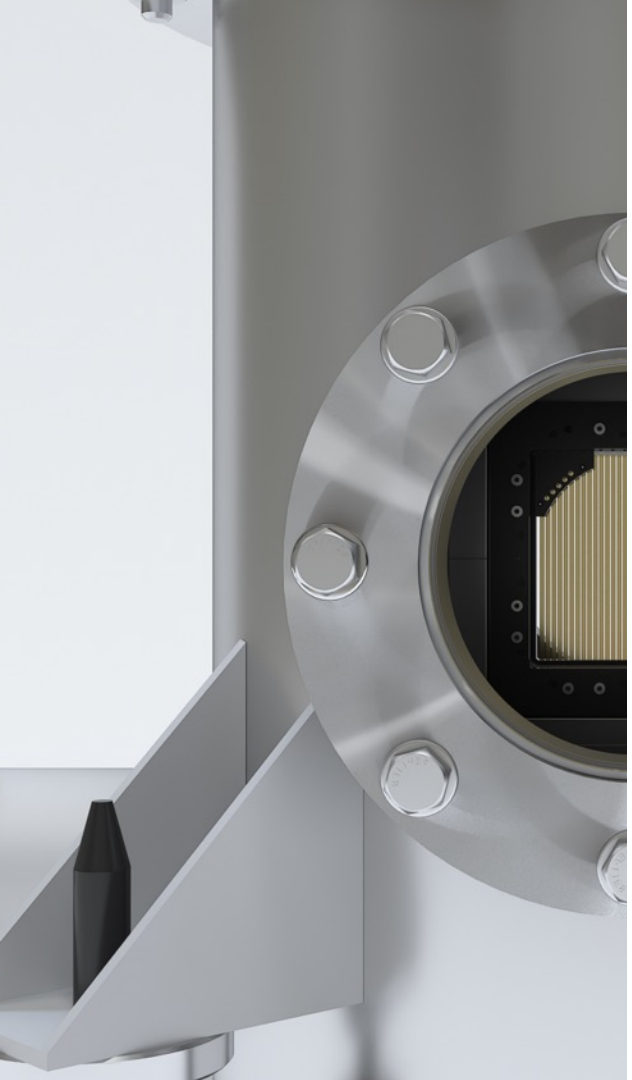

CYC 2019 22-27 SEPTEMBER CAPE TOWN

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

PEPITES

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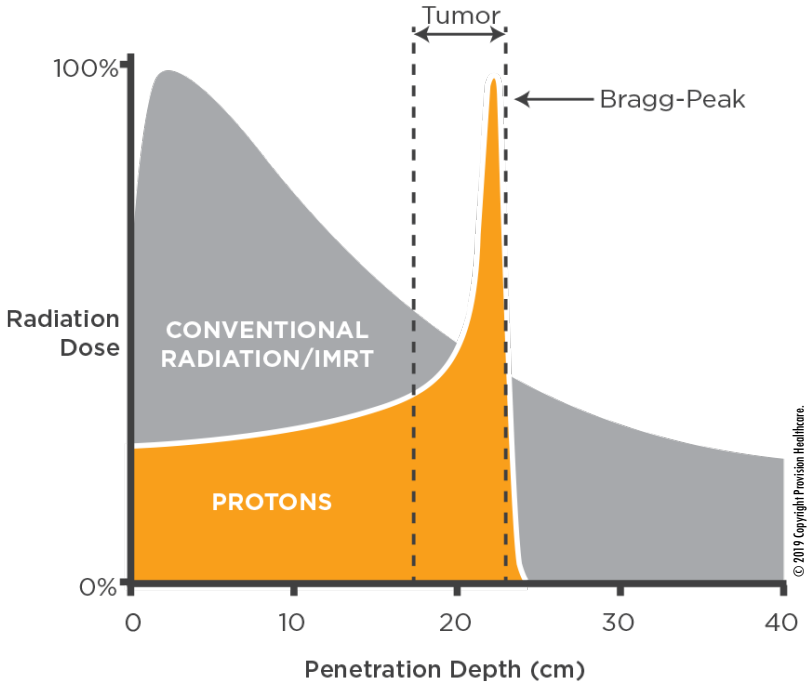
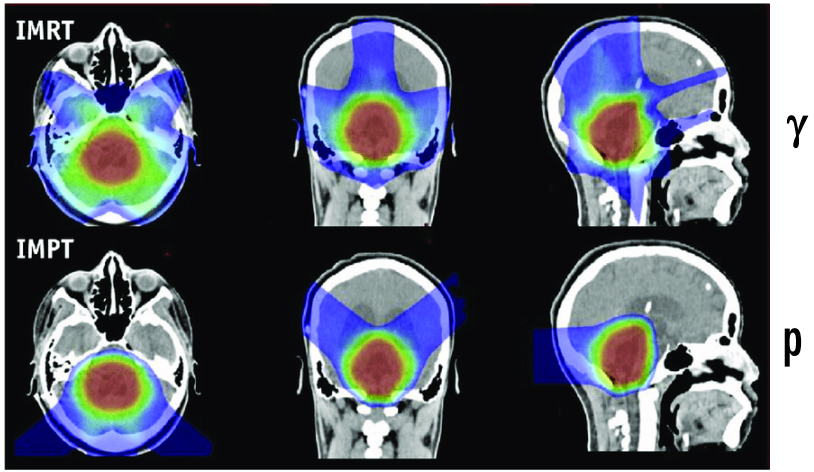
Introduction

