Data Preservation in Particle Physics

GORDON WATTS

JANUARY 18, 2016

ACAT 2016

Data Preservation

↓

Raw Data
Reprocessed Data
Simulated Data
Final Plots
Documentation

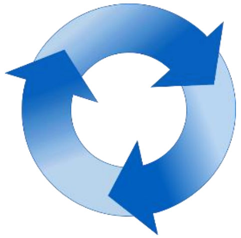
Data Preservation

↓

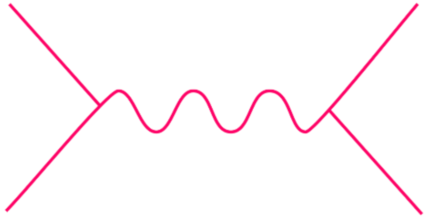
Where
How
Why

How Much Work?

What does Data Preservation Enable?



Reproducibility



New Physics/New Ideas

$

Funding Agencies

Experimental Uniqueness

#OpenScience

Education and outreach

Documents

Documentation

Journal Articles
(archived in journal of record as well!)

Internal Notes

Cornell University Library
arXiv.org

- Built to hold large public collections of documents
- Conference proceedings
- Peer Reviewed journal submissions
- Notes written by people in the field (particularly theory authors)
- Requires author to be *known*. There is a bar, but not much…

Documentation

Journal Articles
(archived in journal of record as well!)

Internal Notes → INSPIRE HEP

Cornell University Library arXiv.org

- Can host private or public collections
- The paper and the meta-data are separate

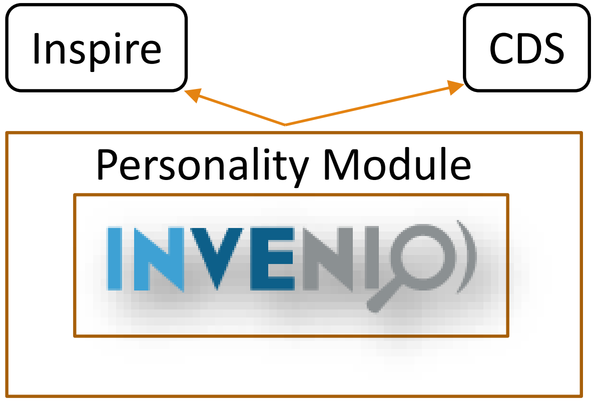
If there is one thing we in HEP do right, it is article archives!

Invinio

A toolkit that provides all the plumbing to build an article archive

Large collections	CDS is ~ 1 Million articles
Open Source	https://github.com/inveniosoftware
MARC Database	Standard bibliographic data format

- In many cases standards already exist, and it is a matter of implementing them to suit our needs
- This is especially true in data preservation, which touches on fields of computer science and information science.



Fidelity

Data Size ⟷ Information Content

PDF	TeX + Images	Text, Tables, Plots, Images
Extract text, reconstruct plot, search PDF text…	Text, loose table reconstruction, formulas	Build new plots from data, tables, combine with other papers…

HepData

A structured data repository

- Can download data as yaml, yoda, root, or csv
- API so you can write apps to ingest it
- IPPP Durham
- Tuned for very small data (e.g. plots)

Also now powered by INVENIO

‹ Hide Publication Information

Measurement of χ_{c1} and χ_{c2} production with $\sqrt{s}$ = 7 TeV pp collisions at ATLAS

Aad, Georges , Abajyan, Tatevik , Abbott, Brad , Abdallah, Jalal , Abdel Khalek, Samah , Abdinov, Ovsat , Aben, Rosemarie , Abi, Babak , Abolins, Maris , AbouZeid, Ossama

JHEP 1407 (2014) 154

ATLAS

DOI | View paper in Inspire | View old HepData | Additional Resources

Abstract (data abstract)
CERN-LHC. The prompt and non-prompt production cross-sections for the chi_c1 and chi_c2 charmonium states are measured in pp collisions at sqrt(s) = 7 TeV with the ATLAS detector at the LHC using 4.5 fb-1 of integrated luminosity. The chi_c states are reconstructed through the radiative decay chi_c --> J/psi + gamma (with J/psi --> mu+ mu-) where photons are reconstructed from gamma --> e+ e- conversions

Filter 13 data tables

Table 1
Data from Figure 3a, Table 5
Differential cross-section for prompt chi_c1 production, measured in bins of J/psi pT, assuming unpolarised chi_c production. The measurements are not...

Table 2
Data from Figure 3b, Table 5
Differential cross-section for prompt chi_c2 production, measured in bins of J/psi pT, assuming unpolarised chi_c production. The measurements are not...

Table 3
Data from Figure 5a, Table 6
Differential cross-section for non-prompt chi_c1 production, measured in bins of J/psi pT, assuming unpolarised chi_c production. The measurements are not...

Differential cross-section for prompt chi_c1 production, measured in bins of J/psi pT, assuming unpolarised chi_c production. The measurements are not corrected for the branching fractions of the decays chi_c --> J/psi + gamma and J/psi --> mu+ mu-. The uncertainty envelope associated with the unknown chi_c spin alignment is also shown.

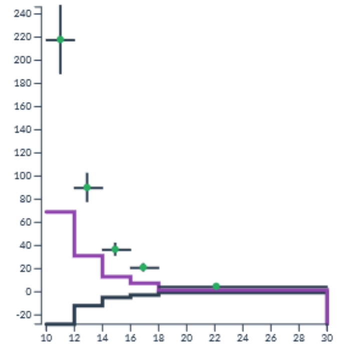
cmenergies 7000 | observables DSIG/DPT | reactions P P --> CHI/C1 X

Data

Download data as ▾

SQRT(S)	7000.0 GeV		
RE(Q=CHI/C)	P P --> CHI/C1 < J/PSI GAMMA > X		
ABS(YRAP(C=J/PSI))	< 0.75		
PT(C=J/PSI) [GEV]	D(SIG)/DPT [PB/GEV]	+Spin Env.	-Spin Env.
10.00 - 12.00	218 ±9.00 stat ±28.00 sys	69	-28
12.00 - 14.00	90.2 ±4.20 stat ±11.40 sys	31.1	-12
14.00 - 16.00	36.8 ±2.20 stat ±4.70 sys	13	-4.9
16.00 - 18.00	21.2 ±1.50 stat ±2.70 sys	7.4	-2.8
18.00 - 30.00	4.81 ±0.25 stat ±0.62 sys	1.52	-0.58

Visualize



Sum errors ☑ Fill bars ☐

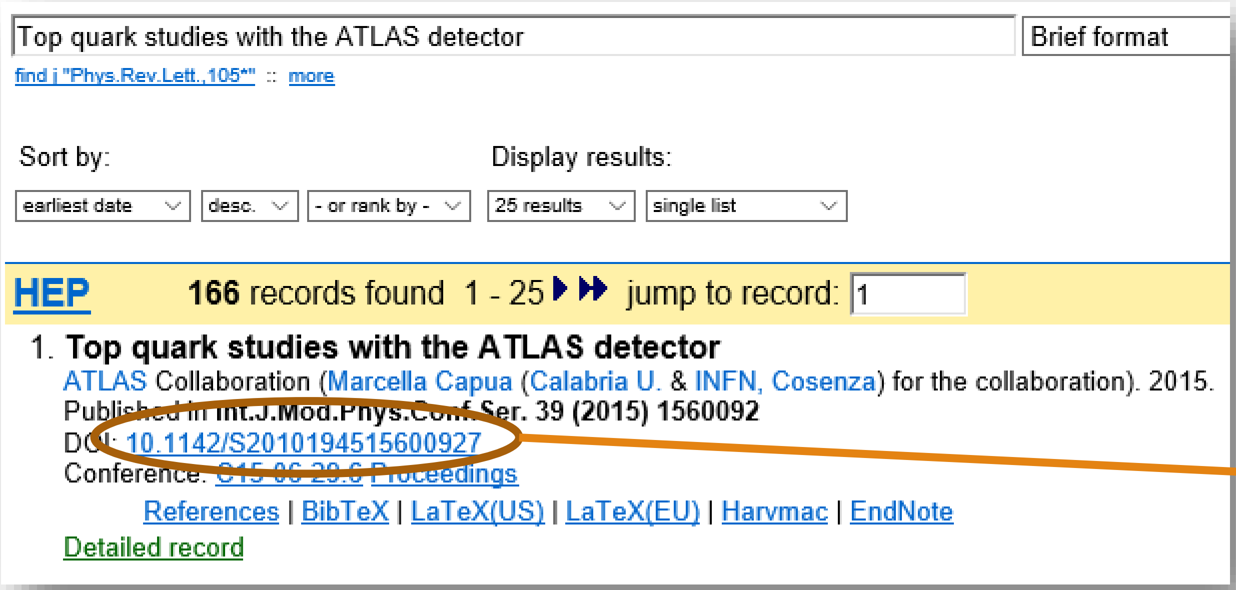
Log Scale (X) ☐

The Digital Object Identifier

10 . 13126 / Book . 2015 . 6

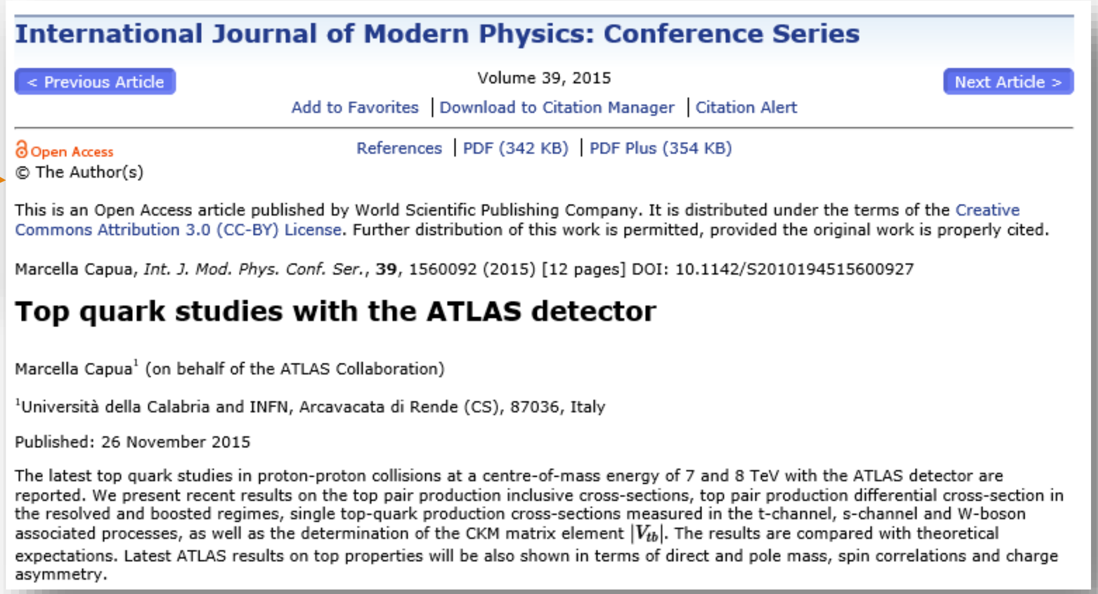
DOI Directory Publisher Publisher Defined ID

The DOI



Meant for objects that will be around forever

A paper reference



There are ~100 Million DOI's now (birth: 2000)

Growing at ~ 16%/year

Custom Software

TeX

Well recognized file formats

Publically documented

How important is it to preserve the software along with the files?

