Friedrich-Alexander-Universität
Erlangen-Nürnberg

Erlangen Centre for Astroparticle Physics

FAU

Beam Position Monitoring with the hybrid Pixelated Detector Dosepix and Nitrogen Fluorescence Light

Florian Beißer
Erlangen, 16.09.2025

Agenda

1. NitroFLASH Project
2. The Dosepix Detector
3. Beam Position Monitoring with Dosepix
4. Beam Position Monitoring with UV-Cameras
5. Conclusion

NitroFLASH Project

NitroFLASH Project

Collaboration

- Joint Project of
  - Erlangen Centre for Astroparticle Physics at FAU Erlangen-Nürnberg
  - D3 at DESY Hamburg
  - PITZ at DESY Zeuthen
  - Berthold Technologies GmbH
- Acknowledgements to ARES accelerator team at DESY Hamburg
- Funding from Federal Ministry of Research, Technology and Space: Förderkennzeichen (13K2300021 NitroFLASH)

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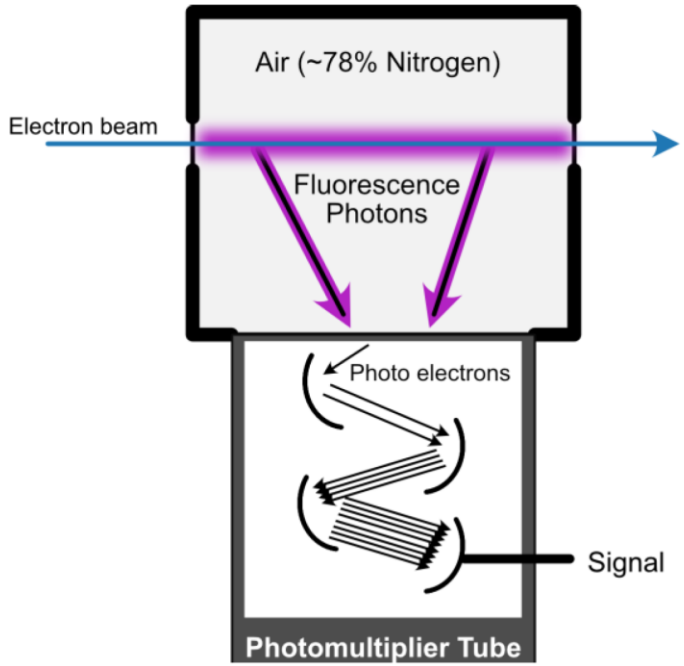
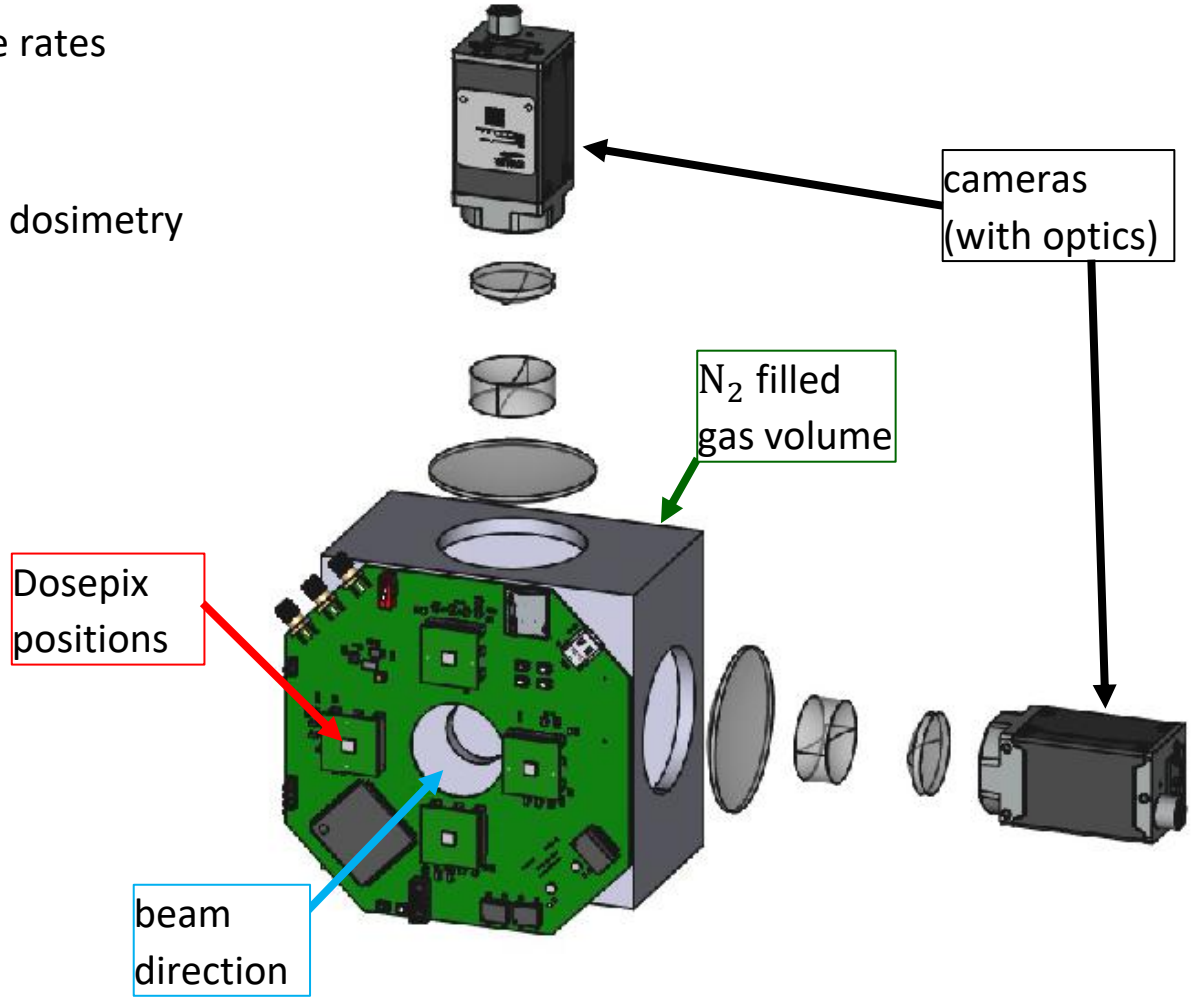
With funding from the:

Federal Ministry of Research, Technology and Space

NitroFLASH Project

- PITZ accelerator capable of delivering high dose rates
- Beam parameters must be known
- Non-destructive beam position monitoring and dosimetry

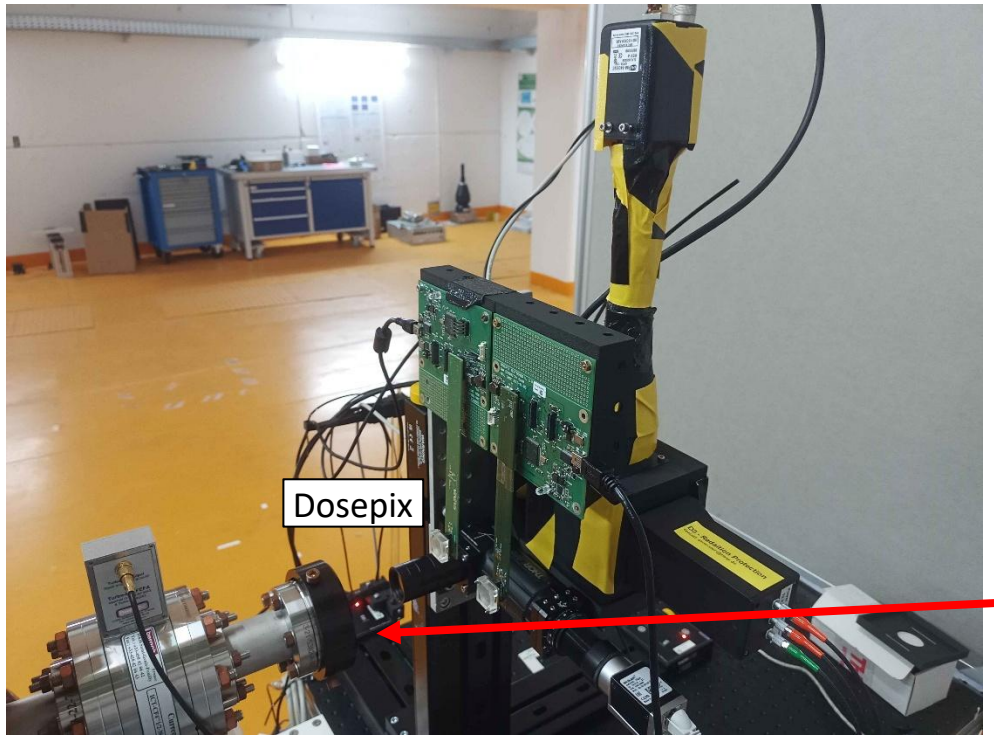


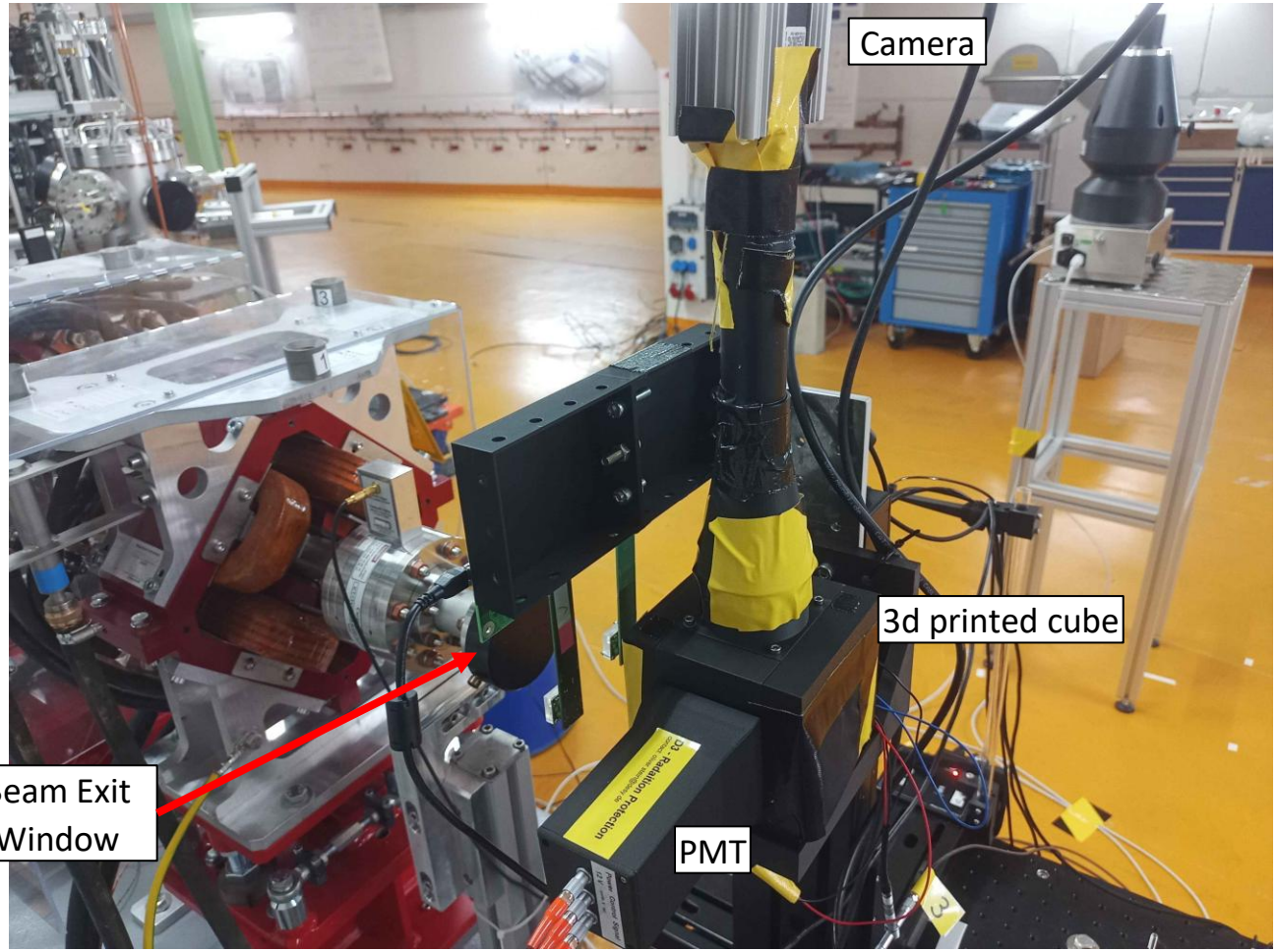


NitroFLASH Project

Setups

- Dosepix detectors ~1.4 cm next to beamline
- Imaging with UV sensitive cameras JAI 1405/Basler ace2 a2A2840-14gmUV
- Measurements performed at ARES accelerator

