HEP results that shape the future program: What's New?

Joseph Lykken

Fermilab

CMS

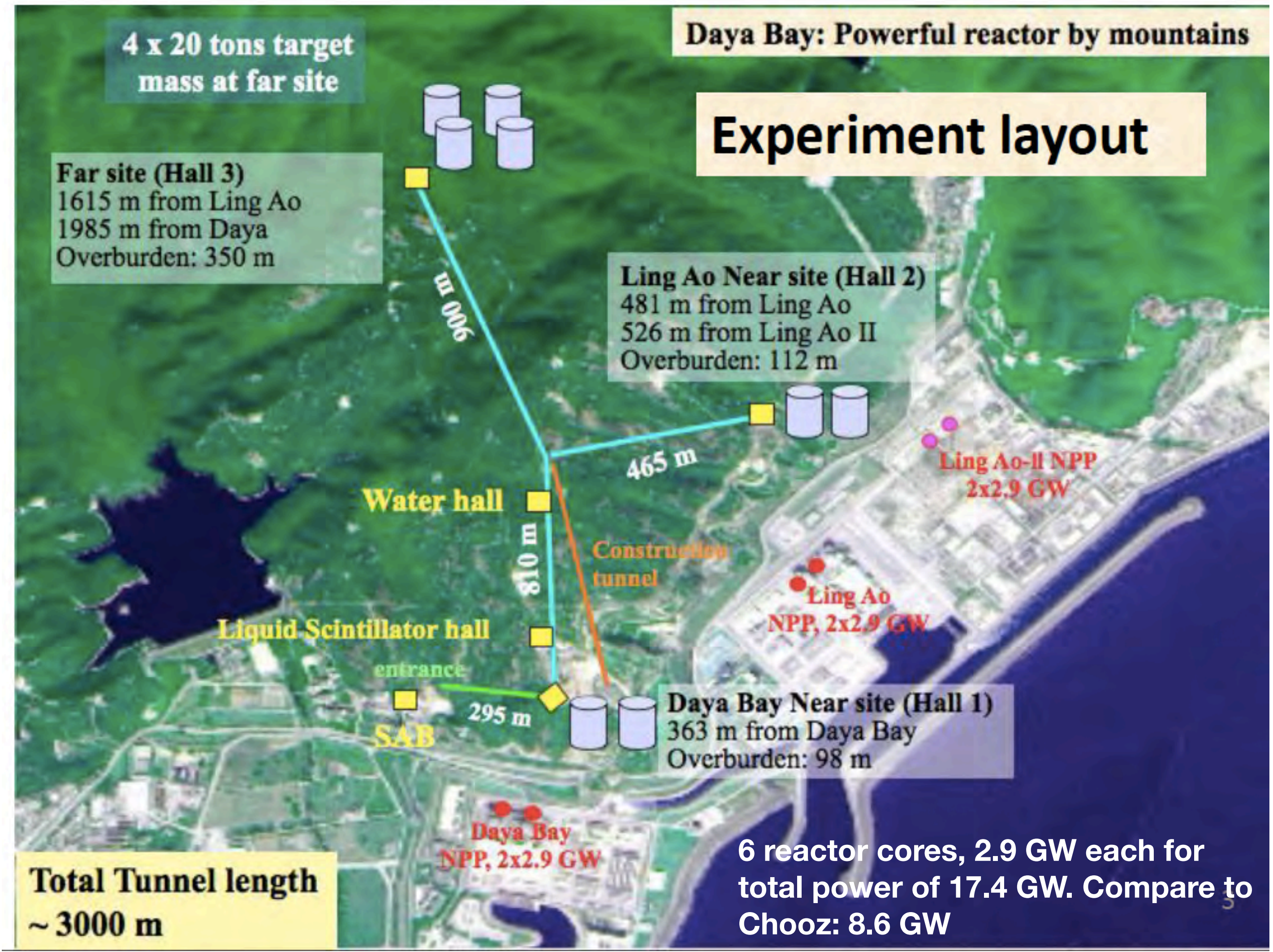
P5 Subpanel

Outline

- What's New at the Intensity Frontier?
  - Neutrinos
  - Flavor
- What's New at the Energy Frontier?
  - Higgs
  - SUSY
- What's New at the Cosmic Frontier?
  - Dark Matter (direct, WIMPs only)

Many results reviewed here are < 1 week old

What's New at the Intensity Frontier: Neutrinos



Questions for the future

As the first chapter in the study of neutrino oscillations comes to an end, a new chapter begins. The great progress in neutrino physics over the last few decades raises new questions and provides opportunities for major discoveries. Among the compelling issues today:

1) What is the value of θ_{13}, the mixing angle between first- and third-generation neutrinos for which, so far, experiments have only established limits? Determining the size of θ_{13} has critical importance not only because it is a fundamental parameter, but because its value will determine the tactics to best address many other questions in neutrino physics.

2) Do neutrino oscillations violate CP? If so, how can neutrino CP violation drive a matter-antimatter asymmetry among leptons in the early universe (leptogenesis)? What is the value of the CP violating phase, which is so far completely unknown? Is CP violation among neutrinos related to CP violation in the quark sector?

3) What are the relative masses of the three known neutrinos? Are they "normal," analogous to the quark sector, ($m_3 > m_2 > m_1$) or do they have a so-called "inverted" hierarchy ($m_2 > m_1 > m_3$)? Oscillation studies currently allow either ordering. The ordering has important consequences for interpreting the results of neutrinoless double beta decay experiments and for understanding the origin and pattern of masses in a more fundamental way, restricting possible theoretical models.

4) Is θ_{23} maximal (45 degrees)? if so, why? Will the pattern of neutrino mixing provide insights regarding unification of the fundamental forces? Will it indicate new symmetries or new selection rules?

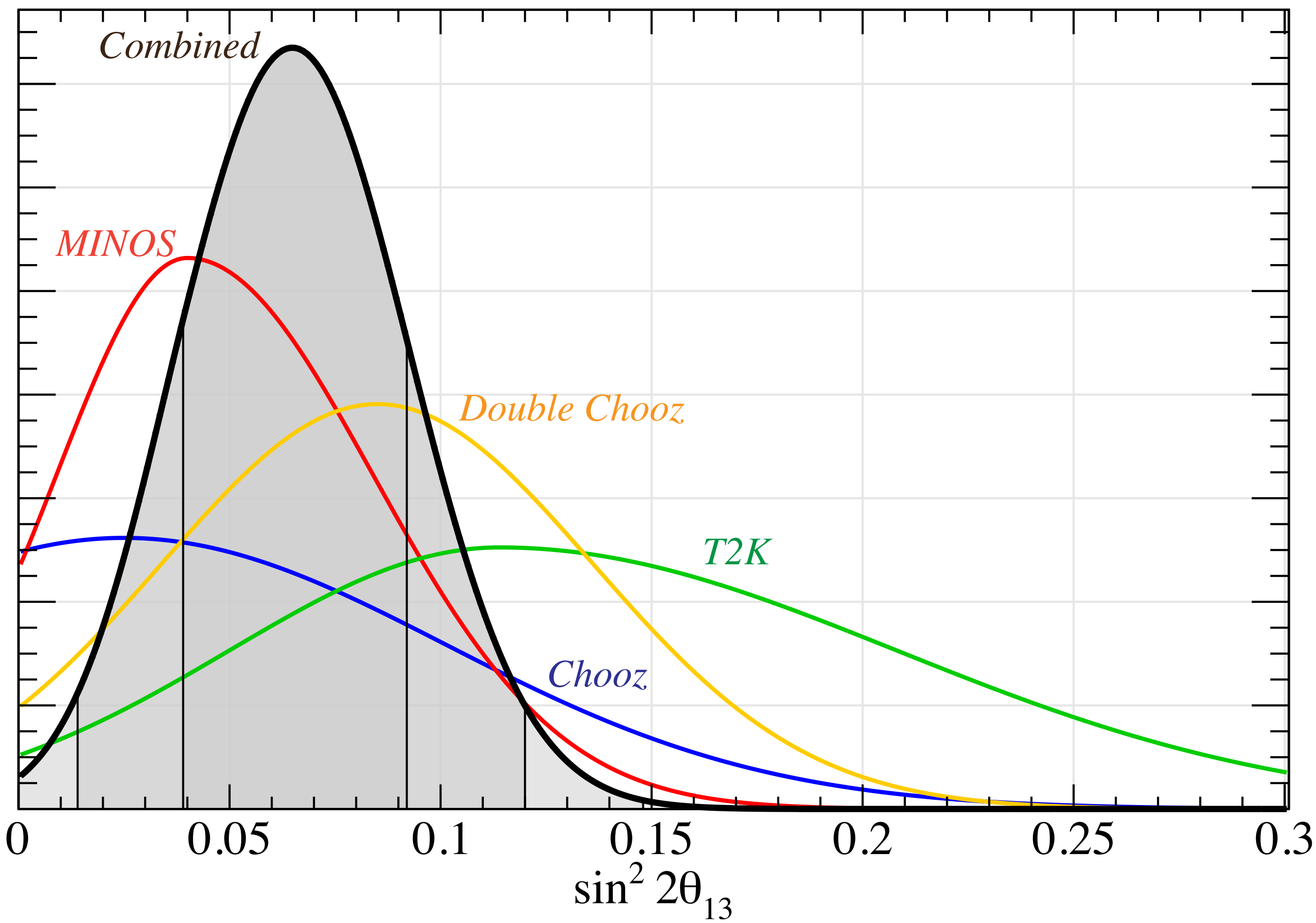
5) Are neutrinos their own antiparticles? Do they give rise to lepton number violation, or leptogenesis, in the early universe? Do they have observable laboratory consequences such as the sought-after neutrinoless double beta decay in nuclei?

6) What can we learn from observation of the intense flux of neutrinos from a supernova within our galaxy? Can we observe the neutrino remnants of all supernovae that have occurred since the beginning of time?

7) What can neutrinos reveal about other astrophysical phenomena? Will we find localized cosmic sources of very-high-energy neutrinos?

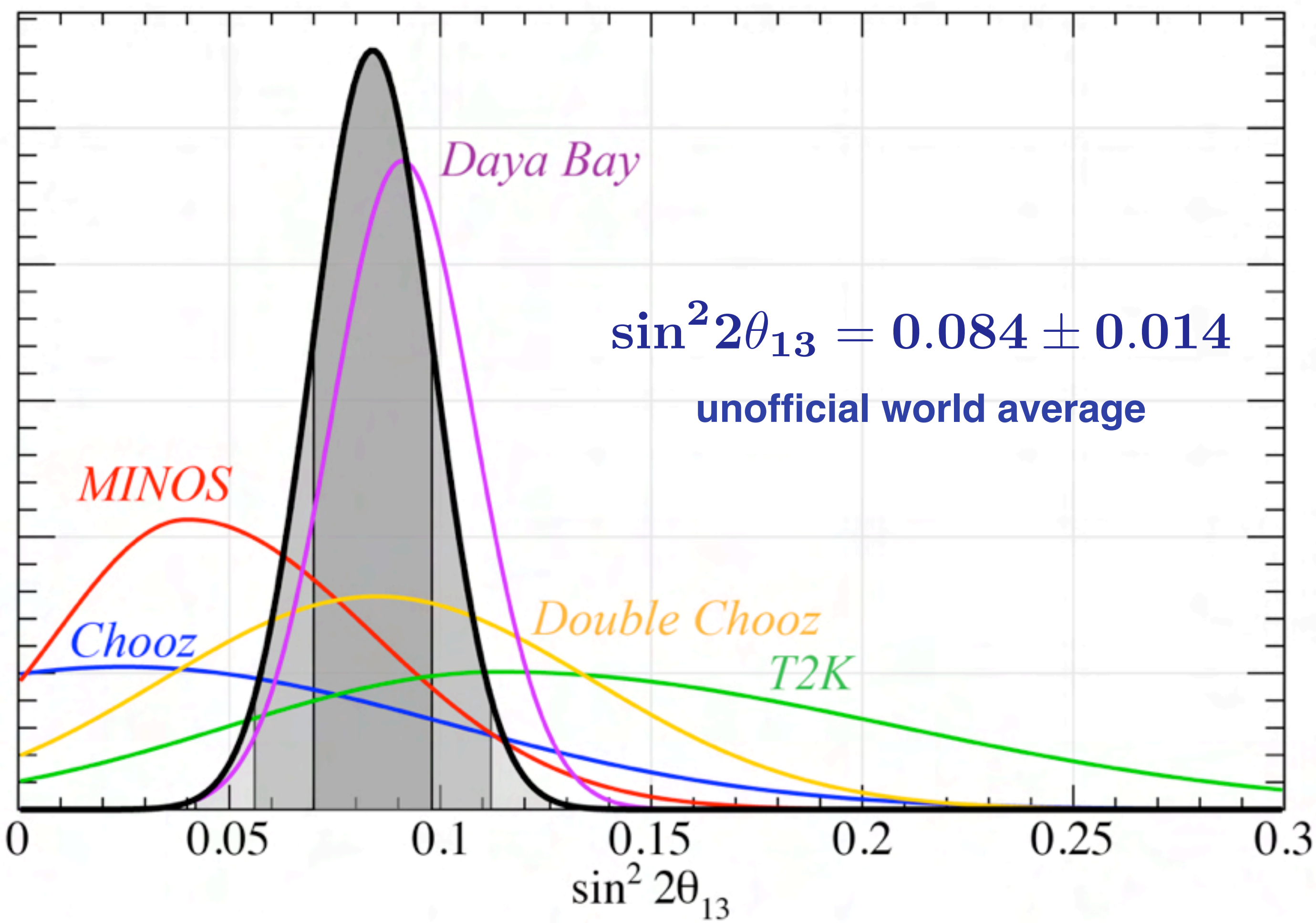
8) What can neutrinos tell us about new physics beyond the Standard Model, dark energy, extra dimensions? Do sterile neutrinos exist?

status of θ_{13} a week ago



Ideogram of recent θ_{13} results for normal hierarchy, δ_{CP}=0, and maximal θ_{23}

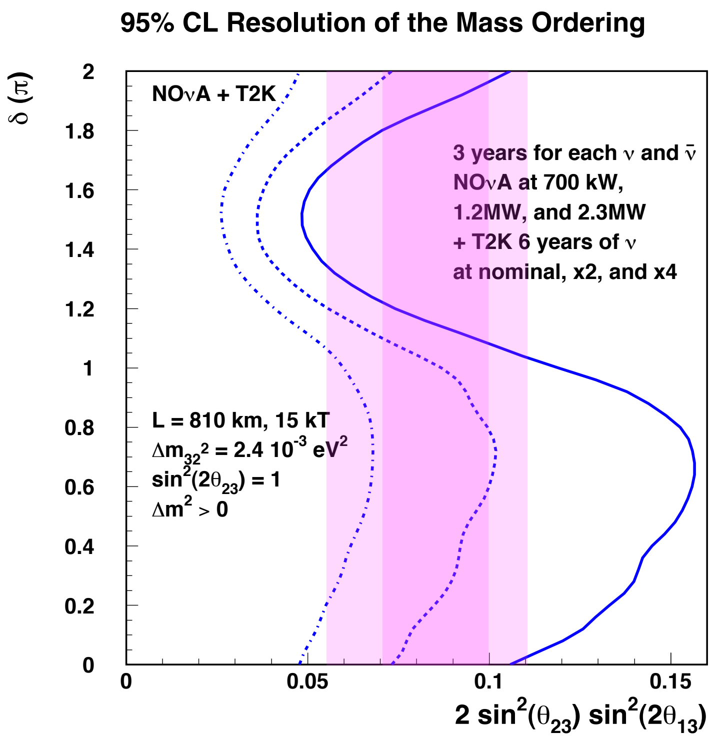
status of θ_{13} today



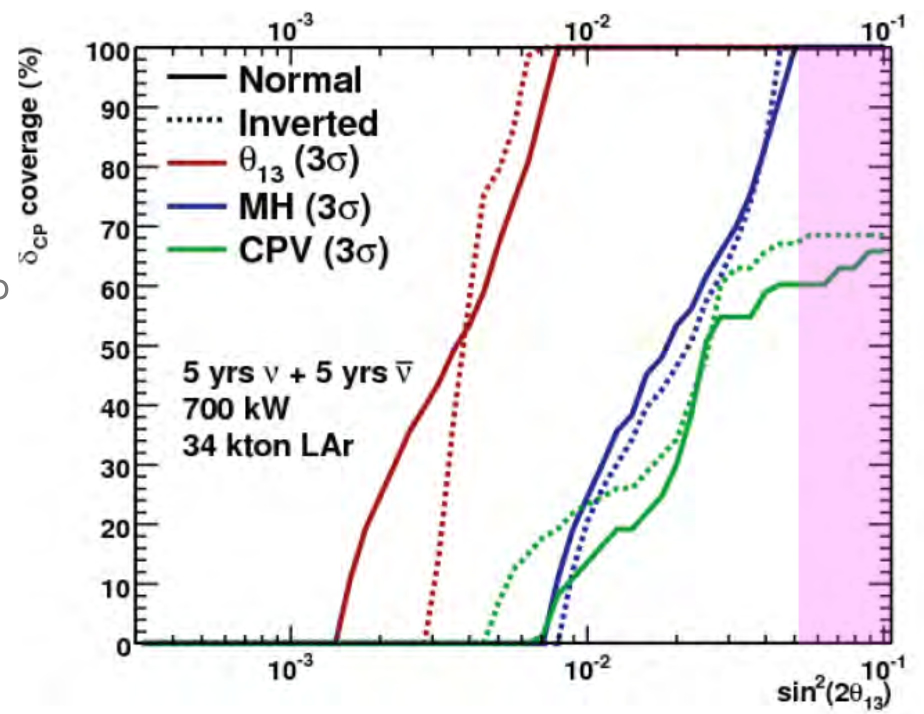
Ideogram of recent θ_{13} results for normal hierarchy, δ_{CP}=0, and maximal θ_{23}

impact of θ_{13} measurement

- It's bad news for some models of neutrino masses, e.g. tri-bimaximal
- It's good news for NovA's chances to resolve the neutrino mass hierarchy and to determine if θ_{23} is maximal
- It's good news for LBNE to find neutrino CP violation



