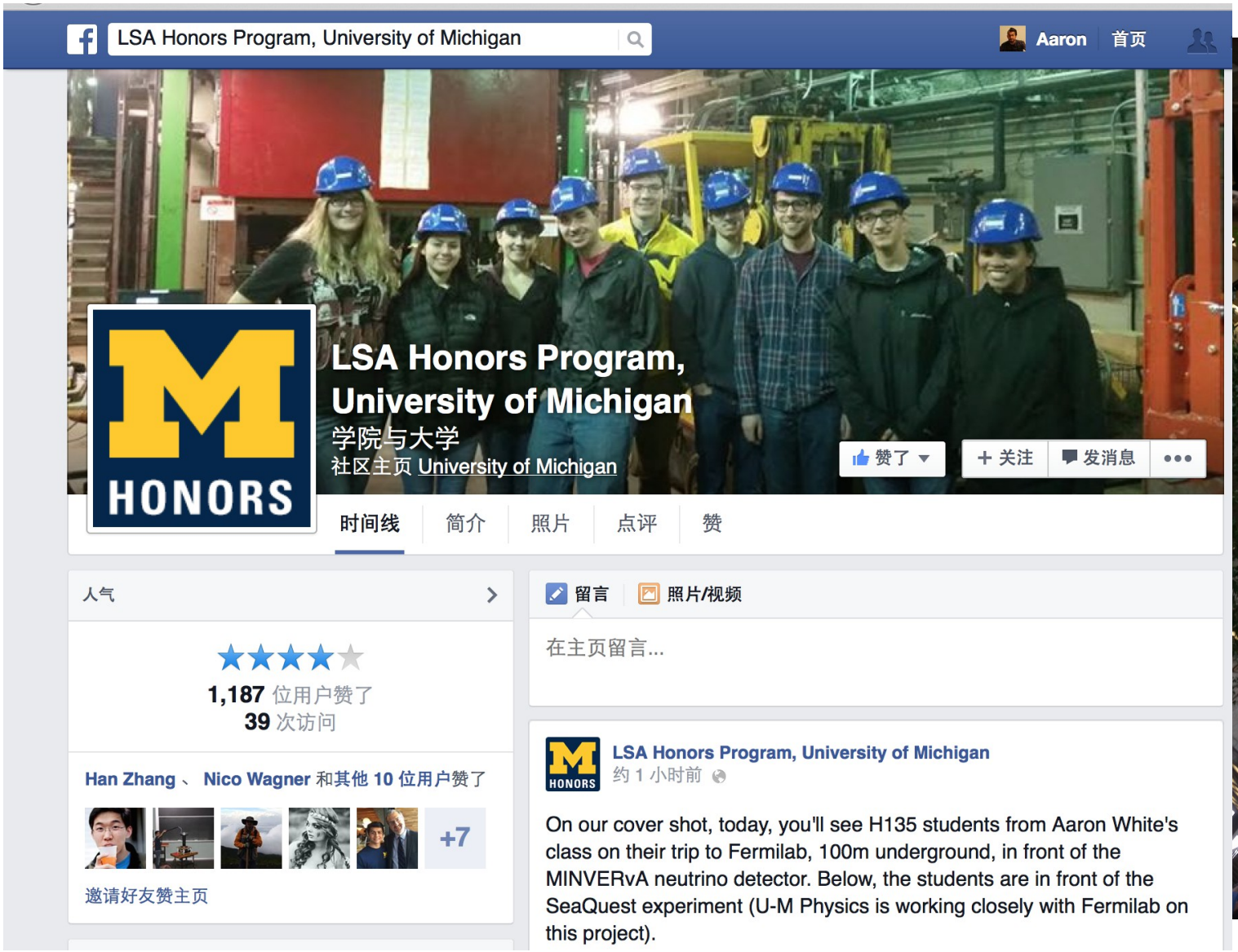
DAQ and Analysis

Aaron White

Today

- Geiger counter demo
- Review detector methods
- Slides for DAQ
- Slides for Analysis

