Upgrade to the Birmingham Irradiation Facility

The University Of Sheffield.

K. Parker,

R. French, P. Hodgson, H. Marin-Reyes

J. Wilson, M. Baca

P. Dervan

Also many thanks to Prof. David Parker and Mike Smith at the Medical Physics Cyclotron as well as Paul Kemp-Russell and Simon Dixon

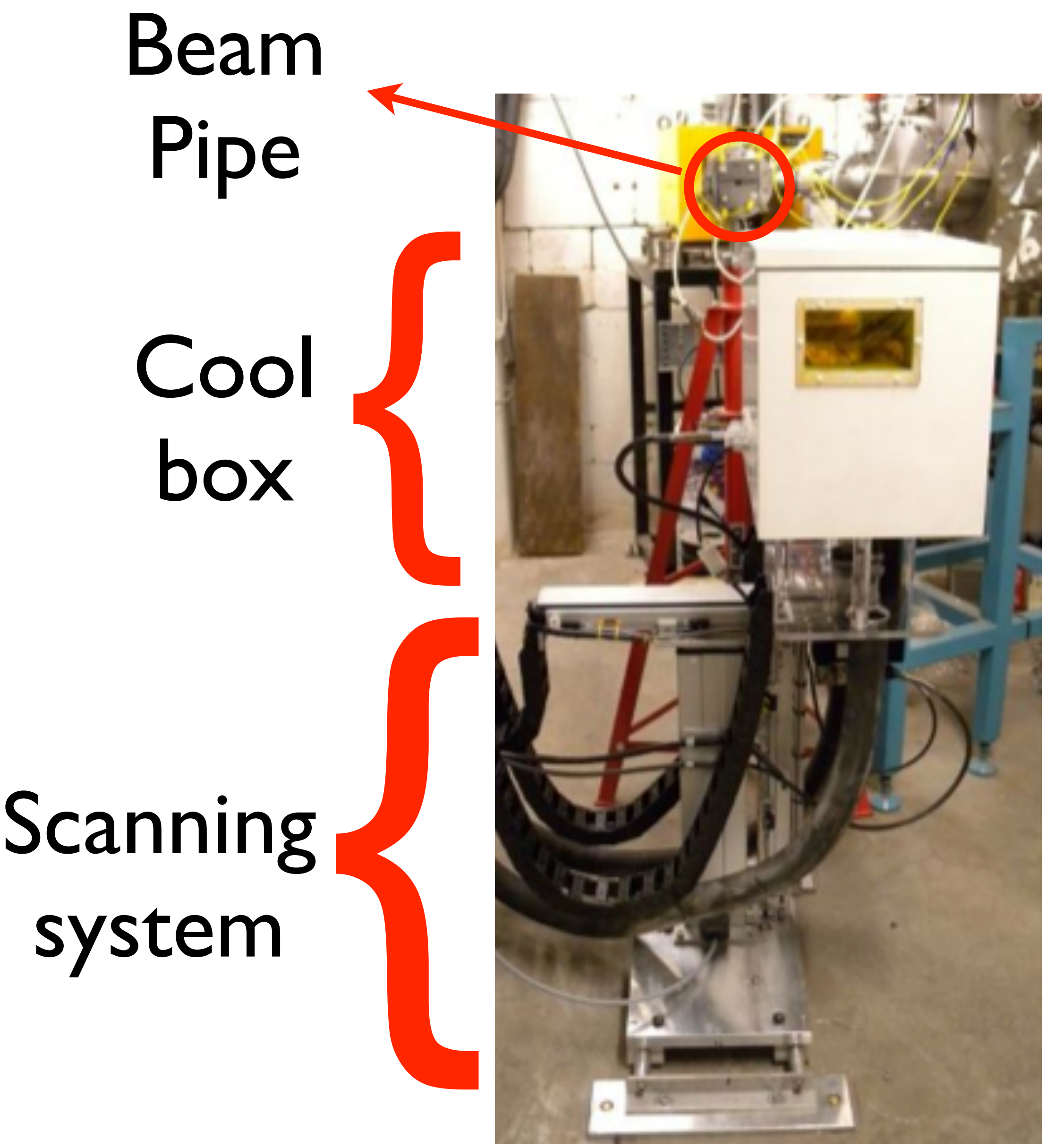
RESMDD14, 9th October 2014

Introduction

- Medical Physics Cyclotron (MC40) at University of Birmingham is used to irradiate materials and sensors for HL-LHC
- 27 MeV proton beam can achieve HL-LHC fluences of ATLAS inner layer of strip system (10^{15} cm^{-2} 1 MeV n_{eq}) in 80s with 1 μA beam current
- Pre-configured XY-axis cartesian robot system (scanning system) has been installed in the radiation area to allow homogeneous scanning through the beam
- Samples are placed in a cool box on the scanning system
  - Initially recirculating glycol for cooling
  - Recent upgrades with instalment of new LN_2 cooling system
- Window for initial cool box: 80 x 140 mm^2, upgraded cool box: 150 x 150 mm^2

