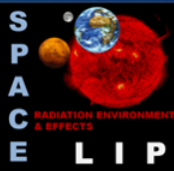# CODES

SIMULATION OF SINGLE EVENT EFFECTS AND RATE PREDICTION

Patrícia Gonçalves, LIP patricia@lip.pt
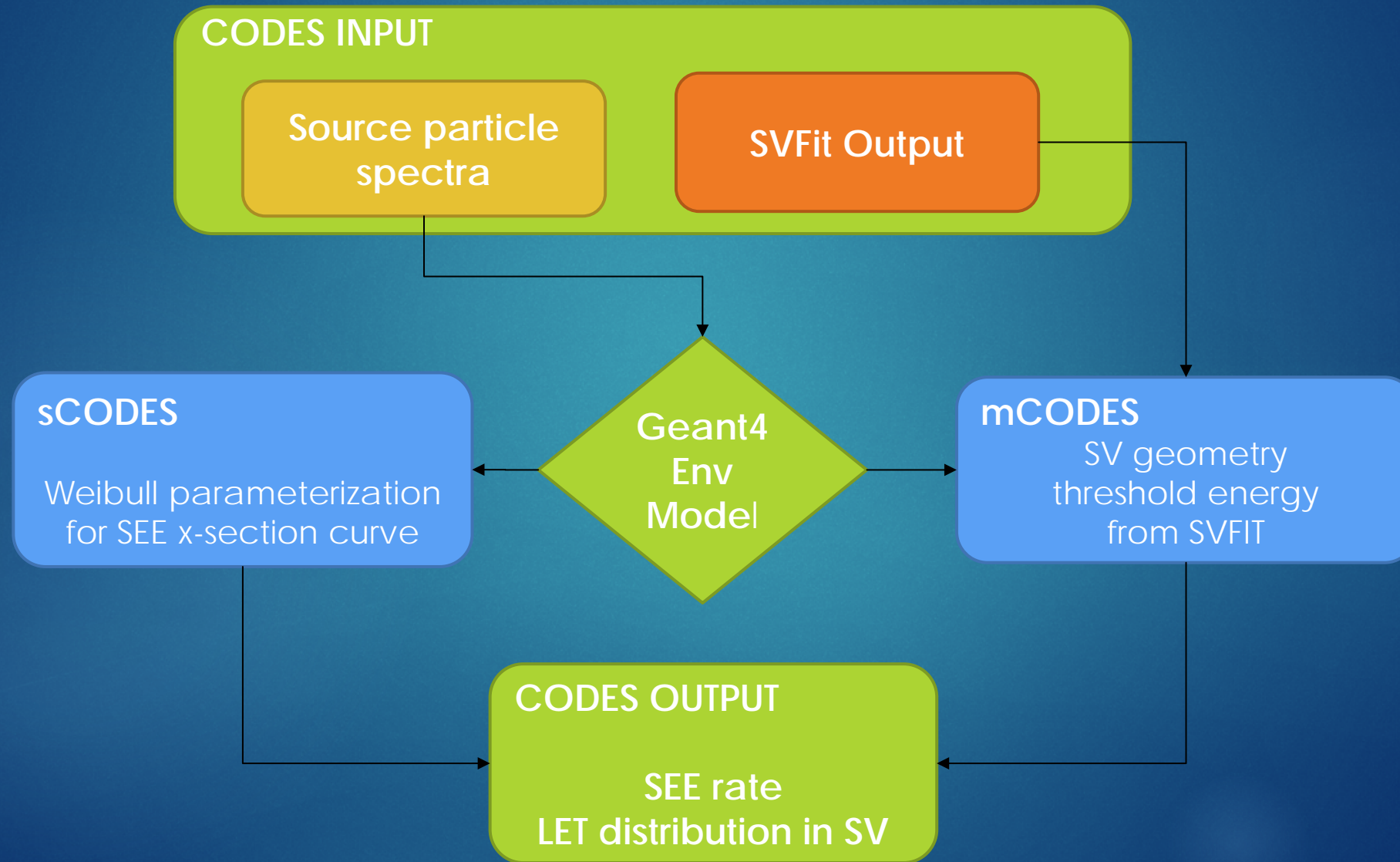
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What is CODES?

CODES – COmponent DEgradation Simulation tool

- CODES framework is a web-based interface for simulating SEE based on Geant4

- CODES enables an effective modelling of Component Sensitive Volume and of SEE threshold energy with Geant4

- CODES computes device response to radiation input spectra

- CODES framework is composed by 2 GEANT4-based applications:

  - **SVFIT** : Modeling of Effective SV and threshold energy based on Real Data
  - **EnvModel** : Simulation of SEE using specific environment and effective SV from SVfit or Weibull

- CODES has the potentiality to keep a device library to be incremented by user cases

- CODES output is sent to the Users by email –> CODES User register in next version

