1 List of methods, instrumentation, laboratory facilities

We have the SST camera (calibration methods, SiPMs, reconstruction algorithms).

2 Training

Training - can use the existing Oxford Ph.D. graduate school – many topics across astro and particle physics. If we combine with HU we can probably argue it is one of the most comprehensive around?

Training – there is a significant impetus in Oxford now to build a coherent training programme in machine learning for physicists.

Thesis topics – Oxford can offer possibilities with AGN jet physics, APL's / Lorentz invariance, possibly GRB's if Rob gets involved, and image reconstruction.

A good complementarity could be achieved if Oxford students spend time at DESY doing lab work which cannot be done in Oxford, and HU students could do some astrophysics topics

3 Possible projects across AP,PP Detectors

next-generation SiPMs would be interesting (on-chip digitisation?), what else?

4 Possible internships

Jason Watson could work on a paper with an intern on the first SST camera pointing calibration. Interns in Oxford could work on AGN astrophysics or image reconstruction algorithms (again can highlight Machine Learning). Example of this is Mario Hörbe who visited me last year from Bochum, he and Paul Morris have got a nice paper from the visit.

More detail - potential three Master/Ph.D. projects in the CTA SST-camera area
Project 1: Photon-list pipeline for Cherenkov Shower reconstruction

Continue work started with the Non-Negative Least Squares (NNLS) pulse extraction algorithm. The purpose of this algorithm is to reduce a waveform into a list of photon (Cherenkov and NSB) arrival times. This photon list has a huge amount of potential in Cherenkov shower reconstruction, but does not fit into the usual IACT analysis chain (including ctapipe). The subtopics include:

- Further development of the NNLS algorithm, using improved pulse descriptions (from Jon Lapington)

- The use of the photon list as a data volume reduction algorithm (important for CTA) (previously explored by FACT – Sebastian Mueller, now at MPIK)

- Using clustering or ML algorithms to extract the signal photons from the 3D photon list cube

- Cherenkov Shower Reconstruction (3D fitting, ML, templates, ...)
  Huge amount of potential here, with each subtopic being somewhat isolatable.

Appropriate for either Masters or PhD.

Project 2: SST camera simulations

Since Tom Armstrong left Oxford, we currently have very little expertise for the SST camera simulations in simtelarray. Most importantly, this would involve the student getting familiar with simtelarray and ctapipe, and for them to reach the level that they can improve the model used in simtelarray to more accurately represent the SST camera. However, as simtelarray does not include a lot of the low-level aspects of the SST camera, there is also a desire (from Rich and I) that we develop an inhouse Python low-level simulation of the SST camera. This will be used to investigate things like:

- optimal pulse shaping
- in situ trigger threshold calibration technique
- Impact of delayed optical crosstalk
- Electronic crosstalk
- NNLS pulse extraction algorithm development

  And it can help us further improve the simtelarray model.

This would be more appropriate for a PhD student.

Project 3: Pointing Calibration

Samuel's algorithm works quite well, but it is very simple (and fast enough for even online pointing calibration!). We need something more complex to meet the offline pointing calibration requirements. This could involve improving certain components of Samuel's algorithm:

- Star image extraction method
- Inclusion of PSF information
- Star catalogue table generation
- Definition of "score"
- Accounting of additional information (such as the time the image was taken) Or it could involve taking a completely different direction for the algorithm used.

Appropriate for either Masters or PhD.