# Superheroes in STEM: Keynote

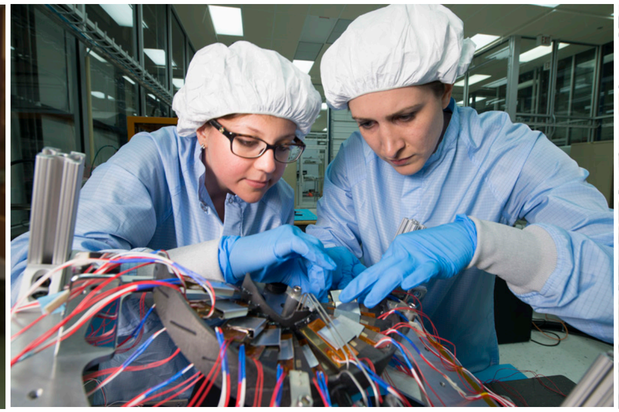
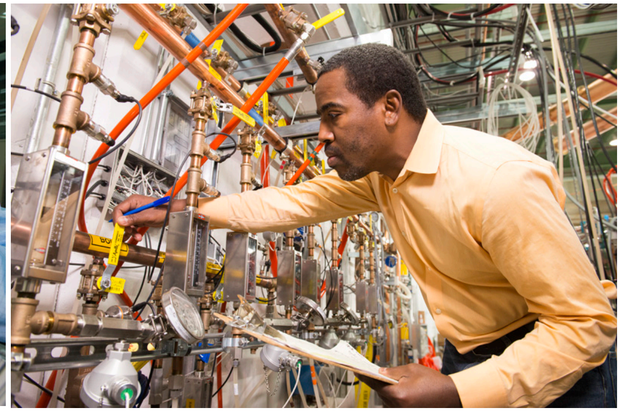
**Dr. Bo Jayatilaka**

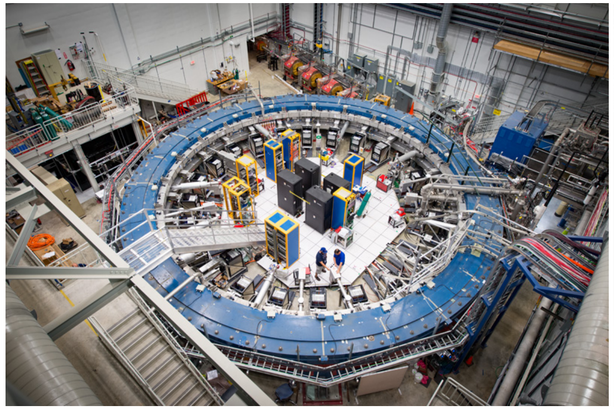
*Scientist, Fermilab*

November 16, 2019

# Welcome to Fermilab!

- **America's particle physics and accelerator laboratory**
- Over 1800 employees including scientists and engineers from around the world
- Collaborates with more than 50 countries on physics experiments



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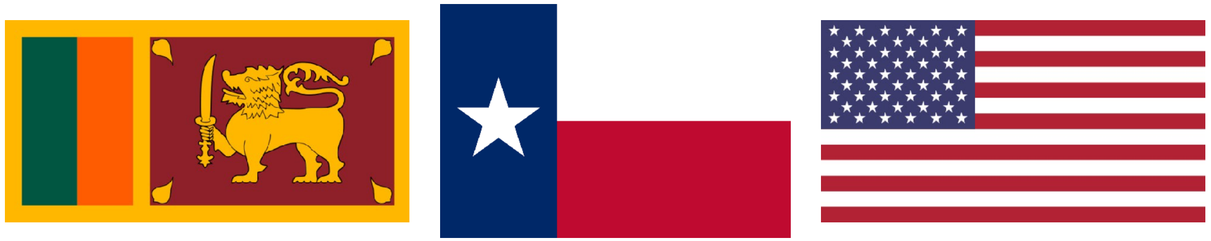

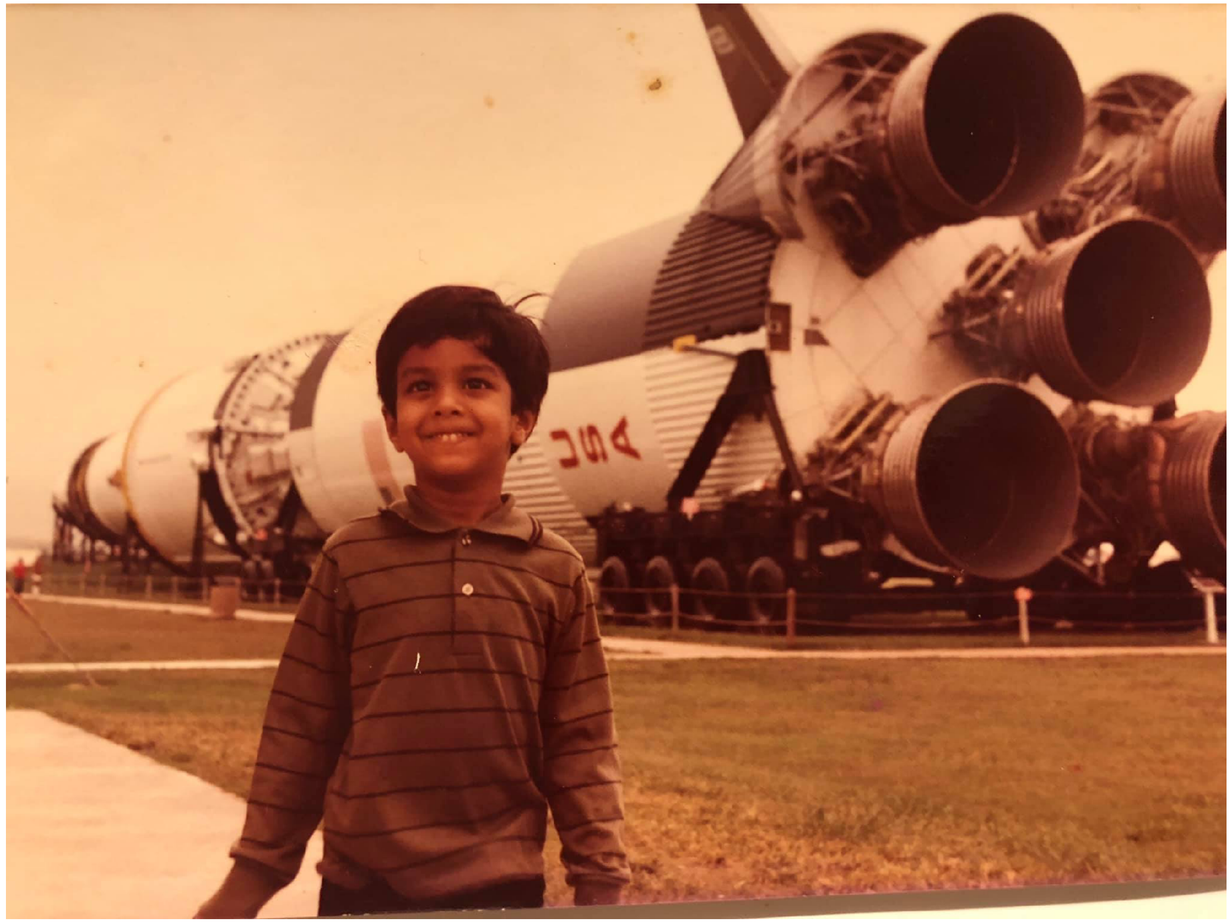

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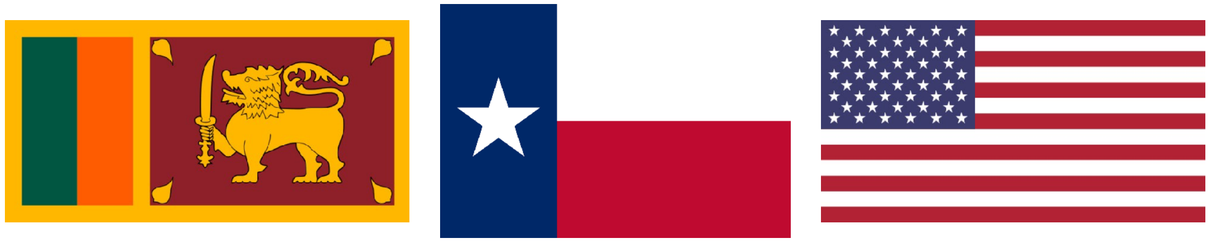

