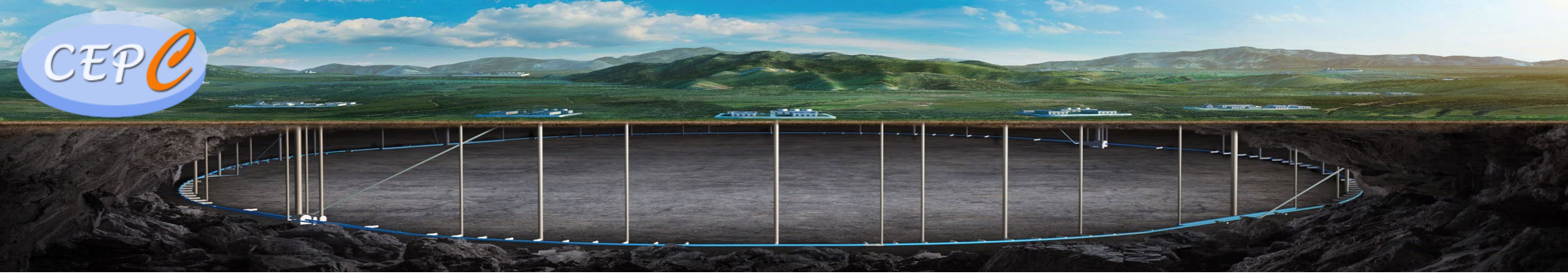


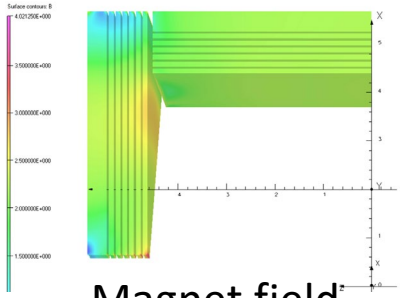
CEPC Muon Detector
--- design and status

Xiaolong Wang
(for the Muon Detector Group)
Fudan University
Tuesday Meeting, 09/10/2024

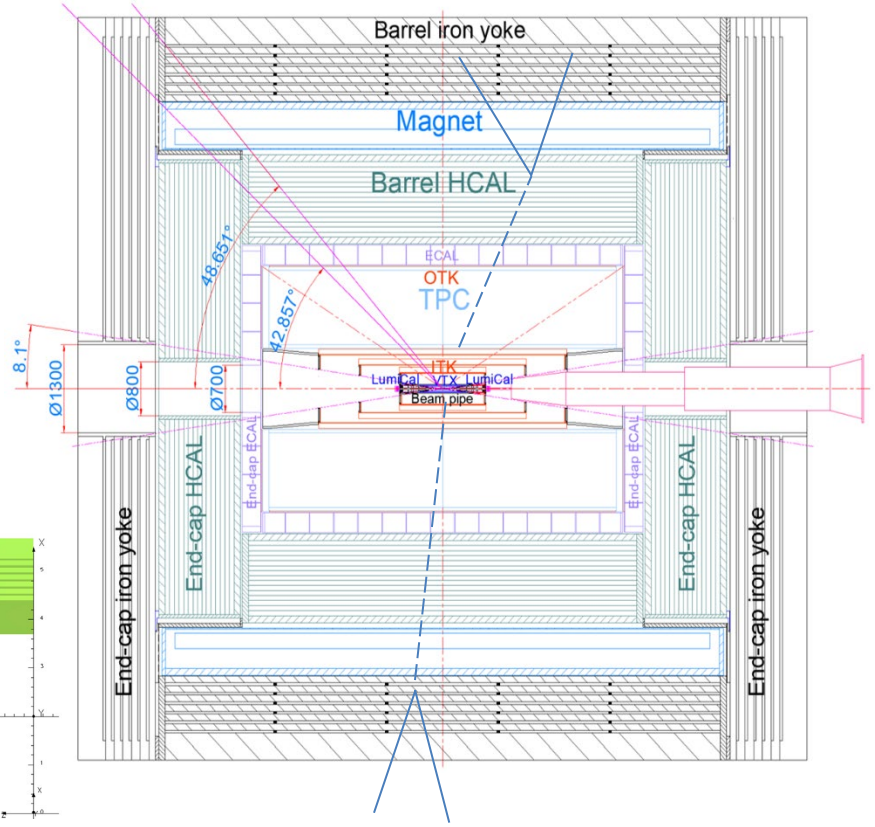
Functions expected from the muon detector

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:

