

Tape Storage in Scientific Organizations

Fujifilm's 7th Annual
Global IT Executive Summit

October 8, 2015 Los Angeles

David Yu



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ENERGY

Office of
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Brookhaven National Laboratory (BNL)



Brookhaven Lab is one of ten national laboratories overseen and primarily funded by the Office of Science of the U.S. Department of Energy



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Brookhaven National Laboratory (BNL)

Brookhaven National Laboratory is a multipurpose research institution funded primarily by the U.S. Department of Energy's Office of Science. Located in the center of Long Island, New York About 70 miles from New York City.



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Brookhaven National Laboratory (BNL)

Brookhaven research has been honored by
7 Nobel Prizes

- 2009 Steitz, Ramakrishnan
- 2003 Roderick MacKinnon
- 2002 Raymond Davis Jr.
- 1988 Lederman, Schwartz, Steinberger
- 1980 Fitch and Cronin
- 1976 Samuel C. C. Ting
- 1957 C.N Yang, T.D. Lee



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Brookhaven National Laboratory (BNL)

Brookhaven's Research Facilities

- Relativistic Heavy Ion Collider (RHIC)
- National Synchrotron Light Source-II (NSLS-II)
- Center for Functional Nanomaterials (CFN)
- NASA Space Radiation Laboratory
- Computational Science Center
- Radiotracer Chemistry, Instrumentation and Biological Imaging
- Accelerator Test Facility
- Long Island Solar Farm
- Brookhaven Linac Isotope Producer
- Tandem Van de Graaff



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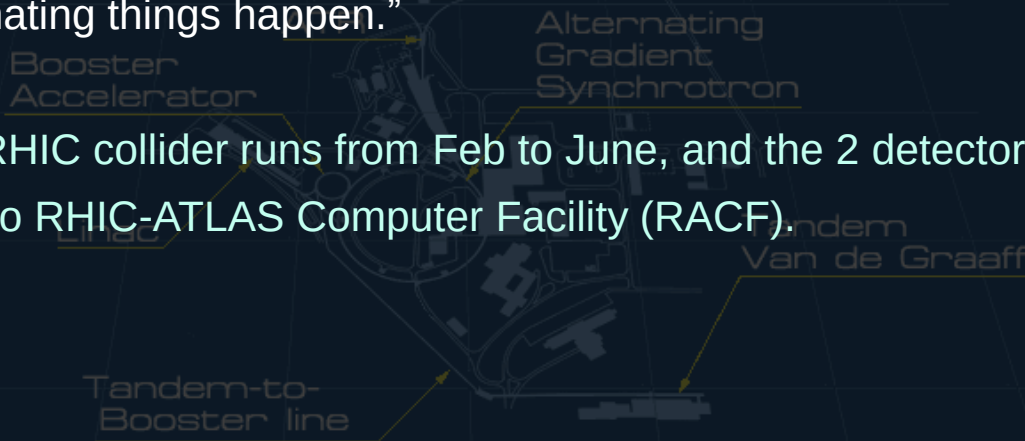
Brookhaven National Laboratory (BNL)

Brookhaven's Research Facilities

- Relativistic Heavy Ion Collider (RHIC)

“RHIC collides two beams of gold ions head-on when they're traveling at nearly the speed of light (what physicists call relativistic speeds). The beams travel in opposite directions around RHIC's 2.4-mile, two-lane "racetrack." At six intersections, the lanes cross, leading to an intersection. When ions collide at such high speeds fascinating things happen.”

The RHIC collider runs from Feb to June, and the 2 detectors will send the collected data to RHIC-ATLAS Computer Facility (RACF).



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Brookhaven National Laboratory (BNL)

Brookhaven's Research Facilities

- Relativistic Heavy Ion Collider (RHIC)

RHIC / ATLAS Computing Facility (RACF)

- Provides computing services for RHIC experiments
 - Data storage for all experiment data.
 - Primary center for data processing.
- Serves as LHC ATLAS Tier-1 for the US.
 - Secondary data storage for fraction of data (23% - 25%).
 - Primary US site for data storage, processing and distribution.



