
CERN
HSE
Occupational Health & Safety
and Environmental Protection unit

Detector Development for Medical Applications

A Large Area GEMPix detector for treatment plan verification in hadron therapy

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Supervisor: Marco Silari

Start date: 01-09-2018

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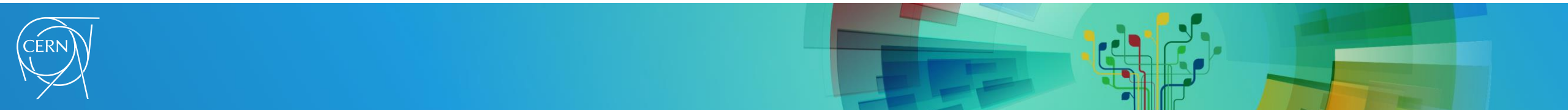


Introduction

Myself

Beginning of Academic Period
Sept 2012

IJUP 2015
May 2015

FISMED 2017
Nov 2017

PRS2017
Sep 2017

ICDA-3
May 2019

End of FCT Trainee
Aug 2020

Conclusion of PhD
Feb 2022

2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022

Today

Master Thesis
"Optimization of an in vivo verification system using TLD dosimetry"

BSc. in Technological Physics — FCUP & FEUP

Internship in Nanomaterials and Nanodevices — REQUIMTE, Department of Chemistry and IFIMUP-IN, Department of Physics

MSc. in Medical Physics — FCUP & IPO-Porto

Internship in Dosimetry for External Radiotherapy — IPO-Porto

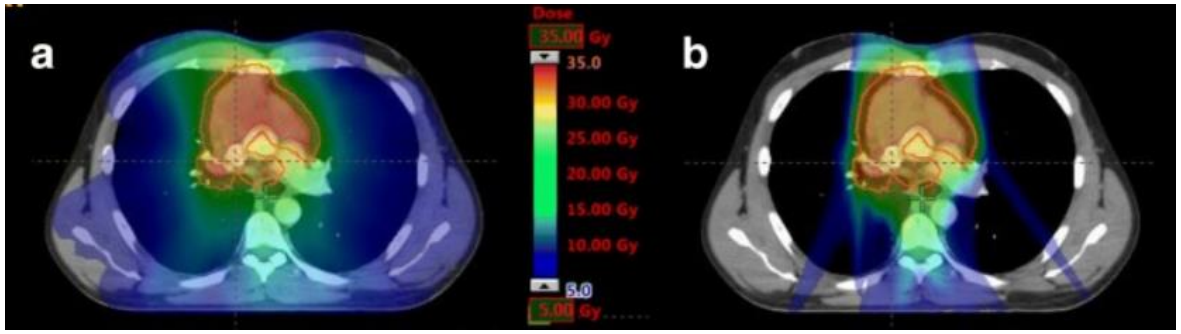
Radiation Protection (RP) Technician — ISQ

Medical Applications Detector Engineering — CERN

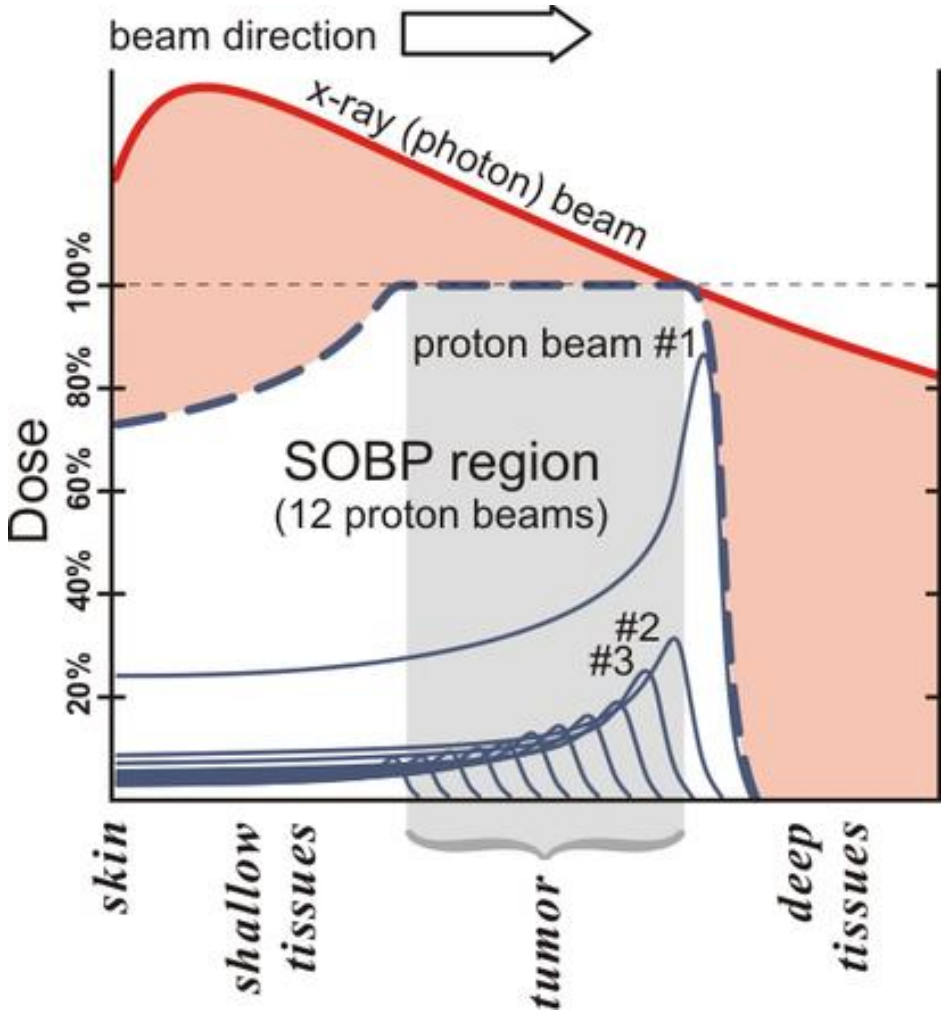
PhD. Medical Applications of Particle Physics — *University of Bern, Albert Einstein Center, LHEP*

Hadron Therapy & Quality Assurance

- Hadron therapy: Well-defined region of energy deposition
- 2D images with better spatial resolution than ion chambers
- QA: check range, spread of Bragg peak, treatment plan verification
- QA: typical dose uncertainty O(1%)



[1] doi: 10.1186/s13014-018-1066-2



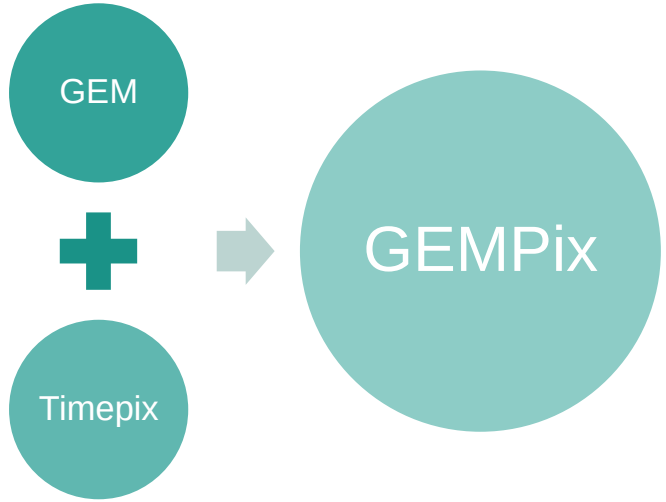
[2] doi:10.1038/sj.bjc.6602754

My goal

LaGEMPix

Combination of two existing CERN-developed technologies

- Detection of all types of radiation with a high spatial resolution
- Proven potential → hadron therapy active dosimetry
- Current active detection area of the GEMPix detector is a limitation for some medical applications



The **aim** of the my internship:

- Implement a larger detection area upgrade on the GEMPix detector
- Redesign the detector from the hardware to the data acquisition firmware.
- Built a prototype
- Characterization of the detector at CERN calibration facilities.
- Validation in a radiation therapy facility and comparison of the results obtained by standard techniques.

