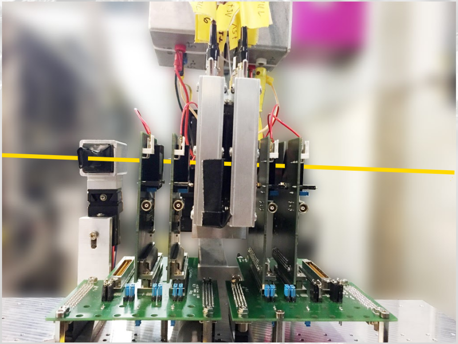


# Beam Tests Investigating Diamond as Detector Material

Michael Reichmann

# Table of contents I

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 $\mathrm{fb}^{-1}$ of integrated luminosity
  - High-Luminosity LHC: replace detector every 12 month
- **→ look for more radiation hard detector designs and/or materials**

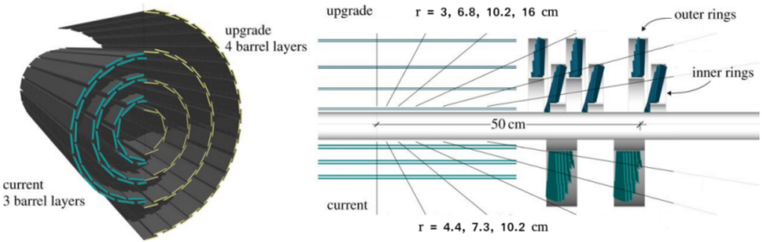


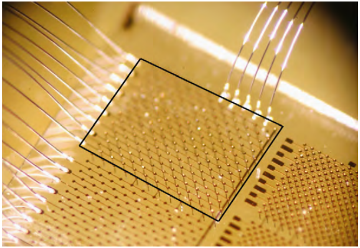

Figure: CMS Barrel Pixel Detector upgrade with end caps

Section 2

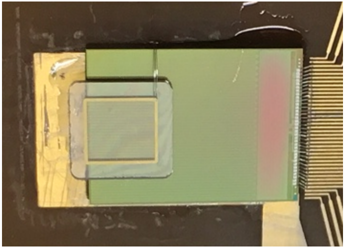
# Diamond Detectors and Materials

# 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

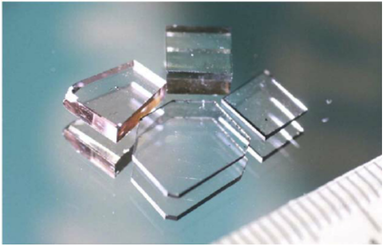
Figure: 3D diamond detectors

# Diamond as detector material

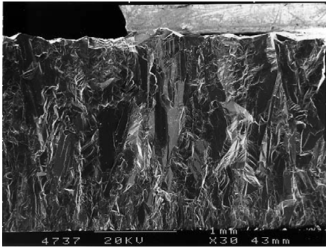
- 7 – 10 times smaller charge loss due to radiation damage then in silicon
- signals (electrons created by a charged particle) two times smaller than in silicon
- → diamond becoming superior than silicon at a certain irradiation
- other advantageous properties:
  - isolating material → negligible leakage 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

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



(a) single crystal CVD



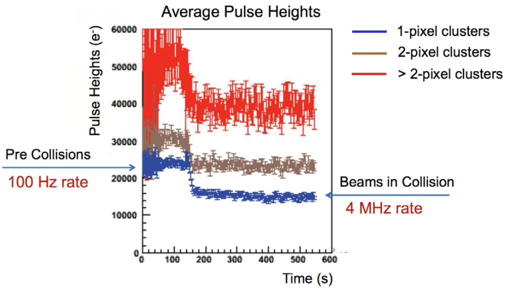

(b) poly crystal CVD

- 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)
- 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:**

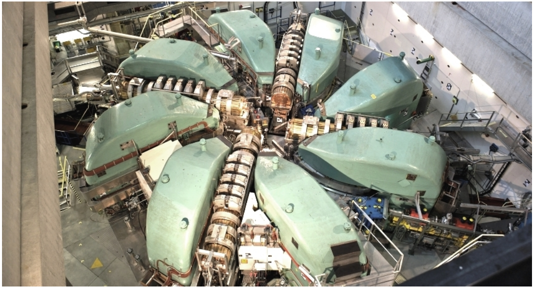
- investigation of the rate effect in scCVD diamonds
- using pCVD diamonds and proof that they show no rate dependence

Section 3

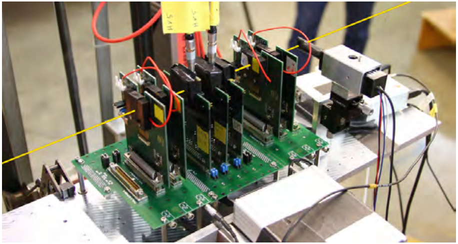
# Rate Studies at PSI

# 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
  - ~1.4 MW → most powerful proton accelerator in the world
- using beam line $\pi$M1 with 260 MeV positive pions ($\pi^+$)
- tunable rate from 2 kHz to 10 MHz



- performing several beam tests starting in 2013
- utilising a modular self-built beam telescope with two optional 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 $1 \times 10^{16}$ neq/cm$^2$)



Section 4

# 3D Detectors at CERN

nada

Section 5

# Edge TCT

nada

Section 6

# Conclusion

## Bla

nada