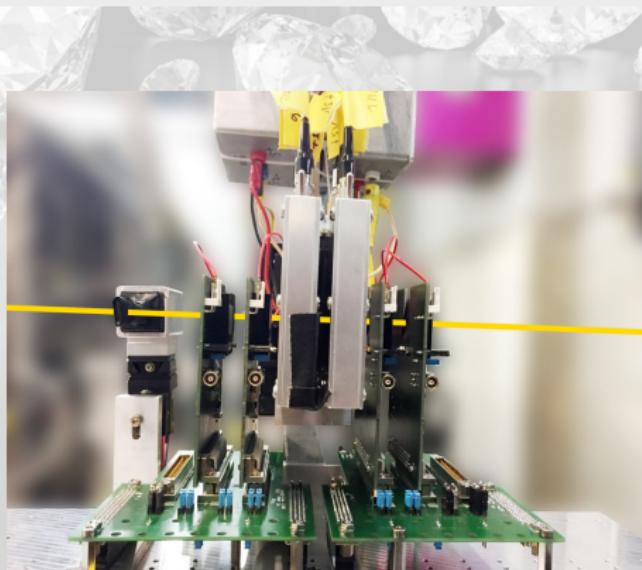


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Beam Tests Investigating Diamond as Detector Material

Michael Reichmann



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Section 1

Motivation

Motivation

- diamond as possible future material for the tracking detectors of the LHC
- innermost layers → highest radiation damage
- current detector designed to withstand 250 fb^{-1} of integrated luminosity
 - ▶ High-Luminosity LHC: replace detector every 12 month
- → **look for more radiation hard detector designs and/or materials**

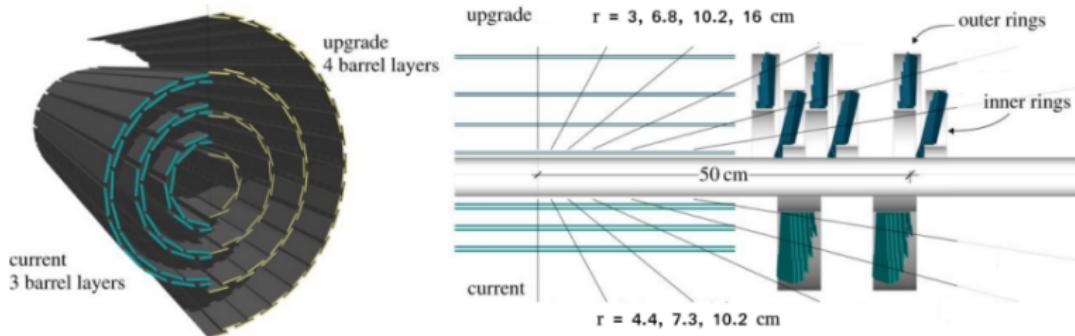


Figure: CMS Barrel Pixel Detector upgrade with end caps

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Section 2

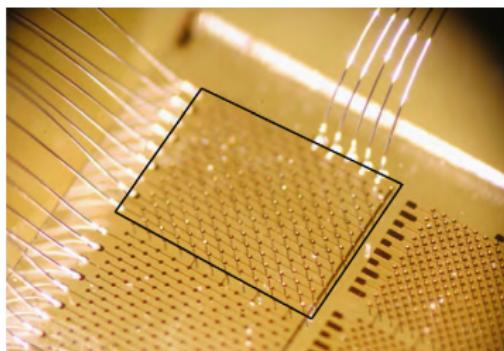
Diamond Detectors and Materials



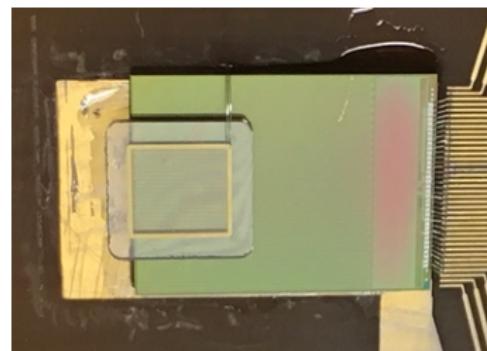
Detector designs

Detector designs

- Investigation of two different detector designs
 - ▶ **planar diamonds**
 - ★ exchange of material
 - ▶ **3D diamonds**
 - ★ new type of detector



