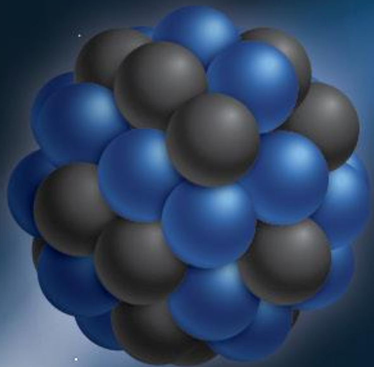
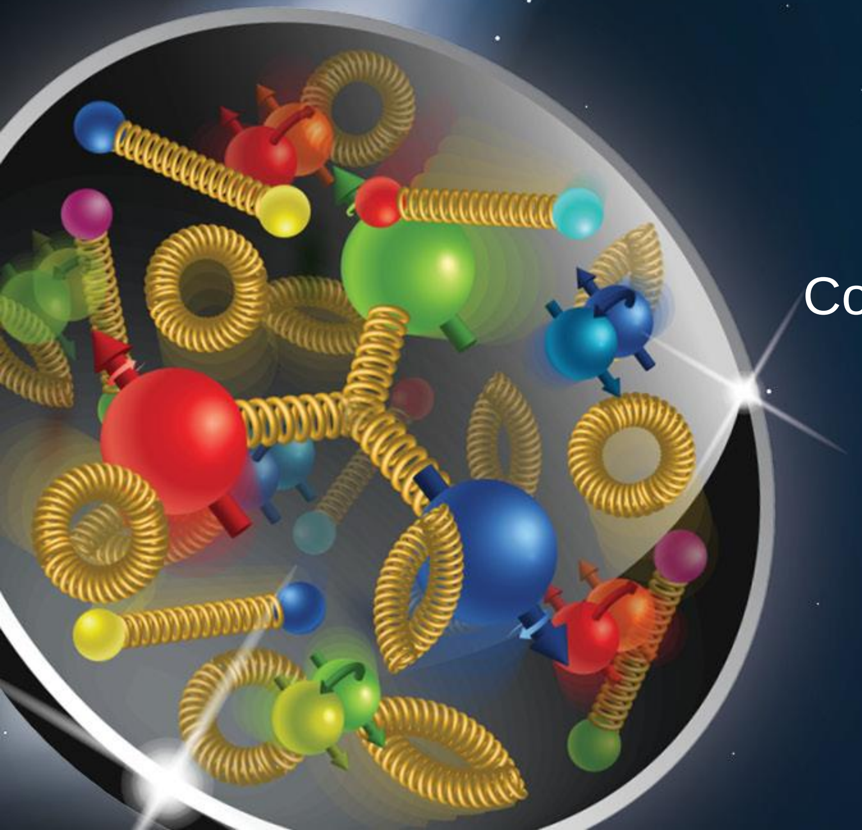


