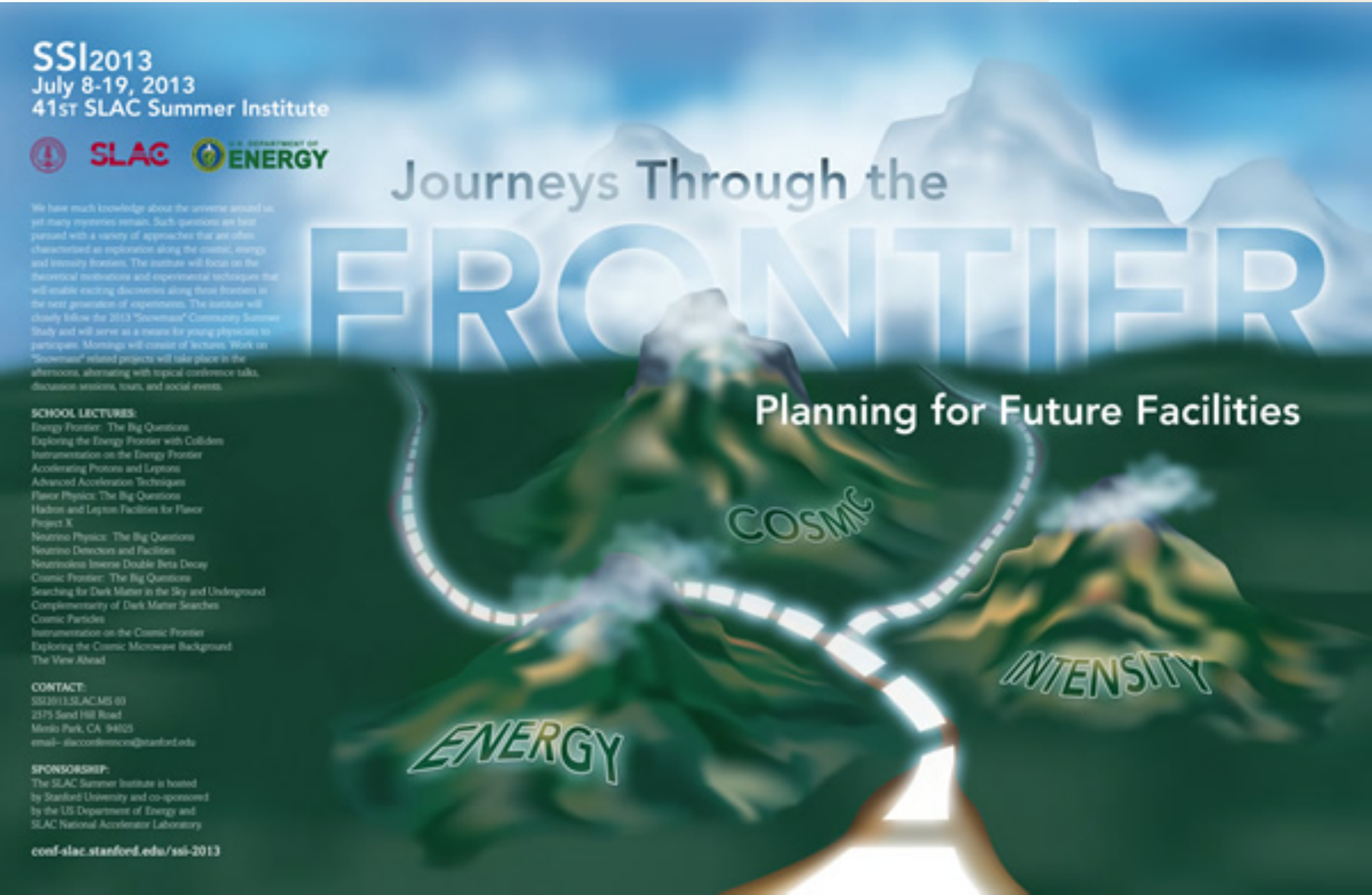
2013 SSI Contest



SSI2013
July 8-19, 2013
41st SLAC Summer Institute

Journeys Through the FRONTIER

Planning for Future Facilities

We have much knowledge about the universe around us, yet many mysteries remain. Such questions are best pursued with a variety of approaches that are often characterized as explorations along the cosmic, energy and intensity frontiers. The institute will focus on the theoretical motivations and experimental techniques that will enable exciting discoveries along these frontiers in the next generation of experiments. The institute will closely follow the 2013 "Snowmass" Community Summer Study and will serve as a means for young physicists to participate. Mornings will consist of lectures. Work on "Snowmass" related projects will take place in the afternoons, alternating with topical conference talks, discussion sessions, tours, and social events.

SCHOOL LECTURES:
Energy Frontier: The Big Questions
Exploring the Energy Frontier with Colliders
Instrumentation on the Energy Frontier
Accelerating Protons and Leptons
Advanced Acceleration Techniques
Flavor Physics: The Big Questions
Hadron and Lepton Facilities for Flavor
Project X
Neutrino Physics: The Big Questions
Neutrino Detectors and Facilities
Neutrinoless Inverse Double Beta Decay
Cosmic Frontier: The Big Questions
Searching for Dark Matter in the Sky and Underground
Complementarity of Dark Matter Searches
Cosmic Particles
Instrumentation on the Cosmic Frontier
Exploring the Cosmic Microwave Background
The View Ahead

CONTACT:
SSI2013,SLAC,MS 60
2575 Sand Hill Road
Menlo Park, CA 94025
email– slacconferences@stanford.edu

SPONSORSHIP:
The SLAC Summer Institute is hosted
by Stanford University and co-sponsored
by the US Department of Energy and
SLAC National Accelerator Laboratory

conf-slac.stanford.edu/ssi-2013

The Question:

What exciting physics will you lecture about at the 2023 SLAC Summer Institute and why?

Sample Entries:

Greetings SSIers,

Sorry to miss your wonderful Summer School but I am very busy working on my ATLAS analyses.

Like most people I believe in New Physics beyond the Standard Model. I would imagine that in 2023 I would like to come to the SSI and give a lecture on something really EXOTIC & bizarre like the observation of different kinds of Higgs bosons that would be produced in SUSY particle cascades. This would be a wonderful and unexpected discovery & change our view of what happens at the TeV scale! I do hope we see something like this at 14 TeV.

Good luck with your studies..I hope to see you at CERN Cheers, Fabiola

Sample Entries:

The intentional ambiguity of this question belies the existential desperation in the HEP community…… it means NOTHING.

– Anonymous

Panel of Distinguished Experts

SLAC

The Runner Up

- Geert-Jan Besjes

….However, at 14 TeV cracks started appearing readily, leading to a discovery of heavy super-particles around 1.5 TeV. This discovery proved very timely for the ILC, which came online at the end of the decade. Not only did the ILC's experiments measure SM-particles to astonishing precision, but their Higgs-properties programs clearly provided further constraints of yet undiscovered SUSY particles…

The Winner

-David Caratelli

“ν’s: the precision frontier” A journey through the history of precision neutrino measurements and the new physics we have and can expect to learn along the way.

- How we gained incredible precision on ν mixing parameters
- How we now have hints for the MH
- How IceCube has produced precise maps of the ν sky
- Results from 0νββ decay and overall mass scale
- Sterile ν’s answer from μBooNE/Cosmic

SSI2013 Journeys Through the FRONTIER

A View Ahead

J. Hewett

U.S. DEPARTMENT OF ENERGY
Office of Science

SLAC NATIONAL ACCELERATOR LABORATORY

What is the world made of?

What holds the world together?

Where did we come from?

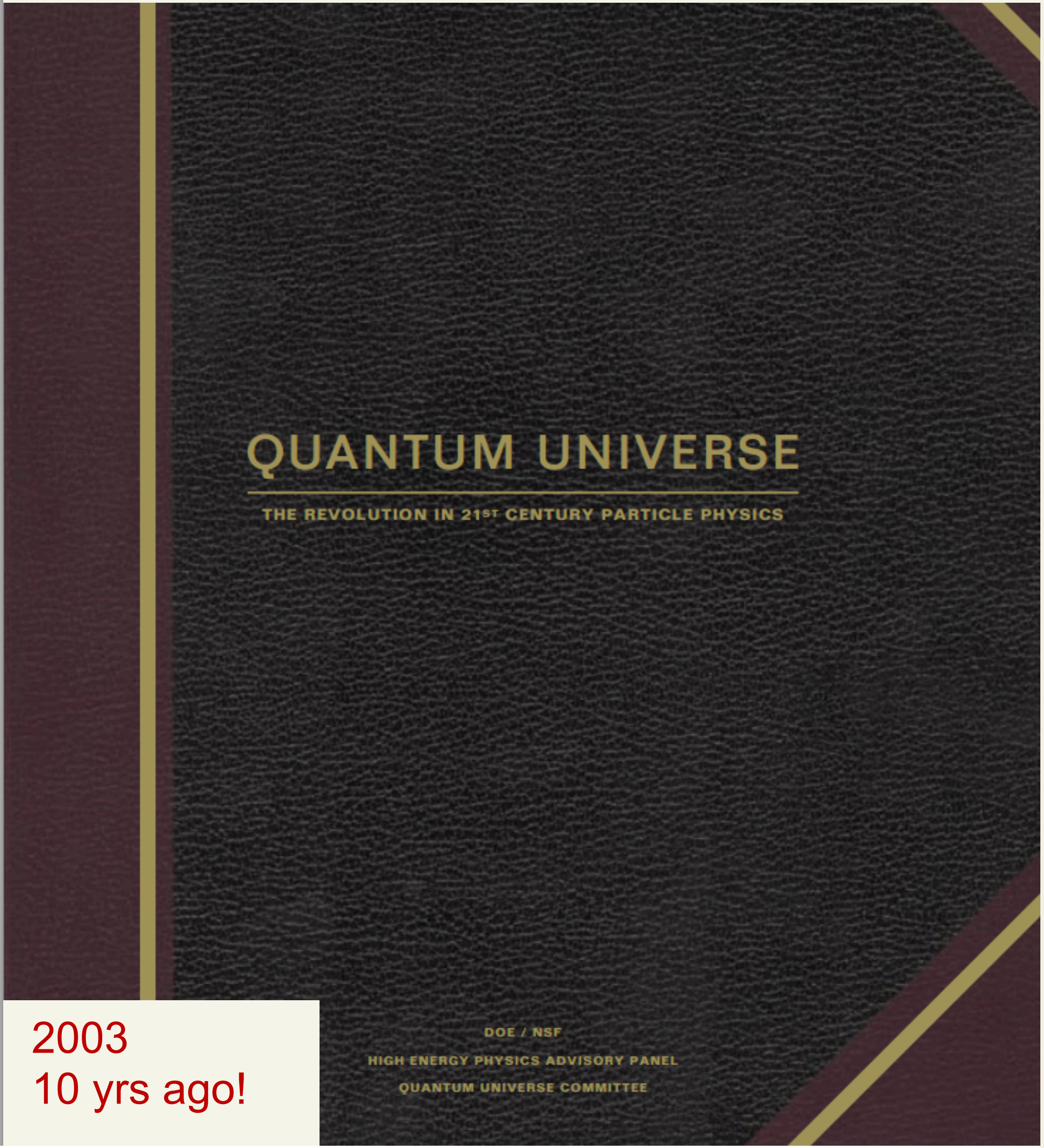
Evolved Thinker

1. Are there undiscovered principles of nature: New symmetries, new physical laws?
2. How can we solve the mystery of dark energy?
3. Are there extra dimensions of space?
4. Do all the forces become one?
5. Why are there so many kinds of particles?
6. What is dark matter?
   How can we make it in the laboratory?
7. What are neutrinos telling us?
8. How did the universe come to be?
9. What happened to the antimatter?

From ‘Quantum Universe’


Evolved Thinker

QUESTIONS FOR THE UNIVERSE



QUANTUM UNIVERSE

THE REVOLUTION IN 21ST CENTURY PARTICLE PHYSICS

DOE / NSF
HIGH ENERGY PHYSICS ADVISORY PANEL
QUANTUM UNIVERSE COMMITTEE

2003
10 yrs ago!

EINSTEIN'S DREAM OF UNIFIED FORCES

1

ARE THERE UNDISCOVERED PRINCIPLES OF NATURE : NEW SYMMETRIES, NEW PHYSICAL LAWS?

2

HOW CAN WE SOLVE THE MYSTERY OF DARK ENERGY?

3

ARE THERE EXTRA DIMENSIONS OF SPACE?

4

DO ALL THE FORCES BECOME ONE?

THE PARTICLE WORLD

5

WHY ARE THERE SO MANY KINDS OF PARTICLES?

6

WHAT IS DARK MATTER?
HOW CAN WE MAKE IT IN THE LABORATORY?

7

WHAT ARE NEUTRINOS TELLING US?

THE BIRTH OF THE UNIVERSE

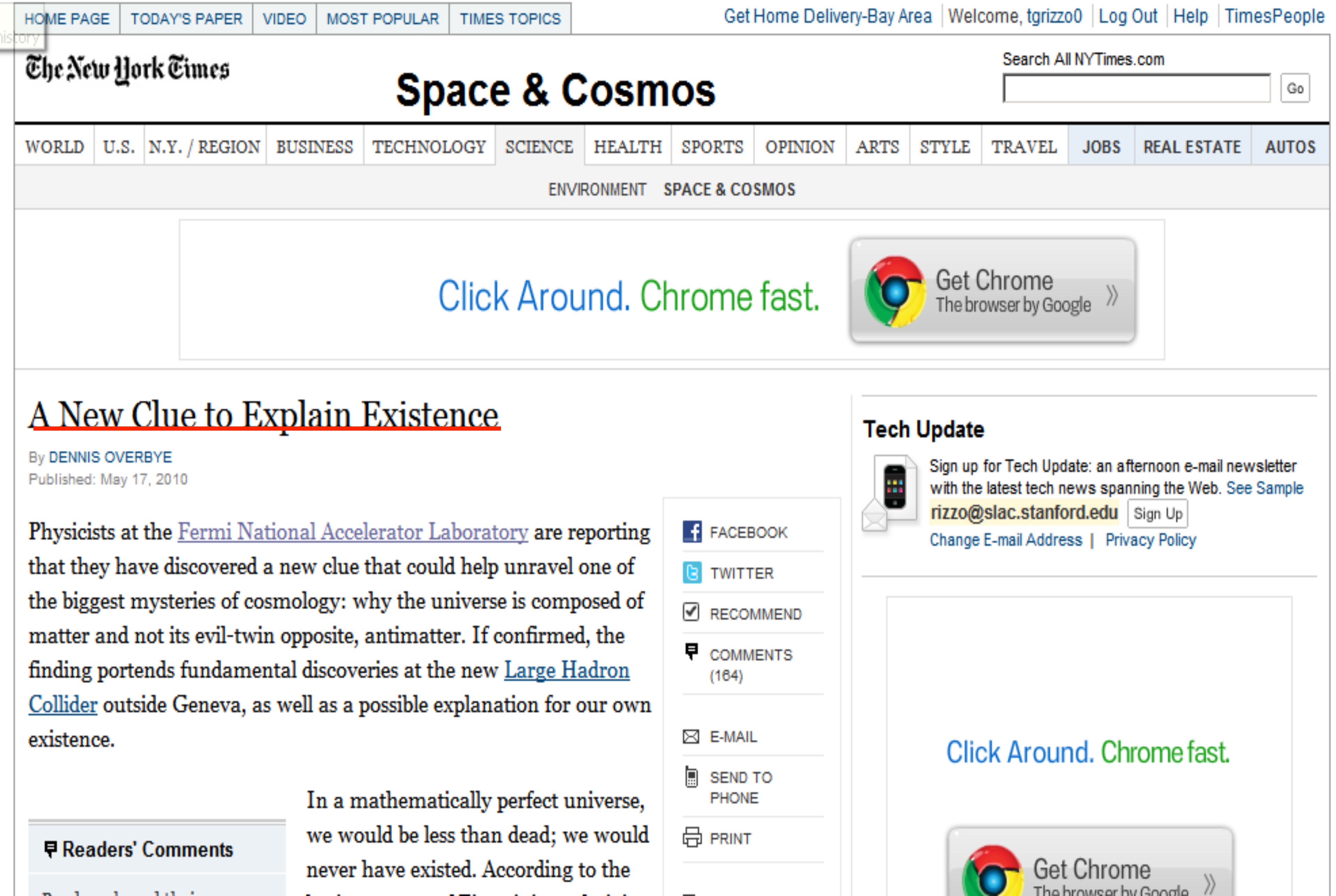
8

HOW DID THE UNIVERSE COME TO BE?

9

WHAT HAPPENED TO THE ANTIMATTER?

Questions like these capture ‘universal’ interest



Space & Cosmos

A New Clue to Explain Existence

By DENNIS OVERBYE
Published: May 17, 2010

Physicists at the Fermi National Accelerator Laboratory are reporting that they have discovered a new clue that could help unravel one of the biggest mysteries of cosmology: why the universe is composed of matter and not its evil-twin opposite, antimatter. If confirmed, the finding portends fundamental discoveries at the new Large Hadron Collider outside Geneva, as well as a possible explanation for our own existence.

In a mathematically perfect universe, we would be less than dead; we would never have existed. According to the

Readers' Comments

Tech Update

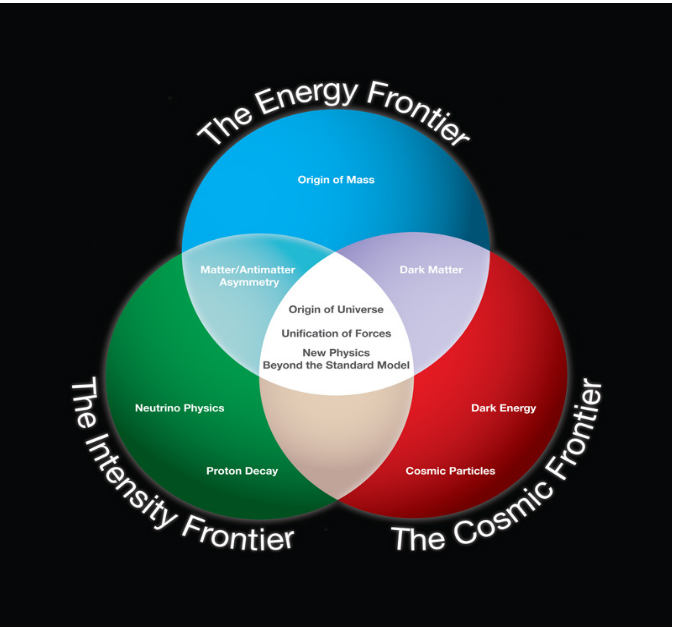
Sign up for Tech Update: an afternoon e-mail newsletter with the latest tech news spanning the Web. See Sample

rizzo@slac.stanford.edu

Change E-mail Address | Privacy Policy

HEP and the Frontiers

Good representation of HEP

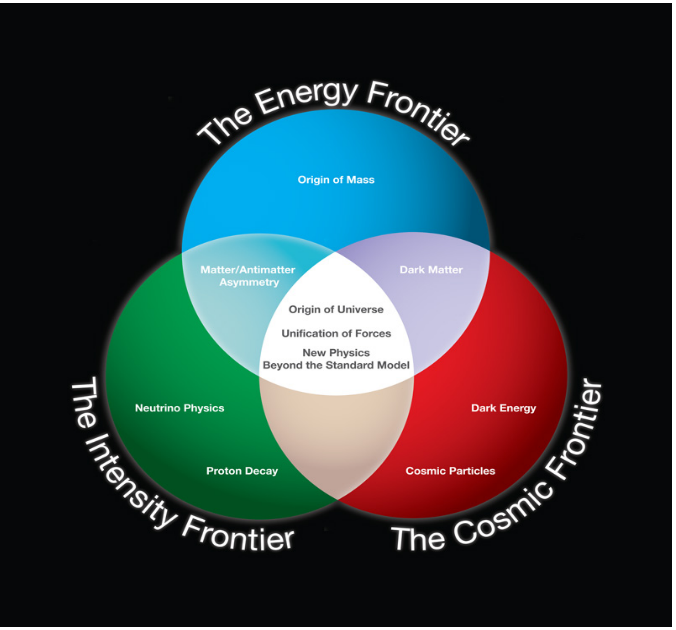


Shows multi-pronged approach to search for new physics

- **Direct Searches**
- **Precision Measurements**
- **Rare and Forbidden Processes**
- **Fundamental Properties of Particles and Interactions**
- **Cosmological observations**

HEP and the Frontiers

Good representation of HEP



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Lesson: Easy to lose sight of the big picture and forget we are all addressing the same questions

HEP and the Frontiers

Good representation of HEP


The Knowledge Frontier

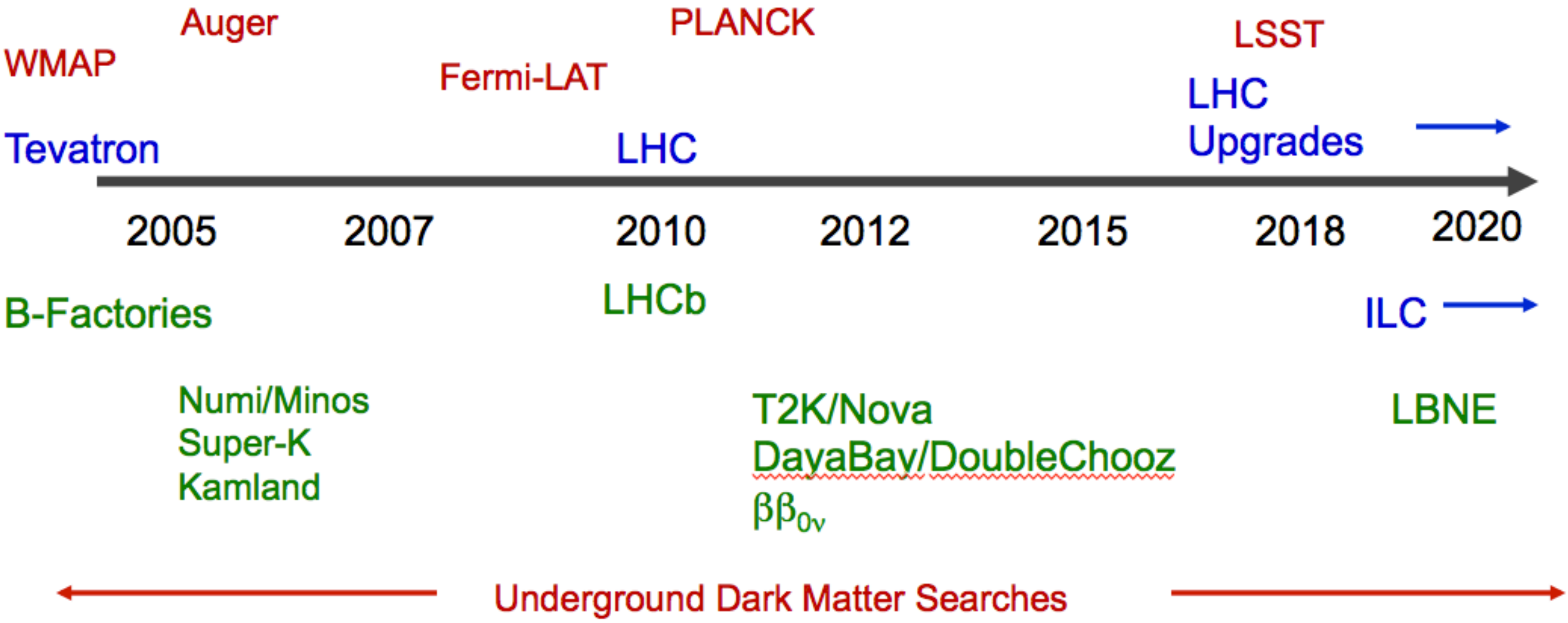
Shows multi-pronged approach to search for new physics

- **Direct Searches**
- **Precision Measurements**
- **Rare and Forbidden Processes**
- **Fundamental Properties of Particles and Interactions**
- **Cosmological observations**

Lesson: Easy to lose sight of the big picture and forget we are all addressing the same questions

What have we learned since the Quantum Universe?

The Science Toolbox Timeline: we learn from experiment



Auger

PLANCK

LSST

WMAP

Fermi-LAT

LHC Upgrades

Tevatron

LHC

2005

2007

2010

2012

2015

2018

2020

B-Factories

LHCb

ILC

Numi/Minos
Super-K
Kamland

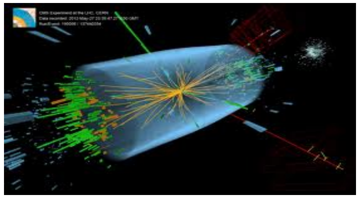
T2K/Nova
DayaBay/DoubleChooz
$\beta\beta_{0\nu}$

LBNE

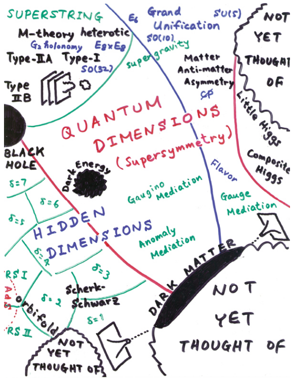
Underground Dark Matter Searches

What have we learned since the Quantum Universe?

- Higgs: Discovered!

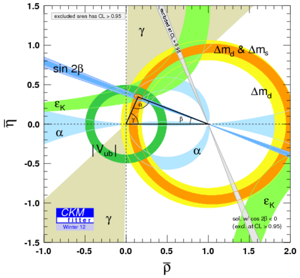


- Where’s SUSY? Or any other BSM?

