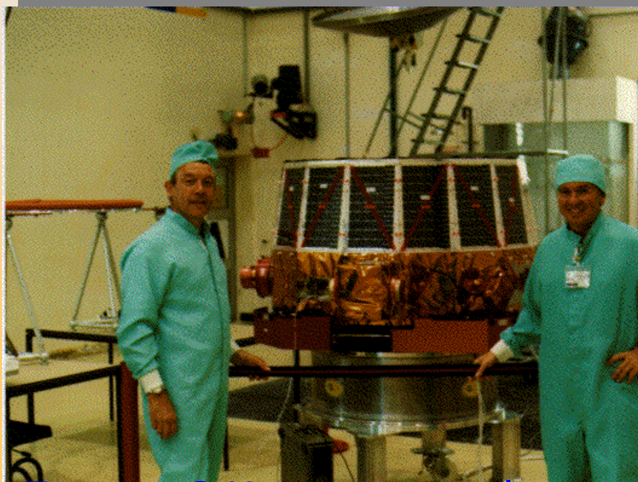
Outlook

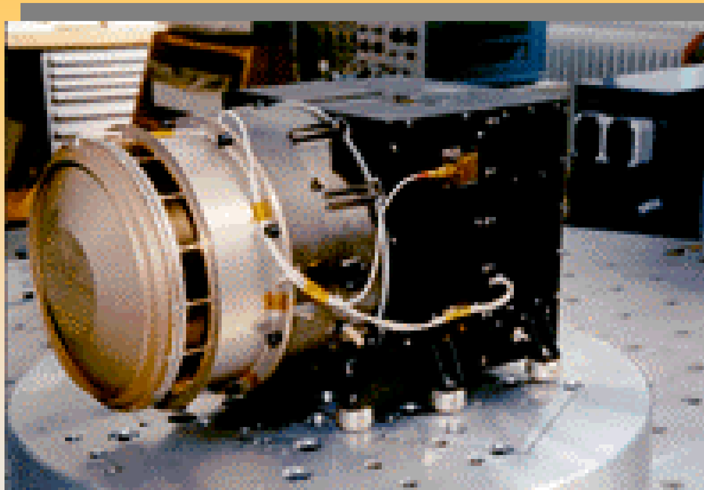
- **Selected instrumentation:**
  - **- Interplanetary space: Particles instruments**

CIS on Cluster-1, Equator-S, Cluster-2 & DoubleStar

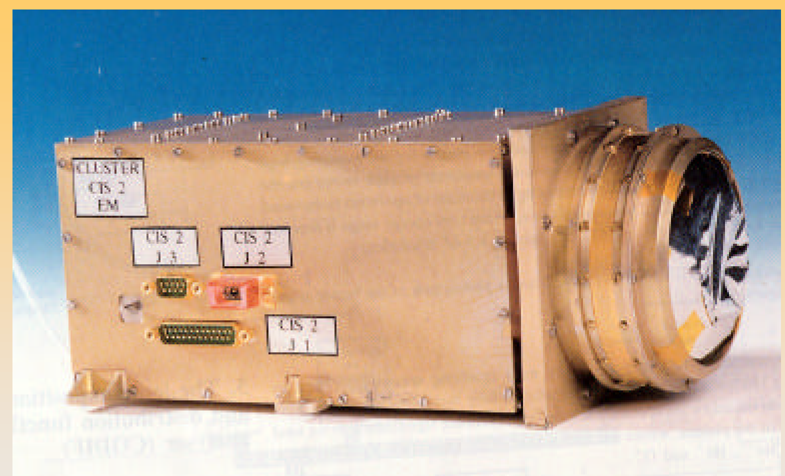


Equator-S Kourou campaign

Cluster Fleet

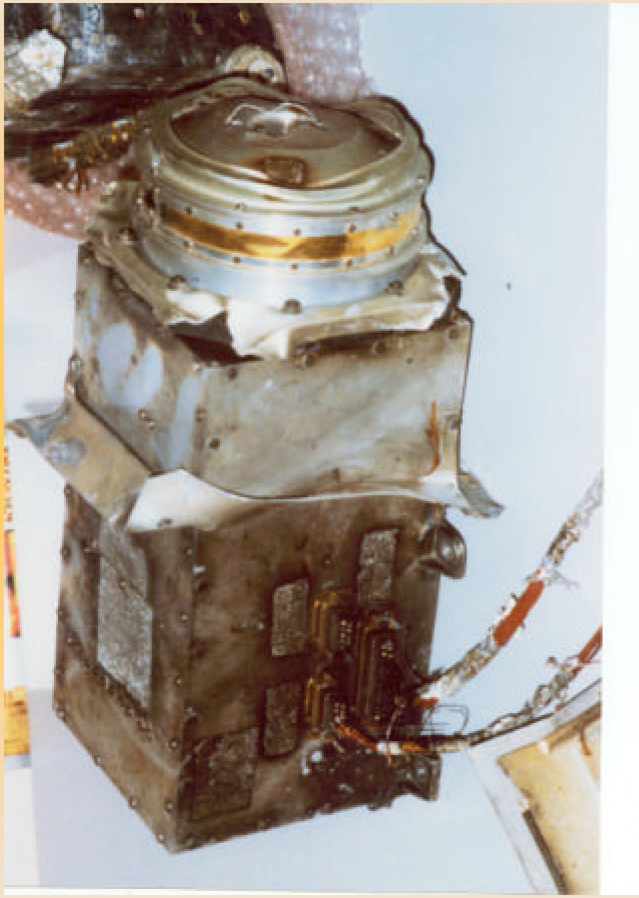


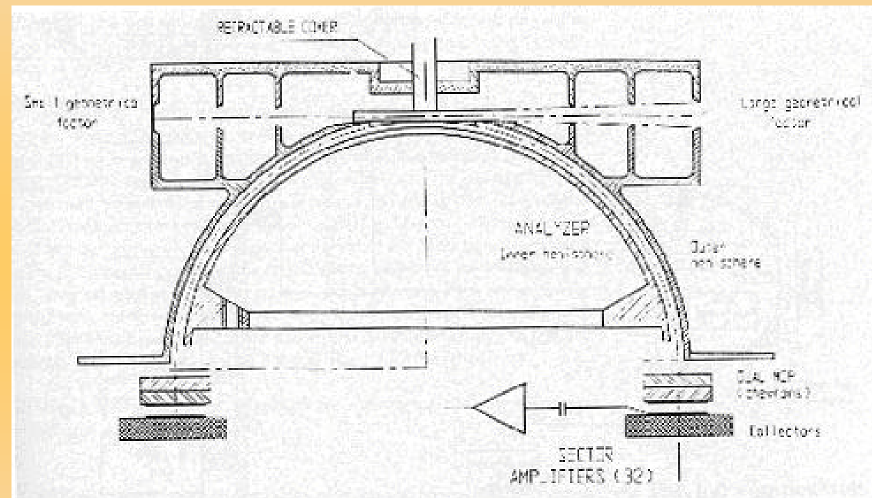
Cis-1 / Esic



Cis-2

CIS-2





Cis-2 / HIA Qudrispherical analyzer concept

Cis-2 Recovered after the Ariane 5 first flight

CIS 3D-Distributions reconstruction

$$CR = \int_{\vartheta=-\pi/2}^{\vartheta=\pi/2} \int_{\phi=0}^{\phi=2\pi} \int_{v=-\infty}^{v=\infty} T(\theta,\phi,v)\vec{\mathbf{S}}.\vec{\mathbf{v}}f(\vec{\mathbf{v}})v^2 \cos\vartheta d\vartheta d\phi dv$$

$$CR = \overline{S}\,\Delta\alpha\Delta\phi\Delta v f(\alpha_o,\phi_o,v_o)v_o^3$$

$$f(\mathbf{v}_O) = (v_O{}^4 K)^{-1} CR$$

CIS On-board Momenta computation - 1 of 2

Density:

$$n = \iiint f(\vartheta, \varphi, v)\, v^2 \cos\theta\, d\vartheta\, d\varphi\, dv$$

$$n = \Delta\theta\Delta\phi / K \sum_{vi} \frac{\Delta v_i}{< v_i^2 >} \sum_{\varphi j} \sum_{\vartheta k} < \cos\vartheta_k > CR_{ijk}$$

Bulk Velocity:

$$V_x = \frac{1}{n} \iiint f(\vartheta, \varphi, v)\, v^3 \cos^2\theta \cos\varphi\, d\vartheta\, d\varphi\, dv$$

$$V_y = \frac{1}{n} \iiint f(\vartheta, \varphi, v)\, v^3 \cos^2\theta \sin\varphi\, d\vartheta\, d\varphi\, dv$$

$$V_z = \frac{1}{n} \iiint f(\vartheta, \varphi, v)\, v^3 \cos\theta \sin\vartheta\, d\vartheta\, d\varphi\, dv$$

$$V_x = \Delta\theta\Delta\phi / n K \sum_{vi} \frac{\Delta v_i}{< v_{vi} >} \sum_{\varphi j} < \cos\varphi_j > \sum_{\vartheta k} < \cos^2\vartheta_k > CR_{ijk}$$

$$V_y = \Delta\theta\Delta\phi / n K \sum_{vi} \frac{\Delta v_i}{< v_{vi} >} \sum_{\varphi j} < \sin\varphi_j > \sum_{\vartheta k} < \cos^2\vartheta_k > CR_{ijk}$$

$$V_z = \Delta\theta\Delta\phi / n K \sum_{vi} \frac{\Delta v_i}{< v_{vi} >} \sum_{\varphi j} \sum_{\vartheta k} < \cos\vartheta_j \cos\vartheta_k > CR_{ijk}$$

CIS On-board Momenta computation - 2 of 2

Pressure Tensor:

$$P_{xx} = m_p \iiint f(\vartheta,\varphi,v)\, v^4 \cos^3\theta \cos^2\varphi \, d\vartheta \, d\varphi \, dv$$

$$P_{xy} = m_p \iiint f(\vartheta,\varphi,v)\, v^4 \cos^3\theta \sin\phi \cos\varphi \, d\vartheta \, d\varphi \, dv$$

$$P_{xz} = m_p \iiint f(\vartheta,\varphi,v)\, v^4 \cos^2\theta \sin\theta \cos\varphi \, d\vartheta \, d\varphi \, dv$$

$$P_{yy} = m_p \iiint f(\vartheta,\varphi,v)\, v^4 \cos^3\theta \sin^2\varphi \, d\vartheta \, d\varphi \, dv$$

$$P_{yz} = m_p \iiint f(\vartheta,\varphi,v)\, v^4 \cos^2\theta \sin\theta \sin\varphi \, d\vartheta \, d\varphi \, dv$$

$$P_{zz} = m_p \iiint f(\vartheta,\varphi,v)\, v^4 \cos\theta \sin^2\theta \, d\vartheta \, d\varphi \, dv$$

$$P_{xx} = \Delta\theta\Delta\phi\, m_p / K \sum_{vi} \Delta v_i \sum_{\varphi j} <\cos^2\varphi_j> \sum_{\vartheta k} <\cos^3\vartheta_k> CR_{ijk}$$

$$P_{xy} = \Delta\theta\Delta\phi\, m_p / K \sum_{vi} \Delta v_i \sum_{\varphi j} <\sin\phi_j \cos\varphi_j> \sum_{\vartheta k} <\cos^3\vartheta_k> CR_{ijk}$$

$$P_{xz} = \Delta\theta\Delta\phi\, m_p / K \sum_{vi} \Delta v_i \sum_{\varphi j} <\cos\varphi_j> \sum_{\vartheta k} <\cos^2\vartheta_k \sin\vartheta_k> CR_{ijk}$$

$$P_{yy} = \Delta\theta\Delta\phi\, m_p / K \sum_{vi} \Delta v_i \sum_{\varphi j} <\sin^2\varphi_j> \sum_{\vartheta k} <\cos^3\vartheta_k> CR_{ijk}$$

$$P_{yz} = \Delta\theta\Delta\phi\, m_p / K \sum_{vi} \Delta v_i \sum_{\varphi j} <\sin\varphi_j> \sum_{\vartheta k} <\cos^2\vartheta_k \sin\vartheta_k> CR_{ijk}$$

$$P_{zz} = \Delta\theta\Delta\phi\, m_p / K \sum_{vi} \Delta v_i \sum_{\varphi j} \sum_{\vartheta k} <\cos\vartheta_k \sin^2\vartheta_k> CR_{ijk}$$

