

# The Physics in Front of Us

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Community Planning Meeting, October 11-13, Fermilab

# Discovery of the Century:

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**a spin zero elementary particle!**

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bosons are gauge force carriers & fermions are matter

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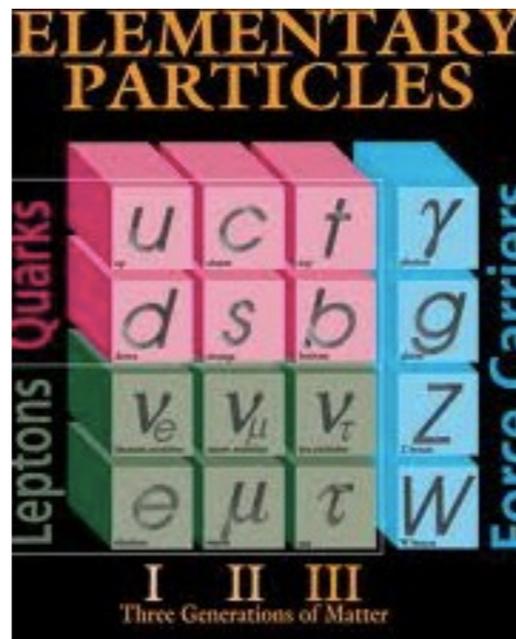
Higgs boson is neither nor; it is **both!**

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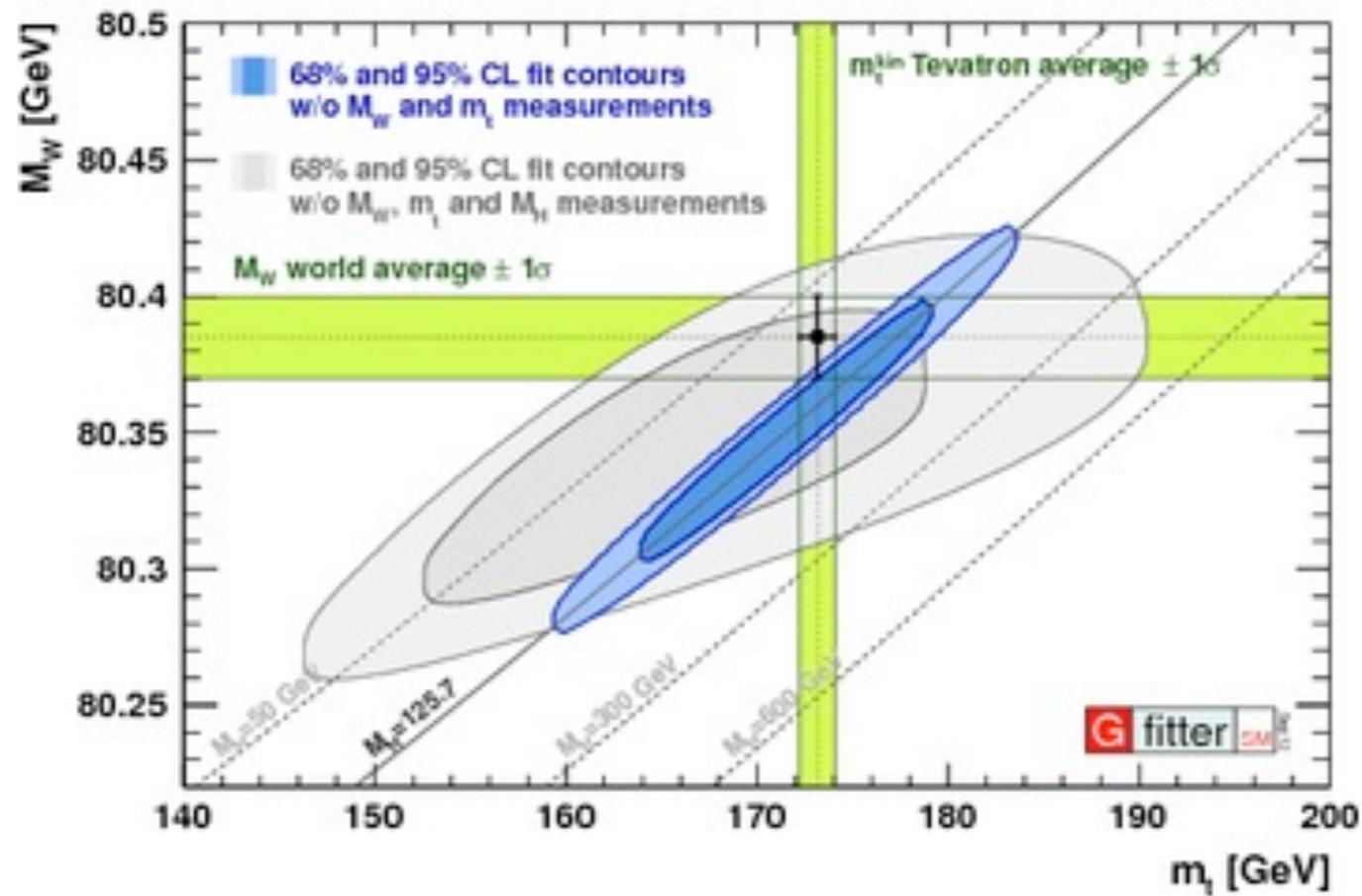
a spin zero elementary particle!

bosons are gauge force carriers & fermions are matter

Higgs boson is neither nor; it is **both!**



is there any doubt about the LHC particle?



