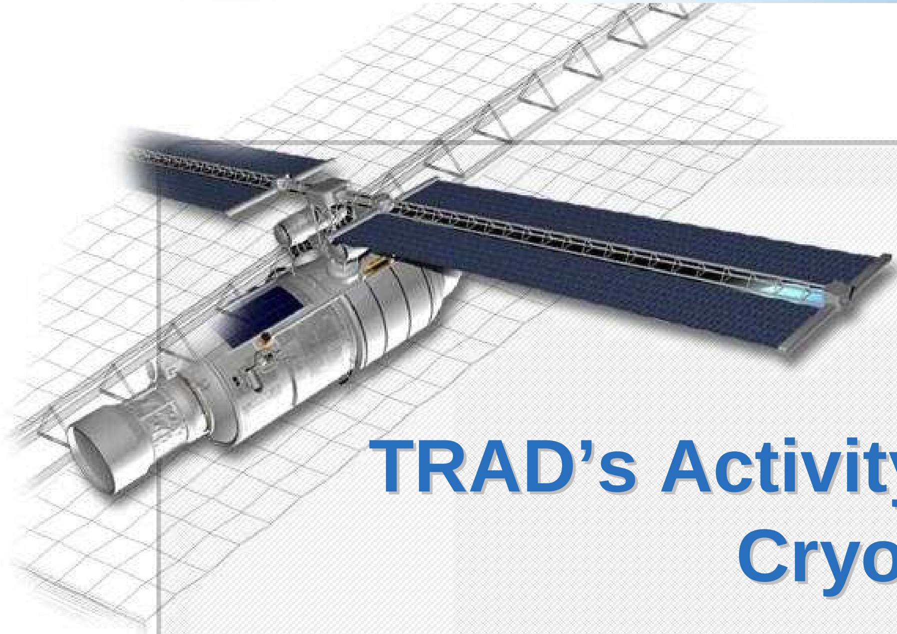


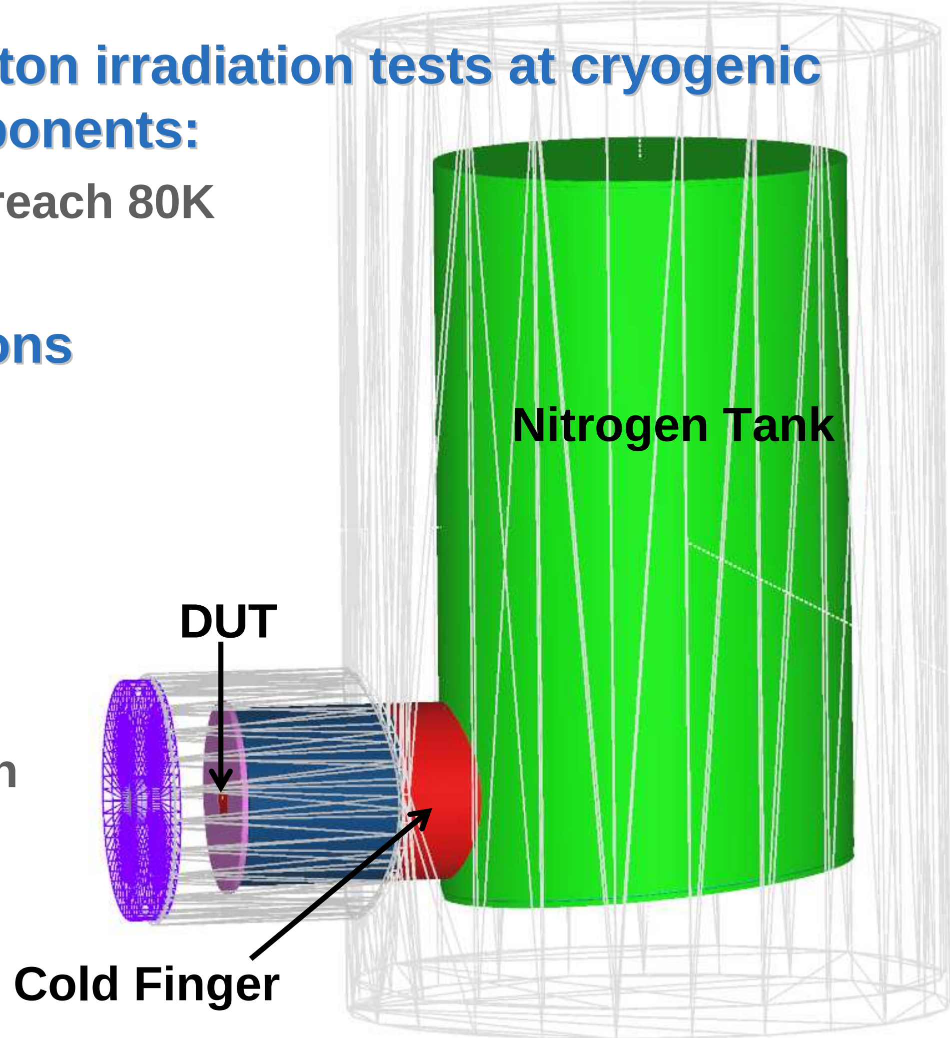
TRAD's Activity related to GEANT4: Cryostat Study