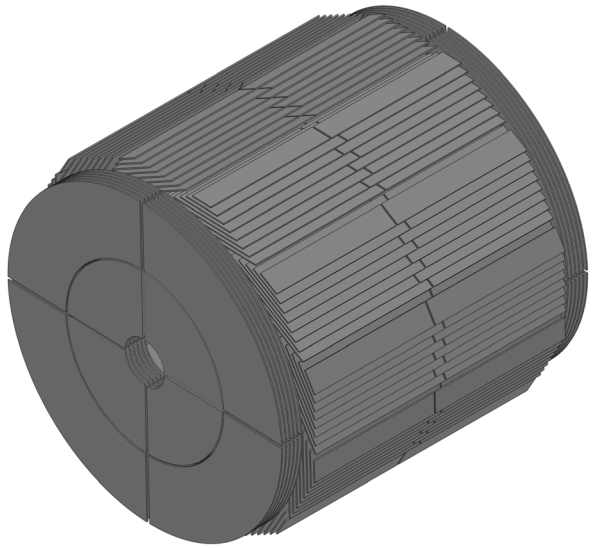
- **Muon ID**
- Track reconstruction

Scenarios

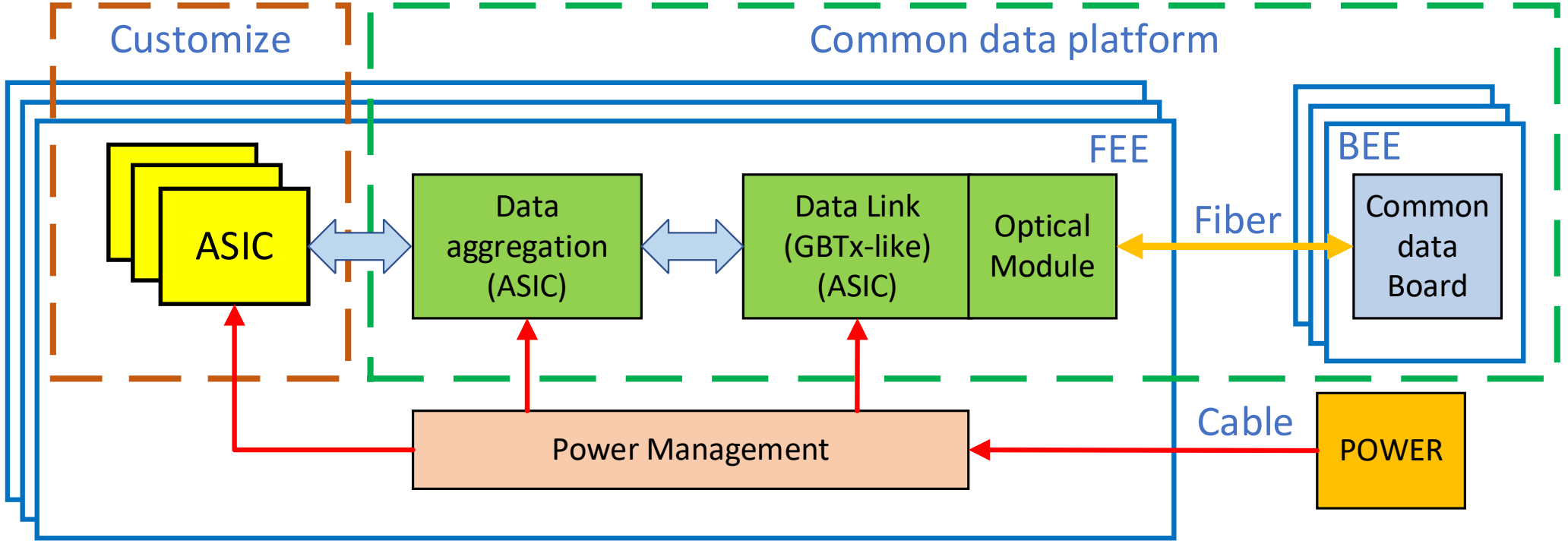
- Scenario #1: 8 layers of barrel, 6 layers of endcaps
  - Cost 27M
- Scenario #2: all 8 layers
  - Cost 30M; better performance in endcaps
- Scenario #3: all 6 layers
  - Cost 25M; OK for muon ID, tracking will be difficult in some area
- Scenario #4: all 4 layers
  - Save budget, but it only works 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

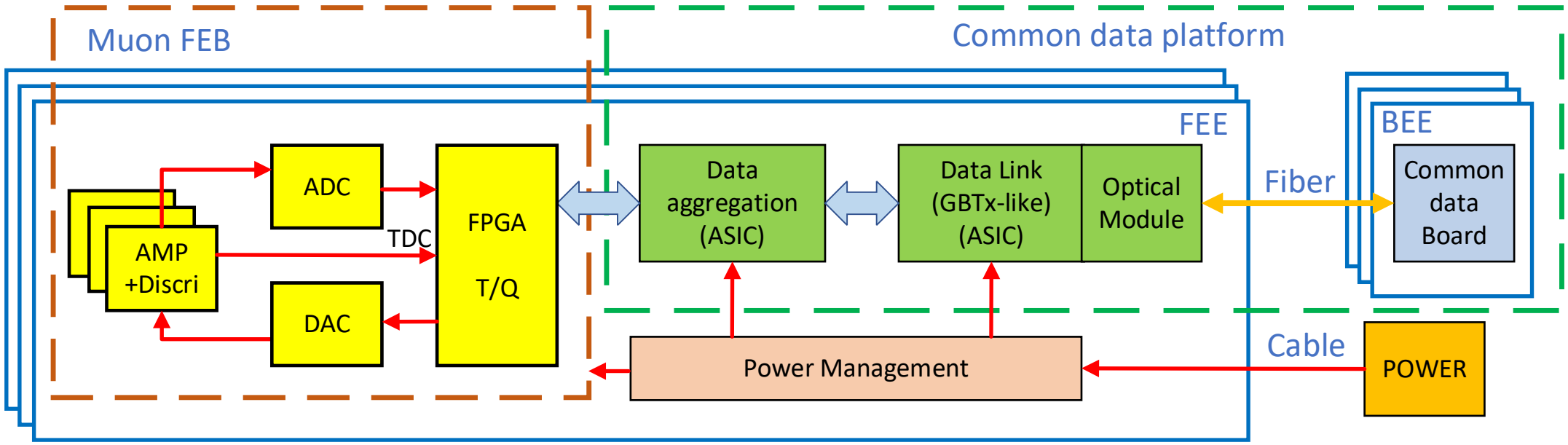


Baseline for SiPM readout



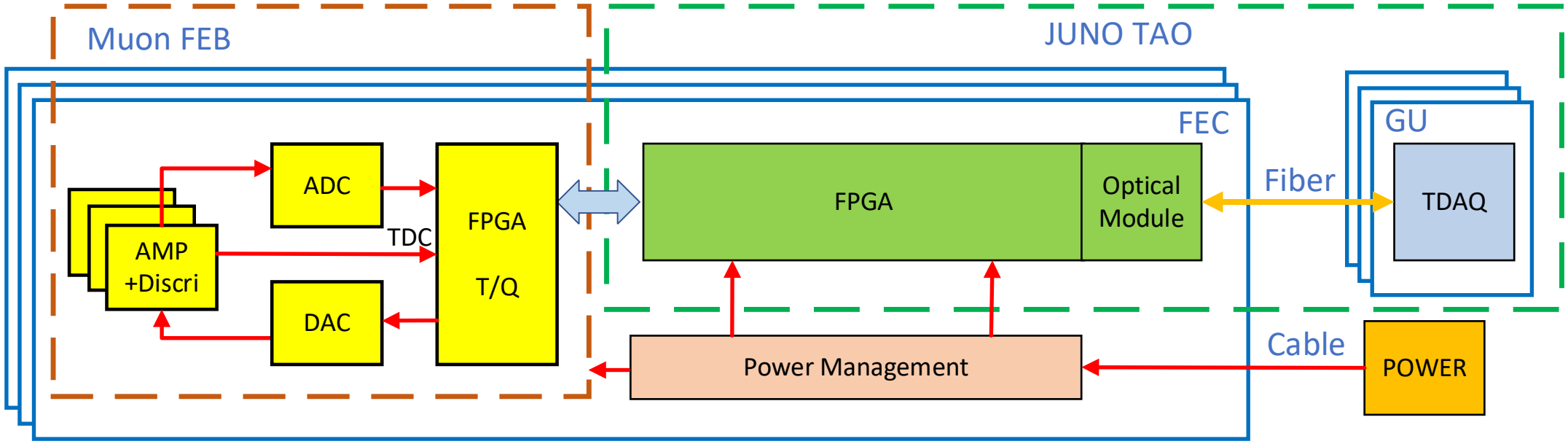
- Reuse the ASIC scheme from ECAL or HCAL
- Revise according to the constraints from cooling and mechanical structure of the detector

