SPACE TRANSPORTATION

MEMSRAD – MEMS Sensitivity to Space Radiation

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All the space you need

EADS astrium

Outline

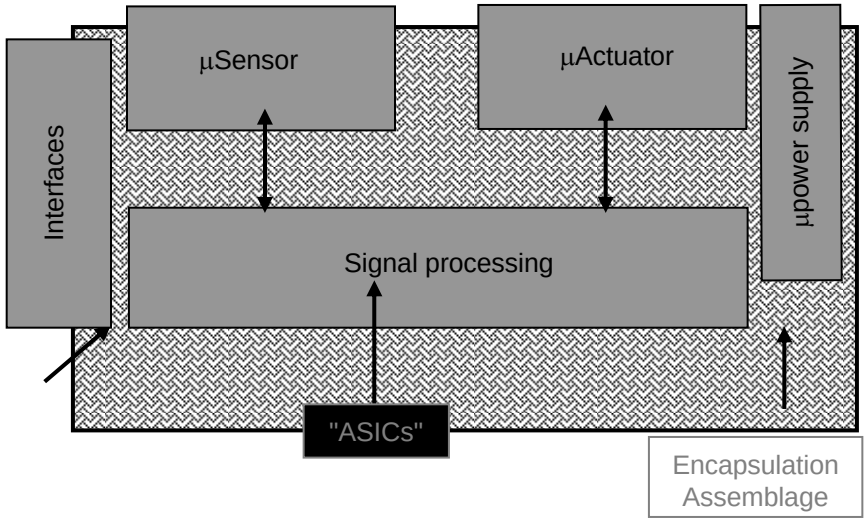
- Introduction
- MEMSRAD Goal
- MEMS Selection Criteria
- Selected MEMS Presentations
  - Accelerometers
  - RF MEMS
- Preliminary Results
  - Acceleromaters
  - RF MEMS
- Conclusions

Introduction (1/3)

- MEMSRAD Contract
  - ESA/ESTEC Contract n°: 20293/06/NL/CP
  - Duration : 24 months
- Members of Consortium
  - EADS - Astrium Space Transportation : Prime
  - Sub Contractors:
    - EADS Innovative Works, Ottobrun (Ge)
    - Thales Alenia Space, Toulouse (Fr)
    - Infoduc (Fr)

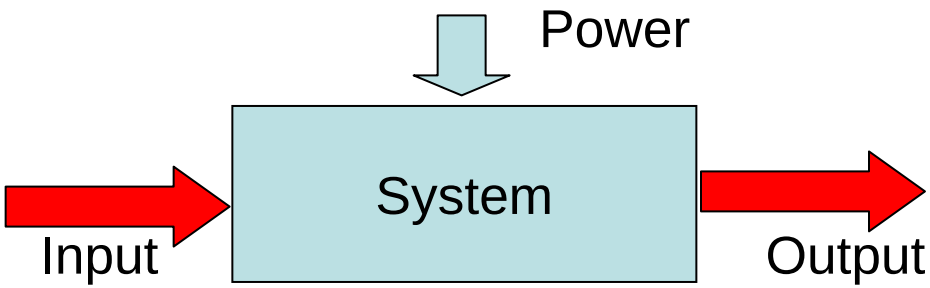
Introduction (2/3)

- MEMS :
  - A system with atleast 2 functions:
    - Sensor / Actuator + Signal treatment
  - Manufactured / assembled:
    - On a single wafer: monolithics,
    - With few wafers: hybride



USA MEMS : Micro-ElectroMechanical Systems
MOEMS : Micro-OptoElectroMechanical Systems
JAPON Micromachines
EUROPE Microsystèmes
MST(MicroSystems Technology)

Introduction (3/3)
MEMS and Microelectronics

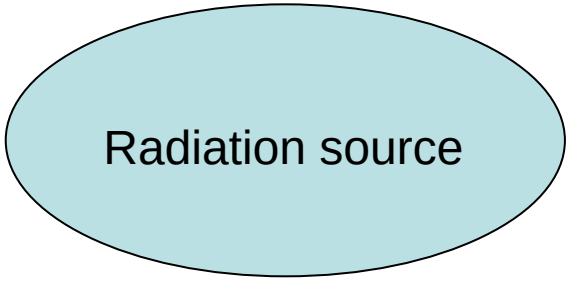


System	Input	Output
Microelectronic	Current, Voltage, frequency	Current, Voltage, frequency
MEMS Sensor	*Acceleration, Temperature, Rotation Pressure*	Current, Voltage, frequency
MEMS Actuator	Current, Voltage	*Contact, Rotation, Translation,…*

