Advanced Technology and Instrumentation

Detectors, Read-out Electronics and High Reliability Computing Systems

Monica Alderighi
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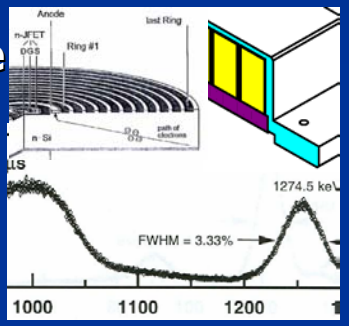
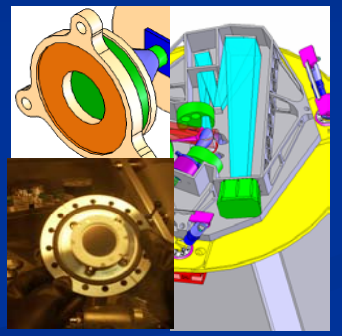
Scientific objective

Development of technologies supporting advanced instrumentations for Astrophysics

Extended Range Detector

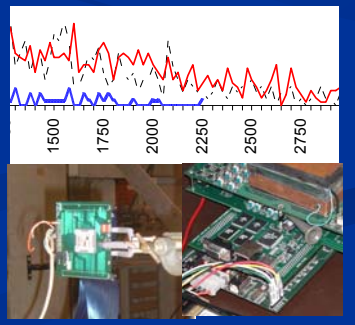


R&D Projects



UV Detectors

CZT Detectors



Hi rel Computing Systems

CZT Detectors

E.M. Quadrini, M. Uslenghi, M. Fiorini, S. Monti, N. La Palombara, M. Alderighi, F. Casini, S. D'Angelo, M. Mancini, S. Pastore, G. Sechi

- Goals:
  - Provide an Italian source of quality solid state spectrometers for Astrophysics applications
    - Develop proprietary procedures for 2-3" CZT crystals growth, including bonding and contact philosophy, and a newly designed low-power electronics readout chain
  - Evaluate commercial applications
    - Non-intrusive inspections in medical, industrial and security fields
- R&D study co-funded by ASI (8 months), up to '07
- Future projects
  - Improvement of crystal characteristics and readout chain features, IASF Milano (PI), proposal submitted to ASI
  - 3-D CZT prototype, IASF Bologna (PI), proposal submitted to PRIN/INAF

CZT Consortium

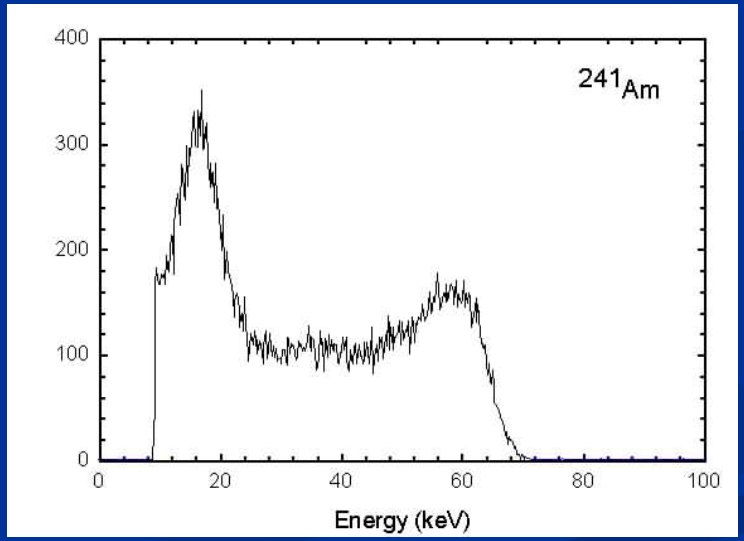
- **INAF-IASF, Palermo:** *On Board Data Handling*
  - G. La Rosa
- **INAF-IASF, Roma:** *HE instrument applications*
  - P. Ubertini A. Bazzano, S. Di Cosimo, M. Frutti, M. Federici, L. Natalucci
- **INAF-IASF, Bologna:** *Detector characterization*
  - E. Caroli, N. Auricchio, J.B. Stephen, S. Del Sordo
- **INAF-IASF, Milano:** *Read-out electronics, AFEE, DFEE*
  - E. M. Quadrini, M. Alderighi, F. Casini, S. D'Angelo, M. Fiorini, N. La Palombara, M. Mancini, S. Monti, G. Sechi, M. Uslenghi
- **CNR – IMEM, Parma:** *Crystal growth, metallization, bonding*
  - A. Zappettini, E. Gombia, L. Marchini, R. Mosca, P. Sanviti, L. Zanotti, M. Zha
- **UNI-Parma:** *Cristal growth, metallization, bonding*
  - M. Pavesi, M. Zanichelli
- **Thales Alenia Space Milano**: *ASIC feasibility study*
  - P. Bastia, A. Bonati, J. M. Poulsen, N. Ratti
- **Venezia Tecnologie:** *Industrial application & market analysis*
  - M. G. Guadalupi

Results

- Growth of CZT crystals including contacts, bonding, characterization
- Readout chain
- New generation instrument design
  - GRI
  - EDGE
- ASIC feasibility

