SCIENTIFIC RESEARCH IN PROGRESS

MULTI ENERGY CT

At the Physics Department of the University of Bologna is active, from time, a research group that has as its aim the development of new equipment for *diagnostic imaging in medicine*.

In particular, has been made and is operating a scanner for Computed Tomography (***Multy-Energy Computed Tomography*** - MECT) for small animals (also adapted for some clinical studies) based on an innovative source, which generates two or three quasi-monochromatic X-ray beams with selectable energies (Fig. 1).

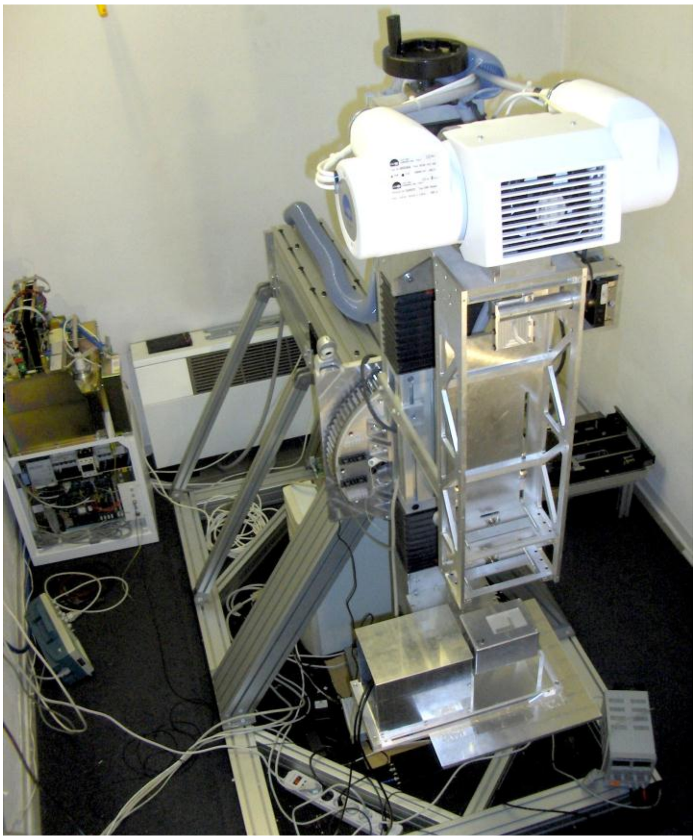

Fig. 1: Il tomografo MECT durante la fase di sviluppo.

The quasi-monochromatic beams tomograph is based on the properties of highly oriented mosaic crystals of pyrolytic graphite that allow to monocromatize, by the Bragg diffraction, the X-ray beam emerging from a conventional X-ray tube by reducing the intensity of the beam to about 1/7 - 1/10 of the initial one (Fig. 1). The intensity that is obtained is not yet sufficient to meet all the clinical needs but allows you to carry out research on small animals or limbs as well as mammography.

Diagnostic radiology is moving toward the use of monochromatic radiation and all the major manufacturers have developed systems that use two X-ray beams with different kVp and suitable filtration, so as to operate in dual energy (mammography, angiography, bone densitometry and even CT). However, the beams are still widely polychromatic (Fig. 2).

The facility we have made is currently the only one in the world to be able to provide the tomography with one, two or three beams quasi-monochromatic as those highlighted in Fig 3. In the bibliography concerning the works of characterization so far, we have demonstrated that the MECT is able to highlight the contrast medium iodate with **a sensitivity ten times greater** than a commercial angiograph. In addition, using two beams quasi-monochromatic, *algorithms like Alvarez-Macovsky for the suppression of a tissue* are applicable (similarly to the technique of RM with the inversion recovery sequence). Method that we have improved with the introduction of a third beam for the elimination of the so-called "projection error".

Finally, the technique allows the imaging of the atomic number and the effective density of tissues, potentially able to distinguish - in some specific cases - the pathology from healthy tissue.

