FEE-DD Simulations: Large Area continuous position sensitive Diamond Detector

Mircea Ciobanu,
Institute for Space Sciences – Bucharest, Romania

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Outline

1 Motivation.

2 Simulations of a Large Area continuous position sensitive Diamond Detector.

3 Summary and Outlook.

Motivation

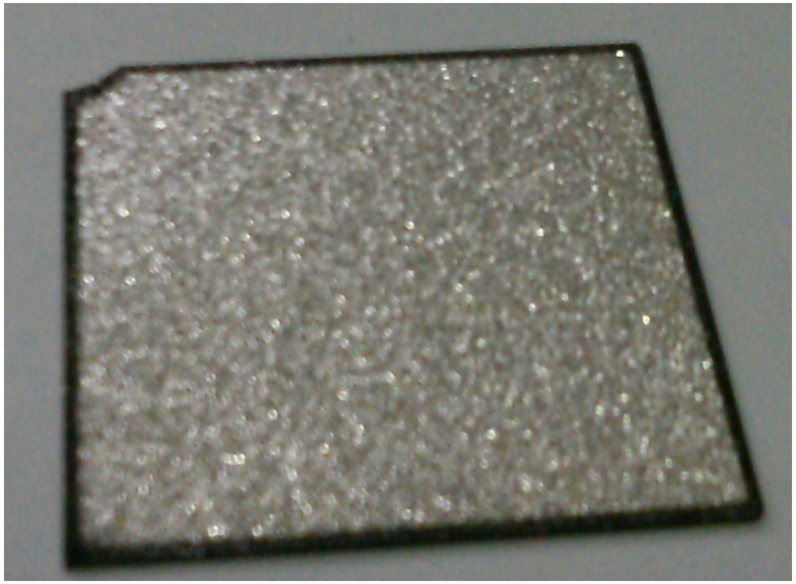
The DD can be a very good candidate for a Detector to be used e.g. in Beam Monitoring, Hadron Therapy, or Space Applications.

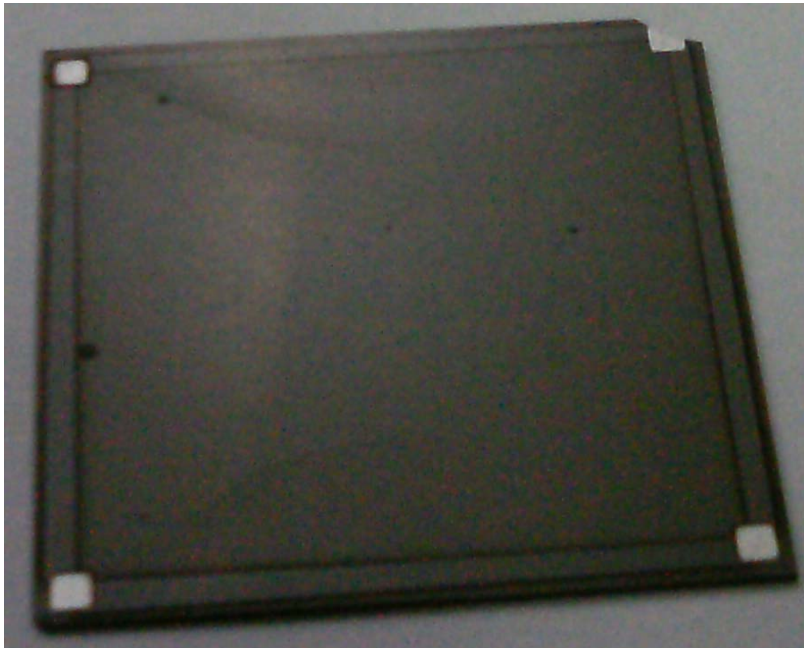
It is compact and robust, has a low mass, needs a low biasing power, is radiation hard, can work in vacuum, can work in a large temperature interval.

We intent to develop a Large Area continuous position sensitive Diamond Detector together with a matched Front End Electronics.

We have started with a 30 mm x 30 mm pcDD. Dr. Michal Pomorski has deposited the main DLC layer, the secondary DLC strips and the aluminum contacts.

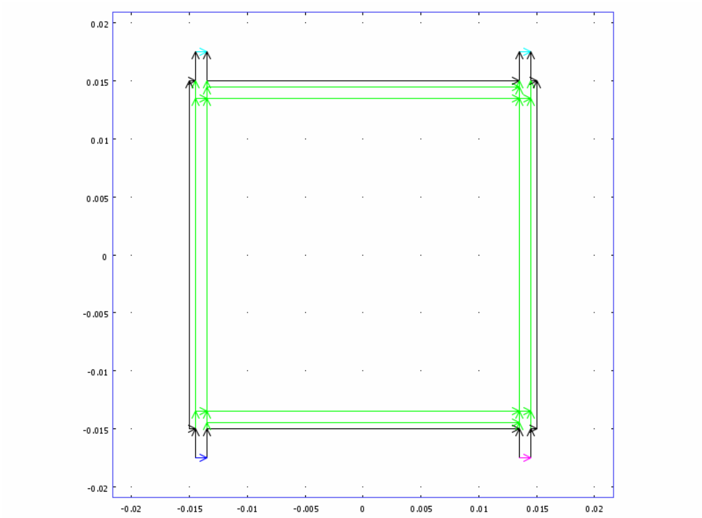
Finally, we shall use the sc DOI with the needed area.

