G4SEE – The open-source* SEE simulation toolkit and its applications

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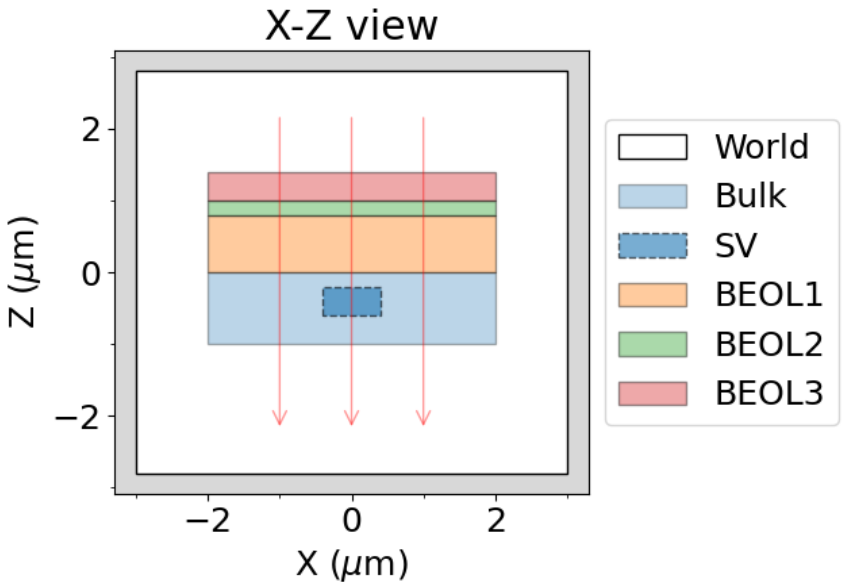
https://indico.cern.ch/event/1116677

