UK Light Injection System

JENNIFER2 Kick Off Meeting
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On behalf of the UK calibration group

Introduction

- The UK group are designing the optical calibration system for Hyper-K

- We had the chance to deploy a fully functioning prototype system at Super-K
    - **Hardware** in tank: during tank open work in summer 2018

    - **Electronics**: in February and July 2019

- Goals:
    - **For SK:** provide new calibration techniques and data

    - **For HK:** excellent chance to develop the calibration methods and new hardware ahead of HK construction

Calibration Goals

- Our system is designed to run in parallel with normal data taking, and allow in-situ measurement and calibration of a number of key properties in HK:

- Measuring all properties with the same system requires the system to produce different beam widths and intensities
  - Use **diffusers** and **collimators** to achieve this

- Characterisation of PMT response:
  - Timing calibration
  - PMT gain measurement
  - Evolution of PMT gain

- Measurement of optical properties of the detector:
  - Attenuation length of water
  - Scattering, absorption
 - Depth dependence of water quality

SK Installation

- We installed injectors at 5 locations in the SK tank, ~6m apart in depth

- Each position has a diffuser, collimator, bare fibre, so 15 total injectors

- Each injector has its own dedicated light source

- Also an external monitor PMT connected to all sources

~6m

B1

B2

B3

B4

B5

Diffuser

Bare fibre

ID PMT

Collimator
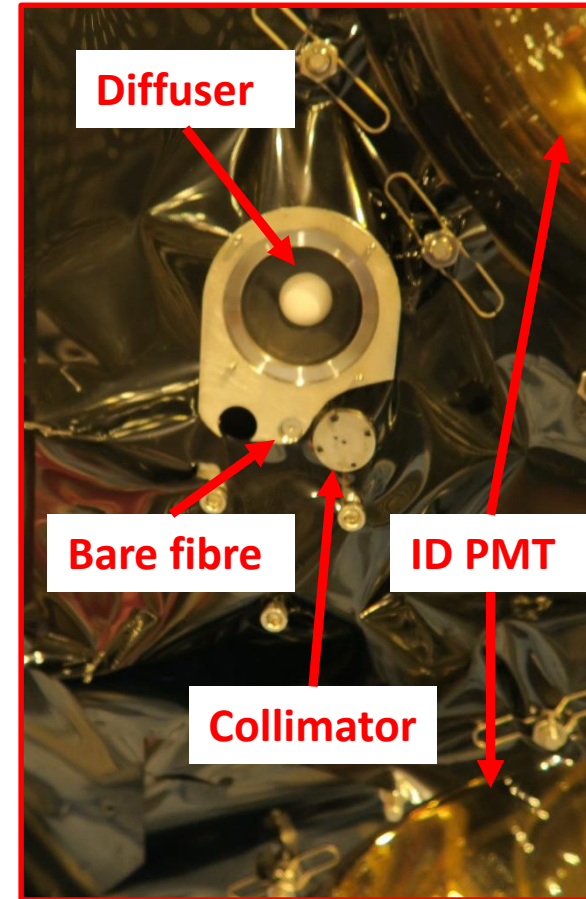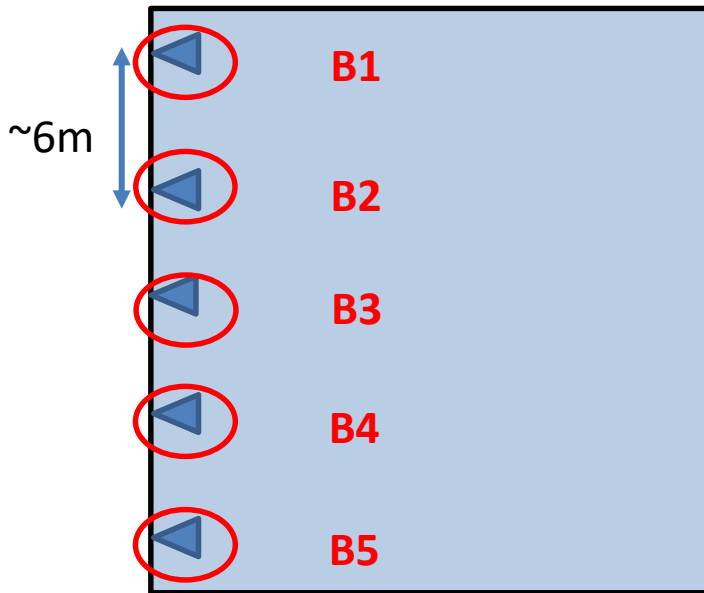
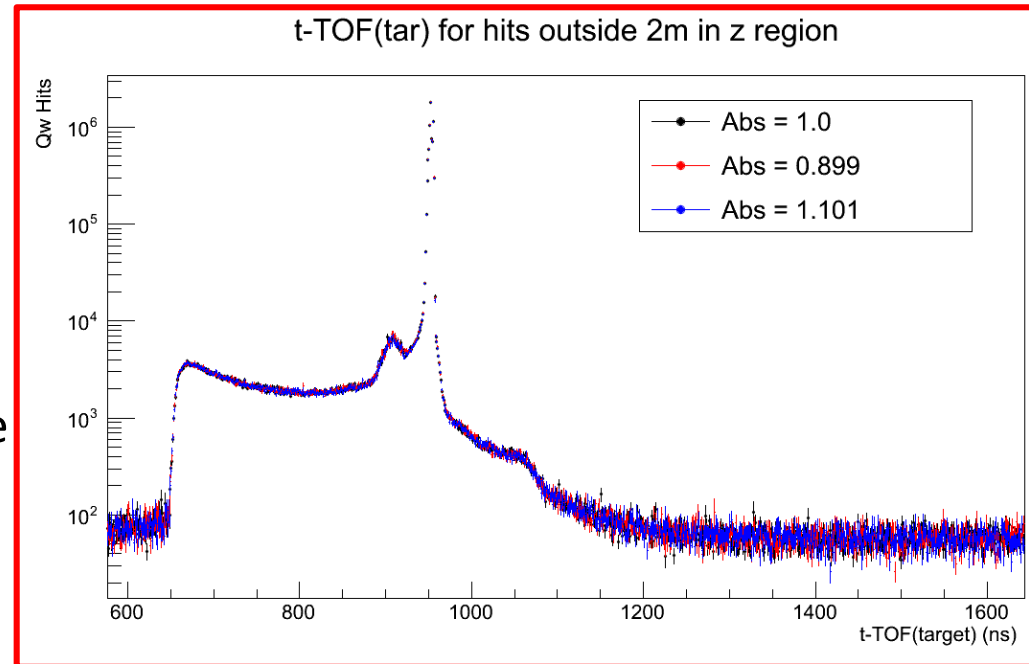# Hardware Installation In Super-K
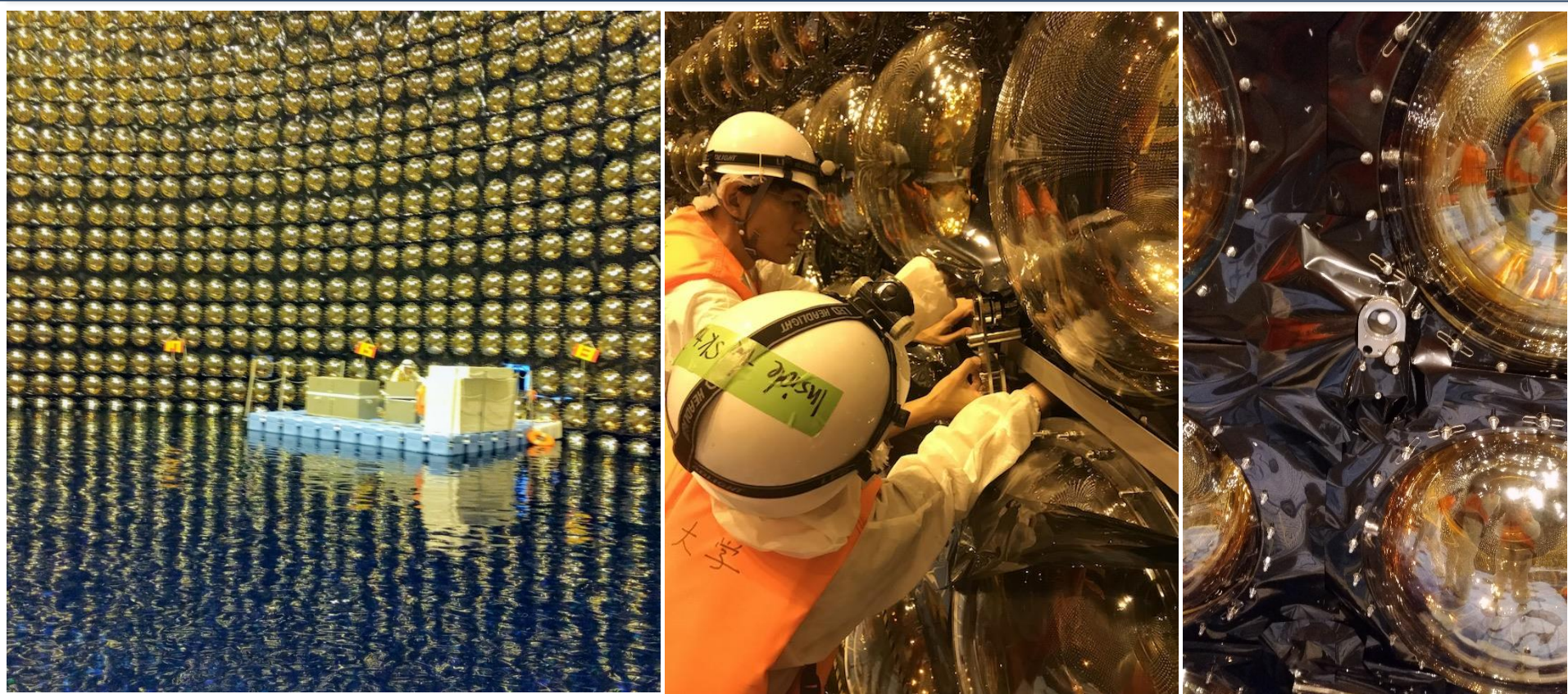
- We accessed the various levels from a floating platform as the water drained from the tank

