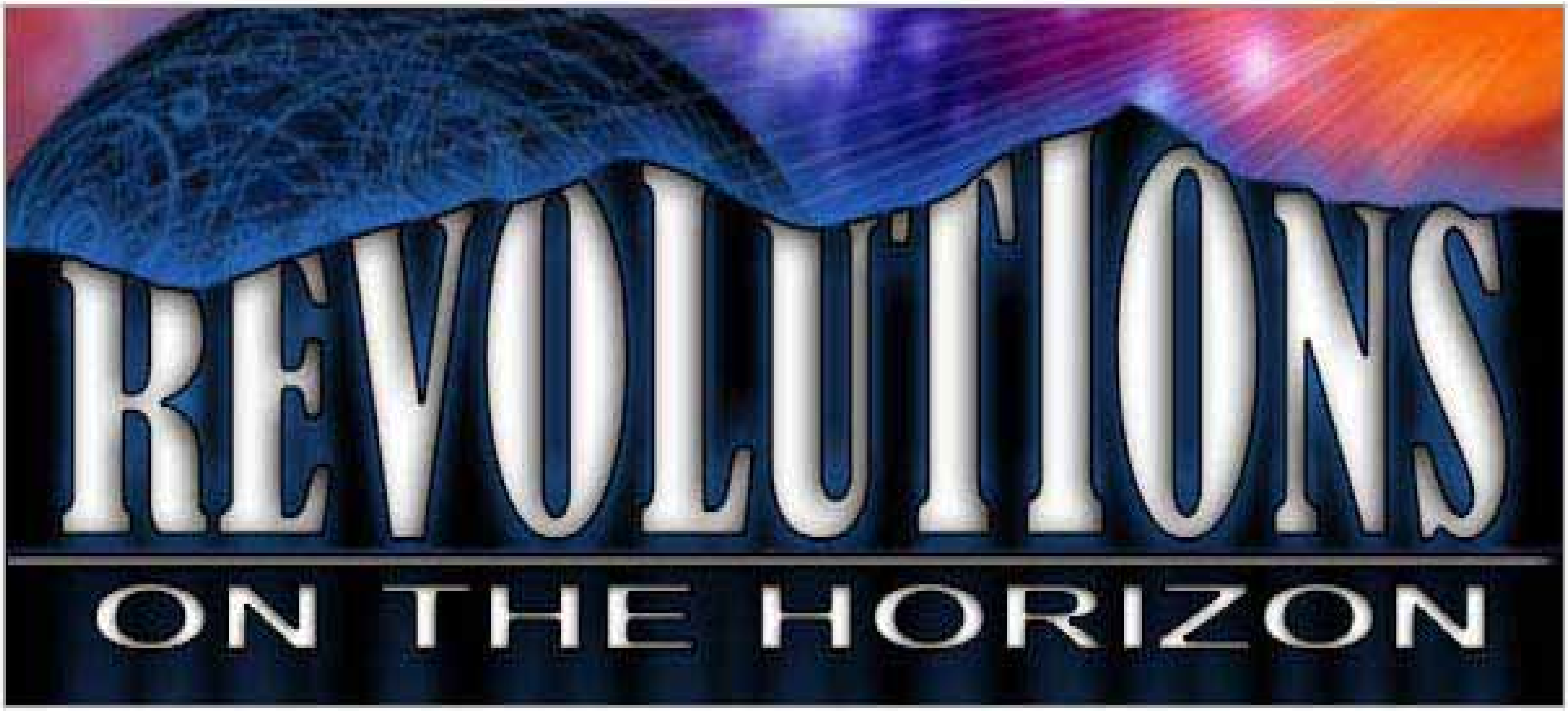
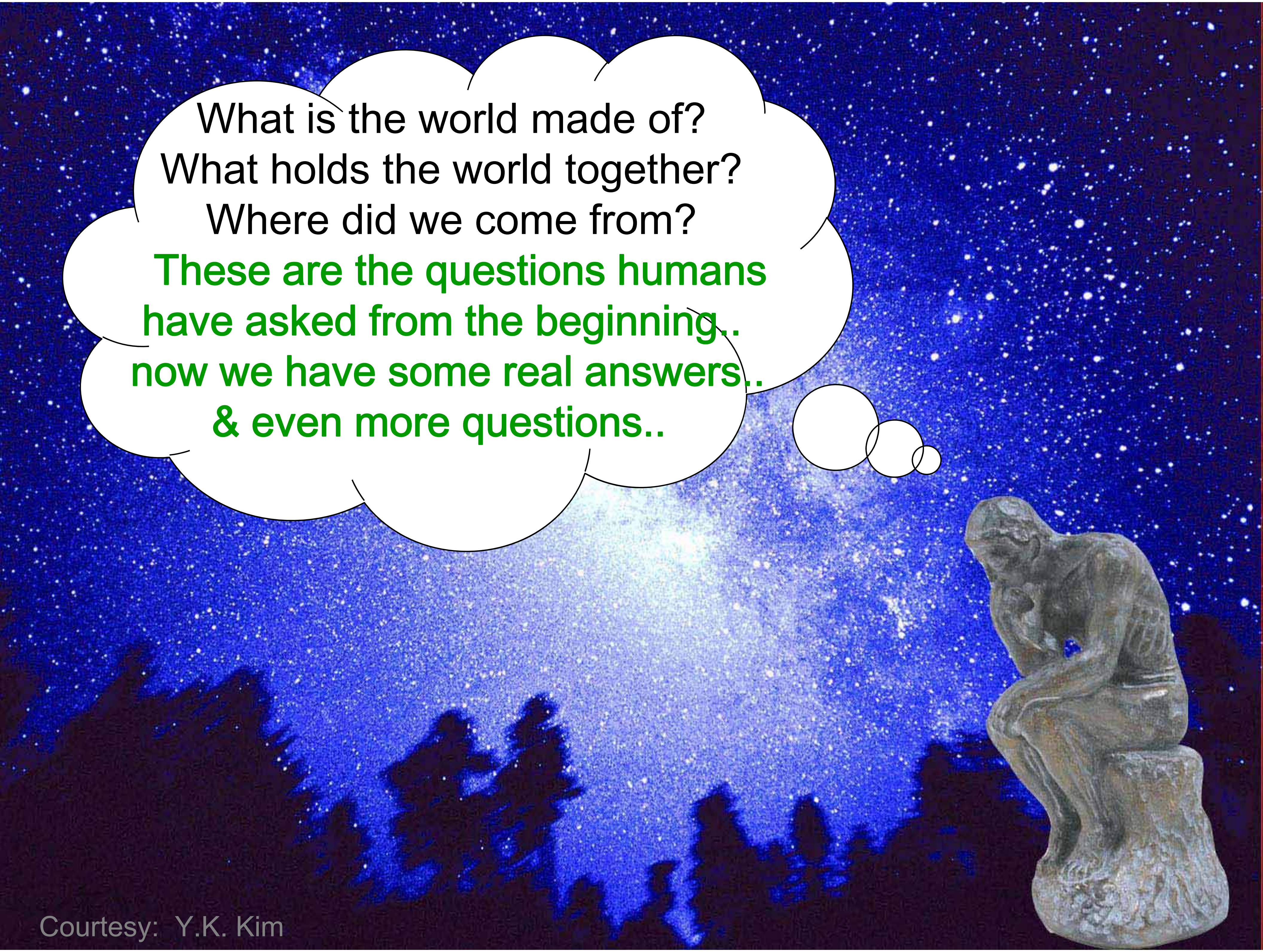
Theoretical High Energy Physics



-- stolen from SSI-2009

SLAC NATIONAL ACCELERATOR LABORATORY

Tom Rizzo 6/25/2009


What is the world made of?
What holds the world together?
Where did we come from?
These are the questions humans have asked from the beginning..
now we have some real answers..
& even more questions..
Courtesy: Y.K. Kim

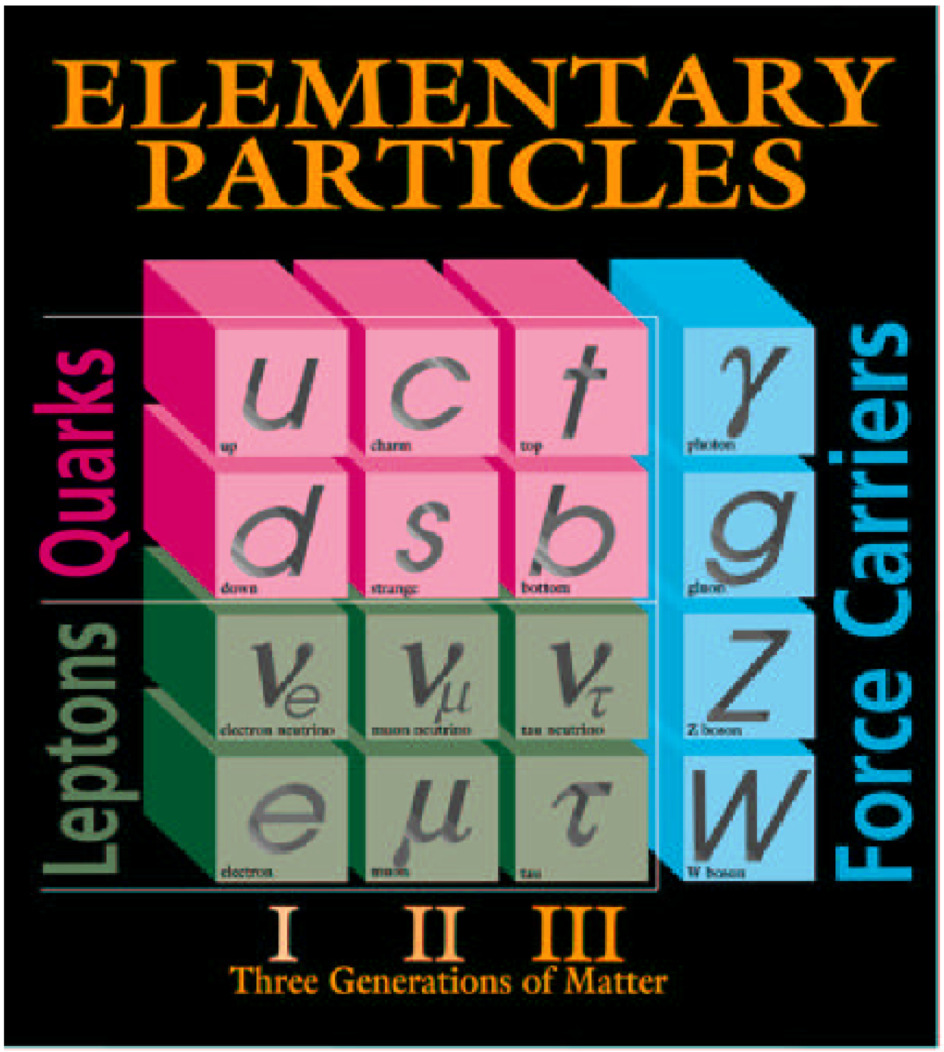
The purpose of High Energy (= Particle) Physics is to discover & understand the basic components of matter and their various interactions at the most fundamental level. More generally, we seek the answers to the following questions:

1. What are the basic laws of nature?
2. What is the composition of the universe?
3. How did the universe get to be as it is?

→ Here we immediately see the overlap between HEP and astrophysics

One of the great scientific triumphs of the past century is the development of the 'Standard Model' which, together with General Relativity, well describes all of the matter & interactions that we see around us (and in all of the existing laboratories on Earth) on scales as small as 10^{-16} cm and as large as 10^{23} cm.

The Standard Model describes the strong nuclear force, the weak nuclear force, and electromagnetism (light, electricity, magnetism…) while General Relativity describes all of gravity.



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Quarks & leptons are spin-1/2 *fermions* making up all of the matter we know (proton ~ uud) They come in 3 'generations' or copies for some *unknown* reason .

The strong force is 'carried' by gluons, the weak force by $W^{\pm}$ & Z bosons and electromagnetism by the photon ; all are spin-1 *bosons.* Gravity is carried by gravitons which have spin-2.

The Forces result from ‘Gauge Symmetries’:

$$\underbrace{SU(3)_C}_{\text{QCD}} \times \underbrace{SU(2)_L \times U(1)_Y}_{\text{Electroweak}}$$

Electroweak → ‘Spontaneously Broken’ to QED

Gauge invariance leads to massless force carriers like the γ & forces of infinite range . But the weak force is short ranged so W/Z bosons are massive requiring a ‘breaking’ of the gauge symmetry by some mechanism. In the SM this is done by the spin-0 *Higgs boson*.

While all the gauge bosons, quarks & leptons of the SM have been observed experimentally, the Higgs has not yet been seen in any experiments….

Origin of Mass:

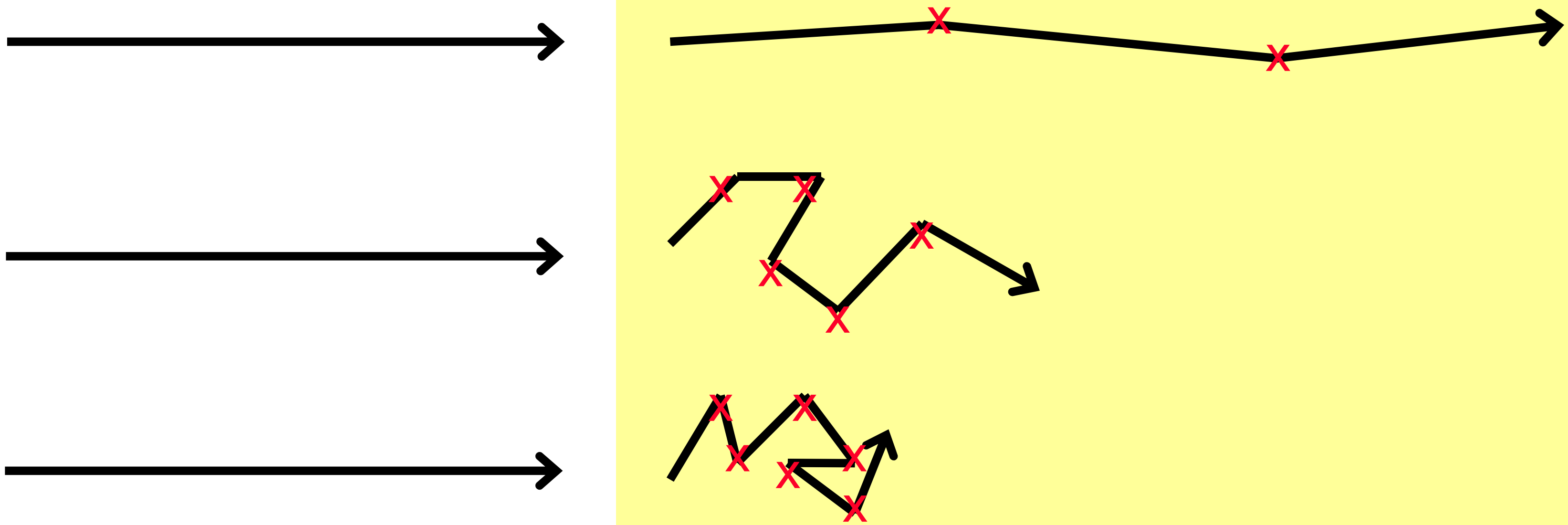
Something in the universe gives mass to particles

