Calculate + Observe:

Fundamental Physics in the 21st Century

Triumph of 20th Century

Relativity + Quantum Mechanics

↓

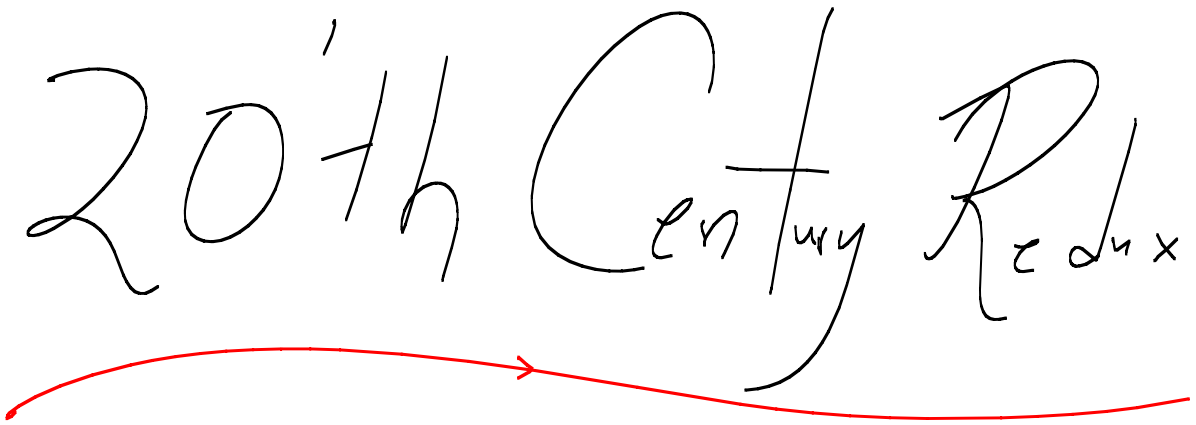
Universe is Inevitable

Central Dramas of 21st Century

★ End of Space-time [Gravity]

Limitations of QM [Cosmology]

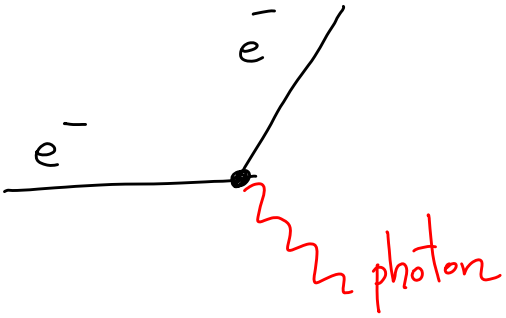
★ Why is the Universe BIG, with BIG THINGS in it?

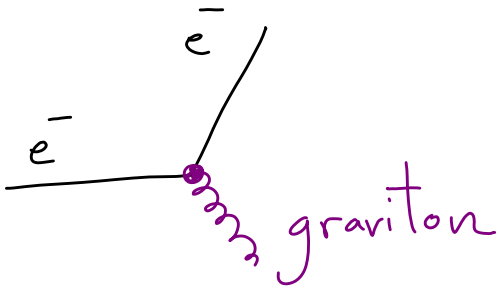

20th Century Redux

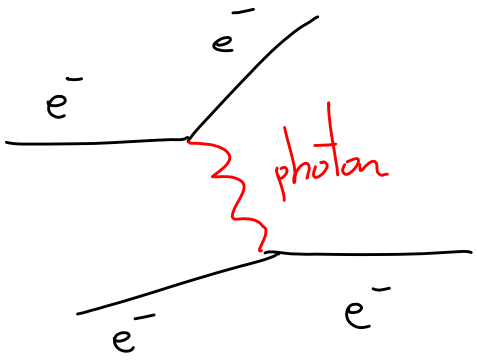
Relativity + QM

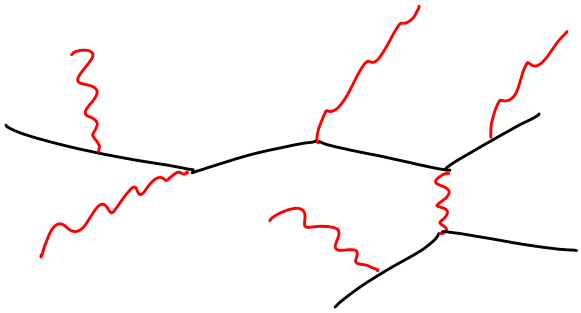
"Quantum Field Theory"

