Centre for Electronic Imaging

Trap Pumping for Euclid

Identifying radiation induced traps in-orbit

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Position Sensitive Detectors 11, Open University, 5th September 2017

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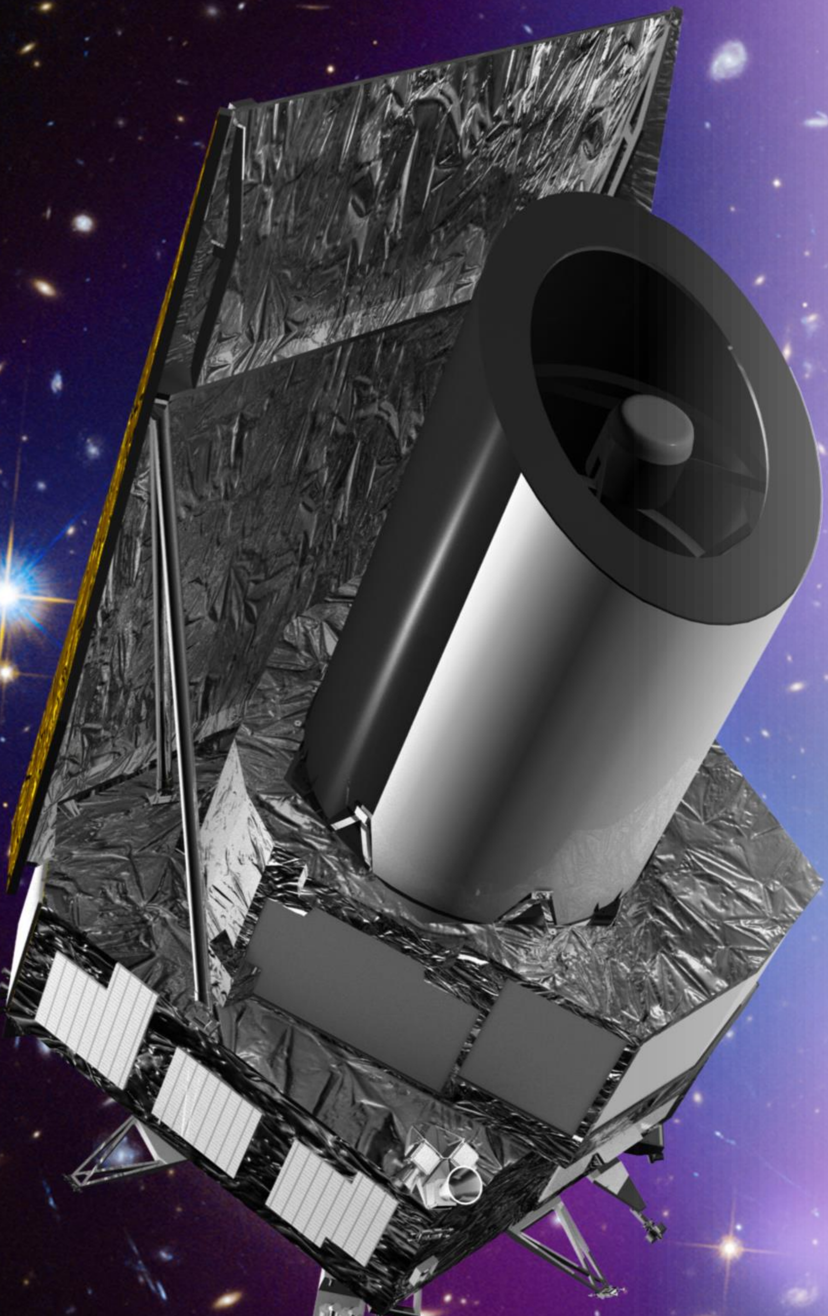
Euclid



