UK PP Community & LSST

- Edinburgh (Clarke)
- Imperial (Colling, Egede)
- Lancaster(Love, Jones)
- Liverpool (Barrett, Bowcock, Coleman, Mehta)
- Manchester(Pilkington, Price)
- Open (Stefanov, Holland)
- Oxford (Azfar, Tseng, Shipsey)
- Swansea (Tasinato, Zavala)
- UCL (Korn)

PP interests in LSST

Science

Standard Model of Particle Physics describes the behaviour of 5% of the Universe

The nature of dark energy, dark matter and neutrino mass are all probed by LSST

Technical

The PP community has a long tradition of building complex detectors and computational systems, designed to perform systematics limited measurements. These skills are well matched to LSST

In the US a significant fraction of the LSST project are particle physicists & about ¼ of the construction funds are coming from the DOE particle physics budget

Areas where PP expertise is valuable include: camera, DAQ, database development, simulations, algorithm development, dark energy science, annual data release processing, support for the UK Data Access Centre

UK PP adds complementary value to the UK AST contributions to LSST and helps secure UK leadership in the science

OUTLINE

PP Interest in LSST

Camera (sensors)

Observatory Control System – Camera Control system bridge

DAQ

GridPP

UK Tier 0

Database

Magnification & cosmic shear

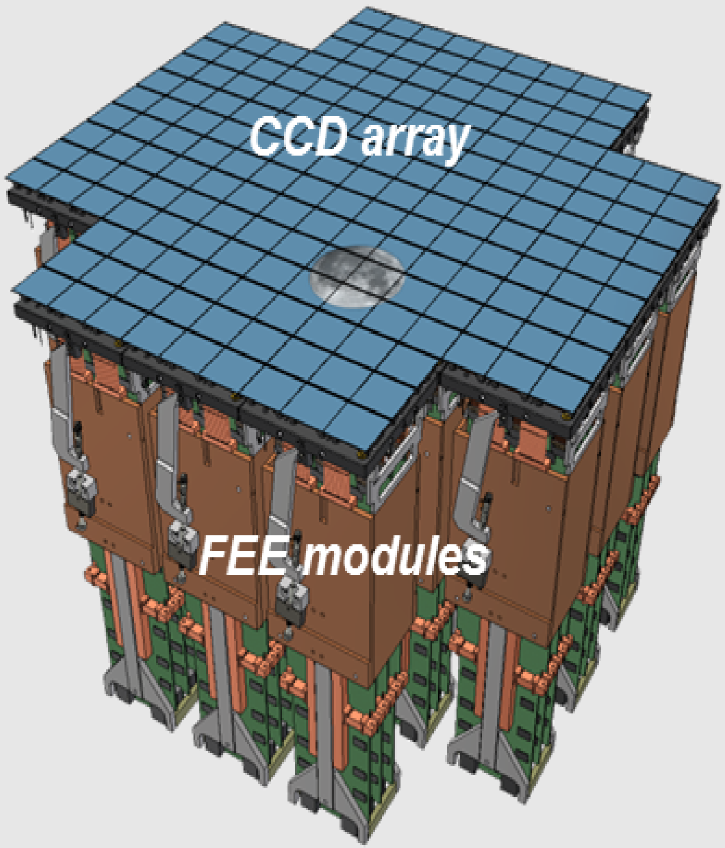
Theoretical Cosmology / computational physics
/ CDT for Data Intensive Science

PP Community

The interest in LSST is growing within the particle physics community

Edinburgh (Clarke)
Imperial (Colling, Egede)
Lancaster(Love, Jones)
Liverpool (Barrett, Bowcock, Coleman, Mehta)
Manchester(Pilkington, Price)
Open (Stefanov, Holland)
Oxford (Azfar, Tseng, Shipsey)
Swansea (Tasinato, Zavala)
UCL (Korn)

For scientific exploration, everybody is involved in the Dark Energy Science Collaboration (DESC).



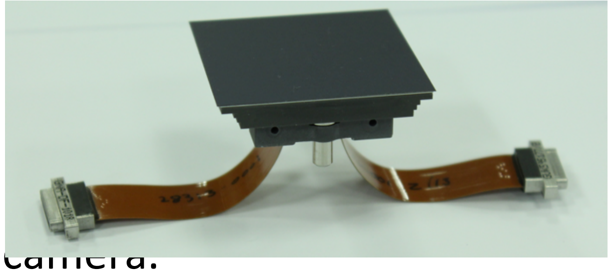
CCD Technology	Fully-depleted 100μm thick silicon, ≥ 10kΩ/cm resistivity 10μm pixel pitch 4Kx4K full-frame format 16 outputs/CCD
Science focal plane	189 CCDs, 3.024 Gpixels
Trace pitch: Silicon Ceramic package Flex cable	 5mm 0.4mm (6 layers) 0.64mm (2 layers)
PCB area/channel	8.8cm^2 (full signal chain)
Pixel rate	550Kpix/s
Power budget	350mW/channel total

Sensor characterisation

LSST CCD Camera (3 Gpix) largest ever constructed for astronomy

Thick 100 micron red-sensitive full depletion CCDs grew out of SSC silicon work in 1990's.

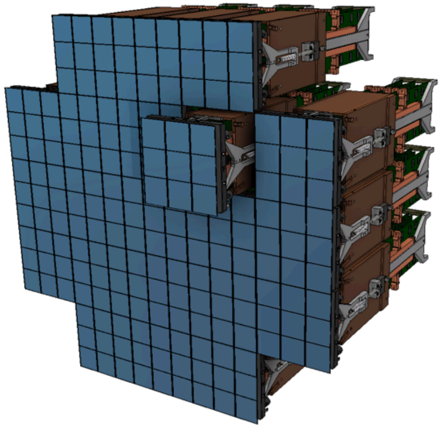
LSST prototype sensors meet project requirements.



Procurement under way with e2v (UK) & ITL (US)

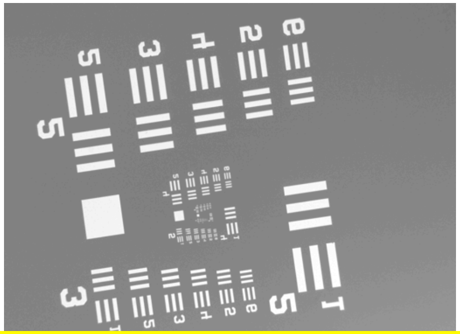
Sensor delivery rate is the critical path pacing item for the LSST camera.

