OMERE

[COMET-ENV] Tools to predict Single Event Effects - 13 Dec 2022

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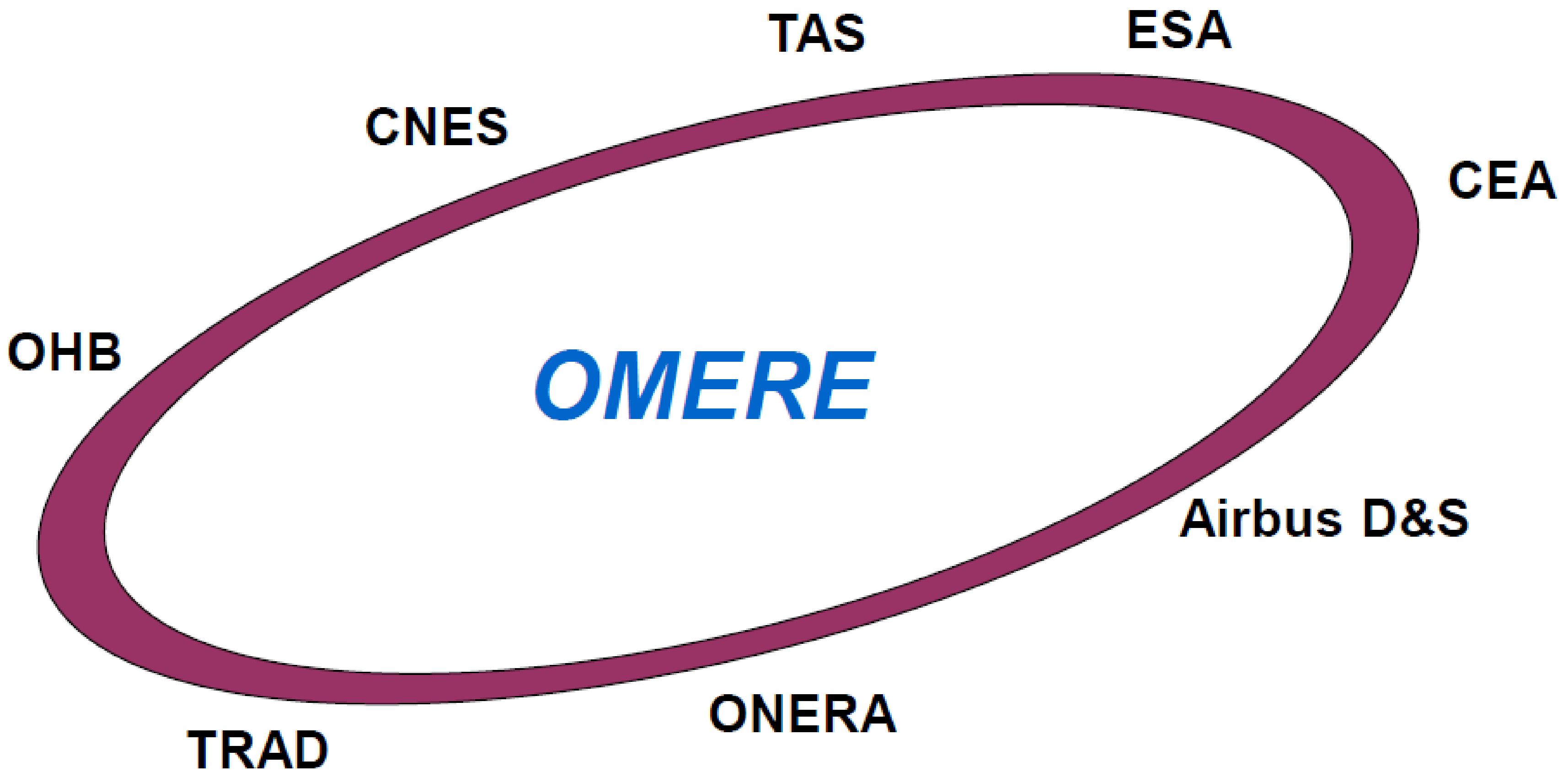
OMERE in summary

- The project
  - Since 1999
  - TRAD development with CNES support
  - Freeware for space radiation environment and effects on electronic components
  - Stand alone software (no internet connection needed)
  - Conceived to meet industrial requirements
  - Integrates ONERA models
  - Integrates outcomes of Research and Technology projects financed by CNES
  - Coupling with FASTRAD.

