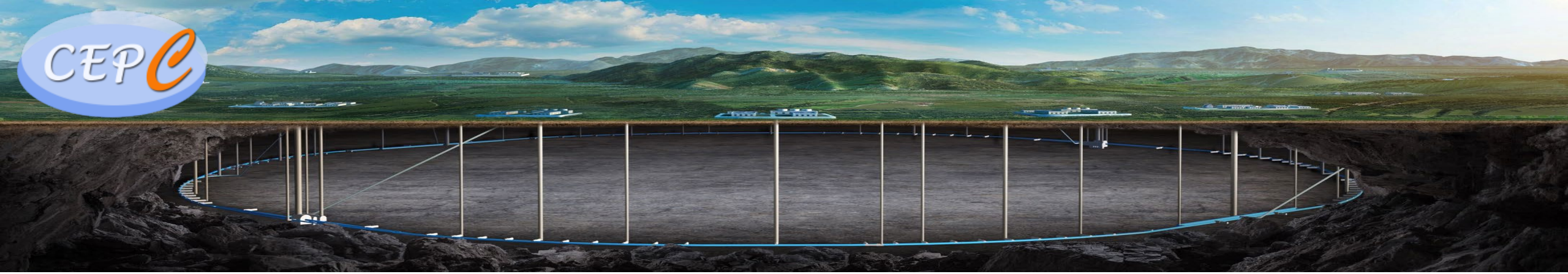

CEPC Muon Detector
--- design and status

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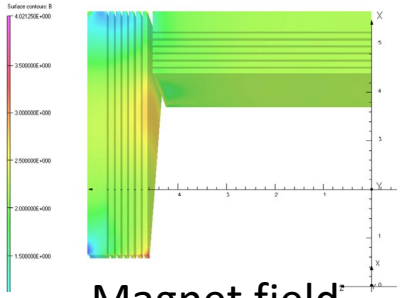
(for the Muon Detector Group)
Fudan University
Tuesday Meeting, 09/03/2024

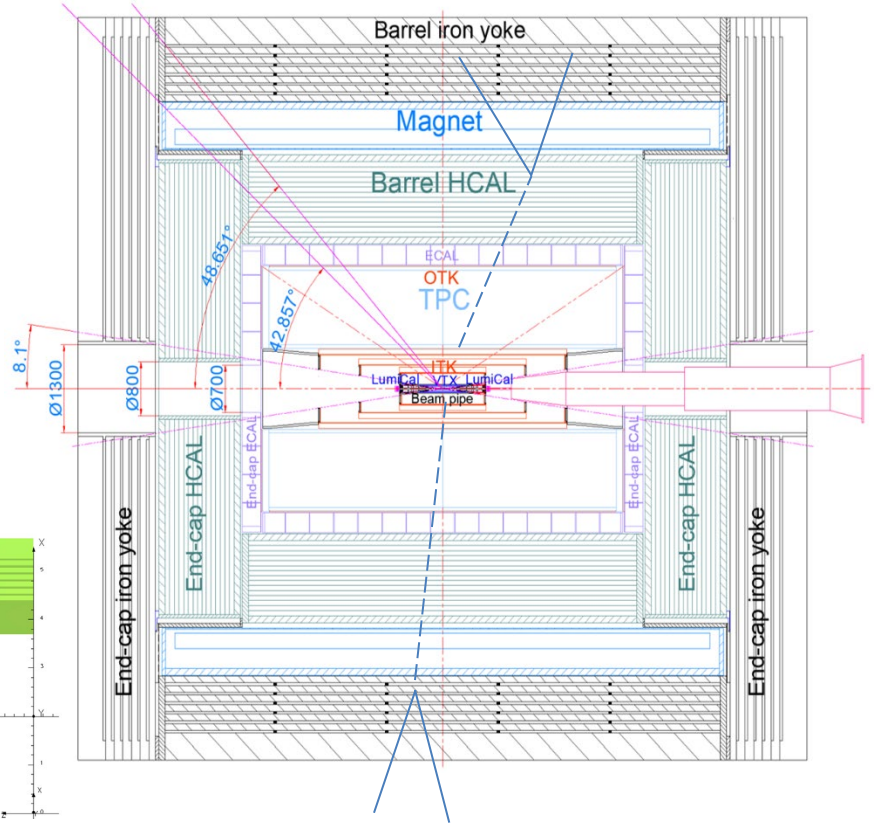
Functions expected from the muon detector

Muon detector, the outermost detector with the largest volume, clean environment.

