Noble Liquid Calorimetry: Plans for R&D

Nicolas **Morange**, *IJCLab,* on behalf of Noble Liquid Calorimetry study group

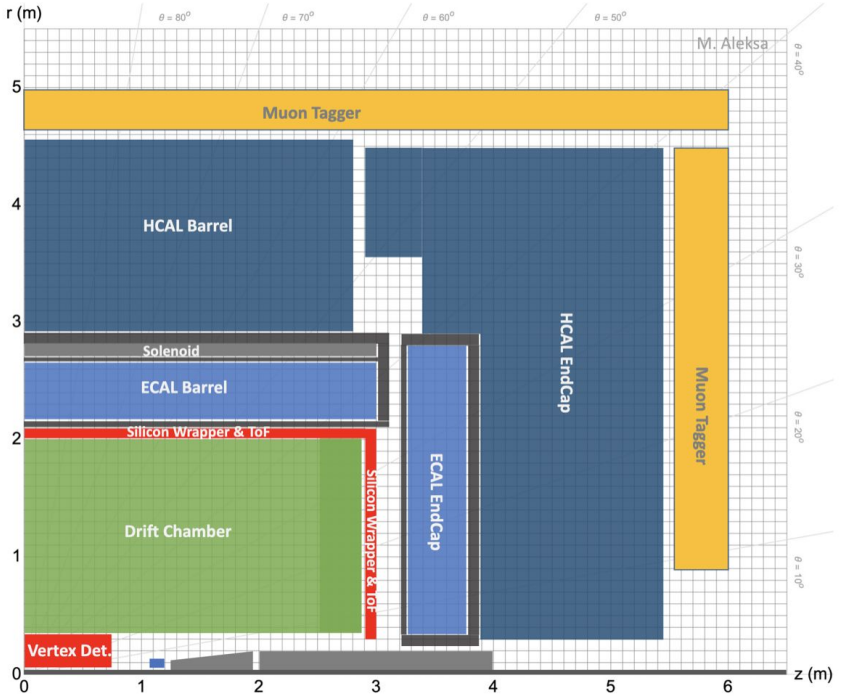
DRD Calorimetry meeting, 12/01/2023

Introduction

- Noble Liquid Calorimetry R&D started in context of FCC-hh CDR
  - Main design concept: straight finely segmented readout electrodes inclined around the barrel
- Further interest in context of FCC-ee (or other e^+e^- collider)
  - “Simpler” conditions allow for significant design optimizations
- Still a quite recent development
  - Fairly small but active team of collaborators so far
  - Very open to new collaborators
  - And to new ideas !

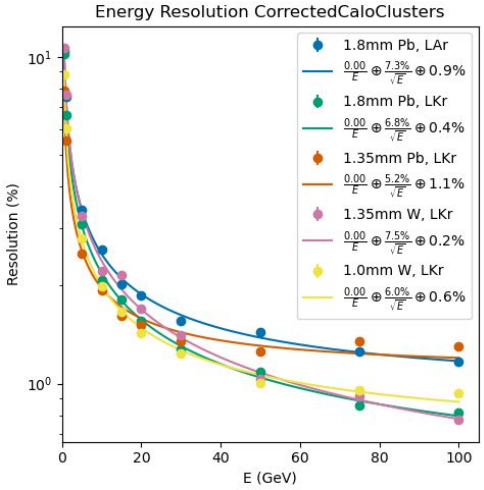
Main medium-term goals

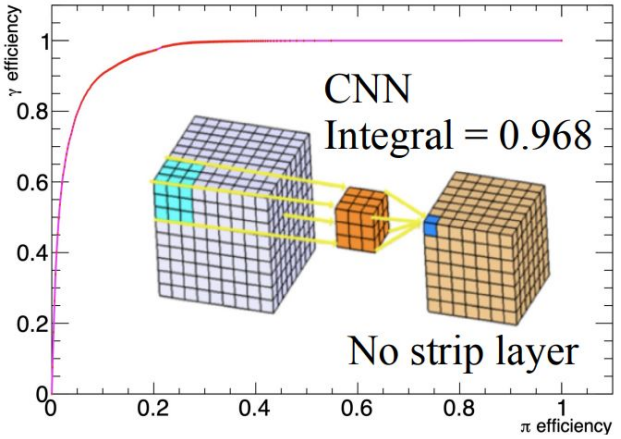
- Develop the calo design into a full detector concept
  - Study design solutions for endcaps
  - Study general performance in simulation, in combination with some HCAL concept
- Build a first prototype and measure performance in testbeam
  - Can then be refined to test further developments / new ideas



