THE MONODIAM-HE PROJECT : MONOCRISTALLINE DIAMOND FOR HL-LHC PIXEL DETECTORS

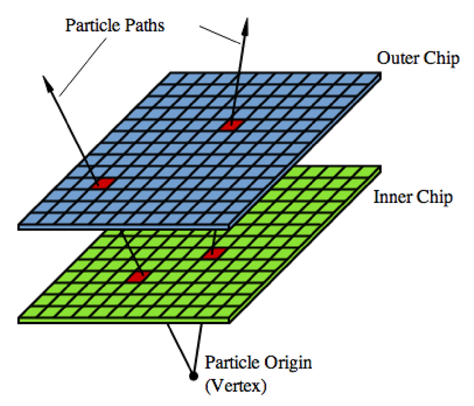
J-M. BROM : IPHC @ STRASBOURG
J. COLLOT - J-Y. HOSTACHY - J-F. MURAZ - M. YAMOUNI - A.PINGAULT : LPSC @ GRENOBLE

EPSHEP 2013 STOCKHOLM, SWEDEN, 18-24 JULY, 2013

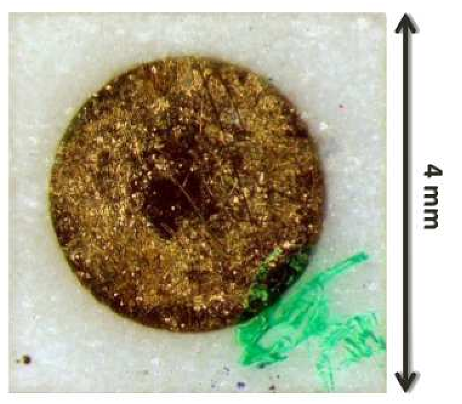
INTRODUCTION

A new 4-year R&D endeavor carried out by four French laboratories involved in LHC experiments and in material science is aiming at elaborating sizeable ($1x1$ cm^2) monocrystalline diamonds that could be used in the inner most parts of the High-Luminosity LHC pixel detectors. Polycrystalline diamonds are already used in several collider experiments [1] thanks to their good capability to withstand high radiation doses. Monocrystalline diamond (MCD) sensors could feature enhanced detection properties and a more homogeneous response.

DIAMOND AS A DETECTION SENSOR



A vertex reconstruction



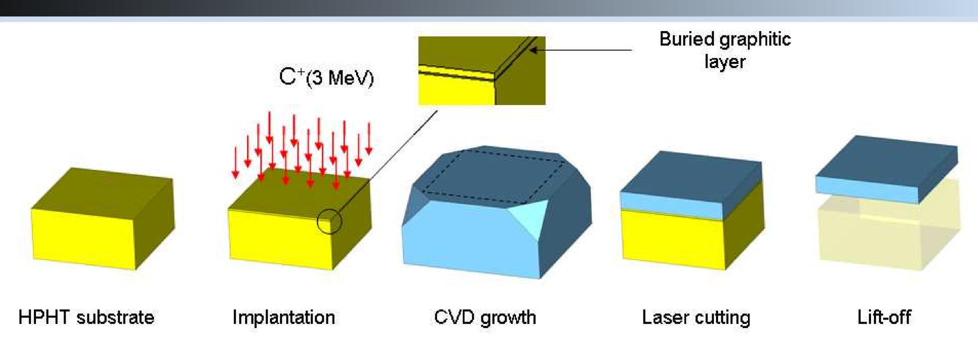
Picture of a diamond sample top view

Property	Diamond	Silicon	Best
Density [g cm^{-3}]	3.52	2.33	/
Band Gap [eV]	5.48	1.12	/
Energy to create e-h pair[eV]	13.1	3.62	Silicon
Mean Signal (MIP)	$36\ e^- / \mu m$	$89\ e^- / \mu m$	
Resistivity [Ω cm]	$10^{13} - 10^{16}$	$10^5 - 10^6$	
Thermal Conductivity [W cm^{-1}K^{-1}]	> 1800	1.48	
Displacement Energy[eV]	43	25	Diamond
Electron mobility [cm^2 V^{-1} s]	1900	1450	
Hole mobility [cm^2 V^{-1} s]	2300	505	
Breakdown Field[V cm^{-1}]	10^7	$3 \cdot 10^5$	

