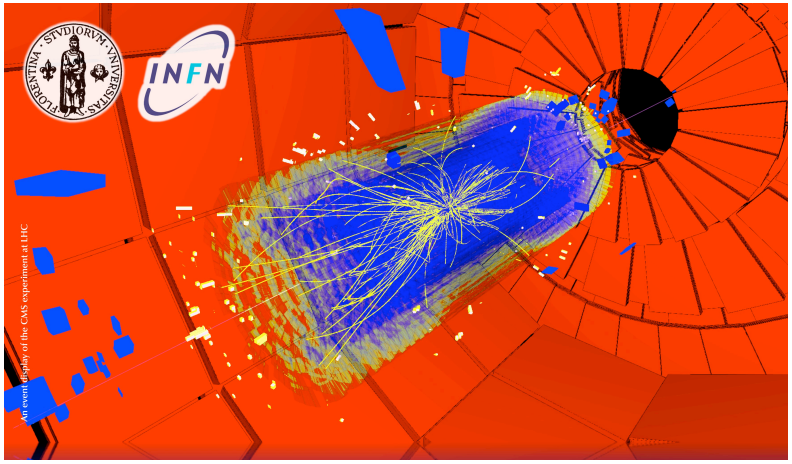


RD11 10th International Conference on Large Scale Applications and Radiation Hardness of Semiconductor Detectors

Semiconductor Detectors - Tracking Systems - Radiation Effects and Hardness - Electronics

Large-area high-quality polycrystalline Chemical Vapour Deposited diamond films as pixel detectors for Intensity Modulated Radiotherapy applications

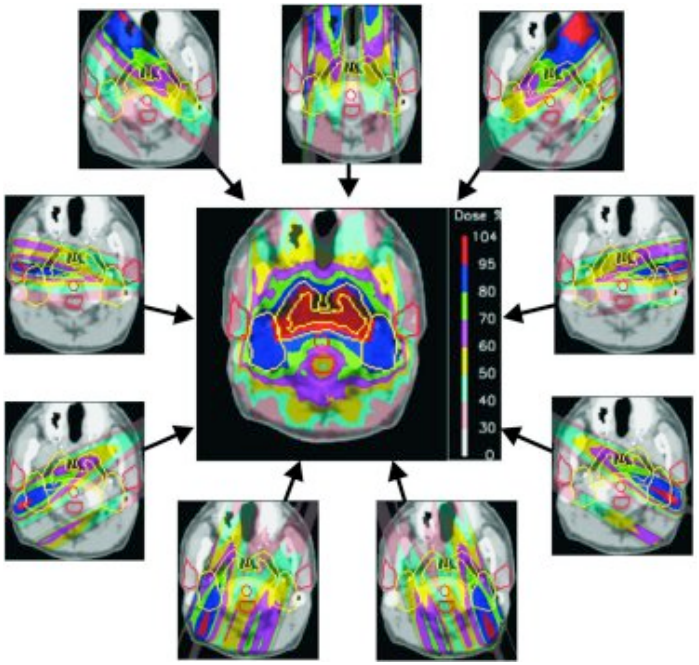
C. Talamonti

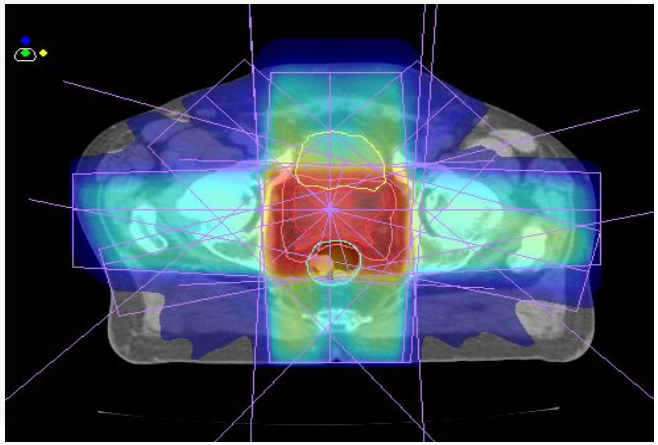
M. Bruzzi, M. Bucciolini, A. De Sio, E. Pace, M. Scaringella, L. Tozzetti, M. Zani

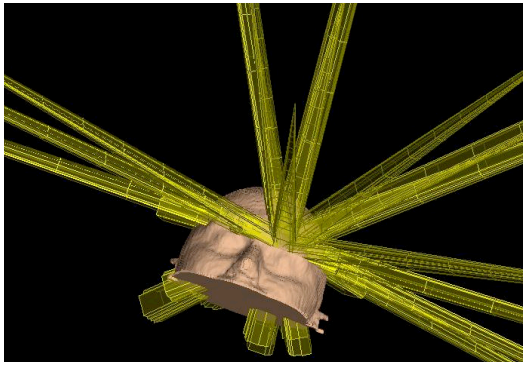
Outline

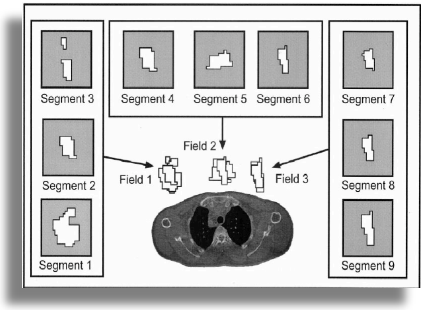
- Introduction
- Diapix
- Dosimetric characterization
- Conclusion

Clinical dosimetry in radiotherapy is well known matter but high conformal radiotherapy modalities (IMRT, Stereotactic treatments with photons and protons, IMPT) pose problems due to the **small radiation fields** with **high dose gradients**, to the **variation in space and time of the dose rate** and to the **variation in space** and **time of the beam energy spectrum.**









Radiation dosimetry must exhibits the following characteristic:

- High spatial resolution,
- Independent of the dose rate,
- Independent of the energy,
- Stable in time, with a good linearity and high dynamic range
- Tissue equivalent

Why Diamond?

- Diamond is potentially the best material for dosimetry due to its almost tissue equivalence.
- Dosimeters made with natural diamond are already commercially available but extremely expensive and rare due to the difficulty in selecting stones with proper dosimetry characteristics
- pCVD diamond films are low cost but their major drawback is the slow rise and decay time and the poor response stability
- The high crystalline quality of single crystal CVD diamond makes this material best suited to this purpose, main disadvantage is the limited active area (typically lower than 1cm2) and the high cost .

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Zero-bias operation of polycrystalline chemically vapour deposited diamond films for Intensity Modulated Radiation Therapy

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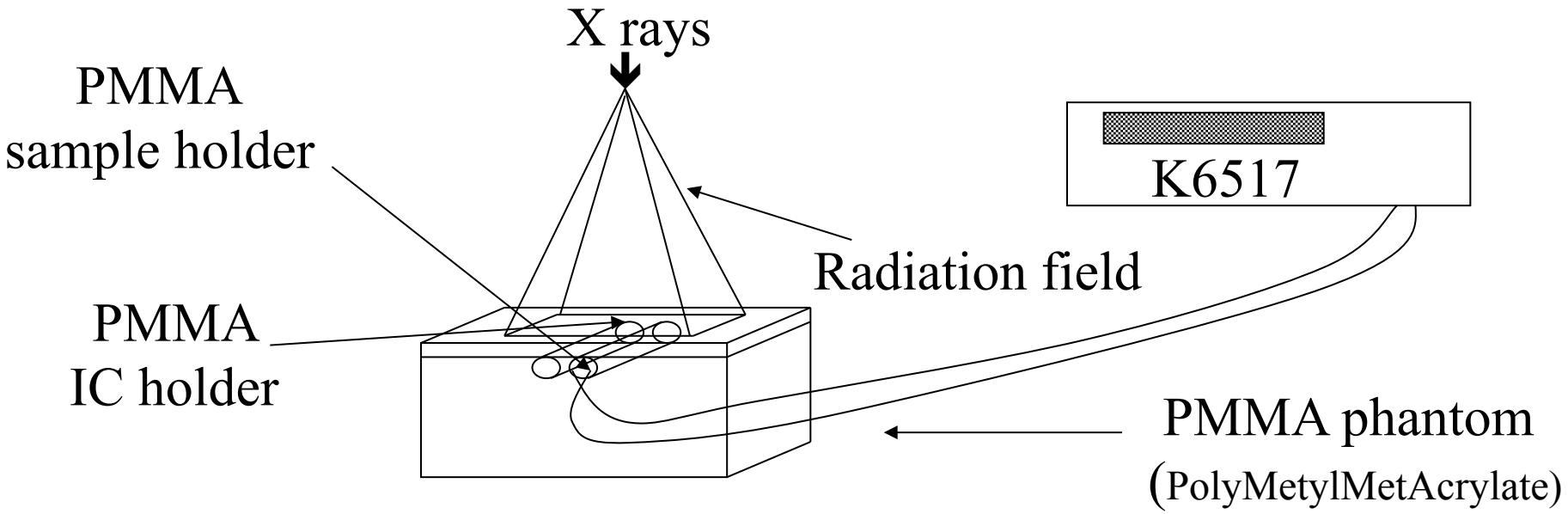
This paper investigates the use of high-quality state-of-art polycrystalline diamond films in clinical dosimetry, both for conventional and intensity modulated radiotherapy, in **photovoltaic regime**, namely in zero-bias operation.

