Queen Mary
University of London
Science and Engineering

Organic Semiconductor Development

Dr Theo Kreouzis

M.Ali, A.J.Bevan, J.Borowiec, P.Finn, G.Gannaway, C.B. Nielsen, S.Moss, F.Noyes, K.Scott, F.E.Taifakou, C.Timis

Detector Development Group Industry Event

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Organic Semiconductors (OSCs)

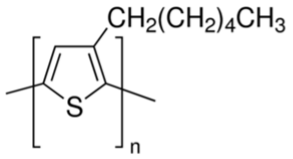
Characterised by conjugated carbon-carbon bonds

- Easy to Fabricate
  - Solution processed
  - Vacuum deposited
- Suitable for large area devices
- Large chemical parameter space
  - binary/ternary systems
- Different devices possible
  - Diodes
  - Field Effect Transistors
- etc

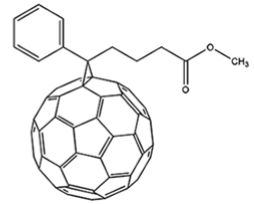
- Low charge carrier mobilities
- Environmental instability

Diode test structures

P3HT

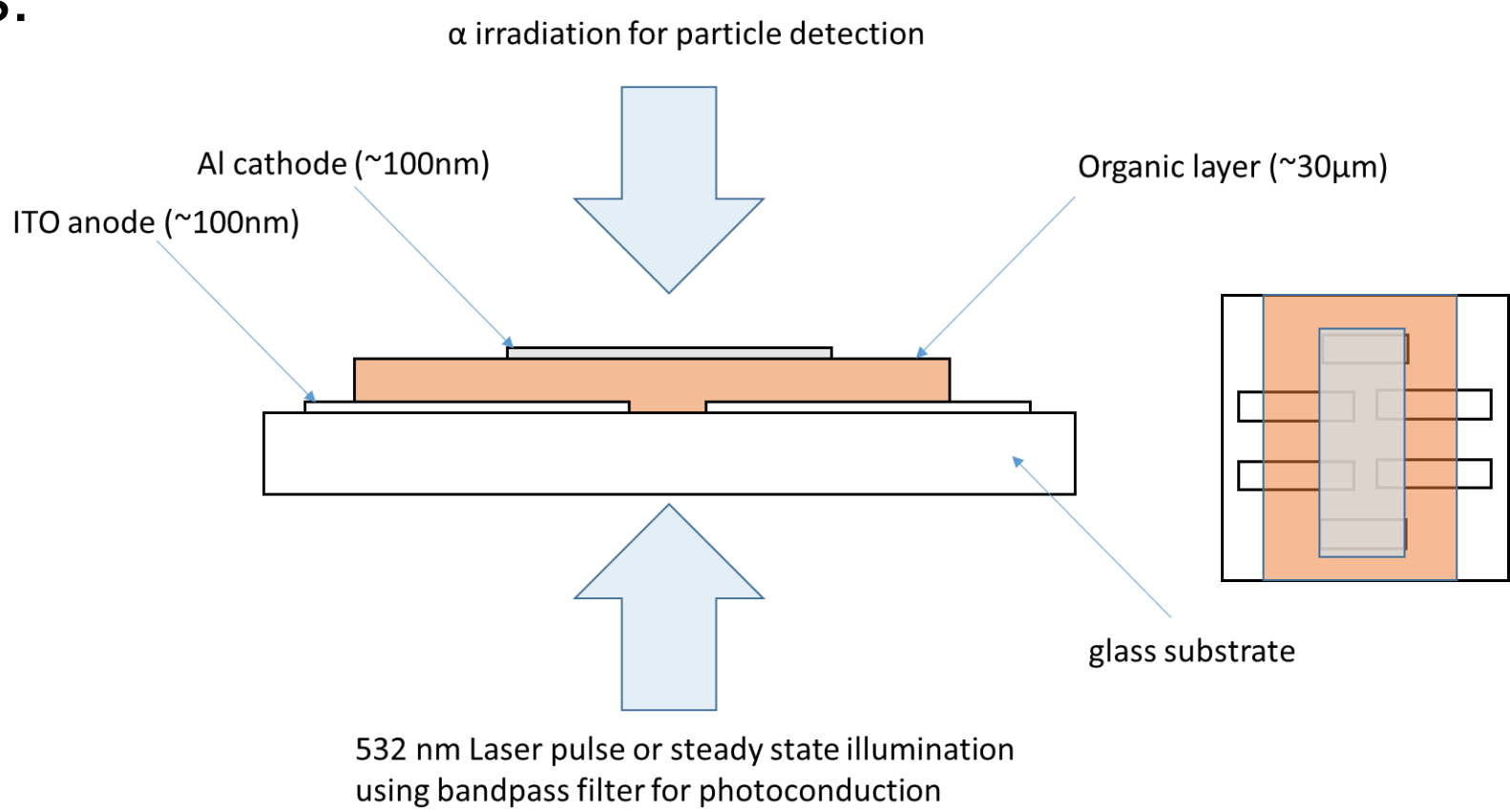


$PC_{60}BM$



"standard" structure allows:

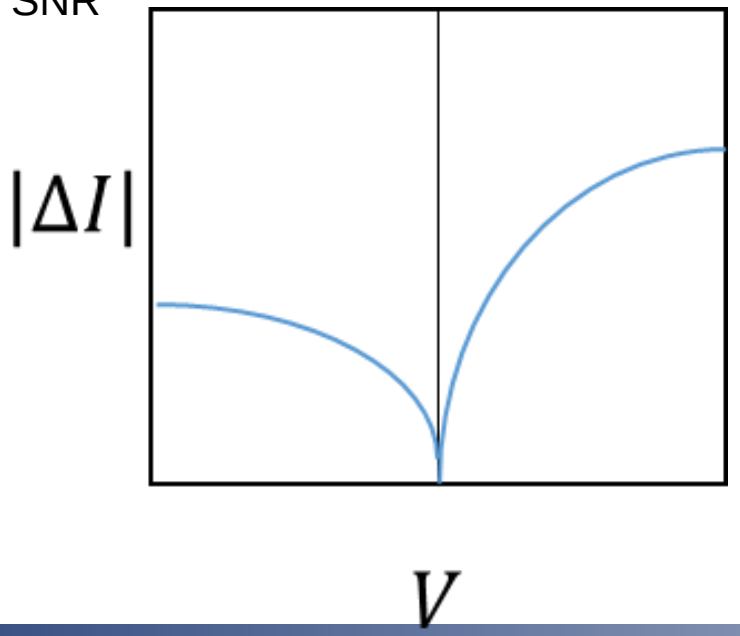
- Radiation response
- electronic characterisation
  - I-V, C-V etc
- Time of Flight Photoconduction
  - hole/electron mobility
- Optical/electronic/Raman/scanning probe microscopy
- Profilometry



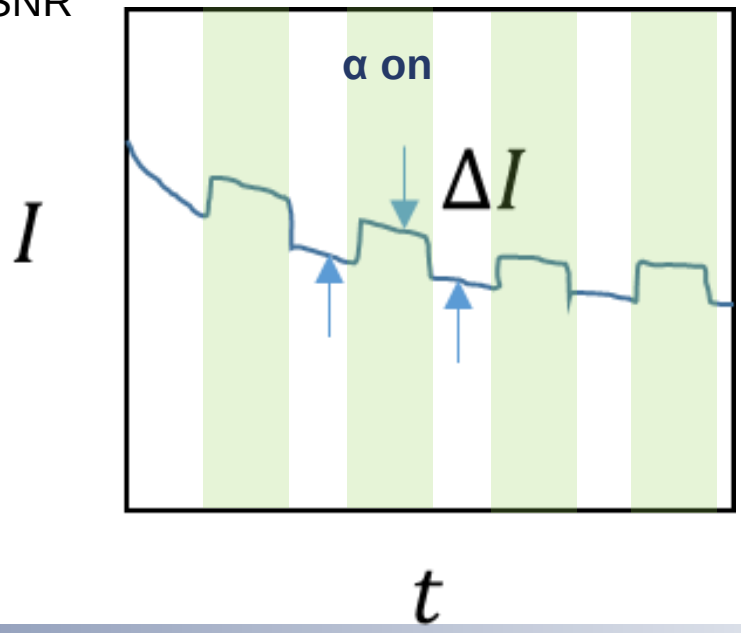
(quasi) Steady state α measurements

"standard measurements"

- Steady State
  - I-V in presence/absence of α
  - off-on-off sequence
  - Can calculate ΔI and SNR



