The PicoSEC-MCNet researchers and Partners:

22 researchers from **15** home countries working in **11** Partners located in **6** European countries

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Aliakbar Ebrahimi
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Daniele Cortinovis
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Alejandro Gil Ortiz
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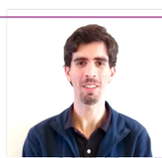

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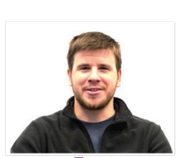

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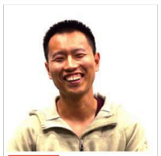

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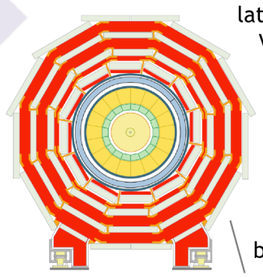
Brochure finalized in October 2015. Texts: Tom Meyer, on inputs from the PicoSEC-MCNet researchers; concept and realization: Rita Giuffredi.

THE PICOSEC MC-NET PROJECT

Training young researchers from all around the world to develop ultra-fast photon detectors for High Energy Physics and Medical Imaging

Developments in High Energy Physics accelerators are **pushing the limits of photon detector** speed. Future high-luminosity accelerators will have unprecedented, short bunch crossing intervals to produce sufficient luminosity.

This has an **immediate impact on detector design and performance which are predominantly speed and time resolution driven.**
Calorimeters are well placed in that way to provide **sub-nanosecond timing resolution** and hence cope with the new accelerator environment.
High time resolution will also improve the identification of particles in hadronic showers, so as to identify late soft neutrons and apply proper weighting factors to reconstruct the true shower energy, being important for jet energy resolution.



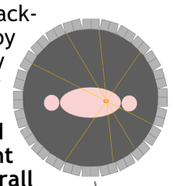
CMS experiment at CERN: example of a current detector in High Energy Physics

The **training** of young researchers is embedded in this type of fundamental research, working with **international, world-renowned, research groups and institutions.**

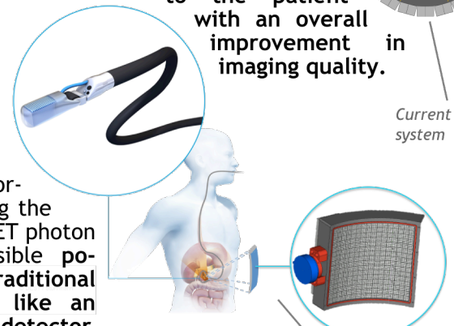
Ultra-fast photon detectors for High Energy Physics

Ultra-fast photon detectors for Medical Imaging

PET (Positron Emission Tomography) systems crucially depend on the speed of photon detectors; faster detection means a reduction of the photonic background and, by that fact, allow **earlier stage tumor detection, lower radioactive dose delivered to the patient with an overall improvement in imaging quality.**



Current PET system



PicoSEC-MCNet is working on improving the timing of current PET photon detectors, with possible **positive effects both on traditional and new PET systems, like an asymmetric endoscopic PET detector.**
PicoSEC-MCNet is in particular collaborating with the FP7 European project EndoTOFPET-US, aiming to realize a novel endoscopic PET system geared to target and detect prostate and pancreas cancers at the earliest stages.

The EndoTOFPET-US (FP7 grant n° 256984) endoscopic PET system, consisting of an external plate and an inner multimodal endoscopic probe.

This research project is supported by a **Marie Curie Early Initial Training Network** Fellowship of the European Union's Seventh Framework Programme under contract number (PITN-GA-2011-289355-PicoSEC-MCNet).

The PicoSEC-MCNet scientific project

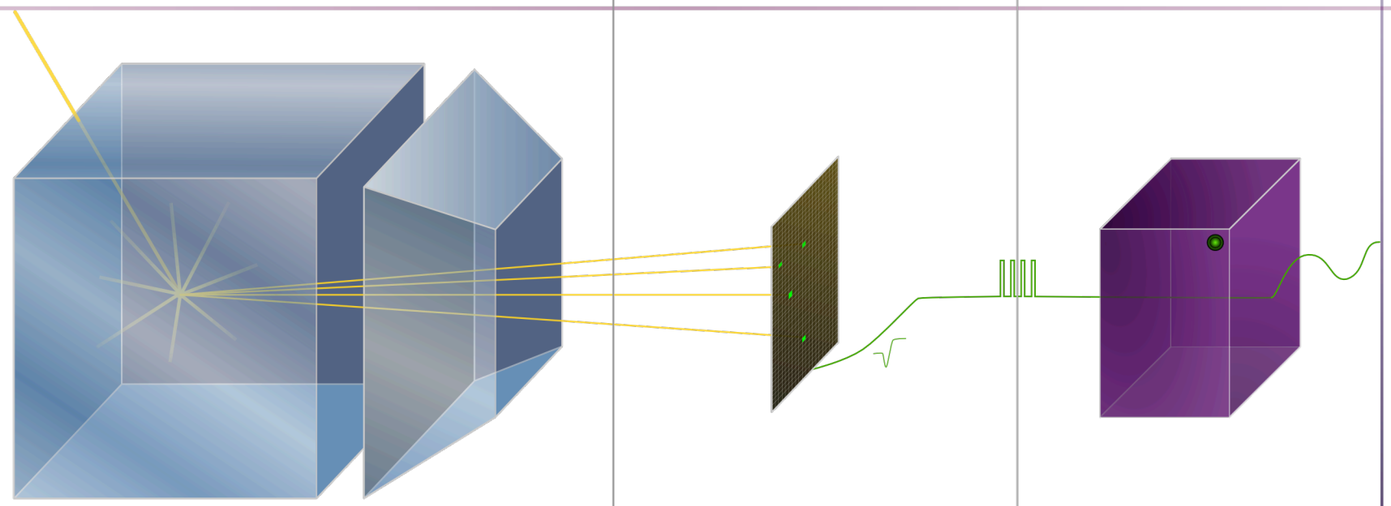
Time-resolving of events means:

- **PET**: *reduce background and improve image quality*
- **HEP**: *resolve congested events in high luminosity and improve jet energy resolution*

key concept #1

The challenges:

to preserve the performance of each component	to be fast and bright	to convert light	to preserve speed	to adapt to a completely new geometry



WP4 DETECTOR INTEGRATION AND PROTOTYPING

Objectives: preparing the final TOF-PET detector system for modular assembly of the previously evaluated single detector components as well as preparing a calorimeter prototype for high energy physics.

