ICHEP2012 Physics Highlights

36th ICHEP
Melbourne, July 4-11, 2012

Riccardo Barbieri
SNS and INFN, Pisa

Particle Physics in one page

$$\mathcal{L}_{\sim SM} = -\frac{1}{4} F^a_{\mu\nu} F^{a\,\mu\nu} + i\bar{\psi}\,\not{D}\psi$$ The gauge sector 1

$$+|D_\mu h|^2 - V(h)$$ The EWSB sector 4

$$+\psi_i \lambda_{ij} \psi_j h + h.c.$$ The flavour sector 3

$$+N_i M_{ij} N_j$$ The ν-mass sector 2 (if Majorana)

+

Dark Matter √

Baryon Asymmetry √

Dark Energy

(not included in current knowledge of particle physics)

1. The gauge sector

$$-\frac{1}{4}F^a_{\mu\nu}F^{a\,\mu\nu} + i\bar{\psi}\,\not{D}\psi$$

Can QCD ever be solved?

A neat, challenging theory question

$\updownarrow \quad \updownarrow$

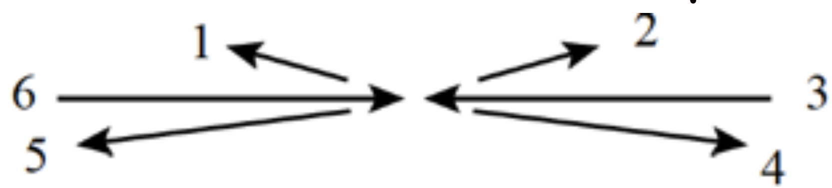
and a significant phenomenological pressure

From theory to "hard" phenomenology in QCD

Dixon

⇒ N=4 super-Yang-Mills at large Nc as simple QCD cousin

2 to 4 gluons in the Multi-Regge limit almost known at all loops



⇒ "Maximal unitarity" methods for NLO and perhaps NNLO calculations of important and highly non trivial processes

