Developing a new detector system for the Synchrotron XAFS beamlines

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on the behalf of the INFN
R&D project RedSox collaboration and
Elettra Synchrotron Trieste

RESEARCH DRIFT FOR SOFT X-RAYS

redsox

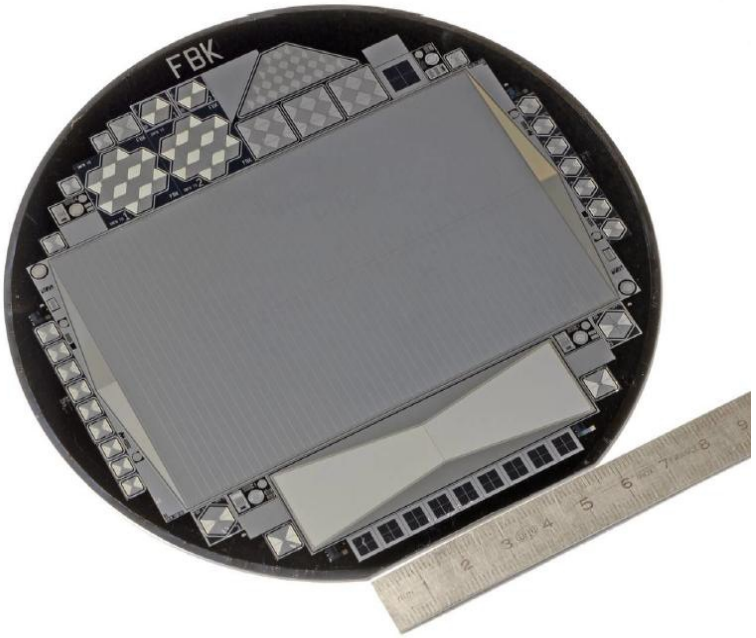
23-26 February 2016, Cogne

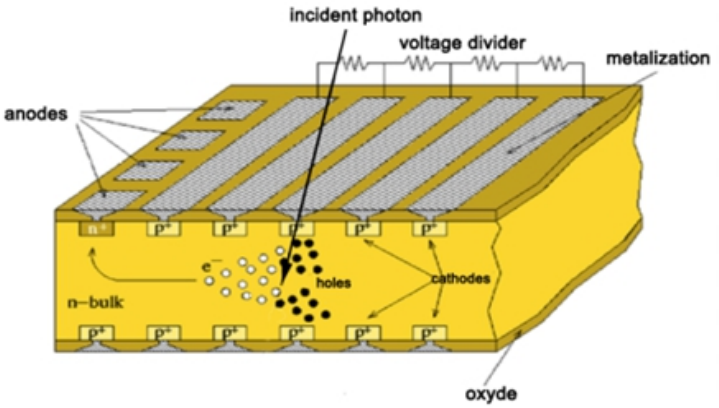
Outline

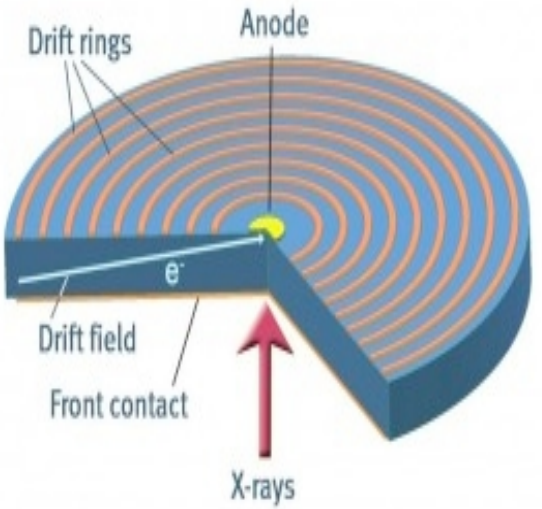
- The Silicon Drift Detector (SDD) technology and heritage at INFN-Ts
- Our goals: New detectors for the XAFS beamlines at Elettra (Trieste – Italy) and SESAME (Amman – Jordan) synchrotrons
- The new detector prototype
- Very preliminary results

