# Activities at the Calliope facility at ENEA - Casaccia

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# Calliope facility

*irradiation plant*

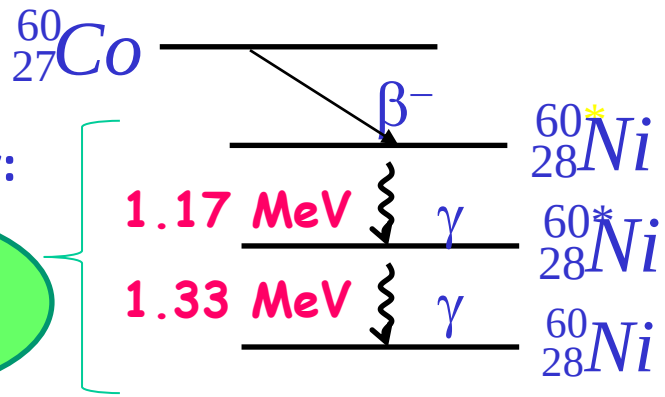
*laboratory*

**Qualification test**
Nuclear and space applications

**Experimental researches**
Chemical, physical and biological effects

# $^{60}$Co Calliope irradiation plant - 1

## Casaccia R.C., Rome




**Mean energy:**

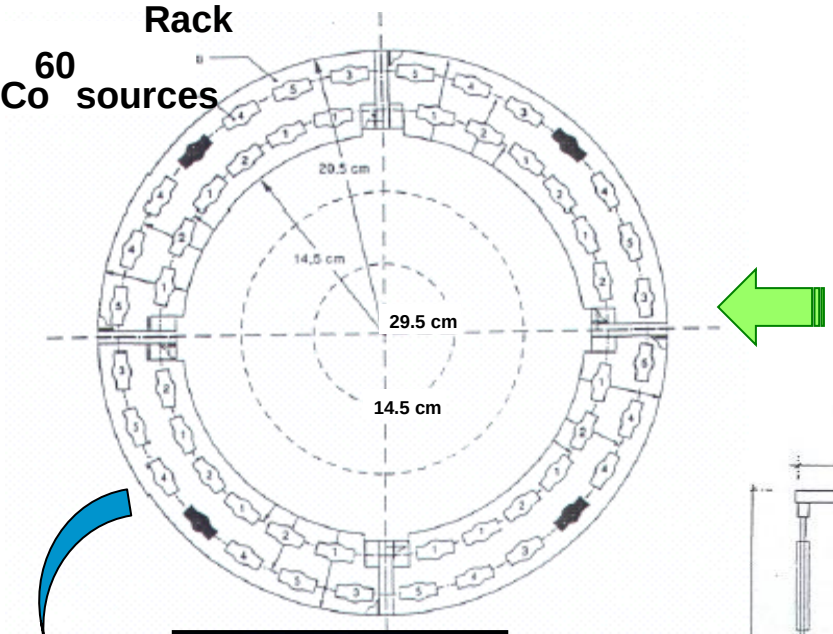
**1.25 MeV**

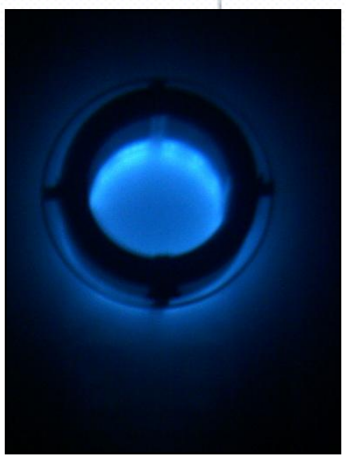
**Maximum allowed activity: 3.7x10$^{15}$ Bq (100kCi)**

**Maximum dose rate along the rack longitudinal axis**

Pool-type irradiation facility equipped with a $^{60}$Co γ source in a **high volume** (7×6×3.9 m$^3$) **shielded cell**.

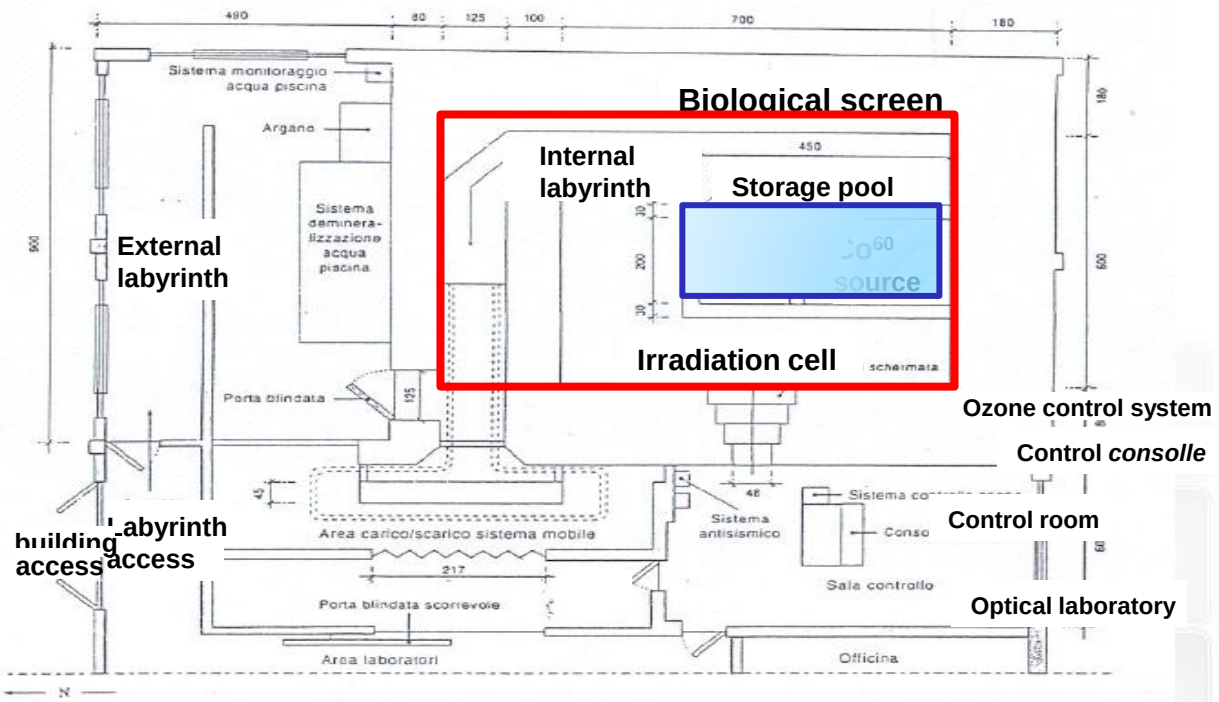
# $^{60}$Co Calliope irradiation plant - 2