CIS-2, ESIC: On board S/W, Cis-1 Compression

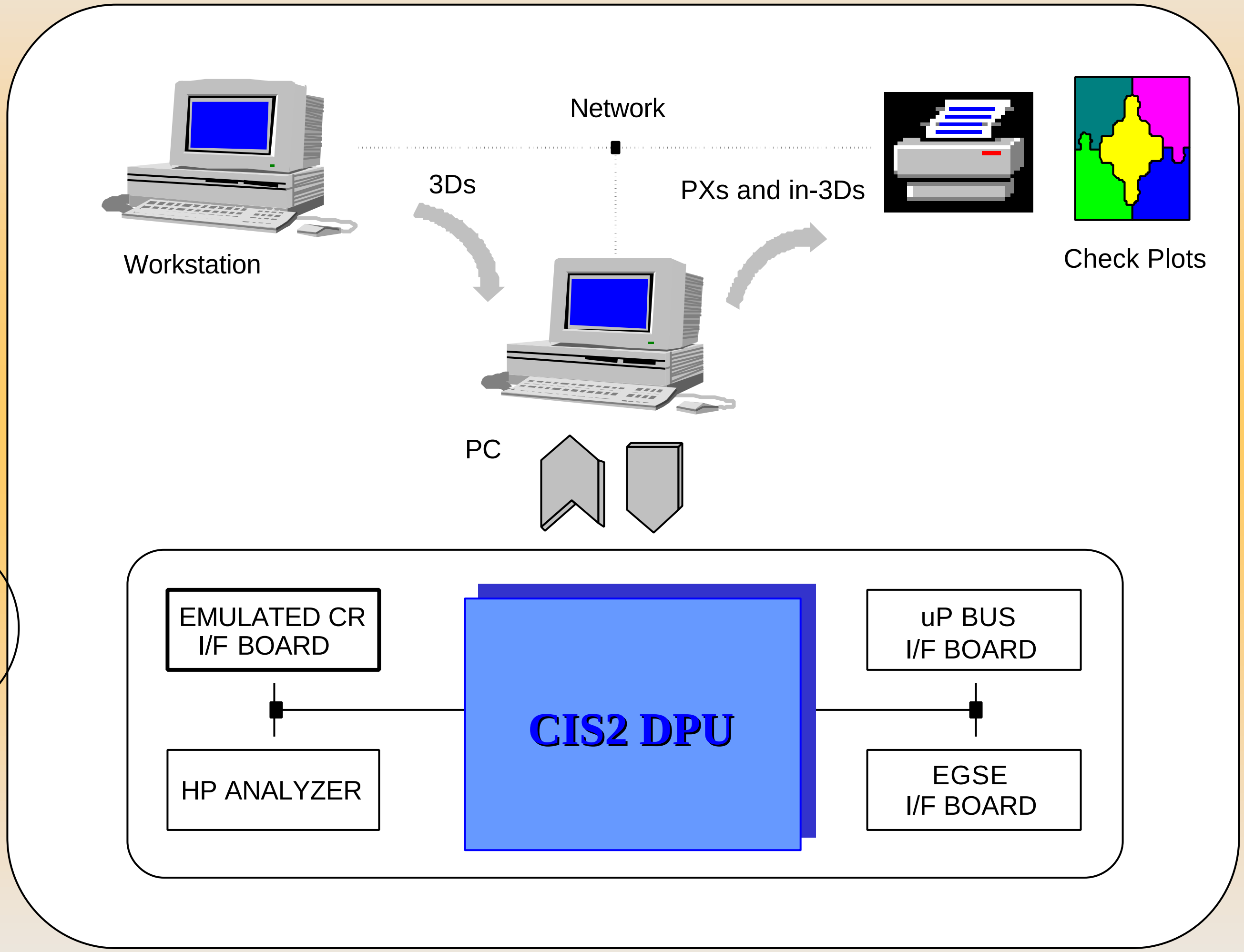
CLUSTER 1&2

Equator-S

DoubleStar

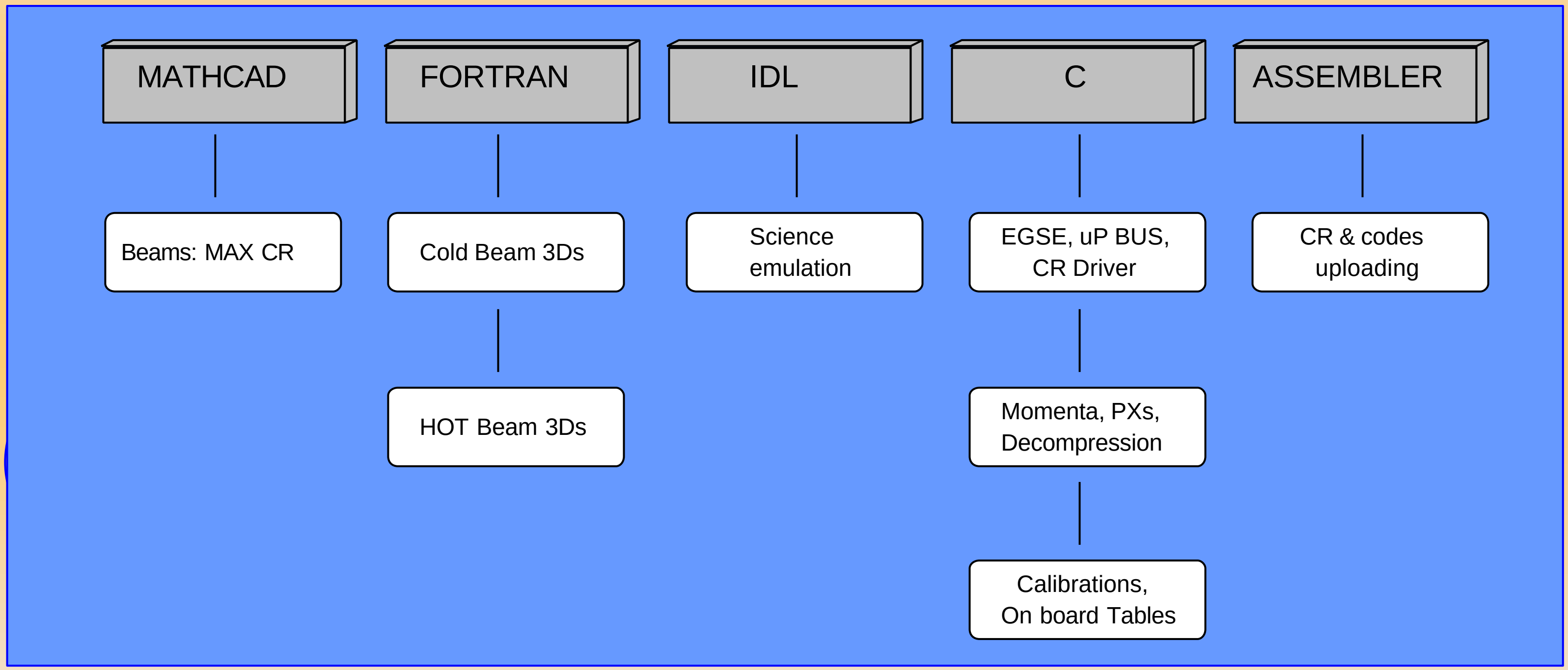
- *Solar Wind / Backstreaming ions operations*
- *Magnetospheric and Calibration operations*
- *TLM activity 16 Modes * 7 TLM regimes i.e.112 modes*
- *Products formatting Routines*
- *Cold /Hot ion populations momenta computation*
- *3D on board compression*
- *Beam tracking*
- *Automatic mode switching*
- *Spin accumulated samples*
- *Spin tagging*
- *Magnetic field handling for PAD slices sampling*
- *Burst (scratch memory) activity*
- *Azimuthal coverage*

CIS-2 On-Board S/W validation facility



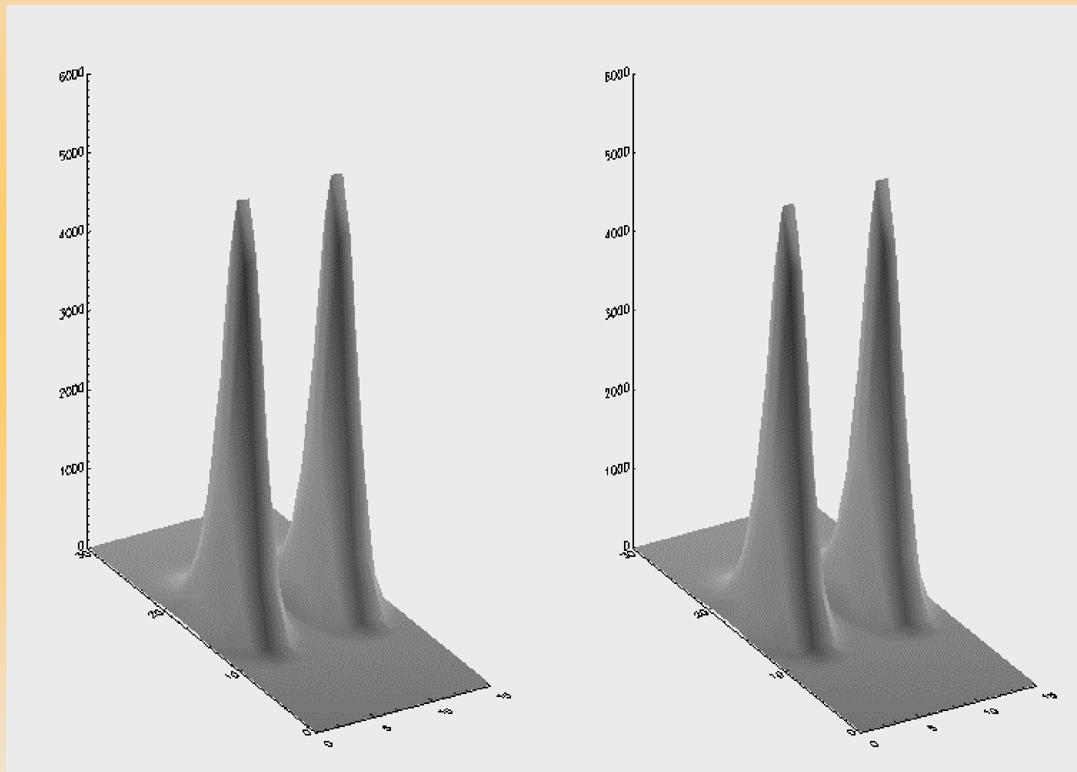
Ground testing S/W

S/W developed for detectors Beams emulator facility



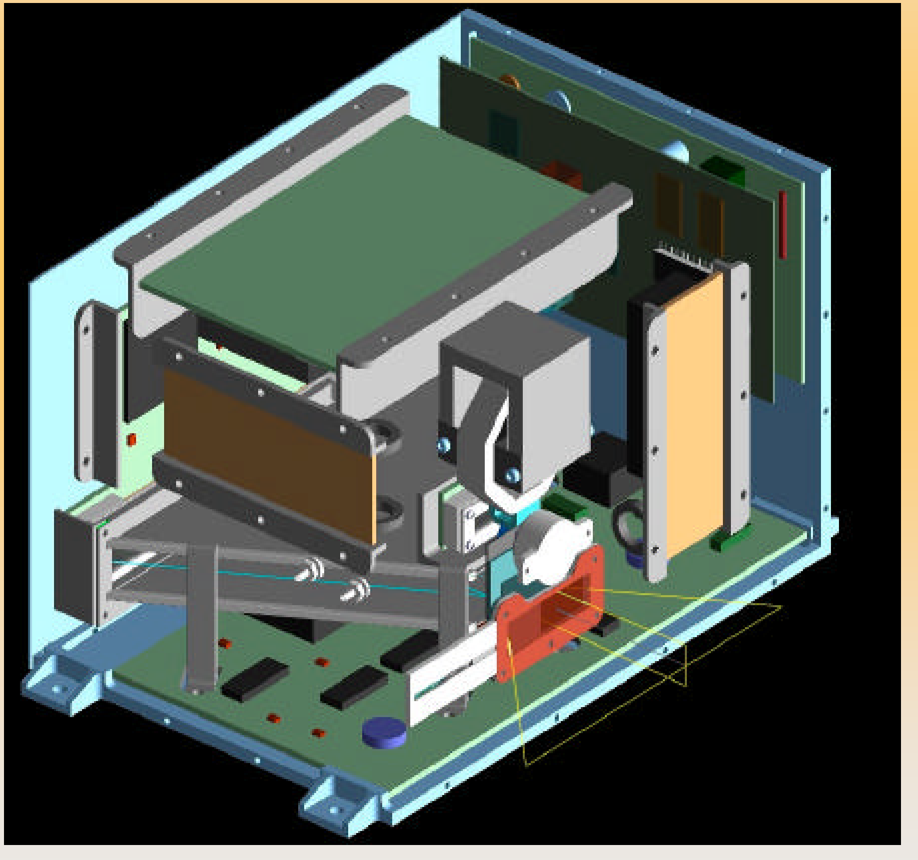
On-Bord S/W validation

Workstation computation Vs On-Board computations extracted from TLM

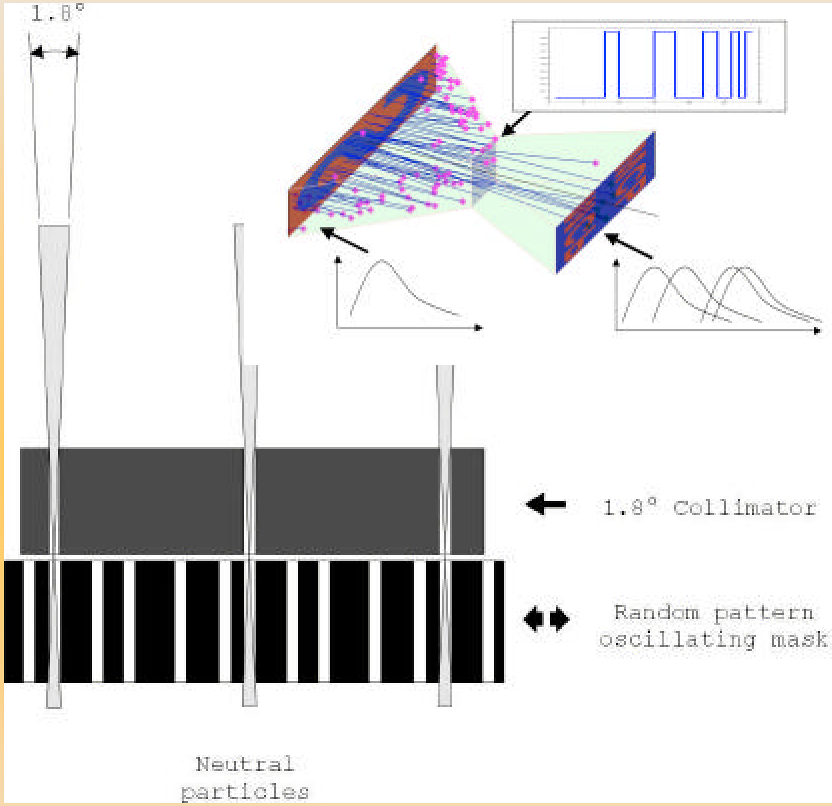


ELENA
The Neutral Particle Analyzer for BepiColombo

Breaking the limits for low energy high angular resolution neutral atom detection by means of micro-shuttering techniques