Kosower

Z + n jets, $t\bar{t}$ + n jets, etc

PDFs from Inclusive jet and multi-jet cross sections

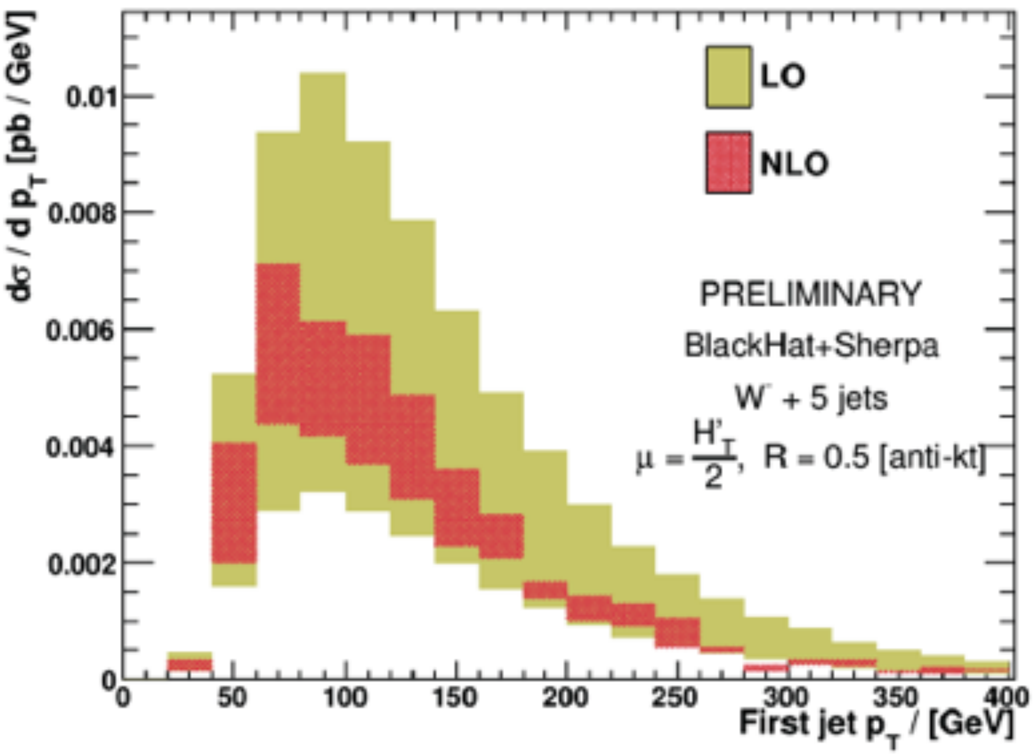
Jet shapes in pp collisions

competing/bypassing more traditional methods

Examples

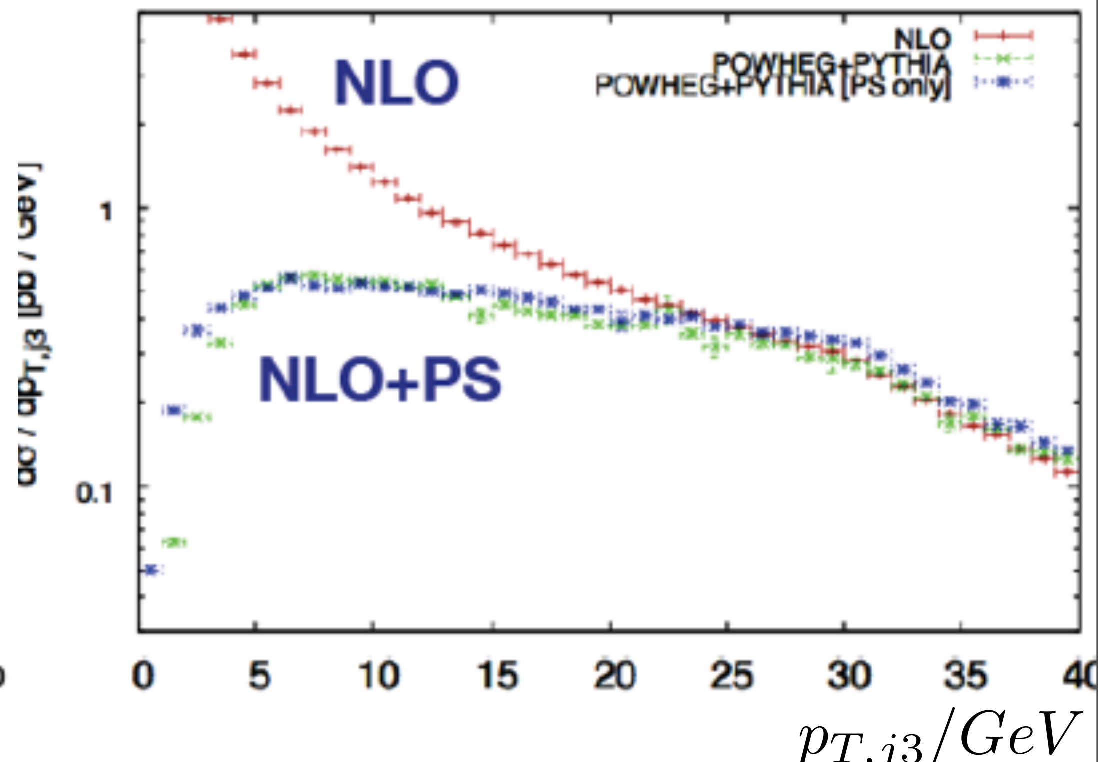
Campbell

W + 5 jets at NLO



Kosower

3rd jet p_T in Z+2 jets



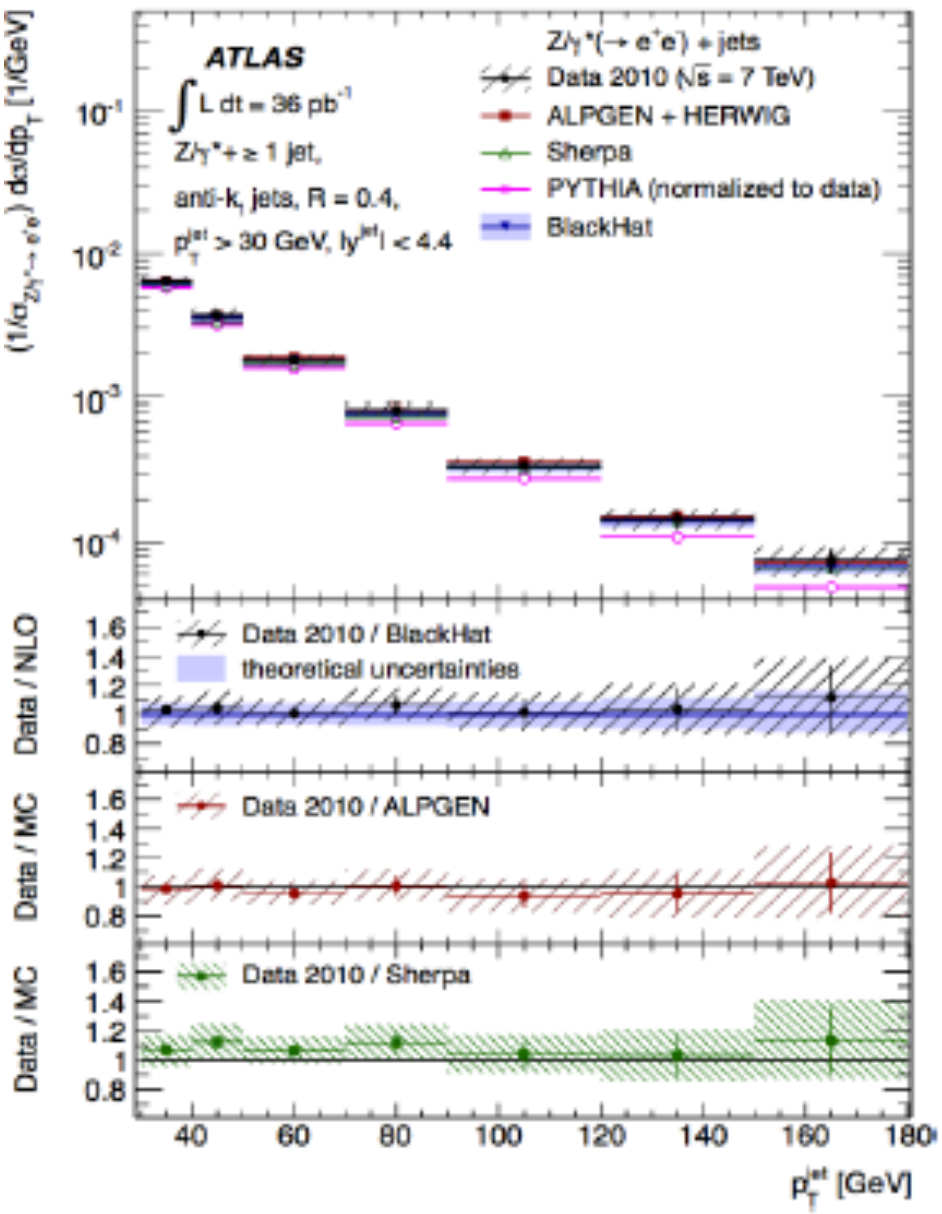
Alioli et al

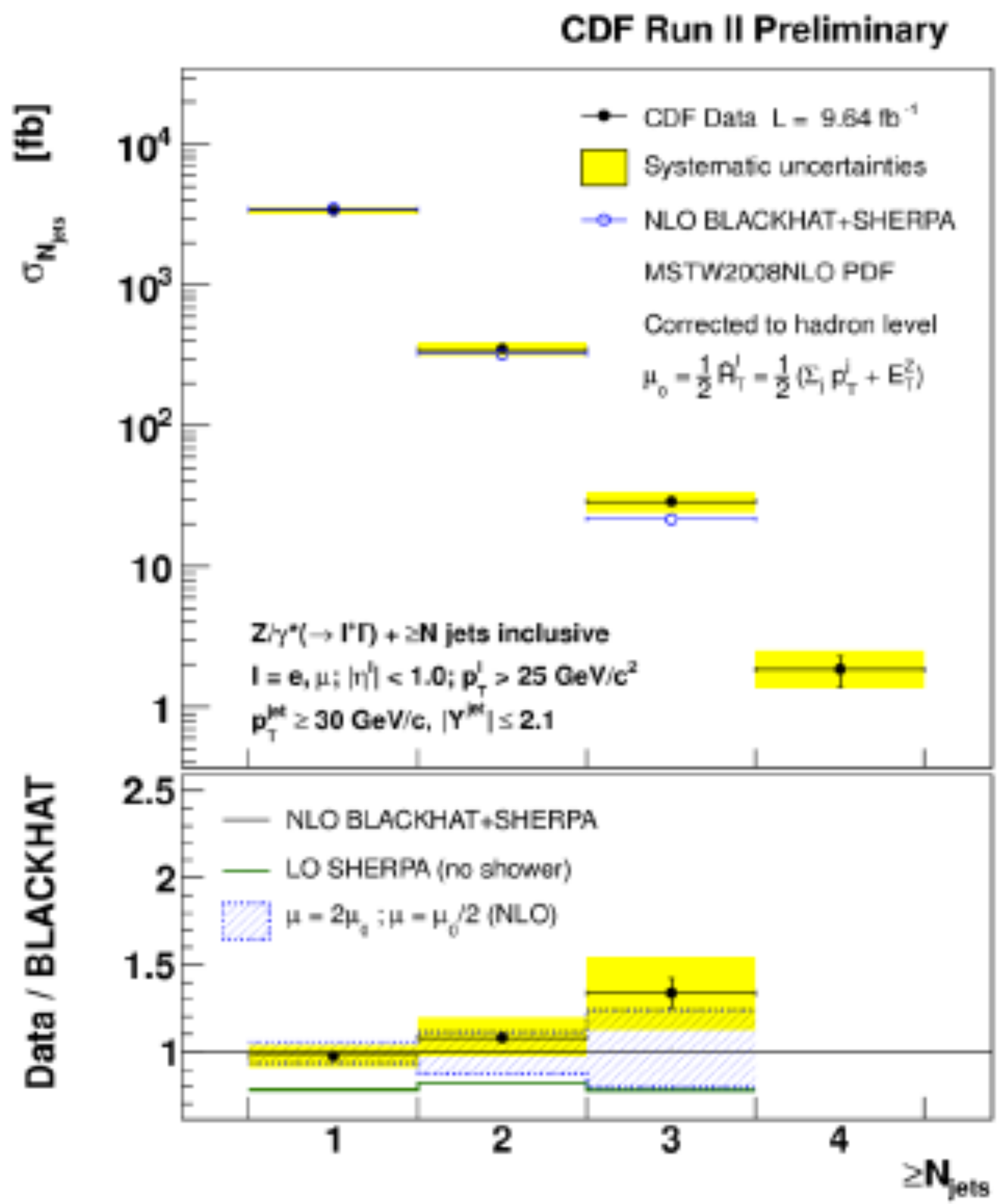
Z/γ* + ≥ N jets

Bandurin

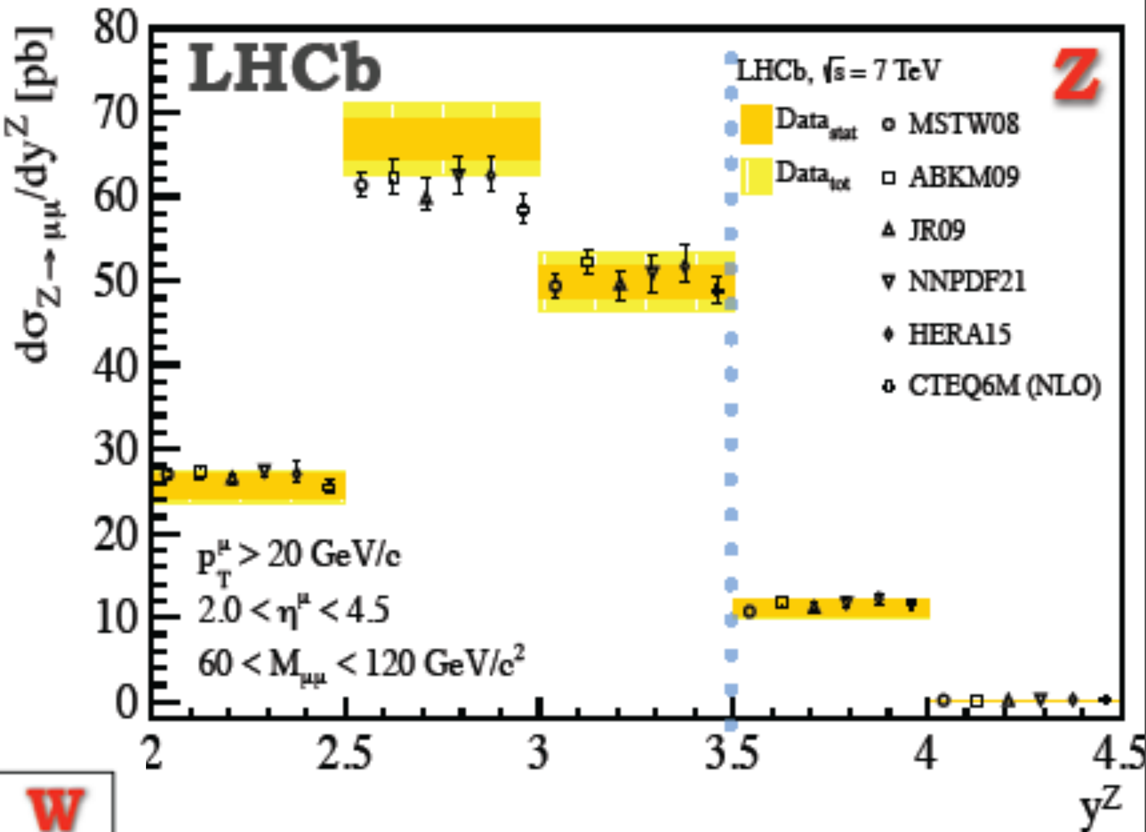
Vellidis

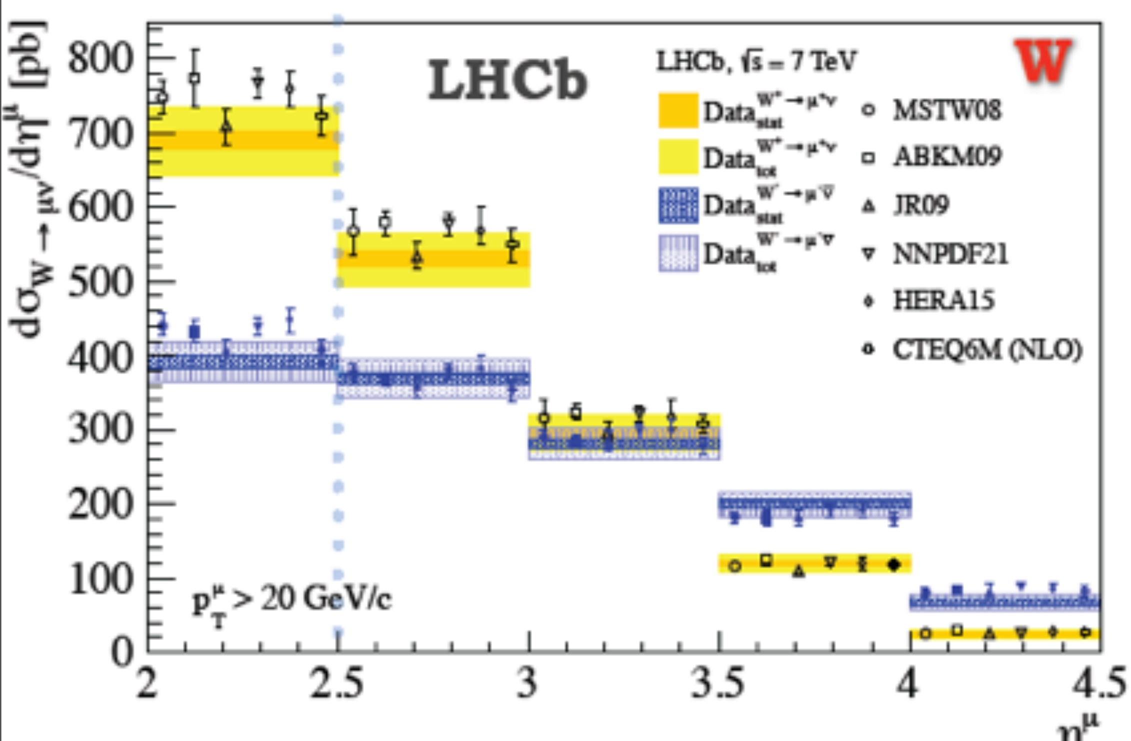
ATLAS, jet pT





W,Z at LHCb versus NNLO-PDFs

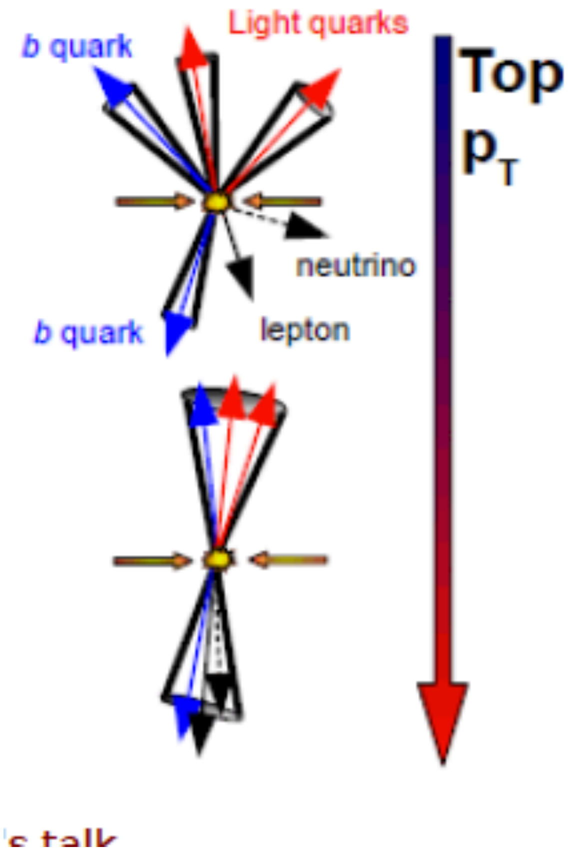


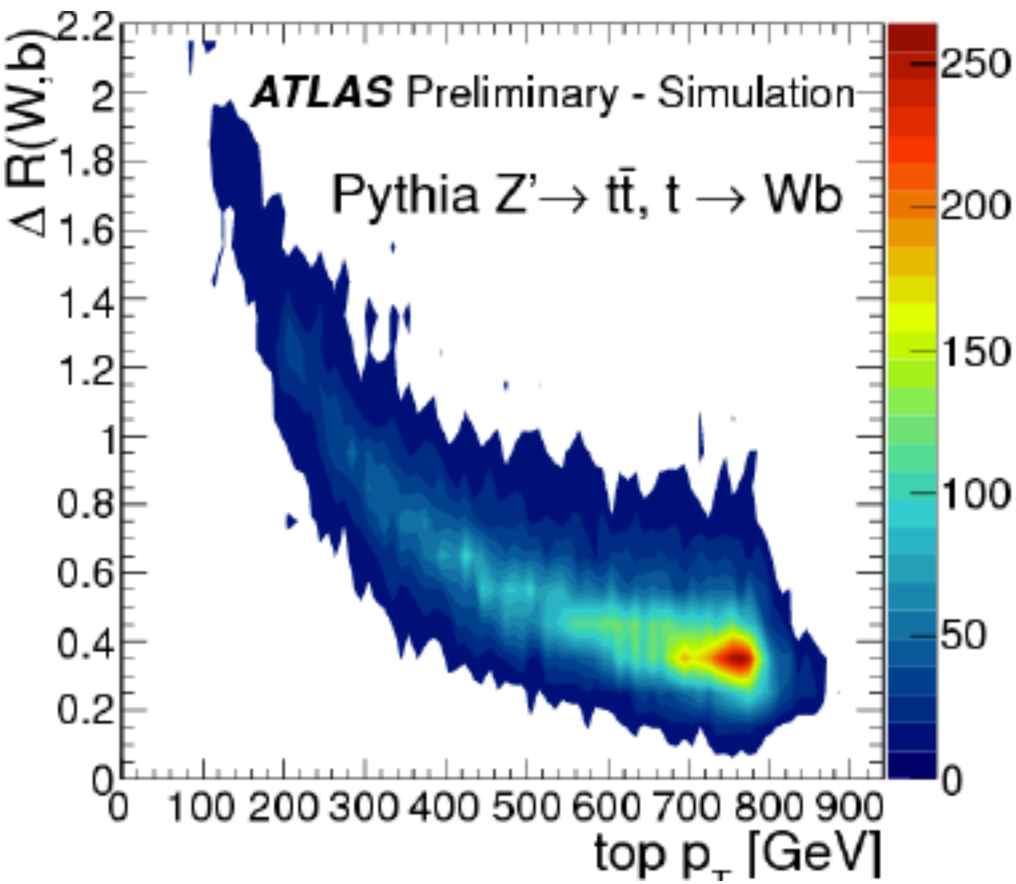


da Costa

Substructure of high Pt jets

Chapleau





useful for Higgs studies and new physics searches

2. The neutrino sector

$$+\psi_i \lambda_{ij} \psi_j h \quad +N_i M_{ij} N_j$$

Open questions:

1. Majorana or Dirac?

~~2. Which value of $\sin\theta_{13}$?~~

3. Which is the c.o.m. of the neutrinos?

4. "Normal" or "inverted spectrum"?

5. Is there CPV in the leptons as well?

6. How many neutrinos there are: 3 +?

(ordered in my own taste)

θ_{13} now known

Sakashita
Novella

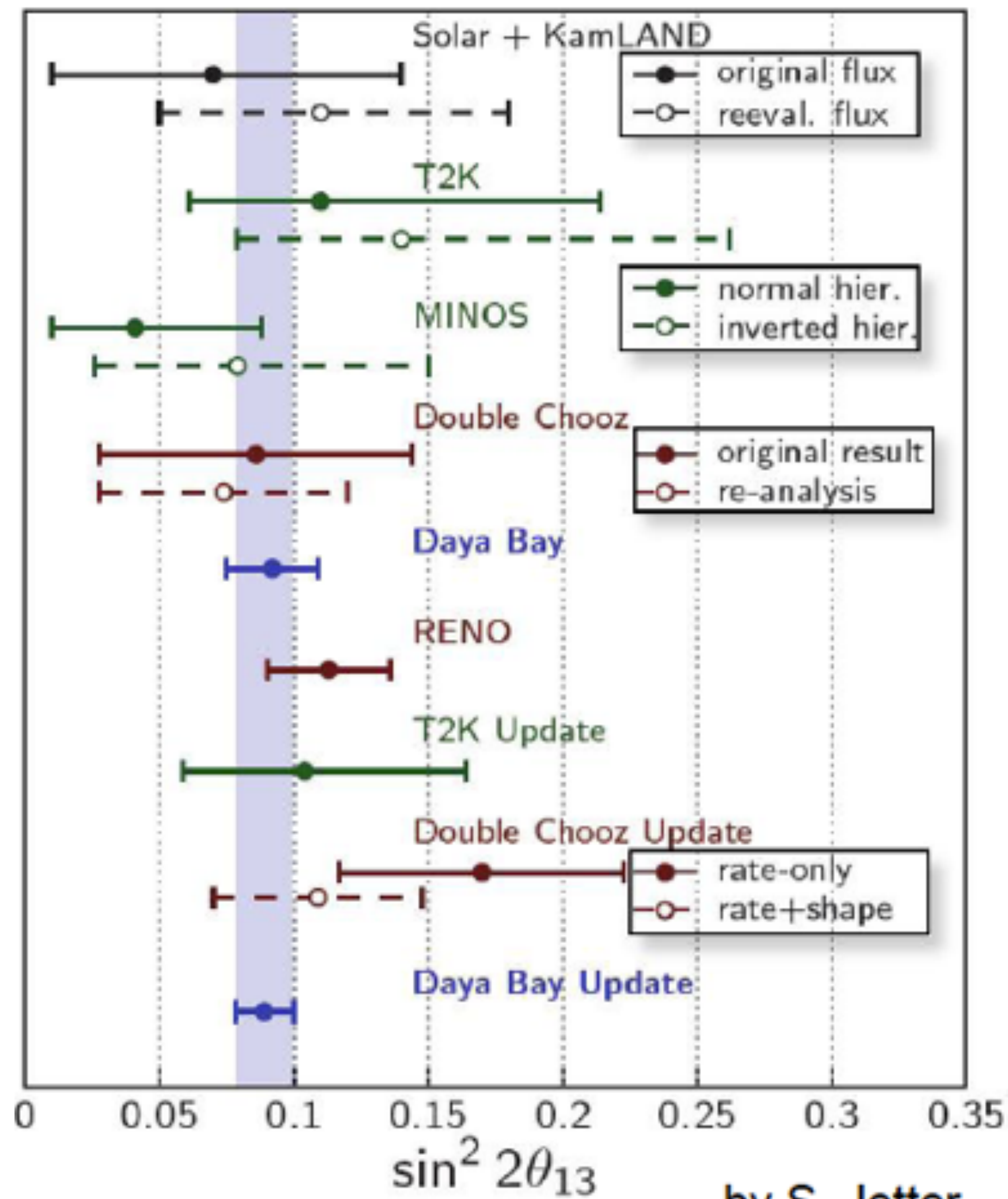
Quantity	$\sin^2 2\theta_{13}$	$\sin^2 \theta_{13}$
T2K [9]	$0.11^{+0.11}_{-0.05}$ $(0.14^{+0.12}_{-0.06})$	$0.028^{+0.019}_{-0.024}$ $(0.036^{+0.022}_{-0.030})$
MINOS [10]	$0.041^{+0.047}_{-0.031}$ $(0.079^{+0.071}_{-0.053})$	$0.010^{+0.012}_{-0.008}$ $(0.020^{+0.019}_{-0.014})$
DC [11]	$0.086 \pm 0.041 \pm 0.030$	$0.022^{+0.019}_{-0.018}$
DYB [12]	$0.092 \pm 0.016 \pm 0.005$	0.024 ± 0.005
RENO [13]	$0.113 \pm 0.013 \pm 0.019$	0.029 ± 0.006
AVERAGE	0.0945 ± 0.0123	0.0242 ± 0.0032

T2K[ICHEP]	$0.094^{+0.053}_{-0.040}(0.116^{+0.063}_{-0.049})$
DC[ICHEP]	$0.109 \pm 0.030 \pm 0.025$
DYB[ICHEP]	$0.089 \pm 0.010 \pm 0.005$

$\sin\theta_{13} \approx 0.156$

A consistent picture for θ_{13}

Cao



by S. Jetter

Summary of neutrino parameters

Fogli *et al.* 1205.5254 (see also [Forero, Tortola and Valle 1205.4018])

(Normal Hierarchy)

Kobayashi
Cao
Gonzales-Garcia

$$\Delta m^2_{\rm sol} = (7.54^{+0.26}_{-0.22}) \times 10^{-5}\,{\rm eV}^2$$

$$\Delta m^2_{\rm atm} = (2.43^{+0.07}_{-0.09}) \times 10^{-3}\,{\rm eV}^2$$

$$\sin^2\theta_{12} = 0.307^{+0.018}_{-0.016}$$

$$\sin^2\theta_{23} = 0.398^{+0.030}_{-0.026}$$

Indication of θ_{23} non maximal

$$\sin^2\theta_{13} = 0.0245^{+0.0034}_{-0.0031}$$

$$\delta = \pi(0.89^{+0.29}_{-0.44})$$

Indication of $\cos\delta < 0$

3. The flavour sector

$$+\psi_i \lambda_{ij} \psi_j h$$

How to interpret the mounting empirical evidence for the CKM picture of flavour and CP violation?
(up to a few "exceptions")

A recent flavour "problem"

$$a_f \equiv \frac{\Gamma(D^0 \to f) - \Gamma(\bar{D}^0 \to f)}{\Gamma(D^0 \to f) + \Gamma(\bar{D}^0 \to f)}$$

CDF - Tonelli
LHCb - Tico
Belle - Ko

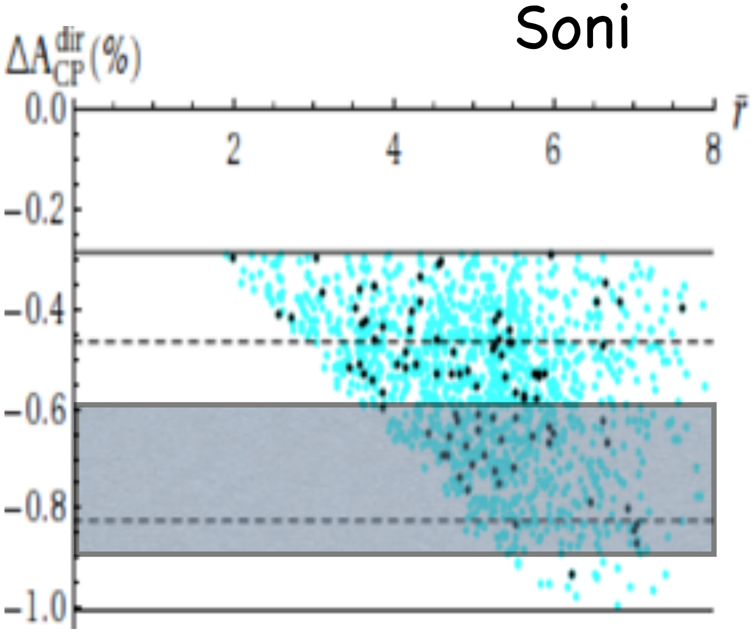
$$\Delta A_{CP} \equiv A_{CP}\left(K^+K^-\right) - A_{CP}\left(\pi^+\pi^-\right) = (-0.74 \pm 0.15)\%$$

Question: Old or new physics?

Usual theoretical tools (factorization, $SU(3)$, etc) not at ease, to say the least

Expectation versus exp (1 sigma)

Soni



More data can perhaps clarify the situation

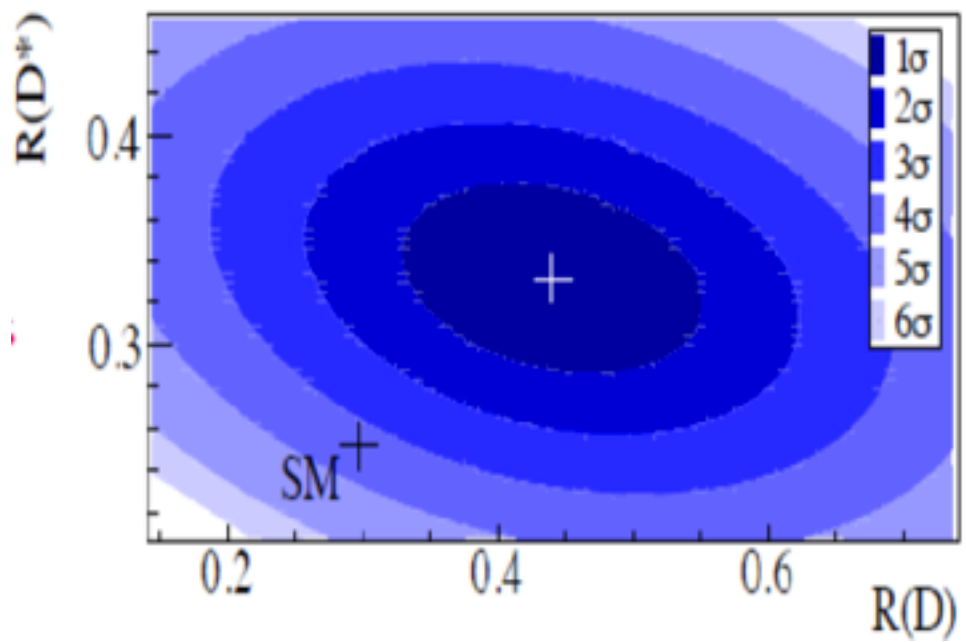
If new physics, "plausible"

A very recent flavour "problem"

	SM Theory	BaBar value	Diff.
R(D)	0.297±0.017	0.440±0.058±0.042	+2.0σ
R(D*)	0.252±0.003	0.332±0.024±0.018	+2.7σ

Stone

De Nardo



Combinination yields

χ^2 / n.d.o.f. = 14.6/2

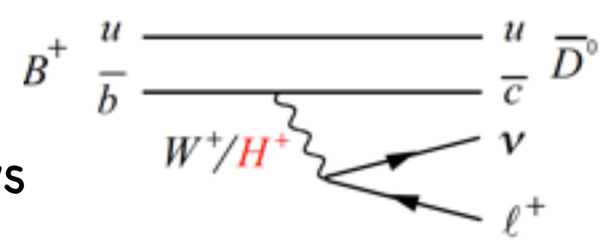
(probability: 6.9×10^{-4})

3.4σ away from SM

Note:

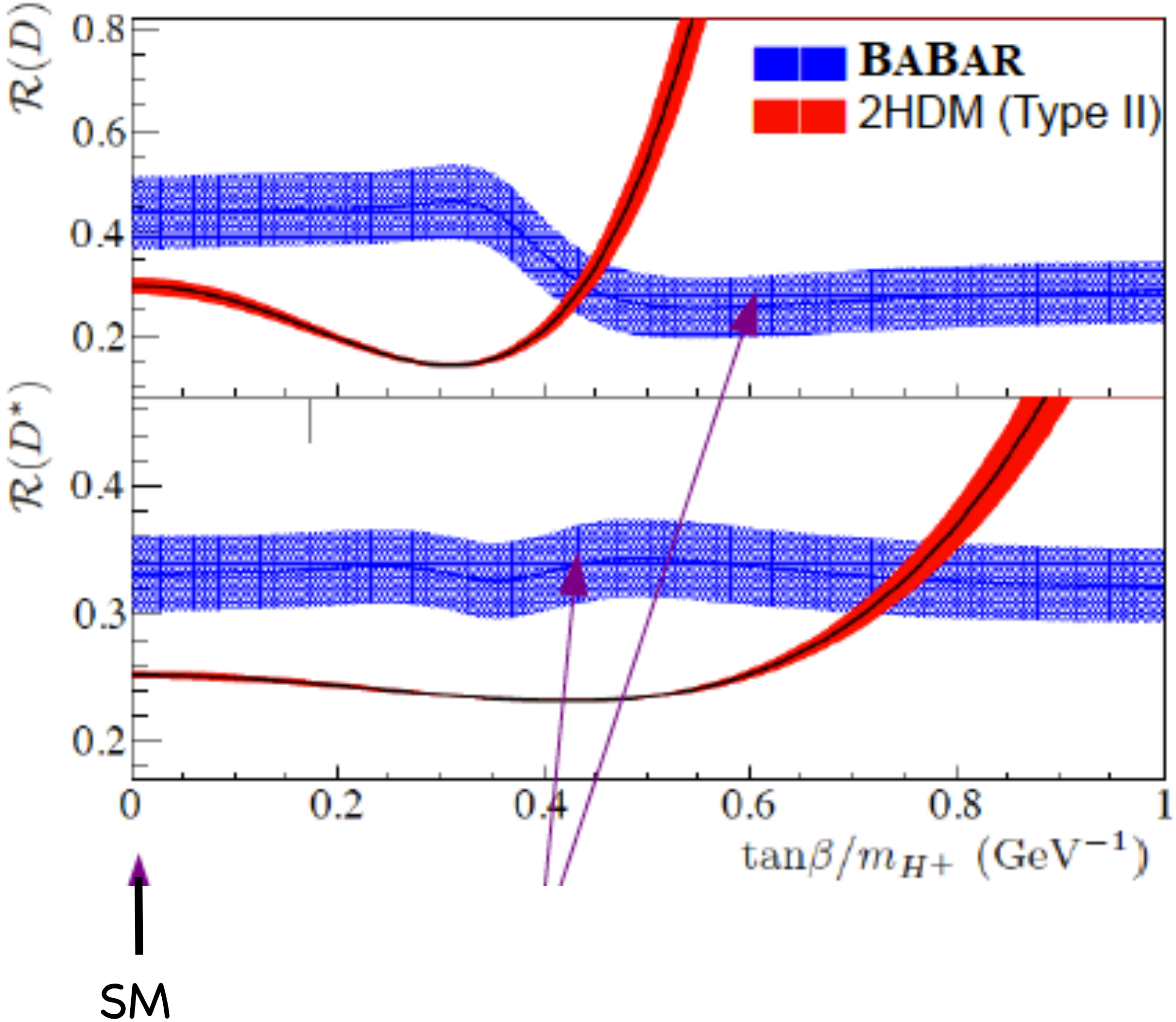
Errors of $\mathcal{R}_{\tau/l}$, $\mathcal{R}^*_{\tau/l}$ experimentally dominated

Large deviations from 1 of $\mathcal{R}/\mathcal{R}^{SM}$ in tree level decays hence, not so easy to explain by new physics