- In worst case hierarchy + δ_{CP} combination, NOvA + T2K taken together can have hierarchy reach down to 0.1 if they can double their planned exposures.
- In case of NOvA this could be achieved with a 5 kt liquid argon detector



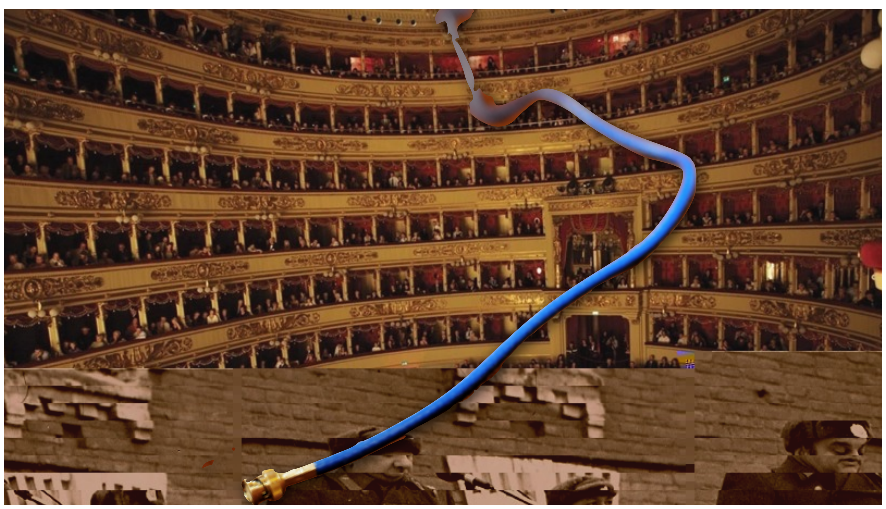
M. Messier Moriond EW slides

OPERA FTL neutrinos?

elevator conversation, Sept 22, 2011

Naive Fermilab Theorist: "This OPERA result is exciting! Do you think it's real?"

Veteran Neutrino Experimentalist: "No. It's probably an issue with the cables."



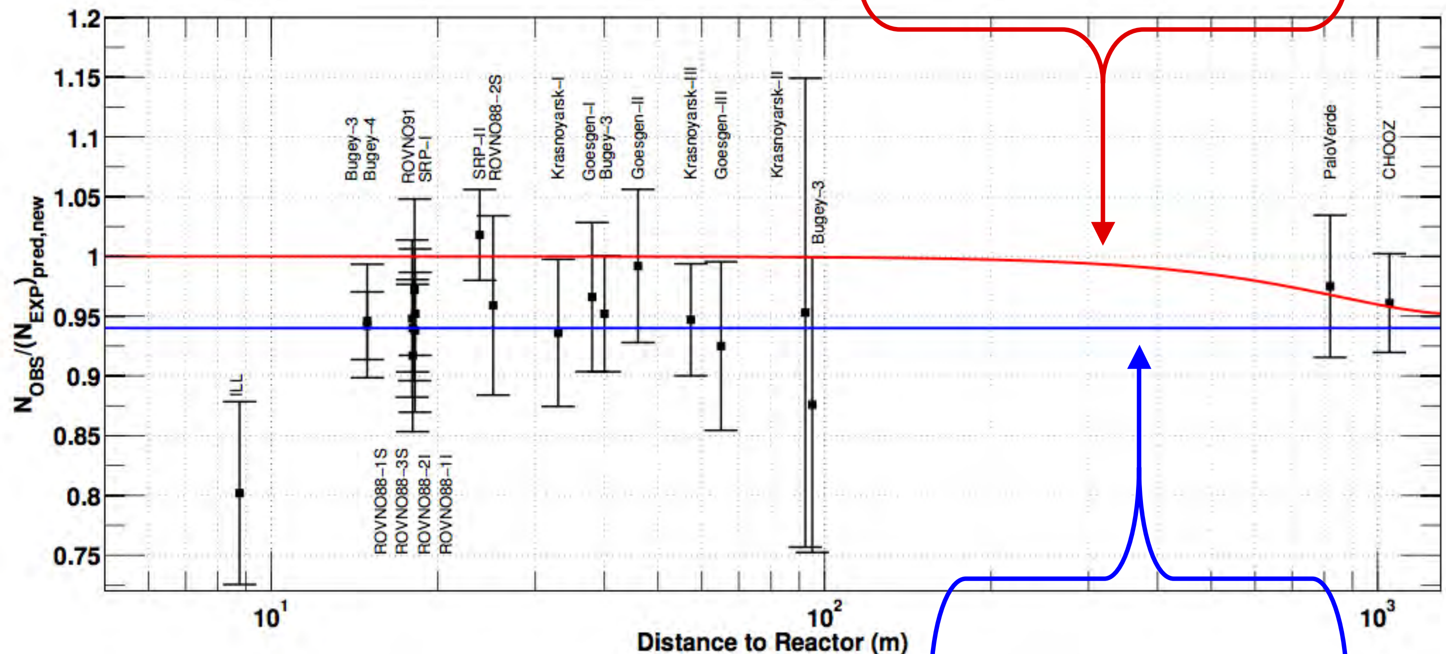
Too soon to reach any conclusions

do reactor data hint at sterile neutrinos?

The prediction for the un-oscillated $\overline{\nu}_e$ flux from reactors, which has $\langle E \rangle \sim 3$ MeV, has increased by about 3%.

(Mueller et al., Huber)

Oscillation with only 3ν and $\sin^2 2\theta_{13} = 0.06$



Oscillation with 4ν and one $\Delta m^2 >> 1$ eV^2

B. Kayser Moriond EW slides

does BBN and/or the CMB hint at sterile neutrinos?

Model	Data	$N_{\rm eff}$	Ref.
$\eta+N_{\rm eff}$	$\eta_{\rm CMB}+Y_{\rm p}$+D/H	$3.8^{(+0.8)}_{(-0.7)}$	[10]
	$\eta_{\rm CMB}+Y_{\rm p}$+D/H	$< (4.05)$	[11]
	$Y_{\rm p}$+D/H	3.85 ± 0.26	[13]
		3.82 ± 0.35	[13]
		3.13 ± 0.21	[13]
$\eta+N_{\rm eff}, (\Delta N_{\rm eff} \equiv N_{\rm eff} - 3.046 \geq 0)$	$\eta_{\rm CMB}$+D/H	3.8 ± 0.6	[12]
	$\eta_{\rm CMB}+Y_{\rm p}$	$3.90^{+0.21}_{-0.58}$	[12]
	$Y_{\rm p}$+D/H	$3.91^{+0.22}_{-0.55}$	[12]

B. Kayser Moriond EW slides

Model	Data	$N_{\rm eff}$	Ref.
$N_{\rm eff}$	W-5+BAO+SN+H_0	$4.13^{+0.87(+1.76)}_{-0.85(-1.63)}$	[26]
	W-5+LRG+H_0	$4.16^{+0.76(+1.60)}_{-0.77(-1.43)}$	[26]
	W-5+CMB+BAO+XLF+$f_{\rm gas}$+H_0	$3.4^{+0.6}_{-0.5}$	[29]
	W-5+LRG+maxBCG+H_0	$3.77^{+0.67(+1.37)}_{-0.67(-1.24)}$	[26]
	W-7+BAO+H_0	$4.34^{+0.86}_{-0.88}$	[18]
	W-7+LRG+H_0	$4.25^{+0.76}_{-0.80}$	[18]
	W-7+ACT	5.3 ± 1.3	[23]
	W-7+ACT+BAO+H_0	4.56 ± 0.75	[23]
	W-7+SPT	3.85 ± 0.62	[24]
	W-7+SPT+BAO+H_0	3.85 ± 0.42	[24]
	W-7+ACT+SPT+LRG+H_0	$4.08^{(+0.71)}_{(-0.68)}$	[30]
	W-7+ACT+SPT+BAO+H_0	3.89 ± 0.41	[31]
$N_{\rm eff}+f_\nu$	W-7+CMB+BAO+H_0	$4.47^{(+1.82)}_{(-1.74)}$	[32]
	W-7+CMB+LRG+H_0	$4.87^{(+1.86)}_{(-1.75)}$	[32]
$N_{\rm eff}+\Omega_k$	W-7+BAO+H_0	4.61 ± 0.96	[31]
	W-7+ACT+SPT+BAO+H_0	4.03 ± 0.45	[32]
$N_{\rm eff}+\Omega_k+f_\nu$	W-7+ACT+SPT+BAO+H_0	4.00 ± 0.43	[31]
$N_{\rm eff}+f_\nu+w$	W-7+CMB+BAO+H_0	$3.68^{(+1.90)}_{(-1.84)}$	[32]
	W-7+CMB+LRG+H_0	$4.87^{(+2.02)}_{(-2.02)}$	[32]
$N_{\rm eff}+\Omega_k+f_\nu+w$	W-7+CMB+BAO+SN+H_0	$4.2^{+1.10(+2.00)}_{-0.61(-1.14)}$	[33]
	W-7+CMB+LRG+SN+H_0	$4.3^{+1.40(+2.30)}_{-0.54(-1.09)}$	[33]

let's see what Planck says

Fermilab Short Baseline Neutrino Focus Group

From the charge:

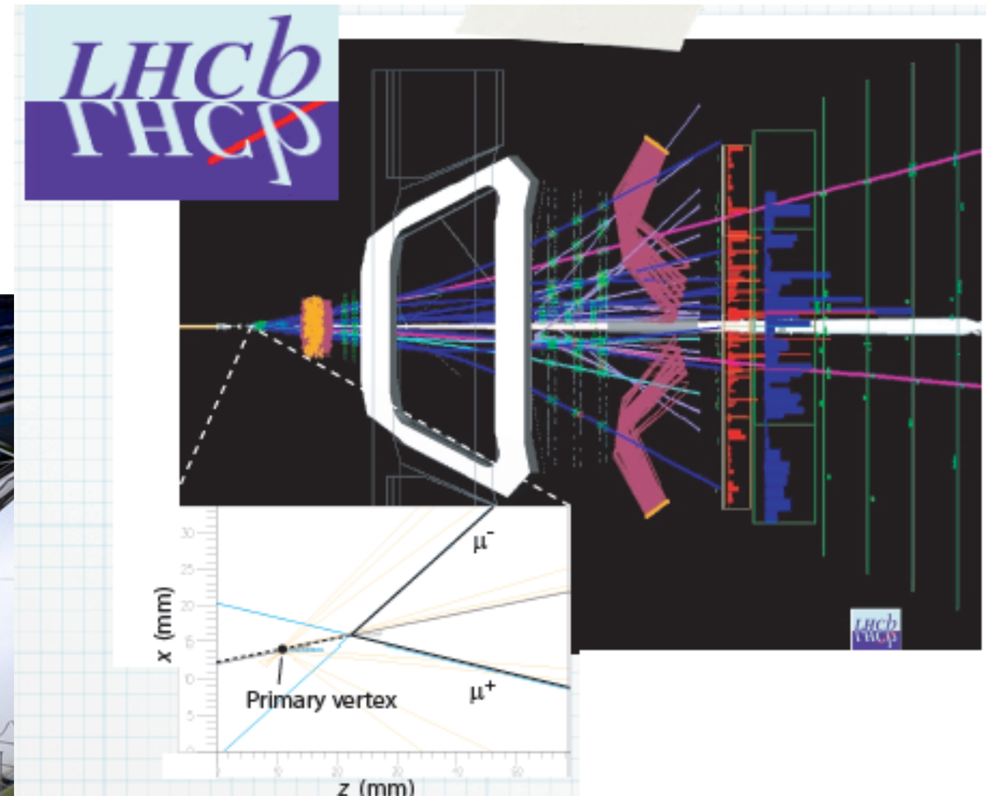
"… consider new generation detectors and/or new types of neutrino sources that would lead to a definitive resolution of the existing anomalies."

Started ~ January, 2012

Report due ~ May, 2012

40

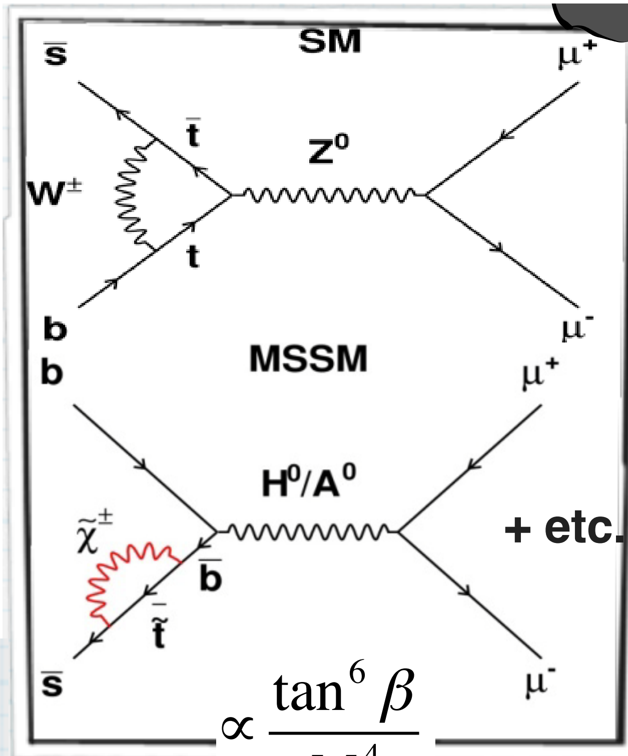
What's New at the Intensity Frontier: Flavor



LHCb closing the window

- SM prediction (FCNC, helicity suppressed)
  - SM $B(Bs \to \mu\mu) = (3.2 \pm 0.2)\ 10^{-9}$
  - SM $B(B \to \mu\mu) = (0.1 \pm 0.01)\ 10^{-9}$

arXiv:1005.5310
arXiv:1012.1447



$B(B_s \to \mu\mu) < 4.5\ 10^{-9}$ at 95% CL

$B(B \to \mu\mu) < 10.3\ 10^{-10}$ at 95% CL

best limit!

$$\propto \frac{\tan^6 \beta}{M_A^4}$$

- **SUSY and 2HDM can make large contributions**
- **For large tan β SUSY you had better have large M_A**
- **Makes the lightest SUSY Higgs more like a SM Higgs**

CP asymmetry in $D^0 \to K^+K^-, \pi^+\pi^-$

- Measured value:

CDF : $\Delta A_{CP} = (-0.62 \pm 0.21 \pm 0.10)\%$

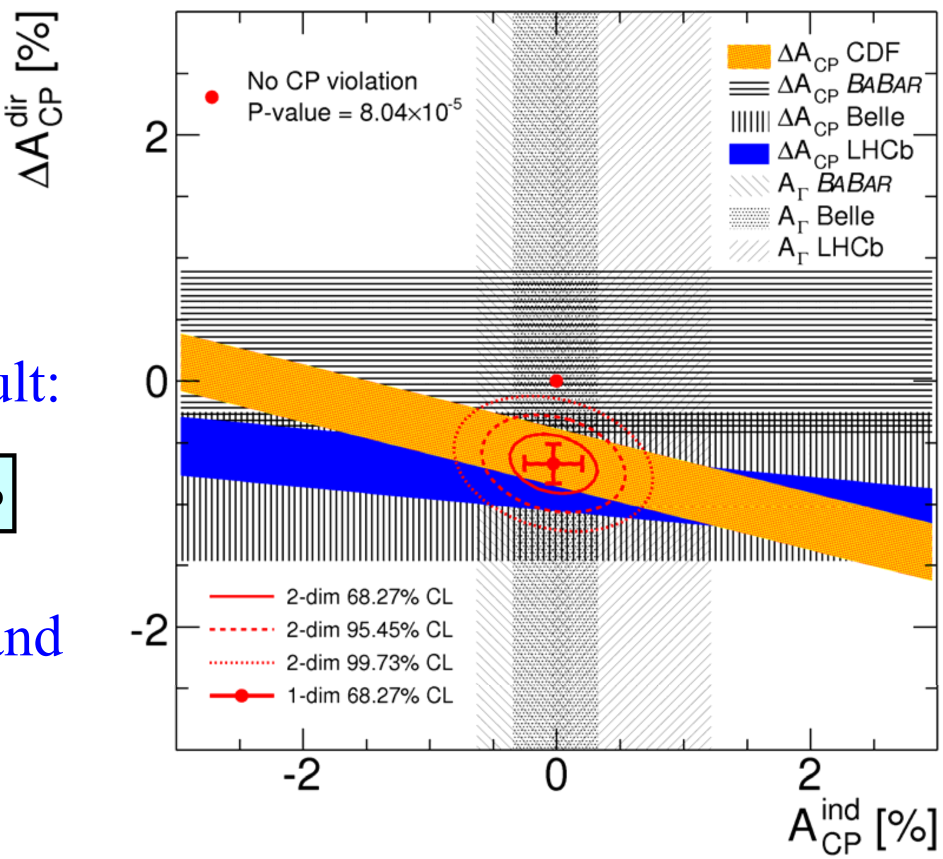
  - 2.7 σ deviation from zero

- Consistent with the LHCb result:

LHCb : $\Delta A_{CP} = (-0.82 \pm 0.21 \pm 0.11)\%$

- The combination of the CDF and LHCb results gives ~3.8σ deviation from zero.