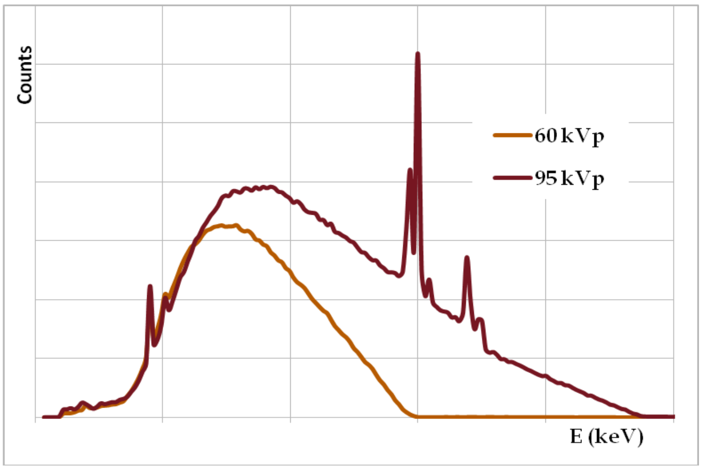

Fig. 2: Continuous spectra of X-radiation. The spectra of the two energy beams of radiation emitted by an X-ray tube, supplied to 60 kV and 95 kV are presented. As can be seen, there are radiations with very different energies, starting around 10 keV and reach up to a maximum value (respectively 60 keV and 95 keV). For diagnostic imaging, the ideal solution would be to have spectra of energy much more monochromatic as those of the next figure.

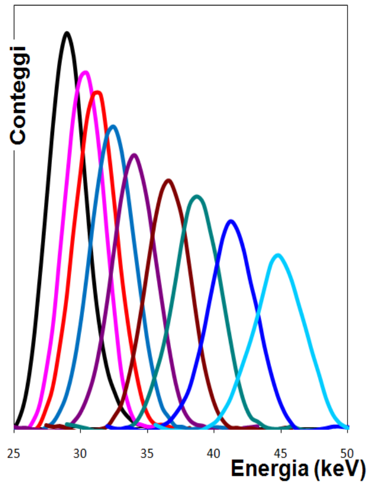

Fig. 3: Some of the "peaks" of energy generated by multi-energy tomograph. As you can see the energy spread is much smaller (the peaks are relatively "narrow", for this are called quasi-monochromatic). In addition, it is possible to vary the energy with continuity between about 10 keV and 70 keV. To perform a radiography one, two or three peaks can be used, depending on the diagnostic results that you want to obtain.

Characterization of Healty and Tumoral Tissues

In collaboration with the section of cancerology of the Department of Experimental Pathology, at the University of Bologna, is in progress *the radiological characterization of pathological tissues with respect to the corresponding healthy tissues*.

The Team from the Laboratory of Cancer, directed by Prof. Lollini, has experience of in vivo models for the study of human and murine tumors grown in mice and offers various murine models of tumor for studies on biological tissues. The animal breeding is "steadily authorized" for both the breeding and for the research. All the projects of research are subject to the authorization to the Ethics and Scientific Committee of the University of Bologna and later sent to the italian Ministry of University and Research (MIUR).

The work consists of experimental determination - by means of a facility provided by the Institute INAF-IASF of Bologna (Figure 4) - of the curves of the linear attenuation coefficients of tissues from mice just sacrificed. Through statistical techniques it is possible – in some cases – *to distinguish the pathological tissues from healthy ones through their attenuation coefficients*. In these cases the MECT technique will certainly be of election for the recognition of the disease by the only radiological imaging. The work is in progress and has already produced several results of interest.