CODES Model Framework
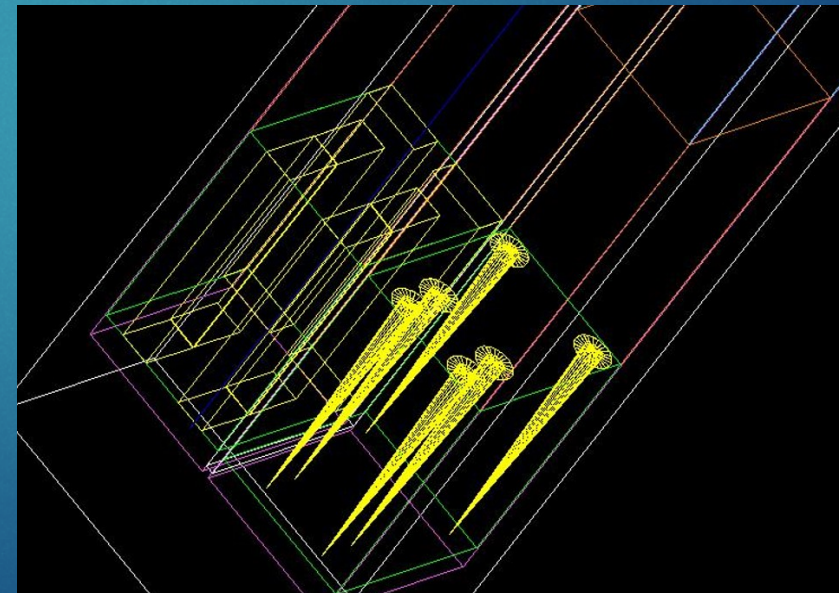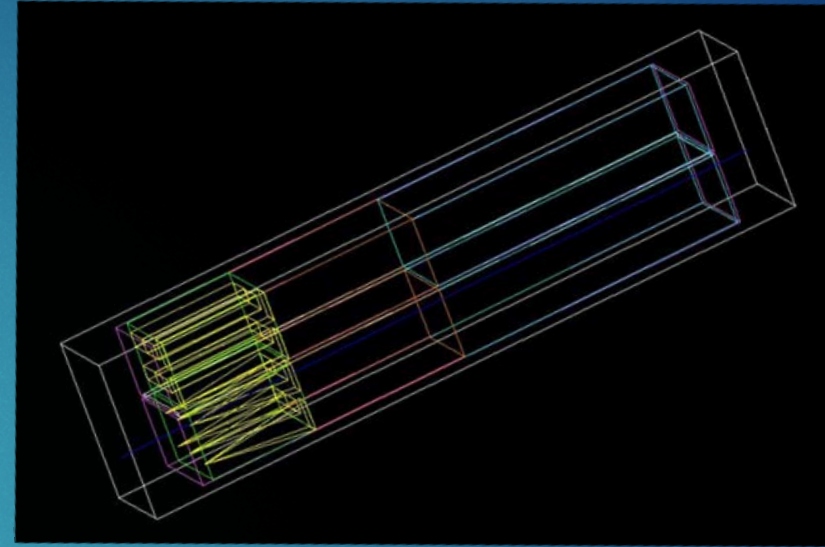
CODES INPUT

Source particle spectra

SVFit Output

sCODES

Weibull parameterization for SEE x-section curve

Geant4 Env Model

mCODES
SV geometry threshold energy from SVFIT

CODES OUTPUT
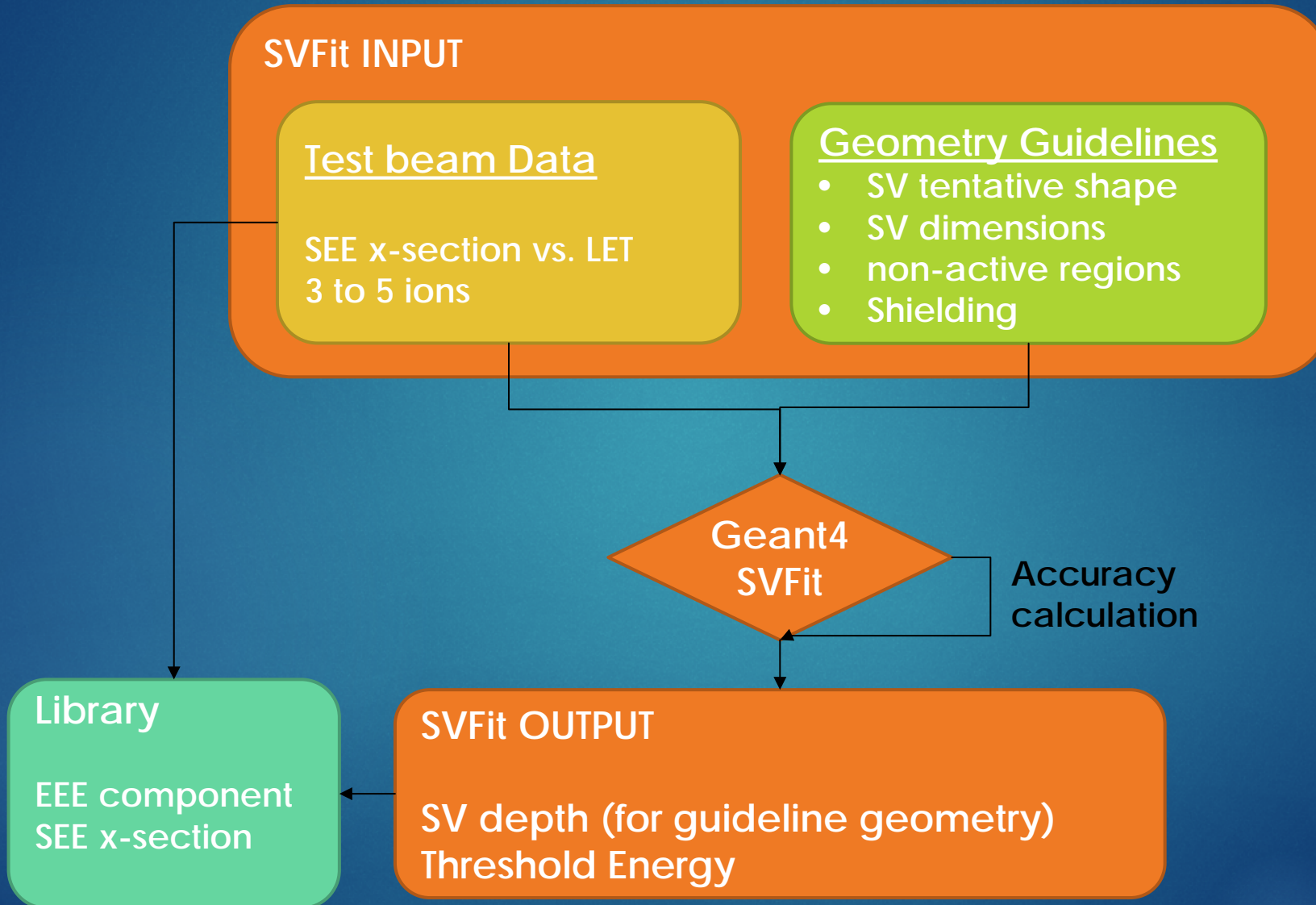
SEE rate
LET distribution in SV