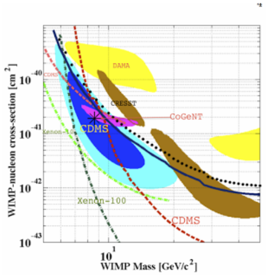


- All neutrino mixings are large: θ_{13}

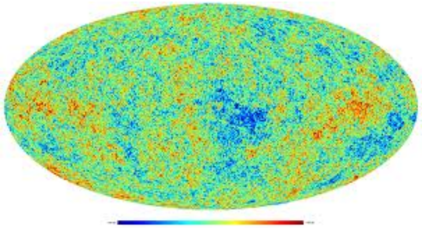
- Quark Flavor Sector is SM-like
  - » New XYZ States @ 4-5 GeV: Who ordered that?



- Signals for Dark matter? or NOT!



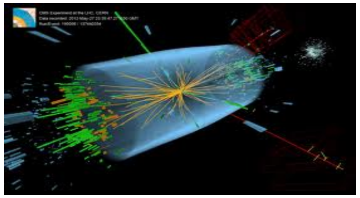
- Standard Model of the universe: Λ_{CDM}



This knowledge is reflected @ the SSI

How does this data guide the next decade?

- Higgs: Discovered!



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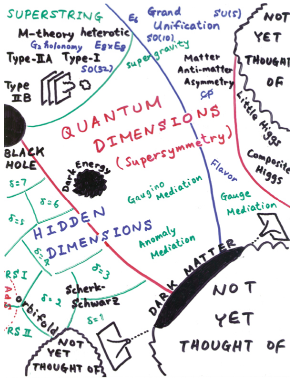

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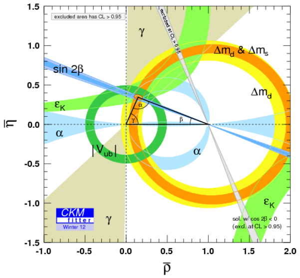

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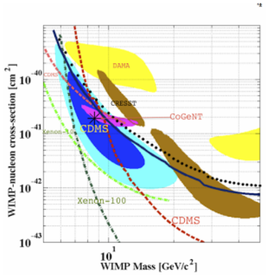

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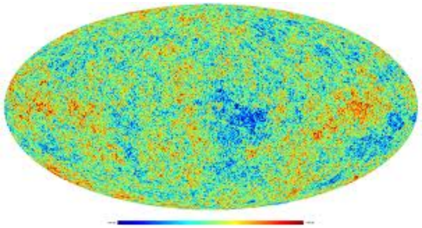
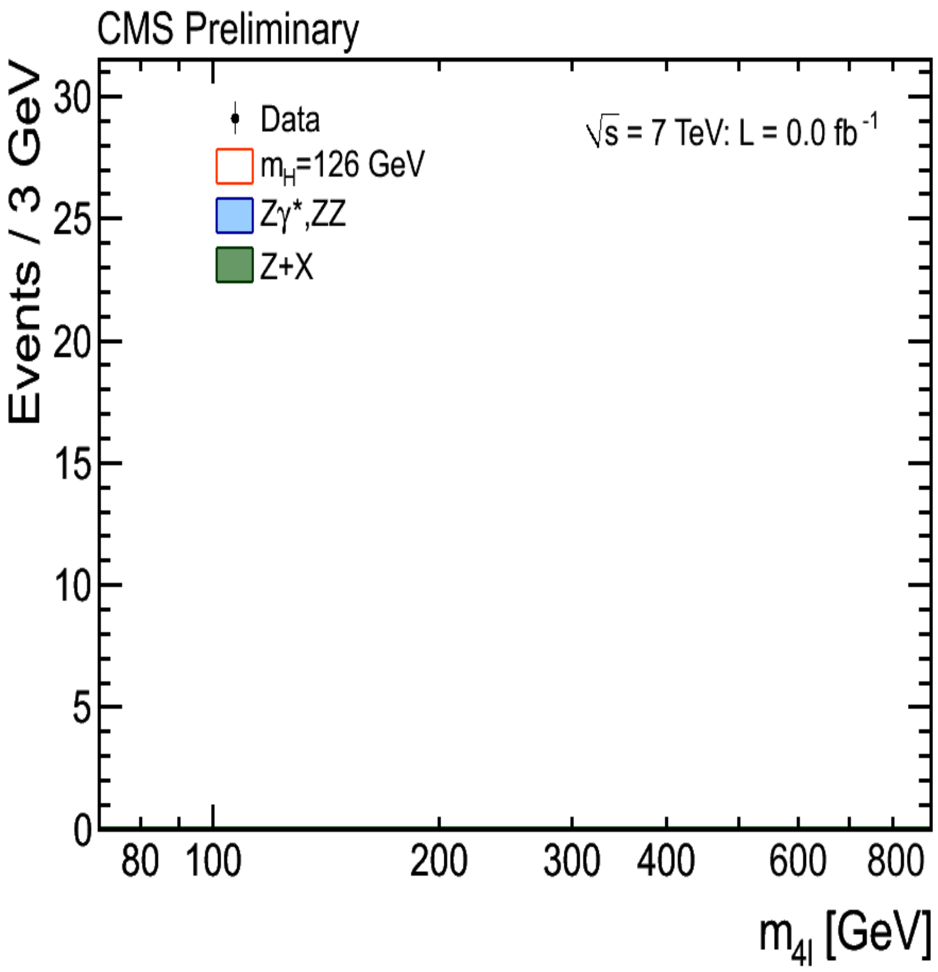
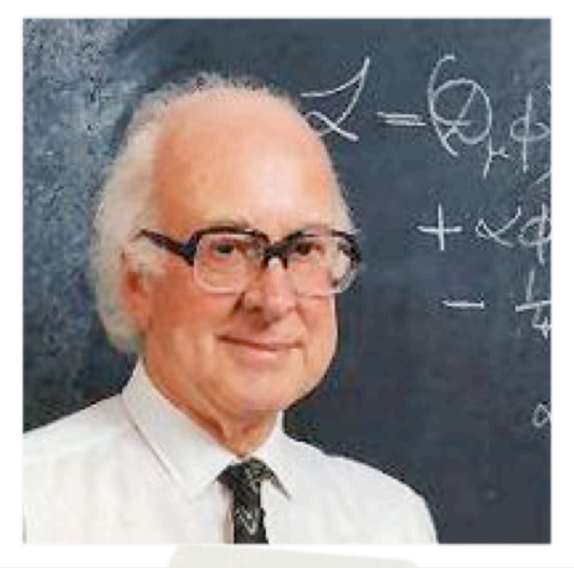


Higgs: Discovered!



Higgs et al (1964)

a fundamental scalar field with self-interactions can cause spontaneous symmetry-breaking in the vacuum without picking a preferred frame or direction, and can give gauge bosons mass

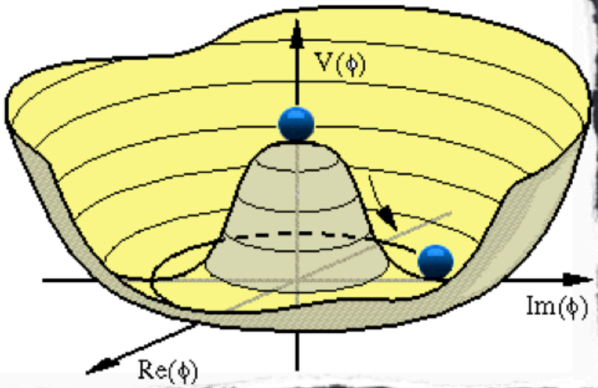


> The purpose of the present note is to report that...the spin-one quanta of some of the gauge fields acquire mass...This phenomenon is just the relativistic analog of the plasmon phenomenon to which Anderson has drawn attention

$$V(\varphi) = -\mu^2\varphi^2 + \lambda\varphi^4$$

$$\varphi^{\pm}, \mathrm{Im}\{\varphi^0\} \Rightarrow W_L^{\pm}, Z_L$$

$$\mathbf{Re}\{\varphi^0\} \Rightarrow \langle\varphi\rangle + \underset{\uparrow}{H}$$



BROKEN SYMMETRY AND THE MASS OF GAUGE VECTOR MESONS*

F. Englert and R. Brout
Faculté des Sciences, Université Libre de Bruxelles, Bruxelles, Belgium
(Received 26 June 1964)

BROKEN SYMMETRIES, MASSLESS PARTICLES AND GAUGE FIELDS

P. W. HIGGS
Tait Institute of Mathematical Physics, University of Edinburgh, Scotland

Received 27 July 1964

OLUME 13, NUMBER 16 PHYSICAL REVIEW LETTERS 19 OCTOBER 19

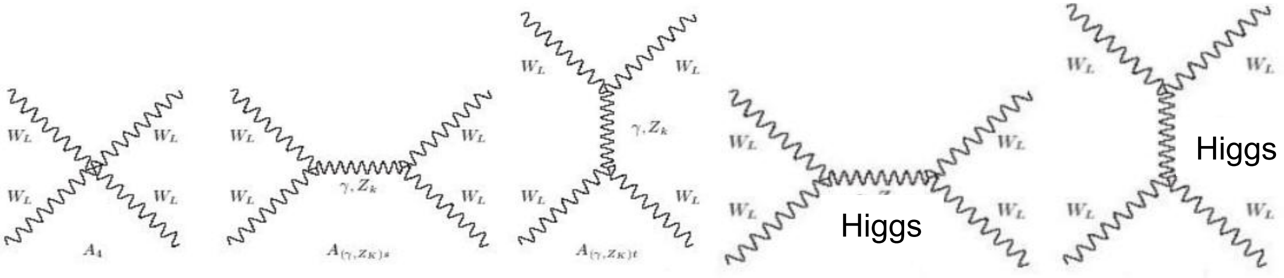
BROKEN SYMMETRIES AND THE MASSES OF GAUGE BOSONS

Peter W. Higgs
Tait Institute of Mathematical Physics, University of Edinburgh, Edinburgh, Scotland
(Received 31 August 1964)

GLOBAL CONSERVATION LAWS AND MASSLESS PARTICLES*

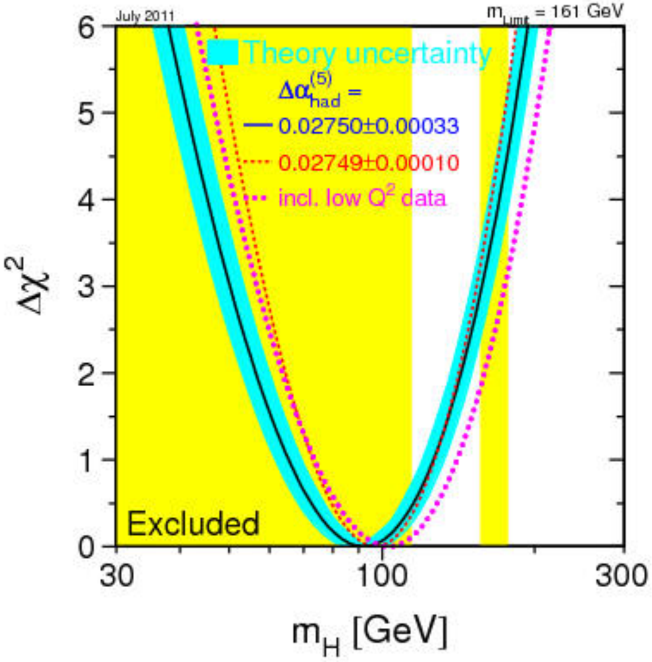
G. S. Guralnik,† C. R. Hagen,‡ and T. W. B. Kibble
Department of Physics, Imperial College, London, England
(Received 12 October 1964)

Higgs: Discovered! It took a long time…



Perturbative Unitarity gave us the mass range

Precision EW measurments narrowed the mass range



Higgs Hunters Guide (1989)

Although the Higgs mechanism [1] was used to introduce mass into the Standard Model [2,3] two decades ago, experimental sensitivity to a Standard Model Higgs boson remains extremely limited. Masses below about $2m_\mu$ can be excluded by a combination of low energy experimental data on nuclear transitions and rare decays of K mesons. Recent results in K and B decays probably rule out masses from $2m_\mu$ to $2m_\tau$. Upsilon decays are potentially

sensitive to ma
ing the exact r
conclusions at
such decays. C
begin to probe
expect to find t

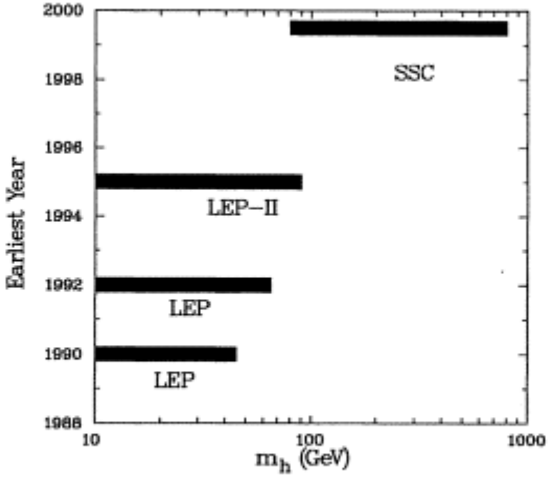


Figure 1.1 Survey of Higgs mass reach based on expected experimental data to be obtained at existing accelerators or colliders presently under construction as an estimated function of year.

Theorists calculated

Colliders were built
(or not)

Higgs: Discovered! People Celebrated.

Science

21 December 2012 | $10

BREAKTHROUGH of the YEAR

The HIGGS BOSON

Physicists Find Elusive Particle Seen as Key to Universe

The New York Times

The Economist

In praise of charter schools

Britain's banking scandal spreads

Volkswagen overtakes the rest

A power struggle at the Vatican

When Lonesome George met Nora

Economist.com

A giant leap for science

Finding the

Chasing the Higgs Boson | INTRODUCTION PROMISED FIREBALLS GAME OF BUMPS STILL MISSING OOZING INTO VIEW OPENING THE BOX

Chasing the Higgs Boson

the Large Hadron Collider near Geneva, two
ies of scientists struggled to close in on physics'
lusive particle.

ENNIS OVERBYE
blished March 5, 2013 | 252 Comments

ughter.

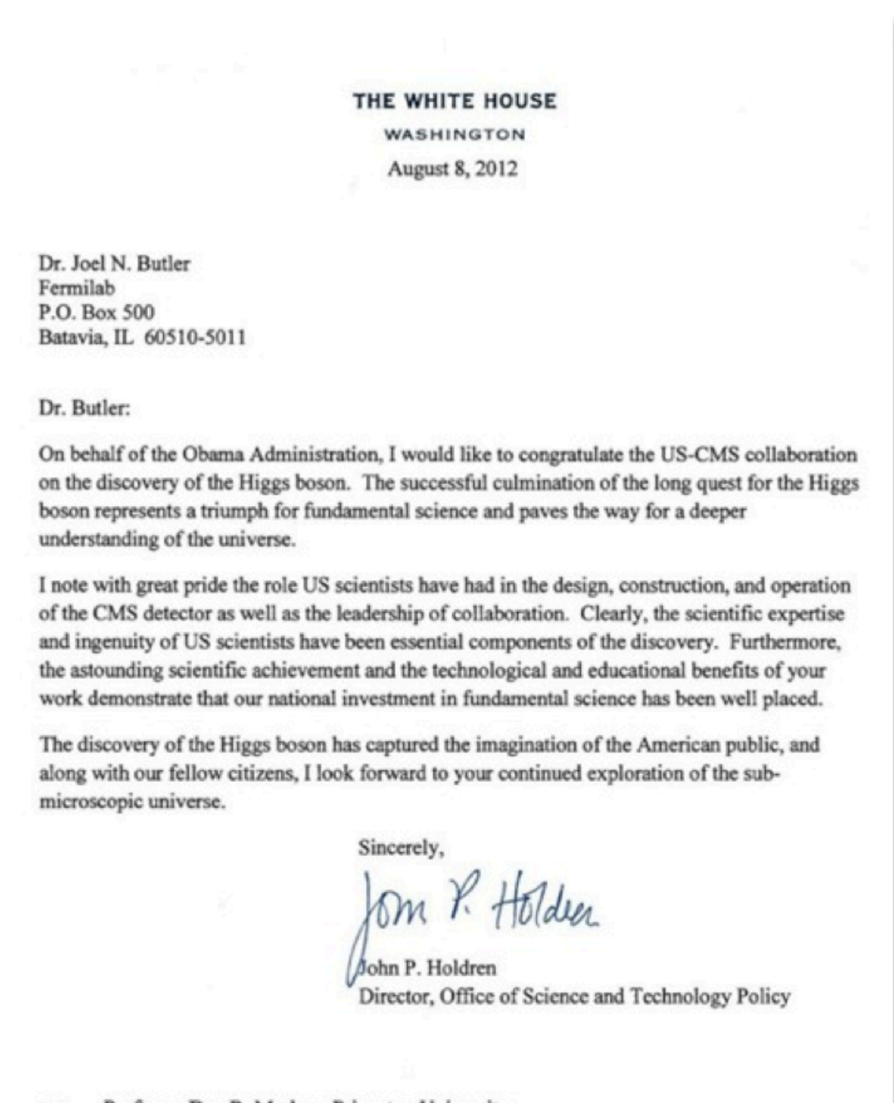
iversity of
, Dr. Sharma
at a time away
ting a team of
e Hadron

The first time that the entire NYT Science section is devoted to a single story

TIME

Nº5 PARTICLE PHYSICIST FABIOLA GIANOTTI

Higgs: Discovered! People Celebrated.



THE WHITE HOUSE
WASHINGTON
August 8, 2012

Dr. Joel N. Butler
Fermilab
P.O. Box 500
Batavia, IL 60510-5011

Dr. Butler:

On behalf of the Obama Administration, I would like to congratulate the US-CMS collaboration on the discovery of the Higgs boson. The successful culmination of the long quest for the Higgs boson represents a triumph for fundamental science and paves the way for a deeper understanding of the universe.

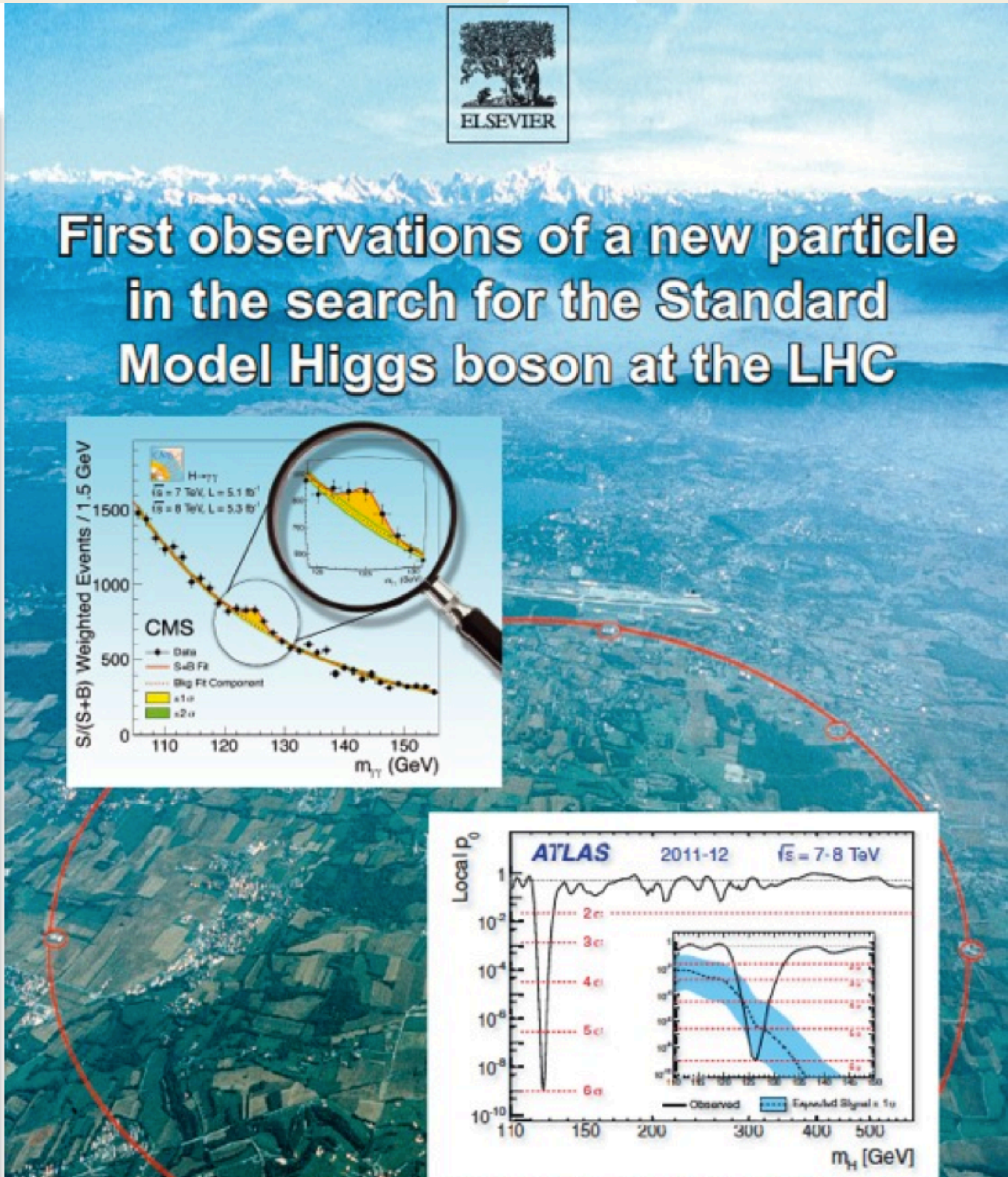
I note with great pride the role US scientists have had in the design, construction, and operation of the CMS detector as well as the leadership of collaboration. Clearly, the scientific expertise and ingenuity of US scientists have been essential components of the discovery. Furthermore, the astounding scientific achievement and the technological and educational benefits of your work demonstrate that our national investment in fundamental science has been well placed.

The discovery of the Higgs boson has captured the imagination of the American public, and along with our fellow citizens, I look forward to your continued exploration of the sub-microscopic universe.

Sincerely,

John P. Holdren

John P. Holdren
Director, Office of Science and Technology Policy



Higgs: Discovered! People Celebrated.

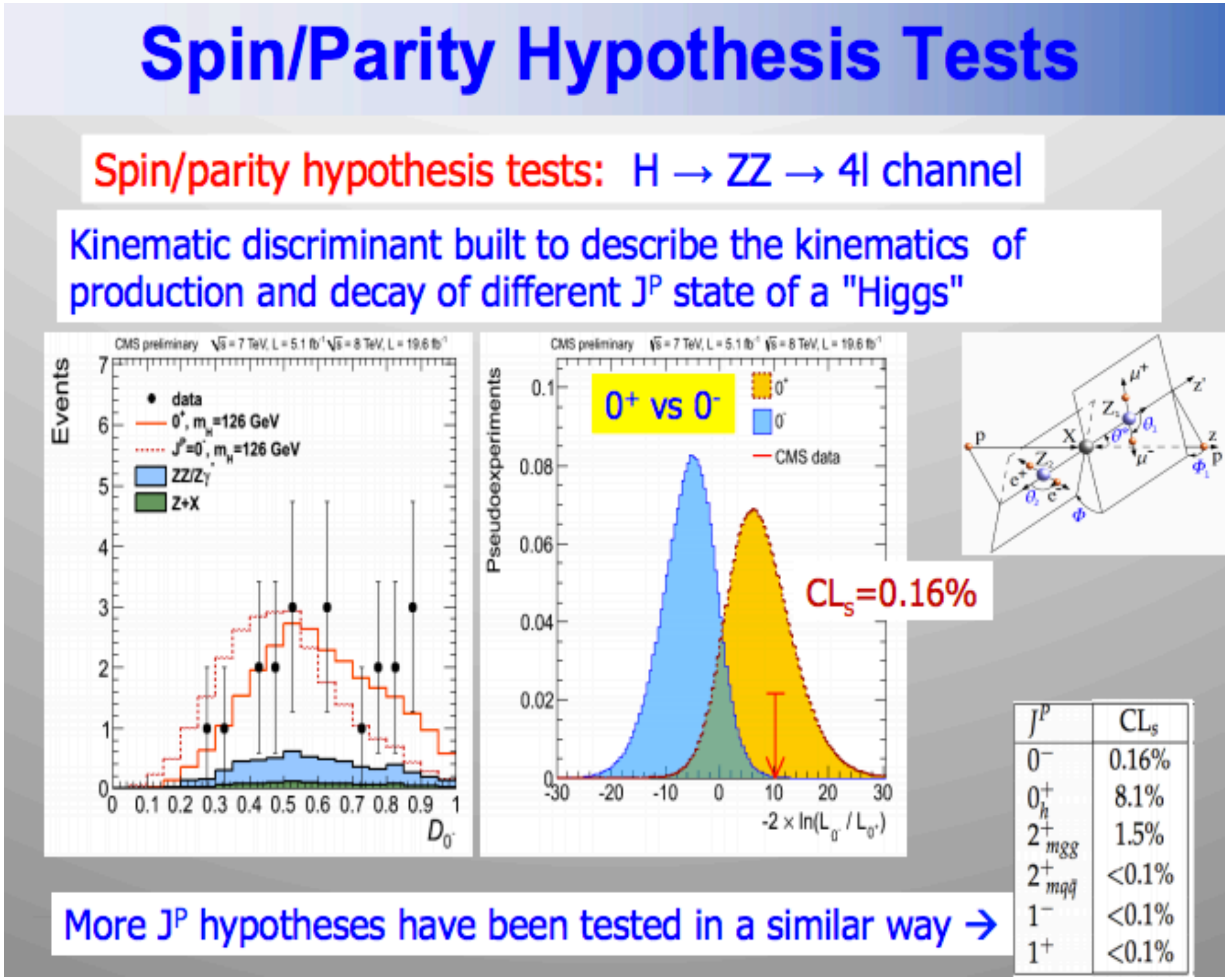
Higgs: Discovered! Not just another particle.