Experimental Data

Experimental Data

Tevatron (Fermilab)

About 10 Petabytes per experiment

$1M/year in the cloud
(high availability storage, Azure)

Large Hadron Collider (CERN)

About 15 Petabytes per experiment per year

$1.5 M/year in the cloud
(high availability storage, Azure)

Almost certainly cheaper over time

Data

Tevatron (Fermilab)

About 10 Petabytes per experiment

Large Hadron Collider (CERN)

About 15 Petabytes per experiment per year

Time

Bits are a universal format

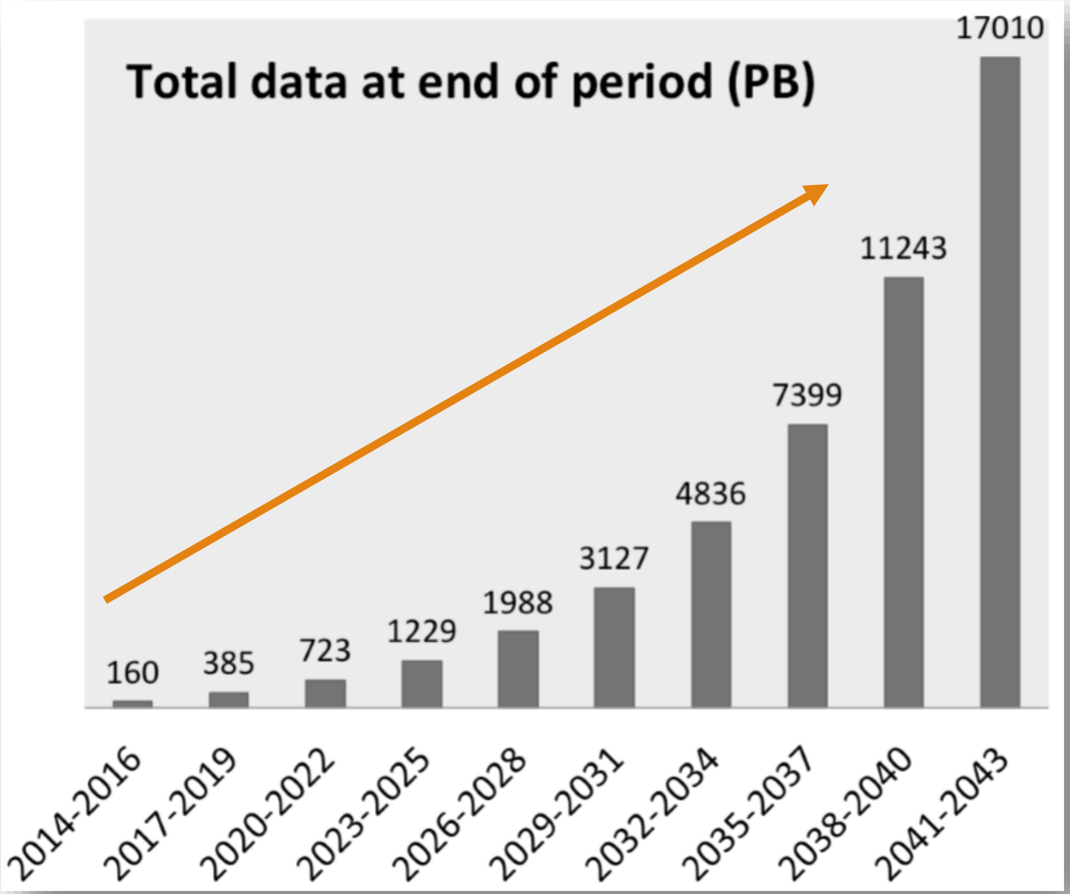
As technology changes… → Just copy the bits to the new technology

Data

The biggest problem with data is that each year we project to produce more.

The nature of HEP

We are relying on technology to solve this problem for us



Data Preservation

The physical preservation of the data turns out to not be too difficult

Where
How
Why

What you want to do with the data is where

What format will you store the data in?
What detail level will you keep?
How long must you keep it readable?

What do you want to do to the data

- Repeat previously done analyses?
- Do new analyses on old data?
- Develop new object-ID algorithms?

What format does the data start in?

- Can you convert it?
- Can your tools be converted?
- Will the format be readable long term?
- How much money do you have?

4-Vectors

Higgs challenge

Completed • $13,000 • 1,785 teams

Higgs Boson Machine Learning Challenge

Mon 12 May 2014 – Mon 15 Sep 2014 (16 months ago)

Several large csv files
(30 MB compressed)

- Derived quantities: mass, sum p_T, etc.
- Primary quantities: leading jet p_T, Missing E_T

All quantities are highly processed

- Calibrations applied
- Selection cuts to remove *uninteresting data*
- Dataset is tuned for a very narrow type of analyses

Easy to produce while running (by product of existing analysis)
Small, and easy to export to the world
Format is simple
But limited usefulness down the road

Raw and Reconstructed Data

Fidelity

Reconstructed Data

- Repeat analyses already done
- New analysis with reconstructed object quantities

Raw Data

- New Object ID (jet algorithm, soft jets, sub-jets, etc.)

Do you want to archive both?

Yes → the raw data is not useful without a huge investment in computing

No → Can only do an analysis possible with high level data

- Calibrations, luminosity database, detector configuration, etc.
- MC Generation files and configuration
- Monte Carlo common background samples
- Analysis Scripts

What Version of the Data Do You Store?

It is the same raw data

Data 21 fb^{-1}
Reco 17.5.6.11


EUROPEAN ORGANISATION FOR NUCLEAR RESEARCH (CERN)

arXiv:1601.03297v1 [hep-ex] 13 Jan 2016

Measurement of the CP-violating phase ϕ_s and the B_s^0 meson decay width difference with $B_s^0 \to J/\psi\phi$ decays in ATLAS

The ATLAS Collaboration

Abstract

Data 21 fb^{-1}
Reco 17.5.6.11


EUROPEAN ORGANISATION FOR NUCLEAR RESEARCH (CERN)

Submitted to: Eur. Phys. J. C.

arXiv:1601.03567v1 [hep-ex] 14 Jan 2016

Probing lepton flavour violation via neutrinoless $\tau \longrightarrow 3\mu$ decays with the ATLAS detector

The ATLAS Collaboration

Abstract

“Ancillary” Preservation

Tools	Common tools like ROOT
Operating Systems	Experiments validate their software against various versions of scientific Linux!
Software Frameworks	Many developed in-house by experiments, typical IoC containers
Databases	Calibration data, detector *conditions* data, providence of data, etc.
Production System	Batch systems, coordinated with data tracking, etc.

How Long Would You Like To Keep It?

5 years
- It might be cheapest to keep the current systems running

20 years
- Wrap everything up into virtual machines
- Rewrite infrastructure (if needed) to deal with new environment at end of experiment lifetime.
- Is the Docker interface stable on this timescale?
- Physical media change at least once perhaps twice

50 years
- Will hyper-visor technology change?
- x86 still around?

Alternative…
- Roll forward with each technology change and update infrastructure
- Do you have the money?

http://opendata.cern.ch/collection/Data-Policies

Politics

Difference between preservation and open access

Each experiment "owns" the data

Host lab could eventually force the issue

Current Policies at the LHC experiments:

CMS

50% 3 years after data was taken → CMS: 50% of 2010; 30TB

LHCb

50% after 5 years, 100% after 10 years

ATLAS:

join the collaboration

ALICE

10% after 5 years, 100% after 10 years

The Solution

Well…

Current experiments are rather unique in their approach

Most software grew up organically and had been constantly re-engineered.

Best we can do is a bunch of toolkits that can be put together into a solution with a great deal of work by the experiment.

Data Preservation in Particle Physics

This is a big enough deal that ICFA got involved

- Formed a study group: DPHEP

- Series of workshops exploring current trends and costs, and status of the various experiments

Lots of meetings – can gather current state. See:

https://indico.cern.ch/category/4458/

Next workshop is Feb 2nd, at Lisbon.

