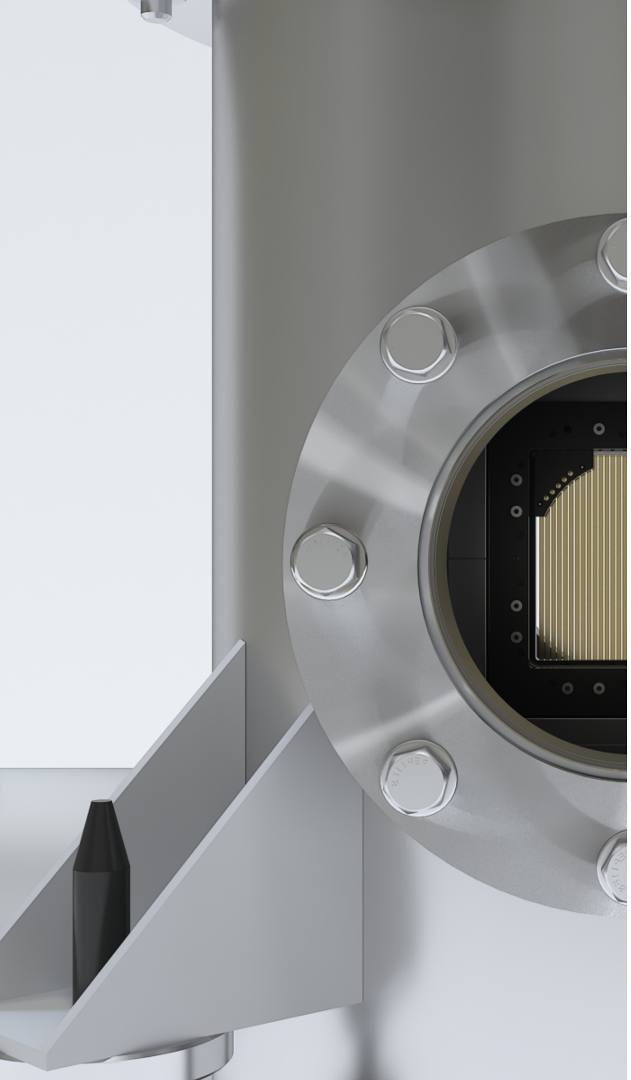

CYC 2019 22-27 SEPTEMBER CAPE TOWN

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

PEPITES

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Laboratoire Leprince-Ringuet

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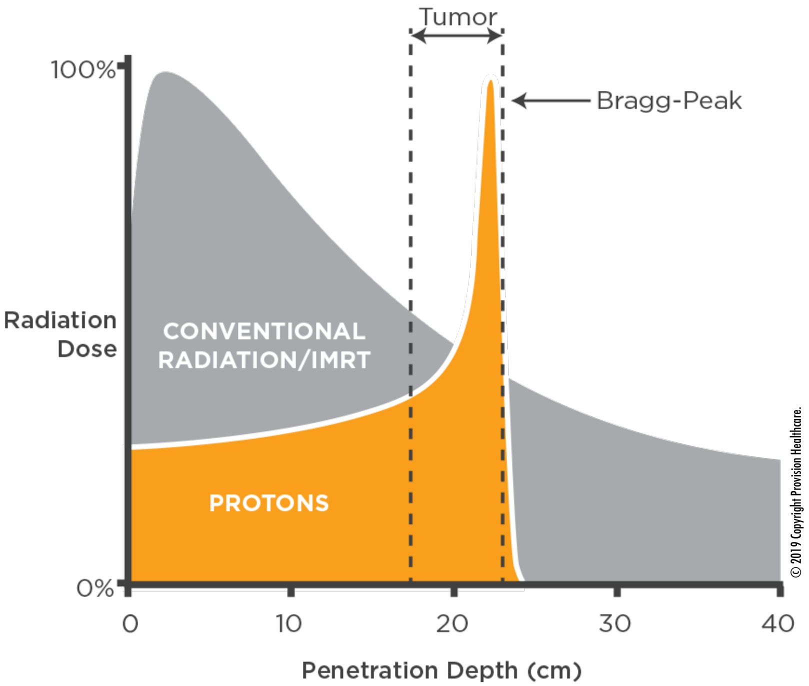
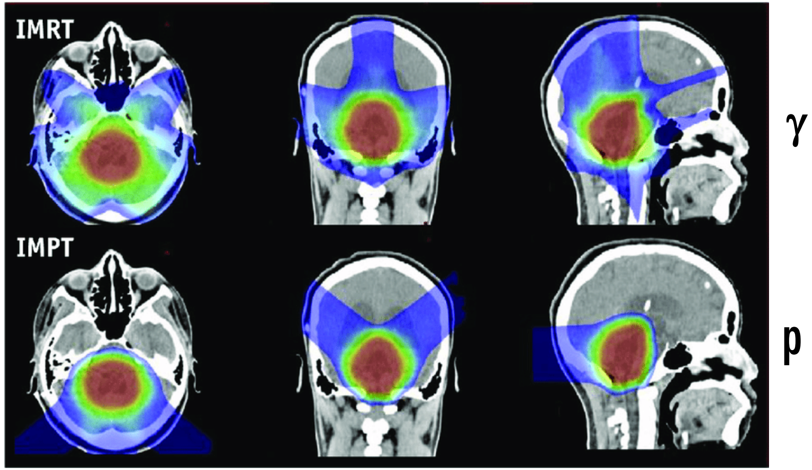
Introduction

