Preservation of the Direct Photon and Neutral Pion Analysis in the PHENIX Experiment at RHIC

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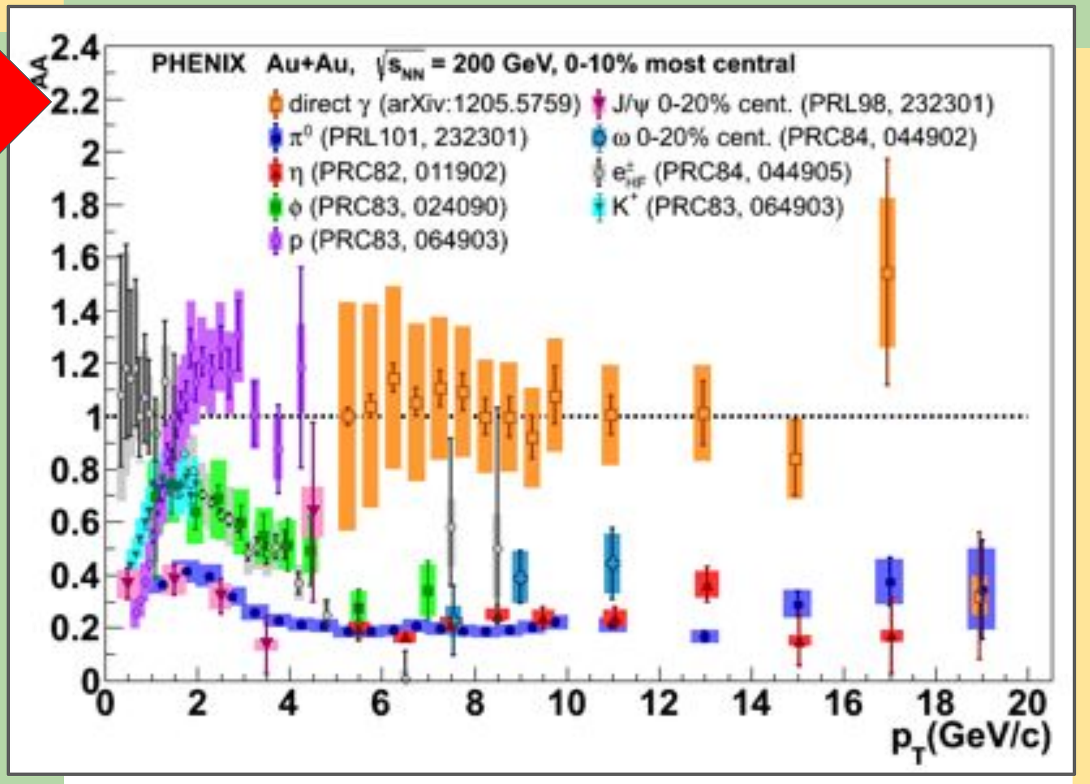
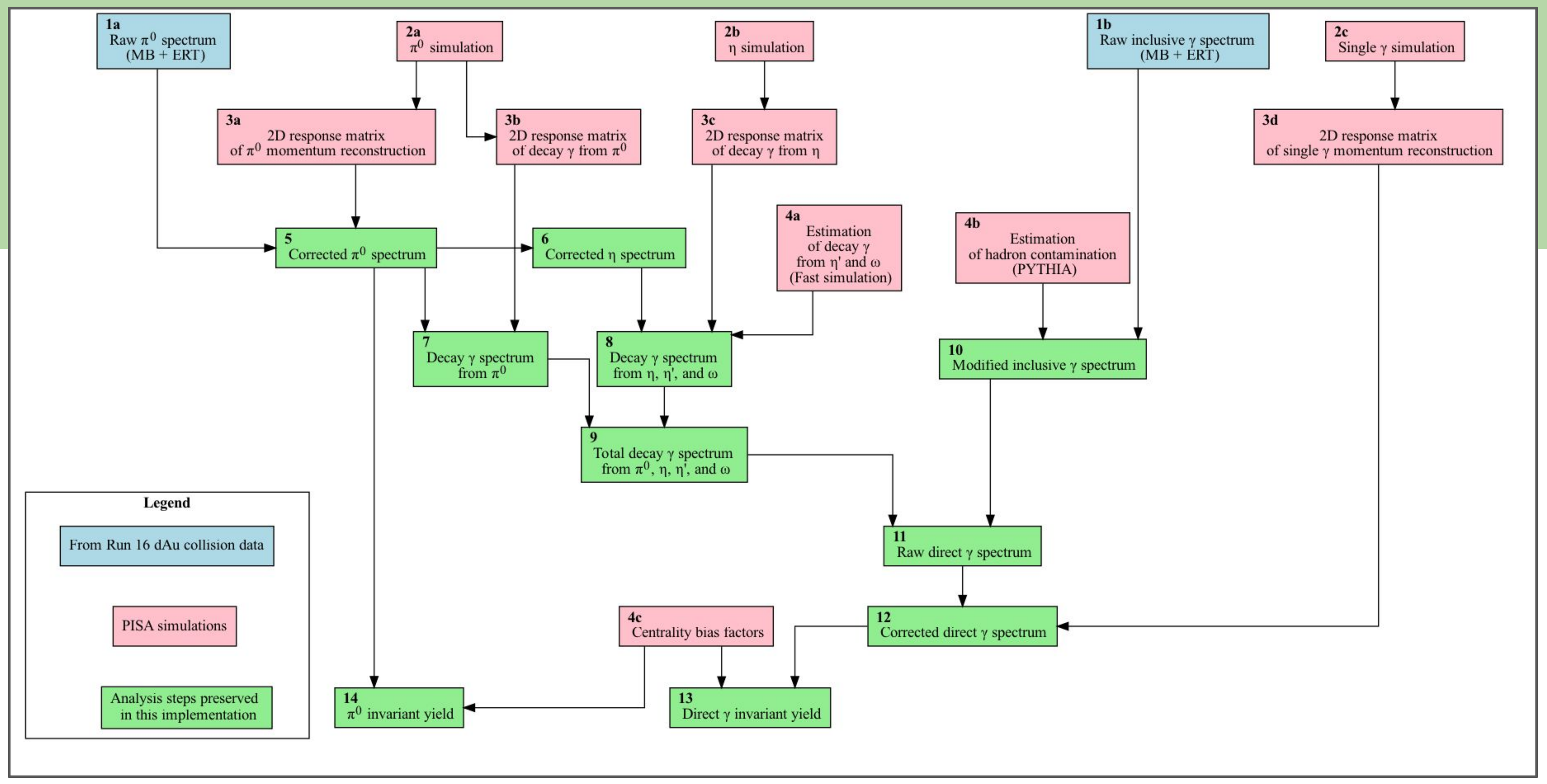
PHENIX | Brookhaven National Laboratory

