Letter of Intent

Acronym: DRESS

Project Title: ***D****igital High* ***RE****solution position-sensitive room temperature* ***S****emiconductor detectors for high precision radiation* ***S****pectroscopy in hadron physics and related areas*.

Project Leaders:

-Prof. Leonardo Abbene, Department of Physics and Chemistry (DiFC)-Emilio Segrè University of Palermo, Italy (Coordinator)

-Dott. Florin Sirghi, INFN – Laboratori Nazionali di Frascati, Italy (Co-Coordinator)

1. Research Objectives

The **DRESS** project aims to develop advanced room-temperature position-sensitive semiconductor-based radiation detectors for high-precision X-ray and gamma-ray spectroscopy. These technologies are crucial for advancing hadron physics research, particularly in studies involving exotic atoms, hadron and nuclear structures, astrophysical processes, and searches for physics beyond the Standard Model. Currently, the development of large-area room-temperature radiation detectors with sub-keV energy resolution and nanosecond-level timing resolution remains challenging. The proposed leading-edge detector technology will enhance the services of the transnational infrastructures involved in the project, opening the road towards new Hadron physics research and significant societal applications, including nuclear medicine, industrial inspection, and security. The overarching goal is to achieve a **sub-keV energy resolution and nanosecond-level timing resolution** across a broad energy range (keV to MeV), with stable performance at room temperature or with minimal cooling requirements. To achieve this, **DRESS activities will cover the full detection chain**, from advanced detector materials and sensor design to custom read-out electronics and digital pulse processing:

- **Detector materials:** DRESS will focus on Cadmium Zinc Telluride (CdZnTe or CZT) and, for the first time in this context, on halide perovskites. CZT is currently the benchmark for room-temperature radiation detectors due to its high atomic number and wide band gap. Innovations will target improved charge transport properties, reduced leakage currents and enhanced timing. Detectors with co-planar, strip, and hemispherical layouts will be proposed, taking into account the enhancements of the detection area, spectroscopic and timing resolution, the reduction of the noise and the number of readout channels. Halide perovskites can offer a promising low-cost alternative and will be explored for their scalability and eco-friendly synthesis.
- **Front-end electronics:** development of ultra-low-noise and fast charge-sensitive preamplifiers, based on a low-noise CMOS technology, will be pursued. The objective is to achieve sub-electron intrinsic equivalent noise charge (ENC) levels.
- **Digital pulse processing (DPP):** the signals from detector/preamplifiers will be promptly digitized and processed by using advanced DPP approaches. DPP allows the application of dedicated filtering and pulse shape analysis for timing/energy resolution improvements and high-flux measurements. AI-driven analysis techniques will also be used to improve radiation detection.
- **Demonstrators and deliverables:** The project will deliver at least **three detector prototypes** (low-flux-CZT, high-flux-CZT and perovskites detectors**)**, tested in beamlines and laboratory settings, with documented performance benchmarks (energy resolution, timing, stability) and a comprehensive evaluation report comparing CZT and perovskite solutions under identical conditions for use in hadron physics and related area experiments and applications.

The consortium brings together leading European expertise in semiconductor physics, electronics, and experimental hadron physics, with complementary know-how in detector development, signal processing, and access to major test infrastructures.

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

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

- **INFN-LNF (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.

- **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, or FAIR**) may be considered during project implementation.

3. Estimated Budget Request and 4. Participating and Partner Institutions

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

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