Gravity + Electromagnetism

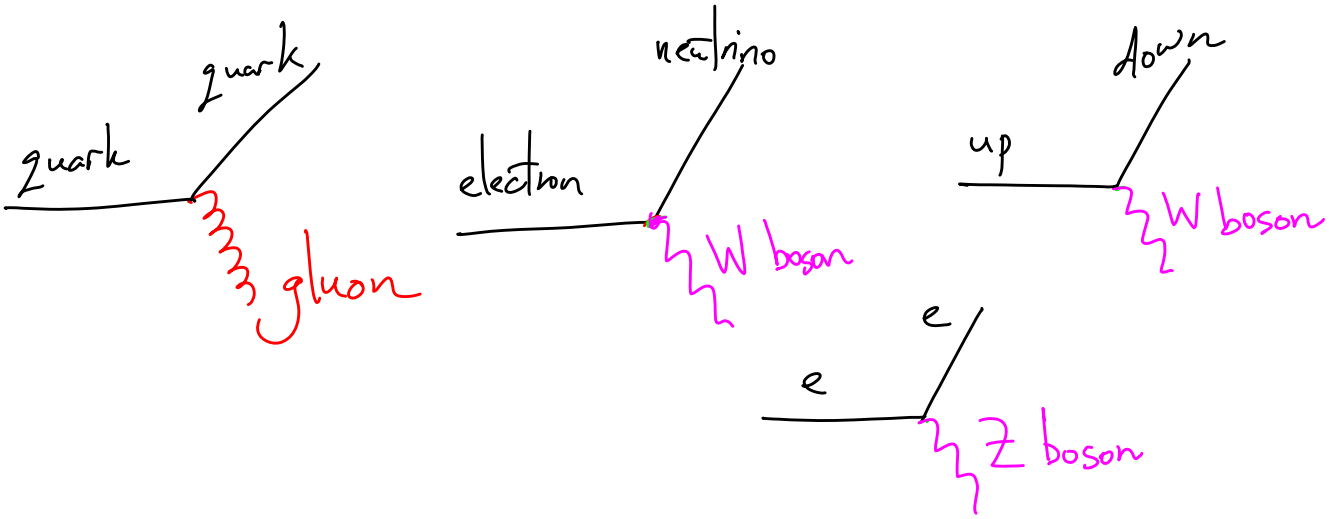


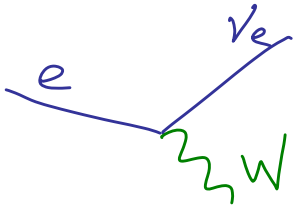


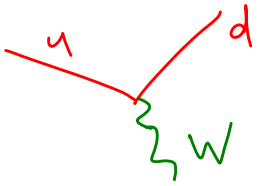


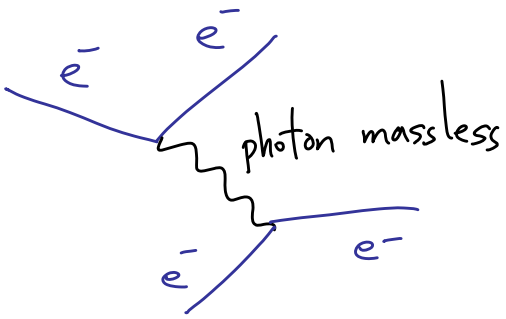


Strong + Weak: Same Structure!