P. Pourrouquet, C. Dossat, P. Garcia, A. Ait Ali Sahid, M. Vaille, N. Chatry (TRAD)
M. Boutillier, F. Bezerra (CNES)

Context

- **CNES needs to perform proton irradiation tests at cryogenic temperature on space components:**
  - Use of CNES's cryostat to reach 80K

- **This may induce perturbations compared to a normal test**
  - Parts of the cryostat could modify the proton beam (glass window)
  - Study of possible activation (may create safety and delay issues)



Context

Feasibility study of cryogenic tests for high energy protons using a cryostat funded by CNES performed by TRAD

- **Need of a chain of tools:**
  - FASTRAD® for cryostat modeling,
  - GEANT4 for dose and transmitted spectra calculation in different cryostat volumes including Devices Under Test (DUT) inside the cryostat,
  - FISPACT for activation calculation,
  - RAYXPERT® for radio protection calculation.
- **Calculation validation by comparisons with measurement values**

Outline

- Software presentation
- Cryostat model
- Dose estimation after irradiation
  - GEANT4 results
  - DUT level measurements
- Radioprotection calculation
  - Activation level determination
  - Dose rate calculation and radio protection conclusion
- Conclusion

Tool presentation

- **FASTRAD**

  Commercial 3D CAD software dedicated to dose calculation (sector analysis and RMC) in space environment. It is developed and distributed by TRAD

- **GEANT4**

- **FISPACT:**

  'Multiphysics platform providing advanced simulation methods and employing complete nuclear data for both neutron and charged-particle interactions.'