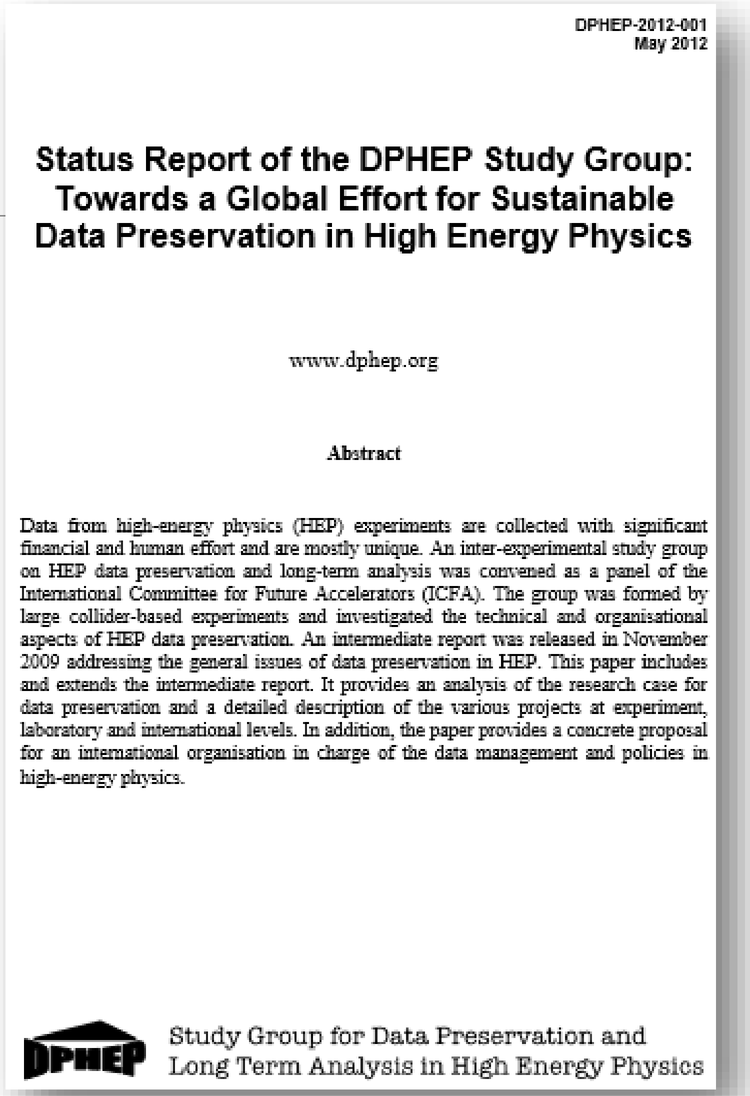
The Problem

Documentation

Paper that attempts to outline all this
Defined 4 levels of data preservation

1. Provide additional documentation
2. Preserve the data in a simplified format
3. Preserve the analysis level software and data format
4. Preserve the reconstruction and simulation software and basic level data

Raw Data



DPHEP-2012-001
May 2012

Status Report of the DPHEP Study Group: Towards a Global Effort for Sustainable Data Preservation in High Energy Physics

www.dphep.org

Abstract

Data from high-energy physics (HEP) experiments are collected with significant financial and human effort and are mostly unique. An inter-experimental study group on HEP data preservation and long-term analysis was convened as a panel of the International Committee for Future Accelerators (ICFA). The group was formed by large collider-based experiments and investigated the technical and organisational aspects of HEP data preservation. An intermediate report was released in November 2009 addressing the general issues of data preservation in HEP. This paper includes and extends the intermediate report. It provides an analysis of the research case for data preservation and a detailed description of the various projects at experiment, laboratory and international levels. In addition, the paper provides a concrete proposal for an international organisation in charge of the data management and policies in high-energy physics.

DPHEP Study Group for Data Preservation and Long Term Analysis in High Energy Physics

BaBar

Experiment that ended in 2008

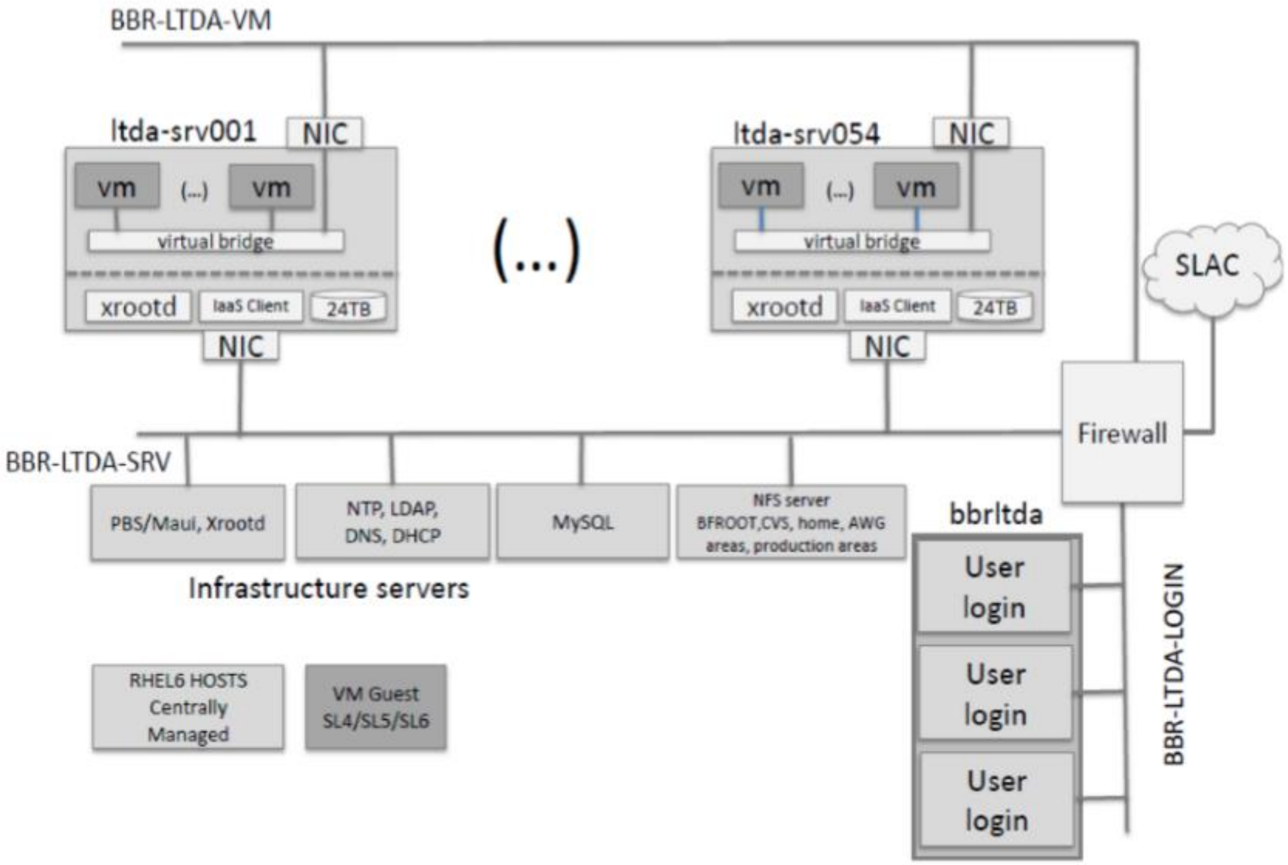
- The next b-factory won't be built for a while yet

This was meant to be a long-term preservation effort

Dedicated hardware with VM's

- All data available on local disk served by xrootd

Behind a firewall so that the OS version doesn't have to be upgraded



Tevatron Experiments

The only $p\bar{p}$ machine – no new similar collider foreseen.

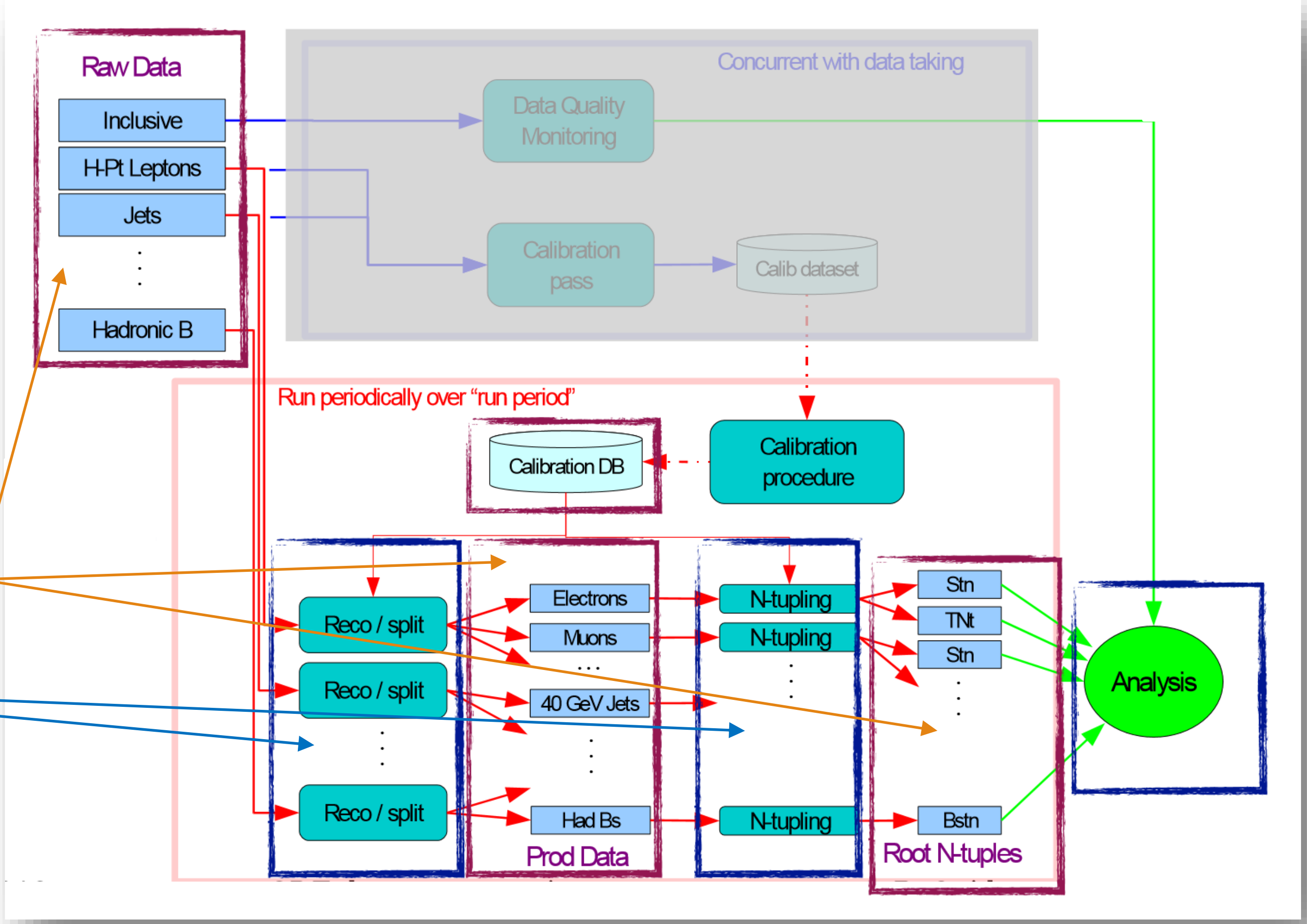
So it is important to preserve as long as possible

Preservation goals:

- Ability to do full analysis
- Until Scientific Linux 6 end-of-life (2020)

About 10 PB per experiment have been archived

All source code has been archived



Tevatron Experiments

Fermilab is an active laboratory

Current experiments are at the Intensity Frontier

↓

A lot of common software infrastructure

Adapt the Tevatron experiments to use the IF infrastructure

A significant amount of retro-fitting had to be done

- All machines are virtual – no dedicated hardware.
- Use CERNVM as the virtual machine tool
- Transition from old data storage system (SAM) to new (SAMWeb)
- Maintain the Oracle DB used for all data provenance records

- All software releases are now distributed by the cernvmfs
- Retro fit job submission to use general purpose virtual machine farm at Fermilab.