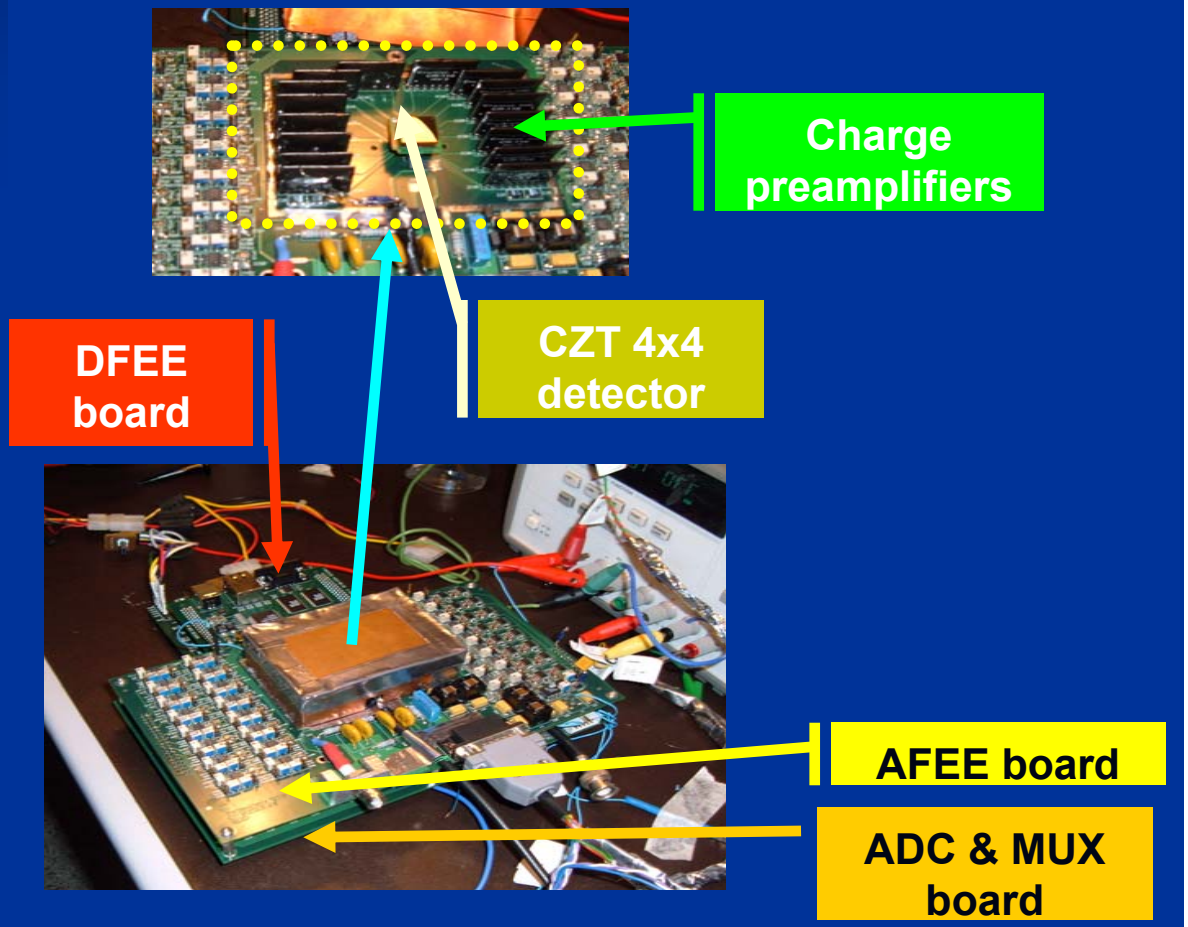
Results

- Growth of CZT crystals including contacts, bonding, characterization

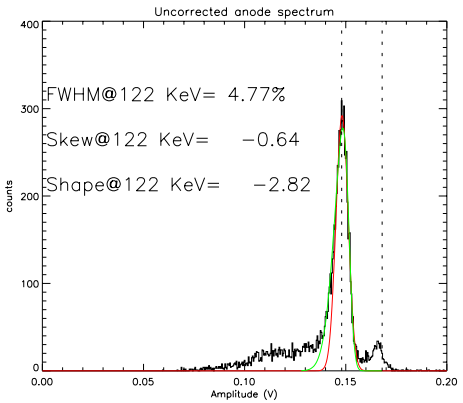


Results

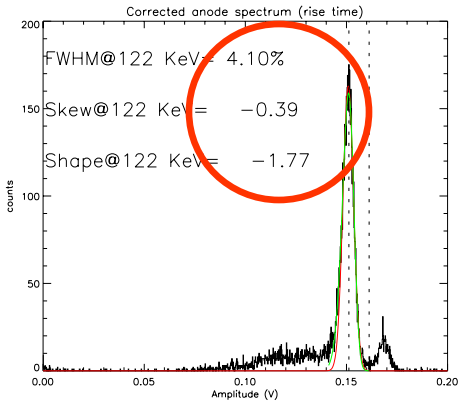
- Readout chain



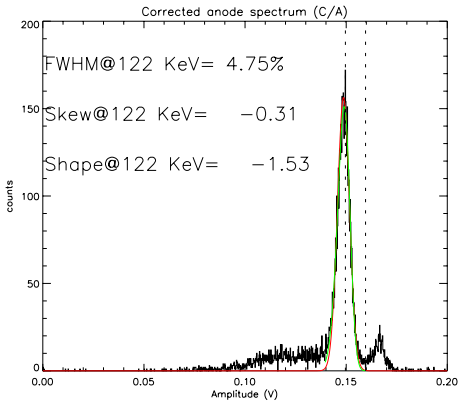
pixel



Original spectrum

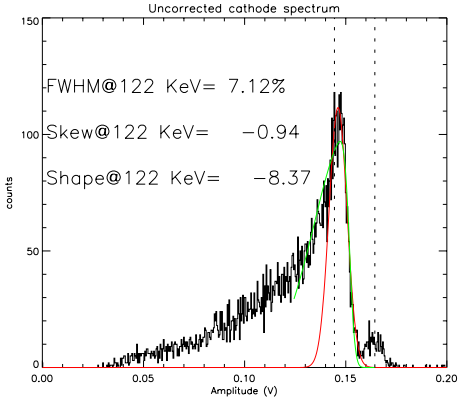


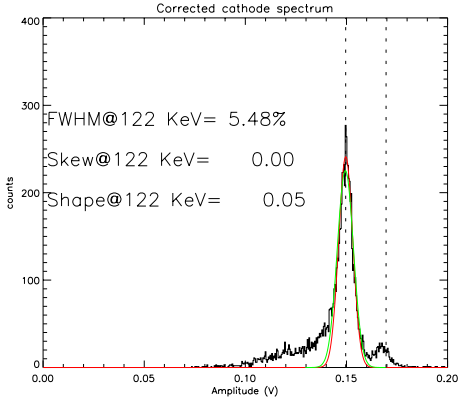
Rise-time correction

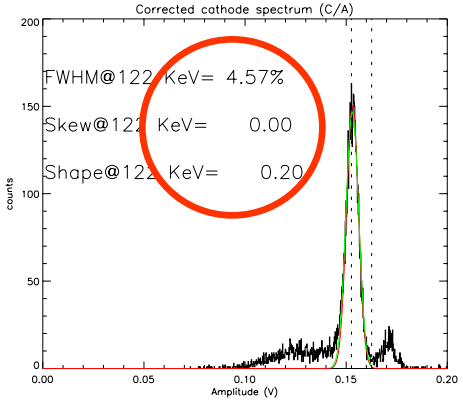


C/A correction

cathode



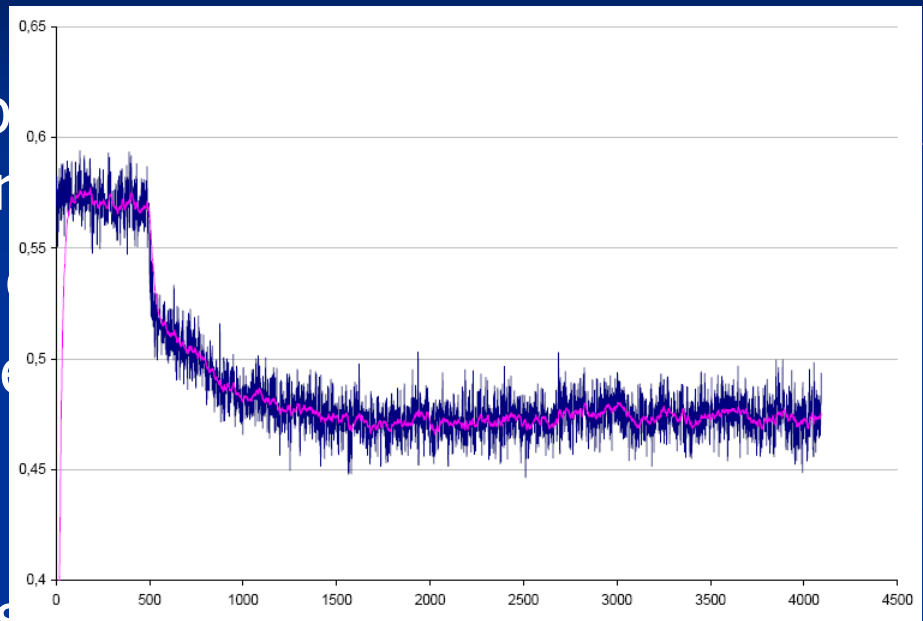




Response dependent on the interaction depth and multiple hit events. Correction methods based on waveform shape information (like rise time, cathode/anode) can be used to improve the energy resolution.

Results

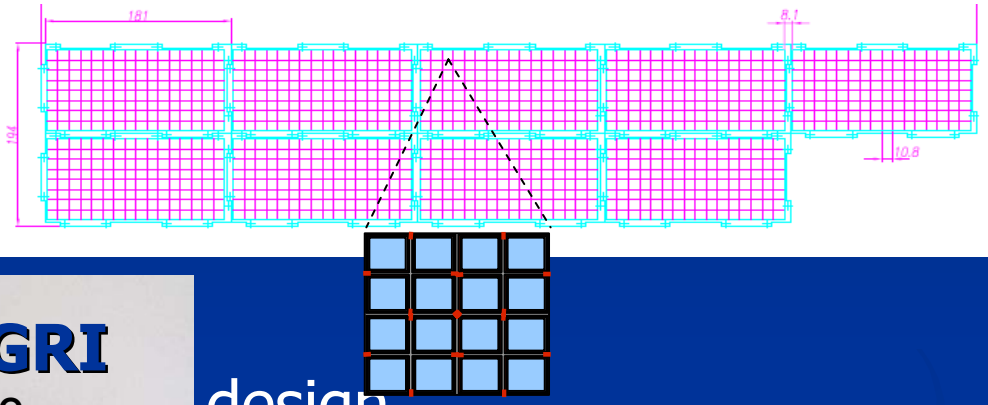
- Growth o , bonding, character
- Readout
- New gene
  - GRI
  - EDGE
- ASIC feas



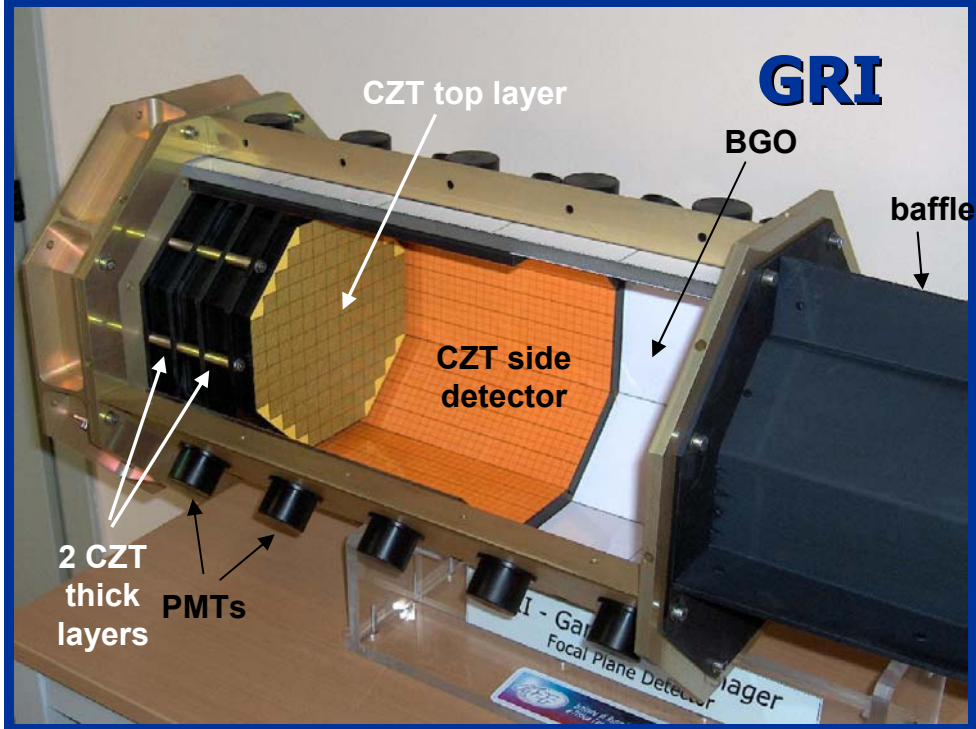
Digital filtering

- Bessel IIR Filter (straightforward h/w implementation)
- Algorithm parameters can be easily set directly in hardware, without changing the circuit

