Birmingham Irradiation Facility

Cold Irradiations
AIDA 2020 Kick off meeting CERN
4th June 2015
WP15.5

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On behalf of the UK Irradiation Team

LN_2 cooling background

- We want to be able to irradiate test samples at the Birmingham High Intensity Irradiation Facility at relatively high beam currents, between 0.1 – 2.0 μA.
- Standard silicon sensors are 300um thick x (10 x 10) cm^2; mini sensors (1 x 1) cm^2

- For protons of energy 27.5 MeV, the energy loss, dE/dx = 15.7 MeV $(g\ cm^{-2})^{-1}$

  Therefore, dE/dx = 15.7 x 2.33 = 36.6 MeV cm^{-1} = 3.66 MeV mm^{-1} = 1.1 MeV in 300 μm

  i.e. each proton will deposit 1.1 MeV in the sensor.

- Therefore a 1μA beam will generate 1.1W of heating in the sensor (300μm thick).

  (Heating due to a beam current of N μA = $(N \times 10^{-6} \times 10^{6} \times 1.6 \times 10^{-19}) / (1.6 \times 10^{-19})$ = N W).

  We need to be able to dissipate this heat efficiently from the mounted samples to keep the temperature below 0.0˚C (preferably).

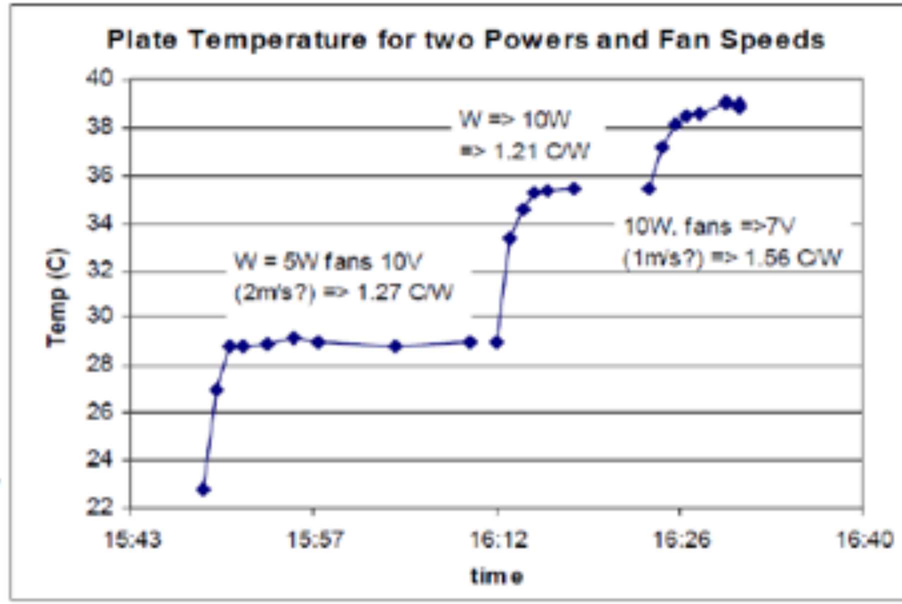
- The previous generation of thermal boxes, based on a design used at CERN PS, uses recirculating glycol pumped by a refrigerated chiller unit, through a heat exchanger system with indirect air circulation within the box. Tests have shown that this system (installed on the pre-2013 beam line at Birmingham) can cool the circulating air within the box volume down to -15.0˚C. Lack of direct air flow over the irradiated sensors can allow them to experience brief temperature changes of up to a ΔT = 50.0˚C

- The existing system the samples could have reached temperatures of ~40.0˚C with a 1 μA beam, hence reduced beam current running to prevent annealing of sensors and thermal runaway. Charge collection measurements of samples previously irradiated at the Birmingham irradiation facility show evidence of overheating when using beam currents of 1 μA or above.

