

RAMSEES

**(RADIATION ATMOSPHERIC MODEL FOR SINGLE
EVENT EFFECTS SIMULATION)**

AN OVERVIEW

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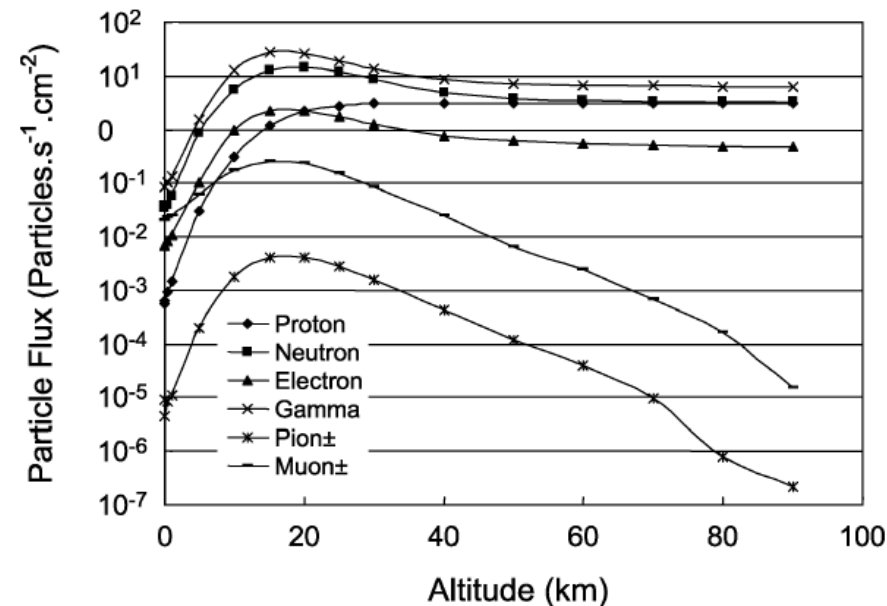
ATMOSPHERIC IONISING RADIATION

Atmospheric Ionising Radiation is generated as a result of the interaction of space radiation with the atmosphere on earth

Sources of radiation in space are, notably:

- Galactic Cosmic Rays (GCR)
- Solar Energetic Particle Events (SE + CME)

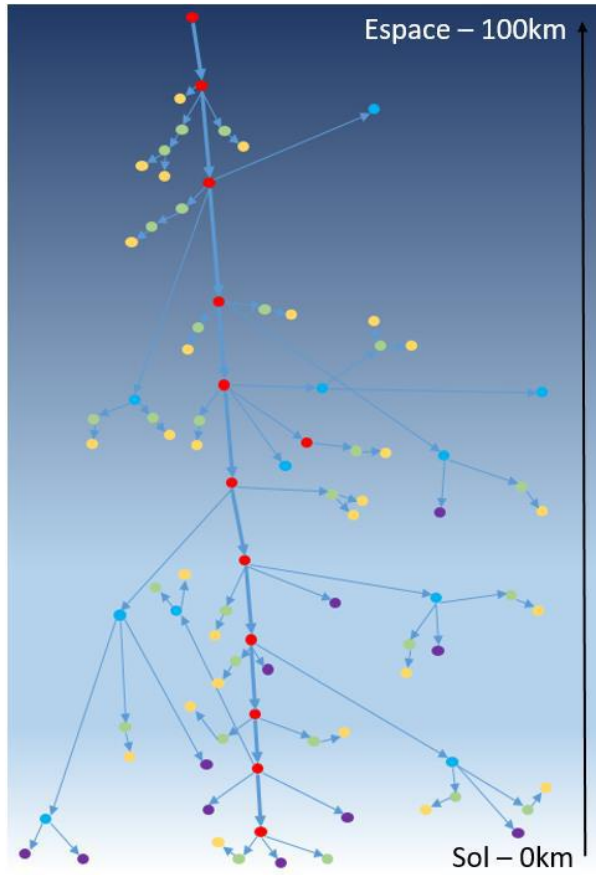
The primary particles are mostly protons



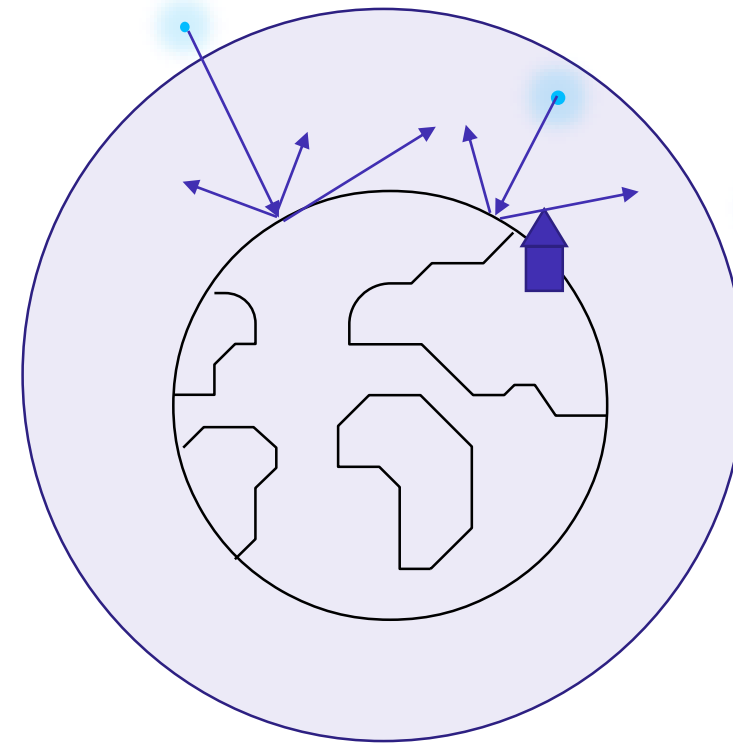
<- Graph from F. Lei, S. Clucas, C. Dyer, and P. Truscott, 'An atmospheric radiation model based on response matrices generated by detailed Monte Carlo Simulations of cosmic ray interactions', IEEE Trans. Nucl. Sci., vol. 51, no. 6, pp. 3442–3451, Dec. 2004, doi: 10.1109/TNS.2004.839131

PRIMARY, SECONDARY PARTICLES AND THEIR PHENOMENA

EAS (Extensive Air Shower)



Albedo



SINGLE EVENT EFFECTS ON EARTH - WHY WE SHOULD FRET.