The SDD technology and heritage at INFN-Ts

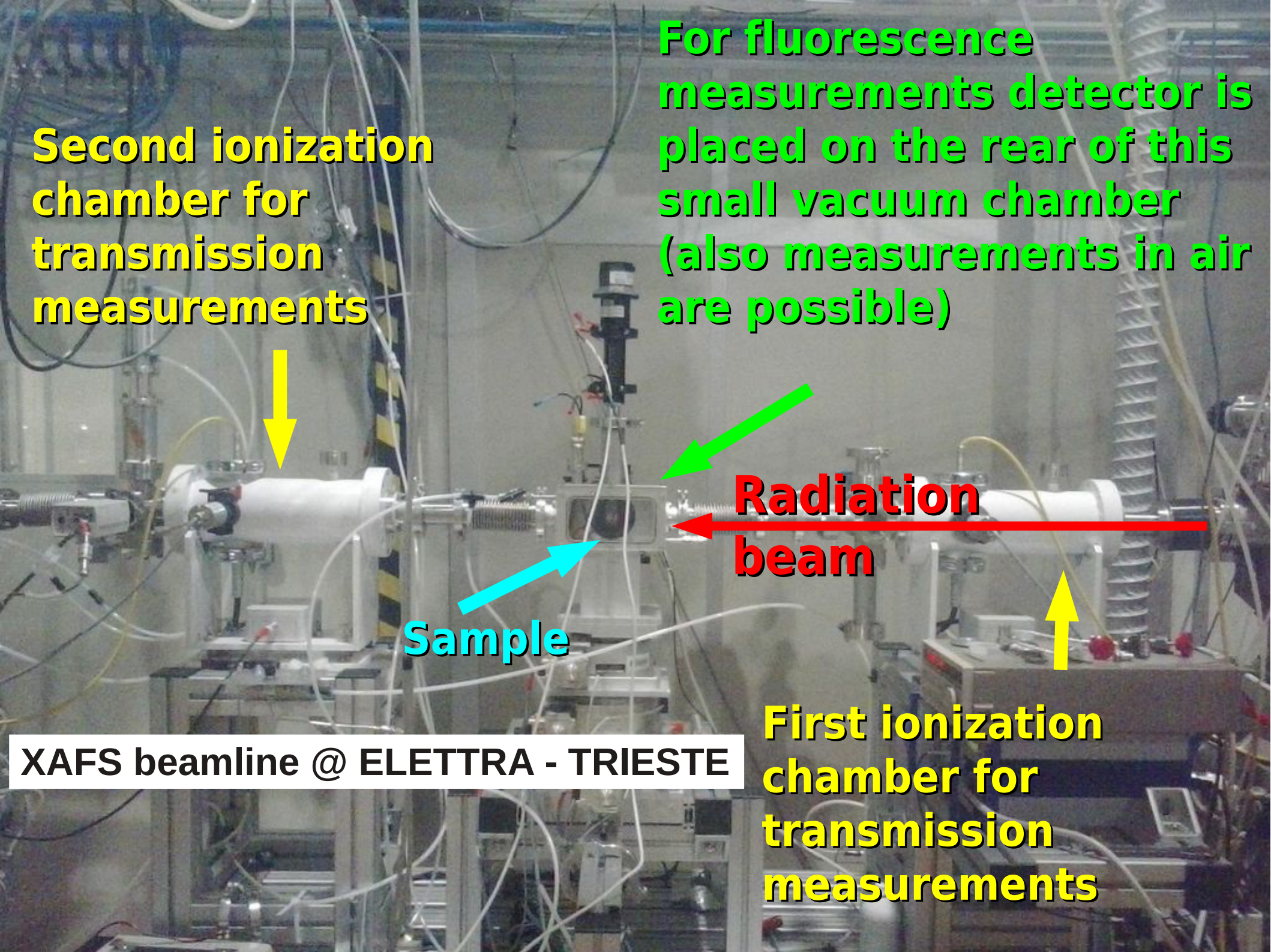
- SDDs were designed to provide 2D tracking of ionizing particles (ALICE at LHC) [Vacchi, et al., NIMA 1991]
- Linearly scaling potentials are applied to drift cathodes to generate a constant electric field directed outwards an array of anodes
- Capability to design new geometries to match different needs (scientific requirements, volume occupancy ...), the production is in collaboration with FBK (Trento) [Zampa et al. NIMA 2011, Campana et al. NIMA 2011, Rachevski et al. NIMA 2015, Bufon et al. J.Inst. 2014,...]
- Development of new low-noise dedicated electronics (Politecnico di Milano) [Bertuccio et al. J.Inst. 2015] also for high rate experiments.







The new detectors for XAFS beamlines at...


For fluorescence measurements detector is placed on the rear of this small vacuum chamber (also measurements in air are possible)
Second ionization chamber for transmission measurements
Radiation beam
Sample
First ionization chamber for transmission measurements
XAFS beamline @ ELETTRA - TRIESTE

The XAFS beamline at ELETTRA

- Beam photon flux on the target — 10^{11} - 10^{12} ph s^{-1} mm^{-2}
- Target — solid few cm^2, also liquid
- Energy Range — 2.2 - 27 keV (4-30 keV for SESAME)
- Side effects — 1) fluorescence from the matrix elements; 2) scattering from the set-up
- Environment — Air and Vacuum

Detector set-up present status at ELETTRA

- Detector — AXAS-M VITUS SDD Series by KETEK
- Geometric area — 80 mm^2 (single SDD cell)
- Energy resolution — ~170 eV at 1.32 μs of peaking time (with Peltier cooling)
- Typical dead time of operation — 12%-20%

The new detector prototype for XAFS at Elettra

Goals:

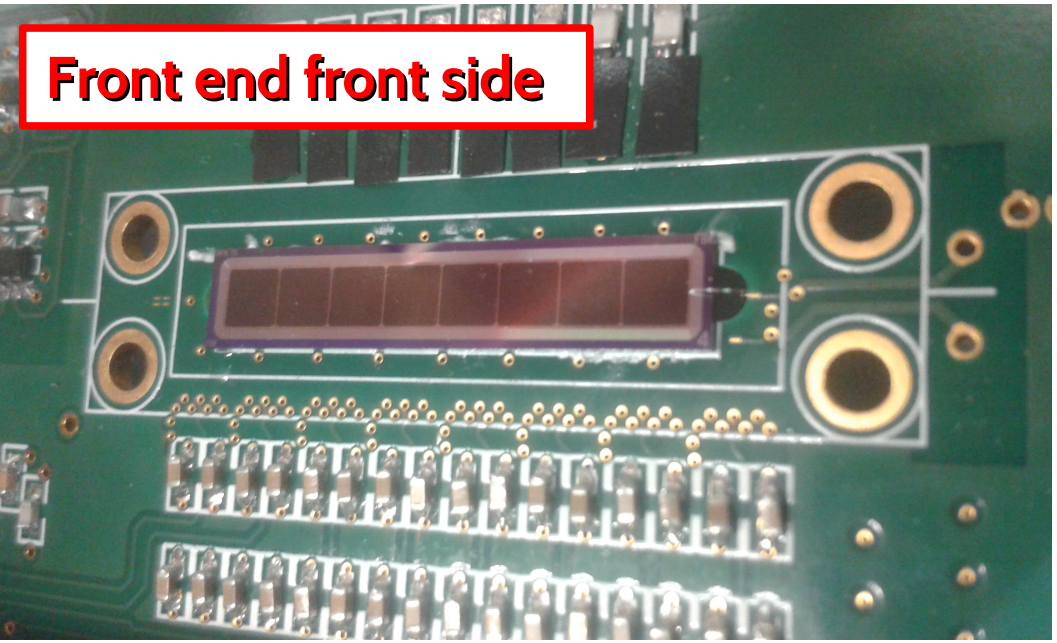
- Sustain a higher count rate with low dead time and pile up
  - Larger collecting area (more counts)
  - Segmented SDD sensor (less dead time and pile up, ~100kcounts s^{-1} each segment)
  - Reduction of the time needed to perform a measurement
- Energy resolution 150 eV at 6 keV at 0°C