SVFit
Sensitive Volume Fit

▶ SVFIT is the CODES GEANT4-based module that fits device sensitive volume, shape and dimensions, to reproduce the experimental SEE x-section curve and output the correspondent computation accuracy.

▶ The sensitive volume shape can vary from a rectangle parallelepiped to a polycone with varying transverse radius and depth.

SVFit Model

SVFit INPUT

Test beam Data

SEE x-section vs. LET
3 to 5 ions

Geometry Guidelines
- SV tentative shape
- SV dimensions
- non-active regions
- Shielding

Geant4
SVFit

Accuracy
calculation

Library

EEE component
SEE x-section

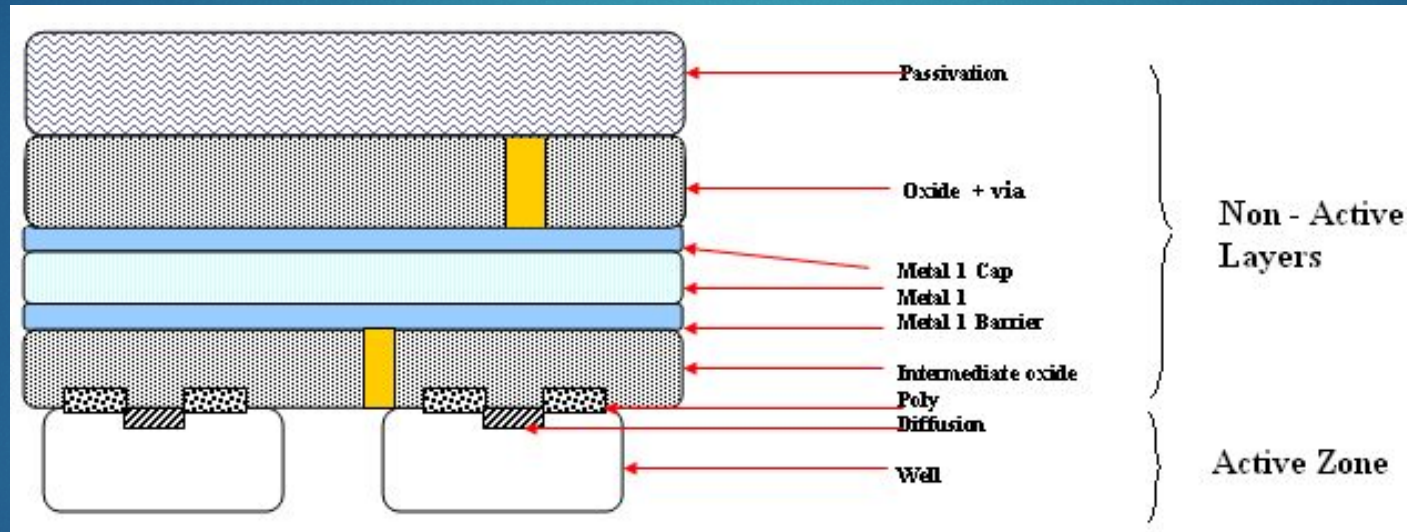**SVFit OUTPUT**

SV depth (for guideline geometry)
Threshold Energy

SVfit

- ▶ The minimum input configuration required to run SVFIT:
  - ▶ is the description of the experimental ion cocktails (with 3 to 5 ions), with experimental cross-sections
  - ▶ reasonable guideline dimensions for the device active region represented by a block of silicon.

