

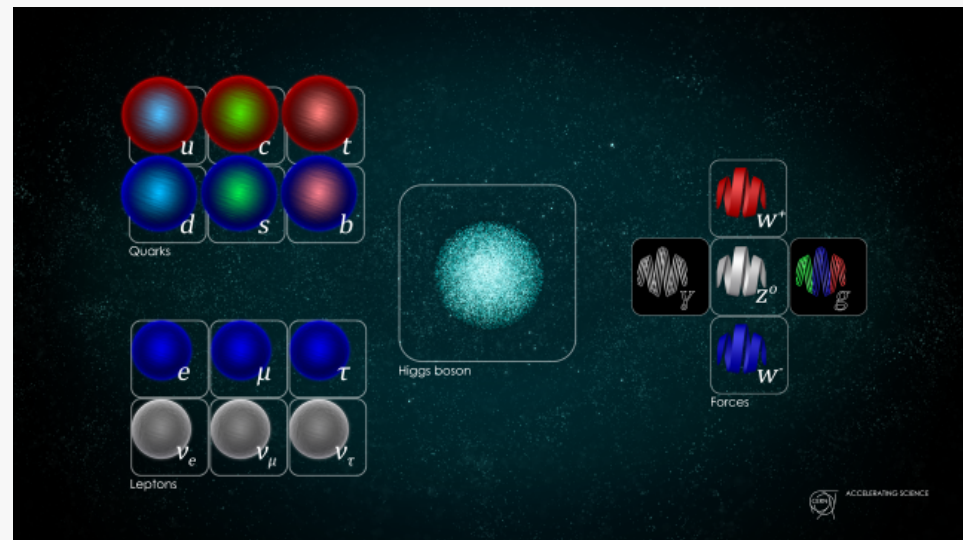
# *PROGRESSIVELY SHARPER ROCKS*

*Building the most advanced tools to answer the most basic questions*  
*Dr. Jesse Heilman*

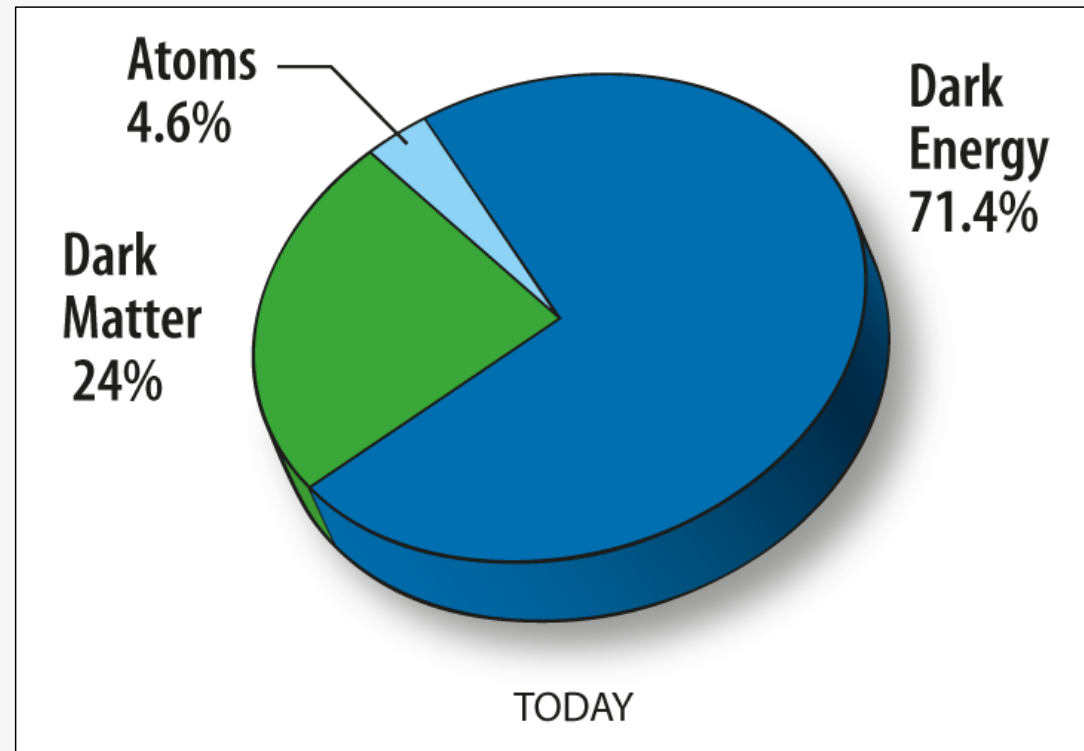
# Basic Science



# The Standard Model



# *Cracks in the Standard Model*



*The Large Hadron Collider*

# *A ROCK TO CUT GOD*

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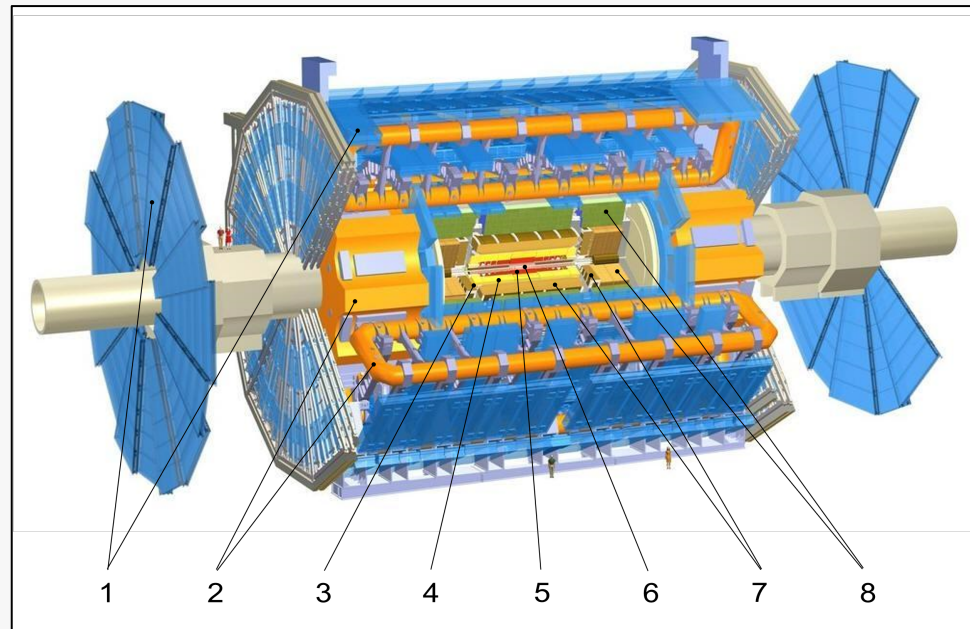
# *The Large Hadron Collider*