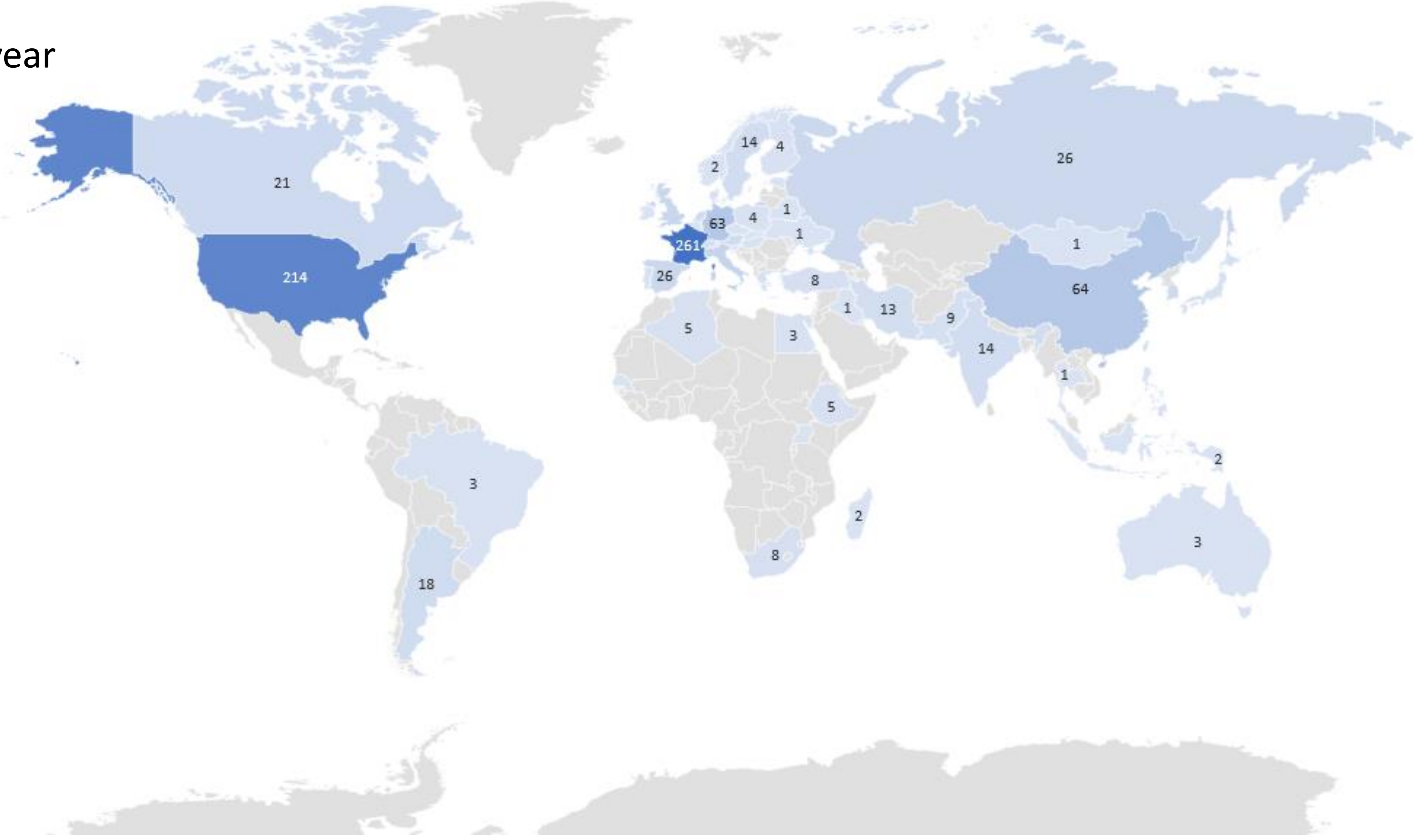
OMERE in summary

- The partnership



OMERE in summary

- OMERE software
  - One major release per year
  - Support for users
  - Radiation analysis
  - Education purpose



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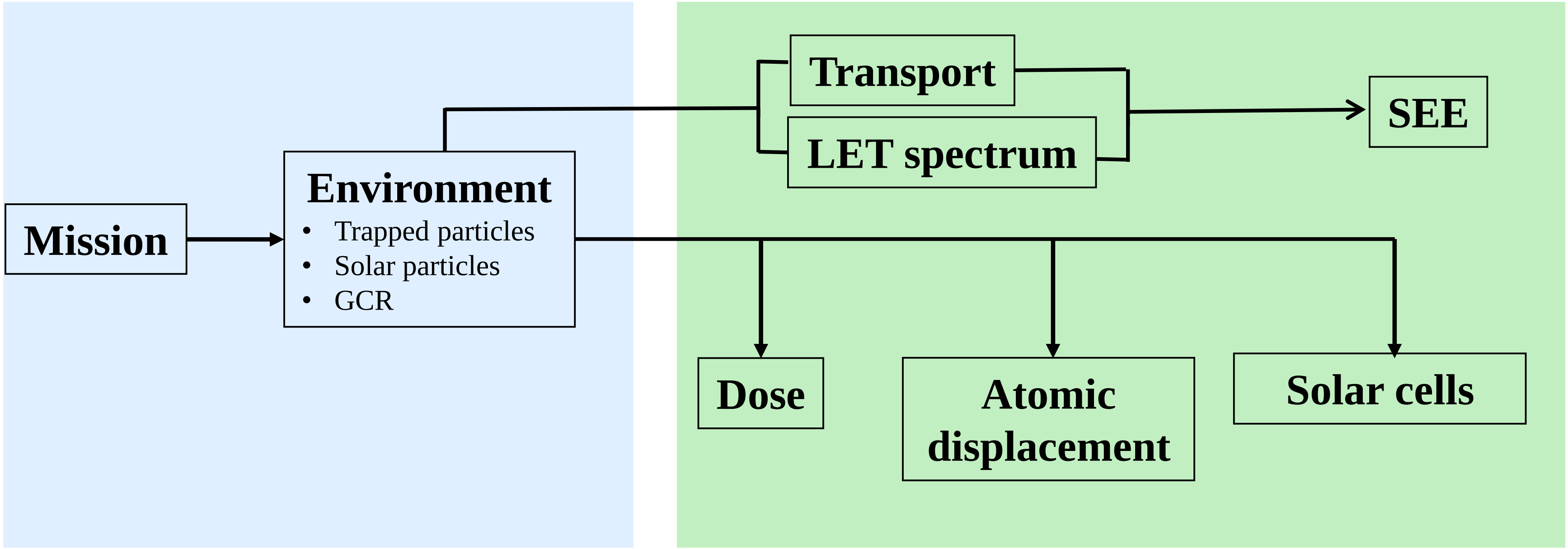
OMERE architecture