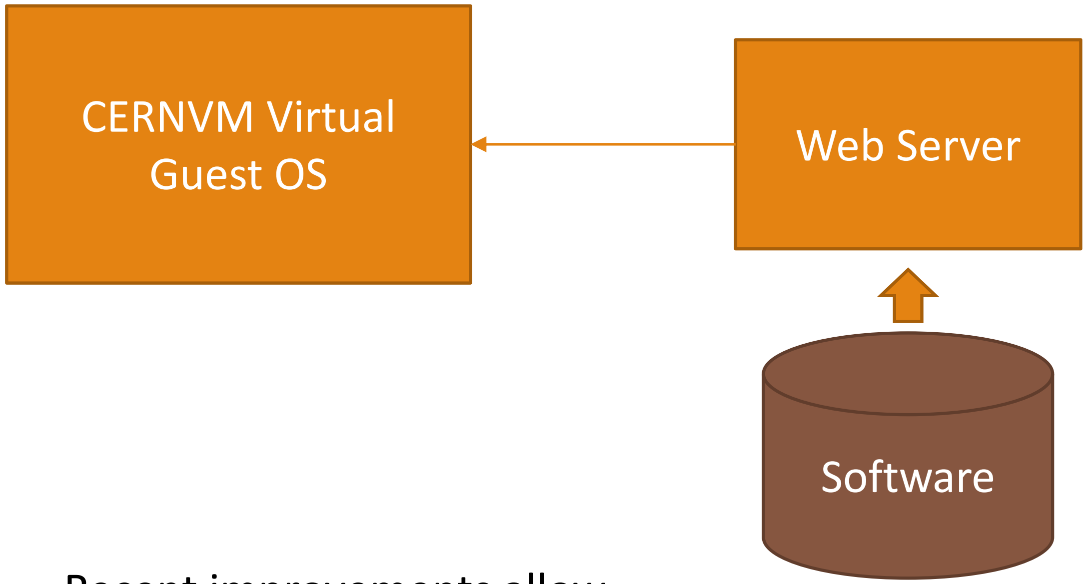
CERNVM

The VM image is very small – the boot loader can be 15 MB

cernvm filesystem (cvmfs)

- Caching filesystem
- Uses webserver to get files on an as needed basis
  - ATLAS release: ~ 7 GB
  - Required to run reconstruction: 400 MB

Uses normal infrastructure, and very easy to setup
Now compatible with Docker



Recent improvements allow for 100 GB data files to be efficiently distributed

The LHC Experiments

The LHC is projected to produce collisions till 2043!

Data preservation is going to be on-going → Looking at data from 2010 is already hard

Active feedback to the experiments software infrastructure and design for Data Preservation issues

Tools that lend themselves to data preservation are already in use in the software environment

CERNVM, xrootd, etc.

CERN’s Open Data Portal

Based on Invineo

Attempts to serve as one stop shopping for:

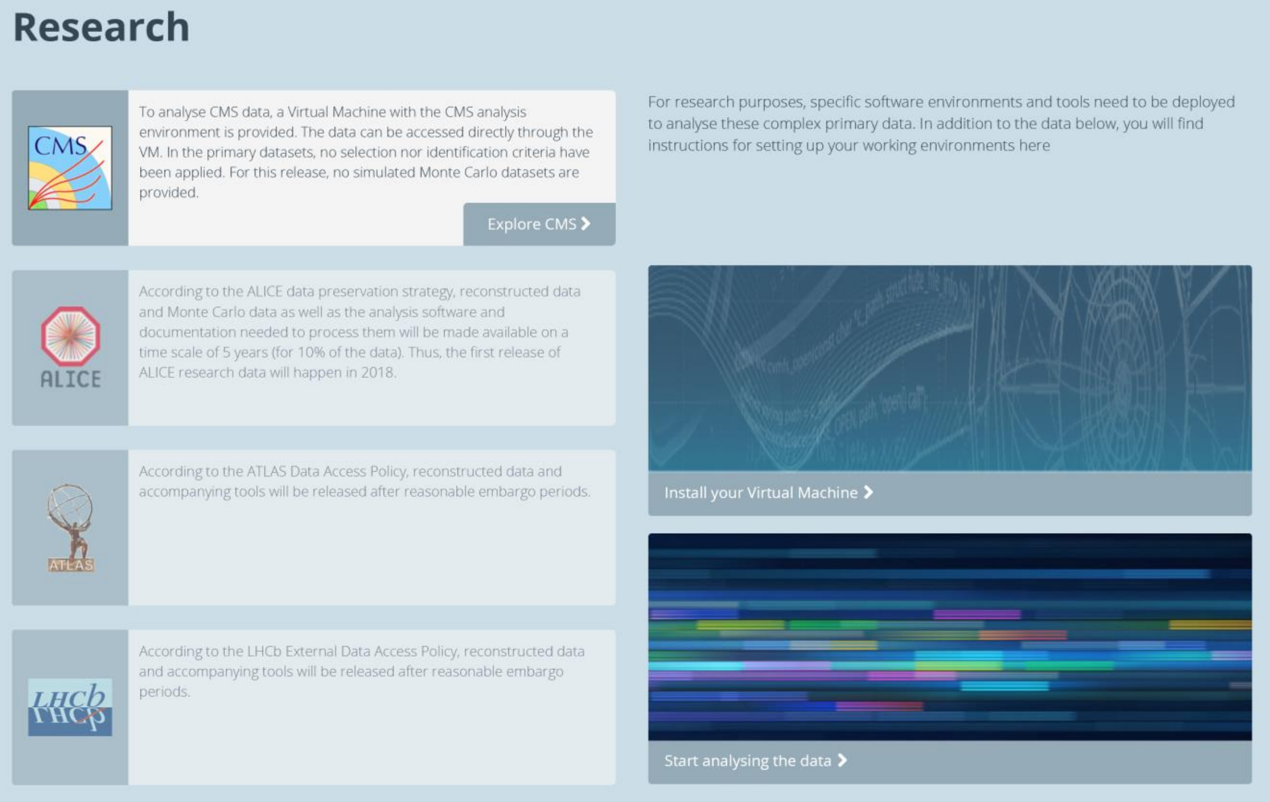
Education & outreach data

The ATLAS Higgs Challenge

Full Analysis Data

CMS: 50% of its full 2010 dataset

- Data is served by xrootd
- Software and environment by CERNVM
- All analysis software is open source



Analysis Capture

The Mess

The Next Frontier

Analysis Capture

Relatively easy
Can't extend

Preserve the mess

- The analysis environment is essentially untouched.
- Techniques must capture everything that is done
  - Setup
  - Software accessed
  - Database accesses
  - Network accesses
  - Etc.

Hard
Easier to extend

Encourage Cleanliness

- Force analyzer to use a restricted set of tools
- Tools leave behind a log of input, output, config
- Less choices for analyzer, but makes capture relatively easy
- Buy-in from analyzers is hard to see!

Capture

Open Data Portal

- Wo
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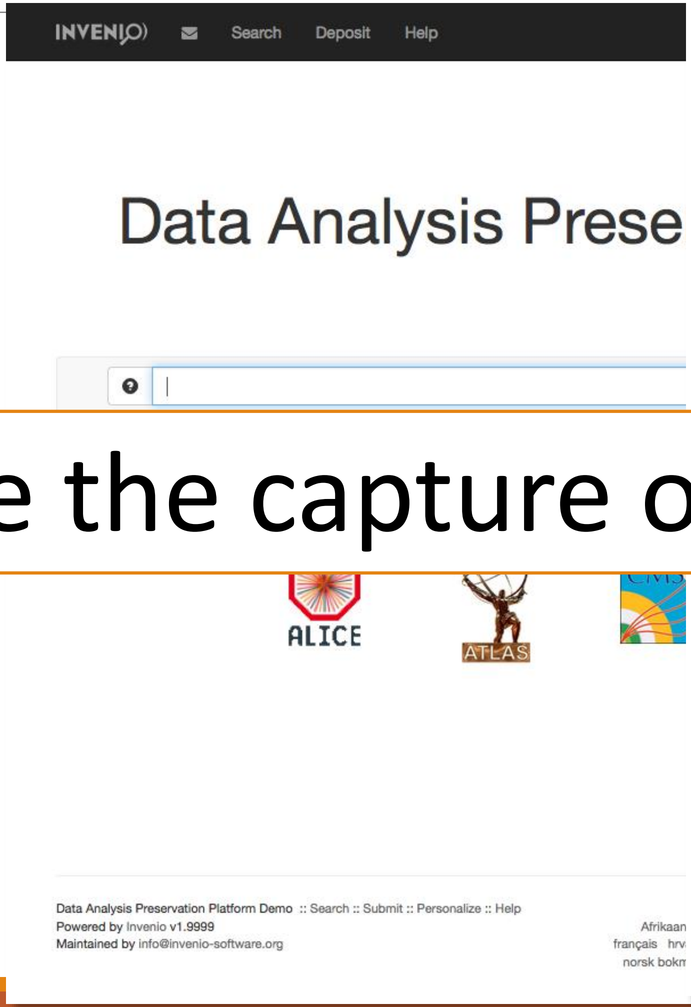
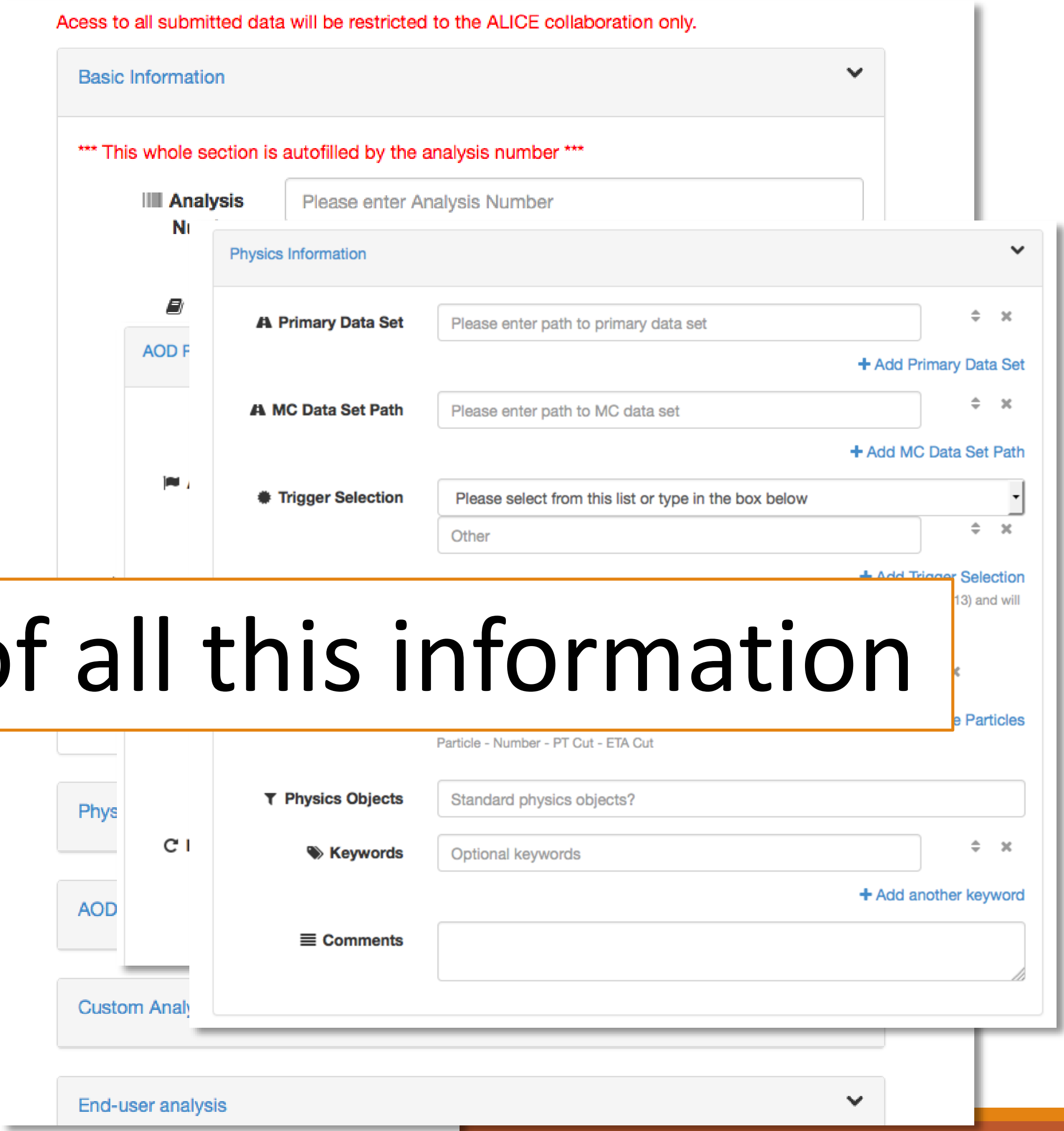
- Documentation
- Data
- Environment



