Very innovative diamond portal imager for the Micro Beam Radiation Therapy (MRT) at ESRF

M.-L. Gallin-Martel*, J.-L. Bouly, J. Collot, S. Curtoni, D. Dauvergne, P. Everaere, L. Gallin-Martel, C. Hoarau, O. Jaafoura, E. Lagorio, S. Marcatili, R. Molle, J.-F. Muraz, N. Ponchant, A. Portier, F. Rarbi, O. Rossetto, N. Rosuel, M. Yamouni

J.-F. Adam, N. Rosuel

Journées thématiques du Réseau Semi-conducteurs IN2P3-IRFU. Applications médicales des détecteurs semi-conducteurs : dosimétrie et imagerie

*mlgallin@lpsc.in2p3.fr

Context

- **Development of new generations of ion accelerators:**
  - medical applications: hadrontherapy, flash therapies and X-ray or synchrotron radiation therapy

  ⇒ very precise monitoring of the beam with rapid counting in a highly radiative environment.

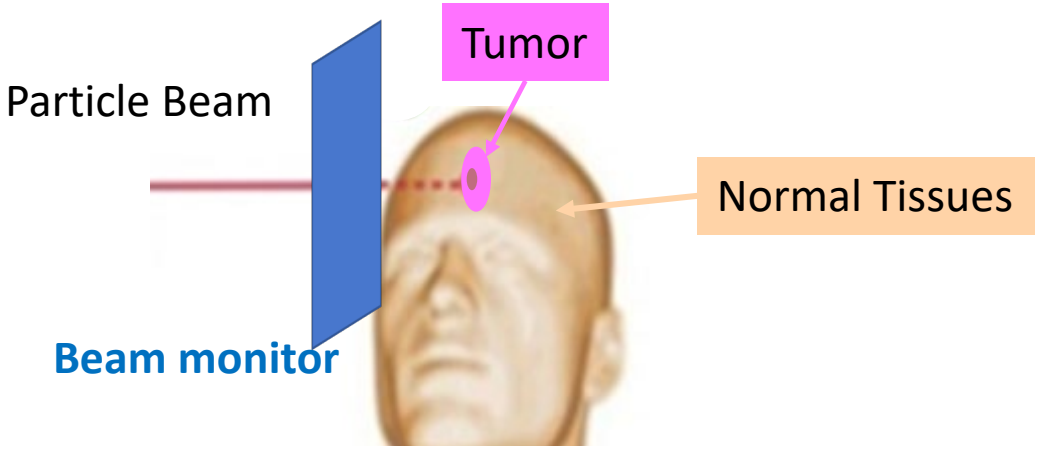
- **The intrinsic qualities of diamond:**
  - speed, low leakage current, excellent SNR, resistance to radiation

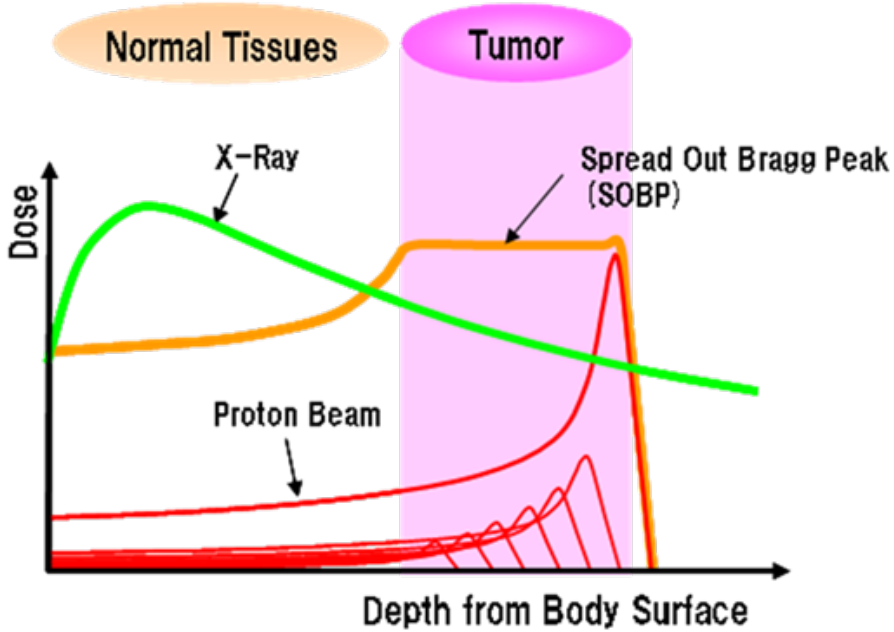
  ⇒ an excellent candidate to meet such monitoring requirements over a wide dynamic range from a fraction of pA (single particle) up to µA.

Marie-Laure Gallin-Martel et al. mlgallin@lpsc.in2p3.fr

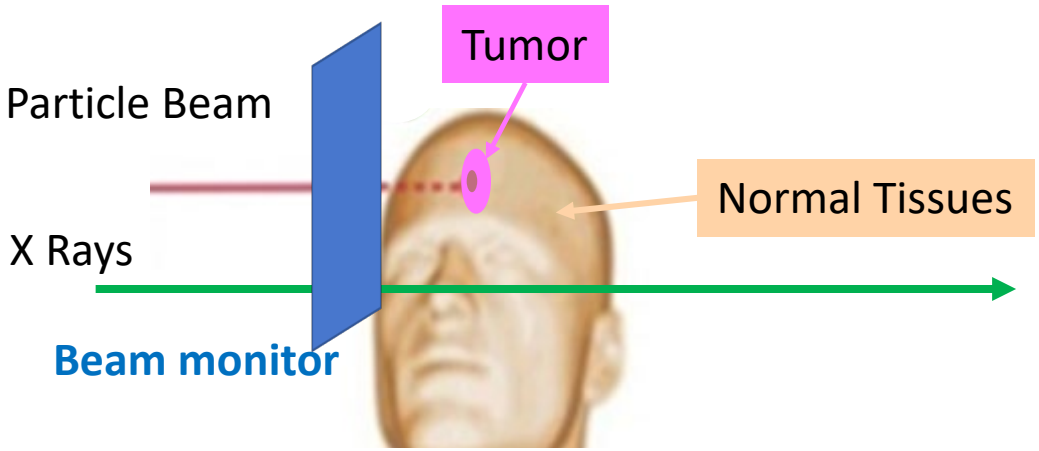
X-rays versus ion beams irradiations for medical applications

