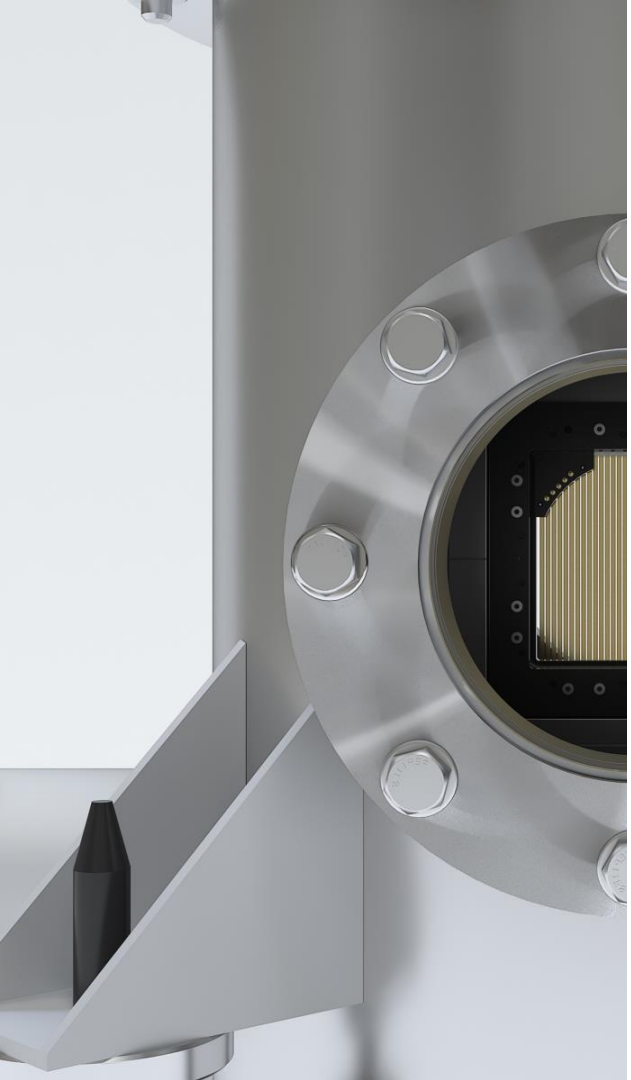


PEPITES

DEVELOPMENT OF A TRANSPARENT PROFILER BASED ON SECONDARY ELECTRONS EMISSION FOR CHARGED PARTICLE BEAMS

PEPITES

Marc Verderi
Laboratoire Leprince-Ringuet

Authors

The PEPITES consortium

	• **Laboratoire Leprince-Ringuet CNRS-Ecole polytechnique-Institut Polytechnique de Paris, Palaiseau, France** • L. Bernardi, R. Guillaumat, F. Magniette, P. Manigot, C. Thiébaux, M. Verderi	Sensitive area, mechanics, connection, acquisition
	• **IRFU-CEA, Université Paris-Saclay, Gif-sur-Yvette, France** • E. Delagnes, O. Gevin	Low noise & high dynamic read-out
	• **Cyclotron ARRONAX, Saint-Herblain, France** • F. Haddad, C. Koumeir, F. Poirier	Material irradiation & damages studies
	• **Laboratoire SUBATECH IMT Atlantique, Nantes, France** • G. Blain, N. Michel, N. Servagent, T. Sounalet	

Funded by the French National Agency for Research (ANR), France (ANR-17-CE31-0015) and the labex P2IO. ANR grant "Investissements d'Avenir", Equipex Arronax-Plus (ANR-11-EQPX-0004), Labex IRON (ANR-11-LABX-18-01) and ISITE NExT (ANR-16-IDEX-0007).

