Theory Summary

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Fermilab

LHCP 2013, Barcelona, May 18, 2013

Outline

- Condensed matter physics in vacuo
- Higgs quo vadis?
- Supersymmetry: aut vincere aut mori
- Natura abhorret vacuo inconstans
- QCD: hic sunt dracones
- What theorists want: scientia ipsa potentia est

Higgs discovery: condensed matter physics in vacuo

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

Nambu and Goldstone (1960)

Nobel Lecture: Spontaneous symmetry breaking in particle physics: A case of cross fertilization*

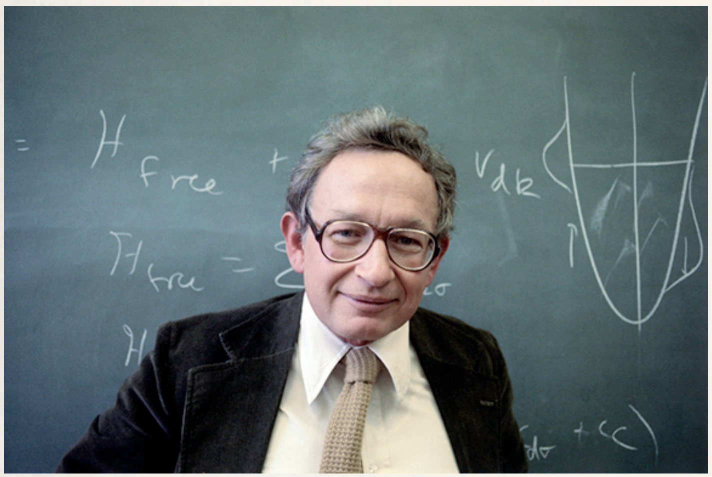
Yoichiro Nambu

Physical system	Broken symmetry
Ferromagnets	Rotational invariance (with respect to spin)
Crystals	Translational and rotational invariance (modulo discrete values)
Superconductors	Local gauge invariance (particle number)

- Apply condensed matter ideas to particle physics
- ***Now the quantum vacuum is "the medium"***

Anderson (1962)

gauge bosons “eat” Goldstone bosons and get mass, just like a photon inside a superconductor



Physical system	Broken symmetry
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Superconductors	Local gauge invariance (particle number)

Goldstone modes

spin waves

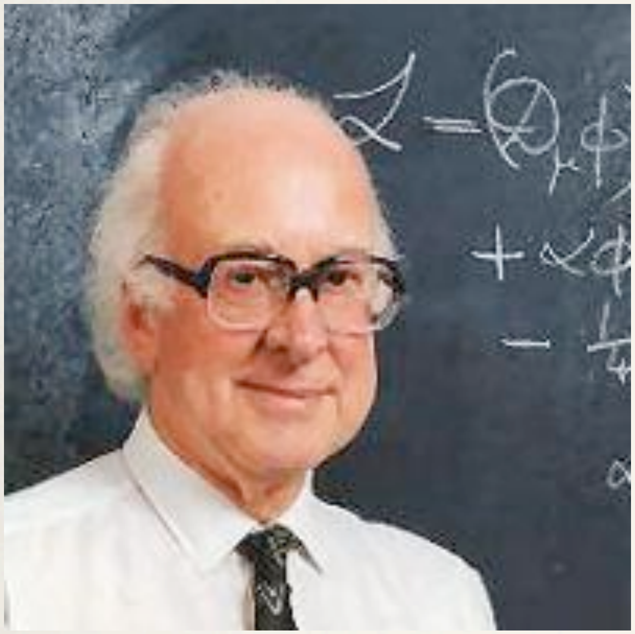
phonons

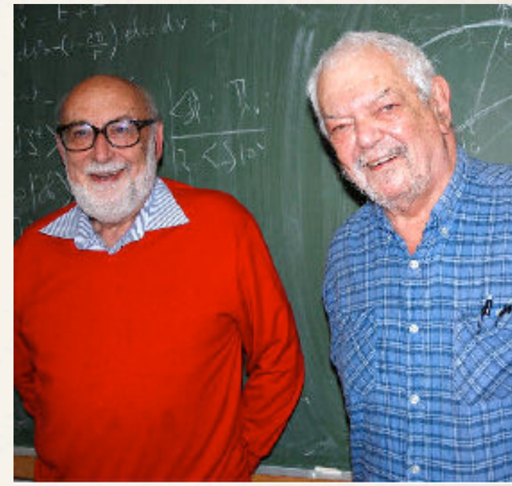
???

> It is likely, then, considering the superconducting analog, that the way is now open for a degenerate-vacuum theory of the Nambu type without any difficulties involving either zero-mass Yang-Mills gauge bosons or zero-mass Goldstone bosons. These two types of bosons seem capable of “canceling each other out” and leaving finite mass bosons only.

Higgs et al (1964)

a fundamental self-sourcing scalar field
can cause spontaneous symmetry-breaking in the vacuum
and give gauge bosons mass



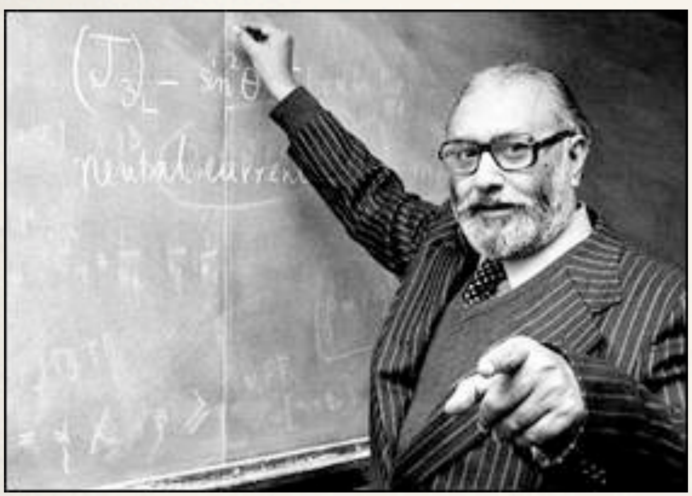


The purpose of the present note is to report that...the spin-one quanta of some of the gauge fields acquire mass...This phenomenon is just the relativistic analog of the plasmon phenomenon to which Anderson has drawn attention

the Higgs Mechanism

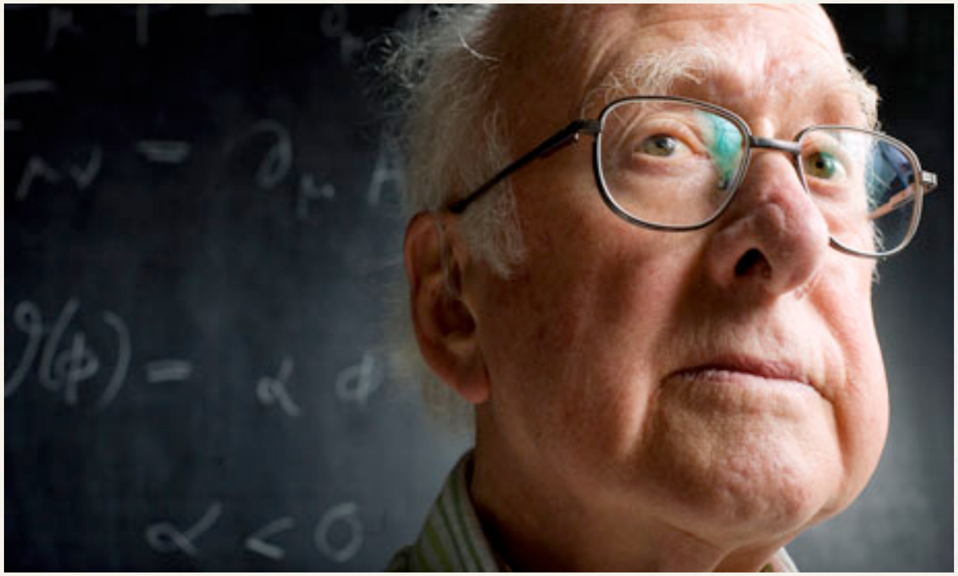
Weinberg, Salam (1967)

the Electroweak Standard Model



- An $SU(2)_L$ x $U(1)_Y$ nonabelian gauge theory with chiral fermions
- Spontaneously broken by a complex doublet scalar field with self-interactions
- Three of the four real scalar components are eaten to give mass to the W^+, W^-, and Z, leaving one neutral Higgs boson and a massless photon
- ***The fermions also get mass*** from their Yukawa couplings to the scalar field

Higgs Quo Vadis?



Higgs boson = a new force carrier

Fermions = Matter ; Bosons = Forces

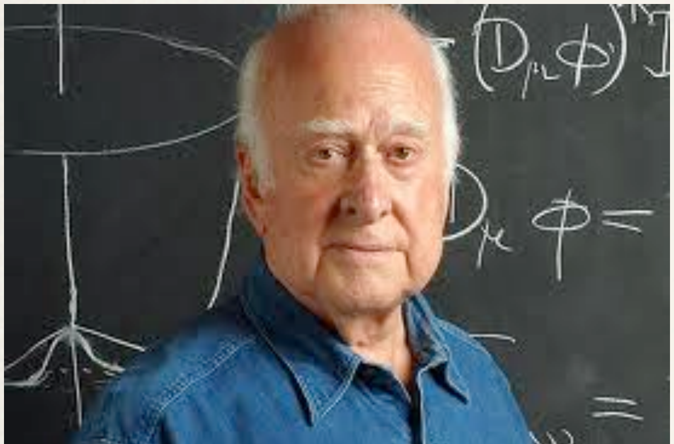
- **Fundamental Boson:** **New interaction which is not gauge**
- **Composite Boson:** **New underlying dynamics**

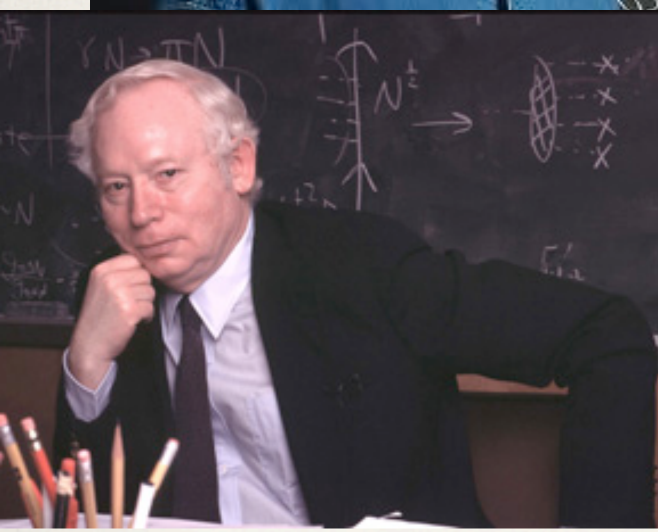
Talk by Tony Pich

- 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

what makes a Higgs a Higgs?





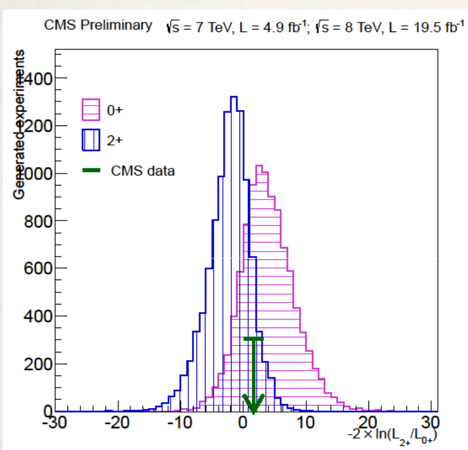
- Spin 0 boson
- Neutral CP even component of a complex SU(2) doublet with hypercharge +1
- Couples to W and Z bosons proportional to their masses
- Couples to quarks and leptons proportional to their masses
- Couples to massless photons and gluons through loops involving virtual charged/colored particles (top quarks, W bosons, ...)

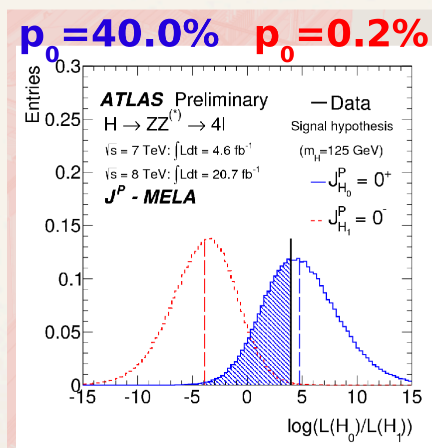
Higgs Imposters

- First job of the experiments is to rule out Higgs imposters
- Does the new particle look more like spin 0, or like spin 1 or spin 2?
- Does the new particle look more like a scalar or a pseudoscalar?
- Does it decay ~8 times more often to WW than ZZ, as predicted for a boson from an SU(2) doublet?

Talk by Javi Serra

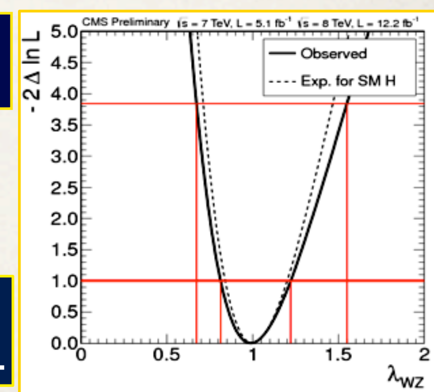
- Can tune a dilaton imposter or spin 2 imposter to survive, but looks like a Higgs



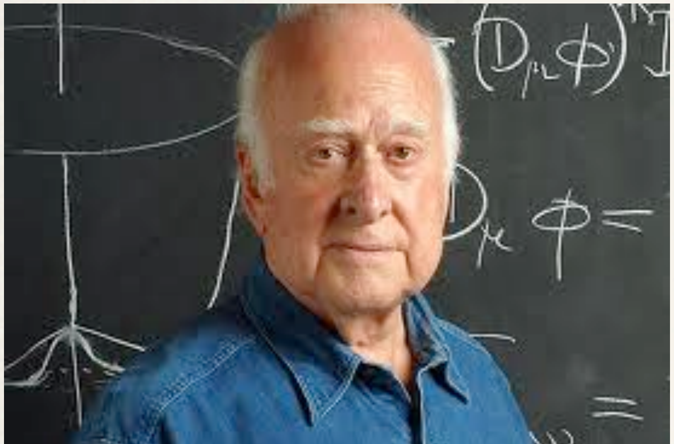


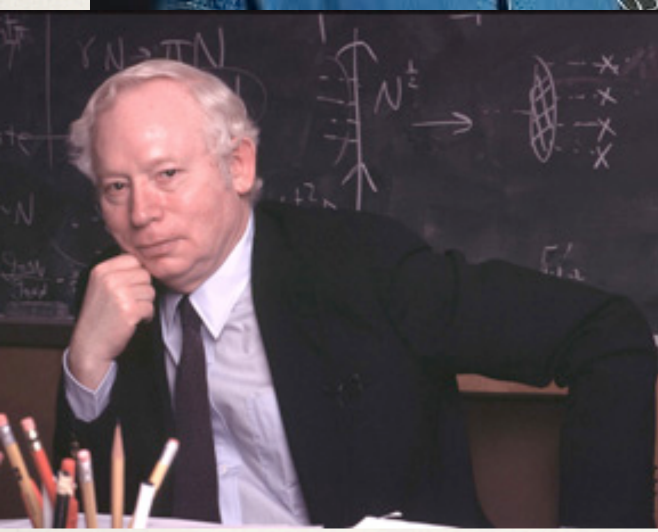
- κ_Z, $\lambda_{WZ} = \kappa_W / \kappa_Z$.
- κ_F = 1 as in SM

- Full profiling of κ_Z, κ_F
- λ_{WZ} in [0.68 - 1.55] 95%CL



is it a non-SM Higgs?