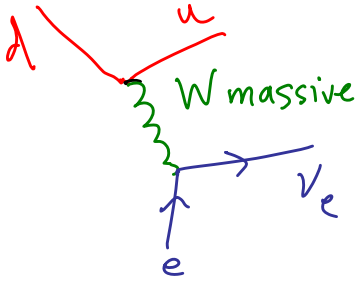






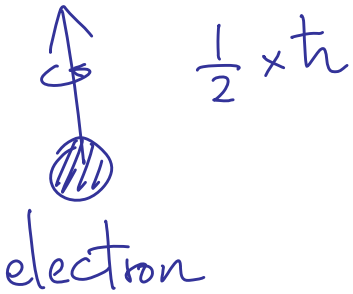


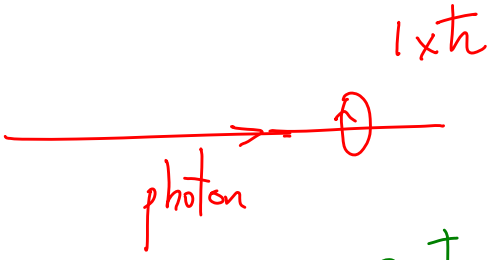
long-range force

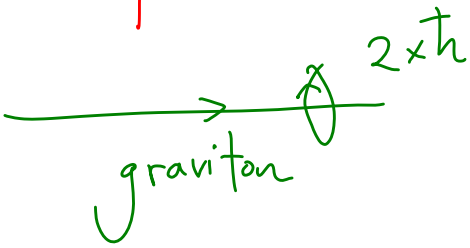


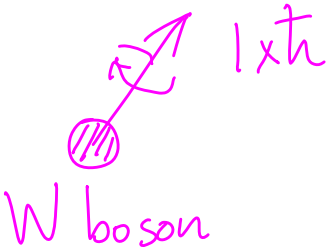
short-range!
($\sim 10^{-16}$ cm)

Particles have "Spin"









Allowed:

0,

$\frac{1}{2}$,

1,

$\frac{3}{2}$,

2,

$\frac{5}{2}$,

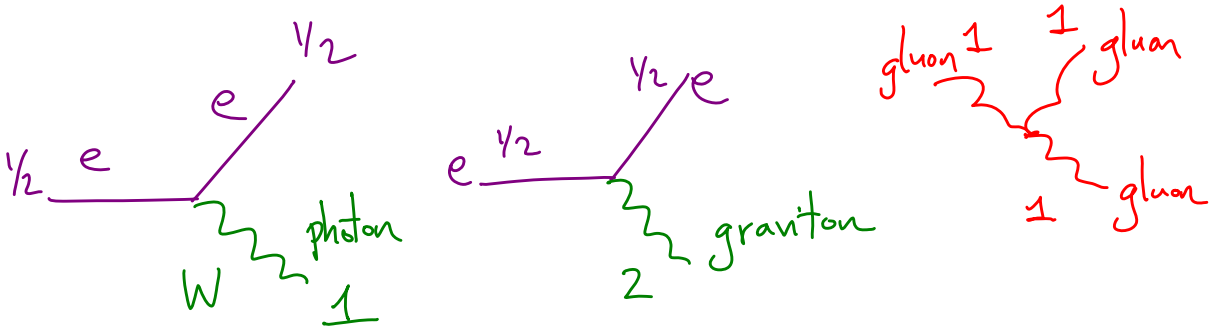
3,

⋮

x ħ

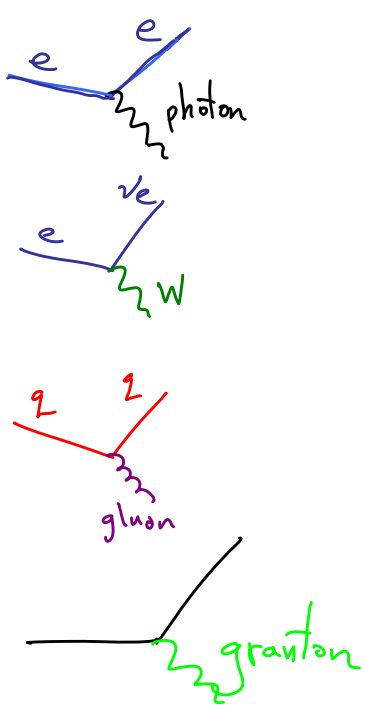
Particles we see extremely simple!