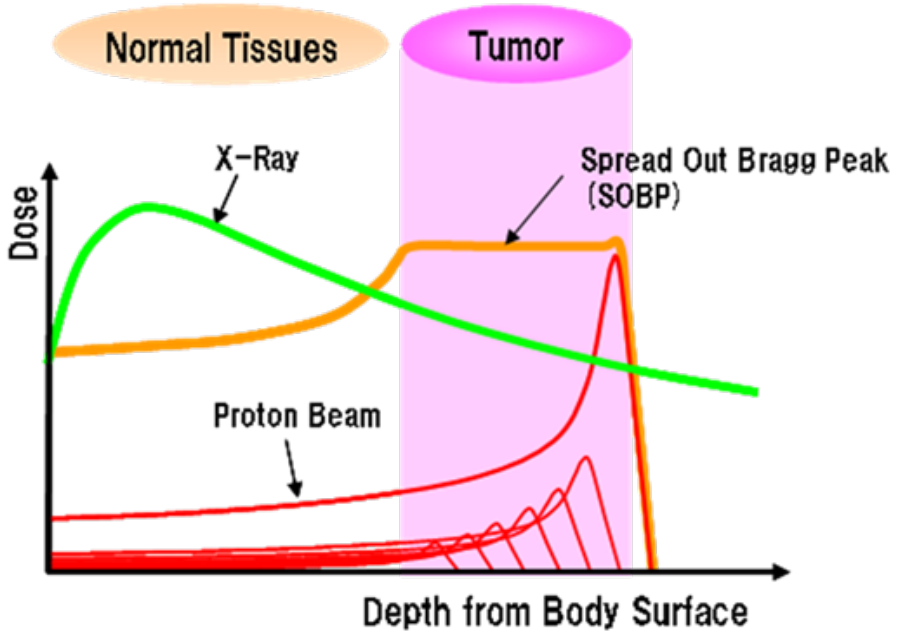
- The diamond hodoscope **in single particle regime**
- **DIAMMONI** for Flash therapy **at high beam intensity**



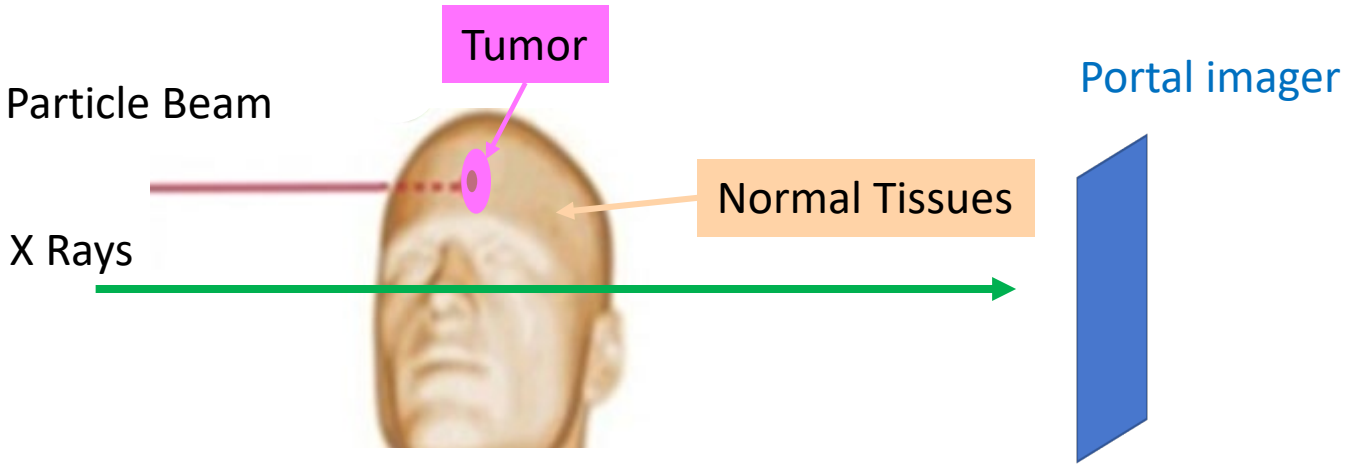


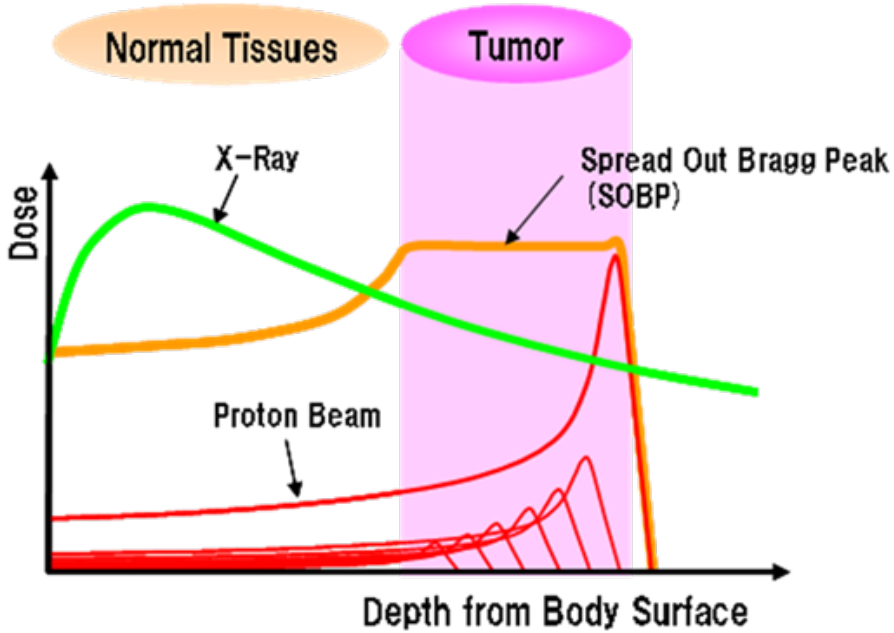
X-rays versus ion beams irradiations for medical applications





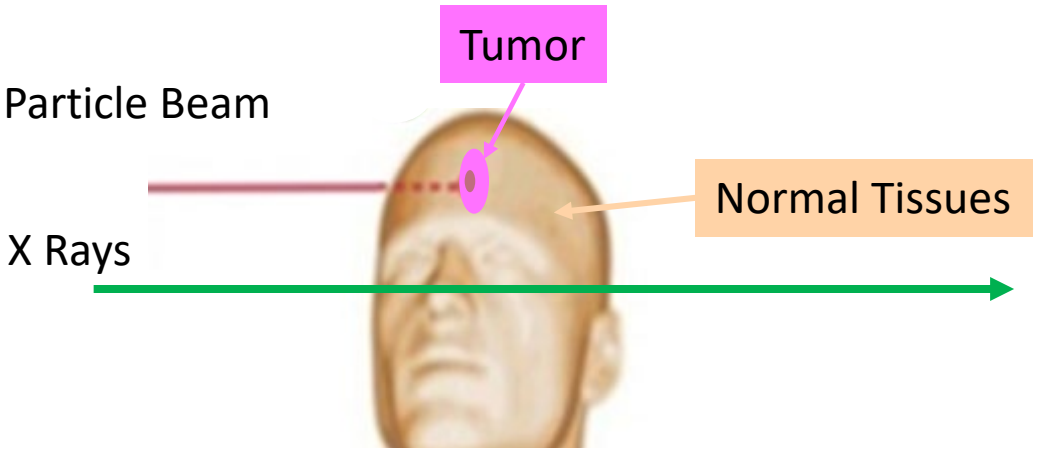
X-rays versus ion beams irradiations for medical applications