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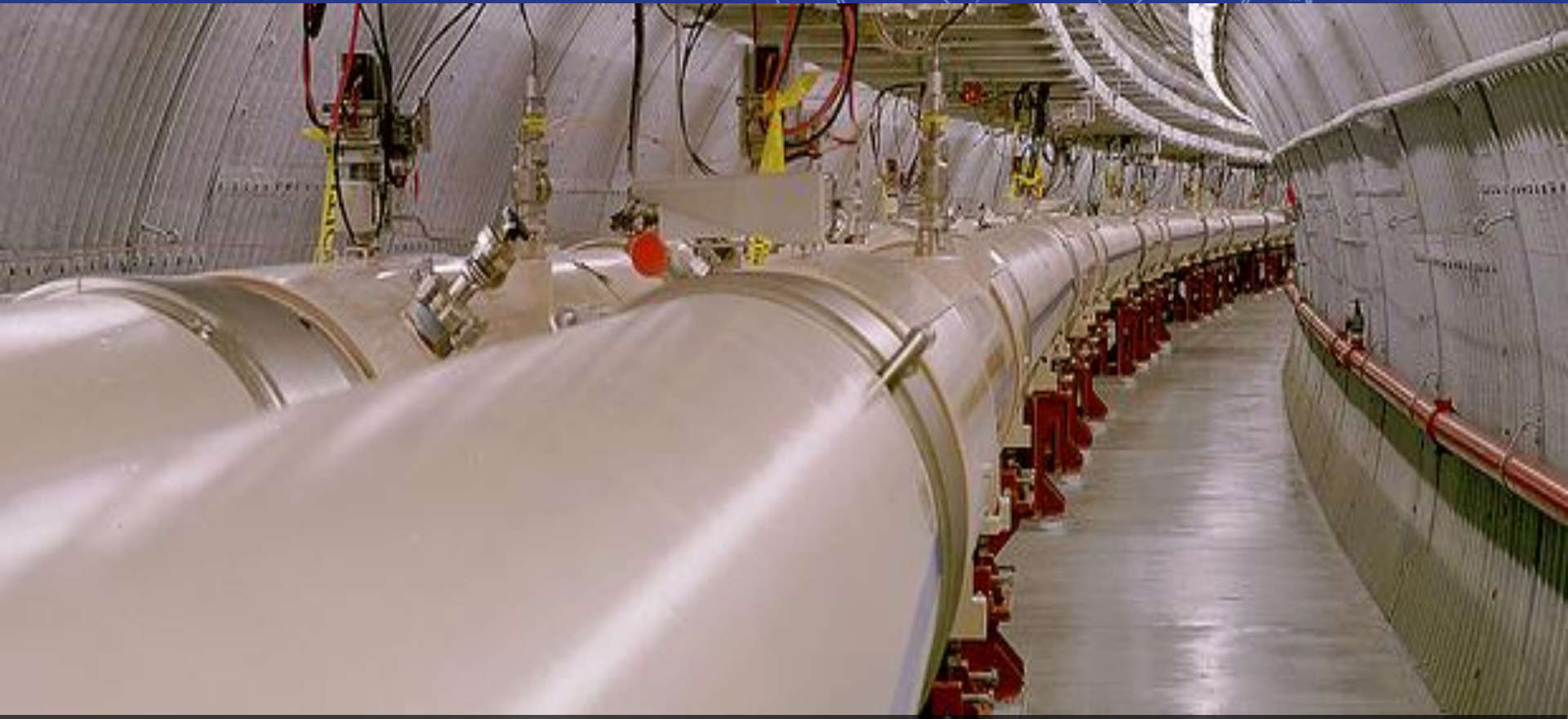


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RHIC

Brookhaven National Laboratory's Relativistic Heavy Ion Collider



RHIC is a world-class particle accelerator at Brookhaven National Laboratory where physicists are exploring the most fundamental forces and properties of matter and the early universe.

RHIC accelerates beams of particles to nearly the speed of light, and smashes them together to recreate a state of matter thought to have existed immediately after the Big Bang some 13.8 billion years ago.

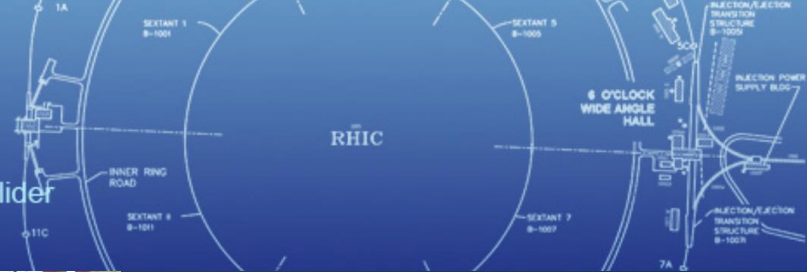


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RHIC

Brookhaven National Laboratory's Relativistic Heavy Ion Collider



Phenix Detector

The Pioneering High Energy Nuclear Interaction eXperiment, is a detector designed to investigate high energy collisions of heavy ions and protons. The primary goal of PHENIX is to discover and study a new state of matter called the Quark-Gluon Plasma

