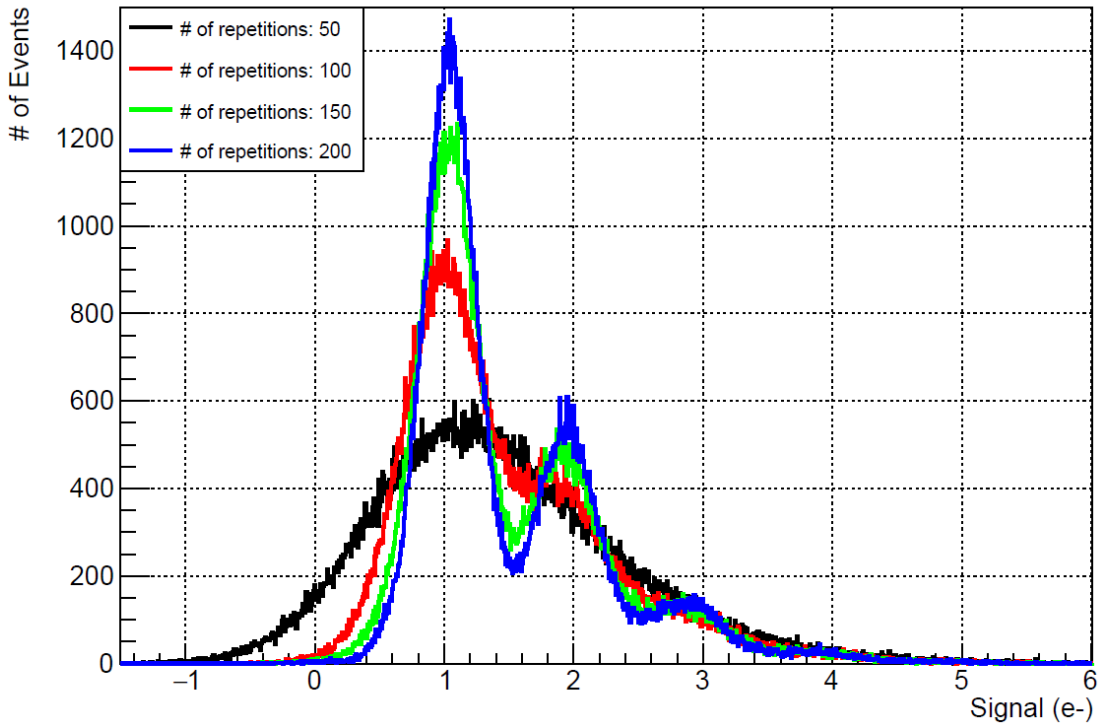


DANAE

Light dark matter searches with RNDR-DEPFET detectors

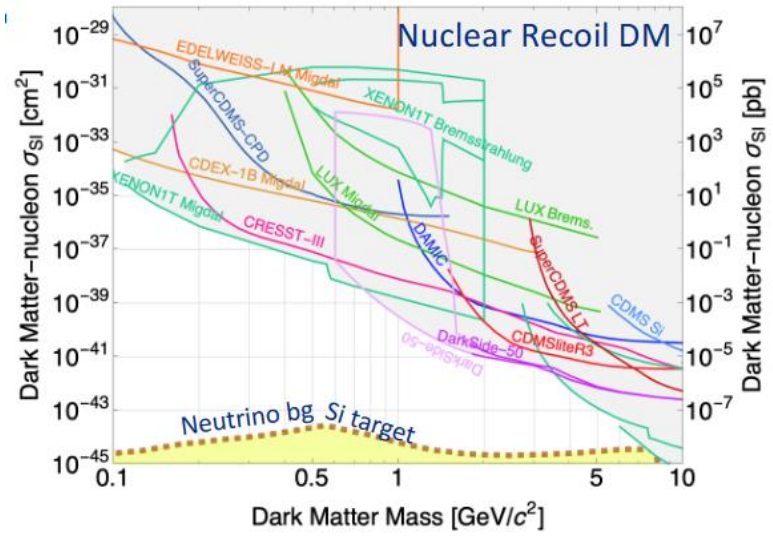
HEPHY/FHWN

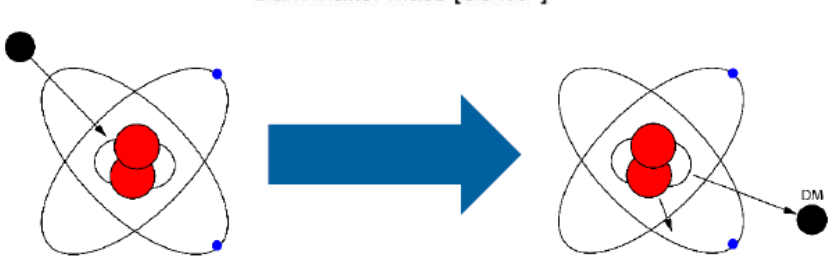
I. Introduction: Light dark matter

Classical approach

- Motivated by SUSY, Lee-Weinberg bound
- Particle mass: above 1 GeV/c^2
- Main event signature: nuclear recoils
- Experiments: large scale, no discoveries

[L. Hsu, ICHEP 2020]

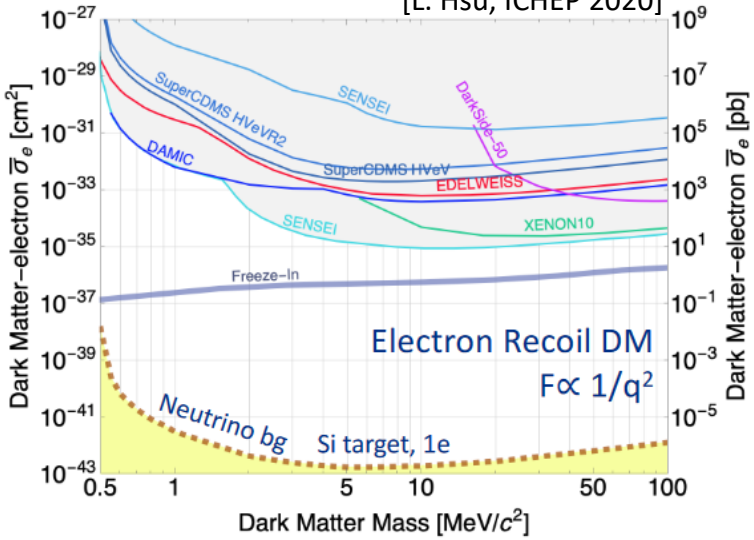


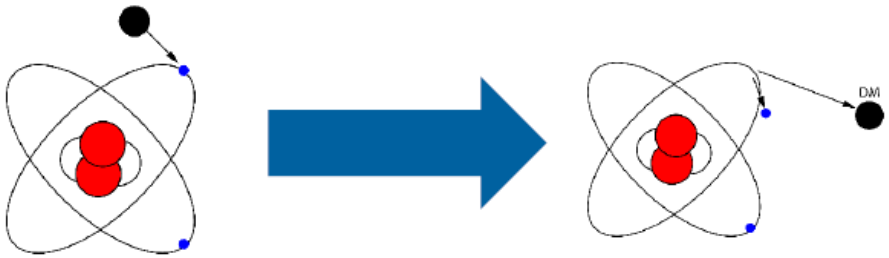


Light dark matter approach

- Motivated by dark sector, ELDER, SIMP
- Particle mass: above 100 keV/c^2
- Main event signature: electron recoils
- Moderate sensitive mass needed

[L. Hsu, ICHEP 2020]