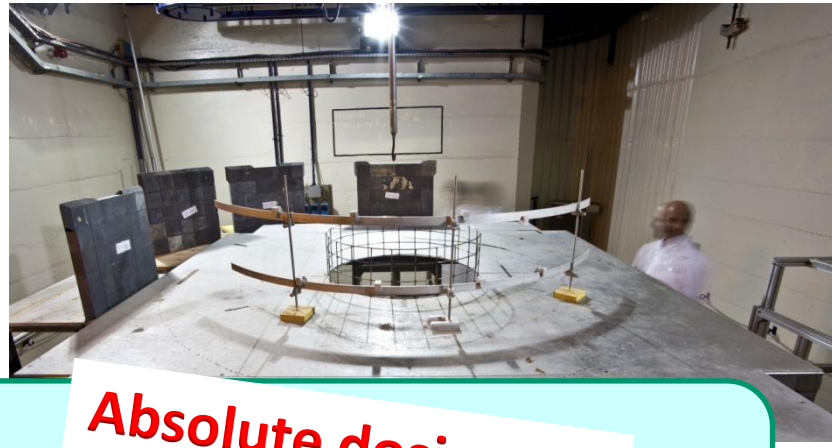
Cherenkov effect

The present source has **cylindrical geometry** with the **48 source rods** arranged in two concentric cylinders of about 20 cm outer radius and 26 cm height



# $^{60}$Co Calliope irradiation facility - Dosimetry

**Certification**



## 4 dosimetric systems:

### Fricke dosimeter (20-200 Gy)

$Fe^{2+} + H_2O_2 + g \Rightarrow Fe^{3+} + HO^- + OH^\bullet$

$Fe^{2+} + OH^\bullet + g \Rightarrow Fe^{3+} + OH^-$

**Absolute dosimeter**

Spectrophotometer UV-VIS (304 nm)

### Red-Perspex dosimeter (5-40 kGy) and radiochromic (1 kGy-3 MGy)

Polimetilmetacrilate and radiocromic film + γ

Spectrophotometer UV-VIS and radiocromic analyser (640 and 510 nm) *Optical density*

### Thermo Luminescent Dosimeter (TLD)

LiF, $CaF_2$

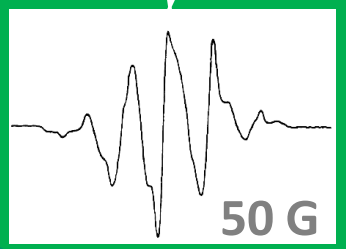
n & γ

(1 mGy-100 Gy)

### ESR dosimeter with alanine

(1Gy-500 kGy)

γ

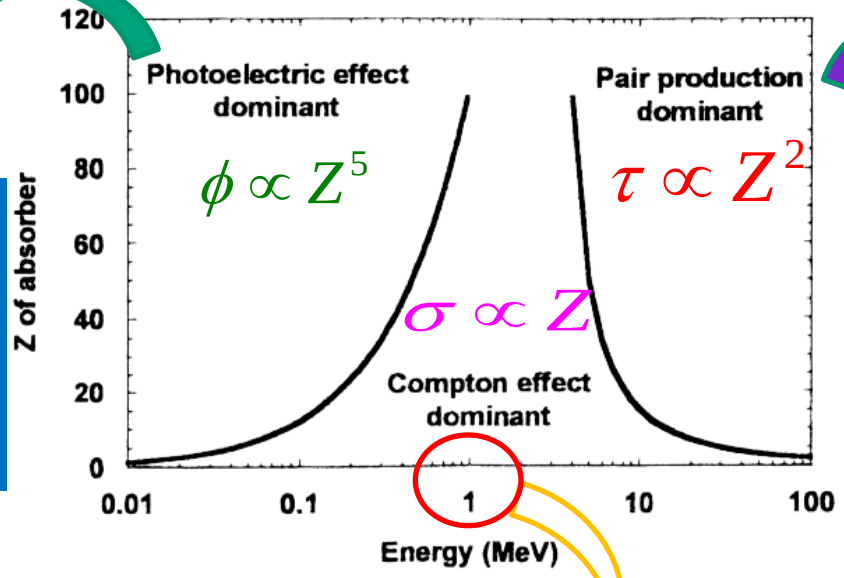


# Interaction of gamma rays with matter

**Photoelectric process**

a photon is completely absorbed in a collision with an electron and the electron is ejected from the atom

$E = h\nu - E_0$

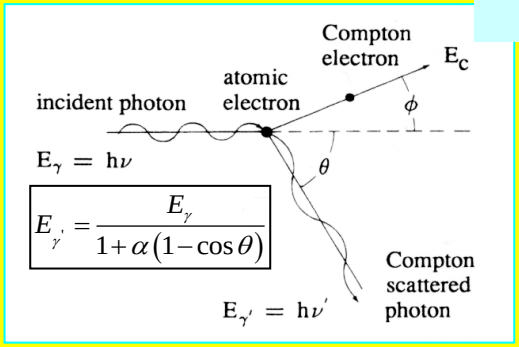



**Pair production**

a photon interacts with a nucleus and disappears with the production of two particles, a positive and a negative electron.