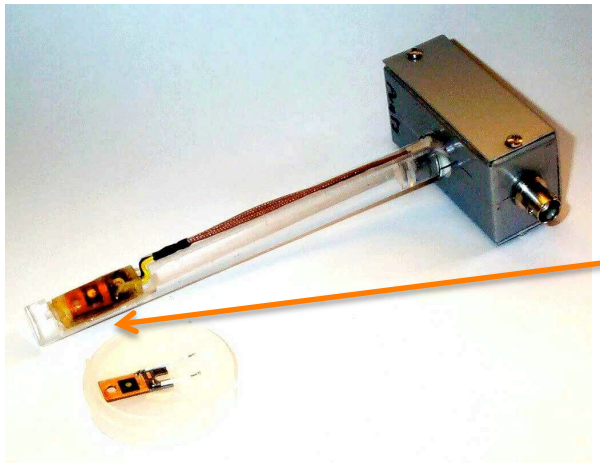
Experimental set-up

6-10 MV photon beam (Elekta linear accelerator)

10 cm x 10 cm

SSD = 95 cm d= 5 cm

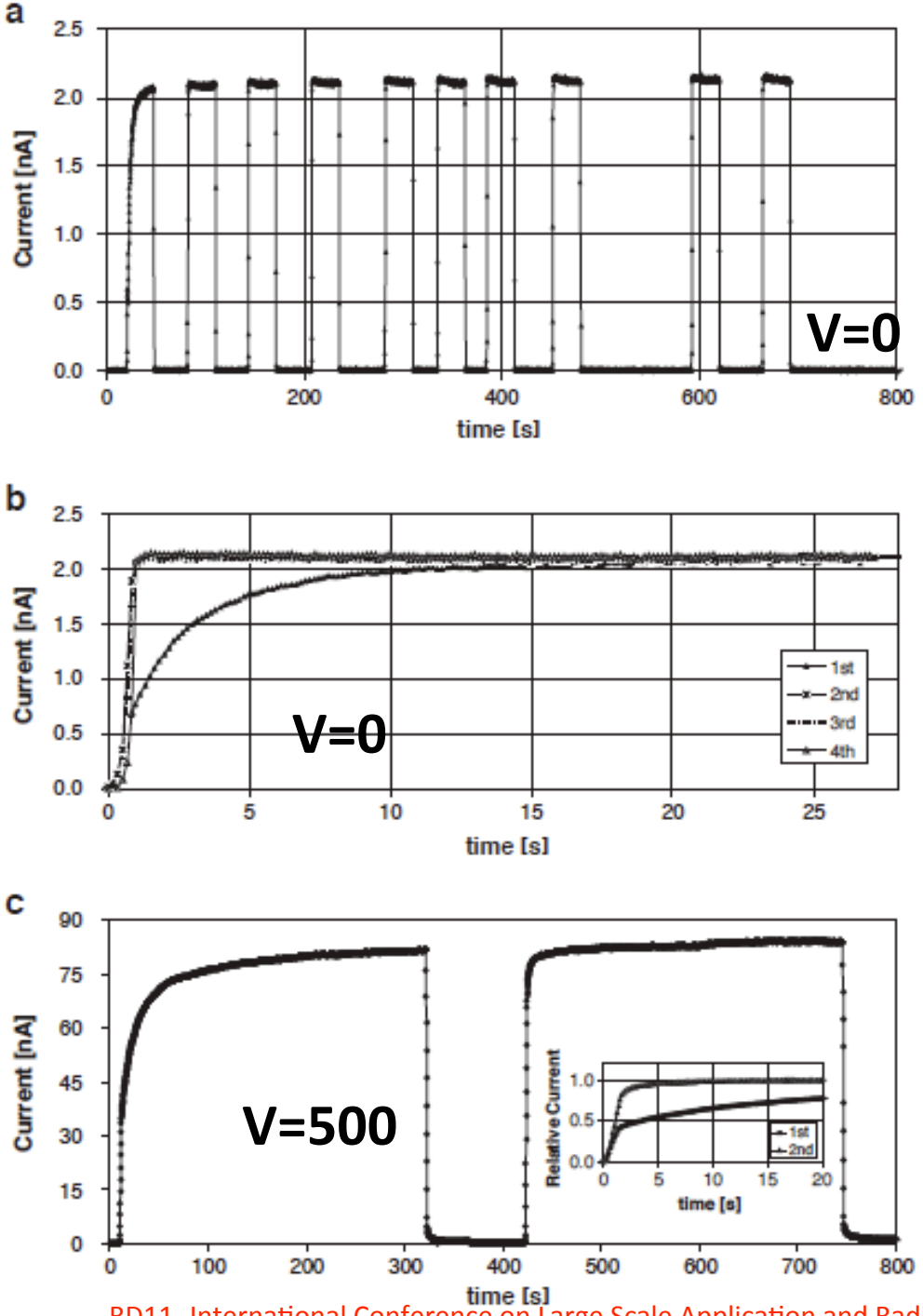




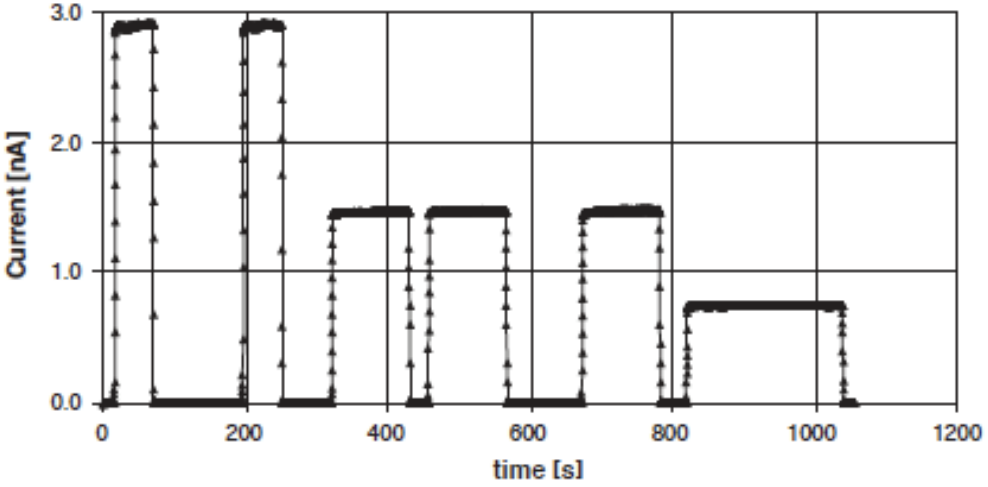
PMMA
sample holder

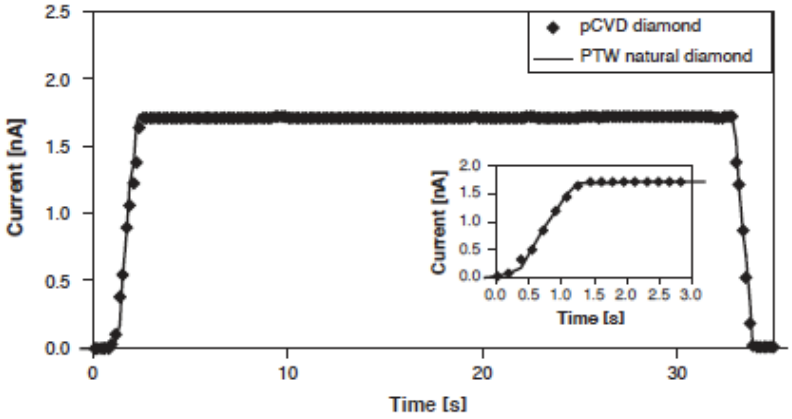
SAMPLES: polycrystallineCVD , undoped,
0.5 —0.5 cm2 size,
500 µm thick, produced by Element Six, U.K., in the framework of the RD42 CERN collaboration
Cr/Au electrical contacts on the front and rear surface