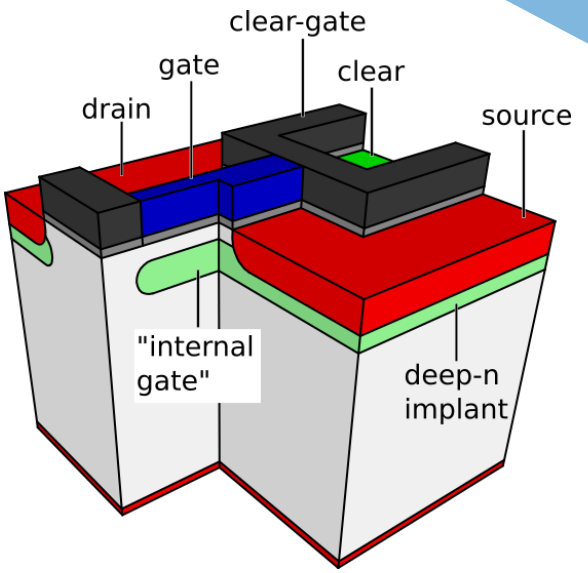




II. DANAE: RNDR-DEPFETs

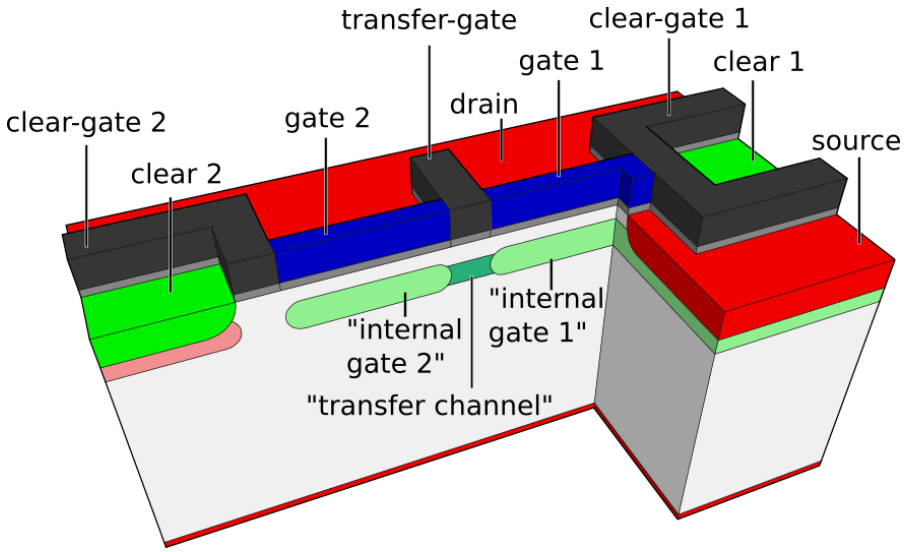
DEPFET detectors

- Technology established in astrophysics (Bepi-Columbo, ATHENA) and particle physics (Belle)
- DEPFET principle:
  - Side wards fully depleted bulk
  - e^- are collected in internal gate
  - conductivity of transistor channel is proportional to number of e^-
  - e^- are removed by the clear contact



RNDR-DEPFET detectors

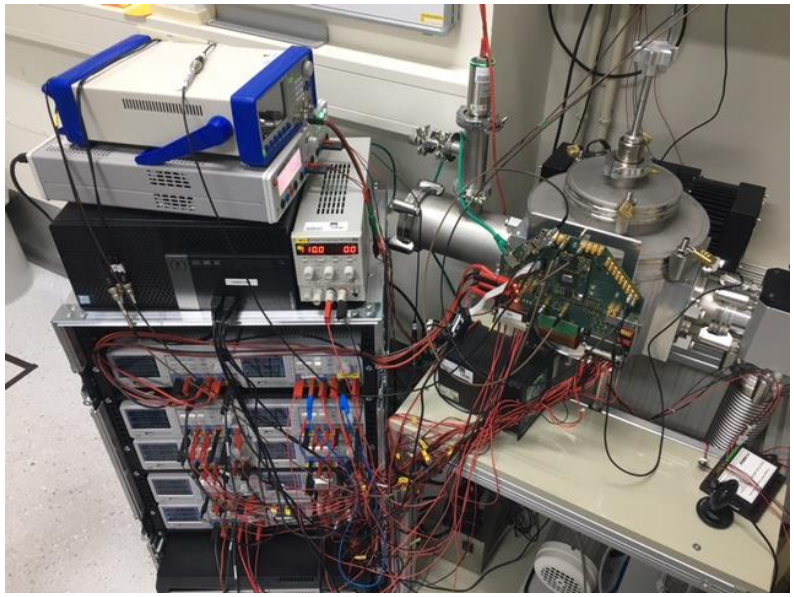
- Instead of removing the e^-, they are shifted to a second internal gate
- Repetitive independent (n) readout cycles of same signal
- Reduction of noise by $1/\sqrt{n}$

