribbon card prototypes





Signal collection

- TRB-3 card for signal collection
- located outside MPD detector
- ethernet connection to a site
- dedicated station for data collection
- based on 3.2 GBps optical links
- either stand-alone or part of a complex system

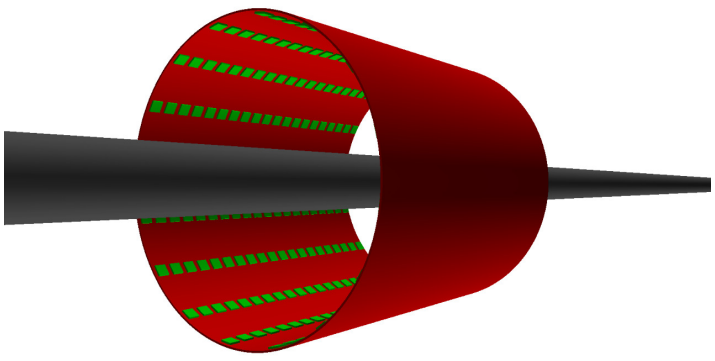
Material budget

- Energy loss of primary particles (pions and muons) in the range (IE) of 5 MeV to 5 GeV using Geant4.
- Detector Elements (DE): 4 mm BC404 + PVC
- Blind Area (BA): 6.56 mm polyacrinolitrile

IE (GeV)	E_{loss} in DE (MeV)	E_{loss} in BA (MeV)
0.05	0.94 ± 0.01	2.58 ± 0.23
0.1	0.67 ± 0.07	1.85 ± 0.18
1	0.48 ± 0.01	1.35 ± 0.15
3	0.49 ± 0.06	1.35 ± 0.15
5	0.49 ± 0.06	1.35 ± 0.15

- Radiation length: $X0_{\mathrm{BC404}} = 0.7\%X0$; $X0_{\mathrm{CF}} = 0.36\%X0$ (nominal ITS $0.8\%X0$)
- Material budget detailed optimization in process

miniBeBe geometry within MPDRoot



Simulations with UrQMD+MPDroot			
miniBeBe geometry	collision species	$\sqrt{s_{\mathrm{NN}}}$ (GeV)	Centrality bins
length 60 cm radius 25 cm MBB-60-25*	Bi + Bi C + C	9	min bias 0-20% 40-60% 80-100%
	p + p	9,11	

Transport
magnet ON with/without ± 60cm flat smearing miniBeBe, FFD, BeBe

miniBeBe: a TOF trigger for collisions
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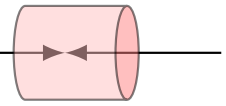
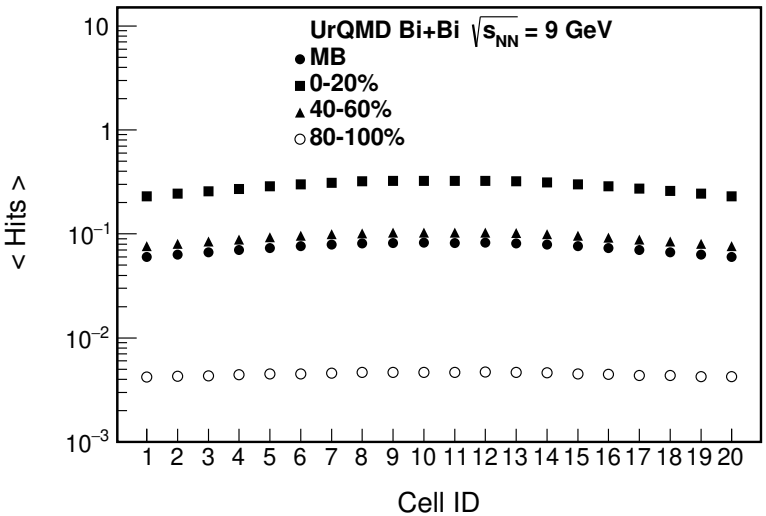
M.E. Tejeda-Yeomans (UCOL, MexNICA)