- **PHENIX** was one of the two large RHIC experiments, until data taking was finished in 2016
- A large and complex general purpose detector
- 24PB of raw data accumulated, active analyses ongoing in 2024
- Since 2019, PHENIX is actively pursuing the **Analysis Preservation** program
- This includes knowledge and software management, as well as major upgrade of the website and the document management system
- The Direct Photon and Neutral Pion Analysis is an example of this preservation effort
- This is the first such effort at RHIC

- Study of the Quark-Gluon Plasma (QGP) is the main research topic in PHENIX
- QGP is transparent to the *direct photons* produced in the early (hard) collisions of the nucleons – however hadrons are “suppressed”, reflecting the QGP properties
- Measuring photons and neutral pions at high transverse momenta is a unique capability of PHENIX
- Importantly, *direct photons* can also help us validate the Glauber-model based mapping of the collision geometry to experimental observables (arXiv:2303.12899), which is critical to this study.

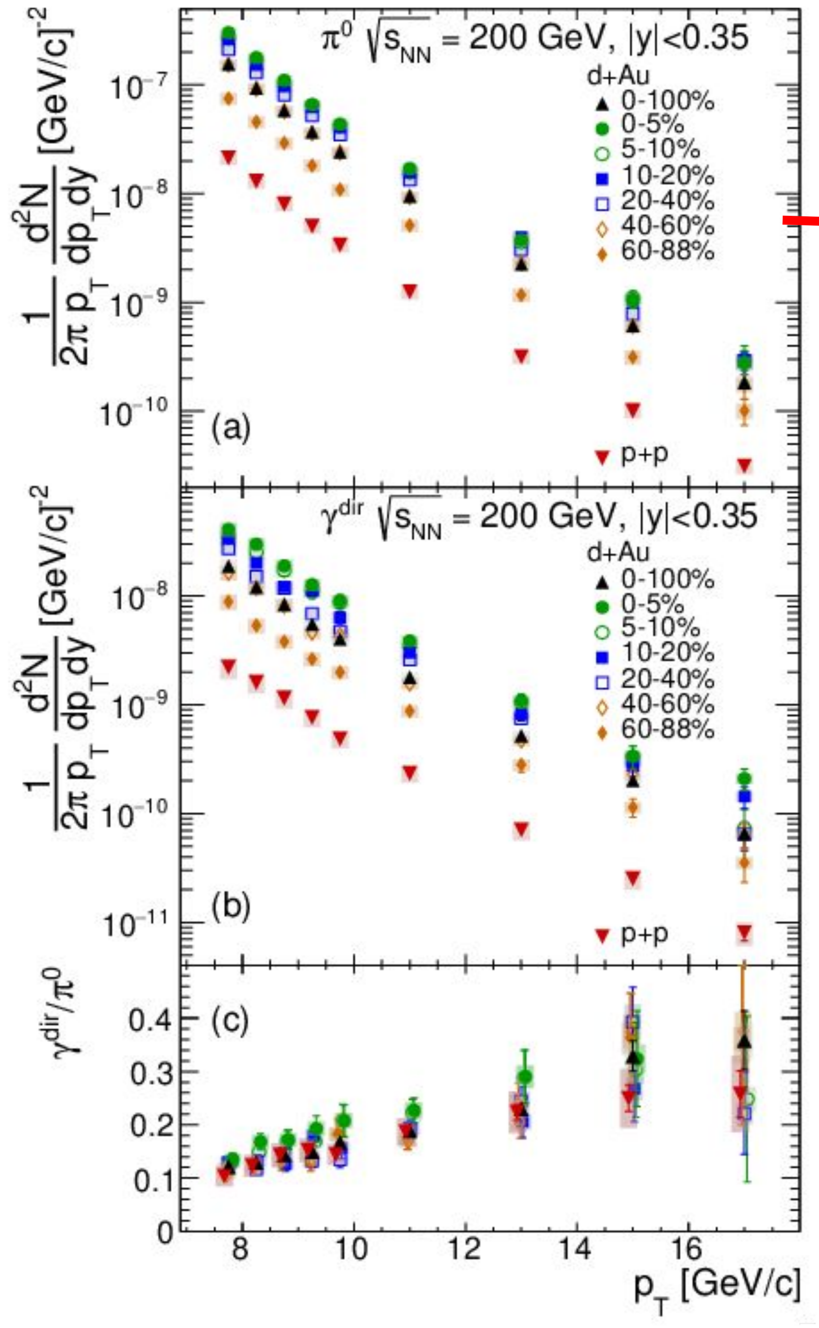
- Summary plot of the PHENIX results on the suppression factors (nuclear modification)
- Good understanding of the collision geometry is crucial for interpretation of these results.
- The PHENIX Electromagnetic Calorimeter is the most important tool for measuring the direct photons and neutral mesons, and its data form the basis of this analysis.
- The analysis workflow is quite complex, and involves simulation and embedding components. It is presented in the flowchart below.

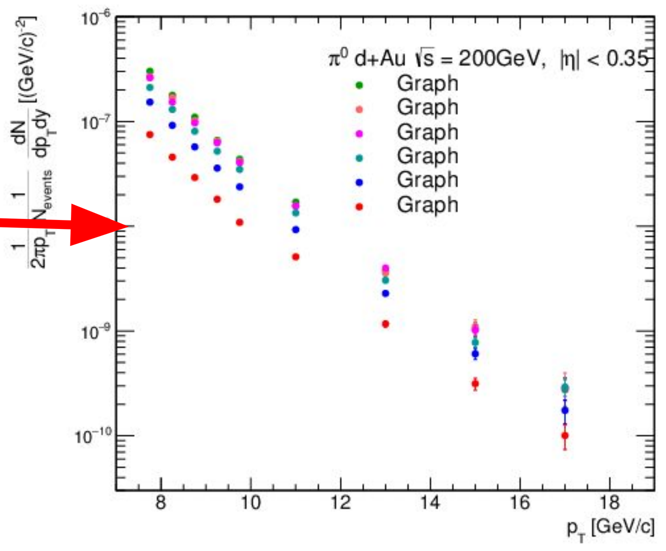




Analysis preservation strategy:

- Capture and document all elements of the workflow, and keep it compartmentalized to ensure reliable testing and validation
- Use version control to reliably capture both the software and the details of the setup
- Use software images to capture and preserve the software environment
- Leverage the **REANA** platform to run analysis payloads (the BNL instance)