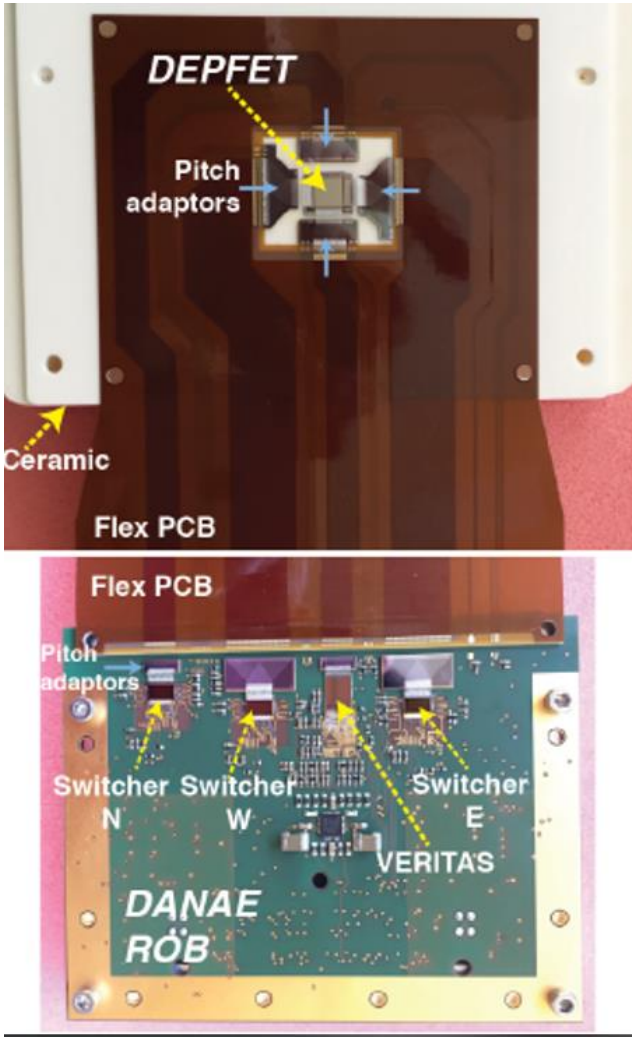


II. DANAE: RNDR-DEPFETs

DANAE prototype Setup

- 64x64 RNDR-DEPFET pixels a 50x50 μm^2
- Sensor glued on carrier ceramic and wire bonded to flexible PCB
- Sensor mounted in inner and outer Al shielding block with separated front end electronic
- Inner block connected to Stirling cooler, placed in vacuum chamber



