Data & Analysis Preservation: status update

Maxim Potekhin
Nuclear and Particle Physics Software Group

BROOKHAVEN NATIONAL LABORATORY

PHENIX

PHENIX Conveners Meeting
01/20/2021

This presentation

- An introduction to the PHENIX website redesign was presented in March 2020:
  - https://docs.google.com/presentation/d/1Vnq0wl9PyZKYmfRw_k9ZOHko6IwZDDQymUixDA-Srvg/edit?usp=sharing
  - Please see the link above for a more generic discussion of motivations, technology choices etc
- Discussion today: current status of the website
  - Leveraging the available cloud resources
  - How to ensure usefulness of the website as a component of Analysis Preservation and its potential to advance more immediate goals of PHENIX
- Evaluating containers for analysis preservation, training and general improvement of software deliver and use in PHENIX
- Leveraging the website and other tools for the PHENIX School

The website: a bit of history

- The legacy PHENIX website had been showing its age for a while
  - Some useful information was spread over multiple web servers
  - Used as a document repository with limited functionality and lack of external visibility
  - Certain software modules (PHP) in its framework were potentially vulnerable security-wise
- Technical problems encountered in 2020 illustrate operational risks due to difficulty of upgrades e.g. maintaining the legacy software stack in the evolving OS environment while staying abreast of security requirements
- Less DB support available as time goes on (actually none at this point)

Strategy 2020

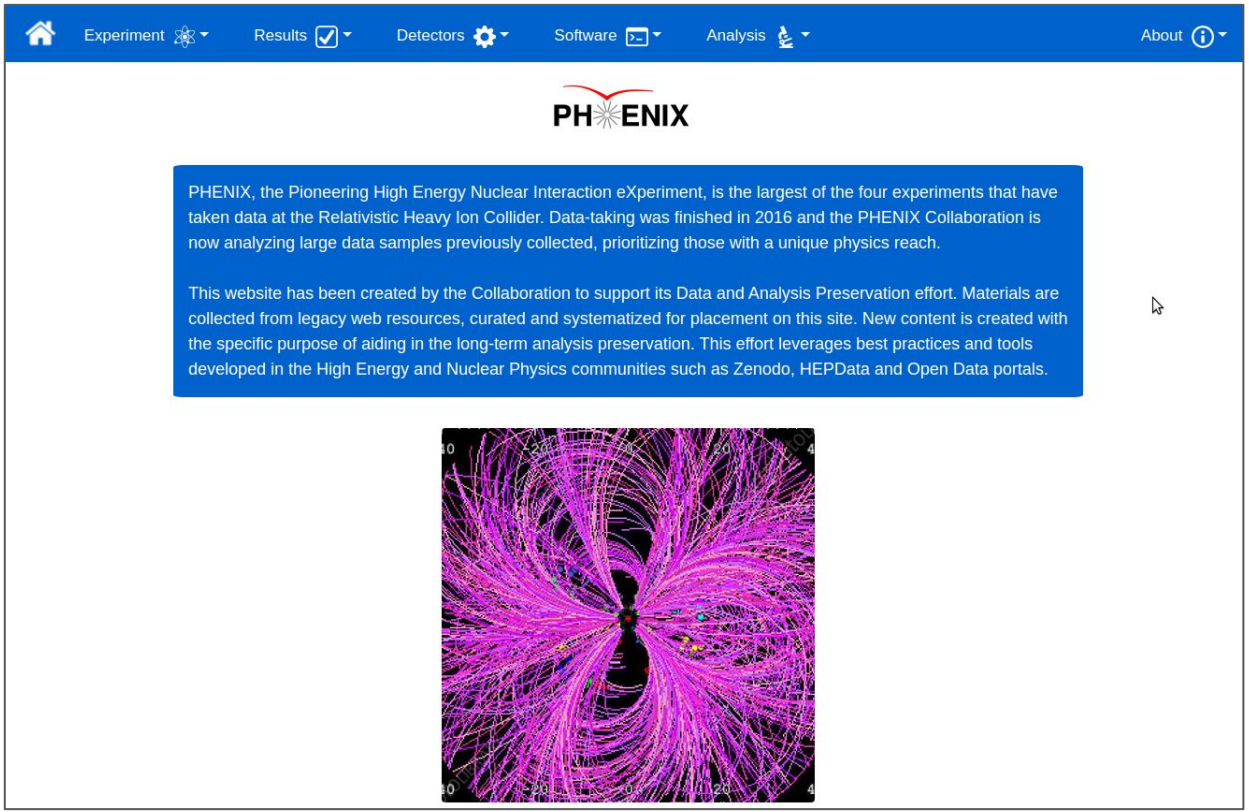
- DAP = Data and Analysis Preservation
- Design a new website aligned with the goals of DAP
  - Emphasis on ease of maintenance and long-term durability
  - Collect and curate materias from available resources
  - Create new materials where necessary
- Factor out the repository and other similar functionality by leveraging modern solutions developed and employed in the NP and HEP communities
  - The website effectively becomes a portal to cloud resources, with a moderate amount of material still hosted locally

The website technology and status

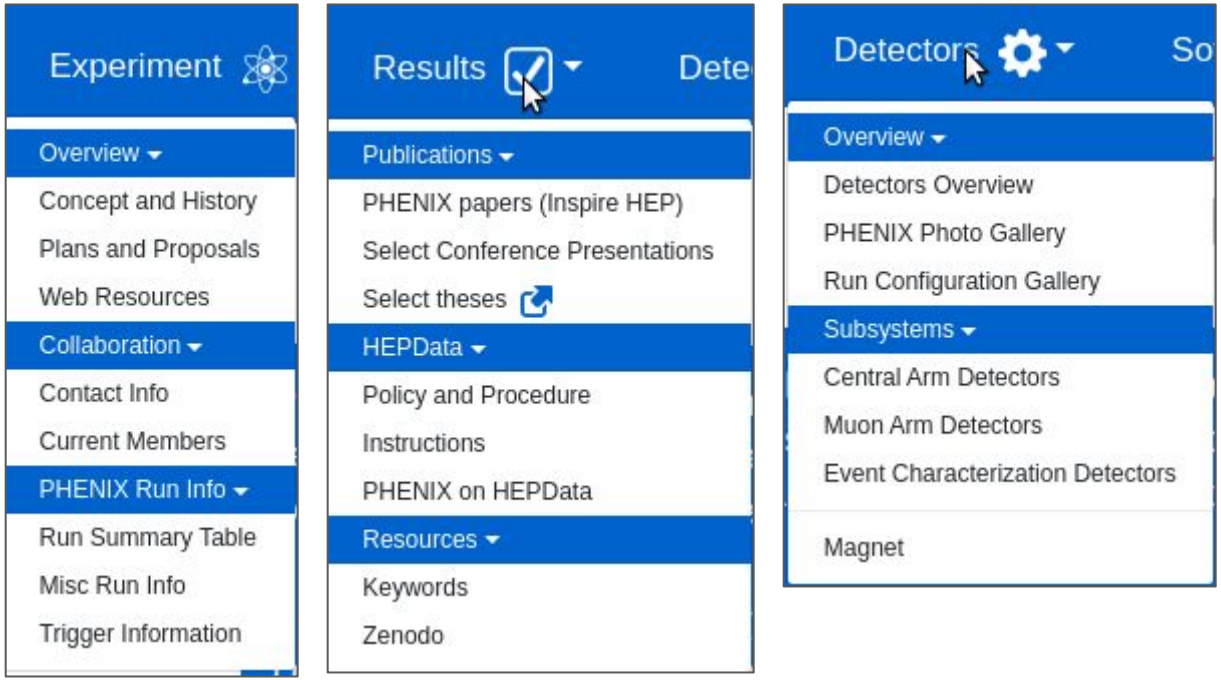
- Use a static website generator for speed and security
- Content and layout are separate; easy to use markup (not HTML)
- Data kept in specially formatted files (YAML) to provide DB-like functionality without having an actual database
  - Flexibility and consistency across multiple pages - define data once, use in many places
  - Powerful macros can be created
- All materials hosted transparently on GitHub
  - Leveraging free hosting of the development version of the website on GitHub pages
- As of Fall 2020 the production version is hosted at BNL at the canonical URL: https://www.phenix.bnl.gov/
  - Releases approximately every two weeks
- In the following few slides we will review the site