Protontherapy context



Indication:

- Resistant tumors
- Non operable
- Pediatrics



D.J. Indelicato et al. DOI: 10.1016/j.ijrobp.2016.06.2446

Introduction

Protontherapy

Cyc

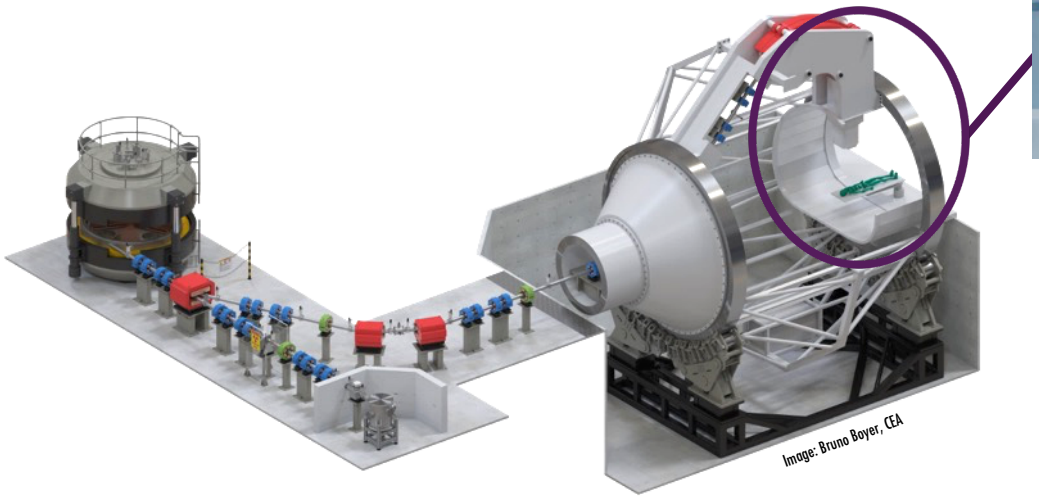


Image: Bruno Boyer, CEA

Treatment room

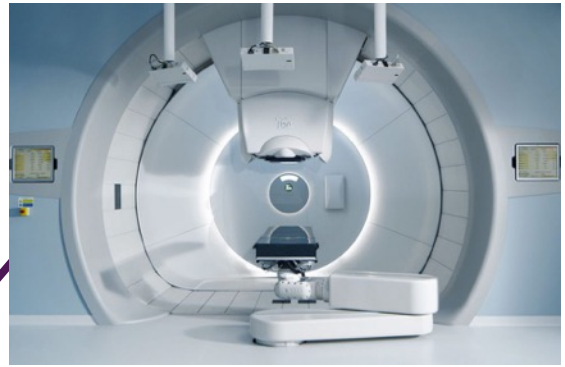


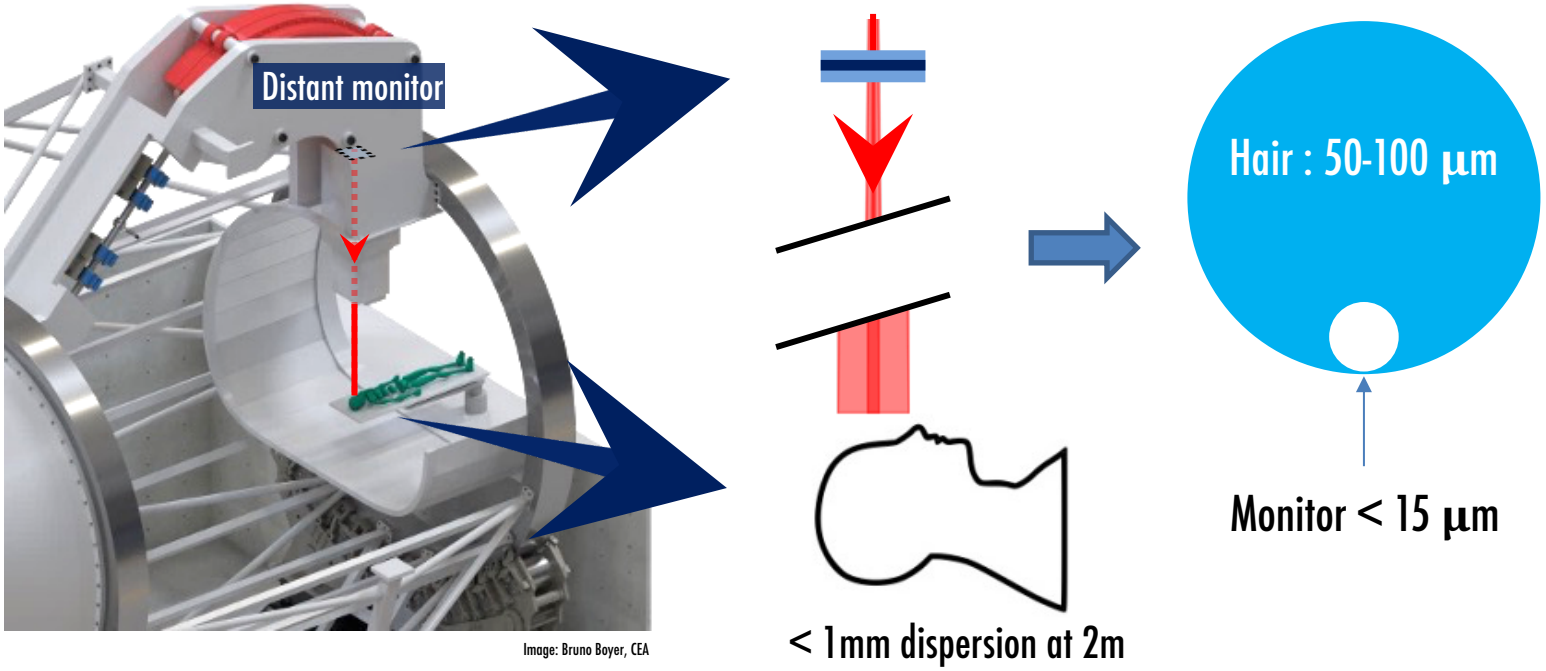
Image IBA

70 MeV < E < 230 MeV

2-4 Gy / min
40-50 Gy treatment

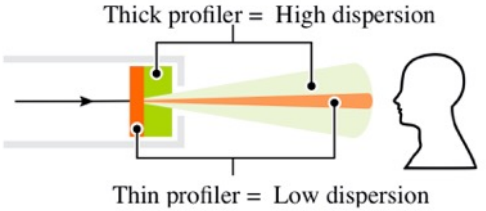
Introduction

Measuring without perturbing



Introduction

Specifications



Goals

Beam minimal perturbation
→ Material budget: 10 µm WET

Minimum deposited dose 10^8 Gy
→ Radioresistance

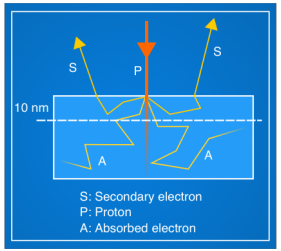
Strategy

- PEPITES (Profileur à Electrons secondaires Pour Ions ThérapeutiquES)
- Development of a fully working prototype (2020) for routine operation at ARRONAX cyclotron
- Experience to go on hadrontherapy machines