From Motivation

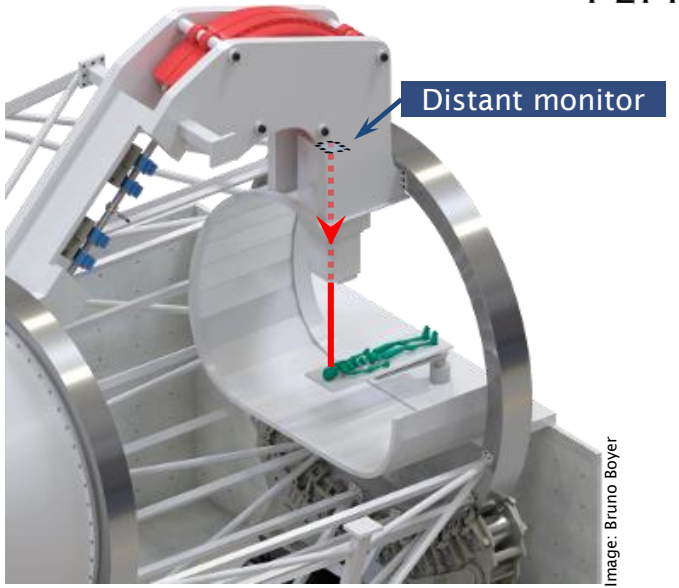
To Specification & Strategy

PEPITES

Goals :

Beam minimal perturbation
→ Material budget < 10 µm WET

Minimum deposited dose 10^8 Gy
→ Radioresistance

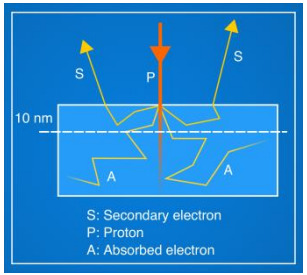


Strategy:

- Development of a **fully working prototype** for routine operation at **ARRONAX** cyclotron, to operate from O(< 1pA) to 10 nA, continuous proton beams
  - Experience to go on hadrontherapy machines
  - End of project planned for June 2022 !
- → PEPITES (Profileur à Electrons secondaires Pour Ions ThérapeutiquES)
- In addition : build a complete spare monitor, to experiment in various places

PEPITES

Monitor Principles



Signal

Secondary Electrons Emission (SEE) :

- Surface process (few nm)
- Very linear with beam current
- Low energy e^- (few eV)

→ Need to work in vacuum

- Rate proportional to dE/dx

→ High signal= high Z → Au

Substrate

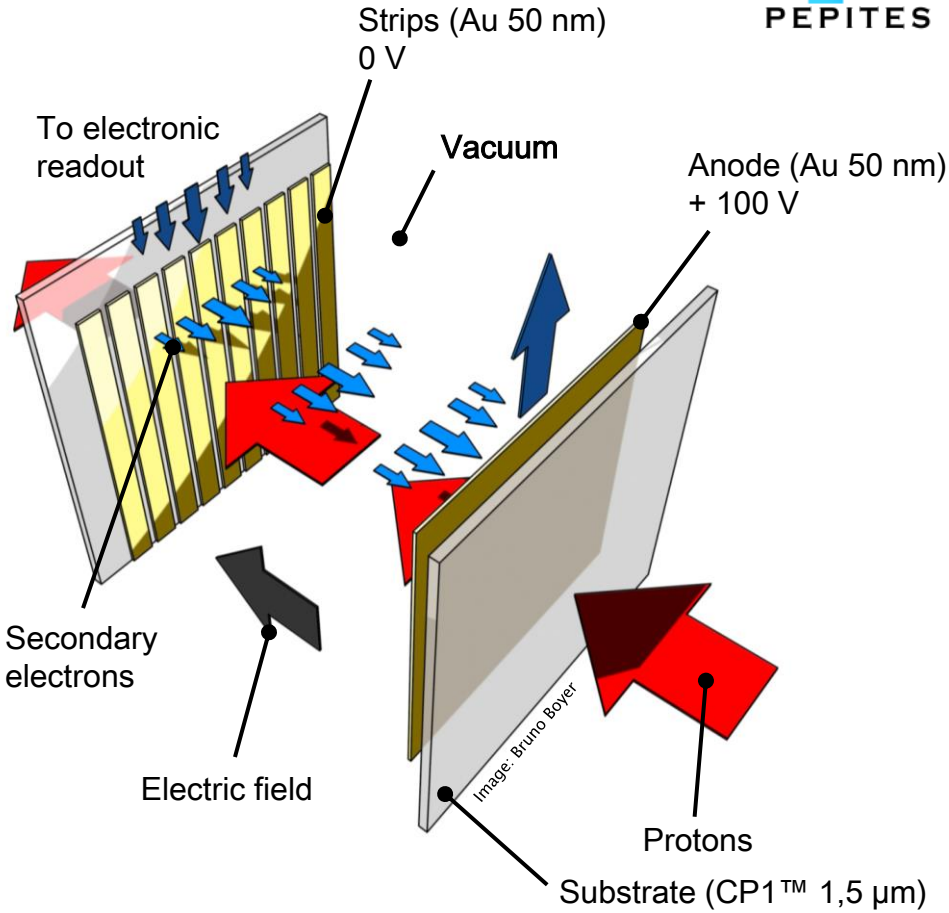
CP1™ (Colorless Polyimide) :