Website: the landing page

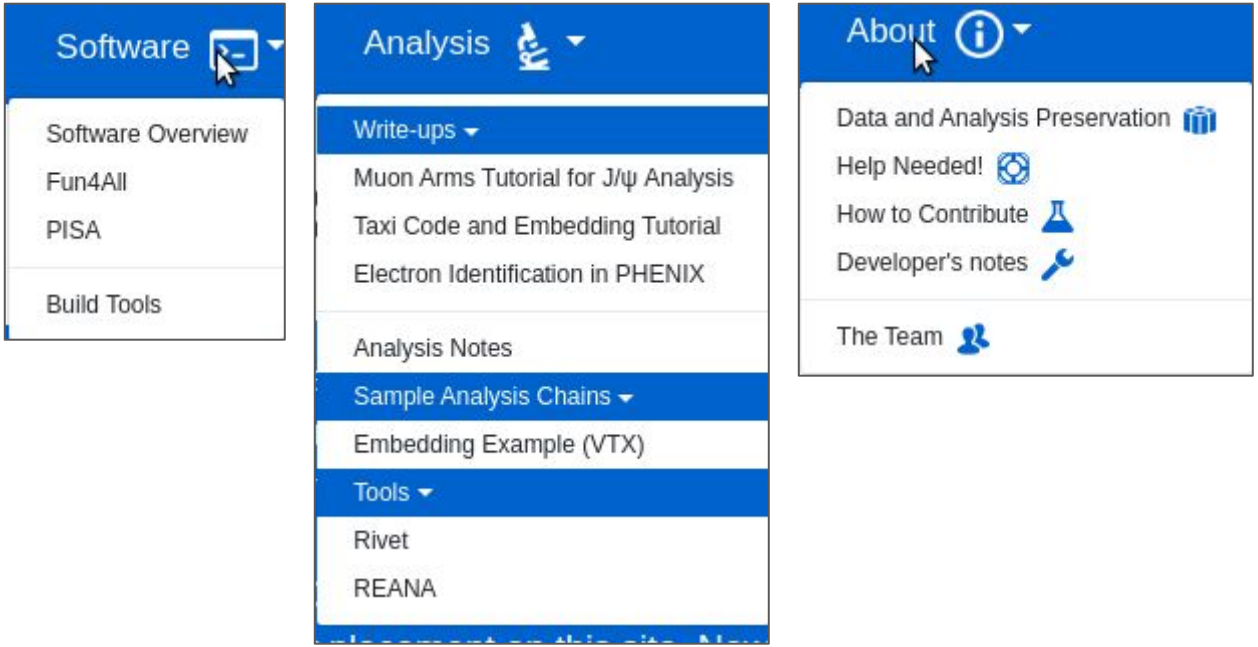
Menus



Website: dropdown menus (1)



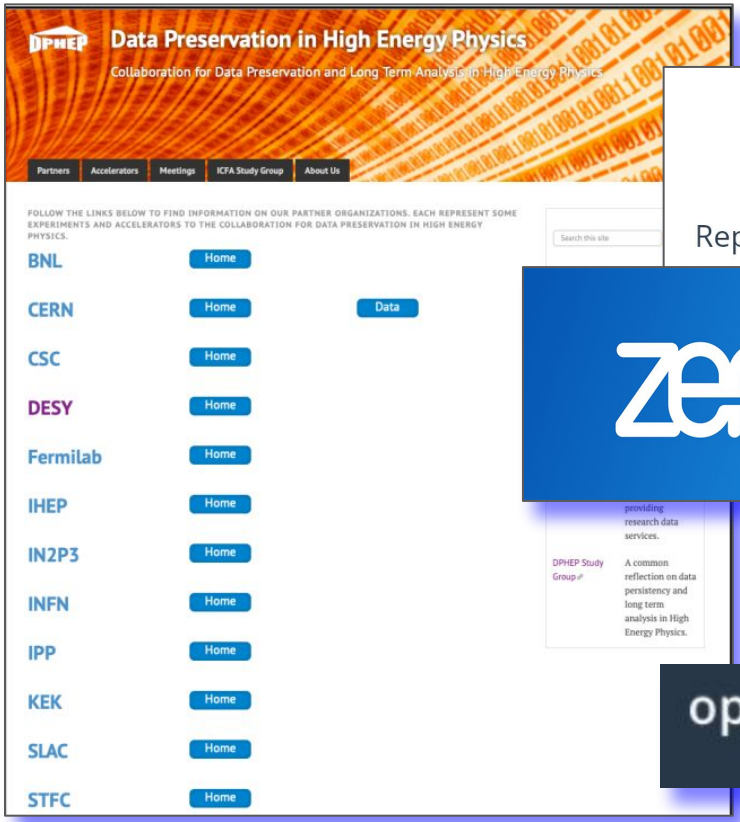
Website: dropdown menus (2)



Leveraging the community cloud resources

- Use well established solutions widely adopted in the community
  - NB. solid back-end and support
  - Look at best practices at CERN and other labs
  - Reduces cost and increases long-term viability of the PHENIX Web infrastructure
- Resources already adopted by PHENIX
  - Zenodo (a general-purpose digital repository)
  - HEPData - a repository for numerical data used in publications
  - InspireHEP - a searchable publication catalog
- So a few types of functionality effectively migrated to the cloud from the legacy site
- Heavy investment in Zenodo and HEPData
- Upcoming
  - OpenData: a DAP-oriented portal for sharing datasets, software and documentation
  - REANA: a framework for reproducible analysis based on containerization