it is the  $0^+$  Higgs boson

clear picture of the Universe  
when it was a few millifermis "big"

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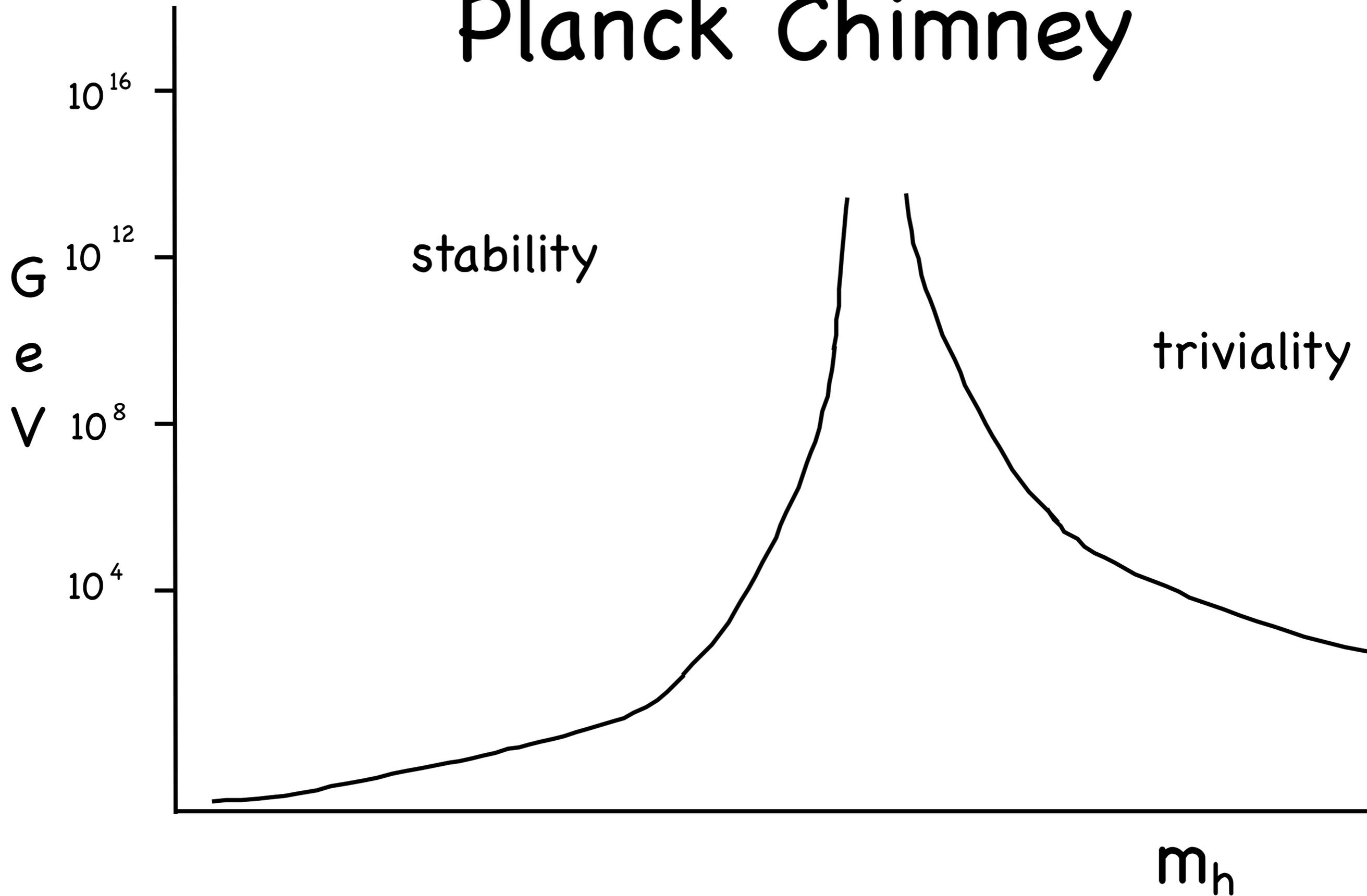
## The Light Higgs