- Thermostable
- Radioresistant
- Developed for solar sails !

Fabrication

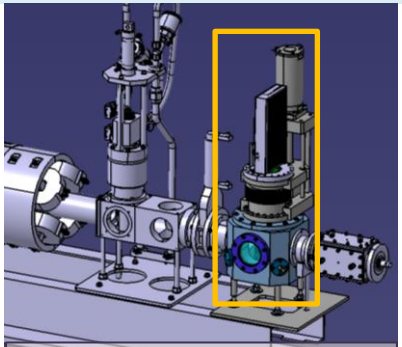
Thin film techniques

- Chemical Vapor Deposition (CVD)



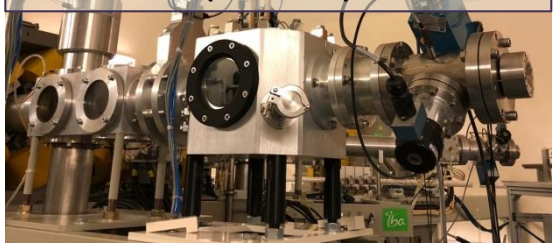
PEPITES

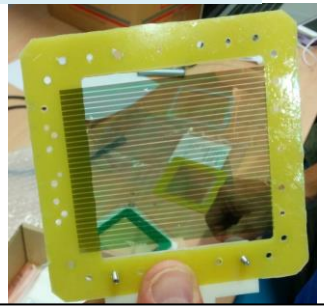
Pictures & Status



Sketch of final system, on ARRONAX beam line

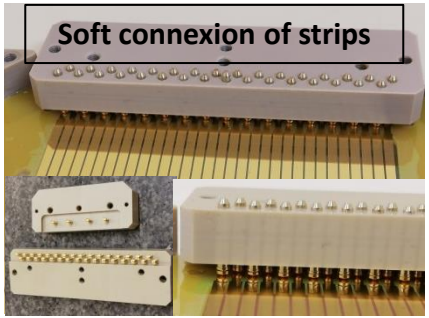
First part or real system installed (Feb. 2021)



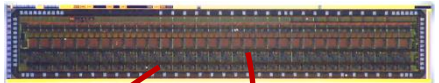


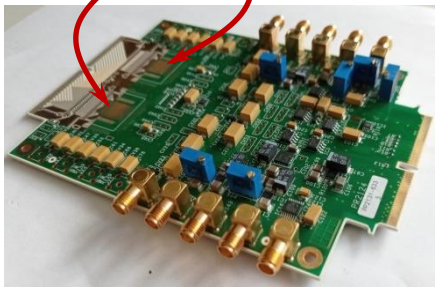
Strip plan (CP1™ 1,5 µm), 32 strips (Au 50 nm, 1.65 mm wide, 2 mm pitch)

Soft connexion of strips



Test mounting of sensitive area & its support





Read-out ASIC & host board. Tests starting in few days !