Backward Detector Integration



Elke Aschenauer and Rolf Ent

Co-Associate Directors for the Experimental Program

ePIC GD/I Meeting

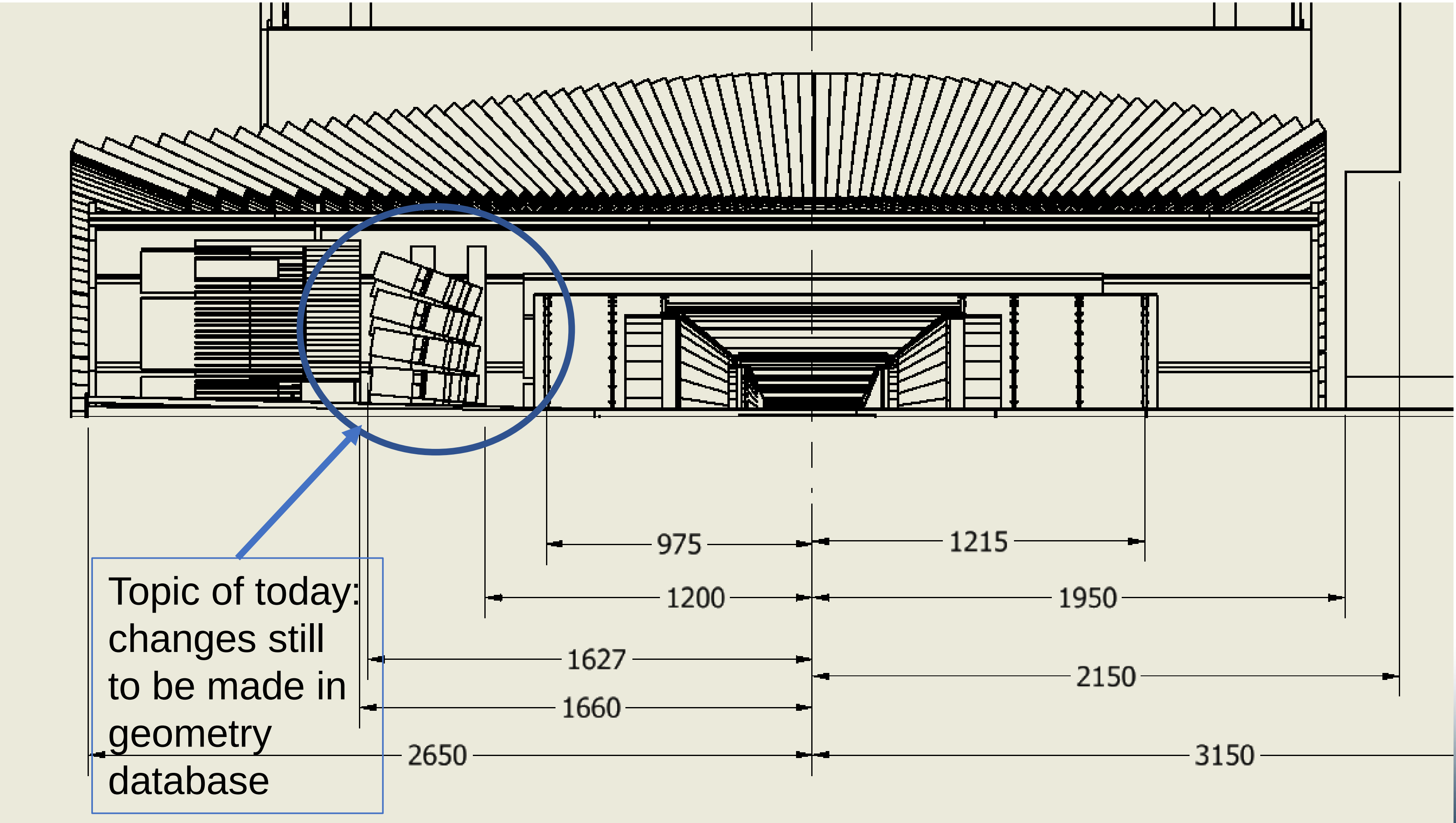
September 19th 2022

Backward Detector Integration

What we need to watch out for

- Do we have enough space for the detector, its readout and services
- Does a detector, i.e. its material, impact the performance of other ones

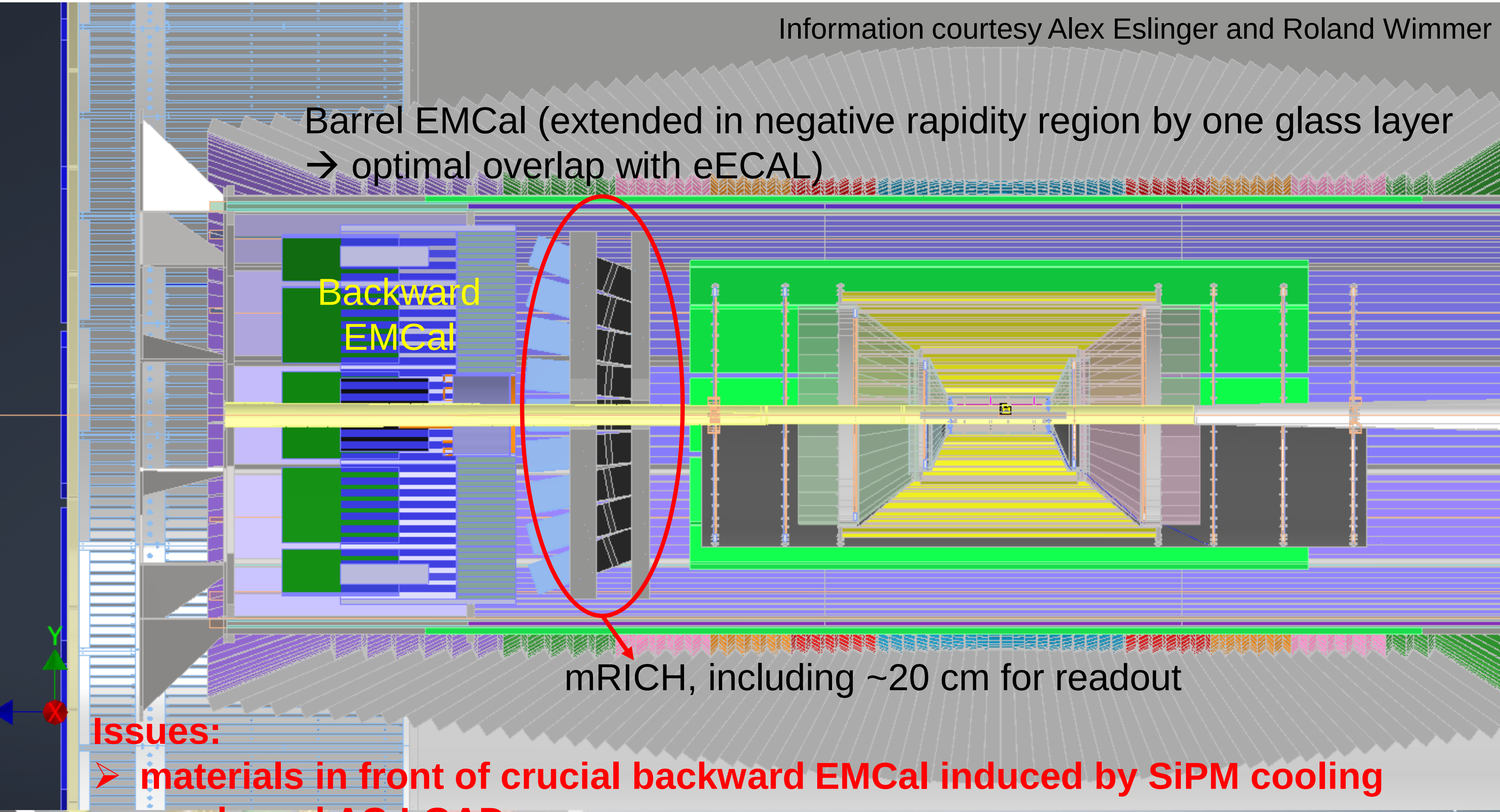
Overall integration model that we try to keep consistent with the geometry database



Information courtesy Roland Wimmer

Backward (m)RICH Integration

Folds in detector information from GSU, readout needs estimate from Roberto P.