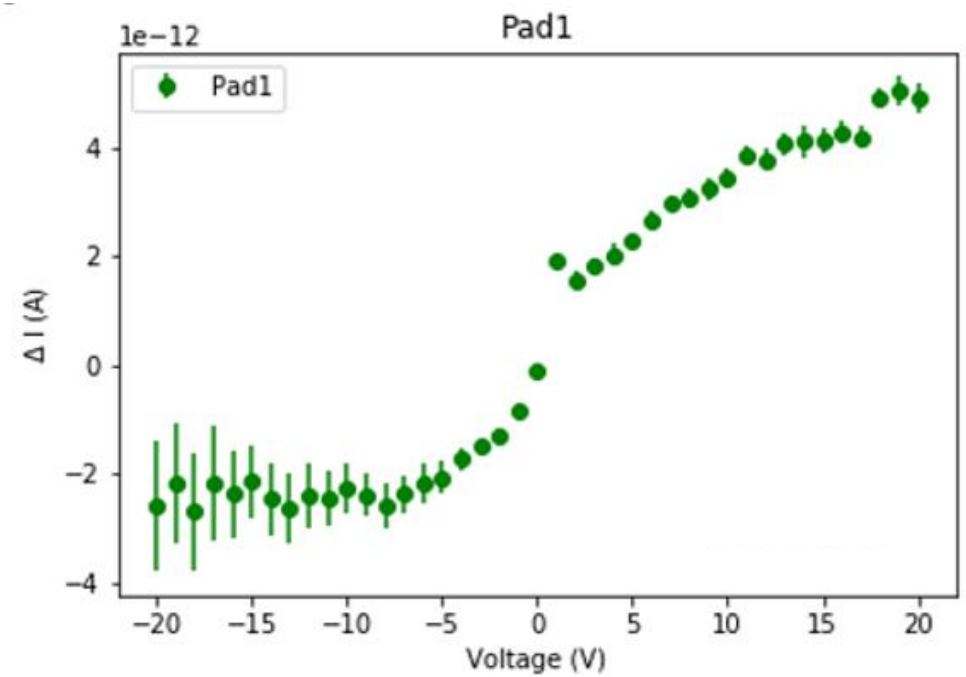
- Time Dynamic
  - I-t in presence/absence of α
  - off-on-off sequence
  - Can calculate ΔI and SNR



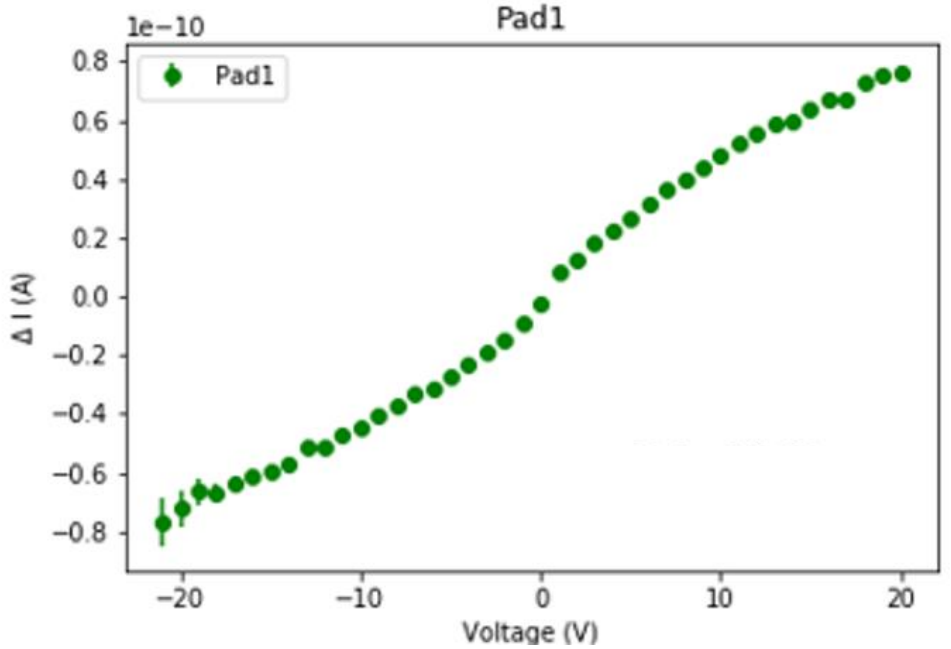
Longevity and air stability - 1

type 23 devices Steady State α detection

- **90 days** storage under nitrogen
  - Measured under **vacuum**
  - Device functional