The GEMPix Detector

Triple GEM

- 3 Gas Electron Multipliers (GEMs)
- Kapton foil + thin copper layers
- Large field in the holes, electron multiplication

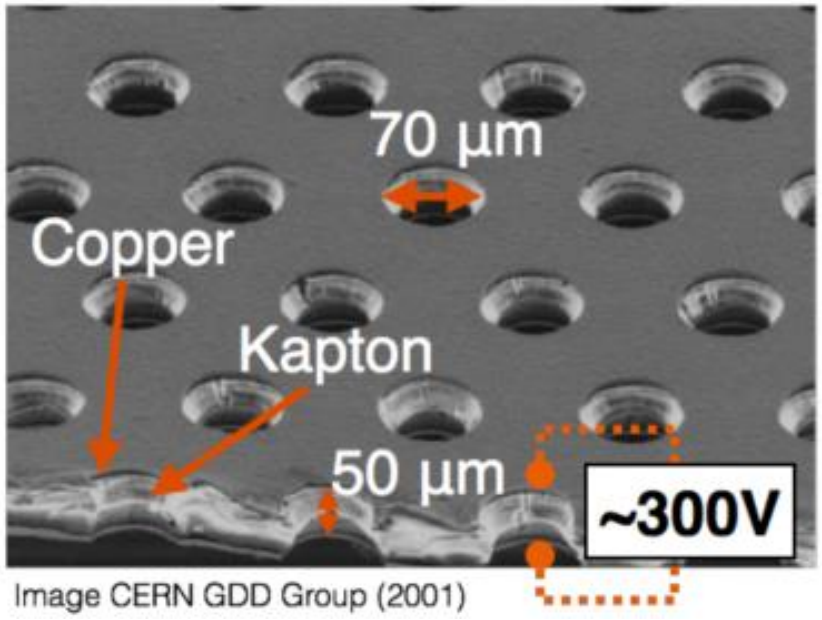
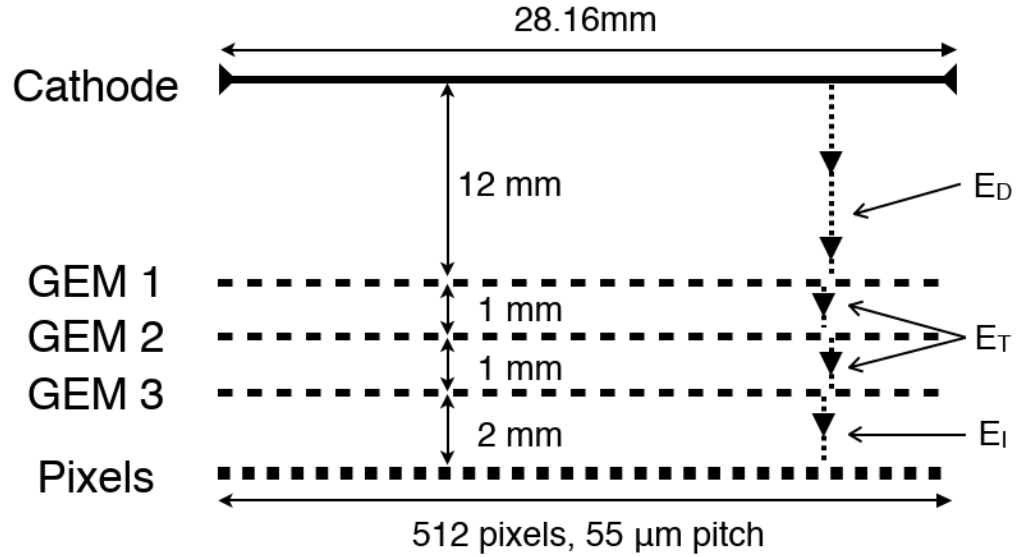
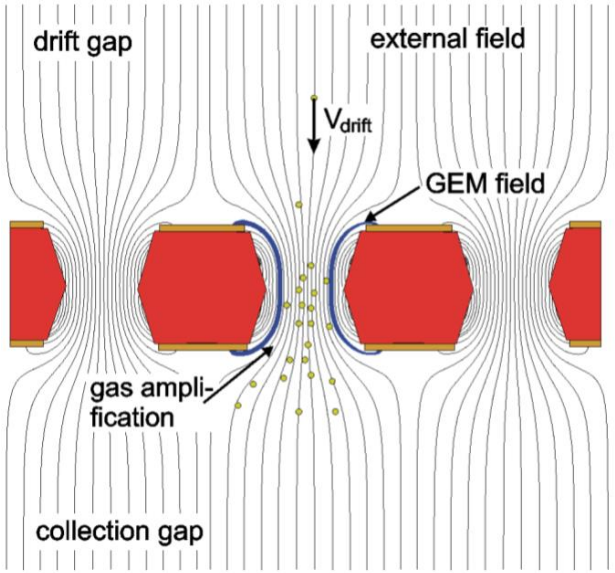


Image CERN GDD Group (2001)





[3]

The GEMPix Detector

Gas Electron Multipliers (GEMs) + Pixelated Read-out

(1) FITPix

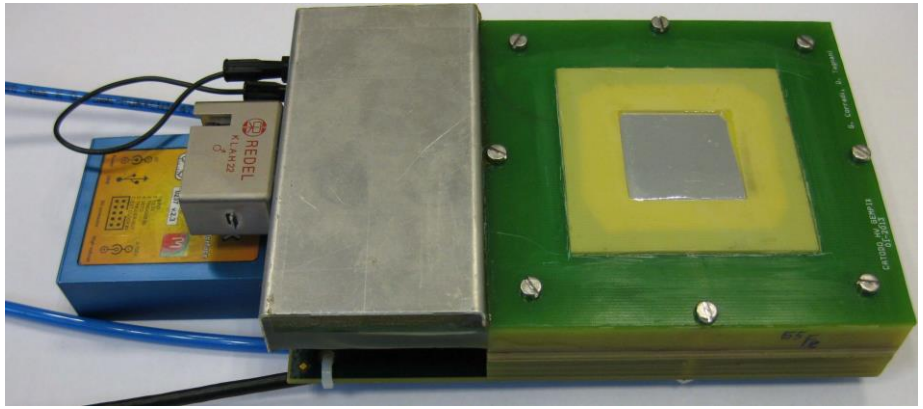
(2) Temperature, pressure and humidity sensor