Chiller system at CERN PS 2009

Dummy silicon heater tests using $100mm^2$
Aluminium plates with Kapton film heaters

- Chiller cooling the heated plate gives :
- 10W Sensor at -7C + Integrated hybrid => need to cool gas (N_2)to -22C
- Chiller cooling heated plate gives DT ~ 1.5C/W => 1W sensor at -7C => cool the N_2 to -8.5 C
- 3x ATLAS Upgrade 250nm strip sensors $100mm^2$ + hybrids, 2 fans at 10w, 12m of cooling circuit, 800w chiller power.
  Sensors 3 x 1W + Hybrid: 10W
  Fans: 10W
  Ambient conduction (DT=35C): ~20W (estd.)
  => sub-total for HEX: ~30 – 40W (*tested - ok! G.Beck et al 2009)*
- Conduction through insulation (2 x 6m) ~ 100W
- => total load for circulating chiller to remove ~ =< 150W or 50W per sensor



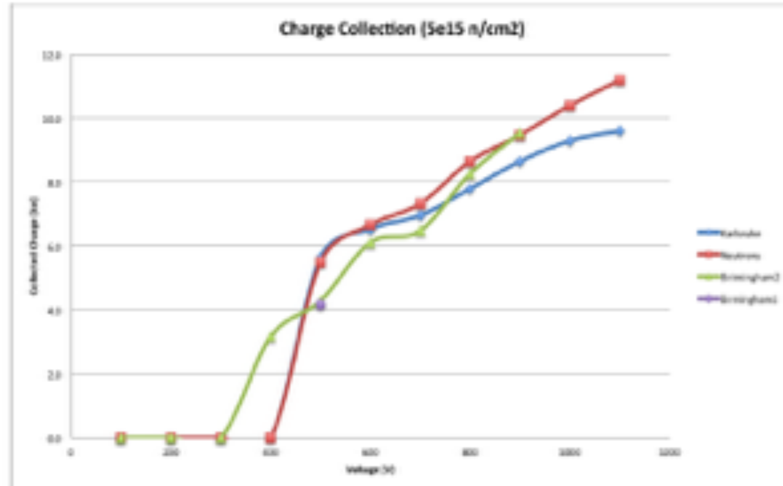
CONCLUSIONS

- Thermal chamber and chiller have more than enough head room to cool multiple sensors (powered)
- Temperature losses through transfer lines will be a problem if length exceeds 20m, loss per m is more dramatic the longer the length..........

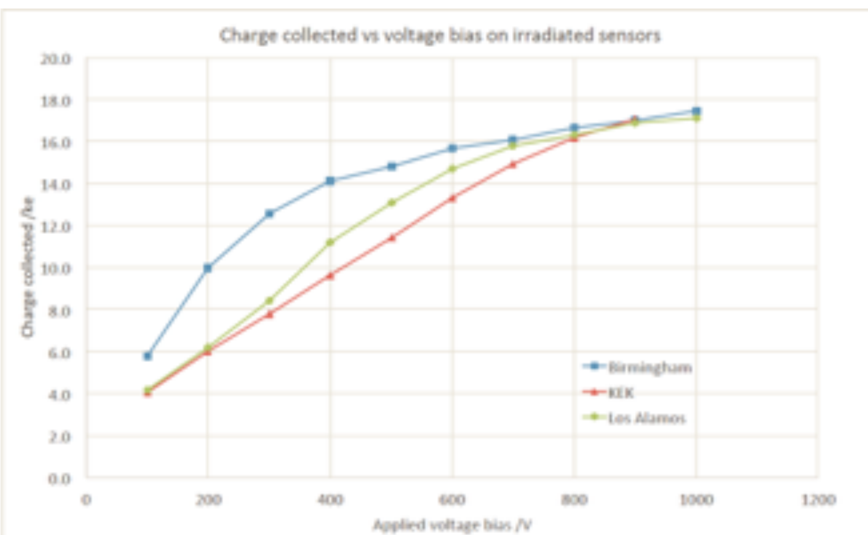
Initial Comparison

TR: Nov 2012 measurements presented at RD50 workshop, CERN

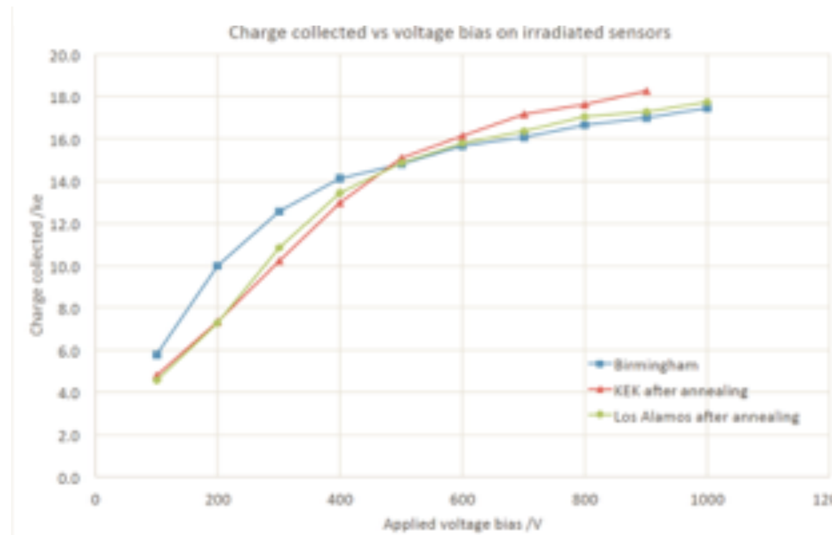
BL & BR: CCE measurement comparison plots with other facilities, confirmed initial signs of annealing. Presented in RESMDD14, Florence