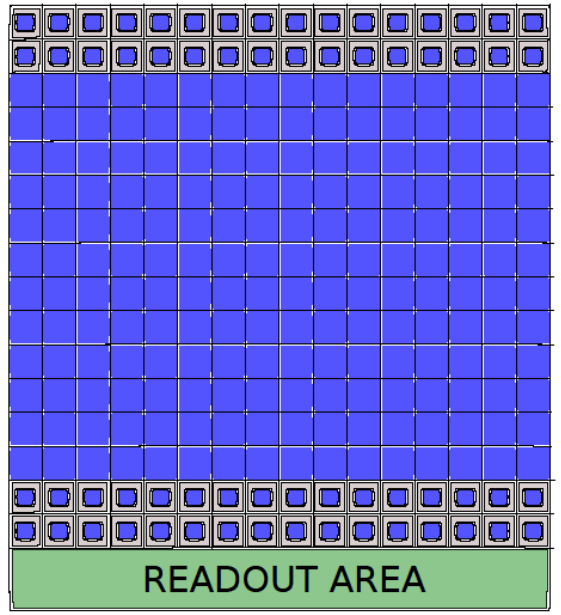




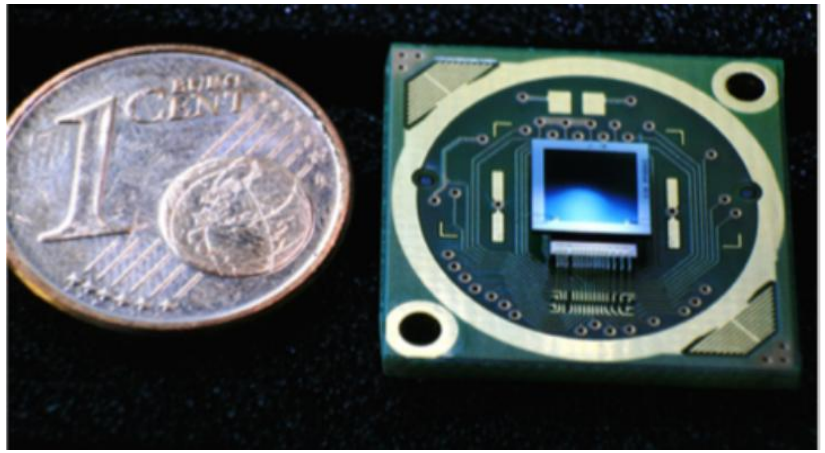
The Dosepix Detector

The Dosepix Detector

- Hybrid pixelated detector
- 300 µm thick p-in-n doped silicon sensor layer
- 16×16 quadratic pixels
  - Pixel pitch: 220 µm
  - 192 large pixels (edge length 220 µm)
  - 64 small pixels (edge length 55 µm)
  - Area: $3.52\ \mathrm{mm} \times 3.52\ \mathrm{mm}$
- Energy threshold: ≈ 10 keV



D. Haag: Active personal dosimetry with the hybrid pixelated DOSEPIX detector, 2018

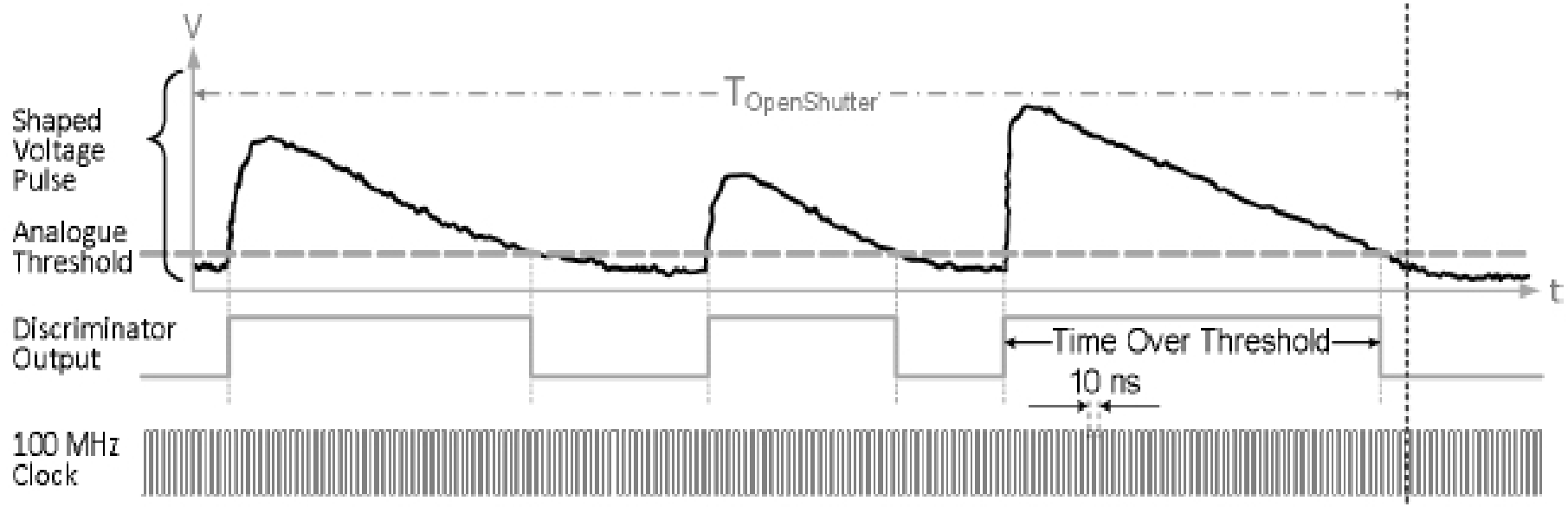


T. Gabor: Simulationen und Experimente zur Anwendung eines neuartigen spektroskopischen Pixeldetektors in der Personendosimetrie, 2012

The Dosepix Detector

Time-over-Threshold (*ToT*)

- Dosepix's measure of event energy
- Counting clock cycles of 100 MHz Ref-Clk
- Number of clock cycles: *ToT*
- Procession in each pixel
- Integration Mode: Read-out integrated ToT (iToT) of each pixel



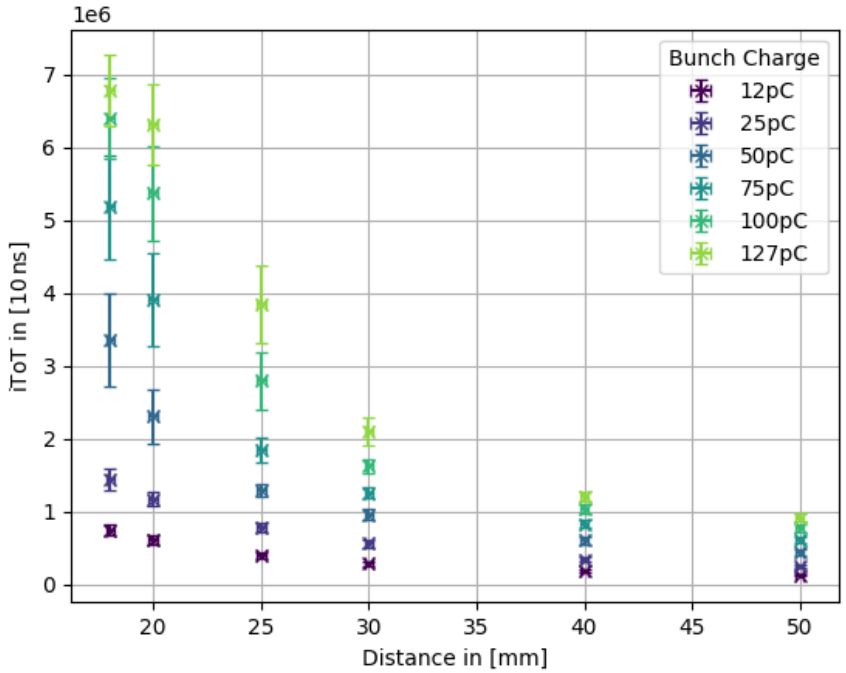
W. Wong: A Hybrid Pixel Detector ASIC with Energy Binning for Real-Time, Spectroscopic Dose Measurements, 2012

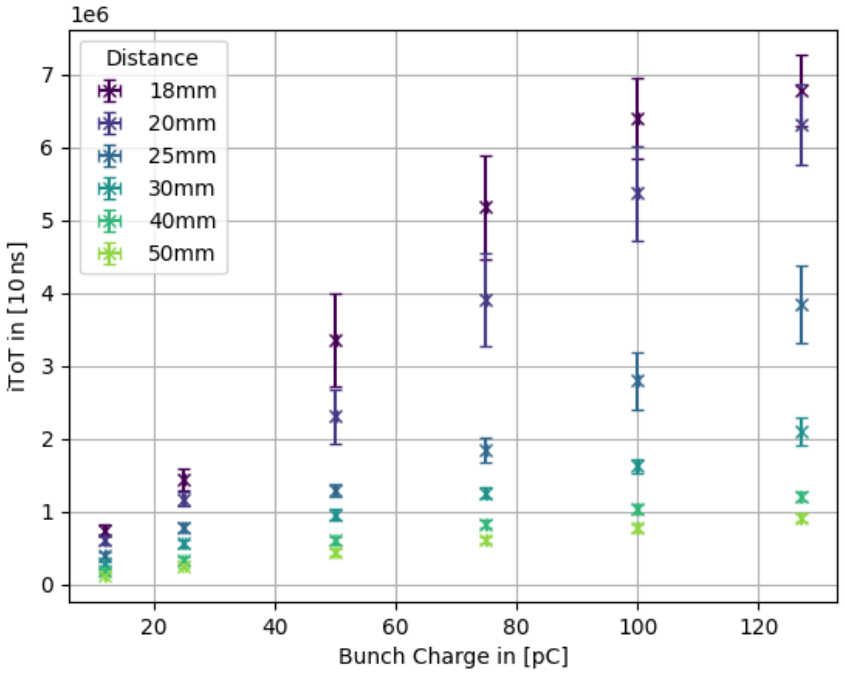
Beam Position Monitoring with Dosepix

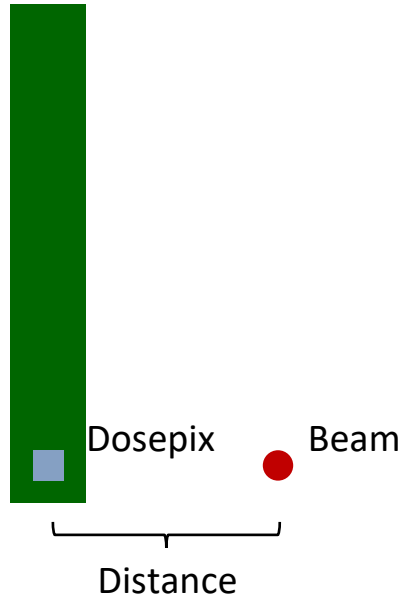
Beam Position Monitoring

First Results

- Measurements at ARES beam: 153 MeV, single bunches
- Single Dosepix detector
- Integration over 2000 bunches



