PIN-photodiodes array for AREAL electron beam monitoring

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Designed to measure visible radiation, PIN-photodiodes are also sensitive to charged particles and neutrons because of their specific structure features. PIN-photodiodes can be used as detectors of nonionising energy losses in neutron and proton fields (due to radiation degradation of the carrier lifetime and the changing resistivity of the material) and also as detectors of ionizing radiation/particles. In this work we present a device consisting of 64 PIN-photodiodes arranged on a 70 x 70 mm^2 matrix. Preliminary calibration of the matrix is made by light irradiation (at complete absence of light and at about 60 % of the upper range). The first experiments were performed on the electron beam of the AREAL accelerator at the beam exit from the vacuum chamber at different distances from the output window (up to 1000 mm). The data were compared with measurements by an reference dosimeter.

https://www.ujf.cas.cz/export/sites/ujf/.content/files/CRREAT/kakona_thesis.pdf

Silicon PIN diode is a semiconductor structure with three layers - heavily doped p^+ and n^+ layers and i layer from intrinsic silicon. Practically, the intrinsic region is manufactured from very lightly doped n^- silicon. This diode is operated with reverse bias voltage as we can see in figure 5. An advantage of this diode is a wide thickness of depleted region (sensitive volume) stretching over the i region and slightly beyond it.

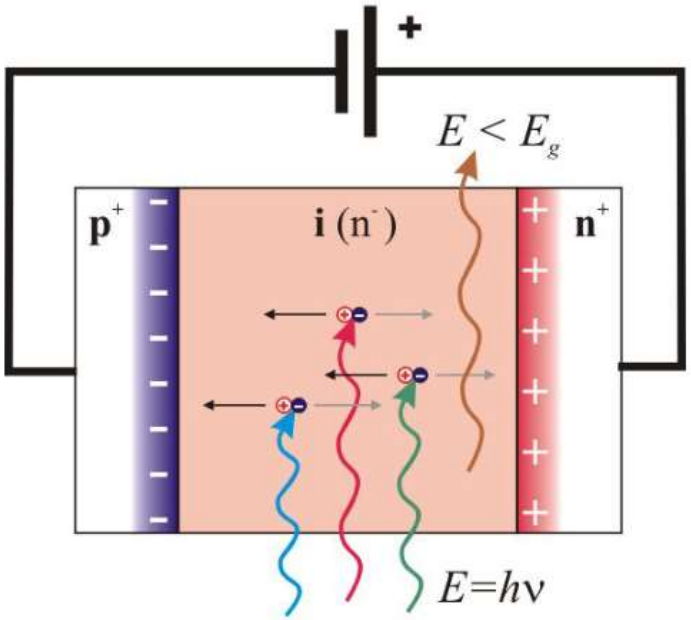
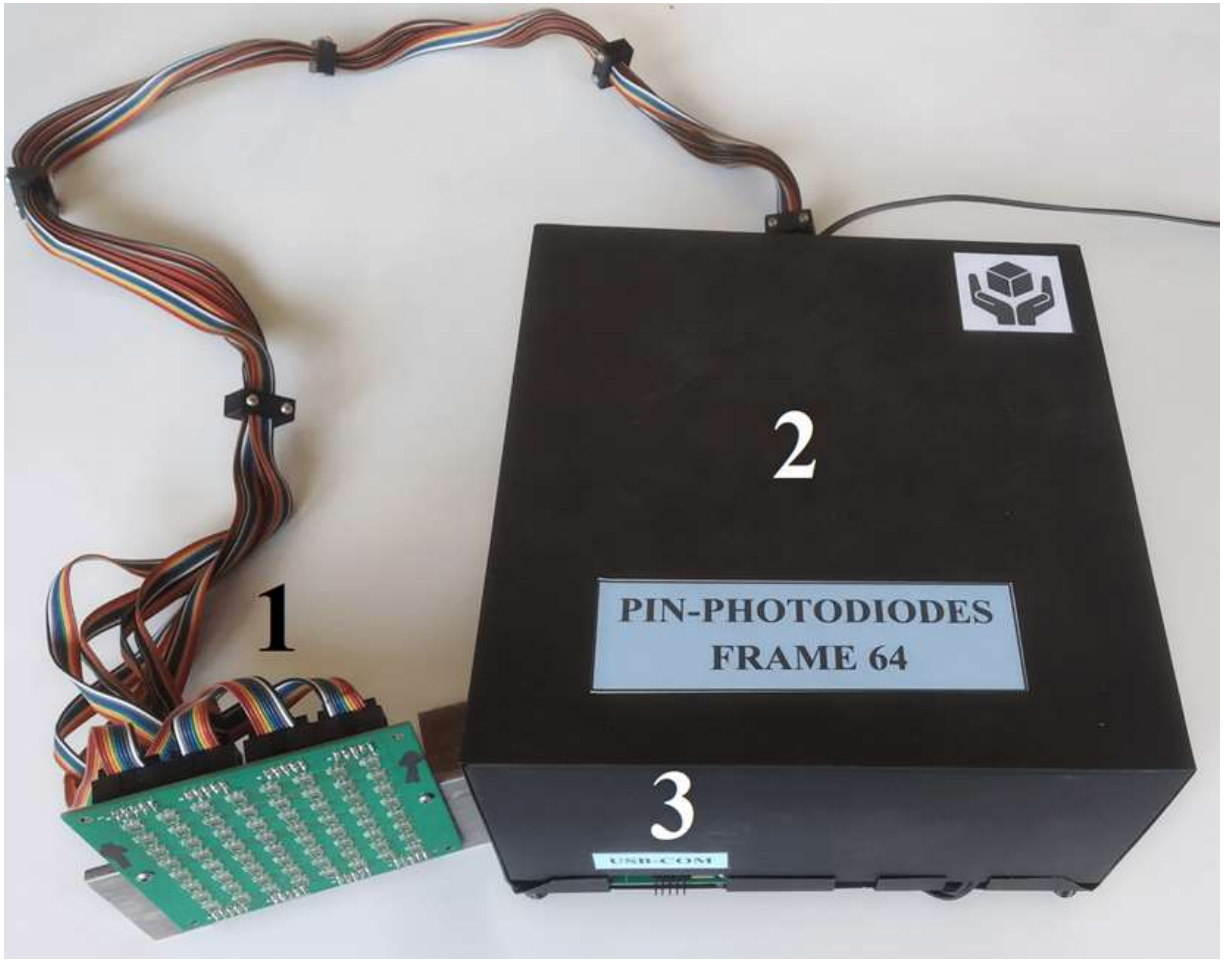
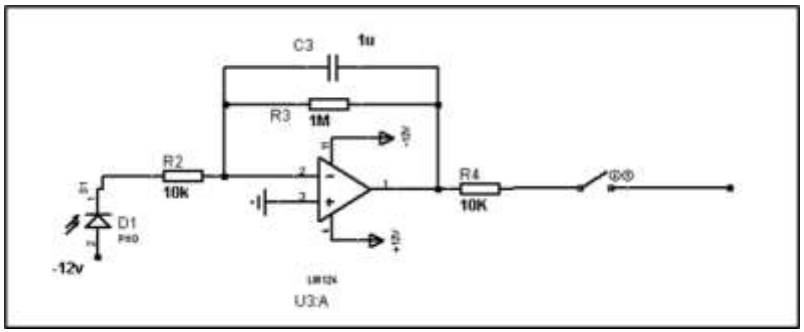