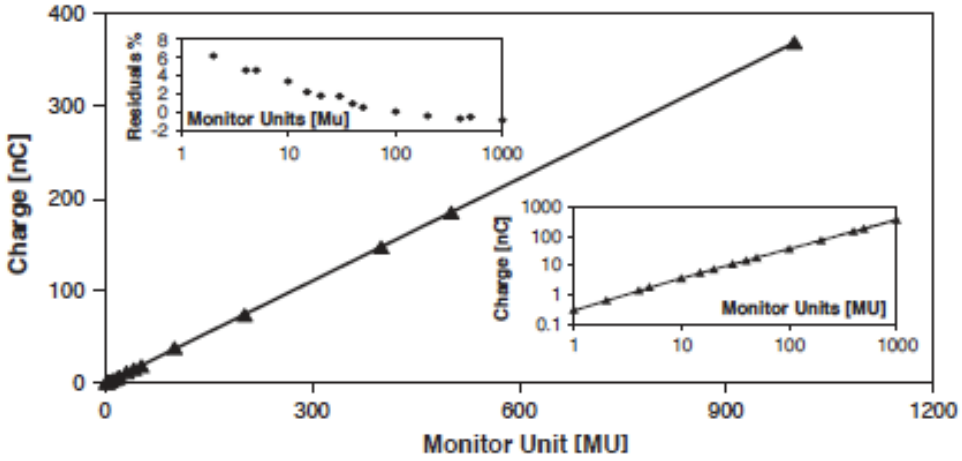
Measurements



A pre-irradiation dose reduced to almost half of that needed when external voltage is applied; excellent time stability after pre-irradiation, characterised by standard deviations less than 0.5% and a repeatability of about 0.4%;

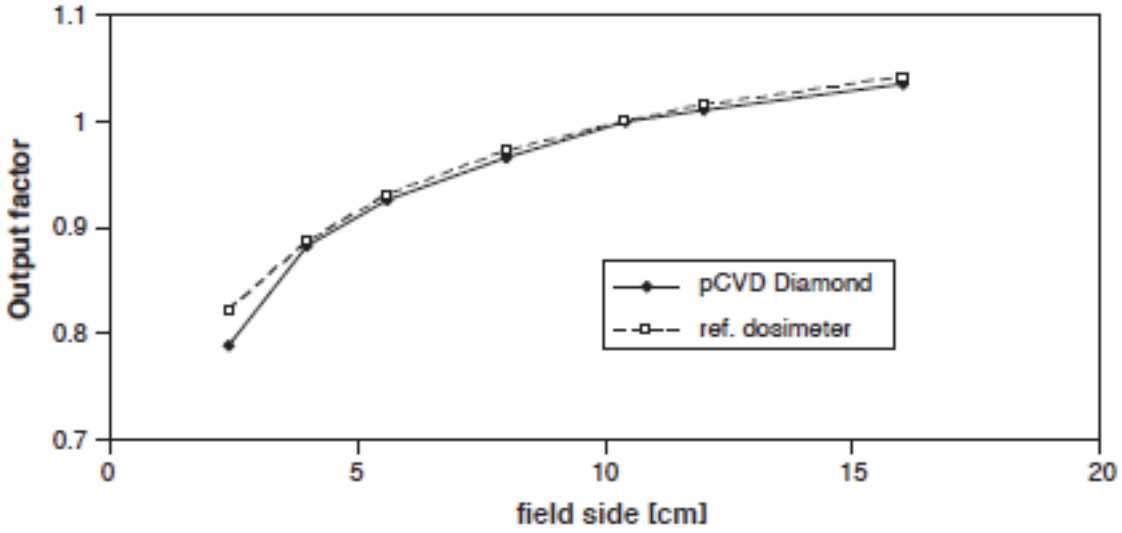




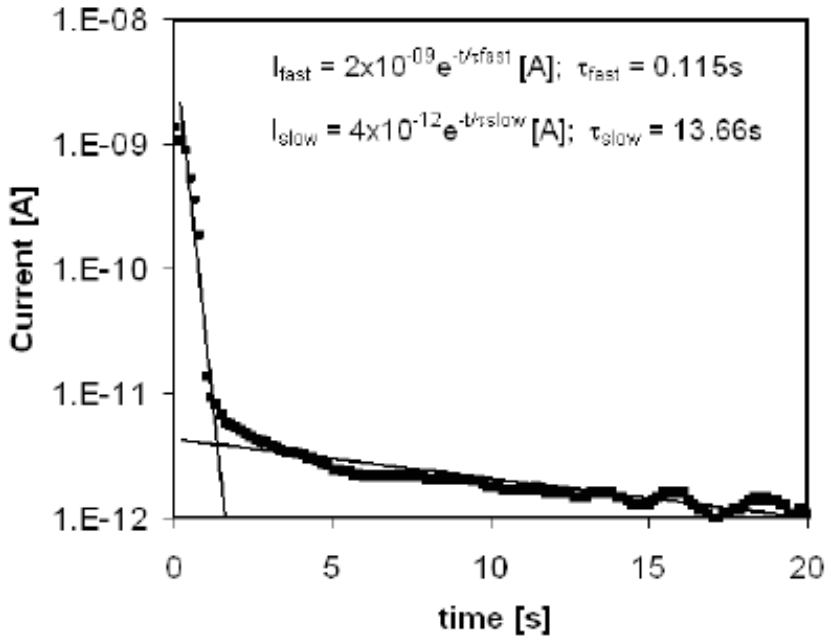


Fast rise times of the current signal, comparable to that of commercial reference dosimeters;

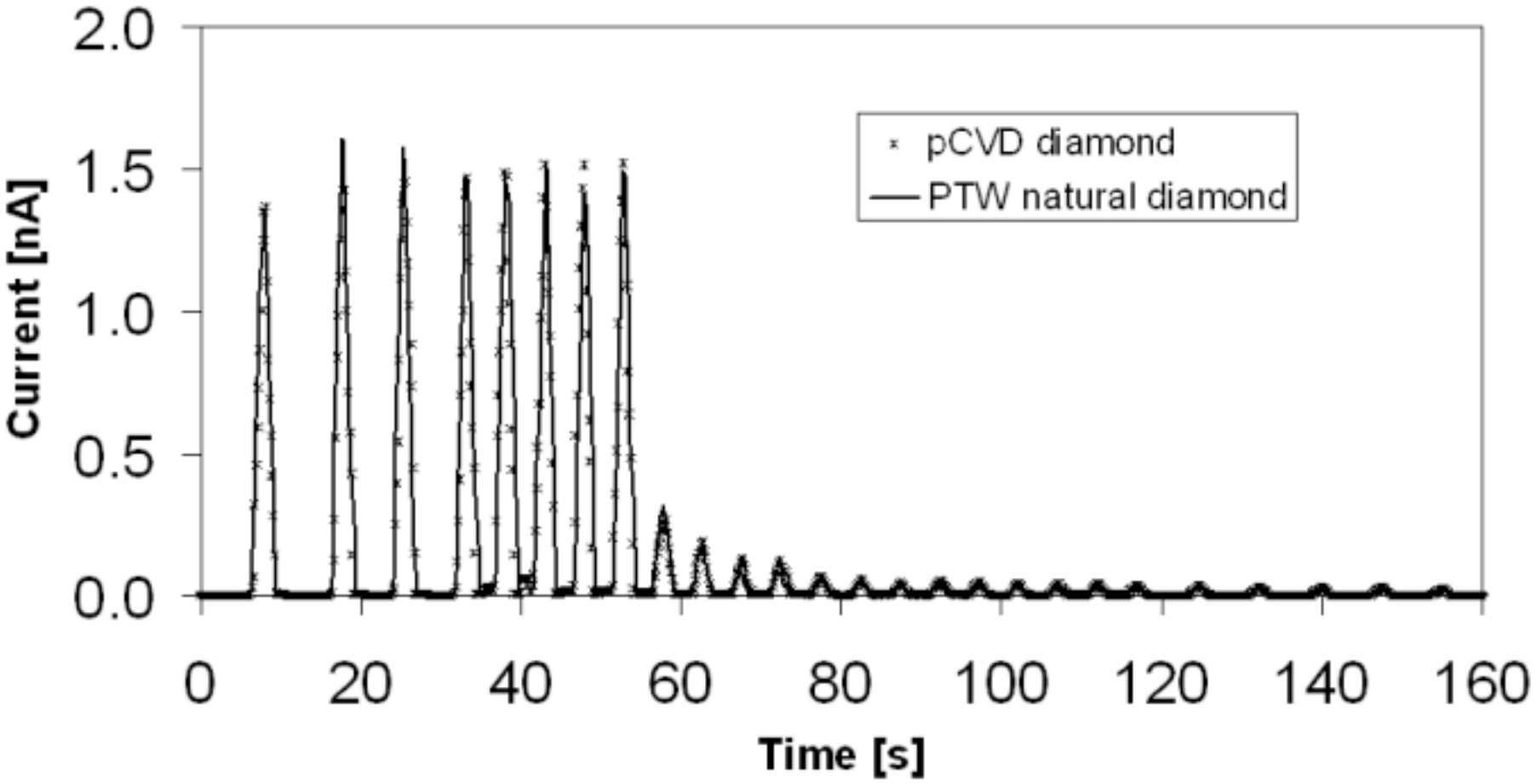
Linearity with dose of the collected charge proven over three decades, with mean value of residuals of 0.3% and a maximum deviation of 1.7%;