Not explainable by H^+ exchange in 2Higgs Doublet Models

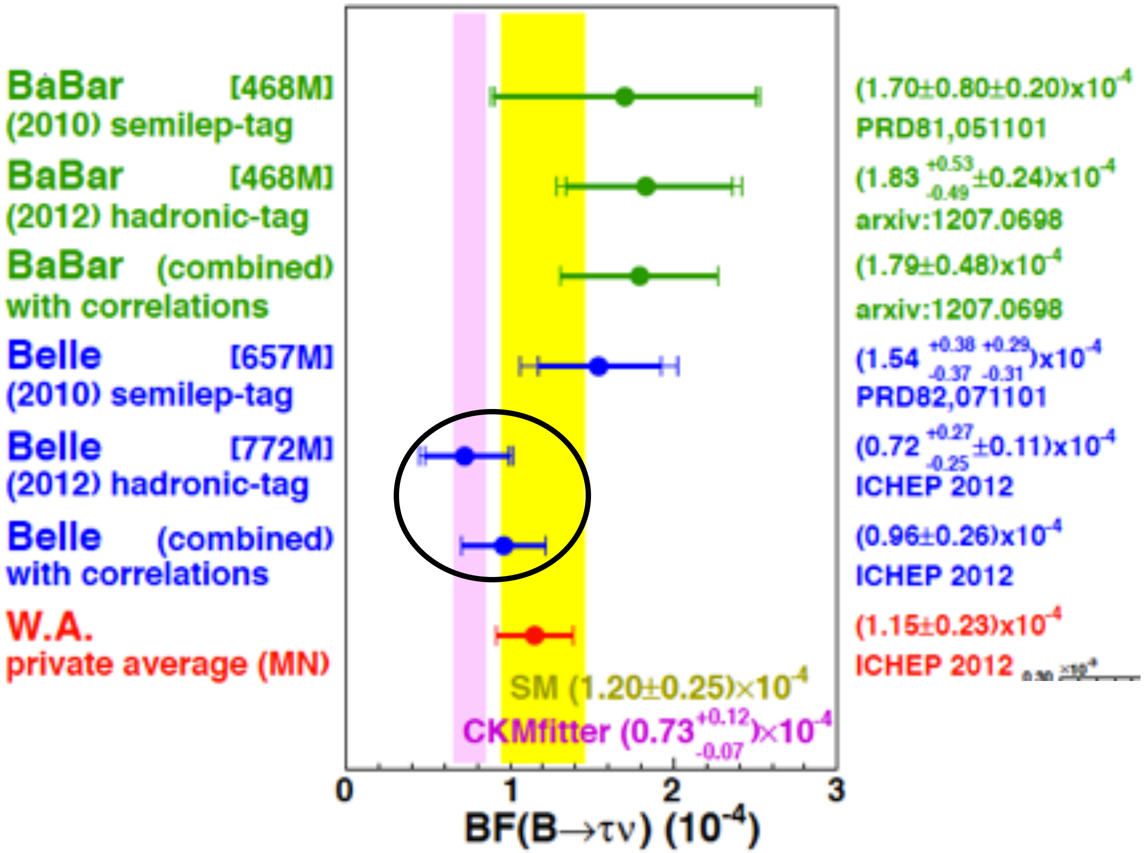
De Nardo

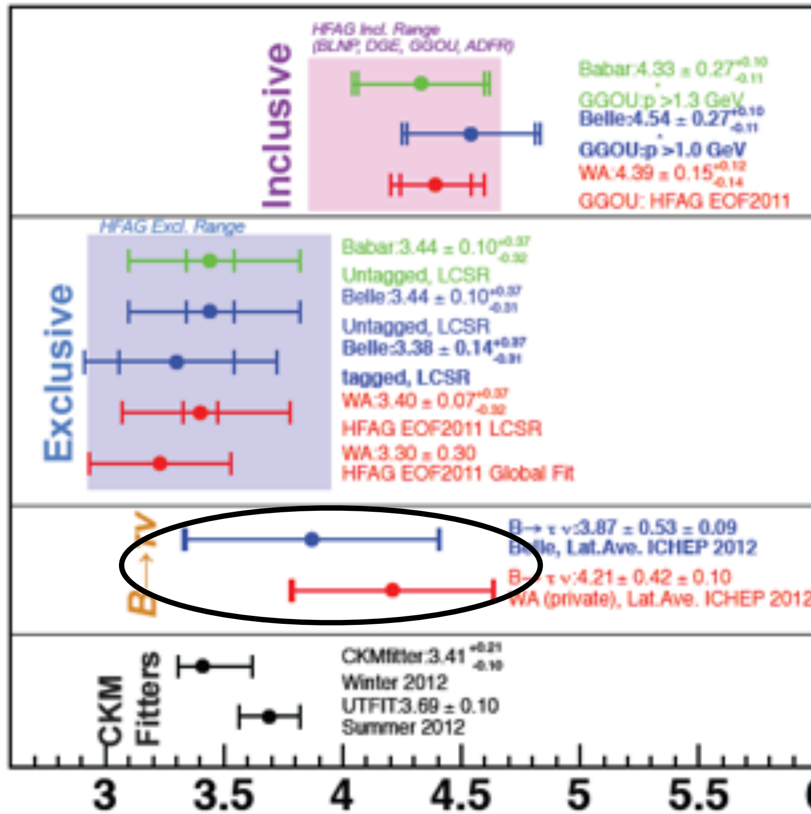


incompatible among each other for any value of $\dfrac{\tan\beta}{m_{H+}}$

The $B \to \tau\nu$ "problem"

Nakao
Yook
Urquijo





V_{ub}

Better agreement than before ICHEP with CKM fits

(The V_{ub} problem still there)

A less recent flavour "problem"

Perez
Muller
Cambell

TEVATRON $t\bar{t}$ forward backward asymmetry

Top - asymmetry (CDF + D0)	QCD + EW
$A_{FB}^{inc} \approx (18 \pm 4)\%$	$A_{FB}^{inc} \approx (6.6 \pm ??)\%$
$A_{FB}^{>450GeV} \approx (28 \pm 6)\%$	$A_{FB}^{>450GeV} \approx (10 \pm ??)\%$

Lepton - asym (CDF)	L-a (D0)	L-a (SM)
$A_l = (6.6 \pm 2.5)\%$	$A_l = (11.8 \pm 3.2)\%$	$A_l = (4 \pm ??)\%$

Questions:

Isn't it necessary to reduce the ?? of the SM?

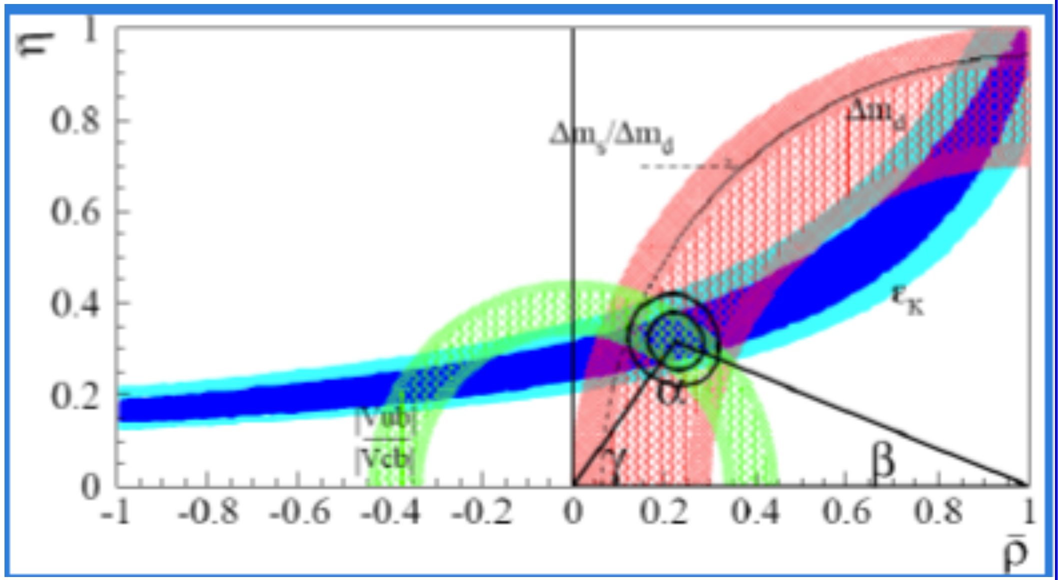
How far can the LHC go in resolving the issue?

In case, are we ready to digest new particles
with peculiar flavour couplings to u and t?

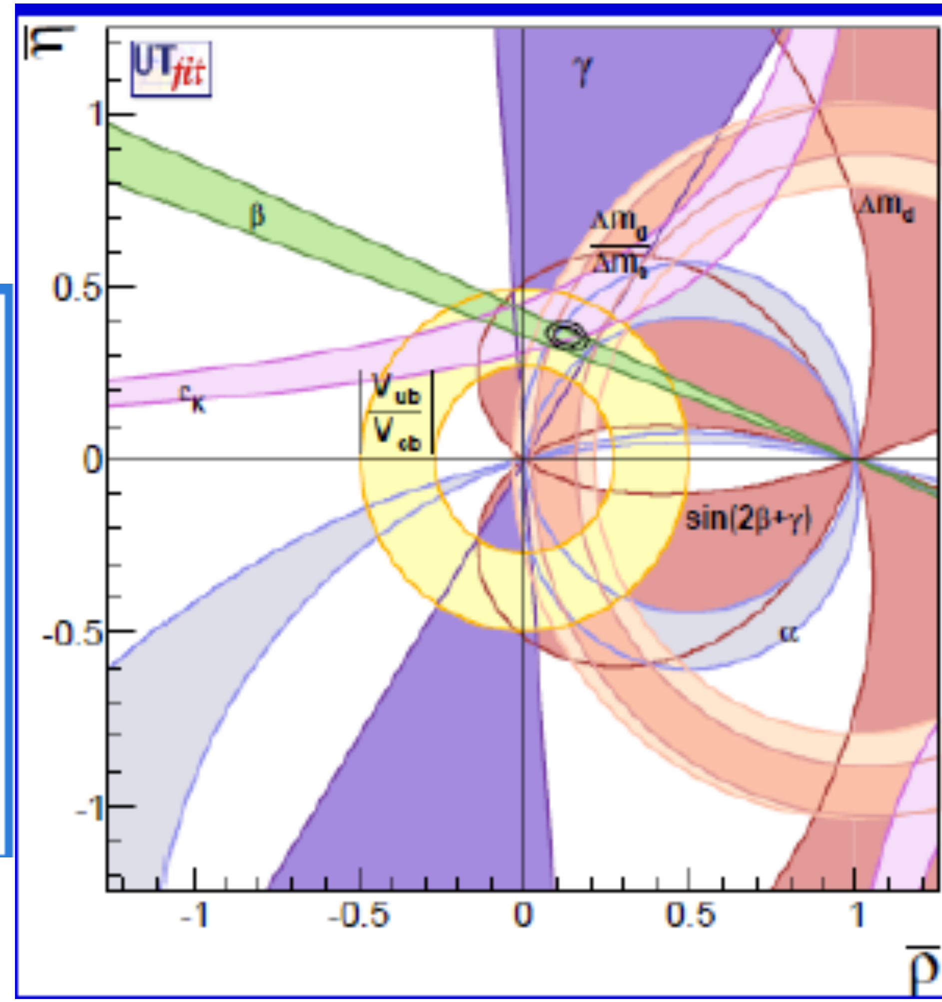
The progress of flavour in a popular figure

Tarantino

BEFORE



AFTER



actually a gross underestimate of the real evolution

A different way to represent the flavour constraints

Isidori, Nir, Perez

$$\mathcal{L}_{eff} = \mathcal{L}_{SM} + \mathcal{L}_{eff}^{NP}$$

$$\mathcal{L}_{eff}^{NP} = \Sigma_i \frac{c_i}{\Lambda_{NP}^2} O_i$$

Operator	Bounds on Λ in TeV ($c_{ij} = 1$) Re	Im	Bounds on c_{ij} ($\Lambda = 1$ TeV) Re	Im	Observables
$(\bar{s}_L \gamma^\mu d_L)^2$	9.8×10^2	1.6×10^4	9.0×10^{-7}	3.4×10^{-9}	$\Delta m_K; \epsilon_K$
$(\bar{s}_R d_L)(\bar{s}_L d_R)$	1.8×10^4	3.2×10^5	6.9×10^{-9}	2.6×10^{-11}	$\Delta m_K; \epsilon_K$
$(\bar{c}_L \gamma^\mu u_L)^2$	1.2×10^3	2.9×10^3	5.6×10^{-7}	1.0×10^{-7}	$\Delta m_D; \lvert q/p \rvert, \phi_D$
$(\bar{c}_R u_L)(\bar{c}_L u_R)$	6.2×10^3	1.5×10^4	5.7×10^{-8}	1.1×10^{-8}	$\Delta m_D; \lvert q/p \rvert, \phi_D$
$(\bar{b}_L \gamma^\mu d_L)^2$	6.6×10^2	9.3×10^2	2.3×10^{-6}	1.1×10^{-6}	$\Delta m_{B_d}; S_{\psi K_S}$
$(\bar{b}_R d_L)(\bar{b}_L d_R)$	2.5×10^3	3.6×10^3	3.9×10^{-7}	1.9×10^{-7}	$\Delta m_{B_d}; S_{\psi K_S}$
$(\bar{b}_L \gamma^\mu s_L)^2$	1.4×10^2	2.5×10^2	5.0×10^{-5}	1.7×10^{-5}	$\Delta m_{B_s}; S_{\psi\phi}$
$(\bar{b}_R s_L)(\bar{b}_L s_R)$	4.8×10^2	8.3×10^2	8.8×10^{-6}	2.9×10^{-6}	$\Delta m_{B_s}; S_{\psi\phi}$

Aren't we supposed to see new physics related to the Fermi scale?

The (scary) success of the CKM picture

$$\Delta\mathcal{L} = \Sigma_i \frac{1}{\Lambda_i^2}\mathcal{O}_i$$

In some cases $\Lambda_i \gtrsim 10^3 \div 10^4 TeV$, unless some restriction operative

Is it possible that...

$$\Delta\mathcal{L} = \Sigma_i \frac{c_i}{\Lambda_i^2}\xi_i\mathcal{O}_i$$

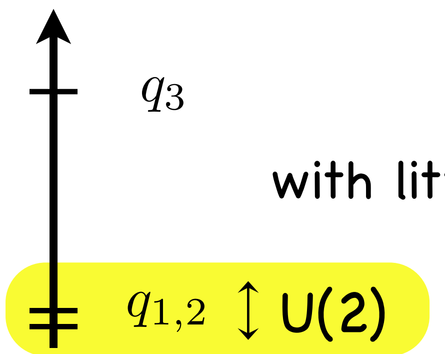
with ξ_i controlled by symmetries or some dynamics and $c_i = O(1)$

and $\Lambda_i \approx 4\pi v \approx 3\ TeV$ → strongly interacting EWSB

→ new weakly int. particle(s) at ~v

Flavour ⇔ EWSB

A plausible explanation (among others, see Perez)



with little communication between $q_{1,2}$ and q_3

$$\mathcal{L} \approx \Sigma_{i=1,2,3}(\bar{q}^i_L \not{D}\, q^i_L + \bar{u}^i_R \not{D}\, u^i_R + \bar{d}^i_R \not{D}\, d^i_R) + \lambda_t H_u \bar{t}_L t_R + \lambda_b H_d \bar{b}_L b_R$$

An observed approximate symmetry: $U(2) \to U(2)_Q \times U(2)_u \times U(2)_d$

and its possible breaking terms in fermion bilinears (Yukawa couplings)

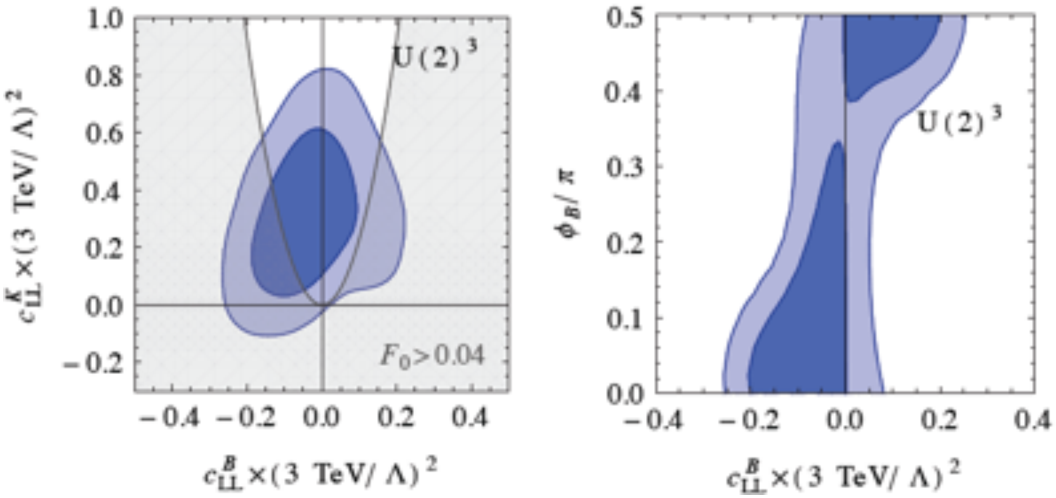
$$\lambda_t(\bar{Q}_L V)t_R \qquad \lambda_t \bar{Q}_L \Delta Y_u U_R \qquad \lambda_t \bar{q}_{3L}(V_u^+ U_R)$$

$$\lambda_b(\bar{Q}_L V)b_R \qquad \lambda_t \bar{Q}_L \Delta Y_d D_R \qquad \lambda_b \bar{q}_{3L}(V_d^+ D_R)$$

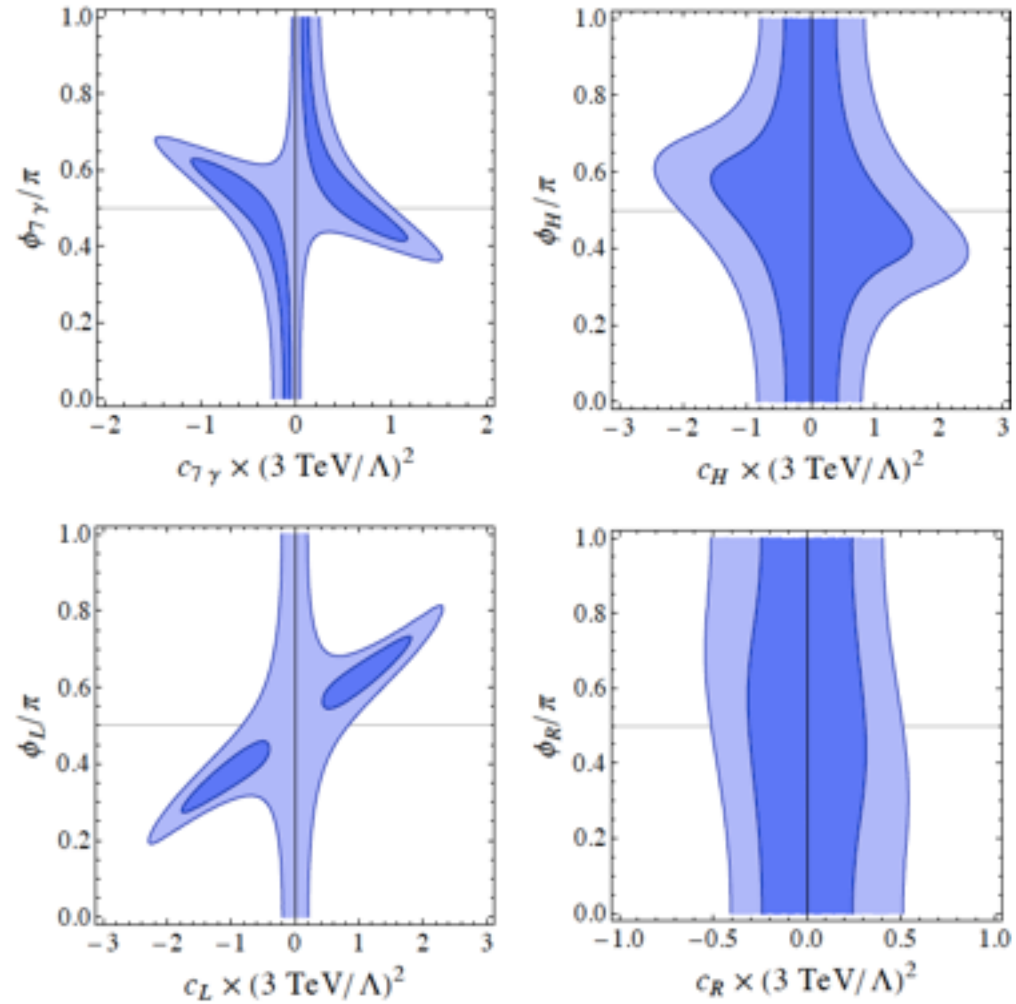
Capital letters = U(2) doublets

Fit of data in minimal $U(2)^3$

$\Delta F = 2$



$\Delta F = 1$



$$B_q^0 - \bar{B}_q^0,\ K^0 - \bar{K}^0$$

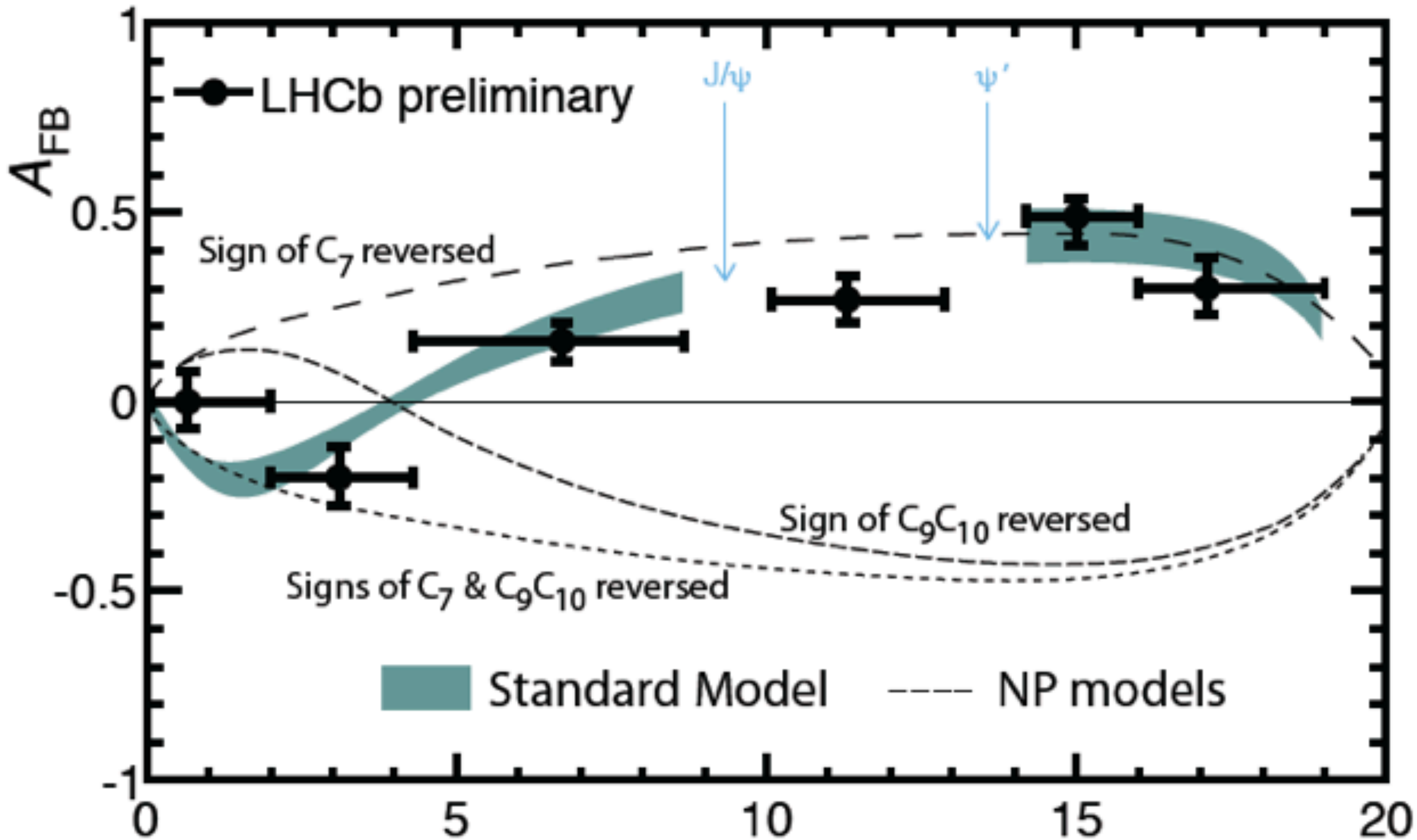
$$b \to s\gamma,\ b \to s\ l\bar{l}$$

Consistent with $\Delta\mathcal{L} = \Sigma_i \frac{c_i}{(4\pi v)^2}\xi_i\mathcal{O}_i$ and $|c_i| = 0.2 \div 1$

