Exploring Our Universe:

The Smallest, The Biggest, The Invisible

UChicago 2020

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Professor of Physics, The University of Chicago

APS Conference for Undergraduate Women in Physics
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Fermilab

About me:

I am a theoretical physicist doing research in particle physics

I am the head of the Fermilab Theoretical Physics Department

I teach at the University of Chicago

I work on international relations to help bring scientists around the world to Fermilab

I am the mom of two amazing young men
My husband, Carlos, is also a physicist at UChicago

I enjoy cooking and sharing time with many good friends

I get excited about bungee jumping, scuba-diving, horse back-riding, dancing & adventure trips

I keep very close ties with my extended family and friends in Argentina where I go regularly

How I came to be a physicist?

How I came to be a physicist?

My mom wanted me to be a well-educated young lady…..

How I came to be a physicist?

I had other dreams …

Science that matters to all of us

From our earliest days, humankind has yearned to understand the universe,
to know how we all got here and how it all works,
from the vastness of space to the smallest parts of all we can see.

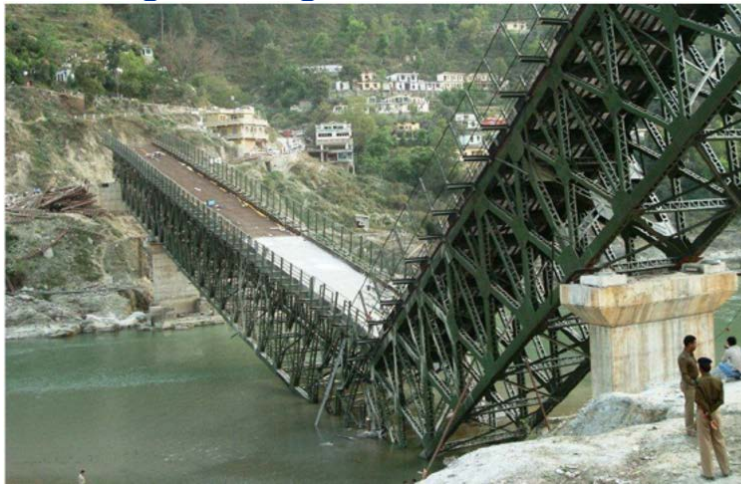
My career path as a physicist:

Undergrad experience: [Argentina]

I was really good at math in High School, but it was a liberal arts one….

Didn't know what to study….. **so I went into engineering** (~ 10% women in my class)

Didn't enjoy my design of civil engineering structures at all!!!



Started to study philosophy…but found it too fluffy

Finally after ~3 years I took a very competitive admission exam
and was admitted in a special program to study physics !!
(only 10% of the admitted were women)

My career path as a physicist:

Graduate School: **[Germany]**

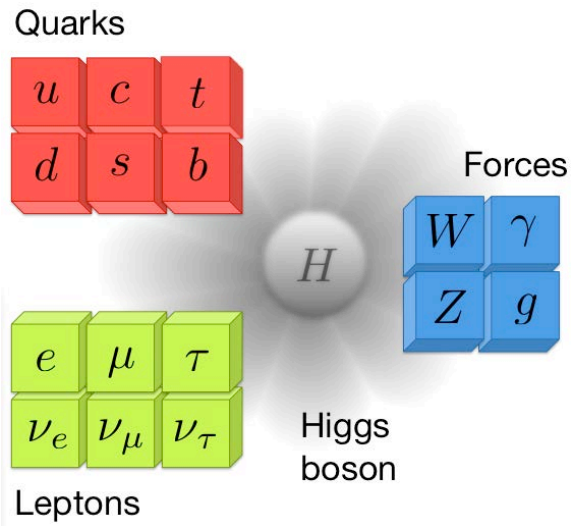
As an undergrad, I was fascinated with learning how to use math to make sense of our world

I went to grad school in Hamburg to study Particle Physics,

learned the basics, got interested in understanding:

- **Why is there more matter than antimatter?**
- **Are there other symmetries/dimensions in nature?**
- **How do elementary particles get mass,**

  the Higgs mechanism?