has lifted the fog of TeV strong interactions

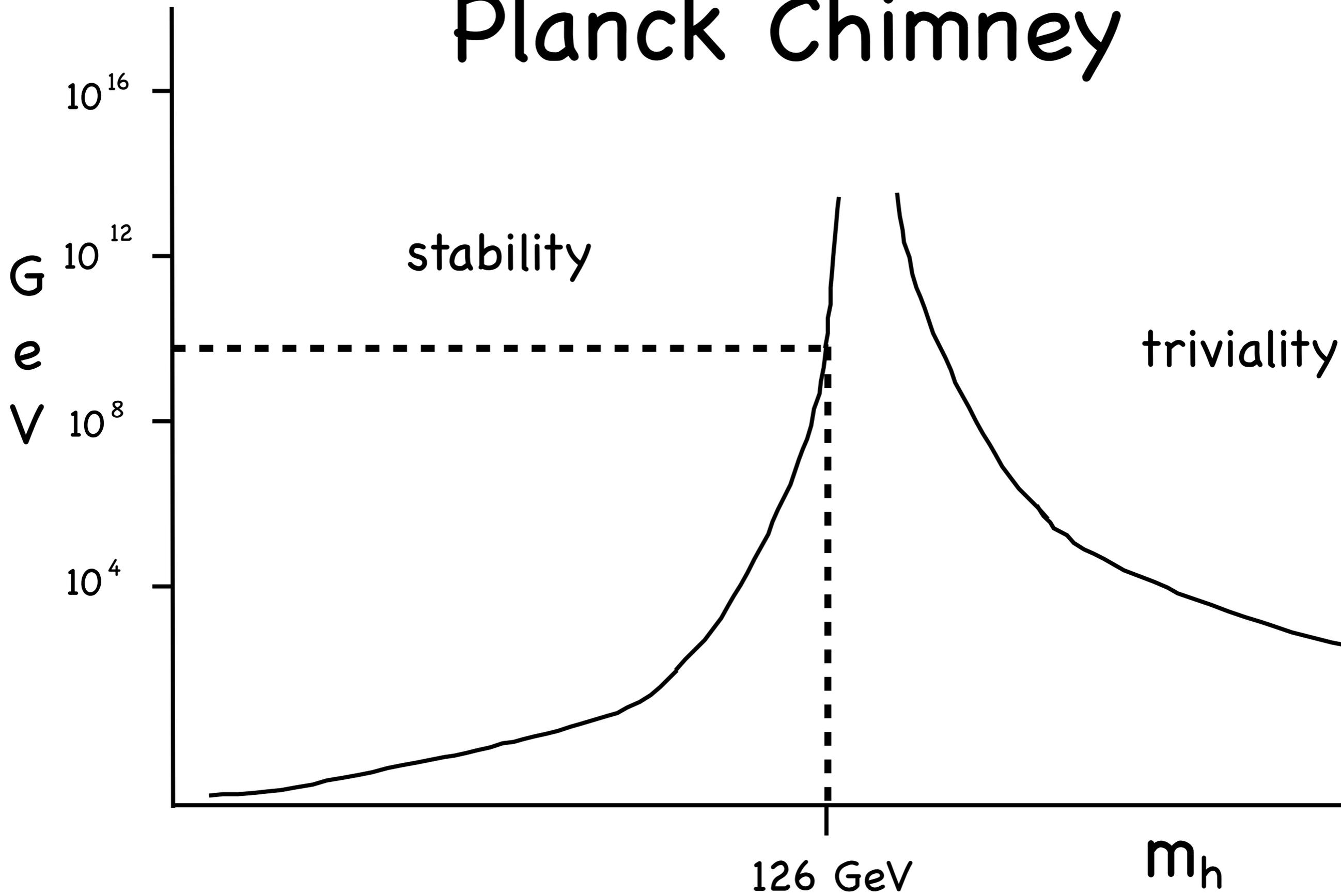
On a clear day

theorists can see **almost** to the Planck scale!