- Production of Higgs: $e^+e^- \rightarrow ZH$, Higgs could be determined in the recoil of $Z \rightarrow \mu^+\mu^-$.
  - Special determination of muon with $p \approx 40\ \mathrm{GeV}/c$. (High momentum muon)
- Muons provide in many theoretical models a characteristic signature for new physics.
- Muon detector is designed for muon identification, but not limited to this.
  - Could be used to detect the leakage of HCAL.
  - Can be used for trigger, like in ATLAS.
  - Could be useful for additional T0 determination. $\sigma(T0) = \sigma(T_{hit})/\sqrt{n_{hits}}$
  - Can be used to search for Long-lived particles.
- Functions: muon ID, search for NP, leakage of HCAL, trigger and timing information.



Magnet field



Key requirements:

- **Muon ID**
- Track reconstruction

Scenarios

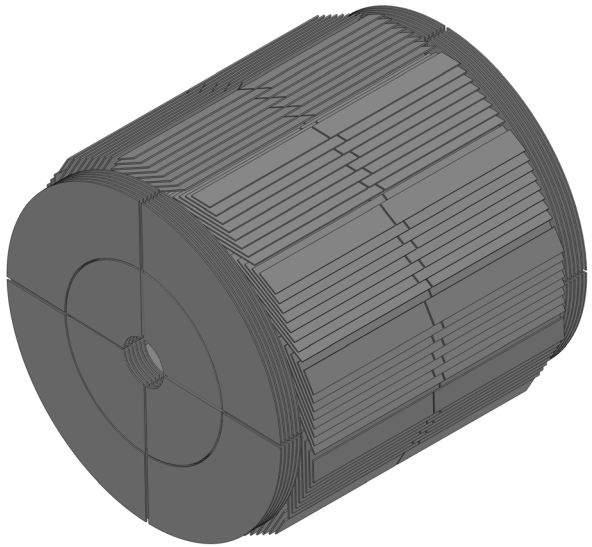
- Scenario #1: 8 layers of barrel, 6 layers of endcaps
  - Cost 27M
- Scenario #2: all 8 layers
  - Cost 30M; better performance in endcaps
- Scenario #3: all 6 layers
  - Cost 25M; OK for muon ID, tracking will be difficult in some area
- Scenario #4: all 4 layers
  - Save budget, but it only works for muon ID, and 50% in barrel has only 3 superlayers. Width of iron plate is ~20cm, too thick.

Current emergency for the muon group:

- Software and simulation → performance study
- Design of electronic system, FEE & BEE
  - Requirements from the detector
  - Design and performance
  - Consistent with the frame of CEPC electronics

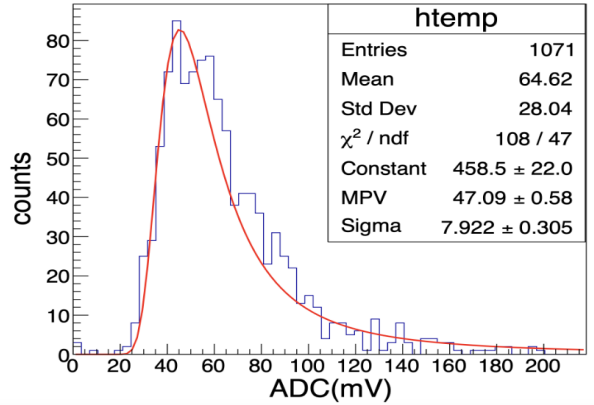
Software update: simulation

- New baseline geometry implemented in CEPCSW.
  - 8 layers for the Barrel section and 6 layers for the Endcap section, as discussed in last week's talk.
  - Define as baseline for following detector optimization.
  - Bug fix: fixed an issue of missing simulated muon detector tracker hits in the output collections.
  - Merge request Ready to be merged.

