miniBeBe Conceptual Design

MexNICA Collaboration

Detector Advisory Committee Meeting

October 19, 2020

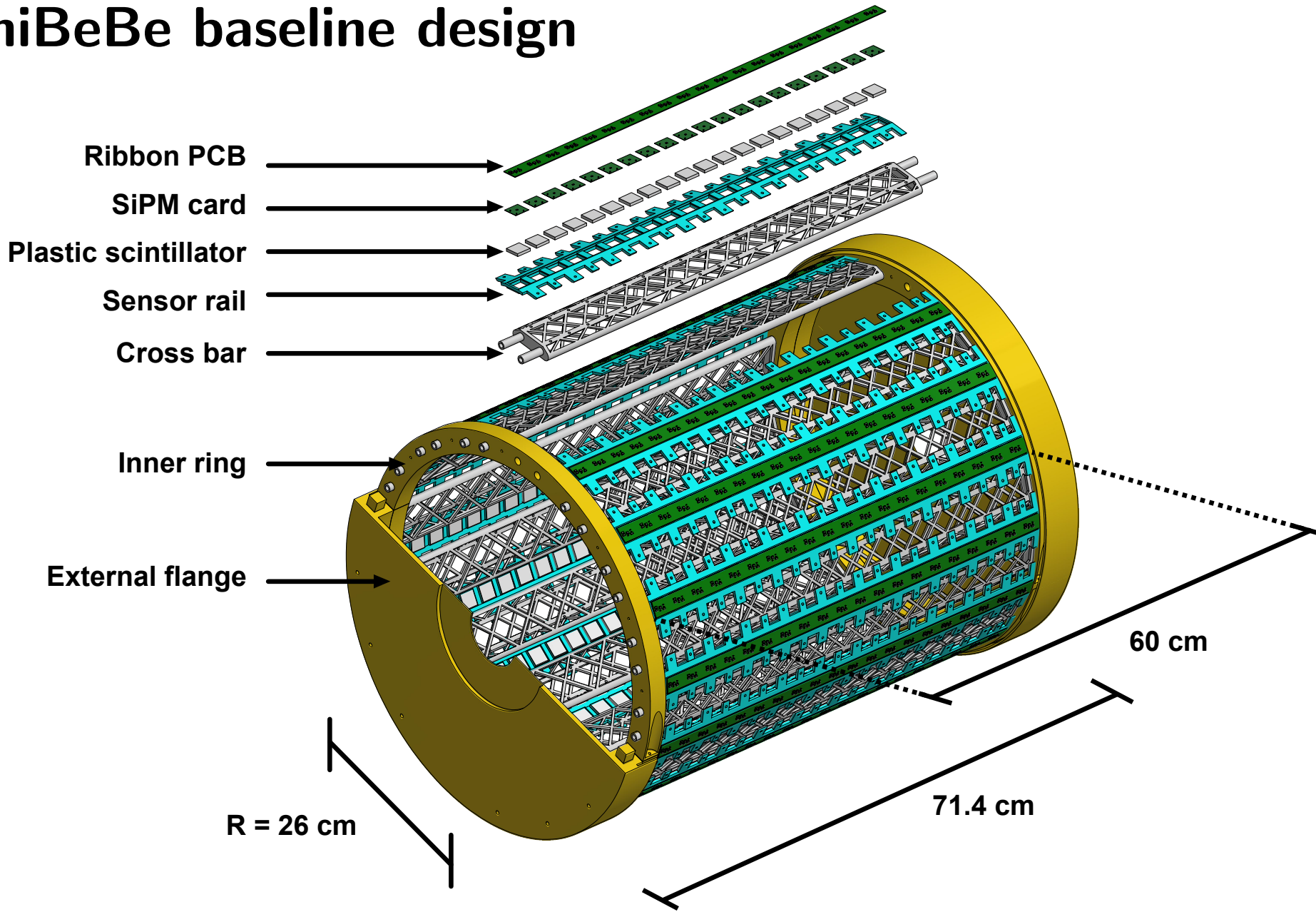
1. miniBeBe baseline design overview
2. Mechanical structure
3. Electronics, basic cell time resolution and material budget
4. Simulations for trigger efficiency
5. Costs
6. Improvements

Requirements

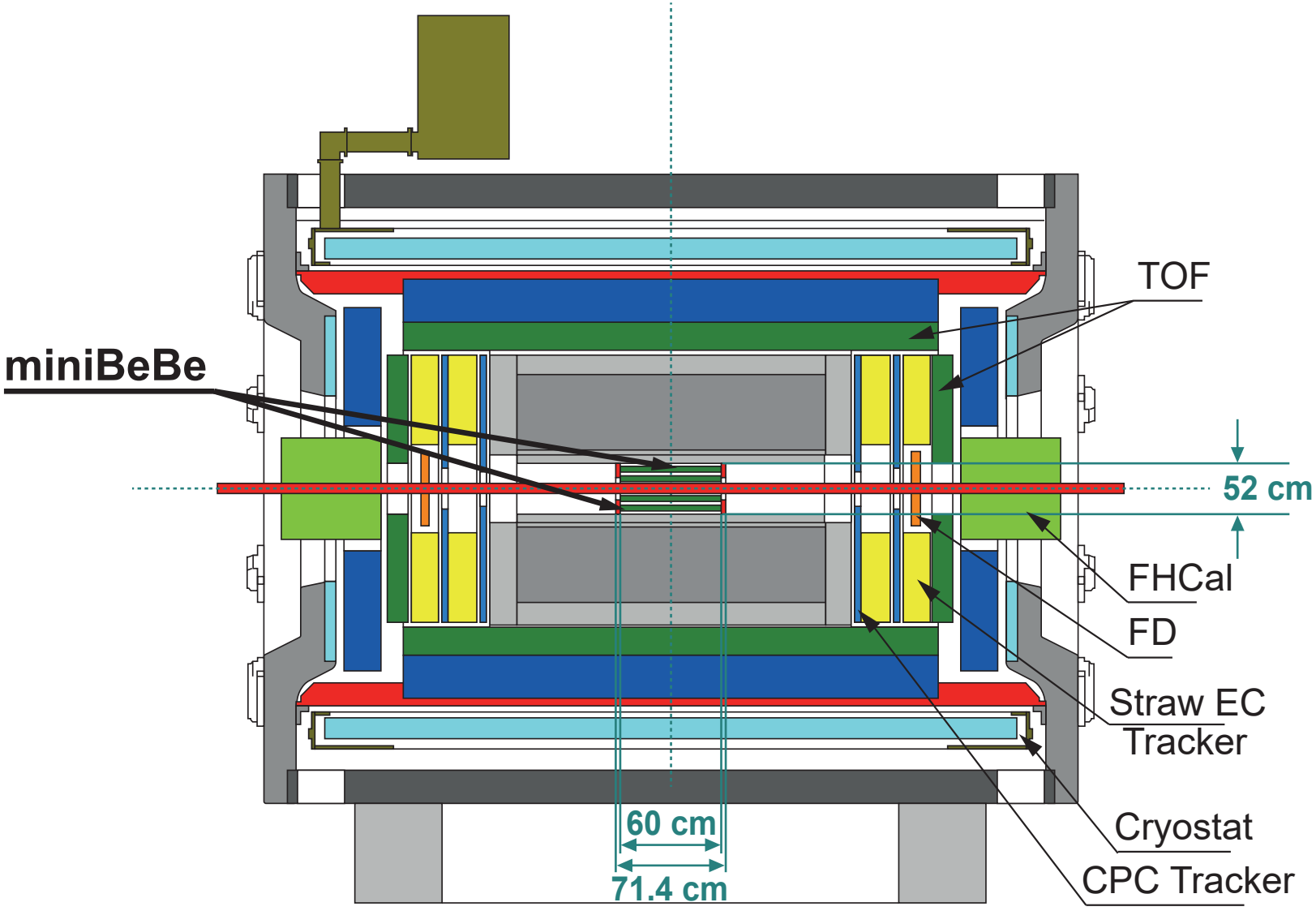
- To provide a wake-up trigger signal for events ranging from low to high multiplicities, for the TOF.
- To reliably separate pions, kaons and protons in a wide range of momenta, the TOF is expected to have an overall time resolution better than 100 ps. This requires the trigger signal to be optimized.
- The nominal MPD element designed to provide this trigger is the FFD, which in simulations has proven to be efficient for central and semi-central A + A collisions, although its efficiency decreases below 50% for multiplicity events with less than 25 particles.
- To improve the trigger, the miniBeBe is required to be efficient for low multiplicity p + p, p + A and A + A events as well as to have a fast response.

