Development and Benchmarking of a Bayesian Inference Pipeline for LHC Physics

Scientific Thesis for the procurance of the degree

Bachelor of Science

from the Physics Department at the Technical University of Munich.

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Abstract

TODO

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Abbreviations

BAT	Bayesian Analysis Toolkit.
HMC	Hamiltonian Monte Carlo.
MCMC	Markov chain Monte Carlo.
NP	nuisance parameter.
pdf	probability density function.
POI	parameter of interest.

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Introduction

Chapter 2

Mathematical Preliminaries

2.1 Frequentist versus Bayesian Inference

2.2 MCMC Sampling

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2.2.2 Metropolis Hastings

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Chapter 3

HistFactory

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Chapter 4

Bayesian Inference with HistFactory

4.1 BAT

Bayesian Analysis Toolkit (BAT)

4.2 batty – BAT to Python Interface

4.3 Priors from `auxdata`

4.4 Gradients for HamiltonianMC

4.5 Python HistFactory Benchmarks

While running code on a PC, the execution time of a function varies due to other active processes. A typical run time statistic is illustrated in Figure 4.1.

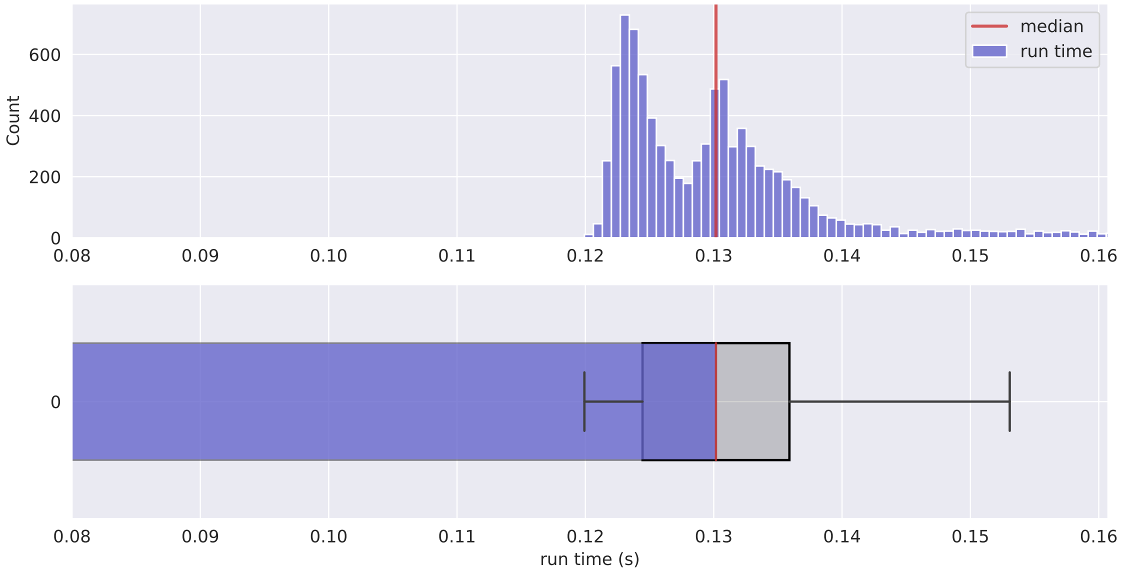


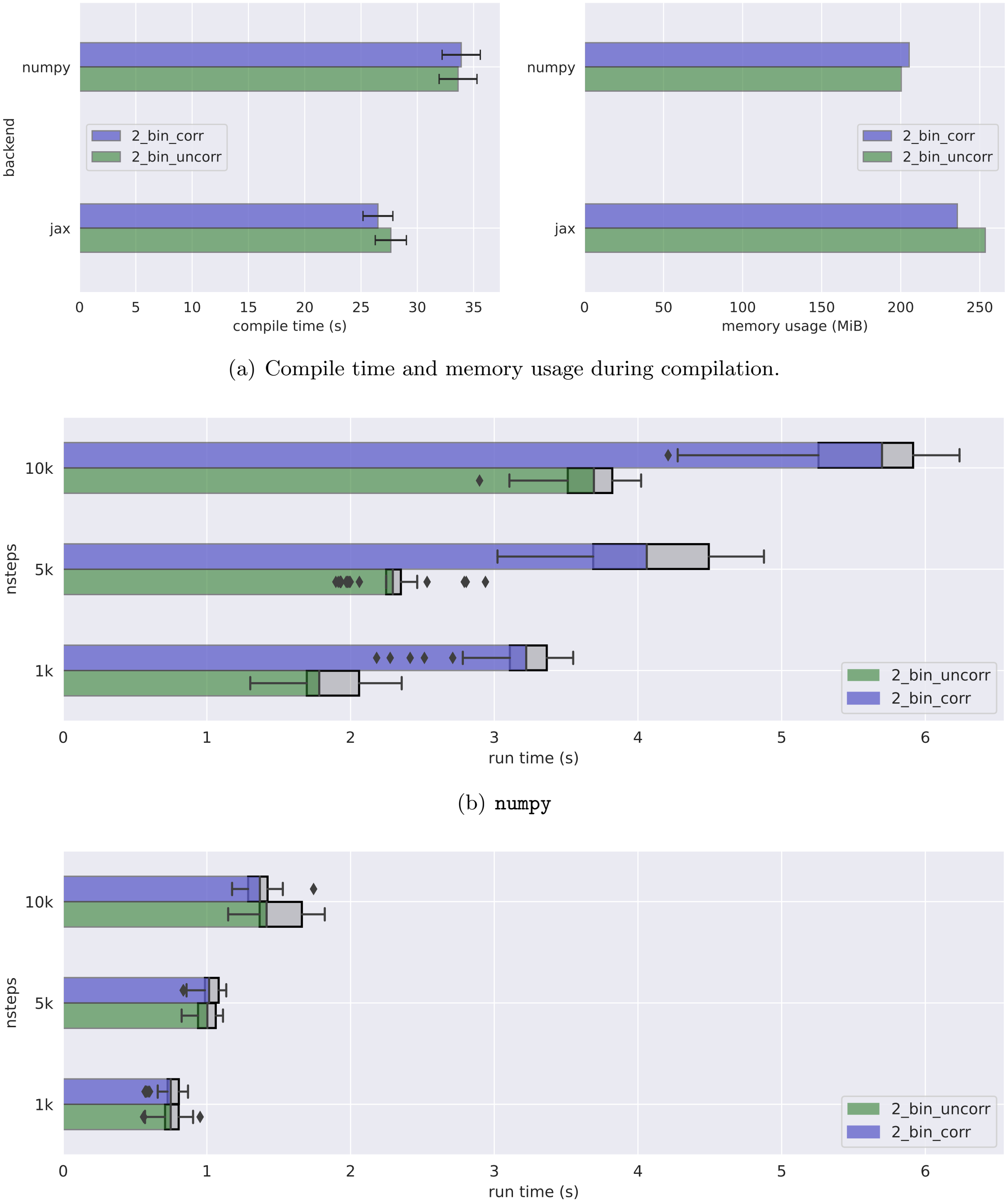
Figure 4.1: Run time statistics of (xx)

- use median instead mean
- use bar + box plot

4.5.1 `pyhf` Backend

- `jax` vs `numpy`
- 2 simplemodels

- `jax` jitted log likelihood is 4 times faster with `numpy` backend



(a) Compile time and memory usage during compilation.

(b) `numpy`

(c) `jax`

Figure 4.2: Compile benchmark and run time performance of `bat_sample()` once using the `numpy` backend of `pyhf` and once with `jax` backend. The run time is evaluated for two different models XX.