General design and expected performance

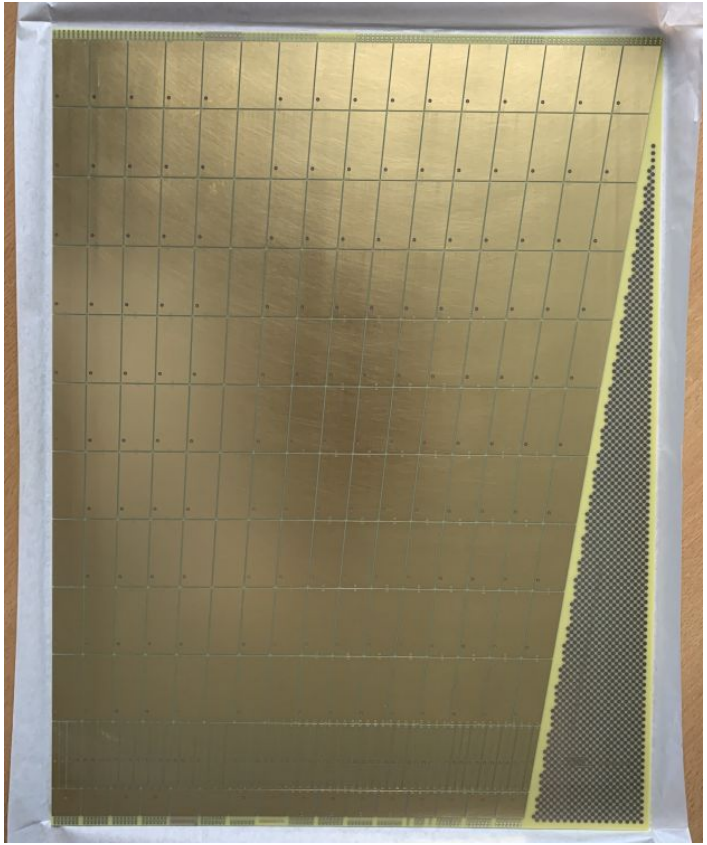
- Full simulation integrated in FCC software chain is a big asset
- First EM physics studies performed in 2022
  - Many more can be performed
  - Can guide LAr/LKr, granularity…
- Next major step will be addition of some HCAL in simulation, along with PFlow algorithms
  - Then can look at all physics performance metrics
- Performance in endcaps also has never been looked at
- Many opportunities for software development
  - Clever ML techniques for clustering / PID ?





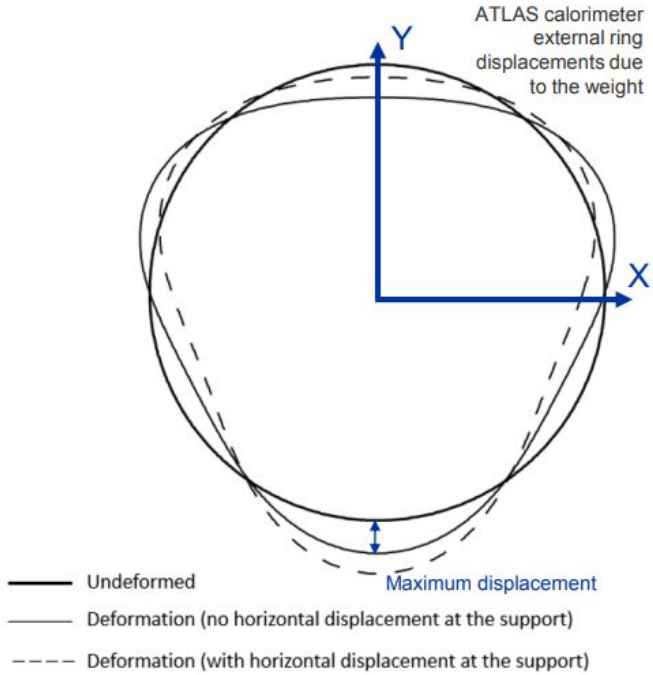
Readout electrodes

- Very nice progress over the past two years
- Optimize granularity based on physics simulations and measurements of noise and cross-talk
- Readout everything at the back ?
- Iterate on prototypes with manufacturing companies
- Connectors ?
- How to do the HV layer ? (also resistors etc...)
- How to do the endcaps ?