- Optics bolted to the PMT frame on the ID, optical fibre connections made in OD

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MC Feasibility Studies

- We have made MC studies to develop some analyses ahead of data taking

- Studies have been performed using a collimated (narrow angle) beam
  - Using approximately 5 days of data in normal data taking conditions

- So far focused on measuring the scattering and absorption in the water

- New PhD students have started work on studies using a diffuse (wide angle) beam, and will work on monitor calibration studies (not discussed here)

Absorption From Total Charge

- Changed absorption by the RMS/mean values for SK-IV

- Determine the change to total charge measured in SK when absorption is varied

- **Conclusion:** change in total charge is <1% even with 10% variation in absorption

- Needs precision of monitoring <<1%, probably unfeasible to measure this way

t-TOF(tar) for hits outside 2m in z region

Qw Hits

Legend:
- Abs = 1.0
- Abs = 0.899
- Abs = 1.101

t-TOF(target) (ns)

Wavelength (nm)	Charge Change Abs + RMS/mean	Charge Change Abs - RMS/mean
337	+0.49%	-0.67%
405	+0.48%	-0.43%
473	+0.92%	-0.95%

Water Parameters From TOF Corrected Time Profiles

- Include timing information by using χ^2 comparison method with MC to measure water quality

- Use of narrow beam allows localised measurement of water parameters

- **Conclusion:** accurately measure absorption with ~7% (~6% stat, ~3% sys) precision using 5 days data with perfect monitor information