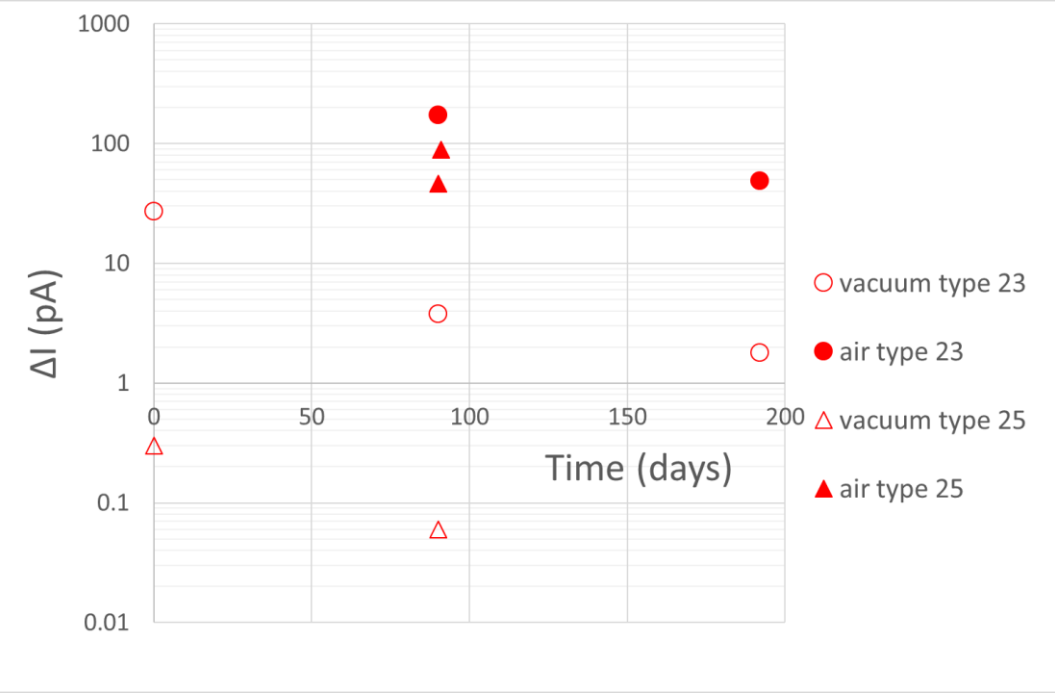
- **90 days** storage under nitrogen
  - Measured in **air**
  - Device performance improved!



