STRING THEORY AND OUR REAL WORLD

-- greatly improved understanding

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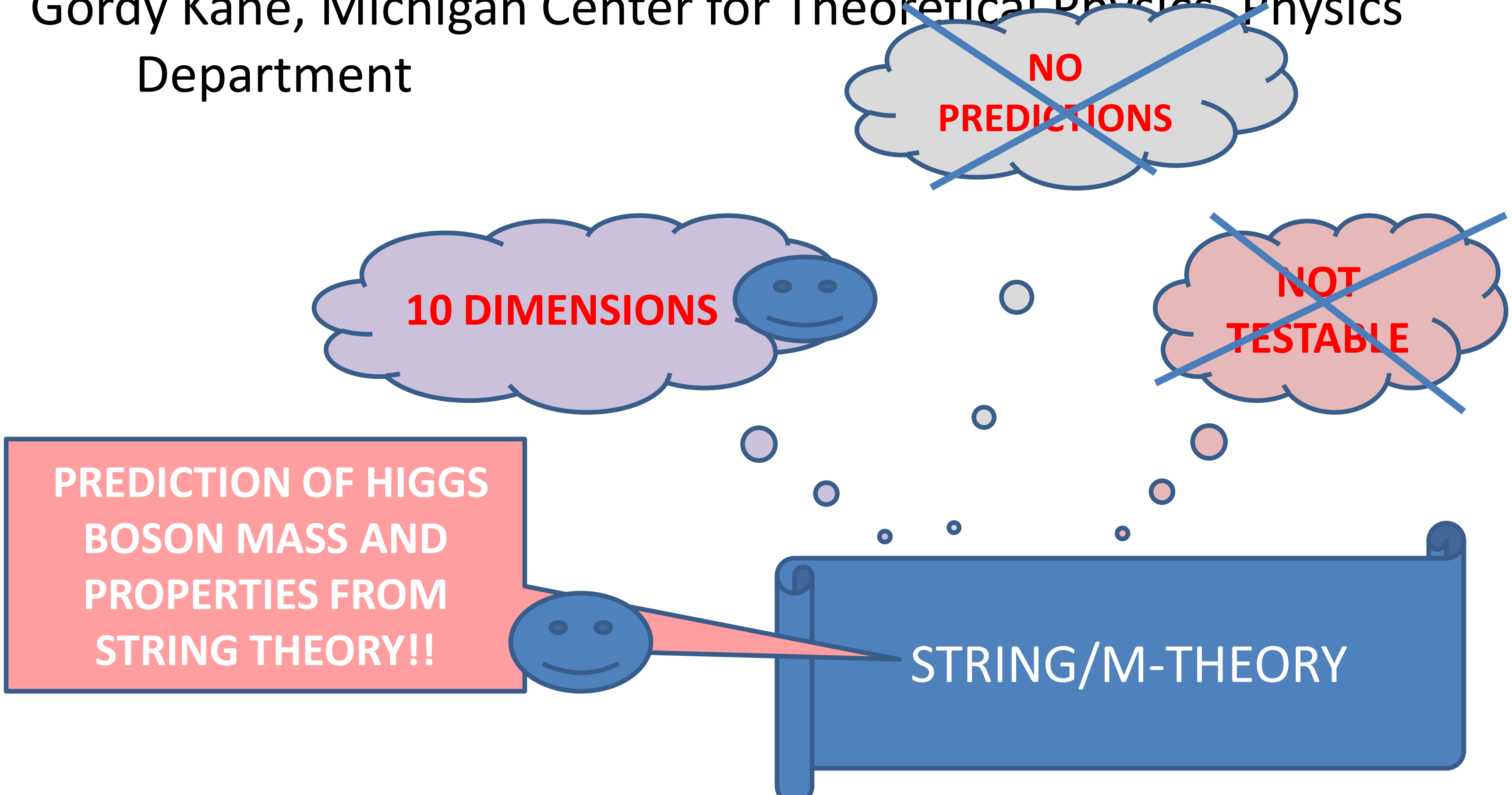


Particle physics is entering a very exciting era – **data** from **CERN LHC**, (and from **dark matter** satellite and laboratory detection experiments), is beginning to emerge

There is another, less appreciated reason why we are entering an exciting time!

Today finally a consistent theoretical framework to address basic questions physicists want to ask

– about **particles** – about **forces**

– how they fit into a deeper and broader framework

– **why** they are what they are

"**string theory**" – started mid 1980s, now getting well understood

OUTLINE

- **Brief introduction**
- **What can we already or hope to explain about the physical universe?**
- **Is string theory likely to provide new interconnected answers? (yes)**
- **Is string theory testable? (yes)**
- **An LHC prediction for squark masses**
- **A cosmological history testable prediction**
- **Higgs boson – string/M theory prediction of mass, properties**

  FIRST STRING/M-THEORY TESTED PREDICTION FOR NEW PHYSICS -- predicted 125 GeV (August)
- **Very brief topics – LHC superpartners – M-theory and our string vacuum – CC? – multiverse, landscape? – 10 dimensions?**
- **Final remarks**

Shadowed topics more technical – but you wouldn't believe me without technical details

String theory hard – we try to find ways to make contact with experiment by using general arguments and properties, and work around some difficult issues – can do this in certain areas!

String theorists – study theory for its own sake

String phenomenologists – traditional physics, find our string vacuum – growing subfield for decade – 11th international conference at Newton Institute, Cambridge June 2012; NSF SVP

String theory is exciting because it allows us to address many questions we want to understand

”**GENERIC**” $\approx$ perhaps not theorem, but holds very generally – just calculate naturally without special assumptions – have to work hard to find or construct (non-generic) exceptions (if possible), and to show possible exceptions don’t have problems that exclude them

“**COMPACTIFY**” – string theory must be formulated in 10 dimensions (or 11 for M-theory) – must separate into 4 large space-time dimensions and 6 (7) small, curled up ones to test it

“**MODULI**” – the small dimensions are described (parameterized) by scalar fields that specify sizes, relative orientations, etc – called “moduli fields” – their quanta are scalar bosons, “moduli” – no familiar analogy, but properties calculable – moduli *c*ouple gravitationally to all matter

COMPACTIFY *(small extra dimensions)*

We focus here, try to work around issues that are problems

EMBED MSSM, study spectrum, masses of quarks and leptons, gauge group of forces – now many examples of successful embeddings

Stabilize moduli, generate TeV scale from Planck scale, calculate supersymmetry breaking Lagrangian, study Higgs and LHC and DM predictions

STRING THEORY USUALLY VIEWED AS QUANTUM THEORY OF GRAVITY, OR MATHEMATICAL FRAMEWORK – I AND SOME OTHERS VIEW IT INSTEAD AS ADDRESSING QUESTIONS ABOUT OUR WORLD, AND PROVIDING POSSIBLE SOLUTIONS, RELATED SOLUTIONS

Want to know **our string vacuum**

EXCITING THAT STRING THEORY ADDRESSES THE QUESTIONS -- but

CAN "STRING THEORY" PROVIDE ANSWERS AND *TESTABLE* UNDERSTANDING?

If your impression of string theory came from some popular books and articles and blogs (or from formal string theorists) you might be suspicious of taking string theory explanations seriously

Often claimed that string theory is not testable – untestable explanations would not be helpful!