AERONAUTICS INDUSTRY

Airplanes have represented one of the first fields of application of RHA in atmospheric conditions.



AUTOMOTIVE INDUSTRY

The automotive industry is becoming more and more integrated and critical for society. Self driving applications, for instance, make it imperative to ensure reliability.



ROCKETS

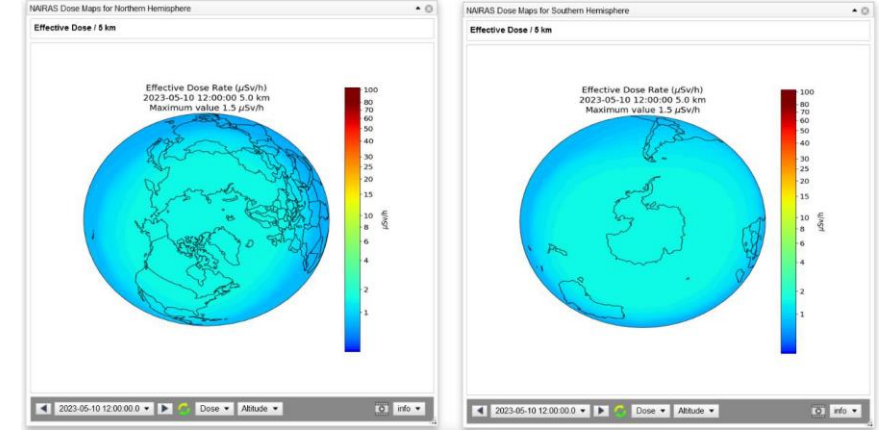
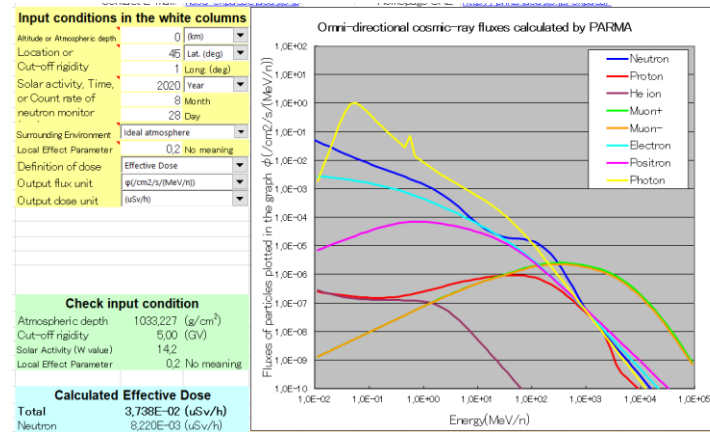
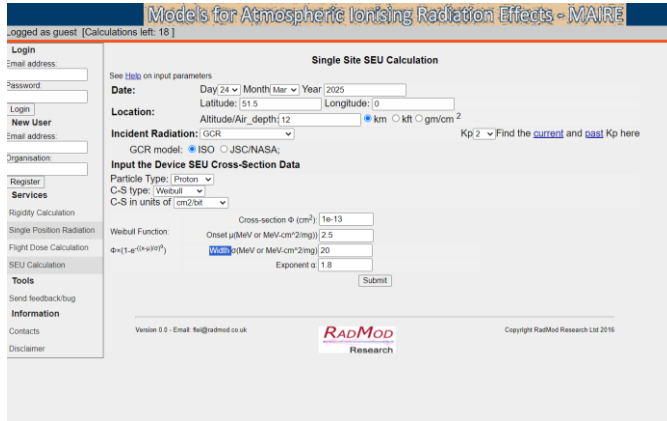
Rockets have always been subject to strict RHA procedures, due to the altitudes reached, the risks involved and the importance of their correct functioning towards the payload.



BALLOONS

Radiation effects on balloons are to be assessed and mitigated. The altitudes reached are already important, and RHA is applied on missions.

PREVIOUS RADIATION MODELS



MAIRE (UK)

- ✓ Model of Atmospheric Ionising Radiation Effects
- ✓ Based on FLUKA+MNCPX for neutrons
- ✓ Website (black box and confidentiality issues)

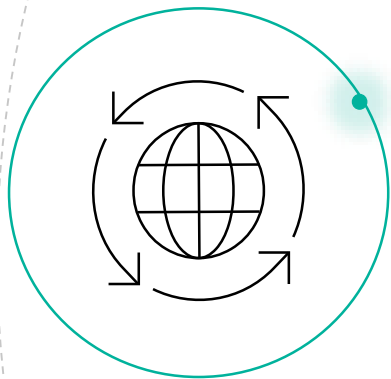
EXPACS (JAP)

- ✓ Excel Based Program For Calculating Atmospheric Cosmic Ray Spectrum
- ✓ Based on Monte Carlo simulations
- ✓ PHITS Particle and Heavy Ion transport system
- ✓ Flight plans not supported

NAIRAS (USA)

- ✓ Nowcast of Aerospace Ionising Radiation System
- ✓ Real time information
- ✓ Particle transport based on HZETRN (NASA)
- ✓ Website (black box and confidentiality issues)

