Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

Research Plan

for the Dissertation of Michael Reichmann
born on 15$^{\text{th}}$ December 1988

submitted in May 2018

High Rate and High Resolution Studies of Planar and 3D Poly-Crystalline Diamond Detectors

version 1.2

The Collaboration

The RD42 Collaboration at CERN investigates Chemical Vapour Deposition (CVD) diamond as a future material for high energy particle detectors and is leading an effort to develop a tracking detector that can be operated in the extremely high radiation environment of the LHC's (and the HL-LHC's) innermost layers close to the beam pipe. Its advantageous properties make diamond a suitable material for such detector applications.

The collaboration is investigating the bulk and surface properties of this interesting material and develops own procedures on preparing the diamonds for different detectors geometries and designs which are namely pad, pixel and 3D detectors to address specific issues related to their use at the LHC. Theses prototypes are then qualified using various different testing methods including long time current and irradiation studies as well as the investigation of their signal behaviour depending on incident particle flux and high resolution studies of the detector structure.

During the last few years the RD42 group has already shown that diamonds are radiation tolerant up to a fluence of 2×10^{16} hadrons/cm^2 and thus can operate for several years in the environment of the HL-LHC. They also do not show evidence of any damage due to electrons and photons up to 100 Mrad.

Research Topics

Within the RD42 Collaboration Mr. Reichmann is investigating the behaviour the signal response of planar and 3D poly-crystalline CVD (pCVD) diamond detectors in pad or pixel geometries depending on incident particle flux. He is also characterising the composition of 3D detectors and the internal structure of the pCVD diamond material with a high resolution beam telescope.

The high rate tests are performed at Paul Scherrer Institut (PSI) using the beam line piM1 with a positive 260 MeV/c pion beam and tunable particle fluxes from 1 kHz/cm^2 up to 20 MHz/cm^2 whereas the high resolution test are performed at CERN using the SPS beam line H6 with pions or protons up to momenta of 200 GeV/c.

Mr. Reichmann is in charge of organising and conducting the RD42 high rate beam tests at PSI. This includes the maintenance and further development of the ETH beam telescope and the overall set-up at PSI, qualifying the data-taking and improving as well as adapting the data acquisition (DAQ) framework EUDAQ.

In order to proof that pCVD diamond material is suited as a particle detector at high rates, the most simple detector geometry - a pad detector - is investigated. The detectors which are built at Ohio State University (OSU) by metallising them with a thin layers on both sides, are measured at various fixed rates recording their signals as digital information. These waveforms are then analysed to get conclusions about their behaviour at the tested rates.

Since the current technology at the innermost tracking layers of the LHC is based on planer pixel detectors also pCVD diamond sensors read out with state of the art pixel detectors are investigated. The readout chips (ROCs) digitise the signals above a tunable threshold already on chip using an analogue to digital converter (ADC). Therefore also the effects of threshold as well as the more complex electric field in the pixel geometry are analysed.

3D detectors are a very promising radiation tolerant detector concept. Within RD42 these detectors are built in collaboration with the Universities of Manchester, Oxford and

Ohio utilising a femtosecond laser. Mr. Reichmann is testing the general working principal as well as the rate behaviour of these detectors in both pad-like and pixel geometry.

The pCVD diamond is a material consisting of many single crystalline cells along the direction of growth which vary in size and shape. This fact also plays an important role for the detectors, especially 3D. Therefore the current ETH telescope is upgraded in order to measure both the inner structure of the material as well as the structure of the various detector geometries and designs with a high spatial resolution.

Time Frame

Mr. Reichmann started his work as a doctoral student in February 2016.