Most of what is written on testing string theory is very misleading, even by experts(!) – formal string theorists do not think much about it ("string theorists have temporarily given up trying to make contact with the real world" – 1999)

Fortunately, increasingly active subfield of "**string phenomenology**" -- focuses on formulating testable string-based description of **our world (formal string theorists study string theory for its own sake)**

NSF has funded the "**String Vacuum Project**", SVP, consortium of 8-10 universities – support for PHD students in string phenomenology http://www.northeastern.edu/svp

Vacuum is ground state, lowest energy state, of universe

2010 international string phenomenology meeting, Paris http://stringpheno.cpht.polytechnique.fr/

2011 Madison
http://conferencing.uwex.edu/conferences/stringpheno2011/index.cfm

2012 University of Cambridge (England), June,
http://www.newton.ac.uk/programmes/BSM/bsmw05.html

String theory is too important to be left to string theorists

Surprisingly some people have claimed that because string theories are naturally formulated at Planck scale high energies or small distances they cannot be tested!

Obviously collisions will never probe energy scales such as the Planck energy 10^{16} TeV (about 10^{15} times LHC), or see distances as small as 10^{-33} cm

Equally or more obviously don't have to be somewhere to test something there

– always relics

-- stars elsewhere are made of same chemical elements as ours

-- big bang – evidence includes [1] expanding universe, [2] Helium abundance and nucleosynthesis, [3] Cosmic microwave background radiation

-- don't have to be present 65 million years ago to test whether asteroid impact was a major cause of dinosaur extinction

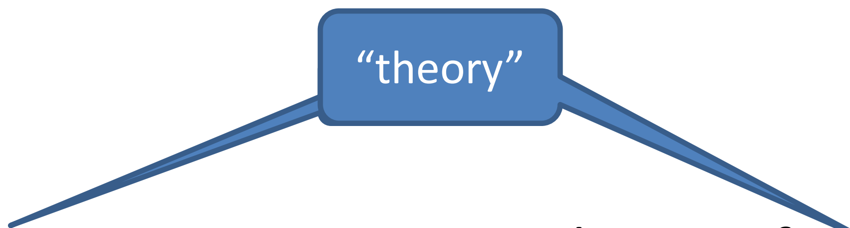
Once you have a theory it suggests new tests – e.g. Maxwell's equations → light outside visible spectrum, radio waves

More fundamentally, what does it mean to test theories?

In what sense is F=ma testable?

- -- claim about actual relation between forces and particle behavior
- -- might not have been correct
- -- can test it for any particular force, but *not in general*

In what sense is string theory testable? Same!!!



Predictions from F=ma

-- pick F, pick m

-- ***find solutions***

-- calculate acceleration a

Predictions from string theory

--**compactify** to 4D, choose manifold

-- ***find solutions***

-- calculate Higgs boson mass, etc

Theories are Lagrangians, Hamiltonians – they have many solutions – the world, physical systems, are described by the ***solutions***

Normally the system relaxes to the lowest energy state, where we study its properties

String theory like having Lagrangian, many solutions – physical systems described by compactified string theories, in vacuum state

We want to describe *our string vacuum*

SO COMPACTIFIED STRING THEORIES GIVE TESTABLE 4D RELATIVISTIC QUANTUM FIELD THEORY CALCULABLE PREDICTIONS – for masses of superpartners (LHC), dark matter (direct, indirect detection, LHC), axions, cosmology, CP violation, etc)

Simply wrong to say string theory not testable in normal way

(Note – one falsifiable prediction is sufficient for a theory to be testable)

Can we do better than tests in particular compactifications?

Yes, can find some tests that hold for *generic* compactifications of the 10/11D theory to ANY manifold!

→ Predictions for squark masses, cosmological history, Higgs boson mass and properties

DESCRIBE HIGGS PREDICTION – somewhat technical

- Overview – 2 slides
- Physics summary – 3 slides
- Details of string-based connection of moduli, gravitino masses – 2 slides
- Connect high scale theory to TeV scale prediction
- Results – 2 slides
- Data – 1 slide
- Note "μ" included

HIGGS MASS PREDICTION – overview – two slides

arXiv:1112.1059 GK, Piyush Kumar, Ran Lu, Bob Zheng (Acharya)

Assume world described by compactified string/M-theory – no relevant free parameters (some quantities not yet fully calculable)

***Look for, find, generic solutions of compactified string/M-theories having certain properties like our world* – moduli can be "stabilized"** i.e. get definite vacuum values **, softly broken supersymmetry, supergravity field theory limit, MSSM spectrum below compactification scale, non-zero Higgs field in lowest energy state of universe via "radiative electroweak symmetry breaking", be consistent with all cosmology and particle data**

In such solutions can calculate $M_h/M_Z \rightarrow M_h \approx 125$ GeV (for $\tan\beta \gtrsim 6$)

- **And h predicted to be closely SM-like, so h production and decays must not deviate significantly from h looking like a SM Higgs boson – consistent with current data**

- Results depend strongly on existence and properties of moduli, and on stringy relation of moduli and gravitino masses (below)

- Results depend a little on gravitino mass, on gauge group and spectrum below compactification scale, on how μ problem solved

HIGGS MASS PREDICTION – more detailed physics argument – 3 slides

- Compactify to 4D – generically have moduli fields that parameterize curled up space – all corners of string/M-theory
- Moduli generically stabilized (get a potential energy, settle at minimum) by non-perturbative contributions to superpotential – any moduli interactions ok, don't need to be able to calculate them – supersymmetry generically broken
- Moduli quanta couple universally via gravity to everything – can write operators for widths, $\Gamma \sim M^3_{mod}/M^2_{pl}$ with coefficient ~ unity – can check coefficient in model, calculate moduli lifetime
- Generically, to avoid cosmology problems such as destroying good nucleosynthesis results, or overclosing universe, moduli must decay before nucleosynthesis – [any possible ways out less likely as more studied, non-generic – no workable example – for late inflation see Fan Reece Wang]→ $M_{mod} \gtrsim 30$ TeV

- Next consider moduli mass matrix – don't need to calculate it
- Note supersymmetry breaking generates gravitino mass ($M_{3/2}$), splitting from graviton
- Gravitino has spin 3/2, so projections 3/2, 1/2, -1/2, -3/2 – it has absorbed spin ½ Goldstino – Goldstino has scalar partner sGoldstino – generically all have $M_{3/2}$
- sGoldstino complex scalar, mixes with moduli – part of moduli mass matrix
- Theorem: lightest eigenvalue of mass matrix < eigenvalue of any diagonal 2x2 submatrix

→ $\mathbf{M_{mod} \lesssim M_{3/2}}$ follows from string/M theory, not field theory

→ $M_{3/2} \gtrsim 30$ TeV

- Assume supergravity theory in field theory limit, generic – scalars from soft breaking supersymmetry Lagrangian all have $M_{scalars} \approx M_{3/2}$

- **So squarks $\gtrsim$ 30 TeV, not observable at LHC!**

- Scalars include Higgs sector soft terms M^2_{Hu} , M^2_{Hd}
- Ask for solutions that have a higgs mechanism (higgs field nonzero in vacuum) – occurs by radiative EWSB, so higgs field zero in vacuum at compactification, but RGE running down to TeV scale shifts minimum of Higgs potential away from origin – find many solutions
- Study supersymmetric higgs sector → mass eigenstates H, A, $H^{\pm}$ also $\gtrsim$ 30 TeV , h light – can calculate M_h /M_Z – h like SM higgs, few per cent deviations from chargino loops, etc
- tanβ (ratio of two Higgs vevs) not yet accurately calculable so show it as parameter

MODULI MASS MATRIX – RELATE MODULI, GRAVITINO MASSES – 2 slides

- Can write 4D scalar potential V in terms of function

G= $K + m_{pl}^2 ln(W\bar{W}/m_{pl}^6)$ $V = m_{pl}^2 e^{G/m_{pl}^2}\left(G^i G_i - 3m_{pl}^2\right)$

