Geant4 - a focal HEP simulation tool

- While HEP experiments use variety of tools to perform detector simulations, Geant4 is a toolkit used by most, if not all of them. It has become **a de-facto standard for many aspects of HEP detector simulations**

  o It is **used** not only in **detector and facility design**, but also in the **extraction of physics results and estimation of systematic uncertainties**

  o While being **widely and successfully used** in various contexts, it **also has its limitations**, in part, because of the **lack of a sufficient number of people** working on it.

    - Quoting from the Snowmass2021 Book Rare Processes and Precision Measurements Frontier (RPF) p538-539:

  The RPF wants to send a strong and emphatic message, also discussed in the Computing Frontier report: **GEANT4 is not sufficiently supported in the U.S.** The physics models of some crucial processes, including but not limited to their cross-sections, rates, and spectra, are in disrepair [...] Many experiments in RPF rely on low-energy phenomena whose simulations are not kept up to date; when bugs and errors are found, they are **not fixed because there is no one to fix them**. GEANT is infrastructure akin to "roads and bridges"; *the current trajectory endangers progress across particle physics.* [emphasis/abbreviation by KLG]

Sustaining Geant4 Physics Models

- Geant4 **physics models** have a **similar impact** on the simulation of experiments, extraction of physics results and estimation of systematic uncertainties as **physics event generators**

- Ensuring that there are **people who can maintain and develop Geant4**, including its physics models, is **critical to Geant4 usability**

  o The most widely used **models** [have been shown](#) to **require more work** to fully describe the existing data

    - Unfortunately, one of these models **has not been actively developed** over the last few years due to the **lack of people**

- Establishing **strong partnerships** and collaboration among **theorists, developers of event generators, and Geant4 physics model developers** would be **beneficial** for the entire HEP community

- **To benefit US experiments the most, the people working on the physics models relied on by these experiments should be specifically funded to do so.** Just a best effort of people having other priorities has not been sufficient

- Geant4 is a very complex toolkit; **Its all elements**, not only its physics models, **need to function well and run efficiently and fast** on modern (super)computers; **It all requires <u>constant</u> human attention and work**

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Sustaining Geant4 and Geant4 Collaboration

- **The people of the (international) Geant4 Collaboration are aging**

- Many Geant4 developers have retired over the last few years, and many are approaching retirement (specific data can be provided upon request)

- **Scarcity of** dedicated **permanent** HEP **positions** is a negative and discouraging factor; There are many job opportunities outside of HEP for people with the skills needed to develop Geant4; Some **Geant4 developers** decided to, or **had to, leave** when their **contracts ended**

- Experience shows that **it takes several years of learning and knowledge transfer for a new person to be able to contribute to Geant4 development at an expert level**; If new people are not hired in a timely manner, a significant loss in productivity occurs

- Given the prevalent use of Geant4, the **impact of investing in it is large** (**and so is the *impact of insufficient funding***)

- As the needs of experiments and computing environments evolve the Geant4 toolkit requires **constant** *development, maintenance, and user support.* All that **requires an adequate number of people and stable funding**

- Also see: SnowmassCompF2DetSim20220718 and https://arxiv.org/abs/2203.07614, https://arxiv.org/abs/2203.07645

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