- CCE measurements

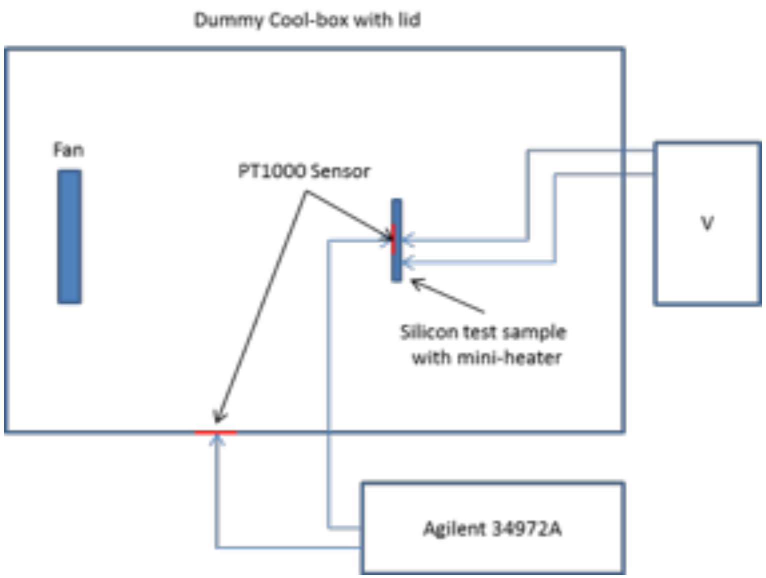


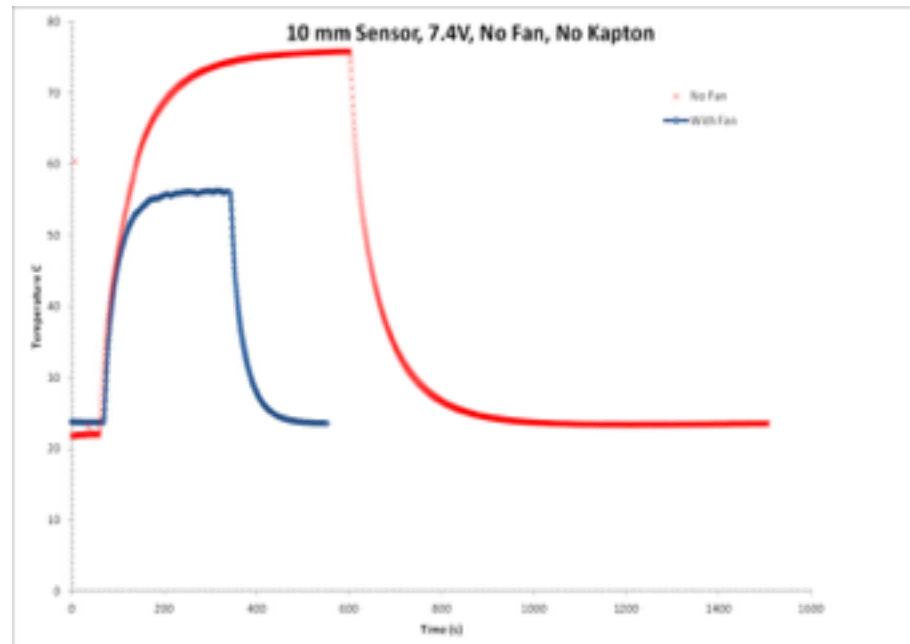
CCE measurements, before annealing



CCE measurements, after annealing

Sensor cooling test

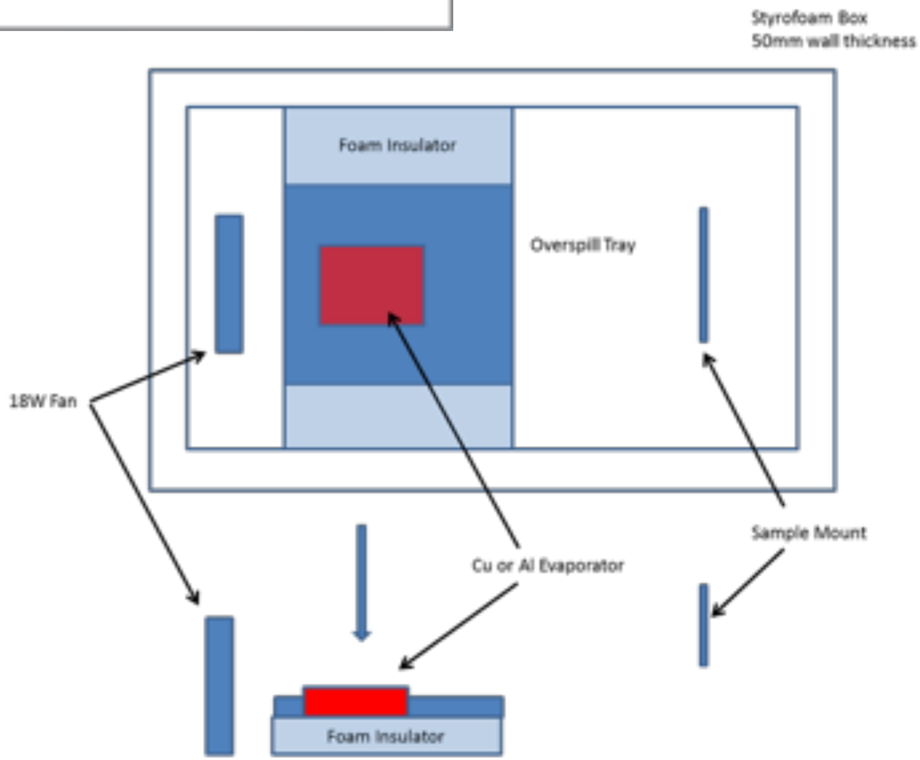


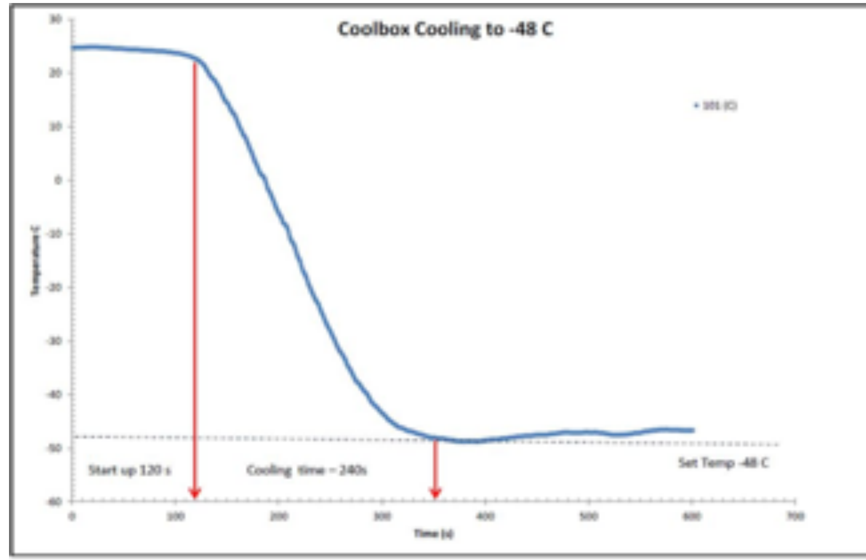


Test heating and cooling curves for 10 mm^2 silicon samples with a simulated 1 μA beam. Note these measurements were made at room temperature for convenience. The red curve shows the temperature profile for a sensor without any active air flow. The blue curve is for an identical sensor with a reasonable air flow over its surface.

The University Of Sheffield.