CERN and community tools for DAP



reana

Reproducible research data analysis platform

HEPData

zenodo

iNSPIRE HEP

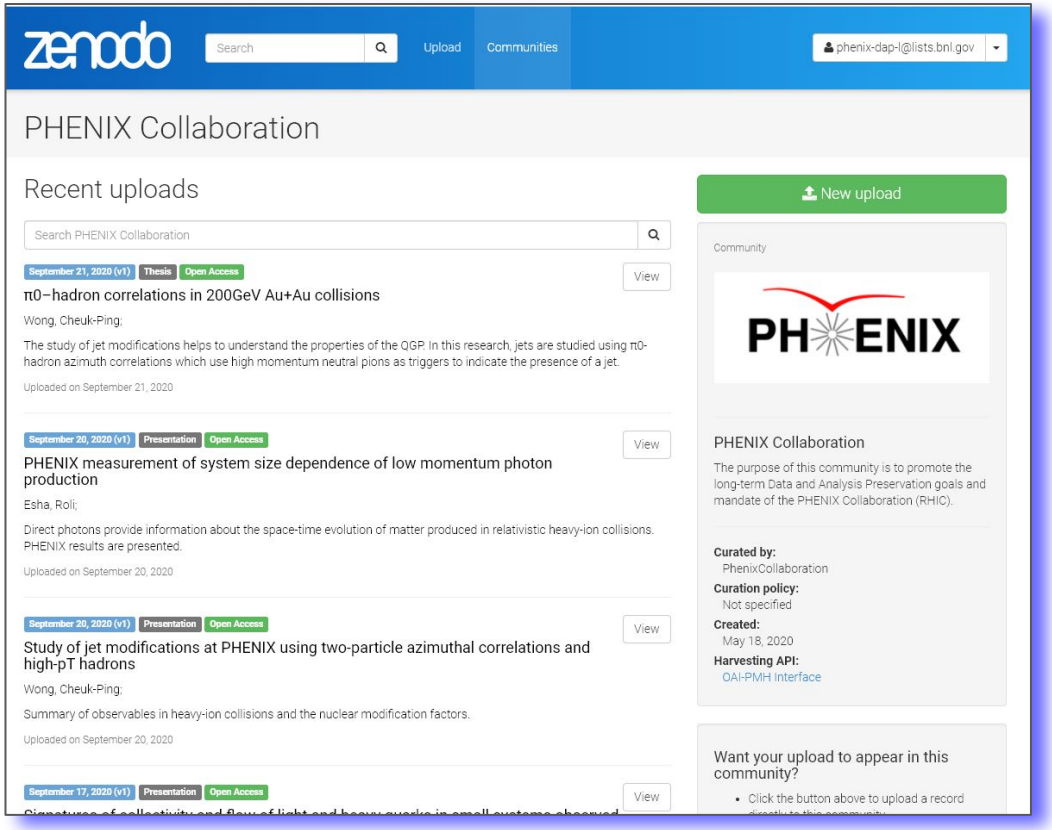
opendata CERN

Zenodo

- Zenodo - close to 200 PHENIX items were made available on the portal
- DOIs are an important feature for long-term preservation (“permalink”)
- Uploaded and tagged ⅔ of PHENIX theses with keywords (currently at 124), work in progress with completion date in 2021 - thanks to Stacyann Nelson
- Steady upload of conference/workshop and other presentation, with a dedicated page on the new site
- Keywords - essential for discoverability and integrity of references
    - A list is curated, updated and used with all uploads

Zenodo@CERN - the PHENIX community

- Branded
- Curated
- Discoverable
- Indexed (keywords)
- Elastic search capability



An example of a PHENIX item on Zenodo

December 1, 2013

Thesis | Open Access

Low Momentum Direct Photons as a Probe of Heavy Ion Collisions

Petti, Richard

Thesis supervisor(s)

Drees, Axel

Essential to the study of heavy ion collisions are probes that are produced in the collision itself. Photons are a very useful probe of the collisions, since they escape the fireball virtually unmodified and carry with them information about the environment in which it was produced. Recent interest in low momentum direct photons has increased, due to the onset of the "thermal photon puzzle" and the apparent inability for typical models to explain both a large direct photon yield excess and large azimuthal production asymmetry (v2) at low momentum measured by PHENIX.

Preview

Page: 39 of 192 — + Automatic Zoom

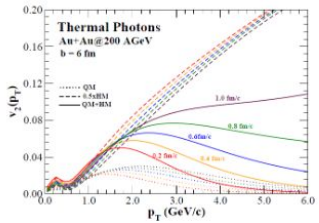


Figure 1.20: A calculation of the thermal photon v_2 from [23]. The dotted curves represent the v_2 of thermal photons emitted from the QGP, dashed curves represent the v_2 of thermal photons emitted from the hadron gas, and solid curves represent the time averaged thermal photon v_2 integrated over the entire evolution of the system. The various colors represent the calculation

Files (10.8 MB)

Edit

New version

Communities

PHENIX Collaboration — Remove

8 views

5 downloads

See more details...

Indexed in OpenAIRE

Publication date:
December 1, 2013

DOI:
DOI 10.5281/zenodo.3887326

Keyword(s):
RHIC | direct photon | PID | emcal | PHENIX | hbd | zdc | run07 | heavy ion

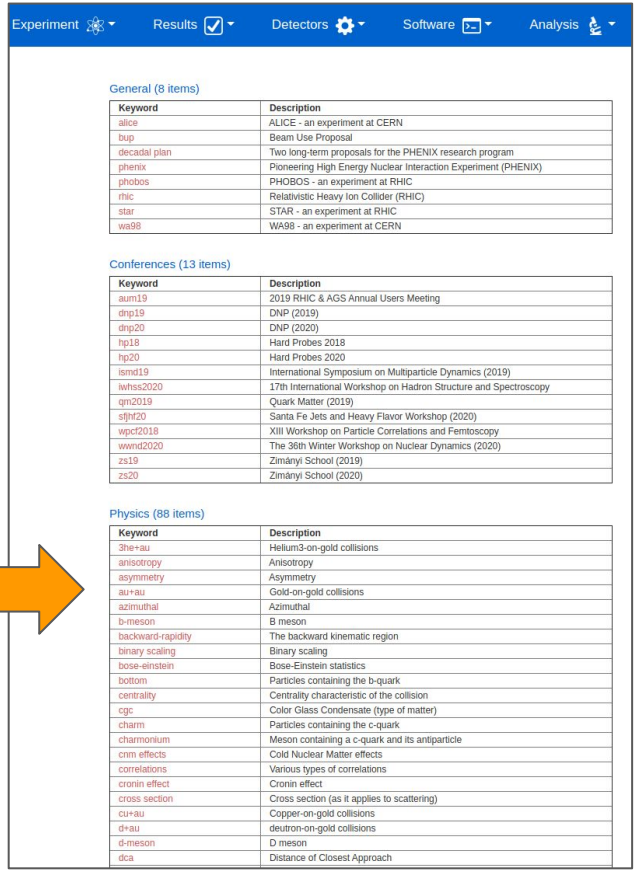
Keywords

Awarding University:
SUNYSB

Communities:
PHENIX Collaboration

Zenodo keywords page

Working query links



Experiment | Results | Detectors | Software | Analysis

General (8 items)

Keyword	Description
alice	ALICE - an experiment at CERN
bup	Beam Use Proposal
decadal plan	Two long-term proposals for the PHENIX research program
phenix	Pioneering High Energy Nuclear Interaction Experiment (PHENIX)
phobos	PHOBOS - an experiment at RHIC
rhic	Relativistic Heavy Ion Collider (RHIC)
star	STAR - an experiment at RHIC
wa98	WA98 - an experiment at CERN

Conferences (13 items)