**Compton scattering**

$$E_{c(\max)} = \frac{E_\gamma}{1 + \frac{0.511}{2E_\gamma}} MeV$$




***Secondary processes:***

Auger emission and fluorescence (photoelectric effect),

recoil electrons emission (Compton effect),

positron annihilation (pair production).

# Calliope irradiation process monitoring system - 1

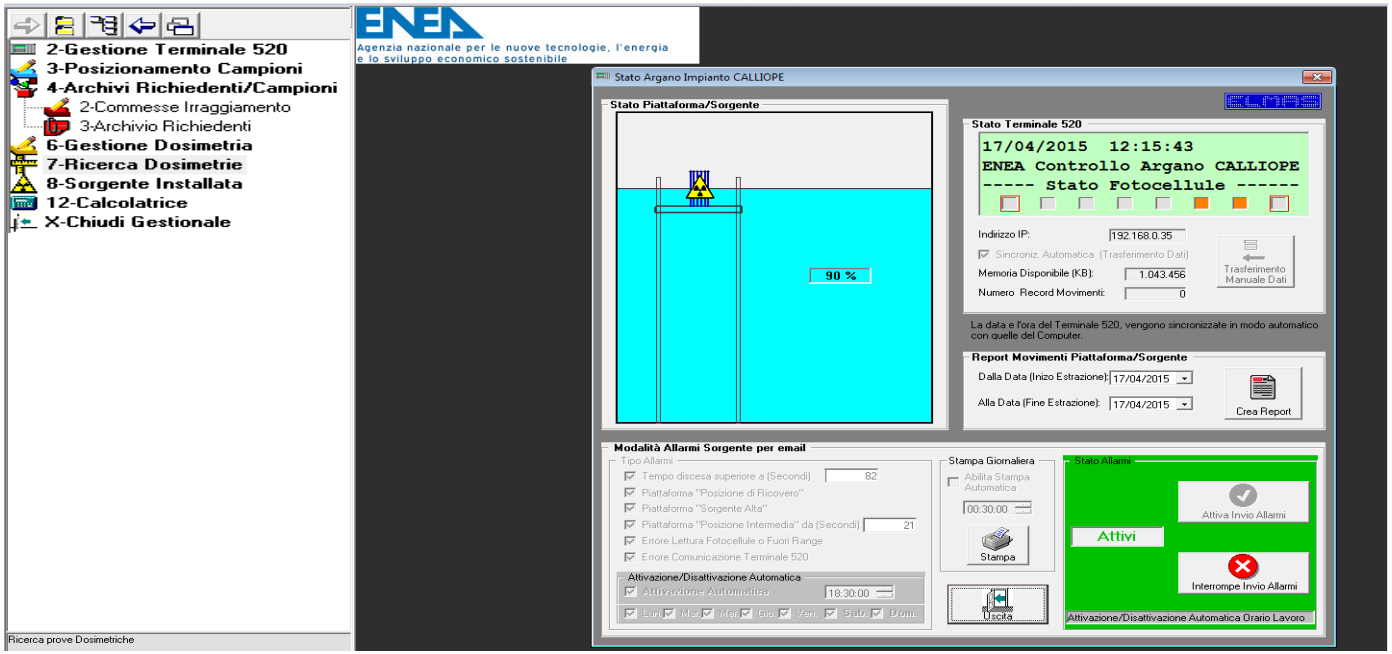
**A dedicated software is set up for different purposes :**

- **source information (dimension, geometry, activity)**
  - **dosimetry (dosimetric experimental measurements, dose rate values and related irradiation positions)**
    - **source rack position monitoring (optical sensor array, local interface) to check the exact position of the source rack at any time**

optical sensors array

source platform wrinch reel

# Calliope irradiation process monitoring system - 2



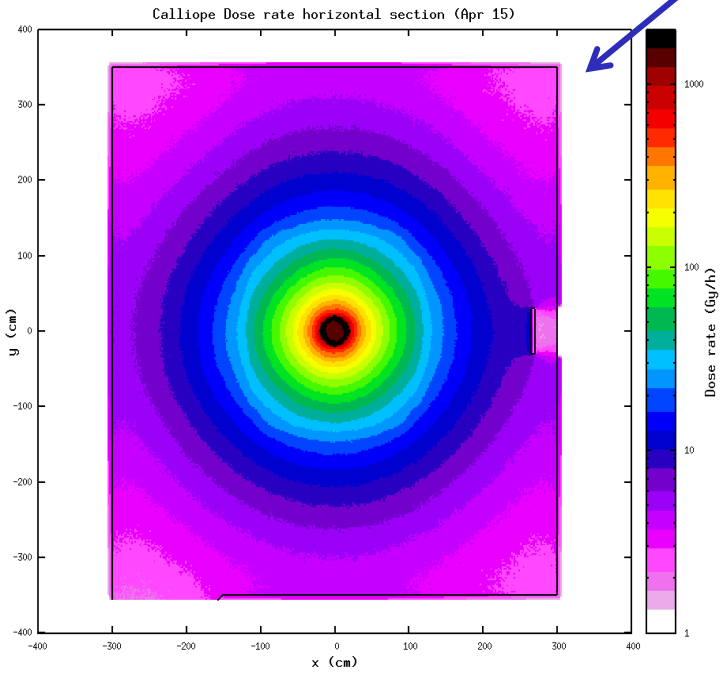

**Screen shot of the source rack monitoring system**

- **samples management and dose certification (scheduling and reporting software for the planning of the irradiation tests; interfaced with the source rack position monitoring system to allow the filling of the irradiation certificates)**

# Simulation of γ radiation field inside the cell - 1

To **map** the γ radiation field inside the irradiation cell, a simulation of Calliope dose rate profile has been performed by using **FLUKA code.**

