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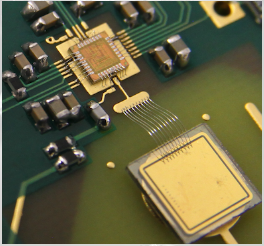

Signal Behaviour of pCVD Diamond Pad Detectors Depending on Incident Particle Flux

ADAMAS Workshop

Michael Reichmann

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Motivation

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- innermost layers $\rightarrow$ highest radiation damage
- current detector is designed to survive $\sim$12 month in High-Luminosity LHC
- completely new regime of particle flux $\mathcal{O}\left(\mathrm{GHz/cm^2}\right)$
- $\rightarrow$ **R/D for more radiation tolerant detector designs and/or materials**

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Diamond as Detector Material:

- advantageous properties
  - radiation tolerant
  - isolating material
  - high charge carrier mobility

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- → **R/D for more radiation tolerant detector designs and/or materials**

Diamond as Detector Material:

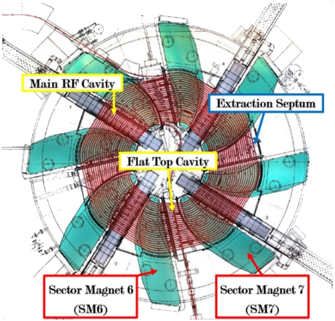
- advantageous properties
  - radiation tolerant
  - isolating material
  - high charge carrier mobility
- investigation of the rate effect in various detector designs:
  - **pad → full diamond as single cell readout of the whole signal → shown here**
  - pixel → diamond sensors on state-of-the-art pixel chips
  - 3D → pixel detector with clever design to reduce drift distance

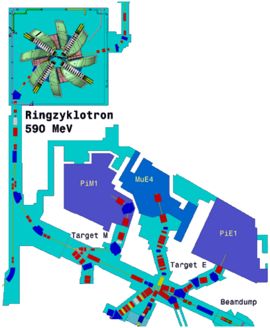
Section 2

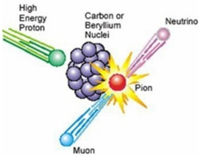
Test Site & Setup

Test Site

- High Intensity Proton Accelerator (HIPA) at PSI
- beam line PiM1
- positive pions (π^+) with momentum of 260 MeV/c
- tunable particle fluxes from $\mathcal{O}\left(1\,\mathrm{kHz/cm^2}\right)$ to $\mathcal{O}\left(10\,\mathrm{MHz/cm^2}\right)$







Setup

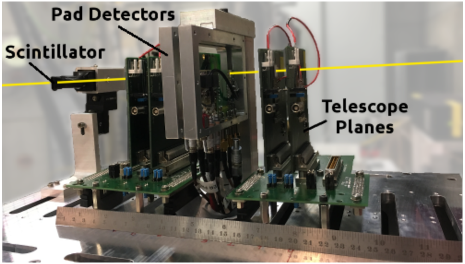
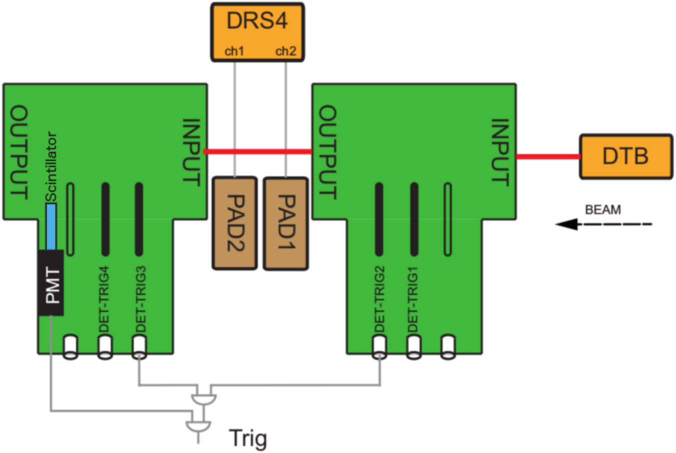