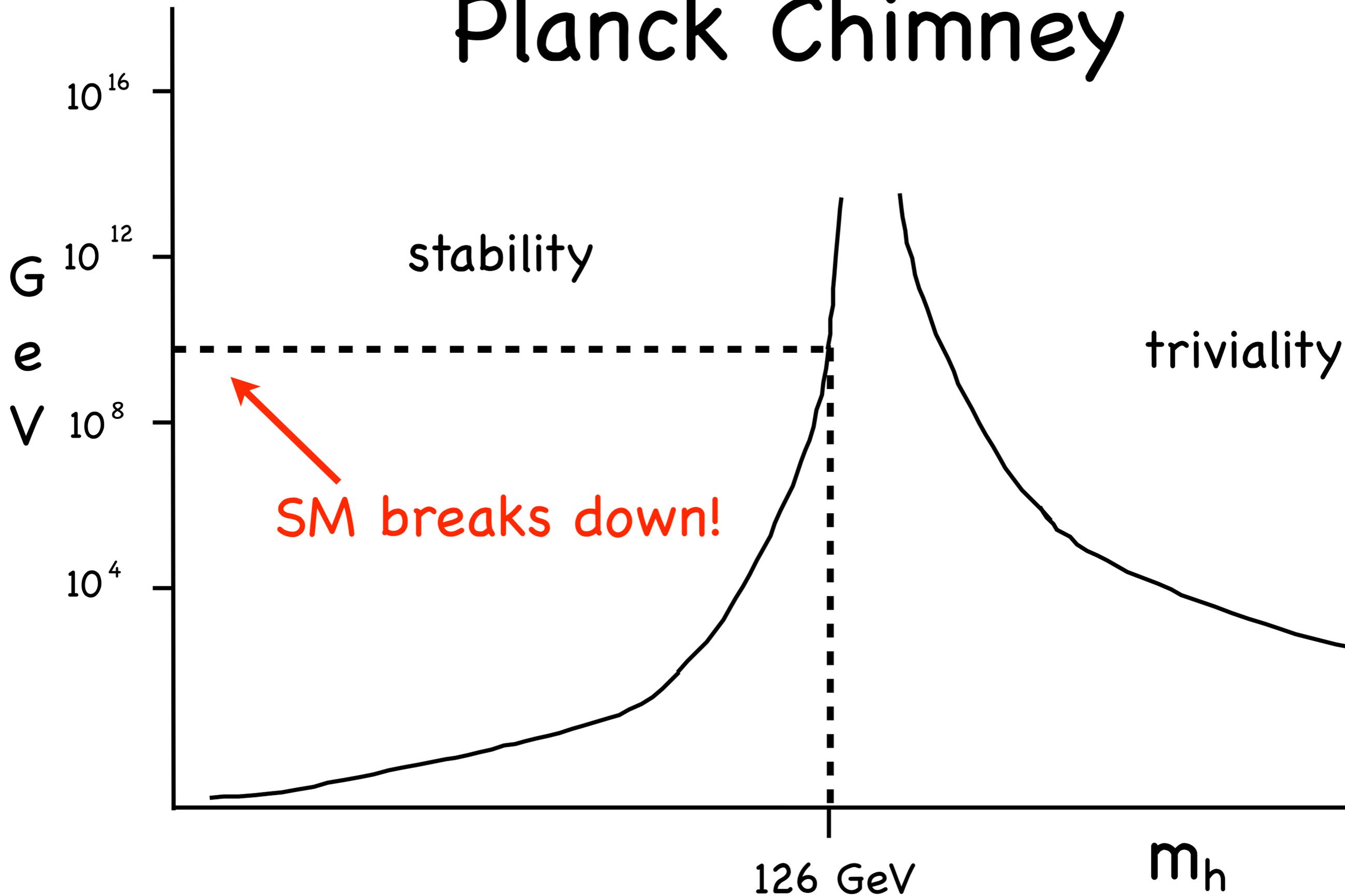
# Planck Chimney



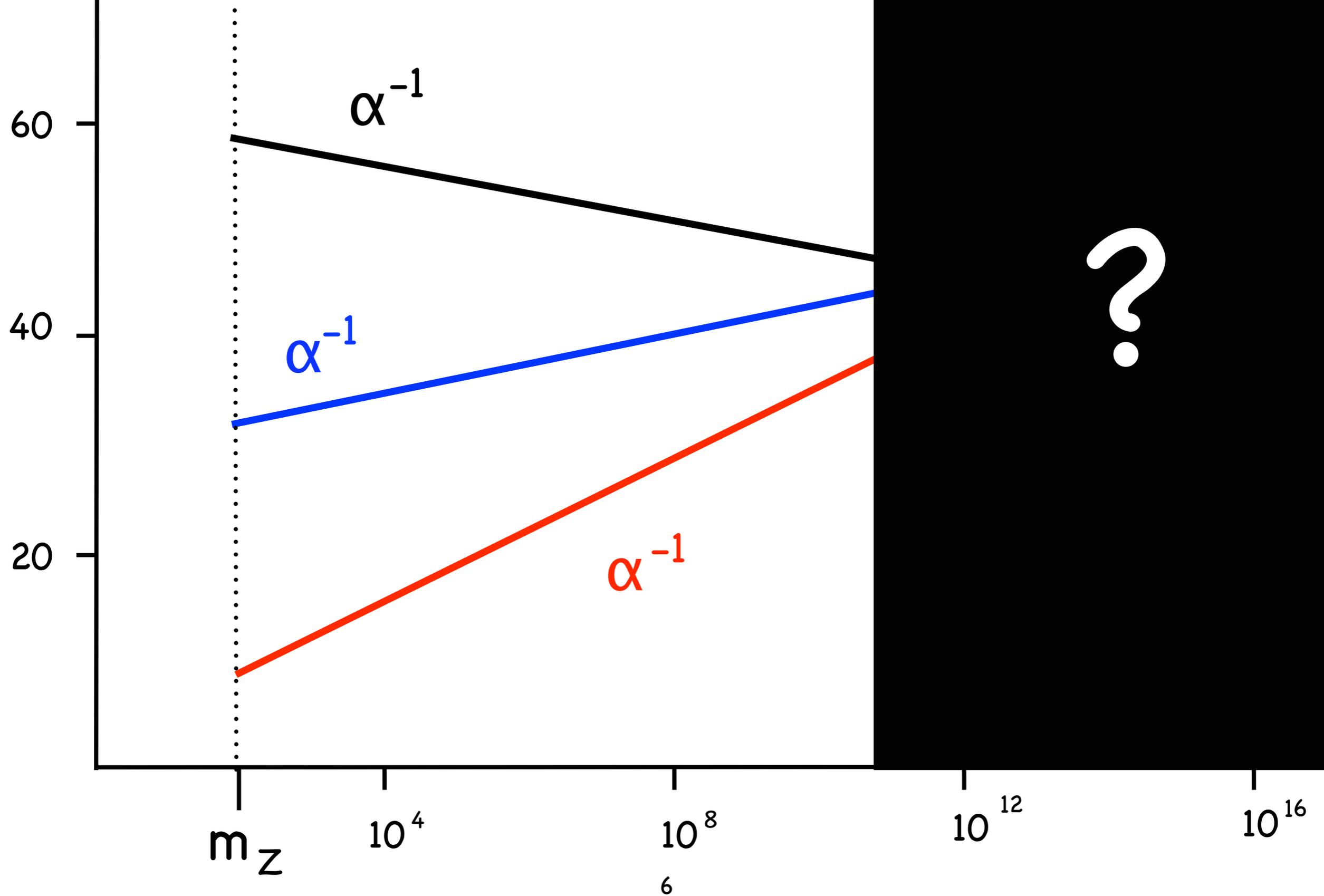
# Planck Chimney



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# Standard Model



?