Baseline MBB-60-25

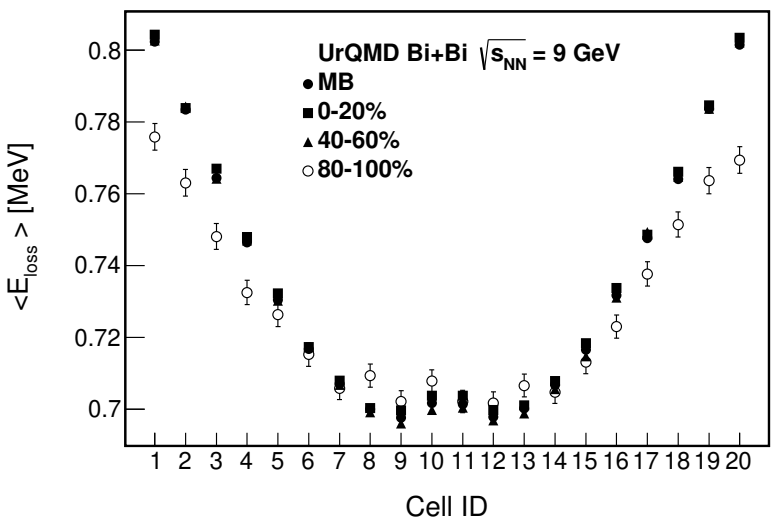
Bi  Bi

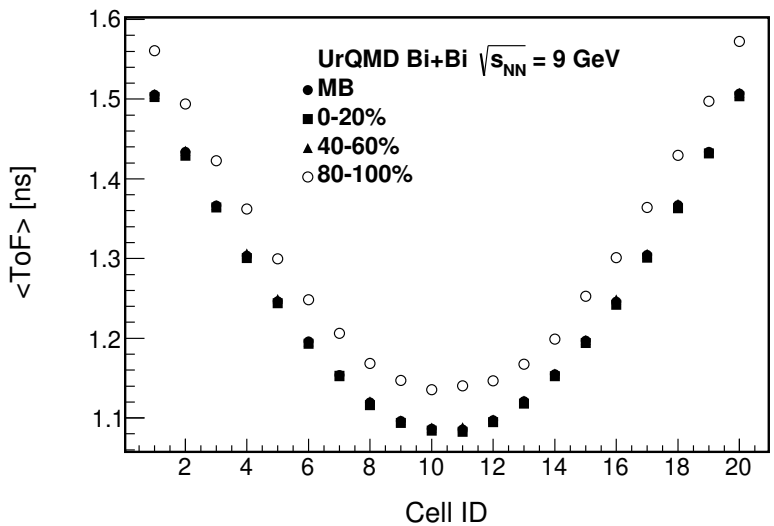
$\sqrt{s_{NN}} = 9$ GeV



⟨Hits⟩	0-20%	80-100%
cell	0.2294 - 0.3248	0.0042 - 0.0047
detector	91.84	1.43

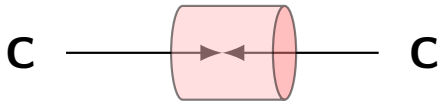
$\langle E_{loss} \rangle$ = 0.7-0.8 MeV, $\langle ToF \rangle$ = 1.1-1.6 ns



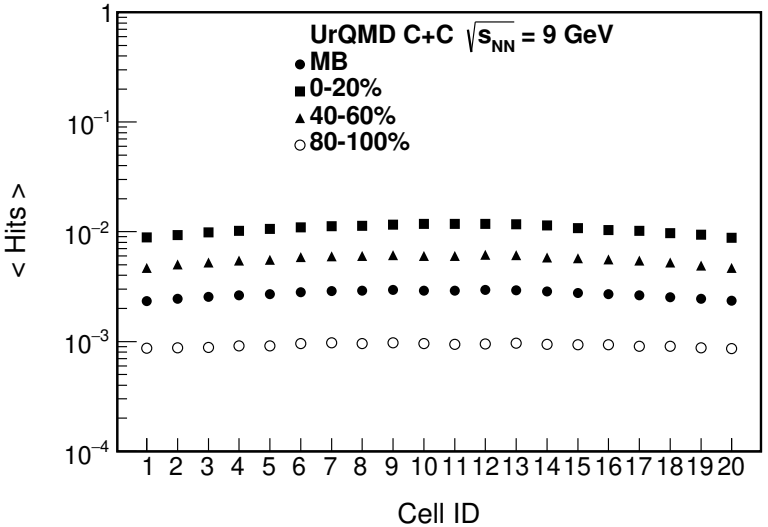


miniBeBe: a TOF trigger for collisions
of small systems at MPD-NICA
M.E. Tejeda-Yeomans (UCOL, MexNICA)