MEMSRAD GOAL (1/2)
Radiation Guidelines

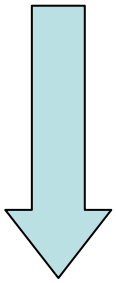
- Purpose of this work
  - Prepare guidelines for Radiation Testing of MEMS
  - Help to perform characterization of MEMS and obtain meaningfull results.
  - Allow different « End-Users » to share and compare results obtained with a common testing procedure.
- Methodology
  - Analysis of existing Radiation Testing Guidelines and Methods
  - Identification and Classification of MEMS
  - Identify important points to adapt or modify the guidelines
    - a priori
    - after performing tests on MEMS
  - Consider other Guidelines applied to MEMS:
    - Reliability evaluation
    - Specific testing methods related to the specific function

MEMSRAD GOAL (2/2)
MEMS sensitivity to space RADiation



Particle, Energy,
Flux, Fluence,
Dose Rate,
Dosimetry

Effects:
TID, DD, SEE



MUT
(MEMS Under Test)

Inputs, bias,
temperature,
ouputs,….

Radiation Tests Facilities:

- Total dose: Co60 (ESA/ESTEC)
- Single Event Effects
  - Heavy ions (UCL)
  - Protons (PSI)
- Displacement Damage
  - Protons PSI (E=150MeV)

Selection criteria for MEMS (1/2)

Criteria:

- European source
- Matured Technology,
- Matured Product with high TRL for other applications
- Industrial production (avoid prototypes!)
- Availability
- Manufacturer cooperation (highly recommended)
  - Willingness to work for space applications
  - Providing samples
  - Providing sufficient technical informations (not a « black box »)
  - Possibility to exchange technical data's during the testing
  - Short & mid term participation
    - to improve the product, if necessary
    - appropriate packaging, redesign an ASIC (rad tolerant/hardened), etc.

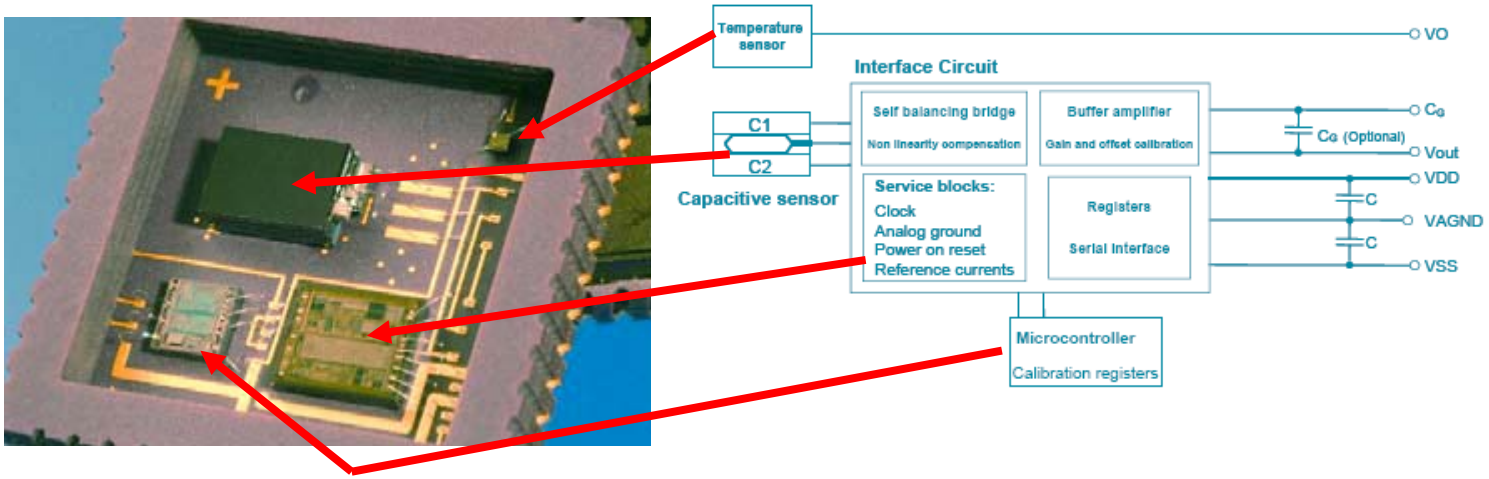
Selection criteria for MEMS (2/2)