- A new **force** has been discovered, the first ever seen* not related to a gauge symmetry.
- Its **mediator** looks a lot like the SM scalar

Talk by Fabio Maltoni at LHCP 2013

- Fundamental Boson: New interaction which is not gauge
- Composite Boson: New underlying dynamics

Higgs: Discovered! Exclude imposters.



Spin/Parity Hypothesis Tests

Spin/parity hypothesis tests: H → ZZ → 4l channel

Kinematic discriminant built to describe the kinematics of production and decay of different J^P state of a "Higgs"

J^P	CL_s
0^-	0.16%
0^+_h	8.1%
2^+_{mgg}	1.5%
$2^+_{mq\bar{q}}$	<0.1%
1^-	<0.1%
1^+	<0.1%

More J^P hypotheses have been tested in a similar way →

- Spin determinations
  - Spin-1: no
  - Spin-2: Probably not
- Pseudoscalar?
  - No, but could be CP admixture
- SU(2) triplet?
  - No
  - λ_{WZ} = 0.8 ± 0.15 (ATLAS)
- Can still tune dilaton or spin-2 imposter to fit current data

(Chacko, Hubisz)

Higgs: Discovered! Is it non-Standard Model like?

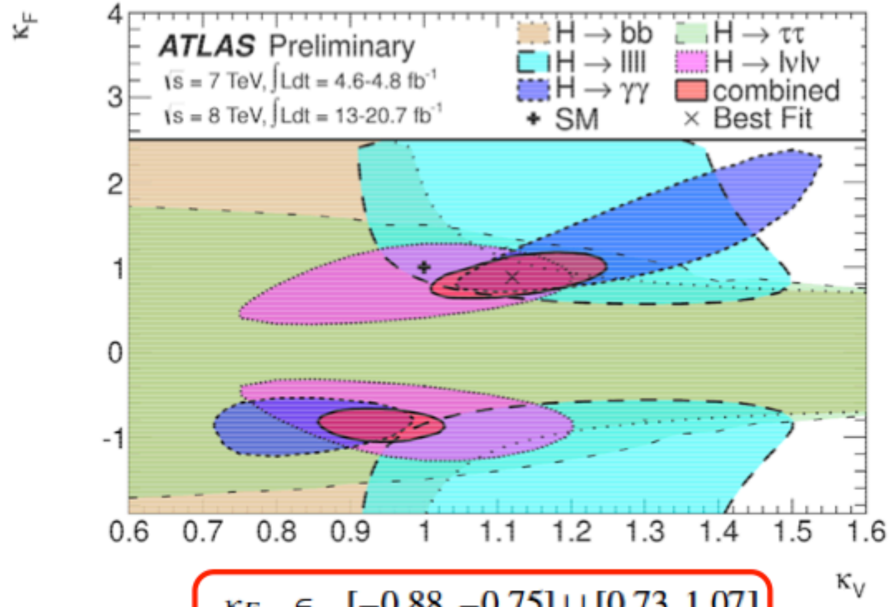
- Could be a mixture from more then one SU(2) doublet, singlet or triplets
- Could be a mixture of CP even and odd
- Could have enhanced/suppressed couplings to photons or gluons if there are heavy exotic charged/colored particles
- Could decay to exotic particles (e.g., dark matter)
- May not couple to fermions proportionally to their mass
- Could be composite and not unitarize WW scattering by itself

All these possibilities are currently allowed by data and are examined in ~1000 theory papers!

Higgs: Discovered! What we know now.

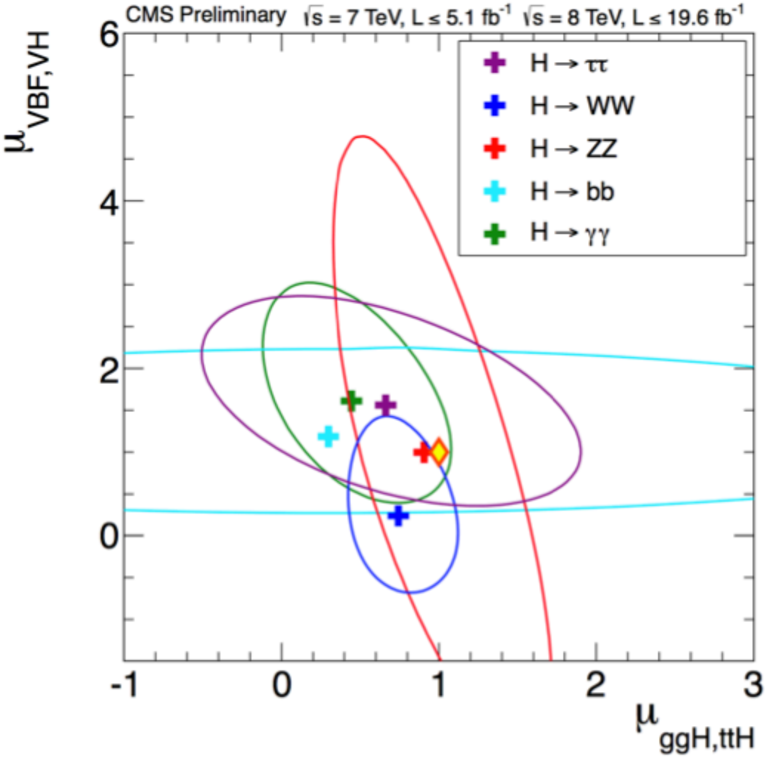
- Current fits to Higgs signal strengths

Assume no BSM contribution to the total Higgs width or the H→γγ loop

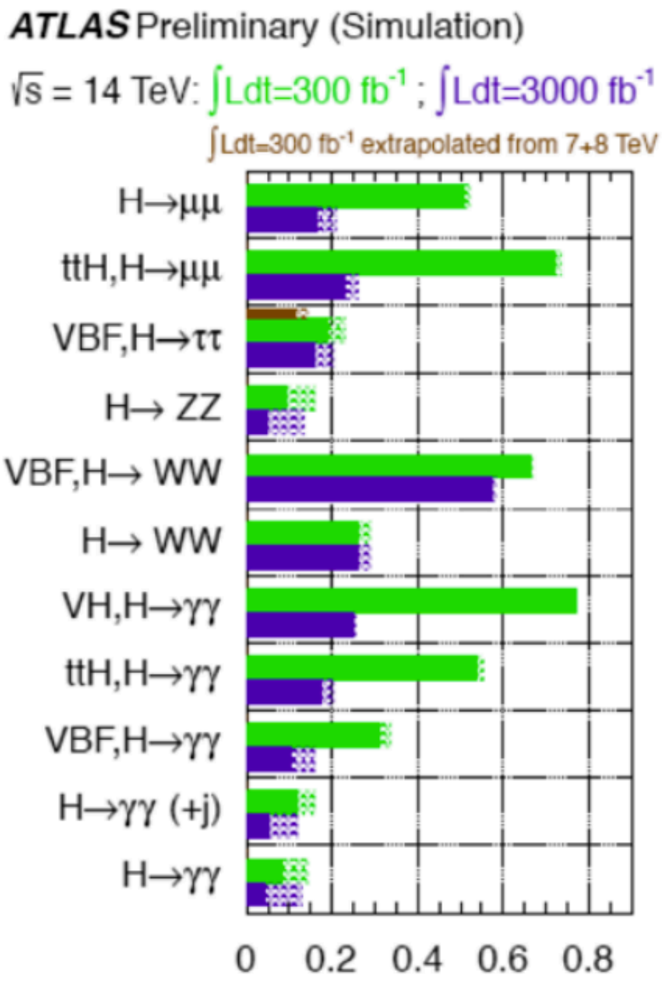


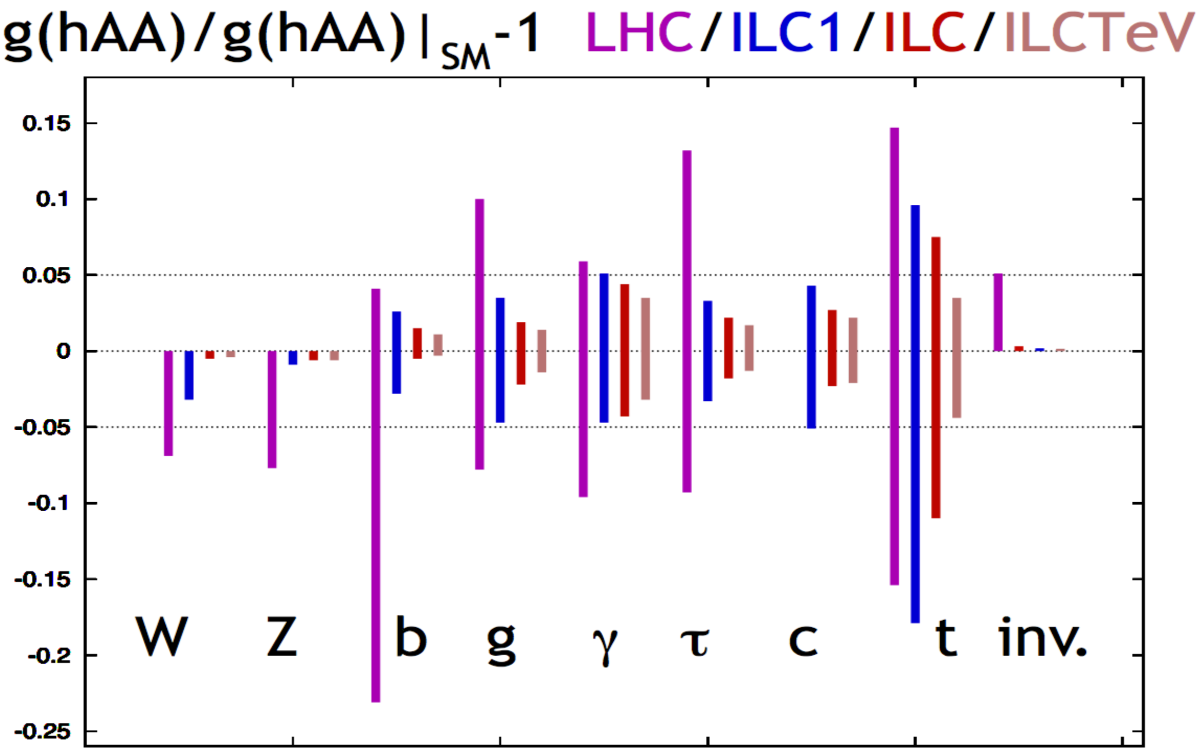
$$\kappa_F \in [-0.88, -0.75] \cup [0.73, 1.07]$$
$$\kappa_V \in [0.91, 0.97] \cup [1.05, 1.21]$$

68% CL interval



Higgs: Discovered! Future Precision.





Peskin: 1207.2516

This will be updated @Snowmas by the experiments

Federation of Diet Members for Promotion of the ILC

- multi-partisan group
- Re-invigorated after the Higgs discovery: now **>150 members!**
- New chair: Mr. Kawamura (former MEXT minister)
- Meet *twice a month*

Kickoff Meeting : July 31st, 2008

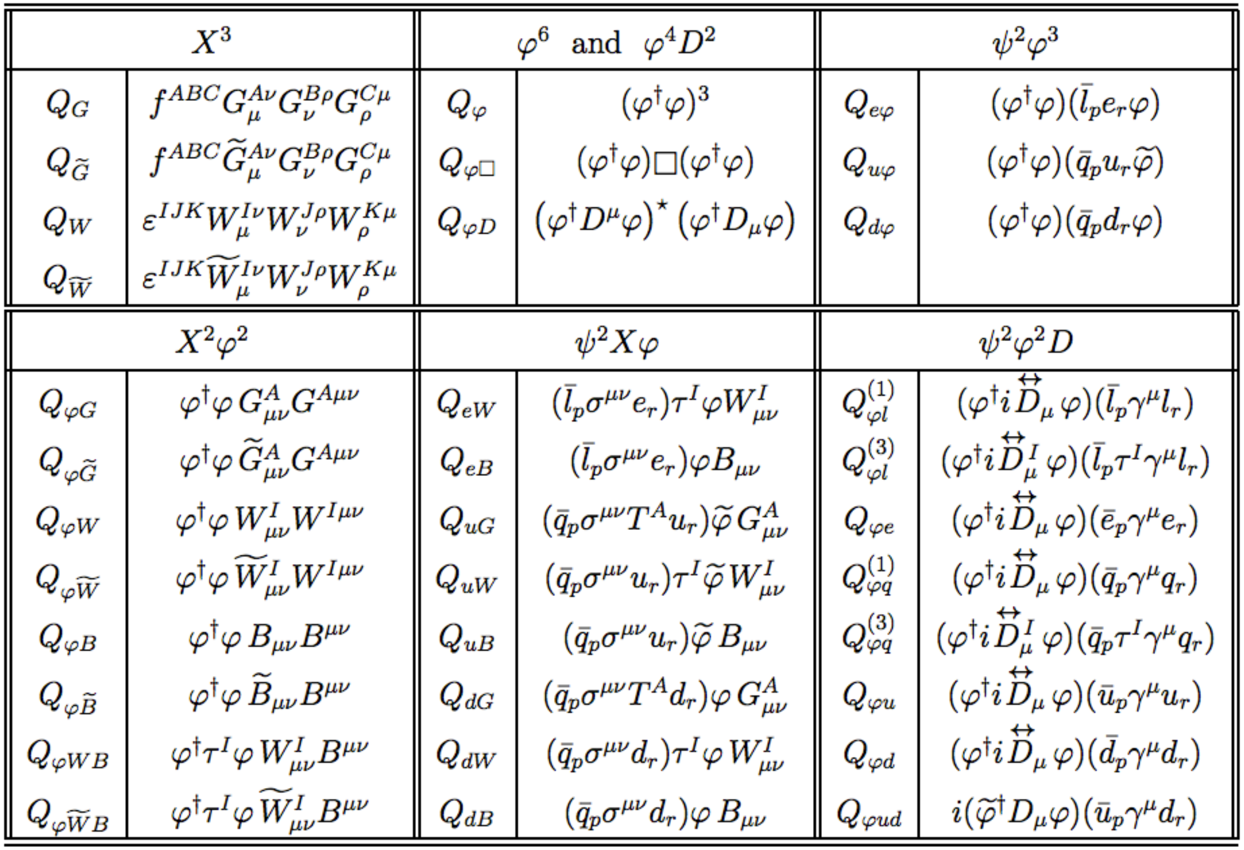
Murayama LP13

Japan is making overtures….


私たちは
国際リニアコライダー
計画を応援しています。
We support the International
Linear Collider Project.
一関商工会議所／岩手県ILC推進協議会

Higgs: Discovered! Full model-independent approach.

- In a complete analysis all 34 + 25 4-fermion operators need to be considered.
- Demonstrates the art of choosing a basis

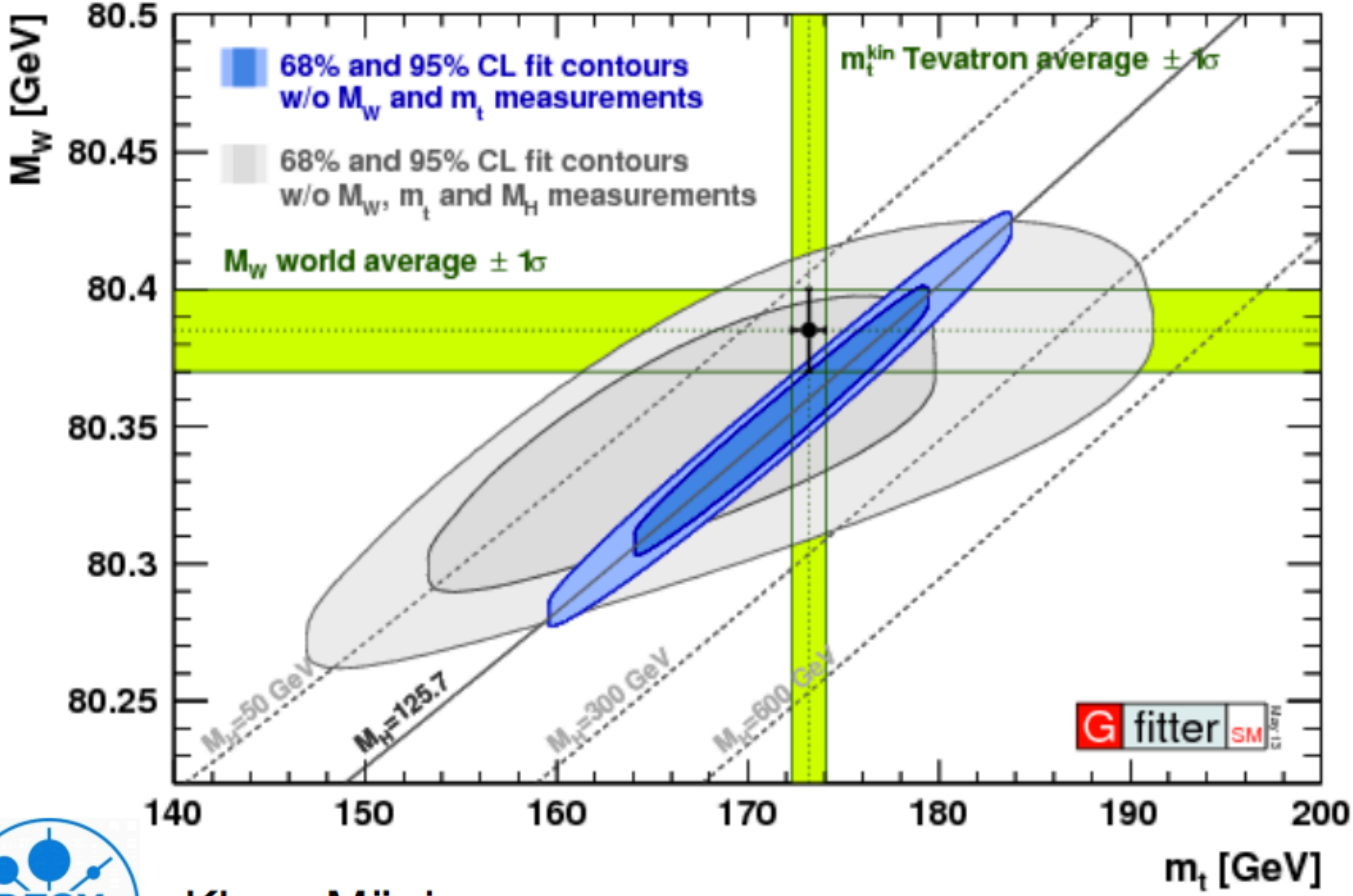


X^3		φ^6 and $\varphi^4 D^2$		$\psi^2\varphi^3$	
Q_G	$f^{ABC}G_\mu^{A\nu}G_\nu^{B\rho}G_\rho^{C\mu}$	Q_φ	$(\varphi^\dagger\varphi)^3$	$Q_{e\varphi}$	$(\varphi^\dagger\varphi)(\bar{l}_p e_r \varphi)$
$Q_{\widetilde{G}}$	$f^{ABC}\widetilde{G}_\mu^{A\nu}G_\nu^{B\rho}G_\rho^{C\mu}$	$Q_{\varphi\Box}$	$(\varphi^\dagger\varphi)\Box(\varphi^\dagger\varphi)$	$Q_{u\varphi}$	$(\varphi^\dagger\varphi)(\bar{q}_p u_r \widetilde{\varphi})$
Q_W	$\varepsilon^{IJK}W_\mu^{I\nu}W_\nu^{J\rho}W_\rho^{K\mu}$	$Q_{\varphi D}$	$\left(\varphi^\dagger D^\mu\varphi\right)^\star\left(\varphi^\dagger D_\mu\varphi\right)$	$Q_{d\varphi}$	$(\varphi^\dagger\varphi)(\bar{q}_p d_r \varphi)$
$Q_{\widetilde{W}}$	$\varepsilon^{IJK}\widetilde{W}_\mu^{I\nu}W_\nu^{J\rho}W_\rho^{K\mu}$				
$X^2\varphi^2$		$\psi^2 X\varphi$		$\psi^2\varphi^2 D$	
$Q_{\varphi G}$	$\varphi^\dagger\varphi\, G_{\mu\nu}^A G^{A\mu\nu}$	Q_{eW}	$(\bar{l}_p\sigma^{\mu\nu}e_r)\tau^I\varphi W_{\mu\nu}^I$	$Q_{\varphi l}^{(1)}$	$(\varphi^\dagger i\overleftrightarrow{D}_\mu\,\varphi)(\bar{l}_p\gamma^\mu l_r)$
$Q_{\varphi\widetilde{G}}$	$\varphi^\dagger\varphi\, \widetilde{G}_{\mu\nu}^A G^{A\mu\nu}$	Q_{eB}	$(\bar{l}_p\sigma^{\mu\nu}e_r)\varphi B_{\mu\nu}$	$Q_{\varphi l}^{(3)}$	$(\varphi^\dagger i\overleftrightarrow{D}_\mu^I\,\varphi)(\bar{l}_p\tau^I\gamma^\mu l_r)$
$Q_{\varphi W}$	$\varphi^\dagger\varphi\, W_{\mu\nu}^I W^{I\mu\nu}$	Q_{uG}	$(\bar{q}_p\sigma^{\mu\nu}T^A u_r)\widetilde{\varphi}\,G_{\mu\nu}^A$	$Q_{\varphi e}$	$(\varphi^\dagger i\overleftrightarrow{D}_\mu\,\varphi)(\bar{e}_p\gamma^\mu e_r)$
$Q_{\varphi\widetilde{W}}$	$\varphi^\dagger\varphi\, \widetilde{W}_{\mu\nu}^I W^{I\mu\nu}$	Q_{uW}	$(\bar{q}_p\sigma^{\mu\nu}u_r)\tau^I\widetilde{\varphi}\,W_{\mu\nu}^I$	$Q_{\varphi q}^{(1)}$	$(\varphi^\dagger i\overleftrightarrow{D}_\mu\,\varphi)(\bar{q}_p\gamma^\mu q_r)$
$Q_{\varphi B}$	$\varphi^\dagger\varphi\, B_{\mu\nu}B^{\mu\nu}$	Q_{uB}	$(\bar{q}_p\sigma^{\mu\nu}u_r)\widetilde{\varphi}\,B_{\mu\nu}$	$Q_{\varphi q}^{(3)}$	$(\varphi^\dagger i\overleftrightarrow{D}_\mu^I\,\varphi)(\bar{q}_p\tau^I\gamma^\mu q_r)$
$Q_{\varphi\widetilde{B}}$	$\varphi^\dagger\varphi\, \widetilde{B}_{\mu\nu}B^{\mu\nu}$	Q_{dG}	$(\bar{q}_p\sigma^{\mu\nu}T^A d_r)\varphi\,G_{\mu\nu}^A$	$Q_{\varphi u}$	$(\varphi^\dagger i\overleftrightarrow{D}_\mu\,\varphi)(\bar{u}_p\gamma^\mu u_r)$
$Q_{\varphi WB}$	$\varphi^\dagger\tau^I\varphi\, W_{\mu\nu}^I B^{\mu\nu}$	Q_{dW}	$(\bar{q}_p\sigma^{\mu\nu}d_r)\tau^I\varphi\,W_{\mu\nu}^I$	$Q_{\varphi d}$	$(\varphi^\dagger i\overleftrightarrow{D}_\mu\,\varphi)(\bar{d}_p\gamma^\mu d_r)$
$Q_{\varphi\widetilde{W}B}$	$\varphi^\dagger\tau^I\varphi\, \widetilde{W}_{\mu\nu}^I B^{\mu\nu}$	Q_{dB}	$(\bar{q}_p\sigma^{\mu\nu}d_r)\varphi\,B_{\mu\nu}$	$Q_{\varphi ud}$	$i(\widetilde{\varphi}^\dagger D_\mu\varphi)(\bar{u}_p\gamma^\mu d_r)$

Table 2: Dimension-six operators other than the four-fermion ones.