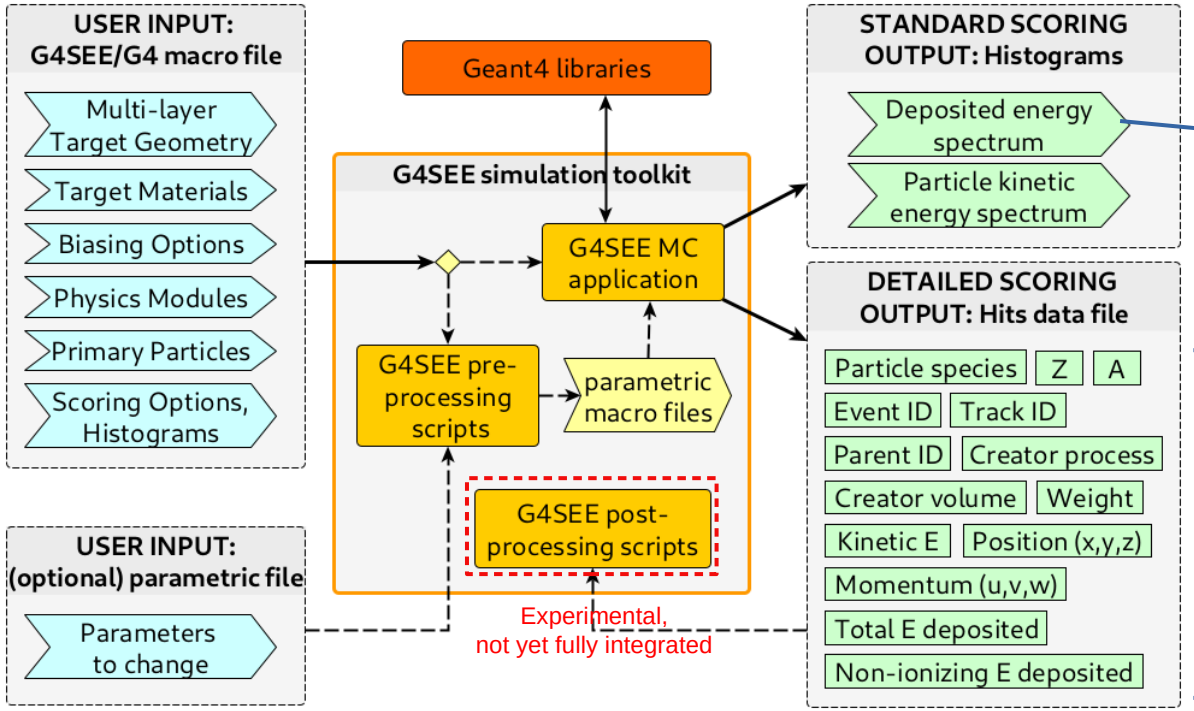
Introduction

- **G4SEE** is a Geant4-based Monte Carlo Single Event Effect simulation toolkit
- Developed **for the whole radiation effect community** worldwide, so it will be fully open-source soon*
- Goal is to extract all information **event-by-event** and **particle-by-particle** relevant for SEE studies, according to the needs of users
- **Direct and indirect energy deposition scoring** in a micro-metric sensitive volume based on user inputs ⇒ SEE cross-section or rate estimation
- **Complement & supplement SEE simulation studies** performed using FLUKA (e.g. in case of < 20 MeV neutrons)

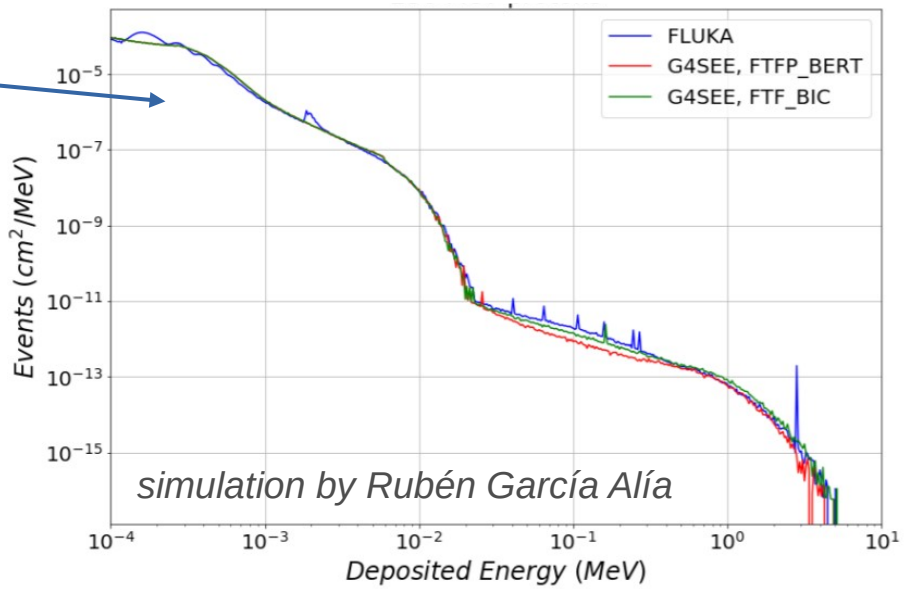


* (work is ongoing, but much slower as expected)

User Inputs & Outputs, Features



Standard scoring example: 230 MeV protons into Si



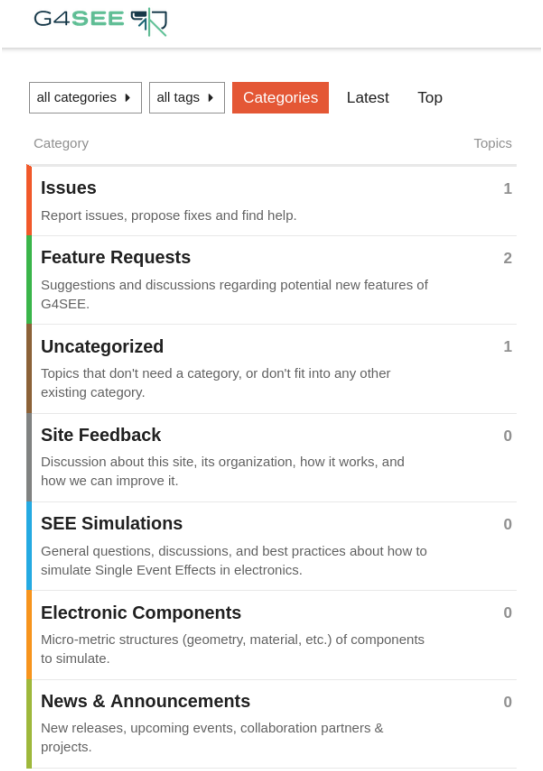
Detailed scoring example: atmospheric neutrons into SiC