My career path as a physicist:

Postdoctoral Experience:

[US - Germany - Switzerland]

- Awe-inspiring Science
- Exhilarating research projects
- Complete intellectual independence
- Work with brilliant colleagues and mentors
- Culture of growth and collaboration
- Diverse international community
- Competitive environment
- Lack of job security for postdoctoral years
- Salary much less than in private sector
- Challenging for relationships and family

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Tenure track/Tenure experience:

Fermilab Associate Scientist, tenured in < 2 years; promotions regularly
Several competitive offers to move elsewhere in the past two decades.
Became Professor at UChicago, Head of the Fermilab Theory Department

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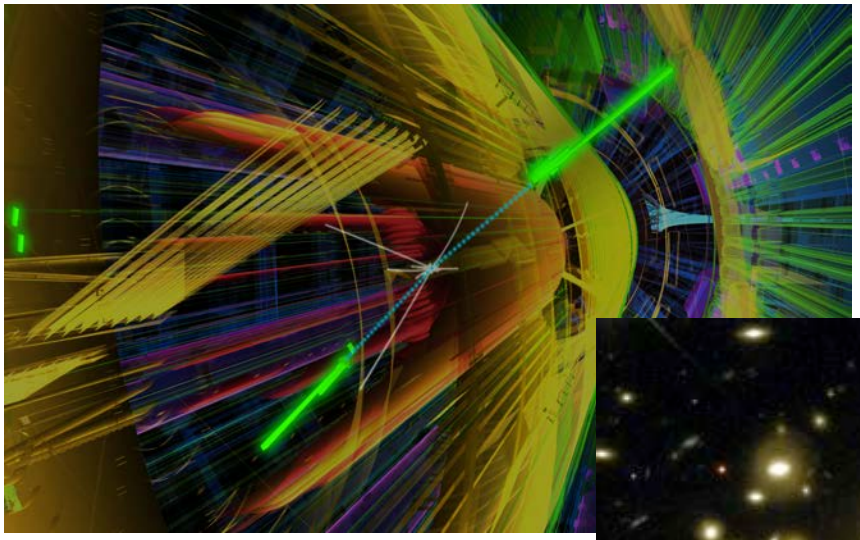
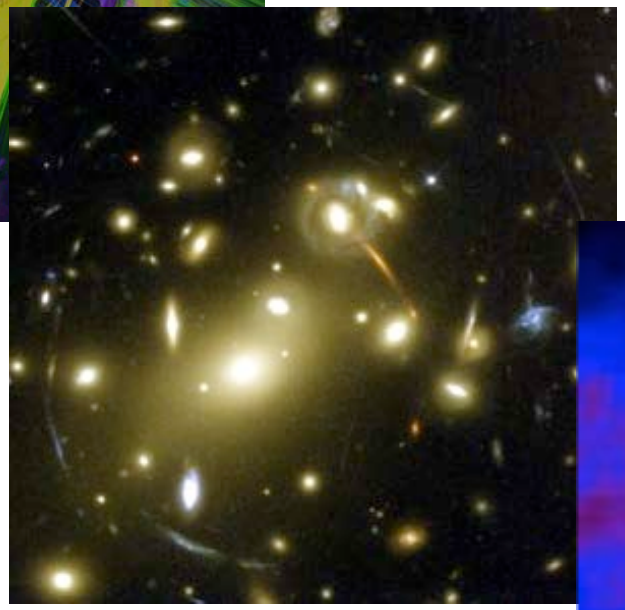
The Questions that I spend my time on:

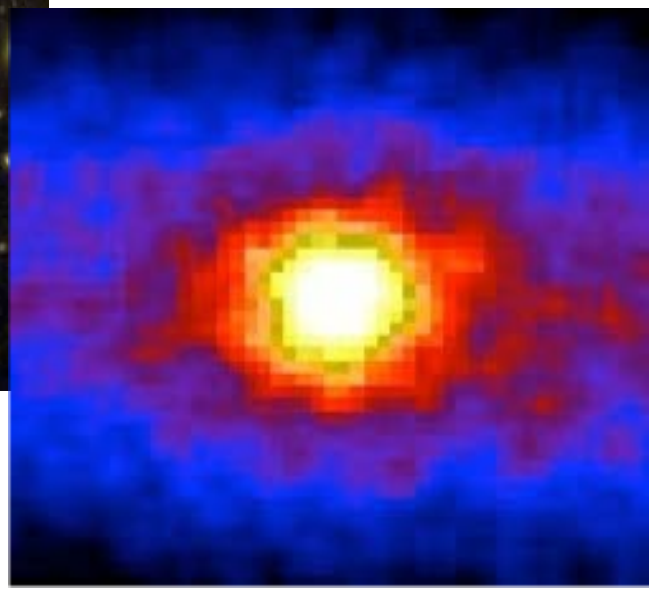


What makes particles massive and slows them down from moving at the speed of light?



What distorts the images of distant galaxies?