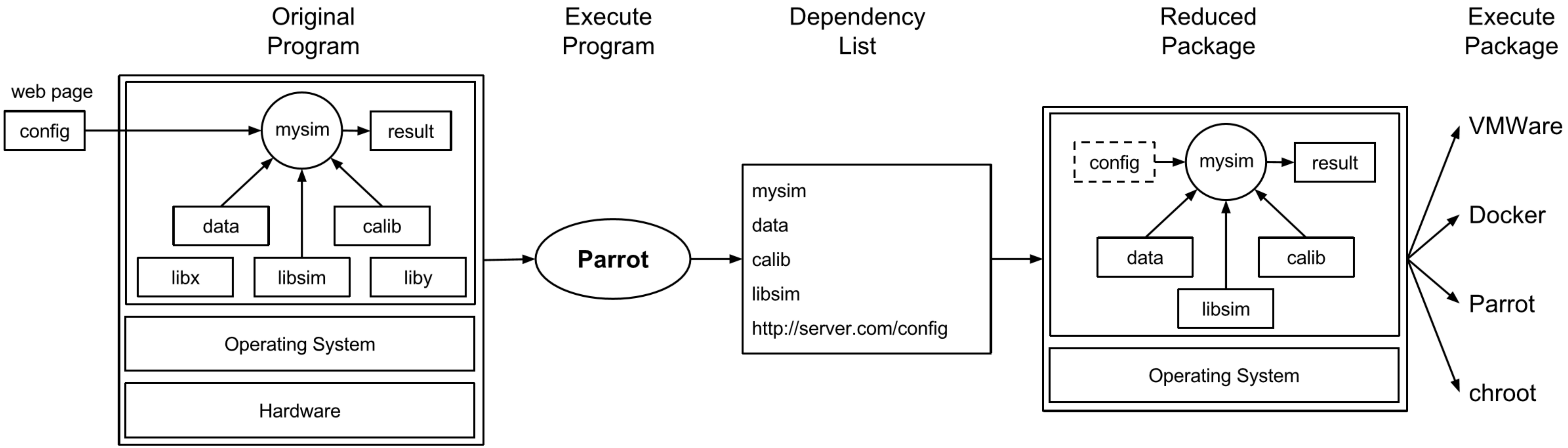


Automate the capture of all this information

Using Parrot to Preserve The Mess

Parrot traps all file and network system calls

And allows one to arbitrarily modify the results



Clean Up The Mess

Production systems are automated

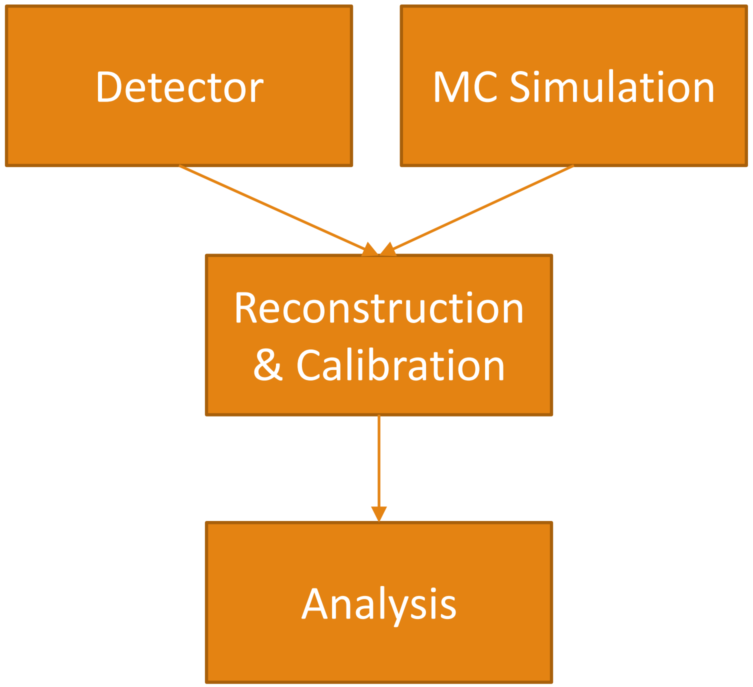
- Reconstruction, MC production
- Instructions and configurations often stored in databases
- Thus each to reproduce

The steps analysis is the hardest part to archive and preserve

- Arbitrary scripts
- Multiple jobs
- “Weird” files communicate output of one job to input of another

Clean Up The Mess means making analysis look more like production

- Explicitly declaring the various steps
- Automating it
- Build server?



RECAST

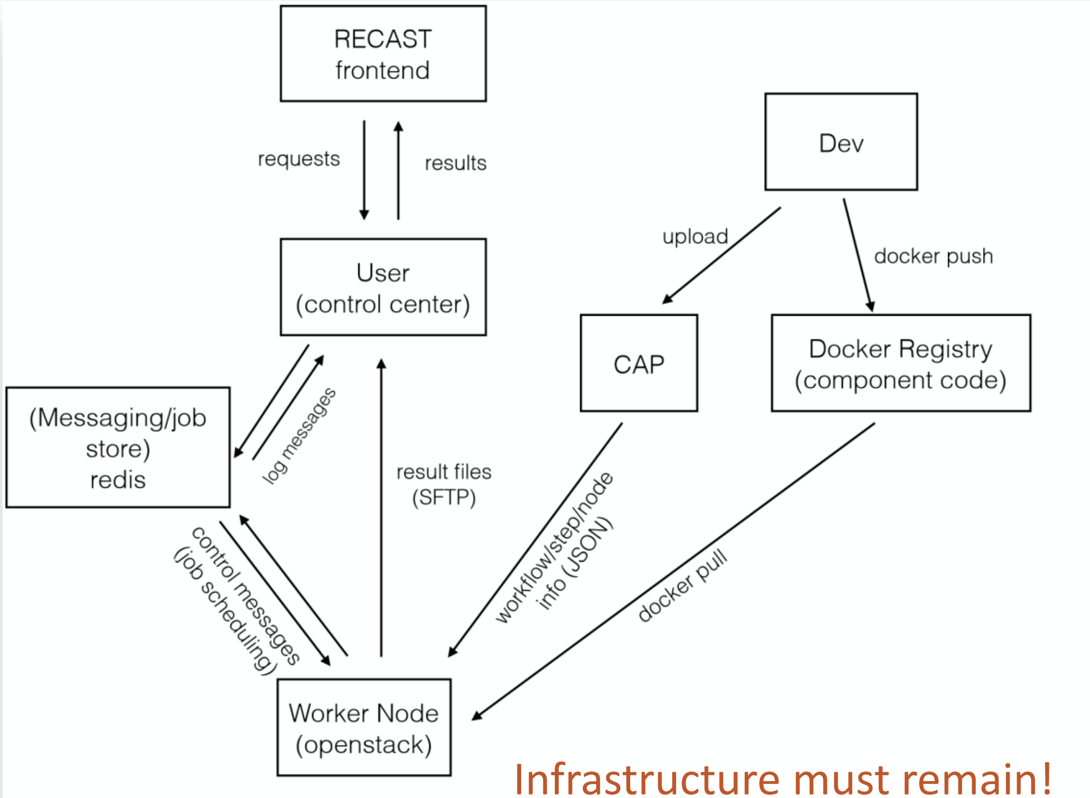
Preserve the analysis as a series of steps.

Each step is a Docker container

A JSON configuration stiches together the steps in the right order

“RECAST”

Run the “same analysis” against a new simulated signal



Infrastructure must remain!