Protontherapy context



Indication:

- Resistant tumors
- Non operable
- Pediatrics



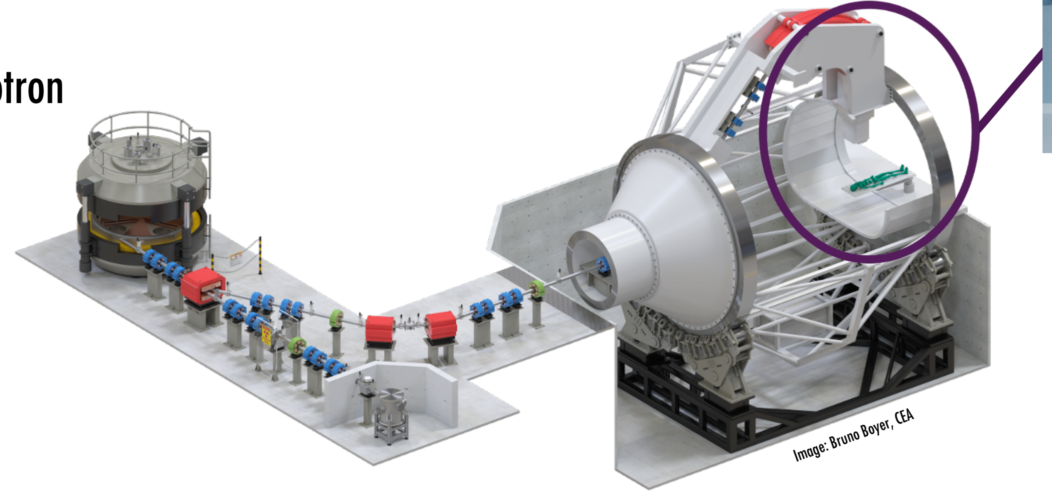
D.J. Indelicato et al. DOI: 10.1016/j.ijrobp.2016.06.2446

