G4SEE Monte Carlo simulation tool

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on behalf of R2E/BMI unit

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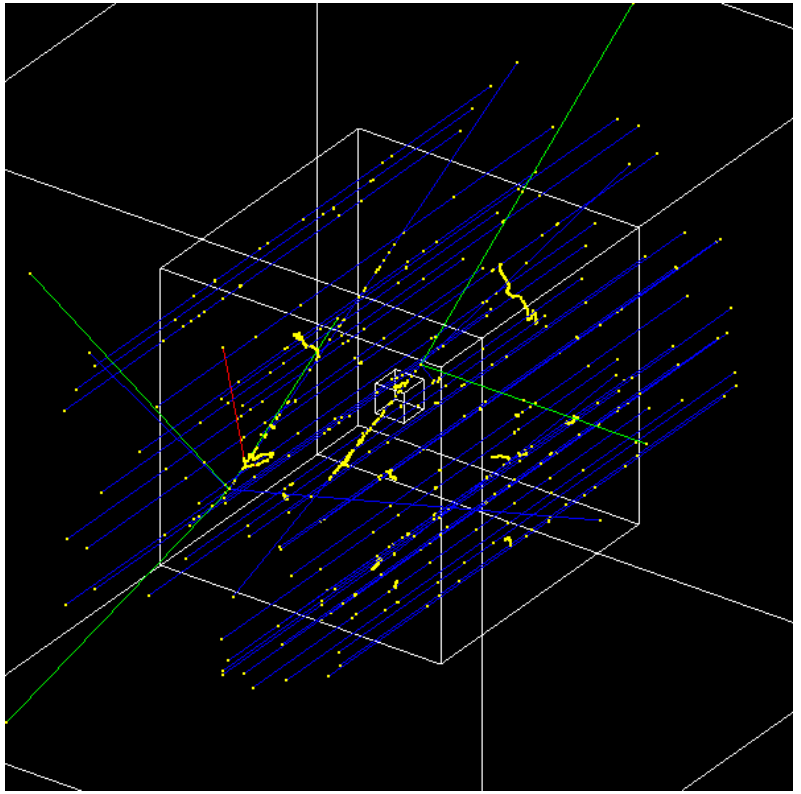
https://indico.cern.ch/event/971222/