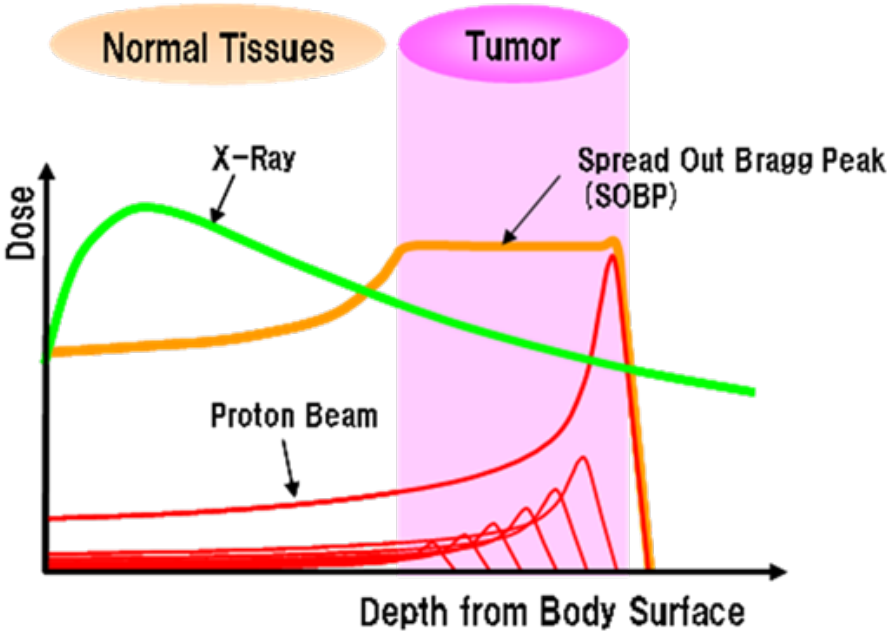


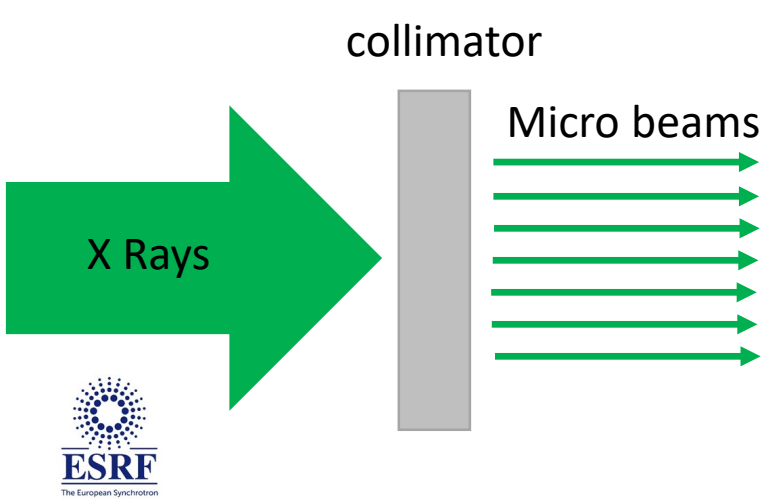


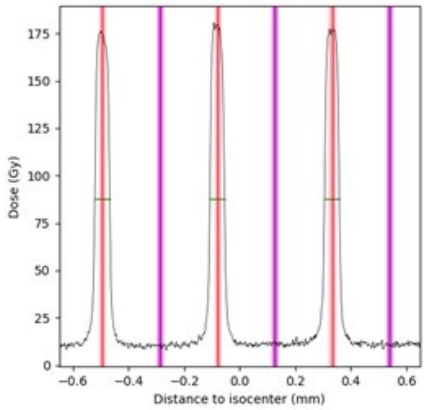
Marie-Laure Gallin-Martel et al. mlgallin@lpsc.in2p3.fr

X-rays versus ion beams irradiations for medical applications









MRT: 50 µm
Micro Beam Radiation Therapy

Micro Beam Radiation Therapy

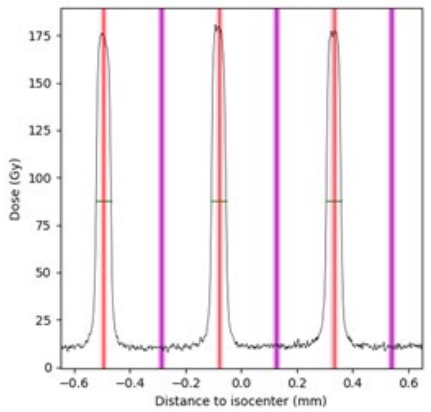
- Innovative radiotherapies using spatially segmented photon beams
- Energy 50-200 keV@ ESRF compensated by very high dose rate 10^4 Gy/s

Xrays @ESRF Micro Beam Radiation Therapy (MRT)

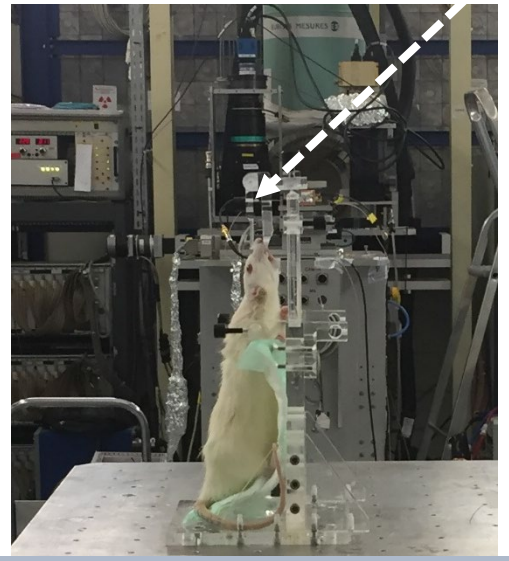
Fluence measurement in Micro-beam Radiation Therapy

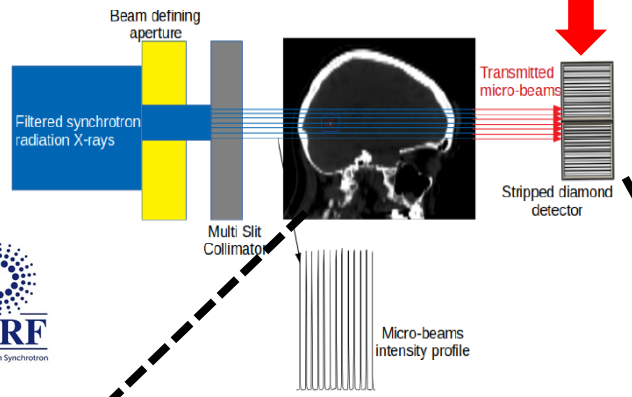
Collaborations :

- **LPSC (IN2P3), STROBE (Université Grenoble Alpes INSERM)**
- **ESRF medical beam line ID17**



MRT: 50 µm
Micro Beam Radiation Therapy



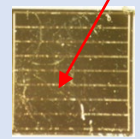


Diamond 1D monitoring

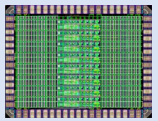
sCVD x 8

Strips on diamond to satisfy MRT beam structure

Detector = 8 x sCVD
(4.5 × 4.5 mm²) strip metallized on 1 side



elec FE = QDC
Discret @IPSC
32 channels
ASIC @ LPSC
~150 channels

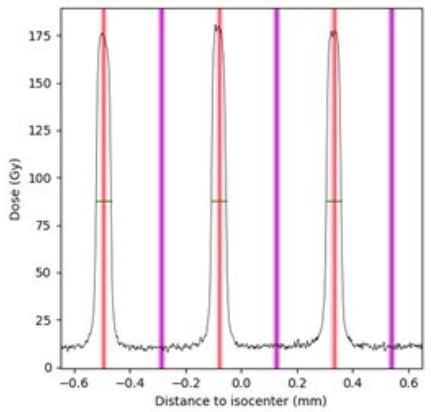


Xrays @ESRF Micro Beam Radiation Therapy (MRT)