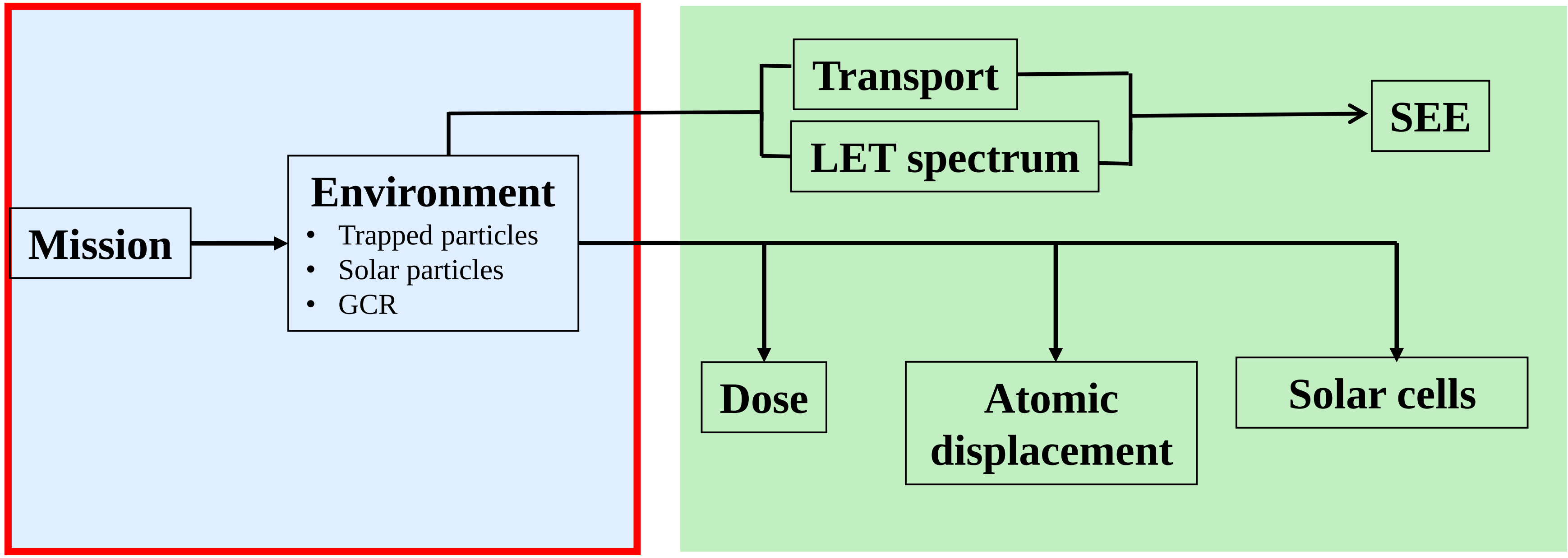
1- Defines the spectra around the spacecraft

- Isotropic environment
- No shielding considered

2- Estimates the effects on components

- SEE rate, ionizing dose, non-ionizing dose
- Shielding: simple geometry

OMERE architecture



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Environment engineering models

- Engineering models including (but not limited to) ECSS standards

- Models:
  - In-situ measurements
  - Range of validity of L and energy
  - Standards

- Options:
  - Solar min/max
  - Confidence level [%]
  - Magnetic field
  - Magnetospheric cutoff