Fermilab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Aaron
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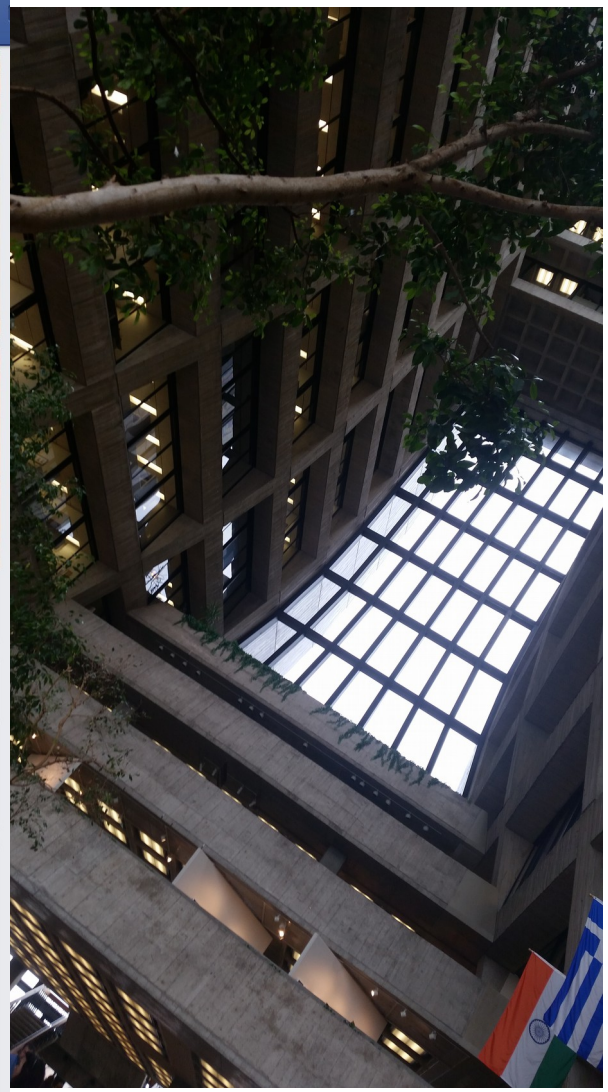
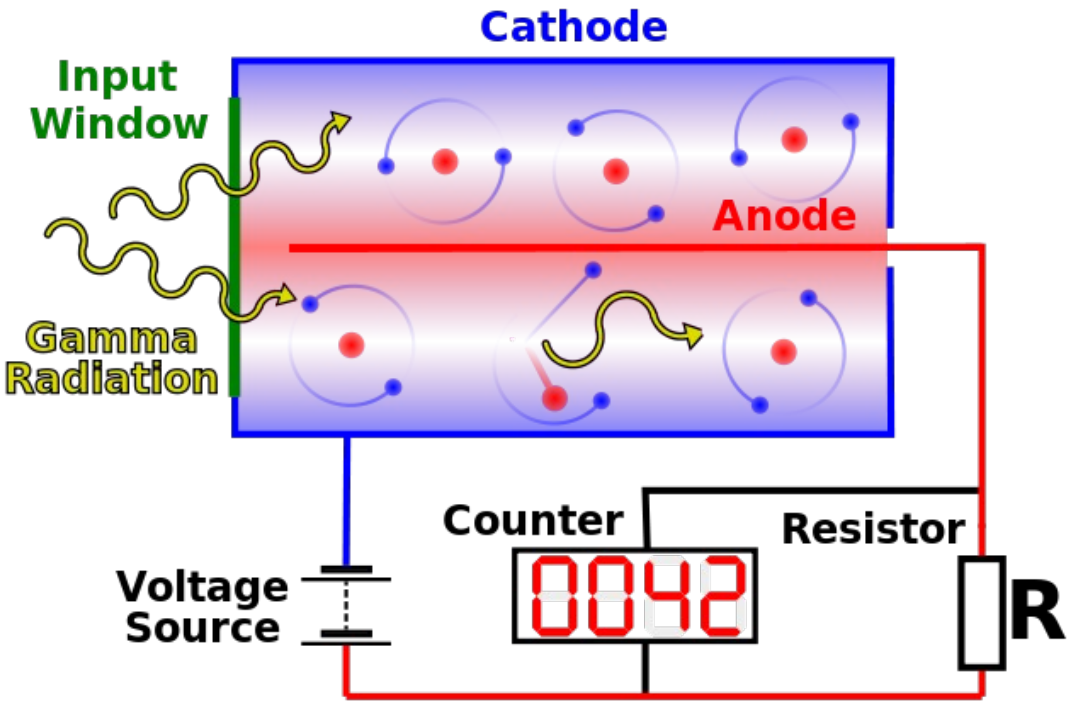
LSA Honors Program, University of Michigan
约 1 小时前
On our cover shot, today, you'll see H135 students from Aaron White's class on their trip to Fermilab, 100m underground, in front of the MINVERvA neutrino detector. Below, the students are in front of the SeaQuest experiment (U-M Physics is working closely with Fermilab on this project).