Summary of several properties of diamond and silicon

- **Diamond interest :** Radiation hardness
- **Flaw :** Lower Signal

PRODUCTION PROCESS



- sCVD Diamonds (single-cristal Chemical Vapor Deposition)
- Low pressure (~0.1 bar) and T ~1000 K
- Small sized diamond (up to 5x5 mm^2) [2]
- Need to cut off the seed from the substrate (Laser cut/acid bath)
- Induce surface defects=> need for polishing the surface

CHARGE COLLECTION DISTANCE (CCD)

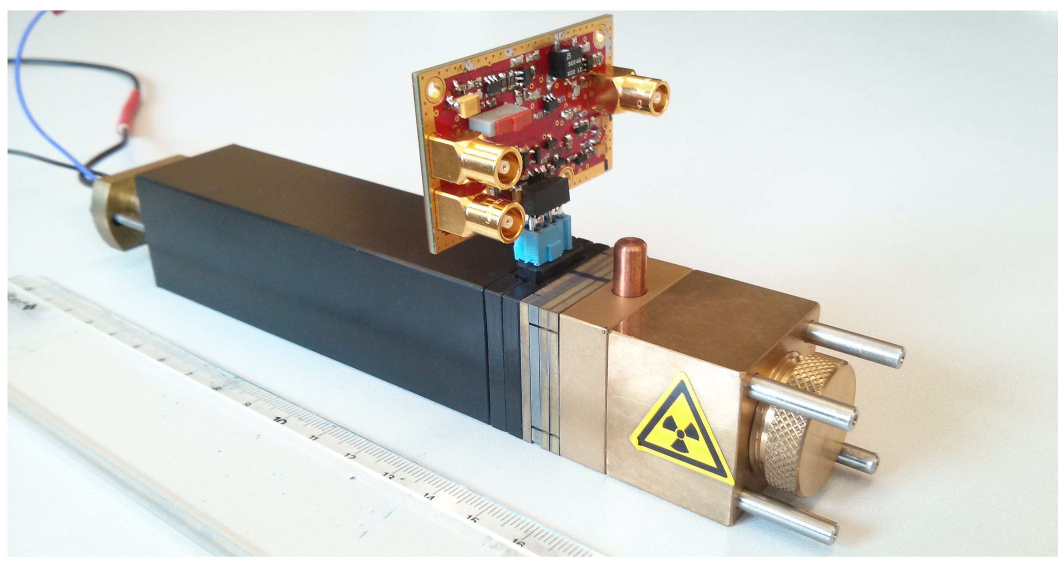
Mean distance of separation between electron-hole

- **Most important parameter** for a HEP use
- Limited by crystal defects
- **Approximated by :**

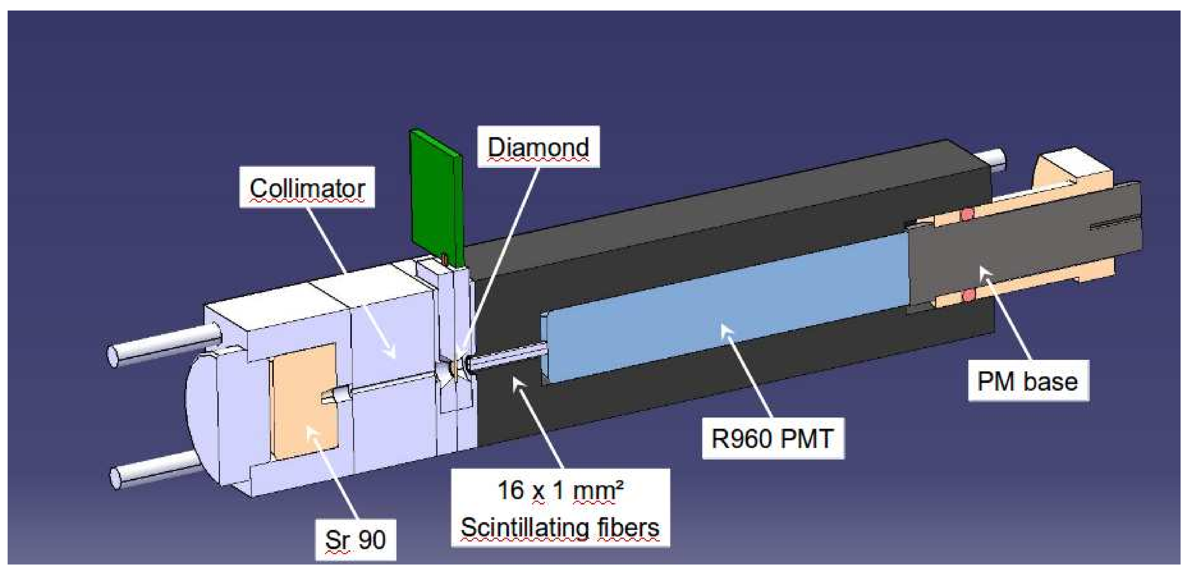
$$CCD\ (\mu m) = \frac{Number\ of\ electrons\ collected}{36}$$