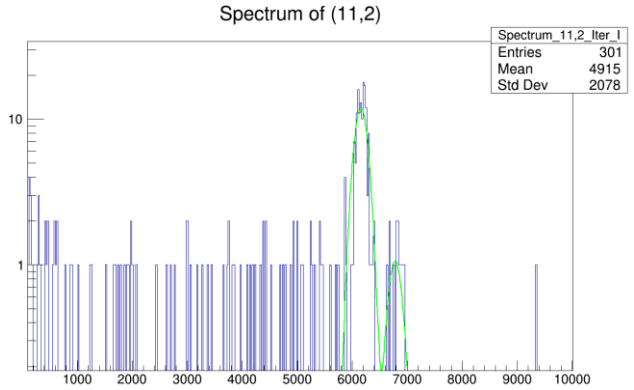


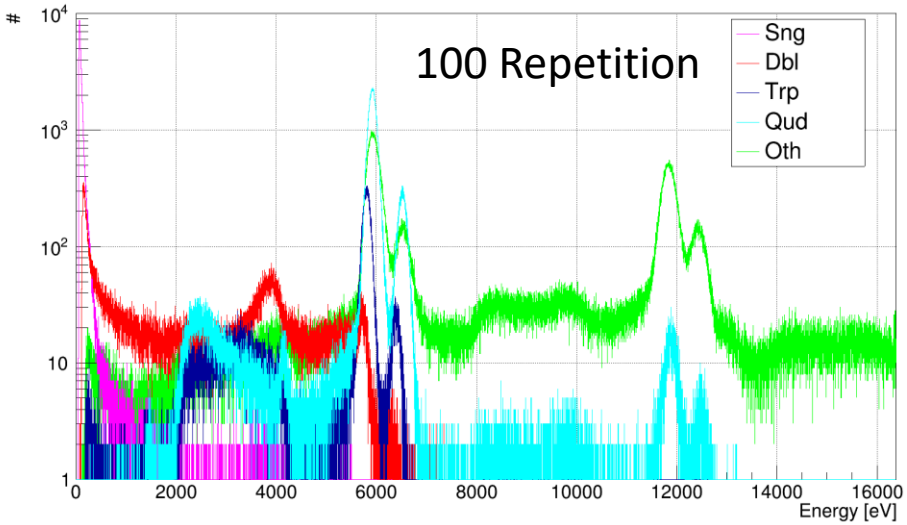
Detector Results

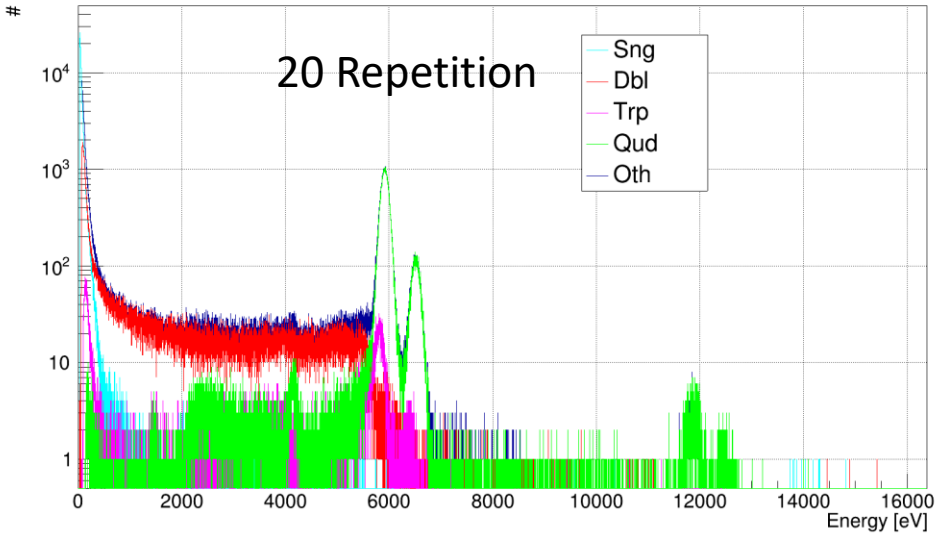
III. DANAE: Performance – ^{55}Fe

Detector performance and calibration

- ^{55}Fe spectrum recorded with
  - Calibration on 6 keV lines
- Effects to be considered:
  - Small pixels and thick bulk material ➔ large charge cloud (> four pixels)