Mechanical structure

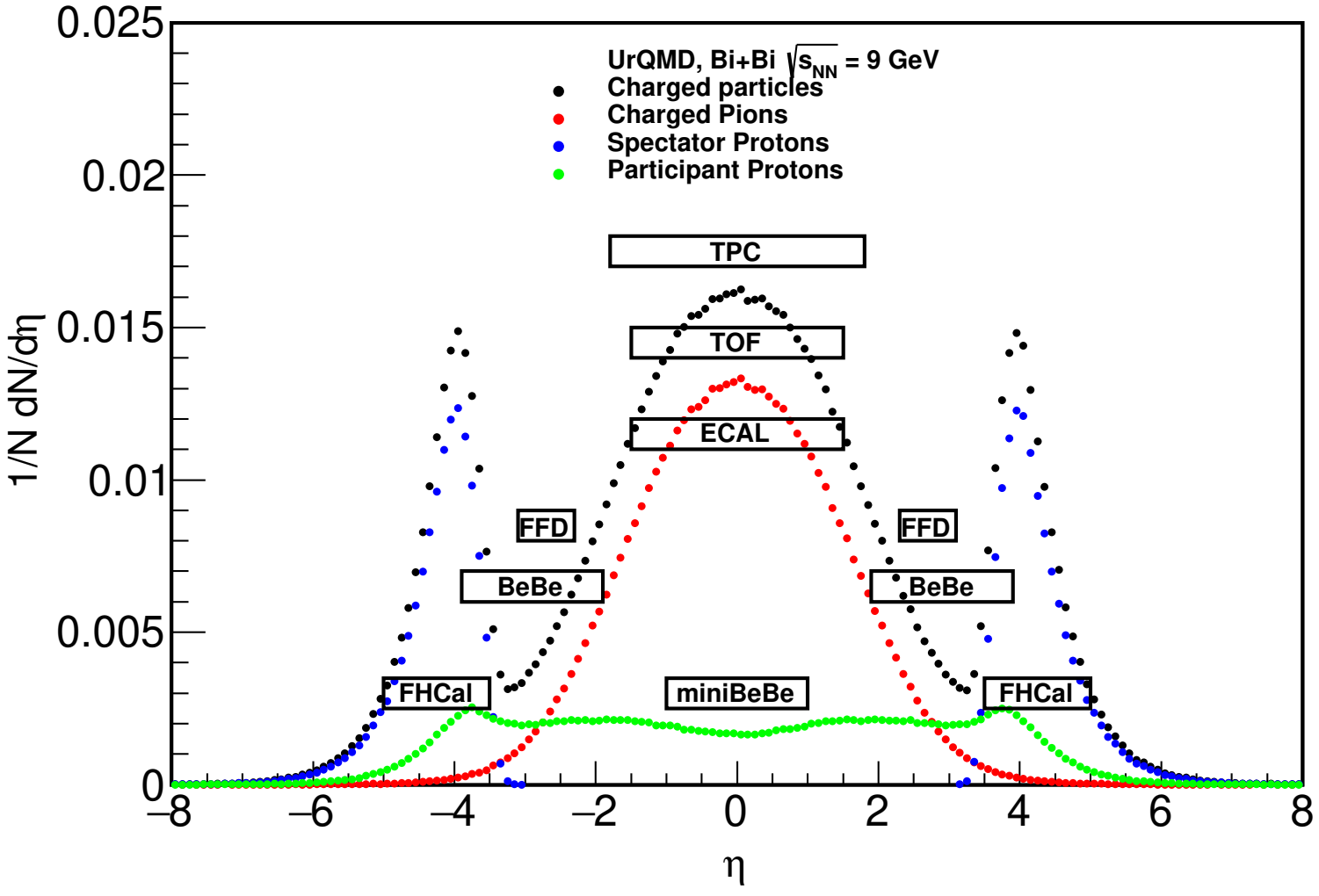
miniBeBe baseline design



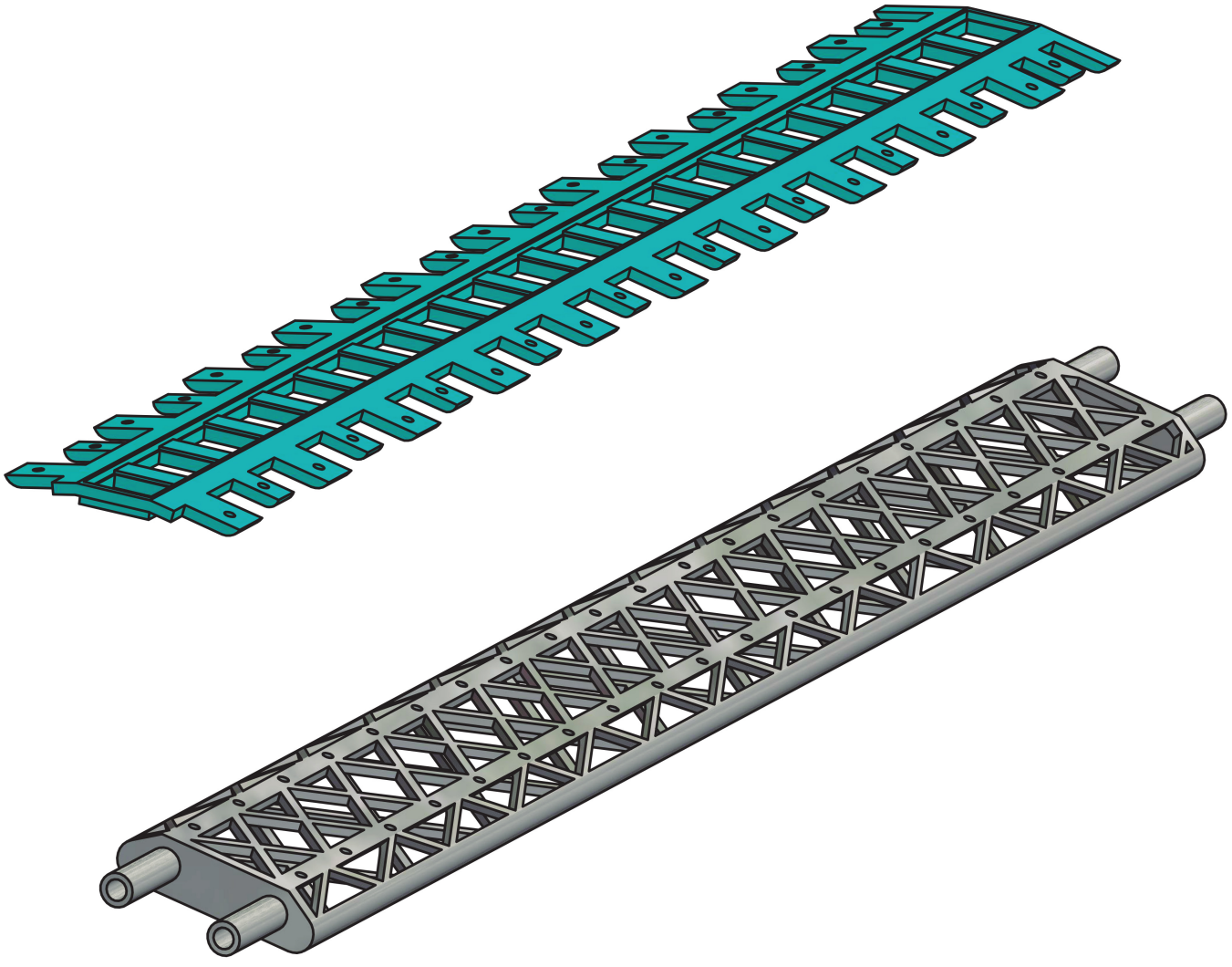
miniBeBe @ MPD



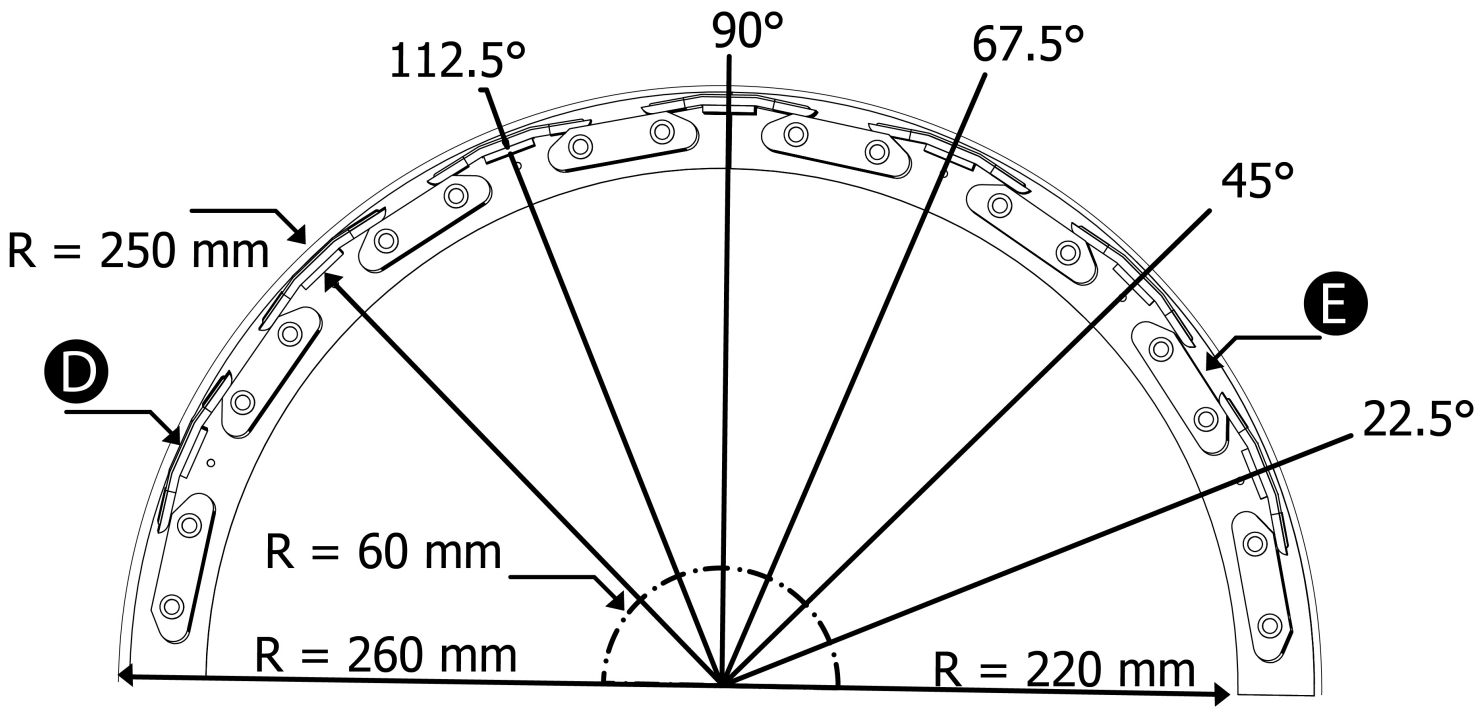
Pseudorapidity coverage



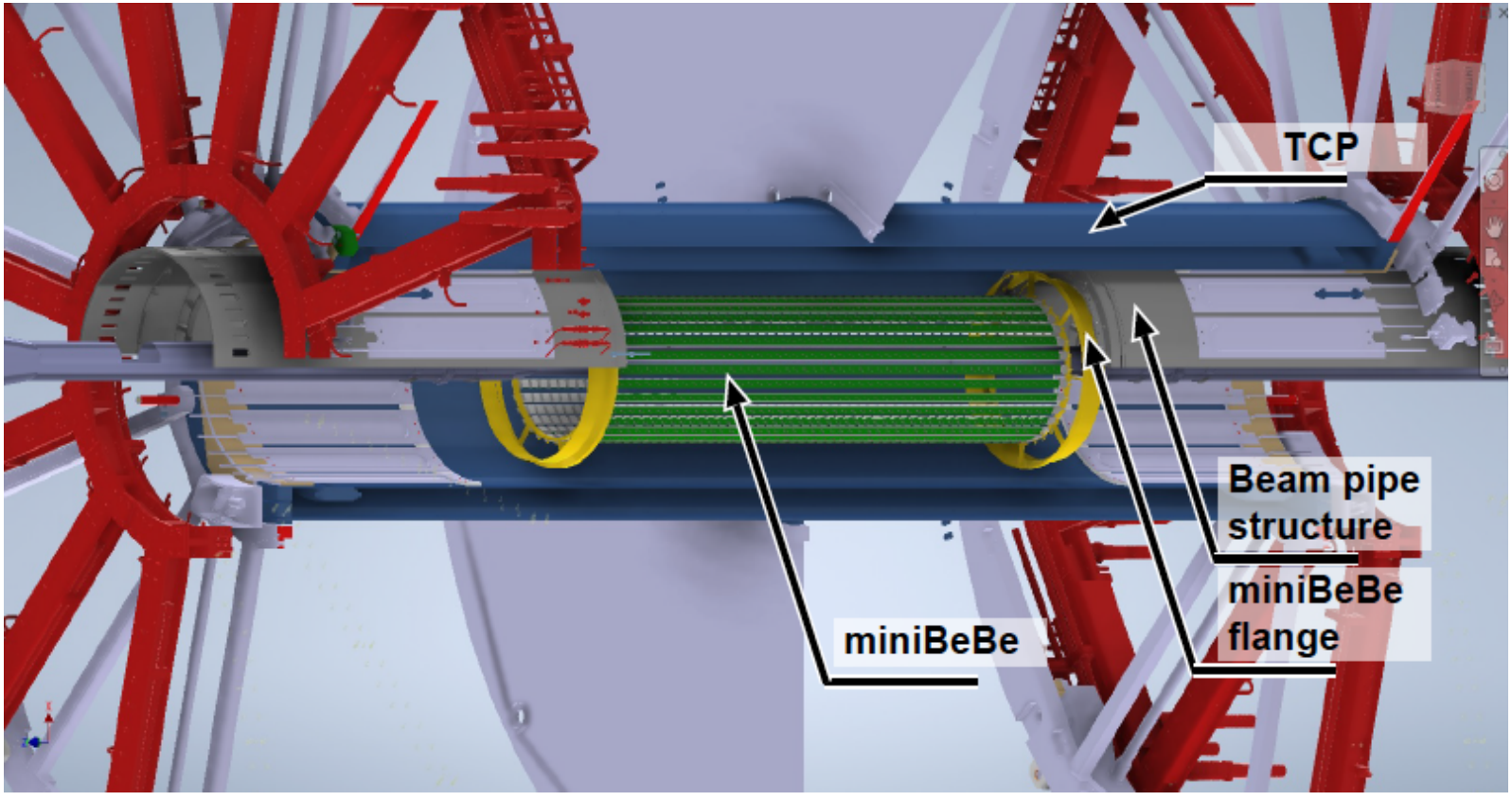
Sensor rails



Transverse plane view of sensor rails array



Integration with beam pipe support

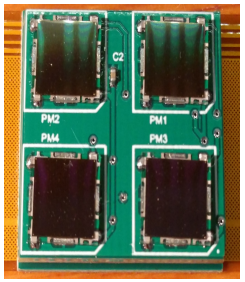


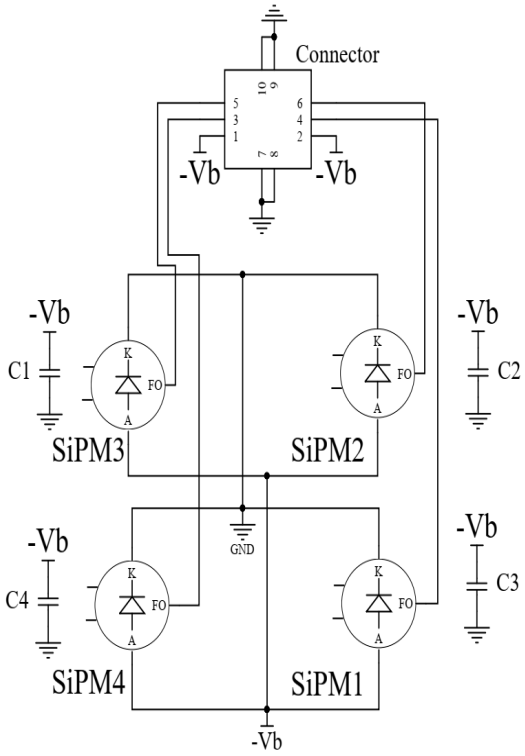
Electronics, basic cell time resolution and material budget

SiPMs coupled to plastic scintallator cells

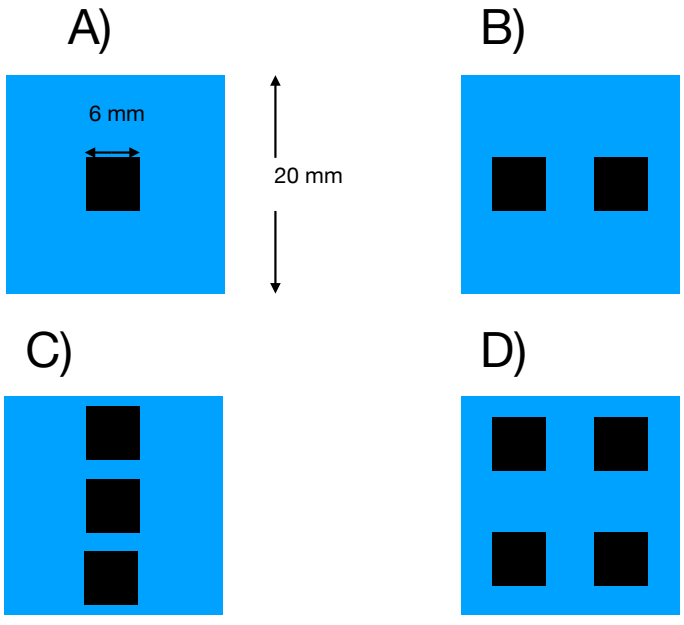
Basic cell with four SiPMs & electronics

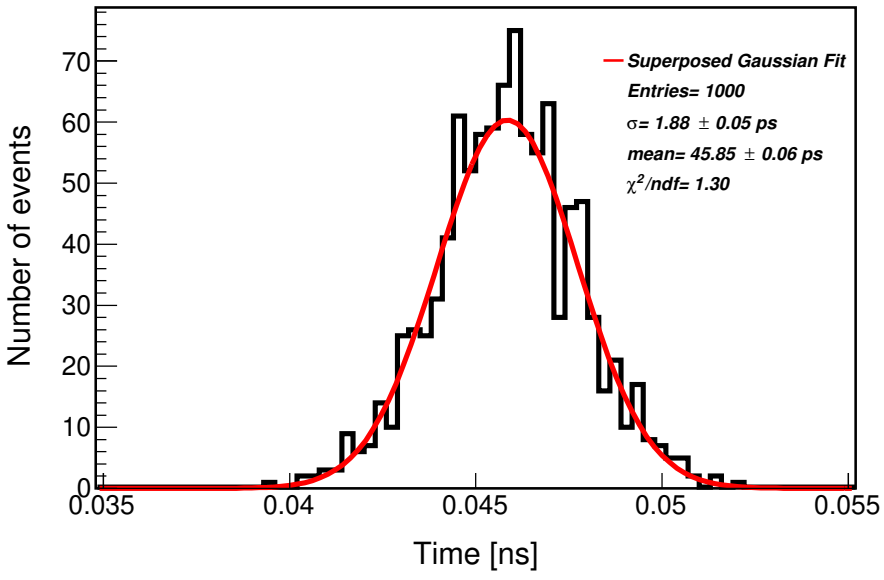
- 20x20 mm^2
- 4 SiPMs card attached to BC404 plastic scintillator
- Fast outputs to “connector” (micro mezzannine)
- DC decoupling capacitors





Plastic cell & SiPM intrinsic time resolution



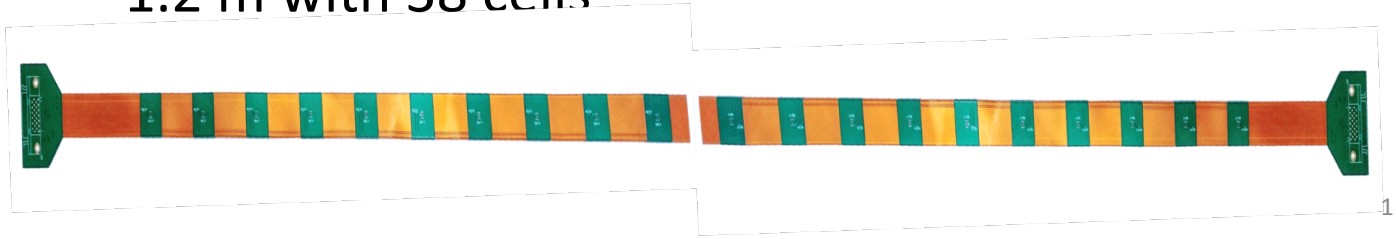


- Charged particle interaction in the cell perimeter leads to a time resolution ∼2.6 ps.
- For an interaction in the middle, the time resolution increases to ∼26 ps.