Keyword	Description
aum19	2019 RHIC & AGS Annual Users Meeting
dnp19	DNP (2019)
dnp20	DNP (2020)
hp18	Hard Probes 2018
hp20	Hard Probes 2020
ismd19	International Symposium on Multiparticle Dynamics (2019)
iwhss2020	17th International Workshop on Hadron Structure and Spectroscopy
qm2019	Quark Matter (2019)
sfjhf20	Santa Fe Jets and Heavy Flavor Workshop (2020)
wpcf2018	XIII Workshop on Particle Correlations and Femtoscopy
wwnd2020	The 36th Winter Workshop on Nuclear Dynamics (2020)
zs19	Zimányi School (2019)
zs20	Zimányi School (2020)

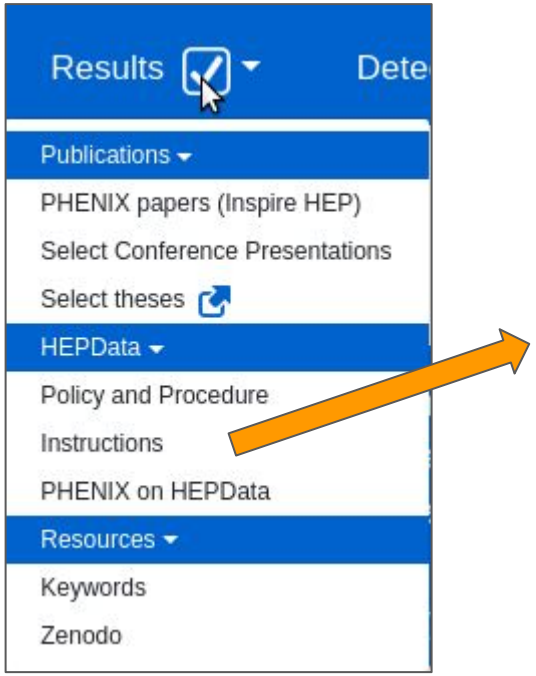
Physics (88 items)

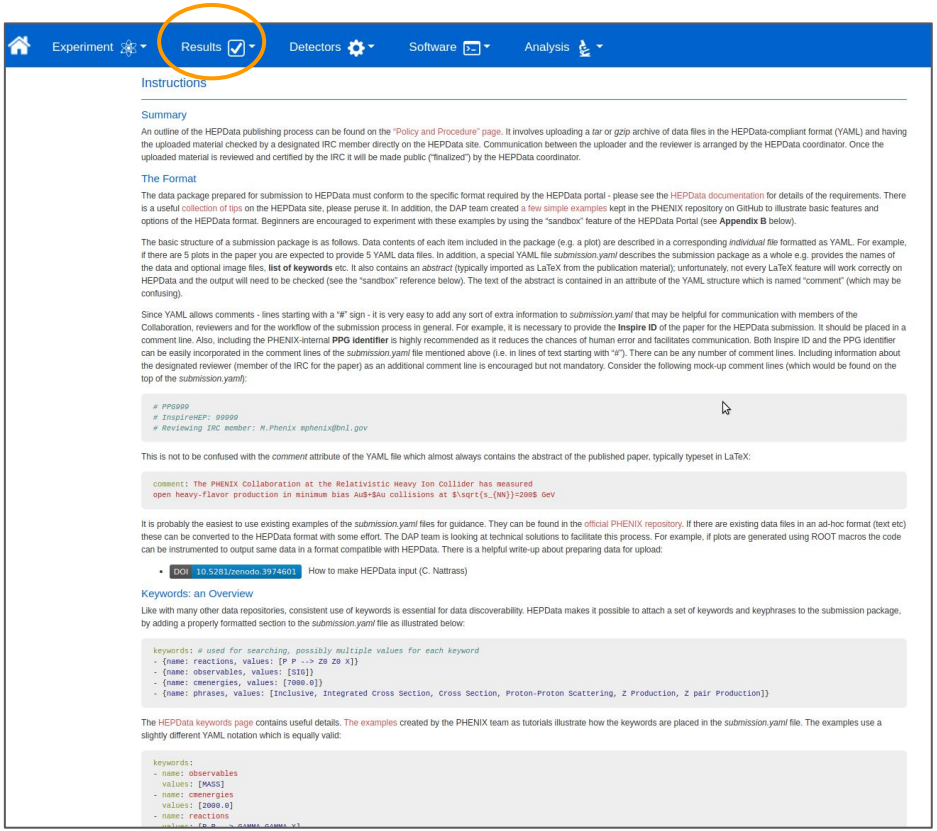
Keyword	Description
3he+au	Helium3-on-gold collisions
anisotropy	Anisotropy
asymmetry	Asymmetry
au+au	Gold-on-gold collisions
azimuthal	Azimuthal
b-meson	B meson
backward-rapidity	The backward kinematic region
binary scaling	Binary scaling
bose-einstein	Bose-Einstein statistics
bottom	Particles containing the b-quark
centrality	Centrality characteristic of the collision
cgc	Color Glass Condensate (type of matter)
charm	Particles containing the c-quark
charmonium	Meson containing a c-quark and its antiparticle
cnm effects	Cold Nuclear Matter effects
correlations	Various types of correlations
cronin effect	Cronin effect
cross section	Cross section (as it applies to scattering)
cu+au	Copper-on-gold collisions
d+au	deutron-on-gold collisions
d-meson	D meson
dca	Distance of Closest Approach

HEPData

- A repository for numerical data used in publications (e.g. data points in plots).
- Standard practice in many experiments.
- We are still catching up with other major experiments who started investing in this earlier.
- Data from 46 published PHENIX papers has been uploaded
  - Available for reliable download in a standard format
  - Indexed and discoverable.
  - Once again, DOIs.
- The official publication policy in PHENIX mandates the HEPData process for each potential publication. Steady state work now.
- HEPData/Rivet workshops in Fall 2020 (thanks to Christine for organizing this).
- Based on our experience the policies and procedures have been discussed and updated.
  - Extensive re-write of the corresponding documentation on the website (next page)