Nothing in the universe | Something in the universe

Electron

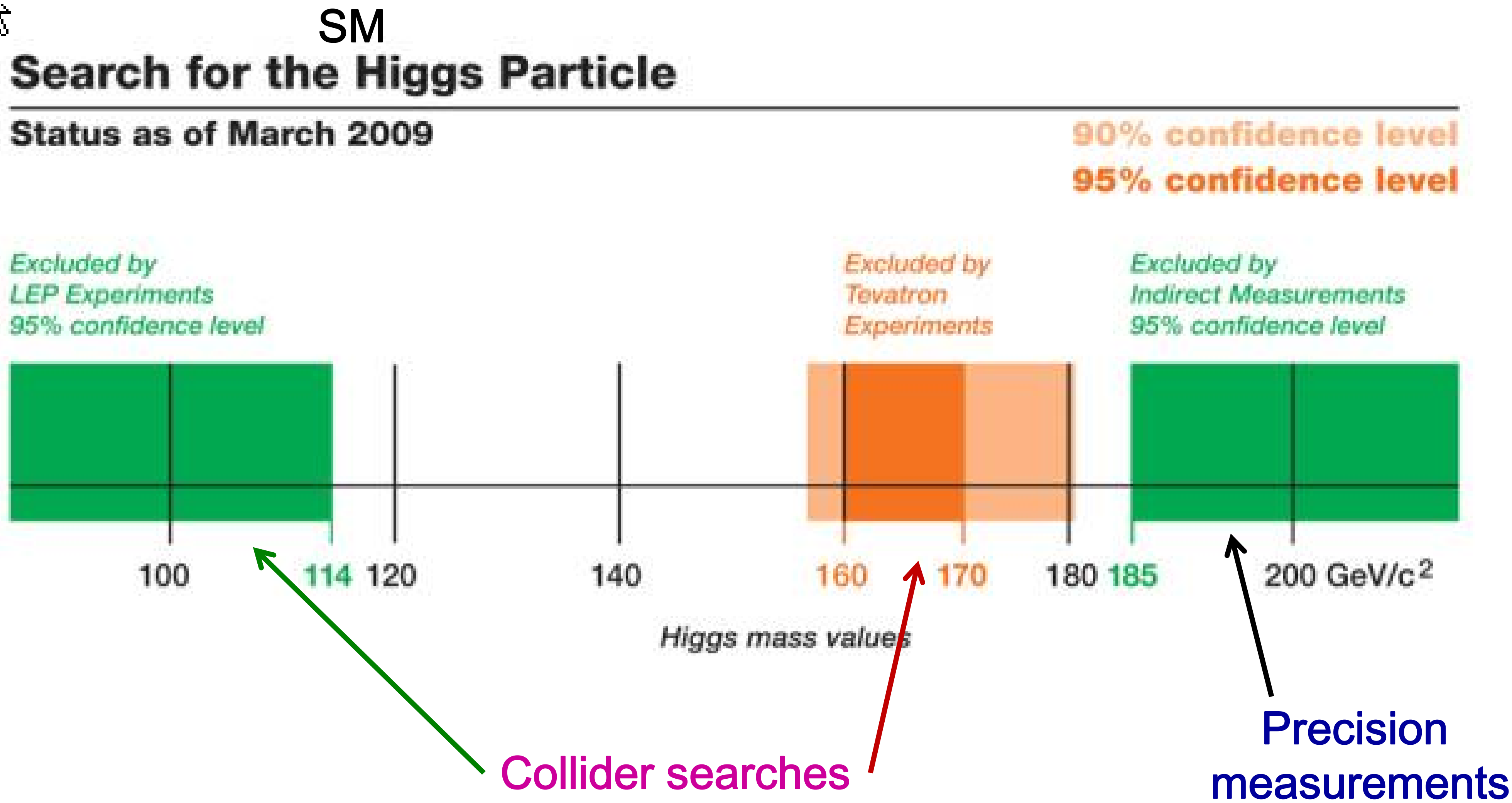
Z,W Boson

Top Quark

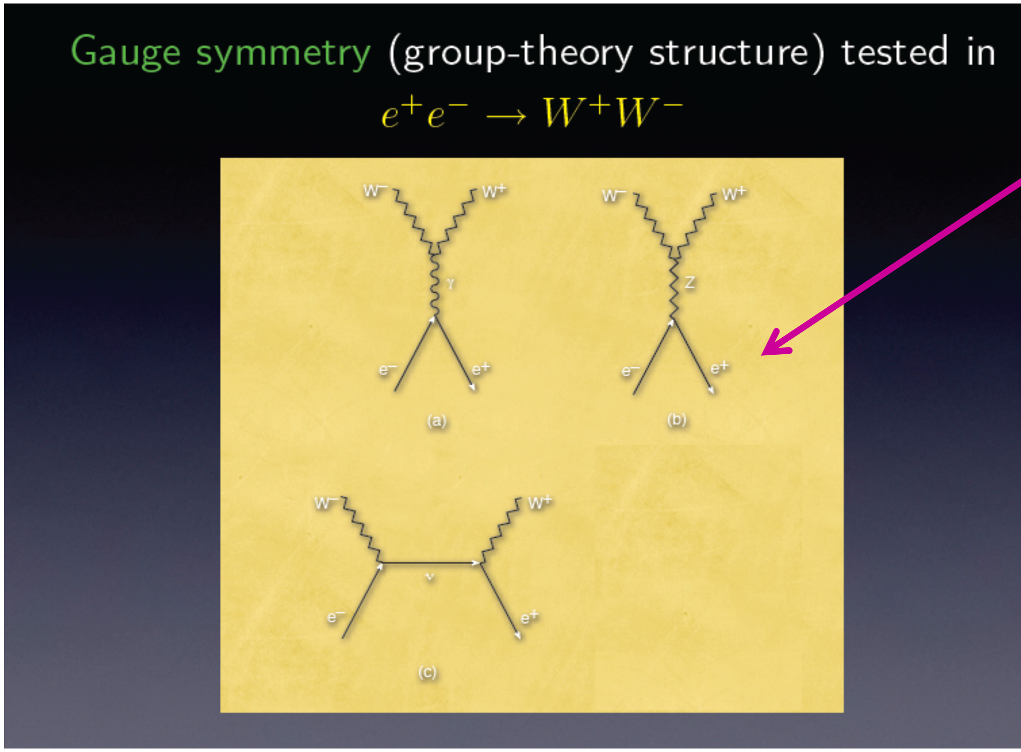


We believe it's a Higgs Field

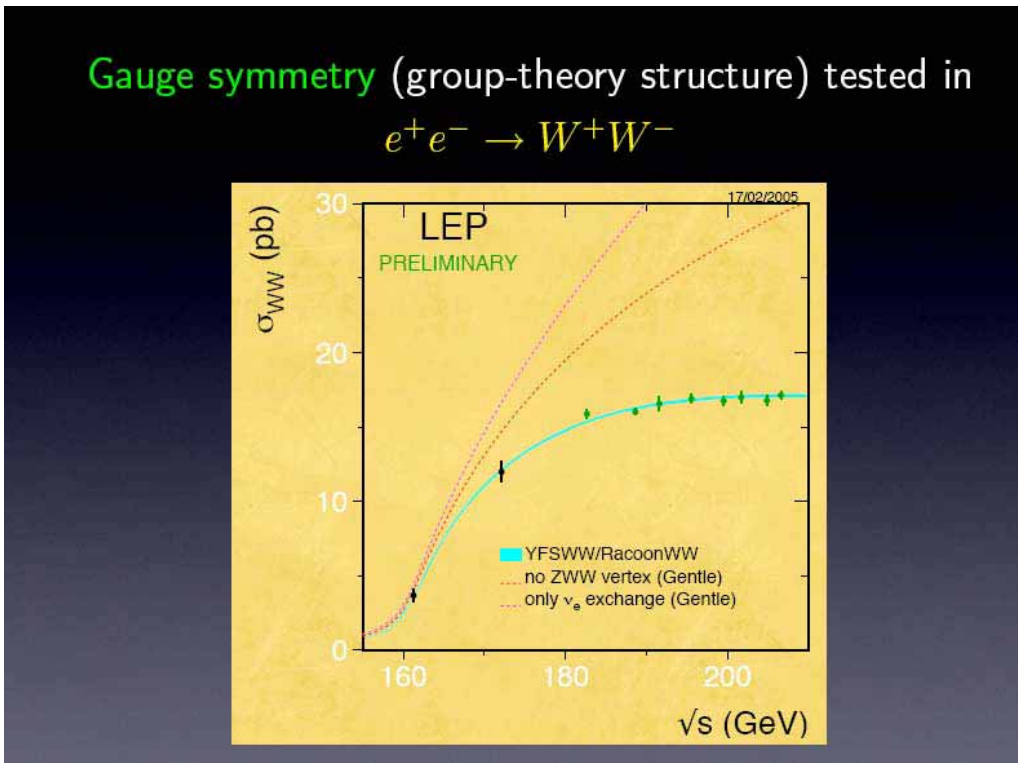
A particle which couples proportionally to mass



The Higgs is being hunted for right now at the Tevatron collider near Chicago and, this Fall, Higgs searches will begin at the Large Hadron Collider near Geneva, Switzerland…more on the LHC & possible discoveries later.



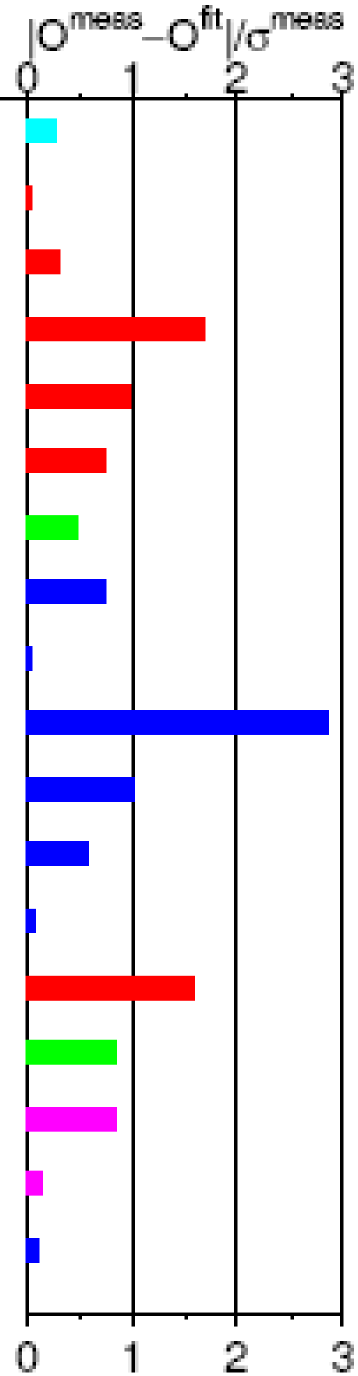
Feynman diagrams …
more about them later



The symmetries of the SM can lead to a complex, yet precise cancellations among the various contributions to cross sections so that they are 'well-behaved' (i.e., unitary=satisfy probability ≤1) at very high energies. If these relations are violated by only a small amount , significant shifts in cross sections would be observed even before such energies are reached.

They aren't seen and here is one example…

	Measurement	Fit
$\Delta\alpha^{(5)}_{had}(m_Z)$	0.02758 ± 0.00035	0.02767
m_Z [GeV]	91.1875 ± 0.0021	91.1874
Γ_Z [GeV]	2.4952 ± 0.0023	2.4959
σ^0_{had} [nb]	41.540 ± 0.037	41.478
R_l	20.767 ± 0.025	20.742
$A^{0,l}_{fb}$	0.01714 ± 0.00095	0.01643
$A_l(P_\tau)$	0.1465 ± 0.0032	0.1480
R_b	0.21629 ± 0.00066	0.21579
R_c	0.1721 ± 0.0030	0.1723
$A^{0,b}_{fb}$	0.0992 ± 0.0016	0.1038
$A^{0,c}_{fb}$	0.0707 ± 0.0035	0.0742
A_b	0.923 ± 0.020	0.935
A_c	0.670 ± 0.027	0.668
A_l(SLD)	0.1513 ± 0.0021	0.1480
$\sin^2\theta^{lept}_{eff}(Q_{fb})$	0.2324 ± 0.0012	0.2314
m_W [GeV]	80.399 ± 0.025	80.378
Γ_W [GeV]	2.098 ± 0.048	2.092
m_t [GeV]	173.1 ± 1.3	173.2



March 2009

The SM picture has been precisely tested in many ways & over many years generally to the level of ~ 0.1% & in some cases to 1 part in 10^{15} !

Though there are a few tiny discrepancies, it works so well & in so many places that it has been turned into a wall poster…

Standard Model of

FUNDAMENTAL PARTICLES AND INTERACTIONS

The Standard Model summarizes the current knowledge in Particle Physics. It is the quantum theory that includes the theory of strong interactions (quantum chromodynamics or QCD) and the unified theory of weak and electromagnetic interactions (electroweak). Gravity is included on this chart because it is one of the fundamental interactions even though not part of the "Standard Model."

FERMIONS matter constituents spin = 1/2, 3/2, 5/2, ...

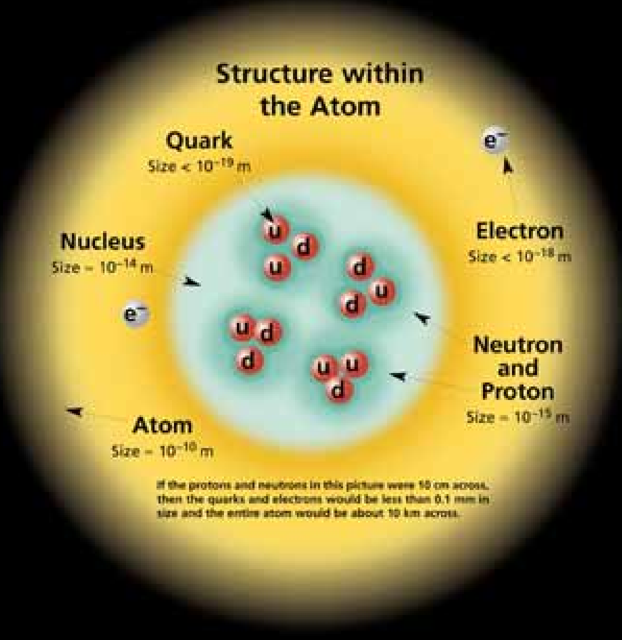
Leptons spin = 1/2		
Flavor	Mass GeV/c^2	Electric charge
ν_e electron neutrino	$<1\times10^{-8}$	0
e electron	0.000511	−1
ν_μ muon neutrino	<0.0002	0
μ muon	0.106	−1
ν_τ tau neutrino	<0.02	0
τ tau	1.7771	−1

Quarks spin = 1/2		
Flavor	Approx. Mass GeV/c^2	Electric charge
u up	0.003	2/3
d down	0.006	−1/3
c charm	1.3	2/3
s strange	0.1	−1/3
t top	175	2/3
b bottom	4.3	−1/3

Spin is the intrinsic angular momentum of particles. Spin is given in units of $\hbar$, which is the quantum unit of angular momentum, where $\hbar = h/2\pi = 6.58\times10^{-25}$ GeV s $= 1.05\times10^{-34}$ J s.

Electric charges are given in units of the proton's charge. In SI units the electric charge of the proton is 1.60×10^{-19} coulombs.

The **energy** unit of particle physics is the electronvolt (eV), the energy gained by one electron in crossing a potential difference of one volt. **Masses** are given in GeV/c^2 (remember $E = mc^2$), where 1 GeV $= 10^9$ eV $= 1.60\times10^{-10}$ joule. The mass of the proton is 0.938 GeV/c^2 $= 1.67\times10^{-27}$ kg.



If the protons and neutrons in this picture were 10 cm across, then the quarks and electrons would be less than 0.1 mm in size and the entire atom would be about 10 km across.

BOSONS force carriers spin = 0, 1, 2, ...

Unified Electroweak spin = 1		
Name	Mass GeV/c^2	Electric charge
γ photon	0	0
W^-	80.4	−1
W^+	80.4	+1
Z^0	91.187	0

Strong (color) spin = 1		
Name	Mass GeV/c^2	Electric charge
g gluon	0	0

Color Charge

Each quark carries one of three types of "strong charge," also called "color charge." These charges have nothing to do with the colors of visible light. There are eight possible types of color charge for gluons. Just as electrically-charged particles interact by exchanging photons, in strong interactions color-charged particles interact by exchanging gluons. Leptons, photons, and ***W*** and ***Z*** bosons have no strong interactions and hence no color charge.

Quarks Confined in Mesons and Baryons

One cannot isolate quarks and gluons; they are confined in color-neutral particles called **hadrons**. This confinement (binding) results from multiple exchanges of gluons among the color-charged constituents. As color-charged particles (quarks and gluons) move apart, the energy in the color-force field between them increases. This energy eventually is converted into additional quark-antiquark pairs (see figure below). The quarks and antiquarks then combine into hadrons; these are the particles seen to emerge. Two types of hadrons have been observed in nature: **mesons** $q\bar{q}$ and **baryons** qqq.

Residual Strong Interaction

The strong binding of color-neutral protons and neutrons to form nuclei is due to residual strong interactions between their color-charged constituents. It is similar to the residual electrical interaction that binds electrically neutral atoms to form molecules. It can also be viewed as the exchange of mesons between the hadrons.

PROPERTIES OF THE INTERACTIONS

Baryons qqq and Antibaryons $\bar{q}\bar{q}\bar{q}$ Baryons are fermionic hadrons. There are about 120 types of baryons.					
Symbol	Name	Quark content	Electric charge	Mass GeV/c^2	Spin
p	proton	uud	1	0.938	1/2
$\bar{p}$	anti-proton	$\bar{u}\bar{u}\bar{d}$	−1	0.938	1/2
n	neutron	udd	0	0.940	1/2
Λ	lambda	uds	0	1.116	1/2
Ω^-	omega	sss	−1	1.672	3/2

Property \ Interaction	Gravitational	Weak (Electroweak)	Electromagnetic	Strong: Fundamental	Strong: Residual
Acts on:	Mass – Energy	Flavor	Electric Charge	Color Charge	See Residual Strong Interaction Note
Particles experiencing:	All	Quarks, Leptons	Electrically charged	Quarks, Gluons	Hadrons
Particles mediating:	Graviton (not yet observed)	W^+ W^- Z^0	γ	Gluons	Mesons
Strength relative to electromag for two u quarks at: 10^{-18} m	10^{-41}	0.8	1	25	Not applicable to quarks
3×10^{-17} m	10^{-41}	10^{-4}	1	60	
for two protons in nucleus	10^{-36}	10^{-7}	1	Not applicable to hadrons	20

Mesons $q\bar{q}$ Mesons are bosonic hadrons. There are about 140 types of mesons.					
Symbol	Name	Quark content	Electric charge	Mass GeV/c^2	Spin
π^+	pion	$u\bar{d}$	+1	0.140	0
K^-	kaon	$s\bar{u}$	−1	0.494	0
ρ^+	rho	$u\bar{d}$	+1	0.770	1
B^0	B-zero	$d\bar{b}$	0	5.279	0
η_c	eta-c	$c\bar{c}$	0	2 .980	0

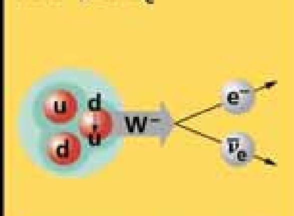
Matter and Antimatter

For every particle type there is a corresponding antiparticle type, denoted by a bar over the particle symbol (unless + or – charge is shown). Particle and antiparticle have identical mass and spin but opposite charges. Some electrically neutral bosons (e.g., Z^0, γ, and $\eta_c = c\bar{c}$, but not $K^0 = d\bar{s}$) are their own antiparticles.