**FLUKA Simulation of the source rack and of the irradiation cell**

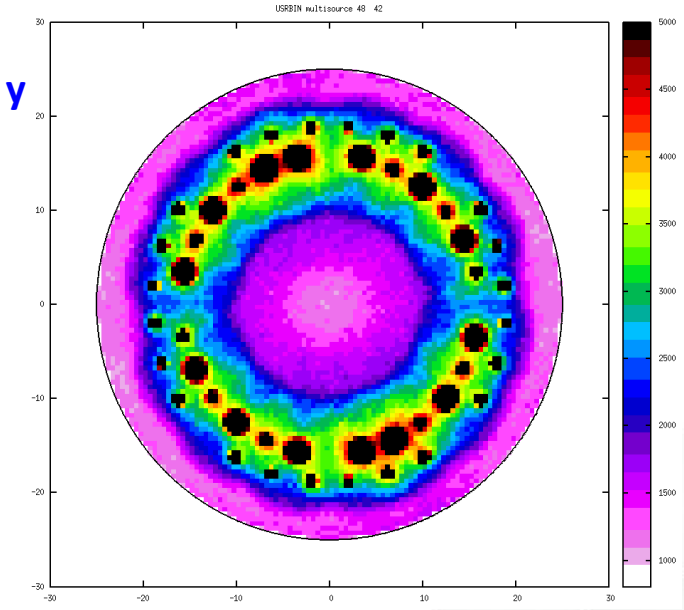



Top view x-y of the dose rate profile in the overall irradiation cell

**Colors are proportional to dose rate.**

Usable area for irradiation now is up to 1.7 kGy/h

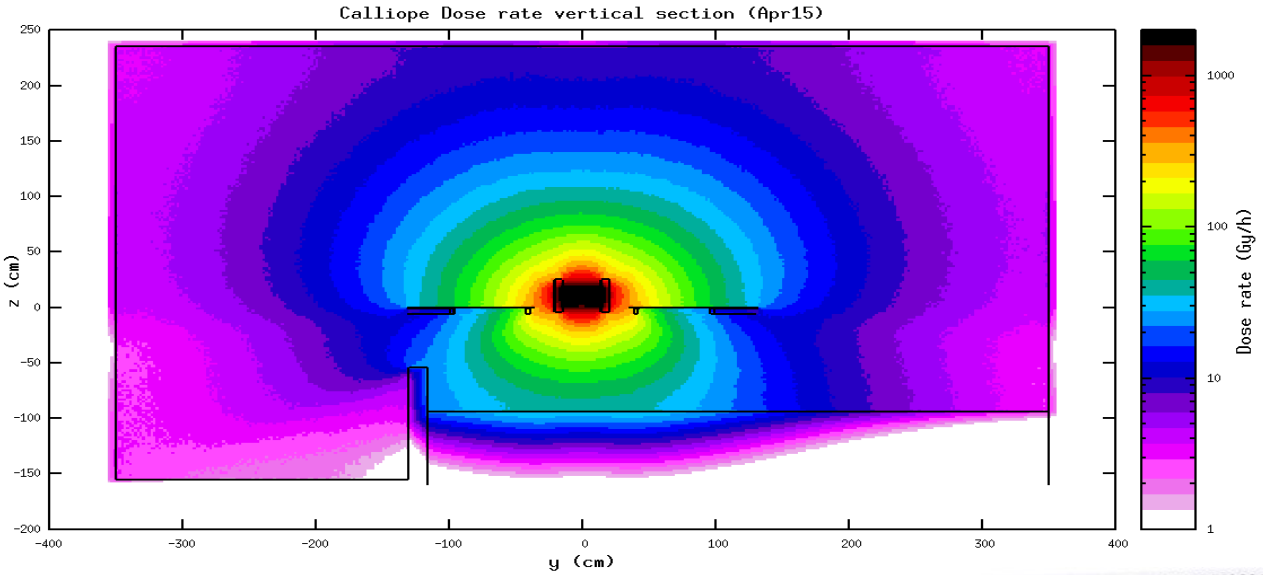
View of the 48 $^{60}$Co rods in the rack. Surrounding media is air




Top view

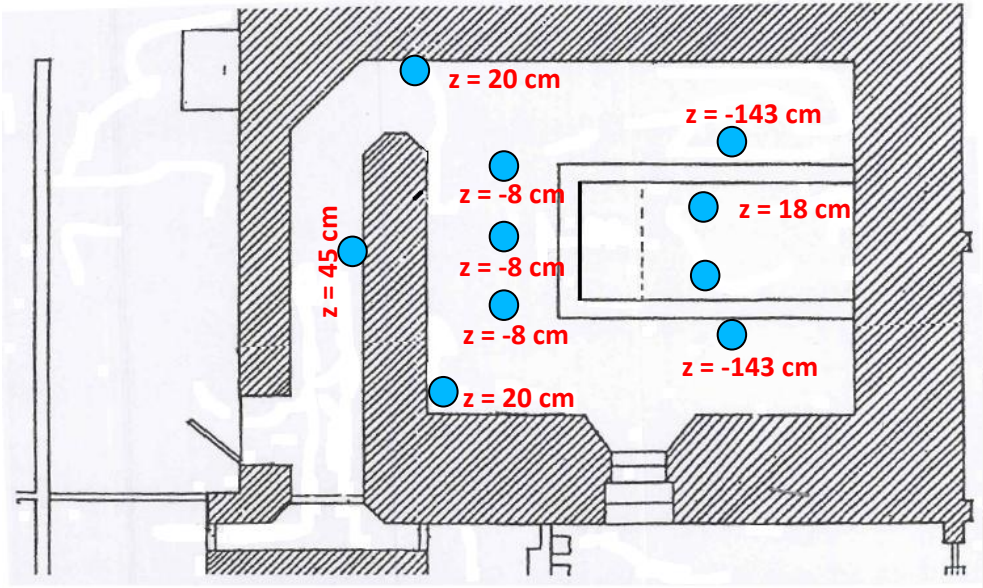
**Symmetrical dose rate distribution in the middle of the rack**

