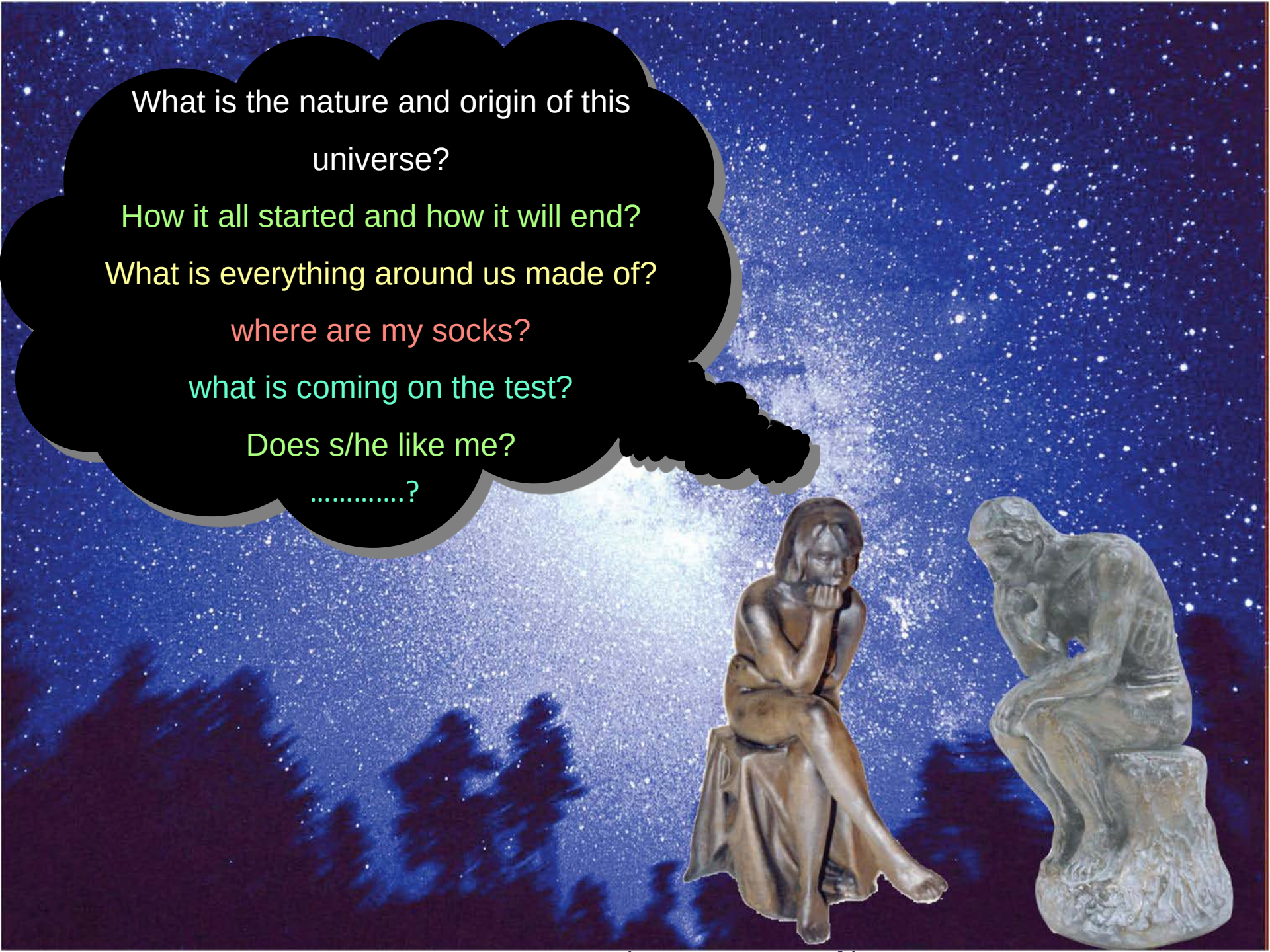
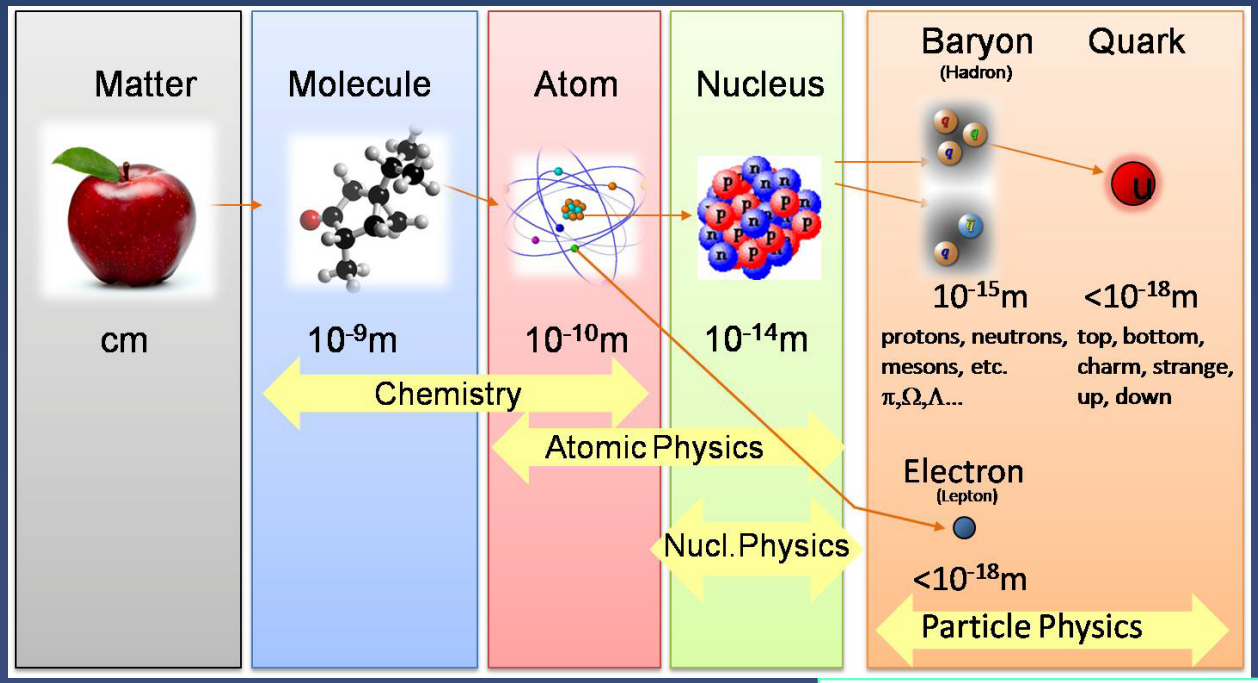
Discovery of Singles and First Kiss of The God Particle

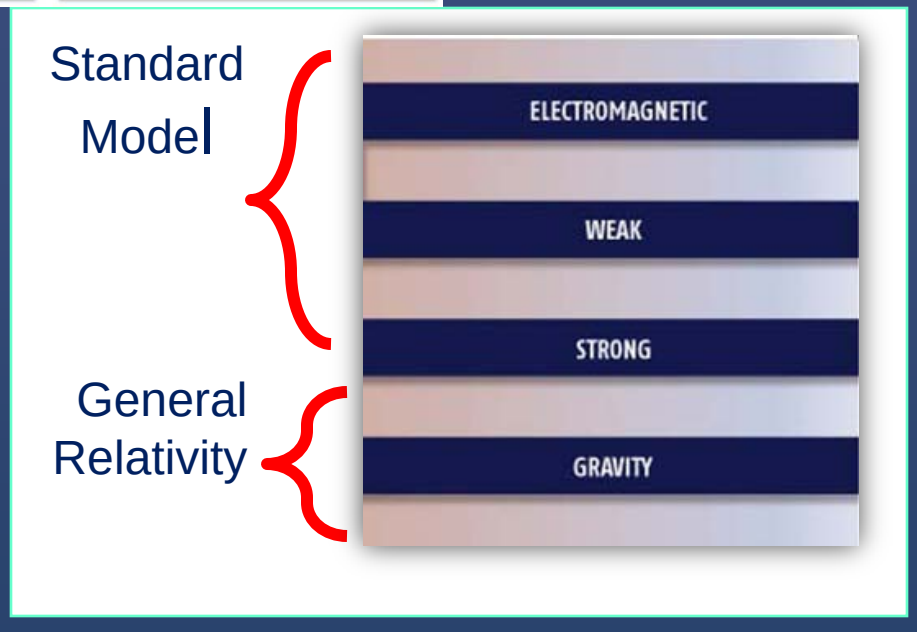
Latest News From The High Energy Frontiers

Shabnam Jabeen

Boston University

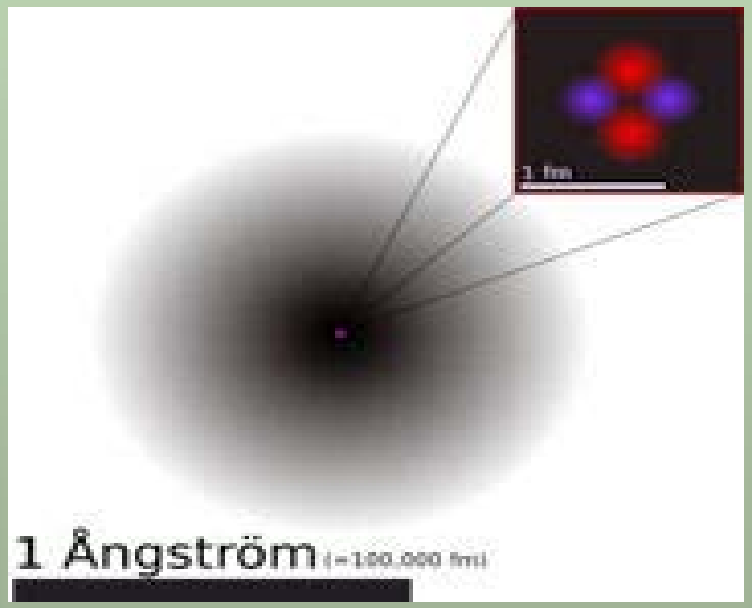

What is the nature and origin of this universe?
How it all started and how it will end?
What is everything around us made of?
where are my socks?
what is coming on the test?
Does s/he like me?
.....?


Matter
Molecule
Atom
Nucleus
Baryon
(Hadron)
Quark
cm
10^{-9}m
10^{-10}m
10^{-14}m
10^{-15}m
$<10^{-18}$m
protons, neutrons, mesons, etc. π,Ω,Λ...
top, bottom, charm, strange, up, down
Chemistry
Atomic Physics
Nucl. Physics
Electron
(Lepton)
$<10^{-18}$m
Particle Physics

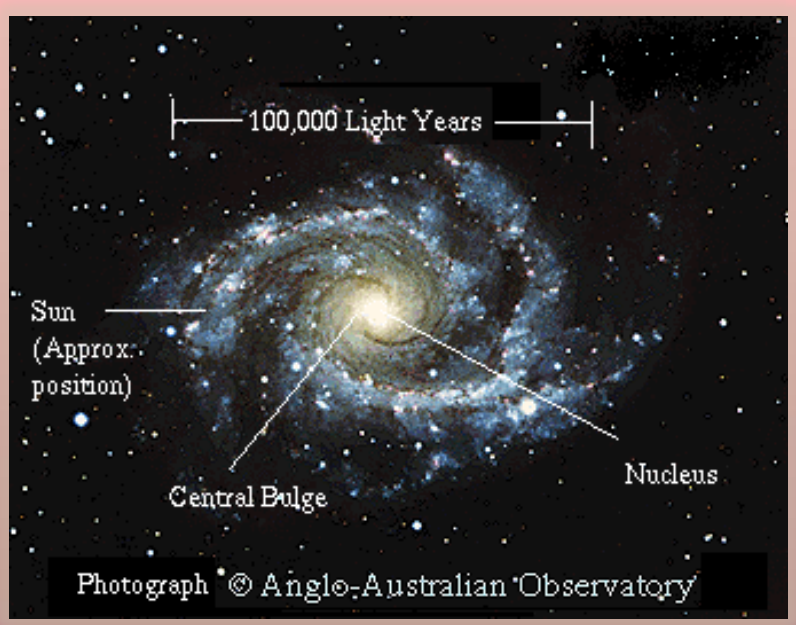

Standard Model
General Relativity
ELECTROMAGNETIC
WEAK
STRONG
GRAVITY

Two Different Worlds

Standard Model



General relativity



We have yet to discover something that contradicts either of these theories – but they are both incomplete and incompatible

SM: Theory of (Almost) Everything

…..(Standard Model) surpasses in precision, in universality, in its range of applicability, from the very small to the astronomically large, very scientific theory that has ever existed …

Robert Oerter

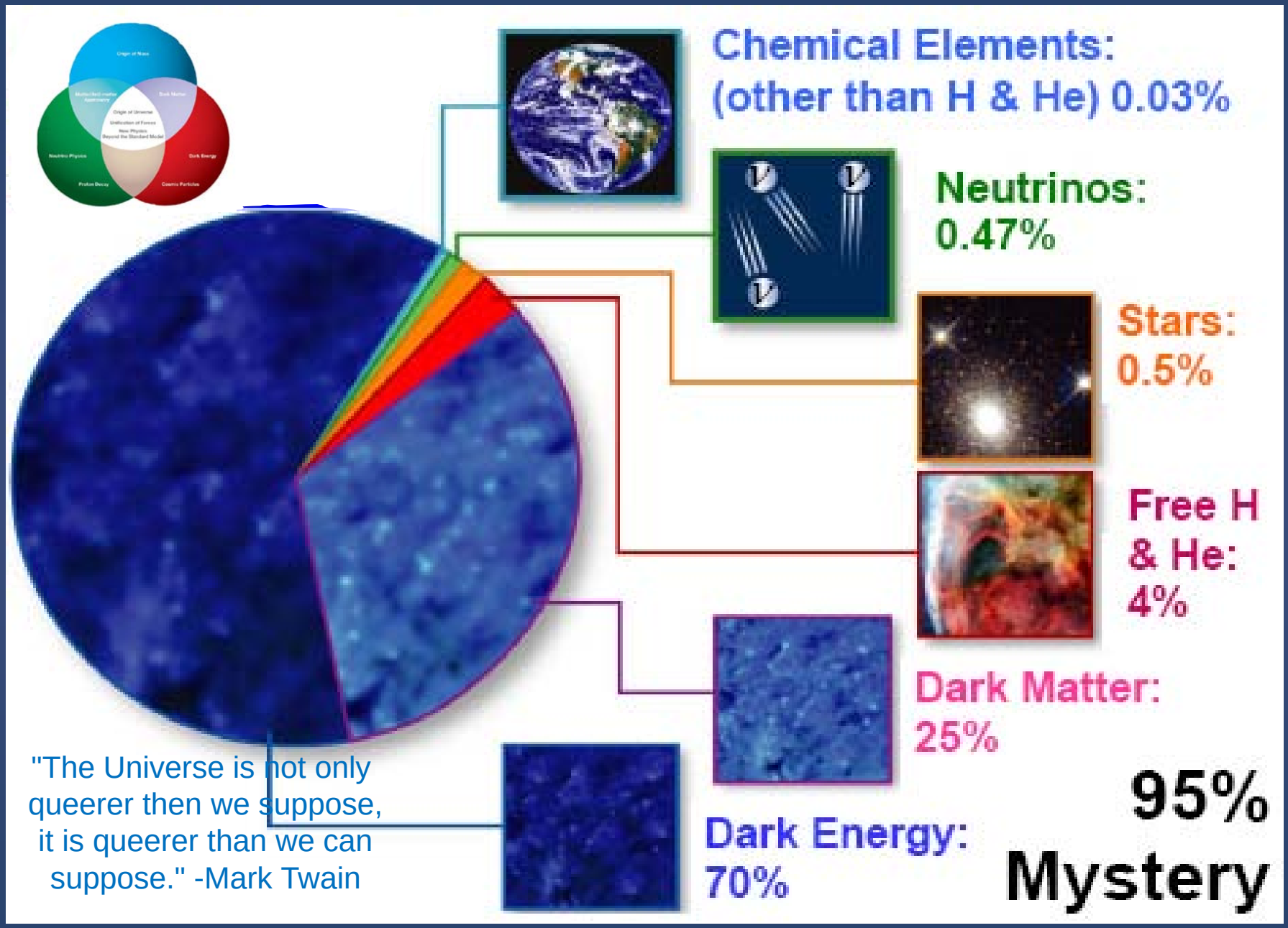
But

Standard Model is NOT the theory of everything

It does not explain origin of mass

It does not include gravity

and ….

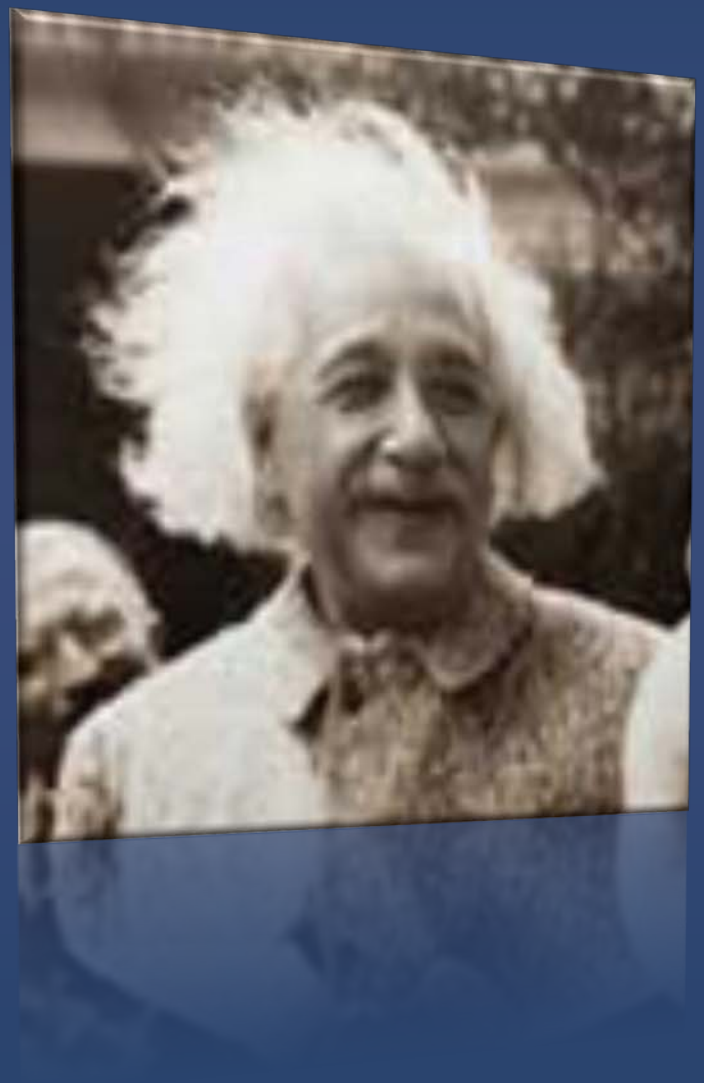

Chemical Elements:
(other than H & He) 0.03%
Neutrinos:
0.47%
Stars:
0.5%
Free H
& He:
4%
Dark Matter:
25%
Dark Energy:
70%
95%
Mystery
"The Universe is not only queerer then we suppose, it is queerer than we can suppose." -Mark Twain

The Outstanding Questions

- What is origin of mass?
- Why the values of quark and Lepton masses so different?
- Why are there 3 generations of particles ?

  (everyday matter comprises particles only from first generation)

- What about gravity?
- What is dark matter?
- What is dark energy?
- Matter antimatter asymmetry?



I want to know how God created this world.
I am not interested in this or that phenomenon, in the spectrum of this or that element.
I want to know His thoughts; the rest are details.