Geiger Counter

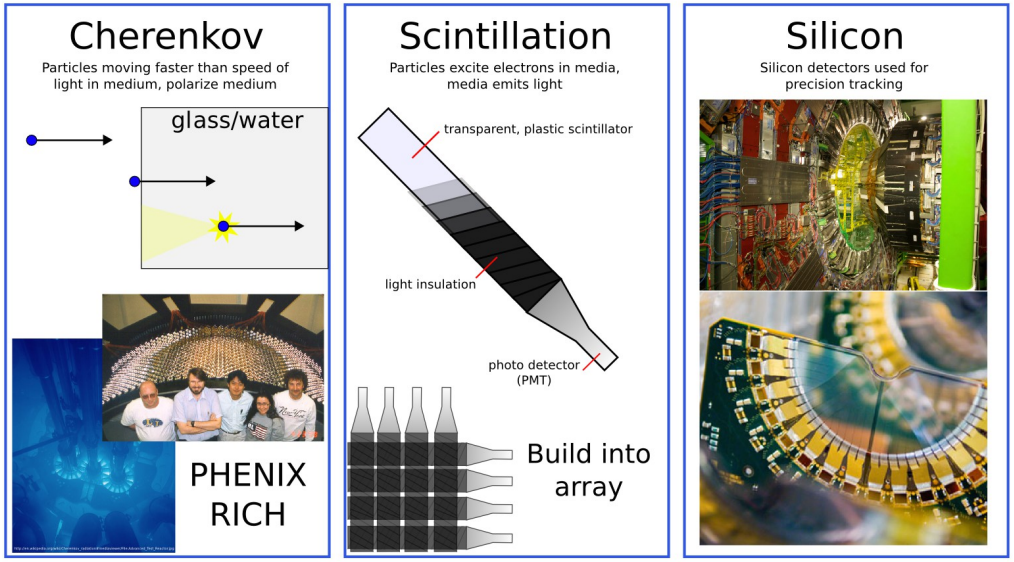
How the Geiger counter works



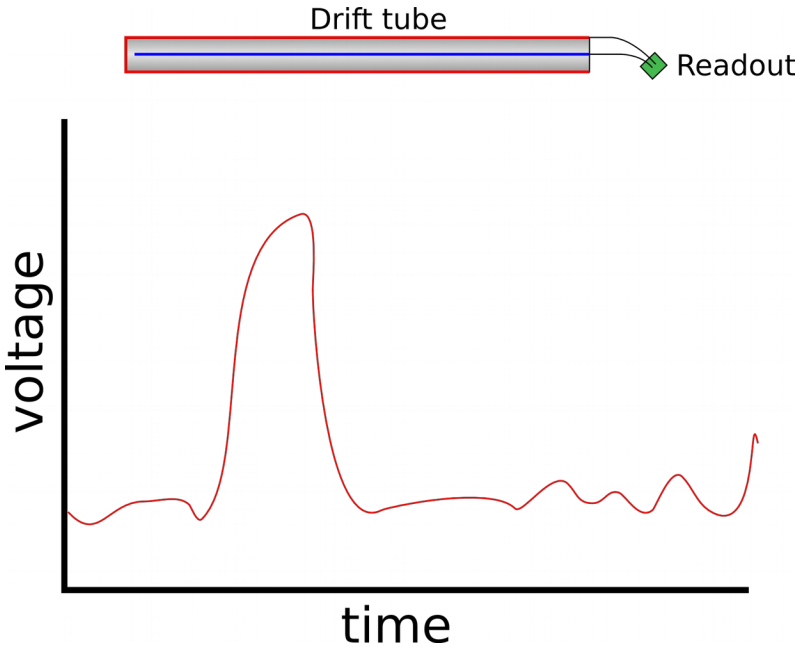
http://upload.wikimedia.org/wikipedia/commons/thumb/4/44/Geiger_Mueller_Counter_with_Circuit-en.svg/640px-Geiger_Mueller_Counter_with_Circuit-en.svg.png

Review Detector Methods

Methods of particle detection



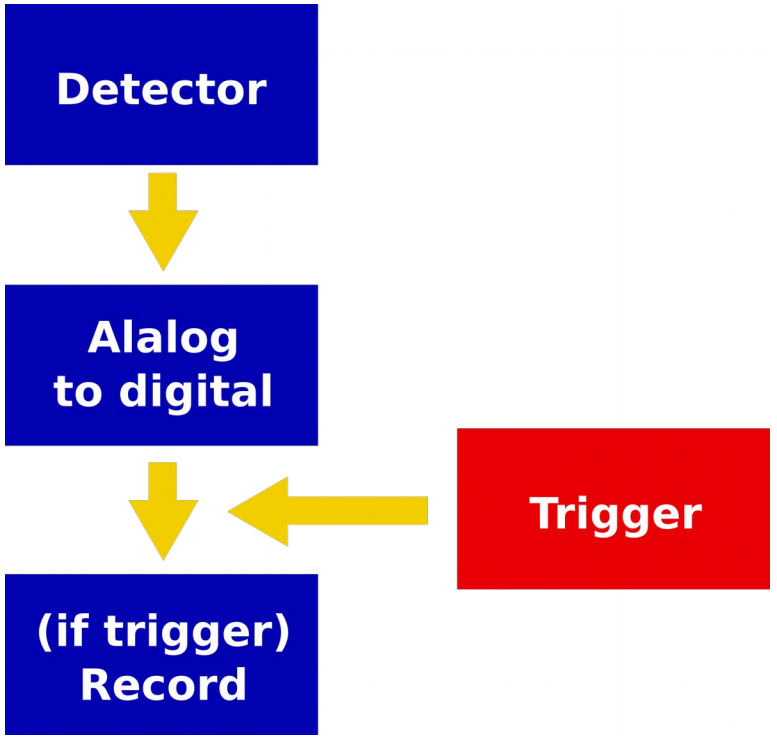
Produce an analog signal:



Data Acquisition (DAQ)

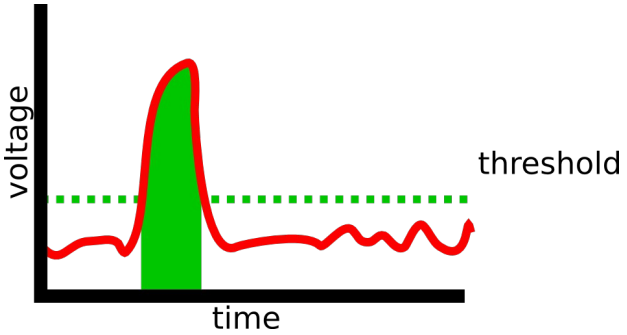
The Goals of DAQ

- Identify when a particle has been detected
- Discard uninteresting events
- Analog to Digital
- Record important information
  - Time
  - Location
  - Energy

