Diamond membrane detectors

GSI, 7.2.2019

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CVD diamonds

- CVD = Chemical Vapor Deposition
- Little impurities
- High temperature, low pressure
- Ionized hydrogen, methane gas
- 0.1 µm to 10 µm per hour

Why diamond detectors

- Radiation resistant
- Low noise
- Low leakage current
- No cooling required
- Fast response – sub nanosecond

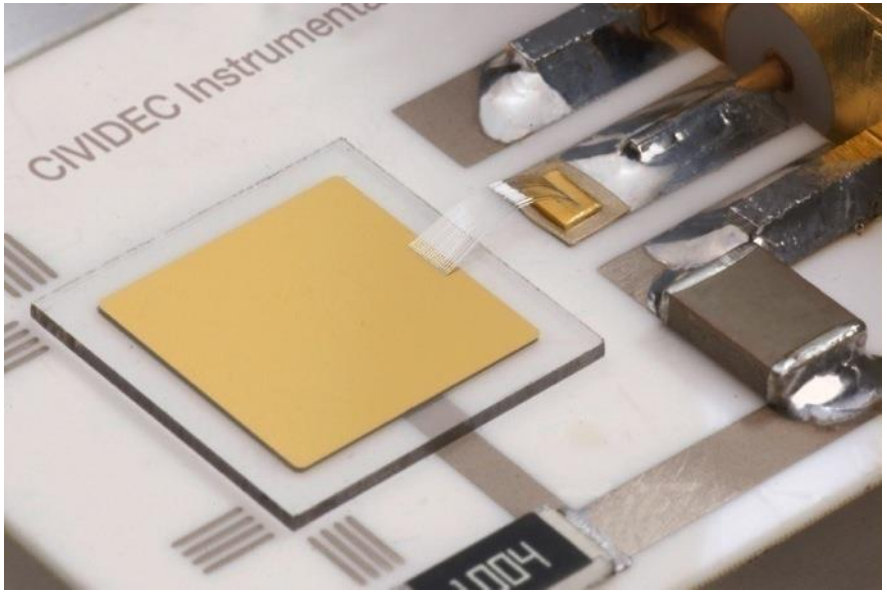
Applications for diamond detectors

- Beam instrumentation and spectroscopy
- Neutron spectroscopy and flux monitoring
- X-ray and gamma beam position and beam intensity monitoring

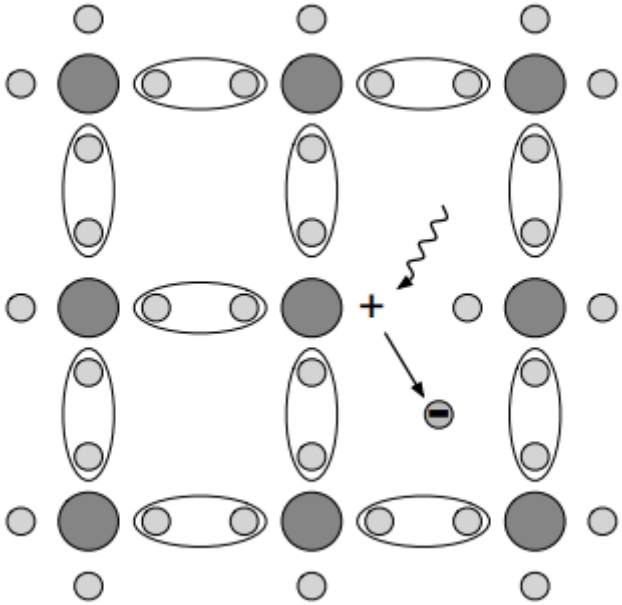
pCVD and sCVD

- Polycrystalline (pCVD)
  - Cheaper per area
  - Can be up to 75 cm^2
- Single crystal (sCVD)
  - Smaller sizes – up to 8mm * 8mm
  - For spectroscopy, particle recognition

