Laboratory of Radiation Detectors and Nuclear Electronics (RADLAB)

(2 staff, 8 PhD students and post-doc, 8-10 master thesis positions)

Topics for Master Thesis: (for both ELN and BIO students)

• Detectors, electronics and instrumentation for X and gamma rays applications in medical imaging, X-ray astronomy, nuclear physics, study of matter and industrial applications

• Integrated circuits for signal processing of detector signals in scientific and industrial applications

Pre-requisites:

• interest/attitude to experimental activity in laboratory

• basic background on electronics (in particular, for thesis in integrated circuits design)

• motivation, curiosity
**INSERT:** INtegrated SPECT/MRI for Enhanced Stratification in Radio-chemo Therapy

GA n. 305311
Kickoff: 01/03/13
Duration: 4 years

**Goal:** to provide improved personalized radio-chemo therapies for brain tumour (Glioma) patients using a specifically developed multi-modality imaging tool

**INSERT members**
- Politecnico di Milano (Italy)
- Mediso Medical Imaging Systems (Hungary)
- Fondazione Bruno Kessler (Italy)
- Nuclearfields International BV (Netherlands)
- MRI.Tools GmbH (Germany)
- University College London (UK)
- Universita Vita-Salute San Raffaele (Italy)
- Universita Degli Studi di Milano (Italy)
- Cromed Research and Services ltd. (Hungary)
- CF Consulting srl. (Italy)
MRI:
- 3 T MRI (internal bore diameter ~60 cm)
- Customized RF coil

SPECT:
- Stationary system
- Multi Slit-Slat collimator
- 20 independent detection modules (FOV ~ 10x5 cm²)

Example of coregistration of non-simultaneous SPECT (colourscale) – MRI (grayscale) acquisitions
SPECT-MRI Compatibility

MRI compatibility tests

- The MRI field and signals should not interfere with the detection module
- The detection module should not produce artifacts on the MRI images

MRI off
MRI on

with PMT
Detection module (Anger camera):

1. Monolithic slanted scintillator (CsI:Tl. Area~10x5 cm². Thickness 8 mm)
2. Silicon PhotoMultipliers matrix
3. ASIC readout and Data Acquisition System

Expected performance from Monte Carlo simulations:

- **Spatial resolution**: between 0.8 and 1 mm
- **Energy resolution**: between 11% and 15% (Tc-99m - 140 keV)
Csl(Tl) crystal (Teflon wrapped)
50mm x 100mm x 8mm

SiPM Tiles
Heat Sink
ASIC board
ASIC 1
ASIC 2
DAQ
Digitization and optical transmission

Standard design
MRI-Compatibile design
thesis topics:

- detection module: development and experimentation of new reconstruction algorithms (Depth-Of-Interaction, reconstr. of edge events, Multiplexing, ..)
- experimentation of clinical SPECT, in collaboration with University College London
event reconstruction is made through processing of ALL photodetector signals (e.g. 64 in an 8x8 array)

⇒ can we achieve the same results with subsets of data (multiplexing)?
⇒ can we implement on-chip X,Y reconstr.?
γ-ray

multi pinhole collimator

$\Delta X$

⇒ different DOI (Depth Of Interaction) produces an error in X and Y reconstruction
GAMMA project (Spectroscopy and imaging of wide-range gamma rays)

thesis topics:
• development and experimentation of a gamma-ray detector based on 3'' LaBr₃ scintillator
• development of imaging algorithms for Doppler broadening correction
• development of an ultra high (10,000) dynamic range ASIC
• study and experimentation of timing properties of the detector+electronics
144 SiPMs matrix
**GOAL:** design of a readout ASIC able to cover a high dynamic range (1ph → ~10,000ph)

- **200keV gamma ray:** SiPm signals
- **20MeV gamma ray:** SiPm signals
Adaptive-Gain Control ASIC

SiPM signal

filter output

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Position sensitivity in large scintillators

Reconstructed $Z$ of irradiated points along the depth of the scintillator: horizontal axis is the true $Z$, vertical axis is the reconstructed $Z$. 
Goal: Development of a versatile detector based on arrays of Silicon Drift Detectors and low-noise electronics for Synchrotron applications.

Sample

“ARDESIA” Array of Detectors for Synchrotron Radiation Applications

Synchrotron X-ray beam

X-ray Fluorescence beam

$I_0$

$I_T$

Cu K edge

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Prof. Carlo Fiorini
thesis topics:

• development of detectors and instruments to be installed at synchrotrons, measurements and beam tests
• development and test of a high-rate readout ASIC (TERA)
• Development of an ultra-fast detector (SCARLET)
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Prof. Carlo Fiorini
Example of readout ASIC architecture

E = hc/λ

CSA → Shaper Amplifier → Peak Sampler → ADC → Multichannel Analyzer → Counts

RE

\[ V_{o,R} \]

\( C_{IN} \)

\( V_{o,A} \)

