Town Meeting, Hadron Physics in Horizon Europe
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DRESS

Digital high REsolution position-sensitive room temperature Semiconductor detectors for high precision radiation Spectroscopy in hadron physics and related areas

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Outline

- Research Objectives
- Connection to Transnational Access (TA) and Virtual Access (VA) Infrastructures
- Partner Institutions
- Project Development
- Estimated Budget

Research Objectives

DRESS project

The main goal of the ***DRESS*** project is to develop **advanced room temperature detection systems for high-precision X-ray and gamma ray measurements**, from **few keV to MeV region**.

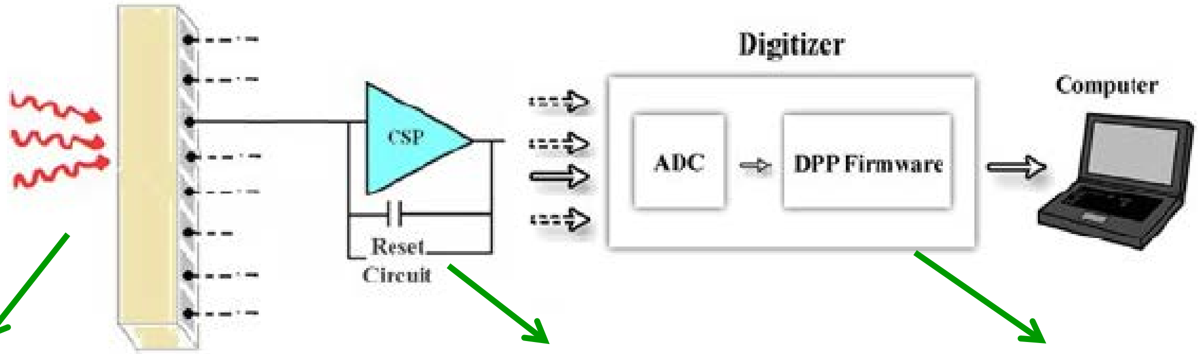
DRESS proposes the development of **beyond state-of-art** high-performance radiation detectors, in terms of:

- **energy and timing resolution,**
- **efficiency and compactness,**
- **stability and linearity,**

enabling instrumentation in hadron physics, with high potential impact also in several societal applications (medical imaging, food and material inspection industry,..)

DRESS project

We will work on all the key elements of the detection chain:



Room temperature semiconductor detectors (CdZnTe, Perovskites)

Low noise charge sensitive preamplifiers

Custom Digital Pulse Processing (DPP) Techniques

Key Performance Indicators

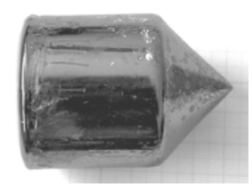
- **High efficiency over a wide energy range: 1 keV to 5 MeV**
- **Sub-keV energy resolution (at 100 keV) even at room temperature**
- **nanosecond-level timing resolution**

Beyond the current state-of-the-art performance
1-2 keV at 60 keV
> 300 ns

Detector Materials: CdZnTe

DRESS will focus on Cadmium Zinc Telluride (CdZnTe or CZT) detectors:

- **High atomic number (Z_{max} = 52) gives enhancements in detection efficiency (alternative material to silicon Z = 14 in terms of efficiency)**



- **Wide band gap (~ 1.6 eV) allows room temperature operation (alternative material to germanium 0.7 eV in terms of operating temperature)**

- **Poor charge carrier transport properties ($\mu\tau_e < 10^{-2}$ cm^2/V; $\mu\tau_h < 10^{-4}$ cm^2/V) limits the energy resolution and the detection area (< 4 cm^2 single crystal)**

These negative effects can be mitigated through a proper growth and selection of the crystals, the electrode geometry and pulse processing.

