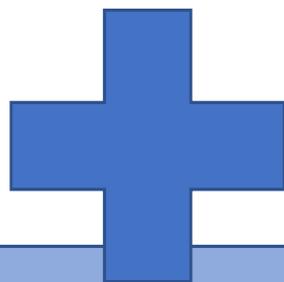


# FIRE

Flexible organic Ionizing  
Radiation detectors

# Organic electronics... Why?



1. Thin and flexible devices.



2. Very low cost production



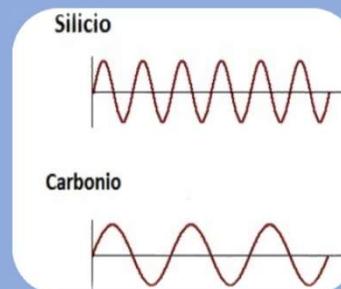
3. Spread of materials



1. Very low charge mobility.

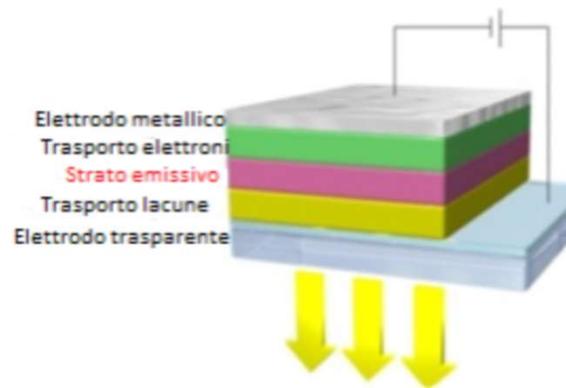


2. Low frequency devices



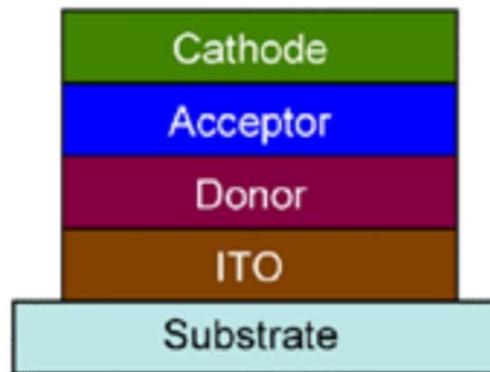
# Different Application of Organic Electronic

## Organic Light Emitting Diode



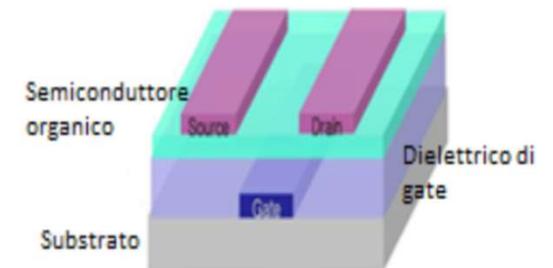
OLED

## Organic Photovoltaic Cells



OPVC

## Organic Thin Film Transistor



Top Contact OTFT

# FIRE Goals

- 1. Indirect detectors based on Organic Photo Transistors (OPTs) coupled with plastic scintillators**
- 2. Direct X-ray detectors based on semiconducting organic thin films OTFTs**
- 3. The FIRE project will develop an innovative, multidisciplinary and synergic collaboration between INFN research units*

# Budget

RU	Total FTE	2019	2020	2021	RU total (€)
<b>BO</b>	5.0	Inventariabile: <del>80K</del> 40k Consumo: <del>10k</del> 8k€ Missioni: <del>10k</del> 8k PostDoc: <del>30K</del> 24k	Consumo:25k Missioni: 25k PostDoc:45K	Consumo:5k Missioni: 5k PostDoc: <del>15k</del> 24K	163000 (-35%)
<b>LNL</b>	2.3	Inventariabile: 1.5k Consumo:5k Missioni:3k PostDoc: <del>30K</del> 24k	Inventariabile: 5k Consumo:3k Missioni:3k PostDoc: <del>30k</del> 24k	Consumo:3k Missioni:5k PostDoc: <del>30k</del> 24k	100500 (-21%)
<b>TIFPA</b>	3.2	Inventariabile: <del>50K</del> 25k Consumo:15k Missioni:4k Servizio:2k	Consumo:17k Missioni:5k Servizio:2k	Consumo:15k Missioni:5k Servizio:2k	92000 (-25%)
<b>RM3</b>	5.5	Inventariabile: <del>73K</del> 50k Consumo: <del>20K</del> 15k Missioni: 3k PostDoc: <del>30K</del> 24k Licenze:3k	Consumo:33k Missioni: 10k PostDoc:24K	Consumo:3k Missioni: 15k PostDoc: <del>15K</del>	180000 (28%)
<b>NA</b>	2.4	Inventariabile: <del>56K</del> 37k Consumo: <del>35K</del> 25k Missioni: <del>10K</del> 4k	Consumo:48k Missioni: 18k PostDoc:24K	Consumo:18k Missioni: 7k PostDoc: <del>25K</del>	181000 (-28%)
<b>Total</b>	<b>18.4</b>	<b>483000</b> <b>320500</b>	<b>359000</b> <b>265000</b>	<b>158000</b> <b>131000</b>	<b>1.000.000</b> <b>716500</b>