Meanwhile, outside HEP

Fermi

A particle physics detector in space

A calorimeter with some tracking

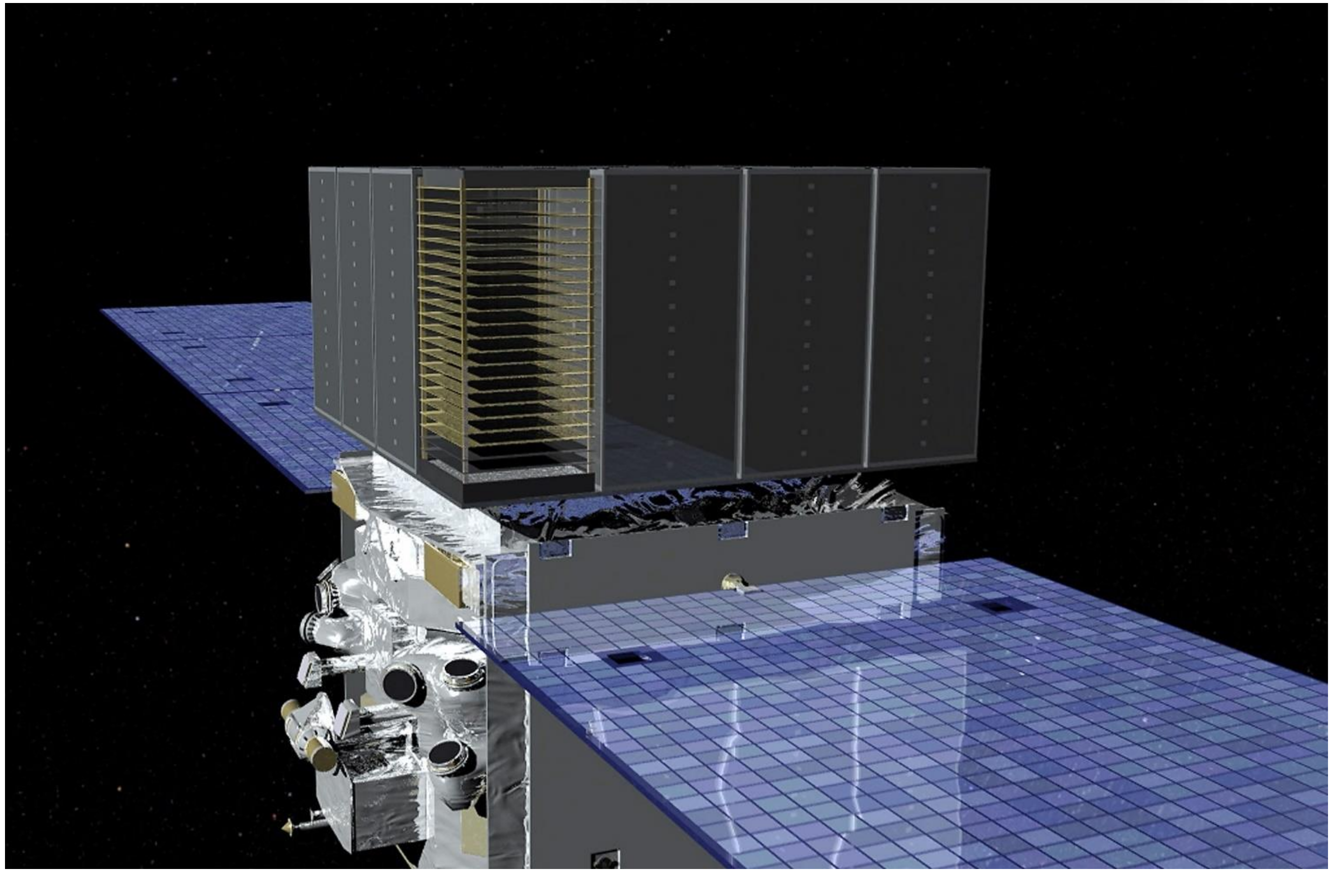
Immensely successful experiment

Funded by NASA

- Data must be made available to public!
- Tight restrictions on how quickly (months)

They have made all their analysis software available

Download main software – 1 GB



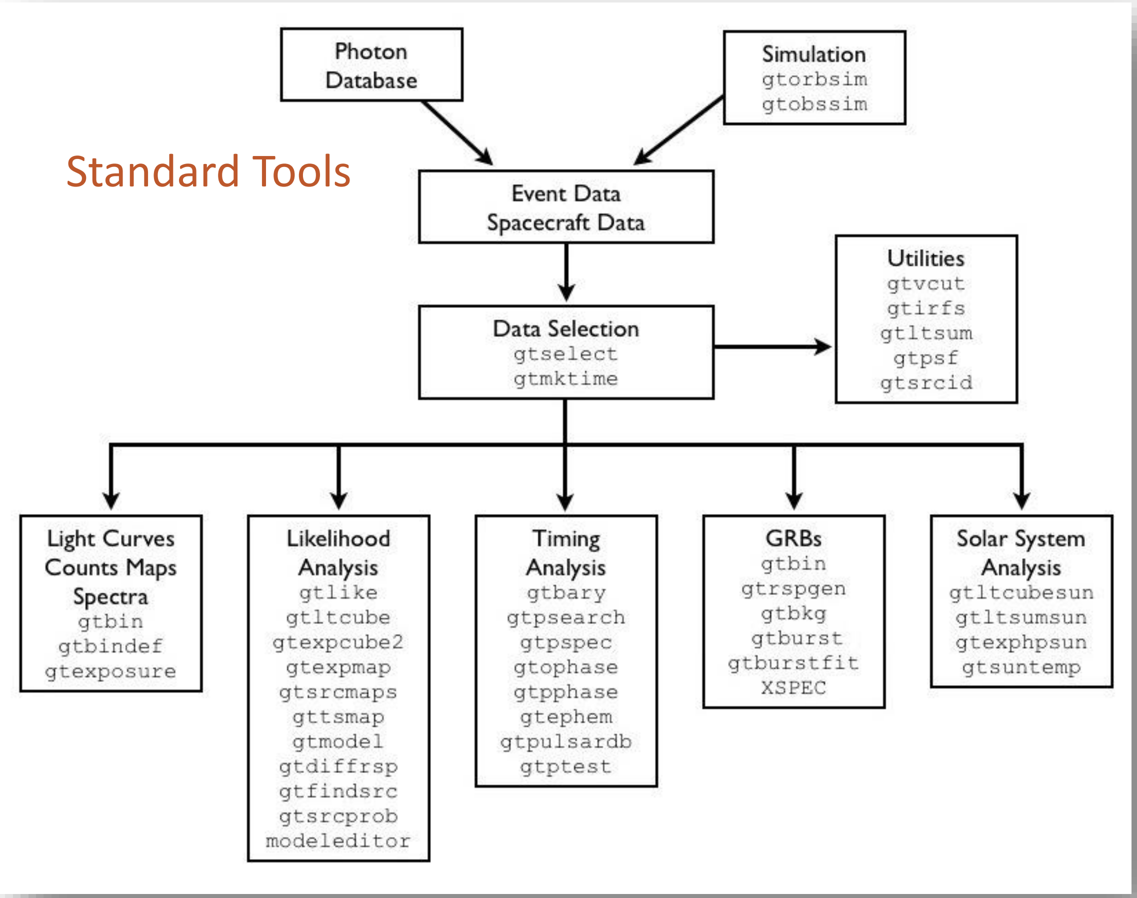
Step By Step Instructions

Sample Analysis page for practice

```
prompt> gtselect evclass=128 evtype=3
Input FT1 file[] @binned_events.txt
Output FT1 file[] 3C279_binned_filtered.fits
RA for new search center (degrees) (0:360) [] INDEF
Dec for new search center (degrees) (-90:90) [] INDEF
radius of new search region (degrees) (0:180) [] INDEF
start time (MET in s) (0:) [] INDEF
end time (MET in s) (0:) [] INDEF
lower energy limit (MeV) (0:) [] 100
upper energy limit (MeV) (0:) [] 500000
maximum zenith angle value (degrees) (0:180) [] 90
Done.
prompt>
```

We have binary distributions for:

- Scientific Linux release 7 (Nitrogen)
- Scientific Linux release 6 (Carbon)
- Scientific Linux release 5 (Boron), x86_64
- Scientific Linux release 5 (Boron), i686 i386
- Ubuntu release 14.10
- Ubuntu release 14.04



Successful?

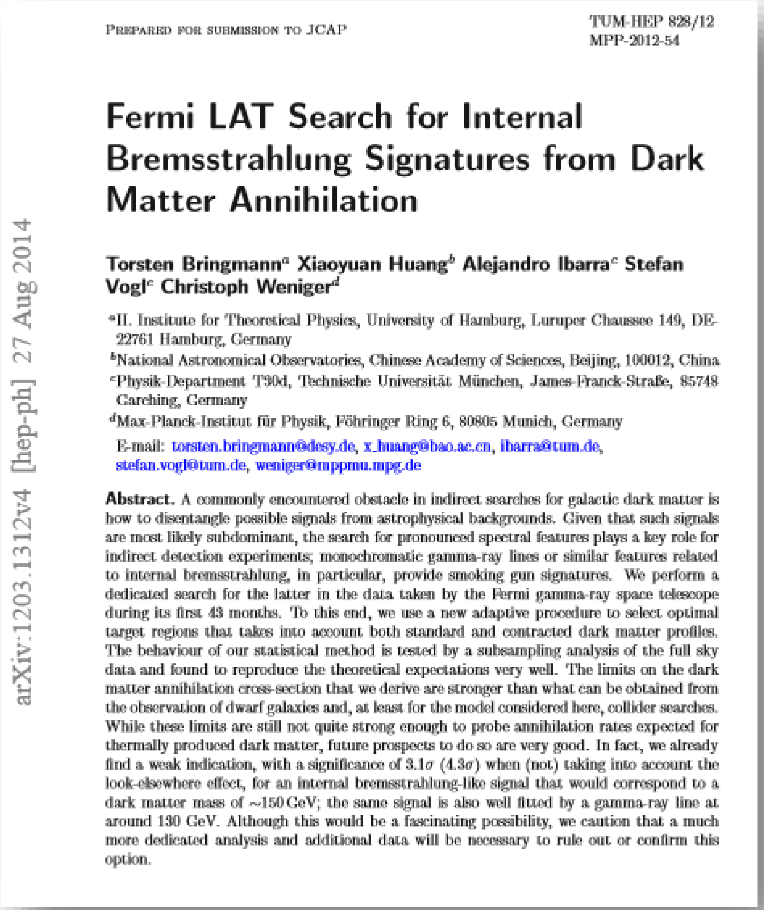
Definitely

The goal was public sharing of data

- But they ended up with something that could be easily archived
- They designed their processing pipeline to be easily exportable