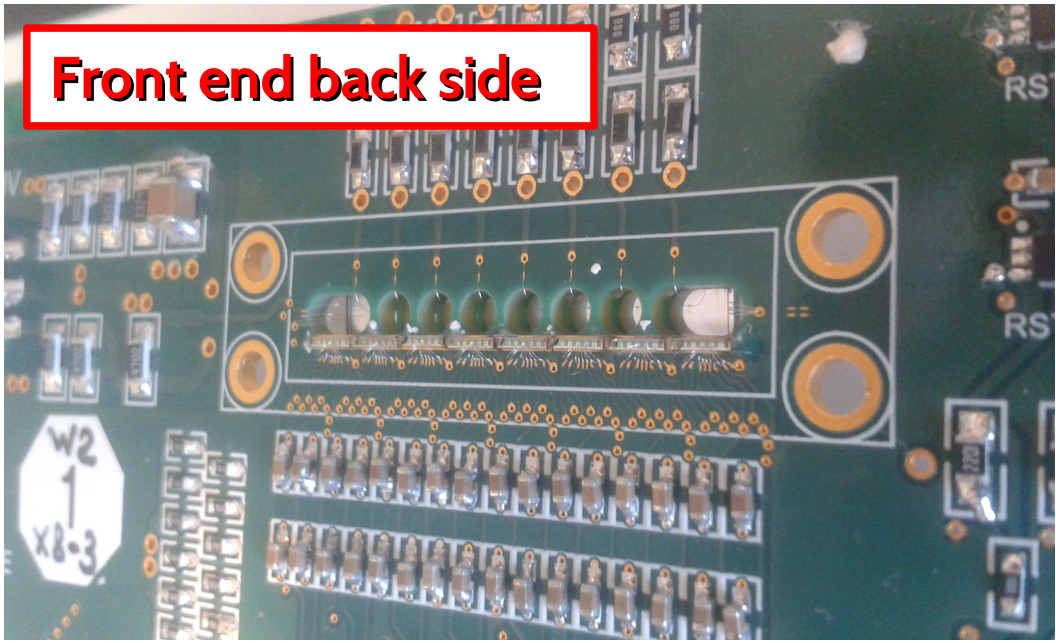
Therefore:

- Modular detector custom designed for the beamline
  - 1 sensor is an array of 8 SDD cells 3x3 mm^2 each
  - more sensors (we are thinking to 8 sensors) are modularly assembled with the electronics
    8*8*9 mm^2 = 576 mm^2 (vs 80 mm^2 of current detector)

The new detector prototype for XAFS at Elettra

- The **prototype** comprises:
  - 1 array of 8 SDD cells mounted on a font end electronics (by INFN-Ts). The SDD cells are bonded to ultra low noise SIRIO preamplifiers (by Politecnico di Milano)