# State of the Art: OPT

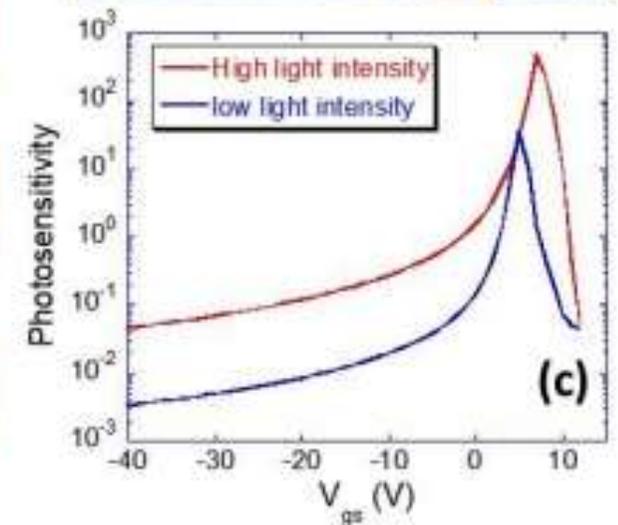
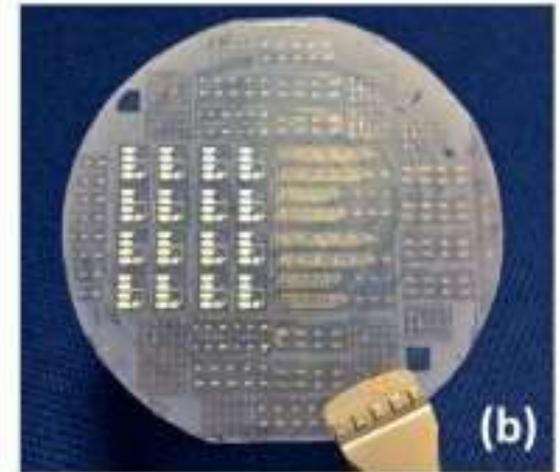