Figure 5: *Structure and principle of ionising particle detection with reverse biased PIN diode. Picture taken from (Lappetito 2017) .*

PIN diodes with relatively large areas are available commercially as photodiodes. Sample of diodes used in this work are S2744 (manufactured by Hamamatsu) and BPW34 (many manufacturers).

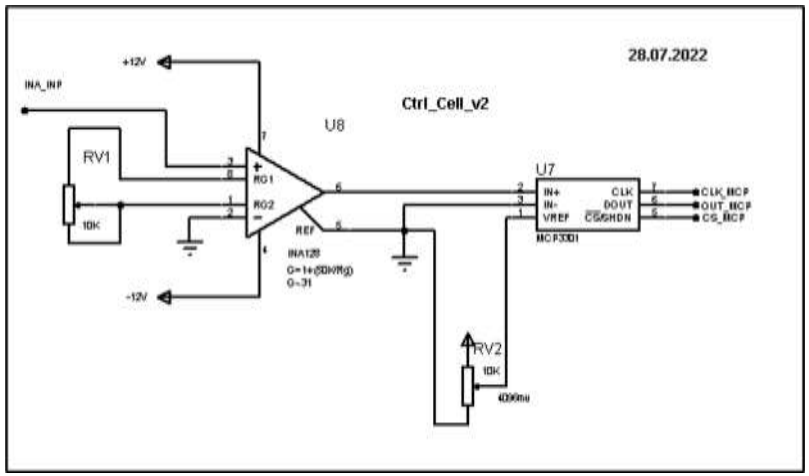


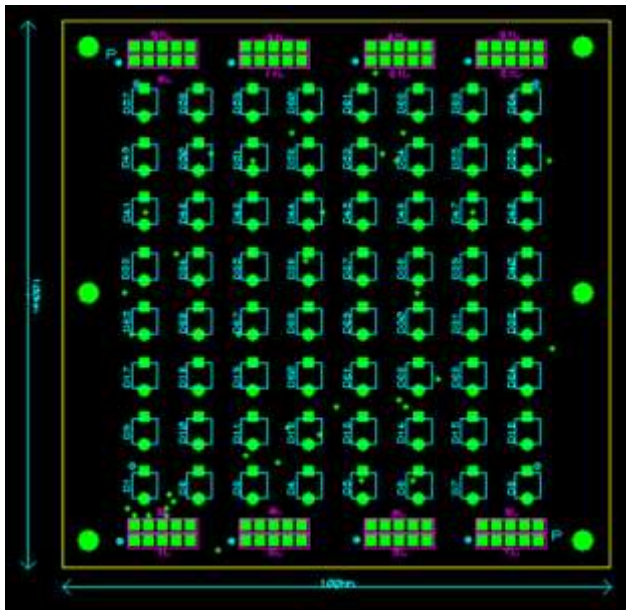
1 - PIN-photodiodes array, 2 - box with electronics, 3 – COM/USB interface.