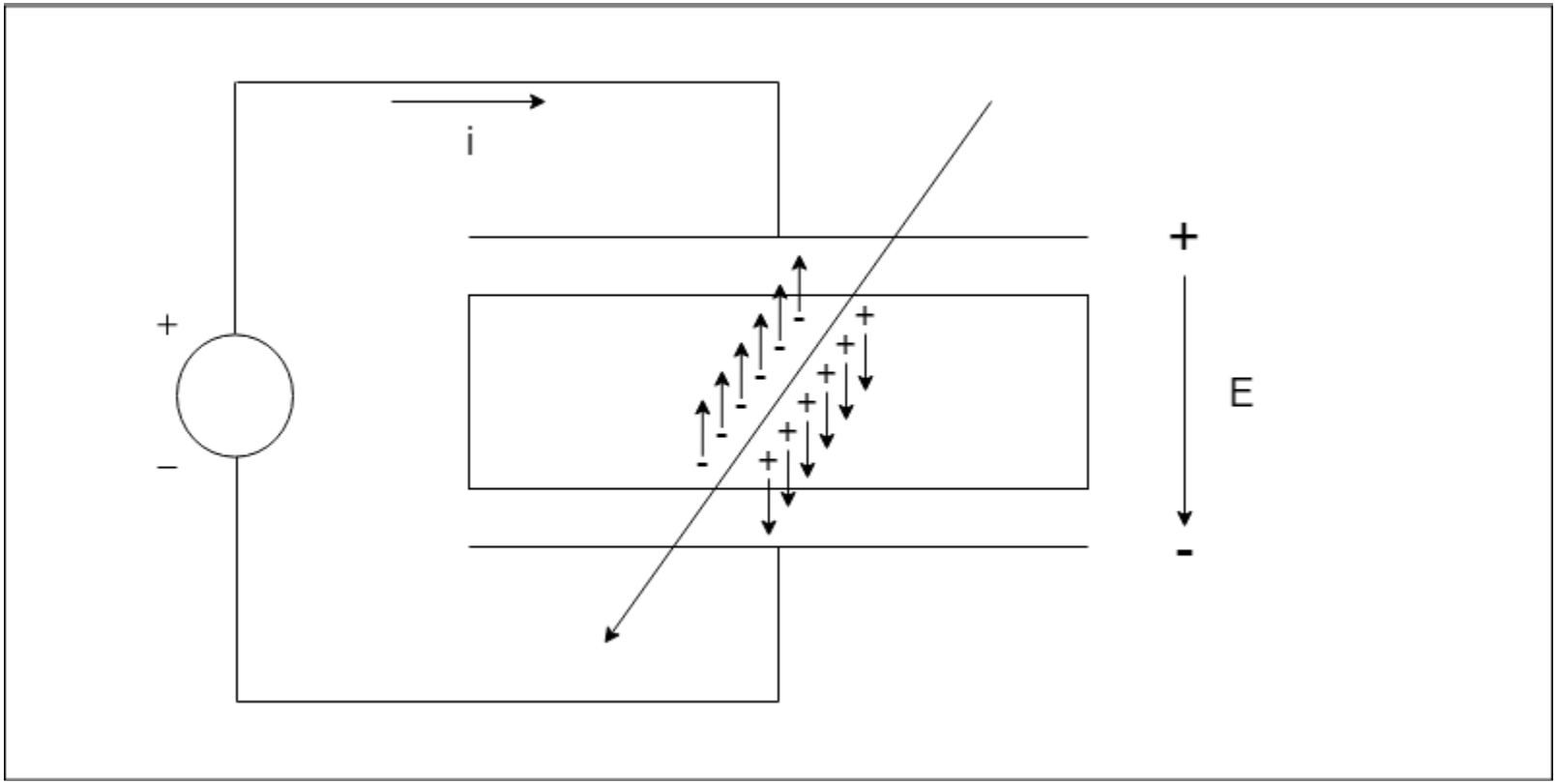
pCVD diamond detector



Ionization

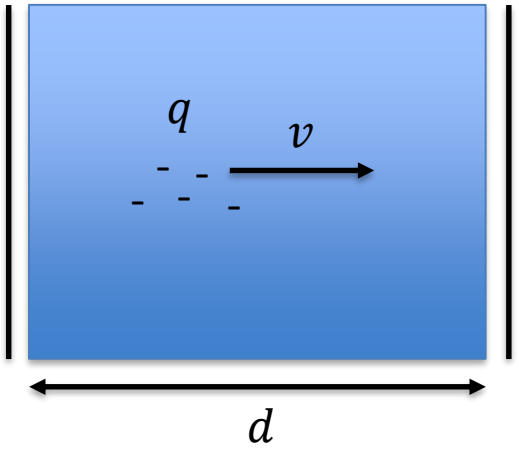


Particle detection

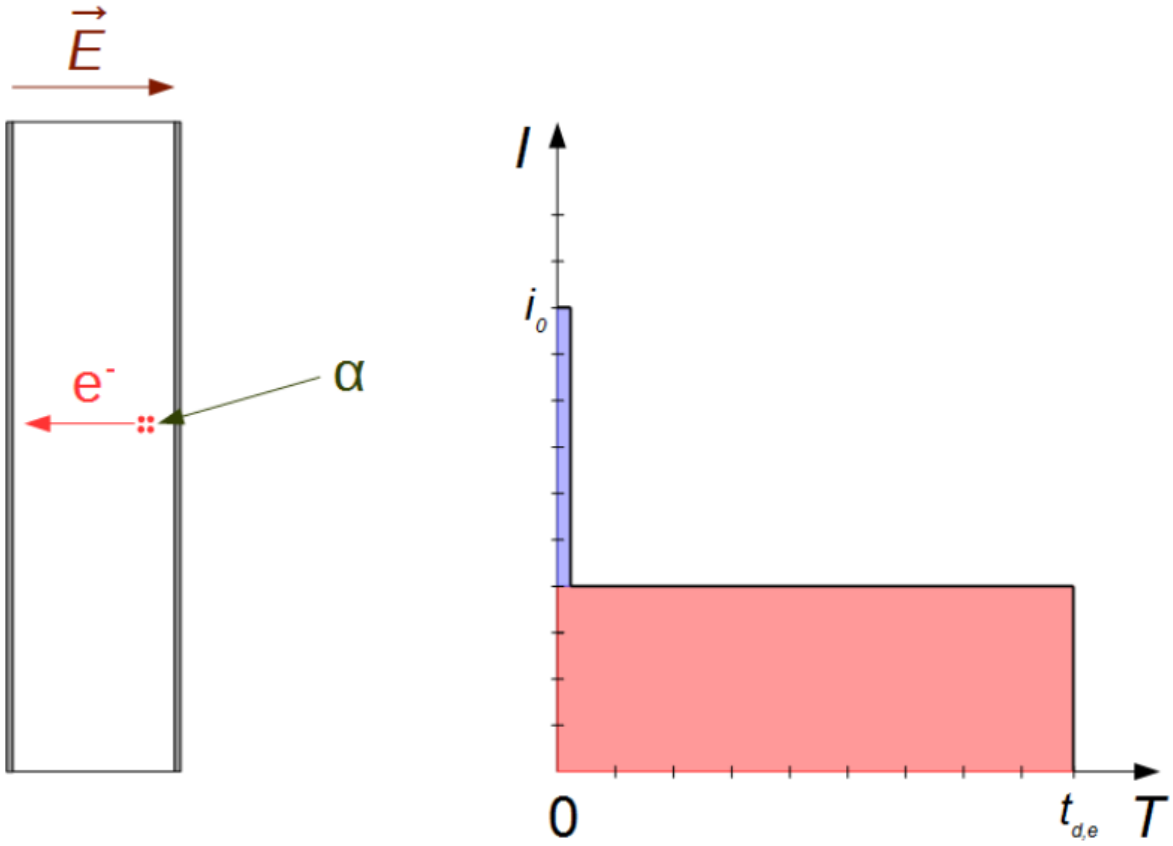


Drift velocity

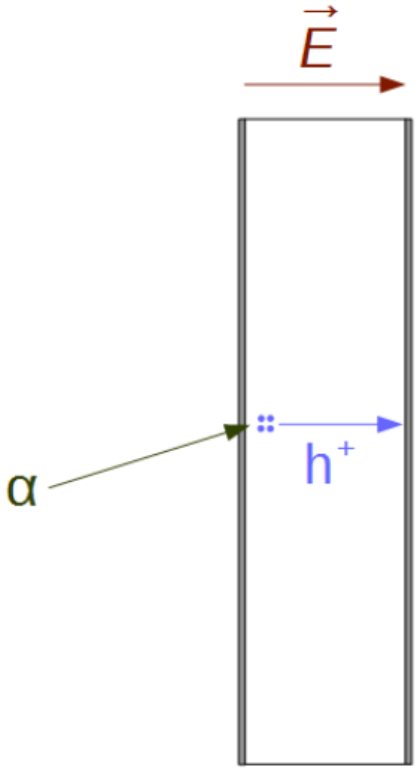
- Electrons and holes have different mobilities
- Holes have higher mobility
- Shockley-Ramo theorem : $I = \frac{q * v}{d}$