Science developed only when men began to restrain themselves not to ask general questions, such as:

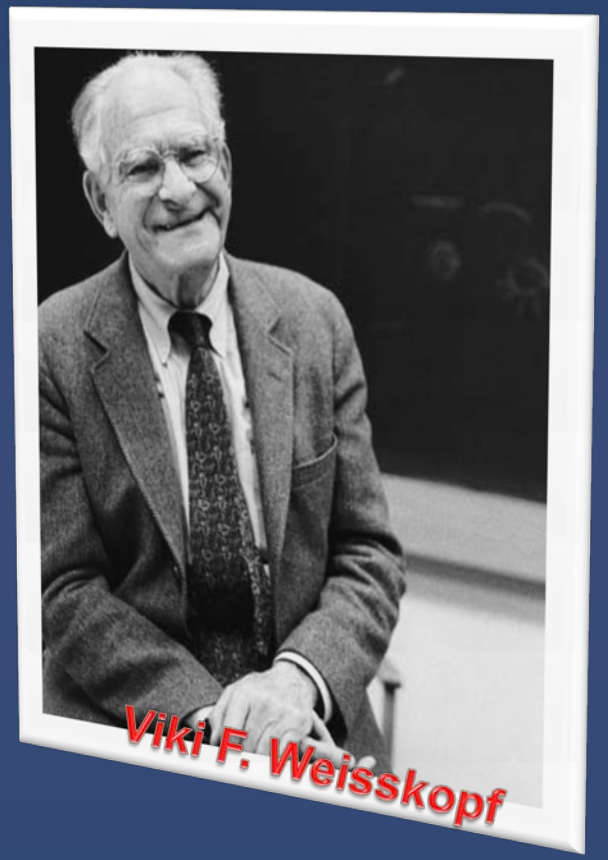
What is matter made of?

How was the Universe created?

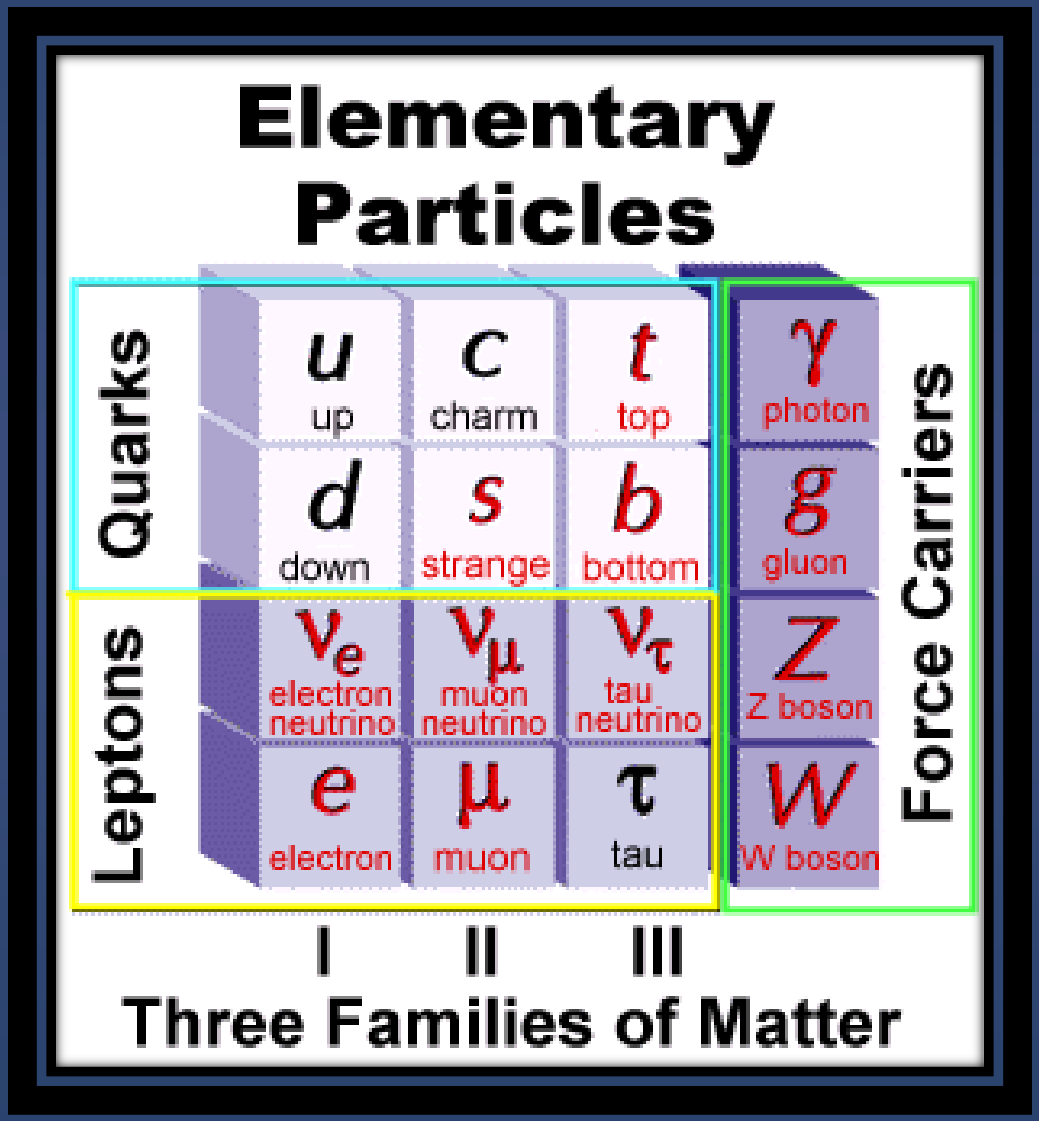
What is the essence of life?

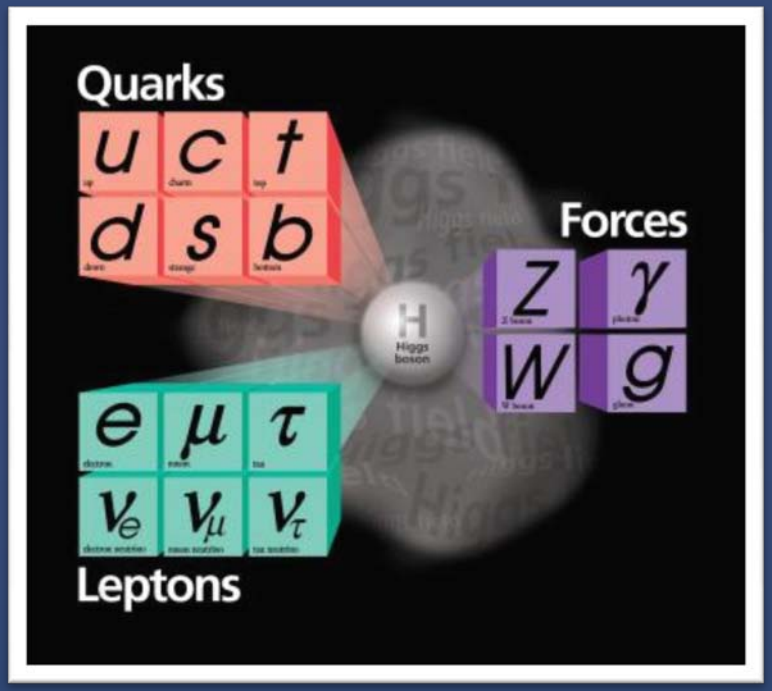
They asked limited questions, such as:

How does an object fall? How does water flow in a tube? etc. Instead of asking general questions and receiving limited answers, they asked limited questions and found general answers.

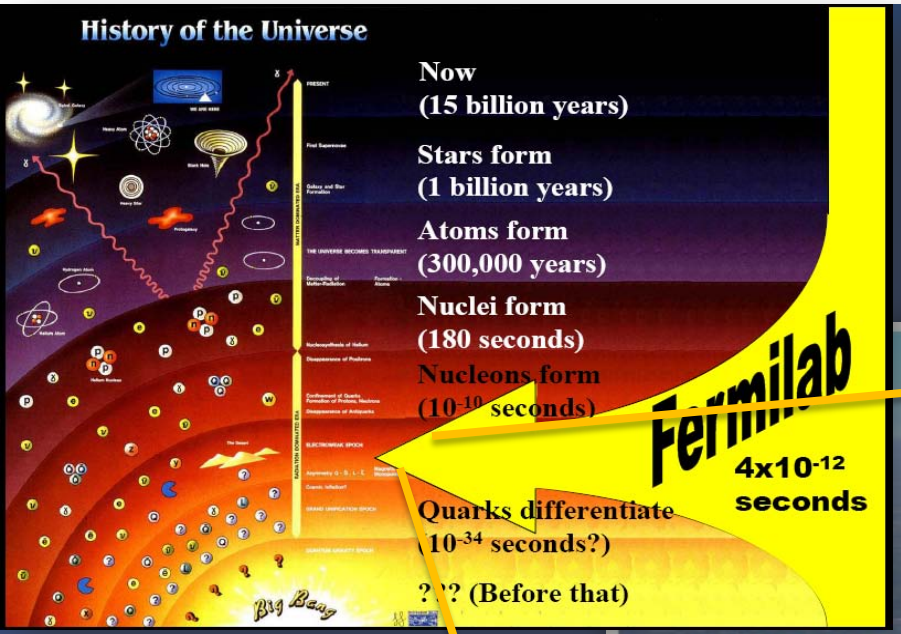


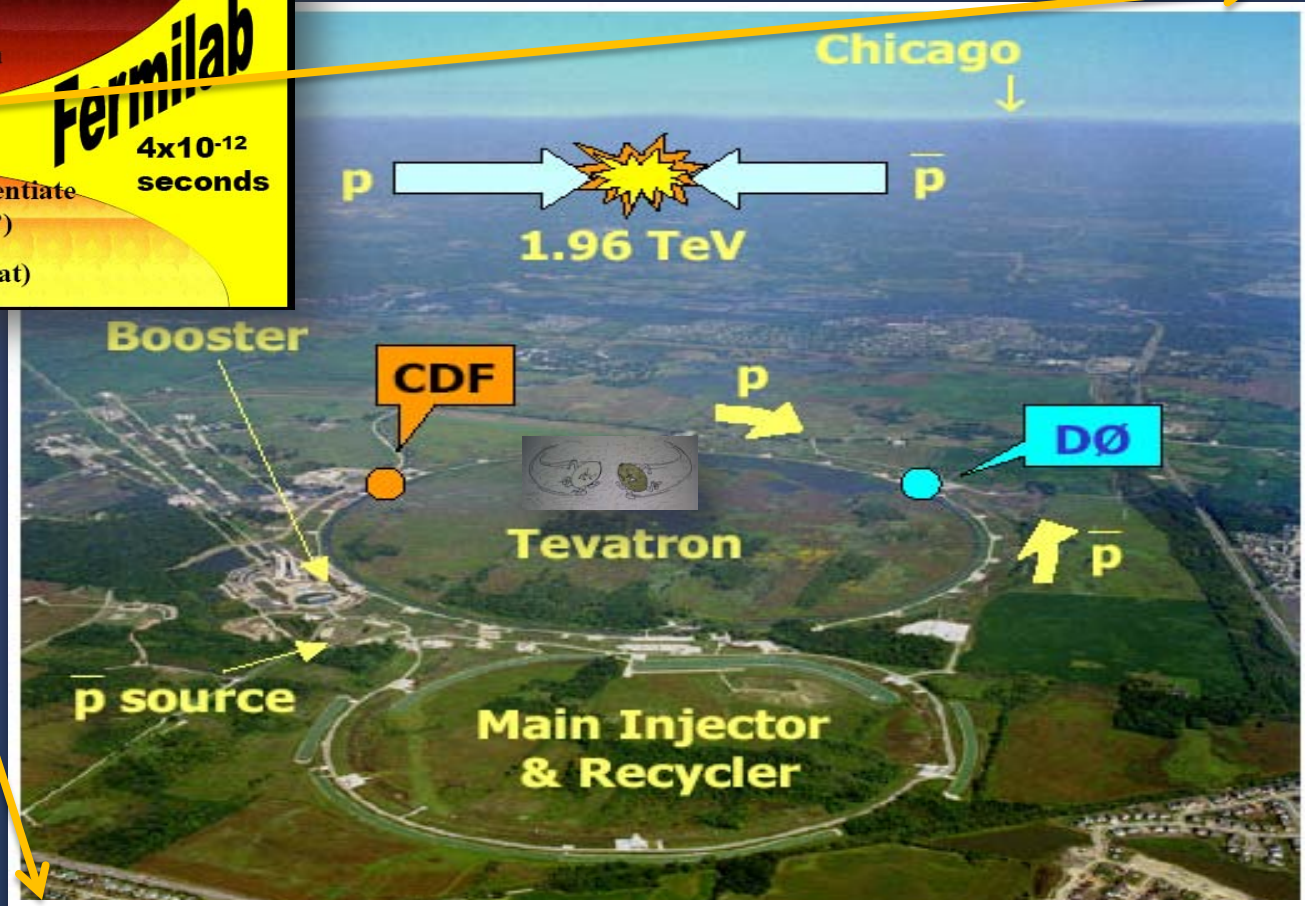
The Standard Model of Particle Physics





The Tevatron Accelerator



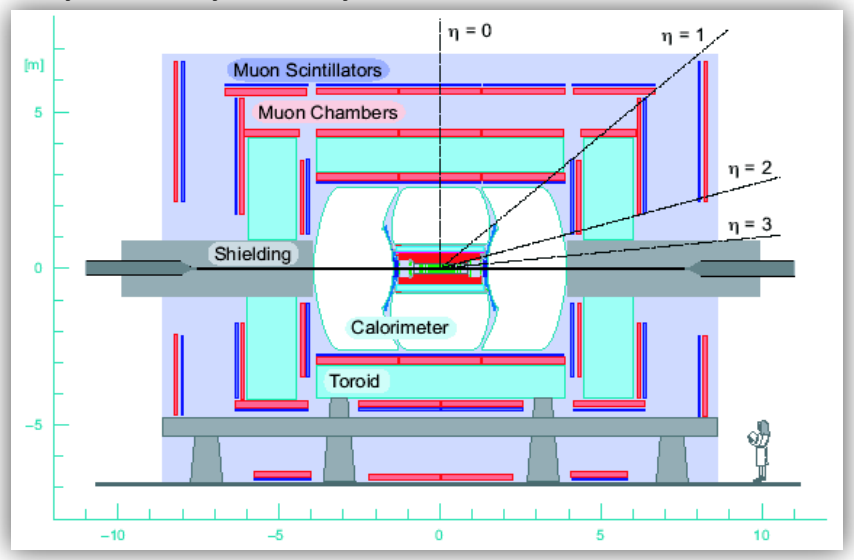


~ 20 countries
~ 80 institutions
~ 700 enthusiastic physicists per experiment

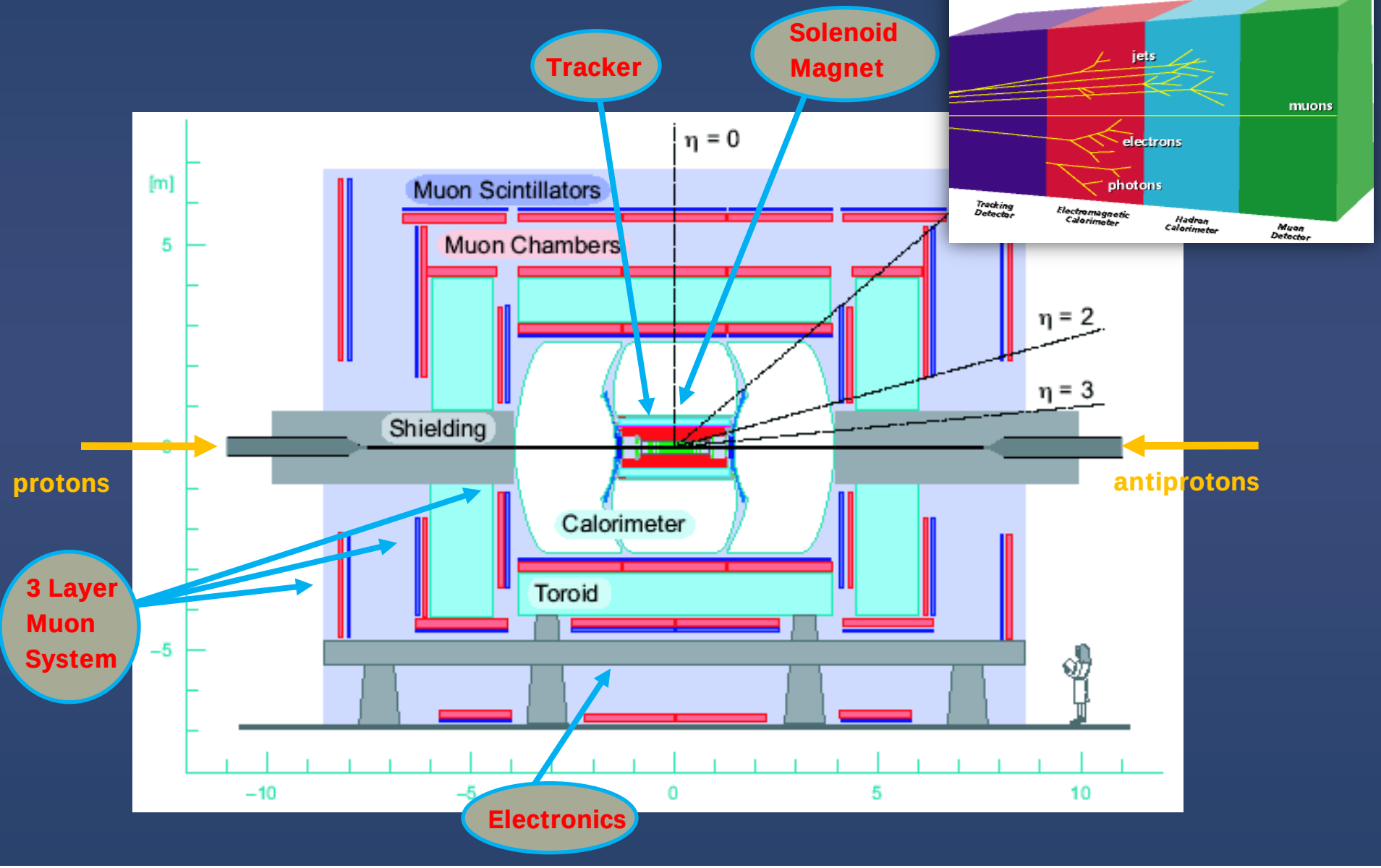
The only place where top quarks are produced and measured
(on average, we are collecting more than 400 top pairs per week)