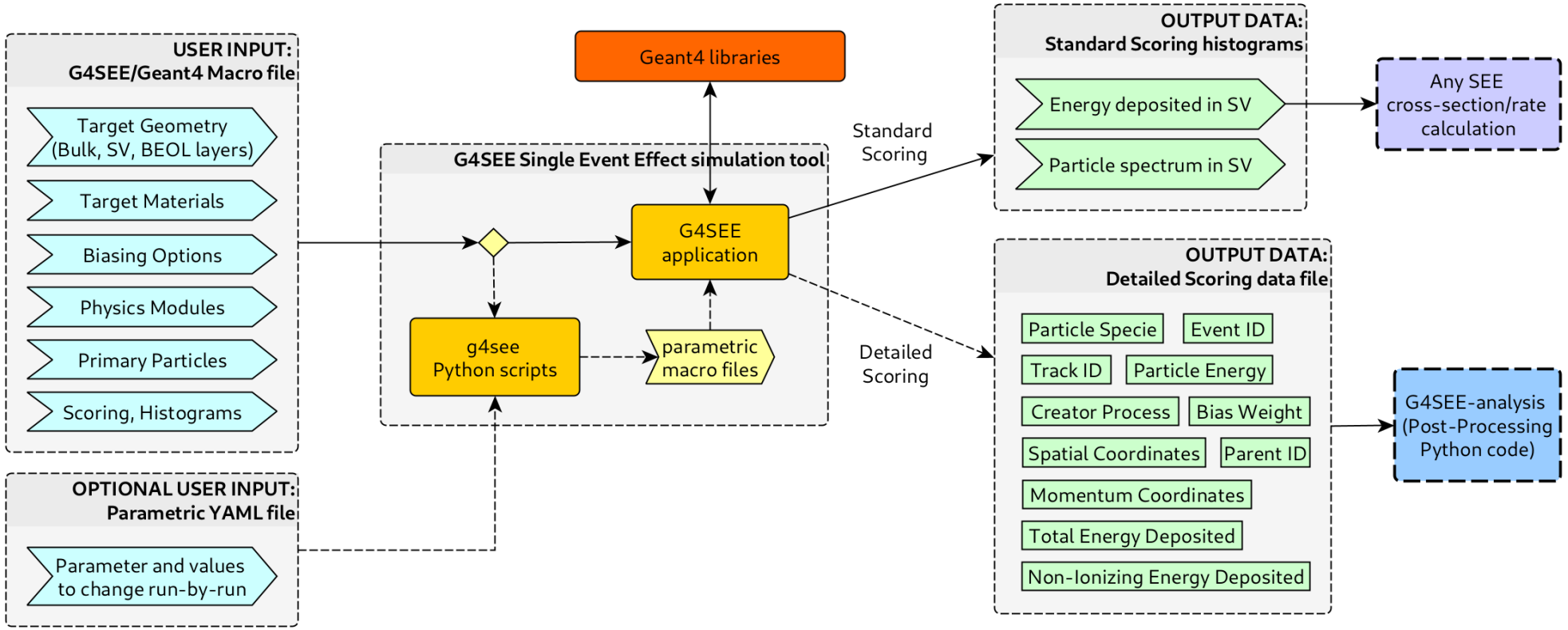
Introduction

- **G4SEE** application is based on **Geant4** (G4) Monte Carlo simulation toolkit
- **Developed for and by the R2E community**, and planned to be fully open-source, since no such tool exists today
- **Goal:** extract all information relevant for SEEs on an event-by-event and particle-by-particle basis, according to the needs of users
- **Complement & supplement SEE simulation studies** performed using FLUKA (example: <20 MeV neutrons)



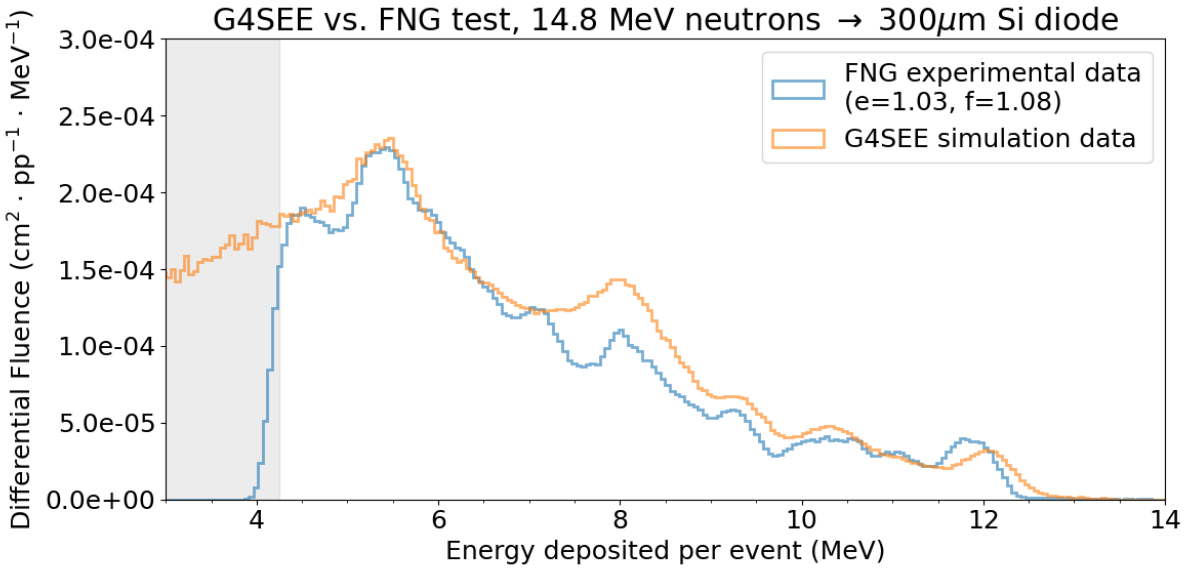
High-level architecture & features

- **Direct and indirect energy deposition scoring** in micro-metric volumes (based on user inputs)
  ⇨ SEE cross-section or rate estimation
- **Standard and Detailed Scoring in Sensitive Volume**