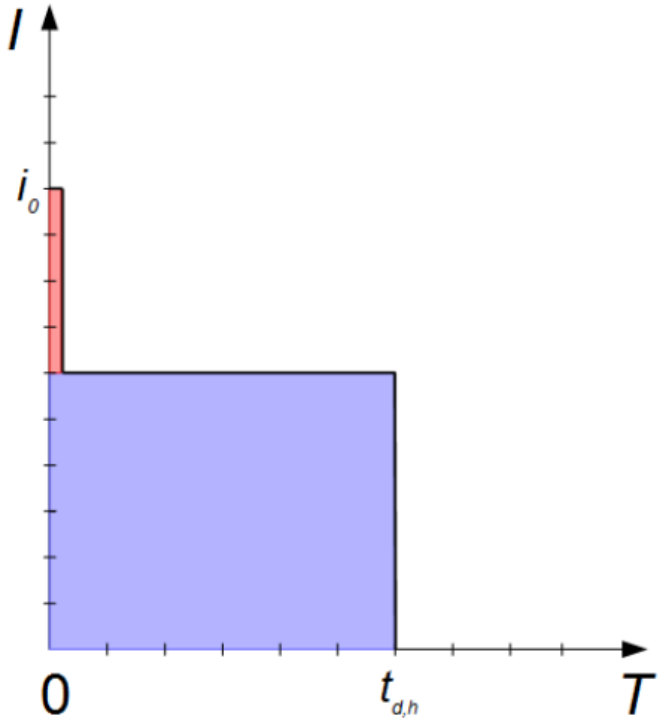


Electron drift



Hole drift

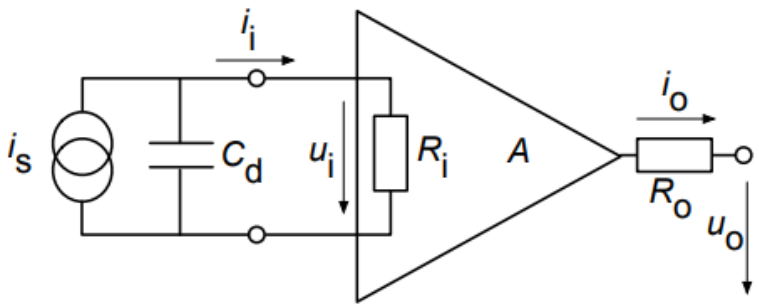


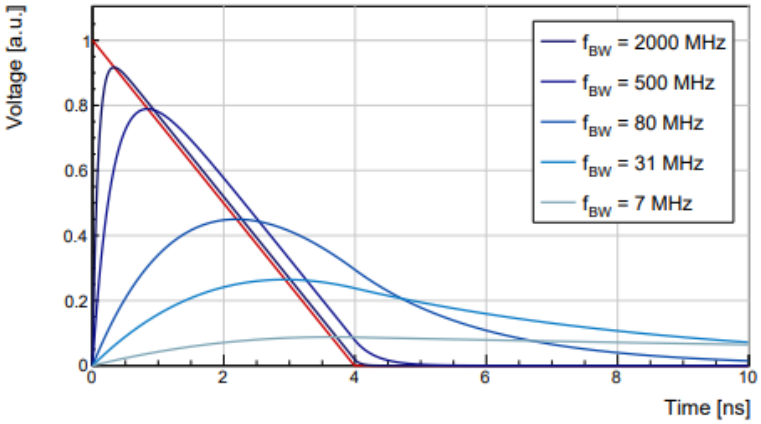


Amplifiers

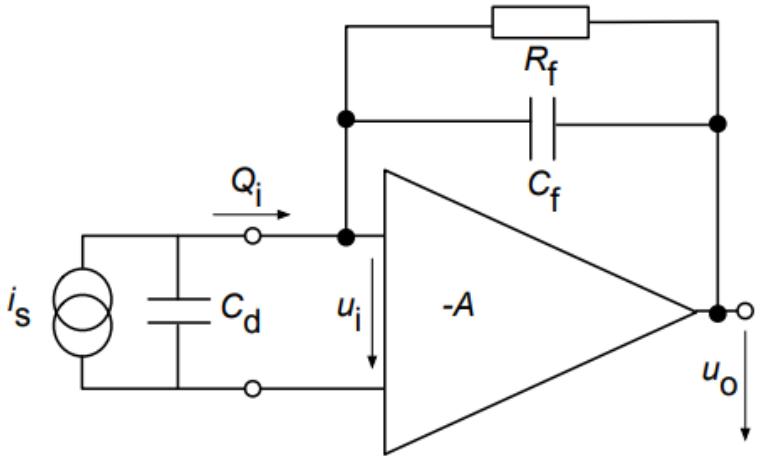
- Current amplifiers
  - Counting
  - Pulse shape analysis
- Charge amplifiers
  - Spectroscopy