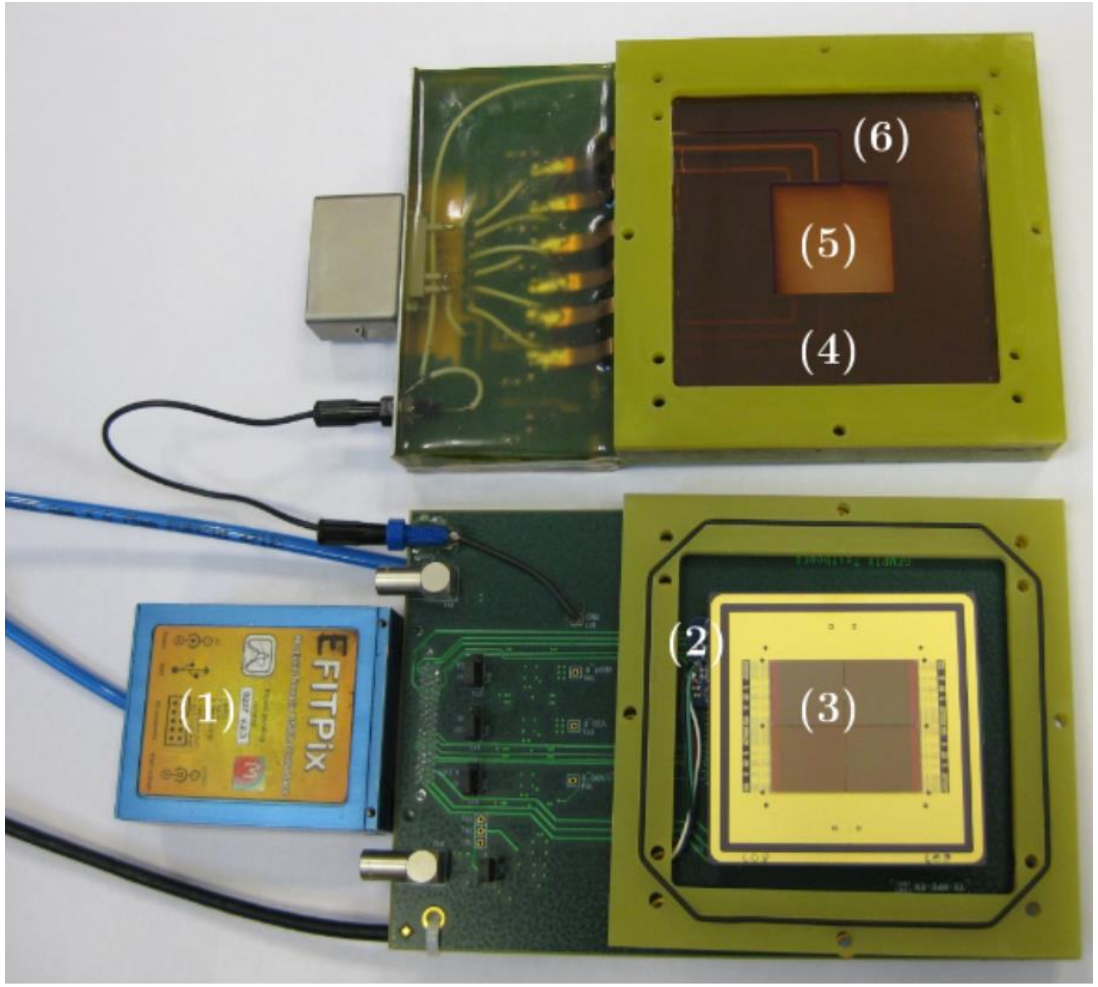
(3) 4 TimePix ASIC

(4) Kapton foil + (5) Copper = (6) GEM

• 2.5 cm^3 gas detection volume

• Applications: Hadron Therapy, Radioactive Waste, Microdosimetry

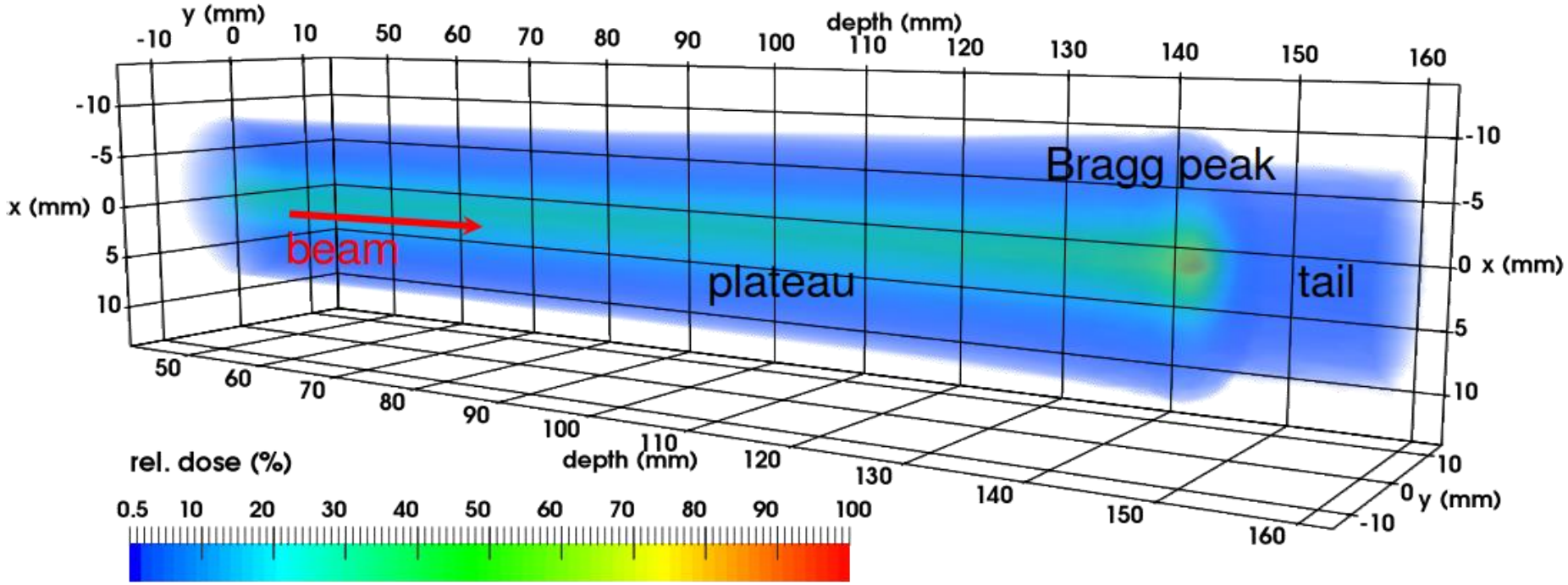




Measurements at CNAO

3D energy deposition by ^{12}C ion beam

3D dose reconstruction after depth scan

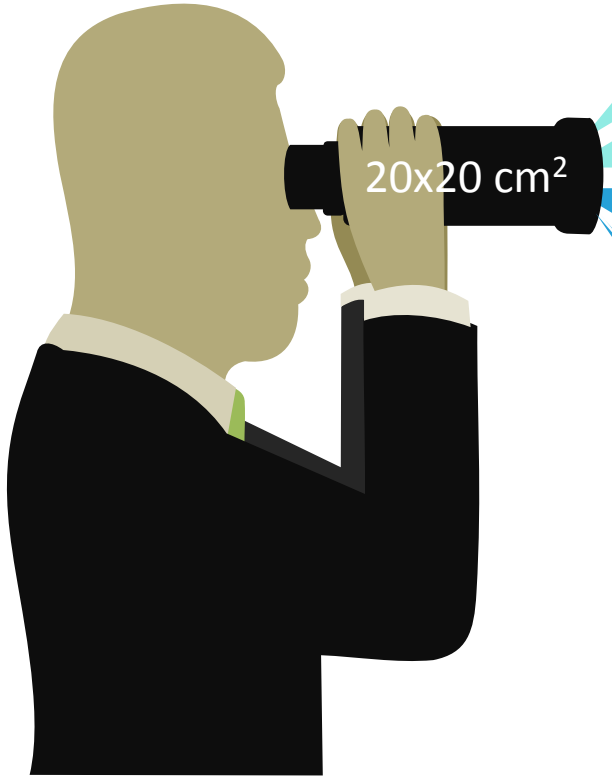


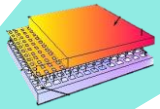
paper on proof-of-concept: J. Leidner et al. 3D energy deposition measurements with the GEMPix detector in a water phantom for hadron therapy. JINST. 2018.