Baseline MBB-60-25

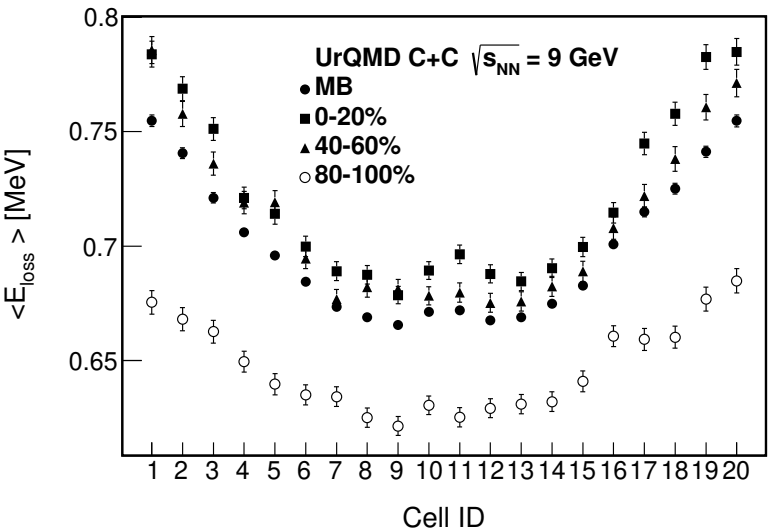


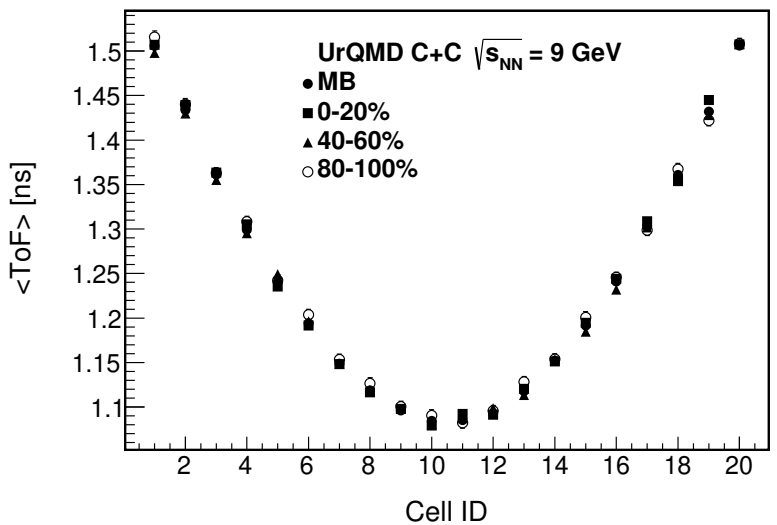
$\sqrt{s_{NN}} = 9$ GeV



⟨Hits⟩	0-20%	80-100%
cell	0.00882-0.01182	0.00085-0.00097
detector	3.390	0.295

$\langle E_{loss} \rangle = 0.62\text{-}0.78$ MeV, $\langle ToF \rangle = 1.1\text{-}1.5$ ns

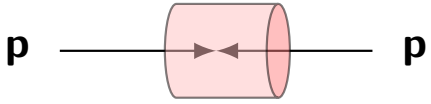




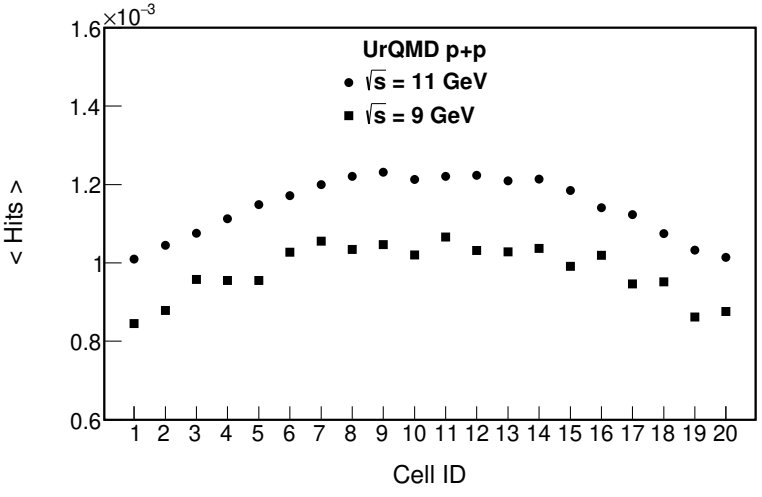
miniBeBe: a TOF trigger for collisions of small systems at MPD-NICA

M.E. Tejeda-Yeomans (UCOL, MexNICA)

Baseline MBB-60-25

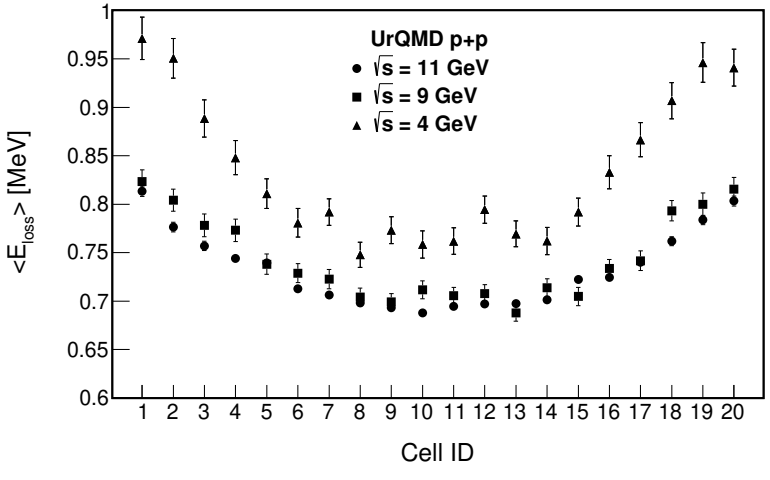


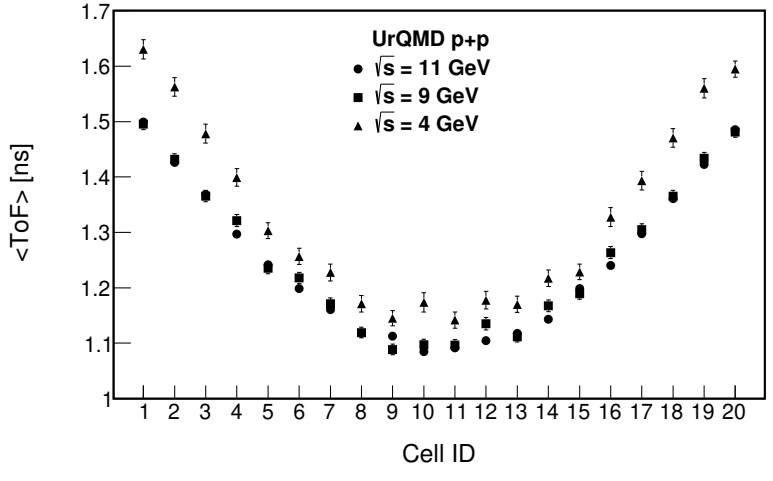
$\sqrt{s_{NN}}$ = 9, 11 GeV



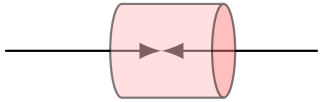
⟨Hits⟩	9 GeV	11 GeV
cell	0.00084-0.0011	0.00100 - 0.00122
detector	0.313	0.365