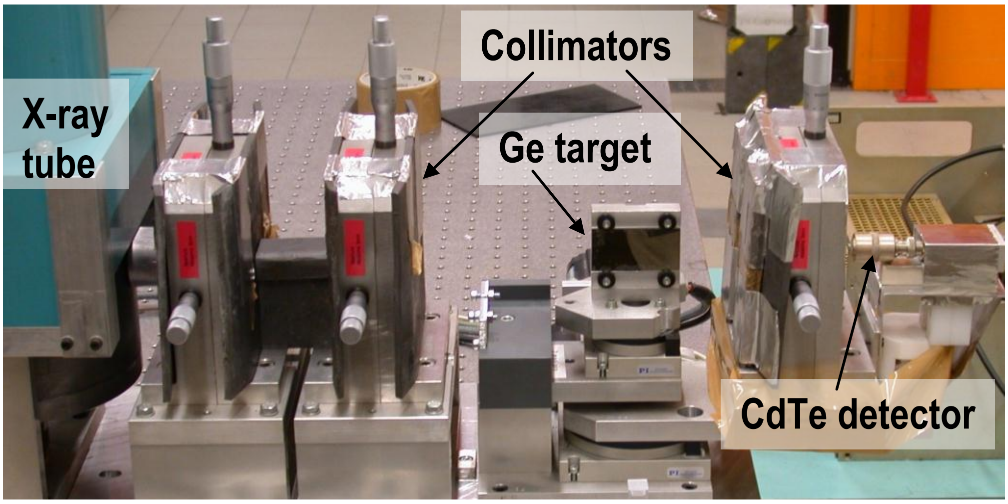

Fig. 4: il monocromatore di Bragg dell'Istituto di Astrofisica Spaziale e Fisica Cosmica (INAF/IASF).

EXPERIMENT XDXL - NATIONAL INSTITUTE OF NUCLEAR PHYSICS (INFN)

The Italian national collaboration XDXL proposes to develop apparatus for the detection of X-ray or gamma-ray based on ***silicon drift detectors*** (SDD) ***of large area*** (7x7 cm^2, the same used in the Alice Experiment at LHC) that, together with the use of innovative architectures – in particular using the Compton effect for the detection of gamma rays – can determine a leap forward in the quality of equipment currently used for the research in *nuclear medicine* (Compton chamber as advancement of the Anger Camera) and in *on satellite astronomy and astrophysics* (All Sky Monitor and Timing at the X-ray energies; gamma-ray telescope based on Compton chamber).

In practice, we are developing a ***Compton Chamber*** for applications in Nuclear Medicine that is proposed as a substitute for the Anger Camera due to its greater detection efficiency (without the use of the collimator that heavily reduces the efficiency of the traditional gamma-chambers) and above all, the Compton Chamber will allow you to use gamma-emitters radionuclides with energies much higher (up to 600 keV) of the 140 keV emitted from ^{99m}Tc on which are calibrated the today's gamma-chambers.

In Fig. 5, below, you can see the advanced position-sensitive photomultiplier with 256 anodes (Hamamatsu H9500) on which it is based the calorimeter stage of the Compton Chamber and whose reading electronics – made by eight ASIC type VA32HDR11 – is currently in development. In the same figure you can see, in the lower part, a photomicrograph of the ASIC, which is also in development, intended for the readout of the SDD detectors that will be the tracker of the Compton Chamber.

The collaboration of INFN with INAF/IASF of Bologna and INAF/IASF of Rome, within the framework of the Project XDXL led to the presentation, to the European Space Agency, of the Project LOFT that has been evaluated positively by ESA (Program ESA's Cosmic Vision, which is the Subject Matter under extreme conditions) and that is now in the phase of assessment (URL: *http://loft.iasf-*

roma.inaf.it/). This is an Italian project that can sees a wide international participation: Holland, Great Britain, Germany, Spain, Switzerland, Ireland, Turkey, Greece and the Czech Republic. Are involved also the United States and Brazil.