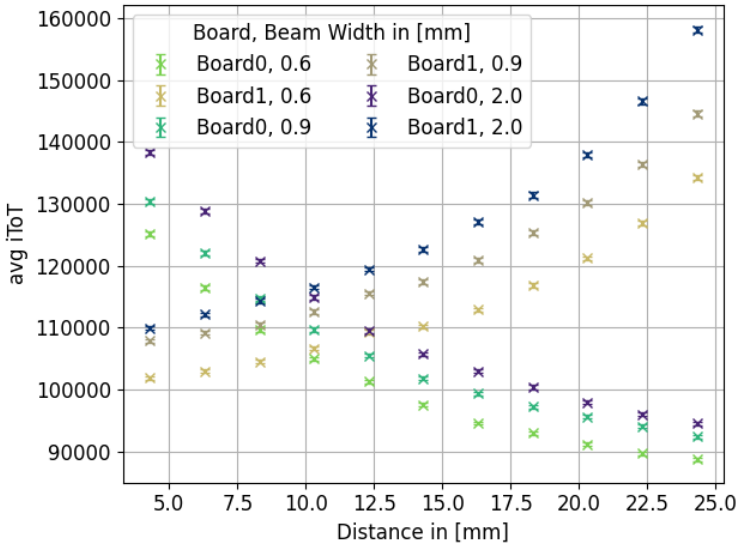


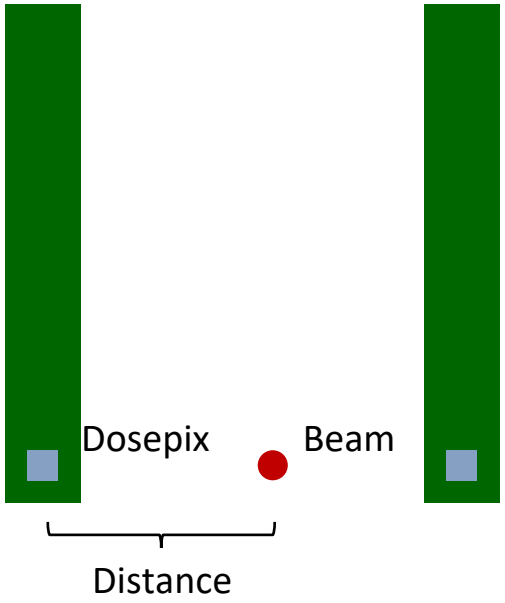


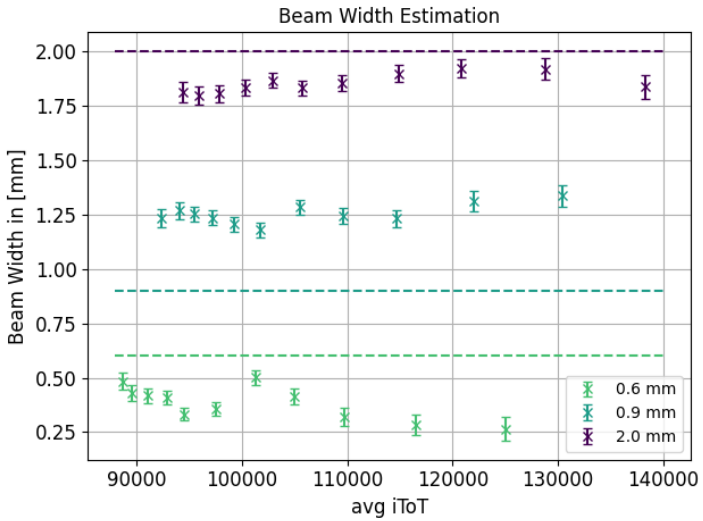
Beam Position Monitoring

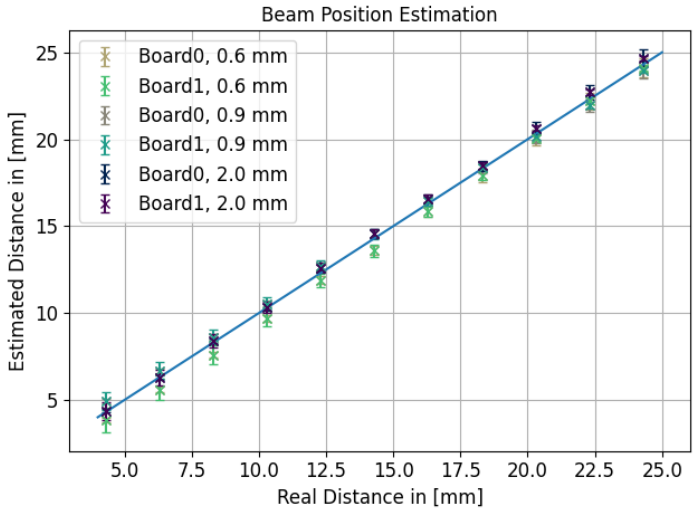
Current Results: Preliminary

- Extension to two Dosepix detectors
- Strong beam width dependence
- Independent beam width determination crucial
- Beam monitoring with Dosepix detectors possible
- Extension to four detectors in progress







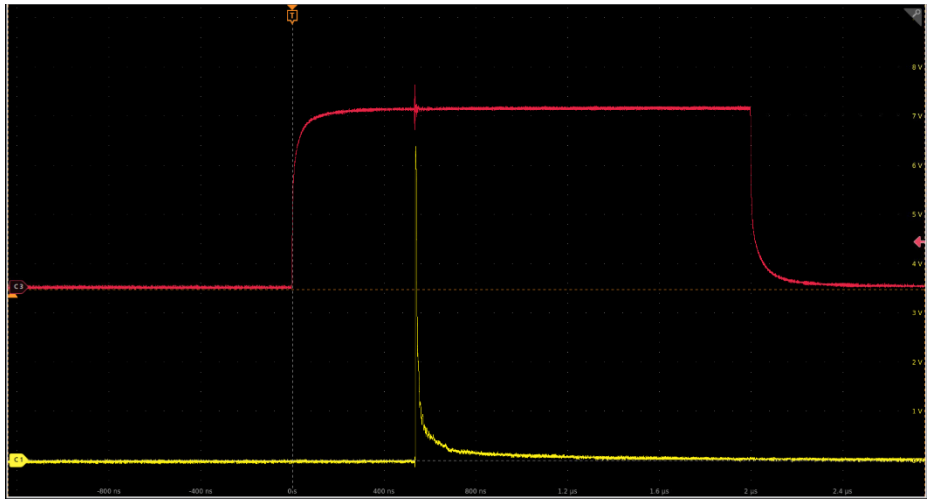


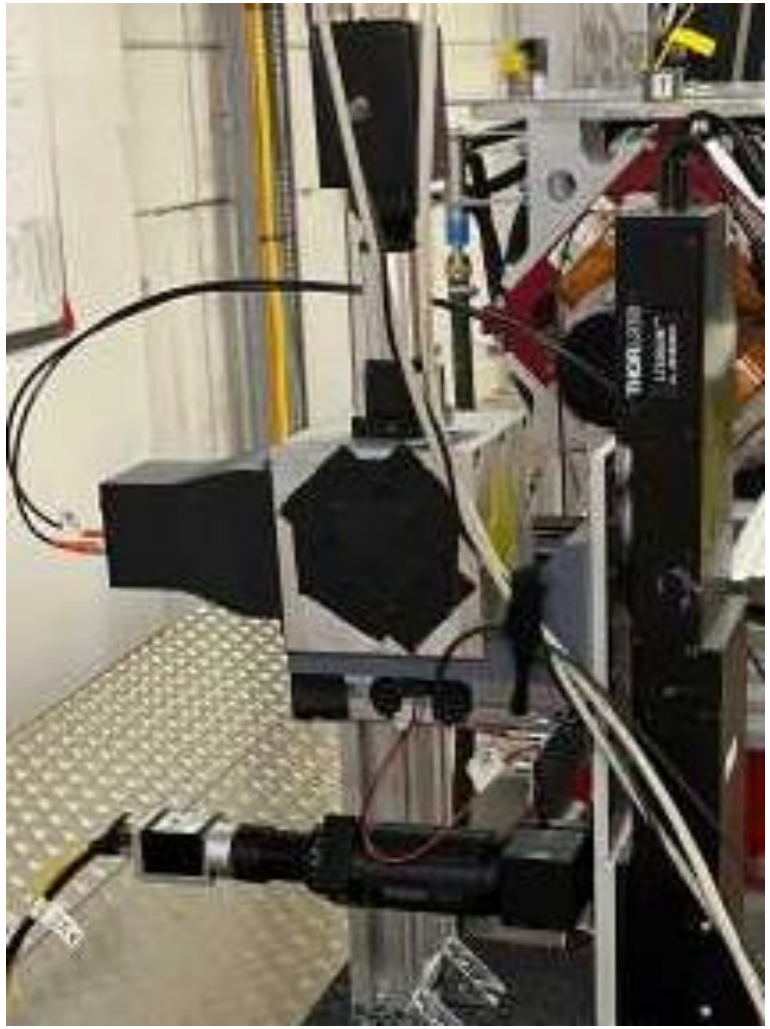
Beam Position Monitoring with UV -Cameras

Beam Position Monitoring

Jai 1405 Camera

- Cube (edge length: 10 cm)
- One imaging lens
- Two 25 mm side openings for cameras and PMT
- 20 mm entrance and exit window for electron beam
- 25 mm hole at bottom for LED
- LED synchronised with beam
- Validation via PMT