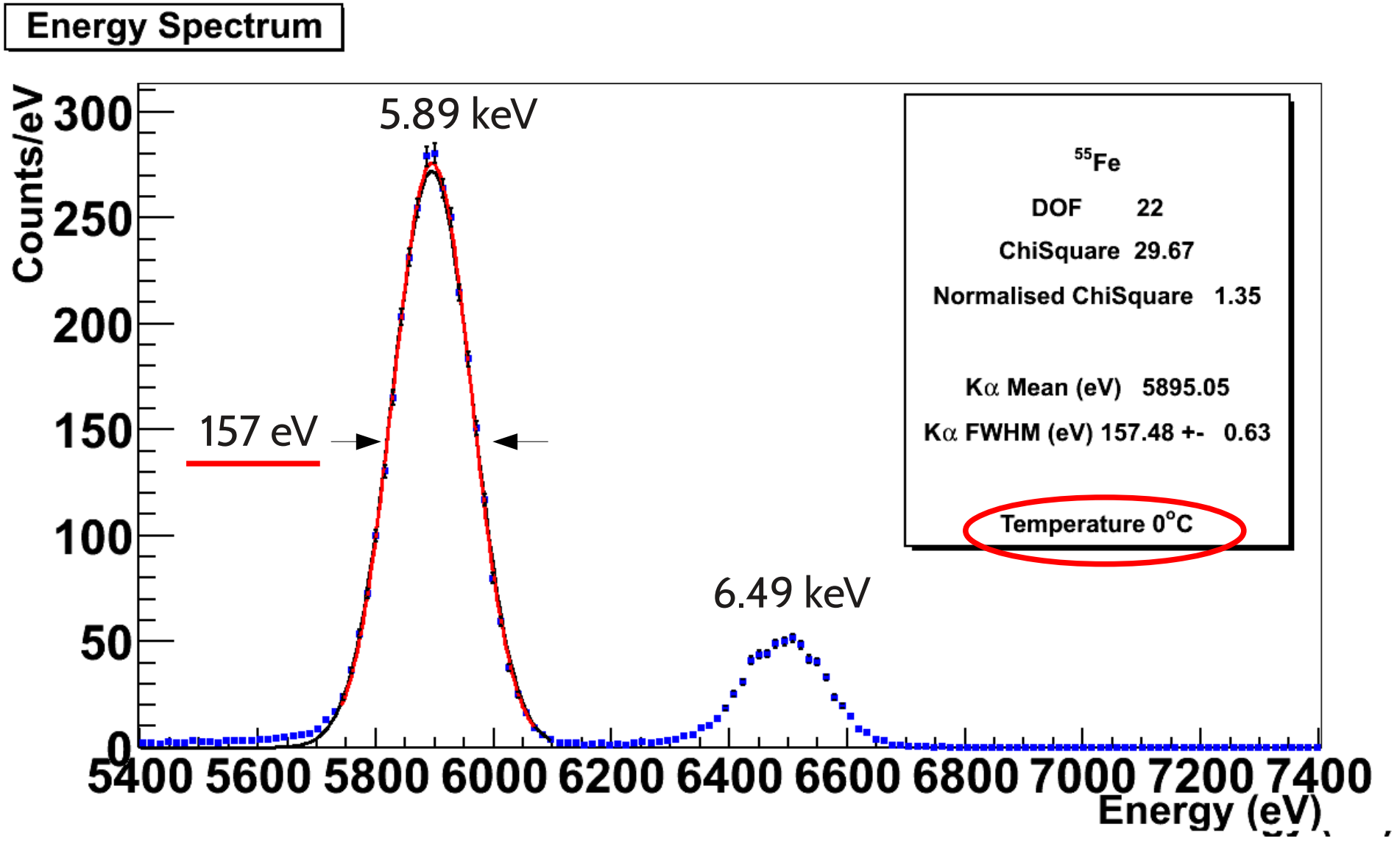




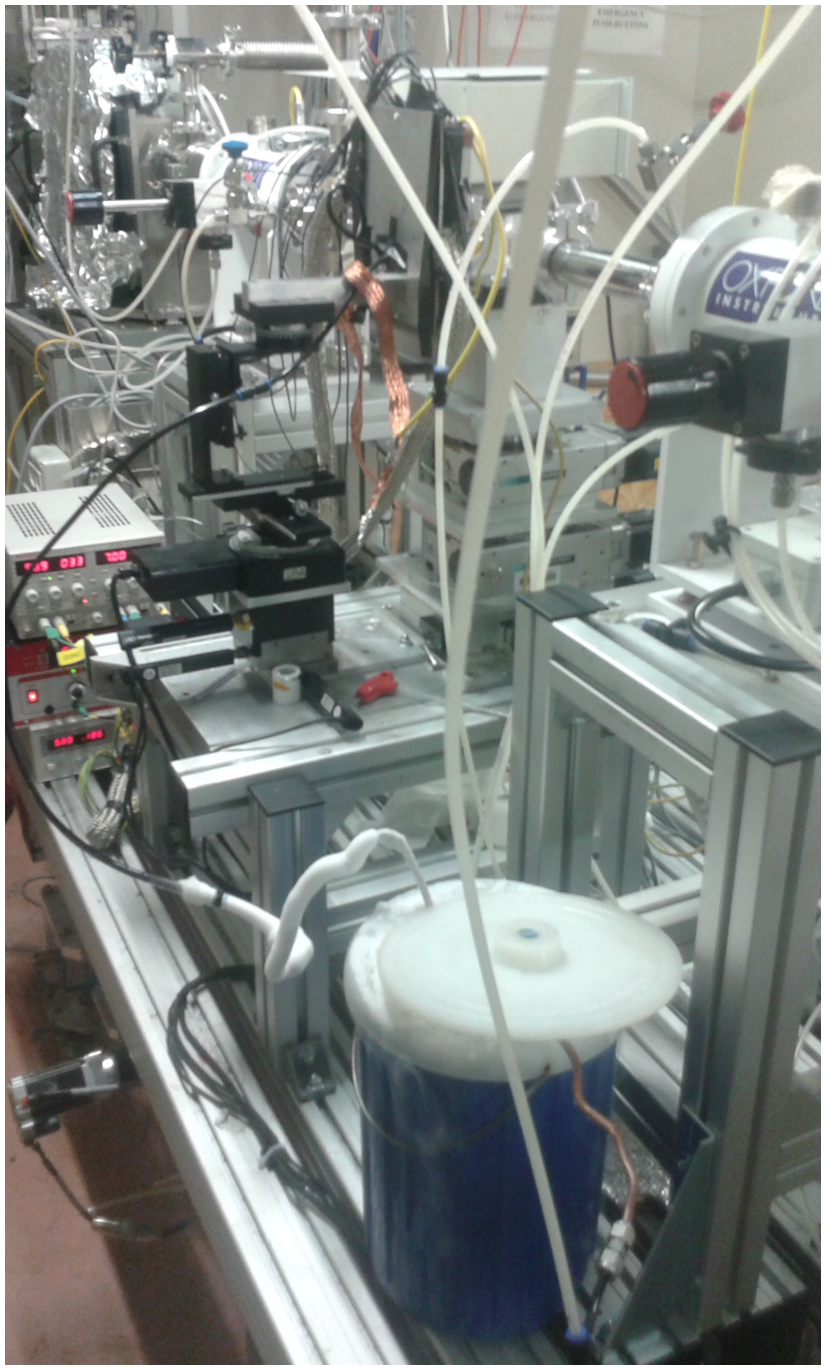
  - back end electronics equipped with 8 ADCs for each independent channel and an FPGA (by Elettra)
  - The acquired data are transmitted over a TCP / IP connection to a PC running a dedicated LabVIEW software.

