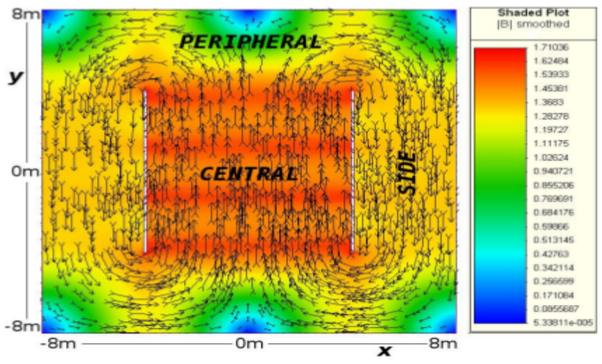
Simulations and Magnetic field measurements on mini-ICAL

Honey*
Homi Bhabha National Institute, Mumbai, India

Introduction

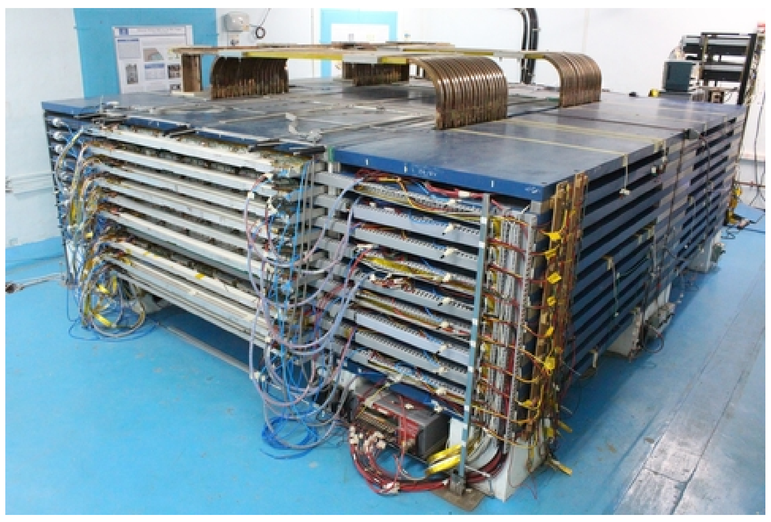
- **ICAL** is a magnetized 51 k-Ton detector with $B_{max} \sim 1.5$ Tesla. This allows measuring the charge and momentum of muons produced in charged current interactions of atmospheric muon neutrinos.



- **mini-ICAL** is an 85-Ton prototype ICAL detector. One of the aims of mini-ICAL is to compare the measured and simulated magnetic field to validate the magnet design.

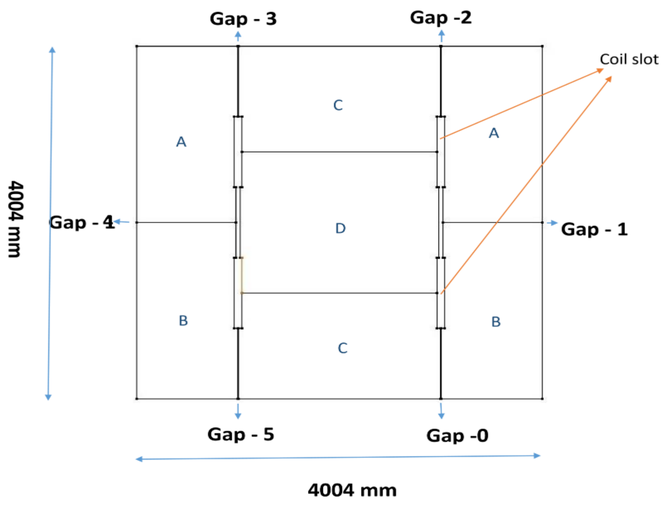
mini-ICAL Geometry

- mini-ICAL consists of 11 layers tiled with soft iron plates of 56 mm thickness. Each layer is 4 m x 4 m in dimension.
- 10 air-gaps of 40 mm thickness between the iron layers accommodating Resistive Plate Chambers capable of detecting charged particles.
- 2 sets of copper coils consisting of hollow OFHC copper conductor with 30 mm x 30 mm cross section and a 17 mm bore for water cooling , each having 18 turns. The current passed through these coils produces magnetic field in the mini-ICAL.