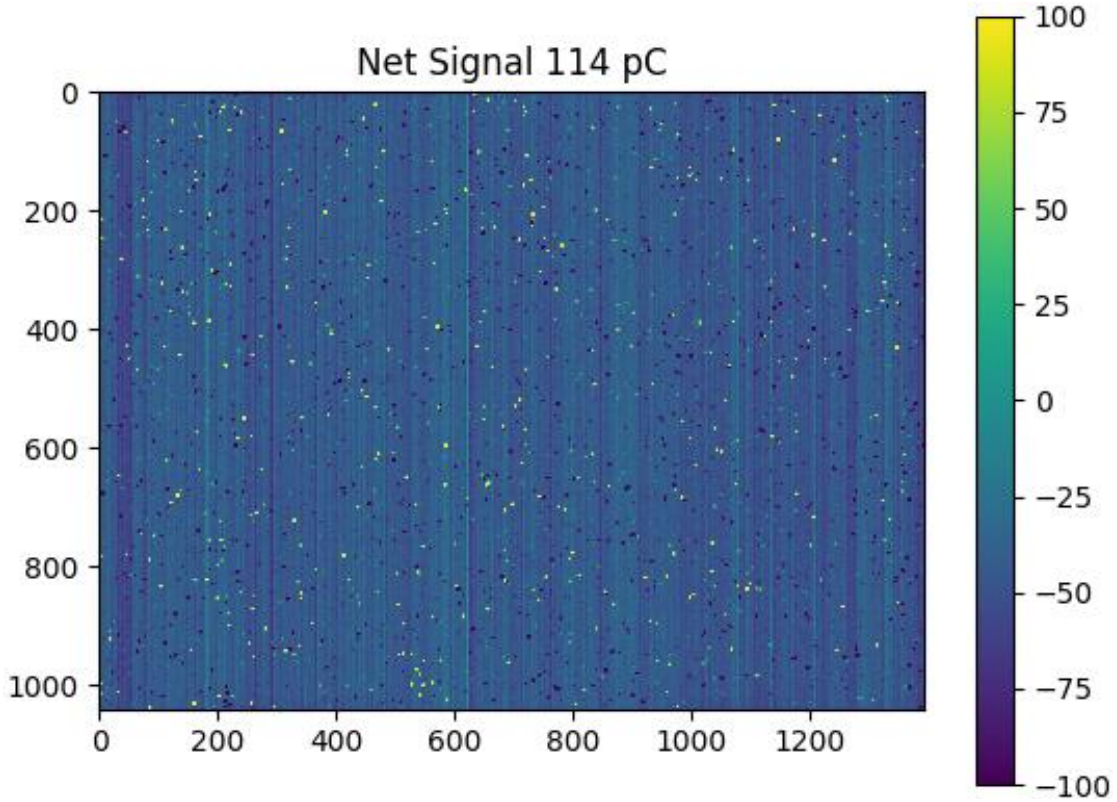


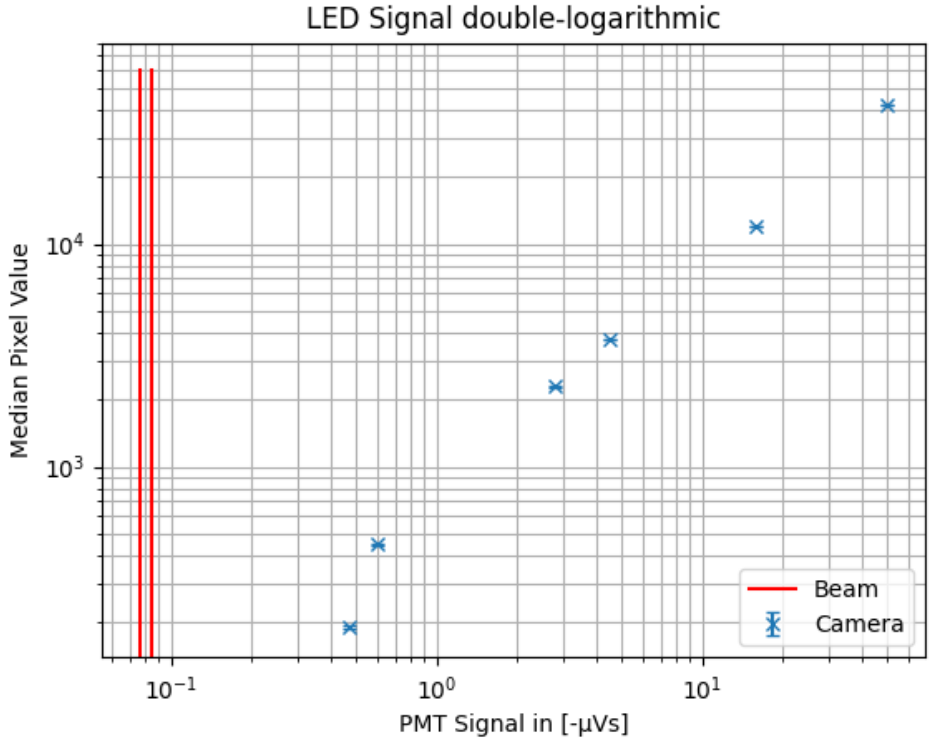


Beam Position Monitoring

Jai 1405 Camera

- Tests at ARES, LED with different illumination times
- Not enough signal for simple 1-lens-setup