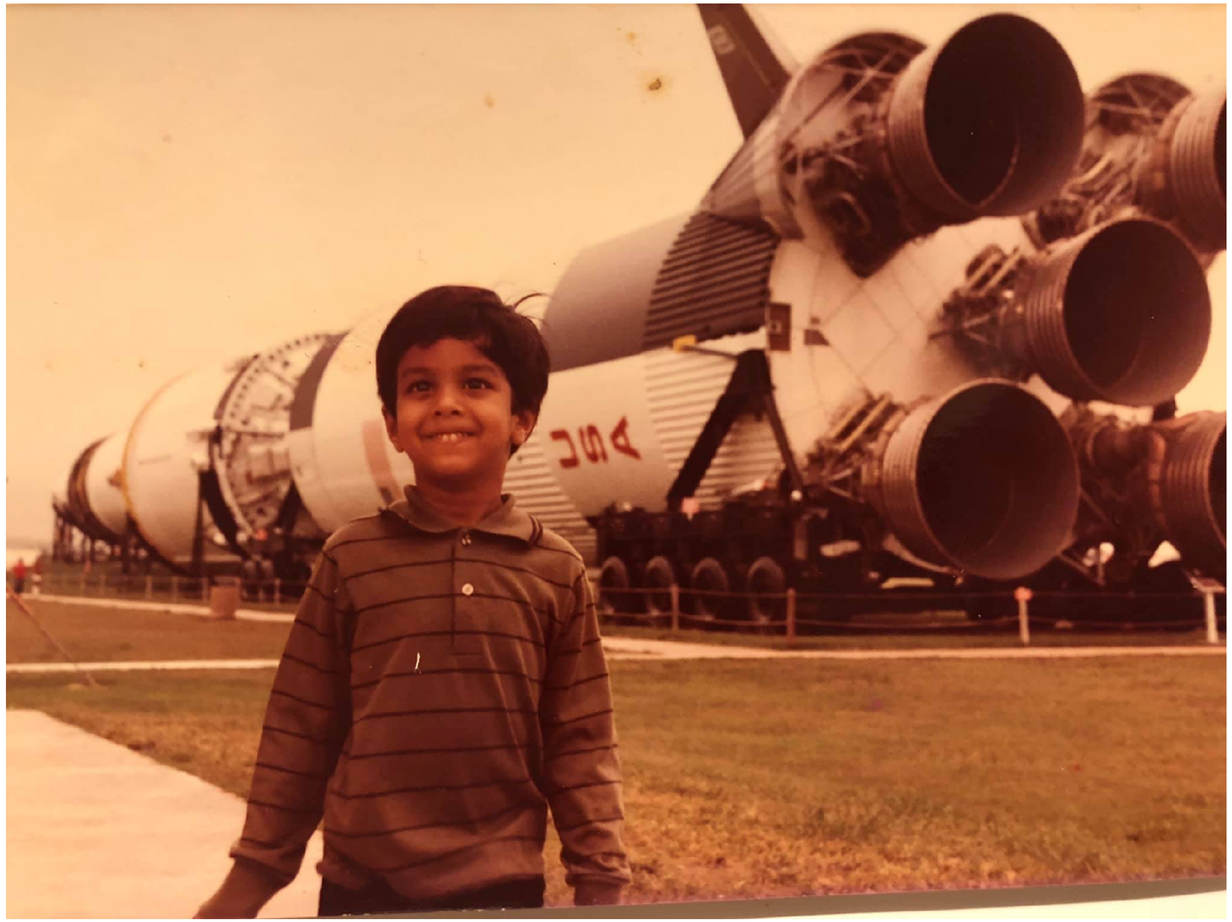

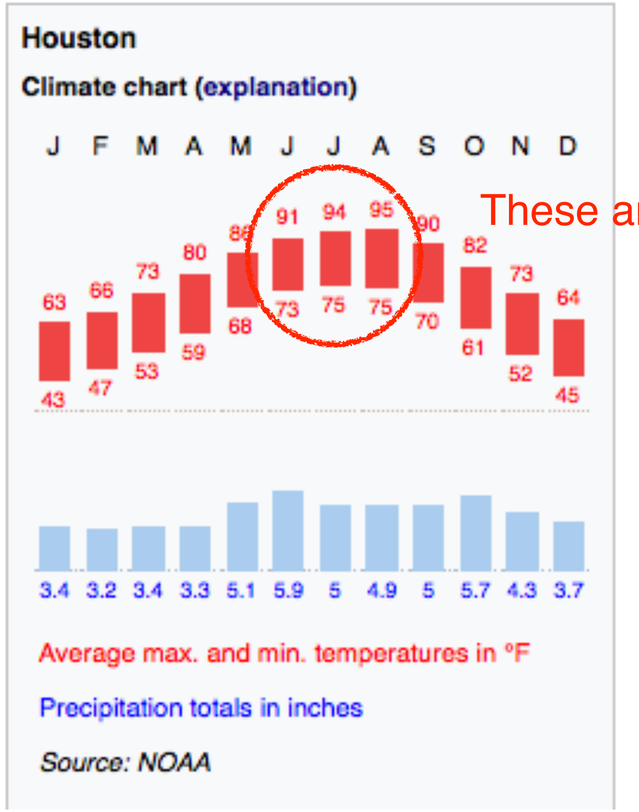


These are averages!

# Getting into physics

Getting a backyard telescope

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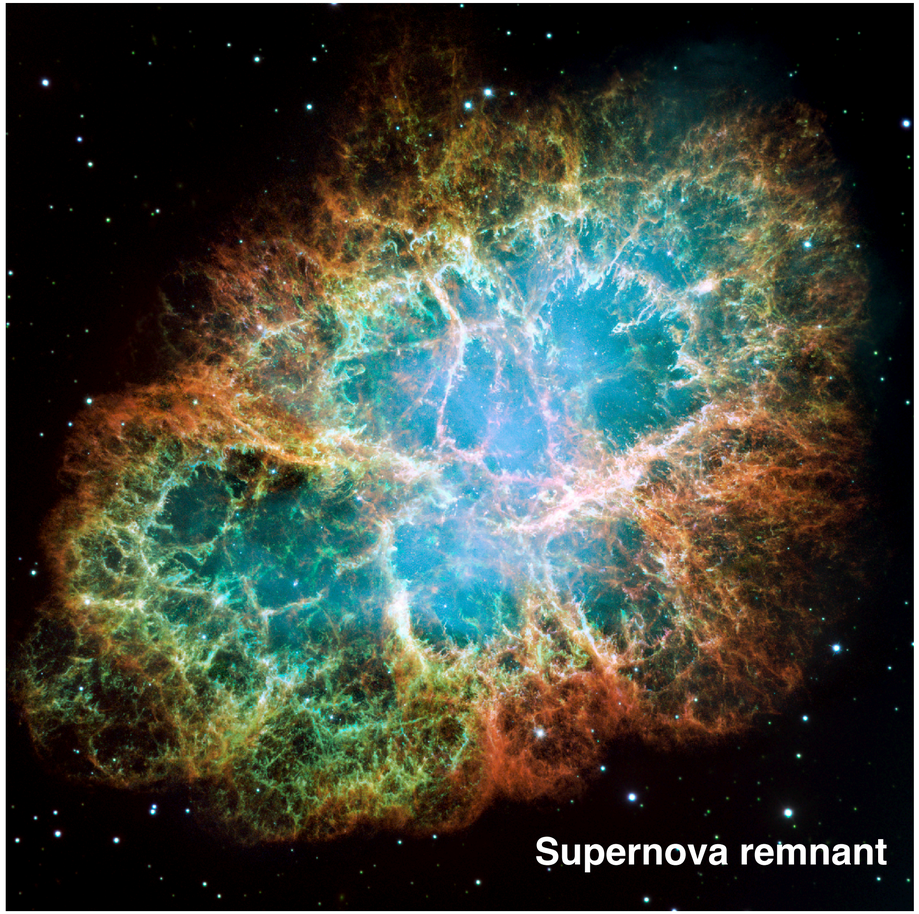
Getting a backyard telescope

**Carl Sagan:**

*The nitrogen in our DNA, the calcium in our teeth, the iron in our blood, the carbon in our apple pies were made in the interiors of collapsing stars.* ***We are made of starstuff.***



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This was hard!