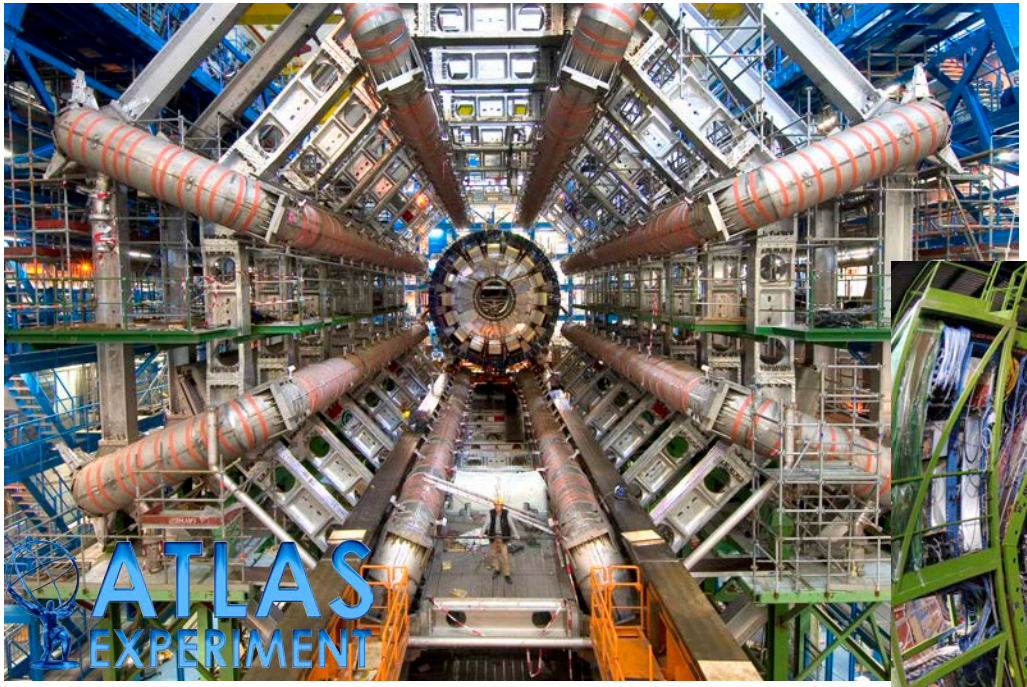
What makes the fabric of the cosmos and holds it together?



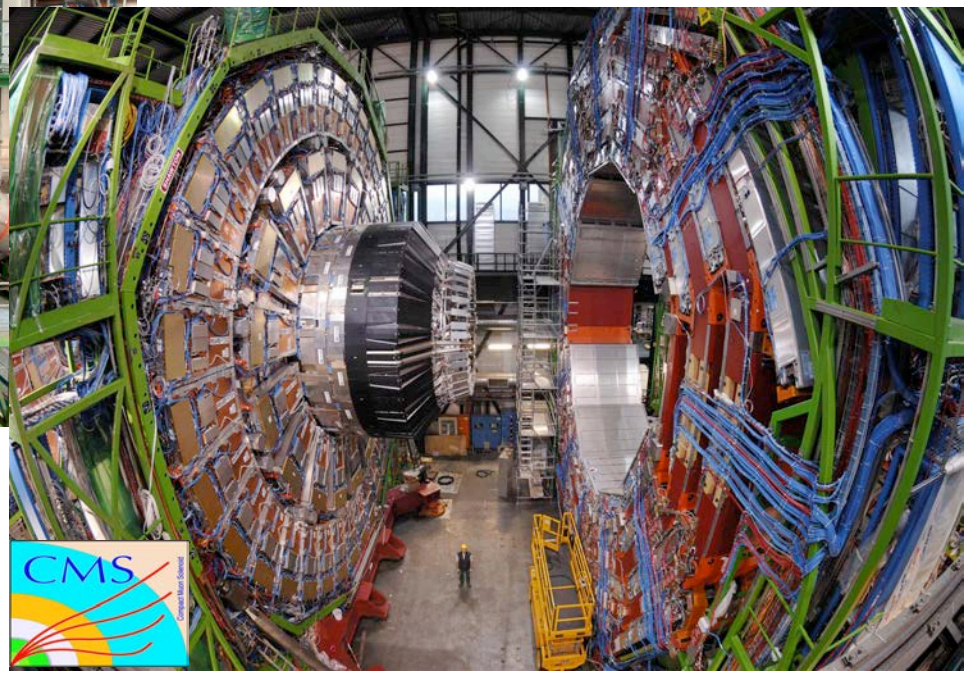
What are the secrets encoded in the tiny but mighty Neutrinos?