ELENA shuttering concept: the theory



$$Z(t) = C \int_0^T F(s)*S(t-s)ds + U(t)$$

Z(t) = Count rate at stop detector
F(t) = the TOF distribution
S(t)= modulation function of period T
C = Normalization constant
U = background

$Zj - Uj = C\Delta t \sum_{i=1}^{N} s_{ji} Fj$ where s_{ji} is a circulant matrix:

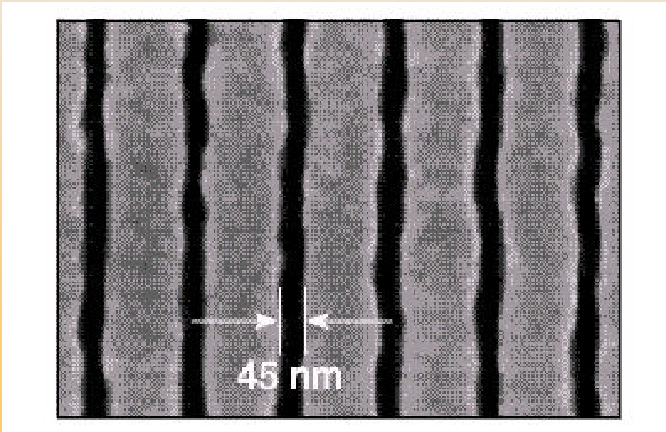
$$\begin{matrix} S_N & S_{N-1} & S_{N-2} & \cdots & S_1 \\ S_1 & S_N & S_{N-1} & \cdots & S_2 \\ \cdot & & & & \\ \cdot & & & & \\ S_{N-1} & S_{N-2} & S_{N-3} & \cdots & S_N \end{matrix}$$

$$\mathbf{Z = S \times F + U \quad or \quad F\ @\ S^{-1} \times Z}$$

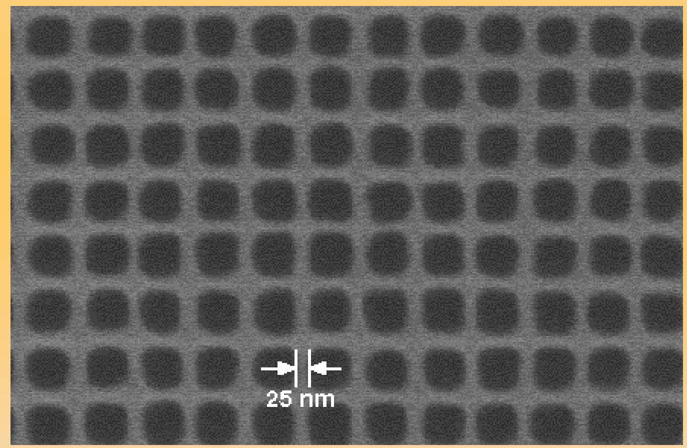
G Wilhemi and F. Gompf, **Nucl. Instrum Methods 81, 36 (1970)**
Binary sequences and error analysis for pseudo statistical neutron modulators with different duty cycles.

A. Brock, N. Rodriguez,and R.N. Zare, **Rev. of Sci. Inst., 71, 1306-1318 (2000)**
Characterization of a Hadamard Time-of-Fligth spectrometer.

ELENA shuttering:
Samples of gratings technologies from abroad

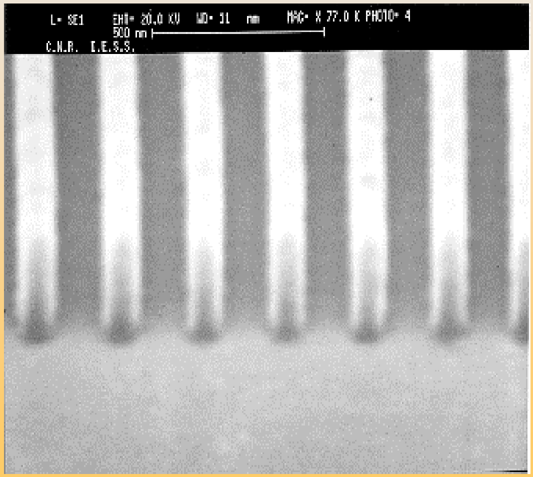


(Courtesy from Space Nat. Laboratories - MIT)
Scanning-electron micrograph of a deep-UV blocking grating used in atom telescopes on the NASA IMAGE and TWINS missions. The grating blocks deep-UV radiation while passing energetic neutral atoms. Due to the narrow slot width of 45 nm and the large slot depth (~500 nm), the UV transmission is extremely low (~10^-6 at lambda =121.6 nm), while decreasing the transmitted atomic flux by only a factor of 10.

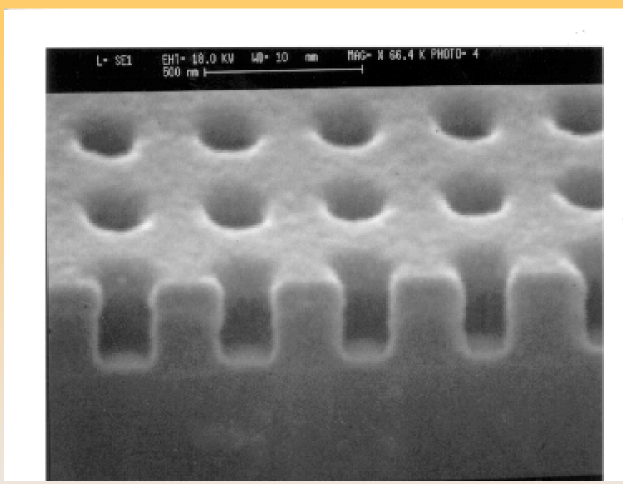


(Courtesy from Space Nat. laboratories - MIT)
Scanning electron micrograph of a free-standing 100 nm period grid in a silicon nitride membrane of area 500 micron by 5 mm.

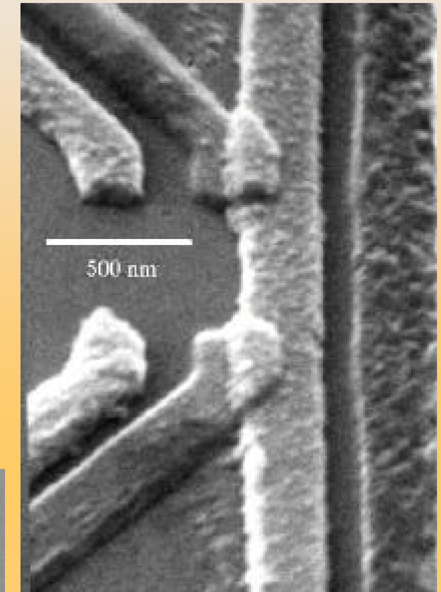
....and Samples FROM IFN TEAM



Resist - resolution 80 nm



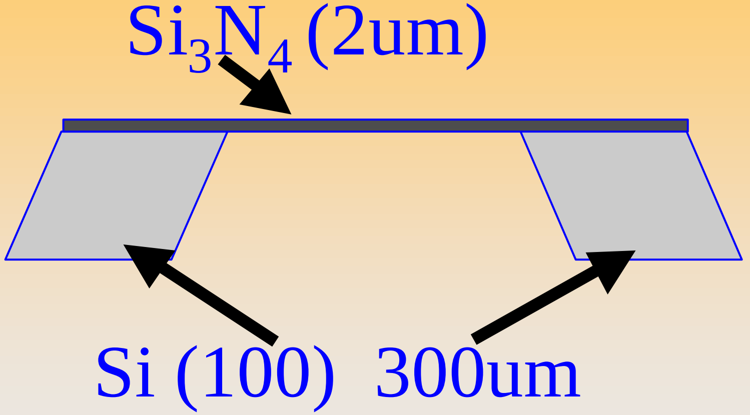
Single electron devices



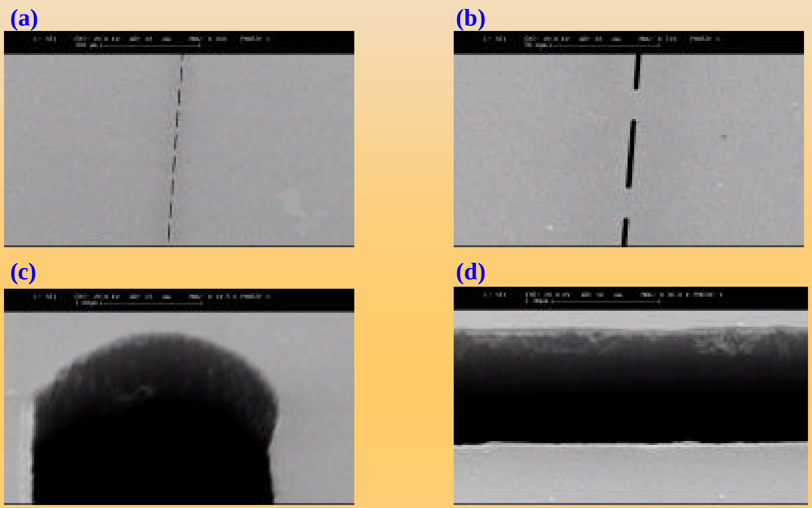
Zone plates -
Circular difraction grating res. 50 nm

Grids Proposed fabrication process @IFN

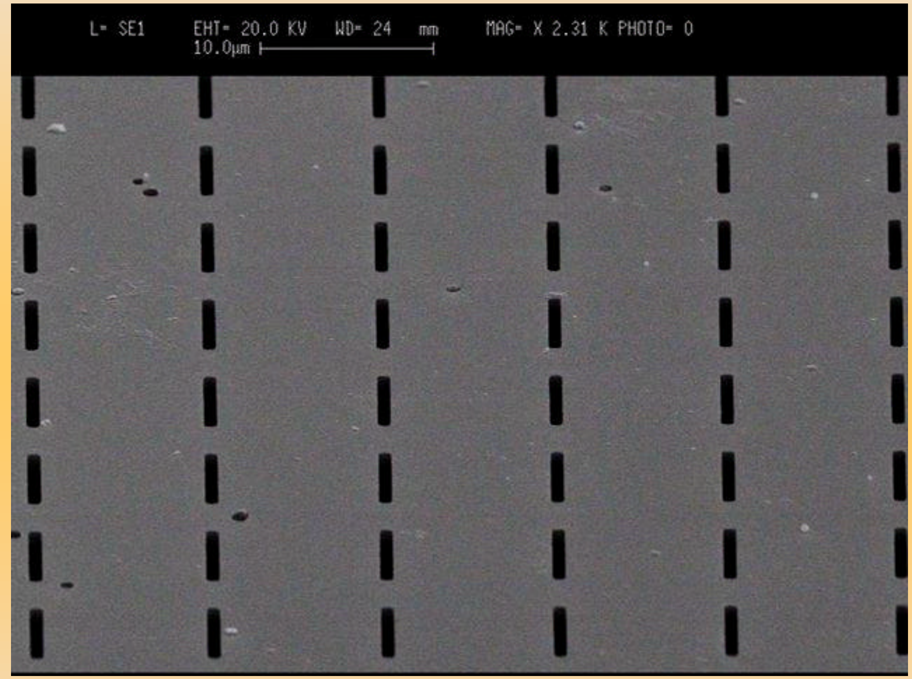
- Si wafer (300 um) covered with Si_3N_4 (2 um thick)
- resist coating and electronic lithography to define slots
- metal deposition (Cr) and lift-off
- use Cr mask to dry etch Si nitride
- suspend the membrane by wet etching of Si from backside



ELENA GRIDs IFN PROTOTYPEs

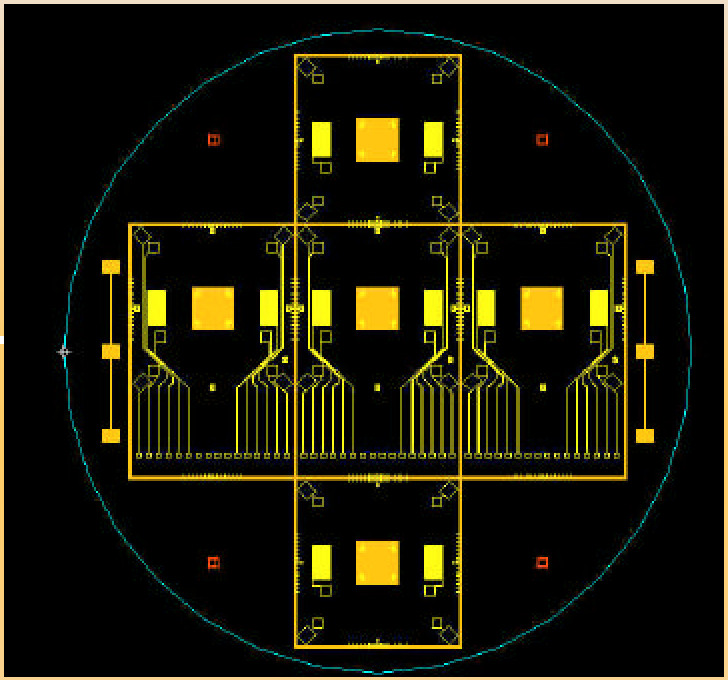


SEM images of the in line series of slots as a whole (a) and (b), and two details of a single slot (c) and (d).

