Validation of Sensor Features in Simulations

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2013/12/5

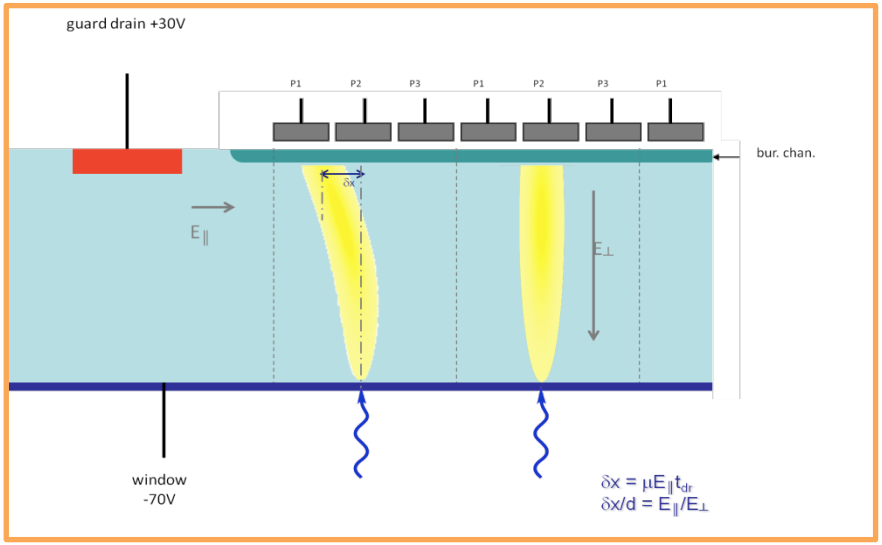
BNL involvement in LSST simulations

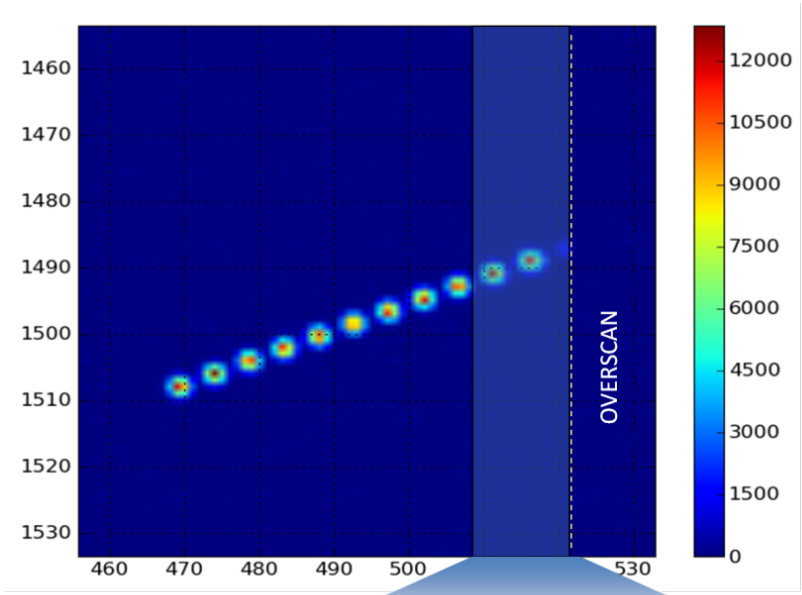
- Validation of sensor effects in PhoSim (silicon.txt)
  - Edge and anti-bloom stop roll-off effects
  - Tree rings
  - Fringes
  - Brick-wall pattern from laser annealing
  - Intensity dependence
  - Crosstalk in sensors and rafts
  - ..