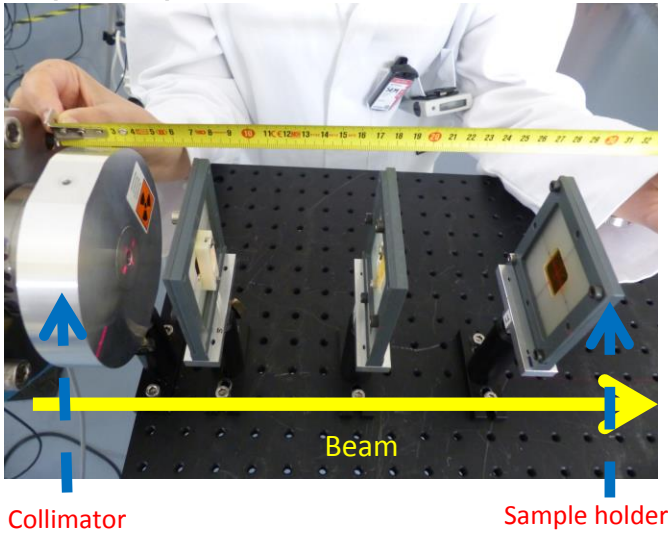
June 2022 goal : assemble the system & measure beam profiles…
Later : measure ion beam profile with spare detector ?

Additional content

Test Beam

Radiations studies

Kapton 8µm irradiation with H+ beam 68 MeV @ ARRONAX



Characteristics of irradiation:

- I beam: 150 -200 nA
- Dose: 0,5, 1 et 10 MGy

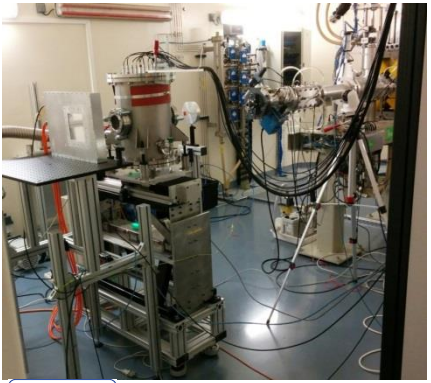
Samples analysis:

- Spectroscopy UV-Visible (structural defects)
- Scanning electron microscopy (surface condition analysis)

- Preliminary results show slight change in optical properties for the 10 MGy sample.
- The study will continue with new irradiations of Kapton and CP1

Test Beam

Validation (ARRONAX)

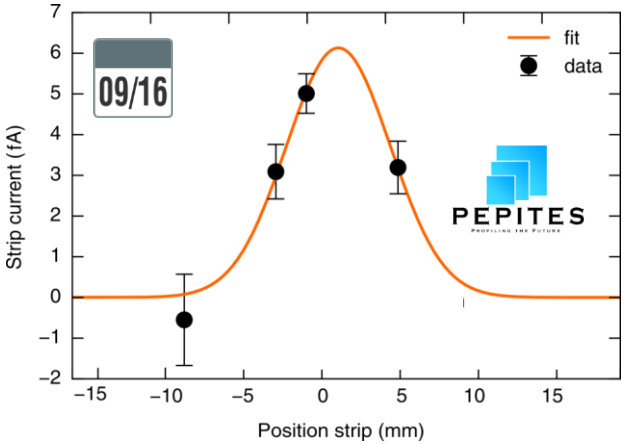


09/16 4 strips prototype,
profiles from 170 fA to 10 nA (proton beam)

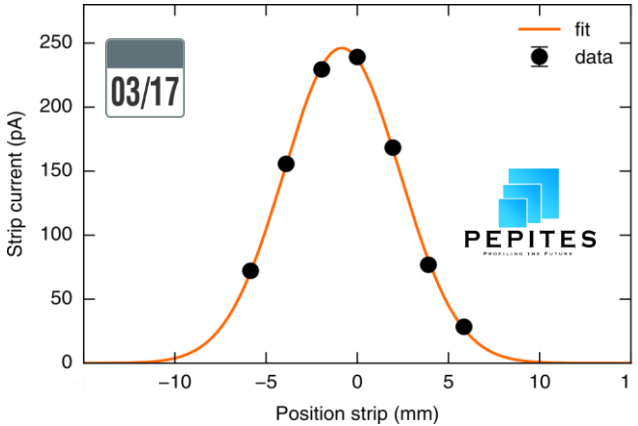
03/17 7 strips prototype
Profiles up to **10 nA** (proton beam)

→ PEPITES validated on a wide dynamic range

ARRONAX has no profiler for this beam current range (1- 10 nA).
Therapeutic beams : 5 nA and more in the future



Protons 60 MeV, I_{beam} = 170 fA



Protons 66 MeV, I_{beam} = 10 nA

Test Beam

Signal studies (ARRONAX + CPO)