  - Specific (slow) r/o in combination with large charge cloud ➔ interframe splits (broken patterns)
- Mitigation by:
  - Long exposure time (in relation to readout time)
  - Small number of repetitions







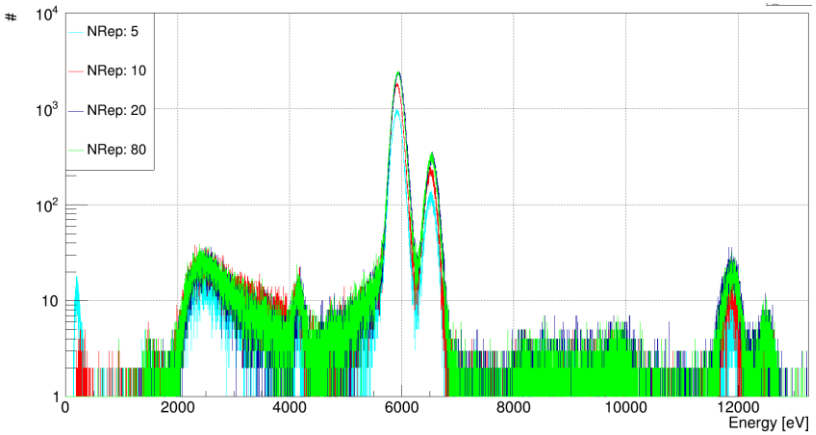
III. DANAE: Performance – ^{55}Fe

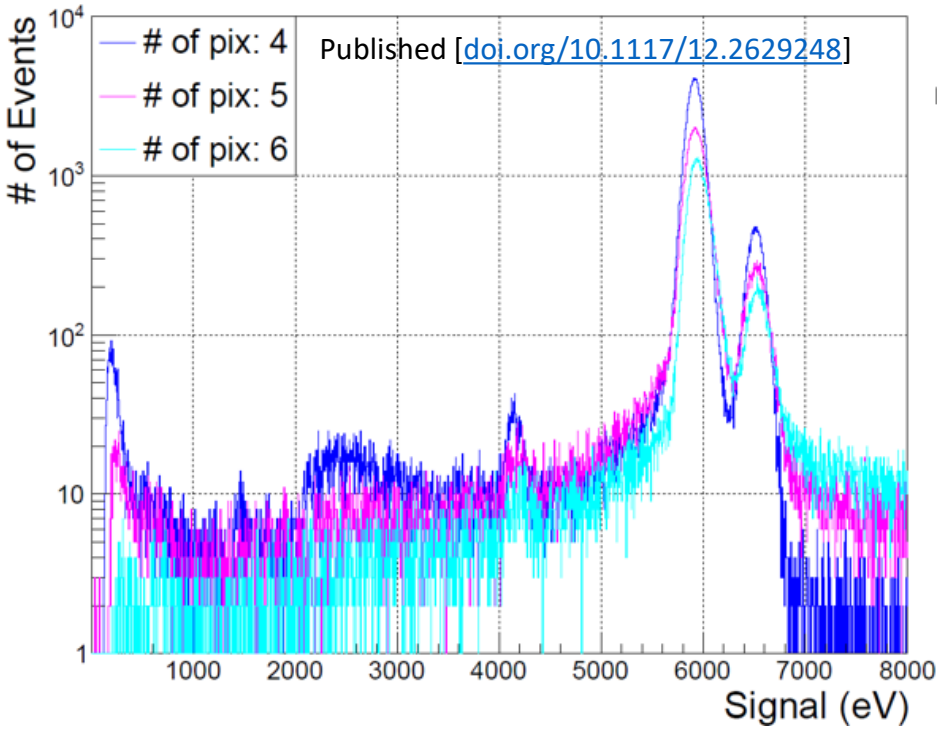
Further effects:

- Adapted number of evaluated repetitions at a similar measurement has minor effects

- Calibration of single pixel considers max. four pixel events ➔ small noise results in large patterns ➔ threshold above 10 sigma was applied

- Achievable resolution limited (appr. 170 eV)



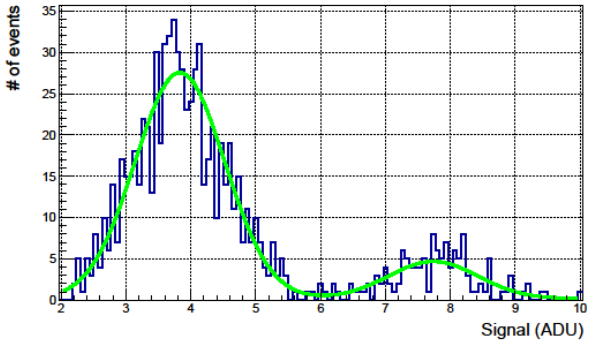


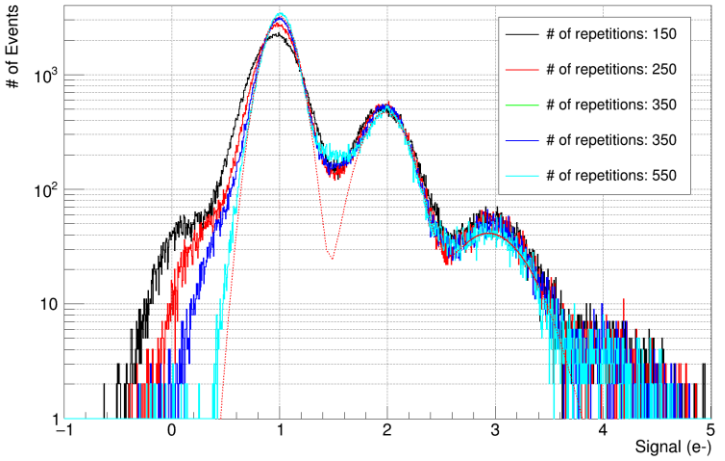
Published [doi.org/10.1117/12.2629248]

