A beam radiation monitor based on CVD diamonds for SUPERB

FRONTIER DETECTORS FOR FRONTIER PHYSICS

12th Pisa Meeting on Advanced Detectors La Biodola, Isola d'Elba (Italy), 20-26 MAY 2012

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CVD Diamond Sensors application as Radiation Monitor

A radiation monitor addresses the following issues:

- Allow to protect equipment during beam instabilities / accidents
- Provide feedback to the machine thereby helping them to routinely provide optimum conditions
- Monitor the instantaneous dose during operation

The goal is to detect signs of beam losses and monitor beams.

Chemical Vapour Deposition (CVD) diamond has a number of properties that make it suitable for very harsh radiation environments. Its large band-gap (5.5 eV) and large displacement energy (42 eV/atom) make it a material that is inherently radiation tolerant in terms of the very low leakage currents, even at extreme fluencies.

In recent years CVD diamond sensors have been successfully employed as beam monitoring in several experiments:

- i.e. BaBar, Belle, CDF, ATLAS, CMS, LHC-b, ALICE

SVT Radiation Monitoring

A radiation monitor near the interaction point is crucial to protect the Silicon tracker (SVT) of SUPERB from a high radiation dose and give the abort to the beam in presence of a current spike or a prolonged radiation dose lethal for the detector.

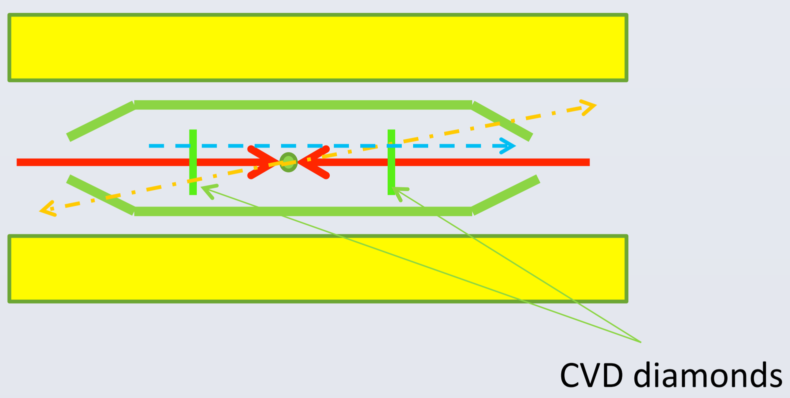
Primary goal of the detector is to measure interaction rate and background level in an high radiation environment to provide inputs to background alarm. In addition it can be used for luminosity measurements and a detailed background characterizations in both during stable beams and setting up for collisions.

To make a full use of this detector is therefore needed:

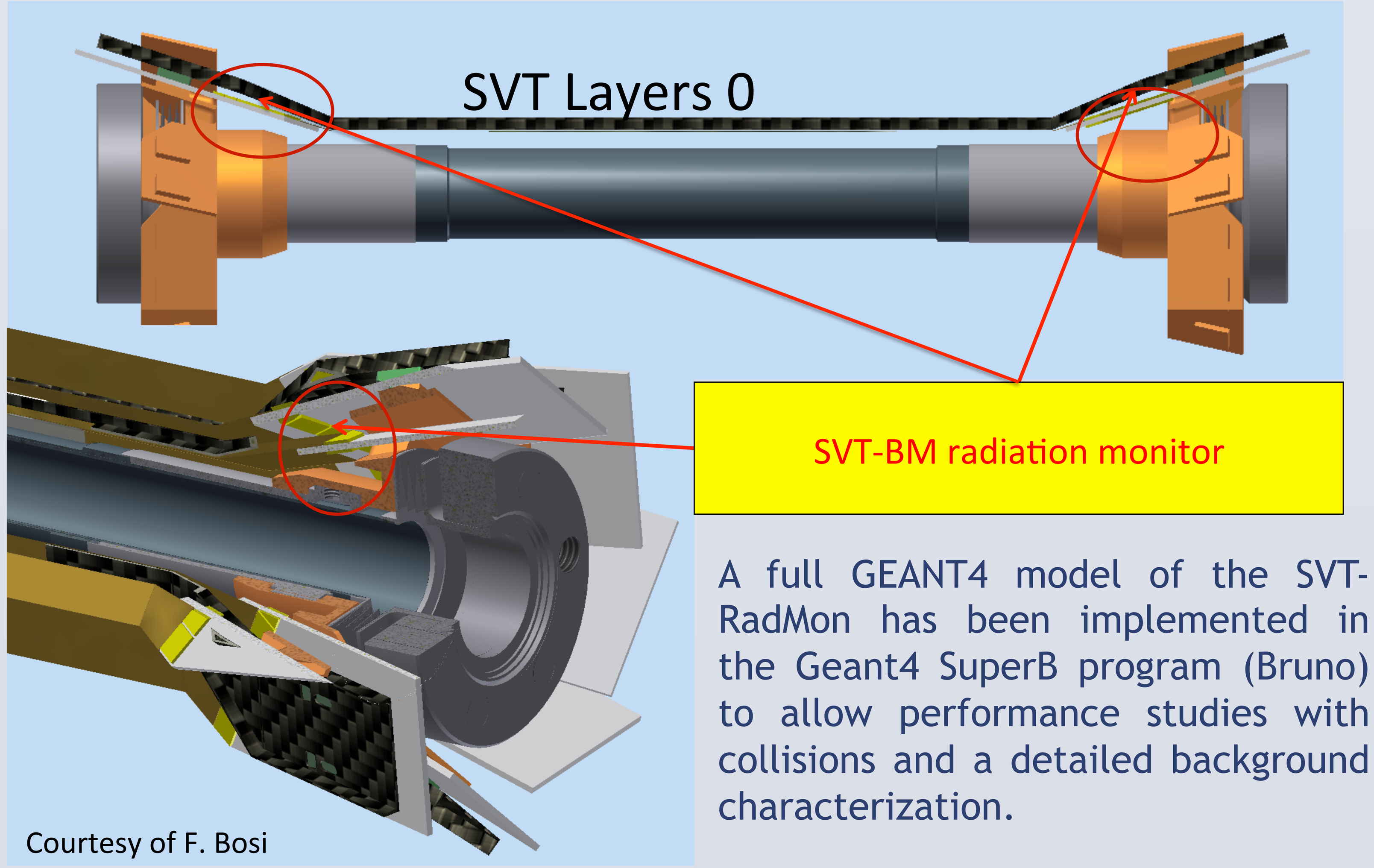
1. A simple DC (or slow amplification) readout to measure the beam induced DC current. Benefits from very low intrinsic leakage current of diamond.
2. A fast electronics with very low noise
   - For detection of minimum ionizing particles. Benefits from fast diamond signal
   - To allow more sophisticated logic coincidences,i.e. timing measurements

In SUPERB the idea is to implement time of flight measurements to distinguish collisions events from background

- Very high time resolution required (order of 100ps)



Location of the SVT Radiation Monitor



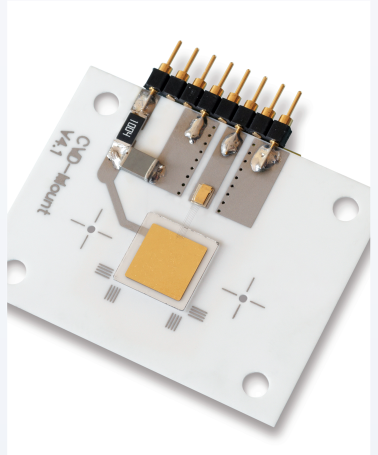
A full GEANT4 model of the SVT-RadMon has been implemented in the Geant4 SuperB program (Bruno) to allow performance studies with collisions and a detailed background characterization.

Conclusions

First laboratory tests with ^{241}Am and ^{90}Str radioactive sources of a mono-crystalline and poly-crystalline CVD diamond sensors read out with a SiGe amplifier, located at a 4 m distance, gave very promising results.

