Albert De Roeck
CERN

ICHEP in a Nutshell

- Milestone conference: announcement of the observation of a Higgs-like particle observed by ATLAS and CMS
- Interesting results from Neutrino experiments
- Lots of other new data on heavy flavors, etc.
- In general no convincing sign yet for new physics

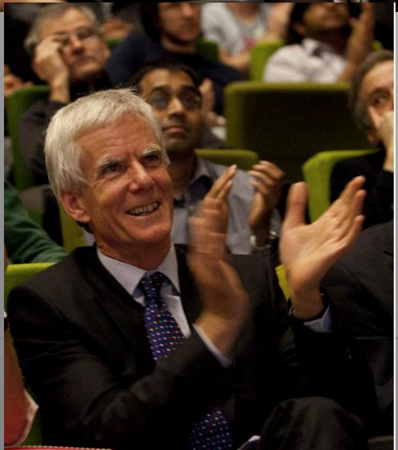
Conference passport:
Venue: Melbourne in winter !
Organization: Excellent!!
Participants: ~ 717
Talks: ~ 490
Climate: cold with sunny spells
Costs: barely affordable…

Contents

- Observation of a Higgs-like particle
- QCD and Heavy Ions
- New EWK/Top measurements
- Searches for New Physics
- Heavy flavor measurements
- Neutrinos
- Dark matter/Dark Energy

July 4th 2012 17:00 Melbourne

- Official announcement of the observation of a Higgs-like particle with mass of 125-126 GeV by CMS and ATLAS.
- Historic seminar at CERN with simultaneous transmission and live link at the large particle physics conference of 2012 in Melbourne, Australia



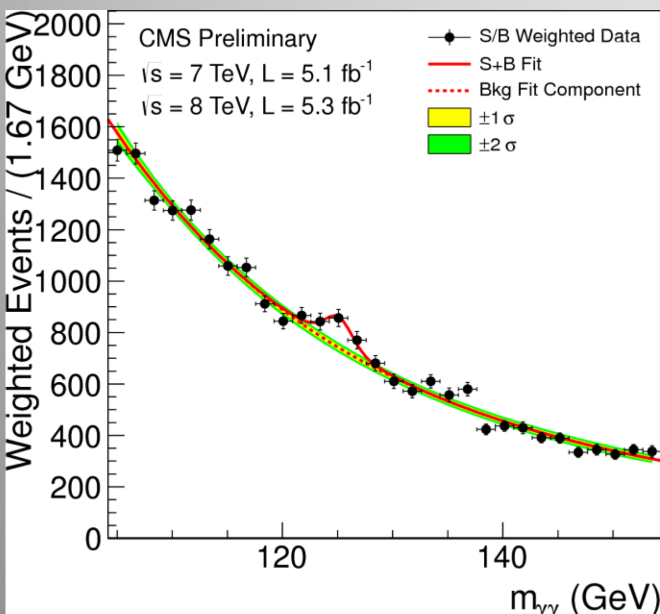
Melbourne

CMS: Higgs

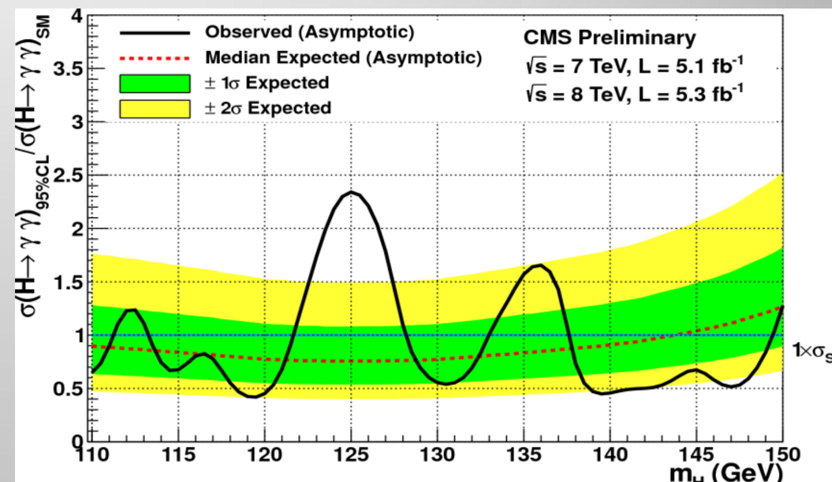
Search for the Higgs boson: use ALL Luminosity delivered for 2011 and 2012
We analysed five low mass channels + combination (plus a few high mass channels)

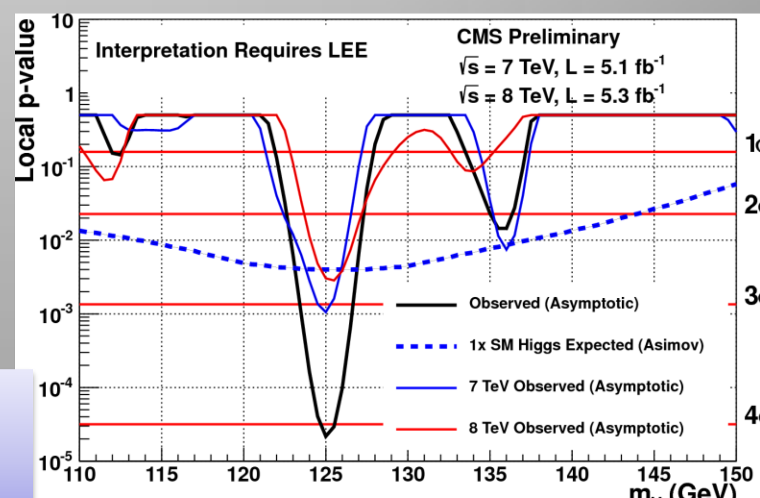
Incandela

Higgs to γγ



Diphoton mass spectrum
Analysis classes weighted with S/B

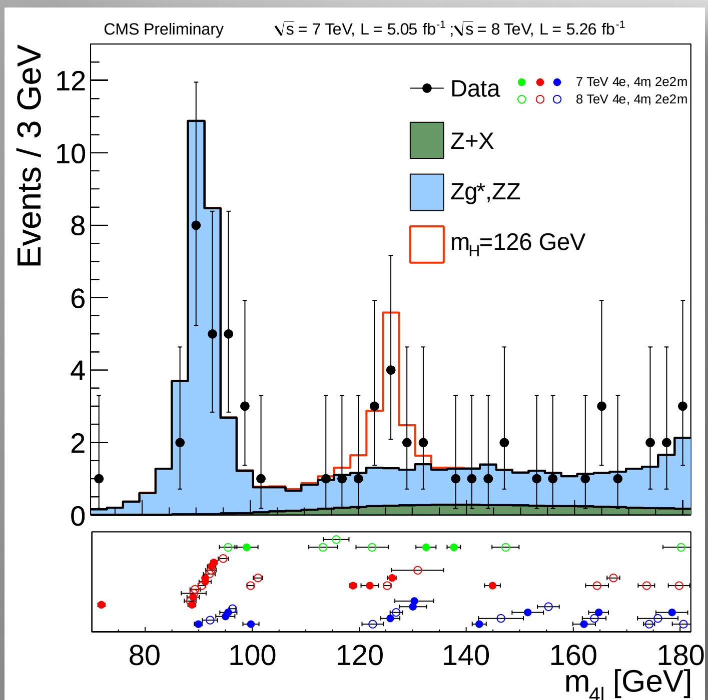


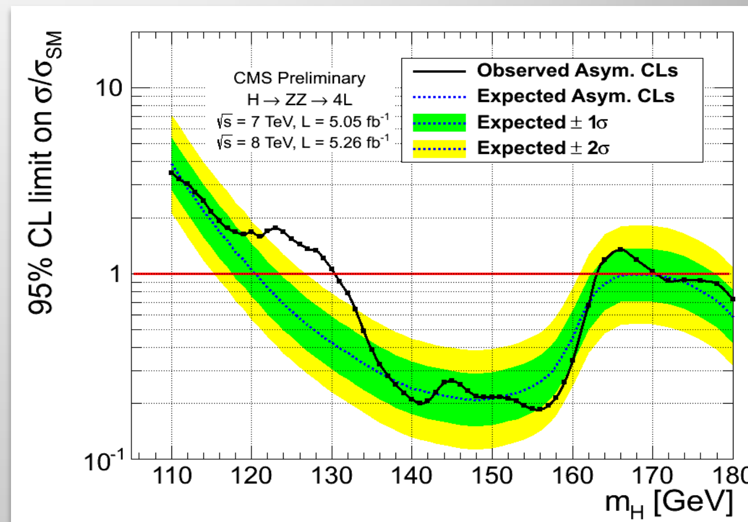


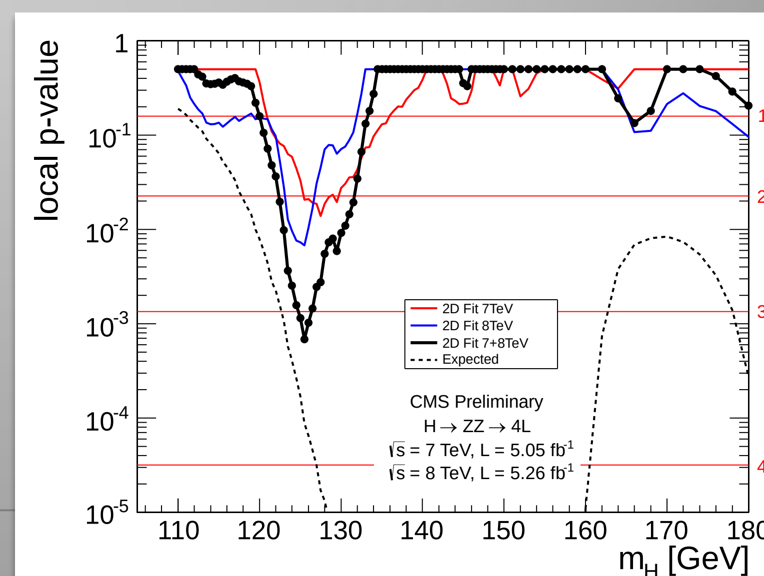
Observed significance at 12 GeV:
4.1 σ

CMS: Higgs

Higgs to ZZ to 4 charged leptons





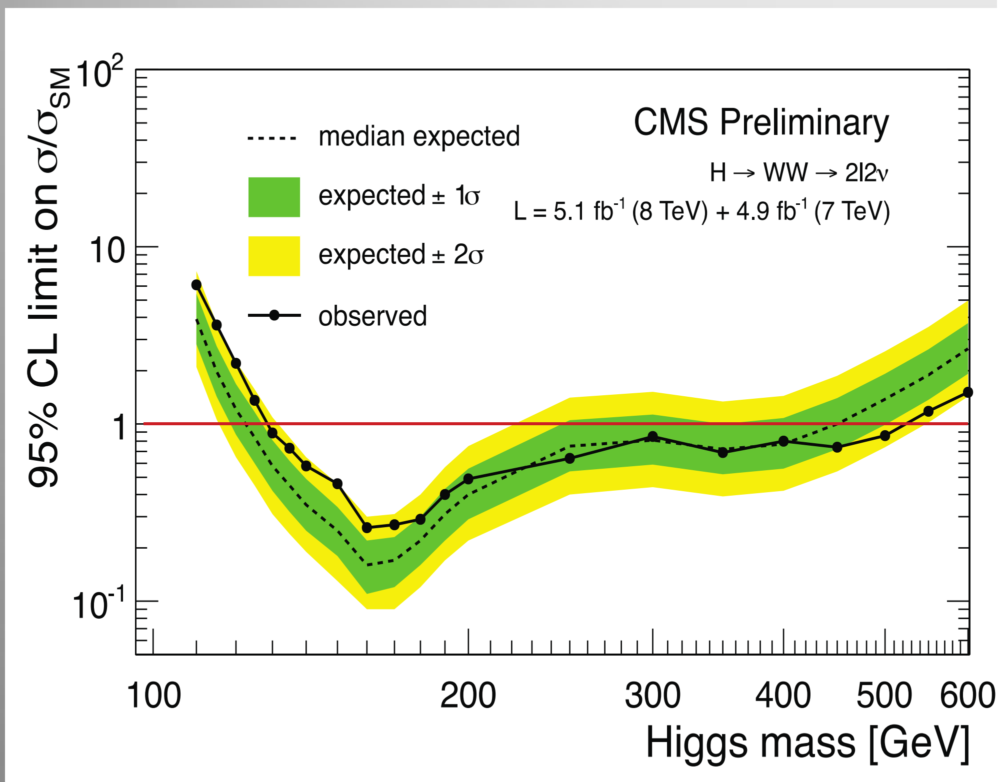


Observed significance at 125.5 GeV:

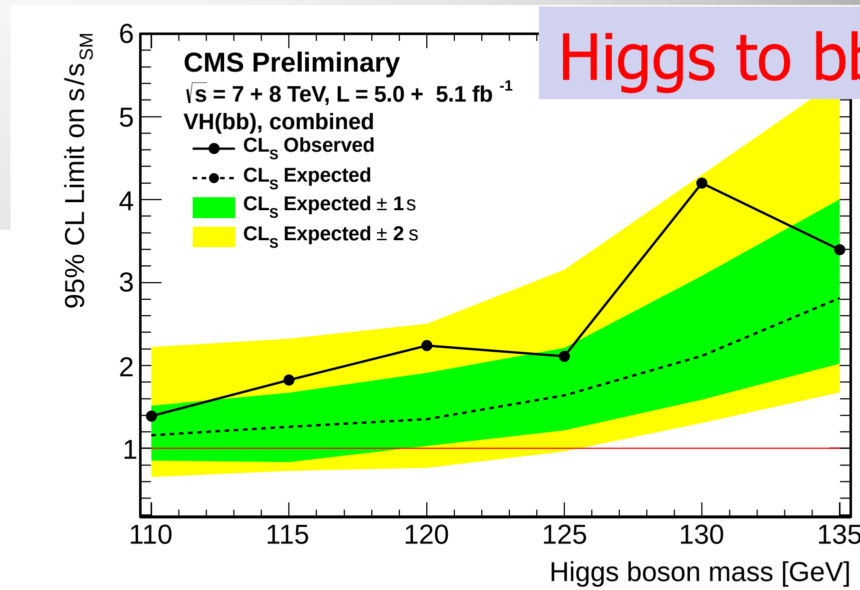
3.2 σ

CMS: Higgs

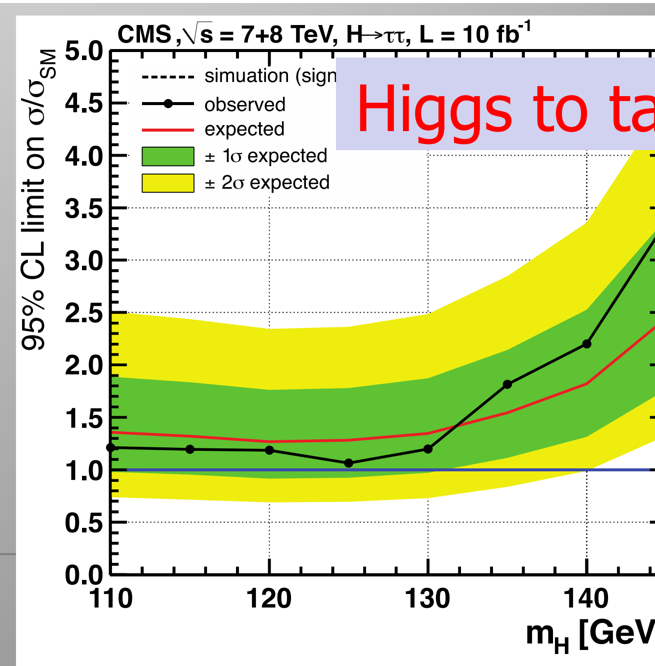
Higgs to WW



Higgs to bb

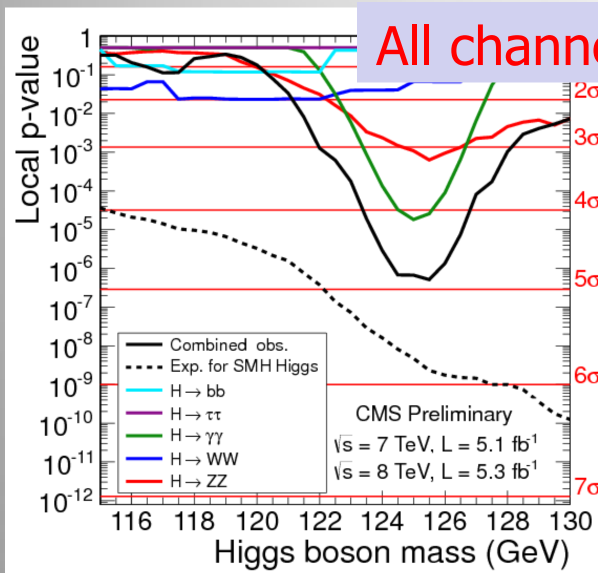


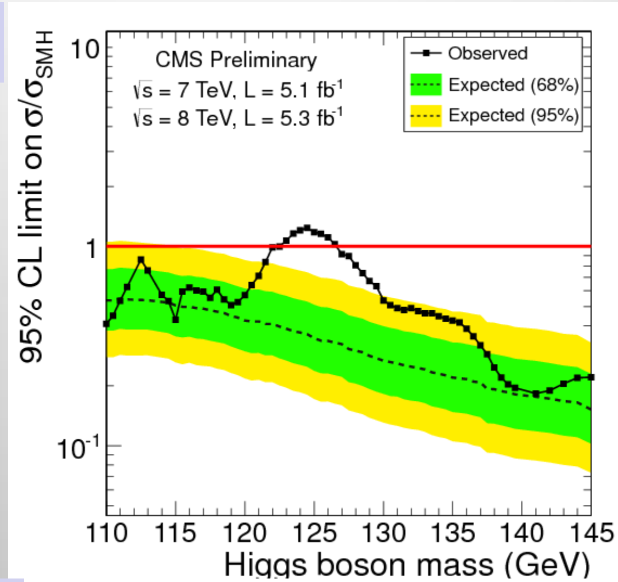
Higgs to tau tau



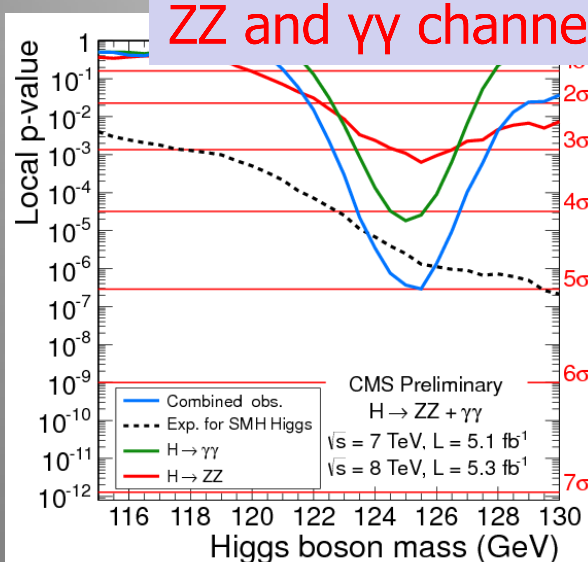
CMS: Higgs

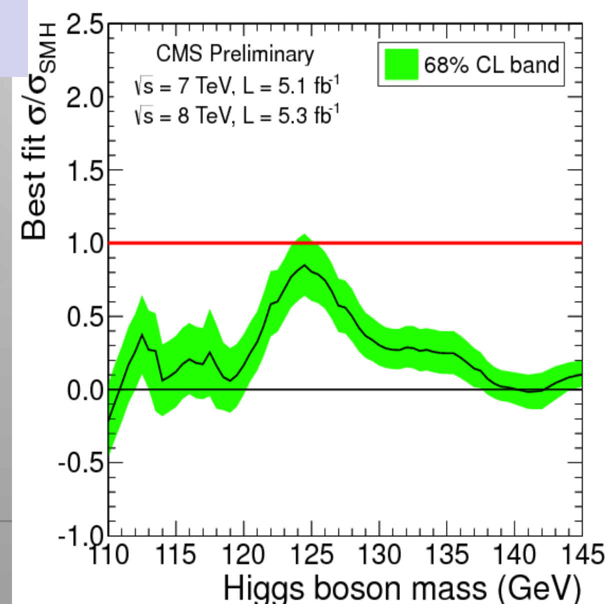
All channels





ZZ and γγ channels



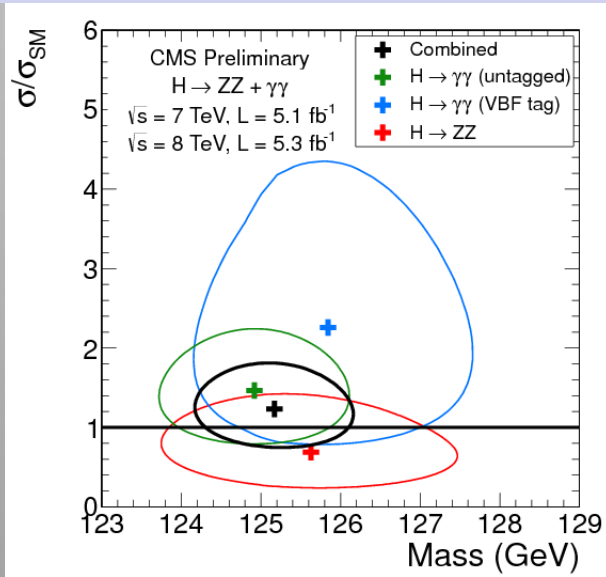


CMS observes a new boson with a significance of about 5 sigma

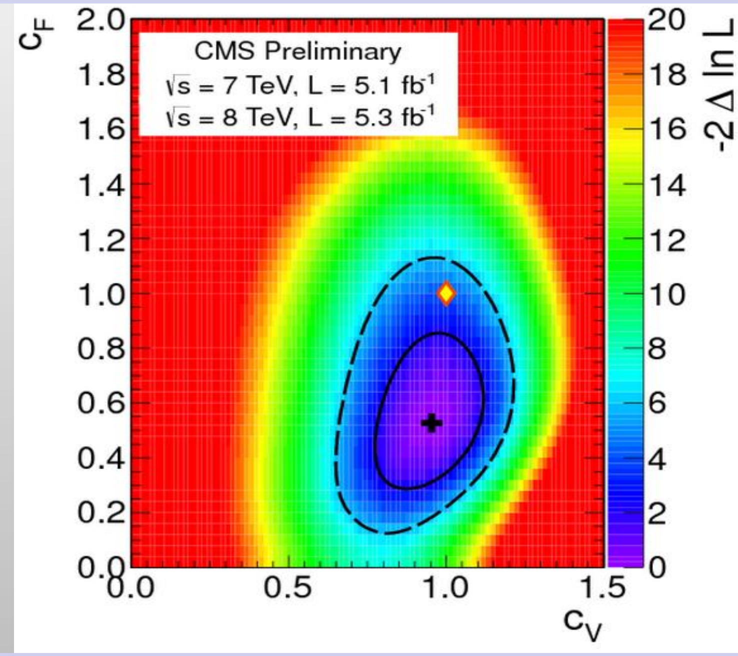
The particle is consistent with a Higgs-like boson