B, Buttazzo, Sala, Straub

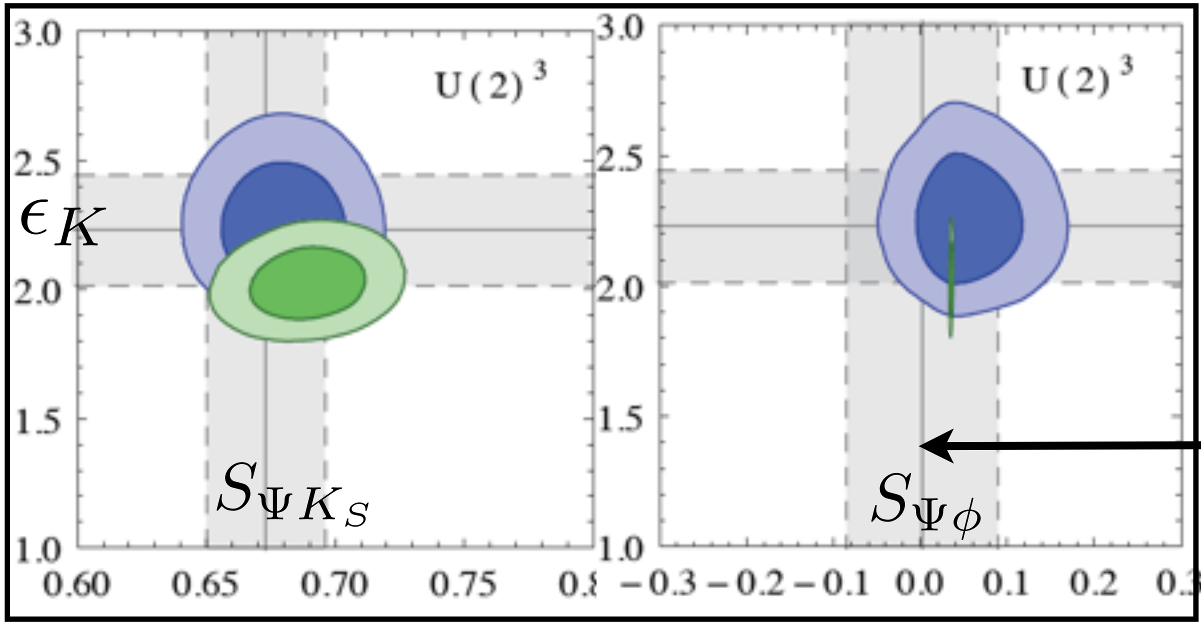
A remarkable measurement/constraint

Stone



Forward-backward B-asymmetry in $B \to K^* l^+ l^-$

SM versus $U(2)^3$ fit in ΔF=2

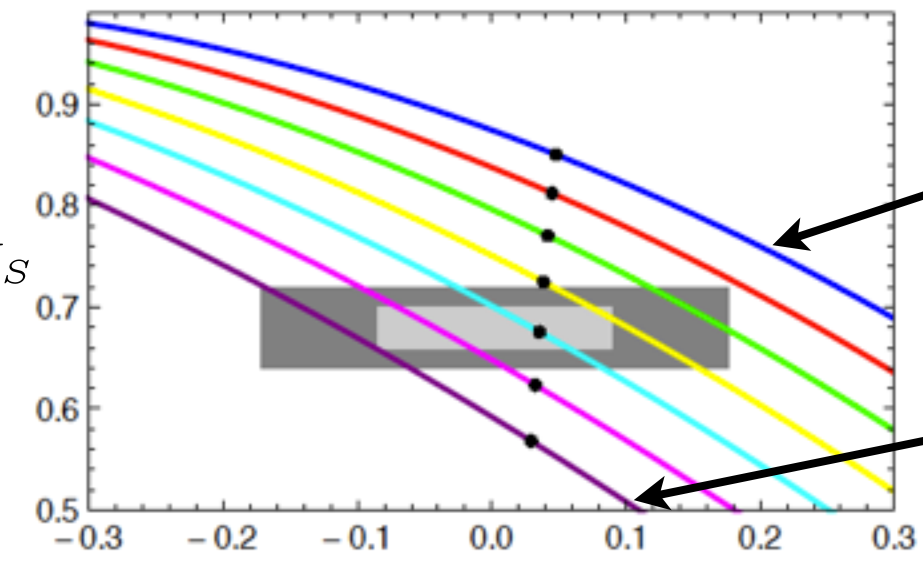


Green = SM

Blue = $U(2)^3$

LHCb

Straub



$|V_{ub}| = 0.0046$

$|V_{ub}| = 0.0028$

$S_{\Psi\phi}$

Buras, Girrbach

4. The EW Symmetry Breaking sector

$$+|D_\mu h|^2 - V(h)$$

The Higgs boson is with us

A coronation of the Standard Model?

or

A great milestone along
a path yet largely unexplored?

The Higgs boson (general)

1. Facts we know since quite some time:

⇒ Two (dominant) ways to give rise to mass, at least to ordinary matter:

A. By back-reaction to QCD forces (quantitatively dominant)
B. By intrinsic mass of elementary quanta (qualitatively crucial)

⇒ In both cases spontaneous symmetry breaking crucial

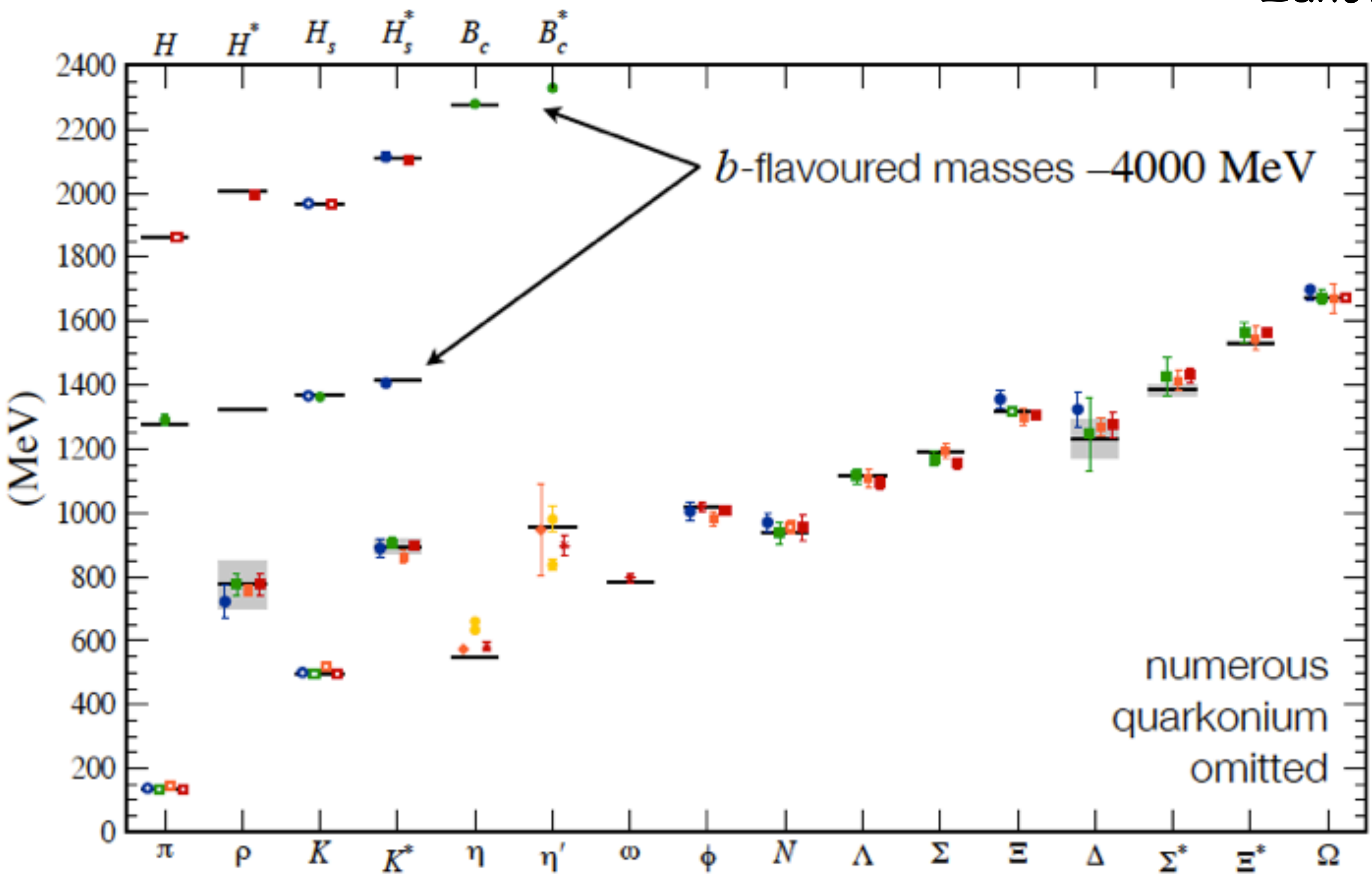
The corresponding Nambu-Goldstone particles either appear in the spectrum, the 3 pions of QCD, or become the longitudinal modes of the W and Z bosons (2 +1)

2. Now emerging experimentally:

In case B, at least a 4th particle exists, the Higgs boson, as theoretically foreseen long ago in the minimal model

Mass from QCD forces (from the lattice)