$\langle E_{loss} \rangle$ = 0.68-0.82 MeV, $\langle ToF \rangle$ = 1.1-1.5 ns

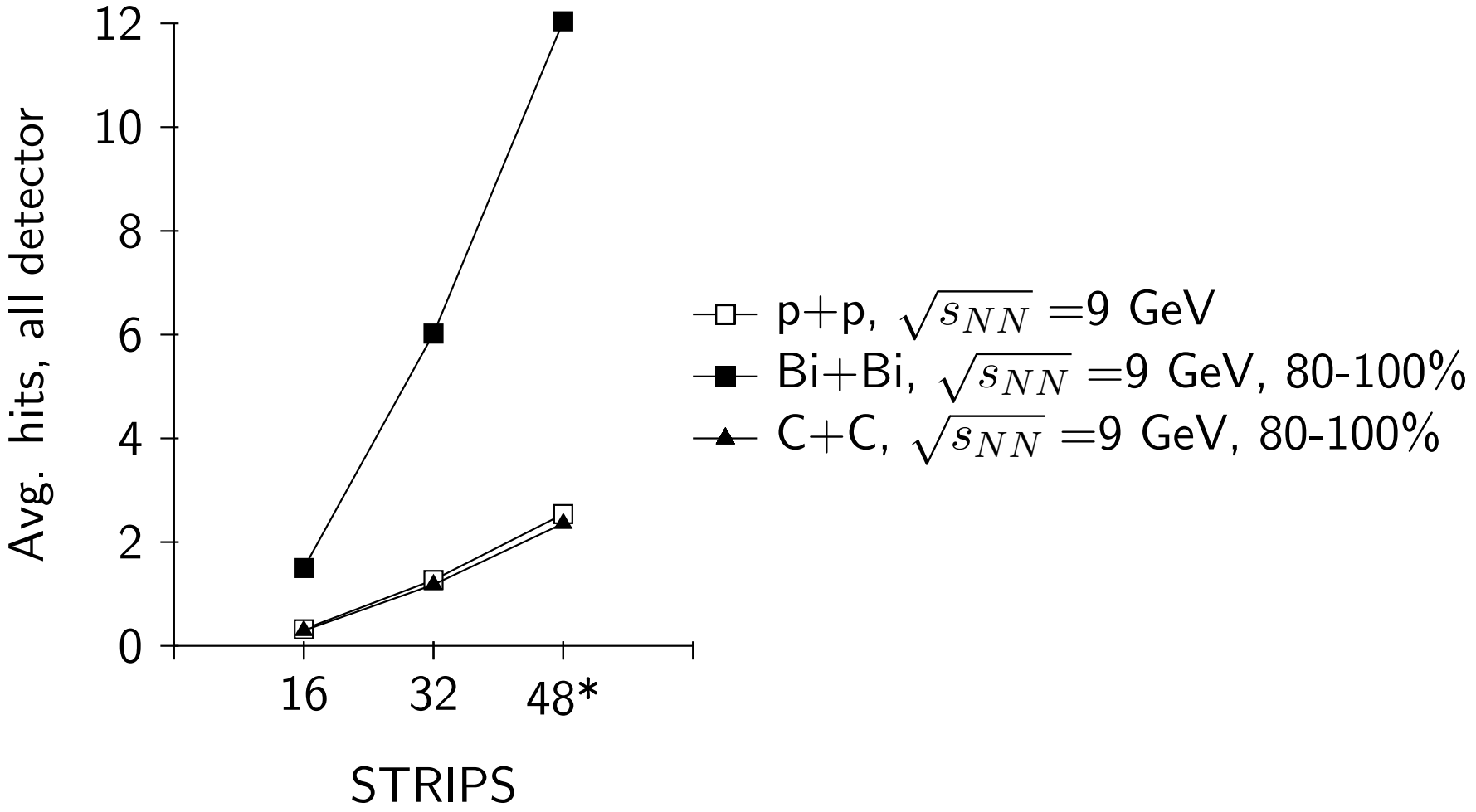




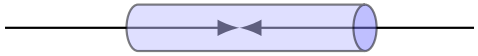
Simulated 16/32 strips, MBB-60-25



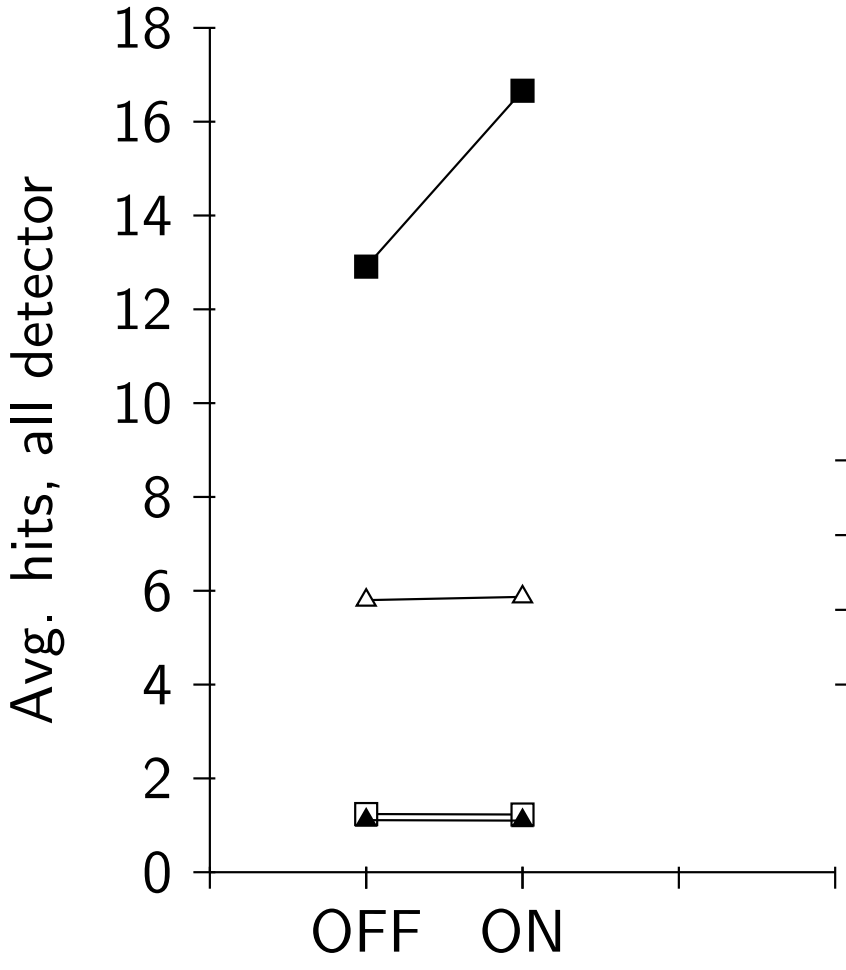
16 → 32 strips: factor of 4 increase in the avg. number of hits in detector per event, then we