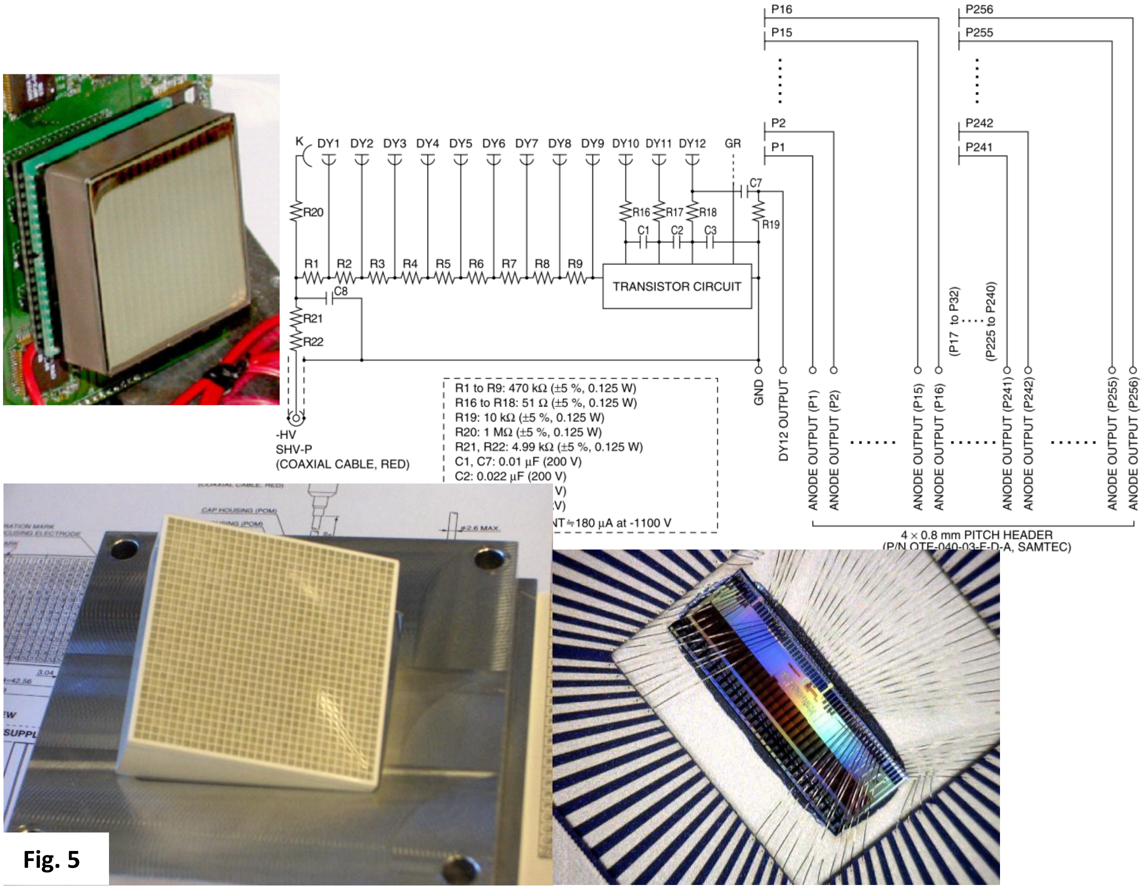

Fig. 5

This project will lead to the construction of a Satellite entirely based on the technology of the SSD (about 20 m^2 of detector) and, consequently, on the ASIC that is now developed under the abbreviation XDXL. Also the Compton Chamber complete has a great interest for space applications: it can operate as telescope for gamma rays cosmic in the range 100 keV - 1 MeV.

Diagnostic X-ray Beam Spectrometry

The S. E. V. and the air kerma, with which it is usual qualitatively and quantitatively characterized the diagnostic beam, are now inadequate to the purposes of modern imaging for their character of integral measures. It follows a wide tolerance in the choice of the beam to use for a given radiological examination. For the modern techniques of diagnosis and therapy with use of X-rays, the knowledge of the spectrum of the radiation used would be of great help in order to be able to modulate it with appropriate filters (made-up of different layers of rare earths with different energies of K-edge) to reduce the dose to the patient while maximizing imaging quality. In addition, the knowledge of the spectrum would be a decided improvement in the dosimetry of the beam and for the quality controls with the possibility of industrial fall-out.

In the first proposed technique, the primary X-ray beam interact with a suitable target and the spectrometry is performed on photons scattered, mainly for Compton effect, in a narrow cone around at an angle of 90°. The reconstruction of the spectrum of the primary beam ss subsequently carried out – via software – by the inversion of the scattering matrix experimentally determined.

Three prototypes have been developed – and another is now in the phase of experimental characterization – for the study of different types of detectors (Figure 7-8). The software that performs the reconstruction of the primary beam spectrum, starting from experimental data, use an empirical parametric equation of the bremsstrahlung spectrum is now fully functional.

