EU Seventh Framework Programme (FP7) Marie Curie Initial Training Network (ITN)

INtelligent, Fast, Interconnected and Efficient devices for Frontier Exploitation in Research and Industry (INFIERI)

This project proposes to establish a special training network aiming to use the cutting edge technological advantages of several fields of Physics and Technology to Astrophysics, High Energy Physics (HEP), Medical Physics and Telecommunication research, through the development of intelligent devices and tools. Intelligent devices have embedded ability to deliver in real-time, high level functionalities coming from the elaboration of simpler operations. The embedded intelligence targets fast, efficient, smart, high fault tolerant, high rate data flow handling, real time and very sophisticated data processing that performs detailed analysis and diagnoses.

This Network is intended to be an inter-disciplinary, multi-national initiative to train a generation of young physicists and engineers in the new domain of intelligent and fast devices useful for Astrophysics, Medical and Particle physics, and Telecommunication research.

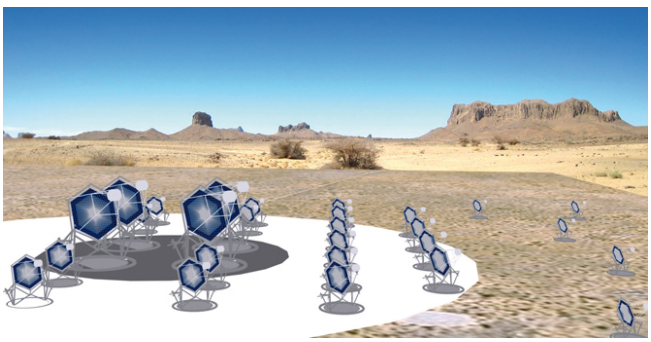
These research fields usually need to handle data at high rates sometime from multiple distributed sources, to perform first an on-site (local, or front-end) data reduction, followed by a fast data transfer to a high capacity tier (the far-end), where further analysis is performed, resulting in high level diagnoses and results, easy to visualize or to interpret. In some cases, the data sources are not directly accessible, or are located in unfriendly environments. The sources can be very close or largely dispersed in space, as for instance an array of pixelated devices assembled into a medical imaging instrument (PET) or an array of Cerenkov detectors spread over kilometers, forming a terrestrial telescope. Although different in size, both cases have very similar needs in terms of treatment of the information.

There are three distinct focused applications around which the training network develops:

- The processing of the detector information for the CTA (Cerenkov Telescope Array) one of the most important project in preparation in Astrophysics.
- The medical imaging based on PET technology compatible with Magnetic Resonance Imaging (MRI).
- The tracking trigger for the CMS experiment at LHC-CERN, in particle Physics.

Cherenkov Telescope Array (CTA)

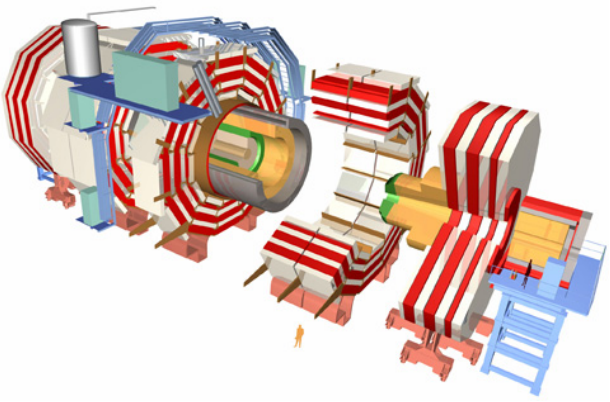
CTA is an initiative to build the next generation ground-based very-high-energy gamma-ray instrument. The new generation of major astroparticle physics infrastructures will exploit photosensors, fast electronics and advanced telecommunications technology. For example, Silicon-based photomultipliers (SiPMs) are under consideration for CTA and are a feature of new-generation instrumentation in many other fields. The geographical spread of telescopes in CTA and the very large data volume present very significant telecommunications challenges. The time tagging of events and triggering scheme are critical aspects, which share many common aspects with the Particle Physics case. A typical observatory is made by 40-50 telescopes of different sizes with a trigger rate of 1 kHz and a



data rate of the order of several Tbit/s. The project is in the road-map of the European Strategy Forum on Research Infrastructures (ESFRI), the European Astroparticle Physics network ASPERA and the European Astrophysics network Astronet.