Ribbon card to collect signal from sensor cells

Strip card

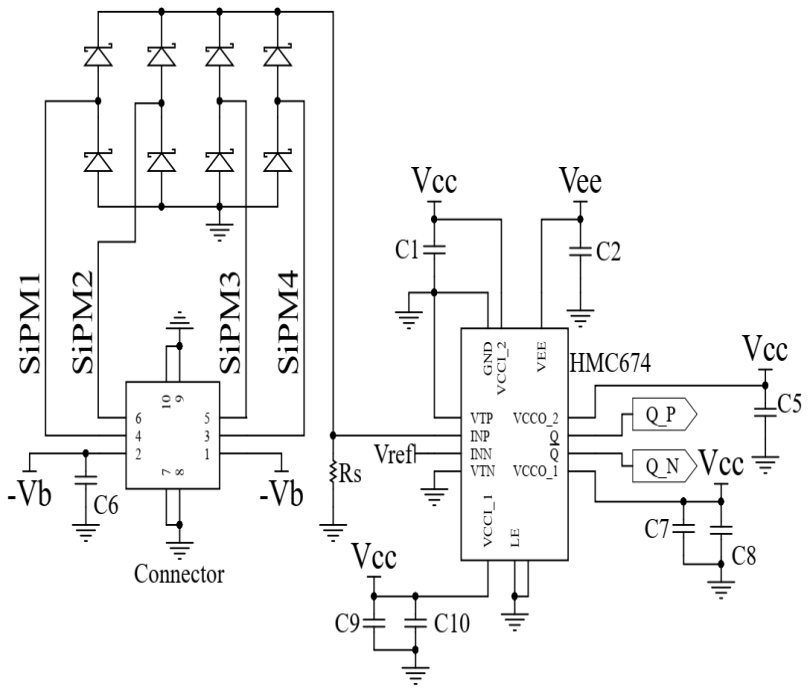
- First prototype length: 0.6 m
- Number of cells: 20
- RSP-ECL differential outputs
- Rigid-Flex design
- Possible improvements:
  - 1.5 m with 48 cells (under development)
  - 1.2 m with 38 cells



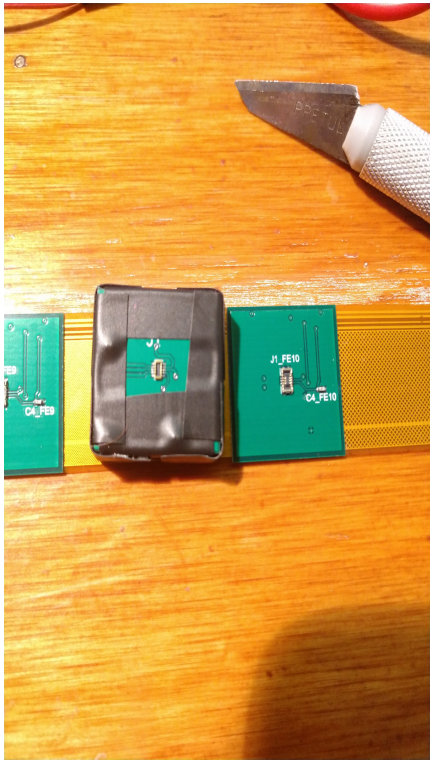
Ribbon card electronics

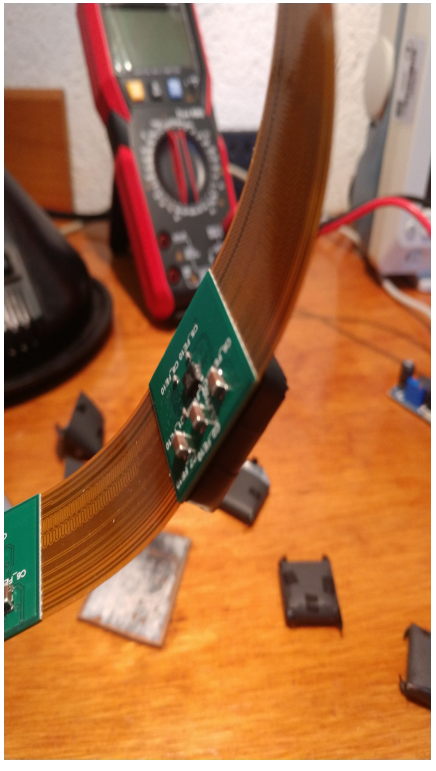
Strip card electronics

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



Card Prototypes





Signal collection: FPGA card

- TRB-3 card for signal collection.
- Located outside MPD detector (under consideration).
- Estimated cable length of 3 m, from each connector.
- Ethernet connection to a site (under consideration).
- Dedicated Linux station for data collection.
- Based on 3.2 GBps optical links
- Either stand-alone or part of a complex system

Material budget

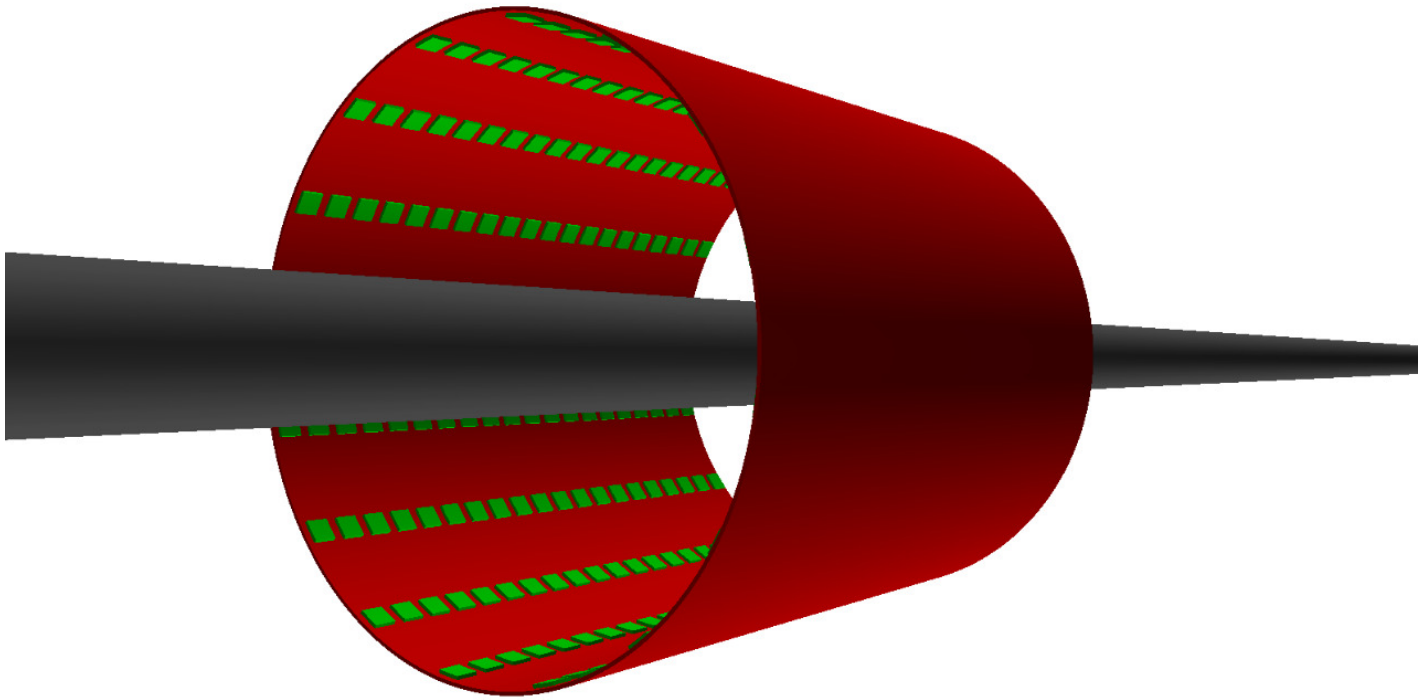
- Energy loss of primary particles (pions and muons) in the range (IE) of 5 MeV to 5 GeV using Geant4.
- Analysis for both, the Detector Elements (DE) and blind area (BA).

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 lengths $X0_{\mathrm{BC404}} = 0.7\% X0$; $X0_{\mathrm{CF}} = 0.36\% X0$ ($X0$: characteristic radiation length, CF stands for Carbon Fiber)

Simulations for trigger efficiency

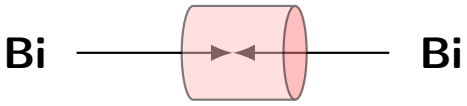
miniBeBe geometry within MPDRoot



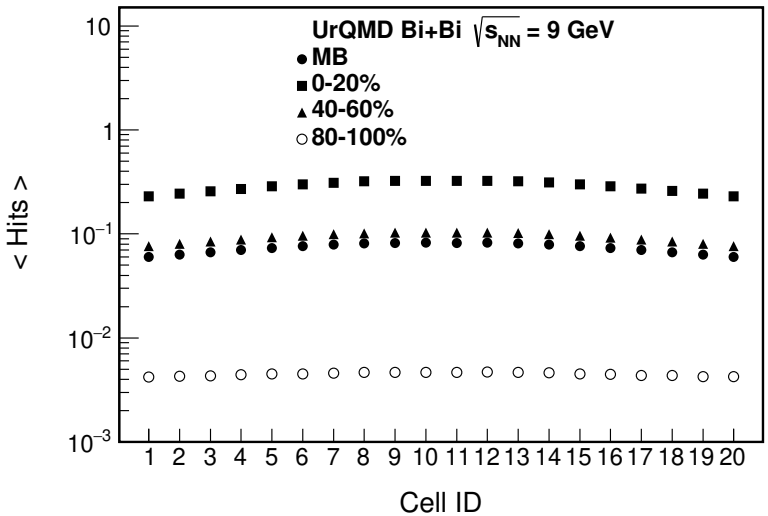
<table>
<tr><th colspan="4">Simulations with UrQMD+MPDroot</th></tr>
<tr><th>miniBeBe
geometry</th><th>collision
species</th><th>$\sqrt{s_{\mathrm{NN}}}$
(GeV)</th><th>Centrality
bins</th></tr>
<tr><td rowspan="2">length 60 cm
radius 25 cm
MBB-60-25*</td><td>Bi + Bi
C + C</td><td>9</td><td rowspan="2">min bias
0-20%
40-60%
80-100%</td></tr>
<tr><td>p + p</td><td>9,11</td></tr>
<tr><td colspan="4">Transport</td></tr>
<tr><td colspan="4">magnet ON
with/without smearing: flat ± 60 cm
miniBeBe, FFD, BeBe</td></tr>
</table>

* baseline miniBeBe geometry as reported in CDR

Baseline MBB-60-25

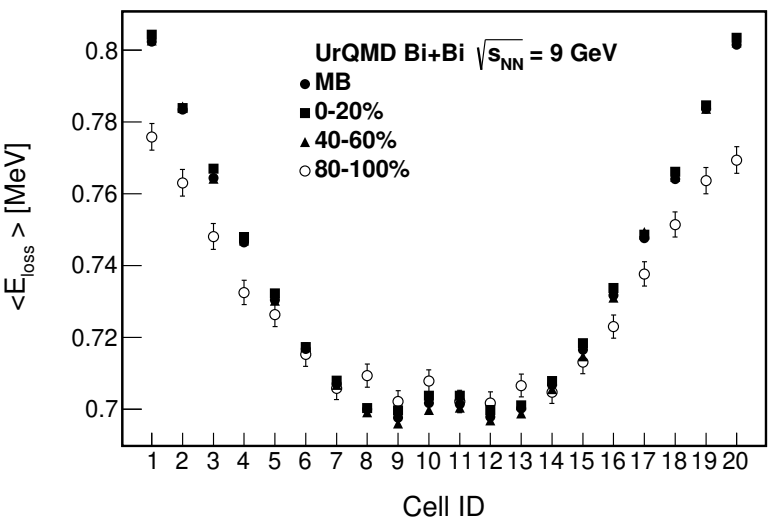


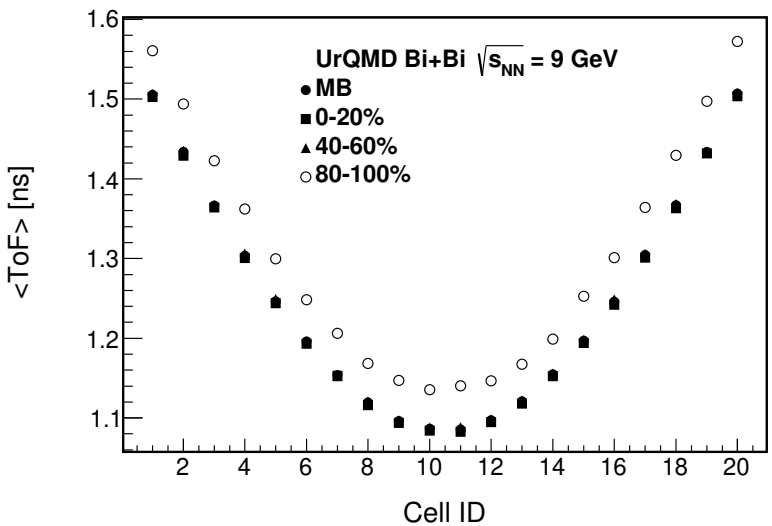
$\sqrt{s_{NN}} = 9$ GeV



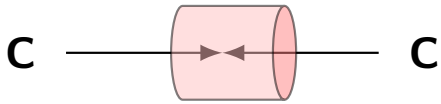
⟨Hits⟩	0-20%	80-100%
cell	0.2294 - 0.3248	0.0042 - 0.0047
detector	91.84	1.43

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

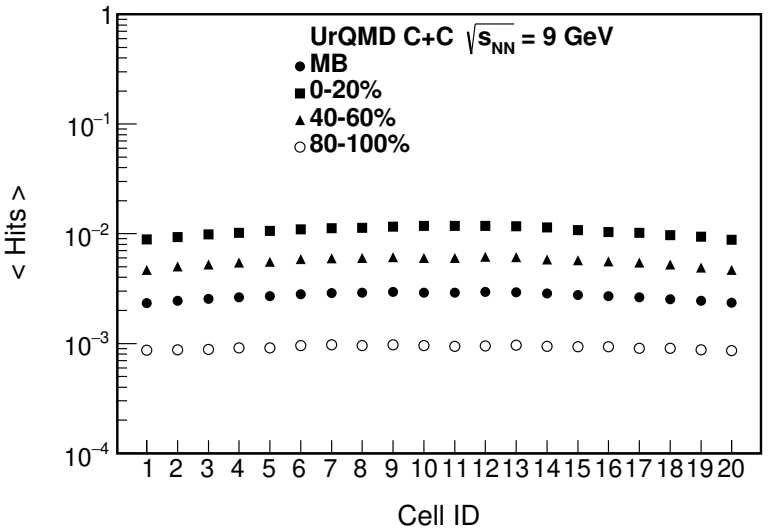




Baseline MBB-60-25

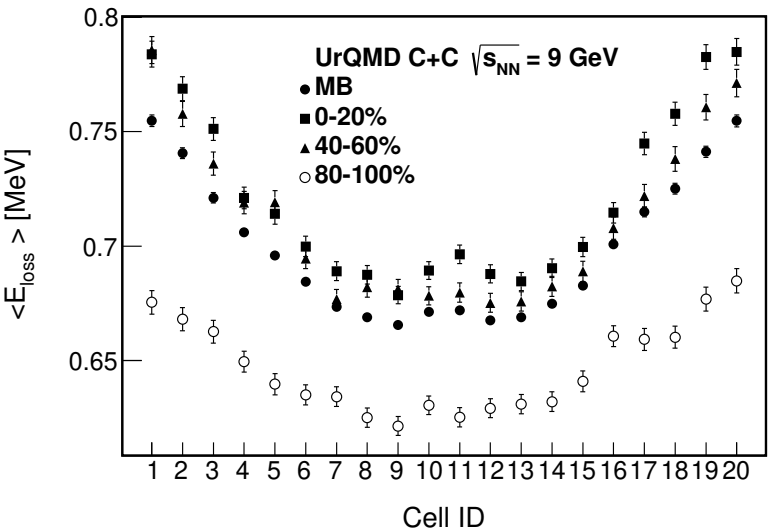


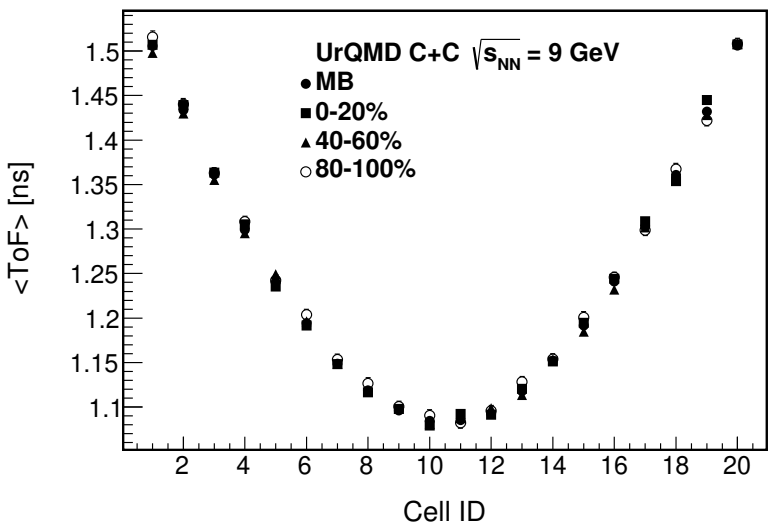
$\sqrt{s_{NN}} = 9$ GeV



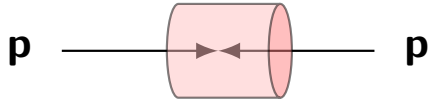
⟨Hits⟩	0-20%	80-100%
cell	0.00882-0.01182	0.00085-0.00097
detector	3.390	0.295