Standard Model **limited**

to lengths larger than nanofermis

(much bigger than Planck length)

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LHC's reach of the order of millifermis

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Neutron electric dipole moment  $\theta_{CP}$

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Mass & mixing patterns of quarks & leptons

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Dark Matter

Dark Energy

# Standard Model Legacies

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## Greater Symmetry in the Very Early Universe

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## Greater Symmetry in the Very Early Universe

boson-fermion symmetry?  
(from superstrings)

Supersymmetry

lepton-quark symmetry?  
(from asymptotic freedom)

Grand (gauge) Unification

family symmetry?  
(from neutrino mixings)

Discrete Family group

# Implications of TeV Supersymmetry

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**Energy Frontier**

discovery of superpartners

# Implications of TeV Supersymmetry



## Energy Frontier

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## Intensity Frontier

detect (virtual) superpartners  
in rare processes

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## Intensity Frontier

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in rare processes



## Cosmic Frontier

lightest superparticle as Dark Matter

# spin zero: squarks & sleptons

$\tilde{e}_R$



$\tilde{\nu}_e \tilde{e}_L$



$\tilde{u}_R \tilde{d}_R$



$\tilde{u}_L \tilde{d}_L$



$\tilde{t}_1$



$\tilde{t}_2 \tilde{b}_1$



$\tilde{t}_1$



$\tilde{b}_1$



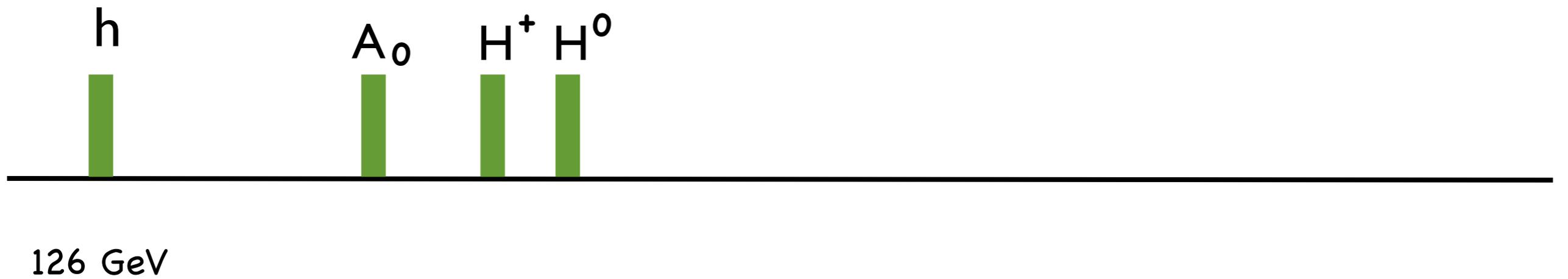
$\tilde{b}_2$



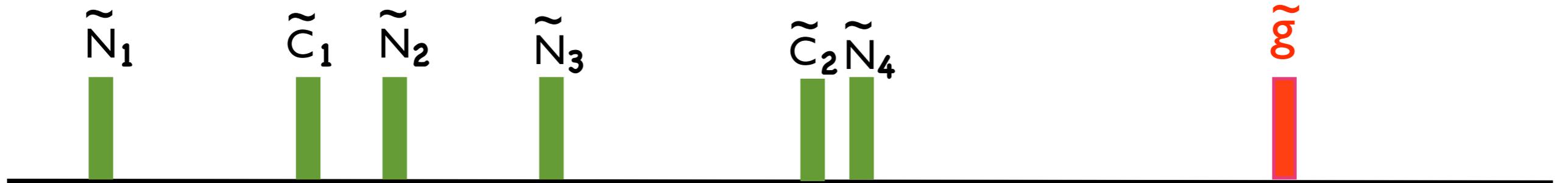
$\tilde{t}_2$

||

# spin zero: higgs system



# spin half: neutralinos, charginos & gluinos



# TeV Supersymmetry

removes the Planck Chimney

(extends the SM to smaller distances)

enables gauge couplings unification

triggers electroweak symmetry breaking

(large  $\tan \beta$ )

