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The Key4hep turnkey software stack

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Detector studies for future experiments rely on advanced software tools to estimate performance and optimize their design and technology choices. The Key4hep project provides a turnkey solution for the full experiment life-cycle based on established community tools such as ROOT, Geant4, DD4hep, Gaudi, PODIO and Spack. Members of the CEPC, CLIC, EIC, FCC, and ILC communities have joined to develop this framework, and merged or are in the progress or merging their respective software environments into the Key4hep stack. The software stack contains the necessary ingredients for event generation, detector simulation with Geant4, reconstruction algorithms, and analysis. Ongoing developments include the integration of the ACTS toolkit for track reconstruction, the PandoraPFA toolkit for clustering and particle flow, and the CLUE package for calorimeter clustering in high-density environments. This contribution gives an overview of the Key4hep project and highlight use cases from the involved communities, showcasing the synergy obtained through the adaptation of this common venture.

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1. Introduction

High Energy Physics (HEP) experiments rely on software for their entire life cycle, but need accurate and detailed simulations as a crucial tool to study and optimize their design in the planning phase. Sharing algorithms, implementations and experience is therefore of particular importance to future collider design studies, which typically have limited resources. The Key4hep project tries to offer a solution to this issue by providing an ultimately complete software stack of common tools and community-developed libraries and framework components. Central libraries in the stack include ROOT, Geant4, Delphes and Gaudi that are used for I/O, full and fast simulation and framework interfaces. Key4hep is also a platform for open developments of components for which no experiment-independent implementation currently exists, and a testbed for software research and development in HEP.

In these proceedings we discuss the status of the Key4hep project in some selected areas of work. In Sec. 2 we report on developments for common reconstruction software packages. Sec. 3 describes how build tooling helps to construct a consistent software release from a large number of individual packages.

2. Integration of experiment independent packages

The Key4hep project places particular emphasis on the integration and support of experiment independent packages and libraries. A key part of the software stack is iLCSoft, the collection of linear collider software as used by the International Linear Collider (ILC) and the Compact Linear Collider (CLIC). This software used its own framework (Marlin) and data model (LCIO). In order to provide backwards compatibility and interoperability, Key4hep includes a component that allows calling code written for the Marlin framework from Gaudi, thus wrapping the framework code in another framework (k4MarlinWrapper). The native EDM4hep data objects can be converted from and to LCIO for this purpose.

iLCSoft provides a full reconstruction chain for detector simulation, but research and development in alternative and complementary reconstruction algorithms and implementations is ongoing in order to achieve optimal performance of the detectors. CLUE (clustering of energy) is one of these new developments: a fast, parallel clustering algorithm for high granularity calorimeters which is relevant for the future experiments participating in Key4hep. Gaudi components to use CLUE with EDM4hep input and output in the Key4hep ecosystem have been developed under the name k4CLUE. In addition, an ongoing effort tries to integrate the established experiment-independent tracking toolkit ACTS (A Common Tracking Software) [6] in a similar manner.

Reconstruction based on particle flow algorithms will be crucial for several future higgs factories participating in the Key4hep project. iLCSoft already uses the Pandora particle flow toolkit, but a direct integration in the Key4hep framework is developed as well (named k4Pandora).

3. Build infrastructure

The attempts to make use and develop common libraries come at the price of increased complexity and additional dependencies compared to other experiment software. Build tooling can help to reduce the effort of developing and installing the Key4hep software. The scientific package manager Spack [5] was evaluated for this task and has proven to be a suitable tool: the possibility to install different versions to different prefixes outside the system directories is particularly important for scientific software as it allows for easier comparisons of complex configurations of the stack. Workflows can thus be validated more easily in order to use the results in calculations. Spack also facilitates compilation of the whole stack with different compilers and for different micro-architectures, which can help with fully exploiting computational resources and allow to run the software on High Performance Computing (HPC) systems. The archspec library, originally part of Spack, makes these special builds easier as it assigns human-readable names to different architecture and allows comparisons between them. More than any individual feature, the widespread adoption of Spack in the scientific community helps share the maintenance burden as patches, dependency information and additional know-how are available in a central package recipe repository. Looking forward, Spack can also aid in the development of Key4hep packages by automatically setting up dependencies for developers.

4. Summary and Outlook

The Key4hep project aims to provide a complete software ecosystem, initially targeting future collider design studies but of possible interest to running experiments and to software research and development efforts as a testbed. The use of common core packages avoids duplications of developments and allows developers to focus on new challenges.

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