Choices for liquid argon detector.

Veljko Radeka suggested that we consider Liquid Krypton as an option to either reduce the size of the detector, increase the mass, or improve containment. (or all of the above).

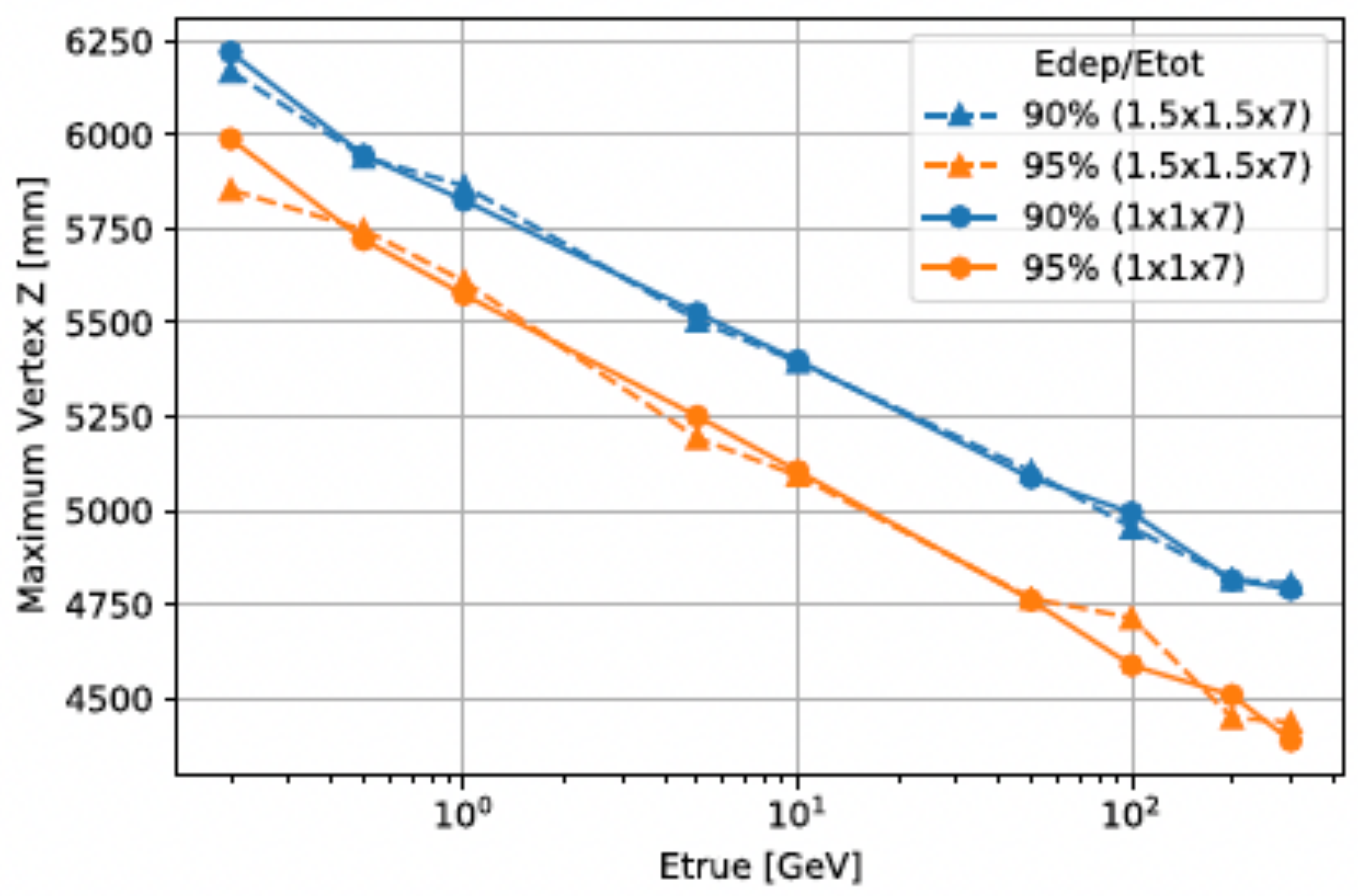
Upon discussion this cannot be rejected, and so we have made a few slides.

Milind Diwan/Veljko Radeka Oct 14, 2021

Brookhaven National Laboratory

Possibility of a higher density higher Z target

Can we use liquid Krypton for the target in FLARE ?