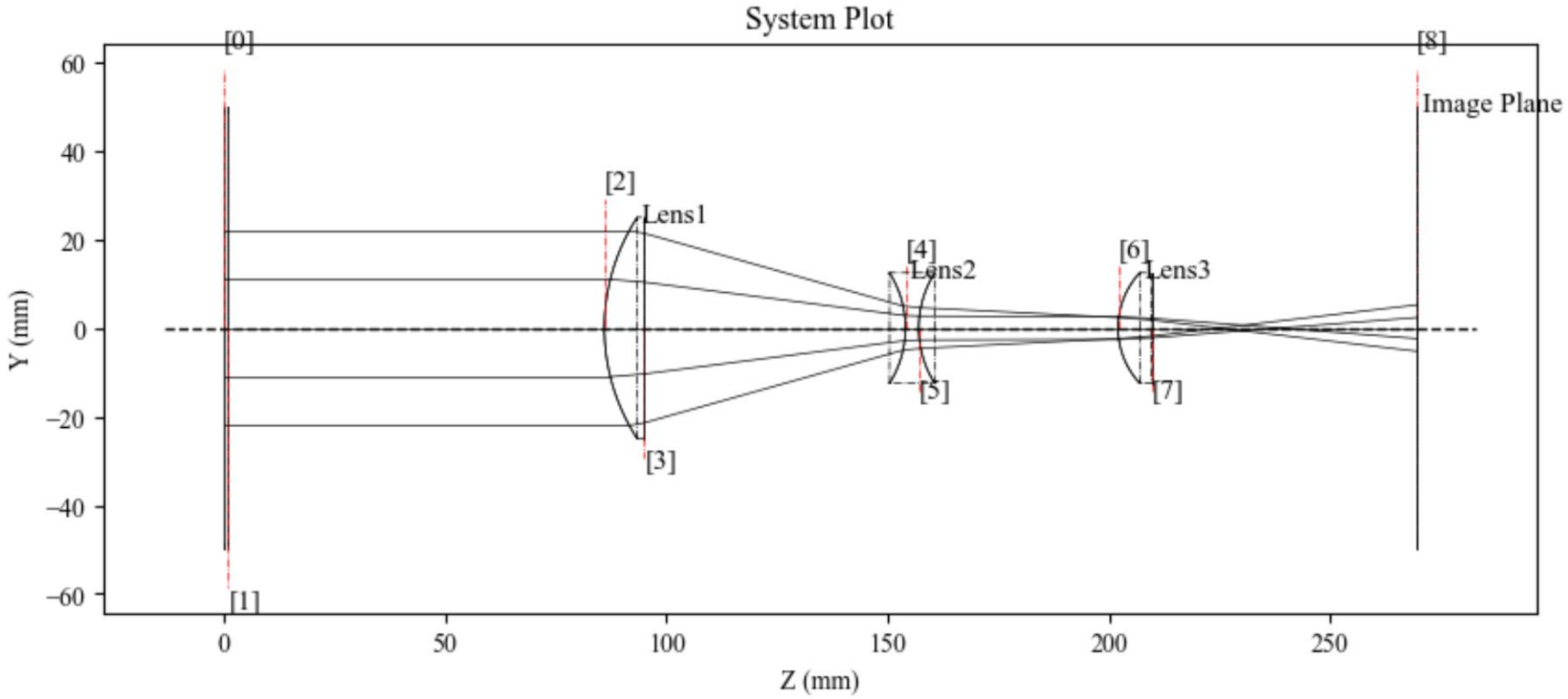




Beam Position Monitoring

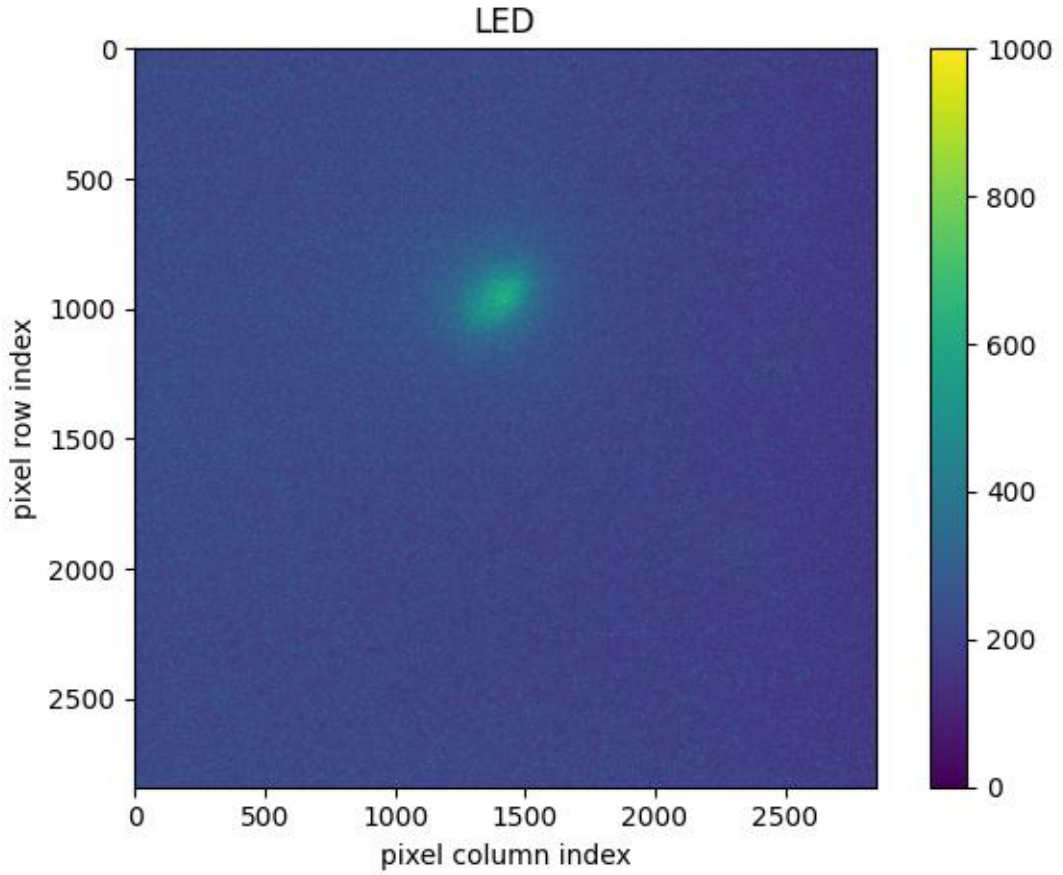
Camera: New Setup

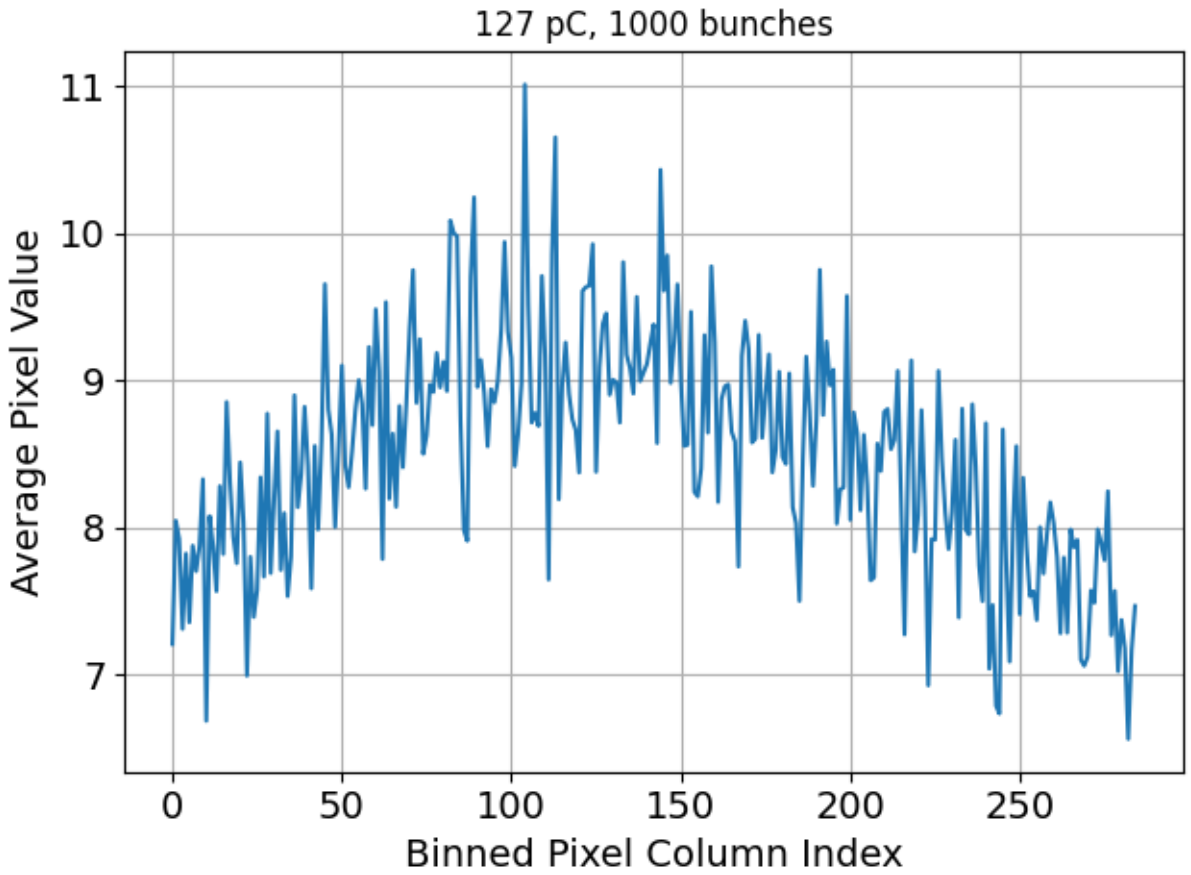
- Switch to 3-lens setup
- Increased light collection
- Basler ace2 A2a2840-14gmUV camera



Beam Position Monitoring

Camera: New Setup: Preliminary





Conclusion

Conclusion

- Electron beam monitoring device for PITZ
- Dosepix detectors and UV sensitive camera
- Several tests at ARES accelerator
- Dosepix results very promising
- UV light intensities very low
- Much higher expected intensities at PITZ
- Visible beam signal with Basler camera

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Thank You for Your Attention!

With funding from the:

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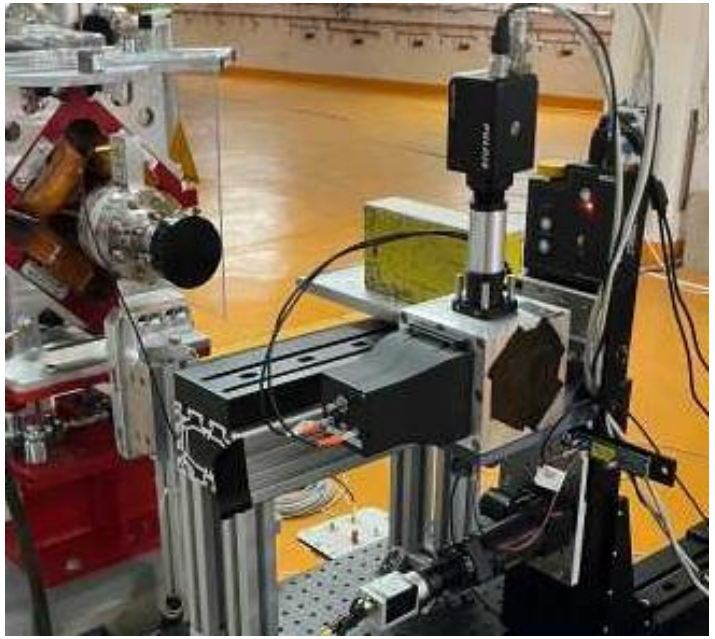
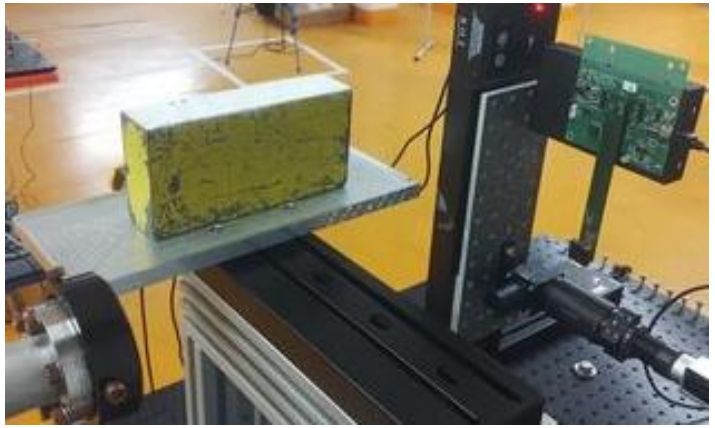
Bonus Slides

Conclusion

- NitroFLASH ambitious ErUM transfer project until Q2 2026
- Integrated dosimetry system
  - Stray radiation, non-linearity response, position dependence
  - Behind schedule
- Beam Position Monitoring
  - Individual setups established
  - Camera monitoring tricky
  - Time constraints hard to achieve with Dosepix
- Frank‘s plan: Determine dose from camera signal
- Enough work for PhD

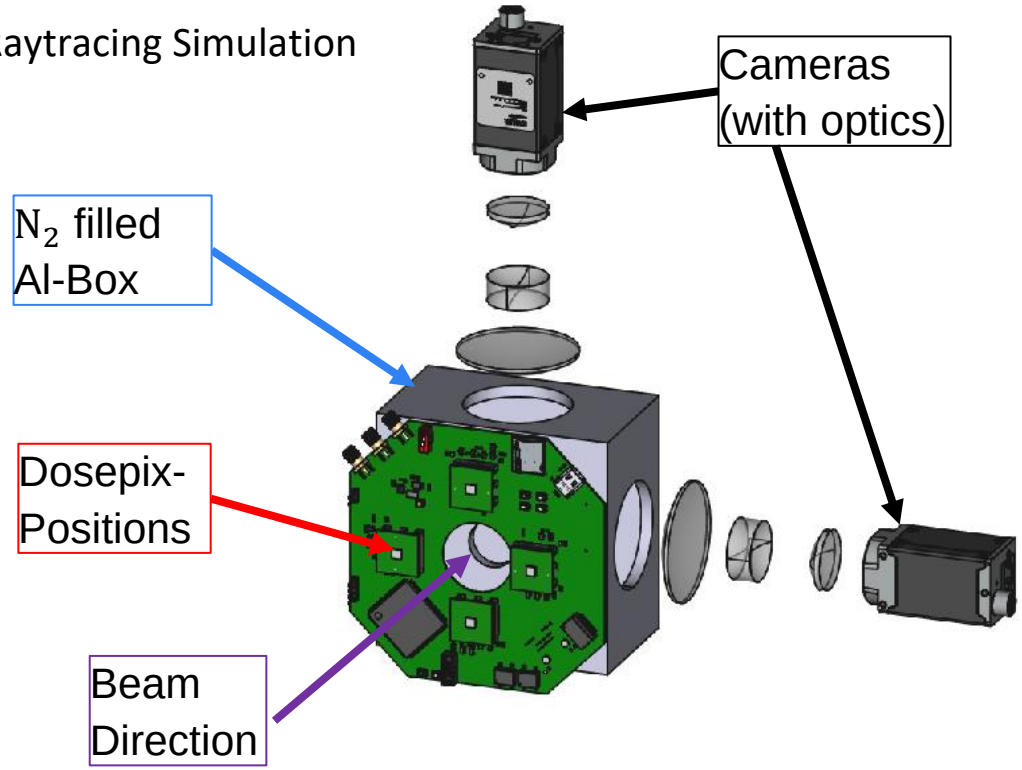


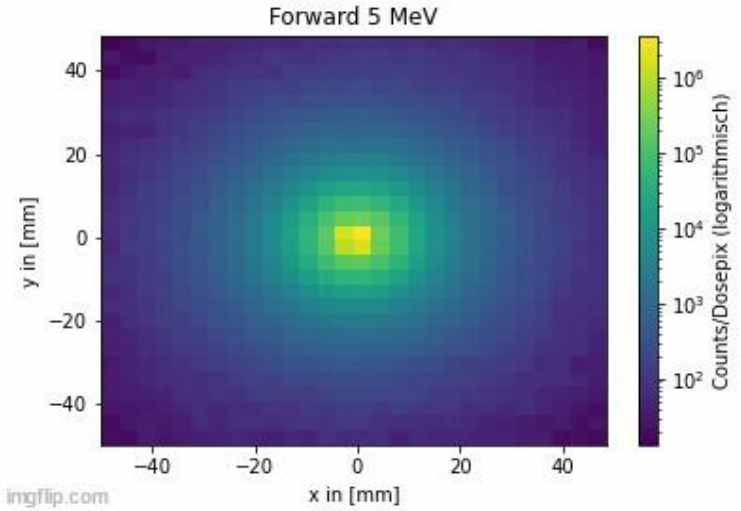


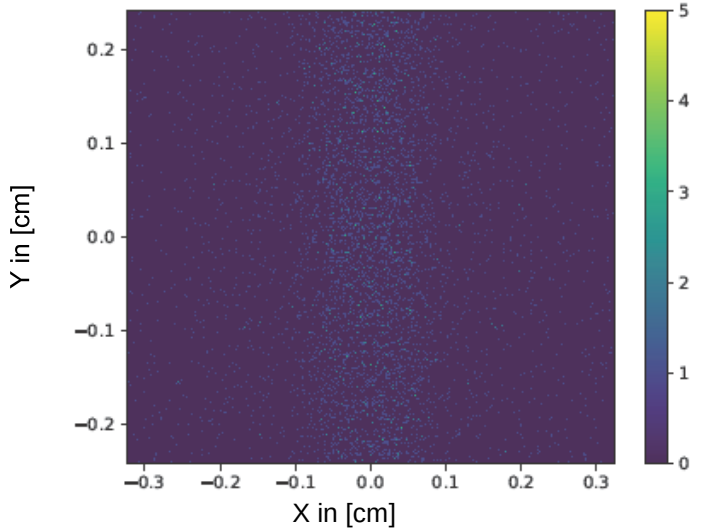
Motivation

Beam Position Monitoring

- First Simulations in 2023, Measurements in June 2024, December 2024, March 2025
- Dosepix detectors next to beam measuring stray radiation
- UV-Camera taking pictures of nitrogen fluorescence
- Raytracing Simulation