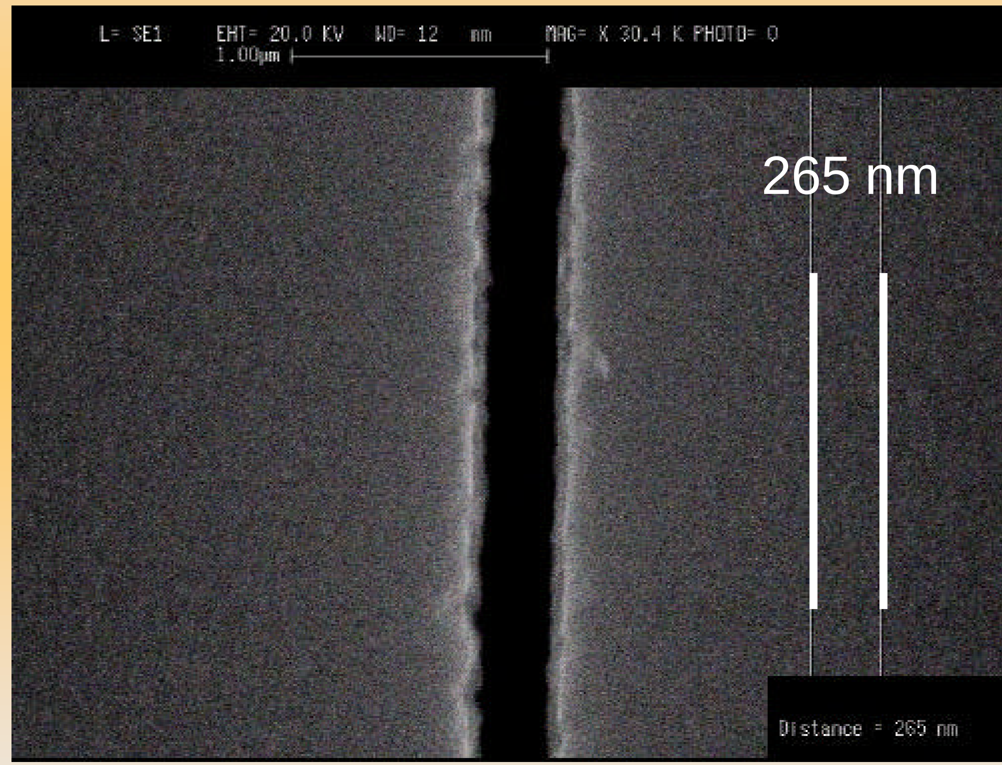


SEM image of the first ELENA multi aperture slit.

IFN Nano-Grid Manufactoring

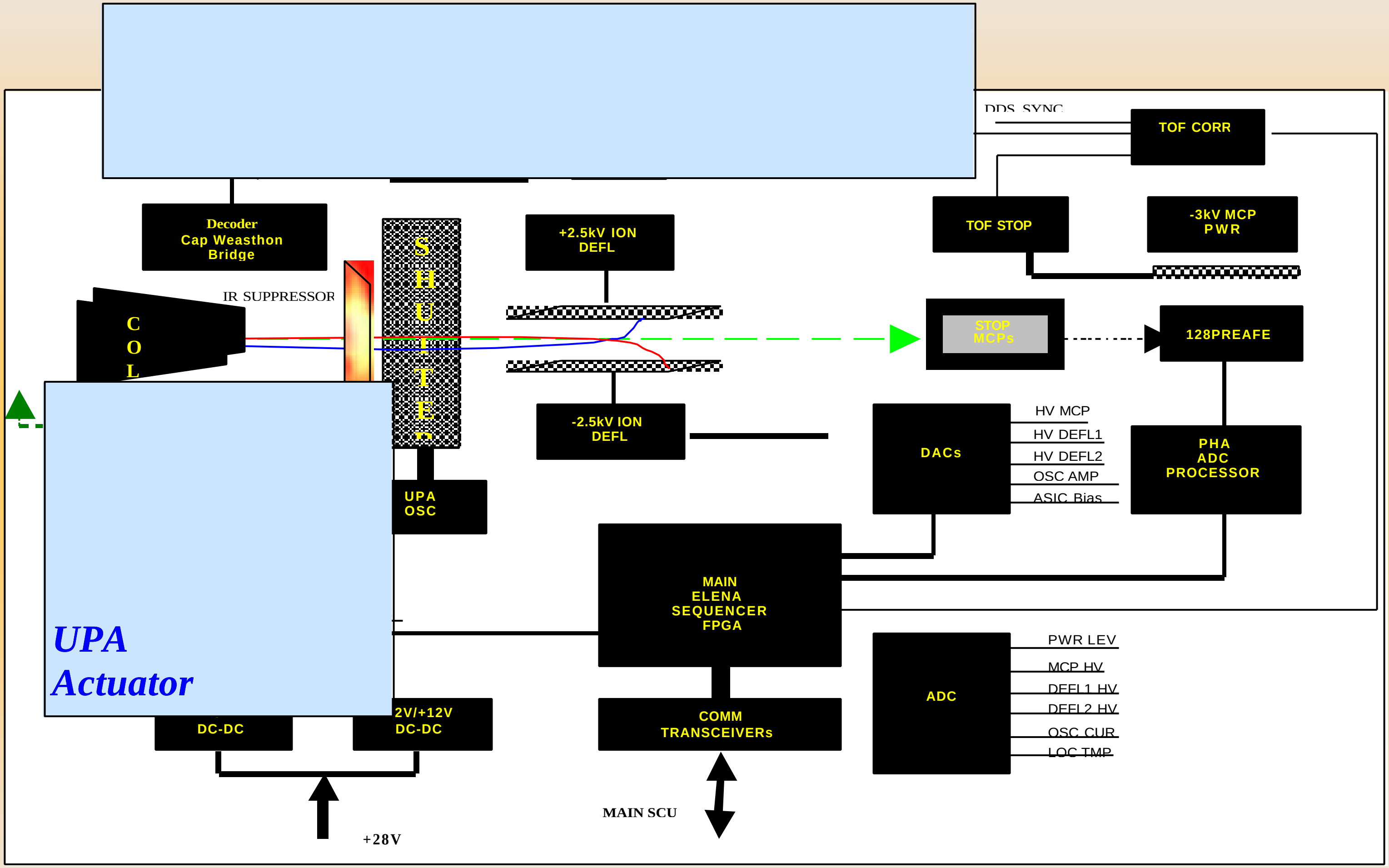


- 2 inch diameter wafer. 2 µm Silicon nitride double side

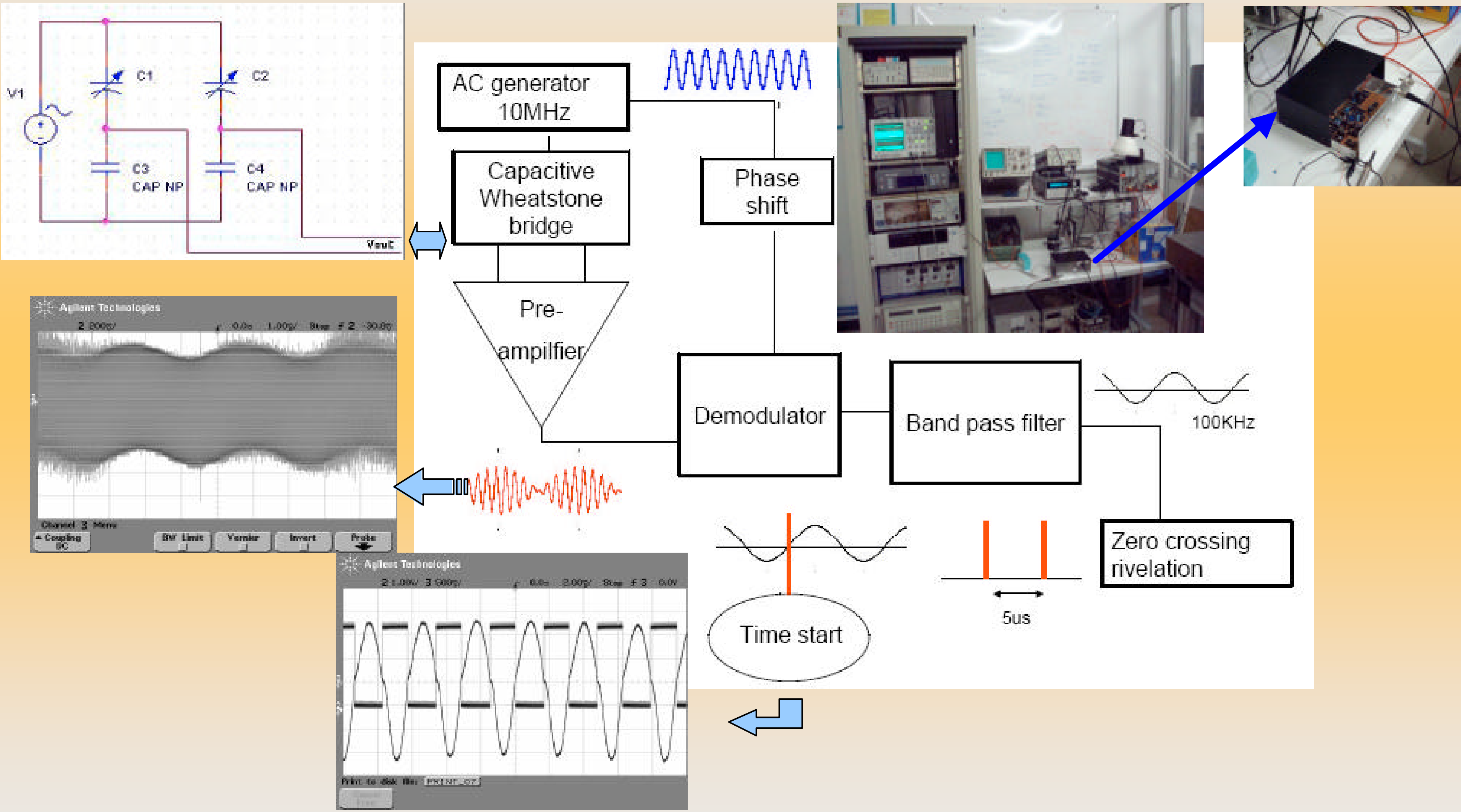


- Defined 5th generation process for implementing chromium enconding mask for motion tracking