Grzadkowski etal 1008.4884

Updating the Electroweak Global Fits

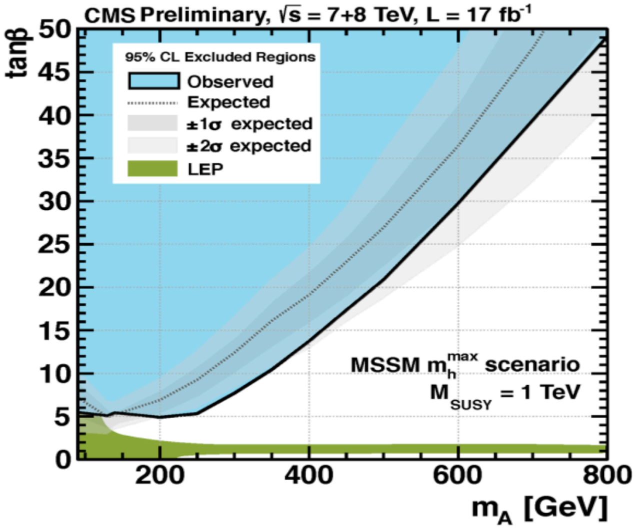


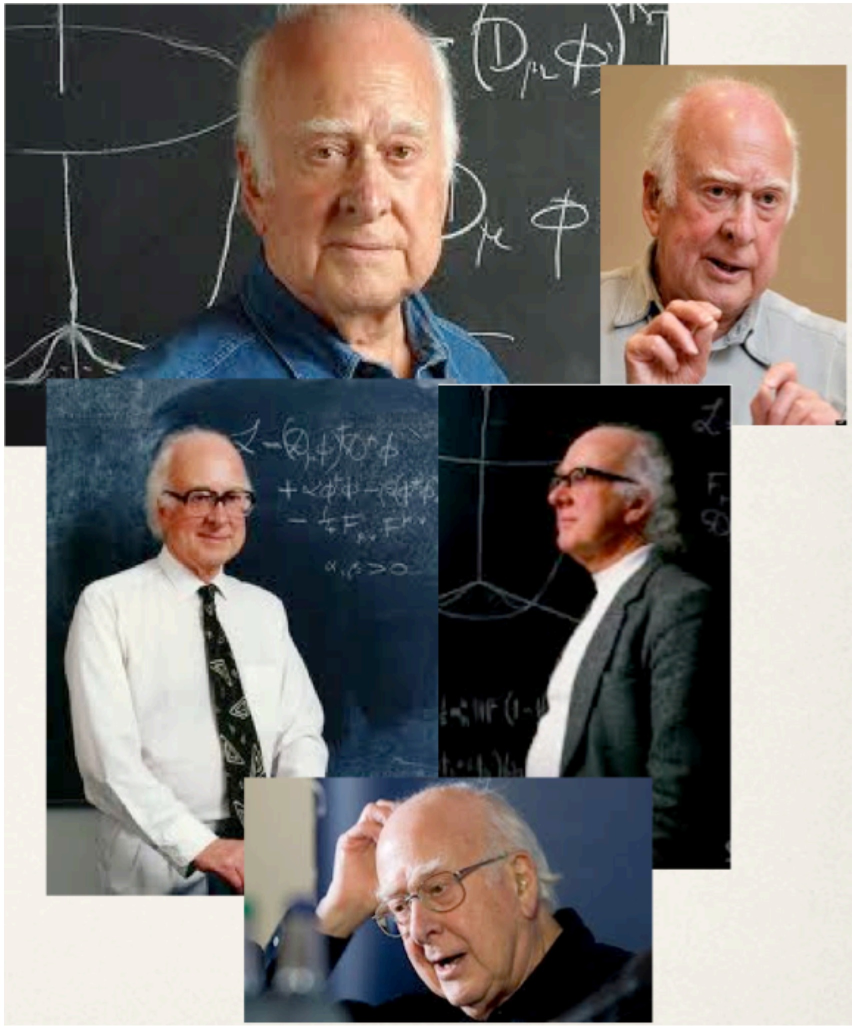
Klaus Mönig

LP13

Higgs: Discovered! How Many?

- How many Higgs are there?
- Minimal SUSY has 5…
- This search is a long-term challenge for the LHC
  - » Heavy Higgs undetectable wedge
  - » Light exotic states





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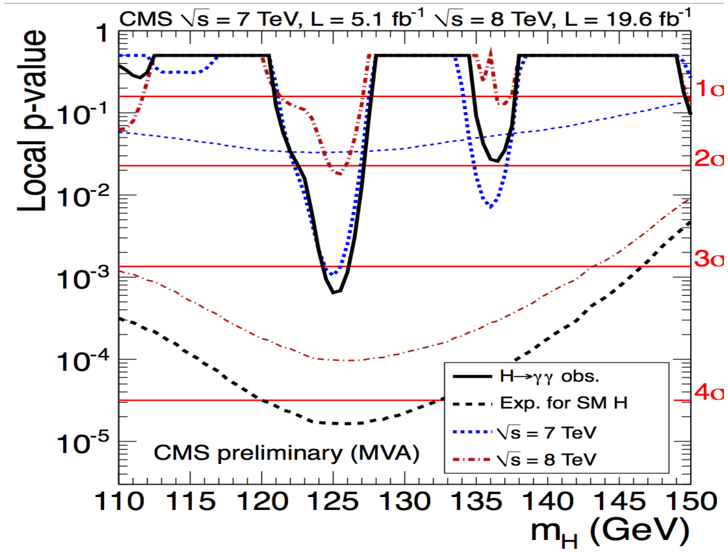
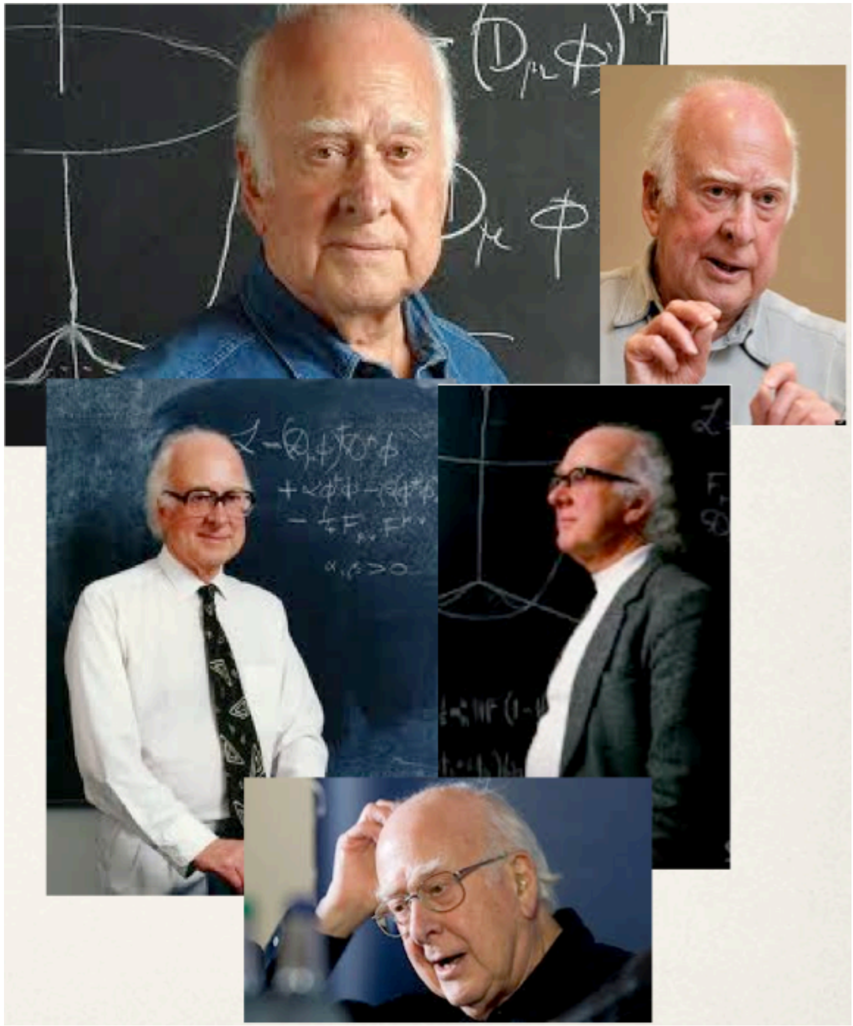




Higgs: Discovered! Connections.

- Is there a Higgs portal to Dark Matter?
- What is the origin of the EW scale?
- Does the Higgs trigger UV instabilities?
- Electroweak Baryogenesis
- How does the Higgs talk to neutrinos?
- Is the Higgs related to inflaction or Dark Energy?

Higgs is connected to all HEP Frontiers!

Where’s SUSY? Or any other BSM?

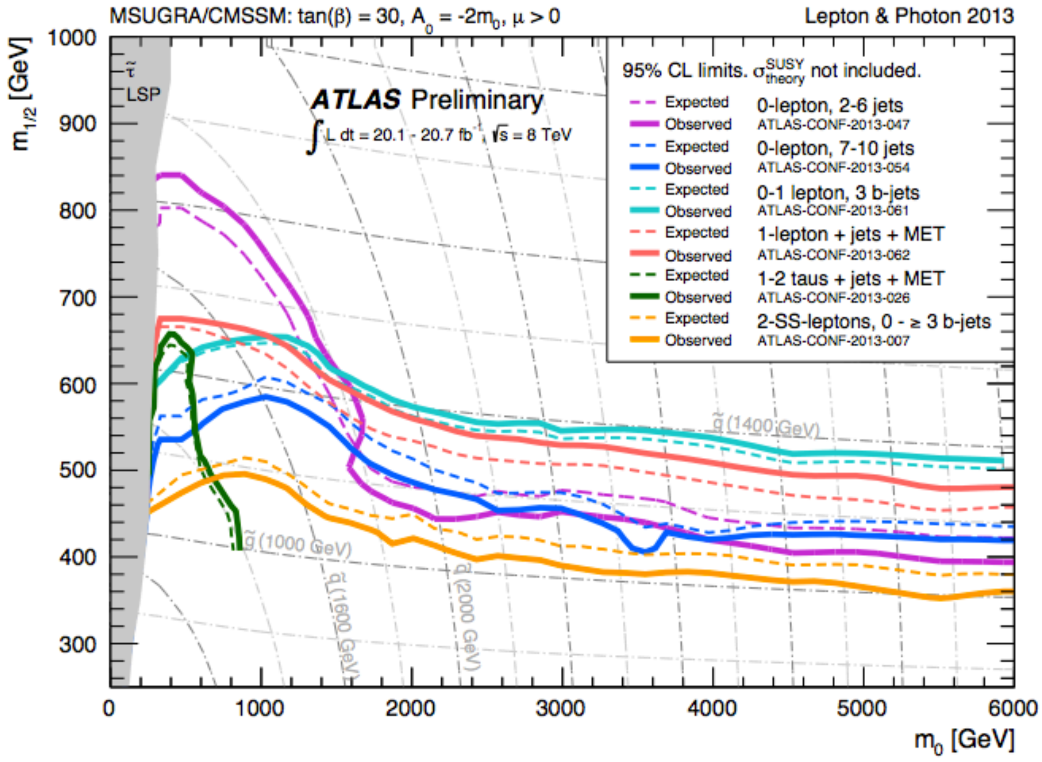
The canonical BSM paradigm

- Natural and MFV SUSY @EW scale
- Neutralino Dark Matter
- A grand desert populated at the high scale by a hidden sector for dynamical SUSY breaking, some heavy Majorana neutrinos, maybe PQ axions, inflatons
- Gauge coupling unification ~10^{16} GeV accompanied by GUTs or stringy unification
- Planck scale strings with structure to explain flavor

Talk by J. Lykken @KITP

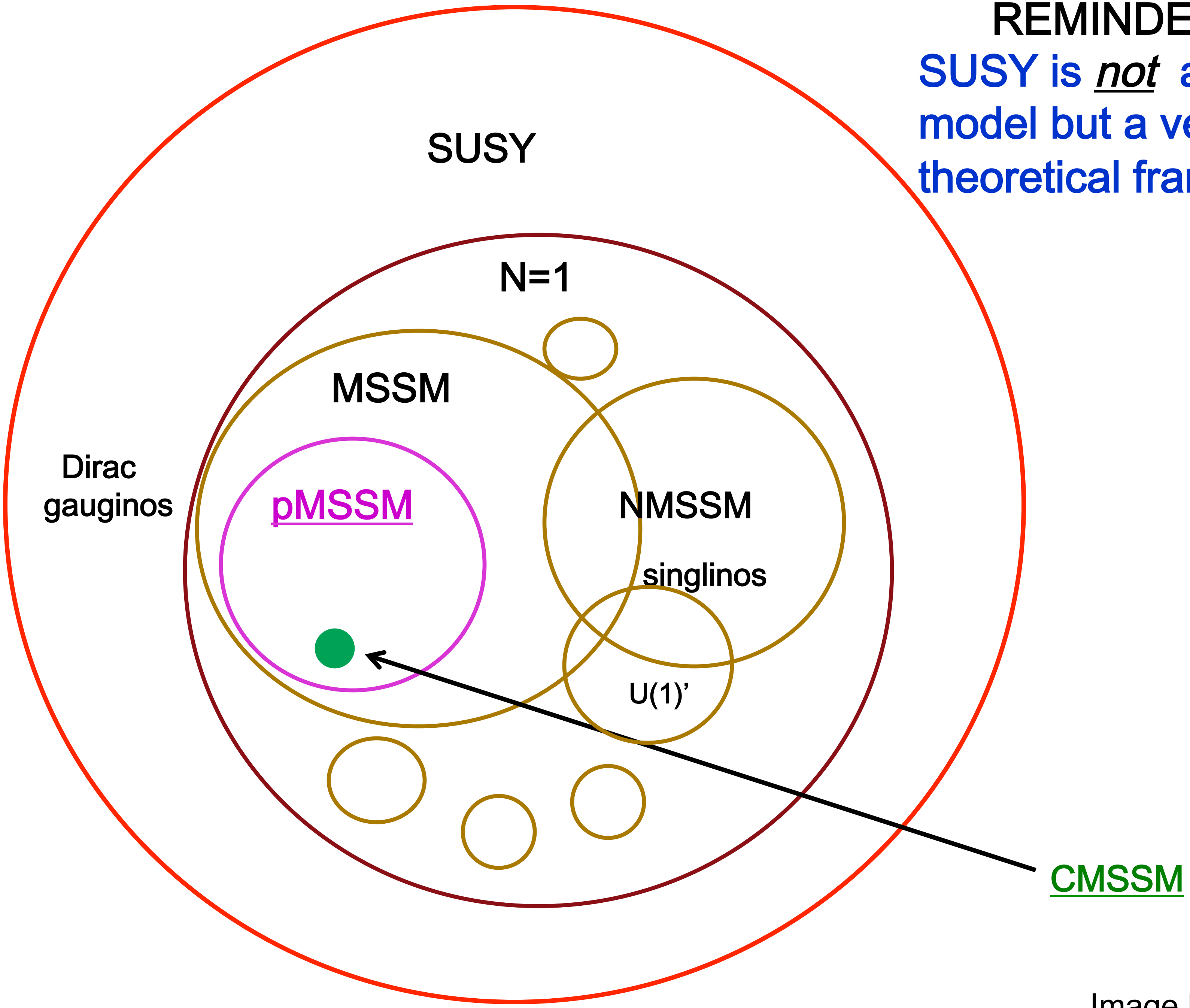
Where's SUSY?

No sign of SUSY (yet)…



REMINDER:

SUSY is *not* a single model but a very large theoretical framework



SUSY

N=1

MSSM

Dirac gauginos

pMSSM

NMSSM

singlinos

U(1)’

CMSSM

Image by T. Rizzo

Where's SUSY? The pMSSM Model Framework

The phenomenological MSSM (pMSSM)

- Most general CP-conserving MSSM with R-parity
- Minimal Flavor Violation, First 2 sfermion generations are degenerate w/ negligible Yukawas
- No GUT, SUSY-breaking, high-scale assumptions!
- 19/20 real, weak-scale parameters (Neutralino/Gravitino LSP)

scalars:

$m_{Q_1}, m_{Q_3}, m_{u_1}, m_{d_1}, m_{u_3}, m_{d_3}, m_{L_1}, m_{L_3}, m_{e_1}, m_{e_3}$

gauginos: M_1, M_2, M_3

tri-linear couplings: A_b, A_t, A_τ

Higgs/Higgsino: $\mu, M_A, \tan\beta$

(Gravitino: M_G)

Supersymmetry without Prejudice

Berger, Gainer, JLH, Rizzo 0812.0980

Where's SUSY? The pMSSM

Scan with Linear Priors

Perform large scan over Parameters

100 GeV $\leq m_{\mathrm{sfermions}} \leq$ 4 TeV

50 GeV $\leq |M_1, M_2, \mu| \leq$ 4 TeV

400 GeV $\leq M_3 \leq$ 4 TeV

100 GeV $\leq M_A \leq$ 4 TeV

$1 \leq \tan\beta \leq 60$

$|A_{t,b,\tau}| \leq$ 4 TeV

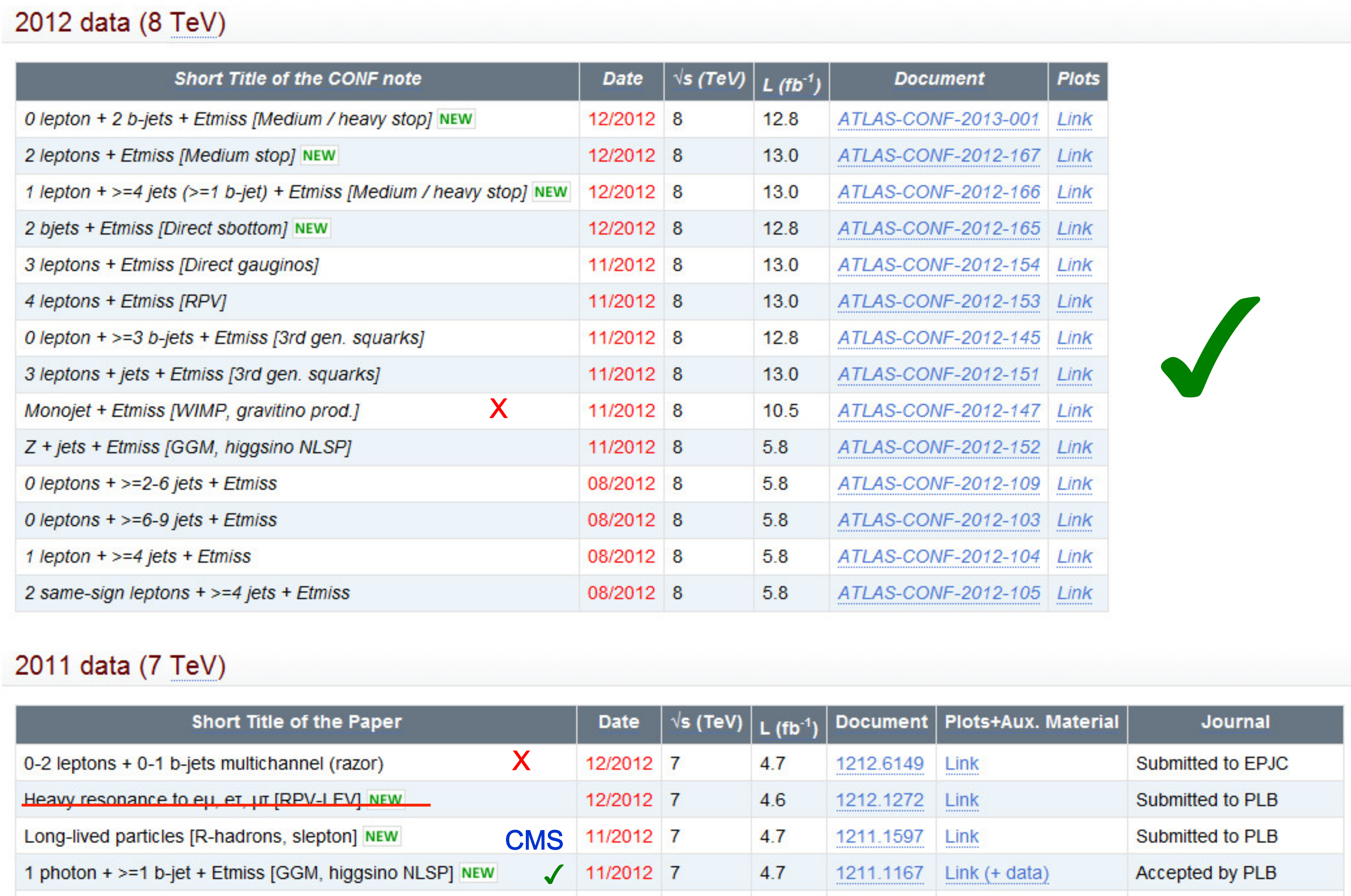
(1 ev $\leq m_G \leq$ 1 TeV) (log prior)

Subject these points to Constraints from:

- Flavor physics
- EW precision measurements
- Collider searches
- Cosmology

~225,000 models survive constraints for each LSP type!

Employ all publically released ATLAS analyses since 1 March



2012 data (8 TeV)

Short Title of the CONF note	Date	$\sqrt{s}$ (TeV)	L (fb^{-1})	Document	Plots
0 lepton + 2 b-jets + Etmiss [Medium / heavy stop] NEW	12/2012	8	12.8	ATLAS-CONF-2013-001	Link
2 leptons + Etmiss [Medium stop] NEW	12/2012	8	13.0	ATLAS-CONF-2012-167	Link
1 lepton + >=4 jets (>=1 b-jet) + Etmiss [Medium / heavy stop] NEW	12/2012	8	13.0	ATLAS-CONF-2012-166	Link
2 bjets + Etmiss [Direct sbottom] NEW	12/2012	8	12.8	ATLAS-CONF-2012-165	Link
3 leptons + Etmiss [Direct gauginos]	11/2012	8	13.0	ATLAS-CONF-2012-154	Link
4 leptons + Etmiss [RPV]	11/2012	8	13.0	ATLAS-CONF-2012-153	Link
0 lepton + >=3 b-jets + Etmiss [3rd gen. squarks]	11/2012	8	12.8	ATLAS-CONF-2012-145	Link
3 leptons + jets + Etmiss [3rd gen. squarks]	11/2012	8	13.0	ATLAS-CONF-2012-151	Link
Monojet + Etmiss [WIMP, gravitino prod.] X	11/2012	8	10.5	ATLAS-CONF-2012-147	Link
Z + jets + Etmiss [GGM, higgsino NLSP]	11/2012	8	5.8	ATLAS-CONF-2012-152	Link
0 leptons + >=2-6 jets + Etmiss	08/2012	8	5.8	ATLAS-CONF-2012-109	Link
0 leptons + >=6-9 jets + Etmiss	08/2012	8	5.8	ATLAS-CONF-2012-103	Link
1 lepton + >=4 jets + Etmiss	08/2012	8	5.8	ATLAS-CONF-2012-104	Link
2 same-sign leptons + >=4 jets + Etmiss	08/2012	8	5.8	ATLAS-CONF-2012-105	Link

✓

2011 data (7 TeV)

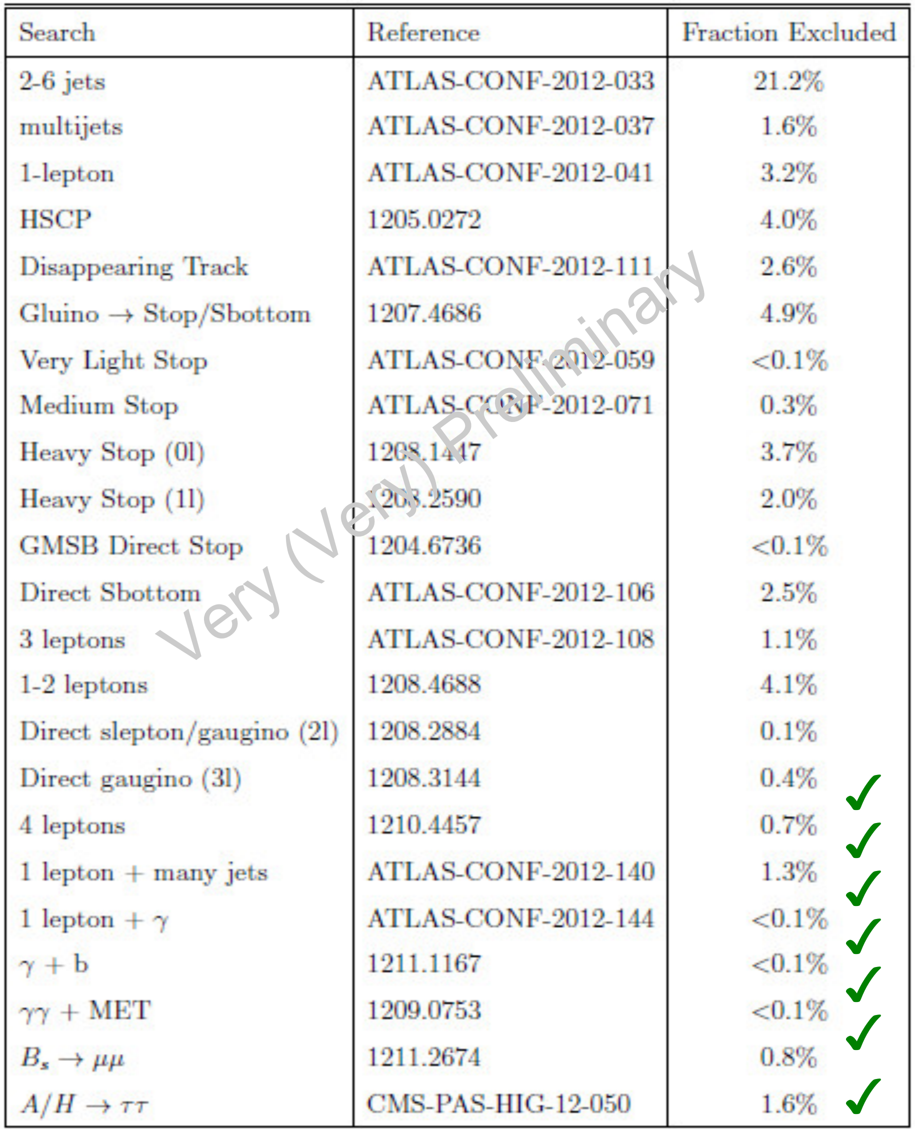
Short Title of the Paper	Date	$\sqrt{s}$ (TeV)	L (fb^{-1})	Document	Plots+Aux. Material	Journal
0-2 leptons + 0-1 b-jets multichannel (razor) X	12/2012	7	4.7	1212.6149	Link	Submitted to EPJC
~~Heavy resonance to eμ, eτ, μτ [RPV-LFV] NEW~~	12/2012	7	4.6	1212.1272	Link	Submitted to PLB
Long-lived particles [R-hadrons, slepton] NEW CMS	11/2012	7	4.7	1211.1597	Link	Submitted to PLB
1 photon + >=1 b-jet + Etmiss [GGM, higgsino NLSP] NEW ✓	11/2012	7	4.7	1211.1167	Link (+ data)	Accepted by PLB