Alternative: discrete device scheme



- FEB (Front-end Electronics Board)
  - Commercial chips with radiation tolerance based on past studies for particle physics experiments
  - FPGA based TDC for TOA and TOT measurement with ~1 ns time resolution
  - ADC for charge measurement or TOT calibration
  - DAC for threshold setting or SiPM bias voltage adjustment

Near-term test environment



- Reuse JUNO-TAO electronics for readout, clock synchronization and TDAQ
  - To accelerate the development schedule

Software update

Everything based on CEPCSW framework.

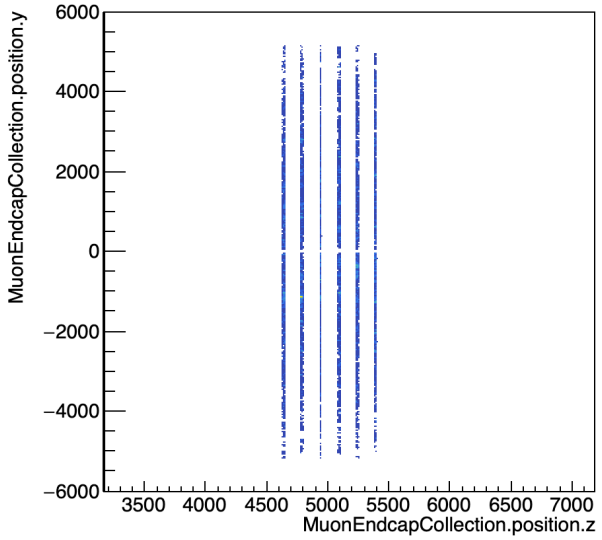
Tasks & Status	Last week	Today
Geometry: **Update to new baseline geometry:** **Barrel (8-layers) / Endcap (6-layers)**	Bug fix for output sim hits, merge request ready.	**Merged and tested.**
Digitization: **from "Sim. Hit" (GeV)** **to "Raw Hit" (ADC counts)**	Preliminary implementation strategy proposed.	**A first experimental version implemented:** **- A simplified model from GeV to ADC counts directly.** **- Only for barrel at the moment.**
Detector Optimisation **& Physics Performance**	Not started.	**Preliminary optimisation of:** - **the muon tracker hit vs. energy threshold** - **Muon id efficiency vs. momentum**

Software update: simulation

Everything based on CEPCSW framework.

