DANAE

Direct dArk matter search using DEPFET with repetitive-Non-destructive-readout Application Experiment

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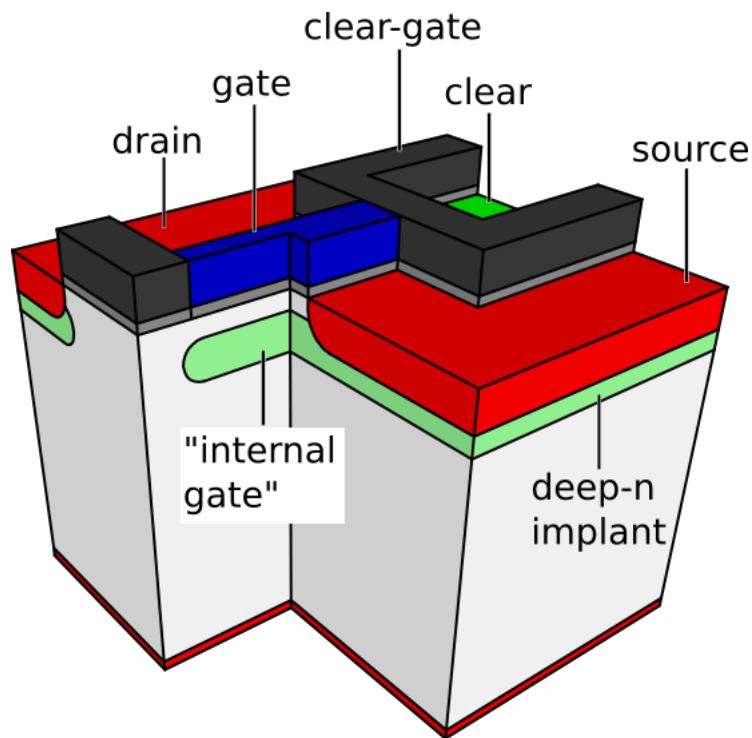Jochen Schieck[2,3], Johannes Treis[1], Hexi Shi[2]

[1]Halbleiterlabor der Max-Planck-Gesellschaft, Germany
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[3] Atominstitut, Technische Universität Wien, Austria

DePFET

## DePleted p-channel Field Effect Transistor

(Kemmer & Lutz 1987)

▷ MOSFET on n-substrate
▷ deep-n implant below gate
  ↳ potential minimum for electrons
  ↳ „internal gate" (IG)
  ↳ Conductivity modulated by electrons
    ↳ Source Follower
    ↳ Drain Current Readout
▷ reset via clear and clear gate
▷ good signal to noise
▷ unobstructed backside contact; 100% fill factor
▷ Implementation of additional functionality on pixel level

DePFET - Matrix

Prototype
256x256 pixels
75x75 μm²
„standard DePFET"

- **DePFET as base cell of pixelated sensor**
  - ▷ horizontal row selection
  - ▷ vertical signal columns
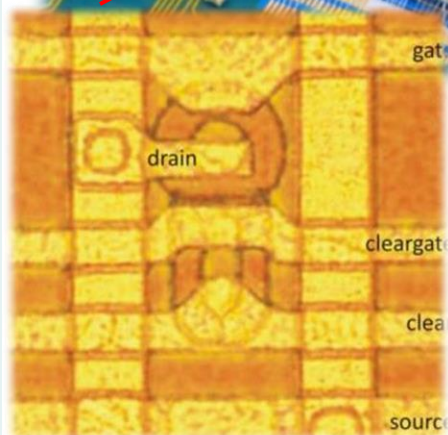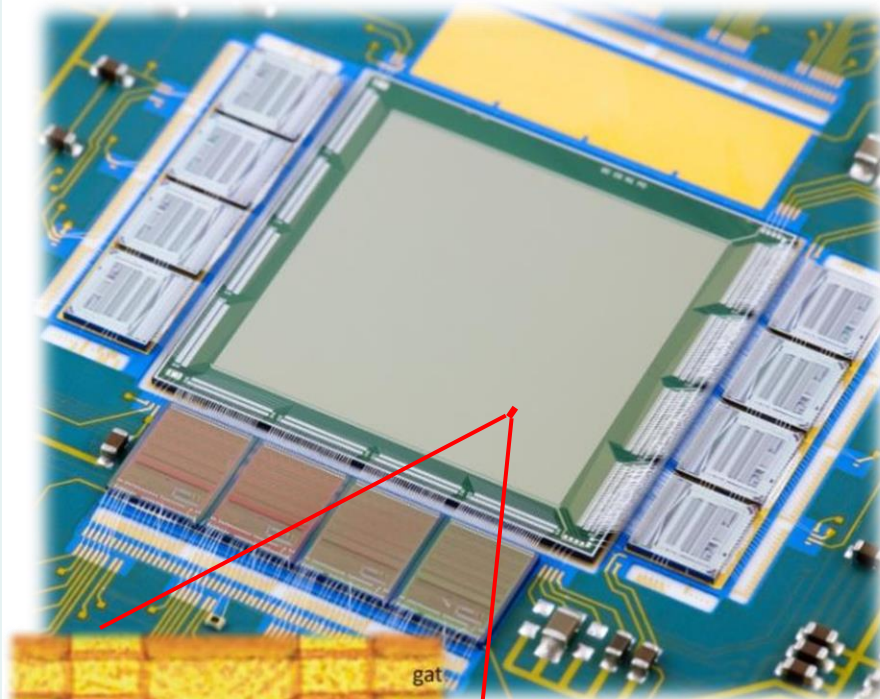