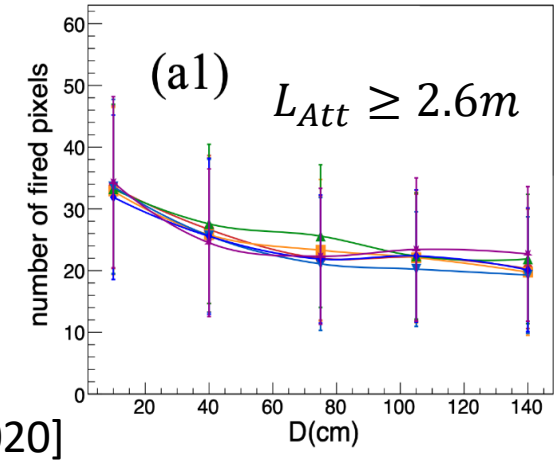


Software update: digitization

MIP peak distribution in unit of ADC counts



- Digitization from sim hit -> reco hit:
  - Plan to skip simulation of optical photon propagation step.
- Steps:
  - Retrieve energy deposition and distance to SiPM for each hit in the simulation.
  - Convert the energy to the number of MIPs.
  - Using distance to SiPM to get number of p.e. per MIP according to real cosmic ray measurements Now we have number of MIPs for each sim hit.
  - Randomly generate number of ADC counts for 1 MIP according to real cosmic ray measurements.
  - Convert number of MIPS to number of ADC counts for each sim hit.



[2024 JINST 19 P06020]

