SHINE (2023-2025)

Beyond (Young Grant 2023-2024) – I. Fratelli

Employees INFN

Walter Raniero (LNL)

Marco Cinausero (LNL)

Employees UNIPD (INFN fellows)

Sara Maria Carturan (DFA)

Gianluigi Maggioni (DFA)

Giorgia Franchin (DII)

Sandra Moretto (DFA)

Felix Pino (DFA)

Jessica Delgado (DFA)

Hanna Skliarova (LNL up to June 2023, now with DFA)

Research line: Materials for radiation detectors

Scientific context: Organic scintillators

Bottom-up chemical synthesis of novel radiation hard polymers-based scintillators aiming at

- overcoming the ageing effects experienced with traditional plastic scintillators, preserving light yield
- providing elasticity to match state-of-art flexible photosensors
- detection of fast and thermal neutrons
- achieving discrimination between different particles through light pulse shape processing
- enabling additive manufacturing to produce complex geometries

Can we produce such materials through chemistry?

Scientific context

Acting on the basics of the scintillation mechanism

Steering concepts and methods

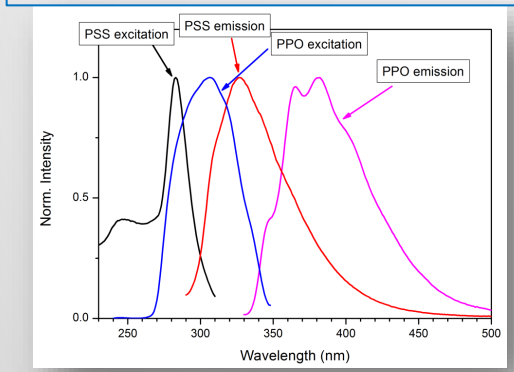
- Exploiting the chemical bonds strength of the matrix to enhance radiation resistance → C-C based ⇨ Si-O-Si based
- Polysiloxane matrix design to achieve
  - dyes solubility
  - maximum energy transfer
  - emission λ matching responsivity of the photosensor
  - high light yield (>5000 photons/MeV)
  - boosted triplet-triplet annihilation mechanism
  - optimal dispersion of ^{6}Li and ^{10}B synthesized compounds for thermal n capture

→ Optical properties investigation: excitation/fluorescence spectroscopy

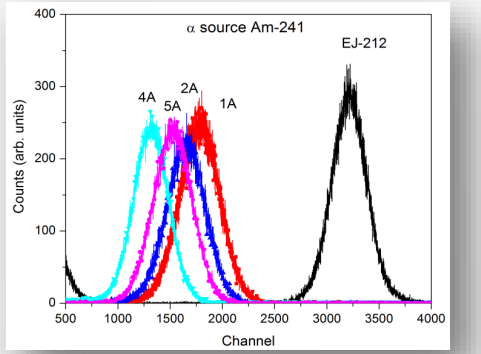
→ Light yield evaluation with α and γ-rays

→ Test with fast/thermal neutrons (@CN-LNL) →TOF/PSD discrimination from γ

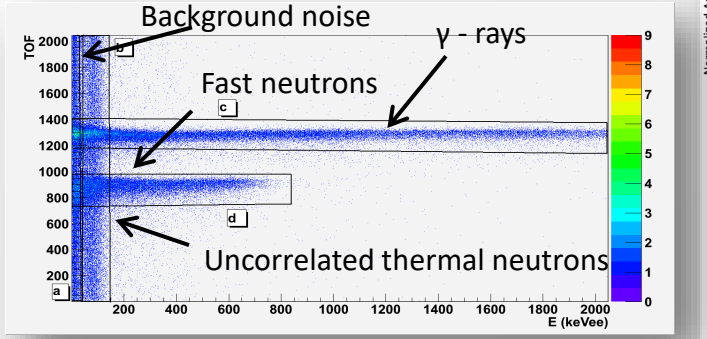
Quaranta et al. IEEE TNS , 57 (2010) 891
Quaranta et al. Opt. Mater. 32 (2010) 1317



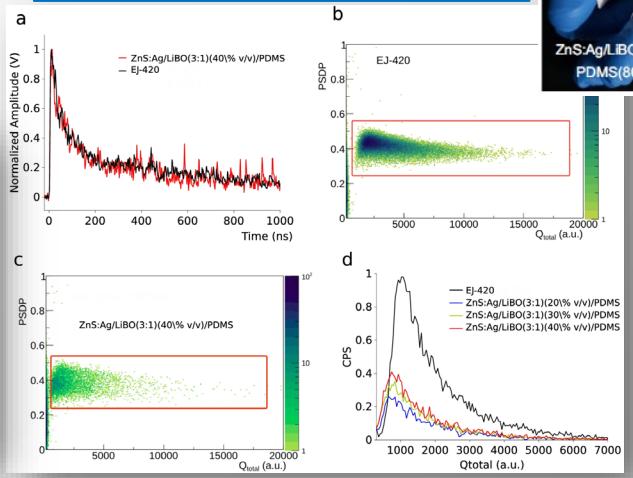
S.M. Carturan et al. Rad. Prot. Dosim. 143 (2011) 471