LN_2 cooling measurements

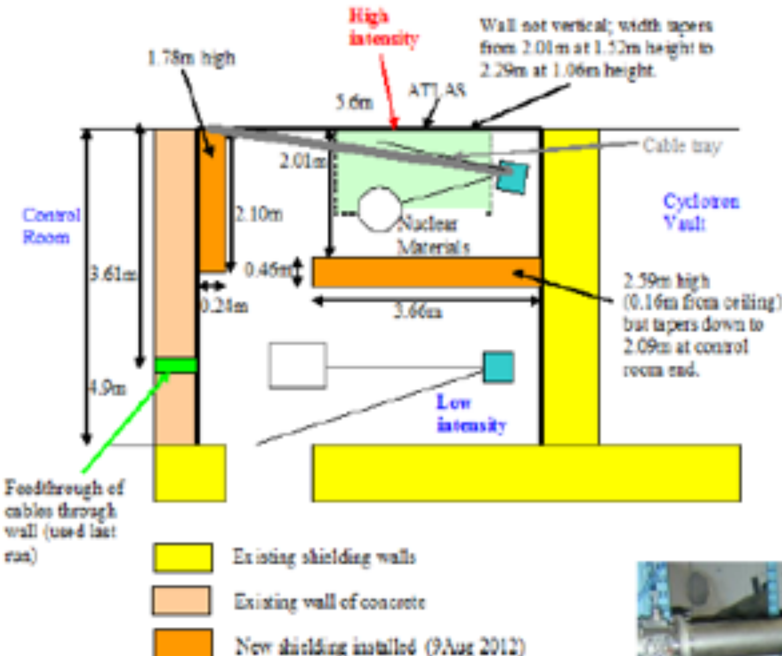


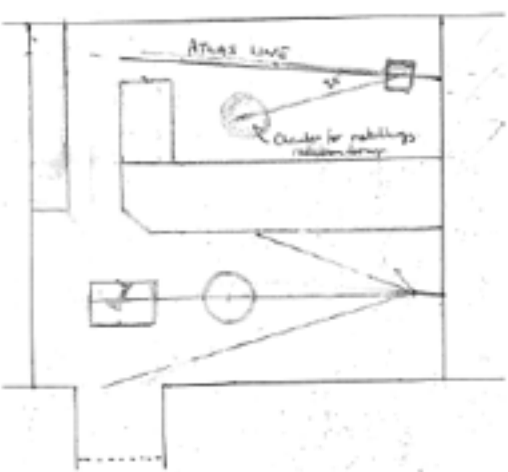


During normal operations at the cyclotron the standard beam current used is 1.0 μA. The LN_2 allows a quick cool down pre-irradiation. In initial tests, none of the samples were heated above 0.0˚C and the cooling was reasonably efficient with k values of 0.034 ± 0.003 s^{-1}

Measurement	0.1μA	0.5μA	1.0μA
k, Cooling [s^{-1}]	*0.0485±0.001*	*0.0292±0.001*	*0.0335±0.001*
k, Heating [s^{-1}]	*-0.0516±0.001*	*-0.0332±0.001*	*-0.0321±0.001*
ΔT cooling	*3.62˚C*	*16.98˚C*	*38.9˚C*
ΔT heating	*3.35˚C*	*18.52˚C*	*40.8˚C*

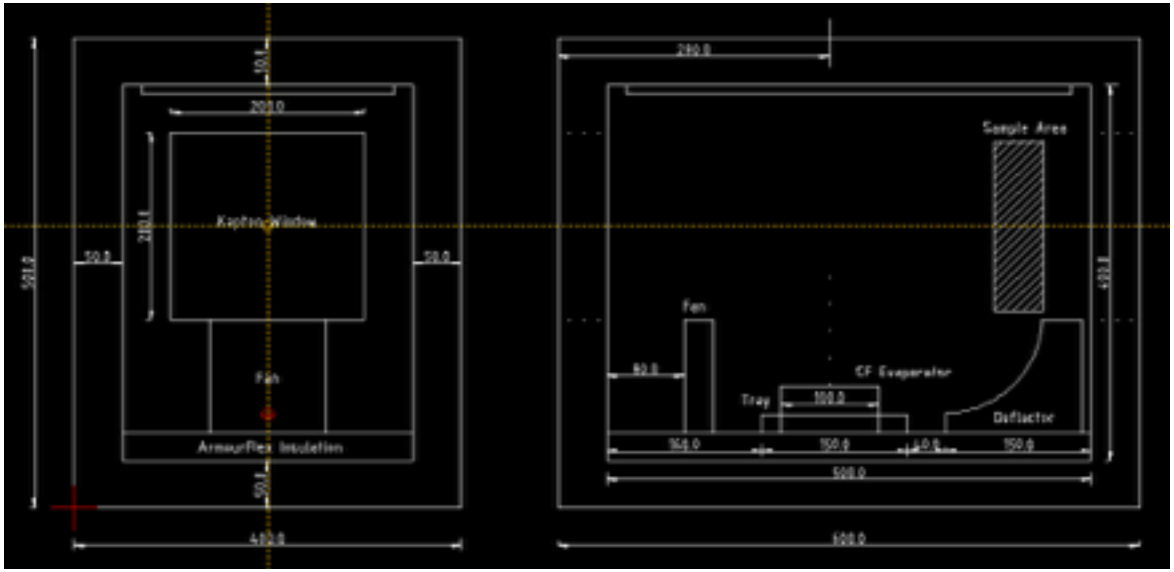
New 2013 beam area for HL-LHC irradiation at Birmingham University