Issues:

- **materials in front of crucial backward EMCal induced by SiPM cooling needs and AC-LGAD.**
- **Plus by space available and heat induced by AC-LGAD Power**

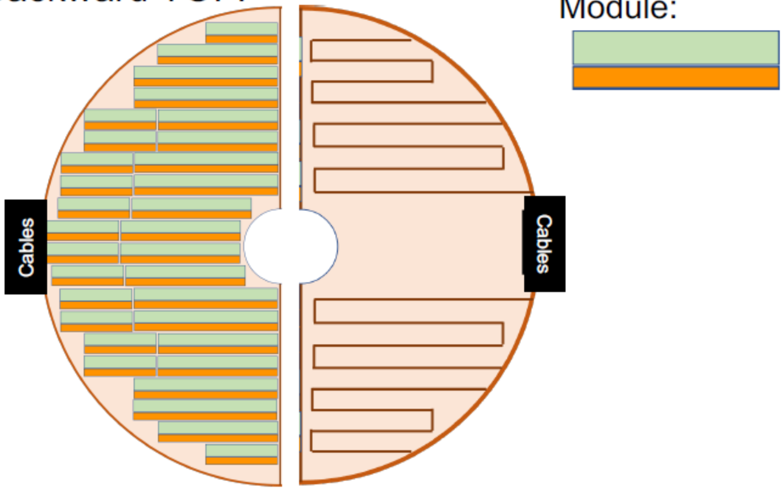
Note: AC-LGAD not yet included in layout

ETOF Power budget

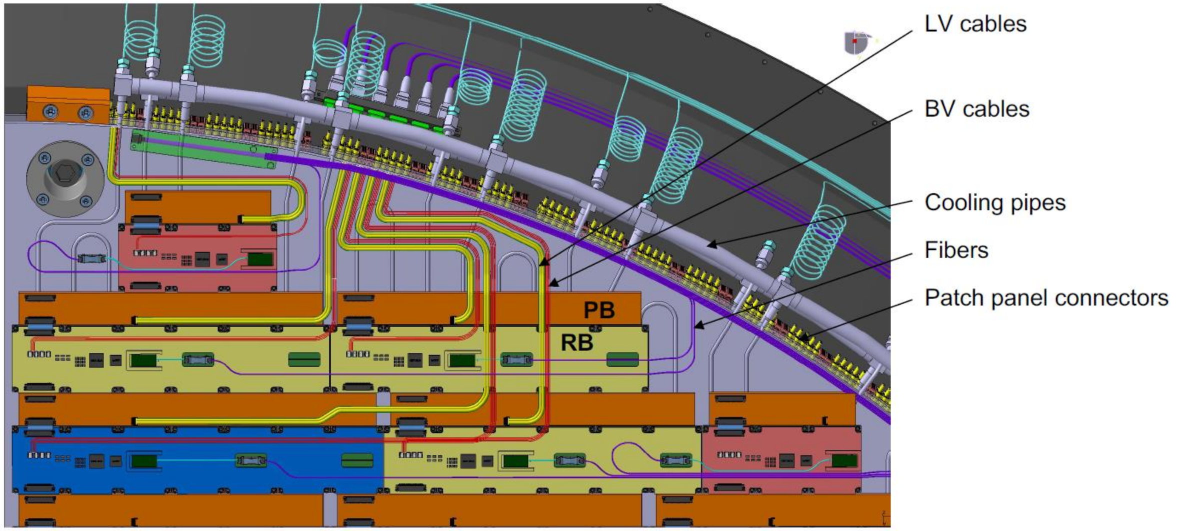
Backward AC-LGAD Info

	Forward	Backward
Sensors	0.6kW	0.35kW
EPTROC	8.5kW (17kW)	4.8kW (9.6kW)
DC-DC	3.5kW	2kW
lpGBT, VTRx+, SCA	0.5kW	0.3kW
Power cables	0.5kW	0.3kW
Total	13.6kW (22.1kW)	7.75 (12.55kW)

Backward TOF:



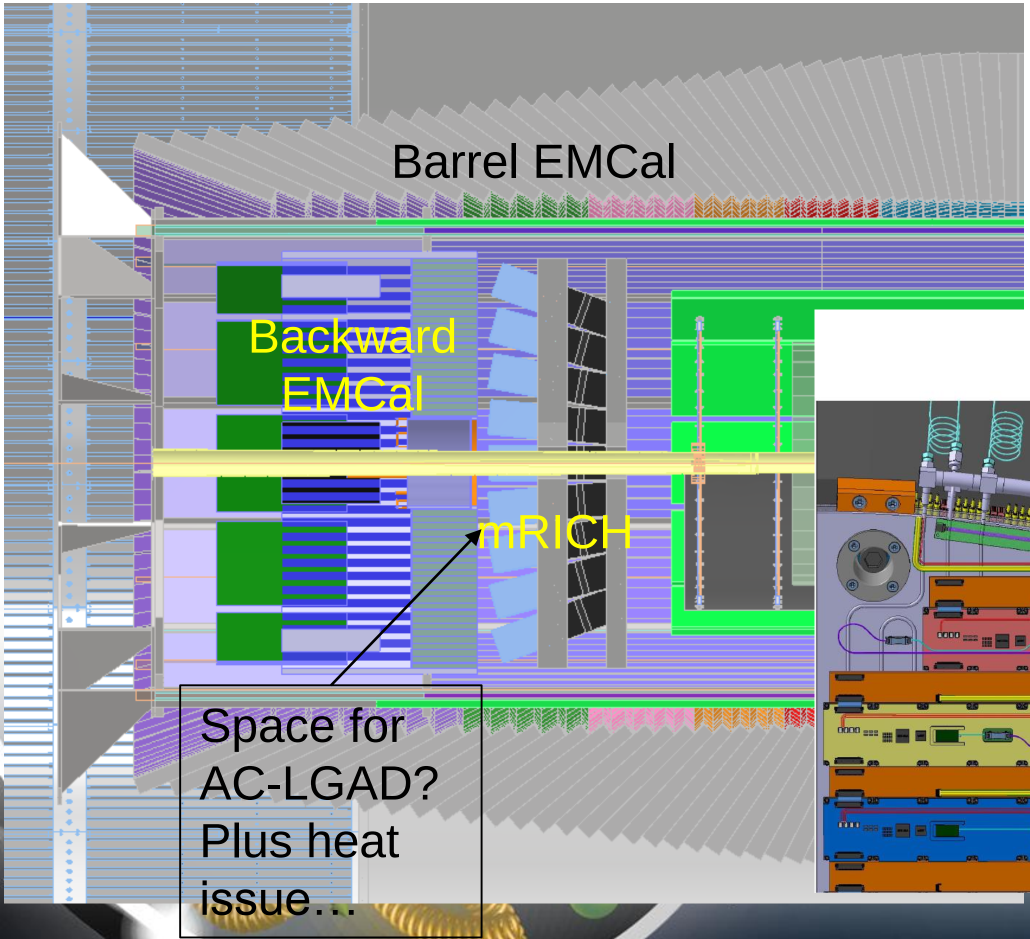
Service routing in CMS ETL

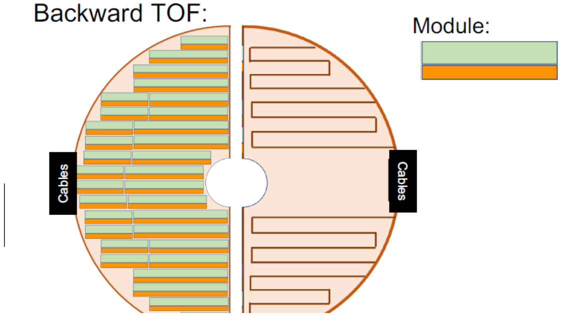


Information courtesy Wei Li , slides of Aug. 29 TOF/PID WG meeting

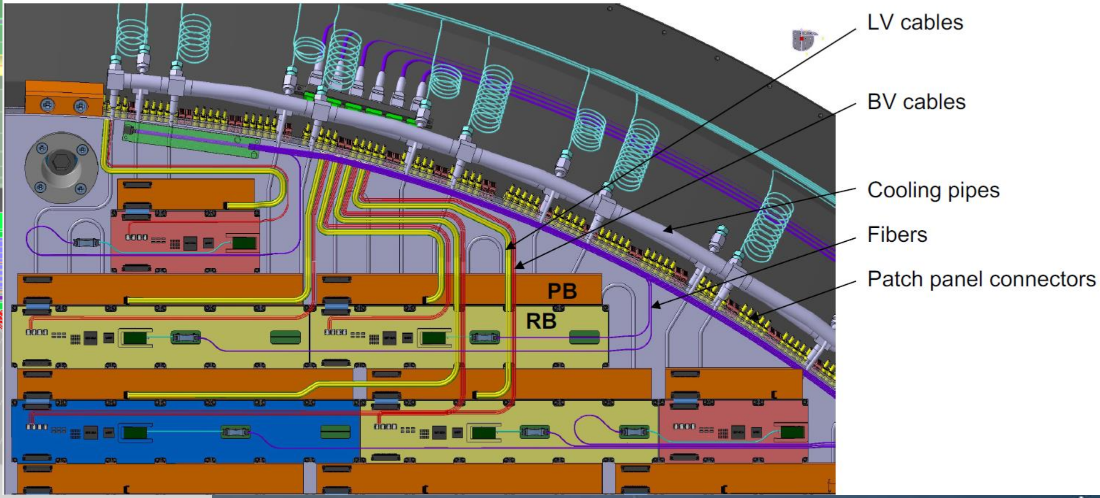
Integration Progress – Backward Detectors

- Backward EMCal is crucial for EIC, and we rely on it's high-precision performance.
- It has to be in a stable ambient temperature environment (< +/- 1º C)
- Even if material at the front face will not affect performance much, materials further away will and have to be minimized.
- AC-LGAD would provide both material and "a toaster" nearby…





Service routing in CMS ETL



Integration Progress - Iteration

Dear All,

I have some question to the sizes of the mRICH and pfRICH. What is currently modeled seems not fully correct in longitudinal. So let me summarize my understanding of the sizes of the different components and you correct me please where I'm wrong.