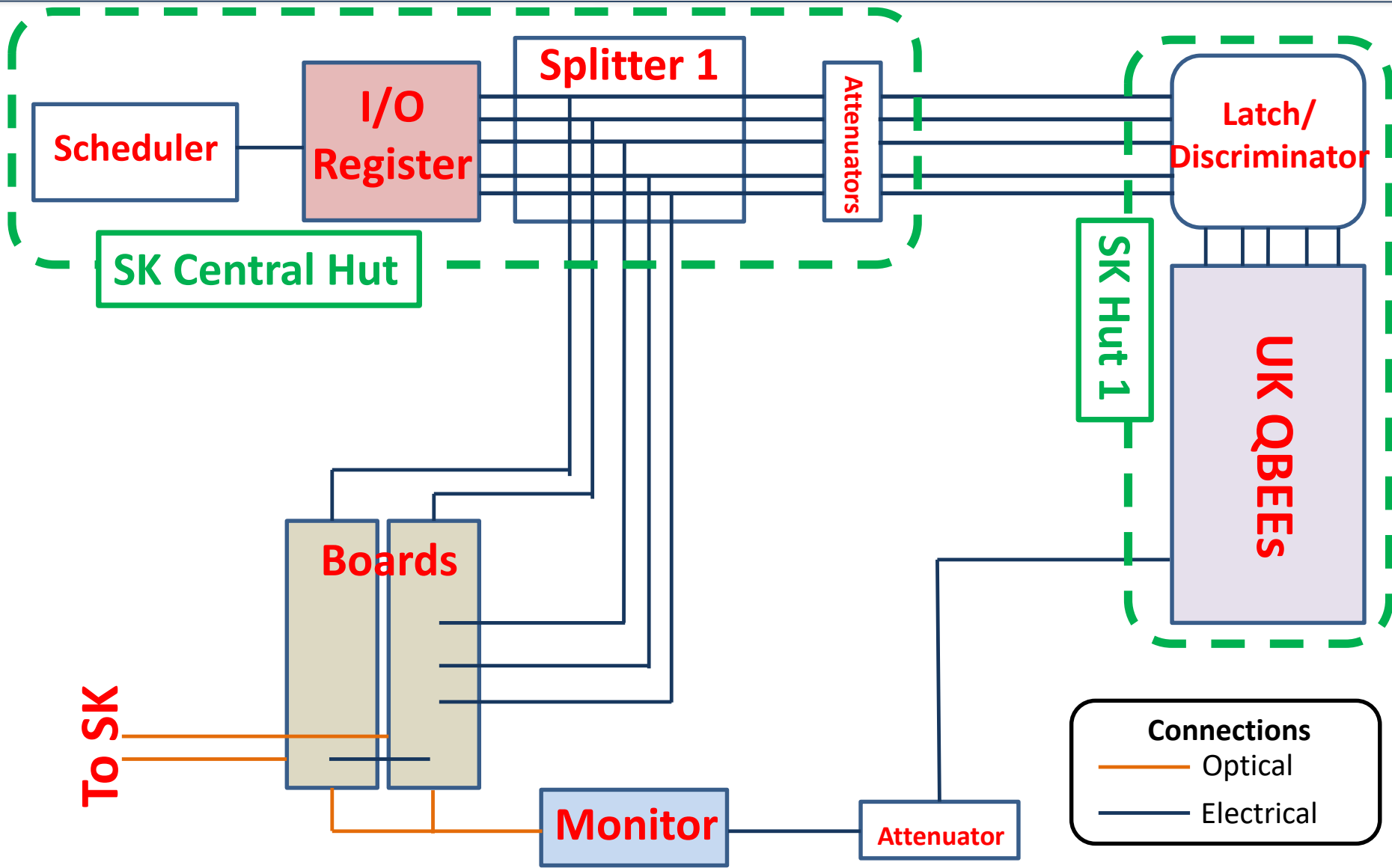Absorption value vs injector position
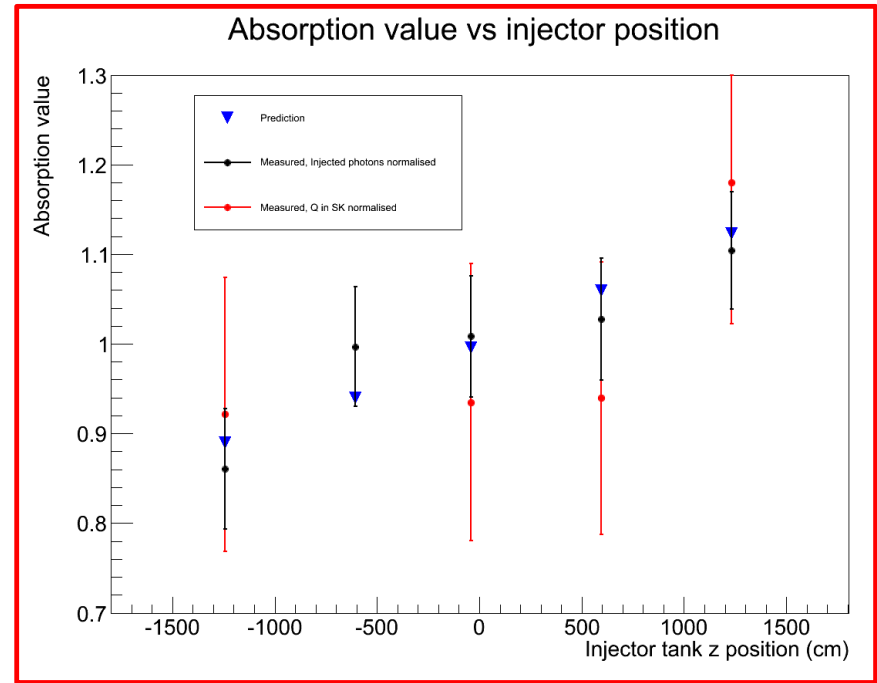
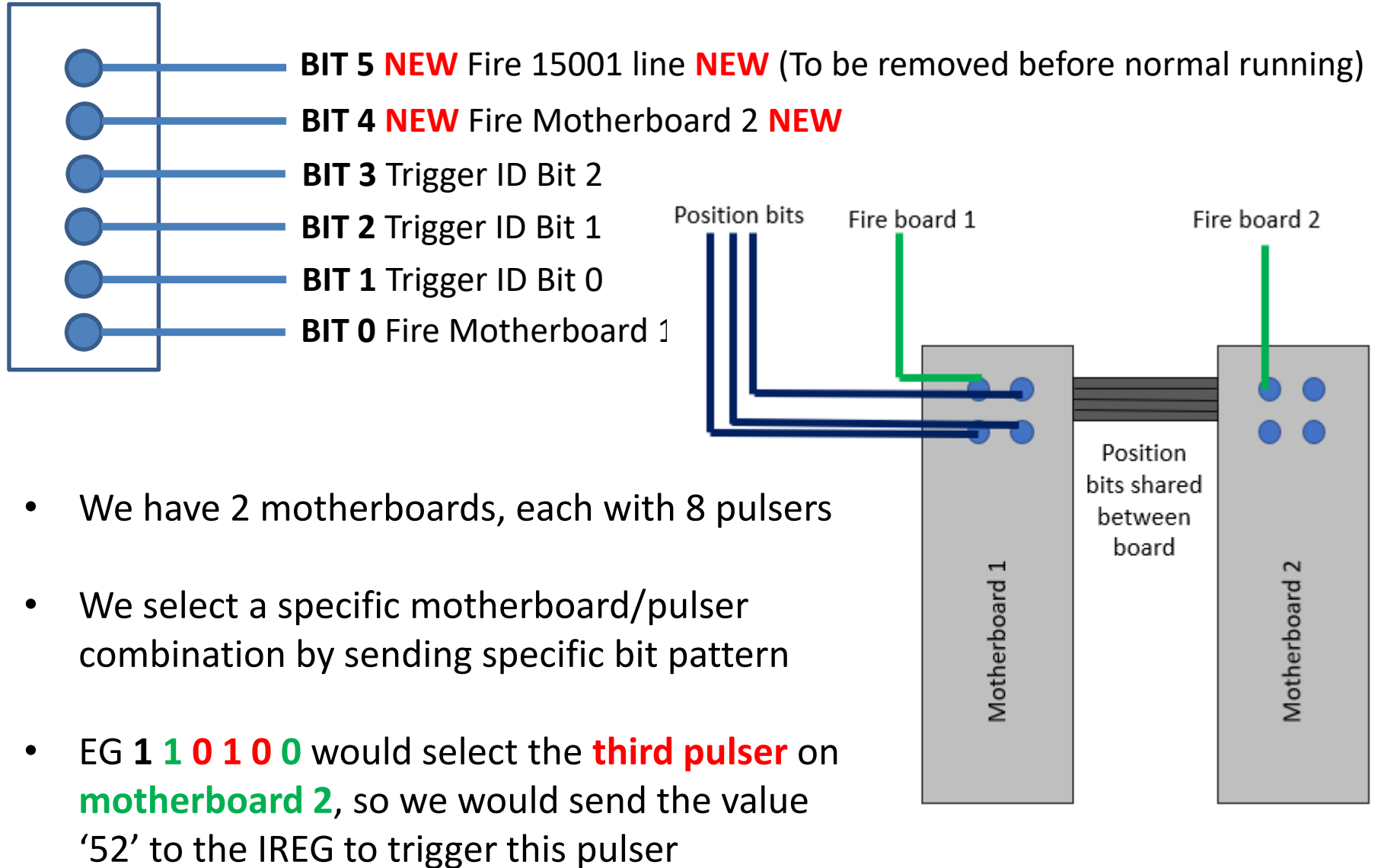| Injector	Expected	Injected Photons Norm (Precision)	Total Q in SK Norm (Precision)
B1	1.123	1.1042 ± 0.0658 **(5.96%)**	1.1800 ± 0.1573 **(13.33%)**
B2	1.060	1.0278 ± 0.0679 **(6.61%)**	0.9394 ± 0.1517 **(16.15%)**
B3	0.996	1.0083 ± 0.0676 **(6.71%)**	0.9350 ± 0.1547 **(16.55%)**
B4	0.939	0.9969 ± 0.0669 **(6.71%)**	0.6453 ± 0.1536 **(23.81%)**
B5	0.890	0.8604 ± 0.0670 **(7.78%)**	0.9215 ± 0.1528 **(16.58%)**