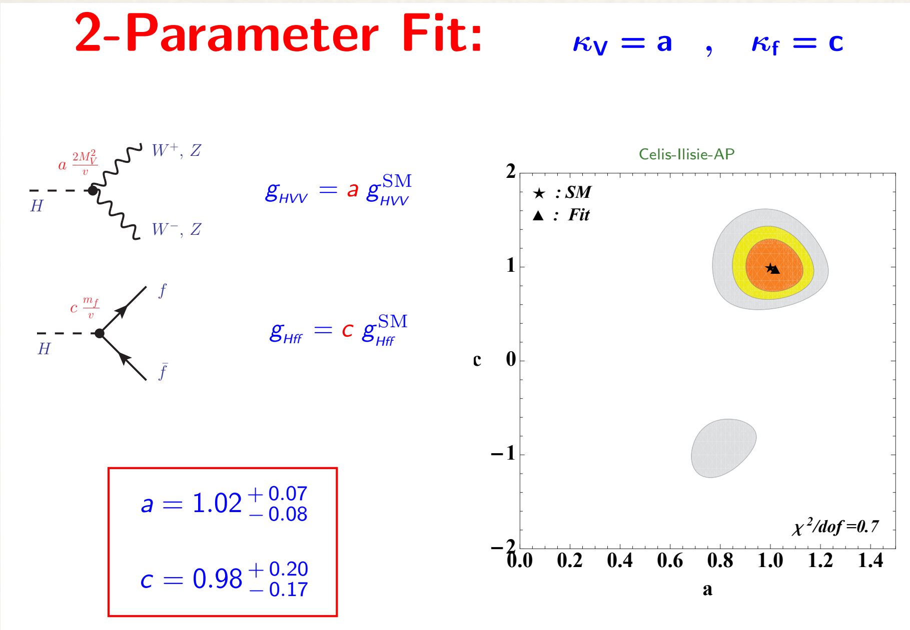


- Could be a mixture from more than one Higgs SU(2) doublet, singlets or triplets
- Could be a mixture of CP even and CP odd
- Could have enhanced/suppressed couplings to photons or gluons if there are exotic heavy charged or colored particles
- Could decay to exotic particles, e.g. dark matter
- May not couple to quarks and lepton proportional to their masses
- Could be composite, by itself does not unitarize VV scattering

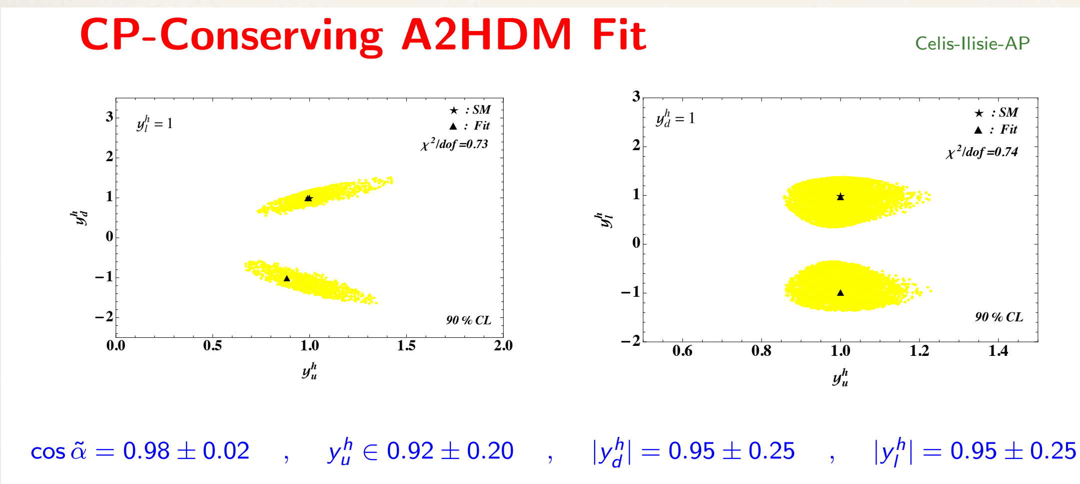
Talks by Tony Pich, Andreas Weiler, Rogerio Rosenfeld, Domeneq Espiriu

the precision Higgs era has begun

Talk by Tony Pich



A simple start is to fit measured Higgs signal strengths to two parameters expressing possible non-SM behavior: one for couplings to vector bosons, another for couplings to fermions



Slightly more ambitious is a fit to general two-Higgs-doublet models w/o tree-level FCNCs

EWPO constrain Higgs couplings

Assumption:

Giudice et al;Contino et al;Azatov et al;Contino et al

- the main effect in EWPO is due to a possibly modified Higgs coupling a to vectors (GB's):

$$S = \frac{1}{12\pi}(1-a^2)\ln\left(\frac{\Lambda^2}{m_h^2}\right), \quad T = -\frac{3}{16\pi c_W^2}(1-a^2)\ln\left(\frac{\Lambda^2}{m_h^2}\right),$$

LHCP 2013 Barcelona L. Silvestrini

$$\Lambda = 4\pi v/\sqrt{|1-a^2|}$$

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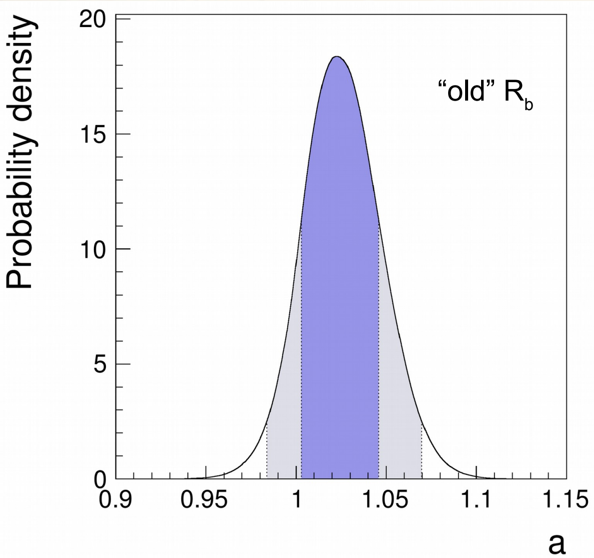
Talks by Luca Silvestrini, Jorge De Blas, Margherita Ghezzi, Ignasi Rosell



See also Falkowski,Riva&Urbano; Contino et al.;Pich et al

Strongly constrains composite Higgs models

Strong bound from EW fit

- $a = 1.02 \pm 0.02$
- $a \in [0.98,1.07]$@95%
- Composite Higgs models typically generate $a < 1$

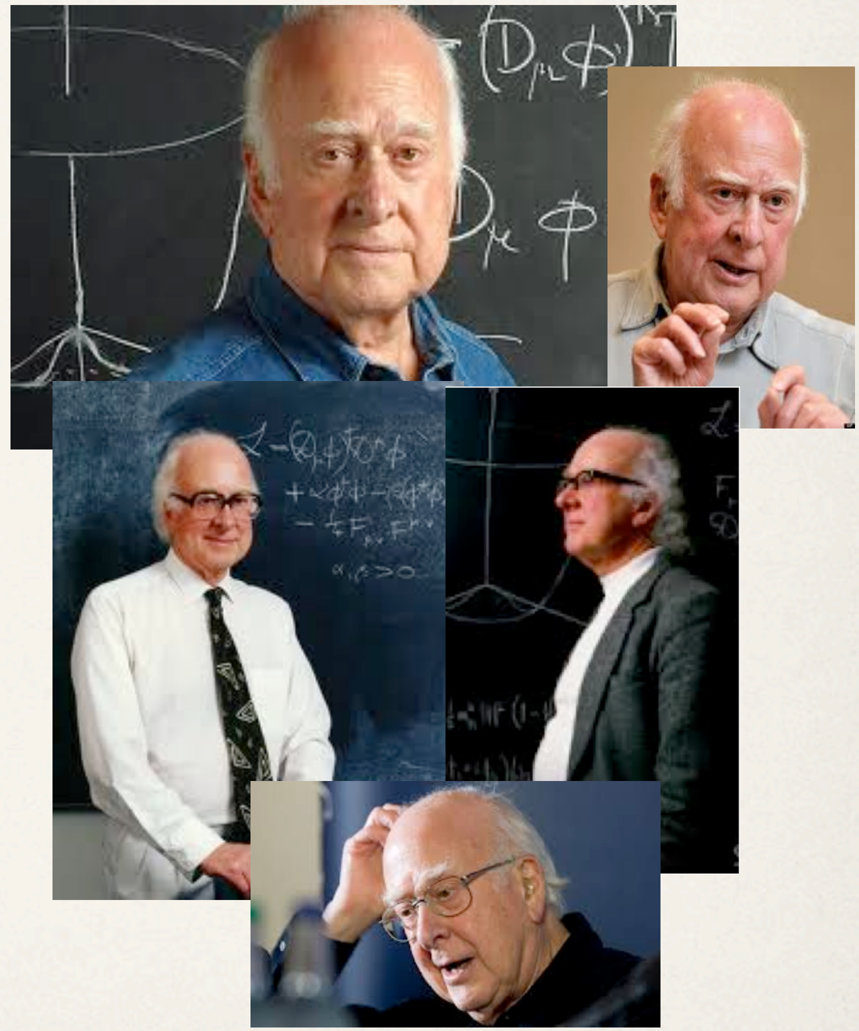
Falkowski,Rychkov&Urbano

- for $a < 1$, $\Lambda > 15$ TeV
- need additional light states to fix EW fit!

see Talk by Andreas Weiler

How many more Higgs?

- Finding heavier/lighter Higgs bosons with non-standard couplings is a major long-term challenge for the LHC
- Supersymmetry and other BSM scenarios predict ***many additional*** kinds of Higgs bosons, differing in their masses, couplings and other properties
- These searches are just as important and promising as measuring the properties of the Higgs that we have in hand



Higgs connections

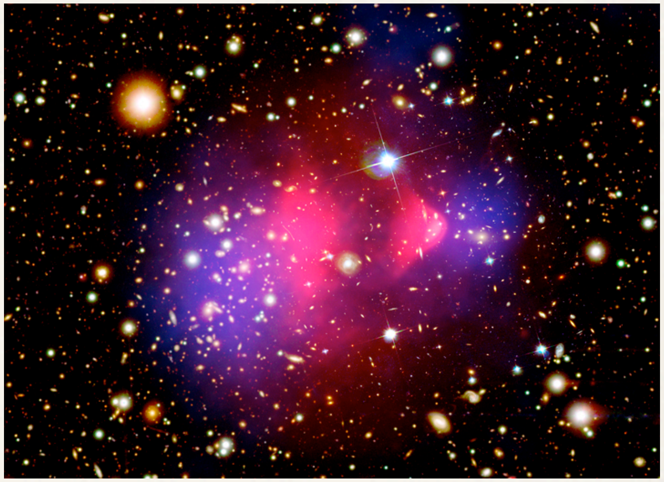
We have always claimed that understanding the Higgs and EWSB would then shed light on everything else. Now do it!

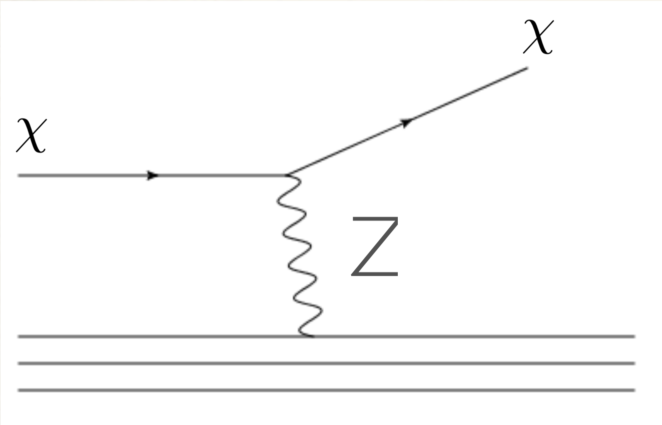
Examples:

- **Dark matter**
- **Quark and charged lepton flavor**
- **Neutrinos (talk by Pilar Hernandez)**
- **Baryogenesis (not this talk)**
- **Inflation, dark energy, ... (not this talk)**

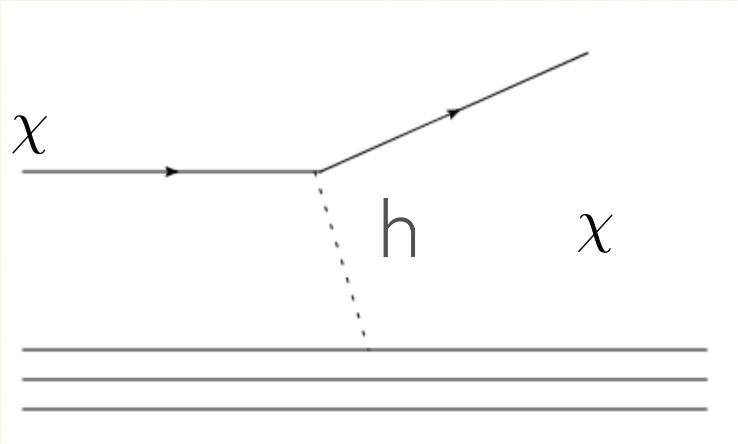
How does dark matter interact with baryonic matter?

via gravity
we know



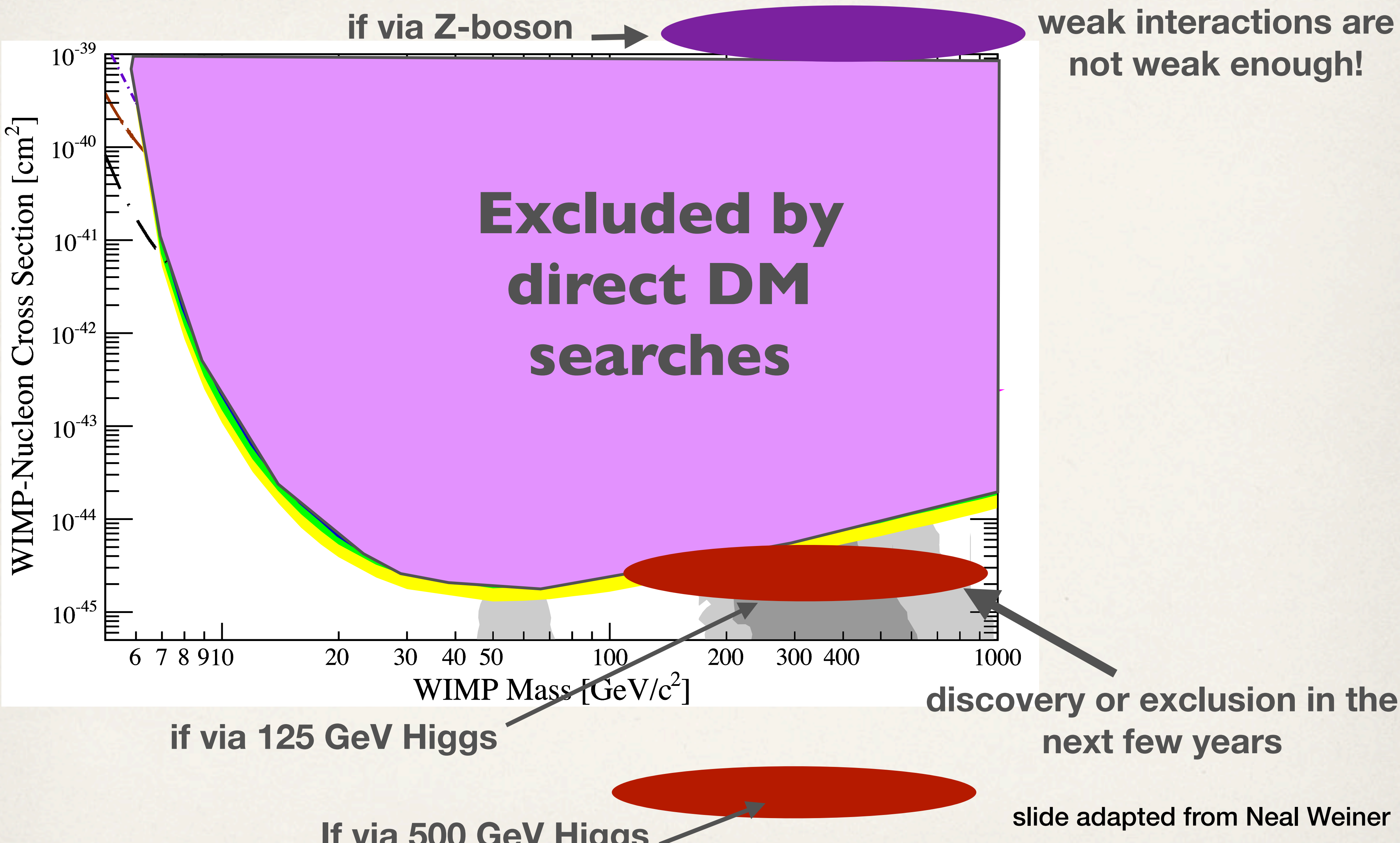


via the Standard Model
weak interactions?



via the Higgs boson?