(a) prototype



(b) on CMS-Pixel chip

Figure: 3D diamond detectors



Diamond as detector material

Diamond as detector material

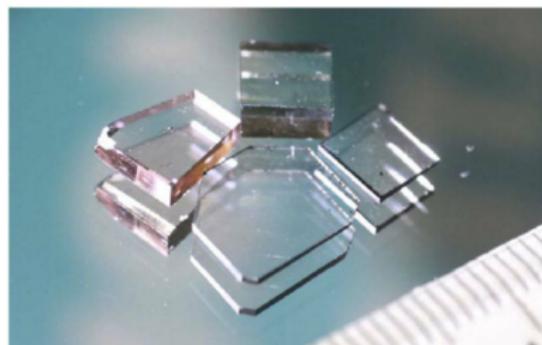
- 7 – 10 times smaller charge loss due to radiation damage than in silicon
- signals (electrons created by a charged particle) half the size of silicon
- → diamond becoming superior than silicon at a certain irradiation
- other advantageous properties:
 - ▶ isolating material → negligible leakage current → power saving
 - ▶ high thermal conductivity → heat spreader for electronics
 - ▶ large band gap → no cooling required
 - ▶ high charge carrier mobility → fast signals
 - ▶ working principle like a solid state ionisation chamber → no pn-junction required
- disadvantages:
 - ▶ high price
 - ▶ some not fully understood behaviours



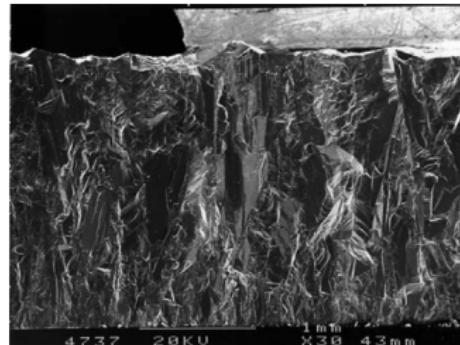
Artificial diamond types

Artificial diamond types

- diamonds in use artificially grown in chemical vapor deposition (CVD) process
- investigation of two different diamond types:



(a) single crystal CVD



(b) poly crystal CVD

- grown on existing diamond crystal
- only small sizes ($\sim 0.25 \text{ cm}^2$)
- larger signals than pCVD (5 : 3)

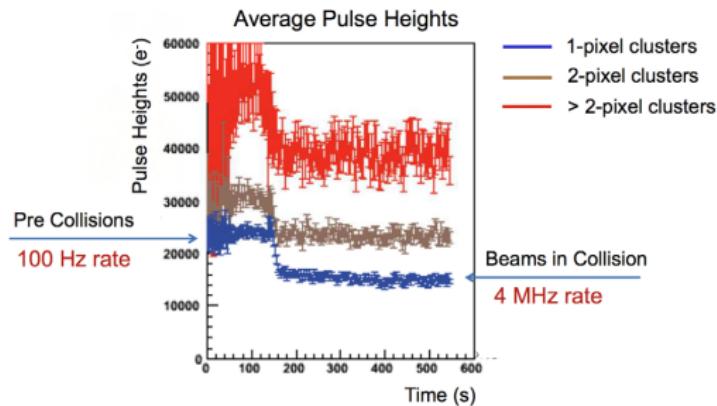
- grown on Si substrate with diamond powder
- large wafers (5 cm to 6 cm \varnothing)
- non-uniformities and grains



Artificial diamond types

Diamonds in CMS

- scCVD diamond pixel detector used in Pixel Luminosity Telescope (PLT)
 - ▶ goal: stand-alone luminosity monitor for CMS
- observation of a signal dependence on incident particle rate:



Consequences:

- investigation of the rate effect in scCVD diamonds
- using pCVD diamond and prove that they show no rate dependence

Section 3

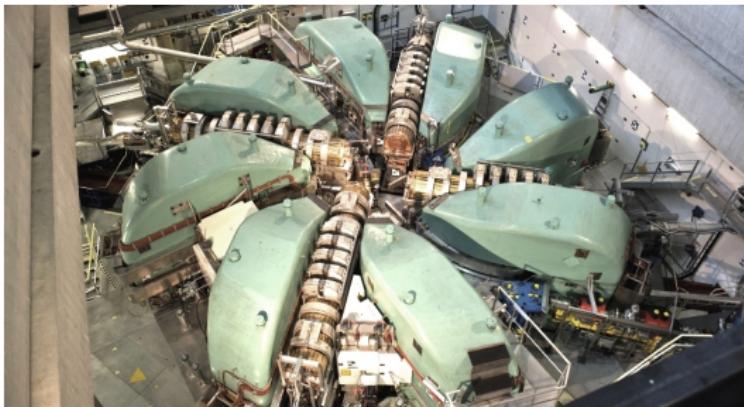
Rate Studies at PSI



General information

Beam line at Paul Scherrer Institute (PSI)