Figures

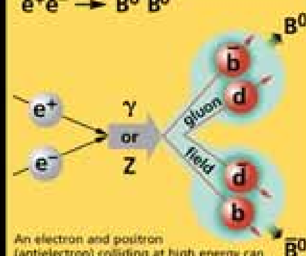
These diagrams are an artist's conception of physical processes. They are *not* exact and have **no** meaningful scale. Green shaded areas represent the cloud of gluons or the gluon field, and red lines the quark paths.

$n \rightarrow p\, e^-\, \bar{\nu}_e$



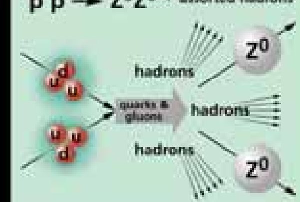
A neutron decays to a proton, an electron, and an antineutrino via a virtual (mediating) W boson. This is neutron β decay.

$e^+e^- \rightarrow B^0\, \bar{B}^0$



An electron and positron (antielectron) colliding at high energy can annihilate to produce B^0 and $\bar{B}^0$ mesons via a virtual Z boson or a virtual photon.

p p → Z^0Z^0 + assorted hadrons



Two protons colliding at high energy can produce various hadrons plus very high mass particles such as Z bosons. Events such as this one are rare but can yield vital clues to the structure of matter.

The Particle Adventure

Visit the award-winning web feature *The Particle Adventure* at
http://ParticleAdventure.org

This chart has been made possible by the generous support of:
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Despite its many successes the SM is incomplete & leaves MANY questions *unanswered:*

1. Are there undiscovered principles of nature: New symmetries, new physical laws?

2. How can we solve the mysteries of dark energy and dark matter? Can we make dark matter in a laboratory on Earth?

3. Why are there 4 space-time dimensions? Are there extra dimensions of space? Can we see them?

4. Do all the forces become unified? Why do the SM parameters take on the particular values that they do?

5. Why is the EW scale at ~100 GeV & not, e.g., at the (Planck) scale of gravity ~10^{19} GeV?

6. Why are there so many kinds of particles? Why are there three generations of quarks & leptons with such diverse masses?

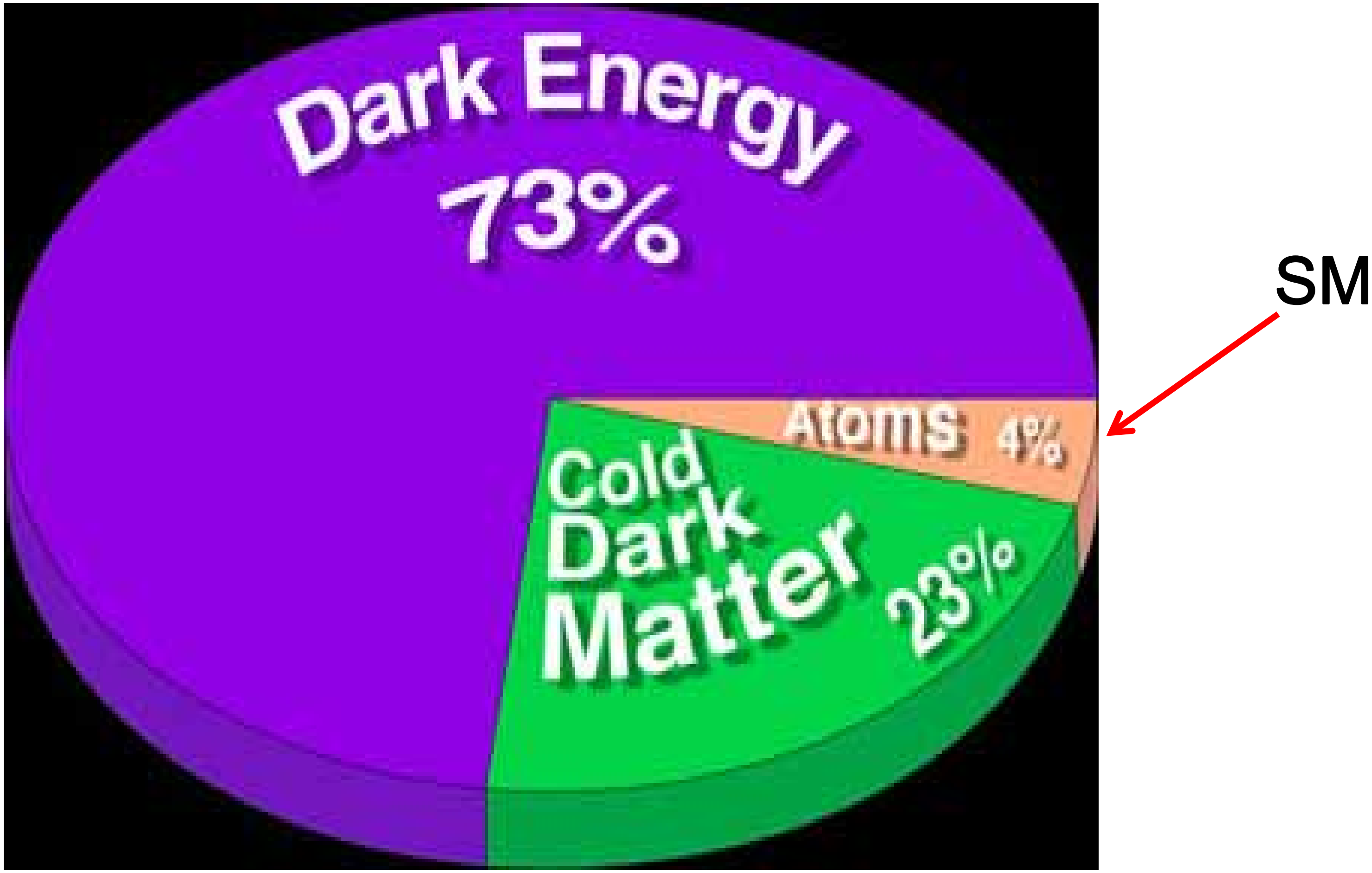
7. What are the very tiny neutrino masses telling us?

8. How did the universe come to be? Why is gravity so much weaker than the other forces? How do we incorporate GR into this SM picture? Is GR the correct theory of gravity?

9. Why is there only matter; what happened to the antimatter?

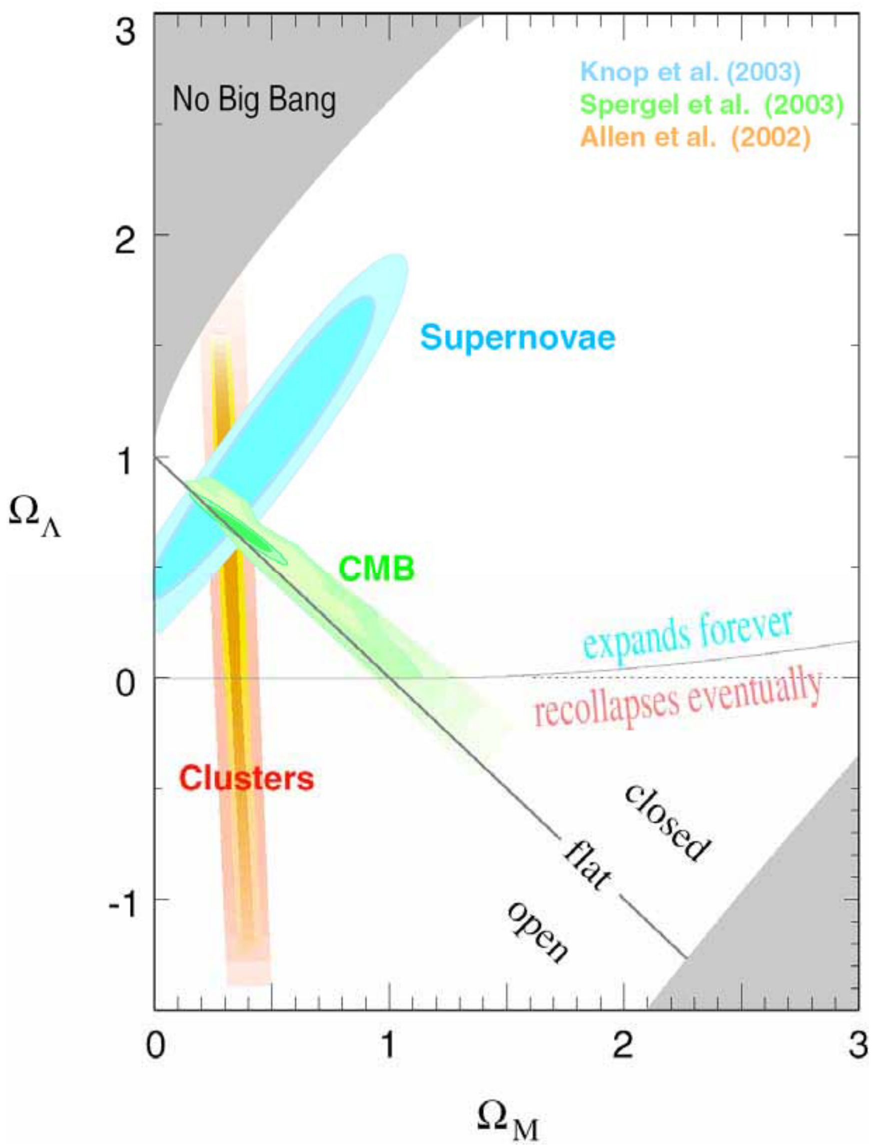
10. ……

One can add many other questions to this list…let's talk about a few of them..



A combination of a number of astrophysics measurement now tell us that most of the universe is made up of stuff that is not part of the SM….what is it????

EVIDENCE FOR DARK MATTER



- We are living through a golden age in cosmology.

- There is now overwhelming evidence that normal (atomic) matter is not all the matter in the Universe:

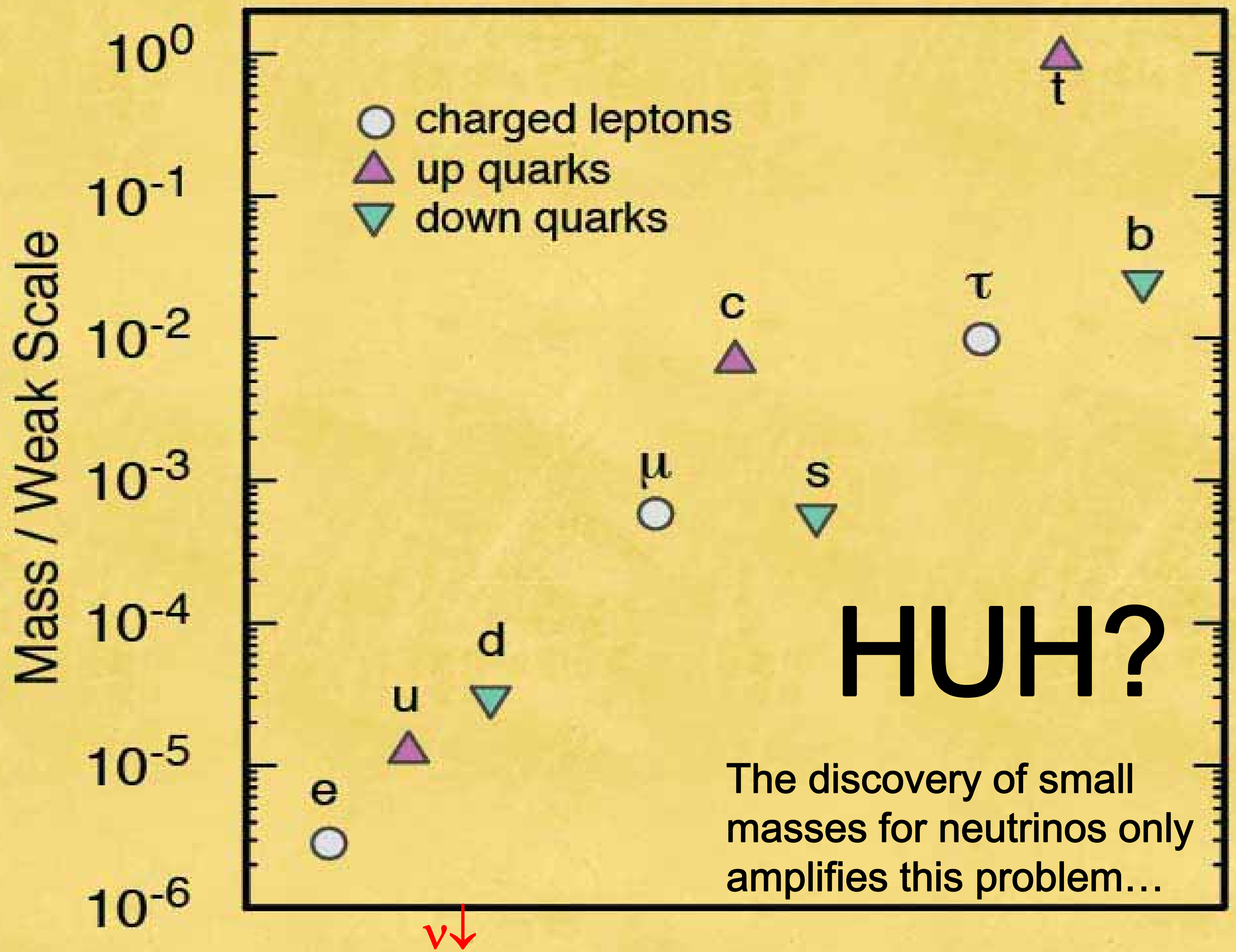
  Dark Matter: 23% ± 4%

  Dark Energy: 73% ± 4%

  Normal Matter: 4% ± 0.4%

  Neutrinos: 0.2% (Σm_ν/0.1eV)

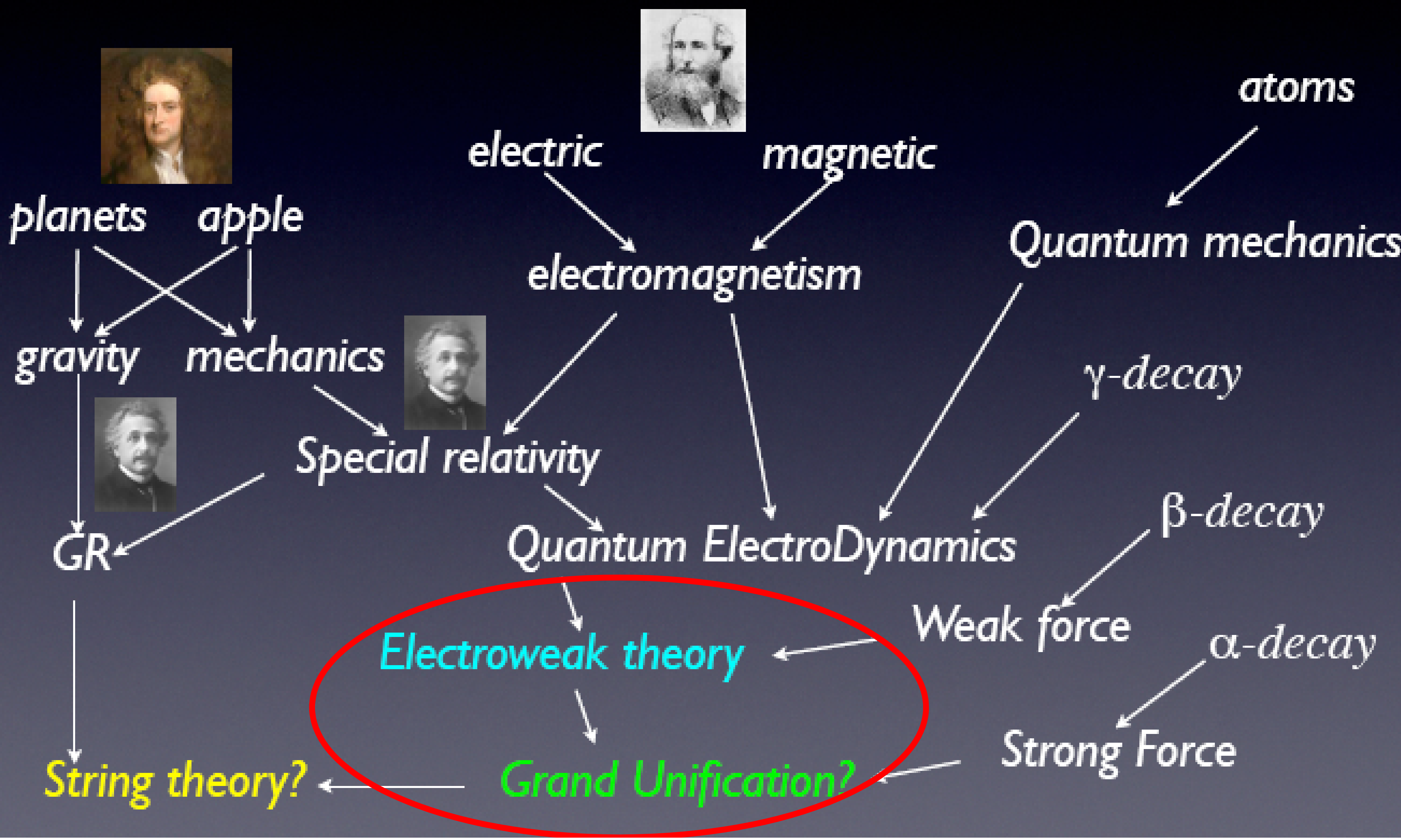
- To date, all evidence is from dark matter's gravitational effects. We would like to detect it in other ways to learn more about it.