Just: $\frac{1}{2}$, 1, 2



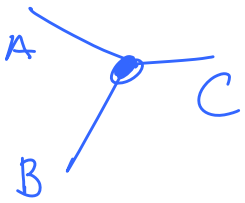
The Menu

		Gluons	"W's + Photon"	
		$SU(3)_c$	$\times$ $SU(2)_L$	$\times$ $U(1)_Y$
$3\times$	Q	3	2	$+\frac{1}{6}$
	U^c	$\bar{3}$	-	$-\frac{2}{3}$
	D^c	$\bar{3}$	-	$+\frac{1}{3}$
	L	-	2	$-\frac{1}{2}$
	E^c	-	-	$+1$

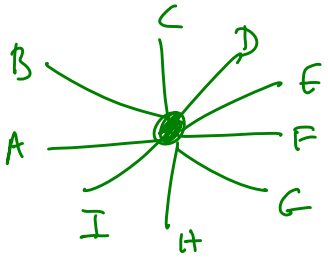


Why So Simple?

- Why simple fundamental interaction



why not

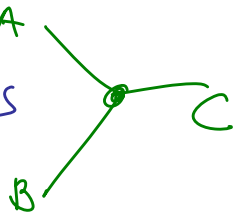


?

- Why such a tiny menu of spins ?