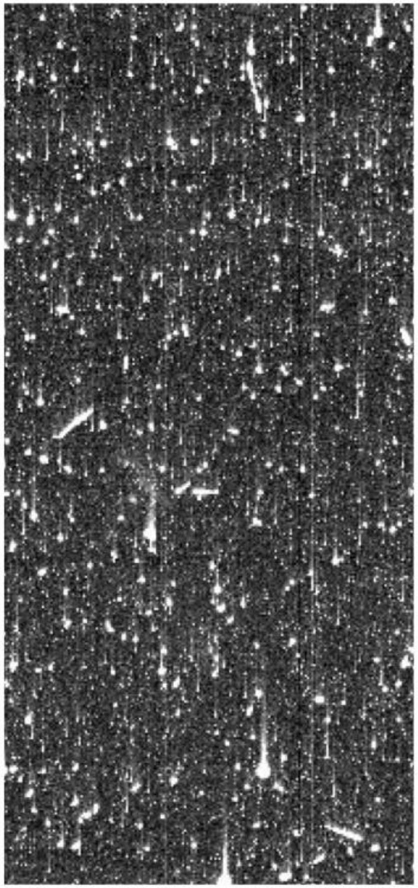
- ESA M2 mission
  - ‘Mapping the Dark Universe’
  - Dark Matter and Dark Energy
  - Two instruments (VIS and NIR)

- VIS instrument (weak lensing)
  - Measure shapes of galaxies of large part of the sky down to R~24.5
  - Use these data to infer Dark Matter distribution
  - Large focal plane
    - 36 CCDs (4k x 4k)
    - Over half billion pixels
    - 0.01 arcsec pixel scale
    - 0.5 deg^2 Field of View

Radiation damage

- High energetic particles from the Sun can damage the silicon lattice in the CCD
  - Creates defects
- These defects (or traps) can capture electrons and release them later in time
  - Leads to smearing of the data
- For Euclid radiation damage over 6 year mission will be major issue
  - High level of correction is needed
  - Requires improved knowledge of trap species and parameters
- Trap pumping method can identify and characterise single defects (or traps)
- Trap pumping will be used in-orbit for Euclid

