Development of CVD Diamond Tracking Detectors for Experiments at High Luminosity Colliders

RD42 Status Report
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for the RD42 Collaboration
LHCC Meeting – June 3, 2015

Outline of Talk
- RD42 Collaboration
- LHCC Milestones 2014
- New Diamond manufacturers
- Rate studies of diamond signal
- Results from 3D sensors
- Plans and Request
Irradiation studies of highest quality material
Publication of completed irradiation studies
Beam tests with diamond strip and pixel detectors.
Develop diamond pixel modules for LHC experiments
Continue to develop pCVD and scCVD material
Continue to develop additional manufacturers to expand production capabilities
Improvements at New Supplier: II-VI

- II-VI provided first sensors for ATLAS DBM in 2013
  - 200-225um collection distance comparable to E6/DDL
- Delivered growing numbers of final finished parts
  - To ATLAS and CMS
  - Typically have 275-300um collection distance

![II-VI Samples: HV Curve by Part](image-url)
Development of New Diamond Supplier: IIa

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  • Show less signal loss at high rate than DDL
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- IIa committed to further improvement and pCVD growth
Diamond Signal vs. Rate

- Have published analysis of 2014 testbeam
  - JINST_006P_0115
- Improved understanding of pedestal shifts due to flux at highest rates
- Irradiated scCVD (DDL/PLT) still shows signal loss
- pCVD signal stable up to fluxes of $10^6 \text{cm}^{-2}$
  - Even after irradiation to $5 \times 10^{13}$ neutrons/cm$^2$
Rate Dependence at PSI Testbeam: Setup
Signals in Low/High Flux Environment

- Studying diamond pads and pixel detectors
- high rate pion beam at PSI

![Graphs showing signals in low and high flux environments.](attachment:graphs.png)
**pCVD Signal vs. Flux**

- **pCVD diamond** shows little variation in signal size vs. fluence.
- **LHC rates** about a factor of 10 higher at inner radii.
Pulse Height vs. Flux

- scCVD unirradiated and pCVD irradiated show less than few% signal variation up to $3 \times 10^5$ Hz/cm$^2$

- scCVD irradiated with neutrons and in CMS (PLT pilot run 2012) show 10% drop in signal
Unirradiated scCVD gives robust pulse heights to 20 MHz/cm² in CMS Pixel prototypes.
Irradiated scCVD (5 x 10^{13} neutrons/cm^2) show similar loss of pulse heights to PLT pilot run modules
New Tool: Spatial Structure of Diamond Signal

- Using CMS (silicon) pixel telescope to determine testbeam particle position in diamond pad sensor
- Studying spatial uniformity of signal in scCVD pads
  - Currently studying pCVD and possible rate variation
Diamond Devices for Experiments

- Beam conditions monitors
  - Alice, ATLAS, CMS, LHCb
- LHC machine BLMs ➔ New for RD42
  - Operating in cryogenic conditions
- Current generation Pixel Detectors
  - ATLAS DBM, CMS PLT
- Future LHC trackers
  - ATLAS, CMS, LHCb
  - 3D diamond devices
The ATLAS Diamond Beam Monitor

- Build on success of BCM - pixelate the sensors
  - Use IBL demonstrator modules
  - Installed in 2013 during service panel replacement
  - Four 3-plane stations on each side of ATLAS
DBM Telescope Installation
Detector being integrated in **ATLAS** readout

- Thresholds tuned to **2500e** (below silicon settings)
  - Must eventually go lower
    - 1100e achieved on bench
- Soon to see beam
3D Diamond Tracker Prototype

Now published in NIM A 786 (2015) p97
Sensor Design for 2012 Testbeam

92% column yield
Pulse Height in 3D Diamond Sensor

- Missing charge around ~9 broken readout columns
Remarkable agreement between signal in 3D and planar/strip geometry
- In good fiducial region
- 3D sensor @ 25V
- Planar @ 500V
- 3D geometry collects full charge at lower E
Summary

- Working closely with two new manufacturers
  - II-VI has delivered even higher quality pCVD material
  - IIa is producing better scCVD samples than E6
- Quantifying understanding of high rate effects on diamond
  - pCVD appears less susceptible to these effects
- First pixel project is about to start taking data
  - ATLAS DBM being commissioned for 13 TeV collisions
- 3D prototypes show great promise
- Published two important results for future diamond systems
- RD42 played a pivotal role in making all this happen
RD42 Research Priorities for 2015-16

- Continue to expand diamond manufacturer production capabilities.
- Perform beam tests with diamond strip and pixel detectors.
- Continue to support LHC upgrade pixel projects.
Request of CERN LHCC

The RD42 Role at CERN

- Irradiations, development of new manufacturers, sample procurement, test beams
- Central facilities for all experiments ➔ this worked for BCM’s
- CERN Group in RD42 to be maintained

RD42 Request to CERN/LHCC

- RD42 is supported by many national agencies:
  ➔ continuation of official recognition by CERN critical
  ➔ ~200kCHF from outside CERN
- RD42 requires access to CERN facilities:
  ➔ maintain the present 20 m² of lab space (test setups, detector prep, ...)
  ➔ maintain present office space
  ➔ test beam time (2014++) critical for next generation of proposals

RD42 & CERN play a critical role in diamond development
Negative Pulses from 3DTestbeam

- Understood origin of negative pulses
  - Due to missing bias columns
- Simulated with Spice
  - Could fix by biasing from back side
  - Need to improve electrical contact with back side of columns
Location of Negative Pulses

- Clustered around ~16 missing bias columns