New Models

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with

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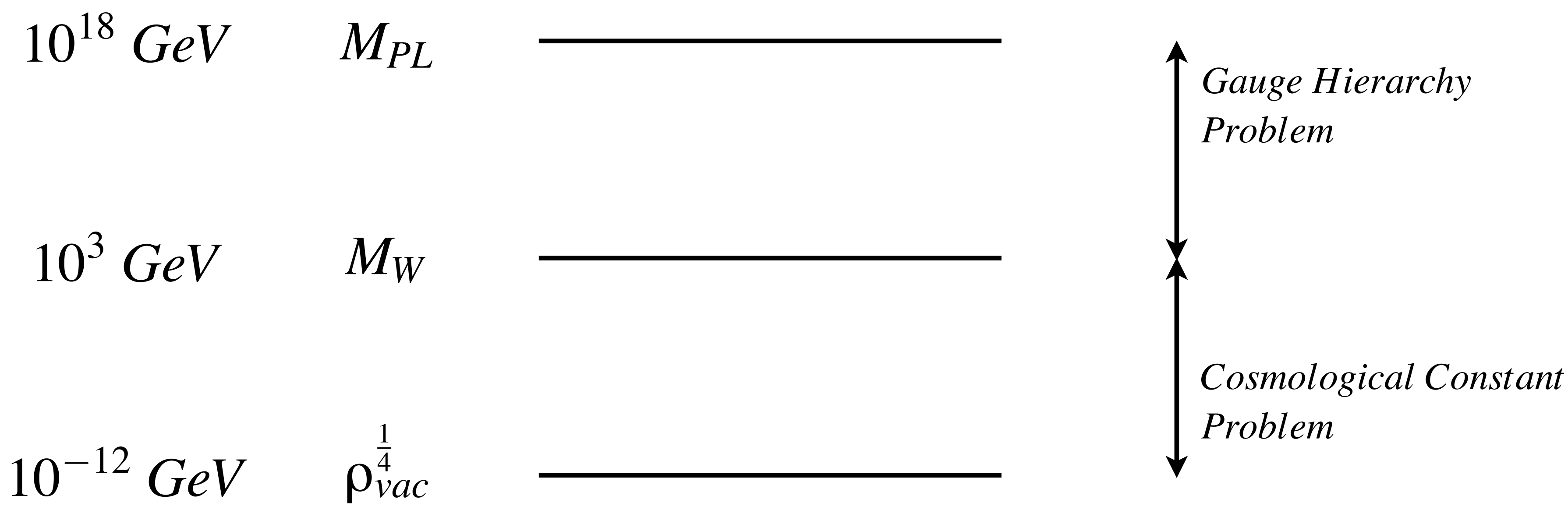
Small numbers and hierarchy problems



Program of the last 30 years:

Seek "Natural" explanations of these numbers

Outline

- M_{weak} in theories with few vacua
- ρ_{vacuum} in theories with many vacua
- M_{weak} in theories with many vacua: Split Supersymmetry

Approaches to the gauge hierarchy problem

Stages:

- Philosophy (1974) [Wilson]
- Technicolor (1978) [Susskind, Weinberg]
- Supersymmetric Standard Model (1981) [S.D., Georgi]
- Low Scale Gravity (1998) [Antoniadis, Arkani-Hamed, S.D., Dvali]
- Warped Gravity (1999) [Randall, Sundrum]
- Little Higgs (2001) [Arkani-Hamed, Cohen, Georgi]

Supersymmetric Standard Model

Introduces "Superpartners" at the weak scale

<u>Successes</u>

- $\circ$ *Unification*
- $\circ$ *Dark Matter*

Fermions

<u>Shortcomings</u>

- $\circ$ *Higgs* ?
- $\circ$ *Sparticles* ?
- $\circ$ *FCNC* ; *CP*
- $\circ$ *Proton Decay*
- $\circ$ *Gravitino – Moduli Problem*