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RHIC

Brookhaven National Laboratory's Relativistic Heavy Ion Collider



HOW THE UNIVERSE WORKS

WEDNESDAY

9/8c



ENERGY | Science



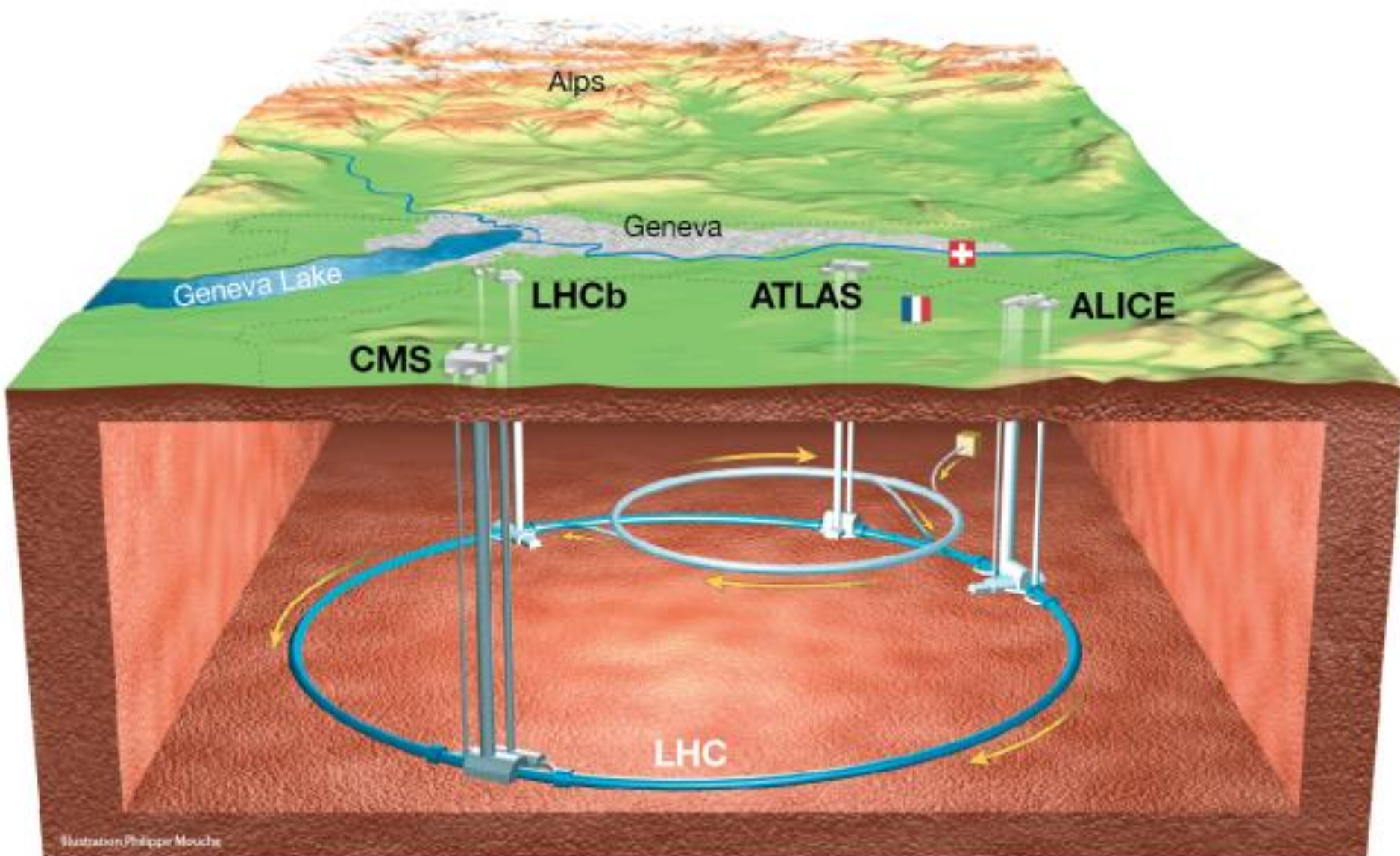
The Large Hadron Collider

The Large Hadron Collider (LHC) is the world's largest and most powerful particle accelerator. It first started up on 10 September 2008, and remains the latest addition to CERN's accelerator complex. The LHC consists of a 27-kilometre ring of superconducting magnets with a number of accelerating structures to boost the energy of the particles along the way.





The Large Hadron Collider



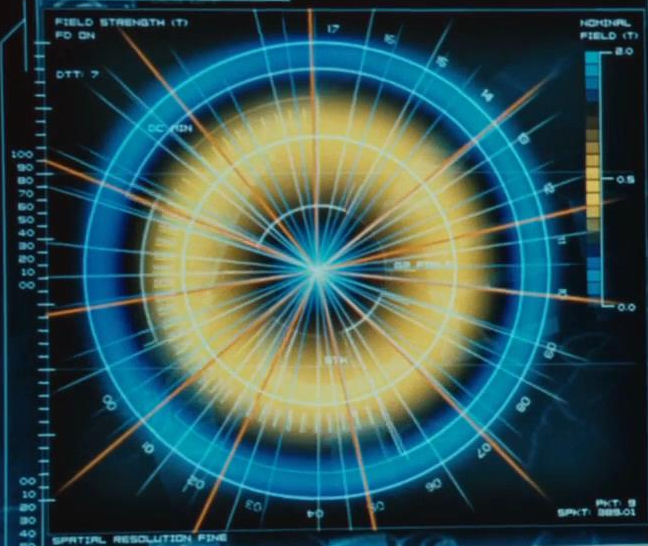


The Large Hadron Collider

HADRON COLLISION SPECTROMETRY

DCS LEVEL 3 RPT 4.03.201

D1 DIPOLE (SINGLE BORE)



TGR-052	47.108368	USEN	5.285714286	0.383	0.004
TGR-053	48.850335	BIN	5.357142857	0.381	0.004
TGR-054	50.592305	BIKE	5.428571429	0.379	0.004
TGR-055	52.334275	DEFAULT	5.5	-0.378	0.004
TGR-056	54.076245	BIN	5.571428571	-0.376	0.004

IR1

IR1-01	ACTIVE
IR1-02	ACTIVE
IR1-03	ACTIVE
IR1-04	ACTIVE
IR1-05	ACTIVE
IR1-06	ACTIVE
IR1-07	ACTIVE
IR1-08	ACTIVE
IR1-09	ACTIVE
IR1-10	ACTIVE