Direct dark matter detection via the Higgs portal?



slide adapted from Neal Weiner

Higgs and Flavor

Talk by Jure Zupan

- If there is BSM physics, couplings of the Higgs doublet to quarks and leptons may not be just the minimal Yukawas of the SM
- if EFT description valid

$$\Delta\mathcal{L}_Y = -\frac{\lambda'_{ij}}{\Lambda^2}(\bar{f}^i_L f^j_R)H(H^\dagger H) + h.c. + \cdots$$

Giudice, Lebedev, 0804.1753
Agashe, Contino, 0906.1542
Goudelis, Lebedev, Park, 1111.1715
Arhrib, Cheng, Kong, 1208.4669
McKeen, Pospelov, Ritz, 1208.4597
Blankenburg, Ellis, Isidori, 1202.5704
Harnik, Kopp, JZ, 1209.1397

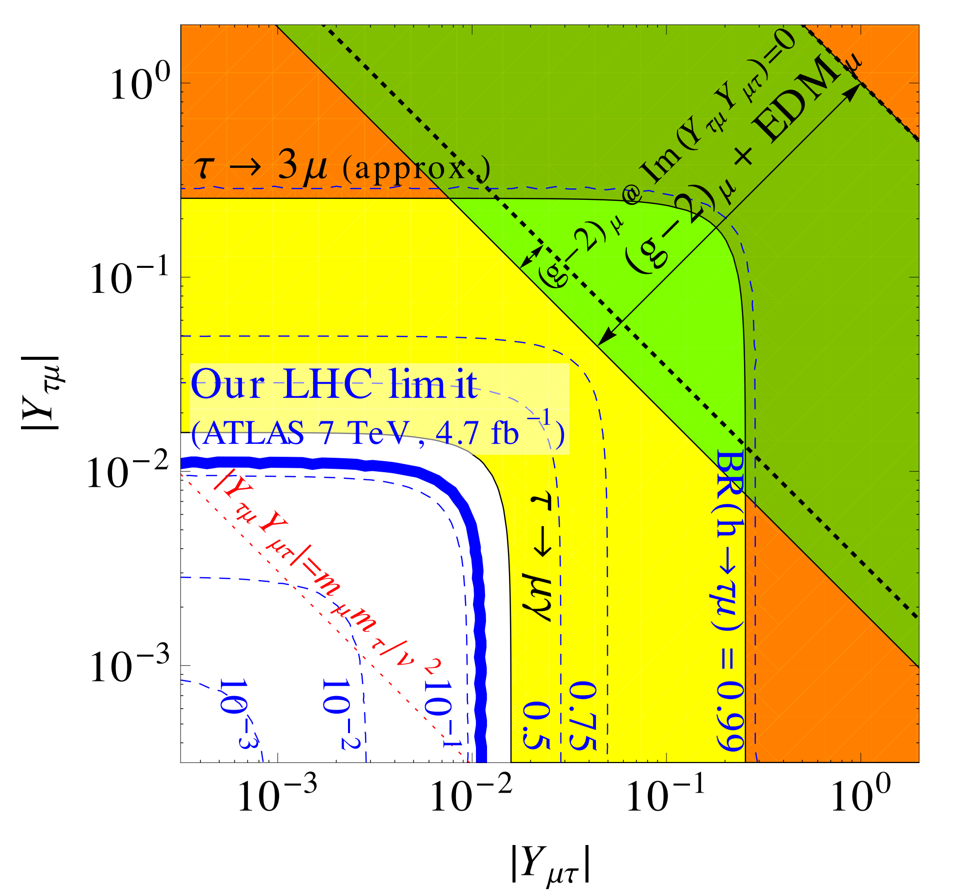
$$\mathcal{L}_Y = -m_i \bar{f}^i_L f^i_R - Y_{ij}(\bar{f}^i_L f^j_R)h + h.c. + \cdots$$

$$Y_{ij} = \frac{m_i}{v}\delta_{ij} + \frac{v^2}{\sqrt{2}\Lambda^2}\hat{\lambda}_{ij}$$

- Both flavor diagonal and flavor violating possible
- FV couplings involving taus or tops not yet strongly constrained

Higgs and Flavor

- So e.g. look for CLFV at LHC more generally
- But specifically also in Higgs decays



$$\mathcal{L}_Y = -m_i \bar{f}_L^i f_R^i - Y_{ij}(\bar{f}_L^i f_R^j)h + h.c. + \cdots$$

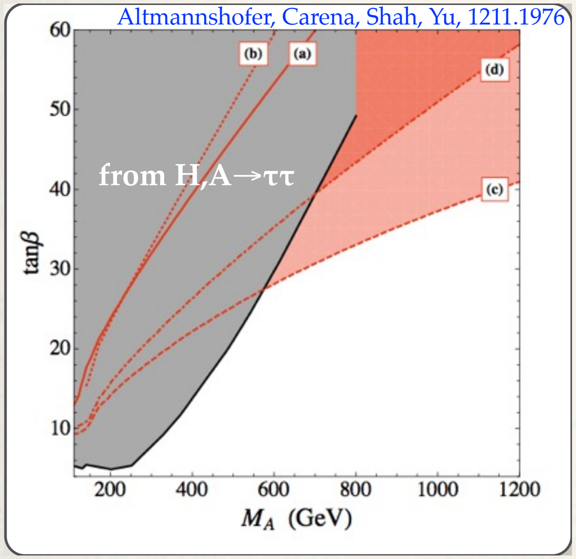
$$Y_{ij} = \frac{m_i}{v}\delta_{ij} + \frac{v^2}{\sqrt{2}\Lambda^2}\hat{\lambda}_{ij}$$

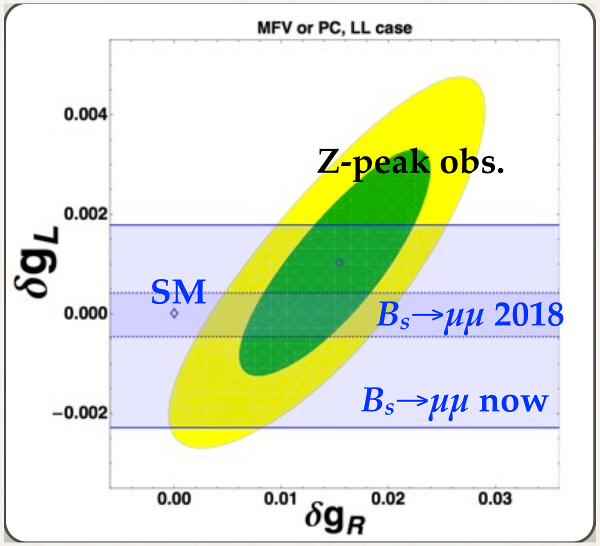
Talk by Jure Zupan

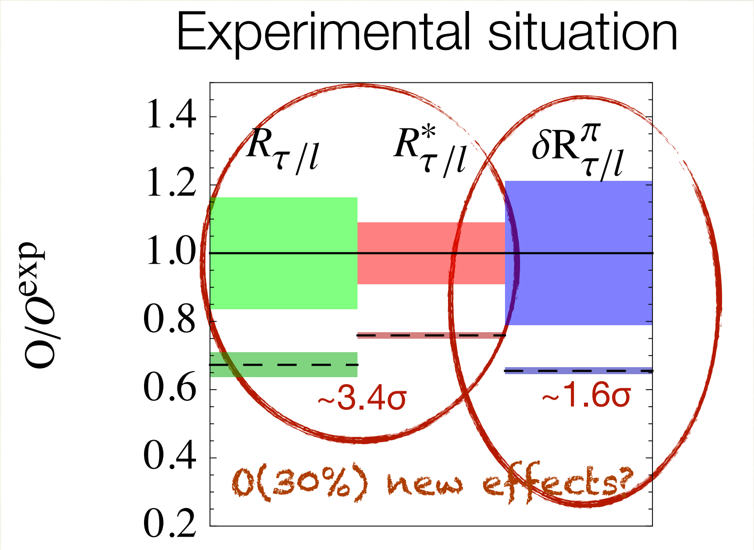
Higgs and Flavor

Talks by Jure Zupan,
Francisco del Aguila
Iftah Galon
George WS Hou
Jernej Kamenik

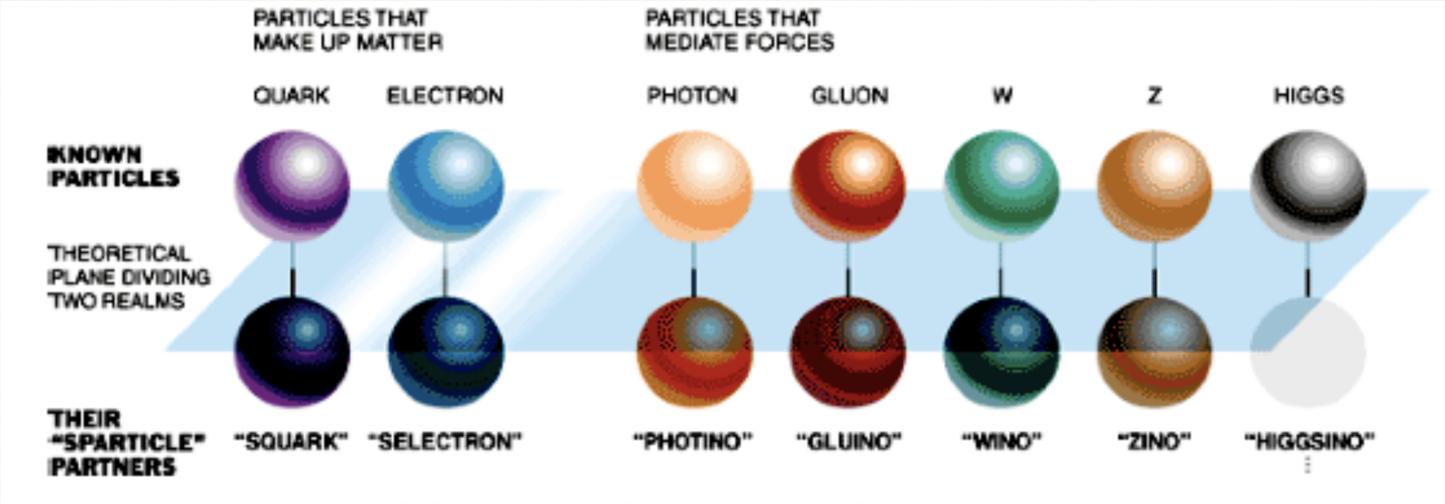
- If there is an extended Higgs sector, expect flavor effects
- Interplay between flavor and direct LHC searches for extra scalars
- Some promising channels, like $\mathbf{B_s} \to \mu^+\mu^-$, are getting quite constrained
- Anomalies in data, e.g. $\mathbf{B} \to \mathbf{D}^*\tau\nu$, may be hints of extended Higgs sector







Supersymmetry:
aut vincere aut mori

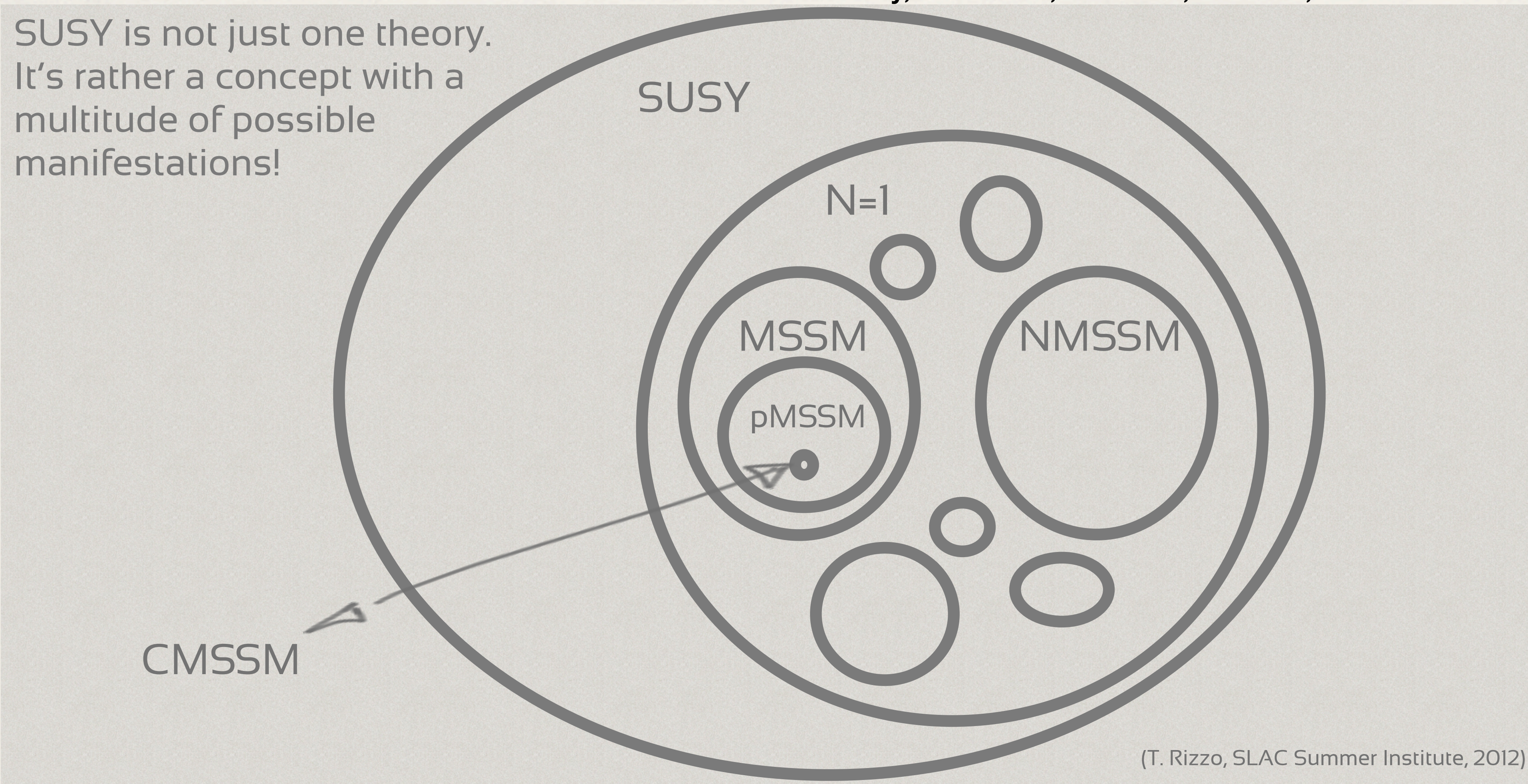


where are the superpartners?