WHY A NEW MODEL - DEVELOPMENT CONTEXT AND OBJECTIVES



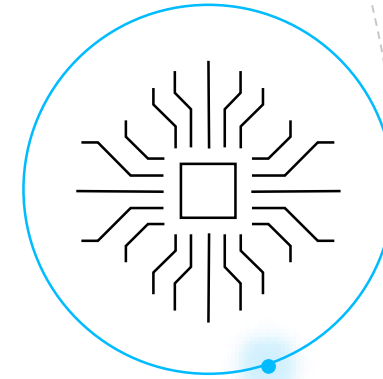
Standalone software



**Technically up to
date - based on
GEANT4**



**Developed in
Europe**



**Targeted at SEEs
on electronics**

The RAMSEES model will be distributed through the OMERE tool



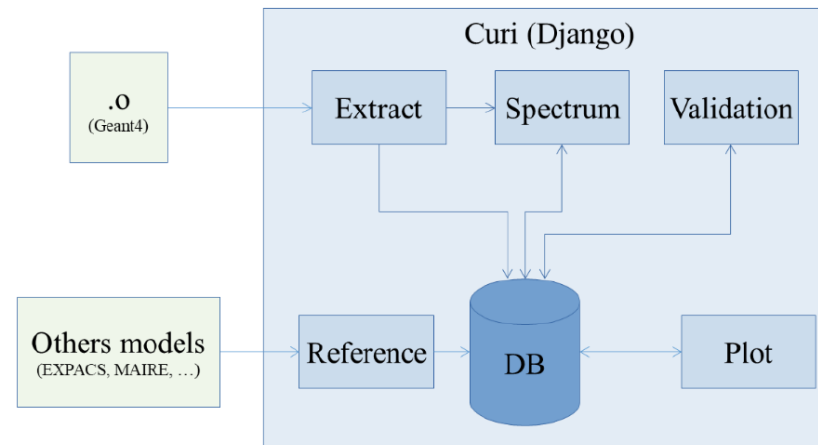
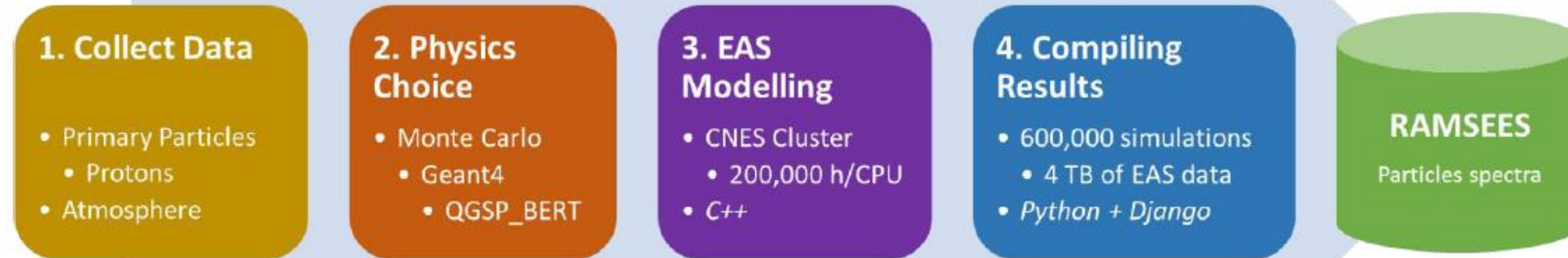
RAMSEES RADIATION ATMOSPHERIC MODEL FOR SINGLE EVENT EFFECTS SIMULATION

- Developed in the frame of Hugo Cintas' PhD project, affiliated to Université de Montpellier
- Co-sponsored venture by CNES (Centre Nationale d 'Etudes Spatiales) and TRAD, Tests and Radiations



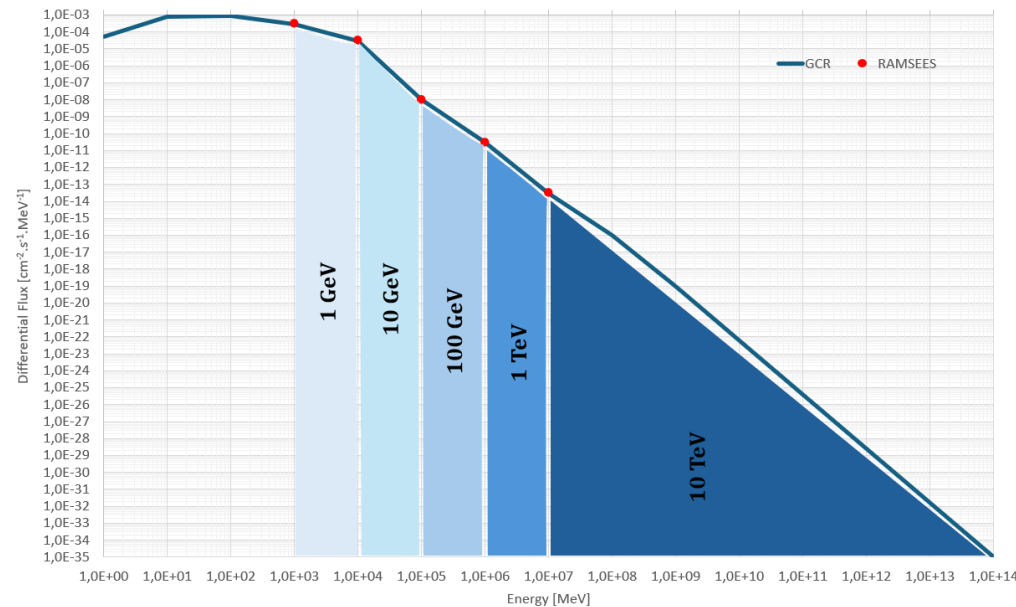
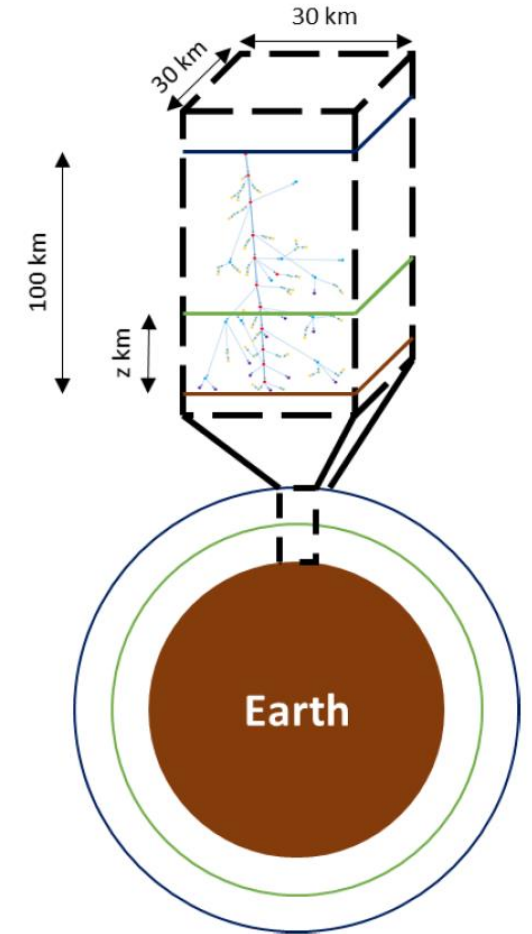
Related publication: H. Cintas et al. « RAMSEES: a model of the atmospheric radiative environment based on geant4 simulation of extensive air shower”, MDPI Aerospace, 2023