Detector Materials: Perovskite semiconductors

Halide perovskites ($CsPbBr_3$) represent a new generation of room temperature radiation detection materials:

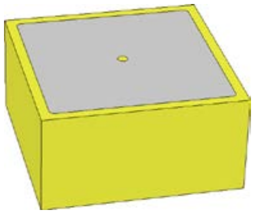
- **High atomic number (Z_{max} = 82) and wide band gap (~ 2.3 eV) gives enhancements in both detection efficiency and room temperature operation.**

- **The cost of materials and solution processes is very low (3 to 4 orders of magnitude cheaper than CZT crystals)**

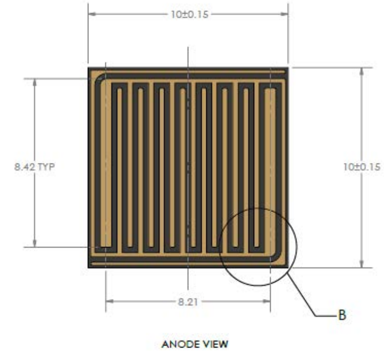
- **Current electrical contact technology produce high leakage currents, poor charge transport properties similar to CZT and time instabilities.**

Great efforts on crystal growth, electrode deposition and detector geometry

Proposed Detector Geometries



- **[Quasi-Hemispherical Detectors]**



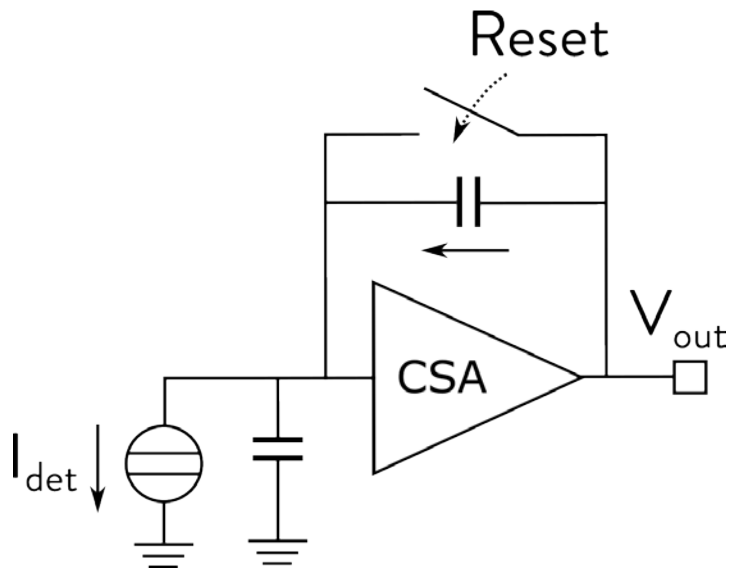
- **[Coplanar Detectors]**

- **Large detection area with a low number of channels**
- **Reduction of the effects of incomplete charge collection**
- **Timing enhancements**

Front-end Electronics

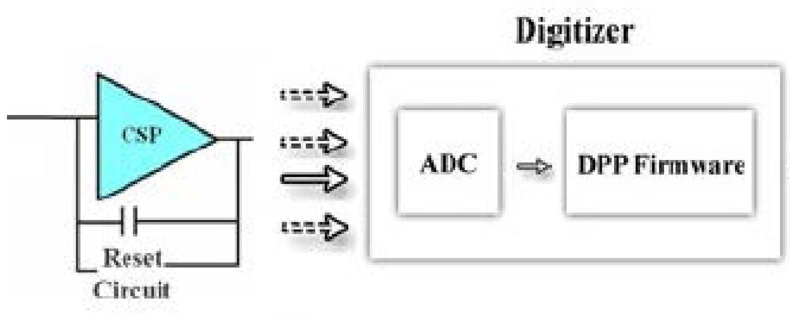
Development of ultra-low-noise and fast charge-sensitive preamplifiers.

- Charge-Sensitive Preamplifiers (no analog pulse shaping) based on low noise CMOS technology.
- ENC < few electrons (rms).
- Pulsed-mode reset strategy.



Digital Pulse Processing

The direct sampling of CSP pulses with digitizers allows the implementation of complex algorithms for performance improvements.



Dedicated pulse processing techniques:

- reduction of the effects of incomplete charge collection
- minimization of noise
- timing enhancements
- particle identification
- high flux measurements

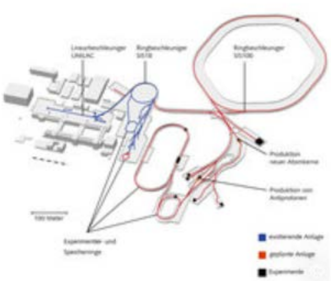
Connection to Transnational Access (TA) and Virtual Access (VA) Infrastructures

Involved Infrastructures

DRESS will extensively leverage existing research infrastructure services through TA and VA schemes.