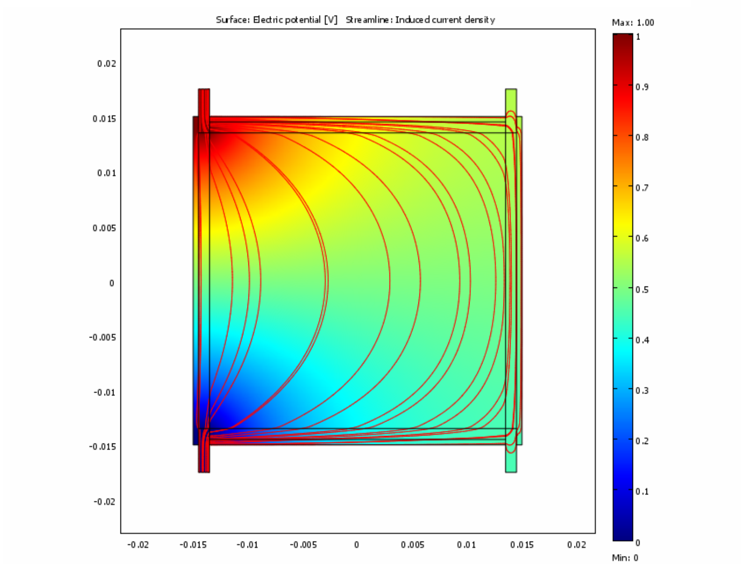




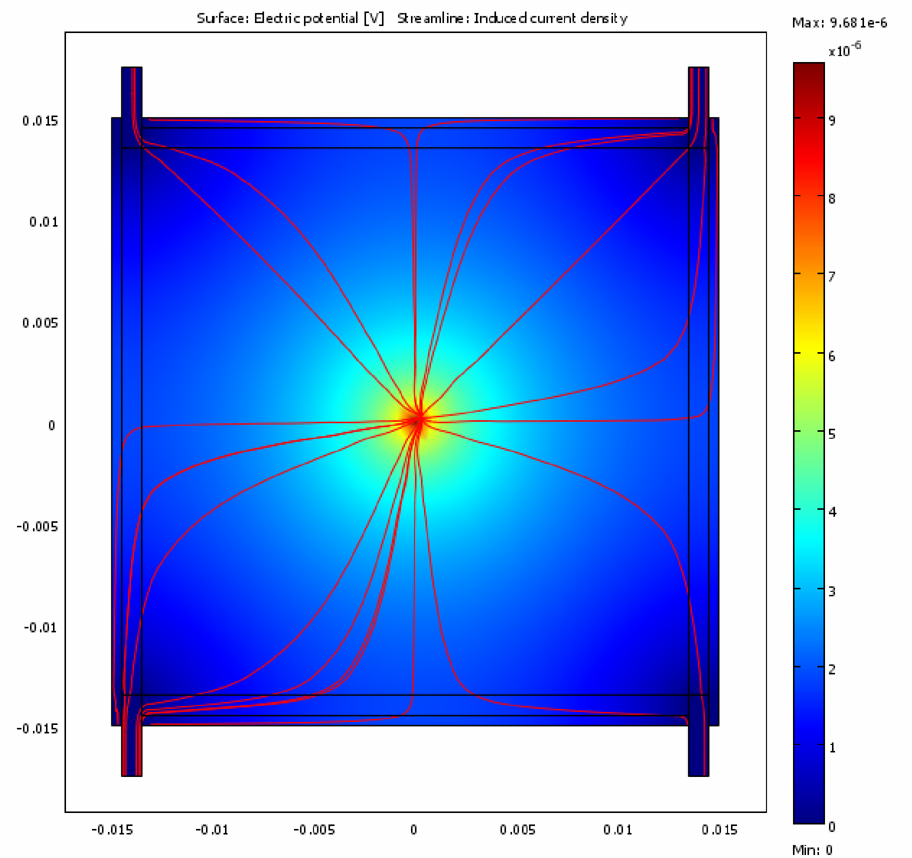
Simulations

geometry

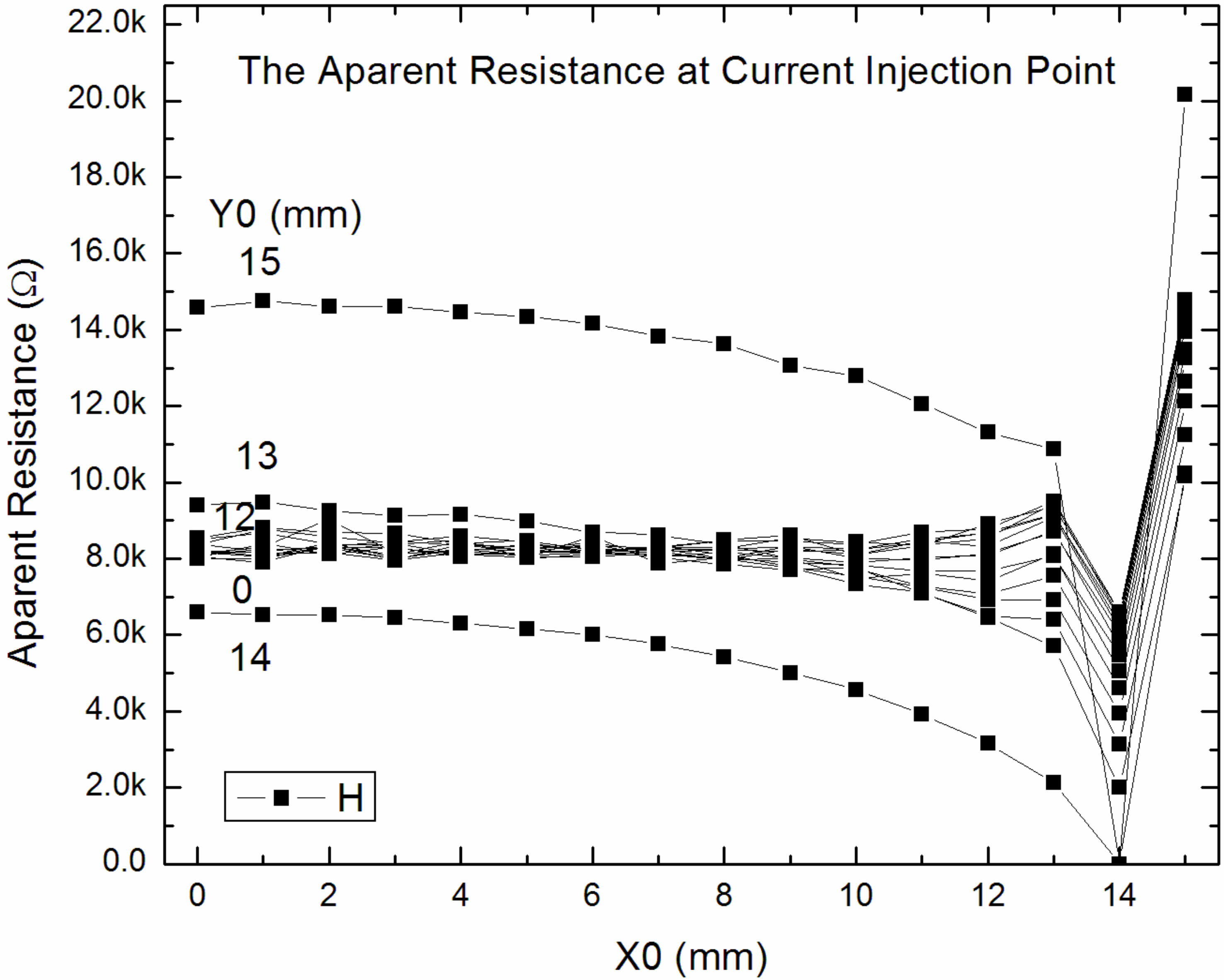




calibration



Simulation of the response : 4 currents depending of the excitation point position.



The Aparent Resistance at Current Injection Point
Apparent Resistance (Ω)
22.0k
20.0k
18.0k
16.0k
14.0k
12.0k
10.0k
8.0k
6.0k
4.0k
2.0k
0.0
Y0 (mm)
15
13
12
0
14
H
0
2
4
6
8
10
12
14
X0 (mm)

The error minimization algorithm

The error minimization algorithm starts from 4 measured currents:
j1(i), j2(i), j3(i) and j4(i).
We generated a table containing the response of the PSD (four currents) to a current injected in different points of the detecting area. Due to the symmetry of the geometry, we investigated 1/4 the whole area of 30 mm x 30 mm; the injecting currents cover the 0 - 15 mm range, on two axes, with 1mm pitch. These correspond to a total of 256 investigated points.

With these four currents, there are calculated non corrected relative positions: xr and yr.

$$yr=(j3(i)+j4(i)-j1(i)-j2(i))/(j1(i)+j2(i)+j3(i)+j4(i))$$
$$xr=(j2(i)+j3(i)-j4(i)-j1(i))/(j1(i)+j2(i)+j3(i)+j4(i))$$

We try to make a polynomial correction of these measured currents.
The polynomial fit is of degree 3, in two variables xr and yr.
There are needed 10 parameters: p1 - p10

$tx1=(p1) + (p2)*xr + (p3)*yr + (p4)*xr^2 + (p5)*yr^2 + (p6)*xr*yr$