CMS: Higgs

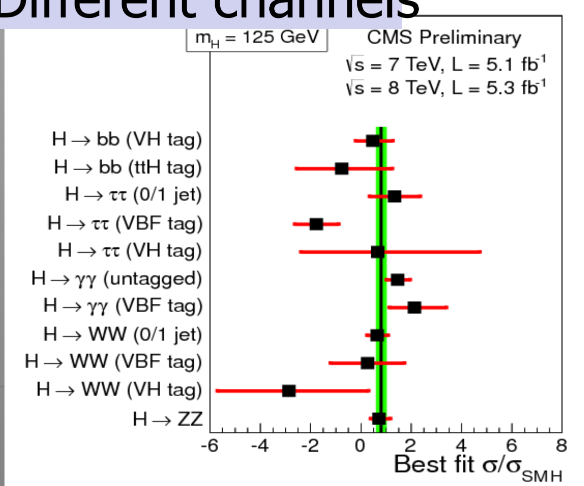
Preliminary mass = 125.3 +/- 0.6 GeV



Couplings to vector bosons and fermions



Different channels



Now we need more data to study this new particle

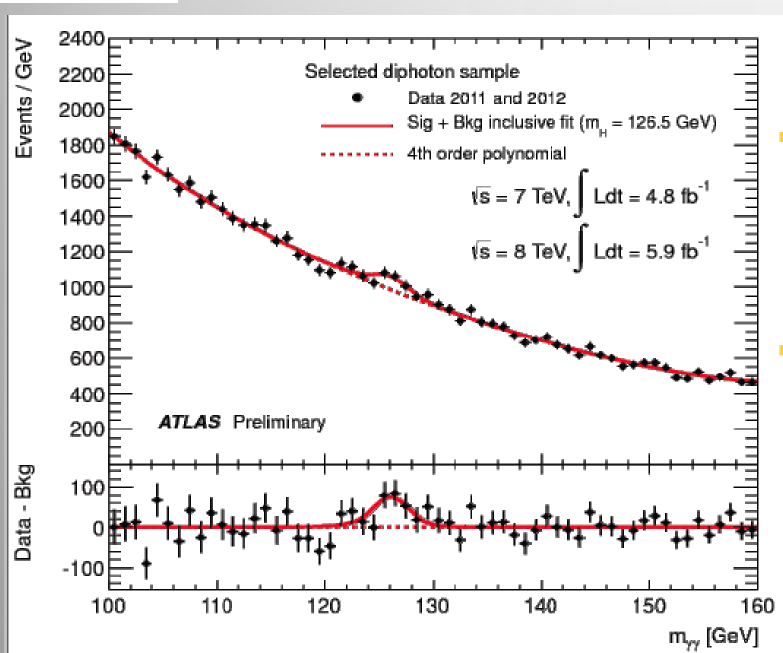
- Spin and CP studies
- Couplings
- Deviations from Standard Model? Composite?
- Is it alone or accompanied?

Another 10-20 fb^{-1} at 8 TeV will help!!

ATLAS : Higgs

Hawkings

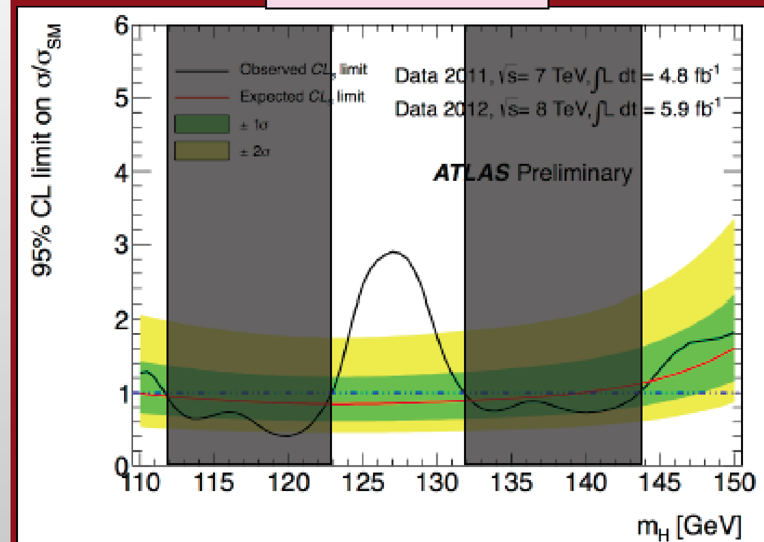
Higgs to γγ

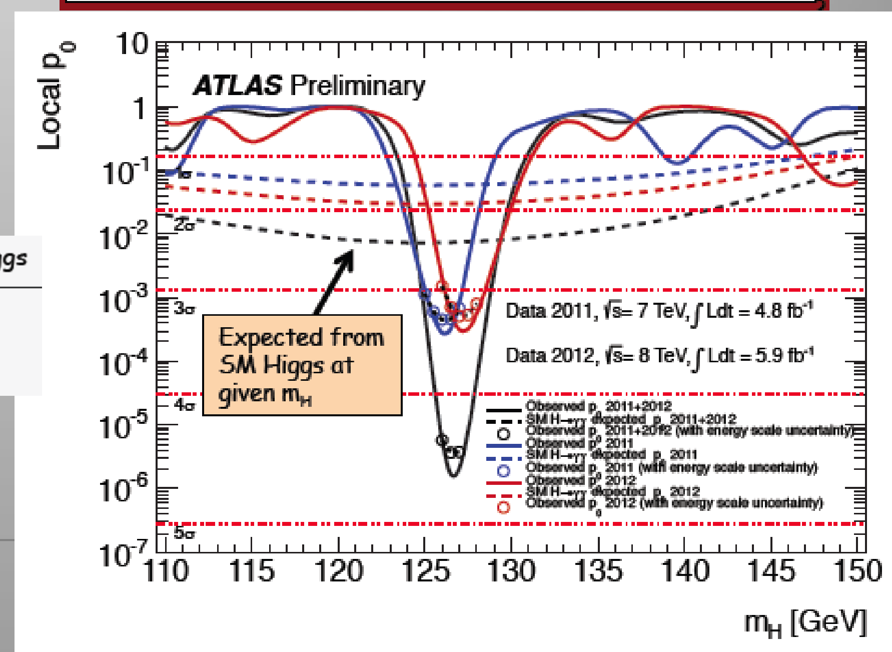


Data sample	m_H of max deviation	local p-value	local significance	expected from SM Higgs
2011	126 GeV	3×10^{-4}	3.5 σ	1.6 σ
2012	127 GeV	3×10^{-4}	3.4 σ	1.9 σ
2011+2012	126.5 GeV	2×10^{-6}	4.5 σ	2.4 σ

Global 2011+2012 (including LEE over 110-150 GeV range): 3.6 σ

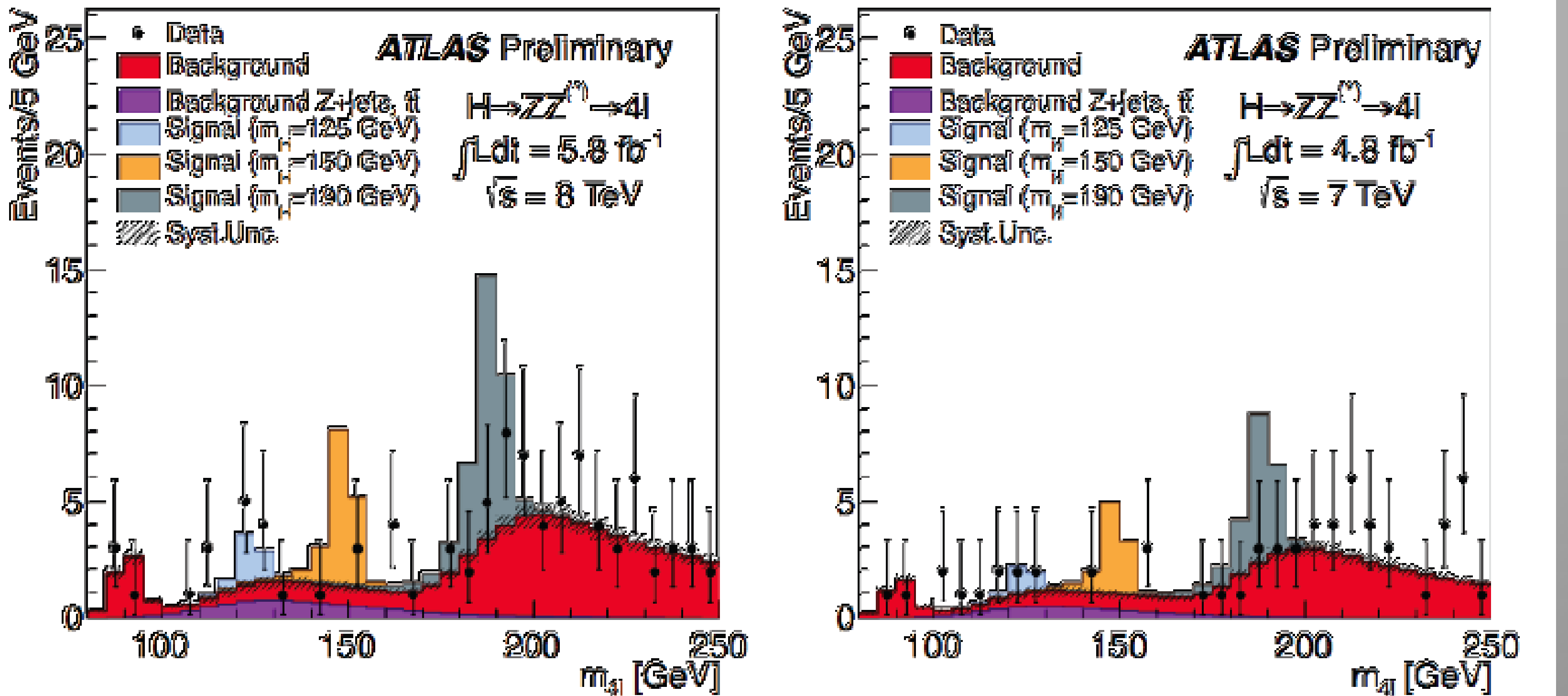
2011+2012 data





ATLAS: Higgs

Higgs to ZZ to 4 charged leptons

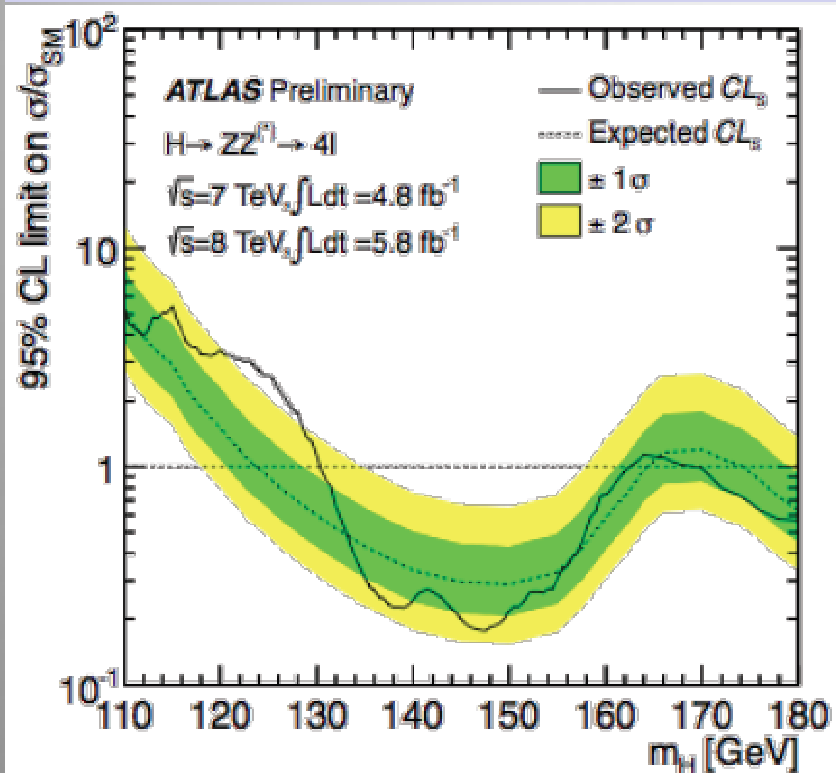


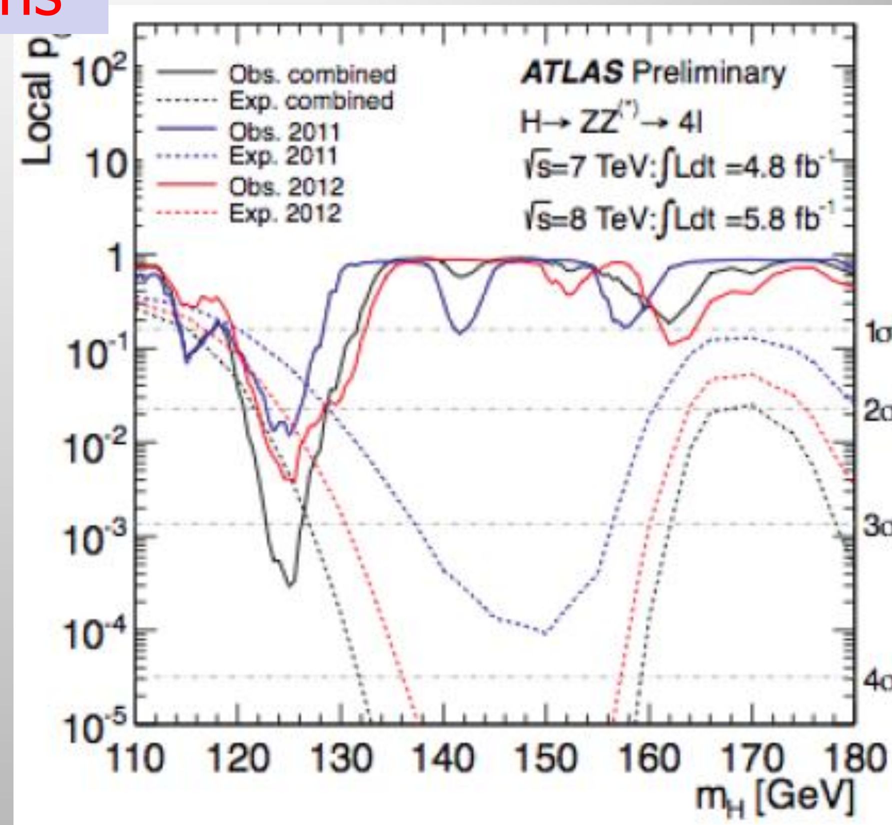
120<m_{4l}<130 GeV
Event counts

7+8 TeV	4μ	2e2μ	4e
Background	1.3±0.1	2.2±0.2	1.6±0.2
Data	6	5	2
m_H=125 GeV	2.1±0.3	2.3±0.3	0.9±0.1
S/B	1.6	1.0	0.6

ATLAS: Higgs

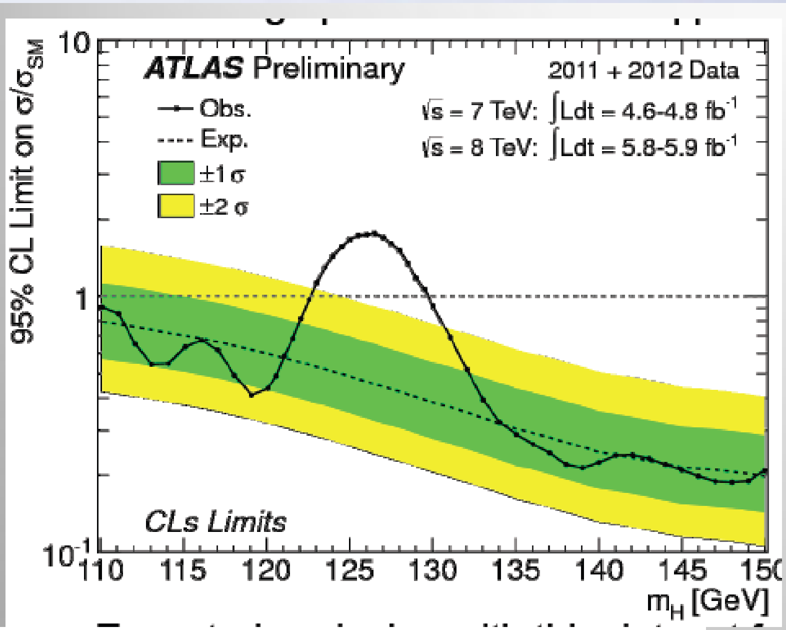
Higgs to ZZ to 4 charged leptons



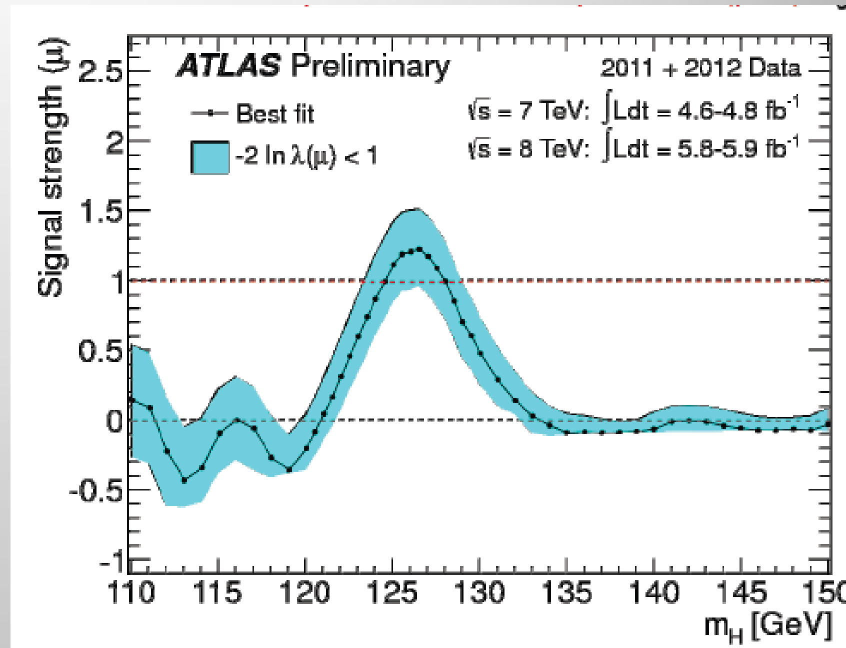


- Most significant deviation from background-only hypothesis at m_H=125 GeV
  - Local p_0 value 0.029% or 3.4σ, globally 2.1σ with LEE in range 110-600 GeV
  - Both 2011 and 2012 data contribute to excess in same mass range
  - Signal strength μ compatible with 1 around this mass