Scalars

- *Hierarchy Problem*
- *Cosmological Constant*

Strategy for the last 30 years

m_{weak}

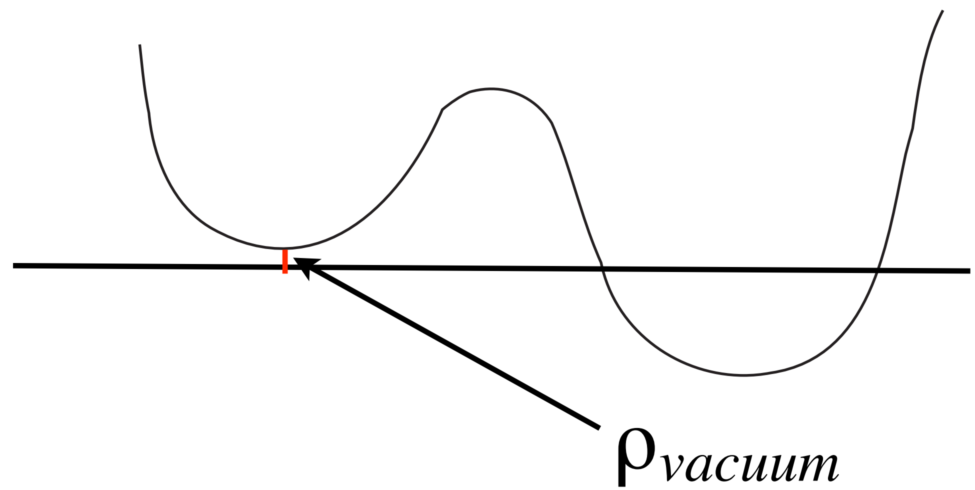
Focus on this

ρ_{vacuum}

Ignore this

This could be flawed

In theories with few vacua

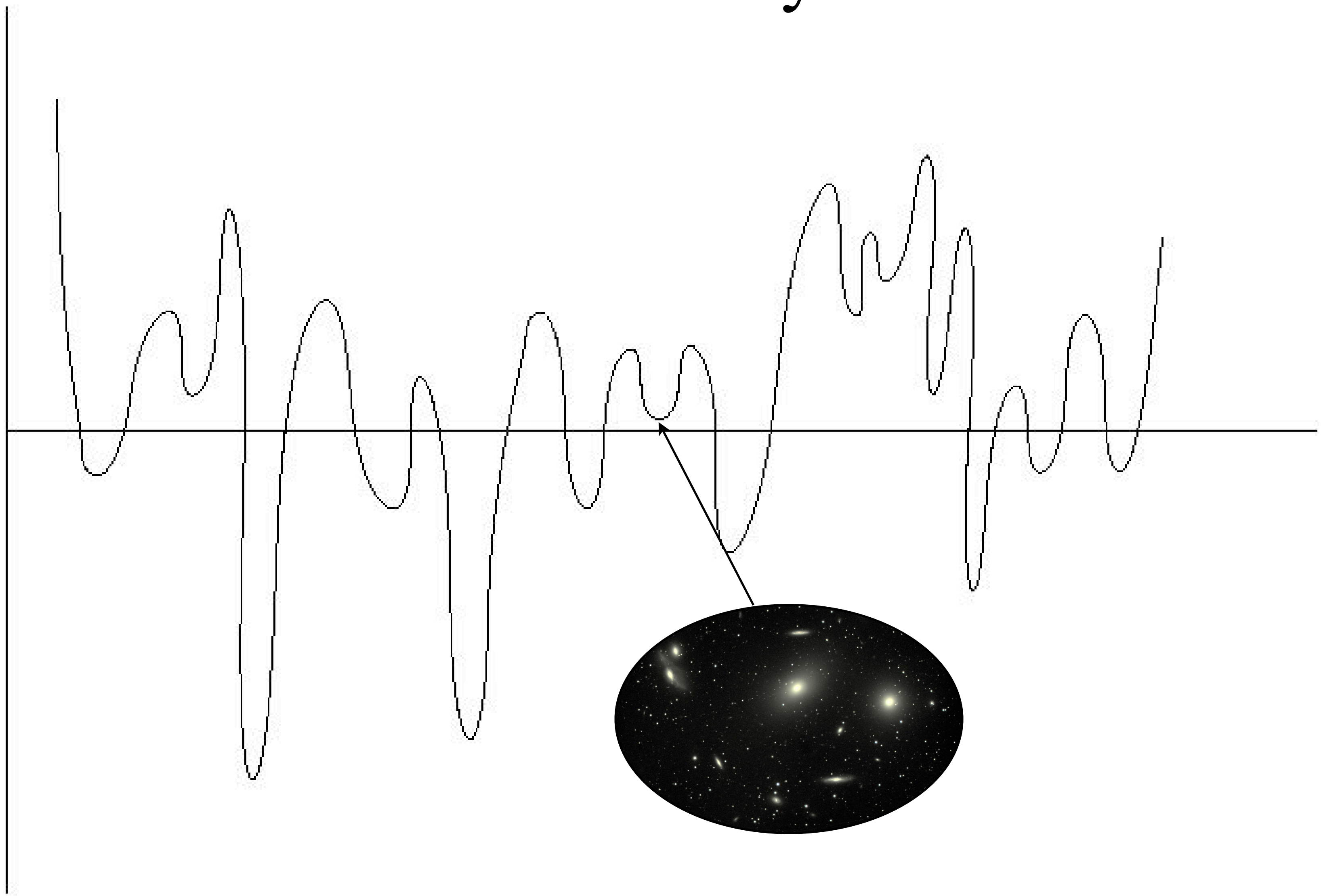


Getting $\rho_{vacuum} \sim (10^{-15} M_W)^4$

Looks like divine intervention!
Since any bigger value would rip apart galaxies

However... (Weinberg 1987)

In theories with many vacua



Therefore, if there are enough vacua with different ρ_{vacuum}, the "structure" principle can explain why we live in a universe with small, but nonzero, ρ_{vacuum}

This reasoning correctly predicted a small ρ_{vacuum}

and has recently gained momentum because string theory may well have a vast "landscape" of metastable vacua

$$10^{100s}$$

Bousso, Polchinski; Kachru et.al.; Douglas et.al.; Susskind