Fluence measurement in Micro-beam Radiation Therapy

Collaborations :

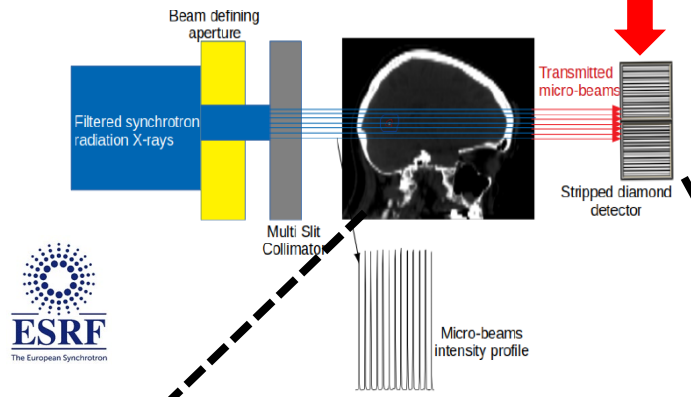
- **LPSC (IN2P3), STROBE (Université Grenoble Alpes INSERM)**
- **ESRF medical beam line ID17**

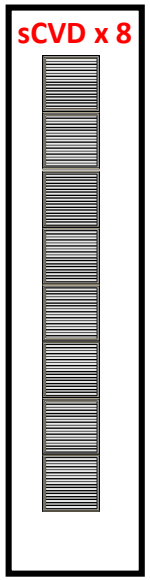


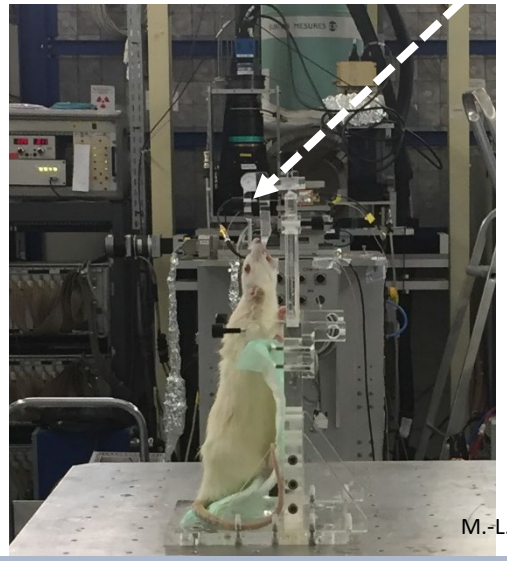
MRT: 50 µm

Micro Beam Radiation Therapy

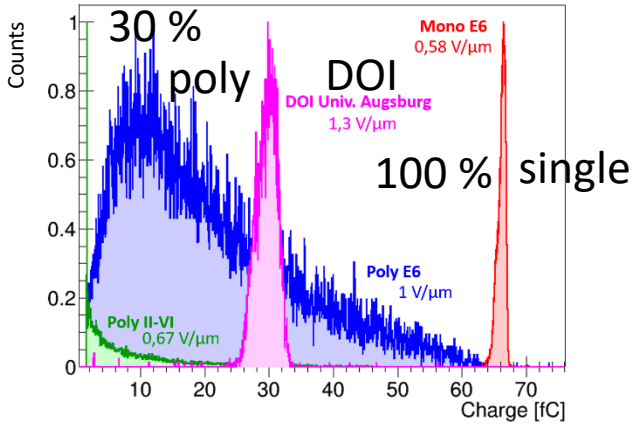
Diamond 1D monitoring







Why sCVD ?



Am α source test resuls @lab

5.5 MeV => 67 fC charge deposition

M.-L. Gallin-Martel et al, Front. Phys., 2021 https://doi.org/10.3389/fphy.2021.732730

Diamond sensors preliminary tests

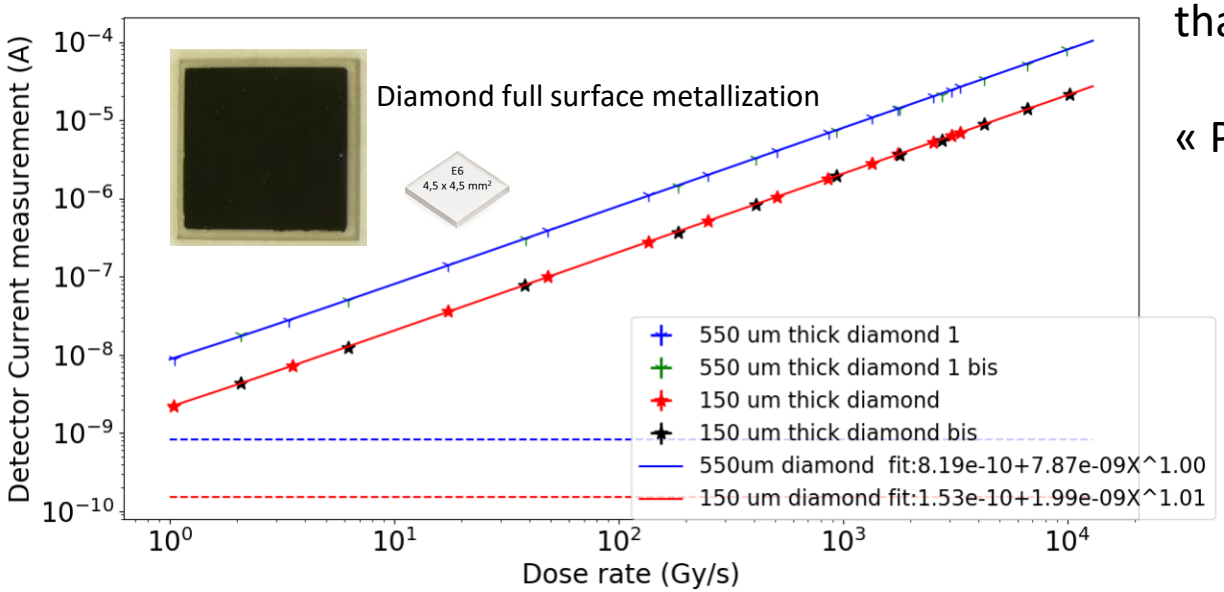
➢ First measurement on a full surface metallized diamond

No loss of linearity as a function of the dose rate (dose rate measured on the diamond)

➢ Results with diamonds of 2 different thicknesses

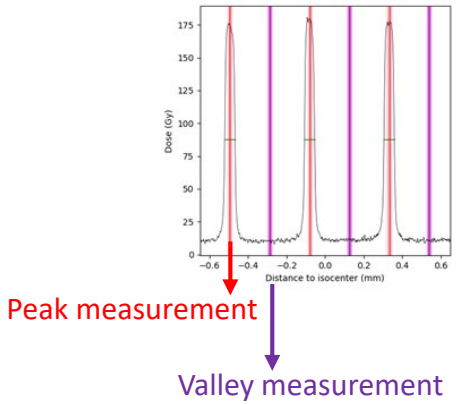
550 µm sCVD from E6 and 150 µm sCVD E6 + etching Almax EasyLab