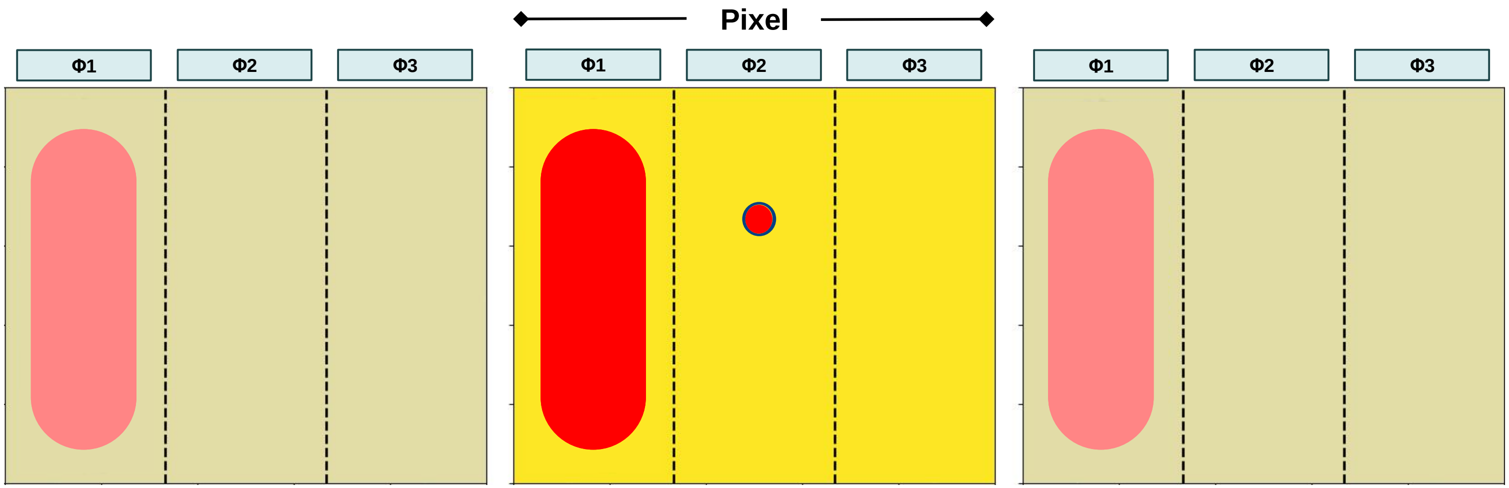
Before Correction



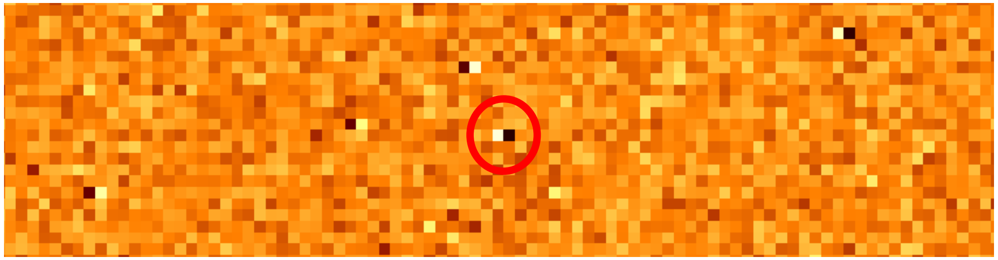
From: Massey et al. (2010)

Trap pumping theory

- Trap pumping works by clocking charge back and forth between phases



- If the phase time (t_{ph}) resonates with the emission time constant (τ_e) of the trap
  - Charge will be effectively shuffled from one pixel to the other
- Repeating this cycle a number of times (N) will result in a dipole for each trap



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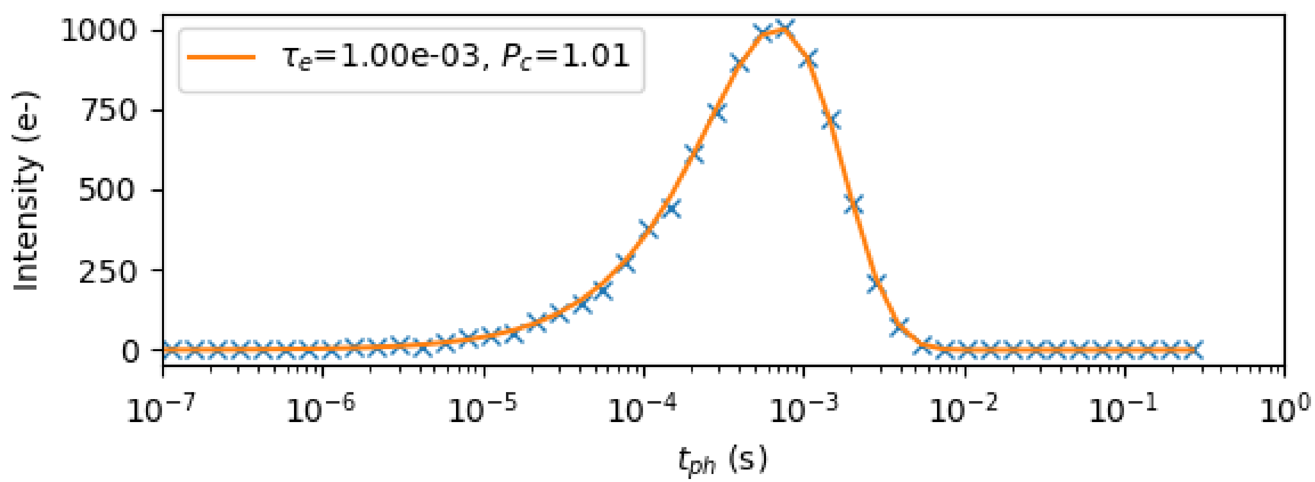
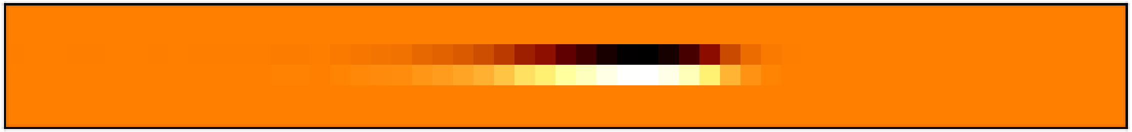
Trap pumping theory

- The intensity of the dipoles is given by

$$I = NP_c\left[exp\left(\frac{-t_{ph}}{\tau_e}\right) - exp\left(\frac{-2t_{ph}}{\tau_e}\right)\right] \qquad \textbf{(Eq. 1)}$$

