ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

IPA

Research Plan

for the Dissertation of Michael Reichmann
born on 15th December 1988

submitted in May 2018

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

version 0.0

The Collaboration

This dissertation is done within the CERN's RD42 Collaboration which investigates diamond as a future material for high energy particle detectors. Aiming to build a fully functional 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 it's beam pipe the RD42 Collaboration is involved in every process leading to that purpose.

Starting from the close relation and constant exchange with the manufactures of artificial diamonds which grow diamonds using a Chemical Vapour Deposition (CVD) process the collaboration is investigating the bulk and surface properties of this interesting material and develops own procedures on preparing the diamonds for different detectors designs which are namely are pad, pixel and 3D detectors. 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.

The collaboration has already shown that diamonds are radiation tolerant up to a fluence of $1 \times 10^{16}\,\mathrm{hadrons/cm^2}$ and can operate for several years in the environment of the HL-LHC and that they 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 and characterising their internal structure with a high resolution beam telescope. The rate tests are solely performed at Paul Scherrer Institut (PSI) using the beam line piM1 with a positive 260 MeV/c pion beam and tunable particle fluxes from $1\,\mathrm{kHz/cm^2}$ up to $10\,\mathrm{MHz/cm^2}$ whereas the high resolution test are performed at CERN using the SPS beam H6 with pions or protons up to momenta of 200 GeV/c.

Rate Beam Tests:

Mr. Reichmann is in charge of organising and conducting the RD42 high rate beam tests at PSI as well as assisting other members of the collaboration performing experiments at this facility. This includes maintaining and operating the ETH beam telescope and the overall set-up at PSI, supervising the data-taking and running and improving the data acquisition (DAQ) framework EUDAQ.

Pad Detectors:

As a proof of principle that pCVD diamond material is suited as particle detectors at high particle rates, the most simple detector geometry - pad detectors - are investigated. The investigated detectors are built at Ohio State University (OSU) by cleaning diamonds from the company II-IV and metallising them with a thin Cr-Au layer on both sides. They will then be measured at PSI at various fixed rates recording their signals as digital waveforms which are then to be analysed to get conclusions about their behaviour at

different rates.

Pixel Detectors:

Since the current technology at the innermost tracking layers of the LHC is based on planer pixel detectors it also very important that Mr. Reichmann will investigate pCVD diamond sensors read out with state of the art pixel detectors which digitise the signals already on chip using an analogue to digital converter (ADC).

3D Detectors:

3D detectors are a very promising detector concept. Within RD42 these detectors are built in collaboration with the Universities of Manchester, Oxford and Ohio utilising a femtosecond laser. Mr. Reichmann will test the general working principal as well as the rate behaviour of these detectors both pad-like and pixel geometry.

High Resolution Beam Tests:

As the name already suggests pCVD material is not uniform and therefore Mr. Reichmann shall also upgrade the current ETH telescope in order to measure the various detector geometries and designs with high resolution and resolve their inner structure.

Time Frame

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

2016:

- reading into the topic
- planning improvements for the ETH pixel telescope with Felix Bachmair
- performing beam tests at PSI
  - general investigation of pad, pixel and 3D detectors
  - rate studies of the diamond detectors at different irradiation points
- helping with 3D beam tests at CERN
- setting up / modifying the framework for the pad analysis started by Mario Seeli
- modifying DAQ framework EUDAQ to convert beam test data from binary to root trees

2017:

- finalising improved version of ETH telescope
- improving pad analysis
- including pixel and 3D analysis into the framework
- further beam tests at PSI and CERN

- start planning and construction of the high resolution telescope

2018:

- testing the improved version of ETH telescope
- testing and installing of the high resolution
- finish analysis
- writing pad, pixel, telescope papers
- further beam tests at PSI and CERN

Results & Progress

So far Mr. Reichmann works regarding to his schedule. Until now he has almost finished the pad analysis and is working towards the a paper summarising the results claiming 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. Also the telescope upgrade works well and it's mounting is about to be finished.

Teaching

25 % of Mr. Reichmann's working time is designated to the function as teaching assistent at ETH Zürich.

Zürich, May 7, 2018

Michael Reichmann	Rainer Wallny

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Department of Physics

Research Plan

Doctoral thesis:

Investigation of the Rate Dependence of pCVD Diamond Pad, Pixel and 3D-Pixel Detectors
Doctoral thesis title (provisional)

02/12/2016
Beginning date of doctoral thesis

Doctoral student:

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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

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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.