CALCULATION STRUCTURE AND MODEL ARCHITECTURE



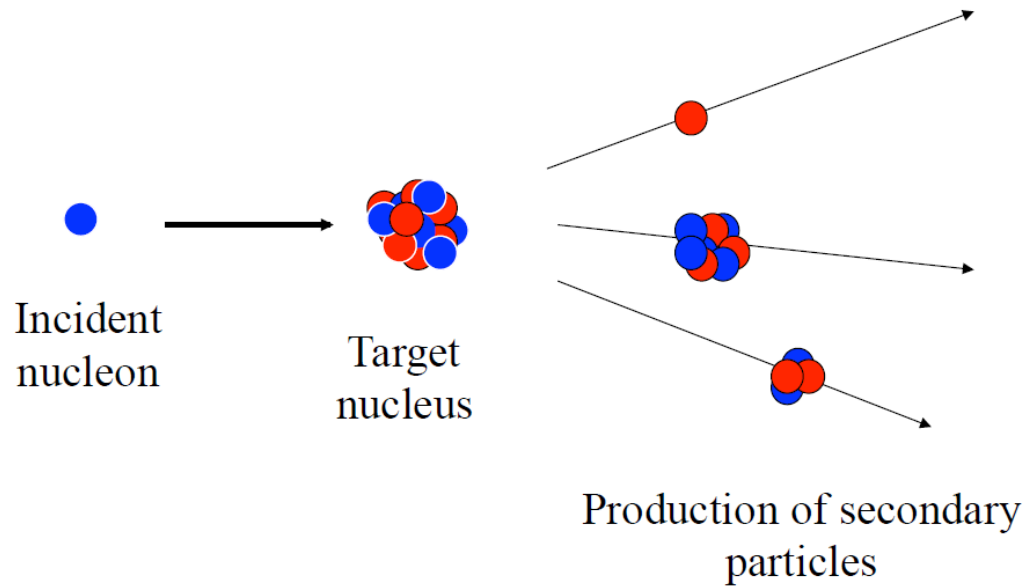
RAMSEES - A CLOSER LOOK

- The atmosphere column was simulated as a 30km x 30km x 100 km parallelepiped
- Such a volume was divided into 10km layers, where density was taken as uniform. Planar detectors were placed between layers.
- 1 GeV, 10 GeV, 100 GeV, 1 TeV et 10 TeV energy protons were chosen as primaries



Images from H. Cintas « Modélisation de l'Environnement Radiatif Atmosphérique Terrestre et Mise en Oeuvre de Mesures Expérimentales pour sa Validation »