estimate 32 → 48 strips: extra factor of 2 increase



MBB-150-15



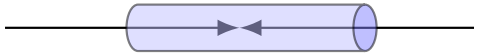
16 strips



± 60 cm flat smearing

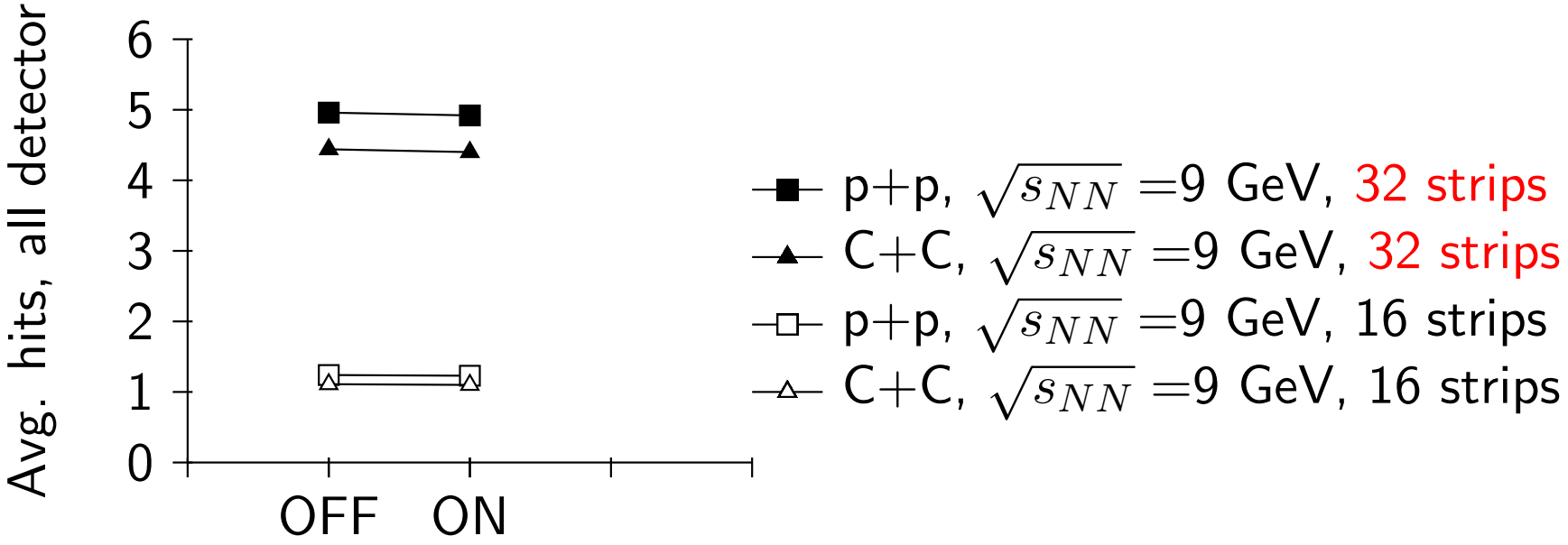
- Bi+Bi, $\sqrt{s_{NN}}$ =9 GeV, 80-100%
- p+Bi, $\sqrt{s_{NN}}$ =9 GeV, 40-60%
- p+p, $\sqrt{s_{NN}}$ =9 GeV
- C+C, $\sqrt{s_{NN}}$ = 9 GeV, 80-100%