# Getting into particle physics

## Categorizing matter: the periodic table

| Group → / Period ↓ | 1 | 2 | 3 | | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 H | | | | | | | | | | | | | | | | | | 2 He |
| 2 | 3 Li | 4 Be | | | | | | | | | | | | 5 B | 6 C | 7 N | 8 O | 9 F | 10 Ne |
| 3 | 11 Na | 12 Mg | | | | | | | | | | | | 13 Al | 14 Si | 15 P | 16 S | 17 Cl | 18 Ar |
| 4 | 19 K | 20 Ca | 21 Sc | | 22 Ti | 23 V | 24 Cr | 25 Mn | 26 Fe | 27 Co | 28 Ni | 29 Cu | 30 Zn | 31 Ga | 32 Ge | 33 As | 34 Se | 35 Br | 36 Kr |
| 5 | 37 Rb | 38 Sr | 39 Y | | 40 Zr | 41 Nb | 42 Mo | 43 Tc | 44 Ru | 45 Rh | 46 Pd | 47 Ag | 48 Cd | 49 In | 50 Sn | 51 Sb | 52 Te | 53 I | 54 Xe |
| 6 | 55 Cs | 56 Ba | 57 La | * | 72 Hf | 73 Ta | 74 W | 75 Re | 76 Os | 77 Ir | 78 Pt | 79 Au | 80 Hg | 81 Tl | 82 Pb | 83 Bi | 84 Po | 85 At | 86 Rn |
| 7 | 87 Fr | 88 Ra | 89 Ac | * * | 104 Rf | 105 Db | 106 Sg | 107 Bh | 108 Hs | 109 Mt | 110 Ds | 111 Rg | 112 Cn | 113 Nh | 114 Fl | 115 Mc | 116 Lv | 117 Ts | 118 Og |
| | | | | * | 58 Ce | 59 Pr | 60 Nd | 61 Pm | 62 Sm | 63 Eu | 64 Gd | 65 Tb | 66 Dy | 67 Ho | 68 Er | 69 Tm | 70 Yb | 71 Lu | |
| | | | | * * | 90 Th | 91 Pa | 92 U | 93 Np | 94 Pu | 95 Am | 96 Cm | 97 Bk | 98 Cf | 99 Es | 100 Fm | 101 Md | 102 No | 103 Lr | |



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# Getting into particle physics

## Categorizing matter: the periodic table

Dmitri Mendeleev's Periodic table: 1866

**Atoms as basic building blocks of matter**

**ОПЫТЪ СИСТЕМЫ ЭЛЕМЕНТОВЪ,**

ОСНОВАННОЙ НА ИХЪ АТОМНОМЪ ВѢСѢ И ХИМИЧЕСКОМЪ СХОДСТВѢ.

| | | | | | |
|---|---|---|---|---|---|
| | | | Ti=50 | Zr= 90 | ?=180. |
| | | | V=51 | Nb= 94 | Ta=182. |
| | | | Cr=52 | Mo= 96 | W=186. |
| | | | Mn=55 | Rh=104,4 | Pt=197,1. |
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| Li=7 | Na=23 | K=39 | Rb=85,4 | Cs=133 | Tl=204. |
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Д. Менделѣевъ



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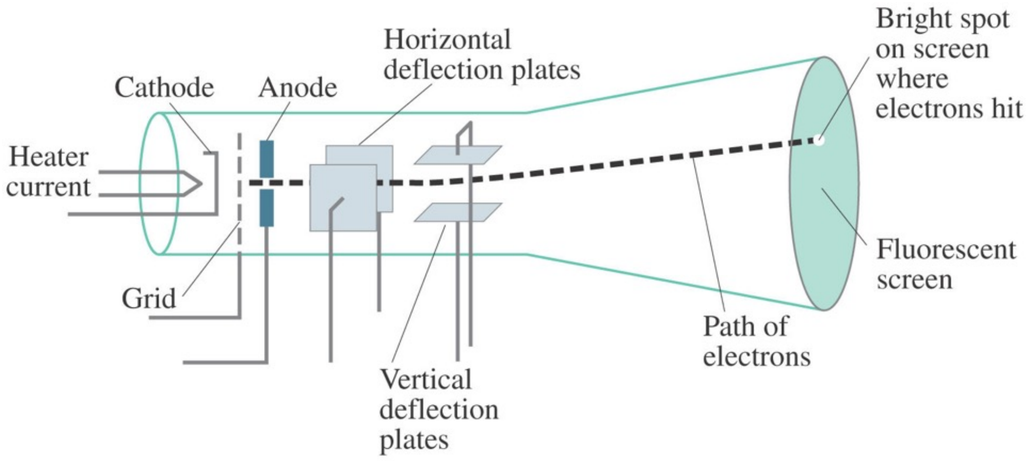
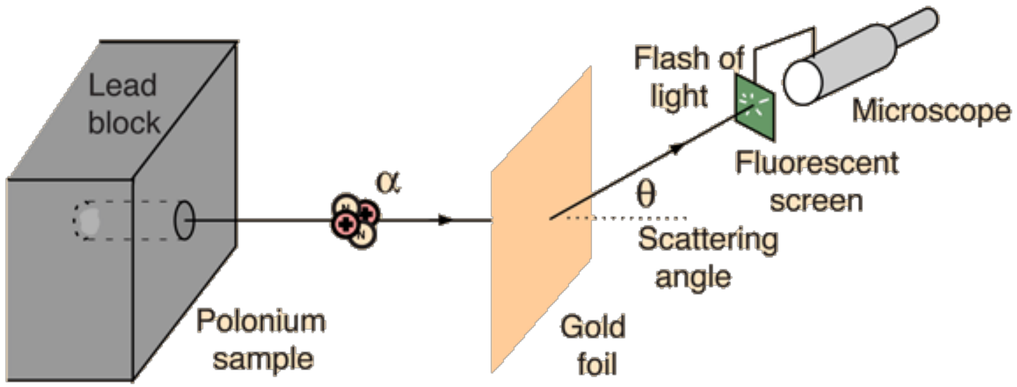
# Getting into particle physics

From atoms to the subatomic

## J. J. Thompson: Discovery of the electron (1897)




## E. Rutherford: Discovery of the nucleus (1909)




*Early uses of particle accelerators and detectors. What drives the science at Fermilab today!*

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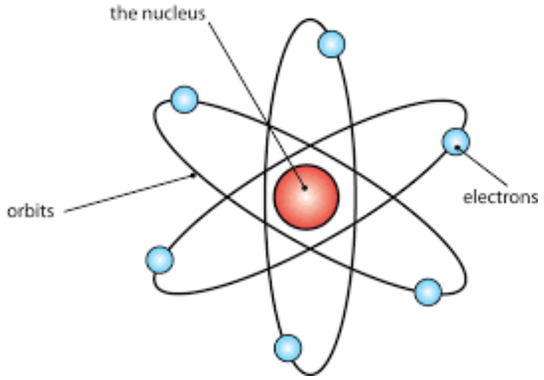



Early 20th century:

**Protons, neutrons, and electrons as building blocks**

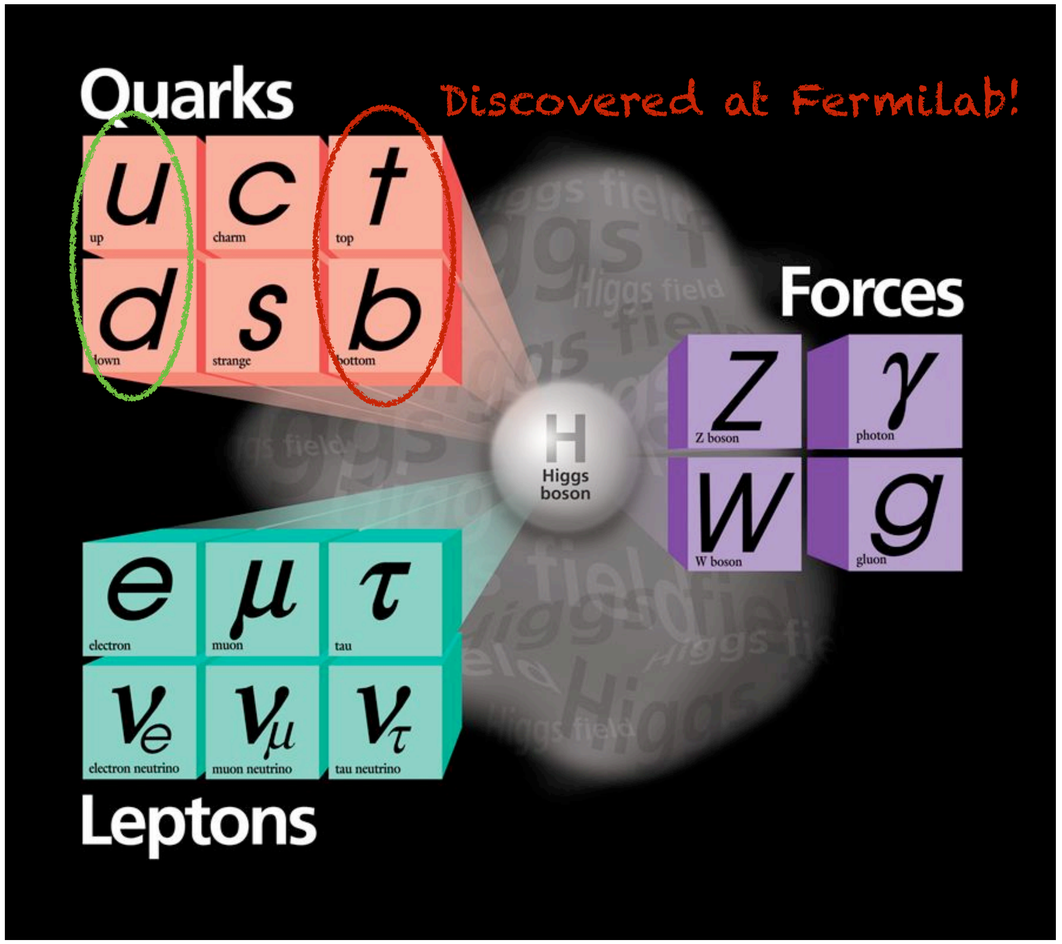


Fermilab

# Getting into particle physics

These make up protons and neutrons

Categorizing ~~matter~~ everything: the standard model of particle physics



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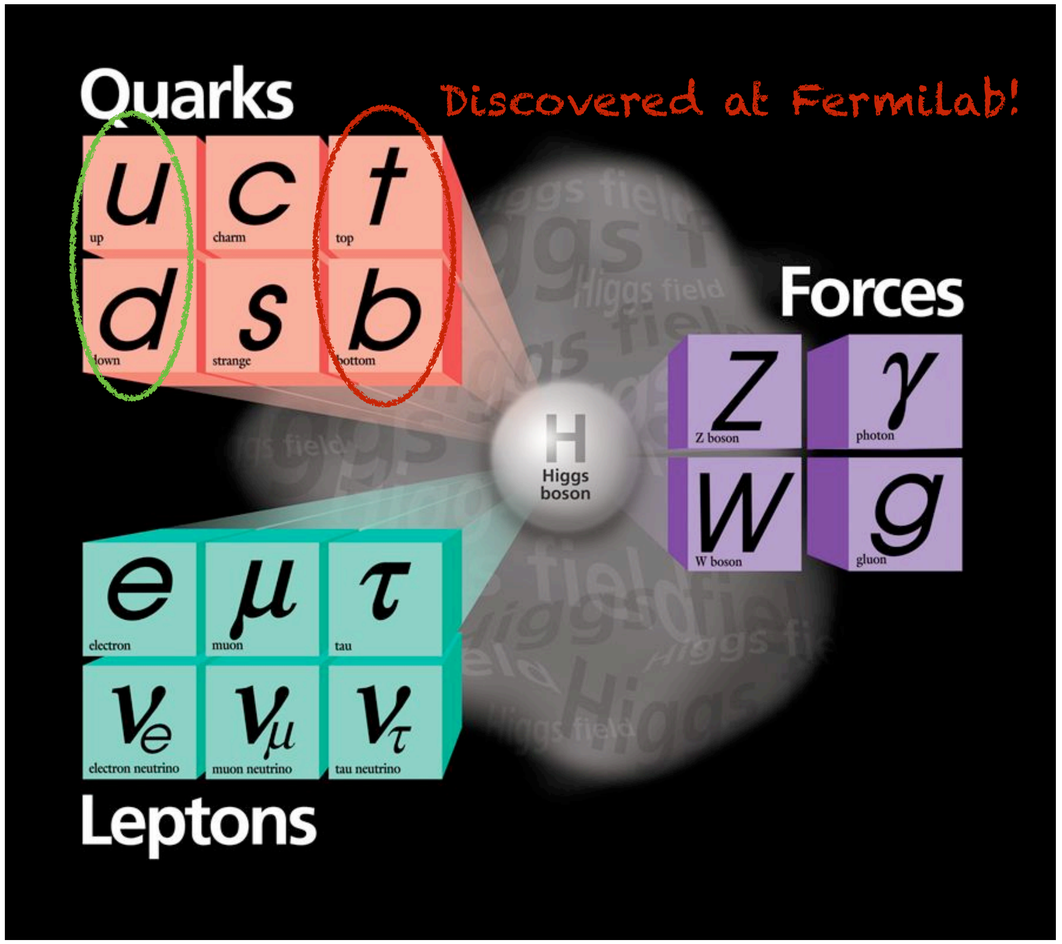
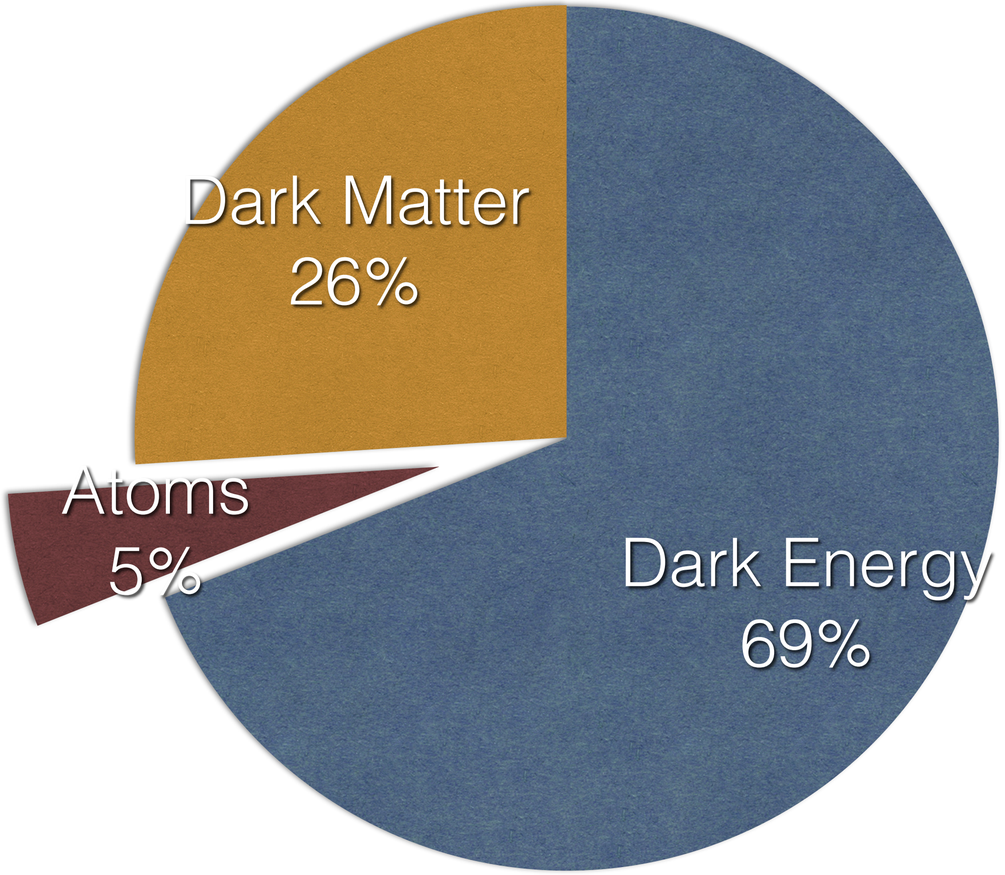
These make up protons and neutrons

Categorizing ~~matter~~: the standard model of particle physics

everything that we know of!



