

Bando n. 18203/2016 Concorso per il finanziamento di n. 6 progetti per giovani ricercatrici e ricercatori nell'ambito delle linee di ricerca e sviluppo tecnologico: acceleratori, elettronica/informatica, rivelatori, interdisciplinare

- Title: High performance **3D Ca**dmium-Zinc-**T**ellurium **S**pectro-imager for X and gamma-ray applications

- Acronym: 3CaTS



- Research area: DETECTORS
- Project Proposer: Nicoletta Protti (PhD in Physics: 16th of February 2012)
- Research team:

Unit 1 = INFN, PV Unit 2 = Università di Palermo,PA Unit 3 = Istituto Nazionale di Astrofisica INAF, BO

#### Research team composition

• Unit 1: INFN, Unit of Pavia

Nicoletta Protti, 80% Setareh Fatemi, 100% Antonio de Bari, 40% (2018) Saverio Altieri, 30%

• Unit 2: University of Palermo, Department of Physics and Chemistry (DiFC)

Leonardo Abbene, 50% Fabio Principato, 20%

• Unit 3: INAF, Unit of Bologna

Natalia Auricchio, 35% Ezio Caroli 20%; John Stephen, 20%; Angelo Basili, 20%, Stefano Silvestri, 20%

### Project goals

- The goal of the project is to develop and build an innovative fully functional prototype of a segmented CdZnTe (CZT) semiconductor spectrometer with 3D spatial resolution capabilities suitable for different spectroscopic imaging applications in the range from tens of keV up to 700 keV
- A real step forward in **room temperature solid state spectro-imager** technology; a highperformance (high efficiency, fine spectroscopy and imaging) detector will be obtained limiting the complexity of its design and realization. **Innovative electronics (digital multichannel electronics, Unit3)** will be proposed. The prototype should allow **sub-millimeter spatial resolution in 3D** and consequent fine spectroscopy (1% at 511 keV) using limited number of electronic readout channels (30) over a sensitive volume of 20x20x5 mm<sup>3</sup>
- The CZT crystal will be manufactored by due2lab s.r.l. following the detector system design project delivered by Unit 1
- The performance of the prototype will be evaluated in different environmental and operational conditions:
  - Medical Physics (BNCT-SPECT) (Unit 1);
  - hard X and soft-gamma rays Astronomy (Unit 3).

## Project goals

• BNCT-SPECT (Unit 1)

One of the main problem to be solved in Boron Neutron Capture Therapy is the measurement of the spatial boron dose distribution in the patient during the treatment. This measurement can be done by SPECTdetecting the 478 keV gamma-ray emitted in the 94% of captures by residual <sup>7</sup>Li-ions

• hard X and soft-gamma rays Astronomy (Unit 3)

New focusing systems (e.g. broad band Laue lens) could allow to improve by 100 times the sensitivity with respect to current instruments. To fully exploits its capability, these new telscopes require focal planes with high dynamic range (5-1000 keV), high efficiency (>80% at 500 keV), fine spectroscopy (1-2% FWHM @ 511 keV) abd fine spatial resolution (<0.5 mm) over few tenths square cm sensitive area. 3D spectro-imagers are a very efficient way to fulfill these requirements.

## Why CZT detectors?

- Efficient yet compact due to their high density
- Wide photon energy range (10keV-1MeV)
- Do not require cooling (room temperature operation)
- Solid-state: do not require fragile photomultiplier tubes
- Robust and able to withstand rapid temperature changes
- Excellent energy resolution
- Easily enabled imaging capabilities (courtesy of A.Zappettini, IMEM-CNR Parma)







#### CdTe e CdZnTe

materiale	Si	Ge	GaAs	CdTe	Cd <sub>0.9</sub> Zn <sub>0.1</sub> Te	$HgI_2$	
density (g/cm <sup>3</sup> )	2 3 3	5 33	5 32	6 20	5 78	6 40	
eternie energie (	14	22	22	52	5.70	0.40	
atomic number (max)	14	32	33	52	52	80	
band-gap ( eV)	1.12	0.67	1.43	1.44	1.57	2.15	
<b>w</b> ( <b>eV</b> )	3.62	2.96	4.20	4.43	4.64	6.50	
resistivity ( $\mathbf{\Omega} \cdot \mathbf{cm}$ )	104	50	107	109	10 <sup>10</sup>	1013	
$\mu\tau_e(cm^2/V)$	>1	>1	8 · 10 <sup>-5</sup>	3 · 10 <sup>-3</sup>	3 · 10 <sup>-3</sup>	3 · 10 <sup>-4</sup>	
$\mu\tau_h(cm^2/V)$	~1	> 1	4 · 10 <sup>-5</sup>	10-4	10-4	4 · 10 <sup>-5</sup>	

Alto Z  $\longrightarrow$  Efficienza elevata, predominanza effetto Fotoelettrico su Compton Ampia band-gap  $\longrightarrow$  Correnti di leakage < nA ; room temperature operation Trapping  $\longrightarrow$  Riduzione risoluzione energetica ed accelerazione del crollo dei rivelatori ad alto rate

(courtesy of L.Abbene, University of Palermo, DiFC)

#### CdTe e CdZnTe



L. Abbene et al... CdTe detectors, in Comprehensive Biomedical Physics, (2014) Elsevier.

(courtesy of L.Abbene, University of Palermo, DiFC)

#### **Digital Read-out Electronics**



(courtesy of L.Abbene, University of Palermo, DiFC)

## Project timetable

		2017			2018				
WP	Task	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
1	Dector system design and construction								
2	Digital multichannel electronics								
3	SensorCharacterizationandSignal/Imaging reconstruction								
4	Medical Imaging and BNCT application								
5	Astrophysical application								

## Project costs

Costs (k€)	Year 1	Year 2	Total	Motivations
Instrumentation	73	17	90	Year 1: acquisition of CZT detectors <sup>*</sup> and digital electronics Year 2: acquisition of mechanical support @ LARIX facility, liquid cold plate, X/gamma ray collimator, radioactive sources for detector performance testing with SPECT-BNCT and astrophysics purposes
Consumables	0	14.5	14.5	Year 2: <sup>6</sup> Li-enriched Li <sub>2</sub> CO <sub>3</sub> powder to be used as neutron shield of CZT detector, consumables at LARIX facility, general electronics components
Services	0	23	23	Year 2: irradiation time at the research nuclear reactor of Pavia University, expenses to access LARIX facility
Travels	2	11	13	Project advancement meetings, detector measurement campaigns at external labs (LARIX facility, Grenoble ESRF facility)
Total	75	65.5	140.5	

# In-kind cofinancy

• Unit 2: 42000 euro

detectors and electronics laboratory equipped with instrumentation for characterization of electronics and detectors (euro 150x70hx40d)

• Unit 3: 42000 euro

physics and electronics laboratory equipepd with instrumentation, micrometric positioning systems and multi-parameters data acquisition system to characterise the detectors using radioactive sources (euro 150x7hx40d)