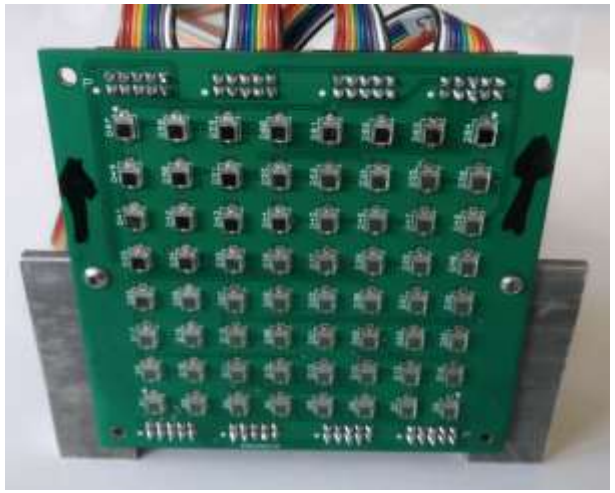


Integrating circuit of photodiode readouts based on LM124 operational amplifier. The electronic key controlled by the microcontroller is depicted as a conventional key.

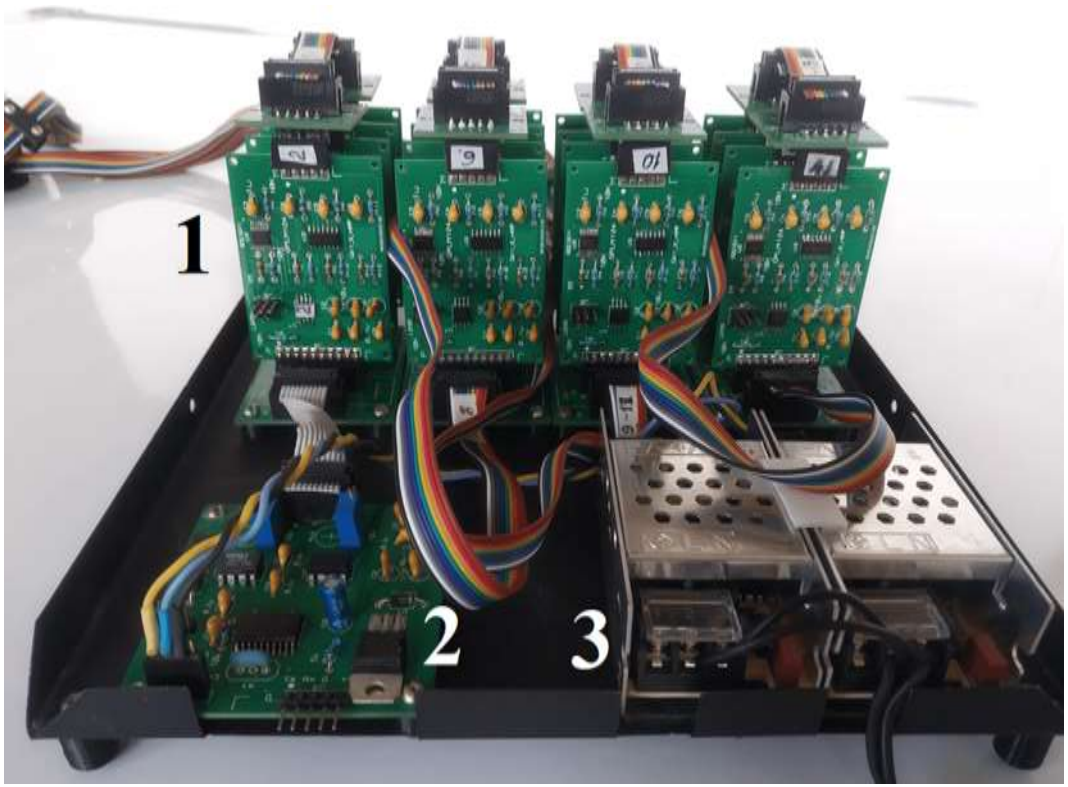
INA128 amplifier and MCP3301 ADC block common to all photodiodes.