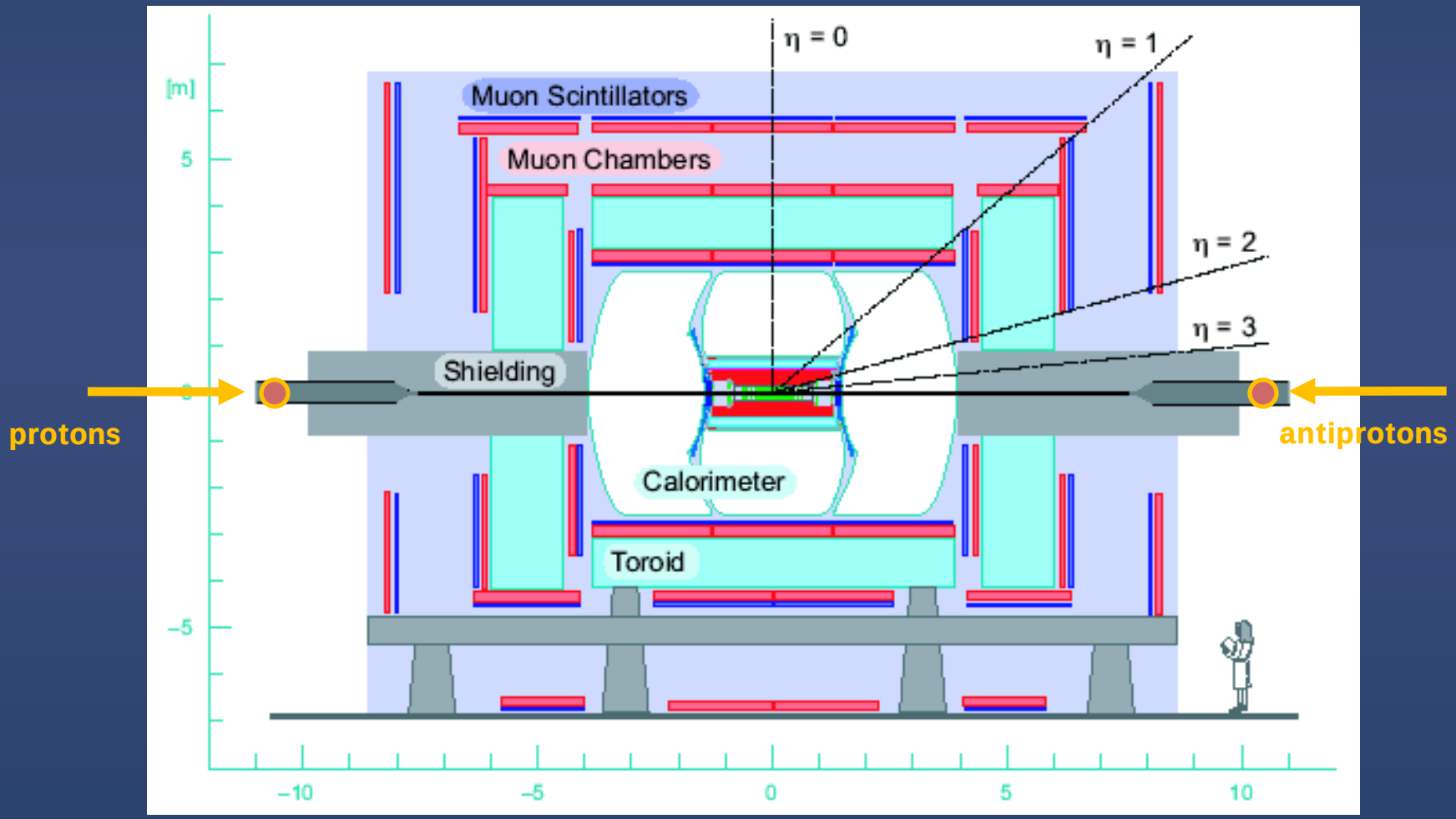
The DØ Detector

5000 tons of iron, uranium Liquid argon, coils, cables, wires, …



The DØ Detector

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η = 2
η = 3
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5
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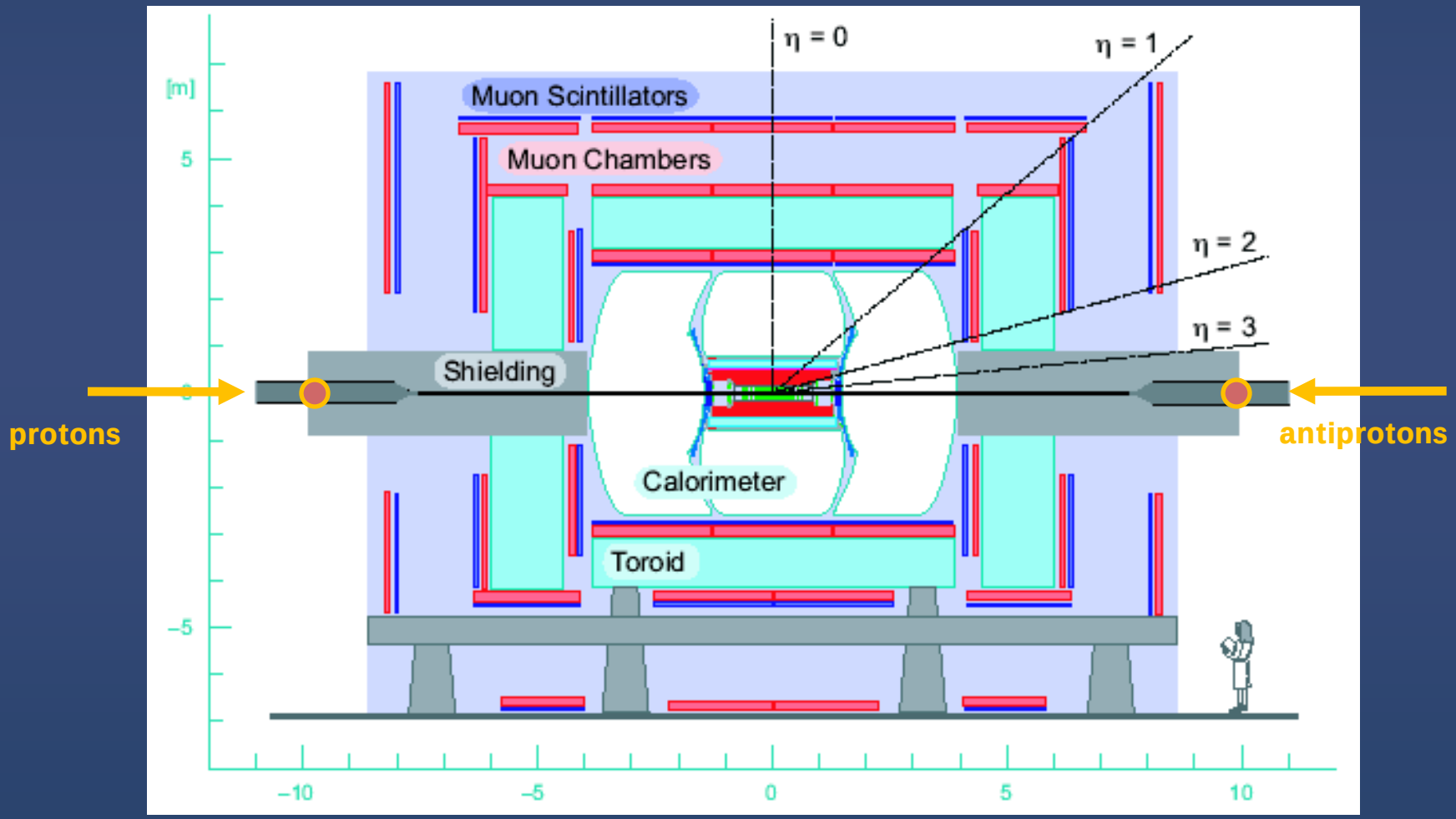
−5
Muon Scintillators
Muon Chambers
Shielding
Calorimeter
Toroid
protons
antiprotons
−10
−5
0
5
10