T. Marchi et al. Scientific Reports 2019



F. Pino et al. Scientific Reports 2023



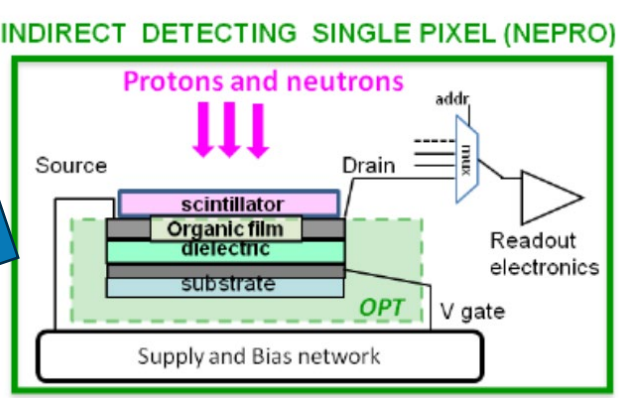
Prior art: the FIRE project (Call 2019-2022)

Flexible organic Ionizing Radiation dEtectors

PI: Prof. Beatrice Fraboni, Univ. of Bologna and INFN-BO

Research Units: TIFPA, LNL, Bologna, Roma3, Napoli

Indirect detectors based on Organic Photo Transistors (OPTs) coupled with polysiloxane scintillators



Results @Labec

npj | flexible electronics
www.nature.com/npjflexelectron

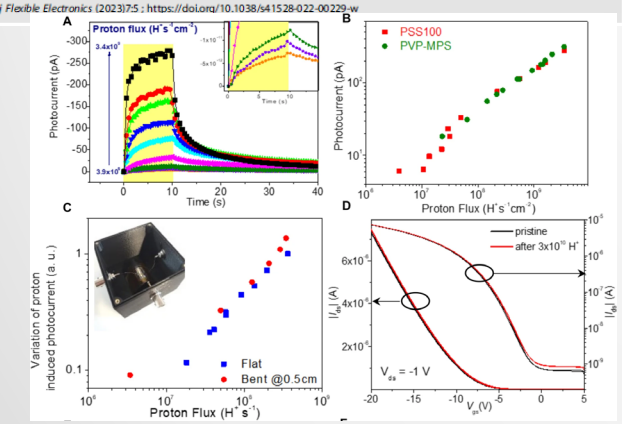
ARTICLE OPEN

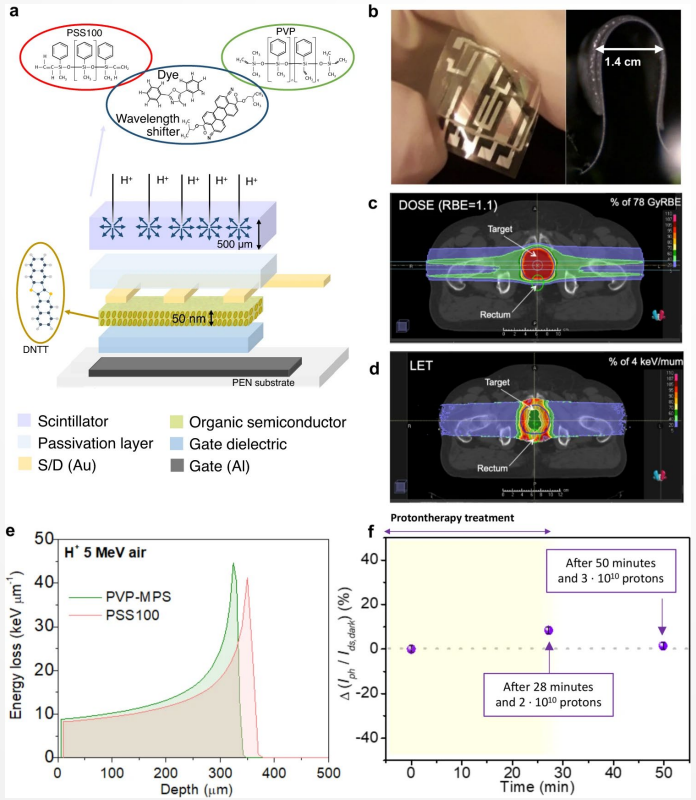
Flexible fully organic indirect detector for megaelectronvolts proton beams