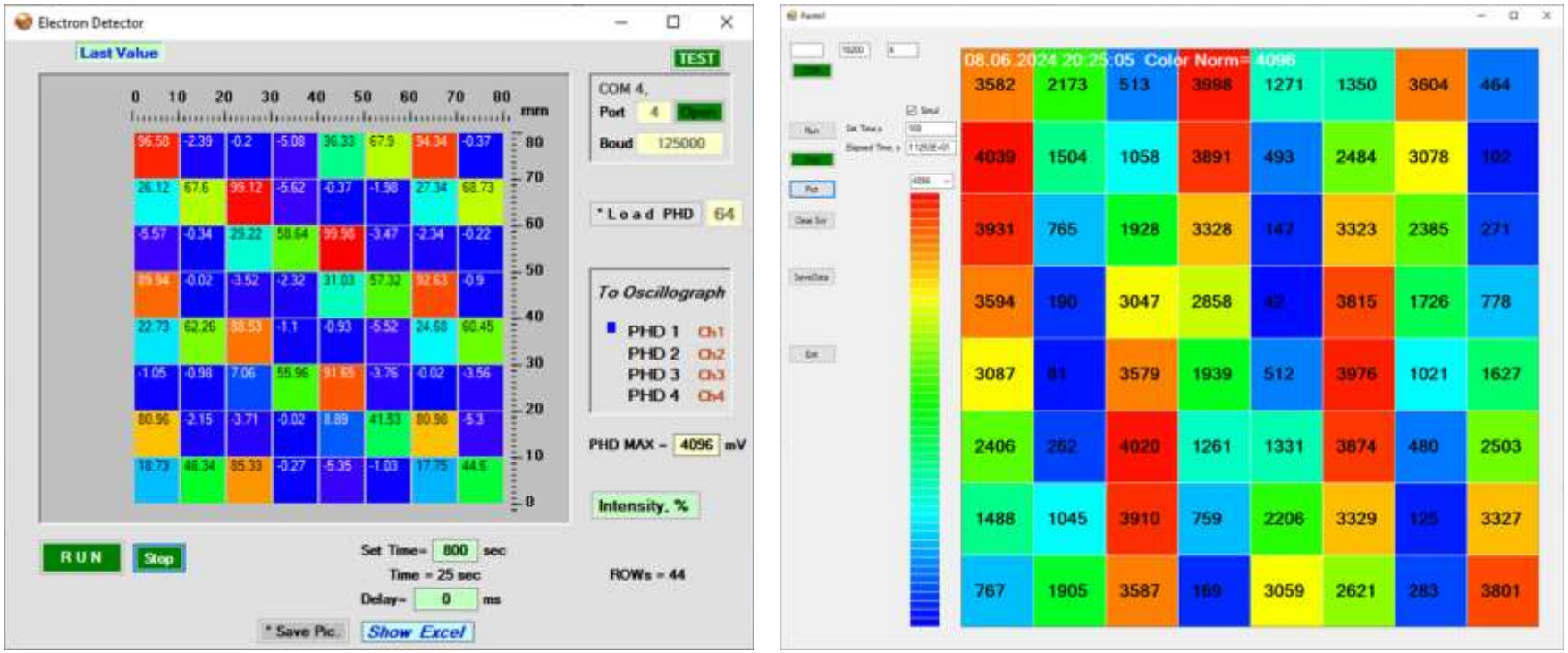




PIN-photodiodes board. Numbering of photodiodes was performed by rows from left to right, with an offset upwards, photodiode D1 at the bottom left, D64 - at the top right



