The Muon System

Needs and Ideas

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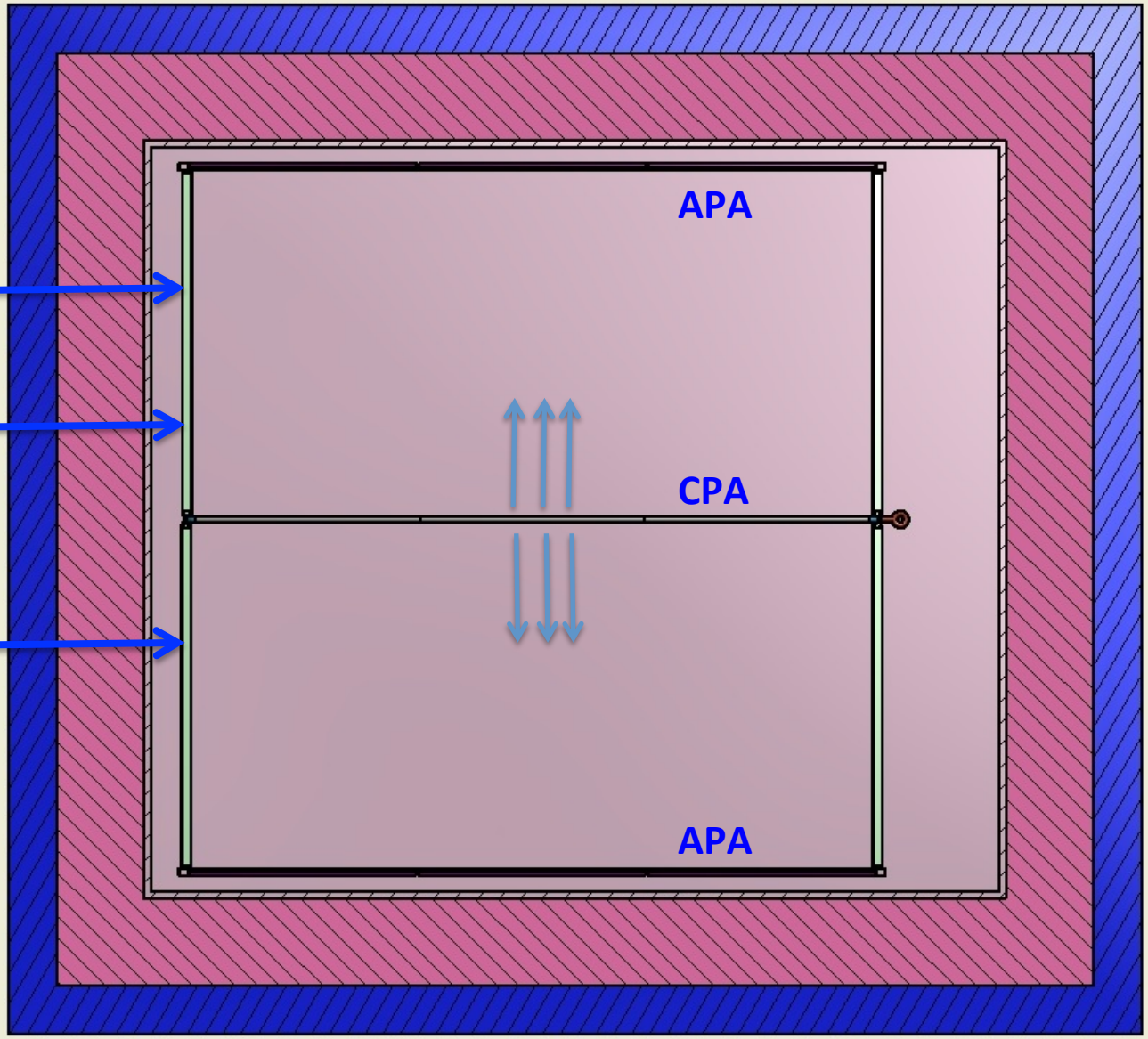
Purpose of the Muon System

- GeV muons lose energy through ionization at a ~constant rate of 2 MeV/cm and generate uniform paths of electrons. This could be used to calibrate the electric field, liquid argon purity, electron lifetime, etc.