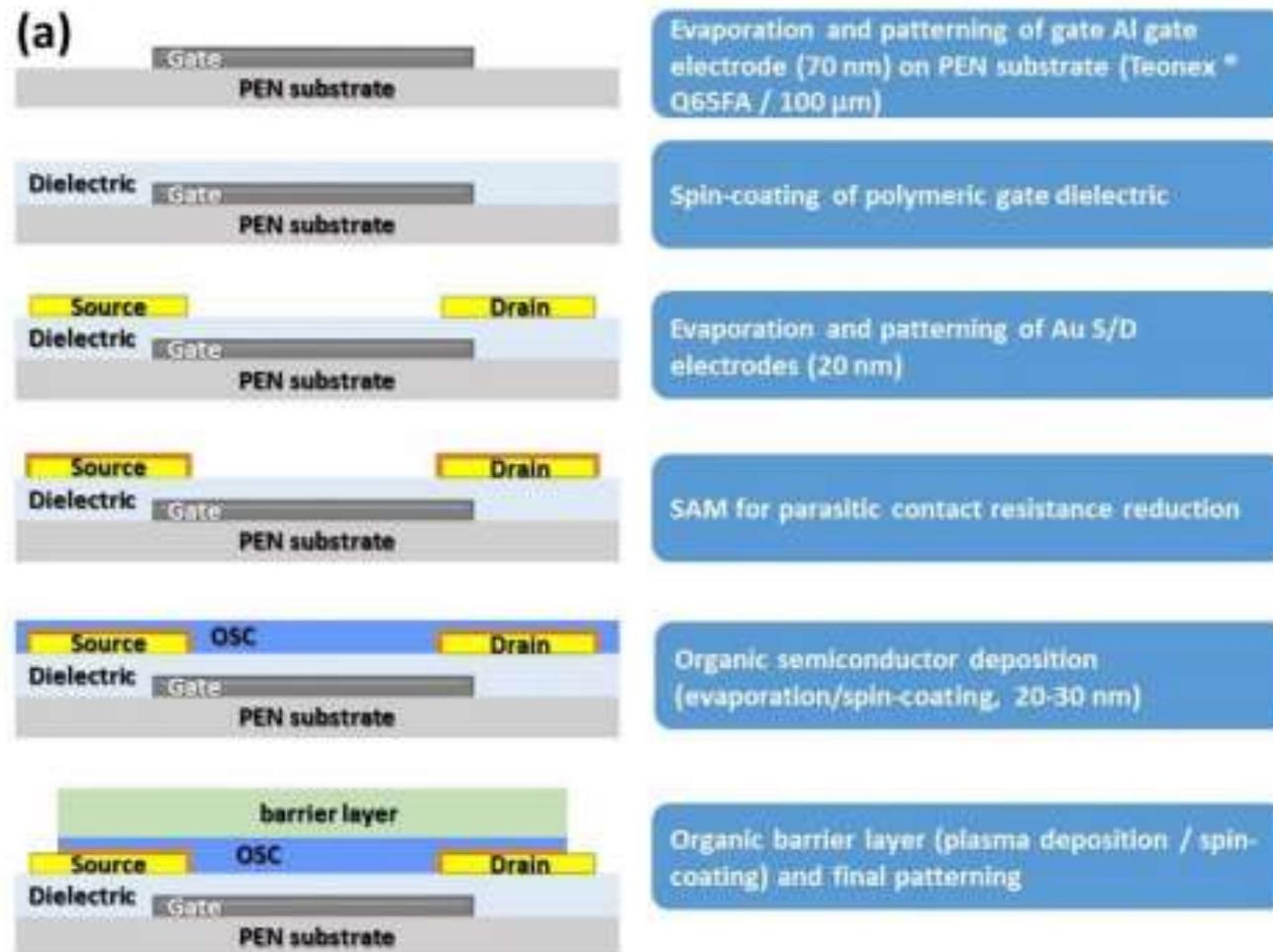
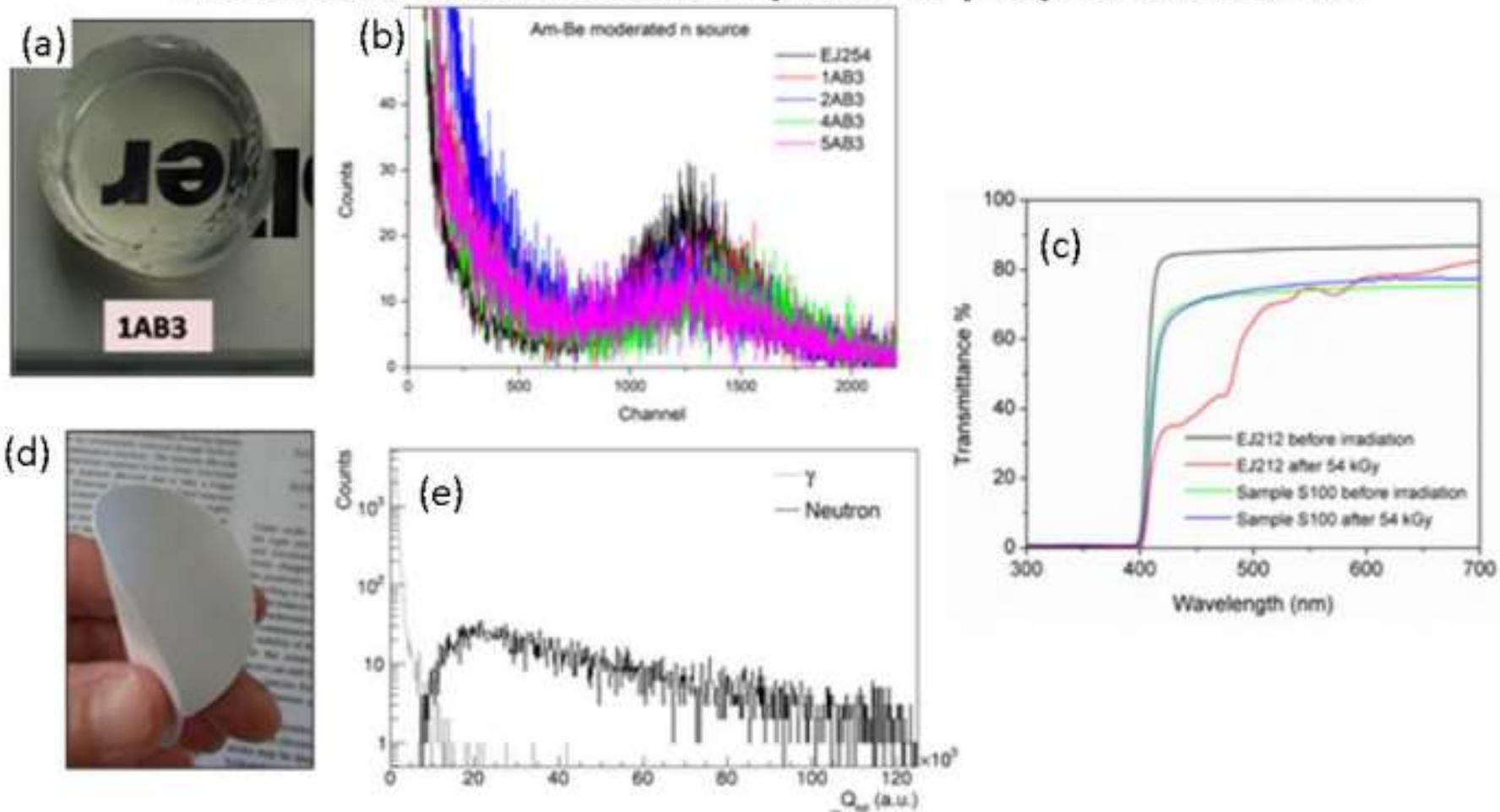