amplifier / multiplexer
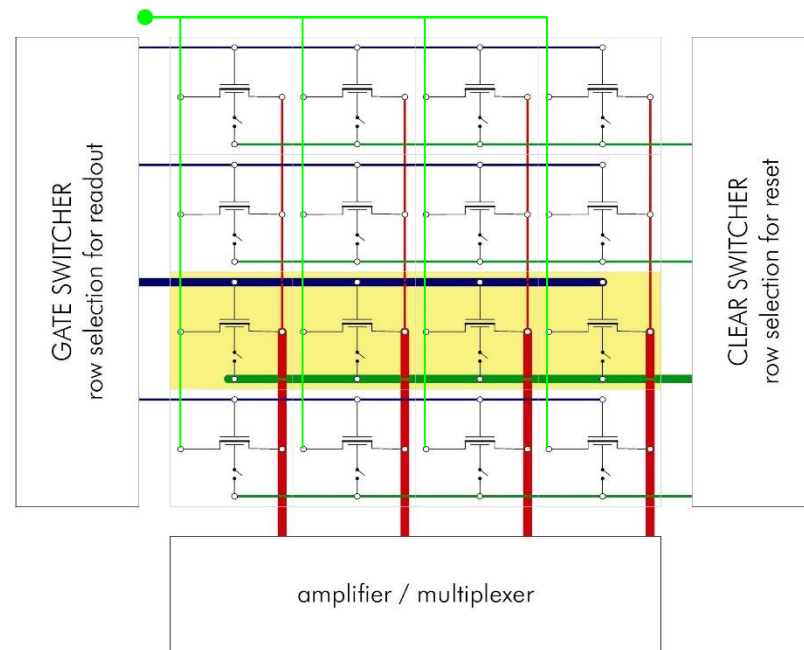
  - ▷ 1 active row, other pixels integrating
  - ▷ Charge storage and amplified in pixel
  - ▷ Noise 2-4 e⁻ per pixel (@ ~5 μs/row)
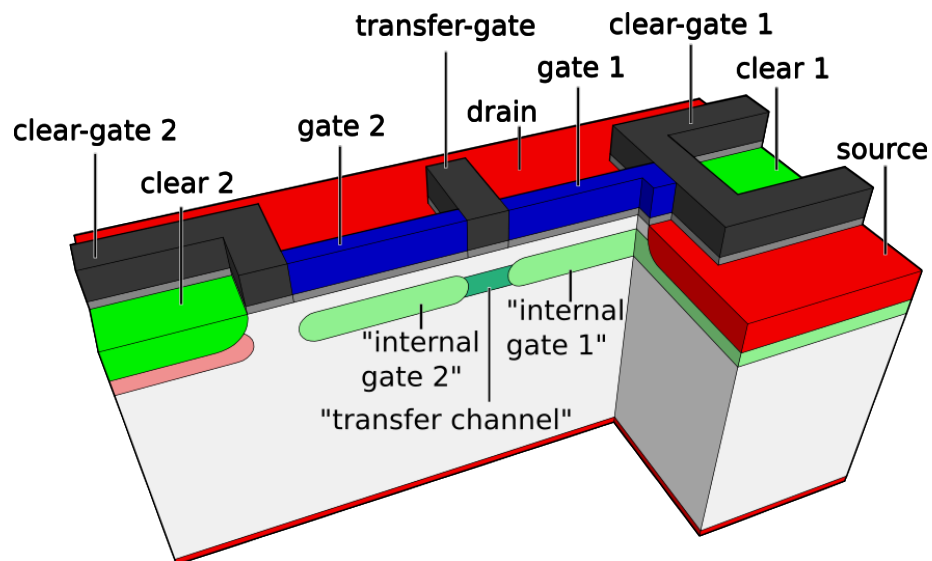 - ▷ Energy resolution @ 5.9 keV