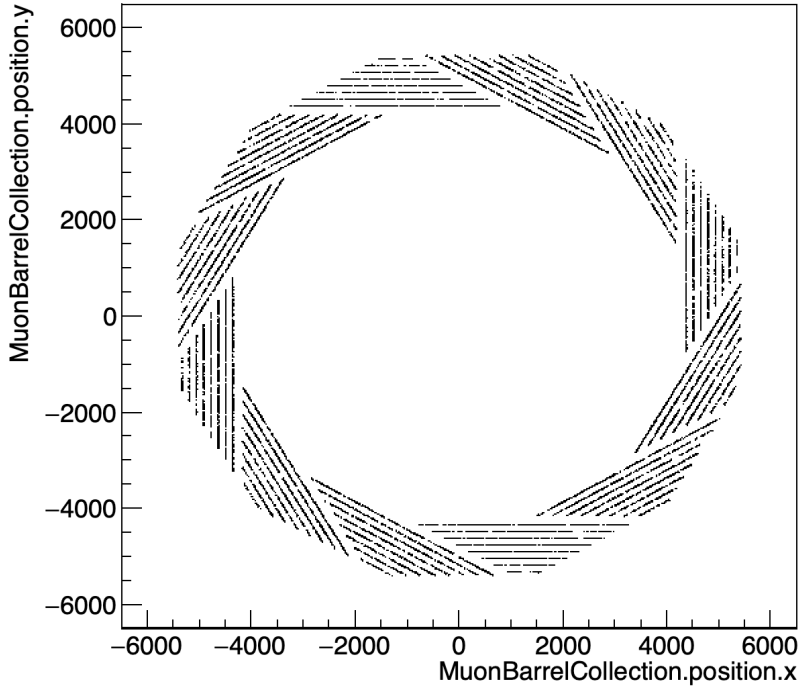
Muon Sim Hit positions

z-y position map in Endcap



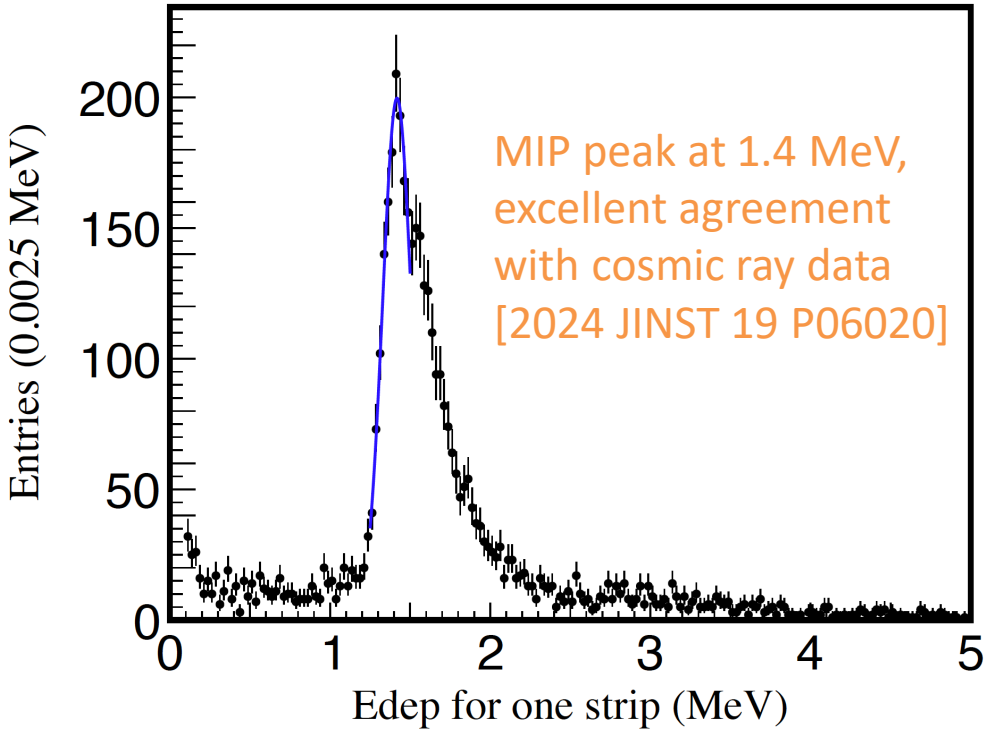
1k muons at 10 GeV muons

x-y position map in Barrel



Muon detector geometry is clearly visible!

Muon Sim Hit Energy deposition

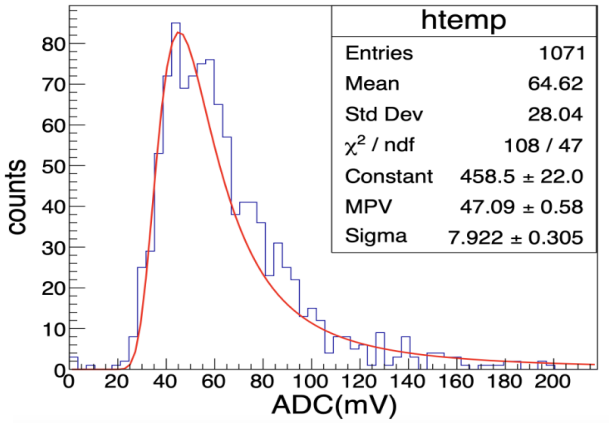


Software update: digitization

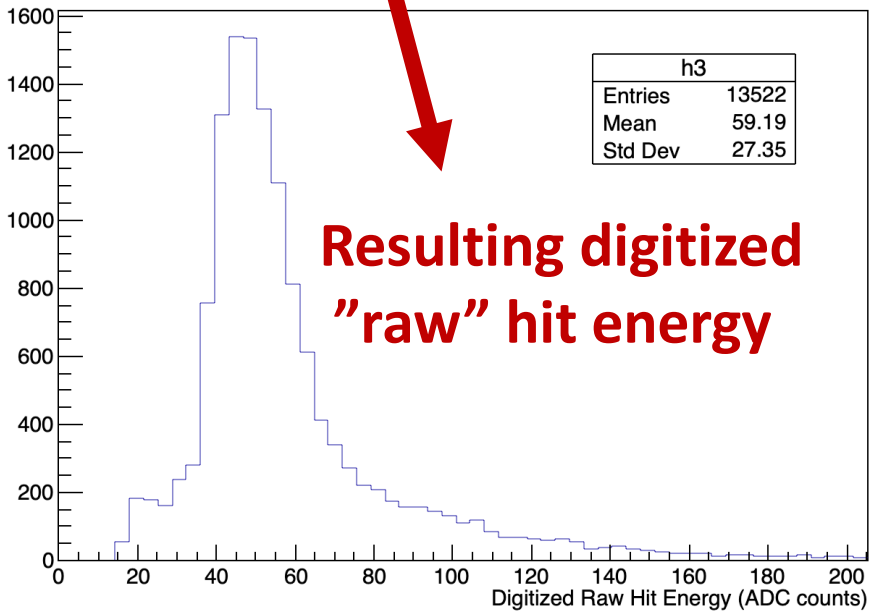
- Digitization from “Sim. Hit” (GeV) to “Raw Hit” (ADC counts)
- A first experimental version implemented:
  - A simplified model from GeV to ADC counts directly.
  - Only for barrel at the moment.

$E_{digi.}$ (ADC counts) = $E_{sim.}$ (MeV) ÷ 1.4 MeV. ⊗ a mip.

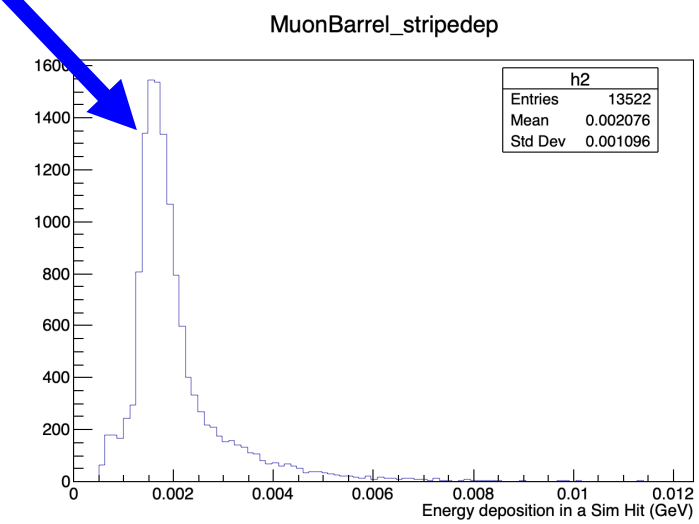
MIP peak distribution in unit of ADC counts



[2024 JINST 19 P06020]