- 27 km particle collider ~100m under the Swiss-French border near Geneva
  - Nominal collision energy of 14 TeV
    - 40 MHz collision rate
- Utilizes superconducting magnets and radio frequency cavities to accelerate protons to replicate conditions immediately after the Big Bang



# *ATLAS: Precision on a Large Scale*

1. Muon Detectors
2. Toroid Magnets
3. Solenoid Magnet
4. Transition Radiation Tracker
5. Semi-Conductor Tracker
6. Pixel Detector
7. Liquid Argon Calorimeter
8. Tile Calorimeter



[http://commons.wikimedia.org/wiki/File:ATLAS\\_Drawing.jpg](http://commons.wikimedia.org/wiki/File:ATLAS_Drawing.jpg)

*Only take home the shiniest rocks*

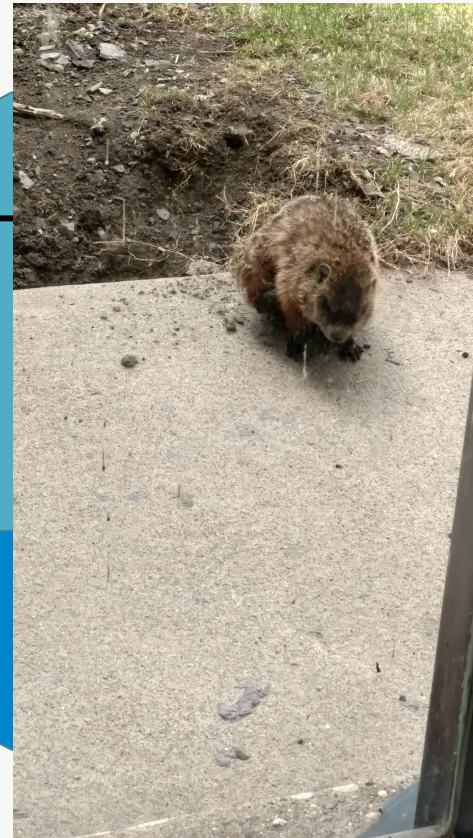
# *PULLING THE TRIGGER*

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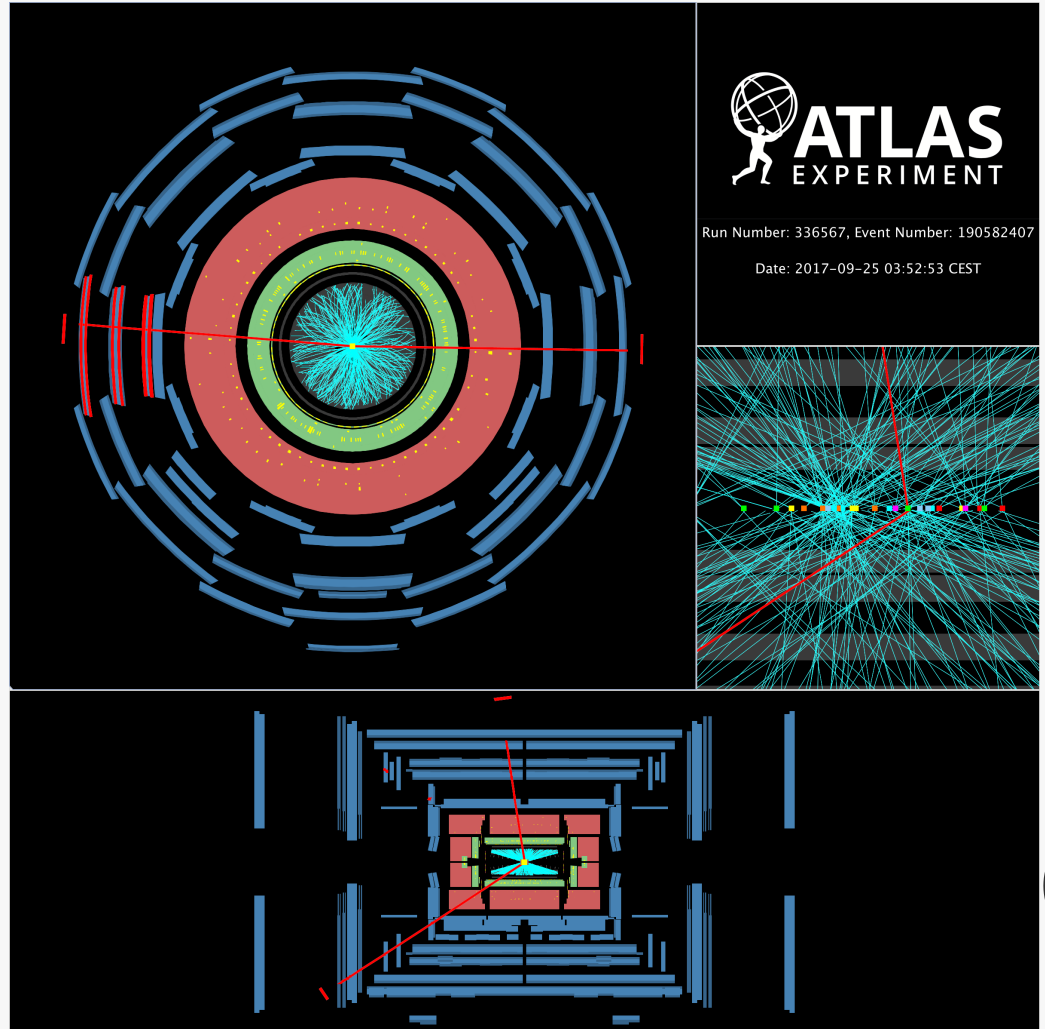
# *Too Many Pictures*

- LHC collision rate -> 40 MHz
    - Event size -> ~1.6 MB
    - Record all data -> ~70 TB/s
  - Global storage -> ~1,500,000,000 TB
  - ATLAS exhausts global storage in ~250 days
- 