WET: Water Equivalent Thickness (0.1 μm Au $\simeq$ 1 μm water 1 μm Kapton $\simeq$ 1.4 μm water)

PEPITES

Profileur à Electrons Pour Ions ThérapeutiquES



Signal

Secondary Electrons Emission (SEE) :

- Surface process
- Low energy (few eV)

→ Need to work in vacuum

- Rate proportional to dE/dx

→ Linear with beam current

→ High signal= high Z → Au

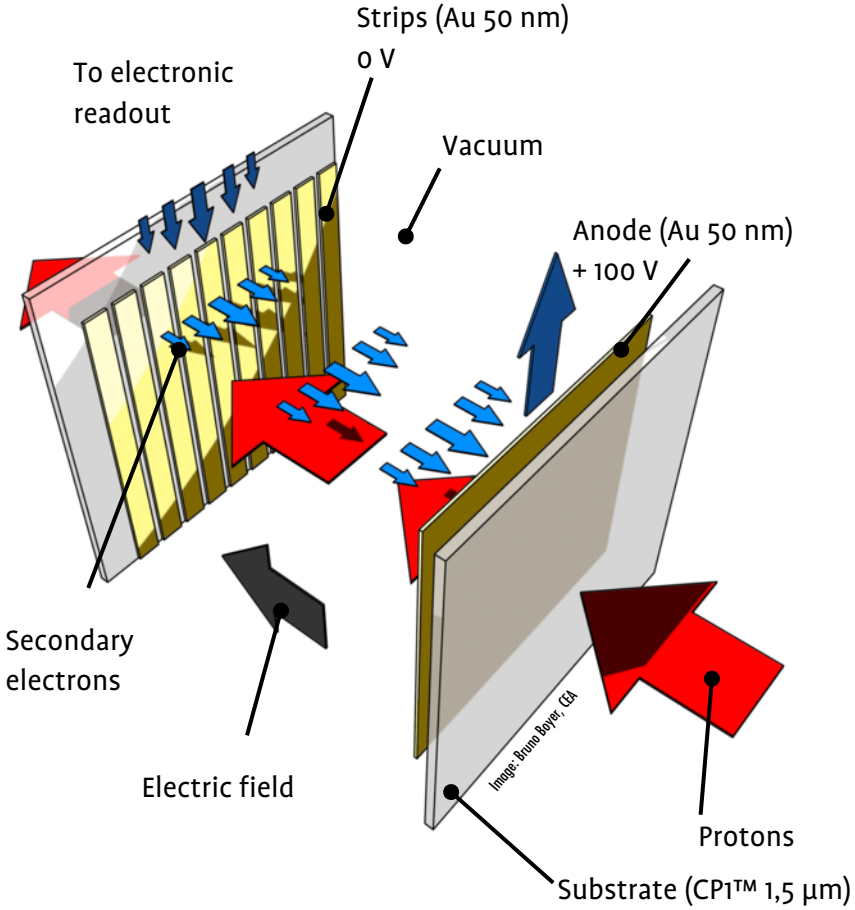
Substrate

CP1™ (Colorless Polyimide) :

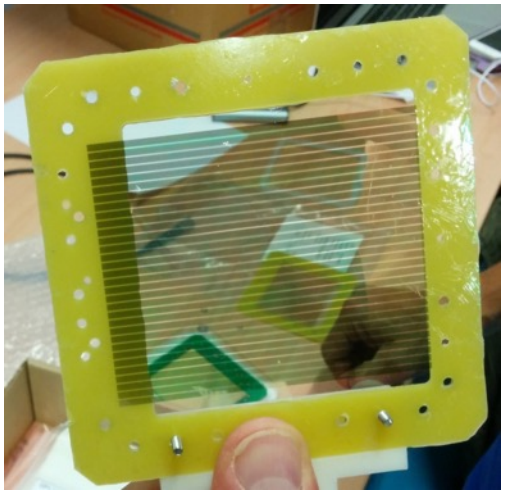
- Thermostable
- Radioresistant
- Used for solar sails !