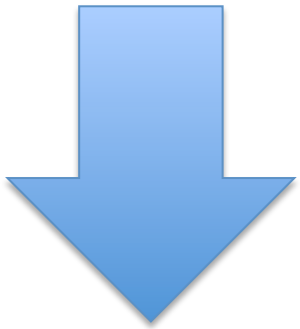
Output factors comparable to that of commercial reference dosimeters even for small fields.



High quality polycrystalline CVD diamond samples show promising results for IMRT when used in zero bias operation. This could open the way to the production of large active area 2D diamond dosimeters.



Results show that pCVD diamond detectors improve dramatically their dosimetric performances when operated in null-bias.

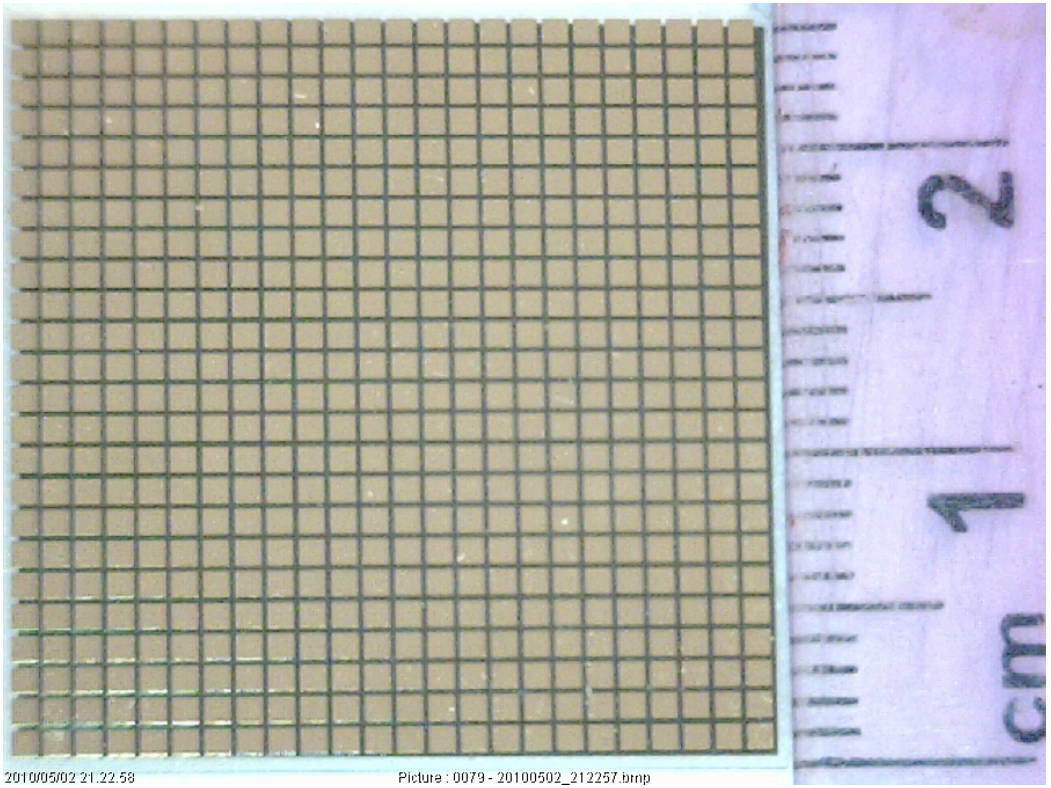


DIAPIX

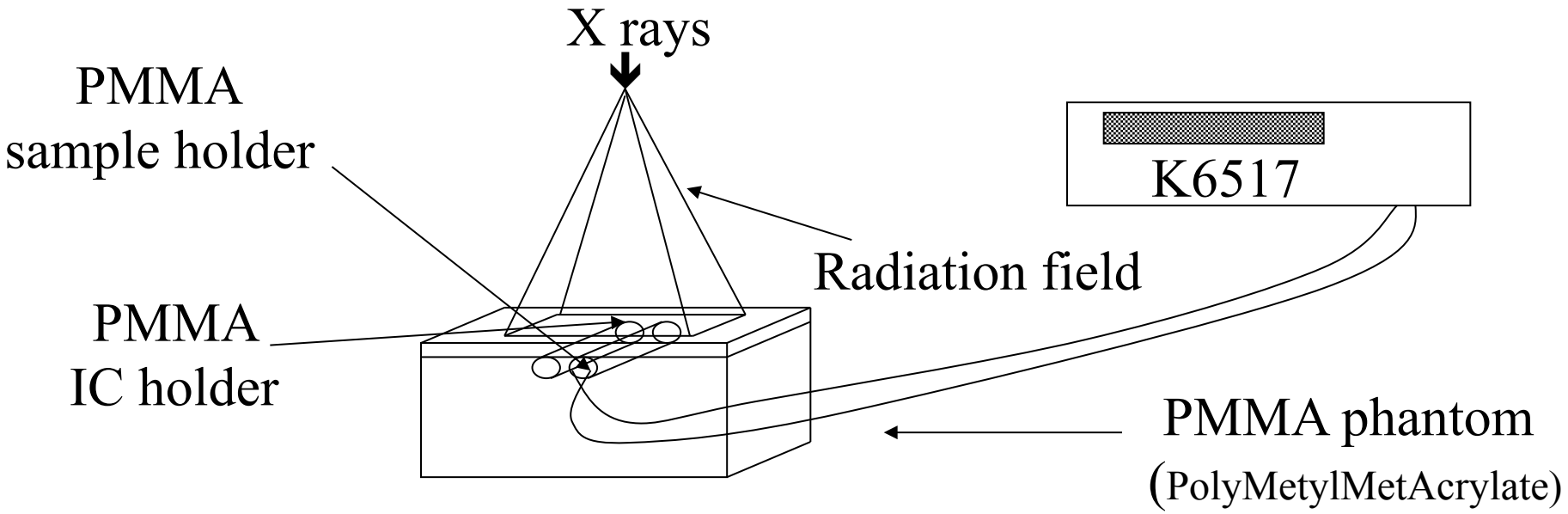
Development of a large-area high-quality polycrystalline Chemical Vapour Deposited diamond films as pixel detectors for Intensity Modulated Radiotherapy and proton therapy applications