# Simulation of γ radiation field inside the cell - 2

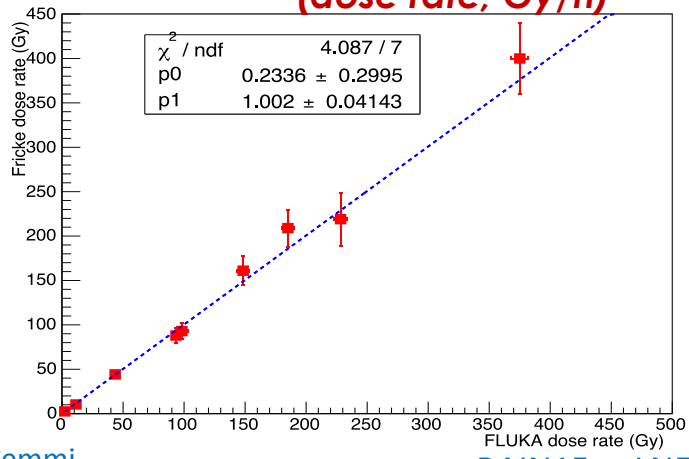



**Lateral y-z dose rate profile inside the radiation cell.**

***Fricke dosimeters in different positions (x; y; z) of the irradiation cell***




***Good agreement within experimental Fricke dosimetric measurements and simulation (dose rate, Gy/h)***



# Investigation of gamma irradiation effects on chemical and physical properties of different materials

**Optical characterizations:**

- UV-VIS spectrophotometer
- FTIR spectrophotometer
- luminescence measurements

**Spectroscopic analysis:**

- ESR spectrometer

**Light yield**

# Radiation effects

## Physical and chemical analyses

*Processing of materials or components*

- Polymerization
- Sterilisation
- Food identification

*Exposition to radiation of materials or components during their life time*

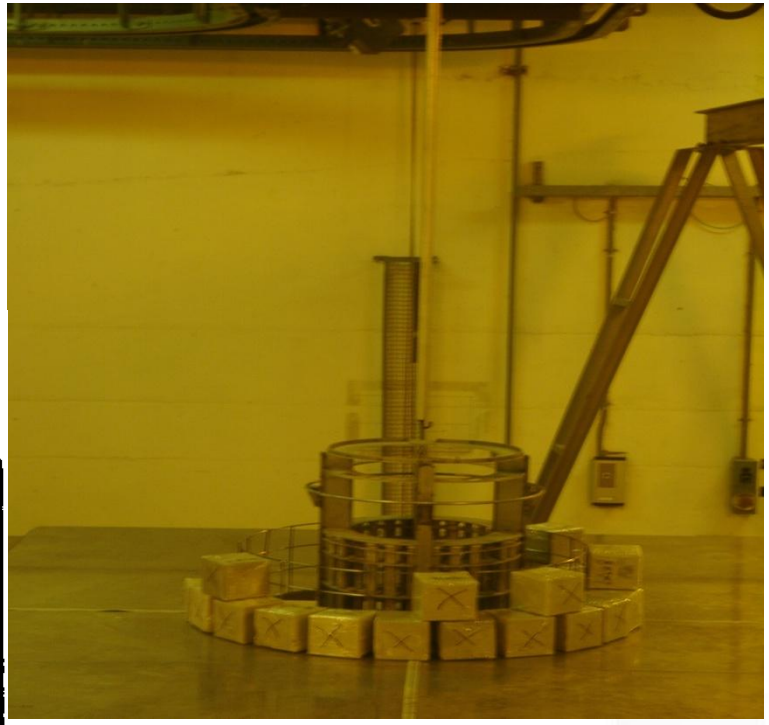
- Reliability
- Life time prevision
- Radiation resistance

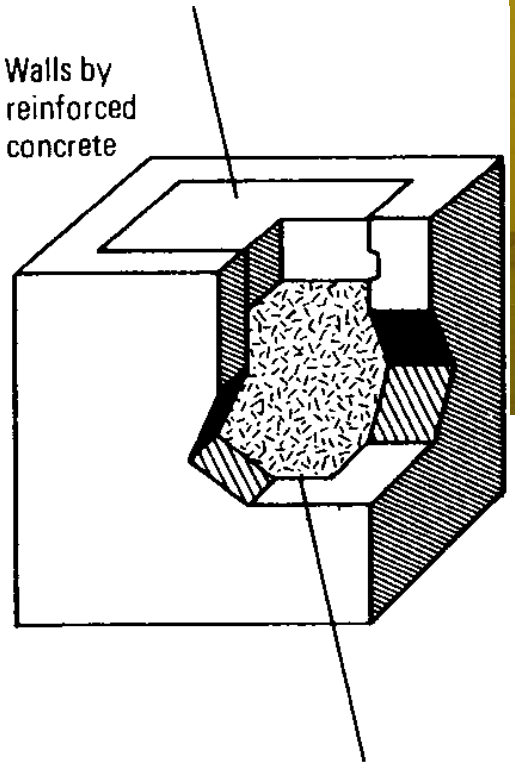
$^{60}$Co PLANT

LABORATORY

# RADIATION DAMAGE OF MATRICES FOR NUCLEAR WASTE

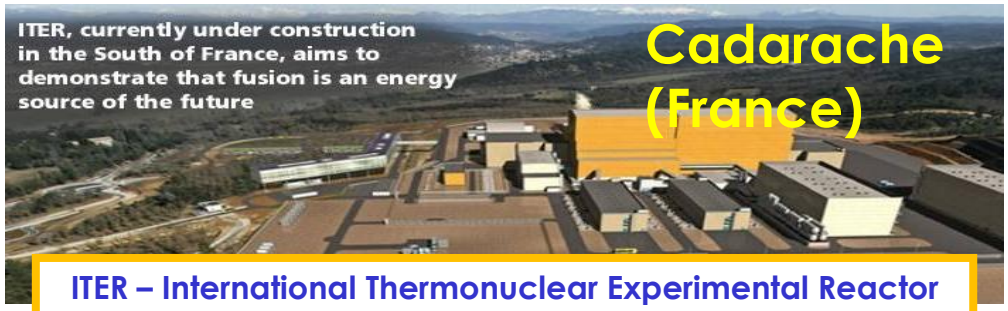
According to Waste form Technical Position (United States Nuclear Regulatory Commission) absorbed dose 10E+8 rads (10E+6 Gy) corresponding to a period of 300 years