Irradiation Facility

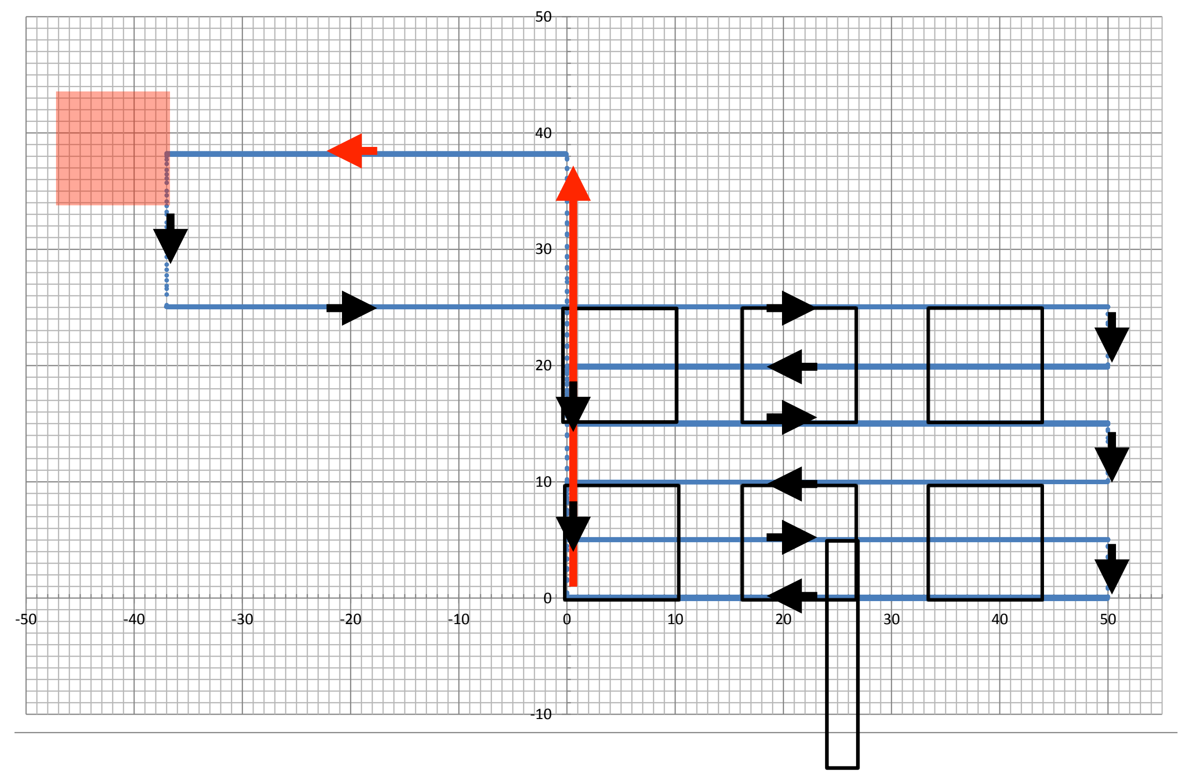
- System commissioned in early 2013
- Until September 2014, 211 samples irradiated including:
  - ✓ Carbon Fibre (CF) sandwiches for staves
  - ✓ Pixel and strip sensors
  - ✓ PCB material
  - ✓ JFETs
- Various tests performed on samples before and after irradiation to test their response to HL-LHC fluences



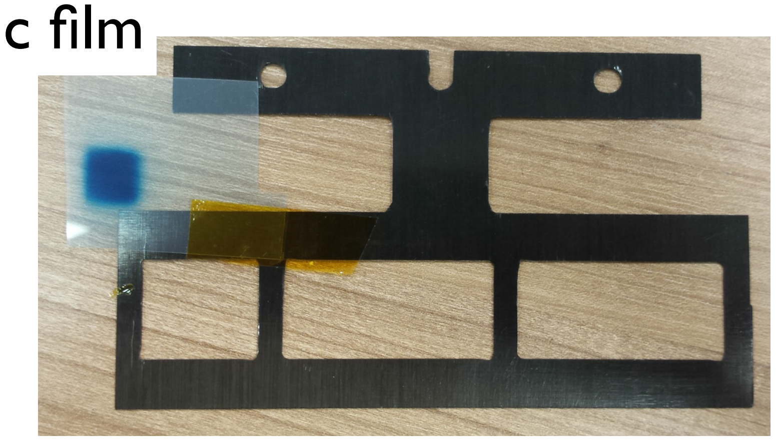
Scanning system

- Controlled using a NI RIO Real-Time programmable controller with a LabView GUI
- Scans through the beam at 1mm/s horizontally and 25mm/s vertically
- Several iterations of scans are done to ensure any beam fluctuations are removed
- Beam profile and position is checked using Gafchromic film before the scan
- Nickel foils and Faraday cup are also used to cross-check the fluence

Scan path of irradiation

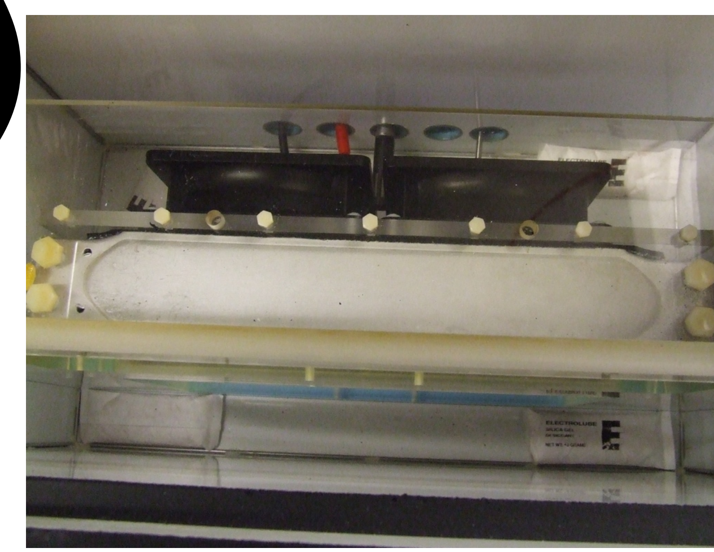


CF Pixel Frame
with Gafchromic film



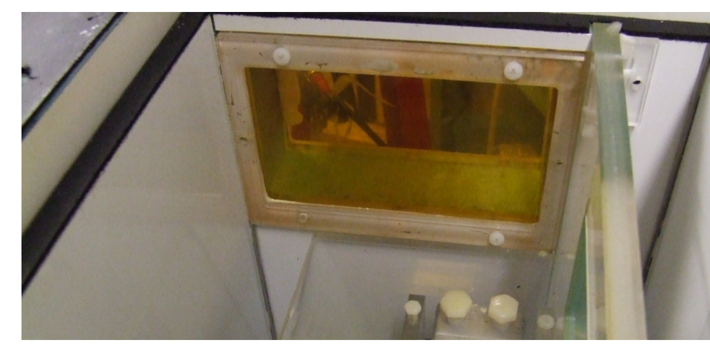
Cool box (1)