- Cosmic rays
  - **GCR ISO 15390**
  - CREME 86
  - CREME 96

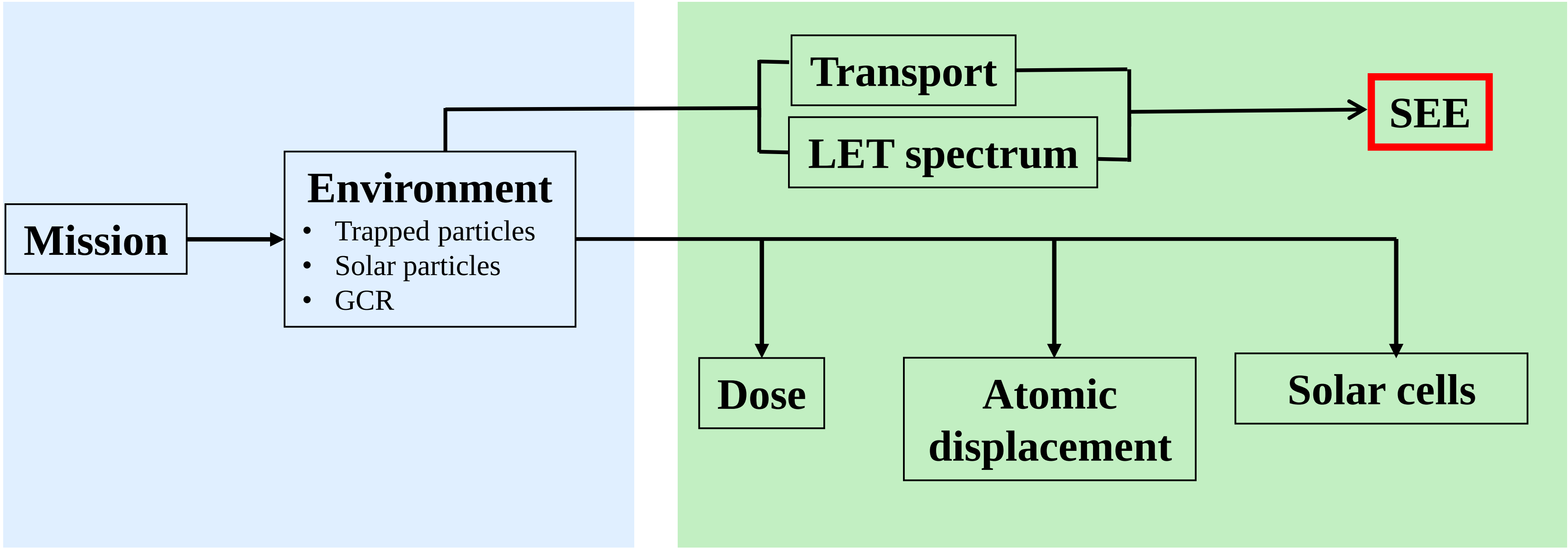
- Solar particles
  - Protons (average)
    - **ESP**
    - JPL91
    - JPL91 Extended
    - SOLPRO
    - SPOF
    - SAPPHIRE
  - Ions (average)
    - PSYCHIC
    - Helium
    - SAPPHIRE
  - Solar flare models
    - CREME 86
    - **CREME 96**
    - IOFLAR
    - SAPPHIRE

- Trapped particles
  - Electrons
    - **AE8**
    - **IGE 2006**
    - **MEO**
    - OZONE
    - SLOT
    - AE9
    - GREEN
  - Protons
    - **AP8**
    - AP9
    - OPAL
    - GREEN

- *Magnetospheric cutoff*
  - **Störmer**
  - ONERA

- *Magnetic field*
  - **Jensen Cain**
  - Dipolar
  - IGRF
  - GSFC

OMERE architecture



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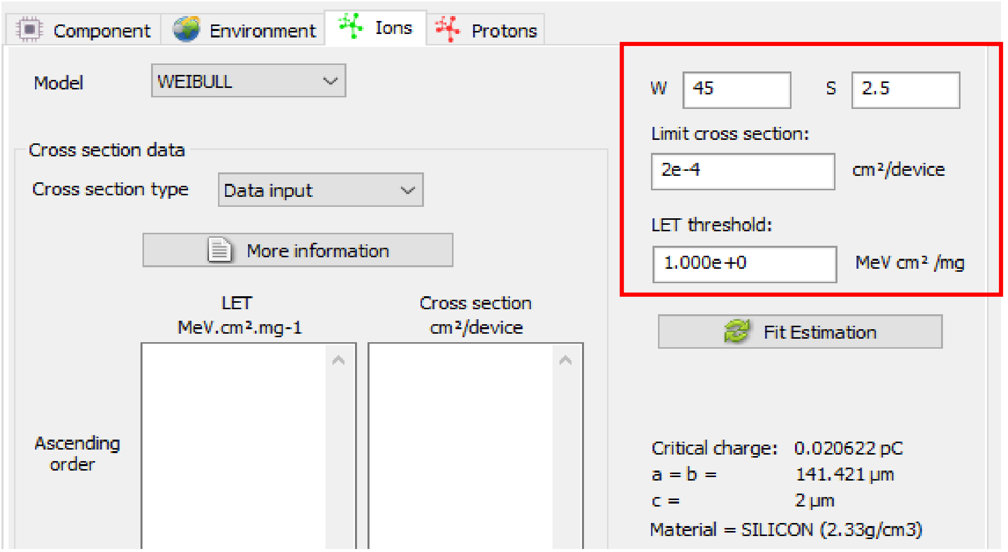
Cross section