Muon + displaced vertex [RPV]	✓	10/2012	7	4.7	1210.7451	Link	Accepted by PLB
~~Pair of 2-jet resonance [N=1/2 scalar gluon]~~		10/2012	7	4.6	1210.4826	Link	Accepted by EPJC
~~Pair of 3-jet resonance [RPV]~~		10/2012	7	4.6	1210.4813	Link	JHEP 12 (2012) 086
>=4 leptons + Etmiss [RPV]		10/2012	7	4.7	1210.4457	Link (+ data)	JHEP 12 (2012) 124
Monojet + Etmiss [WIMP]	X	10/2012	7	4.7	1210.4491	Link	Submitted to JHEP
Disappearing track + jets + Etmiss [Direct long-lived charginos - AMSB]	✓	10/2012	7	4.7	1210.2852	Link	JHEP 01 (2013) 131
~~1-2 taus + 0-1 leptons + jets + Etmiss [GMSB]~~		10/2012	7	4.7	1210.1314	Link	EPJC 72 (2012) 2215
Monophoton [ADD, WIMP]	X	09/2012	7	4.7	1209.4625	Link	PRL 110 (2013) 011802
2 leptons + jets + Etmiss [Medium stop]	✓	09/2012	7	4.7	1209.4186	Link (+ data)	JHEP 11 (2012) 094
1-2 b-jets + 1-2 leptons + jets + Etmiss [Light Stop]	✓	09/2012	7	4.7	1209.2102	Link	Accepted by PLB
2 photons + Etmiss [GGM, bino NLSP]	✓	09/2012	7	4.7	1209.0753	Link (+ data)	PLB 718 (2012) 411
1-2 leptons + >=2-4 jets + Etmiss	✓	08/2012	7	4.7	1208.4688	Link	PRD 86 (2012) 092002
2 leptons + >=1 jet + Etmiss [Very light stop]	✓	08/2012	7	4.7	1208.4305	Link (+ data)	EPJC (2012) 72 2237
3 leptons + Etmiss [Direct gauginos]	✓	08/2012	7	4.7	1208.3144	Link (+ data)	PLB 718 (2013) 841
2 leptons + Etmiss [Direct gauginos/sleptons]	✓	08/2012	7	4.7	1208.2884	Link	PLB 718 (2013) 879
1 lepton + >=4 jets (>=1 b-jet) + Etmiss [Heavy stop]	✓	08/2012	7	4.7	1208.2590	Link (+ data)	PRL 109 (2012) 211803
0 lepton + 1-2 b-jet + 5-4 jets + Etmiss [Heavy stop]	✓	08/2012	7	4.7	1208.1447	Link (+ data)	PRL 109 (2012) 211802
0 lepton + >=2-6 jets + Etmiss	✓	08/2012	7	4.7	1208.0949	Link (+ data)	PRD 87 (2013) 012008
0 lepton + >=3 b-jets + >=(1-3) jets + Etmiss [Gluino med. stop/sb]	✓	07/2012	7	4.7	1207.4686	Link	EPJC 72 (2012) 2174
0 lepton + >=(6-9) jets + Etmiss	✓	06/2012	7	4.7	1206.1760	Link (+ data)	JHEP 1207 (2012) 167

	Short Title of the Conf. note	Date	√s (TeV)	L (fb^{-1})	Document	Plots
✓	*1 photon + 1 lepton + Etmiss [GGM, wino NLSP]*	10/2012	7	4.8	*ATLAS-CONF-2012-144*	*Link*
✓	*1 lepton + >=7 jets + Etmiss*	10/2012	7	4.7	*ATLAS-CONF-2012-140*	*Link*
✓	*3 leptons + jets + Etmiss [3rd gen. squarks]*	08/2012	7	4.7	*ATLAS-CONF-2012-108*	*Link*
✓	*2 b-jets + Etmiss [Direct sbottom]*	08/2012	7	4.7	*ATLAS-CONF-2012-106*	*Link*
	General new phenomena search	08/2012	7	4.7	*ATLAS-CONF-2012-107*	*Link*
	Disappearing track + jets + Etmiss [AMSB Strong Prod.]	03/2012	7	4.7	*ATLAS-CONF-2012-034*	*Link*

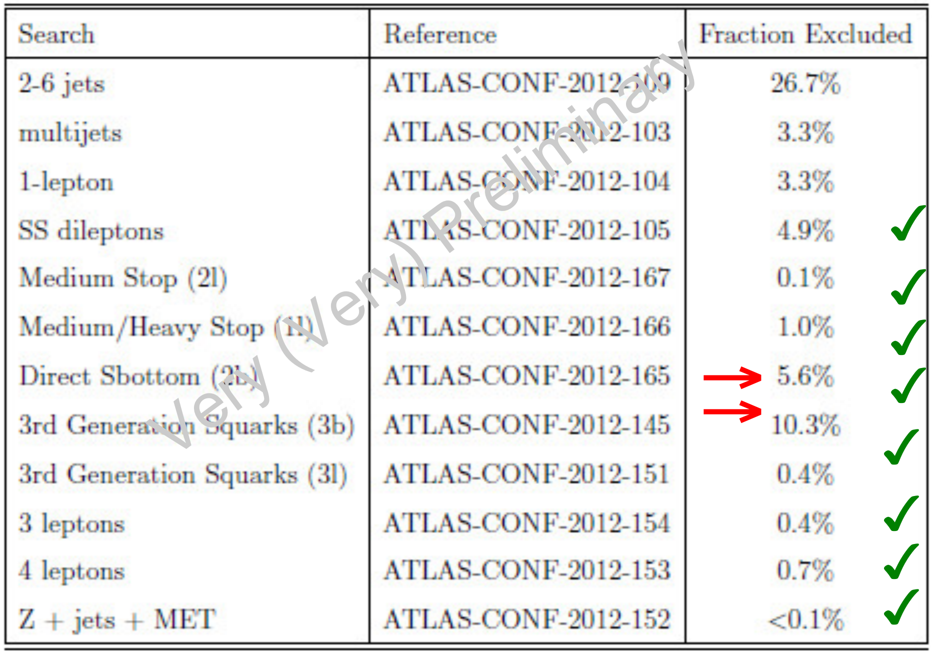
LHC Search Results for the pMSSM with Neutralino LSP: percentage of models excluded by data

7 TeV Searches



Search	Reference	Fraction Excluded	
2-6 jets	ATLAS-CONF-2012-033	21.2%	
multijets	ATLAS-CONF-2012-037	1.6%	
1-lepton	ATLAS-CONF-2012-041	3.2%	
HSCP	1205.0272	4.0%	
Disappearing Track	ATLAS-CONF-2012-111	2.6%	
Gluino → Stop/Sbottom	1207.4686	4.9%	
Very Light Stop	ATLAS-CONF-2012-059	<0.1%	
Medium Stop	ATLAS-CONF-2012-071	0.3%	
Heavy Stop (0l)	1208.1447	3.7%	
Heavy Stop (1l)	1208.2590	2.0%	
GMSB Direct Stop	1204.6736	<0.1%	
Direct Sbottom	ATLAS-CONF-2012-106	2.5%	
3 leptons	ATLAS-CONF-2012-108	1.1%	
1-2 leptons	1208.4688	4.1%	
Direct slepton/gaugino (2l)	1208.2884	0.1%	
Direct gaugino (3l)	1208.3144	0.4%	✓
4 leptons	1210.4457	0.7%	✓
1 lepton + many jets	ATLAS-CONF-2012-140	1.3%	✓
1 lepton + γ	ATLAS-CONF-2012-144	<0.1%	✓
γ + b	1211.1167	<0.1%	✓
$\gamma\gamma$ + MET	1209.0753	<0.1%	✓
$B_s \to \mu\mu$	1211.2674	0.8%	
$A/H \to \tau\tau$	CMS-PAS-HIG-12-050	1.6%	✓

8 TeV Searches



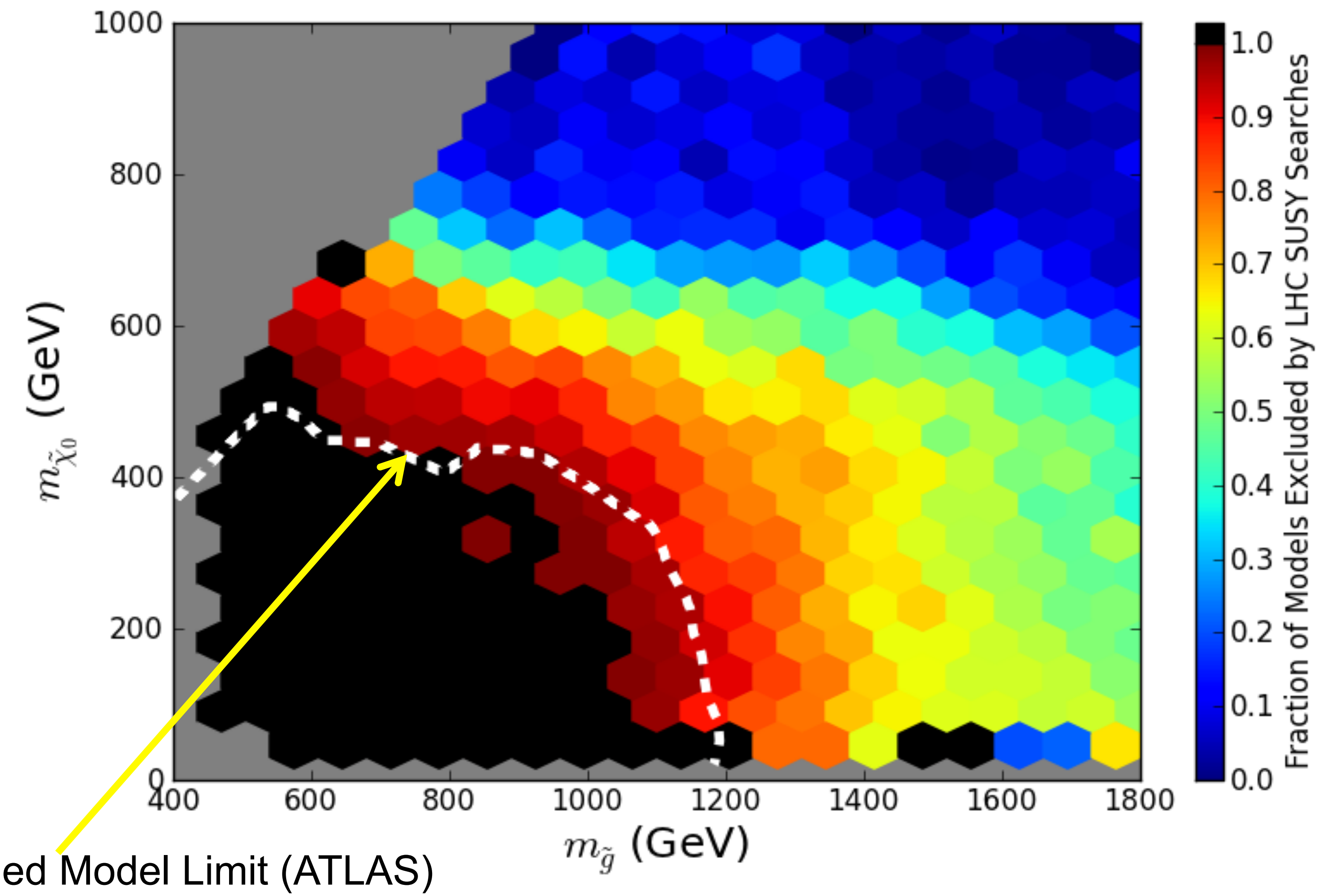
Search	Reference	Fraction Excluded	
2-6 jets	ATLAS-CONF-2012-109	26.7%	
multijets	ATLAS-CONF-2012-103	3.3%	
1-lepton	ATLAS-CONF-2012-104	3.3%	
SS dileptons	ATLAS-CONF-2012-105	4.9%	✓
Medium Stop (2l)	ATLAS-CONF-2012-167	0.1%	✓
Medium/Heavy Stop (1l)	ATLAS-CONF-2012-166	1.0%	✓
Direct Sbottom (2b)	ATLAS-CONF-2012-165	→ 5.6%	✓
3rd Generation Squarks (3b)	ATLAS-CONF-2012-145	→ 10.3%	✓
3rd Generation Squarks (3l)	ATLAS-CONF-2012-151	0.4%	
3 leptons	ATLAS-CONF-2012-154	0.4%	✓
4 leptons	ATLAS-CONF-2012-153	0.7%	✓
Z + jets + MET	ATLAS-CONF-2012-152	<0.1%	✓

✓ = Newly added search

Total Excluded ~35% (was ~32% !)
No effect from m_h = 126±3 GeV cut

The new 8 TeV 3rd gen searches are seen to have more power !

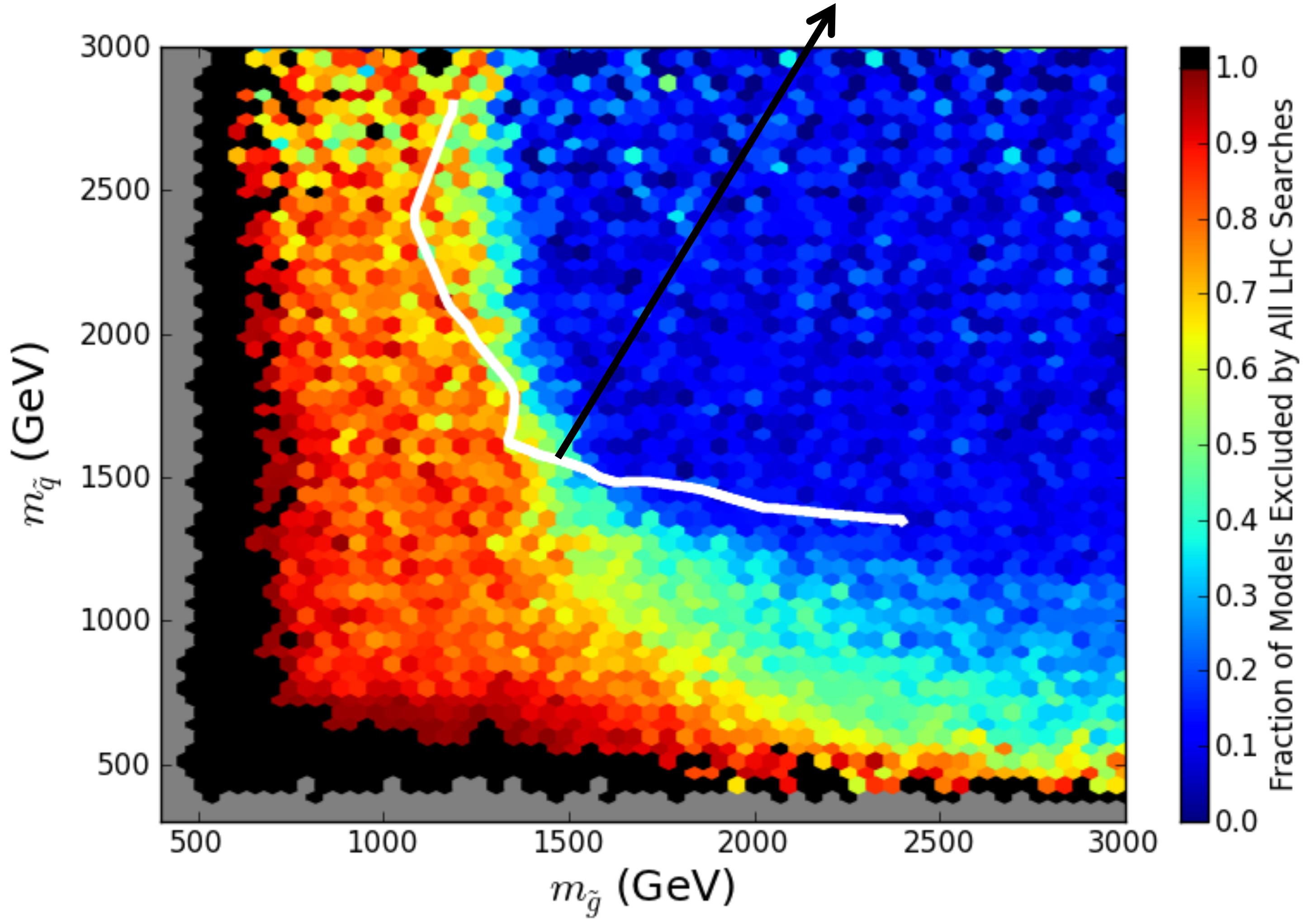
Effects of LHC Searches on Neutralino LSP Sample



Simplified Model Limit (ATLAS)

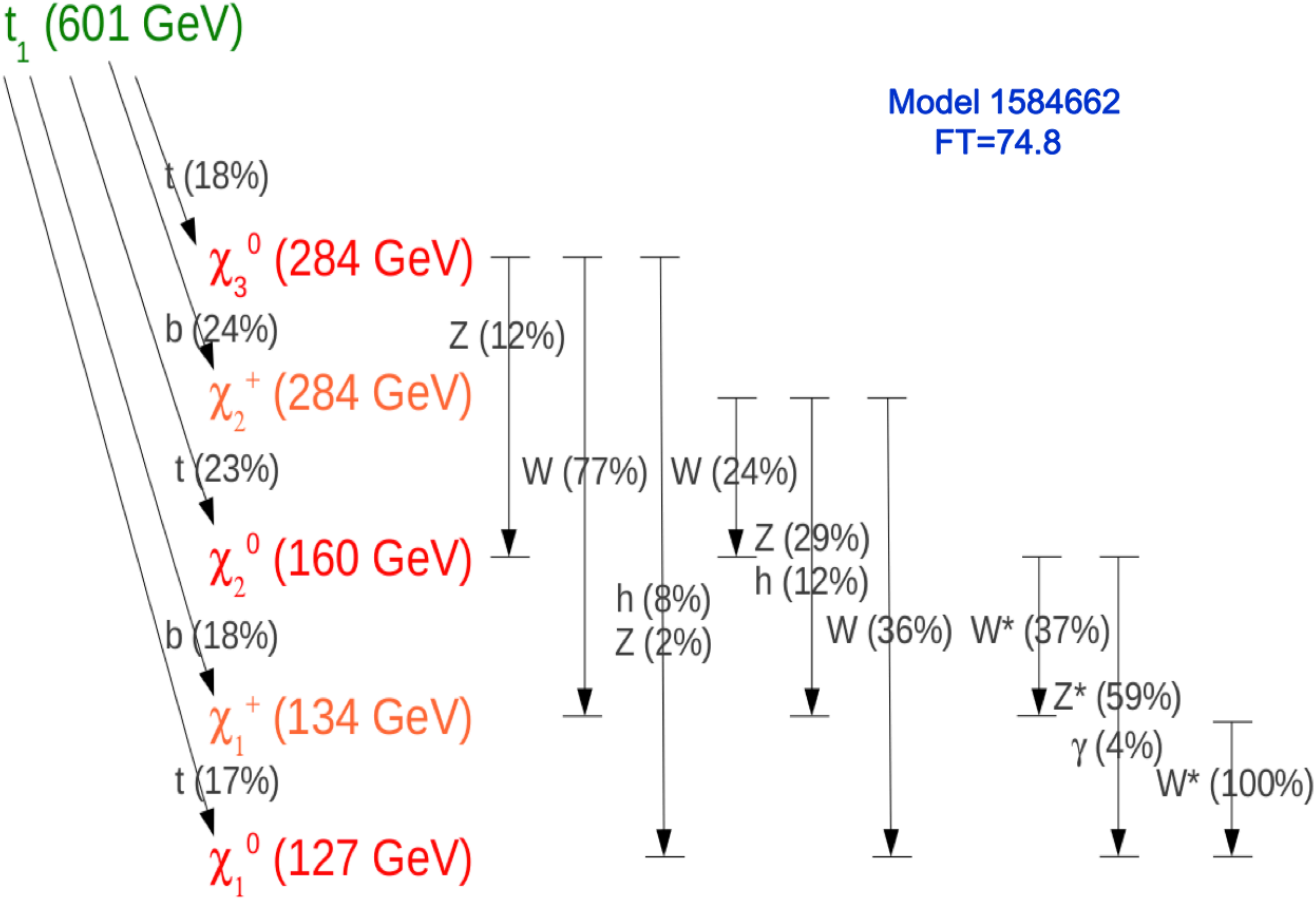
Effects of LHC Searches on Neutralino LSP Model Set 7/8 TeV

Simplified Model result (ATLAS)



All available analyses through 3/1/13

37% of 225k model set excluded


t_1 (601 GeV)
Model 1584662
FT=74.8
t (18%)
χ_3^0 (284 GeV)
b (24%)
χ_2^+ (284 GeV)
t (23%)
χ_2^0 (160 GeV)
b (18%)
χ_1^+ (134 GeV)
t (17%)
χ_1^0 (127 GeV)
Z (12%)
W (77%)
W (24%)
Z (29%)
h (12%)
h (8%)
Z (2%)
W (36%)
W* (37%)
Z* (59%)
γ (4%)
W* (100%)

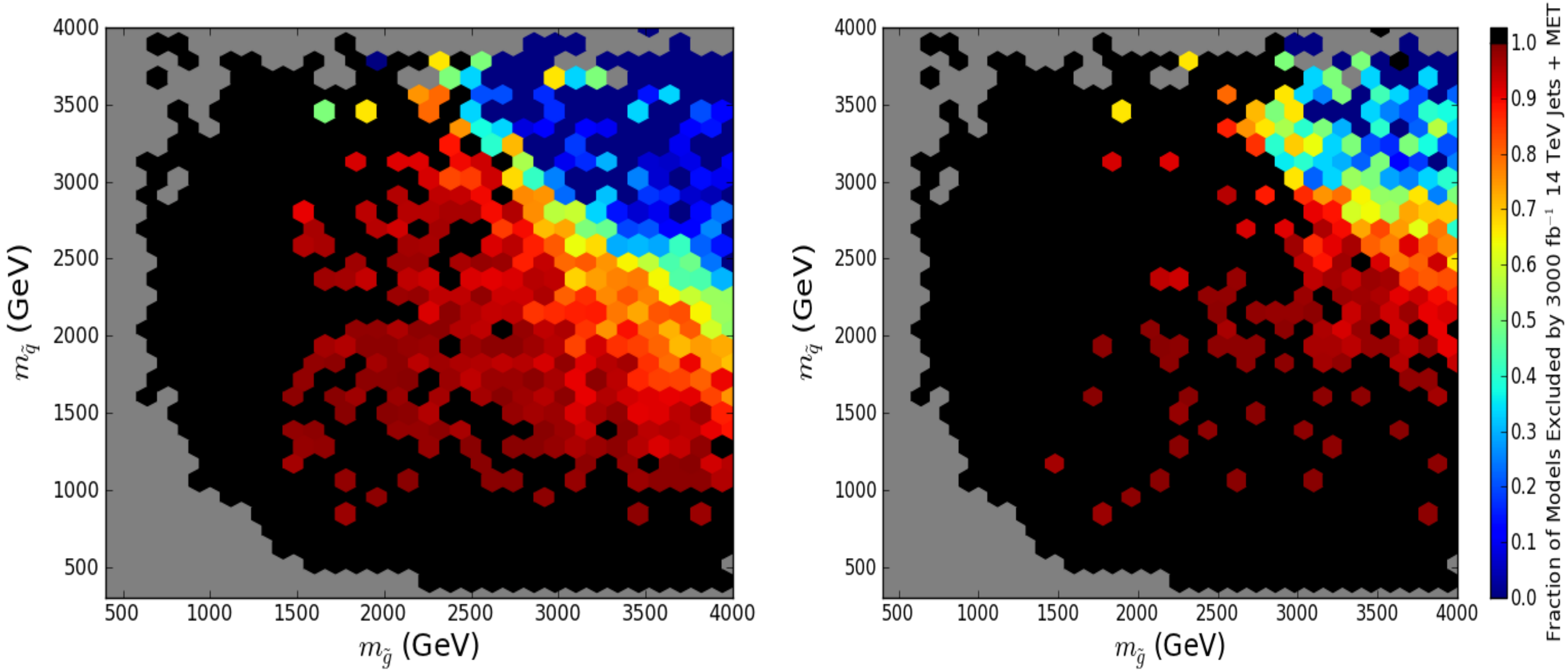
14 TeV LHC pMSSM Coverage for 0.3 & 3 ab^{-1}

Jets+MET Analysis only (ATLAS European Strategy Study)

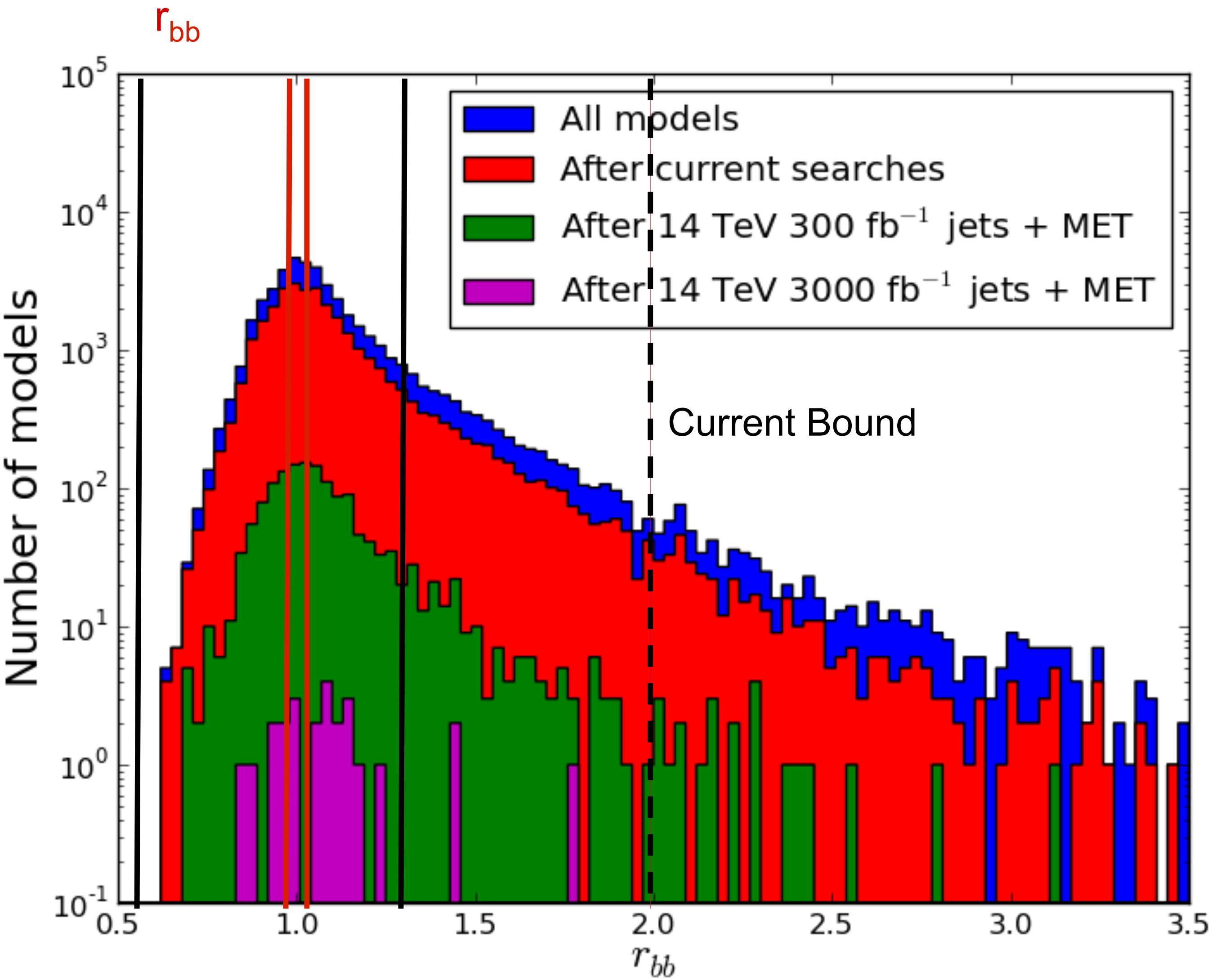
225k Neutralino LSP model set

300 fb^{-1}: 92.1% of models excluded

3 ab^{-1}: 97.5% of models excluded



Higgs partial widths in the pMSSM: $b\bar{b}$



Where's BSM?