<u>Fabrication</u>

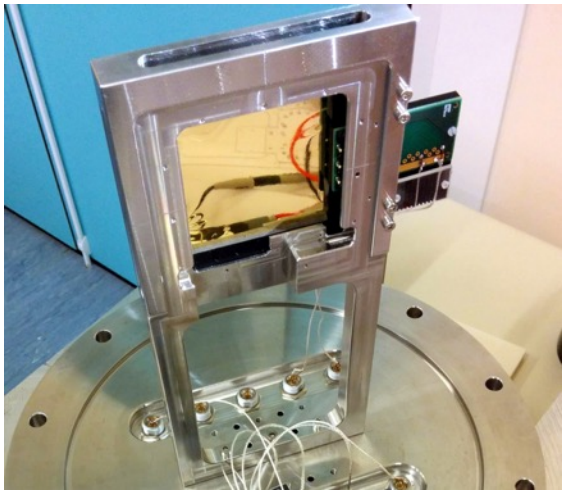
Thin film methods: Chemical Vapor Deposition (CVD)



Pictures



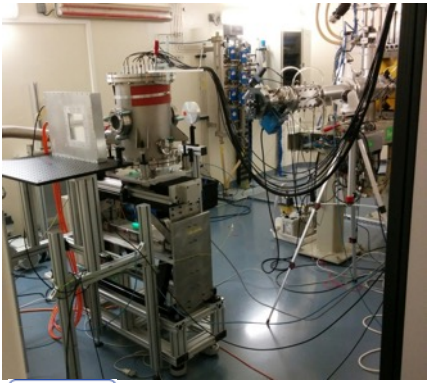
Strips, CP1 ™ 1,5 µm + Au 50 nm



Support mounted Anode plane

Test Beam

Validation (ARRONAX)

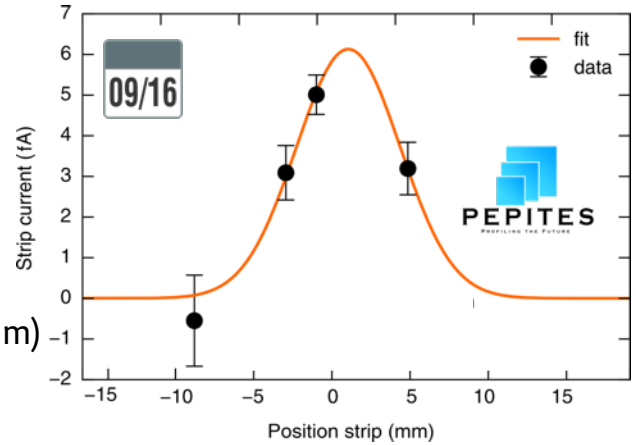


09/16 4 strips prototype,
profiles from **170 fA** to **10 nA** (proton beam)

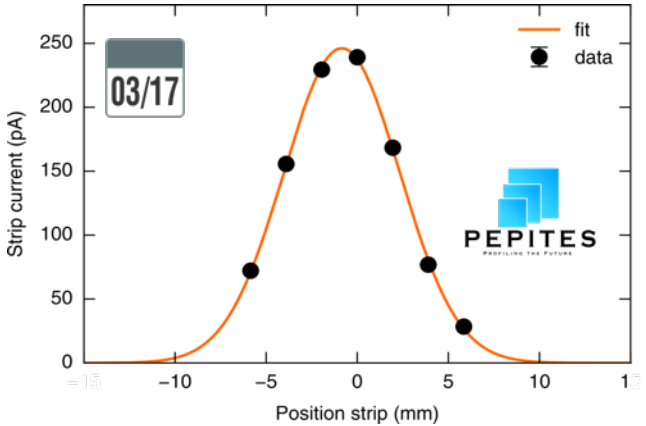
03/17 7 strips prototype
Profiles up to **10 nA** (proton beam)

