Dealing with Quantum Computers Readout Noise Through HEP Unfolding Methods

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Objectives

- The first Goal of our work is to explain how to use a HEP unfolding technique to mitigate errors from a real quantum computer. This technique is called the iterative Bayesian unfolding method.
- A second objective is to analyze and compare the effectiveness of this technique with two other methods: the matrix inversion and the Ignis method (least-squares method).

Introduction

One significant kind of quantum computers errors is known as **Readout Errors**. Current methods, as the *matrix inversion* and *least-squares*, are used to correct readout errors. But these methods present many problems like oscillatory behavior and unphysical outcomes.

Experimental HEP physicist use many methods to unfold (correct) measured histograms from the effects of the detector. In HEP the histograms represent **binned differential cross sections** measurements.

In Quantum Computing, measurement can be represented as histograms **each bin corresponds to one of the possible** $2^{n_{qubit}}$.

This similarity allow a connection between the field of HEP and Quantum computing. The iterative Bayesian unfolding method is used to unfold readout noise from a **real quantum computer** this method allow us to avoid many problems like oscillatory behavior and unphysics outcome and will compare the effectiveness of this method by distorting some true data (Uniform, Gaussian distribution) by the effect of noise of the **Yorktown and the Melbourne IBM Q Machines**. Then, we compare our results with the true distributions and with the matrix inversion and the least-squares methods.

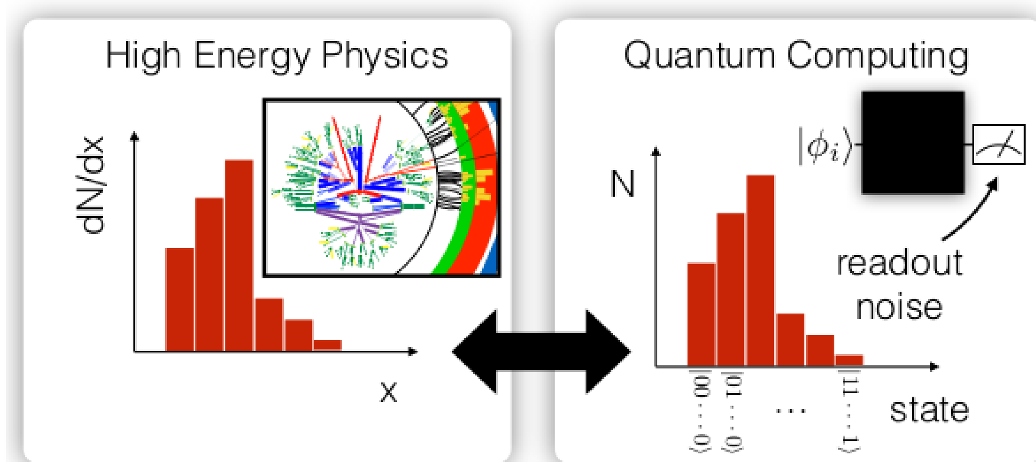

Figure 1:Connection between binned differential cross-section measurements in HEP (left) and interpreting the output of repeated measurements from quantum computers (right).

Methods

In our work, the IBU method is applied to mitigate measured data from a real quantum computer. For this purpose, we use the IBM Yorktown and Melbourne quantum machines to visualize the effect of noise in the uniform and the Gaussian distributions. The method was applied according to the steps outlined below:

- Generate a true distribution. We need it as reference to compare it with the measured distribution.
- Construct the response matrix R of a quantum computer. We need to calculate this matrix for each quantum computer.
- Construct a quantum circuit to Generate a specific distribution. We choose either uniform or Gaussian distribution for each experience.
- Executing the circuit in the IBM Quantum Computer.
- Collect and prepare the measured data to be unfolded.
- Now, We have the essential ingredients for the IBU method: Response matrix, True data, measured Data. We Apply the IBU technique and compare the result with the true distribution and the matrix inversion and the least-squares methods methods.

Yorktown IBM Q Machine

This is our result of unfolding measured uniform and Gaussian distribution from Yorktown IBM QC.