$+ (p7)*xr^3 + (p8)*yr^3 + (p9)*xr^2*yr + (p10)*xr*yr^2$

$ty1=(p1) + (p2)*yr + (p3)*xr + (p4)*yr^2 + (p5)*xr^2 + (p6)*yr*xr$
$+ (p7)*yr^3 + (p8)*xr^3 + (p9)*yr^2*xr + (p10)*yr*xr^2$

We obtain the absolute error on x and y reconstruction (t1 and t2):

t1(i)=x0(i) - xr*tx1

t2(i)=y0(i) - yr*ty1

We combines these errors to obtains the amplitude of the error vector, and we will minimize the total error obtained by quadratic sum of all individual errors.

sum=sum+t1*t1+t2*t2

We use the MINUIT program (CERN library) for this error minimization fit.

In the next table, there are presented the fit result taking different numbers of points (121, 144, 169, 196, 225) from the total of 256 points.

Fitted parameters

No. of Fit points	121	144	169	196	225
p1	23.83	24.239	24.788	25.254	25.067
p2	-6.295	-9.814	-14.12	-17.630	-15.984
p3	27.560	39.297	55.287	75.230	95.716
p4	24.819	30.665	36.247	37.741	23.654
p5	-46.596	-48.968	-52.407	-57.208	-59.931
p6	-11.087	-14.102	-17.997	-22.817	-22.81
p7	18.025	20.771	26.639	38.422	67.983
p8	43.307	48.683	55.208	25.268	76.394
p9	-33.124	-47.773	-67.735	-92.266	-118.56
p10	-26.019	-29.655	-33.157	-15.9847	-56.405

The final results

Nr. of Fit points:	121	144	169	196	225
Det. Area (mm^2):	20 x 20	22 x 22	24 x 24	26 x 26	28 x 28

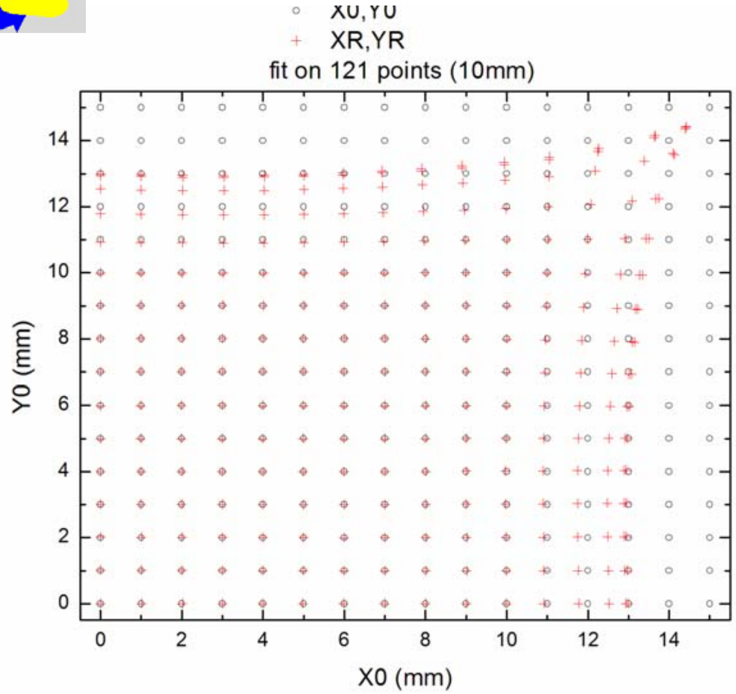
error (mm) on 265 points (equivalent to detection area of 30x30mm):