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

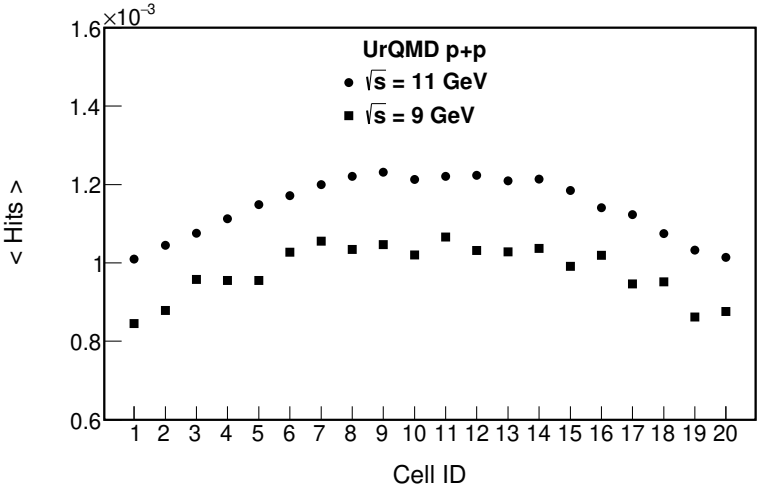




Baseline MBB-60-25

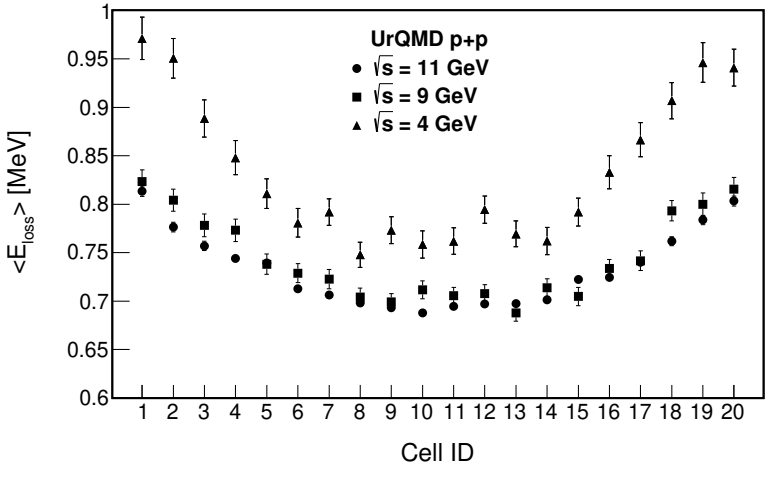


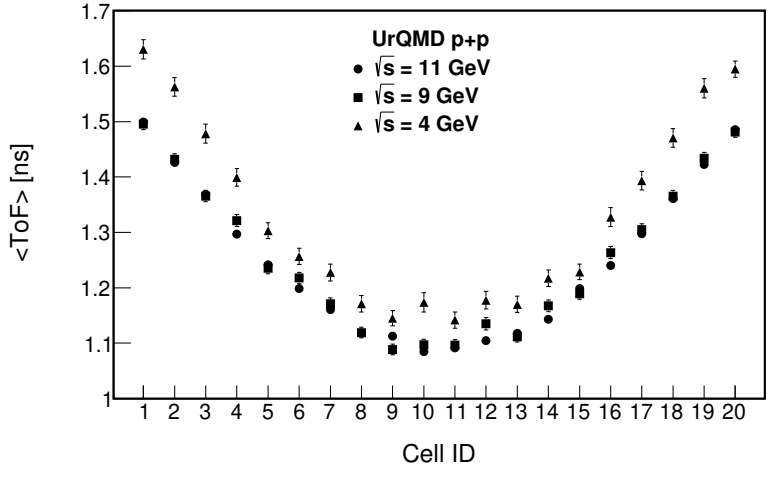
$\sqrt{s_{NN}} = 9,\ 11$ GeV



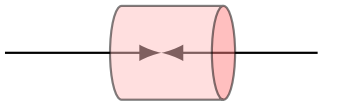
⟨Hits⟩	9 GeV	11 GeV
cell	0.00084-0.0011	0.00100 - 0.00122
detector	0.313	0.365

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

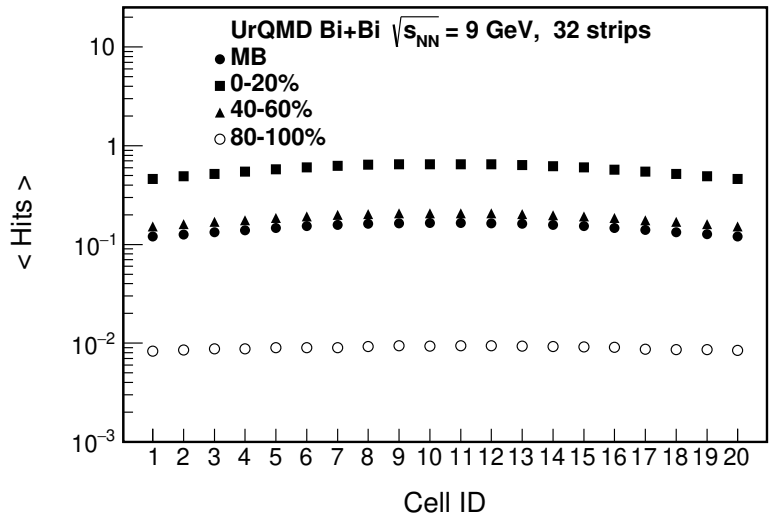




MBB-60-25

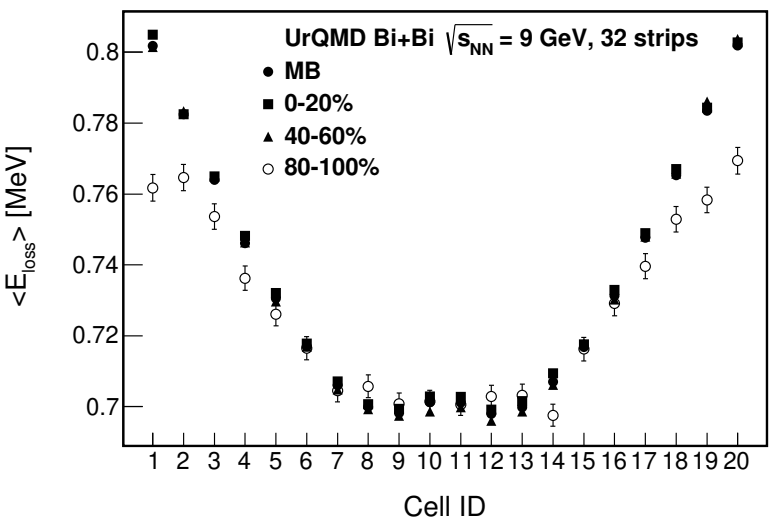
Bi  Bi

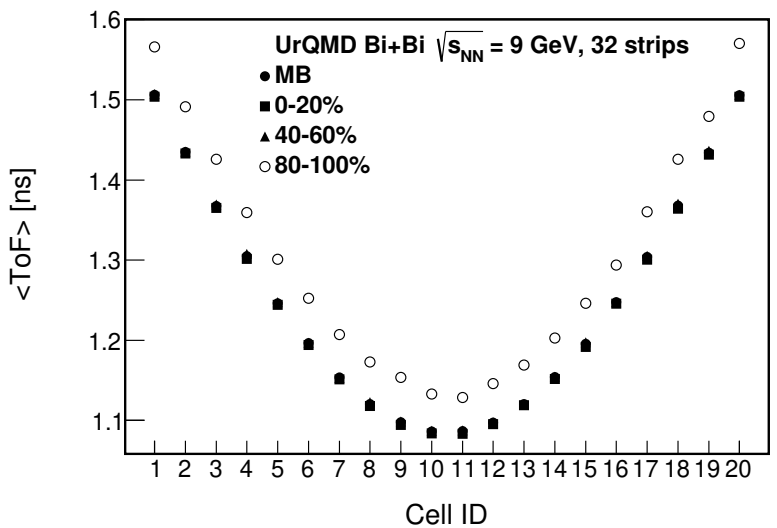
$\sqrt{s_{NN}}$ = 9 GeV, 32 strips



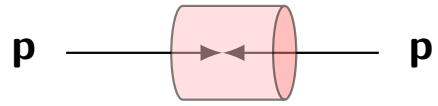
⟨Hits⟩	0-20%	80-100%
cell	0.4588 - 0.6501	0.0083 - 0.0094
detector	367.87	5.75

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

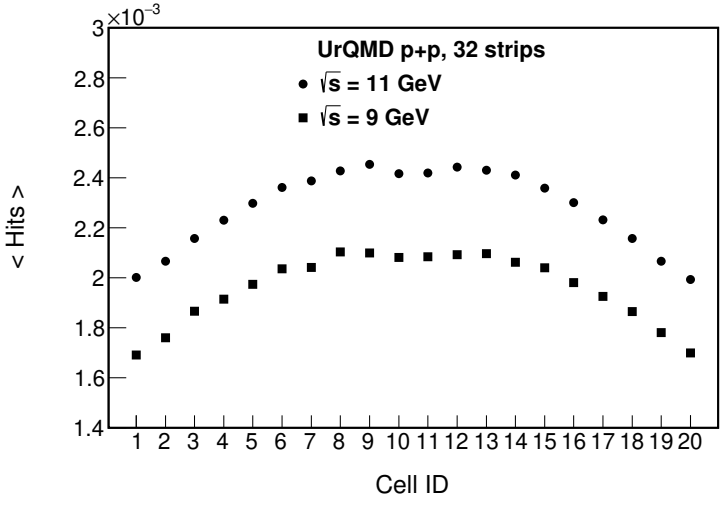




MBB-60-25

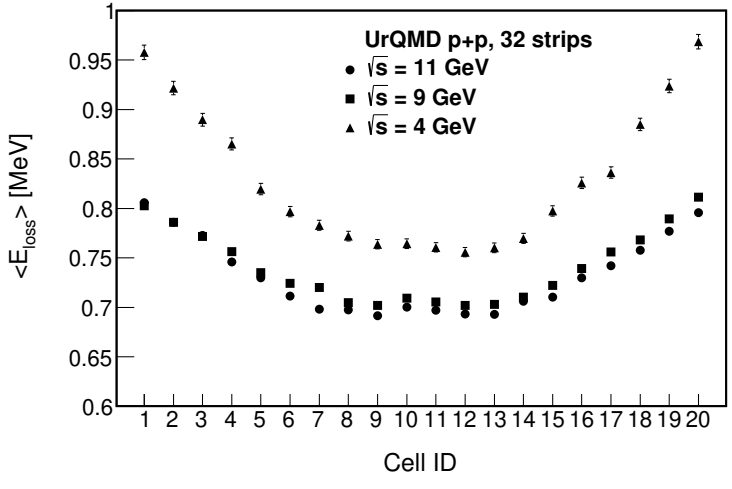


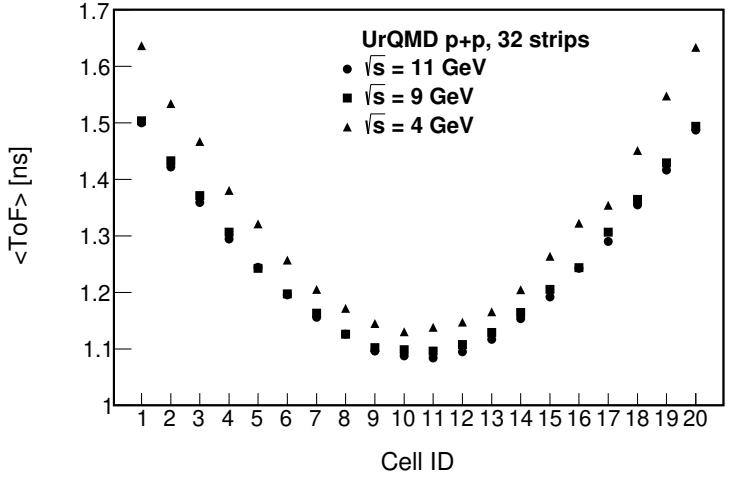
$\sqrt{s_{NN}}$ = 9, 11 GeV - 32 strips



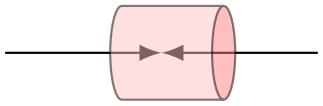
⟨Hits⟩	9 GeV	11 GeV
cell	0.0017-0.0021	0.00199 - 0.00245
detector	1.25	1.46