Criteria:

- Potential Space applications
- Past radiation experiences (internal, external)
- Expected radiation effects
  - TID (Total Induced Dose)
  - SEE (Single Event Effects)
  - DD (Displacement Damage)
- Availability of 2 type of MEMS at same time for radiation testing
- Easy to test:
  - Before and after different radiation testing
  - Possibility to do the « on-line » parameters during different radiation testing
- Possibility to separate the contributions from:
  - Sensing element
  - Electronic circuits
- To allow the improvements in our « Radiation Guidelines » at the end of testing

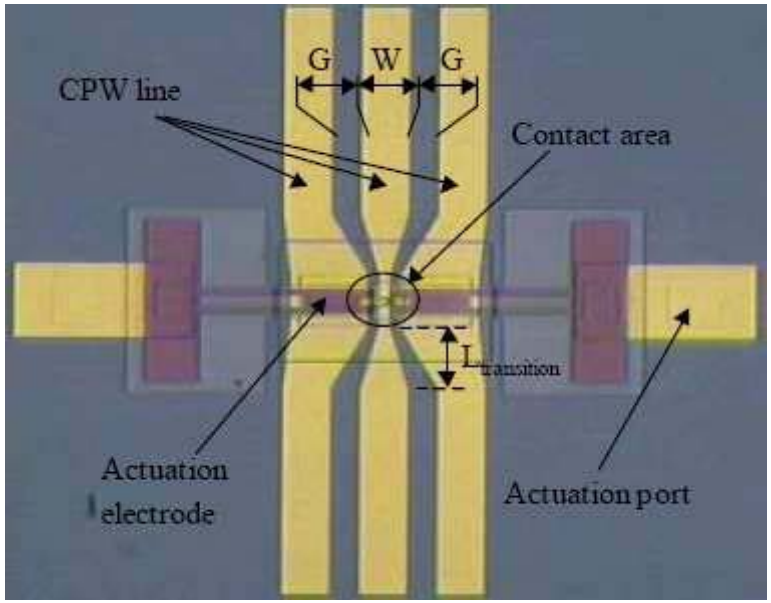
SELECTED MEMS Presentation (1/2)

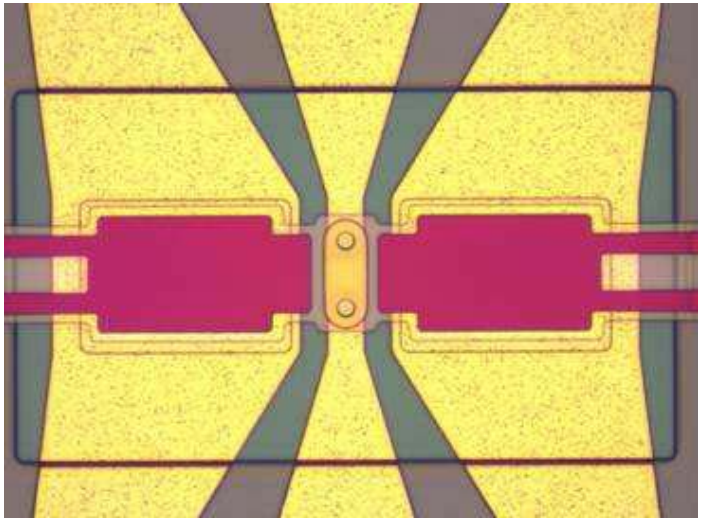
MEMS Type 1: Colibrys Accelerometer description



SELECTED MEMS Presentation (2/2)