BOSON CALORIMETER 2

DCS LEVEL 3 RPT 4.03.201
CPT-003
DLG OFF

PNT: 9
ST REQUIRE ON
OTS OFF

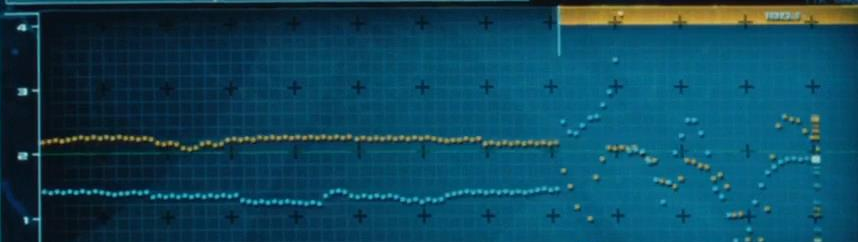
ROT CORRECTOR MAGNET



SPOL. PRECE CORRECTOR MAGNETS

MAIN DIPOLE	TYPE 9 MAGNET
SEXTUPOLE RCS	RCS 93 FIELD
OCTUPOLE-DECAPOLE 1	SCOD TYPE A
OCTUPOLE-DECAPOLE 2	SCOD TYPE A
OCTUPOLE-DECAPOLE 3	SCOD TYPE A
OCTUPOLE-DECAPOLE 4	SCOD TYPE A
OCTUPOLE-DECAPOLE 5	SCOD TYPE A
OCTUPOLE-DECAPOLE 6	SCOD TYPE A
OCTUPOLE-DECAPOLE 7	SCOD TYPE A

SUPERCONDUCTING LOW-β QUADRUPOLE TEMPERATURE





The Large Hadron Collider

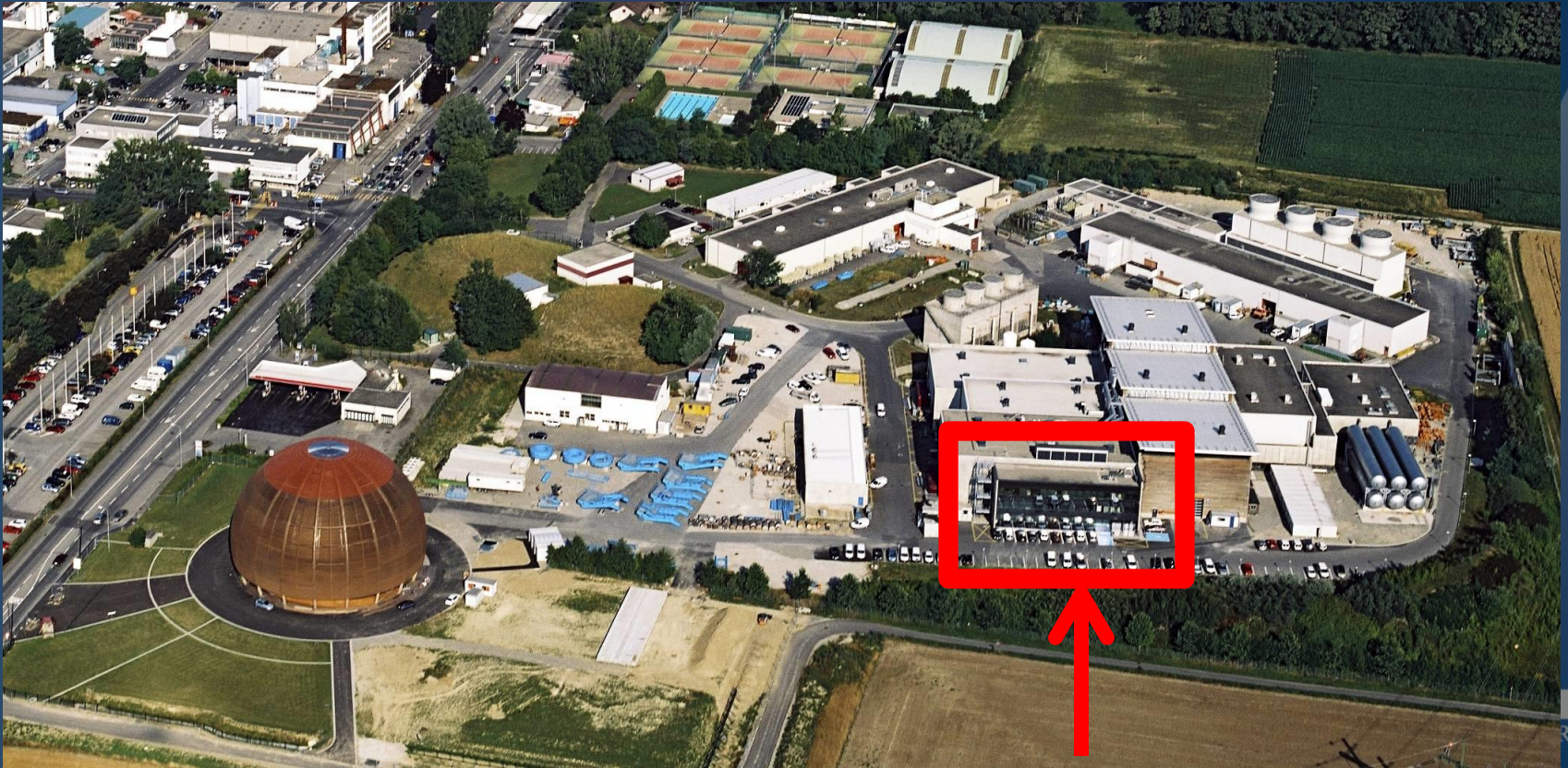
According to Dr. Howard Gordon at BNL

The movie crew did some extensive editing to make it look like the control room has a window which looks on the detector.