Oxford (Shipsey) UK liaison between U.S. LSST and e2v. A joint LSST/Oxford PDRA in place, 50% paid by LSST supporting sensor delivery & sensor characterization (under an NDA).

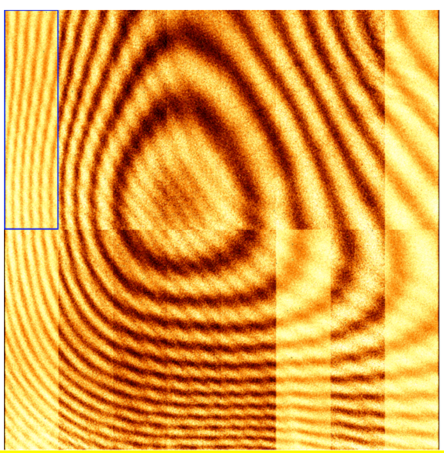


Sensor lab testing

Oxford



USAF test projection in Oxford

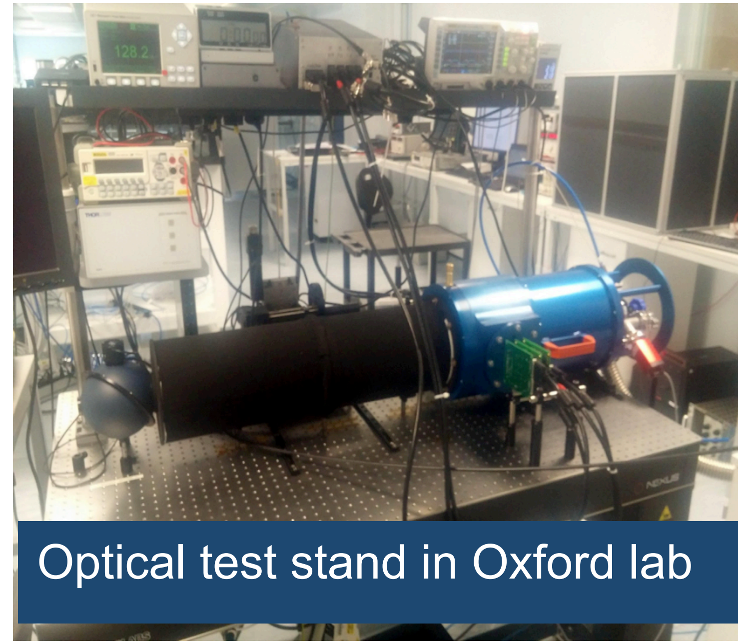


Fringing pattern at 1 micron
Image: H. Park (BNL)

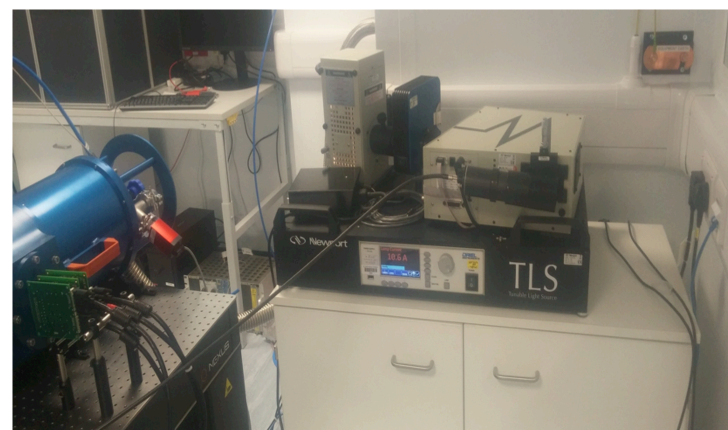
Test stand specialised for low noise, low vibration measurements built in OPMD lab (right)

Will be used to perform detailed optimisation studies, analysing variance of parameters between devices, and investigating highly variable effects such as fringing (left)

Calibration and measurement techniques for e.g. brighter-fatter effect still not fully understood.