MEMS Type 2: RF MEMS from LETI-CEA





Ohmic contact switch

Preliminary Results

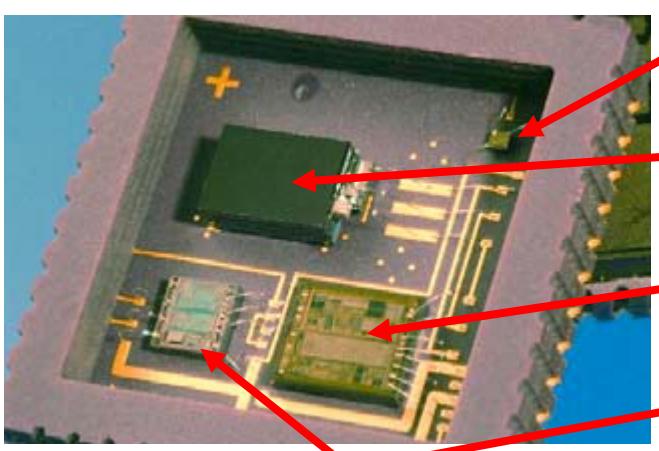
Test preparation: Initial measurements

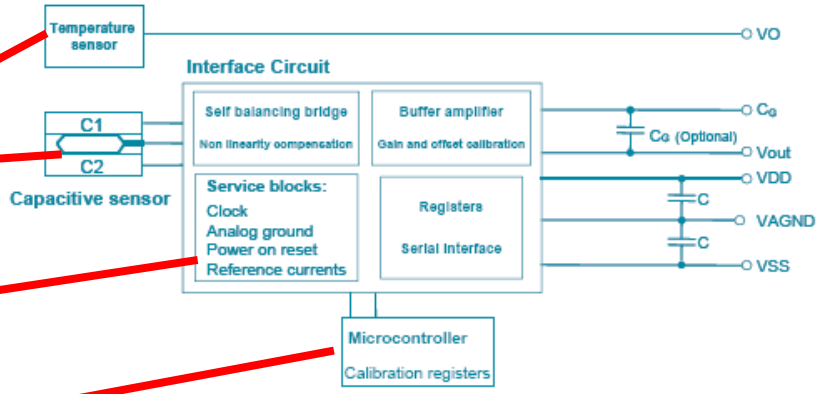
- Obtain devices and verify the stability of the process
- Define or use standards on measurement procedures
  - Verify the homogeneity of a given lot
  - Verify the stability of the parameters:(sensitivity to temperature, humidity)
  - Verify the possibility to test the devices in the irradiation facility (package, thermal dissipation, mechanical state)
- Ex: Special adaptation:
  - Test Jig RF-MEMS
  - Accelerometer positionning

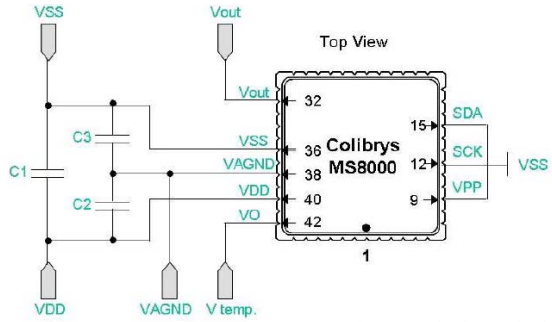
Preliminary Results

Accelerometers

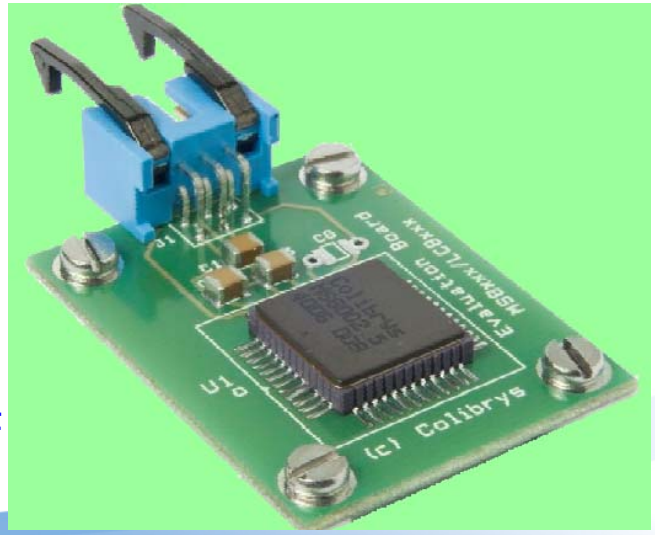
DUT (Accelerometer) description:







C1=C2=C3=1µF

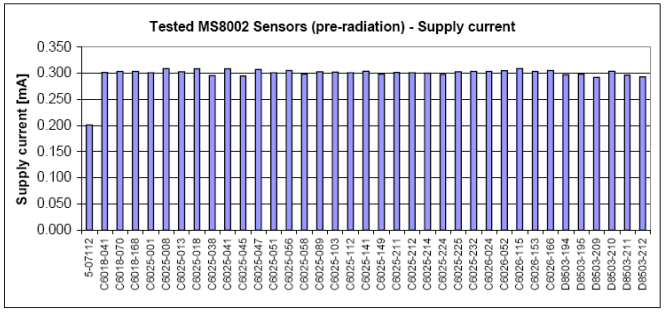


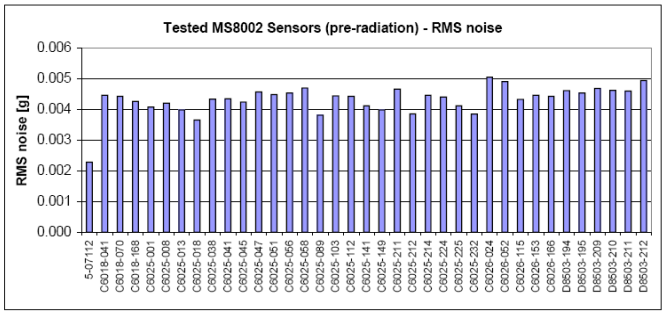
Preliminary Results

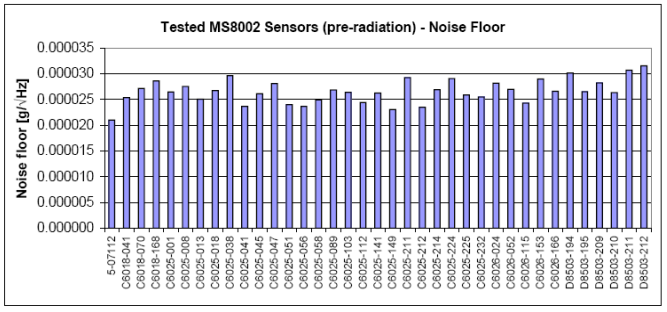
Accelerometers

Pre irradiation measurements

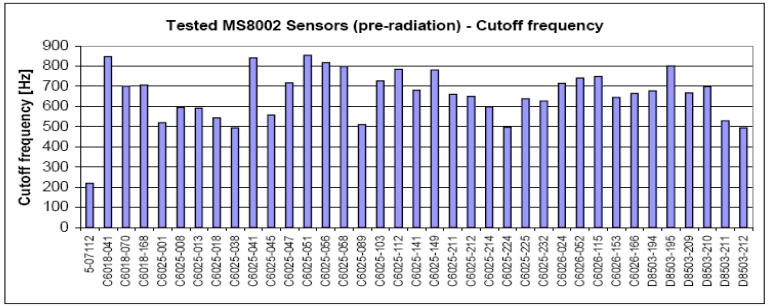
MS8002 Test Results (pre-radiation)

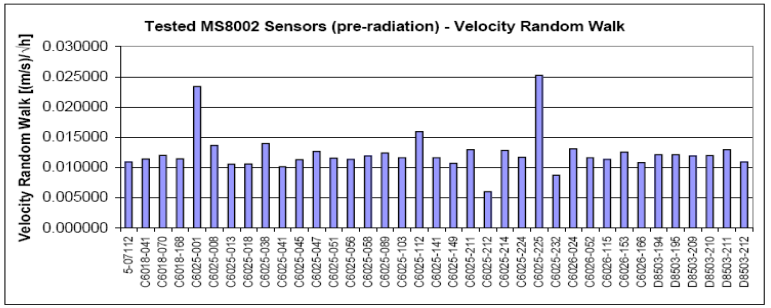


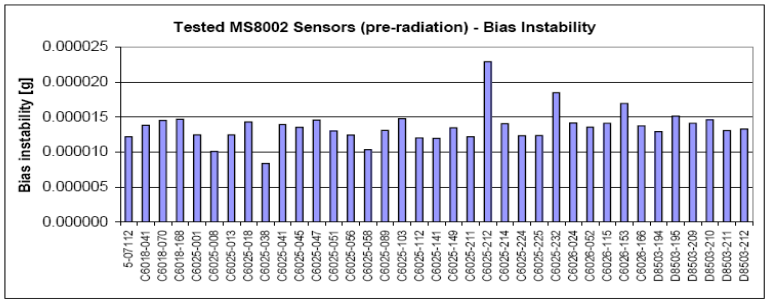




MS8002 Test Results (pre-radiation)