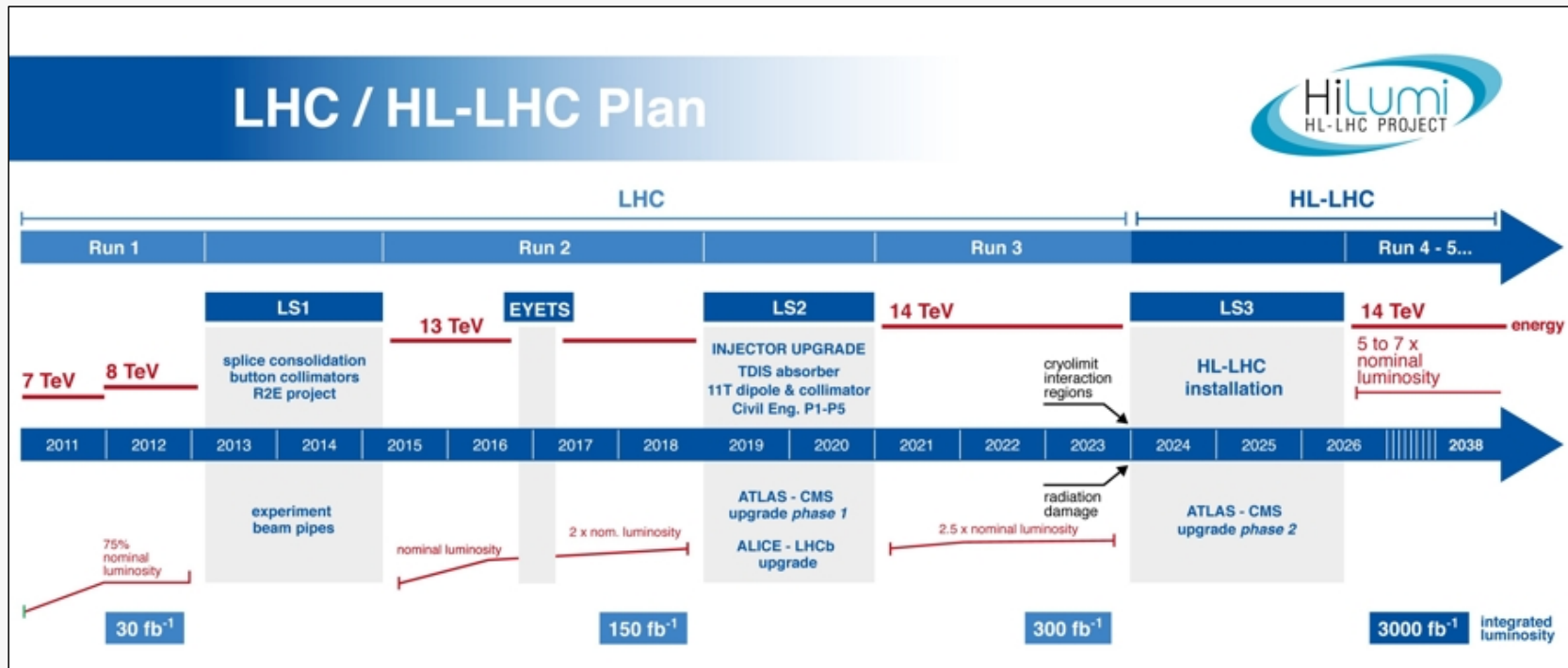


# *One in a Thousand*

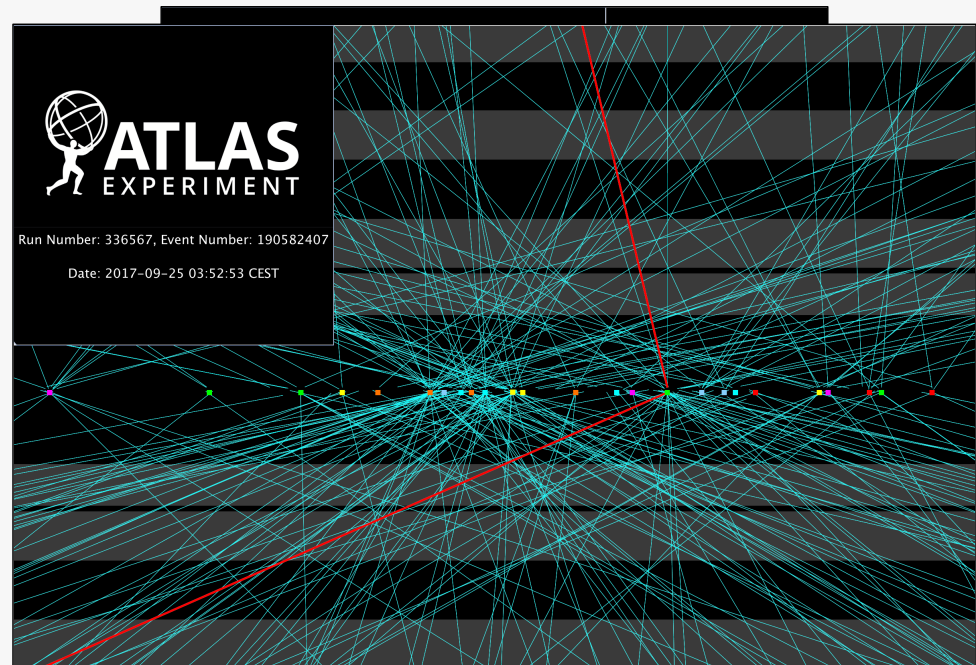
- Triggering selects interesting events
- Presence of basic signal structures programmed by physicists
- Trigger decisions must be processed faster than reconstruction
- ATLAS Phase-I trigger rate -> 100 kHz