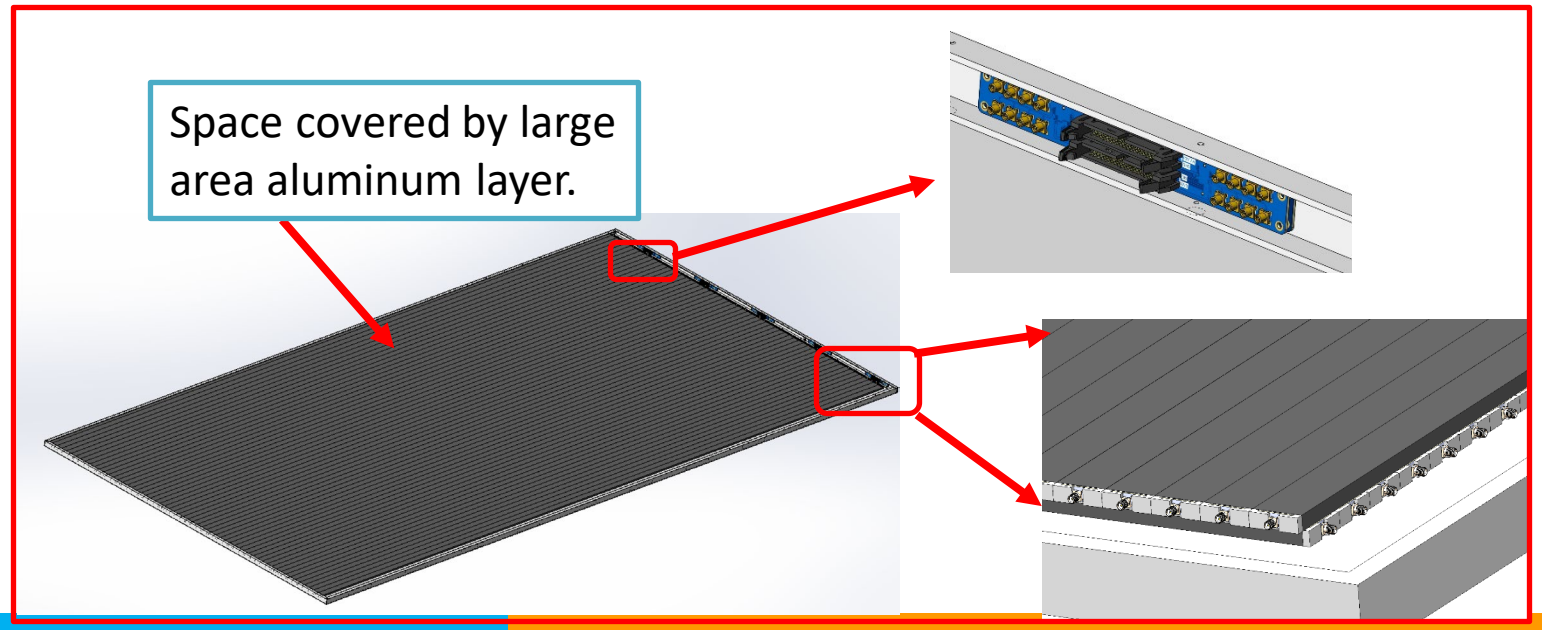
Plan for further detector optimization

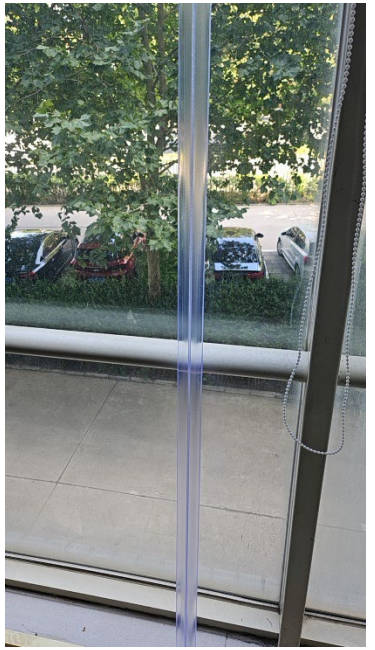
- **Performance study!**
- Further optimization of the number of layers and scintillator thickness.
- Enhancement of muon identification and reconstruction algorithms.
- Continued improvements in the simulation and digitization processes.

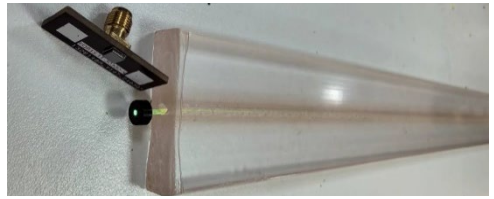
The electronic system

- Invite 张杰 to join the muon group for discussion on the design of the electronic system.
- Discussion on the design for JUNO-TAO, and take this as a reference.
  - Time resolution, FEE, power consumption, space, temperature, mechanic support, COST, etc.

Al frame is ready.



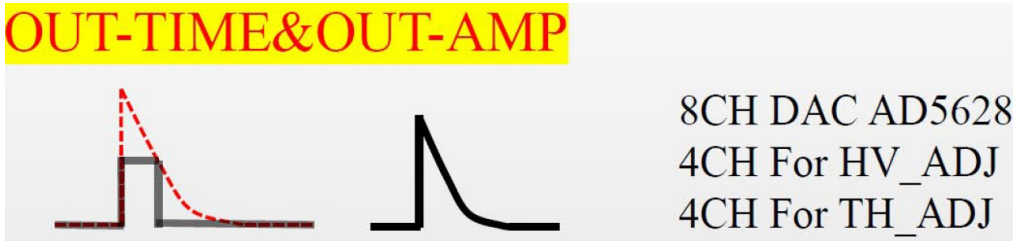




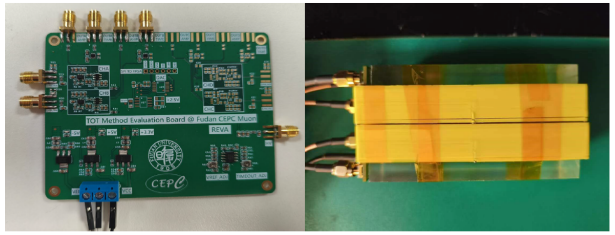
New design of scintillator bar is almost ready. Will test soon.

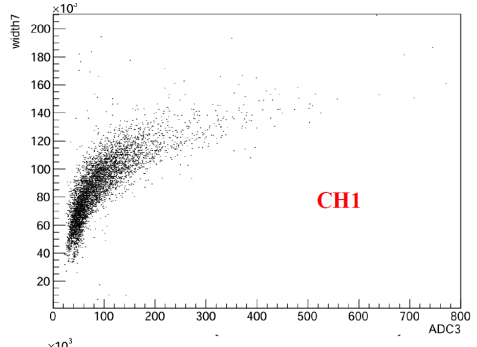
Test on TOT

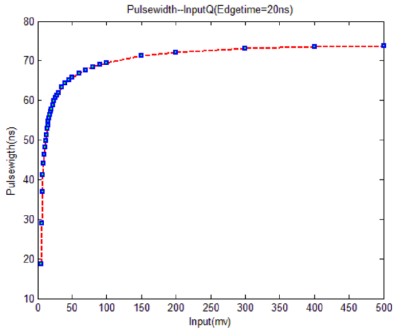
- Start testing on TOT
  - PCB: pream(shaping)+TOT