Some Differences

- No DOI's.
- Data files measured in the GB range
- They could benefit from the container or VM approach



PREPARED FOR SUBMISSION TO JCAP

TUM-HEP 828/12
MPP-2012-54

arXiv:1203.1312v4 [hep-ph] 27 Aug 2014

Fermi LAT Search for Internal Bremsstrahlung Signatures from Dark Matter Annihilation

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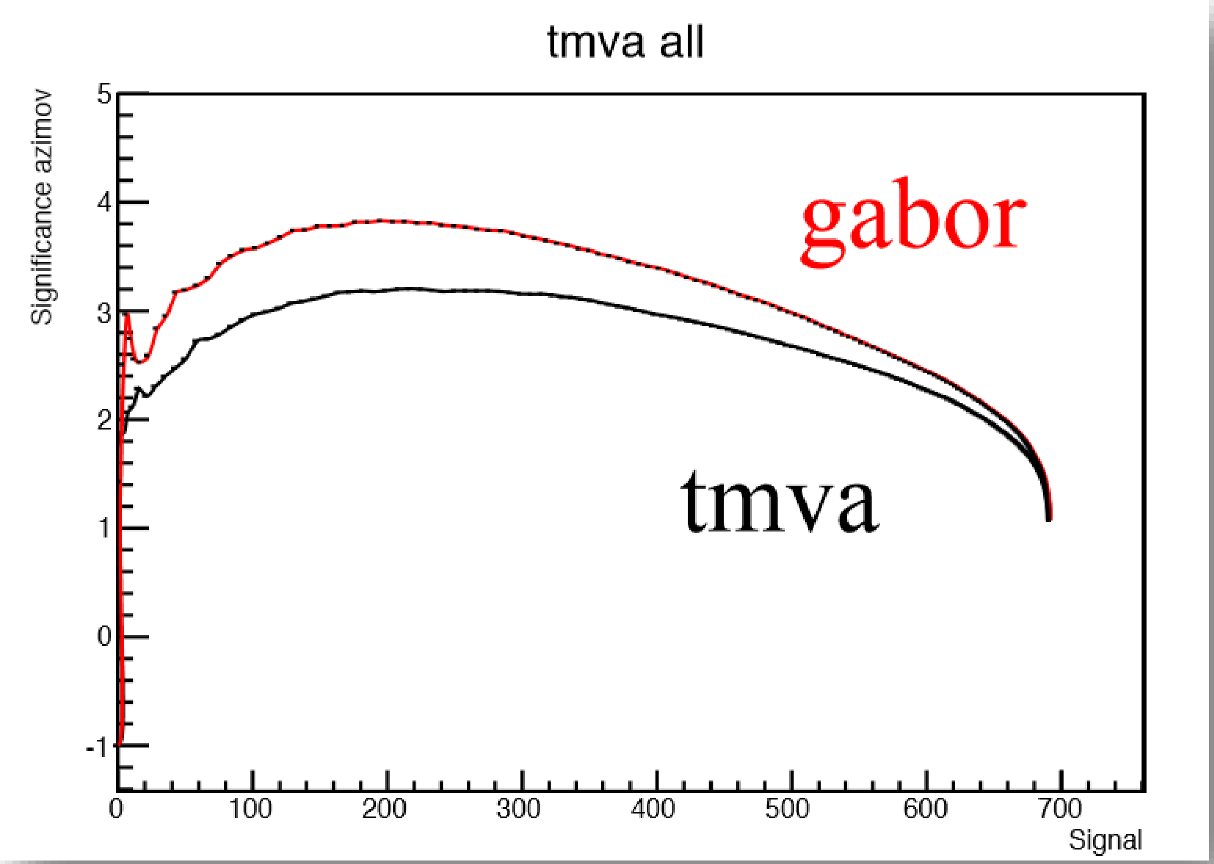
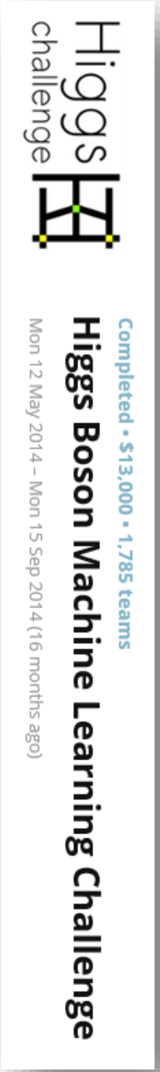
Abstract. A commonly encountered obstacle in indirect searches for galactic dark matter is how to disentangle possible signals from astrophysical backgrounds. Given that such signals are most likely subdominant, the search for pronounced spectral features plays a key role for indirect detection experiments; monochromatic gamma-ray lines or similar features related to internal bremsstrahlung, in particular, provide smoking gun signatures. We perform a dedicated search for the latter in the data taken by the Fermi gamma-ray space telescope during its first 43 months. To this end, we use a new adaptive procedure to select optimal target regions that takes into account both standard and contracted dark matter profiles. The behaviour of our statistical method is tested by a subsampling analysis of the full sky data and found to reproduce the theoretical expectations very well. The limits on the dark matter annihilation cross-section that we derive are stronger than what can be obtained from the observation of dwarf galaxies and, at least for the model considered here, collider searches. While these limits are still not quite strong enough to probe annihilation rates expected for thermally produced dark matter, future prospects to do so are very good. In fact, we already find a weak indication, with a significance of 3.1σ (4.3σ) when (not) taking into account the look-elsewhere effect, for an internal bremsstrahlung-like signal that would correspond to a dark matter mass of $\sim$150 GeV; the same signal is also well fitted by a gamma-ray line at around 130 GeV. Although this would be a fascinating possibility, we caution that a much more dedicated analysis and additional data will be necessary to rule out or confirm this option.

Was the Higgs Challenge Successful?





Git Large File Storage

Git is already a way to preserve code

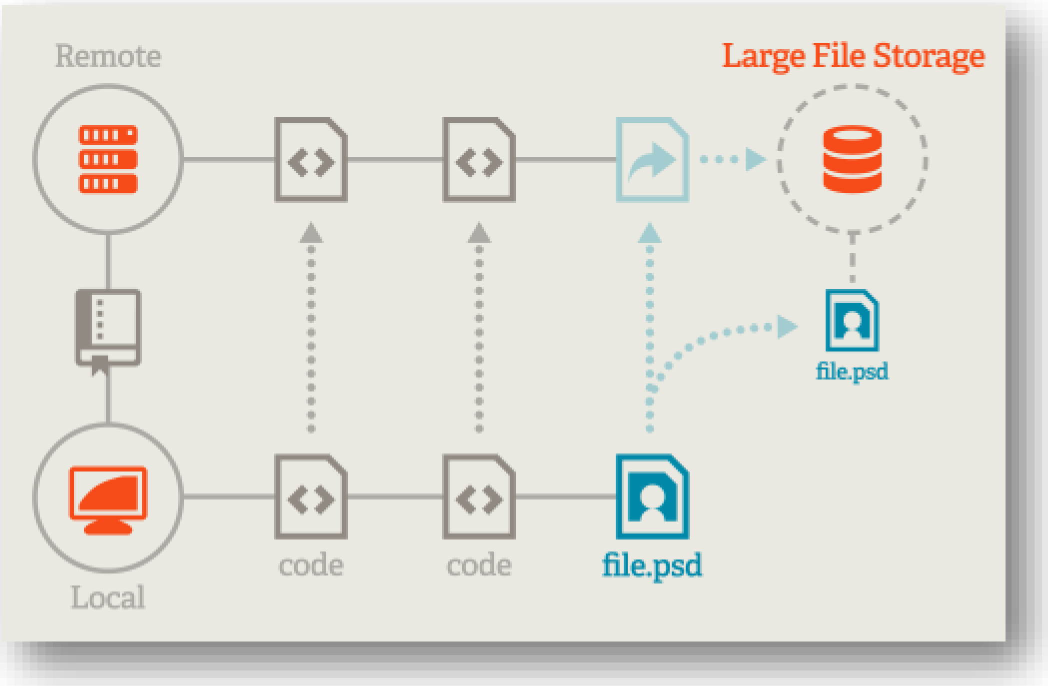
- Data is a little trickier
- Large binary files are not optimal for source control

Git Large File Storage

- Built as an extension to git
- Allows you to store large files in a specially optimized repository