Whatever the Ultimate Theory

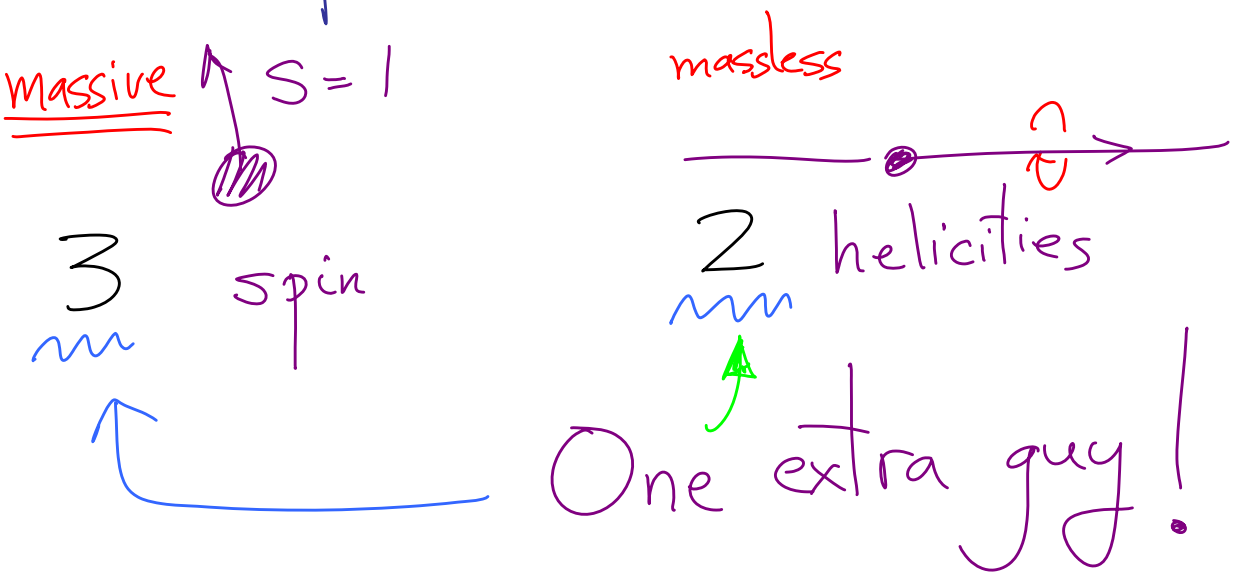
Relativity ↓ Quantum Mechanics

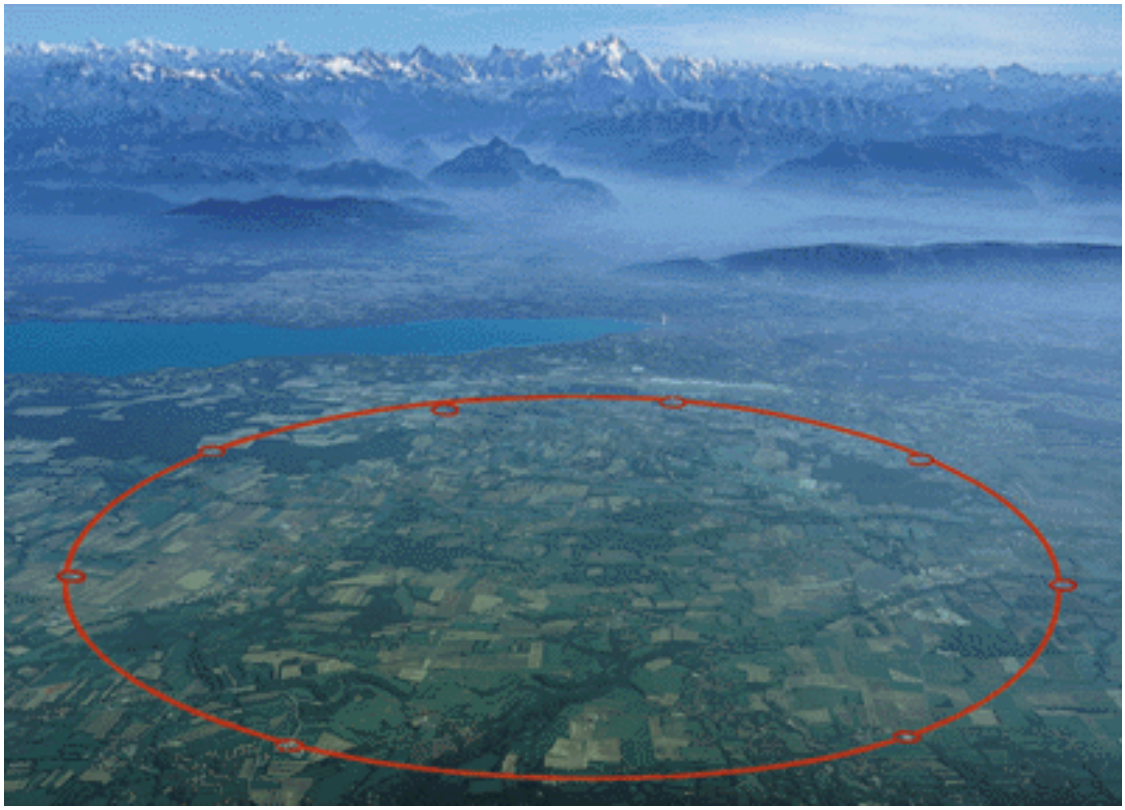
At "Long" distances, particles interacting as 

with spins $0, \frac{1}{2}, 1, \frac{3}{2}, 2$. ← unique, "gravity"

What About The Higgs?

Important difference between massive + massless particles with spin:





Collisions ~ 10,000 GeV ~ 10,000x mass of proton

Velocity ~ 0.9999999 x c light

Probing ~ 10^{-17} cm ~ 1000x smaller than nucleus

TRIUMPH FOR EXPERIMENT

TRIUMPH FOR THEORY

PHYSICS WORKS

Belief in Principles Paid Off

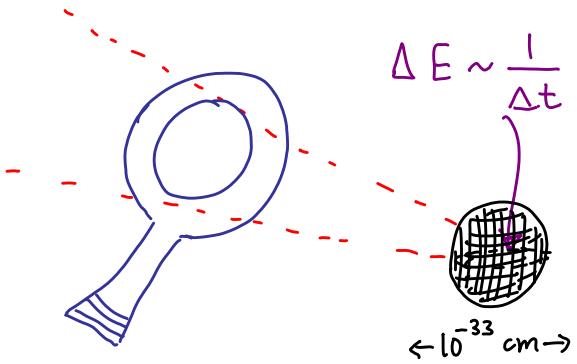
$$0, \frac{1}{2}, 1, \frac{3}{2}, 2$$

Higgs is first "really new" particle we've seen!

21st Century Frontiers

Space-Time is Doomed

What Replaces It?



$\Delta E \sim \frac{1}{\Delta t} \rightarrow$ eventually make Black Hole!

No Operational meaning to distance $< 10^{-33}$ cm, times $< 10^{-43}$ s, ...