- A minimum of 300 µm is required :
  - Corresponds to $\sim$ 10 000 electrons
  - Yielding a comfortable S/N Ratio

TEST BENCH



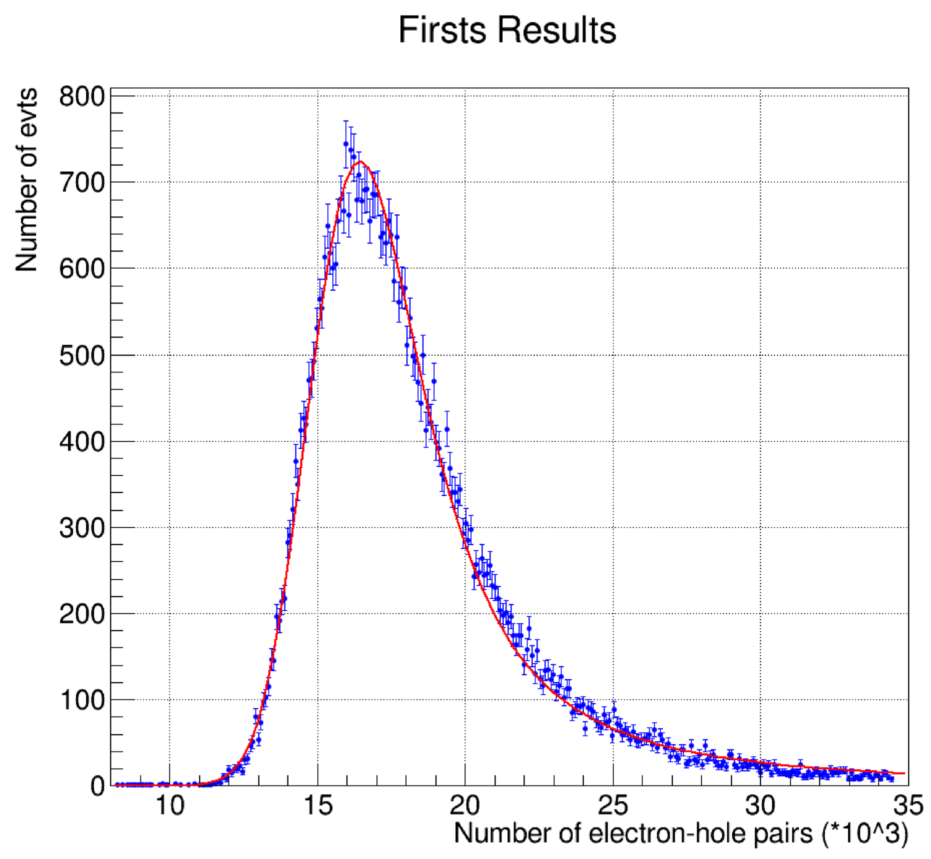
Picture of the test bench



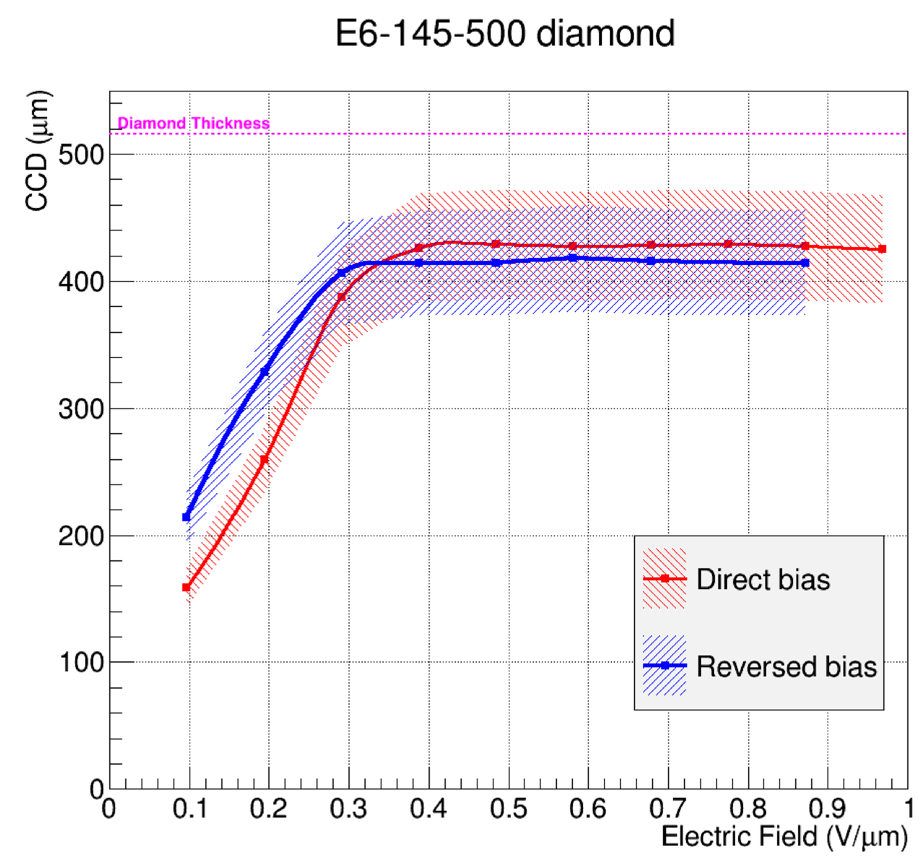
Cross section of the test bench

$$^{90}Sr \xrightarrow[28.78\ year]{\beta^-\ 0.546\ MeV} {}^{90}Y + e^- + \bar{\nu}_e \quad \text{followed by} \quad {}^{90}Y \xrightarrow[64.05\ hours]{\beta^-\ 2.282\ MeV} {}^{90}Zr + e^- + \bar{\nu}_e$$

RESULTS



Distribution of collected electrons for a HV = 450 V



Diamond CCD versus applied field

- **Energy distribution in very thin material : Complicated to calculate**
  - Due to rare phenomena (fast emitted δ-rays mainly)
  - Give the Landau its asymmetry.
- **Fitted curve :** Convolution of a Gaussian with a Landau

Analysis made for several bias voltage :
- One can compute the CCD vs the applied field
- CCD $>$ 400 µm

PROSPECTS AND CONCLUSION

A CCD value $>$ **400** µm can be obtained
$\Rightarrow$ Very encouraging for the future
$\Rightarrow$ **Compatible with a HEP application**

Many things remain to be done:
- Production and tests of bigger diamonds of the same quality
- Mastering of surface preparation and metallization step
- Control of the radiation hardness of samples
- Pixelization
- Beam tests

REFERENCES

[1] ATLAS Collaboration, The ATLAS-IBL Project ATL-COM-INDET-2010-031, (2010)
[2] F. Silva, K. Hassouni, X. Bonnin and A. Gicquel Microwave engineering of plasma-assisted CVD reactors for diamond deposition Journal of Physics: Condensed Matter 21, p. 364202, (2009)