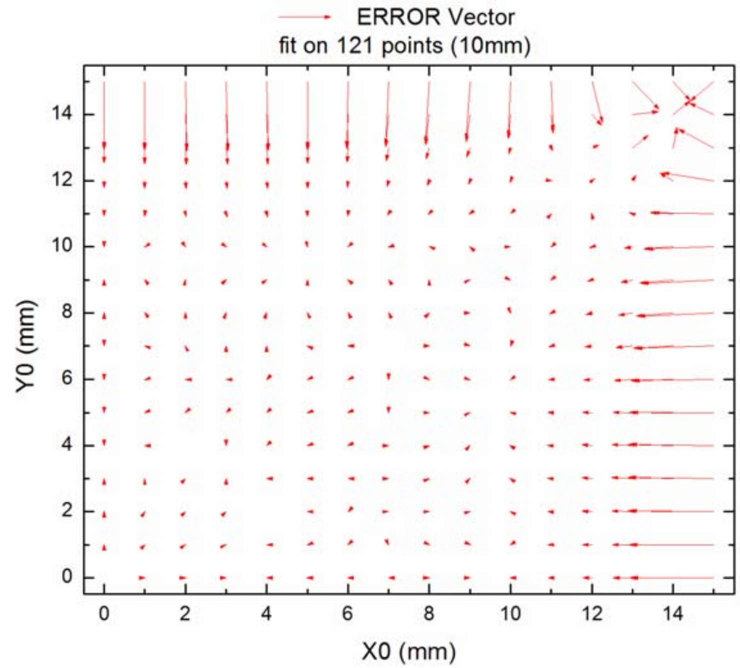
Mean	0.3764	0.36762	0.35498	0.31573	0.27762
St. Dev	0.59138	0.5984	0.60959	0.54465	0.38966
Max.	2	2.7	3.2	2.9	1.8

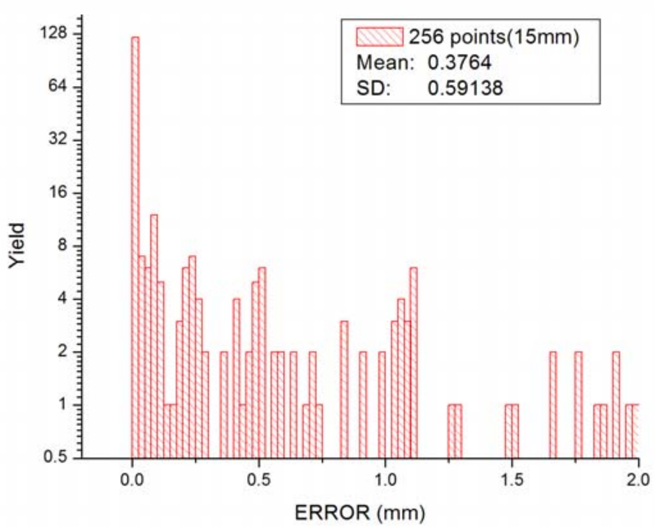
error (mm) on Nr. of Fit points :

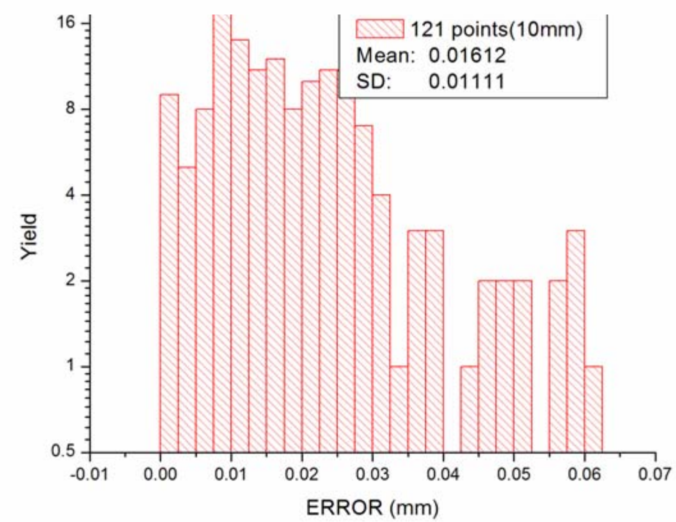
Mean	0.01612	0.01851	0.03255	0.05608	0.14017
St.Dev.	0.01111	0.01026	0.01861	0.0349	0.1121
Max	0.063	0.055	0.098	0.175	0.18