Big Science Questions require Technology Innovation

Advanced Accelerators, Unprecedented Data Handling Capabilities and Ultrasensitive Detectors



The two most powerful cameras in the world
the ATLAS and CMS Detectors



Huge, complex objects with cutting-edge technology

Half a Century after the Higgs Idea comes its Discovery

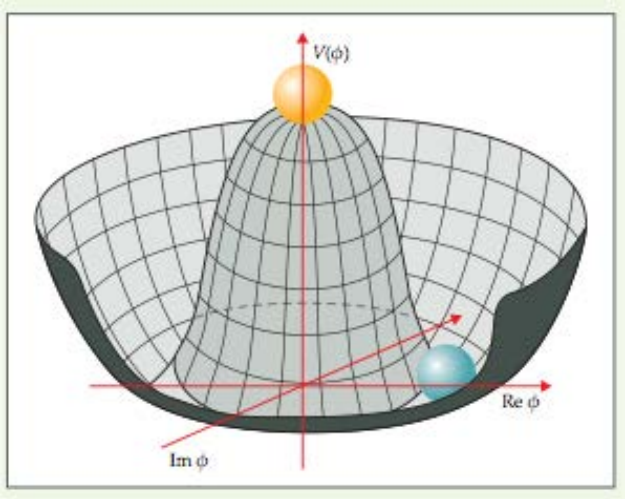
- It is a new type of particle we have never seen before
- It demonstrates the existence of a new force in nature

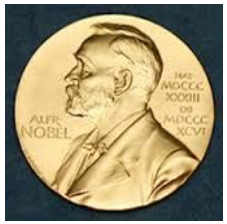
The Discovery of the Higgs Boson

Proves the existence of an invisible field

that has the property to make fundamental particles massive

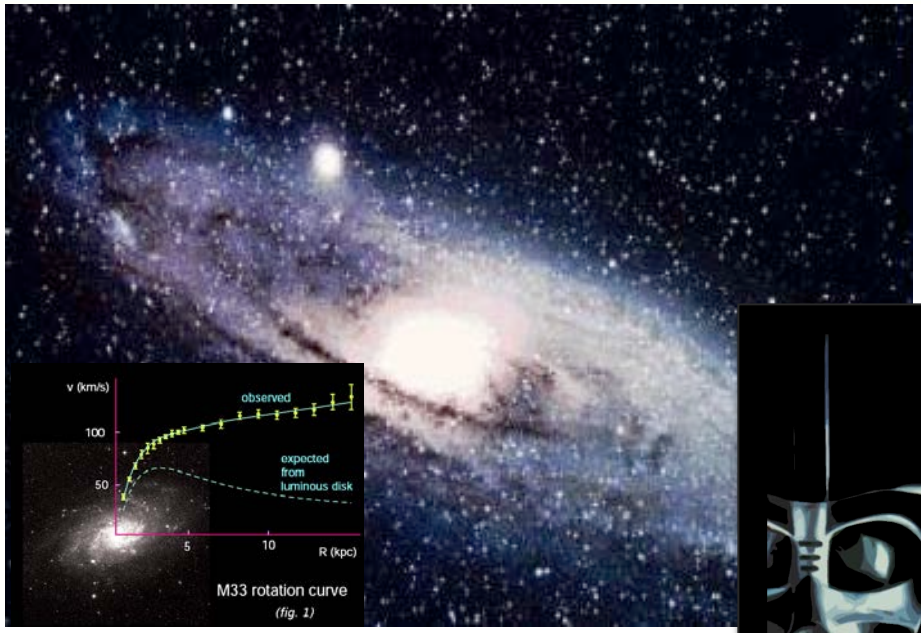
$$V(\phi) = -m^2|\phi|^2 + \lambda|\phi|^4$$