    FWHM = 130 eV

DePFET - RNDR

Repetitive Non-Destructive Readout

Superpixel with 2 DePFETs
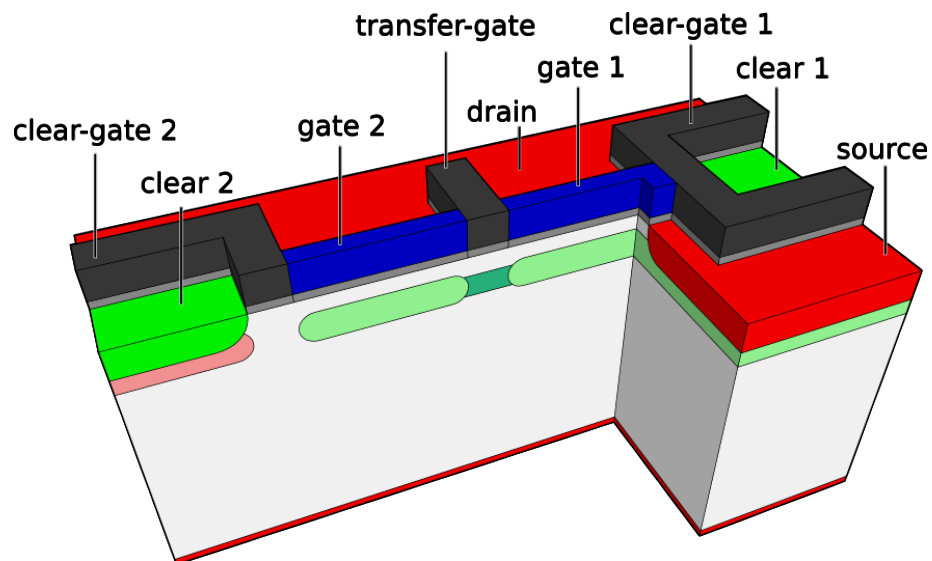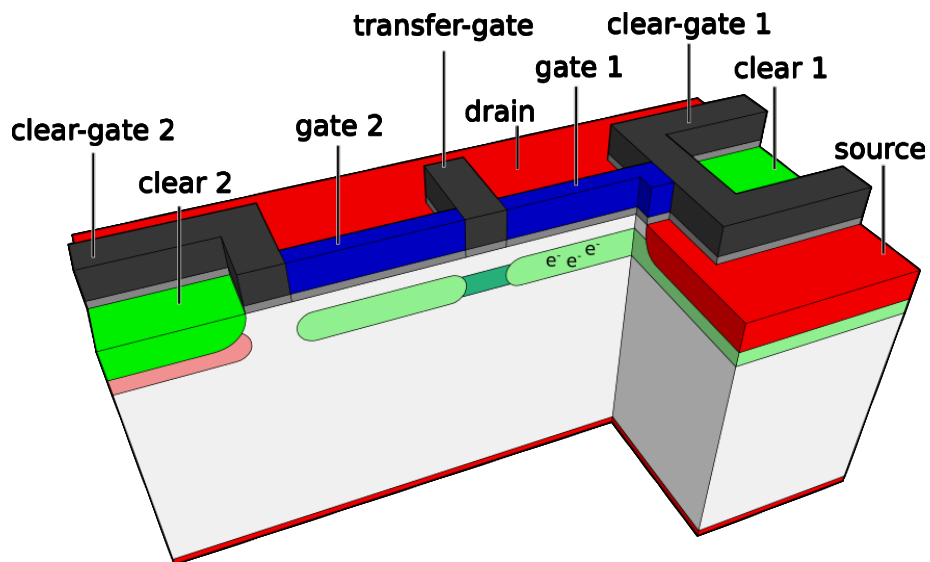Internal gates seperated