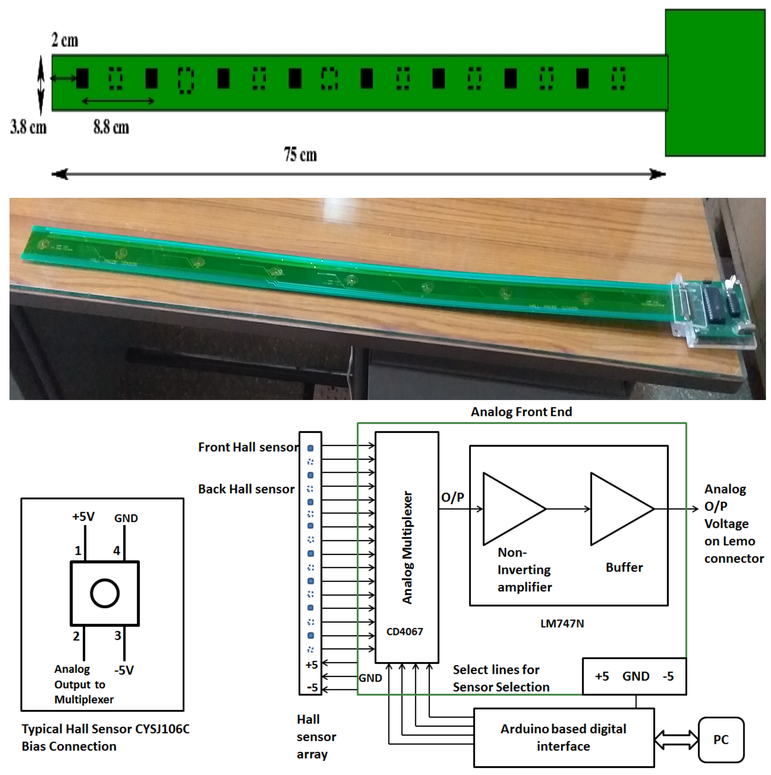
mini-ICAL upper view

- Each iron layer of mini-ICAL is tiled with 7 plates of iron. There are four types of plates - A, B, C and D. An intentional gap of 3 mm and 4 mm is kept between the iron plates in 1st, 6th and 11th layers to insert Hall probe sensors to measure magnetic field.



B-field Measurement system

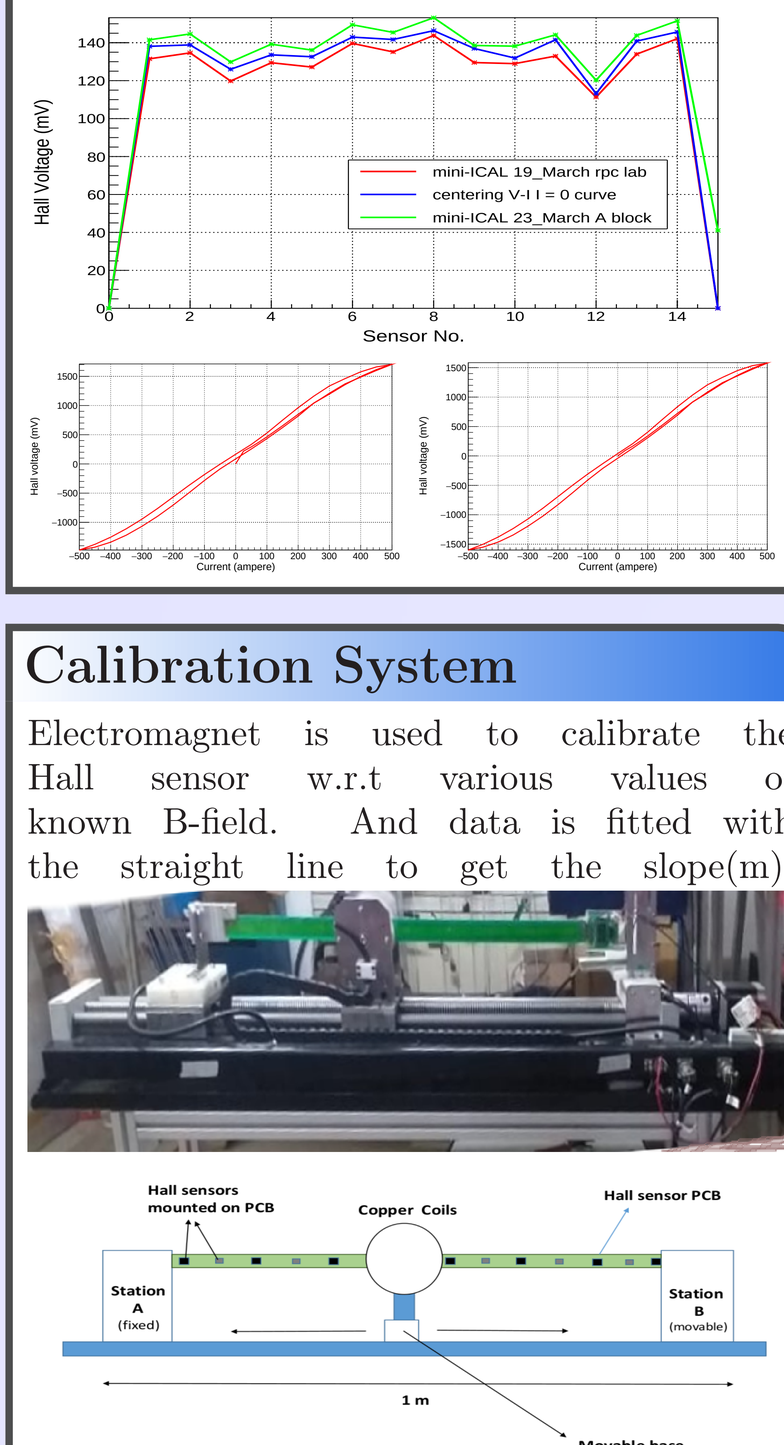
- **Hall probe sensors** are mounted on PCB which are inserted in the gaps between the iron plates at specific locations.
  - Measures Magnetic field in real time(steady state)
  - Basic material - Mono-crystal GaAs
  - Resolution - 10 Gauss