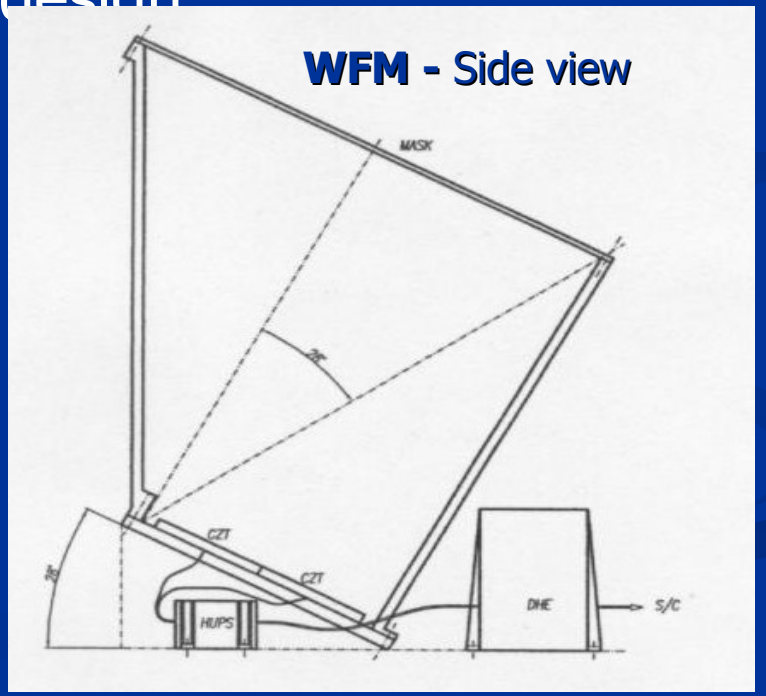
EDGE - WFM detector plane scheme



- Growth of CZT cryst
  characterization

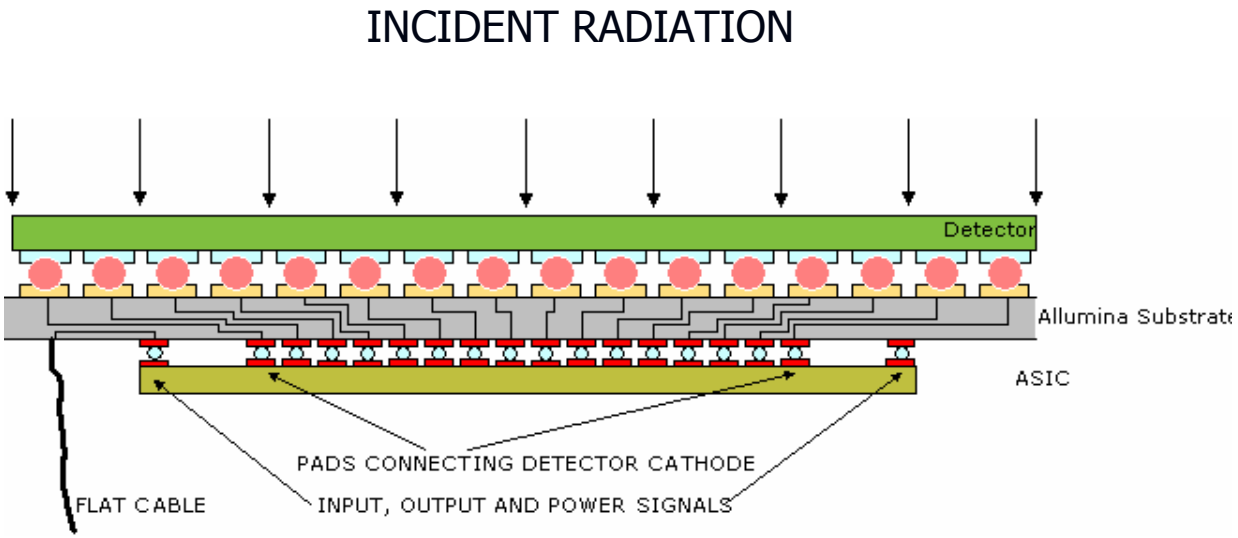


design



Results

- Detector and ASIC are assembled to constitute one single module
- 0.35 μm CMOS technology
- Complete integration from preamplifier to the A-D converter for 256 pixels



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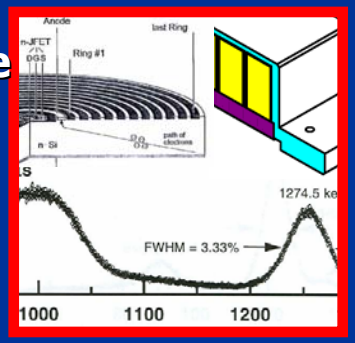
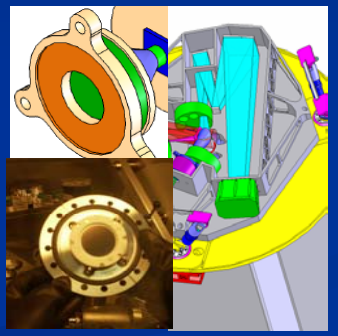
Extended Range Detector