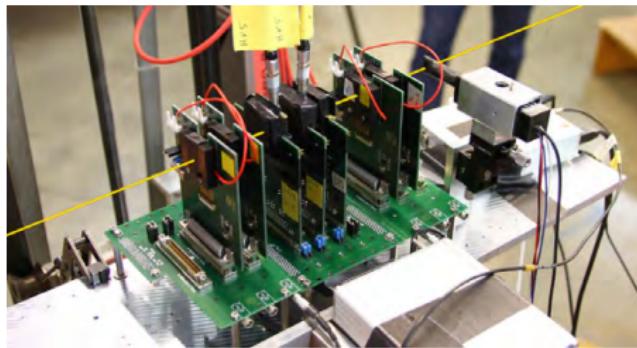
- High Intensity Proton Accelerator (HIPA) at PSI (Cyclotron)
- 590 MeV proton beam with beam current up to 2.4 mA
 - ▶ $\sim 1.4 \text{ MW} \rightarrow$ most powerful proton accelerator in the world
- using beam line $\pi M1$ with 260 MeV positive pions (π^+)
- tunable rate from 2 kHz to 10 MHz



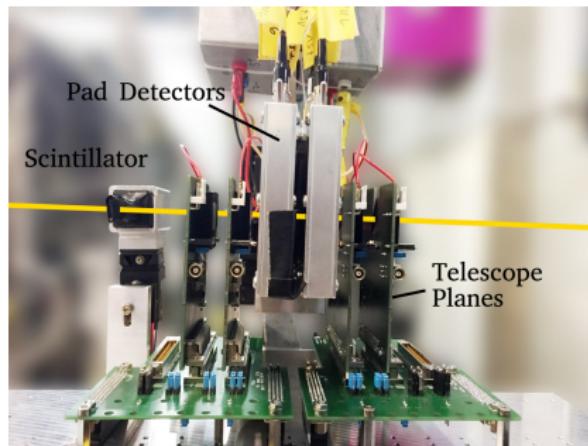
General information

Measurements

- performing several beam tests starting in 2013
- using a modular self-built beam telescope with two possible setups:
 - ▶ pad setup (testing whole diamonds as single pad detector)
 - ▶ pixel setup (testing diamond sensors implanted on CMS-Pixel Chips)
- investigating several materials and devices
 - ▶ scCVD pad detectors (reproduce rate effect)
 - ▶ pCVD pad and pixel detectors
 - ▶ very first 3D pixel detector
- studying non-irradiated and irradiated devices (up to 1×10^{16} neq/cm²)

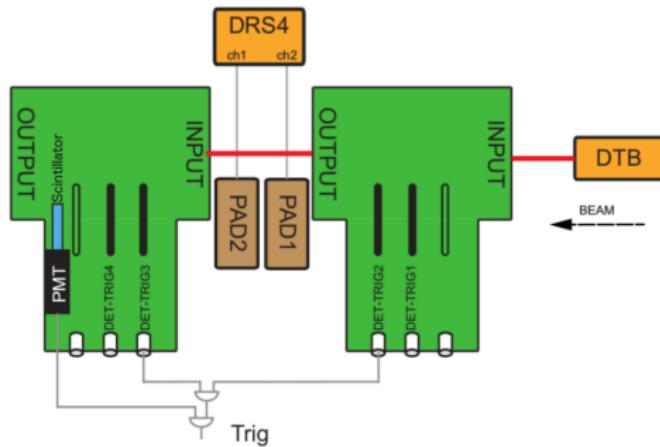


Setup



- 4 tracking planes with analogue CMS pixel chips
- 2 diamond pad detectors
- scintillator for precise trigger timing: sigma of 1.3(1) ns
- resolution: $\sim 80 \mu\text{m} \times 50 \mu\text{m}$