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

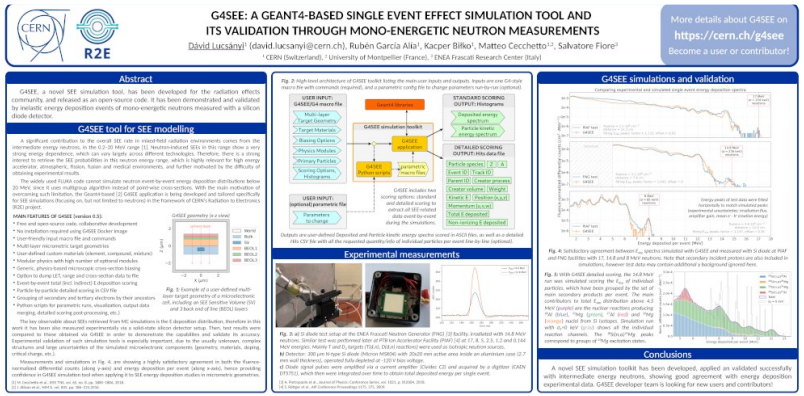
Building a user community

G4SEE logo:
(thanks to CERN graphics design team!)

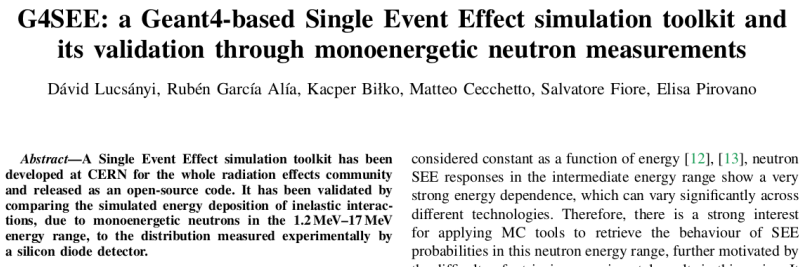
G4SEE website:
https://cern.ch/g4see



G4SEE poster at NSREC 2021



G4SEE paper in IEEE TNS:
https://doi.org/10.1109/TNS.2022.3149989

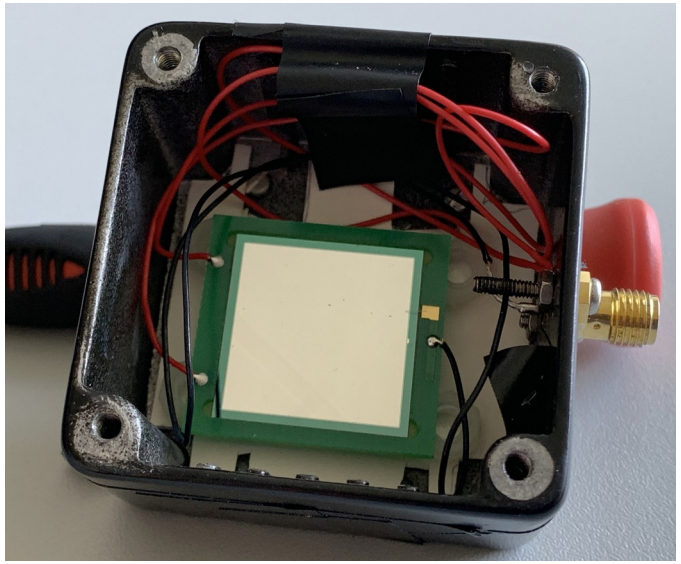


Already many useful user requests and feedback thanks to Andrea Coronetti and Matteo Cecchetto