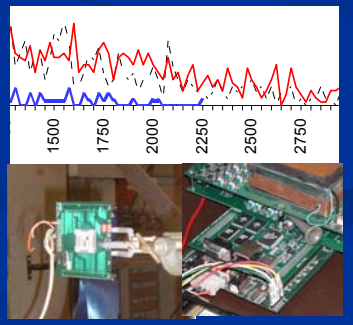


R&D Projects



UV Detectors

Cd(Zn)Te Detectors

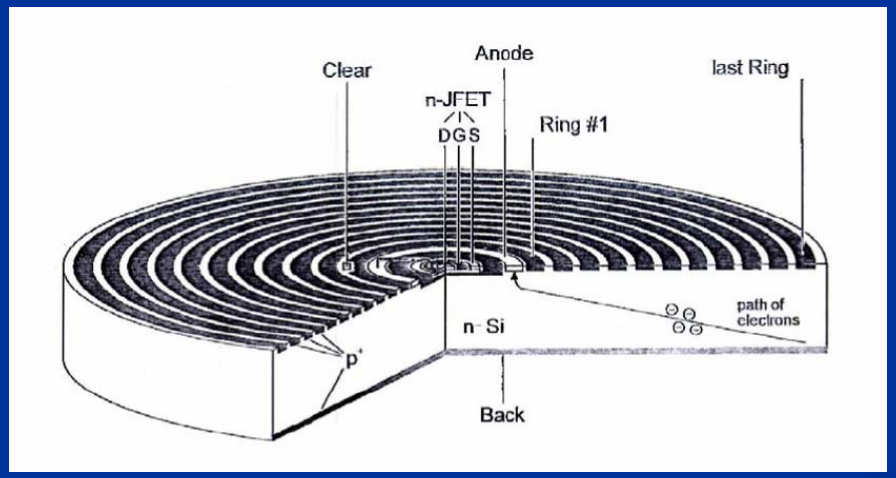


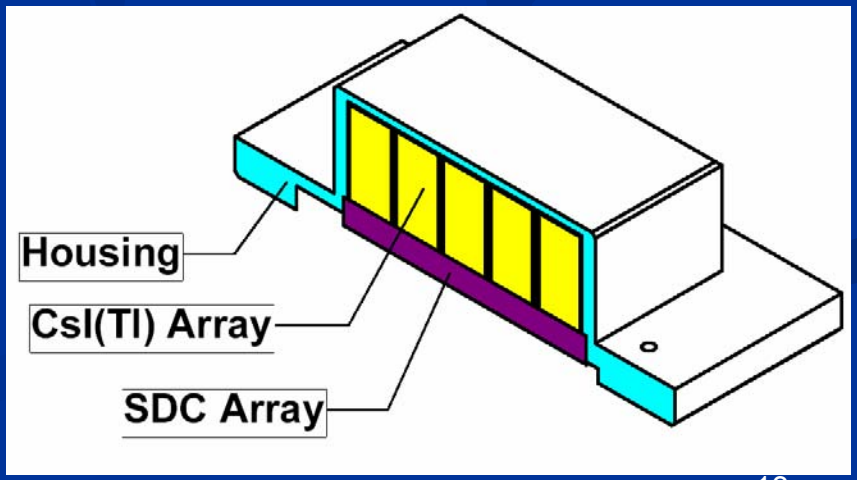
Hi rel Computing Systems

Extended Range Detector

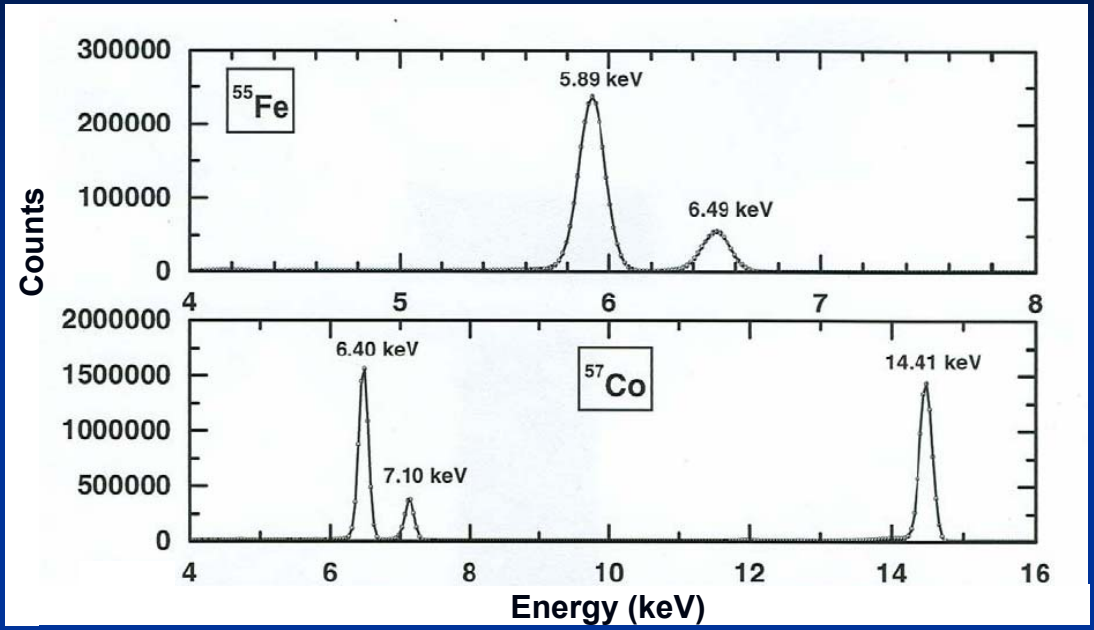
F. Perotti

- Goal
  - Provide spectroscopy detectors with extended range [1 keV – 1 MeV], based on Silicon Drift Chamber coupled to scintillators
- IASF Bologna - IASF Milano collaboration, supported by ASI
- Laboratory electronics for 20 detection lines, as well as ground support equipment for data collection and on-line data analysis, has been developed
- ASIC design has been developed by the University of Pavia
- Study of moon's surface, as a possible application



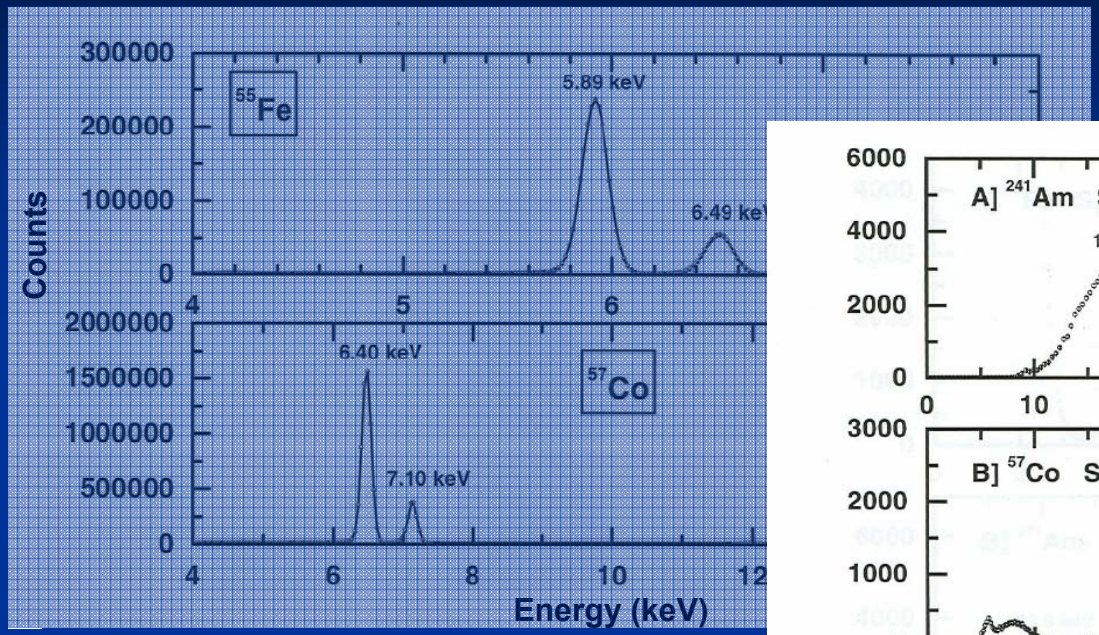


Extended Range Detector (cont'd)

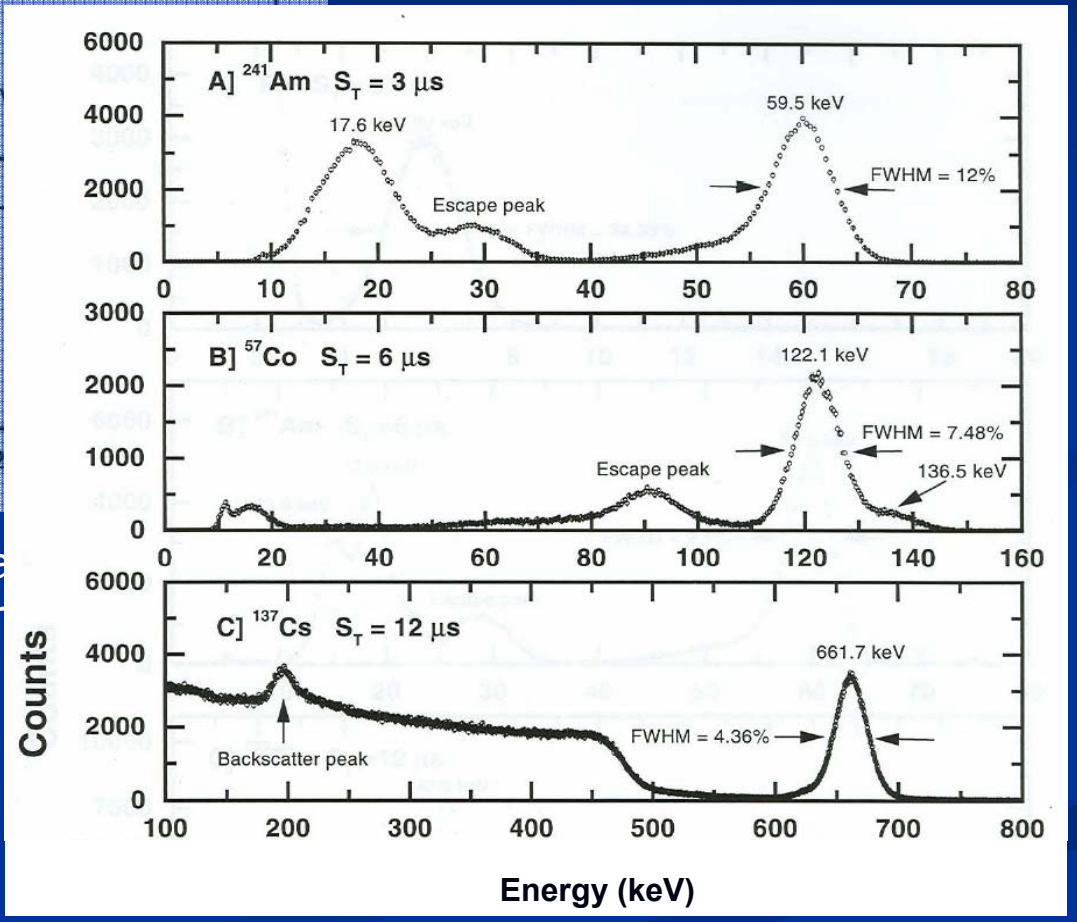


Typical X-ray spectra measured in the past at +20 °C with a Silicon Drift Chamber

Extended Range Detector (cont'd)



Typical X-ray spectra measured in the pa
Silicon Drift Chamber



Typical X-ray spectra measured in the past at +20 °C with a CsI(Tl) scintillator coupled to a Silicon Drift Chamber