HEPData Instructions and Policies

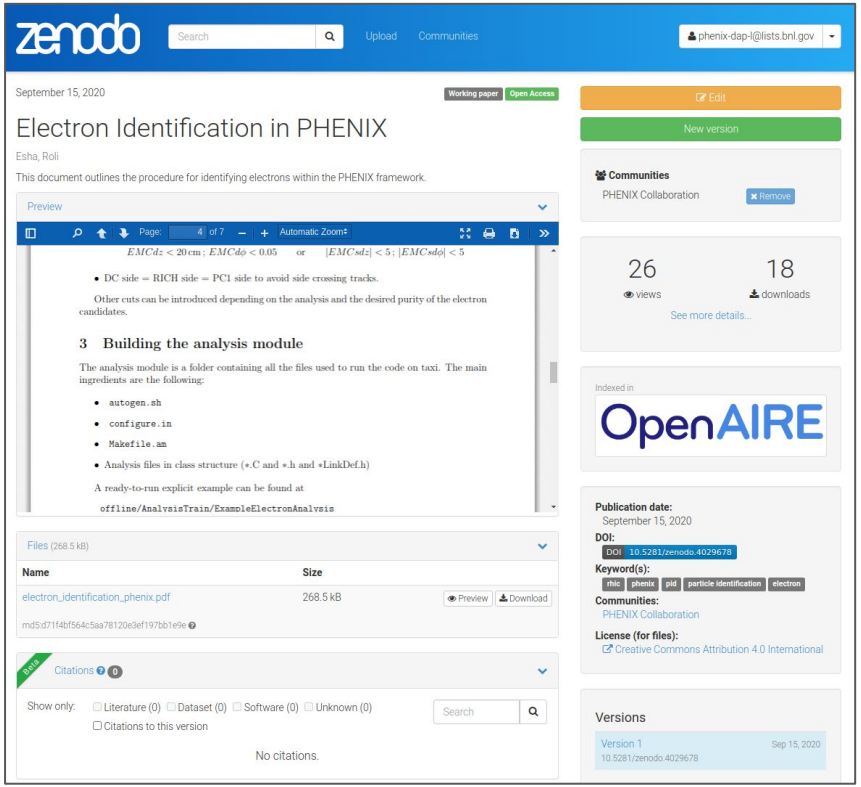




Analysis resources on the site

- Progress has been made with creating updated tutorials for specific work areas (see on the site)
- Currently implemented as write-ups published on Zenodo and linked on the site
- Caveat: these materials need another round of updates to account for mode code access (i.e. update or eliminate references to the code browser only available internally, review placement of code on AFS and whether it's suitable for publication etc)

Example of a tutorial uploaded to Zenodo



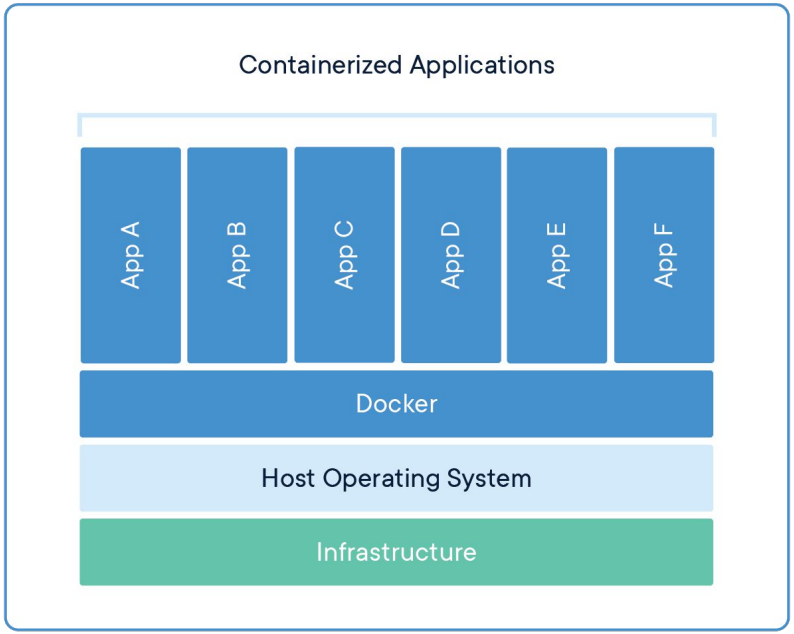
The analysis content

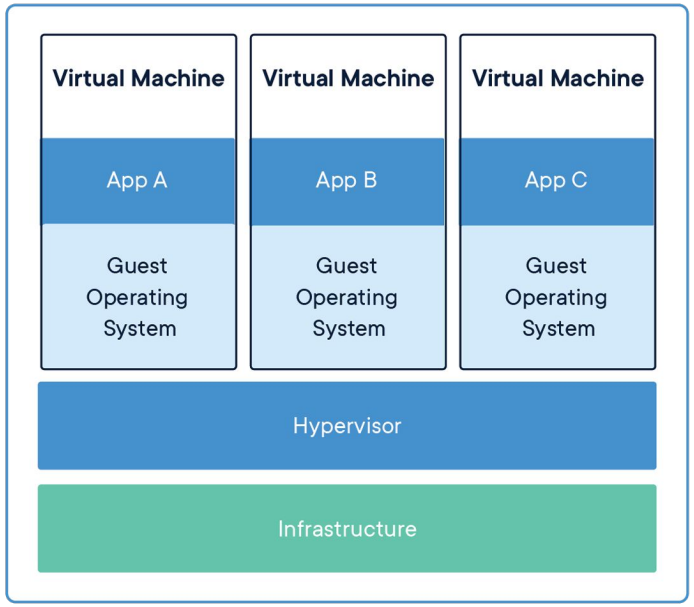
- Having well documented use cases (tutorials and/or complete preserved analyses) is obviously conducive to both efficiencies in medium term and longer term DAP
- Better engagement by the PHENIX community still remains on the critical path
  - Reverse engineering of prior analyses turns out to be close to impossible
  - Analyzers active in a given area are the best resource we have to create materials to meet education and analysis preservation goals
- We have good technology when it comes to all aspects of DAP implementation (Zenodo, REANA etc)
  - Can upload and systematize complete datasets, software, all sorts of documentation
- ...but the actual materials still need to be produced

Containers

- Containerization is a methodology of packaging software into standardized units for development, shipment and deployment. There are two leading platforms:
  - Docker - concept and implementation coming from industry
  - Singularity - originated at LBNL, contributions from Fermilab, adopted in the Open Science Grid and many other venues for scientific computing - used for PHENIX production
  - A high degree of interoperability between the two
- In the following slides some basic Docker concepts will be introduced, apologies to those of you already familiar with the technology
  - There is a plethora of information on the Web for your perusal
  - https://docs.docker.com/
- Both Containers and Virtual Machines provide a layer of abstraction on top of the host operating system thus making deployment possible in a variety of environments
  - But they do it differently

Containers vs VM





- Virtual machines require a “hypervisor” which is responsible for complete emulation of an OS
- However containers share the same OS kernel resulting in more economical storage and better performance
- Containers are made possible by the Linux resources isolation features

Docker: containers and images

- “Image” is a read-only template residing in storage and used to create a running process - the “container”
- “Repository” is a storage and access system for images
  - Can be in the cloud (DockerHub, GitLab) or local to your cluster or machine
- Example: inspect images on a local machine: “docker image ls”

REPOSITORY	TAG	IMAGE ID	CREATED	SIZE
simple_server	latest	3d7b269117a7	20 months ago	158MB
django_import	latest	975596a4f73f	20 months ago	207MB
ubuntu	latest	d131e0fa2585	21 months ago	102MB
alpine	latest	cdf98d1859c1	21 months ago	5.53MB
mediawiki	latest	efd68a02fb8a	21 months ago	691MB
mariadb/server	latest	8fe757be2fd3	23 months ago	368MB
nginx	latest	568c4670fa80	2 years ago	109MB

Docker: building images

- Building images can be conceptualized as adding layers to an underlying image
  - e.g. one can start with a Ubuntu image and build an app (and its dependencies) on top
- The Docker daemon orchestrates the build based on the instructions in the “Dockerfile”
- Too many details to be covered in a short overview
- The key point is that a complete (and potentially complex) environment can be encapsulated in an image which can be preserved and ran as a container on a target system, potentially anywhere

Copy from the current folder

```
FROM ubuntu:18.04
COPY . /app
RUN make /app
CMD python /app/app.py
```