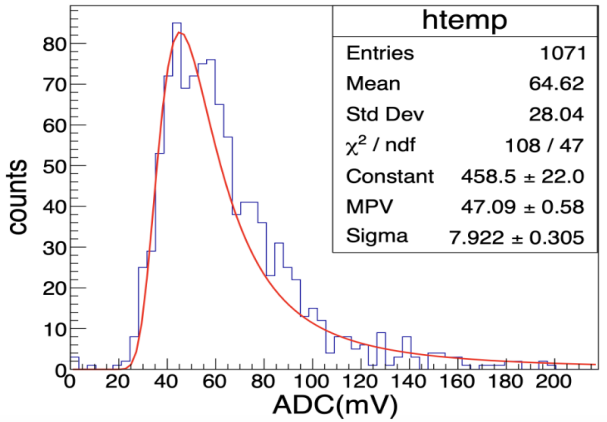
Resulting digitized ”raw” hit energy

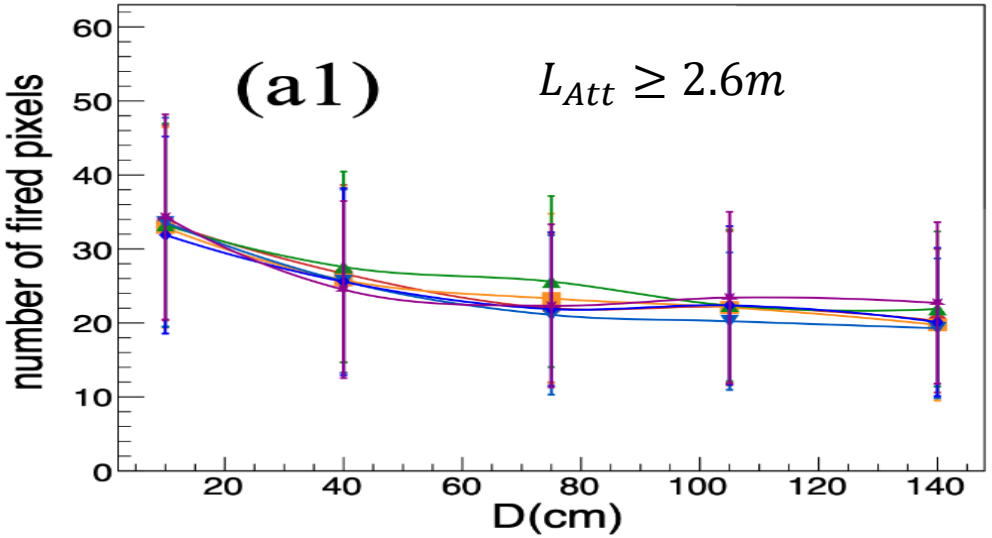


Software update: digitization

- Digitization from “Sim. Hit” (GeV) to “Raw Hit” (ADC counts)
- A first experimental version implemented:
  - A simplified model from GeV to ADC counts directly.
  - Only for barrel at the moment.
- Now, working on a more realistic model with N_p.e. per MIP attenuated along the strip →

MIP peak distribution in unit of ADC counts





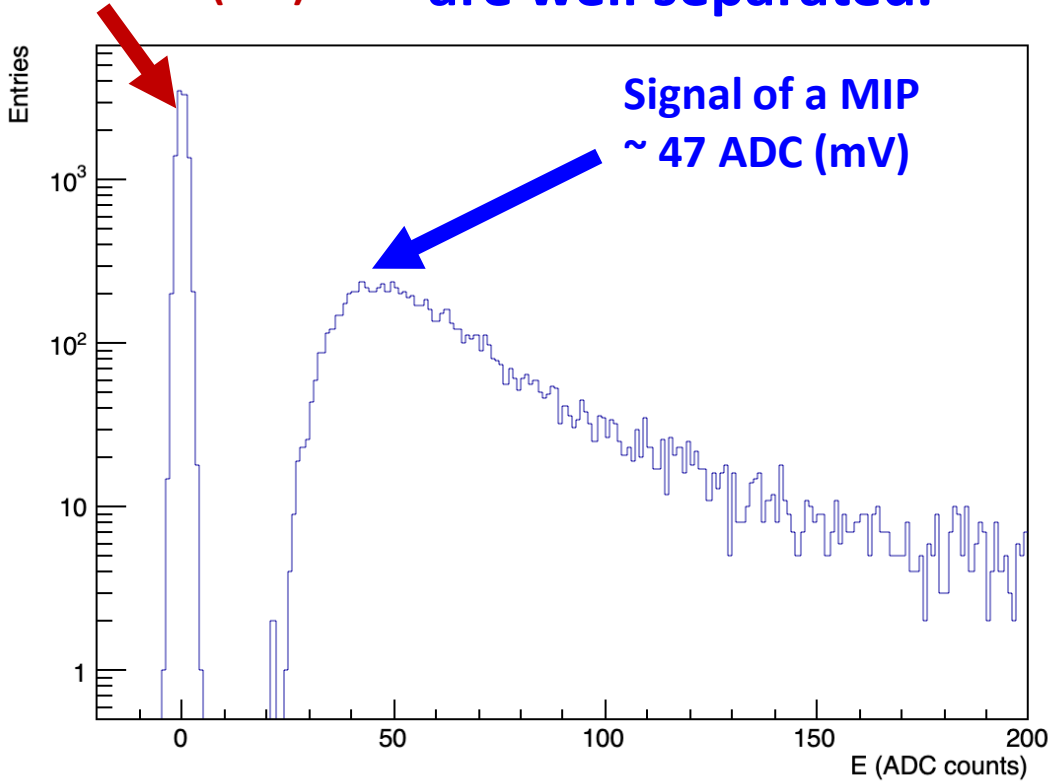
[2024 JINST 19 P06020]

Software update: Optimization

- The muon tracker hit vs. energy threshold:

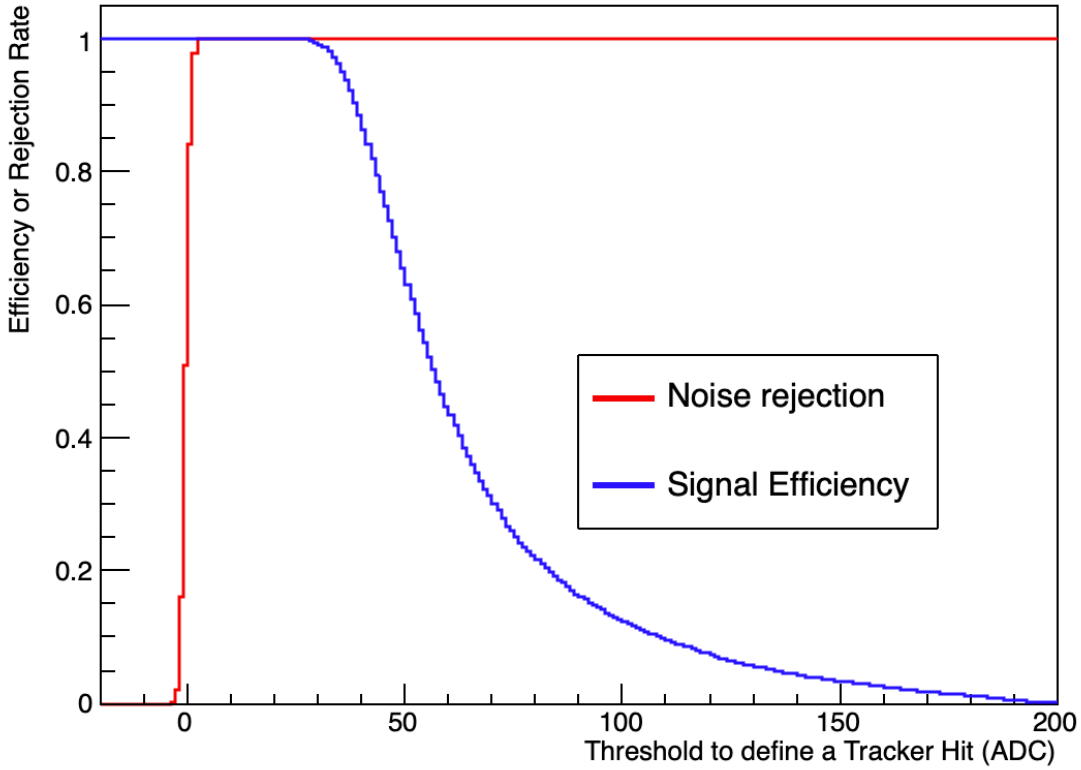
Pedestal peak, width ~ 1 ADC (mV)

Signal and electronic noise are well separated.



[2024 JINST 19 P06020]

The noise rejection (red) as a function of the energy threshold

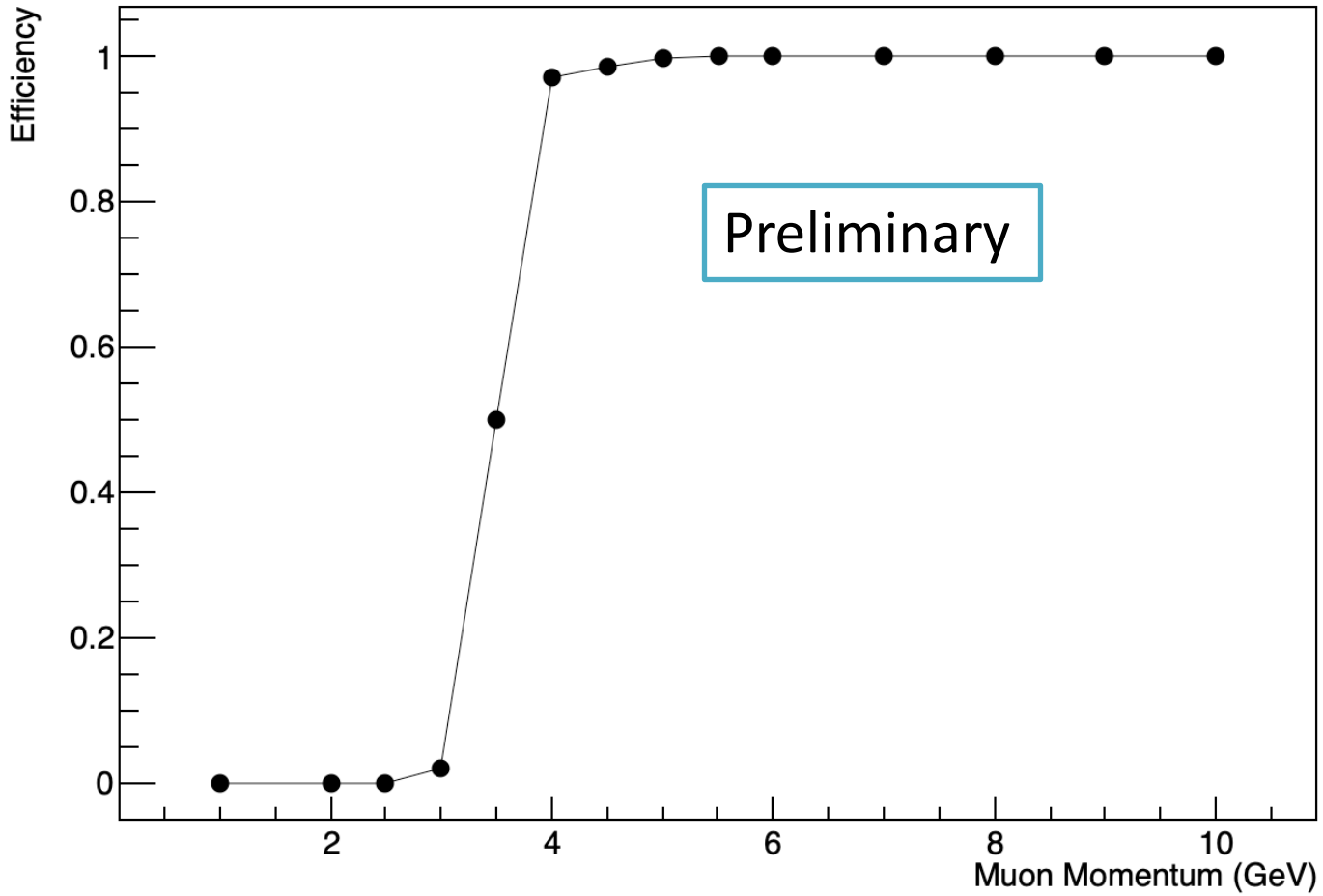


Assuming pedestal : signal = 1:1

Software update: Optimization

- Muon id efficiency vs. momentum
- Define Muon ID:

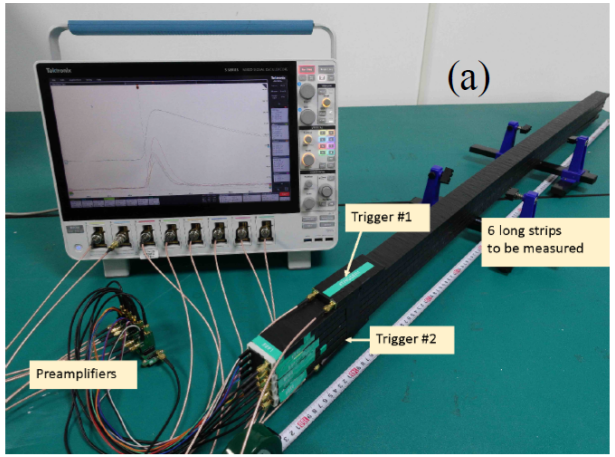
  If a muon candidate has 3 or more hits reconstructed in the muon detector, it is identified as a muon.