# LHC Upgrades

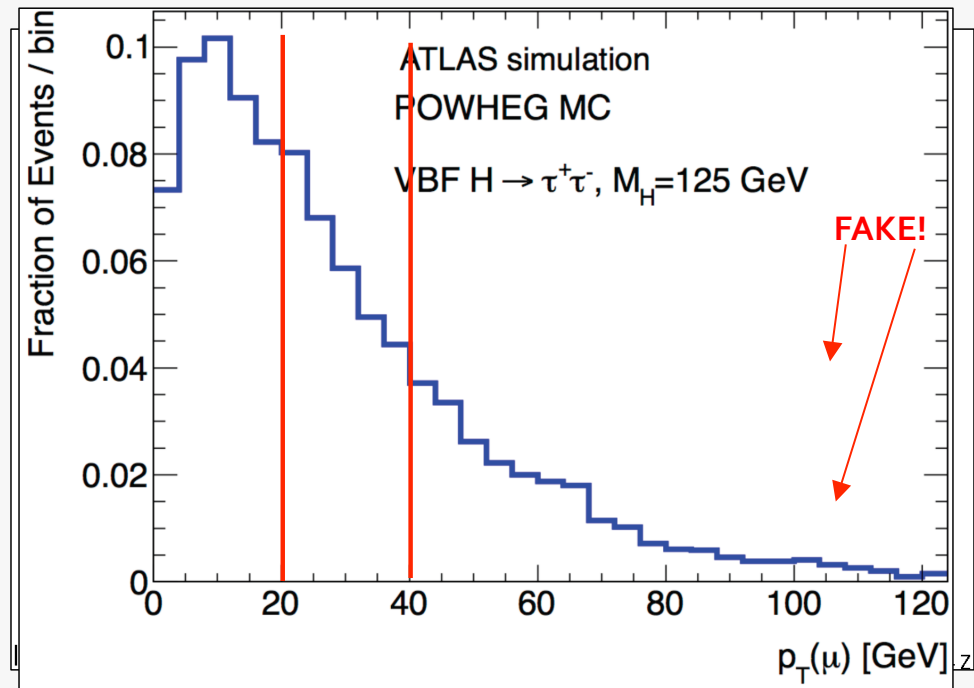


# *Many Overlapping Interactions*



# A Catastrophe of Fakes

- Raising  $p_T$  thresholds would maintain rate but degrade physics reach
- Currently many muon triggers are fakes
- Implementing triggering in the SW will reduce fake rate
- Reject objects that don't point back to the Interaction Point (IP)
- Faster tracking keeps occupancy low for high momentum tracks



# *HL-HLC Muon Trigger Rates*

| L1MU threshold (GeV)         | Level-1 rate (kHz) |
|------------------------------|--------------------|
| $p_T > 20$                   | $60 \pm 11$        |
| $p_T > 40$                   | $29 \pm 5$         |
| $p_T > 20$ barrel only       | $7 \pm 1$          |
| $p_T > 20$ with NSW          | $22 \pm 3$         |
| $p_T > 20$ with NSW and EIL4 | $17 \pm 2$         |

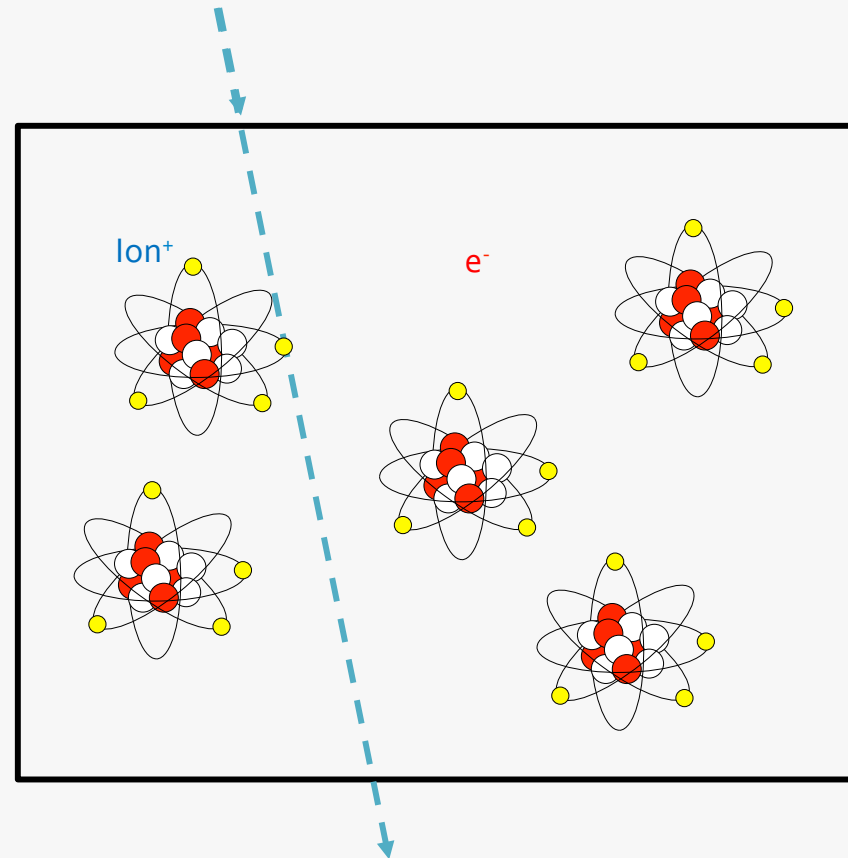
*A Primer on Gaseous Particle Detectors*

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# *AMPLIFYING BASIC INTERACTIONS*

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# *Particle Interactions with Matter*