- Cool box with kapton window based on CERN-PS irradiation setup
- Recirculating glycol system
- Purged with dry N_2 to prevent condensation forming
- Fans within the cool box
- Temperature and humidity monitored using LabView
- Samples within the cool box secured in place with CF frames attached to the lid and secured in place with kapton tape
- Maintained at -15 °C, 2 hour cooling time



Inside of the cool box

Kapton Window

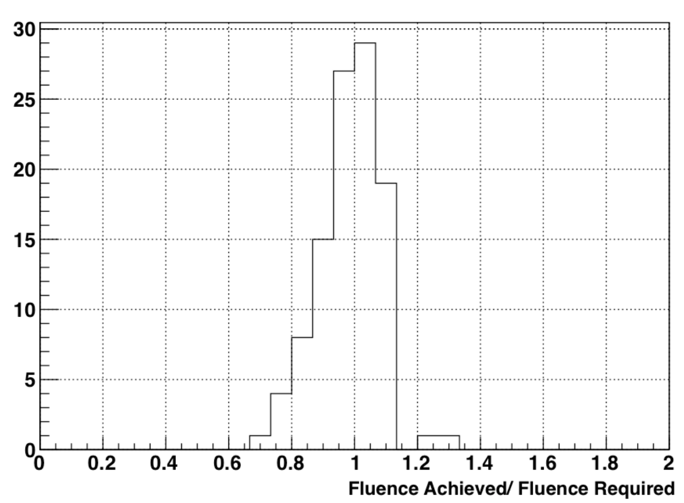


Box lid with matrix of holes

CF Strip Minis Frame

Sample Irradiations

- Table shows irradiations performed between February and July 2013
- Total of 91 samples irradiated during this time



Sample	Number irradiated	Fluence n_{eq} cm^{-2}	Comments
Carbon Fibre	4	$1x10^{15}$	Honeycomb structure
ATLAS07 strip sensors	14	$1x10^{15}$, $5x10^{14}$, $1x10^{14}$, $5x10^{13}$, $1x10^{13}$, $1x10^{12}$	Minis, 2 at each fluence
Silicon pixels	36	$5x10^{15}$, $1x10^{15}$, $5x10^{14}$, $2x10^{14}$	9 at each fluence: 3 single, 3 slim edge, 3 double (Wafer 4, 16, 2873-4)
Parylene coated pixels	8	5@$2x10^{15}$, 2@$2x10^{14}$, 1@$5x10^{14}$	Pixels and medipix
ATLAS12 strip sensors	18	$1x10^{15}$, $5x10^{15}$	9 at each fluence, minis: 3 slim edge, 3 regular 3 full-size slim edge
JFETs	8	$3x10^{14}$	4 bare, 4 mounted to PCB
PCB material	3	$1x10^{15}$	G10, FR4 and ROHS

Table 1: Samples irradiated February - July 2013

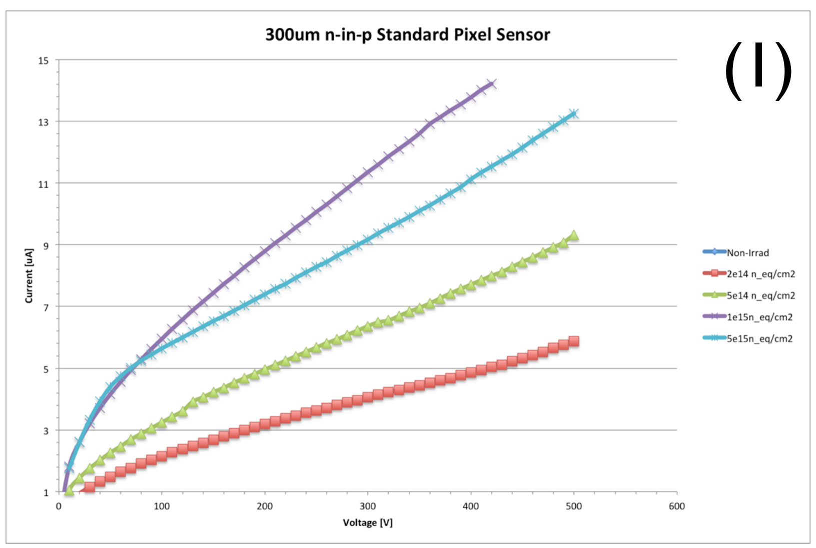
Overall, for the above samples, the fluence received is accurate to within 10% of the target fluence