Schematics

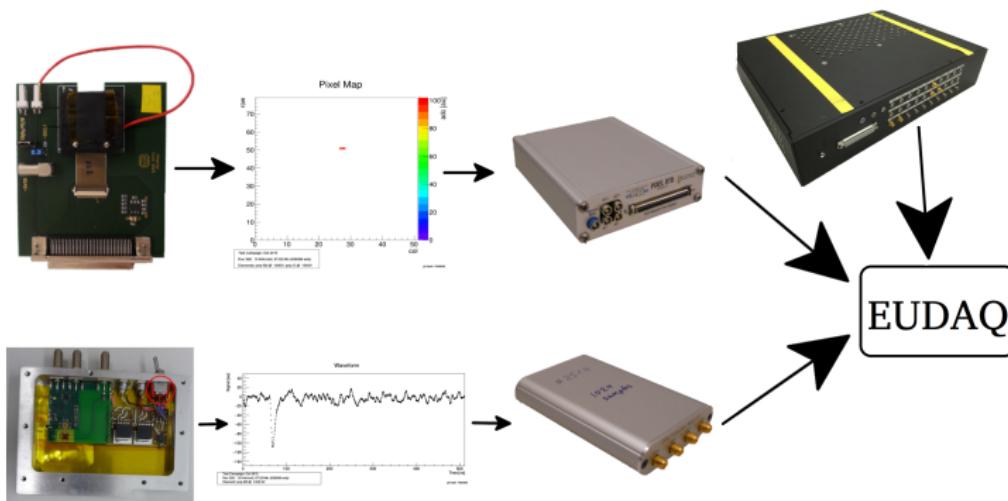


- using PSI DRS4 Evaluation Board as digitizer for the pad waveforms
- using Digital Test Board (DTB) and pXar software for the telescope readout
- global trigger as coincidence of fastOR self trigger and scintillator signal
- EUDAQ as DAQ framework



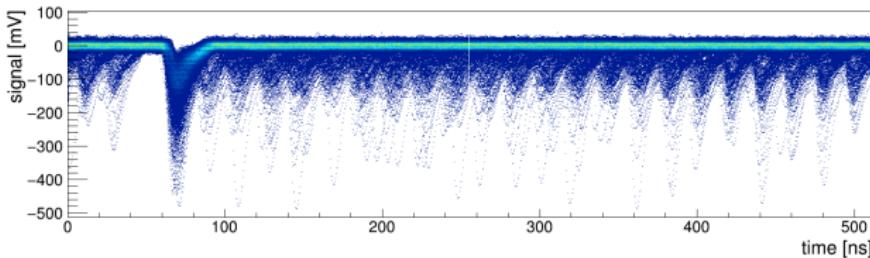
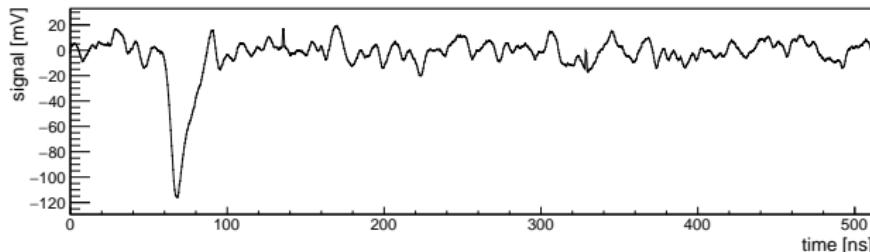
Setup

DAQ



- Trigger Unit to process the single triggers and provide global one for all devices
- saving event based data stream as binary file using EUDAQ

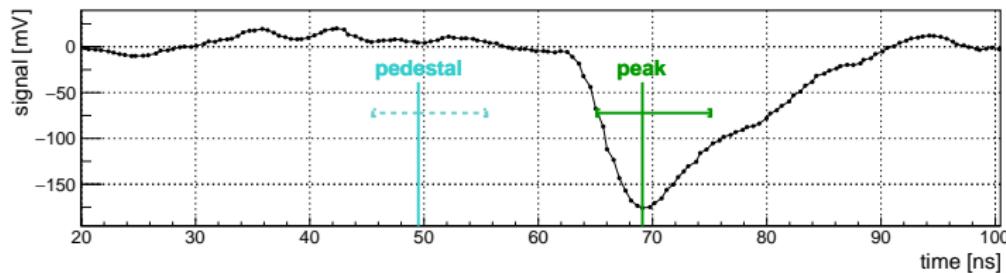
Waveforms



- most frequent peak (~ 70 ns): triggered signal
- other peaks originate from other buckets (\rightarrow resolve beam structure of ≈ 19.7 ns)
- system does not allow signals in pre-signal bucket due to fastOR trigger deadtime

Analysis and Results

Pulse Height Calculation



- finding the peak in the signal region
- integrating the signal in time fixed asymmetric integral around peak
- same integration for pedestal (base line → noise)
- optimising the integral width by highest SNR (Integral / Pedestal Sigma)
- subtracting the pedestal from the signal integral on event-wise basis

Section 4

3D Detectors at CERN

Motivation

Diamond Detectors and Materials

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Rate Studies at PSI

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3D Detectors at CERN

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Conclusion

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Section 5

Conclusion

Motivation

Diamond Detectors and Materials

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Rate Studies at PSI

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3D Detectors at CERN

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Conclusion

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