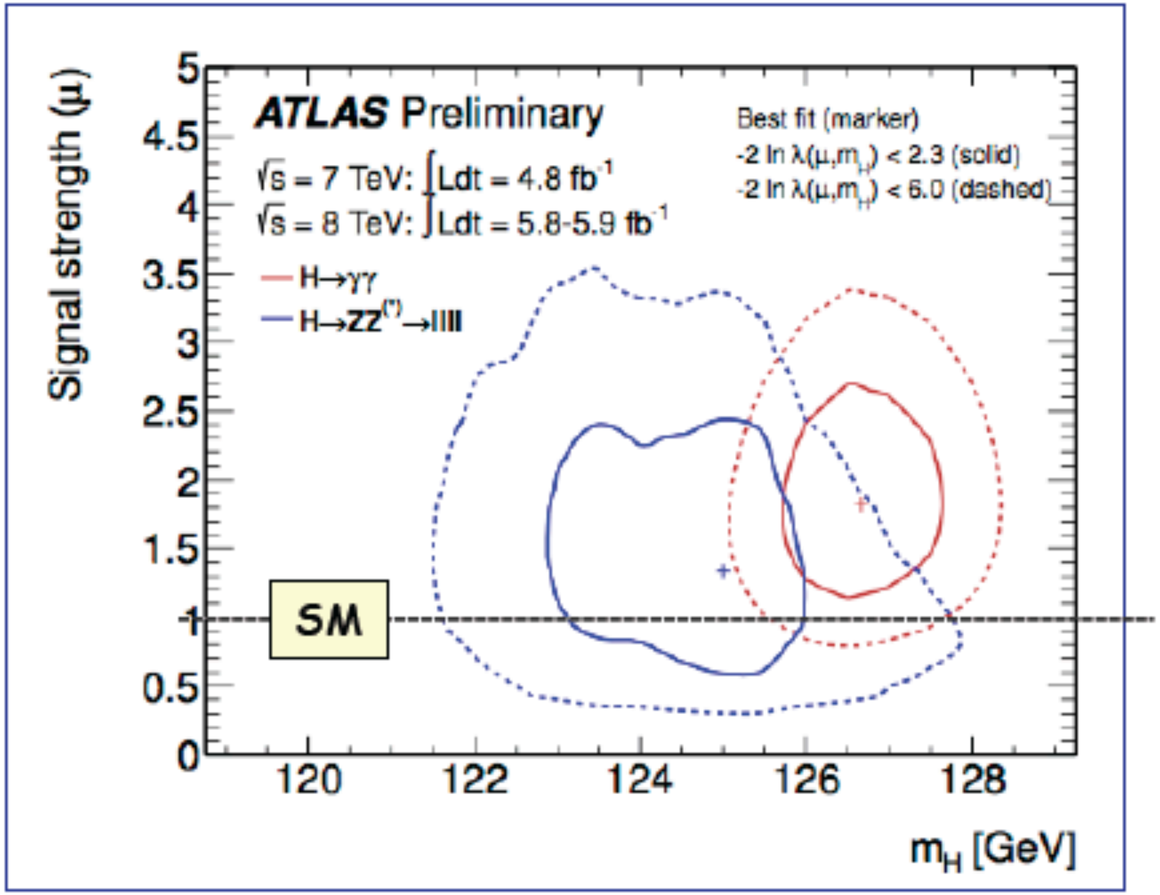
Zanotti

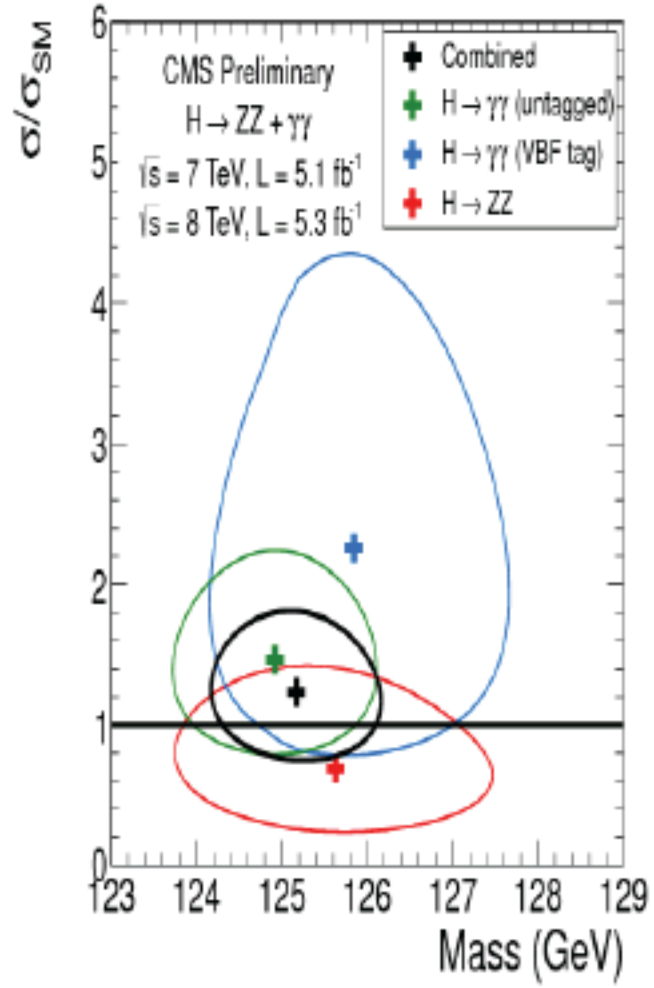


Kronfeld

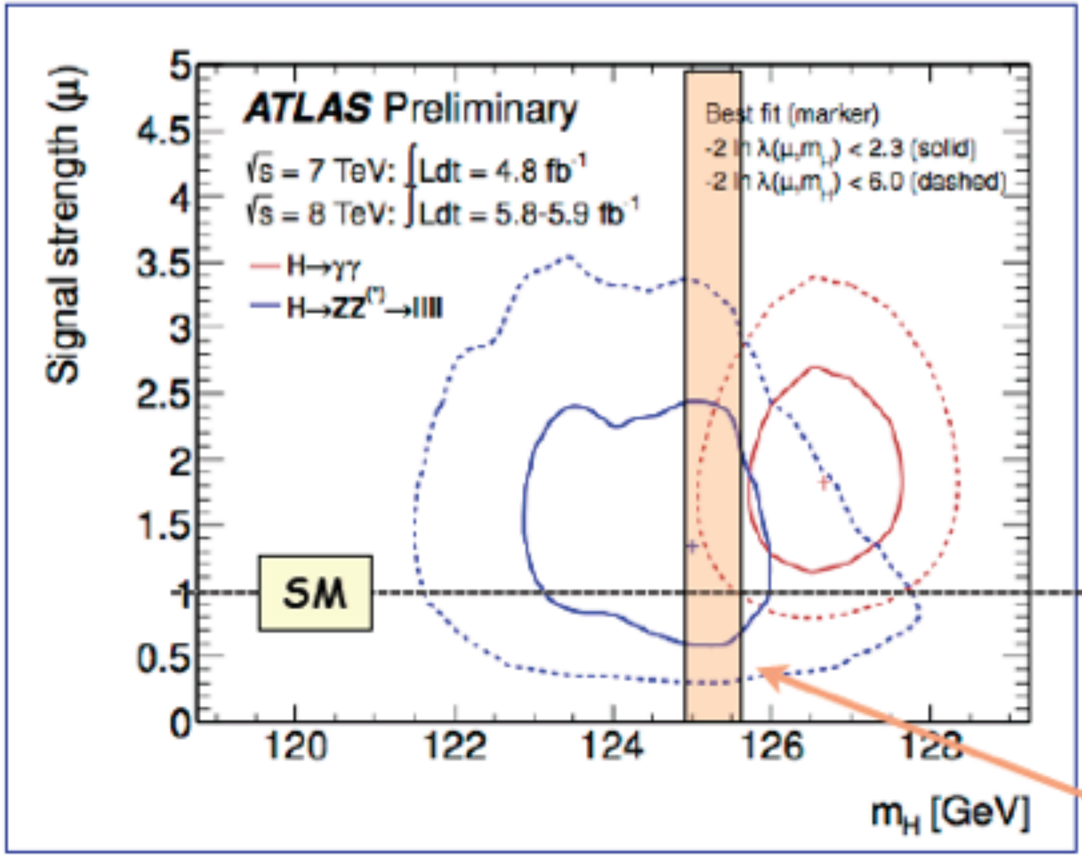
Some of the plots I like most

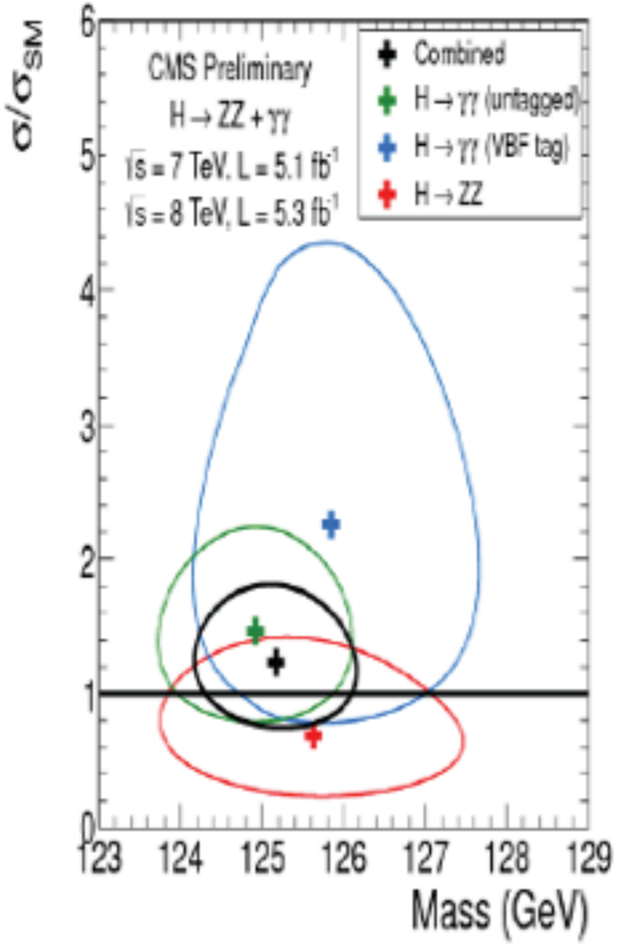
Hawkings
Incandela
Shalhout





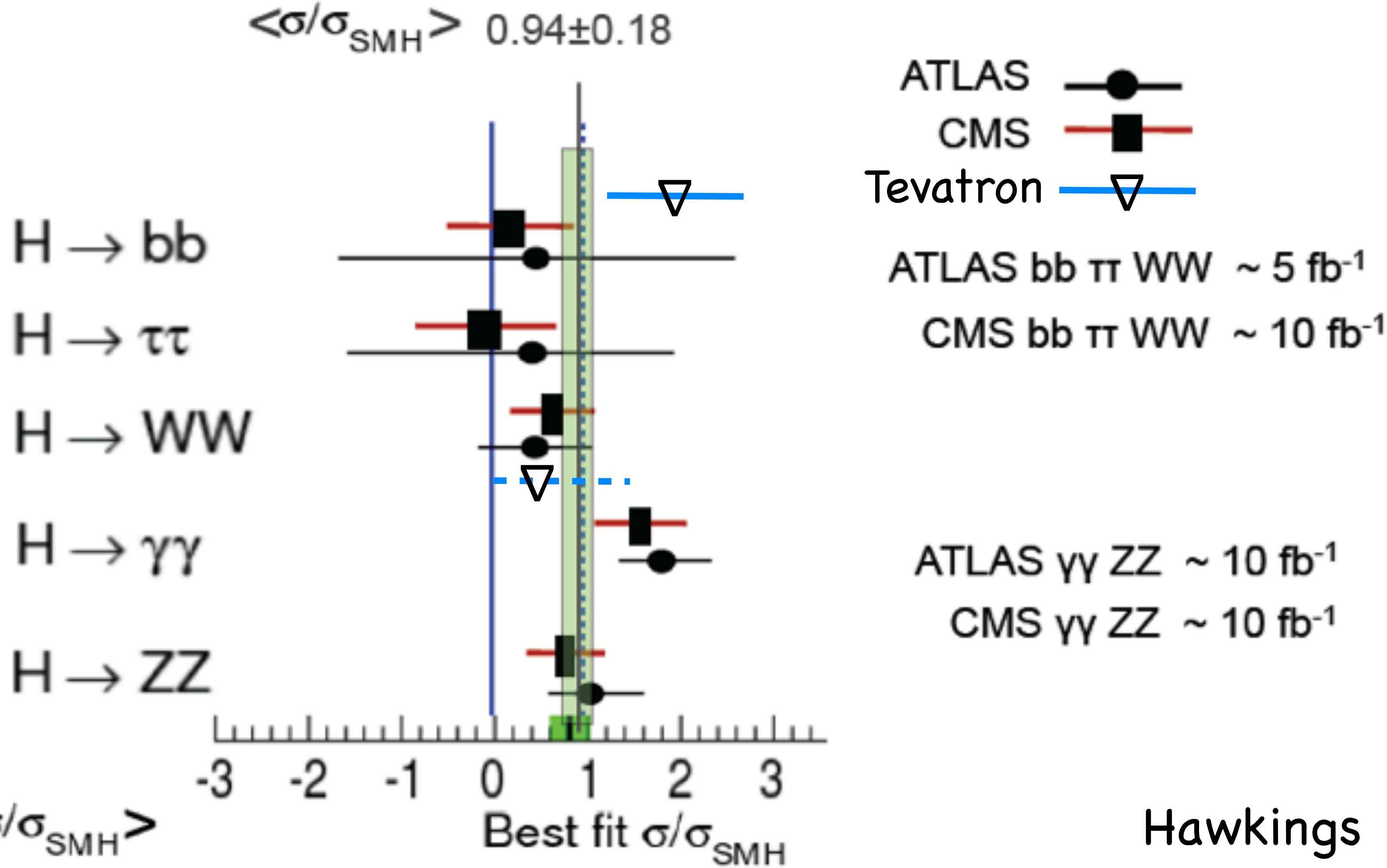
Mass consistency





125.3 ± 0.6 GeV

Compatibility with SM Higgs boson



$\langle\sigma/\sigma_{SMH}\rangle$	
ATLAS	1.2±0.3
CMS	0.8±0.22

Hawkings
Incandela
Shalhout

The Higgs boson (continued)

3. As next step, need to know:

$\Rightarrow$ Its quantum numbers: $J^{PC} = 0^{++}$, gauge q.n.s

$\Rightarrow$ The strength of its interactions
with all other particles and with itself

$\Rightarrow$ Is it alone or accompanied?

$\Rightarrow$ Is it "elementary" or "composite"?

$\Rightarrow$ Is it "natural"?

Standard/Non-standard Higgs couplings (at 125 GeV)

Pomarol

$$\mathcal{L}^{eff}_{<m_h} \approx c_V\left(\frac{2m_W^2}{v}W^+_\mu W^-_\mu + \frac{m_Z^2}{v}Z^2_\mu\right)h + c_b\frac{m_b}{v}\bar{b}bh + c_\tau\frac{m_\tau}{v}\bar{\tau}\tau h$$
$$+c^\gamma\frac{2\alpha}{9\pi v}F^2_{\mu\nu}h + c^g\frac{\alpha_S}{12\pi v}G^2_{\mu\nu}h$$
$$+\mathcal{L}(h\to inv)$$

$$c^\gamma = c_t + \frac{9}{2}\delta c^\gamma$$
$$c^g = c_t + \delta c^g$$

In the SM all 5 $c = 1$ and $\mathcal{L}(h\to inv)\approx 0$

Four ways to go Non-standard:

⇒ Higgs mixing with other scalars: can affect $c_V, c_t, c_b = c_\tau$

⇒ Not an elementary particle: can affect ~ all par.s

⇒ New missed final states E.g.: $h\to\chi_{DM}\chi_{DM}$

⇒ New virtual particles in loops ($\tilde{t}, T, \rho^{\pm,0}_\mu, etc$): affects $\delta c^g, \delta c^\gamma$

Can have large effects, δc/c = O(1), if new physics nearby

Higgs rates in various modes

⇒ For $m_h = 125\ GeV$ various rates, normalized to SM, well approximated by

$$R_{VV^*} \approx \frac{(c^g c_V)^2}{\gamma_{tot}} \qquad R^{gF}_{\gamma\gamma} \approx \frac{(c^g \tilde{c}^\gamma)^2}{\gamma_{tot}} \qquad R^{VBF}_{\gamma\gamma} \approx \frac{(c_V \tilde{c}^\gamma)^2}{\gamma_{tot}}$$

$$R^{Vh}_{b\bar{b}} \approx \frac{(c_V c_b)^2}{\gamma_{tot}} \qquad R^{Vh}_{\tau\bar{\tau}} \approx \frac{(c_V c_\tau)^2}{\gamma_{tot}} \qquad \tilde{c}^\gamma \approx -0.28 c_t + 1.28 c_V - 1.25 \delta c^\gamma$$

$$\gamma_{tot} = \frac{\Gamma_{tot}}{\Gamma^{SM}_{tot}} \approx 0.61 c_b^2 + 0.24 c_V^2 + 0.09 (c^g)^2 + 0.06 c_\tau^2 + \delta_{inv}^2$$

In general, 5 + 1(Γ_{inv}) effective parameters

4 + 1(Γ_{inv}) if $c_b = c_\tau$ 4 if $c_b = c_\tau$ and Γ_{inv} = 0

Educated guess for sensitivity at 14 TeV and $300\ fb^{-1}$:

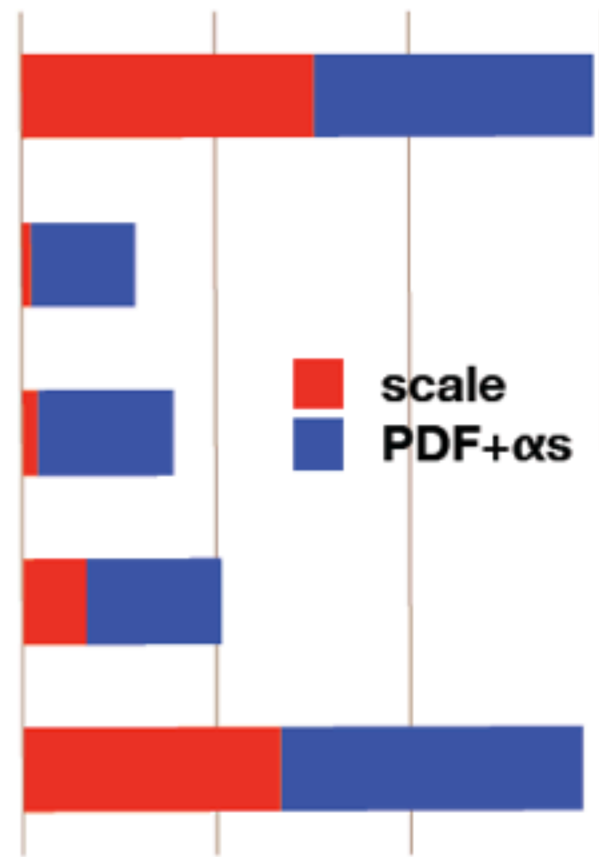
$$\frac{\Delta c_V}{c_V} \lesssim 10\% \longleftrightarrow \frac{\Delta c_{b,\tau}}{c_{b,\tau}} \approx 30\%$$

Uncertainties for Higgs production at 125 GeV

Campbell

- uncertainties from scale variation and PDF+strong coupling

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



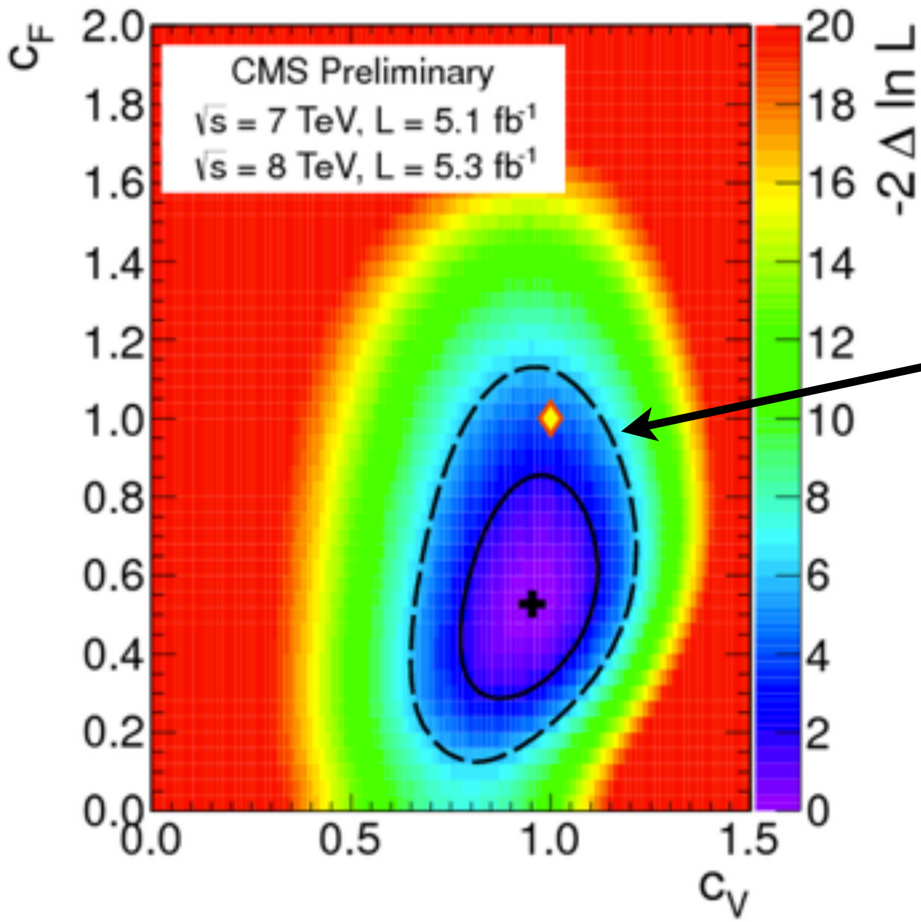
and typical uncertainties on BR's at 4-5% level

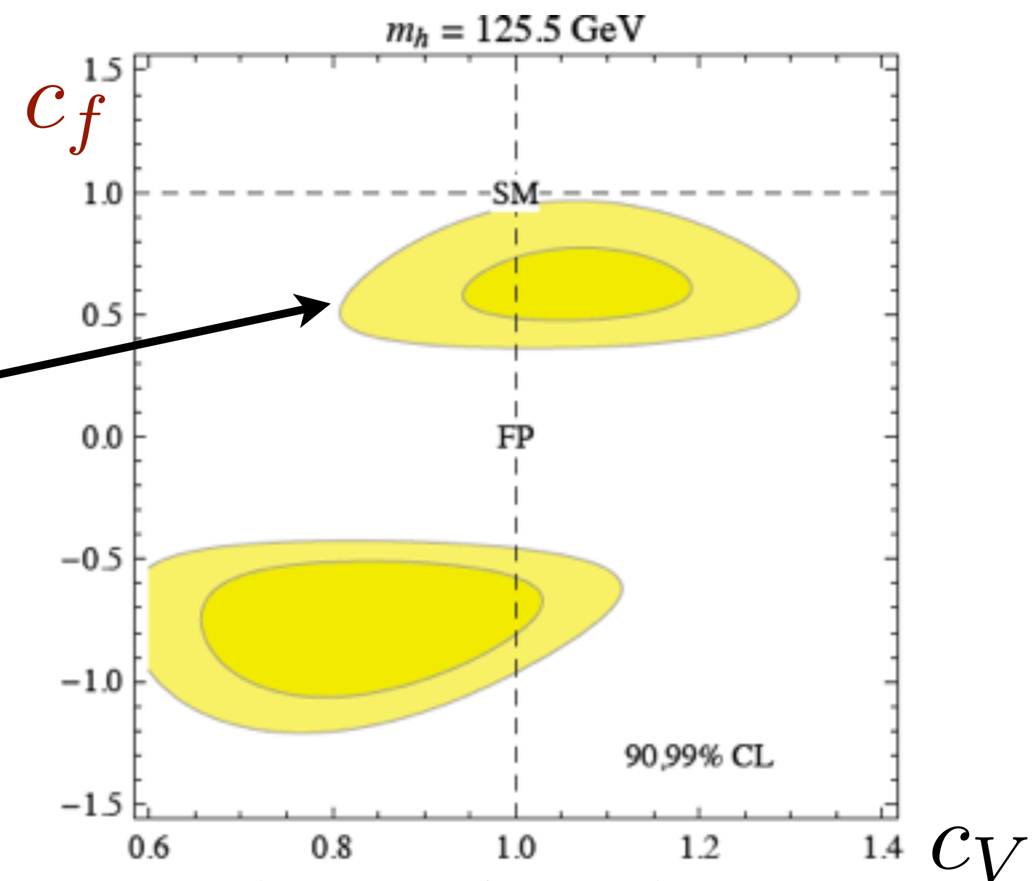
Examples of first fits: c_V and universal c_f

Pomarol

CMS only, by CMS

CMS + ATLAS data





Giardino, Kannike, Raidal, Strumia

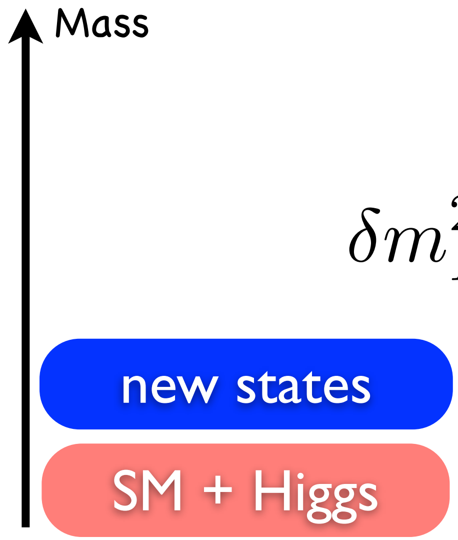
Contino et al

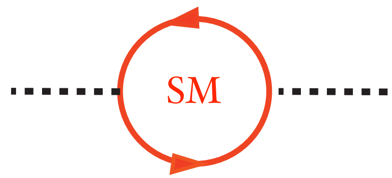
Carmi et al

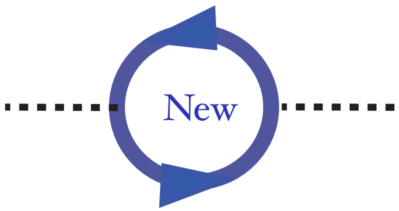
Espinosa et al

Blum et al

A "natural", not Fine Tuned Higgs boson



$\delta m_H^2 =$ 

$+$ 

~ 0

by an (approximate) symmetry

relative to any higher physical scale to which the Higgs boson is possibly coupled

If so, explain why the great empirical success of the SM does not depend on unknown short distance physics

Pomarol
Perez
Sundrum

The (many) reactions to the FT problem

0. Ignore it and view the SM in isolation
   (if no other short distance scale, what about gravity?)

1. Cure it by symmetries: SUSY, Higgs boson as PGB

2. A new strong interaction nearby

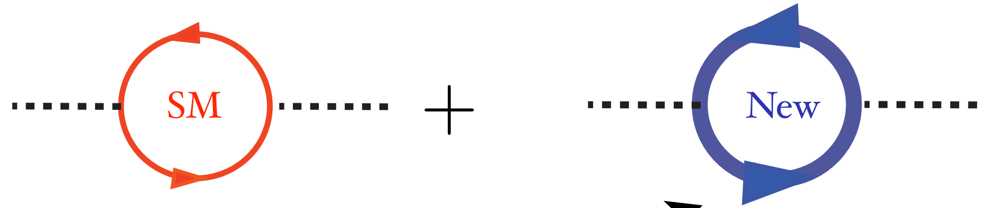
3. A new strong interaction not so nearby: quasi-CFT Dobrescu

4. Saturate the UV nearby: extra-dimensions around the corner

5. Warp space-time: RS

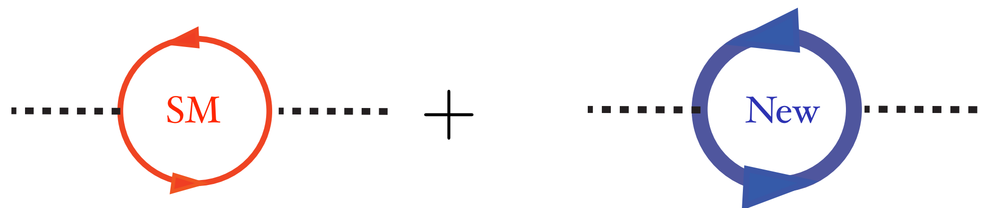
6. Accept it: Fine Tunings exist in nature, anthropic selection, the multiverse, the 10^{120} vacua of string theory, etc.