Every 396 ns....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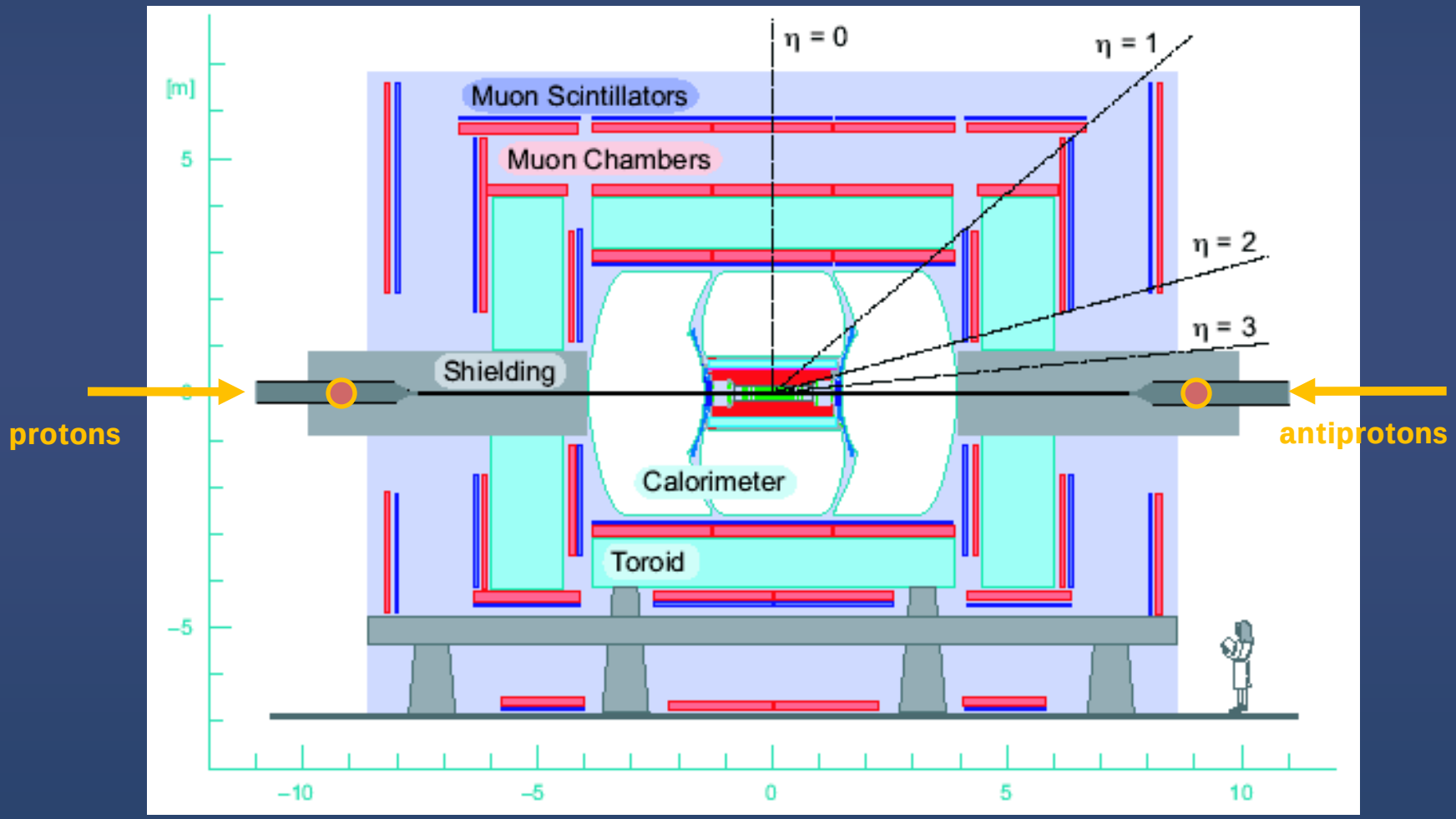
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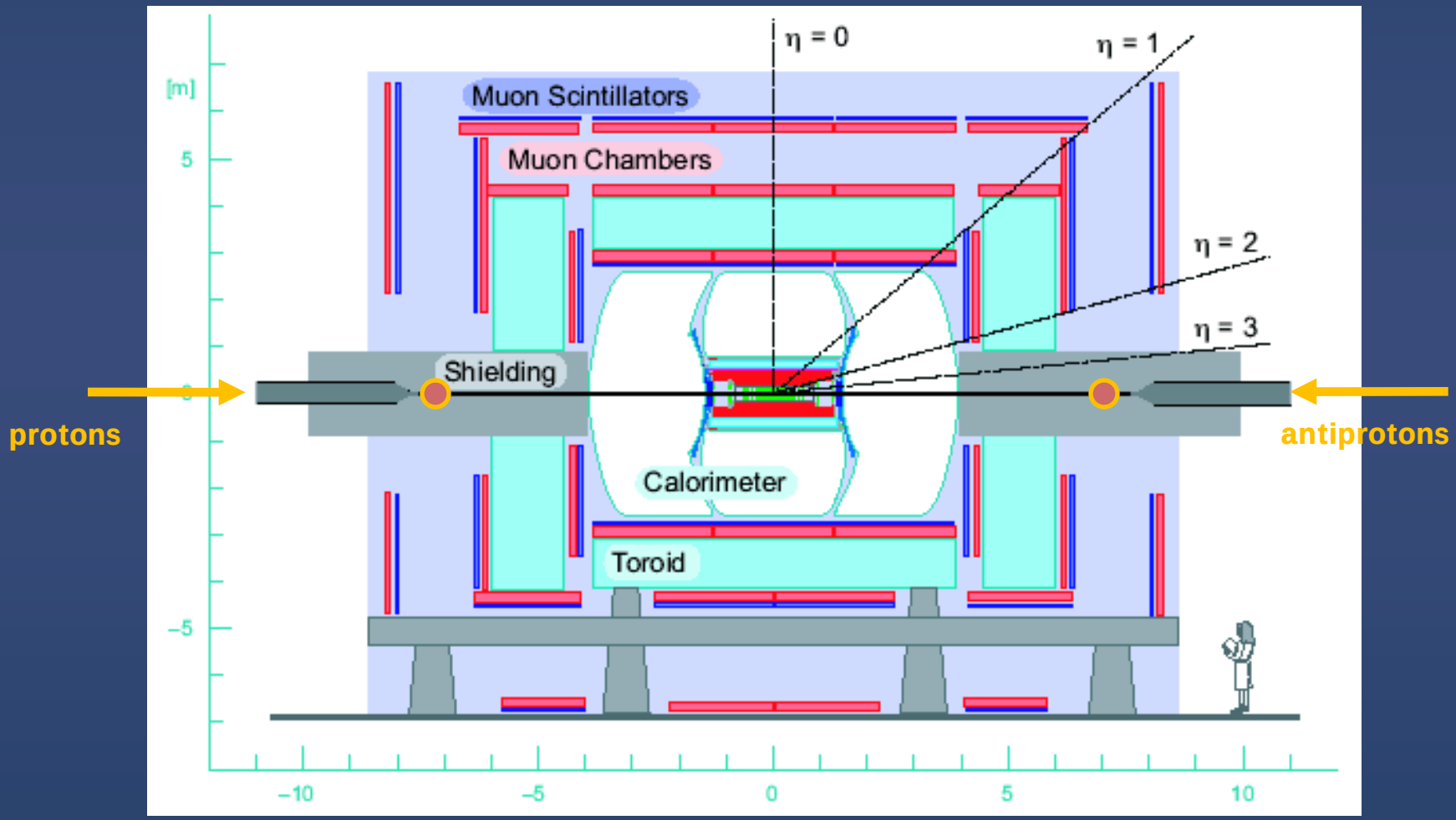
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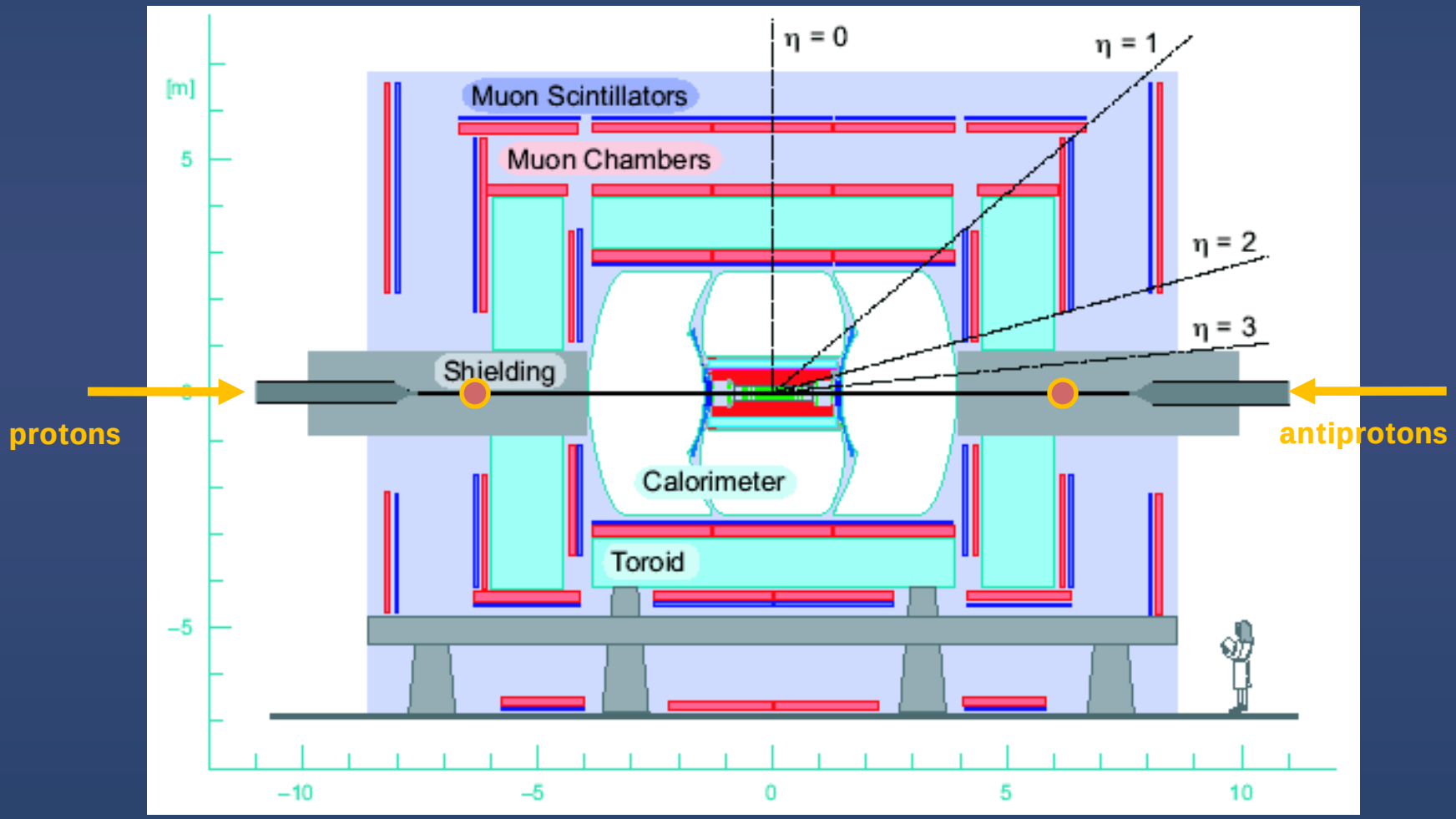
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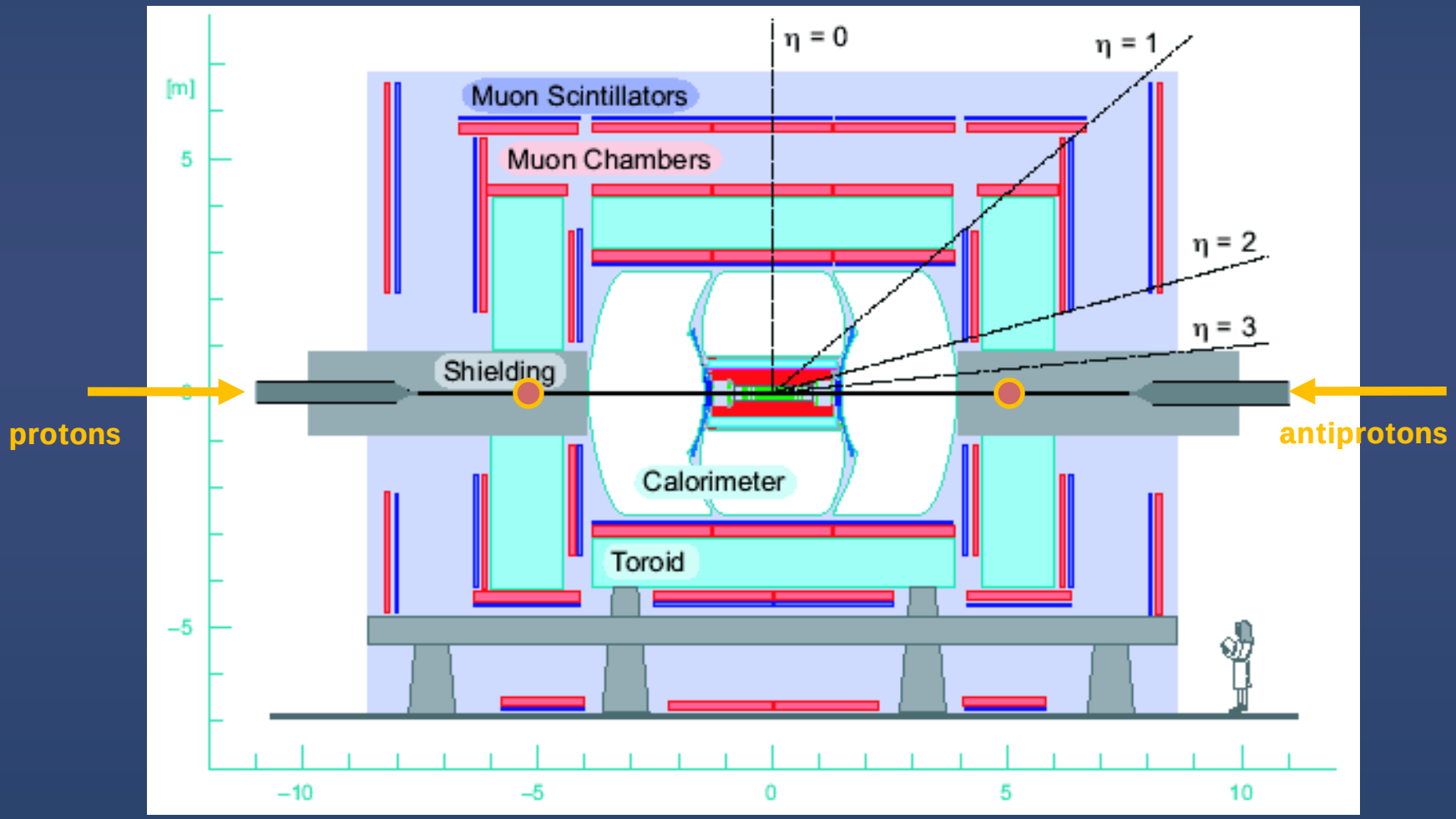
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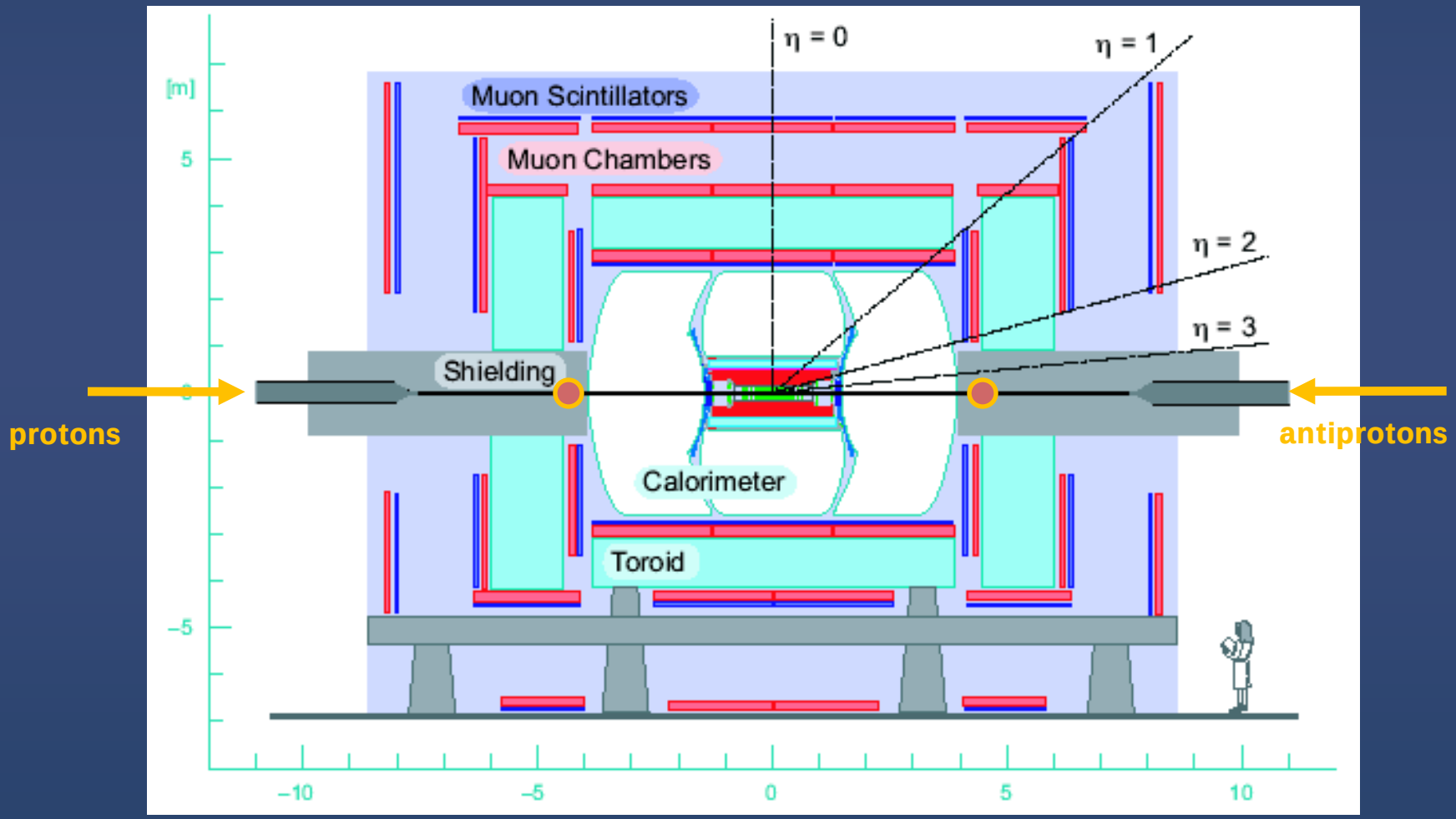
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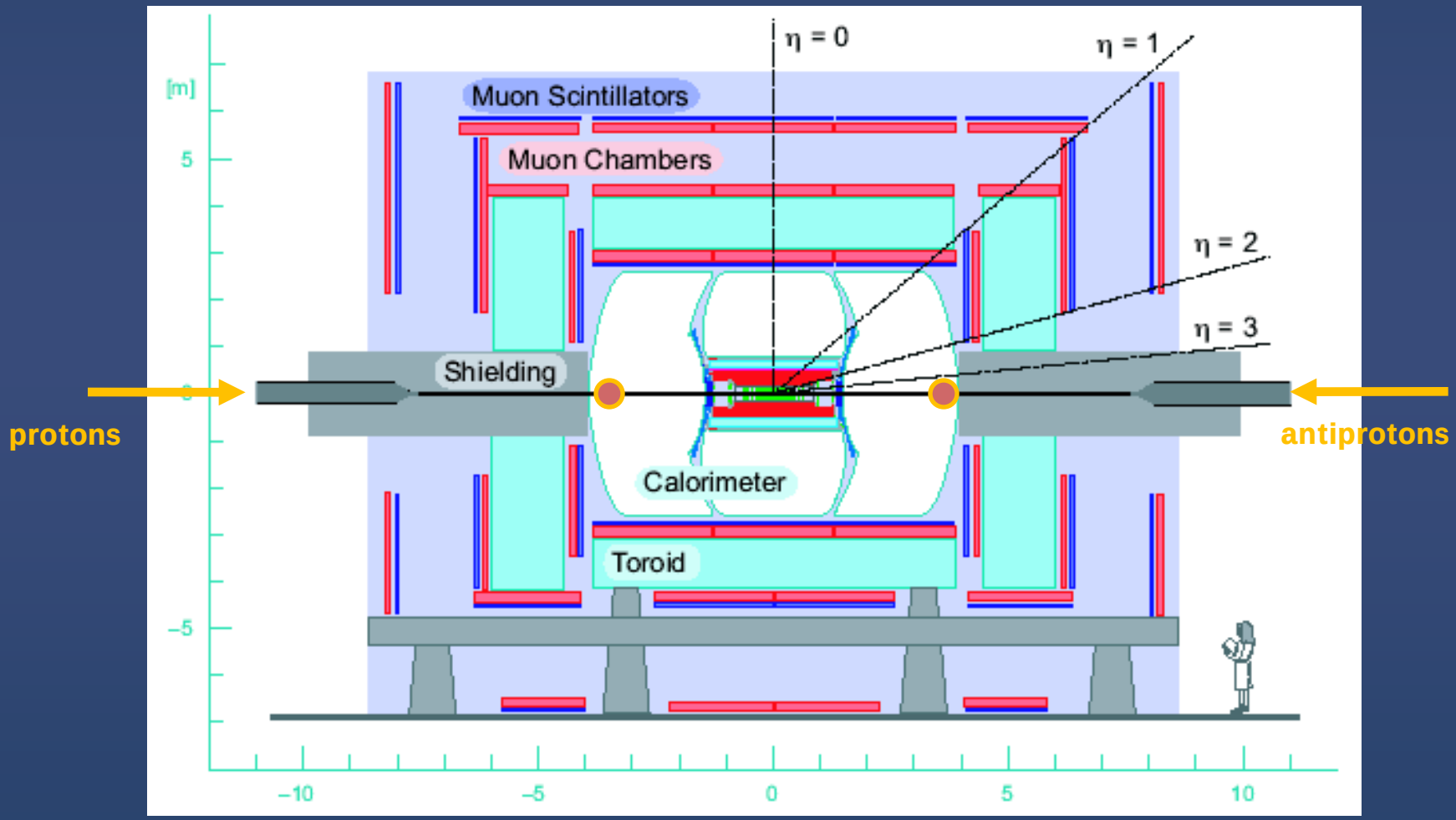
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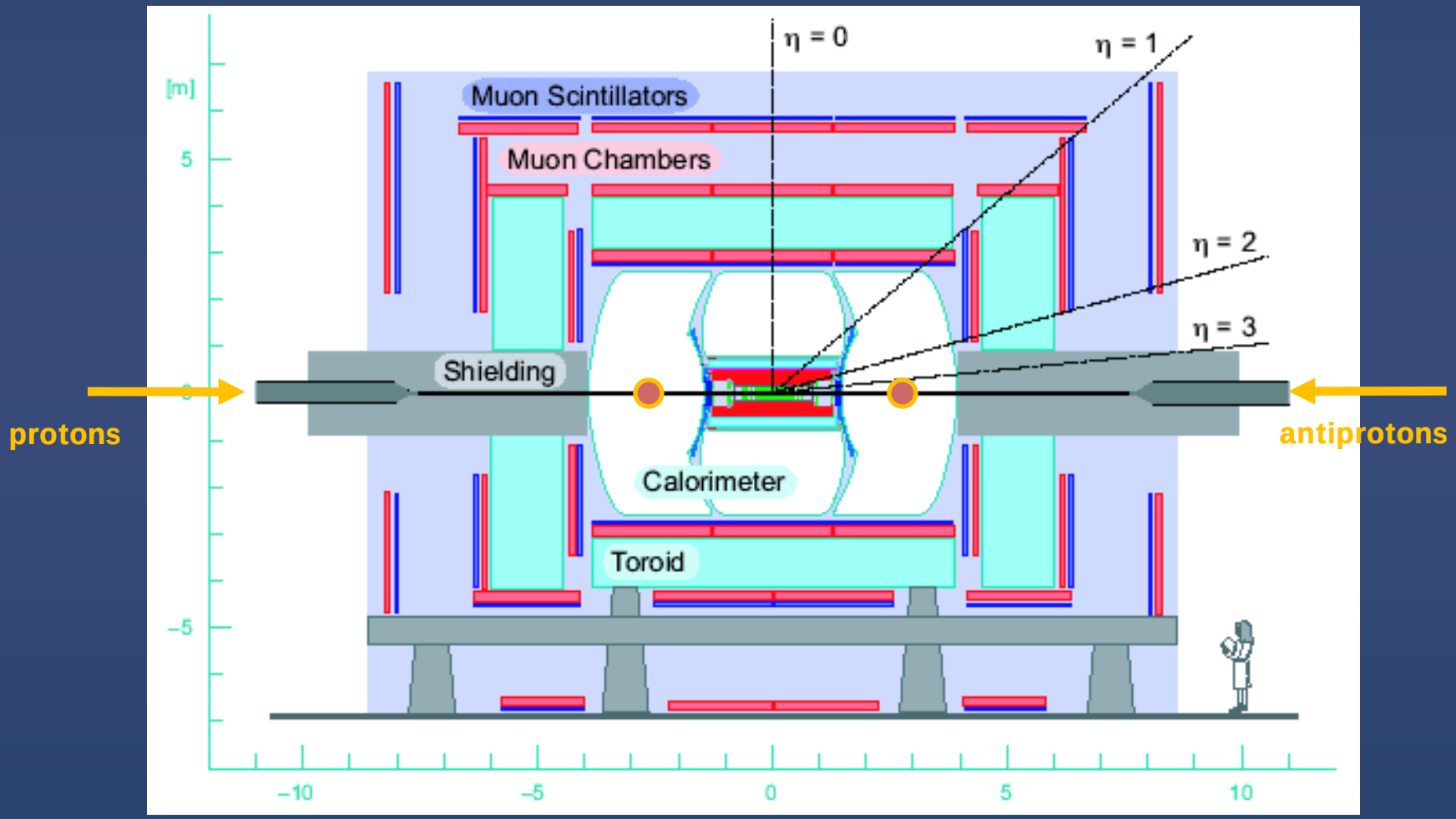
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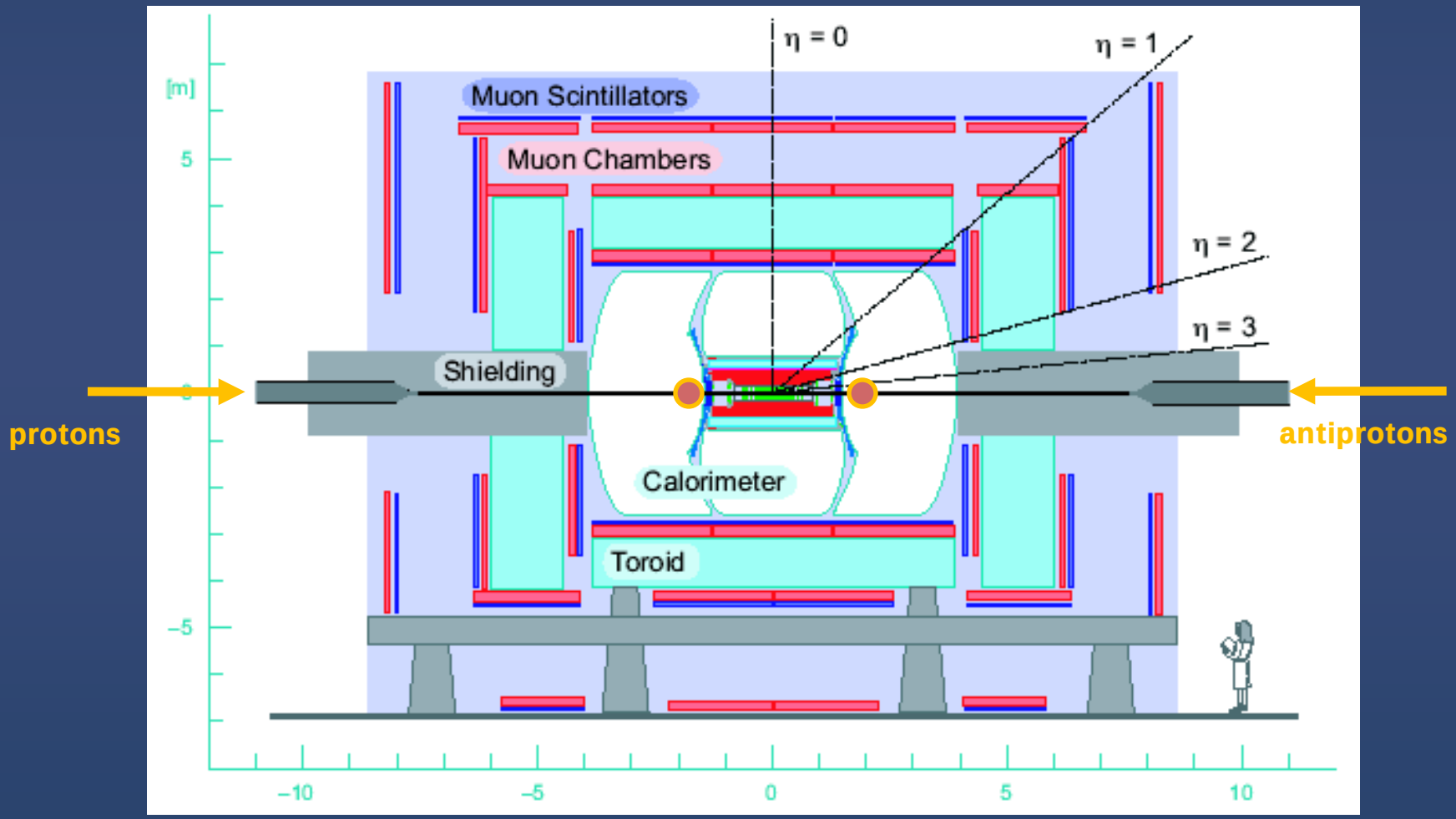
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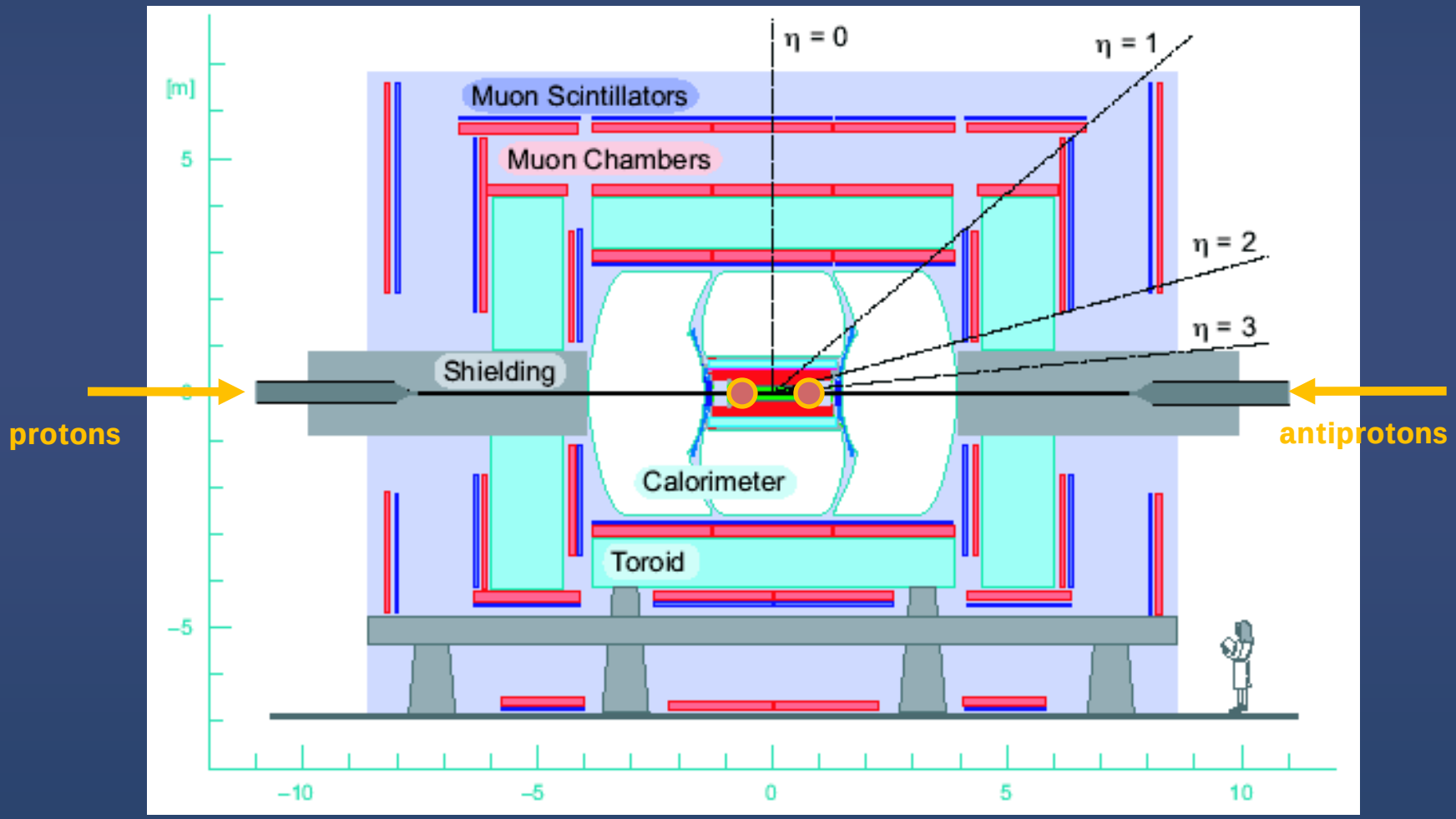
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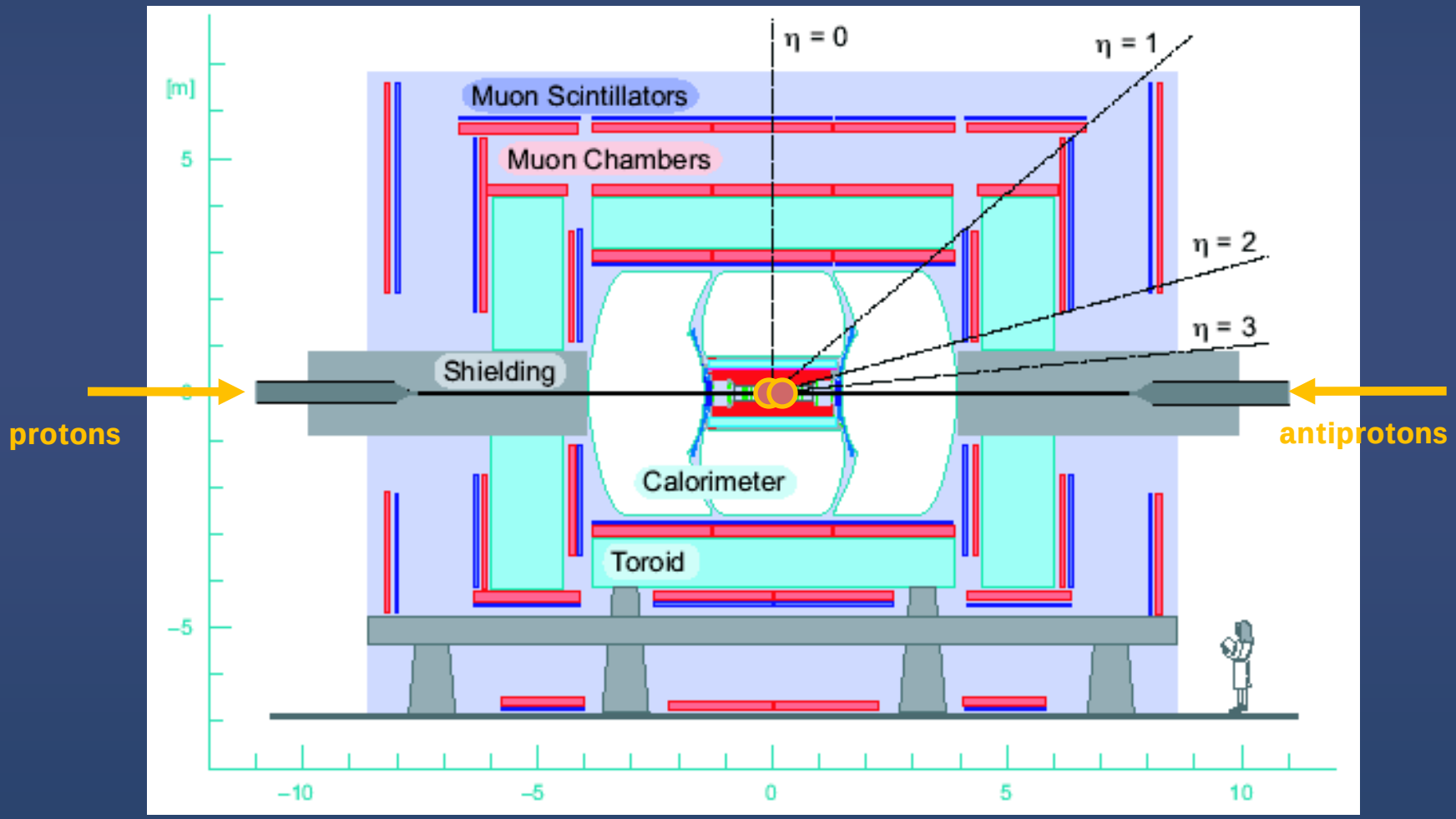
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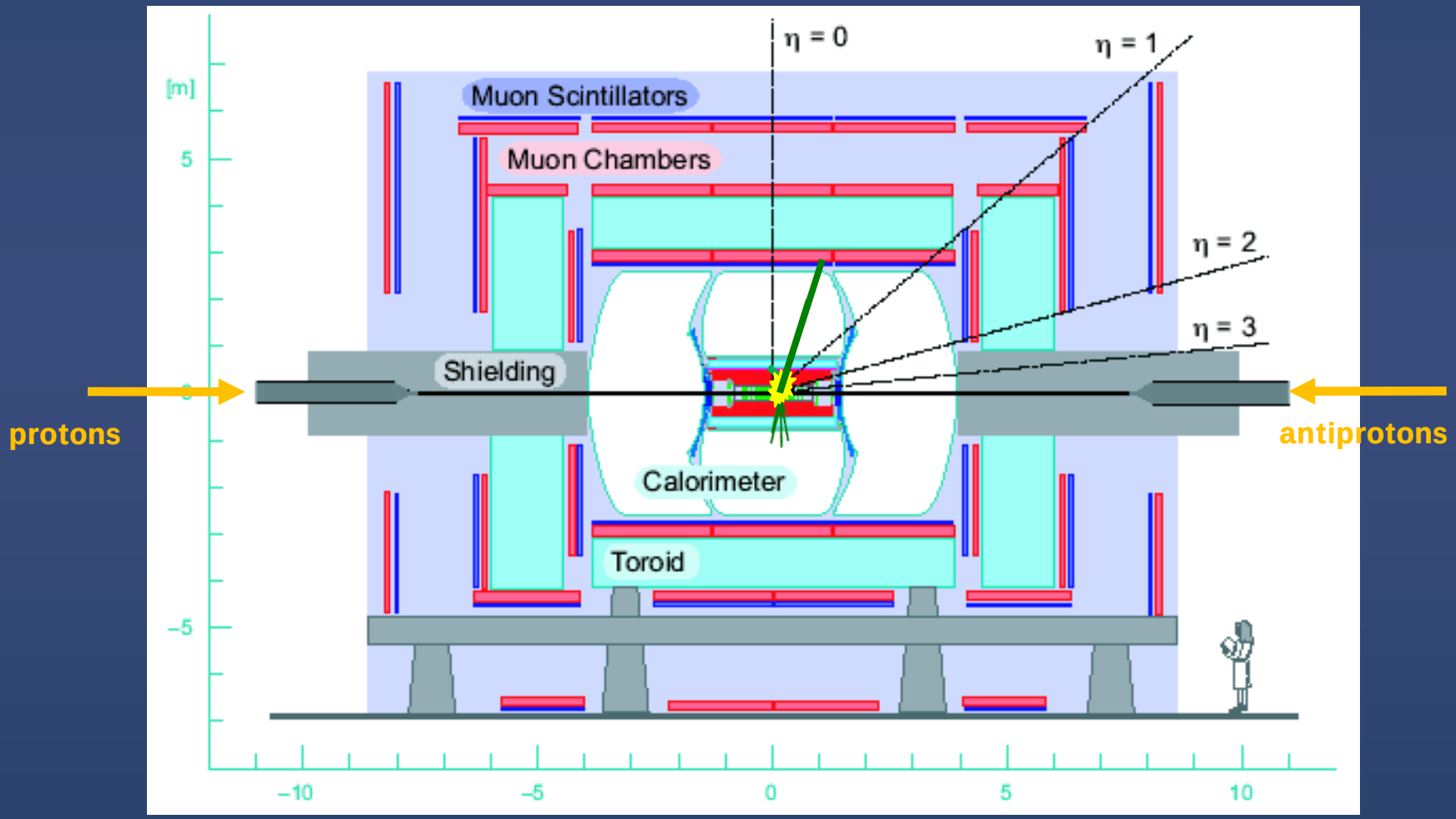
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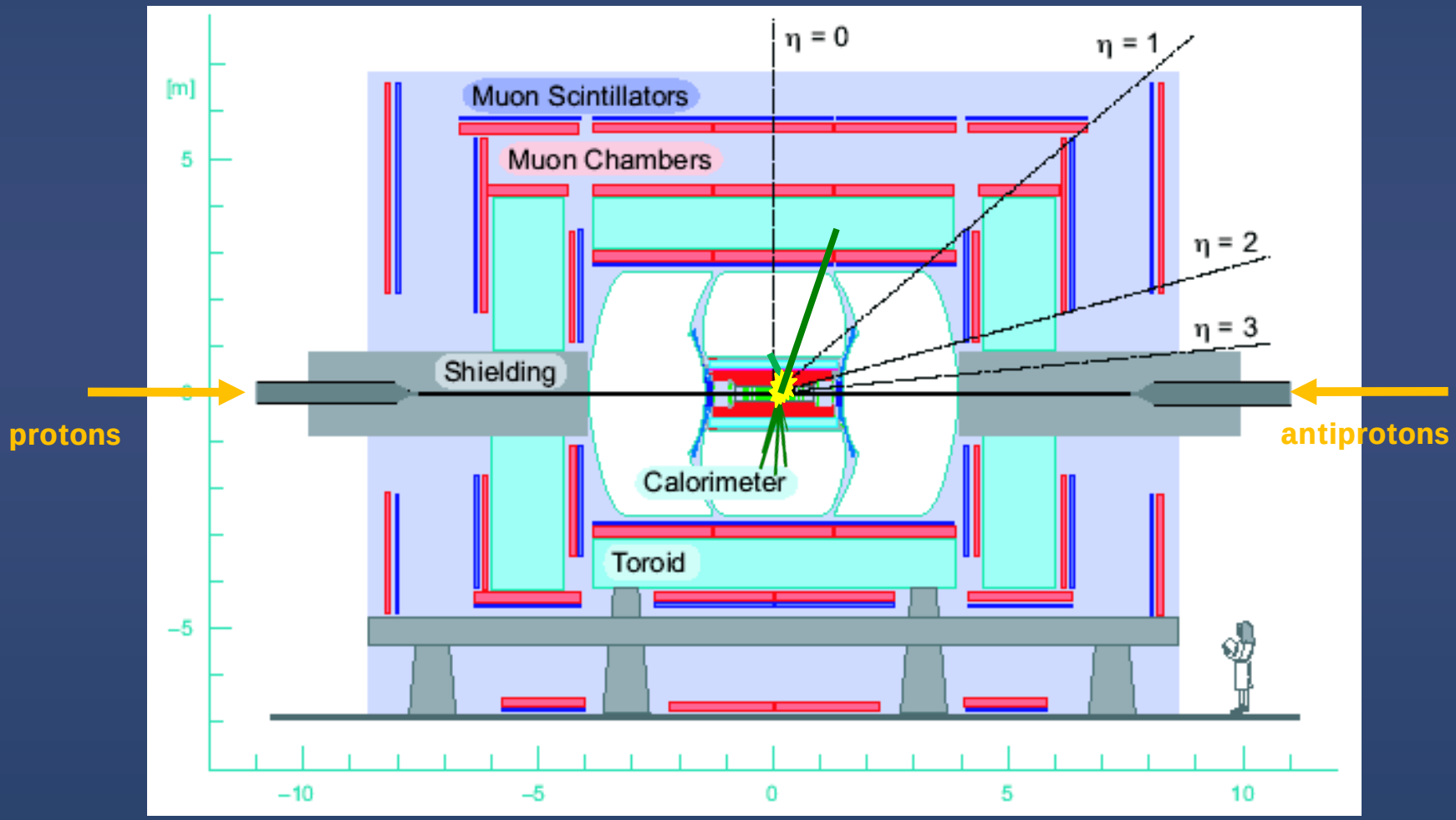
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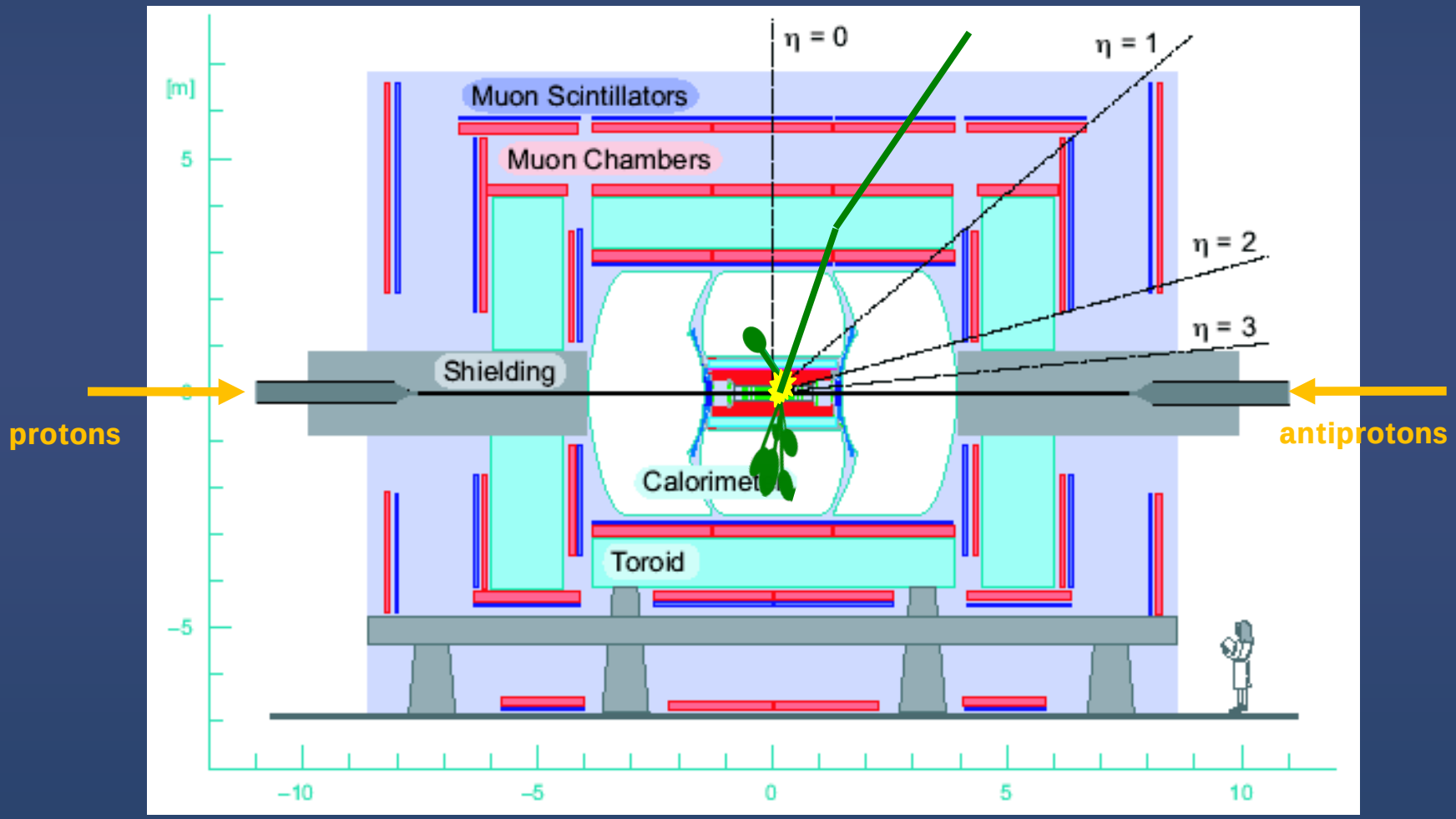
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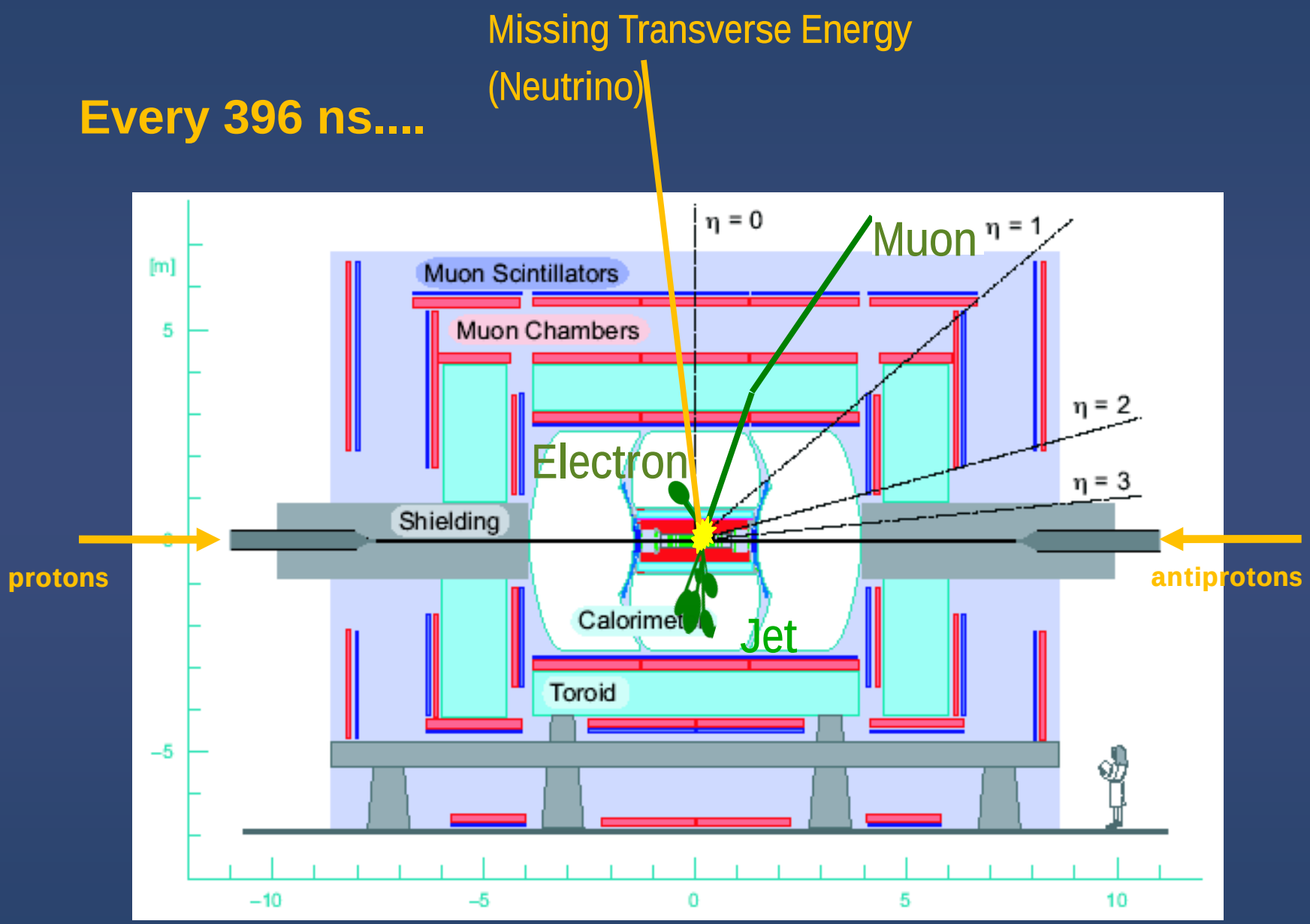
Every 396 ns....