Introduction

Protontherapy

Cyclotron

Gantry



Treatment room

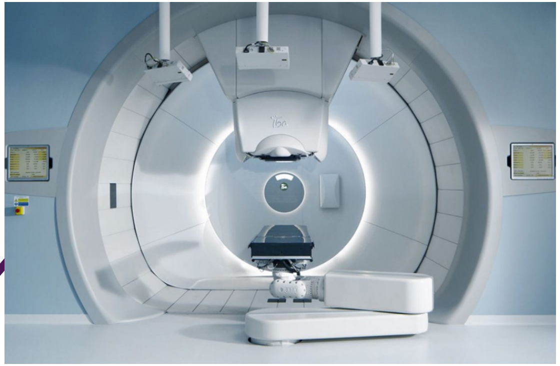


Image IBA

70 MeV < E < 230 MeV

2-4 Gy / min

40-50 Gy treatment

Introduction

Measuring without perturbing

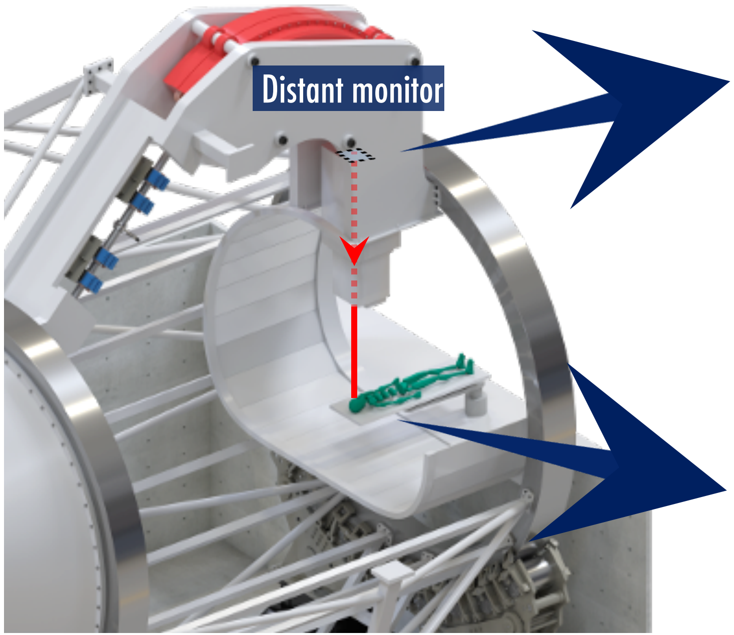
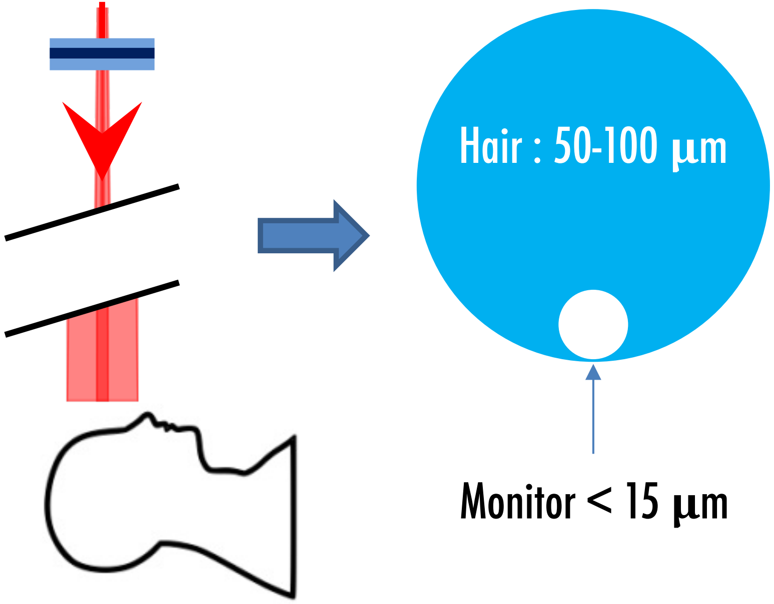
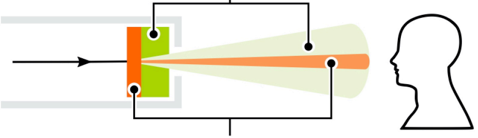


Image: Bruno Boyer, CEA



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) :

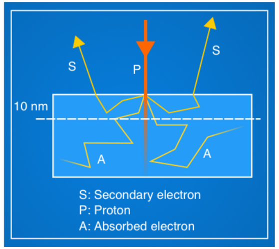
- Surface process
- Low energy (few eV)