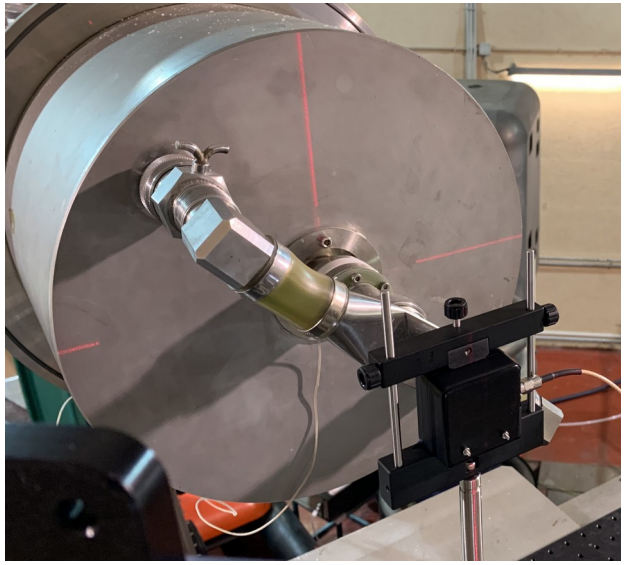
G4SEE community forum:
https://g4see-forum.web.cern.ch

Neutron tests at FNG and PIAF

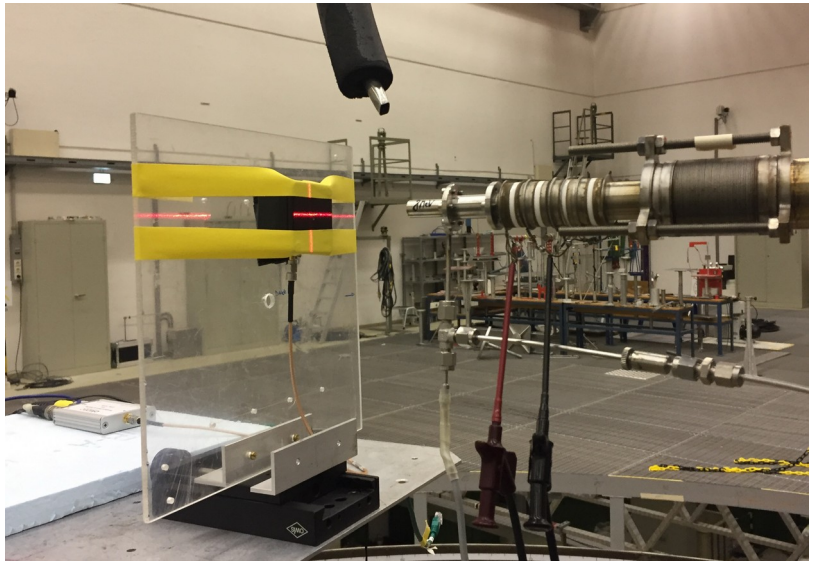
Si diode detector: N-type Micron MSX04, 20mm × 20mm × 300µm sensitive volume, fully depleted at -120 V bias



Irradiating Si diode with 14.8 MeV neutrons at ENEA Frascati Neutron Generator (FNG)



Irradiating Si diode with 1.2, 2.5, 5, 8 and 17 MeV neutrons at PTB Ion Accelerator Facility (PIAF)

