# Combined Function Magnet/Calorimeter

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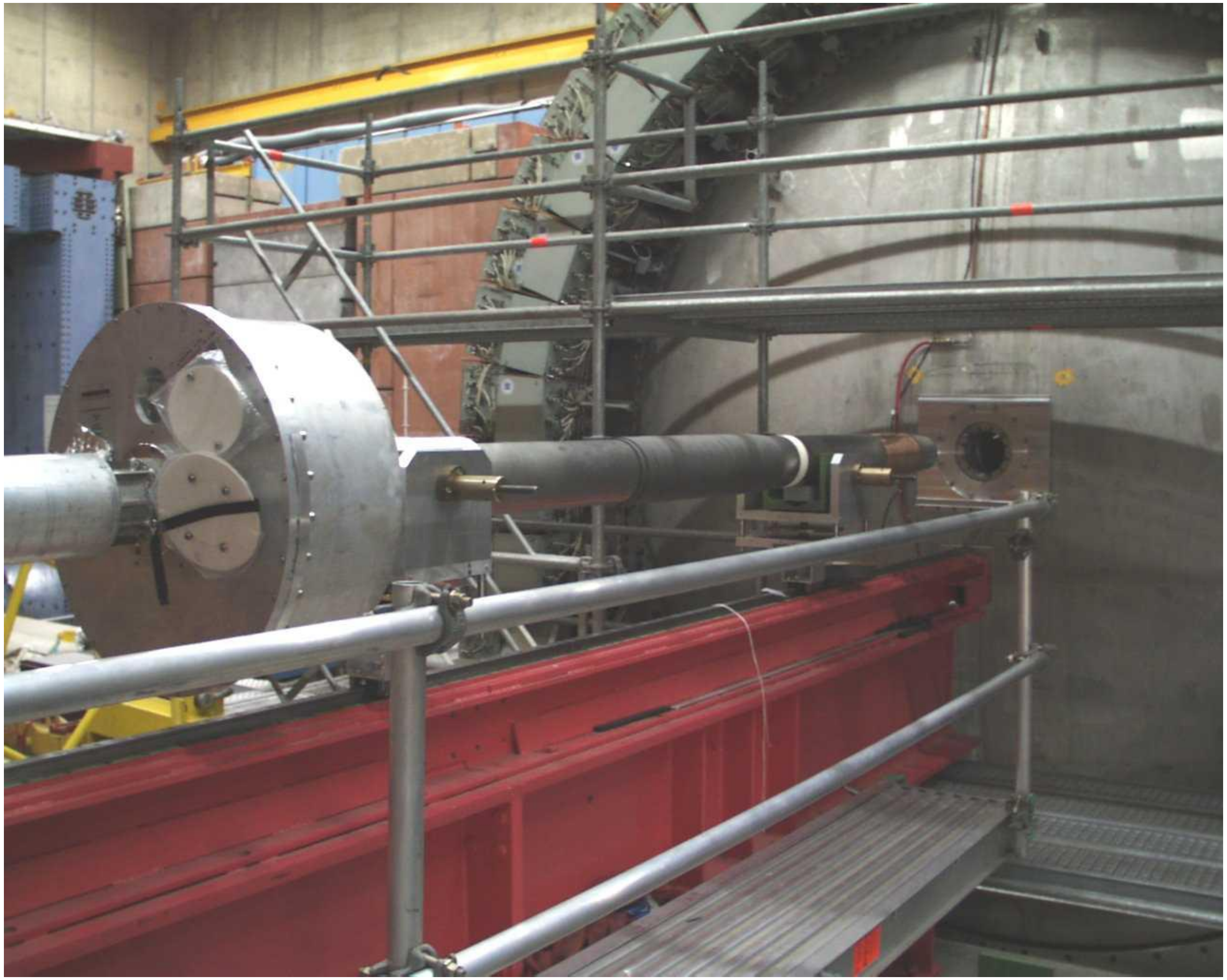
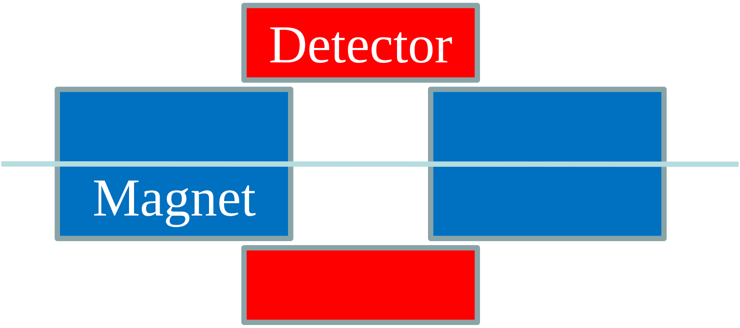