Figure 1: (a) OPT device fabrication steps of Bottom-Gate/Bottom-Contact configuration; (b) OPT devices on PEN substrate made by RU RM3; (c) photosensitivity vs gate bias of OPT for two light intensities

# State of the Art: Organic Scintillators

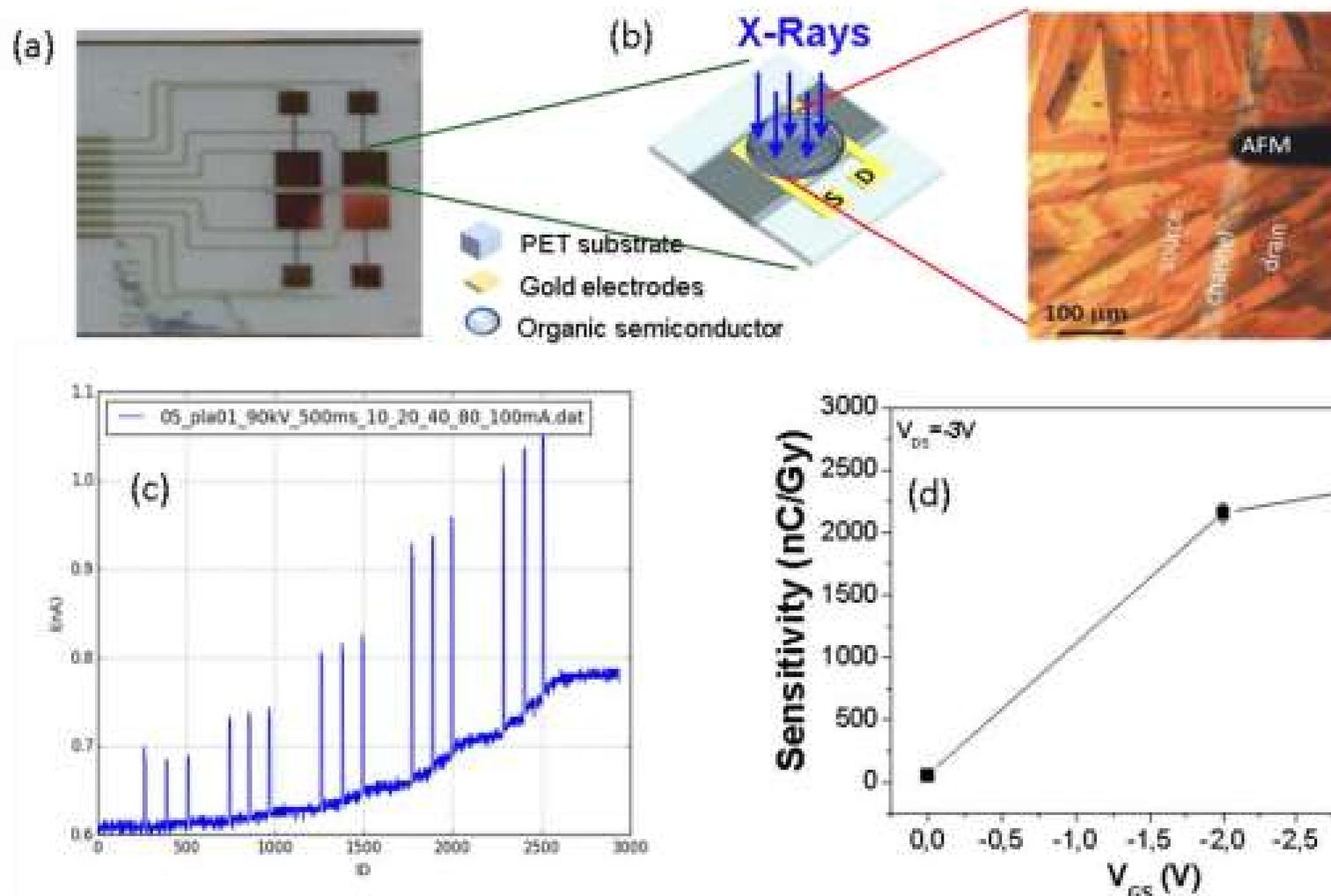
## ORGANIC SCINTILLATORS: response to $\gamma$ -rays and neutrons



**Figure 2:** (a) Photo of a 3% wt loaded boron-siloxane made by RU LNL-TIFPA; (b) pulse height spectra collected under irradiation with thermal neutrons and (c) UV-Vis spectra of standard and siloxane-based scintillators before and after high irradiation dose; (d) photo of a Lithium-6 loaded flexible scintillator and (e) pulse height spectrum showing the different contribution of  $\gamma$ -rays and background radiation (dotted line) and thermal neutrons (continuous line).

# State of the Art: OTFT

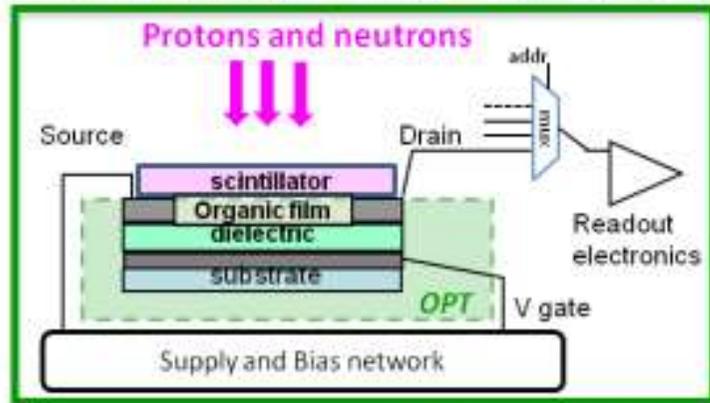
## ORGANIC THIN FILM TRANSISTOR: direct response to x-ray radiation