- We knew already that there was a problem with SUSY, from no Higgs at LEP and no superpartners at LEP or Tevatron
- The only question is whether it is a “small” problem or a “big” problem

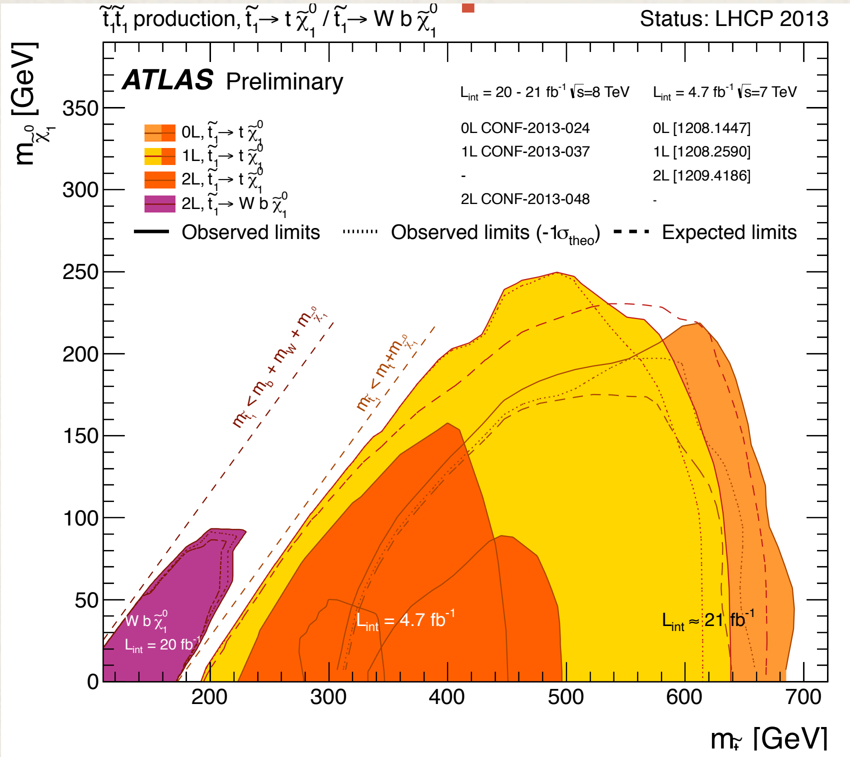
are you getting nervous yet?

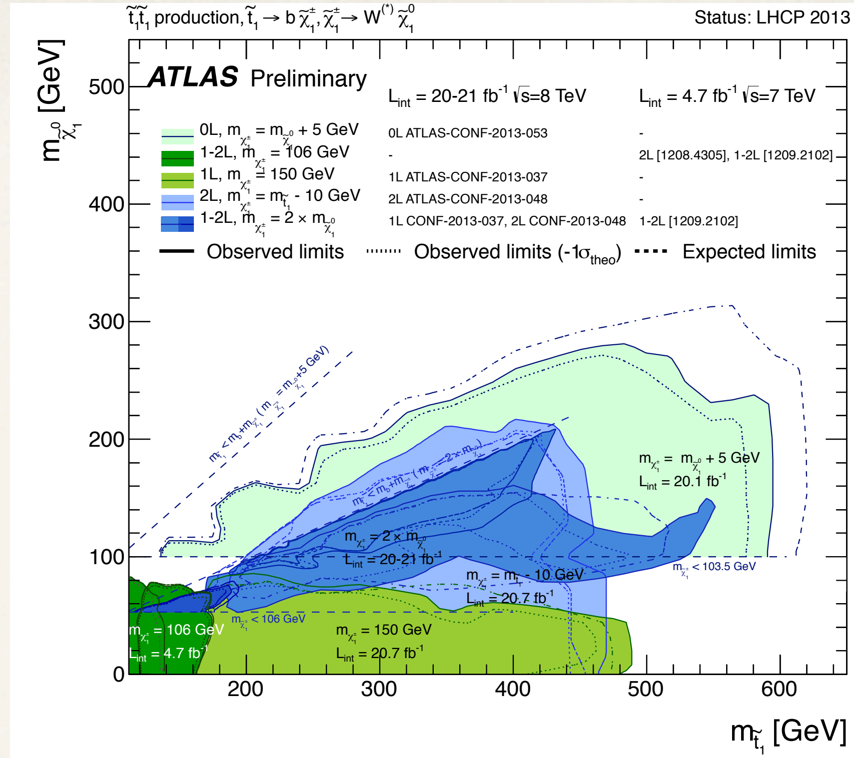
M. Cahill-Rowley, J. Hewett, A. Ismail, T. Rizzo, arXiv:1211.1981



LHC searches at 7 and 8 TeV have so far excluded about 1/3 of the parameter space of the pMSSM; the full parameter space of relevant SUSY models is not even defined

Talk by Fabrizio Salvatore





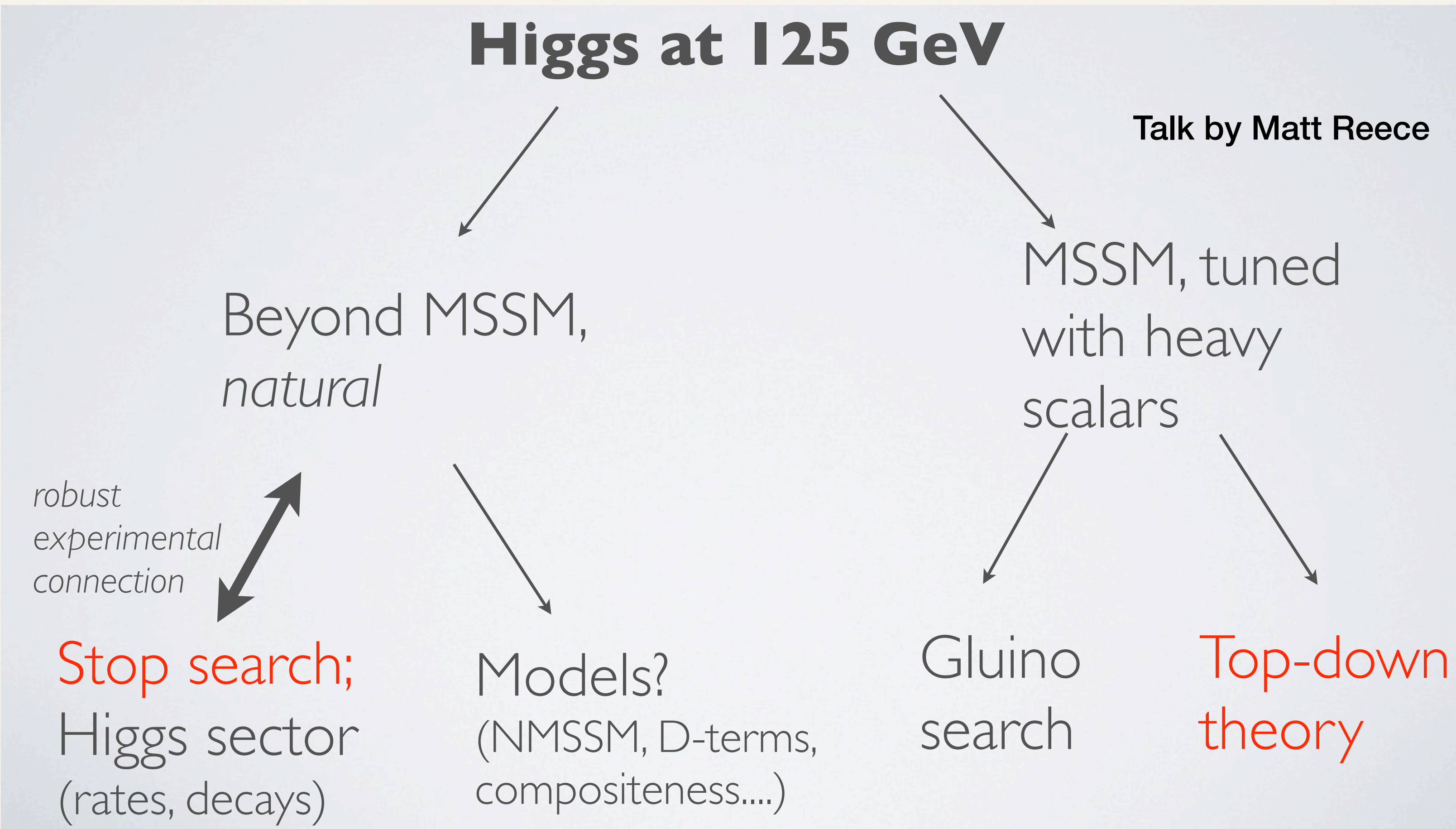
- Need multiple overlapping analyses even to cover the whole parameter space of Over-Simplified Models; this implies a long campaign to discover or exclude SUSY at the TeV scale

- SUSY may have nontrivial flavor features that change the signatures

Talks by Enrico Bertuzzo, Monika Blanke, Francesco Riva

what does a 125 GeV Higgs imply for SUSY?

Note: if Higgs mass had been 20% lighter, easy for SUSY;
if had been 20% or more heavier, (almost) kill SUSY just from this



The Naturalness Dogma: caveat emptor

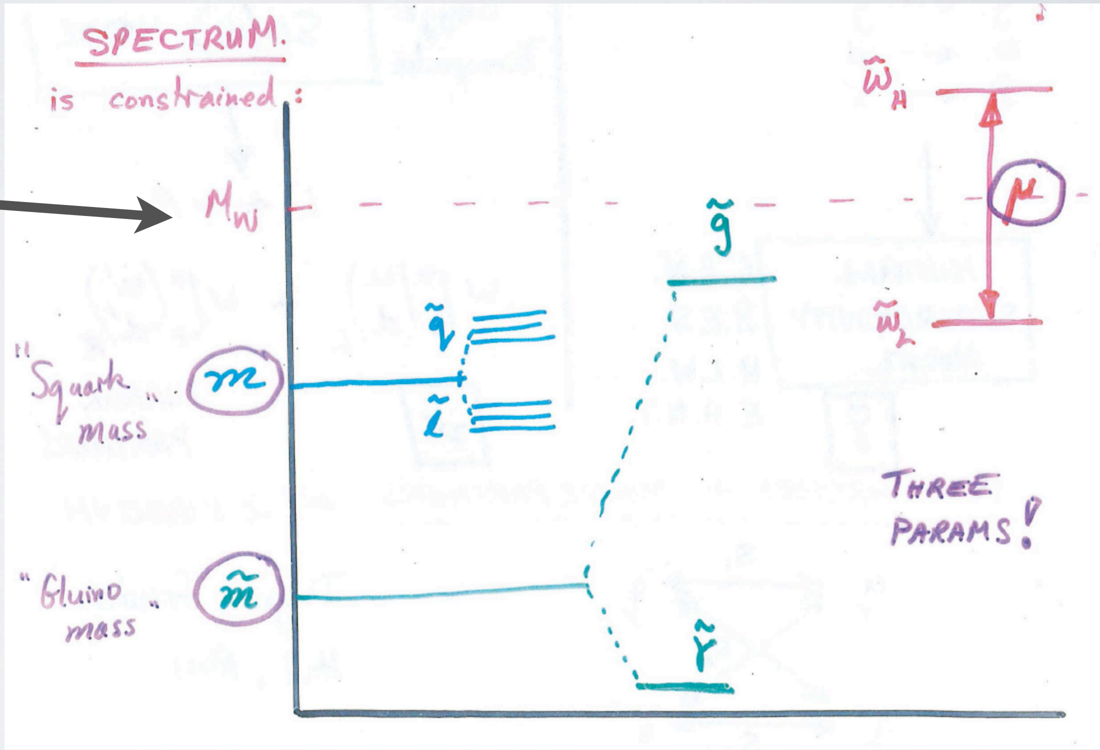
NATURAL SUSY, 1984

From Lawrence Hall's talk at SavasFest

W boson near the top of the spectrum....

1984 was a utopian year for SUSY.

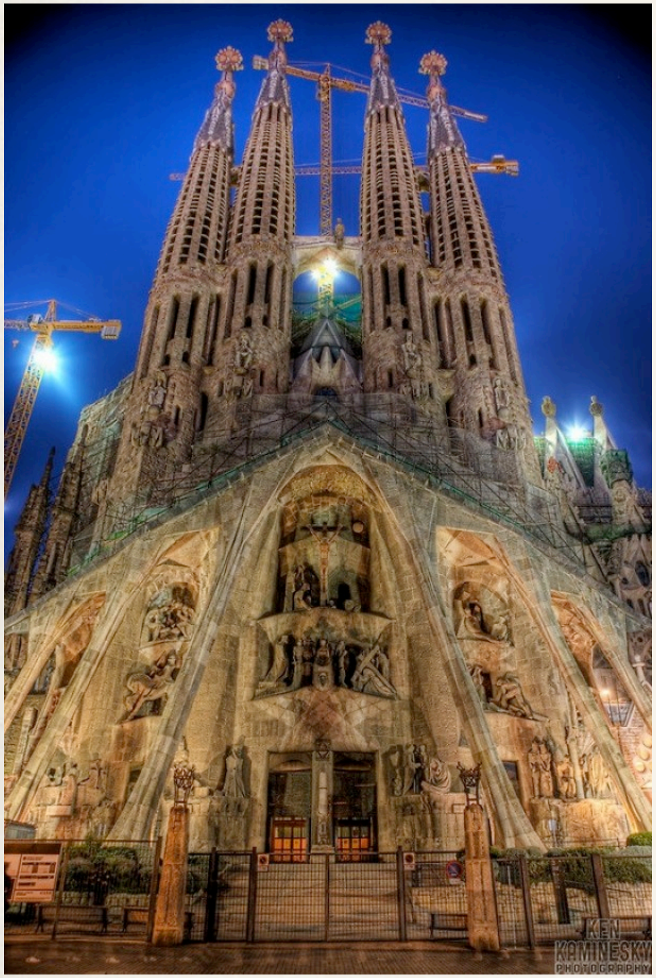
Times have changed!



Talk by Matt Reece

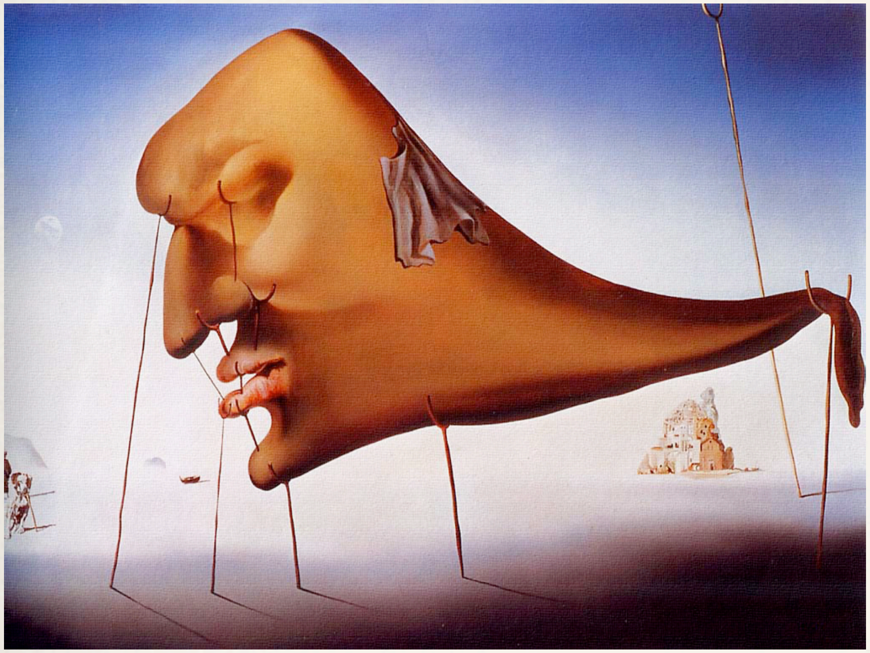
The Naturalness Dogma:

quem deus vult perdere, dementat prius



- If superpartners are discovered at LHC, we will figure out what kind of SUSY model we actually have, and shed light on the tuning issues
- Ditto if we find Higgs compositeness etc
- But it is interesting already to question whether the mighty cathedral of BSM built up over 30 years may rest on shaky foundations...