DePFET - RNDR

Repetitive Non-Destructive Readout

Superpixel with 2 DePFETs
Internal gates seperated

DePFET - RNDR
Repetitive Non-Destructive Readout
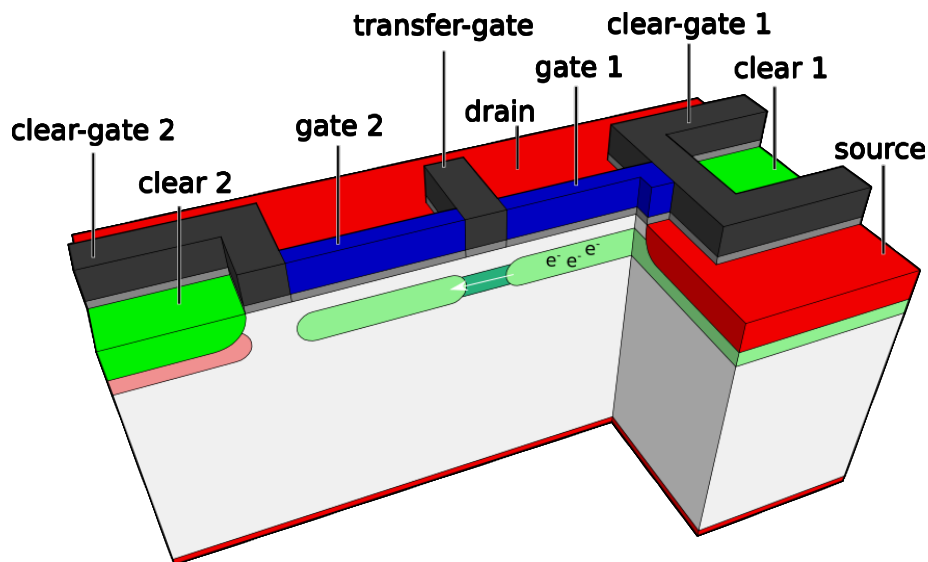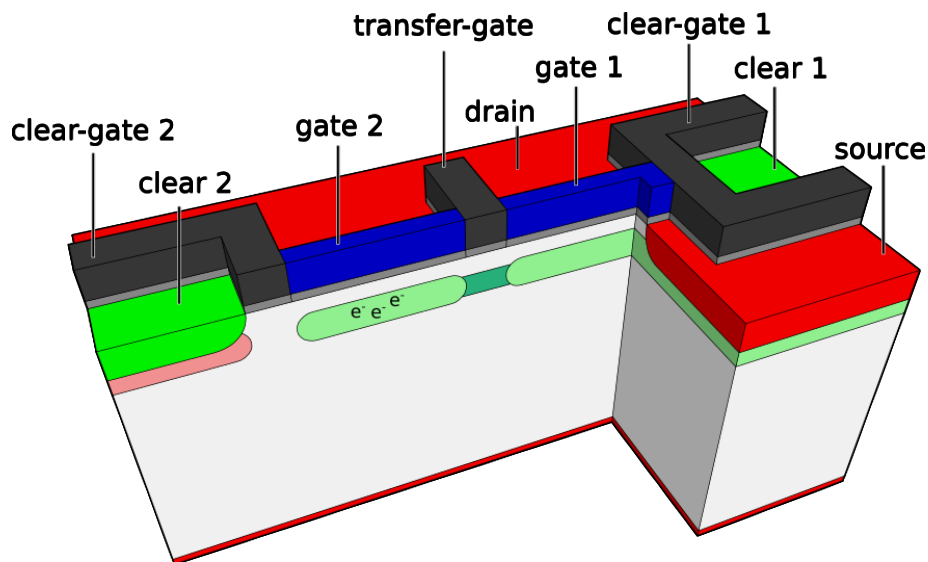
Superpixel with 2 DePFETs
Internal gates seperated