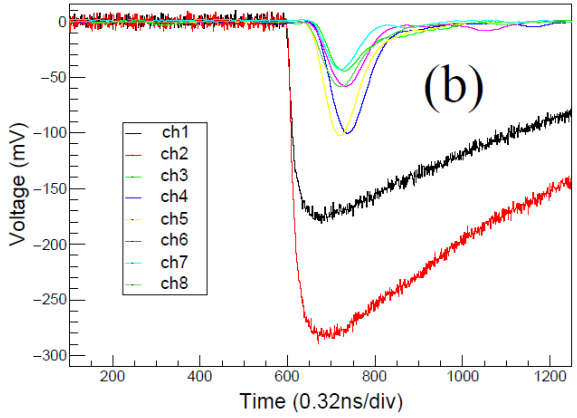


Efficiency in barrel

Next improvements

- According to the tests in lab.
  - Channel efficiency from ~100% → 90-95%.
  - Number of active channels





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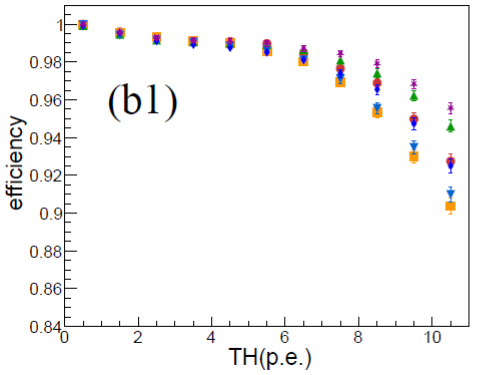
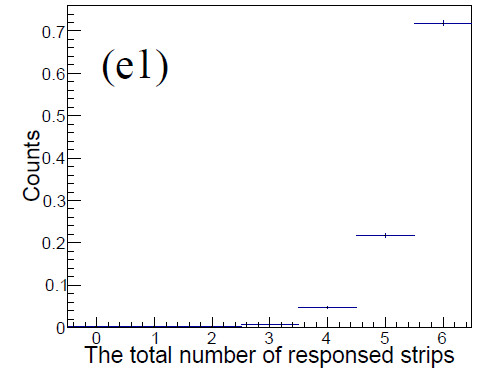
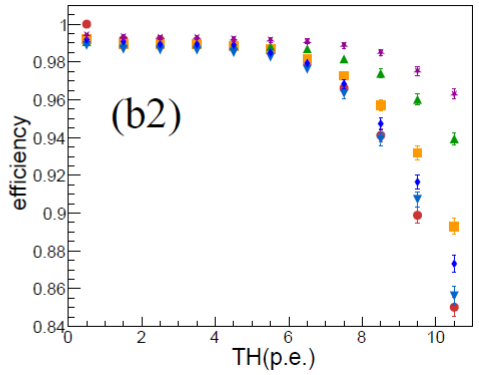
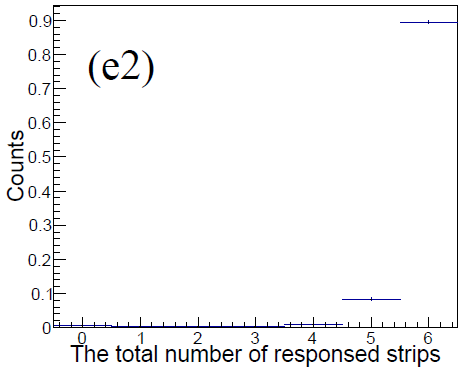
NDL SiPM