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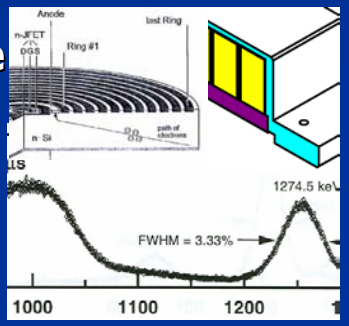
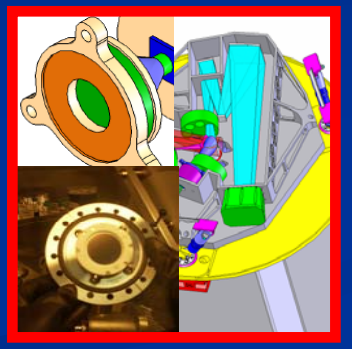
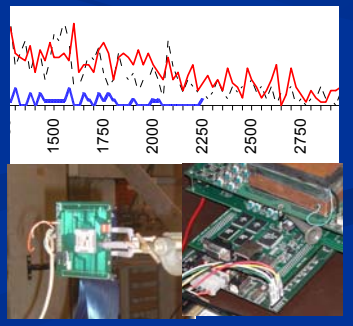


R&D Projects



UV Detectors

Cd(Zn)Te Detectors



Hi rel Computing Systems

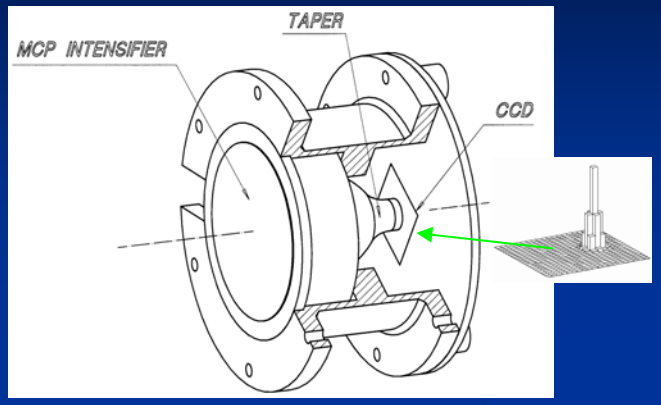
UV Detectors

M. Uslenghi, M. Fiorini

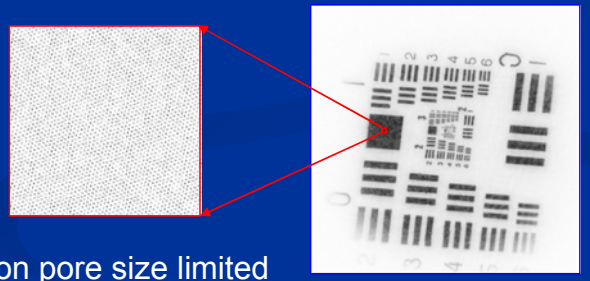
Goal: Develop solar blind UV detectors with high spatial resolution, Detective Quantum Efficiency and dynamic range, and long life

R&D programs carried out at IASF-Mi on photon counting detectors based on:

- Low gain Micro Channel Plate intensifiers coupled to Silicon sensors (CCD, Active Pixel Sensors)
- Z-stack MCPs readout with discrete anodes

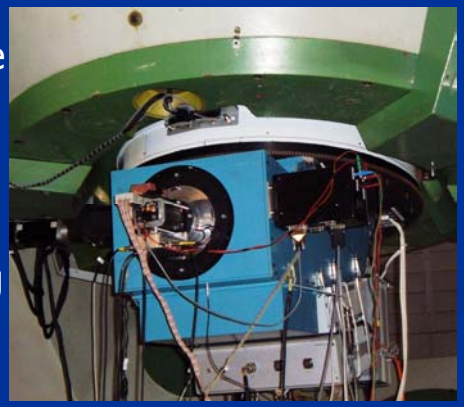


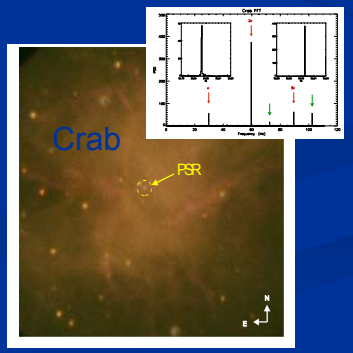
Used in mission concept studies for UV-astronomy (including **World Space Observatory**) and solar physics instruments (including **METIS** proposal to be submitted in response to the ESA Solar Orbiter Payload AO)

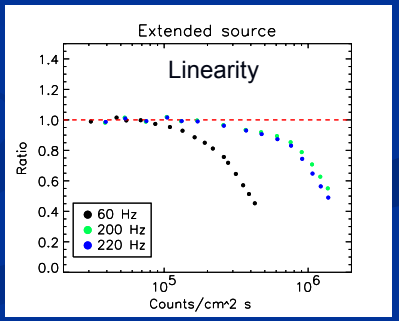


Spatial resolution pore size limited
< 10 μm

MCP detectors prototypes optimized for the optical range used at the Asiago 182 cm telescope for high time resolution photometry & spectroscopy (cataclismic variables, flare stars, pulsating stars)







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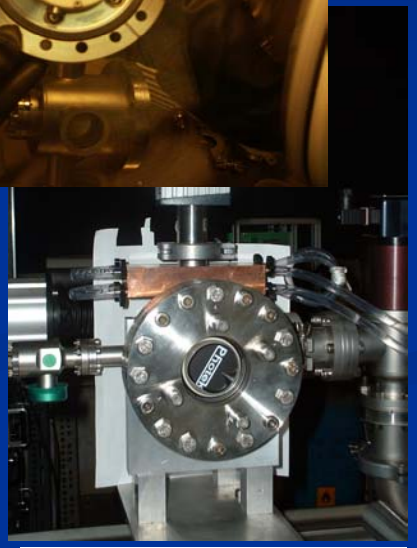

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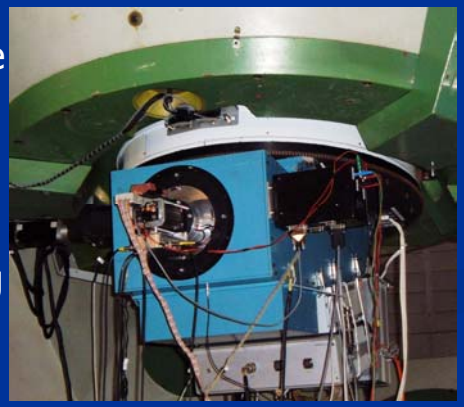
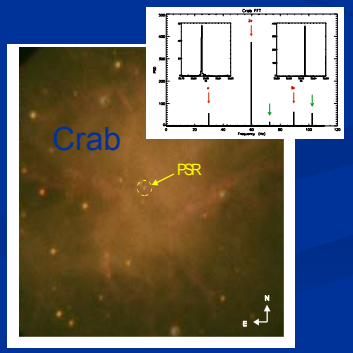
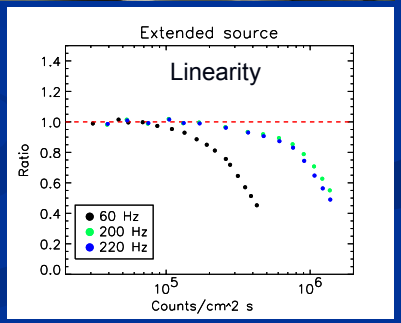






UV Detectors (cont'd)

On-going projects:

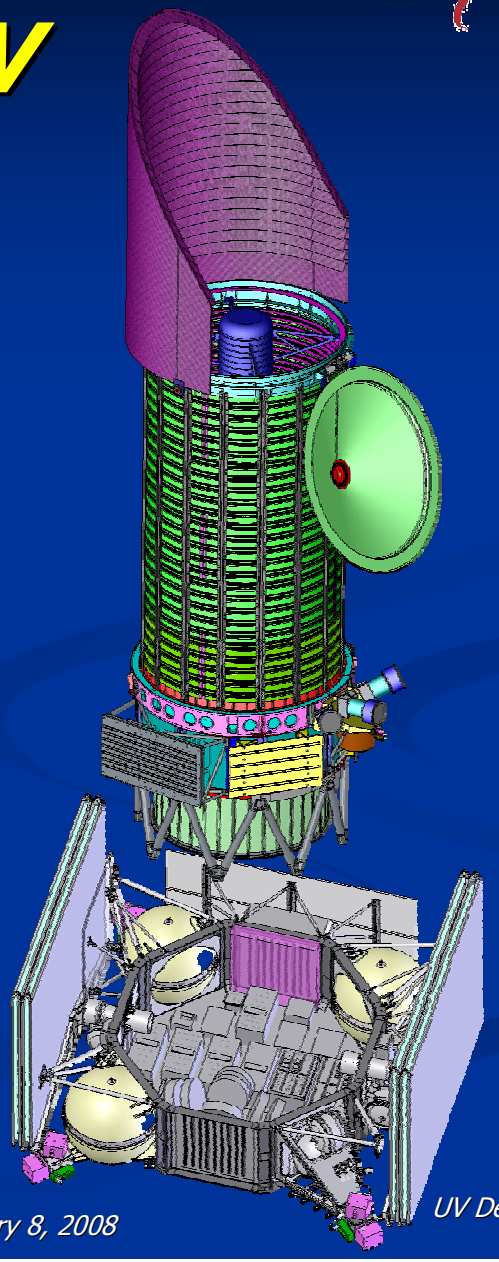
- Specific development of very high dynamic range detectors for solar observations (Uni-Firenze, Uni-Padova, Naval Research Laboratory), based on Active Pixel Sensors double mode readout (integration/photon counting), is ongoing with ASI funding (contract ASI/INAF I/015/07/0, 28 months); evaluation of using a Read-Out IC ASIC with on-chip photon counting capability for direct electrons sensing (Uni-Pisa)
- World Space Observatory Field Camera Unit UV detectors