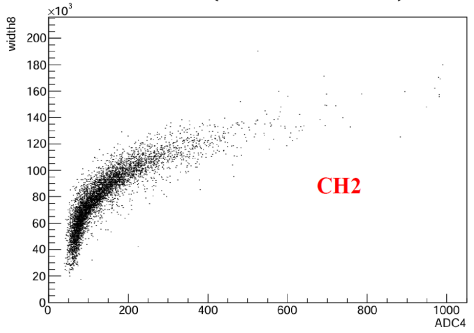


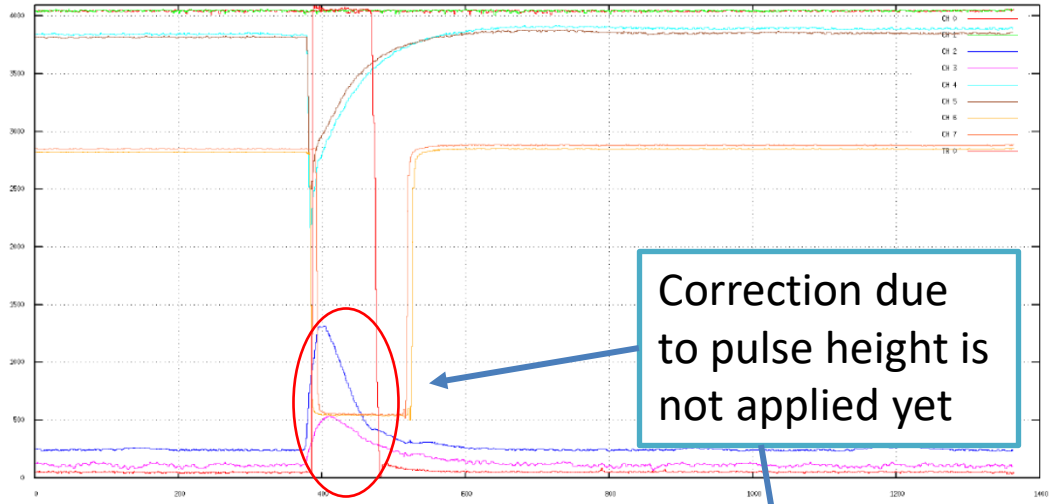
Test for TOT

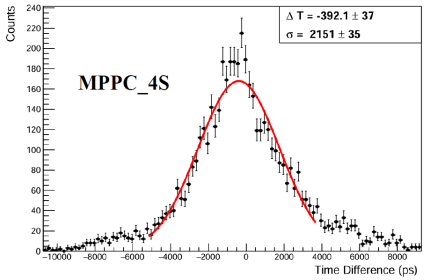


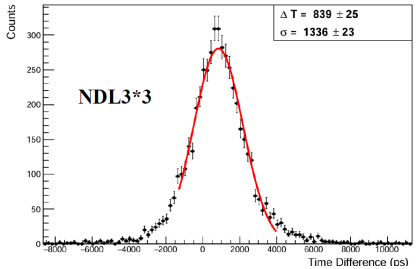


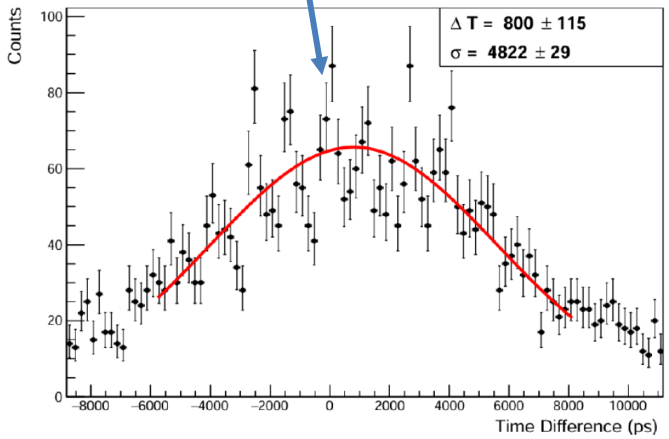












Current time resolution from TOT

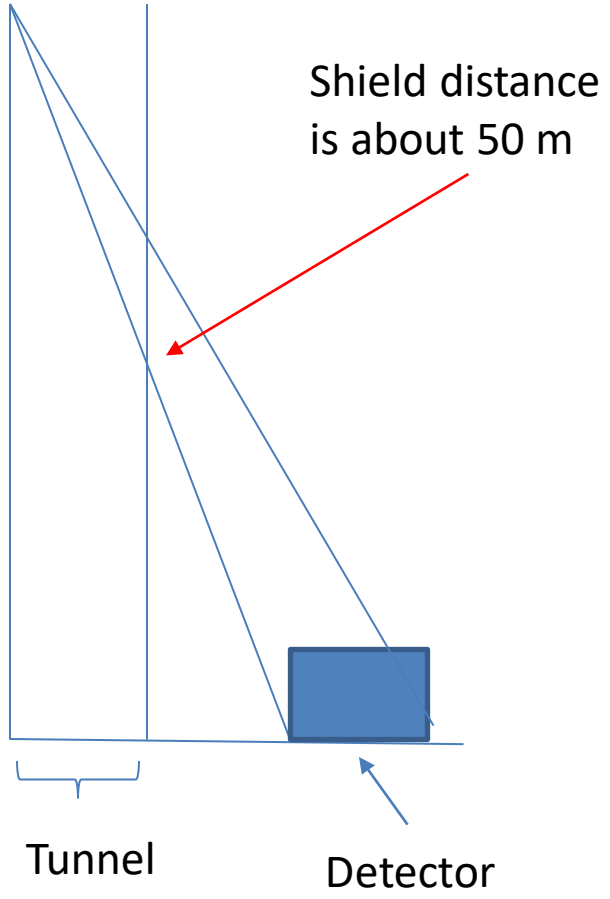
- Need to improve the testing on TOT.

Considerations of the backgrounds

- Very low level of the CR backgrounds, with the earth shield of > 50m.
- Reference to the beam backgrounds in Belle II.

Barrel Layer	Expected Hit Rate (Hz/cm^2)	Expected RPC Efficiency	Bad-case Hit Rate (Hz/cm^2)	Bad-case RPC Efficiency	Worst-case Hit Rate (Hz/cm^2)	Worst-case RPC Efficiency
0	—scintillators—		—scintillators—		—scintillators—	
1	—scintillators—		—scintillators—		—scintillators—	