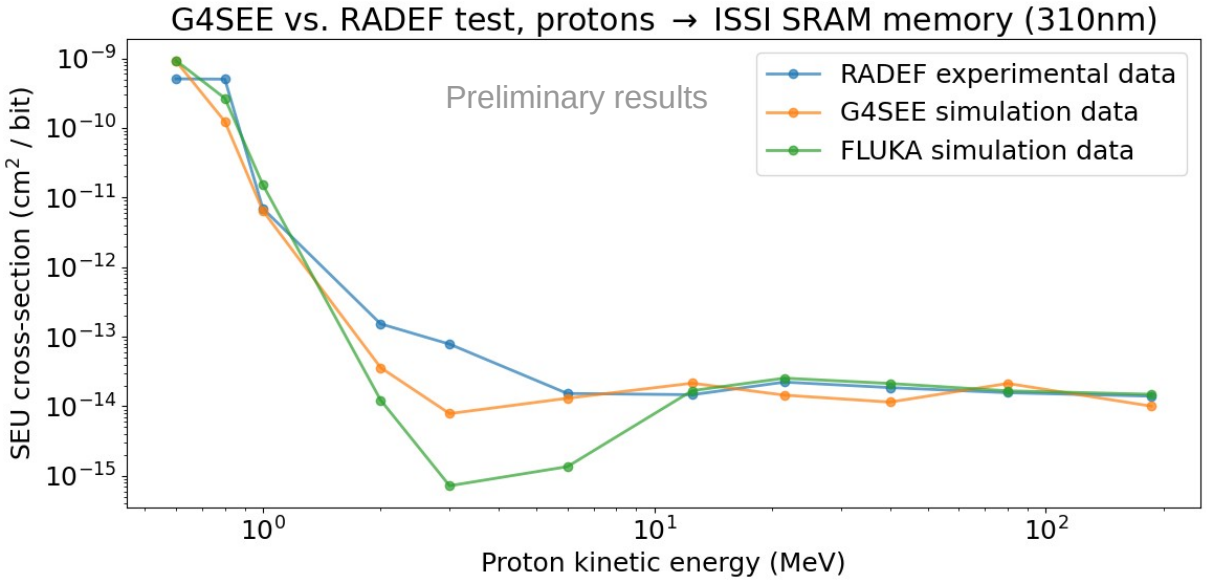


Use cases & Validation (1/2)

- **Fast neutron induced SEE** simulations in Si diode and SRAM memories (144 keV - 17 MeV); Validation with tests performed at FNG and PTB facilities (see talk of Kacper Biłko & Matteo Cecchetto)
- **Proton induced SEE** simulations in ISSI SRAM memory (600 keV - 186 MeV); Validation with test performed at RADEF
- **Thermal neutron induced SEE** simulations; Validation with test performed at ILL using Si diode