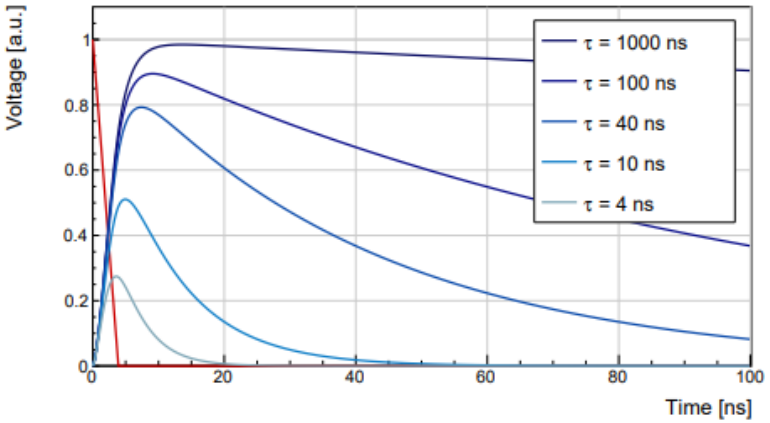
Current amplifier



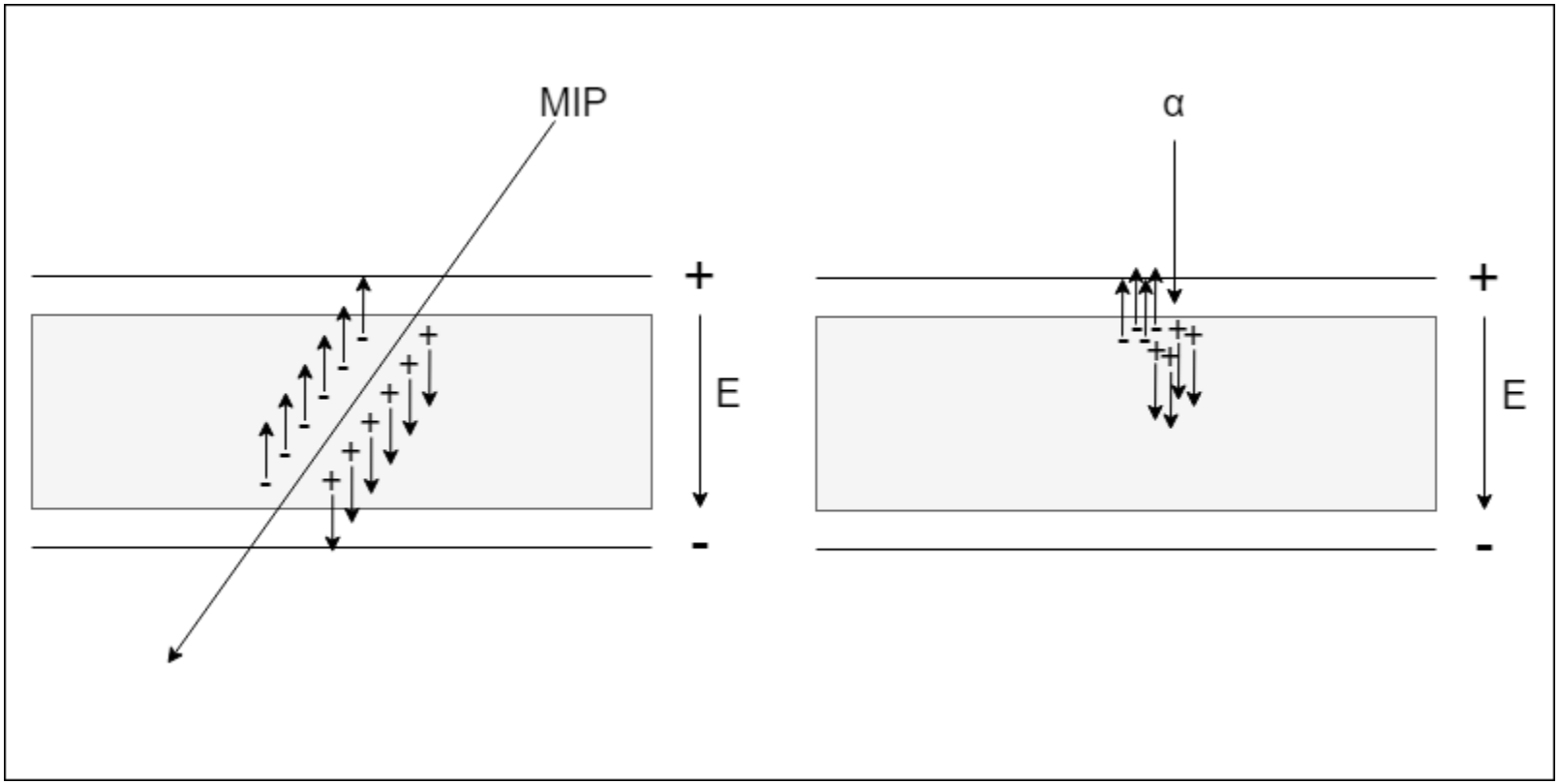


Charge amplifier

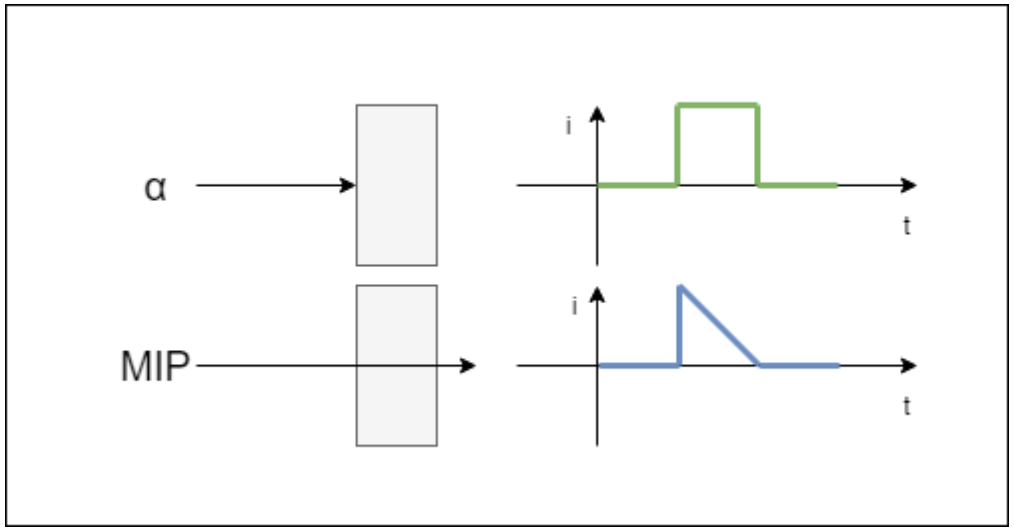




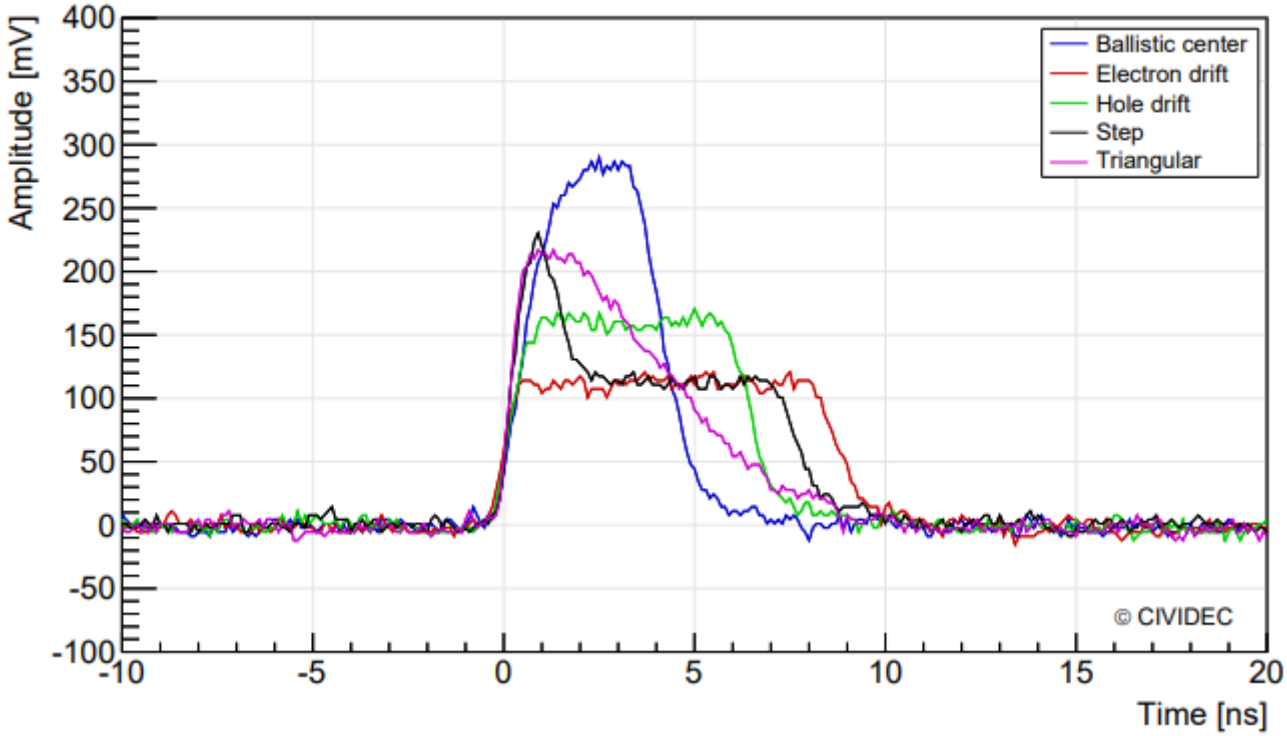
Particle Identification



Particle Identification