$\langle E_{loss} \rangle$ = 0.7-0.8 MeV, $\langle ToF \rangle$ = 1.1-1.5 ns

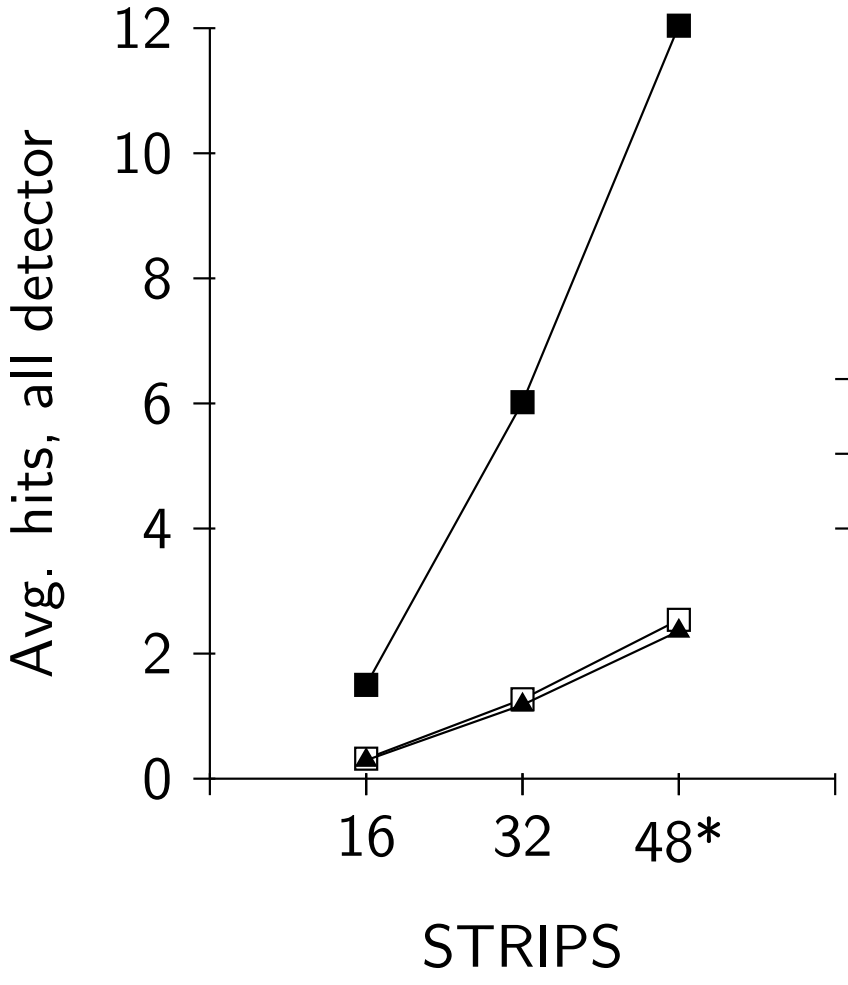




Simulated 16/32 strips, MBB-60-25

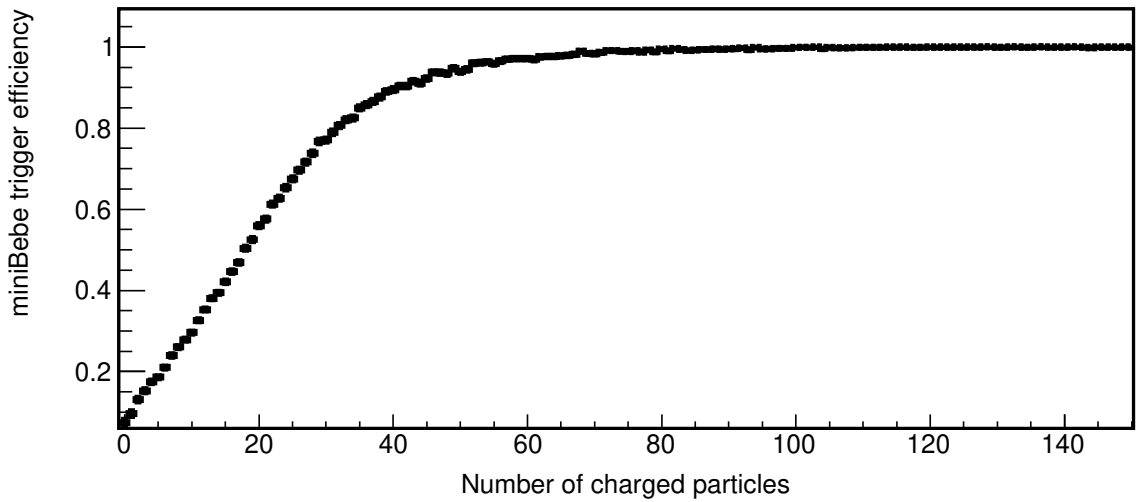


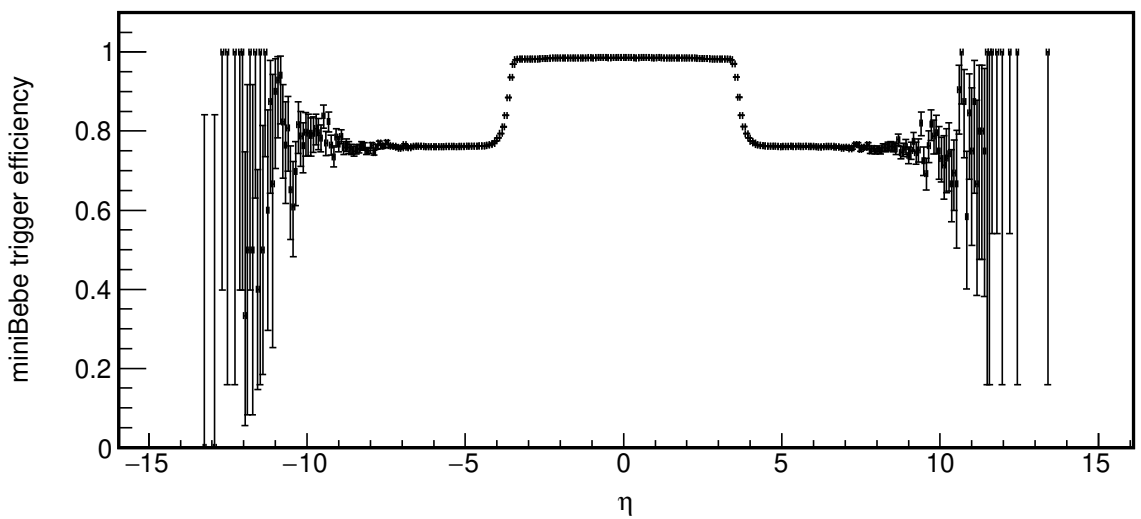
16 → 32 strips: factor of 4 increase in the avg. number of hits in detector per event, then we estimate 32 → 48 strips: extra factor of 2 increase



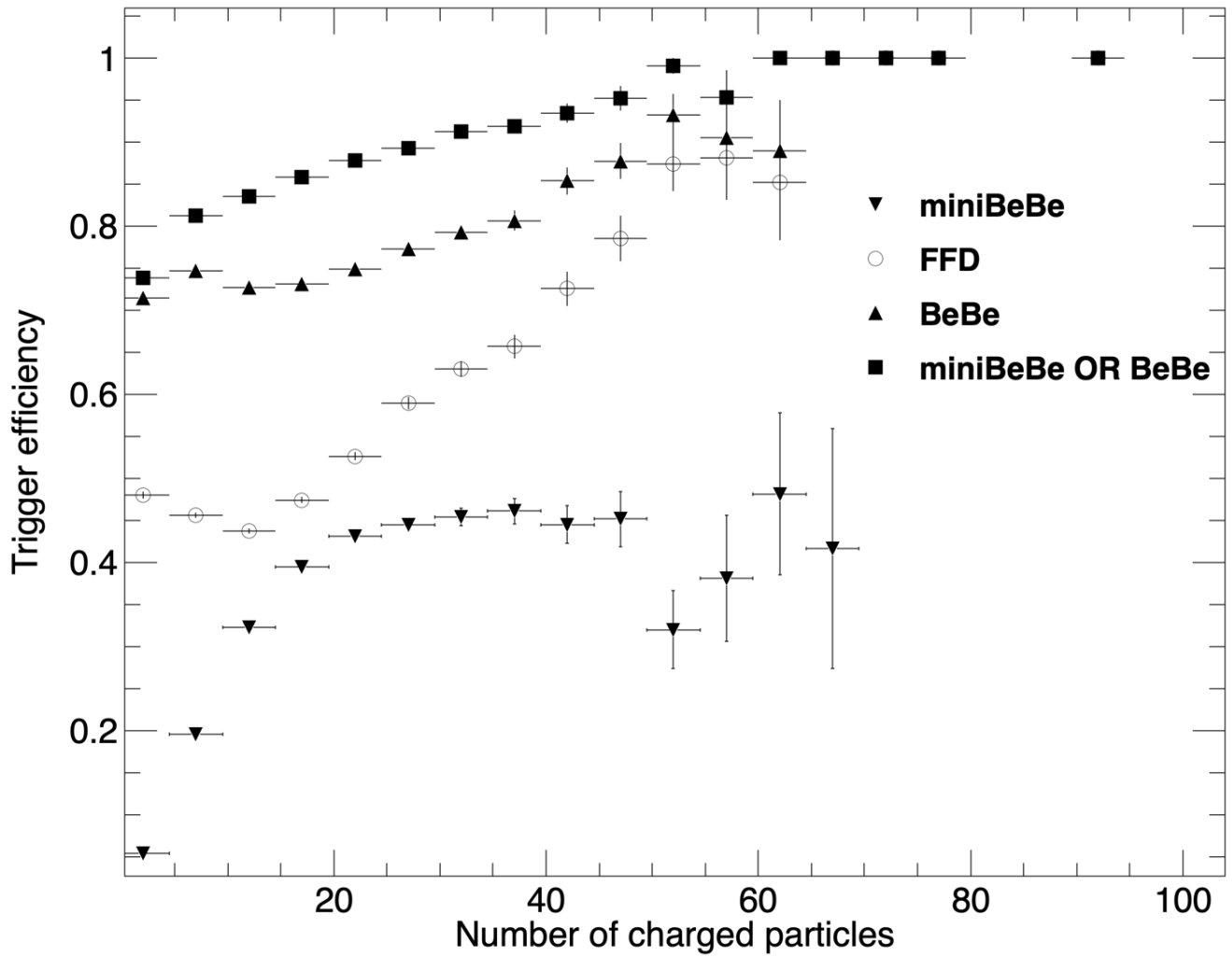
- p+p, $\sqrt{s_{NN}}$ =9 GeV
- Bi+Bi, $\sqrt{s_{NN}}$ =9 GeV, 80-100%
- C+C, $\sqrt{s_{NN}}$ =9 GeV, 80-100%

Trigger efficiency





Combined trigger efficiency



Costs

Cells and electronics

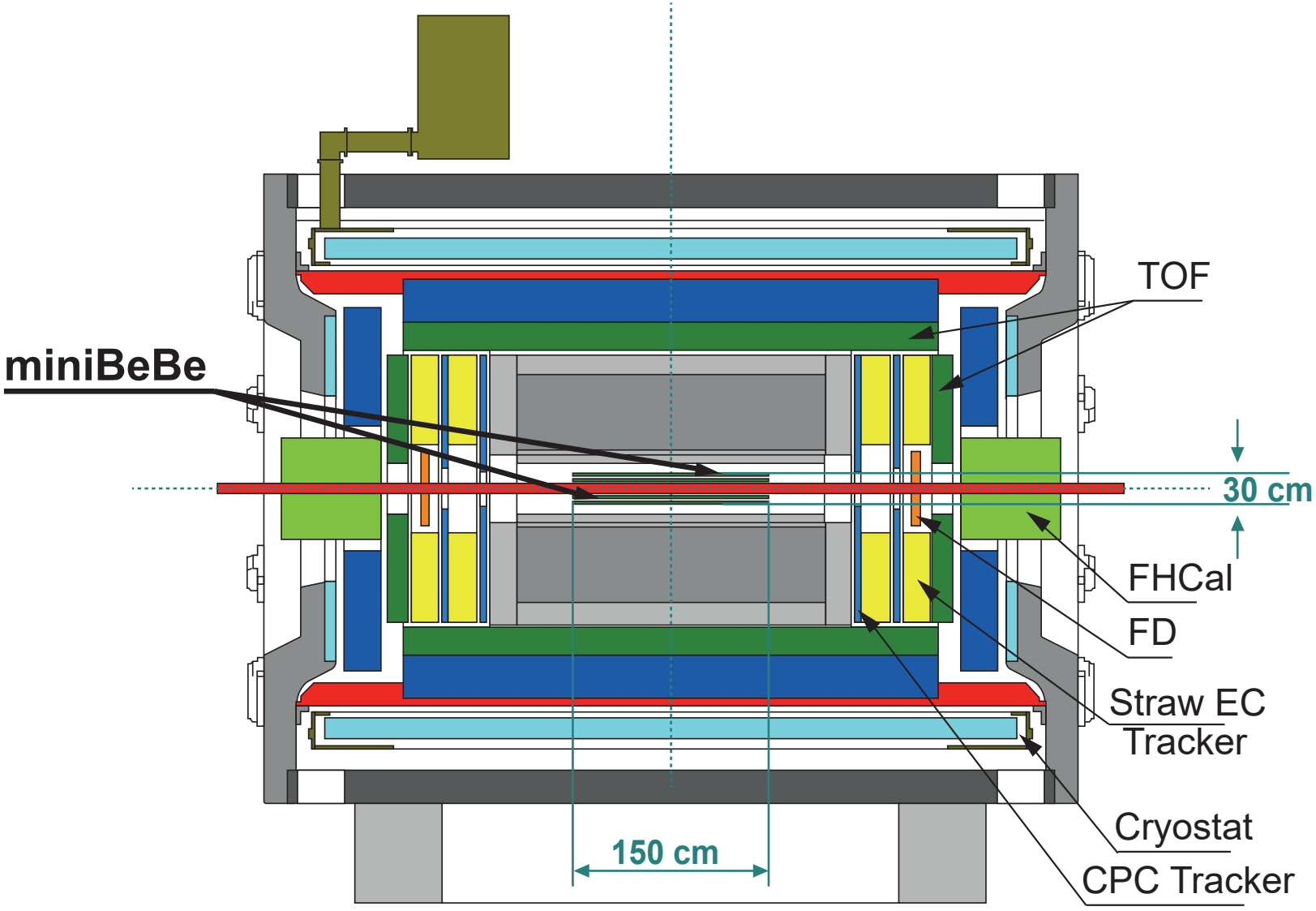
Material	Unit Cost	Cost
Ribbon card	$1,018	$2.036
Front-end	$592	$11.836
Scintillator	$235	$2,350
Total (16 strips)		$259,552