- With liquid argon we are beginning to lose electromagnetic containment at high energies.
- If the trend continues then for 1 TeV showers the containment will cause a loss of ~50% of the events.
- But there are many things to be worked out for LKr.

Comparison of basic properties.

	Liquid Argon	**Liquid Krypton**
Z, A	**18, 39.9**	**36, 83.8**
Density	1.4 gm/cc	2.4 gm/cc
Radiation Length	14 cm	4.7 cm
Moliere Radius	9 cm	5.8 cm (NA48 says 4.7)
critical energy e (mu)	32 MeV (485 GeV)	17 MeV (277 GeV)
Minimum ionization	2.105 MeV/cm	3.28 MeV/cm
Ionization (eV) (atom)	15.8 eV	14.0 eV
Boiling point	87.3 K	119.9 K
index of refraction	1.23	1.3
scintillation wavelength	125 nm	150 nm
Yield	40000/MeV	25000/MeV
Triplet lifetime	1. 6 micros	0.09 micros
Radioactiviity	Ar39, Ar42	Kr81, Kr85
Air abundance (ppm)	9300	1.14

https://pdg.lbl.gov/2012/AtomicNuclearProperties/HTML_PAGES/289.html
https://periodictable.com/Isotopes/018.42/index2.dm.html

$$R_M \approx 0.0265 X_0 (Z + 1.2)$$

Comments —
Advantages and disadvantages of Lar

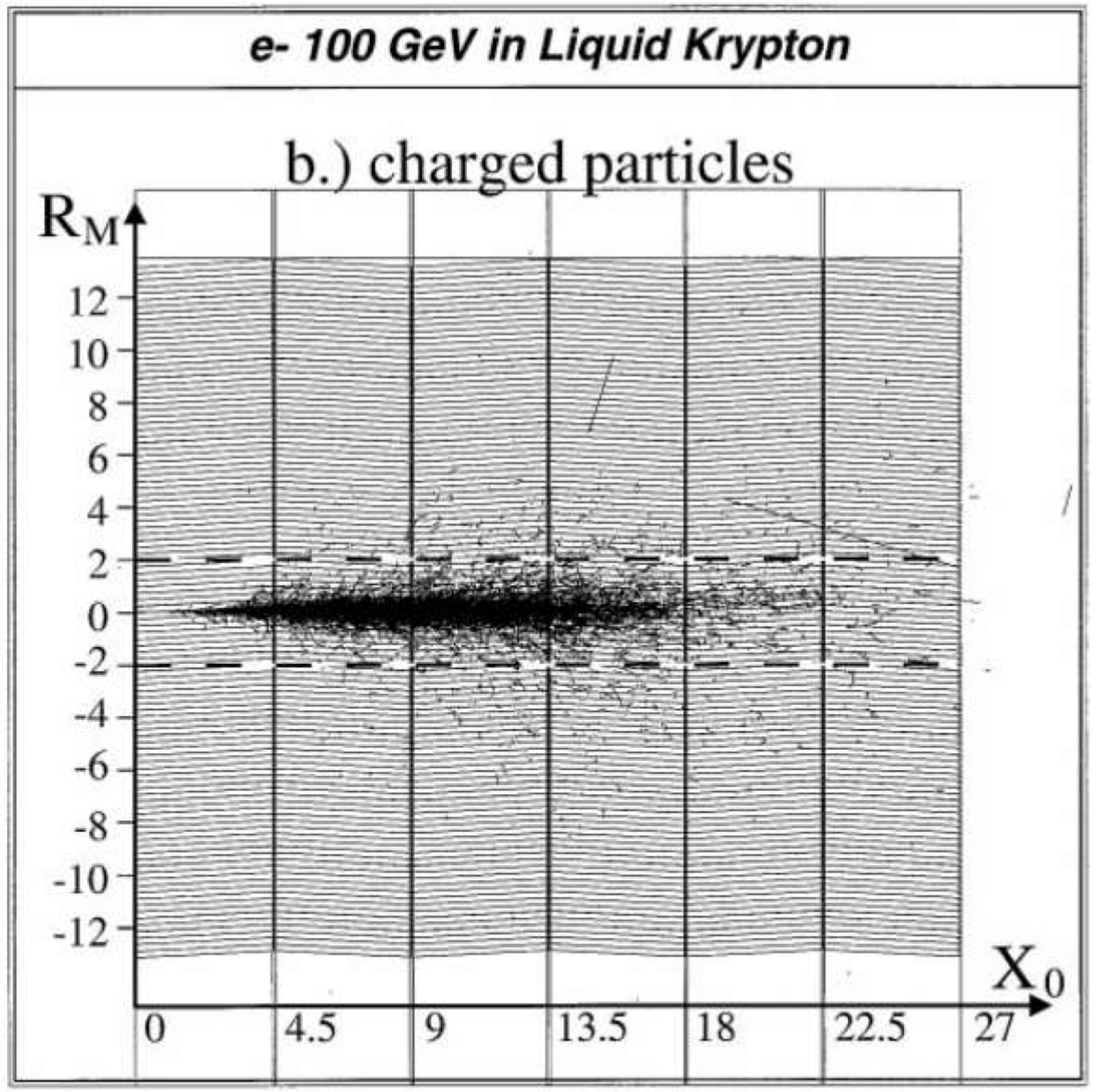


Fig. 3. Electromagnetic cascade of a 100 GeV electron entering the NA48 liquid krypton calorimeter (GEANT). Photons (a), charged shower particles (b).

- **Containment of EM showers will be much better.**
- **Excellent time and energy resolution has been achieved in NA48 at ~27 Tons.**
- **Finer granularity readout could be considered if the detector is made smaller.**
- **SiPMs might work better at 150 nm.**
- **GEM@SSC had done R&D for a large Lar calorimeter and tested successfully in 1993-94 (we have the documents)**
- **LKr calorimeter could be more compact for the same mass. It may be better suited for the FPF.**
- **There is R&D interest: The electrode geometry with charge and light readout will offer opportunities for innovation, at a lower total cost of implementation (smaller system size).**
- **Availability ? What is the lowest amount we need ?**