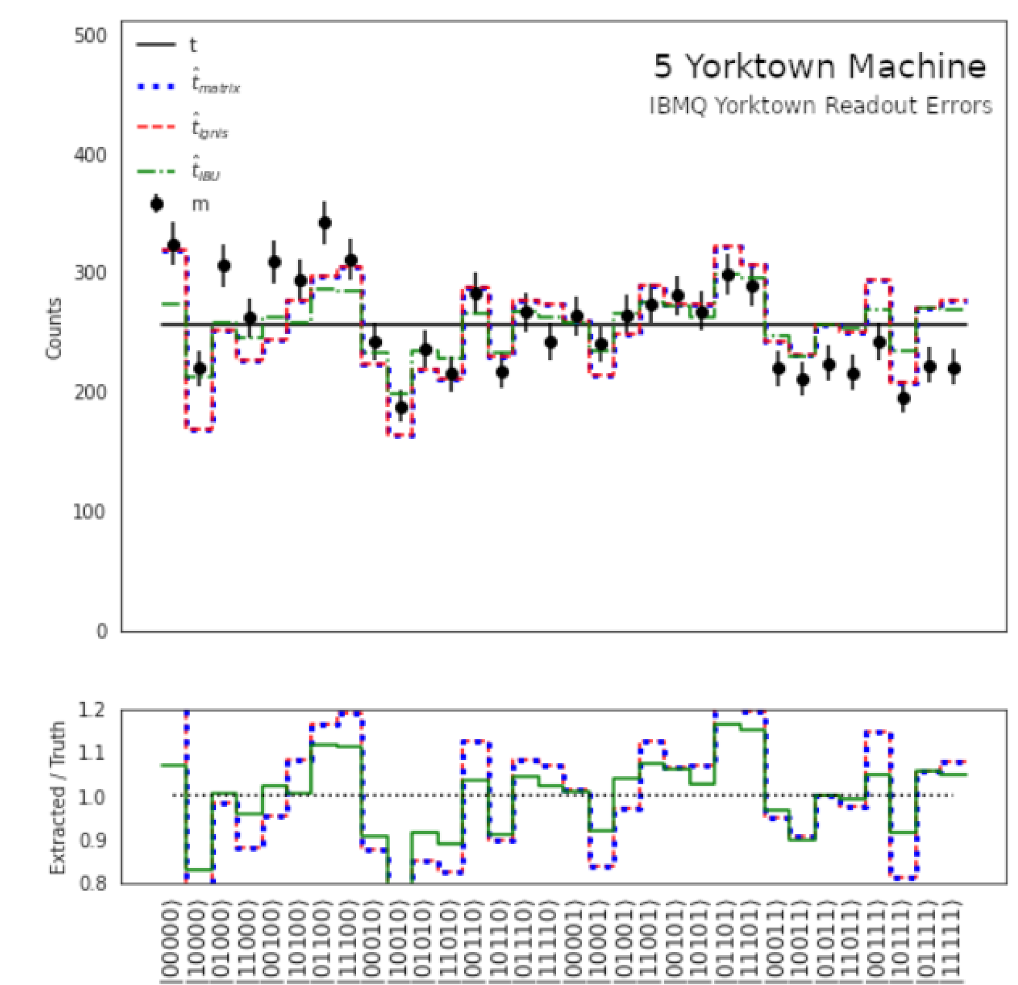

Figure 2:Unfolding results of a uniform distribution using three methods: Matrix inversion, ignis, and IBU with one iteration and a uniform prior truth spectrum.

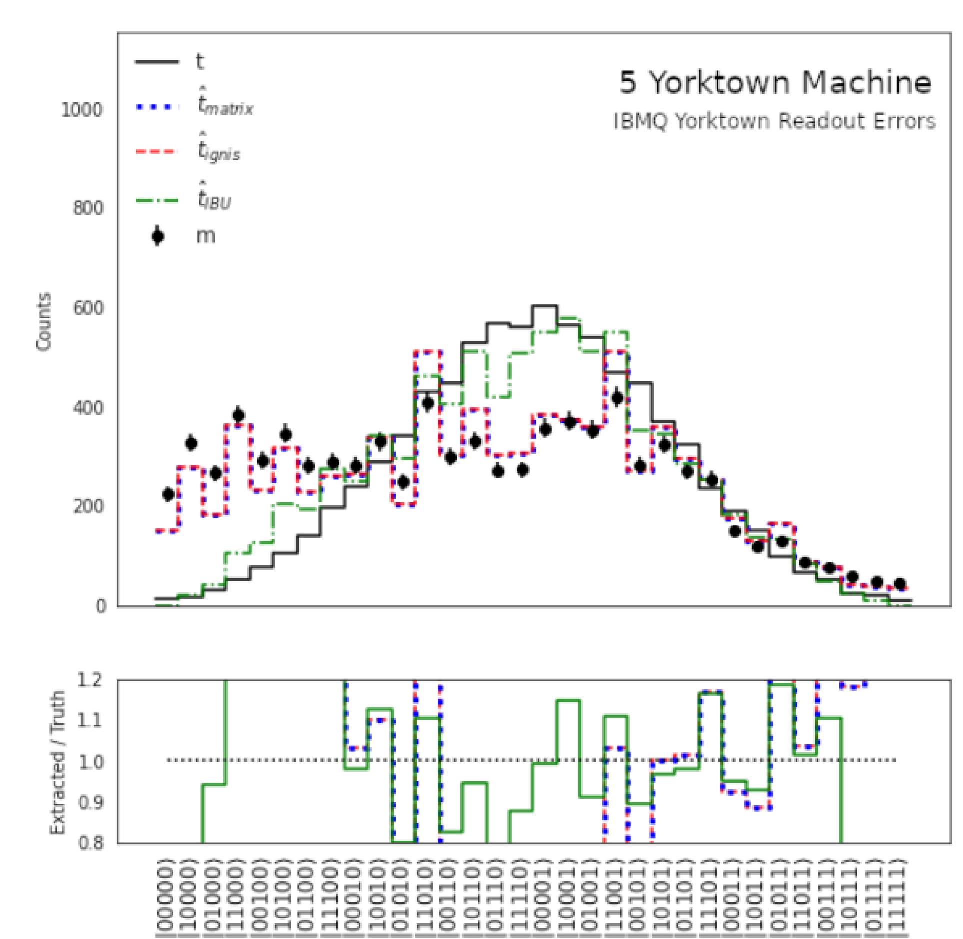

Figure 3:Unfolding results of a Gaussian distribution using three methods: Matrix inversion,ignis, and IBU with one iteration and a prior truth spectrum t0=t$_t$$rig$.