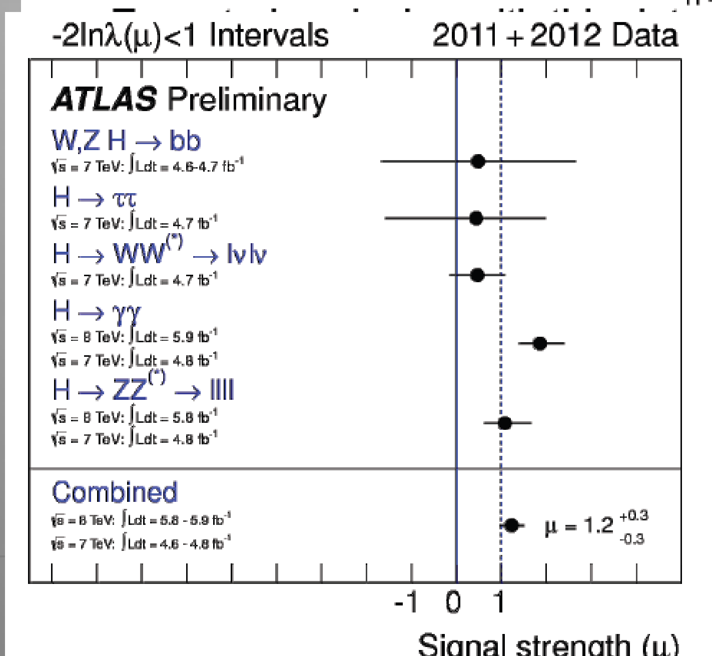
ATLAS: Higgs



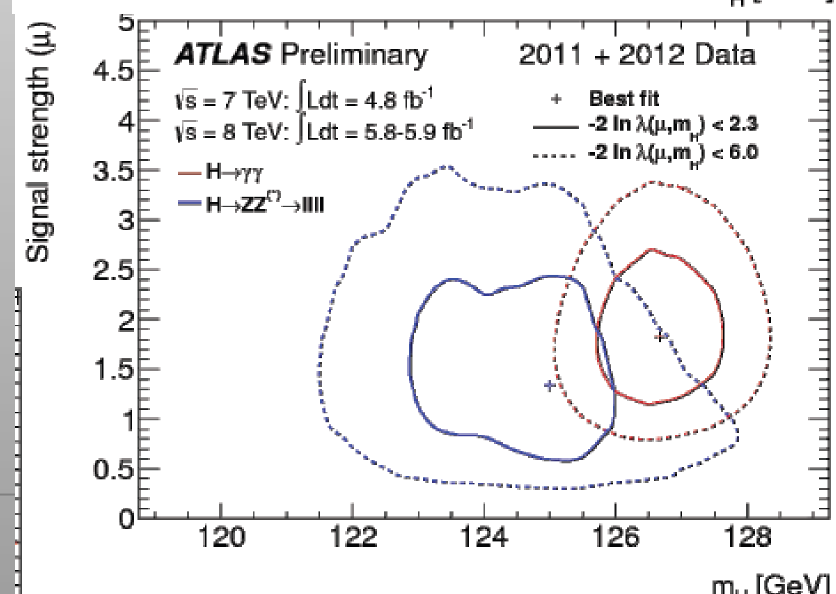
ATLAS Preliminary
2011 + 2012 Data
Obs.
Exp.
±1 σ
±2 σ
√s = 7 TeV: ∫Ldt = 4.6-4.8 fb⁻¹
√s = 8 TeV: ∫Ldt = 5.8-5.9 fb⁻¹
CLs Limits
95% CL Limit on σ/σ_SM
m_H [GeV]



ATLAS Preliminary
2011 + 2012 Data
Best fit
-2 ln λ(μ) < 1
√s = 7 TeV: ∫Ldt = 4.6-4.8 fb⁻¹
√s = 8 TeV: ∫Ldt = 5.8-5.9 fb⁻¹
Signal strength (μ)
m_H [GeV]

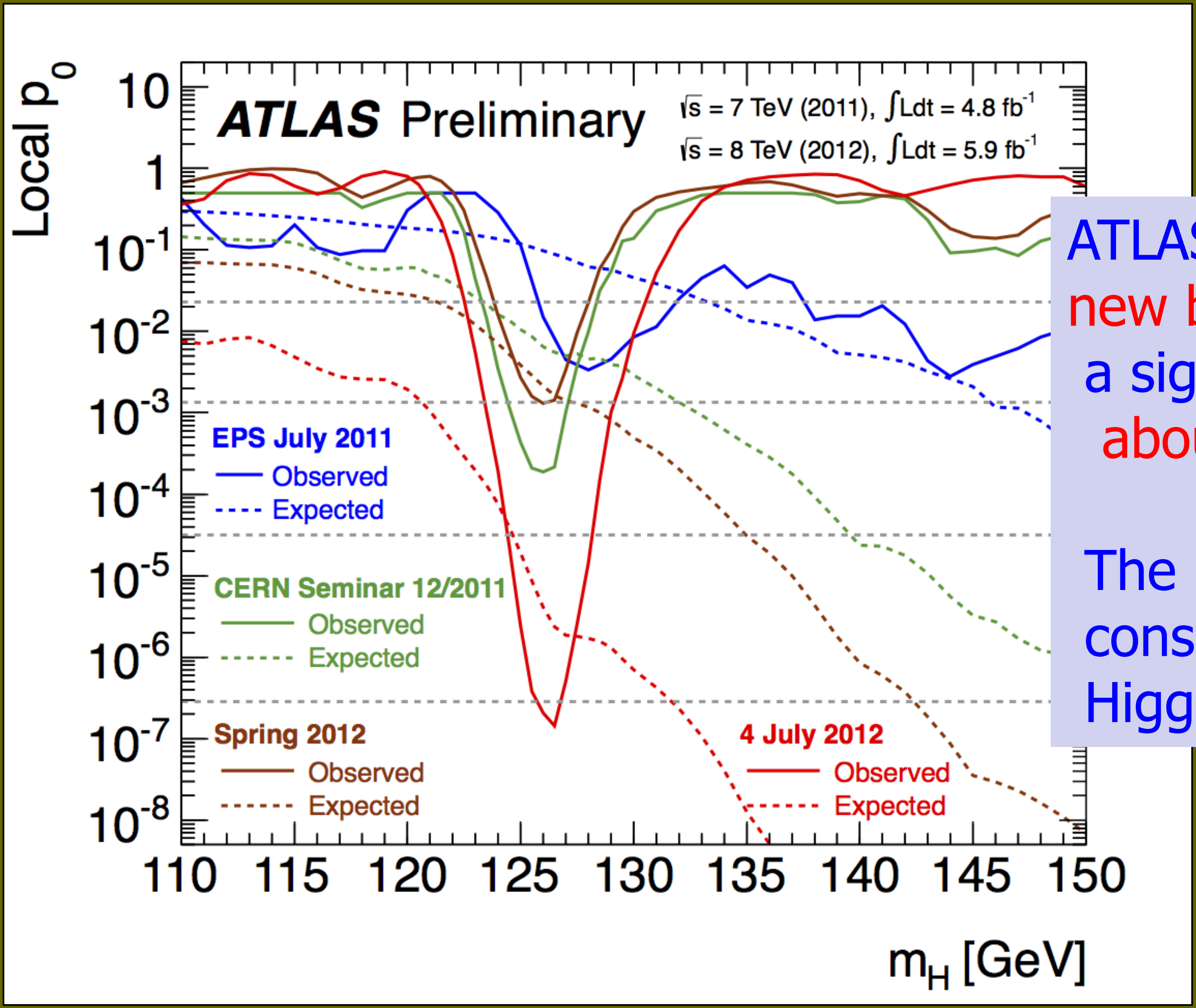


-2lnλ(μ)<1 Intervals
2011 + 2012 Data
ATLAS Preliminary
W,Z H → bb
√s = 7 TeV: ∫Ldt = 4.6-4.7 fb⁻¹
H → ττ
√s = 7 TeV: ∫Ldt = 4.7 fb⁻¹
H → WW(*) → lνlν
√s = 7 TeV: ∫Ldt = 4.7 fb⁻¹
H → γγ
√s = 8 TeV: ∫Ldt = 5.9 fb⁻¹
√s = 7 TeV: ∫Ldt = 4.8 fb⁻¹
H → ZZ(*) → llll
√s = 8 TeV: ∫Ldt = 5.8 fb⁻¹
√s = 7 TeV: ∫Ldt = 4.8 fb⁻¹
Combined
√s = 8 TeV: ∫Ldt = 5.8 - 5.9 fb⁻¹
√s = 7 TeV: ∫Ldt = 4.6 - 4.8 fb⁻¹
μ = 1.2 +0.3 -0.3
Signal strength (μ)



ATLAS Preliminary
2011 + 2012 Data
√s = 7 TeV: ∫Ldt = 4.8 fb⁻¹
√s = 8 TeV: ∫Ldt = 5.8-5.9 fb⁻¹
Best fit
-2 ln λ(μ,m_H) < 2.3
-2 ln λ(μ,m_H) < 6.0
H→γγ
H→ZZ(*)→llll
Signal strength (μ)
m_H [GeV]

Evolution of the excess with time



ATLAS observes a new boson with a significance of about 5 sigma

The particle is consistent with a Higgs-like boson

The Press…

The discovery of the Higgs made the headlines worldwide

Hawking lost $100 bet over Higgs boson

What Comes After Higgs Boson?

The Atlantic Wire — what matters now

'God Particle' 'Discovered': European Researchers Claim Discovery of Higgs Boson-Like Particle

HOW THE HIGGS COULD BECOME ANNOYING

Yes, the discovery of the Higgs boson is thrilling and game-changing. But it could also introduce some aggravating situations.

Хиггс увидит бозон

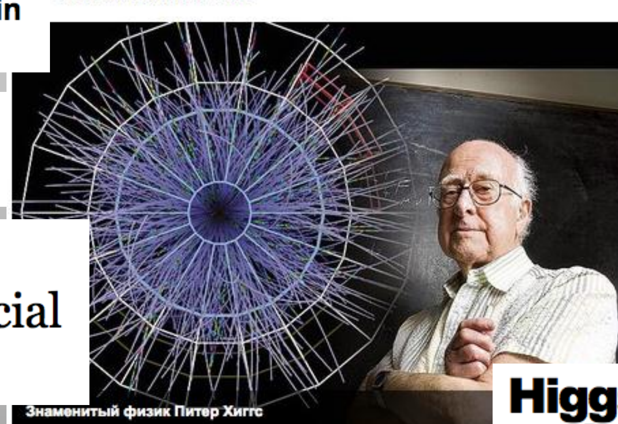
В CERN открыли бозон Хиггса

Текст

— 3.07.12 15:13 —

ТЕКСТ: АЛЕКСАНДРА БОРИСОВА

: SCIENCEUNSEEN.COM



Знаменитый физик Питер Хиггс

Discovery of Higgs Boson Bittersweet News in Texas

Scientists Set The Higgs Boson To Music

3 Ways the Higgs Boson Discovery Will Impact Financial Services

Higgs boson researchers consider move to Cloud computing

"Within another decade the Cloud will be where grid computing is now"

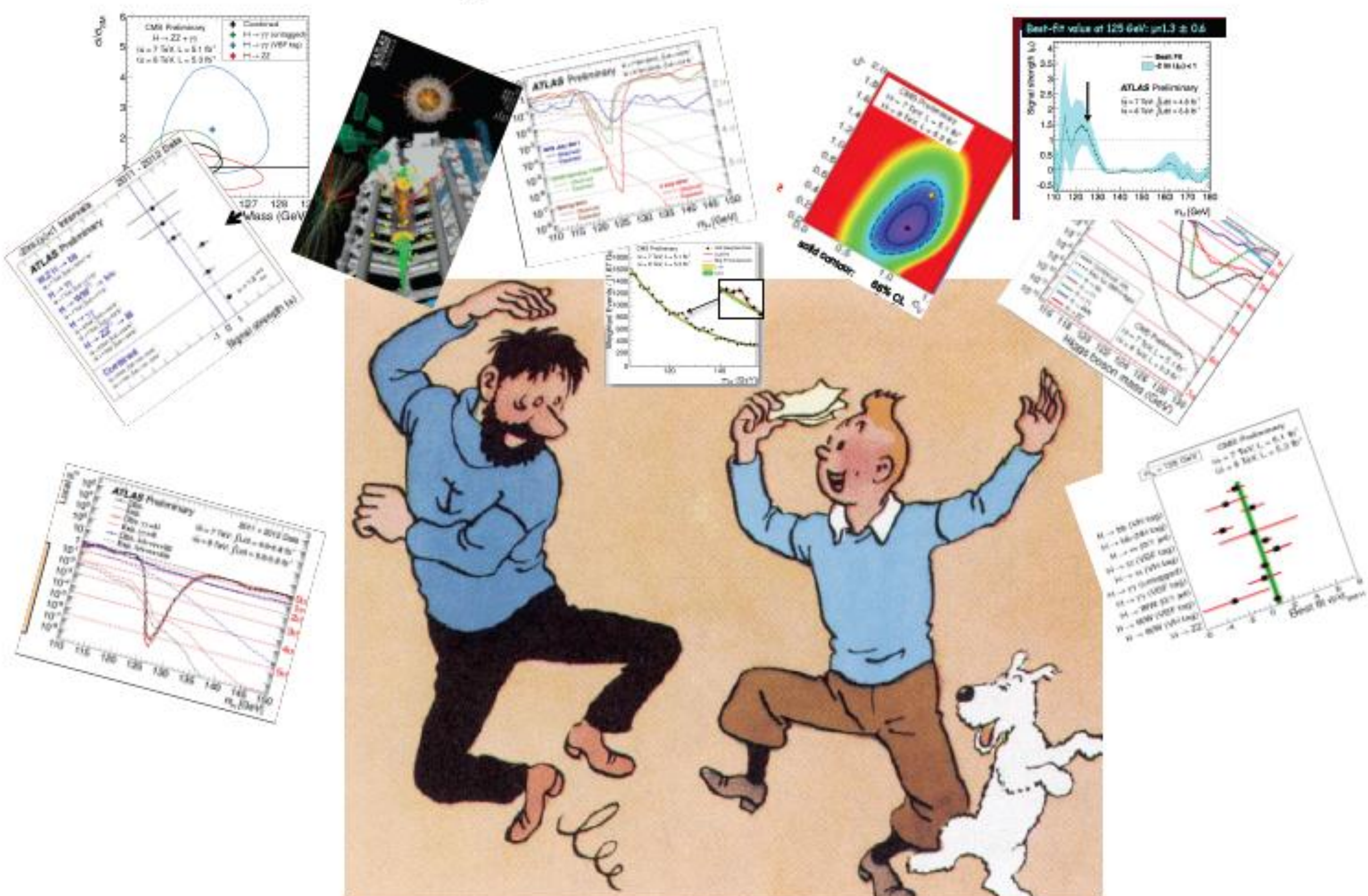
Higgs boson discovery could make science fiction a reality

Discovery of the 'God particle' could make science fiction a reality, and answer one of the most basic questions of our universe: How did light become matter — and us?

The Theorists…

A Pomarol

… and finally plenty of new relevant data has begun to fall over us!



The Theories

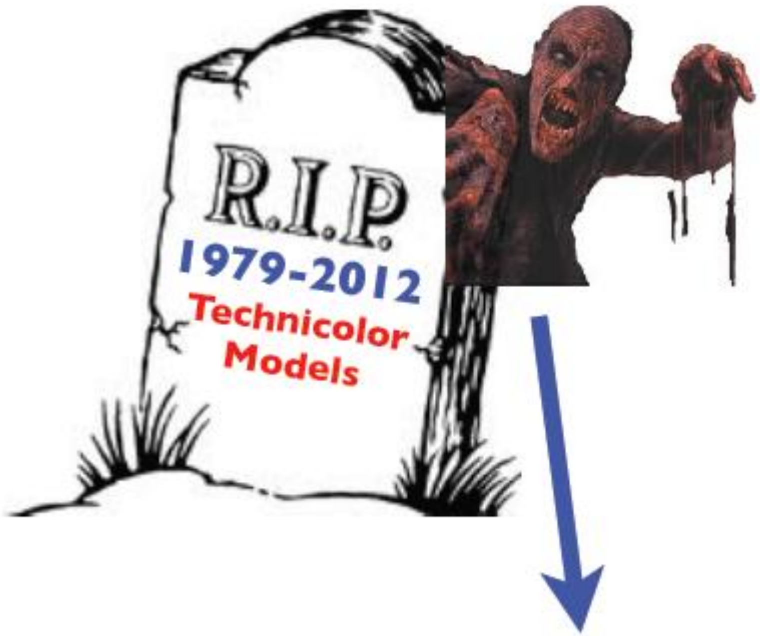
But not so excellent for all theorists:

Specially for fans of **Higgsless models:**

The Theories ??

but be careful about resurrections...

It is *not unconceivable* that a light dilaton appears in Higgsless theories



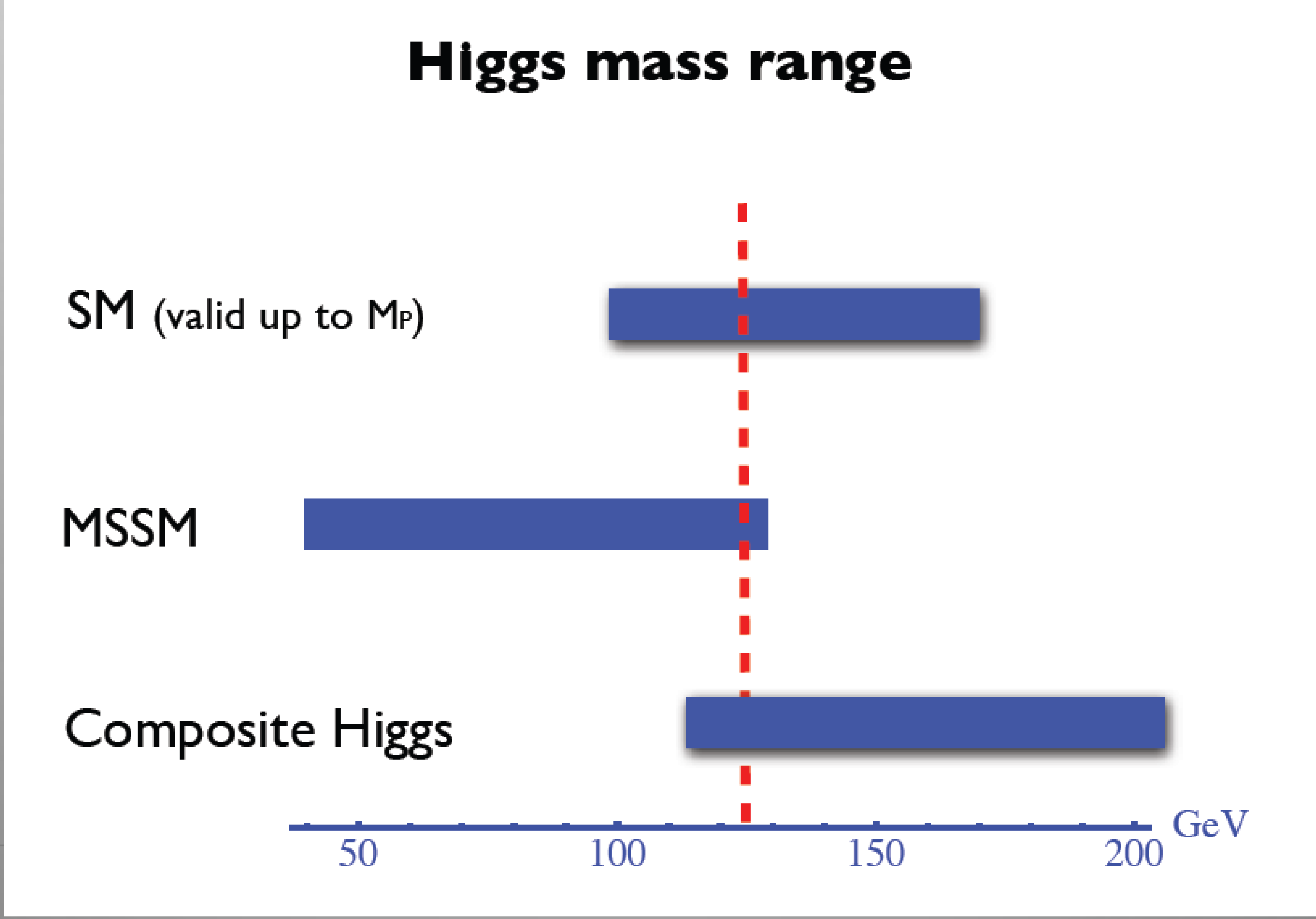
Dilaton

(Goldstone of the spontaneous breaking of scale invariance)