Docker build: a more complex example

```
# Install newer version of CMake
RUN curl https://cmake.org/files/v3.14/cmake-3.14.6.tar.gz | tar -xz -C /tmp \
 && cd /tmp/cmake-3.14.6 && ./bootstrap && make -j $(nproc) && make install \
 && rm -fr /tmp/*

# Install ROOT5
RUN curl https://root.cern.ch/download/root_v5.34.38.source.tar.gz | tar -xz -C /tmp
\
 && mv /tmp/root /tmp/root-5-34-38 \
 && mkdir /tmp/root-build && cd /tmp/root-build \
 && cmake /tmp/root-5-34-38 \
    -DCMAKE_INSTALL_PREFIX=/usr/local \
    -Drpath=ON \
    -Dtable=ON \
    -Dpythia6=ON \
    -Dpythia6_nolink=ON \
    -Dvc=ON \
    -Dkrb5=OFF \
 && make -j $(nproc) \
 && make install \
 && rm -fr /tmp/*
```

Docker: running containers

- “docker run python_server” (can be any image available to you)
- Any number of containers can be run on a machine
- Containers can have ports open to other containers and to the host machine
- Containers can have “volumes” mapped to folders on the host
- Example: inspect containers on a local machine: “docker container ps”

```
CONTAINER ID   IMAGE           COMMAND                  CREATED          STATUS          PORTS
d52bc1bddd84   python_server   "python -m http.serv…"   12 seconds ago   Up 11 seconds   8000/tcp
```

- Complete functional applications can be run by pulling images from repositories and running containers off these images

Why use Docker?

- Building complex applications or software stacks can be difficult because of dependencies on system or 3rd party libraries or packages etc
- Two different versions of the same application may have different dependencies
- This is exacerbated when porting software from one OS/environment to another
- Docker allows for building software in a clean, well-controlled environment of your choice and then being able to run it on virtually any host
- This is valuable for software management in general and for DAP in particular
- Integration with container orchestration systems e.g. Kubernetes
- Globally used by more than 12,000 companies

Docker: is it worth the investment of your time?

- Adoption of the container technology in industry has been overwhelming
- Wide adoption - at least in the early stages - in the LHC community (ALICE, ATLAS, CMS, LHCb)
- Quickly becoming a standard tool for tutorial and workshops
- Docker's cousin - Singularity - has achieved popularity in HEP and NP communities, with current EIC work leveraging this technology in significant ways
  - NB. PHENIX production makes use of Singularity to retain a functional legacy OS environment to ensure that results are 100% reproducible
- Staying abreast of these developments is beneficial for teams and individuals:
  - A highly desirable skill set in both science and industry
  - Capture and transfer of expertise and software within working groups and the Collaboration
  - Can be a part of the solution for Analysis Preservation
- It is a complex product but documentation is good and plentiful

Docker: caveats

- Need to demonstrate integration with AFS since this dependency is hard to remove
- CVS
- Database interaction
- ...a lot of technical points to be investigated
- It is understood that in the current situation Docker is mostly suitable for analysis and perhaps for its final stages
    - Too many dependencies in other parts of the workflow

REANA

- A framework already used by LHC experiments
- https://reanahub.io/
- Captures
  - Details of the analysis workflow by utilizing a structured description (graph/DAG)
  - Software and environment by means of containerization
- Implemented as a cluster configured to run containers and orchestrated according to formalized workflows created by users
- A test instance recently became available at BNL thanks to SDCC, initial testing for PHENIX in progress
- At a minimum, requires Docker expertise
- Still need to evaluate cost/benefit...Looks promising!

REANA - a real world analysis example

```
version: 0.4.0
inputs:
  files:
    - config/geantSim_TrackerPerformance.py
    - config/single_particle_trackFits.py
    - script/numHitsPerTrack.C
    - script/plot_single_particle_resolutions.py
  parameters:
    events: 5000
    seed: 0123456
    particle: 13
    etamin: 0
    etamax: 6
    pt: 1000 2000 5000 10000 100000 1000000 10000000
```

```
workflow:
  type: serial
  specification:
    steps:
      - environment: 'gitlab-registry.cern.ch/vavolkl/fcc-ubuntu:latest'
        commands:
        - fccrun.py config/geantSim_TrackerPerformance.py
            -N $events -s $seed --outName muons_for_seeding_discrete_pt.root
            --singlePart --particle $particle --etaMin $etamin --etaMax $etamax
            --discretePt --pt $pt
            --pathToDetector /usr/local/
          | tee simulation.log 2> simulation.err
        - root -b 'script/numHitsPerTrack.C("muons_for_seeding_discrete_pt.root")'
          | tee plot-tracker-hits.log 2> plot-tracker-hits.err
        - fccrun.py config/single_particle_trackFits.py
            --inputfile muons_for_seeding_discrete_pt.root
            --outputfile single_particle_resolutions.root
          | tee fit.log 2> fit.err
        - python script/plot_single_particle_resolutions.py
single_particle_resolutions.root
          | tee plot-reconstructed-tracks.log 2> plot-reconstructed-tracks.err
```

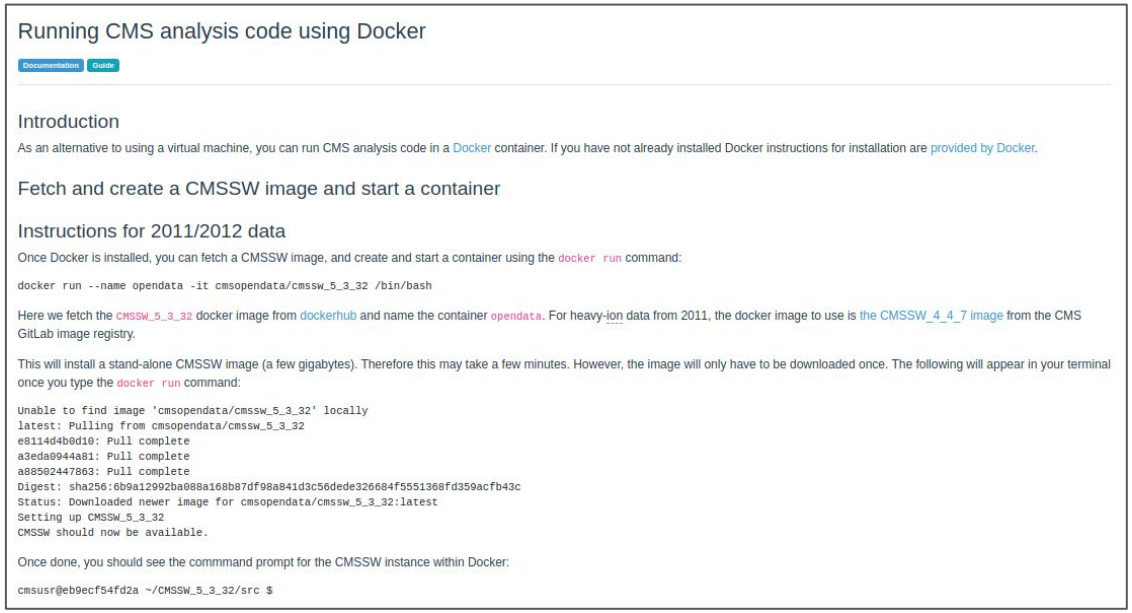
Image

OpenData

- A CERN portal for capture and publishing of data samples, software and documentation
  - Consider - a set of Ntuples and Docker images plus documentation provided as a cohesive package
- Initially reserved for LHC experiments
- PHENIX was given an approval and access in Fall 2020
- Storage allocated
- Currently no cost to PHENIX
- The first package/analysis is currently in the works (thanks Gabor)

Confluence of technologies - CMS use case for Docker published on OpenData

http://opendata.cern.ch/docs/cms-guide-docker



Running CMS analysis code using Docker

Documentation Guide

Introduction

As an alternative to using a virtual machine, you can run CMS analysis code in a Docker container. If you have not already installed Docker instructions for installation are provided by Docker.