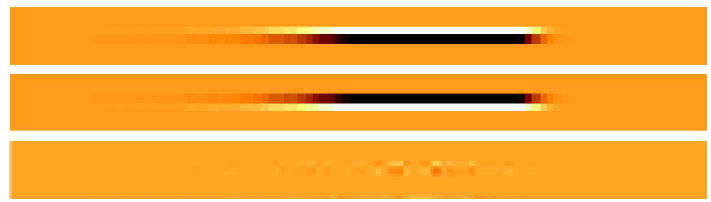
- Different t_{ph} values will give different dipole intensities for each trap
- Fitting Eq. 1 to the intensity curve will give τ_e and capture probability P_c



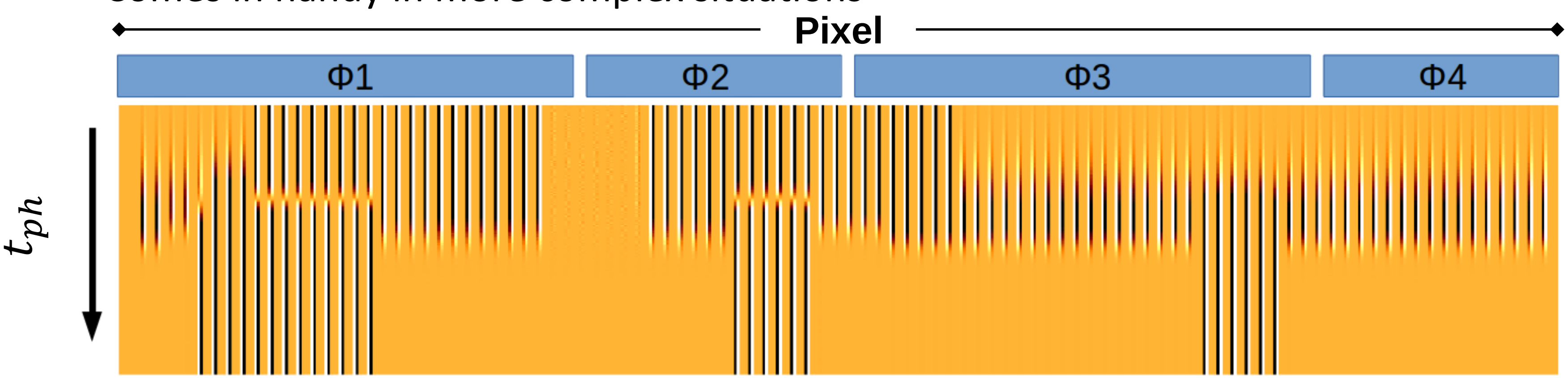


Simulating trap positions

- Dipole intensities also depends on position of the trap in the pixel, signal size, clocking scheme, pixel geometry, etc.
- All these parameters can be simulated using the CEI CCD Charge Transfer Model (C3TM) developed for simulating CTI effects in CCDs (**Skottfelt et al. 2017**)
- Simulating 3 phase device with standard clocking scheme
  - Single trap under $\Phi 3$
  - Single trap under $\Phi 2$
  - Single trap under $\Phi 1$