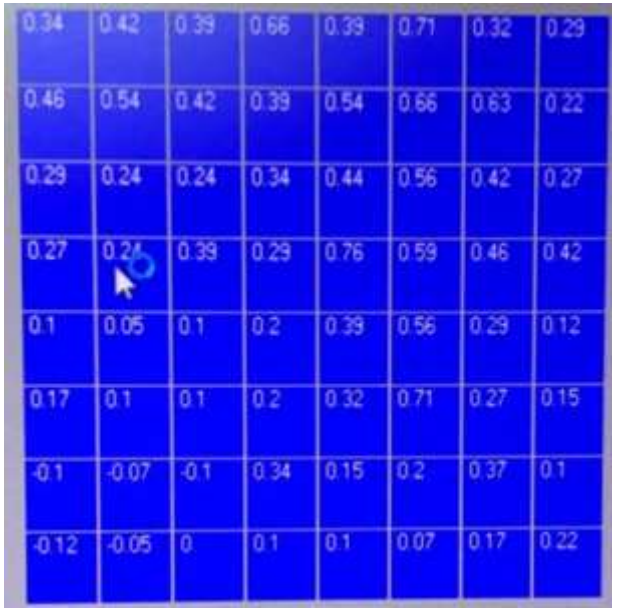
Boards in the electronics box



Graphical interface of the program

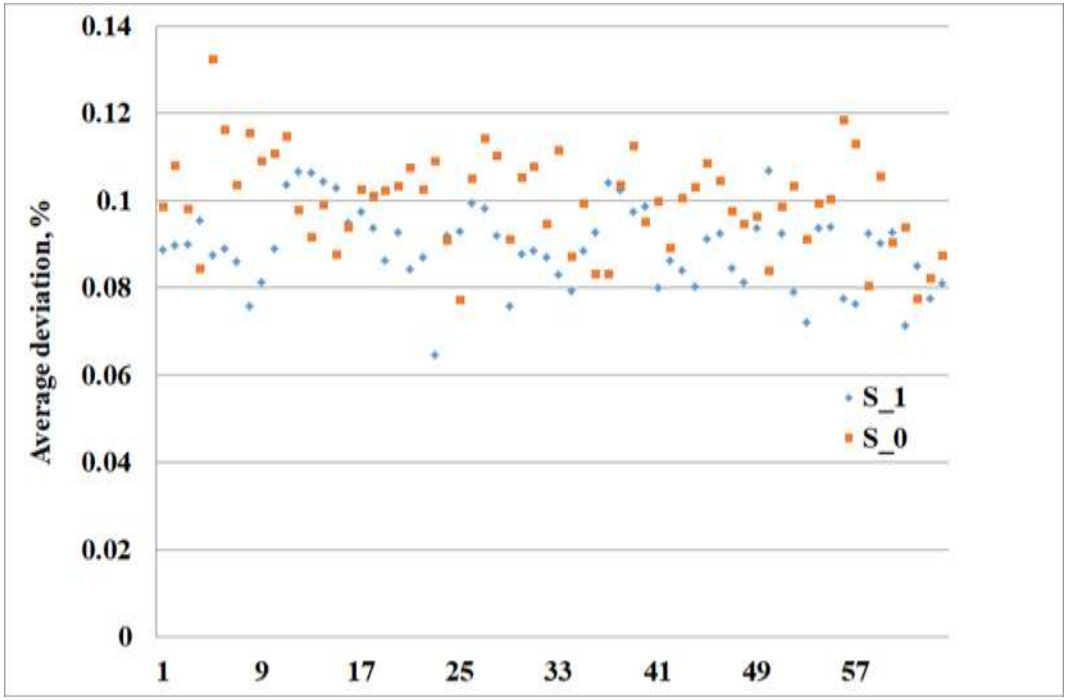
2.29	2.27	2.2	2.34	2.27	2.39	2.34	2.32
2.08	2.29	2.44	2.64	2.08	2.29	2.22	2.37
1.86	2.03	1.88	1.98	1.78	1.73	1.68	1.81
1.44	1.42	1.49	2	1.51	1.83	1.59	1.59
0.83	0.68	1.1	1.25	0.88	0.73	0.63	0.54
-0.17	0.44	0.46	0.66	0.29	0.46	0.39	0.63
-0.59	-0.56	-0.66	-0.2	-0.76	-0.73	-0.71	-0.76
-0.98	-1.05	-1.05	-0.88	-0.95	-0.95	-1.12	-1.12

Readouts in total absence of lighting without calibration procedure



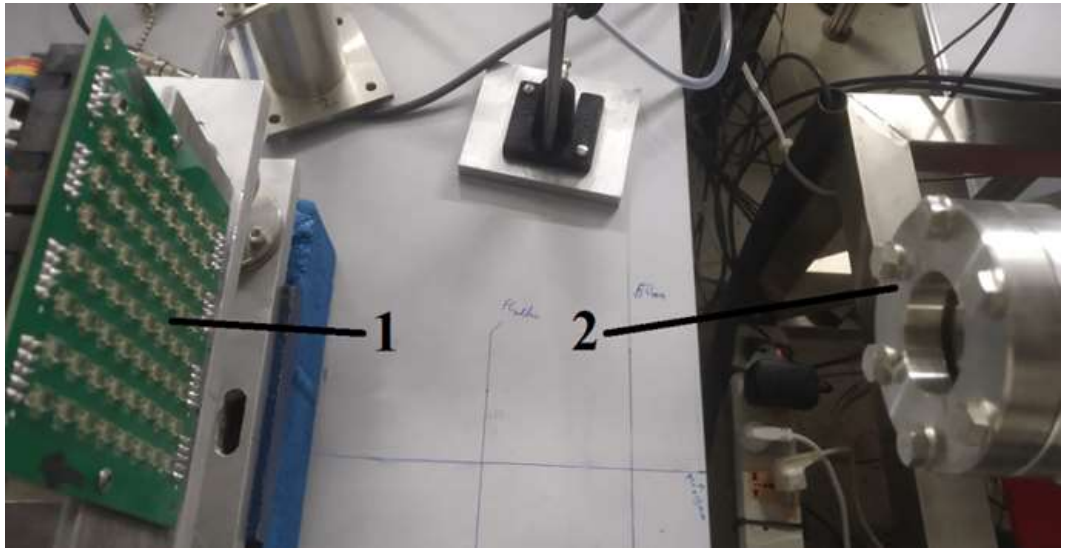
After calibration

"2500" level were recorded in arrays $S_0(i), S_1(i), i = 0,...,63$. Calibration of photodiode readings was performed by the equation $\tilde{S}(i) = \overline{S}_1(S(i) - S_0(i)) / (S_1(i) - S_0(i)), i = 0,...,63$, which returns all readings of photodiodes in the absence of lighting to the zero, and all readings in the calibration lighting to the value $\overline{S}_1$ (average value of readings $S_1(i)$). For the actual calibration that was applied $\overline{S}_1 = 2596.7$.

