Development of an ultra thin monitor for charged particle beams

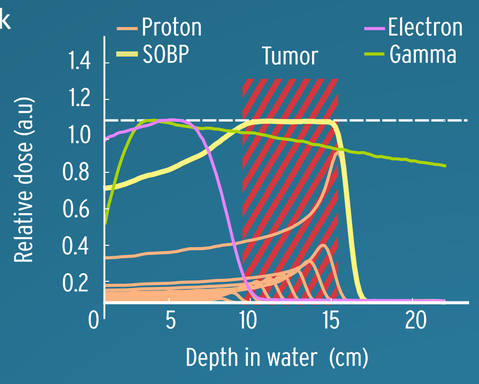
PEPITES

B. Boyer [a], R. Cornat [e], E. Delagnes [d], Y. Geerebaert [a], O. Gevin [d], F. Haddad [b,c], C. Koumeir [b], F. Magniette [a], P. Manigot [a], F. Poirier [b], M. Rubio-Roy [f], N. Servagent [c], C. Thiebaux [a], M. Verderi [a]

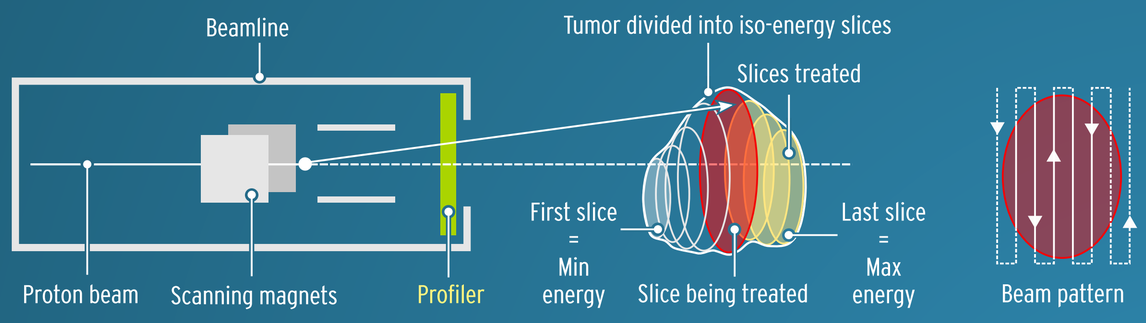
[a] LLR, Ecole polytechnique, CNRS/IN2P3, 91128 Palaiseau, France, [b] GIP ARRONAX, Saint-Herblain, France,[c] SUBATECH, IMT Atlantique CNRS/IN2P3, Université de Nantes, France [d] IRFU, CEA, Université Paris-Saclay, F-91191 Gif-sur-Yvette, France, [e] Laboratoire de Physique Nucléaire et des Hautes Energies, Sorbonne Université - CNRS/IN2P3, [f] UMR 8191 - SPINtronique et technologie des composants

Protontherapy

- Maximum dose near end of proton track → Bragg peak
- Low lateral scattering in the tissue
  → beam stays focused on the tumor
- Bragg peak position adjustable by beam energy
  → Spread Out Bragg Peak (SOBP)
- **Therapeutic energy range : 70 – 230 MeV**
- **Beam current = nA**
- Application : resistant, inoperable (skull) or pediatric cancers



Pencil Beam Scanning Technique



Thickness is a critical parameter
the thicker the profiler, the larger is the geometrical dispersion

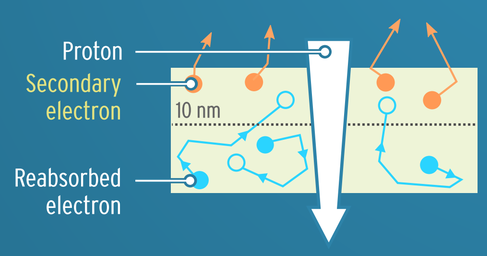
Our beam monitor fulfills this requirement through its features

- **Low beam pertubration thanks to a 10 µm WET (Water Equivalent Thickness)**
- **Durability (dose deposited > 10^6 Gy)**
- **Wide dynamic range**
- **Easy maintenance**

Generating a signal with a thin material

Secondary Electron Emission (SEE)

- Surface process
- Only electrons close to the surface escape
- Low energy (few eV) → vacuum mandatory
- **Yield ≅ dE/dx → Strong signal = High Z**



Detector principle

- Beam sampling with thin SEE emissive pattern deposited on thin dielectric substrat layer
- (X,Y) sampling using SEE currents from strips
- Signal readout from the emission side → unaffected by EM fields in the beamline
- No filling gas → no mechanical constraint → thin materials usable