  It is developed and maintained by the United Kingdom Atomic Energy Authority

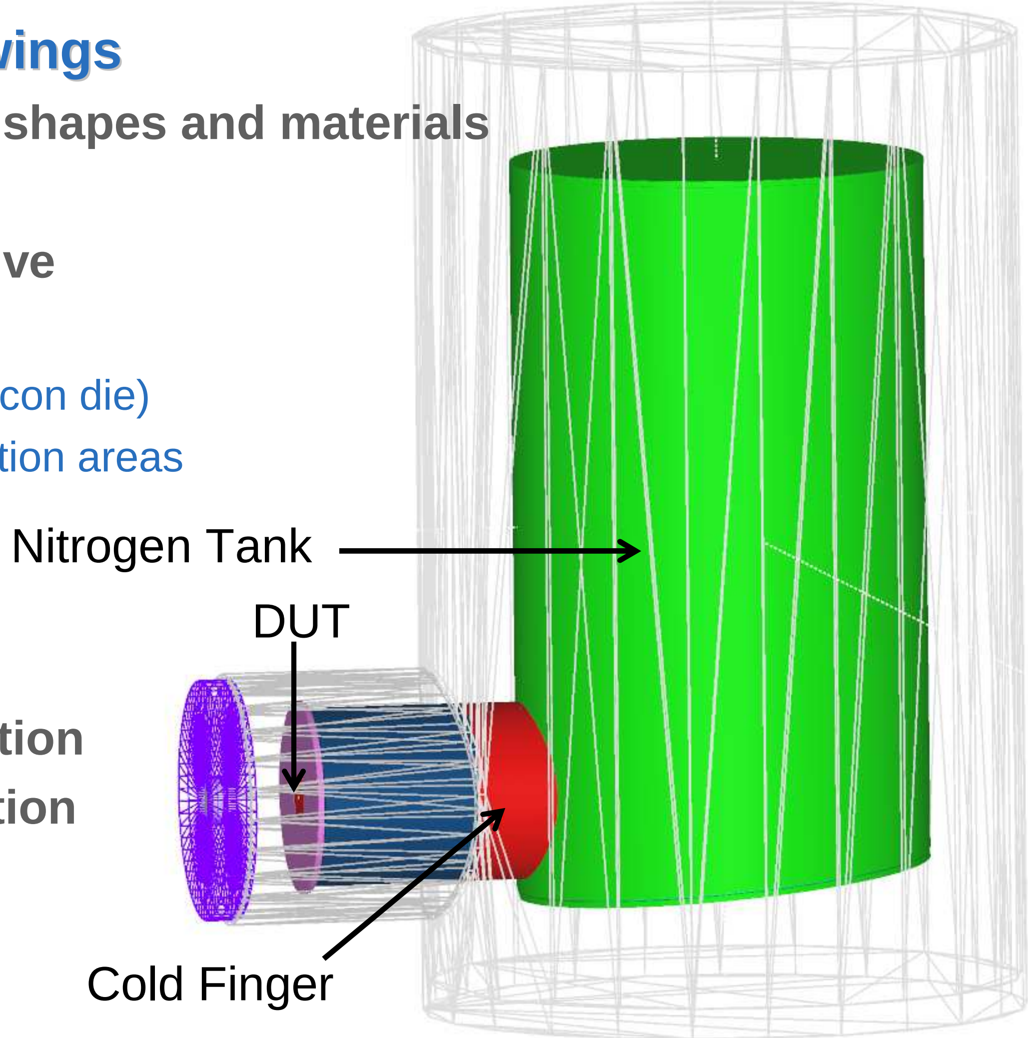
- **RAYXPERT:**

  Commercial 3D CAD software dedicated to dose rate calculation (FMC) in nuclear & medical environment. It is developed and distributed by TRAD

Cryostat model - FASTRAD

- **Based on technical drawings**
  - **Modeling using simple shapes and materials**
  - **Insertion of the DUT**
  - **Definition of the sensitive volumes**
    - for dose calculation (silicon die)
    - corresponding to activation areas

- **Import to GEANT4**
  - **Sensitive volume selection**
  - **Beam parameter definition**