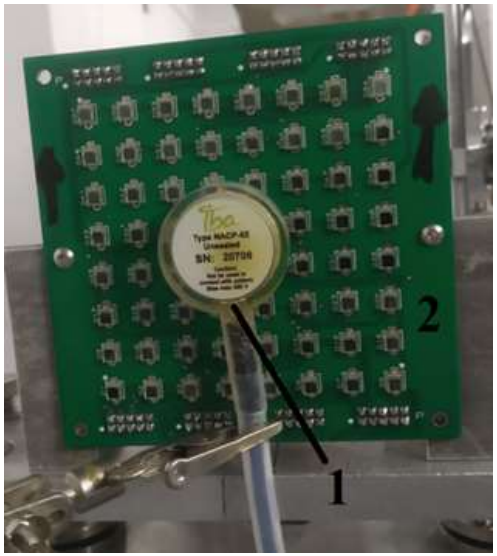


Standard deviations of photodiode readings after their calibration

Experimental setup



1 - photodiodes array, 2 - outlet flange



Positioning of probe ionizing chamber of dosimeter (1) in front of the photodiodes array (2)

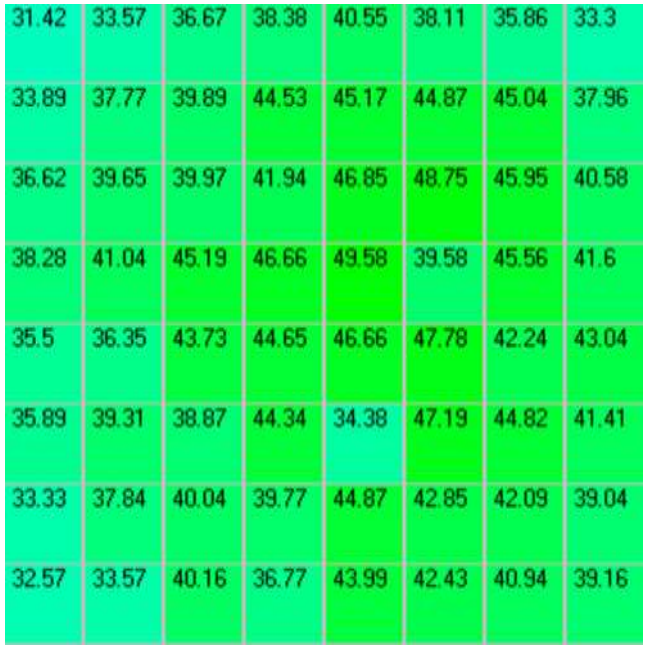
Dose-1 Dose Meter with NACP-02 ionization chamber

9.64	9.13	9.62	10.23	10.03	9.69	9.47	9.55
9.42	9.69	9.81	10.3	10.23	10.3	11.01	9.69
9.16	9.03	9.33	8.89	9.89	9.52	10.42	9.72
9.03	9.16	9.35	9.62	9.52	9.16	9.38	9.03
8.84	8.33	9.06	9.79	9.74	9.23	8.57	9.42
9.01	9.35	9.45	9.35	9.33	9.62	9.16	9.3
8.45	8.89	9.28	8.47	9.59	9.52	9.13	8.89
8.69	8.84	9.79	9.57	9.45	10.08	9.74	9.69

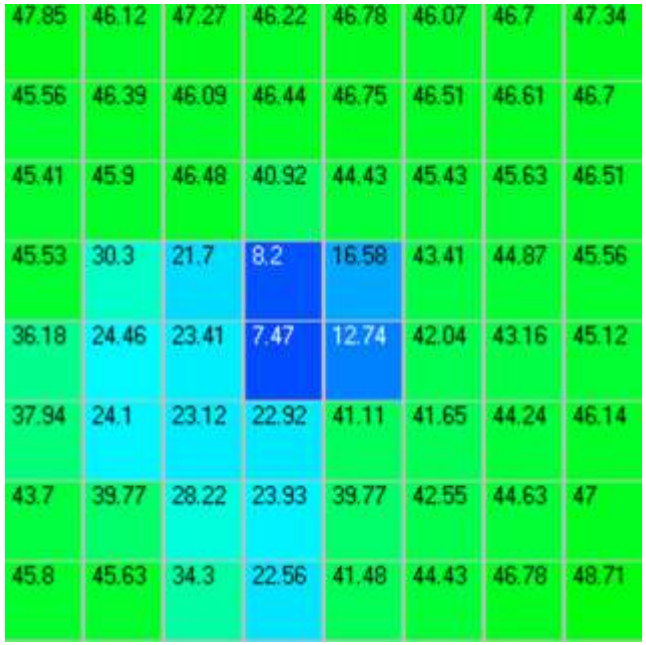
Photodiode readouts at a distance of 1000 mm from the output flange (as a percentage of the upper measurement limit of 4096)