The Large Hadron Collider



ATLAS Control Room



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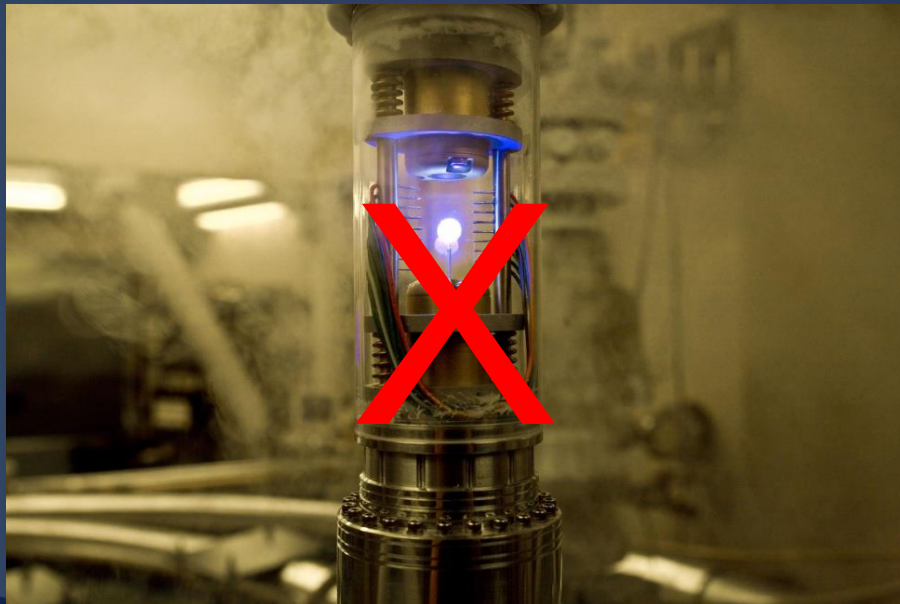
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The Large Hadron Collider

According to Dr. Howard Gordon at BNL

The glass "container" of the antimatter is not in our experiment.



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Antimatter can be used for

- Solving some of the biggest mysteries in science
- Why do we exist?
- Why do we have mass?
- What is most of the universe made of?



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Searching for answers



At particle physics laboratories around the world



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The Large Hadron Collider

Official

Large Hadron Collider 7 TeV
ATLAS Collision Visualization

Brookhaven and the Large Hadron Collider

Brookhaven scientists and engineers designed and constructed 20 of the 1,200 superconducting magnets for the LHC and built key parts of the ATLAS detector.

Brookhaven National Laboratory is the U.S. host laboratory for the ATLAS experiment at the LHC

BNL RACF is the sole Tier-1 computing facility for ATLAS in the United States, and the largest Tier-1 ATLAS computing center worldwide.

RHIC

Brookhaven National Laboratory's Relativistic Heavy Ion Collider



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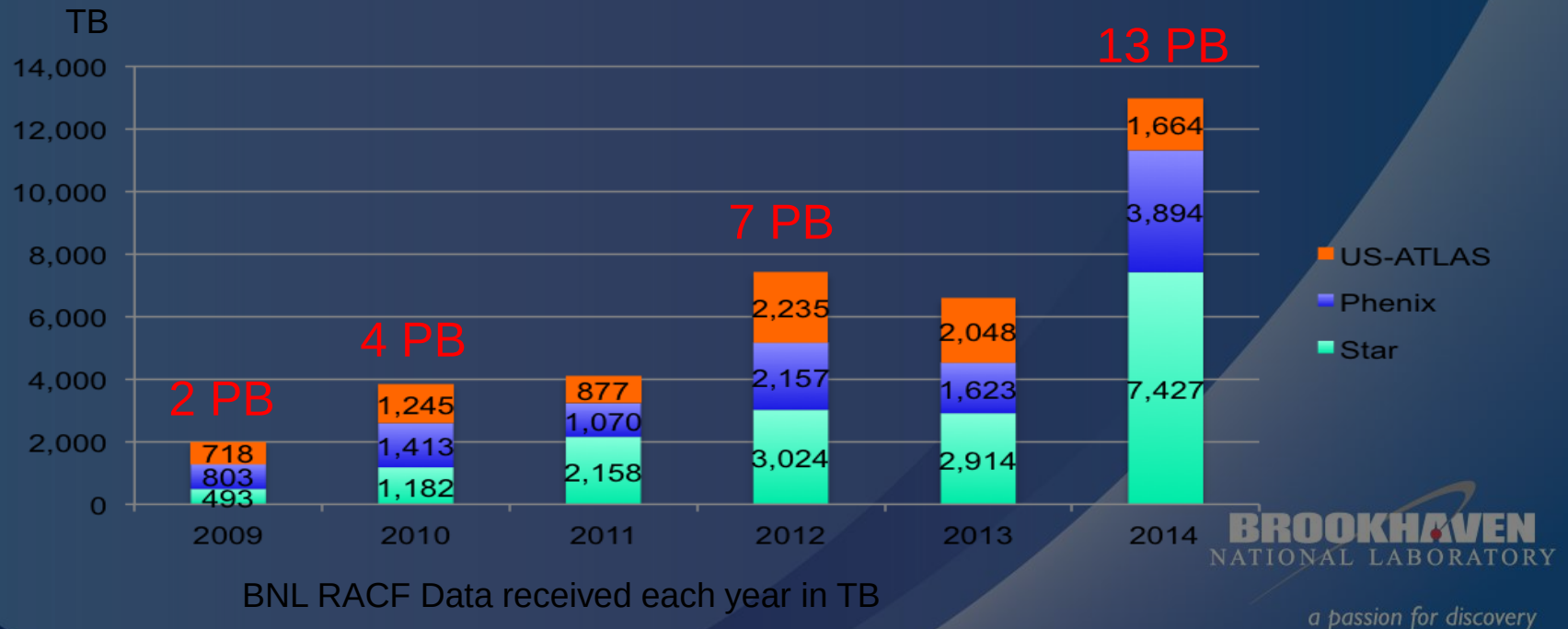
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Brookhaven and the Large Hadron Collider



Data Added Each Year

The amount of scientific experiments data has been increasing exponentially.