Particle identification



My measurements

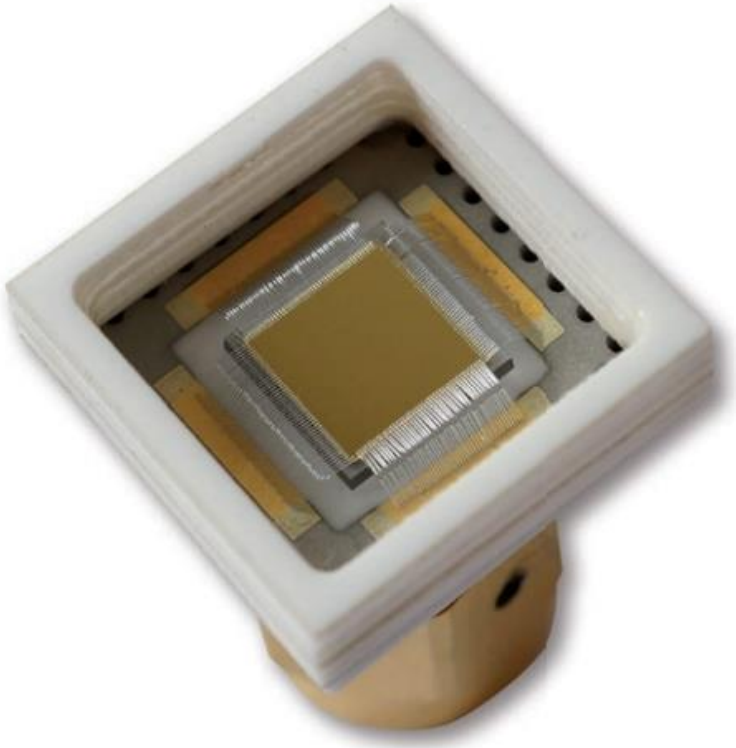
- Grace beam line at AEgIS at CERN
- Low energy antiprotons

Measurement setup

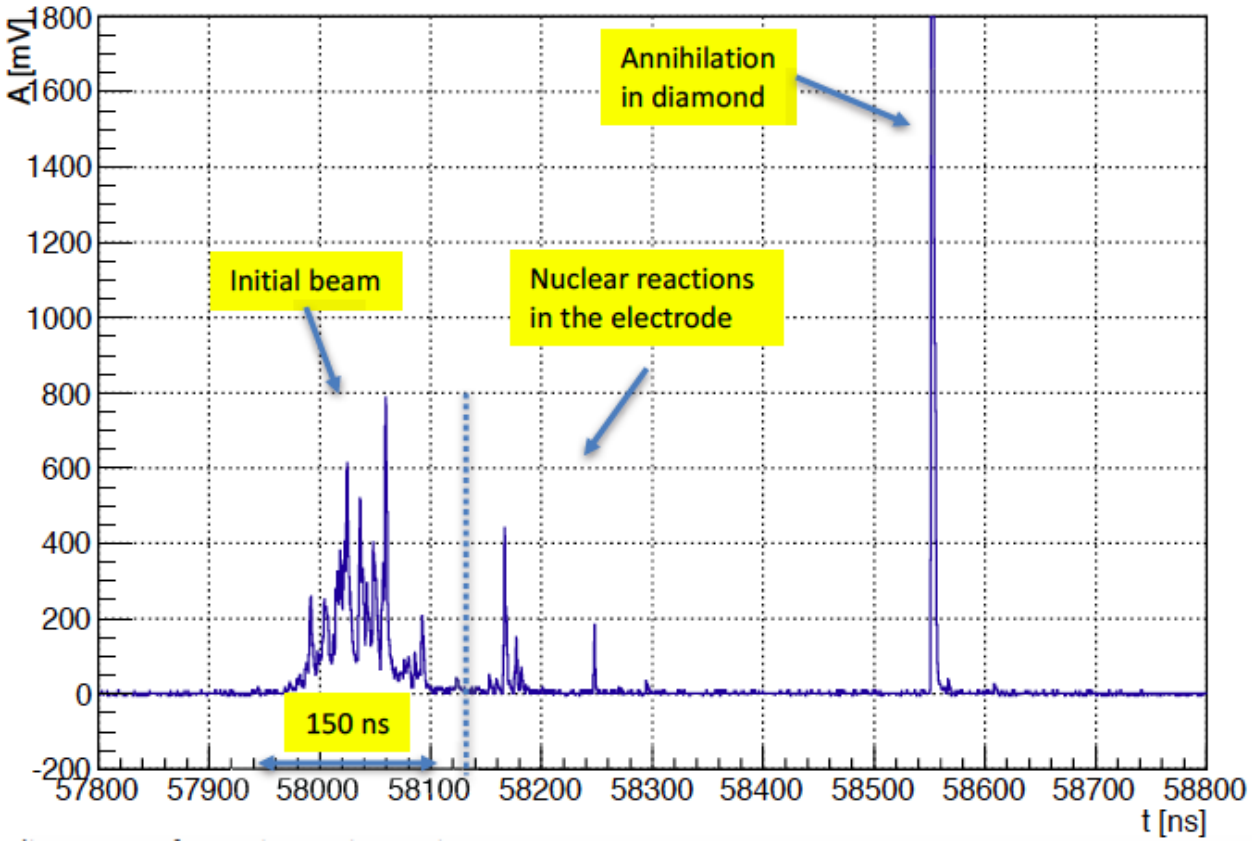
- Knopf detector
- C2 current amplifier
- ROSY readout system