Waste form pre-qualification for "*low and intermediate level waste*"(LILW)

# Activities at Calliope: nuclear qualification - 2



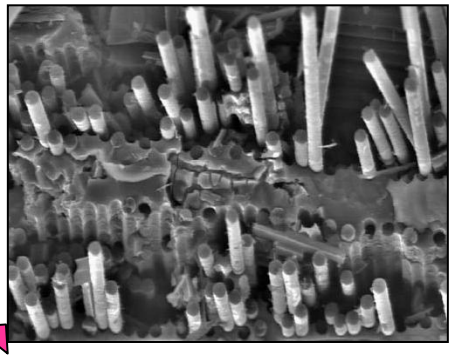

ITER – International Thermonuclear Experimental Reactor

F4E

## Ceramic advanced materials

$Si_f/SiC$

$SiC_f/SiC$

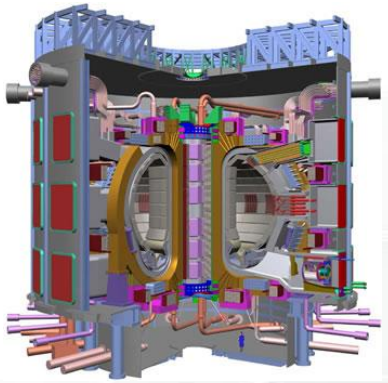


*piezo-motor*

**IVVS actuating components**

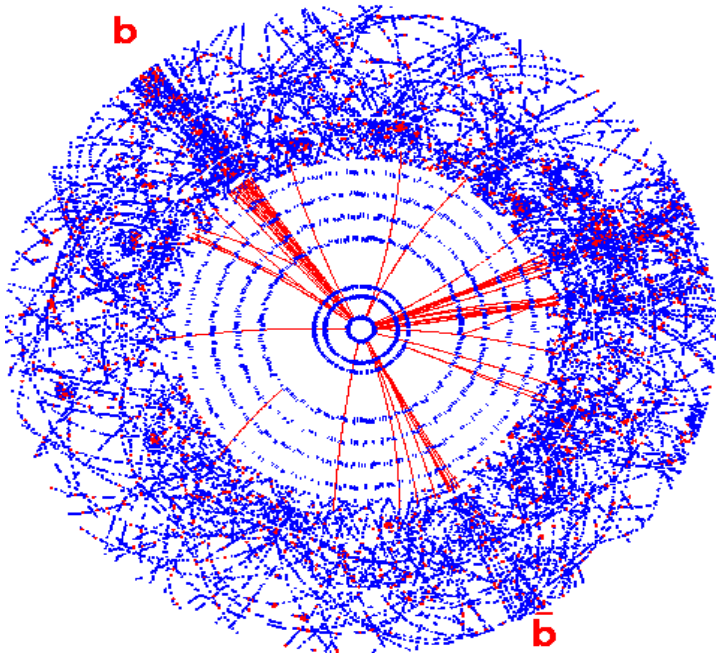
(dose = 4MGy)

*optical components*



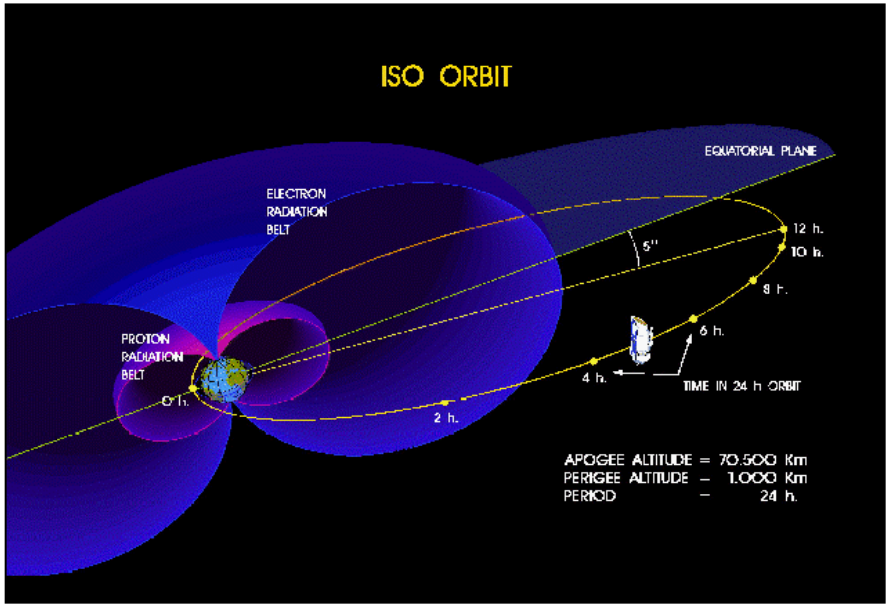
**The radiation damage induced on silicon based devices is widely investigated**

**particle physics (HEP)**




**astrophysics experiments (spacecraft, satellite)**

# Activities at Calliope: electronic devices qualification - 2




## Space application

**Source of radiation:**

- Van Allen belts
- Solar wind
- High Energy solar protons
- Galactic radiation
- *Bremsstrahlung radiation*

**radiation effects on electronic components:**

★ damage mechanisms (surface/bulk)
★ dose rate effects
★ T influence on damage mechanisms

**ionization & displacement damage**

# Irradiation tests on electronic devices

## MIL and ESA STANDARDS PROTOCOLS

### MIL-STD-883E

0.5< dose rate <3 Gy (Si)/s
± 10%

### ESA/SCC BASIC SPECIFICATION No. 22900

Two dose rate windows:
1) The standard dose rate 36-360 Gy/h
2) The low dose rate 0.36-3.6 Gy/h

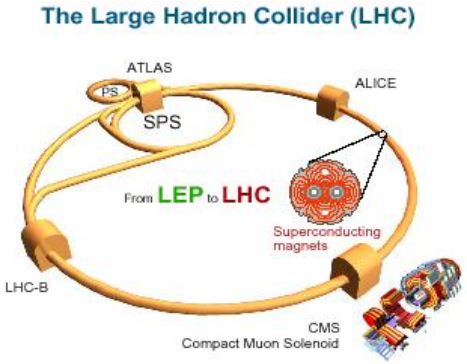
- Time interval between expositions should be < 2 hours.