- Then calculate scalar mass matrix (CC=0)

Scrucca et al, 2006

Douglas and Denef, 2006

Acharya, Kane, Kuflik

1006.3272

$$\begin{pmatrix} M^2_{i\bar{j}} & M^2_{ij} \\ M^2_{\bar{i}\bar{j}} & M^2_{\bar{i}j} \end{pmatrix}$$

$$\begin{aligned} M^2_{i\bar{j}} &= e^{G/m_{pl}^2}\left(\nabla_i G_k \nabla_{\bar{j}} G^k - R_{i\bar{j}k\bar{l}} G^k G^{\bar{l}} + G_{i\bar{j}}\right) \\ M^2_{ij} &= e^{G/m_{pl}^2}\left(2\nabla_i G_j + G^k \nabla_i \nabla_j G_k\right) \end{aligned}$$

- Look near minima of V, mass matrix positive definite – use theorem smallest eigenvalue of mass matrix is less than $\xi^\dagger M \xi$ for any unit vector ξ. (1006.3272 appendix c)
- Take $\xi = (G^{\bar{j}} \quad cG^j)/\sqrt{3(1+|c|^2)}$ with c any complex number
- Get a one complex parameter set of constraints on upper bound of lowest mass moduli eigenvalue

$$m_{\min}^2 \le \frac{1}{3(1+|c|^2)} \begin{pmatrix} G^i & c^\dagger G^{\bar{i}} \end{pmatrix} \begin{pmatrix} M^2_{i\bar{j}} & M^2_{ij} \\ M^2_{\bar{i}\bar{j}} & M^2_{\bar{i}j} \end{pmatrix} \begin{pmatrix} G^{\bar{j}} \\ cG^j \end{pmatrix}$$

$$\le m_{3/2}^2 \left(2\frac{|1-c|^2}{1+|c|^2} + \mathrm{Re}\{ \frac{2c}{1+|c|^2} \frac{u}{m_{pl}^2} \} - \frac{r}{m_{pl}^2} \right)$$

Where $u \equiv \frac{1}{3} G^i G^j G^k \nabla_i \nabla_j G_k$, $r \equiv \frac{1}{3} R_{i\bar{j}k\bar{l}} G^i G^{\bar{j}} G^k G^{\bar{l}}$, $m_{3/2}^2 = m_{pl}^2 e^{G/m_{pl}^2}$

- r is the holomorphic sectional curvature of the scalar field space, projected in the sgoldstino directions
- So

$$m_{\min}^2 < m_{3/2}^2 \left(2 - \frac{r}{m_{pl}^2} \right)$$

This bound is very general – what about r?

- Simple case, $r/m^2_{pl} = 14/N_{mod}$, $N_{mod} \sim 50$?
- Kumar, to be published, sharpen stabilization assumptions, get similar bound with no r dependence – covers all known cases

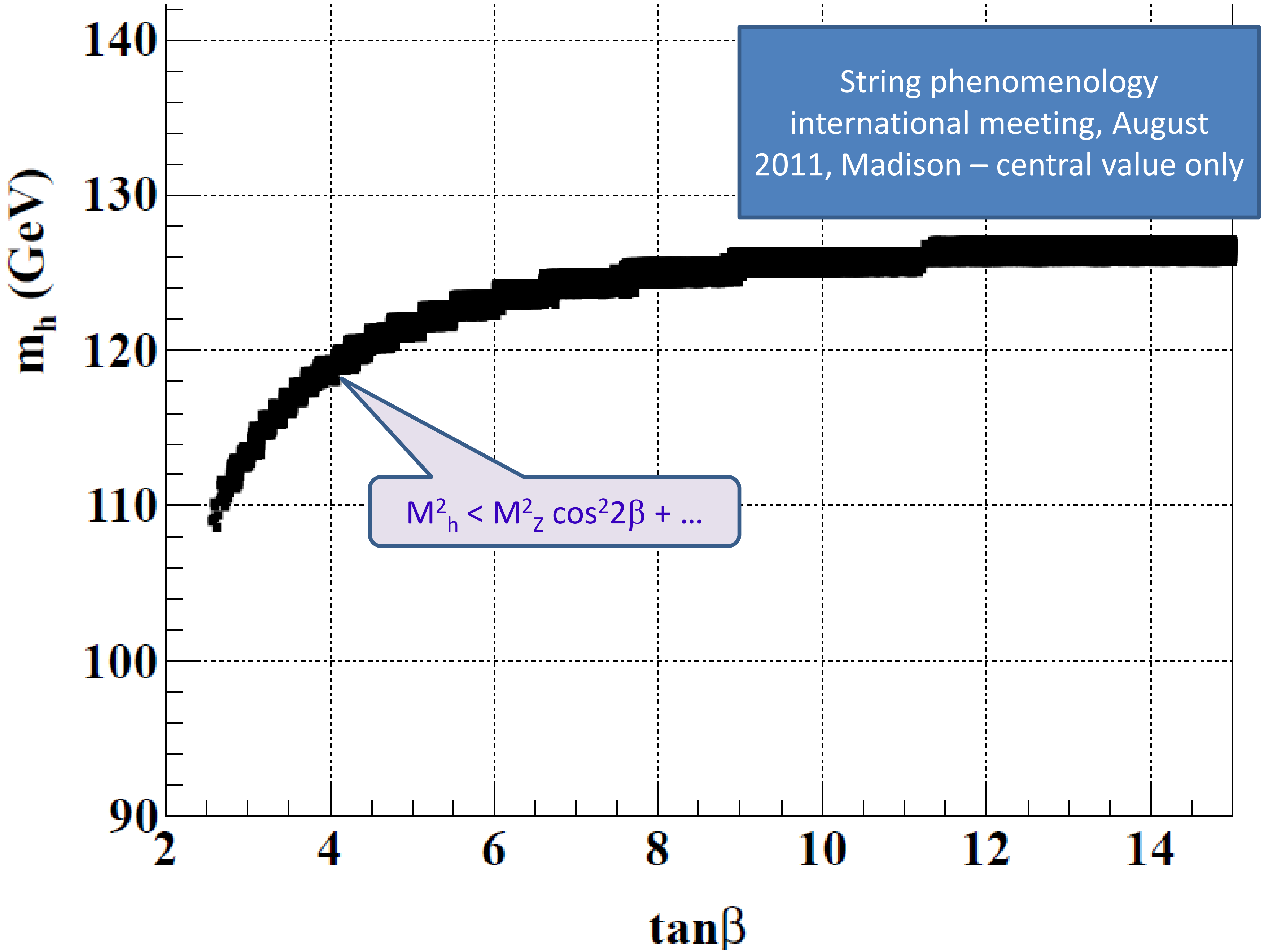
THEORY AT HIGH SCALE, COMPUTE PHYSICAL M_h

- Write theory at scale 10^{16} GeV, fix soft-breaking Lagrangian parameters
- RGE run down, maintain REWSB
- $\tan\beta$ calculable in principle but not yet in practice, but constrained since related to B,μ
- Use "match-and-run" and also SOFTSUSY and Spheno, compare – match at $(M_{stop1}M_{stop2})^{1/2}$ – two-loop RGEs
- Main sources of imprecision