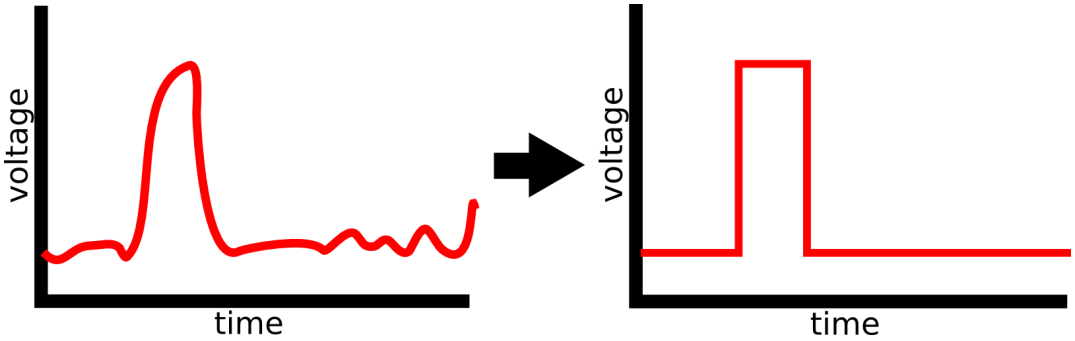


DAQ Steps

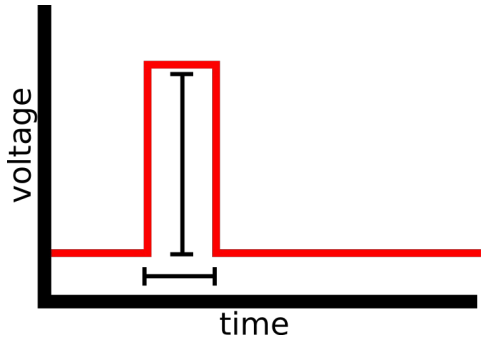
- Pass threshold



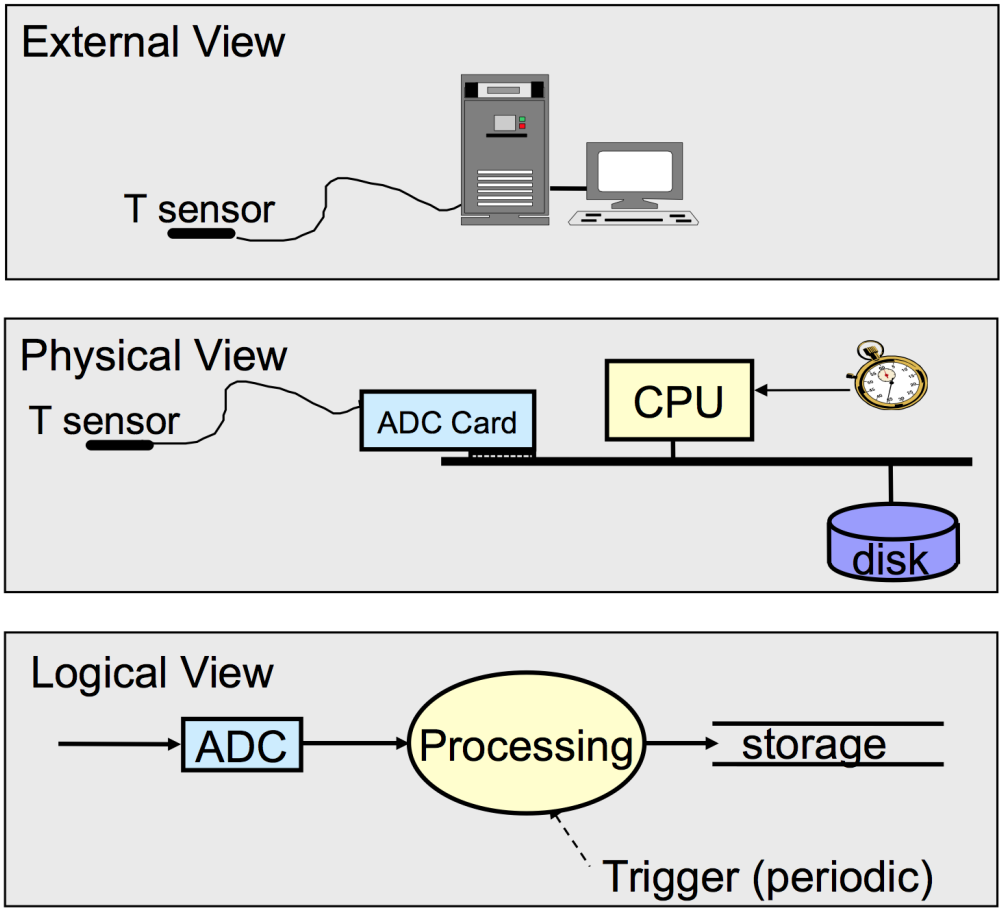
- Analog to Digital conversion



- Feature extraction



Simple DAQ



Vandelli Slides

http://indico.cern.ch/event/318373/material/slides/0.pdf

Trigger

- Select what to record, what to discard
- Pick trigger requirements based on:
  - **Physics interest.** eg look for events with 2 muons
  - **Speed.** To make decisions quickly, need to make guesses
  - **Storage space.** LHC experiments process

40 Terabytes per second

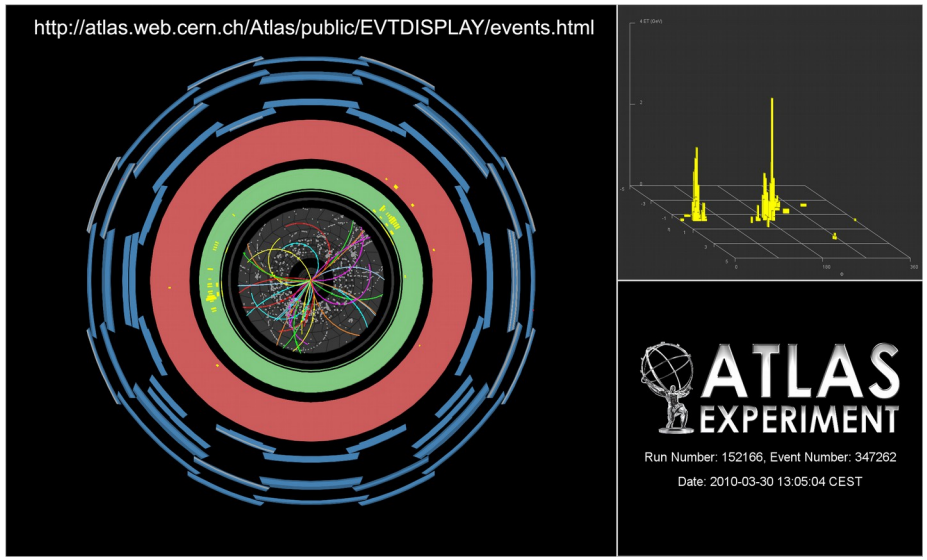
= Annual hard drive production every 5 hours