So the mRICH
- front face of the box
- 3cm Aerogel
- fresnel lense (all three up to now integrated: 4 cm)
- 6 inch drift == 15. 5 cm
- SiPM readout + cooling 20 cm according to Roberto
- back face of box

the angle under which the boxes are inclined is 24^o
—> so total length: ~40 cm

the pfRICH:
- front face of the box
- 4 cm Aerogel
- thin plastic sheet < 0.5 cm (all three up to now integrated: 5 cm)
- expansion volume 40 cm
- SiPM readout + cooling 20 cm according to Roberto
- back face of box

—> so total length: ~65 cm

So the next question I have is for Alexander, can you please give us a number for the radiation length of the LAPPDs and I assume it is correct we do not need the same massive cooling as for the SIPMs.
Roberto why do you think we need 20 cm for the SiPM readout, for the fHCAL we think we can fit a SIP-board, FEB + digitizer or ASIC board all in 10 cm
Alexander I assume we can assume 10cm for an LAPPD readout

Let me say, I think we need to push for the mRICH and the pFRICH what ever we choose for a LAPPD as photon sensor, the massive cooling of the SIPMs and also the AC-LGAD with its enormous power needs are really not okay to place in-front of the eECal. With LAPPDs we also do not need the ToF anymore as we get it from the LAPPD.

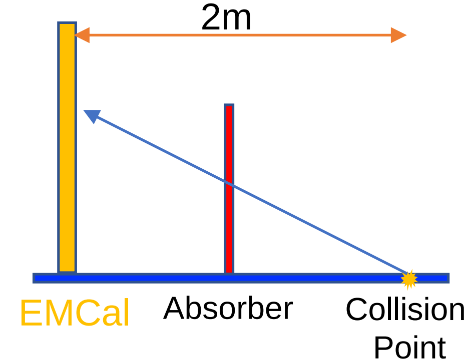
Effect of material on the way

- Material on the way to EMCal is inevitable

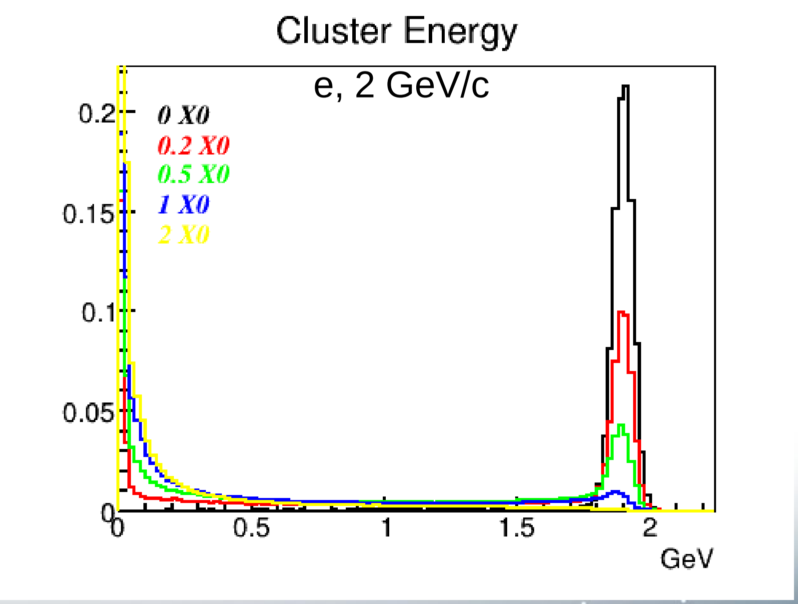
  Other detectors, cables, pipes, frames, etc

- It degrades the performance of the high resolution EMCal
  - Photon conversion
  - Bremsstrahlung radiation by electron
  - Early shower

GEANT simulation for a single electron



- Energy gets absorbed in the material
- Energy gets distributed in the EMCal, e.g. due to Bremsstrahlung radiation by electron
  - Single cluster reco leads to eff. loss
  - The eff. can be recovered by radiated photon reco
  - The closer material to the EMCal the smaller the effect
  - The higher Bdl the larger the effect
  - Rad. photons are localized in arcs with the same polar angle as a parent electron => topological search window