MBB-150-15



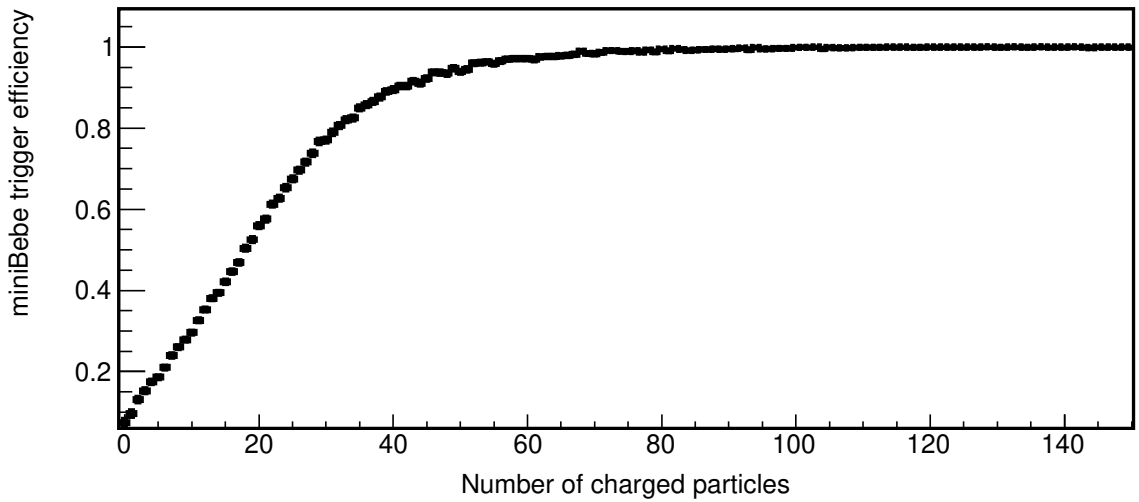
32 strips estimate

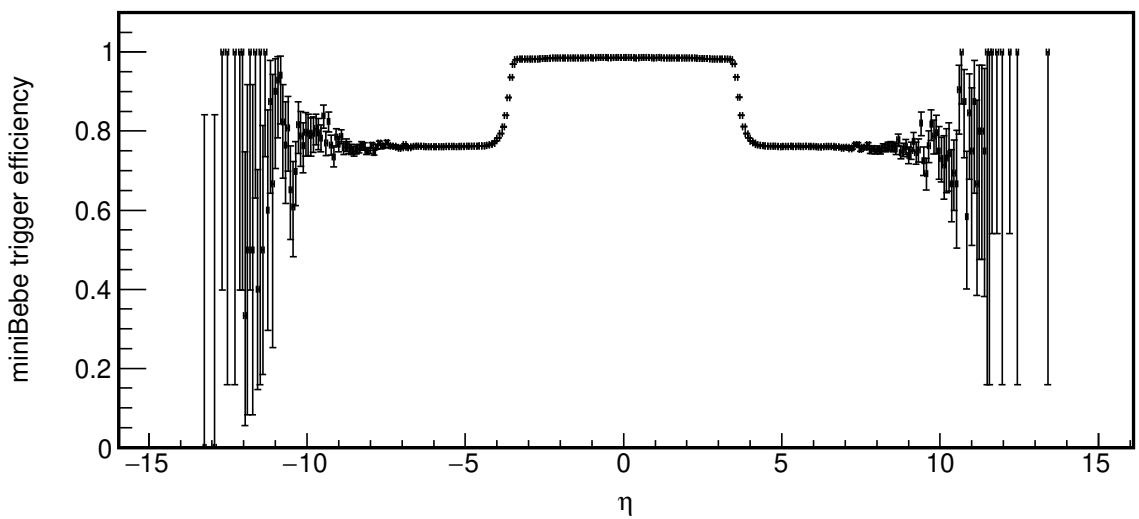
we estimate 16 → 32 strips: factor of 4 increase in the avg. number of hits in detector per event