# Introduction

- A square peg...
  - Luminosity at (ep) collider inversely proportional to transverse area within which bunches collide.
  - Small area requires powerful focussing magnets as close to IP as possible.
- ...and a round hole:
  - Want largest possible experimental acceptance for physics studies.
  - No space for magnets near IP.
- Can we fit the square peg in the round hole?

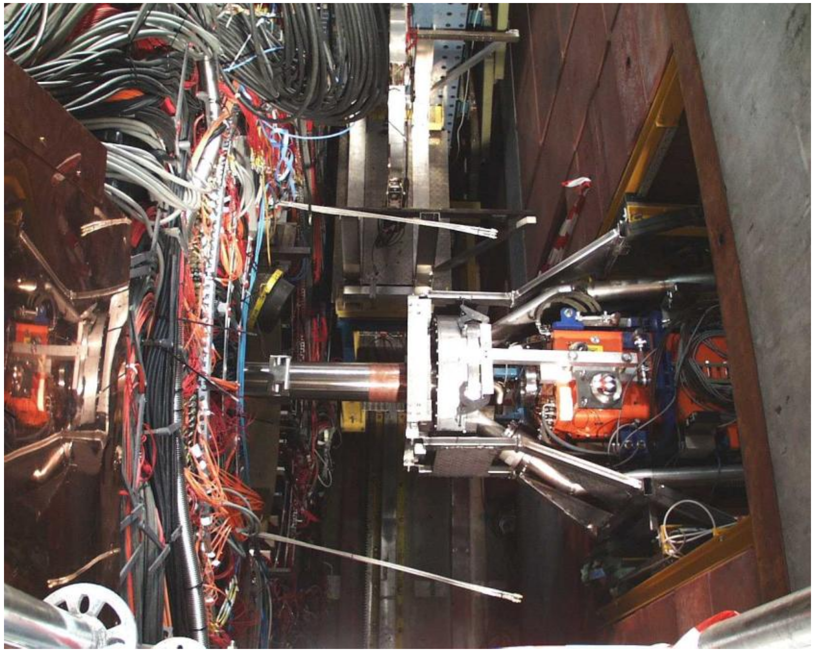


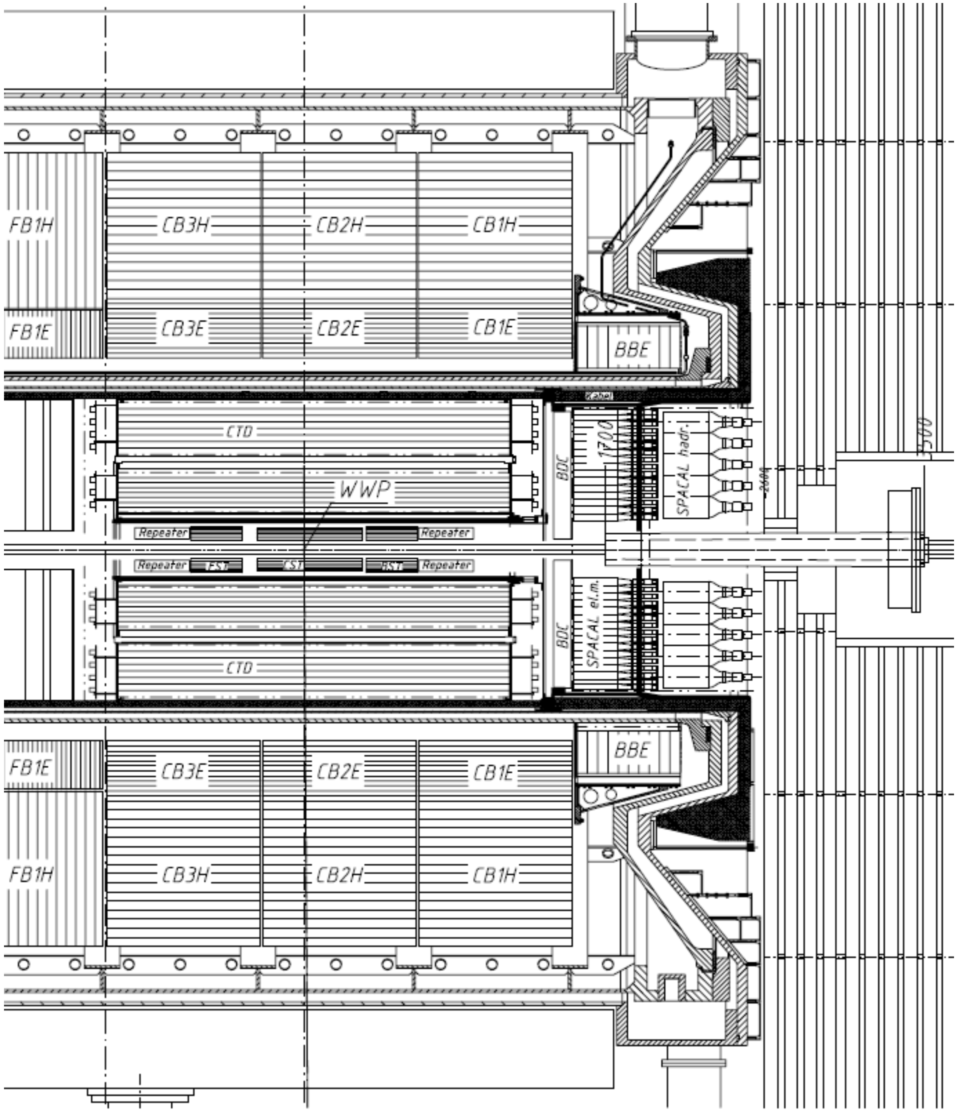
Detector

Magnet

# Introduction

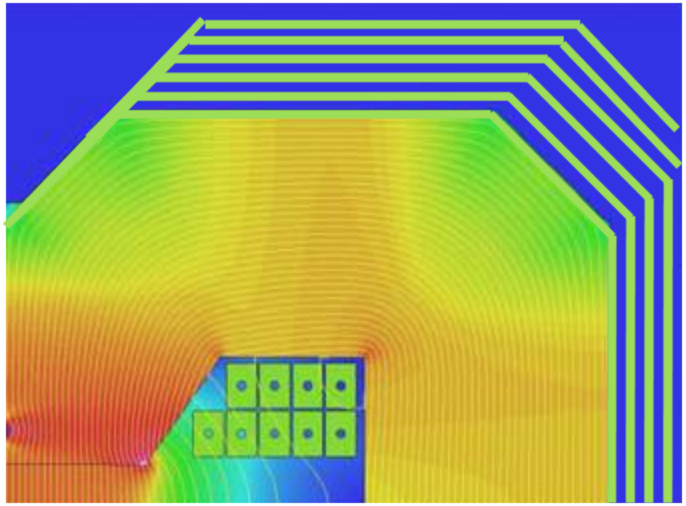
- An example, upgrade of HERA resulted in significant loss of experimental acceptance.
- Illustrated here for H1 detector.