N. Rosuel
PhD LPSC STROBE
http://www.theses.fr/s211637#



Simulation carried out by N. Rosuel shows that 150 µm is an optimal thickness

« Peak » versus « Valley » dose measurement

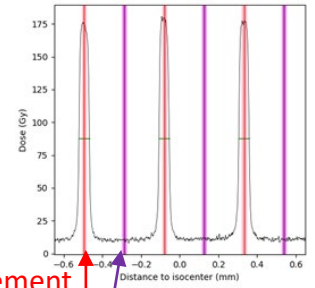


Preliminary tests in the MRT condition at ESRF with diamond samples

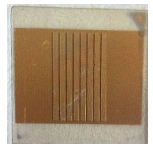
Caracterization of the first prototype 2021

Strips :160 µm x 3 mm on 1 side only – 1 D localization
Gap between 2 consecutive strips : 60 µm

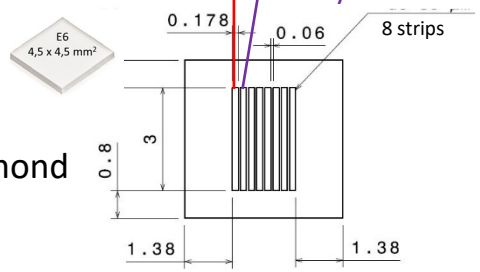
Beam collimator



MRT beams



8 Strips Diamond



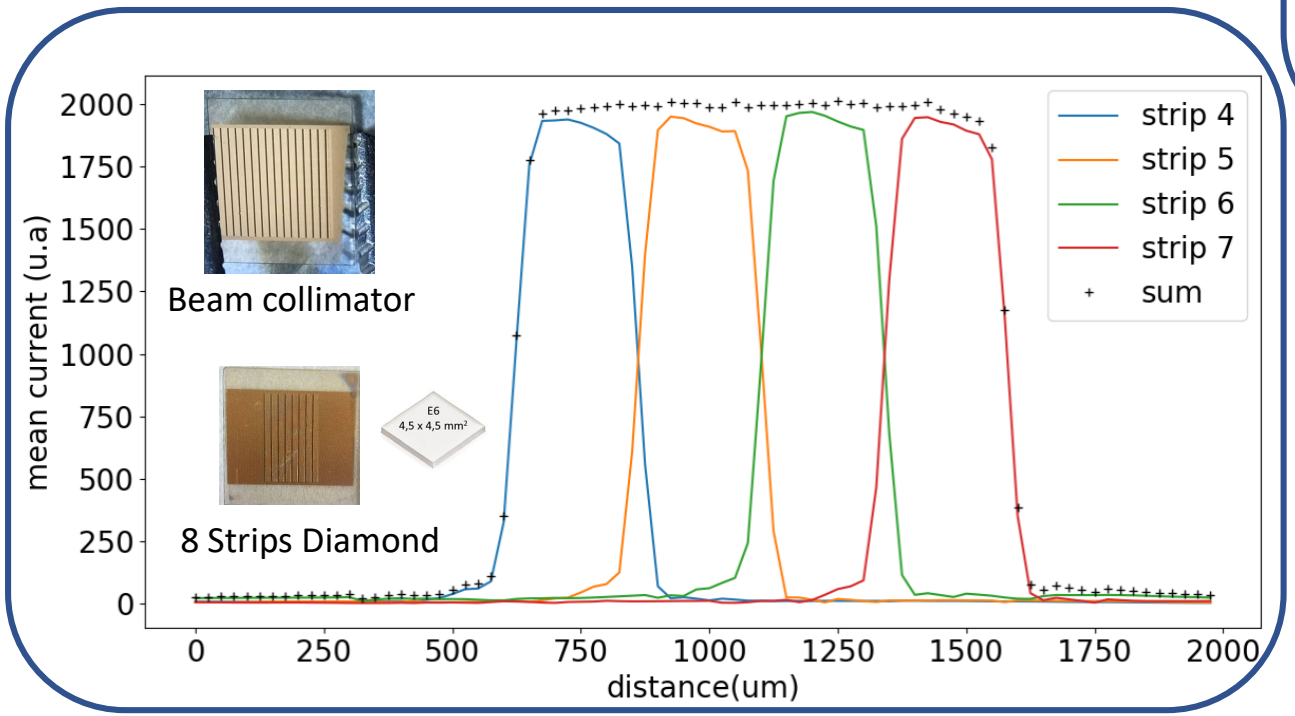
Diamond strip metallization to satisfy peak and valley measurement at detector localization at some distance behind the patient

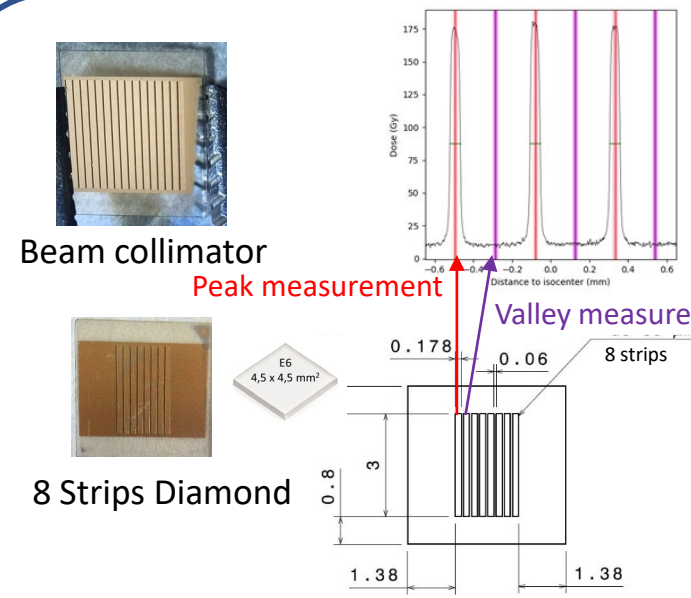
Marie-Laure Gallin-Martel et al. mlgallin@lpsc.in2p3.fr

Preliminary tests in the MRT condition at ESRF with diamond samples

Caracterization of the first prototype 2021

Strips :160 µm x 3 mm on 1 side only – 1 D localization
Gap between 2 consecutive strips : 60 µm





MRT beams

Diamond strip metallization to satisfy peak and valley measurement at detector localization at some distance behind the patient

=> No charge loss in the inter-beam zones using a single micro beam scanning the stripped detector strip by strip