Similarly, if there are enough vacua with different M_{Weak} the "atomic" principle can explain the value of M_{Weak}

Donoghue et.al. 1998

New approach

The mechanism solving the cosmological constant problem, may also solve the hierarchy problem

Can we preserve the successes of the low energy SUSY?

Split Supersymmetry

	$M_{\mathrm{Pl.}}$	10^{16} TeV
Scalars (Squarks, sleptons, ...)	M_{susy}	$? \left\{ \begin{array}{l} 10^{9} \text{ TeV} \\ 10 \text{ TeV} \end{array} \right.$
Fermions (Higgsinos, gauginos) +SM Higgs	M_{weak}	1 TeV

Preserves gauge unification and DM candidate!

Particles and Couplings

H	$\widetilde{B}$ $\widetilde{W}$ $\tilde{g}$	$\widetilde{H}_u$ $\widetilde{H}_d$
Higgs	Gauginos	Higgsinos

$$m_1\widetilde{B}^2 + m_2\widetilde{W}^2 + m_3\tilde{g}^2 + \mu\widetilde{H}_u\widetilde{H}_d$$

$$\lambda|H|^4 - m^2|H|^2$$

$$\kappa_u H\widetilde{H}_u\widetilde{W} + \kappa_d H^\dagger\widetilde{H}_d\widetilde{W}$$