CDF preliminary



G. Borissov Moriond EW slides

SUMMARY OF SM CONTRIBS.

Brod, Kagan, JZ, 1111.5000

- individual power corrections could be enhanced by a factor of a few compared to leading power
- using $\Delta A_{CP} \sim 4 r_f$ we obtain

$$\Delta A_{CP} \sim 0.3\% \ \ (P_{f,1}), \quad \Delta A_{CP} \sim 0.2\% \ \ (P_{f,2})$$

- the results are subject to large uncertainties
  - extraction of tree amplitude E_f from data
  - use of N_c counting
  - the modeling of Q_1 penguin contraction matrix elemnts.
- a cumulative uncertainty of a factor of a few is reasonable
- a SM origin for the LHCb measurement is possible

J. Zupan Moriond EW slides

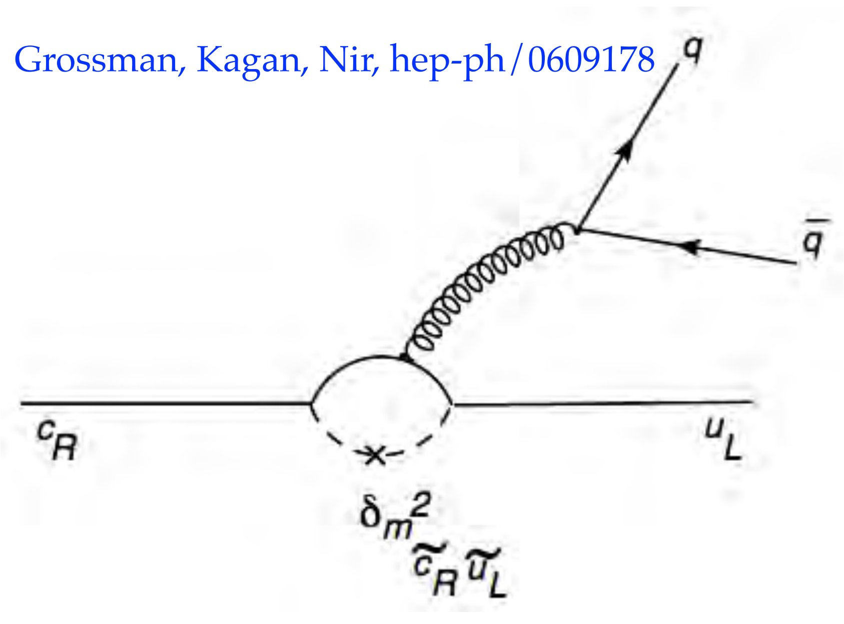
Reasonable theorists argue that the SM contribution could in fact be 5-10 times larger than previously thought!

What if this is BSM physics?

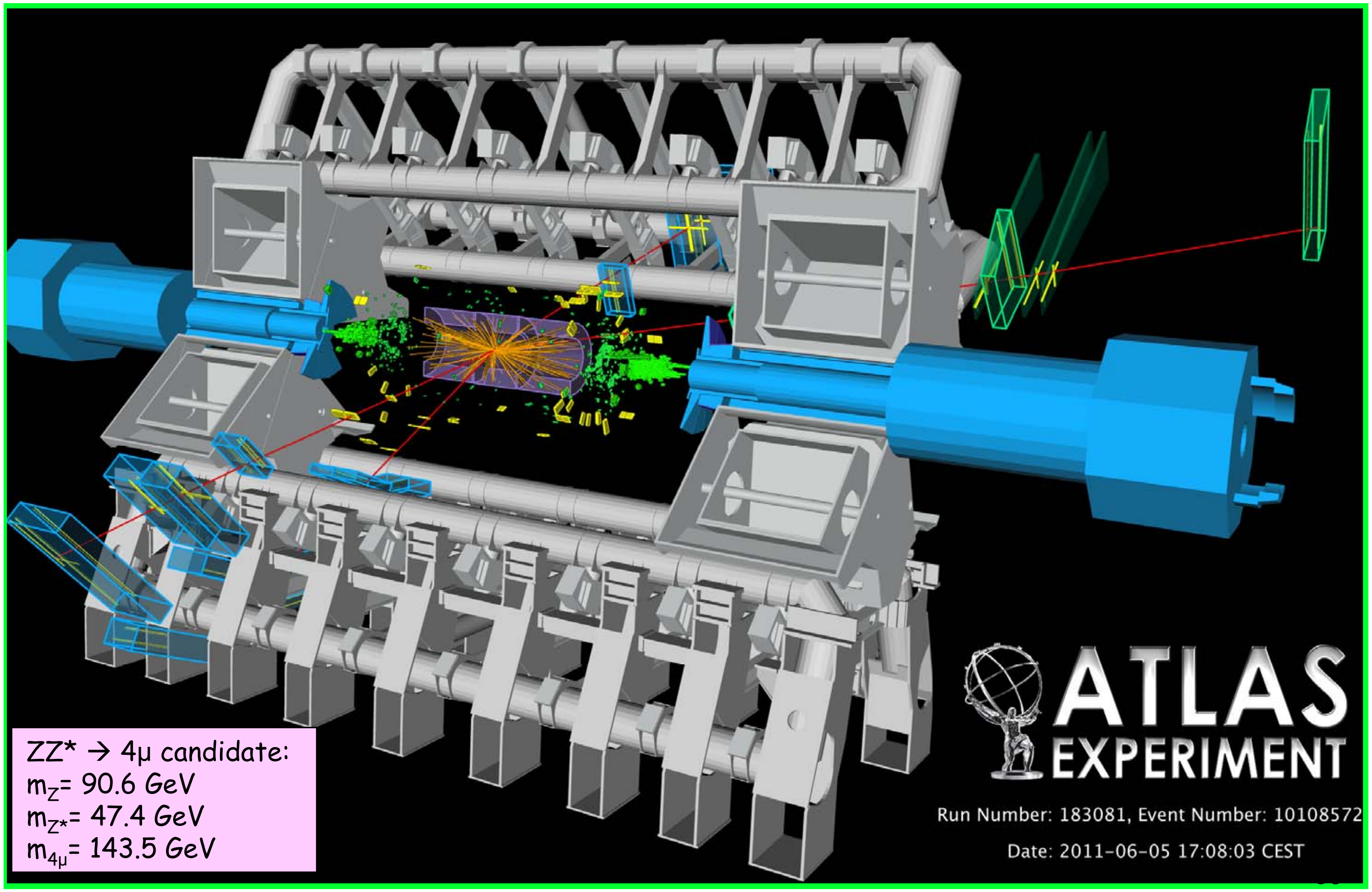
- Could be a chromomagnetic penguin from left-right squark mixing in SUSY
- Compatible with squark/gluino masses larger than a TeV
- Compatible with D-D mixing data
- Borderline for EDMs
- Most other BSM explanations have more serious problems

W. Altmannshofer, R. Primulando, F. Yu

Grossman, Kagan, Nir, hep-ph/0609178

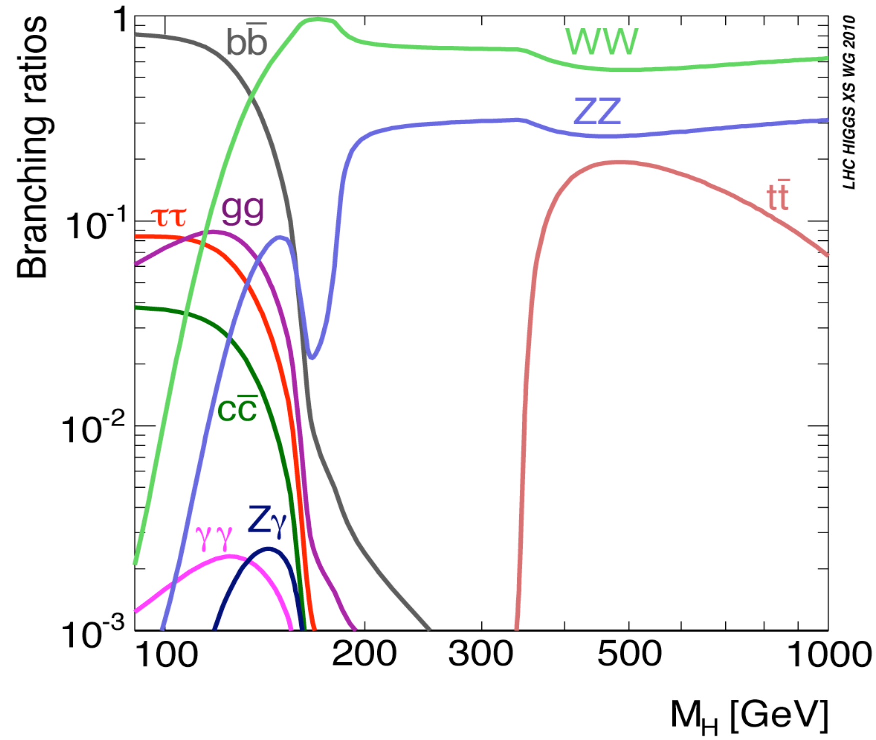


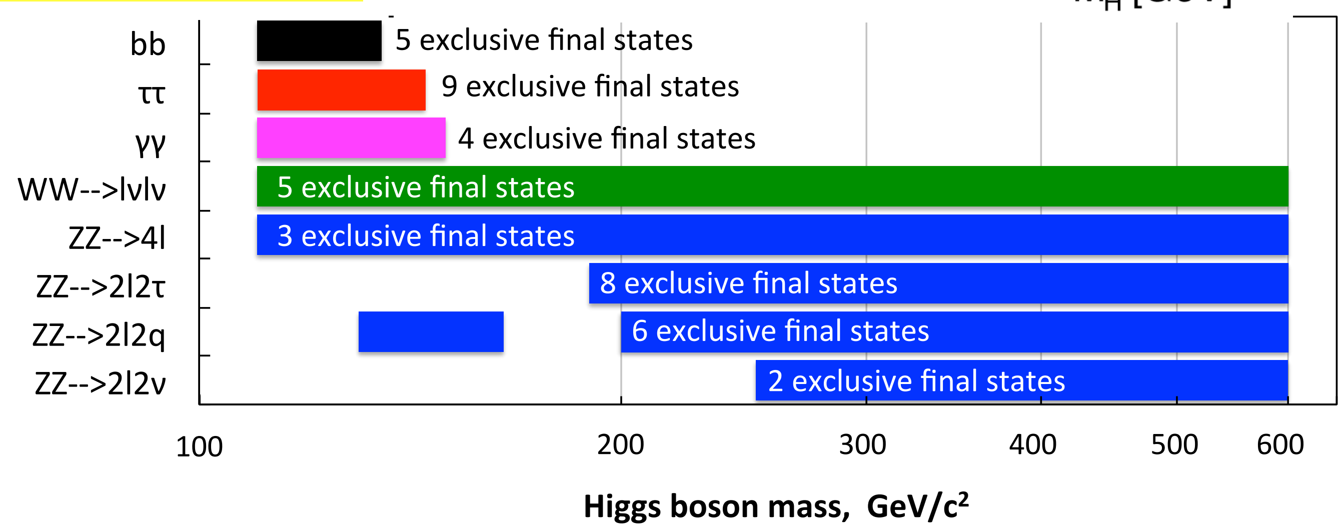
What's New at the Energy Frontier: Higgs



searches for the Higgs (aka BEH, EBHGHK, HEHKBANG) boson at the LHC

Channel	m_H range (GeV/c^2)	Lumi (fb^{-1})	sub-channels	m_H resolution
$H \to \gamma\gamma$	110 – 150	4.7	4	1–3%
$H \to \tau\tau$	110 – 145	4.6	9	20%
$H \to bb$	110 – 135	4.7	5	10%
$H \to WW \to \ell\nu\ell\nu$	110 – 600	4.6	5	20%
$H \to ZZ \to 4\ell$	110 – 600	4.7	3	1–2%
$H \to ZZ \to 2\ell 2\tau$	190 – 600	4.7	8	10–15%
$H \to ZZ \to 2\ell 2\nu$	250 – 600	4.6	2	7%
$H \to ZZ \to 2\ell 2q$	{130 – 164, 200 – 600}	4.6	6	3%