Missing Transverse Energy
(Neutrino)
Muon
Electron
Jet
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η = 2
η = 3
Muon Scintillators
Muon Chambers
Shielding
Calorimeter
Toroid
[m]
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–10
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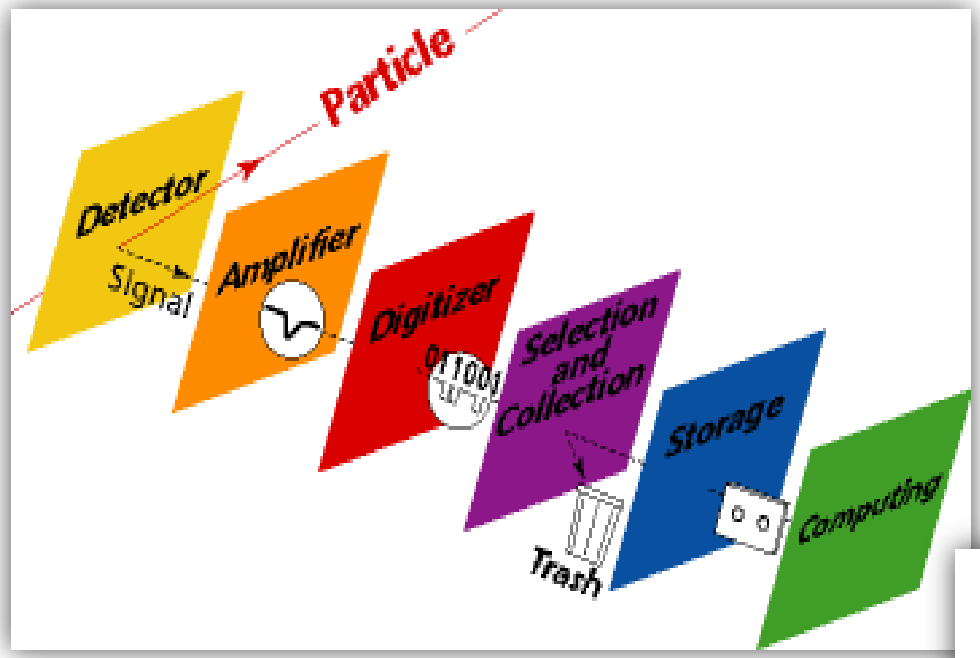
0
5
10
protons
antiprotons