A BIT OF PHYSICS

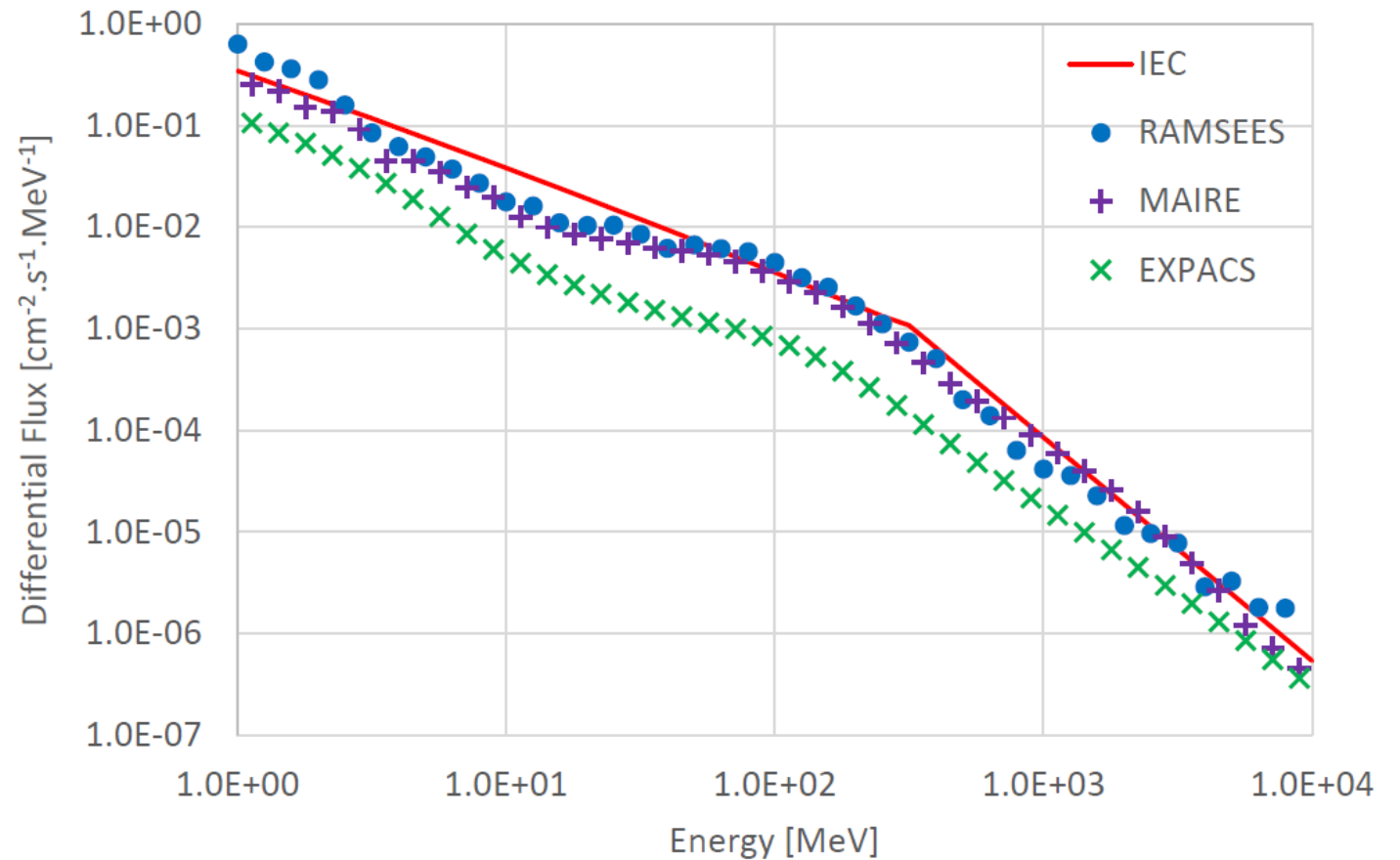


$$\left. \frac{d\phi_i}{dE_i} \right|_z = \iint \left. \frac{dN_i}{dE_i} \right|_z \cdot \frac{d^2\phi_{inc}}{dE_{inc}d\Omega_{inc}} dE_{inc}d\Omega_{inc}$$

- In each layer of the atmosphere, the production of secondaries is simulated
- The secondaries are then tracked through the various detectors
- The obtained data is then compiled into differential spectrum information, which ultimately constitutes RAMSEES
- Produced spectra are associated to a specific altitude, which allows for SEE rates calculation for missions

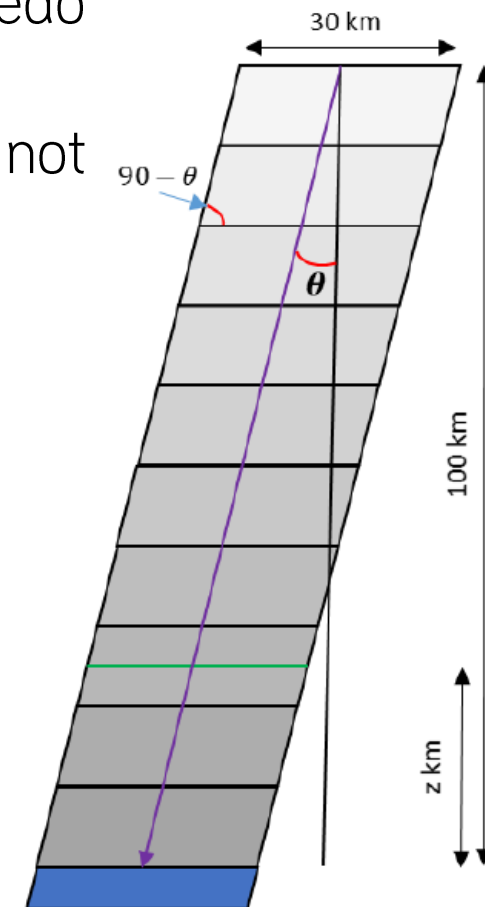
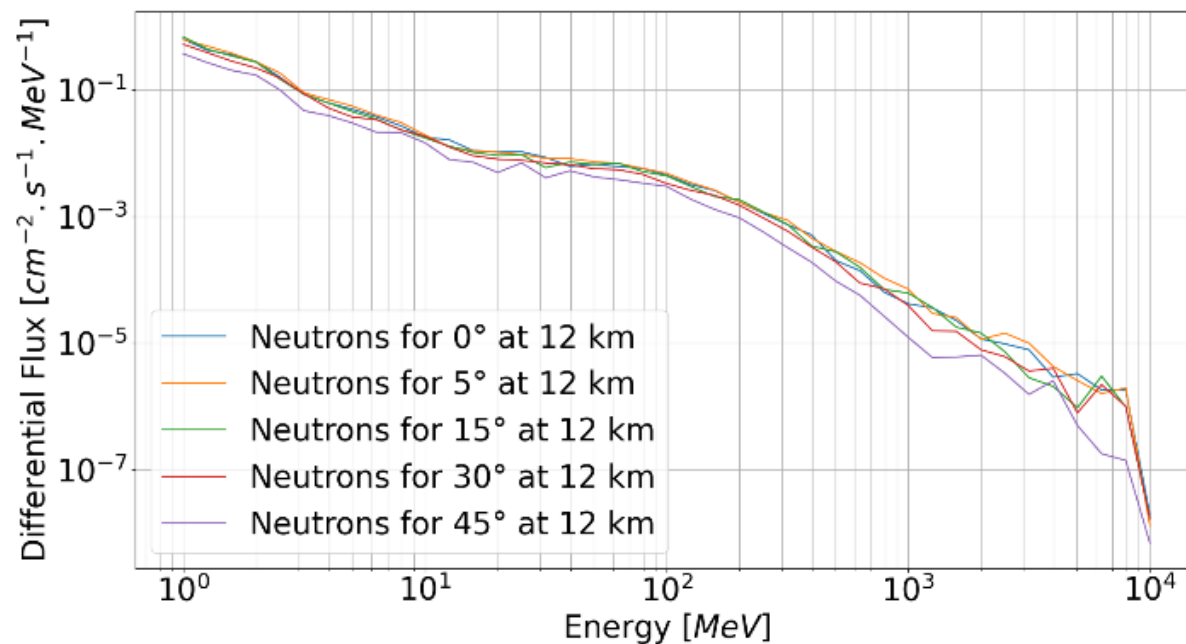
SIMULATION RESULTS WITH WATER LAYER ON GROUND