→ Need to work in vacuum

- Rate proportional to dE/dx

→ Linear with beam current

→ High signal= high Z → Au



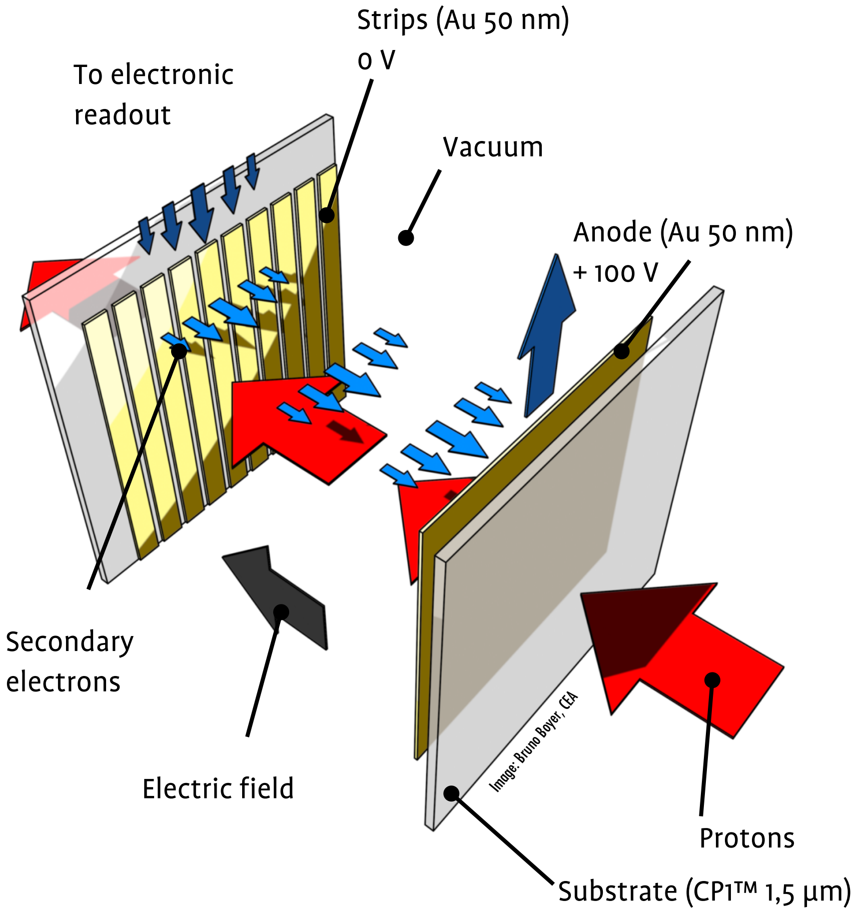
Substrate

CP1™ (Colorless Polyimide) :

- Thermostable
- Radioresistant
- Used for solar sails !

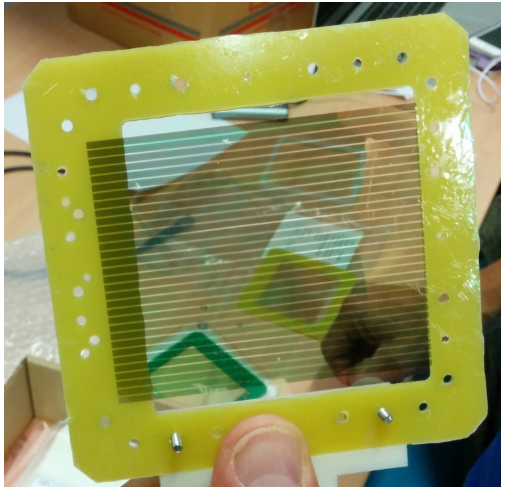
<u>Fabrication</u>

Thin film methods: Chemical Vapor Deposition (CVD)