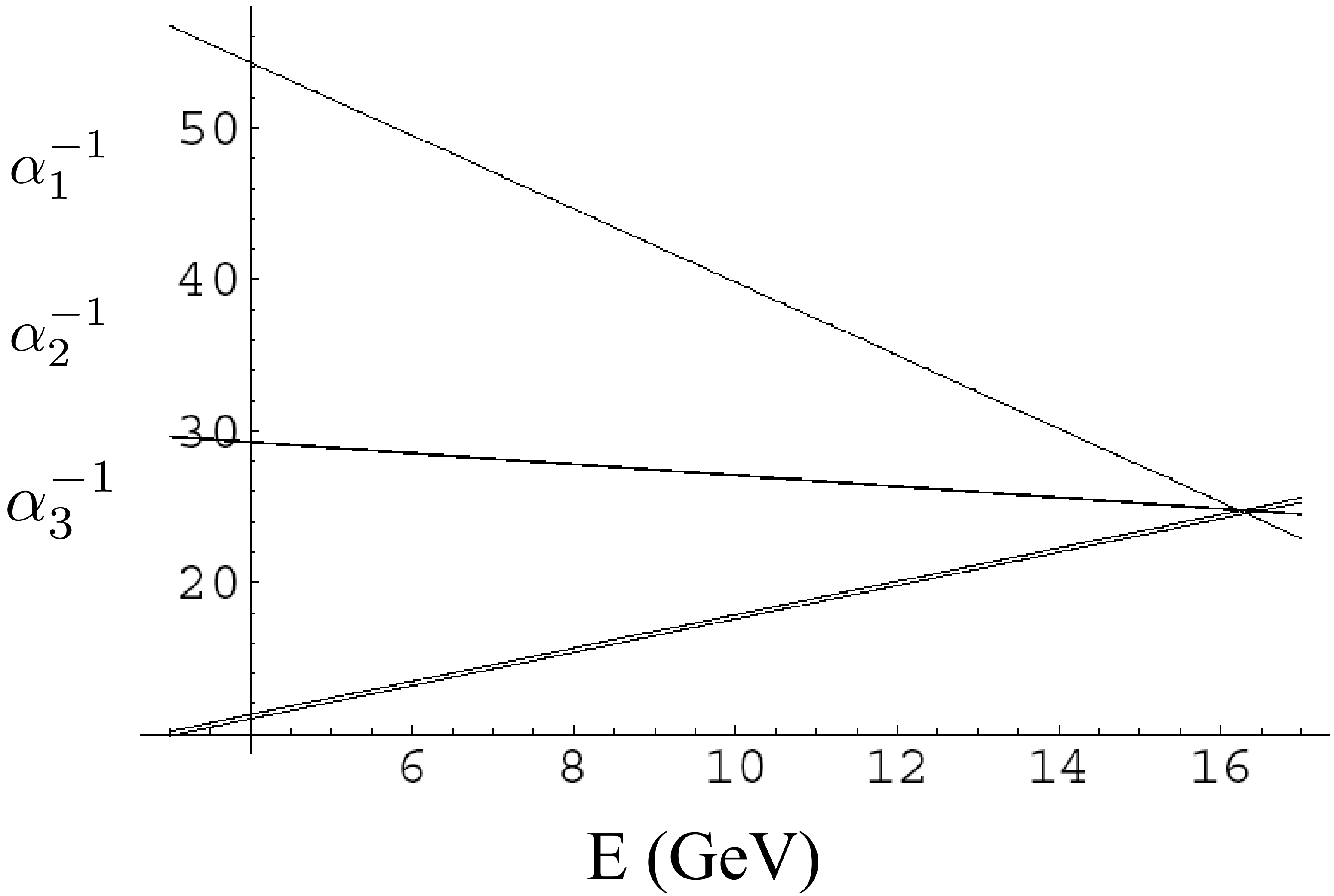
$$\kappa_u' H\widetilde{H}_u\widetilde{B} + \kappa_d' H^\dagger\widetilde{H}_d\widetilde{B}$$