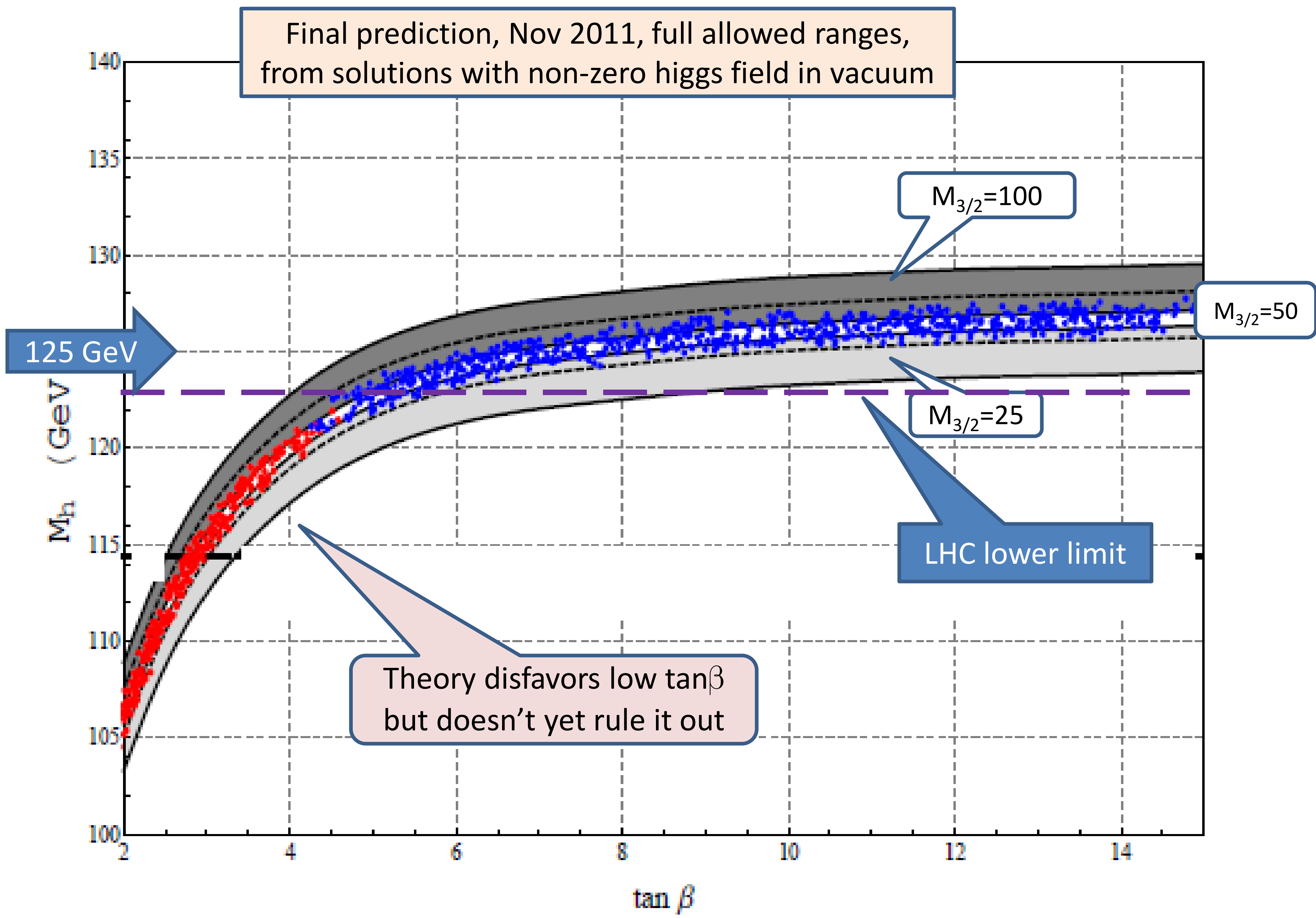
  -- gravitino mass

  – experimental M_{top} , α_{strong}

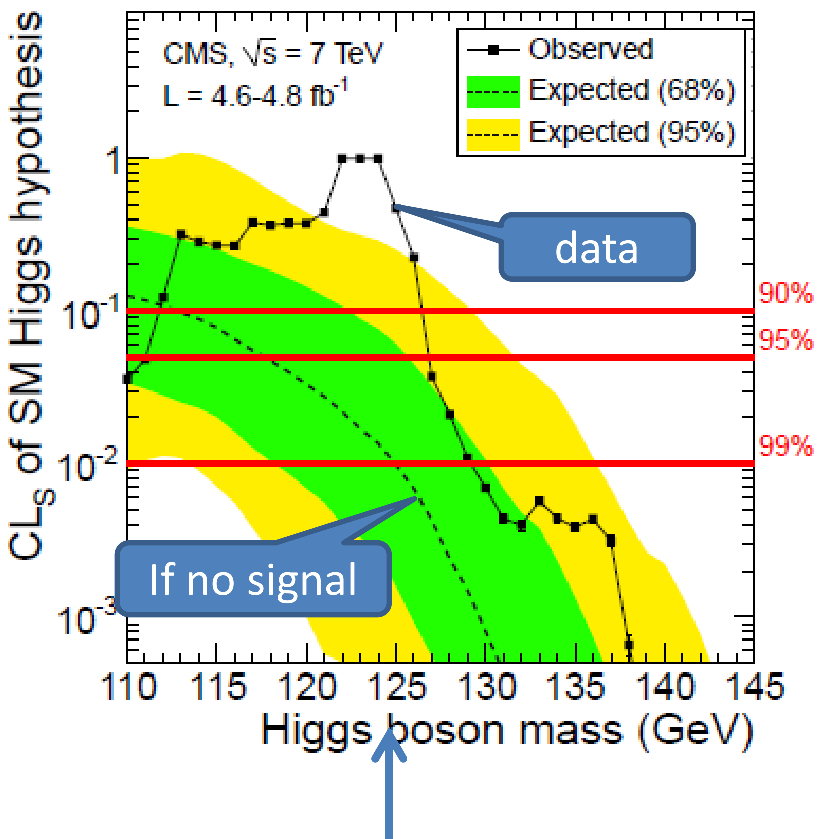
  – theoretical gluino mass (allow 600 GeV to 1.2 TeV), trilinear couplings (allow 0.8-1.5M_0)

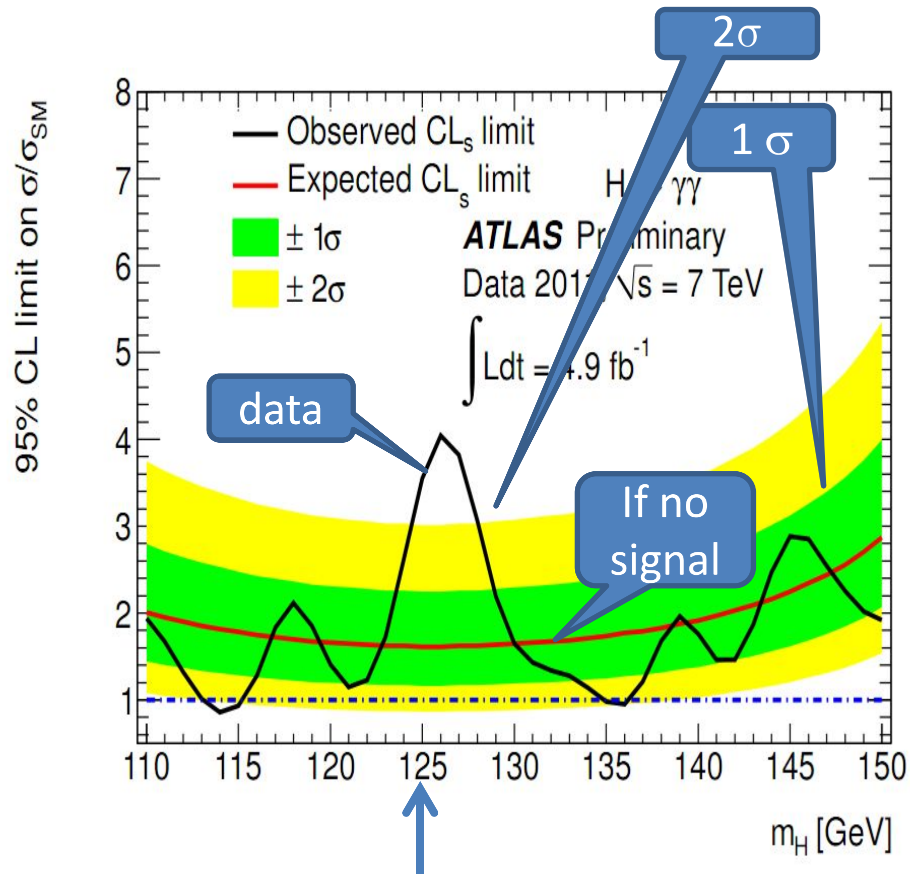


140
130
120
110
100
90
2
4
6
8
10
12
14
m_h (GeV)
tanβ
String phenomenology international meeting, August 2011, Madison – central value only
M²_h < M²_Z cos²2β + ...