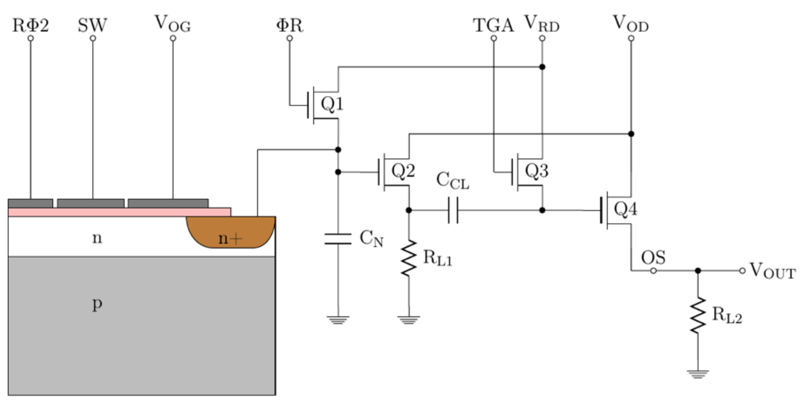


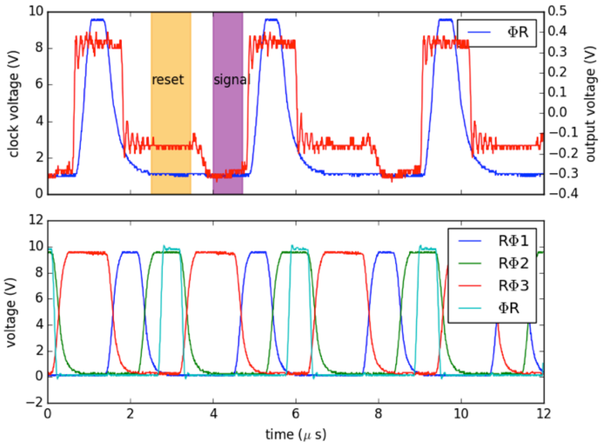
Optical test stand in Oxford lab



CCD operation

Oxford





Cosmic ray & column defects example during commissioning at Oxford

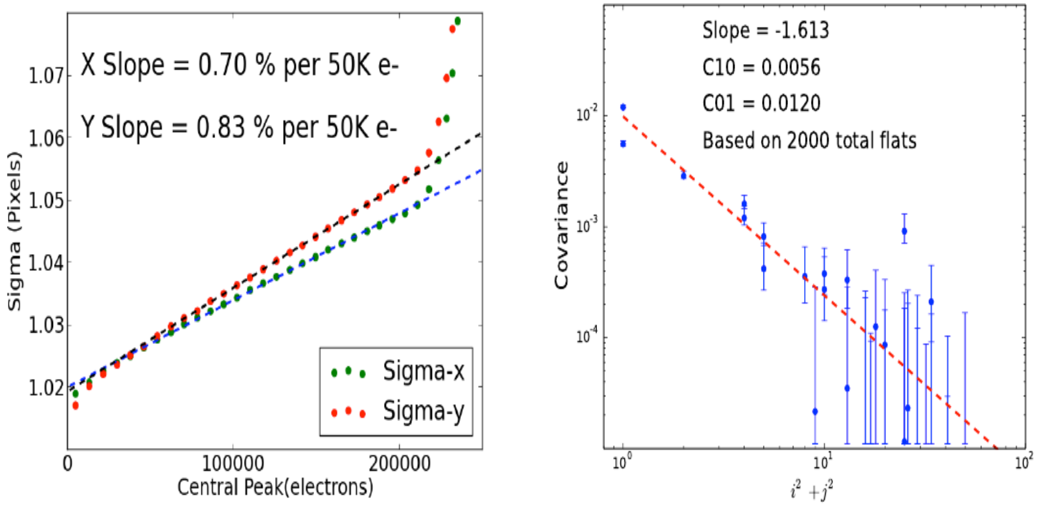
Optimal operation of the CCD clock gates and output circuits (above) depend on carefully optimising clock levels and timing sequences (above right)

Flexible readout operation available in OPMD system can assist in determining optimal conditions.

Sensor modelling

Oxford

Fitting brighter-fatter measurements - Lage et al (JINST 2017)

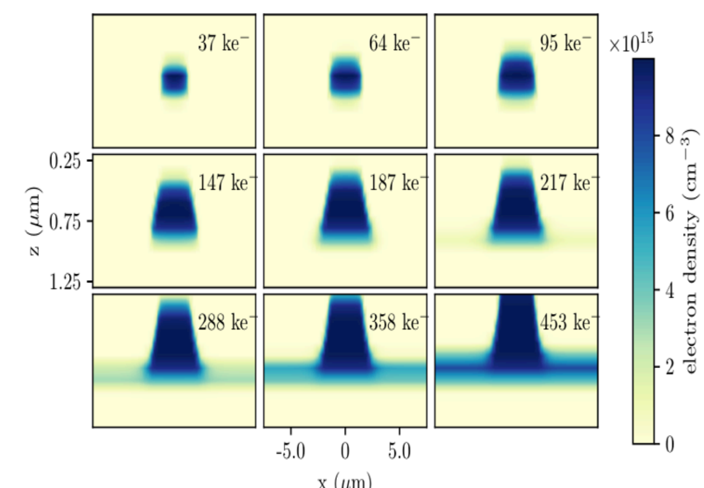


(a) Direct measurements of spot size increase.

(b) Pixel-pixel correlations.

Require more work on brighter-fatter modelling to correctly infer spot size changes (left panel), which will not be measured during device calibration, from pixel correlations (right panel), which will.

Next to leading order corrections for brighter-fatter effect require inclusion of effects such as channel storage depth changing with increasing signal.
We are contributing numerical modelling (e.g. TCAD storage models, right) effort to understand this.



TCAD charge storage models - Weatherill et al (in prep)

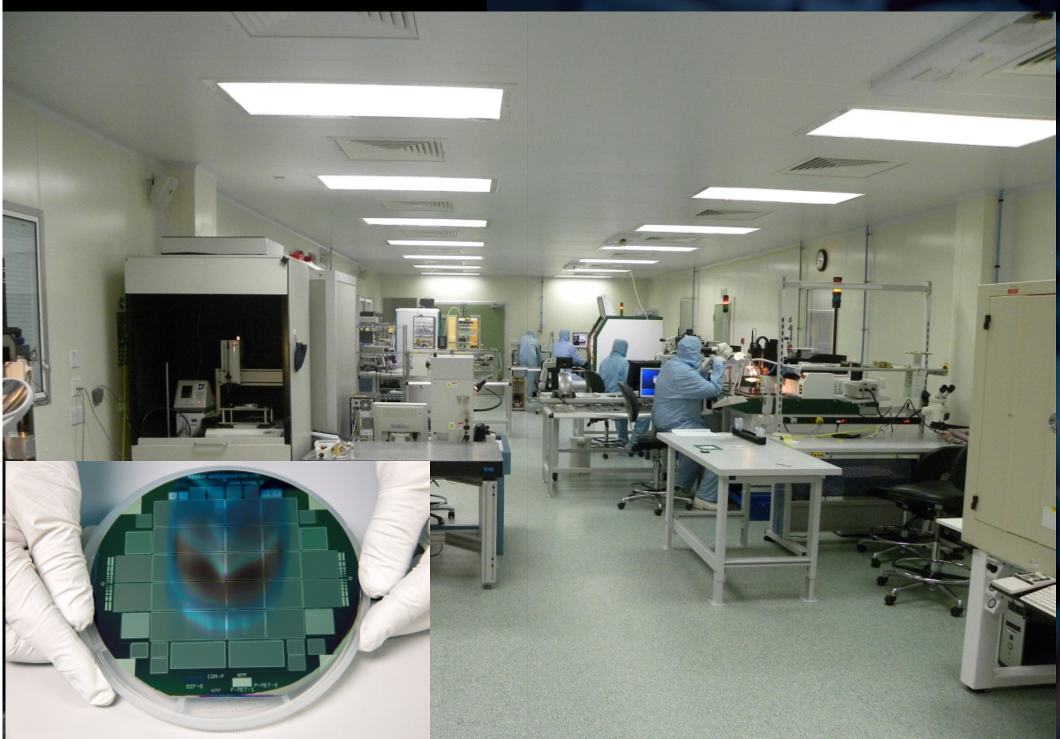
Sensor modelling from TCAD

Open U.