Very preliminary results

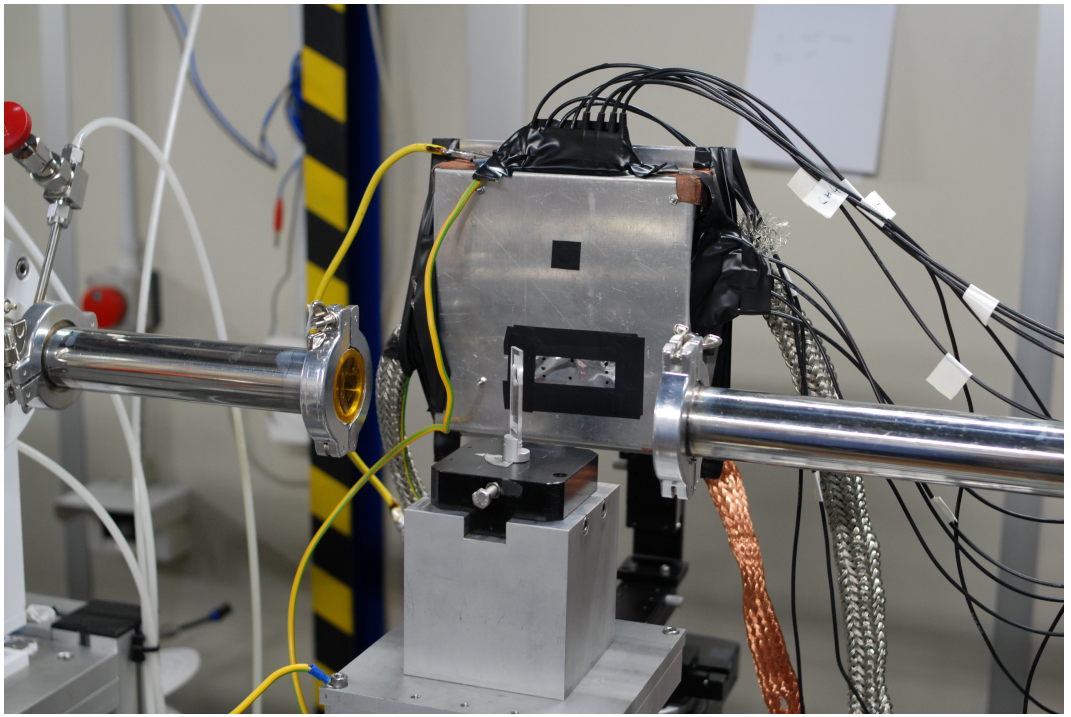
- First tests in **laboratory and climatic chamber**
  (obtained with tapezoidal digital filter, not yet proper filtering)



Test at the Elettra XAFS beamline on 16-18 September 2015



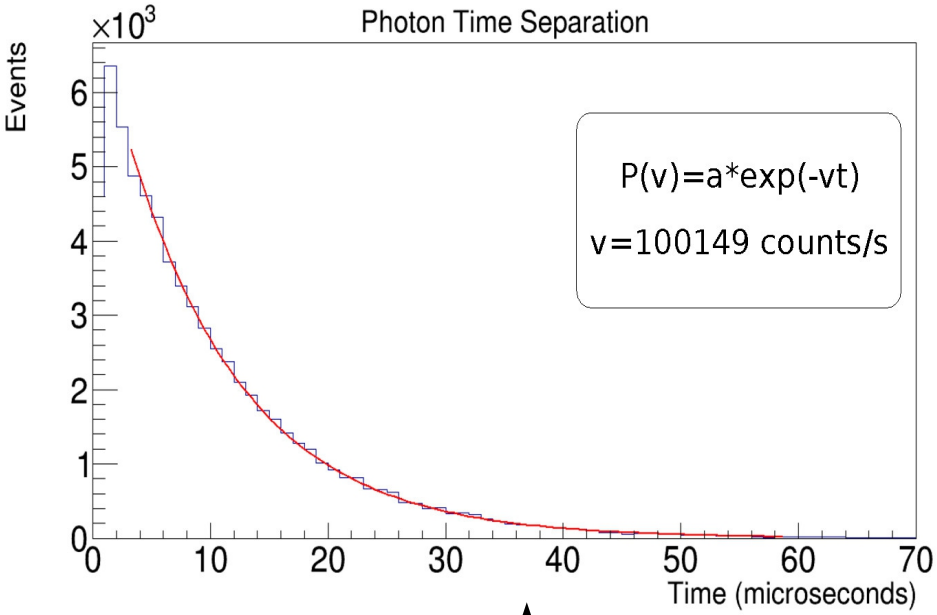
- Detector was operated at nearly ambient temperature by fluxing in the sensor plastic box a weak nitrogen flux previously refreshed in a cooling coil plunged into a dewar filled with liquid nitrogen
- Measurements in different flux conditions with known samples (Mn [Kα at 5.89 keV and Kβ 6.49 keV] and Zr [Kα at 15.75 keV and Kβ 17.67 keV])