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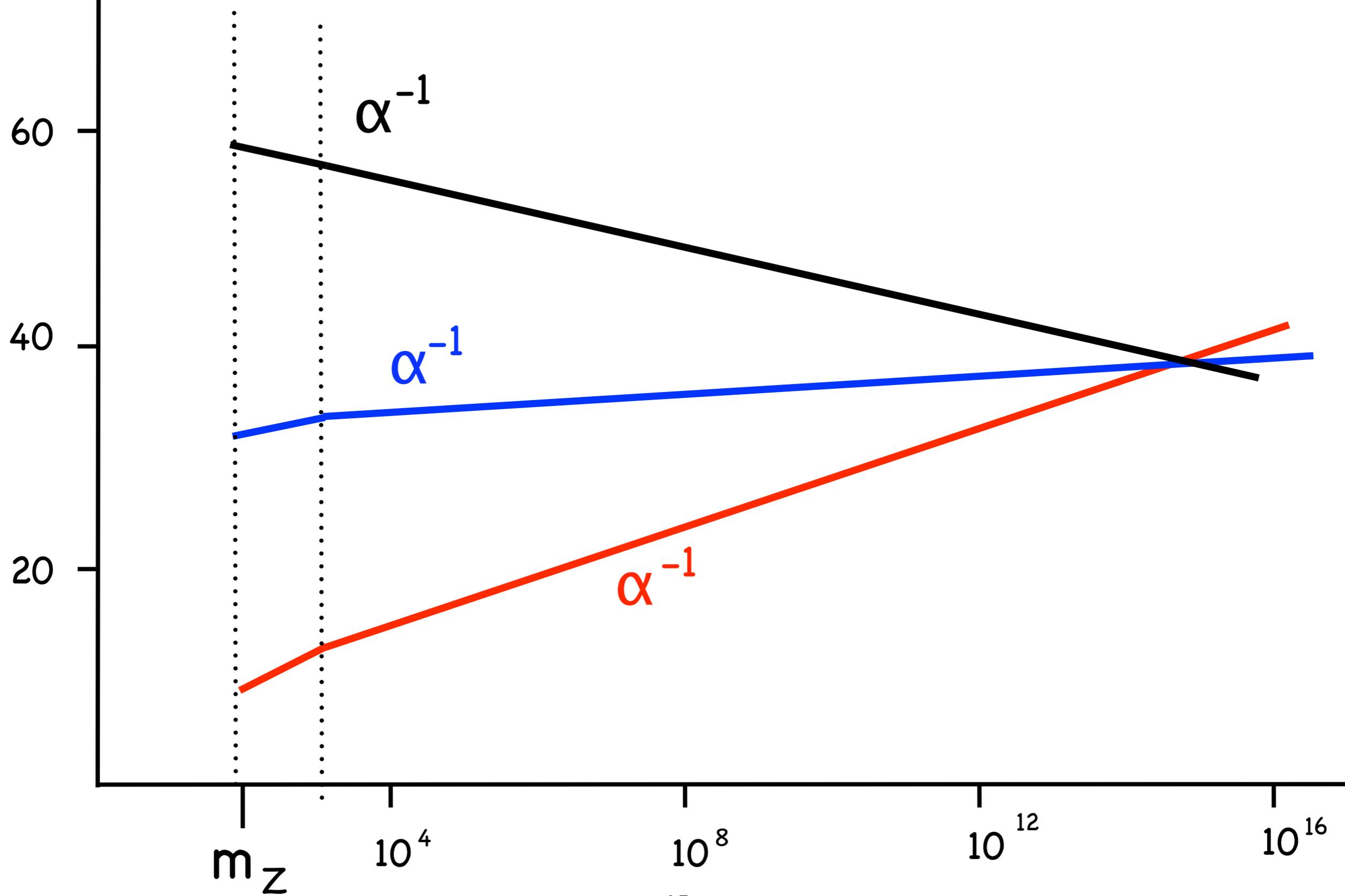
enables gauge couplings unification

triggers electroweak symmetry breaking

(large  $\tan \beta$ )

cures the common cold!

# Supersymmetric Standard Model



# Implications of Grand Unification

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gauge coupling unification

(TeV-supersymmetry required)

proton decay

(\$\$ required)

seesaw mechanism

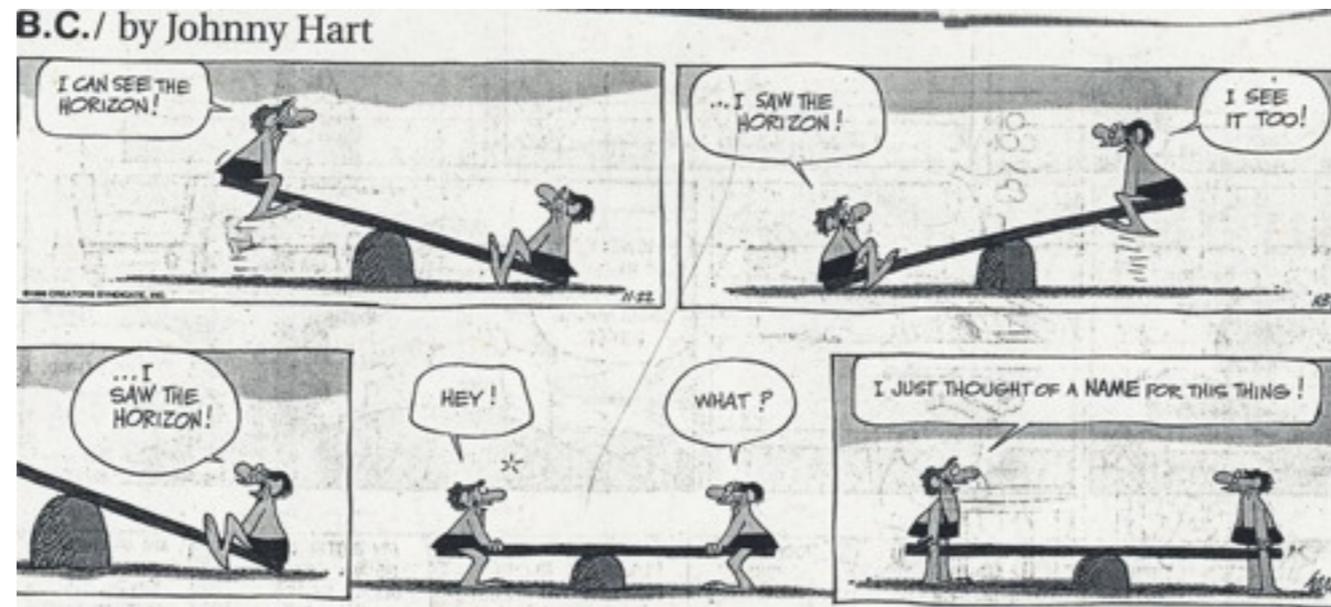
(grand-unification inspired)