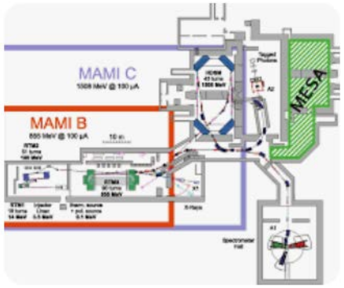
INFN-LNF Frascati (Italy): detector characterization at the Beam Test Facility (BTF); deployment in exotic atom spectroscopy setups and studies involving advanced acceleration (e.g., plasma wakefield acceleration) with implications in astrophysics, hadron and nuclear physics and inverse Compton scattering.

CERN (Switzerland): use of detectors in experiments on exotic atoms, where precise X-ray and gamma-ray spectroscopy is essential.

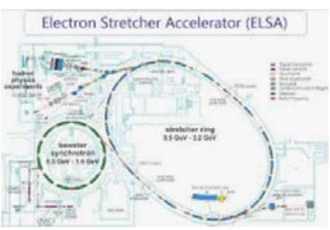


GSI/FAIR (Germany): the performance of the proposed detectors will be key to enhance the current radiation instrumentation at the ESR and CRYRING storage rings.

Involved Infrastructures



MAMI/MESA (Germany): through systematic studies at the MAMI and MESA accelerators, DRESS will design and optimize the detectors for enhanced sensitivity and energy resolution across a broad energy range (keV to MeV), radiation damage effects, and develop signal processing algorithms for real-time particle identification.



ELSA (Germany): the proposed technology is of interest for beam monitoring and high flux photon counting detection.

Additional access to complementary infrastructures (e.g., **PSI Villigen, J-PARC, ELI-NP**) may be considered during project implementation.

Partner Institutions

Partner Institutions

DRESS will exploit the expertise of research groups from different institutions, that already successfully collaborated and currently collaborate in hadron physics experiments (ASTRA, Kaonnis), medical and food industry (COST action ENRICH, Avatar X).

DRESS

IMEM, CNR, Parma, Italy
Detectors Characterization

University of Palermo, Italy (Coordinator)
Detectors
Digital Electronics
Characterization

(LNF) – INFN, Frascati, Italy (Co-Coordinator)
Hadron Physics Experiments
Electronics

Politecnico di Milano, Italy
Front-end Electronics
Characterization

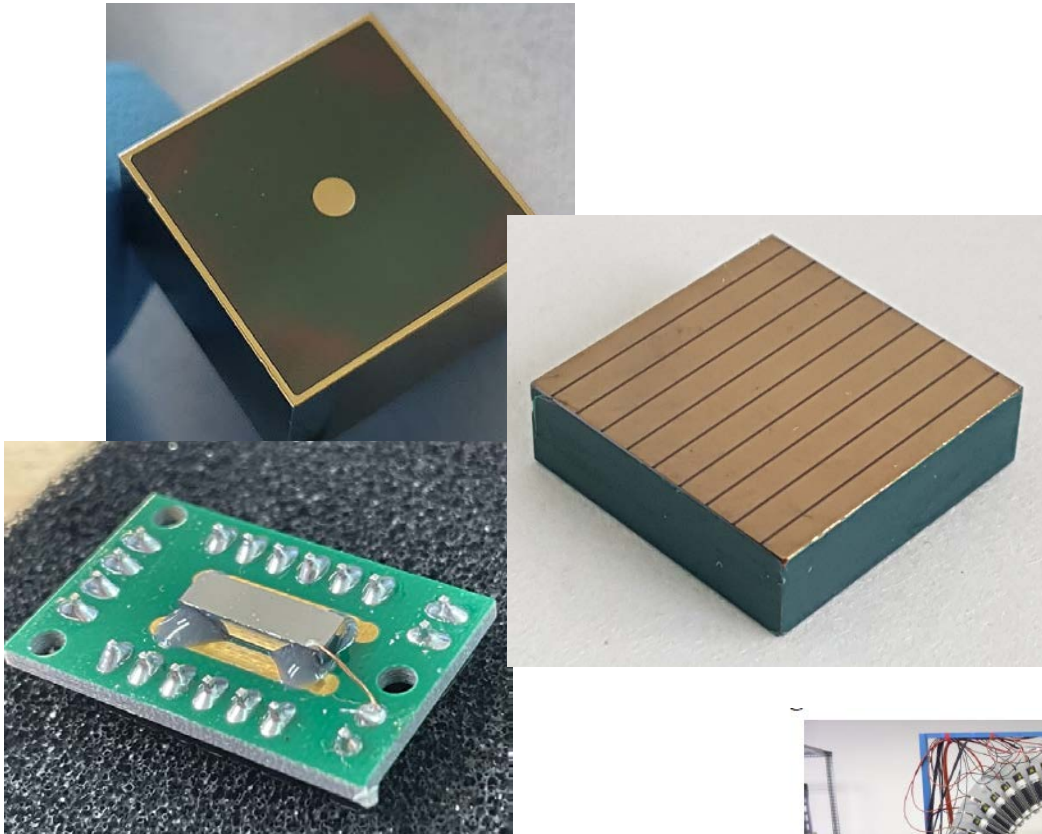
Charles University Prague, Czech Republic
Detectors
Characterization