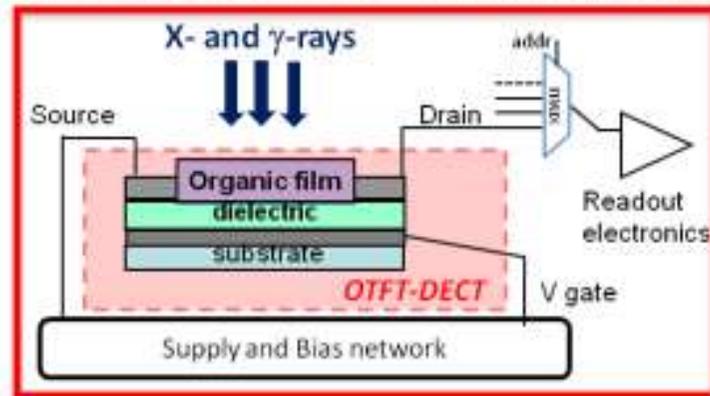
**Figure 3:** (a) the proof-of-principle 2x2 X-ray detector; (b) structure of a single pixel fabricated as a direct detecting Organic TFT with solution drop-cast TIPS pentacene by RU BO; (c) induced photocurrent measured as the direct output of the pixel : when repetitively irradiated with an X-ray beam (energy 90keV, pulse widths 500ms) the signal clearly and reproducibly increases with a good S/N ratio; (d) the sensitivity of the organic thin film TFT vs Vgate: excellent values up to 2500nC/Gy are recorded.

# Project Deliverables

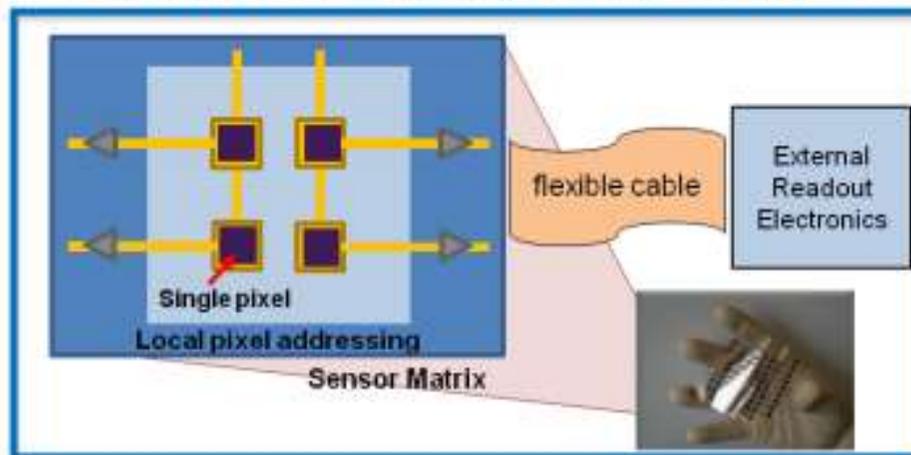
INDIRECT DETECTING SINGLE PIXEL (NEPRO)



DIRECT DETECTING SINGLE PIXEL (PHOX)



FULLY INTEGRATED FLEXIBLE DETECTING SYSTEM



At the core of each one of the two modular units, there are OTFTs. In the NEPRO indirect detector, the OTFT is optimized to work as organic phototransistor (OPT). In the PHOX direct detector, the OTFT is tuned to enhance its direct electrical response to X and gamma-rays (OTFT-DECT).

	NEPRO (protons and neutrons)	PHOX (X- and gamma-rays)
Proton Energy range	50-230 MeV ( $10^9 - 10^5$ p/s x20 min.)	
Neutron Energy range	0.025 eV - 14 MeV	
Photon energy range		15 keV- 1MeV
Sensitivity	$10^5$ p/s $cm^2$	$>20 \mu C/Gy/cm^2$
Limit of Detection (LoD)		100 $\mu C$
Radiation hardness	$>10^{10}$ p/ $cm^2$	$>100$ Gy
Bending radius	$>0.5$ cm	$>0.5$ cm
Dark current		$<10^{-8}$ A
2D matrix area	Up to 5x5cm <sup>2</sup>	Up to 5x5cm <sup>2</sup>
No of pixel in each matrix	up to 9	up to 9
Operating voltage	$<25$ V	$<5$ V