Offset measurement

Offset voltage (V_0) is calculated two ways:-

- Keeping the Hall PCB away from the mini-ICAL.
- Centering the V-I curve.



Calibration System

Electromagnet is used to calibrate the Hall sensor w.r.t various values of known B-field. And data is fitted with the straight line to get the slope(m).

Magnetic field calculation

The magnetic field is calculated using

$$B = \frac{V - V_0 + V_\epsilon}{m}, \qquad \delta B = \frac{B}{m}\sqrt{\frac{\Delta {V_0}^2}{B^2} + \Delta m^2}\ . \tag{1}$$

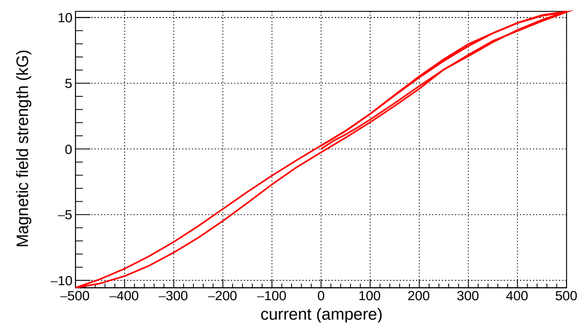
Here, V-measured Hall voltage, V_0-Offset voltage, m-slope of calibration fit and an extra offset $V_\epsilon = 8$ mV (due to alternate positioning of the Hall sensors on the Hall PCB).

Error estimation:-

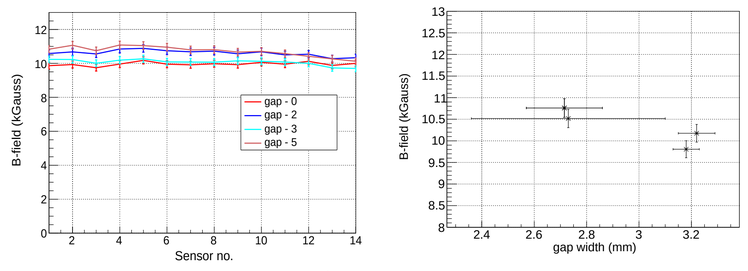
Eq-1 is used to calculate the error in the B-field measurement. Here, $\Delta V_0 = \pm 5$ mV (error in offset measurement), $\Delta m = \pm 3$ mV error in slope of the fit.

Results and Discussions

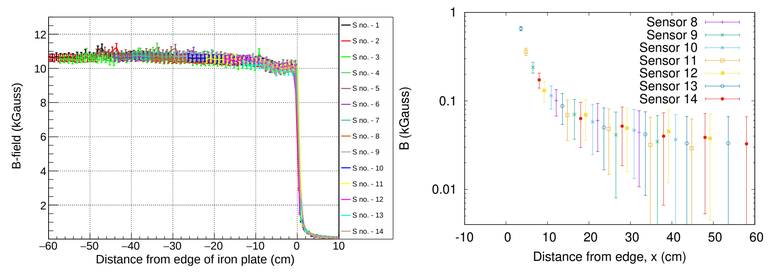
- B-I curve is traced for 500 amp current.



- Magnetic field is measured and compared in the gaps - 0,2,3 and 5



- Fringe field (magnetic field outside the iron plate) is measured



Future plan

- Measurement of the B-field in top, middle and bottom layer each having 8 gaps.
- Measurement of the field at the saturation and comparison of the simulated vs measured B-field.

References

[1] A Kumar et al., Pramana **88**, 79 (2017).

[2] D. Indumathi and M. V. N. Murthy, "A question of hierarchy: matter effects with atmospheric neutrinos and anti-neutrinos", 10.1103, Phys. Rev, **D 71** 013001, arXiv: hep-ph/0407336 [hep-ph].

[3] Shiba P Behera et al., IEEE Transactions on Magnetics **51**, 7300409 (2014).

[4] Honey et al, "Magnetic field measurements on the mini-ICAL detector using Hall probes", submitted to arXiv June 2022.

Acknowledgements

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E-mail: honey@tifr.res.in