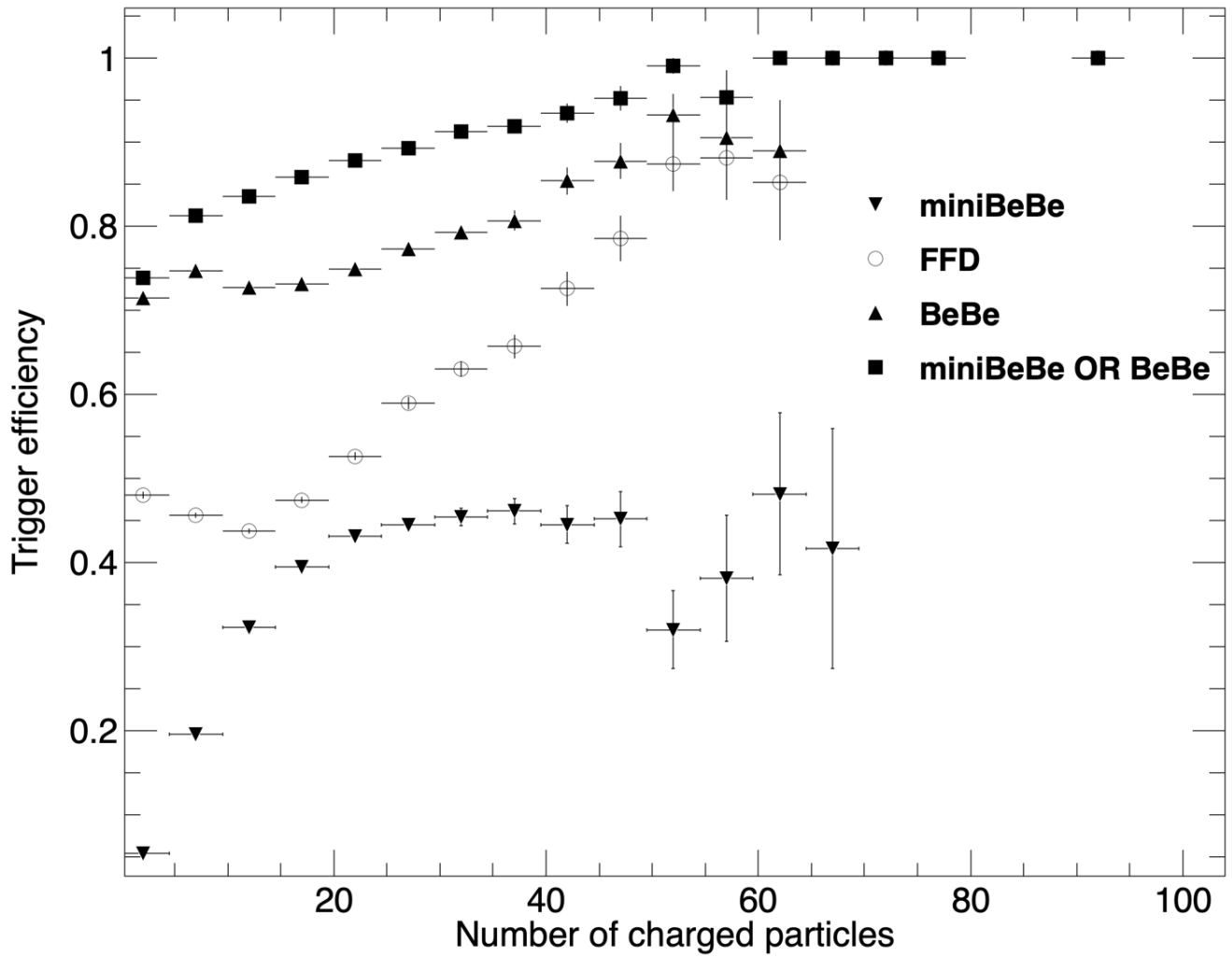
± 60 cm flat smearing

Trigger efficiency - multiplicity



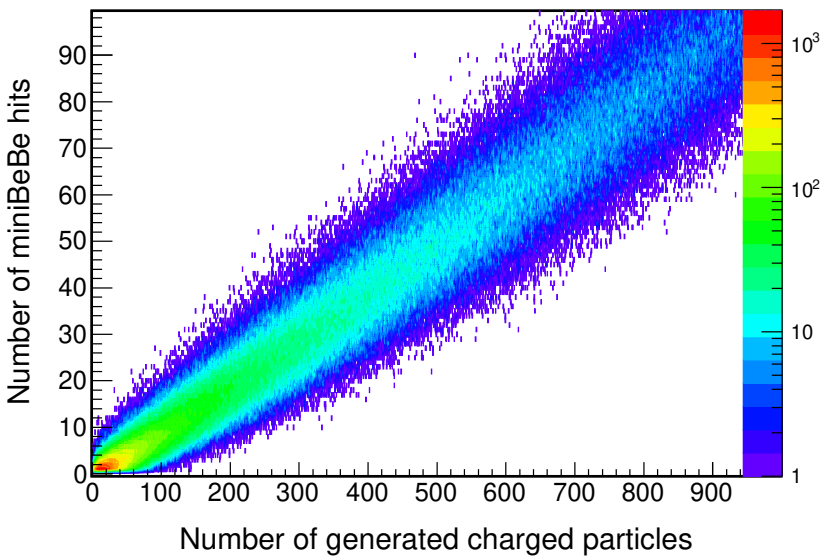


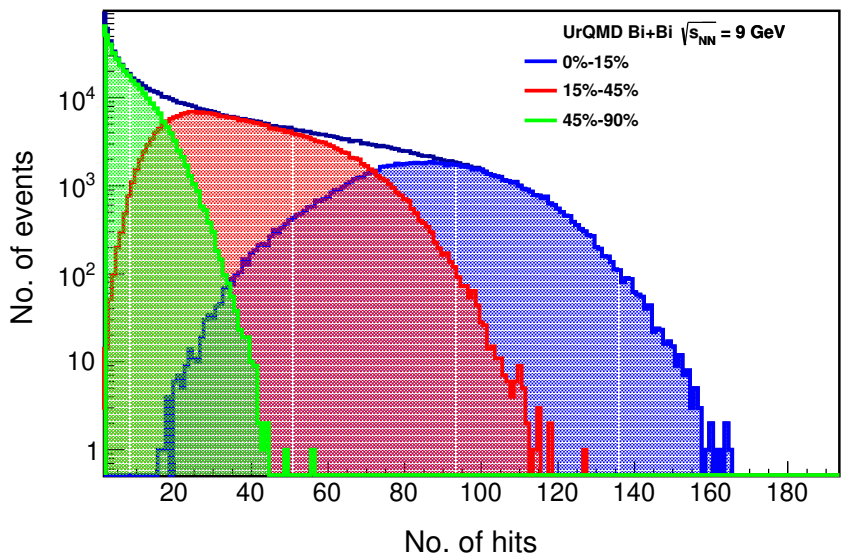
Combined trigger efficiency - multiplicity