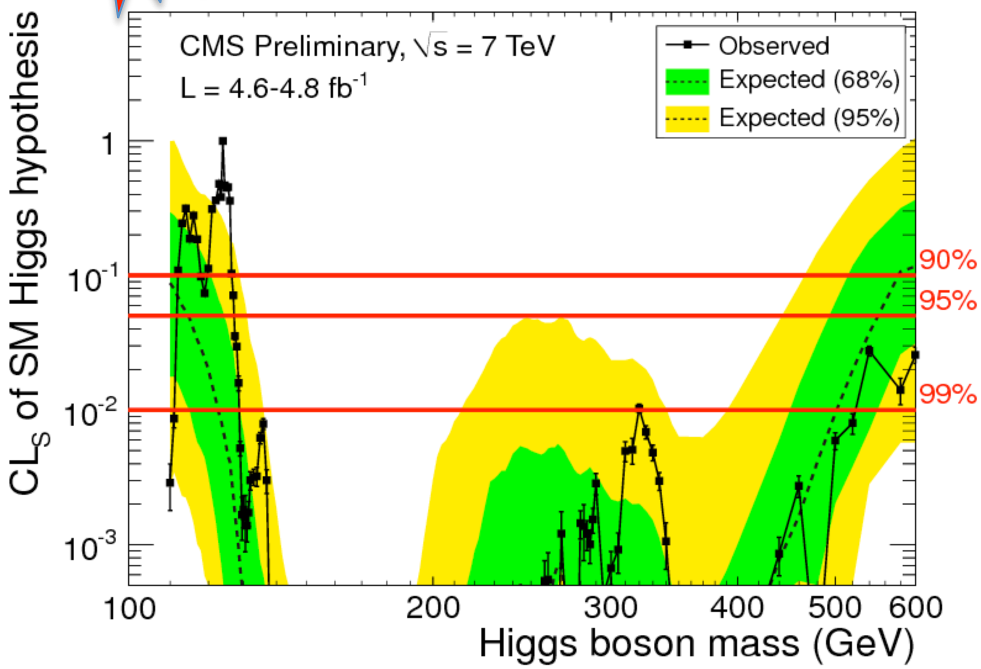


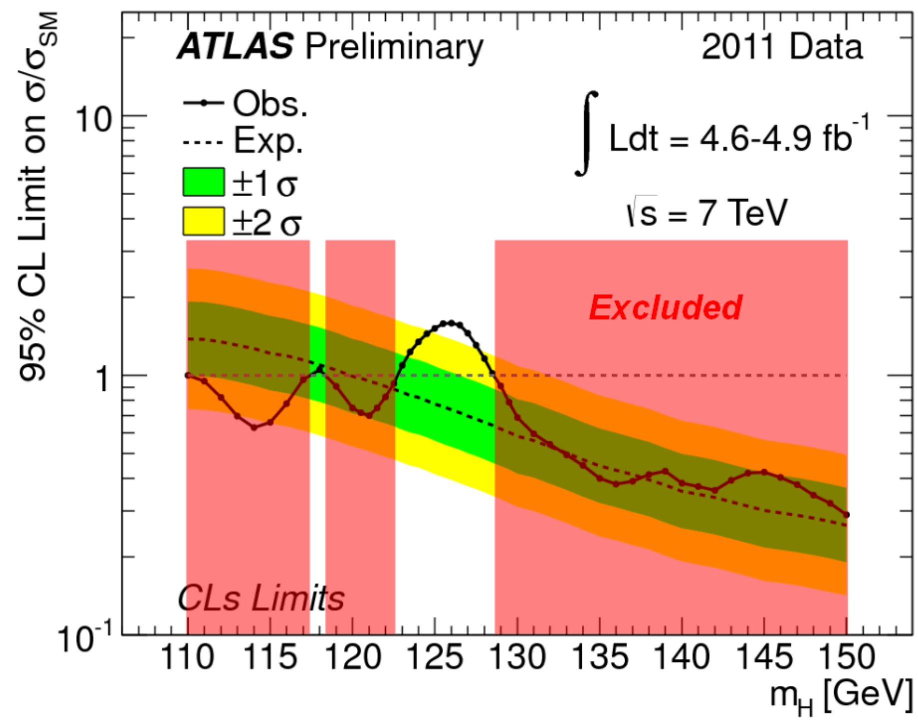


where the Higgs is not

NEW

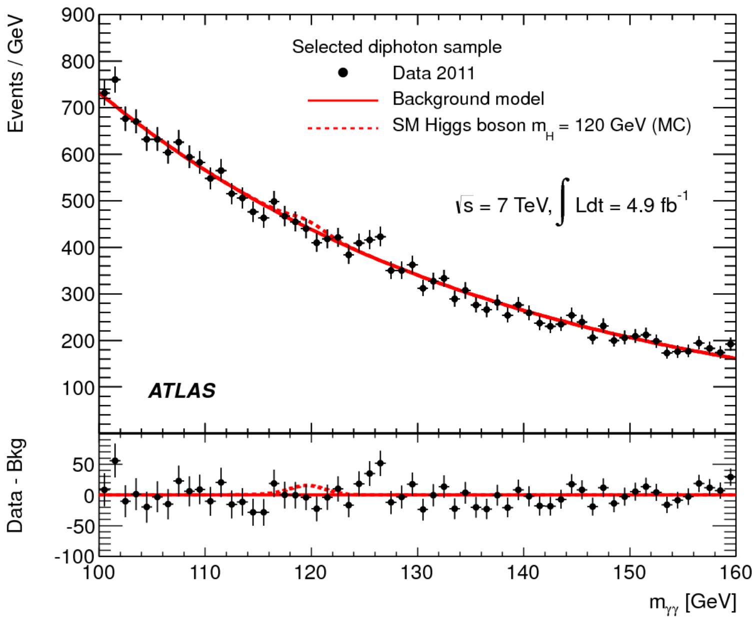
Full mass range

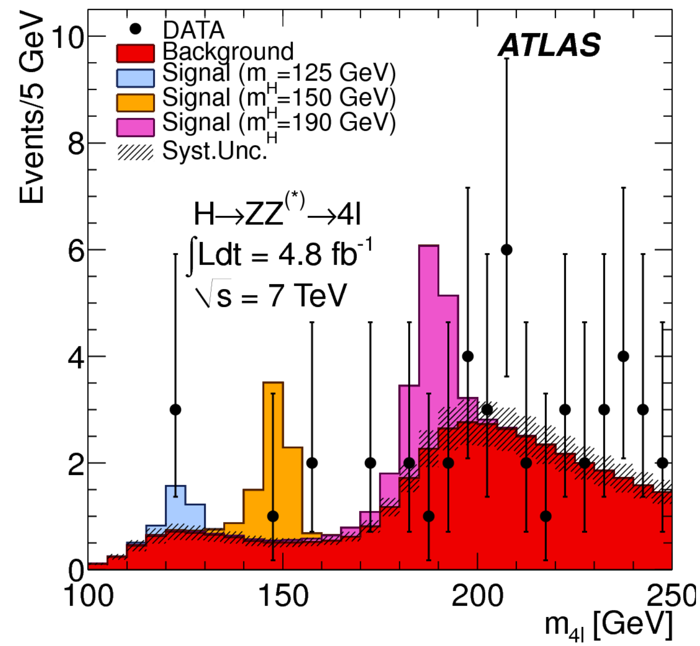




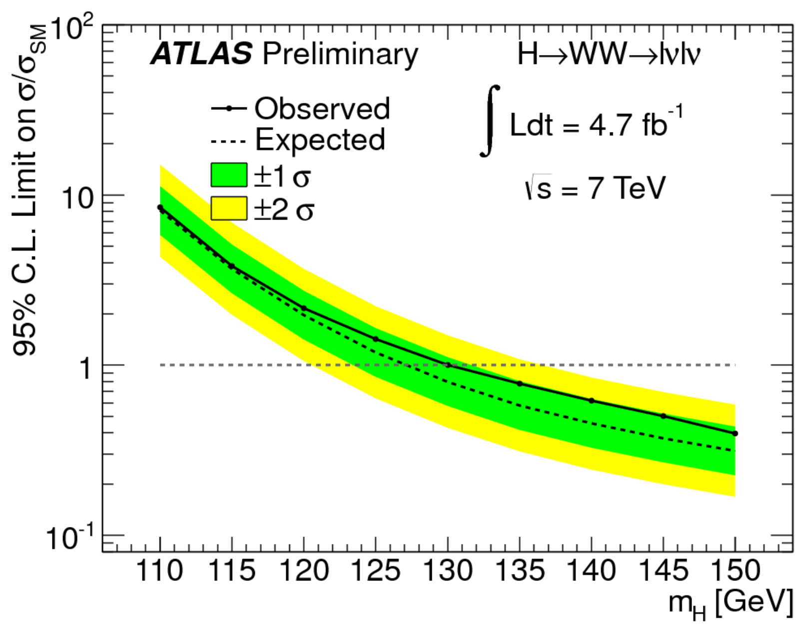
- **Separate ATLAS/CMS 95% CLs exclusions for SM Higgs in mass ranges 110-117.5 GeV, 118.5-122.5 GeV, and 127.5-600 GeV**
- **99% CLs exclusion in mass range 129-525 GeV**

the maybe Higgs: ATLAS





keep in mind that WW is the most sensitive channel for a SM Higgs with mass ~ 125 GeV

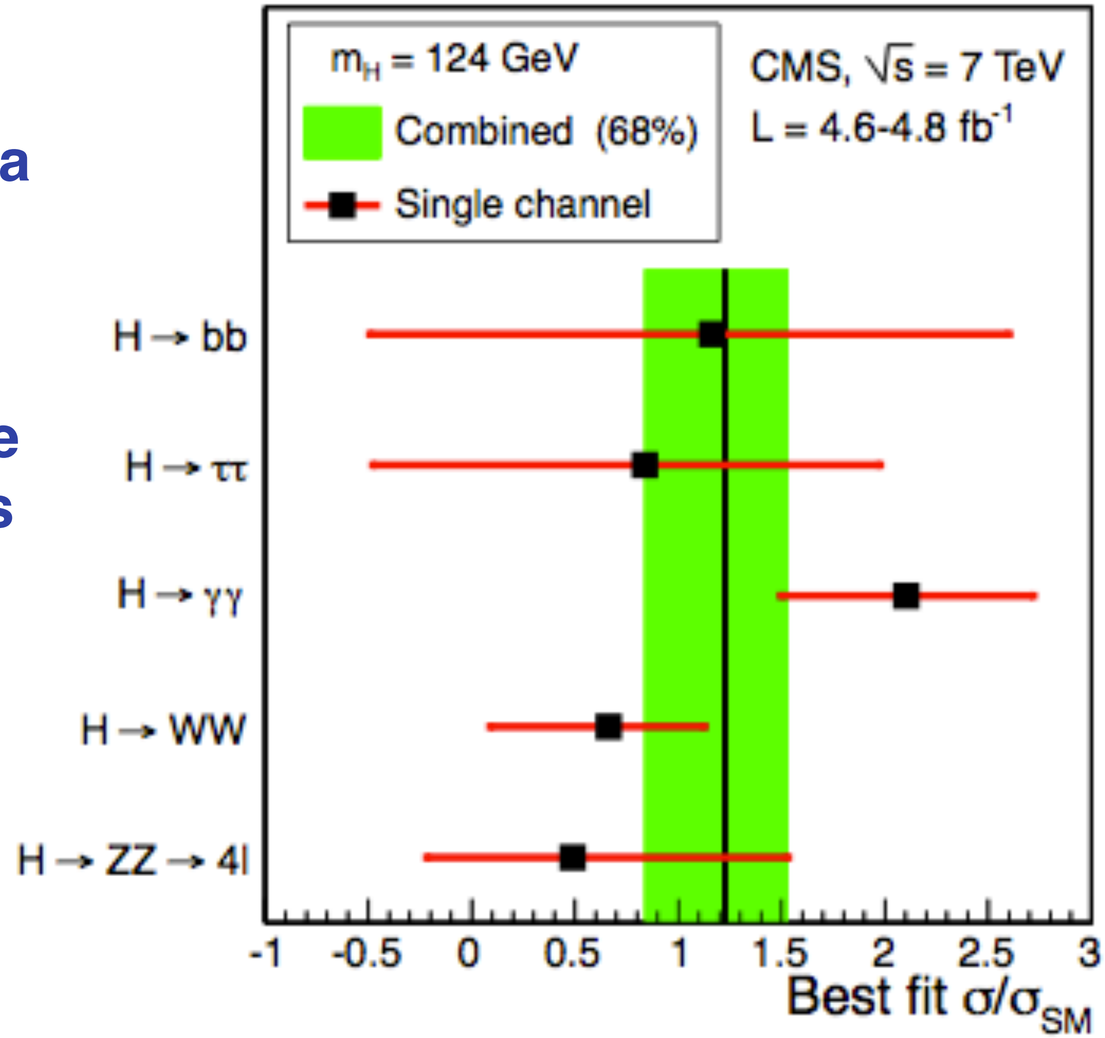


the maybe Higgs: CMS

Highest excess at 124 GeV

consistent at 1 sigma with a SM Higgs

But obviously neither the ATLAS nor the CMS nor the (yet to appear) combined is conclusive

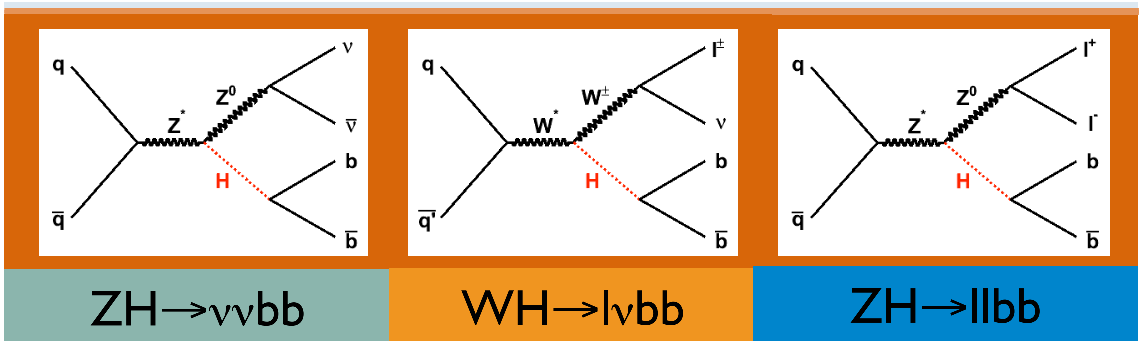


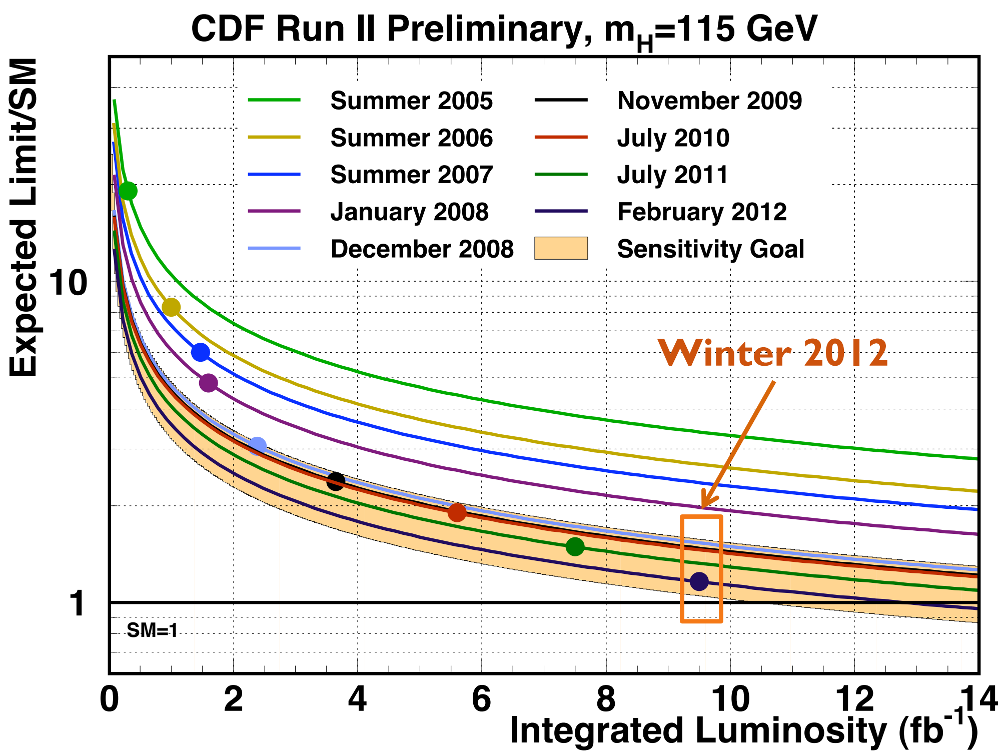
the maybe Higgs: Tevatron

CDF+D0 sensitive to Higgs->bbar

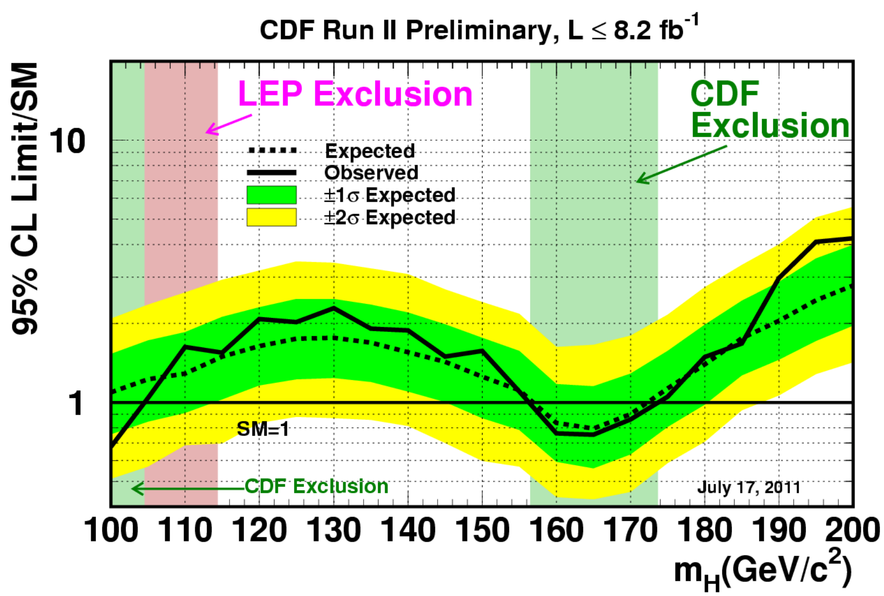
CDF+D0 sensitivity has improved faster than $S/\sqrt{B}$

P5 recognized the Tevatron potential in the case of a light Higgs...