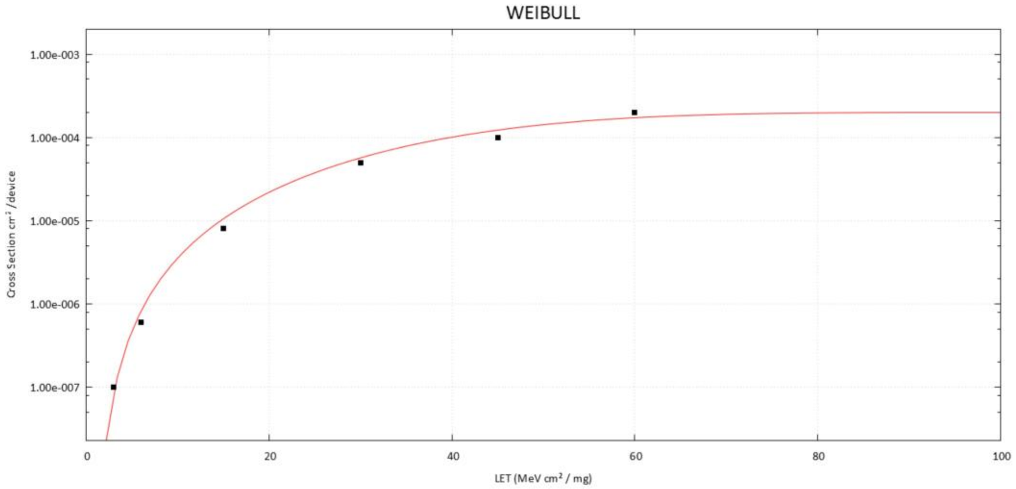
- SEE probability → device Cross Section



- Weibull fit parameters
  - W (width)
  - S (shape)
  - σ_{SAT} (saturated cross section)
  - L_{th} (threshold LET)

$$F(L)=\sigma_0\left[1-exp\left(-\left(\frac{L-L_0}{W}\right)^S\right)\right]$$

- Weibull curve
  - Weibull distribution (red curve) fitted to the test data (black dots)

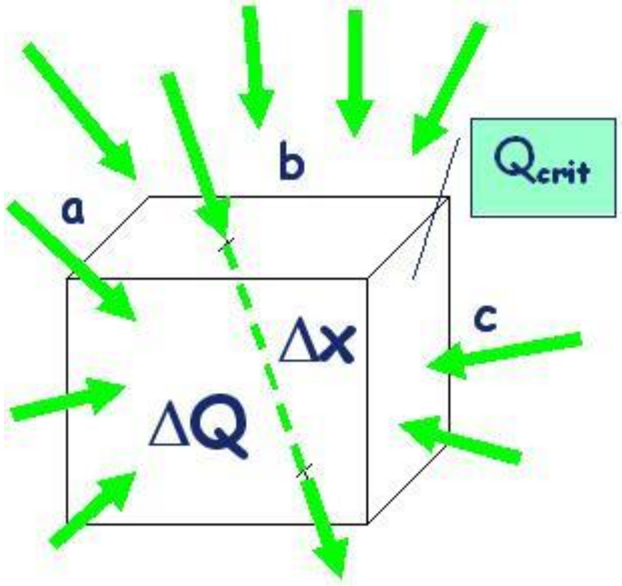


SEE caused by Ions: CREME and RPP Method

- CREME (Cosmic Ray Effect on Electronics)
  - Adams, 1986

- Assumption
  - Rectangular Parallelepiped (RPP) sensitive volume
  - Constant LET all along ion path
  - Qcrit critical charge of this sensitive volume
  - If $Q_{dep} > Q_{crit}$ then an event occurs

- CREME enables to calculate the SEU rate in a given sensitive volume characterized by a specific LET threshold
  - Calculation parameters (a, b, c, Lth)



$$\Delta Q \geq Q_{crit} \longrightarrow \text{Event !}$$

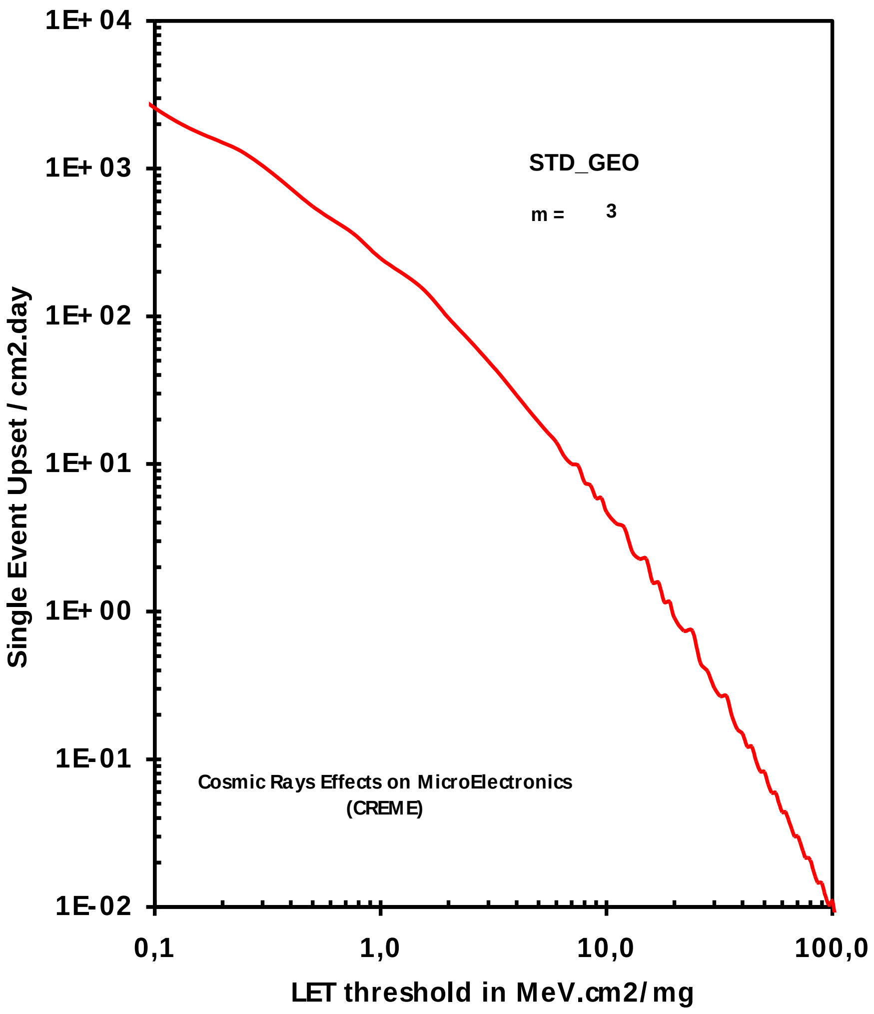
$$\Delta Q \propto \Delta E = LET_{Si}^{ion}(E) \cdot \Delta x$$