# Project Proof of Concept

## Demo 1: Endorectal probe for Proton Therapy

**Dosi:** 2-10Gy , rate 0.5-2cGy/s  
200MeV Protons,  $10^9$ protoni/s  
Sampling Freq. 0.1-1Hz  
Disposable

**State of the Art:** Mosfet «moskin»  
Volume 10-6mm<sup>3</sup>  
Dose measurement uncertain 10%



## Demo 2: Dose measurement at Belle II

**Dosi:** Photons : 10-500keV and 500keV-1MeV (flux  $10^6$ ph/pulse)  
Neutrons 0.02-1MeV (flux  $10^9$  n/pulse)

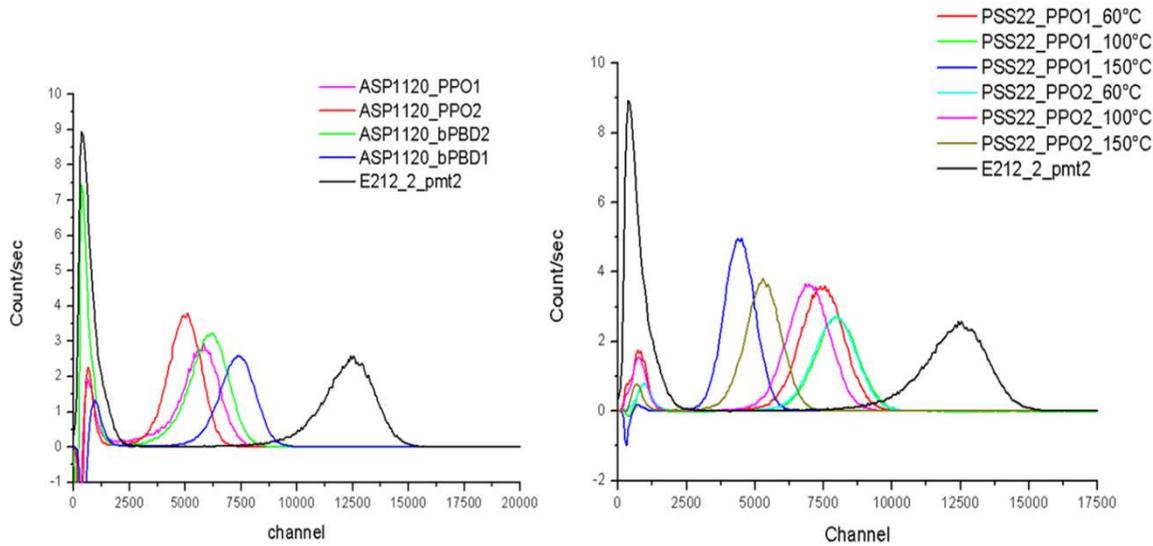
### State of the Art:

- B3 (3kGy-100 kGy), to be positioned very close to interaction point (very Thin (20  $\mu$ m) foils)
- HDV2 (10 Gy – 1kGy) for intermediate range (90  $\mu$ m thickness)
- EBT3 (1-80 Gy) (300  $\mu$ m thickness)



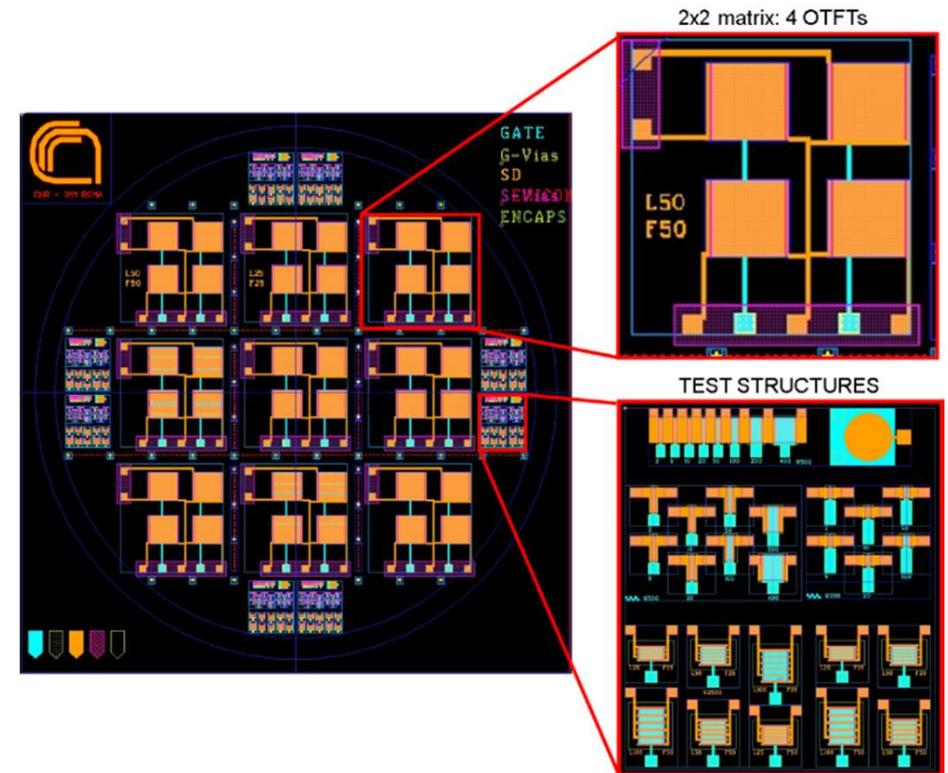
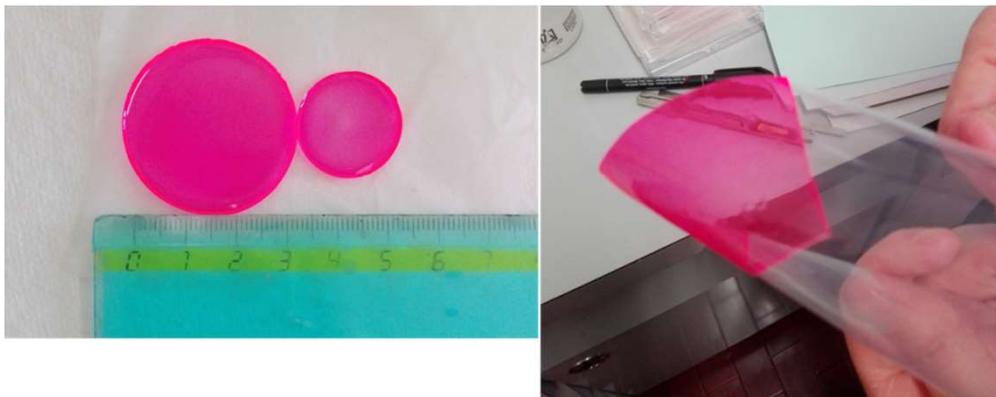