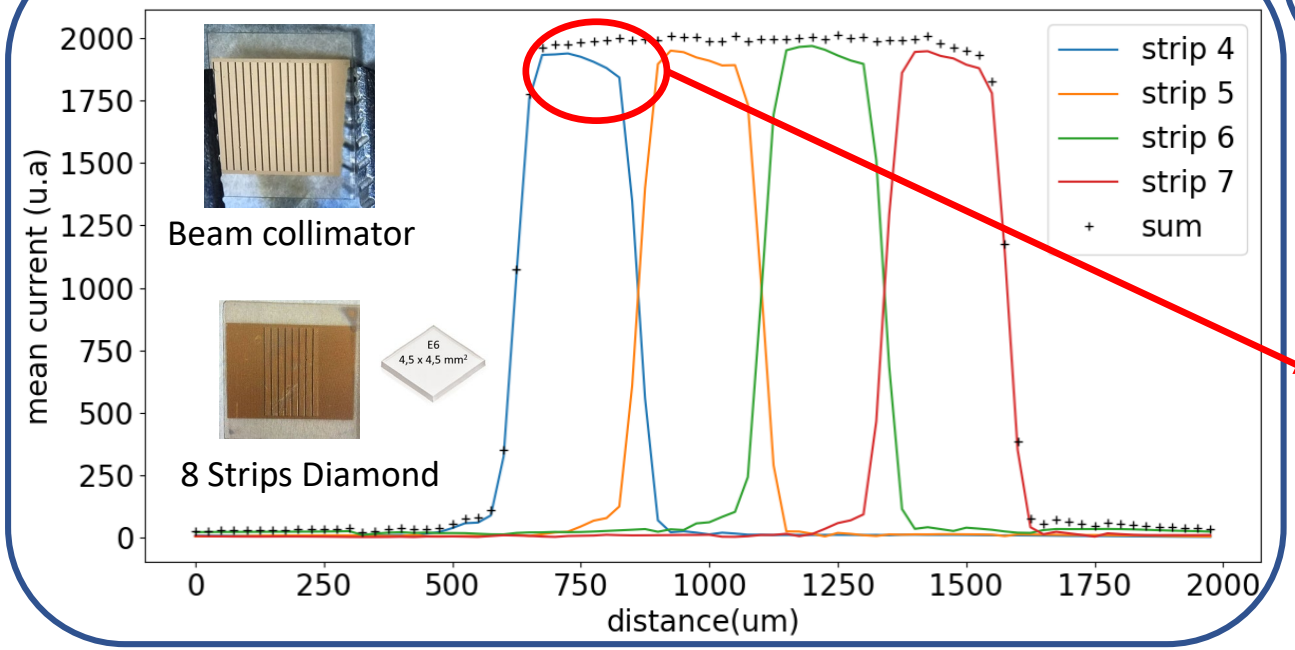
N. Rosuel
PhD LPSC STROBE
http://www.theses.fr/s211637#

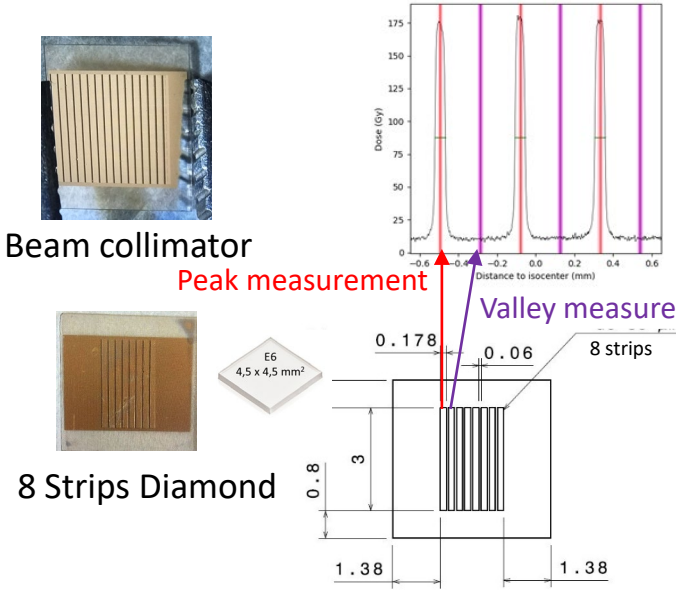
Preliminary tests in the MRT condition at ESRF with diamond samples

Caracterization of the first prototype 2021

Strips :160 µm x 3 mm on 1 side only – 1 D localization
Gap between 2 consecutive strips : 60 µm

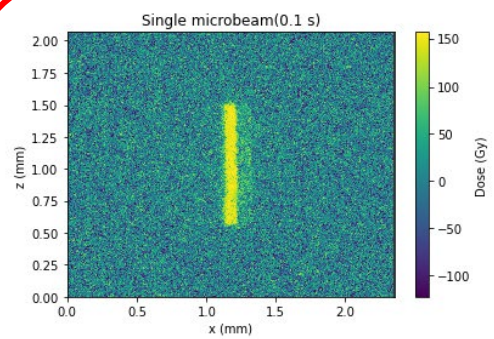
N. Rosuel
PhD LPSC STROBE
http://www.theses.fr/s211637#

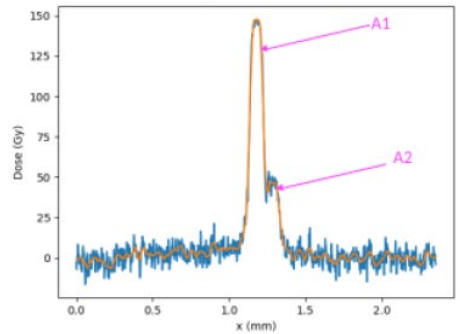




MRT beams

Diamond strip metallization to satisfy peak and valley measurement at detector localization at some distance behind the patient





Gafchromic = dosimeter

Average, on the vertical axis, of the response of the film along the horizontal axis

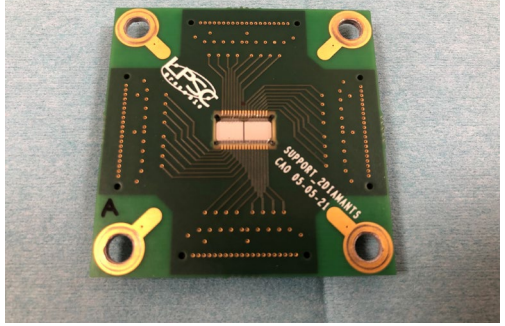
Gafchromic film analysis reveals asymetric microbeam!

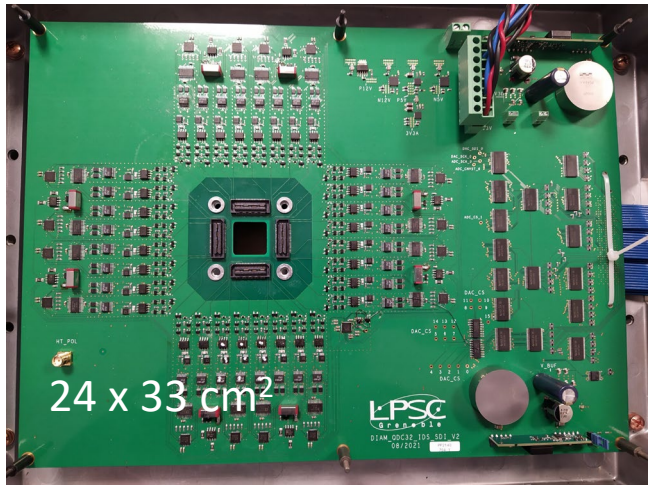
Diamond portal imager with 32 readout chanels for the Micro Beam Radiation therapy

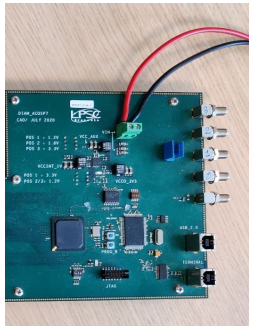
Mother board with QDC 32 readout channels