Mechanical structure

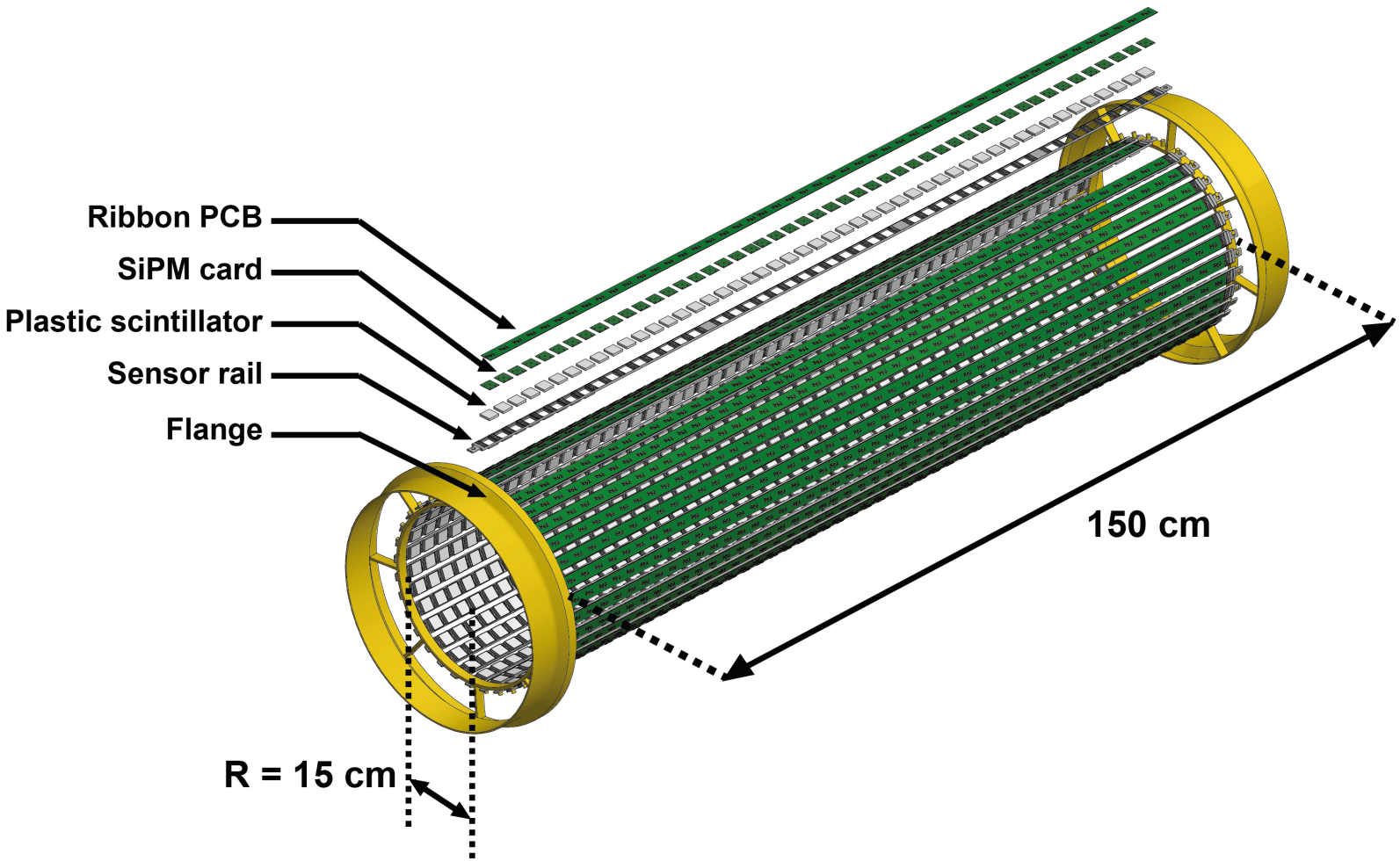
Material	Unit Cost	Cost
ABS and Carbon Fiber for prototype 3D printing	$6,125	$6,125
Commissioning of mechanical support built using carbon fiber including mechanical tests and quality control	$24,000	$24,000
Total		$30,125

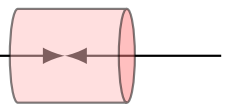
Improvements

miniBeBe @ MPD



$L = 150$ **cm,** $R = 15$ **cm**



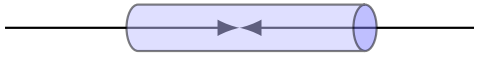
miniBeBe geometries with 16 strips		
	60cm length, 20 cells/strip	150cm length, 50 cells/strip
25cm radius	A/p  A/p MBB-60-25*	
15cm radius		A/p  A/p MBB-150-15

* baseline miniBeBe geometry as reported in CDR

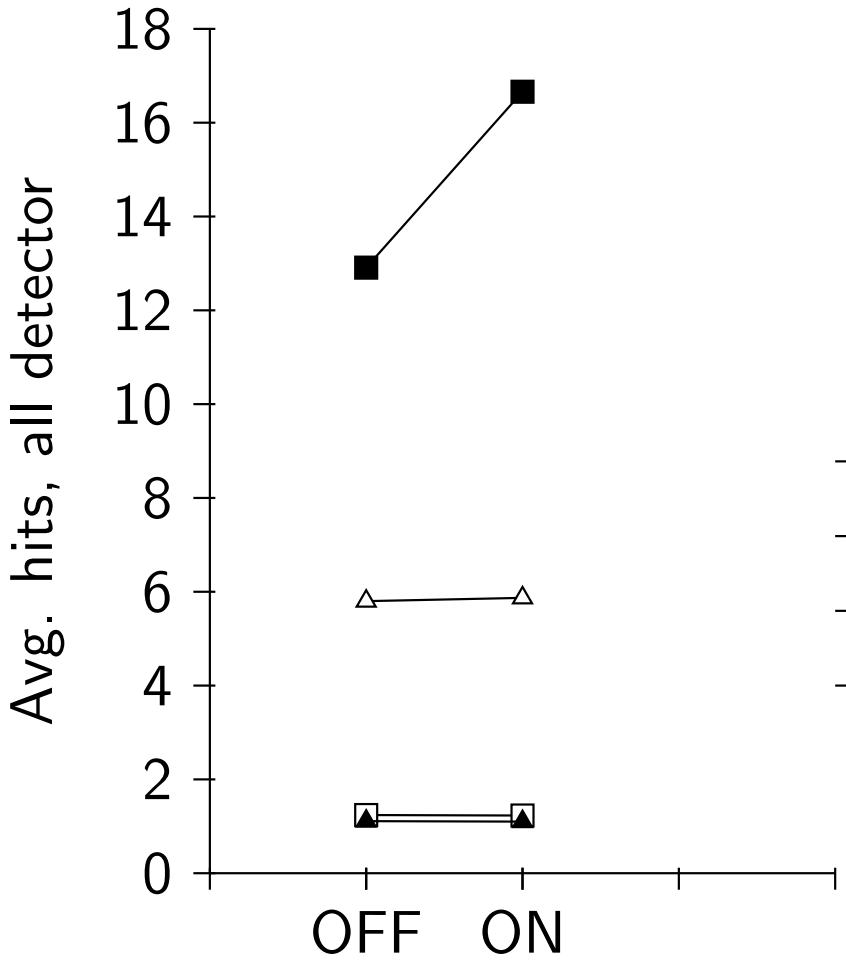
Simulations with UrQMD+MPDroot			
miniBeBe geometries	collision species	$\sqrt{s_{\mathrm{NN}}}$ (GeV)	Centrality bins
length 60 cm radius 25 cm MBB-60-25*	Bi + Bi C + C	9	min bias 0-20% 40-60% 80-100%
length 150 cm radius 15 cm MBB-150-15	p + Bi p + p		
Transport			
magnet ON with/without smearing: flat ± 60 cm miniBeBe, FFD, BeBe			

* baseline miniBeBe geometry as reported in CDR

MBB-150-15



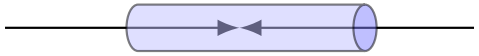
16 strips



- 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%

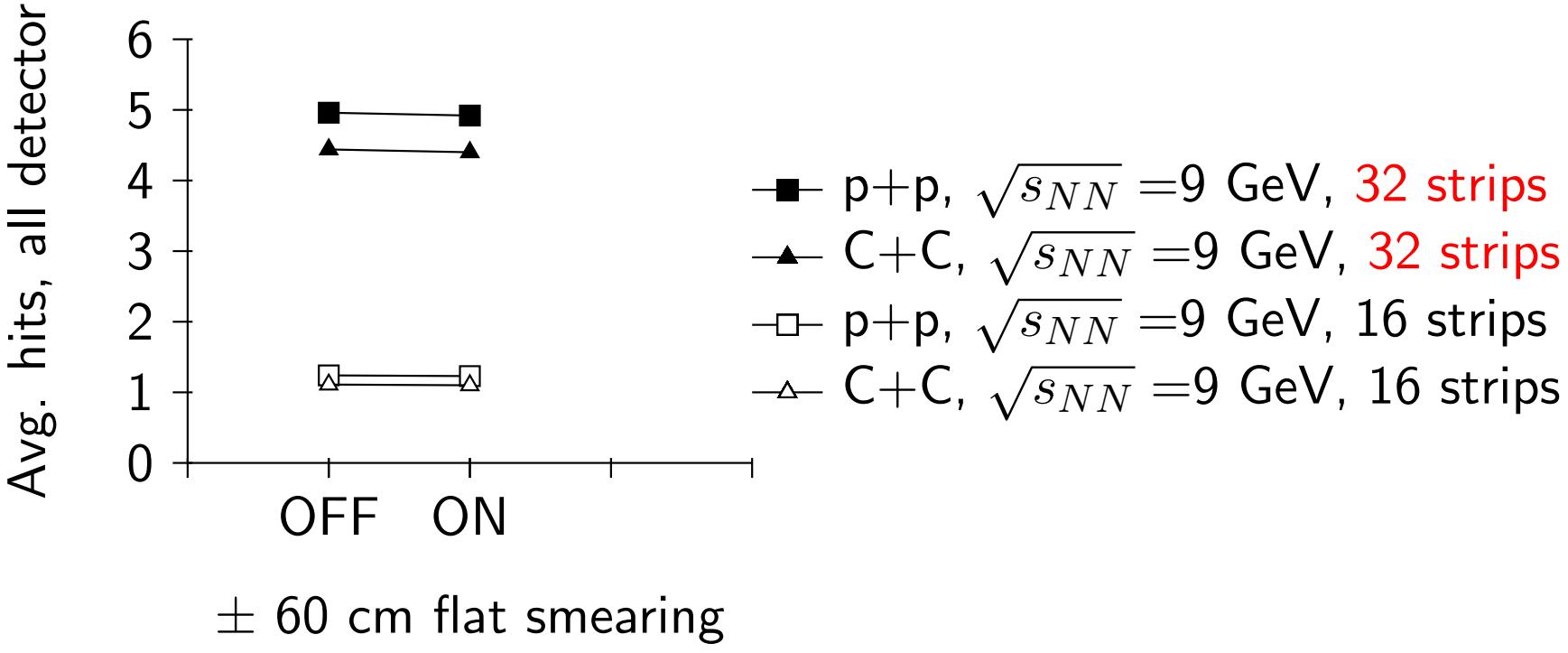
± 60 cm flat smearing

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

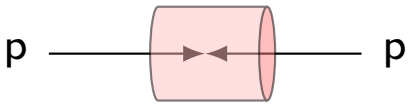
Conclusions

- 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.

GRACIAS

BACKUP

Baseline MBB-60-25



11 GeV

16 strips - no smearing

⟨Hits⟩	11 GeV
cell	0.00100 - 0.00122
detector	0.365

32 strips - no smearing

⟨Hits⟩	11 GeV
cell	0.00199 - 0.00245
detector	1.46

Baseline MBB-60-15

11 GeV

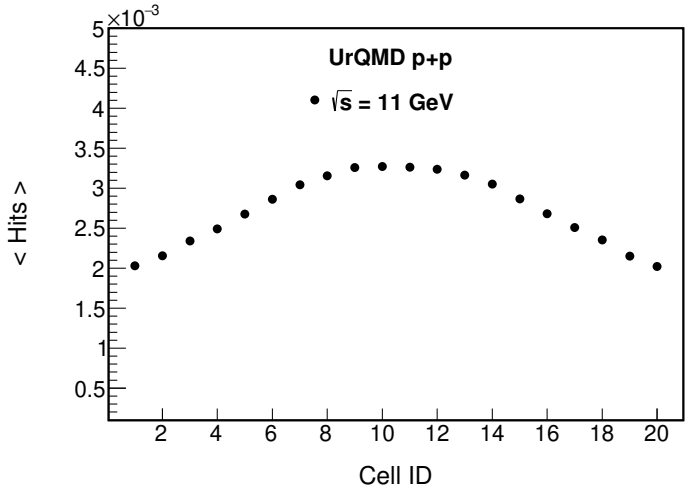
16 strips - no smearing

⟨Hits⟩	11 GeV
cell	0.0020 - 0.0032
detector	0.84

16 strips - with smearing

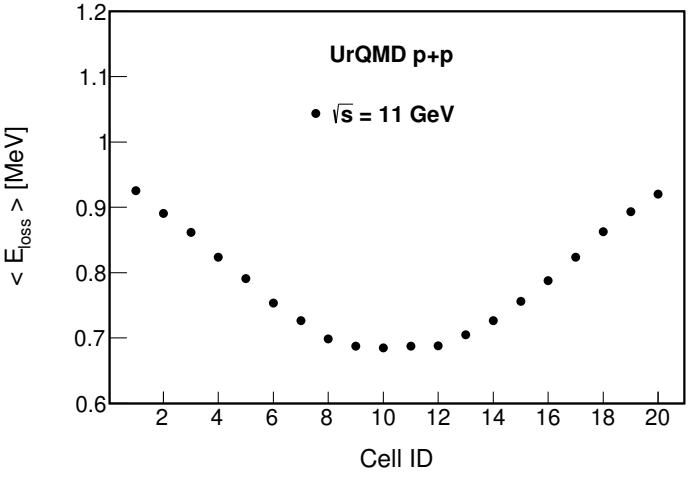
⟨Hits⟩	11 GeV
cell	0.0021-0.0027
detector	0.768

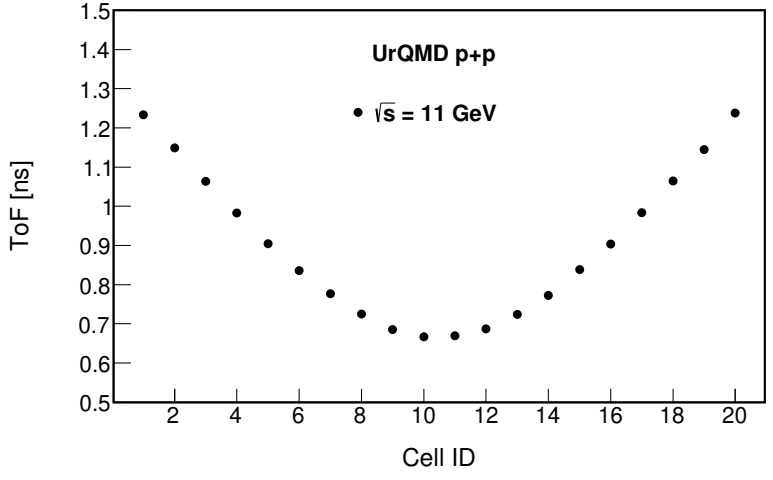
MBB-60-15 p p 11 GeV 16 strips



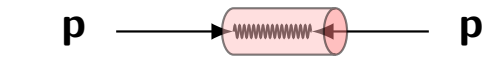
⟨Hits⟩	11 GeV
cell	0.0020 - 0.0032
detector	0.84