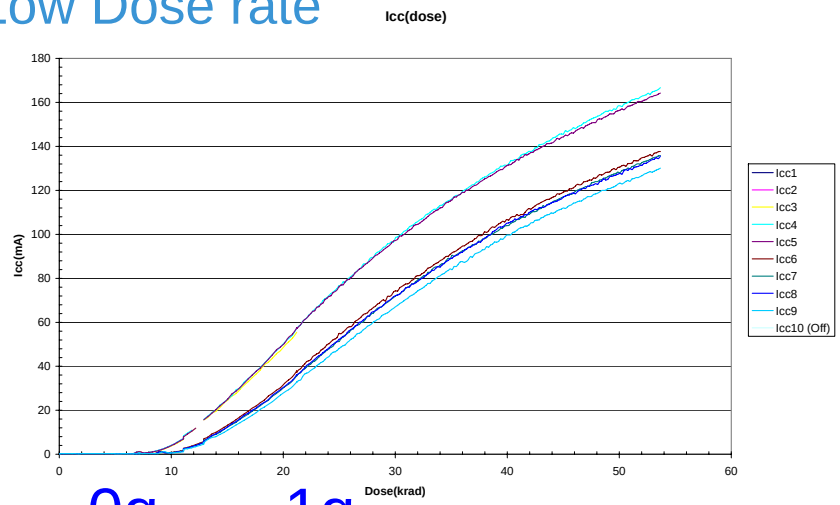


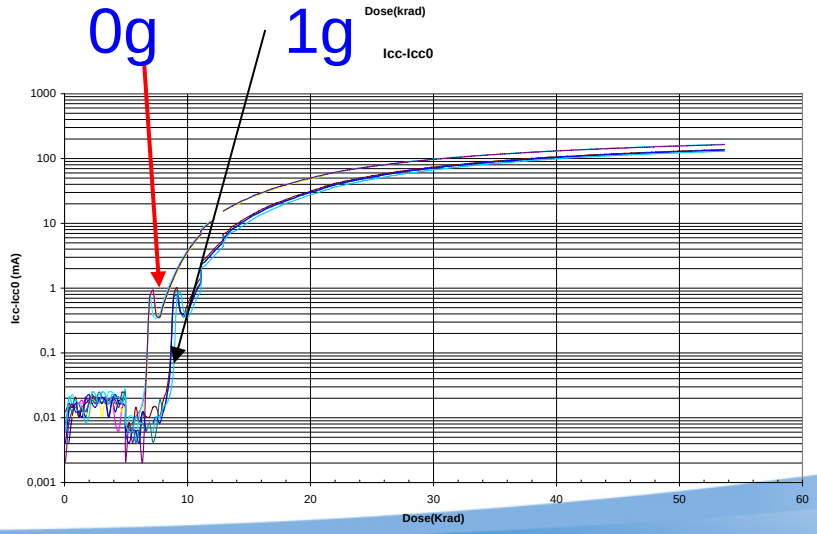


Preliminary Results

Accelerometers **TID**

On line measurements Power supply Current
Low Dose rate





- Strong increase of power supply current

Log scale:
Increase begins at 6-8 krad
Threshold related to input: 1g or 0g

Preliminary Results

Accelerometers – Heavy Ions

Heavy ion test results

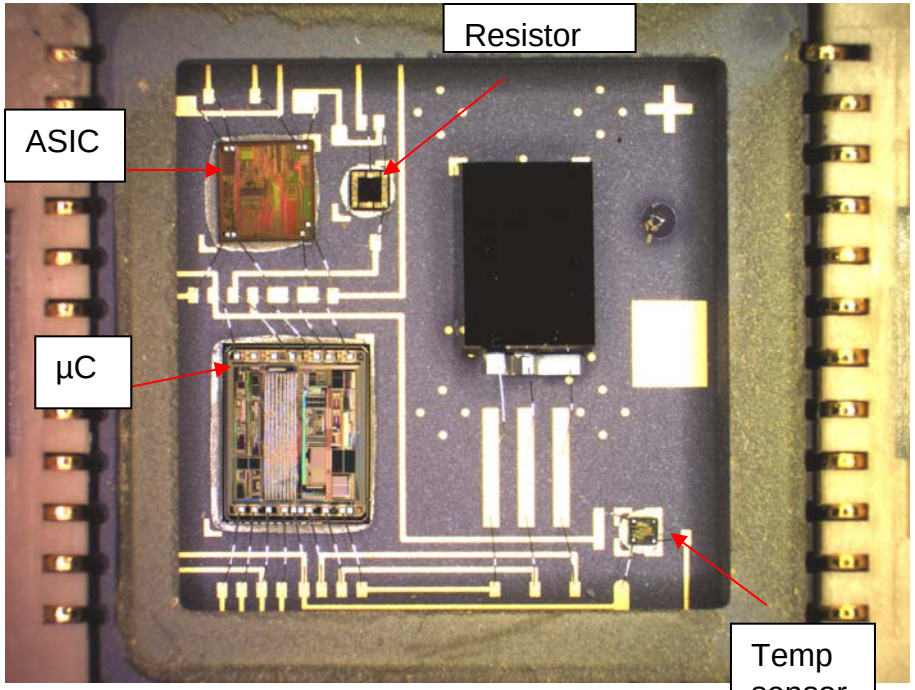
- Heavy ion range: a limitation to test sensors
- System response to heavy ions:
  - Understand the system behaviour: electrical response, calibrations, reset
  - Example of SET