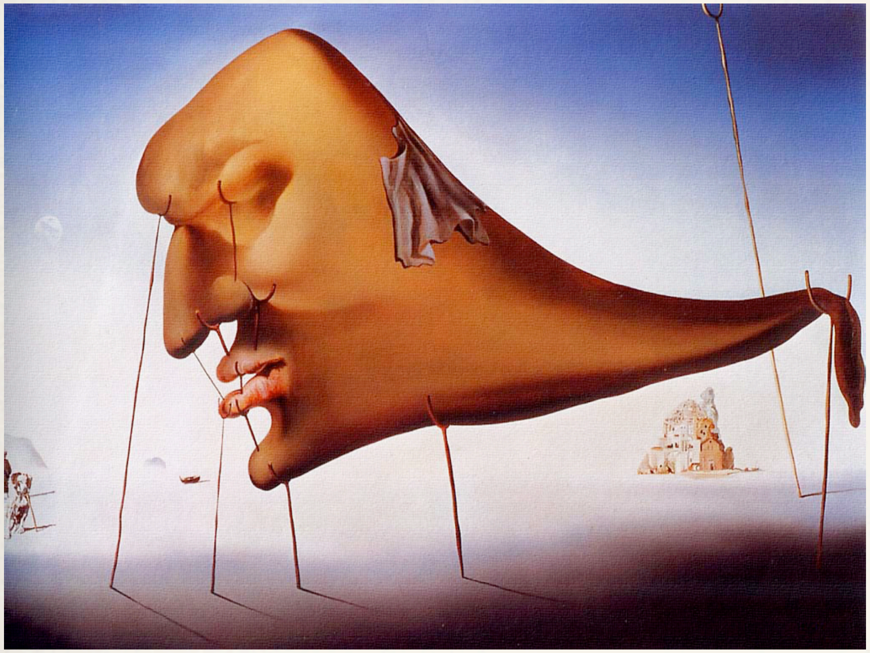
The Naturalness Dogma: how could it be wrong?



possibility #1: SM is all that there is

- The SM plus some renormalizable Terascale additions e.g. to explain dark matter etc is all that there is
- Renormalizable theories don't have naturalness problems, because (at the end of the day) they don't have cutoffs
- Usual counterargument is that at least there is a physical cutoff at M_{Planck}, but this is conjecture

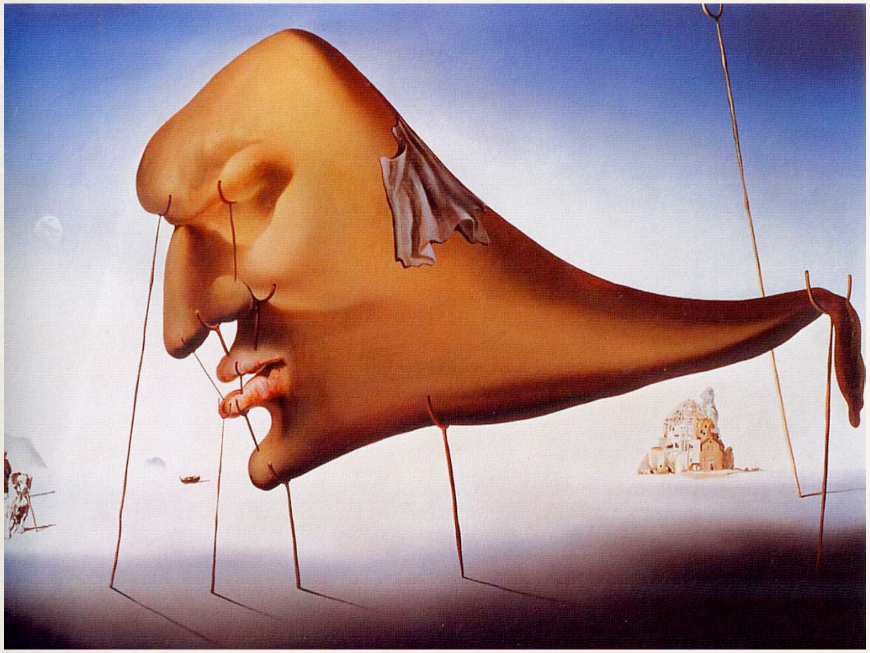
The Naturalness Dogma: how could it be wrong?



possibility #2: 10 TeV is the ultimate energy scale

- Lots of new BSM physics, but no large hierarchy and all tuning issues are “small”
- But: why no strong indirect hints?

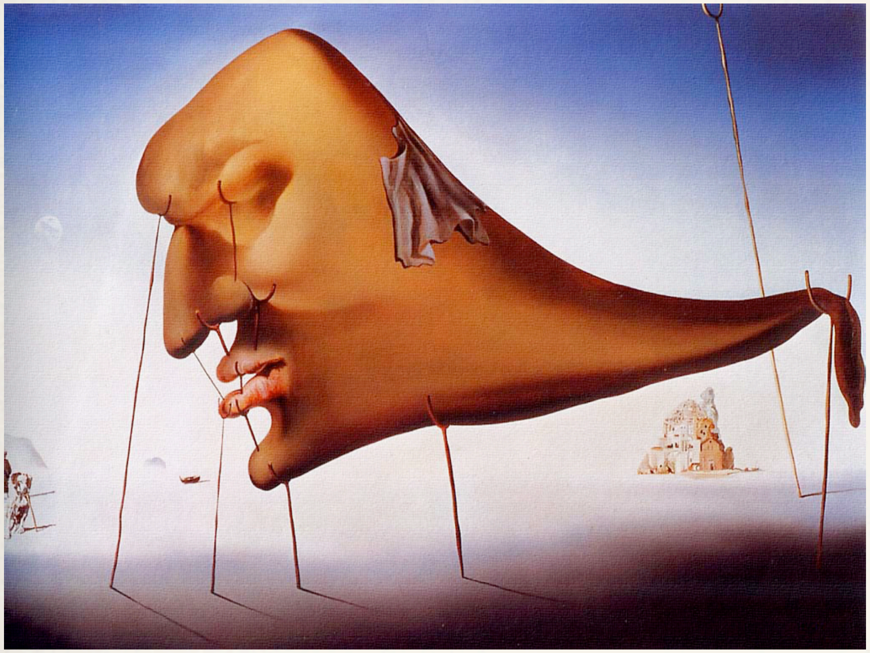
The Naturalness Dogma: how could it be wrong?



possibility #3: it's the Multiverse, Stupid

- Because of eternal inflation at the Planck scale (or something) there are 10^{500} variations on our universe
- The electroweak scale is hierarchically small for anthropic reasons, or for reasons that have to do with the (unknowable) distribution of universes
- Applied "minimally", leads to semi-split SUSY
- If applied arbitrarily, you can explain anything...

The Naturalness Dogma: how could it be wrong?

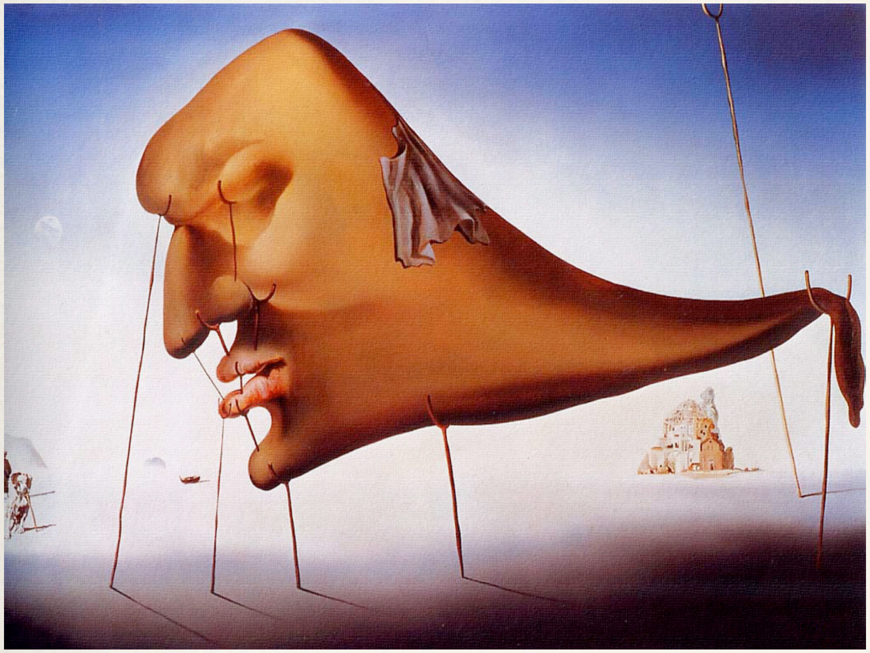


possibility #4: anomalous dimensions

- Naturalness argument depends on relating the Higgs mass-squared to a relevant operator (dimension < 4)
- If somehow new strong interactions are creeping in, perhaps this is not true
- Idea is not controversial, but no working models

M. Strassler hep-th/0309122, R. Sundrum arXiv:0909.5430

The Naturalness Dogma: how could it be wrong?

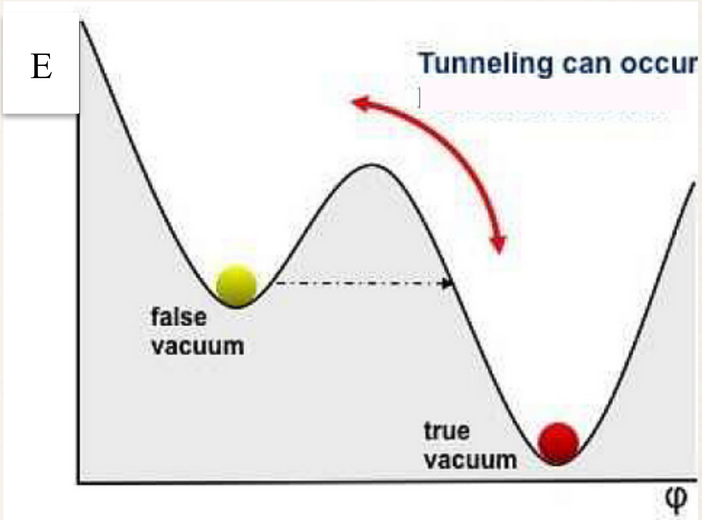


possibility #5: Bardeen naturalness

- SM has a UV completion with no intermediate mass scales
- The UV completion respects the softly-broken scale invariance of the SM
- Use dimensional regularization and be happy; all BSM physics is at the TeV scale or in the magical UV theory
- But: what kind of UV theory does this?

W. Bardeen Fermilab-Conf-95-391-T
K. Meissner and H. Nicolai, hep-th/0612165
etc.

Natura abhorret vacuo inconstans



SM Higgs vacuum instability

- For large field values we can just scale out ϕ^4 and write the RG improved effective potential in terms of a $\lambda_{\mathbf{eff}}$

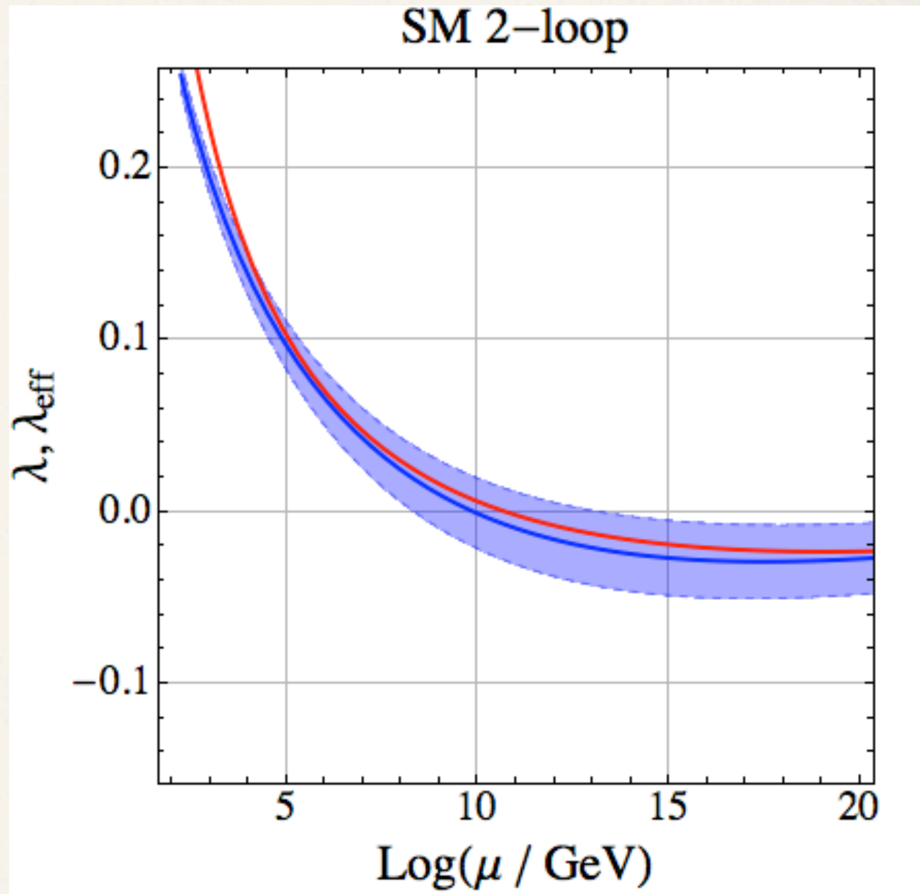
$$\mathbf{V}(\phi) = \mathbf{V_0}(\phi) + \mathbf{V_1}(\phi) \simeq \lambda_{\mathbf{eff}}\, \phi^{\mathbf{4}}$$

J. Casas, J. Espinosa, M. Quiros, hep-ph/9409458

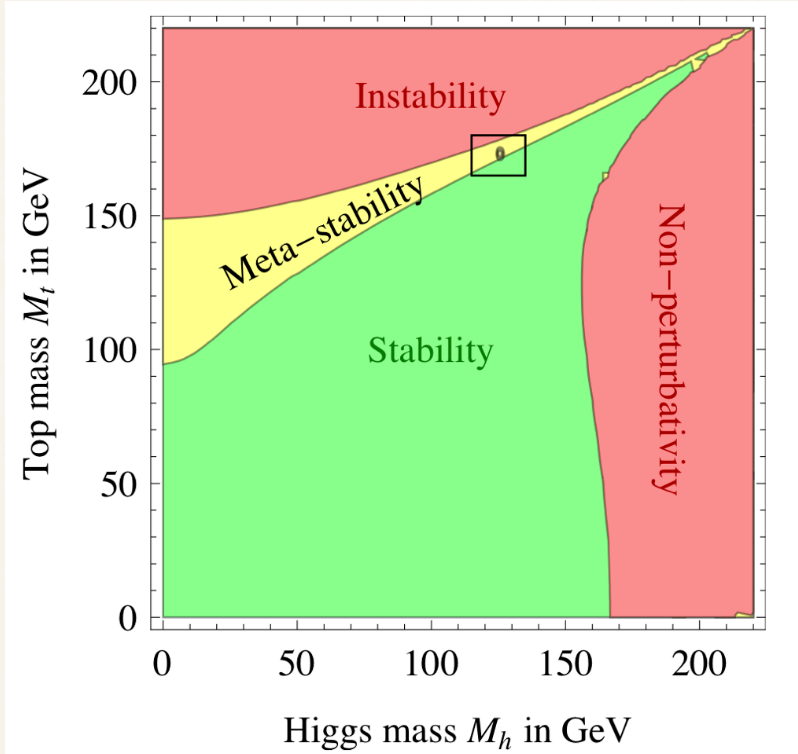
- Then $\lambda_{\mathbf{eff}} < \mathbf{0}$ at large field values implies that the Standard Model vacuum is unstable

- This possibility has been studied since the 1970s, but now we can finally put in the correct numbers

D. Politzer, S. Wolfram, Phys. Lett. 82B, 1979



why do we live on the ragged edge of doom?