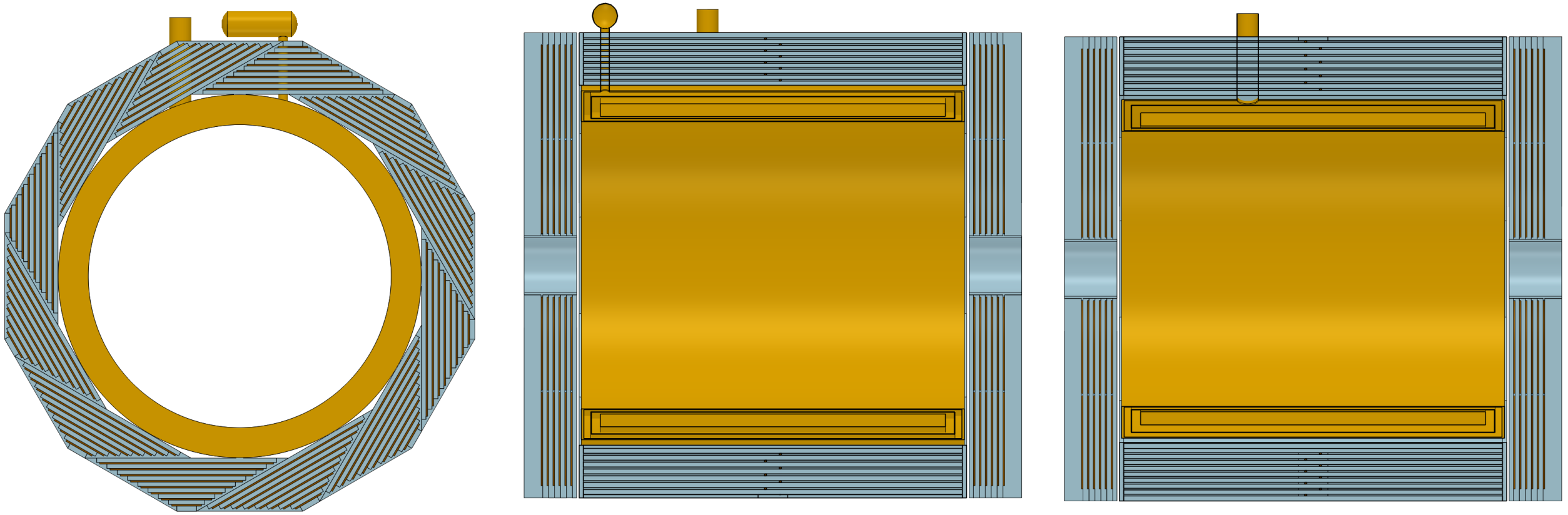
HPK MPPC





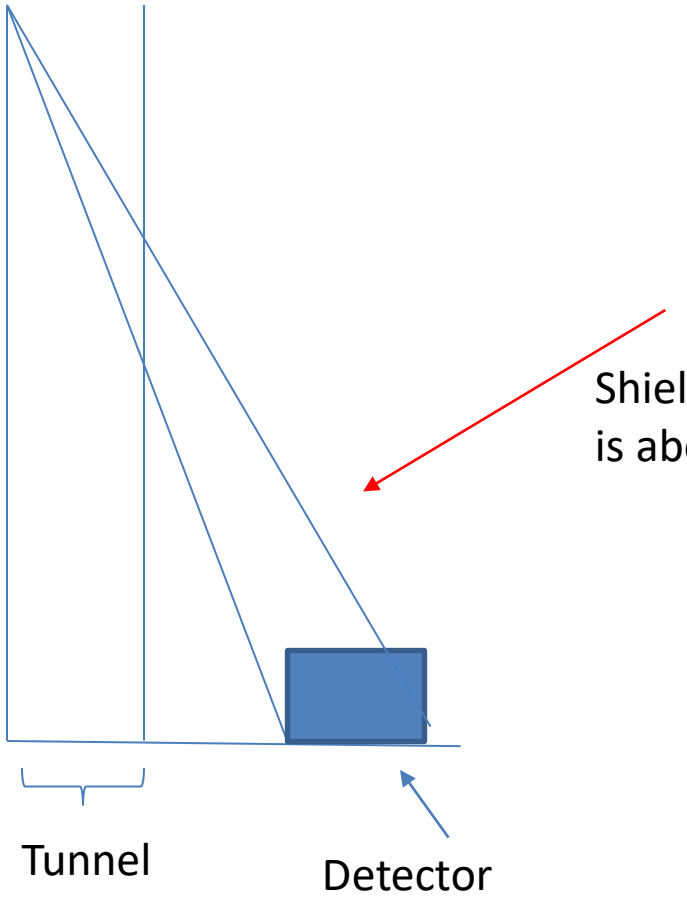
Update on geometry/mechanics

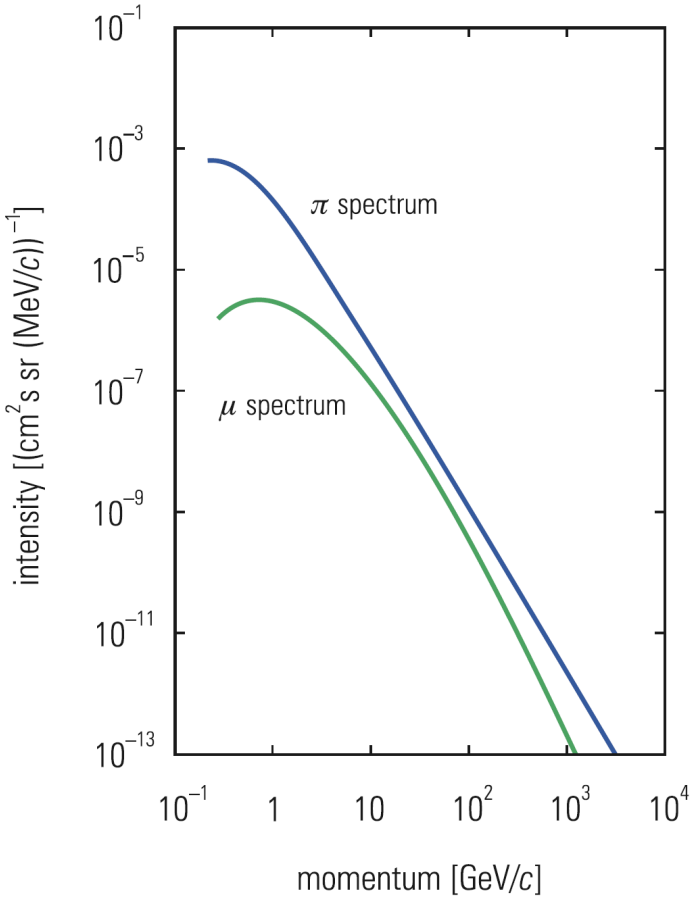
- Input the chimneys of the magnet system.
- It may contribute a dead zone of <0.4%.



Thank you!

Backgrounds from CR





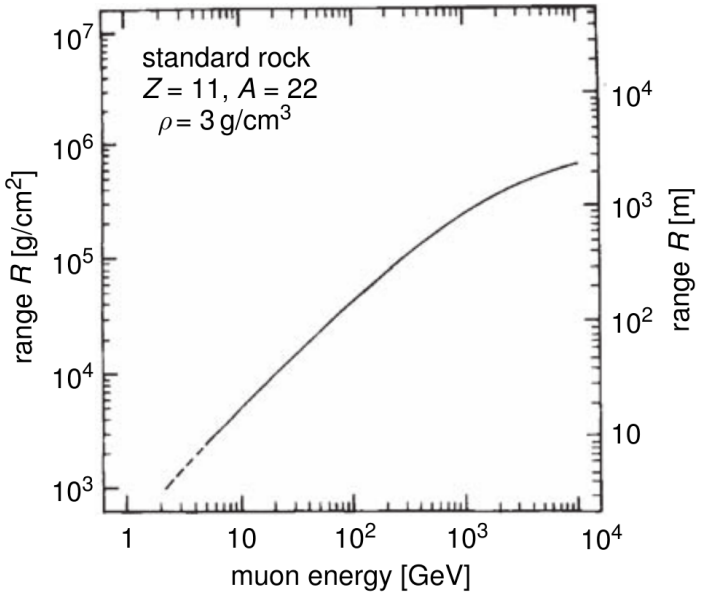


Fig. 1.12. Range of muons in rock [51].