- ▶ The SVfit output can be kept for future reference in a SEE sensitivity device library.

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CODES Framework

Prediction of Single Event Effects in EEE devices

HOME   SVFIT   EnvModel   HELP

SVFIT: Web Interface

Component Description

Component Type:
SRAM

Email:

Component Description:
memory device

Re-Type Email:

Component Number:
AT68166

N. of Bits[unit bit][1-64]:
1

Geometry:
Parallelepiped "RPP"

Manufacturer:
ATMEL

Geometry

Select no. of Transistors Active
Regions in the memory cell: ● 1 ○ 2 ○ 4 ○ 6

Aluminium Equivalent
Shielding Layer [mm]:   0

No. of non-active layers above SV: ?
0

Guideline SV Dimensions[um]:   0.81 x 1 y 2
Depth

Depth Uncertainty Variation: ● 0 ○ 10 ○ 50 ○ 75 ○ 90 [%]

If Uncertainty Variation is left to 0, it is assumed that device dimensions are exact.

Ion Data Table

Clear Data	Load defaults	Browse...

Atomic No.(Z)	Atomic Mass(A)	Charge(Q)	Ion Energy(MeV)	LET(MeV/mg/cm^2)	SEEXS (/cm^2/bit)
7	15	4	139	1.7	6.9700E-12
10	20	6	186	3.5	3.64262E-9
14	30	8	278	6.4	4.63064E-9
18	40	12	372	10	1.12421E-8
36	82	22	768	30	3.27837E-8

No of processing events per ion: 1000   Select Physics list: Electromagnetic (EM)   Run SVFIT

Svfit output

```
SVFIT interactive mode final results
Best geometry description
User input data:
For (1) SV volumes
SVx 0.81 um
SVy 1 um
SVz 3 um    Depth +/- 50% uncertainty

Best geometry shape: trp with SV Depth = 4.5 um and Ecrit = 1.1
MeV
Accuracy: 63.9992%

*************************************************;
Cross section destail for different geometries;
*************************************************;

SVdepth     SVz    3 um

*******************************************;
LET; SEE XS (exp); SEEXS (rpp); SEEXS(trp);
*******************************************;
1.7;6.97e-12;2.42052e-09;6.09505e-09;
3.5;3.64262e-09;5.12247e-08;2.05599e-08;
6.4;4.63064e-09;5.1283e-08;3.27062e-08;
10;1.12421e-08;5.10643e-08;3.86409e-08;
30;3.27837e-08;5.11518e-08;4.68648e-08;

*******************************************;
Best geometry: trp; Accuracy: 38.0656%;

SVdepth     SVz    4.5 um

*******************************************;
LET; SEE XS (exp); SEEXS (rpp); SEEXS(trp);
*******************************************;
1.7;6.97e-12;4.27237e-09;3.70369e-09;
3.5;3.64262e-09;5.08747e-08;1.47127e-08;
```

Environment Model

- CODES Environment Module is used for the computation of degradation rates.

- The Environment Module enables the simulation of the effect of space radiation spectra on the device.

- The Environment model takes as inputs:

  - Source Particle Spectra

  - Device SV Geometry, including shielding: **from SVfit OR User defined**

  - Device sensitivity: **Threshold Energy from SVfit OR Weibull parameters**

CODES Environment Model
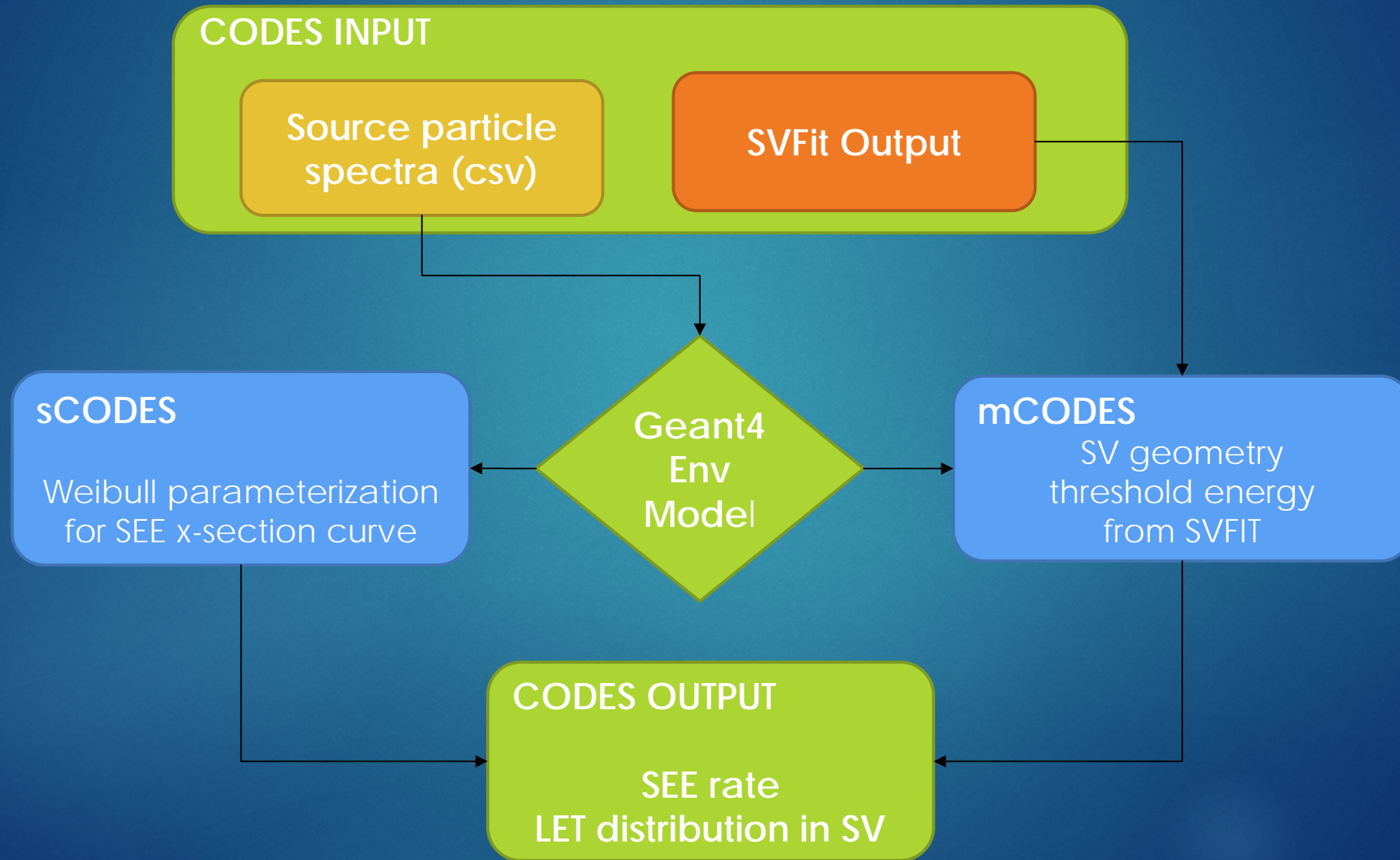
CODES INPUT

Source particle spectra (csv)

SVFit Output

sCODES

Weibull parameterization for SEE x-section curve

Geant4 Env Model

mCODES

SV geometry threshold energy from SVFIT

CODES OUTPUT

SEE rate
LET distribution in SV

CODES Framework

Prediction of Single Event Effects in EEE devices

HOME   SVFIT   ENVMODEL   HELP

Component Description

Component Type: SRAM
Component Description: memory device
Component Number: AT68166
N. of Bits [unit bit] [1-64]: 1
Manufacturer: ATMEL
Email:
Re-Type Email:

Radiation Input

(SPENVIS-like csv file):
⦿ file   (Download Template File Example)

Choose file

Particle: Proton
Ion specific label:
Flux Units: (/cm2/MeV)

Energy [MeV]	Flux
1.1295E+01	3.9822E+05
1.4219E+01	2.1778E+05

Geometry

Aluminium Equivalent
Shielding Layer [mm]: 0
Non active layers: 0
Sensitive volume: Load from SVFIT output

Choose file

Device Response function

Select Method: Montecarlo Simulation

Choose file

Critical Energy [MeV]:
(only for user defined Geometry)

No of processing events per ion: 1000   Select Physics list: Electromagnetic (EM)   Run CODES

CODES Framework

Prediction of Single Event Effects in EEE devices

HOME   SVFIT   EnvModel   HELP

CODES: Web Interface

Component Description

Component Type: SRAM
Component Description: memory device
Component Number: AT68166
N. of Bits [unit bit] [1-64]: 1
Manufacturer: ATMEL
Email:
Re-Type Email:

Radiation Input

(SPENVIS-like csv file):
● file   (Download Template File Example)

Choose file

Particle: Proton
Ion specific label:
Flux Units: (/cm2/MeV)

Energy [MeV]	Flux
1.1295E+01	3.9822E+05
1.4219E+01	2.1778E+05

Geometry

Aluminium Equivalent
Shielding Layer [mm]: 0
Non active layers: 0
Sensitive volume: User define geometry
Regions in the memory cell: ● 1   ○ 2   ○ 4   ○ 6
Geometry: Parallelepiped "RPP"
Dimensions [um]:   X   Y   Depth

Device Response function

Select Method: Montecarlo Simulation
Choose file

Critical Energy [MeV]:
(only for user defined Geometry)

SPACE Radiation Environment and Effects - Study and simulation of the radiation environment in space radiation monitoring and effects on EEE components

CODES Framework

Prediction of Single Event Effects in EEE devices

HOME SVFIT ENVMODEL HELP

CODES: Web Interface

Component Description

Component Type: SRAM
Component Description: memory device
Component Number: AT68166
N. of Bits [unit bit] [1-64]: 1
Manufacturer: ATMEL
Email:
Re-Type Email:

Radiation Input

(SPENVIS-like csv file):
◉ file (Download Template File Example)

[Choose file]

Particle: Proton ▼
Ion specific label:
Flux Units: (/cm2/MeV) ▼

Energy [MeV]	Flux
1.1295E+01	3.9822E+05
1.4219E+01	2.1778E+05

Geometry

Aluminium Equivalent Shielding Layer [mm]: 0
Non active layers: 0 ▼
Sensitive volume: User define geometry ▼
Regions in the memory cell: ◉ 1 ○ 2 ○ 4 ○ 6
Geometry: Parallelepiped "RPP" ▼
Dimensions [um]:   X   Y   Depth