A. Strumia, Moriond EW 2013

- if you believe in supersymmetry, then this is just a coincidence
- but dismissing striking features of the data as coincidence has historically not been a winning strategy...

generating the electroweak scale from the dark matter?

- Add a simple dark matter sector that gets its own O(100) GeV mass scale from somewhere
- Can we generate the EW scale radiatively from the DM scale?
- Try to impose the UV boundary conditions $\mathbf{m_0 = 0, \quad \lambda_0 = 0}$, i.e. **vanishing** of the SM Higgs potential at the high scale

generating the electroweak scale from the dark matter

$$\mathbf{V_0(H,S) = m_0^2|H|^2 + \frac{1}{2}\lambda|H|^4 + \lambda_{sh}|H|^2|S|^2 + m_s^2|S|^2 + \frac{1}{2}\lambda_s|S|^4}$$

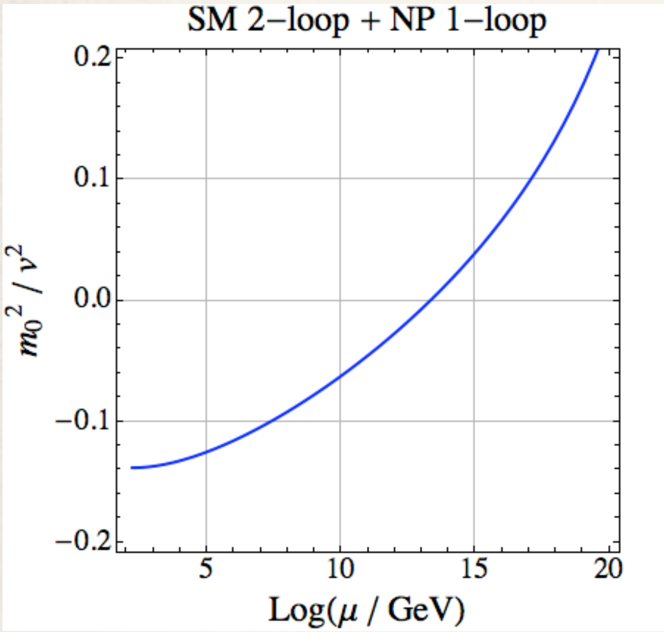
- Example: $\mathbf{m_s(v) = 320\ GeV,\ \lambda_{sh}(M_t) = 0.2,\ \lambda_s(M_t) = 0.3}$
- This is not ruled out by XENON and has more-or-less the correct relic abundance
- Do we get radiative electroweak symmetry breaking?

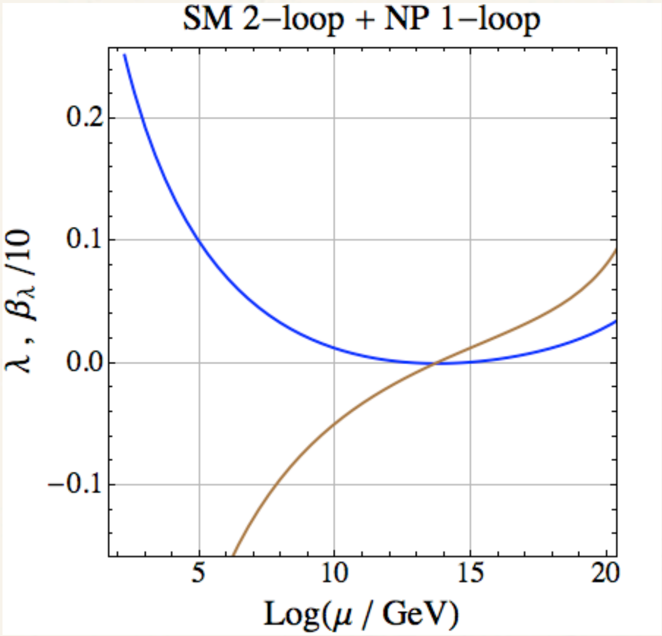
W. Altmannshofer, M. Carena, JL

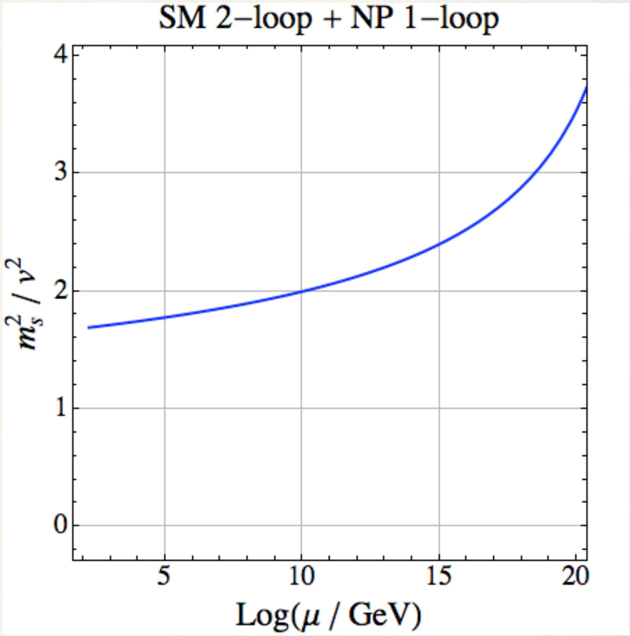
$$\mathbf{V_0(H,S) = m_0^2|H|^2 + \frac{1}{2}\lambda|H|^4 + \lambda_{sh}|H|^2|S|^2 + m_s^2|S|^2 + \frac{1}{2}\lambda_s|S|^4}$$

$$\mathbf{m_s(v) = 320\ GeV,\ \lambda_{sh}(M_t) = 0.2,\ \lambda_s(M_t) = 0.3}$$

W. Altmannshofer, M. Carena, JL







- So at a UV starting point of about 10^{13} GeV we have $\mathbf{m_0 = 0,\ \lambda_0 = 0,\ \beta_\lambda = 0}$
- ***No Higgs potential is input***, but we get correct radiative EWSB from an input dark matter scale of about 360 GeV

QCD: hic sunt dracones

Just when you thought QCD was becoming tame, LHC data reminds us that QCD is full of surprises and challenges

- *pQCD for the masses*
- *parton distributions grow up*
- *QCD hydrodynamics*
- *QCD and string theory*
- *The revenge of quarkonia*
- *What is the X(3872)?*

pQCD for the masses

Slide by S. Pozzorini

$pp \to t\bar{t}b\bar{b}$	[Bredenstein, Denner, Dittmaier, S.P. '09–'10]
	[Bevilacqua, Czakon, Papadopoulos, Pittau, Worek '09]
$pp \to t\bar{t}jj$	[Bevilacqua, Czakon, Papadopoulos, Worek '10–'11]
$pp \to t\bar{t}t\bar{t}$	[Bevilacqua, Worek '12]
$pp \to WWb\bar{b}$	[Denner, Dittmaier, Kallweit, S.P. '11–'12]
	[Bevilacqua, Czakon, van Hameren, Papadopoulos, Worek '11]
$pp \to b\bar{b}b\bar{b}$	[Greiner, Guffanti, Reiter, Reuter '11]
$pp \to WWjj$	[Melia, Melnikov, Rontsch, Zanderighi '10–'11]
	[Greiner, Heinrich, Mastrolia, Ossola, Reiter, Tramontano '12]
$pp \to W/Z + 3j$	[Ellis, Melnikov, Zanderighi '09–'10]
	[Berger, Bern, Dixon, Febres Cordero, Forde, Gleisberg, Ita, Kosower, Maitre '09–'10]
$pp \to W/Z + 4j$	[Berger, Bern, Dixon, Febres Cordero, Forde, Gleisberg, Ita, Kosower, Maitre '11–'12]
$pp \to 4j$	[Bern, Diana, Dixon, Febres Cordero, Hoeche, Kosower, Ita, Maitre, Ozeren '11]
	[Badger, Biedermann, Uwer, Yundin '12]
$pp \to W\gamma\gamma j$	[Campanario, Englert, Rauch, Zeppenfeld '11]
$e^+e^- \to 5j$	[Frederix, Frixione, Melnikov, Zanderighi '10]
$e^+e^- \to 7j$	[Becker, Goetz, Reuschle, Schwan, Weinzierl '12]
pp -> W + 5j	[Bern, Dixon, Fabres Cordero, Hoeche, Ita, Kosower, Maitre, Ozeren '13]

Talks by Matteo Cacciari
Robert Harlander,
Fabio Maltoni,
Christian Schwanenberger,
Luca Barze,
Marco Bonvini,
Alice Maria Donati,
Paul Fiedler,
Leif Lonnblad,
Tom Melia,
Stefano Pozzorini,
Adrian Irles Quiles,
Matthias Steinhauser

The NLO revolution continues, will be of increasing importance for LHC

pQCD for the masses

Talks by Matteo Cacciari
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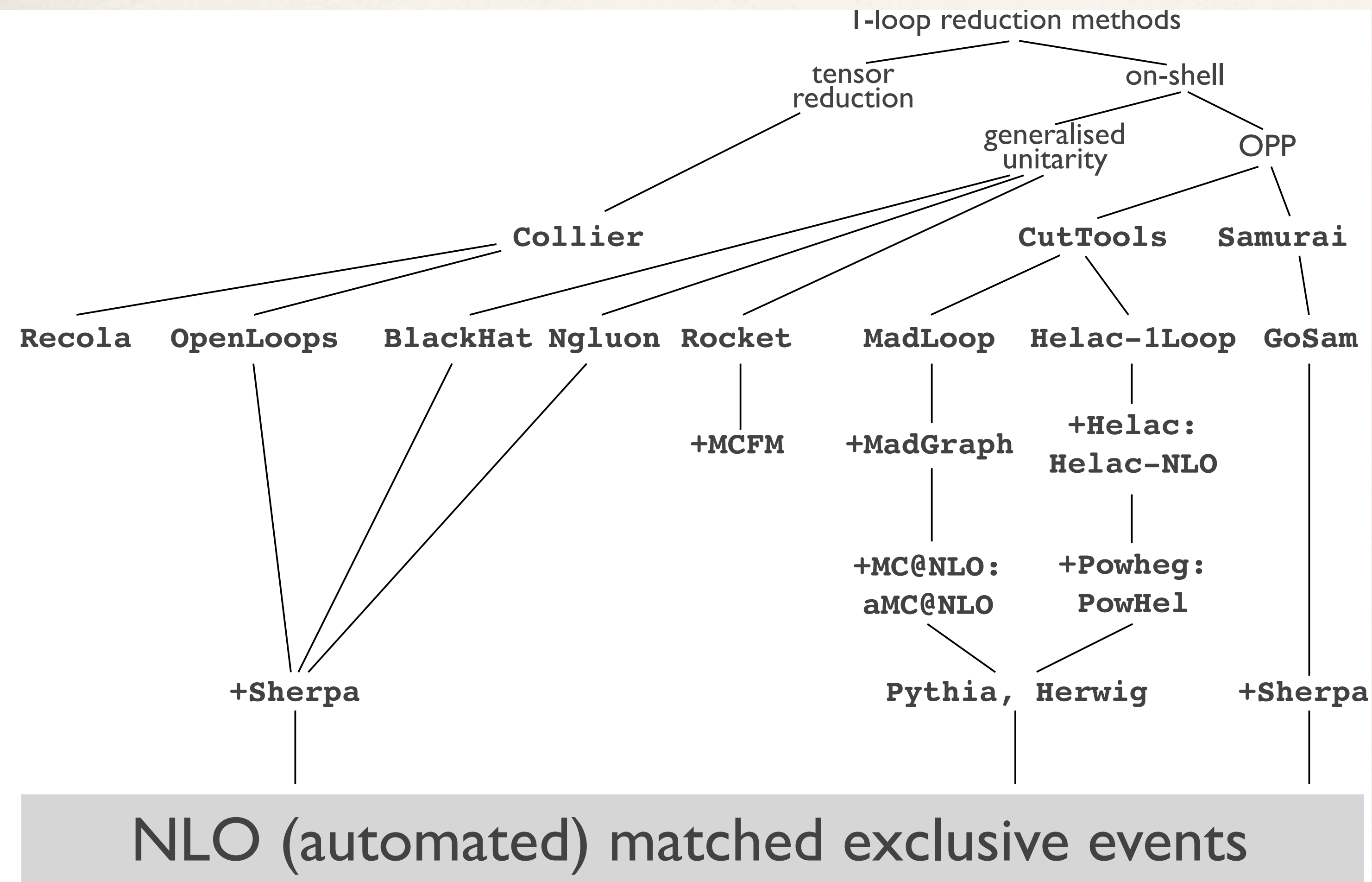


Increasing power of public automated tools for SM and BSM

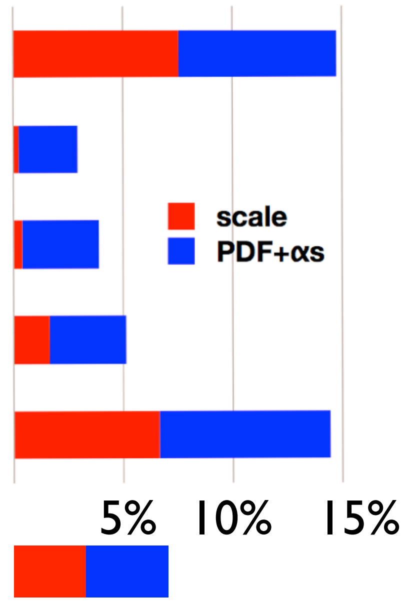
parton distributions grow up

Talks by Matteo Cacciari,
Juan Rojo

Impact of PDFs uncertainties

J. Campbell, ICHEP'12

		σ (8 TeV)	uncertainty
NNLL QCD +NLO EW	gg→H	19.5 pb	14.7%
	VBF	1.56 pb	2.9%
NNLO QCD +NLO EW	WH	0.70 pb	3.9%
	ZH	0.39 pb	5.1%
NLO QCD	ttH	0.13 pb	14.4%
NNLO QCD	tt	245.8 pb	7%



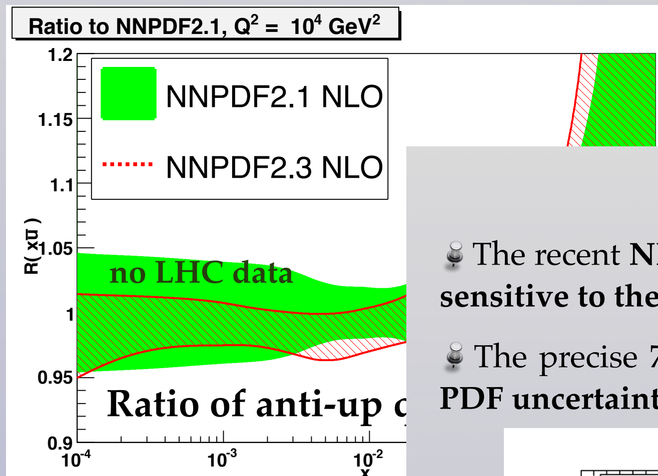
- PDF uncertainties at least comparable to missing higher orders ones

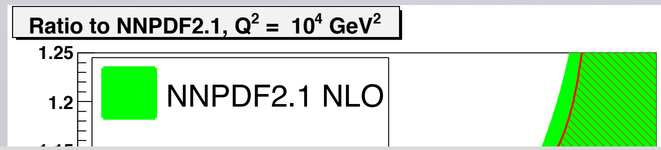
parton distributions grow up

Talks by Matteo Cacciari, Juan Rojo

PDFs with LHC data

- A major improvement in PDF sets is **use of LHC data** to constrain quark and gluon PDFs
- **NNPDF2.3** is only publicly available PDF set that includes constrains from **LHC jet and W,Z data**
- Near future goal: PDFs sets based only on **collider data**