Electronics Installation

- We installed the electronics across two trips to Kamioka:
  - **February 2019**: Installed first motherboard, laid cables, connected to SK DAQ, first data collection

  - **July 2019**: Installed second motherboard, correction of some issues from February, full integration with SK

- Collaborated closely with SK calibration group members in Japan to achieve this

- We were able to take data (~100k events) for each of the 15 SK injectors
  - 5x diffuser
  - 5x collimator
  - 5x bare fibre

- Remaining slides discuss the completed installation and a first look at the first data from the new UK injectors

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Electronics Installation

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Electronics Installation

BIT 5 **NEW** Fire 15001 line **NEW** (To be removed before normal running)

BIT 4 **NEW** Fire Motherboard 2 **NEW**

BIT 3 Trigger ID Bit 2

BIT 2 Trigger ID Bit 1

BIT 1 Trigger ID Bit 0

BIT 0 Fire Motherboard 1

- We have 2 motherboards, each with 8 pulsers

- We select a specific motherboard/pulser combination by sending specific bit pattern

- EG **1 1 0 1 0 0** would select the **third pulser** on **motherboard 2**, so we would send the value '52' to the IREG to trigger this pulser

Electronics Installation

- We completed the full installation of the electronics and integration with SK

- Confirmed that we can selectively pulse every individual pulser

- We took data for all 15 of the light injectors to assess the performance (~100k events each)

- Also took some data for the monitor PMT calibration (analysis ongoing)
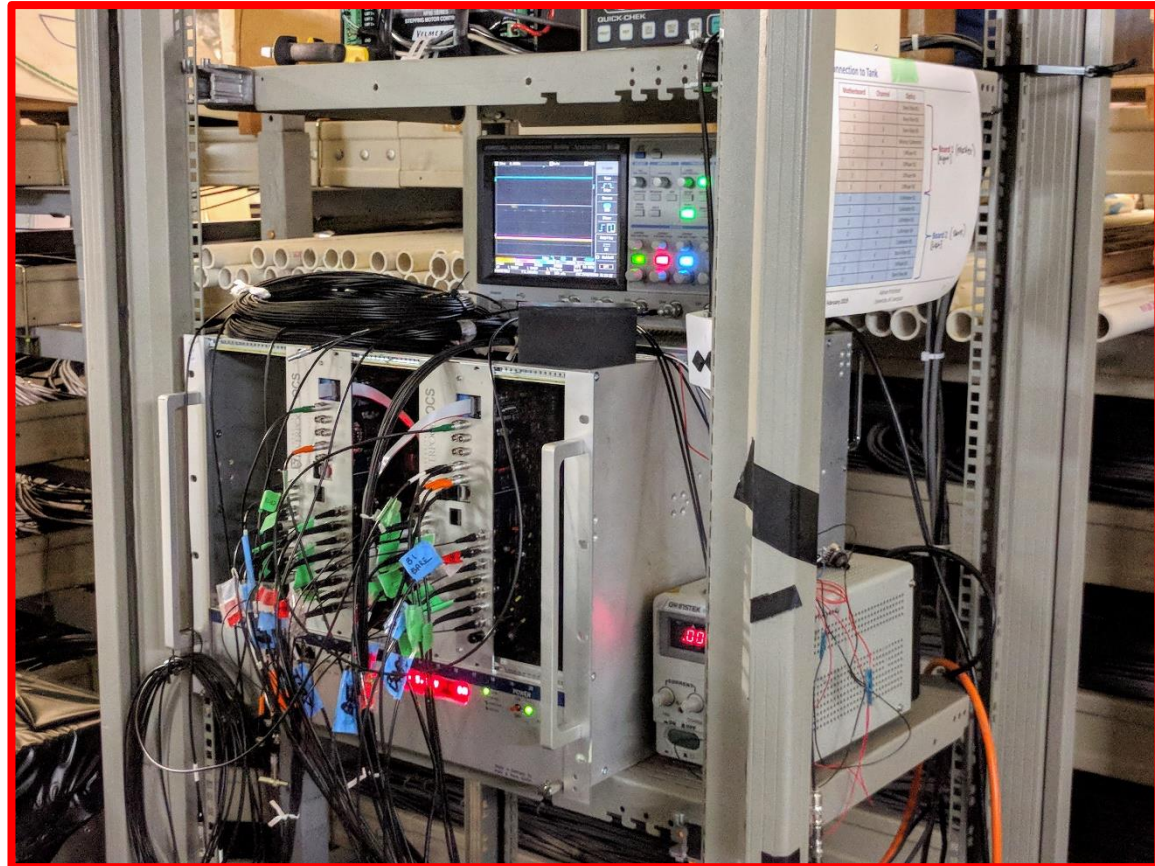
First Data - Collimators