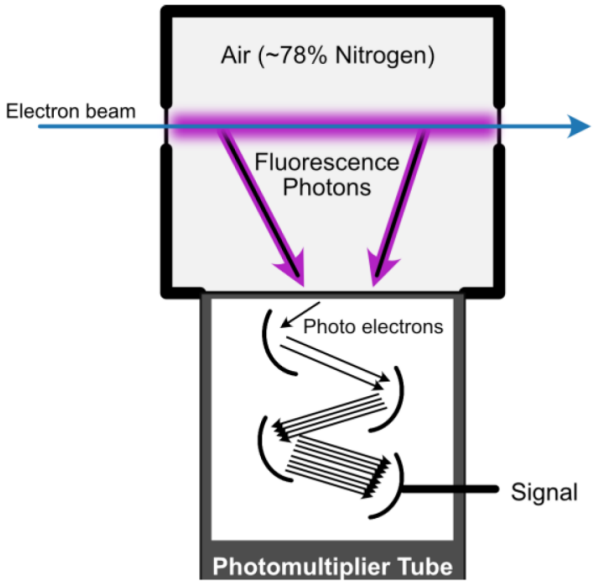


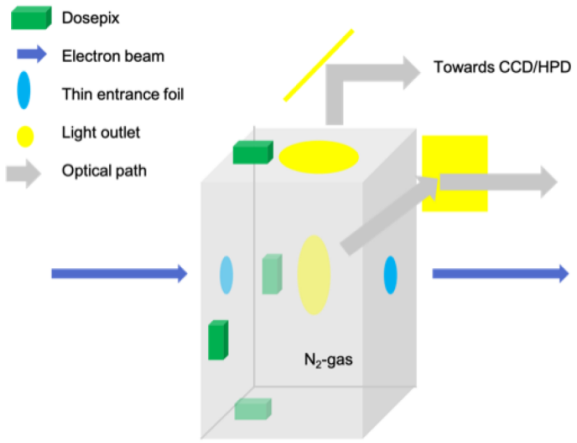


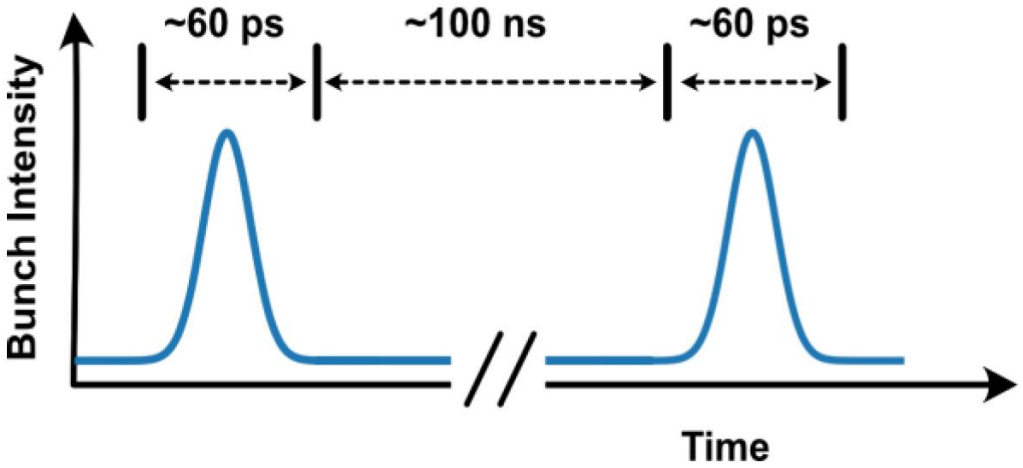
Motivation

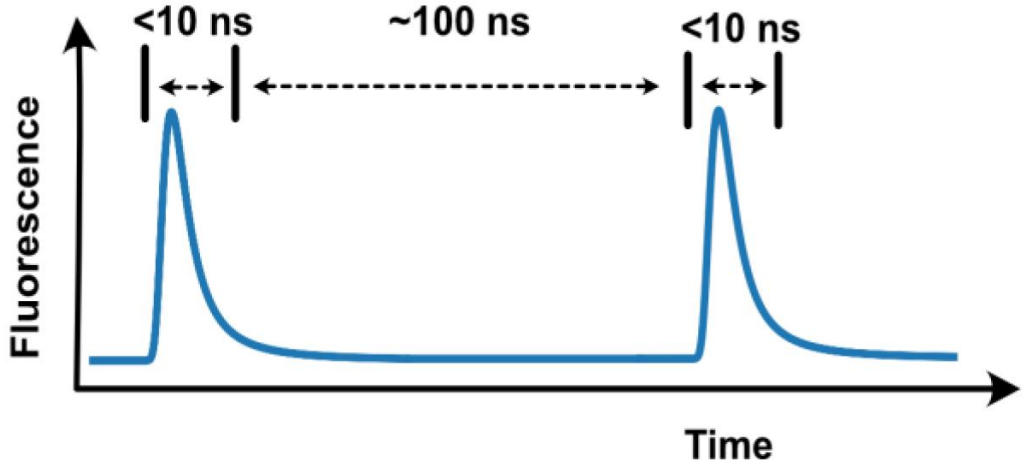
Why Does This Project Exist?

- Determination of the dose per bunch
- Monitoring of the beam position/width
- Online feedback and correction mechanisms
- Short response time required





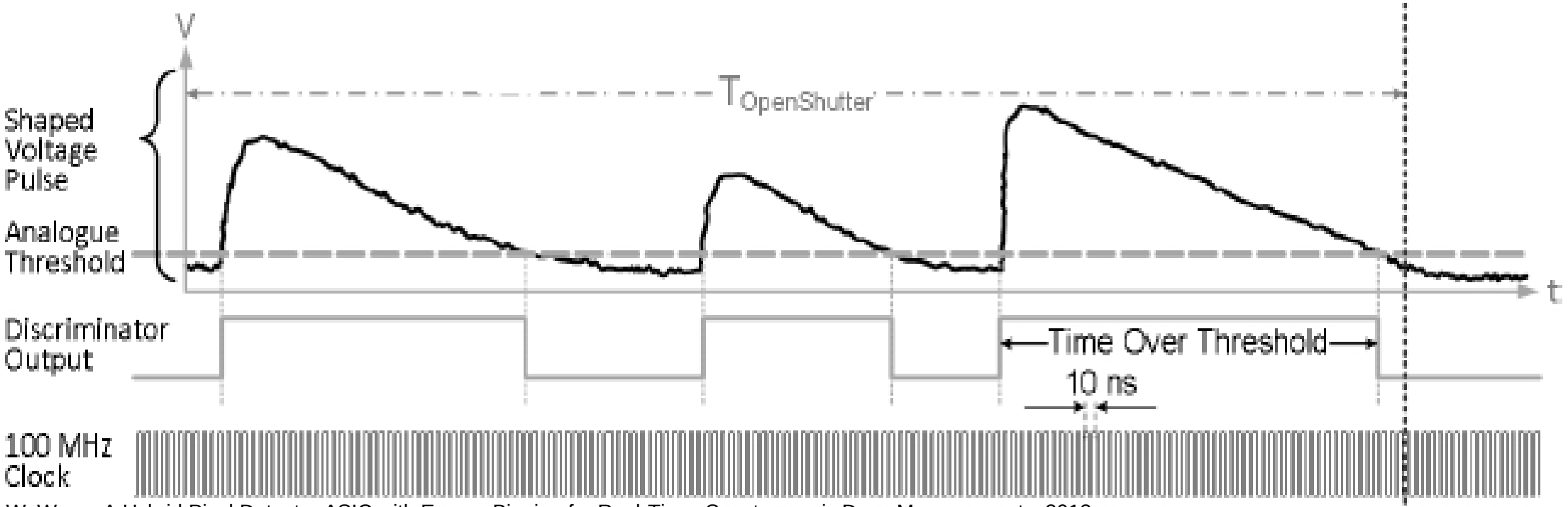




NitroFLASH: Update from Erlangen

Dosepix: Time-over-Threshold (*ToT*)

- Dosepix‘s measure of event energy
- At Pitz beam: always total Pile-Up
- Counting clock cycles of 100 MHz Ref-Clk
- Number of clock cycles: *ToT*
- Procession in each pixel

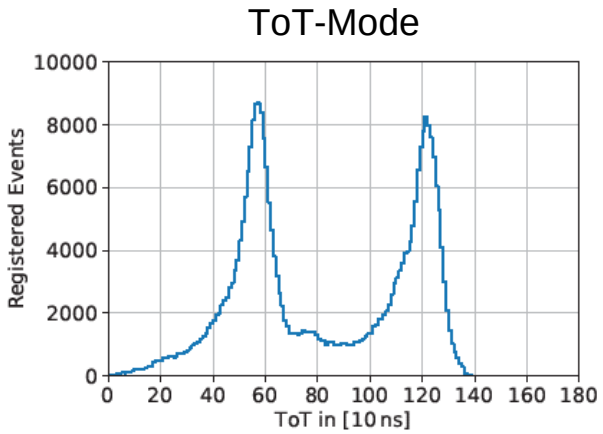


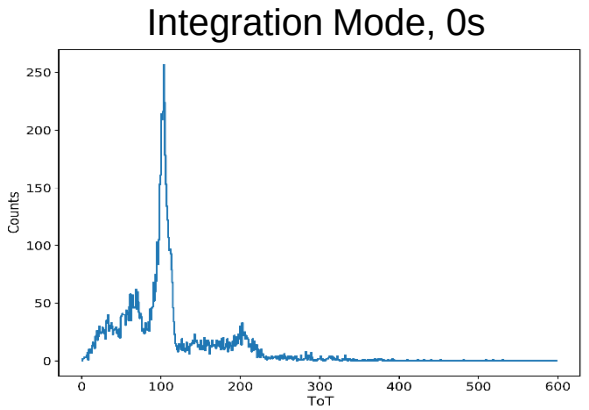
W. Wong: A Hybrid Pixel Detector ASIC with Energy Binning for Real-Time, Spectroscopic Dose Measurements, 2012

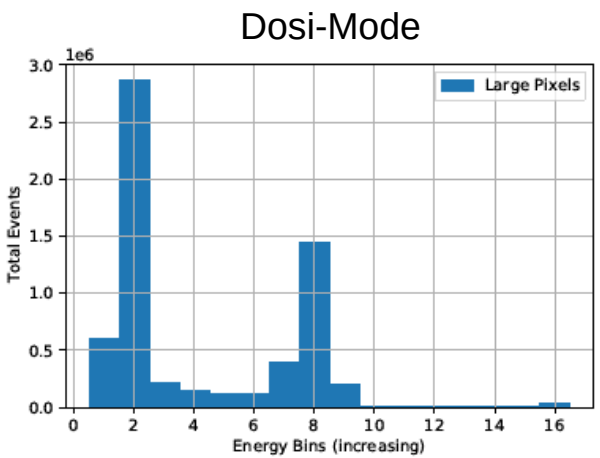
NitroFLASH: Update from Erlangen

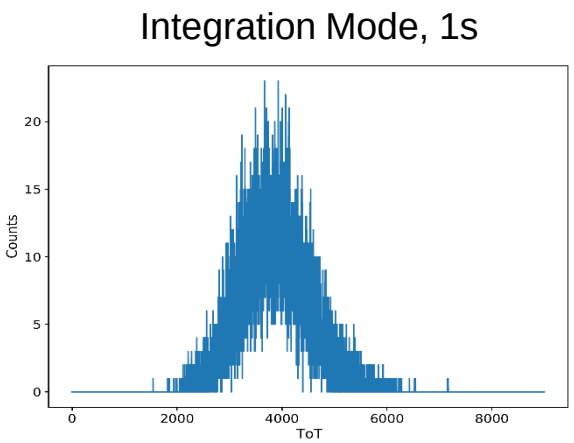
Dosepix: Modes of Operation

- **ToT-Mode**:
  - Direct read-out of pixel-wise ToT registers
  - Overwrite of previous ToT-values no flux information
- **Photon Counting Mode:**
  - Number of threshold passages
  - No spectral information
- **Integration Mode:**
  - Read-out integrated ToT of each pixel
  - Best mode for high fluxes
- **Dosi-Mode/Energy-Binning-Mode**
  - Sort each incoming ToT into 16-bin histogram
  - Bin edges individually adjustable