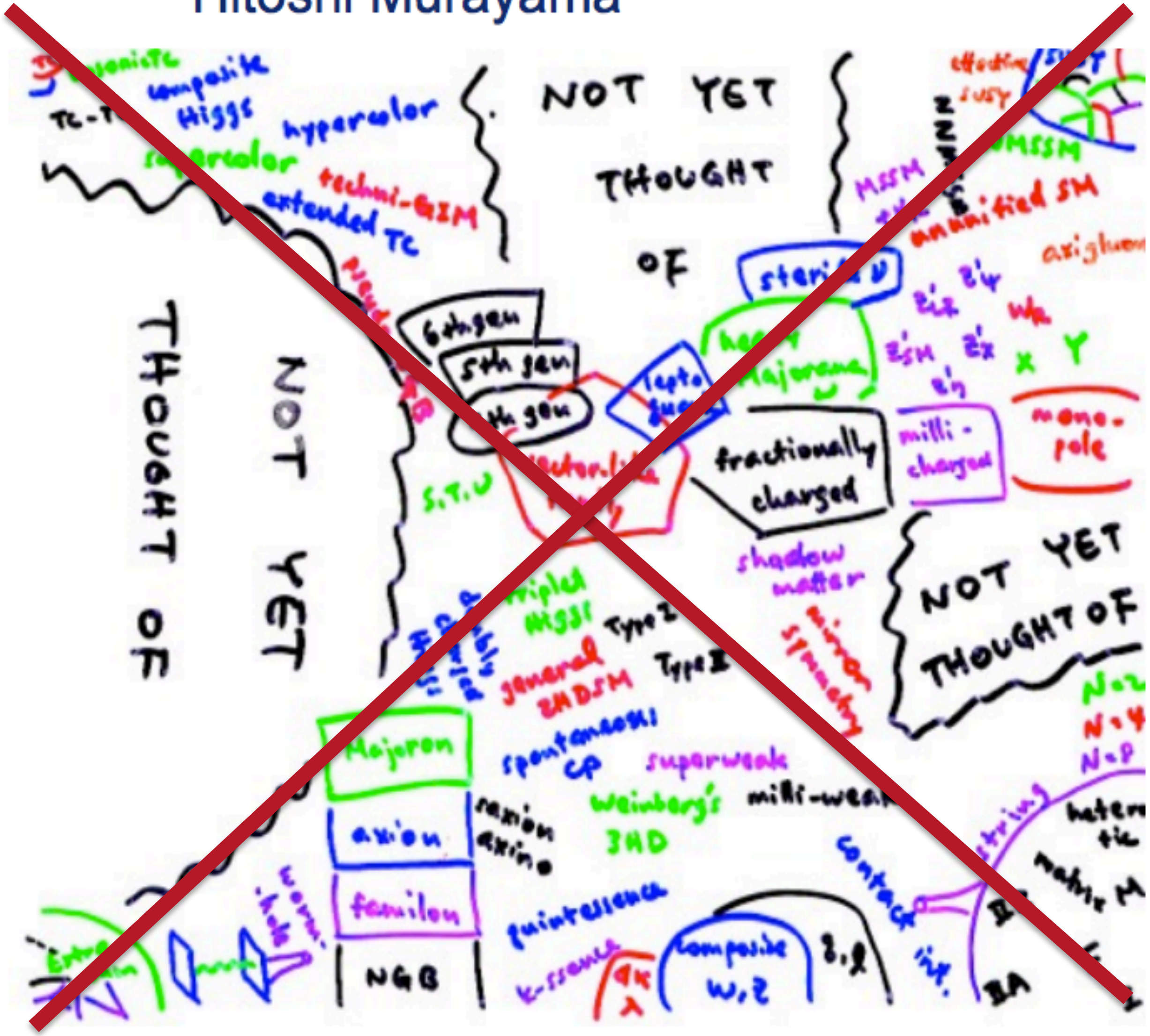
- Lots of possibilities!

Hitoshi Murayama

Where's BSM?

- Lots of possibilities!
- None have been found (yet)

Hitoshi Murayama



Where’s BSM?

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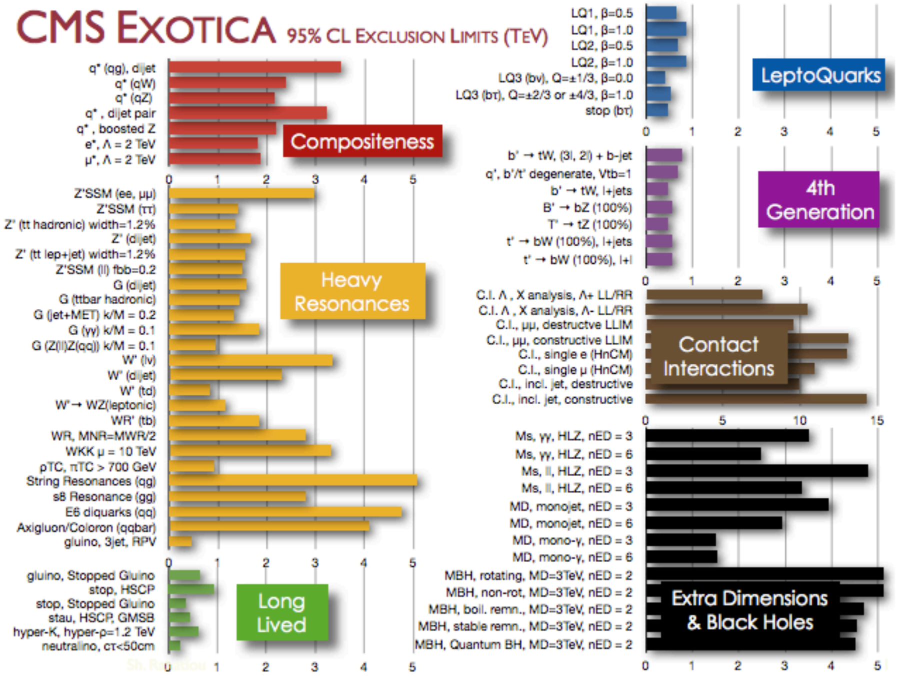
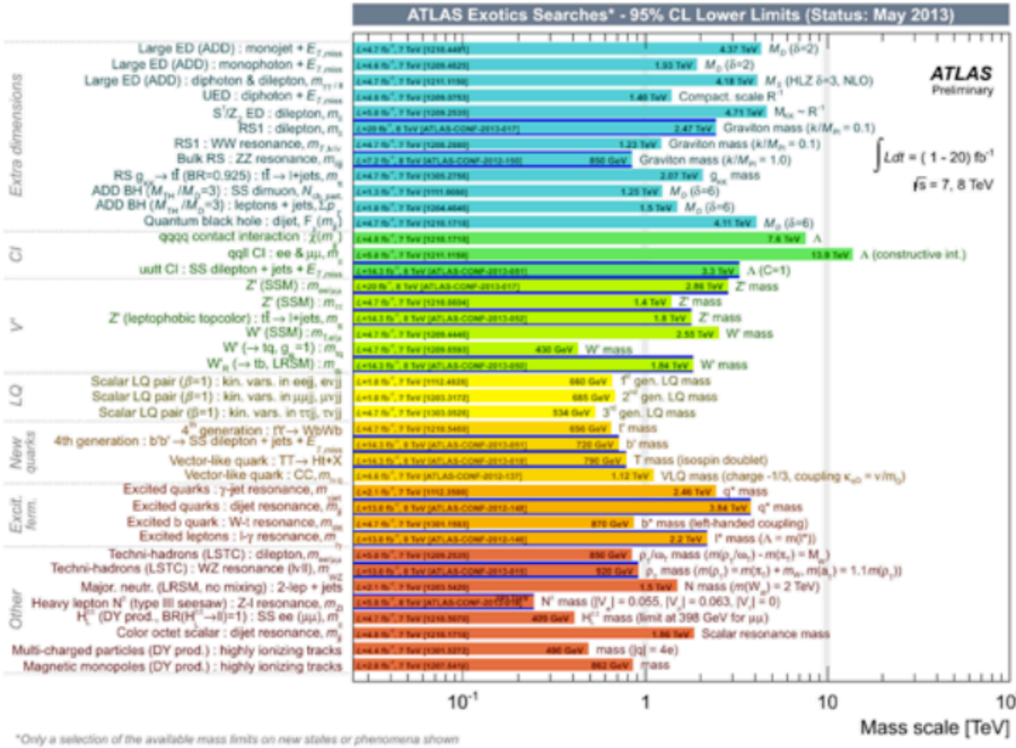




*Only a selection of the available mass limits on new states or phenomena shown

Where’s BSM?

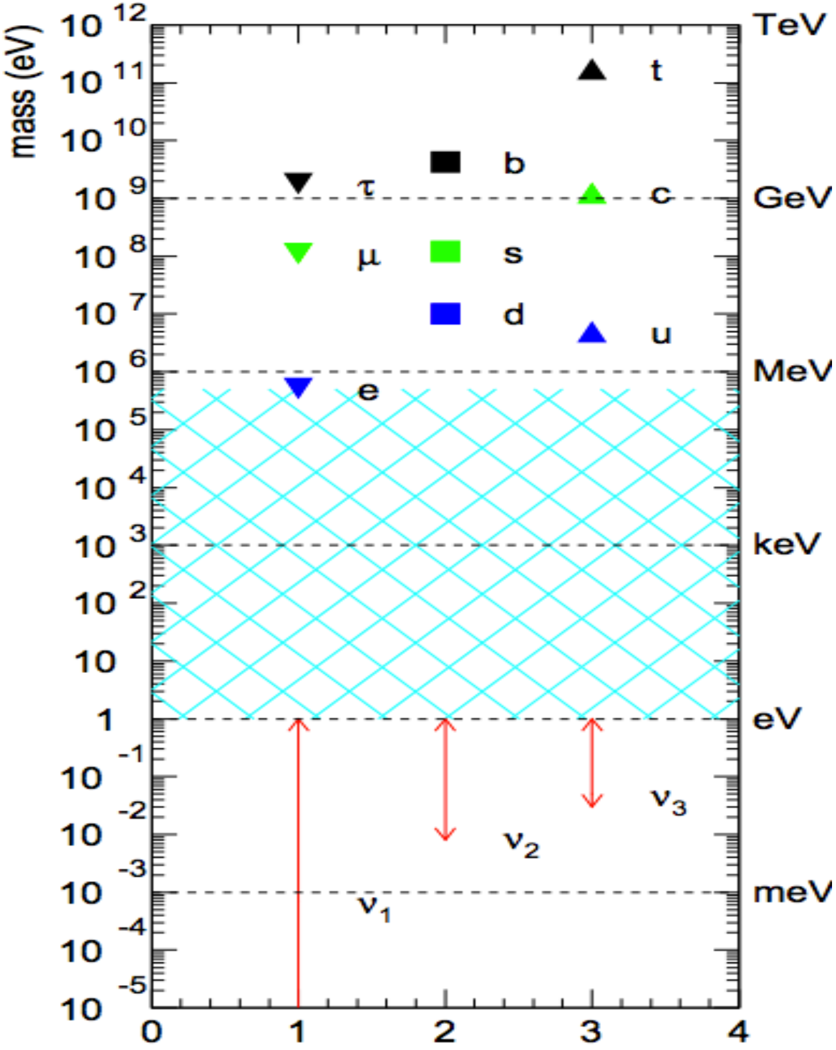
The LHC program has only just begun…

All neutrino mixings are large: θ_{13}

- The neutrino sector presents very fundamental questions
  - Dirac vs Majorana?
  - Is CP violated?
  - What are the neutrino masses?
  - What is the mass hierarchy?
  - Are there sterile neutrinos?
  - How do they talk to the Higgs?
  - Why are the mixing angles so large?
- Most of these questions have already been answered for the other fermions!
- Neutrinos can probe phenomena from vastly different scales

All neutrino mixings are large: θ_{13}

- Neutrino mass is a completely different scale



The only dimension-5 operator allowable by SM symmetries gives rise to neutrino mass

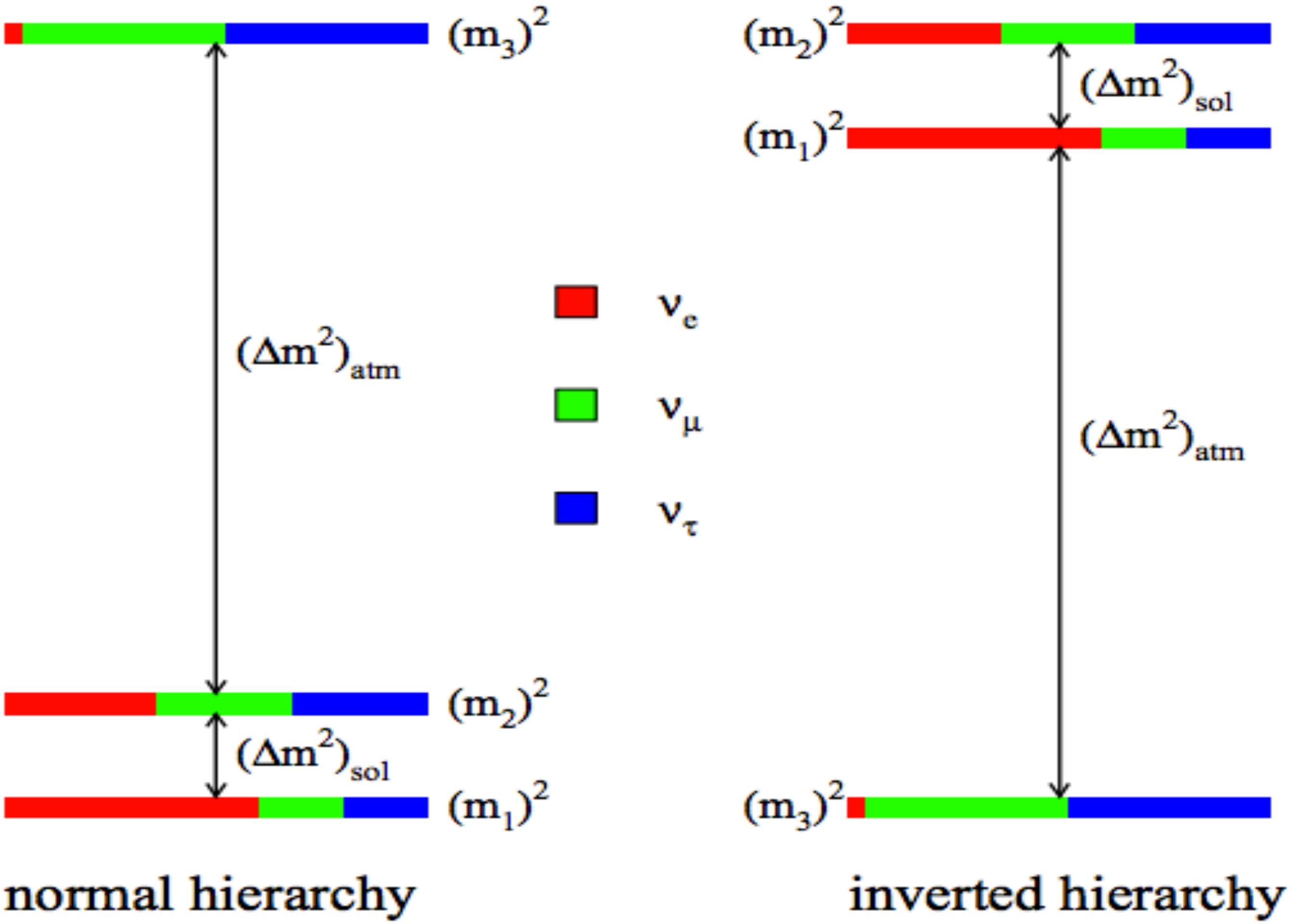
$$\frac{1}{\Lambda}(y_\nu L H)(y_\nu L H) + h.c. \quad \Rightarrow \quad \frac{y_\nu^2 v^2}{\Lambda}\, \overline{\nu_L}\, \nu_R^c.$$

$$V_{MNS} \sim \begin{pmatrix} 0.8 & 0.5 & 0.2 \\ 0.4 & 0.6 & 0.7 \\ 0.4 & 0.6 & 0.7 \end{pmatrix} \qquad V_{CKM} \sim \begin{pmatrix} 1 & 0.2 & 0.001 \\ 0.2 & 1 & 0.01 \\ 0.001 & 0.01 & 1 \end{pmatrix}$$

WHY?

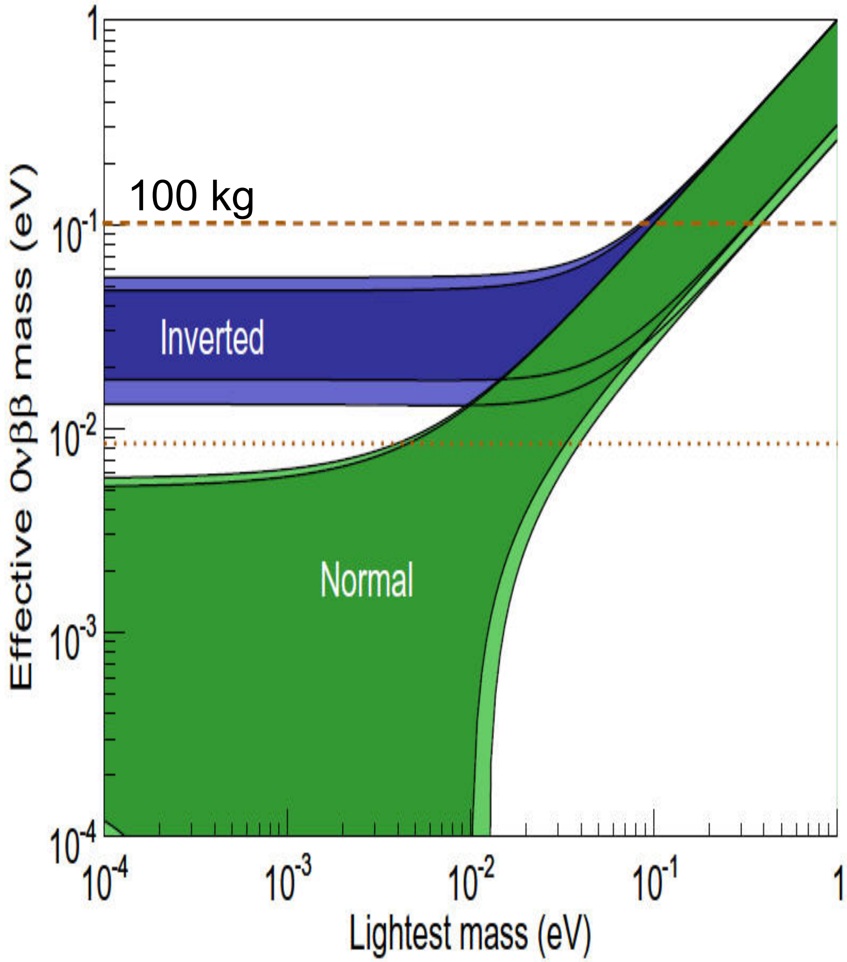
All neutrino mixings are large: θ_{13}

- Mass Hierarchy. How can we not know this? But what does it mean?