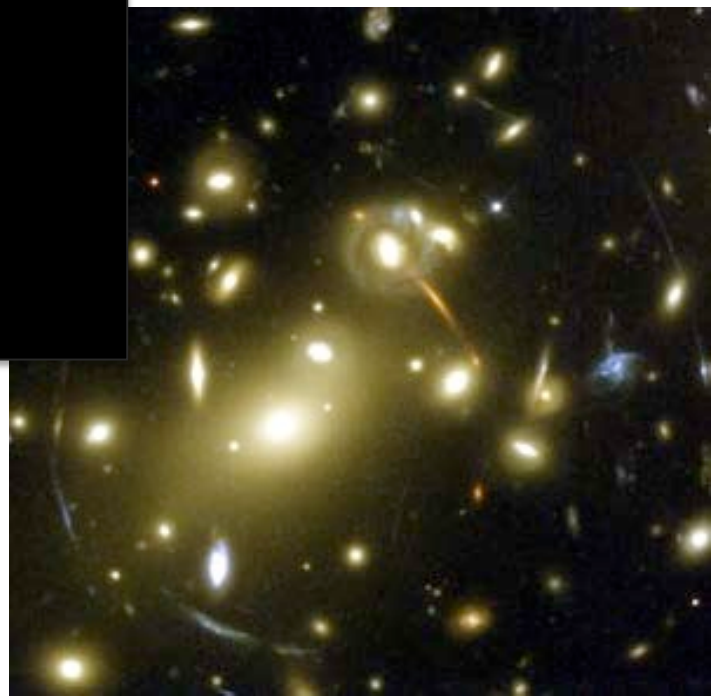
Prof. Higgs explains: My first paper was rejected because it was not relevant to the real world ….

The Power of the Dark Side



What holds the universe together?

And makes 85% of all the matter in it?

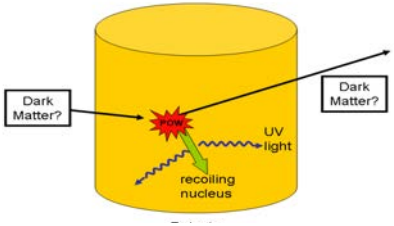


What distorts the images of distant galaxies?

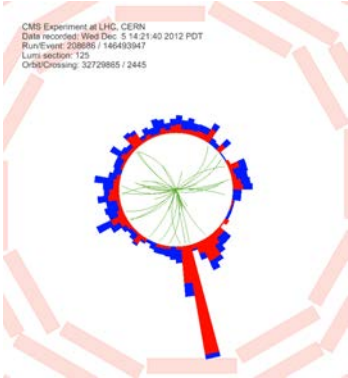
Matter that we cannot see bends light through its gravitational effects

Dark Matter Exists, is awaiting Discovery

Using accelerators, telescopes and specialized detectors!



DM from Space can collide with a single nucleus in the detector and be observed



We can create dark matter at the LHC
Or produce it in the decay of other particles

Interacts very weakly (not charged) **through Gravity**

What about Higgs-like Interactions?

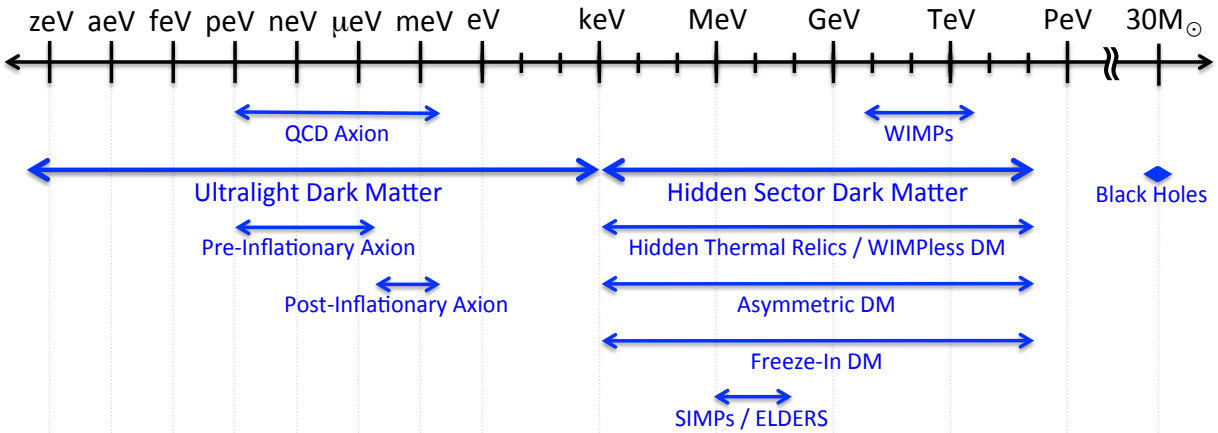
DM could talk to the SM through a Portal

Many theoretical ideas flourishing

A priority for Particle Physics & Cosmology

Dark Matter Candidates: Very little clue on mass scales

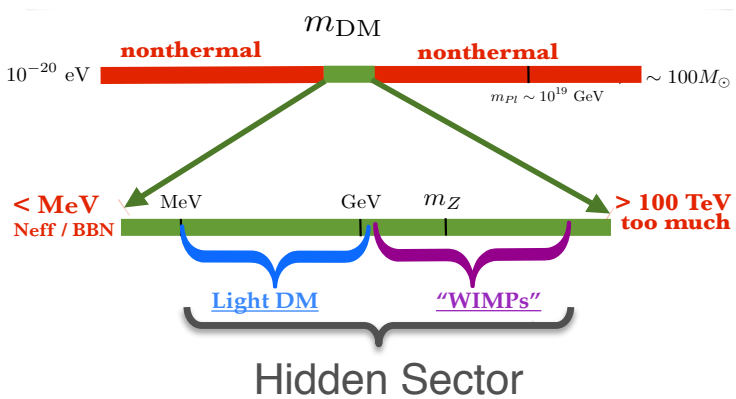
Too small mass
⇒ won't "fit"
in a galaxy!