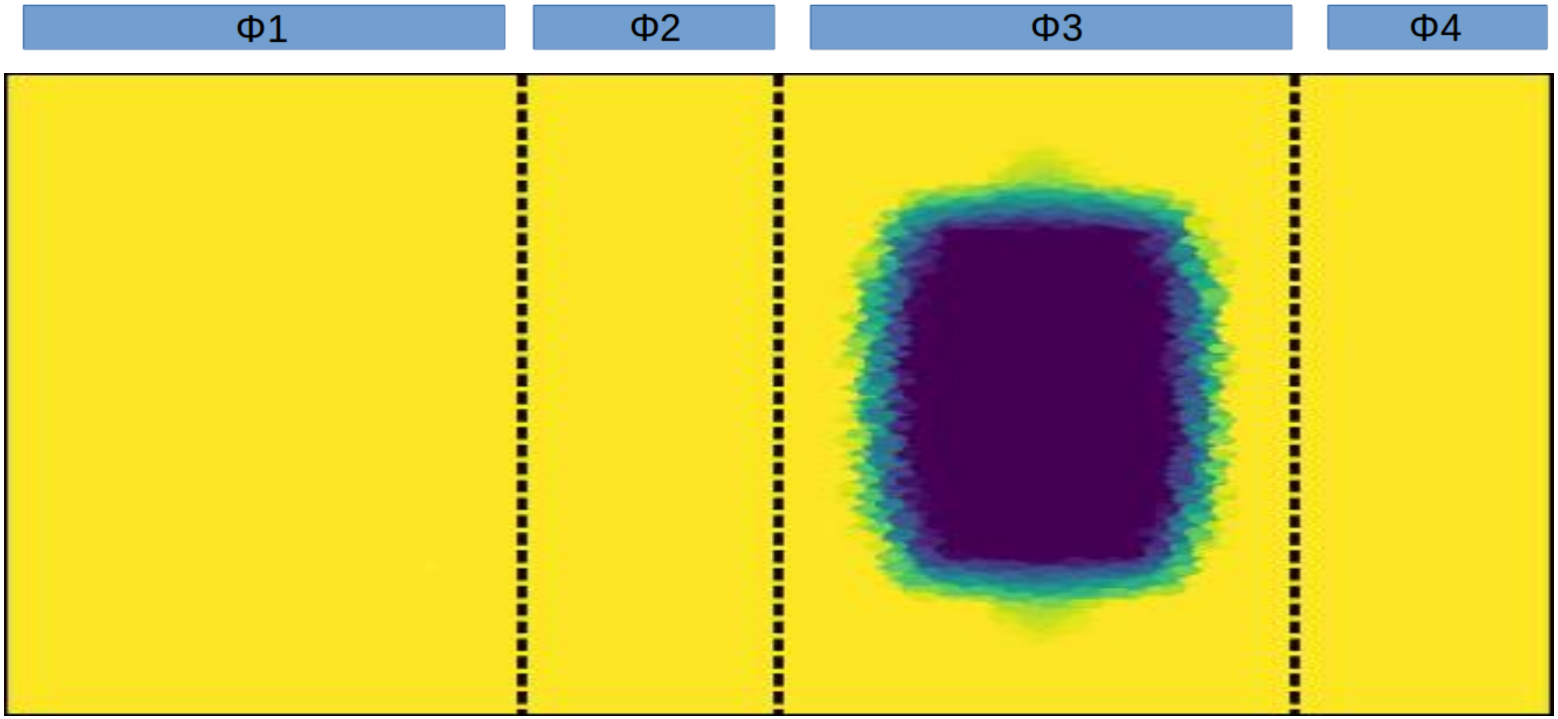


- Direction and shape of dipole can thus give subpixel information
- Simulating all subpixel positions to get map of dipoles for traps across the pixel
- Comes in handy in more complex situations