Medical Physics Positron Emission Tomography (PET) is acknowledged to be the best functional imaging methodology both in clinical applications (mostly in oncology, cardiology and neurology) and in pre-clinical research. In the 4D-PET proposal a new multilayer module will be developed and characterized, composed of a tile for scintillator crystal LSO.Ce,Ca coupled on both sides to a tile of Silicon Photomultipliers (SiPM) matrices and a tile for integrated read-out electronics. By combining the 3D data (spatial coordinates x, y plus time) acquired through SiPM+ROIC layers placed on both the input side of the radiation (front) and the other side (back), it is possible to obtain also DOI and TOF, thus increasing the PET detection accuracy. The data rate of such devices is of the order of 2 MHz of 128 bits/hit for a total of ~250 Mbits/second. The data are sent to the far-end electronics using Gigabit Ethernet links, to a FPGA that performs pattern recognition.

Compact Muon Solenoid (CMS) The Large Hadron Collider (LHC) at Cern (Geneva) is the world's largest and powerful collider ever built for investigating the ultimate origin of matter and fundamental interactions. In the next decade it will be upgraded in both energy and intensity to be able to discover new physics and to answer the most challenging questions in particle physics. This will require unprecedented real time data processing capabilities (Tbit/s data fluxes) in a harsh radiation environment. The CMS detector is undergoing major upgrades in its online selection electronics and algorithms at the speed of 40 MHz. Pixelated silicon-based detectors with embedded intelligence (logical IP cores) will provide the ability to select interesting events with data reduction performance of one part in a million. High speed links will transfer data to FPGA-based boards off detector where pattern recognition is performed. The track reconstruction and pattern recognition is an improved and innovative version of the Associative Memory used in the CDF experiment at the Tevatron (FNAL-USA), whose the pioneer expert is member of this Training Network project.



Covering these three different fields emphasizes the synergy between them and will be of the highest importance to efficiently develop these applications in a strong collaborative framework and with upmost outcomes for the training delivered by this project. It should be noted that the participation to the three applications by the partners of this proposed consortium is well balanced. Here below are explained the S&T objectives in more detailed way.

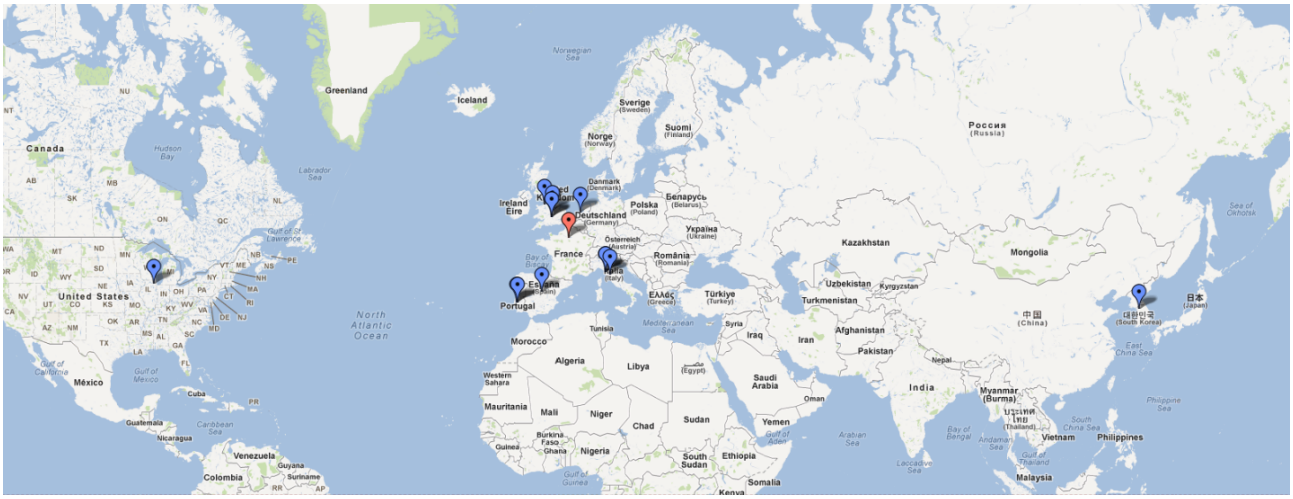
Science & Technology Objectives (S&T) and Private Sector Contribution