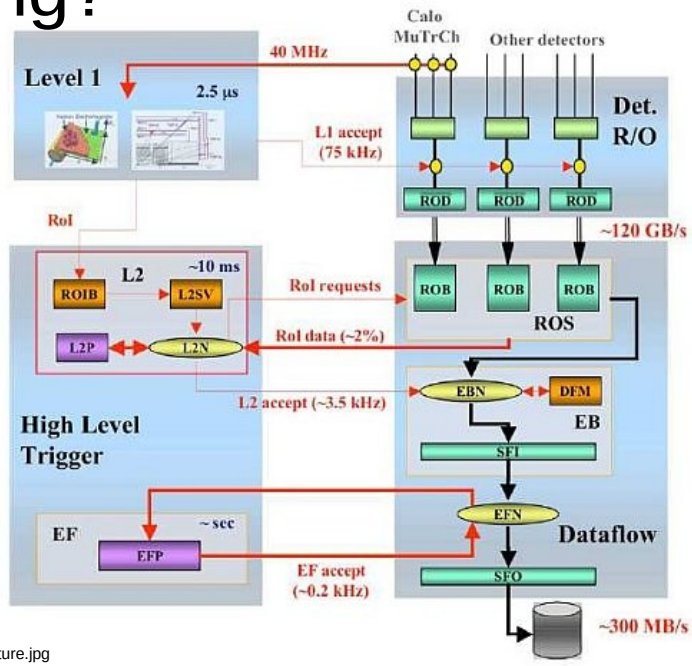
= 1 Google every 7 hours

https://what-if.xkcd.com/63/

Trigger Hierarchy

- Different levels of trigger:
  - Low level triggers “did something happen?”
  - Mid level triggers “was it a particle?”
  - High level triggers “was it interesting?”



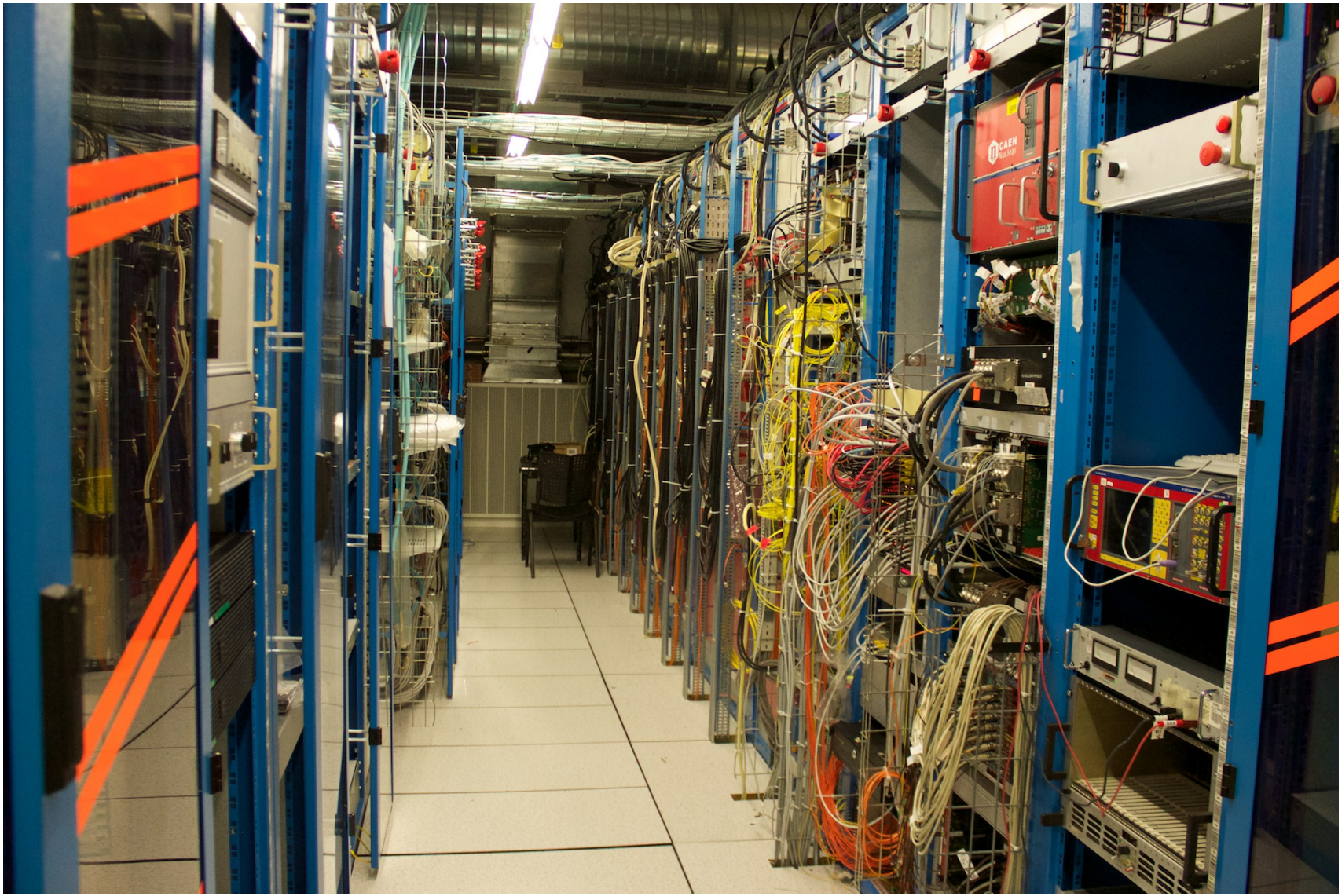


http://www.atlas.ch/photos/atlas_photos/selected-photos/events/JiveXML_152166_347262.png , http://www.fsp101-atlas.de/sites/site_fsp101-atlas/content/e197881/e200233/e200245/triggerarchitecture.jpg