Jagiellonian University in Krakow, Poland
Hadron Physics Experiments
Digital Electronics
Medical Applications

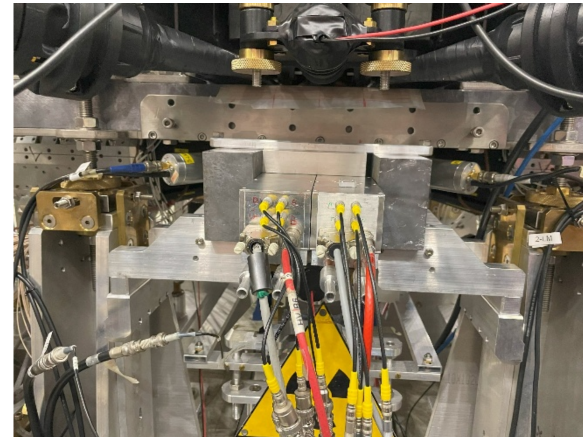
UKRI STFC Rutherford Appleton Laboratory, U.K.
Detectors
Front-end Electronics

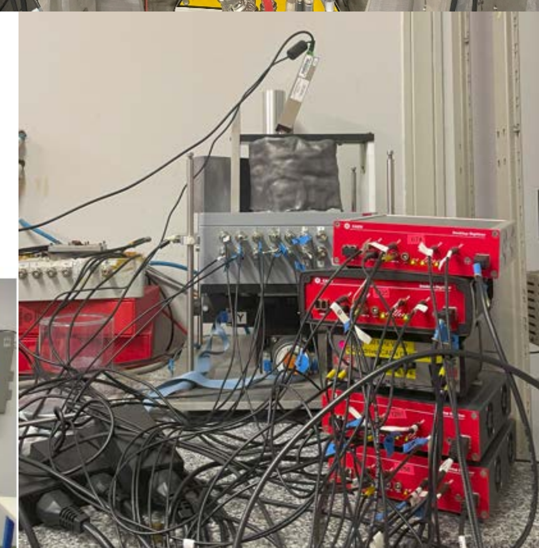
University of Zagreb, Croatia
Detectors
Hadron Physics Experiments
Medical Applications