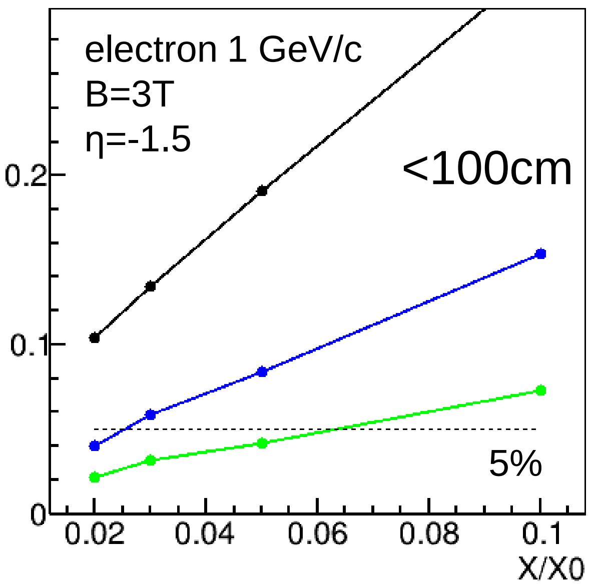


Slides courtesy Alexander Bazilevsky

Effect of material on the way

The most extreme case:
Highest Bdl, lowest *e* momentum, close to coll. point

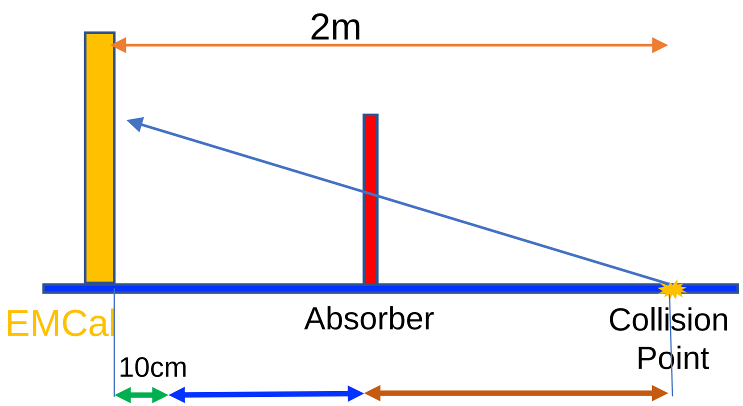
Efficiency loss (with 2σ cut) vs X/X_0



e cluster energy

e cluster and rad γ energy from Ecl>50MeV

e cluster and rad γ energy from Ecl>50MeV and $\Delta\eta=\pm0.2$, $\Delta\varphi=\pm0.5$



<50%X_0	<20%X_0	<(3-6)%X_0	Electron > 1GeV
<30%X_0	<10%X_0	<10%X_0	Photon > 0.1GeV

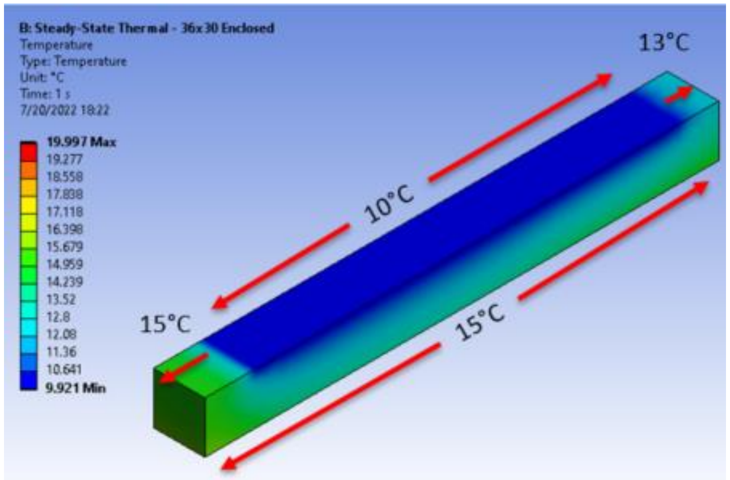
Exclusive requirements
(the whole effect assumed from one region) – % of whole effects are additive, *i.e.*, if one has 10%X0 in the near-collision point region that is it!