# Normal conducting magcal

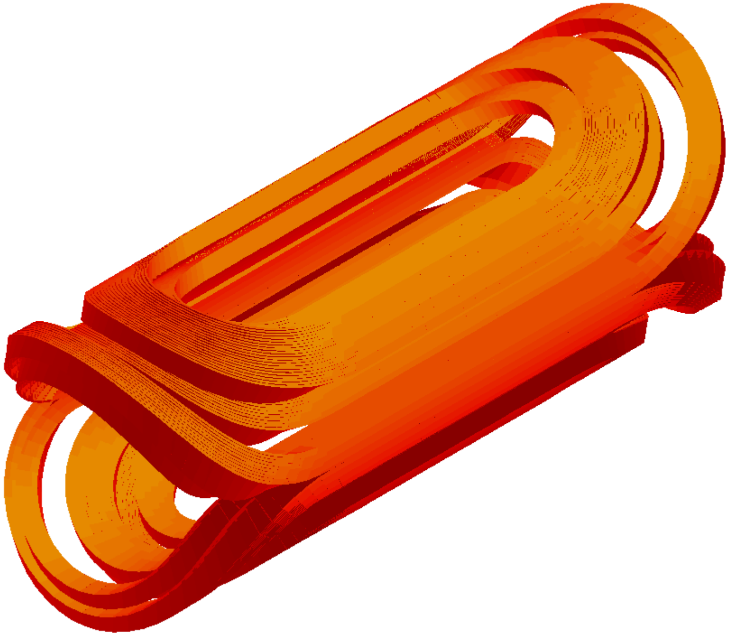
- Highest luminosities will always need magnets close to IP, so attempt to reduce their effects on acceptance.
- Normal conducting magnet, coils surround iron core.
- Segment core and insert scintillator between layers so magnet also becomes calorimeter but:
- Magnet then “all edges”, B-field quality affected?
- Focussing power per metre of magnet length reduced.



- Magnet quality perhaps reduced but want to optimise machine plus detector for physics, may still be worth consideration!
- Other possibilities, e.g. magnetic glasses simultaneously pole pieces and “crystal” calorimeter?

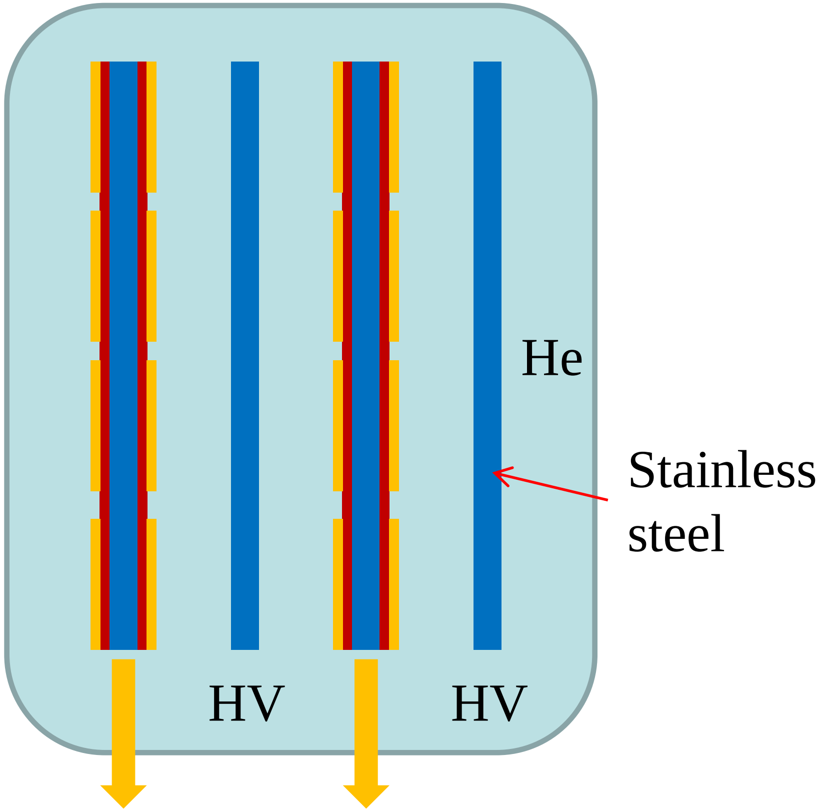
# Superconducting magcal – take one

- Helium cooled SC magnet.
- Coils in He bath.



