H2020-MSCA-RISE-2015 – Grant Agreement N° 690835

MUSE Mid-Term Meeting
Frascati, 11 May 2017

Plans for Medical Applications

SiPM for Particle Therapy

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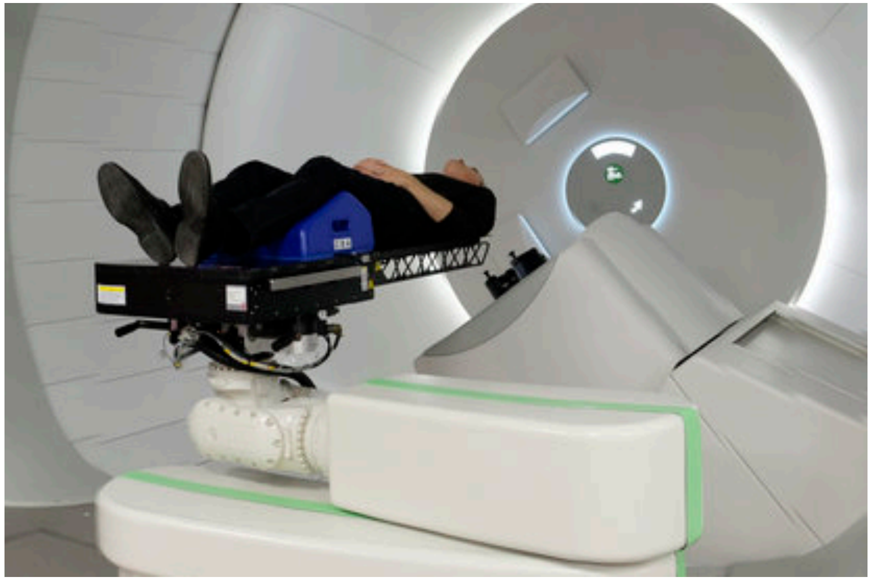
Detectors for Particle Therapy



Signal originates from radiation inside humans. Its magnitude is defined by medical considerations.

It cannot be optimized for detection!

Conditions

- significant neutron background
- short measurement times (seconds)
- magnetic fields from equipment (accelerators, MRI)

Requirements

- fast, efficient, magnetic insensitive sensors
- high bandwidth, background insensitive system design

Why Silicon Photo Multipliers?

SiPM		Benefits

▪ small
▪ inexpensive
▪ efficient
	→	▪ can afford many channels
		  ▪ reduced pileup
		  ▪ good spatial resolution

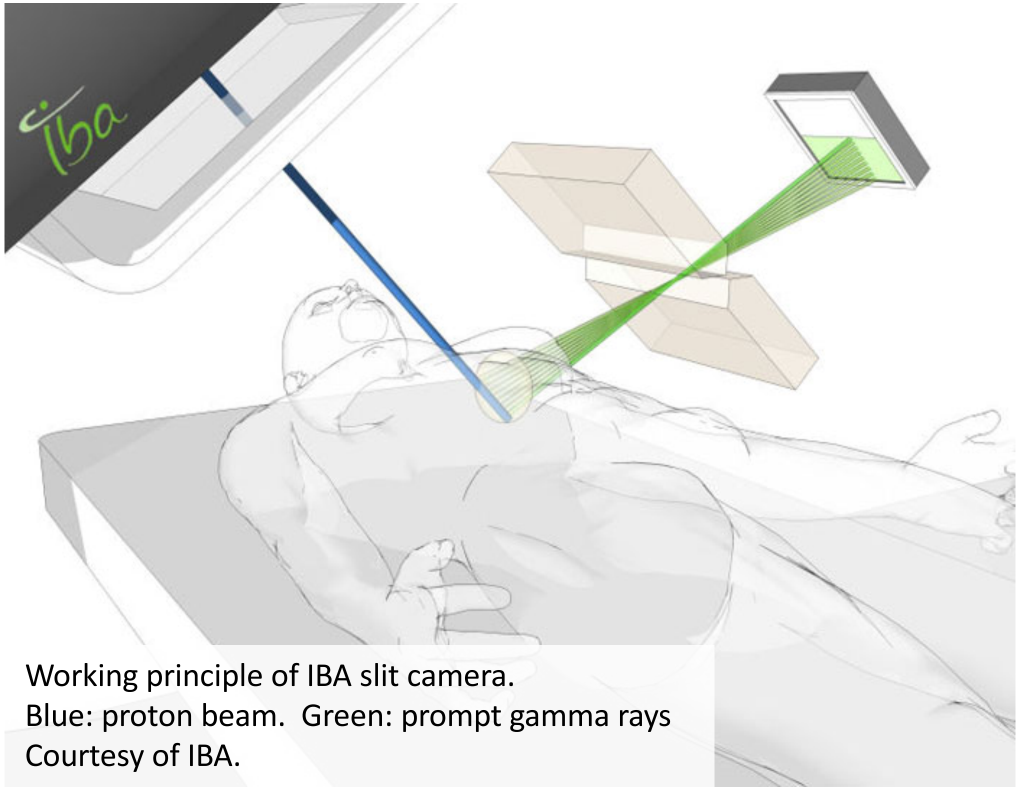
▪ fast	→	▪ time resolution, pileup
▪ magnetic field insensitive	→	▪ compatible with medical environment