Future projects:

- Development of a photon counting intensified APS for UV spectropolarimetry, in the framework of a PRIN/MIUR proposal on *New Techniques and New Technologies for the Study of Solar Magnetism* (Uni-Firenze, Uni-Torino, OA-Catania, OA-Arcetri), 2 years
- Development of UV SiC arrays detectors (wide bandgap → solar blind; internal QE ~ 80% in the NUV; very low dark current). Proposal submitted to ASI (Thales AAS-Milano, Politecnico Milano), 30 months

World Space Observatory WSO-UV

- WSO is an international collaboration led by Russia to build a satellite which will provide **spectroscopy** and **imaging** access to the **UV** sky (**110 - 300 nm**, with extension to the visible)
- The mission consists of a **1.7m** telescope able to perform:
  - high resolution spectroscopy by means of two echelle spectrographs
  - long slit low resolution spectroscopy
  - deep UV and diffraction limited optical imaging
- Launch date is **2012**. No other UV space missions foreseen for the next two decades, after HST will terminate operation



World Space Observatory
WSO-UV

WSO - UV

Russia
Roscosmos
INASAN
Lavochkin

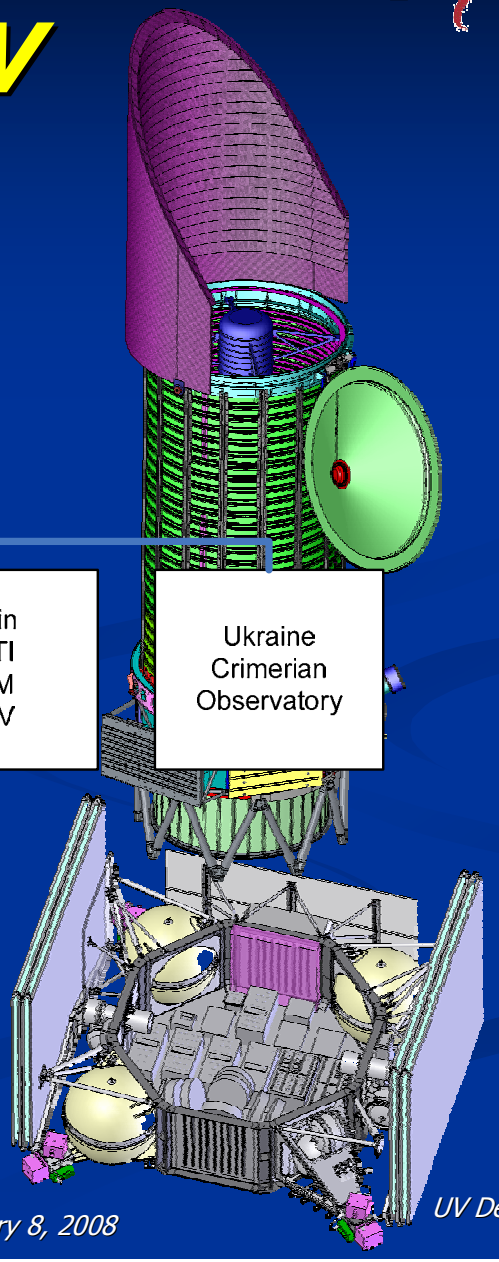
China
CNSA
CAS
tbd

Germany
DLR
Univ.Tuebingen
Kayser-Thrade

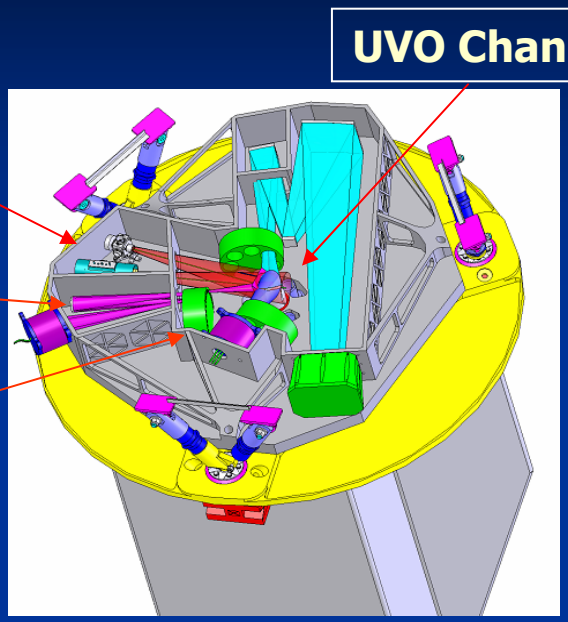
Italy
ASI
INAF
tbd (Galileo
Avionica, TAS)

Spain
CDTI
UCM
GMV

Ukraine
Crimerian
Observatory



WSO-UV Field Camera Unit



	Far-UV	Near-UV	UV-Optical
Range	115-190 nm	150-280 nm	200-800 nm
FOV	6.6'x6.6'	1'x1'	4.7'x4.7'
Scale	0.2"/pix	0.06"/pix	0.07"/pix
Array Size	2kx2k	2kx2k	4kx4k
Detector	MCP (CsI)	MCP (CsTe)	CCD

- The FCU is the main Italian contribution to WSO
- The goal is to give the community tools to:
  - extend ambitious legacy program started with HST
  - complement other contemporary facilities in specific field, e.g.: **JWST**, **GAIA**, ground-based next generation **30m telescopes**
  - allow for the first time **high resolution FUV imaging** with **wide FOV**

WSO-UV in Italy

- 15 Italian Institutes involved + Galileo Avionica and Thales Alenia Space (Milano)

Involved in hardware development

- Phase A/B1 supported under contract ASI/INAF No. I/085/06/0
- Phase A started on January, 18th 2007 (KOM)
- Phase B1 ended on December, 20th (ISRR)

IASF-Mi contribution:

- Participation to science requirements definition
- FUV camera responsibility
- Electronics subsystem management
- Design of UV, MCP-based, focal plane detectors

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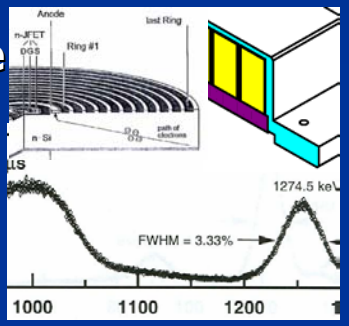
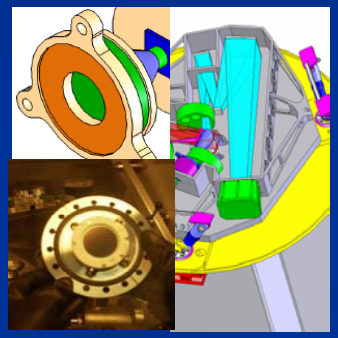


R&D Projects



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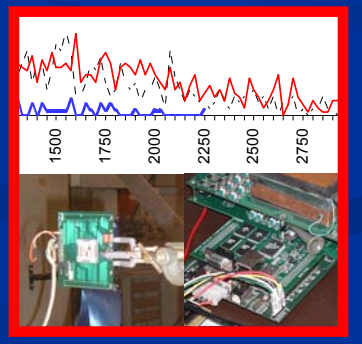
Cd(Zn)Te Detectors



Hi rel Computing Systems

Hi-Rel Reconfigurable Systems

M. Alderighi, F. Casini, S. D'Angelo, M. Mancini, S. Pastore, G. Sechi, G. Sorrenti

- Goal: Definition of high performance, reliable, flexible computing systems for space applications
  - System upgrade need, huge amount of data to be processed, system survival over long term missions
- Implementation technology: reprogrammable logic devices (SRAM-FPGAs)

On-going projects

- *Radiation testing of reprogrammable devices*
- *Fault emulation in reprogrammable devices* (ESA)
- *CZT Digital Front End Electronics* (ASI)

Future projects

- *ALPI: High altitude laboratory for life testing of electronic systems*, proposal submitted to PRIN/MUR, Politecnico Torino, Uni-Padova, 2 years
- *Reconfigurable DSP for on Board Instrument Data Processing*, proposal submitted to ASI, Carlo Gavazzi Space, 30 months

Results

- Flexible multi purpose hardware platform
  - Fault injection tool for SRAM-FPGAs, patented
  - Radiation test apparatus
  - CZT DFEE

Results

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esa Microelectronics
European Space Agency

ESA Home Spacecraft Engineering Electrical Engineering Data Systems

Article contents
- Flipper Product Sheet
- Suitability of reprogrammable FPGAs in space applications
- Functional Triple Modular Redundancy (FTMR)

About us...