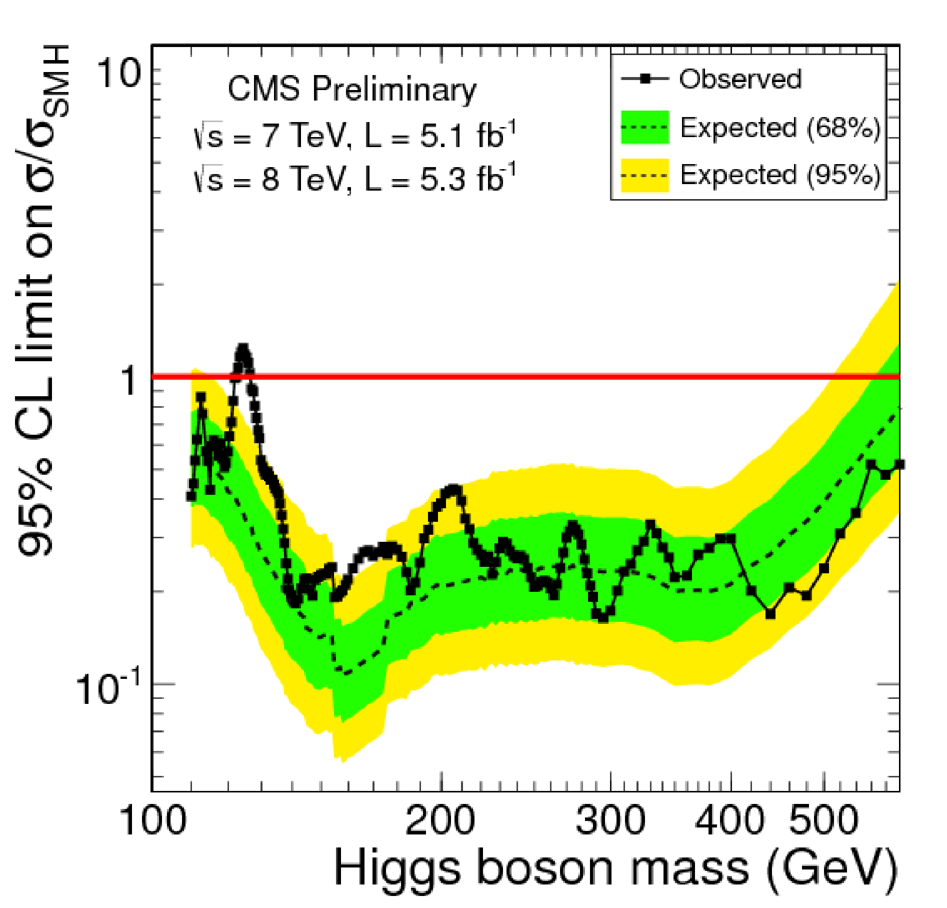
Couples as a Higgs up to an overall scale → **A Higgs impostor**

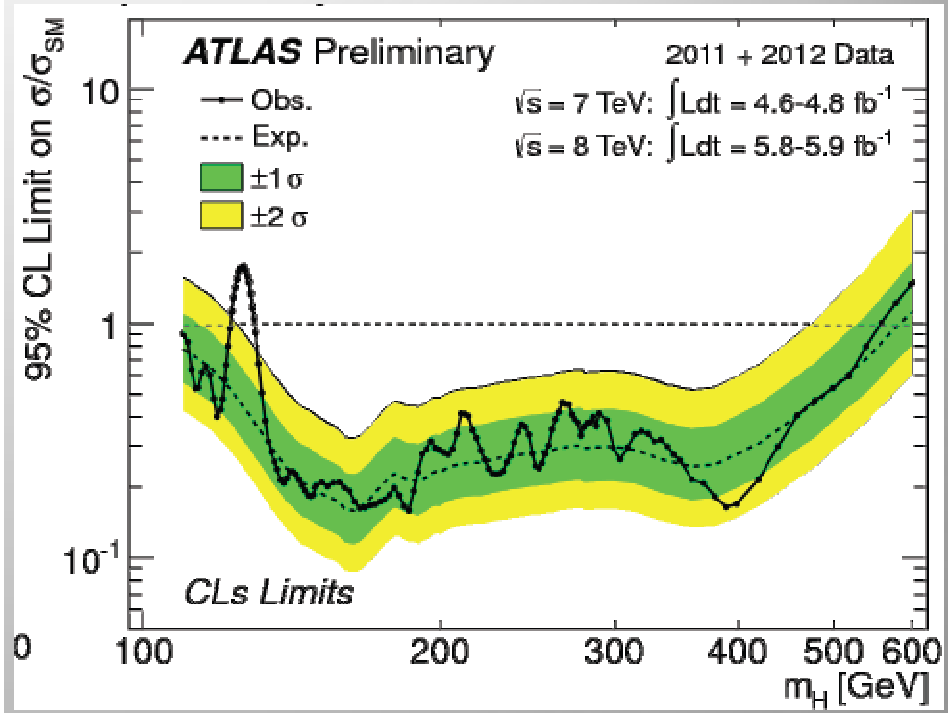
The Theories

"125 GeV is a mass of maximum agony"   N. Arkhani Ahmed May 2012



BTW: The High Mass Region





No evidence for (another) SM Higgs-like particle up to ~600 GeV

Higgs Searches at the Tevatron

S. Shalhout

Updates for Summer 2012

Search Mode	Changes
$H \to W^+W^-$	DØ (technique + new data)
$H \to \gamma\gamma$	DØ (technique)
$ZH \to l^+l^-bb$	DØ (technique) CDF (minor changes)
$WH \to l\nu bb$	DØ (technique)
$VH \to \nu\nu bb$	DØ (technique) CDF (minor changes)
trilepton + X ($H \to ZZ$ / $H \to WW$)	DØ (technique)

- ~10% gains in sensitivity for channels with improved technique

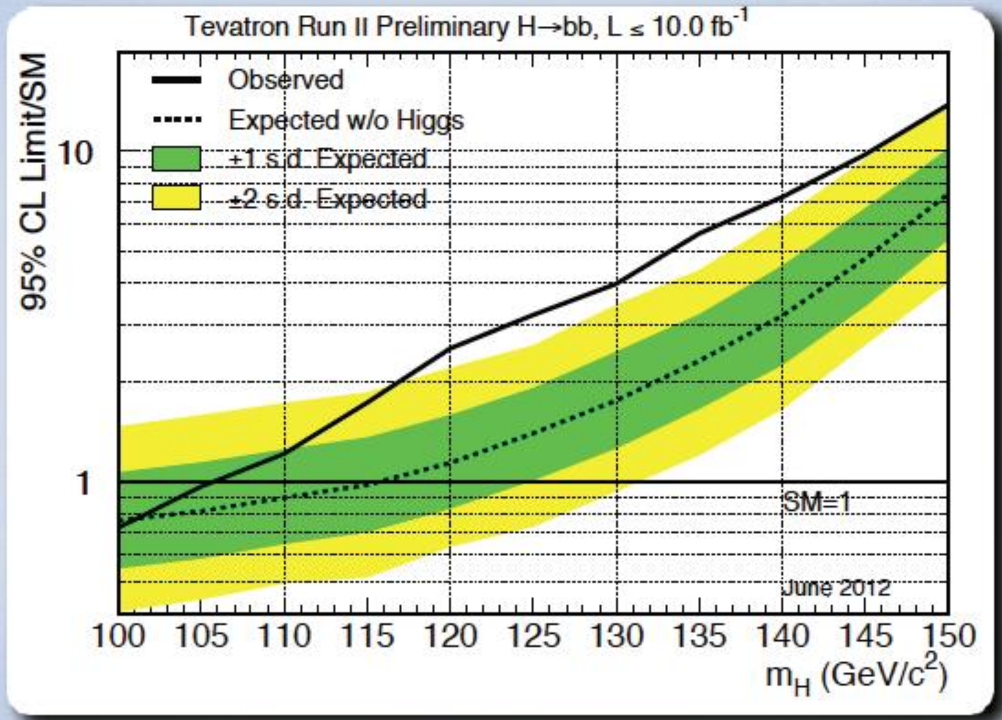
Almost the final word; a few updates still in the works
But the big picture will not change

Higgs Searches at the Tevatron

Largest deviation in the bb channel channel; both in D0 and CDF

H→bb Combination

- Broad excess between 110 and 150 GeV/c^2

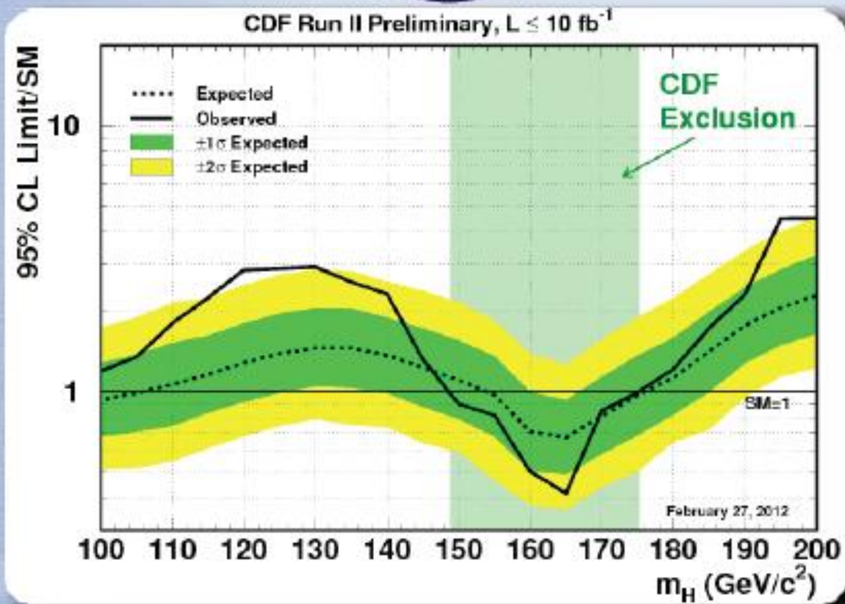


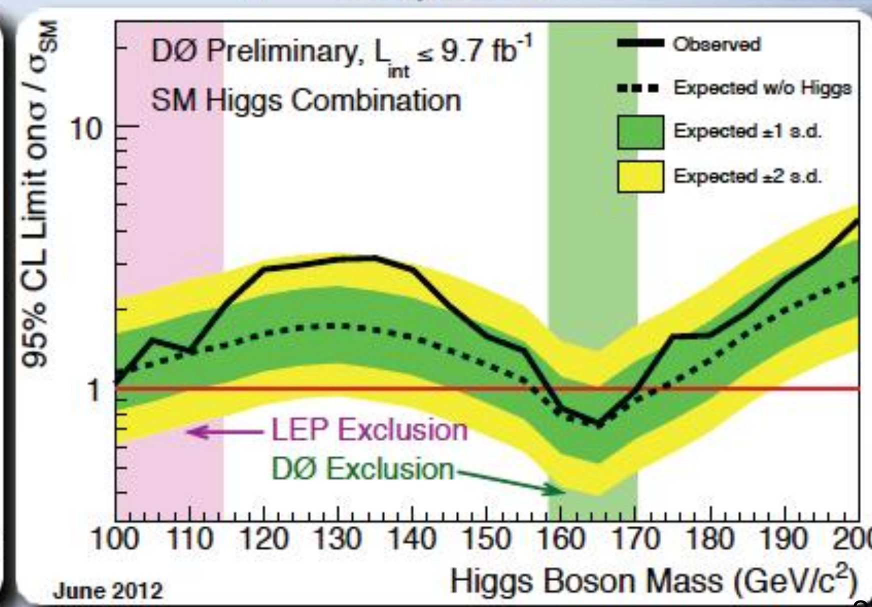
- ~5% more sensitive than March 2012 result

Higgs Searches at the Tevatron

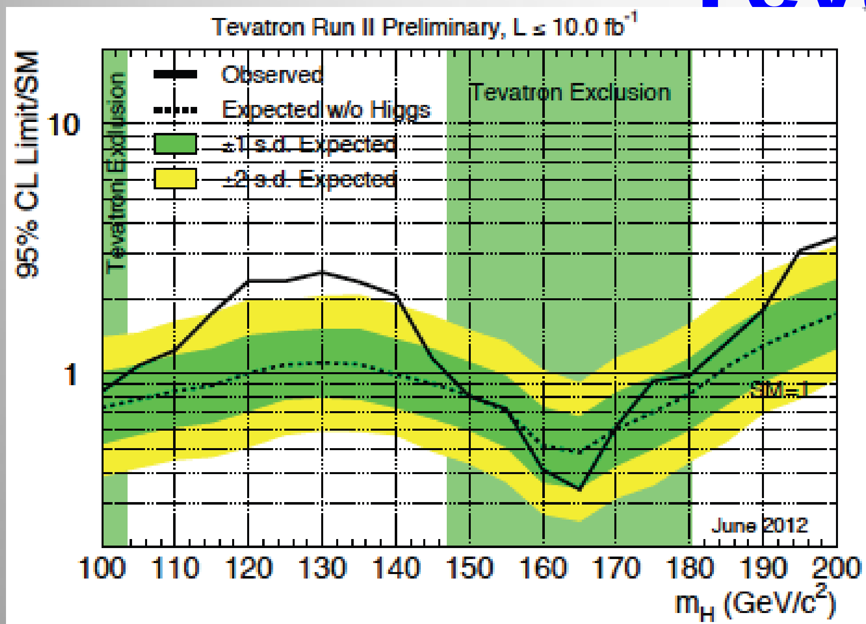
Individual Experiment Results

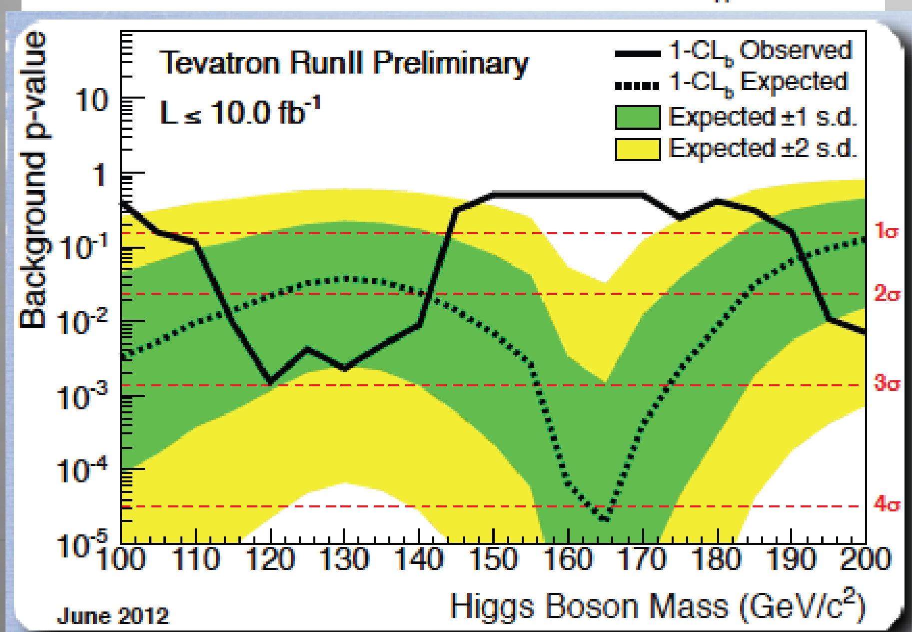
- CDF & D0 single-experiment combinations of all SM Higgs search channels ($H \to WW$, $H \to bb$, $H \to \gamma\gamma$ + other modes)



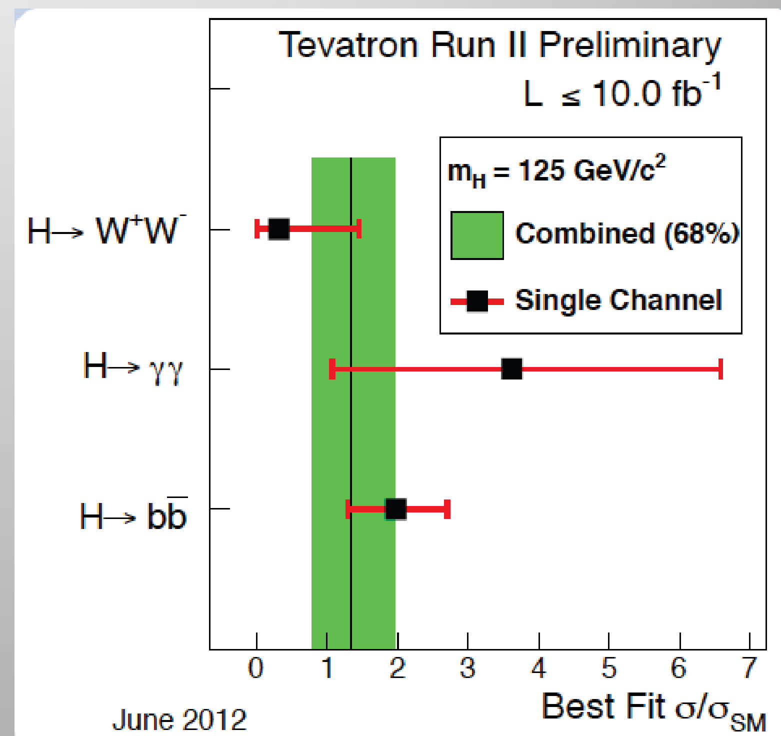


Higgs Searches at the Tevatron





Tevatron combination



But ICHEP 2012 was more…

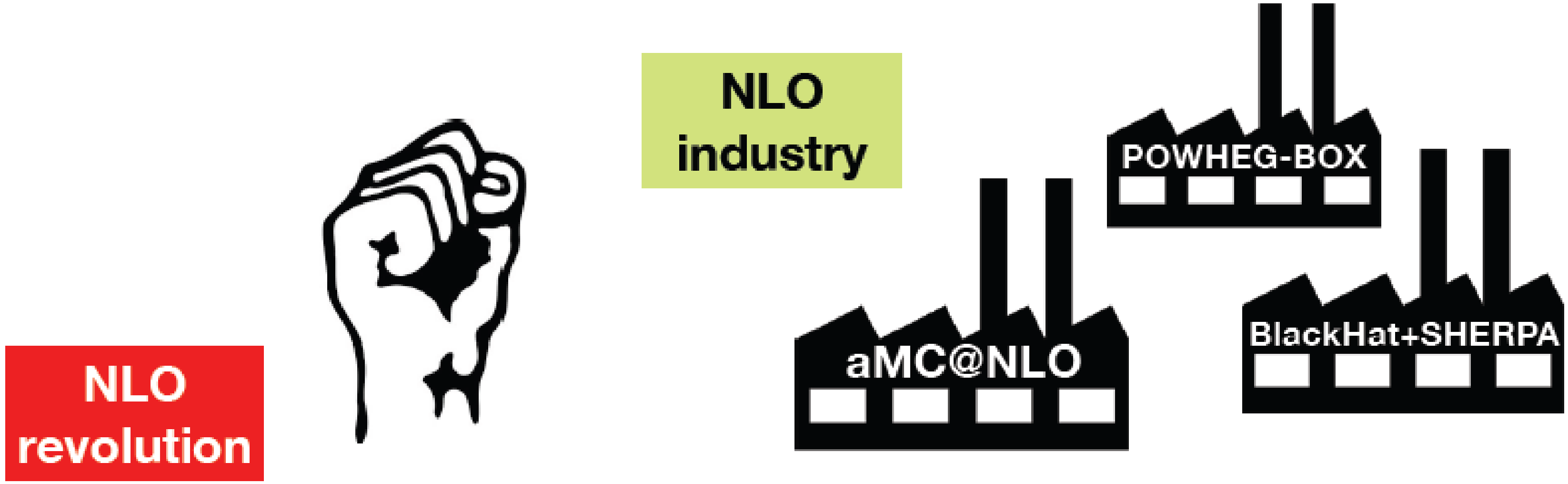
…a personal selection

QCD

The Industrial Age of NLO

J. Campbell

- In recent years, much reference to “NLO revolution”
  - development of new wave of tools in anticipation of LHC
  - especially numerical techniques: straightforward generation of new results for complicated final states
- 2011-12: time for putting these revolutionary ideas to work

