Porting ROOT and Cling to RISC-V

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ROOT Data Analysis Framework

- Store and analyze exabytes of data in High Energy Physics
- Used by all experiments at the Large Hadron Collider (LHC)

Cling

- Interactive C++ interpreter built on top of LLV and Clang
- Central component of the ROOT framework:
  - Queried by IO layer about class members and their types
  - Type-safe analysis code using just-in-time compilation
  - Provides dynamic interoperability between C++ and Python

LLVM JIT and clang-repl

- JITLink backend for RISC-V in LLVM's main branch
- Worked nicely in first tests, enabled by default (D129092)

clang-repl

- Generic parts of Cling being upstreamed into LLVM
- Basic operations worked on RISC-V; one exception:
  - Available registers and ABI depend on ISA extensions (e.g., D extension for double precision floating point)
  - Linux on RISC-V assumes RV64GC, needs to be propagated to LLVM backend and code generation module (D128853)

Porting ROOT and Cling

- Add RISC-V detection to build system
- ROOT and Cling recently upgraded to LLVM 13
  - Has base work for JIT compilation on RISC-V
  - Backport a number of commits from later versions

- Required changes in Cling for RISC-V:
  - Propagate ISA extensions to LLVM backend (see clang-repl)
  - Explicitly propagate computed ABI
  - Implement relocations for compressed branches / jumps: R_RISCV_RVC_BRANCH and R_RISCV_RVC_JUMP (also contributed upstream: D140827)

First Physics Analysis

- Test a number of analysis workflows available as tutorials

- Output from example physics analysis rediscovering the Higgs boson (tutorial df103_NanoAODHiggsAnalysis.py)
- Simplified physics analysis written in Python
  - Uses Cling for dynamic binding to C++ libraries and to just-in-time compile C++ header
- Runs on events recorded with the Large Hadron Collider's CMS detector in 2011-2012
- Output histogram shows mass resonance around 125 GeV of Higgs boson decaying into two Z bosons

Conclusions and Future Work

- Ported clang-repl, Cling, and ROOT to RISC-V
- Contributed the required changes upstream to LLVM
- Working on exception support for RISC-V:
  - Currently ROOT will terminate if exception thrown in JIT compiled code or propagated through interpreted frames → need to register exception handling information