- Space for calorimeter using He as active component?

- Could add stainless steel plates as absorber with readout pads:

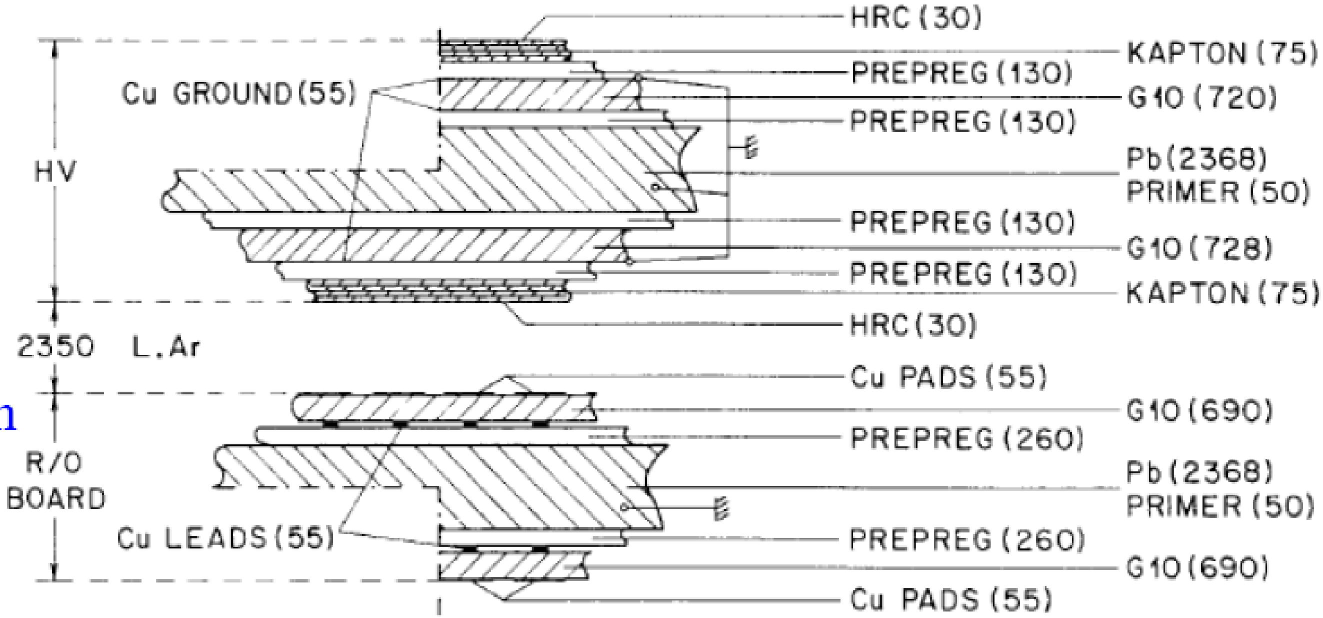


Readout pad signals

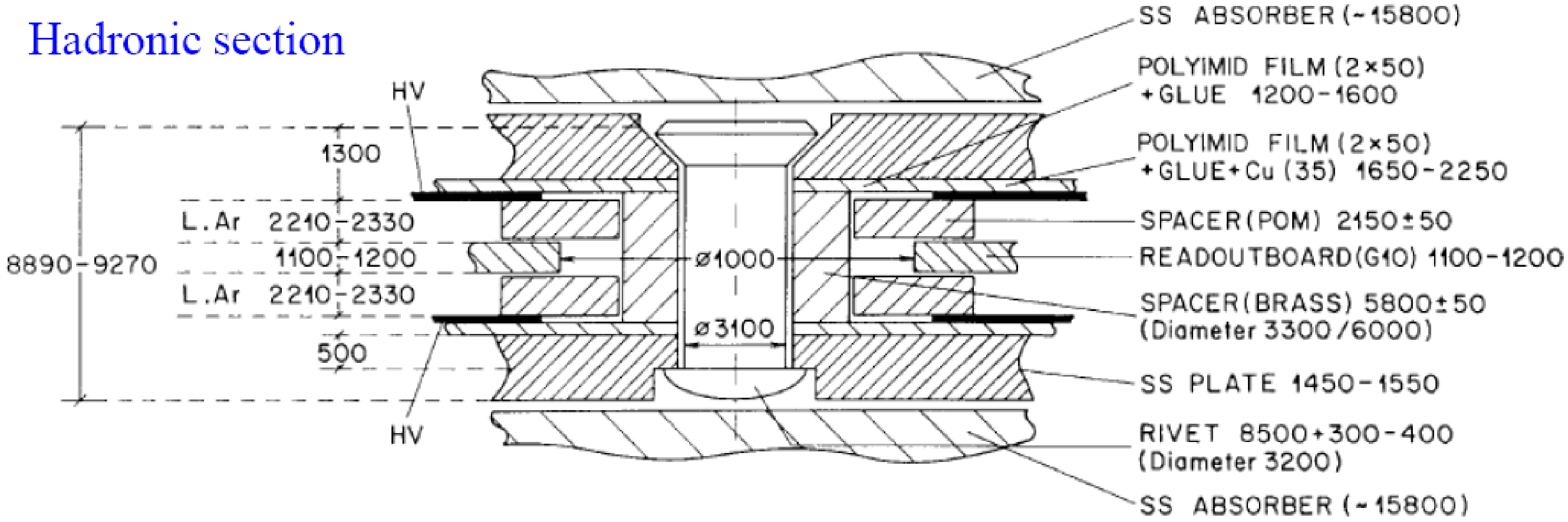
# H1 Lar Calo

## EM section

Dimensions in µm



## Hadronic section



# SC magcal – take one

- Particles interact in absorber.
- Charged particles ionise He.
- Electrons (ions) drift to electrodes inducing signal.
- Problem, mobility of electrons and ions in LHe.
- For $^4$He:

| **Temp (K)** | **$\mu^+$ (cm$^2$ V$^{-1}$ s$^{-1}$)** | **$\mu^-$ (cm$^2$ V$^{-1}$ s$^{-1}$)** |
|---|---|---|
| 0.372 | $5.19 \times 10^4$ | 540 |
| 0.510 | 6420 | 209 |
| 4.16 | 0.0470 | 0.0196 |

- C.f. LAr:
  $\mu^- \sim 500$ cm$^2$ V$^{-1}$ s$^{-1}$ at T = 86 K.