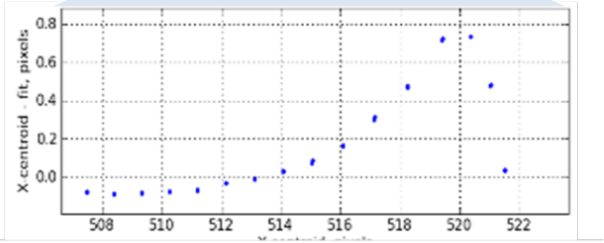
- Simulations of lab setups
  - Describe lab setup in PhoSim, modification of optics file to model a spot projector (for example)
  - Compare simulations and measurements

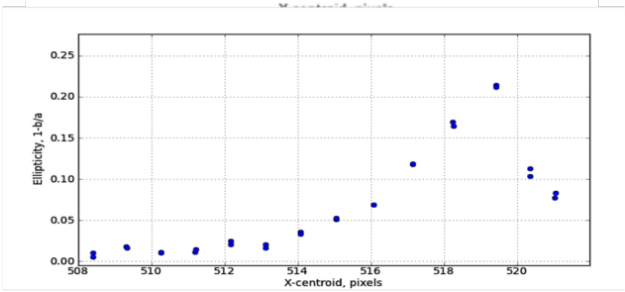
- Use tuned simulations to evaluate sensor effects on science

Laser Spots in CCD









- On the egde:
  - Non-linearity up to 50%
  - Ellipticity up to 20%

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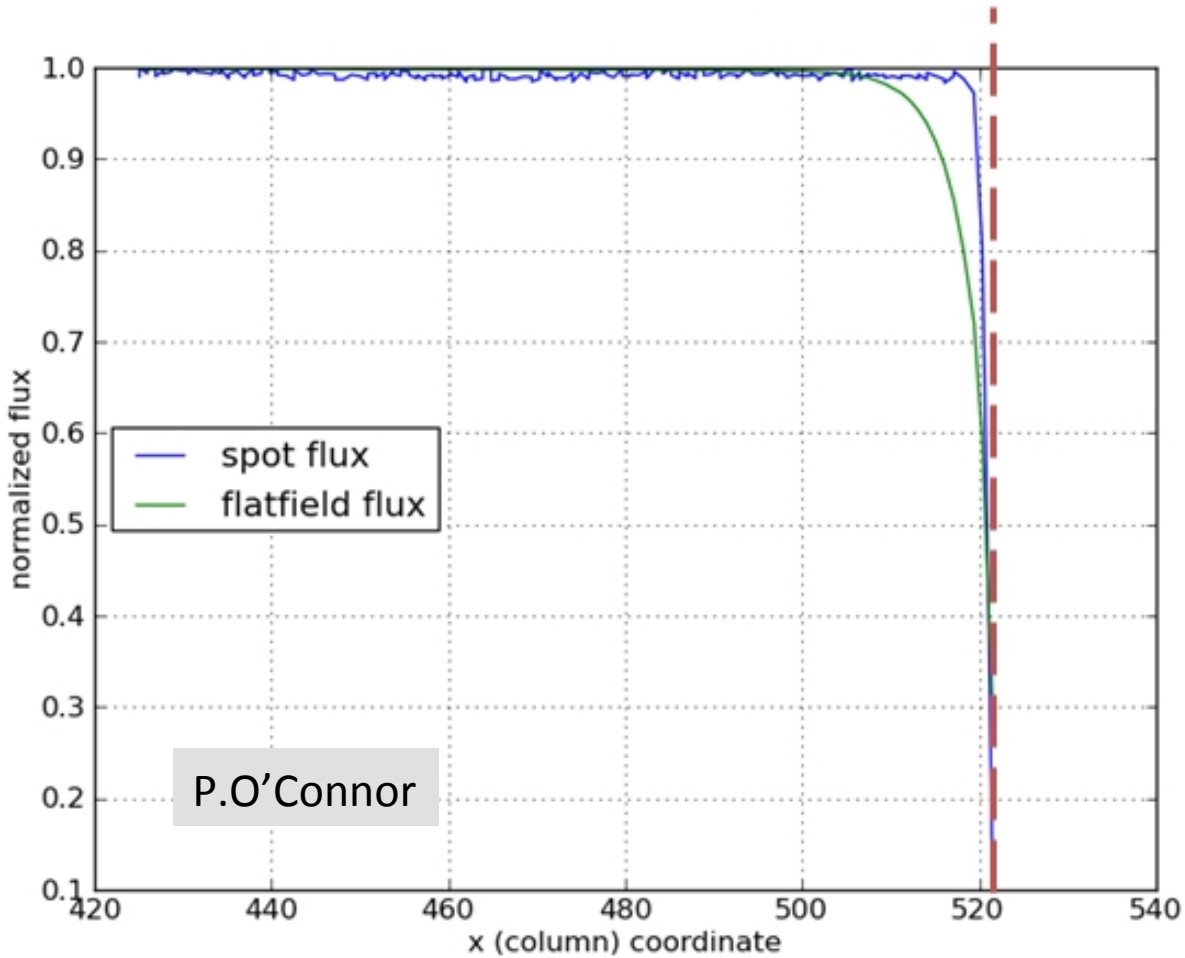
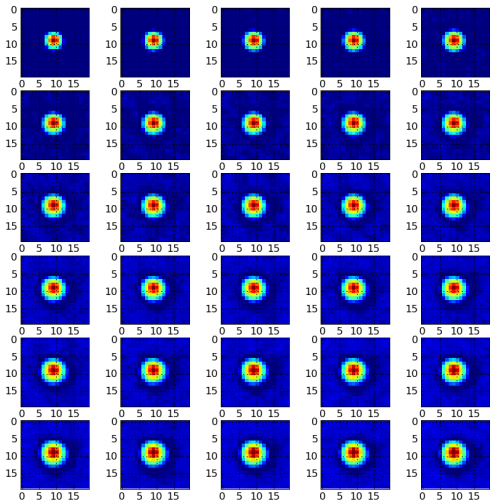
Spot flux does not trace flatfield flux