Sabrina Calvi[1,2], Laura Basiricò[3,4], Sara M. Carturan[5,6], Ilaria Fratelli[3,4], Antonio Valletta[1,2], Alberto Aloisio[7,8,9,10], Stefania De Rosa[1], Felix Pino[5,6], Marcello Campajola[7,8], Andrea Ciavatti[3,4], Luca Tortora[1,2,11], Matteo Rapisarda[1,2], Sandra Moretto[5,12], Matteo Verdi[3,4], Stefano Bertoldo[6], Olivia Cesarini[6], Paolo Di Meo[8], Massimo Chiari[13], Francesco Tommasino[14,15], Ettore Sarnelli[8,9], Luigi Mariucci[1,2], Paolo Branchini[1,2], Alberto Quaranta[15,16] and Beatrice Fraboni[3,4]

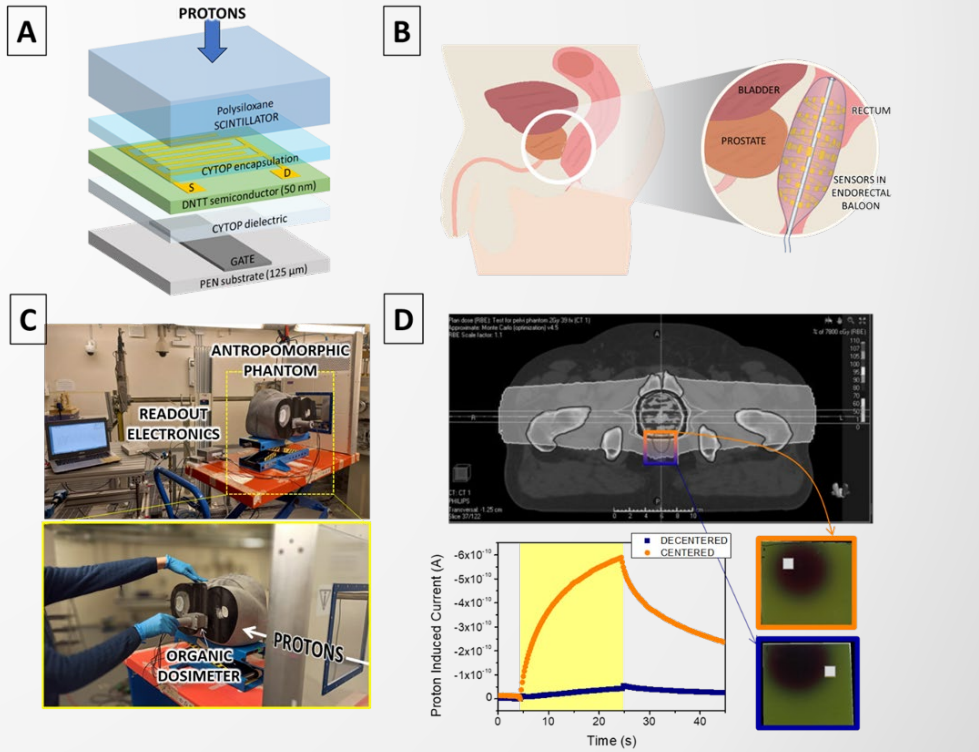
A flexible, fully organic detector for proton beams is presented here. The detector operates in the indirect mode and is composed of a polysiloxane-based scintillating layer coupled to an organic phototransistor, that is assessed for flexibility and low-voltage operation ($V = -1$ V), with a limit of detection of 0.026 Gy min^{-1}. We present a kinetic model able to precisely reproduce the dynamic response of the device under irradiation and to provide further insight into the physical processes controlling it. This detector is designed to target real-time and in-situ dose monitoring during proton therapy and demonstrates mechanical flexibility and low power operation, assessing its potential employment as a personal dosimeter with high comfort and low risk for the patient. The results show how such a proton detector represents a promising tool for real-time particle detection over a large area and irregular surfaces, suitable for many applications, from experimental scientific research to innovative theranostics.