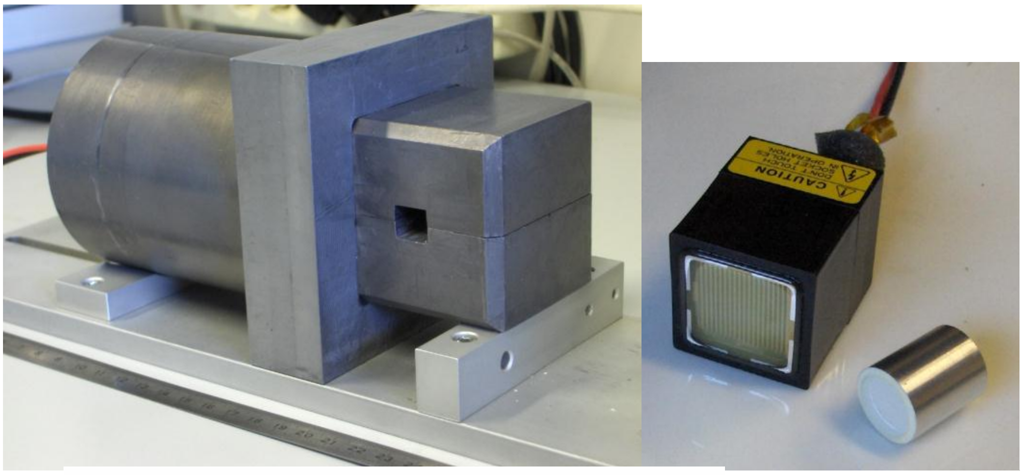

Fig. 7: la Camera di Scattering Compton (ultima versione realizzata) con il sistema di rivelazione spettrometrico basato su l'innovativo scintillatore LaBr3:Ce. Una singola esposizione consente di ricavare lo spettro energetico del fascio.

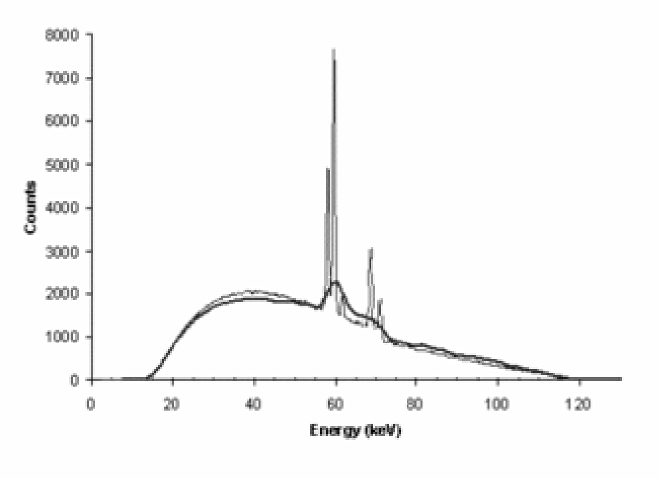

Fig. 8: lo spettro del fascio ottenuto con la Camera di Scattering Compton posto a confronto con quello di riferimento ottenuto con un rivelatore criogenico di Ge iperpuro.

A second instrument is developing to allow the real-time spectrometry (during the normal use of the radiology apparatus). To achieve this objective we use the information coming from three sources: 1) an exposimeter system, specially developed, that is mounted at the output of the X-ray tube, before the collimators group, and intercepts a small section (normally unused) of the beam; 2) the high voltage waveforms and 3) the anodic current drawn by the X-ray tube. These information are used as parameters for a simulation software for the X-ray spectrum. The method is fully operational at the experimental level at the Physics Department of the University of Bologna

A dosimetric card, equipped with a microchip, may be used to register – in addition to the spectrum of X-ray by which was carried out the examination – the anatomic region concerned, the size of the FOV, the source-patient distance and possibly other additional information. If the citizen would be equipped with such an instrument would be possible a precise repeatability diagnostic exam in addition to a precise patient dosimetry.