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2015/16 : RHIC

- In 2015 and 2016 RHIC Run, we expect 20 PB more RAW data...



That will require 8192 LTO-6 cartridges, or 80% of a fully expanded SL8500 library.

Plus 22+% reconstructed data...

We expect a total of 10,000 LTO-6

That will completely fill up a library

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2015: USATLAS

- In 2015
we expect to archive 10 PB data ...

That will require 4096 LTO-6
cartridges, or 40% of a fully
expanded SL8500 library.

Plus ~5PB new raw data...

We expect a total of 6,144 LTO-6



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Tape Libraries



- Tape storage is our permanent data archival solution.
- Each tape library can hold up to 10,088 tapes.
- We have 8 libraries in production.

Tape is not a solution?

- Backups take too long
- Recoveries take too long
- Difficult to validate backup recovery success
- Media management



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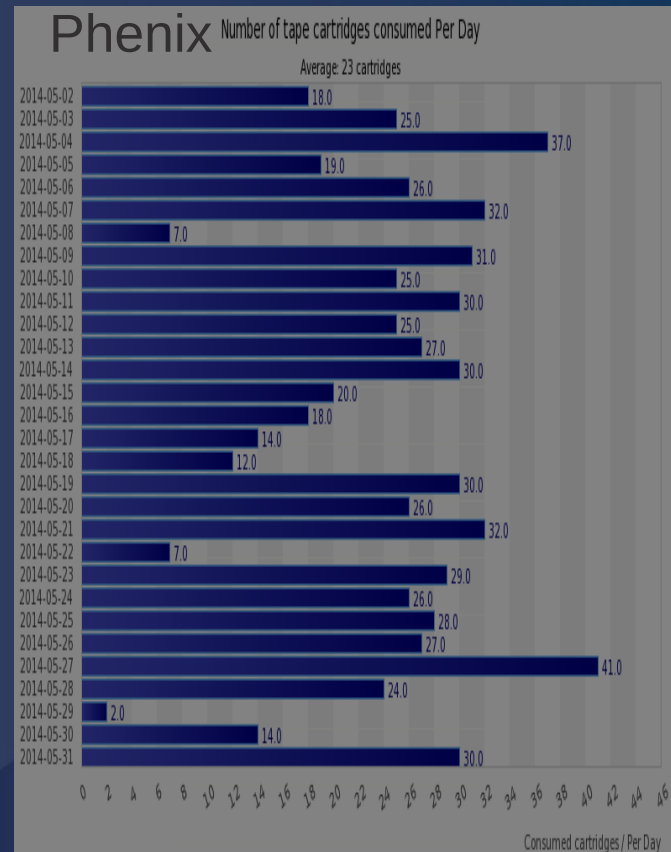
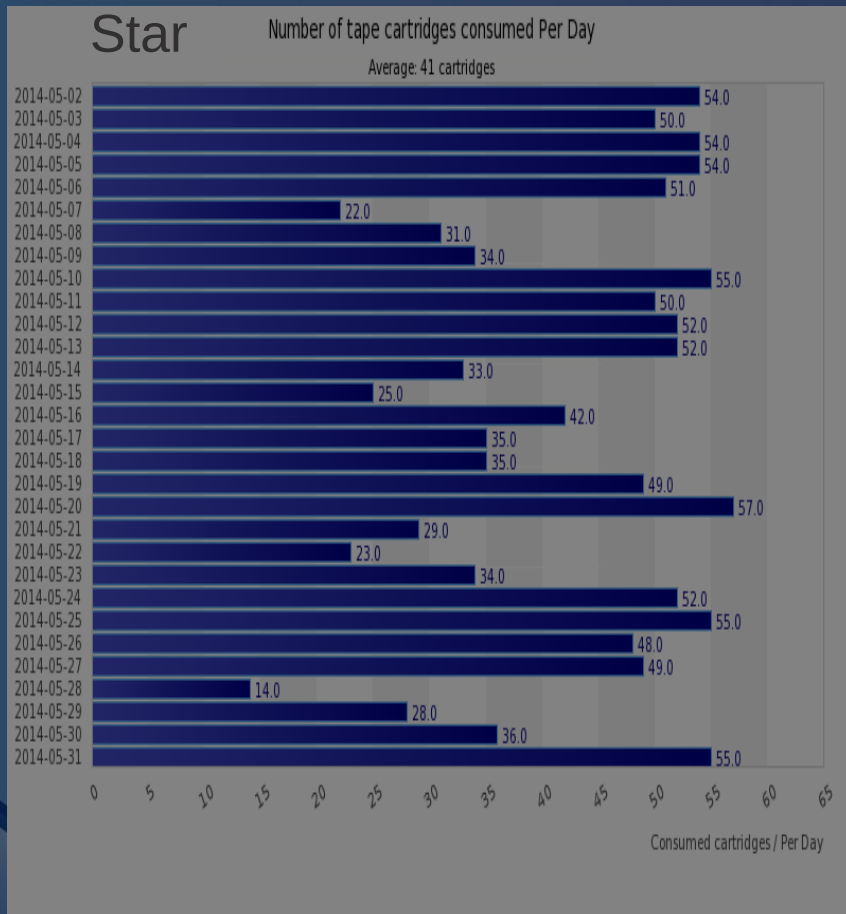