Device Response function

Select Method: Fit Weibull function ▼
Select Weibull Method: Protons ▼
Plateaux [cm2/bit]:
With Parameter [MeV]:
Exponent:
Threshold Energy [MeV]:

SPACE Radiation Environment and Effects - Study and simulation of the radiation environment in space radiation monitoring and effects on EEE components

CODES Framework

Prediction of Single Event Effects in EEE devices

HOME   SVFIT   ENVMODEL   HELP

CODES: Web Interface

Component Description

Component Type: SRAM
Component Description: memory device
Component Number: AT68166
N. of Bits [unit bit] [1-64]: 1
Manufacturer: ATMEL
Email:
Re-Type Email:

Radiation Input

(SPENVIS-like csv file):
◉ file   (Download Template File Example)

Choose file

Particle: Proton
Ion specific label:
Flux Units: (/cm2/MeV)

Energy [MeV]	Flux
1.1295E+01	3.9822E+05
1.4219E+01	2.1778E+05

Geometry

Aluminium Equivalent Shielding Layer [mm]: 0
Non active layers: 0
Sensitive volume: User define geometry
Regions in the memory cell: ◉ 1   ○ 2   ○ 4   ○ 6
Geometry: Parallelepiped "RPP"
Dimensions [um]:   X   Y   Depth

Device Response function

Select Method: Fit Weibull function
Select Weibull Method: Ions
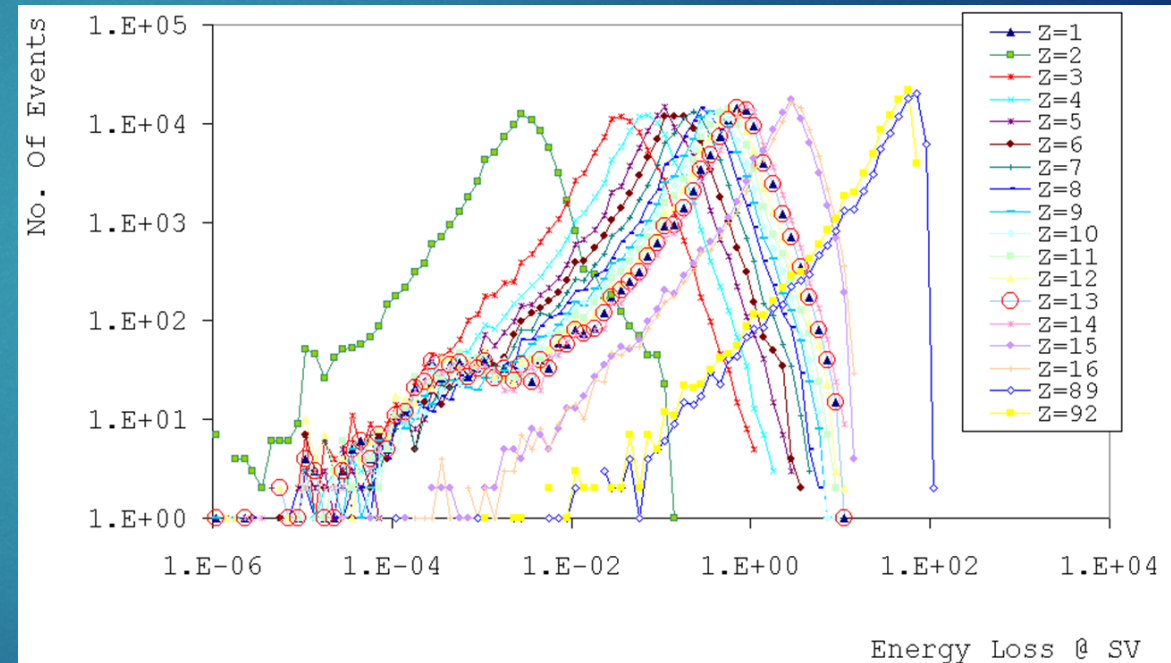Plateaux [cm2/bit]:
With Parameter [MeV*cm2/mg]:
Exponent:
Threshold Energy [MeV*cm2/mg]:

Environment Model

The environmental model output returns

- ▶ the expected SEE rate

- ▶ the distribution of energy deposited in the sensitive volume in MeV as well as the individual contribution from all ions in the simulated spectrum.
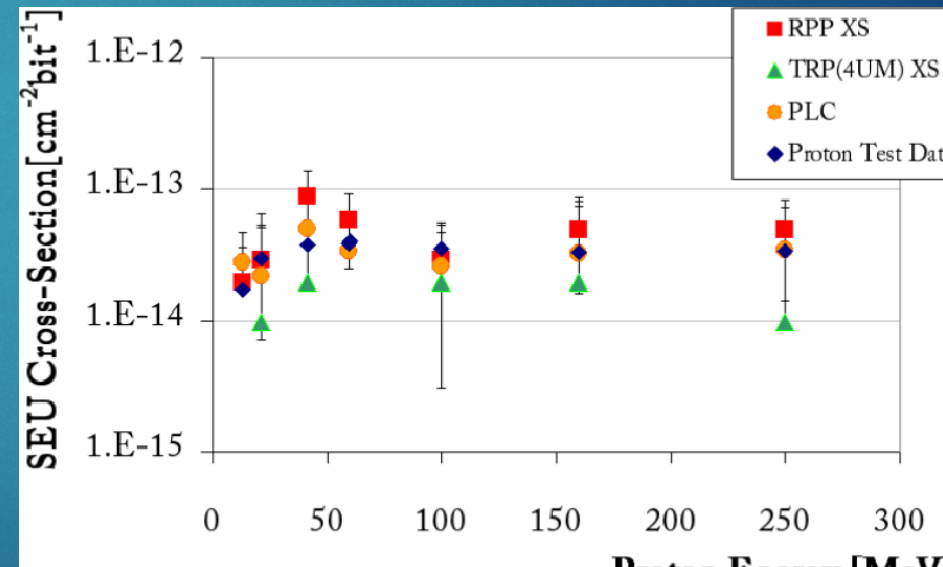
CODES framework results

Reconstruction of Ion SEU cross-sections based on ion test data analysis for the RSEUM
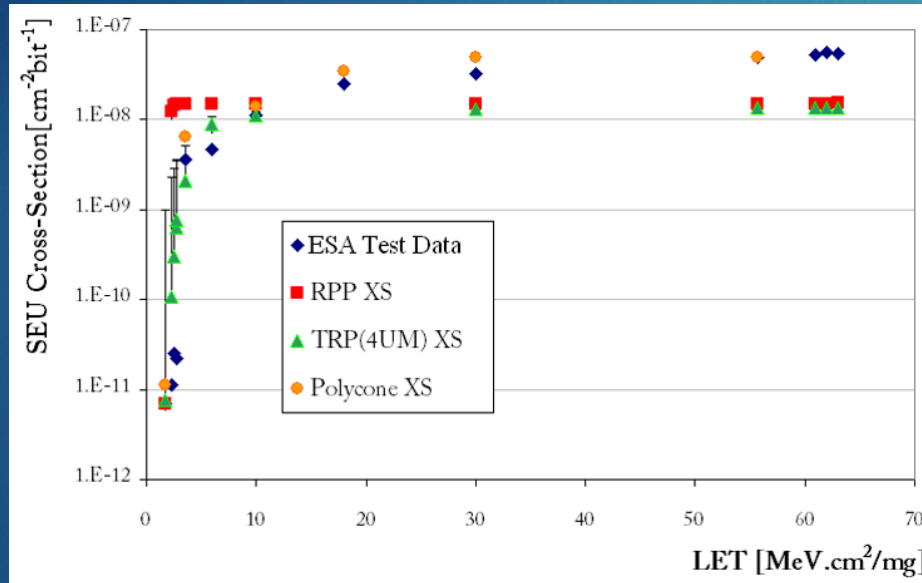
Reconstruction of Proton SEU cross-section test data for the RSEUM

The device sensitivity was determined with SVFIT, based on ion test data.

Example of application

INPUTS:

▶ SVFit output file for a specific case

```
SVFIT interactive mode final results
Best geometry description
User input data:
For (1) SV volumes
SVx 0.81 um
SVy 1 um
SVz 3 um    Depth +/- 50% uncertainty

Best geometry shape: trp with SV Depth = 4.5 um and Ecrit = 1.1
MeV
Accuracy: 63.9992%
```

▶ Response to Fluor Ion Spectra

```
'*',    11,     1,      7,      0,      2,      2,      50,         0
'CODES file                - Wed, 29 May 13 15:12:49 +0100'
'PRJ_DEF', -1,'TEST'
'PRJ_HDR', -1,' '
'MOD_ABB', -1,'CODES v2.0.0.2'
'Env_Desc', -1,'File recreated by CODESFramework'
'PARTICLE', -1, 'F'
'Flux_Omni',  1,  1,' '
'Flux_Type',  1,  1,' '
'Energy','MeV', 1,'Energy'
'Flux','/cm2/MeV/sr/s', 1,'Differential Flux of '
19,6.00842105263E-7
20.9,6.00473684211E-7
22.8,6.00105263158E-7
26.6,5.99315789474E-7
30.4,5.98473684211E-7
34.2,5.97631578947E-7
38,5.96684210526E-7
41.8,5.95789473684E-7
47.5,5.94368421053E-7
53.2,5.92947368421E-7
60.8,5.91157894737E-7
66.5,5.89894736842E-7
76,5.8789473842E-7
85.5,5.86210526316E-7
95,5.84736842105E-7
104.5,5.83526315789E-7
119.7,5.82052631579E-7
134.9,5.81E-7
```

CODES Framework

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CODES Framework
Prediction of Single Event Effects in EEE devices

HOME   SVFIT   ENVMODEL   HELP

CODES: Web Interface

Component Description

Component Type: SRAM
Component Description: memory device
Component Number: AT68166
N. of Bits[unit bit][1-64]: 1
Manufacturer: ATMEL
Email:
Re-Type Email:

Radiation Input

Particle: Ion
Ion specific label: F
Flux Units: (/cm2/MeV/sr/s)

Energy [MeV]	Flux
19	6.00842105263E-7
20.9	6.00473684211E-7
22.8	6.00105263158E-7
26.6	5.99315789474E-7

Geometry

Aluminium Equivalent Shielding Layer [mm]: 0
Non active layers: 0
Sensitive volume: Load from SVFIT output
Browse...