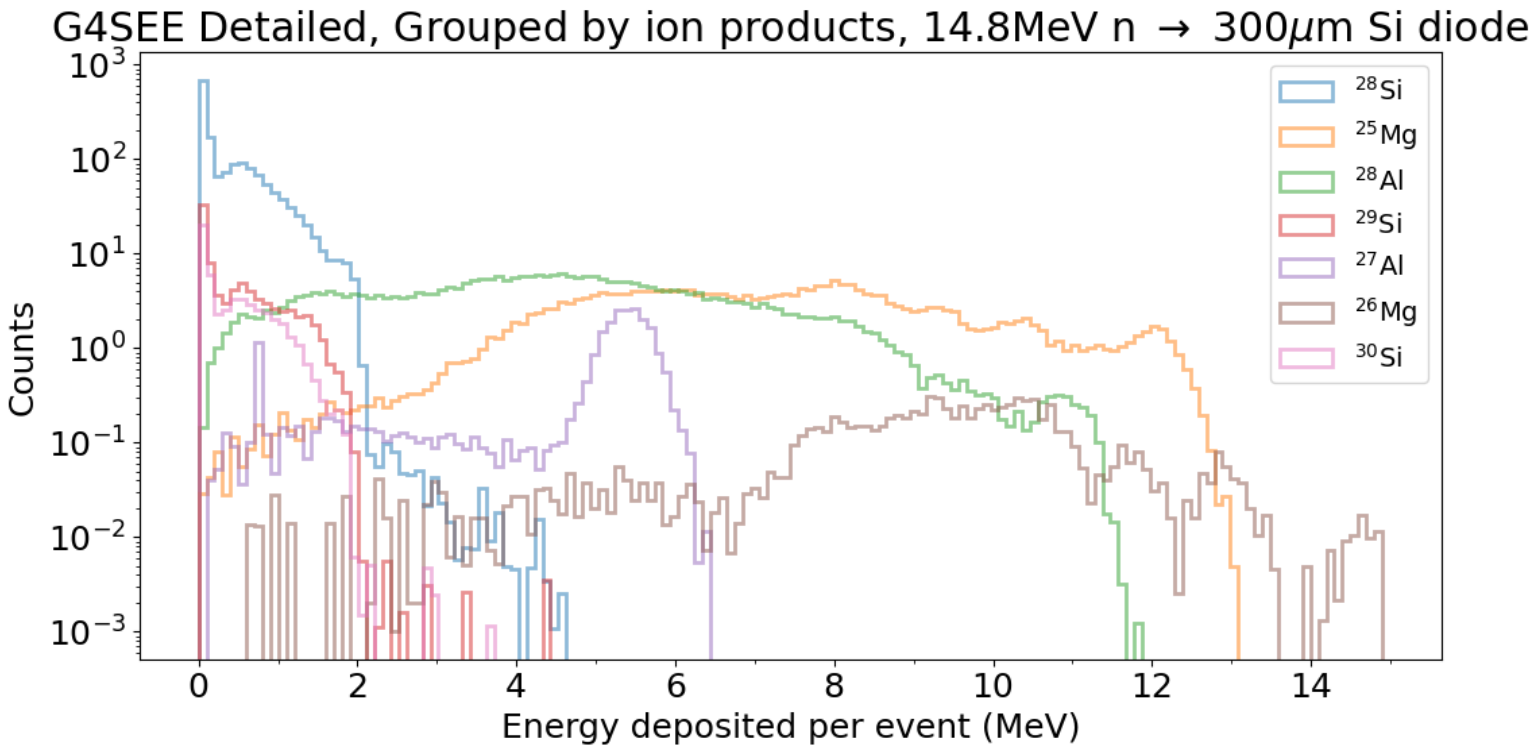
Input from K. Biłko, M. Cecchetto

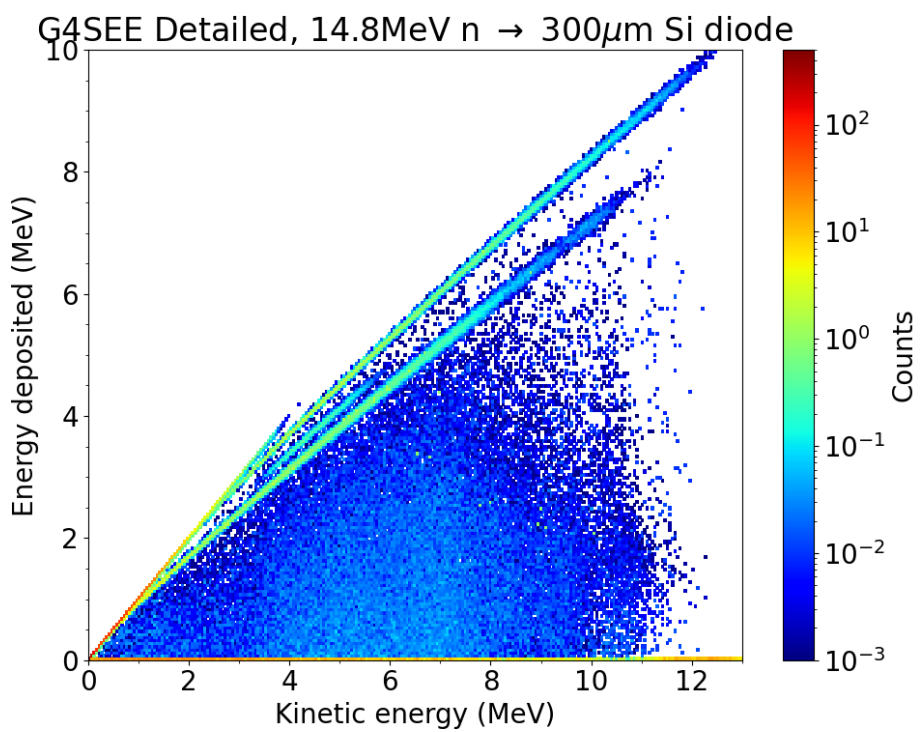


Input from A. Coronetti

Use cases & Validation (2/2)

- **Detailed Scoring** to better understand SEE mechanisms on a nuclear physics level, e.g. secondary ion products causing SEEs, origin of secondaries, dependency between quantities
- Continuous cross-validation with **FLUKA**, and soon also with **MCNP**





How to access G4SEE

- Source code and documentation in **CERN GitLab** here:

  https://gitlab.cern.ch/r2e-bmi/g4see/geant4-see

- Login to ***clueet* cluster** (SY-STI) and submit a job:


```
$ ssh -XYC <username>@clueet
$ cd /home/dlucsany/geant4-see/build-latest
$ python3 scripts/g4see.py submit SRAM_example.mac -o ~/g4see_out/ -j 10 -q short
```

- Pull a G4SEE **Docker image** and run it in a container:


```
$ docker login   gitlab-registry.cern.ch