From MACHOs searches

Folding in assumptions about early universe cosmology we can motivate more specific mass scales

Thermal Equilibrium in early Universe narrows the viable mass range



Phenomenology of low mass region [MeV-GeV] thermal DM quite different from Standard WIMP

==> Demands light mediator/s that in themselves are a search target

Dark Matter/Dark Sectors

In general, Dark Sectors may exist, too

What is meant by a dark sector ?
A Hidden sector, with Dark matter, that talks to us through a Portal

Portal can be the Higgs boson itself or New Messenger/s

Dark sector has dynamics which is not fixed by Standard Model dynamics
→ New Forces and New Symmetries
→ Multiple new states in the dark sector, including Dark Matter candidates

Interesting, distinctive phenomenology with Long-Lived Particles and/or Feebly interacting particles

Over next few decades, important advancements in both astrophysical and terrestrial probes will test WIMPs and Dark Sectors

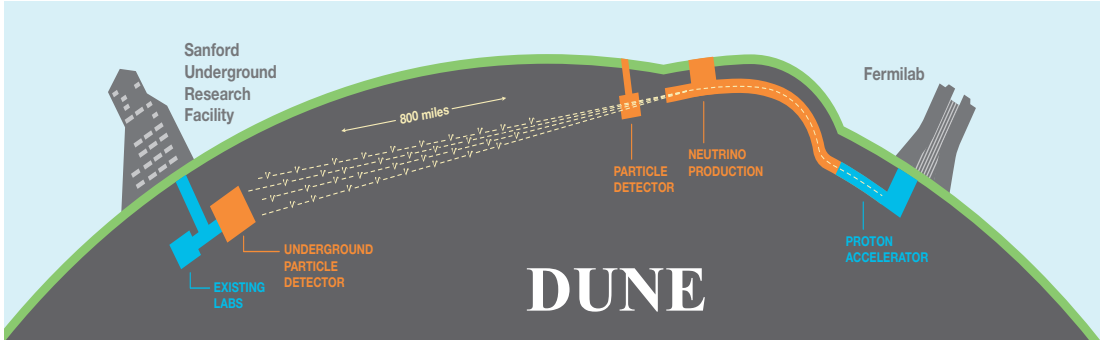
Do Neutrinos hold the key to our existence?

Main actors in important physical processes on Earth and out in the Universe

They come from many sources:
Solar, Atmospheric, Supernovae,
the earth, the big bang
and, we produce them at
Accelerators and Reactors

future experiments will corner the neutrinos' unknowns

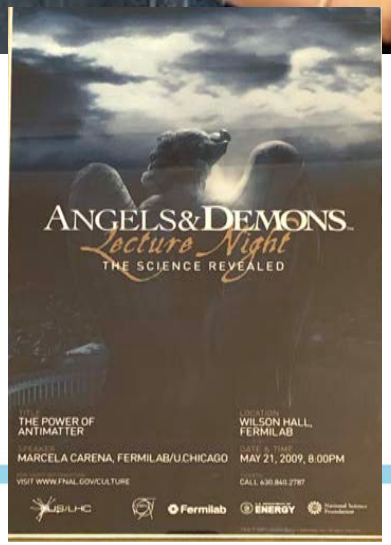
Strong use of powerful controlled
beams of neutrinos and
large, more sensitive detectors



Are neutrinos responsible for the matter over antimatter dominance, "leptogenesis"?