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Performance: Tape Write

RHIC 2014, May : Average 64 LTO-5/day (96 TB/day)



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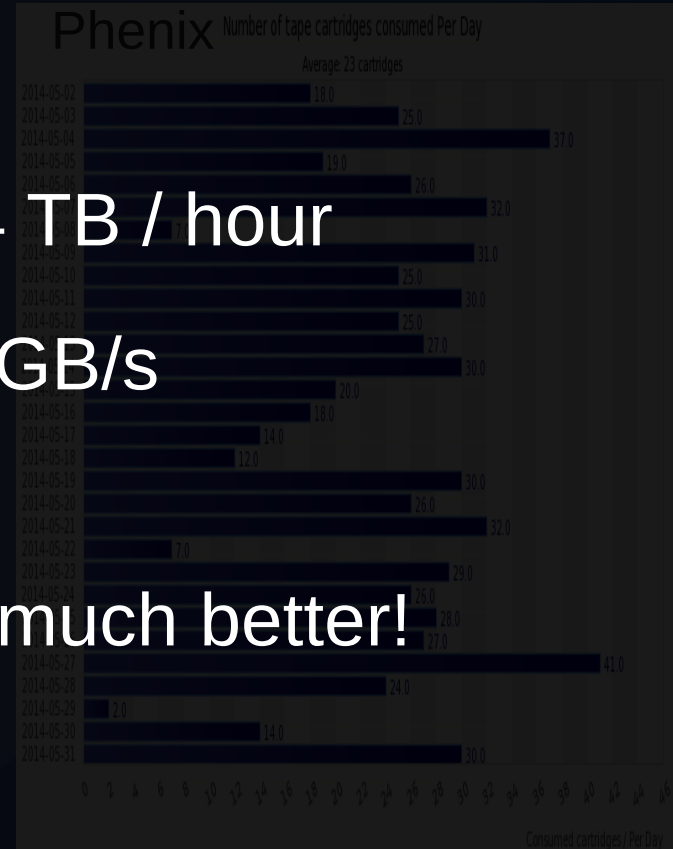
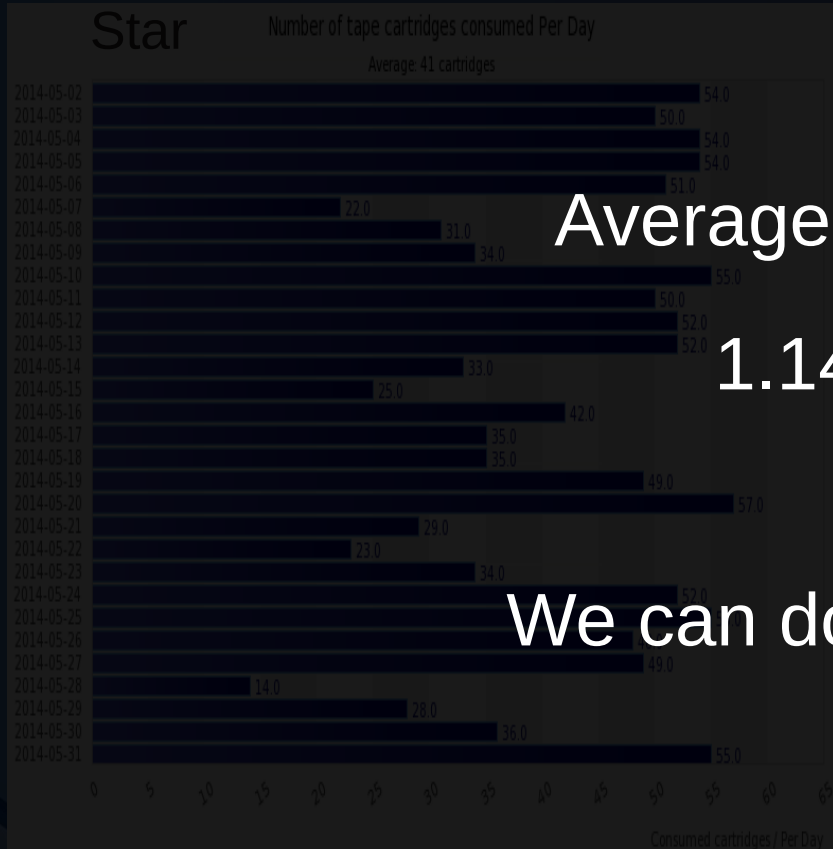


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Performance: Tape Write

RHIC 2014, May : Average 64 LTO-5/day (96 TB/day)



Average 4 TB / hour

1.14 GB/s

We can do much better!