Fit on 121 points

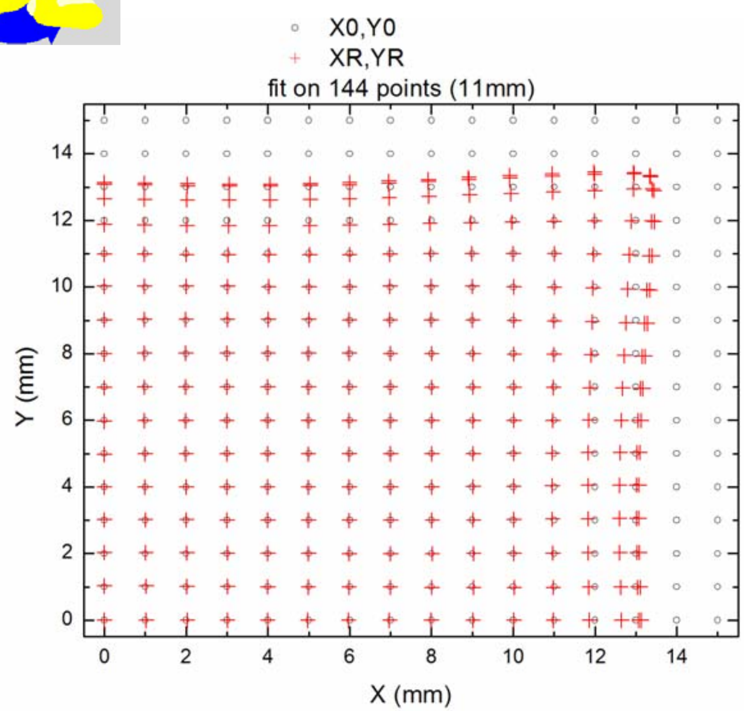


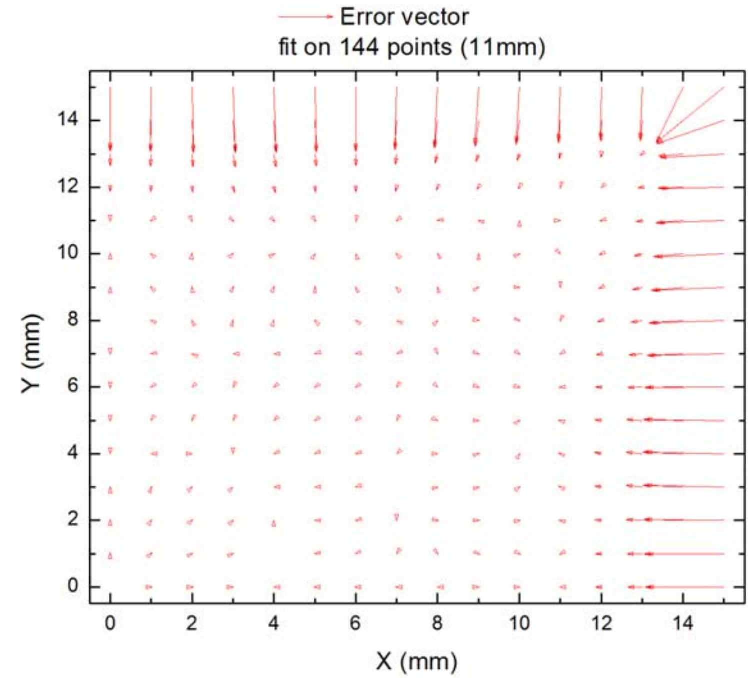


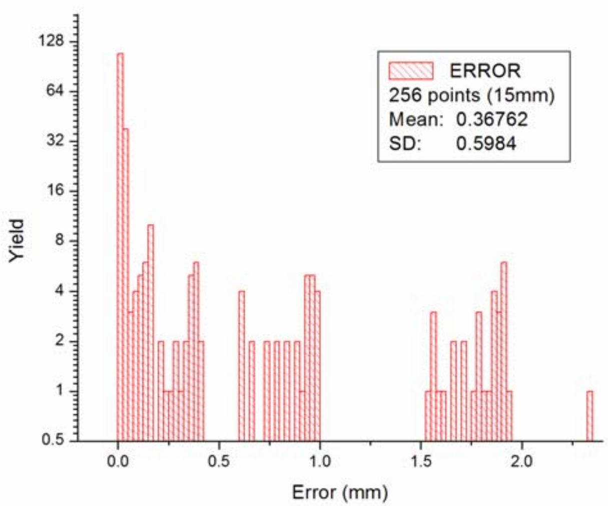


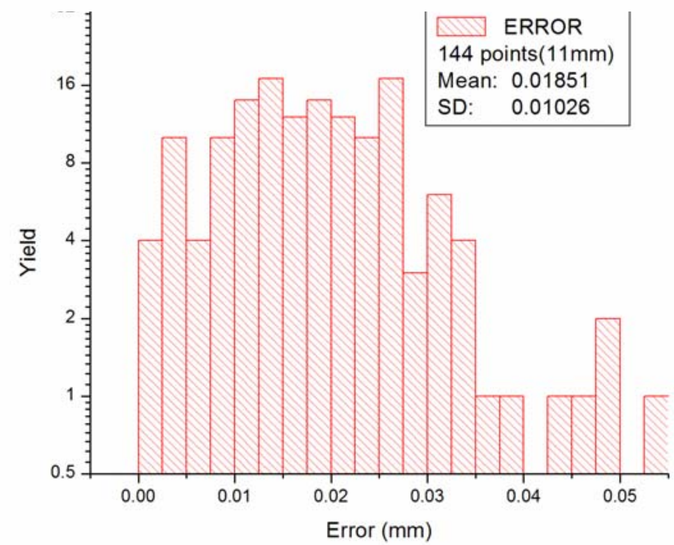


Fit on 144 points

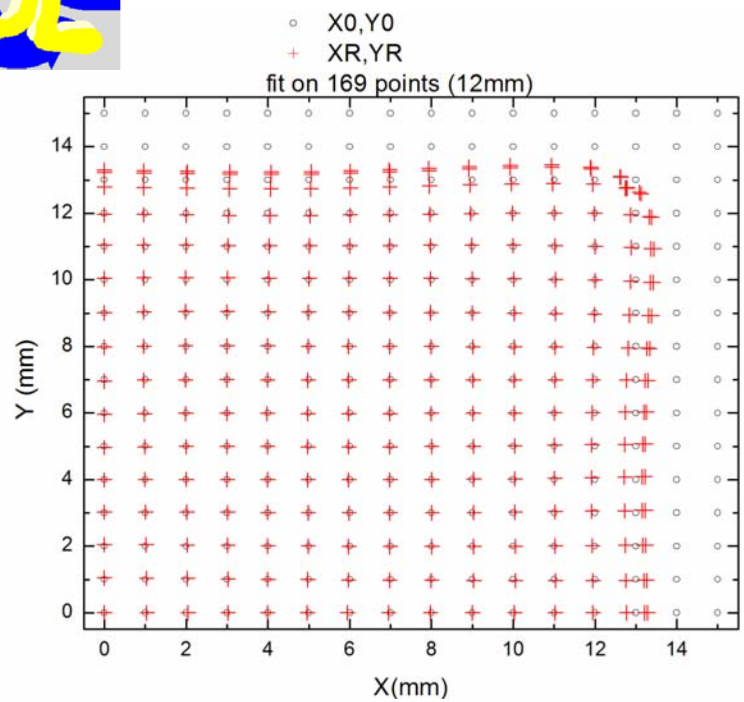


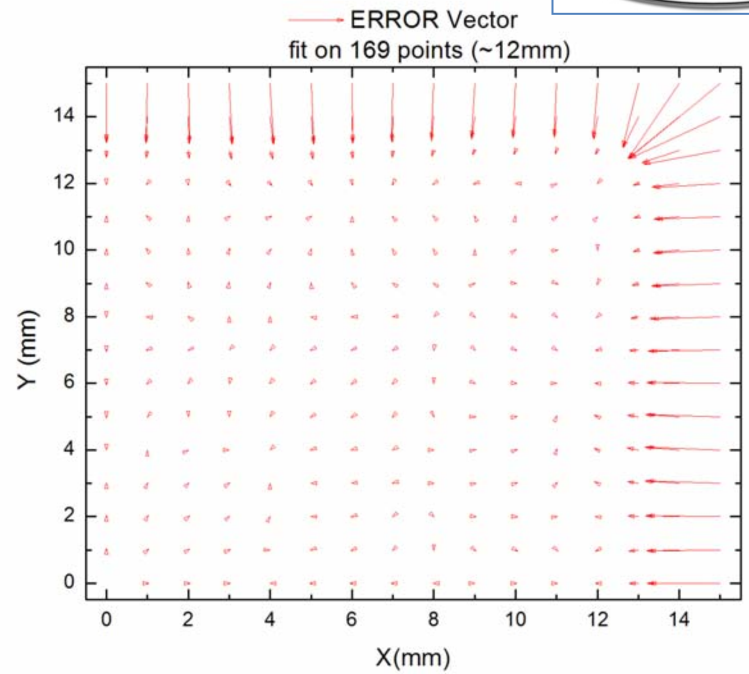


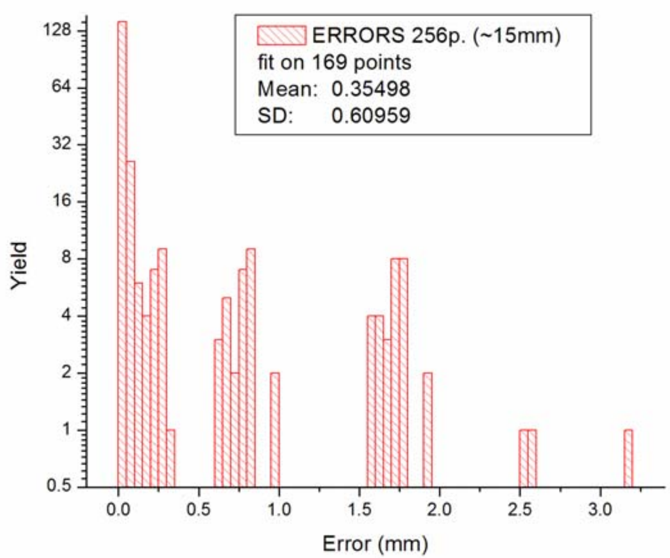


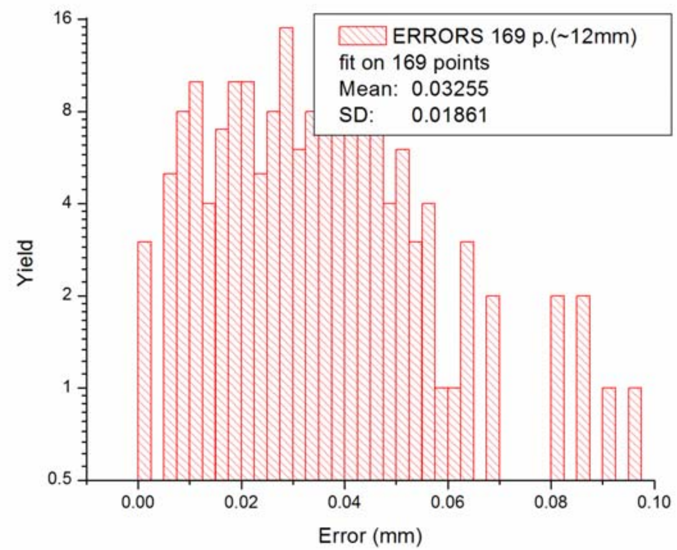


Fit on 169 points

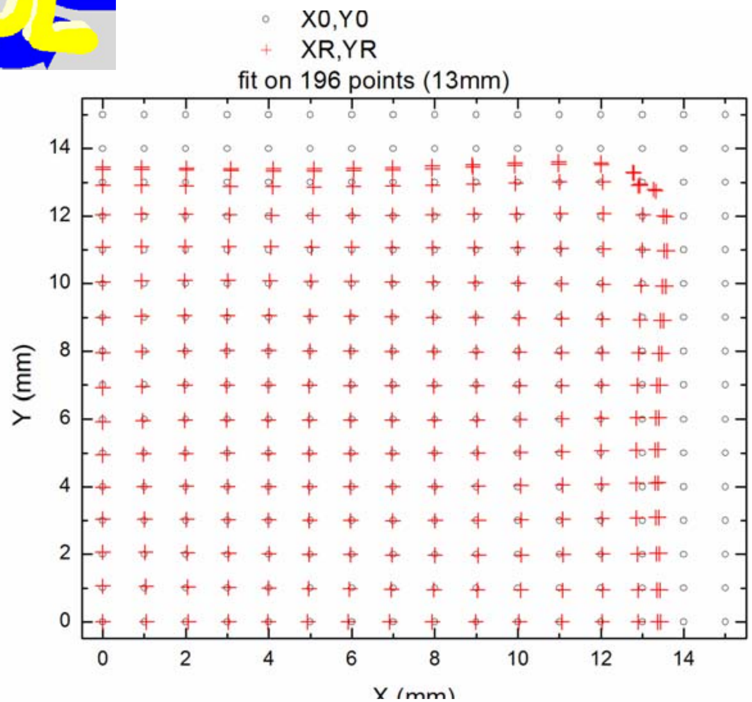


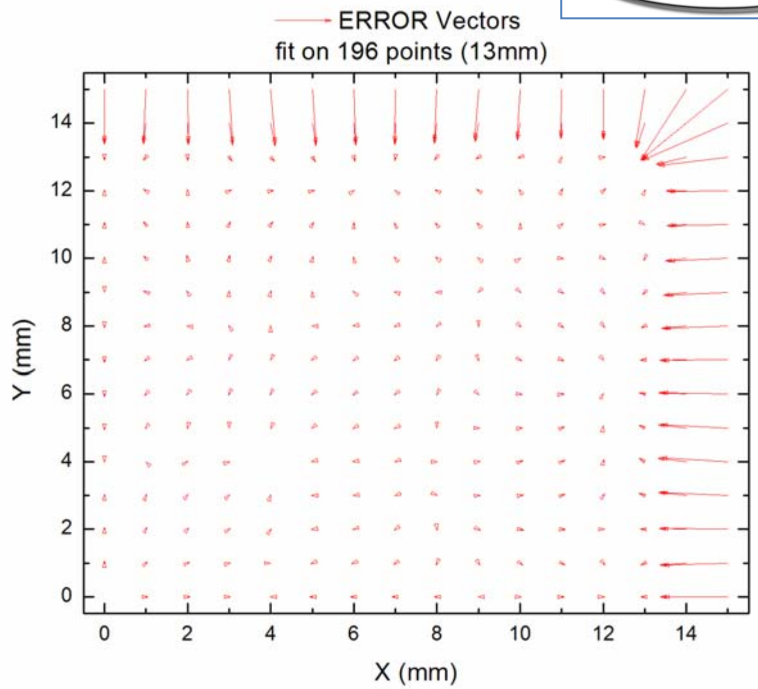


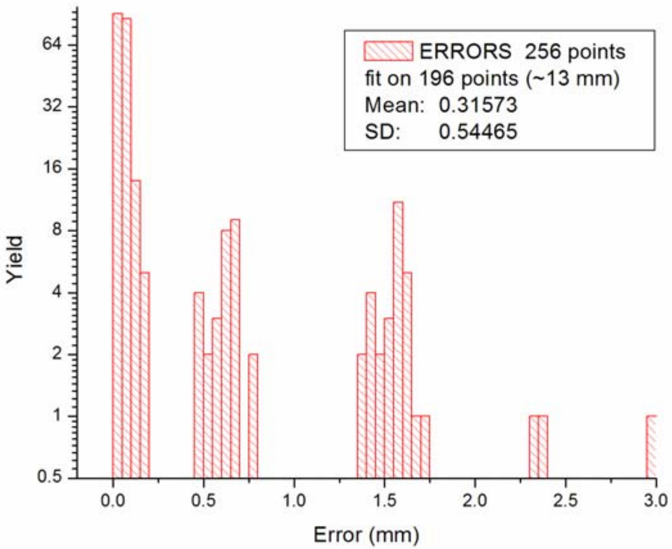


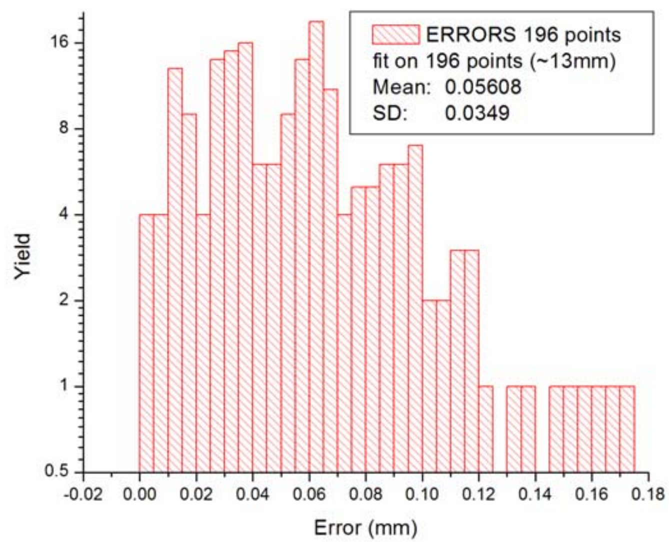


Fit on 196 points

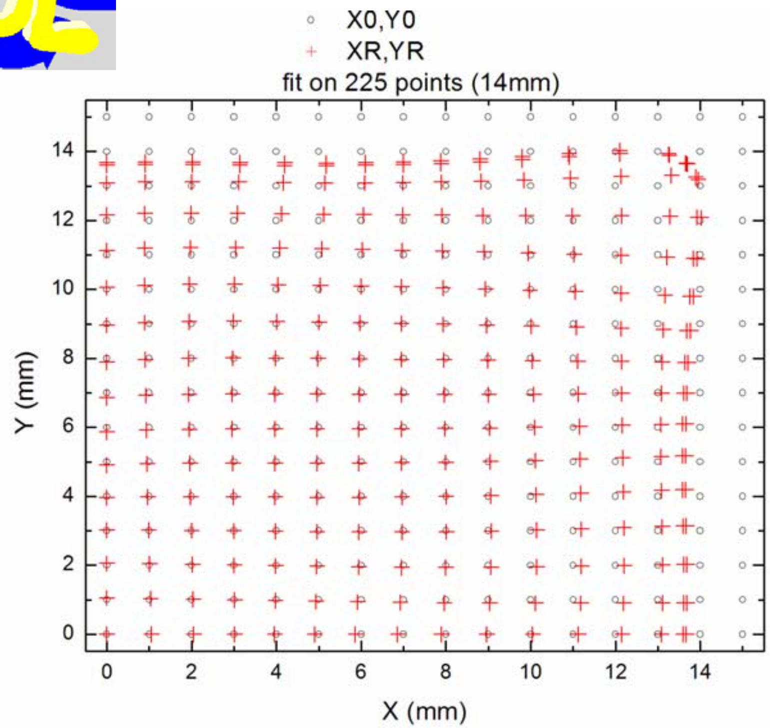


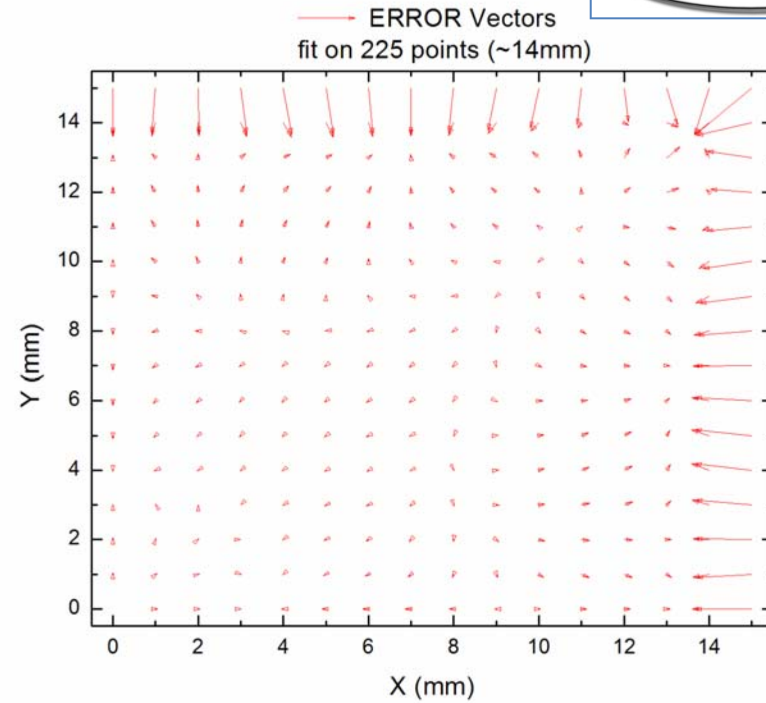


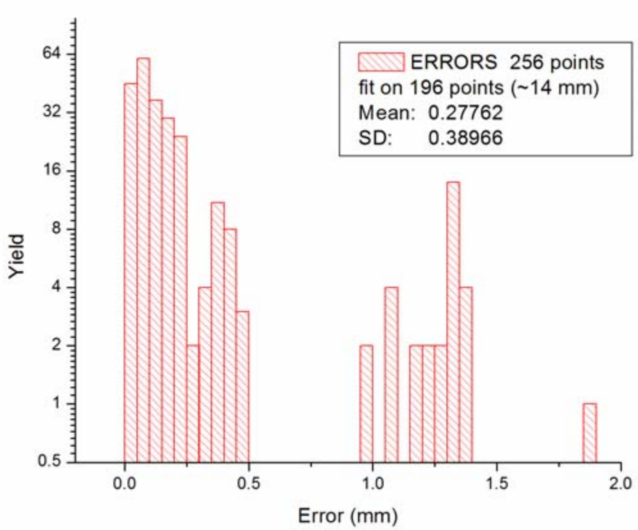


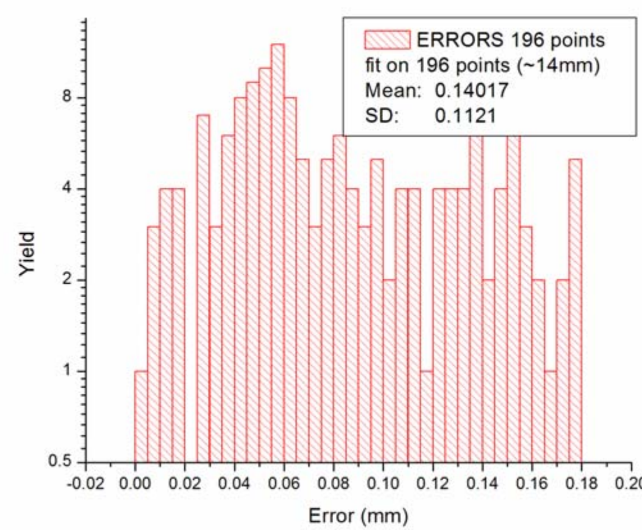


Fit on 225 points









LAcpsDD Proposal Submitted in Romania in Response to a Recent Call, 2012-2014

Executive Summary