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Going to school for a PhD is free AND they pay you!

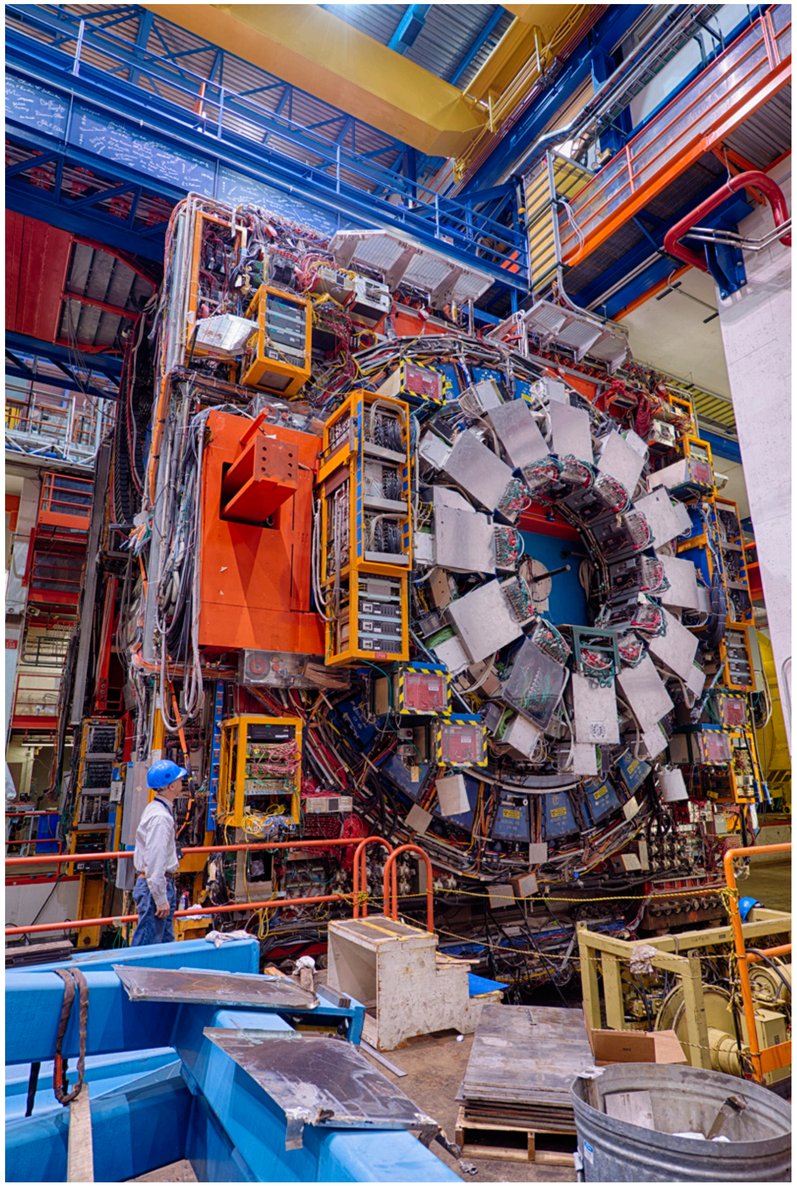
# Grad school research: The Fermilab Tevatron

- A proton antiproton **collider**
  - **4 miles** in circumference
  - Used **superconducting magnets** to accelerate particles
  - Ran from 1992-1996 and 2002-2011
  - Two detectors **CDF and D0** studied collisions
    - **Discovered the top quark in 1995**

- Large scientific collaborations
  - Each of CDF and D0 had **over 500 physicists collaborating**

# Grad school research: CDF

- Grad school
  - Measured the **mass of the top quark**
  - Helped **test and install detector electronics**
  - Wrote **software** used to analyze data
- Awarded a PhD after four years
  - Wrote a dissertation (130 pages!)
  - Presented my research to a committee of professors
  - Got to wear a slightly fancier robe



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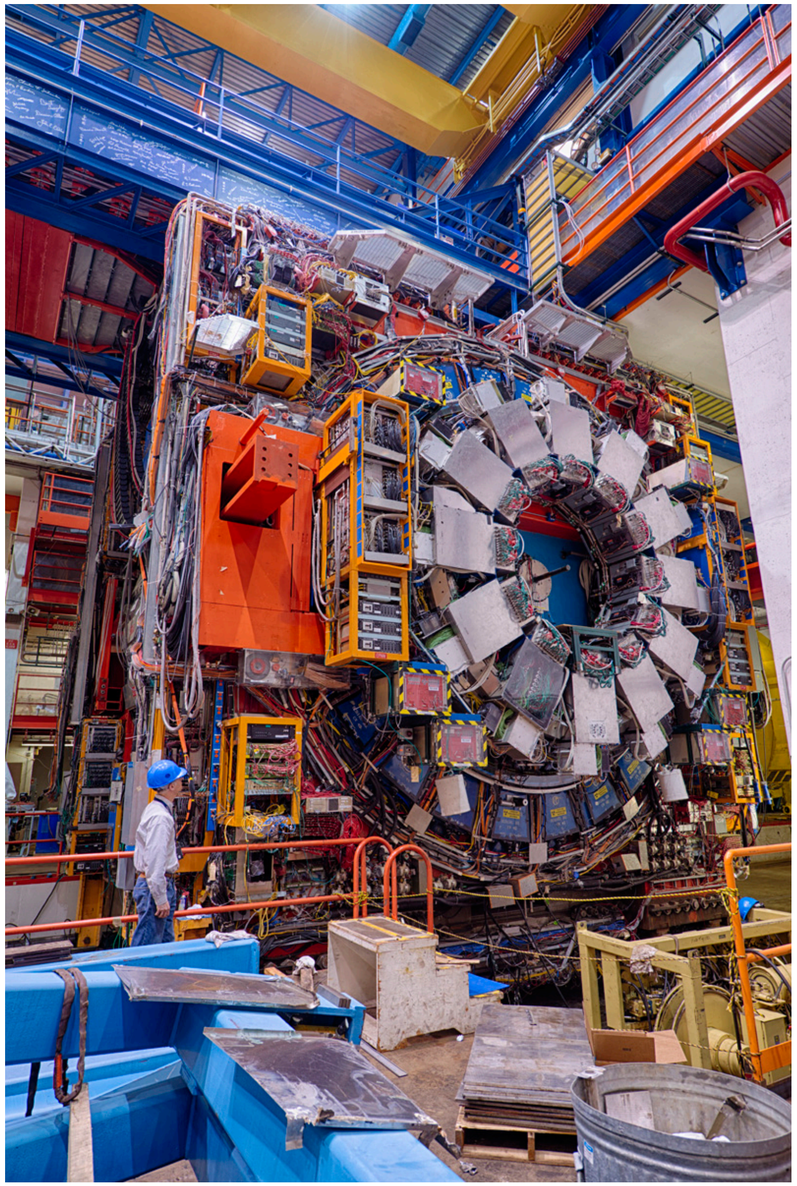
Grad school = stripes