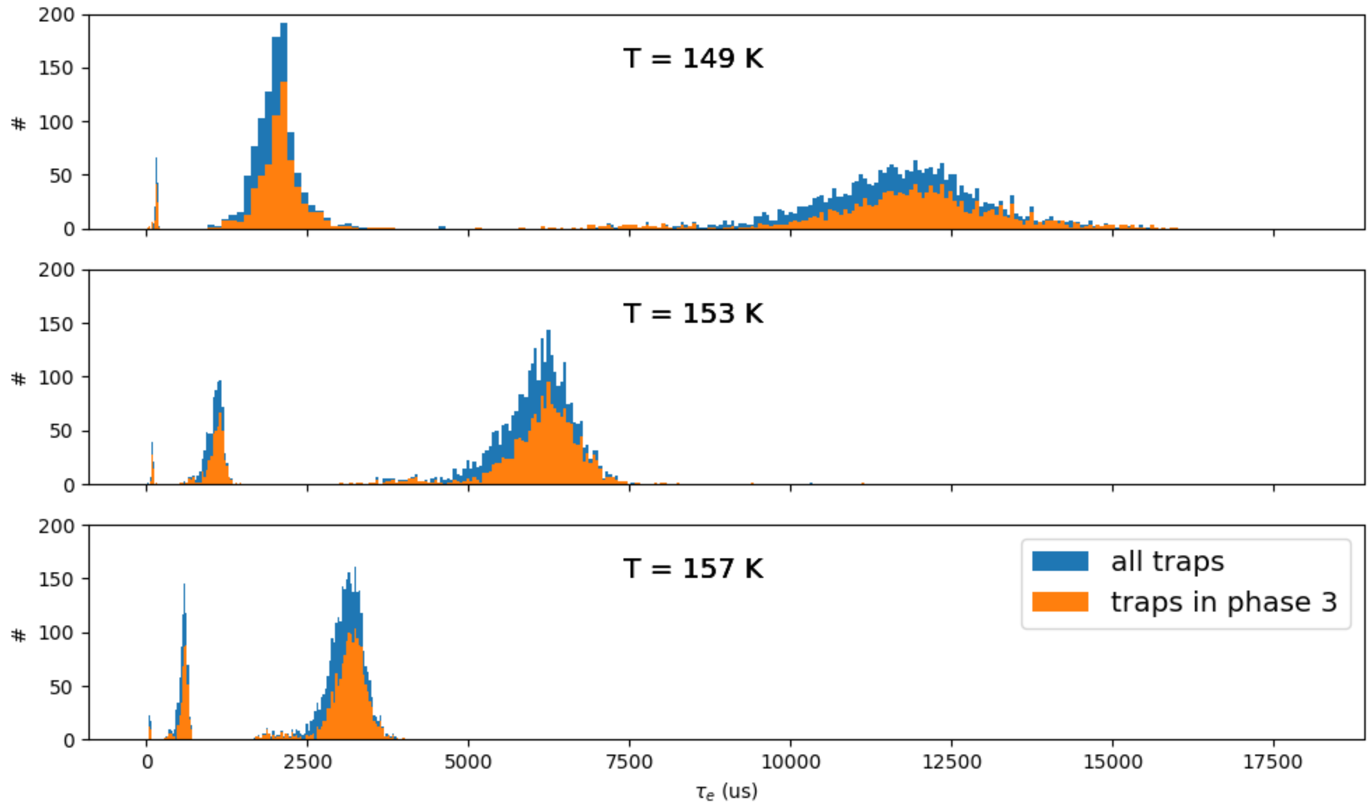
Sub-pixel clocking scheme

- Euclid CCD273 device has 4 phases and alternative clocking scheme thus needed
- Number of possible clocking schemes simulated and tested in lab
- Sub-pixel pumping scheme (1-2-3-2-1) chosen because of its simplicity
- Small part of pixel probed, but low risk of dipoles cancelling
- Direction of dipole can give sub-pixel and sub-phase positions