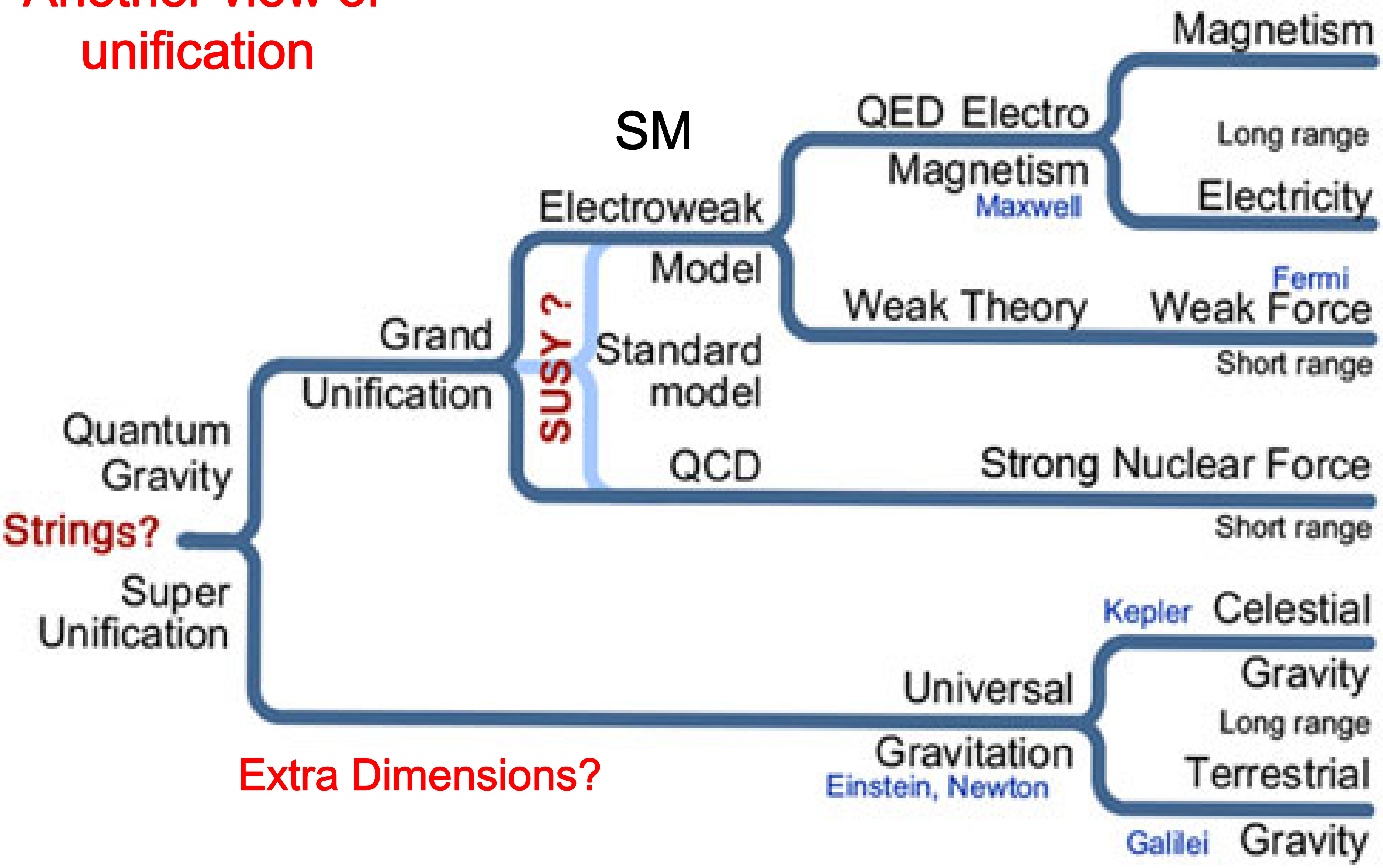
HUH?

The discovery of small masses for neutrinos only amplifies this problem…

History of Unification



Another view of unification



The Hierarchy Problem

Energy (GeV)

10^{19} Planck=Gravity

10^{16} GUT

desert

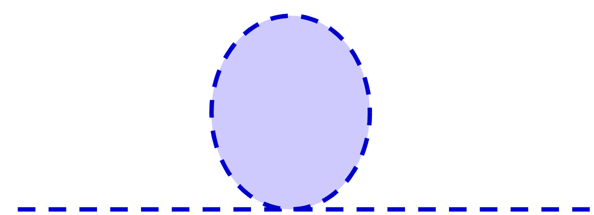
Future Collider Energies → 10^{3} Weak

All of known physics

10^{-18} Solar System Gravity

Quantum Corrections:

NLO effects (more later) drag the Weak Scale to M_{Pl}

$\delta m_H^2 \sim$  $\sim M_{Pl}^2$

It is more 'natural' for the weak scale to be near the Planck scale than ~1 TeV

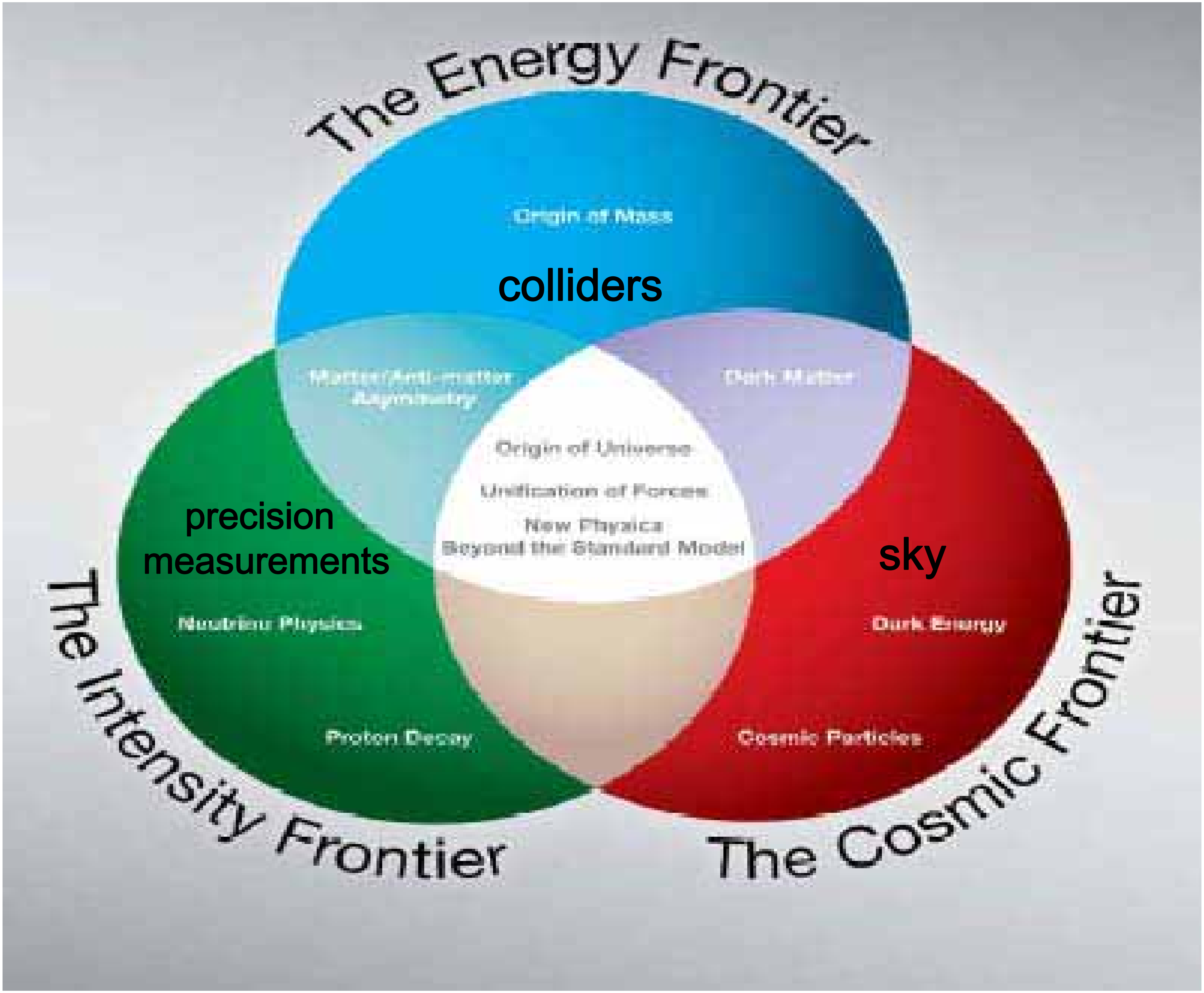
To address these and other questions HE theorists have been very busy over the last 3 decades constructing models of new physics which are various possible extensions of the SM. There are some very good reasons to think that at least some of the answers we seek to the above questions await us at the TeV energy scale..about a factor of 10 beyond where we are today.

How do we look for new physics at higher energies???

There are 3 ways to find new physics beyond the SM:

(i) Make it directly at a collider like the LHC or Tevatron **
(ii) Look for small new physics modifications to SM processes
(iii) Look to the sky …**

** I will focus on these possibilities below


The Energy Frontier
Origin of Mass
colliders
Matter/Anti-matter Asymmetry
Dark Matter
Origin of Universe
Unification of Forces
New Physics Beyond the Standard Model
precision measurements
sky
Neutrino Physics
Dark Energy
Proton Decay
Cosmic Particles
The Intensity Frontier
The Cosmic Frontier

This is a Special Time in Particle Physics

- Urgent Questions

  Provocative discoveries have led to important questions

- Connections

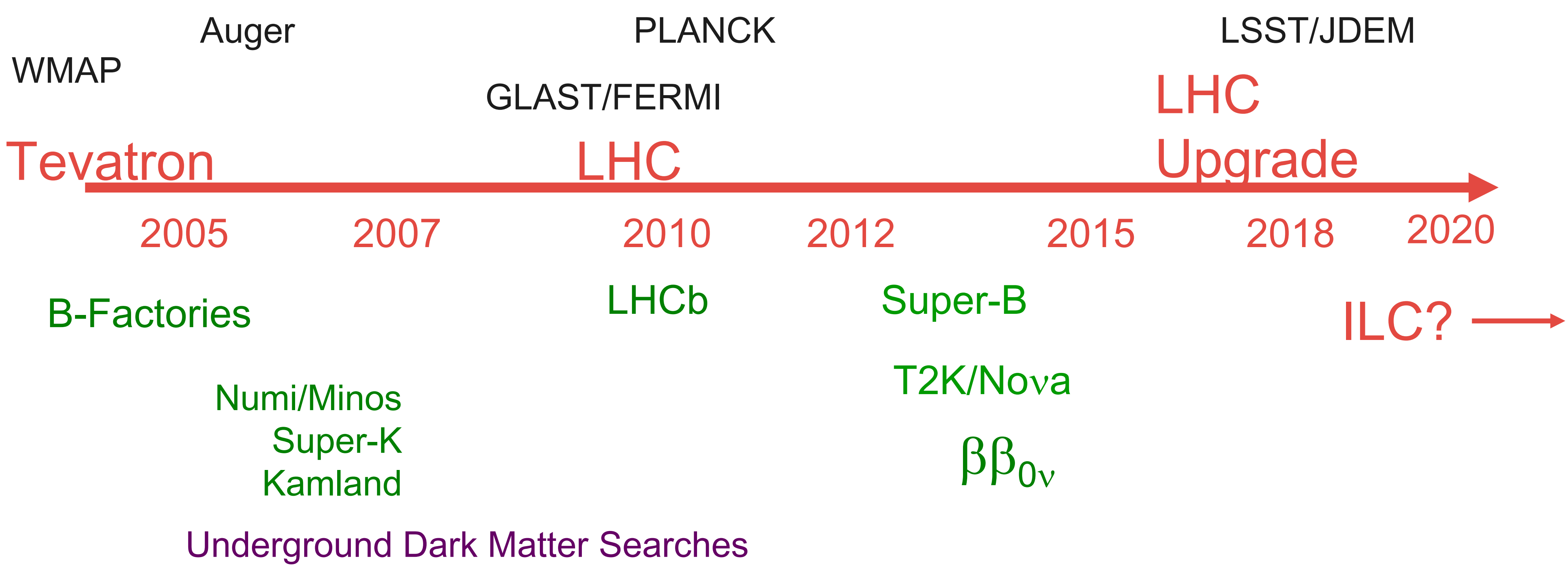
  Questions seem to be related in fundamental, yet mysterious, ways & link high energy and astrophysics

- Tools

  We have the experimental tools, technologies, and strategies to tackle these questions coming on-line!

We are witnessing a Scientific Revolution in the Making!

Science Timeline: The Tools



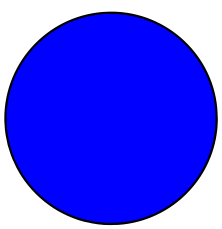
Accelerators are Powerful Microscopes

They make high energy particle beams that allow us see small things : $E \sim 1/x$

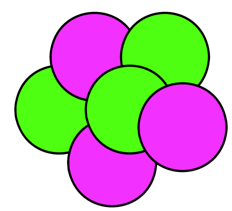
1 MeV ~ $(2 \times 10^{-11}\ \text{cm})^{-1}$

1 GeV ~ $(2 \times 10^{-14}\ \text{cm})^{-1}$

→ 1 TeV ~ $(2 \times 10^{-17}\ \text{cm})^{-1}$

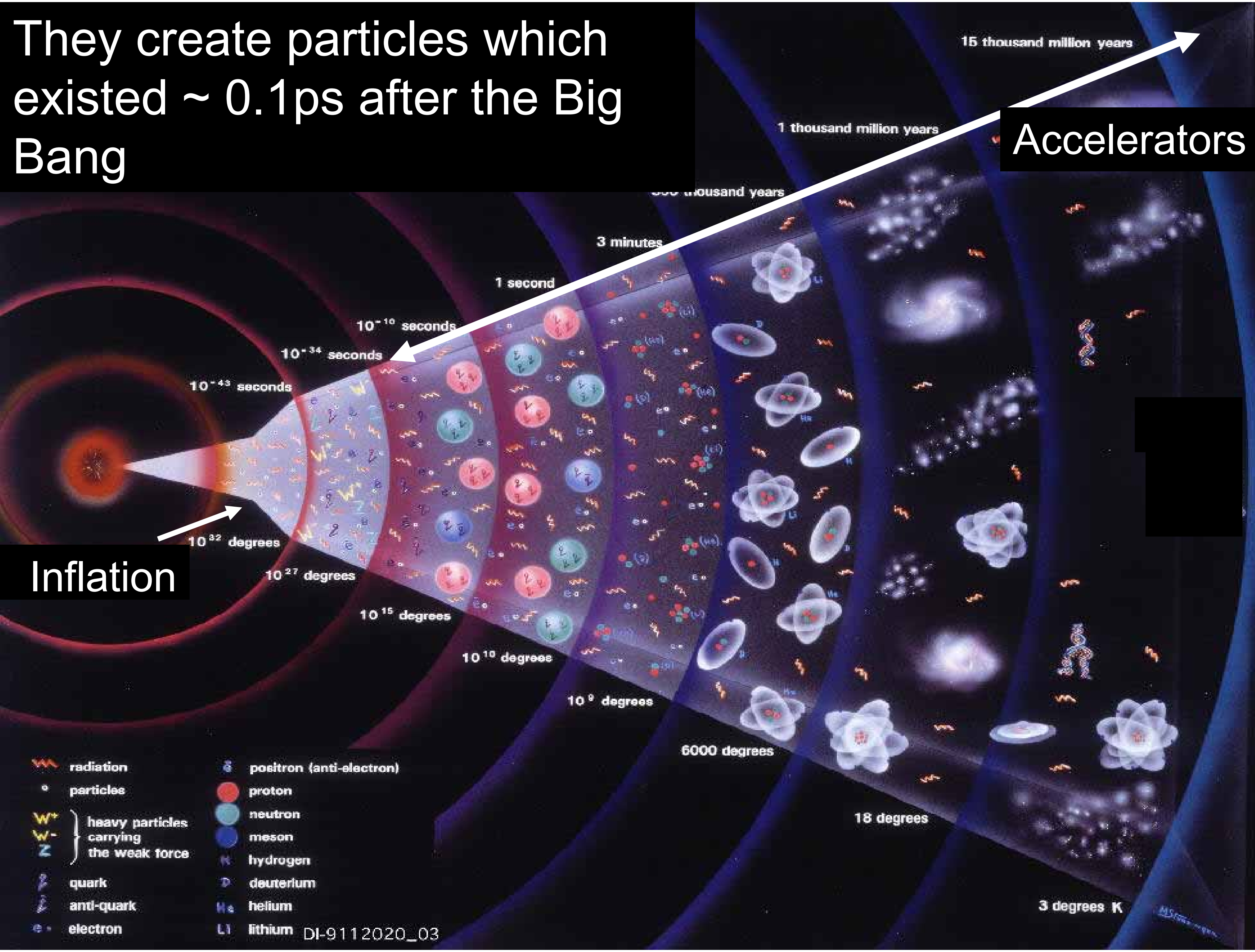


seen by low energy beam (poorer resolution)



seen by high energy beam (better resolution)