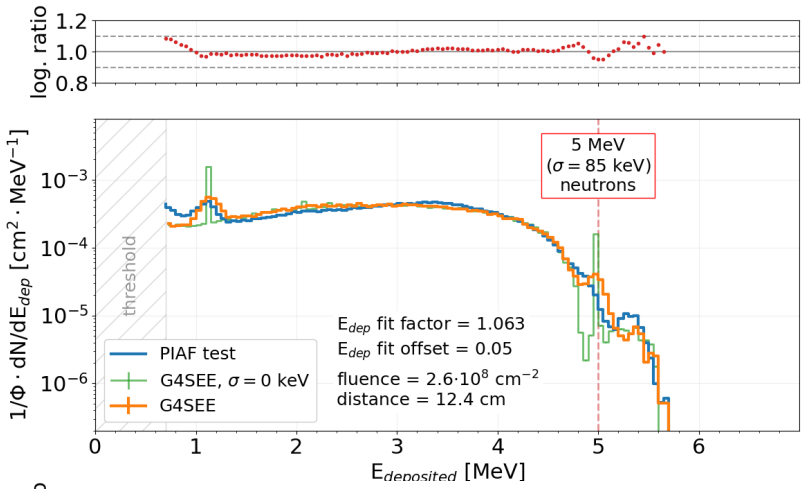


FNG and PIAF tests were performed by Kacper Biłko and Matteo Cecchetto

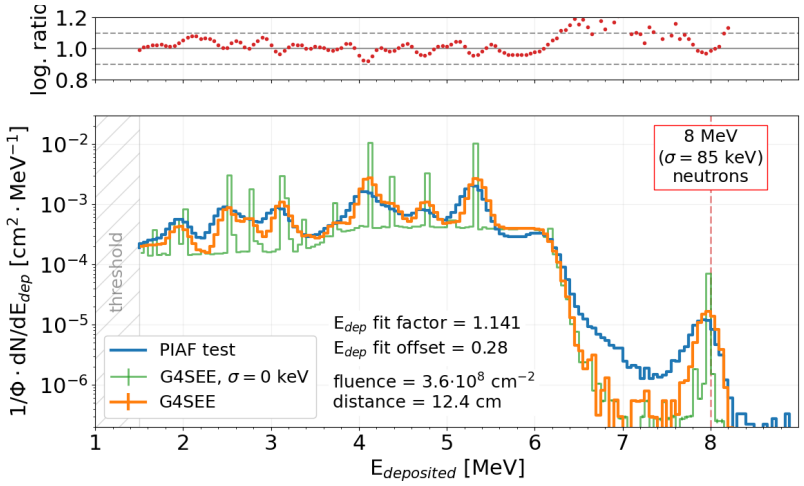
D. Lucsányi, R. García Alía, K. Biłko, M. Cecchetto, S. Fiore and E. Pirovano, *"G4SEE: a Geant4-based Single Event Effect simulation toolkit and its validation through monoenergetic neutron measurements"* in IEEE TNS, doi: 10.1109/TNS.2022.3149989