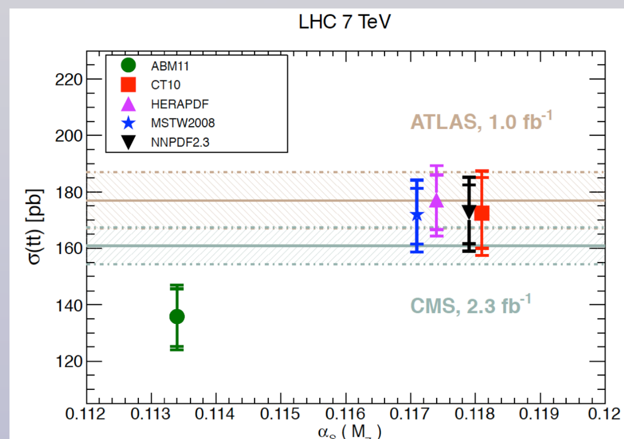


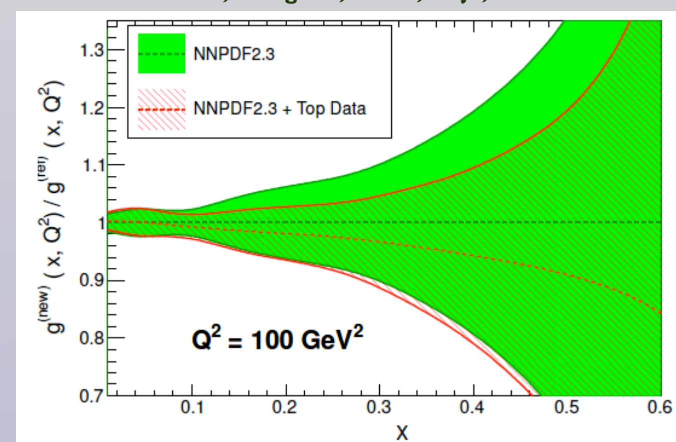


Top quarks as gluon luminometers

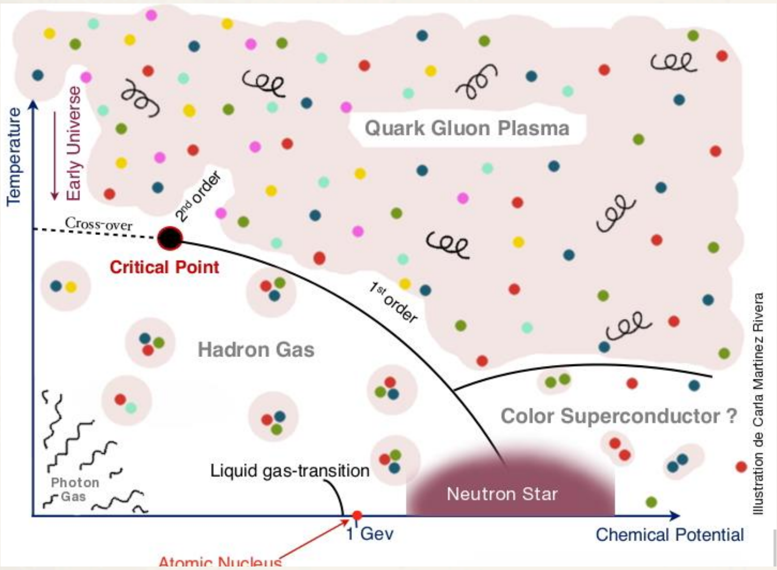
- The recent **NNLO top quark cross section** make top data the **only LHC observable** that is both **directly sensitive to the gluon PDF** and can be included consistently in a **NNLO global analysis**
- The precise 7 and 8 TeV LHC data can be used to **discriminate between PDF sets** and **to reduce the PDF uncertainties on the poorly known large-x gluon**

Czakon, Mangano, Mitov, Rojo, arxiv:1303.7215





QCD hydrodynamics



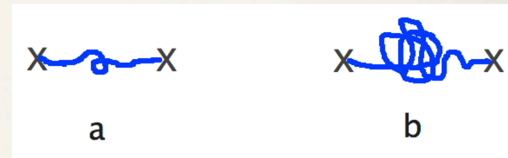
- Heavy ion collisions at LHC produce an excited nonequilibrium strongly-interacting extended state
- It isotropizes extremely rapidly, time scale ~ 1 fermi/c
- Shows flow characteristics of relativistic hydrodynamics
- Quenches jets and melts quarkonia
- This is the Quark Gluon Plasma!

Talks by Urs Wiedemann, Javier Albacete, Jorge Casalderrey-Solana, Cyrille Marquet

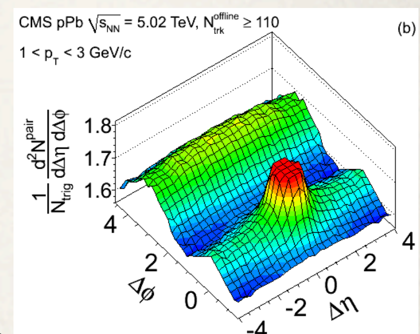
The Golden Age of Heavy Ion physics is now

from strings to QGP to black holes

- At LHC, we see QGP-like features in p-Pb collisions, and even in high multiplicity p-p collisions ("the ridge")!
- An experimental opportunity and a theoretical challenge
- Can we understand the transition from scattering described in terms of gluons and QCD strings, to relativistic hydrodynamics?

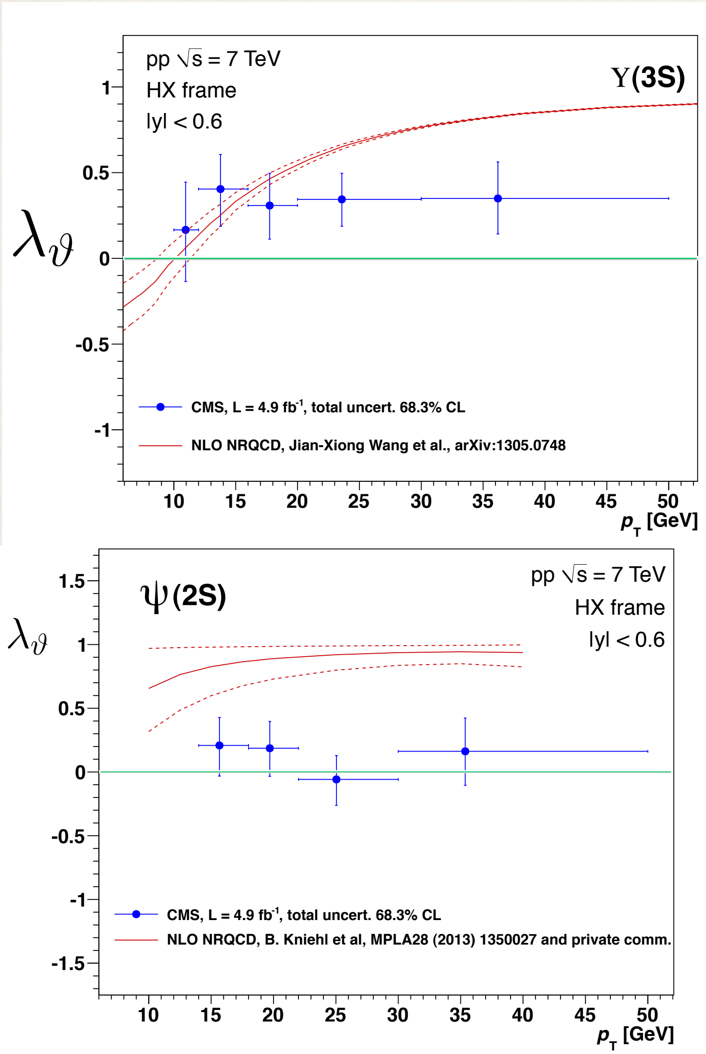


E. Shuryak and I. Zahed arXiv:1301.4470



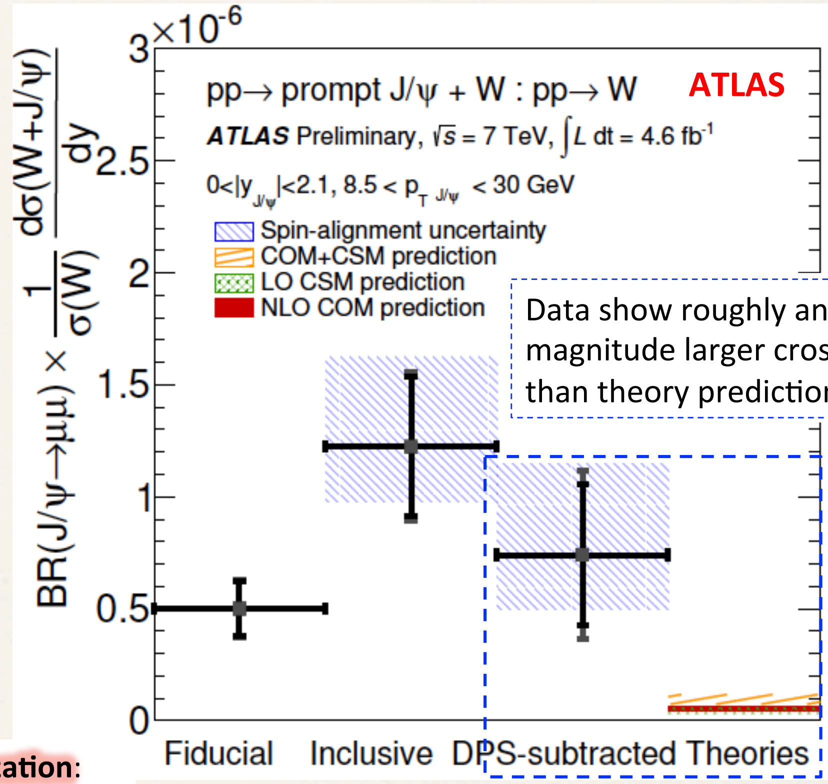
- Can we understand QCD hydrodynamics on the smallest scales? Explain the ridges?
- AdS/CFT duality allows to use perturbed black holes as toy models for strongly-coupled out-of-equilibrium plasmas: how much can we learn from this about QCD?

the quarkonia polarization crisis



Talk by Carlos Lourenco

"We have been comparing our beautiful data to too many bad theories" -- Carlos Lourenco



Data show roughly an order of magnitude larger cross section than theory predictions

- **NRQCD factorization**: quarkonia also produced as ***coloured*** Q-Qbar pairs *of any possible quantum numbers*

Talk by Hermine Wohri

the quarkonia polarization crisis

"We have been comparing our beautiful data to too many bad theories" -- Carlos Lourenco

- **NRQCD *is* QCD, in an unambiguous expansion in powers of both α_s and the heavy quark velocity** $\mathbf{v} \sim \sqrt{\frac{\Lambda_{\mathbf{QCD}}}{\mathbf{M_Q}}}$
- **However the factorization introduces a number of long distance matrix elements that have to be fit to data (like pdfs)...**
- **And it is assumed that these LDMEs are universal...**
- **And for charmonium and bottomonium, v is not especially small...**

the quarkonia polarization crisis

M. Butenschoen, B. Kniehl, arXiv:1212.2037

"In a way, NRQCD factorization ... is the only game in town, which makes its experimental verification such a matter of paramount importance..."

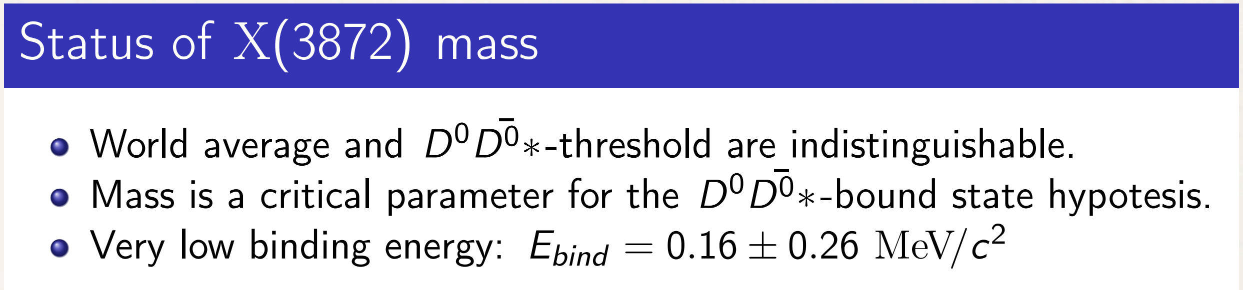
(i) The eagerly awaited J/ψ polarization measurements at the LHC might not confirm the CDF II results.

(ii) Although unlikely, measurements at a future ep collider, such as the LHeC,[49] might reveal that the p_T distribution of J/ψ photoproduction exhibits a drastically weaker slope beyond $p_T = 10$ GeV, the reach of HERA, so that the LDME sets of Refs. 52, 53 might yield better agreement with the data there.

(iii) The assumption that the v expansion is convergent might not be valid for charmonium, leaving the possibility that the LDME universality is intact.

My conclusion: there is a big problem here

what is the X(3872)?



Talk by A. Augusto Alves Jr.

- It is a 1^{++} state, obviously connected to the D^0-D^{0*} threshold
- If bound, it's "size" is between 7 and 11 fermi, more than twice the size of the deuteron...
- May not even be bound, may be a virtual "state"
- Either way, quite peculiar
- Can someone find the $Z_b(10610)$ at LHC now?

What theorists want: scientia ipsa potentia est

Random Theorist: ***"I want CMS to compare your data to this new class of models that I invented yesterday."***

CMS Experimentalist (aka Maurizio Pierini): ***"Yes, and I want a pony."***

Search for new physics in events with same-sign dileptons and b jets in pp collisions at $\sqrt{s} = 8$ TeV

JHEP03(2013)037

The CMS collaboration

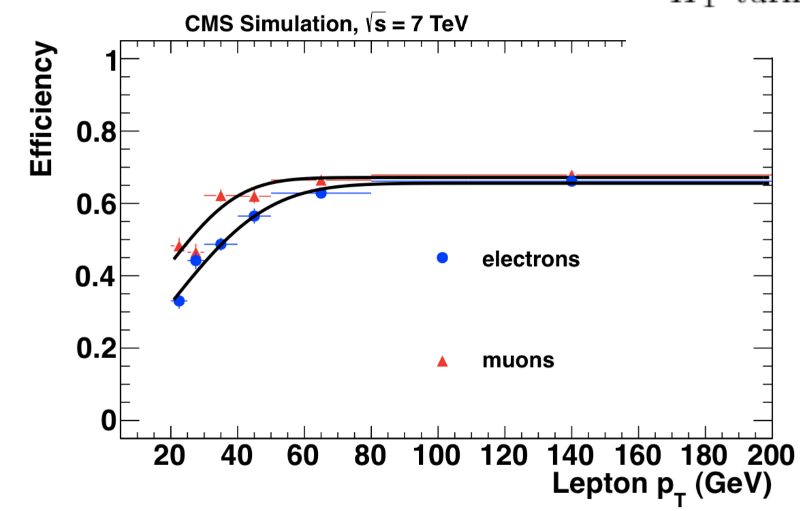
E-mail: cms-publication-committee-chair@cern.ch

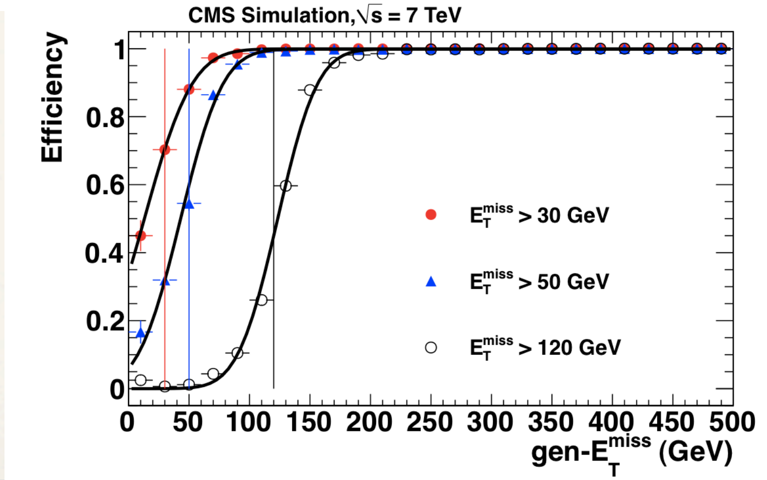
ABSTRACT: A search for new physics is performed using events with isolated same-sign leptons and at least two bottom-quark jets in the final state. Results are based on a sample of proton-proton collisions collected at a center-of-mass energy of 8 TeV with the CMS detector and corresponding to an integrated luminosity of 10.5 fb^{-1}. No excess above the standard model background is observed. Upper limits are set on the
non-standard-model sources and are used to constrain a number o
Information on acceptance and efficiencies is also provided so that t
to confront an even broader class of new physics models.