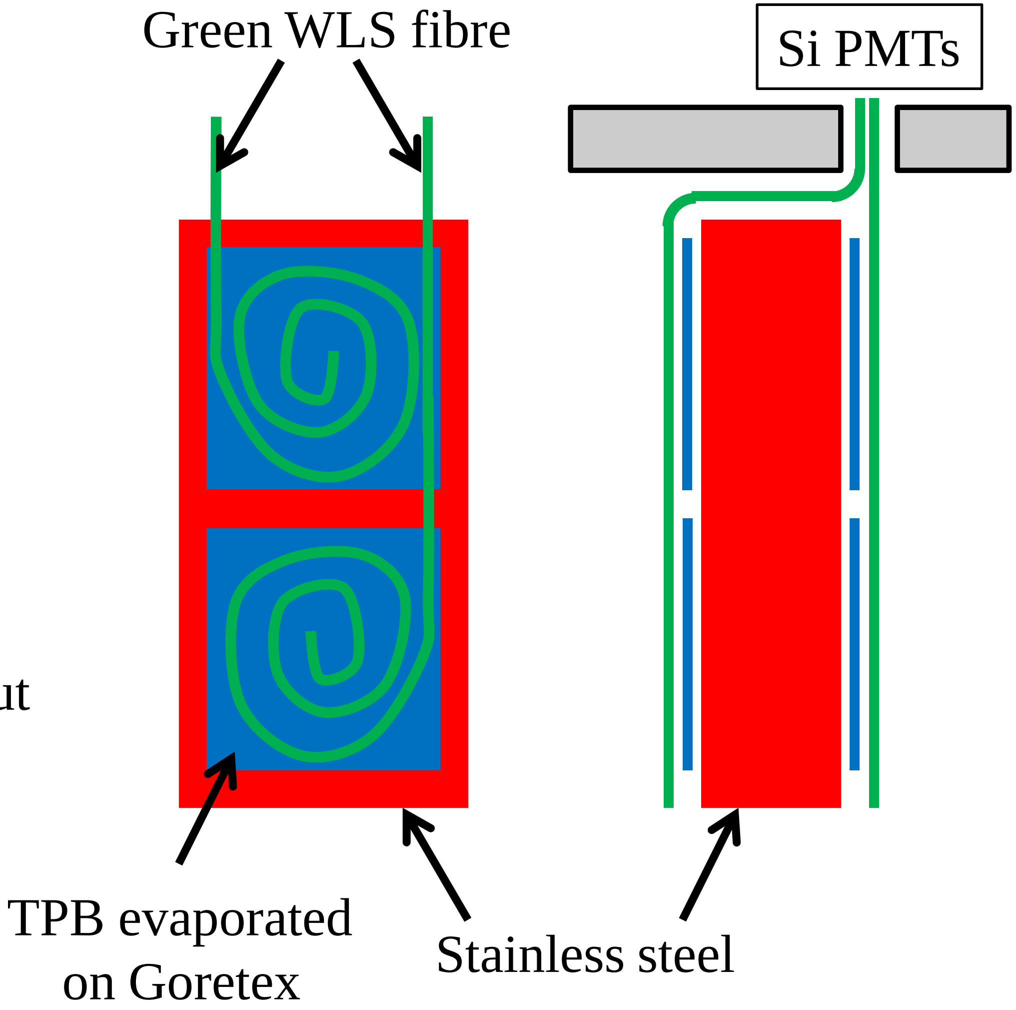
- Slow drift in He due to formation of "electron bubbles".
- Results in slow signals for T ~ 1K or higher.
- E.g. 50 μsecs for E = 100 kV/cm, 1 mm gap at T ~ 4K.
- Probably incompatible with high rate of particles in magnet.
- Ameliorate through very low temperature operation?

# SC magcal – take two

- Alternative: LHe is efficient scintillator, emitting light in the extreme ultra-violet (λ ~ 80 nm).
- E.g. 35% of energy lost by relativistic electrons in LHe emitted as fast (10 ns) pulse of EUV light.
- Mechanism: ion-electron pairs plus excited atoms formed.
- Ions attract ground state atoms and form excited diatomic molecules and excited atoms combine with atoms in ground state to form excited diatomic molecules.
- Diatomic molecules decay to ground state atoms emitting light.
- Energy of light lower than gap between ground and first excited state, so little re-absorption.
- The fluor tetraphenyl betadiene (TPB) absorbs the scintillation light and re-emits in blue (λ ~ 430 nm) with 135% efficiency.
- This (should) allow the construction of a SC fast calorimeter using LHe as active material.
- (Using LHe as a scintillator is being considered for e.g. Solar neutrino experiments.)

# SC magcal – possible design

- Consider steel/LHe sandwich design.
- If have ~ 2 mm thick stainless steel plates with similar width gaps, then:
  - $X_0 \sim 2.2$ cm.
  - $r_M \sim 1.9$ cm.
  - $\lambda_I \sim 21$ cm.
- Above determine necessary size of calorimeter and size of readout cells.
- Possible cell construction illustrated opposite.