- Occupancy for B1 collimator

- Clearly defined narrow beam spot seen

- Other collimators also working as designed
  - Weaker intensity from B3 and B5

  - Partly fixed by running at higher input intensities for those channels

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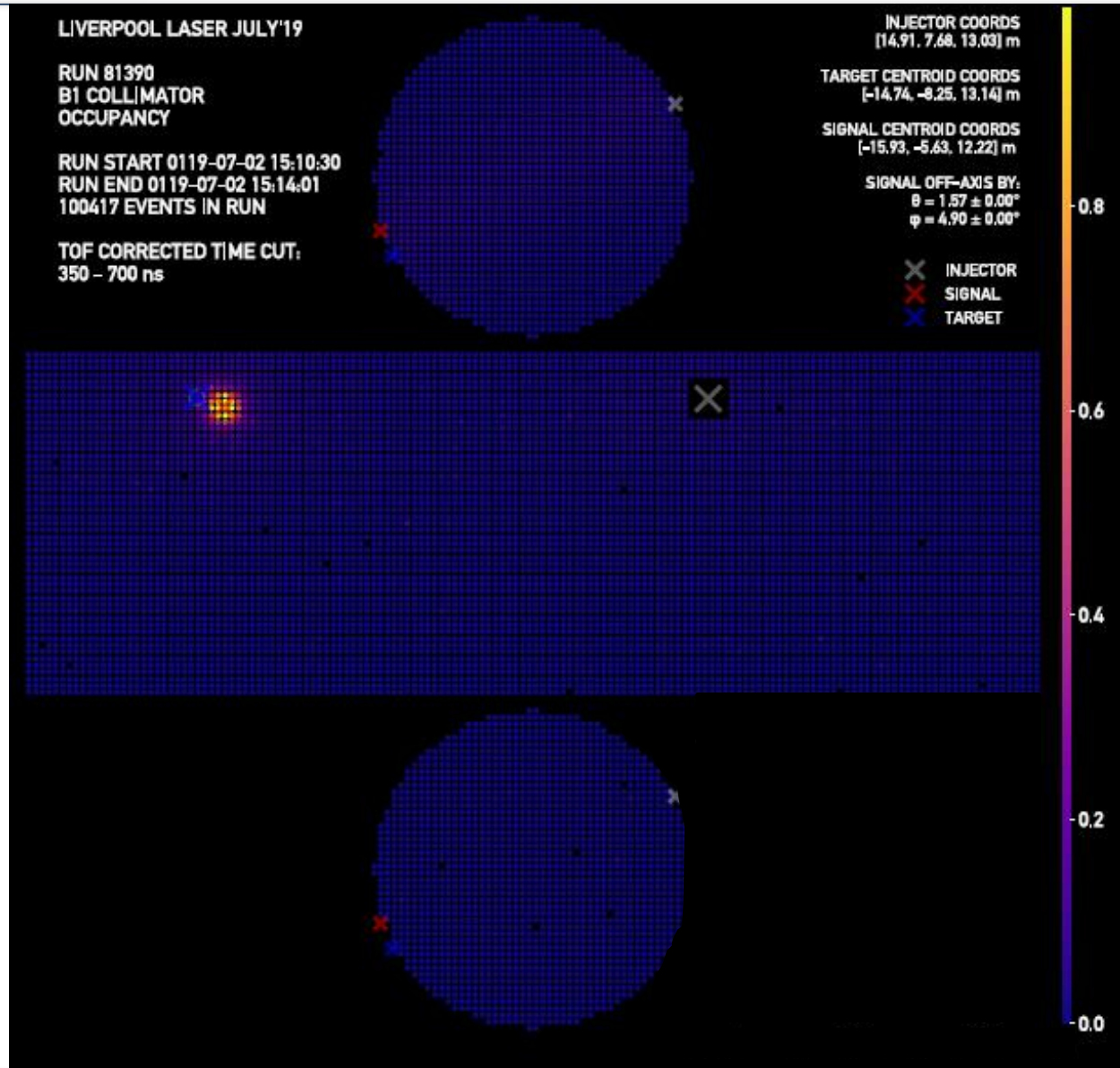
First Data - Diffusers