Readout Options

Gas Electron Multipliers (GEM's) +
Pixelated Read-out

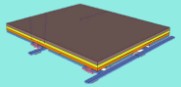
Charge readout
or
Optical readout?





01 Timepix or Timepix3

Well-known system
Good performance
Cost
Hardly possible to increase area



02 TFT (Thin Film Transistor)

Printed on any size
Easy to couple to triple GEM
Radiation hardness (to be studied)

03 TFT + OPD (Organic Photodiode)

Printed on any size
Easy to couple to triple GEM
Two complementary signals: electrons and photons
Radiation hardness (to be studied)

04 CCD/CMOS Camera

High resolution
Complexity of set-up
Radiation hardness

05 Light sensitive Timepix 3

INNOLUX
INNOLUX CORPORATION

European funding project

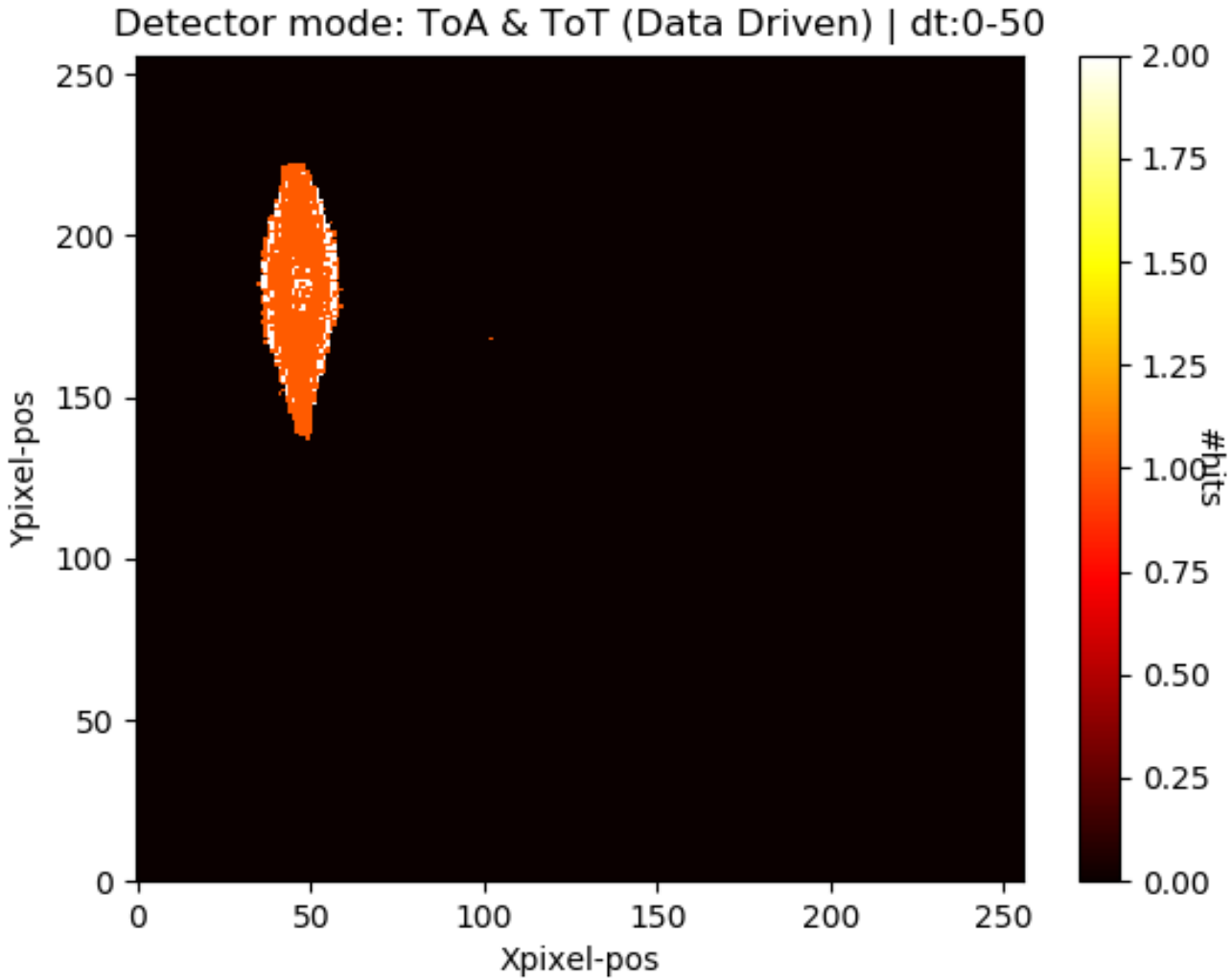
Optical Readout - *preliminary results*

Light sensitive Timepix3

→ **Qualitative tests**

- UV LED
- Red LASER

Timepix3 sensitive to UV and red light



Next steps:

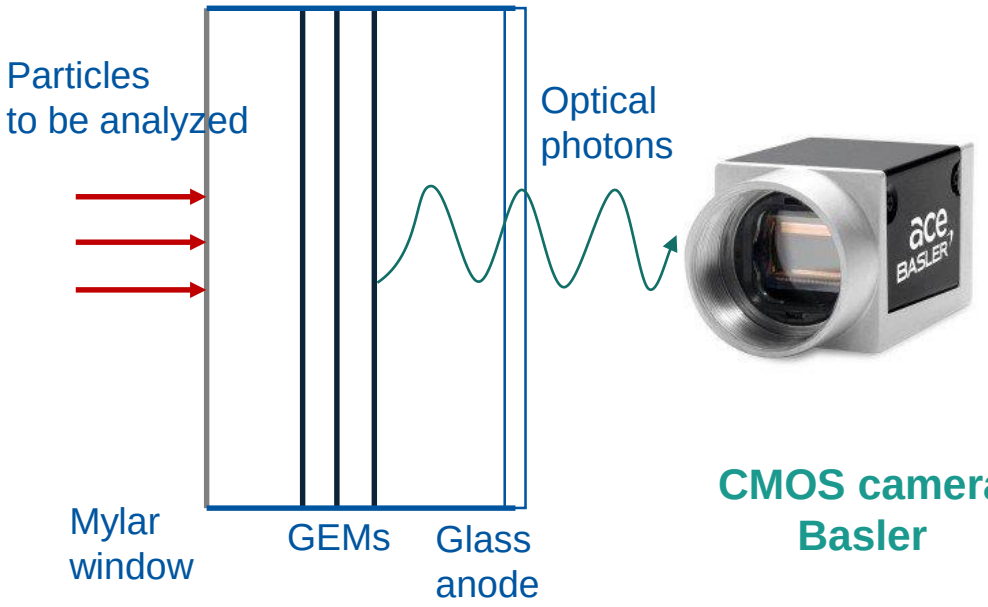
→ **Quantitative studies**

- Dynamic range
- Spectral efficiency

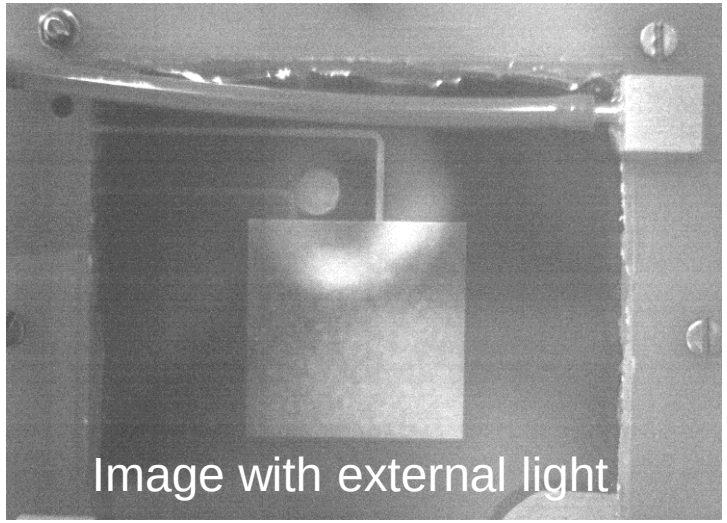
Optical Readout - *preliminary results*

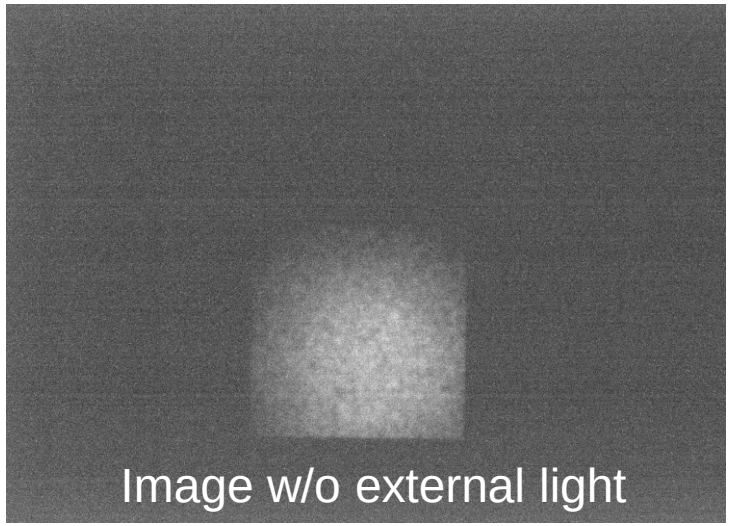
Camera

- Optical photons produced in $ArCF_4$ gas
- Test setup: X-rays from ^{55}Fe are visible in pictures taken with a CMOS camera
- ***Next step:*** Final setup with lenses and mirrors



CMOS camera Basler



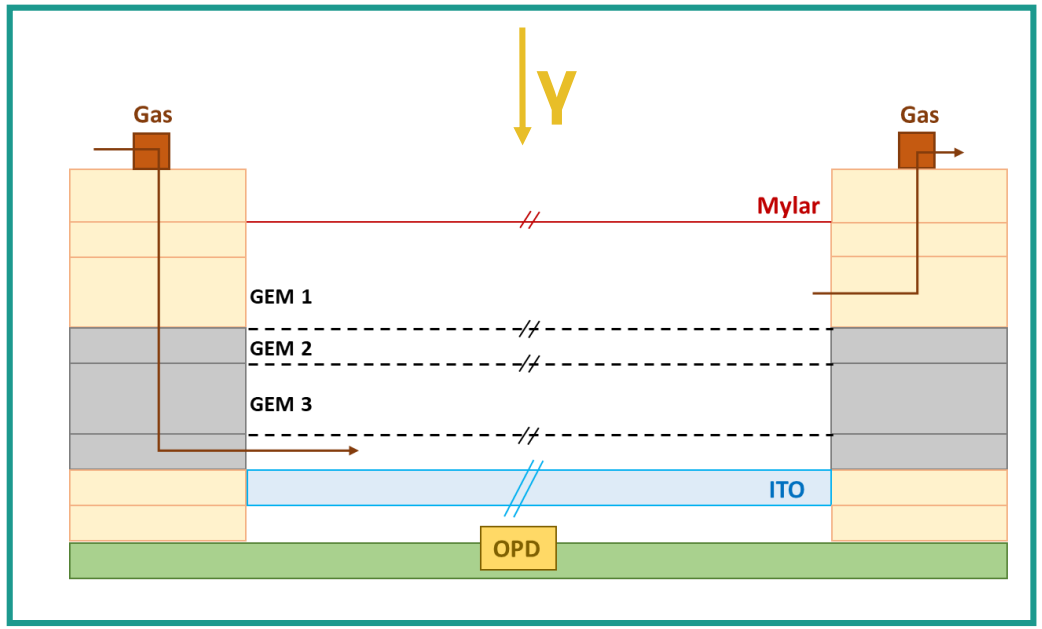


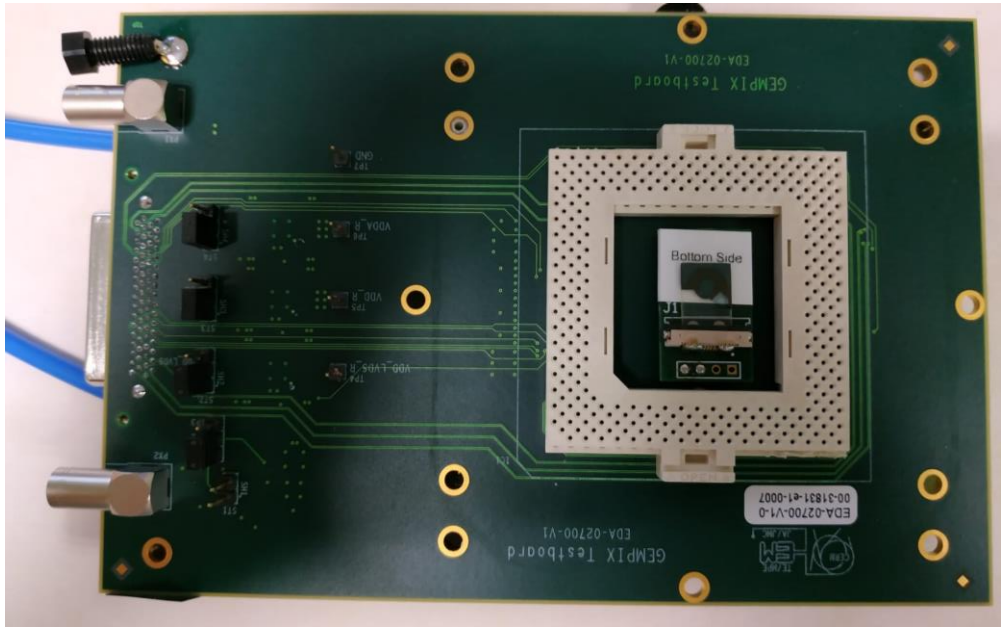
Optical Readout - *preliminary results*

Single OPD

→ Set-up

- γ-rays from 3 TBq ^{137}Cs source
- Triple GEM
- Gas Mixture - ArCF4
- Indium Tin Oxide Glass