Bringing Science to the Public

***The Atom Smashers*, 2008**
A film about the search for "The God Particle"



Making a Difference in Latin American Physics

Leading the Fermilab International Team efforts in building connections on Latin America

Iberoamerican Ministerial meeting in Science, Technology and Innovation, Guatemala,2018

With president of the Cuban Physical Society and the Director of CEADEN. Havana, Cuba 2016

OAS meeting of S&T Ministers and High Authorities, Medellín, Colombia 2017

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A Research Career in Physics

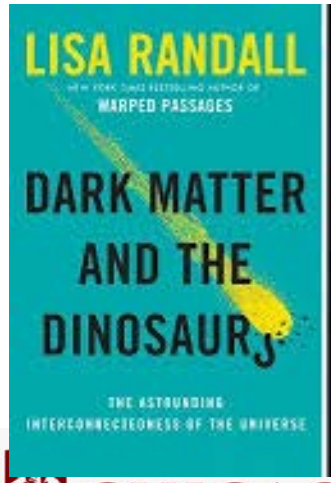
Challenges

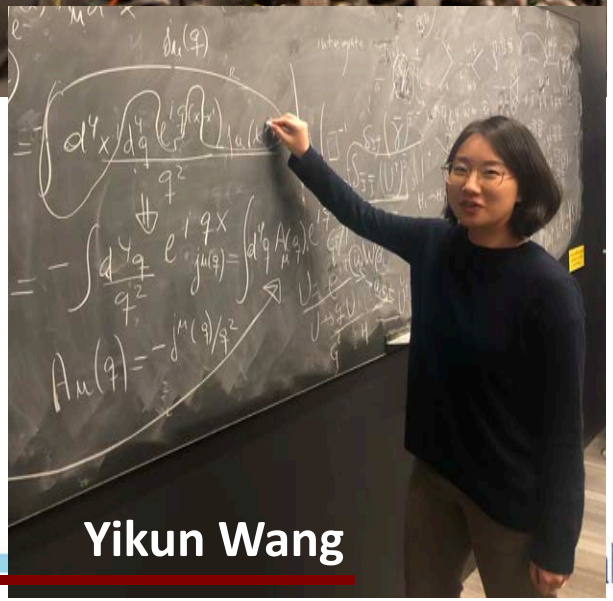
- Very competitive
- Requires a lot of personal flexibility
  - long path before defining the future/settling down
- Male dominance in the field
  - requires extra efforts to get same opportunities
- Weaker salary than the private sector
- Is not just a job, but also a lifestyle
  - Need to be careful to maintain balance
  - Need to accommodate personal commitments around traveling for work
- No guarantee of success in a project

Rewards

- Incredibly rewarding career path
- No limitations to your projects or research
  - Results are incredibly satisfying
  - Allows for projects to have the long term in mind
  - Can probe the most fundamental questions about the universe
- Unparalleled mentorship opportunities with the world's most brilliant minds
- Academic independence
  - freedom in choosing your topics of research and your collaborators
- Lots of opportunities for international travel and collaborations
- Excellent possibilities of switching outside academia at any point
- Independence from corporate bureaucracy