Purpose built and commissioned by UK-ATLAS team in 2013 to allow for HL-LHC activities. See Phil Allport TA access presentation to book.

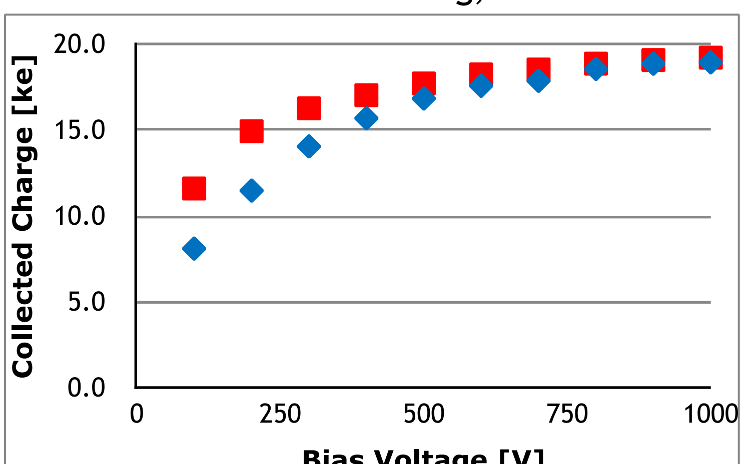
Working prototype LN_2 cooling for HL-LHC activity

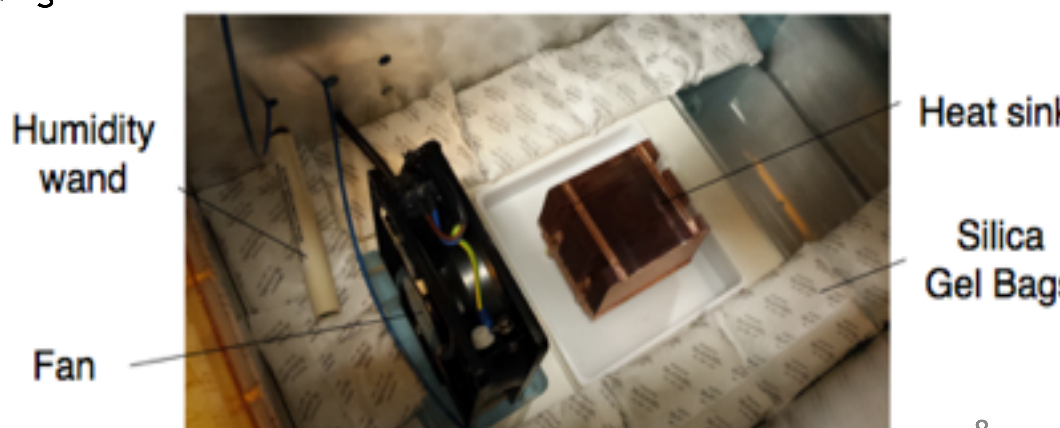


- Evaporative LN_2 system developed
- ~ -50 ºC ambient temperature opperation
- Ambient irradiation dimensions: XY-axis (40cm×45cm) scanning system
- Cold irradiation dimensions: areas up to 15cm×15cm

Charge collection measurements from recent irradiations with LN_2 at 500 nA to 5×10^{14} n_{eq}

Blue: before annealing, Red: after annealing





WP15.5 AIDA2020 plans

- Custom LN_2 dosing system
- Robust thermal chamber
  - Refined from existing prototype
  - Increase cold irradiation area from 150x150mm to 350 x 200mm to allow for multiple large area sensor irradiation
  - The aim is to develop the thermal chamber further and understand the effects on the sensors from the high intensity beam

This includes, development, testing, LN_2 supply, pump, dewar, sensors, DAQ and computing with custom GUI developed in Sheffield, new thermal box with evaporators and CFRP material development