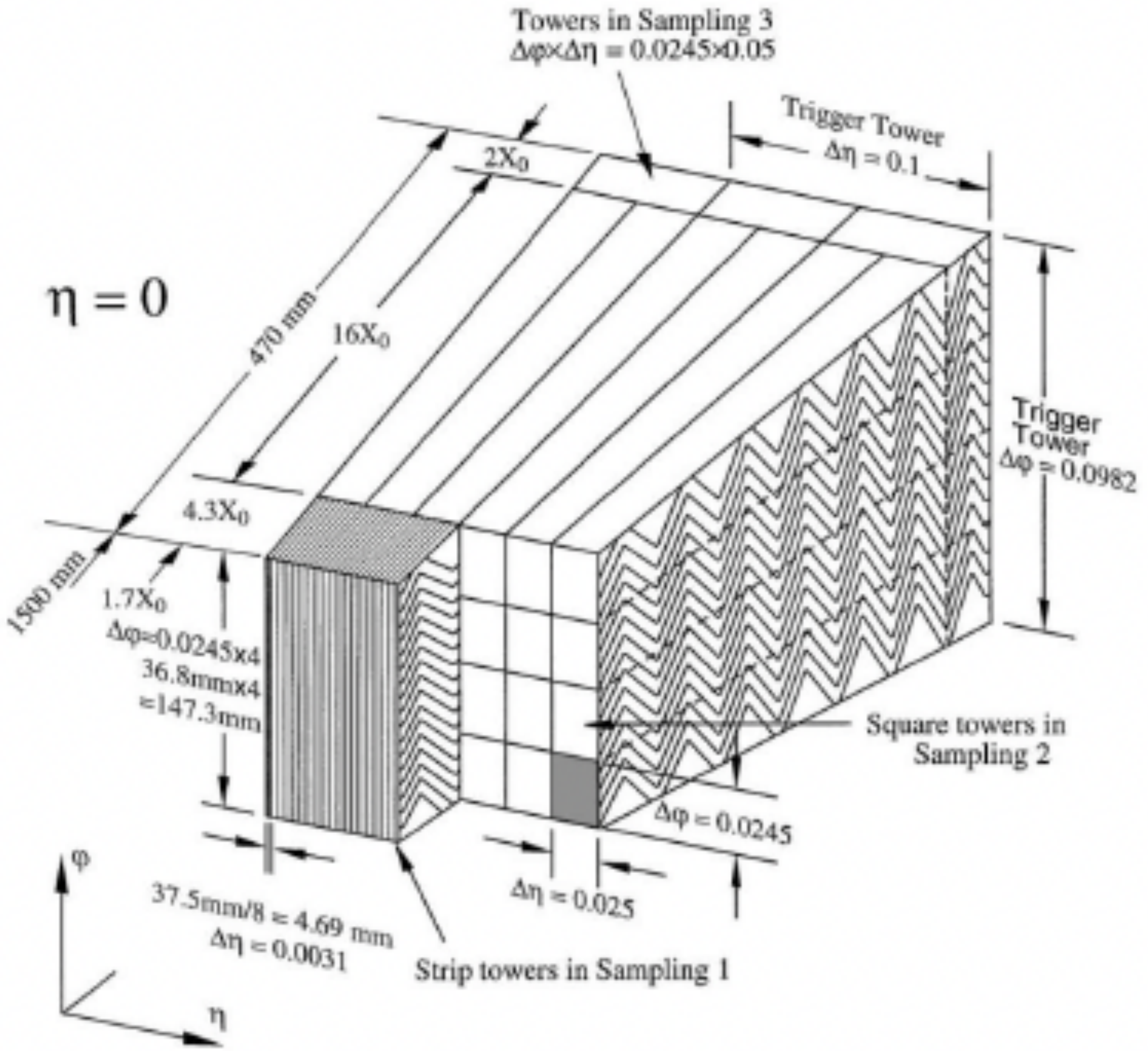


Fig. 5. Read-out granularity of the ATLAS electromagnetic calorimeter.

Experience:

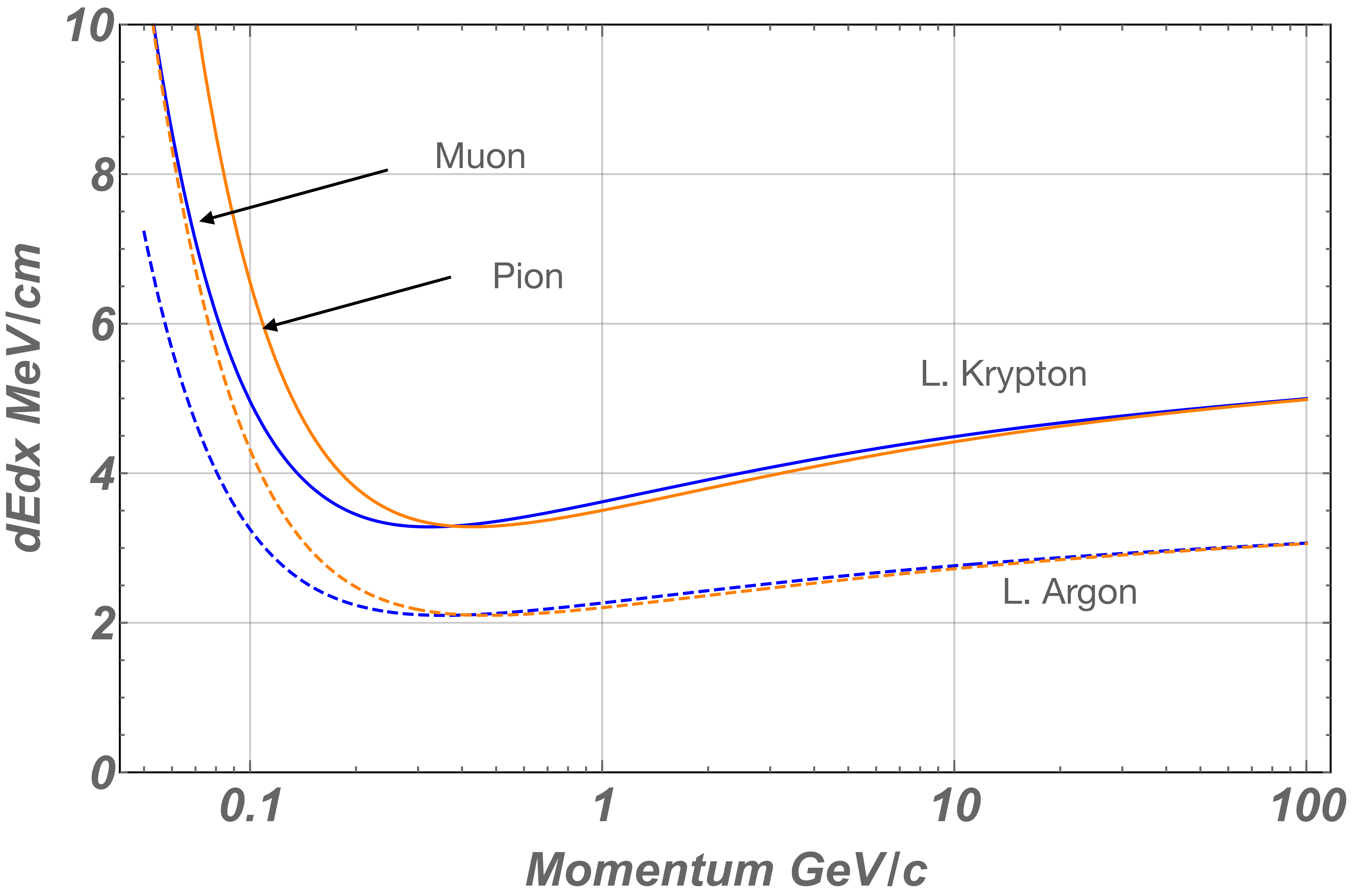
NA48 (and now NA62) has used the Lkr calorimeter for a long time.
F. Constantini, NIM A 409 (1998) 570-574