- Accelerated ageing under bias: 100°C under bias for 168h

# Activities at Calliope: experimental researches - 1

- ✓ **radiation hardness of radiation detectors, optical components and scintillators (optical fibers, crystals, glasses) for High Energy Physics experiments**

## Scintillating crystals

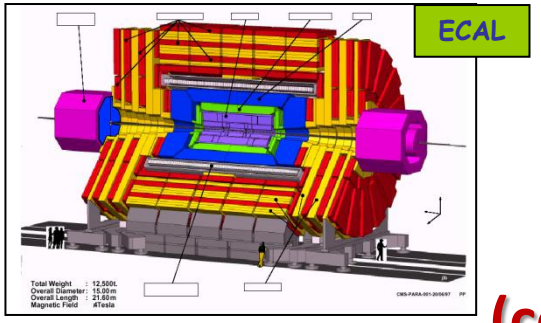



**γ induced *colour centres* can absorb photons emitted by luminescent centres.**

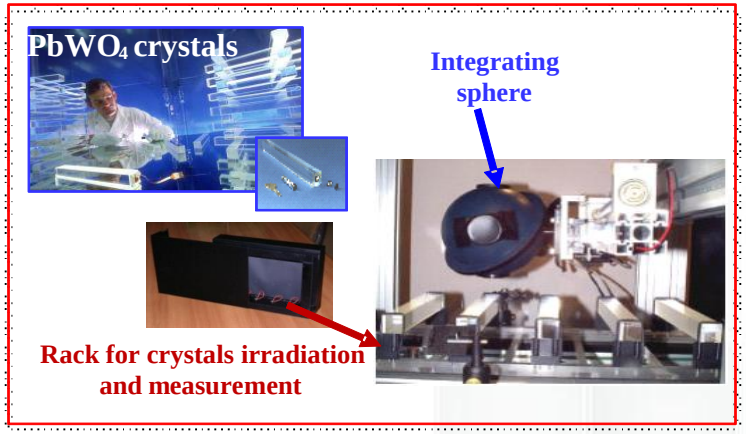
**Optical transmission decrease**

**Loss of scintillation light output**

**CMS ECAL experiment at LHC CERN**

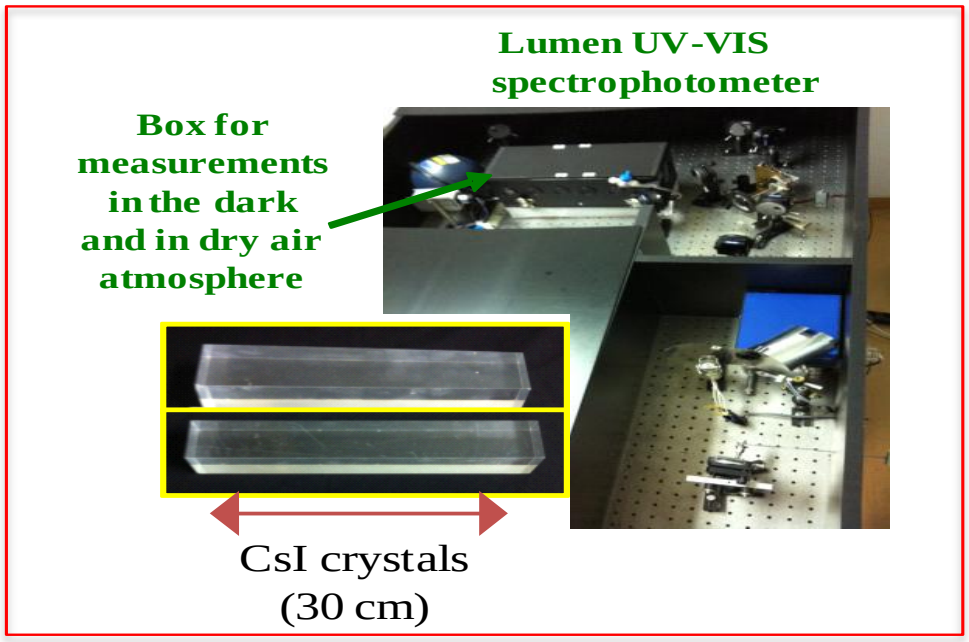



**Crystals qualification and R & D (composition/radiation hardness)**



# Scintillating crystals

## Belle II experiment at SuperKEKB (Japan)




**Optical characterization under irradiation and light yield measurements**

# Activities at Calliope: experimental researches - 3

## Glasses

**Scintillating glassy matrices**
(different energy range)
*radiation hardness, doping ions*

**Doped silicate and phosphate glasses**

**Luminescence and optical properties**
(solid-state lasers, fiber amplifiers, W-LEDs)
*gamma rays composition modification*