- Impact of sensor effects on cosmic shear estimates is not fully understood
    - More work is needed to develop a reliable estimate of the additive bias from sensor effects (including anisotropy and chromaticity)
- Brighter-fatter effect models may need a factor of 10 improvement in accuracy
- Present models don't include detailed sensor parameters such as doping profiles
- Proposed work to include detailed CCD information based on manufacturing input
    - In collaboration between the Centre for Electronic Imaging (CEI), e2v and Oxford
    - Goal is a BF model accurate to ~1%, using FEA electrostatic modelling in 3D TCAD and single electron tracing
    - The model will describe both the amplitude and the statistical behaviour of the charge collection process, and will be validated experimentally
- The long-standing collaboration agreement between the CEI and e2v Technologies gives access to proprietary device information not available to competitor institutions, and crucial for this work

Liverpool Semiconductor Detector Centre

- Design, testing
  - Pixels & CMOS sensors
- Systems Micro/Macro Assembly



LSST @ Liverpool

Investment in Dark Energy/Dark Matter Searches

- Studentships(2017)
  - Data Science CDT
- Collaboration with JMU/Theory
- Investment from School

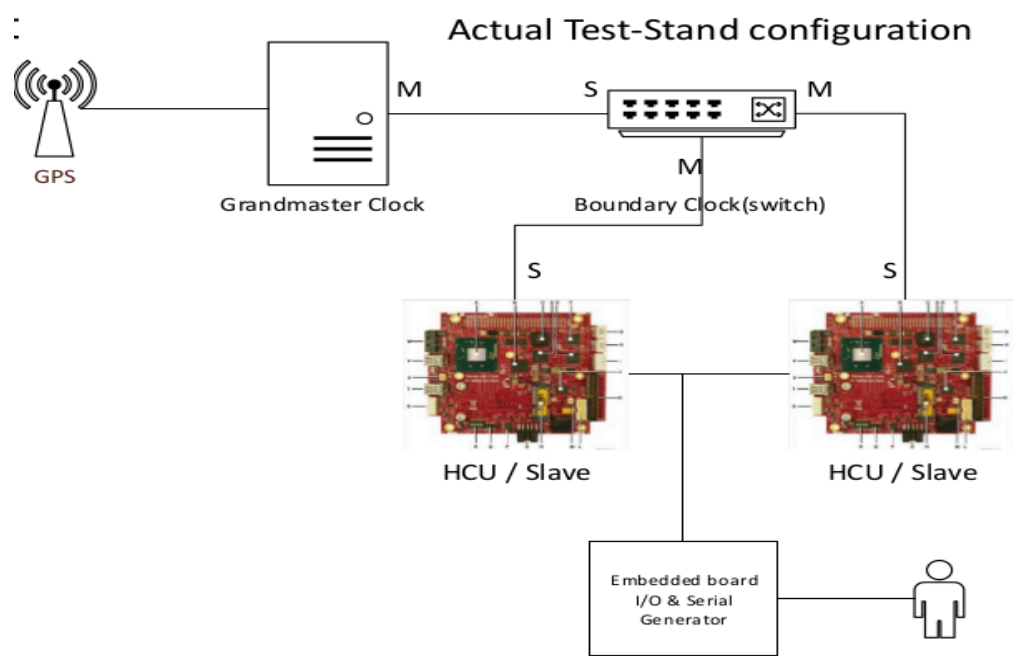
CCS Precise time synching

Oxford

Camera Control System actions must be time stamped across all platforms and users to millisecond accuracy using **Temps Atomique International, (TAI) time, platforms must be synchronised !**

Will be accomplished via GPS using a grandmaster clock and a master PC to distribute time

A test stand in Oxford will help evaluate, setup and benchmark the system - requisite software work underway
(Babak Abi, Farrukh Azfar Oxford)



OCS-CCS Software Bridge

Oxford

Observatory Control System (OCS) software and Camera Control System Software (CCS) exist as separate entities

OCS must provide users a way to control CCS seamlessly

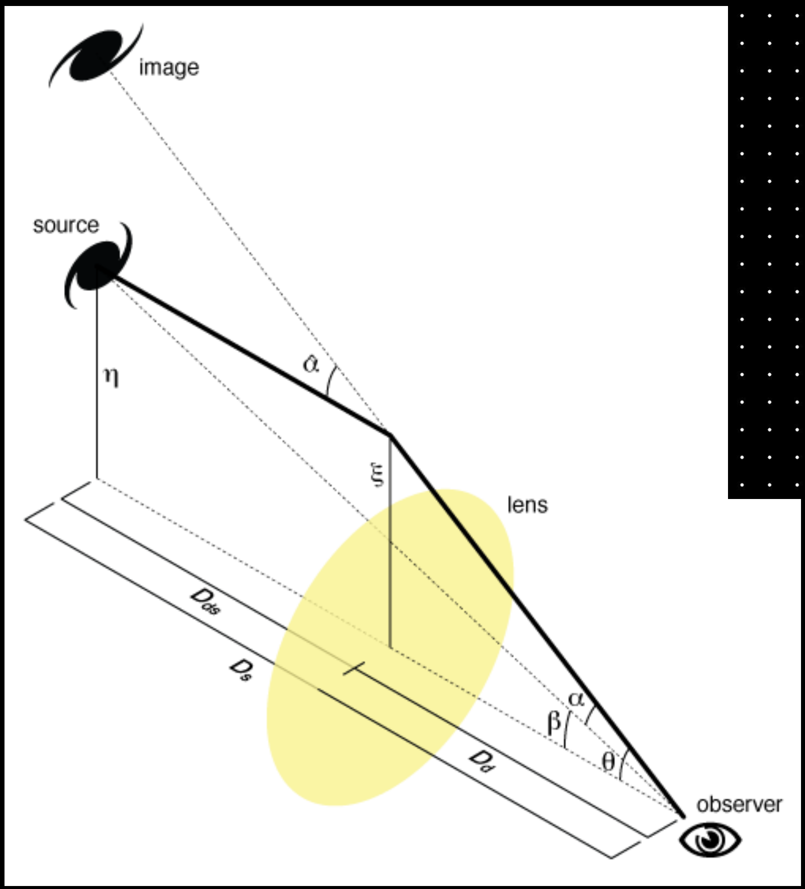
A "bridge" will be needed to translate and communicate commands