$\langle E_{loss} \rangle$ = 0.7-0.95 MeV, $\langle ToF \rangle$ = 0.7-1.25 ns



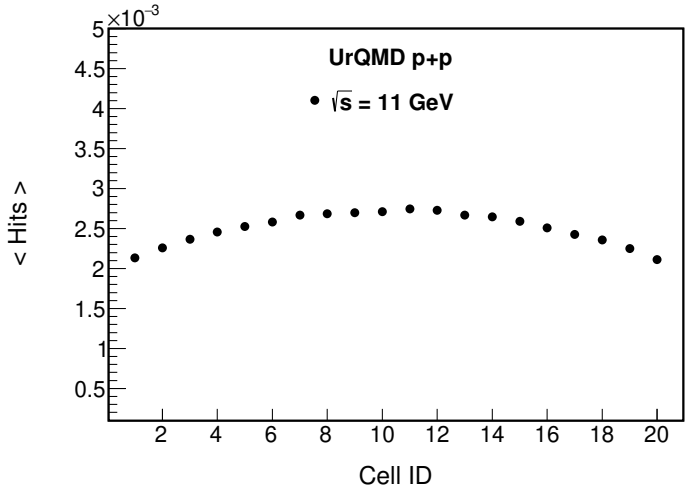


MBB-60-15



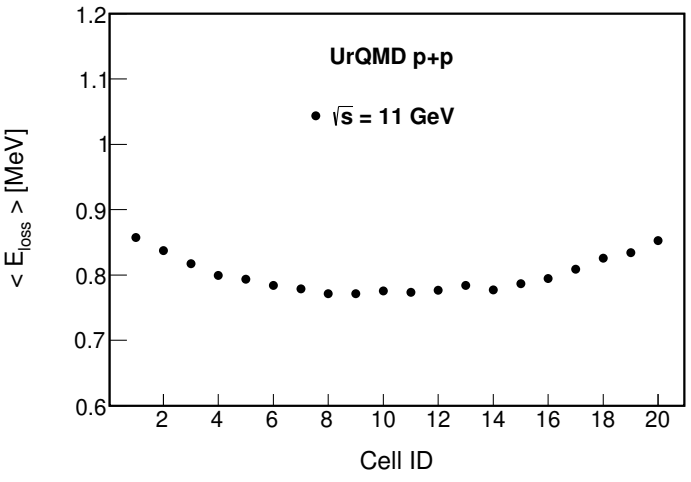
11 GeV with smearing

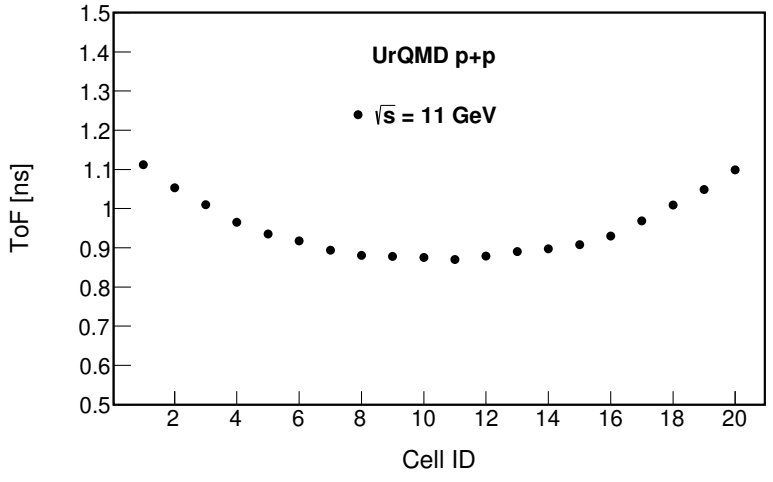
16 strips



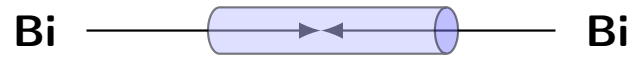
⟨Hits⟩	11 GeV
cell	0.0021-0.0027
detector	0.768

$\langle E_{loss} \rangle$ = 0.78-0.85 MeV, $\langle ToF \rangle$ = 0.9-1.1 ns

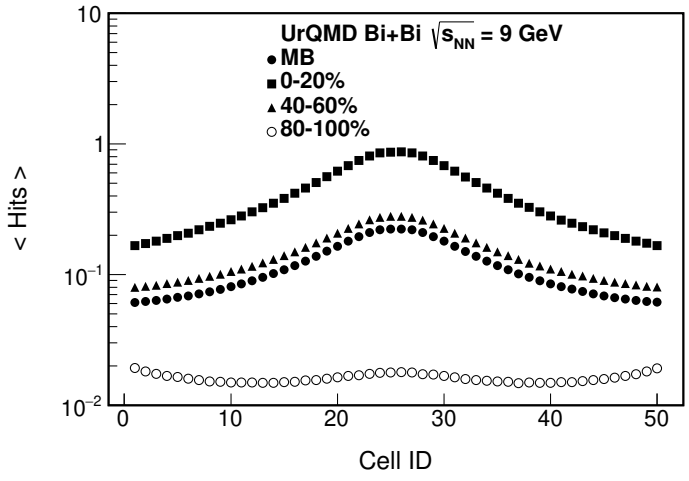




MBB-150-15

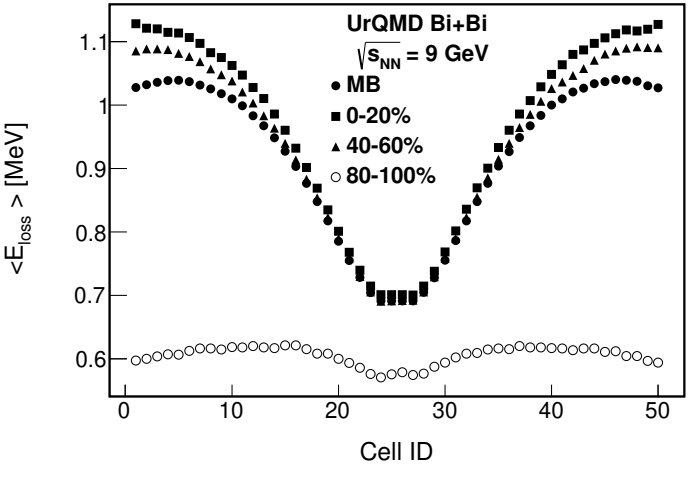


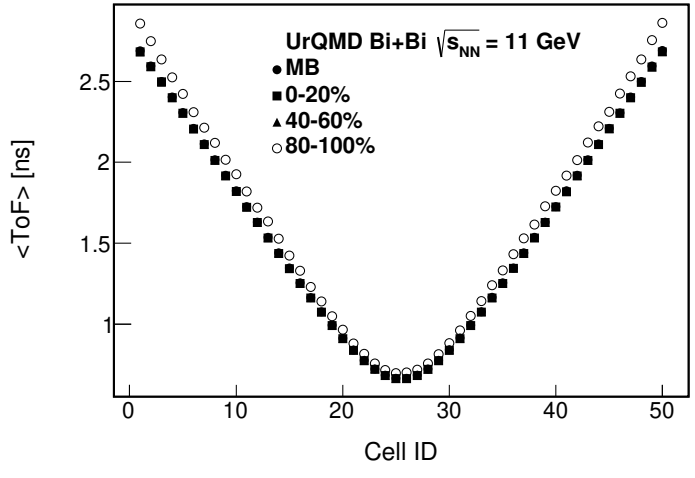
9 GeV

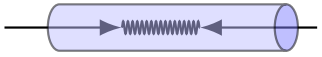


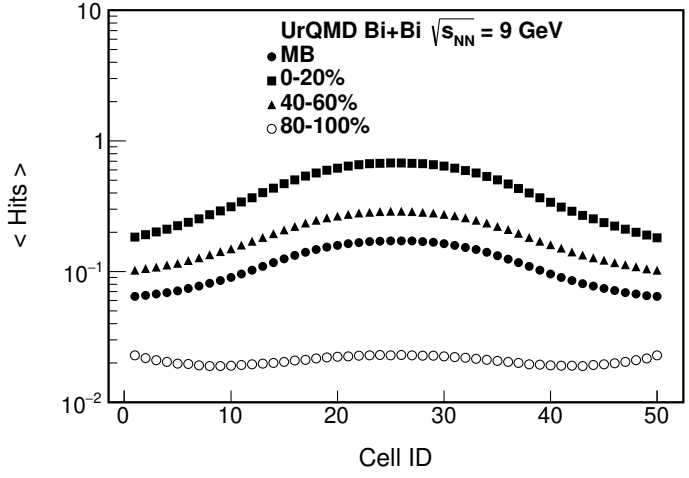
⟨Hits⟩	0-20%	80-100%
cell	0.166-0.868	0.015-0.019
detector	327.6	12.91

$\langle E_{loss} \rangle$ = 0.6-1.1 MeV, $\langle ToF \rangle$ = 0.6-2.9 ns



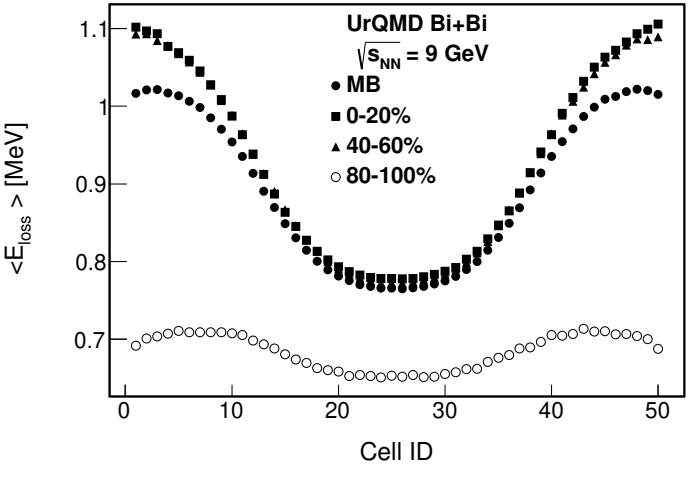


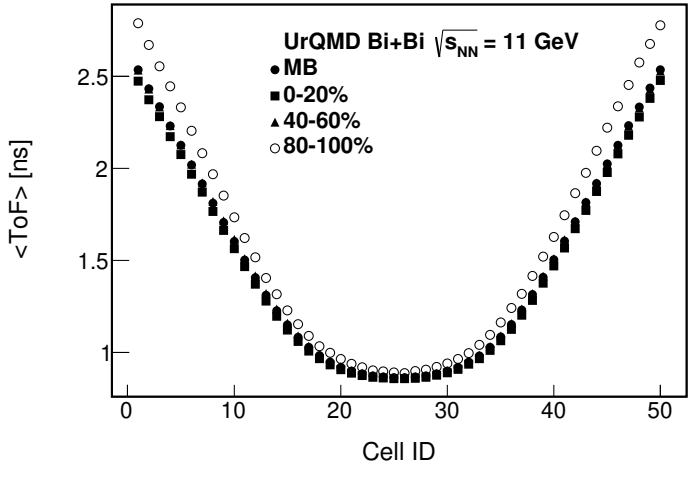
MBB-150-15 Bi  Bi 9 GeV with smearing



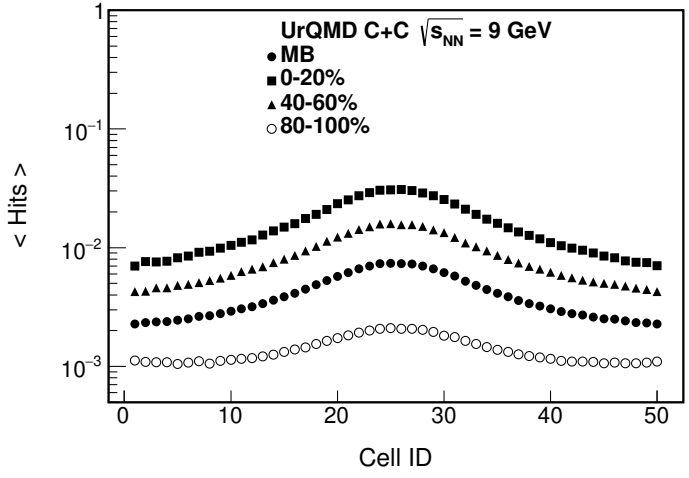
⟨Hits⟩	0-20%	80-100%
cell	0.181-0.678	0.019-0.023
detector	336.5	16.7

$\langle E_{loss} \rangle$ = 0.6-1.1 MeV, $\langle ToF \rangle$ = 0.7-2.8 ns



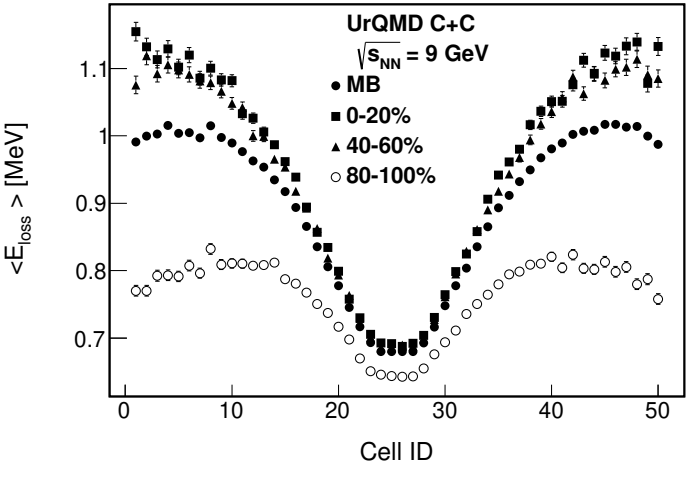


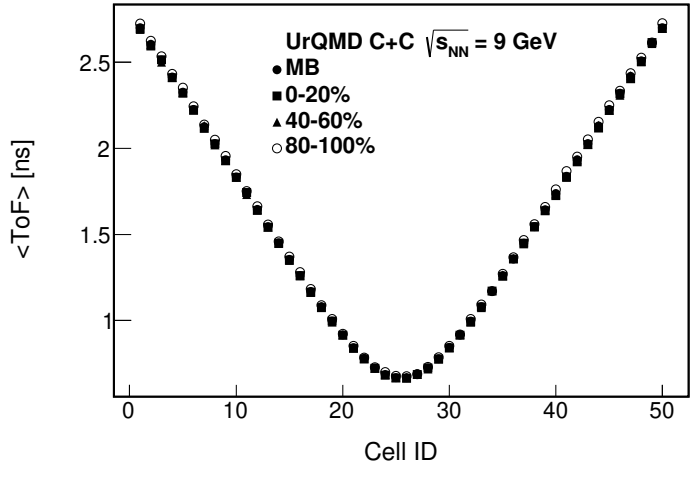
MBB-150-15 C — C 9 GeV

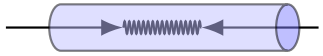


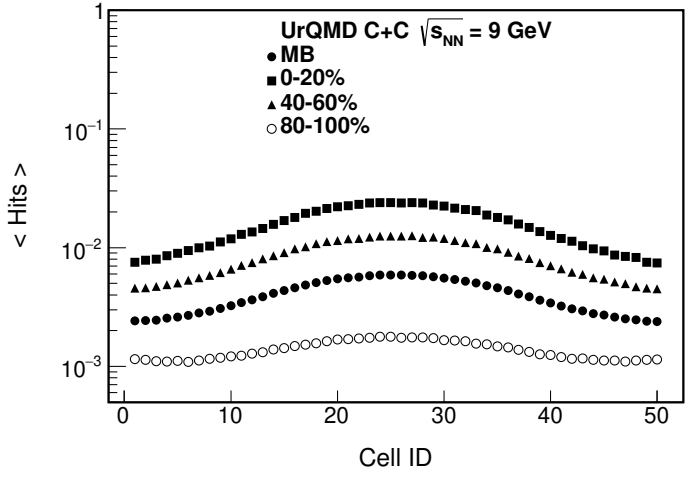
⟨Hits⟩	0-20%	80-100%
cell	0.007-0.0309	0.0010-0.0021
detector	12.5	1.11