III. DANAE: Performance – LED

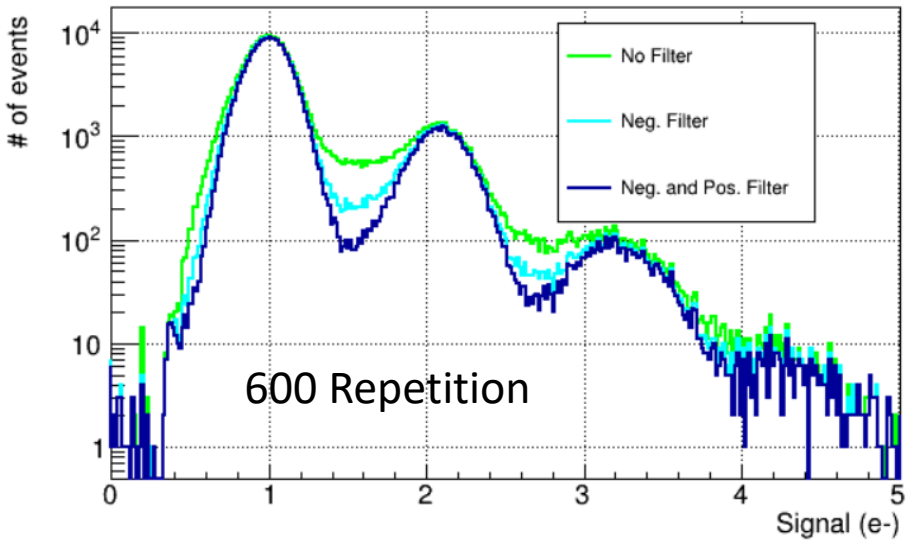
Calibrated spectra of LED

- Calibration with LED and pixel wise gaussian fit on single electron peaks
- Spectra for different number of averaged repetitions (up to 600)
- Performance affected from generated or lost electrons during readout
- Inspection of single events (slope of signal vs. number of repetition) enables to identify and filter affected events





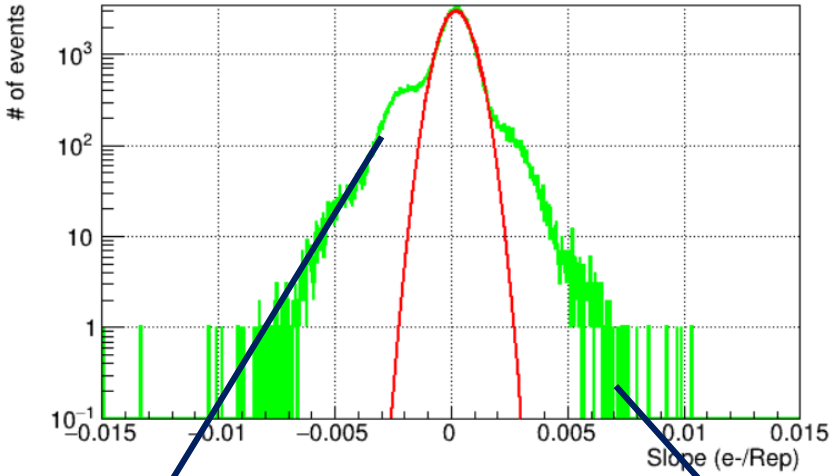
Published [preprint: scipost_202211_00018v2]



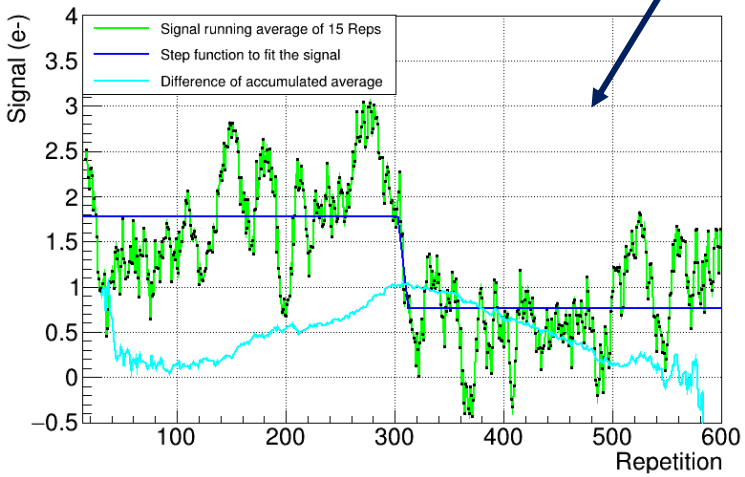
III. DANAE: Performance – LED

What to learn from slopes?

- Sufficient large number of repetitions -> distribution with pos. and neg. shoulders evolves
- Deviation from gauss shape -> identify events
- First shoulder one electrons second two, etc.

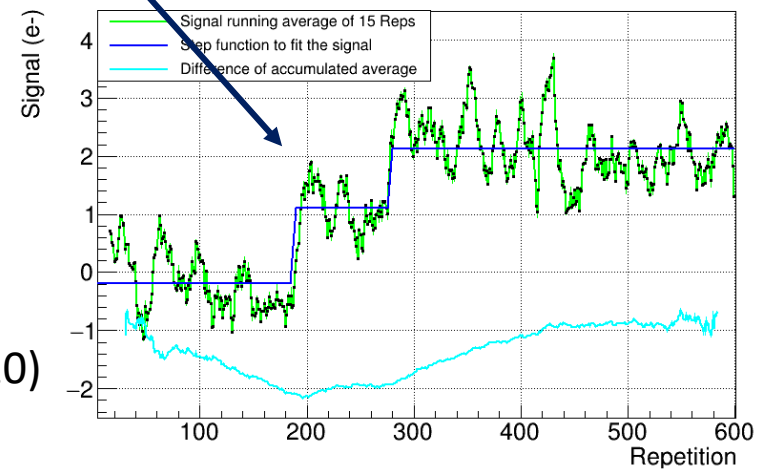


- slope **below** 3 sigma (loss)