Higgs Quartic $\lambda = \frac{1}{8}\left(g^2 + g'^2\right)\cos^2 2\beta$

Gaugino Yukawas $\kappa_u = g\sin\beta$ $\kappa_d = g\cos\beta$

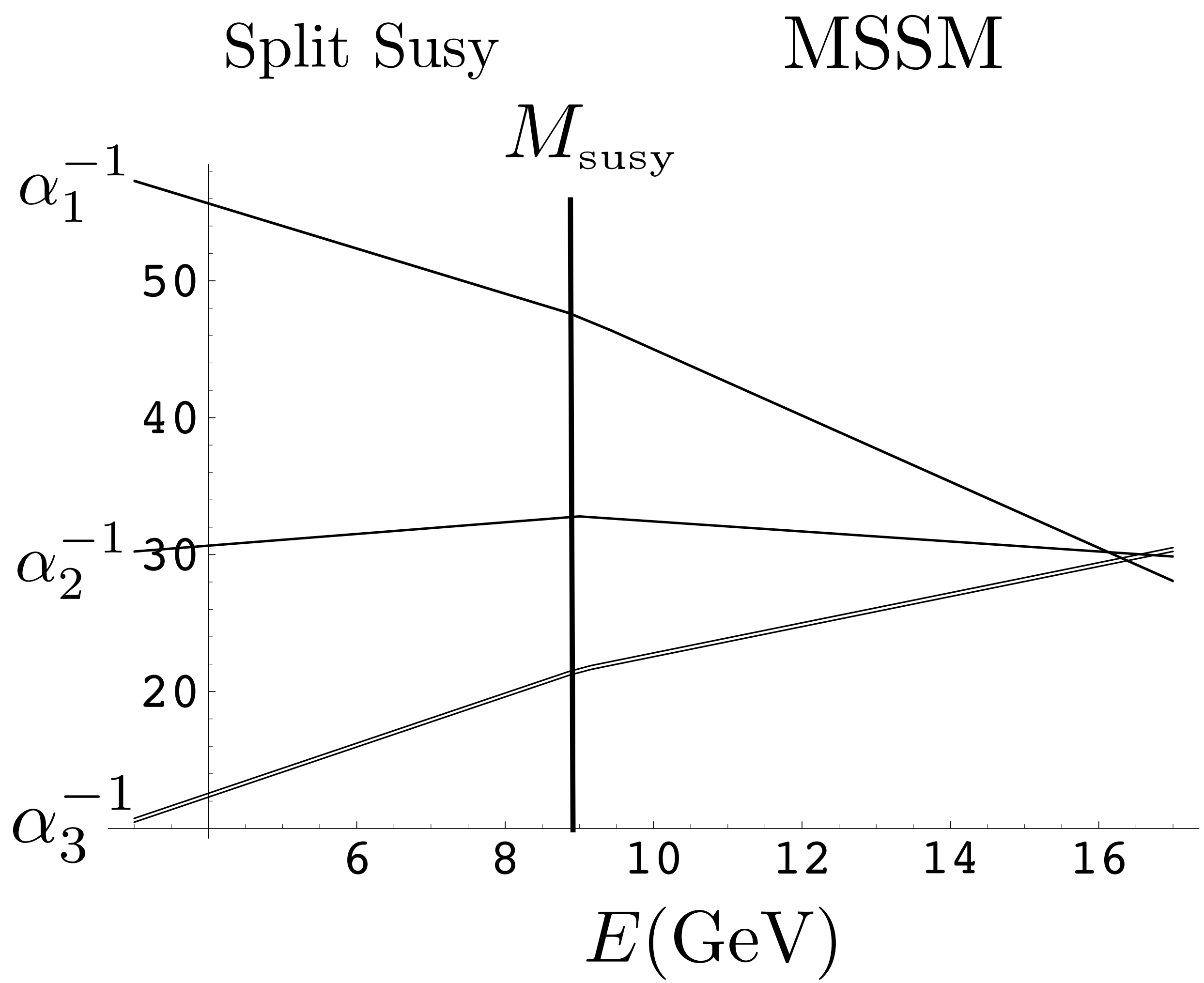
5 Couplings from 1 parameter!