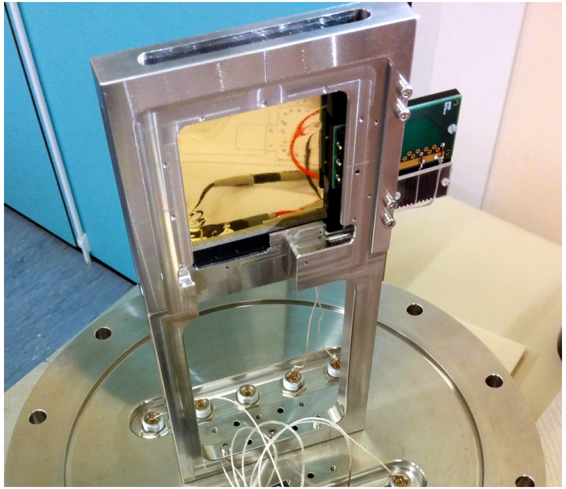


PEPITES

Pictures



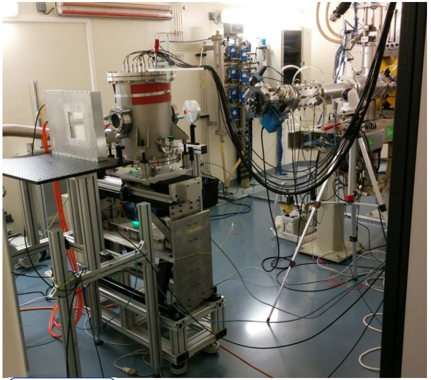
Strips, CP1 ™ 1,5 µm + Au 50 nm



Support mounted Anode plane

Test Beam

Validation (ARRONAX)



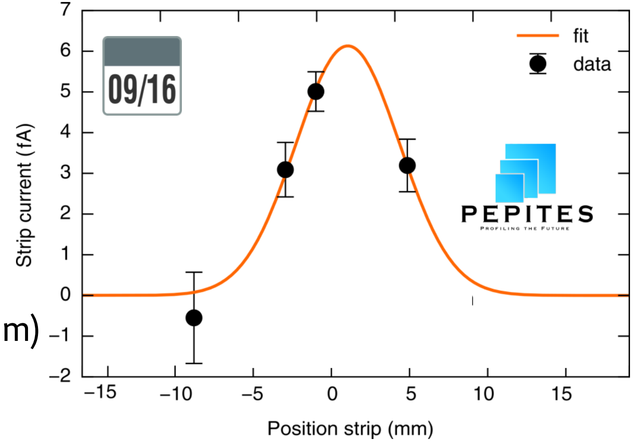
ARRONAX

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

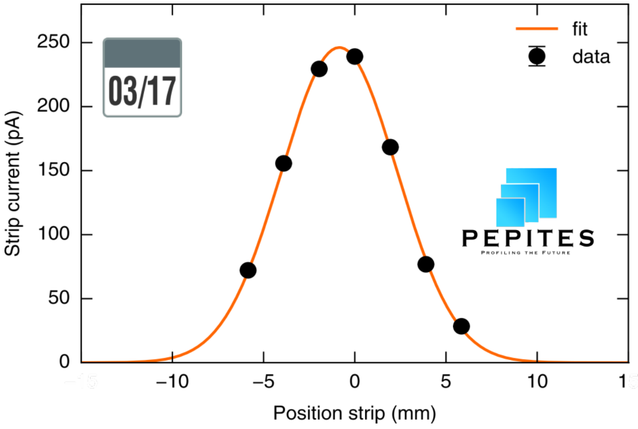
03/17 7 strips prototype
Profiles up to **10 nA** (proton beam)

→ 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)

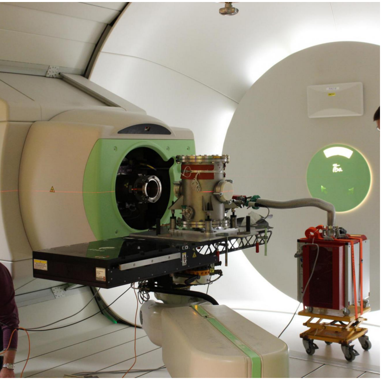
02/18 SEE rate up to **100 nA**
protons 32, 40, 50 et 68 MeV

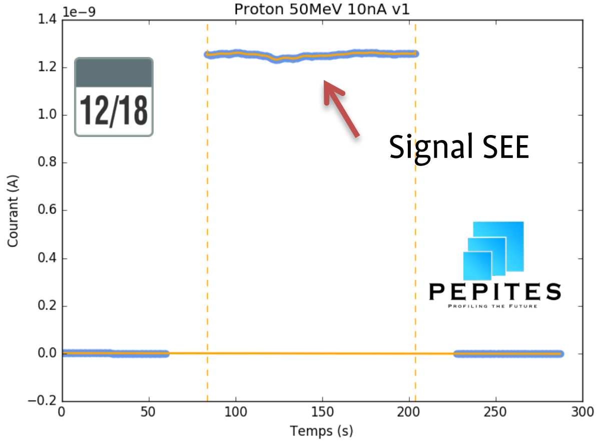
12/18 SEE rate up to **100 nA**
protons 32, 40, 50 et 68 MeV
alpha 68 MeV (17 MeV/u) : **analyses on-going**

