A Faster, More Intuitive RooFit

https://root.cern

Stephan Hageboeck
EP-SFT CERN

Introduction: RooFit

- C++ package for creating statistical models [1]
- Used by all LHC experiments for statistical inference
- LHC’s Run 3: more data and more elaborate models
- **Goals**:
  - **Speed up RooFit >= 5x**
  - **Simpler interfaces, better interoperability**

1. Better Interfaces

ROOT 6.18

- RooFit’s data collection “RooLinkedList” has been replaced by std::vector
  - **25% faster iteration, simpler C++ loops**

```
TIterator* it = pdf.getParameters(obs)->createIterator();
RooAbsArg* p;
while ((p=(RooAbsArg*)it->Next())) {
  p->Print();
}
delete it;
```

Classic RooFit (Supported, **old code still works**)

```
for (const auto p : pdf.getParameters(obs))
   p->Print();
```

ROOT 6.18 **25% faster**

- Also enables **pythonic loops**, as PyROOT works well with STL containers

```
for p in pdf.getParameters(obs):
  p.Print()
```

ROOT 6.18

- **Speeds up real-world fits:**

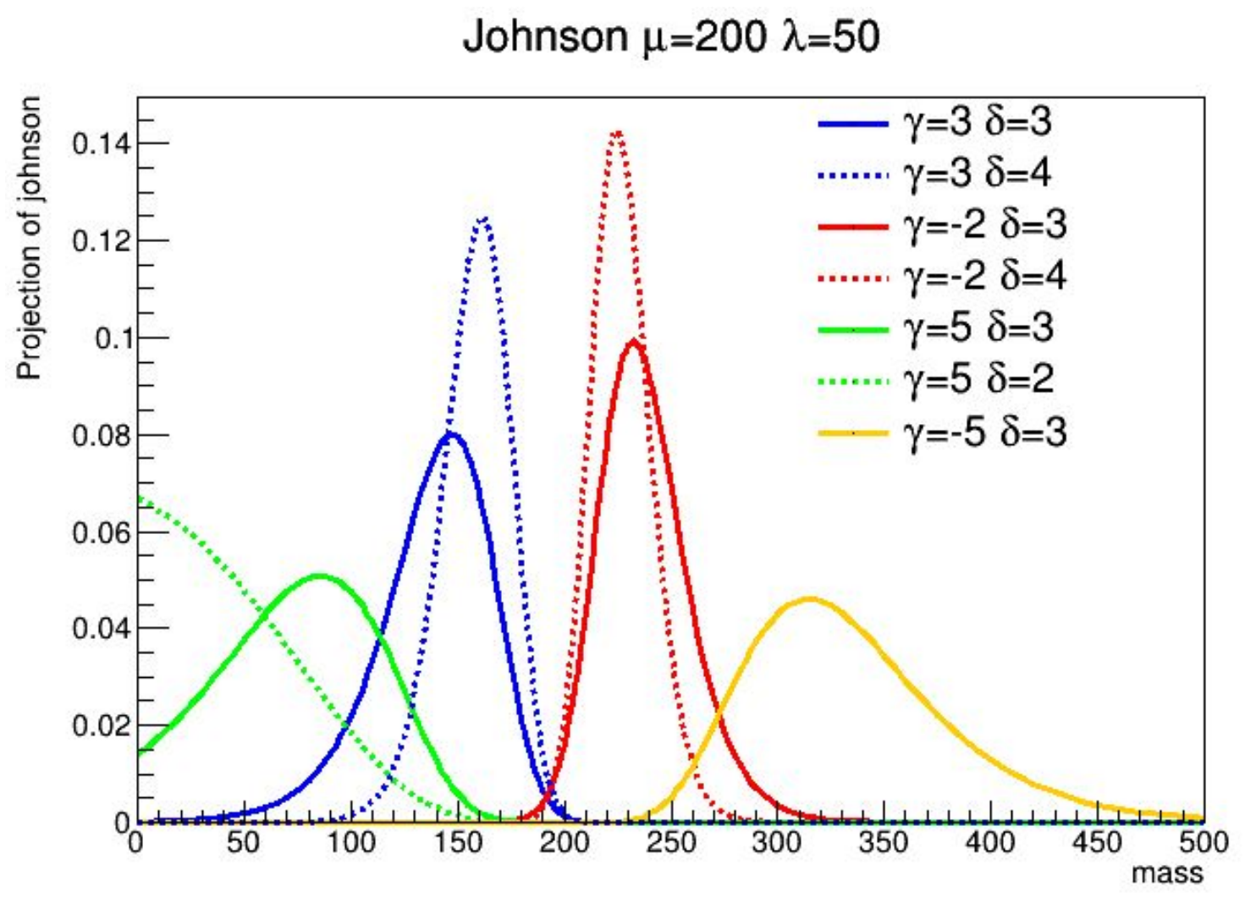
  ATLAS H→bb Run 1 measurement [2] 20% faster:
  11:30 min → 9:20 min, identical result

- **Plans**:
  - Improve interoperability. Read data from e.g.:
    - RDataFrame, STL containers, Numpy arrays
  - Add more STL-like, simpler C++ interfaces
    - Will allow designing pythonic interfaces when new PyROOT available (Talk in Track 6)
    - Ease of use of Python, speed of C++

2. New Built-in PDFs

ROOT 6.18

- Include frequently used PDFs for LHCb
  - Citeable standard
  - Allows for optimisations, e.g. **RooJohnson**: > 6x faster, better stability, more accurate integrals
- **In preparation**:
  - RooHypatia2
  - Double-sided crystal ball shape