lepto-baryo-genesis

lepton-quark mass relations

$$(m_b = m_\tau)$$

# The



# Mechanism

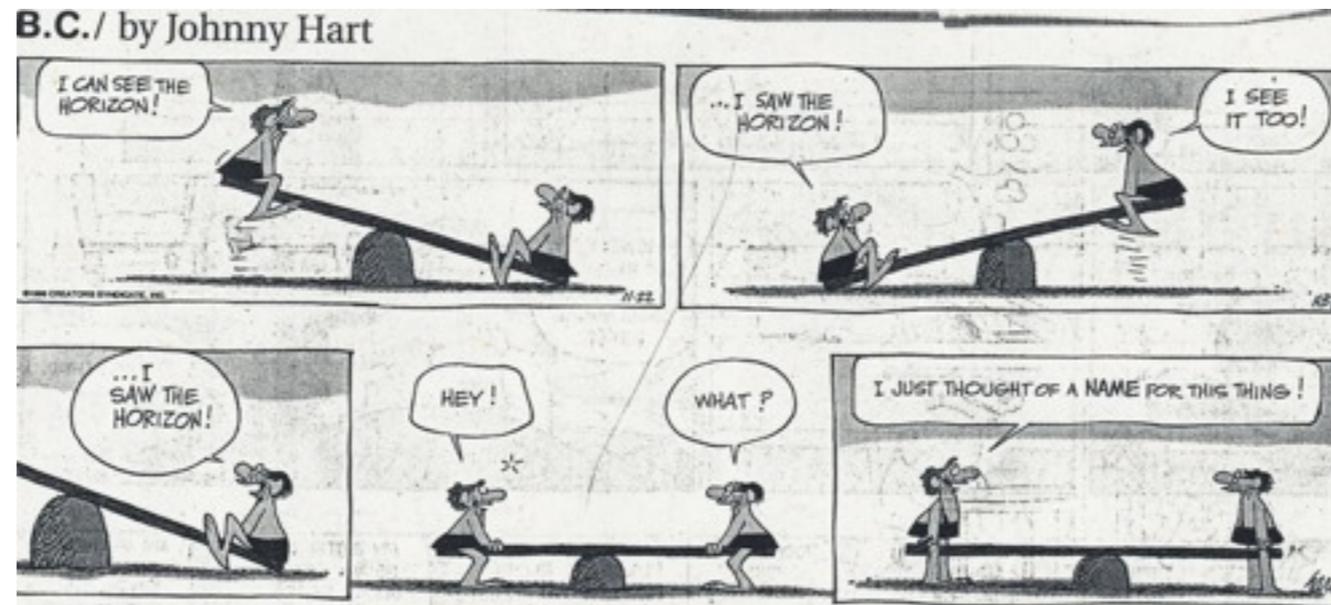
# The



# Mechanism

Majorana neutrinos at Grand-Unified scale:

# The

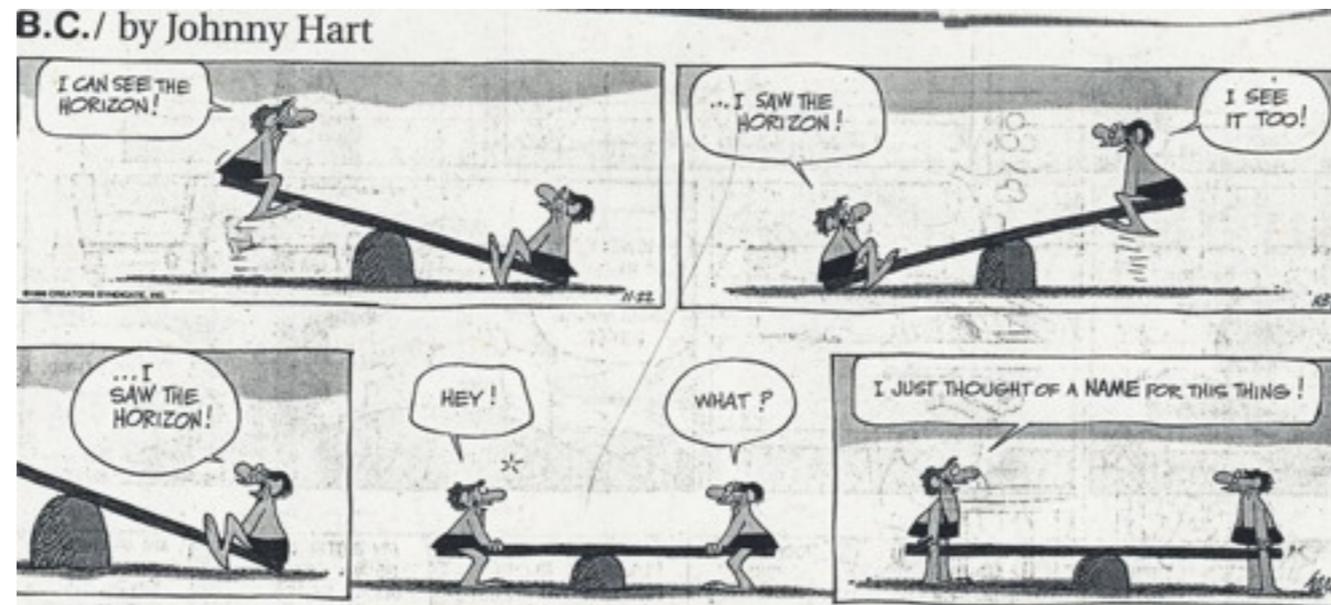


# Mechanism

Majorana neutrinos at Grand-Unified scale:

Leptogenesis: origin of matter-antimatter asymmetry  
(decay of heavy Majorana leptons)

# The



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Majorana neutrinos at Grand-Unified scale:

Leptogenesis: origin of matter-antimatter asymmetry  
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Small neutrino masses

# Flavors & quark-lepton unification

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Quarks' CKM matrix =  $\mathbf{1}$  + (Cabibbo) effects

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$\mathbf{X}$  contains two large angles

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Seesaw diagonalization?