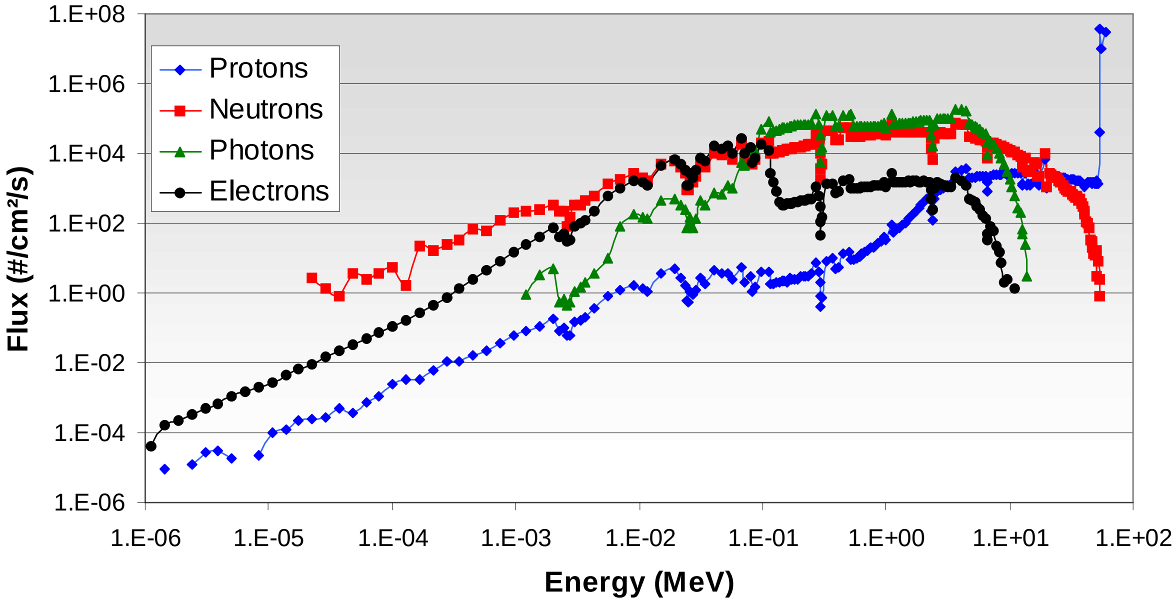
GEANT4 Calculation

Project modifications for post-processing

- **Dose calculation**
  - **Particle importance biasing: dose rate for an equivalent flux of 1 proton/cm²**

- **Transmitted spectra in the activation areas:**
  - **Different particle types:**
    - Electrons,
    - Photons,
    - Protons,
    - Neutrons
  - **Energy group sampling corresponding to input needed for activation software**