Supersymmetry

$\delta m_H^2 =$  ~ 0

s-particles

The Higgs boson as a pseudoGolsdtone

$\delta m_H^2 =$  ~ 0

Heavy "composite" fermions

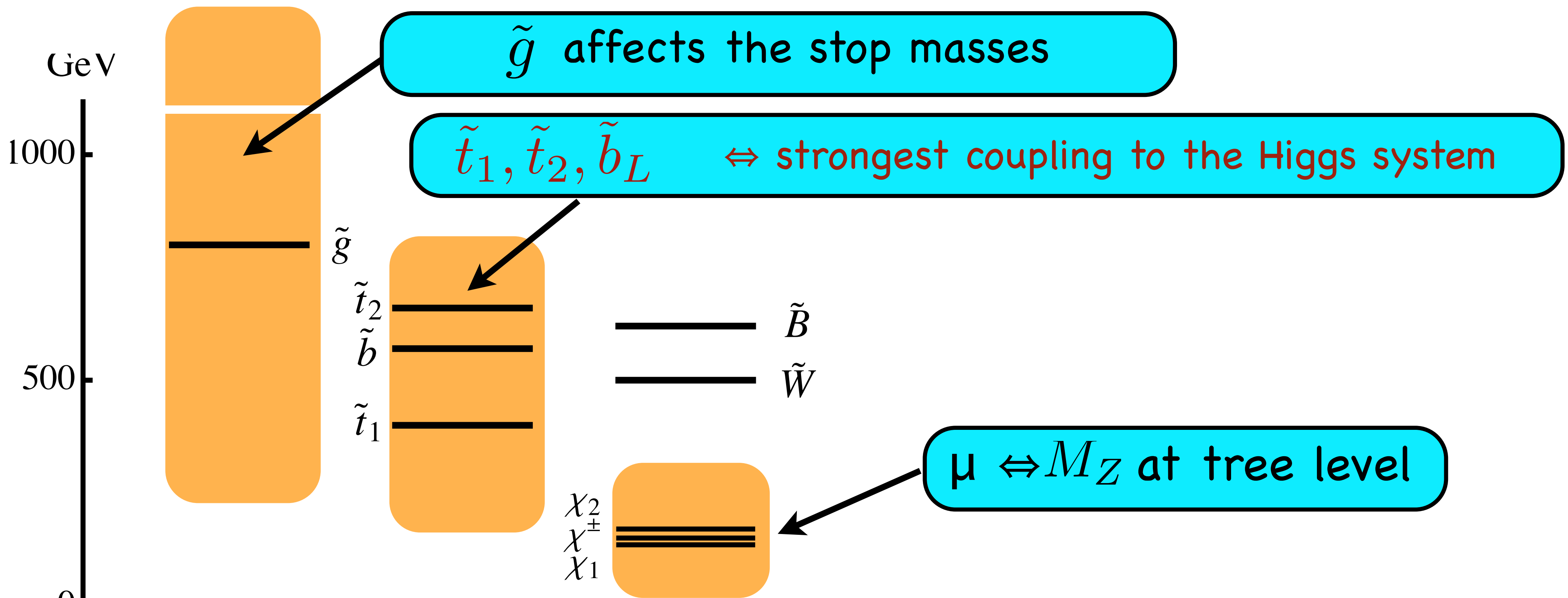
Question: Nothing seen so far. Shouldn't we worry?

Answer: No theorem but this page still offers
the driving criterium

The crucial configuration of supersymmetry

Perez
Sundrum

"s-particles at their naturalness limit"

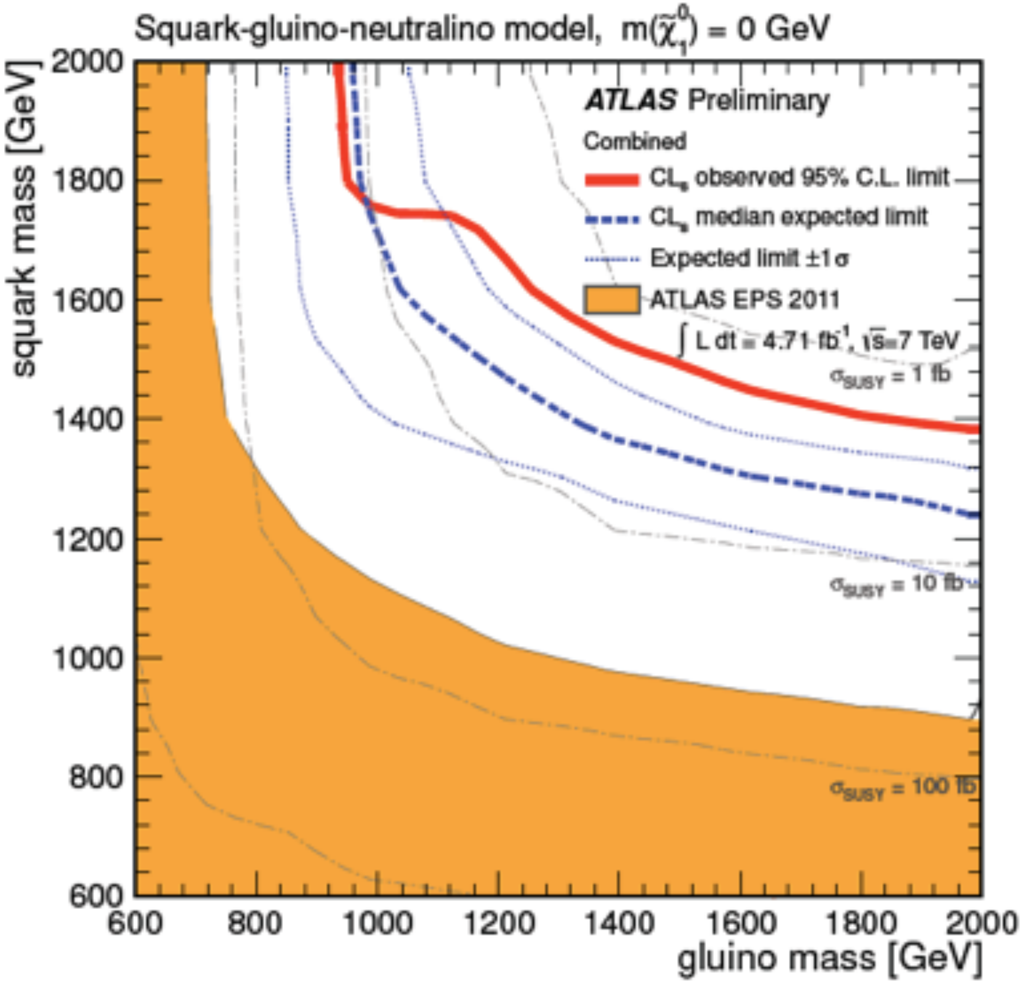


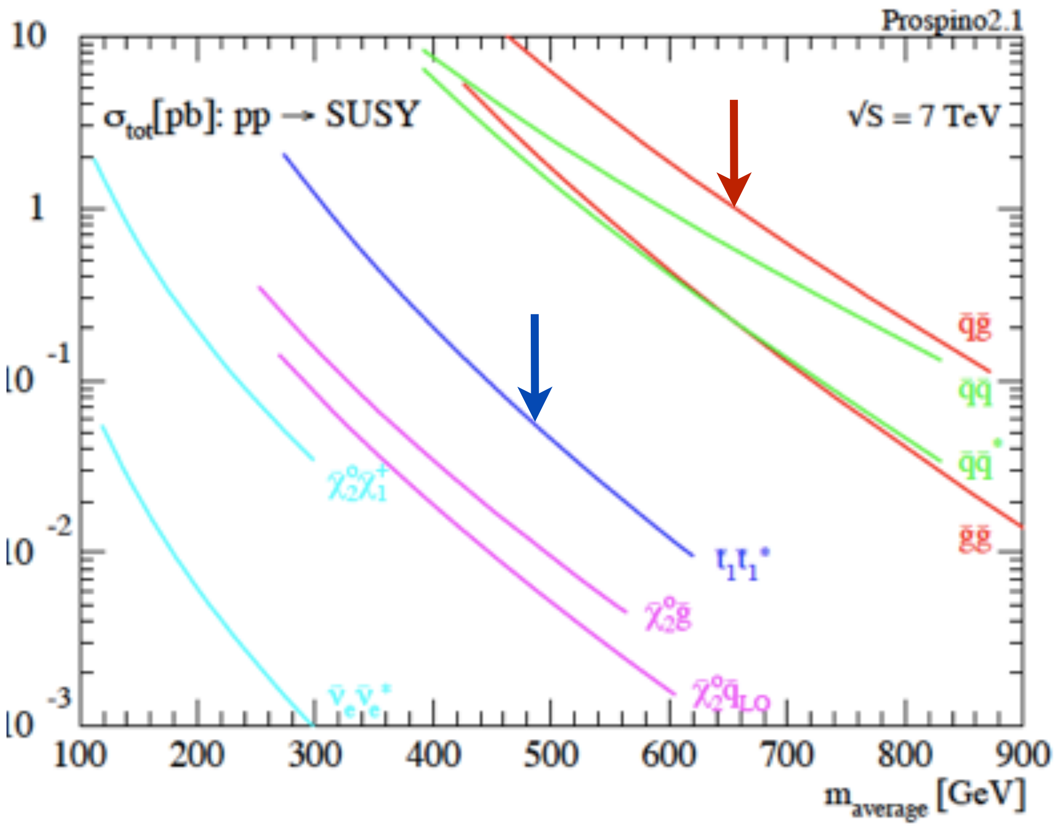
orange areas indicative and dependent on how the Higgs boson gets its mass

$\tilde{B}, \tilde{W}$ not much constrained but expected below $m_{\tilde{g}}$

Strongest current limits on 1st generation squarks

Parker





$$g\ q \longrightarrow \tilde{g}\ \tilde{q}$$
$$q\ q \longrightarrow \tilde{q}\ \tilde{q}$$
$$q\ \bar{q} \longrightarrow \tilde{q}\ \tilde{q}^*$$

$$\Rightarrow m_{\tilde{g}}, m_{\tilde{q}_{1,2}} > 1 \div 1.5\ TeV$$

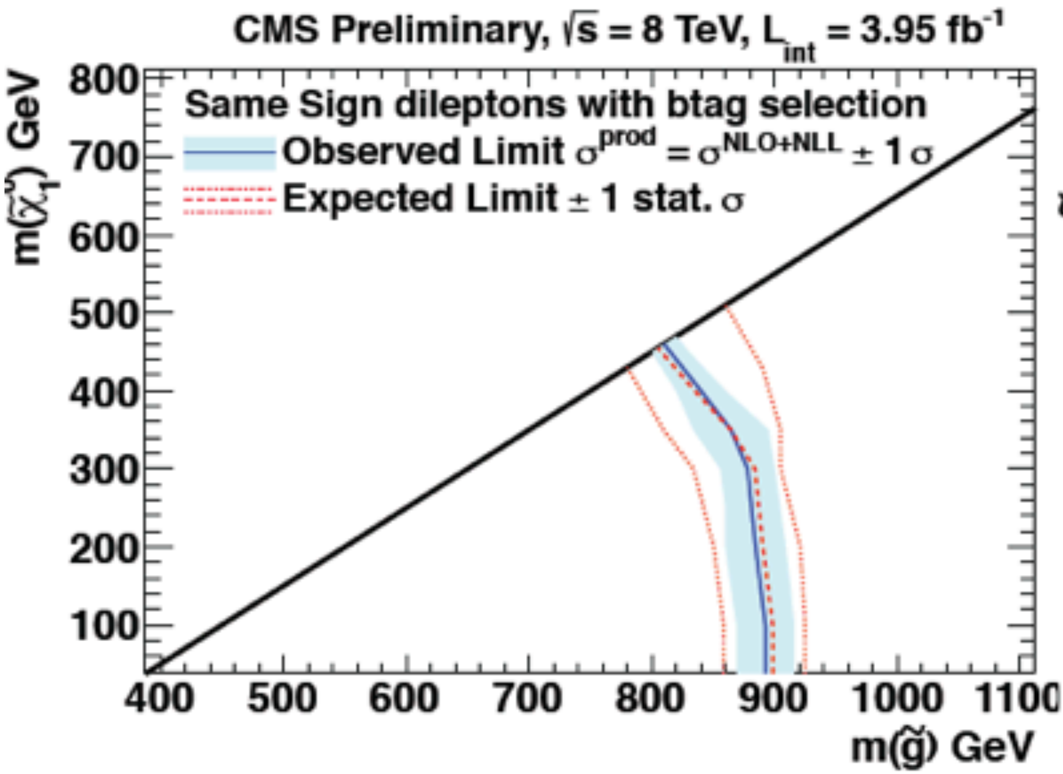
$\tilde{t}, \tilde{b}$ unconstrained

gluino pair production and
$$\tilde{g} \rightarrow t\bar{t} + \chi$$

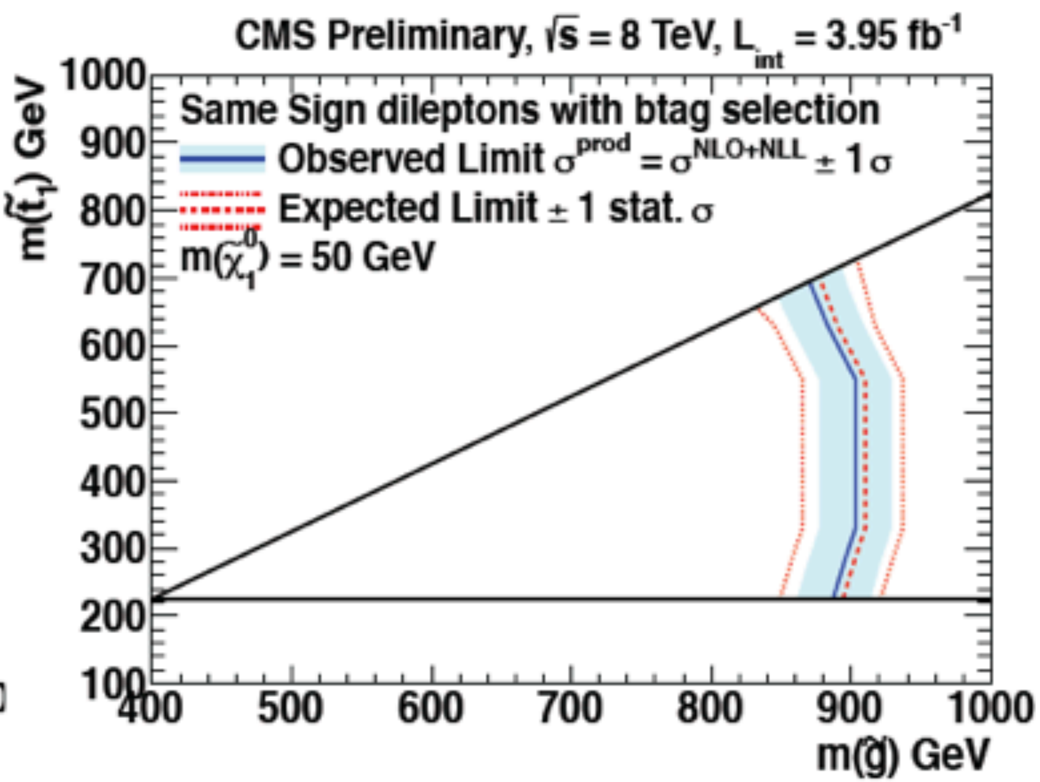
Cakir

Reece

Rogan



gluino → virtual top squarks

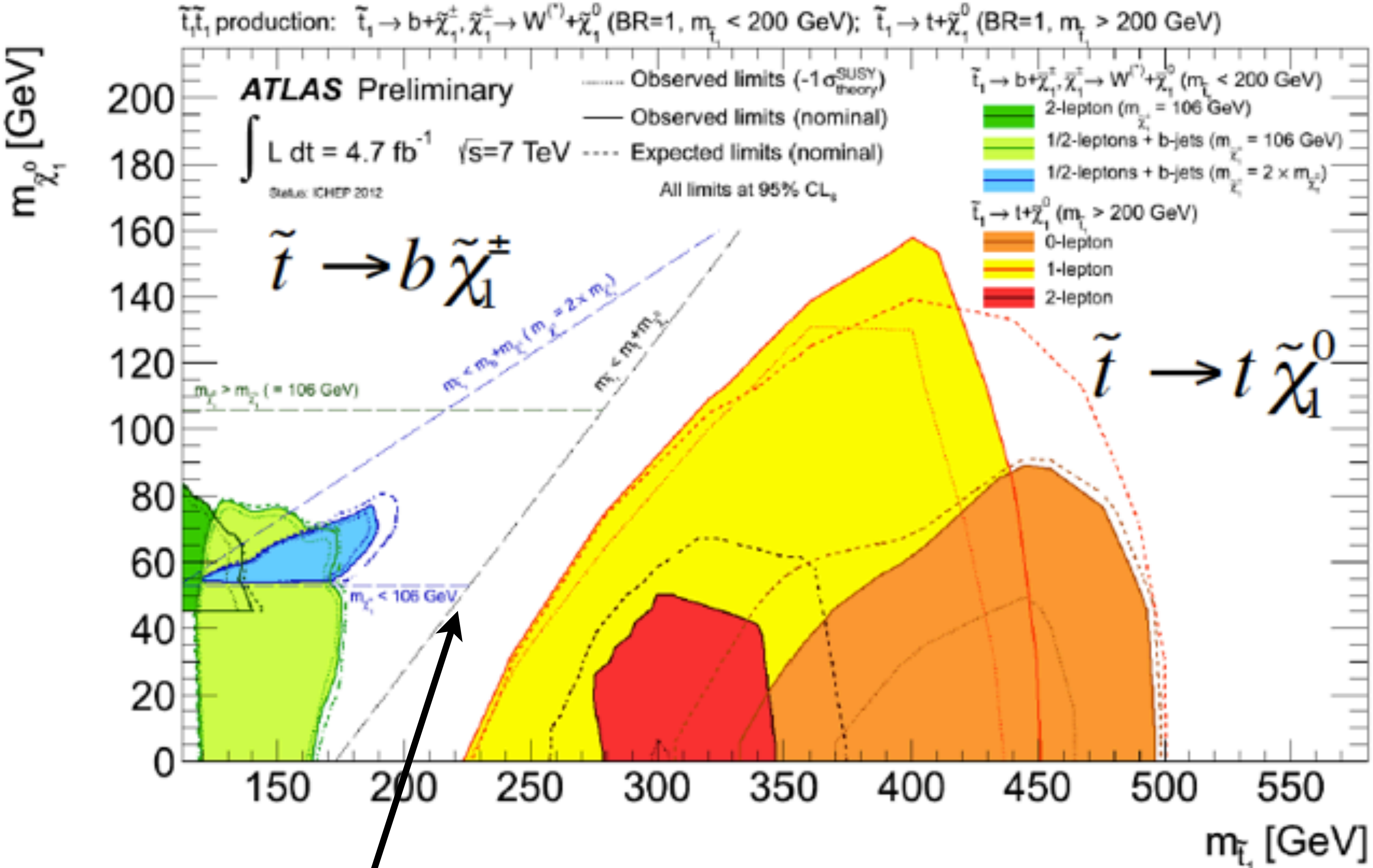


gluino → on-shell top squarks

It matters little if the stop is below (right) or above (left) the gluino

A more crucial parameter is $m(\tilde{g}) - m(\tilde{\chi})$

Parker White



How about the Tevatron here?

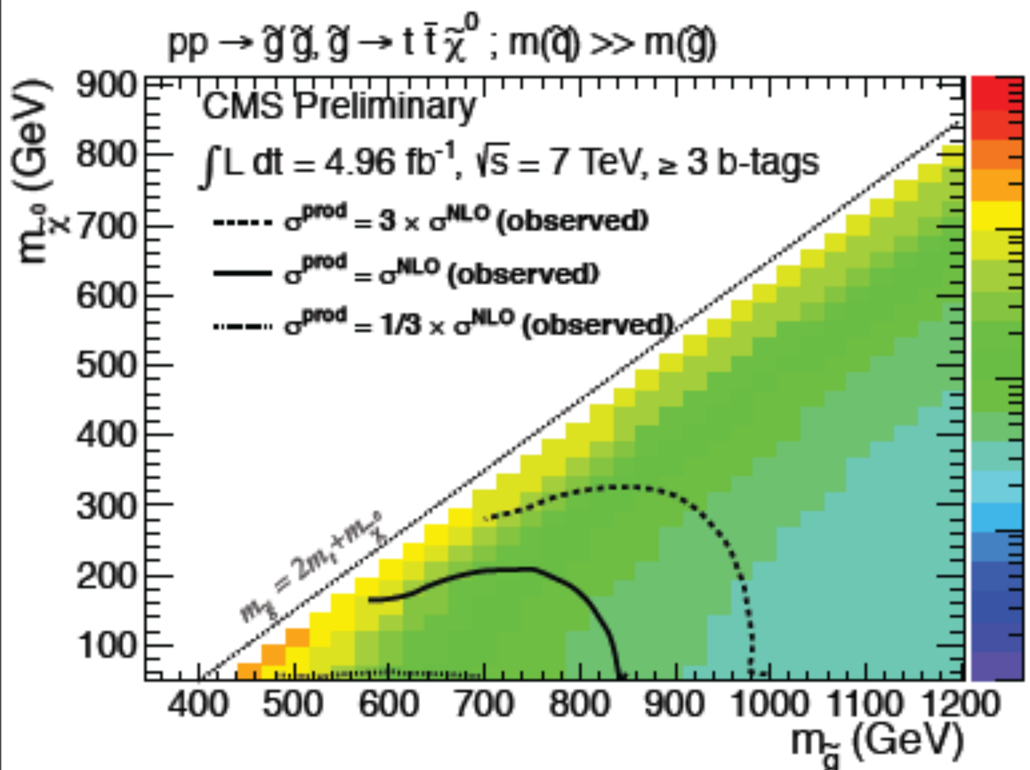
The "sparticles-at-their-naturalness-limit" configuration now being scrutinized

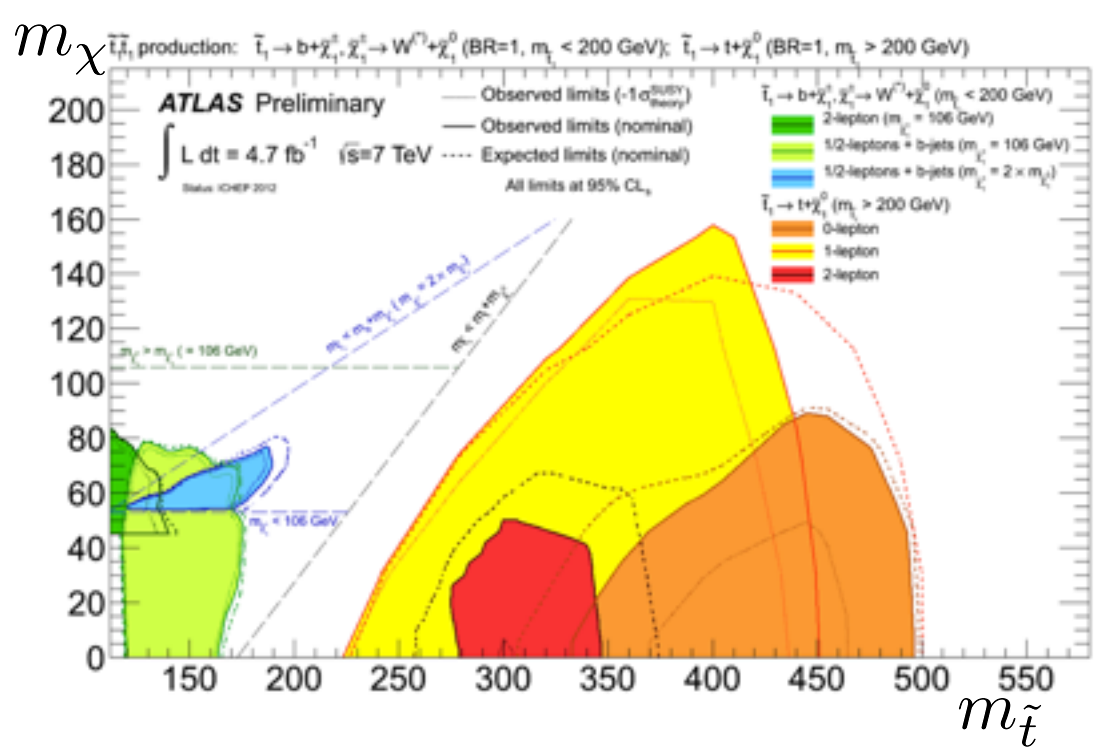
Frequently asked question:

Is supersymmetry at the Fermi scale dead?