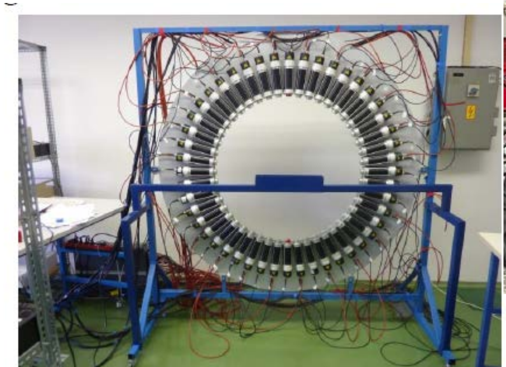
Developed Prototypes and Systems



CZT
Detectors

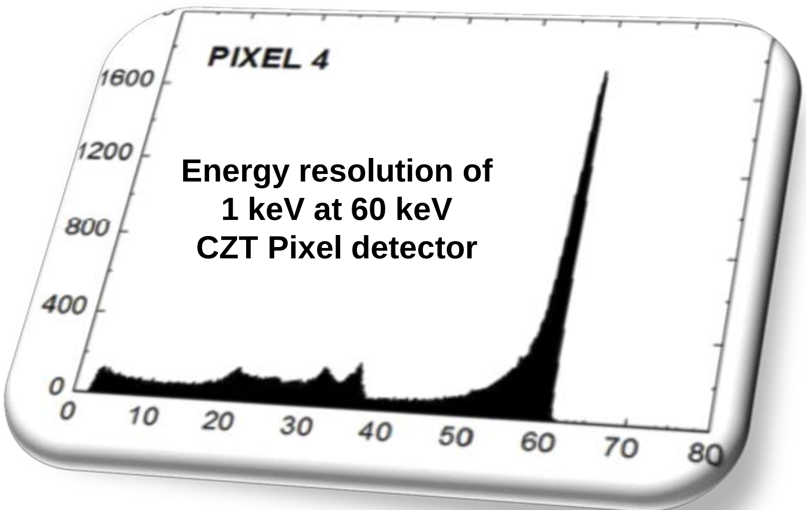


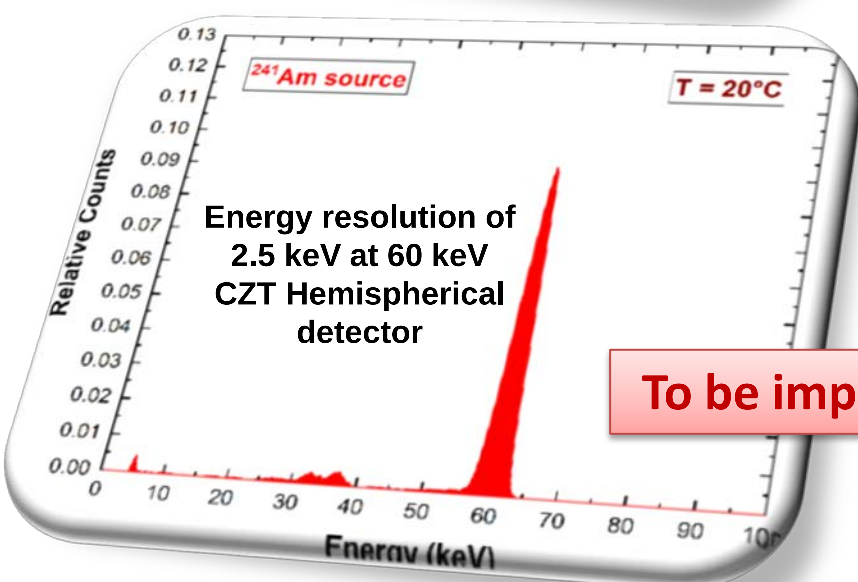




System of 48 BaF_2 detectors

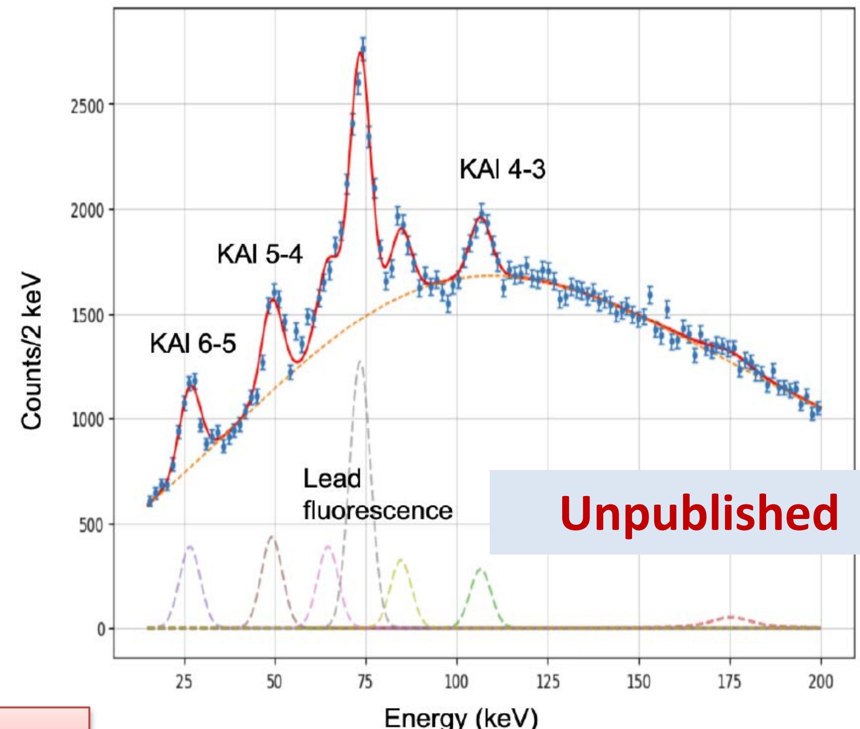
Recent Group Results





To be improved!

Kaonic atom X-ray measurements at LNF-INFN Frascati, Italy with CZT detectors



Unpublished

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CZT Detectors

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- A. Zappettini et al. IEEE TNS (2011) DOI: 10.1109/TNS.2011.2163643.

Perovskite Detectors

- K. Pekárková, E. Belas et al. Laser and Photonics Reviews (2025) DOI: 10.1002/lpor.202401904.
- N. Antonatos E. Belas et al. Nano Letters (2025) DOI: 10.1021/acs.nanolett.4c04945

Front-end Electronics

- G. Deda, G. Borghi et al. IEEE Transactions on Nuclear Science (2024) DOI: 10.1109/TNS.2024.3455424
- M. C. Veale et al. Synchrotron Radiation News (2018) DOI: 10.1080/08940886.2018.1528431

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Digital Electronics

- L. Abbene et al. J. Journal of Synchrotron Radiation (2015) DOI: 0.1107/S1600577515013776.
- L. Abbene et al. Journal of Synchrotron Radiation (2018) DOI: 10.1107/S1600577517015697.

Hadron Physics Experiments

- F. Sirghi, et al. Journal of Instrumentation (2024) DOI: 10.1088/1748-0221/19/11/P11006
- C. Curceanu et al. Frontiers in Physics (2023) DOI: 10.3389/fphy.2023.1240250.
- A. Scordo et al. NIM A (2024) DOI: 10.1016/j.nima.2023.169060.

Medical and Food Applications

- P. Moskal , M. Skurzok et al. Science Advances (2025) DOI: 10.1126/sciadv.ads3046
- A. Buttacavoli, L. Abbene et al. Sensors (2023) DOI: 10.3390/s23063196.

Project Development

Work Packages (WPs)