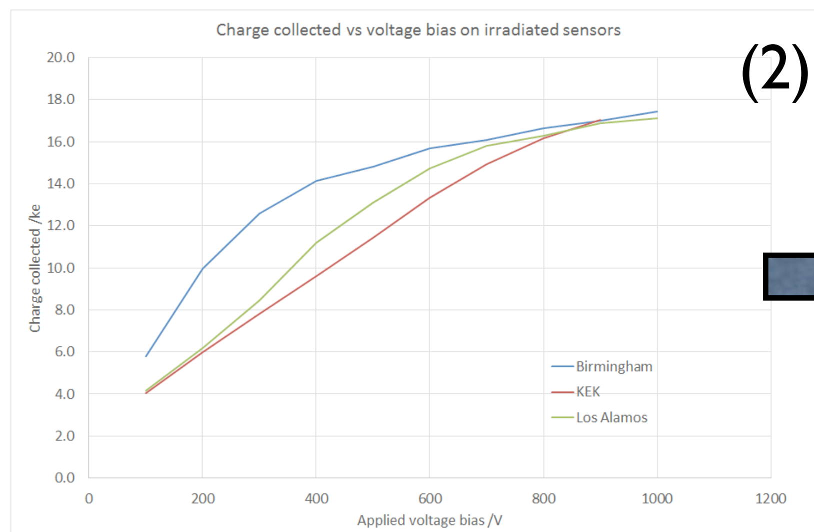
Overheating

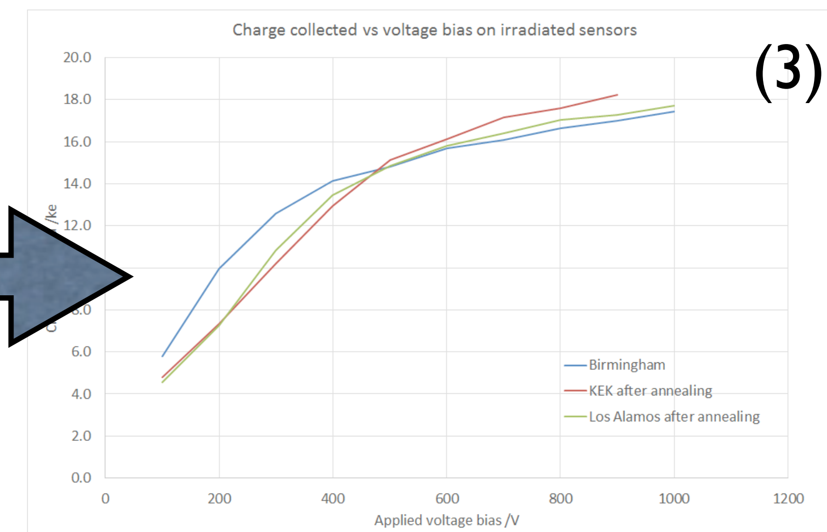
1. IV measurement of Pixel detectors comparing different fluences, all irradiated at Birmingham (Liverpool)

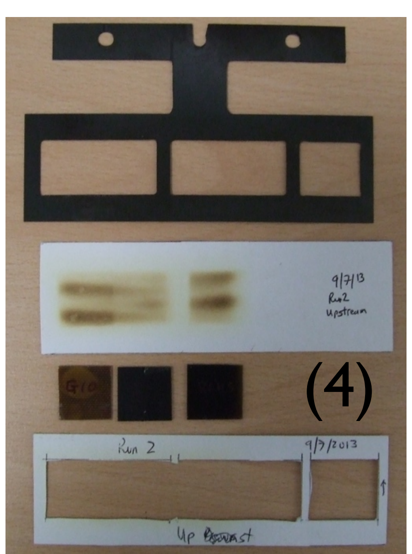
2. CCE measurements comparing irradiations at Birmingham, KEK and Los Alamos

3. Compare with (2), KEK and Los Alamos have been annealed at 80 °C for 60 minutes









4. PCB irradiations with charring of backing card and PCB material

Birmingham (not annealed) similar to KEK and Los Alamos *after annealing*

Indicates overheating causing annealing to sensors during irradiation

Irradiated Samples (1)

- After irradiating pixel sensors, IV and CCE measurements indicated overheating of sensors
- After further cooling tests, it was concluded that the cooling power of the glycol system was not enough to maintain temperatures below 0 °C (ideal temperature to prevent annealing!) during irradiations

80s per cm^2 to irradiate to $10^{15}cm^{-2}$ (1 MeV n_{eq}) at 1 μA

↓

800s per cm^2 at 0.1 μA

- Compromise: To use low beam currents (0.1 μA)

✓ No over heating

➡ Time of irradiations to HL-LHC fluences is not ideal -10x longer than at 1 μA !!!

Scanning Procedure

- Time of each scan depends on the size of the sample
- Number of scans depends on the fluence required and beam current
- Example:

  3x3 matrix of mini strip sensors (10mm x 10mm) irradiated ~ 1 hour at 1 μA

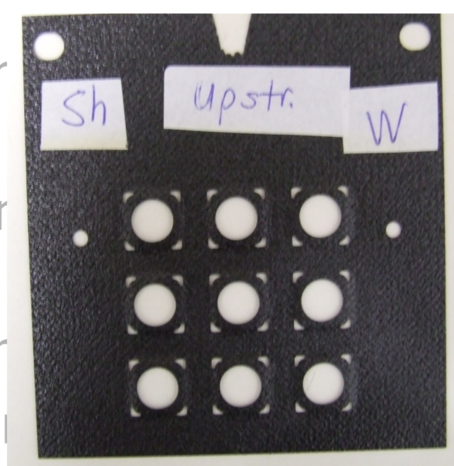
- Increasing the current, reduces the time of scanning, this can cause over heating
- Reducing the current, increases the time of scanning, this limits the possibility of reaching high fluences for large samples
- ✓ Solution: Improve cooling within the cool box
  - ✓ Allows use of high current (limit to 1μA)
  - ✓ Can perform longer scans to achieve HL-LHC fluences