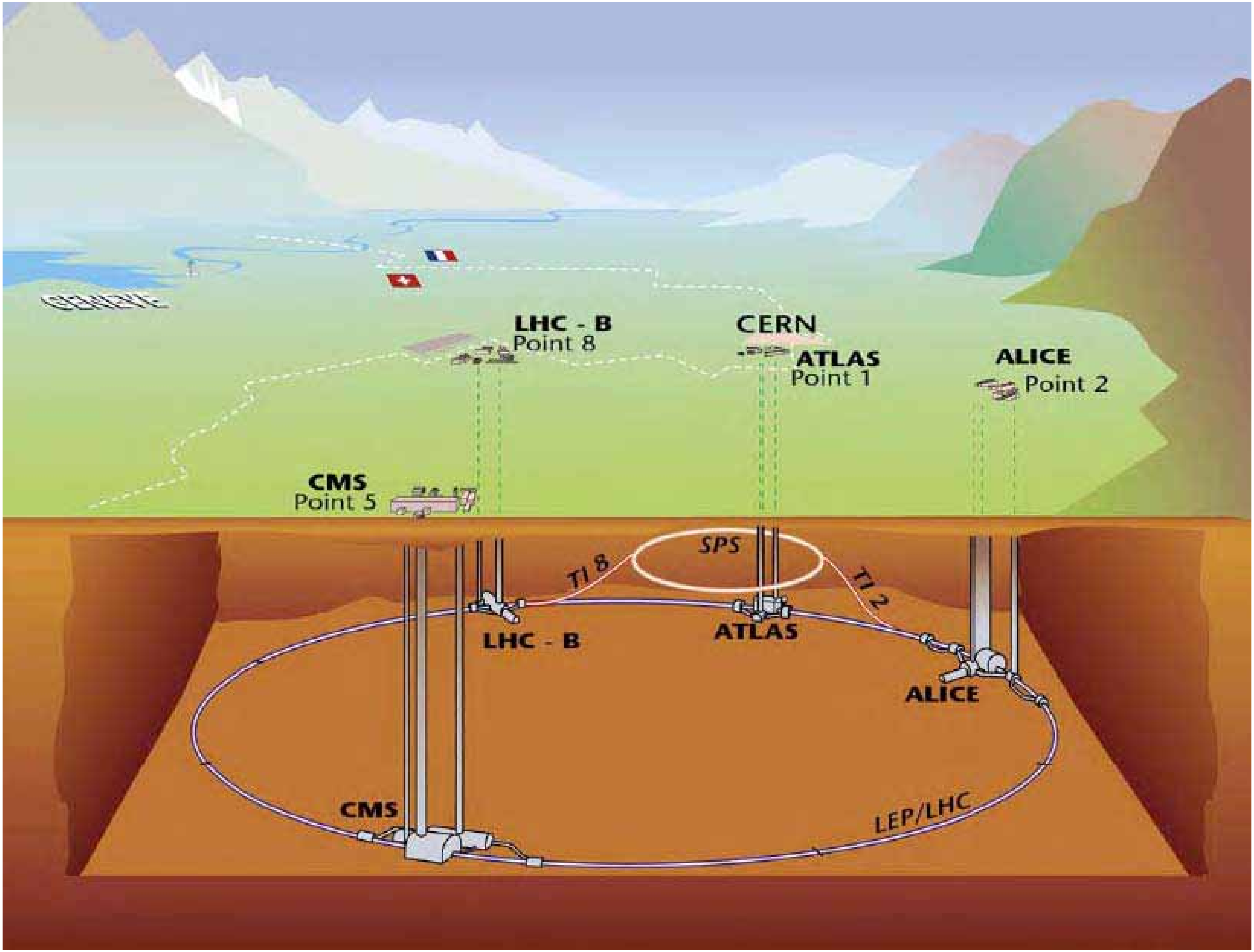
They create particles which existed ~ 0.1ps after the Big Bang



Colliders can allow us to produce new, previously unknown heavy particles by converting the energy of the colliding particles, such as protons at the LHC, into mass via $E=mc^2$

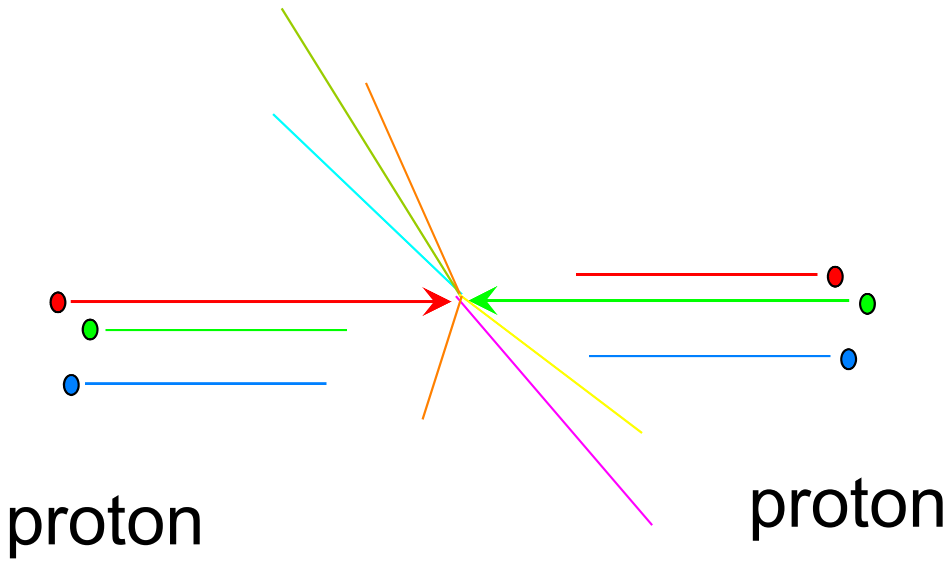
There is no substitute for directly producing & observing new physics!

Depending on their interactions, the LHC should be able to produce new particles with masses as large as a few TeV – more than 10x heavier than the top quark ..



LHC - B
Point 8
CERN
ATLAS
Point 1
ALICE
Point 2
CMS
Point 5
SPS
TI 8
TI 2
LHC - B
ATLAS
ALICE
CMS
LEP/LHC

The LHC: pp collisions @ 10-14 TeV



Hard scattering occurs between two proton's constituents - quarks and gluons

E_{scatt} ~ 1/9 E_{CoM} ~ 1-2 TeV

Current LHC Schedule:

- Closed for beam set-up: Sept 09
- 1st Beam: Oct 09
- 1st Collisions: Nov 09
- 1st Physics run: 09-10, 100 pb^{-1} at ~10 TeV
- Physics runs 2011 and onwards at ~14 TeV 100 fb^{-1}

pp Collisions:

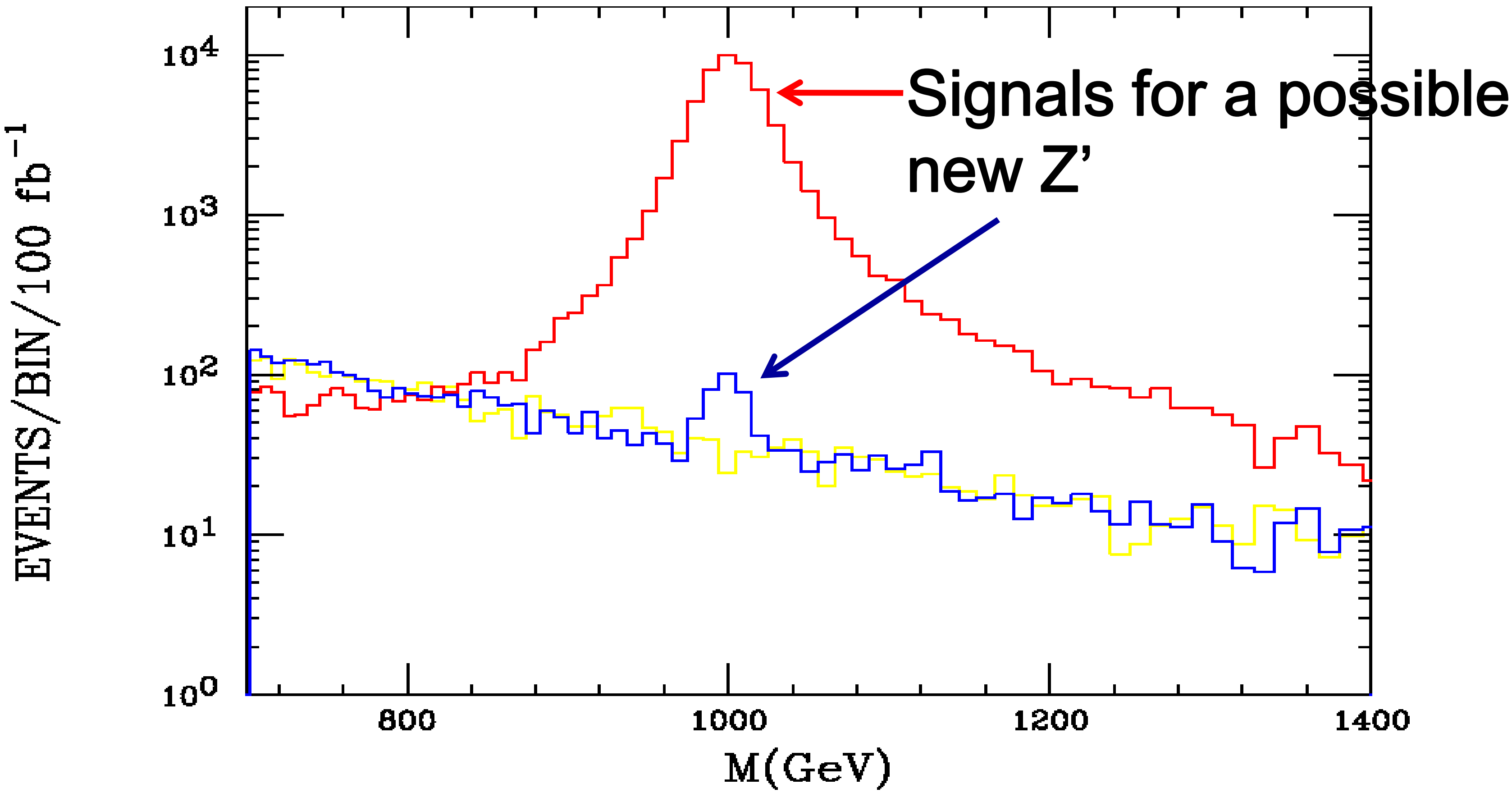
- Broad energy reach
- Large event rate
- Complex environment
- Don't know initial state

BUT if new particles are produced in a collider experiment how will we know? Almost all of the time these new states are *unstable* & decay rapidly back to some set of ordinary SM particles seen in the detectors. There will just be more of them than the SM predicts perhaps distributed in a different way kinematically. How much more? How different?

To see a SIGNAL (S) for the production of new particles, we need to precisely understand the production rate of the SM BACKGROUND (B) in addition to being able to precisely calculate the rate for the production of the new particles that we're looking for.

Of course, some new particles may be more easily seen than others…let's look at a few examples:

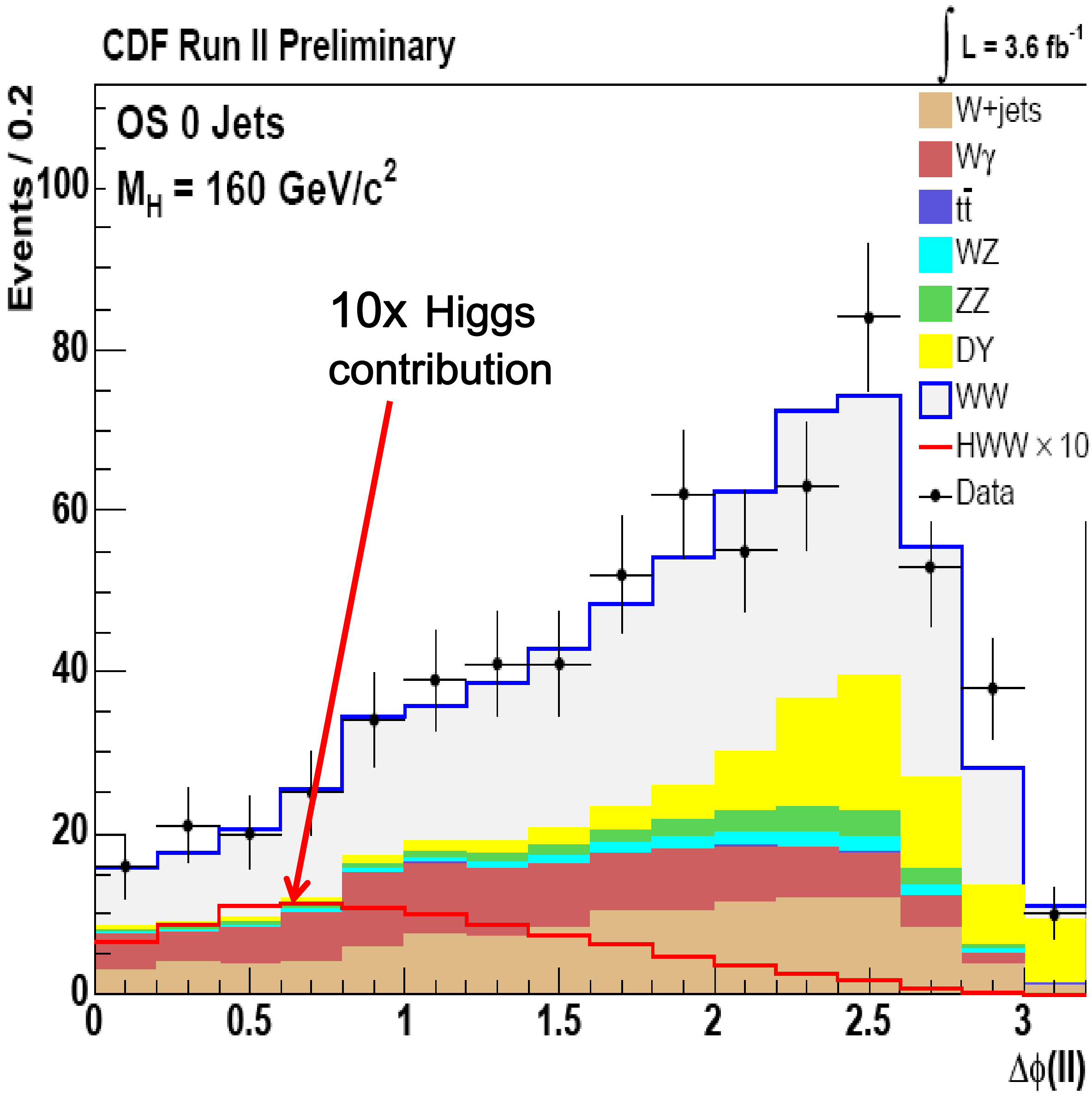
$pp \rightarrow e^+e^-$ + anything at the LHC



Yellow = SM background as a function of the binned invariant mass of the two leptons showing statistical fluctuations

Clearly the red case is very visible while the blue one is not..a small change in background would obscure it…so knowing the background very precisely would be very important in this case.

gg → H → $W^+ W^-$ → $e^{\pm} \mu^{\pm}$ + neutrinos (=ME) at the Tevatron

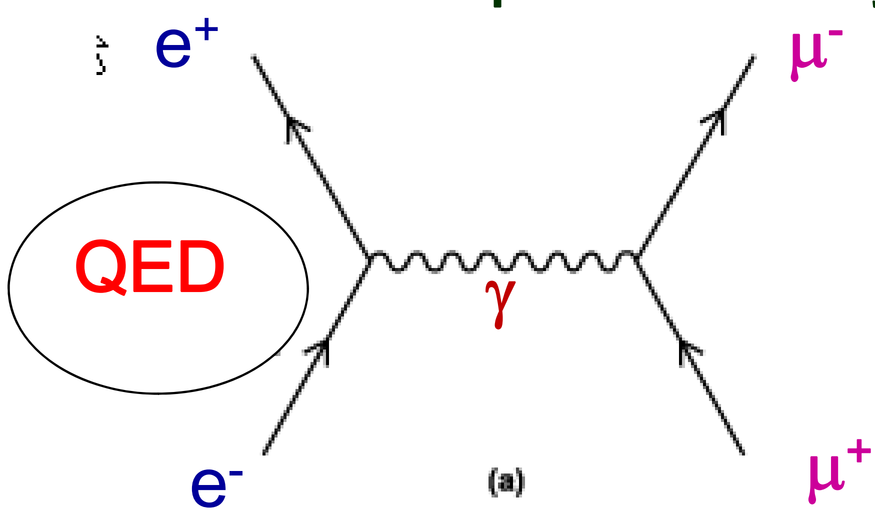


Lots of SM reactions can conspire to look like a Higgs boson which is only a tiny addition to the ordinary SM rate at the Tevatron. Unless the rates for all these processes are very well determined it will be impossible to claim that a Higgs boson has been found in this reaction…

→ Thus it is generally very important to be able to make precise calculations of SM processes in order to find new physics which may be hiding in the background.