WP1: CZT-based detector prototypes

WP2: Perovskites-based detector prototype

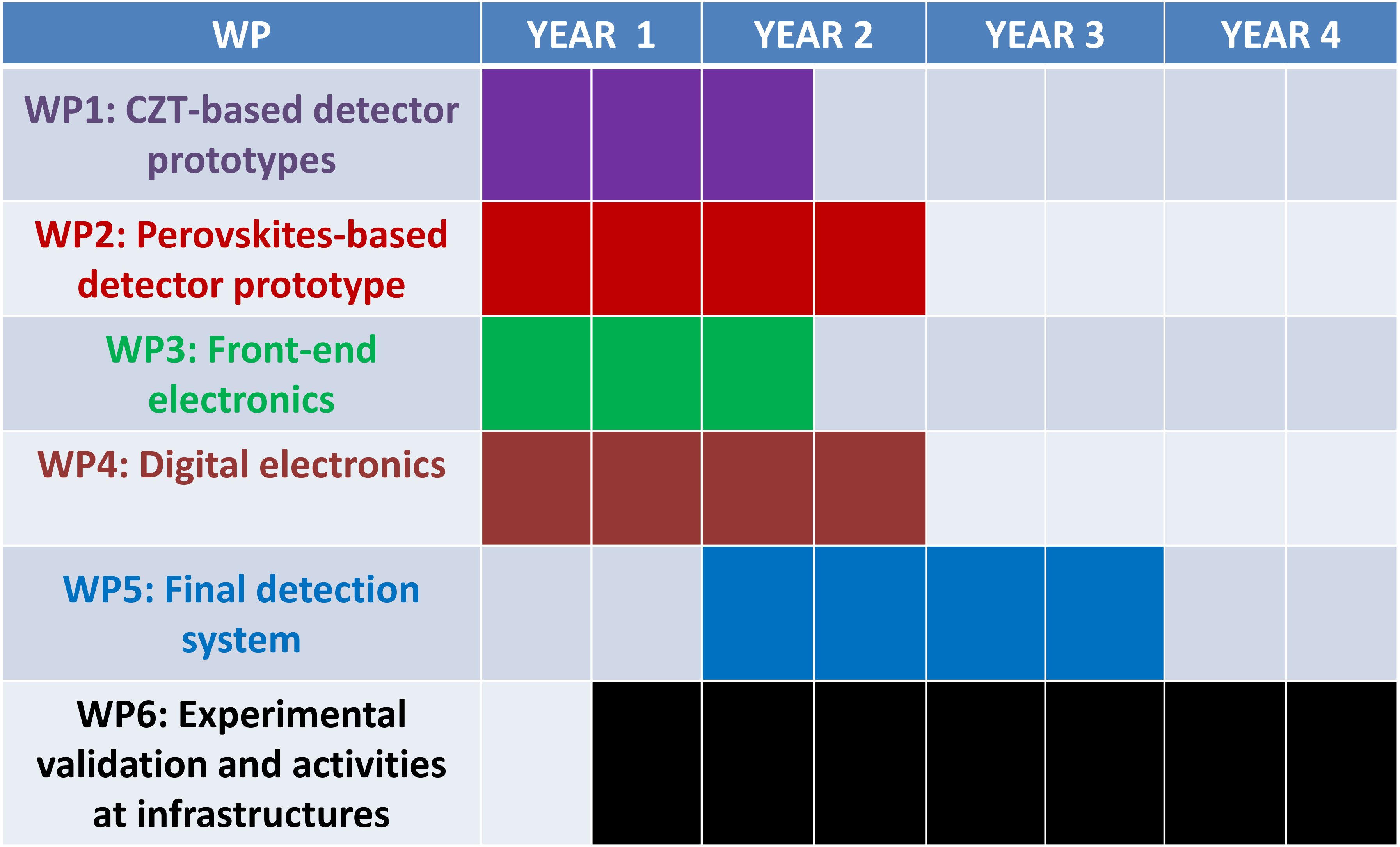
WP3: Front-end electronics

WP4: Digital electronics

WP5: Final detection system

WP6: Experimental validation and activities at infrastructures

GANTT Chart


WP
YEAR 1
YEAR 2
YEAR 3
YEAR 4
WP1: CZT-based detector prototypes
WP2: Perovskites-based detector prototype
WP3: Front-end electronics
WP4: Digital electronics
WP5: Final detection system
WP6: Experimental validation and activities at infrastructures

Estimated Budget

Estimated Budget

The total requested budget is **€ 600,000**, distributed as follows:

	Partner Institutions	Activity Leader	Direct costs	Indirect costs
1	Department of Physics and Chemistry - E. Segrè (DiFC) University of Palermo, Italy (Coordinator)	L. Abbene	100 k€	20 k€
2	Laboratori Nazionali di Frascati (LNF) – INFN, Italy (Co-Coordinator)	F. Sirghi	95 k€	19 k€
3	IMEM, CNR, Parma, Italy	A. Zappettini	95 k€	19 k€
4	Politecnico di Milano, Italy	G. Borghi	80 k€	16 k€
5	Charles University, Faculty of Mathematics and Physics, Institute of Physics, Prague, Czech Republic	E. Belas	40 k€	8 k€
6	University of Zagreb, Croatia	D. Bosnar	30 k€	6 k€
7	Jagiellonian University in Krakow, Poland	M. Skurzok	30 k€	6 k€
8	UKRI STFC Rutherford Appleton Laboratory, U.K.	M. Veale	30 k€	6 k€

Palermo, Italy

Thank you for your kind attention