Community of Women in Physics

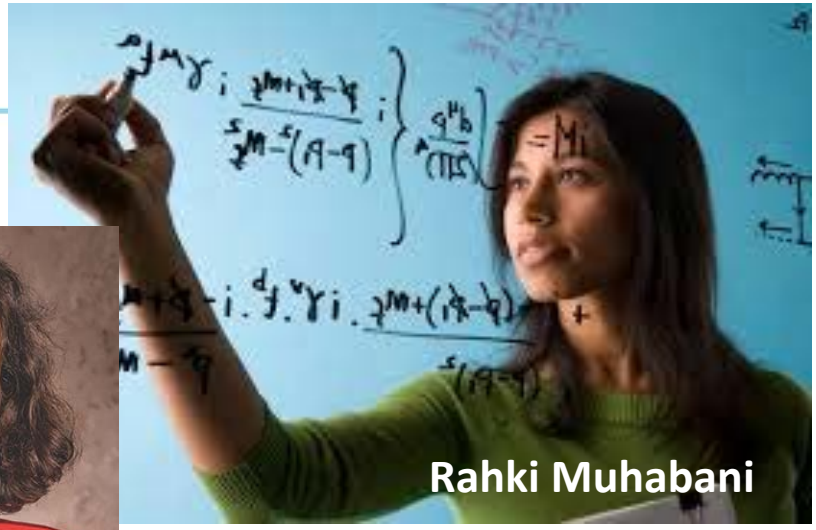




Community of Women in Physics

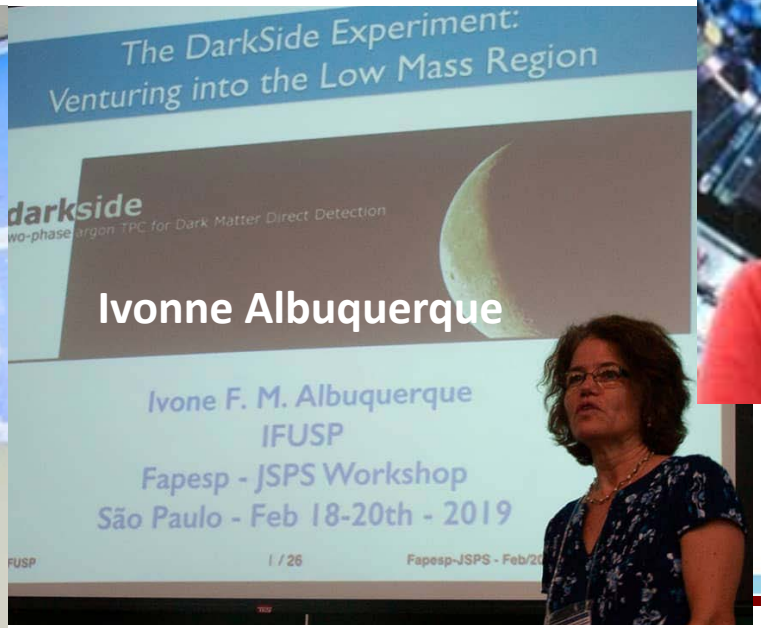

Pilar Coloma
Seyda Ipek


Liz Simons
UCSD Vice Chancellor


Rahki Muhabani


Cecilia Gerber


Ornela Palamara



Ivonne Albuquerque

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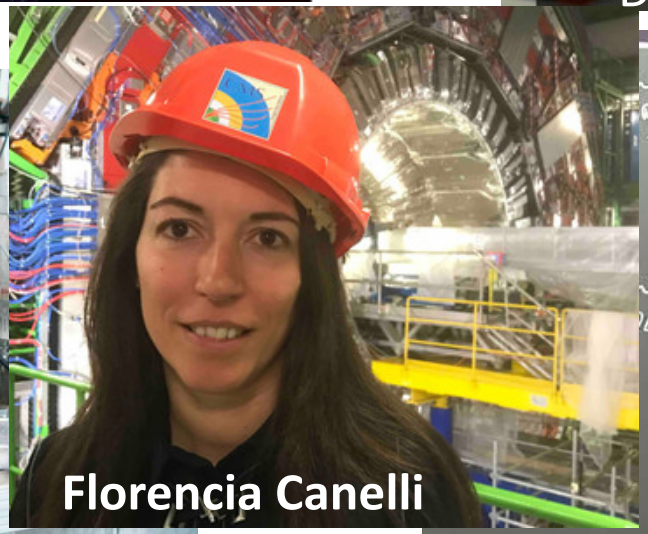

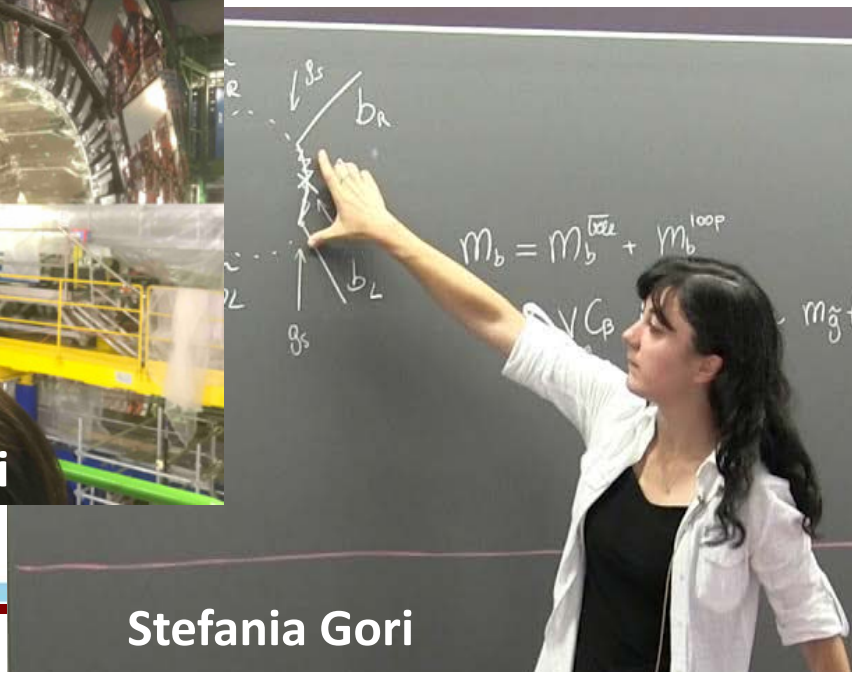

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Thank You !