\( V_{o,B} \)

\( V_{o,C} \)

\( V_{o,D} \)

\( V_{OUT} \)

Multiple Feedback

BLH

\[ H(s) \]

IN

\[ V_{IN} \]

\[ V_{BL} \]

\[ A_0 \]

NL Buffer

Shaper Output

\[ V_{OTA} \]

\[ V_{NL} \]

LP Filter

\[ R \]

\[ C \]

Shaper Input

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TERA: A Readout ASIC for Ultra High Rate X-ray Detection Applications

can analog approach get close to digital processing?
SCARLET: Monolithic pixellated spectroscopy detector

thesis topics:
- study of a new detector: pixel of the ASIC (pre+shaper+ADC, power, area,...);
- technology (bump-bonding); detector performances evaluation; mask for charge sharing

features:
- 1Mcps/SDD (with 200ns analog shaping)
- ~64 Mcps total counting rate
- full analog processing (preamp.+filter) in the ASIC pixel
- E.Res. <150eV @200ns peak. time
- ADC integrated in the ASIC (1 for 4 ch.)
Physics beyond the Standard Model: e.g. sterile neutrinos

Sterile neutrinos as dark matter
- Sterile Neutrinos in the keV mass range are a prime candidate for Dark Matter
- In agreement with cosmological observations
- Search for sterile neutrinos in the laboratory via beta decays

Region close to the endpoint
- $m_n = 0 \text{ eV}$
- $m_n = 1 \text{ eV}$

TRISTAN
KATRIN Working Principle

KATRIN measures the beta spectrum by counting the number of electrons as a function of filter voltage.
Eine unglaubliche Reise
THE TRISTAN DETECTION SYSTEM

- 21 juxtaposed modules
- 166 channels per module
- ~3500 total channels
- 100kcps per channel

small output capacitance (thanks also to JFET integration on the detector) 
⇒ very good energy resolution at fast processing times
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Another challenge is the scalability to 3500 channels of a DPP solution (1k€/ch.).

Solution: integrated multi-channel analog signal processor
thesis topics:

- Development of the TRISTAN detector module
- Development of the ASIC-based readout platform and DAQ
- Experimentation of detector with electrons
Design of integrated circuits:
and finally…

← presentation of the thesis

↓ diploma delivery

← and party…
and it is not over: Awards…!

Innovation Day - Design Contest, 18 ottobre 2018, Museo della Scienza e Tecnologia di Milano. Emanuele Lavelli, premio per miglior tesi di laurea sul lavoro: “Spettrometro di raggi gamma basato su fotorilevatori SiPM per rilevazione sorgenti radioattive”.
Idham Hafizh, student at the Politecnico di Milano, Dipartimento di Elettronica, Informazione e Bioingegneria, has been awarded with the first edition of the Prof. Emilio Gatti Best Master Thesis Award from the Istituto Lombardo Accademia di Science e Lettere.
Preliminary list of available thesis

1) INSERT
- detection module: innovative event reconstruction techniques (machine learning), e.g. DOI, MUX…;
- experimentation of the clinical SPECT in measurements at University College London

2) ARDESIA
- development of a 16ch. detector + ASIC readout, thicker silicon substrate, development of a complete instrument, installation and beam tests at DESY synchrotron (Hamburg)
- development and test of the new high-rate TERA readout ASIC

3) SCARLET
- study of a new detector: pixel of the ASIC (pre+shaper+ADC, power, area,..);
  technology (bump-bonding); detector performances evaluation; mask for charge sharing

4) SIDDHARTA
- characterization of the detection modules and new SFERA ASIC vs. experiment specifications;
  installation in the experiment and beam tests at LNF-INFN in Frascati

5) TRISTAN
- development of new multi-element detector, readout ASICs and DAQ for TRISTAN experiment for neutrino-mass measurement and dark matter search
6) GAMMA
- development and experimentation of the detector based 3" LaBr3 scintillator and beam tests
- development of imaging algorithms for Doppler broadening correction
- development of an ultra high (10,000) dynamic range ASIC
- study and experimentation of timing properties of the detector+electronics

7) SMART FOUNDRY
- development of a new radiation sensors and systems for portable and areal (on board of drones) applications in environmental radiation monitoring

8) PAIRED-X
- development of electronics readout (ASIC+DPP) for microstrip detector for a portable XRF+XRD analyzer of material for mining

9) ESQUIRE
- development of innovative gamma-ray detectors based on nanocristal scintillators (quantum dots) readout by SDDs (Silicon Drift Detectors)

10) NEW ASICs design
- development of innovative readout preamplifiers and ASICs for ultra-low noise and special applications
You are very welcome to visit our lab, to talk with master students and PhD students and spend some time to see what they are doing.....

For visiting the lab and looking to research and development activities (not necessarily only for thesis interest), please organize yourself in small groups (4-5 max.) and provide me by mail desired time slot (day and time) to organize the visit (1-2 hours)