The Melbourne IBM Q Machine

This is our result of unfolding measured uniform distribution from Melbourne IBM QC.

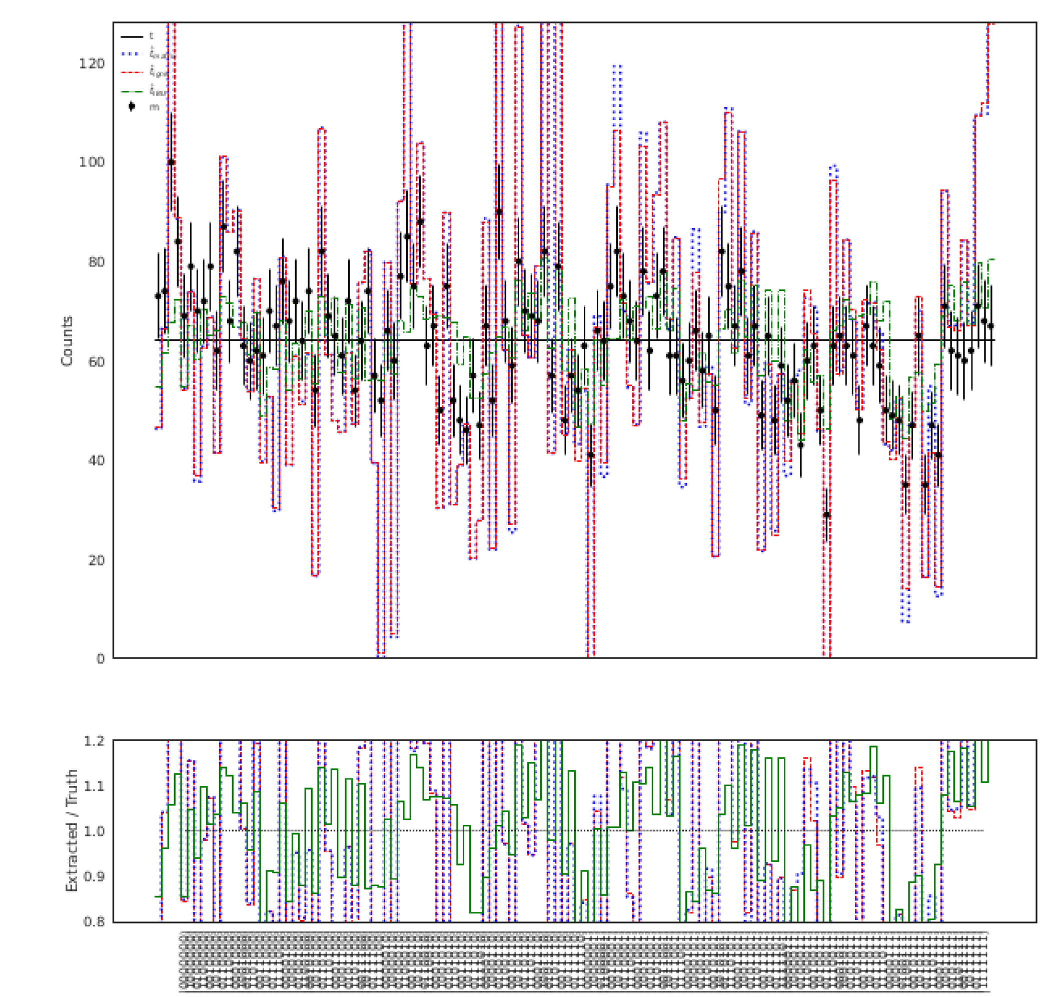

Figure 4:Unfolding results of a uniform distribution based on seven-qubits using 3 methods: Matrix inversion, ignis, and IBU with one iteration and uniform prior truth spectrum.

Conclusion

We studied three unfolding methods (MI, ignis, IBU) through a real Quantum Computer Readout Noise, for a uniform and Gaussian distribution, and we found that it gives good unfolding compared to MI and Ignis, which contribute to confirm the results of the researchers Benjamin Nachman et al.

References

[1] Benjamin Nachman and al.
Unfolding quantum computer readout noise, 2019.

[2] Hacene Rabah Benaissa and Imene Ouadah.
Dealing with quantum computer readout noise through high energy physics unfolding methods, 2021.