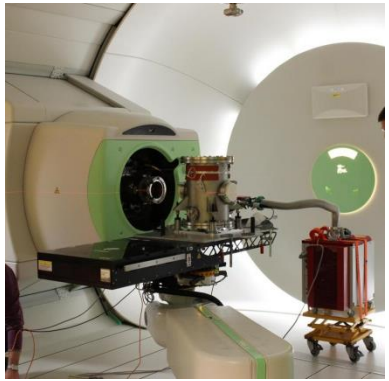
02/18 SEE rate up to 100 nA
protons 32, 40, 50 et 68 MeV

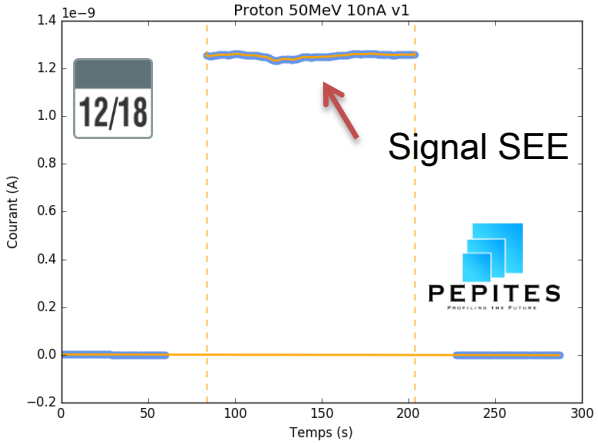
12/18 SEE rate up to 100 nA
protons 32, 40, 50 et 68 MeV
alpha 68 MeV (17 MeV/u) :
analyses on-going

04/19 Centre de Protonthérapie d'Orsay (CPO), protons 100 to 230 MeV, nA beam (therapeutic conditions)

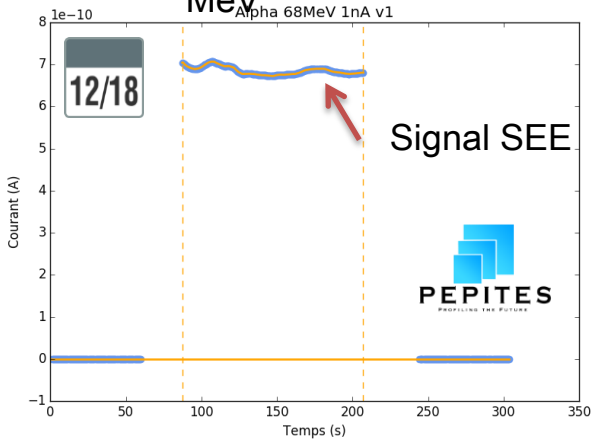
To be published

institutCurie





SEE, protons 50 MeV



SEE, Alpha 68 MeV

Test Beam

Radiations studies

Laboratoire des Solides Irradiés (LSI)

06/18 Electrons 2 MeV : 10^7 Gy

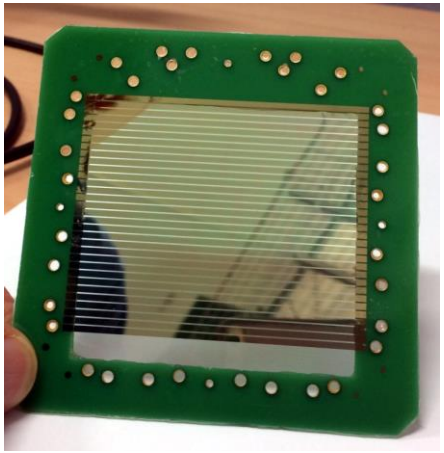
09/18 Electrons 2 MeV : 10^8 and 10^9 Gy
25 µA for beam current

