



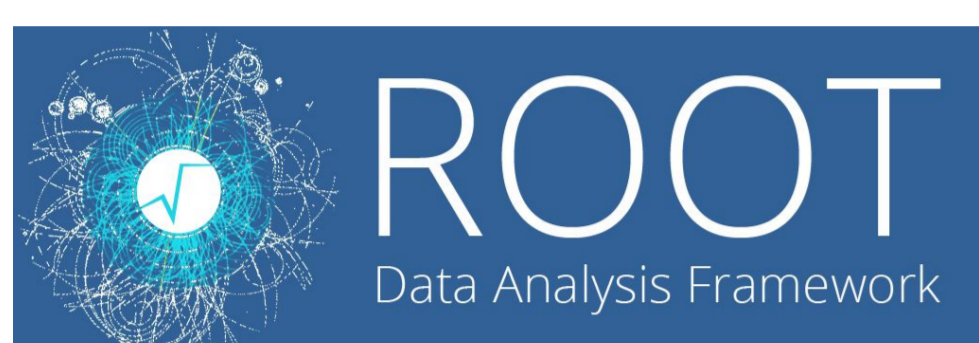
# Porting ROOT and Cling to RISC-V

<https://root.cern>

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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 LLVM 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](#))

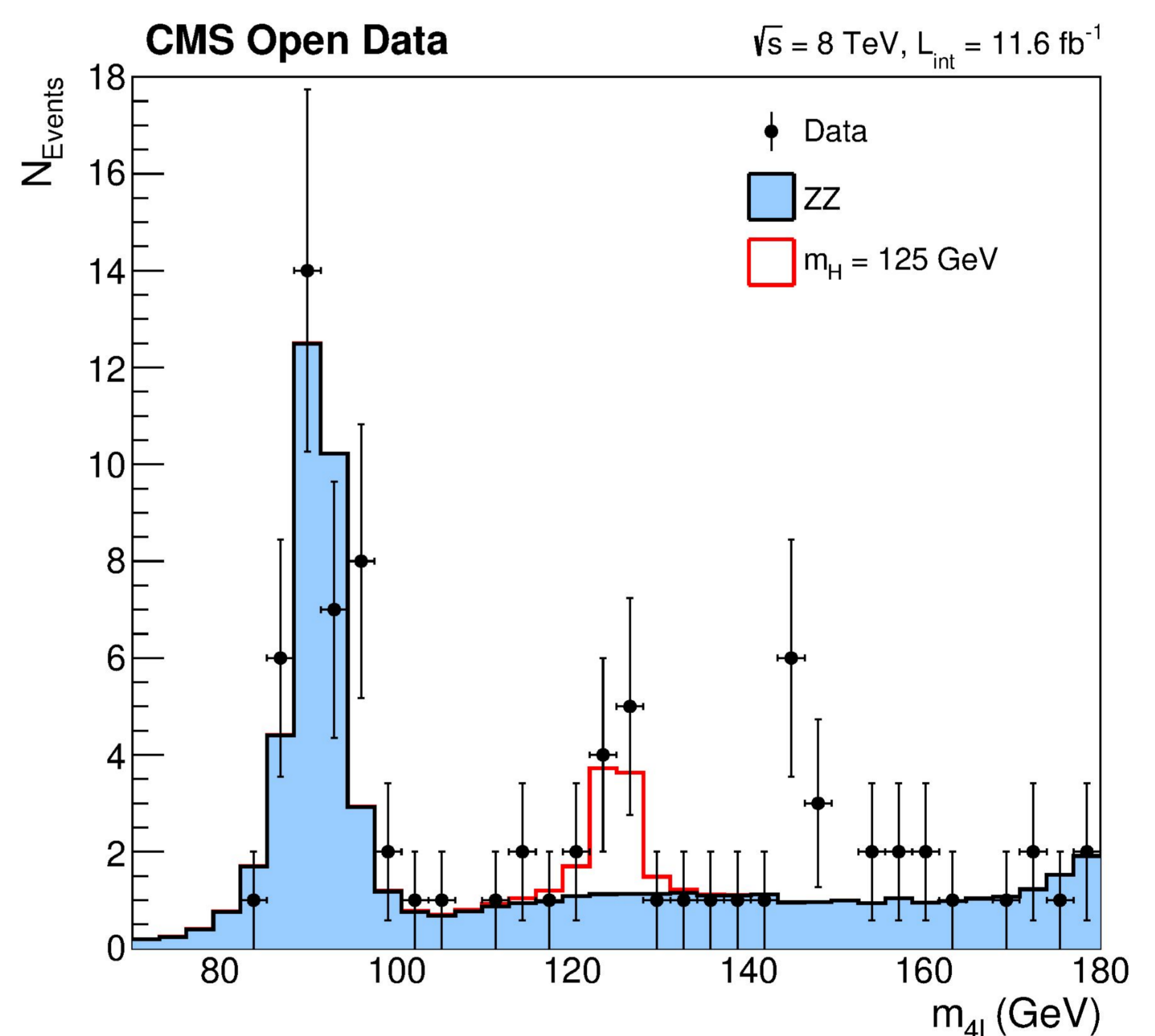
## Porting ROOT and Cling

- 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](#))

```
root [0] std::vector<int> v{1, 2, 3, 4};
root [1] v
(std::vector<int> &) { 1, 2, 3, 4 }
root [2] v.push_back(5);
root [3] v
(std::vector<int> &) { 1, 2, 3, 4, 5 }
root [4]
```

## First Physics Analysis

- Test a number of analysis workflows available as tutorials



## 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

- 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**