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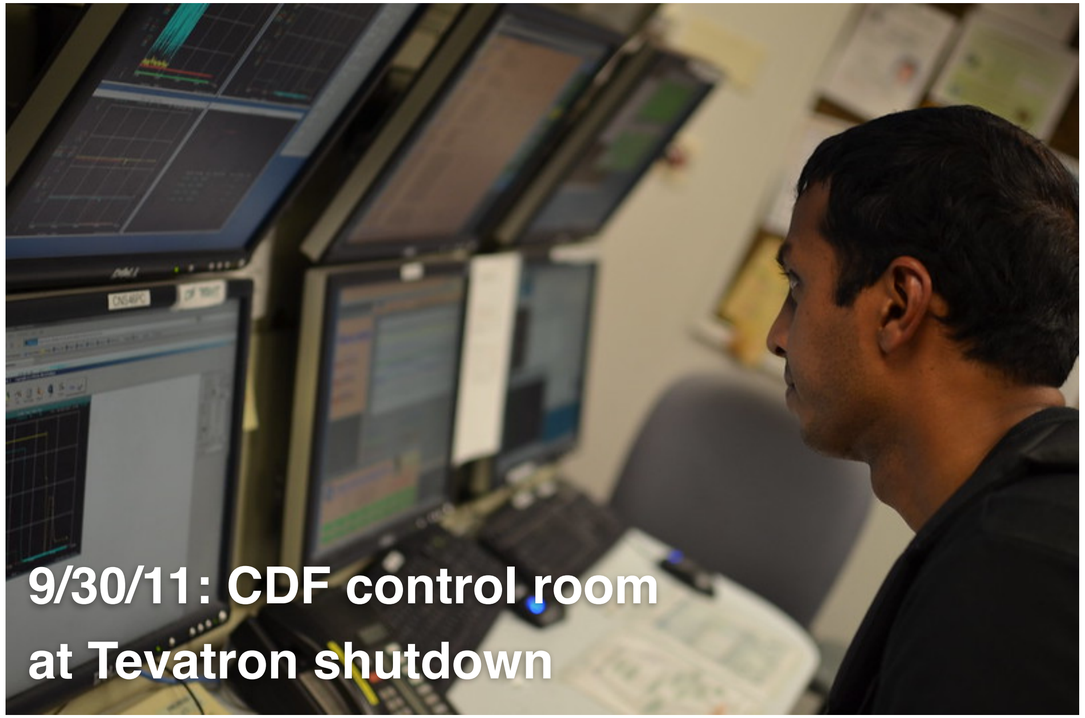

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- Staff at **Fermilab** since 2012
  - Working in the Scientific Computing division
  - Present job title: Scientist*

*Yes, this is literally my job title. No, we aren't good at creative names

# What do I do now? Physics

- At the **Large Hadron Collider** at **CERN** in Geneva Switzerland
  - The largest (15 miles!!) and most powerful (**6x** Tevatron) particle collider ever built
  - Fermilab: crucial roles in design, construction, and operation of the LHC
  - **Over 200** scientists, engineers, and technicians take part in the **CMS** experiment
    - Including me
- My research: Dark Matter
  - Are LHC collisions producing particles that make up dark matter?

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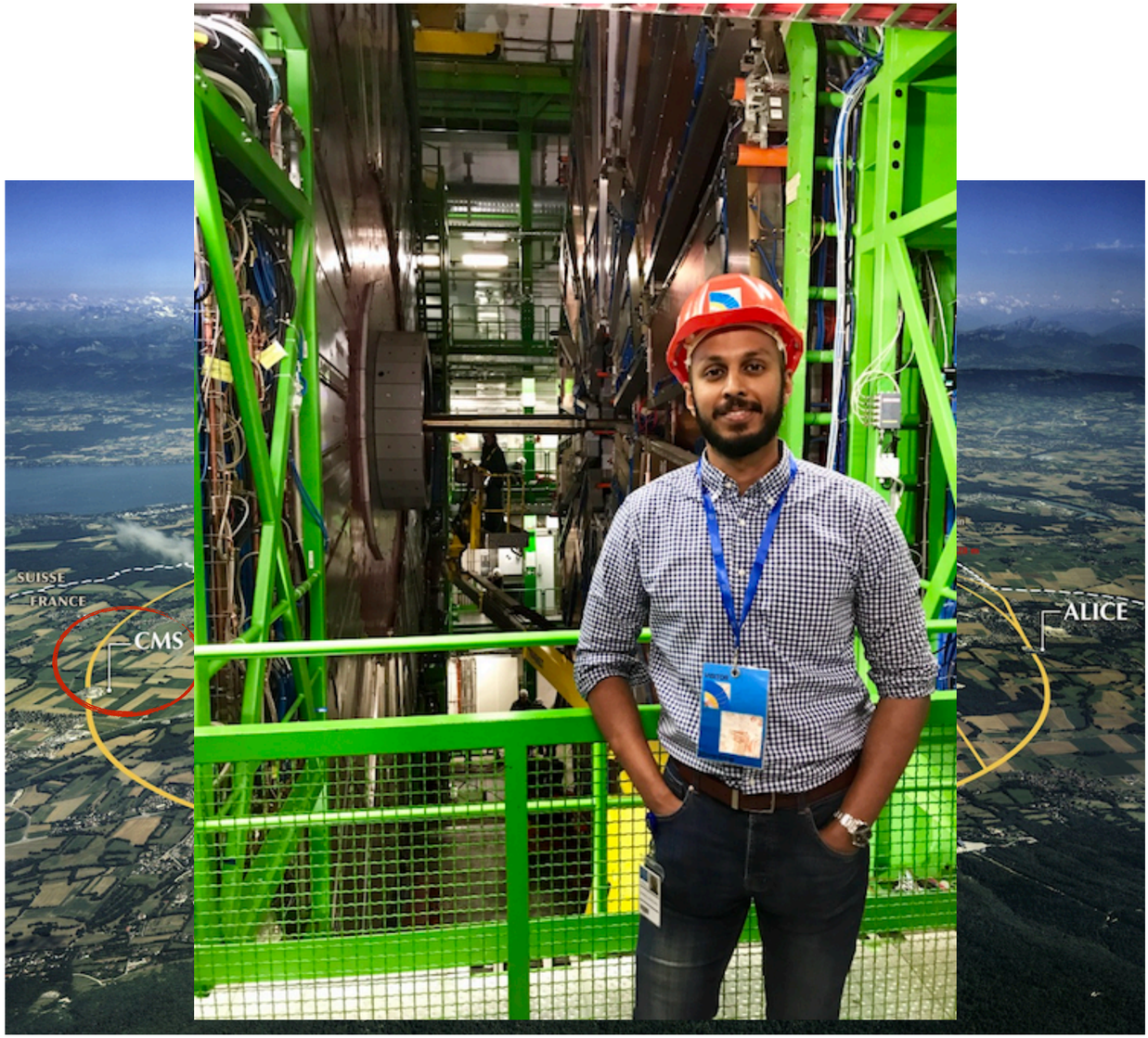
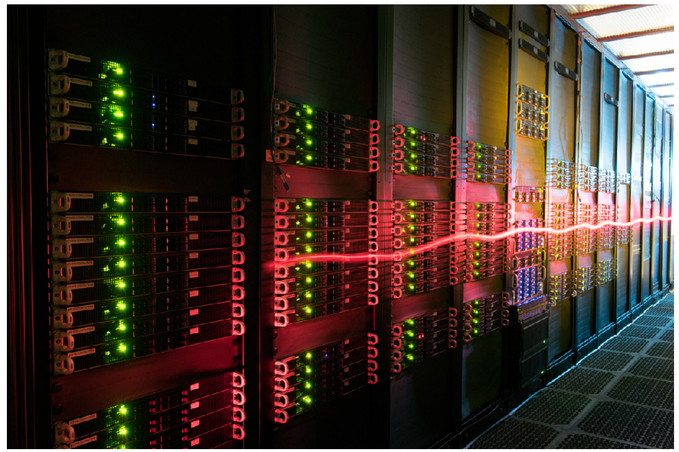


# What do I do now? Computing

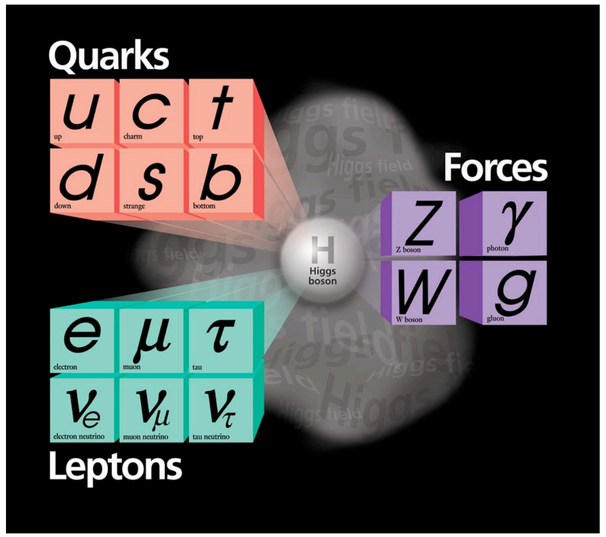
- Challenges of storing and organizing data
  - Particle physics experiments produce **petabytes** (PB) of data
    - 1 PB = 1,000,000 GB (~15,000 smartphones)
    - Fermilab stores over **180 PB** of data