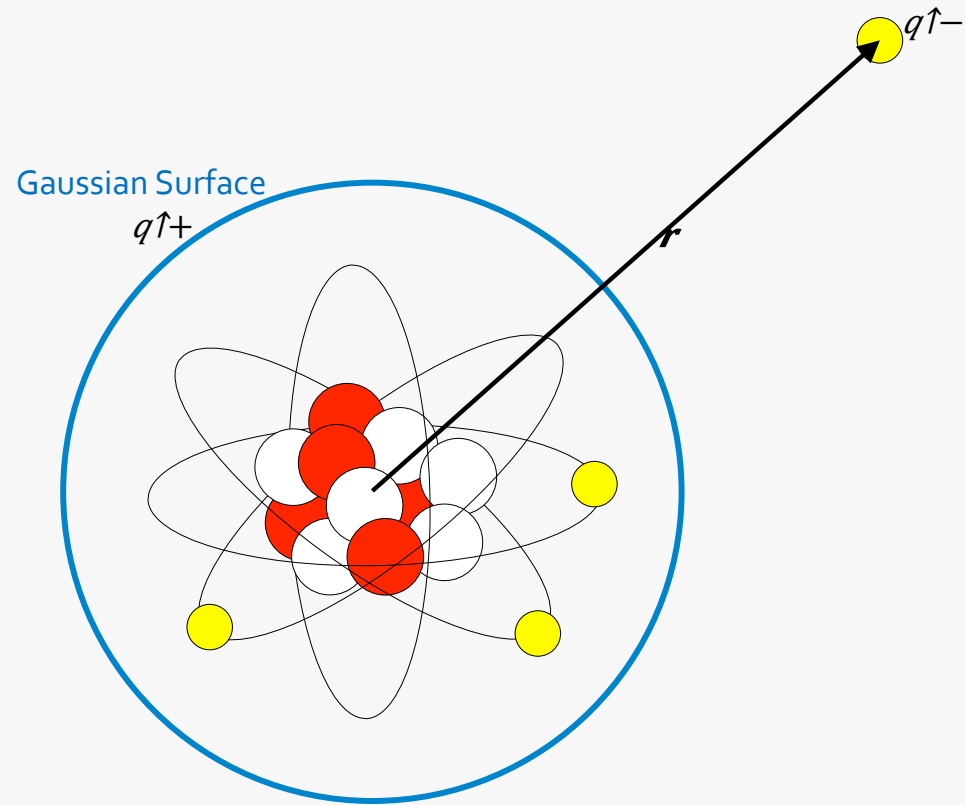




# Opposites Attract

$$\nabla \cdot \mathbf{E} = \rho / \epsilon_0$$

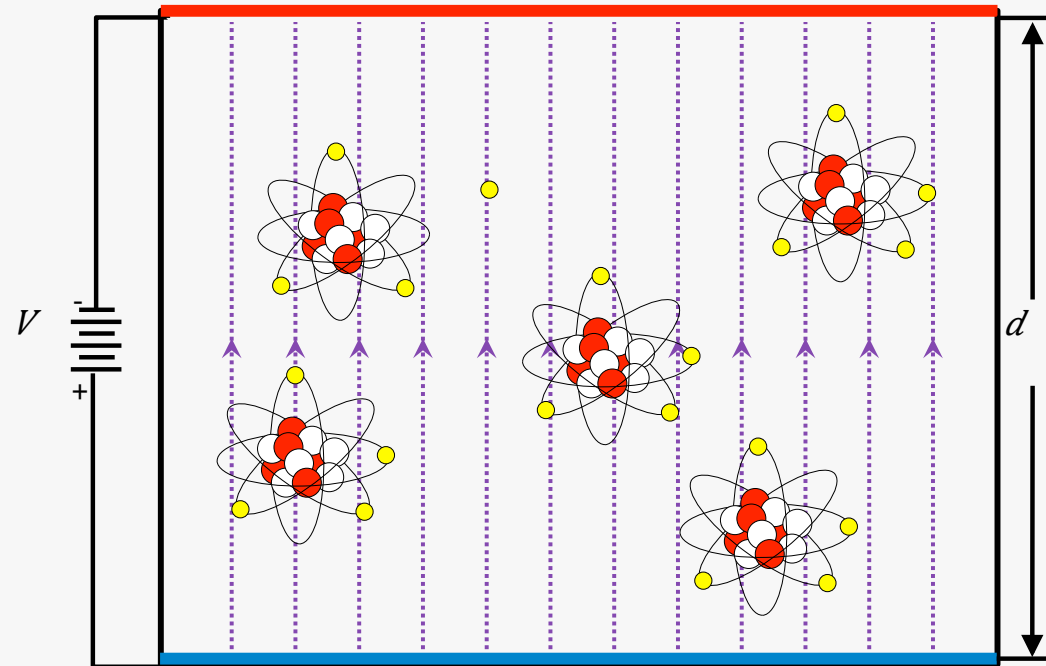
$$\mathbf{F} = k q_1 q_2 / r^2 \mathbf{r}$$