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

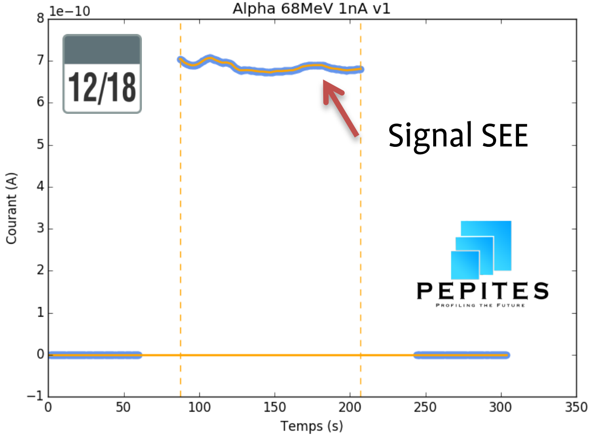
<u>To be published</u>

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

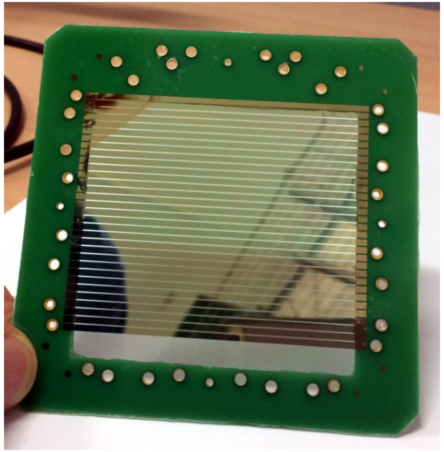
09/18 Electrons 2 MeV : **10^8** and **10^9** Gy
25 µA for beam current

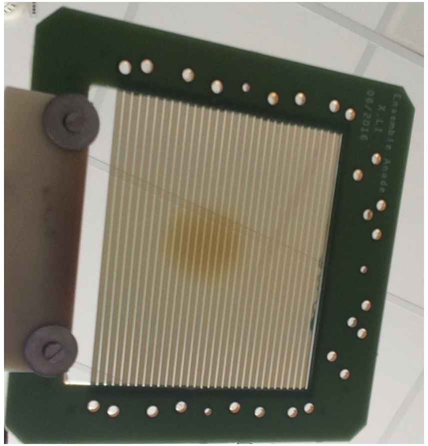
Particle	e- 2 MeV	P 200 keV	P 2 MeV	P 70 MeV	P 230 MeV
dE/dx CP1 (MeV cm²/g)	1.6	0.7	140	8.7	3.7

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^{TM} validated





Irradiated CP1^{TM} at LSI before/after

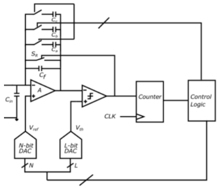
Electronic Readout

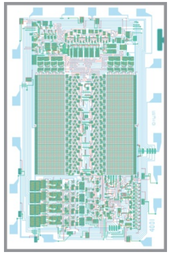
Dedicated ASIC

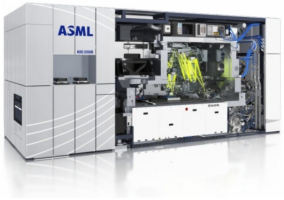
- Development by CEA-DEDI (Saclay, France)
- Large dynamic range (1 fA – 10 nA per channel)
- Techno XFAB 180 nm