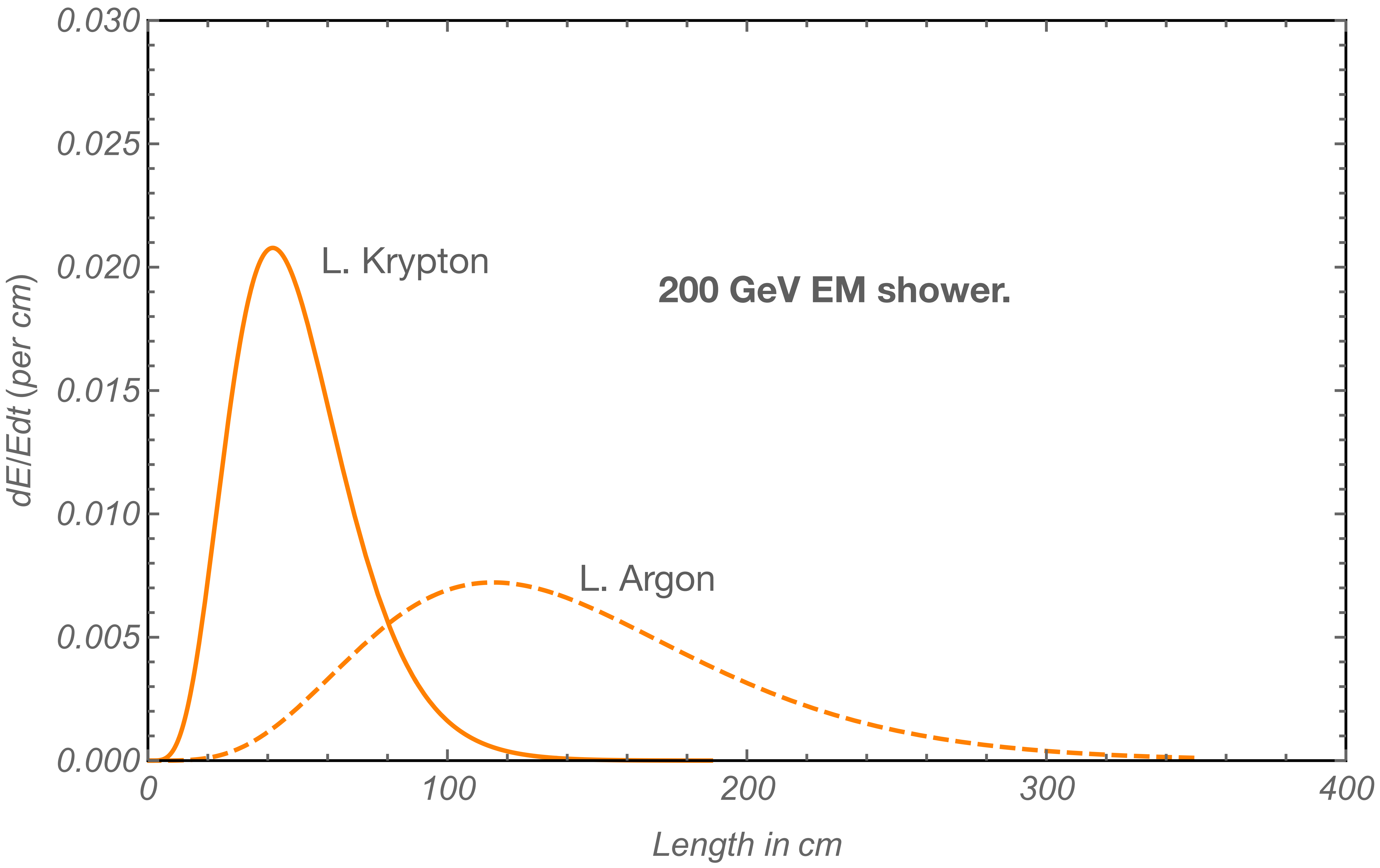
LKr calorimeter drawing from Bo Yu.
D. Schinzel, NIM A 419 (1998) 217-229]

A TPC would be a novel use of this technology.
But fundamentally not too different.