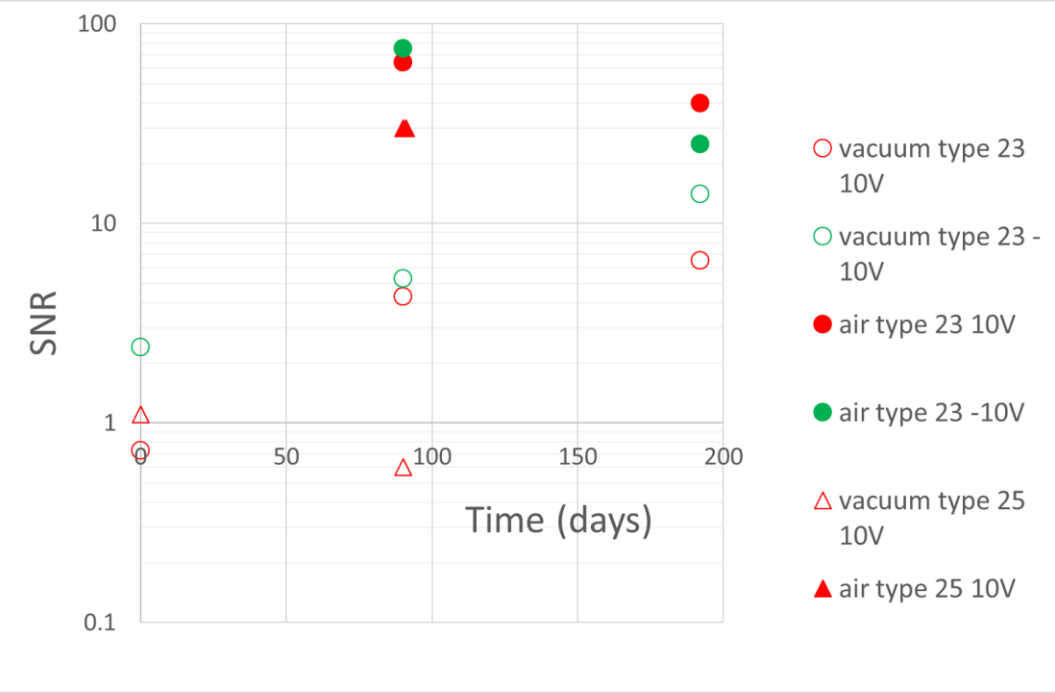
Longevity and air stability - 2

type 23 and 25 devices Time Dynamic α detection

- Storage under nitrogen
  - Measured under vacuum and upon exposure to air
  - 10V bias
  - ΔI



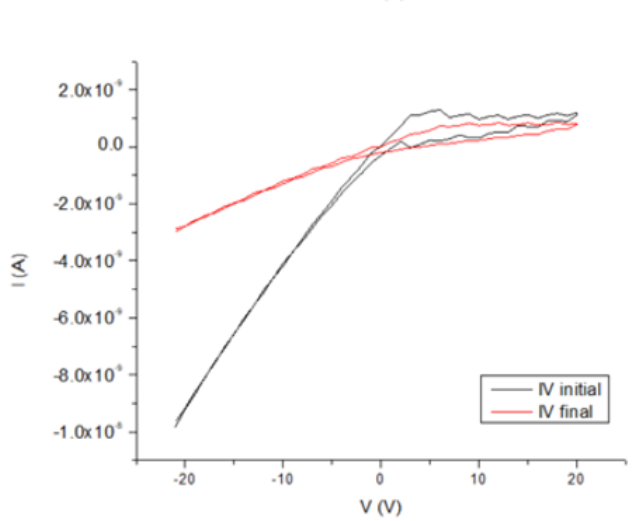
- Storage under nitrogen
  - Measured under vacuum and upon exposure to air
  - ±10V bias
  - SNR