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Seesaw diagonalization?

Family Symmetry?

# precision measurements required at the



**Intensity Frontier**

# precision measurements required at the



## Intensity Frontier

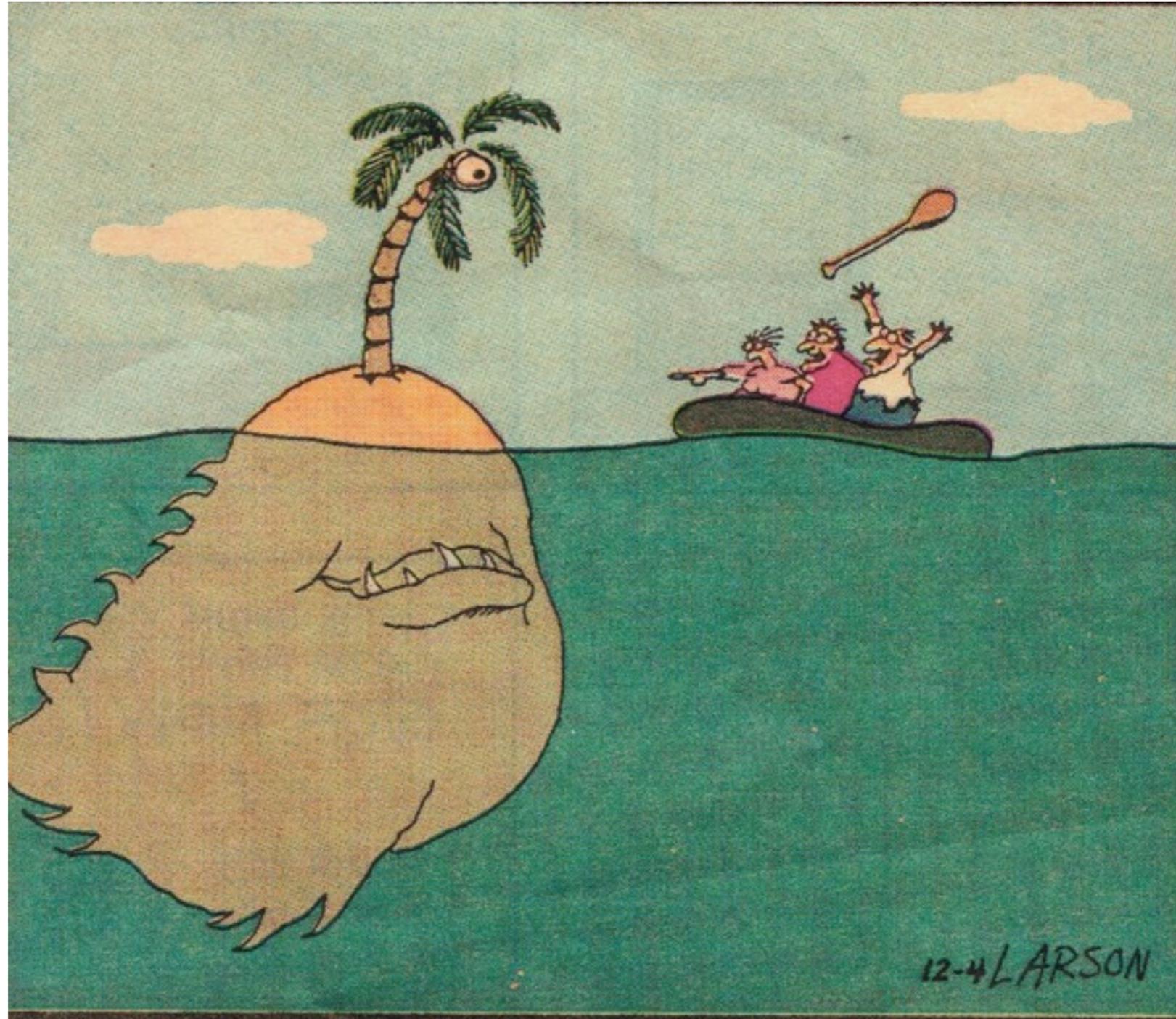
### measure deviations!

example:  $\theta_{13} \approx \theta_c / \sqrt{2}$       deviation from zero?

speculate:  $\theta_{\text{atm}} \approx \pi/4 + O(\theta_c)$       deviation from  $\pi/4$  ?

# Dark Energy

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**Cosmic Frontier**

# Measuring the Vacuum



## Cosmic Frontier

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Cosmological Constant?

two mass scales in gravity

energy not carried by particles

Quintessence?



## Cosmic Frontier

# Measuring the Vacuum

Cosmological Constant?

two mass scales in gravity

energy not carried by particles

Quintessence?

Is it like Brownian motion?

(need a new Einstein to find that out)

Biggest Challenge to Theory:

# Origin of Symmetry Breaking

higher dimensions, branes, Superstrings, M-theory,  
space-time locality breakdown,  
blah, blah, blah ...



Tuesday, October 16, 2012



# Bright Days Ahead for High Energy Physics