Spots and flat field behave differently

- due to space charge effects

Intensity Dependence



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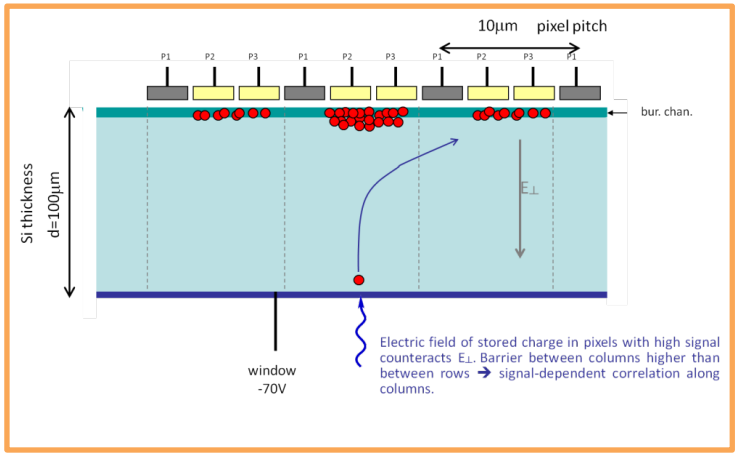
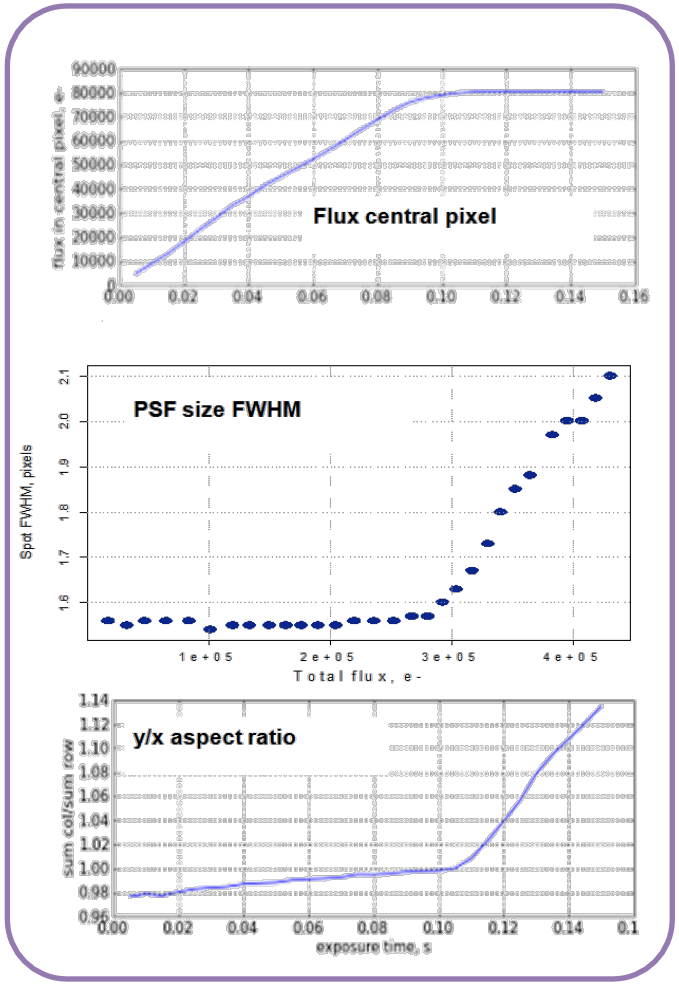
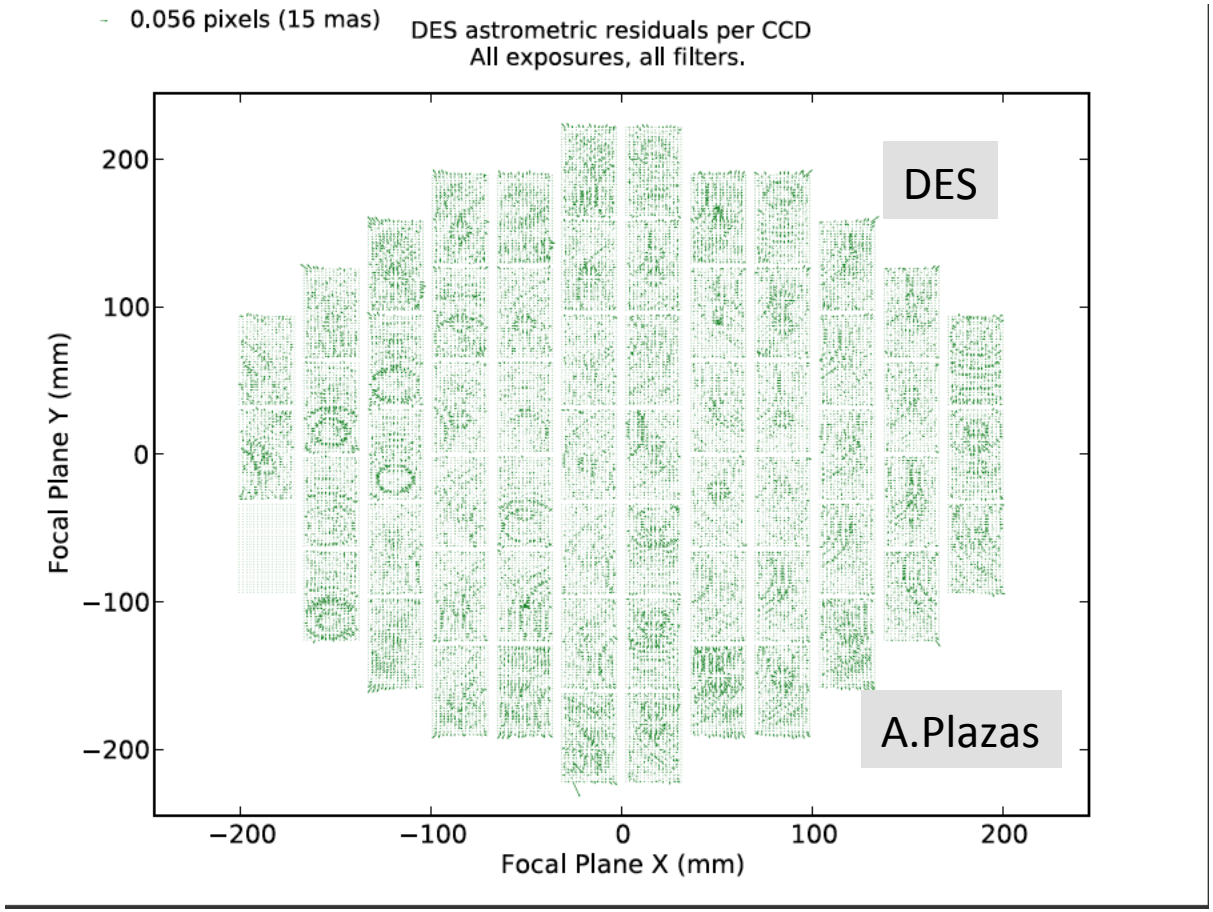