G4SEE validation with neutrons

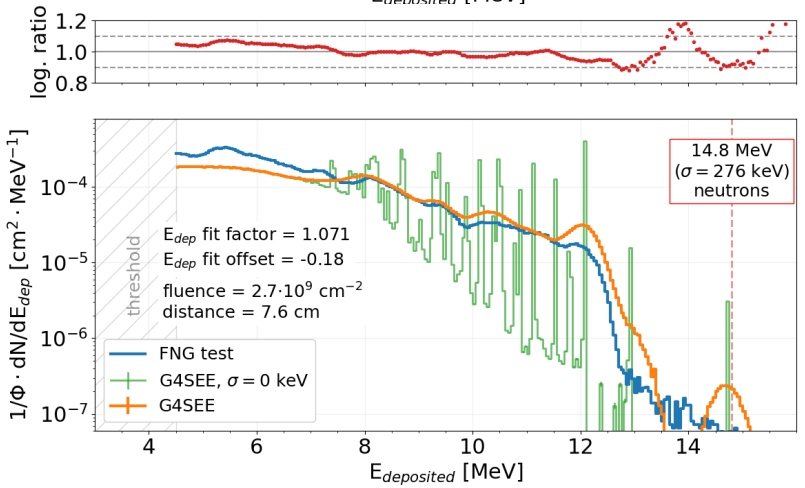
5 ± 0.085 MeV neutrons



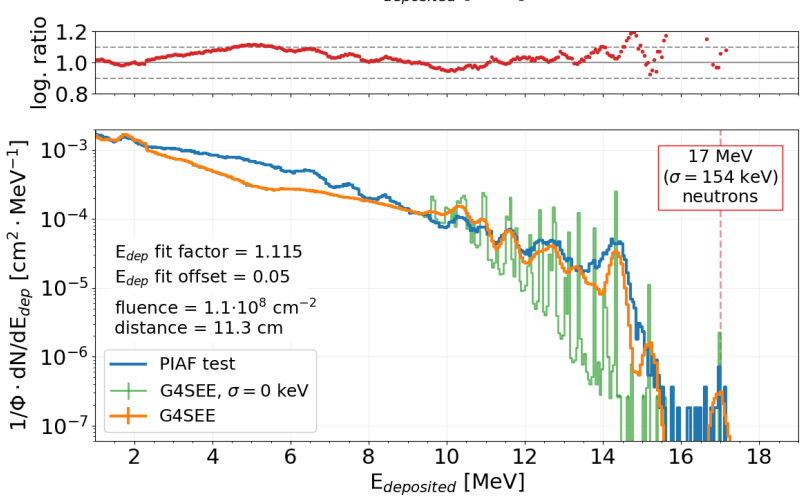
8 ± 0.085 MeV neutrons



14.8 ± 0.276 MeV neutrons



17 ± 0.154 MeV neutrons



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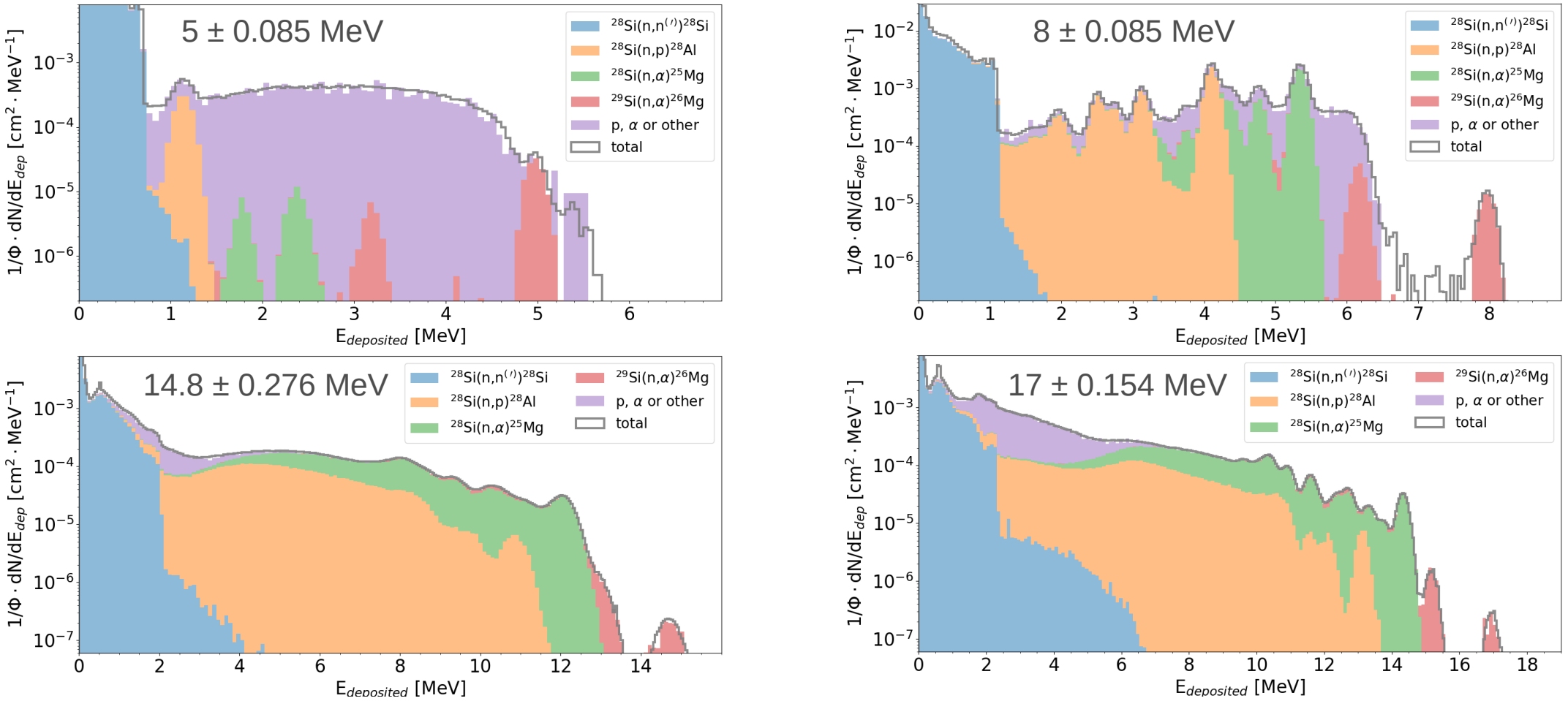
Detailed scoring with neutrons