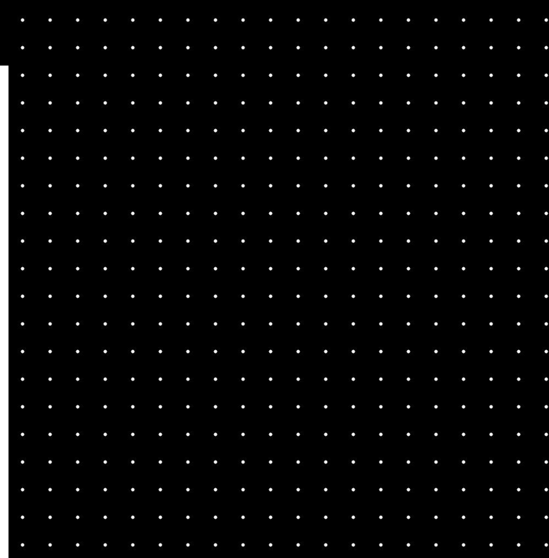
Oxford will begin work this summer to produce the bridge in collaboration with University of Paris Diderot and SLAC (People : Oxford : Farrukh, Paris : Eric Aubourg, + SLAC)

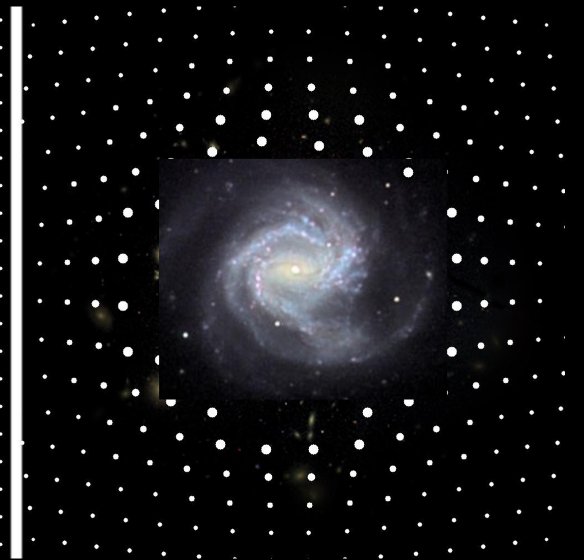
Astro & PP Synergy @ UCL

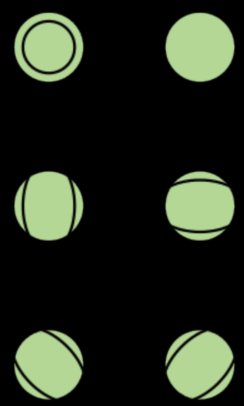
- Cooperate with a strong LSST Astro group at UCL:
  - Benjamin Joachimi, Hiranya Peiris, Ofer Lahav, Jason McEwen, Tom Kitching
- Relevant HEP expertise at UCL:
  - Dark matter
  - Data Acquisition
    - Strong group at UCL (electrical engineers)
    - LSST COB/RCE platform exists at UCL
  - Big Data Analysis (multivariate analysis, grid)
- Physics Interest:
  dark matter from lensing, online corrections/computations
- New PhD student: Constance Mahony, co-supervised by B. Joachimi and A. Korn