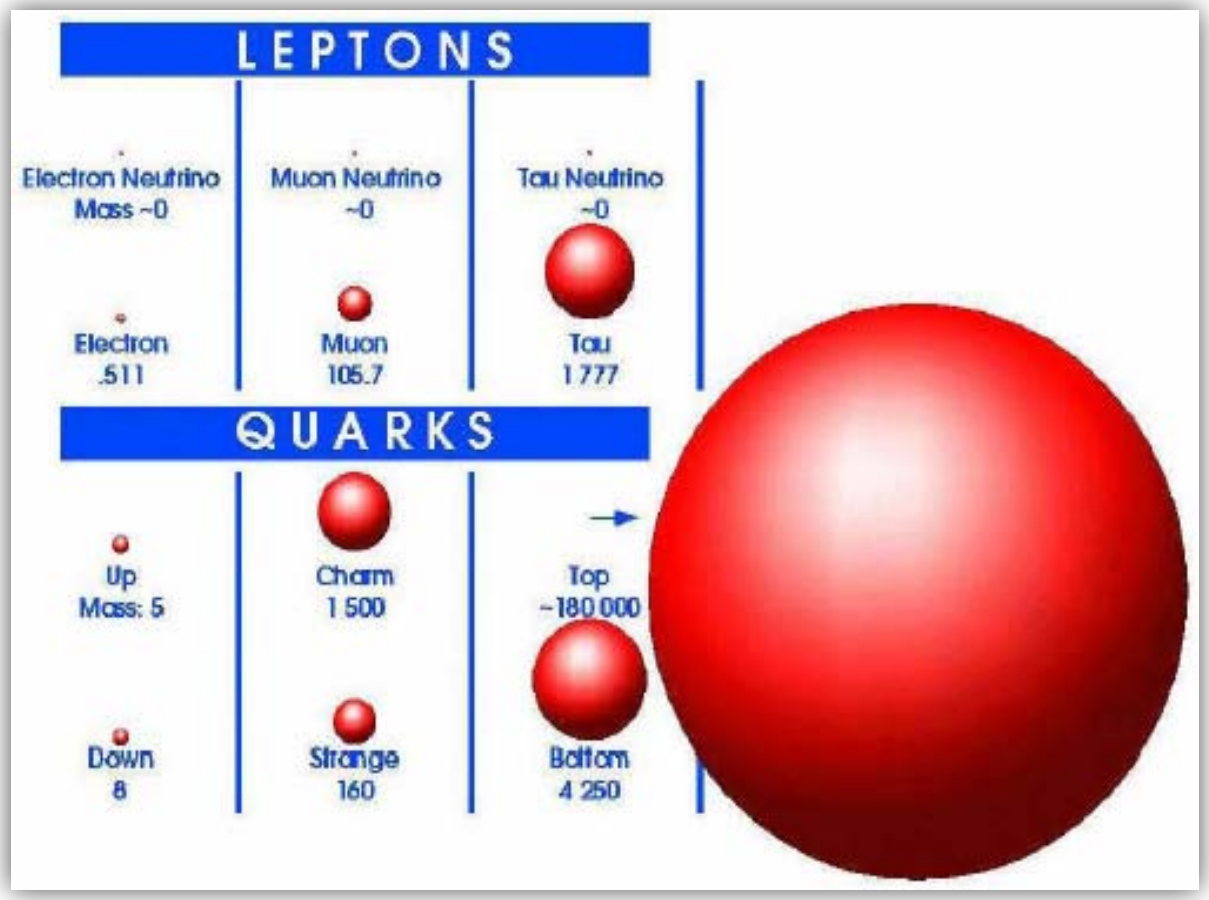

Particle
Detector
Signal
Amplifier
Digitizer
Selection and Collection
Trash
Storage
Computing

238 ft.

We discovered the top quark!

Why Look for the Top Quark?

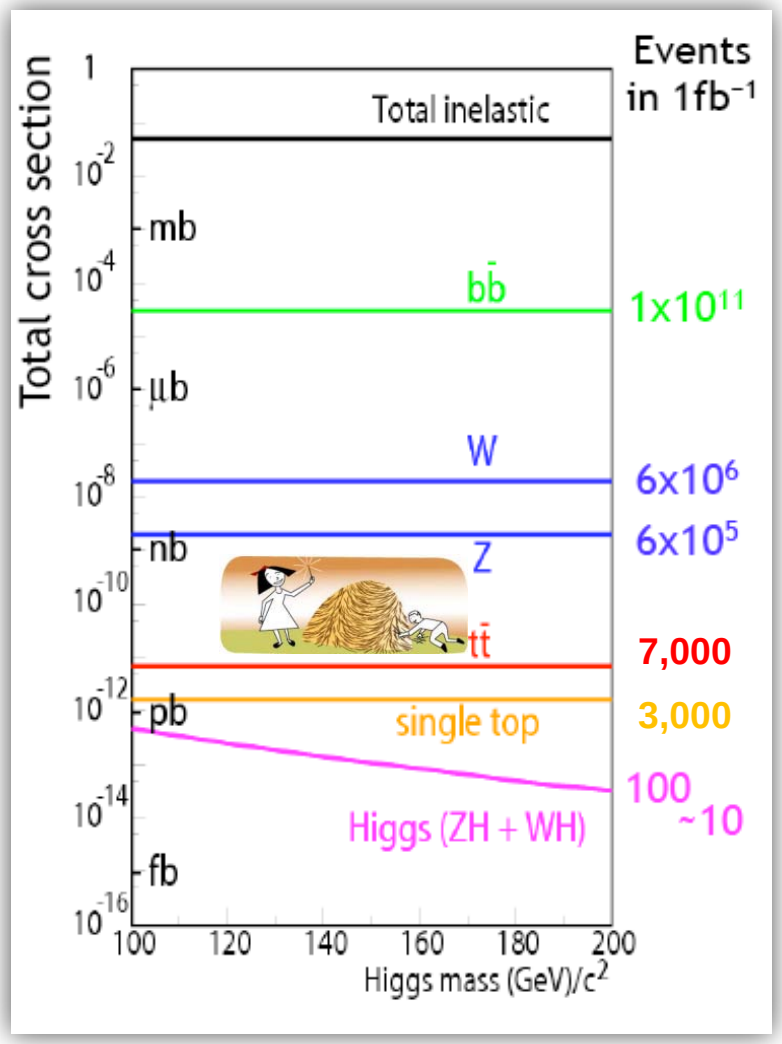
Discovered at Fermilab in1995



Why Keep Looking at the Top?

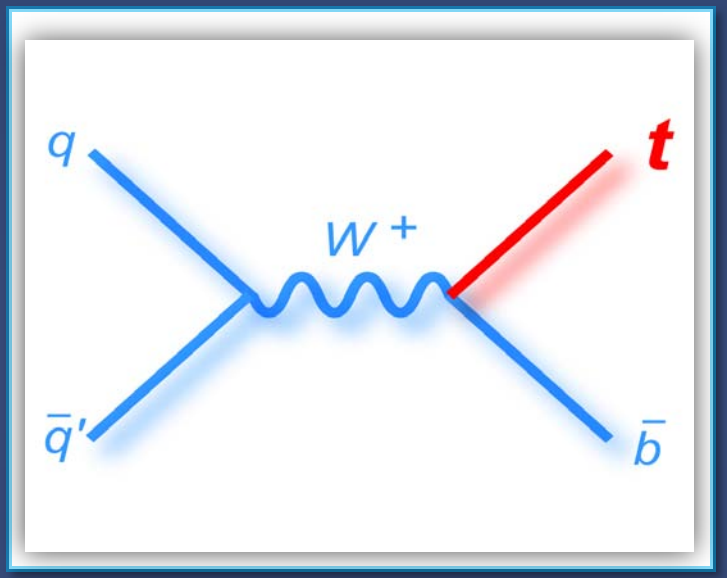
- Tevatron is the only place (so far) where top quarks can be produced
- Even more than a decade after its discovery, our sample consists of ~ 1000 top quark events

Lot of room for surprises!

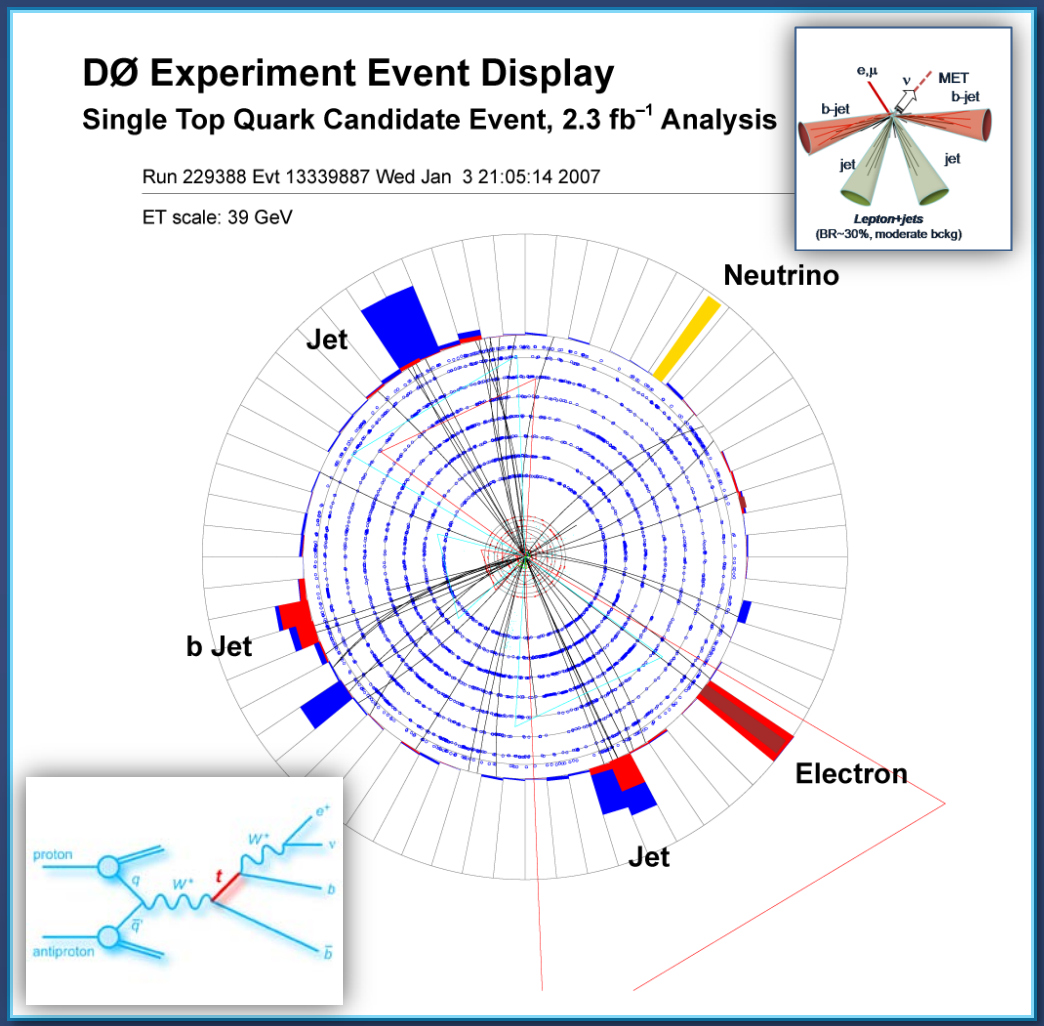


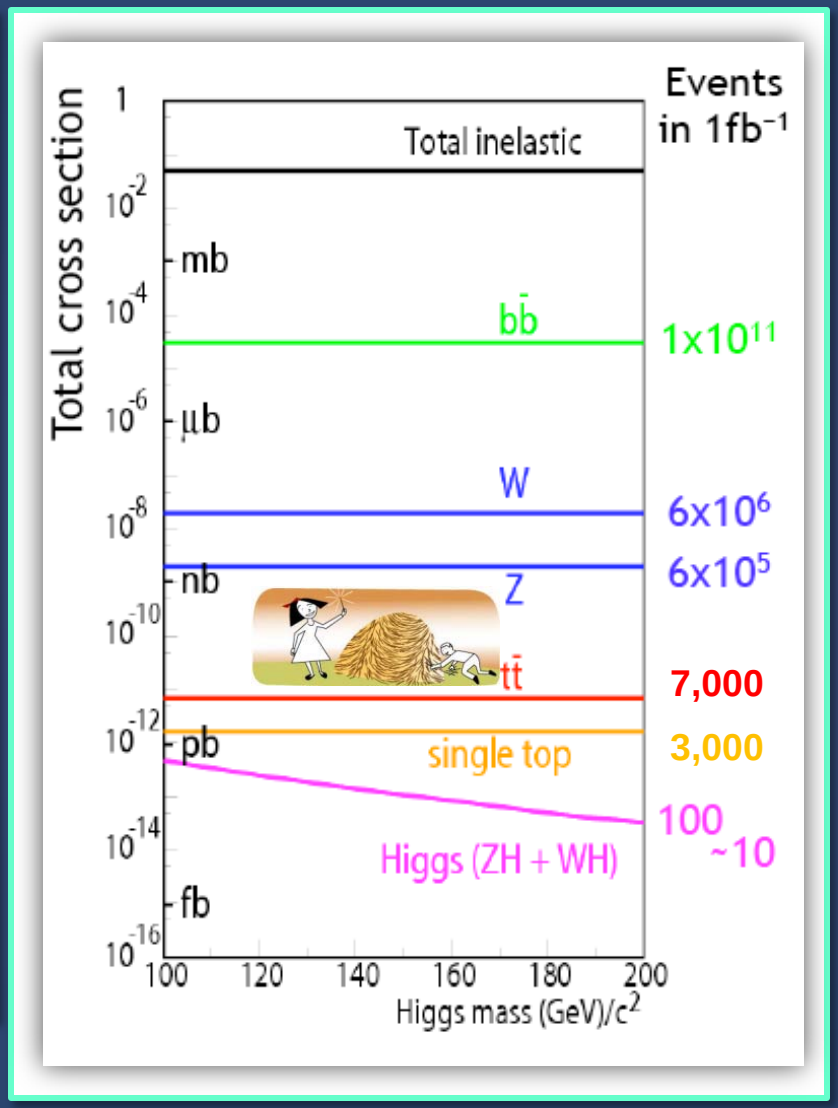
Top AND Single ……

- Study *Wtb* coupling in top production
- Cross sections sensitive to new physics
- Top properties
- Similar search as Higgs