Trigger capabilities: raw centrality

Linear relation between hits in miniBeBe and generated charged particles
$\longrightarrow$ useful to produce an online centrality trigger with miniBeBe



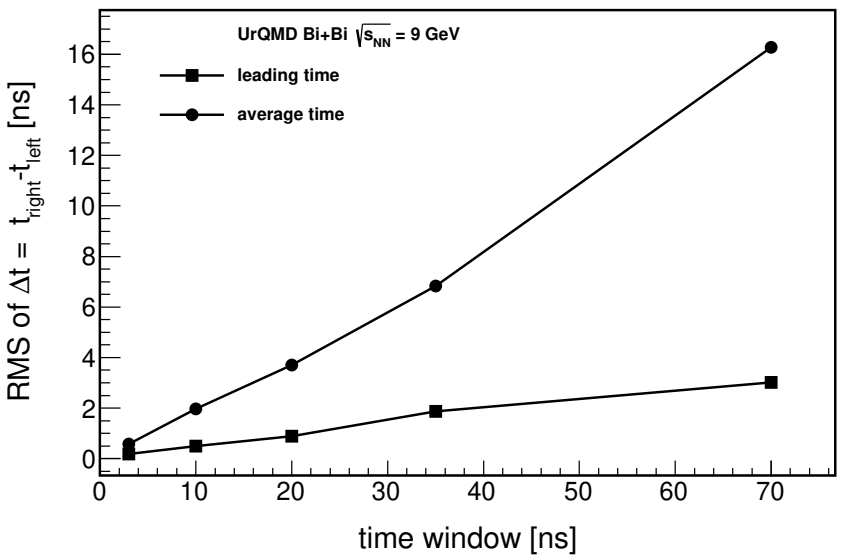


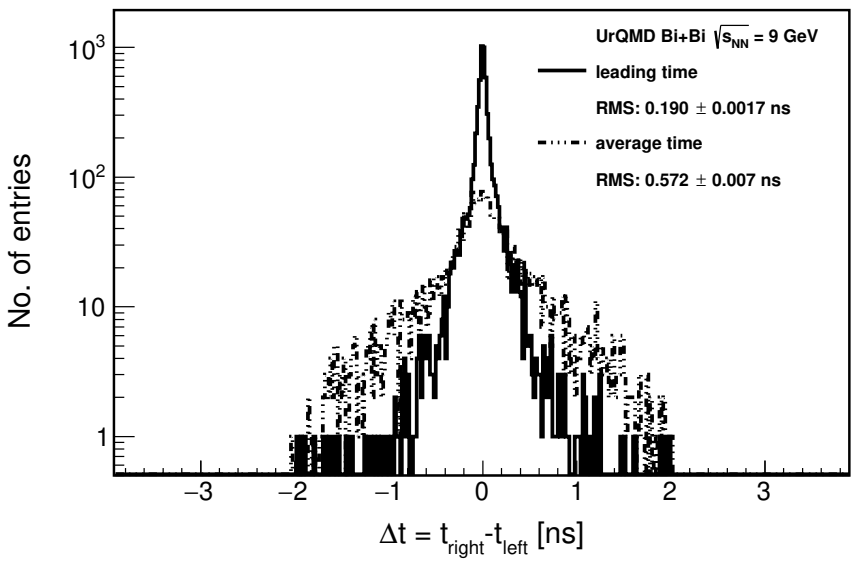
miniBeBe raw multiplicity varies with centrality ranges and some events may be assigned to wrong centrality range $\longrightarrow$ can be corrected offline

Trigger capabilities: time information

Avg hit time and time-of-flight of first charged particle reaching miniBeBe (leading time) for $z > 0$, t_{right}, and for $z < 0$, t_{left}

RMS of $\Delta t = t_{right} - t_{left}$, hint for best time resolution of the miniBeBe





minimum RMS value for the Δt dist is obtained using the leading time for particles reaching miniBeBe

Simulation findings for baseline miniBeBe

- trigger signal with $\simeq 100\%$ efficiency for mid-rapidity and for forward region, trigger efficiency $\leq 80\%$,
- leading time is optimal for trigger, especially for high multiplicity events,
- time resolution of 26 ps for trigger in central collision; non-central collisions, not so stringent time resolution of 85 ps,
- number of hits sensitive to centrality of the collision; good for online raw centrality classes
- able to distinguish beam-gas interactions from beam-beam collisions under certain conditions for vertex

More details in
The conceptual design of the miniBeBe detector proposed for NICA-MPD
https://arxiv.org/abs/2007.11790
Submitted to JINST.

Closing remarks

- Design based on combined use of plastic scintillators and SiPMs.
- Mechanical structure based on a plug & play concept.
- Fast readout electronics.
- Room for improvements when considering larger azimuthal and longer axial coverage.
- miniBeBe can provide a fast wake-up signal for TOF in collisions of small systems at MPD-NICA

GRACIAS