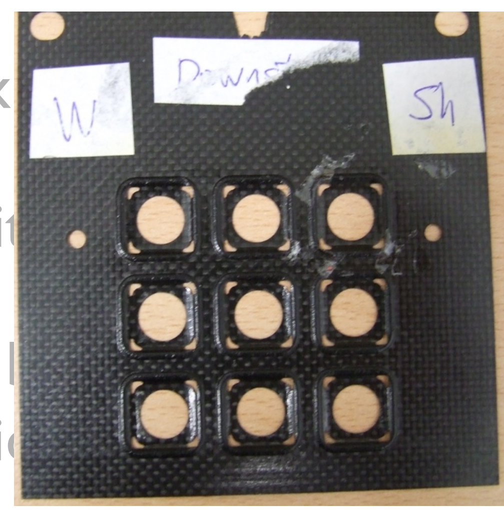
Cool box (2)

• Cool box with kapton window based on CERN-PS irradiation setup	➡ Larger volume and scanning window with new geometry
• Recirculating glycol system	➡ Norhof LN_2 system
• Purged with dry N_2 to prevent condensation forming	✓ Purge before and after
• Fans within the cool box	✓ High power fan
• Temperature and humidity monitored using LabView	✓ As well as LN_2 temperature sensors
• Samples within the cool box secured in place with CF frames attached to the lid and secured in place with kapton tape	➡ Improvements to the CF frames: with exposed back for air circulation; clip in, minimal kapton tape needed
• Maintained at -15 °C, 2 hour cooling time	➡ Achieves -50 °C in 15 minutes

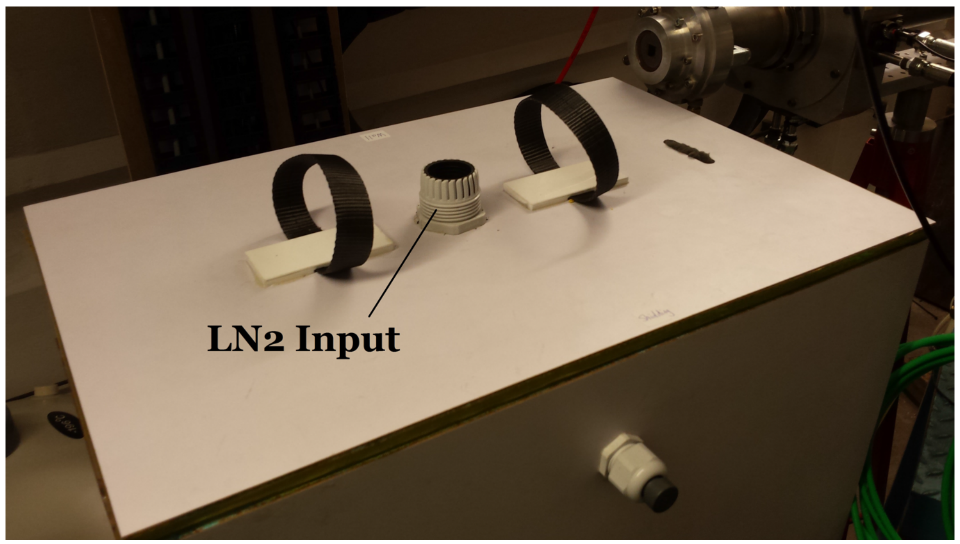
Cool box (2)

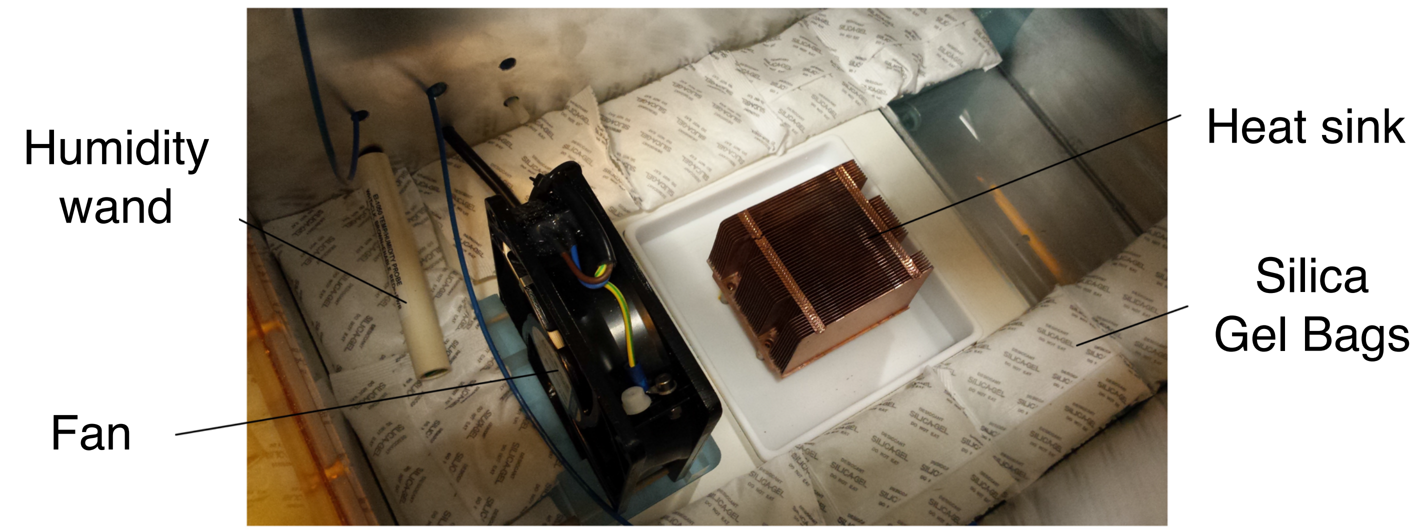
- Cool box with kapton window based on CERN-PS irradiation setup
  - ➡ Larger volume and scanning window with new geometry
- Recirculating glycol system
  - ➡ Norhof LN_2 system
- Purged with dry N_2 to prevent condensation forming
  - ✓ Purge before and after
- Far box
  - ✓ High power fan
- Ter midit LabView
  - ✓ As well as LN_2 temperature sensors
- Sar ool l e with CF fra he li ace with kapton tape
  - ➡ Improvements to the CF frames: with exposed back for air circulation; clip in, minimal kapton tape needed
- Maintained at -15 °C, 2 hour cooling time
  - ➡ Achieves -50 °C in 15 minutes