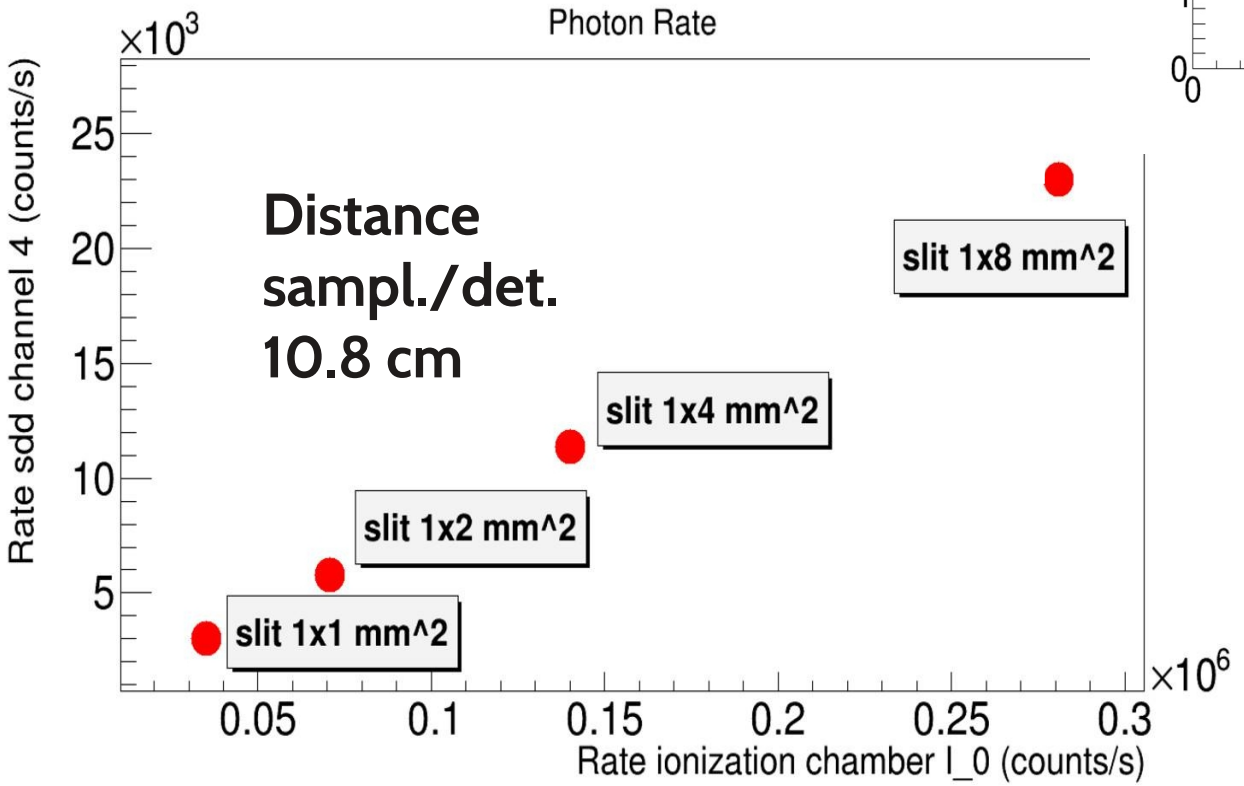


Very preliminary results

- Test at the Elettra XAFS beamline on 16-18 September 2015

  - Count rate for different beamline slit aperture
  - Fluorescence of Mn Kα at 5.89 keV and Kβ 6.49 keV





- Slit aperture 1x8 mm^2
- Distance sampl./det. 5.5 cm (½ distance)
- 100 kcounts/s in one cell

Conclusions

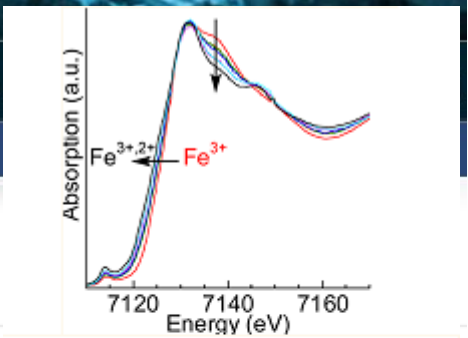
- Within the framework of the INFN R&D project RedSox a wide collaboration is developing Silicon Drift Detectors for X-rays, including advanced light sources such as Synchrotron

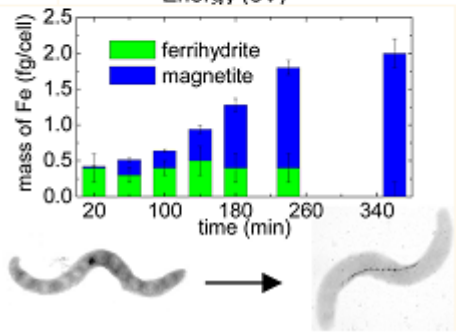
- We report on the developing activity of a customized detector for the XAFS beamline at Elettra Synchrotron in Trieste

- The prototype was successfully tested in laboratory and also during a beam test, we are now analyzing the large amount of data collected.
  First results are very encouraging

The XAFS beamline

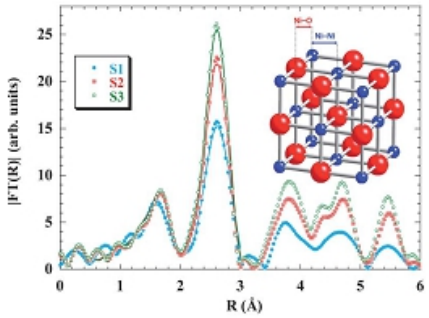
Elettra Sincrotrone Trieste | Elettra and FERMI lightsources

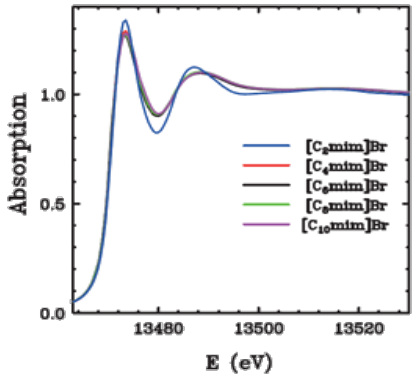




Highlights

- Copper complexes as potential bioinorganic target-specific drugs
- Structural Characterization of Ionic Liquids by X-Ray Absorption Spectroscopy
- Local structure of $LiCoO_2$ nanoparticles studied by Co K-edge x-ray absorption spectroscopy
- Exploring the Effect of Co Doping in Fine Maghemite Nanoparticles NEW
- Structural characterization of electrodeposited copper hexacyanoferrate films by using a spectroscopic multi-technique approach NEW
- Interplay between microstructure and magnetism in NiO nanoparticles: breakdown of the antiferromagnetic order NEW