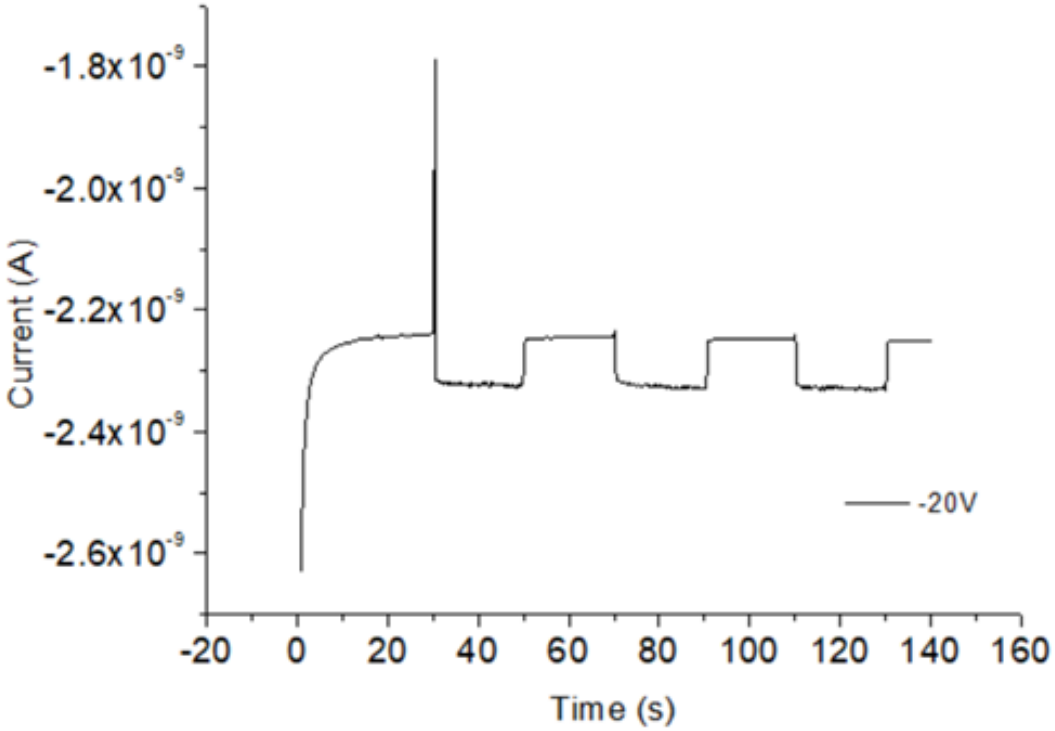
Longevity and air stability - 3

type 23 devices I-V and Time Dynamic

- Dark current suppression on air exposure



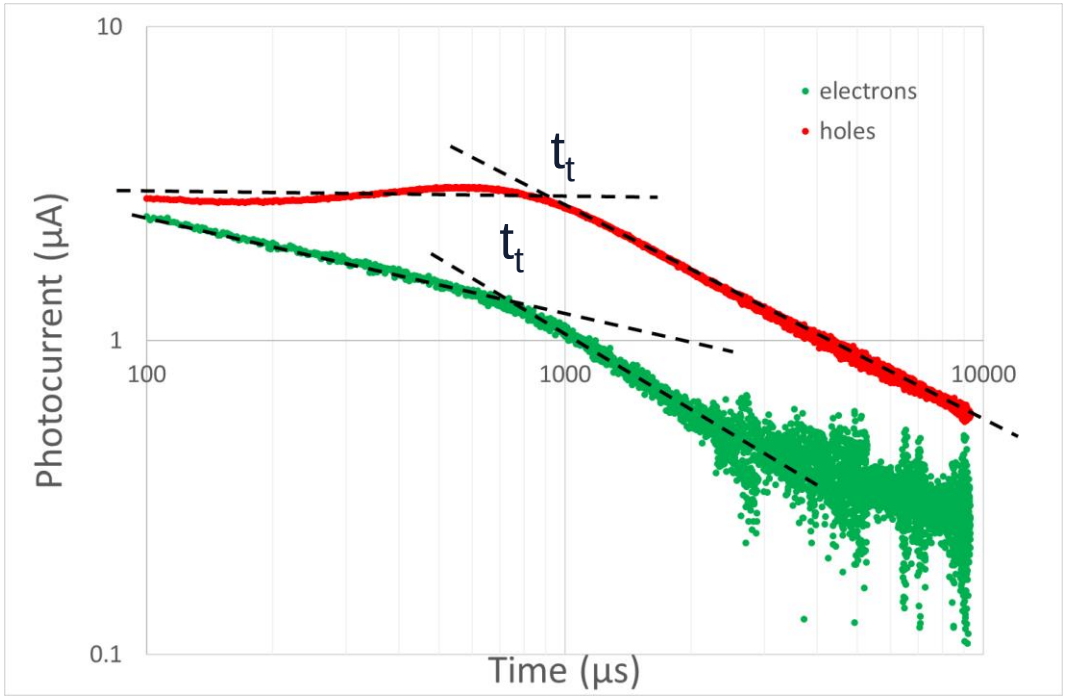
- 90 hours of exposure to ambient
- -20V bias