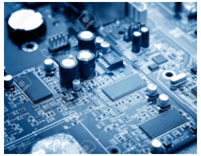
Here we are

XFAB
MIXED-SIGNAL FOUNDRY EXPERTS





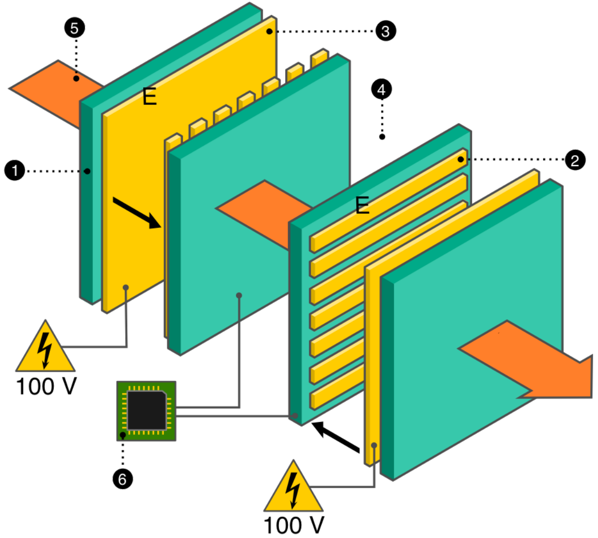


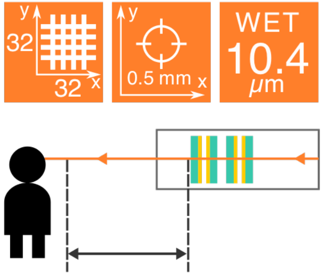


SPECS	DESIGN	LAYOUT	TAPEOUT	PCB	TEST
01/19 – 02/19	03/19 – 06/19	07/19 – 09/19	10/19 – 12/19	01/20 – 03/20	04/20 – 06/20

PEPITES at ARRONAX

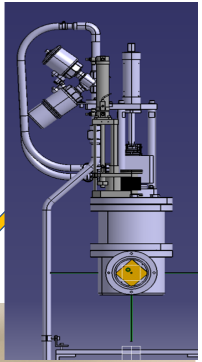
Schematic layout

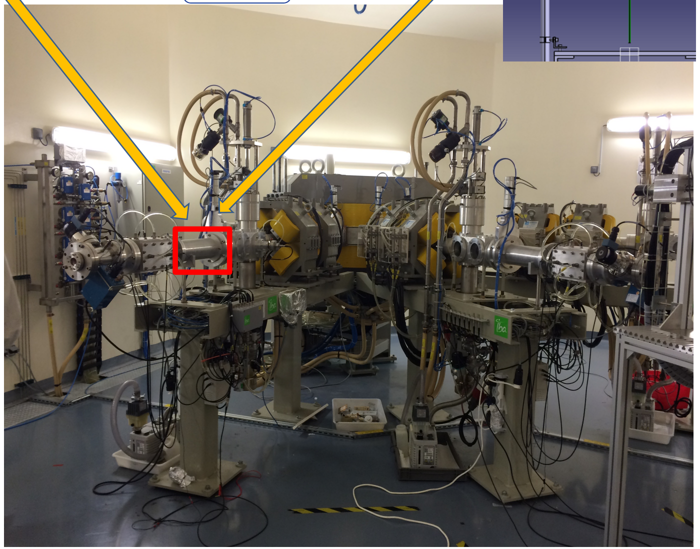




1. Polyimide (CP1™ 1.5 μm)
2. Cathode strips (Au 50 nm)
3. Anode (Au 50 nm)
4. Vacuum
5. Incident beam
6. Readout electronics