Weak Lensing magnification vs shear



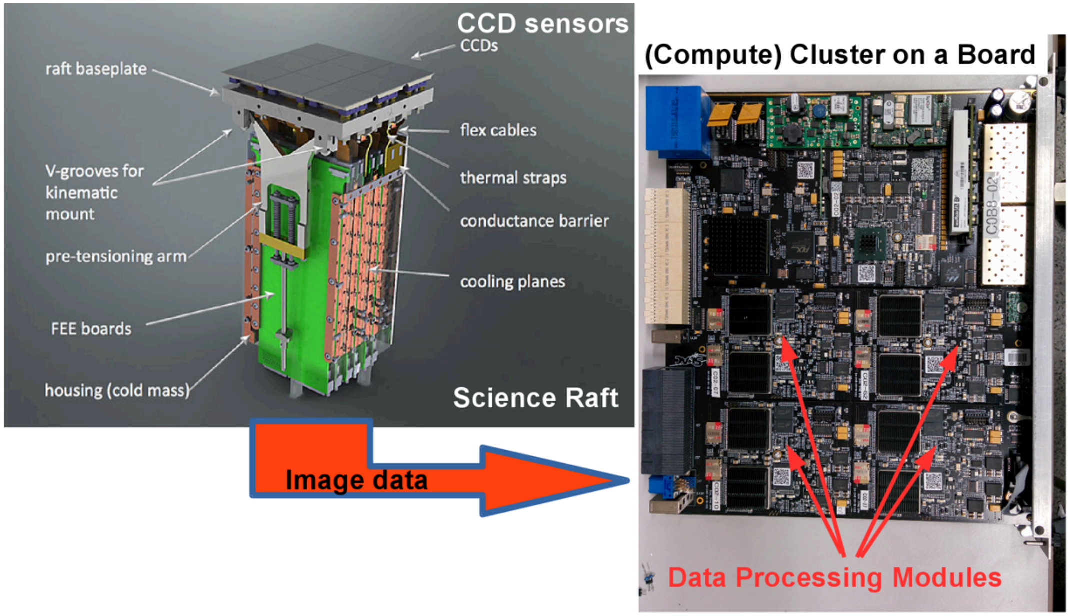




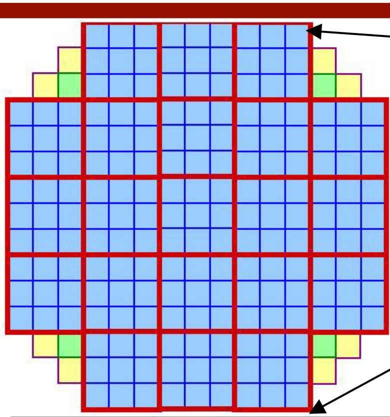


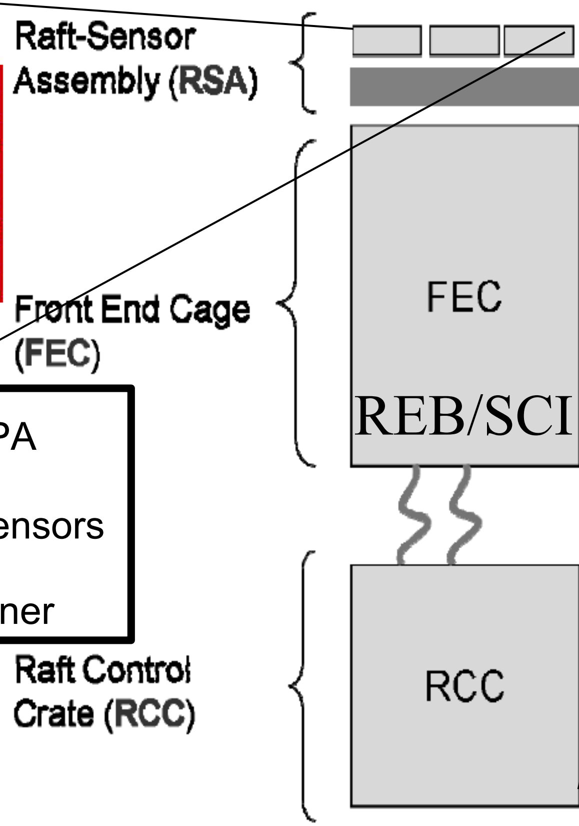
LSST Data Acquisition (DAQ)

Cluster on a Board (COB) used to route and preprocess LSST data
Toolkit planned to be used in ATLAS and DUNE
Test stands at Oxford & UCL allow development and testing of online processing software

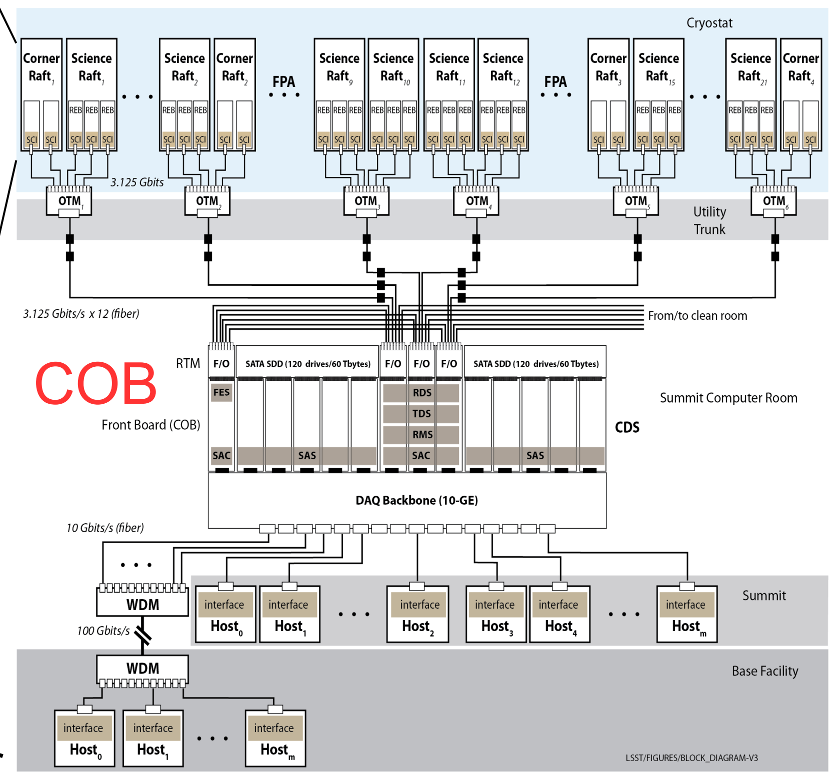


LSST DAQ





21 x 3 + 4 x 2 = 71 REB/SCI Raft-Electronic-Boards/ Source Communication Interfaces