Knopf detector

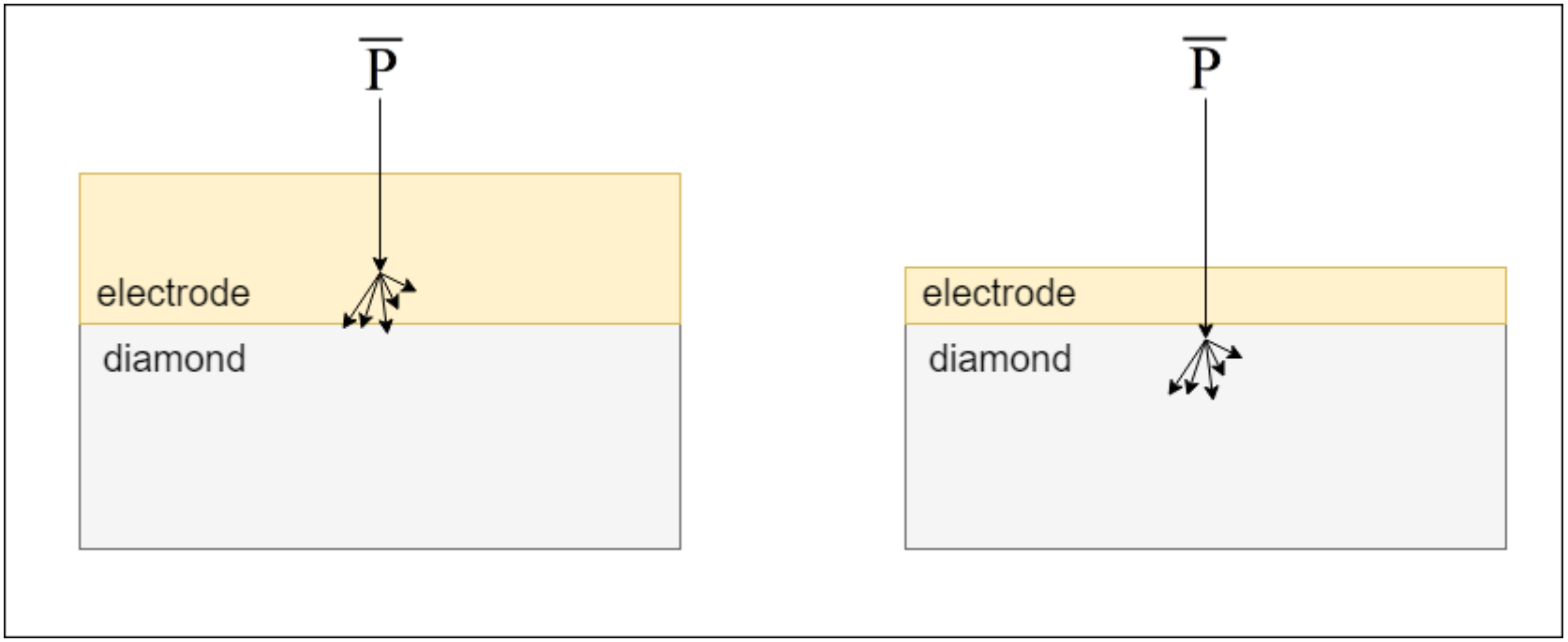
- sCVD diamond
- 500 µm thickness
- 4mm * 4mm sensor area
- Fits directly onto the SMA connector



Measured waveforms

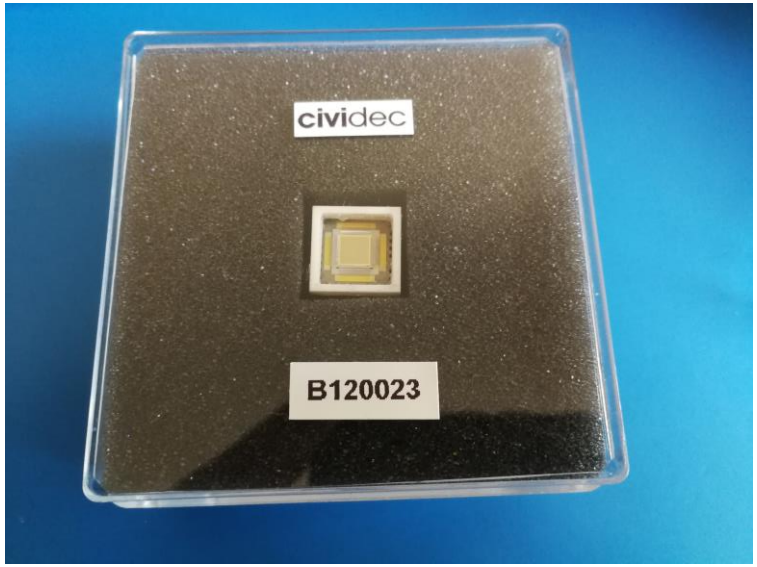


Annihilation



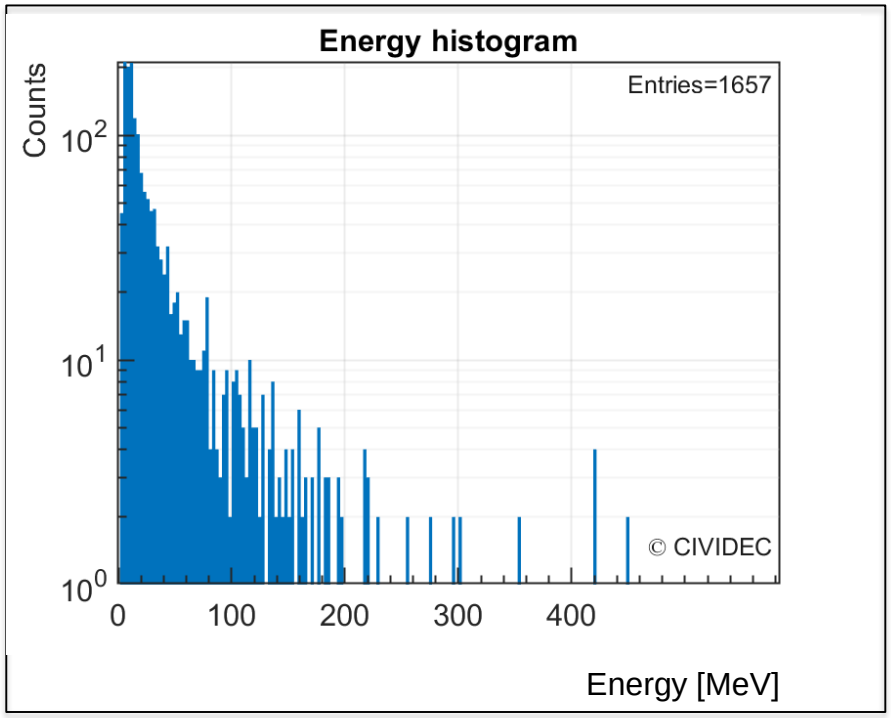
Second measurement

- Repeat measurements with thinner electrode
- Expected more annihilation in the sensor