Trap pumping analysis

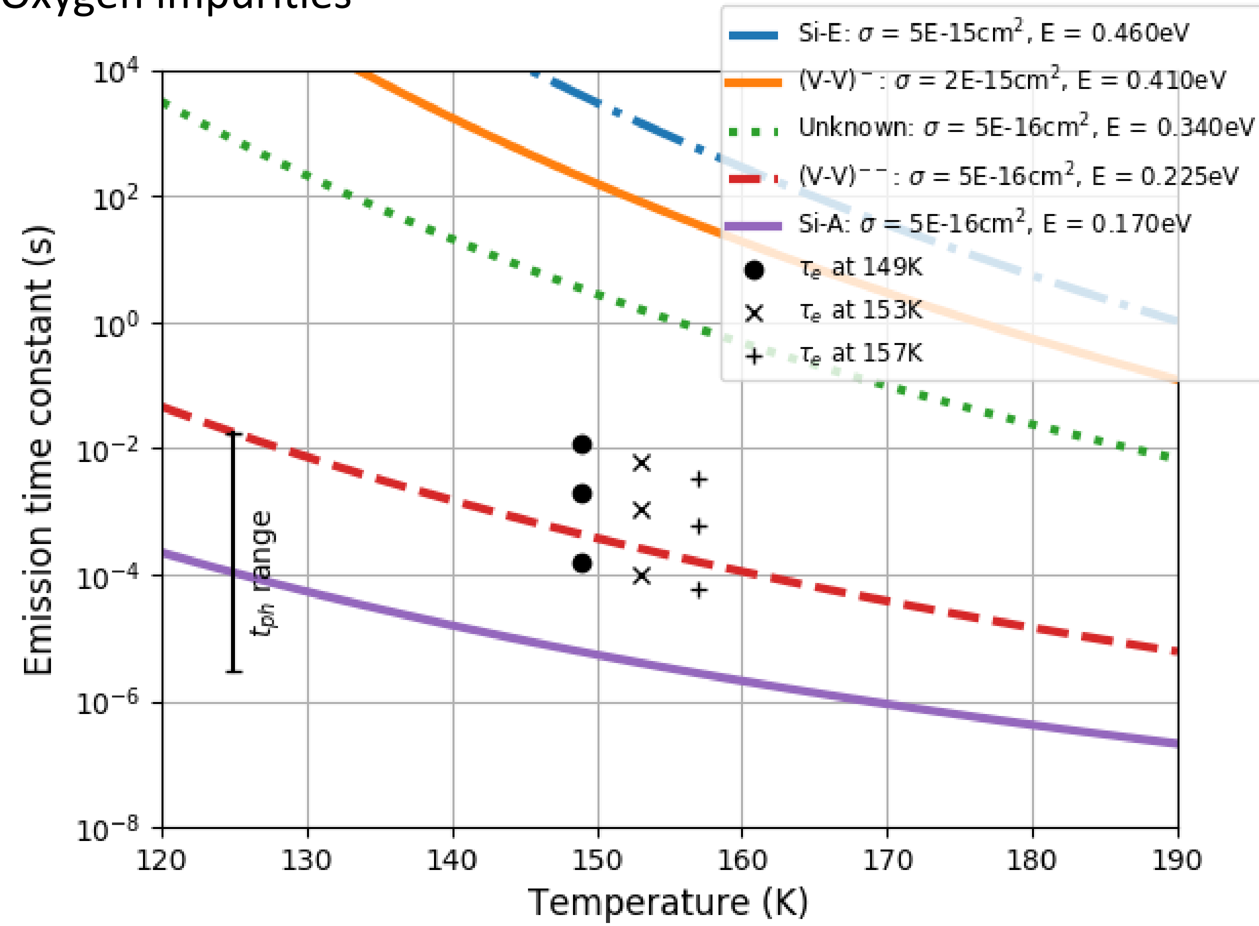
- CCD273 devices tested at OU as part of irradiation campaign for Euclid
- This shows data from pre-irradiated devices (1600 e^-)
- 3 peaks
- τ_e scales with temperature



Trap species

- Plotting the peaks found at the three different temperatures
- τ_e peaks matches defects from Phosphorus and Boron (used as dopants) mixed with Carbon and Oxygen impurities
  - C_iP_s (0.23, 0.26 eV)
  - B_iO_i (0.24 - 0.27 eV)

  (Pichler, 2004)
- Results similar to the the p-channel study (Talk by Ben Dryer)



Electrode widths

- Lab test show that when pumping 2-3-4-3-2 almost no traps are detected
- Possible explanation for this is that electrode widths are slightly skewed
- Simulation of TP with different widths for Φ1 and Φ3 gives similar effect
- Infer knowledge about the electrode widths