Figure: Modular Beam Telescope

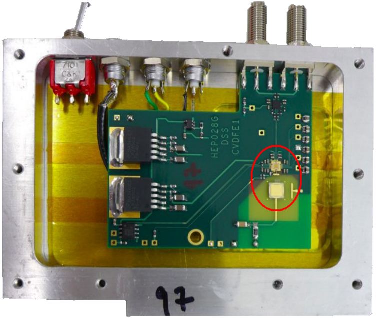
- 4 tracking planes $\rightarrow$ trigger (fast-OR) with adjustable effective area
- diamond pad detectors in between tracking planes
- low time precision of fast-OR trigger
- fast scintillator for precise trigger timing $\rightarrow \mathcal{O}\,(1\,\mathrm{ns})$

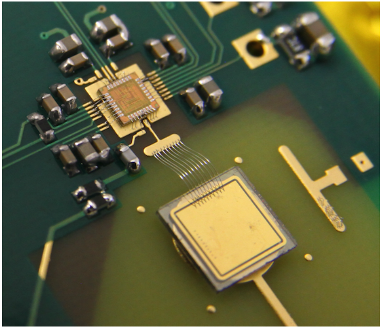
Schematic Setup



- PSI DRS4 Evaluation Board as digitiser for the pad waveforms
- global trigger: coincidence of two telescope planes closest to DUTs and scintillator

Pad Detectors



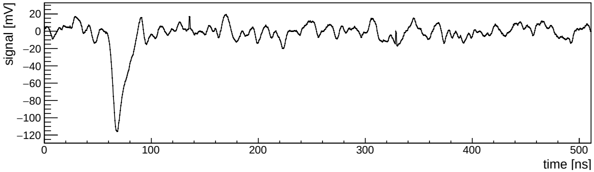


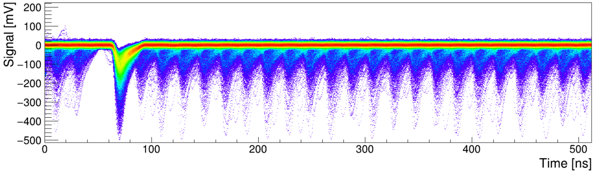
- building the detector: cleaning, photo-lithography and Cr-Au metallisation
- gluing to PCBs in custom built amplifier boxes
- connecting to low gain, fast amplifier with $\mathcal{O}(5\,\mathrm{ns})$ rise time

Section 3

Analysis

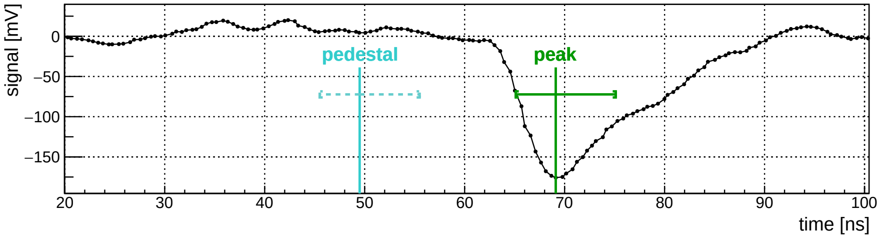
Waveforms





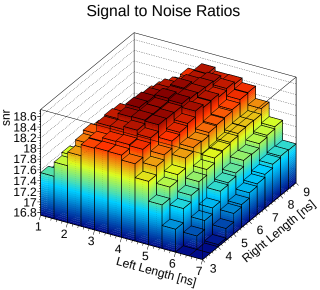
- most frequent peak (∼70 ns): signal from triggered particle
- other peaks originate from particle of other bunches
- resolve bunch spacing of PSI beam: ∼19.8 ns
- signals in in pre-signal bunch forbidden → noise extraction

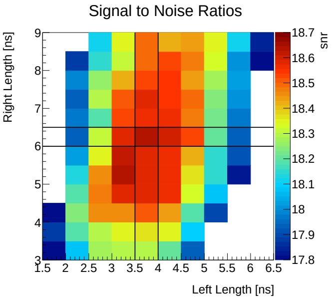
Signal Definition & Calculation



- define signal region: $\sim \pm 10\,\mathrm{ns}$ around peak of the triggered signal $\rightarrow$ [60 ns, 80 ns]
- signal: finding the peak in the signal region and integrate around it [−4 ns, 6 ns]
- pedestal: integrate with same lenght (10 ns) in the centre of the pre-trigger bunch [40 ns, 60 ns]