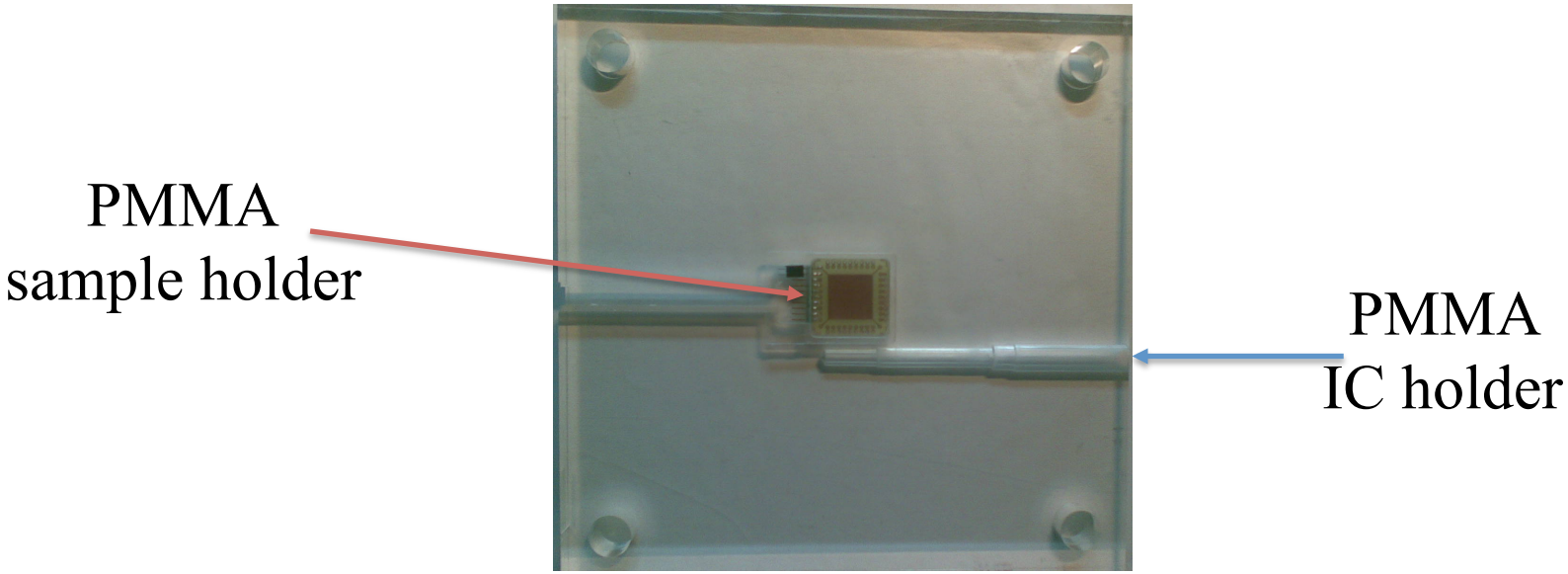
Diamond sample

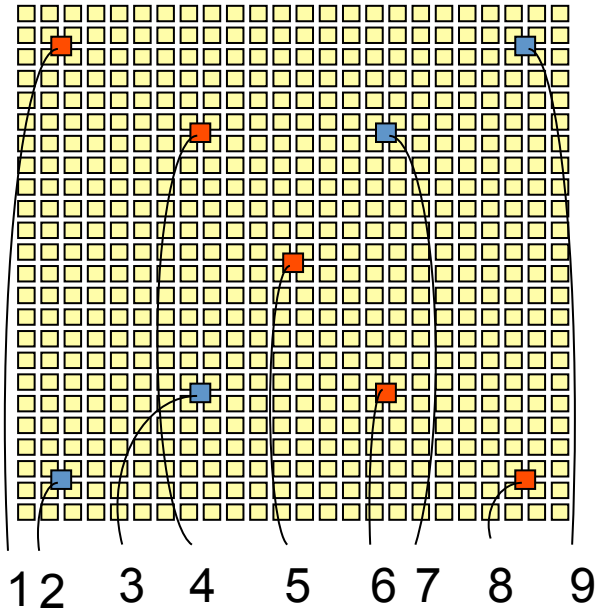
pCVD Diamond Detectors Ltd Detector Premium Grade



area 2.5 cm x 25cm , 24 x 24 pixel, pixel size 0.8 mm x 0.8 mm, 300μm thick, pitch 1mm, Cr-Au eletrical conctats


X rays
PMMA
sample holder
K6517
Radiation field
PMMA
IC holder
PMMA phantom
(PolyMetylMetAcrylate)

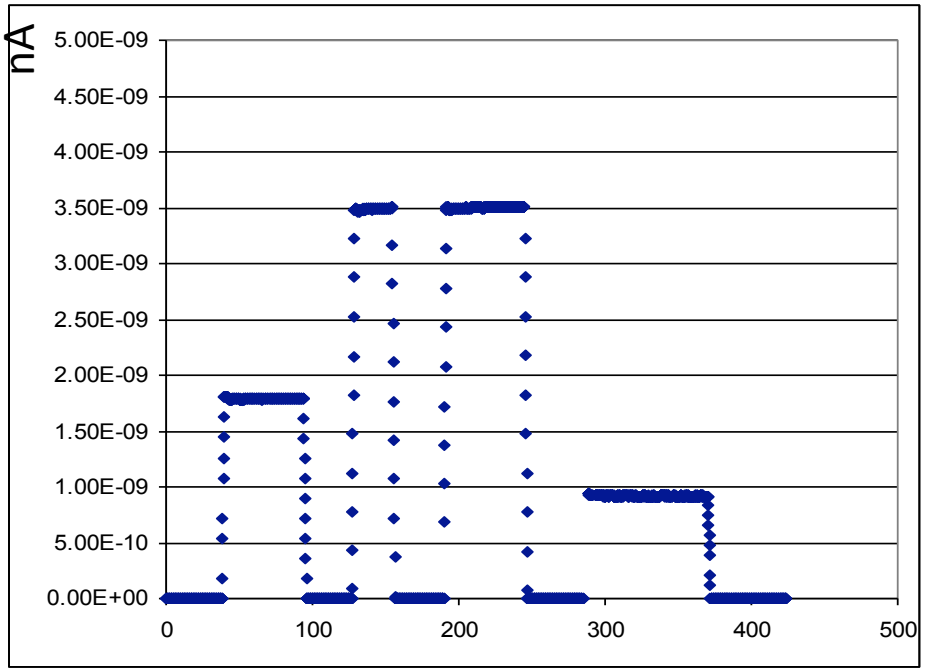

PMMA
sample holder
PMMA
IC holder

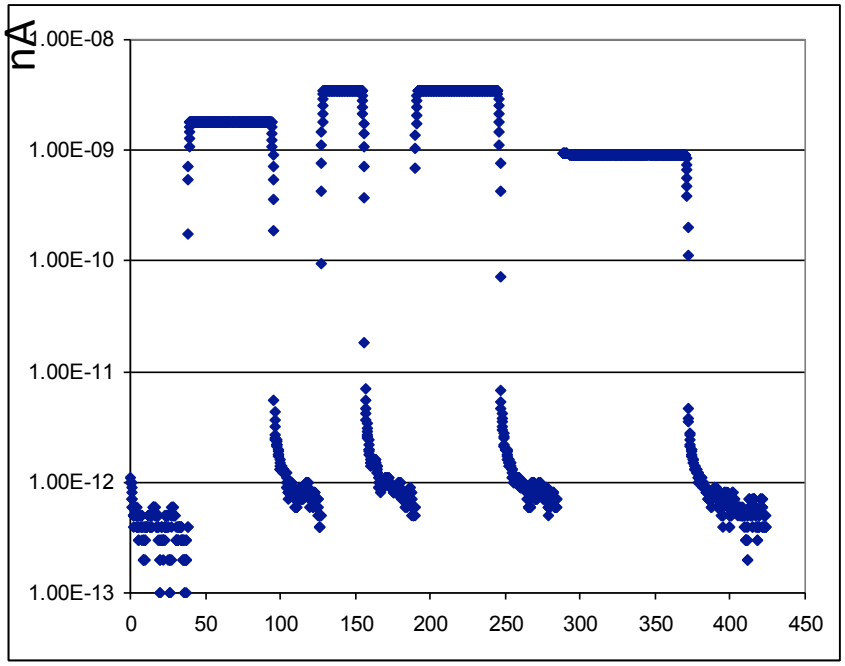


Current signal [nA]

Dose Rate [Mu/min]	Pixel 1	Pixel 4	Pixel 5	Pixel 6	Pixel 8
100	0.70	0.83	0.92	0.82	0.71
200	1.32	1.63	1.80	1.62	1.39
400	2.59	3.17	3.5	3.15	2.71