# First year results

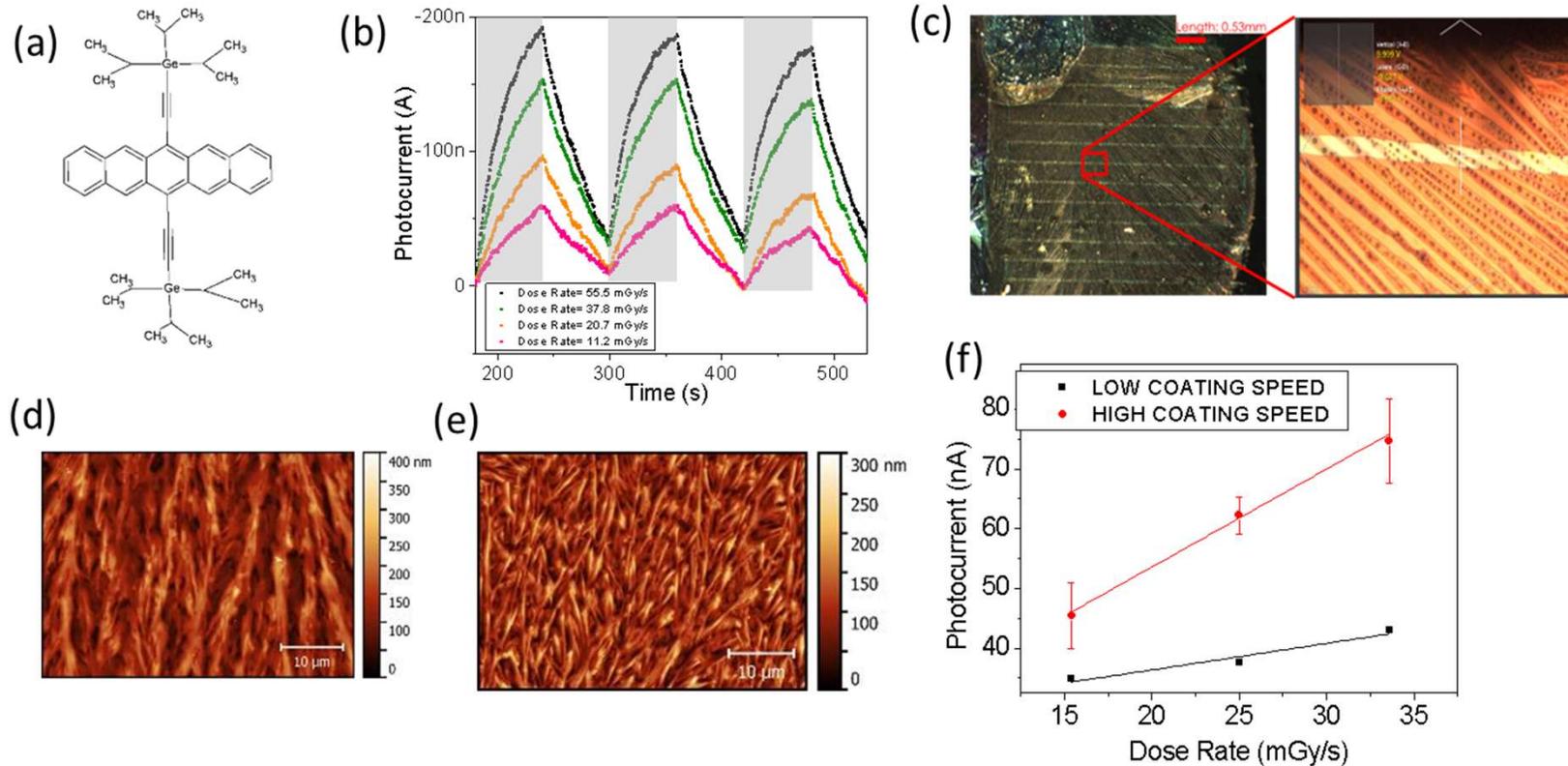


Maschera di processo per la realizzazione dei dispositivi OPT e OTFT-DECT

Spettri di scintillazione dei campioni spessi 6 mm a base di ASP-1120 e PSS22. E' riportato anche lo spettro dello scintillatore di riferimento EJ-212