This effort in the SLAC Theory group is headed by Lance Dixon

Most calculations in the SM are performed using 'Perturbation Theory' which is an expansion of cross sections in a small parameter, e.g., the fine-structure constant α in QED, using Feynman diagrams. These are pictorial representations of complex mathematical expressions which are determined by the interactions in a specific theory.

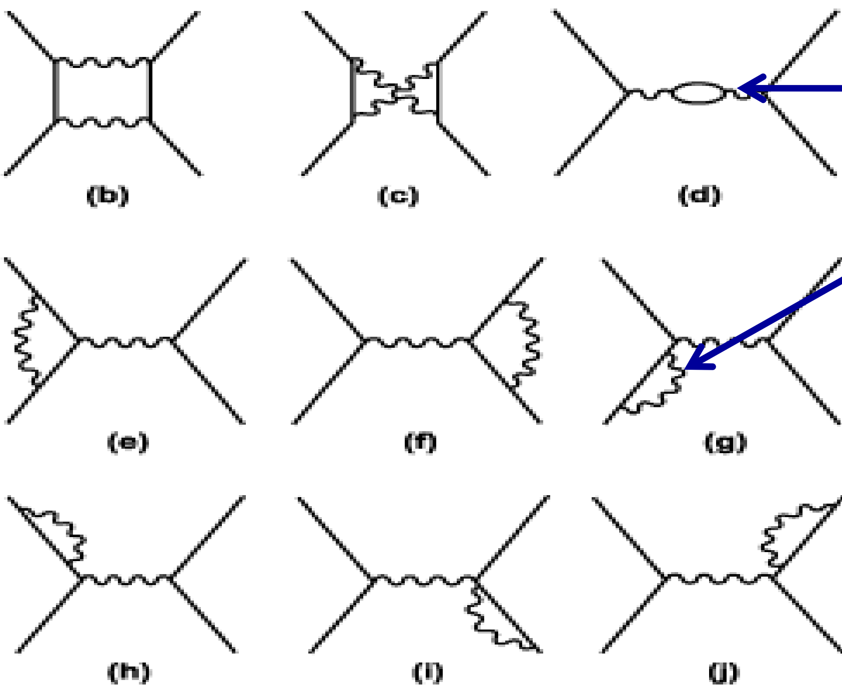


2 particles in and → 2 particles out

2→2

The complexity of these calculations depends upon the number of particles in the final state , e.g., 2→2 is easy involving at most a few graphs, while 2→ 8-10 may involve hundred or thousands of graphs & is VERY hard even at leading order(LO)

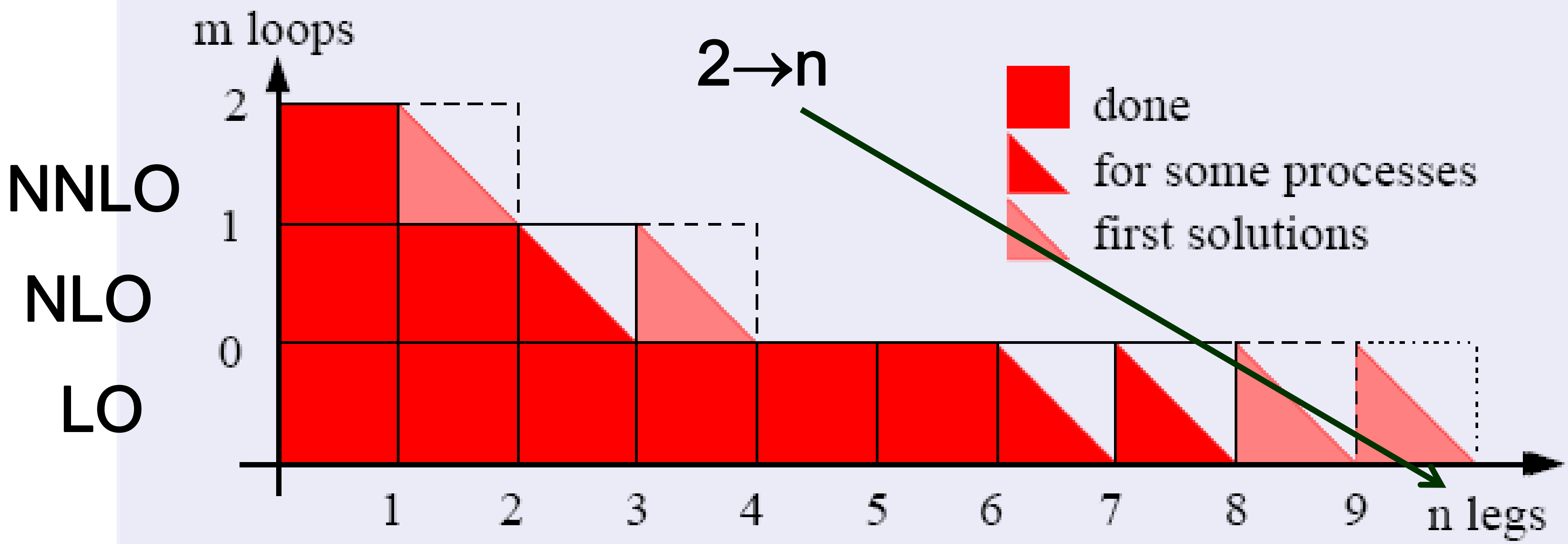
The complexity ALSO depends on the order of the calculation, e.g. , 2→2 at NLO may involve hundreds of graphs depending on the identities of the particles! This is an enormous but important effort..



'loop'

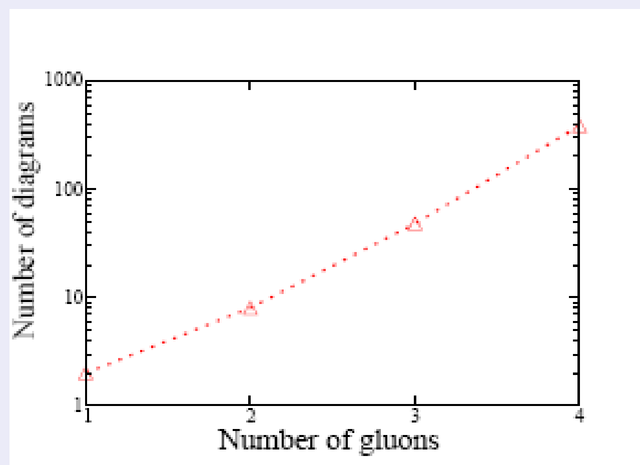
This is the same process in QED but at NLO (with a single loop).. it is STILL 2→2

Availability of exact calculations

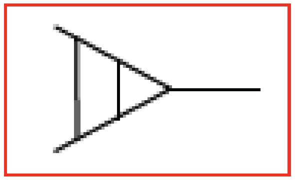


Factorial growth: $e^+e^- \to q\bar{q} + ng$

n	#diags
0	1
1	2
2	8
3	48
4	384



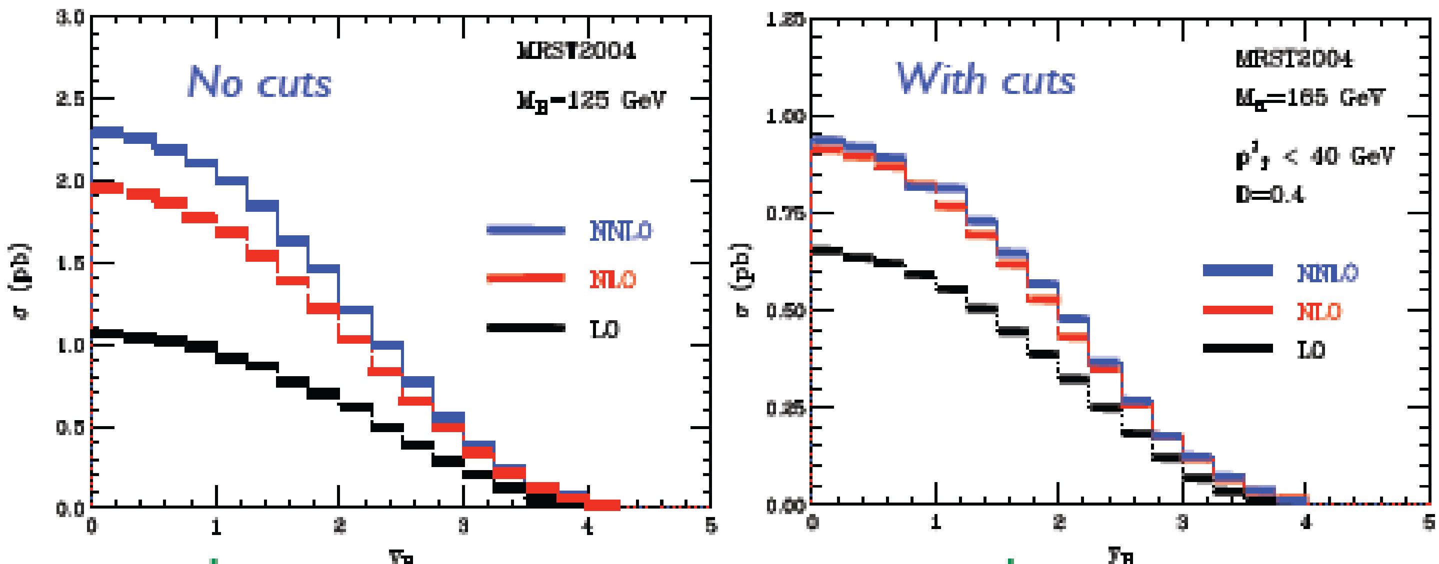
LO



Exclusive NNLO Higgs production

First fully exclusive $H \to WW \to 2l\ 2\nu$ NNLO calculation

Anastasiou, Dissertori, Stoeckli '07; also Catani, Grazzini '08



☛ slow convergence ☛ good convergence

⇒ impact of NNLO dramatically reduced by cuts

Very important to include cuts and decays in realistic studies

C. F. Berger[a], Z. Bern[b], L. J. Dixon[c], F. Febres Cordero[b],
D. Forde[c], T. Gleisberg[c], H. Ita[b], D. A. Kosower[d] and D. Maître[e]
[a] Center for Theoretical Physics, Massachusetts Institute of Technology, Cambridge, MA 02139, USA
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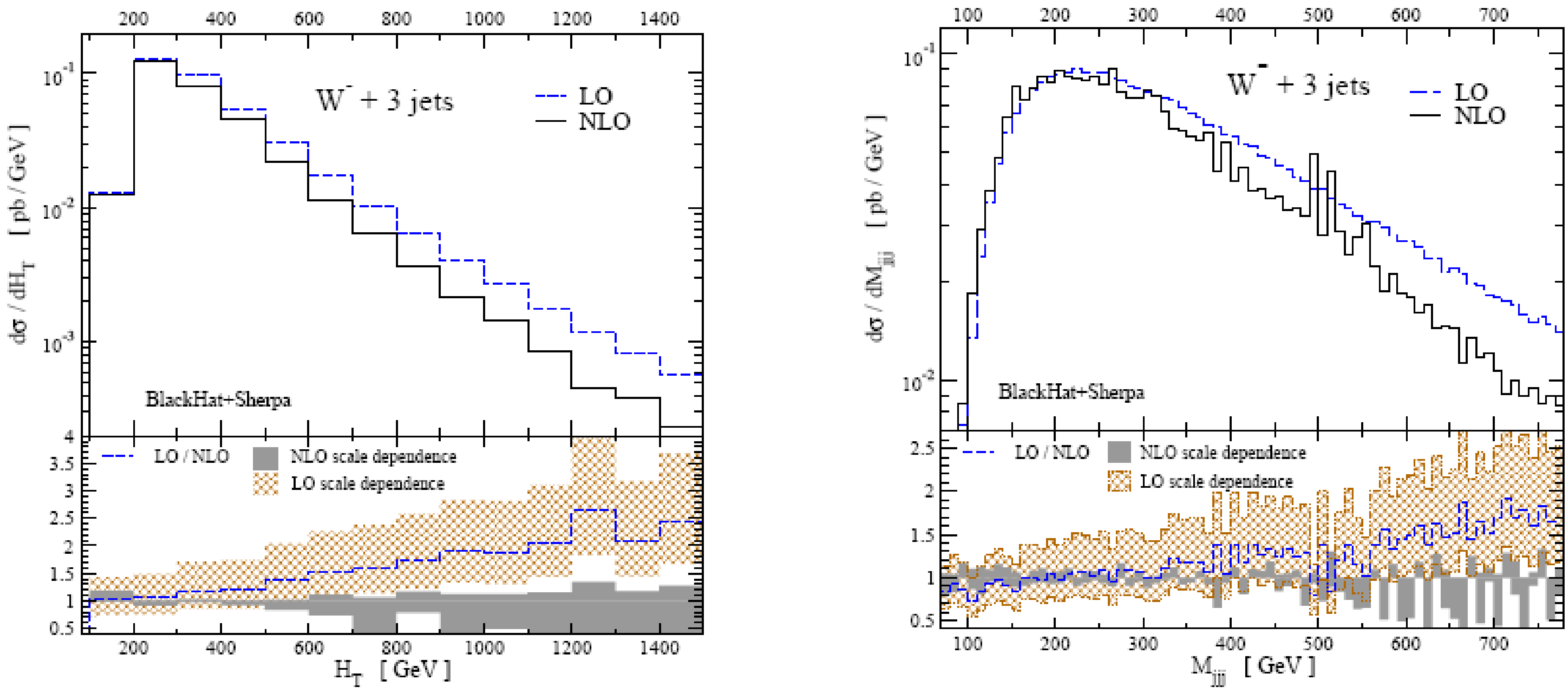
[c] SLAC National Accelerator Laboratory, Stanford University, Stanford, CA 94309, USA
[d] Institut de Physique Théorique, CEA–Saclay, F–91191 Gif-sur-Yvette cedex, France
[e] Department of Physics, University of Durham, DH1 3LE, UK



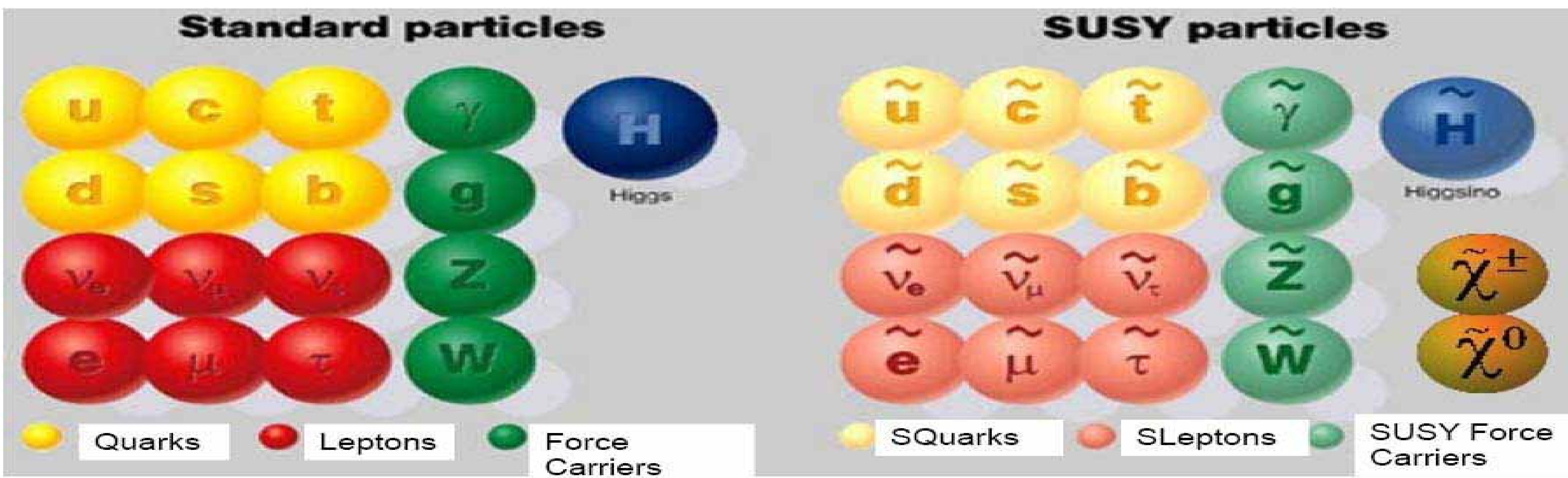
This is an important background for Higgs searches as well as for Supersymmetry, one possible new physics scenario

A large number of people in the Theory Group work on the construction of & signals for various New Physics models :

JoAnne Hewett, Michael Peskin, Jay Wacker & TGR

I will talk about one of them called Supersymmetry or SUSY

SUSY, an extension of relativity, posits that for every SM particle there is an ‘identical’ copy which differs from it by ½ unit of spin (with funny names) linking fermions & bosons



Symmetry between

Fermions ↔ Bosons

(matter) (force carrier)

Spin	Standardparticle	Superpartner	Spin
1/2	Leptons (e, ν_e, ...) Quarks (u, d, ...)	Sleptons ($\tilde{e}$, $\tilde{\nu}_e$, ...) Squarks ($\tilde{u}$, $\tilde{d}$, ...)	0
1	Gluons $W^\pm$ Z^0 Photon (γ)	Gluinos Wino Zino Photino ($\tilde{\gamma}$)	1/2
0	Higgs	Higgsino	1/2
2	Graviton	Gravitino	3/2

SUSY does a lot of nice things for us :

(i) It can 'explain' why the TeV scale can be small compared to the gravity scale

(ii) It can lead to a DM particle which comes in just the right amount

(iii) It leads to a unification of, at least, the non-gravitational forces

(iv) It can be tested in many laboratory experiments

This is an interesting idea but it can't be exactly true because, e.g., there is no spin-0 copy of the electron with the same mass .. SUSY must be a broken symmetry too.