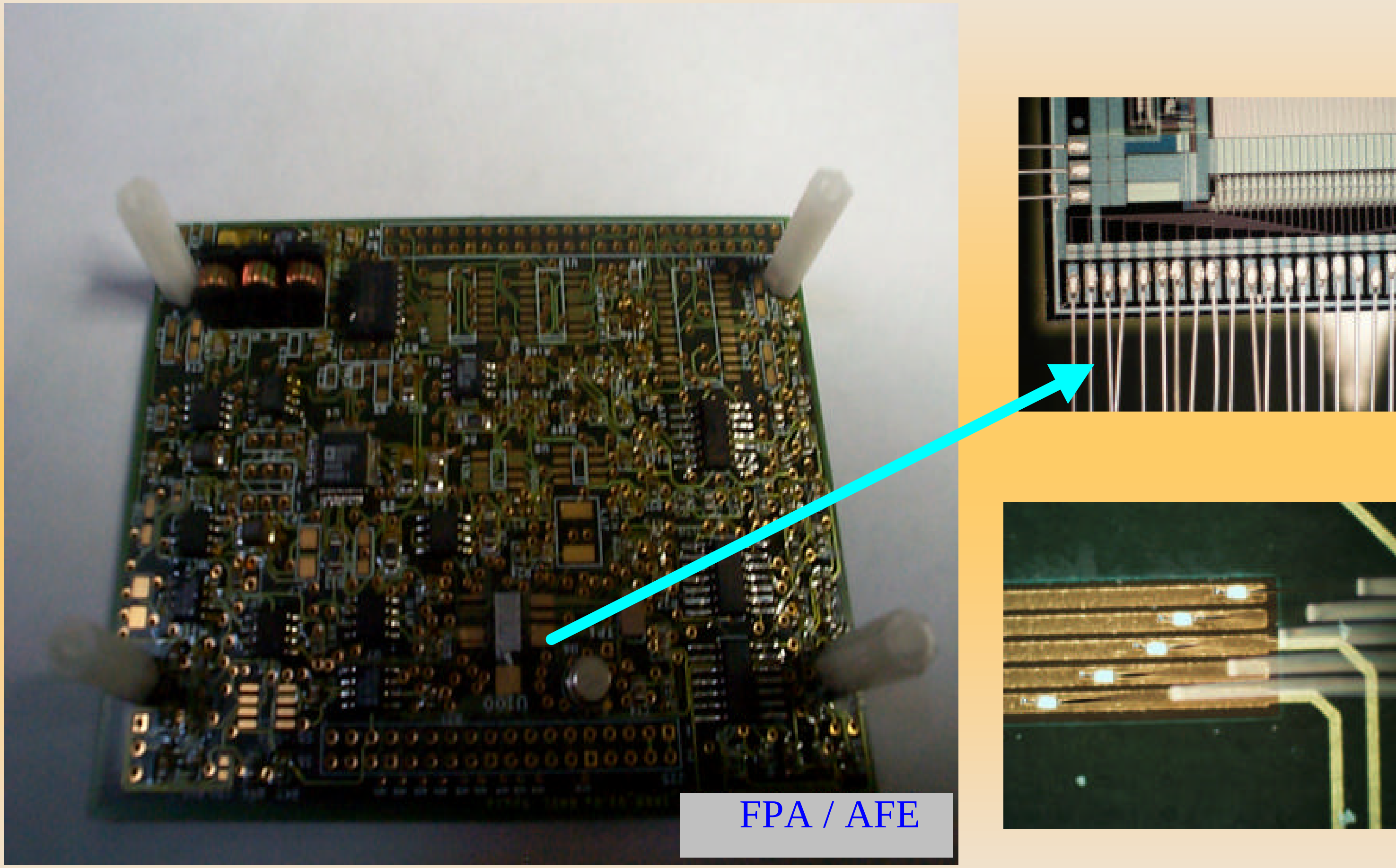
ELENA system



Capacitive encoder reader



ELENA FPA AFE / ASIC



ELENA AFE/ASIC control

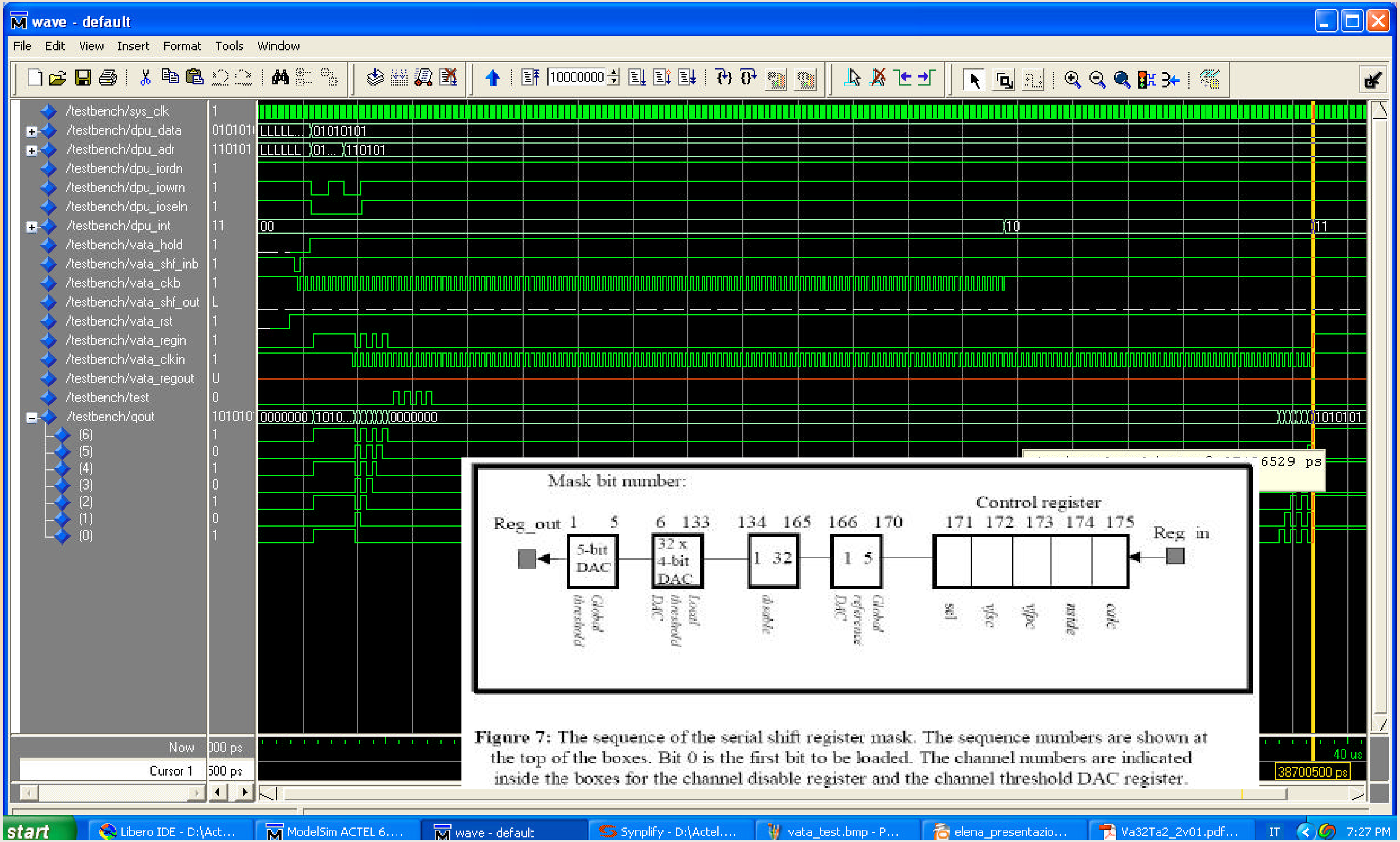
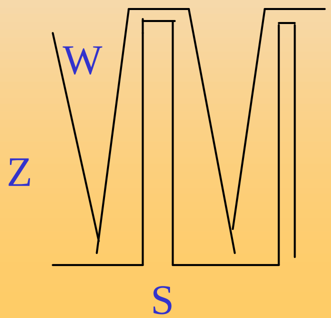
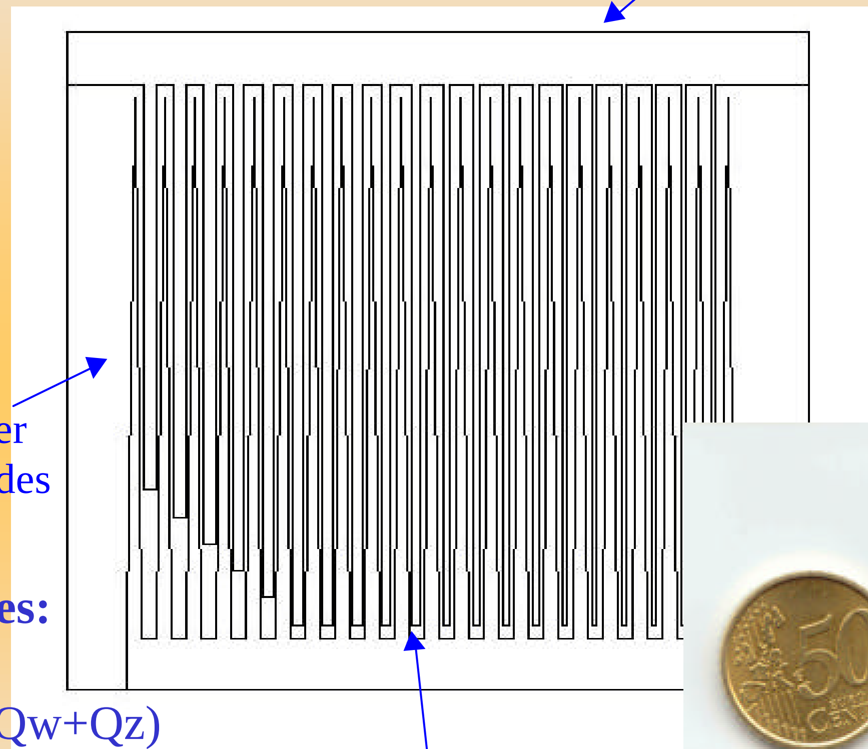


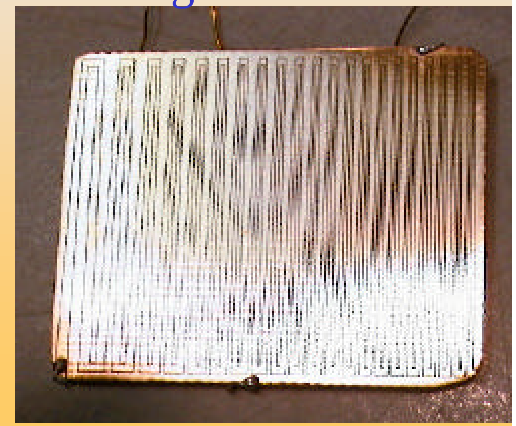
Figure 7: The sequence of the serial shift register mask. The sequence numbers are shown at the top of the boxes. Bit 0 is the first bit to be loaded. The channel numbers are indicated inside the boxes for the channel disable register and the channel threshold DAC register.

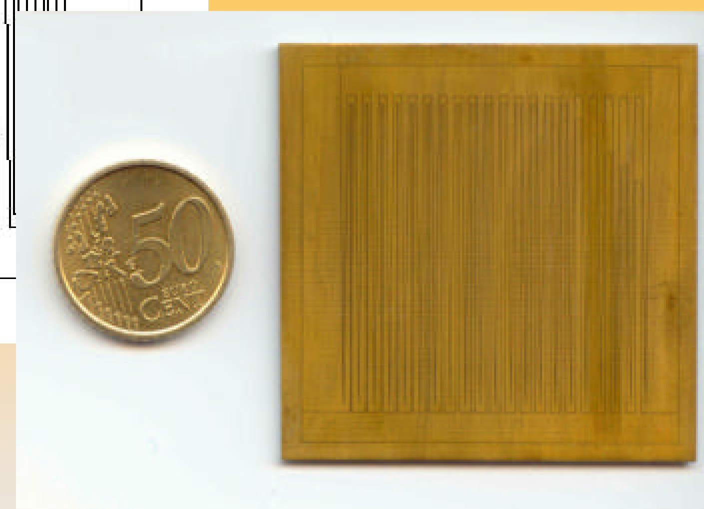
Focal Plane position encoders (WSA)





Former generation WSA





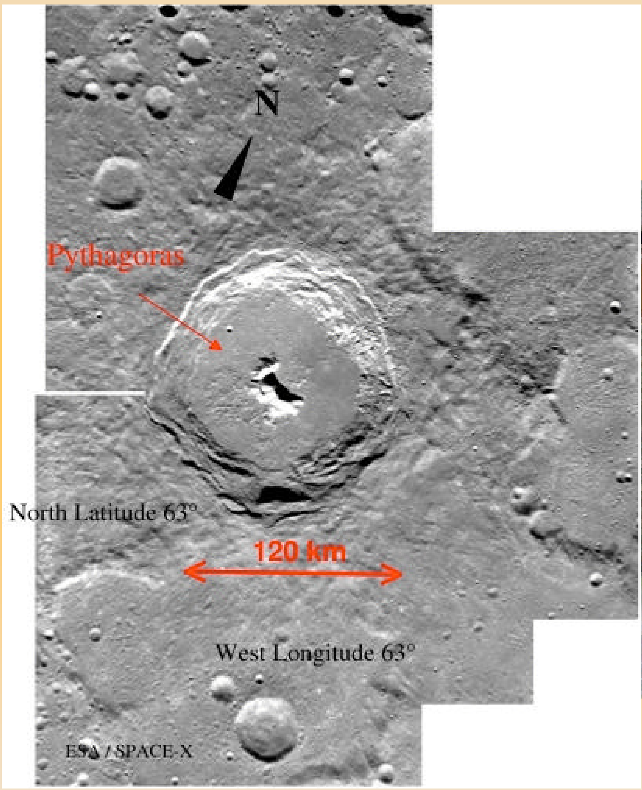
Centroid coordinates:

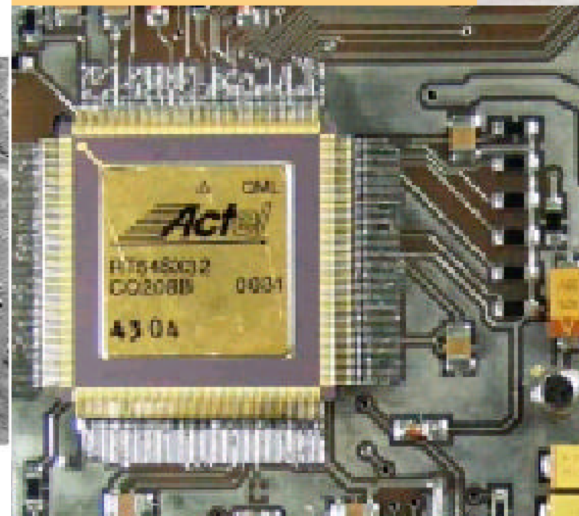
X = 2Qs / (Qs+Qw+Qz)

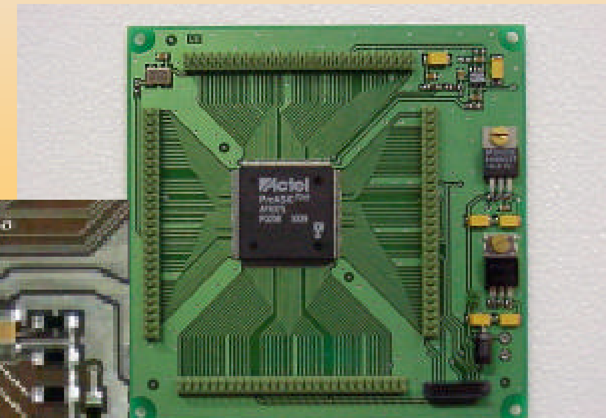
Y = 2Qw / (Qs+Qw+Qz)