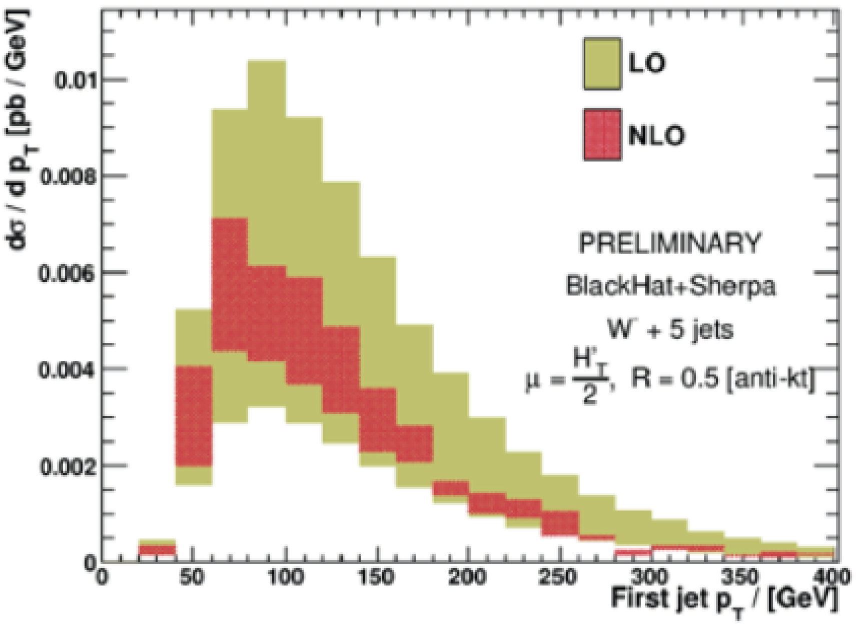


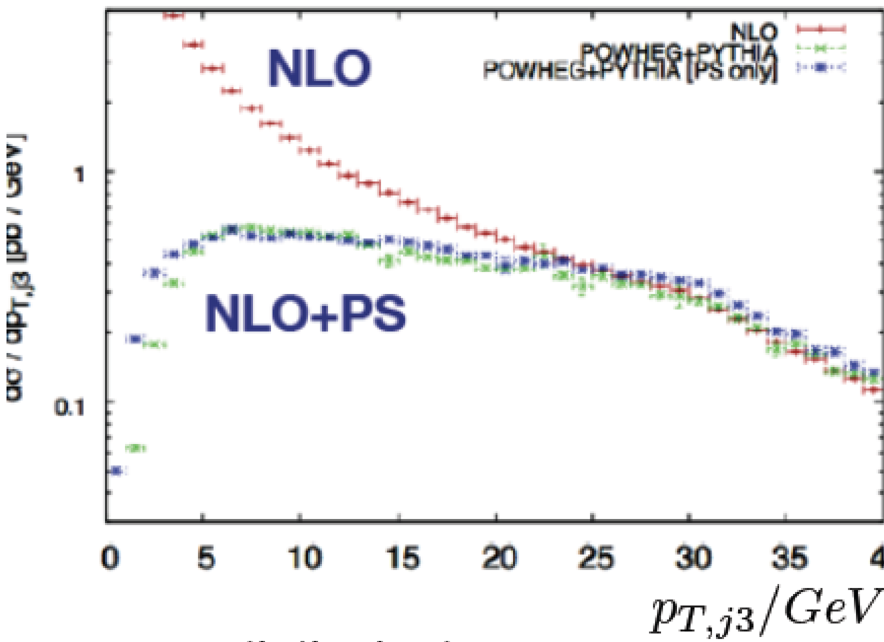
QCD

Examples

W + 5 jets at NLO

3rd jet p_T in Z+2 jets





Kosower

Alioli et al

QCD

NNLO in the pipeline

- Ingredients for fully differential NNLO
  - infrared subtraction terms

    Herzog, Gehrmann-de Ridder, Glover, Pires, Boughezal, Melnikov, Petriello, Currie, Gehrmann, Monni

  - new 2-loop amplitudes for H→3 partons and qq→Wγ,Zγ

    Gehrmann, Jaquier, Glover, Koukoutsakis, Tancredi

  - extension of unitarity methods to two loops

    Badger, Frellesvig, Zhang; Mastrolia, Ossola; Larsen, Johansson, Kosower

    → D. Kosower parallel

- Threshold resummation for W/Z/H production NNLL,NNLO.

  Becher, Bell, Marti; Gonsalves, Kidonakis

  → N. Kidonakis parallel

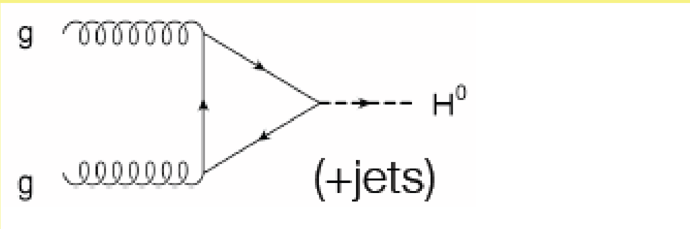
Also: full NNLO calculation for top pair production for q-qbar

QCD: Higgs Production

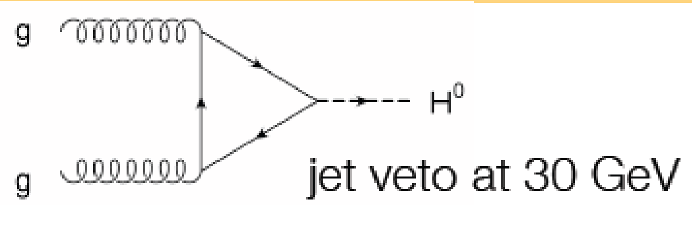
0-jet cross section uncertainty

- Most Higgs sensitivity from the 0-jet bin in gluon fusion
- Example for m_H=125 GeV

approx. uncertainty

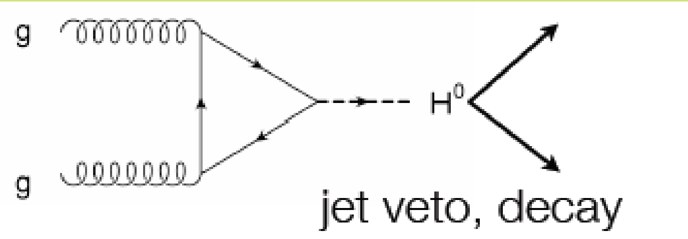


15% (scale~7%, pdf+α_s~8%)



20% (scale→11% from jet veto)

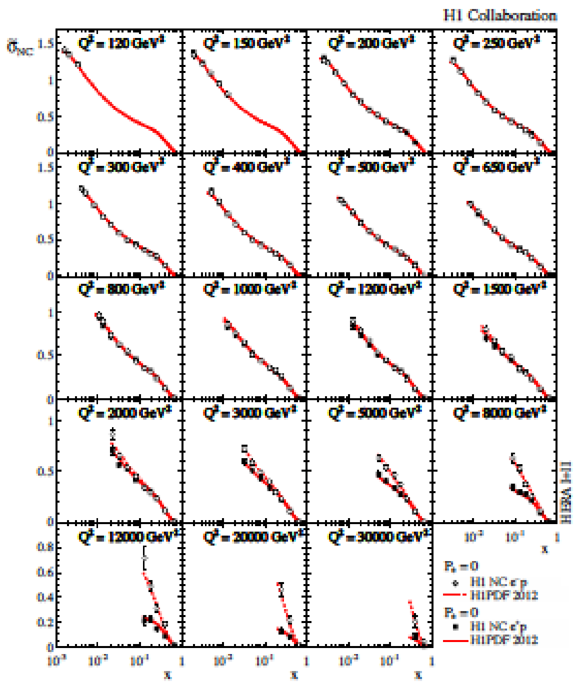
Banfi et al

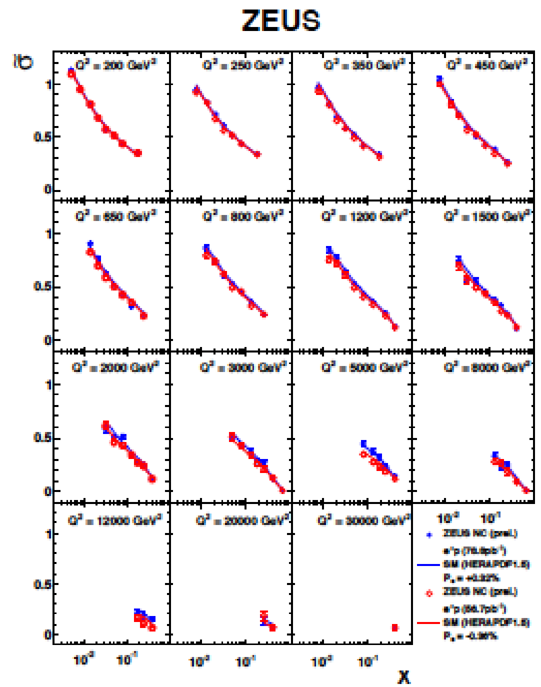


25% (BR uncertainty ~ 5%)

QCD

Towards HERAPDF2.0: ZEUS and H12012





H1 Collaboration, arXiv:1206.7007

ZEUS-prel-11-003

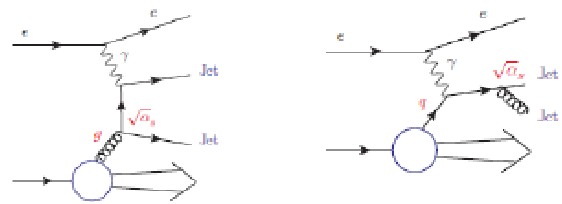
H1 measurement of CC and NC $e^{\pm}p$ cross sections based on complete HERA sample. ZEUS preliminary result for $e^{+}p$ NC cross section, last unpublished result for inclusive measurements at HERA.

LHeC: Higher energy and luminosity: “ultimate” PDFs…

QCD

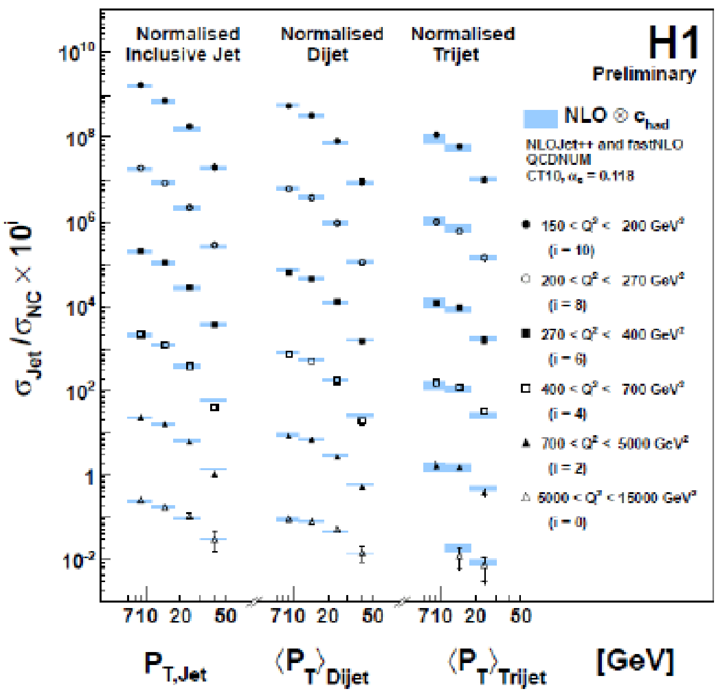
Strong coupling constant

- Inclusive jet, 2-jet, 3-jet productions
- first double-diff. 3-jet measurement at high Q^2
- data are well described by NLO
  => used to extract α_s



A. Glazov

Normalized multijet cross section



H1-Prel-12-031

Normalized inclusive jets:

$$\alpha_s(M_z)=0.1197\pm0.0008(\exp)\pm0.0014(PDF)\pm0.0011(had)\pm0.0053(theor)$$

Normalized Dijets:

$$\alpha_s(M_z)=0.1142\pm0.0010(\exp)\pm0.0016(PDF)\pm0.0009(had)\pm0.0048(theor)$$

Normalized Trijets:

$$\alpha_s(M_z)=0.1185\pm0.0018(\exp)\pm0.0013(PDF)\pm0.0016(had)\pm0.0042(theor)$$

Simultaneous fit to cross-section measurements (42 points):

$$\alpha_s(M_z)=0.1163\pm0.0011(\exp)\pm0.0042(theor)$$

Uncertainties: ±0.9% (exp), ±1.2% (PDFs), ±0.7% (hadr), ±3.4% (HO), ±3.8% (total)

Theor. uncertainties are dominating

18

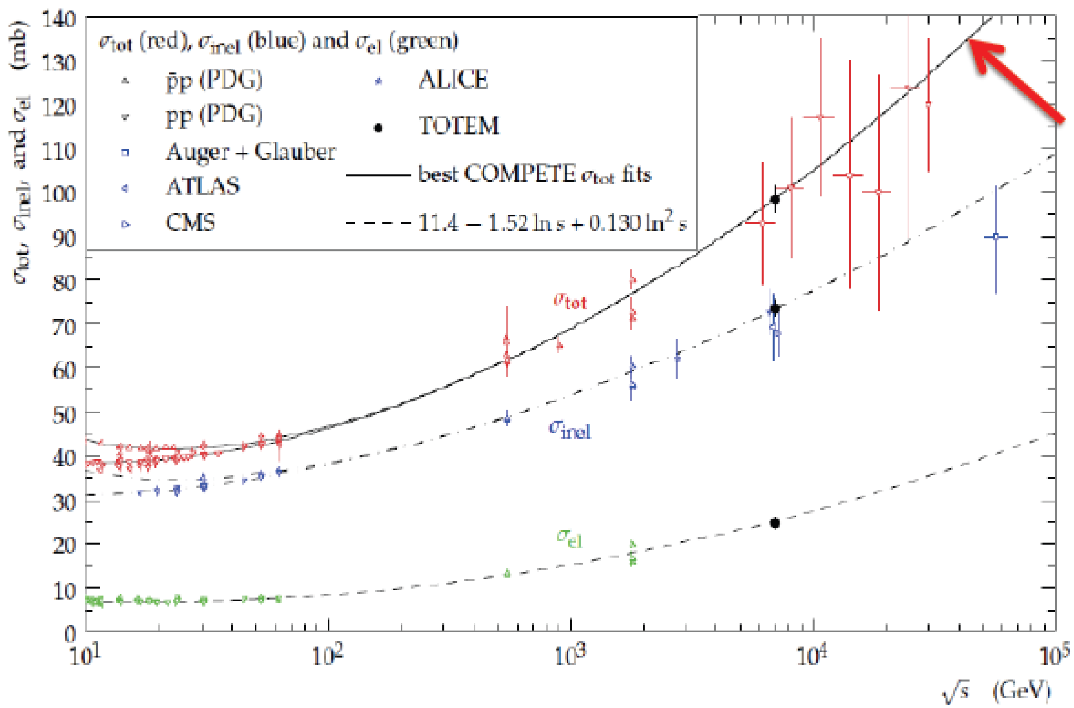
Also still producing high precision results on the proton structure

Soft QCD and Forward Physics

Totem Total (and Elastic) Cross Section

$$\sigma_{el} = \left(24.8 \pm 0.2^{(stat)} \pm 1.2^{(syst)}\right)\text{mb} \quad \sigma_T = \left(98.3 \pm 0.2^{(stat)} \pm 2.7^{(syst)} \left[{}^{+0.8}_{-0.2}\right]^{(syst\ from\ \rho)}\right)\text{mb}$$

P. Newman



Consistent with fits to previous data (leading $\ln^2 s$ dependence, satisfying Froissart unitarity bound)

Inferred total inelastic cross section consistent with ATLAS, CMS and ALICE min-bias measurements (luminosity monitoring)

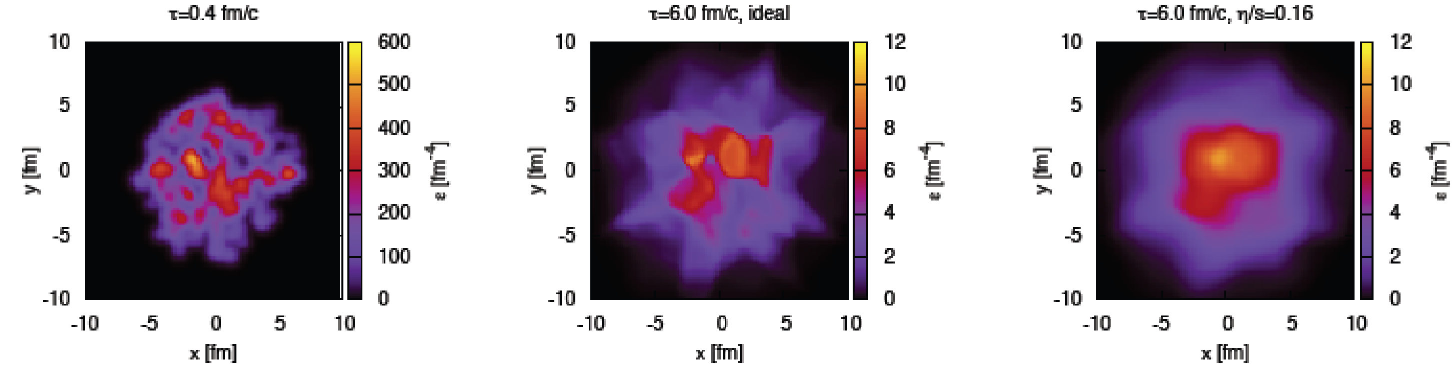
+ lots of forward physics, underlying event, multiple scattering

Heavy Ions

J. Stachel
C. Salgado Lopez

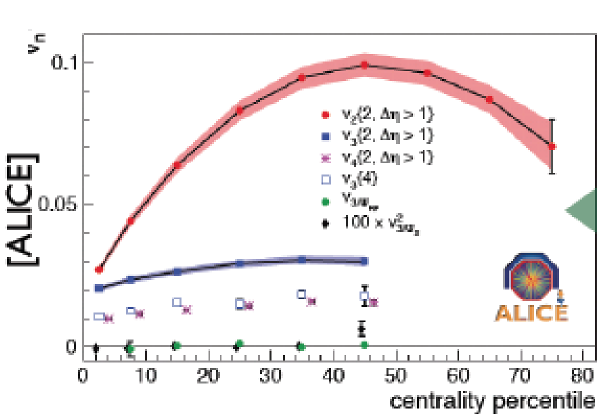
Higher harmonics v_n [talks M. Nyatha (ALICE), E. Duchovni (ATLAS) and S. Padula (CMS)]

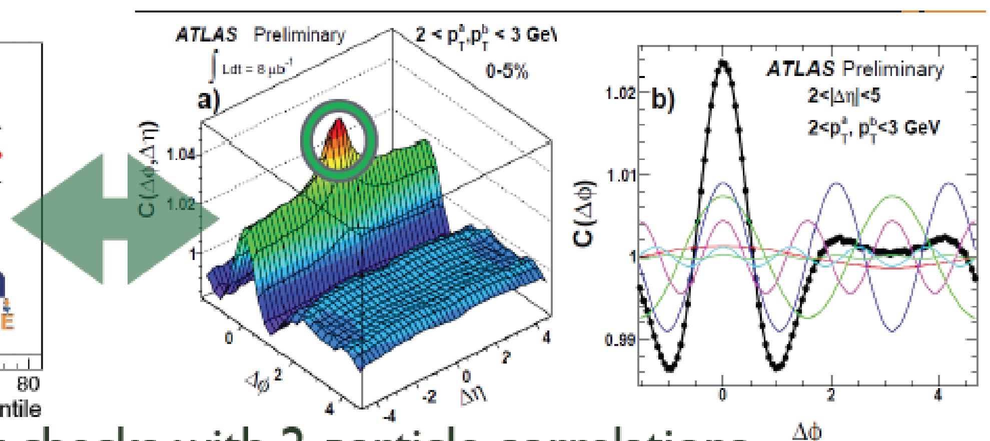
⇒ Fluctuations in initial conditions show-up in higher harmonics



[Schenke, Jeon, Gale 2010]

Precise tests of hydro: constraints to viscosity





Consistency checks with 2-particle correlations

Heavy Ions

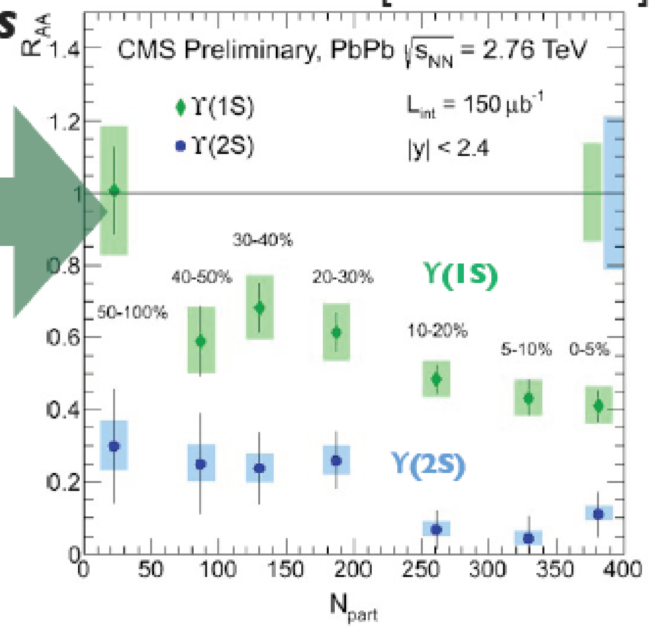
Quarkonia at the LHC

[talk N. Leonardo]

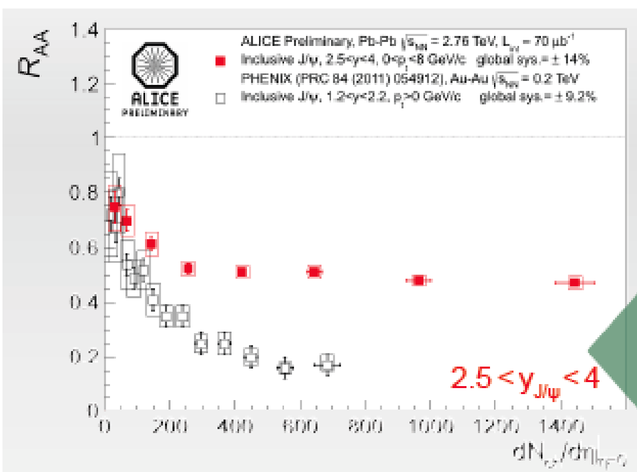
Larger suppression of excited states

$$\frac{\Upsilon(2S)/\Upsilon(1S)|_{PbPb}}{\Upsilon(2S)/\Upsilon(1S)|_{pp}} = 0.21 \pm 0.07 \pm 0.02$$

$$\frac{\Upsilon(3S)/\Upsilon(1S)|_{PbPb}}{\Upsilon(3S)/\Upsilon(1S)|_{pp}} < 0.17 \quad (95\%\ \text{C.L.})$$



Sequential suppression (lattice)?