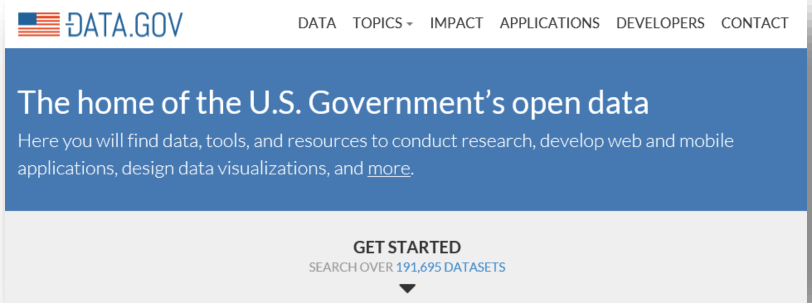
Integrate with data catalog…

- You could refer to large files and use the grid as the storage medium



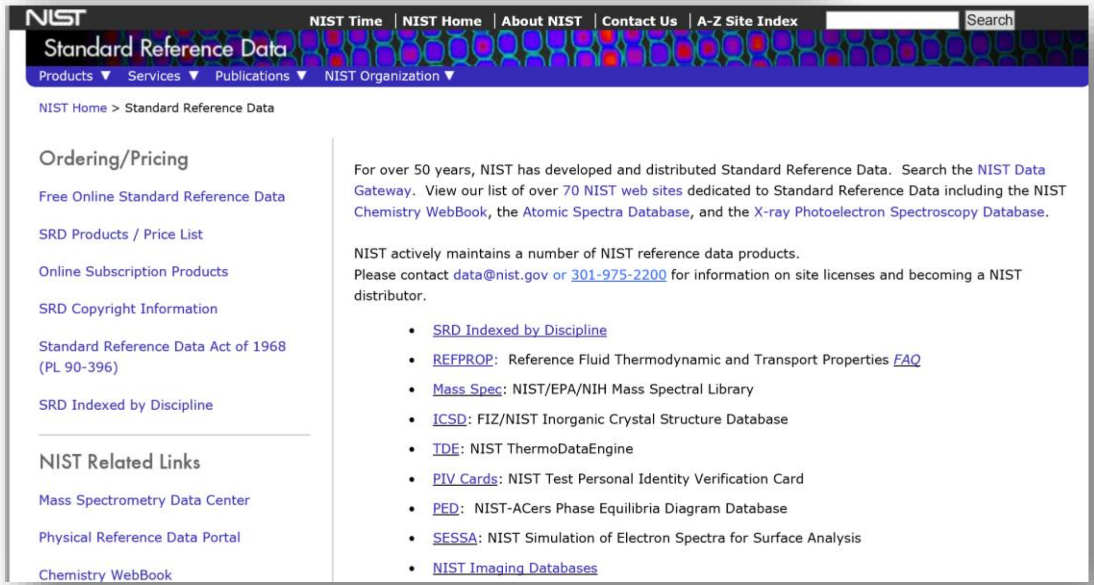
The General Trend of Public Data

US Government: ~20K datasets available

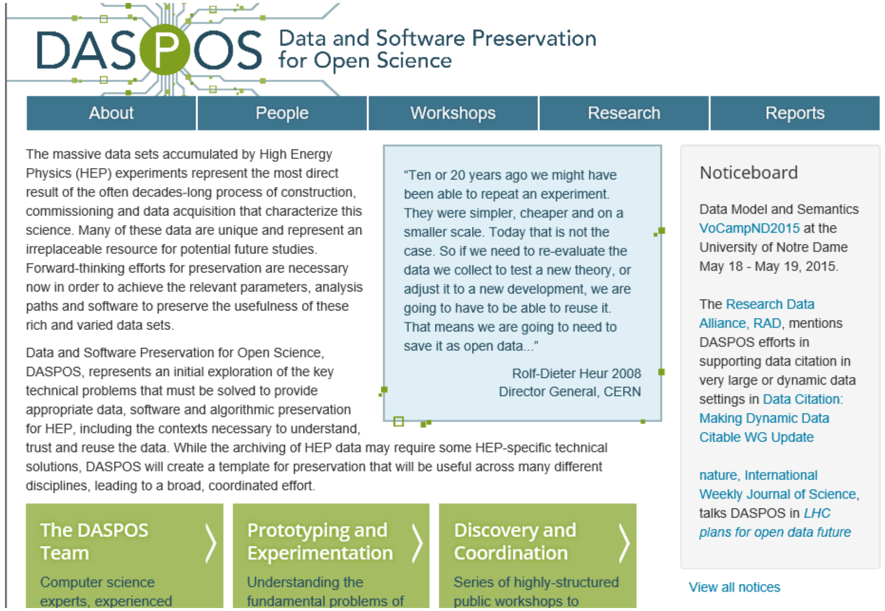


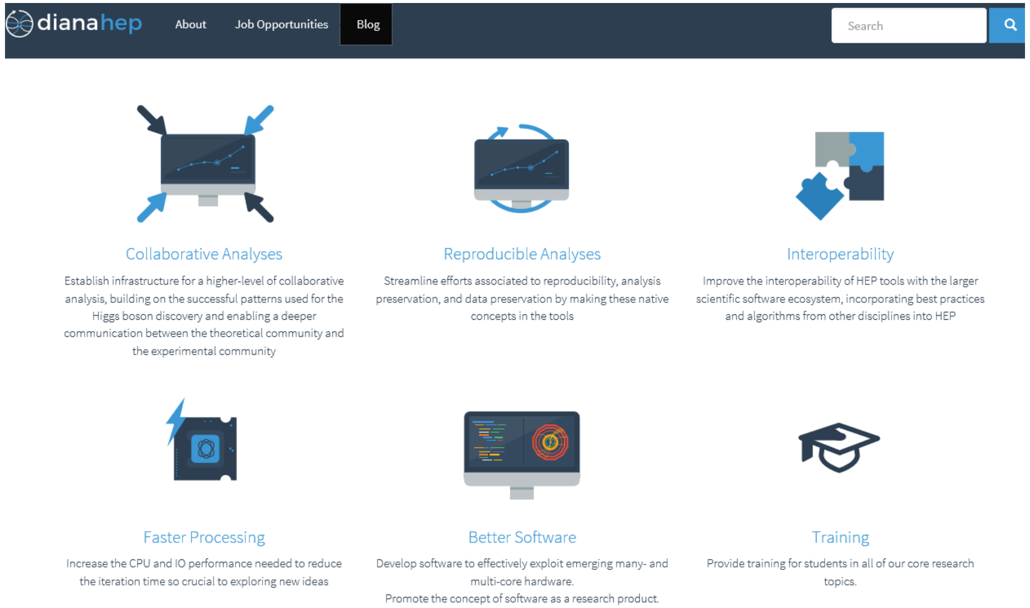
NIST (National Institute of Standards and Technology)

- ~100 databases
- Many different schemas



Other?





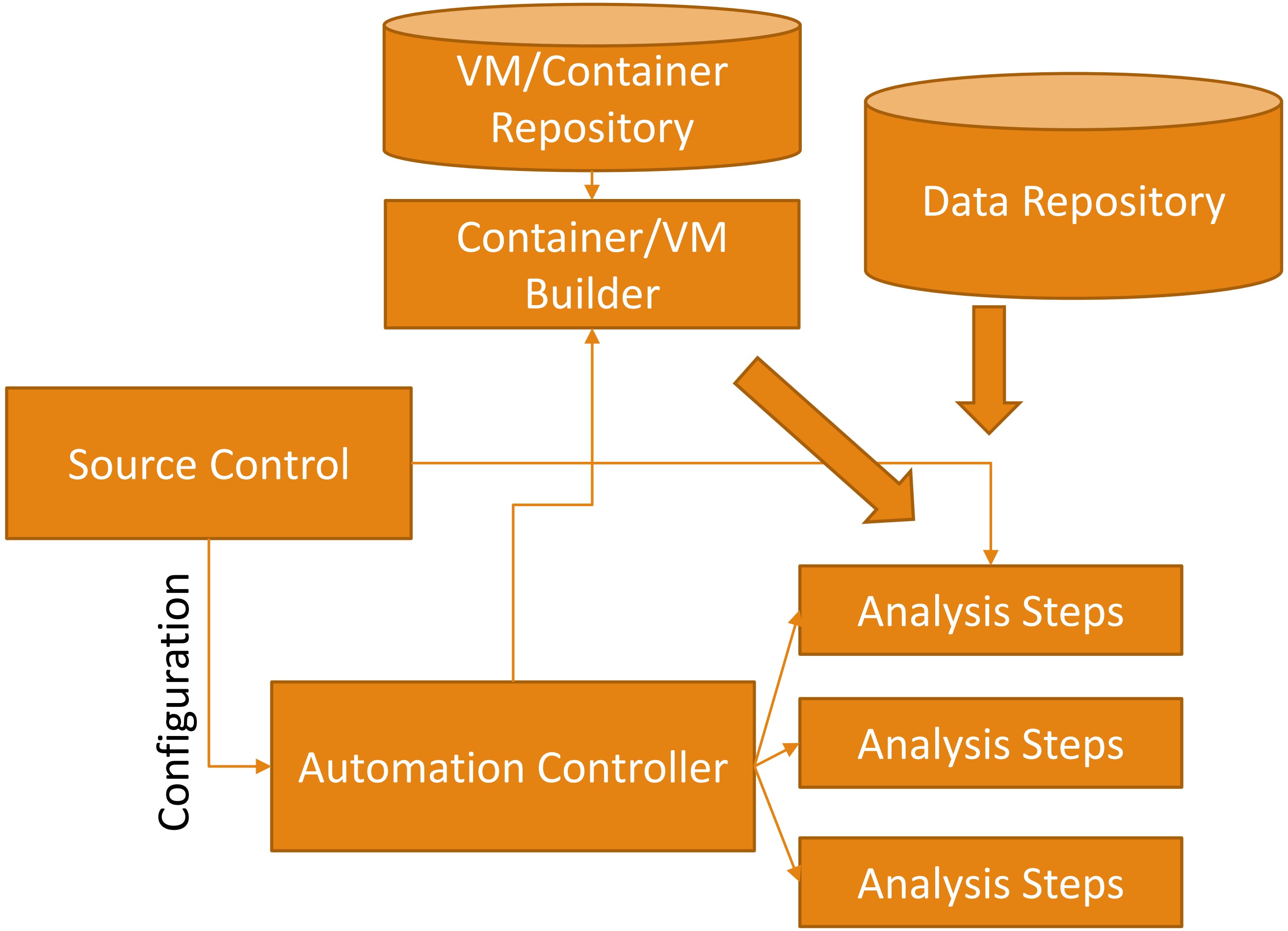
Funding agencies are willing to provide for research!

Future Trends

Automation

Any tool that encourages analysis automation is good for Data Preservation

- Containers
- Continuous Integration Servers



Containers

Virtual Machines replicate the complete environment of a machine

→ Unit of hardware

But there aren't analysis work flows that really are VM aware in any significant way

Infrastructure is aware: batch systems, GRID, etc., can spin up/spin down…

This is clearly been a revolution in how production infrastructure works in HEP

Docker is a light weight VM – usually meant for a single program

- Takes 100 milliseconds to spin up – so much more like running a program
- Runs isolated, in a known environment
- Single point of configuration
- Cross platform (native on Linux, soon on Windows, and perhaps Mac too)

It is very possible analyses will become aware of this.

Analysis Revolution?

What Makes Me Nervous

Commercial Cloud Tools

- More than Infrastructure (VMs and Containers)

Tools that let you play

- Functional Languages
- Web Interfaces

Second Talk

Data Preservation usually comes last

Perhaps we can design it in from the start?

Data Preservation Is Good

Others can search for things you missed
You can reproduce the results quickly a year after publication
You can quickly check the analysis against a new signal
Education and Outreach

Morally, it is the right thing to do

$$

Fears and Hopes

The Resource question is a serious one

- But given computing trends, it is inevitable

Political Will is something that must be over come

Documentation is well in hand

- We have the tools
- We have enough examples

Technical Challenges for Data Preservation

- Each analysis and experiment is a snowflake.
- For large collider experiments that will never change

We have many tools available to us

- Out of which one must build a solution

Automation is key to flexible preservation

- Being able to repeat an analysis with new inputs
- Independent of how you archive the bits that are the input to the analysis steps.

Serious efforts have been ongoing for more than a decade now

The Way Forward

Current in-use frameworks need to adapt to make this task easier!

Perhaps two more iterations?