2016:

- planning improvements for the ETH pixel telescope
- setting up the framework for the pad analysis
  - modifying EUDAQ to convert beam test data
  - setting up tracking and alignment software
  - writing waveform analysis code
- performing beam tests at PSI
  - general investigation of pad, pixel and 3D detectors
  - rate studies of the diamond detectors at different irradiations
- assisting with 3D beam tests at CERN

2017:

- finishing pcb-drawings and start production of the telescope's new version
- further developing and improving pad analysis
- including pixel and 3D analysis into the framework
- conducting further beam tests at PSI and CERN
  - measuring detectors at higher irradiations
  - investigation of the reproducibility of the data
- start planning and construction of the high resolution telescope

2018:

- testing the telescope's improved version
- testing and installing of the high resolution telescope
- conducting further beam tests at PSI and CERN

  - performing high resolution studies

- finishing analysis of all the data
- writing pad, pixel, telescope papers

Results & Progress

Mr. Reichmann is working according to his schedule. He has finished the pad analysis which extracts the signal size information from the waveforms after applying a set of cuts. This software is also used during the beam tests to evaluate the quality of the data. He is working towards a paper summarising the results which claim that pCVD diamond detectors show less than 2 % dependence of the signal on incident particle flux up to 10 MHz/cm^2.

There is also good progress in both pixel and 3D analysis. So far an efficiency above 99 % compared to a planer silicon device can be claimed for a 3D diamond pixel detector with a pixel pitch of 50 µm × 50 µm.

The upgrade of the telescope works well too and the mounting frame for the high resolution upgrade is about to be finished.

Employment

Mr. Reichmann is employed as a scientific assistant at a level of 100 %. One quarter of his working time is designated to the function of teaching assistant at ETH Zürich.

Zürich, May 13, 2018

Michael Reichmann

Rainer Wallny

ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

Department of Physics

Research Plan

Doctoral thesis:

High Rate and High Resolution Studies of Planar and 3D Poly-Crystalline Diamond Detectors
Doctoral thesis title (provisional)

02/12/2016
Beginning date of doctoral thesis

Doctoral student:

12-946-414
Student number

Michael Reichmann
Name

remichae@phys.ethz.ch
E-mail

Institution (if external doctoral thesis)

Date, signature

Supervisor:

Prof. Dr. R. S. Wallny
Name, title

Date, signature

Co-examiner (if already known):

Name, title

Affiliation

E-mail

Please hand in this form together with the research plan and the form "Approval of the research plan" to the Doctoral Administration Office of D-PHYS

ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

Genehmigung des Forschungsplans
(Definitive Zulassung zum Doktorat)

Approval of the Research Plan
(Full admission to doctoral studies)

Studierenden-Nummer *student number*	12 - 946 - 414
Name *family name*	Reichmann
Vorname *first name*	Michael
Departement *department*	D - PHYS

Der Forschungsplan wurde eingesehen und angenommen durch:
The research plan has been seen and approved by:

Prof. Dr. R. S. Wallny		
Name Dissertationsleiter/in *Name of supervisor*	Datum *Date*	Unterschrift *Signature*
Name Bevollmächtigter Doktoratsausschuss *Name of representative of doctoral board*	Datum *Date*	Unterschrift *Signature*

Für Kandidaten mit weiteren Zulassungsbedingungen:
Die Zulassungsbedingungen müssen **vor** Genehmigung des Forschungsplans erfüllt sein!

For candidates who have to fulfil further conditions of admission:
These conditions must be fulfilled ***before*** *the research plan can be approved!*

Frist für Einreichung des Forschungsplans

Frühestens nach erfüllen und offiziell verfügtem Bestehen der Zusatzbedingungen, spätestens ein Jahr nach der Einschreibung

Vorgehen zur Genehmigung des Forschungsplans

Lassen Sie dieses Formular und den Forschungsplan von Ihrer Leiterin / Ihrem Leiter unterzeichnen und senden Sie danach beides an das zuständige **Studiensekretariat**. Dieses kümmert sich um die Unterschrift des Bevollmächtigten des Doktoratsausschusses und schickt das Formular anschliessend an die Doktoratsadministration.

Deadline for submission of the research plan

Only after having passed and received official notification of having successfully fulfilled the further conditions of admission, one year after registration at the latest.

Procedure for approval of your research plan

Please ask your supervisor to sign this form and your research plan and send both to the **Study Administration Office of your department**. They will take care of having it signed by the representative of the doctoral board and will forward it to the Doctoral Administration Office afterwards.