J/Psi less suppressed at the LHC than at RHIC?

Recombination?

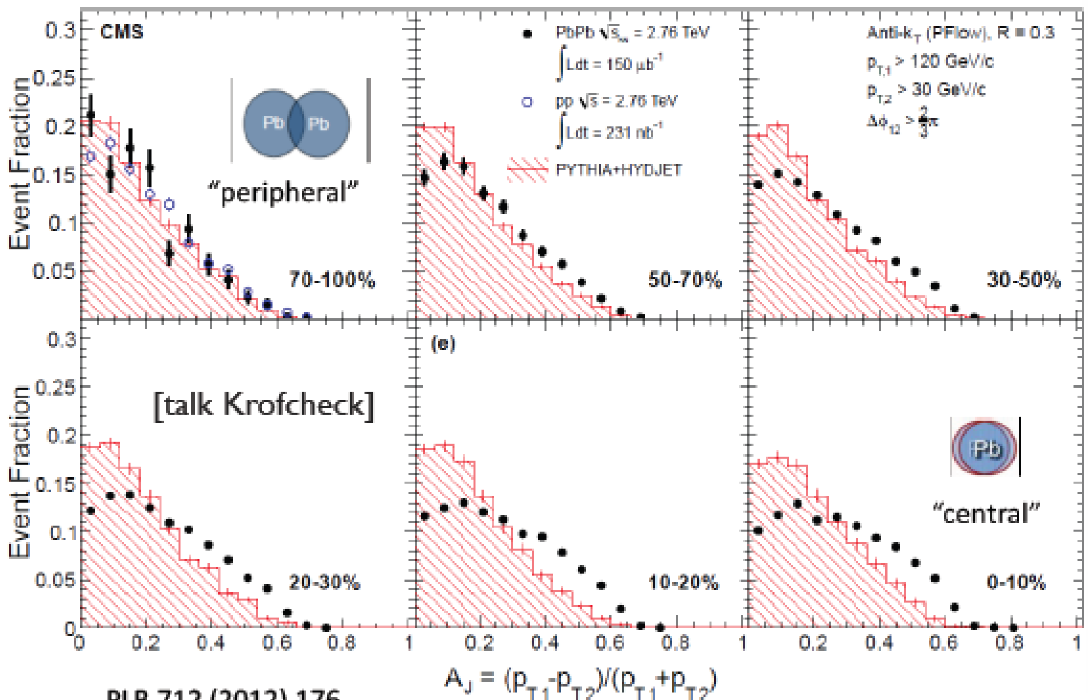
A clearer picture is emerging, pPb data essential

[talk J-P Lansberg]

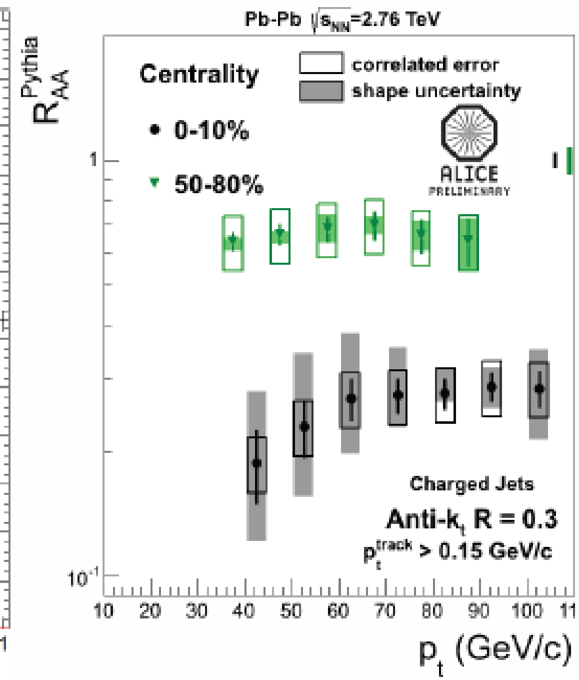
Heavy Ions

Di-jet asymmetry at the LHC

- Energy imbalance indicates **strong energy loss** $A_j = \frac{E_{T1} - E_{T2}}{E_{T1} + E_{T2}}$



PLB 712 (2012) 176



[ALICE - M.Verweij, HP2012]

- Reconstructed jet measurements **sensitive to broadening**
- Jets are suppressed: **Studied sample is a subset of the total**

Heavy Ions

Summary

With LHC new era also for nuclear collisions: TeV's

- *Access to the small-x and large virtualities jets, EW bosons, HQ ...*
- *New theoretical tools (evolution equations, in-medium jet evolution)*
- *New RHIC data important for the complete picture*

Created medium (RHIC+LHC) very dense ideal fluid

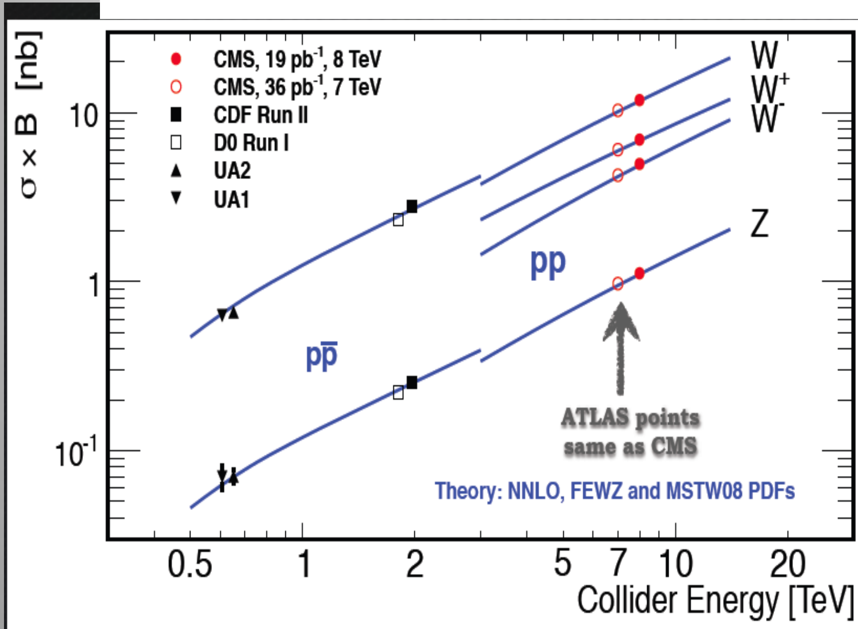
- *Very small viscosity - difficult to reconcile with weak-coupling*
- *Very large energy loss*
- *Jet measurements to characterize the medium parameters*
- *Knowledge on initial conditions essential : next pPb run*

Is it a liquid? Strongly coupled? Are quasiparticles the relevant d.o.f.? Mechanism of thermalization?

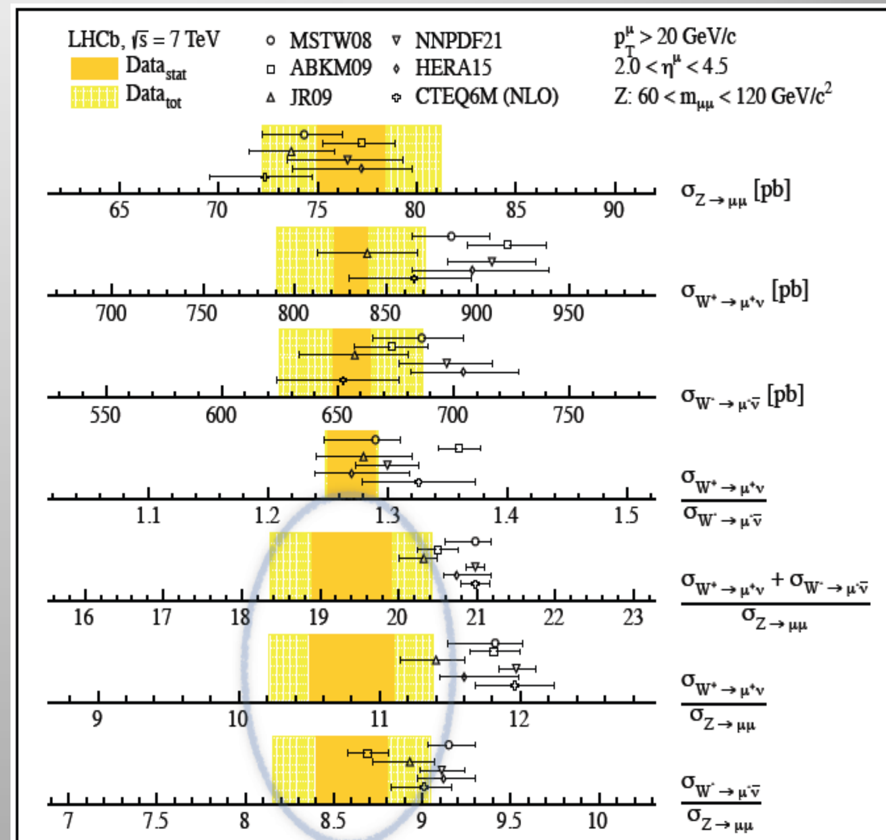
EWK: W/Z bosons

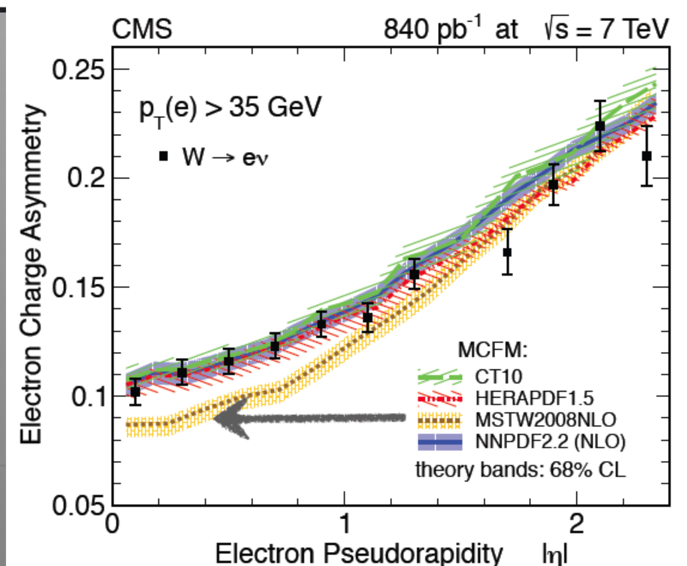
J. Barreiro Guimaraes da Costa

W cross sections at 7 and 8 TeV



W/Z cross sections in LHCb



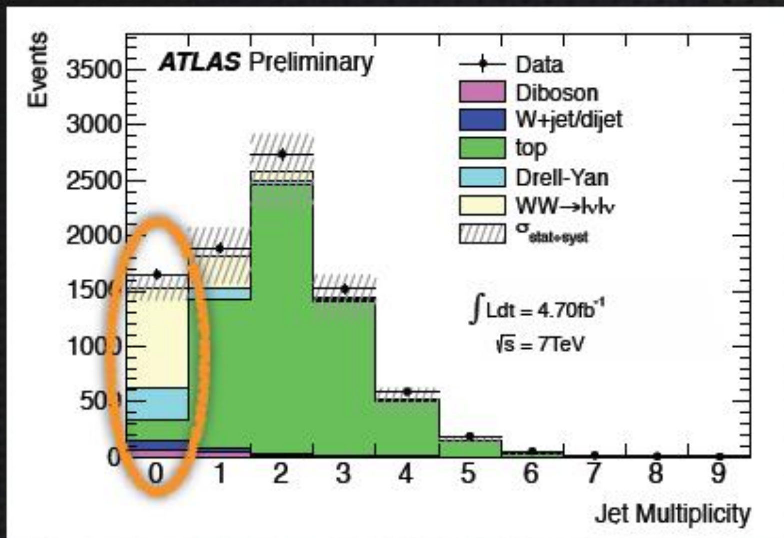


W charge asymmetries and PDFs

EWK: WW Boson Production

ATLAS-CONF-2012-025

$\sqrt{s} = 7$ TeV



ATLAS:

$\sigma = 53.4 \pm 2.1 \pm 4.5 \pm 2.1$ pb

CMS:

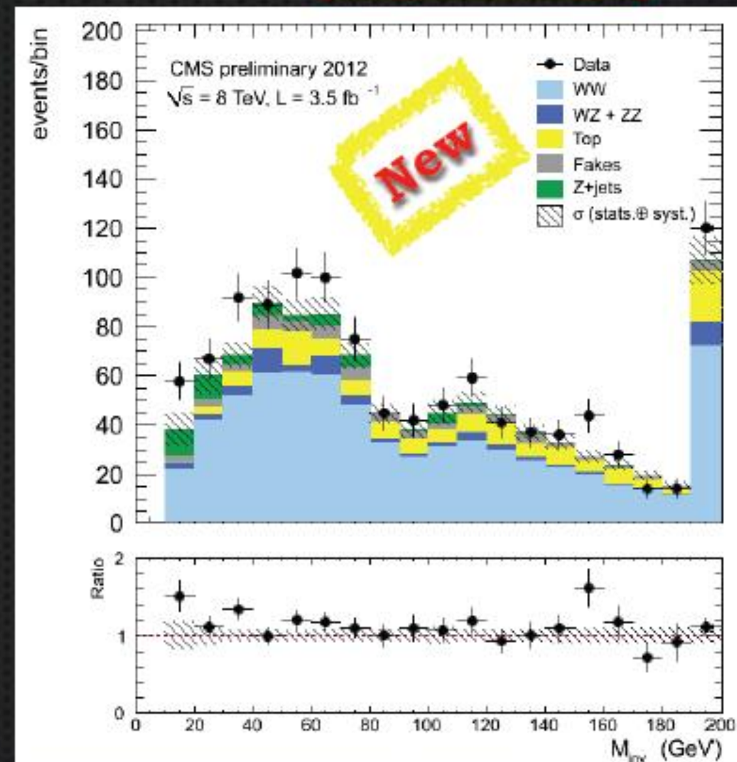
$\sigma = 52.4 \pm 2.0 \pm 4.5 \pm 1.2$ pb

Theory:

$\sigma = 45.1 \pm 2.8$ pb

CMS PAS SMP-12-013

$\sqrt{s} = 8$ TeV



CMS:

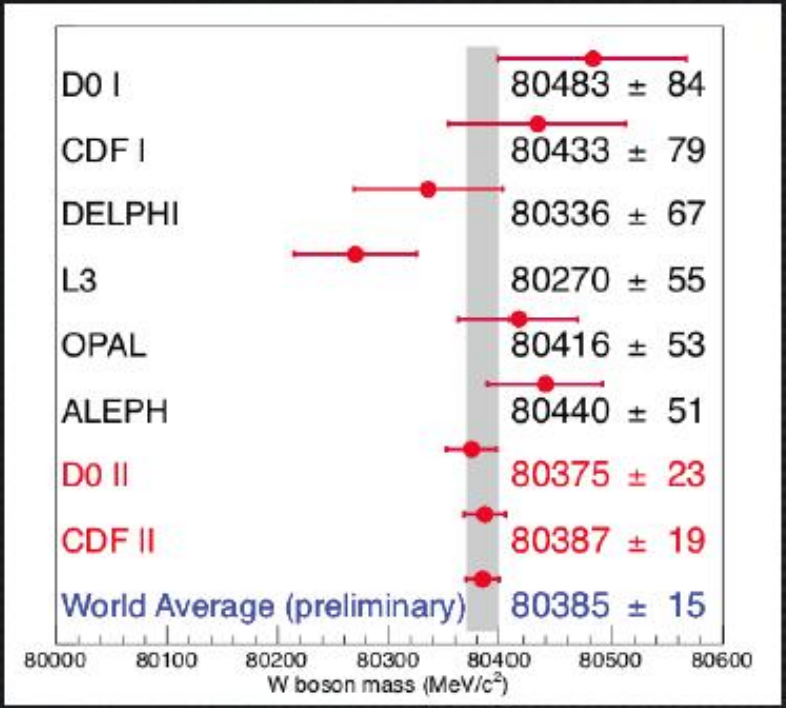
$\sigma = 69.9 \pm 2.8 \pm 5.6 \pm 3.1$ pb

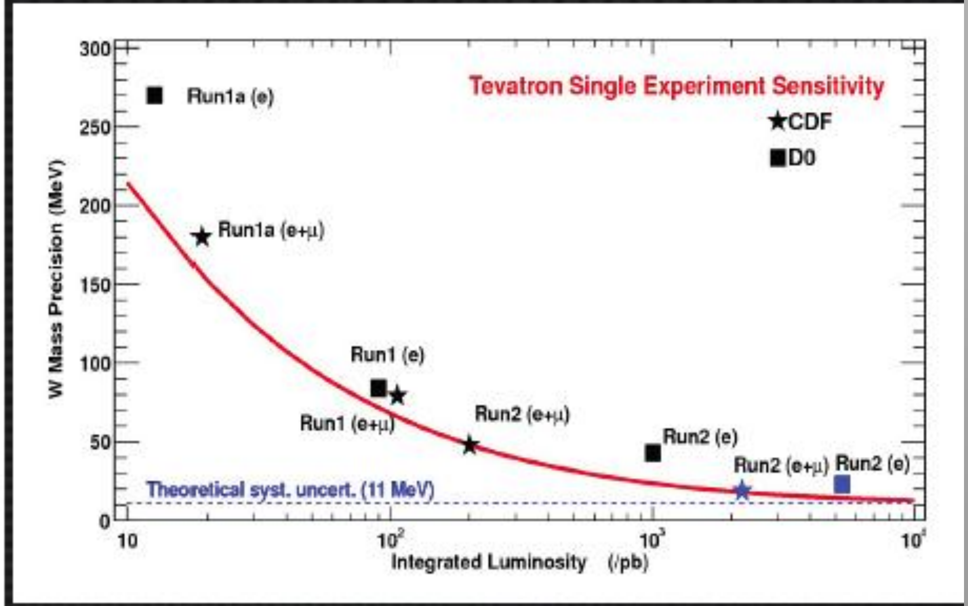
Theory:

$\sigma = 57.3^{+2.4}_{-1.6}$ pb

Measured cross section about 2σ larger than theory prediction… to be watched

W mass measurement at the Tevatron





Dominant uncertainties:

Parton distribution functions: 10-14 MeV

Lepton calibration: 16 MeV (D0) / 5 MeV (CDF)

Improvements still to come

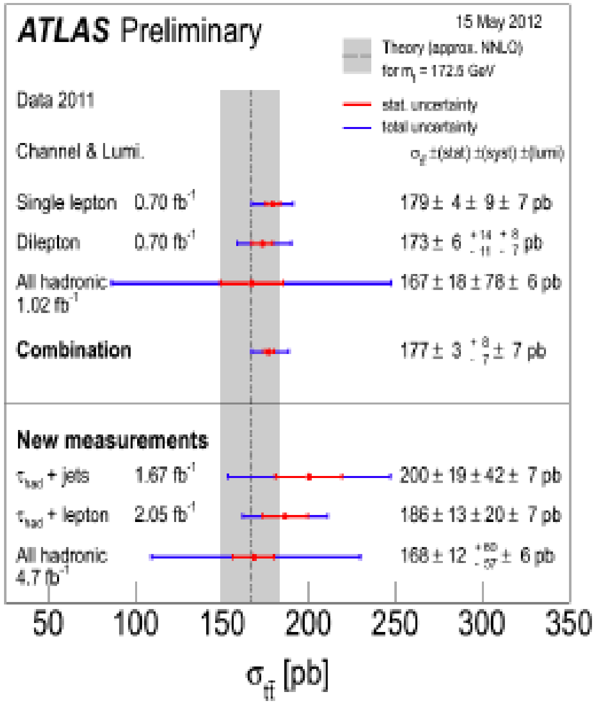
More than double statistics with full run II dataset

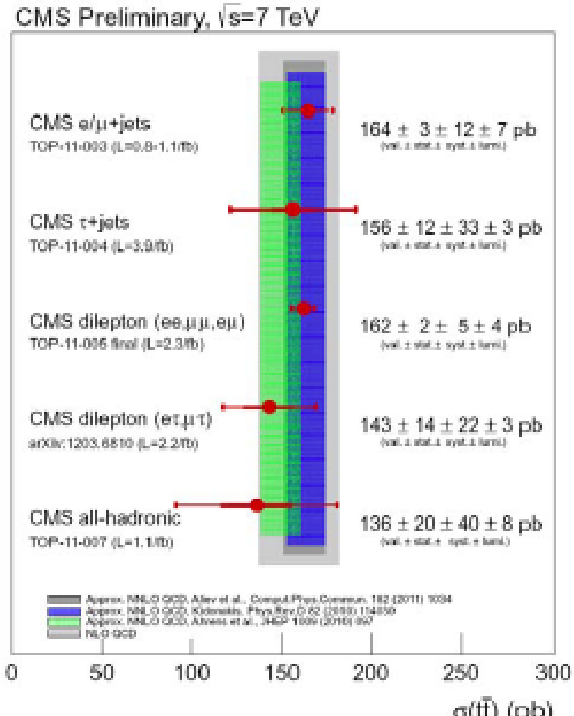
Top quark pair cross section

T. Muller

ATLAS (ATLAS-CONF-2012-024)

- Combination done as product of the individual likelihoods of each channel
- σ = 177 ± 3 (stat) ± 7 (syst.) ± 7 (lum.) pb





CMS (CMS-PAS-TOP-11-024)

- Combination done using a binned maximum likelihood fit
- σ = 165.8 ± 2.2(stat) ± 10.6(syst.) ± 7.8(lum.)pb

Results are compatible with NNLO calculations

Top quark asymmetry

R. Barbieri

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)
$A_l = (6.6 \pm 2.5)\%$	$A_l = (11.8 \pm 3.2)\%$	$A_l = (4 \pm ??)\%$

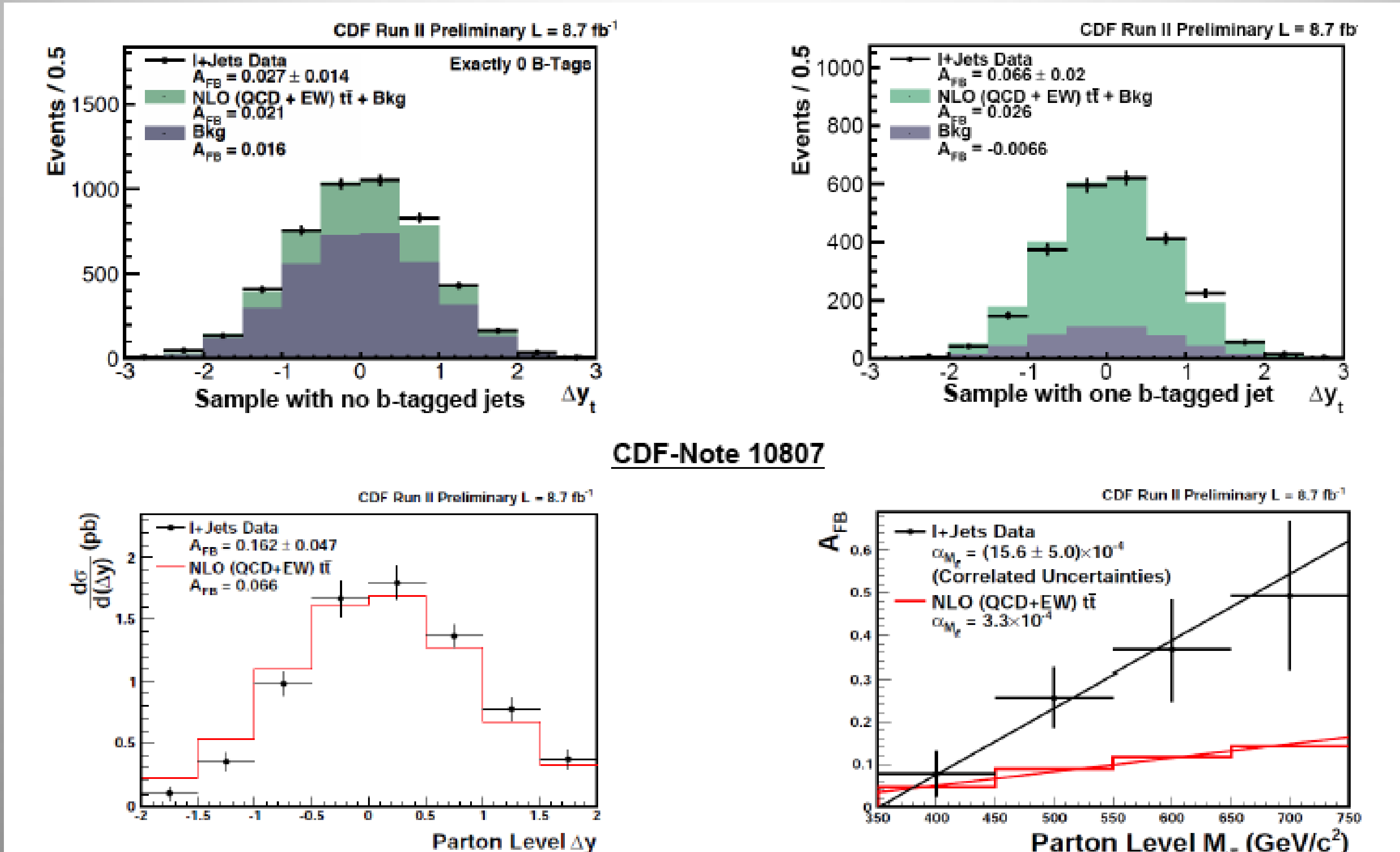
Questions:

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?

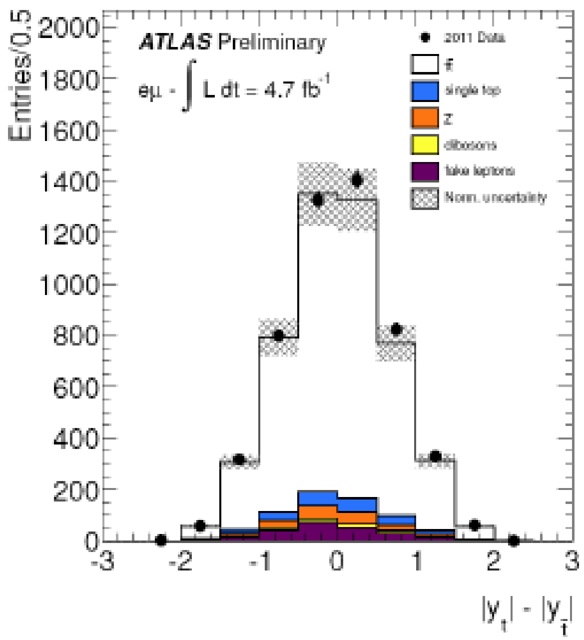
Top quark asymmetry



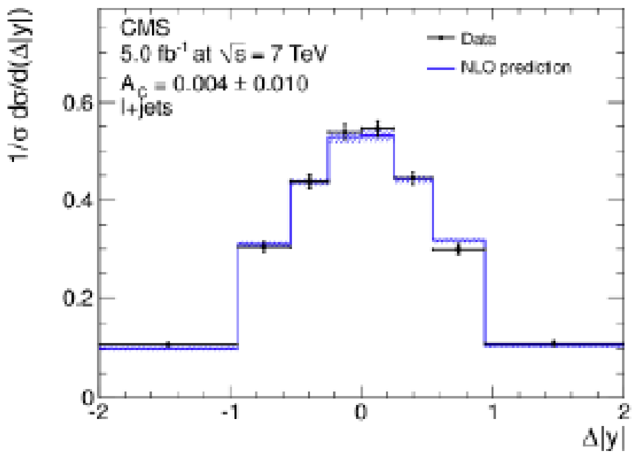
A_{FB} = 0.162 ± 0.041(stat) ± 0.022 (syst)

Status still like in 2011: data and NLO calculation still in disagreement 2-3σ

Top quark asymmetry



ATLAS-CONF-2012-057



CMS PAPER TOP-11-030

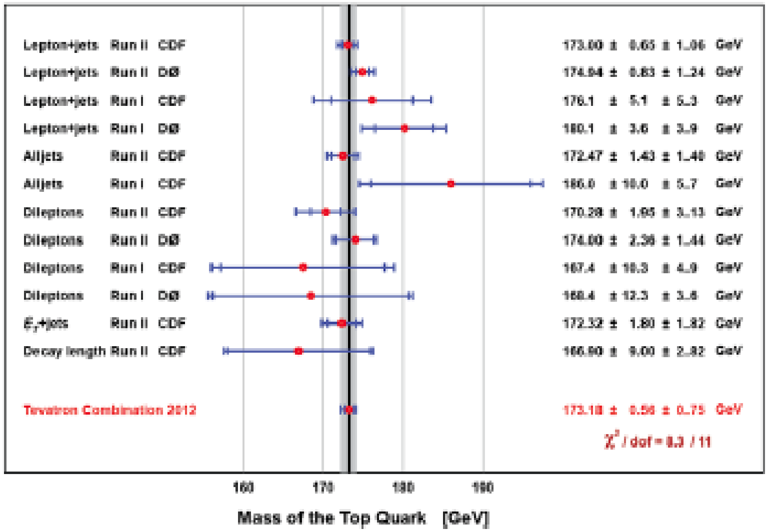
Diluted effect @ LHC
High precision will be needed

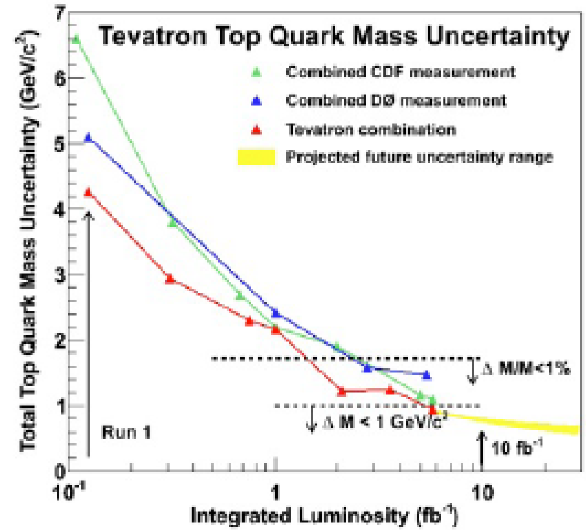
- ATLAS: A_C = 0.029 +- 0.018 (stat.) +- 0.014 (syst.)
- CMS: Corrected: A_C = 0.004 +- 0.010 (stat.) +- 0.011 (syst.)

- Theory (Kühn, Rodrigo): A_c = 0.0115 +- 0.0006

Top quark mass

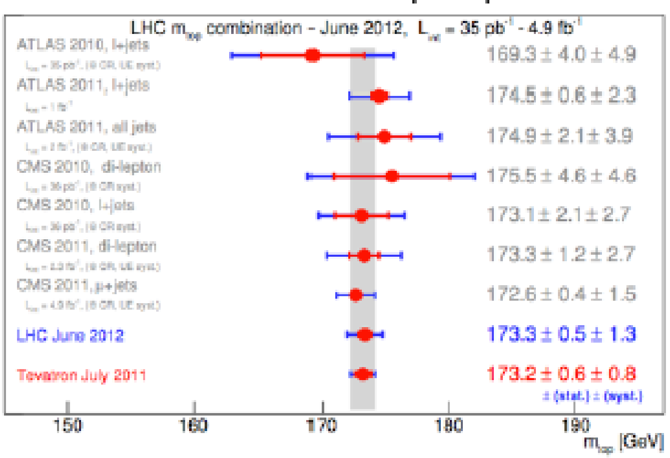
– Tevatron combination and perspectives





Expect to reach precision of 0.7-0.8 GeV

– LHC combination and perspectives



TeV: $$m_t^{comb} = 173.18 \pm 0.56\,(\mathrm{stat}) \pm 0.75\,(\mathrm{syst})\ \ \mathrm{GeV}$$
$$= 173.18 \pm 0.94\ \mathrm{GeV}$$

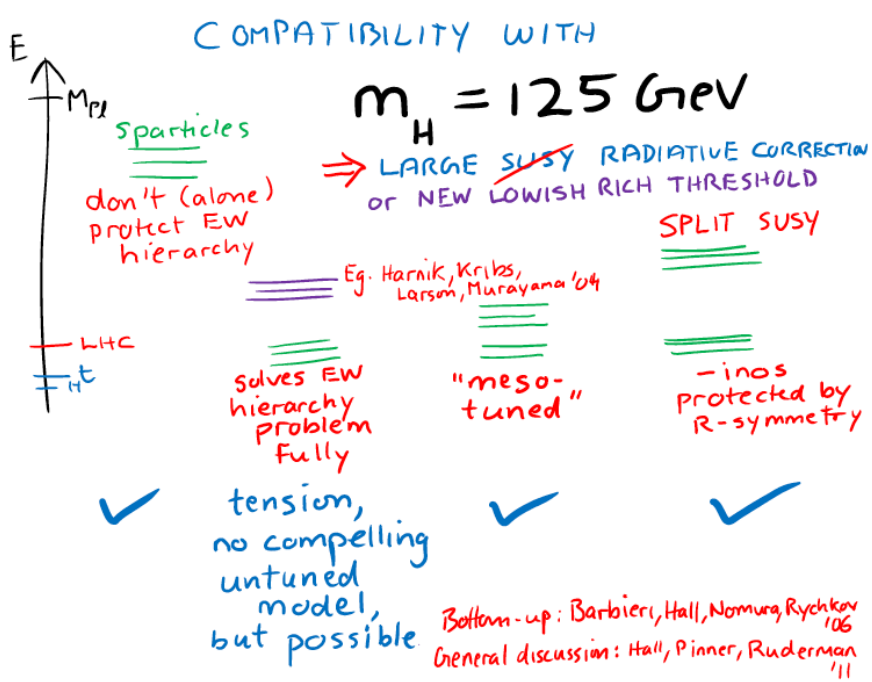
LHC: $$m_{top} = 173.3 \pm 0.5\,(\mathrm{stat}) \pm 1.3\,(\mathrm{syst})\ \ \mathrm{GeV}$$
$$= 173.3 \pm 1.4\ \mathrm{GeV}$$

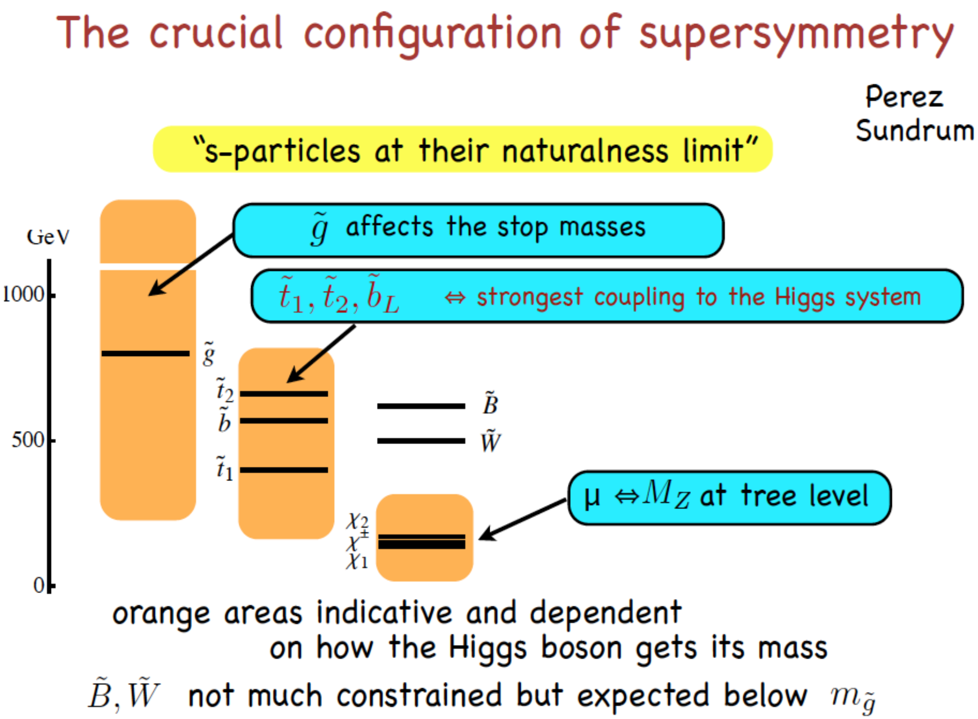
ATLAS-CONF-2012-095

CMS PAS TOP-12-001

Supersymmetry

Where is SUSY?





Importance of the partners of the third generation: stops and bottoms
…Other scenarios, such as compressed spectra, multi-top production…

Supersymmetry: Third Generation

A Parker

ATLAS: $\tilde{g} \to \tilde{t}\ ,\tilde{b}$

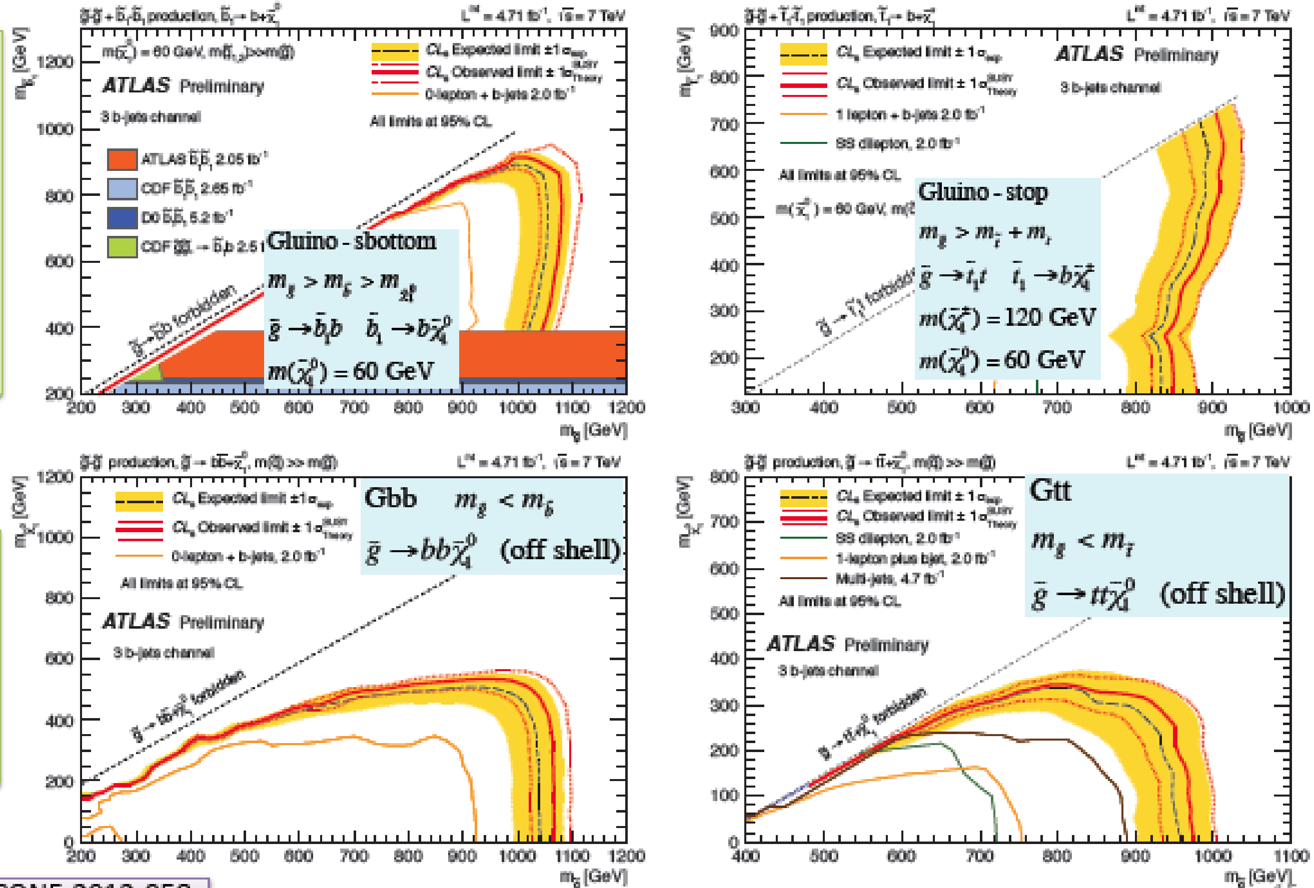
Limits on gluino mass ~1 TeV

4-6 jets (≥3 b-jets), no leptons.