Speaking for myself, I would like to see:

left plot extended to $m_{\tilde{g}} = 1.5 \div 1.8\ TeV$ OR right-plot plane fully explored





Question: Isn't it easier to study the $(m_{\tilde{b}}, m_{\tilde{\chi}})$ plane via $\tilde{b} \to b + \chi$

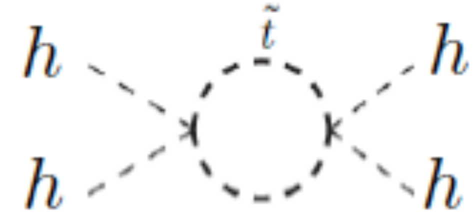
Answer: Yes, but less relevant since $\tilde{b}_L$ wants to go to $t\chi^- \to t\chi(l^-)$

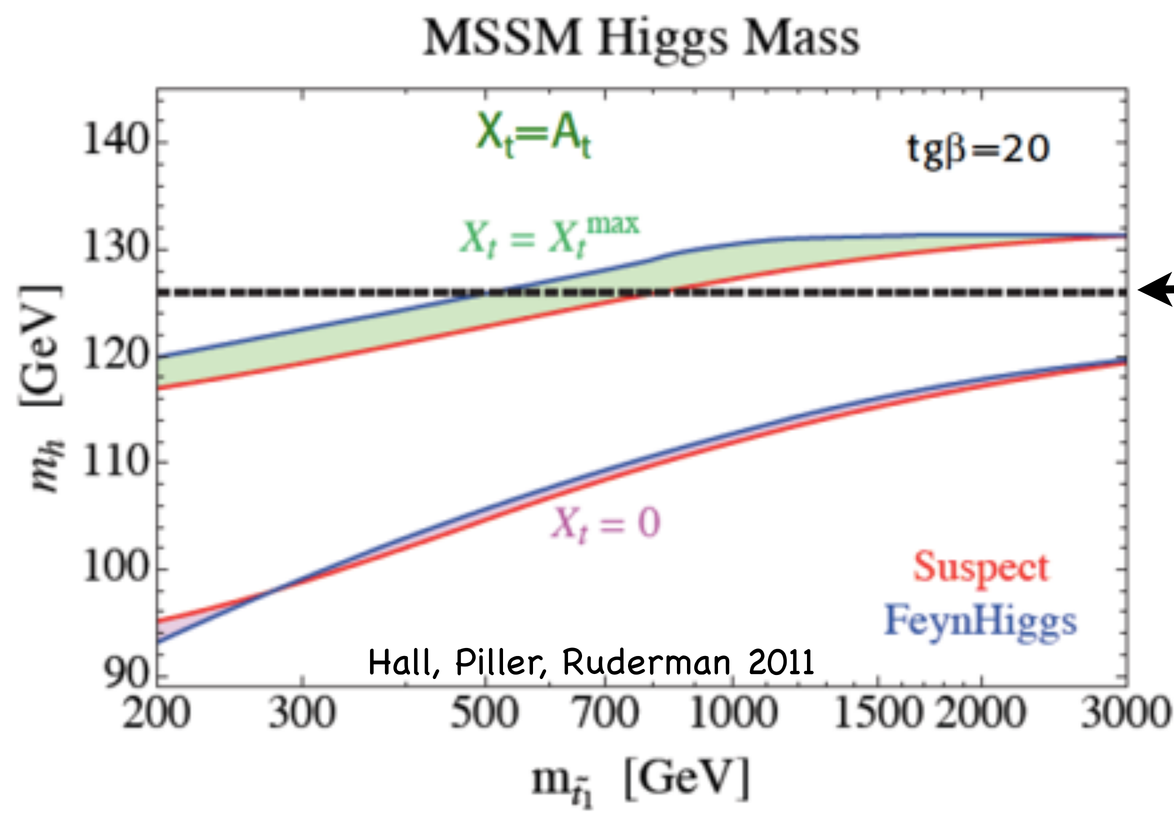
Where is the supersymmetric Higgs boson?

MSSM

Mahmoudi

$$m_h^2 \approx m_Z^2 \cos^2 2\beta + \frac{3}{(4\pi)^2}\frac{m_t^4}{v^2}\left[\ln\frac{m_{\tilde{t}}^2}{m_t^2} + \frac{X_t^2}{m_{\tilde{t}}^2}\left(1 - \frac{X_t^2}{12 m_{\tilde{t}}^2}\right)\right]$$





MSSM expectation well OK with current allowed "SM range"
but 125 GeV too high for naturally light stops

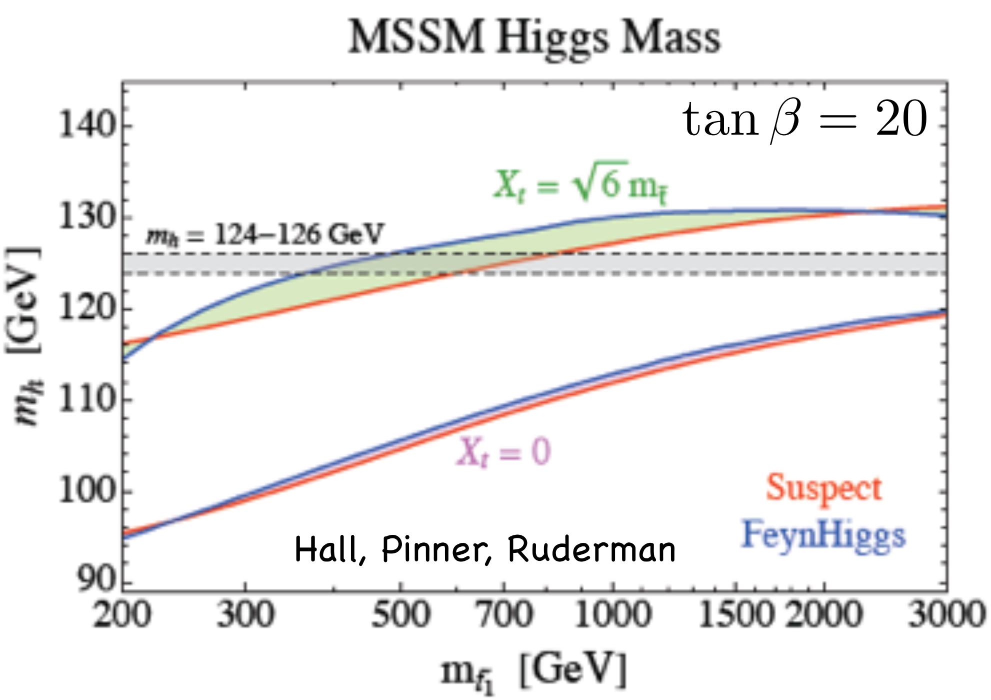
What about the Higgs mass, then?

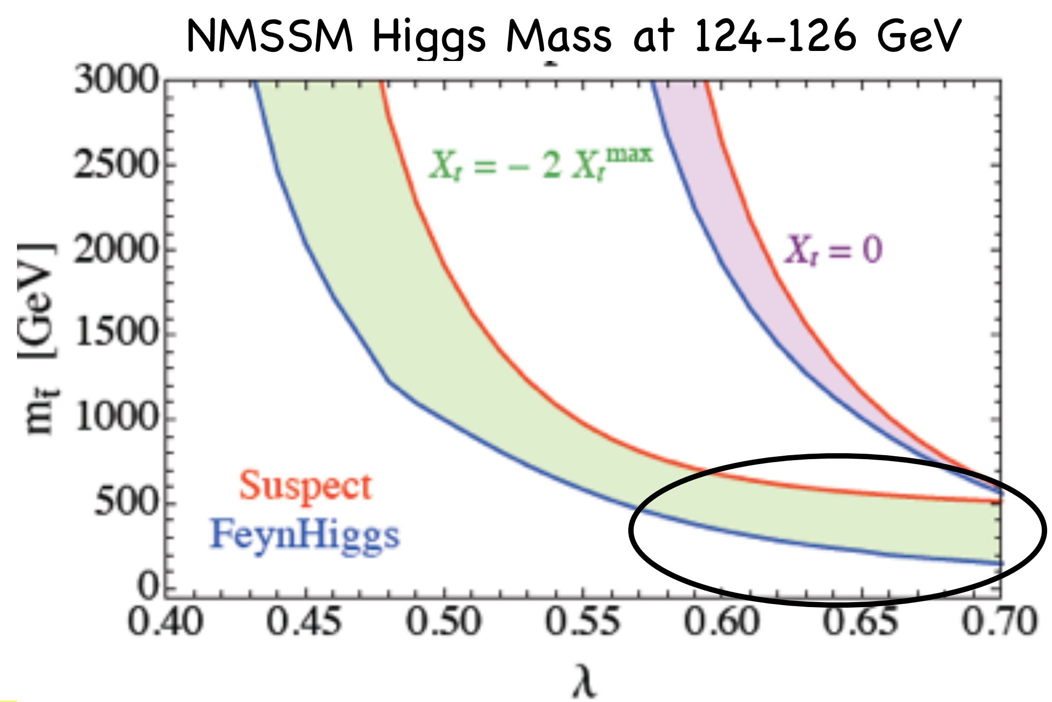
The NMSSM as a possible way out

(since the 70's, Fayet, etc)

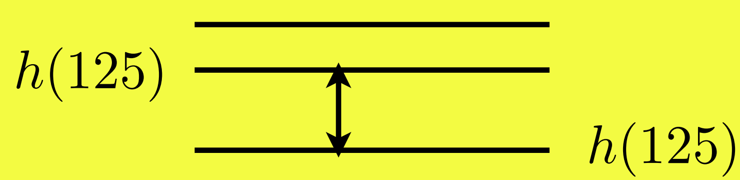
$$f = \mu H_1 H_2 \Rightarrow f = \lambda S H_1 H_2 \qquad m_h^2 \leq m_Z^2\left(\cos^2 2\beta + \frac{2\lambda^2}{g^2+g'^2}\sin^2 2\beta\right) + \delta_t(m_{\tilde{t}_1}, X_t)$$

Schmidt





before mixing with the other 2 scalars
⇒ 2 options:



A "pessimistic" view

Sundrum

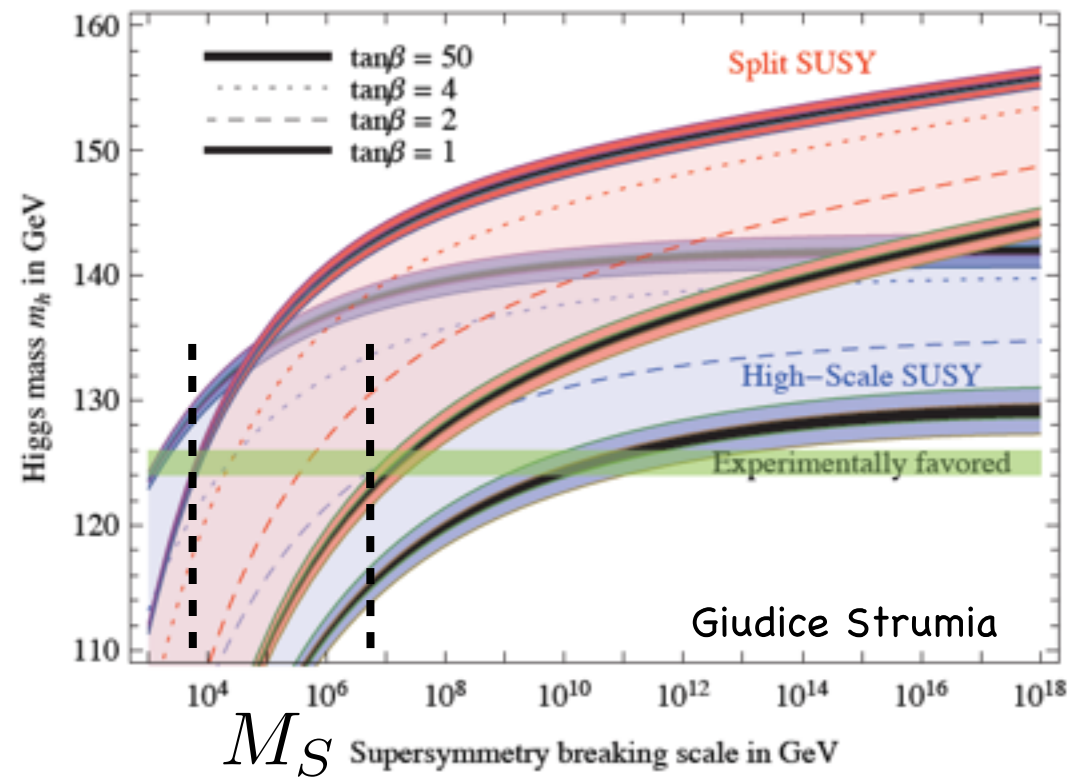
The SUSY scale, M_S, and the Fermi scale, $G_F^{-1/2}$, not so tied together as we thought

$\Rightarrow$ flavour physics, CPV as in SM
$\Rightarrow$ no SUSY at LHC so far

An "extreme" example:

Split-SUSY $\equiv$
SUSY scalars at $\sim M_S$
SUSY fermions at $\sim G_F^{-1/}$

("High-scale" SUSY $\equiv$
all s-particles at M_S)

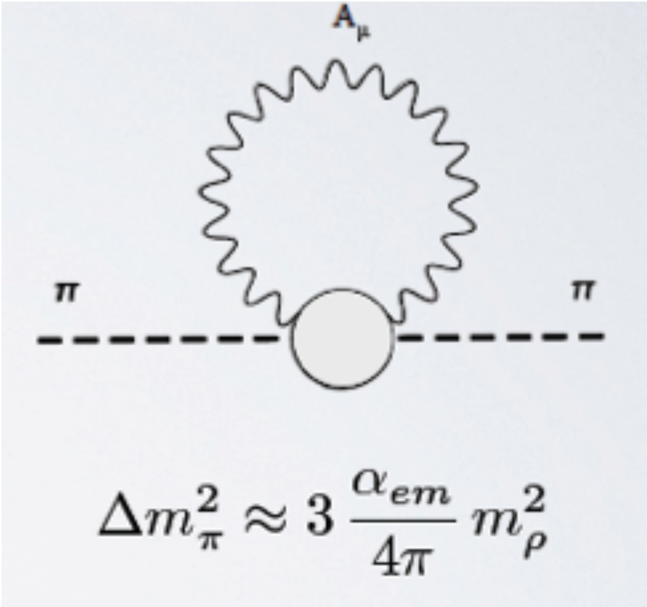


The Higgs boson as a PGB

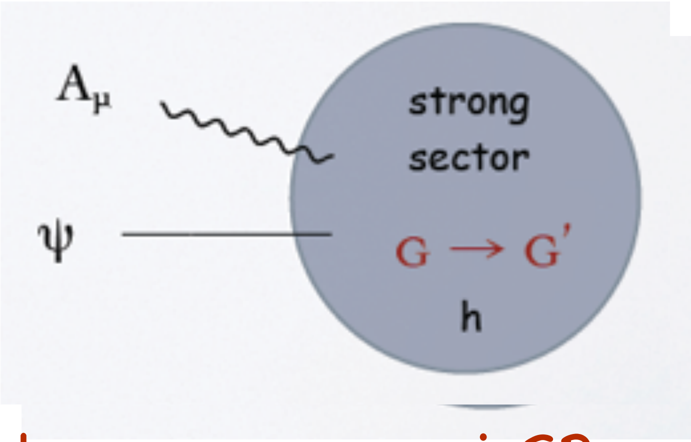
Pomarol

The pion as an analogy:

$$SU(2)_L \times SU(2)_R \Rightarrow SU(2)_I$$
$$\Delta m_\pi^2 = m_{\pi^+}^2 - m_{\pi^0}^2$$

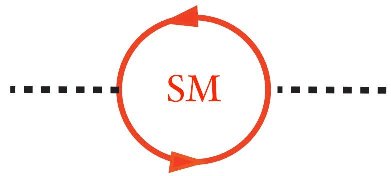
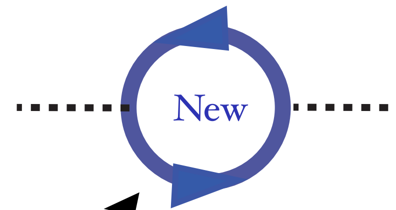


A new strong sector
at the TeV scale

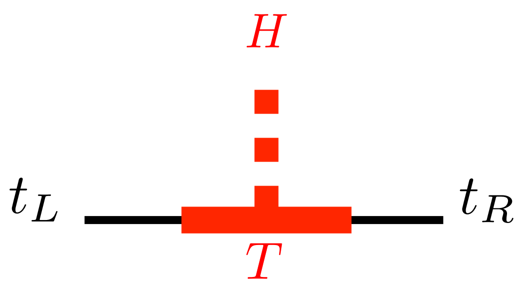


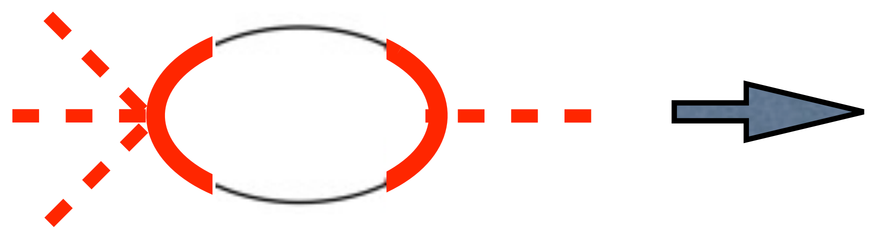
Like the pion in QCD, the Higgs boson as a quasi GB
of a spontaneously broken global symmetry