Signal To Noise Ratio



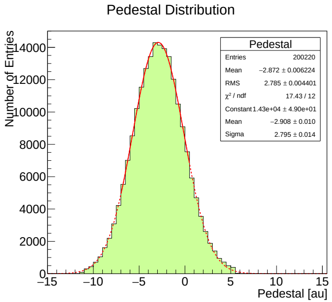


- optimise SNR by scanning the integral width in both directions
- flat plateau around the the FWHM of the waveform peak

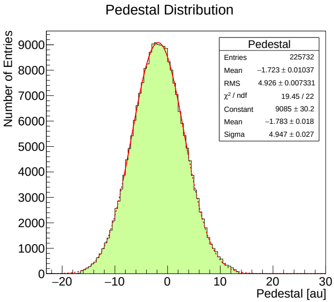
Section 4

Results

Noise Distributions at $\sim$10 MHz/cm^2



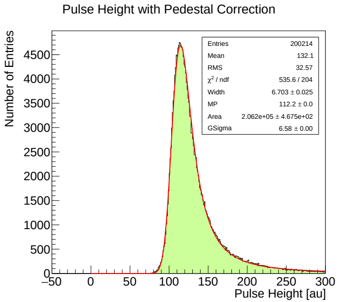
(a) scCVD with 6 dB attenuation



(b) pCVD

- noise distribution agrees well with Gaussian even at high rates
- extract noise by taking the sigma of the Gaussian fit
- noise similar for scCVD and pCVD diamond

Signal Distributions at ∼10 MHz/cm^2



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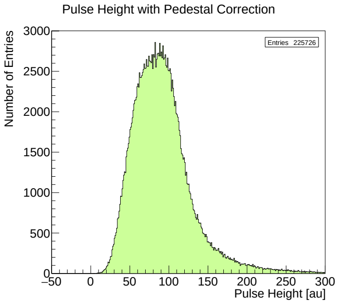
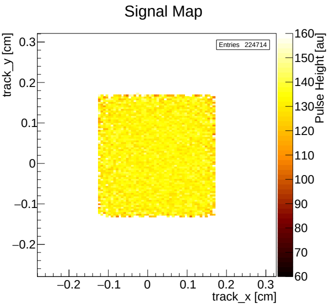


(b) pCVD

- signal gets corrected by the mean of the noise (baseline offset)
- pCVD signal smaller and smeared by different regions in the diamond

Signal Maps



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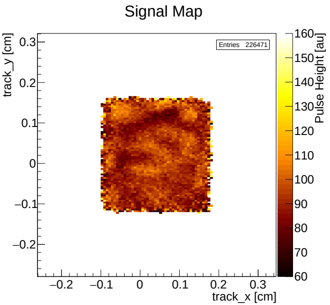
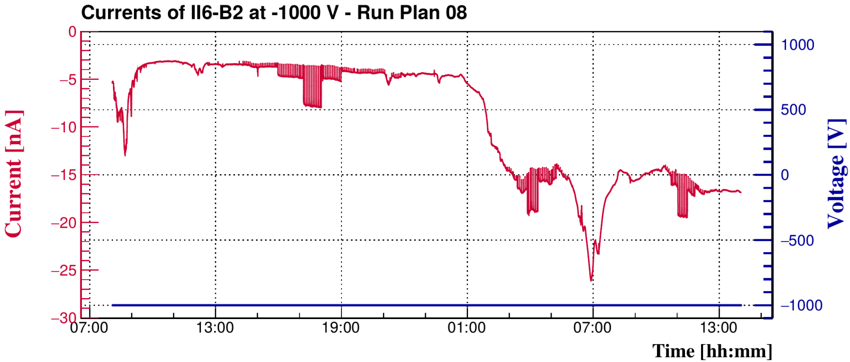