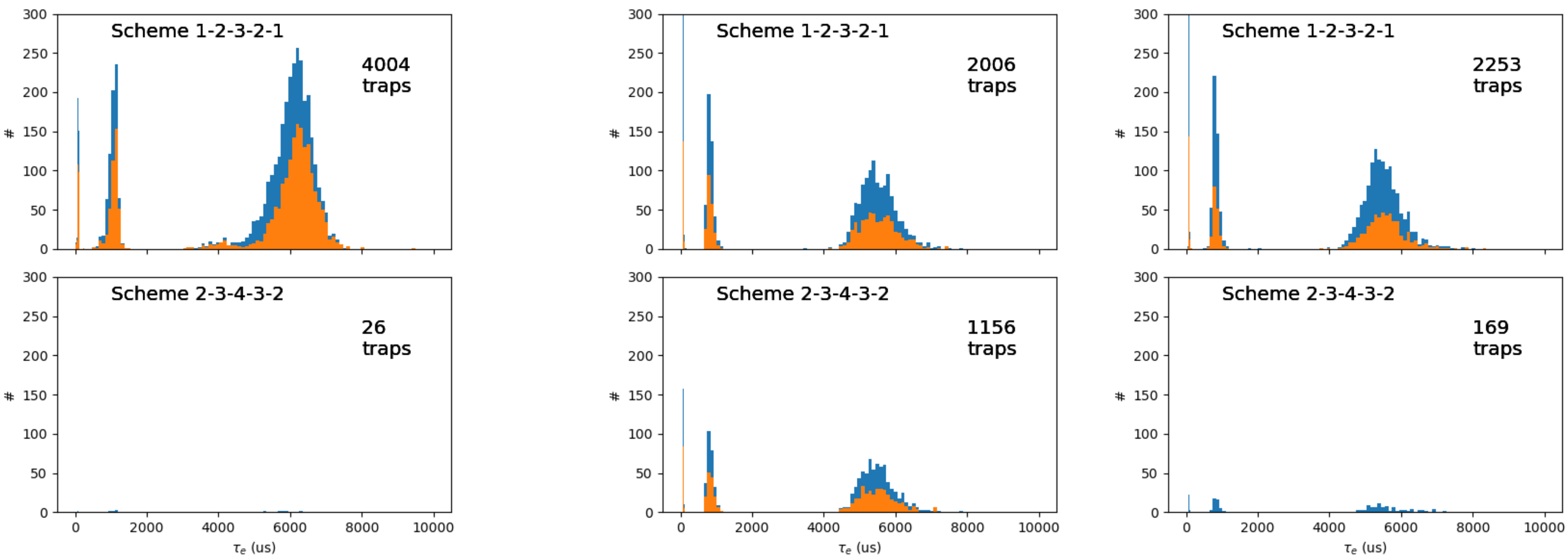
Φ1 = 4.5 µm	Φ2 = 2 µm	Φ3 = 3.5 µm	Φ4 = 2 µm

Simulated data

Lab data

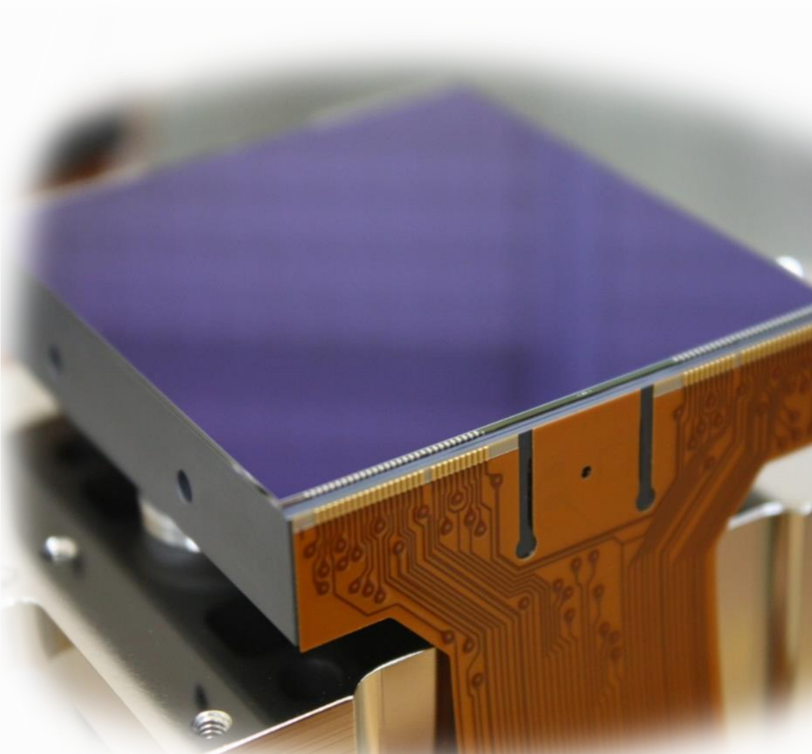
Φ1 = 4 µm, Φ3 = 4 µm

Φ1 = 4.5 µm, Φ3 = 3.5 µm



Summary

- Weak lensing experiment on Euclid mission requires high resolution imaging
- Radiation damage degrades the data and therefore needs to be corrected for
- Trap pumping method can identify and characterise single traps in silicon lattice
  - Will be used by Euclid in orbit
- Trap pumping scheme chosen for Euclid
  - Gives subpixel and even sub-phase positional information
  - Reveals defects from dopants and impurities (pre-irradiated devices)
- Information about electrode width can be inferred from the by comparing lab and simulated trap pumping data



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Information from LOC

The conference BBQ this evening will still take place, but it will be moved indoor if the weather does not improve