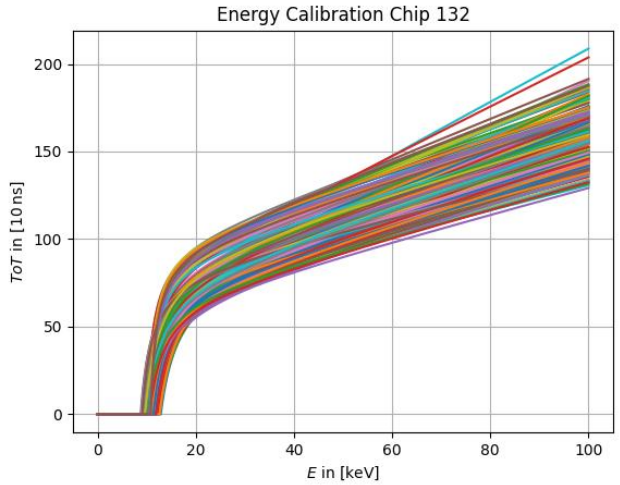


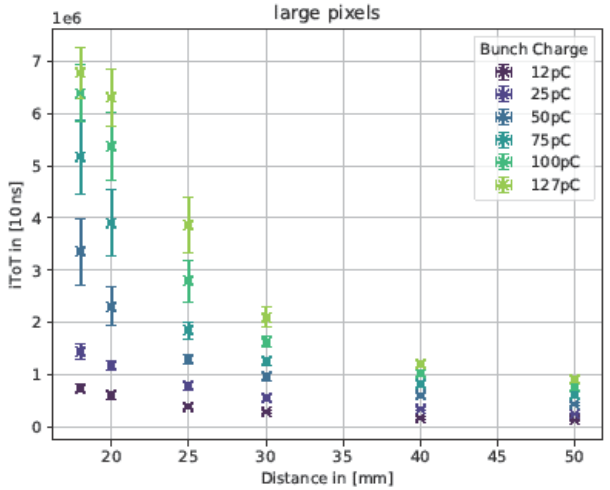
Leonie Ullmann: Untersuchung und Analyse der Bias-Spannungs-Abhängigkeit des hybriden, photonenzählenden Pixeldetektors Dosepix, 2021

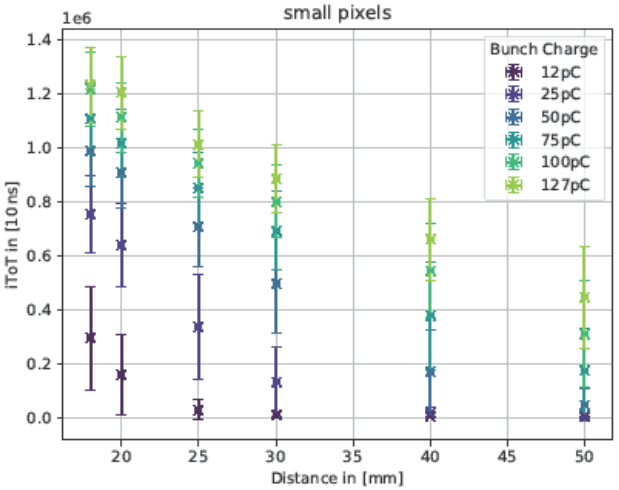
Integration Mode

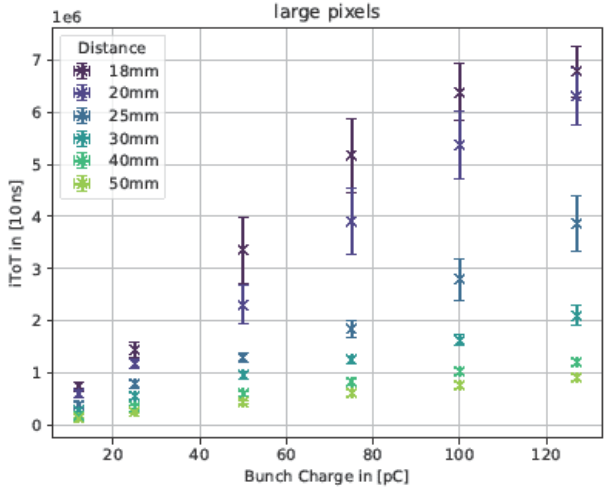
Bunch Charges

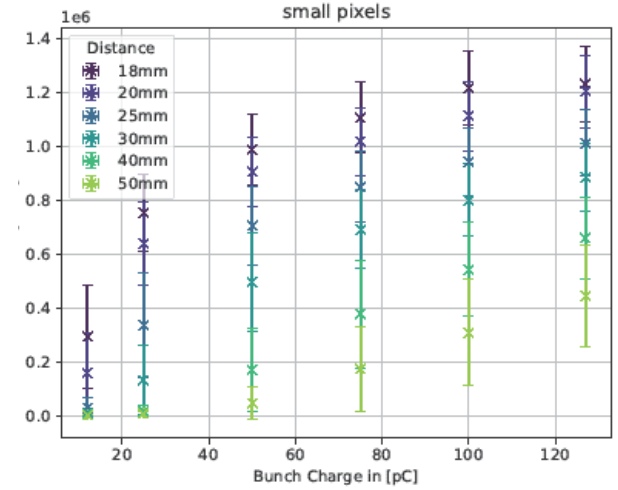
- Time-over-Threshold (ToT): Doseoix‘ measure of deposited energy (roughly proportional)
- Integration mode: Summation of all ToTs in one pixel until read-out
- 10 frames a 20 s







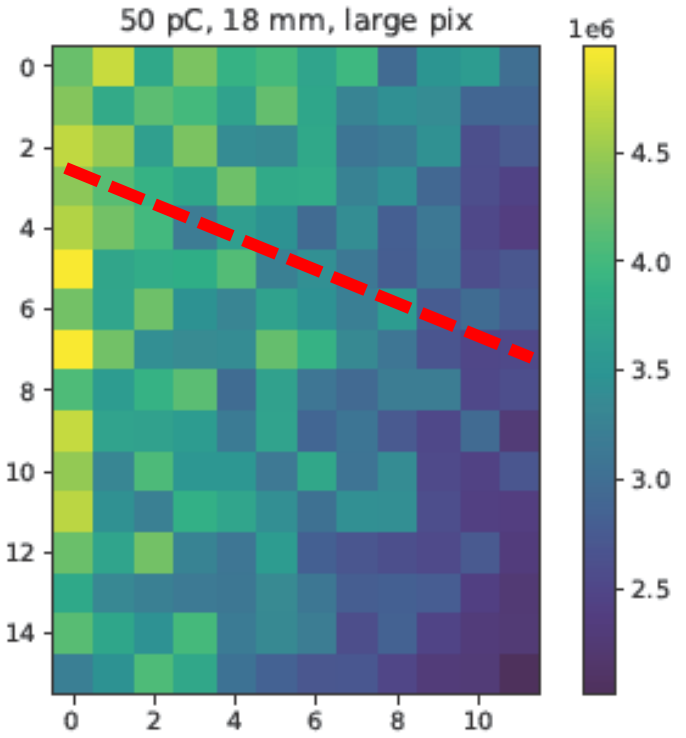


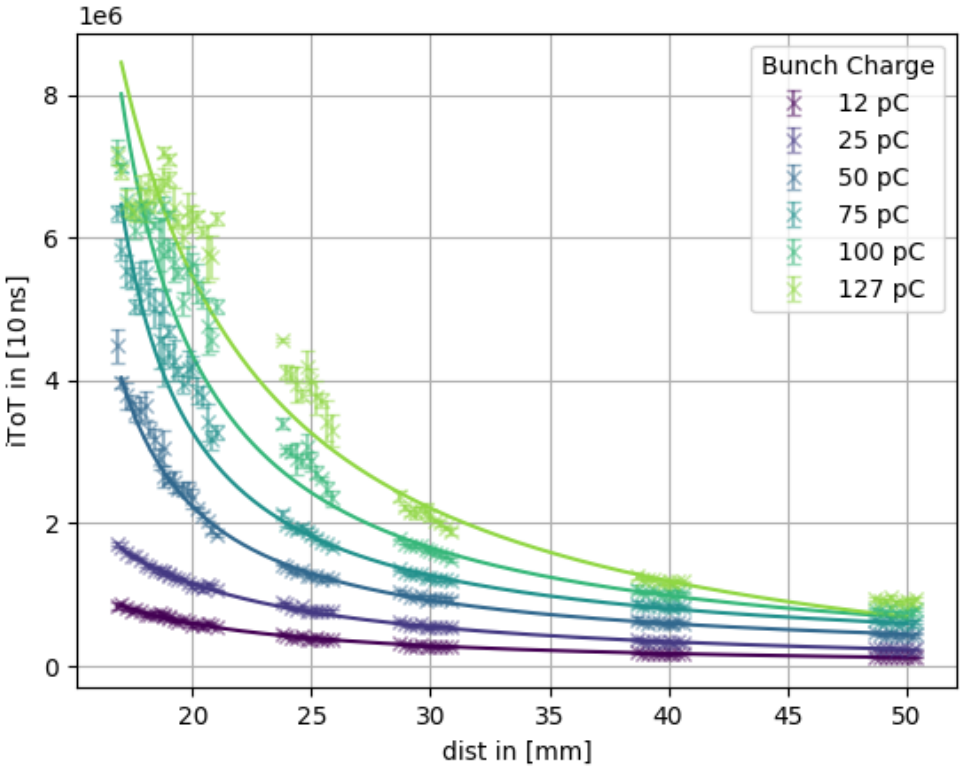


Beam Position Monitoring with Dosepix

Pixel Information

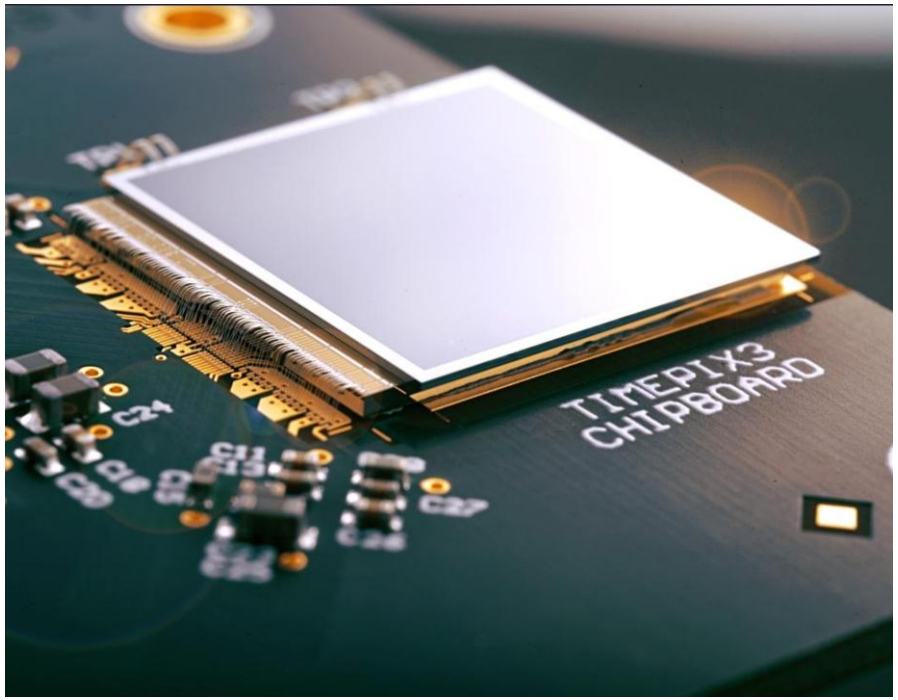
- Additional information from pixel matrix
- Image procession (rotation) necessary
- Probably insuitable for automated reconstruction