- A layer of 5km of water was added to the geometry of the model, in order to better account for albedo effects on the ground
- Here presented are the results for differential neutron fluxes calculated at 12 km of altitude, with primary particles of 10 TeV max energy
- Results from RAMSEES match well their MAIRE counterparts



IMPACT OF PRIMARY PARTICLES' ANGLE OF INCIDENCE

- The primary particles' angle of incidence has an impact over albedo effect produced secondaries
- Different incidence angles of primary particles were simulated, but not much statistical difference was found
- Results currently not included in RAMSEES



COMPARISON BETWEEN THE MODELS

| | Paramètres/Modèles | RAMSEES | MAIRE | EXPACS |
|----------------------|----------------------|-----------------------|-------------------------|----------------------------------|
| Résolution | Toolkits ou Outils | GEANT4 | FLUKA / MCNPX | PHITS |
| | Physic list | QGSP_BERT | - | INCL4.6 |
| Particules Primaires | Particules Primaires | Protons | Protons and Alphas | Protons et Ions (Z<29) |
| | Energie Maximale | 10 TeV | 1 TeV/n | 1 TeV/n |
| | Angle des Primaires | 0° | 0° | 0° |
| Géométrie | Modèle d'Atmosphère | NRLMSISE-00 | NRLMSISE-00 | NRLMSISE-86 |
| | Altitude Maximale | 100 km | 100 km | 86 km |
| | Nb. de Couches | 10 | 310 | - |
| | Matériau du Sol | Eau | SiO2 (1.8 g/cm3) | Air |
| | Epaisseur du Sol | 5 km | 100 m | - |
| Autre | Objectif | SEE | Dose | Dose |
| | Nb. de simulations | > 1,200,000 | - | - |

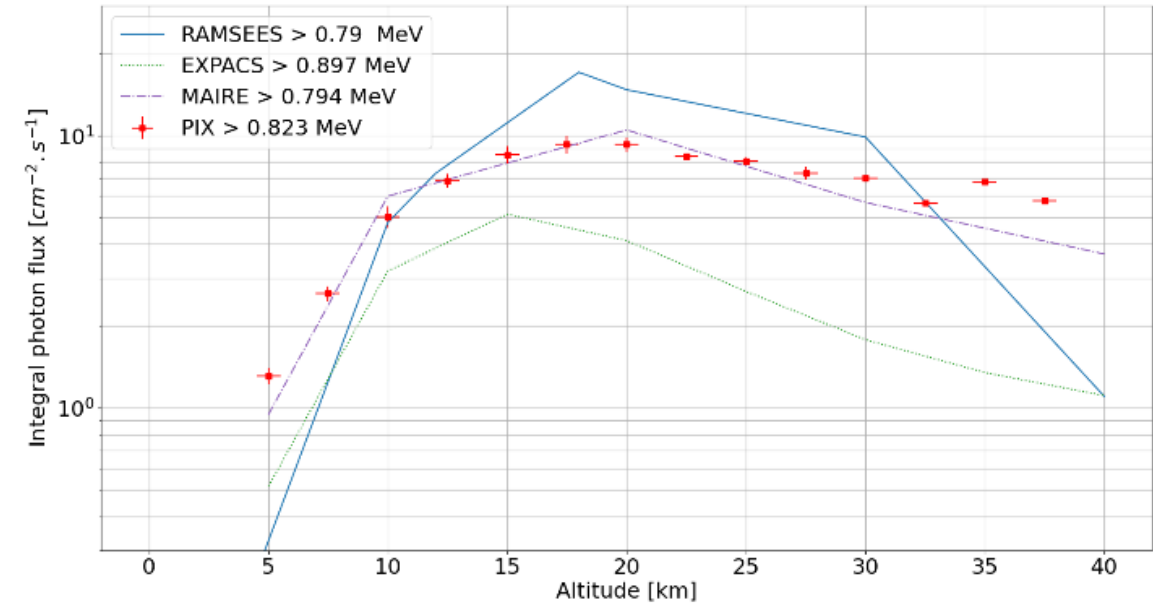
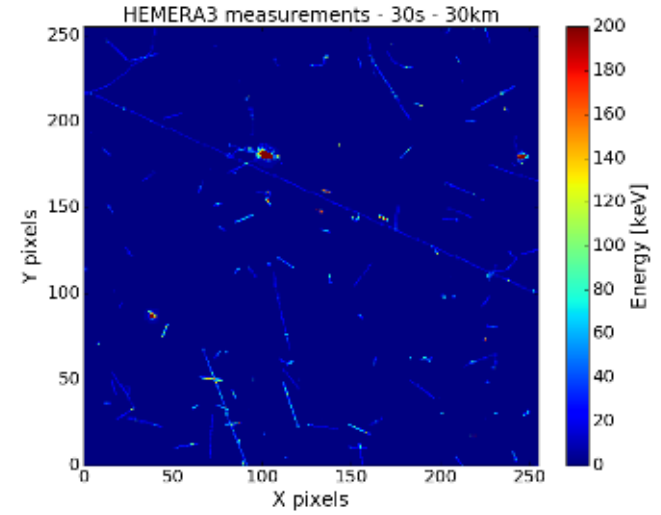
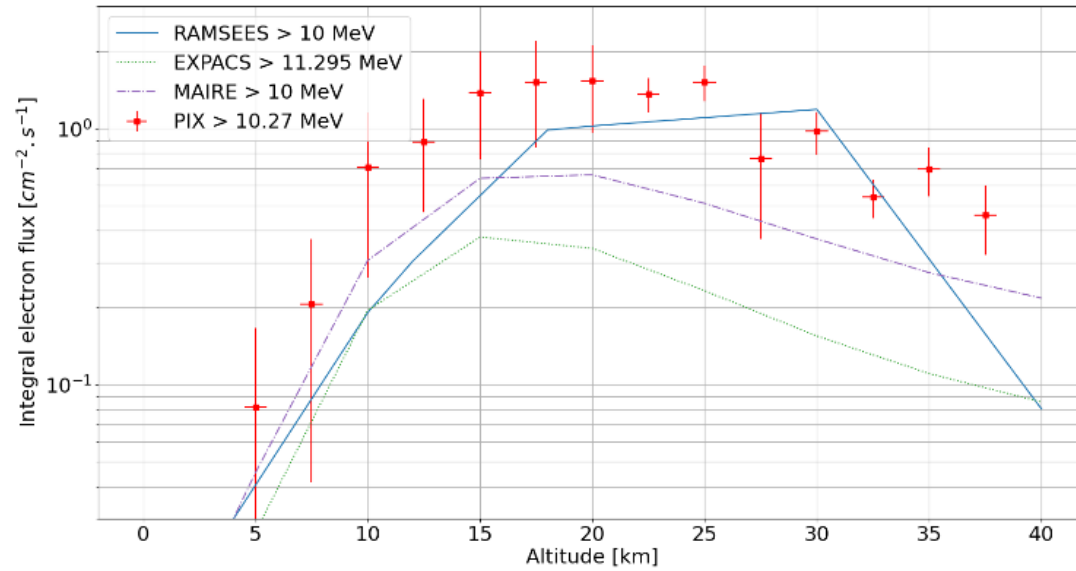
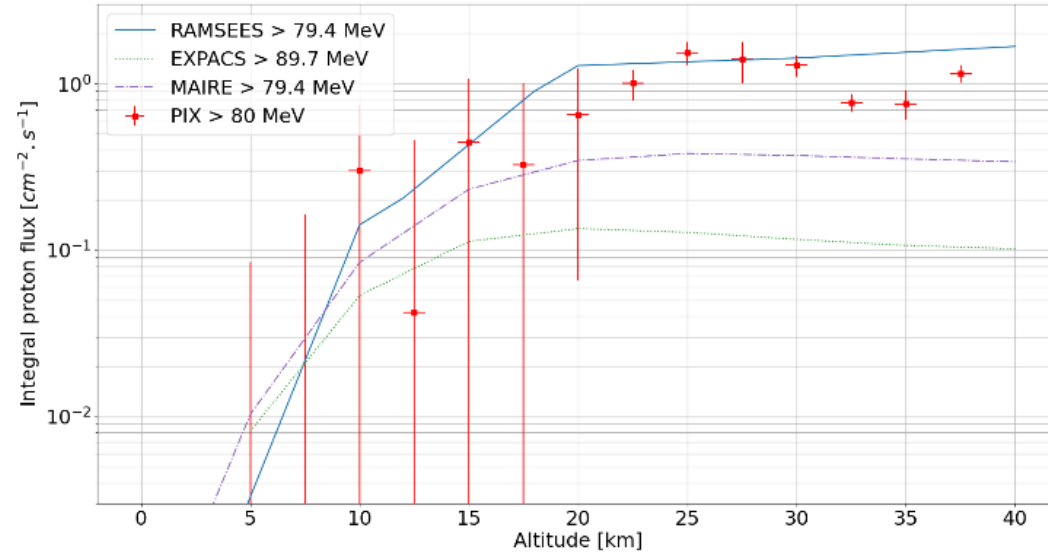
BRAD MEASUREMENTS