Reviewing GEM TDR notes….

Energy loss plots (very rough)





- Krypton has higher energy loss per cm and much shorter shower profile.

Points to consider

- **Physics performance of krypton will likely be better.**
- **The compact shower size and better dE/dx may lead to much better kinematic performance. But this needs detailed study.**
- **The charge signal is larger per MeV and per unit track length.**
- **The light signal long time constant is short. This will reduce the overall rate and better performance. The higher wavelength will be better suited.**
- **We will need to resolve the angular resolution and how fine a pitch is needed.**
- **Clever design of the electrode and the light sensor will be needed.**
- **The drift field and drift velocity will need to be reassessed. Could be favorable.**
- **Cost of LKr compared to LAr will be high unless we find a source that can provide this material. (discussion in progress with Praxair/Linde management/next week)**
- **Are there any physics considerations if a larger nucleus is used ?**

REMINDER: LAR Detector Preliminary Conceptual Drawings: Yichen

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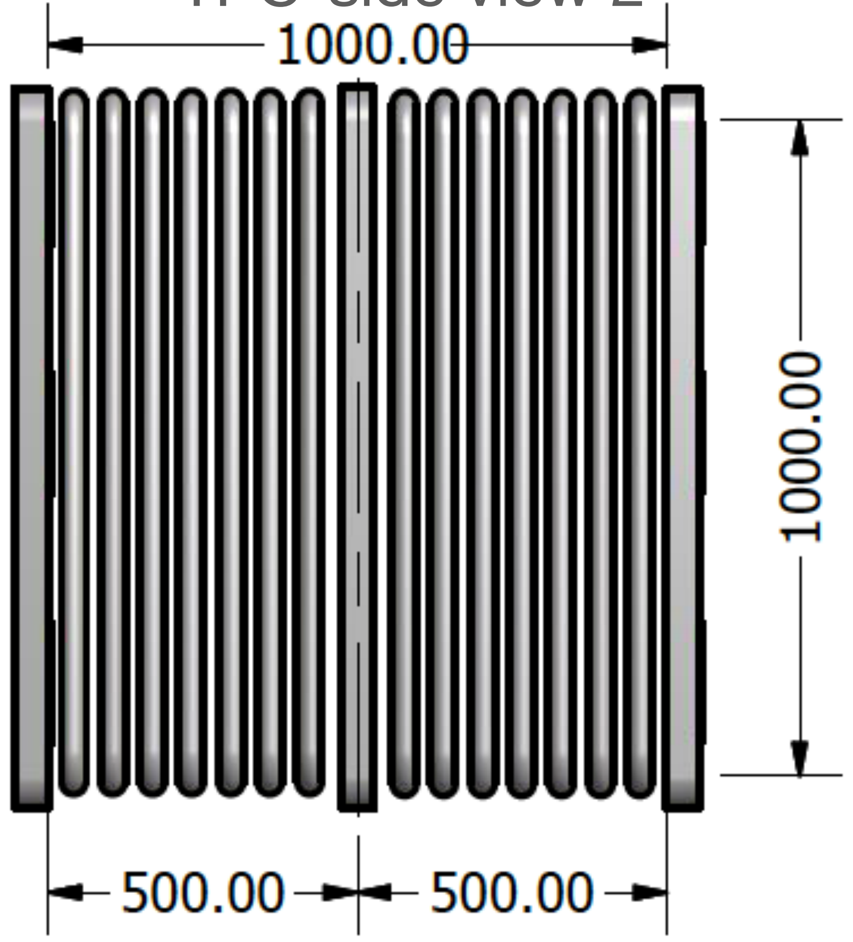
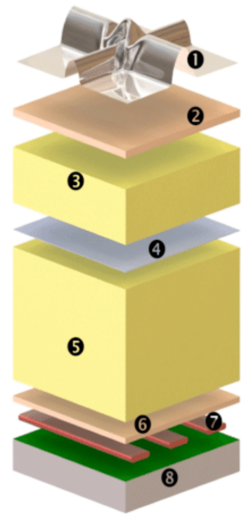
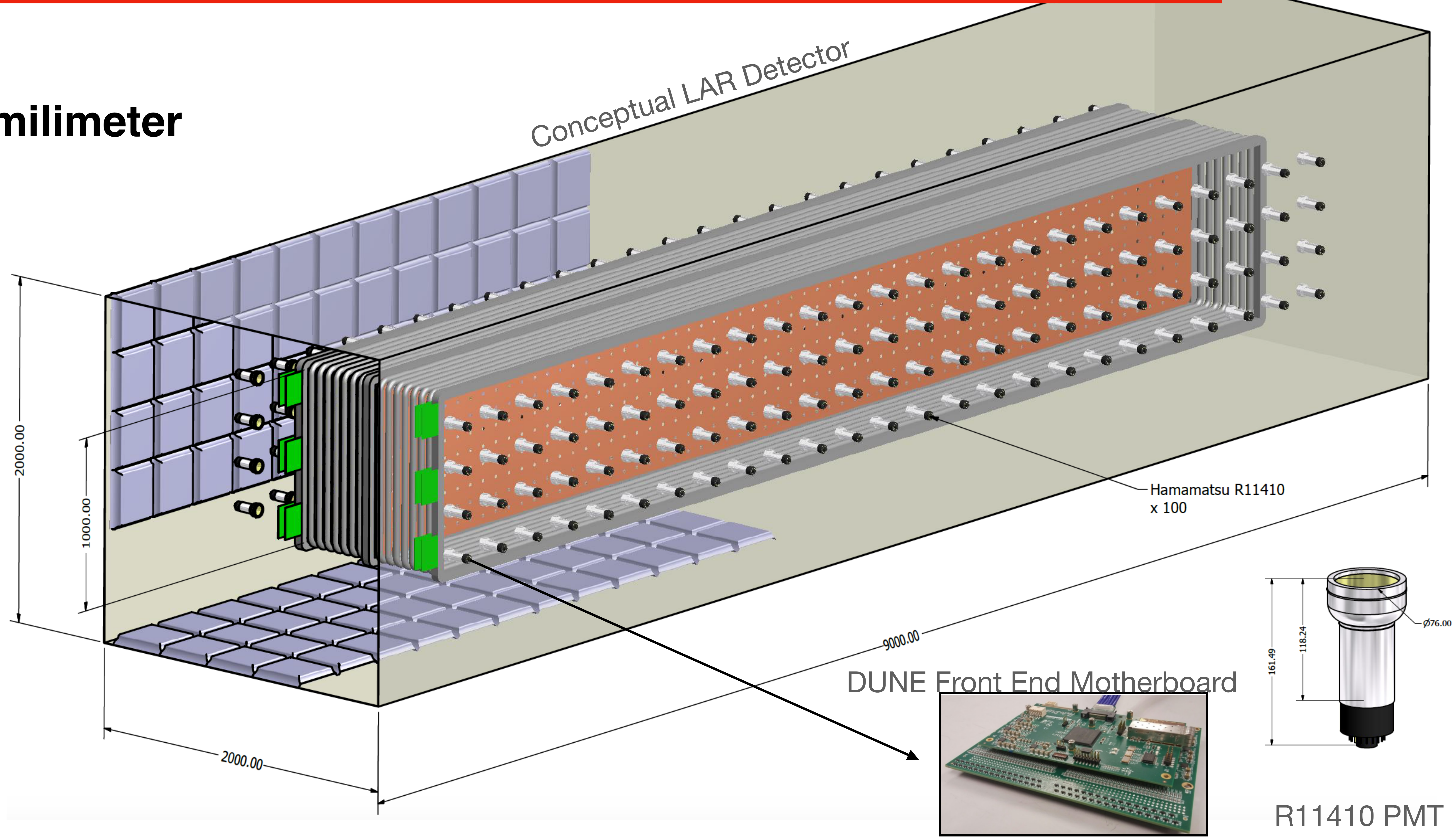
- **All dimension in milimeter**