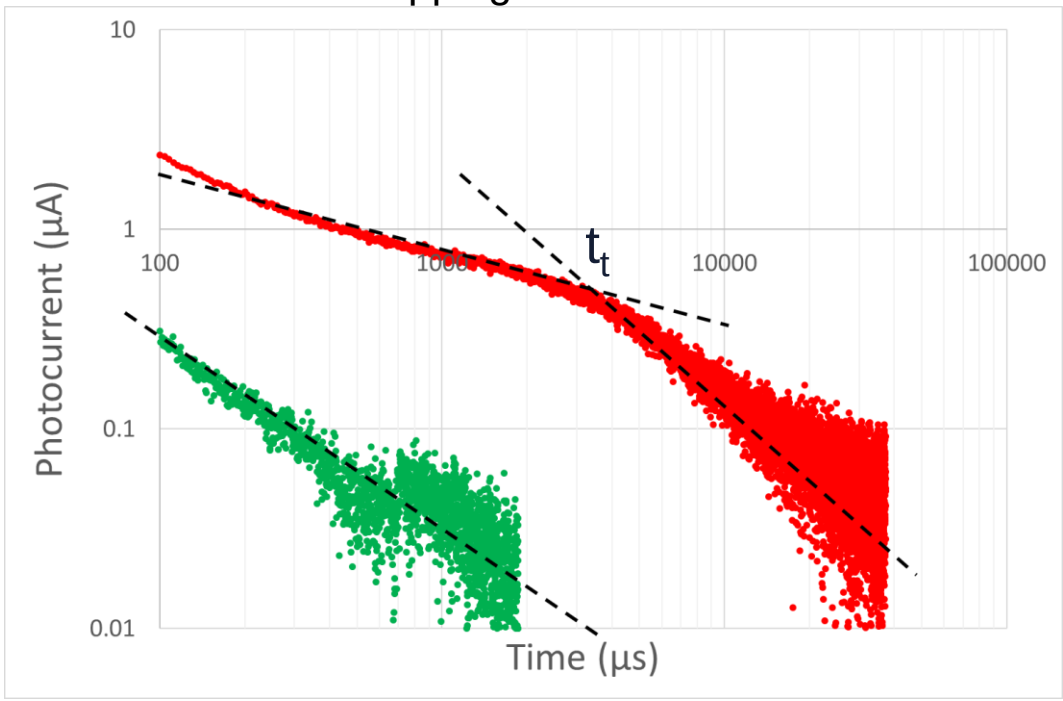
Longevity and air stability - 3

type 23 devices Time of Flight (25 µm, 50 V bias)

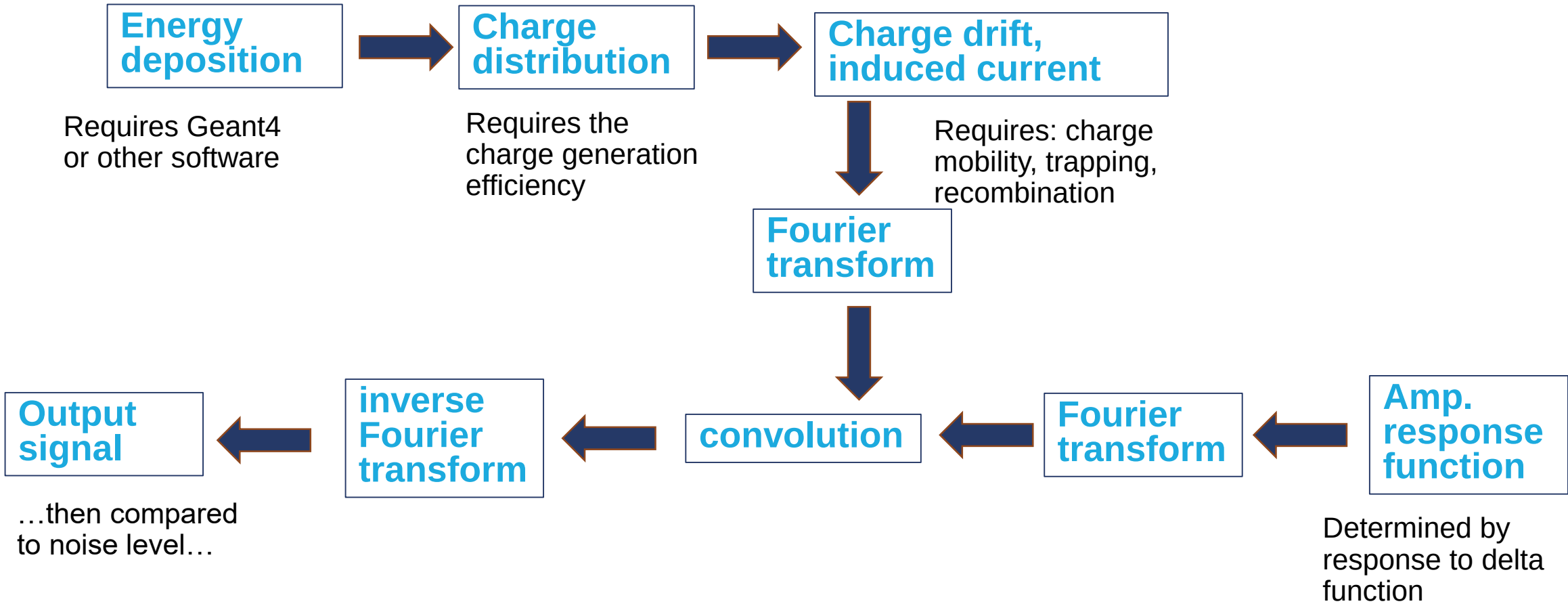
- ToF measured under vacuum
- Hole and electron transits