But:

- limited radiation hardness

Dr. Benjamin Lutz | Institute of Radiation Physics | www.hzdr.de

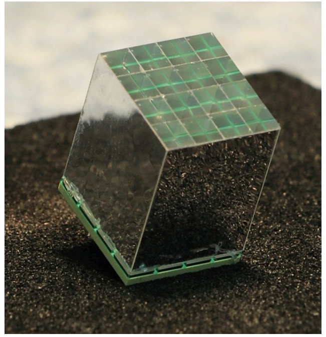
Applications of SiPM:
IBA Slit Camera



Working principle of IBA slit camera.
Blue: proton beam. Green: prompt gamma rays
Courtesy of IBA.

- prototype currently being tested
- range verification system
- exploiting prompt gamma rays emitted when primary beam interacts with patient tissue
- slit focuses beam on crystal array
- crystal array read by SiPM

Applications of SiPM:
In-Beam PET



4×4 LYSO 3×3×15mm^3
SiPM matrix (Hamamatsu)
used in ToFPET

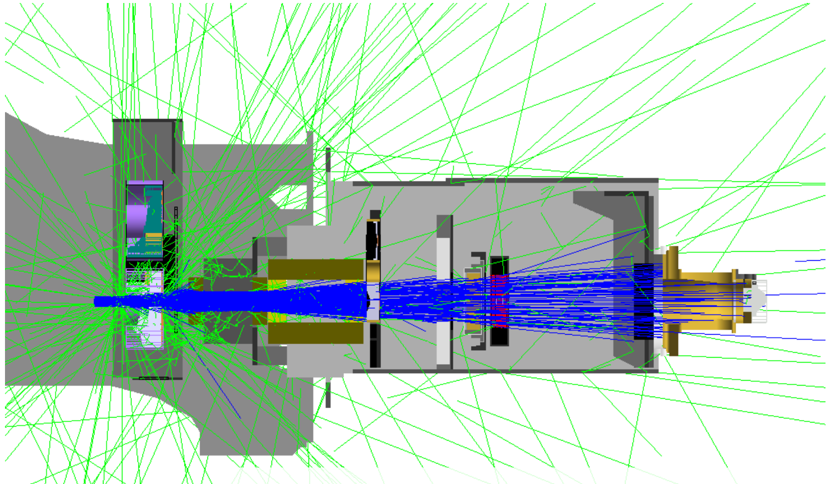
?

BGO-Block:
8 × 8 Kristalle; 2 × 2 PMT

In-beam positron emission tomography

- uses ß$^+$ emitters created by primary beam
- range & dose verification
- very challenging background conditions compared to standard PET
- detection efficiency important
- can we improve by changing the technology from PMT to SiPM?

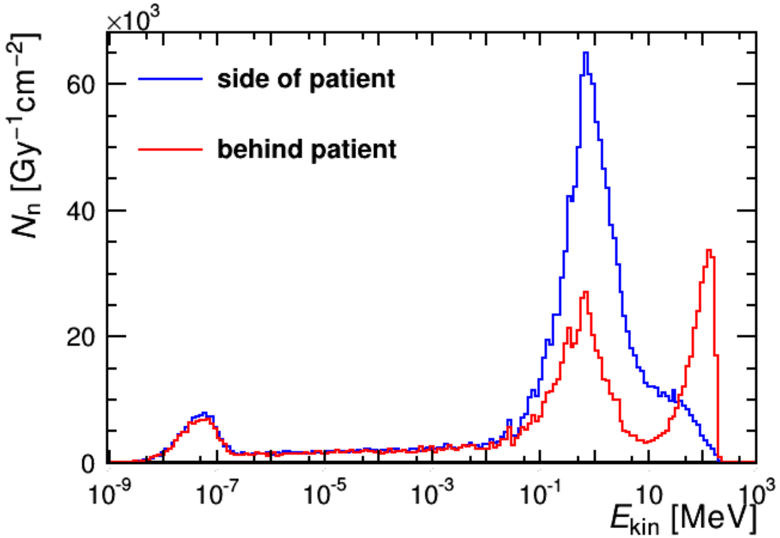
Neutron Background at University Proton Therapy Dresden