Trigger Hardware

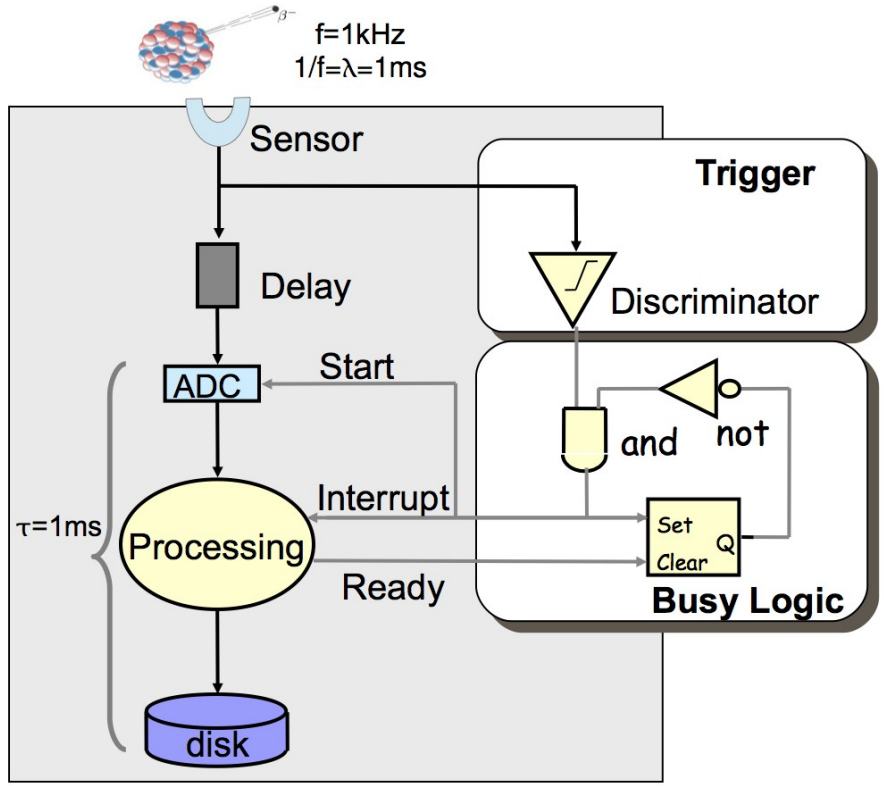
- Quick decisions need to be made *inside* the detector
- Mid level decisions are made in racks of hardware
- High level triggers involve event reconstruction in a cluster of computers.
- This is time consuming, so depends on low level triggers to cut out most events

Trigger Hardware



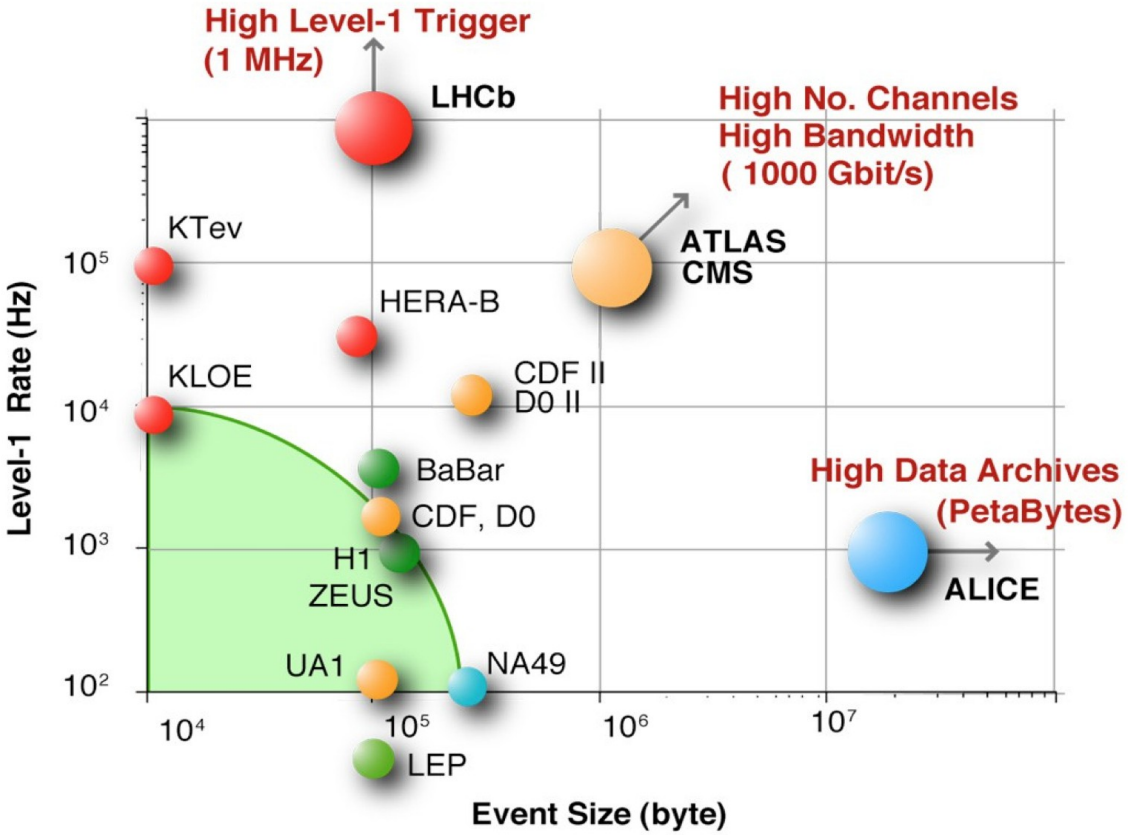
Pileup and Busy Logic

- Electronics have a rate limit
- When event rate ***exceeds*** limit: **pileup**
- **Busy logic** allows recovery
- Interrupts data to processing