Fetch and create a CMSSW image and start a container

Instructions for 2011/2012 data

Once Docker is installed, you can fetch a CMSSW image, and create and start a container using the `docker run` command:

```
docker run --name opendata -it cmsopendata/cmssw_5_3_32 /bin/bash
```

Here we fetch the `CMSSW_5_3_32` docker image from dockerhub and name the container `opendata`. For heavy-ion data from 2011, the docker image to use is the CMSSW_4_4_7 image from the CMS GitLab image registry.

This will install a stand-alone CMSSW image (a few gigabytes). Therefore this may take a few minutes. However, the image will only have to be downloaded once. The following will appear in your terminal once you type the `docker run` command:

```
Unable to find image 'cmsopendata/cmssw_5_3_32' locally
latest: Pulling from cmsopendata/cmssw_5_3_32
e8114d4b0d10: Pull complete
a3eda0944a81: Pull complete
a88502447863: Pull complete
Digest: sha256:6b9a12992ba088a168b87df98a841d3c56dede326684f5551368fd359acfb43c
Status: Downloaded newer image for cmsopendata/cmssw_5_3_32:latest
Setting up CMSSW_5_3_32
CMSSW should now be available.
```

Once done, you should see the commmand prompt for the CMSSW instance within Docker:

```
cmsusr@eb9ecf54fd2a ~/CMSSW_5_3_32/src $
```

PHENIX School in 2021

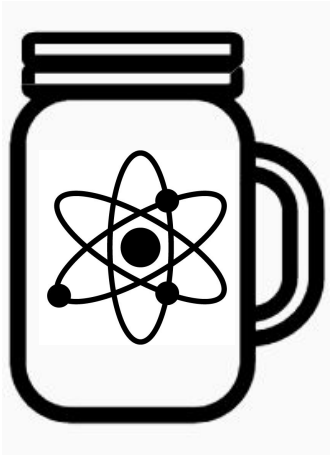
- The website can be leveraged as the portal to the necessary writeups/tutorials and other materials
- How much material can be made reusable for Schools, training and DAP?
- What are the prospects of creating Docker-based tools for the School?
- How much effort can the working groups contribute to the development of the School?

Status and Plans

- The new durable PHENIX website has been commissioned in 2020
  - Serving as a hub for cloud resources utilized by PHENIX
  - Content is being developed and added
- Ongoing creation and uploads of curated and tagged materials to Zenodo
  - Archiving of the PHENIX theses is progressing at a good pace
  - Recent conference presentations are included
- Systematized submissions to HEPData
- Started work on OpenData items for PHENIX
- Planned adoption of REANA (pending evaluation of Docker for PHENIX)
- Main concern is lack of documented analysis use cases and vetted tutorials
  - Containerization could be a useful catalyst
- Preparation for the PHENIX School and DAP are closely related tasks so there can be economies of scale