The Hierarchy Problem: Supersymmetry

Energy (GeV)

10^{19} Planck=Gravity

10^{16} GUT

desert

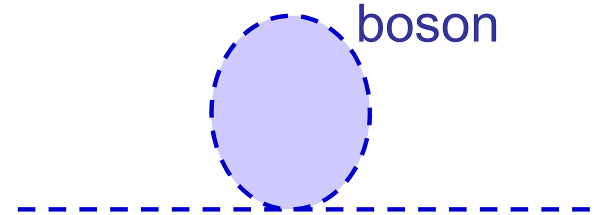
Future Collider Energies → 10^{3} Weak

All of known physics

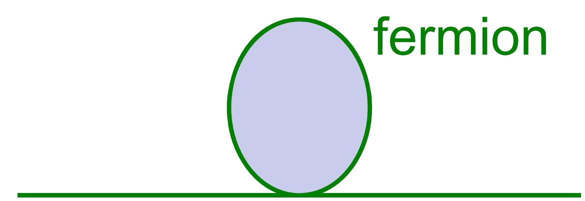
10^{-18} Solar System Gravity

Quantum Corrections:

Higher order effects drag Weak Scale to M_{Pl}



$\delta m_H^2 \sim$ ... $\sim M_{Pl}^2$



$\delta m_H^2 \sim$ ... $\sim - M_{Pl}^2$

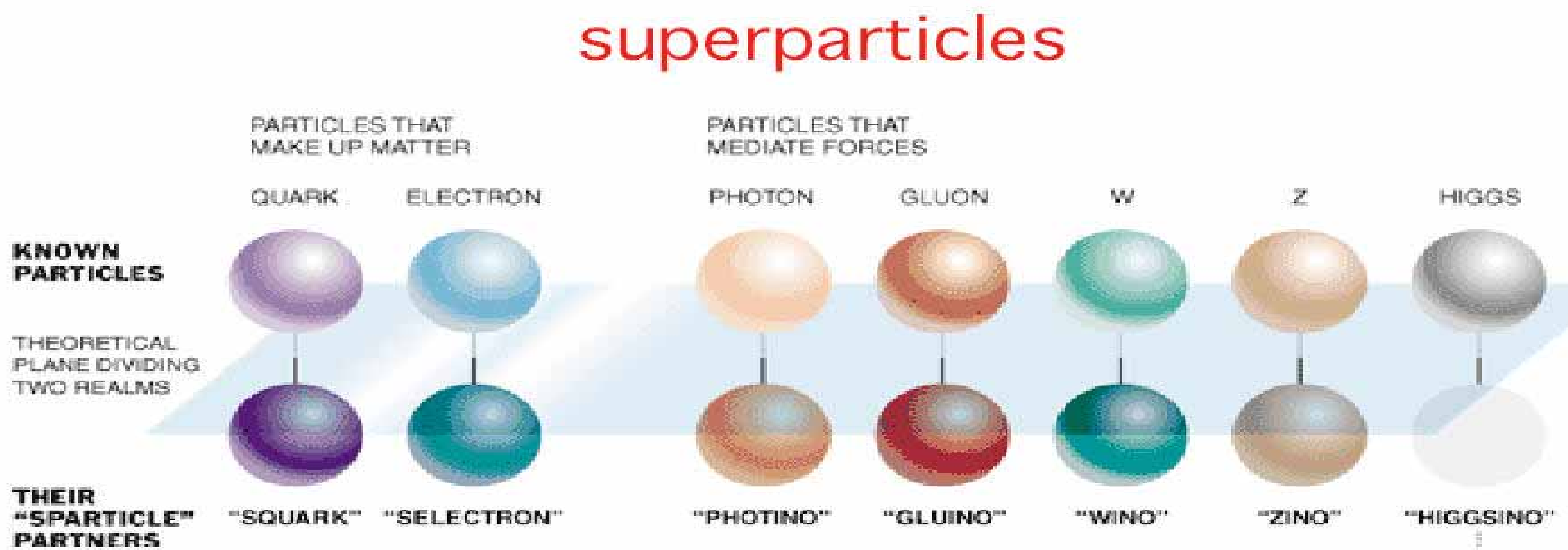
Large effects **cancel** order by order in perturbation theory

Minimal Supersymmetric Standard Model

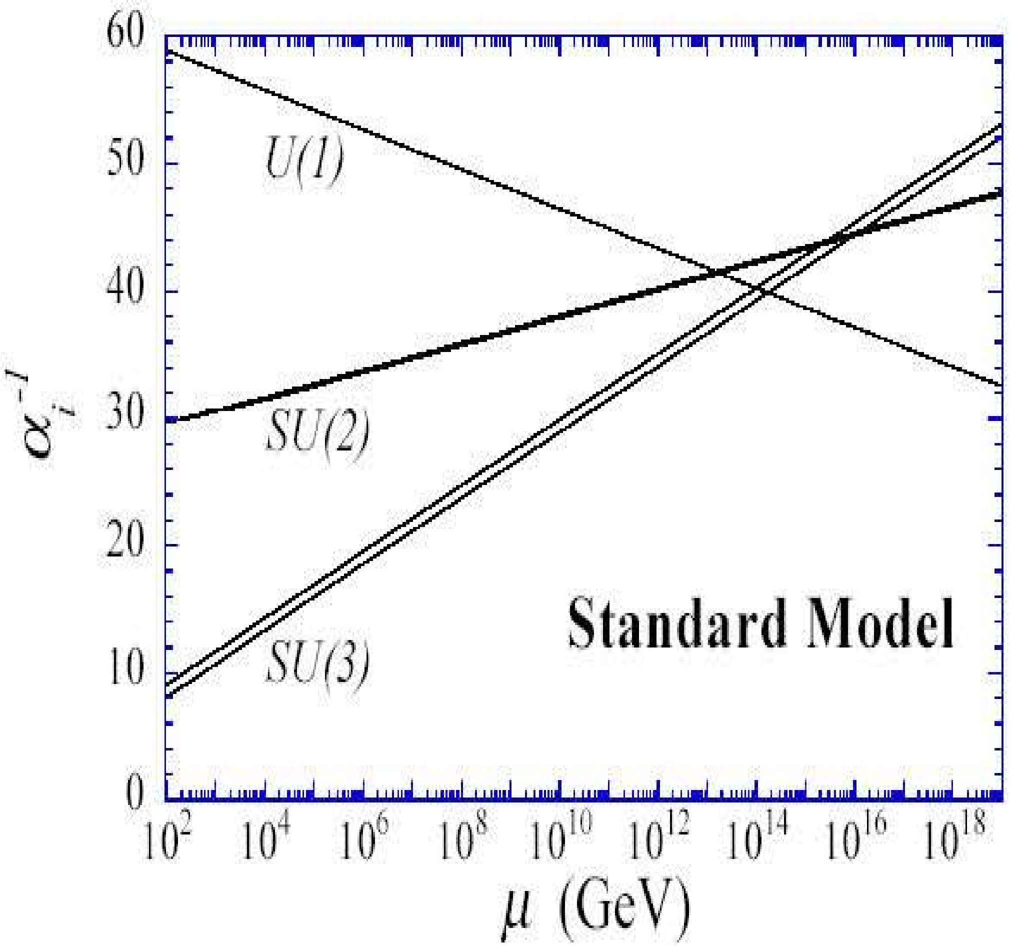
Conserved multiplicative quantum number

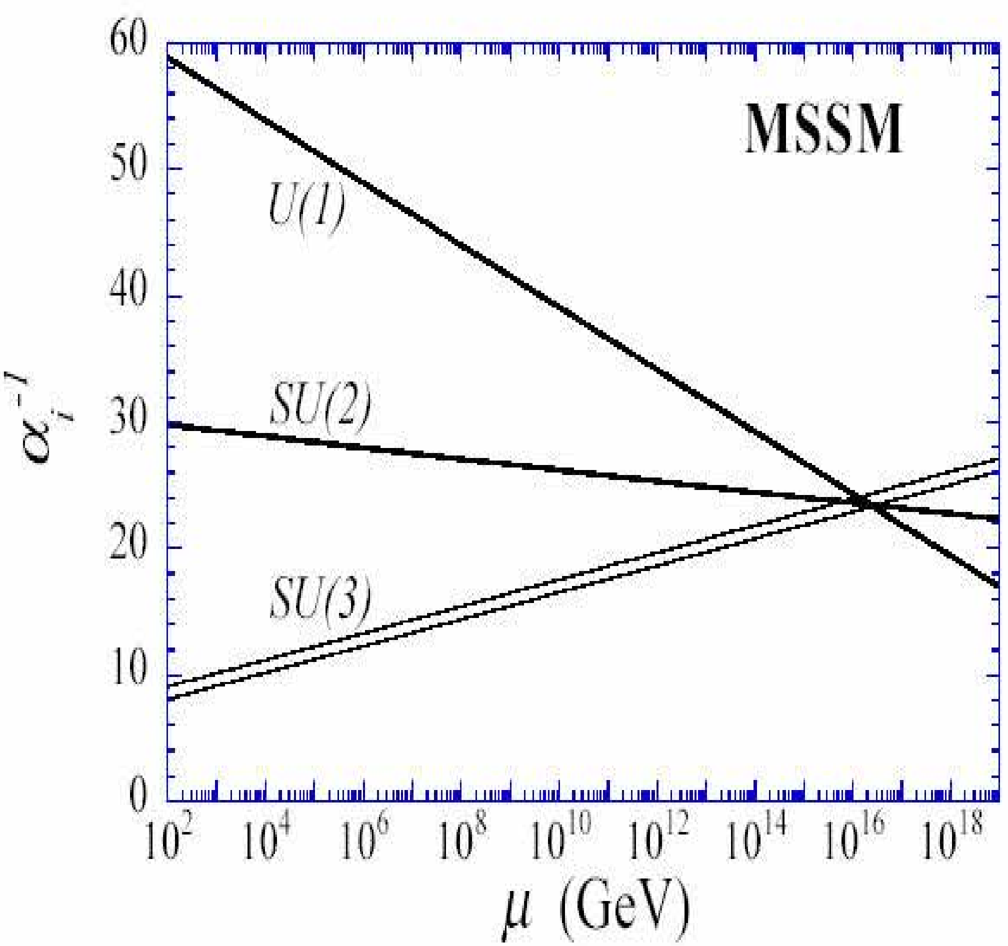
- Superpartners are produced in pairs at colliders
- Heavier Superpartners decay to the Lightest
- Lightest Superpartner is stable and may be DM

Collider signatures dependent on this assumption and on the specific model of SUSY breaking of which many exist



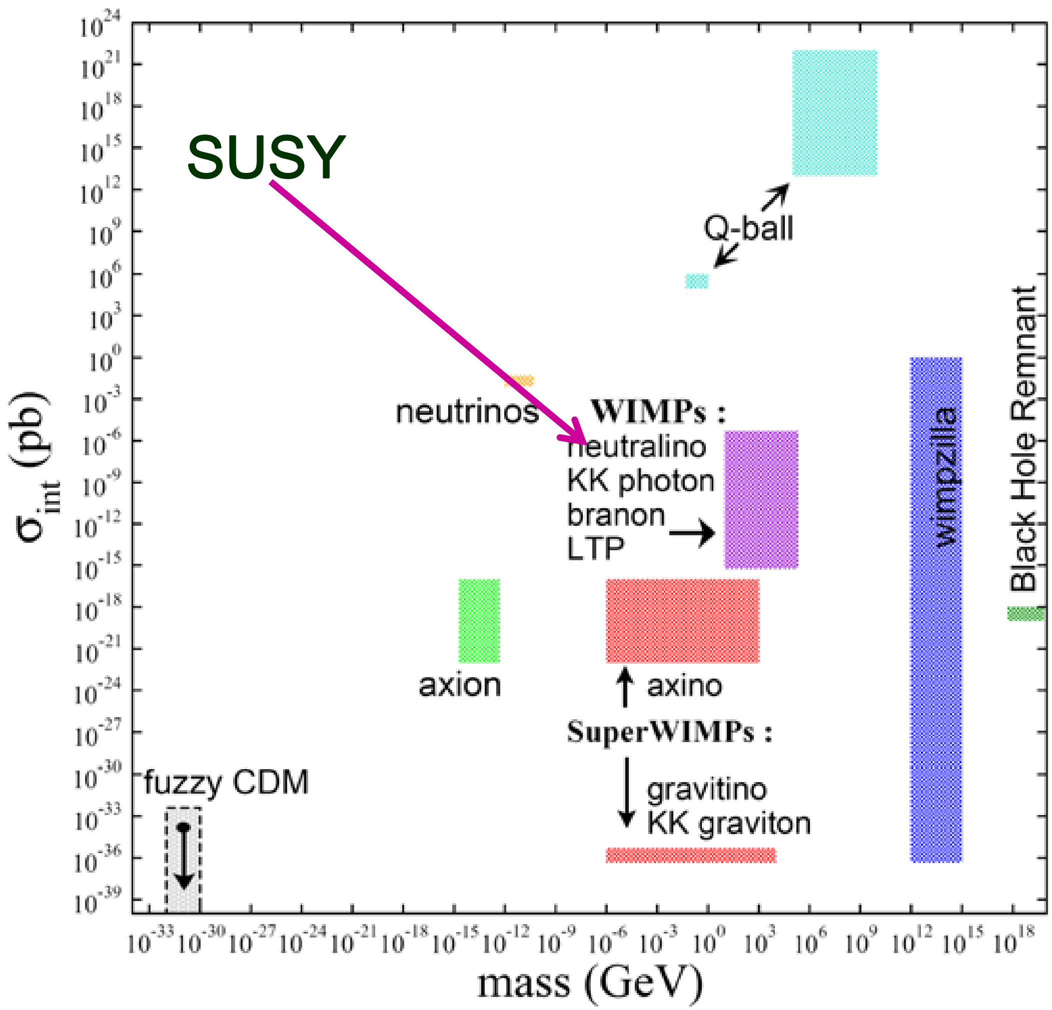
SUSY Leads to a Unification of the Forces





PARTICLE DARK MATTER CANDIDATES

- The observational constraints are no match for the creativity of theorists
- Masses and interaction strengths span many, many orders of magnitude, but not all candidates are equally motivated
- Weakly Interacting Massive Particle (WIMP)



HEPAP/AAAC DMSAG Subpanel (2007)

THE WIMP MIRACLE

(1) Assume a new (heavy) particle χ is initially in thermal equilibrium:

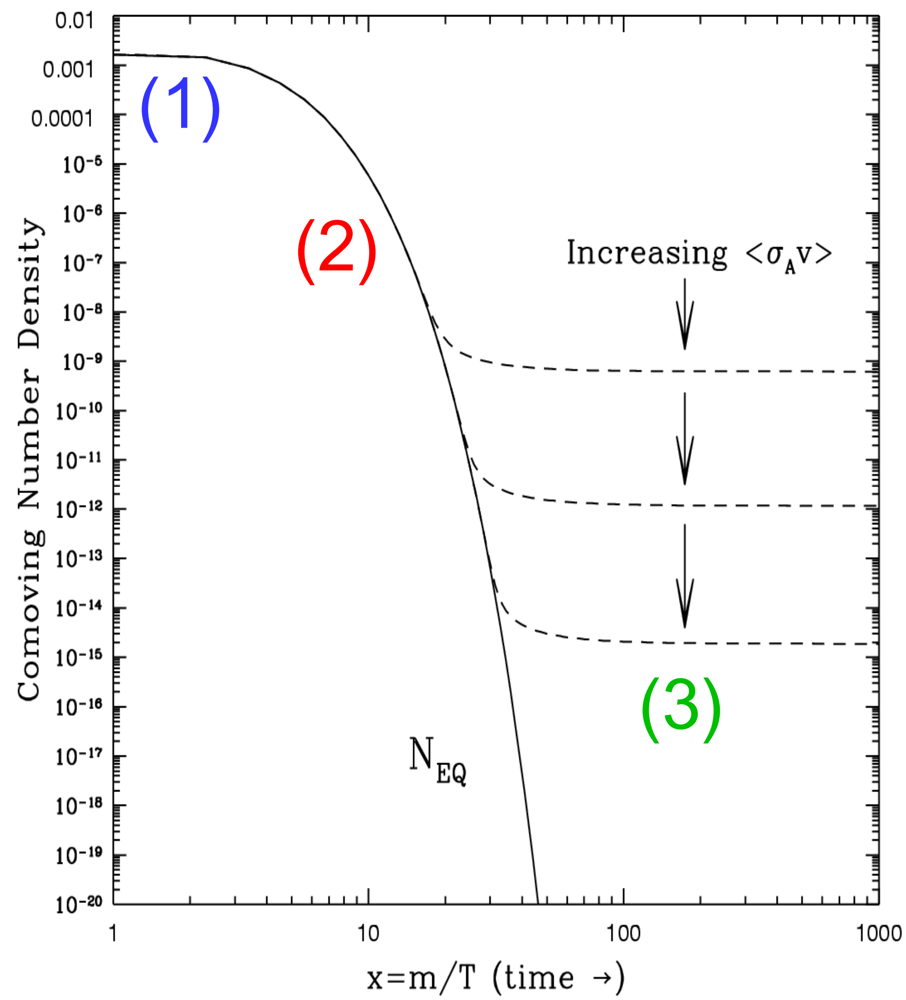
$$\chi\chi \leftrightarrow \bar{f} f$$

(2) **Universe cools**:

$$\chi\chi \rightleftarrows\!\!\!\!/\ \bar{f} f$$

(3) χs **"freeze out"**:

$$\chi\chi \not\rightleftarrows \bar{f} f$$



Zeldovich et al. (1960s)

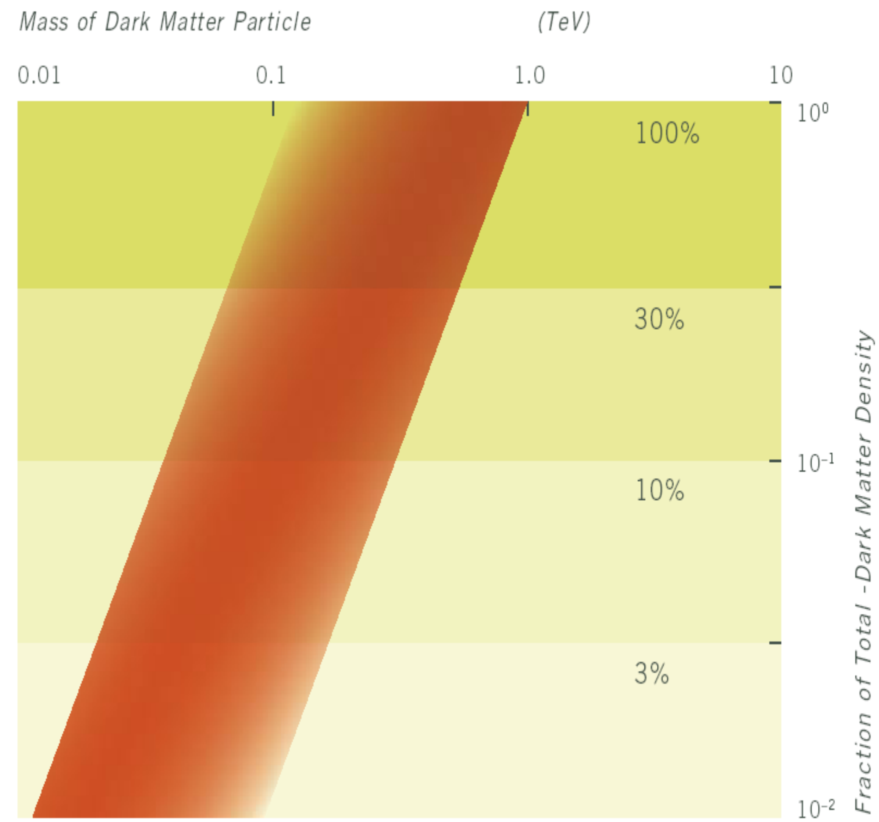
WIMPS FROM SUPERSYMMETRY

- **The amount of dark matter left over is inversely proportional to the annihilation cross section:**

$$\Omega_{DM} \sim \langle \sigma_A v \rangle^{-1}$$

- **The mass & couplings of the Lightest SUSY Particle (LSP) naturally lead to the right amount of DM!**

- **LSP is likely a mixture of photino, Zino & Higgsino**



HEPAP LHC/ILC Subpanel (2006)

[band width from k = 0.5 – 2, S and P wave]

$\chi\chi \rightarrow$ photons, positrons , anti-protons…. ‘in the sky’ may be seen by FERMI & other experiments

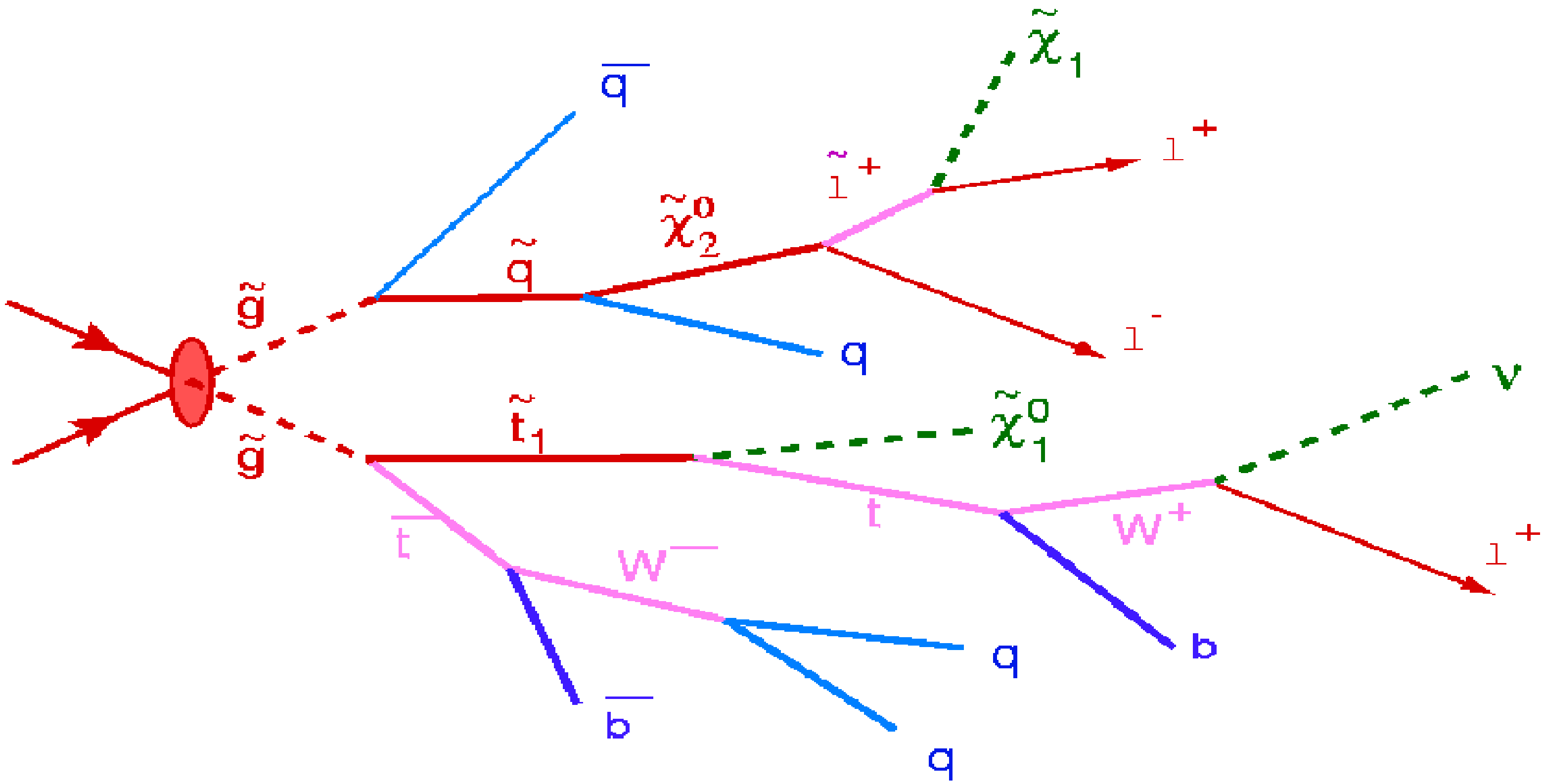
$\chi N \rightarrow \chi N$ elastic scattering may be detected on earth in deep underground experiments like, e.g., CDMS

If χ really is the LSP (or some other WIMP) it may be directly produced at the LHC !

This picture can be tested in many ways….

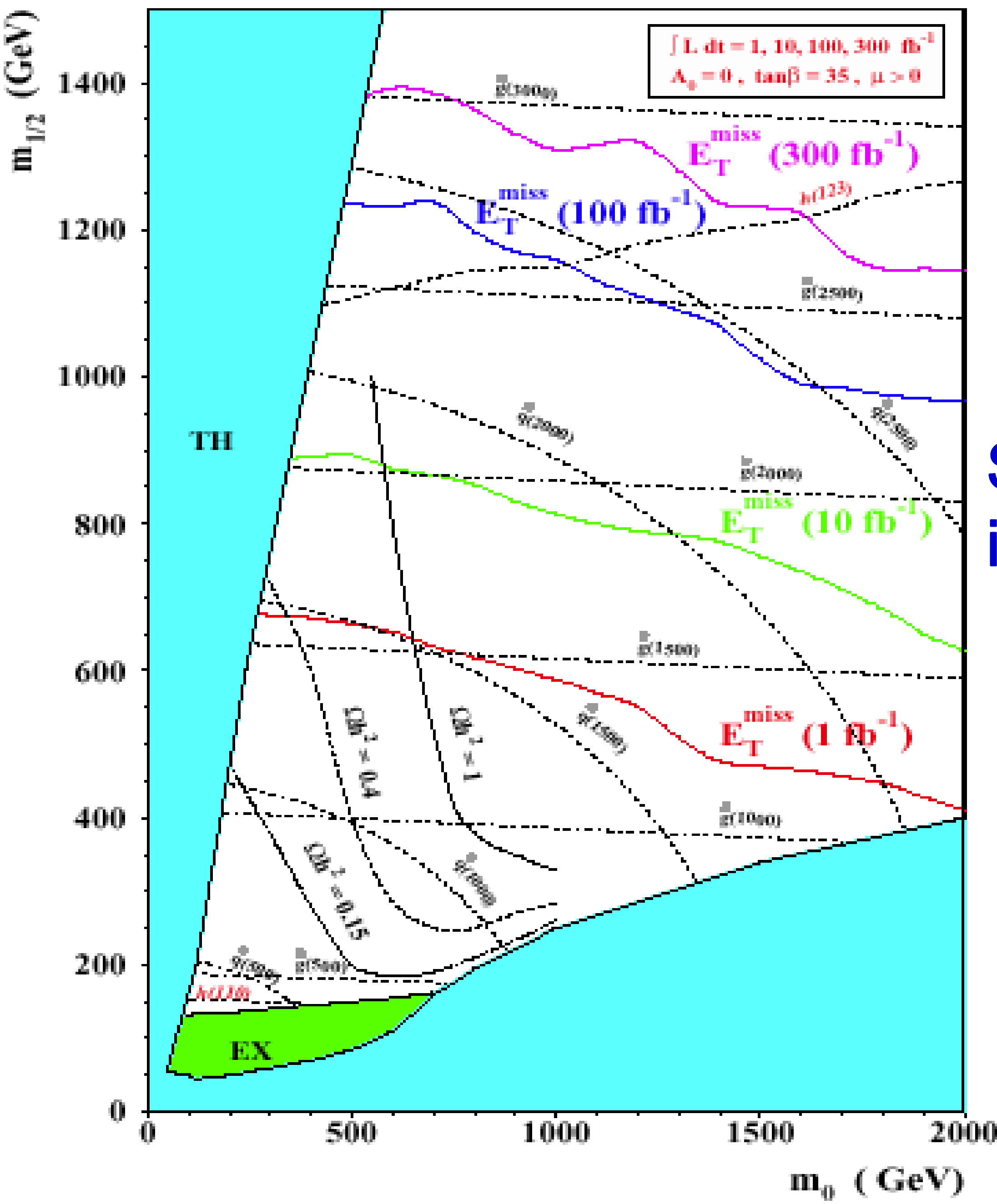
Analyses of SUSY searches at colliders have traditionally relied on the assumption of one or more specific models for How SUSY is broken: mSUGRA, GMSB, AMSB,….. which predict all the masses & interactions of the spartners in terms of only a few unknown parameters. (It's just easier !)

For example, in mSUGRA , at the LHC we may see



LHC searches are designed for specific SUSY breaking models

LHC Supersymmetry Discovery Reach

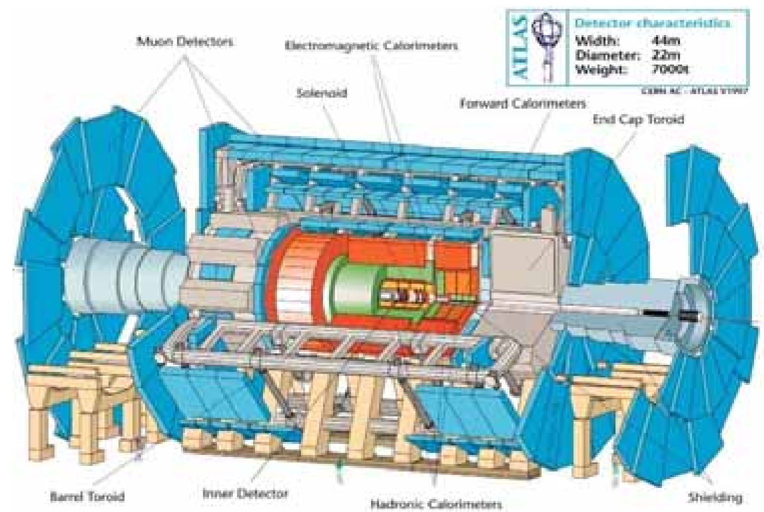


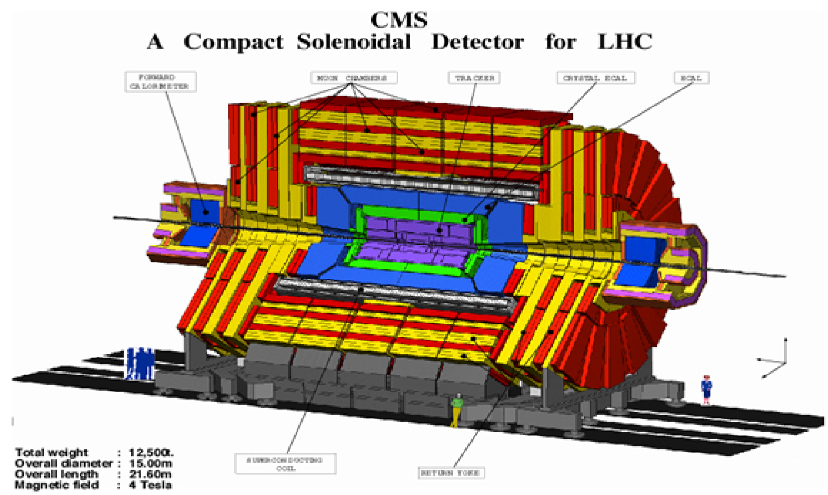
Model where gravity mediates SUSY breaking – 4 free parameters at high energies = mSUGRA

Squark and Gluino mass reach is ~ 2.5-3.0 TeV @ 300 fb^{-1}

But these & other searches depend on the SUSY breaking assumptions…can we be more general and be somewhat less prejudiced??

Supersymmetry Without Prejudice





C. F. Berger, J. G. Cogan, J.A. Conley, R.C. Cotta, J. S. Gainer, J. L. Hewett & TGR

We examined the signals for SUSY at the LHC without any (well, not too many) assumptions about how SUSY is broken by studying a large 19-dimesional parameter space. Such an analysis is very CPU intensive ~150 processor-years

We found that frequently SUSY does not behave like in any of the usual well-studied SUSY breaking scenarios & may be missed at the LHC unless the existing experimental analyses are generalized.

A lot more work needs to be done by both theorists and experimenters to insure the success of the searches for all possible kinds of new physics at the LHC!

We are in a special time in HEP !

The LHC is turning on-the experiments are ready & we will finally access the TeV scale so our theoretical ideas about new physics can be directly tested. The HEP community has been waiting for this for over 25 years.

What will we find at the LHC? Higgs, SUSY, extra dimensions , black holes, something we haven’t thought of yet?? I do expect we will get some important answers..but they will lead to new questions that we haven’t even thought to ask!

In the same time frame, we will also be getting new important complementary information from both the sky & from precision measurements…

EXICITING TIMES ARE AHEAD !!