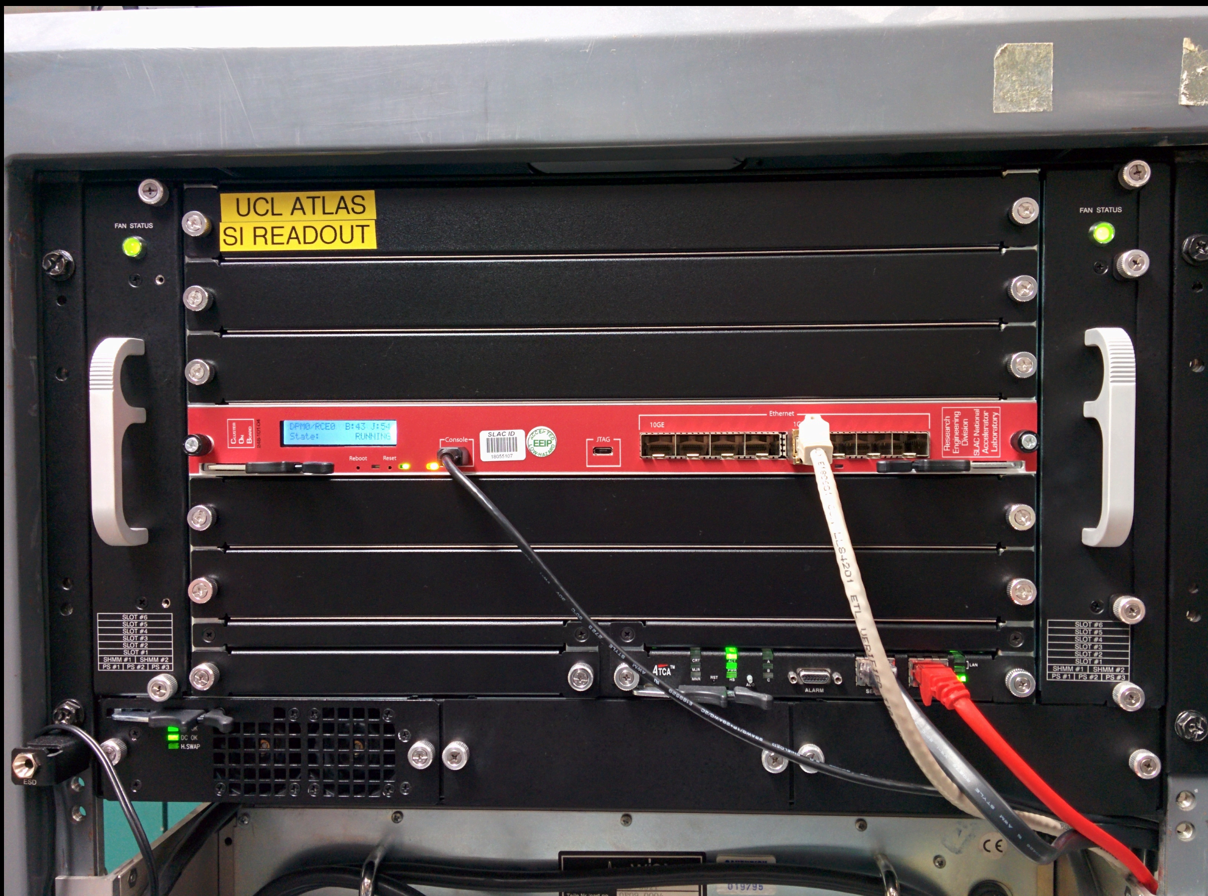


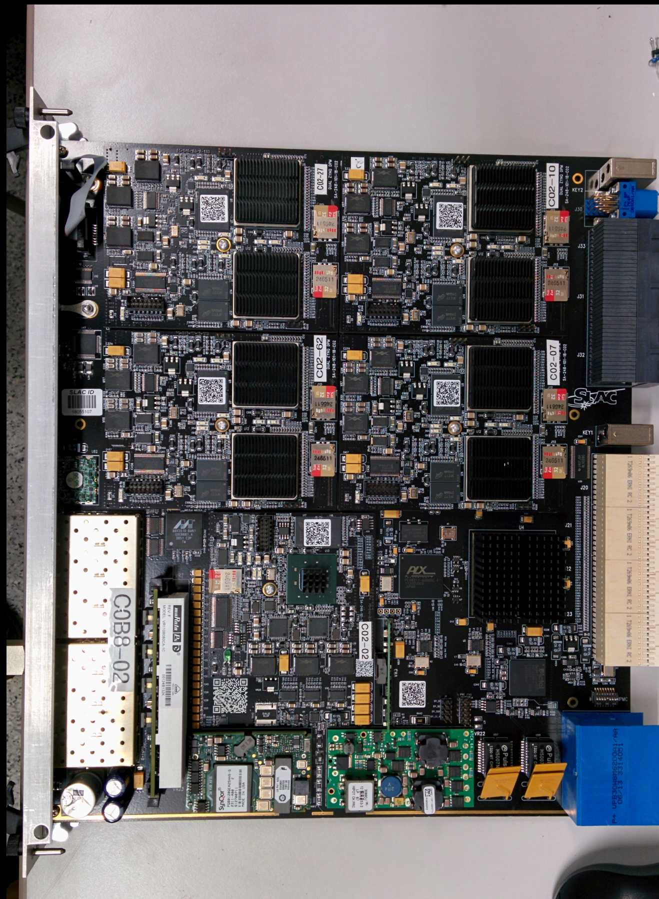
Focal Plane Array FPA
= 21 RAFTS
21 x 9 = 189 CCD sensors
Total 25 RAFTS
= 21 science + 4 corner

14 Cluster on a Board COBs:
- 3 to service Focal Plane Arrays
- 1 data emulation
- 10 data storage

12 Source Communication Interface SCI per Optical Transition Module OTM

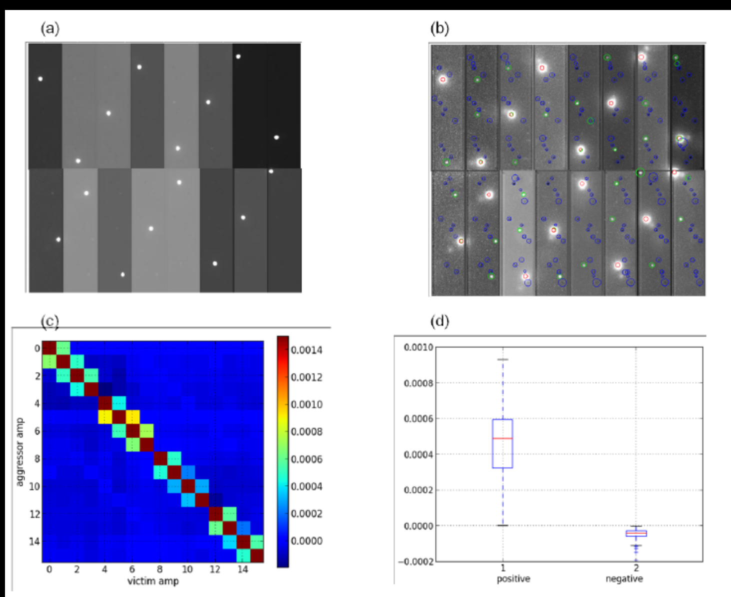
COB/RCE at UCL



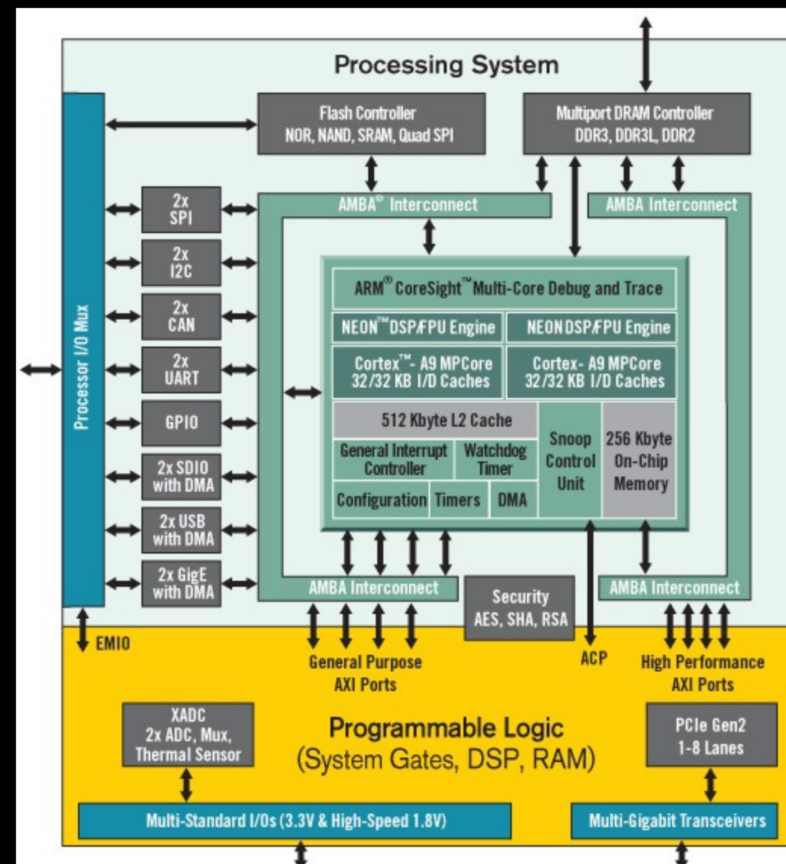


Connecting HW & physics

UCL (Korn) contact with M. Huffer and G. Thayer at SLAC
Plan: contribute to online cross talk correction on the COB
→ CCD performance: magnification systematic
Use ZYNQ NEON co-processor
on the RCE of the COB