TPC-side view 2





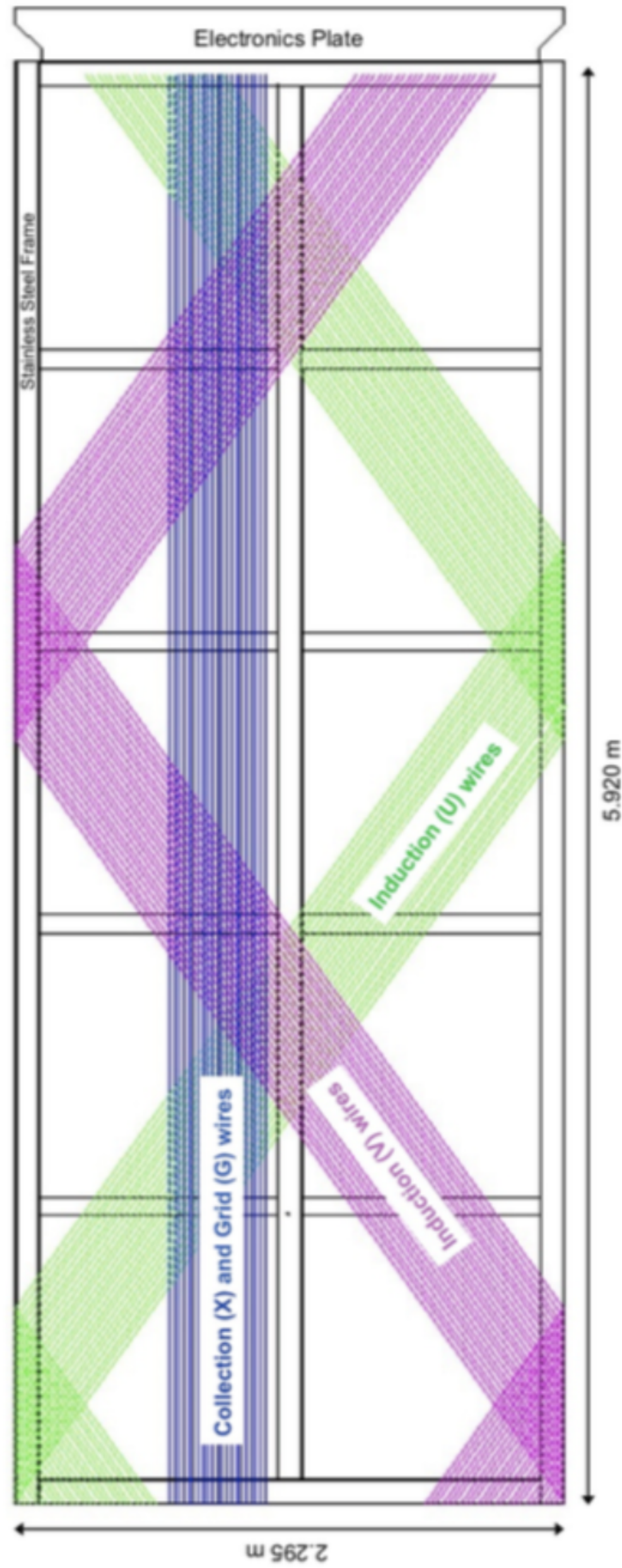
Membrane Cryostat Insulation

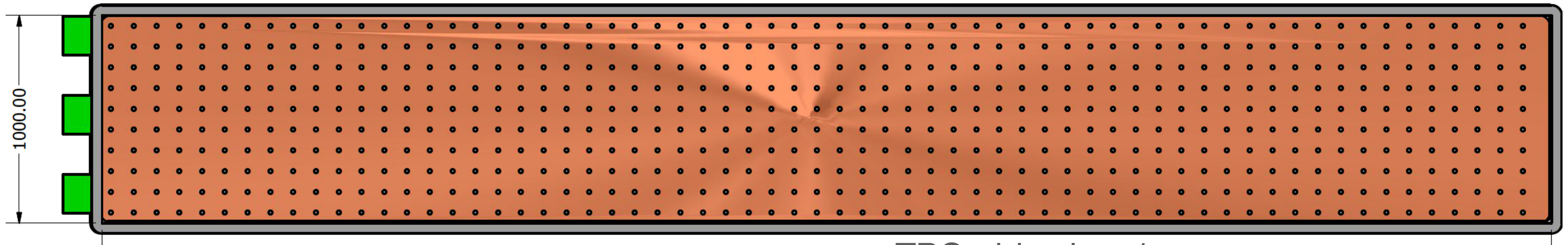


DUNE Front End Motherboard

R11410 PMT

DUNE APA





TPC-side view 1