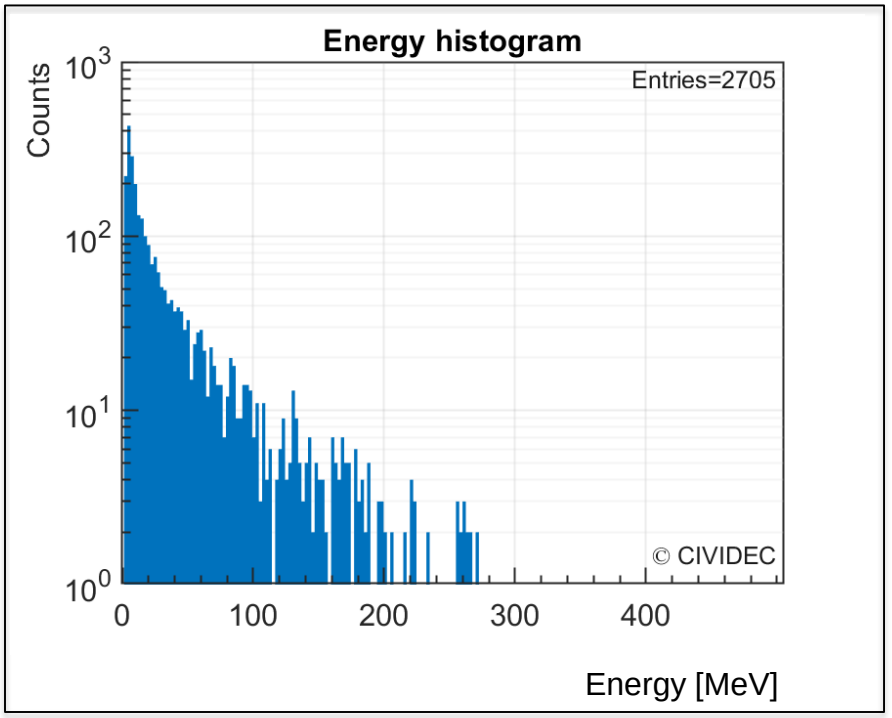


Thin electrode Knopf detector

Energy histogram

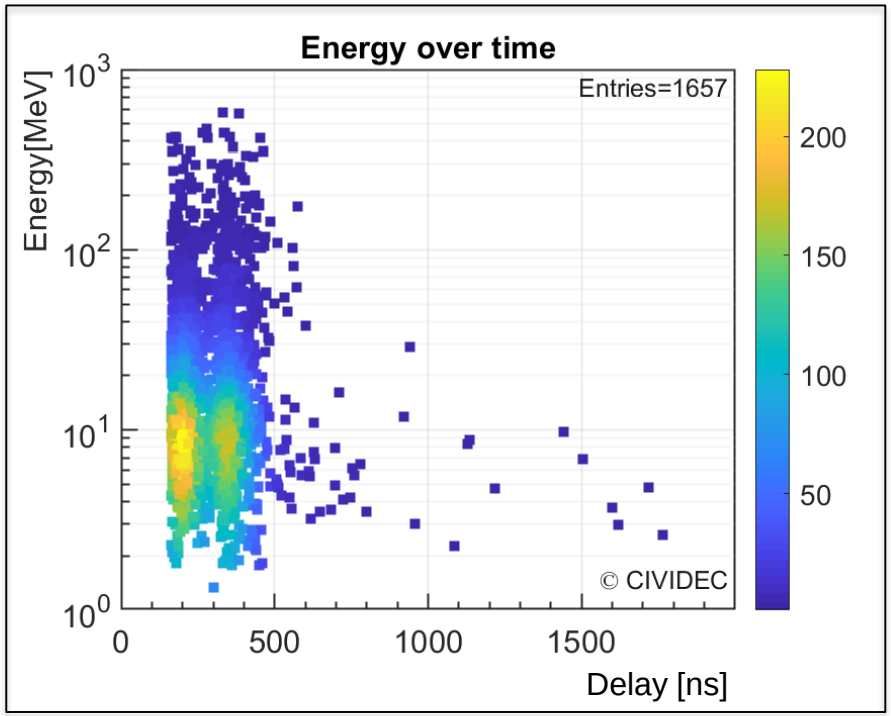


Measurements from 2017

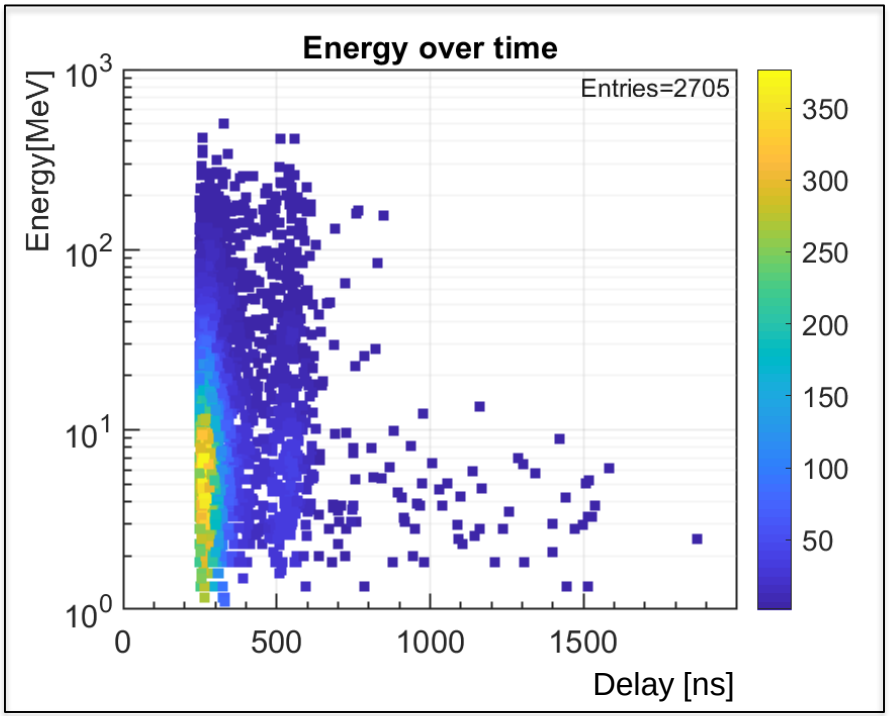


Measurements from 2018

Energy over time plots

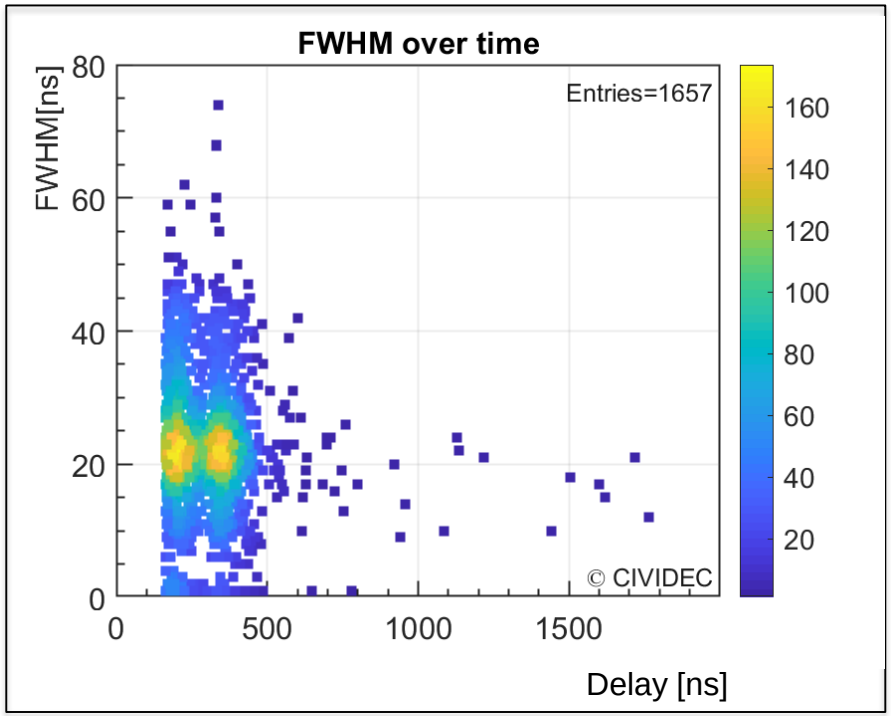


Measurements from 2017

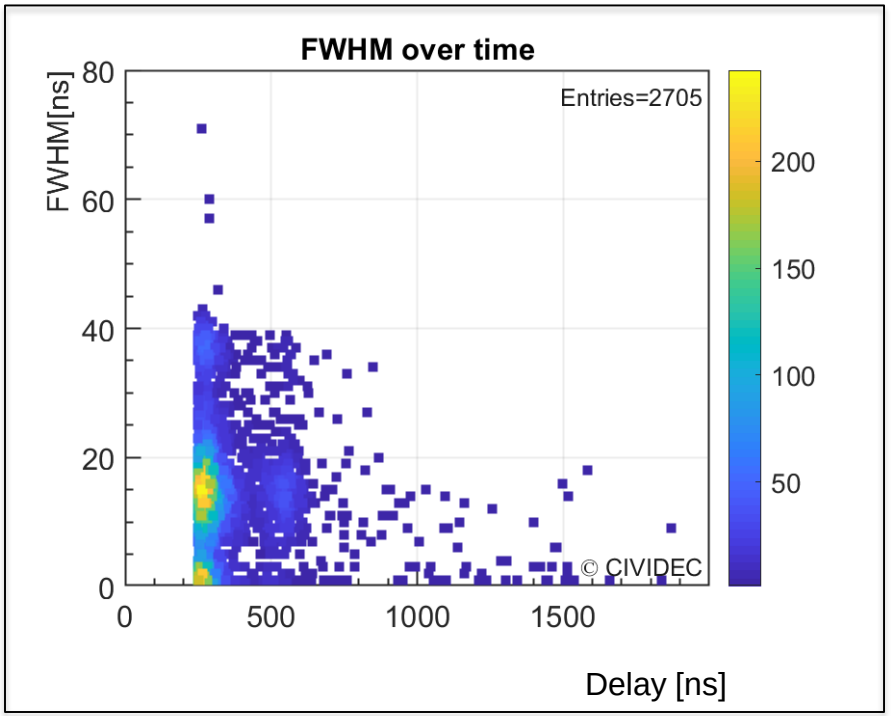


Measurements from 2018

FWHM over time plots



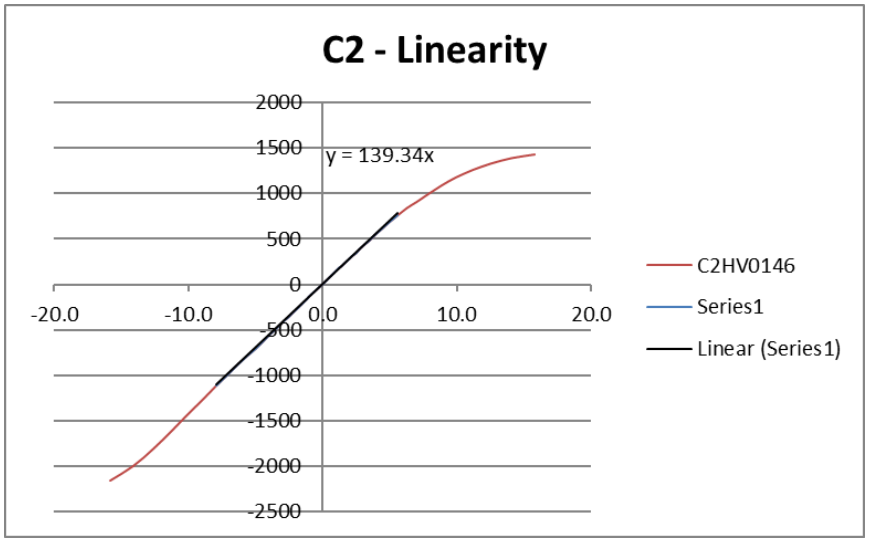
Measurements from 2017



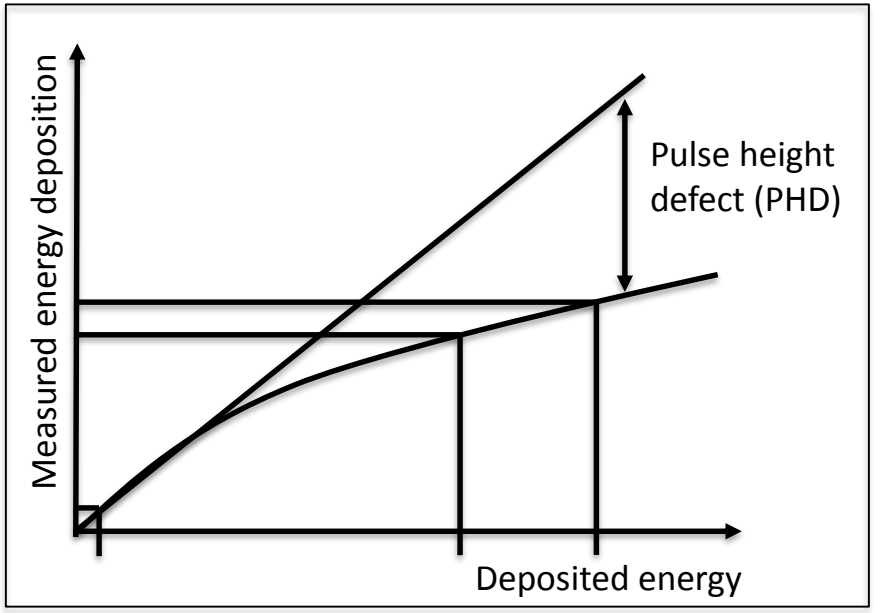
Measurements from 2018

Nonlinearities

- Amplifier nonlinearity
- Pulse height defect



C2 amplifier nonlinearity



Pulse height defect

Thin diamond detectors

- Maximum thickness 500 um
- Standard sizes 140 um and 50 um
- Experiments with 20 um diamonds
  - Limit for producibility
  - Extremely fragile