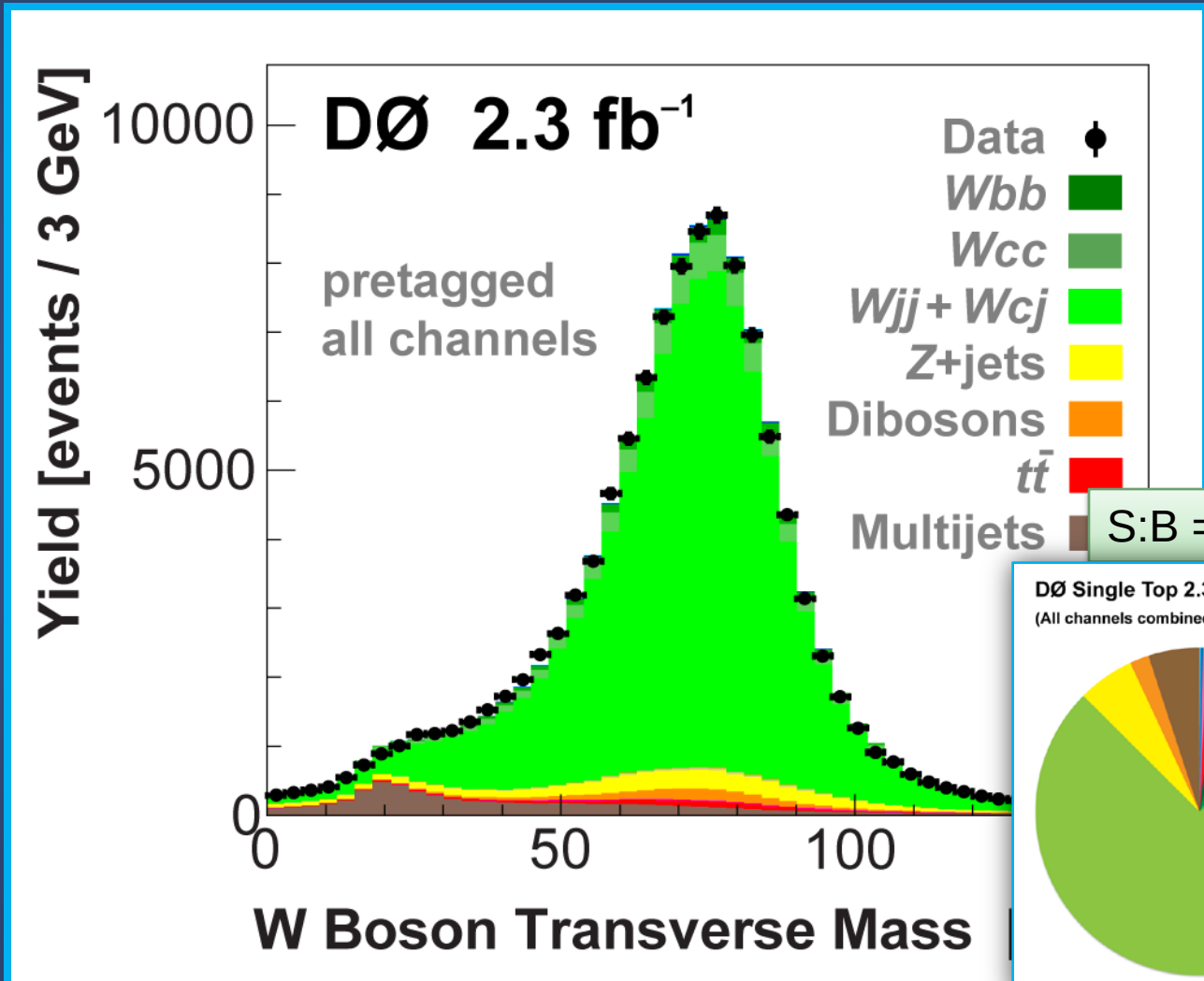


How Does Single Top Look in the Detector

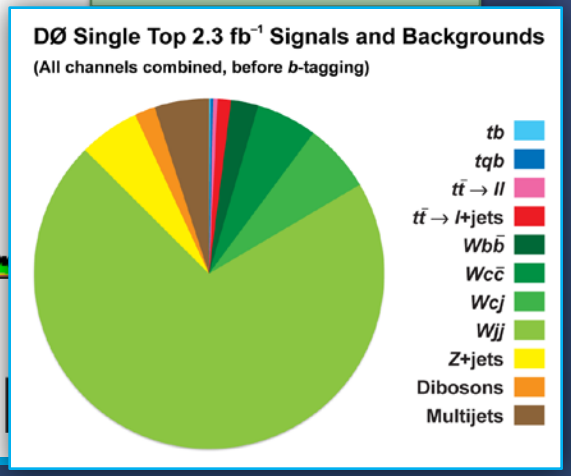




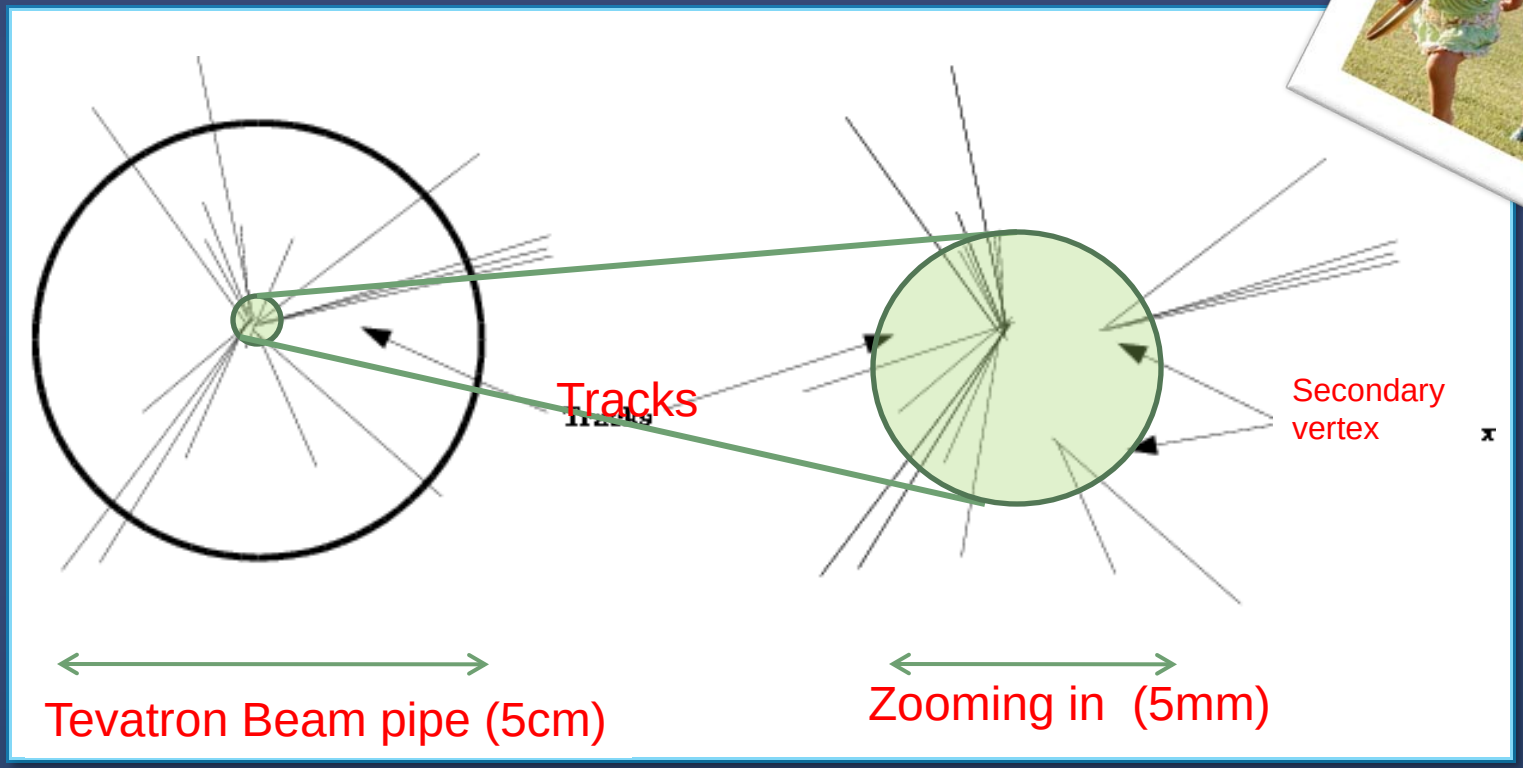
Signal and Back ground Modeling



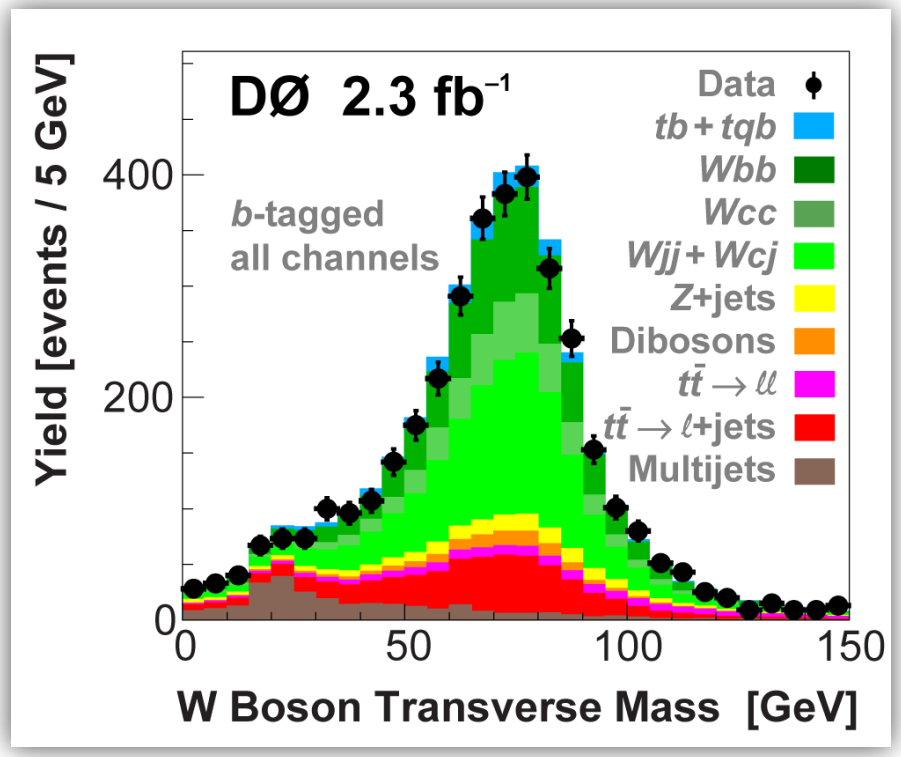
S:B = 1:259



Playing Tag Makes Things Better



….. After B-Tagging



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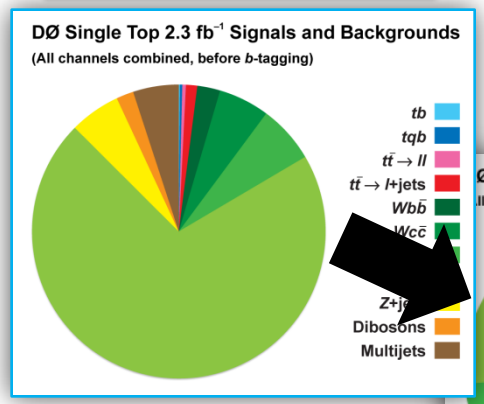
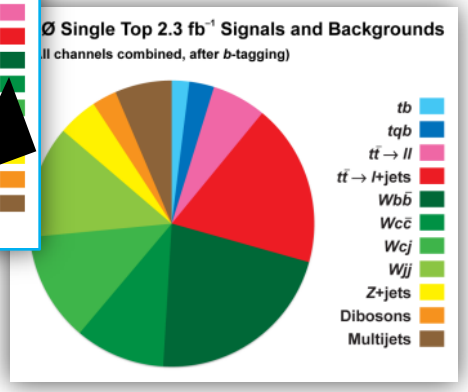


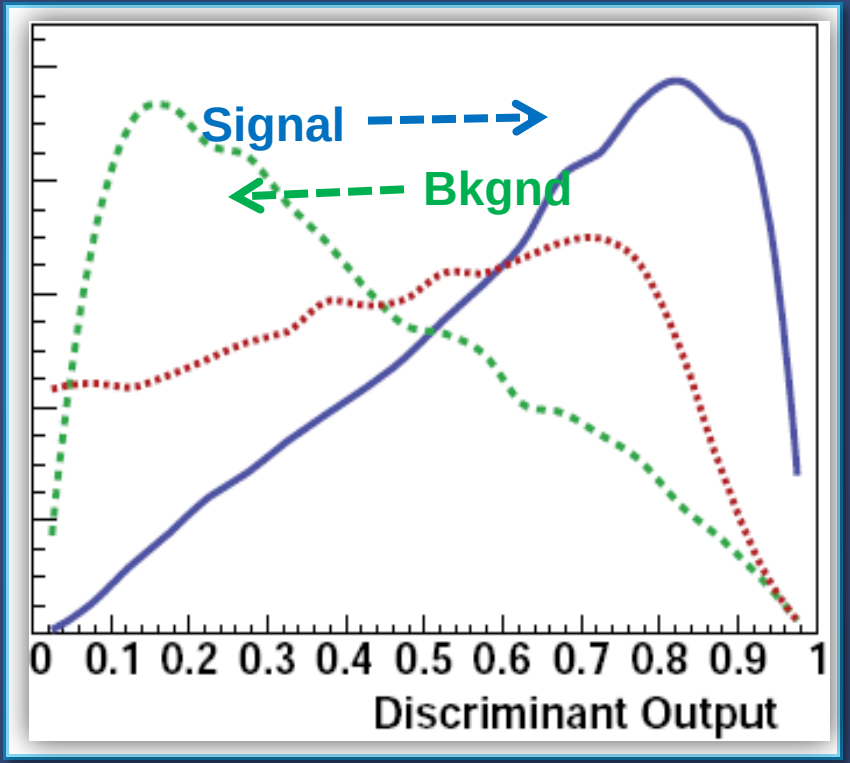


S:B = 1:21 in 1Tag
S:B = 1:15 in 2Tag

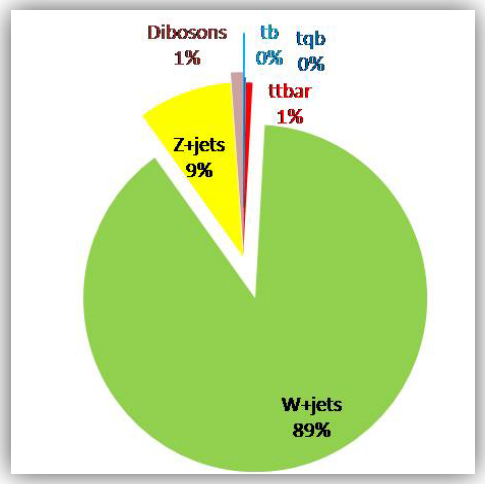
- Single top signal is smaller than total background uncertainty
- Counting events is not a sensitive enough method

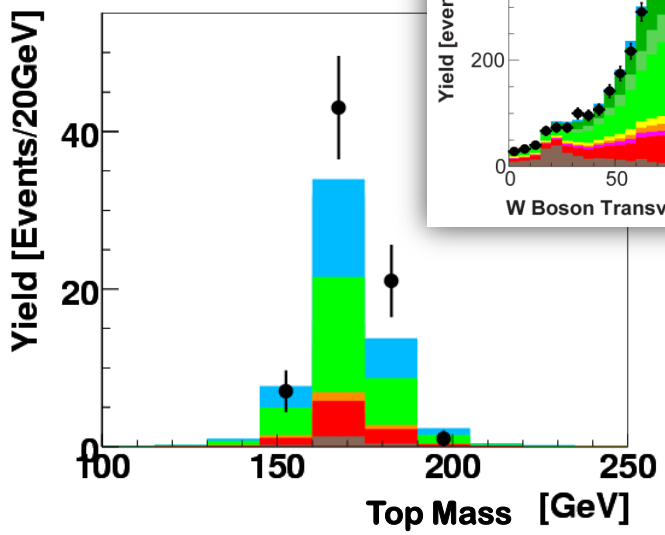
Multivariate Techniques

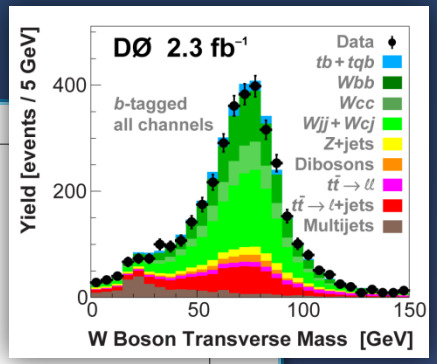
- Three techniques used for this analysis
  - Boosted Decision Trees
  - Matrix Elements
  - Bayesian Neural Networks



Combined Results





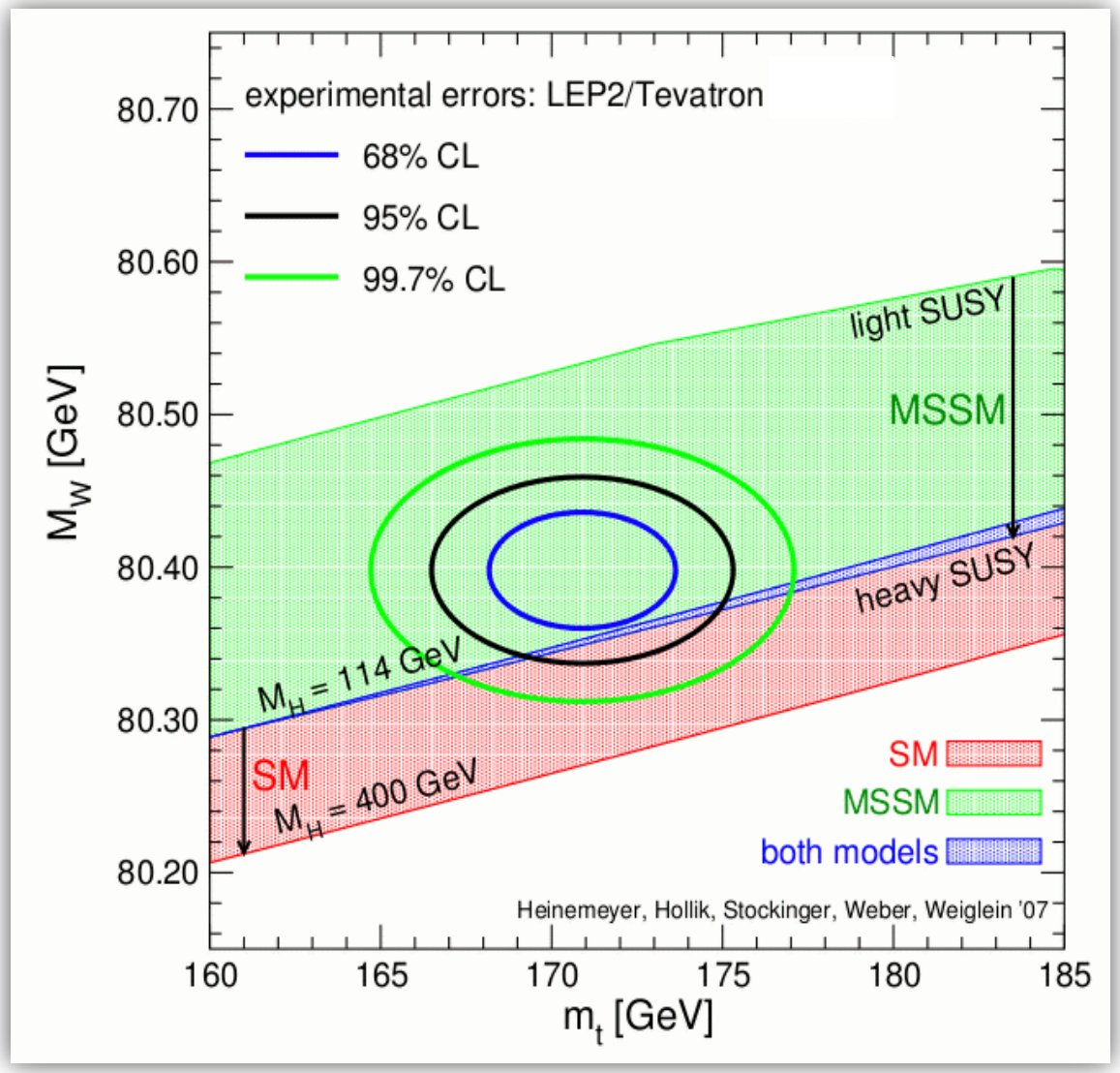


$$\sigma(p\bar{p} \rightarrow tb + X, tqb + X) = 3.94 \pm 0.88 \text{ pb}$$

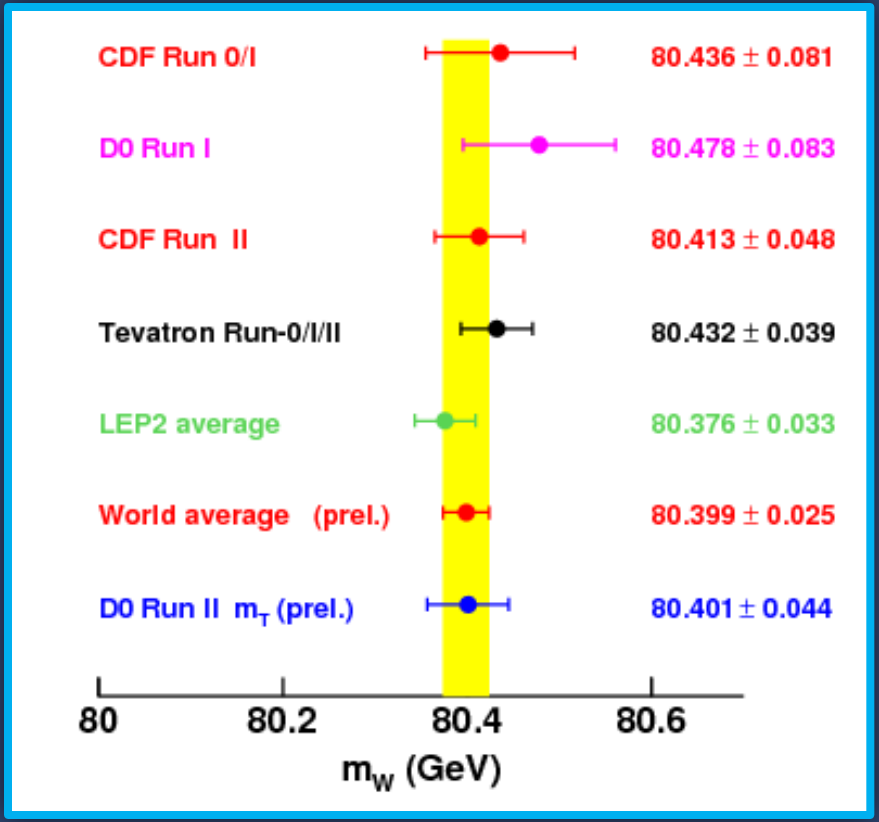
Measured Significance = **5.03σ**

Discovery of single top production!!