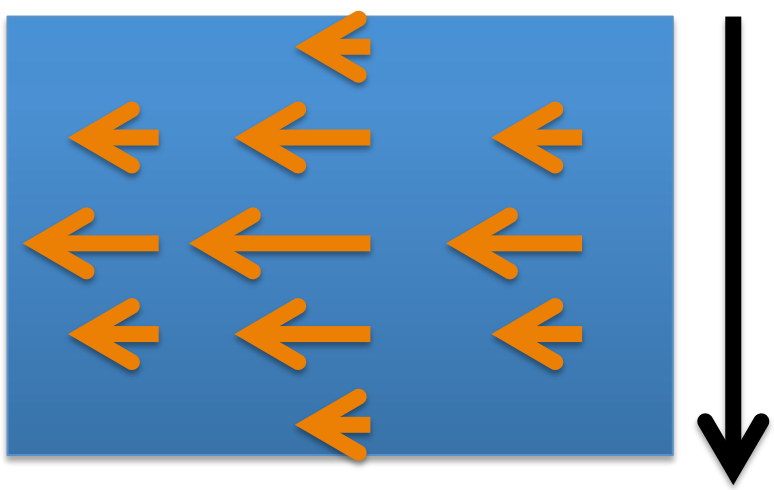
Tree Rings

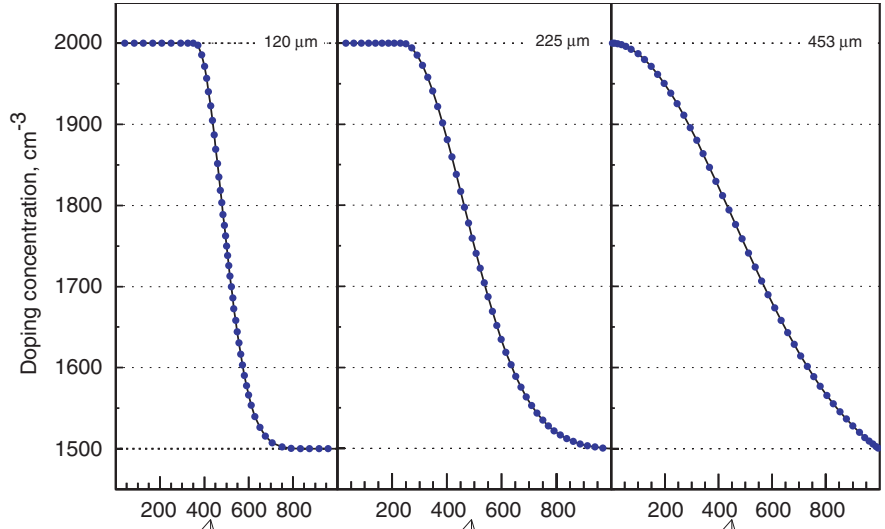


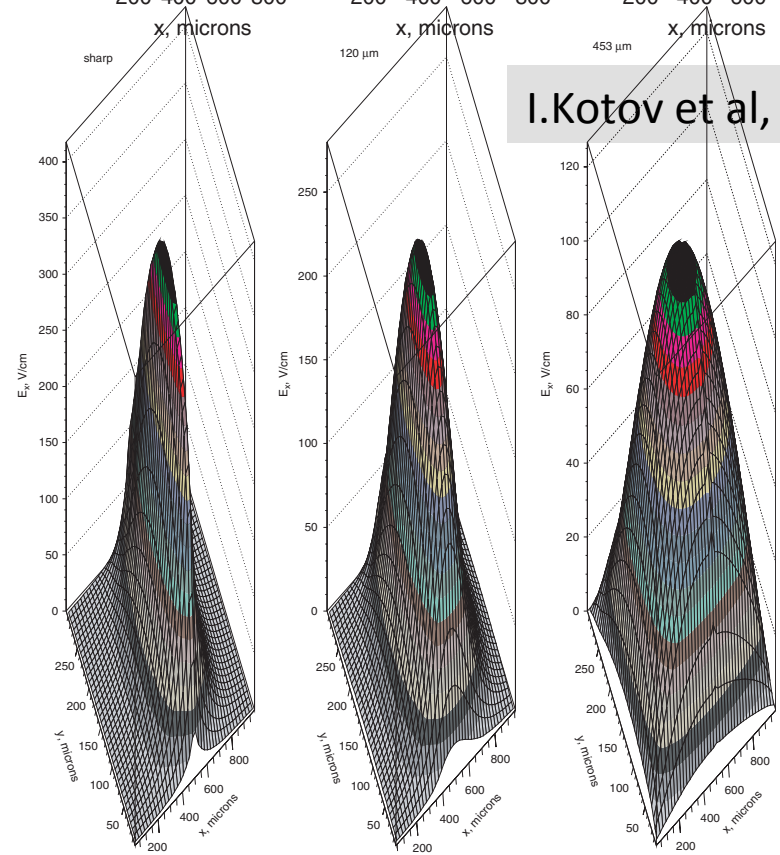
- Due to uneven doping of silicon wafers

Lateral E Field

- Lateral field can be approximated by parabolas (for example) in both directions