Single Cell Rate

- For a given sensitive volume
  - The SEU rate is calculated with the UPSET module of CREME86 (included in OMERE) for all possible LETth

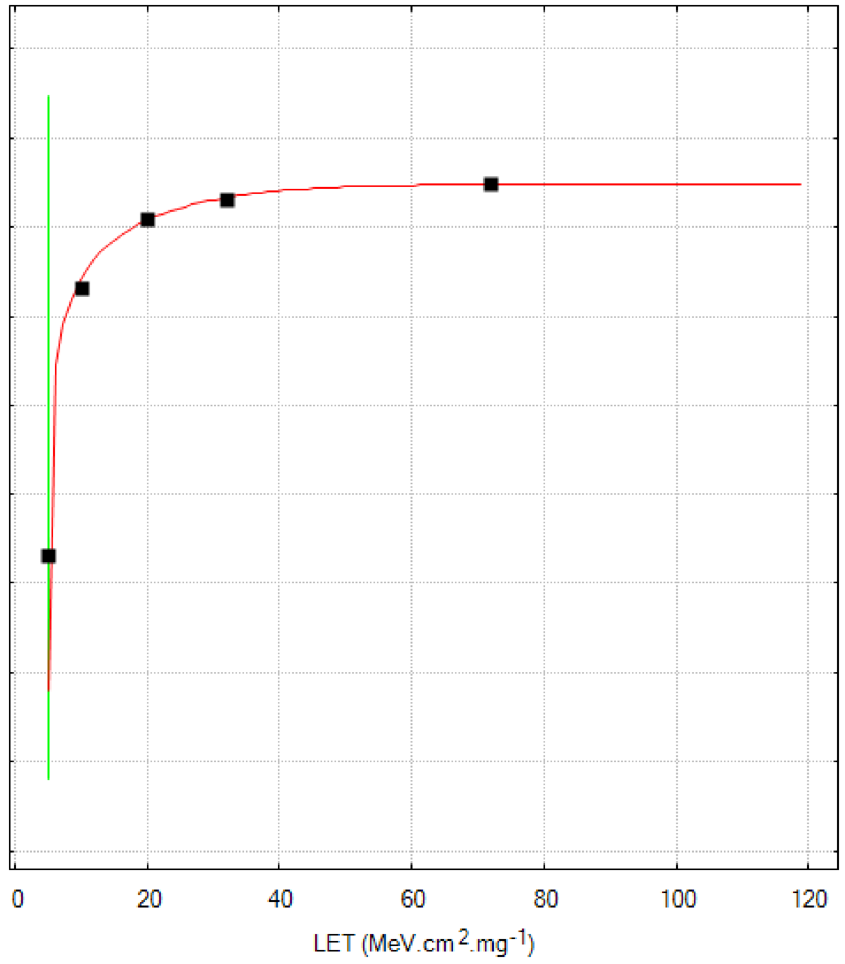
→ Single cell rate

- For the entire device
  - The single-cell rate is correlated to the device under-irradiation response with OMERE



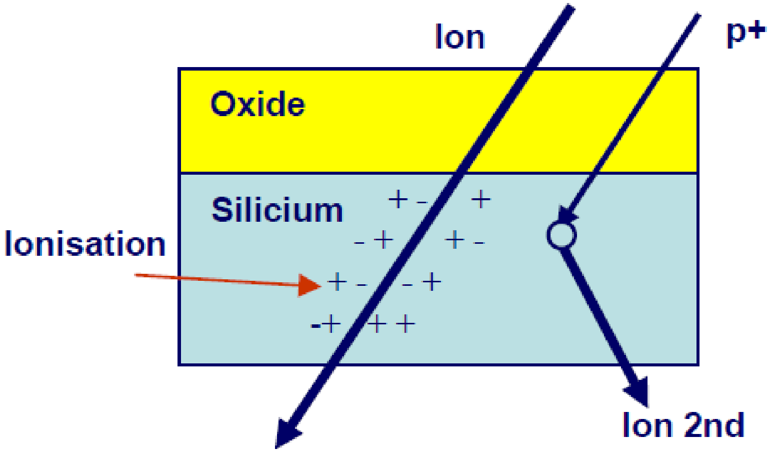
Interpretation of Data

- All cells do not have the same LET threshold in a device
  - Progressive increase of the cross section curve
- The SEE susceptibility of the entire device (including all cells) versus LET is given by the cross section curve
  - The rate for one sensitive volume (one L_{th}) is calculated at each LET and integrated over the whole cross section curve
- This SEE rate is calculated by OMERE
  - With the CREME rate calculated for one cell with a specific LET threshold
  - Taking into account the whole device sensivity as a function of the LET