$ docker pull    gitlab-registry.cern.ch/r2e-bmi/g4see/geant4-see:<tag>
$ docker run -it gitlab-registry.cern.ch/r2e-bmi/g4see/geant4-see:<tag>
```

Would you like to try G4SEE? Send me an email!

david.lucsanyi@cern.ch

Future plans

- Next major features to be implemented:
  - arbitrary number of SVs within target with different weights, nested SVs
  - translational symmetry on geometry boundaries for periodic structures
  - extract XS and LET data of specific particles and interactions
  - user-defined homogeneous electric field + charge transport within field
  - induced electric signal readout on electrode surfaces
- Validation with heavy ion test data (RADEF)
- Going open-source and building open-source community, create website

If you have an idea or specific use case, let us know!

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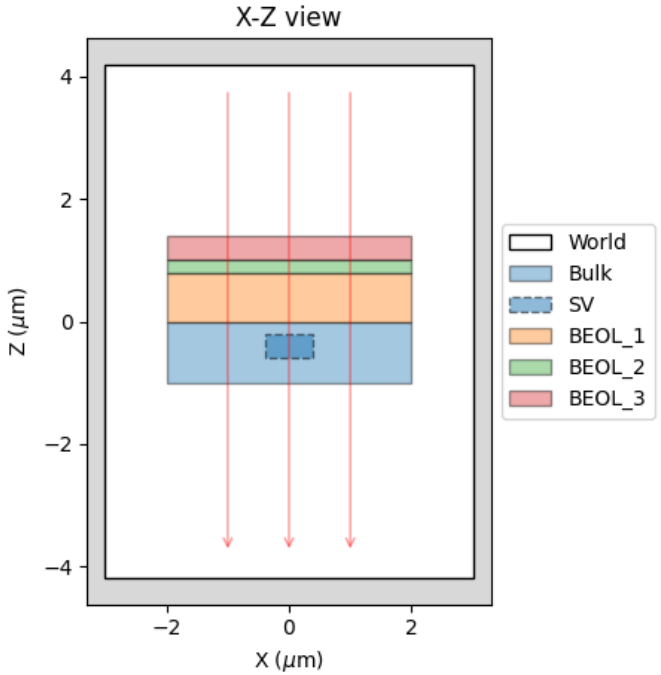
Thank you for
your attention!