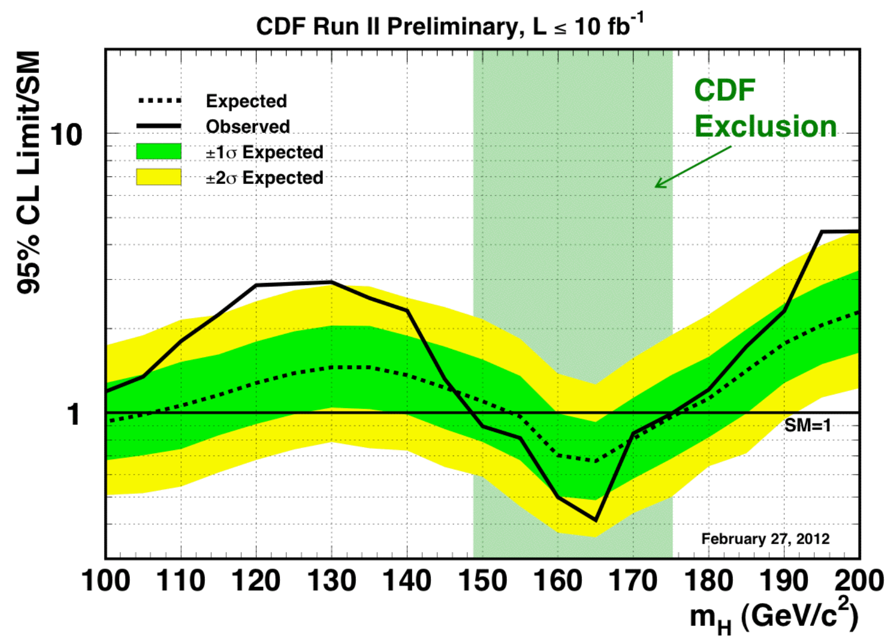




the maybe Higgs: Tevatron



Summer 2011



Winter 2012

Single Channel Searches			
Experiment	Channel	Local P-value	Global P-value
CDF	H->bb	2.9 σ	2.7 σ
ATLAS	H->γγ	2.8 σ	1.5 σ
CMS	H->γγ	3.1 σ	1.8 σ

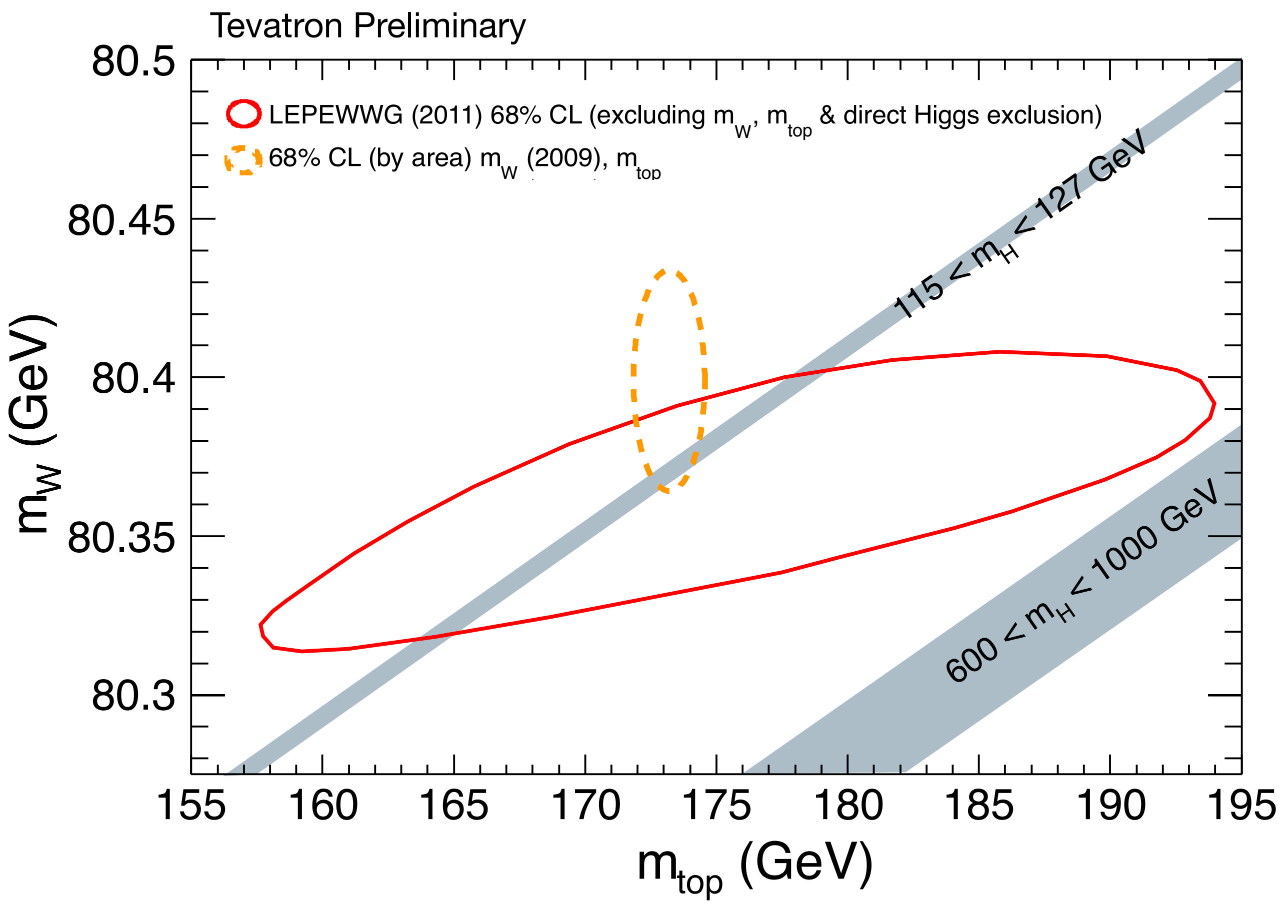
SM Higgs Searches		
Experiment	Local P-value	Global P-value
CDF+D0	2.8 σ	2.2 σ
ATLAS	3.5 σ	2.2 σ
CMS	3.1 σ	2.1 σ

new W mass measurement from CDF+D0

With M_W = 80399±23 MeV

$M_H = 92^{+34}_{-26}$ GeV
$M_H < 161$ GeV @95% CL

LEPEWWG/ZFitter



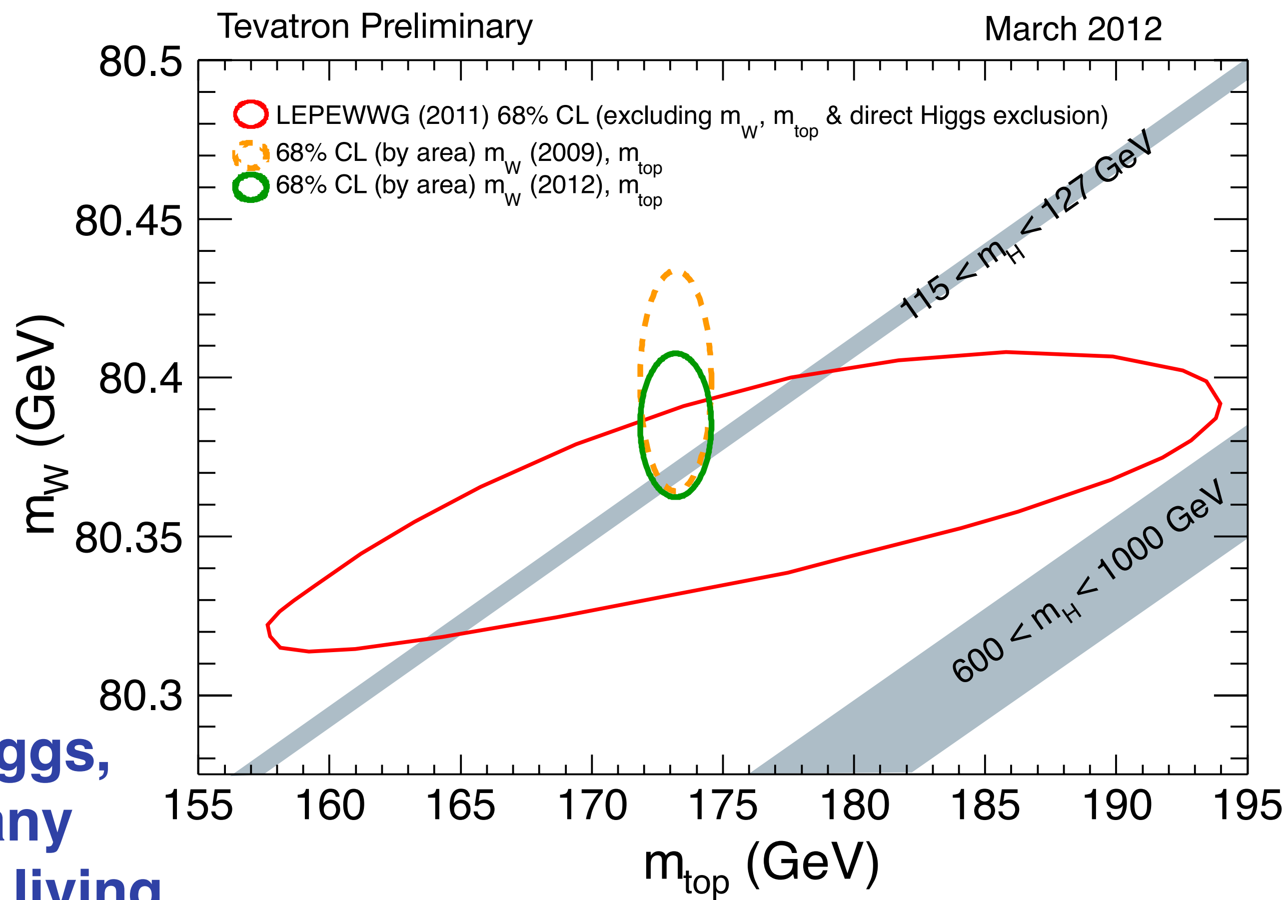
new W mass measurement from CDF+D0

With M_W = 80385±15 MeV

$M_H = 94^{+29}_{-24}$ GeV

$M_H < 152$ GeV @95% CL

LEPEWWG/ZFitter

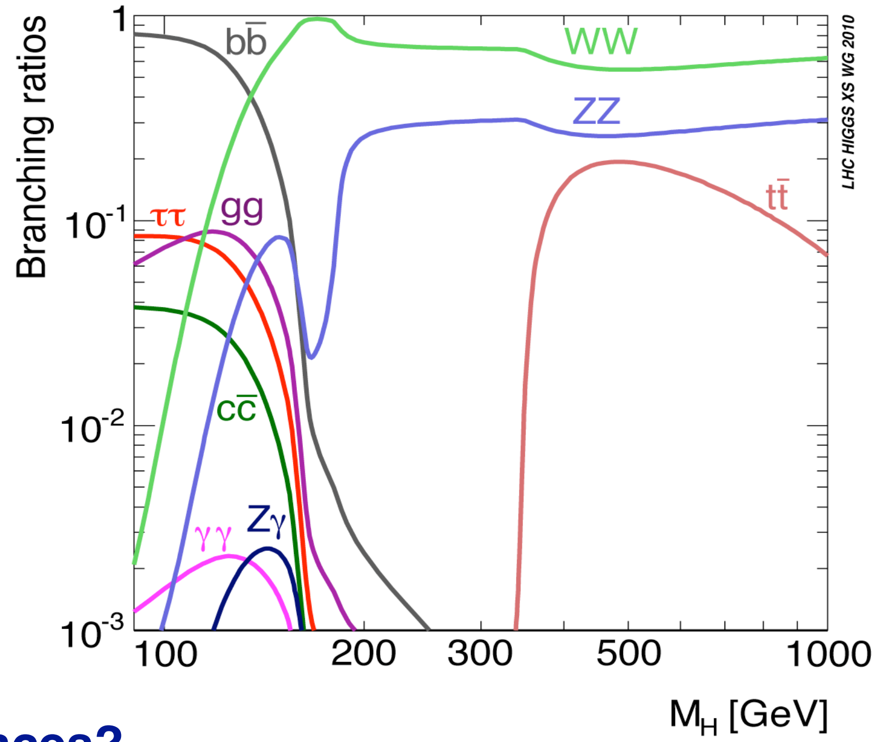


Besides cornering the Higgs, we are also cornering many BSM scenarios that were living on the edge of EWPT viability

What if the 125 GeV resonance is real?

Some immediate questions:

- Is it spin 0?
- Is it CP even? To what extent can you exclude a CP odd component?
- Does it come from a weak doublet?
- Are its couplings proportional to masses?
- Is it composite or an elementary scalar?
- Are there other neutral or charged resonances?
- Does other things decay into it?
- Did you look at all possible associated production of it?

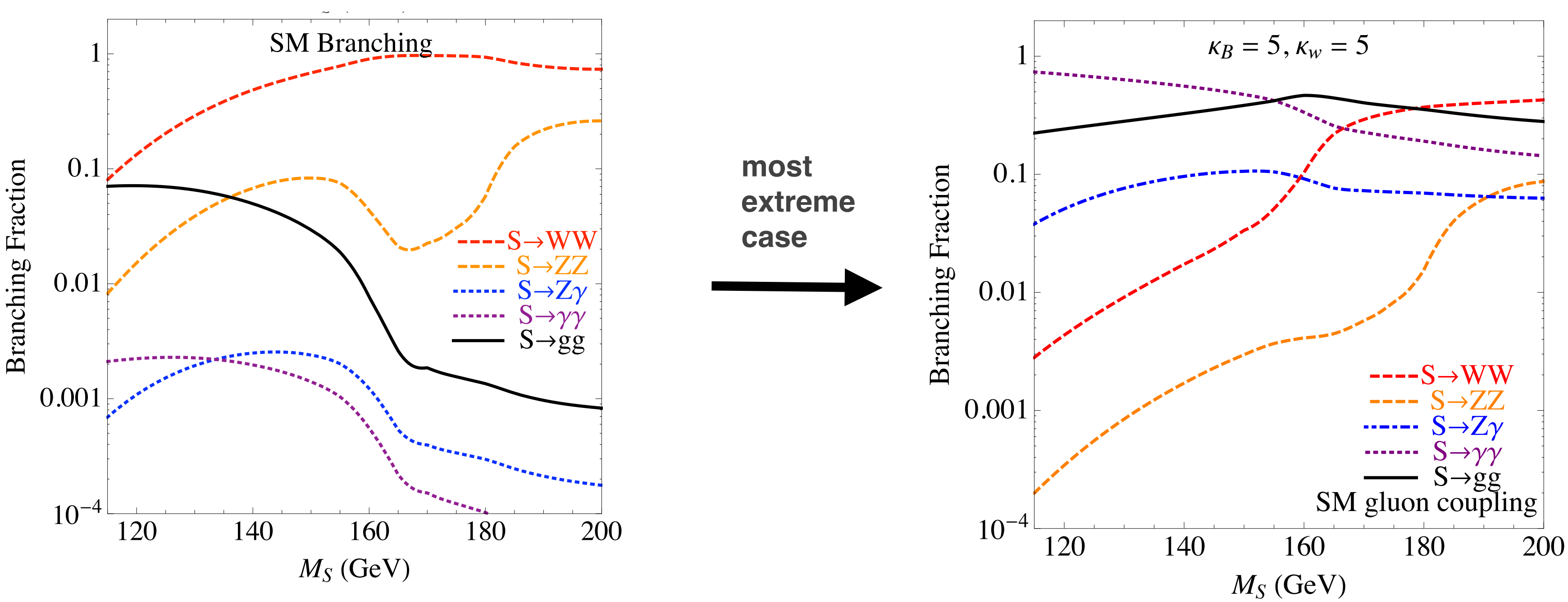


Higgs look-alikes at the LHC

You could have an SM singlet scalar with dim=5 couplings to gauge bosons

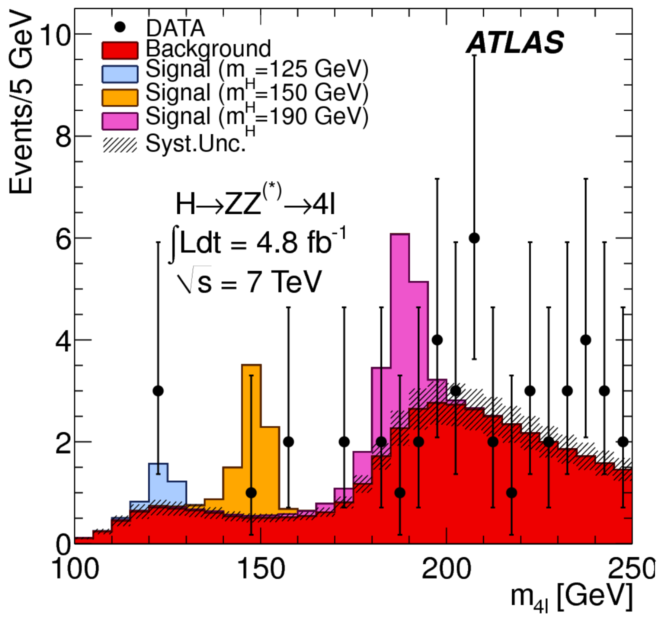
$$\mathcal{L}_{eff} = \kappa_g \frac{\alpha_s}{4\pi} \frac{S}{4m_S} G^a_{\mu\nu} G^{a\,\mu\nu} + \kappa_W \frac{\alpha_{em}}{4\pi s_w^2} \frac{S}{4m_S} W^a_{\mu\nu} W^{a\,\mu\nu} + \kappa_B \frac{\alpha_{em}}{4\pi c_w^2} \frac{S}{4m_S} B_{\mu\nu} B^{\mu\nu}$$