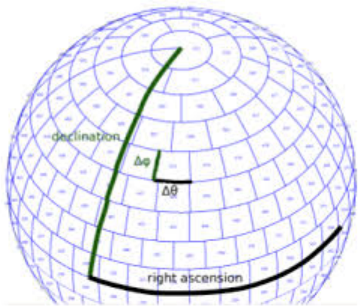
From P. O'Connor arXiv 1501.04137



Data management

Oxford

LSST is developing *qserv* for managing multi-PB, distributed offline data products for trillions of detections



- Focus on SQL-like random access queries
- Oxford investigating query performance, construction
  - Mostly Tseng, small part of Gallas (ATLAS)
- Learning from past surveys and analyses
  - Historical SDSS queries, expected common LSST queries
  - Talking with astrophysics colleagues about past analyses for cosmology, large-scale structure, transients
    → improve understanding of actual analysis needs
- Currently focusing on how qserv transforms queries into workflows
  - Opportunities for optimization, and catch “bad” queries

GridPP

Originally formed in 2001 to provide the UK contribution to the LHC computing Grid.

Comprises of 19 institutes across the UK.

Now provides the major processing power and storage for all particle physics and astro particle physics experiments in the UK.

As well as resources provides infrastructure for workflow submission, data movement etc

Has 16 years of experience in handling/ processing big datasets produced by experiments.

Has personnel who will help new communities

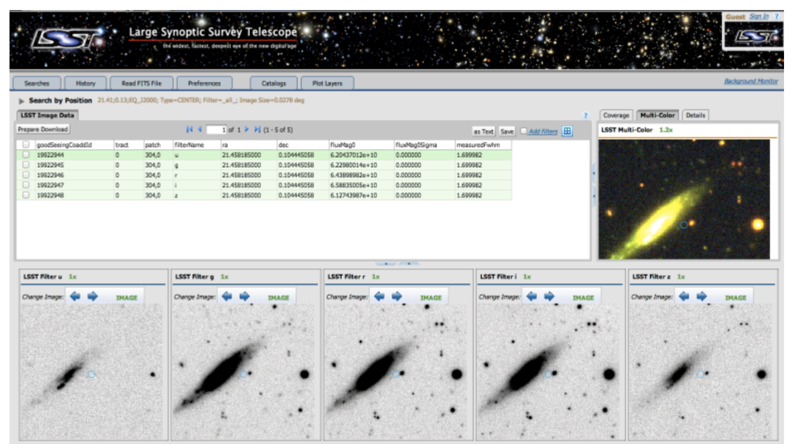
GridPP for LSST

Edinburgh/ Imperial

A joint LSST/GridPP technical post is in place, paid 50% by LSST to transfer expertise and technology. Working on developing the LSST UK Data Access Centre

A successful pilot (processing galaxy shears) has been developed as collaboration between Manchester astronomers (Zuntz, Bridle) and GridPP

LSST-UK has requested GridPP to provide support for LSST-DESC at modest level (~ 2% resources). This has been possible using leveraged resources at collaborating sites.



Workflow management & tools

Lancaster

Lancaster has expertise in the workload management and data flows, and are the UK experts on the Panda and BigPanda systems used by some of the LSST community in the US, and also working in the general on workload/job management. Lancaster also have expertise in resource predication and computing models.

UK Tier 0

Edinburgh/ Imperial

Is an attempt to use the diverse landscape of existing STFC Computing resources (GridPP, DiRAC etc) in a more coherent manner to better serve the expanding range of STFC science.

So far unfunded so progress is slow and on a best effort basis.

If LSST is going to be able to exploit the science in the data there will need to be a considerable investment in computing, either as part of GridPP or a wider UK Tier 0

Swansea Particle Physics Group: expertise for LSST

Swansea

Swansea particle physics group includes *theoretical cosmologists*, *particle physics/string theorists*, *experts in computational physics* applied to lattice QCD

- Theoretical cosmology: work on **dark energy** and **dark matter** model building, **modified gravity**, and **evolution of cosmological perturbations**

  Expertise on **formulating DE and DM theoretical models** aimed to explain cosmological data, and provide theoretical interpretation to new findings.

  - modified gravity with screening mechanisms:
    model building and evolution of cosmological perturbations
  - analysis of cosmological perturbations in non-linear regimes
    to be applied to Large Scale Structure formation and dynamics

  Expertise on embedding DE, inflation, DM scenarios in **broader particle physics and string theory contexts**.

Swansea Particle Physics Group: expertise for LSST

Swansea

- **Computational physics** Research facilities for Big Data and High Performance Computing: the new **Swansea Academy for Advanced Computing**, also in collaboration with Mathematics and Computer Science.
  - Cutting edge hardware facilities and dedicated expertise for analysis of large data sets: astronomical data sets are a welcome application
- **Centre for Doctoral Training Data-Intensive Science** Consortium with Universities of Bristol and Cardiff. First aim: train PhD students in Data Intensive and High Performance Computing. New collaborations with these institutions will develop also on LSST Physics.

Direct contact between theoretical cosmologists and computational physicists with particle physics background is a bonus of our group

Summary

Areas where PP expertise is valuable include: camera, DAQ, database development, simulations, algorithm development, dark energy science, annual data release processing, support for the UK Data Access Centre

UKPP beginning to apply their expertise

UK PP adds complementary value to the UK AST contributions to LSST and helps secure UK leadership in the science