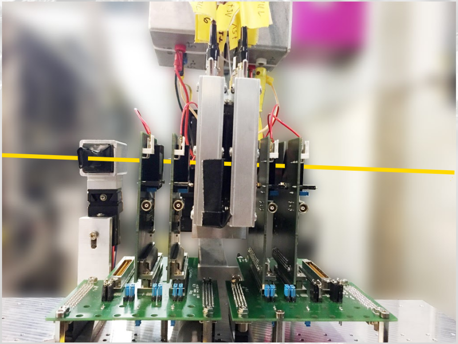

Beam Tests Investigating Diamond as Detector Material

Michael Reichmann

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Section 1

Motivation

Motivation

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

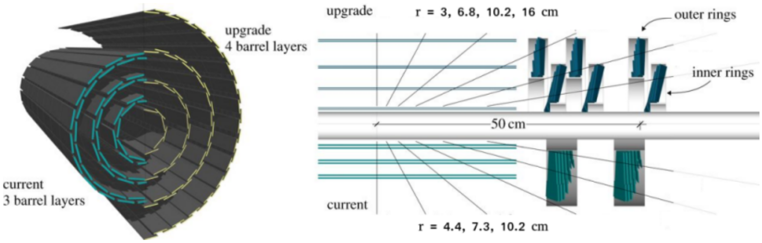


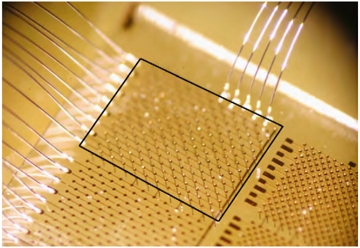
Figure: CMS Barrel Pixel Detector upgrade with end caps

Section 2

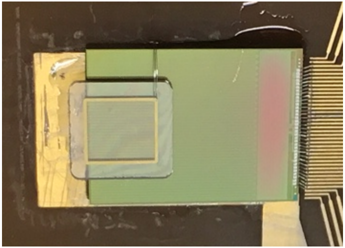
Diamond Detectors and Materials

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

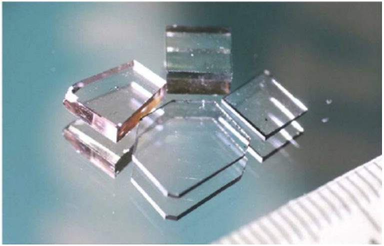
Figure: 3D diamond detectors

Diamond as detector material

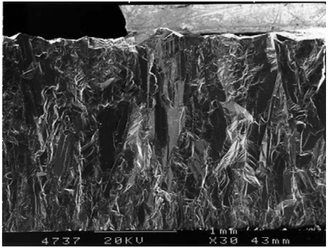
- $7-10$ times smaller charge loss due to radiation damage than in silicon
- signals (electrons created by a charged particle) half the size of silicon
- $\rightarrow$ diamond becoming superior than silicon at a certain irradiation
- other advantageous properties:
  - isolating material $\rightarrow$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

Artificial diamond types

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



(a) single crystal CVD



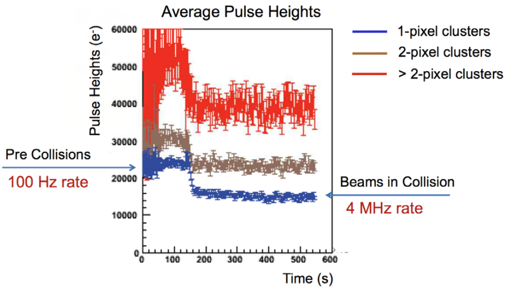
(b) poly crystal CVD

- grown on existing diamond crystal
- only small sizes ($\sim$0.25 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

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:

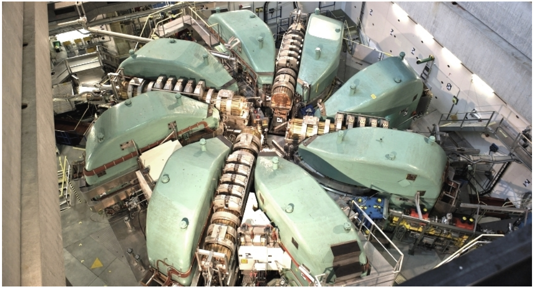
- investigation of the rate effect in scCVD diamonds
- using pCVD diamond and prove that they show no rate dependence

Section 3

Rate Studies at PSI

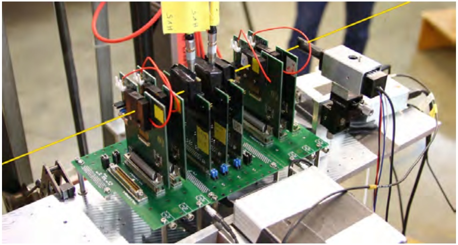
Beam line at Paul Scherrer Institute (PSI)

- High Intensity Proton Accelerator (HIPA) at PSI (Cyclotron)
- 590 MeV proton beam with beam current up to 2.4 mA
  - $\sim$1.4 MW $\rightarrow$ most powerful proton accelerator in the world
- using beam line πM1 with 260 MeV positive pions (π^+)
- tunable rate from 2 kHz to 10 MHz

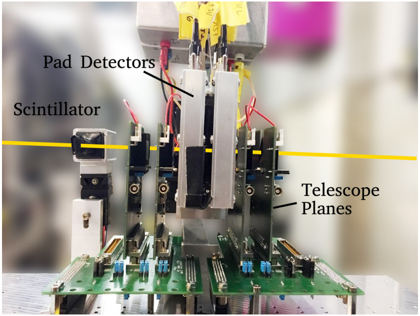


Overview

- performing several beam tests starting in 2013
- utilising 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/cm^2)

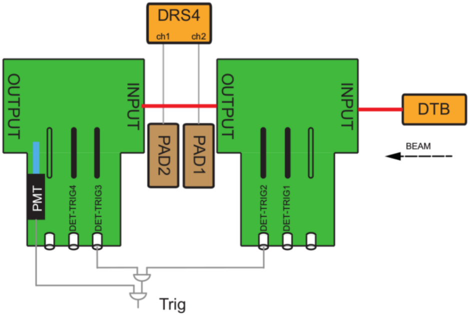


Setup



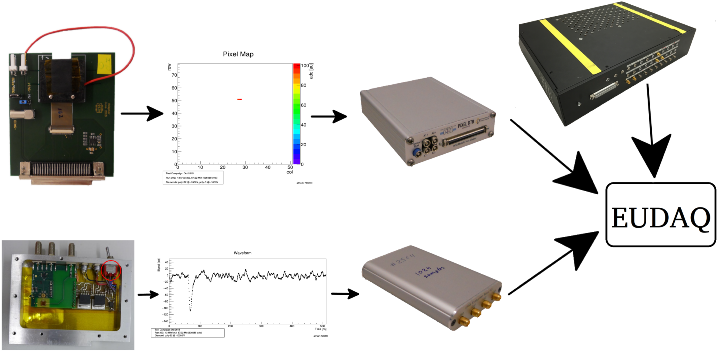
- 4 tracking planes with analogue CMS pixel chips
- 2 diamond pad detectors
- scintillator for precise trigger timing: sigma of 1.3(1) ns
- resolution: ~80 μm × 50 μm

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

DAQ



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

Section 4

3D Detectors at CERN

Bla

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Section 5

Edge TCT

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Section 6

Conclusion

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