SEE Caused by Protons

- Proton cross section
  - Only one particle type (proton)
  - No need to use the LET
  - Proton-caused SEE are indirect
    - No geometry/angle effect taken into account
  - Cross section expressed as the function of the incident energy
  - Can be simulated from Heavy-ion data
    (PROFIT / SIMPA/ METIS models available)



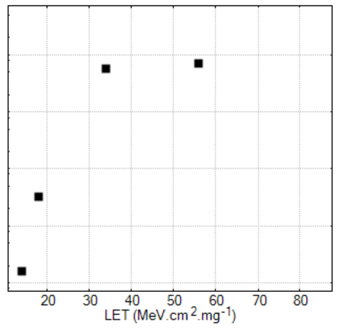
- Proton SEE rate
  - Product of the cross section multiplied by the flux at each energy

$$\tau_{p+} = \int_{E_0}^{\infty} \varphi(E)\Sigma(E)dE$$

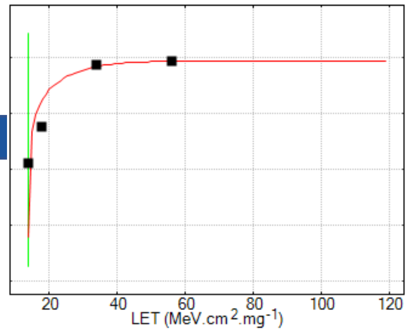
- Device considered as potentially sensitive to protons if the heavy ion LET threshold is smaller than 15 $MeV.cm^2.mg^{-1}$

TRAD Tests & radiations

SEE Rate: Heavy ion summary



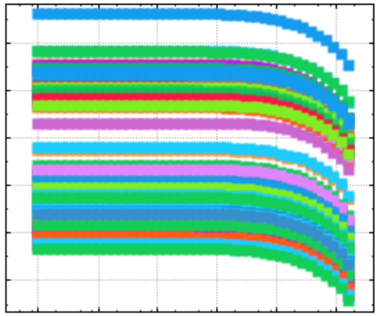
Heavy ion sensitivity
(test data)



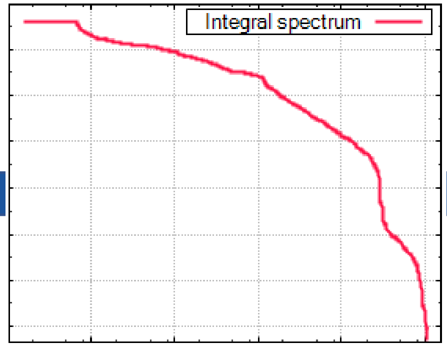
Heavy ion sensitivity
(Weibull Fit)

ERROR RATE

Device description
(number of sensitive volumes
and SV depth)



Space environment
(Integral fluxes)



Space environment
(LET spectrum)

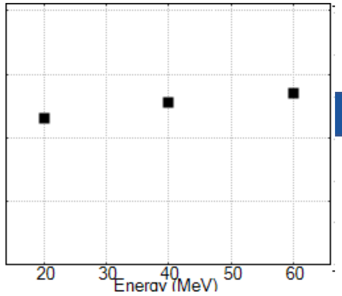
Inputs needed:

- Environment
- Heavy-Ion test data
- Number and depth of SV

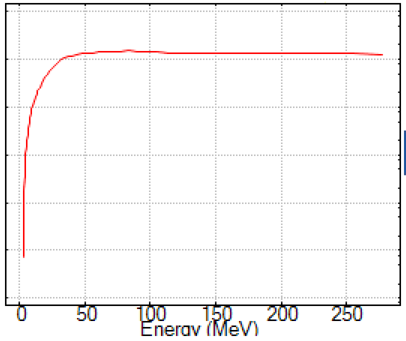
Output:

- SEE rate /day for each environment source

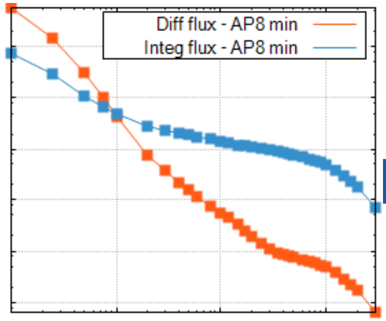
SEE Rate: Proton summary



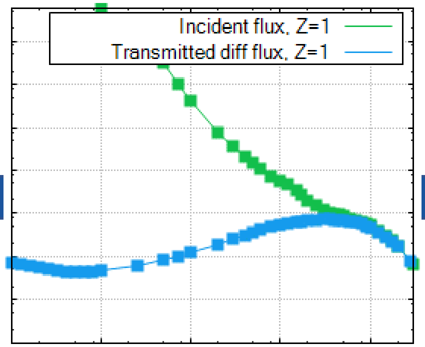
Proton sensitivity
OR
Heavy-ion sensitivity
(test data)