(BALLOON RADIATION ANALYSIS DEVICE)

H. Cintas et al. “Proton, Electron and Photon Flux Measurement And Simulation During Stratospheric Balloon Flights”, IEEE TNS, 2024

M. Ruffenach et al. “PIX: an instrument to measure atmospheric ionizing particles based on a single MiniPIX sensor”, IEEE TNS, 2024

BRAD MEASUREMENTS



MODEL IMPROVEMENT PLANS

Some aspects remain still to be improved in the model - and namely:

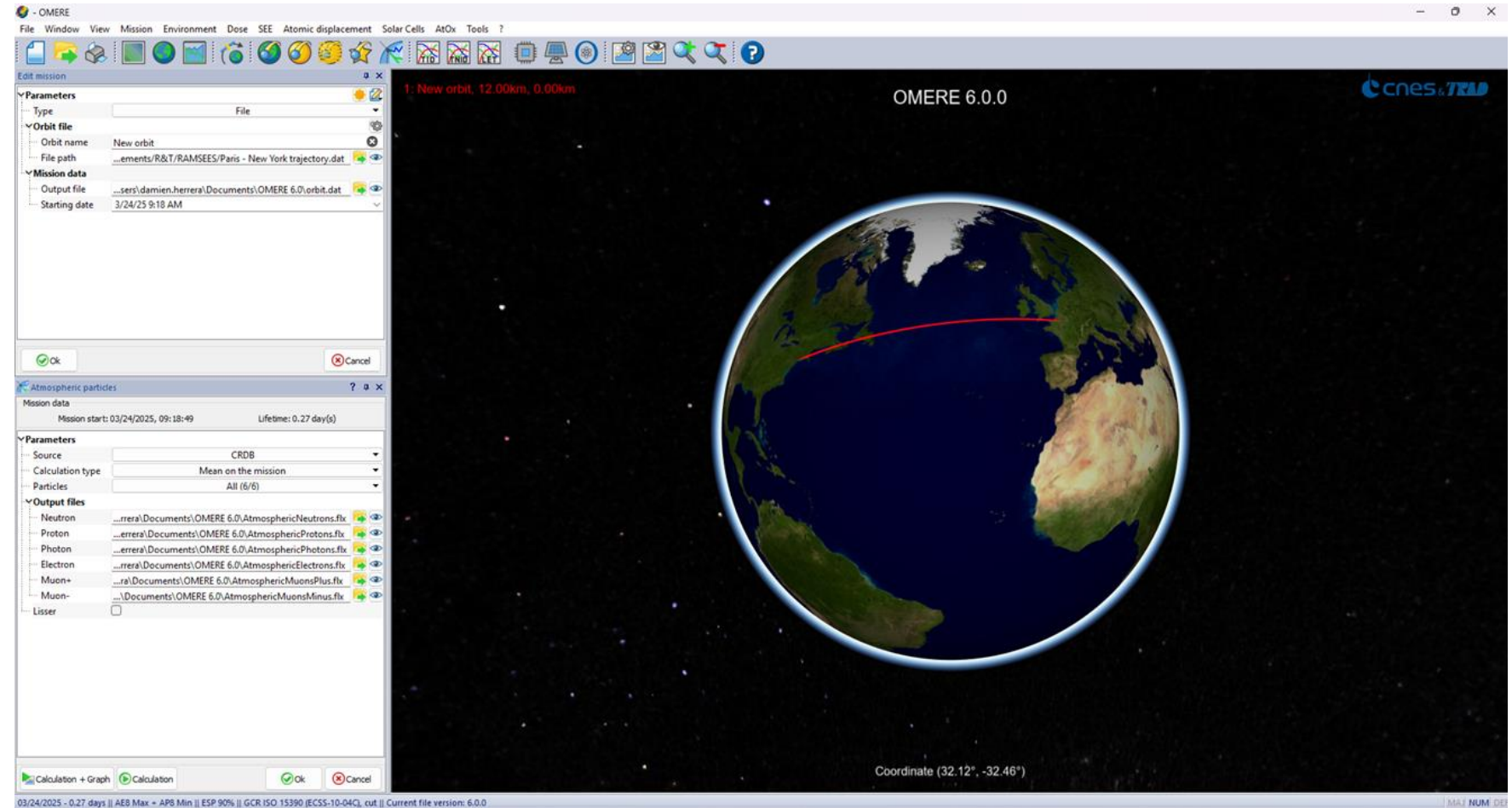
- Better integration of angle of incidence in the model
- Improvement of the energy resolution of the primary spectrum – and adding Heavy Ions
- Improvement of low energy statistics for lower altitude conditions