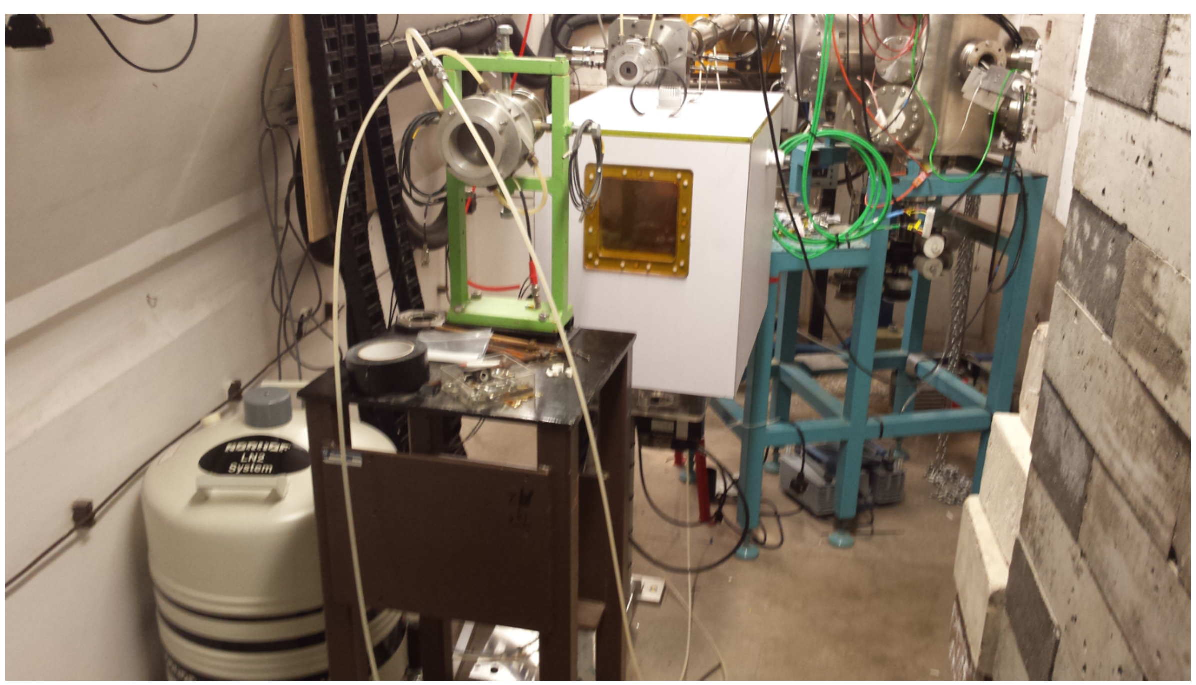




Cool box (2)







- Evaporative cooling is used:
  - Norhof system controls temperature
  - LN_2 dripped onto heat sink
  - Fan used within box to circulate the -50 °C nitrogen gas
  - Box purged with dry N_2 and silica gel bags used, to prevent condensation on samples and in the box

New cooling system

- Initial cooling tests were performed to assess the feasibility of using the LN_2 system with evaporative cooling to lower the temperature within the cool box - SUCCESSFUL
- Installation of the upgraded cool box and new LN_2 system complete (August 2014)
- Initial tests performed
- Already full schedule lined up, with over 100 samples!
    - 114 ATLAS + 16 CMS sensors
    - 20 encapsulated wire bond samples
    - JFETs

Summary

- Initial measurements indicated that sensors were overheating during irradiations at beam currents above 0.5 μA
- Prototype LN_2 system was designed and tested in March 2014
- New LN_2 system installed and commissioned in August 2014
    - Temperature of cool box maintained at -50 ^{o}C
    - Maximum temperature of sensors during irradiation below 0 ^{o}C

Back-up slides

Abstract

In approximately 2024,the Large Hadron Collider (LHC) will be upgraded to the High Luminosity LHC (HL-‐‑LHC). The upgrade is foreseen to increase the LHC design integrated luminosity by a factor ten. This planned increase in luminosity results in significantly higher levels of radiation inside the planned ATLAS Upgrade detector. This means existing detector technologies together with new components and materials need to be re examined to evaluate their performance and durability within this enhanced radiation field. Of particular interest is the effect of radiation on the upgraded ATLAS tracker. To study these effects an ATLAS irradiation scanning facility using the Medical Physics Cyclotron at the University of Birmingham was built in 2013. The intense cyclotron beam allows irradiated samples to receive in minutes, fluences corresponding to years of operation at the HL-‐‑LHC. Since commissioning in early 2013 this facility has been used to irradiate silicon sensors, optical components and carbon fibre sandwiches for the ATLAS upgrade programme. Irradiations of silicon sensors and passive materials can be carried out in a temperature controlled cold box which moves continuously through the homogenous beamspot. This movement is provided by a pre-‐‑configured XY-‐‑axis cartesian robot system (scanning system). In 2014 the cooling and the cold box was upgraded from a recirculating glycol chiller system to a liquid nitrogen evaporative system. This paper reviews the design, development, commissioning and performance results of the new cooling system.