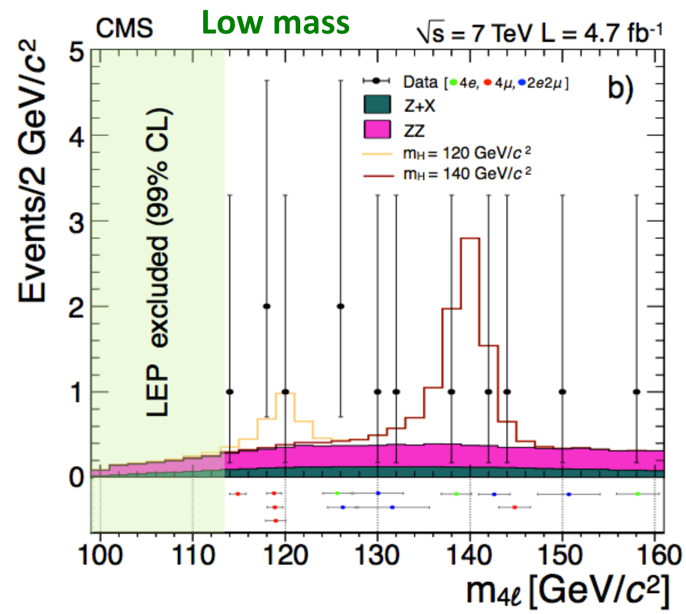
I. Low, J.L., G. Shaughnessy



LHC experiments sees this singlet, which looks approximately like a SM Higgs except, e.g., the gaga mode is enhanced and WW is suppressed

H -> ZZ-> 4 lepton Golden Mode





BG exp.: 9.5±1.3
Data: 13
In 100-160 GeV

- **2011 actual:** 2 events in one bin when you expect 1/3, p-value = 0.04
- **2012 possible:** 10 events when you expect 1.66, p-value = 0.00001

very clean discovery possible in 2012

H-> ZZ -> 4 lepton final state: can you determine the spin and CP of the resonance?

Use all 5 angles and the off-shell Z mass

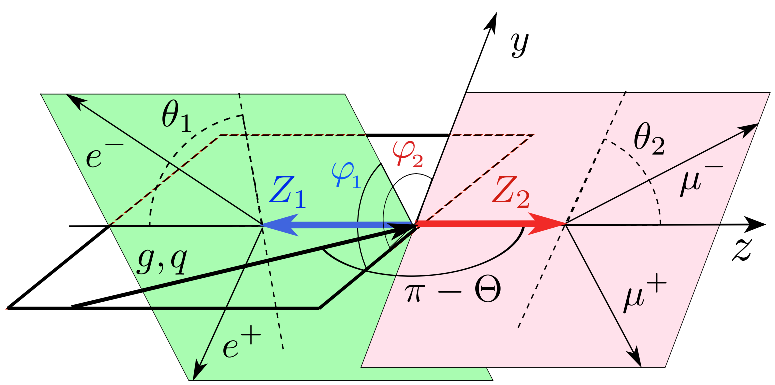


FIG. 1: The Cabibbo-Maksymowicz angles [37] in the $H \to ZZ$ decays.

Use hypothesis testing with the full likelihoods

Just need a handful of events

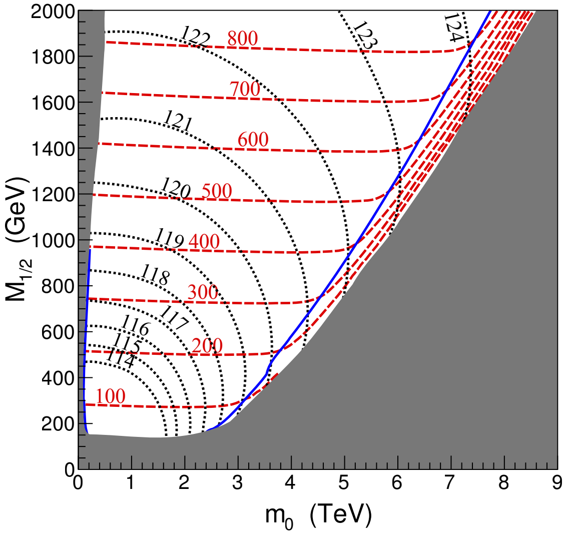
$\mathbb{H}_0 \Downarrow \mathbb{H}_1 \Rightarrow$	0^+	0^-	1^-	1^+
0^+	–	17	12	16
0^-	14	–	11	17
1^-	11	11	–	35
1^+	17	18	34	–

TABLE I: Minimum number of observed events such that the median significance for rejecting $\mathbb{H}_0$ in favor of the hypothesis $\mathbb{H}_1$ (assuming $\mathbb{H}_1$ is right) exceeds $3\,\sigma$ with m_H=145 GeV/c^2.

A. De Rujula, J.L., M. Pierini, C. Rogan, M. Spiropulu

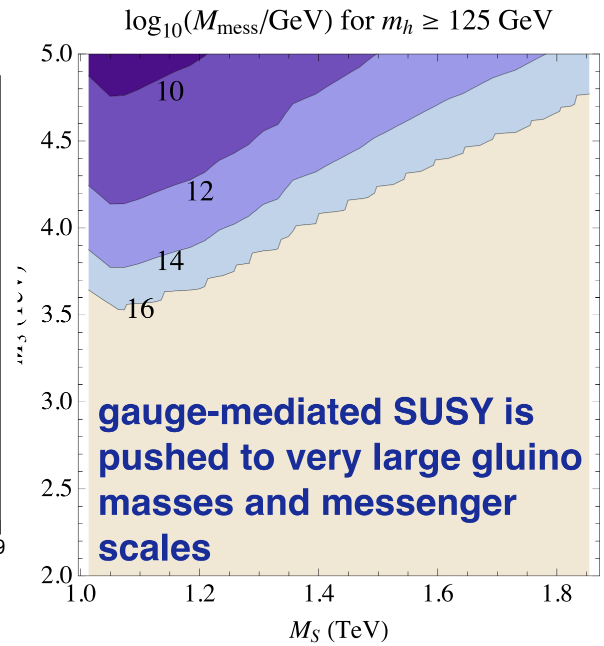
For SUSY, a 125 GeV Higgs is quite heavy

mSUGRA without large mixing doesn't like a Higgs this heavy



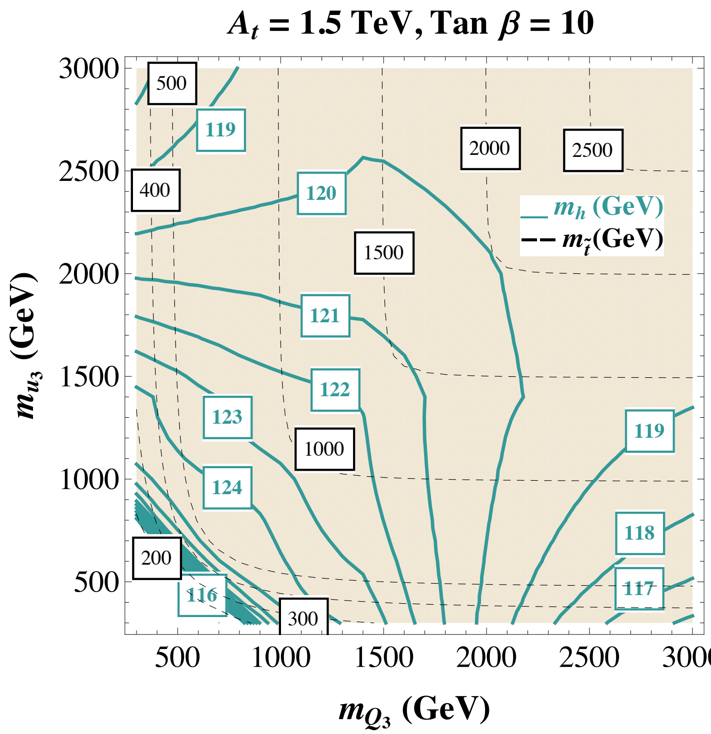
(a) m_h and m_χ in GeV for $\tan\beta = 10$

J. Feng and K. Matchev



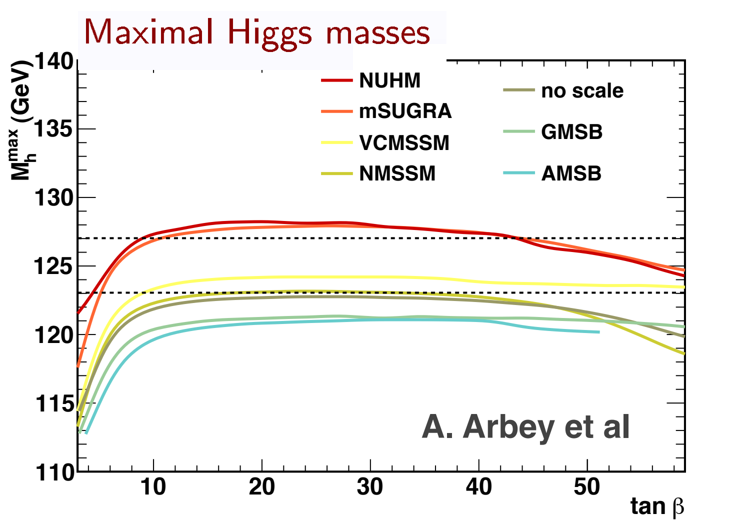
gauge-mediated SUSY is pushed to very large gluino masses and messenger scales

P. Draper, P. Meade, M. Reece, D. Shih



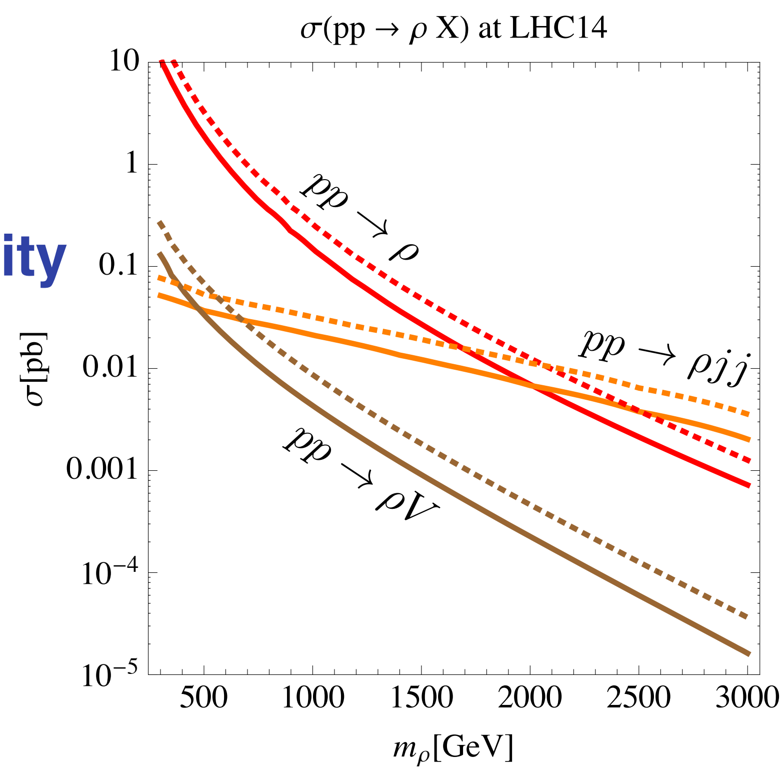
With large mixing, can get 125 GeV Higgs, the lightest stop is less than 600 GeV, and the gluino could be just above current limits

M. Carena, S. Gori, N. Shah, C. Wagner



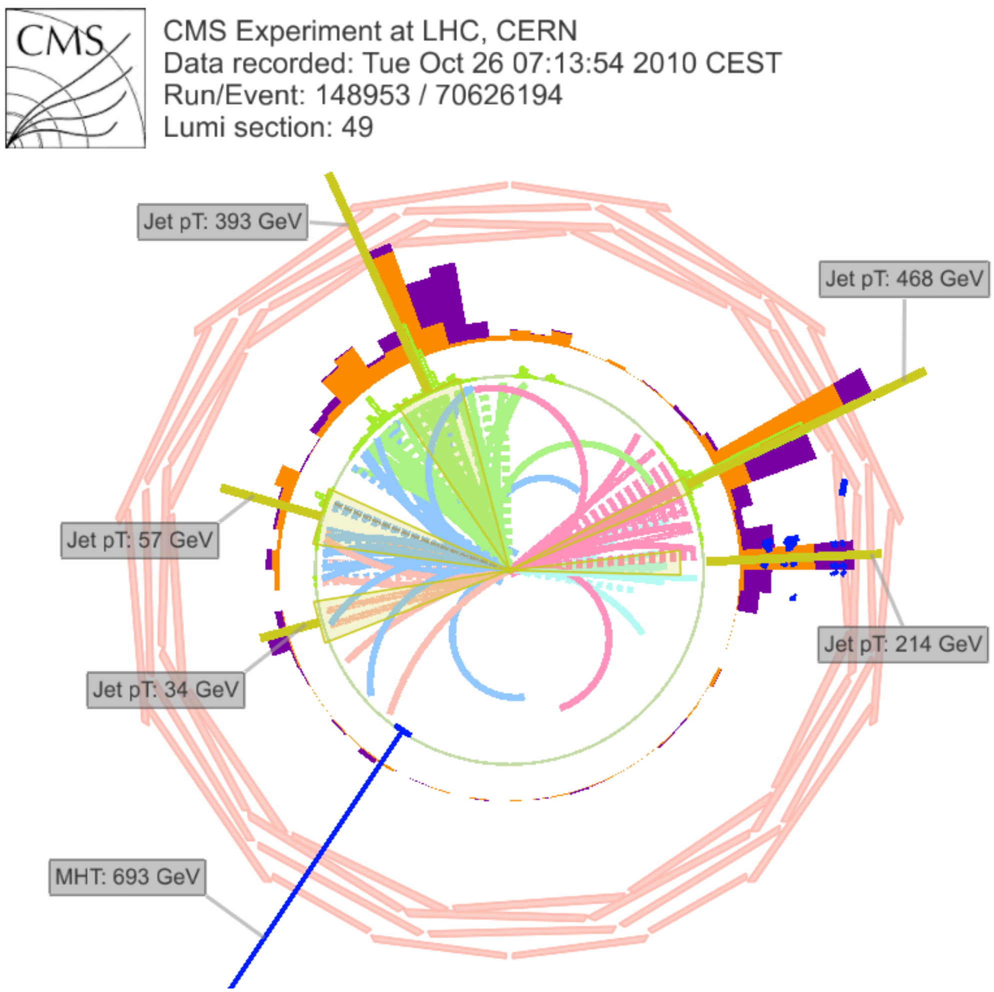
What if a SM Higgs is ruled out completely?