2	2.6	0.86	26	0.00	260	0.00
3	1.7	0.91	17	0.14	170	0.00
4	0.9	0.95	9	0.54	90	0.00
5	0.5	0.97	5	0.54	50	0.00
6	0.5	0.97	5	0.54	50	0.00
7	0.3	0.98	3	0.84	30	0.00
8	0.5	0.97	5	0.54	50	0.00
9	0.2	0.98	2	0.89	20	0.00
10	0.2	0.98	2	0.89	20	0.00
11	0.1	0.99	1	0.94	10	0.49
12	0.1	0.99	1	0.94	10	0.49
13	0.1	0.99	1	0.94	10	0.49
14	0.2	0.98	1	0.94	10	0.49

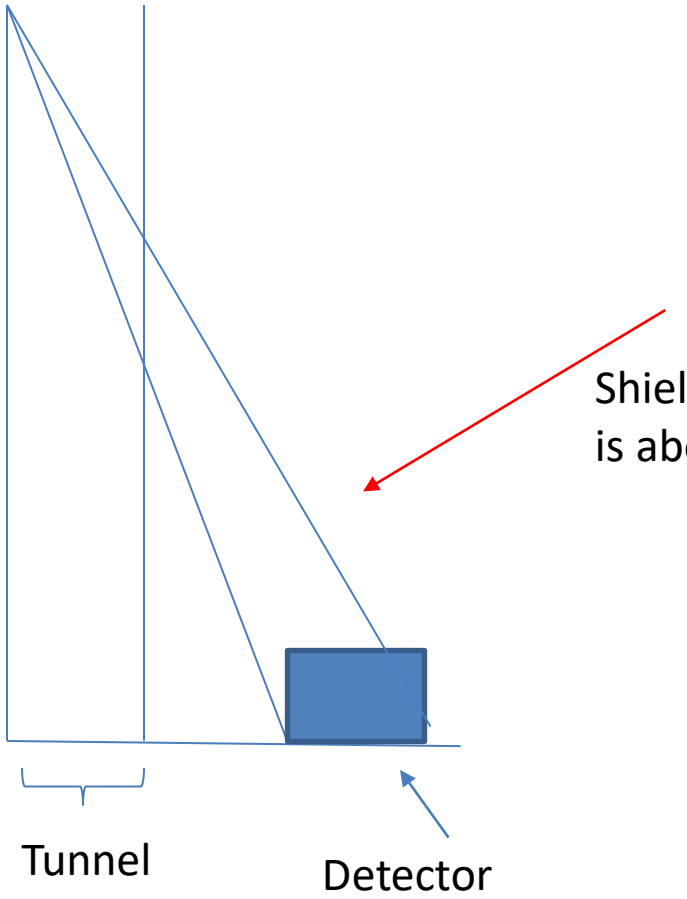
Table 2: *Neutron flux, hit rate per unit area, and instantaneous efficiency in each layer of the barrel KLM from the late-2020 simulations of beam-induced neutron backgrounds at the SuperKEKB design luminosity of* $6 \times 10^{35}\,cm^{-2}s^{-1}$. *Here, the Belle II hybrid configuration replaces the RPCs in the two innermost layers with scintillators and neutron-absorbing polyethylene sheets.*