Final prediction, Nov 2011, full allowed ranges, from solutions with non-zero higgs field in vacuum
140
135
130
125 GeV
120
115
110
105
100
M_h (GeV)
2
4
6
8
10
12
14
tan β
M3/2=100
M3/2=50
M3/2=25
LHC lower limit
Theory disfavors low tanβ but doesn't yet rule it out

$$3.1^2 + 3.6^2 \approx 4.6^2$$





Supersymmetric "μ problem" – affects M_h , affects EWSB

•Need a symmetry to set μ small, but broken symmetry so μ not zero

• recent work on including μ in string theory

•Probably 2 possibilities

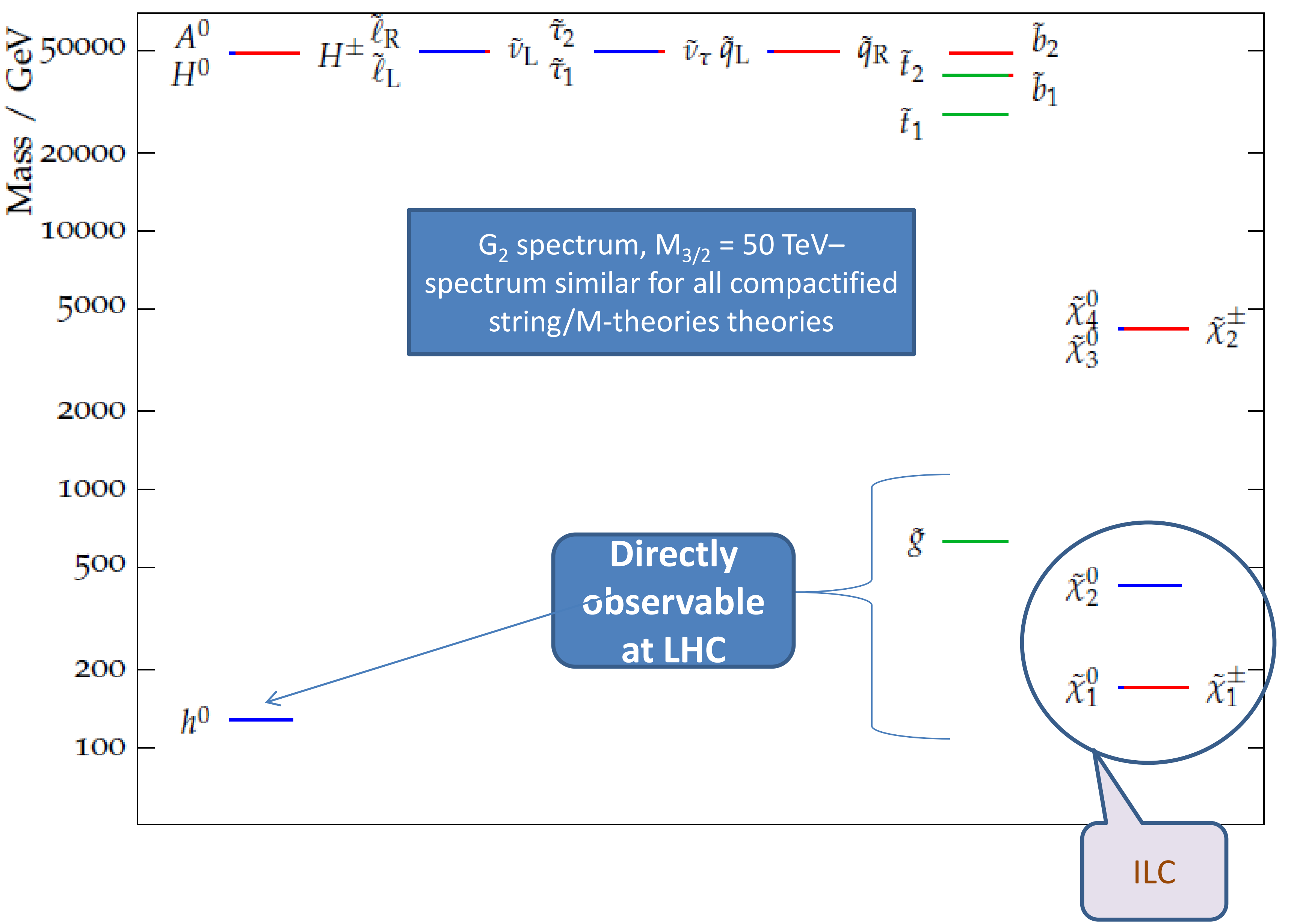
(a) $\mu \approx M_{3/2}$, should vanish if no supersymmetry breaking [IIB?]

(b) $\mu \approx (\langle moduli \rangle / M_{pl}) M_{3/2} \lesssim 1/10\, M_{3/2}$ [M-theory?]

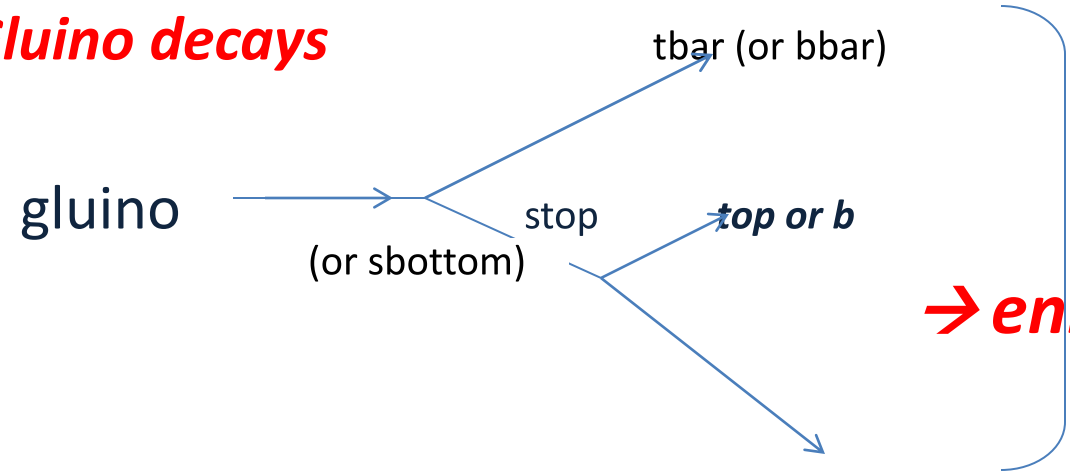
Value of μ also important for direct detection experiments predictions (Xenon100, LUX, CDMS, PandaX…)

Briefly describe LHC predictions

Generic LHC predictions – same physics as Higgs mass prediction



Gluino decays



N1 or **N2** (→ **C1**+W*) or **C1** (over half of gluinos)

4 tops (or bbbb, or btbt) favored for gluino pair!