- Could be a non-SM Higgs with some combination of
  - suppressed coupling to gg (reduced production)
  - very light (LEP hole) or very heavy (broad resonance)
  - decays to exotics



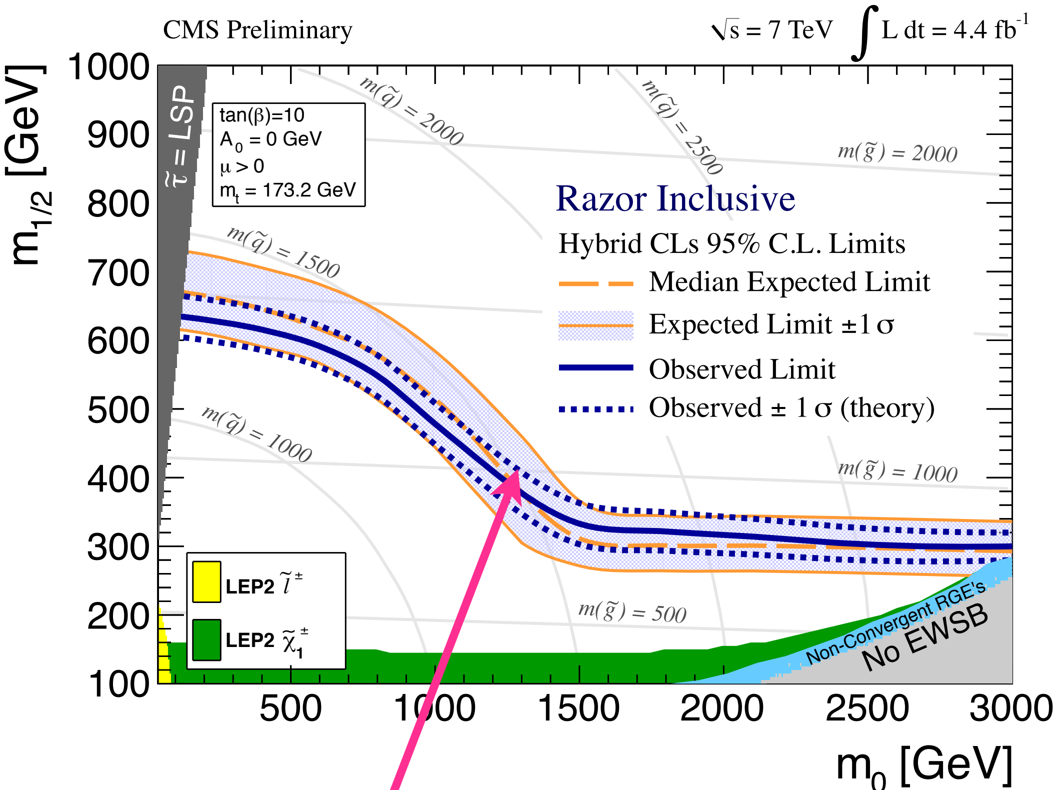
- Could be no Higgs, in which case unitarity requires other heavy resonances (also true if Higgs is a composite)
- Then we have to be very patient...

What's New at the Energy Frontier: SUSY

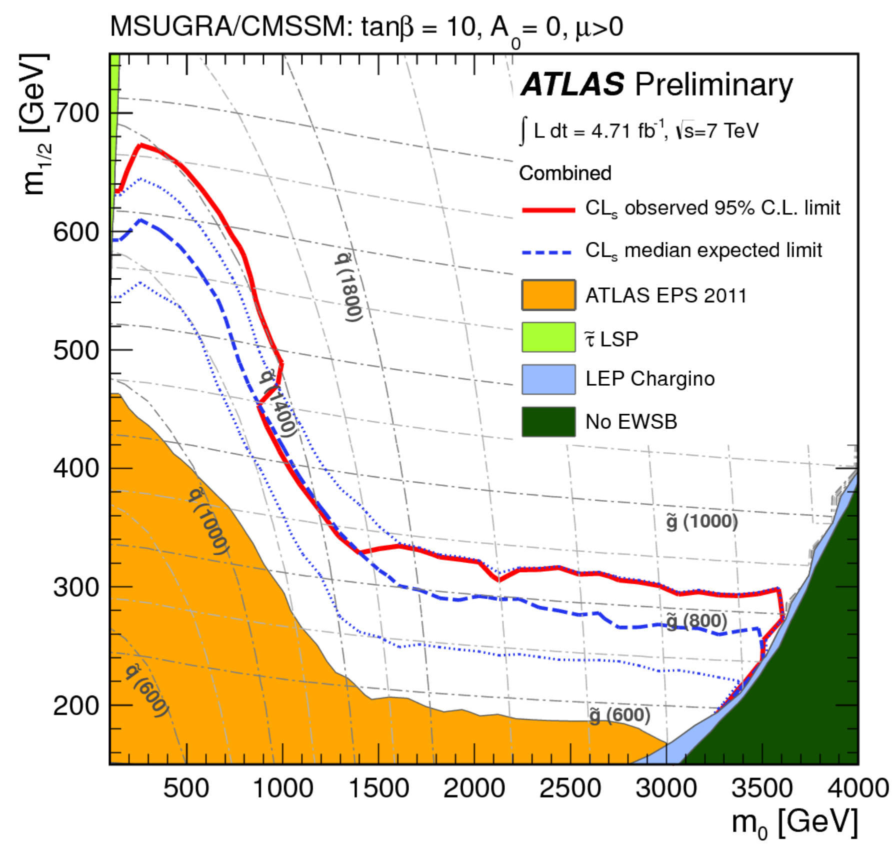


Where is SUSY?

last Thursday



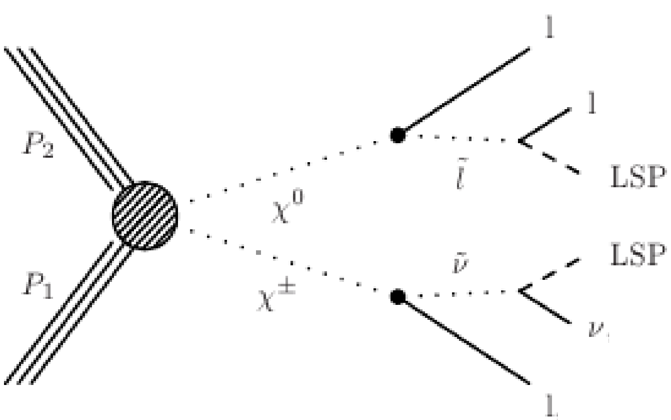
this morning!

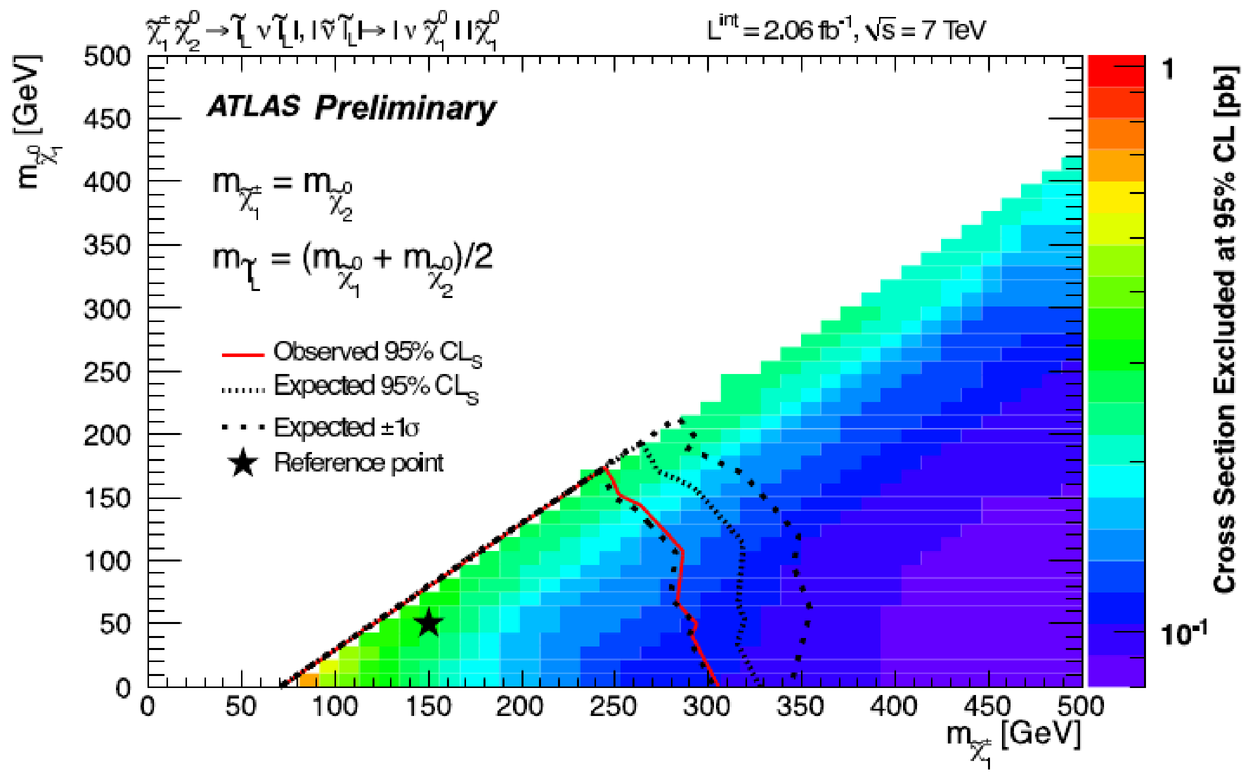


mSUGRA with 1 TeV gluino and 1.5 TeV squarks

Did we miss some lighter superpartners?

- We expect lighter charginos and second neutralinos
- Naturalness would prefer lighter stops and perhaps sbottoms
- Inclusive searches can capture some of this, but better to have targeted searches too





Is SUSY hiding?

H_1	125 GeV	$\tilde{b}_1$	499 GeV
→ $\tilde{t}_1$	188 GeV	A_2	509 GeV
N_1	216 GeV	H_3	530 GeV
$H^\pm$	307 GeV	$\tilde{t}_2$	580 GeV
H_2	326 GeV	N_3	602 GeV
A_1	368 GeV	N_4	635 GeV
C_1	406 GeV	N_5	805 GeV
N_2	426 GeV	C_2	876 GeV

$\tilde{t}_1$	$\to t + LSP$	100%
C_1	$\to \tilde{t}_1 + b^\dagger$	84%
C_1	$\to N_1 + W^\pm$	16%
$\tilde{b}_1$	$\to \tilde{t}_1 + W^-$	97%
$\tilde{b}_1$	$\to \tilde{t}_1 + H^-$	3%
$\tilde{t}_2$	$\to \tilde{t}_1 + Z$	51%
$\tilde{t}_2$	$\to t + N_1$	27%
$\tilde{t}_2$	$\to b + C_1^+$	11%
$\tilde{t}_2$	$\to \tilde{t}_1 + H_1$	10%

C. Csaki, L. Randall, J. Terning

A recent attempt by clever theorists to hide SUSY:

- LSP is a nearly massless gravitino
- NLSP is the lightest stop, only 15 GeV heavier than top
- Suppression of missing transverse momentum in SUSY decays

Is SUSY hiding?

H_1	125 GeV	$\tilde{b}_1$	499 GeV
→ $\tilde{t}_1$	188 GeV	A_2	509 GeV
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$\tilde{t}_2$	$\to t + N_1$	27%
$\tilde{t}_2$	$\to b + C_1^{+}$	11%
$\tilde{t}_2$	$\to \tilde{t}_1 + H_1$	10%

Can this model be discovered/ruled out in 2012?

- **As it turns out, LHC experimentalists are also clever**
- **Already with the 2011 data there are novel analyses aimed at light stops**
- **This particular model will certainly be within reach in 2012**

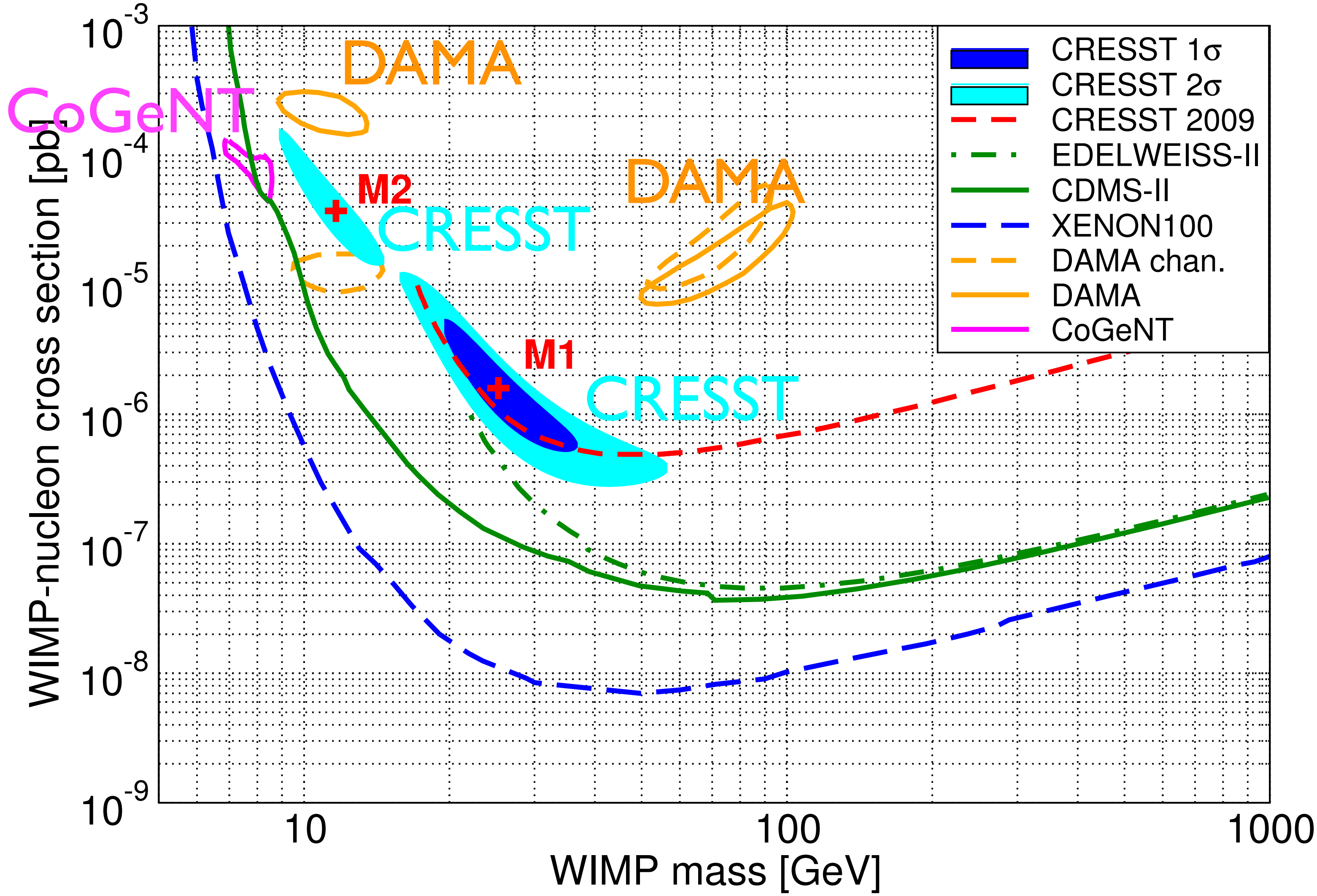
Is SUSY hiding?