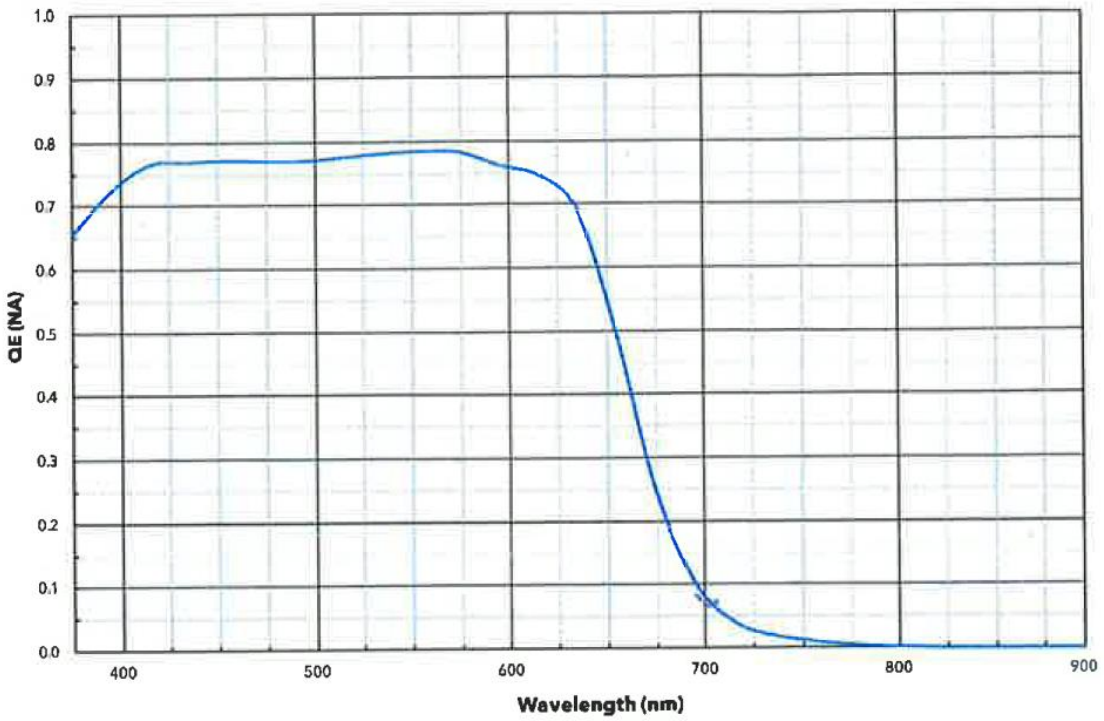


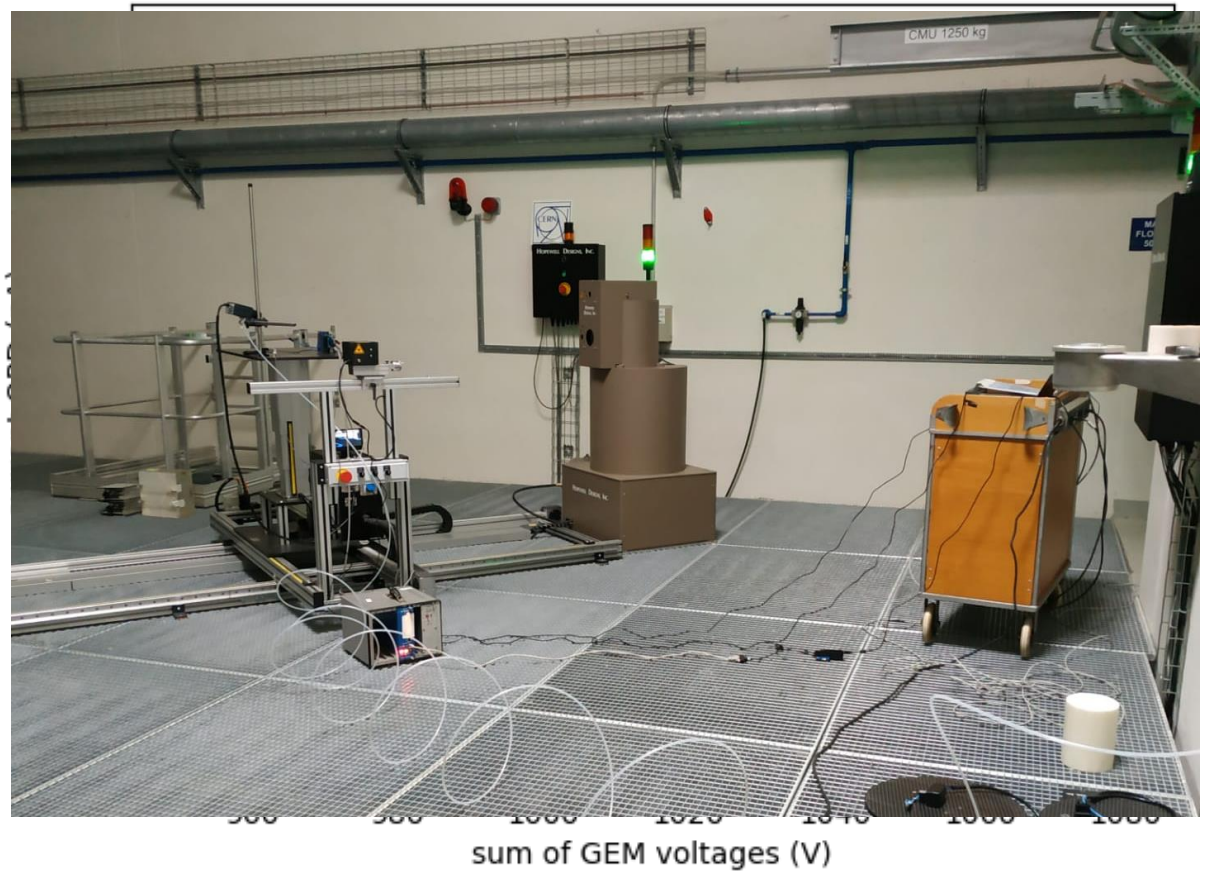
Optical Readout - *preliminary results*

Single OPD

→ ArCF4

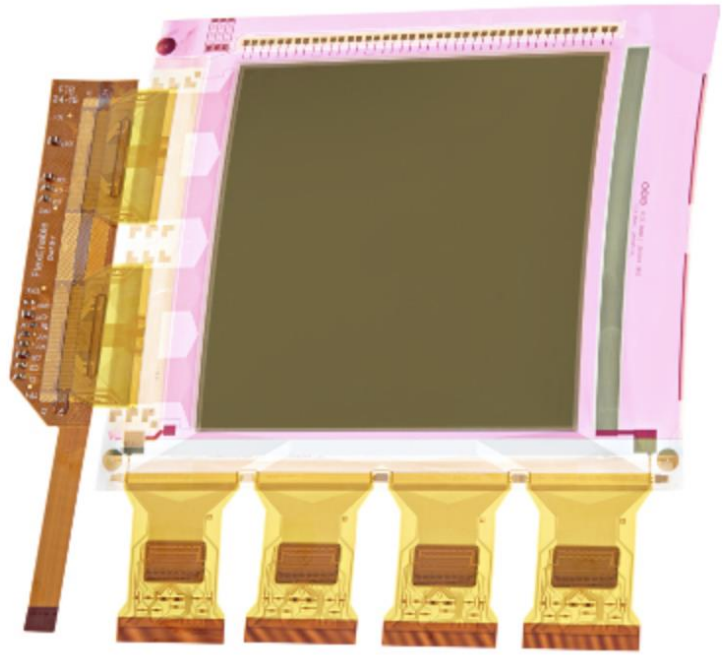
- Emission band centered @ λ = 630 nm
- Increase of the current in OPD