Example: Pixel 5

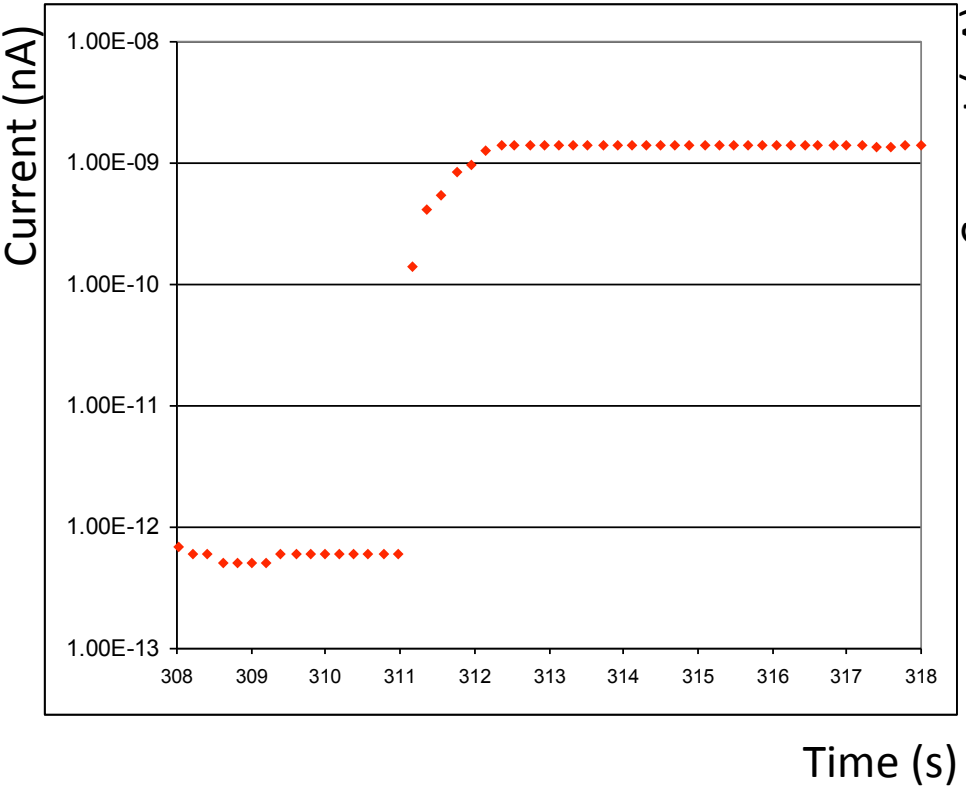


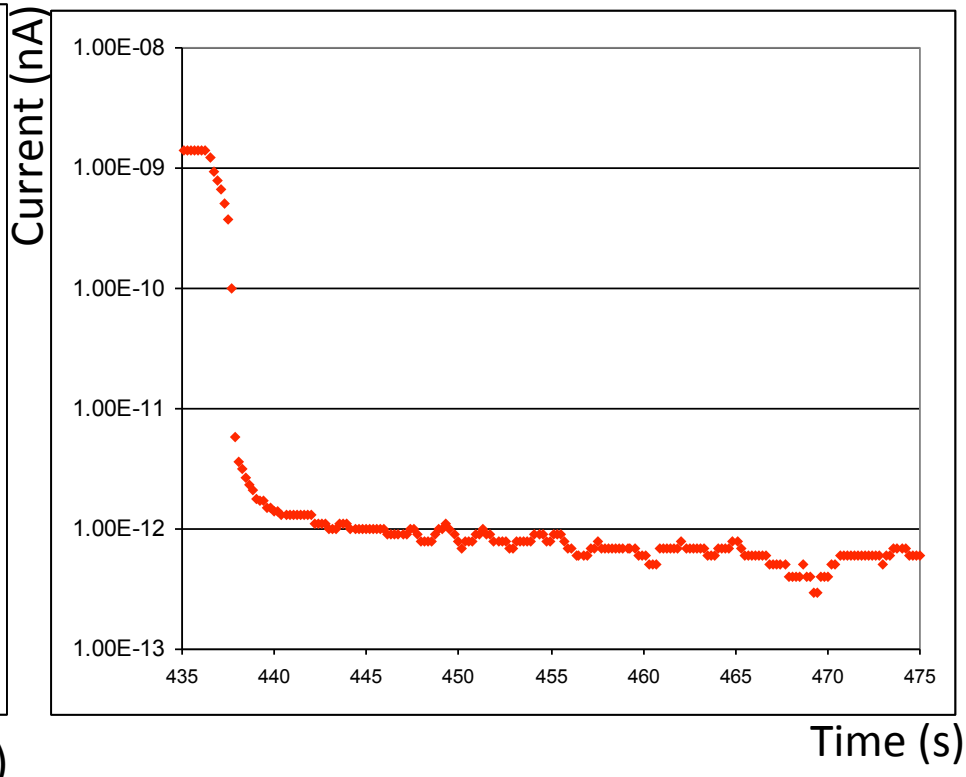


Rise and decay time (s)

Dose Rate [cGy/min]	Pixel 1	Pixel 4	Pixel 5	Pixel 6	Pixel 8
100	Ts=1.5 Td=1.5	Ts=1.4 Td=1.2	Ts=1.8 Td=1.6	Ts=1.3 Td=1.6	Ts=1.4 Td=1.4
200	Ts=1.4 Td=1.5	Ts=1.5 Td=1.8	Ts=1.4 Td=1.8	Ts=1.6 Td=1.4	Ts=1.4 Td=1.4
400	Ts=1.1 Td=1.1	Ts=1.4 Td=1.4	Ts=1.9 Td=2.1	Ts=1.1 Td=1.1	Ts=1.4 Td=1.3

Pixel 8 (Dose rate = 200 cGy/min)





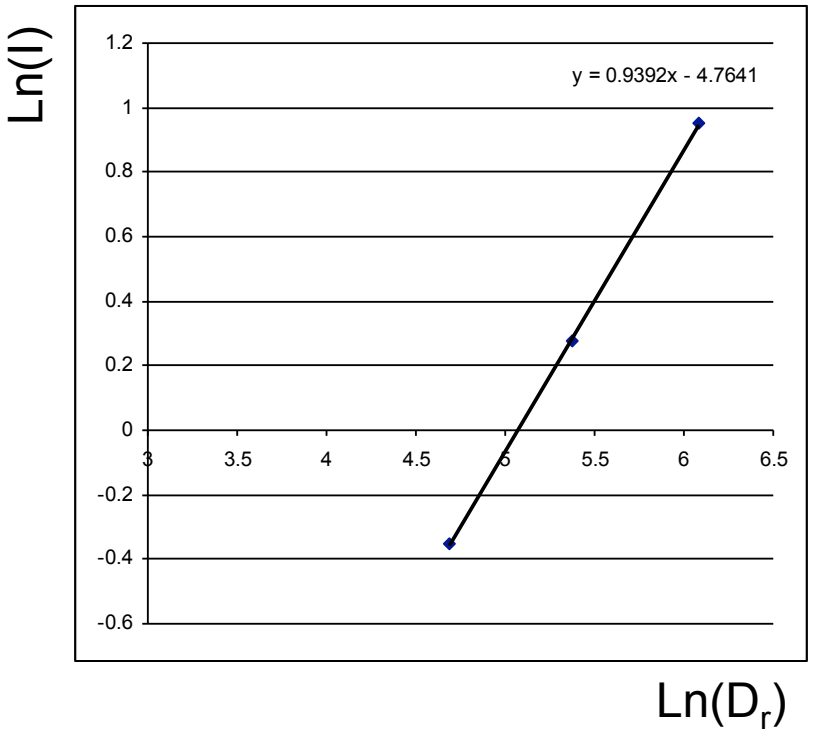
Dose rate dependance

Measurements were performed in integration mode and repeated for dose evaluation with the IC . The current signal has been fitted according to the Foweler model.