- ToF measured in air
- Hole transits and electron trapping



Transient detection simulation outline

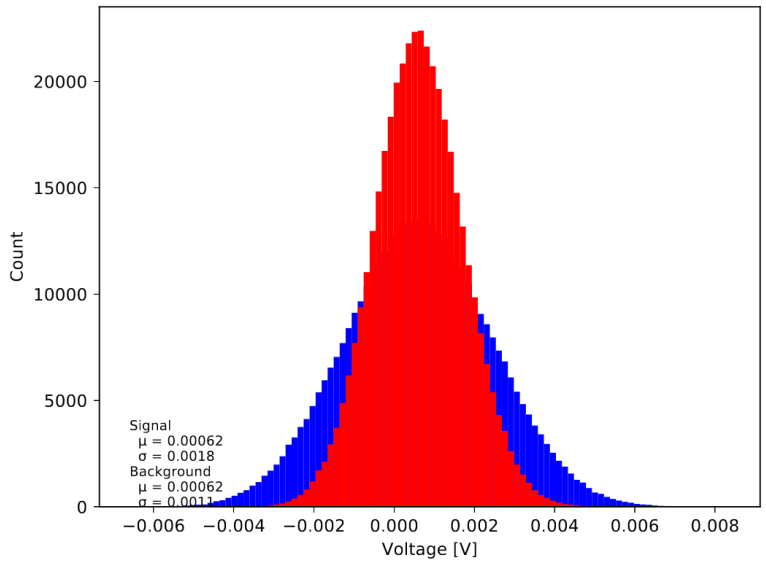


Towards transient detection with OSCs

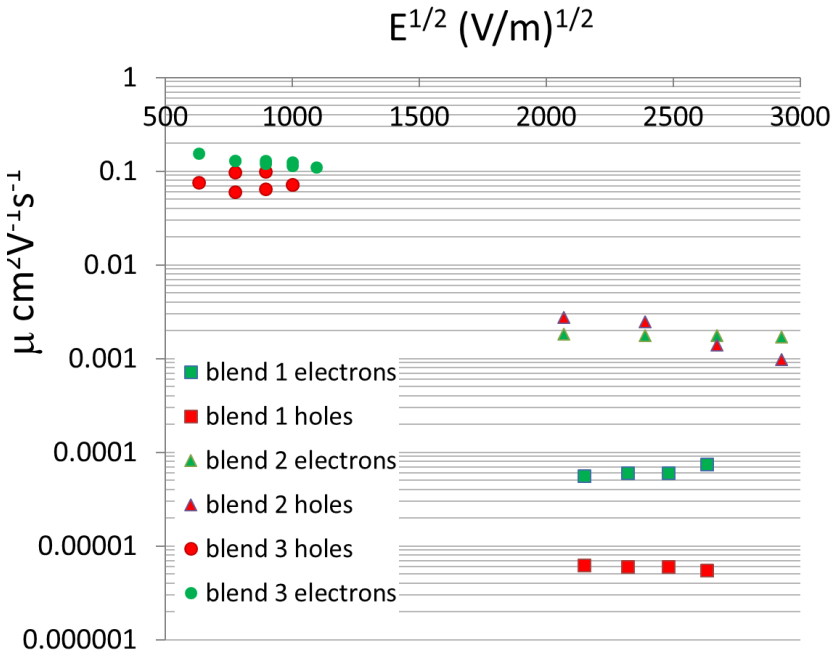
Electronic noise matters!

Charge carrier mobility matters!

- OSC device and charge sensitive amplifier
- mV noise level
- responds to α exposure



- Higher mobility blends identified by Time of Flight



Conclusions

- Steady State α detection achieved using OSC based devices
  - “Traditional” OSC disadvantages do not apply
    - Long “shelf life”
    - Air stable
  - Fundamental device Physics being identified
    - Charge trapping
    - Conductive gain
- Transient response modelling necessary to guide OSC device design
  - Higher mobility OSC blends being identified
  - Instrumentation being characterised/optimised
- Steady State versus Transient response OSC based detectors have very different device and material requirements