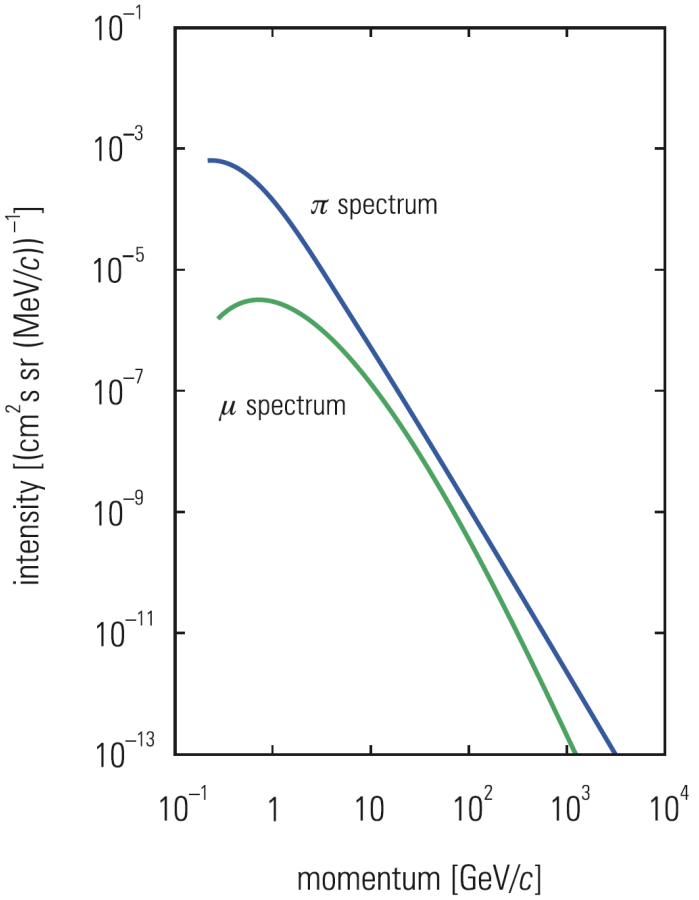


For a 4m long bar, the hit rate might be 160Hz. For the ‘bad-case’, it would be 1.6kHz!

Thank you!

Backgrounds from CR





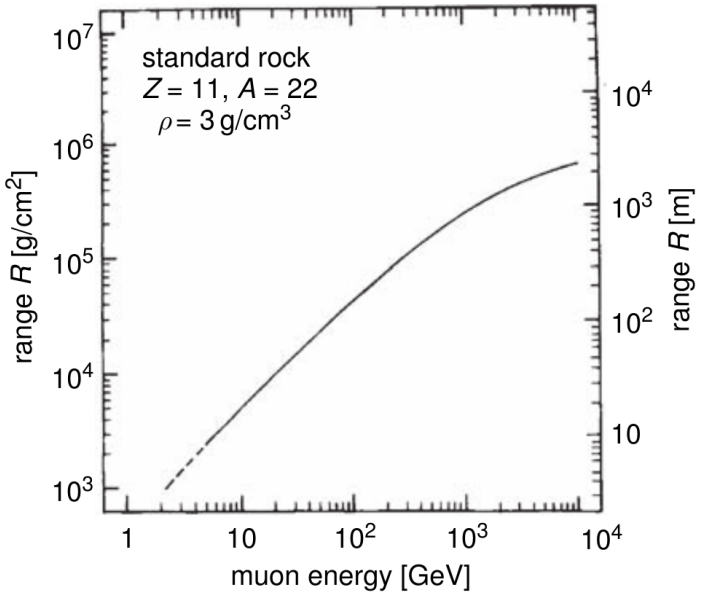


Fig. 1.12. Range of muons in rock [51].