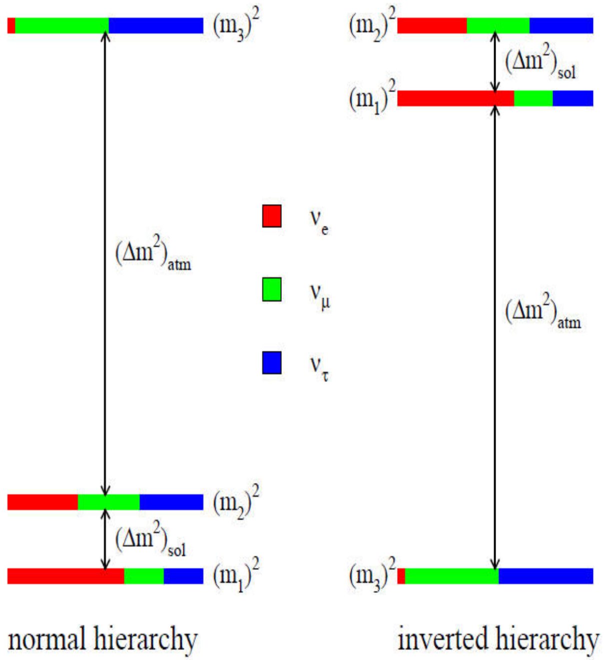


All neutrino mixings are large: θ_{13}

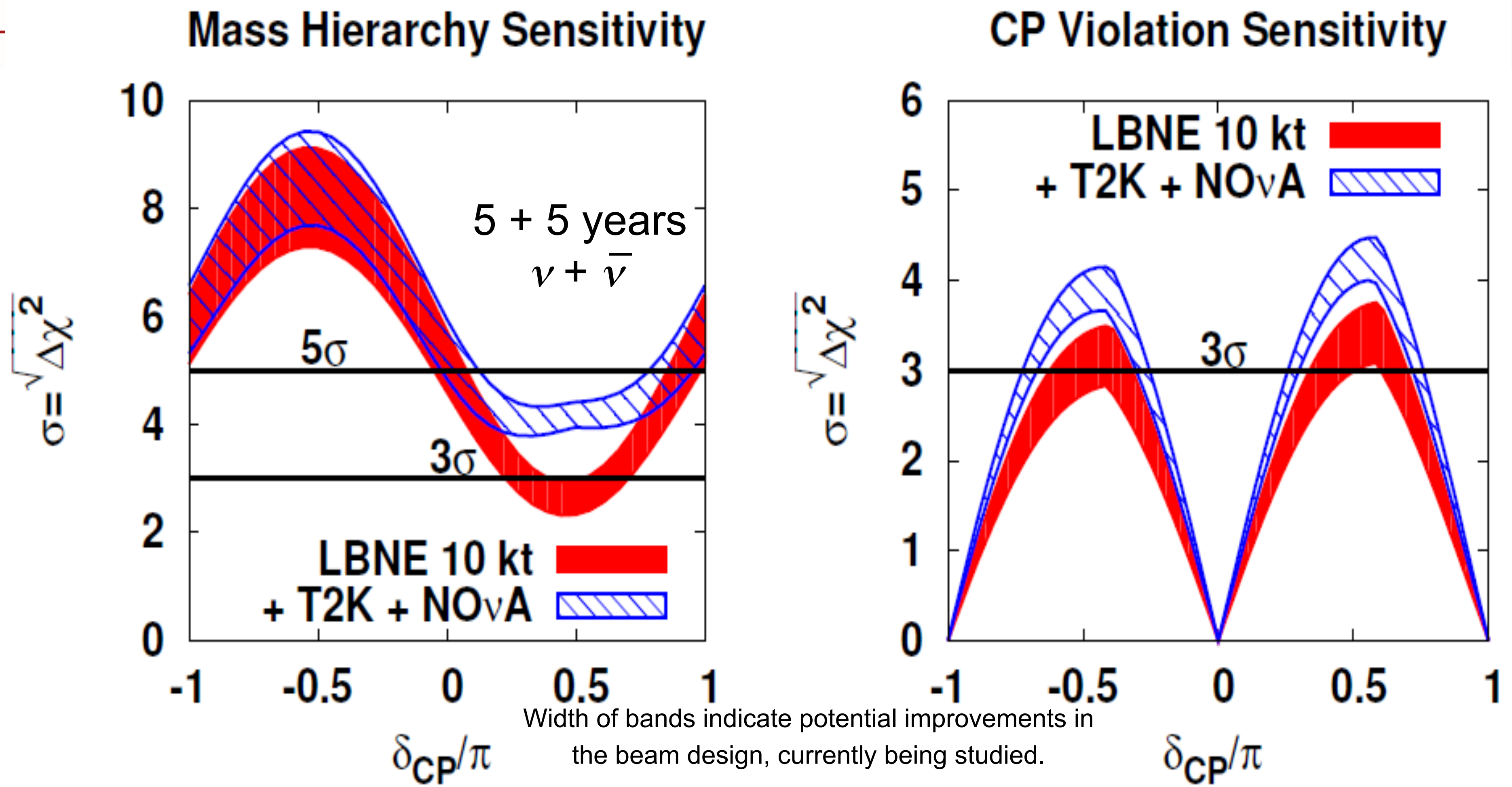
Neutrinoless Double Beta Decay



- Tests fundamental Nature of the neutrino
- Tests Lepton Number Violation



LBNE Phase 1 Sensitivities

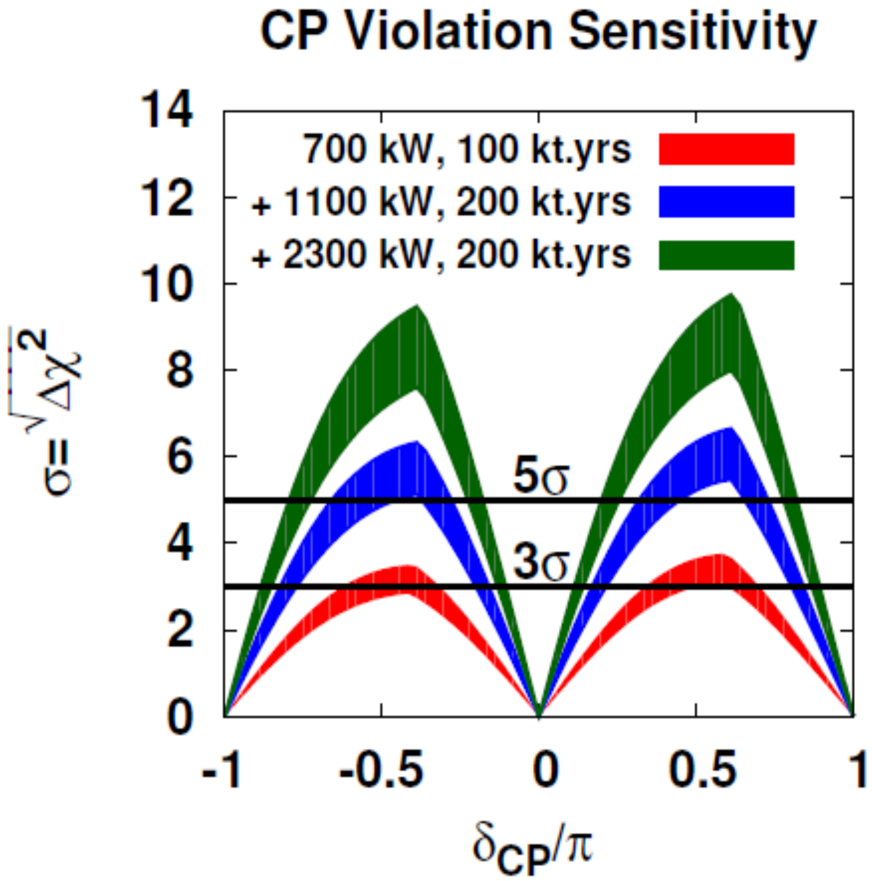


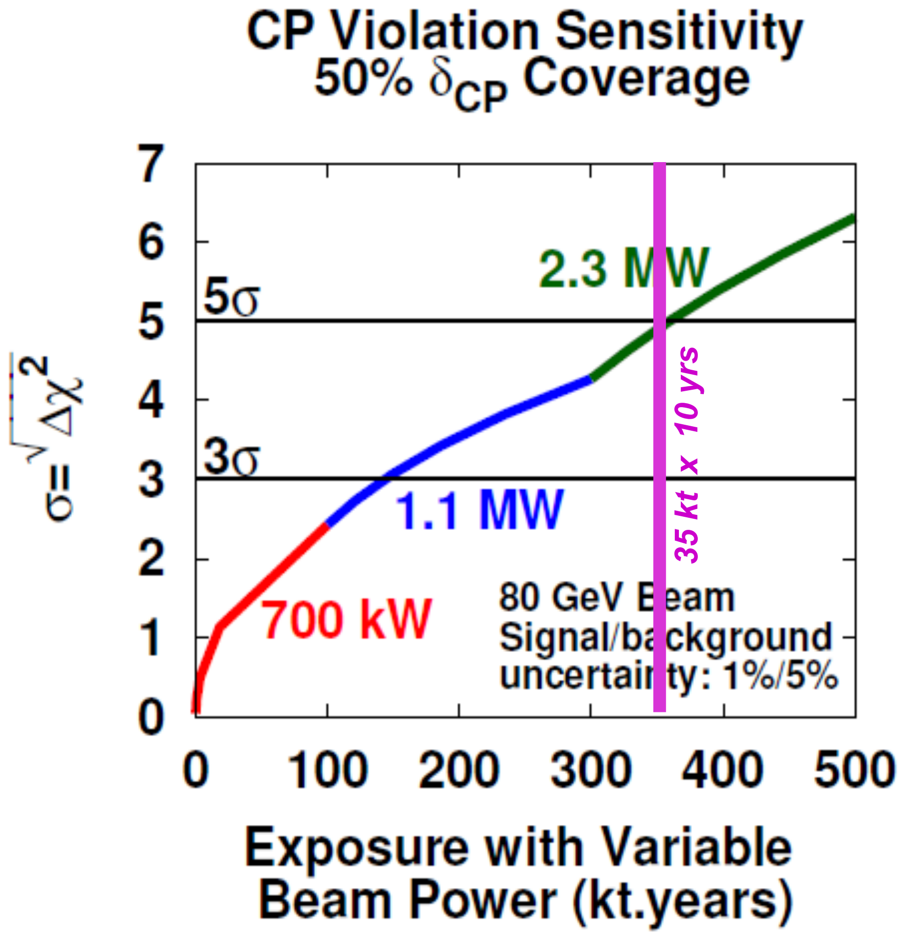
Width of bands indicate potential improvements in the beam design, currently being studied.

Combining atmospheric neutrino data (with an underground LBNE detector location) can further improve the mass hierarchy sensitivity.

J.Strait, FRA Visiting Committee Meeting,
March 28-29, 2013

LBNE Phased with Project X





Phase 1 baseline and beam capabilities enable a program leading to > 5σ CP violation sensitivity.

J.Strait, FRA Visiting Committee Meeting,
March 28-29, 2013

On Electroweak Symmetry Breaking

The LHC has revealed that the minimum SM prescription for electroweak symmetry breaking — the one Higgs double model — is at least approximately correct. What does that have to do with neutrinos?

The tiny neutrino masses point to three different possibilities.

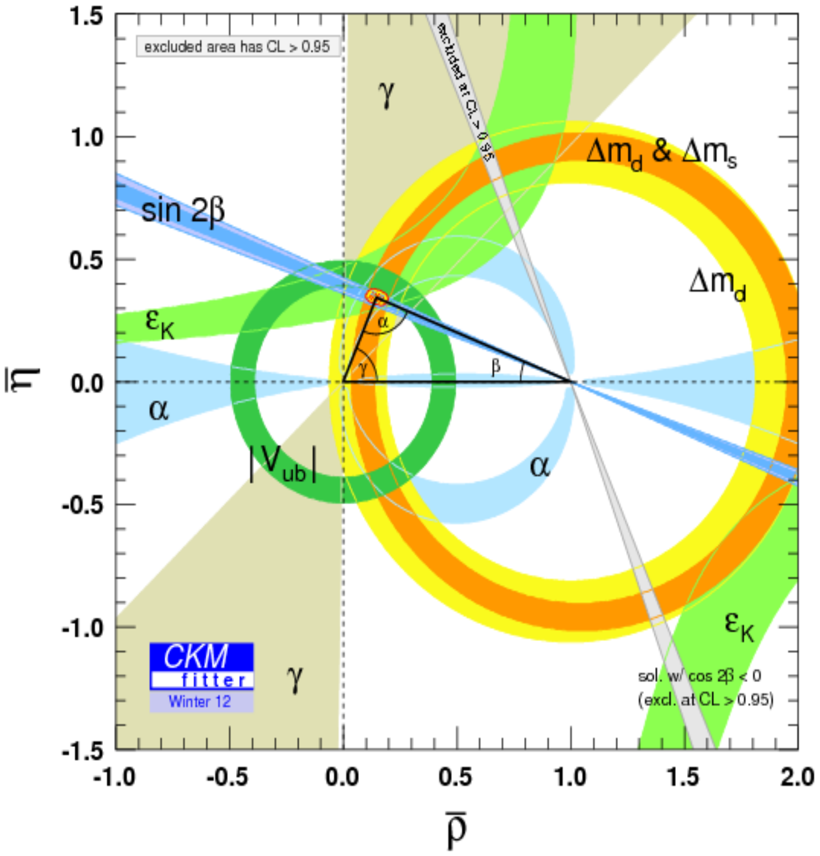
1. Neutrinos talk to the Higgs boson very, very **weakly** (Dirac neutrinos);
2. Neutrinos talk to a **different Higgs** boson – there is a new source of electroweak symmetry breaking! (Majorana neutrinos);
3. Neutrino masses are small because there is **another source of mass** out there — a new energy scale indirectly responsible for the tiny neutrino masses, a la the seesaw mechanism (Majorana neutrinos).

Searches for $0\nu\beta\beta$ help tell (1) from (2) and (3), the LHC and charged-lepton flavor violation may provide more information.

Searches for nucleon decay provide the only handle on a new energy scale (3) if that new scale happens to be very small. Unique capability!

Quark Flavor Sector is SM-like

- The Flavor sector is very well constrained



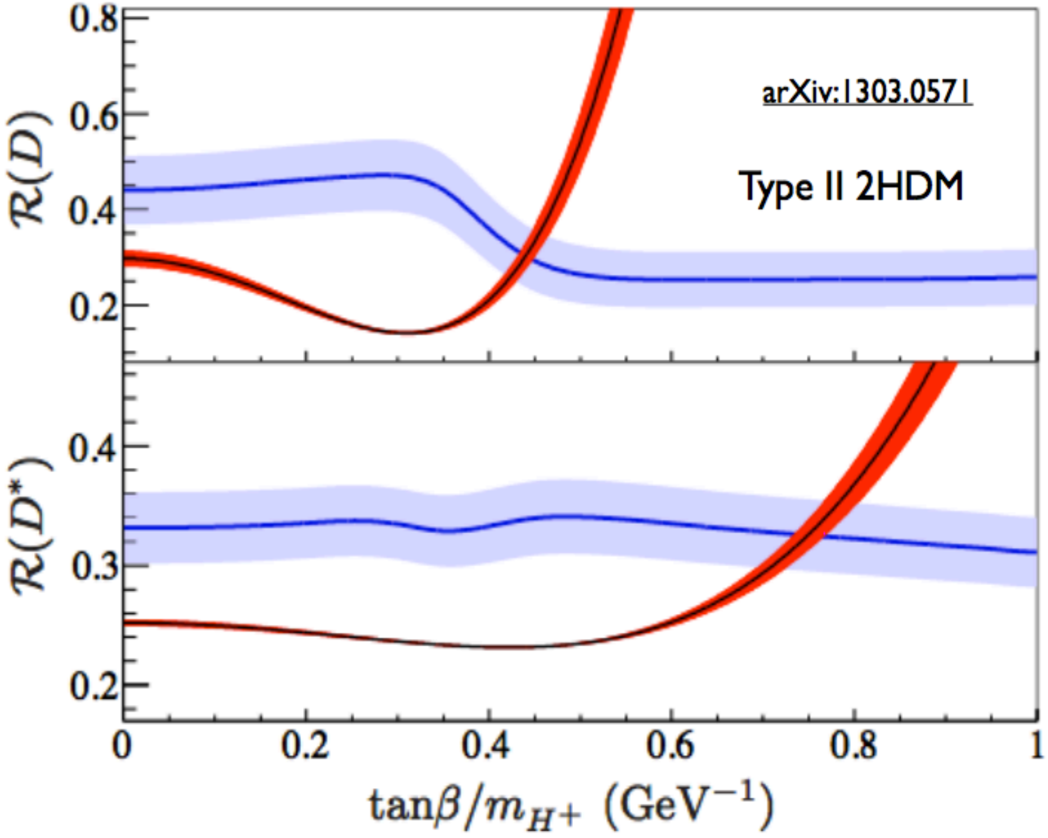
- Legacy of the B-Factories
- Strong constraints on model building

- BaBar D→$\tau\nu$ measurement:

$$\mathcal{R}(D) = \frac{\mathcal{B}(\overline{B} \to D\tau^-\overline{\nu}_\tau)}{\mathcal{B}(\overline{B} \to D\ell^-\overline{\nu}_\ell)}, \quad \mathcal{R}(D^*) = \frac{\mathcal{B}(\overline{B} \to D^*\tau^-\overline{\nu}_\tau)}{\mathcal{B}(\overline{B} \to D^*\ell^-\overline{\nu}_\ell)}.$$

$$\mathcal{R}(D)_{\rm exp} = 0.440 \pm 0.072 \quad \mathcal{R}(D^*)_{\rm exp} = 0.332 \pm 0.030,$$
$$\mathcal{R}(D)_{\rm SM} = 0.297 \pm 0.017 \quad \mathcal{R}(D^*)_{\rm SM} = 0.252 \pm 0.003,$$

3.4σ from SM



Does this truly exclude 2HDMs????

There are lots of XYZ states

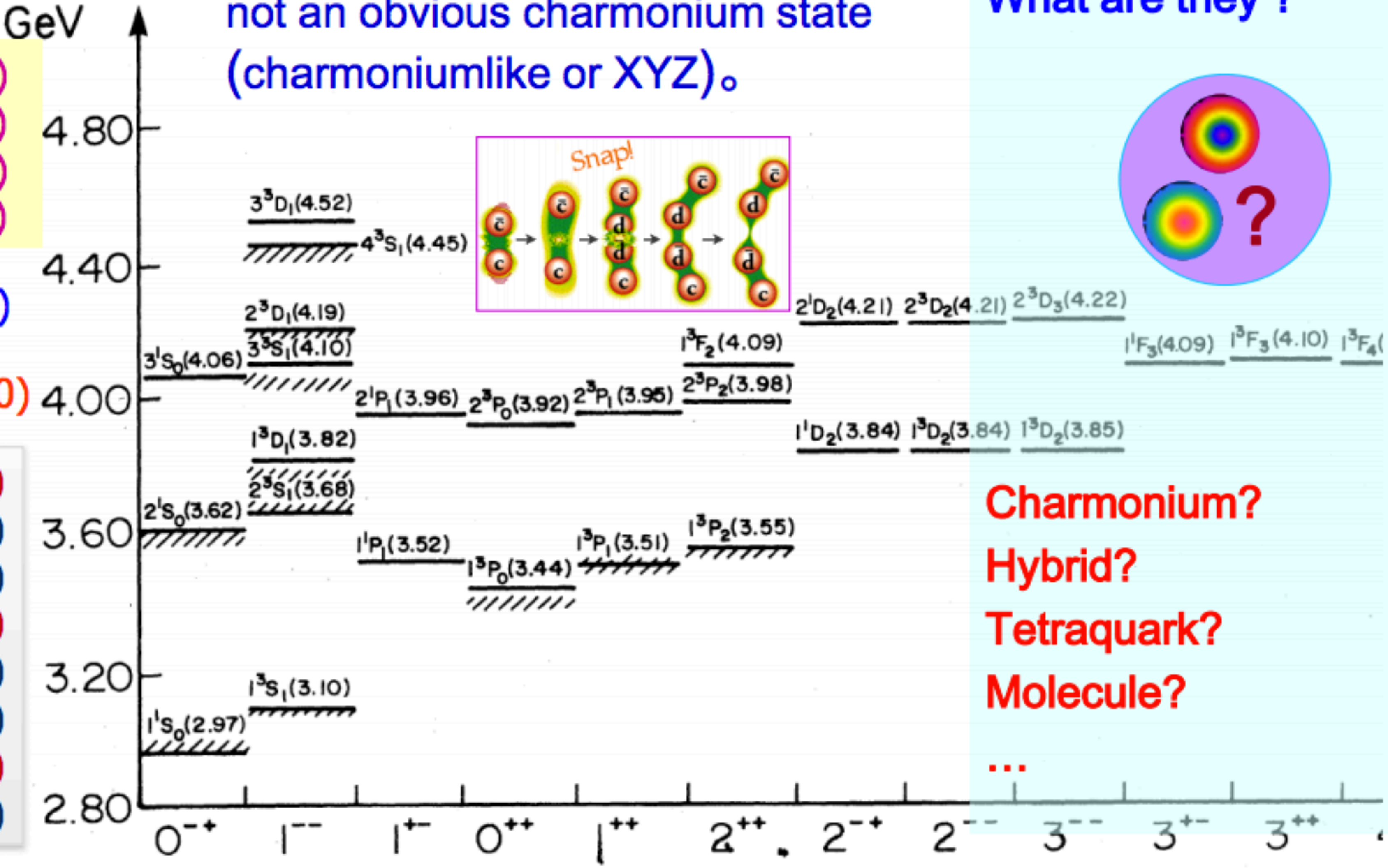
Charmonium in the final state, but not an obvious charmonium state (charmoniumlike or XYZ)。

Z(4430)
Z(4250)
Z(4050)
Z(3900)

X(3872)

XYZ(3940)

X(3915)
X(4160)
Y(4008)
Y(4140)
Y(4260)
Y(4360)
X(4350)
Y(4660)



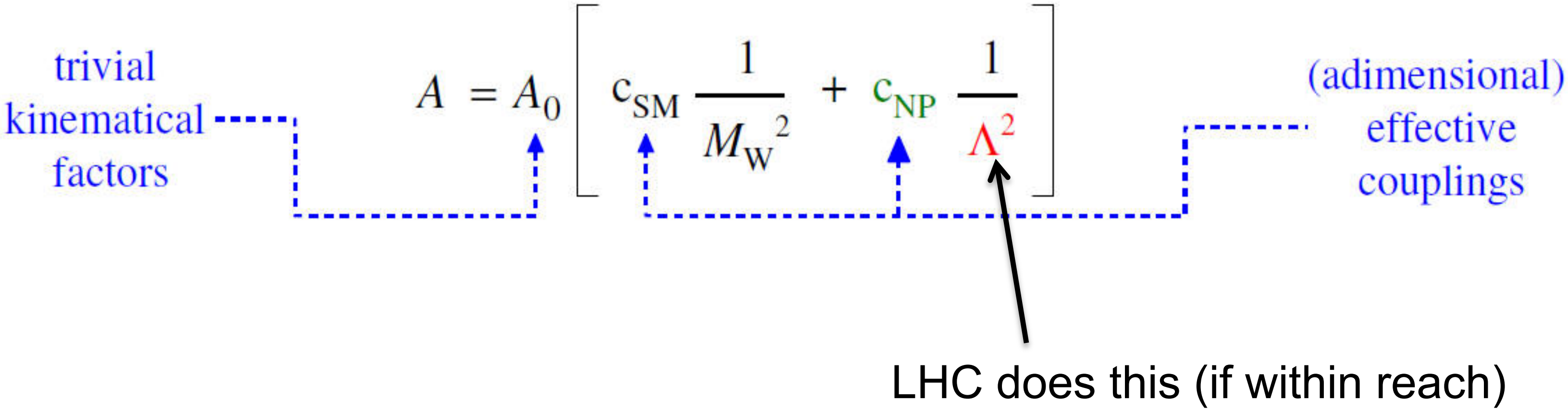
What are they ?

Charmonium?
Hybrid?
Tetraquark?
Molecule?
…

Not all of them are charmonia!

Quark Flavor Sector is SM-like

Flavor physics explores very high energy scales



$$A = A_0 \left[c_{SM} \frac{1}{M_W{}^2} + c_{NP} \frac{1}{\Lambda^2} \right]$$

trivial kinematical factors

(adimensional) effective couplings

LHC does this (if within reach)

New Physics Flavor Problem

New Physics is constrained by flavor physics observables.
E.g. mixing and CP violation.

$$\mathcal{L}_{\mathrm{eff}} = \mathcal{L}_{\mathrm{SM}} + \frac{C_{\mathrm{NP}}}{\Lambda^2} O_{ij}$$

$\Delta F = 2$ operator	Bounds on Λ [TeV] $(C = 1)$		Bounds on C $(\Lambda = 1\,\mathrm{TeV})$		Observables
	Re	Im	Re	Im	
$(\bar{s}_L \gamma^\mu d_L)^2$	9.8×10^2	1.6×10^4	9.0×10^{-7}	3.4×10^{-9}	Δm_K; ϵ_K
$(\bar{s}_R\, d_L)(\bar{s}_L d_R)$	1.8×10^4	3.2×10^5	6.9×10^{-9}	2.6×10^{-11}	Δm_K; ϵ_K
$(\bar{c}_L \gamma^\mu u_L)^2$	1.2×10^3	2.9×10^3	5.6×10^{-7}	1.0×10^{-7}	Δm_D; $\lvert q/p \rvert, \phi_D$
$(\bar{c}_R\, u_L)(\bar{c}_L u_R)$	6.2×10^3	1.5×10^4	5.7×10^{-8}	1.1×10^{-8}	Δm_D; $\lvert q/p \rvert, \phi_D$
$(\bar{b}_L \gamma^\mu d_L)^2$	5.1×10^2	9.3×10^2	3.3×10^{-6}	1.0×10^{-6}	Δm_{B_d}; $S_{\psi K_S}$
$(\bar{b}_R\, d_L)(\bar{b}_L d_R)$	1.9×10^3	3.6×10^3	5.6×10^{-7}	1.7×10^{-7}	Δm_{B_d}; $S_{\psi K_S}$
$(\bar{b}_L \gamma^\mu s_L)^2$	1.1×10^2	2.2×10^2	7.6×10^{-5}	1.7×10^{-5}	Δm_{B_s}; $S_{\psi\phi}$
$(\bar{b}_R\, s_L)(\bar{b}_L s_R)$	3.7×10^2	7.4×10^2	1.3×10^{-5}	3.0×10^{-6}	Δm_{B_s}; $S_{\psi\phi}$

From the Report of the Heavy Quarks working group, Fundamental Physics at the Intensity Frontier (2012), arXiv:1205.2671

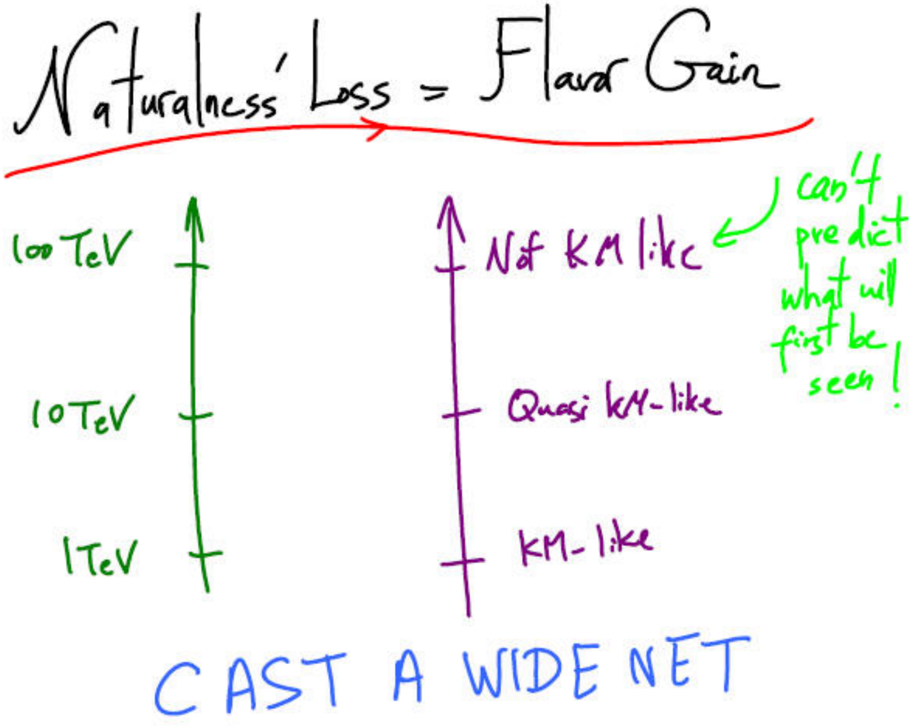
If there is New Physics at the 1 TeV scale, its flavor structure is unnatural.