Technologies for Space
- Microelectronics Technologies for Space
- The use of reprogrammable FPGAs in space

ESA IP Cores...

Development Methodology...

System-On-Chip (SOC) ...

The use of reprogrammable FPGAs in space

Reprogrammable (SRAM based) FPGA (RFPGA), featuring high flexibility, combined with high performance and complexity become increasingly important also for space applications. With satellite lifetimes increased far beyond 10 years, much longer than the validity of telecom standards, reprogrammability in flight becomes a stringent requirement. If software solutions are not possible, RFPGA may soon be the only solution. In contrary to ASIC or one-time (antifuse) programmable FPGA, the configuration of RFPGA is stored in an SRAM, which is sensitive to SEU's. The radiation behaviour of RFPGA and methods for SEU mitigation is investigated in several studies.

Flipper Product Sheet

In an ongoing contract with IASF in Milano, a test system is being developed which allows injection of SEU-like faults into user flip-flops, configuration memory and reconfiguration control registers of a Xilinx FPGA. This will allow testing the impact of configuration SEU on unprotected designs, as well as evaluating the efficiency of fault mitigation methods. The Product Sheet gives advance information on this system.

- Author: INAF, IASF Milano **(pdf available)**

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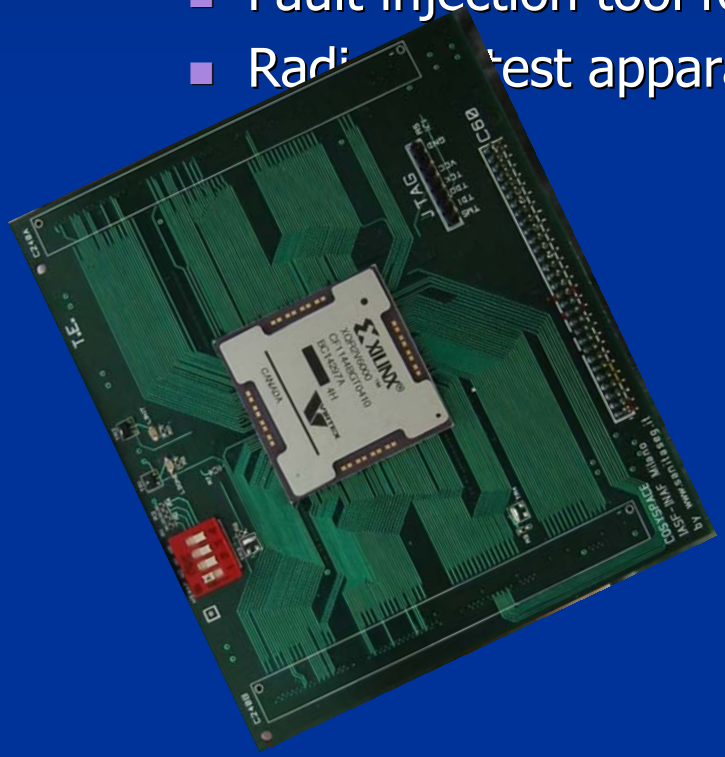
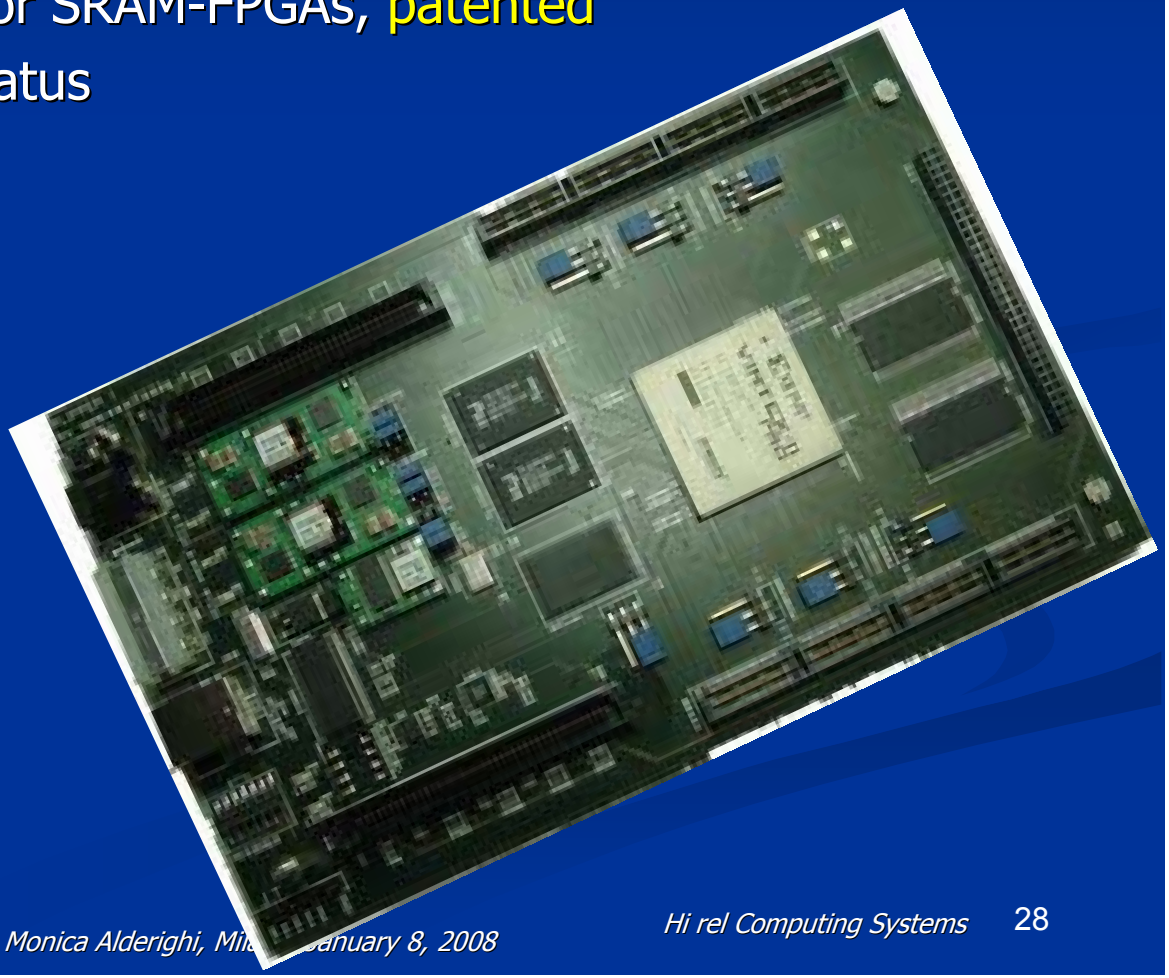


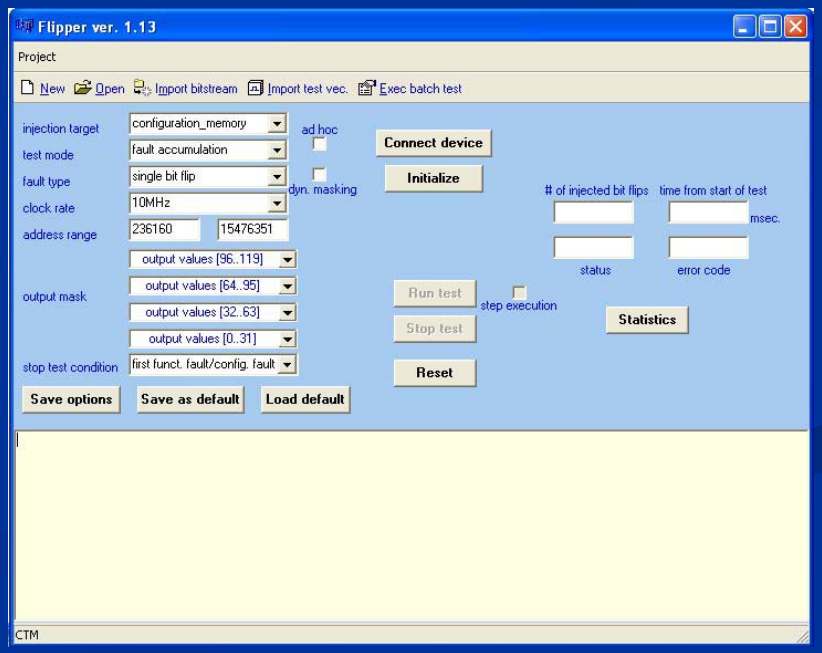


Results

FLIPPER

- Quantitative characterization of design robustness
- Comparison of different design hardening techniques
- Tuning of design redundancy and protection
- Optimization of radiation ground testing time