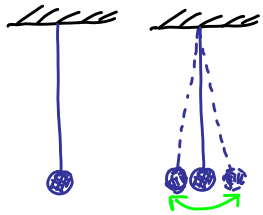
Energy needed $\sim 10^{19}$ GeV

(L.H.C. Energies $\sim 10^{3}$ GeV...)

Why Is There A Macroscopic Universe?

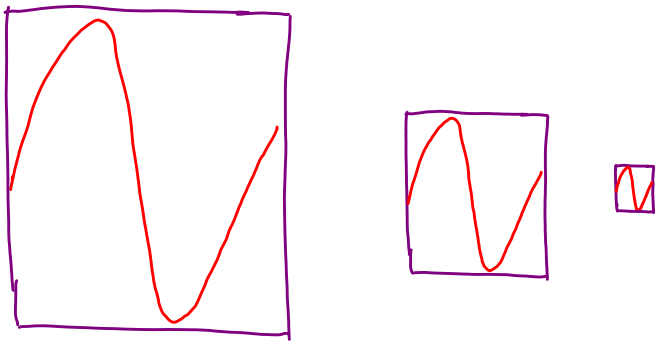
Vacuum is Too Exciting

Even Vacuum has energy!



$E_{min} = 0$
classical

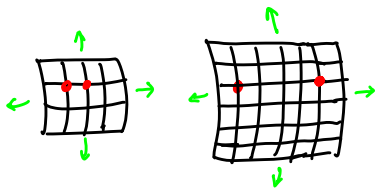
$E_{min} \sim h \times freq.$
Quantum



Bigger Fluctuations at Shorter Distances

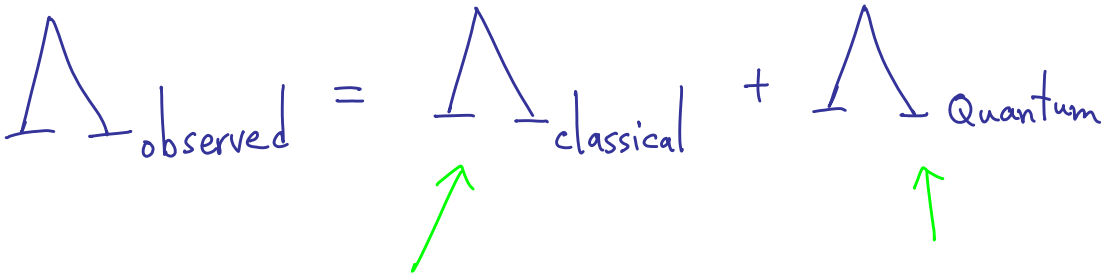
Estimating Λ

"Vacuum Energy Density" $\sim \frac{\text{Energy}}{\text{Volume}} \sim \left[\frac{\text{Planck}}{\text{Planck Volume}}\right]$



Explosive Acceleration –
Doubling size every 10^{-43} s !

What We Do



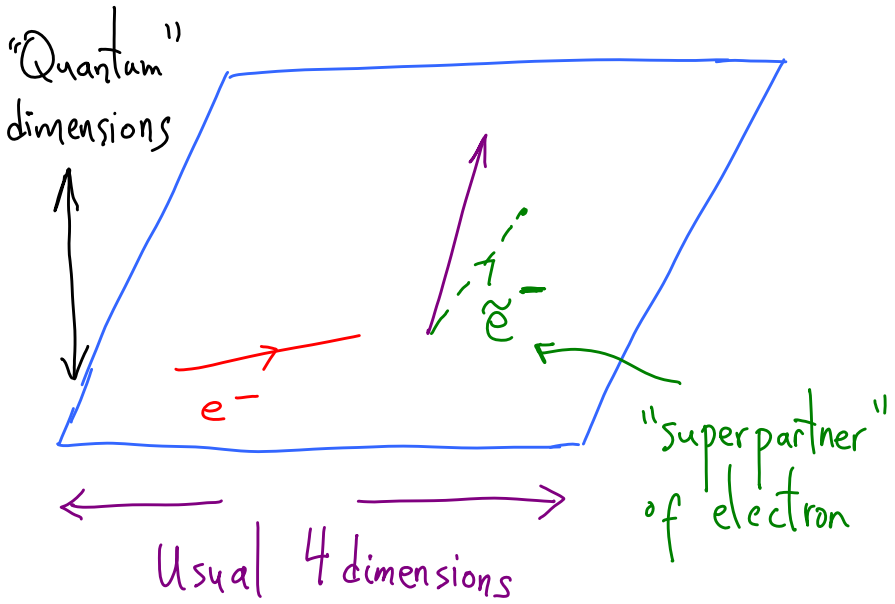
$-2.6493781\ldots.526\ldots$ (120 decimals)