Labels on figure: clear-gate 2, clear 2, gate 2, transfer-gate, drain, gate 1, clear-gate 1, clear 1, source
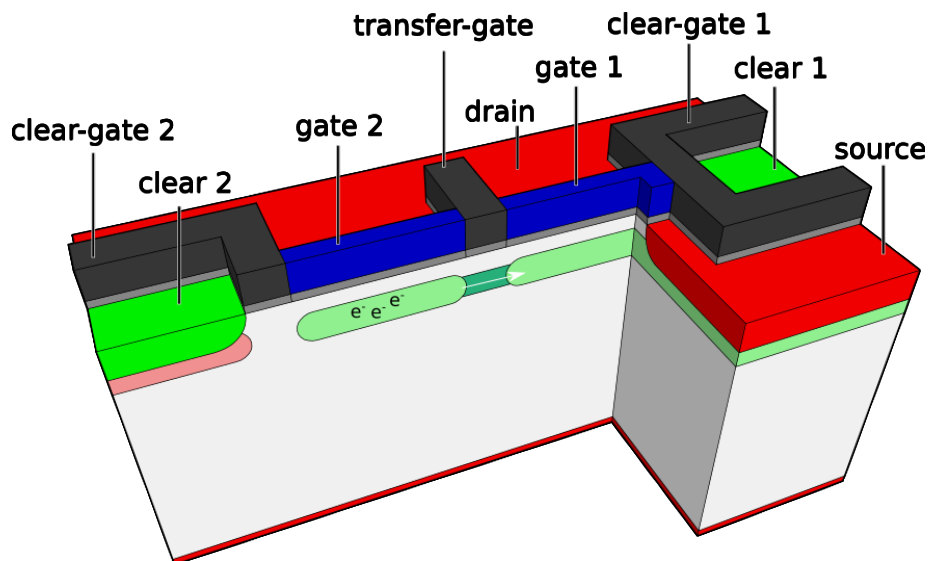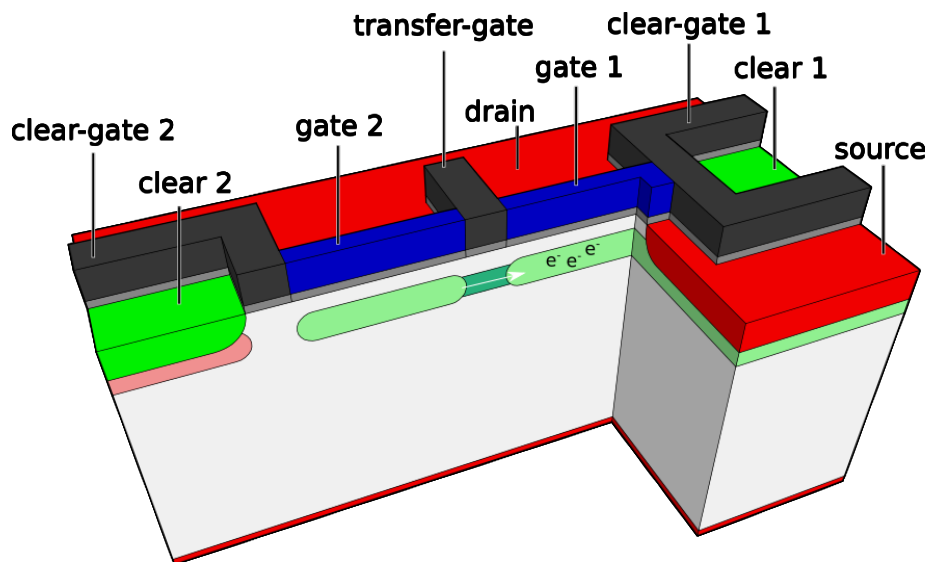
e^- e^- e^-

DePFET - RNDR
Repetitive Non-Destructive Readout

Superpixel with 2 DePFETs
Internal gates seperated
Charge transfered between IG1 and IG2

DePFET - RNDR

Repetitive Non-Destructive Readout

Superpixel with 2 DePFETs
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Repetitive Non-Destructive Readout

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Repetitive Non-Destructive Readout

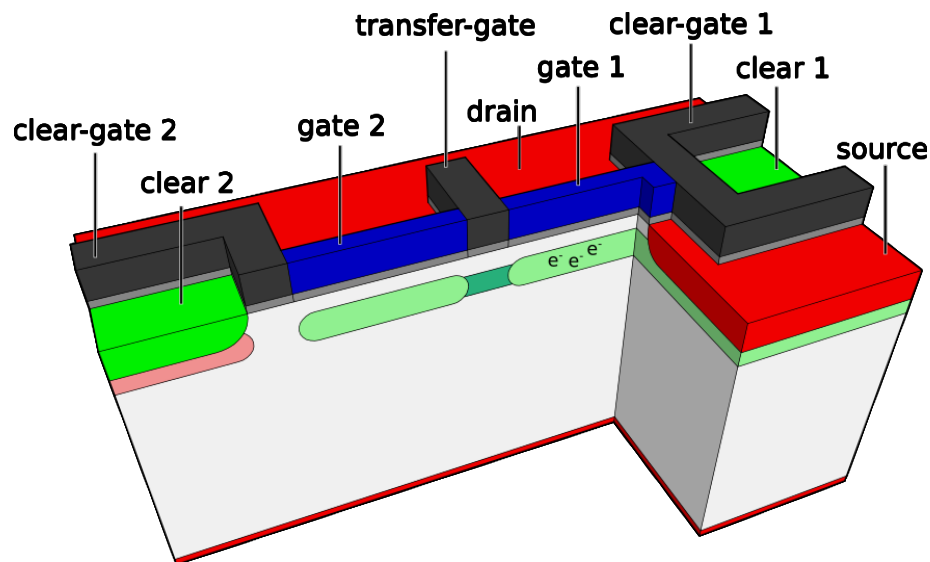Superpixel with 2 DePFETs
Internal gates seperated
Charge transfered between IG1 and IG2