- High number of I/Os
- Fast connections to the PC (USB, Ethernet)
- Software program on the PC managing the application



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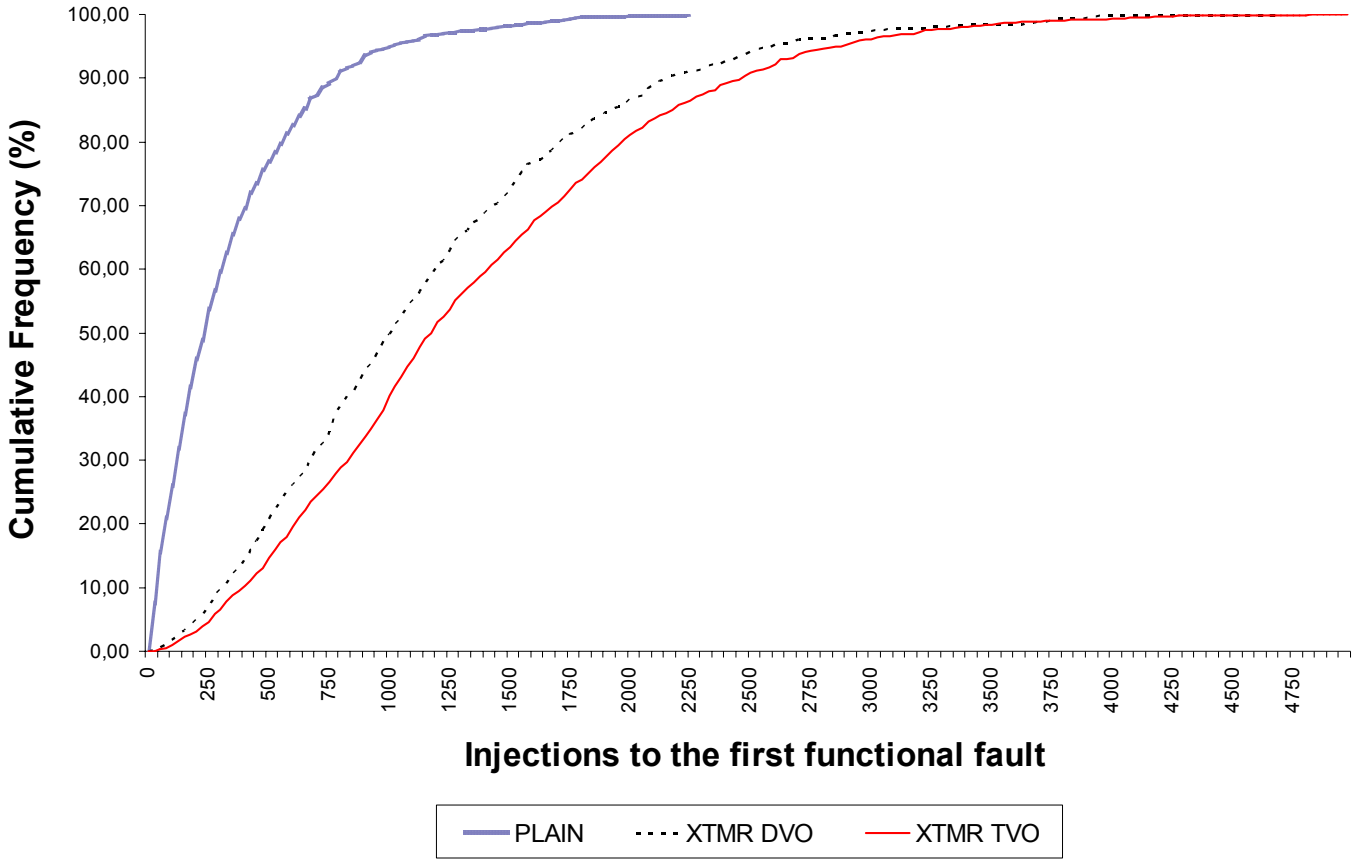

Cumulative distribution of the number of injections to the first functional fault

Results

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FPGAs

Results

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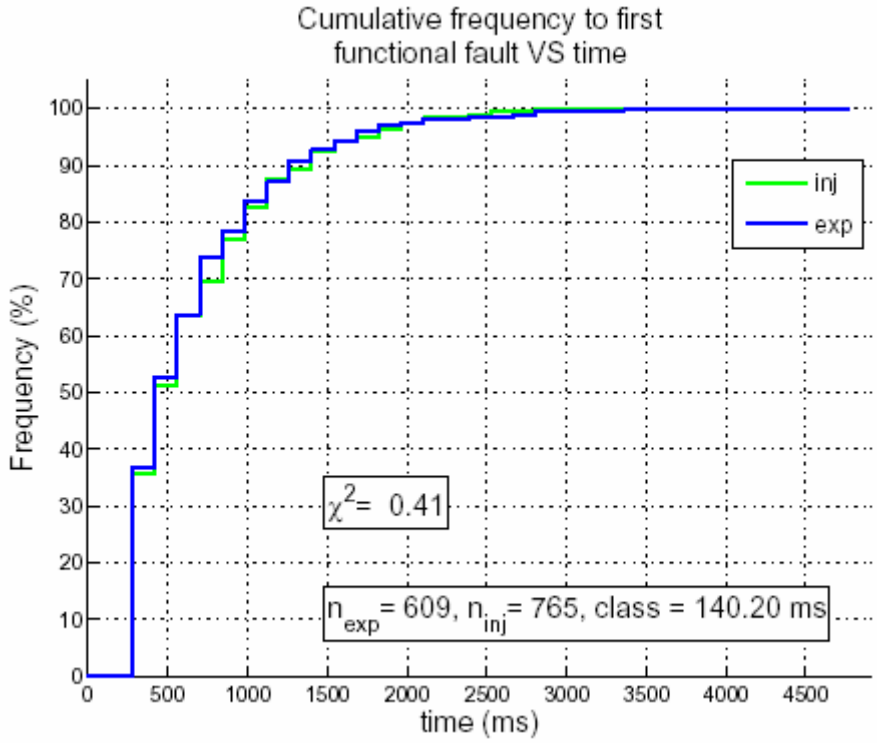
  - Radiation
  - CZT DFEE



Comparison between fault injection test and radiation test on a selected design

Results

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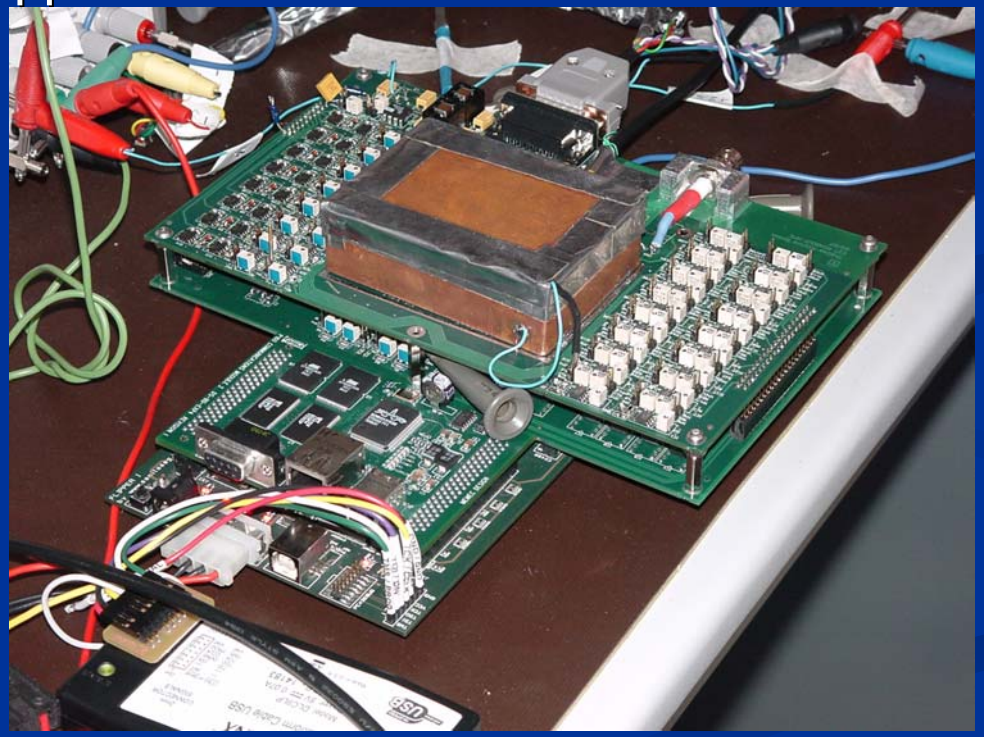

Team

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Detectors

Readout electronics

Digital electronics

Computing systems

Analog electronics

Thank you!