Gold

- High Z: 79 → Good signal level
- SEE is a surface process → 50 nm is enough (emission and conductivity)
- Oxyde free → SEE yield is not modified
- Delamination can occur → Intermediate layer of chromium or plasma surface treatment

Kapton® **PEEK** **Mylar** — **Polymer**

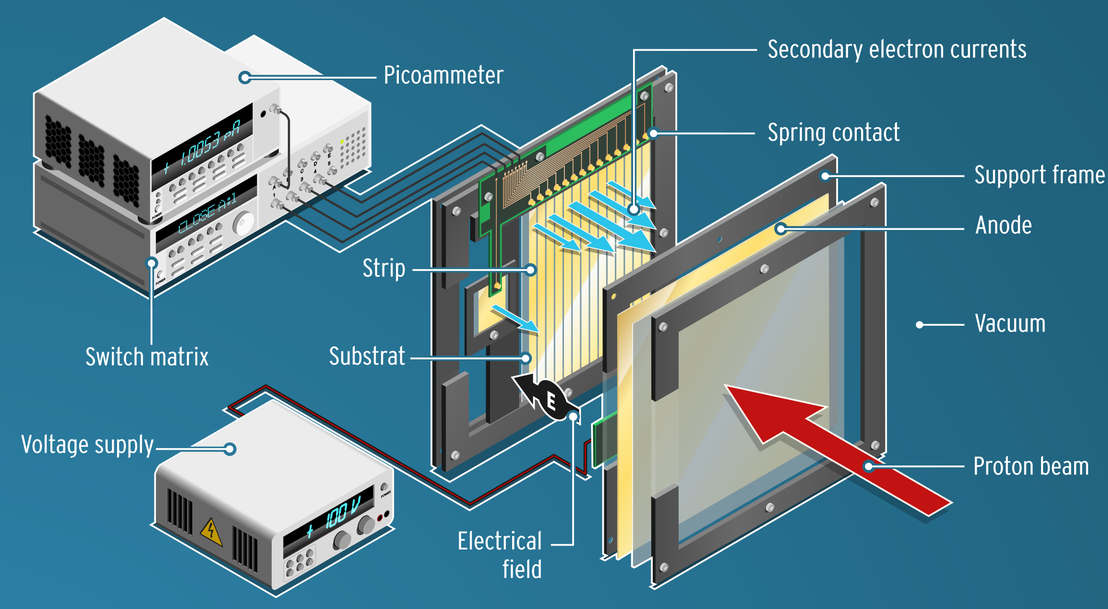
- Light elements (C,H,O,N) = low perturbation
- **Kapton and PEEK sustain high temperature (> 300 °C)**
- Radioresistance due to aromatic cycles
- Thicknesses available on the market: Kapton 8 µm, PEEK 6 µm, Mylar 1.5 µm and less

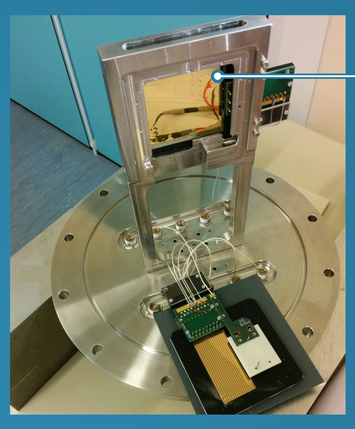
Silicon Nitride — **Ceramic**

- T° decomp = 1900 °C
- **Nanometer thicknesses**
- Brittle (handle with care !)
- No large self-standing foil → R&D