(b) pCVD

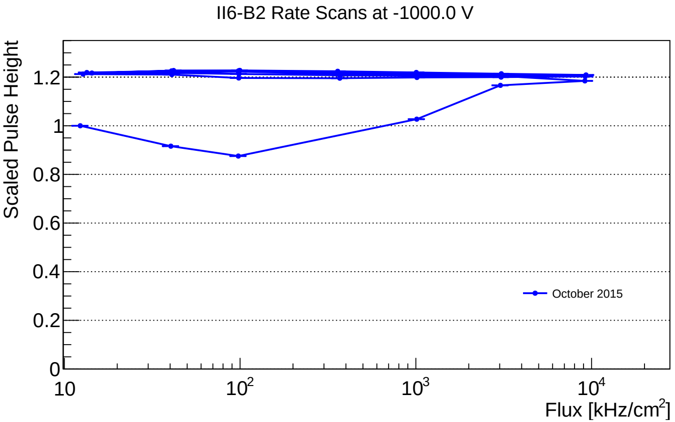
- flat signal distribution in scCVD
- signal response depending on region in the pCVD

Currents



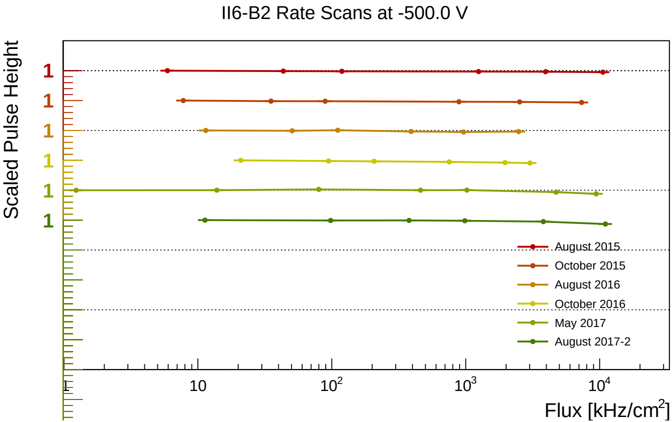
- typical rate scans for ∼30 h with rates up to ∼20 MHz/cm^2
- beam induced current clearly visible
- low leakage currents (<30 nA) at a bias voltage of −1000 V (2 V/μm)

Rate Studies



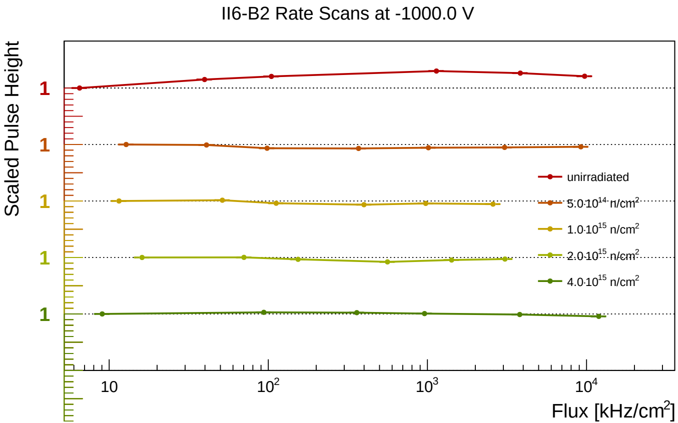
- systematically checking several up and down scans
- also random scans to rule out systematic effects

Rate Studies in Non-Irradiated scCVD



- scCVD as reference in all beam tests
- all scans scaled to 1 and shifted for display
- scCVD diamond shows now rate dependence within the measurement precision

Rate Studies in Irradiated pCVD



- all scans scaled to 1 and shifted for display
- pulse height very stable after irradiation
- noise stays the same of: $\sigma \approx 4.9\,\mathrm{au}$

Section 5

Conclusion

Conclusion

- built beam test setup to characterise the rate behaviour of diamond pad detectors
- pCVD diamond show different signal response depending on the position in the diamond
- nonirradiated scCVD show no rate dependence
- detectors with irradiated pCVD diamond sensors can be built which have a rate dependence below 2 % up to a flux of 20 MHz/cm^2

Acknowledgements

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