Unification in MSSM

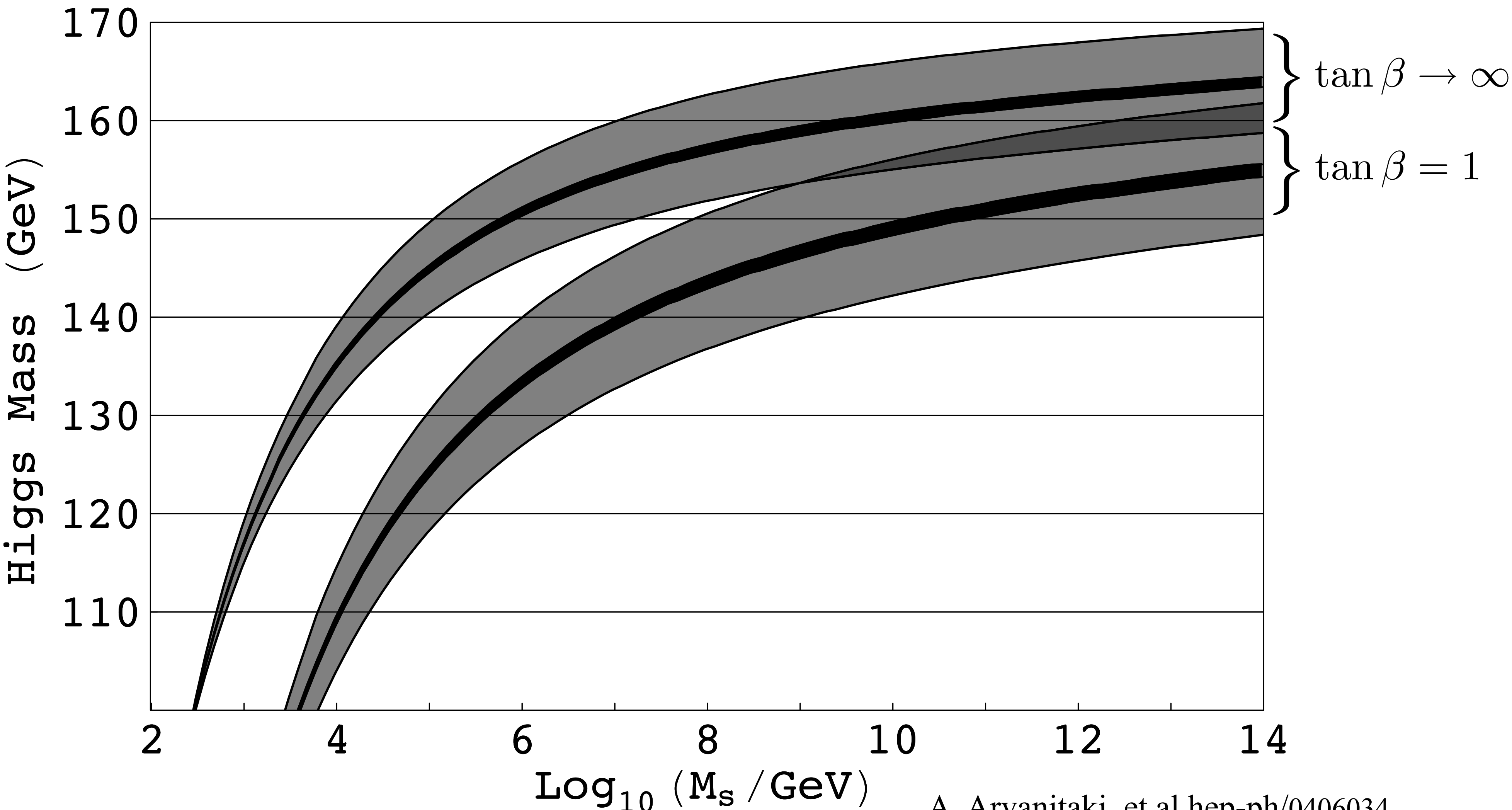


Gauge Coupling Unification

Squarks and Sleptons don't alter unification



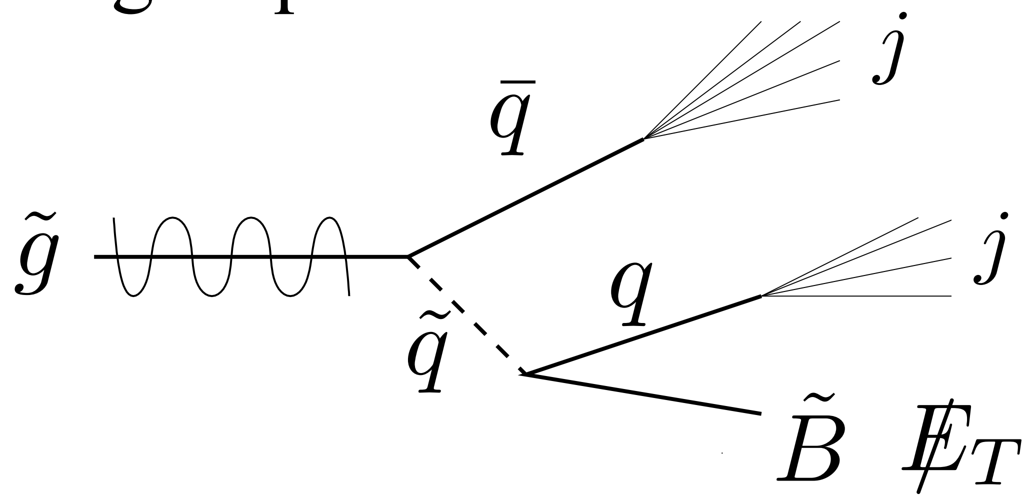
The heavy Higgs of Split SUSY



A. Arvanitaki, et al hep-ph/0406034

Long-Lived Light Gluinos

Must decay through squarks



$$\tau_{\tilde{g}} \simeq 2 \text{ sec.} \left(\frac{350 \text{ GeV}}{m_{\tilde{g}}} \right)^5 \left(\frac{M_{\text{Susy}}}{10^6 \text{ TeV}} \right)^4$$