- Challenges of analyzing those data
  - Using dedicated resources
    - Fermilab: >**40,000** CPU cores
  - Using large supercomputers
  - Using advanced software techniques such as artificial intelligence



# Science at Fermilab: What are we trying to answer?

*Are there more fundamental particles than these?*



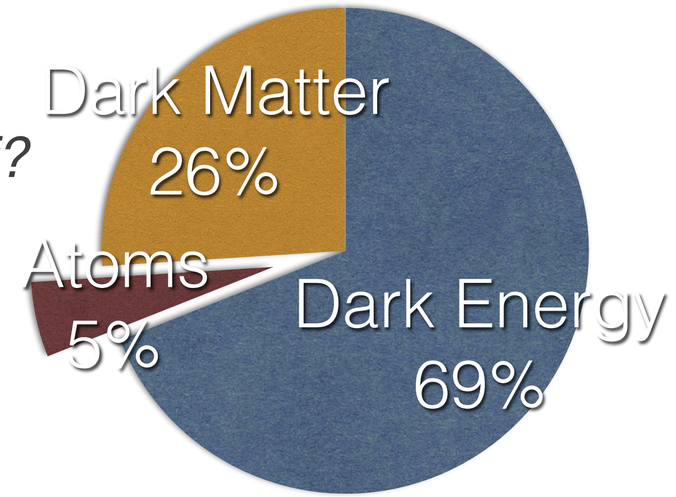

*How does gravity fit into this picture?*

*Why are the masses of these particles so different?*

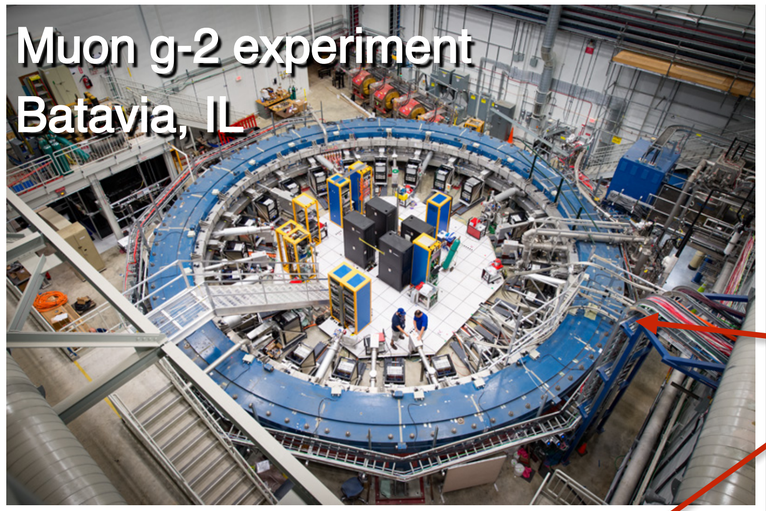
*What is Dark Energy? How has it changed over the history of the universe?*

