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Italiadomani PIANO NAZIONALE DI RIPRESA E RESILIENZA
ICSC Centro Nazionale di Ricerca in HPC, Big Data and Quantum Computing

SPARTAN: SPace pARTicle trAcking with Neural-networks

A. Abba, Nuclear Instruments

Referee: Dr. Fabio Gargano

Spoke 3 Progetti Bandi a Cascata, 24/09, 2024

Project Overview

- **Particle Trackers in High-Rate Environments: Traditional geometric and physical algorithms face challenges due to pileup in high-rate particle environments, making it difficult to distinguish individual particle traces.**

- **Machine Learning for Track Reconstruction: Using deep learning techniques to address pileup challenges, improving resolution and noise rejection, especially with hardware like GPUs and FPGAs.**

- **Applications Beyond Space: This technology has potential uses in high-energy physics experiments, medical imaging (e.g., TOF-PET scanners)**

- **Collaboration with HERD project: The project will integrate real and synthetic data from HERD calorimeter to optimize neural networks for particle tracking.**

Technical Objectives, Methodologies and Solutions

- **Objective: High-Rate Particle Tracking: Develop innovative machine learning algorithms capable of reconstructing particle traces in high-density environments while minimizing computational complexity.**
- **Methodology: Hardware-Optimized Machine Learning: Implement deep learning models on low-power, rad-hard FPGAs:**
  - **Low-Power Design for Space: The project focuses on developing energy-efficient hardware optimized for the limited power available in space missions, ensuring long-term reliability.**
  - **Rad-Hard FPGA Technology: Leveraging Xilinx KRIA/Versal rad-hard FPGAs for low-power, radiation-resistant particle trace recognition and classification in space environments.**
- **Solution: Integrated Hardware and Software: Design a complete system combining real-time data processing, FPGA-based ML, and particle classification to achieve precise tracking and classification in challenging space environments.**

Involved Staff and new recruitments

- **DATA ANALYST AND SOFTWARE DEVELOPER:**
  Dr. V. Arosio, Dr. M. Lazzari, Ing. F. Caponio, F. Bonomelli

- **FIRMWARE DESIGNER:**
  Ing. A. Abba, Dr. L. Ferrentino, Dr. S. Carsi (1), Ing. E. Carlotti (1), Ing. A. Cusimano, D. Bianchi, Dr. M. Petruzzo (2)

- **HARDWARE DESIGNER:**
  Ing. L. Pastori, G. Marelli

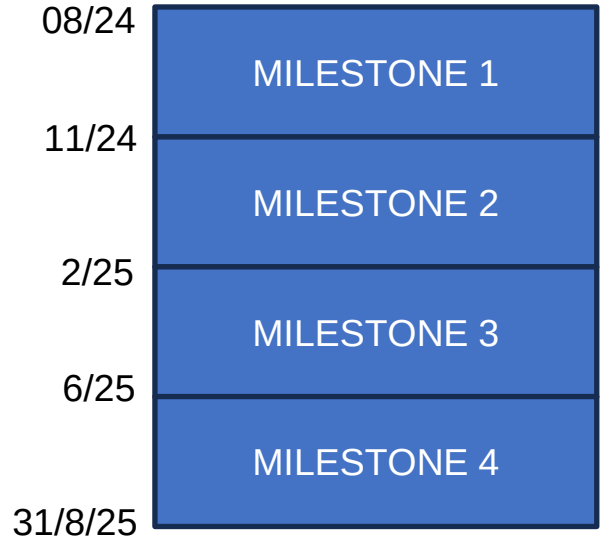
1. Enrolled in September to increase the critical mass on this project
2. Will start in January 2025

Cost summary

	TOTAL COST	STAFF COST	EQUIPEMENT COST	% INCENTIVES	INCENTIVES
RF	30 k€	30 k€	0 k€	100%	30 k€
RI	120 k€	120 k€	0 k€	70%	84 k€
SS	80 k€	80 k€	0 k€	45%	36 k€
TOTAL	230 k€	230 k€	0 k€		150 k€

Timescale, Milestones, SAL

- **Milestone 1: Development of a training dataset and implementation of the tracking algorithm in Python.**
- **Milestone 2: Implementation of the algorithm on an FPGA-based hardware platform (Zynq Ultrascale+ SoC).**
- **Milestone 3: Adaptation of the hardware platform developed for the NUSES satellite to apply the algorithm in real-time to data from the Zirè tracker.**
- **Milestone 4: System validation through particle in a test beam and evaluation of its usability limits for space applications.**



The project cost will be fully allocated to human resources, as NI has already purchased the necessary hardware for Milestones 1 and 2 with its own funds, including servers, GPUs, and an FPGA EVM. Hardware people will be involved to adapt existing hardware.