Backup slides

Main Features (1/2)

- **User Input:** Geant4 macro file with G4SEE specific, and well documented macro commands
- **Geometry & Materials:** Bulk volume + BEOL layer(s); Sensitive Volume (SV) defined in the Bulk; All dimensions, relative positions and materials (elements, compounds, mixtures) can be defined by the user
- **Modular Physics:** Users can build their own physics from various EM, hadron elastic/inelastic and ion physics modules selecting the best set of options for a case




```
8   #### Geometry macro commands
9   /SEE/geometry/Bulk              G4_Si                5 um         1 um     true
10  /SEE/geometry/SV                0 0 -200 nm          600 800 nm   300 nm   true
11  /SEE/geometry/BEOL/addLayer     G4_SILICON_DIOXIDE   5 um         800 nm   false   Oxide
12  #### Physics macro commands
13  /SEE/physics/addPhysics         G4EmStandardPhysics_option4     # Default EM physics
14  /SEE/physics/addPhysics         G4HadronElasticPhysicsHP        # hadron elastic w/ HP neutron models
15  /SEE/physics/addPhysics         G4HadronPhysicsFTFP_BERT_HP     # hadron inelastic w/ HP neutron models
```

Main Features (2/2)

- **Biasing:** General microscopic cross-section (XS) biasing for any particle and interaction to enhance their probability
- **Standard Scoring in SV:** Single quantity scored and saved in user-defined ASCII histogram files (E_{dep} per event or E_{kin} per particle entering or produced in SV)
- **Detailed Scoring in SV:** Set of quantities per particle scored and saved in ASCII files line by line (particle specie, event, particle and parent IDs, spatial and momentum coordinates, kinetic energy, creator process, energies deposited)
  - Additional special grouping of $e^{-/+}$ and γ particles

event	particle	weight	track	parent	E_kin	pos_x	pos_y	pos_z	mom_x	mom_y	mom_z	process	E_dep	N_dep
273	neutron	1.031e-03	1	0	2.2536e+01	4.71e-05	3.35e-04	-1.00e-03	0.00e+00	0.00e+00	-2.07e+02	primary	0	0
273	Al27	1.031e-03	8	1	5.7496e-01	4.71e-05	3.35e-04	-1.88e-03	6.15e+01	4.79e+01	-1.51e+02	biasWrapper(neutronInelastic)	1.3625e-01	1.7882e-02
273	neutron	1.031e-03	5	1	8.9178e-01	4.71e-05	3.35e-04	-1.88e-03	1.64e+01	1.41e+01	-3.48e+01	biasWrapper(neutronInelastic)	0	0
273	proton	1.031e-03	2	1	5.1446e+00	4.71e-05	3.35e-04	-1.88e-03	-7.64e+01	-5.84e+01	-2.08e+01	biasWrapper(neutronInelastic)	5.6802e-03	0
355	neutron	1.031e-03	1	0	1.1524e+01	-5.85e-05	-4.08e-04	-1.00e-03	0.00e+00	0.00e+00	-1.48e+02	primary	0	0
355	C12	1.031e-03	2	1	1.4364e-01	-5.85e-05	-4.08e-04	-2.00e-03	-3.59e+01	4.22e+01	-1.18e+01	biasWrapper(hadElastic)	1.2820e-02	1.1173e-03
457	neutron	1.024e-03	1	0	1.6620e+01	-4.12e-04	-7.01e-05	-1.00e-03	0.00e+00	0.00e+00	-1.78e+02	primary	0	0
457	Si29	1.024e-03	2	1	9.1152e-02	-4.12e-04	-7.01e-05	-1.48e-03	-5.39e+00	6.84e+01	-1.43e+01	biasWrapper(hadElastic)	9.1152e-02	0