→ **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

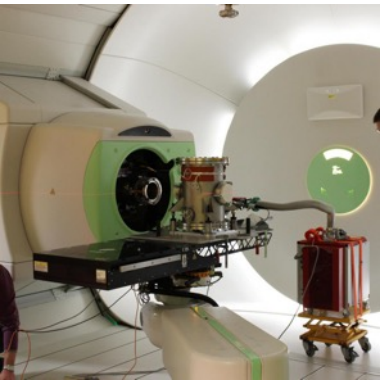
12/18

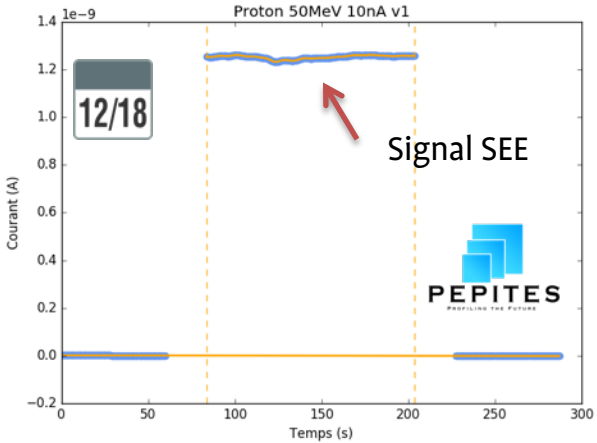
SEE rate up to **100 nA**
protons 32, 40, 50 et 68 MeV
alpha 68 MeV (17 MeV/u) : **analyses on-going**

04/19

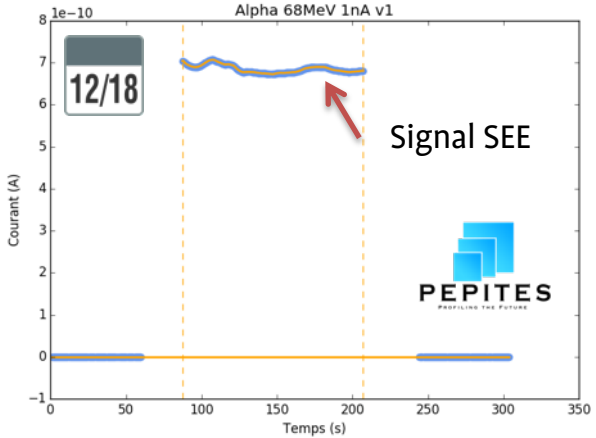
Centre de Protonthérapie d'Orsay (CPO),
protons 100 to 230 MeV, nA beam
(therapeutic conditions)

To be published





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

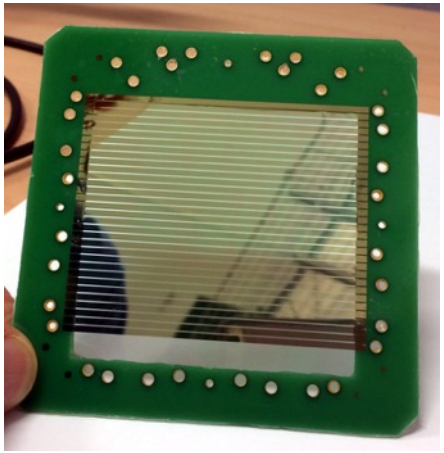
09/18 Electrons 2 MeV : 10^8 and 10^9 Gy
25 µA for beam current

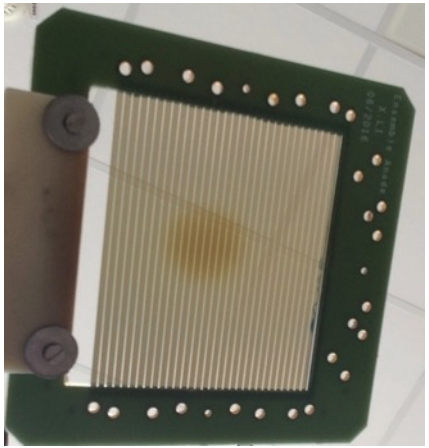
Particle	e- 2 MeV	P 200 keV	P 2 MeV	P 70 MeV	P 230 MeV
dE/dx CP1 (MeV cm²/g)	1.6	0.7	140	8.7	3.7