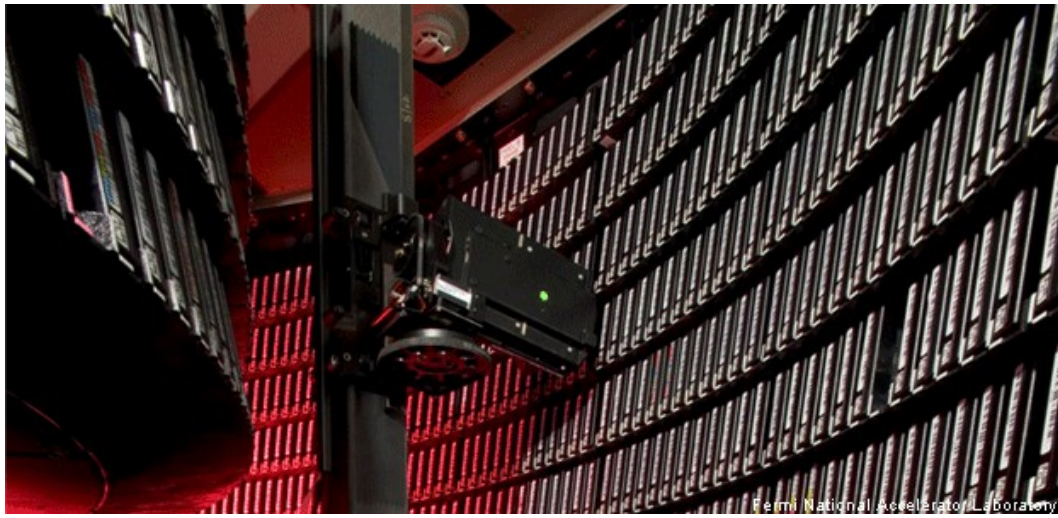
Vandelli Slides

Data Volume


High Level-1 Trigger
(1 MHz)
LHCb
High No. Channels
High Bandwidth
(1000 Gbit/s)
ATLAS
CMS
KTev
HERA-B
KLOE
CDF II
D0 II
BaBar
CDF, D0
H1
ZEUS
UA1
NA49
LEP
High Data Archives
(PetaBytes)
ALICE
Level-1 Rate (Hz)
Event Size (byte)
10⁵
10⁴
10³
10²
10⁴
10⁵
10⁶
10⁷

Data Storage Systems

- Cost ber GB:
  - Tape: $0.008
  - HDD: $0.05
  - SSD: $0.75
  - RAM: $5.50
- Sony: 185 TB per tape
- Quick access storage: tape carousel
- Long term storage: “pile of data tapes”
- Data is grouped into **events**, then into runs



Fermilab data tapes

Data Distribution

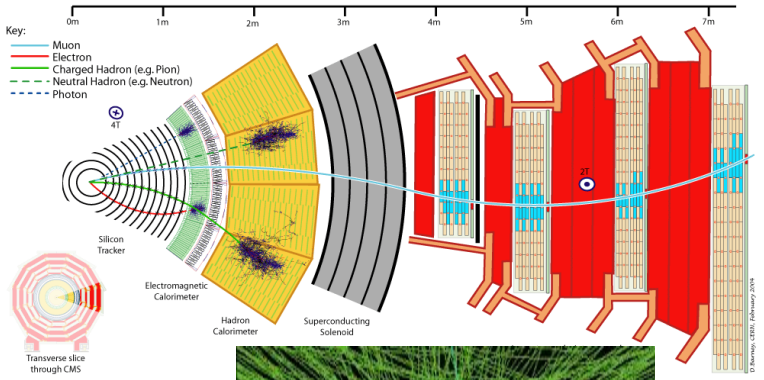
- The World Wide Web, invented at CERN to share data
- Worldwide LHC Computing Grid
  - 170 data centers
  - 30 Petabytes per year
  - 300 trillion events

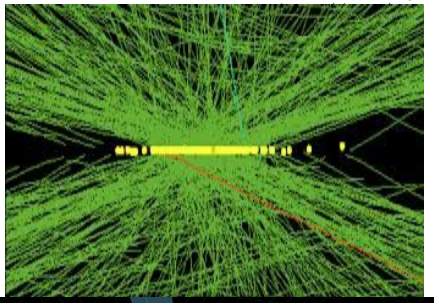
http://www.isgtw.org/sites/default/files/img_2011/CERN_Grid2.jpg

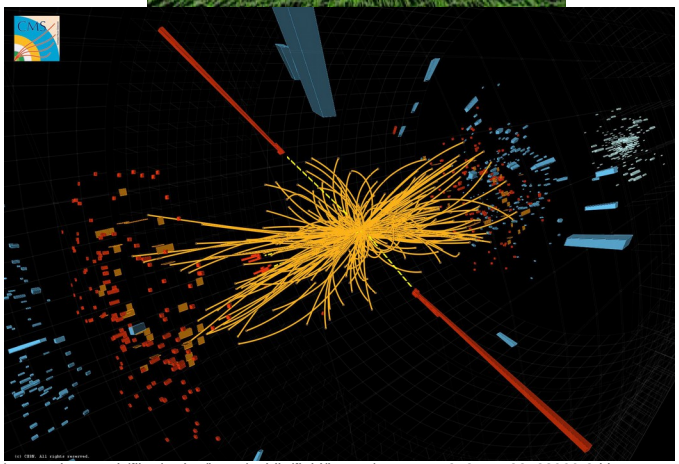
Analysis

Event Reconstruction

- Reconstruct tracks
  - Position (inner tracker)
  - Energy (Calorimeters)
  - Momentum (Magnetic bending)
- Reconstruct event
  - Multiple events coincident
  - Look for common interaction point
  - Filter out, get tracks from single event



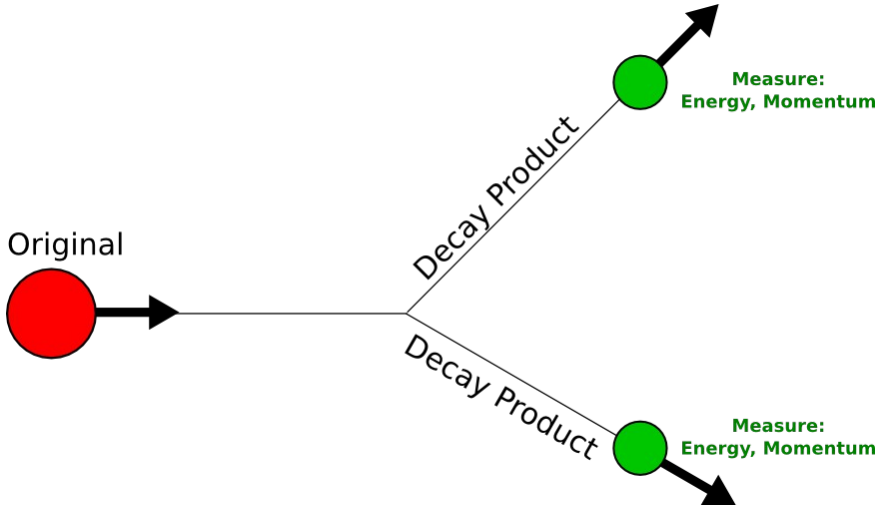




http://cms.web.cern.ch/sites/cms.web.cern.ch/files/styles/large/public/field/image/gg-run177878-evt188723900-3d.jpg