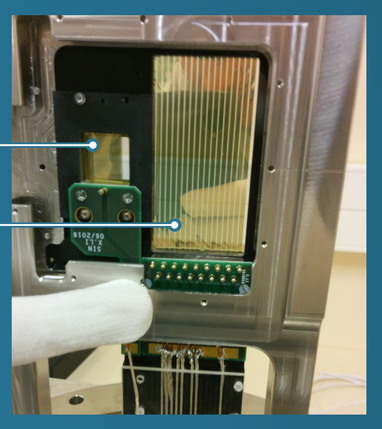
Test of a detector prototype

- One dimension sampling (polymer + gold) and experiment with Si_3N_4 membrane

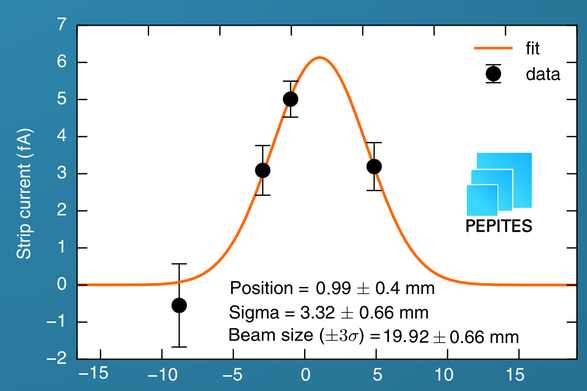


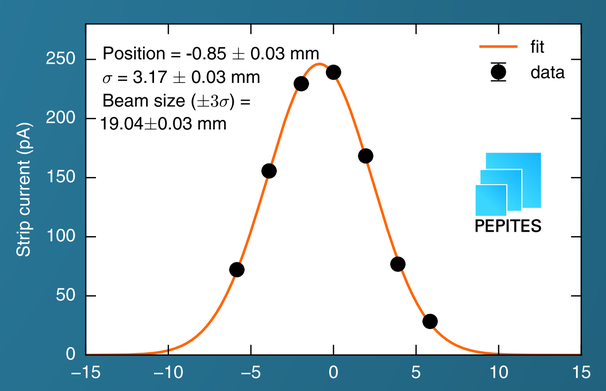


Kapton 8 µm + gold 100 nm (CVD)
Silicon nitride 100 nm + gold 50 nm (S)
Strip : gold 50 nm
Width : 1.6 mm
Interstrip : 0.35 mm
Substrat : PEEK 6 µm (CVD)
CVD = Chemical Vapor Deposition
S = Sputtering

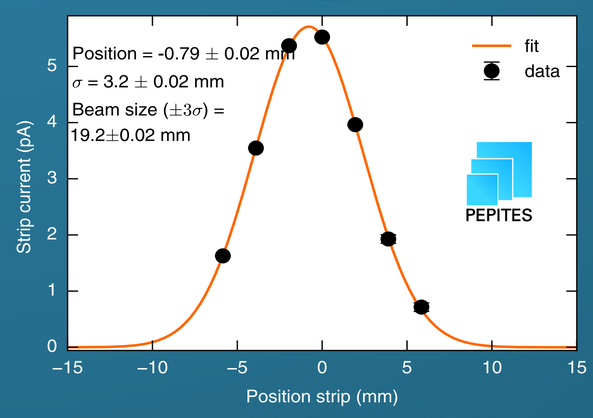


- Measurements have been performed at the ARRONAX cyclotron in St Herblain, France
- **Tested dynamic range: 200 fA to 10 nA allowed by the electronic and SEE yield, respectively**
- Beam profile crosschecked with a pixelated ionization chamber at I_{beam} = 100 pA



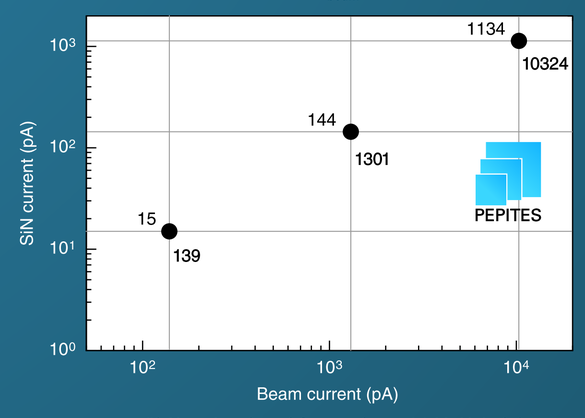


Protons 60 MeV, I_{beam} = 170 fA, 4 strips



Protons 27.9 MeV, I_{beam} = 100 pA, 7 strips

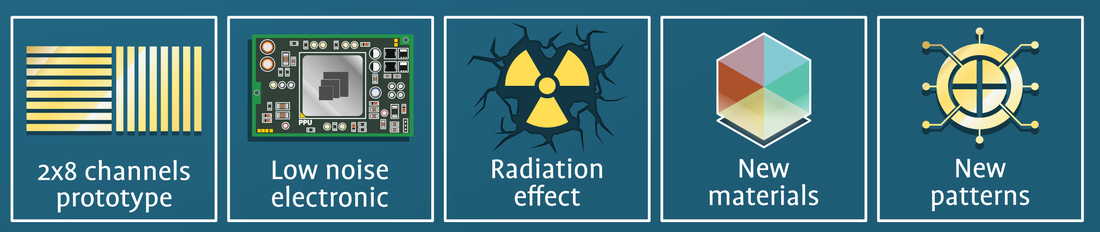
Protons 66 MeV, I_{beam} = 10 nA, 7 strips



Si_3N_4 + Au signal for protons 66 MeV, 1 strip

Detector principle validated
Next beam test planned at Orsay Proton Therapy Center

Future studies



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