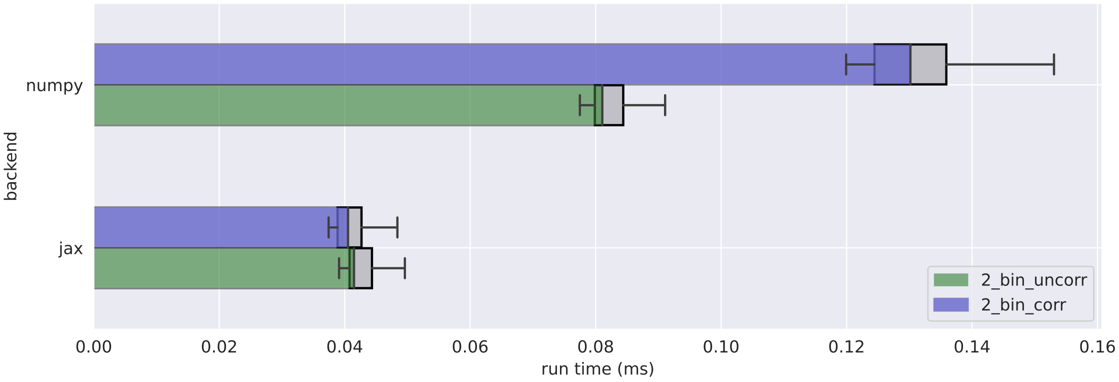


Figure 4.3: Run time of the log likelihood for two different HF models. XX

Chapter 5

Benchmarking the Python-Julia Pipeline against the Julia Implementation

5.1 Overview

Calling Julia code from Python is accomplished by the `PythonCall.jl` module

5.2 Benchmark Setup

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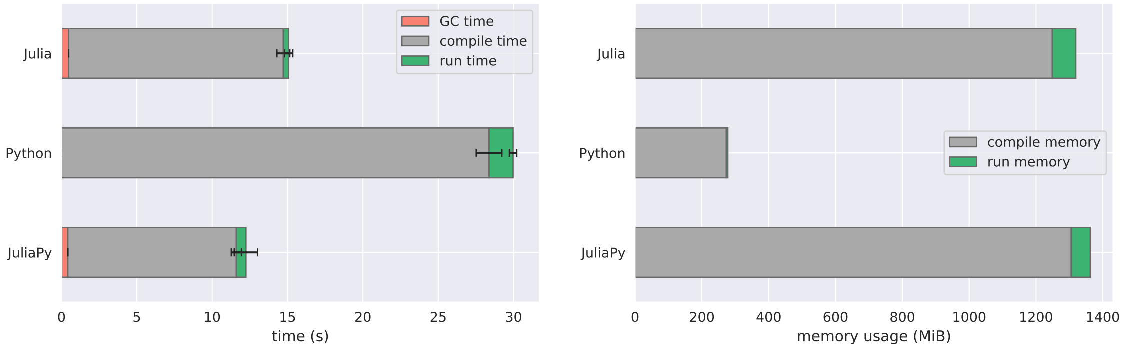
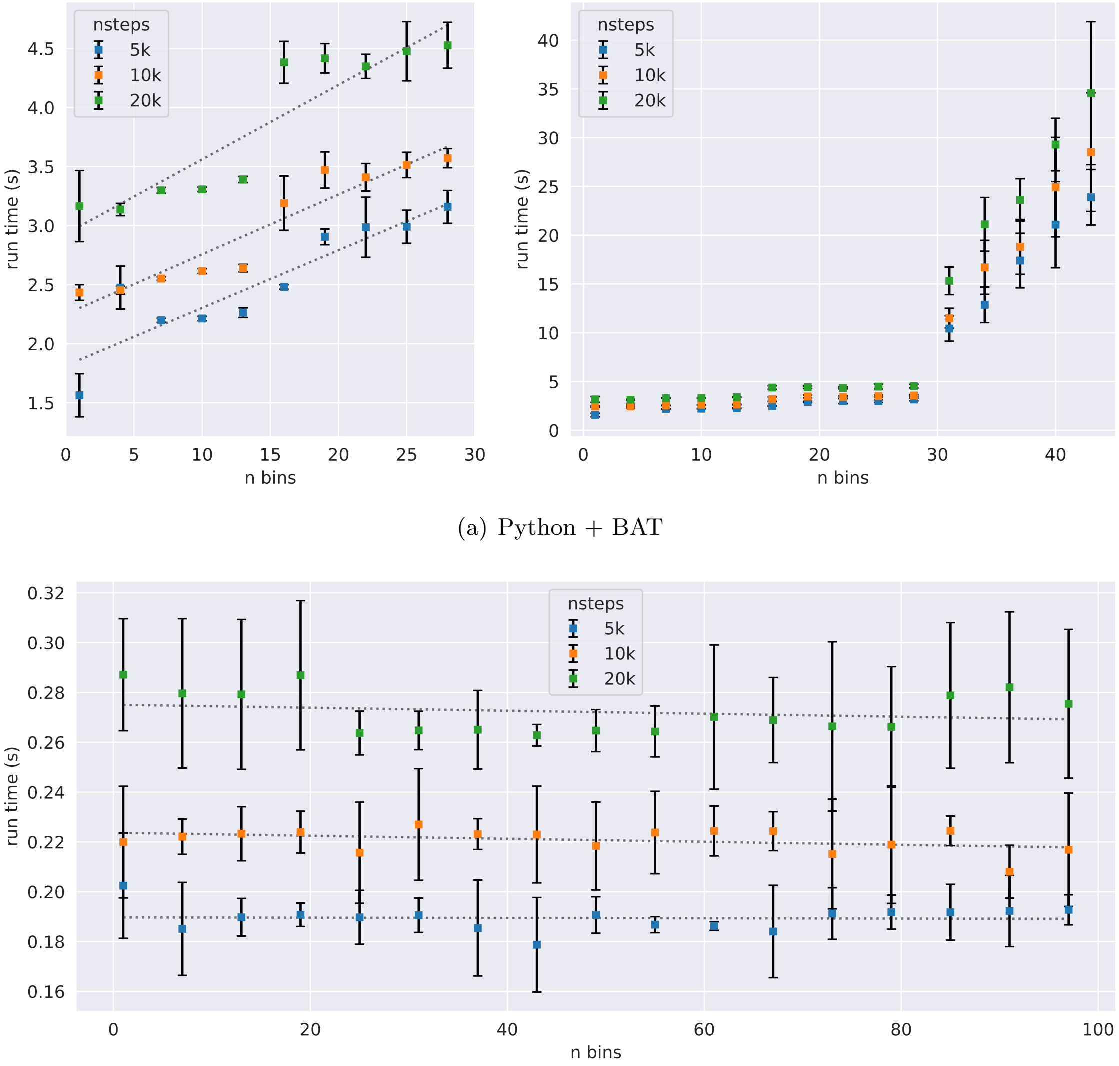


Figure 5.1: Total execution time for `bat_sample()`. (10k steps) ...

5.3 Benchmarks

The pure-Julia implementation is about **10 times faster** than the Python-Julia pipeline.

5.3.1 n-Bin-Model



(a) Python + BAT

(b) Julia + LiteHF

Figure 5.2: n-Bin Model. c) Julia + `pyhf` likelihood fehlt (noch keine Benchmarks gemacht, da LZ intensiv, in nÃ¤chster Version.)

- simple model with uncorrelated background and n bins
- pure Julia ”stable” runtime over 1 to 100 dimensional parameter vector

  (Ich check das nochmal ..)

- Python jump at 30 dim parameter vector

5.3.2 Benchmarks for the "complex" Model

TODO: complex Model benchmarks

- In Progress..
- Ich hab mal Plots erzeugt, fur die simplemodels

  Hier hab ich nur gerade was durcheinandergebracht, ist in der naechsten Version drin (vmtl. mit dem complex model.)
- Ergebnis vorab:
  - pure-Julia ist wieder 10 x Schneller als Python + BAT
  - Python + BAT etwa vergleichbare Laufzeit wie Julia + `pyhf` likelihood

List of Figures

Bibliography

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