- Proper electrostatic simulations can be done if needed
- PhoSim has a simple model which needs tuning







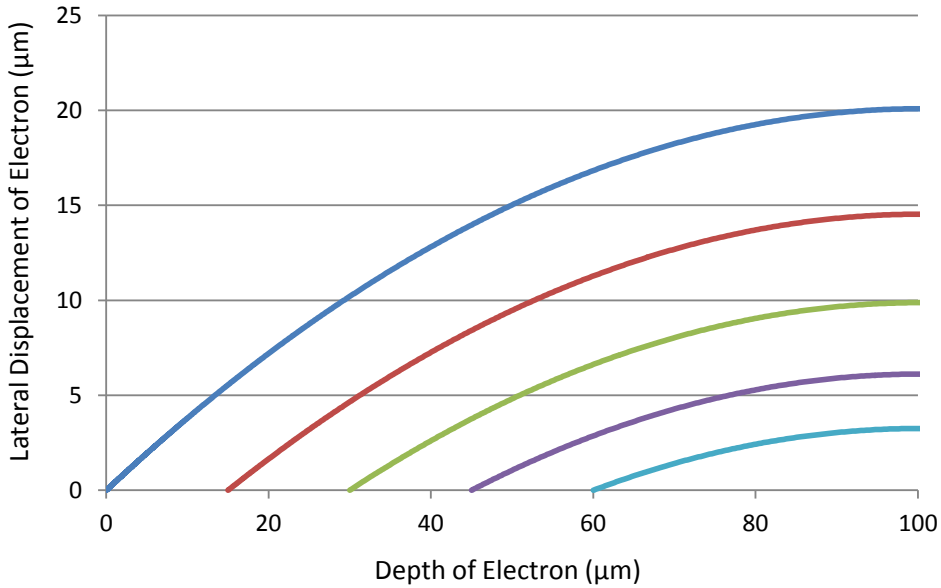
I.Kotov et al, 2006

Fig. 3. The E_x component for "sharp" and Gaussian transitions of the doping profile.