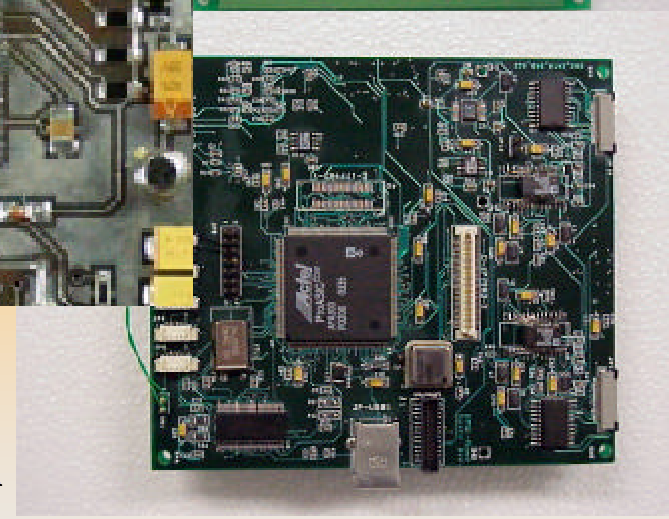
Qs, Qw, Qz = three-anodes signals

THE ELENA FPGA



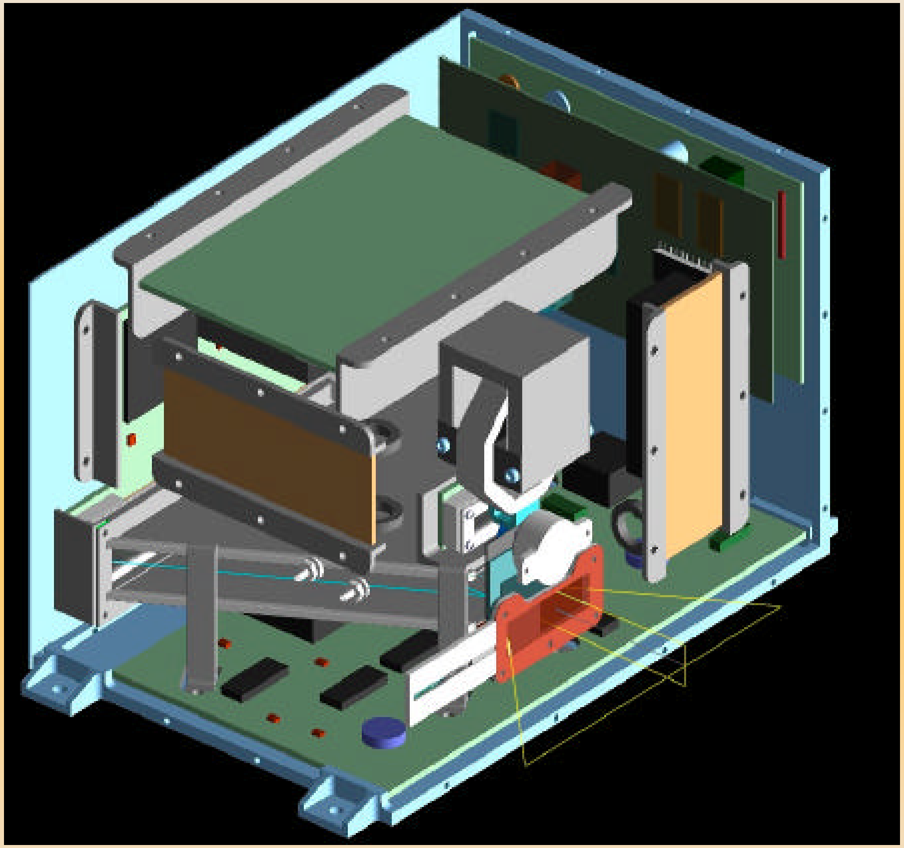


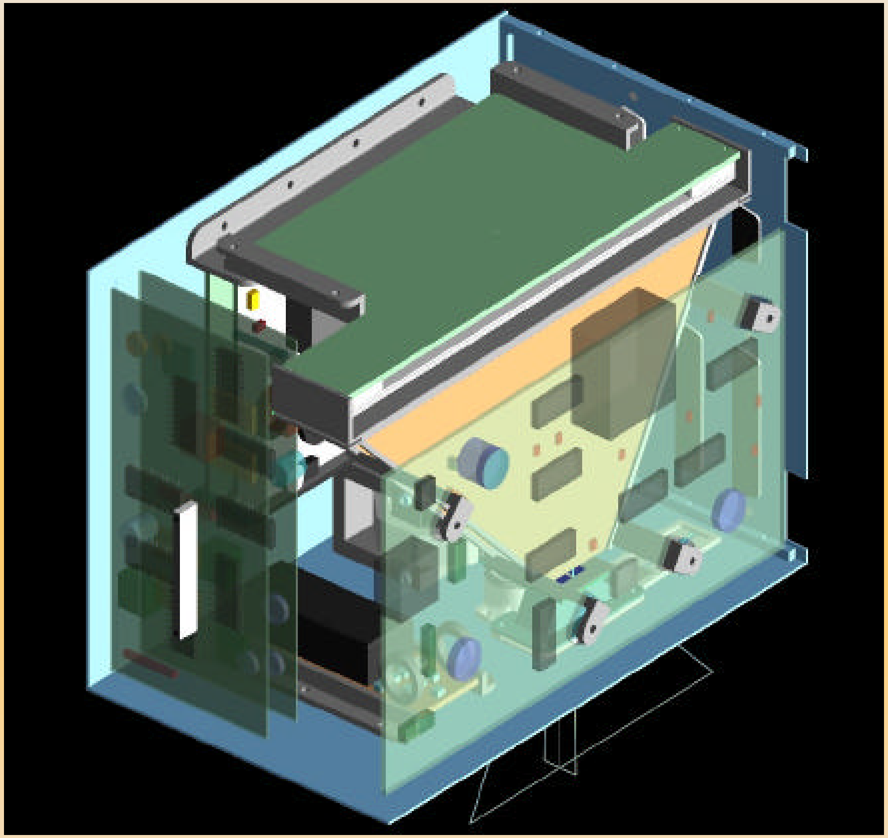




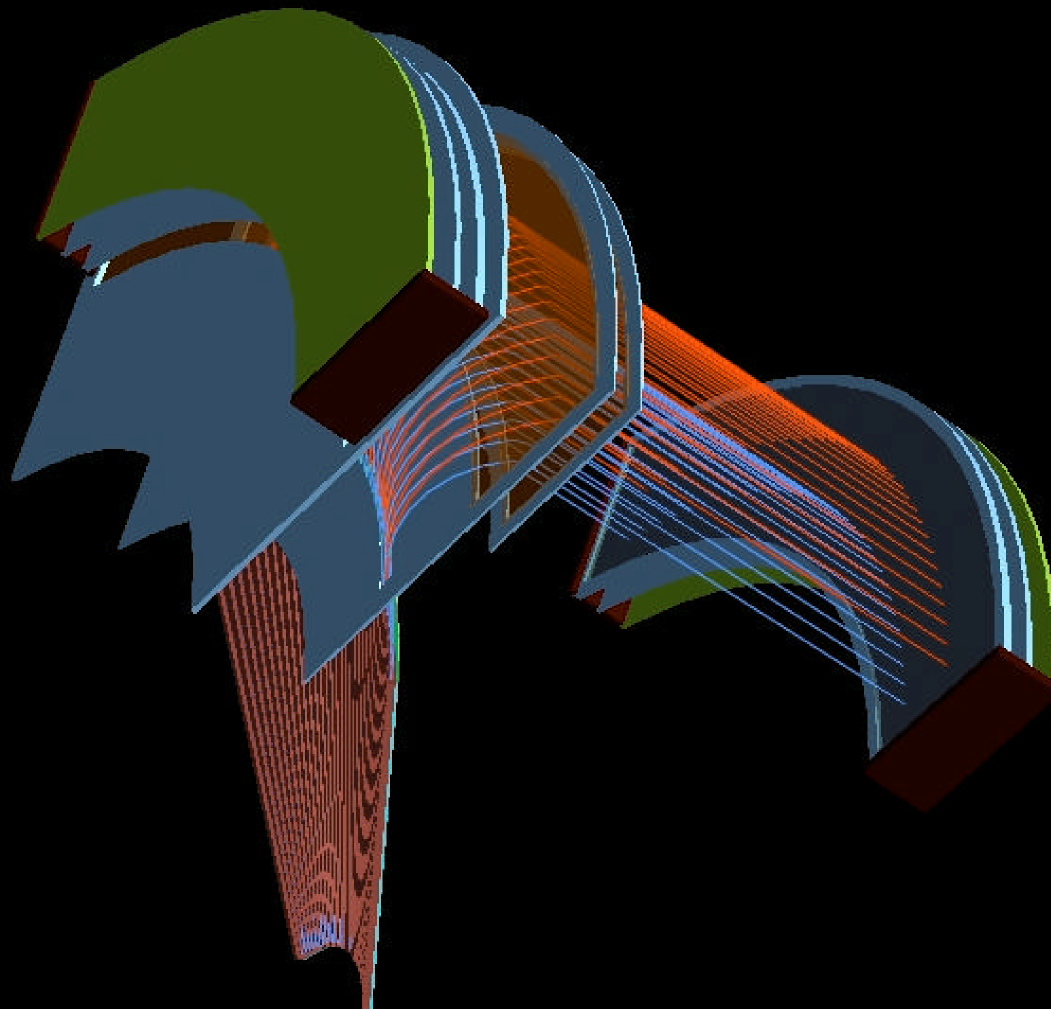
From SMART-1 /AMIE….. to BEPI SERENA

ELENA Layout

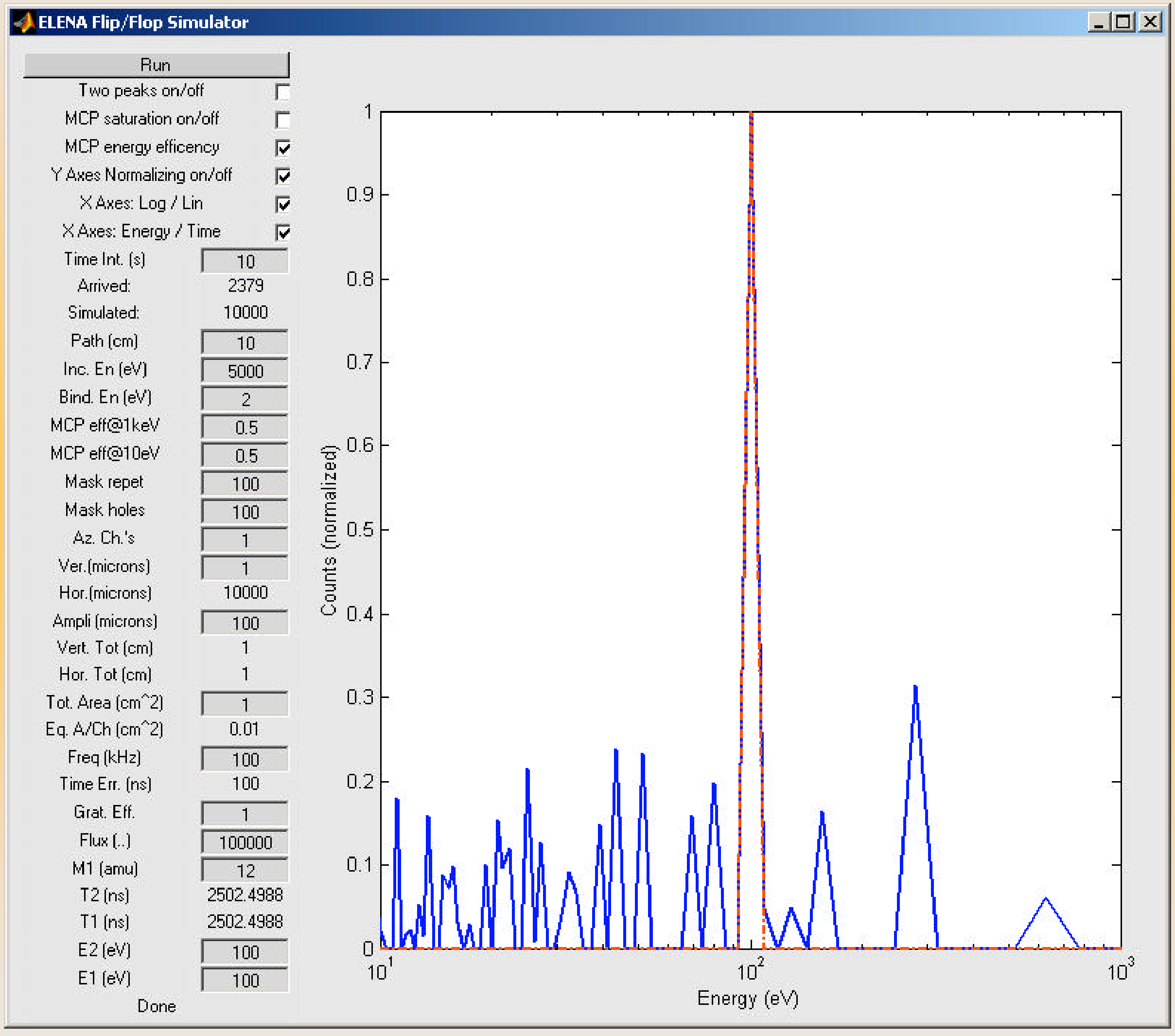




Former ELENA head core detector view



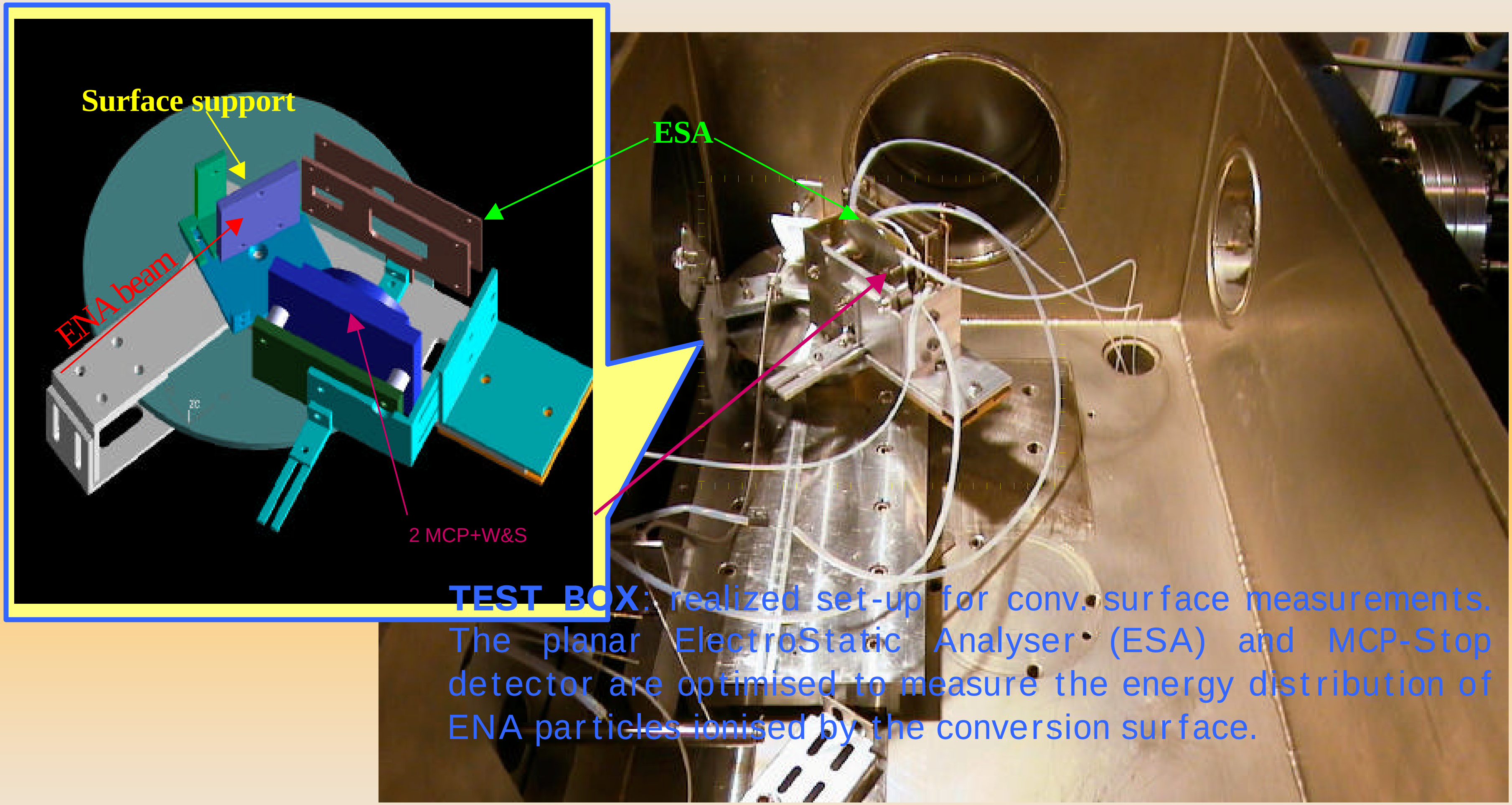
ELENA shuttering concept: the simulations



787-element Hadamard mask courtesy provided by *BeppoSax High Energy techniques and* astrophysics team (E. Costa).

Simulation supported by A. Mura IFSI

ELENA experimental activities



TEST BOX: realized set-up for conv. surface measurements. The planar ElectroStatic Analyser (ESA) and MCP-Stop detector are optimised to measure the energy distribution of ENA particles ionised by the conversion surface.

Outlook

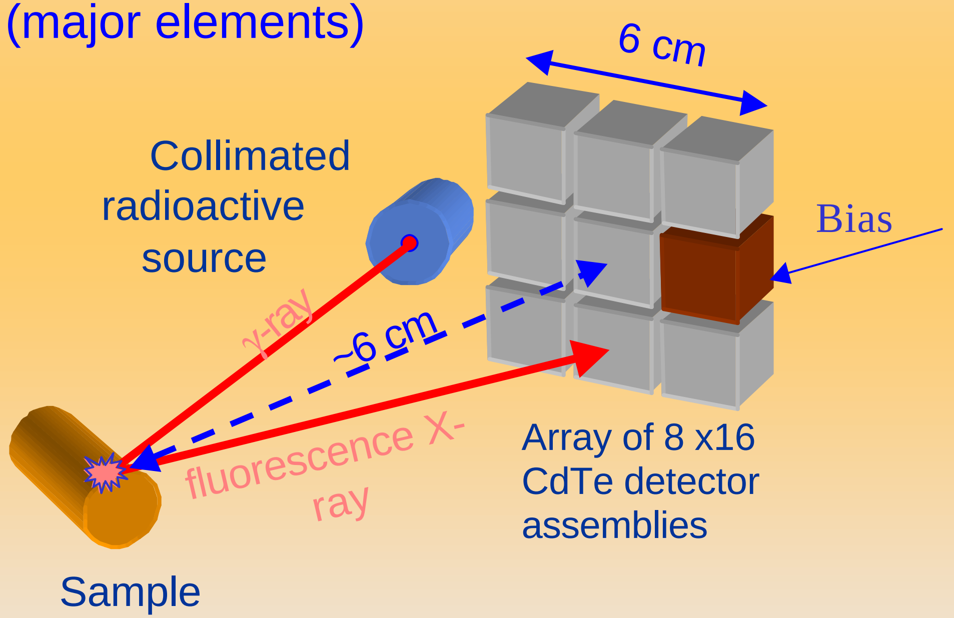
- **Selected instrumentation:**
  - **- Planetary surface instrumentation**

MSR2003 / EXOMARS: Ma_Flux

Geochemical investigation based on X ray fluorescence of trace elements heavier than Fe. This investigation is possible with recent developments of X ray CdTe and CdZnTe detectors. Ma_Flux furnishes 2 major information:

- The content of trace elements inside (few mm to 1cm deep) the geological material

- The measurement of the sample X ray absorption : this matrix effect is a function of the sample composition (major elements)

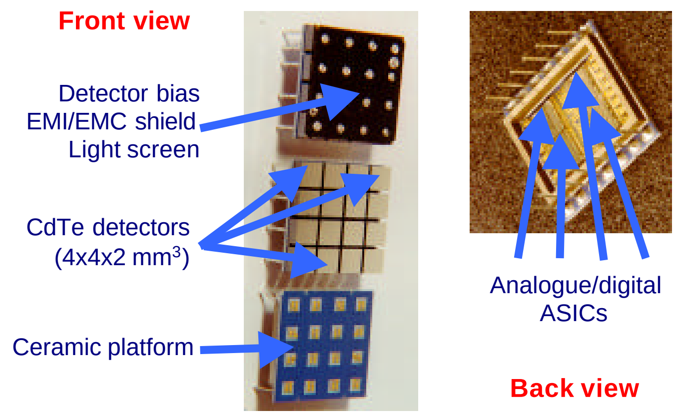


MA_FLUX Targets:

Identification of minerals, materials and geological processes

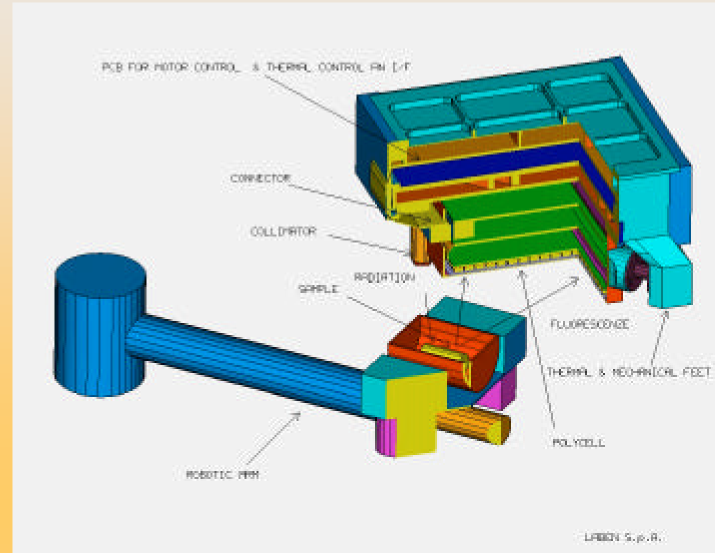
- Intensity of geological processes deduced from trace element abundances.

MSR2003 / EXOMARS: Ma_Flux



Each polycell is an array of 4x4 CdTe semiconductors read by four ASICs.

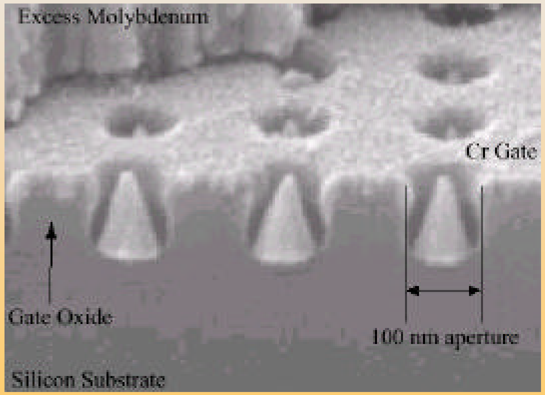
ESA-INTEGRAL ISGRI Detector inheritance

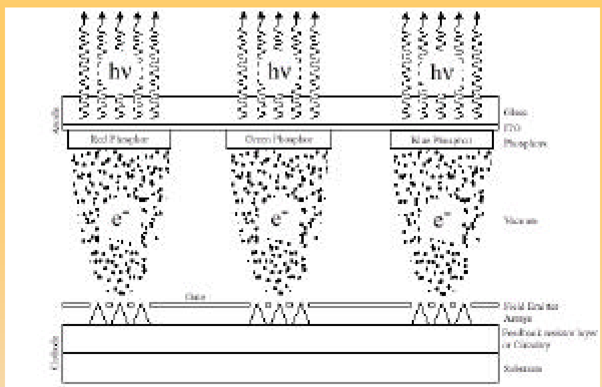


Ma_FluX schematic from LABEN S.P.A.