- Occupancy for B3 diffuser

- Much wider beam is seen for the diffusers, as intended

- All diffusers seen to be functioning correctly

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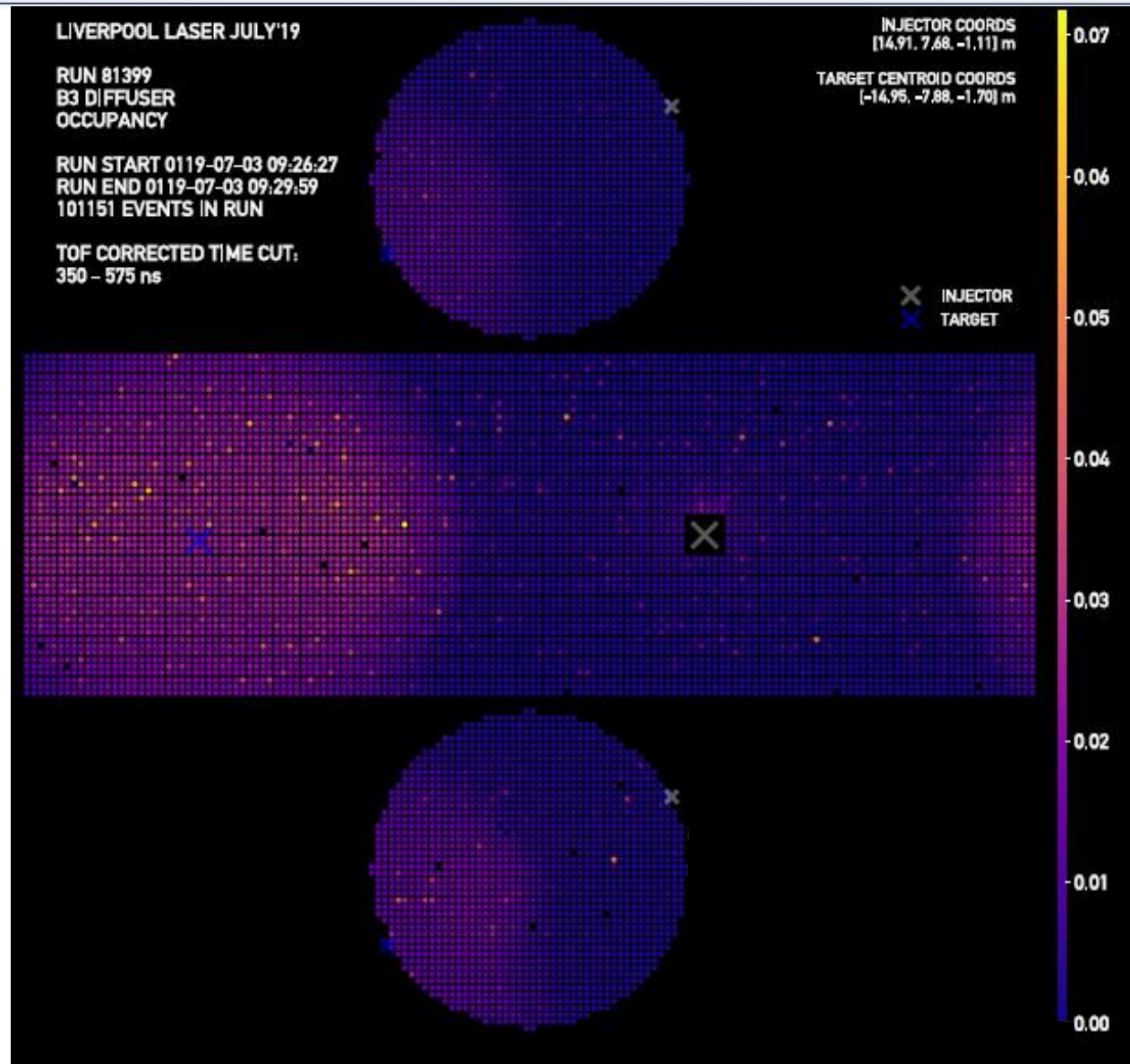
First Data – Bare Fibres