$+2.6493781\ldots.534\ldots$ (120 decimals)

SEEMS LUDICROUS

"Tuning"

Supersymmetry



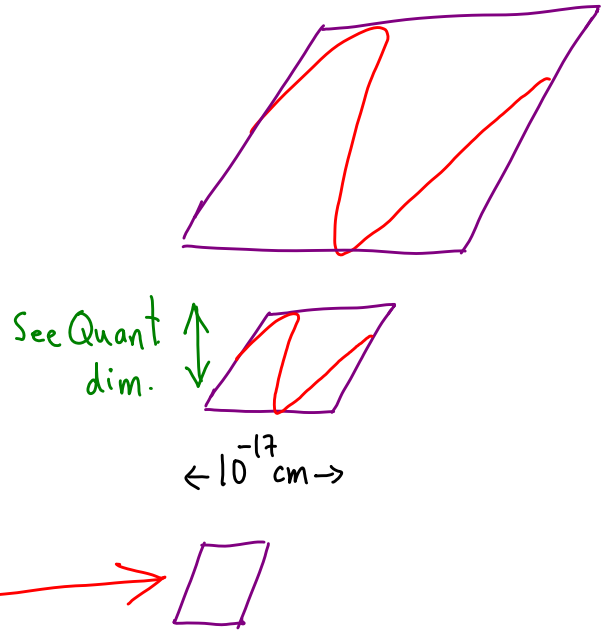
Quantum d_x, Quantum d_y, ...