Reference Material

- The Birmingham Irradiation Facility:
  DOI: 10.1016/j.nima.2013.05.156

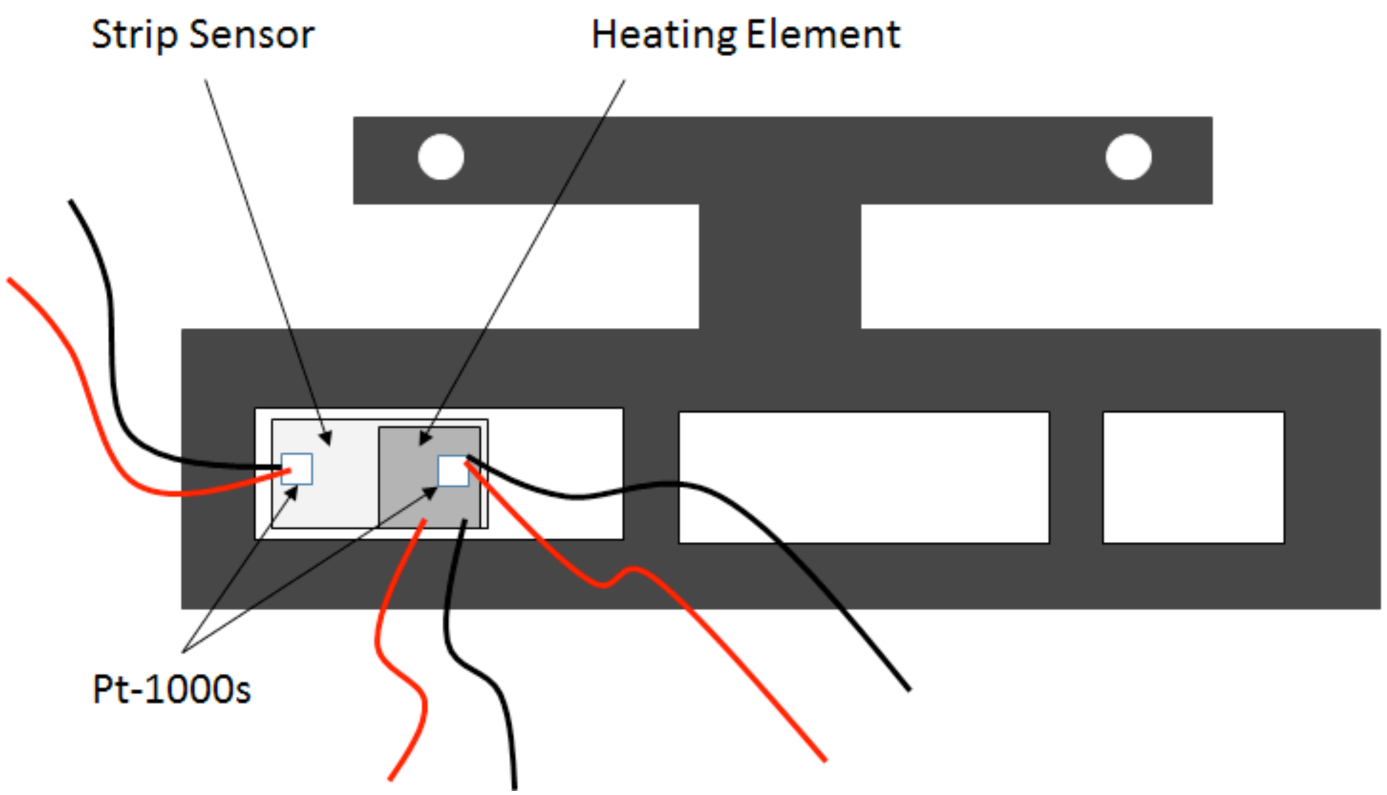
- TIPP 2014 Proceedings
  http://pos.sissa.it/archive/conferences/213/419/TIPP2014_419.pdf