Regions in the memory cell: ● 1 ○ 2 ○ 4 ○ 6
Geometry: TRP
Dimensions[um]: 0.81 x 1 y 4.5 Depth

Device Response function

Select Method: Montecarlo Simulation
Browse...

Critical Energy [MeV]: 1.1
(only for user defined Geometry)

No of processing events per ion: 1000   Select Physics list: Electromagnetic (EM)   Run CODES

SPACE Radiation Environment and Effects - Study and simulation of the radiation environment in space radiation monitoring and effects on EEE components

codes.lip.pt/svfit/svfit.htm

PT   12:08

CODES V2.2.0.0 | Run ID: 233 | Energy Loss distribution @ SV
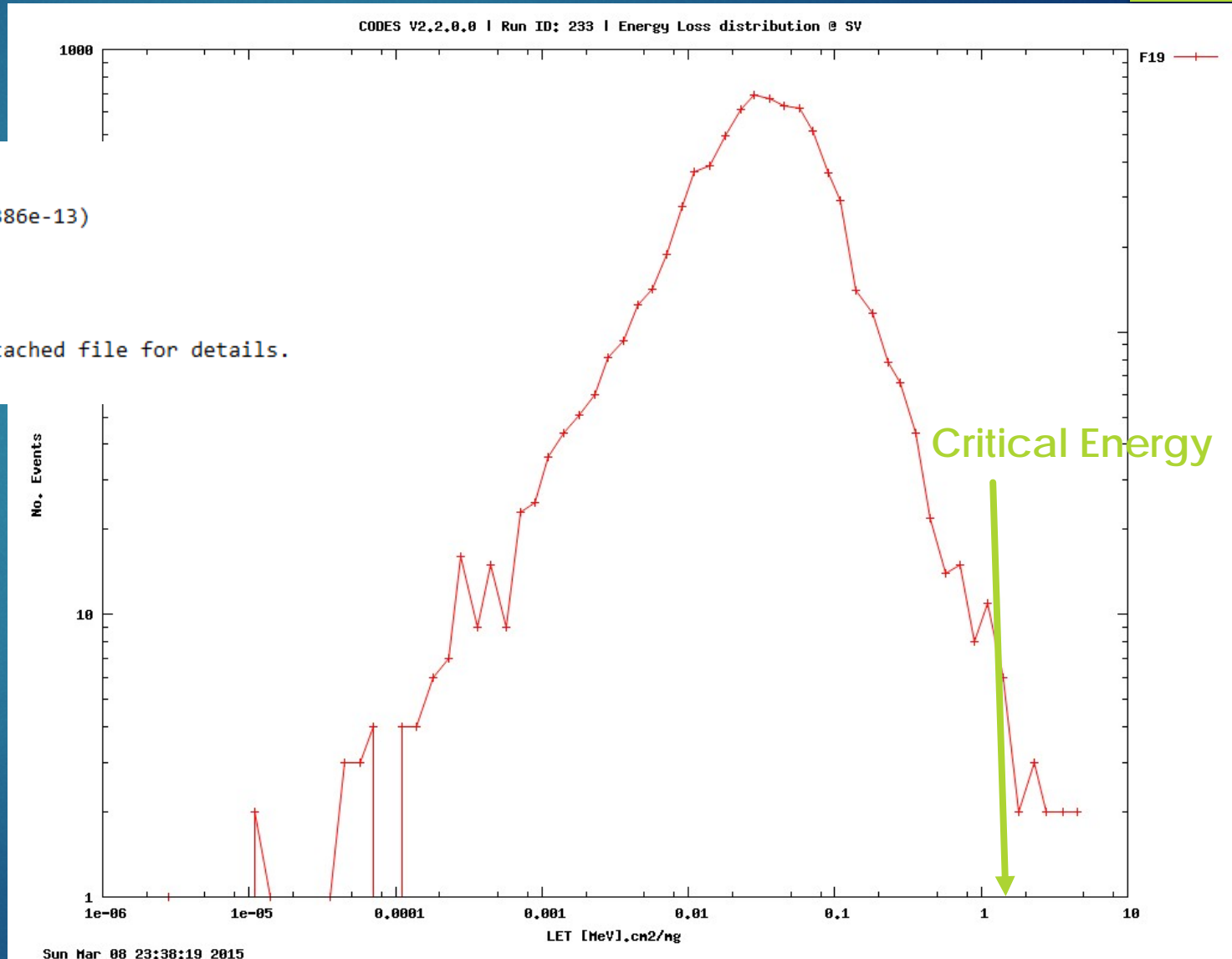
Summary Report:

    (Particle: F19, SEU Rate [bits/s]: 1.23386e-13)

    Total SEU Rate [bits/s]: 1.23386e-13

CODES Energy Dep. Histogram results ok.
Your request has reached final results. Open attached file for details.

Critical Energy

Sun Mar 08 23:38:19 2015

http://codes.lip.pt