Gluino Phenomenology

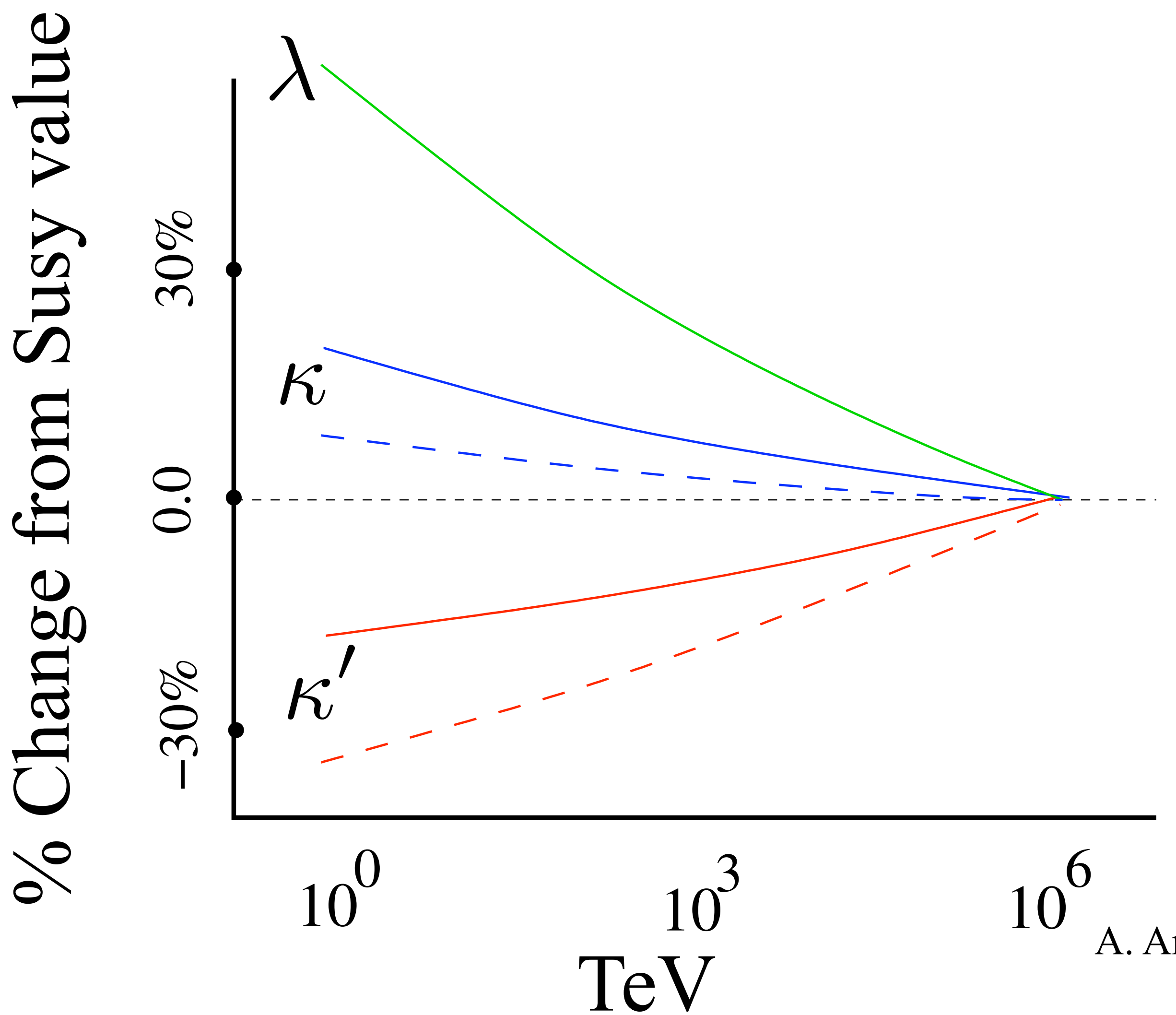
- LHC: Gluino Factory, ~1 gluino/sec! (350 GeV)
- Bound States: $\tilde{g}g,\ \tilde{g}q\bar{q},\ \tilde{g}qqq$ (R-Hadrons)
- Charged and intermittent tracks
- Displaced gluinos
- Stopped, late-decaying gluinos!

Post-LHC

- A long lived strongly interacting particle
- A few ‘electroweakinos’
- Doesn’t match SUSY traditional models’ signatures
- Doesn’t look natural...
- What is it?