The amount and localization of tolerable materials are formulated

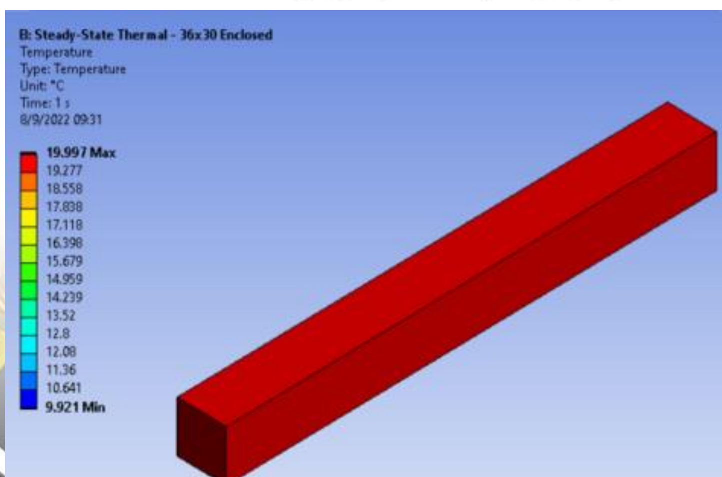
Slides courtesy Alexander Bazilevsky

The Issue with Heat Near the PbWO4 Calorimeter

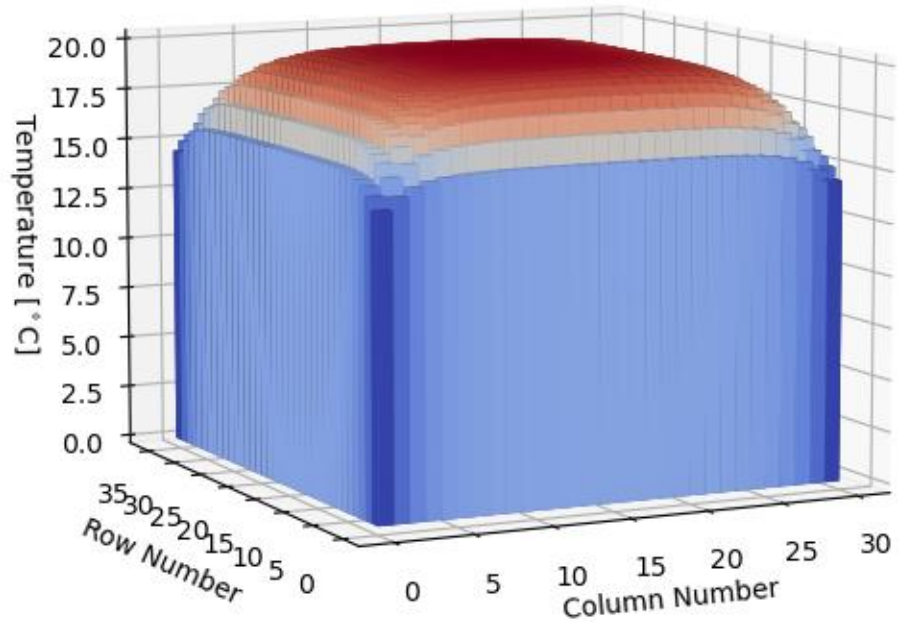
In this ANSYS/FLUENT calculation the ambient room temperature is 20º C and we apply a temperature of 10ºC on the outside periphery. Recall that the PbWO4 light yield has a temperature sensitivity of 2-2.5% per ºC. The precision relies on a stable temperature. This is for the NPS in Hall C, that has 30 x 36 PbWO4 crystals.



Single peripheral crystal (35,15)



Single central crystal (17,15)



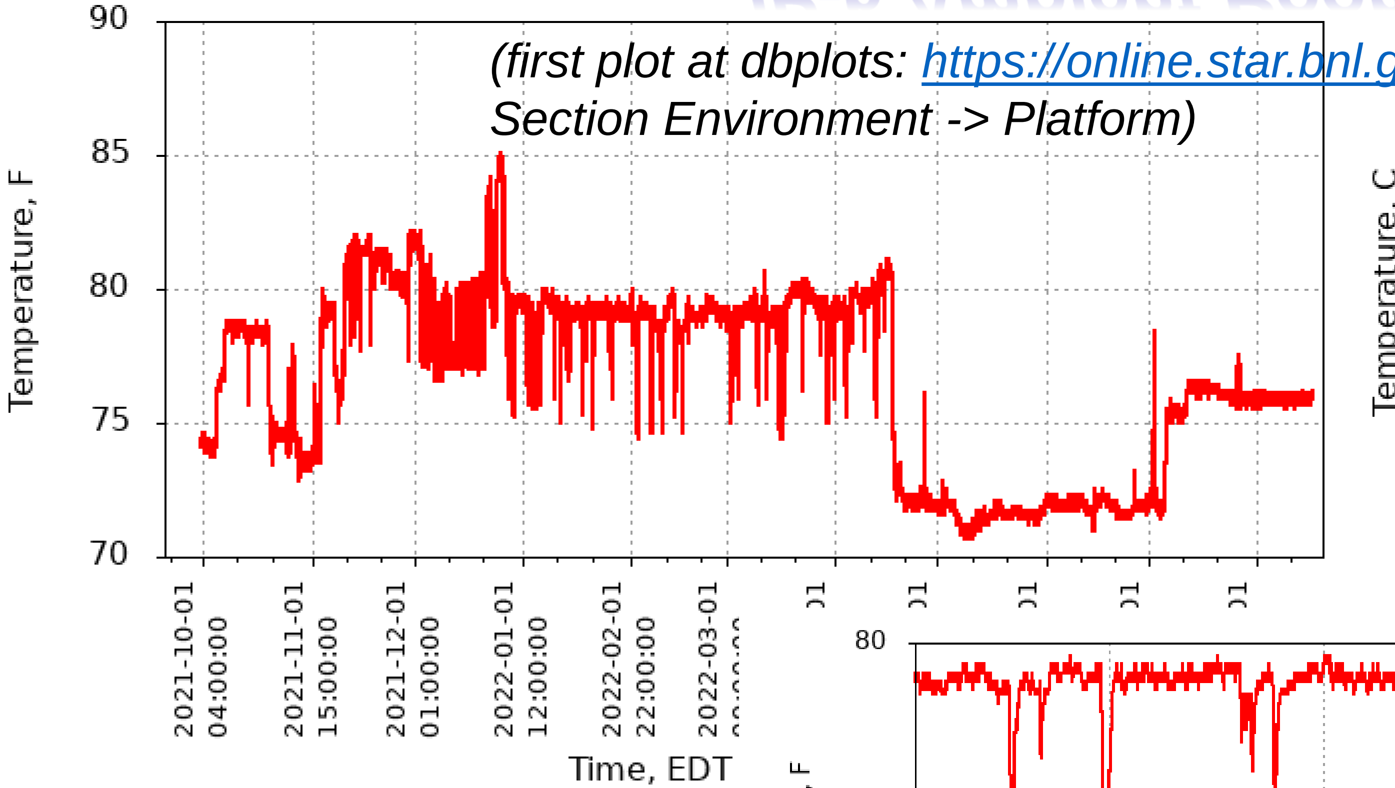
Requirements:

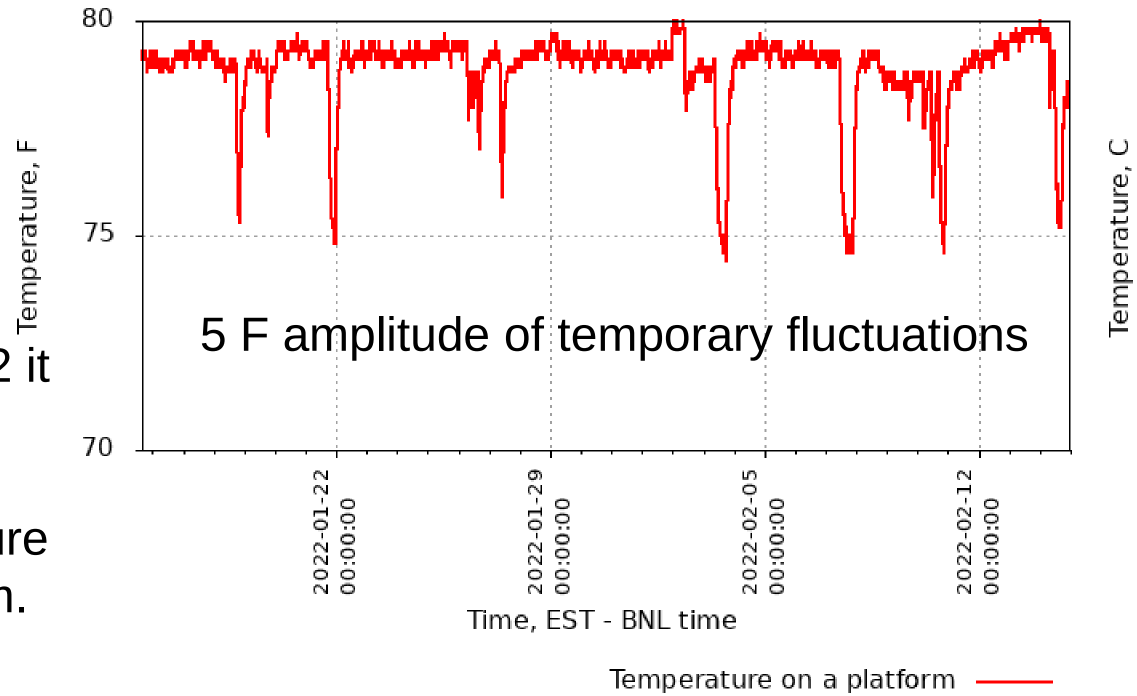
1) **a stable ambient room temperature**
2) **no heat at the front of the crystals where the shower starts.**

Slides courtesy Aaron Brown (JLab) based on work for the NPS

IP-6 Ambient Room Temperature

(first plot at dbplots: https://online.star.bnl.gov/dbPlots/#
Section Environment -> Platform)





During STAR operations, November 2021 to mid of April 2022 it is stable to +/- 2F (1º C) and then if we turn off things it drops a lot
→ rely on stable ambient temperature supplemented by monitoring system.

Alternative Solution Material Budget Estimate - LAPPD

I do not know either the density or the chemical composition of ceramic they presently use for the anode base plate. Same for the capillary glass array. So can give only an approximate estimate now.

Assuming a full ceramic body, and 10um pore MCPs, the essential layers are

- quartz window - 5mm -> ~4% X/X0 (can probably be reduced to ~3%)
- MCPs - 2x600um of a "standard" glass, roughly ~75% transparent -> small, <1% X/X0
- anode base plate - 2mm thick ceramic-> few % X/X0

If a standard readout board is used, ~2mm thick, it is ~1% X/X0 more, and some amount of copper.

Ceramic walls will of course contribute to the material budget as well.

I think one can pack ASIC cards in a ~10cm space, but we have not yet looked into the details. The effective channel count per mm^2 and power consumption per channel will determine the cooling needs.

ECA/RE: roughly 6% X/X0, not including ASICs and cooling
Need of course carefully compare the performance of
LAPPD vs. SiPM photon-detector

Information courtesy Alexander Kiselev

Summary

- It is crucial we do not optimize detector systems in isolation but directly look at the integration issues, including service needs (readout, cabling, cooling, …).
- The EIC science relies heavily on a high-resolution $PbWO_4$-based electromagnetic calorimeter in the backward direction
  - This has implications for the material budget for the other backward-region detectors in front of it – one must obey the total integrated amount and localization of tolerable materials, which are additive (as % of formulated regions).
  - For example, if I need 10%X/X_0 in the close-to-collision region, that's all. If I use Cu tubing for cooling with 2 mm wall thickness near the $PbWO_4$, that may be all.
  - This has implications in that the backward EM calorimeter relies on a stable ambient temperature (+/- 1^{o} C) to achieve high-precision performance, and thus prevents existence of large heat sources nearby.
- Folding in realistic readout space needs for any backward RICH detector invokes space budget issues.
- We suggest to consider study of a backward RICH detector based on LAPPD readout, even if there are also quantum efficiency issues to solve there, it may be the most practical solution compatible with EIC science needs and integration constraints.


BACK UP