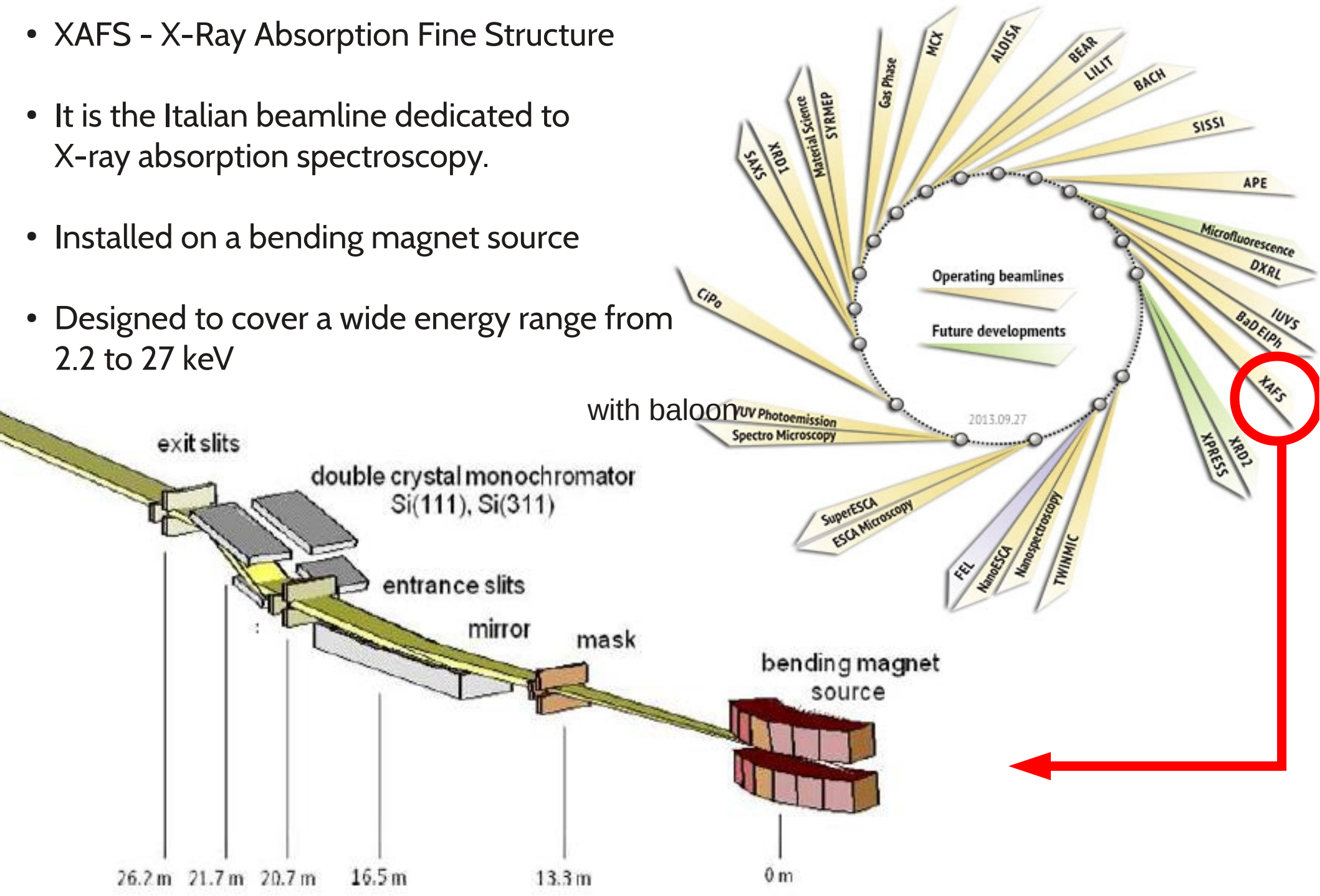




The XAFS beamline

- XAFS - X-Ray Absorption Fine Structure
- It is the Italian beamline dedicated to X-ray absorption spectroscopy.
- Installed on a bending magnet source
- Designed to cover a wide energy range from 2.2 to 27 keV

with baloon



The XAFS beamline

Measurement procedure

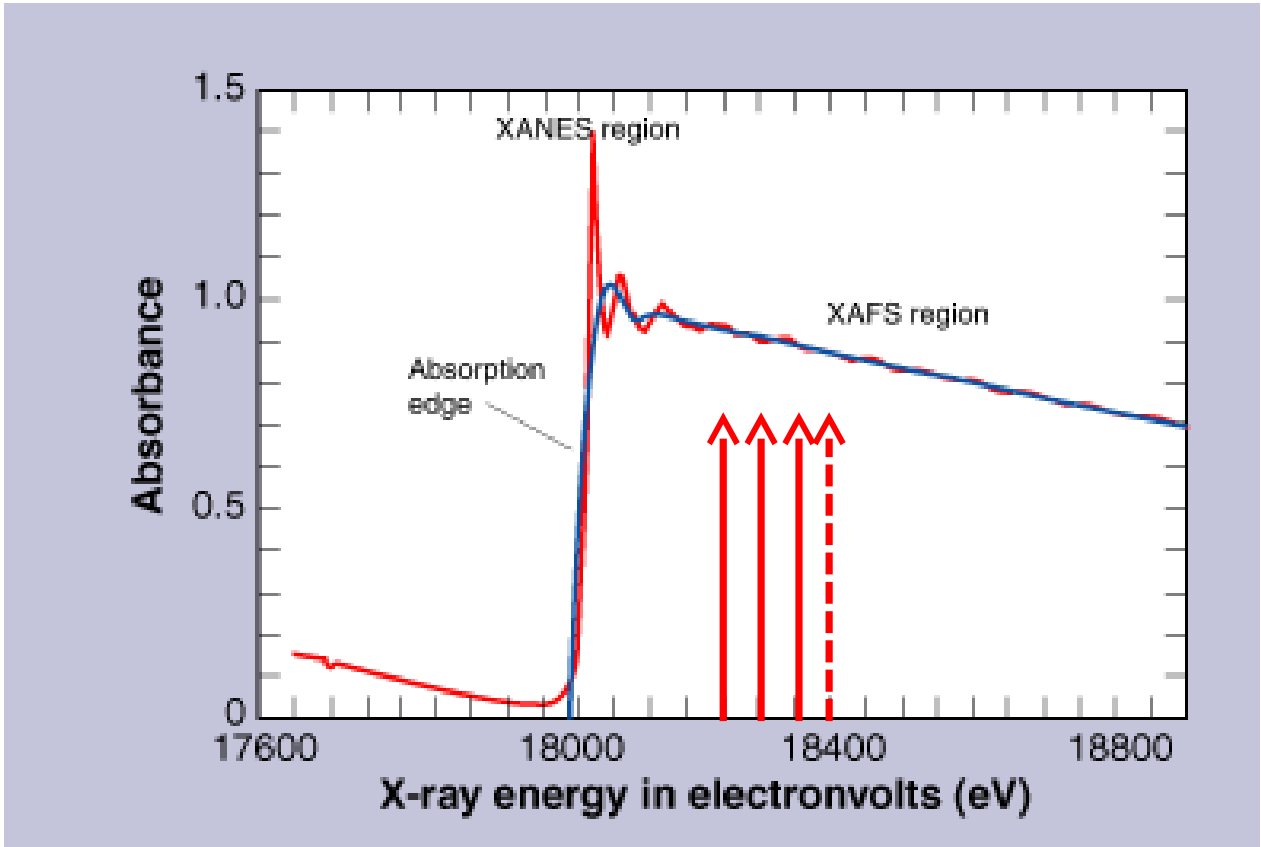
Energy scan by operating on the monochromator (about $\Delta E/E=10^{-4}$)