J. Ritchie

Intensity Frontier Linked to Other Frontiers

The science of the Intensity Frontier is connected to the Energy and Cosmic Frontiers

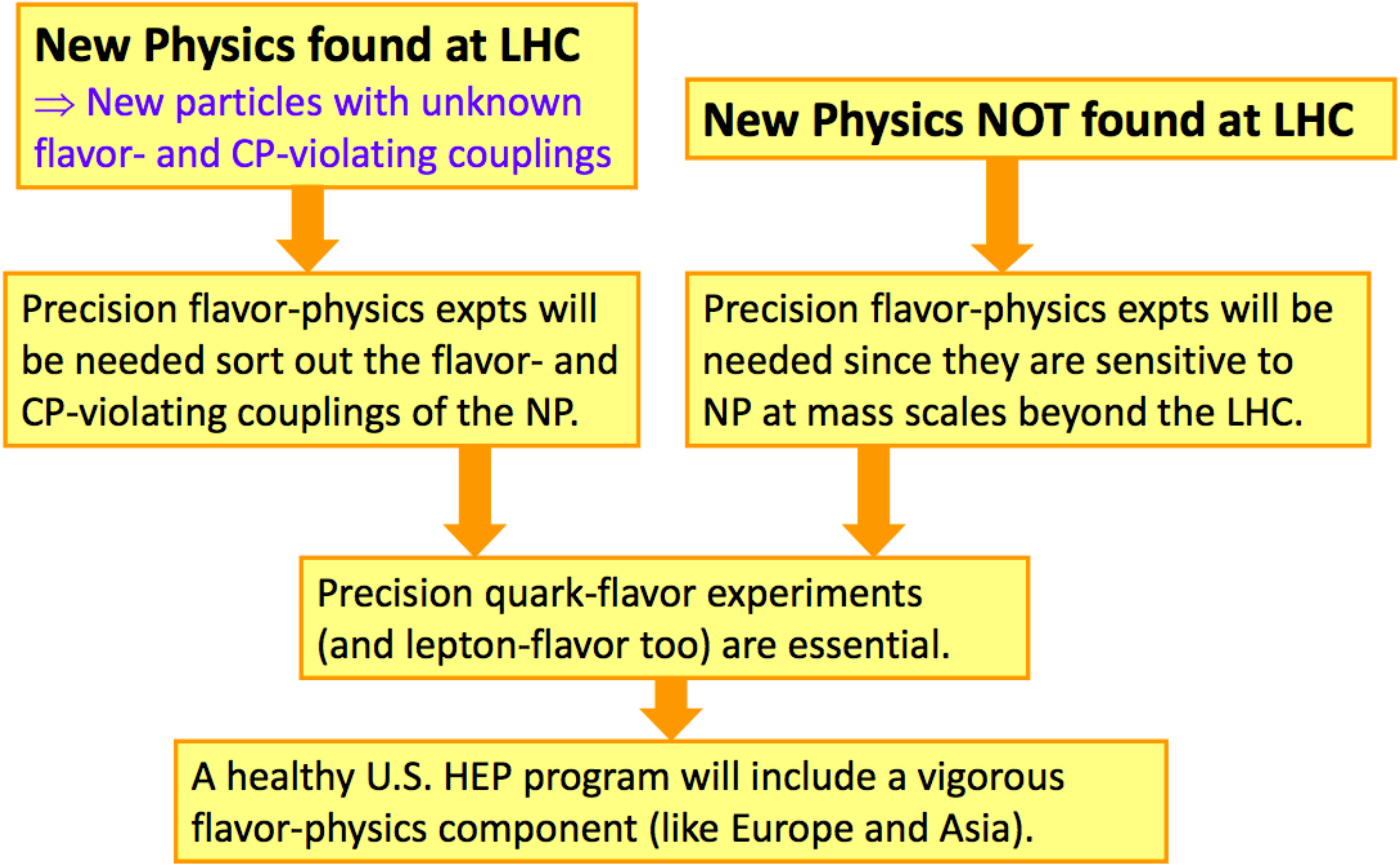
Connections between LHC results and flavor factories



Forced to choose
between MFV
and Naturalness

Arkani-Hamed

Flavor in the LHC Era



New Physics found at LHC

⇒ New particles with unknown flavor- and CP-violating couplings

New Physics NOT found at LHC

Precision flavor-physics expts will be needed sort out the flavor- and CP-violating couplings of the NP.

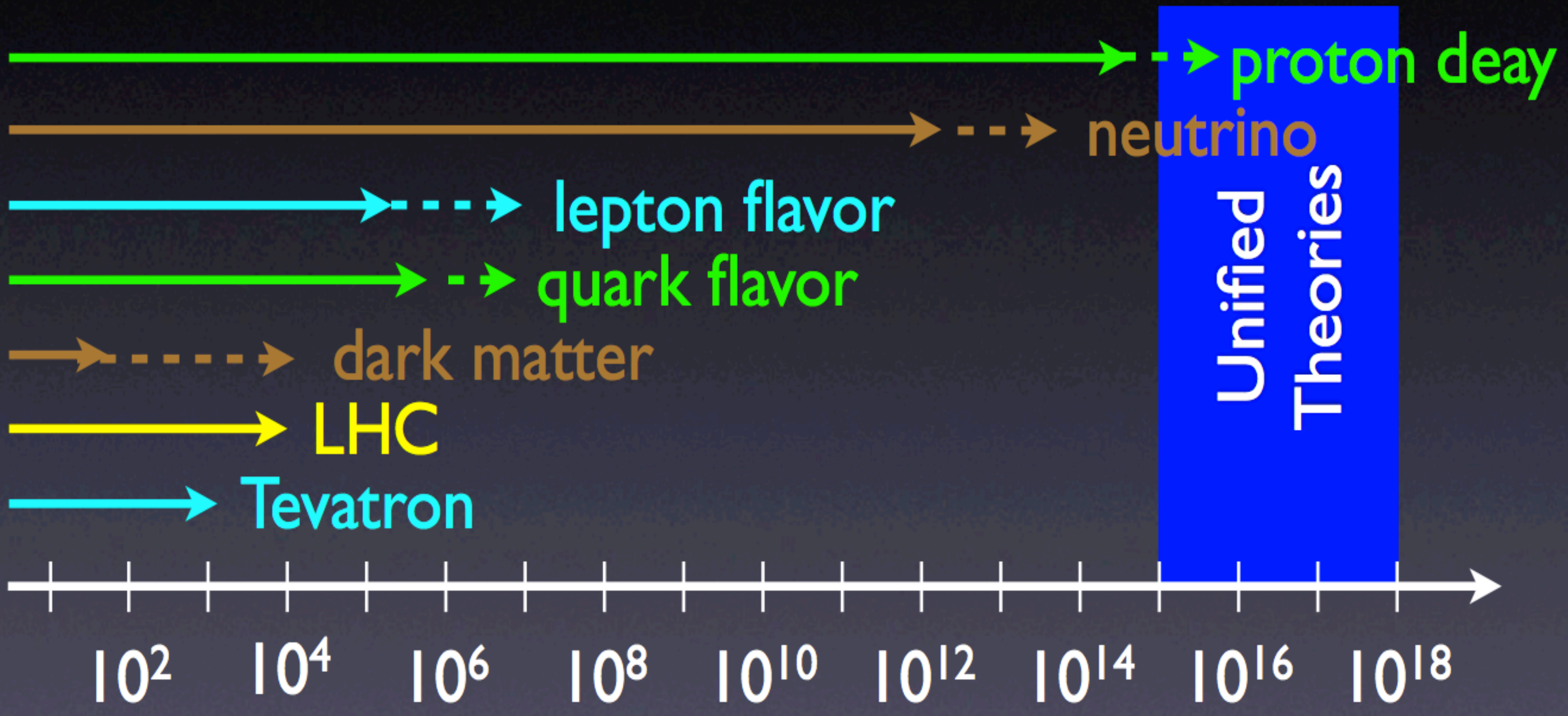
Precision flavor-physics expts will be needed since they are sensitive to NP at mass scales beyond the LHC.

Precision quark-flavor experiments (and lepton-flavor too) are essential.

A healthy U.S. HEP program will include a vigorous flavor-physics component (like Europe and Asia).

J. Ritchie

Power of Expedition



experimental reach [GeV]

(with significant simplifying assumptions)

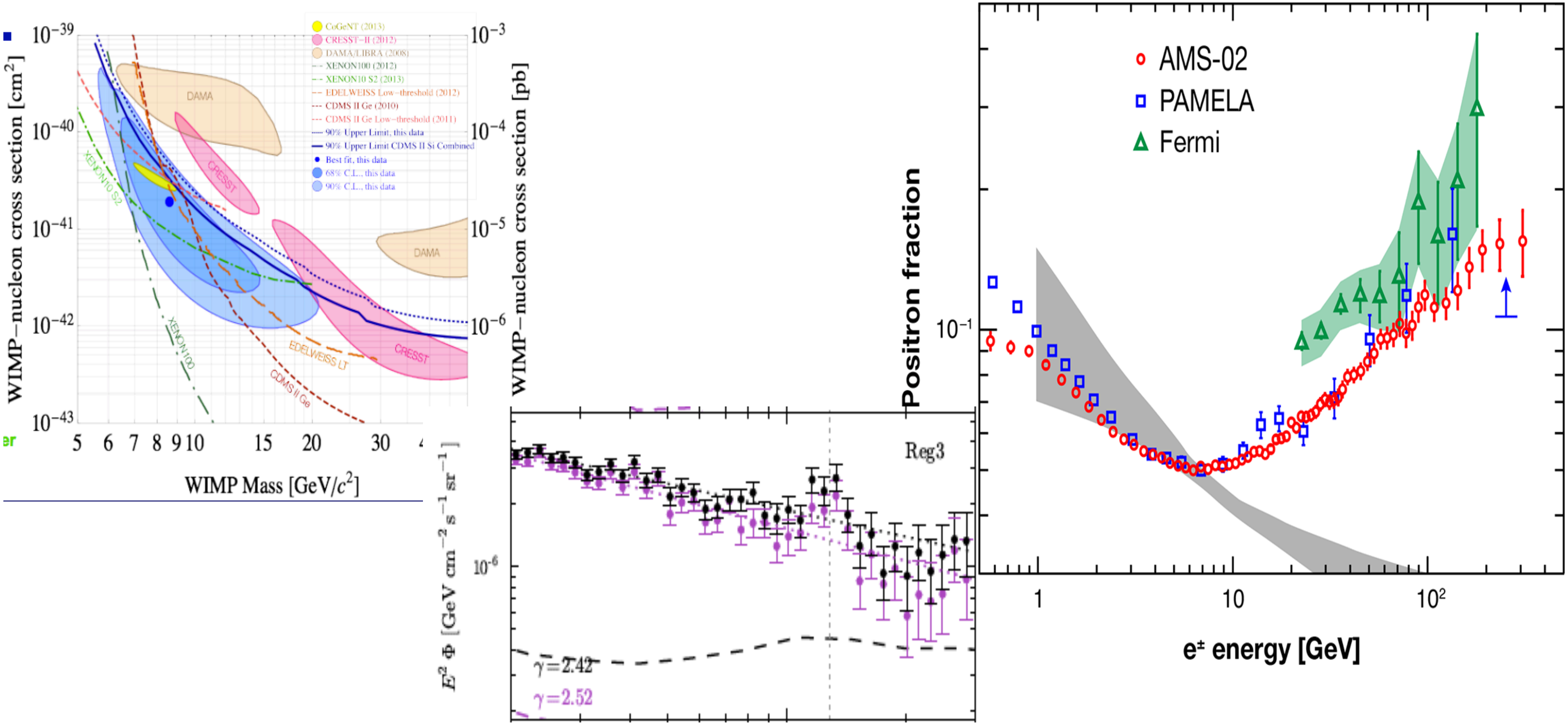
courtesy Zoltan Ligeti

The Intensity Frontier t-shirt

Thanks to
David Hitlin

Signals for Dark Matter? Or NOT!

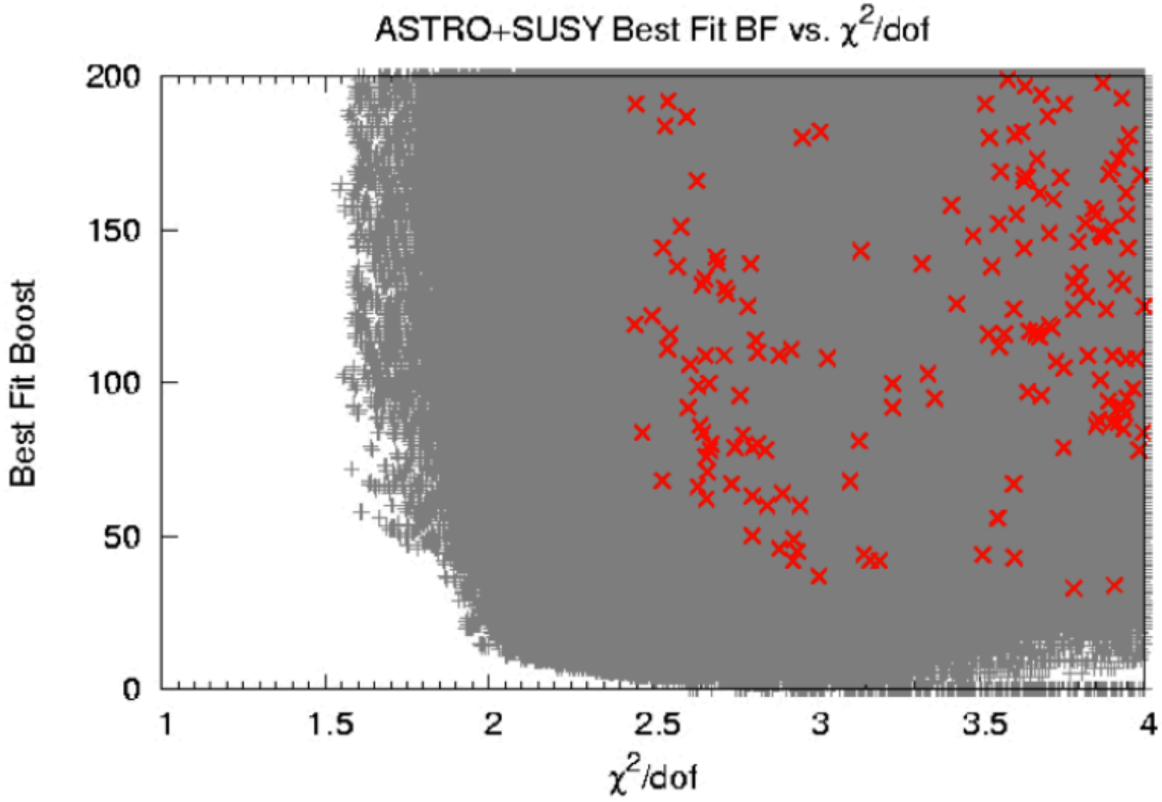
- How do we believe a signal when we see one?



We have 3 distinct potential signals for Dark Matter. Yet we believe none of them. It is difficult to explain any of them in SUSY…

Signals for Dark Matter? Or NOT!

- How do we believe a signal when we see one?

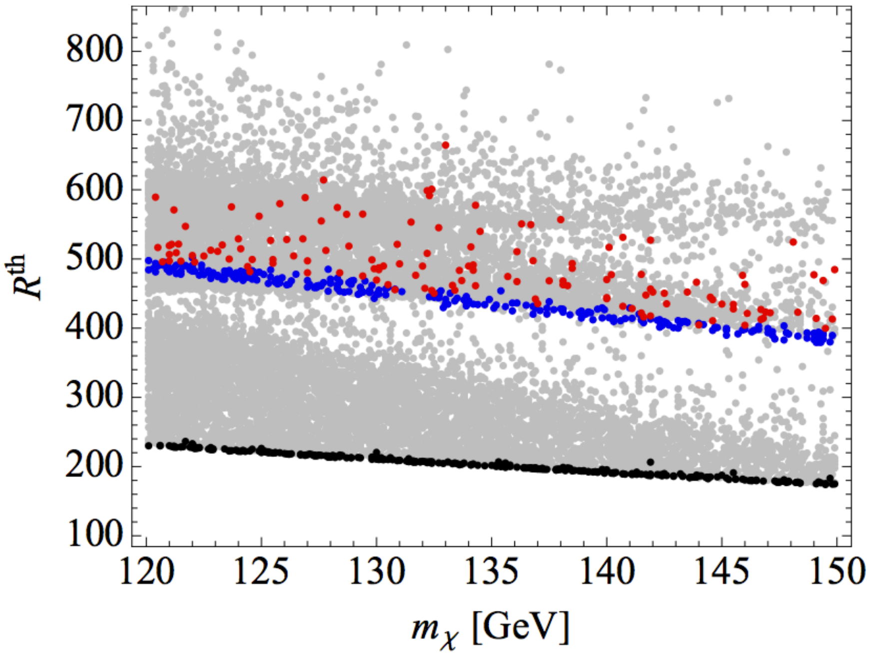


SUSY requires a large boost to fit the positron data

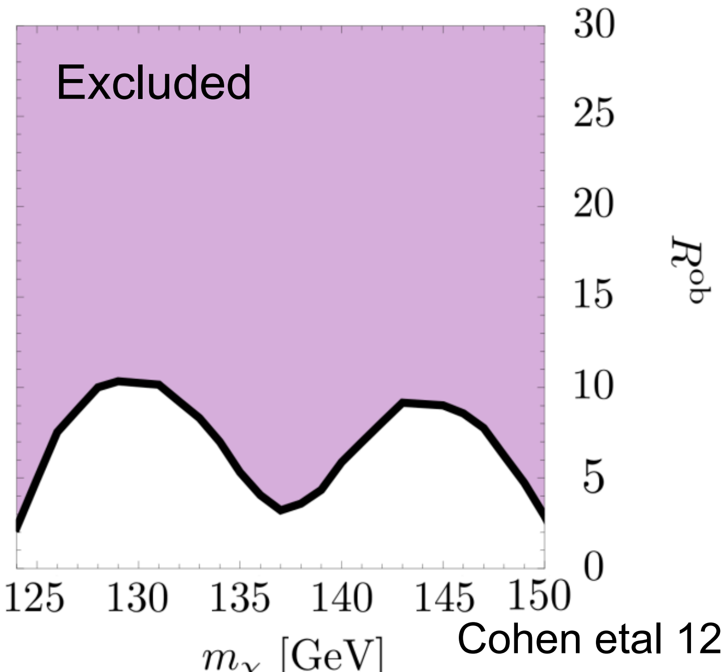
Cotta etal 1007.5520

Relating 130 GeV Y-Ray Line to Photon Continuum

- Fermi data places strong bounds on ratio of continuum photons to monochromatic lines
- These constraints exclude neutralino dark matter as a source of the 130 GeV line



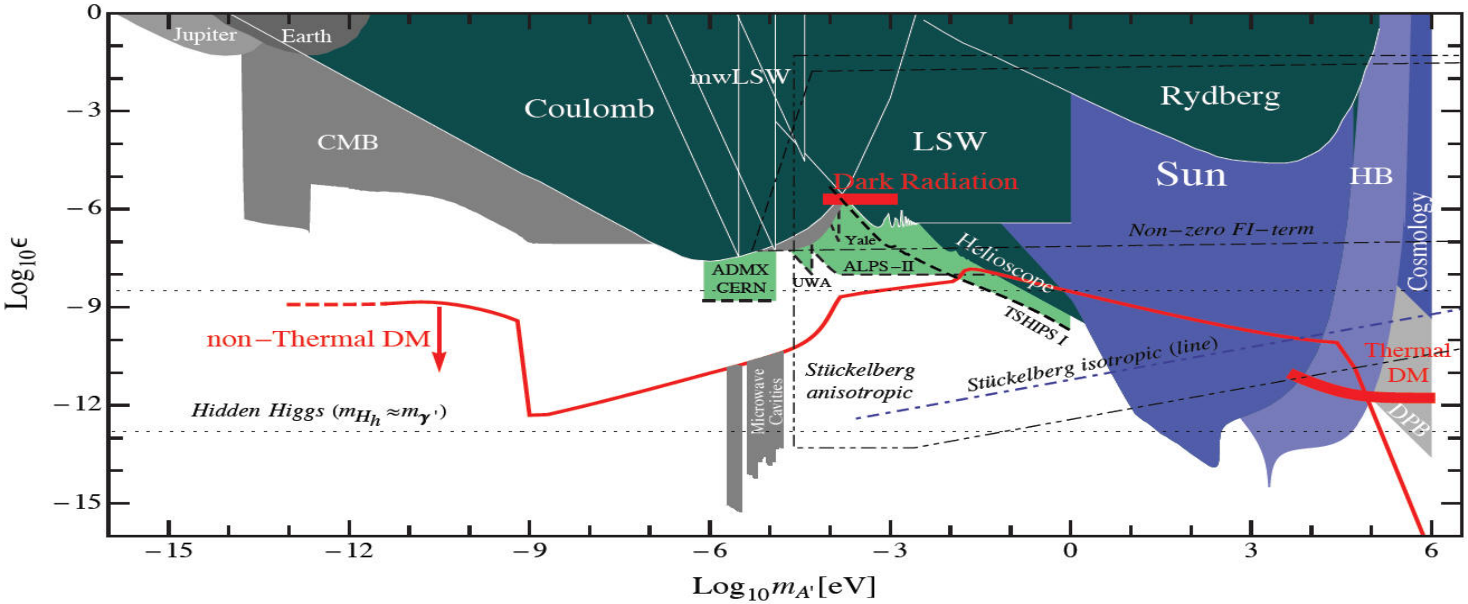
Ratio as predicted by SUSY



Ratio as constrained by Fermi

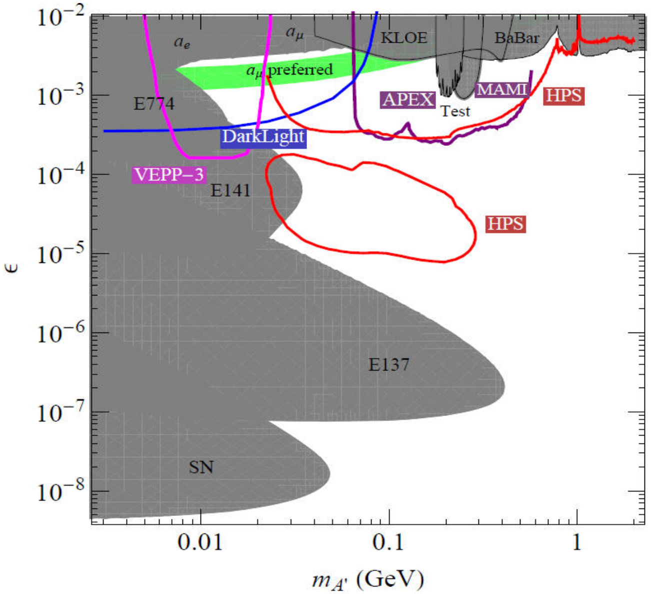
Cohen etal 1207.0800

Ultra-weak Hidden Sectors



Effective coupling to SM vs Mass plane

$m_{A'} < 1$ev



Hidden Sector Vector Portal/Heavy Dark Sector Photons:
Couplings to SM small enough to have missed so far, but big enough to find

Theories motivated by cosmic frontier
Signatures at Intensity and (Energy) frontiers

$m_{A'} > 1$ev

Standard Model of the Universe: Λ_{CDM}

- We have a new Standard Model that fits the CMB data exceedingly well: What’s next?

$$R_{\mu\nu} - \frac{1}{2} R\, g_{\mu\nu} + \Lambda\, g_{\mu\nu} = \frac{8\pi G}{c^4} T_{\mu\nu}$$

Λ

Need new ideas here

Standard Model of the Universe: Λ_{CDM}

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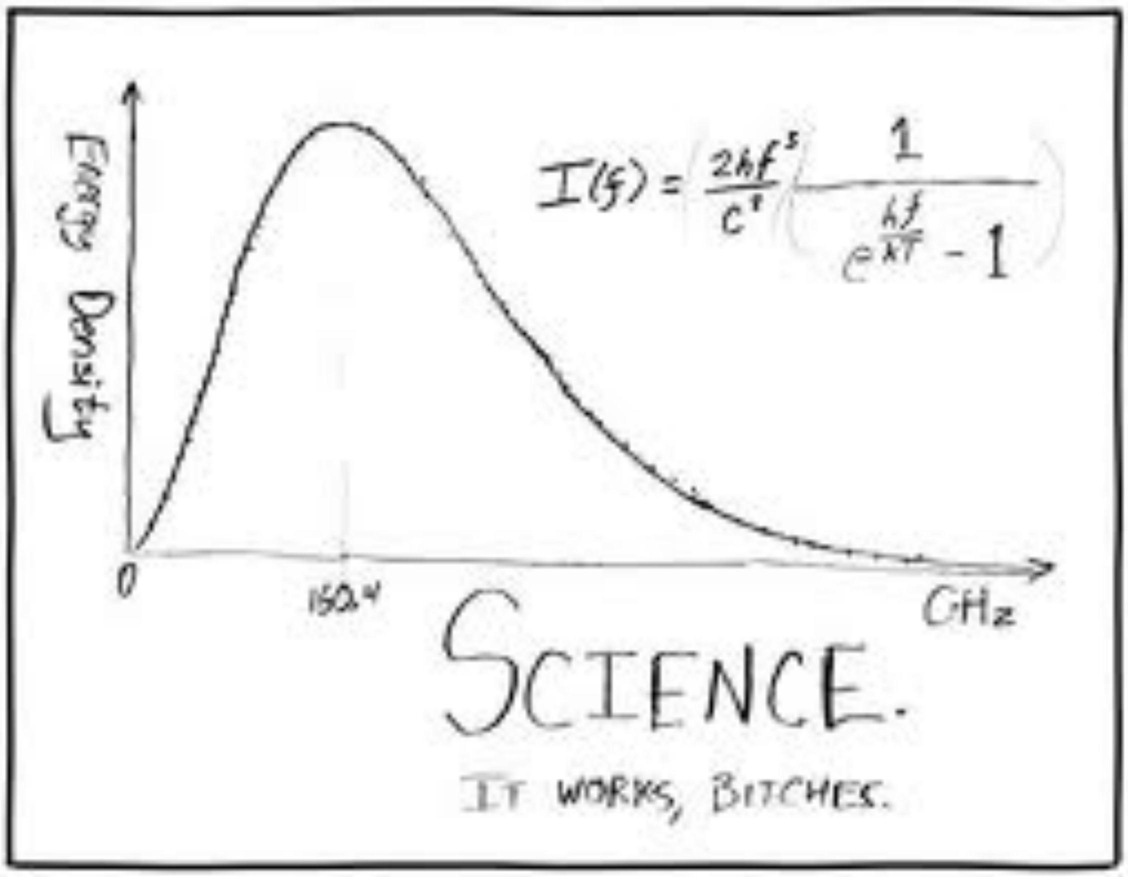

We are in a very exciting time!

- Many discoveries!
- Many experiments on the horizon
- Looking forward to SSI in 2023!