$$d_x^Q d_y^Q = -d_y^Q d_x^Q$$

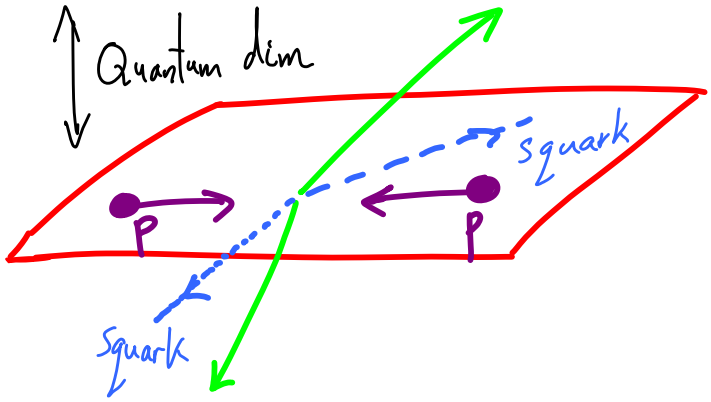
$$\left(d_x^Q\right)^2 = 0$$

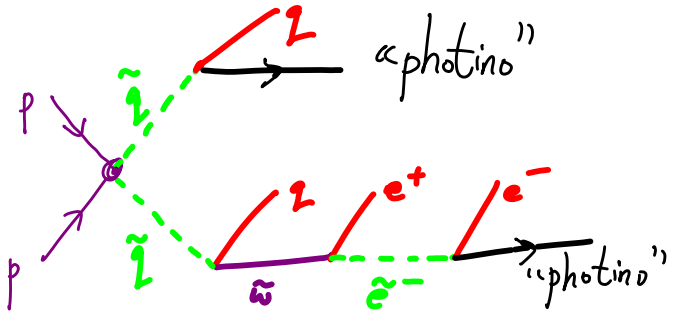
$$d_{xy}^Q$$

Violent
Quantum
Fluctuations
Gone



SUSY at the LHC





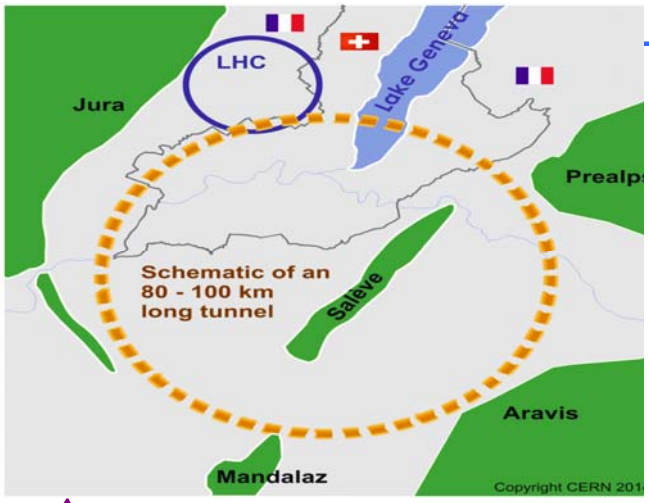
"Missing" Energy

Emergent Spacetime?

We are clearly missing something HUGE about Quantum Mechanics of our Relativistic Vacuum!

Macroscopic Universe?

Next Energy Frontier Machines: 100 TeV Collider



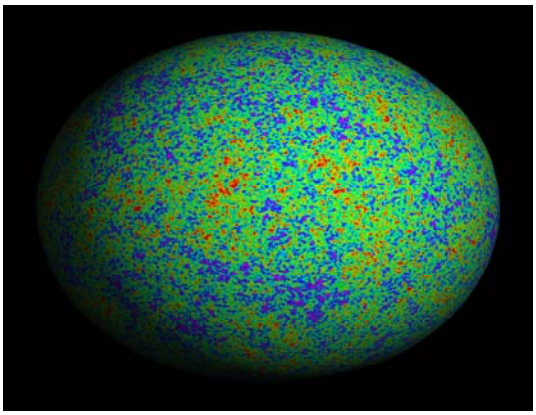
Site

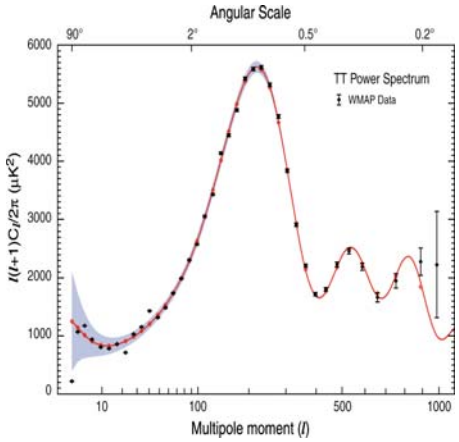
- Preliminary selected: Qinhuangdao (秦皇岛)
- Strong support by the local government

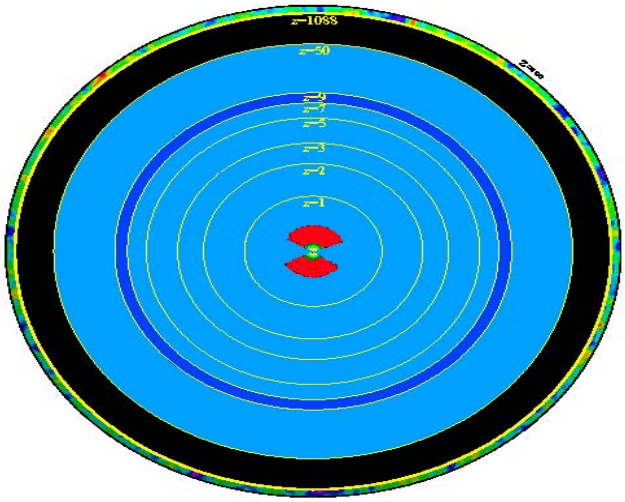
CERN ~100 km, ~10x LHC Energy CHINA

~30 yr Future

Cosmic Microwave Background







~30 yr future

Exhilirating Time To Be Doing Physics

"Next Steps" needed will likely be Revolutionary

JUMP IN!