# Signal Collection

$$E = V/d$$

$$F = qE$$

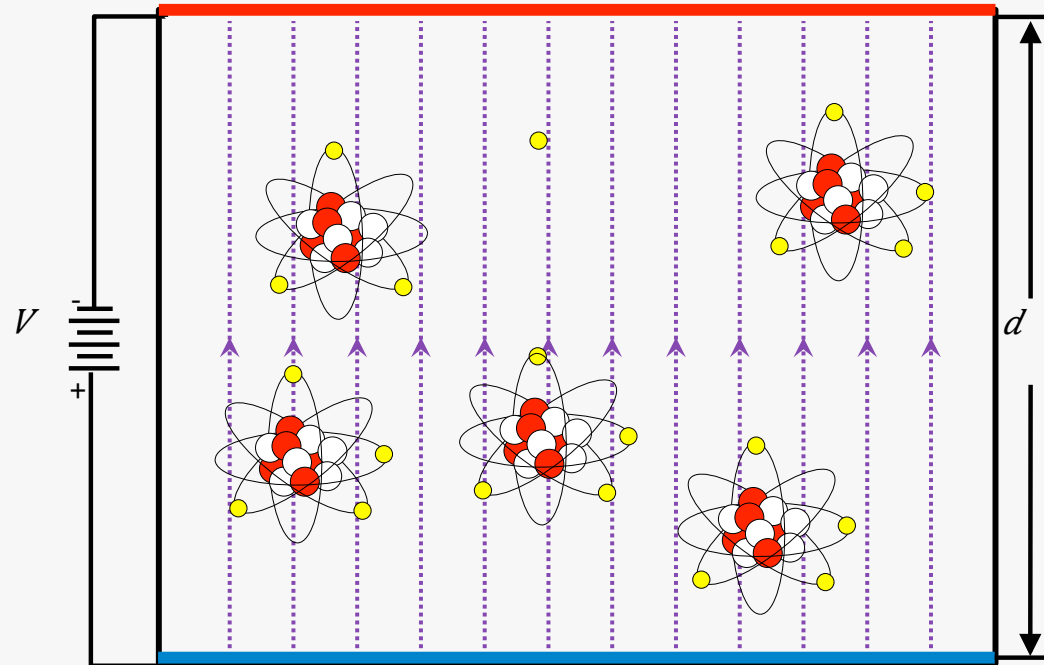


# Amplifying the Signal

$$E = V/d$$

$$F = qE$$

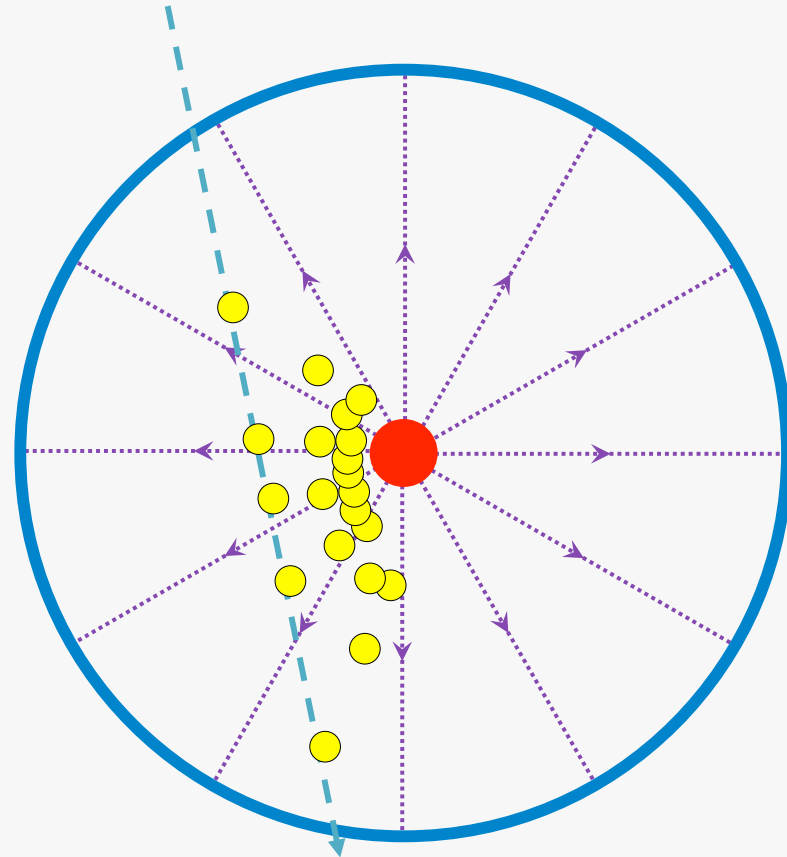
Signal Amplification  $\rightarrow$  Gain



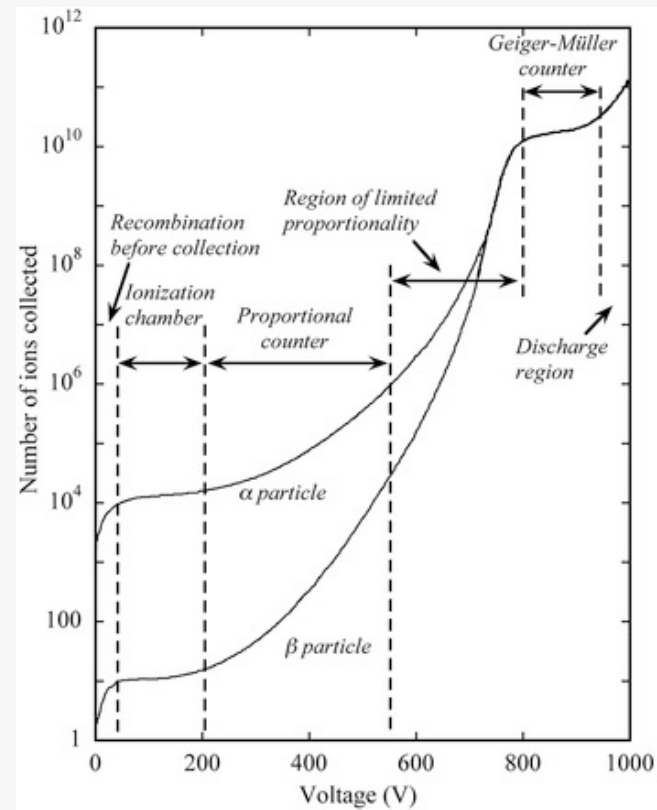
# Cylindrical Geometry

$$E = V/r \mathbf{r}$$

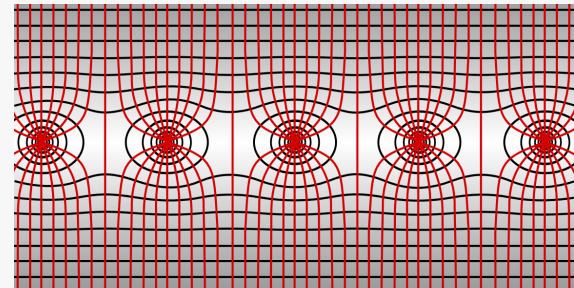
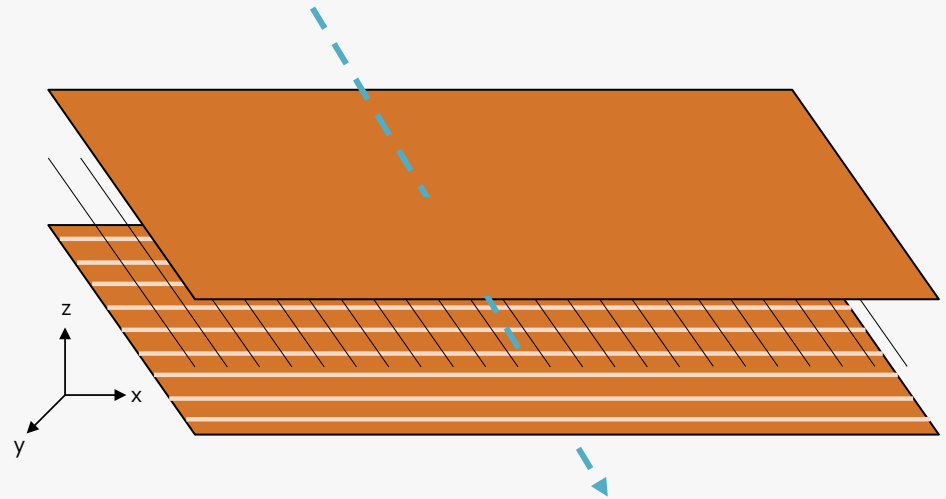
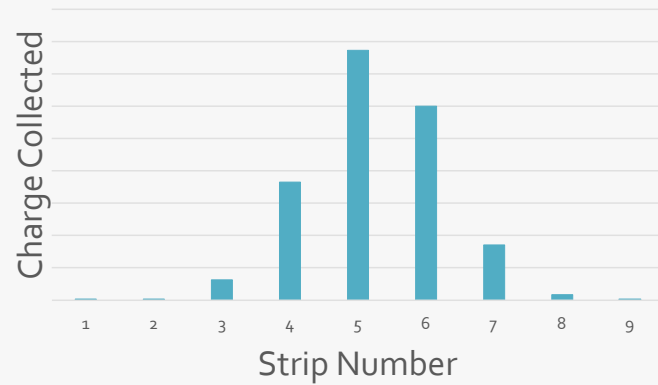
$$F = qE$$