**Doped borosilicate glasses**

**Dosimetric systems**
(industrial application)
*optical properties correlated to the absorbed dose*

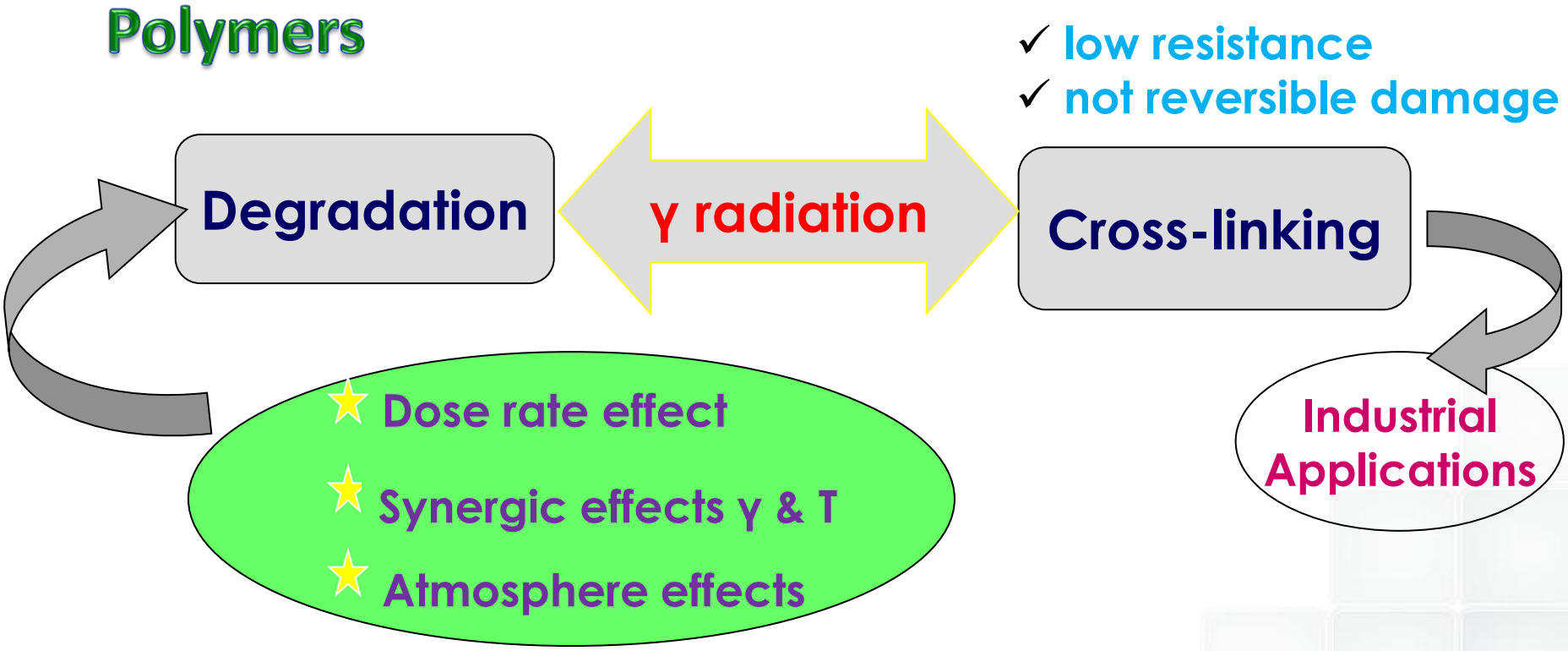
**Ag-doped ChGs**

**Optical data memory**
(photo-induced phenomena)
*glass properties modulation under gamma irr.*

**$WO_3$-based glasses**

# Activities at Calliope: experimental researches - 4

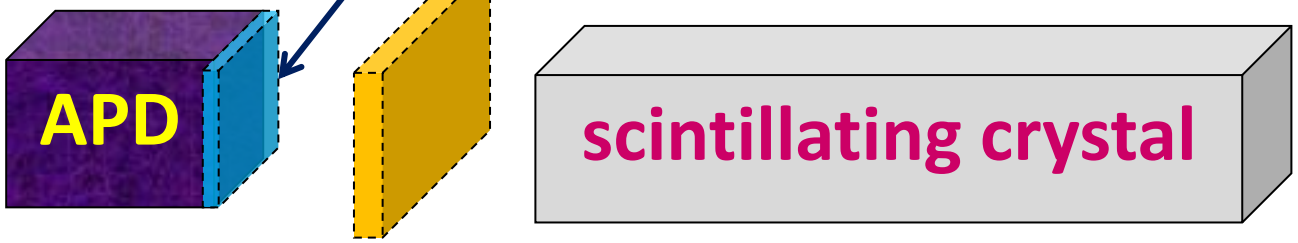
✓ **gamma irradiation induced processes (cross-linking, degradation) in synthetic and natural polymeric materials applied in many field (nuclear and space application, medical devices, food-packaging, cultural heritage)**

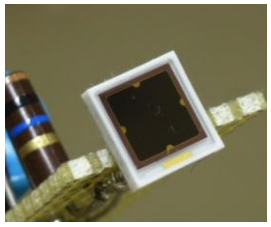


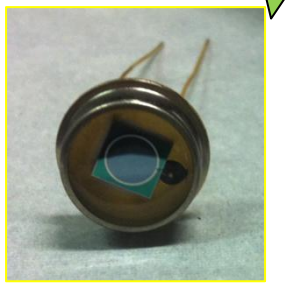
**Polymers**

**optical coupling**

**Optical grease, epoxy and silicon resins**





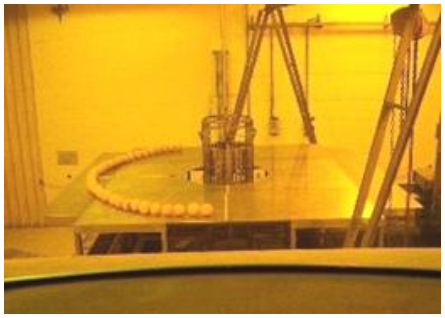
- ✓ **optical properties (UV-VIS-NIR range)**
- ✓ **stability under irradiation**

# Calliope research activities

✓ **biological researches for the conservation and preservation of cultural heritage archived materials (books, images): bio-deteriogen eradication assisted by gamma radiation**

✓ **agricoltural and environmental activities (biological control of pests by SIT, Steril Insect Technique; agricoltural product treatements)**


***Ryncophorus ferrugineus*** **(pest for palm tree)**



**Irradiation of orange fruits infested by *Ceratidis capitata***

# THANK YOU
# FOR
# YOUR ATTENTION

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