- Running average of readings (10)

- slope **above** 5 sigma (generation)



Conclusions and outlook

IV. DANAE: Further applications

Space applications

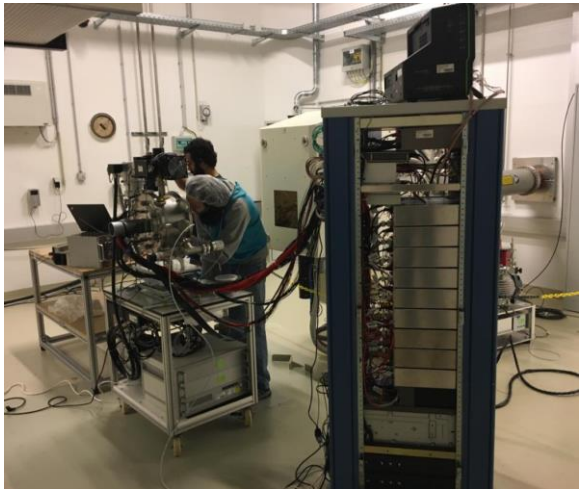
- Photon number resolved detection in the near IR regime with low dark counts required for various space applications (esp. direct detection of exoplanets)
- Available and proposed technology (https://exoplanets.nasa.gov/internal_resources/1390/):
  - EMCCD (high r/o speed but limited spectral performance – multiplicative noise)
  - Skipper CCD (high spectral performance but limited r/o speed)

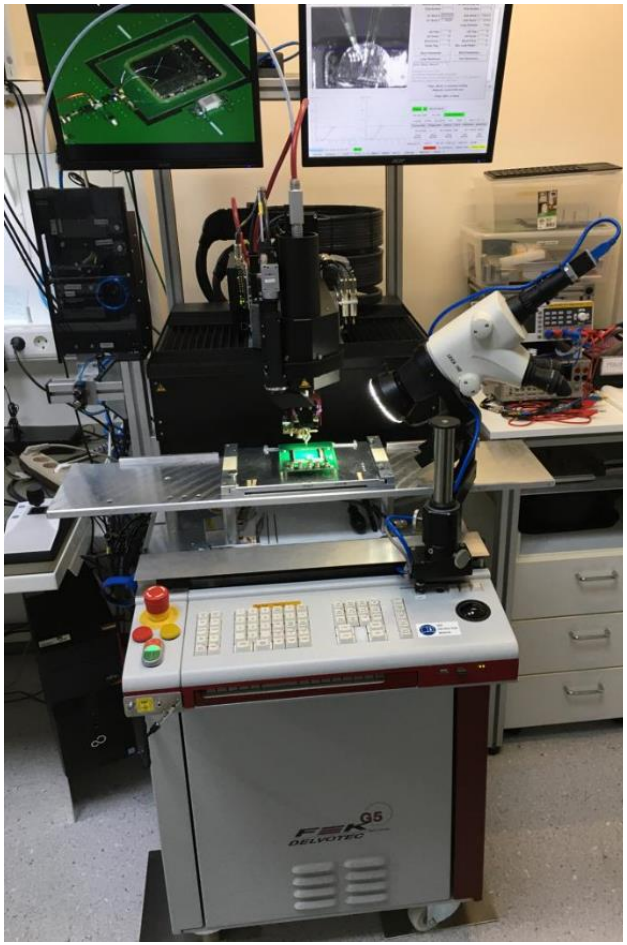
  ➔ Radiation damage is a major concern for both technologies due to the ccd principle

- The active pixel detector technology of DEPFETs is expected to be more radiation hard (no lateral charge transfer)

  ➔ First irradiation tests with conventional DEPFETs at proton accelerator at Wiener Neustadt (MedAustron) with MPE

- A process could be established for irradiation tests (low flux settings, vacuum chamber with beam dump and entrance window)
- Preliminary results ➔ see next talk





Status

- Still non understood high number of generated electrons
- Non reproducible effects on current module observed (affected spectral resolution)

Outlook

- For better understanding and statistics another module shall be assembled this time at HEPHY
- Experience and infrastructure from HEP applications is available (e.g. bonding)
- Set up process for further module assembly

Thank you for the attention