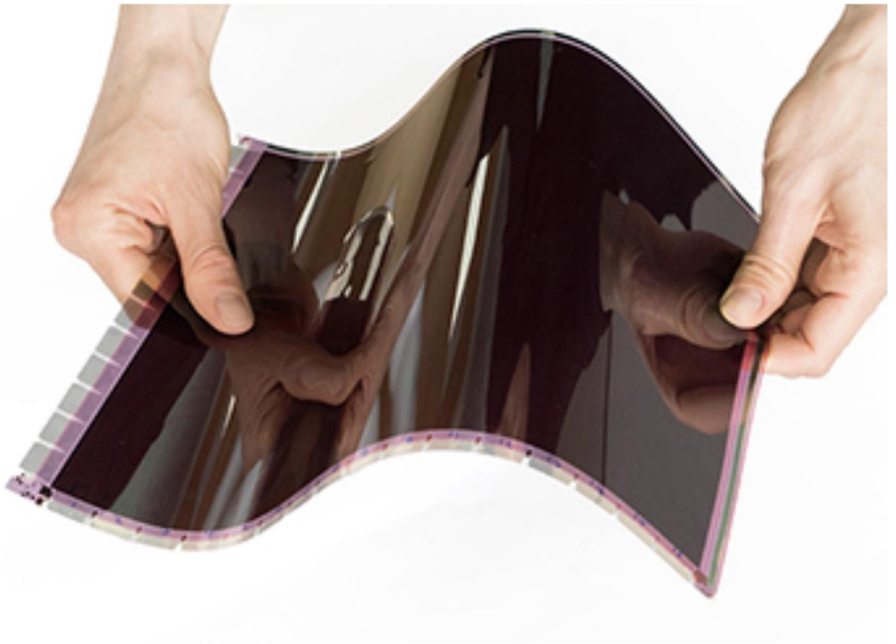




TFT+OPD

Organic photodiodes coated on an organic TFT backplane

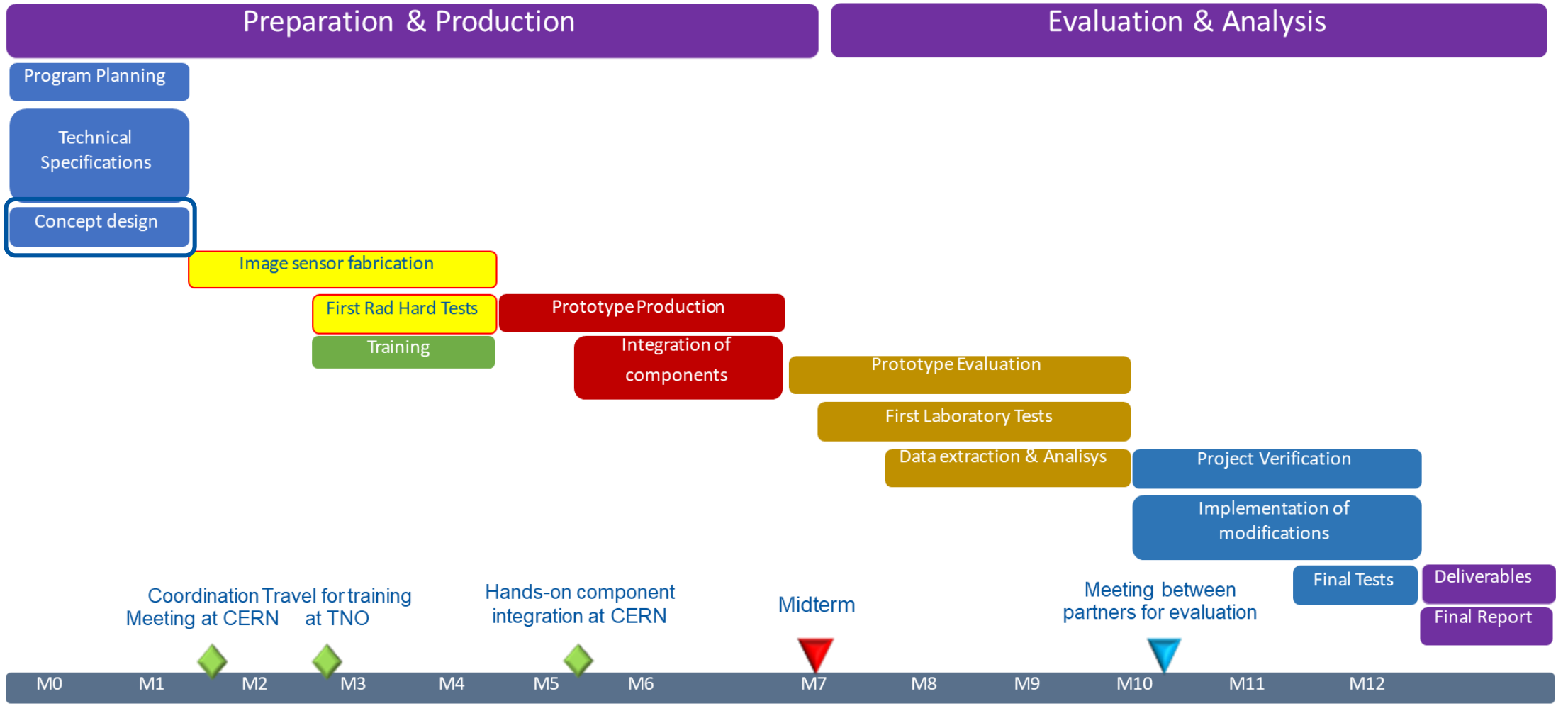




This project has received funding from the ATTRACT project funded by the EC under Grant Agreement 777222