$\langle E_{loss} \rangle$ = 0.6-1.1 MeV, $\langle ToF \rangle$ = 0.5-2.7 ns



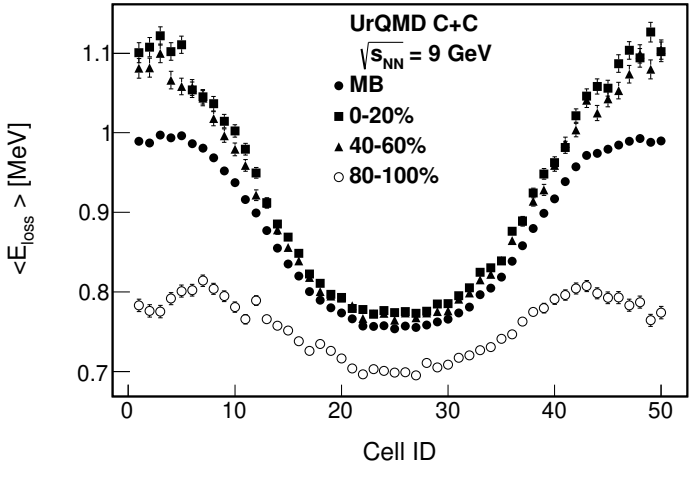


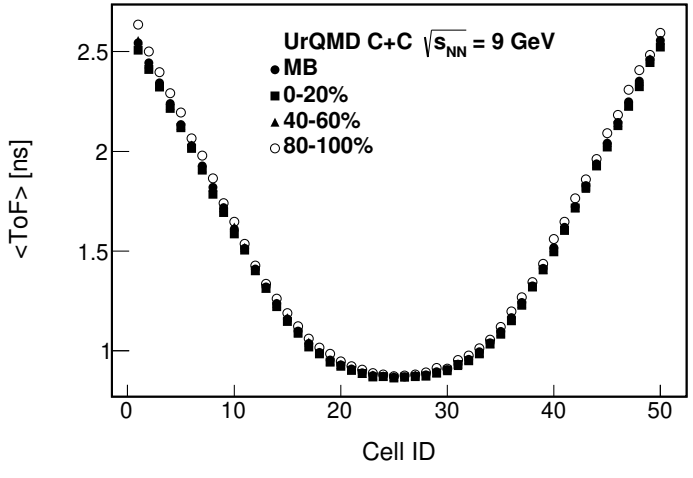
MBB-150-15 C  C 9 GeV with smearing



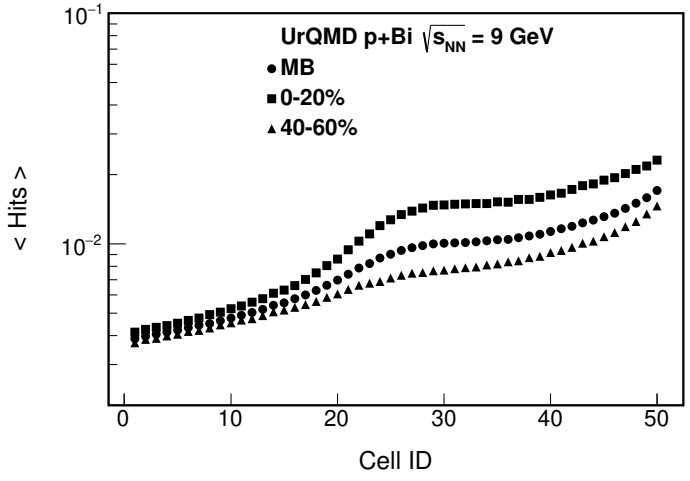
⟨Hits⟩	0-20%	80-100%
cell	0.0074-0.024	0.0011-0.0018
detector	12.32	1.11

$\langle E_{loss} \rangle$ = 0.6-1.1 MeV, $\langle ToF \rangle$ = 0.8-2.6 ns



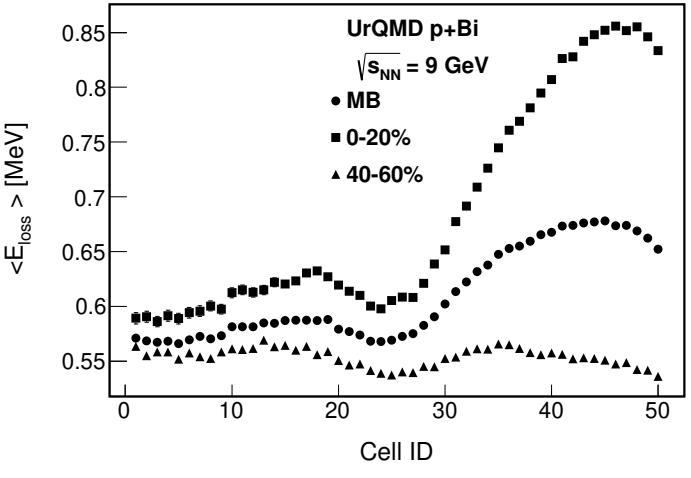


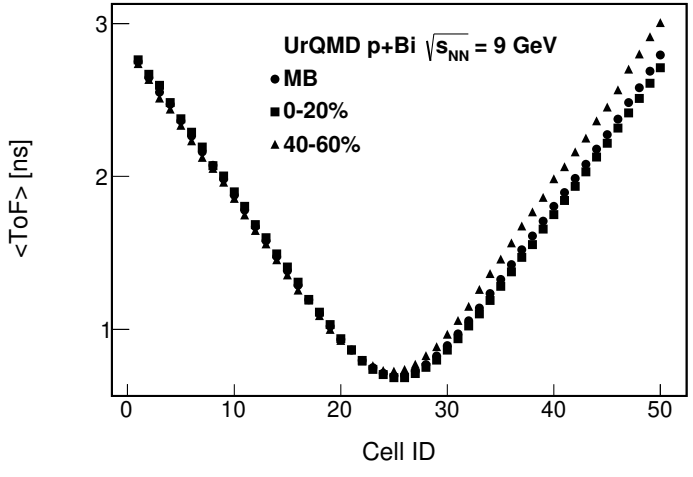
MBB-150-15 p Bi 9 GeV

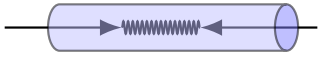


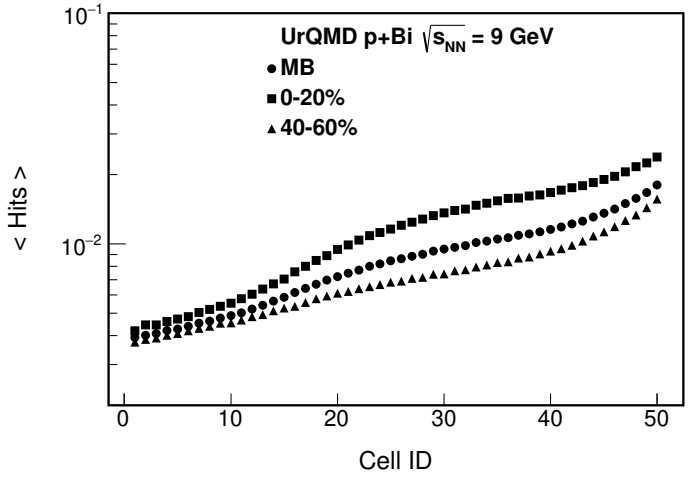
⟨Hits⟩	0-20%	40-60%
cell	0.0041-0.0230	0.0037-0.0146
detector	9.40	5.80

$\langle E_{loss} \rangle$ = 0.5-0.85 MeV, $\langle ToF \rangle$ = 0.6-3.0 ns



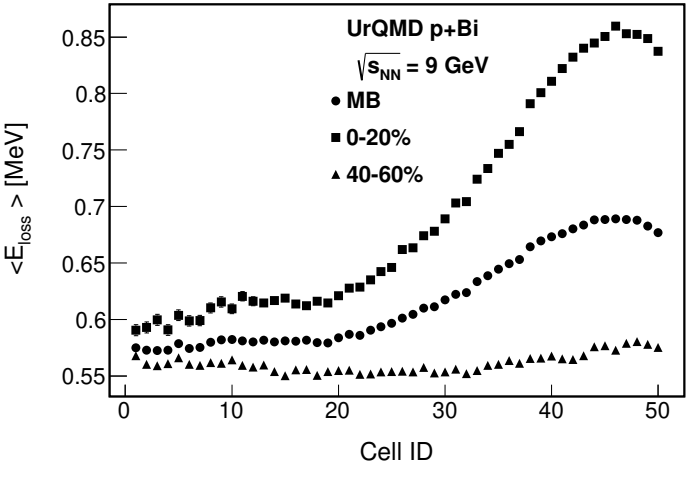


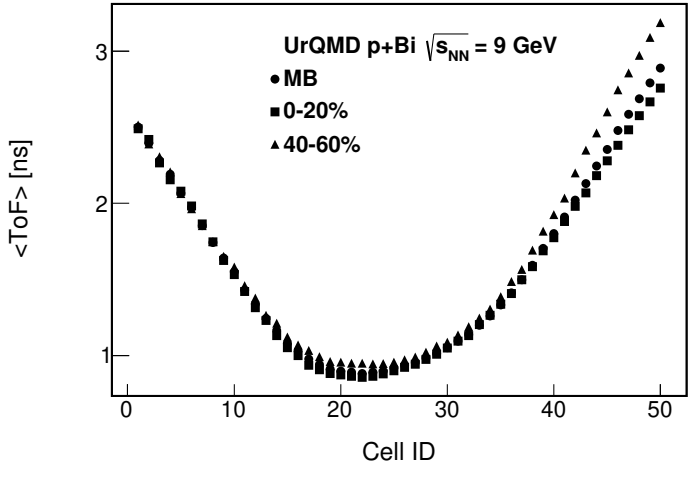
MBB-150-15 p  Bi 9 GeV with smearing



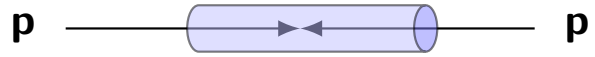
⟨Hits⟩	0-20%	40-60%
cell	0.0042-0.0238	0.0037-0.0156
detector	9.48	5.88

$\langle E_{loss} \rangle$ = 0.5-0.85 MeV, $\langle ToF \rangle$ = 0.8-3.2 ns

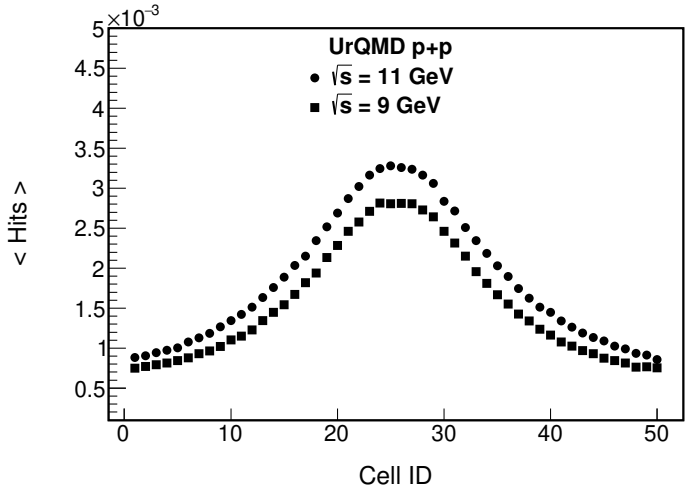




MBB-150-15

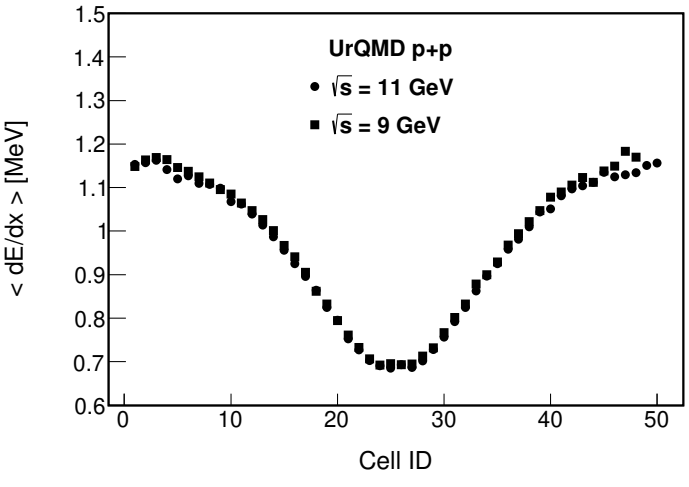


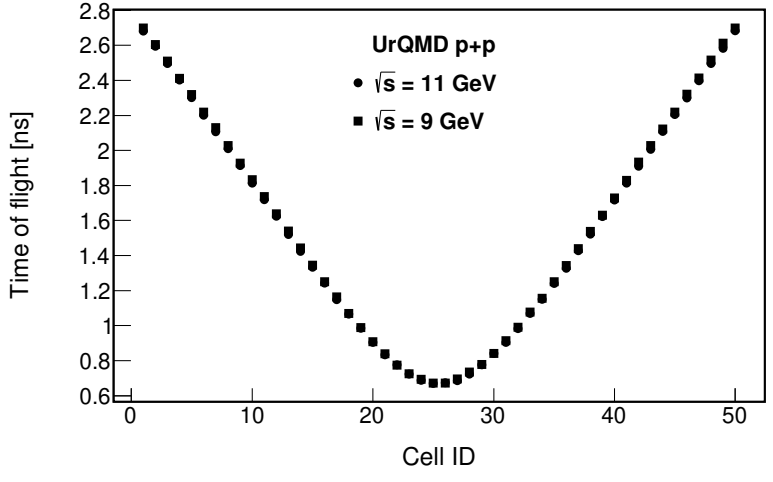
9, 11 GeV

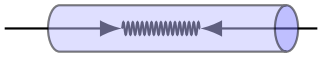


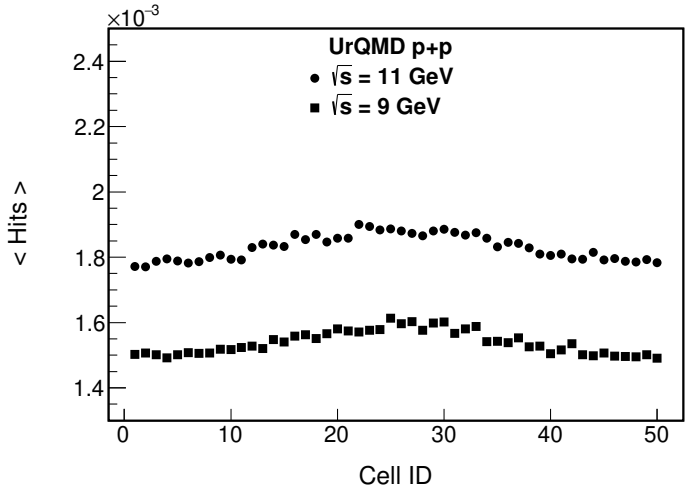
⟨Hits⟩	9 GeV	11 GeV
cell	0.00075-0.0028	0.0009-0.0033
detector	1.24	1.48

$\langle E_{loss} \rangle$ = 0.6-1.2 MeV, $\langle ToF \rangle$ = 0.6-2.8 ns





MBB-150-15 p  p 9, 11 GeV with smearing



⟨Hits⟩	9 GeV	11 GeV
cell	0.0015-0.0016	0.0018-0.0019
detector	1.23	1.46

$\langle E_{loss} \rangle = 0.9$ MeV, $\langle ToF \rangle = 1.2$-$1.3$ ns