Repetitive Non-Destructive Readout

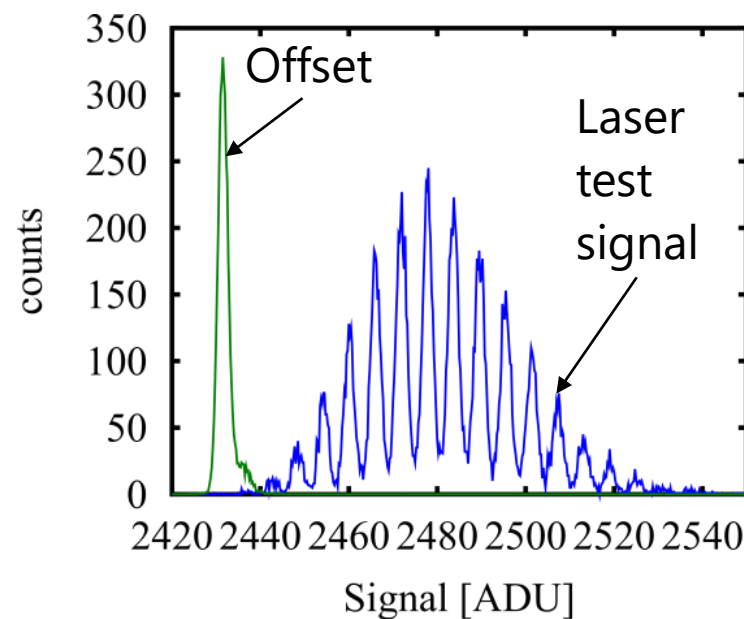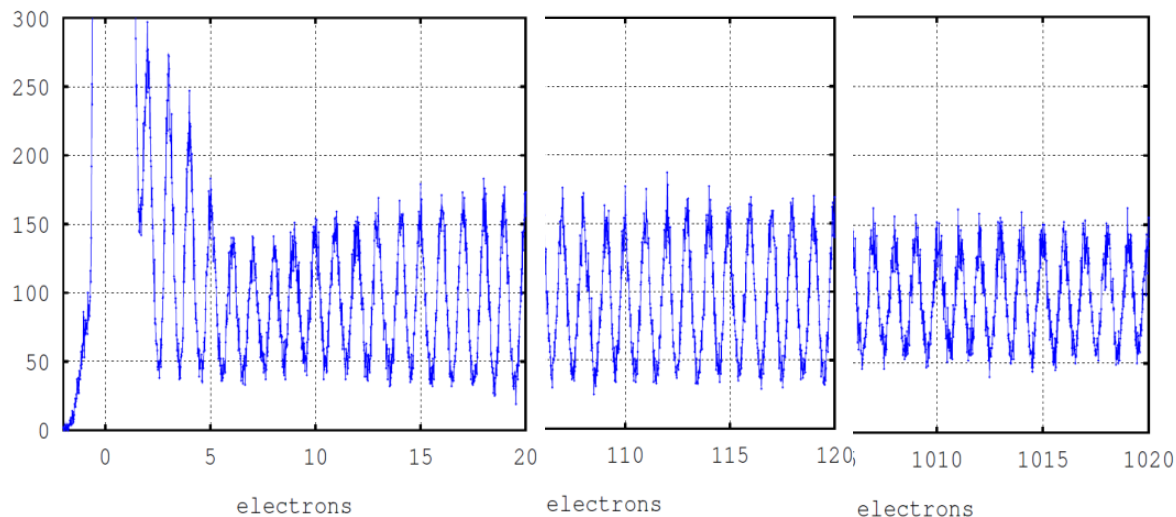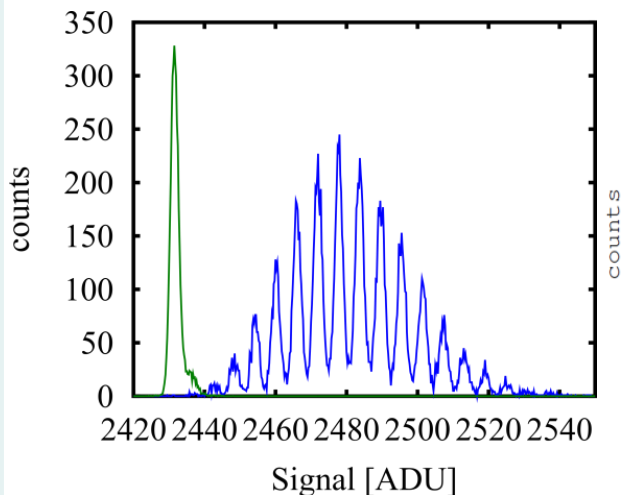