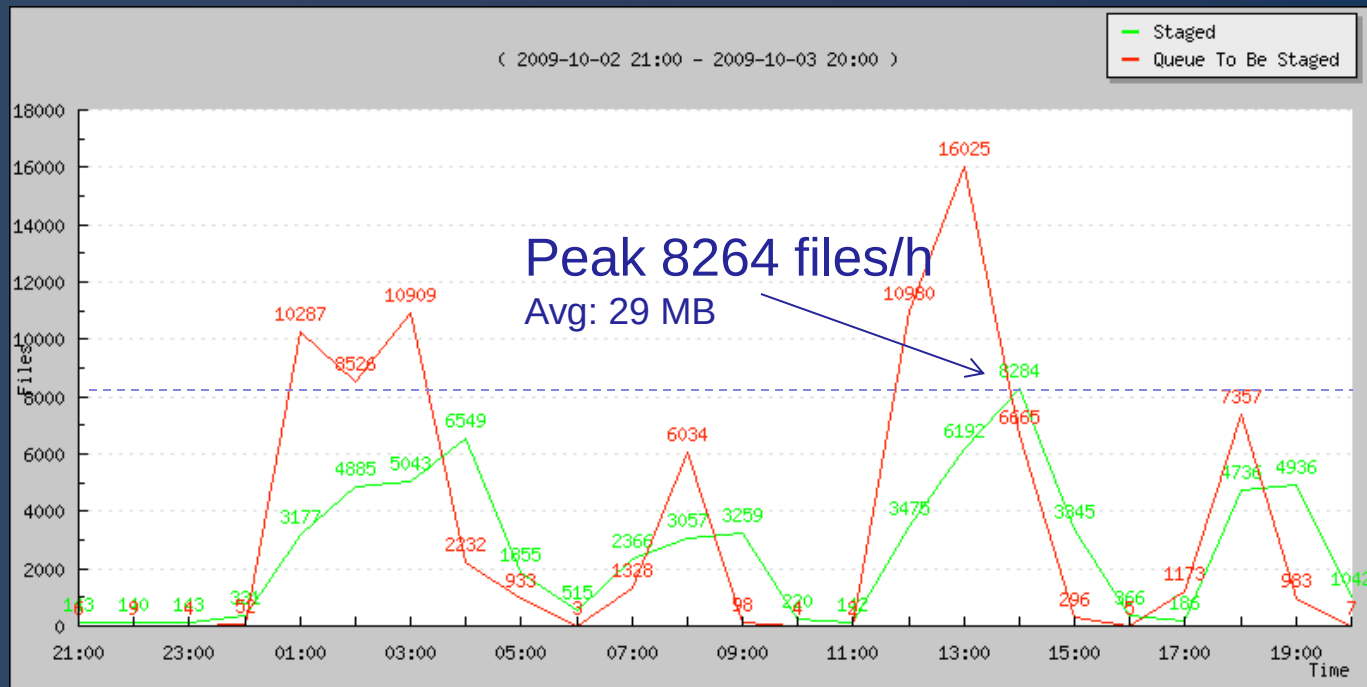
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Performance : Restoration of files

In 2014, we restored 7,607,932 files from tapes

That's average 20,843 files per day, or 868 files / hour



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Tape Storage Maintenance

Tape storage Maintenance

Besides the new data, we are also facing the challenge of running out of tape slots in the libraries.

Repacking old tapes to new tapes.



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Data Recovery

Case Study

- Deleted Files
- Damaged Media



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Data Recovery

Case Study

Deleted Files: files are deleted from “file system”, a file system is actually a database. The actual files are still on tape!

Build a “*Time Machine*”

- 1.Restore: Restore DB to a test server
- 2.Dump the file attributes from DB: Tape ID, offset, length.
- 3.Mount the tape manually (out of production system).
- 4.Read the files out one by one.
- 5.Glue the segments together, if necessary
- 6.Integrity checking
- 7.Get some food and sleep



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Data Recovery

Case Study

Damaged Media

Raymond Blum (Google) said: protect the data!

“We are getting lots of read errors, this is going to damage the tape drive...”

“We are not protecting the tape drive, we are protecting the precious data! Try again!!!”

Retry, retry and... send out for repair



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Question?



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Supplementary Slides



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Performance : **Restore files**

Restore process is optimized by a BNL developed system

Requests are sorted and scheduled

Tape mounts schedule algorithm is optional

- FIFO

- In the order of popularity (by demand)

- LIFO

Tape Drive Resource is under total control

- Dedicated (resource guarantee)

- Shared (resource sharing)

Network flow control (throttle the concurrent transfer)



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Data Recovery

Case Study

Contaminated Tapes

Caused by a vacuum machine with defective filter...

1. Got read error
2. Examine the cartridge visually... **found dust all over it!**
3. Lock down entire library, visually checked inside
4. Visually inspect all tape drives near by
5. Replaced the drives near by
6. Trace the tape history from ACSLS log
7. Located the tapes that had previously mounted on contaminated drive.
8. Repack them in an “isolated environment”



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Antimatter



- It's real
- It's produced at the Large Hadron Collider
- Enough of it could destroy Rome



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Antimatter



- It's real
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Angels & Demons & Antimatter



- Rome is threatened by $\frac{1}{4}$ gram of antimatter
- Annihilation of $\frac{1}{4}$ g matter + $\frac{1}{4}$ g antimatter = 10 kilotons of TNT
- More than enough to destroy the Vatican



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Antimatter's no threat



- Only very little antimatter
- ATLAS will create 50 picograms of antimatter per year
- It would take 5 million years to make $\frac{1}{4}$ gram

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Antimatter's no threat



It's not portable!



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Antimatter's no threat



Antimatter can't be used for

- **Power**
 - Have to make every single antiparticle
 - More energy goes in than is produced

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Searching for answers



At universities and laboratories across the
United States



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The mystery of antimatter



We exist because there is almost no antimatter around

It wasn't always that way



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