Mass Reconstruction

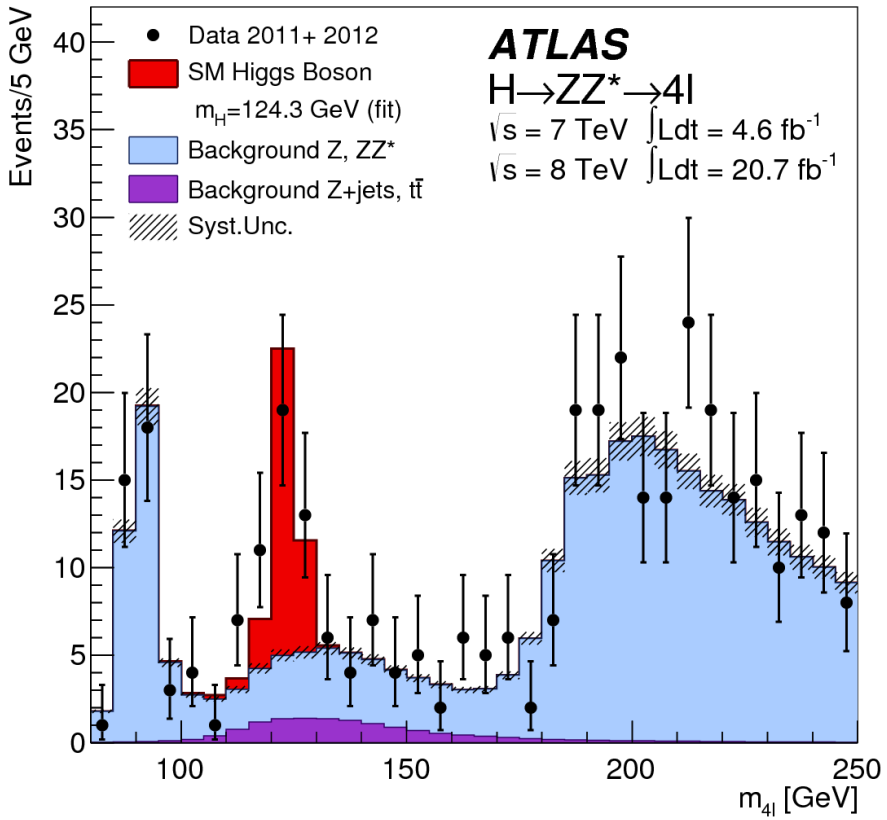
- Most particles decay by the time they reach the detector
- Reconstruct **original** from **decay products**

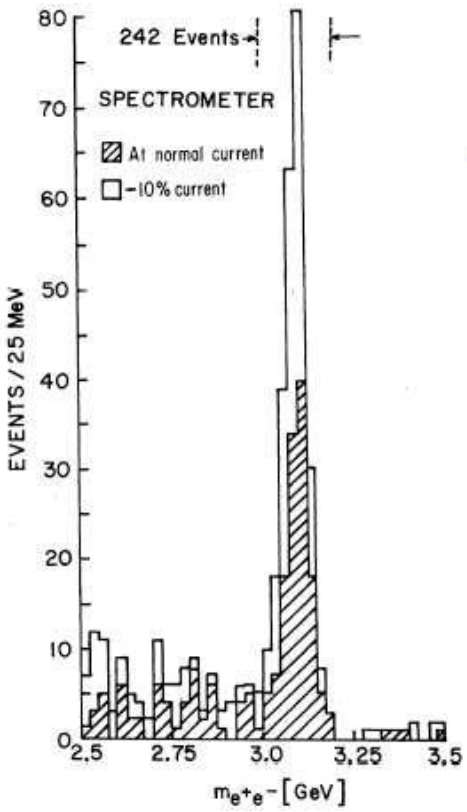


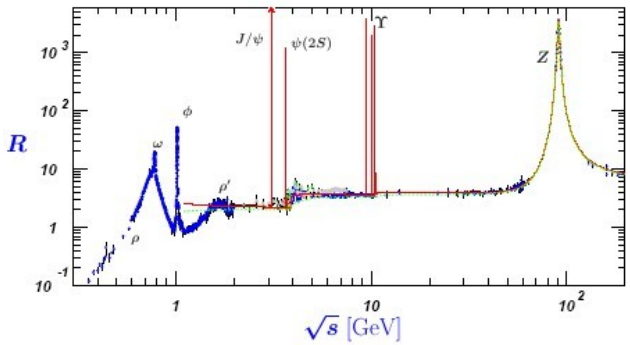
- How?
  - **Momentum**: original = product + product
  - **Mass** and **Energy**: original mass + energy = final mass + energy

Higgs and J/psi Discovery

- This is how new particles are discovered







http://dorigo.wordpress.com/2007/11/15/top-quark-a-short-history-part-i/

Monte Carlo Method

- Simulate many events in detector
- Predict
  - Acceptance
  - Expected rates
  - Backgrounds, notice blue under Higgs plot)
- How it works:
  - Event generator: statistical software, creates random sets of particles/momenta
  - Simulation: propagate through the detector, simulate hits
  - Reconstruction: use same software as for physics
  - Repeat- this is what makes it a Monte Carlo

The End