Proton sensitivity
(Weibull Fit)



Space environment
(Incident flux)



Space environment
(Transported flux)

ERROR RATE

Inputs needed:

- Environment
- Proton test data (or heavy-ion data + simulation model)

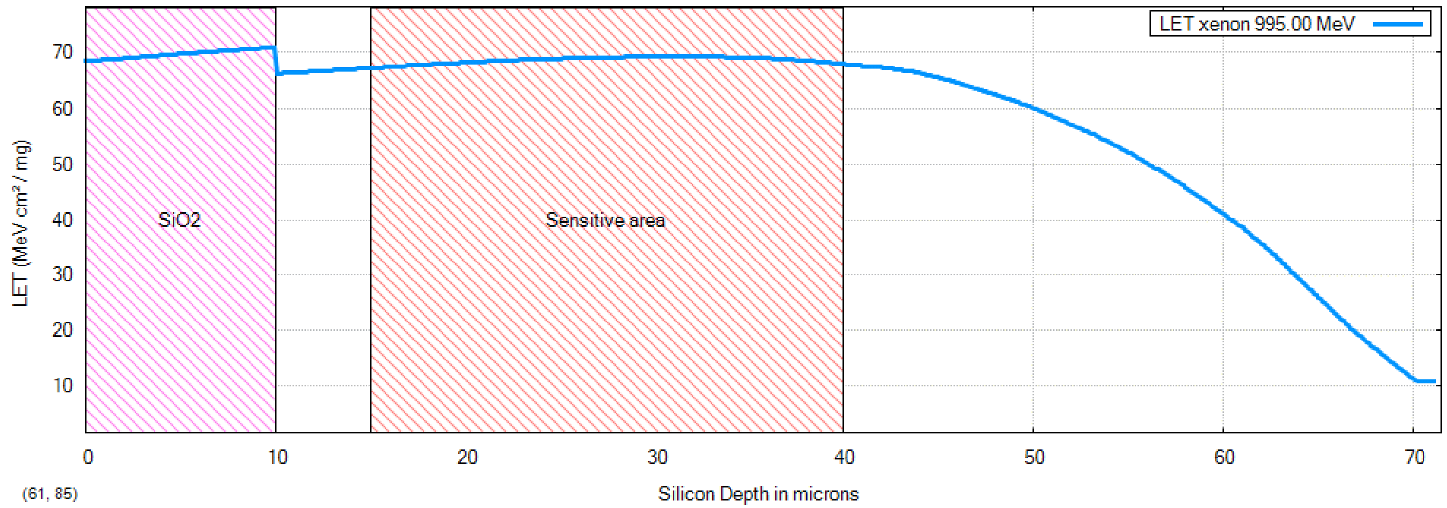
Output:

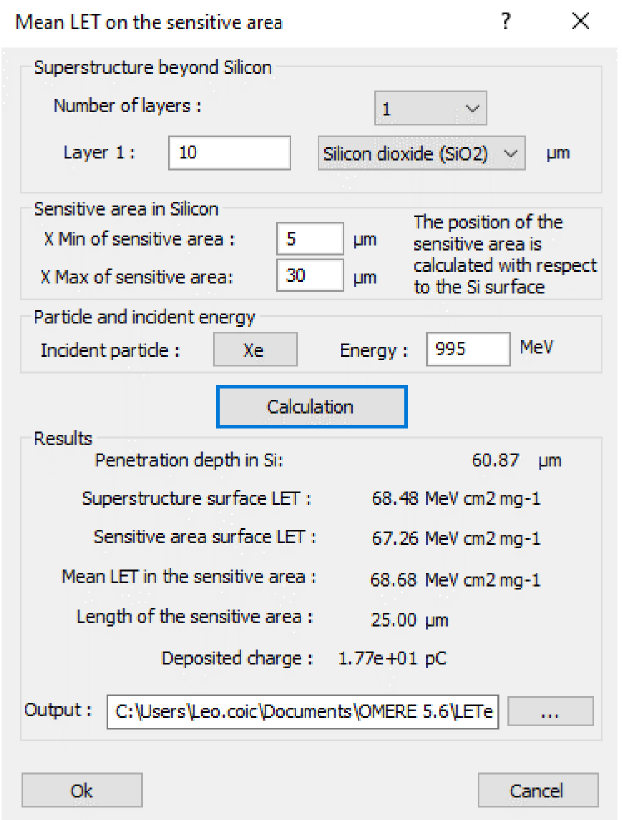
- SEE rate /day for each environment source

$$\tau_{p+}=\int_{E_0}^{\infty}\varphi(E)\Sigma(E)dE$$

Effective LET

- In a heavy ion test, the LET given by the facility is the surface LET
- The LET does not keep a constant value in the device volume
- If the sensitive volume depth is known, the effective LET can be calculated
    - Averaged LET value in the die





Thank you for your attention

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