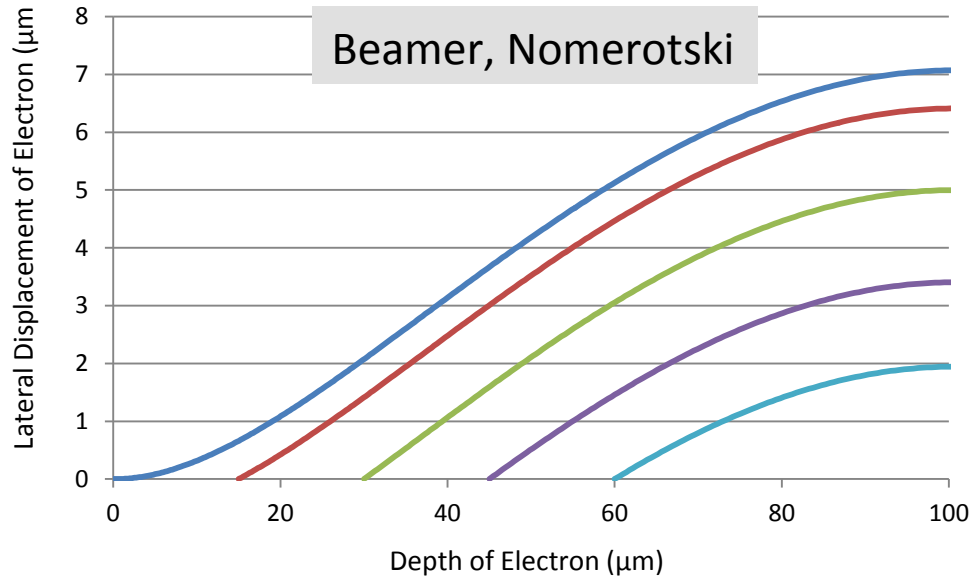
Displacement of Photoelectrons in Si due to tree rings

- Lateral displacement

$$\Delta y = \int_x^d dx \frac{E_y}{E_x}$$



Depleted sensor



Overdepleted sensor

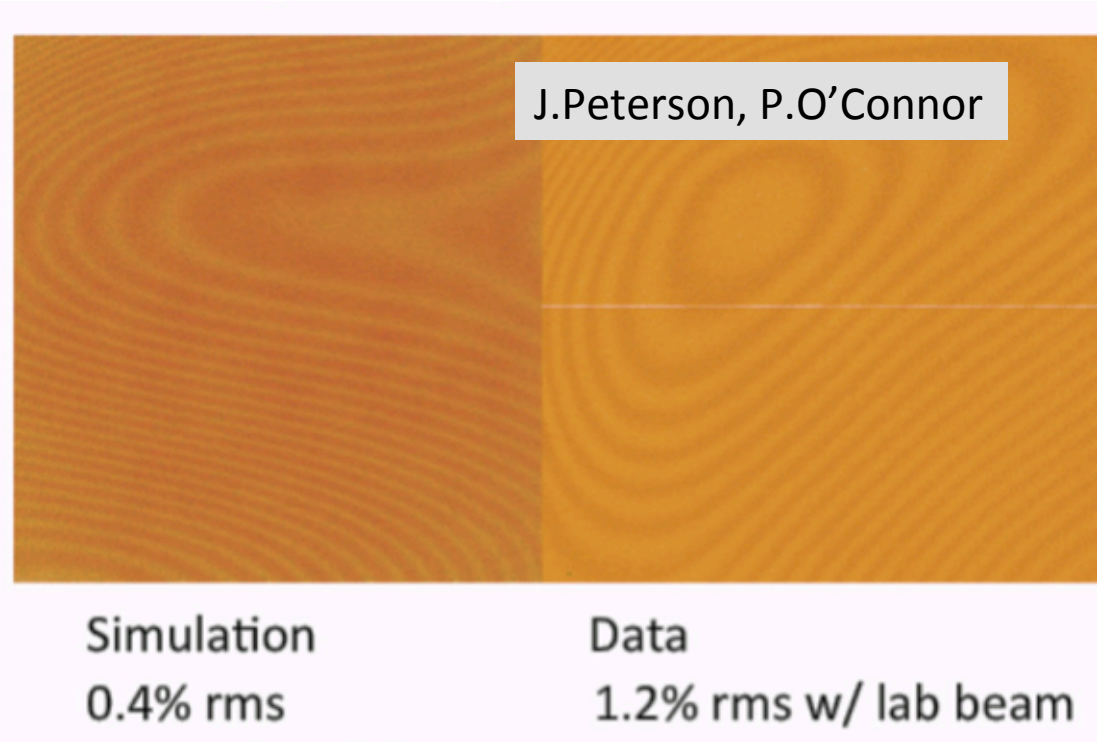
Tree Rings – Next Steps

- Complete analytical calculations, introduce Ey(z) dependence, introduce saturation of drift velocity at large E
- Compare to PhoSim tree rings
- Tune PhoSim tree ring parameters to measurements in LSST and DES sensors