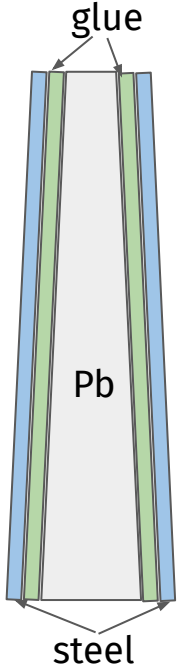
Mechanics

- Everything has yet to be done !
- Studies just starting, by identifying what are our requirements and learning from ATLAS
- Overall challenge: make the whole structure rigid enough, while keeping light on support structures
- Lots of room for new ideas



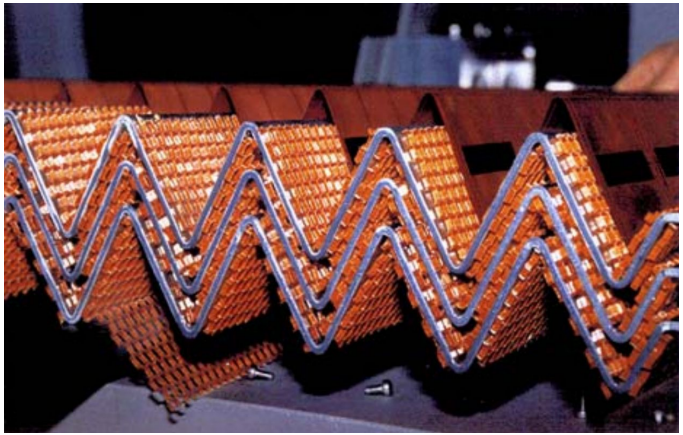
Absorbers

- Basic absorber design directly inspired from ATLAS
  - Can we do better ?
  - Anyway, have to “re-learn” how to get them from the industry
- Simpler because no accordion bending
- New idea of trapezoidal absorbers
  - Can it be done ?
  - With what tolerances ?
  - Need iterations with industry
- Other ideas ?



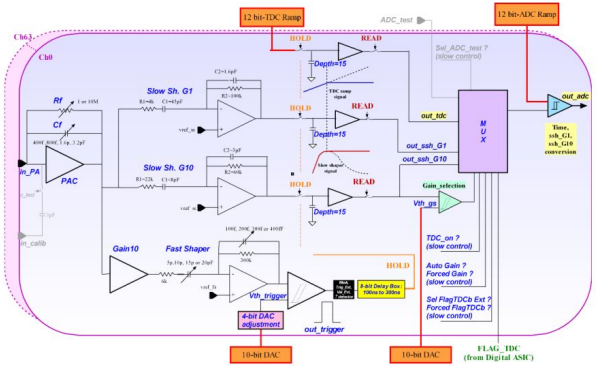
Spacers

- ATLAS used honeycomb with great success
  - Including variable size in the endcaps
- Can we instead 3D-print pillars to be placed regularly ?



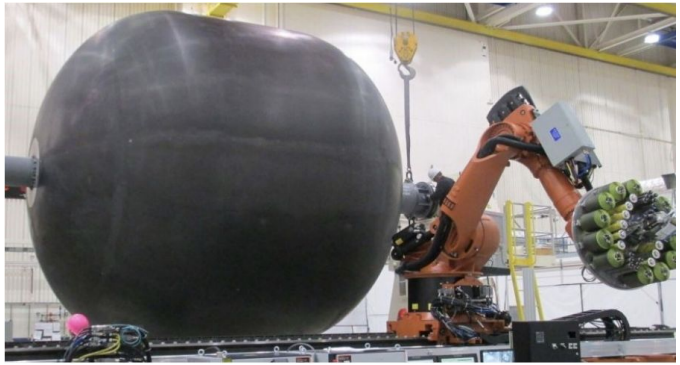
Readout electronics

- Basically, everything is yet to be done
- Warm electronics option
  - Can probably use SKYROC ASICs as a start for frontend
  - Requires work on cables inside the cryostat
- Cold electronics
  - Very appealing option
  - Needs dedicated work
  - How much can we put in the cold ? Preamp, ADC, multiplexer ? Optical conversion ?
  - Power consumption is a huge challenge
- Add dedicated timing measurement ?