L. Gallin-Martel et al, IEEE NSS/MIC, Strasbourg, France, 2016
https://doi.org/10.1109/NSSMIC.2016.8069397

2 diamonds active area

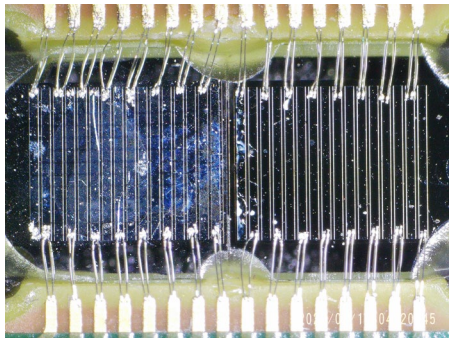


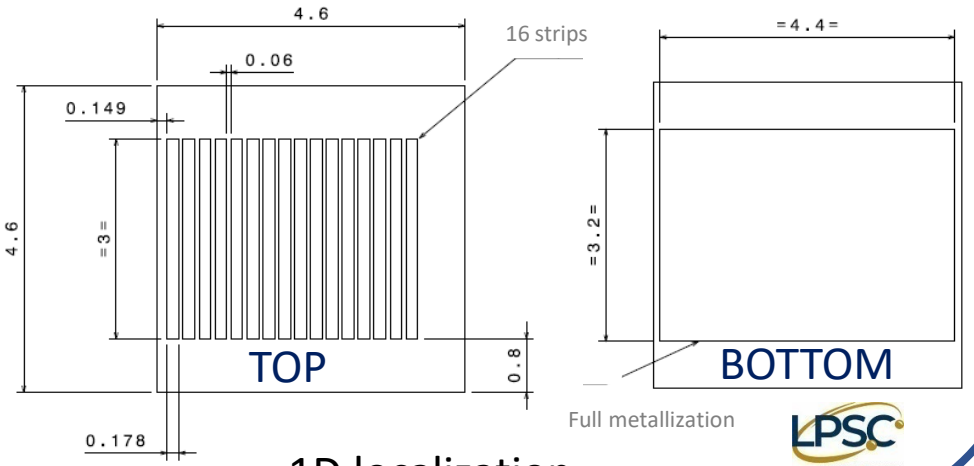




Data ACQ

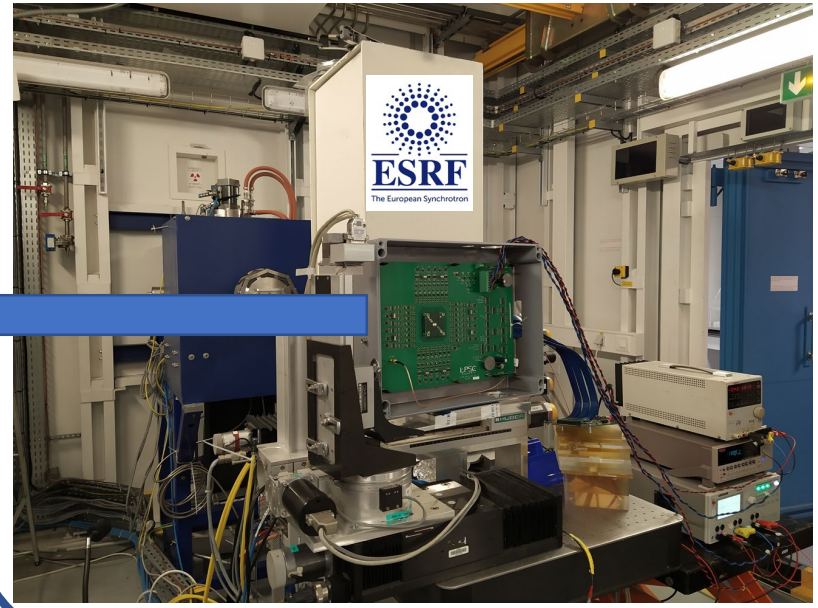
Electrical connexion made by wire bonding