Preliminary Results

Accelerometers - Heavy Ions

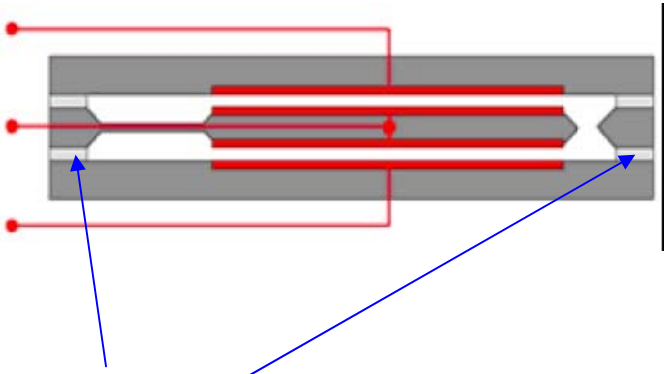
Separation of the contributions

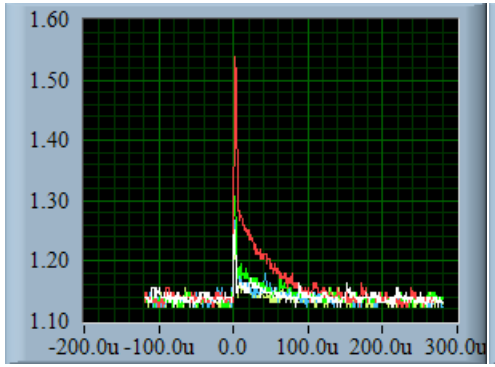
- Irradiation of one part at a time
  - Acceleration Sensor
  - Temperature sensor
  - ASIC +resistor network
  - Microcontroller (µC)
- Difficult to verify if ions do not reach other parts

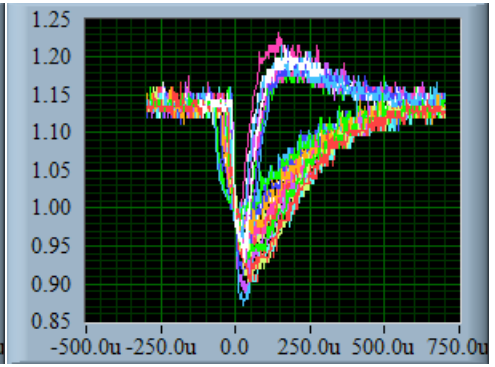


Preliminary Results
Accelerometer - Heavy Ions

Tests on acceleration sensor : at 0g







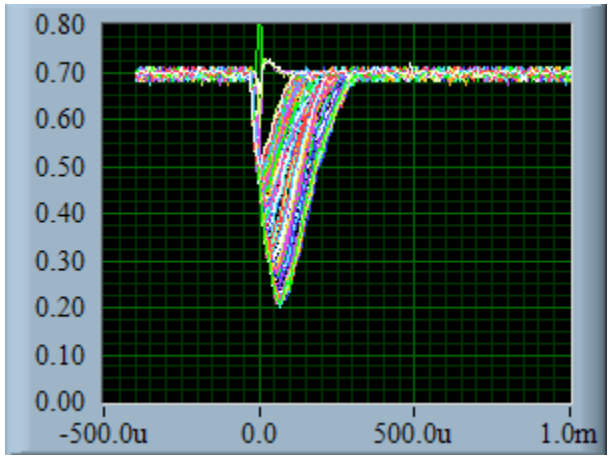
Only Heavy Ions with the highest range induce a transient

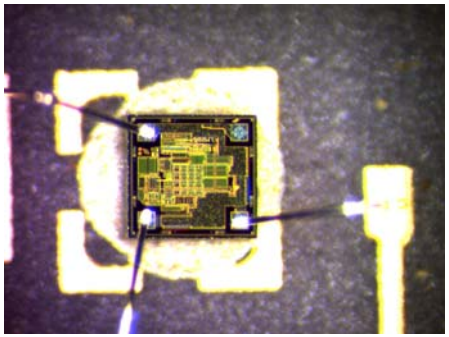
Much more negative than positive transients