Cryostat

- Carbon fiber-based cryostats show excellent perspectives for “transparent” cryostats
  - CFRP shell + Al honeycomb sandwich
  - Optimization between X_0 and mechanical properties
- Ongoing R&Ds at CERN to address CFRP / metal interfaces, and sealing methods
- Will presumably need several generations of prototypes to get everything right



NASA’s lineless cryotank

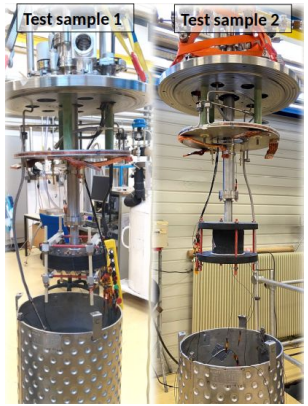
Sandwich Shell

Skin [0,45,-45,90]s
Core : Al Honeycomb
Skin [0,45,-45,90]s

Solid Shell

Radiation length X_0[mm]
Al = 88.9
HM CFRP = 260
Honeycomb Al= 6000

Criteria: Safety Factor = 2	Sandwich shell				Solid shell			
	HM CFRP		Al		HM CFRP		Al	
	OWC	ICC	OWC	ICC	OWC	ICC	OWC	ICC
Material budget X/X0	0.03	0.043	0.094	0.17	0.092	0.12	0.34	0.44
X0 % savings	-68%	-75%	REF	REF	-2%	-29%	262%	159%
Skin Th. [mm]	3.2	4.8	3.9	7.5				
Core Th. [mm]	32	38	40	40				
Total Th. [mm]	38.4	47.6	47.8	55	24	30.4	30	39
Thickness % savings	-20%	-13%	REF	REF	-50%	-45%	-37%	-29%



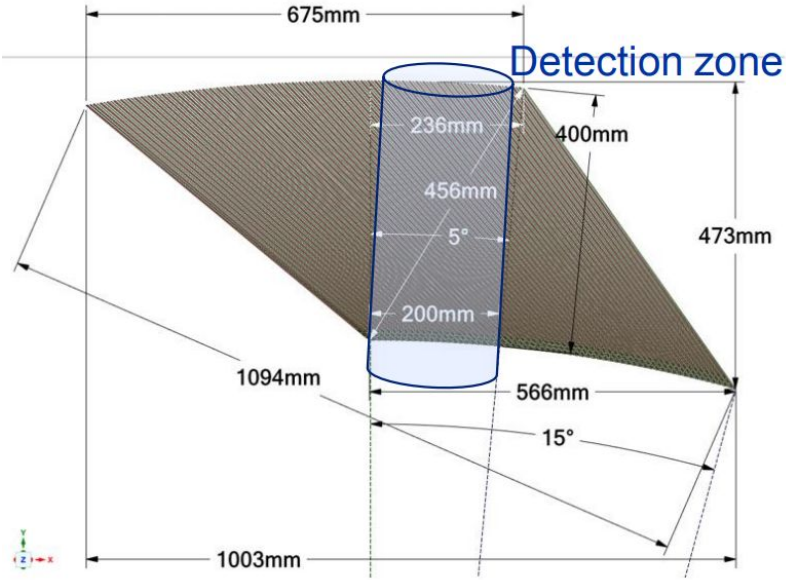
Sealing with Belleville washers

New ideas

- Add precise timing measurement
  - How precise can we get with dedicated electronics ?
  - What do we gain ?
- Measure Cerenkov in LAr/LKr for dual readout ?
  - Add fibers in noble liquid
  - How many photons can we detect ?
  - Interest about it, but sounds difficult
- Other ideas ?

Towards a prototype

- No need to have answers to all items to go for a first prototype in testbeam
  - Cryostat: can find and use an existing one
  - (Warm) electronics: can probably design simple FEB based on existing ASICs
  - etc…
- Difficulty of this design: a small prototype cannot be too small…
  - And Noble Liquid calo implies cryostat and cryogenics
- Still a significant endeavour
- Use of common tools (EUDAQ…) would at least facilitate the integration in a testbeam facility



Conclusions

- We have **a lot** on our plate
- There are some basic design and starting ideas in place
  - So we have a **clear ‘minimal’ route to follow**
- But there is lots of room for new ideas in every aspect of the concept
- Many opportunities for new collaborators !