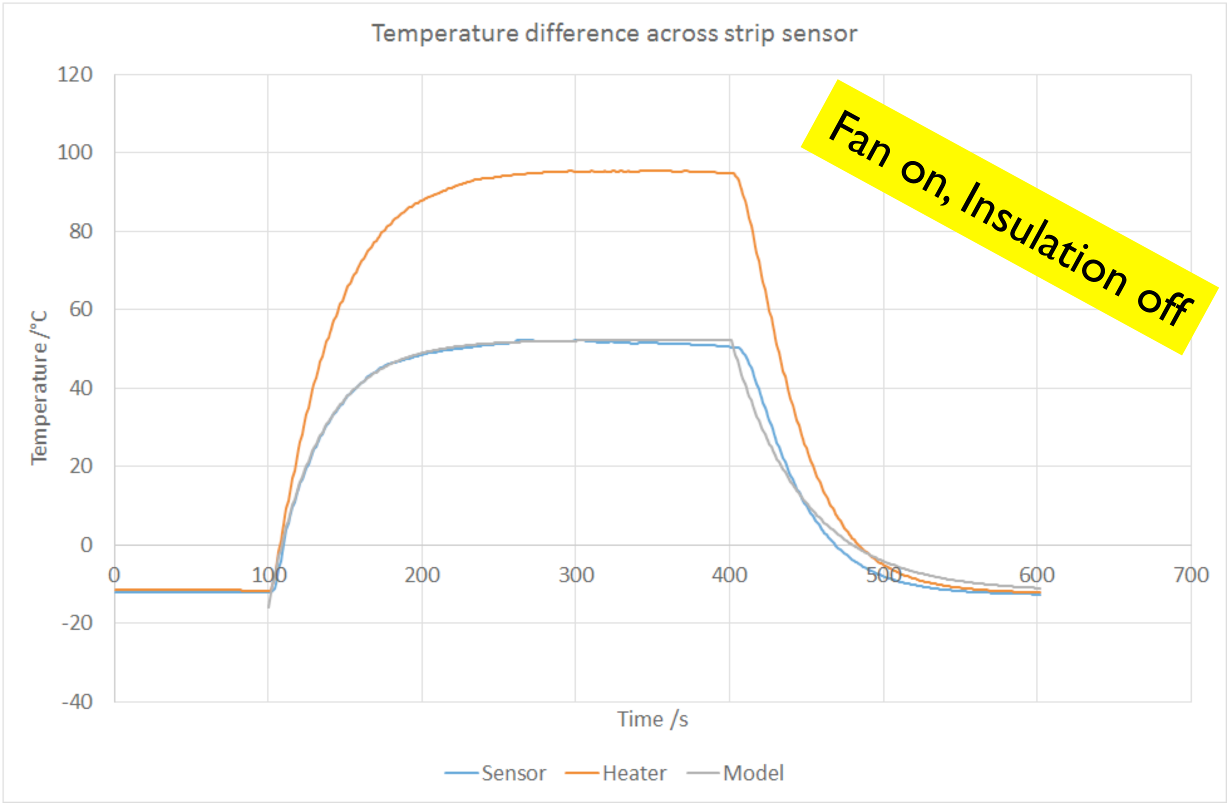
- CLAWAR 2014 Proceedings
  http://www.worldscientific.com/worldscibooks/10.1142/9312

Out of beam

Temperature Tests (1)

- Initial temperature tests in 1 μA beam with glycol cooling and frame setup as below
- Simulated using heating element rather than beam applied to the sample



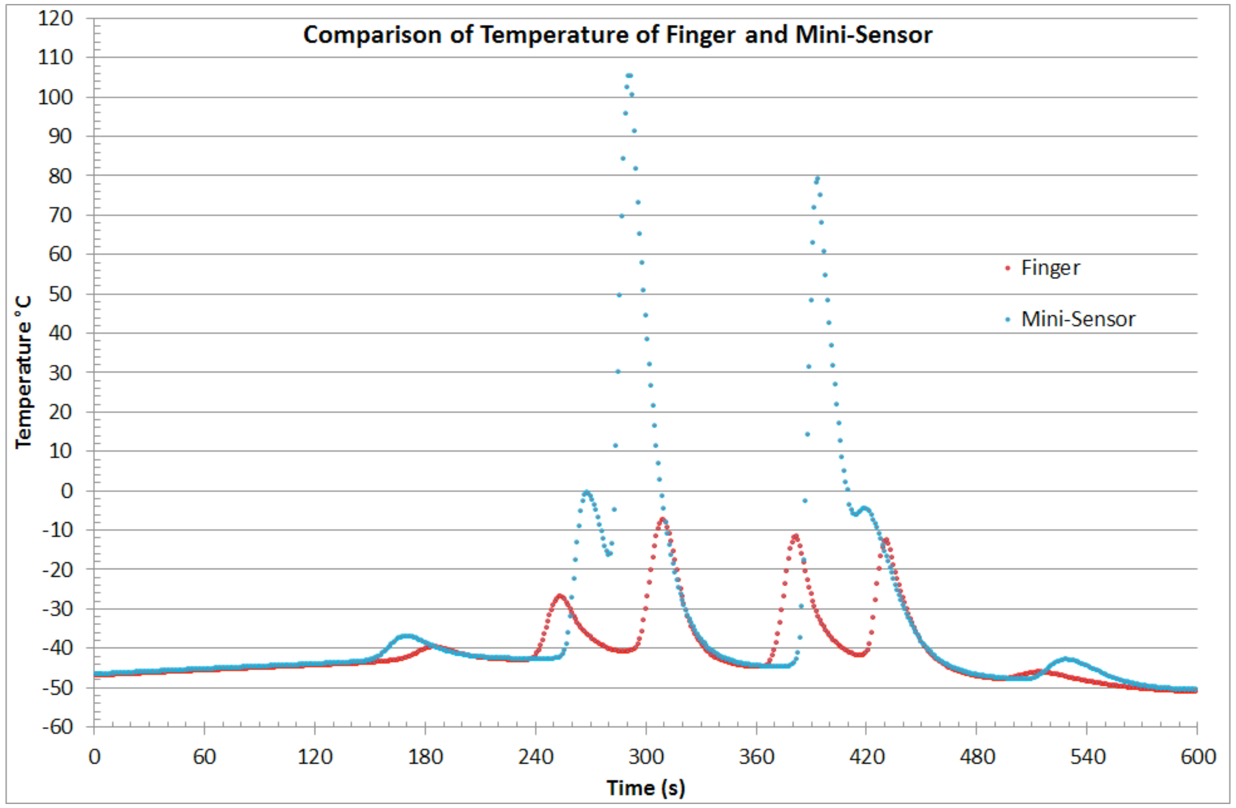


- Maximum temperature reached on sensor, ΔT = 39.7 °C, on the heater ΔT = 89.37 °C

In beam

Temperature Tests (2)

- Initial temperature tests in 1 μA beam with LN_2 cooling and new frame using a finger PT1000 sensor so not directly in the beam



- Maximum temperature reached -7.52 °C on the finger sensor, ΔT = 49.09 °C correcting for heat loss we estimate the sensor temperature to be ΔT = 65 °C
- This means that starting at -56 °C the sensor temperature fluctuates around 0 °C