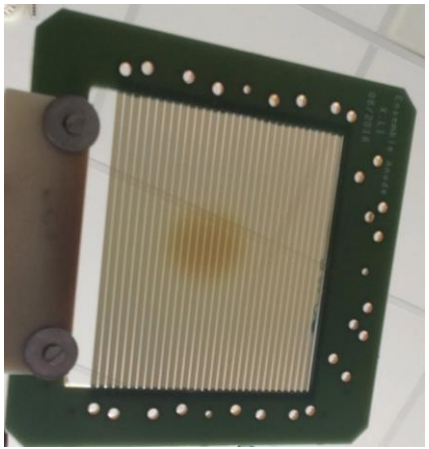
Particle	e- 2 MeV	P 200 keV	P 2 MeV	P 70 MeV	P 230 MeV
dE/dx CP1 (MeV cm²/g)	1.6	0.7	140	8.7	3.7

Centre de Sciences Nucléaires et de Sciences de la Matière (CSNSM)

11/18 Protons 2 MeV and 200 keV (nuclear effets important, max interaction at CP1/Au interface) : 10^8 Gy

→ **CP1™ validated**





Irradiated CP1™ at LSI before/after

PEPITES

Assets

Membranes in vacuum free from mechanical constraints

→ **Radio-induced damages of less consequence**

Ultra-thinness

- Low heating from beam

→ **Tolerate high beam intensities**

SEE linearity

→ **Wide dynamic range**

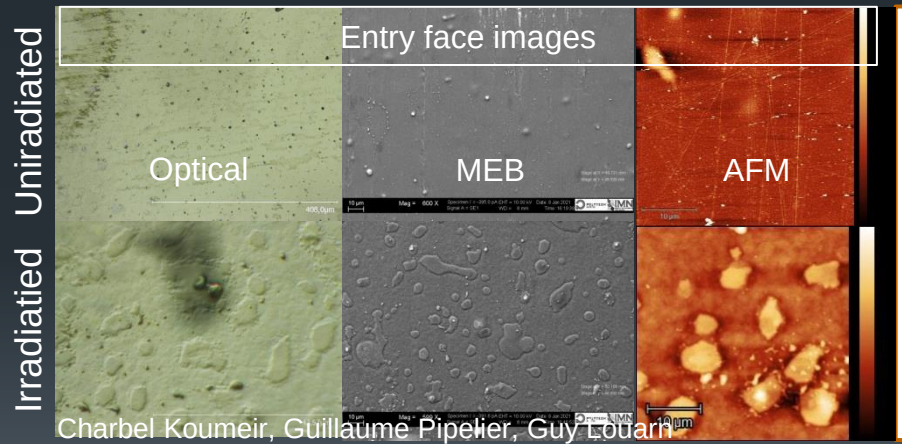
Thin film techniques

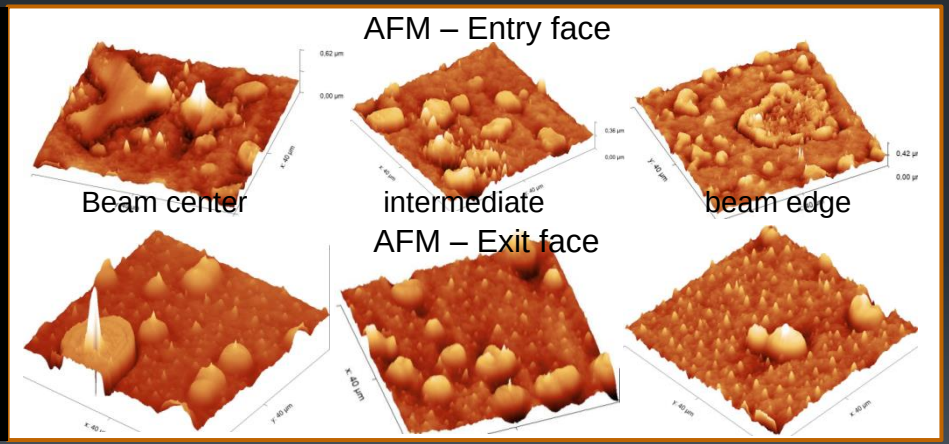
- Flexible methods

→ **Adaptation to beam specifications**

Radiation damages (ARRONAX)

- Protocol to caracterize material damages under radiation
  - Technics employed : optical microscopy, MEB, infrared (chemical bindings), AFM
- Excercised on Kapton samples, before being applied to CP1
  - Uncoated samples, samples with strips, samples fully metallized





- Further irradiations made or planned (electrons 2 MeV) and CNSM (protons 10 keV - 2 MeV)