3. Just-in-time compiled PDFs

ROOT 6.20

- ROOT's TFormula integrated in RooFit
  - Pass any C++ expression, compile just in time
  - Benefit from compiler optimisations
  - Can call user/library functions that have been loaded:

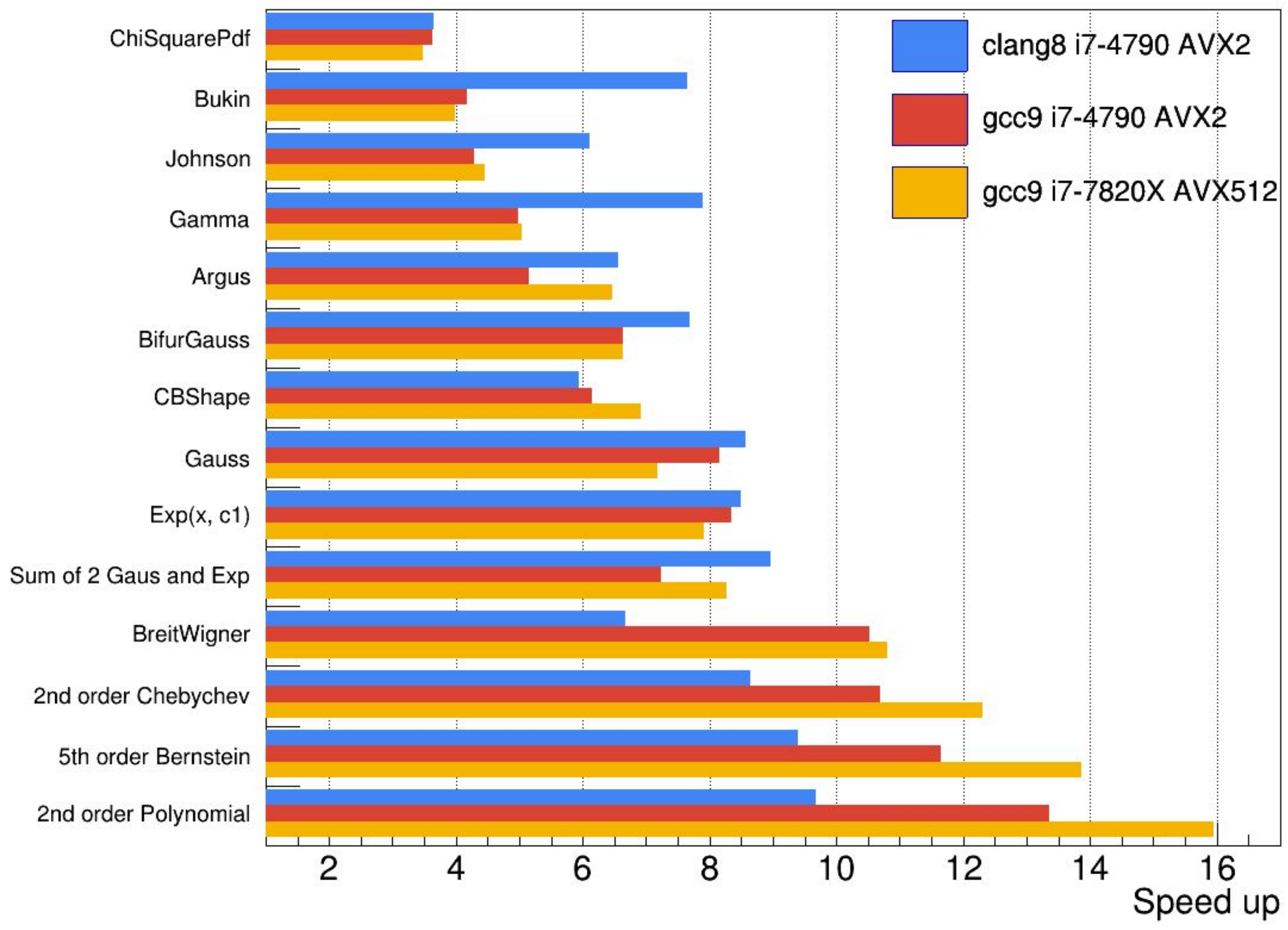
```
// In library/included code
double func(double x, double a) { return a*x*x + 1.;}
[...]
// When building fit model
RooRealVar     x("x", "Observable", 2.);
RooRealVar     a("a", "Parameter", 3.);
RooGenericPdf pdf("pdf", "func(x, a)", {x, a});
```

4. Faster PDF Computations

ROOT 6.20

- In ROOT 6.20, RooFit can compute likelihoods of **large batches of events in one pass**
  - Higher cache locality, fewer function calls
  - **Speed up of 2x - 3.5x**, depending on fit model
- New data structures + VDT math functions [3] allow compilers to vectorise computations
  - **Speed up of 4x - 16x**

Batch computations + auto vectorisation vs. classic RooFit



- **Plans:**
  - Better data structures & vectorisation for binned fits, without needing to change existing models
  - Vectorisation without recompilation:
    - Collect computation kernels in small library
    - Compile for SSE, AVX, AVX2, AVX512 ...
    - Load dynamically depending on hardware
  - Investigate abstraction libraries for parallel loops and GPU offloading

References

[1] W. Verkerke and D. Kirkby, 2003, *The RooFit toolkit for data modeling*, arXiv:physics/0306116

[2] ATLAS Collaboration, 2015, *Search for the H→bb decay of the Standard Model Higgs boson in associated (W/Z)H production with the ATLAS detector*, JHEP01(2015) 069

[3] D. Piparo, V. Innocente and T. Hauth, 2014, *Speeding up HEP experiment software with a library of fast and auto-vectorisable mathematical functions*, J. Phys.: Conf. Ser. 513 052027

stephan.hageboeck@cern.ch