- Use PhoSim to evaluate how science is affected by tree rings
  - Astrometric biases
  - Chromatic effects for WL
  - Corrections and residual systematics
  - etc

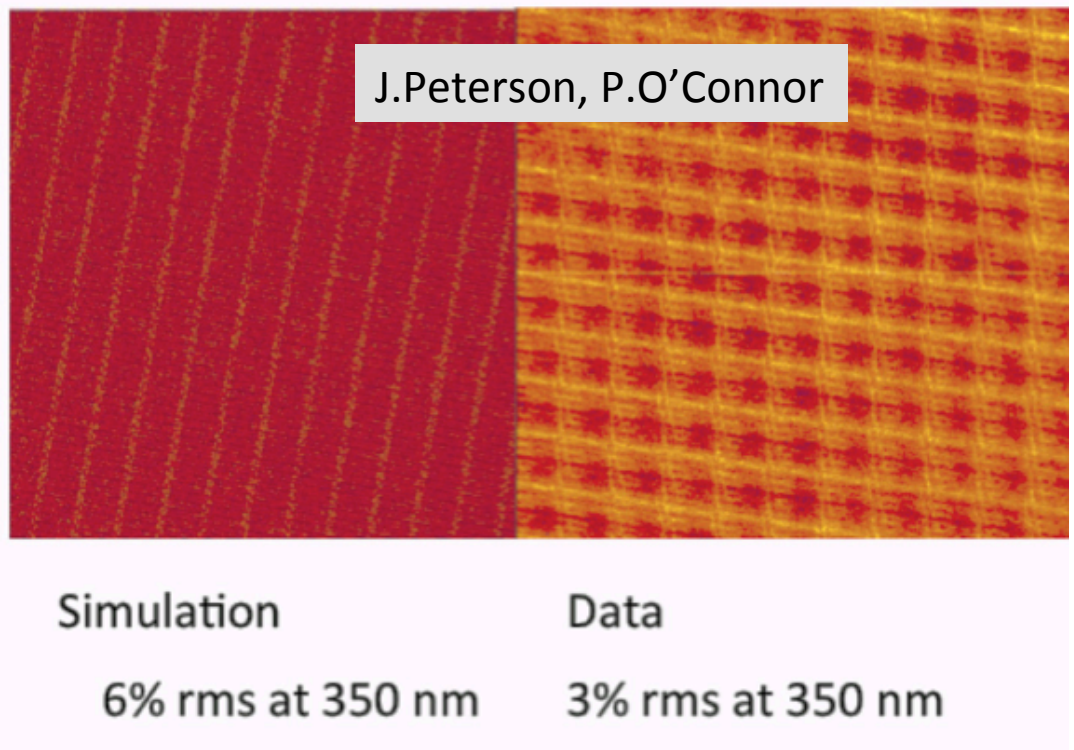
Fringes

- Interference patterns due to reflections off the sensor bottom, visible at longer wavelengths
- Use a random surface with some flatness
- Will use BNL metrology data to validate
- Assumes that the backside is flat
  - Fringe data at different wavelengths should allow to extract the backside flatness



Brick-wall pattern

- From laser annealing of back side, visible at short wavelength
- Described in PhoSim with 11 parameters
- Needs tuning



Summary

- Fully depleted CCD have a non-trivial electrostatics which lead to astrometric biases and PSF distortions (+ other important sensor effects)
- This may affect science and needs to be studied in simulations

- We are working on validation of all main sensor effects in PhoSim and will propagate this to studies of WL systematics