Yukawa Couplings' Unification

$$M_{\rm susy} \quad \tan\beta \qquad \longrightarrow \qquad \lambda \;\; \kappa_u \;\; \kappa_d \;\; \kappa'_u \, \kappa'_d$$



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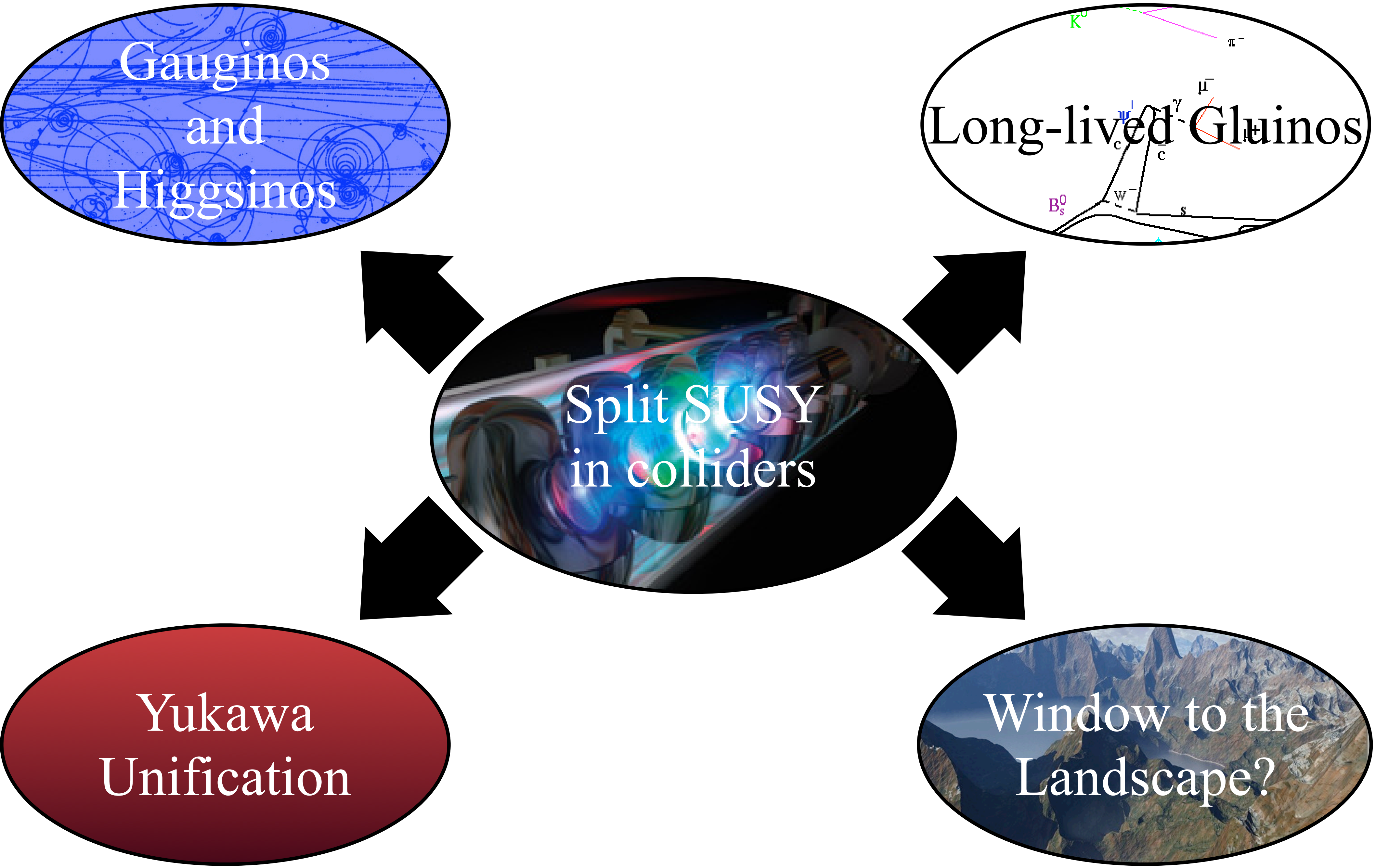
ILC Measurements

Kilian et.al. 2004

- 8 parameters $(M_1, M_2, \mu, \kappa_u, \kappa_d, \kappa'_u, \kappa'_d, \lambda)$
  + CP violating phases
- Charged masses measured through threshold scans
- Mass differences through electroweak decays
- all couplings measurable in multiple ways
- Split SUSY: clean environment
  (free of scalar pollution)


Gauginos and Higgsinos
Long-lived Gluinos
Split SUSY in colliders
Yukawa Unification
Window to the Landscape?