More in detail

$\delta m_H^2 =$  $+$  ~ 0

Heavy "composite" fermions





Heavy "composite" fermion mass

$$m_h \sim m_t \frac{M_T}{\pi f}$$

symmetry breaking scale

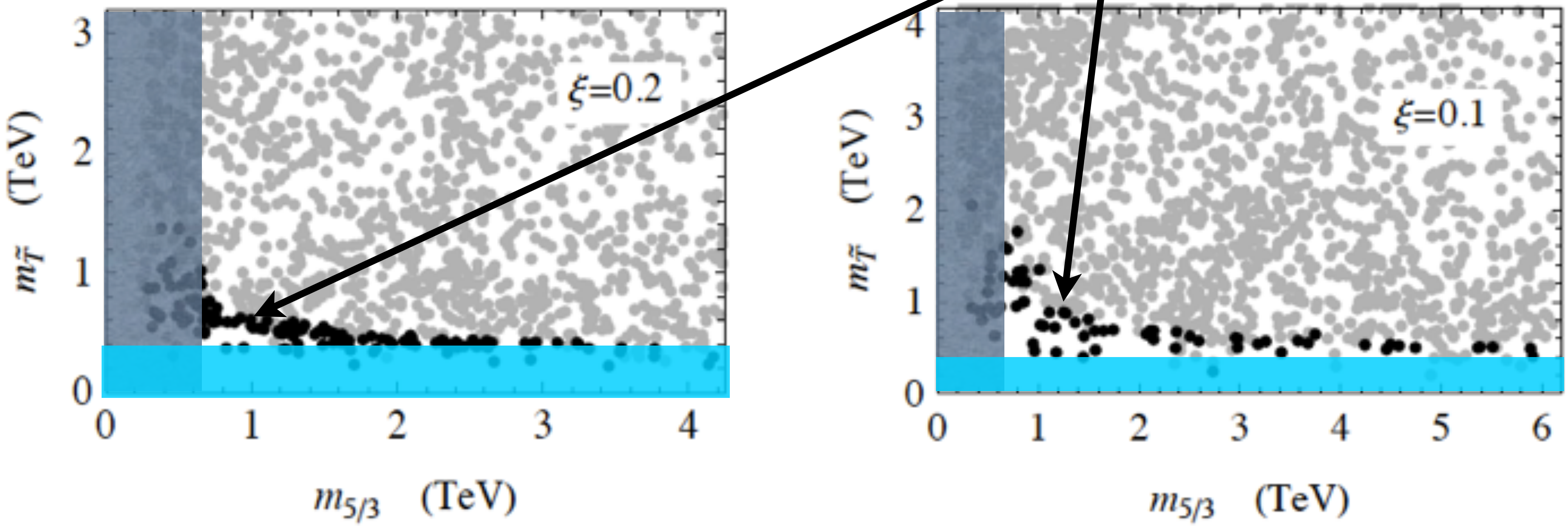
Most common: $Q = \begin{pmatrix} T \\ B \end{pmatrix}, \quad X = \begin{pmatrix} X_{5/3} \\ T_{2/3} \end{pmatrix}, \quad \tilde{T}$

Relatively light composite fermions preferred by currently "allowed" SM range for m_H

Redi

$$m_h \sim A \frac{m_T m_{\tilde{T}}}{\pi v} \xi, \;\; A = O(1)$$

$$m_h \in (115, 130) GeV$$



Matsedonskyi, Panico, Wulzer, 2012

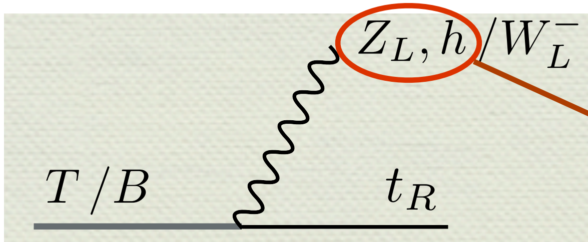
$T, \; \tilde{T}$ lightest fermionic partners of $t_L, \; t_R$

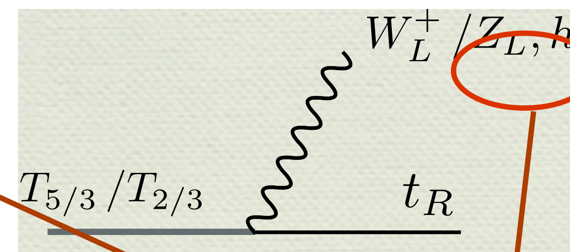
$\xi = \dfrac{v^2}{f^2}$ made small by fine tuning

Phenomenology of the "composite" fermions

Heavy-light couplings

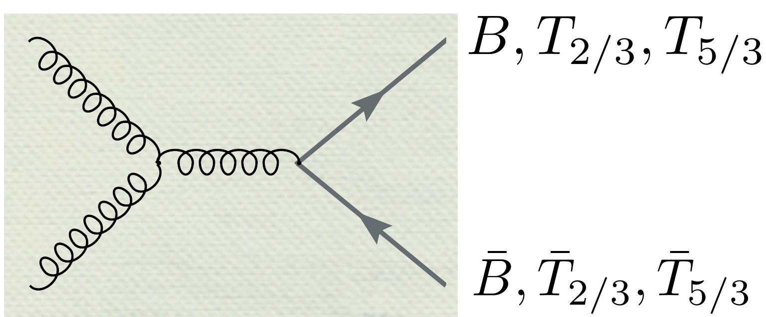
Contino et al



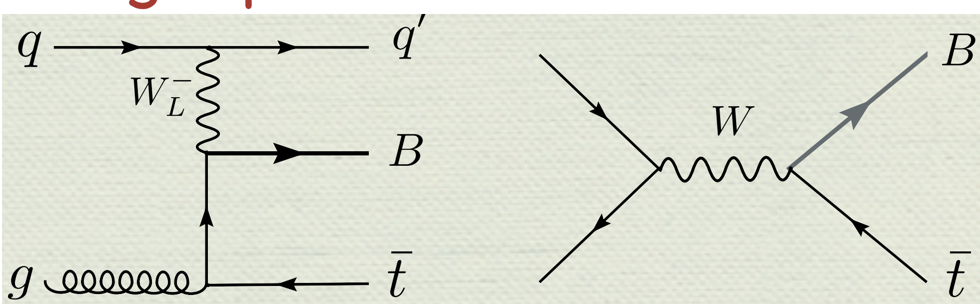


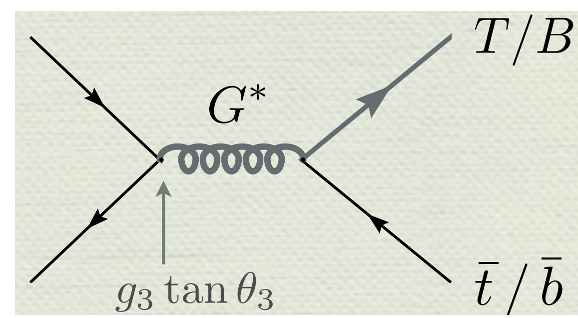
Not like a sequential family

Pair production



Single production



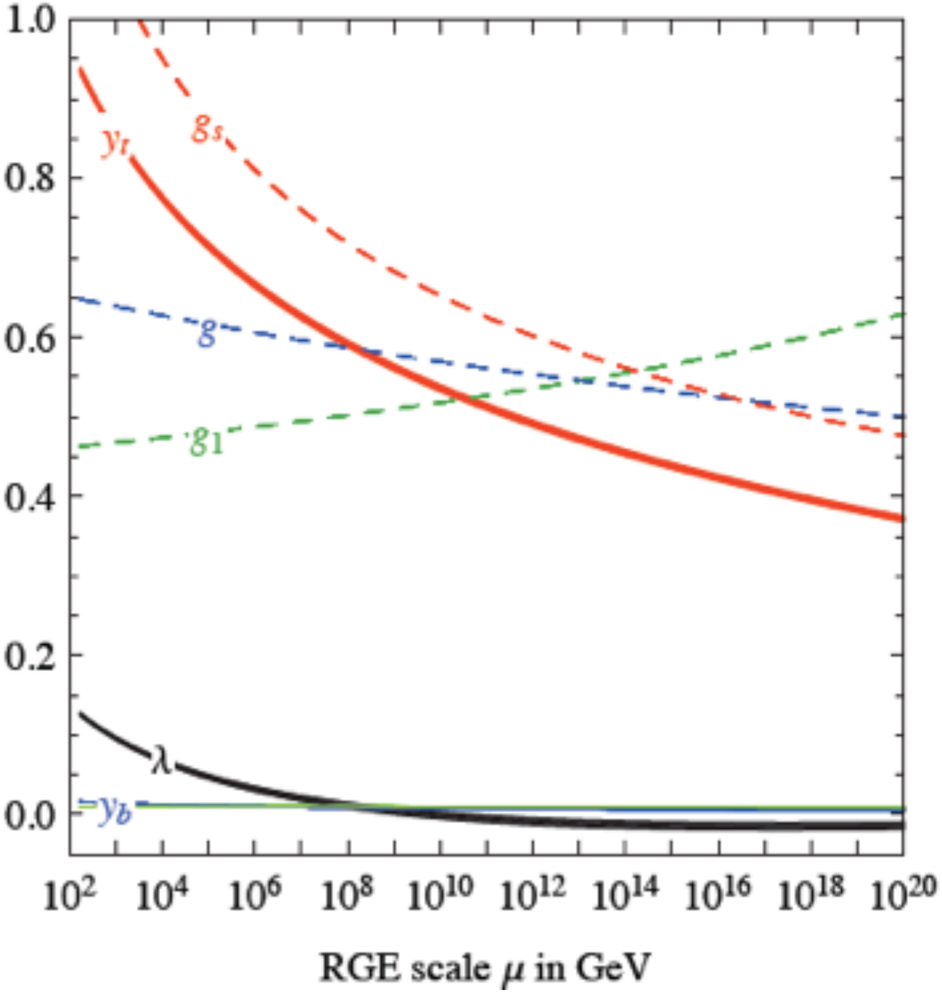


From 4th-generation searches, properly reinterpreted, exclude masses below 450-600 GeV, depending on the charge

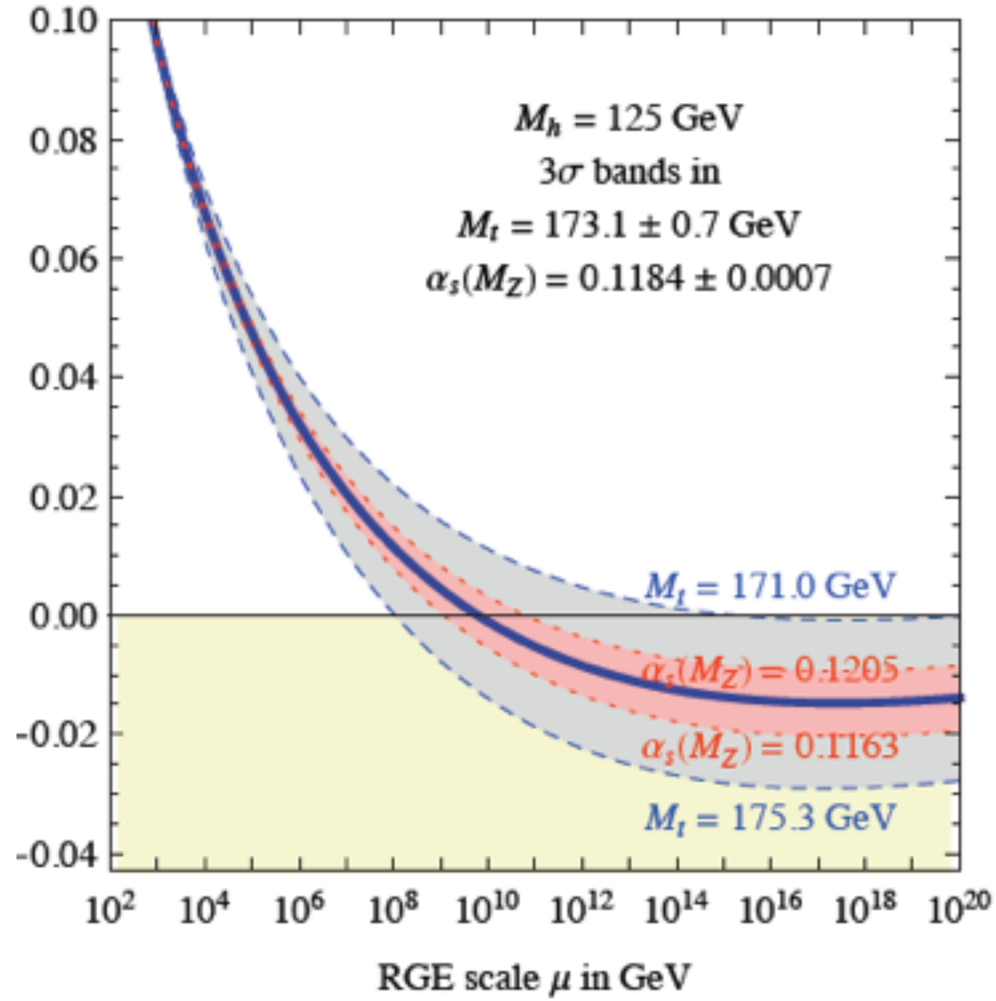
What if the Higgs boson likes to be unnatural and the SM unchanged up to very high energies?

Perez

largest couplings



Higgs self-coupling



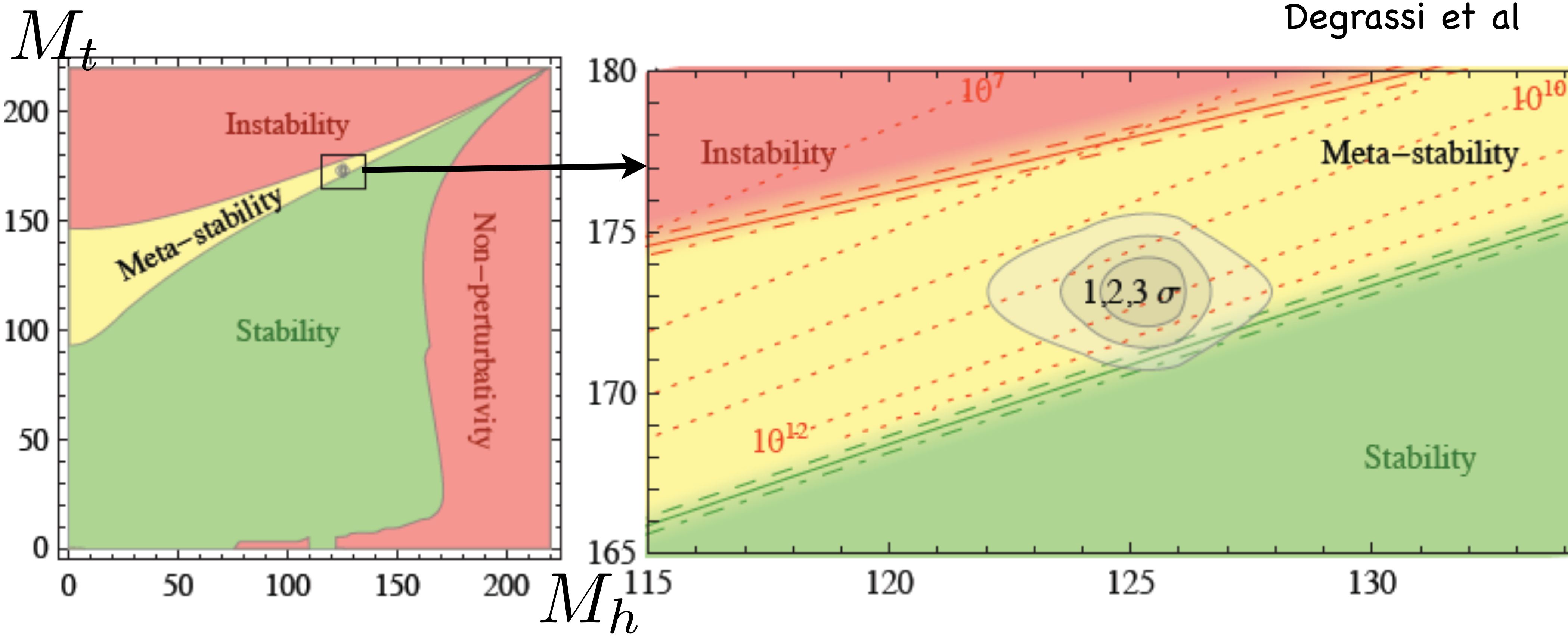
most accurate calculation to date

Degrassi et al

A special meaning for λ≈0 at M_{Pl}?

Assume SM unchanged up to M_{Pl}

Degrassi et al



Absolute stability at $M_{Pl}(\lambda(M_{Pl}) \gtrsim 0)$ not quite achieved for current “best” values of M_t and M_h

Speculations about possible meaning of all this not lacking

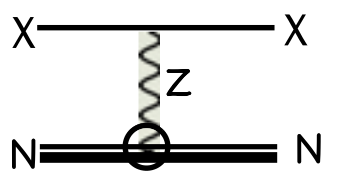
One single DM-search page (spin-ind.)

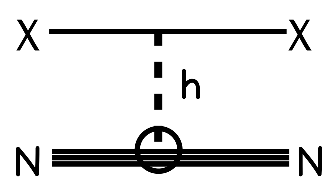
Hsu
Weiner

$$\chi N \to \chi N$$

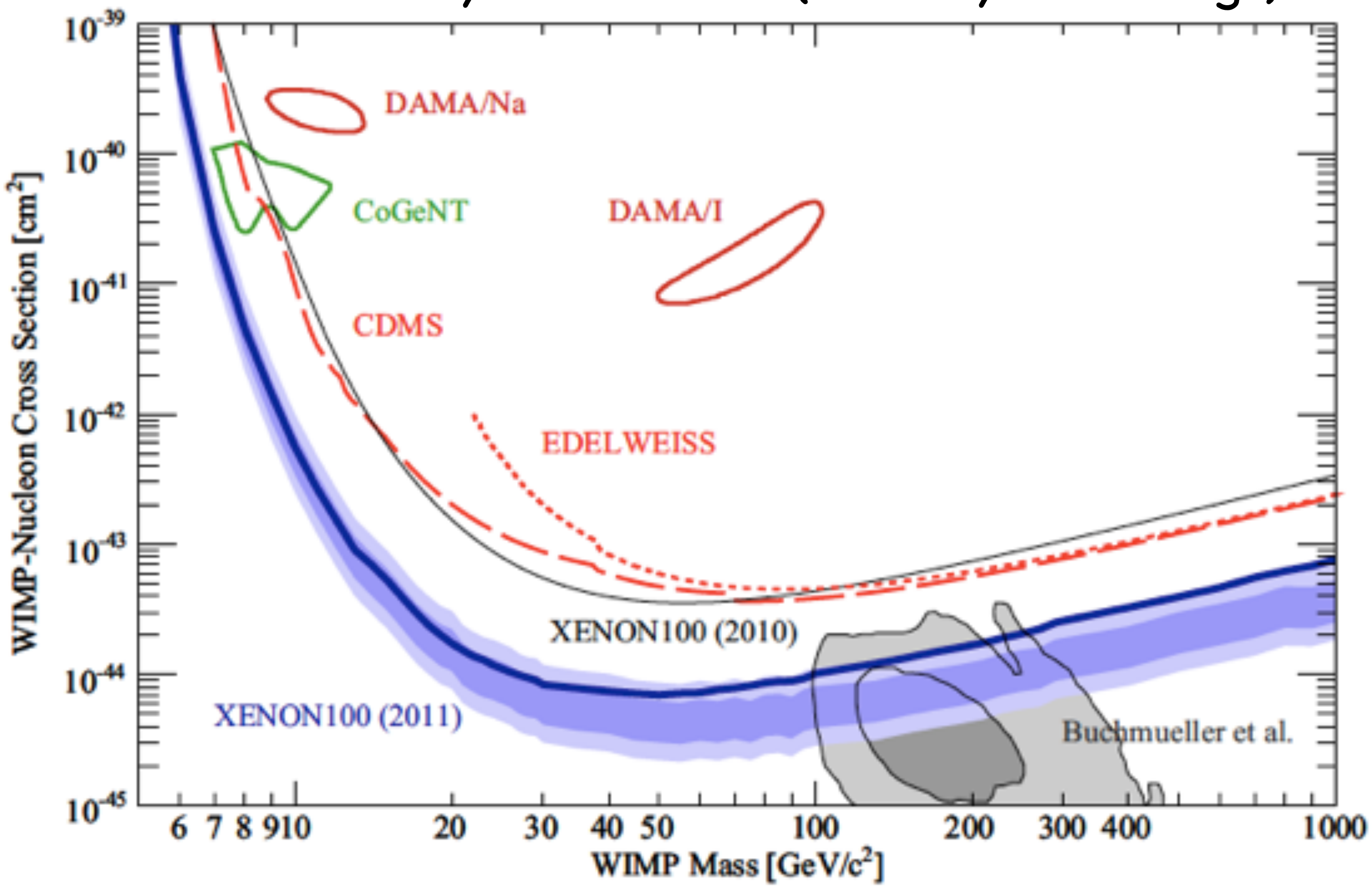
3 events/1.8 backgd

$\sigma_Z(\chi N)$ spin indep. excluded since long time





exclusion by XENON100 (100 days x 48 kgs)



Higgs boson exchange being probed now for $m_h \approx 100\ GeV$

$$\sigma_h(\chi N) \approx 10^{-43} cm^2\ (\frac{\lambda}{0.1})^2 (\frac{100 GeV}{m_\chi})^2 (\frac{100 GeV}{m_h})^4$$

Summary of the (partial) summary

The gauge sector

QCD: an amazingly useful interaction between "deep" theory and "hard" phenomenology

The neutrino sector

One less but still many unanswered questions

The flavour sector

Can it be that NP in flavour is around the corner?
Conceivable (if not necessary)

The EWSB sector

A great milestone passed along a path still to be fully explored

We, as "members of a curious species [that] have dedicated their lives and fortunes to the search for their origin in a dark universe" (NYT, July 4, 2012) are proud of the discovery of the Higgs boson

(Do you recognize yourselves in above definition? I do not)