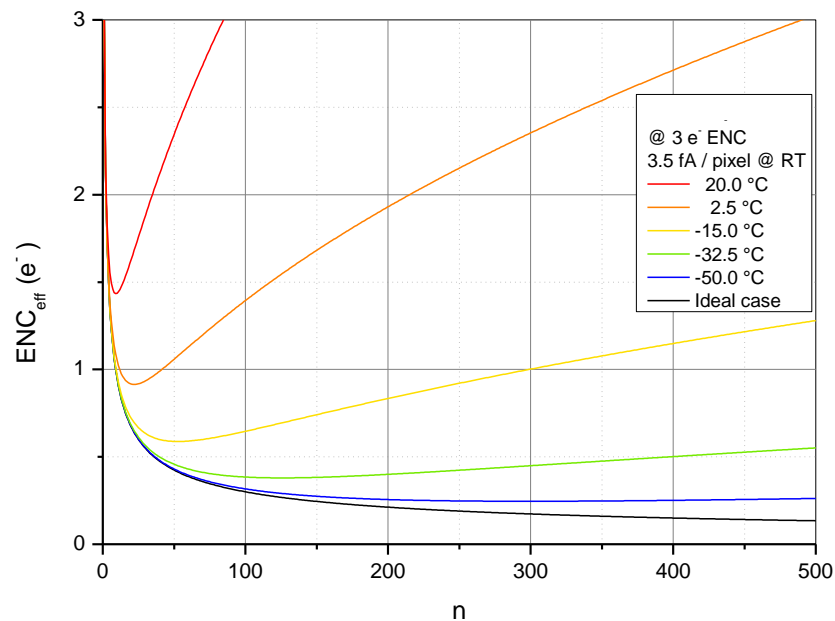Superpixel with 2 DePFETs
Internal gates seperated
Charge transfered between IG1 and IG2
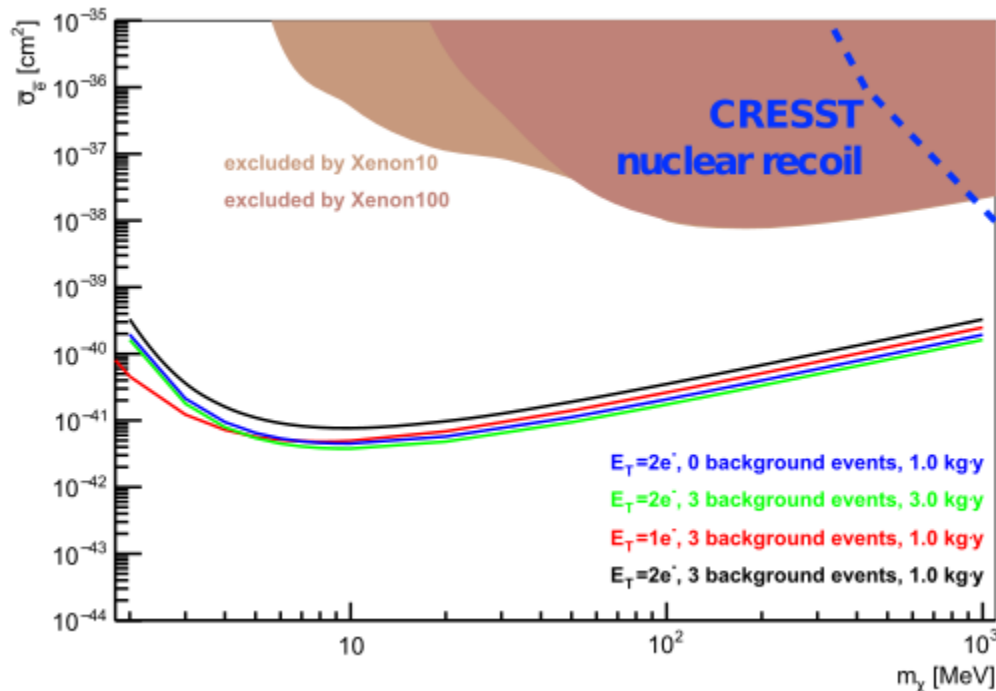Charge read out n times