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**





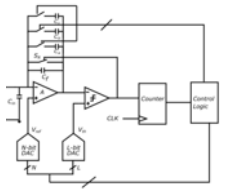
Irradiated CP1™ at LSI before/after

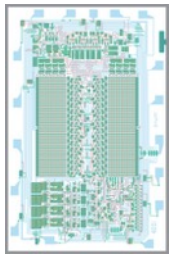
Electronic Readout

Dedicated ASIC

- Development by CEA-DEDI (Saclay, France)
- Large dynamic range (1 fA – 10 nA per channel)
- Techno XFAB 180 nm

Here we are

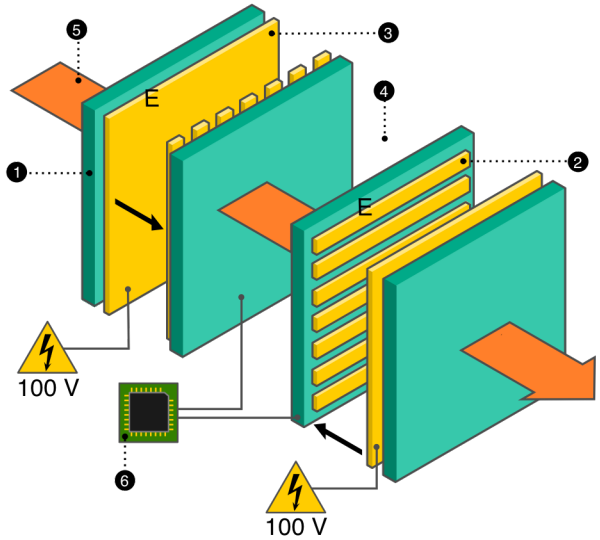


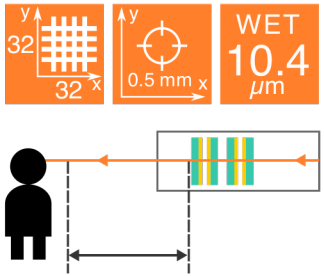


SPECS	DESIGN	LAYOUT	TAPEOUT	PCB	TEST
01/19 – 02/19	03/19 – 06/19	07/19 – 09/19	10/19 – 12/19	01/20 – 03/20	04/20 – 06/20

PEPITES at ARRONAX

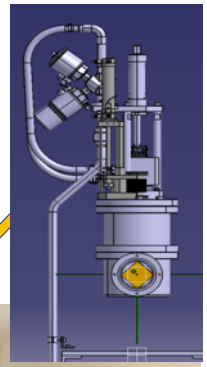
Schematic layout

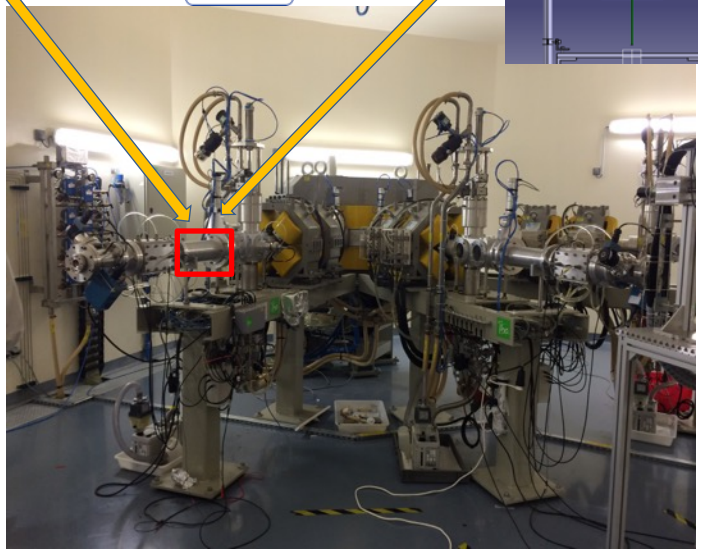




1. Polyimide (CP1™ 1.5 µm)
2. Cathode strips (Au 50 nm)
3. Anode (Au 50 nm)
4. Vacuum
5. Incident beam
6. Readout electronics

Insertion (in-off beam)





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**

Conclusions

- PEPITES: a fully working ultra-thin beam monitor prototype
  - 10 μm WET
  - Able to continuously monitor beam parameters
- Installation at ARRONAX cyclotron (2020)
  - Routine operation
  - Trough further installation on other machines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