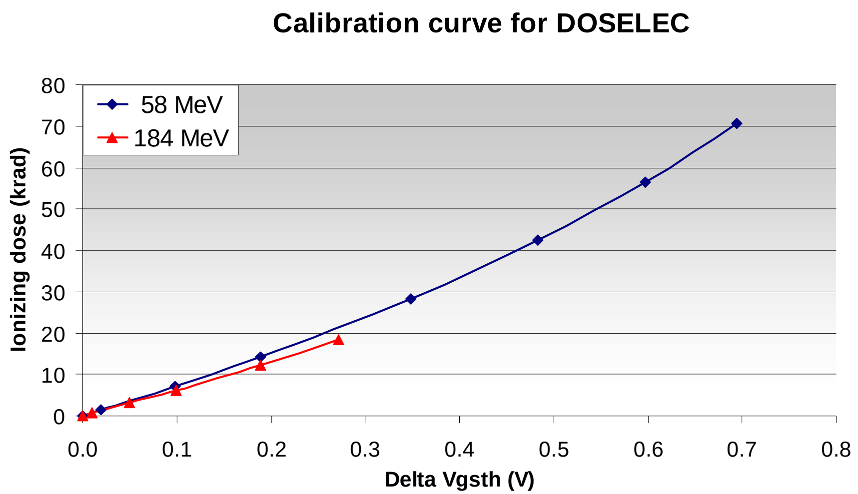
Spectra at DUT level for 60 MeV protons

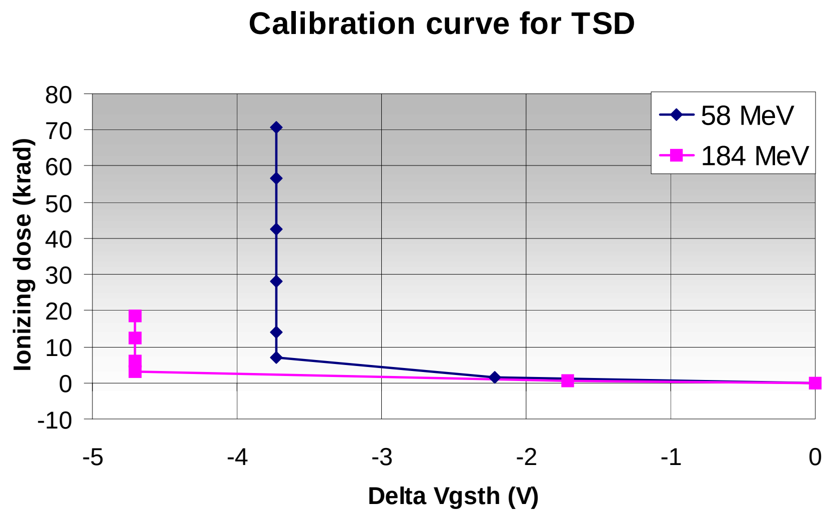


Measurement/Calculation comparisons

First Phase: TID & TNID dosimeter calibration

- List of potential dosimeters
- Dosimeter irradiations without cryostat for different proton energies
- Study of the parameter drifts
- Creation of the calibration curves: deposited dose according to drift





- Selection of the most suitable dosimeter for TID & TNID considering these calibration curves:
  - TID: DOSELEC (TRAD), P-Channel MOSFET
  - TNID: TLP190B (Toshiba), GaAlAs Optocoupler & Photodiode

Measurement/Calculation comparisons

Measurements at DUT level using different dosimeters for 60 MeV protons

- TID: DOSELEC (TRAD), P-Channel MOSFET

	Fluence (protons/cm²)						
Calculation / Measures	1E+10	3E+10	5E+10	7E+10	1E+11	1.5E+11	2E+11
Difference (%)	-15	-14	-14	-13	-13	-12	-12

- TNID: TLP190B (Toshiba), GaAlAs Optocoupler & Photodiode

	Fluence (protons/cm²)						
Calculation / Measures	1E+10	3E+10	5E+10	7E+10	1E+11	1.5E+11	2E+11
Difference (%)	-35	-17	-14	-11	-5	-4	-3

Match between measurement and simulation => chain validated @ 60 MeV

Possibility to use it at higher energies

Activation-FISPACT/Radioprotection-RAYXPERT

60 & 185 MeV proton radiological inventory

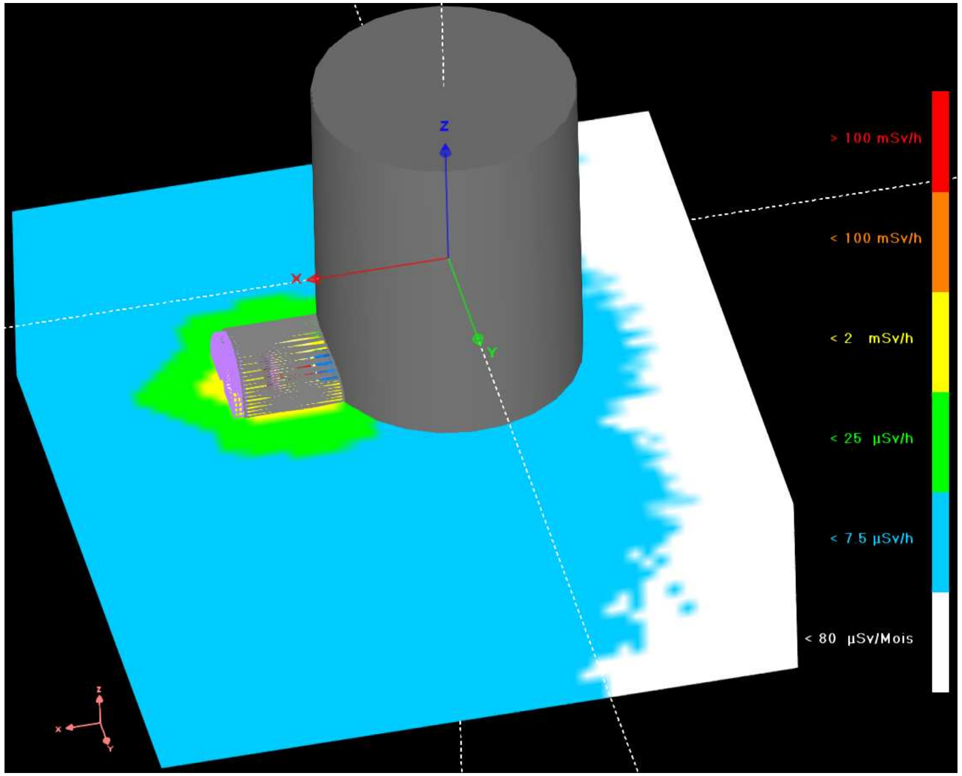
- Activity for each isotope
- Input for radioprotection calculation