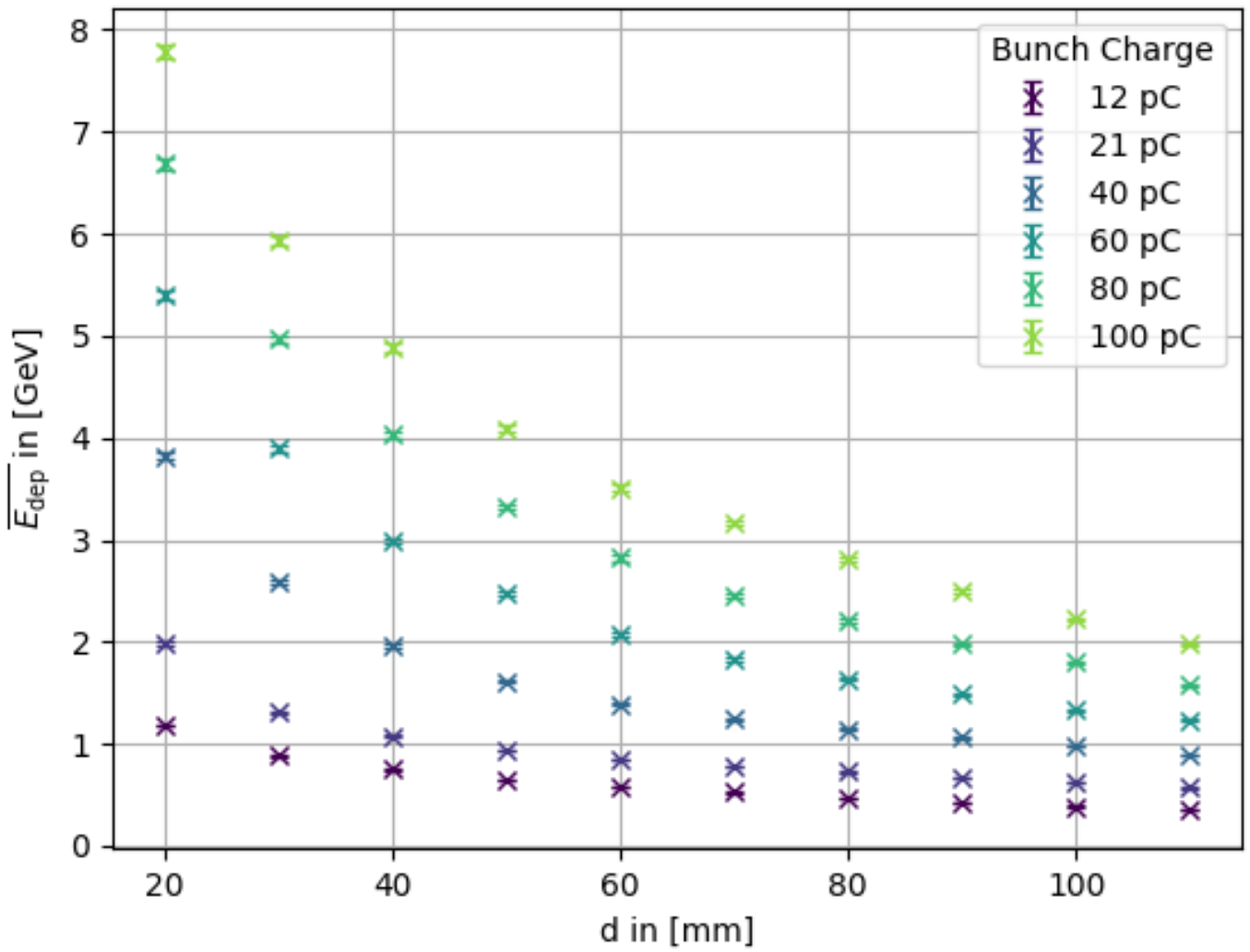
Timepix3

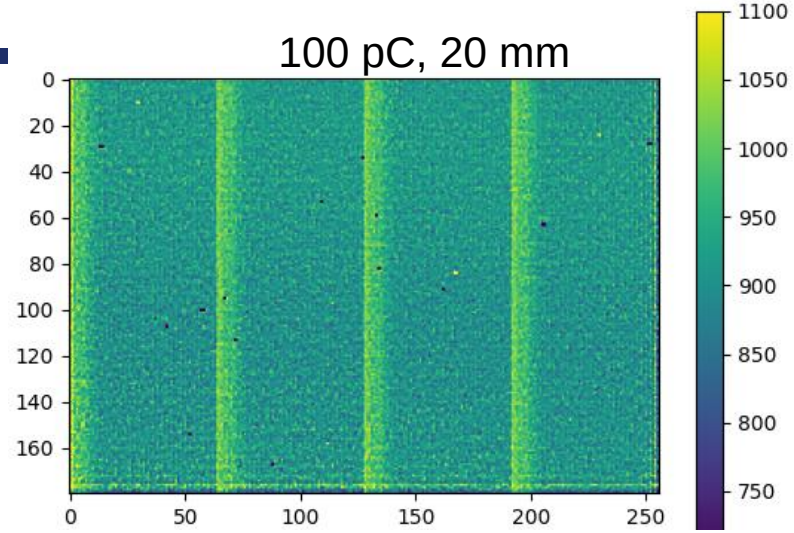
- Energy-resolving photon-counting pixel detector
- 256 x 256 pixels
- Pixel pitch: 55µm (dense)
- time-over-threshold (ToT, deposited energy) and time-of-arrival (ToA) information
- Event clustering possible

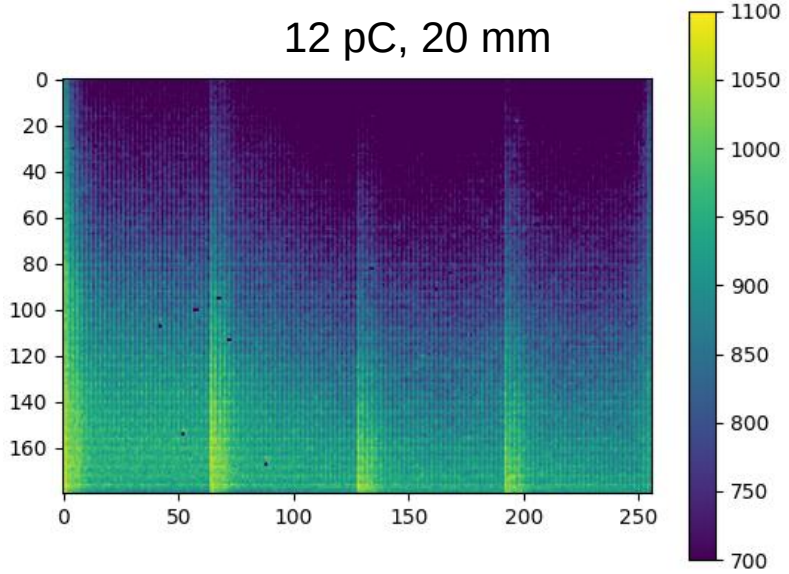


Timepix

Erste Plots



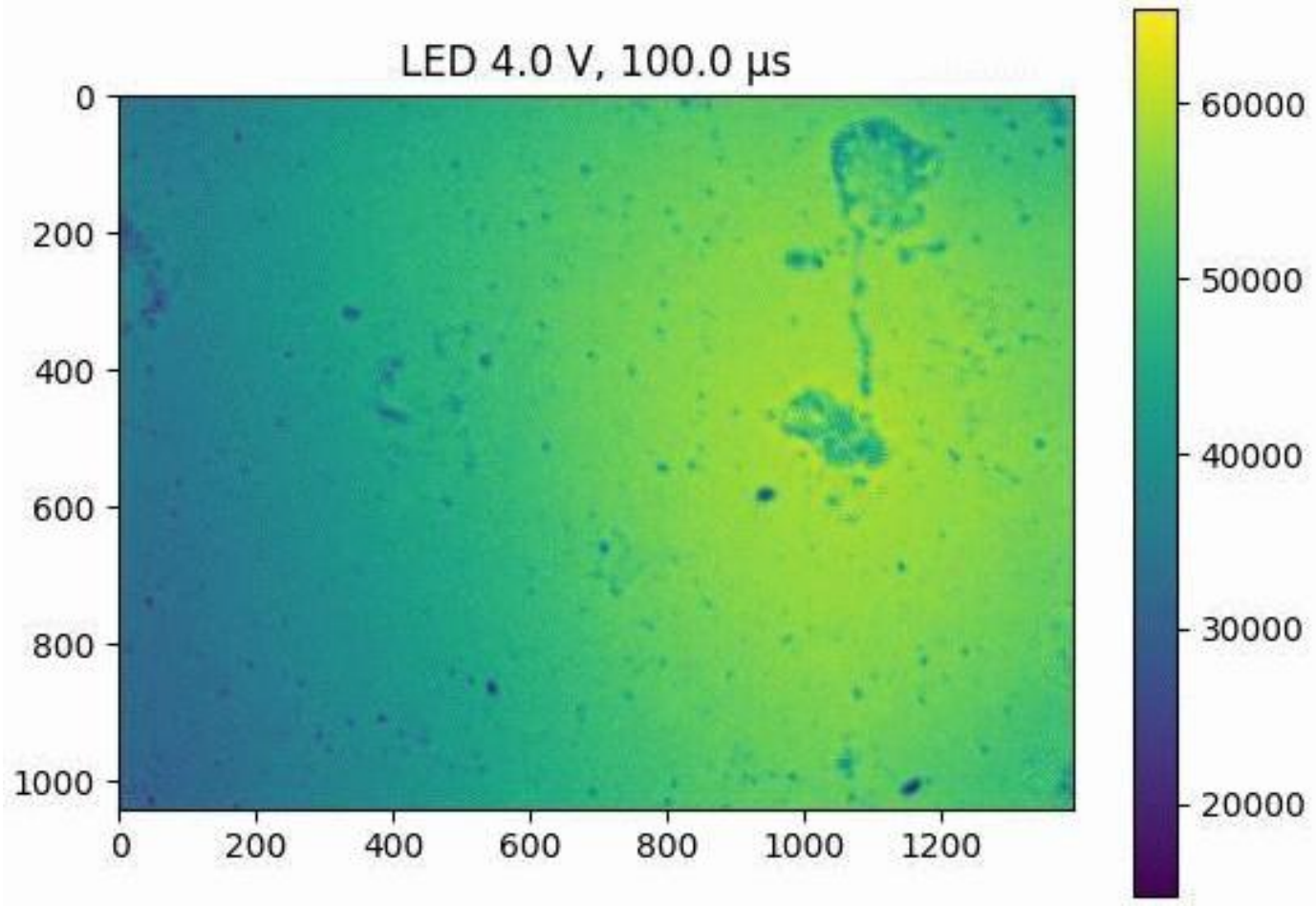




Beam Position Monitoring

Camera

- Pictures from LED-Signal
- LED Voltage varied
- LED illumination time varied
- Synchronised with beam (validated via PMT)



NitroFLASH: Update from Erlangen

Raytracing

- Kraken Optical Simulation (https://github.com/Garchupiter/Kraken-Optical-Simulator/tree/main)
- „easy“ to learn and implement
- Rather slow (python)
- RAM-costly for higher fluences