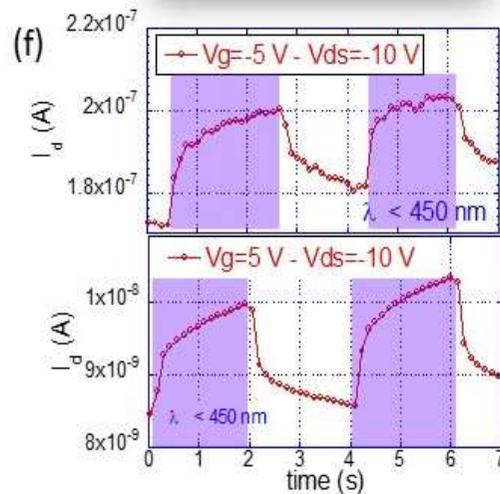
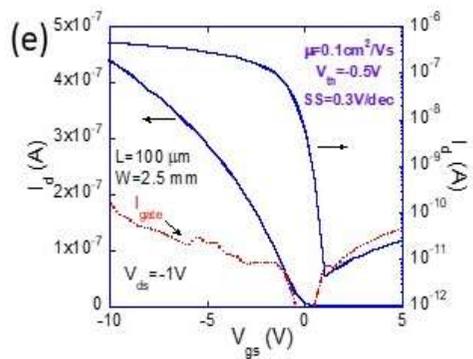
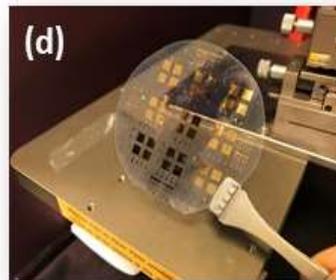
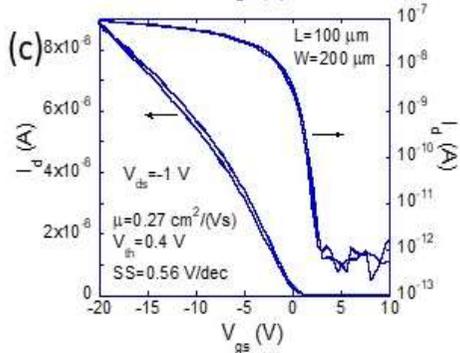
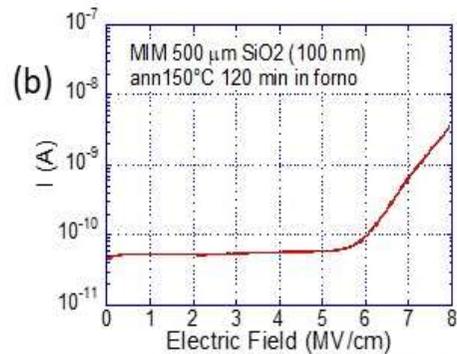
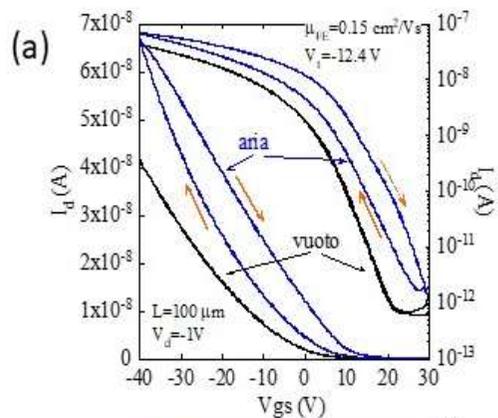


# First year results



(a) Struttura molecolare del TIPGe-pentacene. (b) Tipica risposta a diversi dose rates di radiazione X di un campione di TIPGe depositato per drop casting su substrato plastico. Le aree grigie indicano le finestre di irraggiamento. (c) Immagine ottica che mostra l'area attiva del dispositivo con TIPGe depositato per drop casting. Lo zoom evidenzia il ricoprimento parziale dei cristalliti di semiconduttore organico sulla superficie degli elettrodi e del canale. Immagine AFM di un film di TIPS-pentacene depositato a bassa velocità (4mm/s) (d) e ad alta velocità (28 mm/s) (e) su substrato Si/SiO<sub>2</sub>. (f) Rispettivi plot di sensitivity ai raggi X.

# First year results



a) Caratteristiche di trasferimento, misurate in vuoto ed in aria, di un OTFT con SU8 come dielettrico di gate. b) Caratteristiche I-V di una struttura MIM con ECR-PECV SiO<sub>2</sub>. c) Caratteristiche di trasferimento di un OTFT su substrato rigido con ECR-PECV SiO<sub>2</sub> come dielettrico di gate. d) Dispositivi organici con con ECR-PECV SiO<sub>2</sub> realizzati su substrato plastico flessibile (PEN). e) Caratteristiche di trasferimento di un OTFT con ECR-PECV SiO<sub>2</sub> come dielettrico di gate realizzato su PEN. f) Risposta alla luce ( $\lambda < 450$  nm) di un OPT con ECR-PECV SiO<sub>2</sub> come dielettrico di gate e DNTT come semiconduttore, realizzato su PEN.

# Roma Tre Affiliation

1	<a href="#">Attili Andrea</a>		Dipendente	Ricercatore
2	<a href="#">Branchini Paolo</a>		Dipendente	Primo Ricercatore
3	<a href="#">De Rosa Stefania</a>		Associato	Dottorando
4	<a href="#">Mariucci Luigi</a>		Associato	Primo Ricercatore
5	<a href="#">Rapisarda Matteo</a>		Associato	Ricercatore A Tempo Determinato Tipo A
6	<a href="#">Tortora Luca</a>		Associato	Ricercatore A Tempo Determinato Tipo A
7	<a href="#">Valletta Antonio</a>		Associato	Ricercatore Universitario
<b>Numero Totale Ricercatori</b>				<b>7</b>

## Tecnologi

	Nome	Età	Contratto	Qualifica
1	<a href="#">Budano Antonio</a>		Dipendente	Tecnologo
2	<a href="#">Colace Lorenzo</a>		Associato	Prof. Associato
3	<a href="#">Fabbri Andrea</a>		Dipendente	Tecnologo
<b>Numero Totale Tecnologi</b>				<b>3</b>

# Roma Tre 2020 Budget

Consumo: **33 k€**

Missioni: **10 k€**

PostDoc Position: **24 k€**

Servizio di elettronica : **4 months**