PicoSEC-MCNet key research:

- Characterization and assembly of crystal matrix detectors

- Evaluation and mounting of the crystal matrices;
- Gluing of the crystal matrices to the corresponding SiPM modules;
- Assembly of the combined modules to form the external plate of the EndoTOFPET-US project.

- Integration of the front-end electronics system for SiPM readout and data output

The dedicated ASICs have been tested and mounted onto the photo-detectors of the entire external plate, assuring the timing performance of the whole system.

- Development of calorimeter technology for High Energy Physics

In the context of High Energy Physics:

- 1150 tiles read out by SiPMs have been manufactured, characterized and assembled to form 8 hadron calorimeter base units (AHCAL) for the CALICE Collaboration.
- a new crystal fiber-based concept for a future calorimeter has been developed.

WP5 IMAGE RECONSTRUCTION, TRACKING-NAVIGATION, HARDWARE AND SOFTWARE

Objectives: to develop Image reconstruction, tracking & navigation systems for PET detectors.

PicoSEC-MCNet key research:

- Simulation of the PET detector and the unconventional asymmetric system geometry

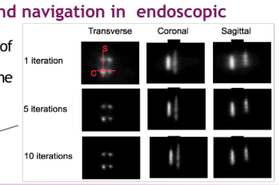
A true challenge and novelty for image reconstruction: the asymmetric arrangement of the endoscopic probe used in conjunction with a planar external plate.

- Image reconstruction of PET data in a non-stationary environment

Development of image reconstruction software to cope with freely moving detectors and to take into account depth of interaction and time of flight information.

- Design of tracking and free-hand navigation in endoscopic PET

- Optical tracking for 3D reconstruction of ultrasound data;
- Merging of previous MRI-data with the ultrasound data.

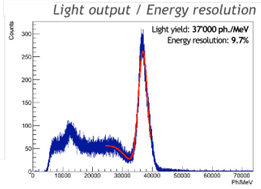


reconstructed images differing by view and number of iterations of the reconstruction algorithm.

WP1 SCINTILLATORS AND OPTICS

Objectives: improve scintillating crystal performance in terms of *light output* and *timing*.

Light output / Energy resolution



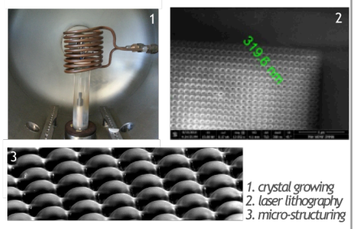
PicoSEC-MCNet key research:

Light output enhancing techniques to improve crystal performance and detector photostatistics. The main research lines are:

- **Search for bright and fast crystals;**
- **Understand light spatial distribution;**
- **Improve light extraction efficiency.**

These research interests are pursued through the development of:

- **Crystal growing techniques**: μ-pulling down technique for inorganic scintillating fibers leading to high granularity and sub-millimeter position information.
- **Micro-structuring**: electron beam lithography, direct nano-structuring of the crystal surface through the FIB (Focused Ion Beam) technique, micro-structuring of crystals to obtain microlenses.
- **Laser lithography**: μ-structures directly built on the crystal surface to act as diffractive coupling between the crystal and the photodetector.



1. crystal growing
2. laser lithography
3. micro-structuring

WP2 PHOTODETECTORS

Objectives: development and characterization of silicon photomultipliers with improved timing, single-photon-counting resolution and dynamic range.

PicoSEC-MCNet key research:

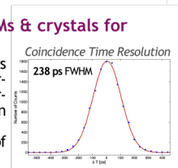
- Design and fabrication of analog and digital SiPMs

Improved analog SiPMs with a dedicated fabrication process and multi-channel Digital Silicon Photomultipliers in Deep Sub-Micron CMOS technology, with lower noise, lower crosstalk and improved timing performance.

- Characterization of SiPMs & crystals for highest time resolution

- Advanced evaluation methods to assess intrinsic "noise" sources, e.g. dark count rate, afterpulsing and delayed crosstalk in the SiPMs;
- Tests to explore the limits of timing performance.

Coincidence Time Resolution



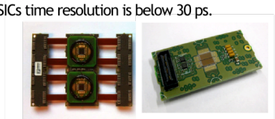
WP3 ELECTRONICS AND DATA ACQUISITION

Objectives: to provide an ultra-fast amplifier/discriminator front-end, coupled to a highly granular TDC and high bandwidth data acquisition system.

PicoSEC-MCNet key research:

- development of high time resolution ASICs

ASICs time resolution is below 30 ps.



- DAQ for TOF-PET scanners and HEP detectors

Distributed and multi-level event triggering for both TOF-PET and high luminosity detectors in future particle physics;

- PET prototype proof of concept

Deployment of this electronics for the development of a fully functional endoscopic TOF-PET probe and external planar TOF-PET detector.

key concept #2

If high speed is a prerequisite, we need to preserve it ***along the whole detection chain***

More info:

Complete references and bibliography available on:

www.cern.ch/picosec/articles.html