The Top, the W and the God Particle

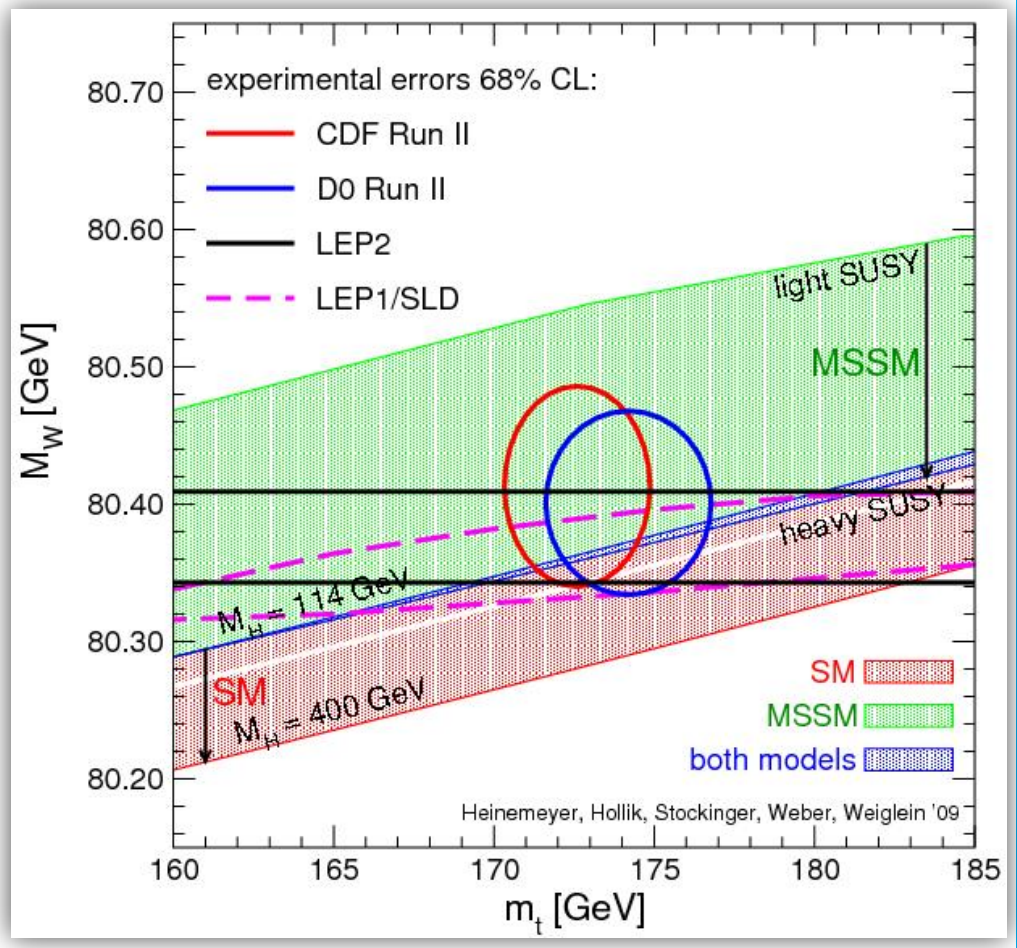


Measurement of W Mass



- The new result from DØ is the <u>single most precise</u> measurement of the W boson mass to date
  - Room for 10% improvement
- 25 MeV per experiment are around the corner, and a final combined error of 15 MeV is realistic

The Top, the W and the God Particle

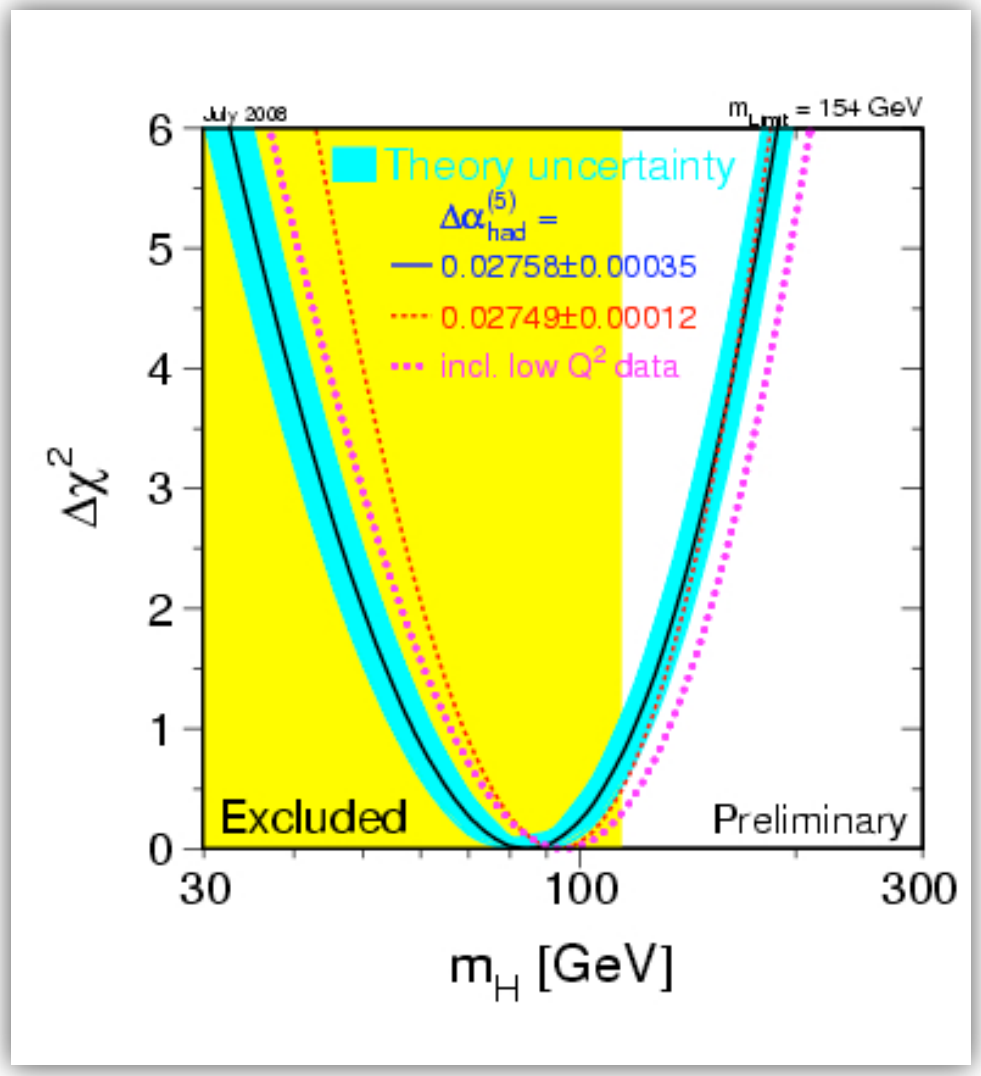


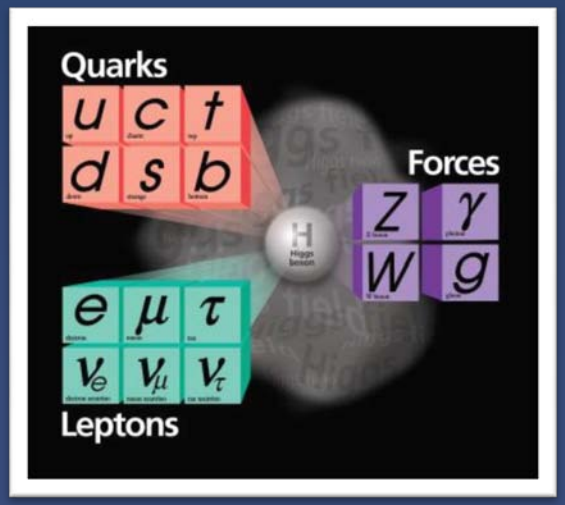
The W boson is squeezing the Higgs boson:

(photo by Robert Tilden)

With top quark mass known to less than 1%, the limiting factor now is how precisely W boson mass is known

Where to Look for Higgs?

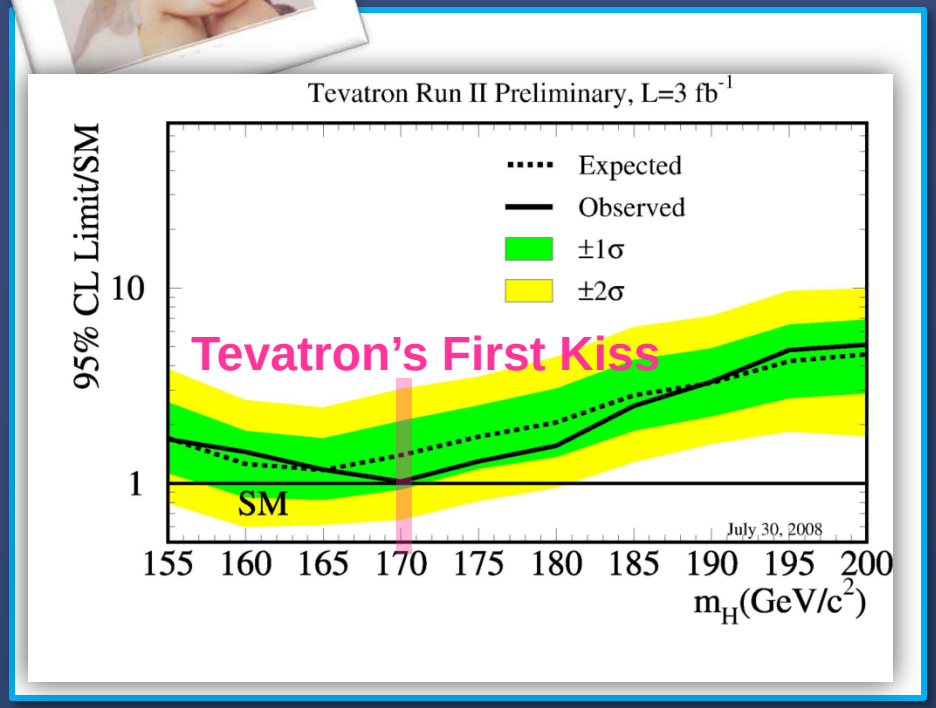


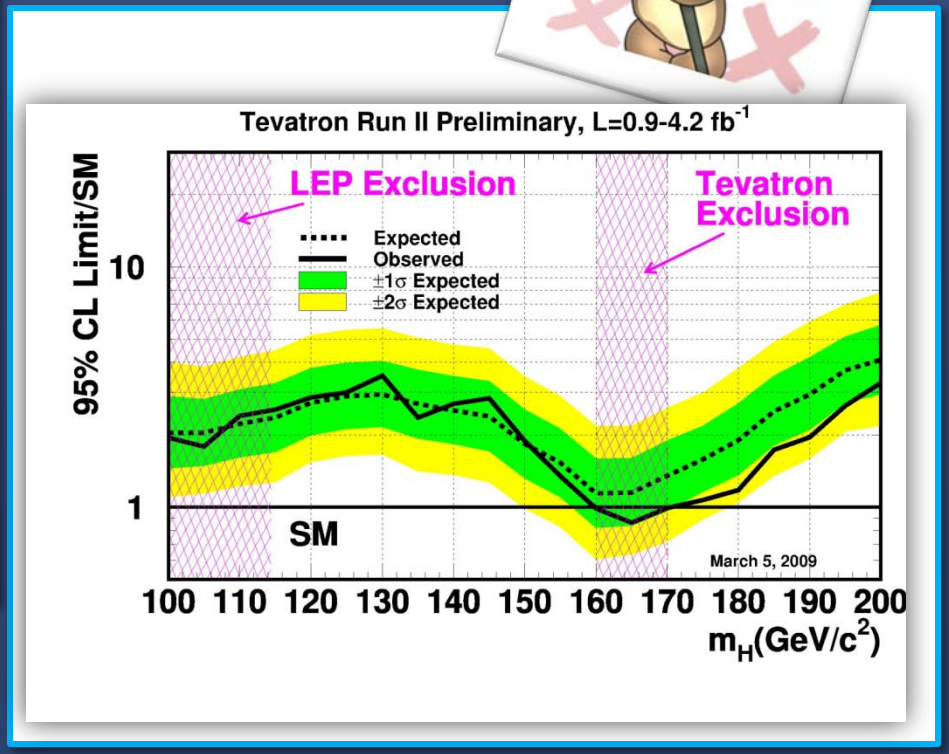


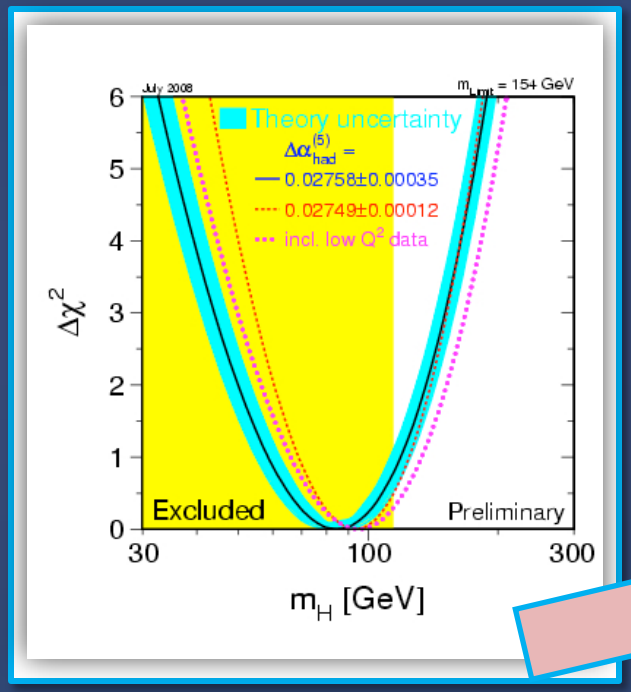
Direct search at LEP:
Hggs mass>114 GeV @ 95%CL

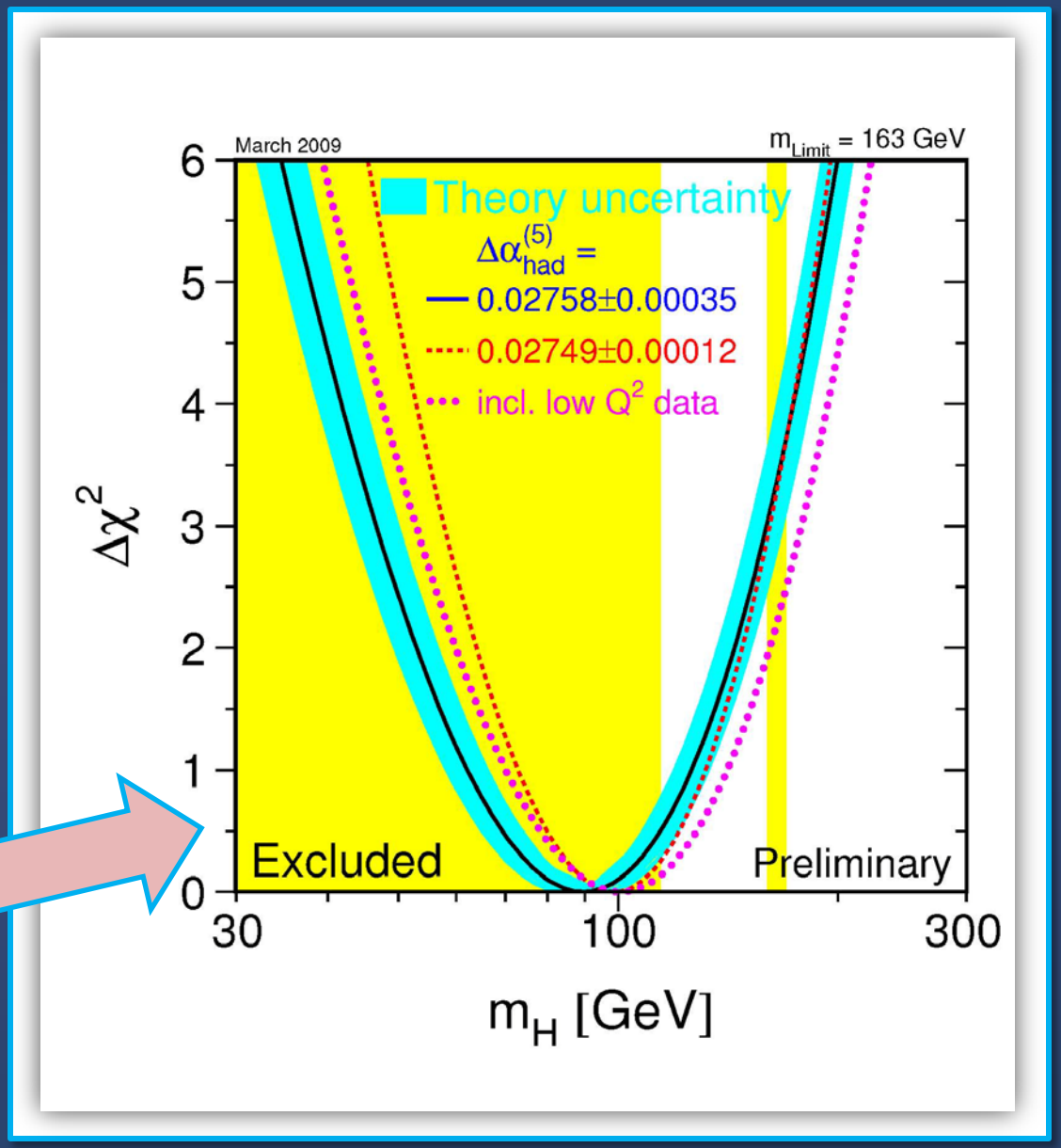
Including indirect electroweak constraints
Higgs mass <154 GeV @ 95%CL

Tevatron's Search for Higgs



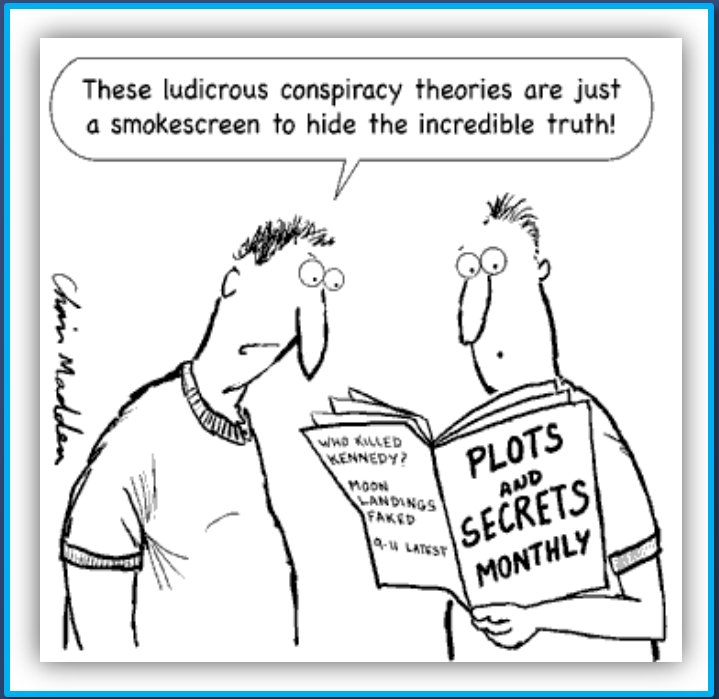



July 2008
m_{Limit} = 154 GeV
Theory uncertainty
$\Delta\alpha_{had}^{(5)}$ =
0.02758±0.00035
0.02749±0.00012
incl. low Q^2 data
$\Delta\chi^2$
Excluded
Preliminary
m_H [GeV]


March 2009
m_{Limit} = 163 GeV
Theory uncertainty
$\Delta\alpha_{had}^{(5)}$ =
0.02758±0.00035
0.02749±0.00012
incl. low Q^2 data
$\Delta\chi^2$
Excluded
Preliminary
m_H [GeV]

Looking Forward to TeV Scale

- Maybe a Higgs (or something like it)
- Maybe supersymmetry (lots of new particles)
  - Supersymmetric models have at least 5 Higgs particles!
- Maybe extra dimensions



Poised to Answer the Big Questions

To Bob Wilson from Chris Quig

"…. thank you for giving us normal, everyday human beings the chance to discover, within every one of us, a little bit of the gods."