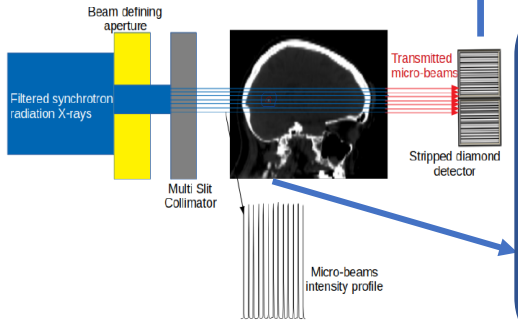




1D localization

The portal imager

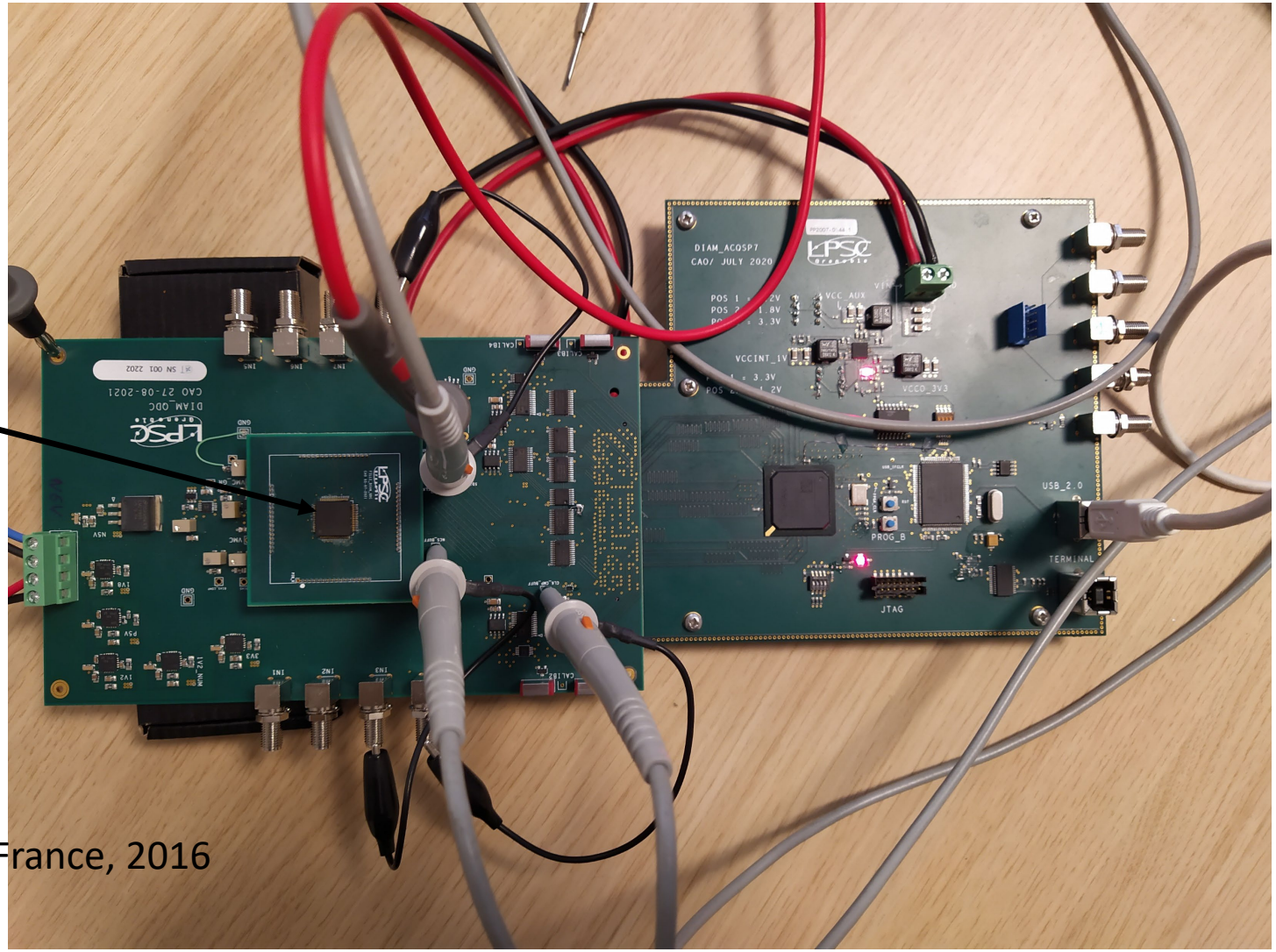




The 1rst veterinary patient

Test of the QDC ASIC (8 channels) at lab

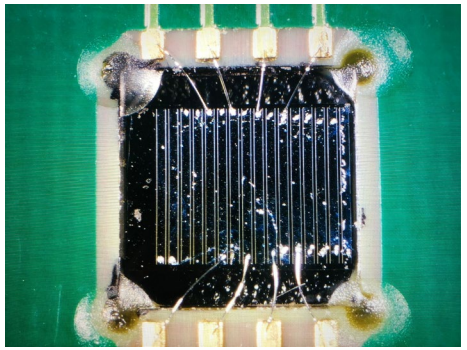
ASIC CMOS 130 nm QDC
8 channels

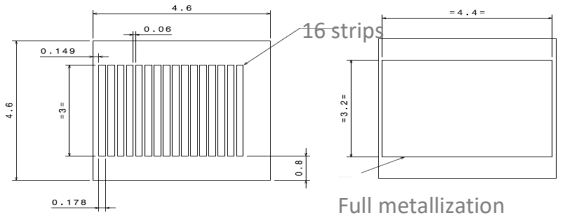


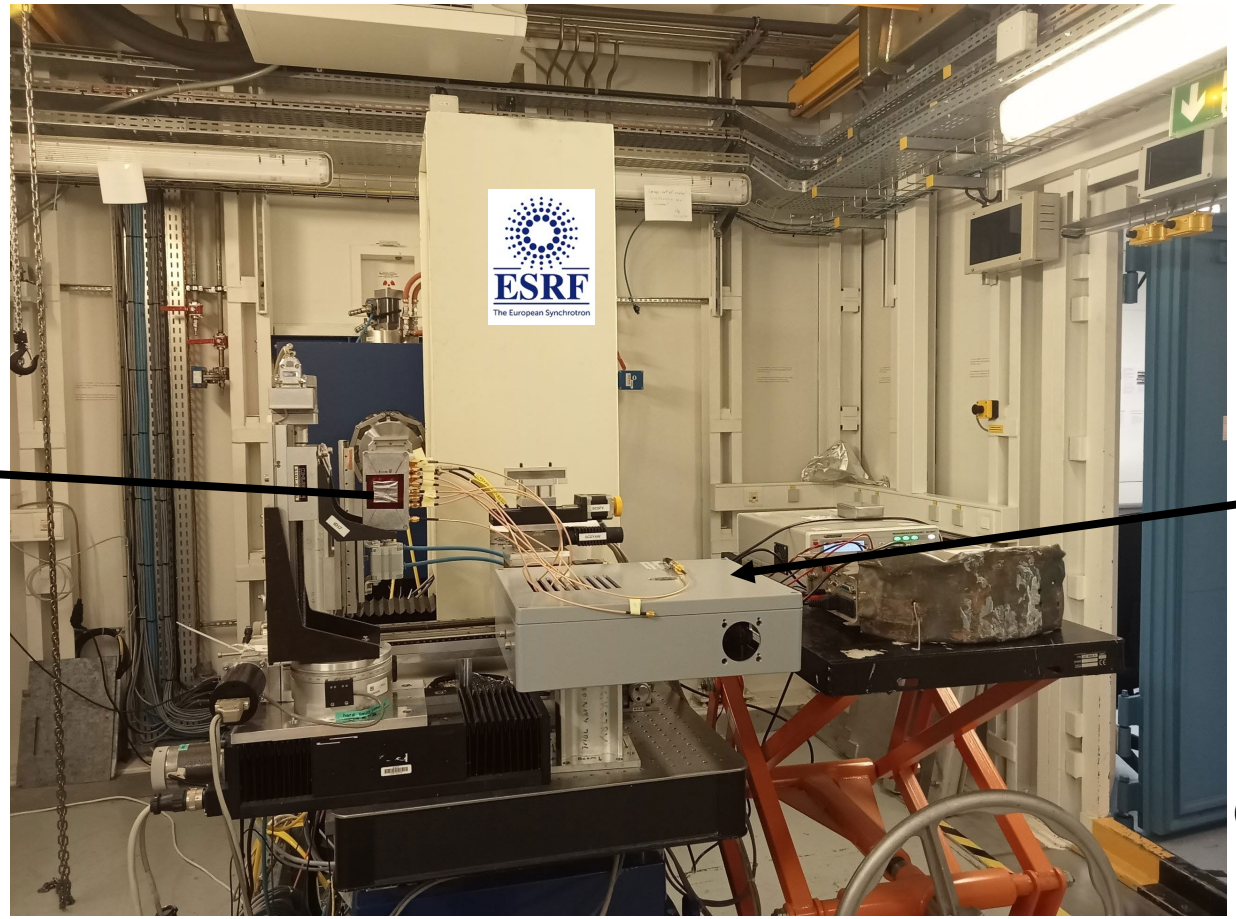
L. Gallin-Martel et al, IEEE NSS/MIC, Strasbourg, France, 2016
https://doi.org/10.1109/NSSMIC.2016.8069397

Diamond portal imager with 120 readout chanels for the Micro Beam Radiation therapy

DIAMOND

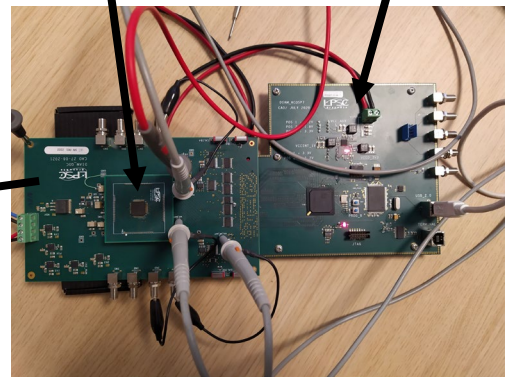






ASIC 8 channels

ACQ board



Charge measurement: dynamic=10^6

Intégration from 1 ms to 100 ms

Conclusion

These developments are

- **in connection with collaborations established at CNRS (CLaRyS – DIAMTECH – ANR DIAMMONI) and ISERM-Université Grenoble Alpes (IDSYNCHRO PAIRS TUMC 2021)**

- **in a context of interdisciplinary research IN2P3 INP INC: skills exchanges take place between**

  - characterization: sources (labs) + eBIC (Institut Néel) + accelerator beams @ IN2P3 (GENESIS GANIL…), GIP - ARRONAX, ESRF +…
  - Instrumentation (IN2P3 labs, Institut Néel, etc.)

- **the proposed detection systems will bring significant added value to the transfer of high dose rate flash radiotherapy or X-rays synchrotron radiation therapy to clinical trials**

THANKS FOR YOUR ATTENTION !

Journées thématiques du Réseau Semi-conducteurs IN2P3-IRFU. Applications médicales des détecteurs semi-conducteurs : dosimétrie et imagerie

Marie-Laure Gallin-Martel et al. mlgallin@lpsc.in2p3.fr