The scientific quality of the research training program is manifold. It is inter/multidisciplinary, inter-sectoral and include newly emerging supra-disciplinary fields. The proposed project relies on a research methodology based on combining the fundamental research, the applied research and the industrial worlds. Very often (especially in several European countries) these different fields are not enough closely linked. Our research methodology combines a few well identified applications and use them as training example to emphasize their similarities and complementarities

- The research methodology is based also on exploiting the common high technological challenges and thus the synergy in various crucial aspects classified as the main Work packages of the project
- to combine R&D efforts and results and thus reinforce the efficiency and chances of success
- as well as sharing or initiating new innovative ideas to solve a common problem.

The originality of this program is already presented in its research methodology and approach and its multi-facets. The innovative aspects are in the scientific and technological objectives tackled by this proposed project, the way to handle them and the training program built around it.
The private sector plays a major role in this project as the major research and technology objectives of this program strongly rely on the close collaboration with Industrial partners. Similarly for the training program where the involvement of the private sector, large and smaller size industrial partners will be providing unique aspects of the training program with internships, co-advising of PhDs, entrepreneurial courses, etc.. The role of the private sector is thus a major asset of this project with the several major Industries that are partners or associated to this project.

Academic Partners of the Training Project



APC Laboratory, Université Paris Diderot (Paris 7), Paris, France
And associated INL: Institut of Nanotechnology of Lyon, France
Nationaal Instituut voor subatomaire fysica (NIKEF), Amsterdam, Netherlands
Laboratório Instrumentação e Fisica Experimental de Partículas (LIP), Lisbon Portugal
Istituto Nazionale di Fisica Nucleare (INFN), Pisa and Siena, Italy
Universidad Carlos III de Madrid (UC3M), Madrid, Spain
Universities of Leicester , Liverpool & Oxford, England
Rutherford Appleton Laboratory, Appleton, England
And Bristol University, England
Scuola Superiore Sant'anna, Pisa, Italy

THALES TRT, France
PHILIPS SA, Eidhoven (Netherlands)

And the following associated partners:
Seoul National University, Seoul, Korea
SAMSUNG S.A, Korea
Fermi National Accelerator Laboratory,FNAL, Batavia, Illinois U.S.A.
CERN, CH.
Purdue University (Indiana, USA)
TEZZARON S.A., (Illinois, USA
SEDECAL S.A. , Madrid, Spain
CAEN S.p.A. Villaregio, Italy
Amsterdam University, Netherlands

All the partners (full or associated ones) participate in dedicated network scientific, technological and training activities and will take part as well in the managerial structures of this consortium.

Keywords

Astrophysics, Particle Physics, Medical Imaging, Front End processing, L1 Track trigger, High speed data transfer, Massive Parallel computing, Through Silicon Vias, Deep Sub Micron technology.

- Through Silicon Vias (TSV) 3D vertical interconnect packaging technology
- Low power dissipation, high fault tolerance, fast and highly performing ASICs
- Embedded intelligence devices
- Advanced Digital Processing Architecture
  New generation of FPGA's and Novel massive parallel computing technology
- Advanced Information and Communication Technologies
  Network, data transmission, communication and computing
- High-speed & high-efficiency light detection
  Photomultipliers, SiPMs,...
- Test bench: dedicated test bench for developing and evaluating demonstrators and new technologies

OUTCOMES:

Advanced Telecom Industry
Medical Imaging
Next generation Computing Industry (novel massive parallel computing)
Mechatronics: *Automation, servo-mechanics, sensing and control systems, microcontrollers,...*
Optics: *Mirror structure, reflective surfaces, light concentrators,.*
High-speed electronics
Power
Safety system: *Telesurveillance, safety control, fire detection,...*
Assembly & test