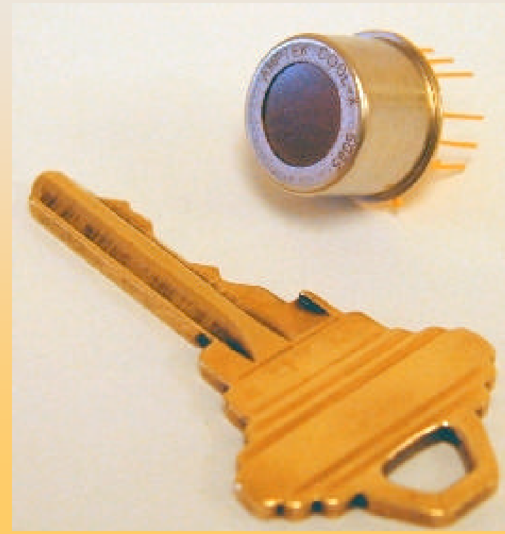
Elements	Fluorescence range (keV)	Gamma source (400 mCi)	Measured concentration in the “Shergotty” meteorite	Sensitivity of MA_FLUX
Rb, Sr, Y, Zr, Nb	13 - 19	^{109}Cd – 22 keV (Source #1)	150 ppm	10 ppm after 5h exposure
Ba, La, Ce, Pr, Nd, Pm, Sm	32 - 45	^{241}Am – 60 keV (Source #2)	50 ppm	10 ppm after 5h exposure
Eu, Gd,Tb, Dy, Ho, Er, Tm,Yb, Lu, Hf, Ta	41 - 65	^{109}Cd – 80 keV (Source #1)	10 ppm	10 ppm after 50 h exposure

EXOMARS Ma_FLuX source evolution





(Courtesy of Space Nat. Laboratories -MIT)
Field Emitter solution.



Integrated X-Ray Generator solution

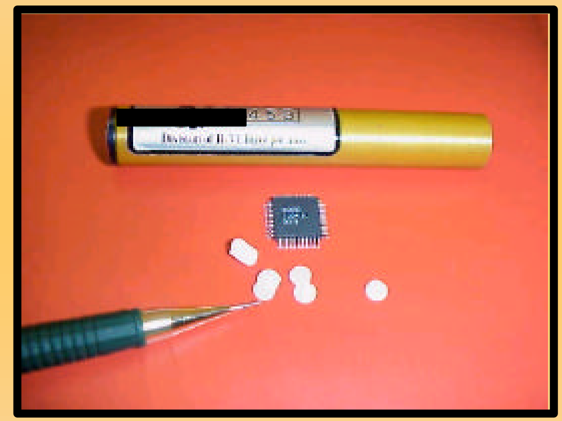
- **Miniature size: 15 mm dia x 10 mm**
- **Low power: < 300 mW**
- **Runs on standard 9 V battery**
- **Variable end point energy: up to 35 kV**
- **Peak x-ray flux: 10^8 photons per second (equivalent to a 2 mCi source)**
- **Solid state: Pyroelectric crystal**

<u>Now on-board R-sources feasible without radioactive elements !</u>

MSR2003 / EXOMARS MARE-Dose

Measurement reproducibility (same pill): 1σ @ 1mGy	within 2%
Readout signal	3000 c/μGy (DOSACUS - Rados) peak at 420 nm (≈ $5*10^3$ photons/μGy)
Annealing temperature (optimum)	≈ 240°C
Annealing time (optimum) at 240°C	≈ 15 min
Dimensions	4.5∅x 0.8 mm
Weight	~ 25 mg

MARE-Dose dual heads DM Lab assembly

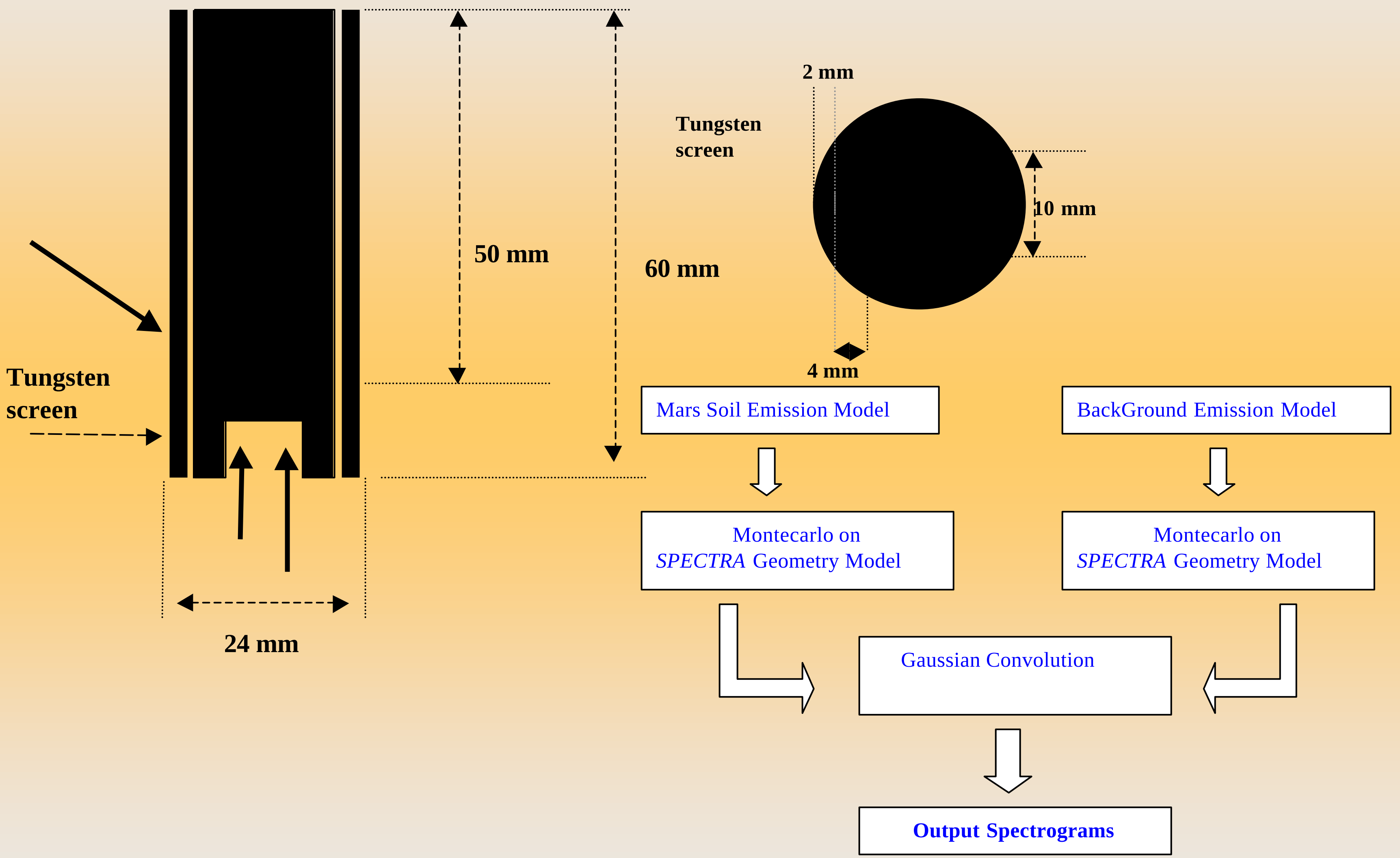


***MARE-DOSE* budgets**

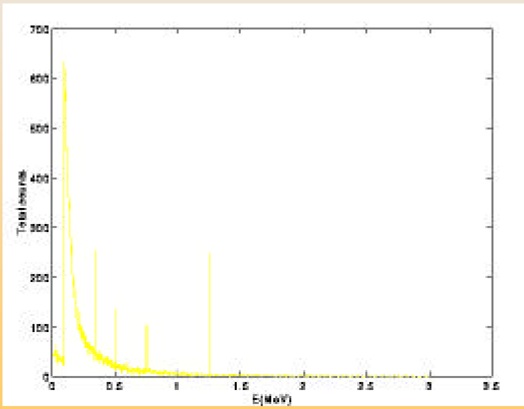
ITEM	WEIGHT (g) [ ] +Contigency	POWER (mW) [ ] +Contigency
Mini Oven	120	< 6500. Only spent during, rising-up to 240 °C for readout (25 s) and reset (10 min)
Box, optics & electronics	410	1325
TOTAL	**530 [640]**	**7825 [9400]**

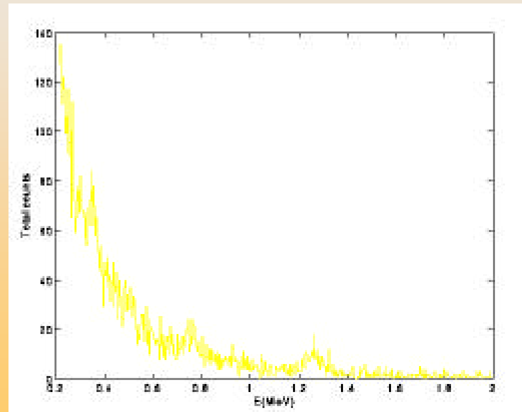
Dosimeters detectors and related processing ASIC with a self consistent CdZnTe unit for X-rays spectroscopy

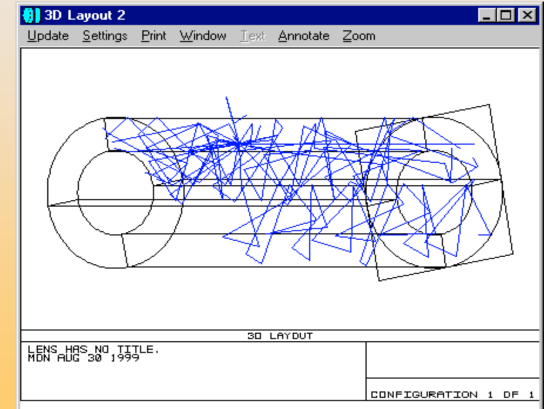
Mars MSR2005 / γ spectrometer



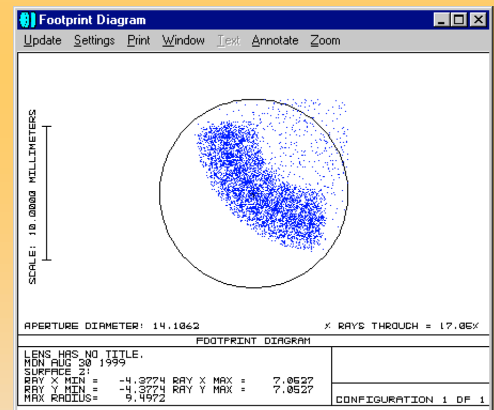
MSR2005 / γ spectrometer







2 hours integration time run. Left panel: total anticoinci-dented output spectrum . Right panel: as left panel but gaussian convoluted by a DE/E =8% line broadening to model the CsI detectorr resolution. Martian crust supposed to have 9000 p.p.m of potassium, 2 p.p.m. of thorium and 0.6 p.p.m. of uranium.



Optical signal propagation of a central event within a BGO quarter coated by 50% reflecting material (upper right). The output efficiency was found to be of the 17.05 % (lower left). The rays out of the BGO quarter geometry are due to the coating penetration.

Exomars - Ionizing Radiation Detector (IRAS)

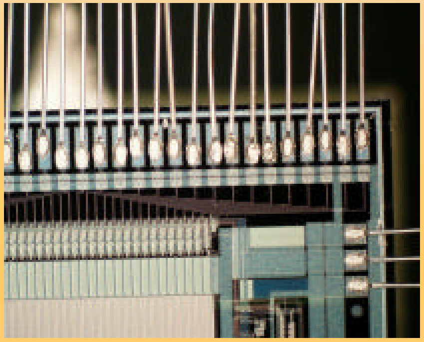
- **Radiation data collected on the surface of Mars are required for projecting crew health risks and designing protective surface habitats**
- **Identifying and quantifying hazards to humans on Mars**
- **Assessing Martian surface habitability in search for putative Martian life**
- **Multiple measurements are preferred to characterize temporal and spatial variations**
  - **Solar Minimum and Solar Maximum**
  - **Atmospheric and Surface Variations**
- **Providing ground truth for Mars environment models**

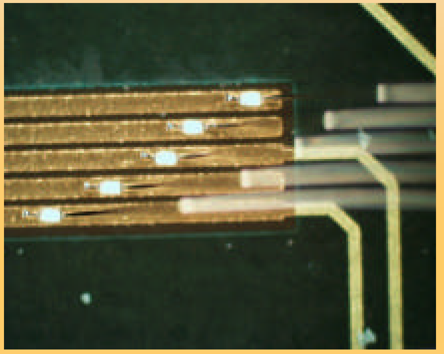
IRAS Returns:

- **IRAS shall monitor the radiation field during cruise to Mars and on Mars**
- **IRAS shall separate between solar and galactic particle**
- **IRAS shall separate ionising particles from neutrons**
- **IRAS shall measure dose and LET spectra on the Martian surface.**
- **Measurements are used to benchmark models**

AMDL supports the IRAS Electronics & S/W

- **Produced a complete DM (EM representative) set of the electronics boards: Power I/F, DPU, Proximity boards**
- **Integrated most critical component i.e. the telescope front-end ASIC (50 um pitch) on Proximity PCB,**





POWER I/F Board

- **Fully Assembled, Fully Operated & Tested, Integrated with Control Unit board**

DPU Board

- **Fully Assembled, Integrated with Power board, Relative CU developing board fully operated, Operated with programmer**

Proximity/AFE Board

- **Fully Assembled including most demanding placement of ASIC**