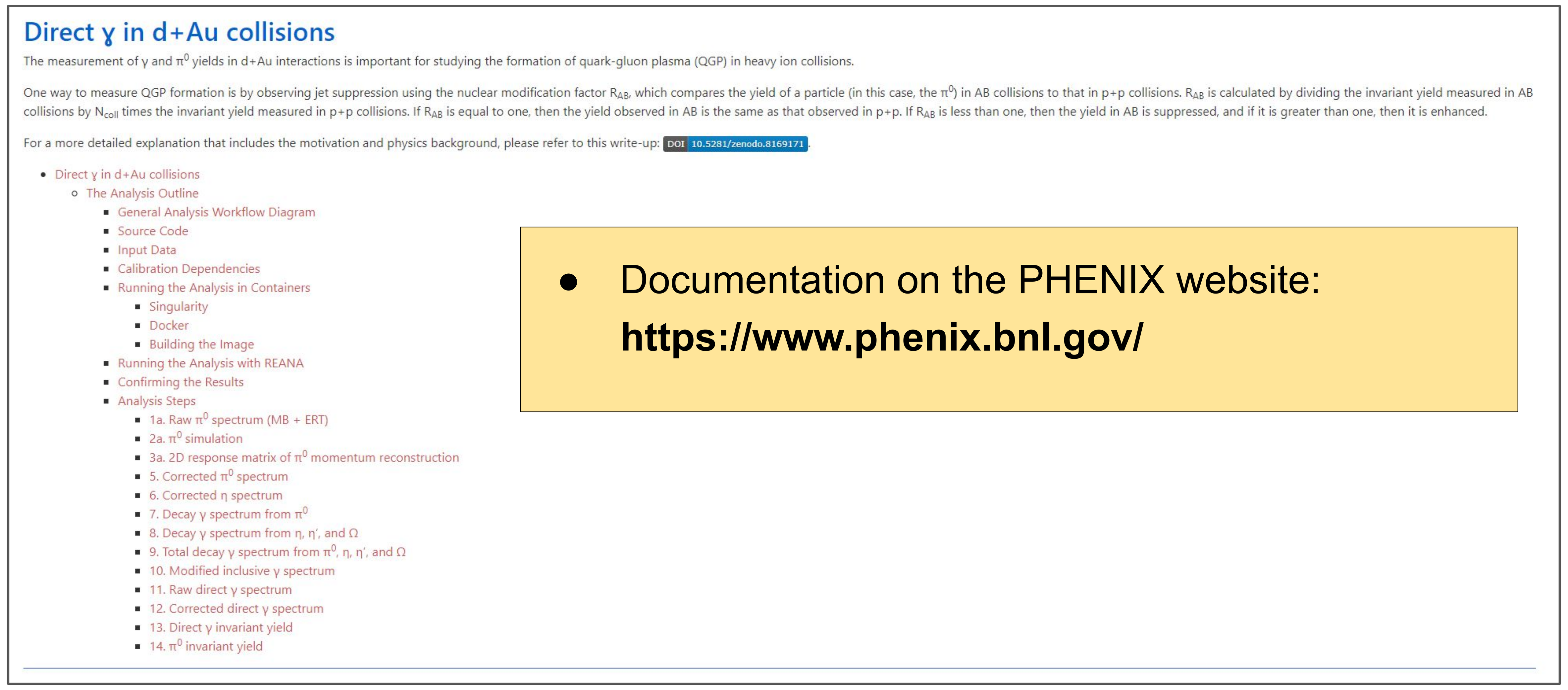


- The results of the captured analysis have been successfully reproduced by non-experts using only the documentation and the packaged software

reana

Status and plans:

- Work on preservation and provisioning of the calibration and conditions data in the preserved analysis context (i.e. separate from the production database)
- Refine the preserved software environment and related procedures in a way that is suitable for reuse in other analyses selected for reproducibility and preservation
- Expand the scope of the analysis preservation in PHENIX



Direct γ in d+Au collisions

The measurement of γ and π^0 yields in d+Au interactions is important for studying the formation of quark-gluon plasma (QGP) in heavy ion collisions.

One way to measure QGP formation is by observing jet suppression using the nuclear modification factor R_{AB}, which compares the yield of a particle (in this case, the π^0) in AB collisions to that in p+p collisions. R_{AB} is calculated by dividing the invariant yield measured in AB collisions by N_{coll} times the invariant yield measured in p+p collisions. If R_{AB} is equal to one, then the yield observed in AB is the same as that observed in p+p. If R_{AB} is less than one, then the yield in AB is suppressed, and if it is greater than one, then it is enhanced.

For a more detailed explanation that includes the motivation and physics background, please refer to this write-up: DOI 10.5281/zenodo.8169171.

- Direct γ in d+Au collisions
  - The Analysis Outline
    - General Analysis Workflow Diagram
    - Source Code
    - Input Data
    - Calibration Dependencies
    - Running the Analysis in Containers
      - Singularity
      - Docker
      - Building the Image
    - Running the Analysis with REANA
    - Confirming the Results
    - Analysis Steps
      - 1a. Raw π^0 spectrum (MB + ERT)
      - 2a. π^0 simulation
      - 3a. 2D response matrix of π^0 momentum reconstruction
      - 5. Corrected π^0 spectrum
      - 6. Corrected η spectrum
      - 7. Decay γ spectrum from π^0
      - 8. Decay γ spectrum from η, η′, and Ω
      - 9. Total decay γ spectrum from π^0, η, η′, and Ω
      - 10. Modified inclusive γ spectrum
      - 11. Raw direct γ spectrum
      - 12. Corrected direct γ spectrum
      - 13. Direct γ invariant yield
      - 14. π^0 invariant yield

- Documentation on the PHENIX website: **https://www.phenix.bnl.gov/**