CVD Diamond Properties

- Fast timing
- High Radiation tolerante (>1 MGy)
- Single-particle detection and current monitoring
- Efficiency for charged particles close to100%
- 500 V @ 100 pA : low power consumption
- Leakage current of a few pA, does not increase with the accumulated dose
- insensitive to temperature variation



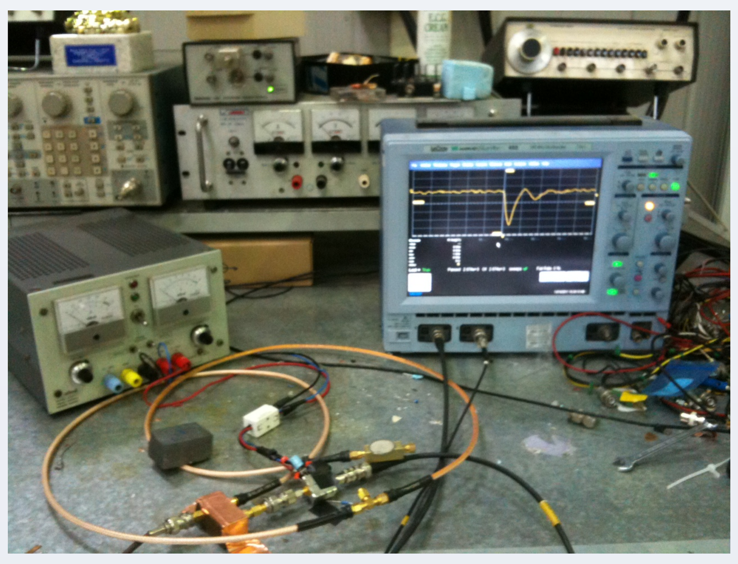
Mono and Polycrystalline CVD diamonds

Weaknesses of polycrystalline CVD diamond:

- Many grain boundaries -> defects
- Non-uniformity of collection properties

Monocrystalline CVD diamond is a solution:

- No grain boundaries -> less defects
- Uniform collection properties



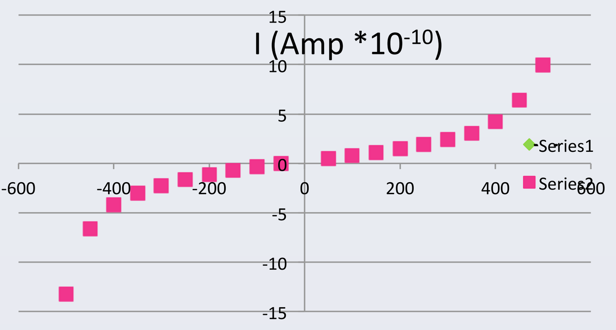
Mono and polycrystalline sensors tested in Roma Tor Vergata laboratory:

- thickness 0,5 mm
- Area 4 x 4 mm^2
- HV 400 Volt

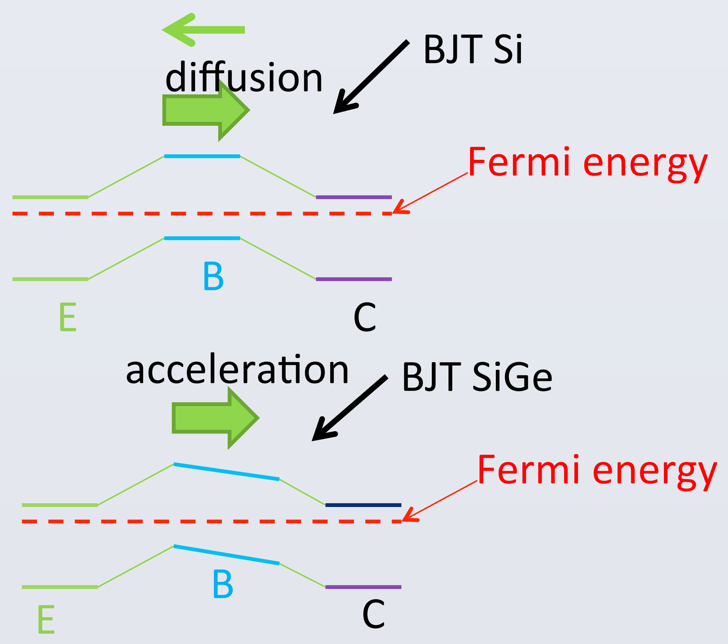
Three different amplifiers located at a distance of circa 4m from sensors were used:

- Two stage amplifier, AC, (BJT Si BFQ67)
- AC, (BJT SiGe, BFP650)
- AC, (BJT SiGe, BFP740)

I vs HV (sCVD- diamond)



BJT Si v.s. SiGe



BJT performances

$\beta=\tau_c/\tau_t$

$f_t=1/\tau_t$

$N= K^*\tau_t$

τ_c= base life time

τ_t = base transient time

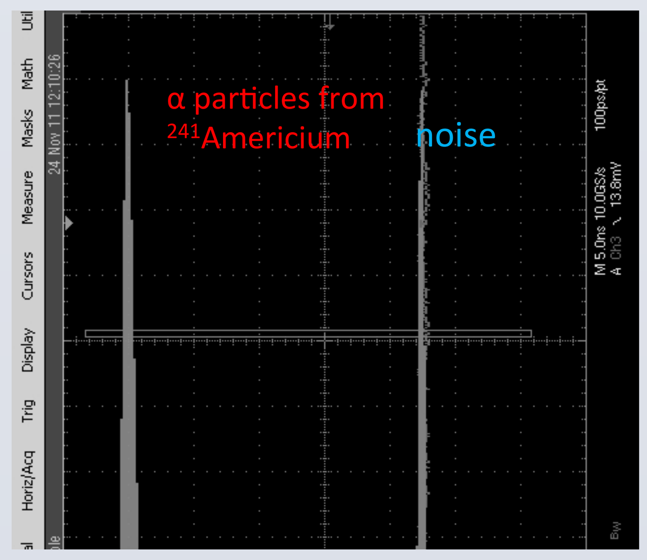
τ_t (Si) >> τ_t (SiGe)

The SiGe transistor exhibits a very short transit time in the base because it takes advantages of the ballistic effect due to the electric field that produces an increase of the performance concerning: transition frequency, amplification and noise reduction.

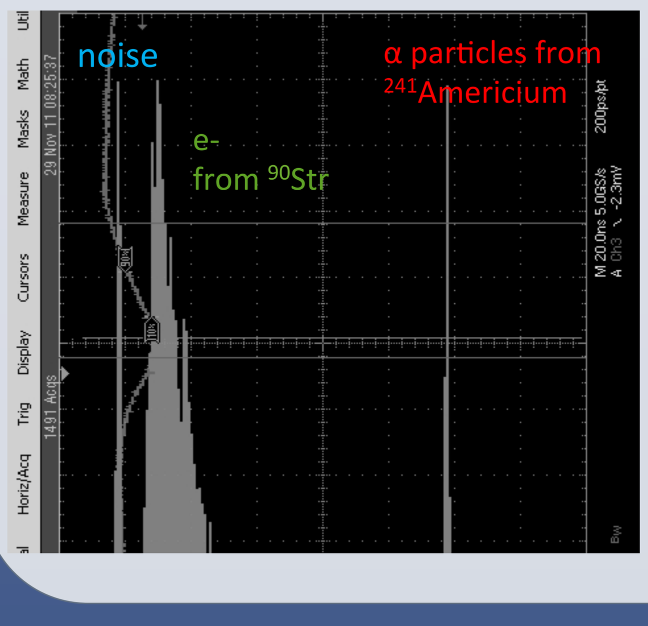
Results with (sCVD + BJT SiGe, BFP650)

Amplifiers features: AC, (BJT SiGe, BFP650)

- Voltage supply 5 Volt
- Sensitivity 6 mV/fC
- noise 1000 e$^-$ RMS
- Input impedance 50 Ohm
- B.W. 30 MHz
- Power consumption 10 mW/ch
- Cost a few €/ch
- Radiation hardness 50 Mrad,10^{15} n/cm^{-2}



Results with (sCVD + BJT SiGe, BFP740)



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