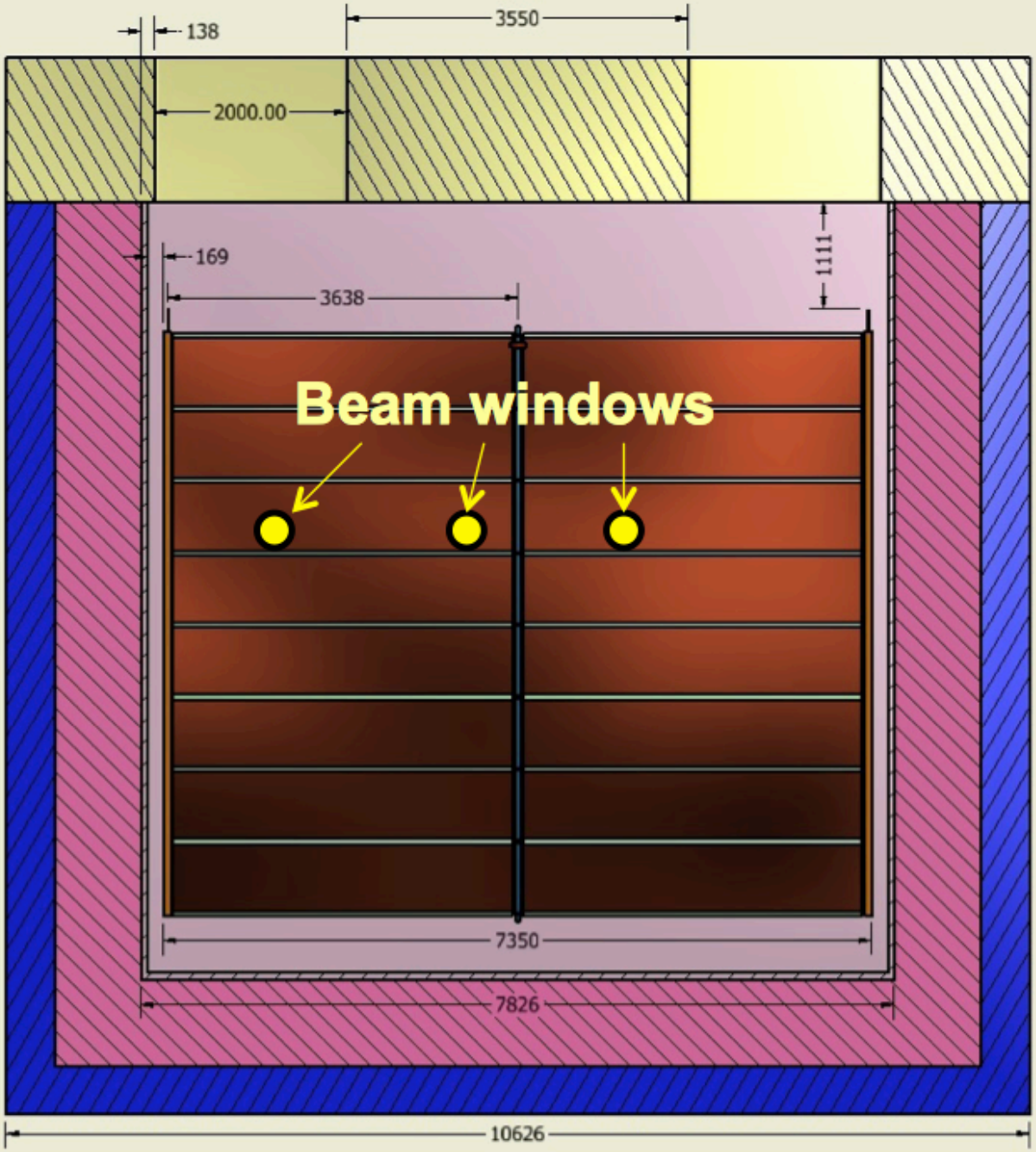
- Cosmic ray muons come 24/7, and reach every corner of the detector. Other instruments inside the cryostat could have various challenges.
  - Localization of LAr purity monitors, usually outside of TPC. Their lifetime?
  - Laser calibrates field in the TPC but has challenge to reach every corner and can only survey a few places at a time

- But muons are not necessarily travelling as a straight line in the detector, as such cast a challenge to the application.