25.71	26.12	28.25	29.83	30.66	29.47	27.91	27.08
26.71	28.86	29.98	32.79	33.47	33.47	34.38	29.17
28.32	30	29.91	30.81	34.08	35.64	34.2	31.42
29.13	30.93	32.86	33.94	35.57	29.61	34.01	31.32
28.98	28.34	33.69	34.47	35.3	34.72	30.86	32.35
28.88	31.45	30.66	34.81	28.15	35.77	34.81	32.54
27.71	29.76	32.08	30.88	34.86	33.94	33.01	32.18
27.83	27.91	32.4	30.69	34.57	34.28	32.96	32.79

At 500 mm



At 400 mm



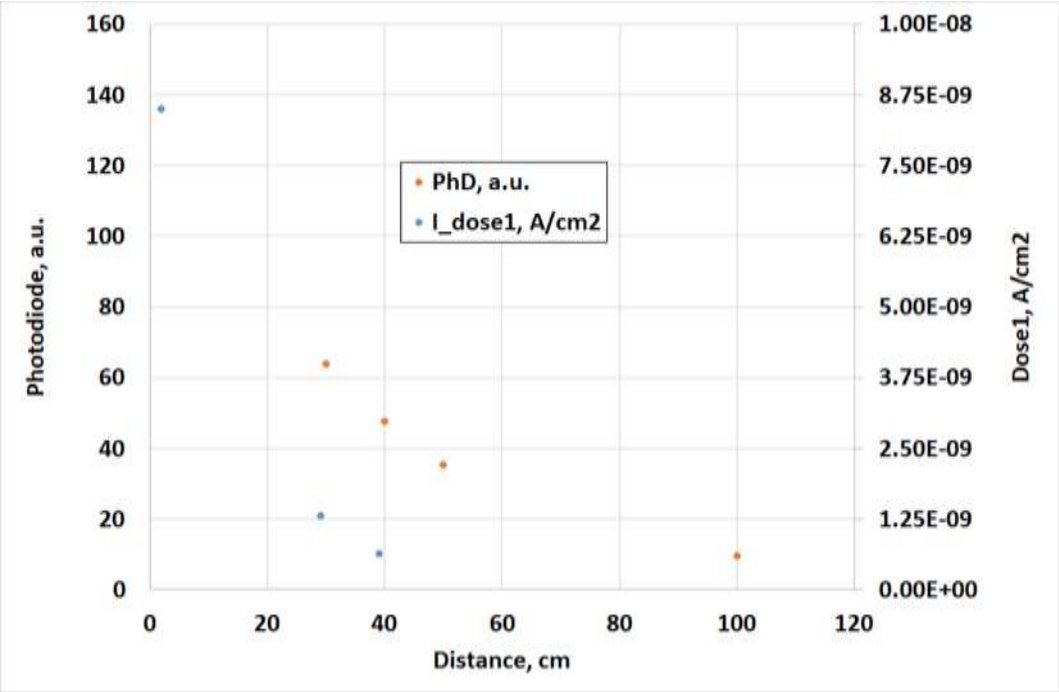
At 400 mm, dosimeter ionizartion chamber in front of array

32.62	37.18	41.67	44.6	47.34	44.09	39.72	36.23
37.35	43.48	48	53.52	55.32	53.86	53.59	43.38
42.09	46.9	47.61	52.51	58.57	60.28	56.1	48.07
44.38	49.66	57.01	59.01	63.82	46.88	56.35	49.32
43.68	46.51	59.11	59.55	64.06	59.3	51.42	52.2
41.26	49.73	49.76	58.79	43.77	62.33	58.5	52.2
37.74	44.68	48.71	48.85	54.88	52.76	51.32	46.22
35.11	38.28	46.29	43.41	52.91	50.63	47.63	44.46

At 300 mm

39.75	45.07	50.34	53.05	57.2	51.64	47.36	43.95
45.78	52.03	57.86	64.62	67.58	63.84	63.4	52.05
50.68	56.08	57.52	19.9	24.51	75.02	66.43	57.52
54.17	59.77	33.5	32.08	31.37	44.41	66.53	58.81
52.05	55.47	62.04	30.76	32.71	69.73	60.45	61.23
51.46	58.86	59.47	75.07	41.24	75.76	67.92	62.04
48.71	56.03	61.62	64.4	39.16	67.31	63.94	58.18
46.14	48.54	58.98	56.1	31.91	66.41	61.11	56.4