Measurement of fluorescence on the target to derive the behavior of the absorption coefficient at different energies

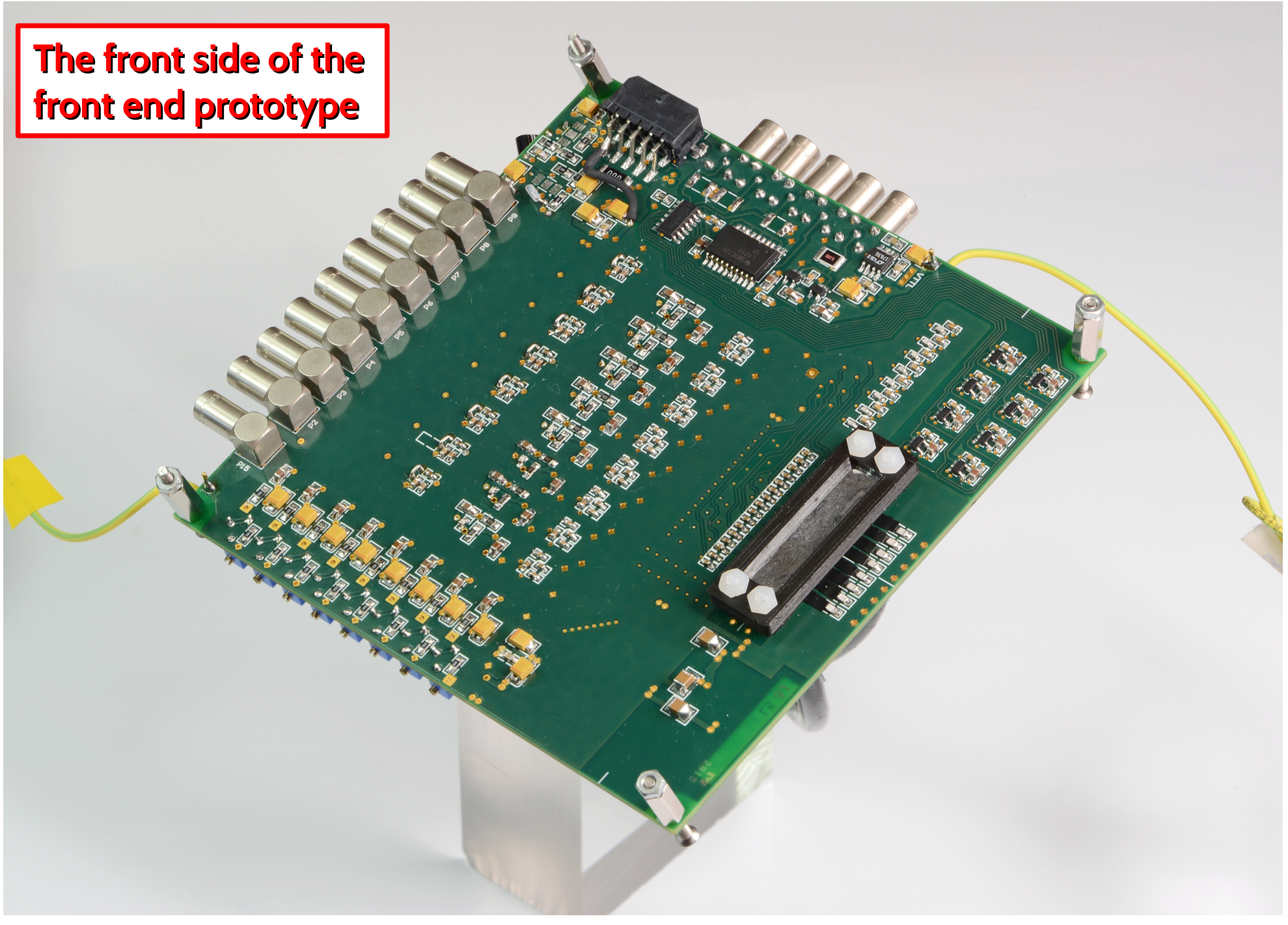
A measurement cycle comprises 1000-2000 points [energy range up to 1-2 keV]

At present 5-10 s are needed for each point (each energy)

Therefore, up to $2x10^4$ s (about 5 h 30m)



The new detector prototype for XAFS at Elettra



The new detector prototype for XAFS at Elettra

- The analogue signals from the 8 preamplifiers are sampled by a 12 bit 8-channel ADC, capable of encoding at 40 Msamples / s

- The digital data are subsequently treated with a set of digital filters [*optimized filtering still coming*] (implemented by Elettra and ICTP MLab), an FPGA also handles the near-saturation reset of the preamplifiers.

- The acquired data are transmitted over a TCP / IP connection to a PC running a dedicated LabVIEW software.

Very preliminary results