- ▷ DePFET – RNDR
- ▷ Demonstrated on single-pixels
- ▷ ENC ~ 0.2 e⁻ at
  - ↳ t_{single} = 6.5 µs
  - ↳ n = 200
- ▷ for 1 to 1000 e⁻
- ▷ Only moderate cooling (-60°C)
- ▷ ENC limited by leakage current

Interaction - electron recoil

Signal of few e⁻

Limitation:
Leakage current
- 1e⁻ threshold:
    - Optimize manufacturing
    - Cool sensor
- 2e⁻ threshold:
    - Readout faster

Intrinsic radiation
- Optimize fabrication
Extrinsic radiation
- Sensor Shielding

- **Until End of 2019**

▷ Operation of Prototype RNDR DePFET matrix
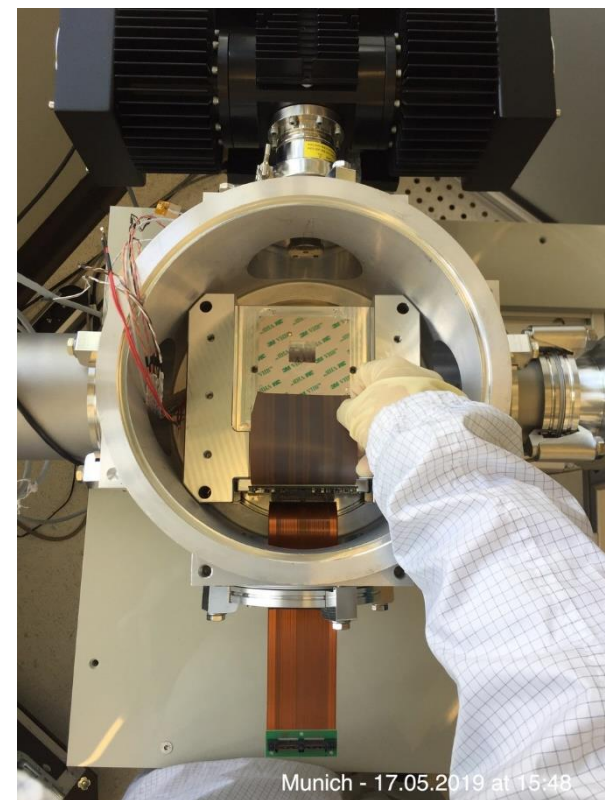- ↪ 64x64 pixel
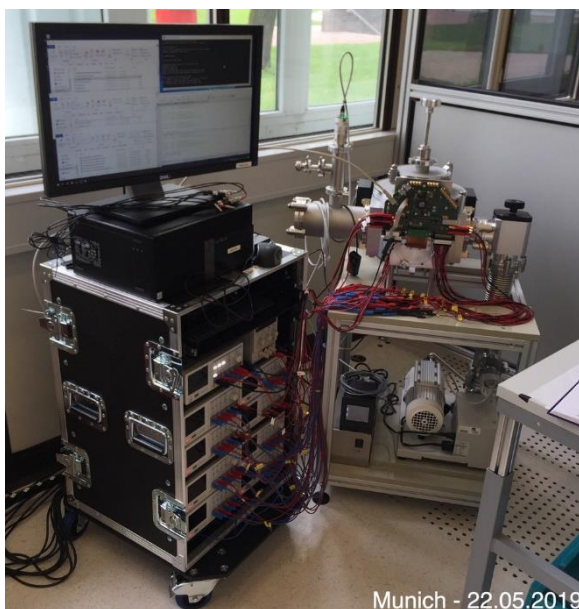- ↪ 75x75 µm² pixel size
- ↪ Temperature down to -150°C

▷ Demonstration of DePFET-RNDR on matrix level
▷ Leakage current at low temperature
▷ Demonstration of incremental readout

Munich - 17.05.2019 at 15:48

Munich - 22.05.2019

A. Bähr, MPG Semiconductor Laboratory

Future Plans

$\triangleright$ Test of smaller pixel sizes (36x36 μm²)

$\triangleright$ Improved technology to reduce single read noise

$\triangleright$ Large area Matrix (1M – 4M Pixels)

$\triangleright$ Thicker sensor substrate (up to 1 mm)

$\triangleright$ Test of Radio purity (already in preparation)

DePFET RNDR benefits

▷ Row-Parallel Readout (Framerate ~0.1 Hz - 1 Hz for n=1000)

▷ Low Noise (newest technology ~2 e⁻ for standard DePFET at 2.5 µs/ row)

▷ „Incremental Readout"
  ↳ Integrate charge over m frames
  ↳ Clear only all kth frame
  ↳ Additional data analysis possible

▷ Manufacturing at MPG Semiconductor Lab
  ↳ Optimization and customization of technology possible

Thanks for your Attention