# Operation Modes



*Our Name is  
Legion for  
We are  
Many*



[https://commons.wikimedia.org/wiki/  
File:MWPC\\_electric\\_field.svg](https://commons.wikimedia.org/wiki/File:MWPC_electric_field.svg)

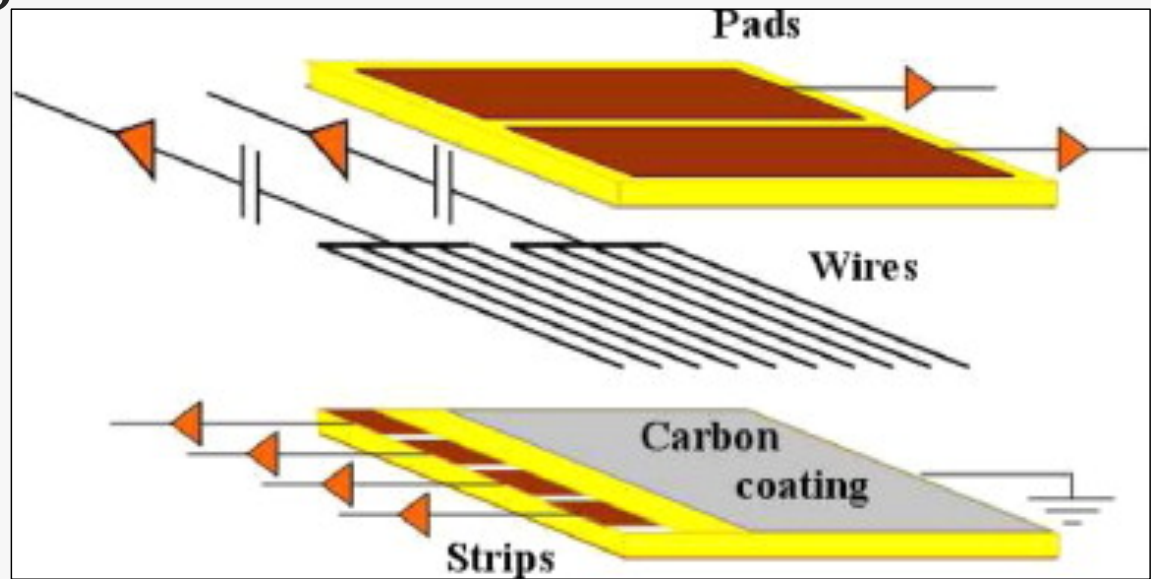
*Triggering and Reconstruction in One Package*

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*SMALL-STRIP THIN  
GAP CHAMBERS  
(STGC)*

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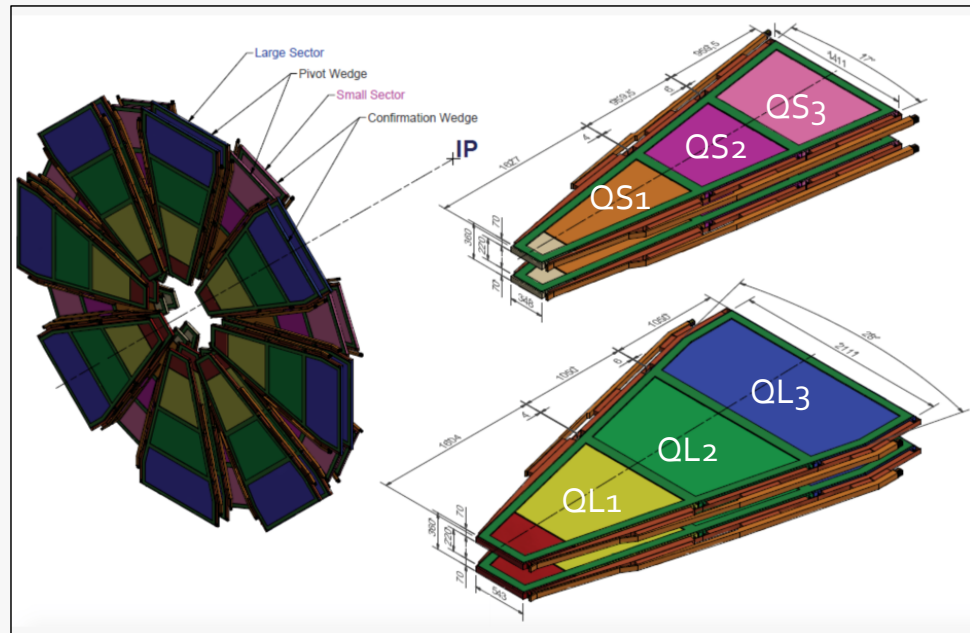
# ATLAS sTGCs