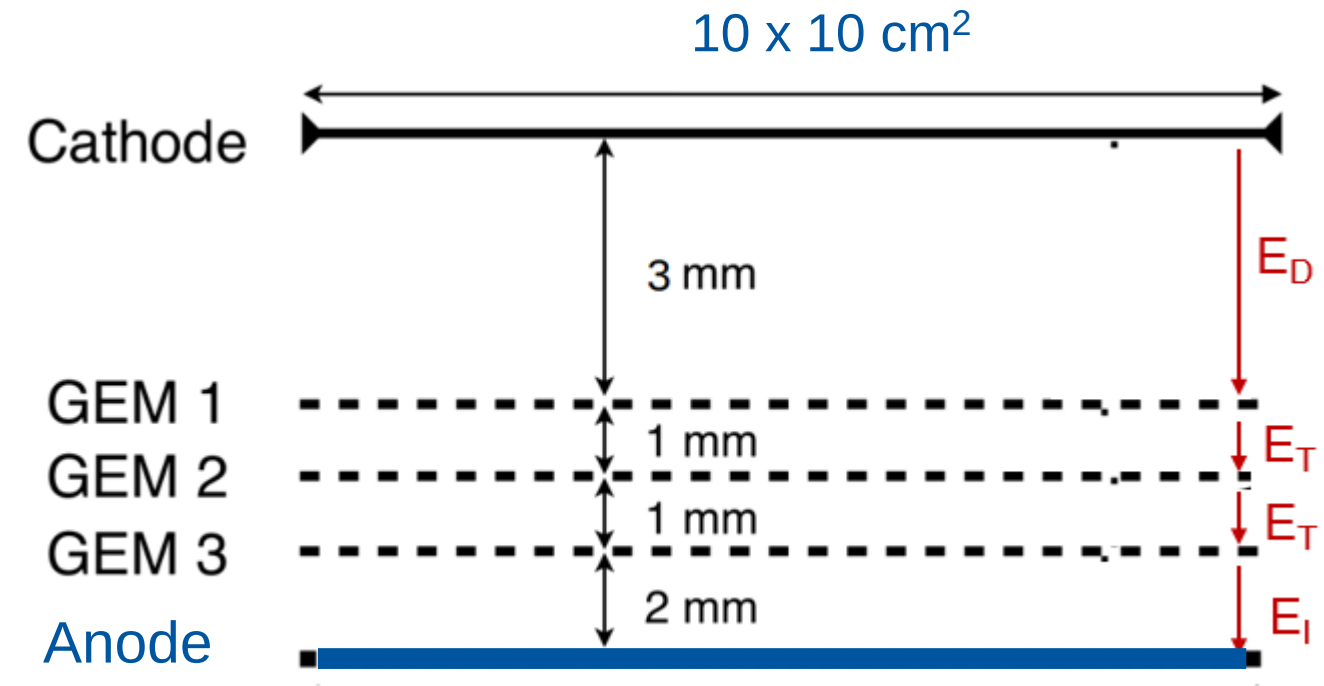
Optical Readout – *Timeline with collaboration of TNO*

TFT+OPD

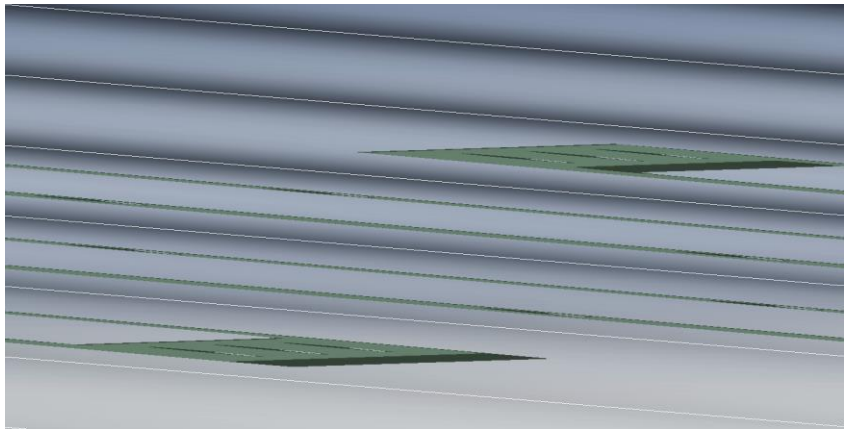


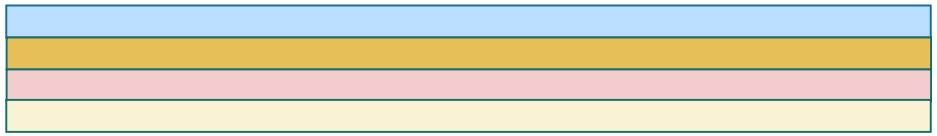
Optical Readout – *Concept design*

TFT+OPD



Cathode: ∽ 20 µm thick Mylar window





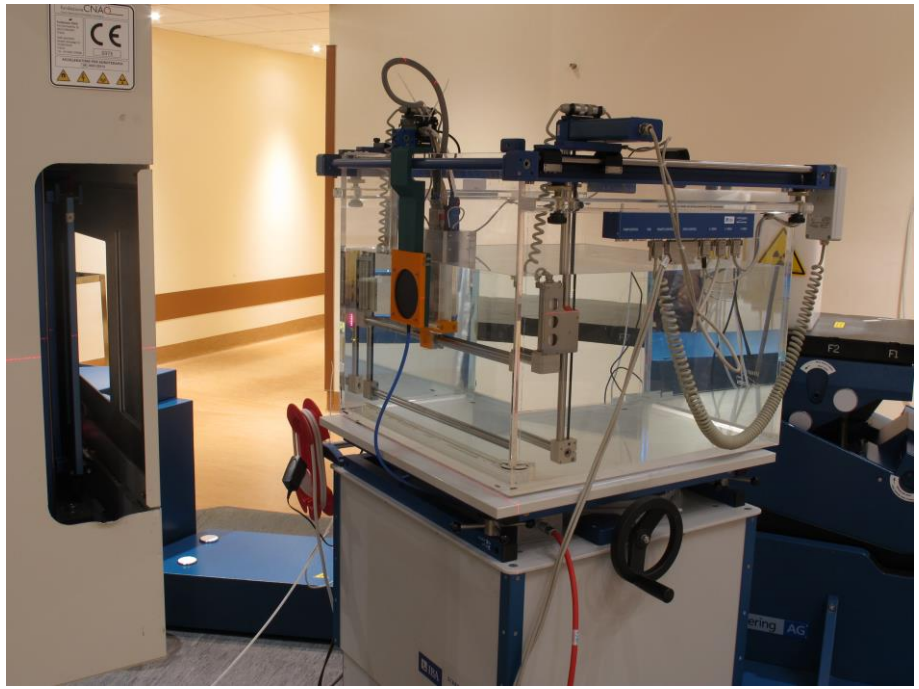
Transparent top encapsulation
OPD
TFT
Substrate + barrier

TNO image sensor

Coupling between ITO glass and TNO image sensor

Conclusions & Outlook

- GEMPix in water phantom is able to provide 2D images, Bragg curves and 3D energy deposition of carbon ion beam
- **On-going work** focused on larger sensitive area with new readout possibilities
- **Future** tests in clinical environment at Centro Nazionale di Adroterapia Oncologica (CNAO) in Italy



Training & Other opportunities

My CERN Training History

Technical training

- Habilitation Electrique - Person making Tests in Labs or on Test Bench - Initial
- Calibration Laboratory Tutorial
- Radiation Protection - Controlled Area
- Procuring supplies at CERN up to 200,000 CHF

Conferences

- Lisbon, Portugal
  - 3rd International Conference on Dosimetry and its Applications (ICDA-3)
- *Hiroshima, Japan*
  - *Summer School (Marko Moscovitch School)*
  - *19th International Conference on Solid State Dosimetry (SSD19SSD)*

Personal training

- Training on Communication to become a CERN Guide
- French course
- First Aider - Level 1 – Initial

Muito obrigada!

Thank you FCT for the trainee opportunity!

Special thanks to my team!
Marco Silari, Natalie Heracleous, Johannes Leidner, Lucia Manzano, Fabrizio Murtas and Prof. Saverio Braccini!

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