Three proposed charged particle beam paths

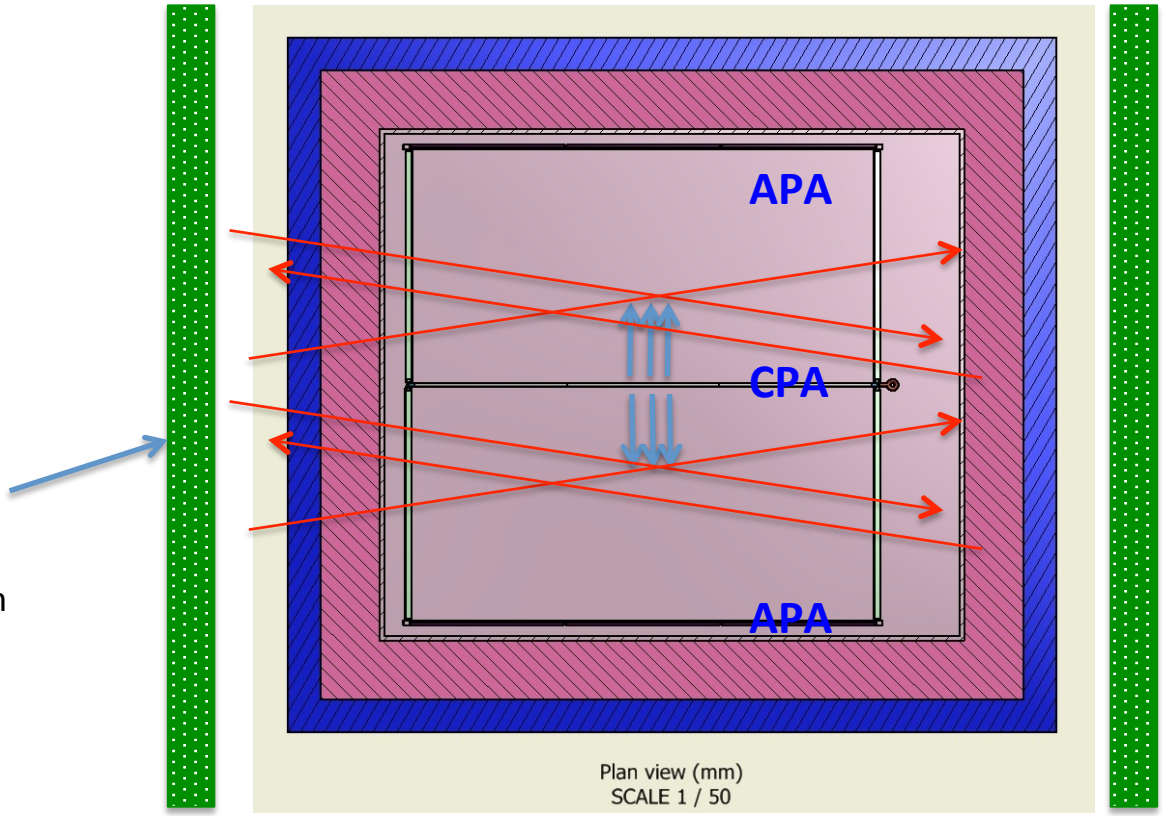


Plan view (mm)
SCALE 1 / 50


138
3550
2000.00
169
3638
1111
Beam windows
7350
7826
10626
End View (mm)
SCALE 1 / 50

It would be preferred to record transverse muons that could be seen by a large fraction of collection wires.

Muon detectors
Leave space for the beam windows



What's the needed space resolution

At large angle, we are expecting muons with energy above 10 GeV.

Muon track wouldn't be straight due to multiple scattering, but the higher the energy, the more straight they would be.

Liquid argon radiation length is about 20 g/cm^2. Thus a 10 GeV track passing 10 meter of liquid argon could be refracted by 0.1 rad, or 11 cm at 10 meter.

If we are using tracks that are > 1 meter away from the anode planes, the multiple scattering effect could be less significant.

Or if we select with higher energy muons (but how to measure the muon energy is an issue)