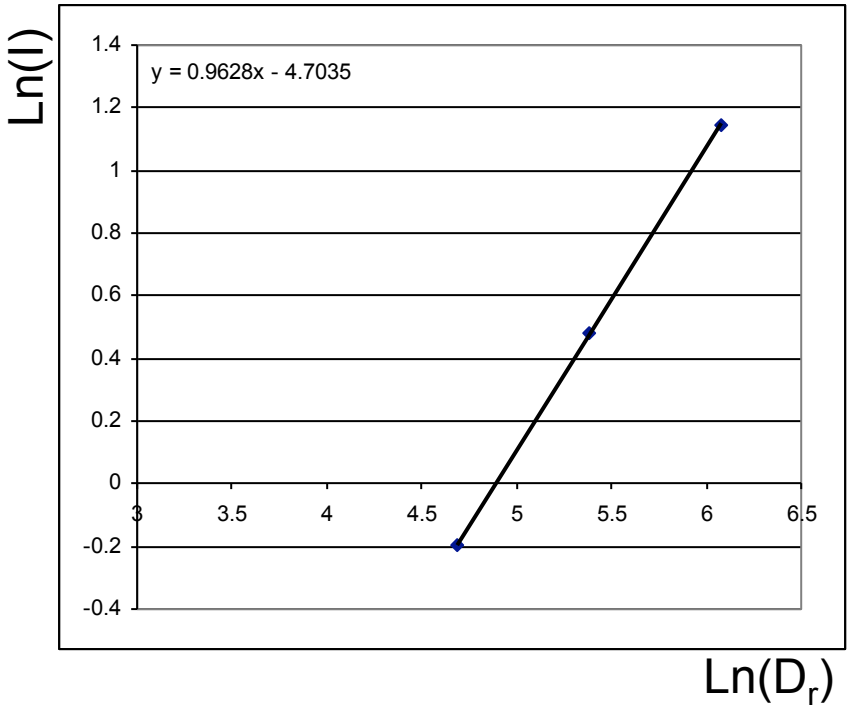
$$I=I_{DARK}+R^{*}(D_r)^{\Delta}$$

	Pixel 1	Pixel 4	Pixel 5	Pixel 6	Pixel 8
Δ	0.94	0.96	0.96	0.96	0.96

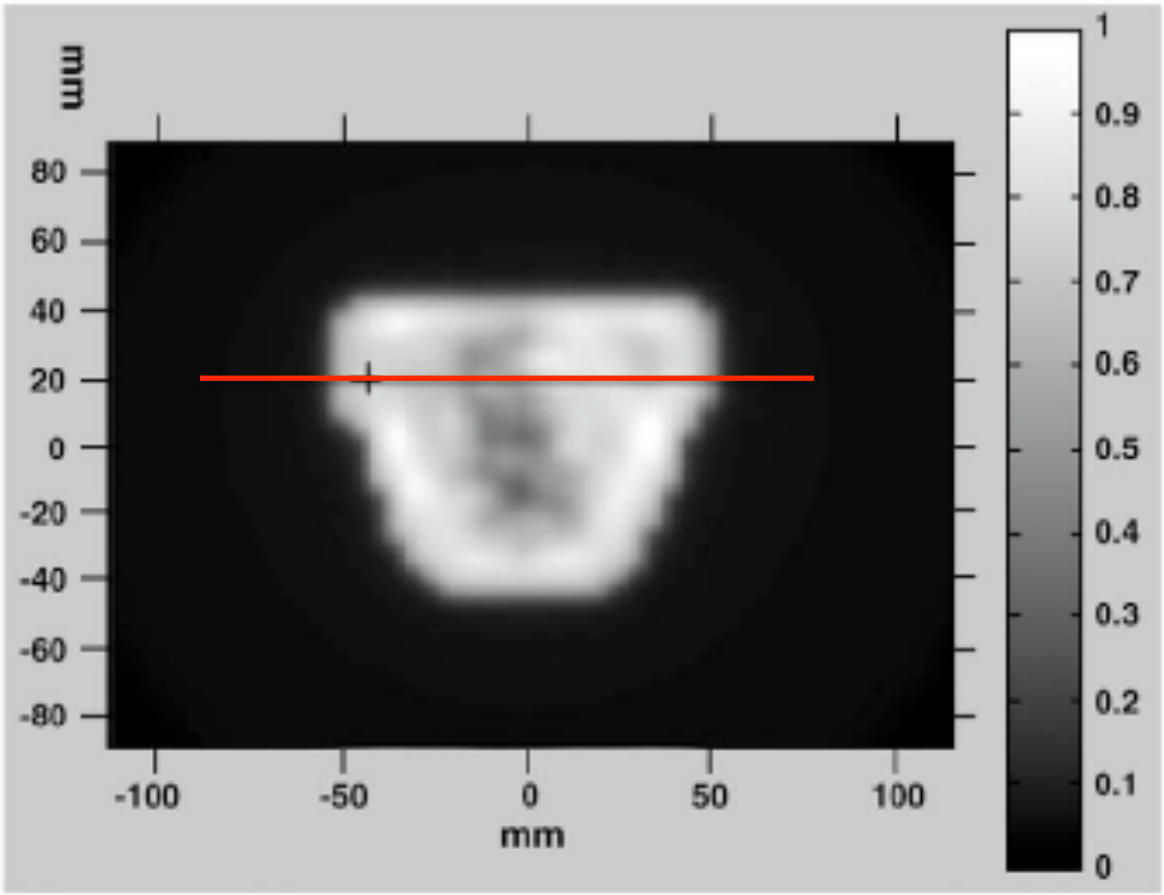
Pixel 1



Pixel 6

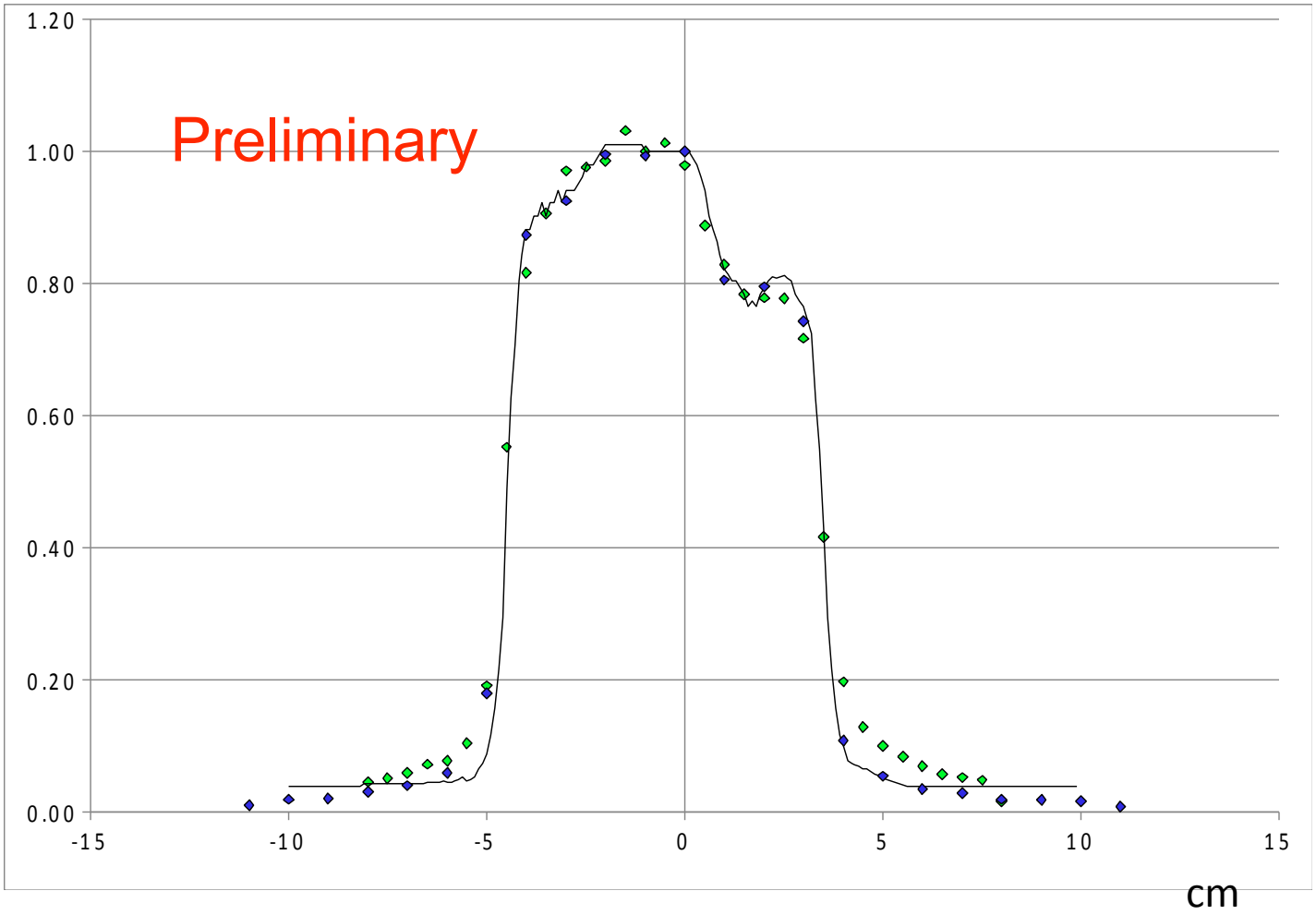


IMRT test: preliminary result



Dosimetric map of a 10MV photon beam for prostate treatment released in step and shoot modality obtained by the treatment planning system used for the IMRT application