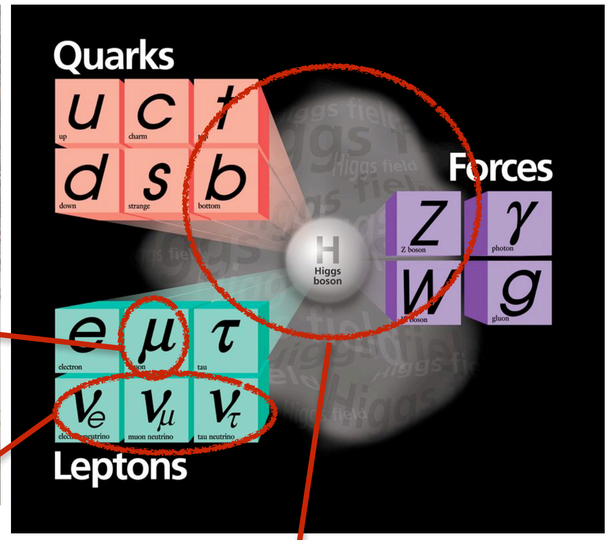
*What happened to all the antimatter?*

*What is Dark Matter made of?*

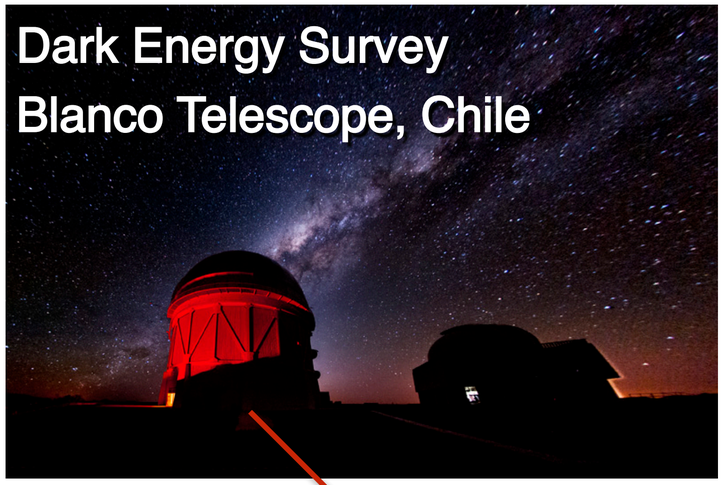


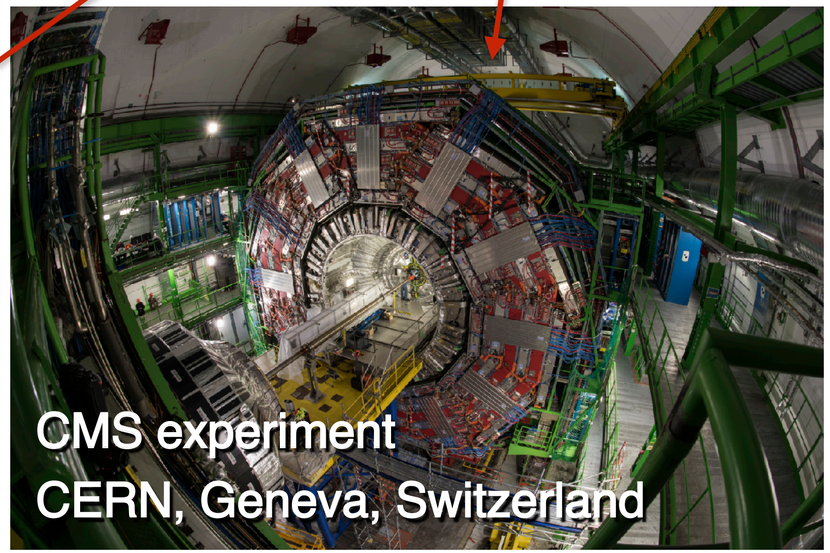
# Science at Fermilab: A sampling

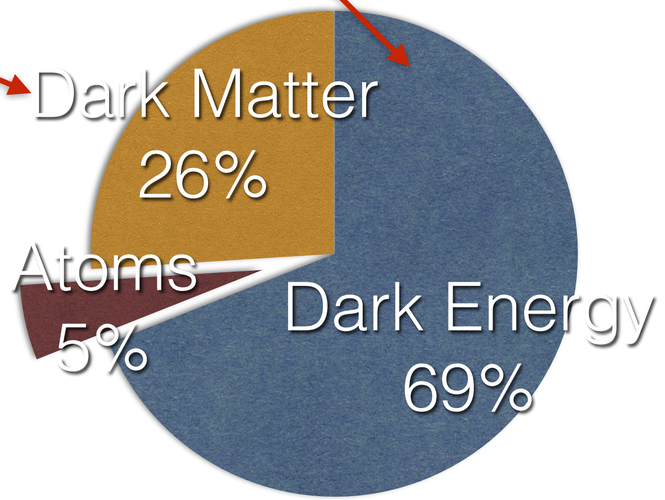


CDMS experiment
Soudan Mine, SD

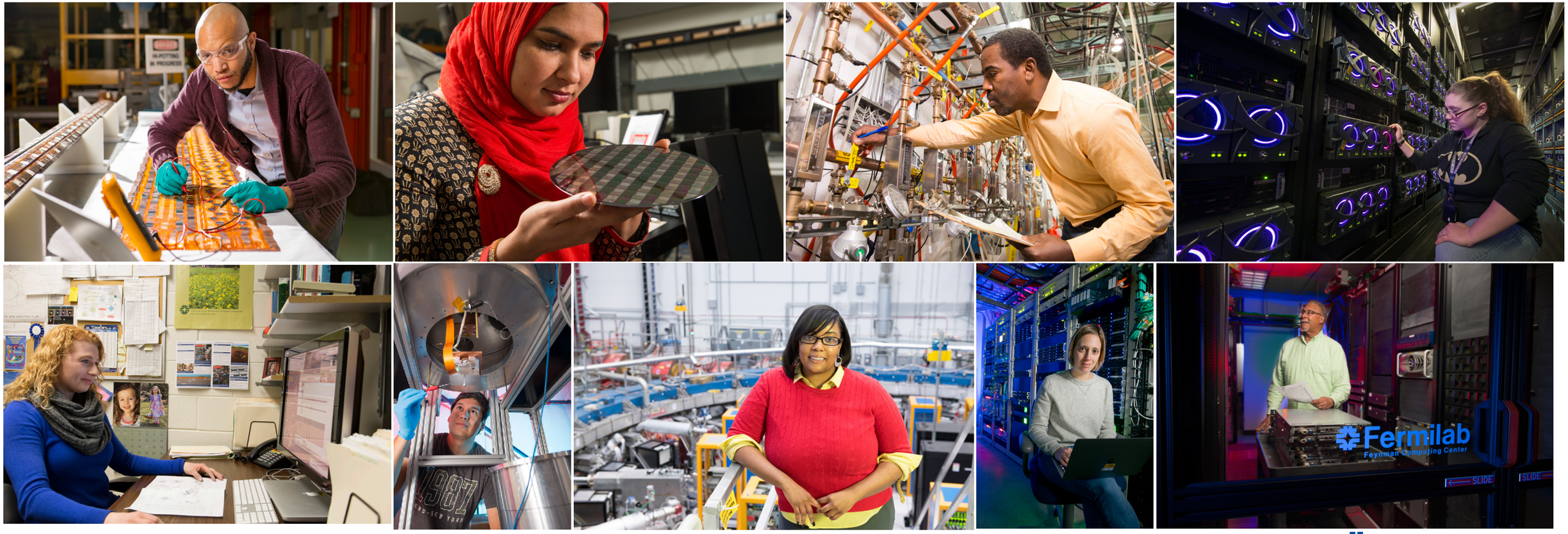




# Who we are

- Scientists (like me) are less than 20% of Fermilab
  - And studying physics is rewarding for careers both in and out of research!
- Engineers, technicians, computing professionals are vital to Fermilab science
  - Involved in the design, construction, and operation of particle accelerators and experiments



# What we work on

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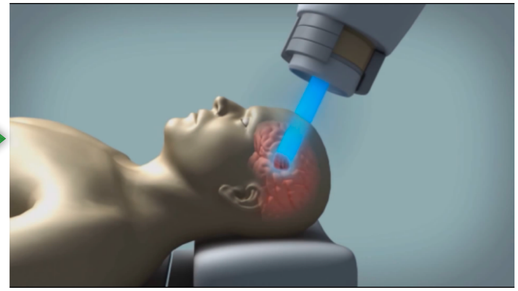
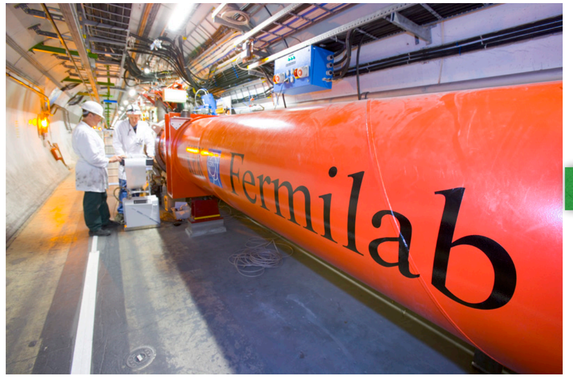
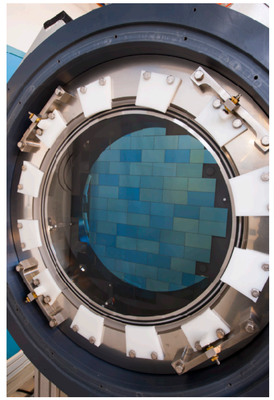


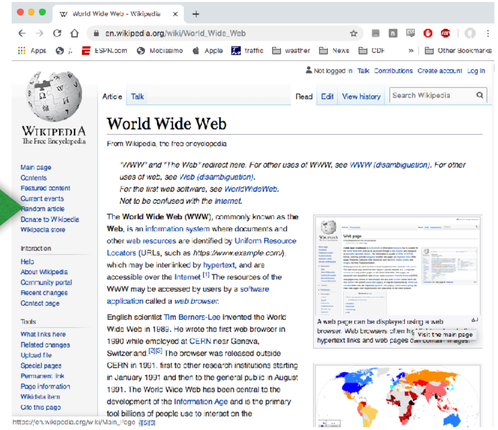
- Developing accelerator and magnet technology



- Developing detector technology

- Developing computing techniques





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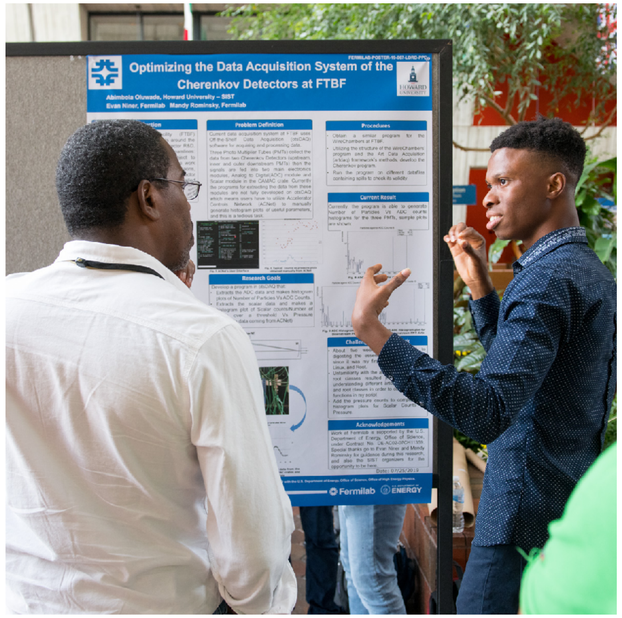
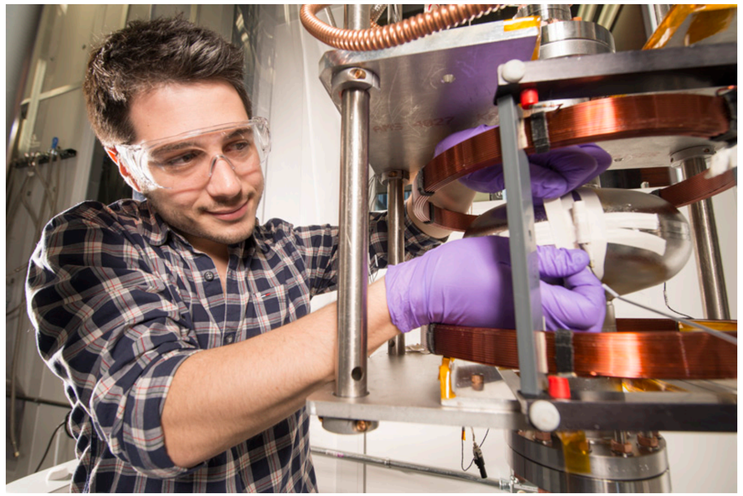
# And investing in the future: YOU!





Internship programs from high school on up

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# Thank you

- **Have fun today!**

- Come back and stay in touch
  - **https://internships.fnal.gov**
  - **https://saturdaymorningphysics.fnal.gov**

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