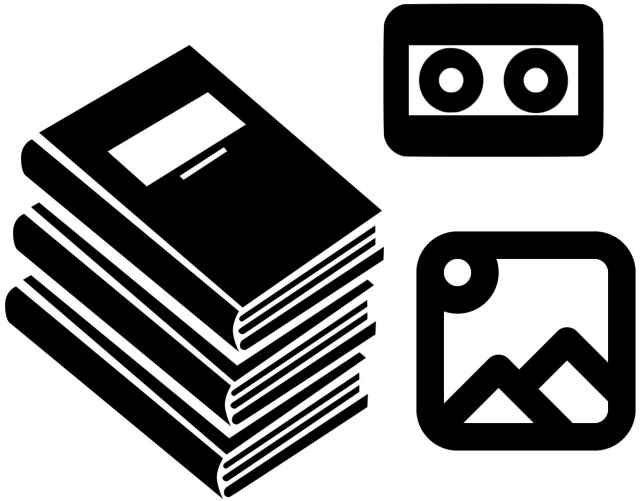
Backup slides

A practical approach to the components of the Knowledge Management in PHENIX



Analysis capture

Web-based documentation



A highly-functional repository for research materials

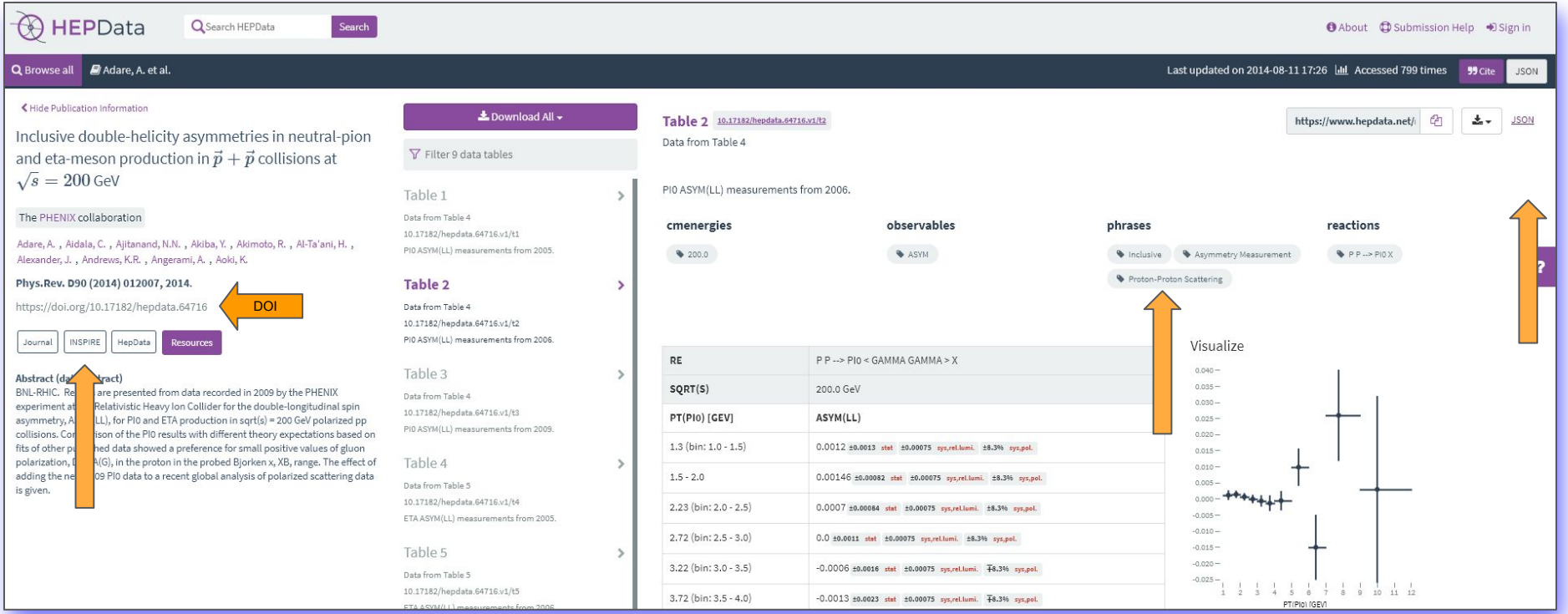
The website technology

- Inspired by the websites of the HEP Software Foundation and NPPS
  - https://hepsoftwarefoundation.org/
  - https://npps.bnl.gov/
- The website is static (no DB) - using the Jekyll static website generator
  - HTML is generated, not written by hand
  - Easy to contribute (Markdown, YAML) and easy to maintain
  - Data content kept separately from the layout
  - Manipulation of structured data in Jekyll makes for a compact and efficient design of pages, and automated content generation - DB-like functionality at compile time
  - GitHub Pages for management and development + version control + Jekyll builds
  - Portability (easy to export/migrate the complete site as HTML)
  - Performance
  - Security
- The “Bootstrap” toolkit for the layouts/navigation (no custom JS/CSS needed)

Structured data used to generate the site

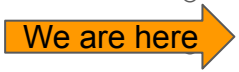
```
############################ RUN 12
- run: run12
  title: Run 12
  period: 2011-2012
  coordinator: Xiaochun He, GSU.
  rhic:
    - {
       species: 'polarized p+p',
       energy: 100.2,
       lumi: '~ /10 <i>pb</i><sup>-1</sup>',
       Nevents:
      }
    - {
       species: 'polarized p+p',
       energy: 254.9,
       lumi: '32/~ <i>pb</i><sup>-1</sup>',
       Nevents:
      }
    - {
       species: '<sup>238</sup>U<sup>92+</sup>+<sup>238</sup>U<sup>92+</sup>',
       energy: 96.4,
       lumi: '0.2<i>nb</i><sup>-1</sup>',
       Nevents: 1.2B/0.8B
      }
    - {
       species: '<sup>63</sup>Cu<sup>29+</sup>+<sup>197</sup>Au<sup>79+</sup>',
       energy: 99.9+100.0,
       lumi: '5<i>nb</i><sup>-1</sup>',
       Nevents: 0.8B/8.1B
      }
    - {
       species: '<sup>197</sup>Au<sup>79+</sup>+<sup>197</sup>Au<sup>79+</sup>',
       energy: 2.5,
       lumi: '-',
       Nevents: Very short
      }
  ert_comment: Summary of thresholds (DAC values). Values in parentheses are for the PbGl.
  ert_thresholds:
    - '02/09/12, 358208, 30(29), 31(30), 29(29), 29(25), 920, Run12pp200 - Pedestal tuned - EMCal dynamic range ~25GeV'
    - '03/20/12, 364957, 30(29), 31(30), 29(29), 29(25), 920, Run12pp510 - EMCal dynamic range ~50GeV'
    - '04/23/12, 369200, 30(29), 31(30), 29(29), 29(25), 920, Run12UU193 - EMCal dynamic range ~25GeV'
    - '05/16/12, 372155, 31(30), 32(31), 30(29), 49(45), 920, Run12CuAu200 - EMCal dynamic range ~25GeV'
```

HEPData: an example of a PHENIX entry



Open Data Definitions

- “Canonical” data levels
  - Level 1 data provides more information on published results
  - Level 2 data includes simplified data formats for outreach and analysis training
  - Level 3 data comprises reconstructed collision data and simulated data together with analysis-level experiment-specific software
  - Level 4 data covers basic raw data
- Where does PHENIX stand?
  - Level 1 is covered by the current HEPData activity and auxiliary info committed to Zenodo
  - Level 2: work underway to create Ntuples illustrating analysis techniques *(next slide)*
  - Level 2: the Open Data Portal *(under discussion)*
  - Levels 3 and 4 are not practical for public access for much of the same reasons as exist in other experiments (e.g. access to calibrations and access to sites)



The Open Data effort: annotated Ntuples (G. David)

system ($x > 0$ is the West Arm, negative x is South).

The *MBntup.root* file is produced from minimum bias data (no lower limit on single cluster p_T in *gnt* or pair p_T in *ggntuple*), whereas in *ERTntup.root* the threshold for single cl p_T in *gnt* is 5 GeV, and the threshold for pair p_T in *ggntuple* is also 5 GeV. Note that here we restrict only the pair p_T, the energy of the individual clusters can be (and oft significantly lower.

Variable name	Description
cent	Event centrality
vtxZ	z-vertex of the event
pt	Transverse momentum of t
costheta	Polar angle of the cluster (
phi	Azimuthal angle of the clu
sec	EMCal sector of the cluste
ecore	"Core" energy of the cluster (γ-candidate)
ecent	Energy in the central tower of the cluster (γ-candidate)
tof	Time-of-flight in the central tower of the cluster (γ-candidate)
prob	Probability that the cluster is a photon (based on χ^2)
disp	Dispersion of the cluster (γ-candidate)
chisq	χ^2 from expected photon shape of the cluster (γ-candidate)
twrhit	Number of towers in the cluster (γ-candidate)
stoch	Combined variable to describe "photonness" of the cluster (γ-candidate)
x	x-position of impact point on the EMCal surface
y	y-position of impact point on the EMCal surface
z	z-position of impact point on the EMCal surface

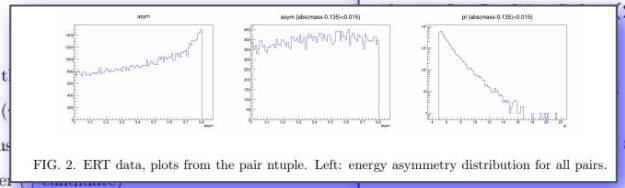


FIG. 2. ERT data, plots from the pair ntuple. Left: energy asymmetry distribution for all pairs.

```
ggntuple->Draw("mass","mass<1.0");
ggntuple->Draw("mass","mass<0.4&&pt>8.0");
ggntuple->Draw("mass>>htemp1","mass<0.4");
ggntuple->Draw("mass>>htemp2","mass<0.4&&chisq1<2.0&&chisq2<2.0");
htemp1->SetLineColor(1);
                                                    (2);
```

see Fig. 1.

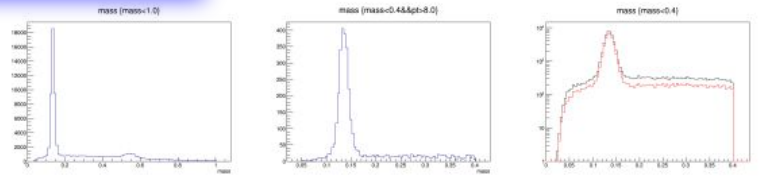


FIG. 1. ERT data, plots from the pair ntuple. Left: Invariant mass in the 0-1 GeV region. You can see a strong π^0 and a well-recognizeable η peak. Middle: π^0 peak for pairs with p_T greater than 8 GeV/c. You can clearly see the combinatorial background outside the peak, which should

Ntuples: O(100MB) each
Hosting options: Zenodo, Open Data