- Occupancy for B2 bare fibre injector

- B2 and B4 fibres appear normal

- B1,B3,B5 fibres show some unexpected behaviour

- Bare fibres only included in system as cross-check in SK installation

- No plans to include bare fibre injectors in HK
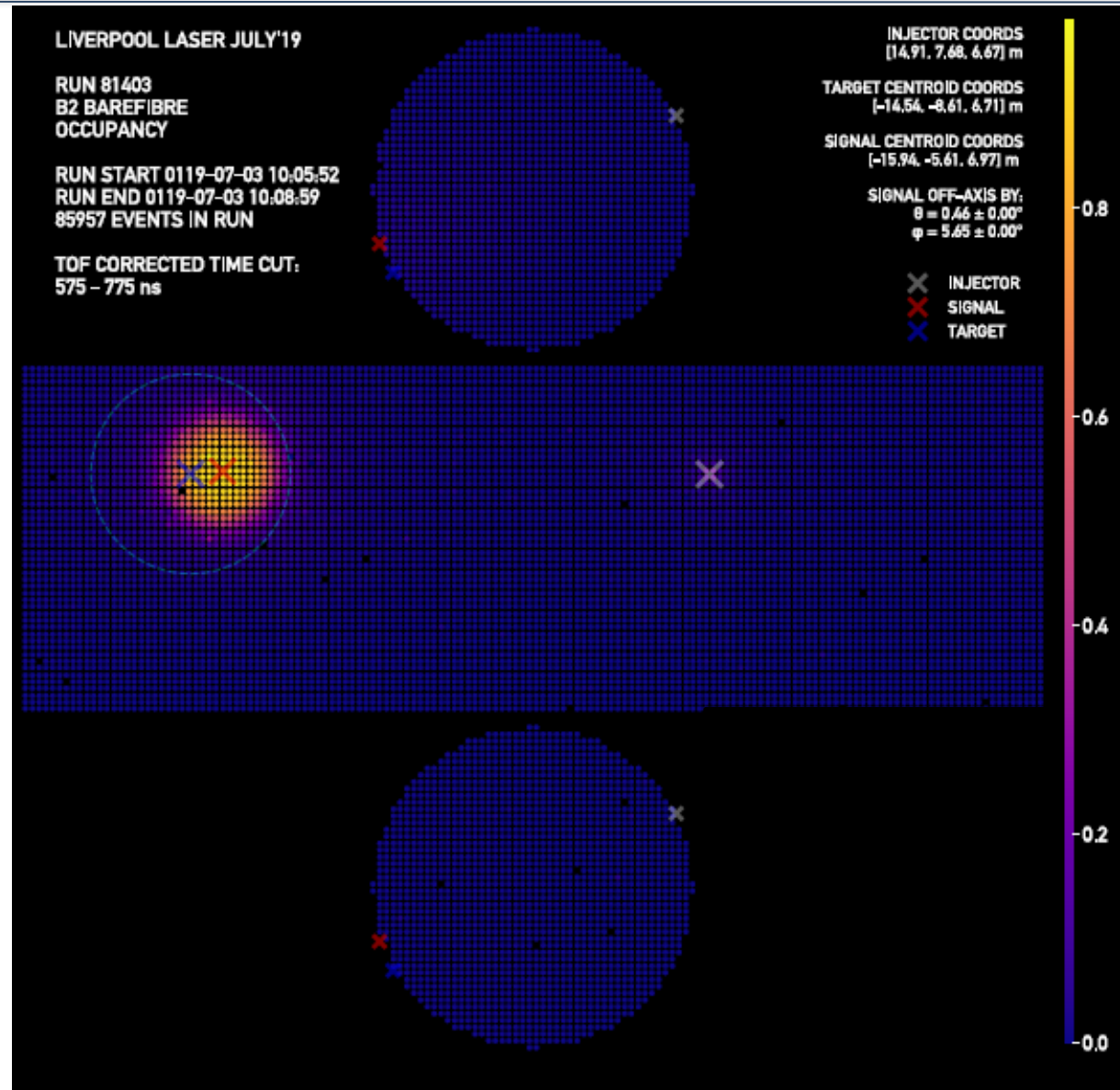
Remaining Work For SK Installation

- The remaining task is to integrate the new UK system in the autocalibration routine at SK

- This will mean our system will start taking data during normal runs

- First test of new scheduler took place last Thursday (thanks to our Japanese colleagues who have learned how to use our system)
  - Test run of ~6 hours using only the B1 collimator
  - Test was successfully completed, further analysis of the data must be completed before testing with all of the optical sources

- Then after SKDetSim for SK-V is ready, can produce the required MC and begin the analysis on data
  - Will reproduce optical profiles of collimator/diffuser in MC based on laboratory measurements from Warwick
  - Beam targets and directions to come from analysis of this first data set

Summary

- The new UK optical calibration prototype system has been fully installed at SK

- Our system is integrated with all of the necessary hardware to receive triggers from SK slow control, and record position tags in data stream

- First studies show that all of the diffusers and collimators are working
  - Some variance in the output efficiency, but can be offset by running individual sources at different intensities

- Final step is to integrate our system in the autocalibration scheduler at SK so we take data during normal runs
  - Work is ongoing for this, should be completed soon

Next Steps

- Begin the analyses with the collimator data from SK

- Design analyses using diffuser balls using MC and apply to data from SK

- Look at reproducing the feasibility studies for HK
  - These will inform the full system design for HK, eg how many injection points, how intense do we need the light?

- I have been working on an instrumentation paper to fully detail the R&D behind the production and installation of the full system
  - First draft is around 75% complete, so hope to have it ready soon

- Full internal review of the installation planned within UK
  - Ensure we identify any issues from SK installation so that we can make improvements for HK (eg, underwater fibre connections)