- **Some LHC analyses provide extra information to allow theorists to recast the limits for their own models with decent accuracy**
- **CMS SS-dilepton SUSY was a pioneer in this**

7 Information for model testing

Our results can be used to confront models of new physics in an approximate way through generator-level studies that compare the expected numbers of events with the upper limits from table 2. The prescription to be used is given in ref. [15], section 7. The E_T^{miss} and H_T turn-on curves in this analysis are the same as those of ref. [15]. However the lepton





- **This even works for a sophisticated 2D shape analysis like the Razor**
- **CMS provides the background model, theorists are expected to generate their own signal MC**

TWiki > CMSPublic Web > Razor-cms > RazorLikelihoodHowTo (22-Mar-2013, MaurizioPierini) Edit Attach PDF

Reproducing The Razor Limit in Your SUSY study

This page guides you through the construction of a binned likelihood which allows you to plug the Razor SUSY constraint in your SUSY pheno study. The page refers to the latest results of the inclusive Razor and inclusive btag Razor analyses, performed on 7TeV CMS data.

You need to start from an event generator which provides you a sample of simulated SUSY events from 7 TeV pp collisions This twiki page shows how to

1. Account for detector effects in the reconstruction of the main objects used in the analysis (jet, MET, electrons, muons, and btag)
2. Calculate the Razor variables
3. Define the boxes
4. Build a 2D PDF with the binning we provide
5. compute the binned likelihood as a product of Poisson (for the observed yield) and Gaussian (for the background systematic) functions.

- This kind of service means a lot of extra work for the ATLAS/CMS analyzers
- But it is a valuable service and is being used by the theory community

TWiki > CMSPublic Web > Razor-cms > RazorLikelihoodHowTo (22-Mar-2013, MaurizioPierini)

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1. Account for detector effects in the reconstruction
2. Calculate the Razor variables
3. Define the boxes
4. Build a 2D PDF with the binning we provide
5. compute the binned likelihood as a product of Poi
functions.

arXiv:1304.3068v1 [hep-ph] 10 Apr 2013

Mixing stops at the LHC

Squark flavor violation models
See talk by Monika Blanke

Prateek Agrawal and Claudia Frugiuele

Fermilab, P.O. Box 500, Batavia, IL 60510, USA

E-mail: prateek@fnal.gov, claudiaf@fnal.gov

Abstract: We study the phenomenology of a light stop NLSP in the presence of large mixing with either the first or the second generation. R-symmetric models provide a prime setting for this scenario, but our discussion also applies to the MSSM when a significant amount of mixing can be accommodated. In our framework the dominant stop decay is through the flavor violating mode into a light jet and the LSP in an extended region of parameter space. There are currently no limits from ATLAS and CMS in this region. We emulate shape-based hadronic SUSY searches for this topology, and find that they have potential sensitivity. If the extension of these analyses to this region is robust, we find that these searches can set strong exclusion limits on light stops. If not, then the flavor violating decay mode is challenging and may represent a blind spot in stop searches even at 13 TeV. Thus, an experimental investigation of this scenario is well motivated.

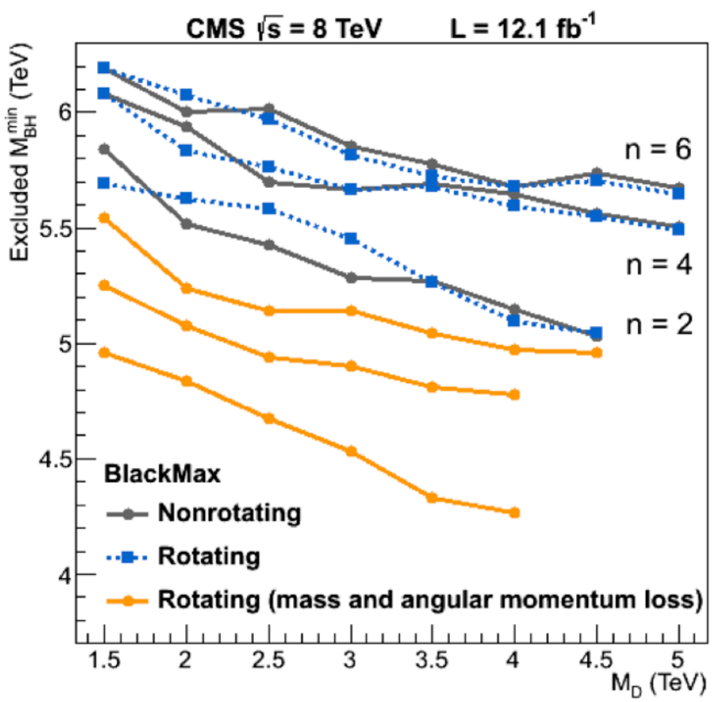
- **Good to constrain specific models, but model-independent limits are even better!**

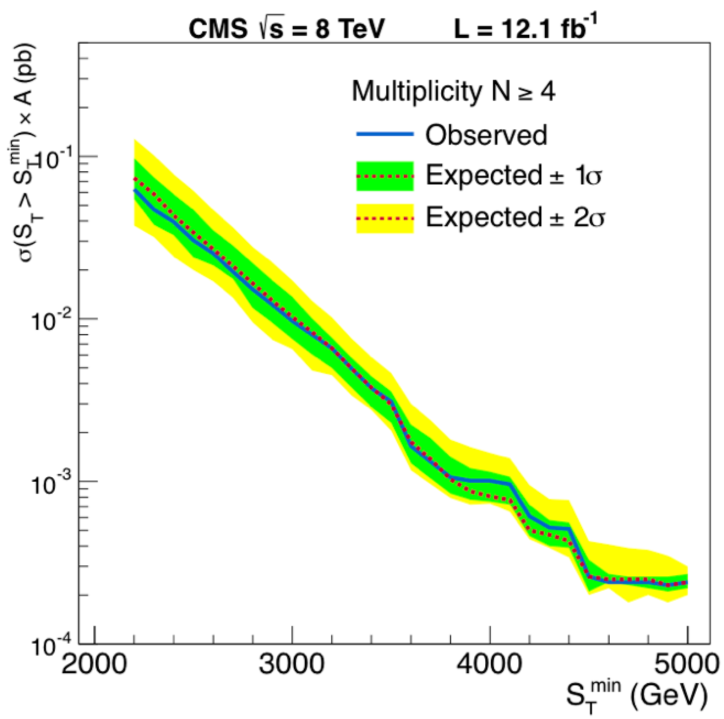
SEARCH FOR BLACK HOLES

Talk by Steve Worm

[arXiv:1303:5338, EXO-12-009]

Also interesting as a model-independent search vs S_T and multiplicity





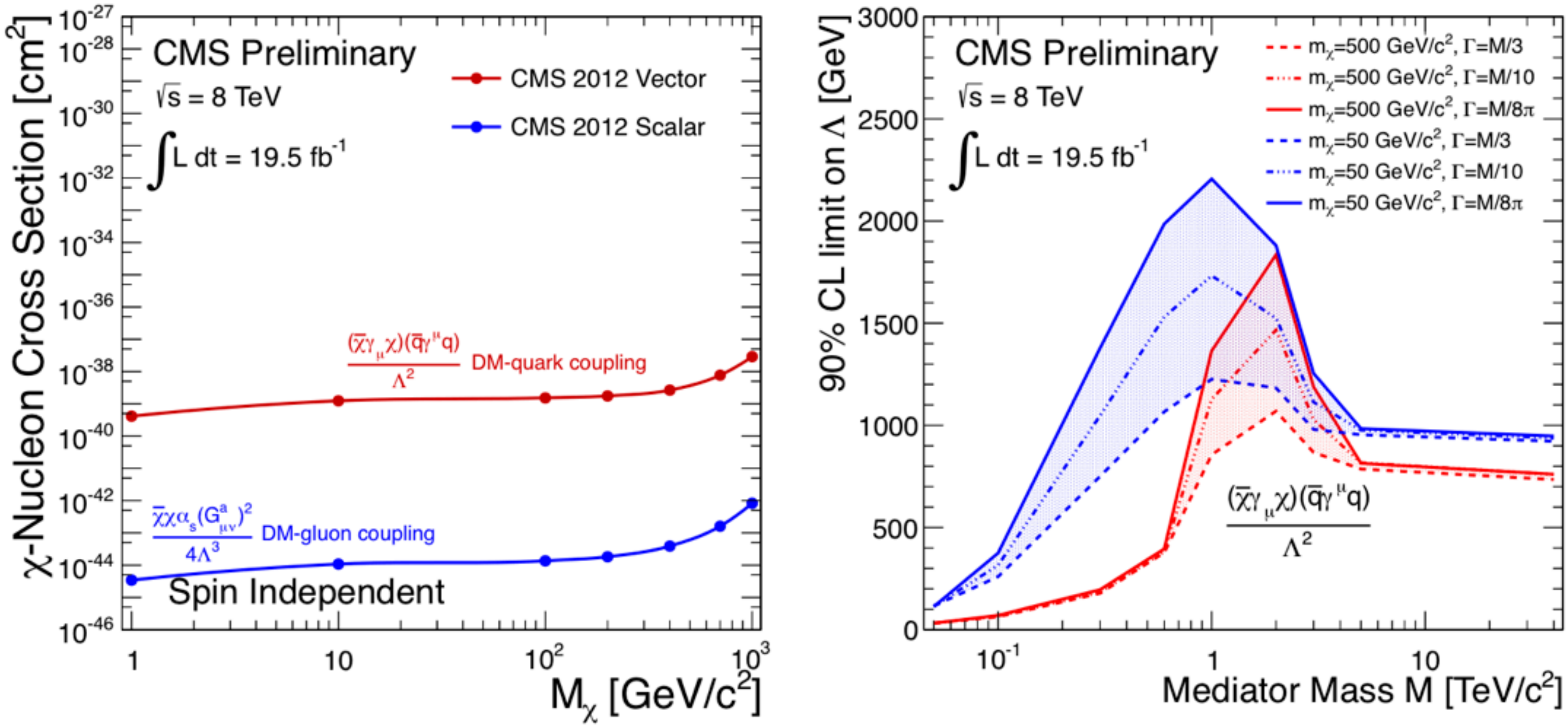
- **Good to provide as much specific and detailed information as possible**

DARK MATTER AND MONOJETS

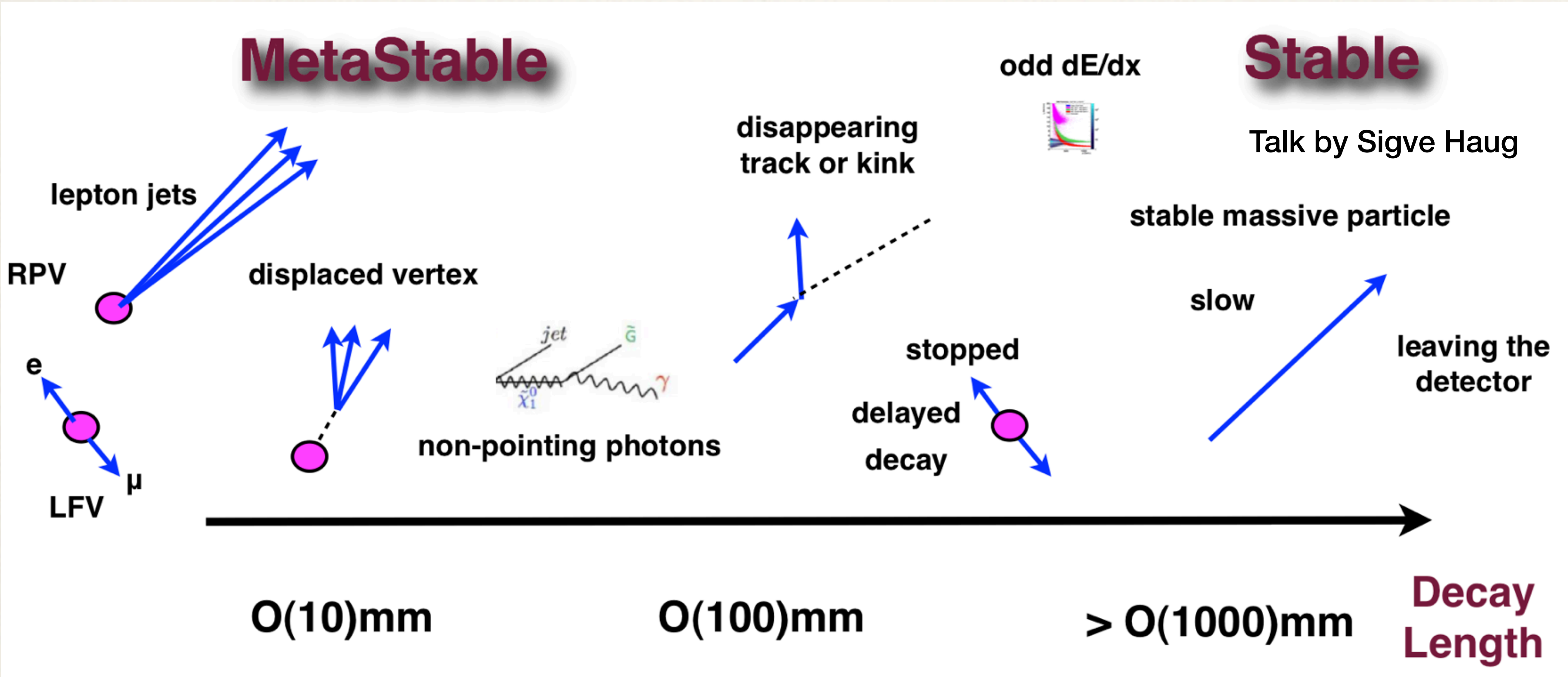
[EXO-12-048]

- Starting to extend simple contact interaction scenario with new operators and a scan over mediator mass

Talk by Steve Worm



- And theorists love special cases...



"We have only scratched the surface" **- Greg Landsberg**

coming soon: displaced jets, displaced tops,...

Outlook

- The Higgs discovery is only the beginning of a story that will bridge all the frontiers of particle physics
- The LHC program will be equal parts precision measurements and searches for new particles and phenomena
- This program is enabled by an ever-more sophisticated understanding of SM physics, and tools that implement this understanding
- Many mysteries already in the data!

Many Thanks To

- The Conference Chairs: Mario Martinez, Gregorio Bernardi, Guenakh Mitselmakher
- The Conference Secretariat: Connie Potter, Sara Strauch
- The Scientific Secretariat: Aurelio Juste, Imma Riu
- The Sponsors
- The Local Organizing Committee
- The Program Committee
- The International Advisory Board
- The Speakers and all the Participants of *THE FIRST* LHCP Conference