We propose to develop a large area, continuous Position Sensitive Diamond Detector (LAcpsDD) for the detection of ionizing particles. We shall take advantage of the exceptional physical properties of the novel polycrystalline (pc) and single crystal (sc) diamond materials developed during the past two decades using the chemical vapour deposition (CVD) technology.

The detector will have an active area of minimum 30 x 30 mm^2 and provide an very low systematic error (0.1%) for the reconstruction of the radiation incidence point. The device will be optimized in position resolution, time response and rate capability for beam monitoring in hadron-therapy, ion accelerators, or particle detection for space research experiments.

For the high precision position read out we propose an innovative approach: we shall use a Diamond Like Carbon (DLC) resistive layer on one side of the detector to collect the electrical charge created by the incident particle in combination with the 'four points measurement' method, reducing considerably the signal processing load. The position information will be derived by a suitable mathematical algorithm. The performance of the detector unit will be enhanced by matched front end electronics (FEE).

LAcpsDD Proposal Submitted in Romania in Response to a Recent Call, 2012-2014

Executive Summary (continued)

The goals of the project are:
1.Definition of the proper geometry and parameters of the resistive DLC layer by simulations.
2. Implementation of Digital Signal Processing (DSP) circuits for high rate, real time data processing.
3. Optimization of the resistive layer geometry, in order to comply with the DSP task and to reduce the online data processing time in such a way that the count rate capability will be close to the intrinsic time resolution of the detector (MHz to GHz).

Two prototypes to be realized during the project:
1. a 30x30 mm^2 pcDD, whose resistive layer geometry and position reconstruction algorithm will be defined. At this stage the FEE will consist preamplifiers read out by a standard NIM-CAMAC.
2. a 30x30 mm^2 scDD, based on the new single crystal Diamond on Iridium (DoI) material. The FEE will be completed with ADC convertors and DSP circuits.

The project will be realized by a multi–disciplinary team covering the required expertise in electrical engineering and detector physics, as well as numerical simulations and computer applications.

Summary

The initial simulations confirm that a Large Area continuous position sensitive Diamond Detector can have systematic errors less than 0.1%.

We intent to make the first prototype with a pcDD having 30 mm x 30 mm size. This prototype will be ready for tests in three months.

If the LAcpsDD proposal will be approved, the second prototype will have a sc DOI DD and the FEE including local data processing.

Outlook

We would like to invite you to cooperate with us:

Very soon we plan to have a prototype ready, together with all the software involved, as a “plug and play system”. As soon as the work is completed, the prototype will be available for tests for our community.