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Some applications of G4SEE

- Impact of direct ionization by low-energy protons on SRAM SEU cross-section

09:15 **Low-energy protons: numerical simulations, modelling, issues and impact for the accelerator** 15m

Direct ionization from low-energy protons has been a hot topic in the space community for 15 years. Recent experimental measurements suggest that it may be an issue for the accelerator as well. The study of this and other proton effects required further push in the development of reliable simulation tools.

Speaker: Andrea Coronetti (University of Jyvaskyla (FI))

- Optimization of neutron sensitive coating for sensors of PLWS neutron spectrometer

16:00 **Puli Lunar Water Snooper R&D activities at CERN** 15m

The PLWS neutron spectrometer is developed by Puli Space Technologies to in-situ measure subsurface water content on the Moon by detecting thermal and epithermal neutrons using modified COTS CMOS image sensors as detectors. PLWS irradiation tests and Monte Carlo simulations are performed at CERN in collaboration with R2E, paving the way for terrestrial neutron flux monitoring applications in the LHC and other mixed-field environments.

Speaker: David Lucsanyi (CERN)

- Timepix3 detector response for calibration with alpha source

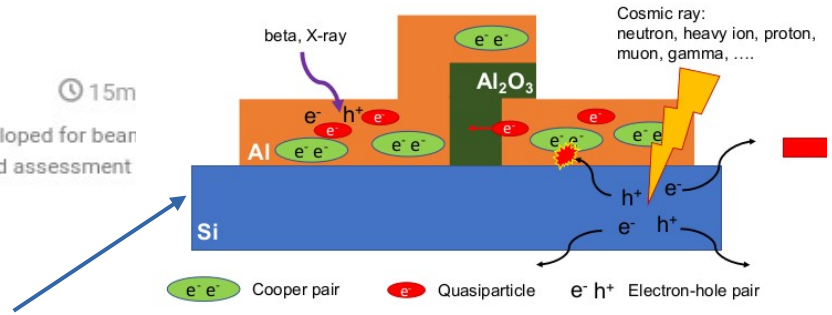
16:15 **R2E applications of TimePix3** 15m

The PS-BGI data acquisition system, based around the Timepix3 pixel detector, was acquired by the R2E project in late 2020. Originally developed for bean loss monitoring applications, this setup has the potential of being one of the key instruments in providing valuable data for the radiation field assessment in the accelerator environment.

Speaker: Ivan Slipukhin (CERN)

All these different applications bring new users (even developers) and a variety of new features to the toolkit!

→ Application driven development



- Planned near-future applications:
  - Charge deposition (SEEs) in superconducting quantum qubits [University of Trento, P. Rech]
  - Displacement damages in CMOS image sensors [ISAE-SUPAERO, V. Goiffon, J.M.Kempf]

Access and License

- [at CERN] Source code and documentation is currently here in CERN GitLab (repo will be moved soon)

- [at CERN] Ready-to-use G4SEE Docker image (Pull image & Run 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>
```

- [outside CERN] The new GitLab repo will be opened to public after the licensing ended
  - Best choice: GPL v3 (GNU General Public Licence version 3)
  - Copyleft licence: “the creation of an **open community of users or developers** where the licensees are encouraged not only to improve, correct, complement and integrate the software they receive but also to **make available these enhancements to the entire community**. With a copyleft license, users cannot take the Open Source Software and turn it into proprietary software, thus preventing any member of this open community to depart from the principles of reciprocal contribution.”

If you are interested and would like to try G4SEE,
send an email to **g4see.toolkit@cern.ch**!

Thank you for
your attention!

david.lucsanyi@cern.ch