→ enhanced 3rd family decays

$\gamma c\tau \approx 10$ cm for wino-like LSP

Gluino lifetime ~ 10^{-19} sec

Current limit for gluinos from string/M theory about 700 GeV

LHC14, arXiv:0901.3367; LHC7, arXiv:1106.1963

For (well-motivated) wino-like LSP, chargino and LSP are nearly degenerate (like anomaly mediation), so chargino → LSP plus very soft π^+ → **disappearing charginos** in $\sim$ half of events

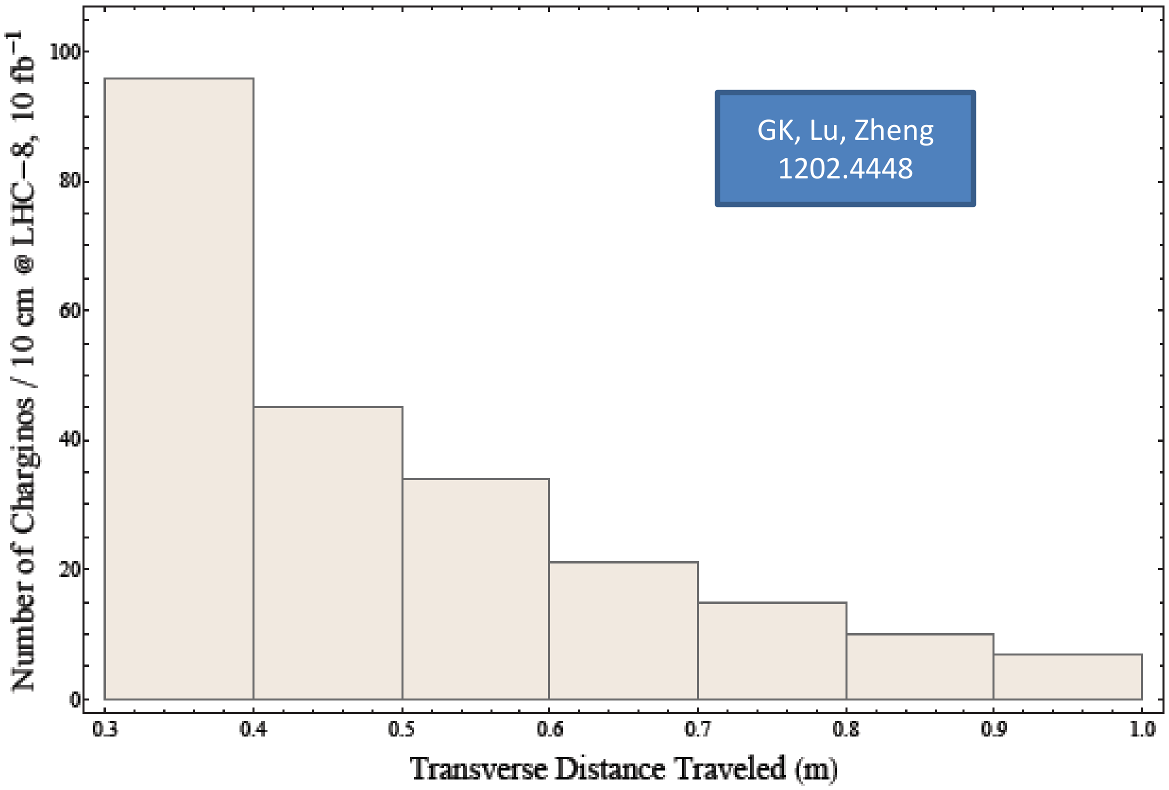


FIG. 1: Charged Winos resulting from gluino pair production, binned as a function of transverse distance traveled from the beam line. These results correspond to 10 fb^{-1} of LHC-8 data ($\sigma_{\tilde{g}\tilde{g}} \sim 235$ fb), with $m_{\tilde{g}} = 750$ GeV, $m_{\widetilde{W}} = 150$ GeV. For graphical purposes, charginos traveling a transverse distance < 30 cm are not shown.

Briefly describe our work on M-theory fluxless compactification – good start toward **a candidate for *our string vacuum*** – gaugino masses

STRINGY

- 7 dimensions form a space with G_2 holonomy, preserves N=1 supersymmetry in 4D
- In these vacua, non-Abelian gauge fields localized along 3D submanifolds at which there is an orbifold singularity [Acharya, th/9812205;th/0011089; Achaya-Gukov th/0409191]
- Chiral fermions localized at points at which there are conical singularities [Acharya and Witten, th/0109152, Acharya and Gukov, th/0409191; Atiyah and Witten, th/0107177]
- Generically two 3D submanifolds do not intersect in a 7D space, so no light matter fields charged under both SM gauge group and hidden sector gauge groups → **susy breaking generically gravity mediated in these vacua**

DE SITTER VACUUM, GAUGINO MASSES

-- With only compactification moduli one gets AdS extrema – minima, maxima, saddle points (no go theorems, Maldacena and Nunez…) – some break susy, some preserve it -- so some other contribution is crucial to get deS minima – see explicitly in M theory

-- For M theory positive F terms from chiral fermion condensates cancel the $3W^2$ and give deS minima

-- also, in M theory case the deS minima come from promoting susy preserving saddle point, so the minima is near a susy preserving point in field space

-- so SM gaugino masses are doubly suppressed – vanish at susy preserving point, and get no contribution from large F terms of mesons

$$M_{1/2} \sim K_{mn} F_m \partial_n f_{SM}$$

-- can't calculate suppression precisely, estimate $\sim 1/60$

-- KKLT puts in anti D brane by hand to uplift in type IIB

-- general situation not known – gauginos suppressed in heterotic?

Other results for M-theory compactification

- Compute full soft breaking Lagrangian
- All terms relatively real! → **no susy CP problem** (GK, Kumar, Shao)

Potential stabilizes real parts of moduli, only a few axions – generically one axion combination t stabilized at cost=-1 – then terms in W align with same phase – overall phase of W can be rotated away – remaining axions stabilized exponentially smaller giving contributions that work to also ***solve strong CP problem*** (Acharya, Bobkov, Kumar)

- **Universe moduli dominated after inflation** so axion limit larger, string axion problem almost solved(Acharya, Bobkov, Kumar)
- **Include μ** (Witten; Acharya, Kane, Kuflik, Lu)
- **Flavor OK** (GK, Kadota, Kirsten, Valesco-Sevilla)
- Gauge Coupling Unification
- **Baryogenesis *and* ratio of baryons to DM from moduli decay after Affleck-Dine baryogenesis** (GK, Shao, Watson, Yu)
- **Higgs physics, EWSB, fine tuning alleviated** (GK, Feldman, Kuflik, Lu)

Mention three final topics:

Cosmological constant/dark energy?

“Landscape”?