Radioprotection calculation

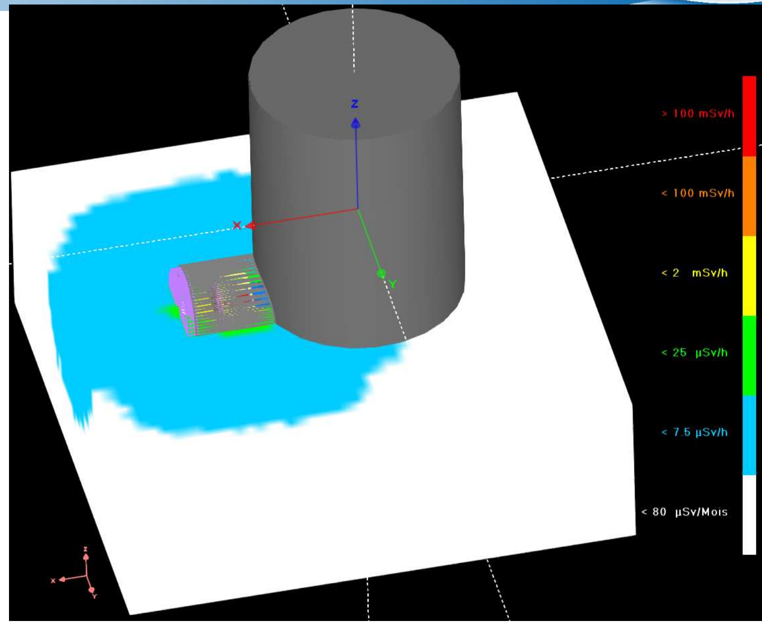
- Maximum H*10 dose rates:
  - 4.1 µSv/h @ 10 cm from the cryostat
  - 69 µSv/h @ cryostat surface

  => Controlled area

- Safety measures:
  - Proton beam room already a controlled area
  - No need to implement additional safety plan



Activation-FISPACT/Radioprotection-RAYXPERT



Decrease of H*10 dose rates

30 minutes after irradiation

- at 10 cm from the cryostat:
  from 4.1 to 1 µSv/h
- at cryostat surface:
  from 69µSv/h to 18µSv/h

Comparisons between calculation and measurements at 60 MeV:

Not possible to consider the same configuration

- Measurement: 20µSv/h for 2E+11 protons/cm², 10 minutes after irradiation and behind a collimator
- Calculation: 46µSv/h for 1E+11 protons/cm² at the end of the irradiation at the glass window contact

H*10 dose rate measurement and calculation give equivalent results

Conclusions

- **A chain of software tools including GEANT4 has been used to assess the feasibility of a proton irradiation at very low temperatures using a cryostat**

- **Comparisons at room temperature for 60 MeV protons between**
  - GEANT4 calculation results and irradiation measurements validating the simulation results
  - H*10 dose rate measurement and calculation give equivalent results

- **185 MeV proton tests are possible without implementing additional safety measures and without delay due to cryostat activation**

Thank you for your attention