Improvements ongoing!

FUTURE OUTLOOKS AND APPLICATIONS

Integration in OMERE 2025

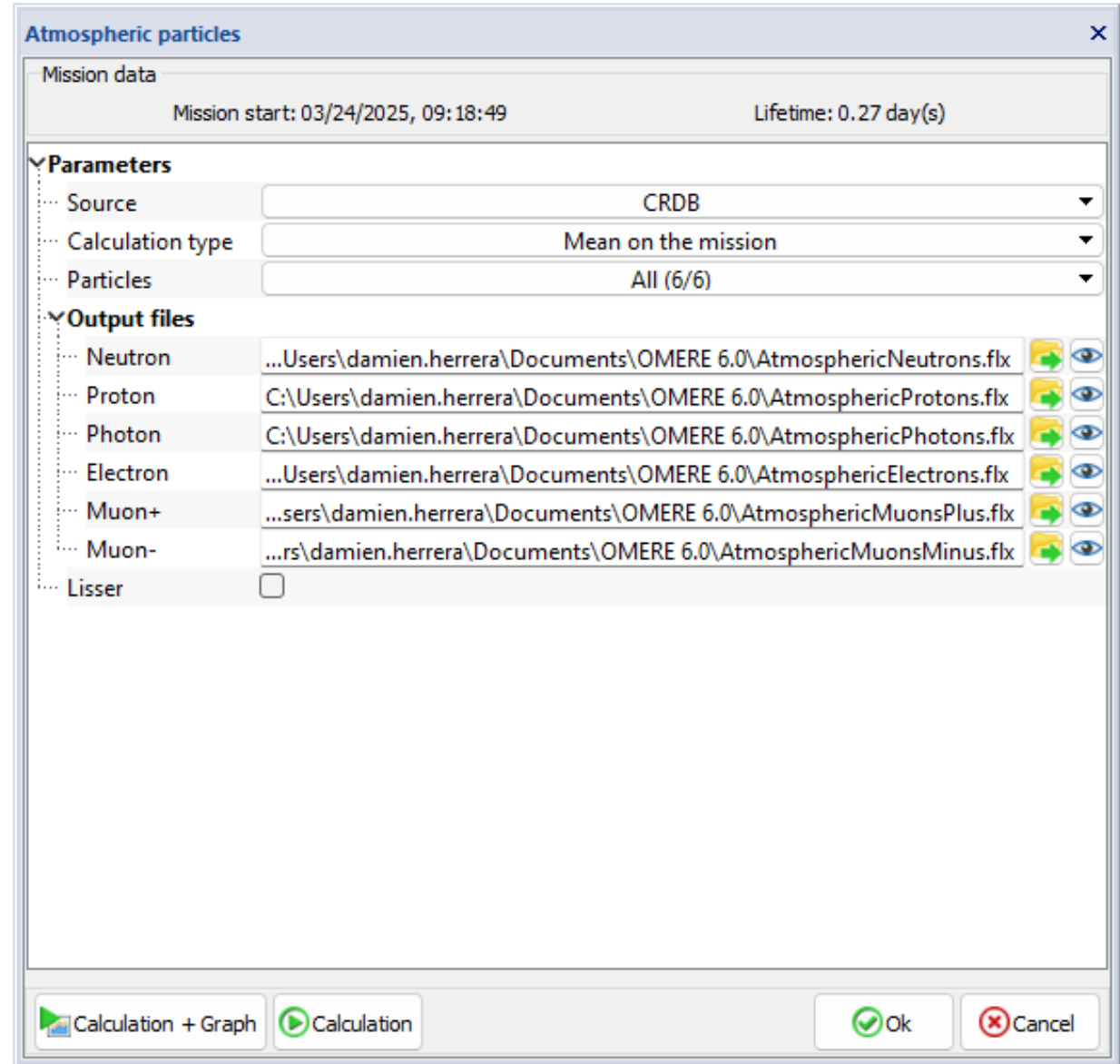
- Freeware (CNES-TRAD development)
- OMERE is vastly adopted by the industry for RHA purposes
- The atmospheric module will allow to assess radiation effects for specific flight plans



INTEGRATION IN OMERE

View of the mission definition panel for Atmospheric particles

Try RAMSEES, when it will be out in OMERE!



THANKS FOR YOUR TIME

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