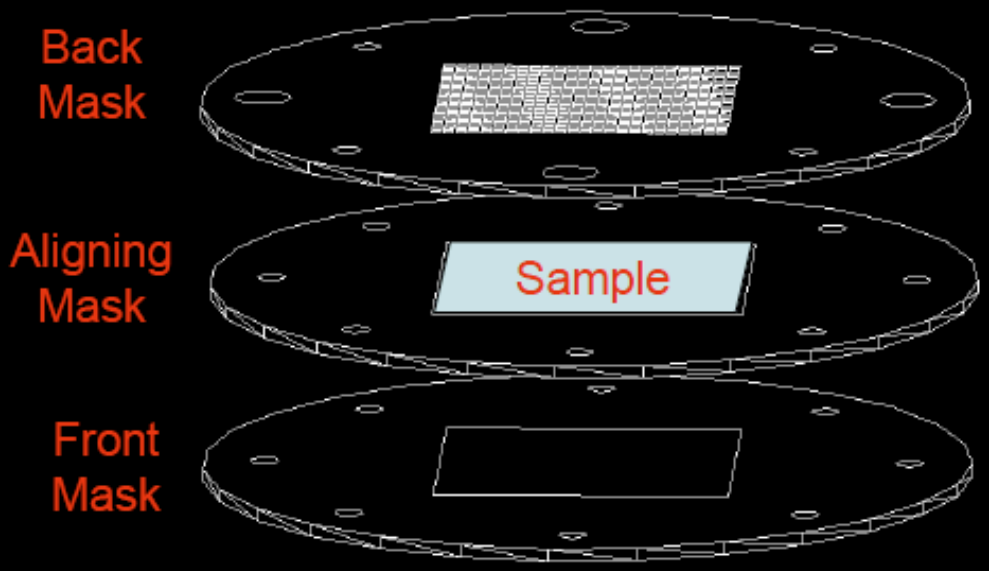
IMRT Profile



Conclusion

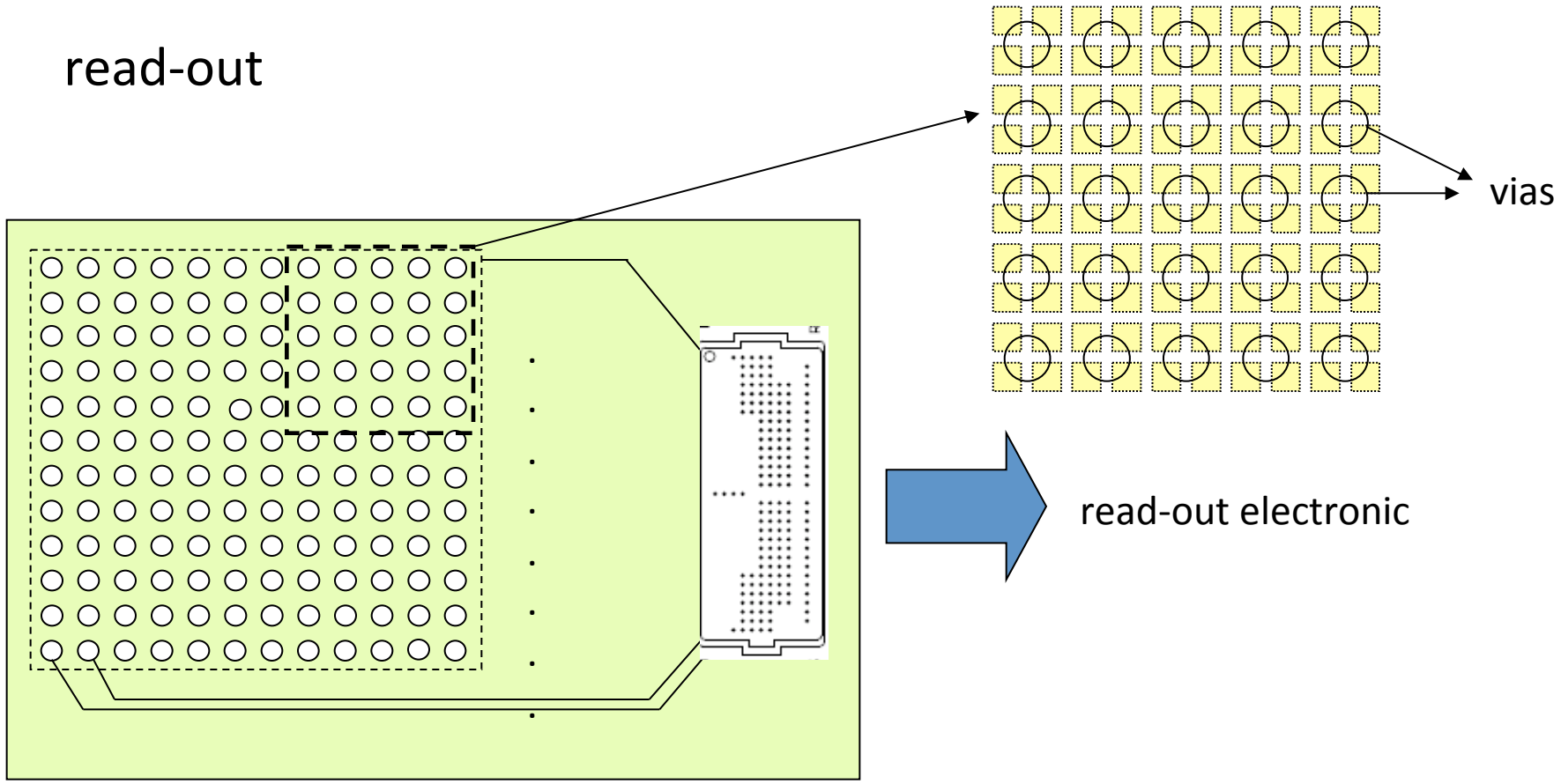
- Results obtained in this work are quite encouraging.
- Future work will be focused on the realization of the readout electronic in order to read all the pixels and on a detailed dosimetric characterization of the whole device.
- The performance of the device will surely further improve if, instead of being made with two back-to-back Schottky contacts, a front Schottky contact would be coupled to a really ohmic back contact.

Shadow Masks: Concept



Design characteristics:

- 25 mm x 25 mm diamond and BK7 substrate
- Back shadow-mask with 24 x 24 pixels on a 100 μm thick metal alloy
- An in-between mask that keeps the substrate aligned with the shadow-masks of the same thickness of the substrate
- Front shadow-mask with 23.8 x 23.8 mm^2 back contact on a 100 μm thick metal alloy



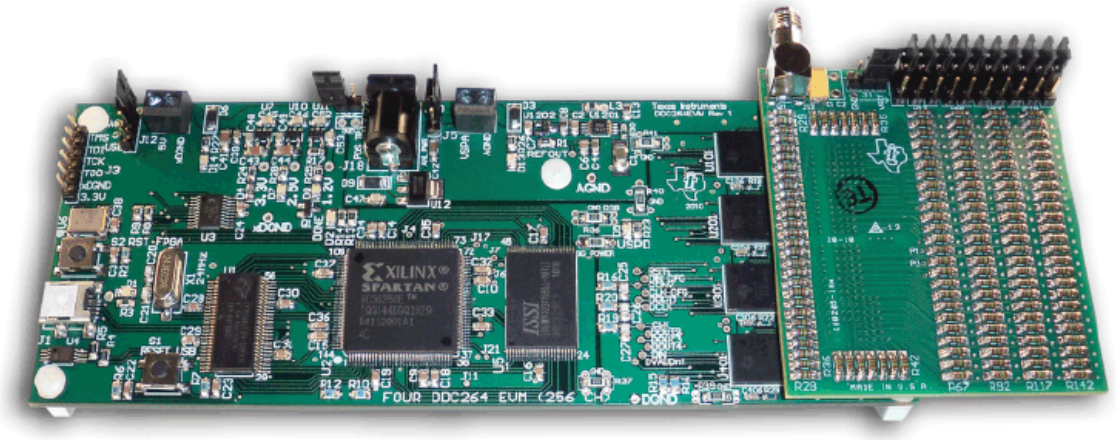
• miltilayer pcb i segnali vengono portati dai pixel al connettore per l'elettronica di read-out tramite una pcb multistrato montata sopra al diamante

• In corrispondenza di ogni gruppo di 4 pixel si realizza una via nella pcb. Il contatto tra la via e i pixel viene fatto con una goccia di pasta conduttiva

• la pcb multistrato viene fissata con delle viti ad una pcb di supporto sulla quale viene realizzato il contatto inferiore

Elettronica di read-out

Evaluation board del chip della texas intruments DDC264: 64-channel, current input, 20-bit analog-to-digital (A/D) converter



4 chip - 256 channel