10 Dimensions?

COSMOLOGICAL CONSTANT/DARK ENERGY

- Important, very interesting problem
- No solution expected in particular string vacuum
- **Expect solution decoupled from all the particle physics issues – this holds in all known approaches**
- **Solving CC/DE unlikely to help answer questions**
- **Not solving CC/DE unlikely to prevent answering questions**
- In practice, set CC to zero for calculations, and ensure can do that and have deSitter minimum for vacuum – requires two contributions to breaking supersymmetry

STRING THEORY FRAMEWORK HAS *MANY* SOLUTIONS ("LANDSCAPE")

- There *are* many solutions – if the theory implies they exist, and the theory is well tested …
- Some have argued that if there are many, then it is unlikely we can find one describing *our* vacuum
- Indeed, probably unlikely if do it purely theoretically
- But not choosing vacua one by one and testing them – we already know so much about what to look for, and are addressing so many questions *with related answers* that it is reasonable to be optimistic about soon finding very good candidates for ***our*** string vacuum
- "if you are looking for golf balls, first find golf courses" [Stuart Raby]
- Already have candidates for our string vacuum in which can calculate Higgs boson mass and properties and solve several problems (dark matter candidate, weak and strong CP problems etc) – also many with MSSM quark and leptons embedded, no extra matter – not yet one with everything

10 dimensions?

Can show that a relativistic quantum theory which includes gravity and is mathematically consistent will have 10D.

Actually this is good!

Think about SM – full descriptive theory in 4D. But ***only descriptive!***
-- Does not explain why quarks exist, why strong force not different, why families of particles, etc.

→ if we want to **understand** need to go beyond 4D! -- By going beyond 4D we have possible real understanding of many questions!

Higgs mass illustrates this – in SM cannot estimate at all – in Supersymmetric SM can get broad range, e.g. about 50 GeV to about 200 GeV – in string theory can derive and calculate precisely

CONCLUDING REMARKS

- *Rigorous generic predictions now possible from compactified string/M-theories*
- **First prediction from string theory for new physics: $M_h \approx$ 125 GeV for $\tan\beta \gtrsim 6$!! And h must be SM-like!!**
- In M-theory case get TeV scale etc – **compactified M-theory on G_2 manifold a good candidate for our string vacuum!**
- **Squarks heavy**, **gluinos probably at LHC in 2012** – enhanced 3rd family decays, disappearing charginos
- Dark matter wino-like, testable, **non-thermal cosmological history**
- **probably the compactified string theory is as simple as any theory could be and explain our world**
- **To understand (not just describe) probably necessary to embed the theory in extra dimensions**

“if people don’t want to come to the ballpark nobody’s going to stop them”

Yogi Berra

Fine tuning? Little Hierarchy problem?

- First – results of a theory never fine-tuned

- Can ask how well have to be able to calculate in the theory to have no tuning – theory has to include μ – in M-theory case led to trilinears A_0 about same size as scalars M_0 generically and both $\gtrsim$ 30 TeV – get EWSB from M^2_{Hu} running down from $\gtrsim$ 30 TeV to $\sim$ TeV generically

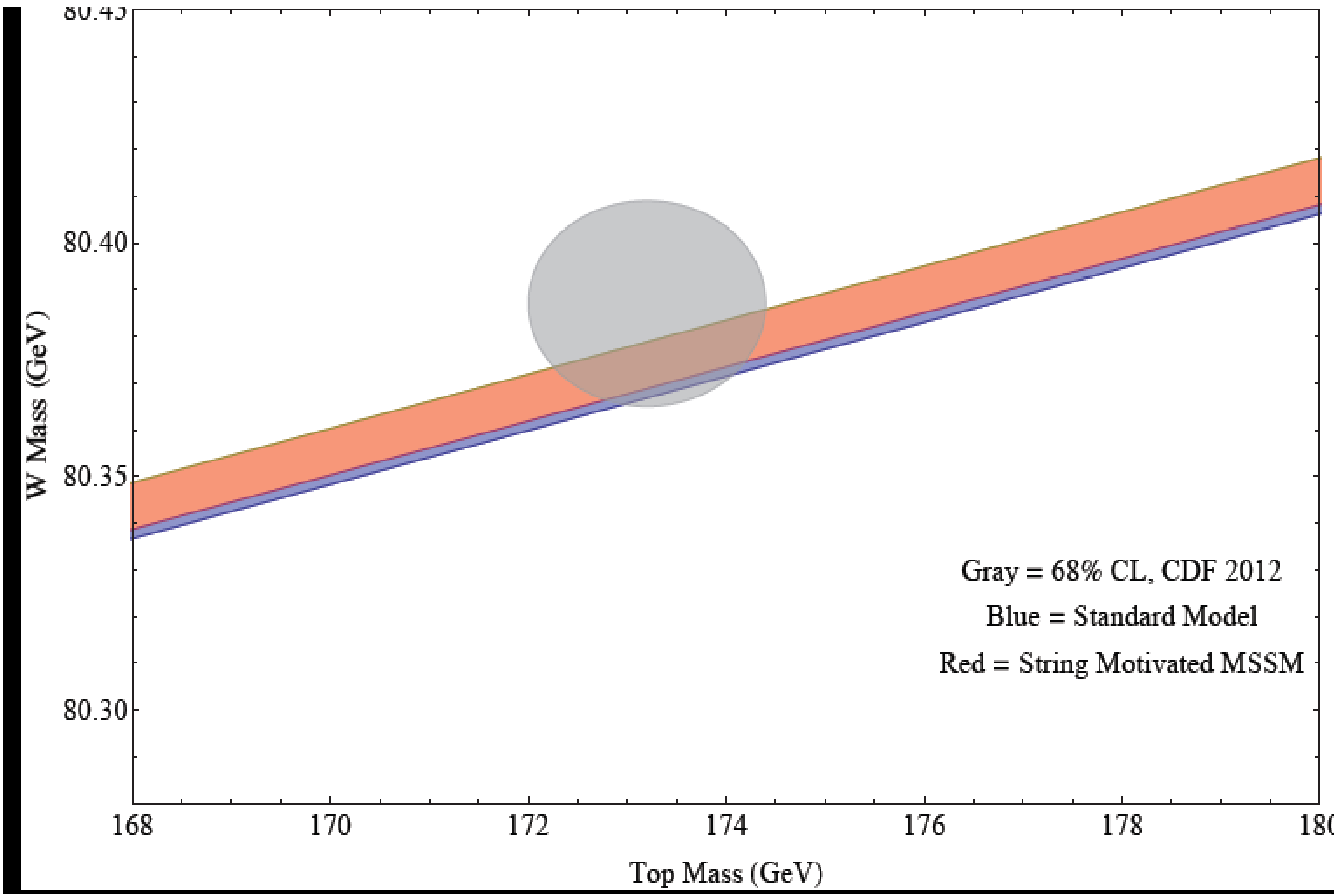
$$M^2_{Hu} \approx f_1 M^2_0 - f_2 A^2_0 \text{ , and } f_1 \approx f_2 \approx 0.1$$