Green WLS fibre

Si PMTs

TPB evaporated on Goretex

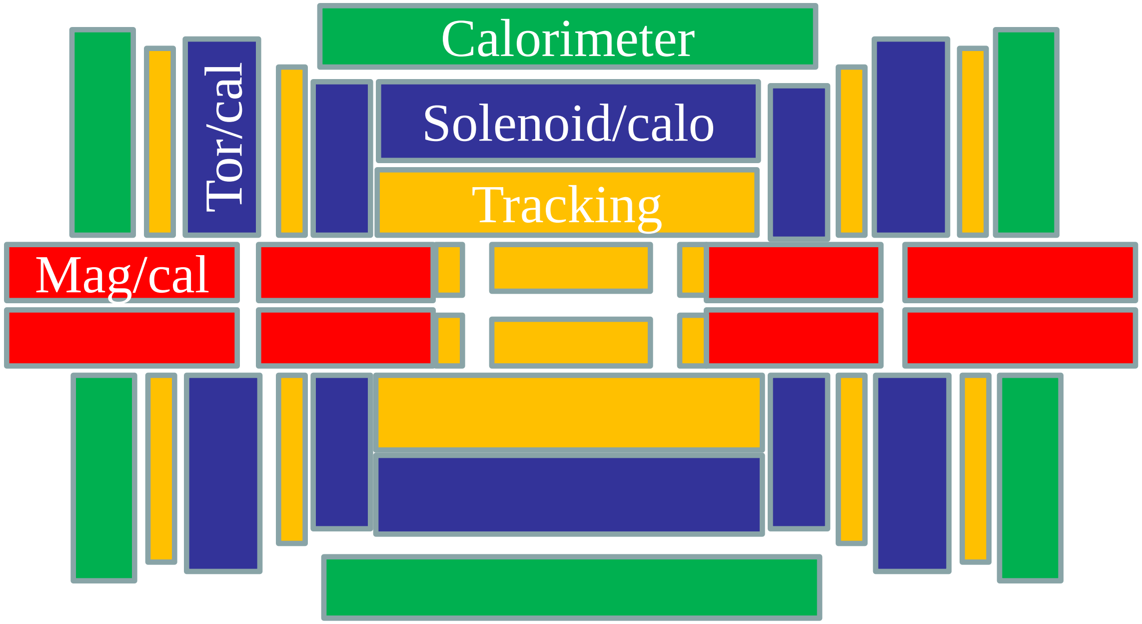
Stainless steel

# SC magcal – possible design

- Alternative materials include acrylic coated with TPB-doped polystyrene – all have been tested at LHe temperatures.
- Given time constants of fast LHe scintillation, TPB and WLS fibre, expect signal within ~ 30 ns.
- Energy to produce electron/ion pair 40 eV.
- MIP loses ~ 60 keV in 2 mm of LHe, produces about 9000 photons.
- Perhaps achieve about 10% “photon efficiency” overall.
- Should get usable signal from energetic showers.
- Any showstoppers?
- Serious simulation/design of magcal worthwhile?
- What is e/h ratio, achievable resolution (energy and spatial) etc.
- Need also study of interaction between calorimeter and magnet:
  - Can calorimeter steel plates be used to support coils.
  - Does “backsplash” into coils increase heat load and cause quenching?

# SC magcal – possible uses

- If it all works:
- Use magcal for machine magnets closest to IP?
- Also use for detector magnet(s) to minimise amount of dead material in front of calorimeter?
- Solenoid for central region plus toroids for forward region?



# Summary

- Highest luminosity at (ep) collider needs magnets close to IP.
- These limit experimental acceptance unless they can be “combined function” and provide (calorimetric) measurements.
- The iron in normal conducting magnets can be used in a sandwich or spaghetti calorimeter (but these not of interest here).
- Superconducting magnets probably cannot usefully be used in a conventional “drift” calorimeter because of low mobility of electrons in LHe.
- LHe/Fe (or Cu or U?) scintillation sandwich calorimeters look more promising.
- Unless someone sees a showstopper, attempt to study this more seriously.
- If can make reasonable combined function magnet/calorimeter, consider how best to incorporate these into machine and detector.