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**

PEPITES

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

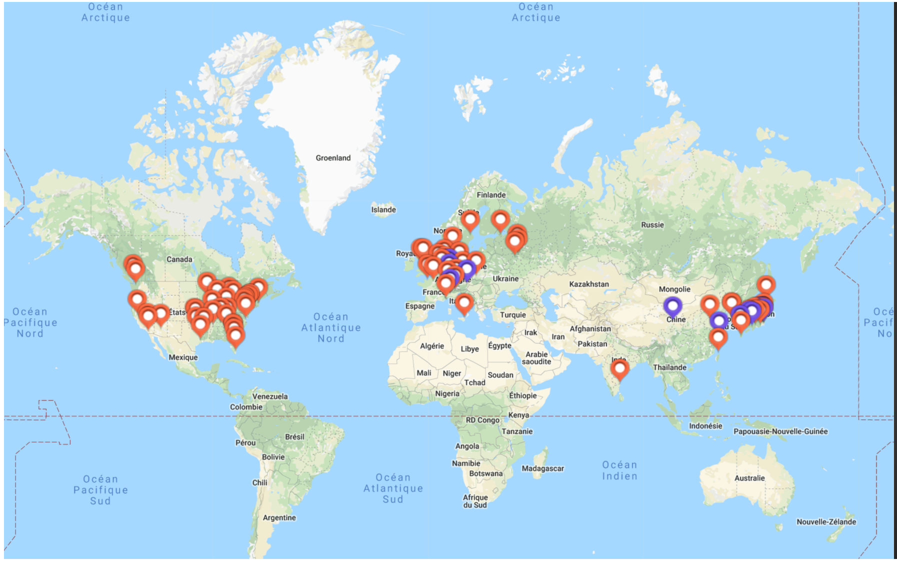
PEPITES

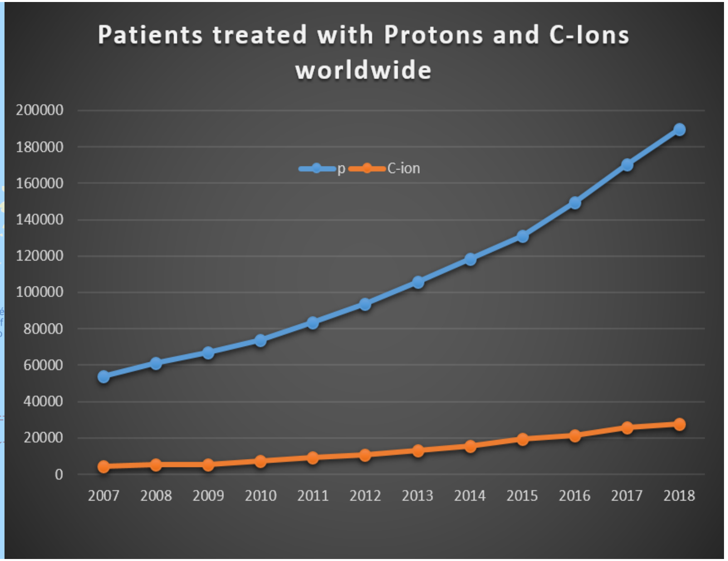
Institut Curie - Centre de Protonthérapie
273 Midtown
GREENWICH

Perspectives

To Medical applications

Routine operation→ Precise knowledge of the detector → trough particle therapy



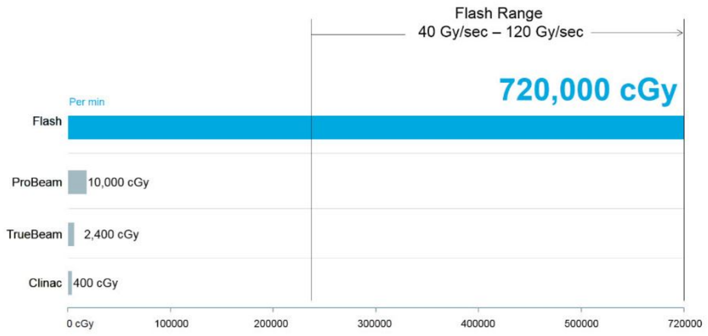


90 particle RT centers worldwide (+ 45 in construction and 25 in project)

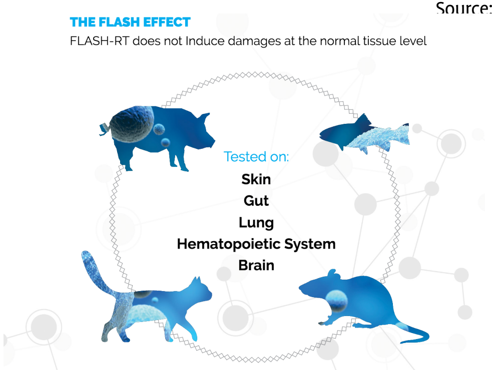
Prospective

Future medical applications

Ultra high dose rates



Source: VARIAN



FLASH THERAPY

Flash spares normal tissue