So suppression > 1/100 natural

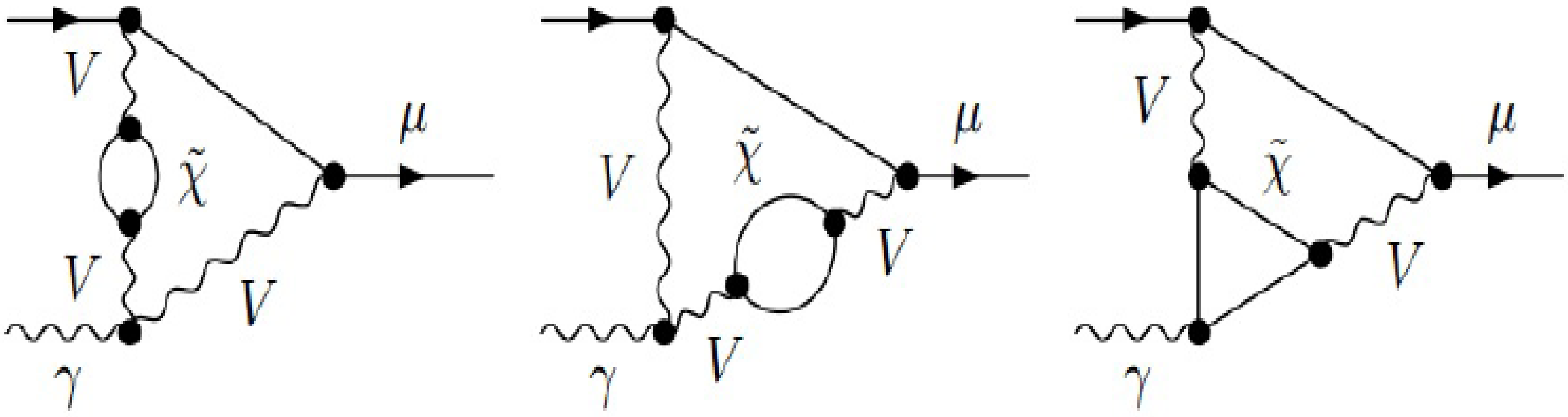
- Final step to $M_Z \approx 0.1$ TeV needs cancellation between M^2_{Hu} , M^2_{Hd} , μ, gluino mass – no tuning in full theory, but can ask anyhow

WHAT IS STRING THEORY?

- What is any theory? We are trying to write a consistent mathematical theory that describes the natural world.
- Must be a quantum theory, must be “relativistic” (consistent with Einstein special relativity)
- SM is a consistent relativistic quantum field theory, works well – treats all particles as point-like objects
- But a relativistic quantum field theory of gravity based on pointlike particles leads to some meaningless predictions
- String theory is an attempt to describe particles not as points but with the equations that would describe the motion of strings – seems to work! – probably any extended objects constrained by special relativity and quantum theory would work – string theory of gravity gives all meaningful results – can describe all particles and forces in mathematically consistent way – if 10/11D!
- An electron is still an electron, just described by equations for a string rather than for a point



80.45
80.40
80.35
80.30
W Mass (GeV)
168
170
172
174
176
178
180
Top Mass (GeV)
Gray = 68% CL, CDF 2012
Blue = Standard Model
Red = String Motivated MSSM



$$\delta a_\mu \sim 5 - 10 \text{ x } 10^{-10}$$

$$\delta a_\mu^{exp} = (26.1 \pm 8.0) \text{ x } 10^{-10}$$

Heinemeyer et. al
arXiv:0405255

PERSPECTIVE

To understand the physical universe and its underlying laws need at least three things:

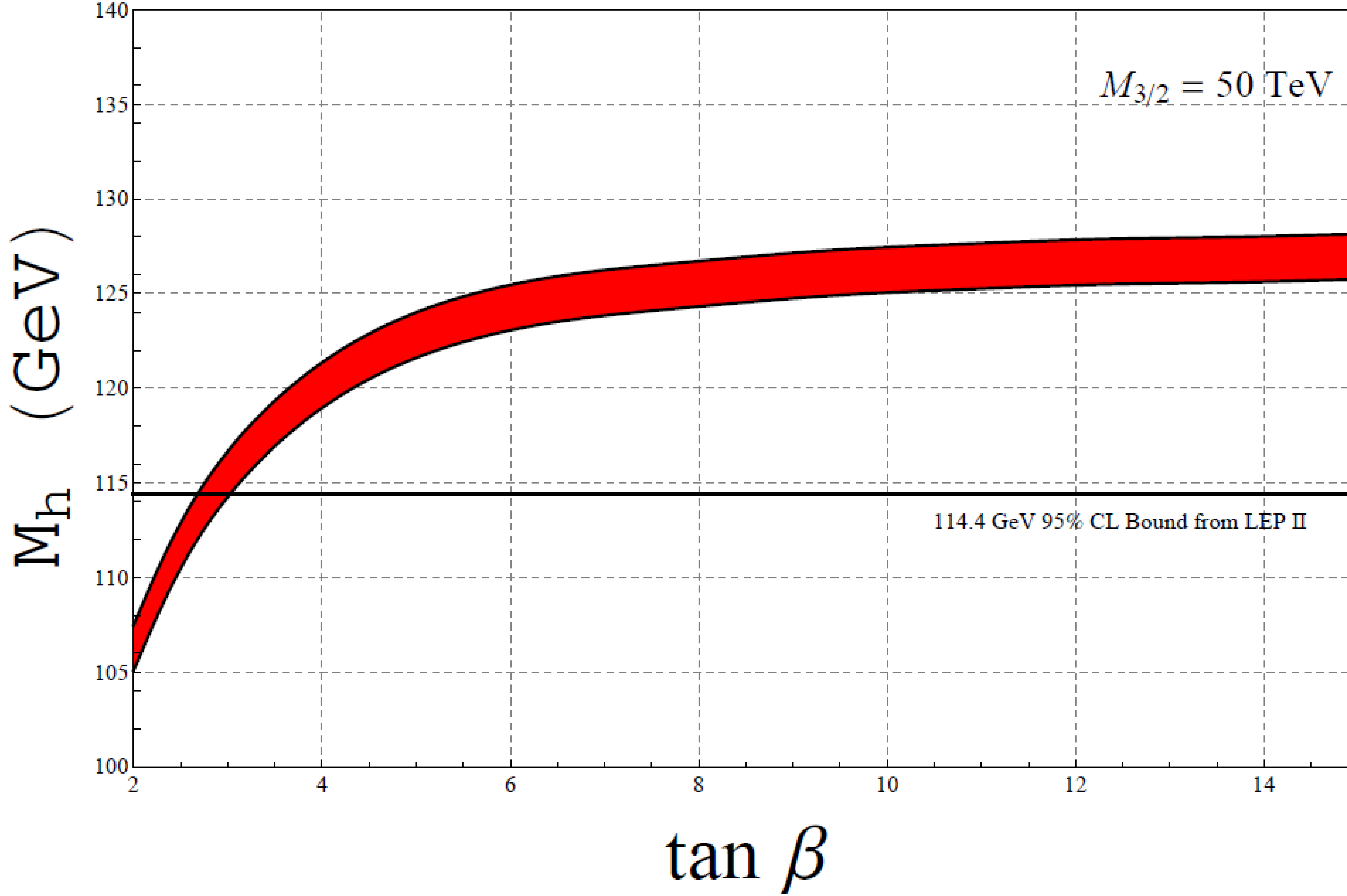
- **Rules** – quantum theory + Einstein relativity – hold for any force, any particles – tell how to calculate any prediction – relativistic quantum field theory in place by about 1930, no change since then (but increasingly better understanding) – no change anticipated
- **Forces** – what forces act on particles to form our world?

  – strong, electromagnetic, weak, gravity
- **Particles** – underlying final constituents? – quarks, leptons

Standard Model, proposed 1972, 1973, confirmed by mid 1980s

E.g. Newton's law F=ma is a rule, for any force, particle

– put in force and calculate motion for any object



$M_{3/2}$ = 50 TeV
114.4 GeV 95% CL Bound from LEP II
M_h (GeV)
tan β
140
135
130
125
120
115
110
105
100
2
4
6
8
10
12
14

Questions for Standard Model and beyond	Standard Model	Supersymmetric Standard Model	String Theory
What form is matter (electrons, quarks, etc)?	√ **(addresses)**		√
What *is* matter?			√
What is light?	√√ (answers)		
Which interactions give our world?	√		√
Gravity?		√	√√
Is supersymmetry valid?			√
Origin of matter asymmetry? Dark matter?		√ √	√ √
Gauge coupling unification		√	√
Dark Energy?			√
Number of dimensions?			√

SM and Supersymmetric SM limited, but **string theory addresses all (?) questions**