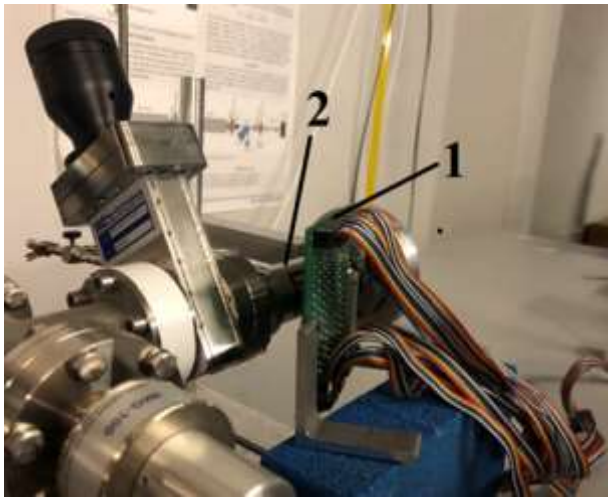
At 300 mm, dosimeter ionizartion chamber in front of array

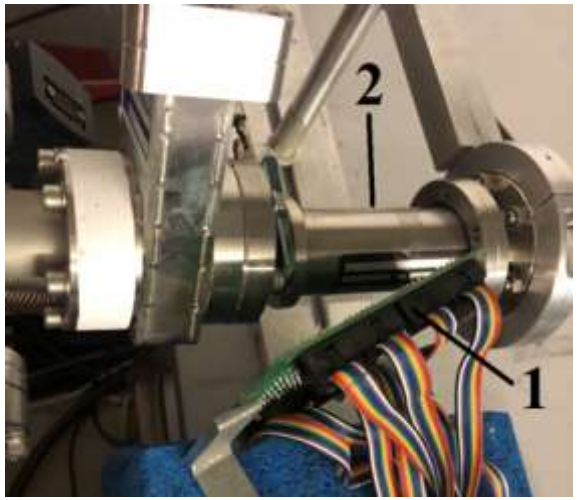


Comparison of photodiode and dosimeter readouts

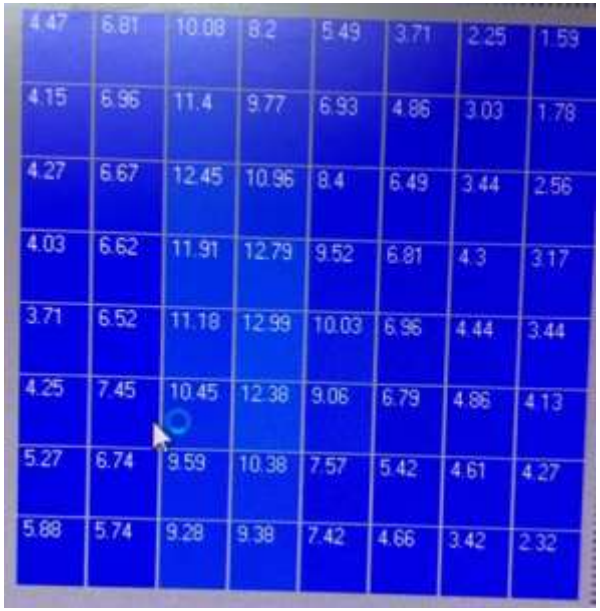
##	L, cm	Q, C	t, s	d, cm	S, cm2	I_dose1, A/cm2	I*L^2, A	I*L, A/cm	PhD, a.u.
1	2	2.67E-06	100	2	3.141593	8.50E-09	3.40E-08	1.38E-08	
2	39	2.02E-07	100	2	3.141593	6.44E-10	9.79E-07	8.36E-09	
3	29	4.15E-07	100	2	3.141593	1.32E-09	1.11E-06	1.39E-08	
4	100								9.7
5	50								35.5
6	40								47.8
7	30								64

Comparison of photodiode and dosimeter readouts





1 - Faradau cup,
2 - PIN-photodiode array



Slit between Faraday cup flange and beamline flange is detected

PIN photodiodes and, in particular, BPW34 caused this type of installations to be included in the catalog SOLID-STATE SENSORS FOR RADIATION MONITORING [F. Ravotti, M. Glaser, M. Moll, CERN - TS Department, TS-Note-2005-002, 2005.]

Dependence of the PIN-photodiode readings on the fluence of the measured beams (integral of the particle flux over time). Recalibration of readings based on the results of measurements with the help of an reference dosimeter.

PIN-photodiodes should be calibrated with the measured beam type. Self-calibration of the array, for example, by rotation or movement of the photodiode array, when different photodiodes are substituted for the same exposure level of the beam and further mathematical processing is performed.

To develop a modification of the device without integrating chains for each photodiode. By decreasing the measurement speed, it would be possible to compactify the device considerably.

Thank you for attention

Acknowledgments
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