Preliminary Results
Accelerometer - Heavy Ions

Test on temperature sensor: LM20

Negative transients are observed
Broad variation of amplitudes





Preliminary Results
RF MEMS

Test plan : Number of sample status

Sample repartition as planned in Test plan

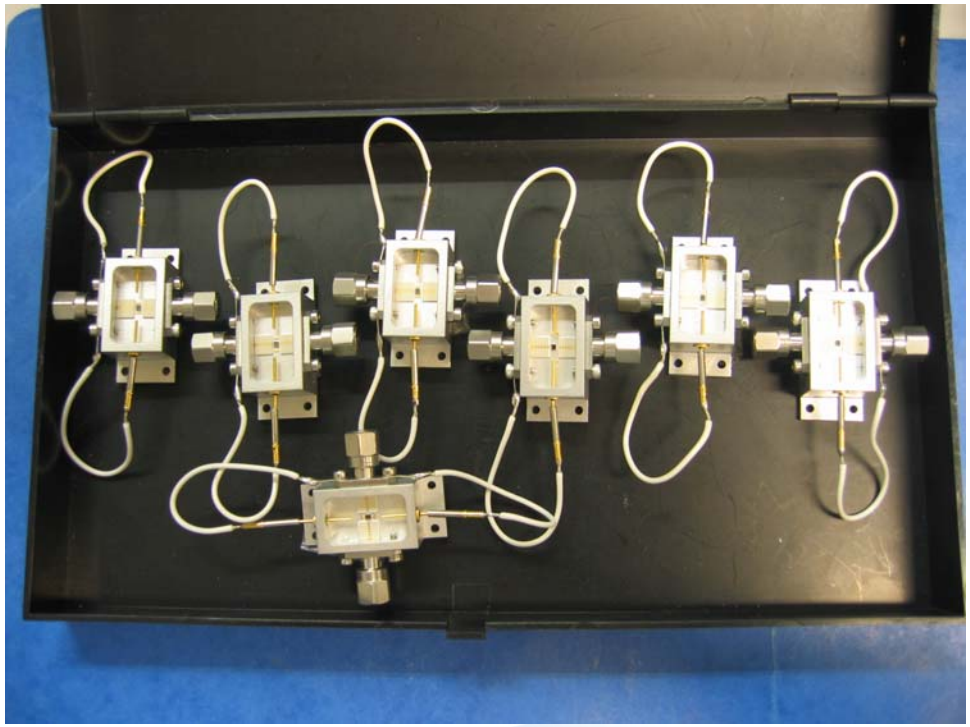
TID LDR		
Conditions	**Samples**	
1	3	
2	3	
3	3	
4	2	
Ref		2
Total (1) :	11	2

TID HDR	
Conditions	**Samples**
x	3
Total (2) :	3

Heavy ions tests			
Total :	3	Ref :	2

Protons			
Total (3) :	8	Ref :	2

Total = (1) + (2) + (3) : 25 Samples
Total ref : 2 Samples



Preliminary Results
RF MEMS

Focus on : Heavy ions test

- During Heavy Ions test we were looking at the following effects:
  - SET: Single Event Transients
  - Permanent Damage (increase of leakage current)

- SET: If the deposited charge in Si3N4 amplified by possible multiplication of charge carriers due to the Electric field

- Permanent Damage: If the heavy ion can modify the structure of the dielectric (thermal spike)

CONCLUSION (1/2)

Preliminary Conclusion on TID & Heavy Ions testing: Accelerometers

- TID : Increase of power supply current starts at 6 – 8 krad
- Heavy Ions:
  - No Latch-up observed
  - SET's observed on acceleration sensing element, temperature sensor
- Next : Deep Analysis on-going with MEMS manufacturer « Colibrys »
  - Protons Testing results
  - TID testing results
  - Heavy Ions

CONCLUSION (2/2)

Preliminary Conclusion on Heavy Ions testing: RF MEMS

- No SET observed
- No significant increase of leakage current
- Pre-radiation and post-radiation measurements:
  - Shift of Vpin and Vpout by about 5 V on all samples including non irradiated piece. Voltage shift is even larger on non irradiated parts.
  - Heavy ion radiation effects cannot be demonstrated with before/after irradiation measurement comparison.
- Next : Testing with Protons (Analysis on-going) and Dose (gamma) testing