Effects of thinning detectors

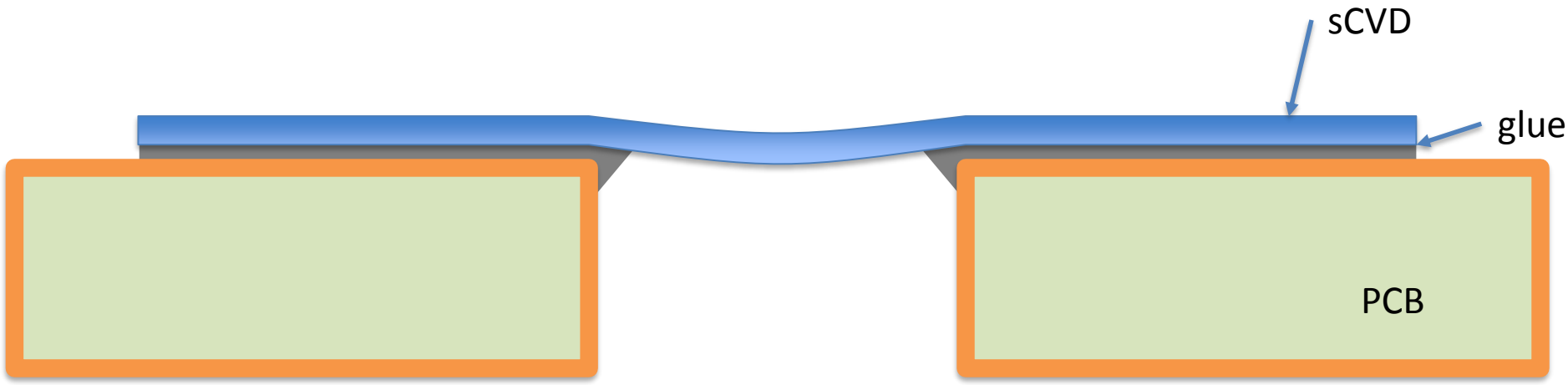
- Higher output signal

$$I = \frac{q * v}{d}$$

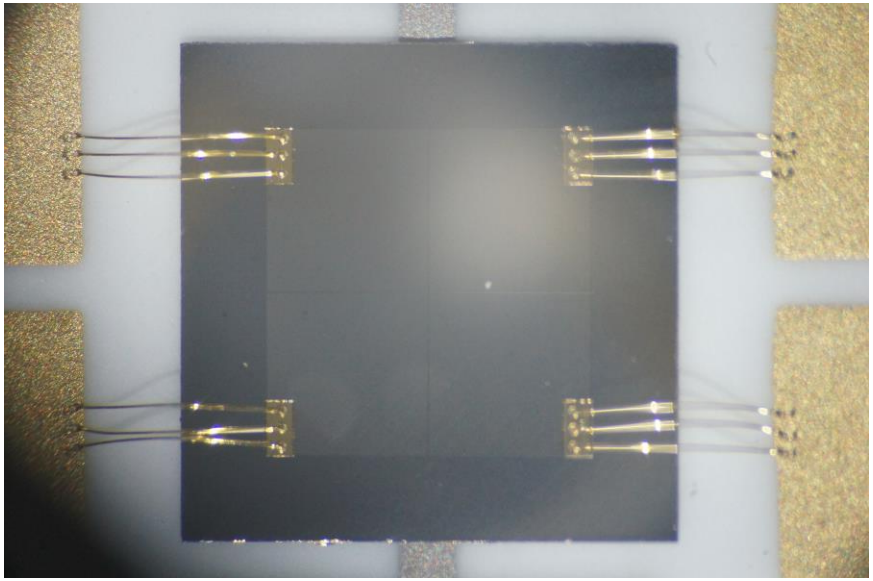
- Higher capacitance

$$C = \varepsilon_r \varepsilon_0 * \frac{A}{d}$$

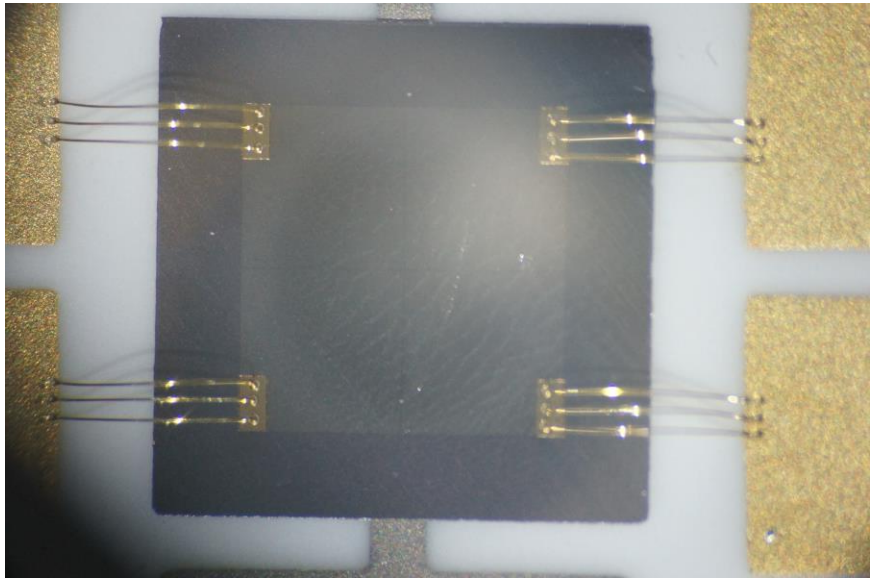
Crystal bending



50 µm and 20 µm crystal comparison

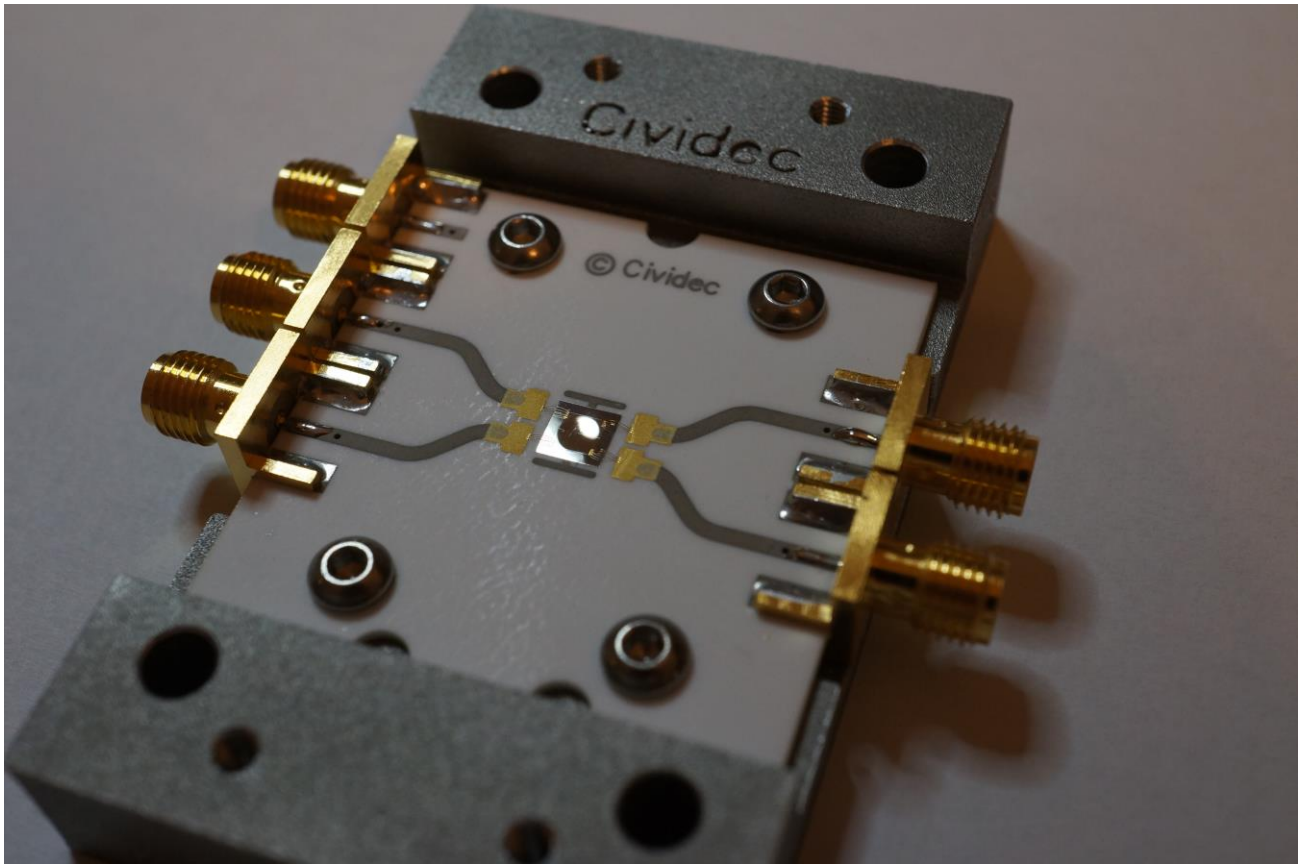


50 µm crystal



20 µm crystal

Bent crystal



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