- **This particular model will NOT be accessible in 2012**
- **It is too soon to make general claims about SUSY one way or the other**
- **But the discovery reach from O(100) ATLAS and CMS searches for SUSY and other BSM in 2012 will have a huge impact on our thinking about new TeV scale physics**

particle	mass [GeV]
h^0	124
χ_1^0 $\chi_1^\pm$ χ_2^0	164 166 167
χ_3^0 χ_4^0 $\chi_2^\pm$	2700 4100 4100
H_0 A_0 $H^\pm$	2200 2200 2200
$\tilde{g}$	4200
$\tilde{\tau}_1$ other sleptons	1900 $2500 - 3600$
squarks	$2700 - 5000$

F. Bruemmer Moriond EW slides

What's New at the Cosmic Frontier: Dark Matter



status summary of direct detection expts

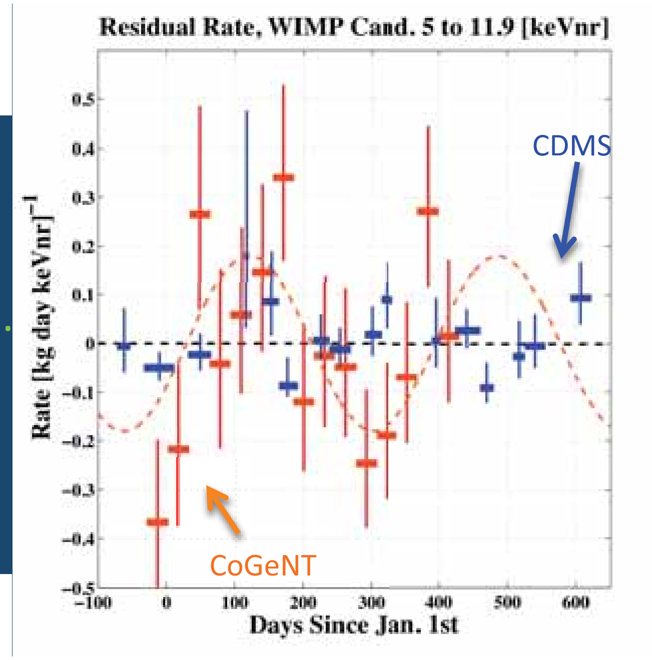
- DAMA/LIBRA - Result is as robust to collaboration tests as ever
- CRESST II - Latest analysis appears to reduce significance of excess events
  - $< 2.5\sigma$ for 29 GeV WIMP, $< 1.9\sigma$ for 13 GeV WIMP
- CoGeNT
  - Ann. Mod. is still 16% consistent with null hypothesis (need more stats)
  - Most recent analysis - fraction of events at low energy attributable to WIMPs is shrinking.
  - Best fit of ann. mod. % of WIMP signal would have to be >> than predicted by astro physical models
- COUPP
  - Having beaten down (α,n) events due to radioactivity in components
  - Now seeing single Nuclear recoil events - many are correlated in time suggesting source is not WIMPs
- CDMS II
  - Expect a new analysis of annual modulation at this conference. ← **New**
  - Shortly starting new run for 2 years with 15 iZIPs 6 kg raw mass
- Edelweiss II / III
  - Approved for 24 kg fiducial in 2012/13
- miniCLEAN / DEAP 3600
  - Under construction. Results from DEAP-1 prototype are important to establish effective discrimination threshold for rejecting ER background from ^{39}Ar
- XMASS
  - Results from 12 months running will be announce at JPS ~March 23, 2012
- XENON100
  - Reduced background by > factor 2x (Kr removal) - 210 live days will be announced in Spring 2012
- LUX
  - Completed surface run. Moving to underground lab in March 2012, for operation Sept 2012

R. Gaitskell slides from UCLA Dark Matter 2012

CDMS (lack of) annual modulation

Results: Nuclear Recoil Singles

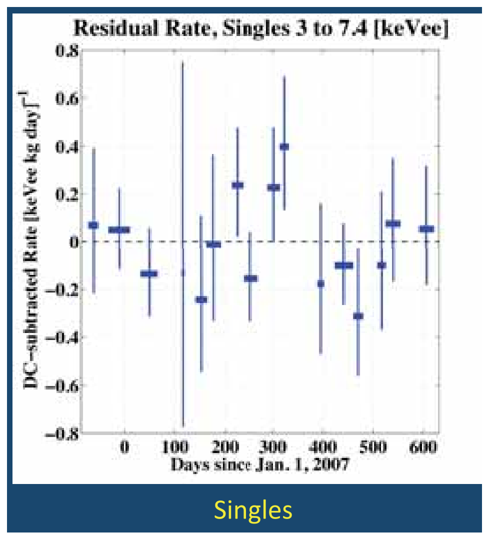
- No significant evidence for annual modulation
- In the energy range [5, 11.9] keV_{nr}, all modulated rate with amplitudes greater than 0.07 $[keV_{nr}\ kg\ day]^{-1}$ are ruled out with a 99% confidence.
  - ➢ Annual modulation signal of CDMS and CoGeNT are incompatible at >95% C.L. (preliminary) for the full energy range (if CoGeNT signal originates in a nuclear-recoil population)



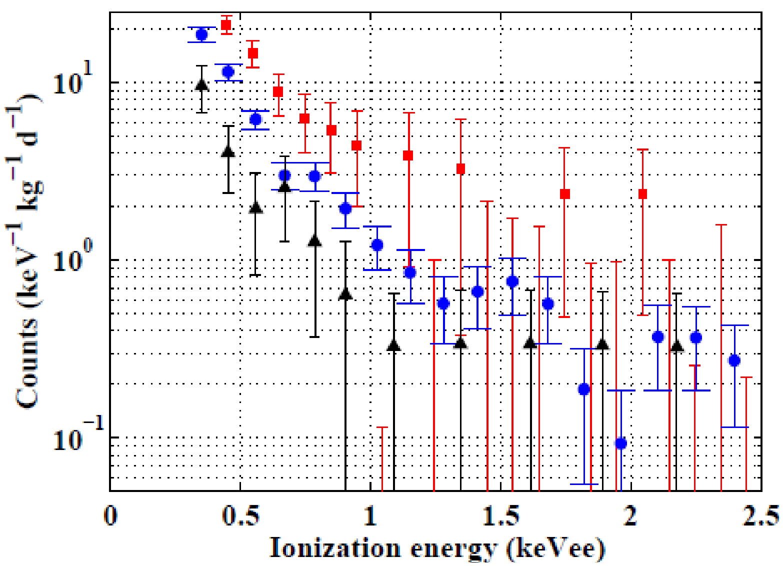
Results: Electron-recoil-dominated Singles/Multiples

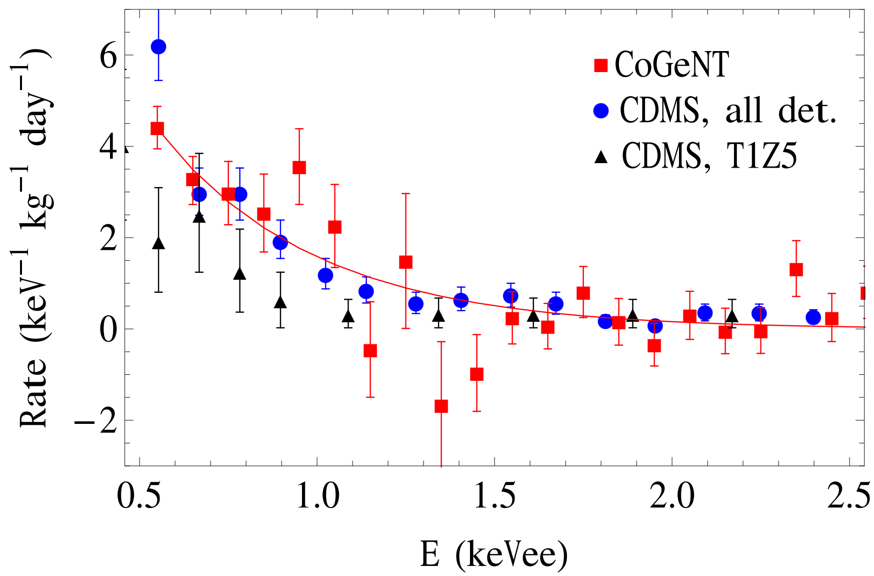
- Little overlap with the energy range of CoGeNT under the hypothesis of an ER modulation. (3.2 keVee max for CoGeNT)

➔ This result cannot exclude the possibility that the modulation observed by CoGeNT is due to electron-recoils.



CDMS vs CoGeNT energy spectra





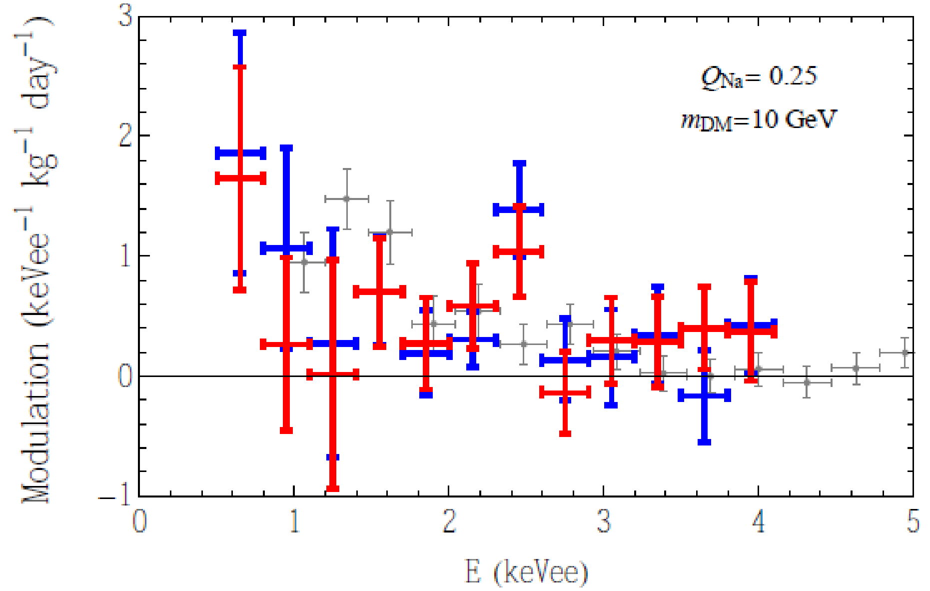
before C. Kelso, D. Hooper, M. Buckley **after**

excluding surface contamination events in CoGeNT produces much better agreement in spectra (CRESST too)

DAMA vs CoGeNT vs CRESST vs ...

- DAMA and CoGeNT modulation agree reasonably well
- But the modulation spectra don't agree with the event spectra
- Hint of either non-standard halo distribution or non-standard DM?

C. Kelso, D. Hooper, M. Buckley

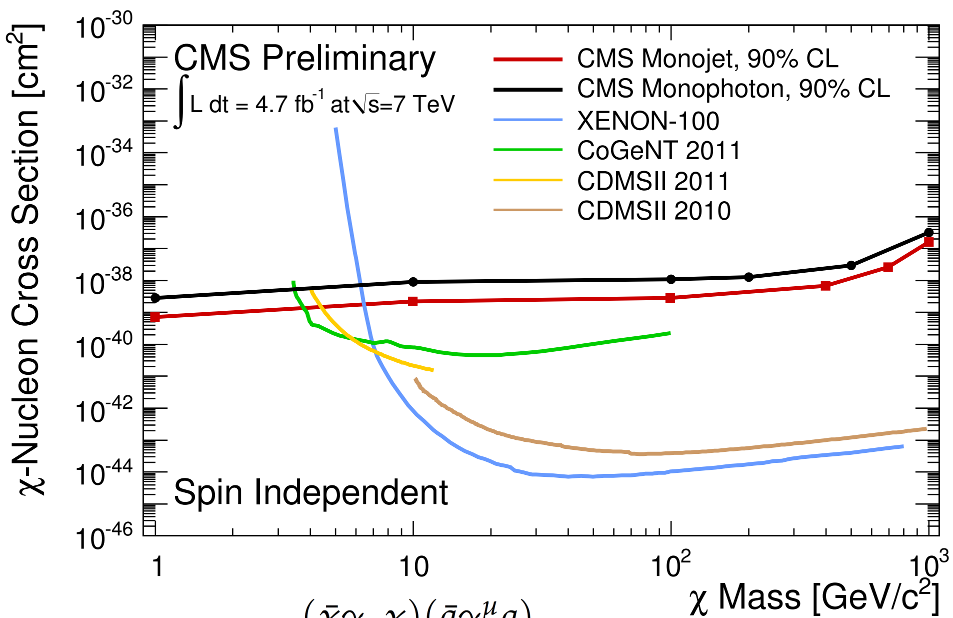


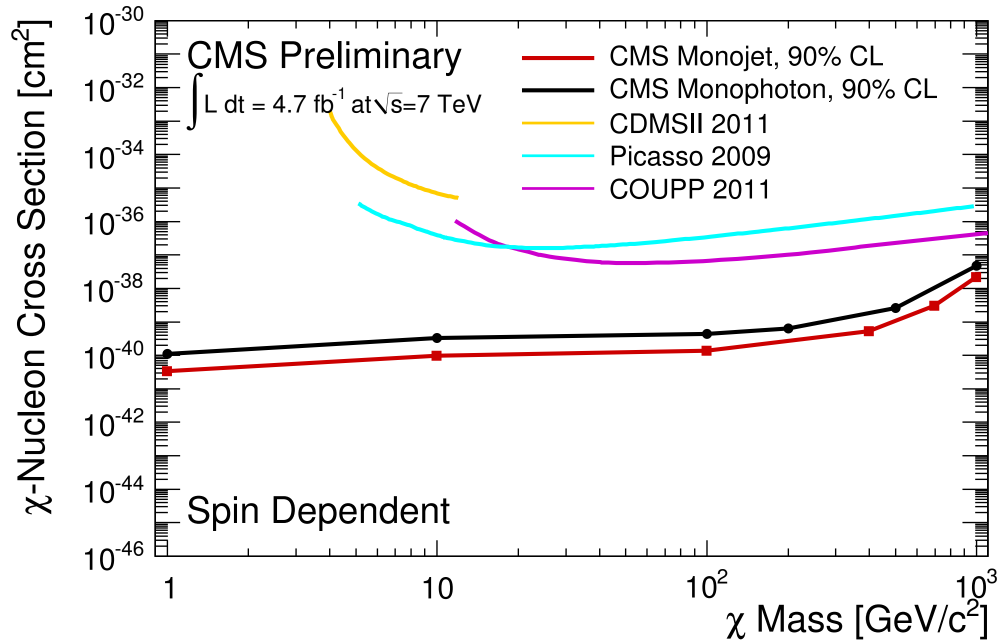
- Even with non-standard DM, difficult to reconcile CRESST with DAMA and CoGeNT

J. Kopp, T. Schwetz, J. Zupan

- And there is also XENON-100...

CDMS vs CMS??





$$\mathcal{O}_V = \frac{(\bar{\chi}\gamma_\mu\chi)(\bar{q}\gamma^\mu q)}{\Lambda^2}$$

S. Worm Moriond EW slides

$$\mathcal{O}_{AV} = \frac{(\bar{\chi}\gamma_\mu\gamma_5\chi)(\bar{q}\gamma^\mu\gamma_5 q)}{\Lambda^2}$$

Y. Bai, P. Fox, R. Harnik

- **Assuming a heavy mediator, can use effective operator analysis to relate collider monojet and monophoton searches to direct DM searches**
- **Already gives strong limits**

Summary
2012 and beyond

- The neutrino program has great prospects
- Flavor keeps surprising us
- Higgs, no Higgs, Higgs look-alikes
- Keep beating the bushes to flush out SUSY or other BSM
- Make the dark matter connections (direct vs direct, direct vs indirect, direct vs LHC)

Backup

side note:
U.S. leadership in LHC science

7.1.2 THE LARGE HADRON COLLIDER

In the near future, the Large Hadron Collider at CERN in Geneva, Switzerland will achieve the highest collision energies. The LHC is an international project with significant US investment and major US involvement: Americans constitute the largest group of LHC scientists from any single nation. Significant US participation in the full exploitation of the LHC has the highest priority in the US particle physics program.

> **The panel recommends support for the US LHC program, including US involvement in the planned detector and accelerator upgrades, under any of the funding scenarios considered by the panel.**

29 May 2008

- **In 2008, P5 made LHC their highest priority, predicated on the belief that U.S. physicists would take a leading role in the science.**
- **Is this actually happening?**

U.S. leadership in LHC science

CMS

- Spokesperson: Joe Incandela (UCSB)
- Physics Coordinator: Greg Landsberg (Brown)
- Collaboration Board Chair-Elect: Ian Shipsey (Purdue)
- SUSY conveners: David Stuart (UCSB), Eva Halkiadakis (Rutgers)
- Higgs Convener: Christoph Paus (MIT)
- etc.

ATLAS

- Deputy Spokesperson: Andy Lankford (UC Irvine)
- Physics Coordinator Elect: Kevin Einsweiler (LBNL)
- Physics Coordinator Emeritus: Tom LeCompte (ANL)
- Physics Coordinator Emeritus: Ian Hinchliffe (LBNL)
- Standard Model Convener: Joao Guimaraes (Harvard)
- etc.

Just as (or more) important is the physics leadership behind the scenes, pushing forward flagship analyses and innovations.

e.g. for CMS (where I know what is happening):

- Higgs -> WW-> lnulnu: Caltech, Fermilab, MIT, Nebraska, Northwestern, UCSB, UCSD
- Higgs -> ZZ -> 4l: Johns Hopkins, UC Davis, UC Riverside
- SUSY inclusive searches: Brown, Caltech, Fermilab, Florida, Princeton, Rochester, Rutgers, UCSB, UCSD
- Higgs -> gaga: Caltech, MIT, UCSD
- etc.

an impressive performance from the home team

ZH→llbb

an example of what changed

- the expected signal is small (~10 events in this channel)
- electron channel got one new golden candidate event, and in general filled in to look more like the muon channel