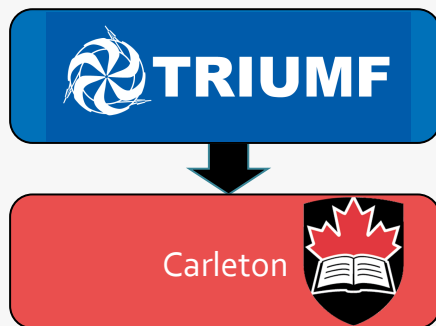


# *sTGC* Construction Effort

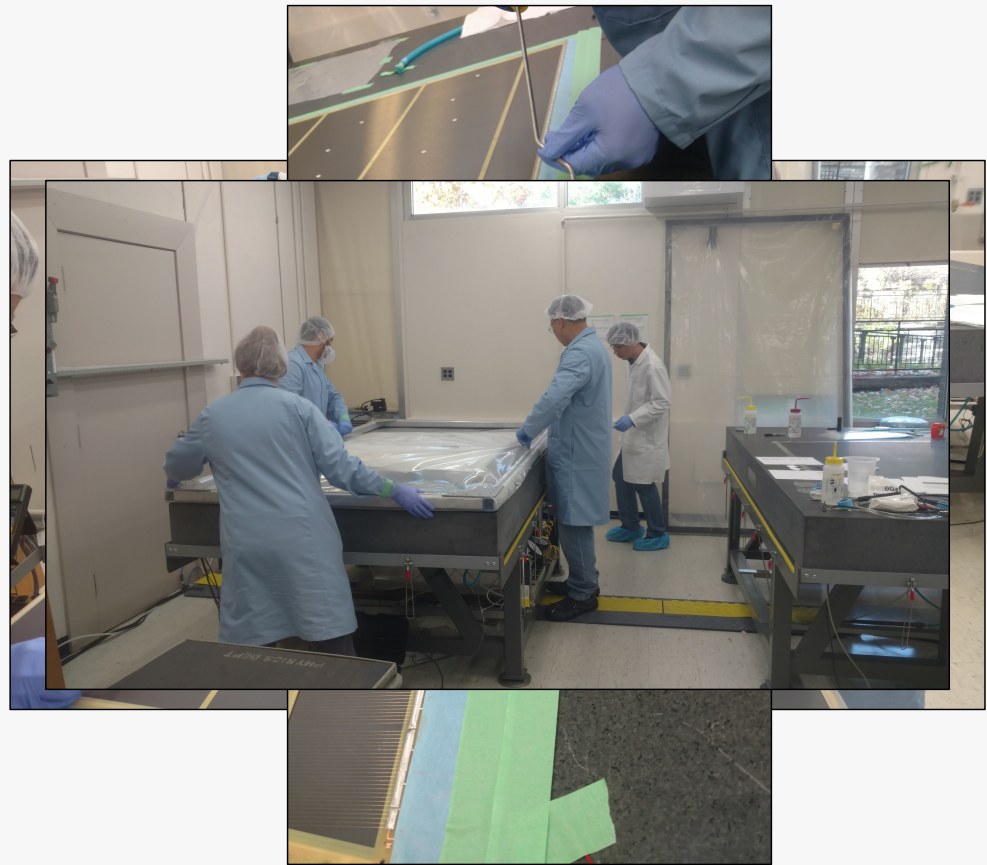
- Shared between five international construction sites (Canada, Chile, China, Israel, Russia)
  - QC acceptance of materials
  - sTGC assembly and testing
  - Readout chain and electronics integration and testing
- Installation and commissioning in the ATLAS Experimental Cavern



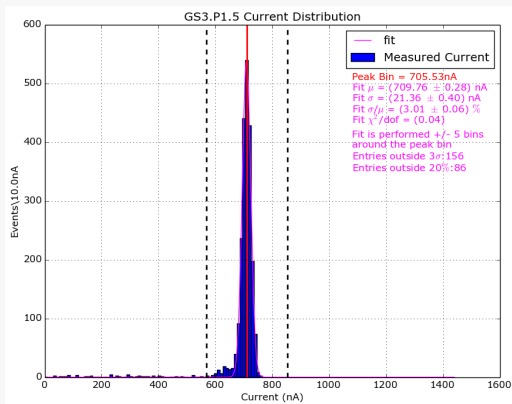
# *Canadian Construction Effort*



# *Carleton sTGC Assembly*



# *sTGC Gain Uniformity Testing*

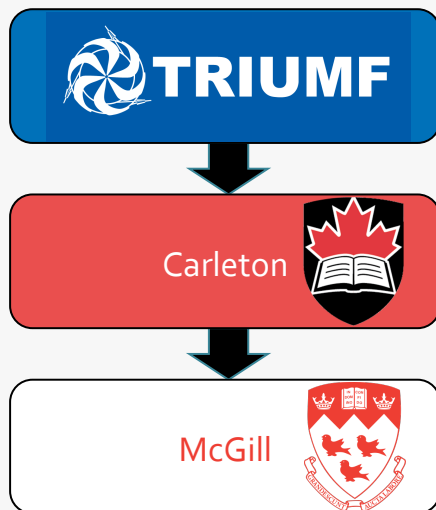


# *Installation of Signal Adapter Electronics*

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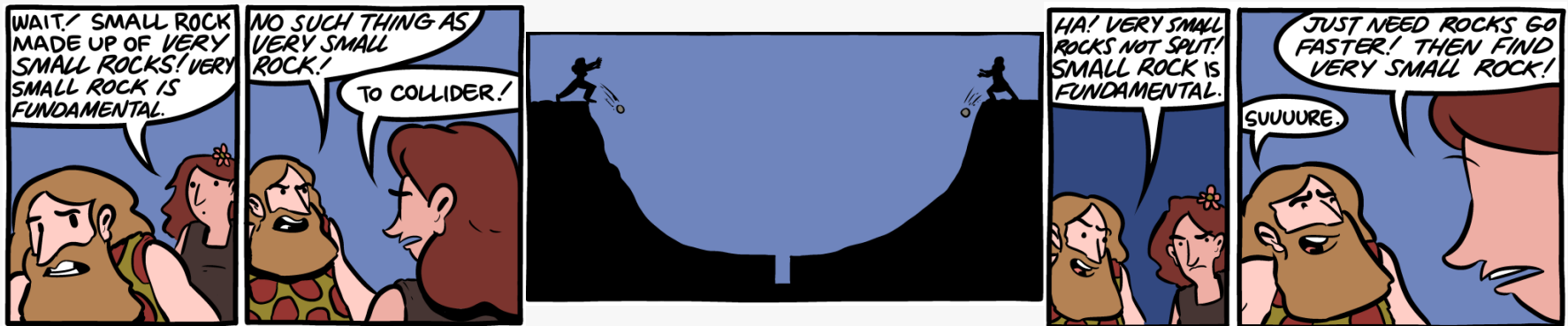
# *Canadian Construction Effort*



# *Leveraging Powerful Tools*

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- ATLAS Muon Spectrometer is an integral part of many searches
- sTGC and NSW will enhance ATLAS's ability to make precision measurements of muons from collisions
- sTGC production underway worldwide
  - Canadian production in full swing
- Involved in many search strategies
  - Top Physics
  - Higgs searches
  - Standard Model measurements
  - Etc



“Remember...a CPU is literally a rock that we tricked into thinking”

-@daisyowl