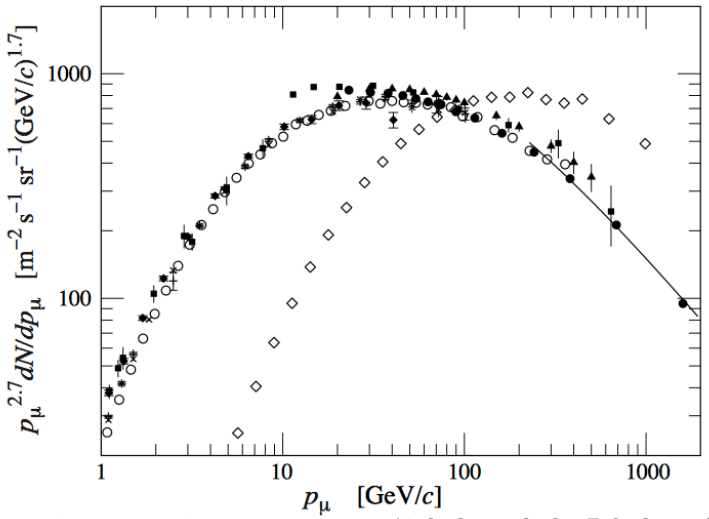


Figure 26.4: Spectrum of muons at $\theta = 0°$ (♦ [41], ■ [46], ▼ [47], ▲ [48], ×, + [43], ○ [44], and • [45] and $\theta = 75°$ ◊ [49]) . The line plots the result from Eq. (26.4) for vertical showers.

What's the needed time resolution

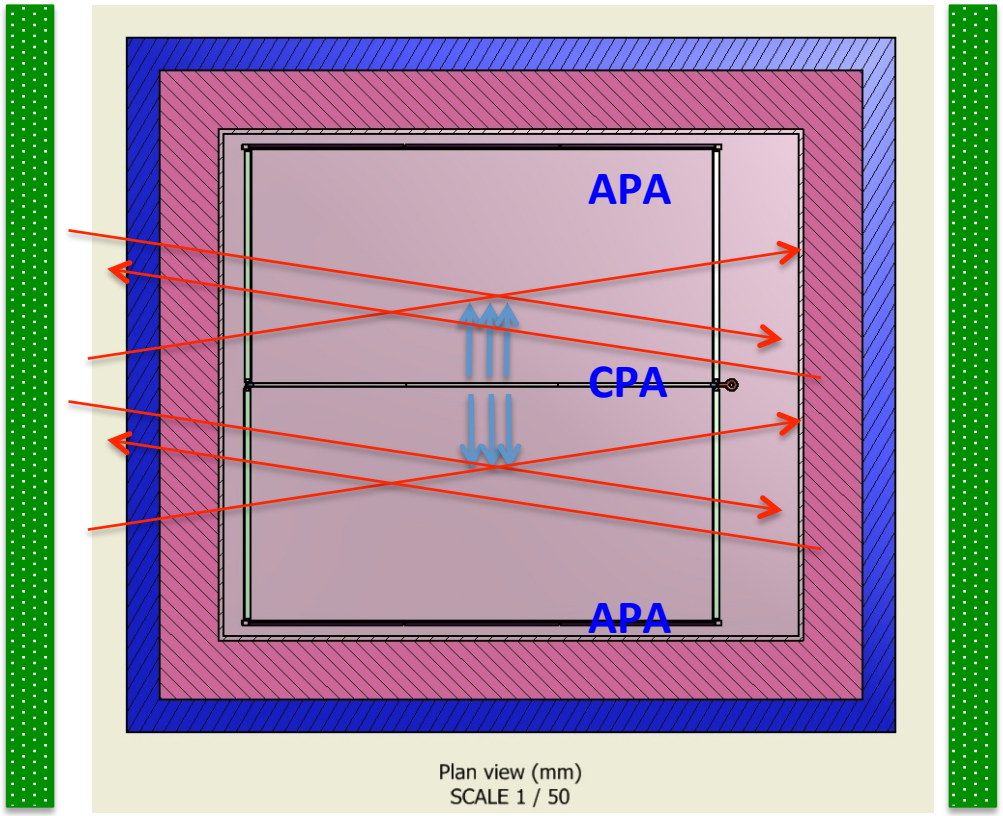
For a 10 GeV muon, it travels at 0.99995C and takes 33 ns to pass 10 meter

If the time resolution is better than 30 ns, we will be able to identify those high energy muons.

To use time-of-flight to determine muon energy, the time resolution needs to be sub-ns.

What's the coverage?

The two entire sides that perpendicular to the particle beam?
What's the corresponding trigger rate?
Energy spectrum vs angle vs trigger rate?



What technique?

Gas wire chamber?
Centimeter space resolution and nanosecond time resolution. Cheap and well-understood

What's the needed space resolution
What's the needed time resolution
What's the coverage
What technique

These questions need to be addressed as soon as possible
Simulation work also needed to carried out to demonstrate such system

We are looking for institutions interested to these tasks and start the designing of the muon system

Please let us know if you are interested or have suggestions!