npj Flexible Electronics (2023)7:5 ; https://doi.org/10.1038/s41528-022-00229-w





Results @APSS/TIFPA. To be published

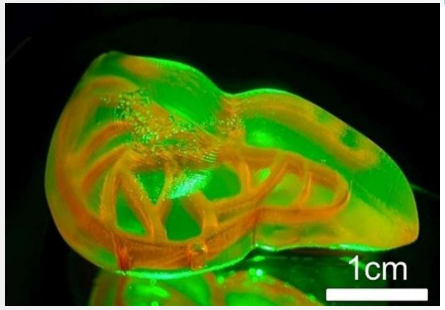


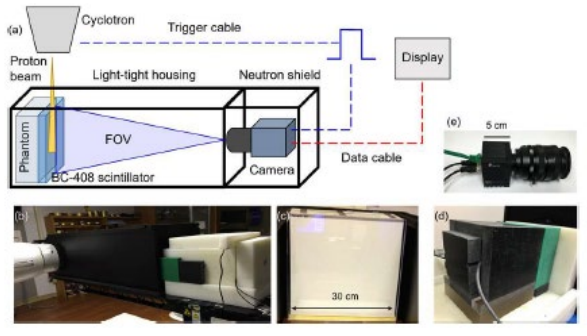
Current project: SHINE

Plastic Scintillators Phantom via additive manufacturing techniques

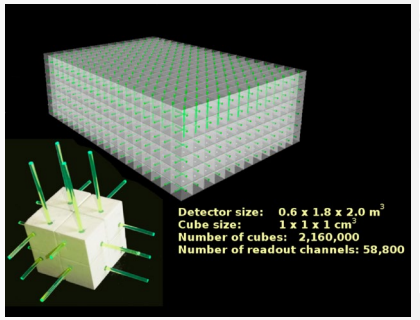
Research Units:
INFN - Lecce (P.I. Anna Paola Caricato)
INFN-LNL (S.M. Carturan)
INFN-PD (S. Moretto)
TIFPA (D. Maniglio)

Time resolved dosimetry in proton therapy



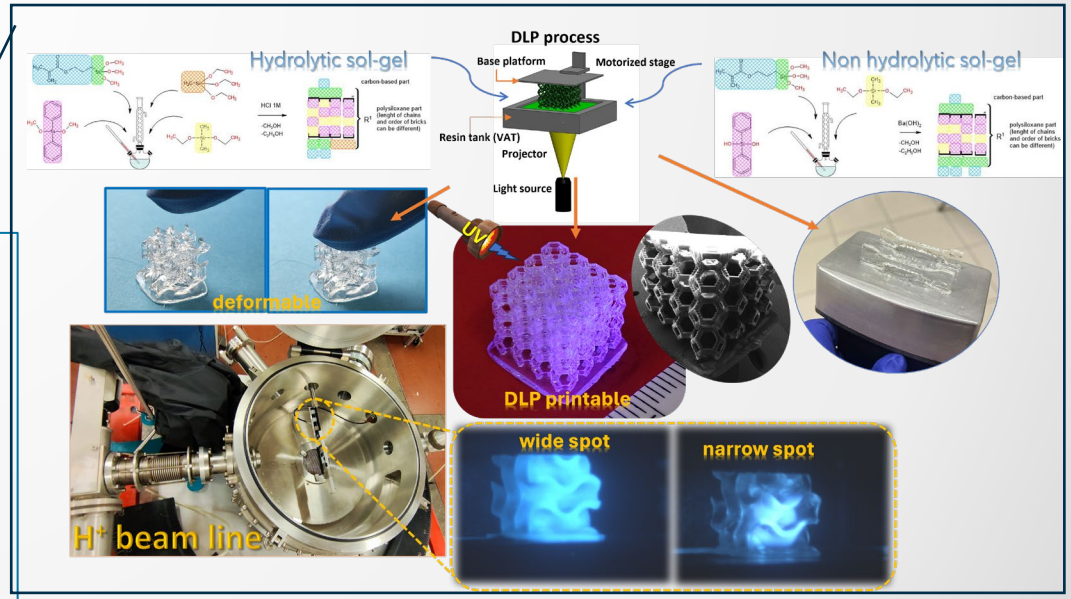


Large volume detector for high energy physics



A. Blondel et al.; 2018 JINST 13 P02006

F. Acerbi et al.; NIM A 2020



Manuscript in submission

LNL in collaboration with DII-UNIPD

- Design and synthesis of photocurable polysiloxane scintillator
- Additive manufacturing of complex geometries
- Incorporation of Perovskites nanocrystals (INFN-CNR Lecce) into flexible siloxane

Internal skills, national and international collaborations

TIFPA: Optical analyses, proton beams test (APSS)
A. Quaranta, D. Maniglio, M. Cazzanelli, M. Polo

INFN_PD, UNIPD_DFA: Scintillator characterization: Light Yield measurements, PSD, TOF
S. Moretto, F. Pino, J. Delgado

INFN_BO, UNIBO: Flexible Organic Photodetectors, Perovskite synthesis
B. Fraboni, L. Basiricò, I. Fratelli, A. Ciavatti

LNL: Chemical synthesis, material compositional and structural characterization, moulds mechanical design
S.M. Carturan, G. Maggioni, W. Raniero, M. Cinausero

UNIPD_DII: polymer structural and mechanical characterization, photocuring kinetics, additive manufacturing
G. Franchin, P. Colombo, A. Zanini

INFN_LE, UNISALENTO: Additive manufacturing, Perovskite nanocrystals, polymer thermal and structural characterization
A. Caricato, C. Corcione, A. Rizzo, G. Quarta

CERN: DRD6 (detectors research and development on calorimetry)
Etiennette Auffray, Loris Martinazzoli