simulation of UPTD beam delivery system

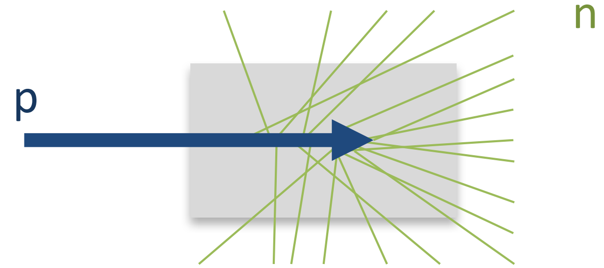
Neutron flux

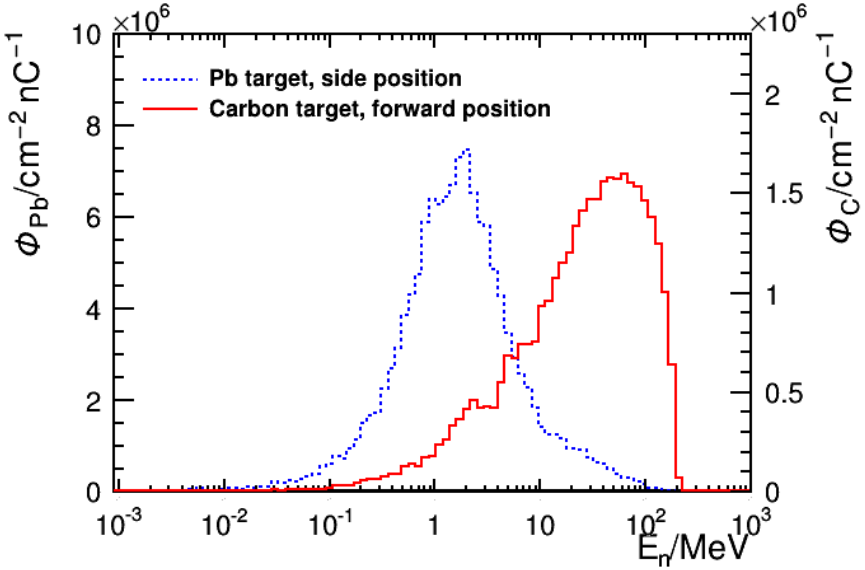
- position dependent
  - intensity
  - spectral shape
- significant contribution of high energetic neutrons (10 – 230 MeV)
- $5 \cdot 10^4$ $cm^{-2}s^{-1}$ (peak rate)
- $1 \cdot 10^{10}$ $cm^{-2}a^{-1}$ (200 patients)



simulated neutron flux

SiPM Irradiation Tests





simulated neutron flux

- field generation:
  - UPTD experimental area
  - absorb proton beam in Pb or C-rich material
  - different materials and location give different neutron spectra
- monitor SiPM during irradiation
- test spectral sensitivity

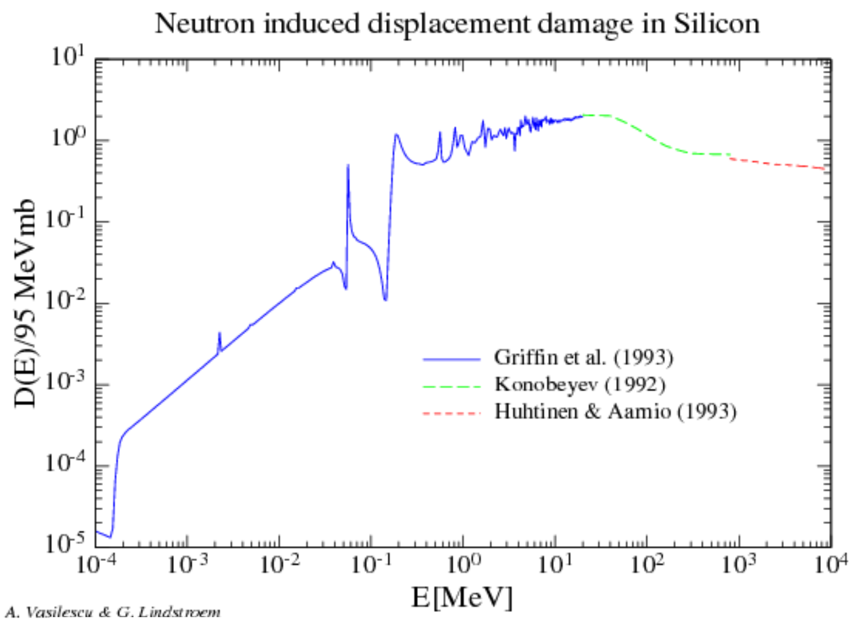
What to learn from irradiation

test for SiPM degeneration

- noise increase
- gain reduction
- shift of working point
- failure of pixel quenching

induced signals

- SiPM material
  - sensitivity
  - abnormal signals
- packaging



Vasilescu (INPE Bucharest) and
G. Lindstroem (University of Hamburg),
Displacement damage in silicon, on-line compilation

Crucial:

close contact with producer

- understand effects
- mitigate/remove sensitivity
- define best SiPM for medical applications

MUSE DRESDEN concept HZDR

Summary

- SiPM are promising candidates for use in medical applications
  - small & inexpensive
  - fast
  - magnetic field insensitive
- Proton therapy has a challenging neutron background
  - spectrum extends to high kinetic energies (230 MeV)
  - high flux

➔ SiPMs need to be qualified for the use at such fields in irradiation test
  - simulation of neutron yield completed for Pb and graphite
  - target holder and targets available
  - beam time request approved
  - SiPM readout currently developed
- First meeting with AdvanSiD this month