Allowed decays depend on masses

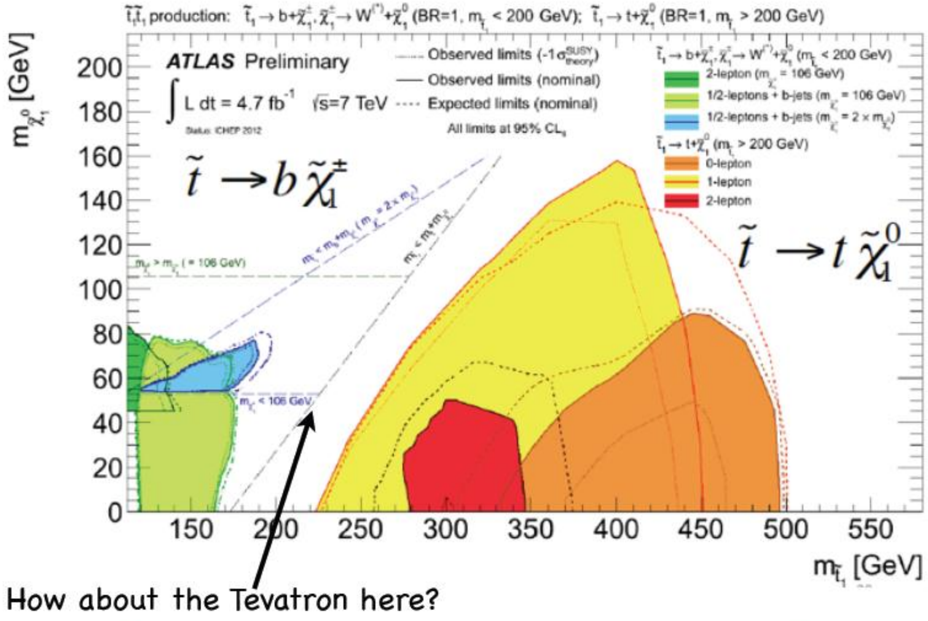
Upper plots – 2-body cascade decays

Lower plots – 3-body decays

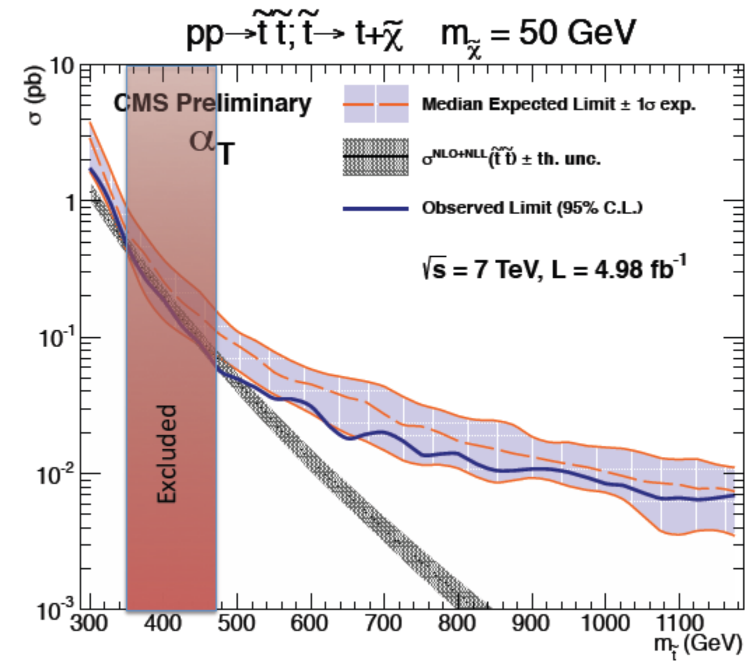


ATLAS-CONF-2012-058

Supersymmetry: third generation



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



Third generation studies reach 500 GeV for the stop exclusion

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

Collider searches for new physics

BSM SEARCHES @ LHC – NEW RESULTS

Heavy Resonance, Leptons

TeV-scale gravity l+j arXiv:1204.4646

Resonant WZ → lvll arXiv:1204.1648

b' to Zb ATLAS arXiv:1204.1265

Like-sign leptons ATLAS-CONF-2012-069

Z' to ττ ATLAS-CONF-2012-067

WW to lvlv ATLAS-CONF-2012-068

Monophoton ATLAS-CONF-2012-085

W' ATLAS-CONF-2012-086

Diphoton ATLAS-CONF-2012-087

μμ contact interact. CMS EXO-11-009

Boosted Z to μμ CMS EXO-11-025

e* CMS EXO-11-033

μ* CMS EXO-11-034

ADD in ee CMS EXO-12-013

Jet-based Searches

Monojet ATLAS-CONF-2012-084

b-jet resonances CMS EXO-11-008

Three-jet resonance CMS EXO-11-060

Dijet resonances CMS EXO-11-094

Boosted VV, Vjet CMS EXO-11-095

Lepton + Jets

LQ1 (eejj + evjj) CMS EXO-11-027

LQ2 (μμjj + μvjj) CMS EXO-11-028

Heavy Majorana N to ll EXO-11-076

VZ to l+jets CMS EXO-11-081

Heavy neutrino to μμjj EXO-11-091

RS Graviton in ZZ(2l2q) EXO-11-102

LQ3 -> τ+b CMS EXO-12-002

Long-Lived

Monopole ATLAS-CONF-2012-062

SUSY R-Hadron ATLAS-CONF-2012-075

Displaced μ jets ATLAS-CONF-2012-089

Non prompt lepton jets in HV decays ATLAS-CONF-2012-110

Stopped HSCP CMS EXO-11-020

Displaced photons CMS EXO-11-035

Fractionally charged CMS EXO-11-074

Multiply charged CMS EXO-11-090

Long-lived to displaced lep EXO-11-101

Top, 4th Gen and Boosted

Z' to ttbar l+j ATLAS arXiv:1205.5371

Z' to ttbar l+j boosted ATLAS-TOPQ-2011-23

t+b resonance ATLAS arXiv:1205.1016

t+j resonance ATLAS-CONF-2012-096

W' to top pair + jet CMS EXO-11-056

B to bZ CMS EXO-11-066

Z' to ttbar in l+jets CMS EXO-11-093

b'/t' inclusive CMS EXO-11-098

W' to tb CMS EXO-12-001

8 TeV Searches

Dijet 8 TeV ATLAS-CONF-2012-088

Black holes in 8 TeV CMS EXO-12-009

W' in 8 TeV CMS EXO-12-010

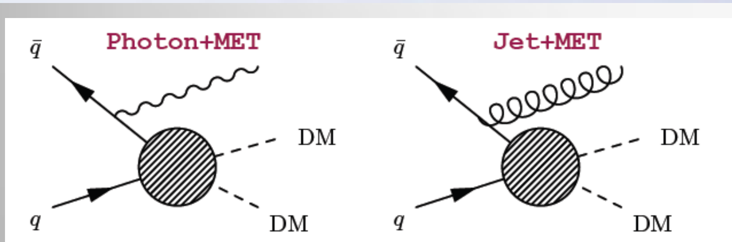
Z' in 8 TeV CMS EXO-12-015

Dijet in 8 TeV CMS EXO-12-016

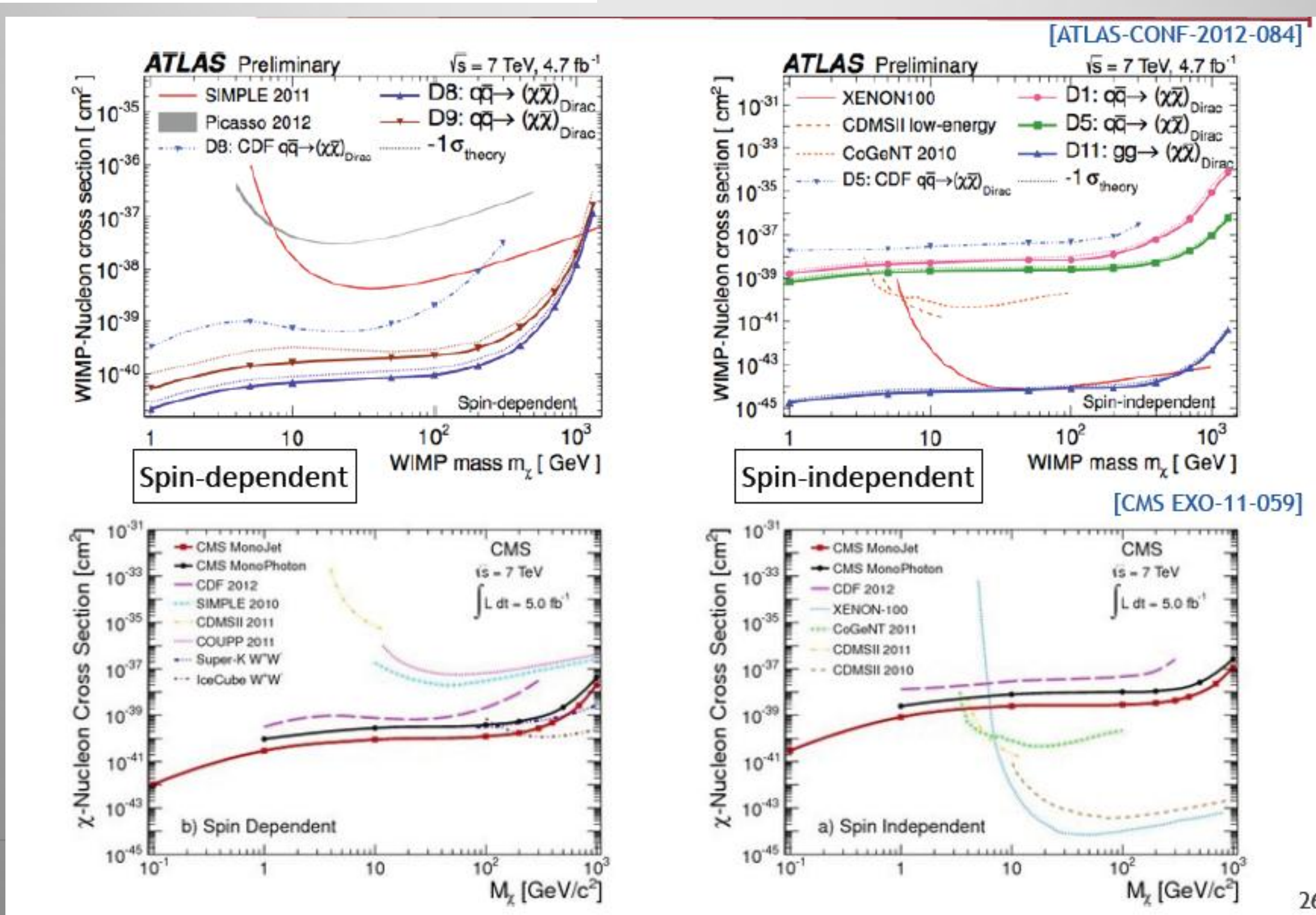
Heavy neutrino 8 TeV EXO-12-017

50 brand-new results since Moriond!

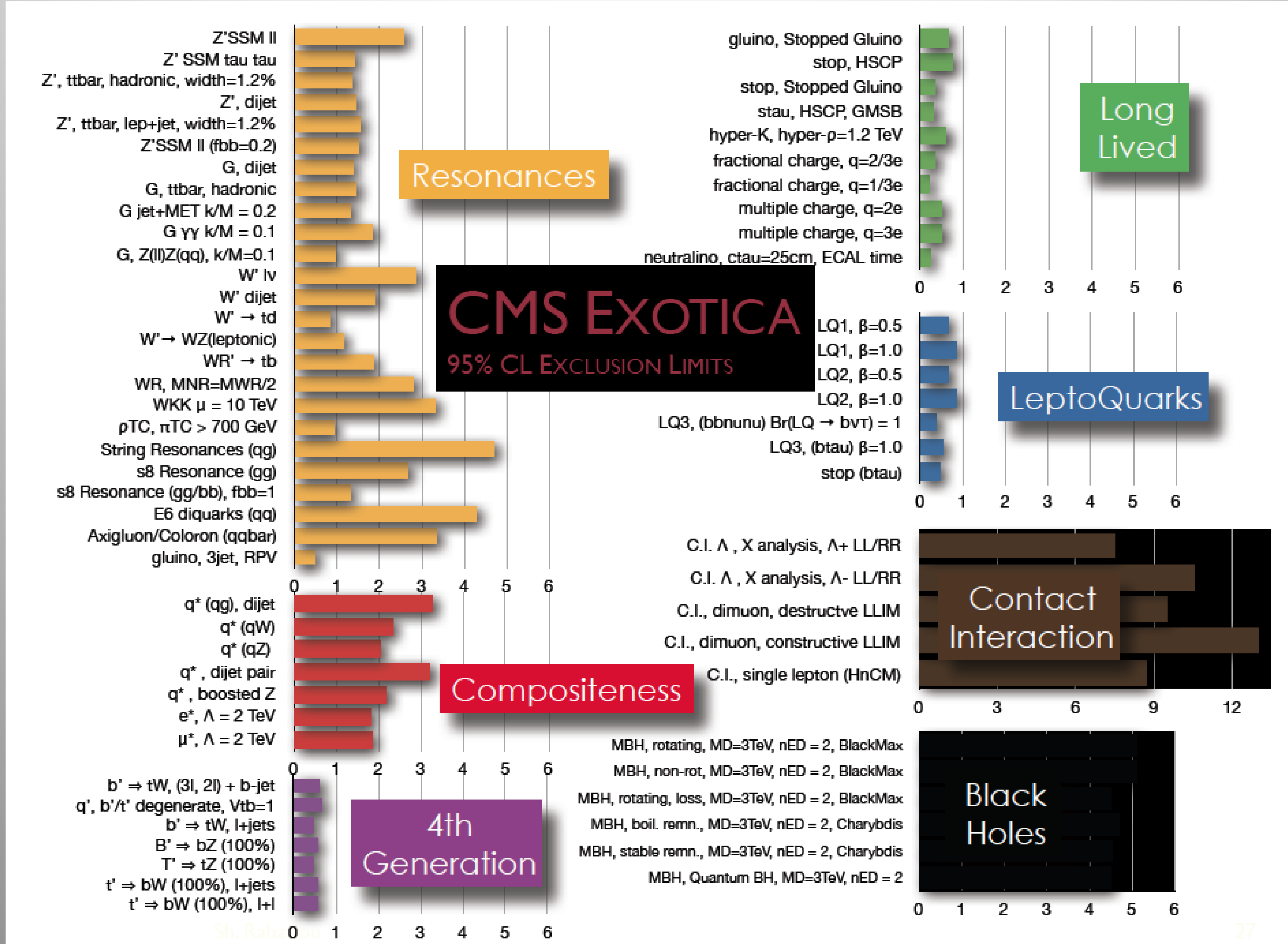
Collider: Direct Dark Matter Production



Monojet and monophoton studies can be used as Dark Matter Searches



Collider Searches Summary



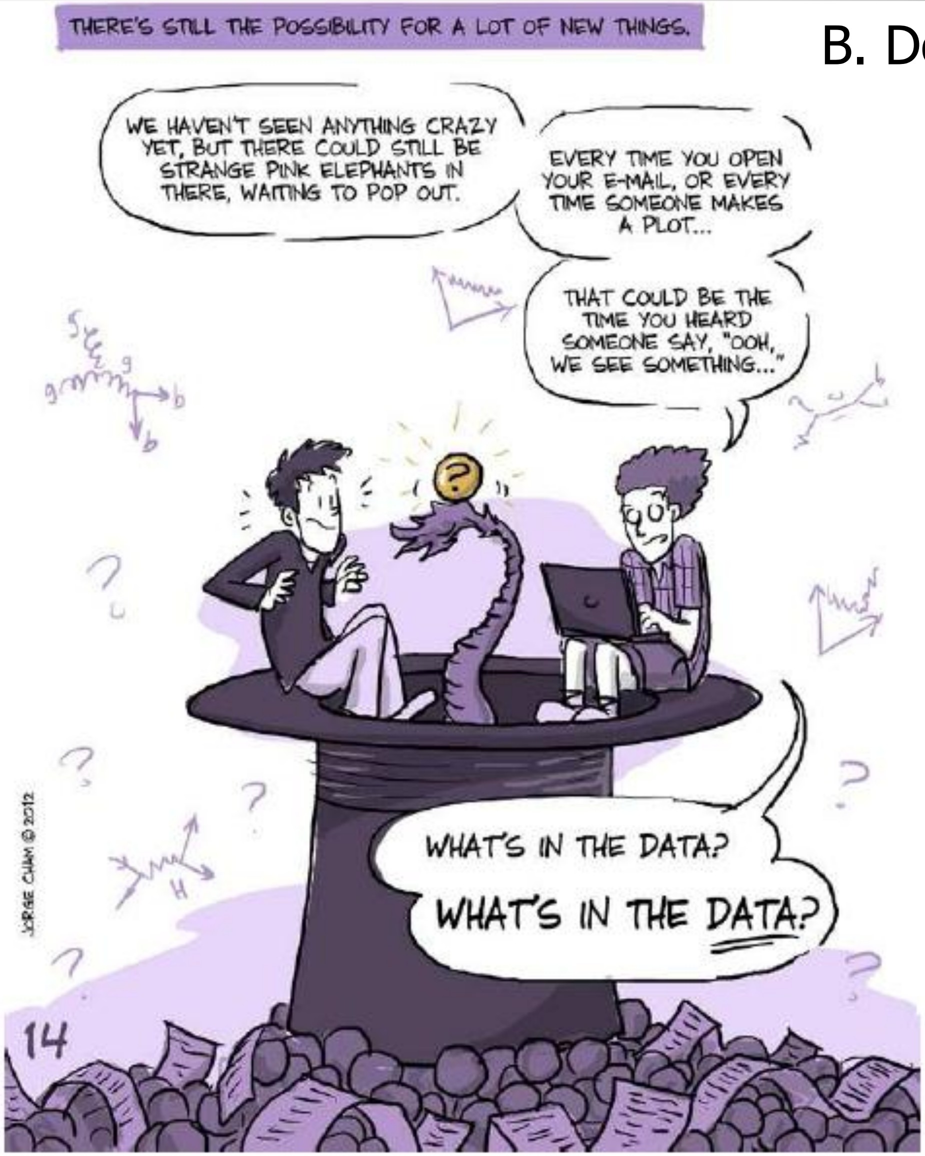
Similar figure exists for ATLAS

Unsolved puzzles

B. Dobrescu

Various unsolved puzzles:

- $jj + W$ excess – CDF
- $A_{FB}^{t\bar{t}}$ – D0 & CDF
- $\mu^{\pm}\mu^{\pm}$ asymmetry – D0
- Cosmic γ line @ 130 GeV
  talk by J. Wacker
- Muon $g - 2$
- MiniBoone low energy data
- $B \to D^{(*)}\tau\nu$ – BaBar
- CPV in D decays – LHCb
- $(bb)b$ final state – CDF & D0
- ...



Theorist view

phdcomics.com/higgs

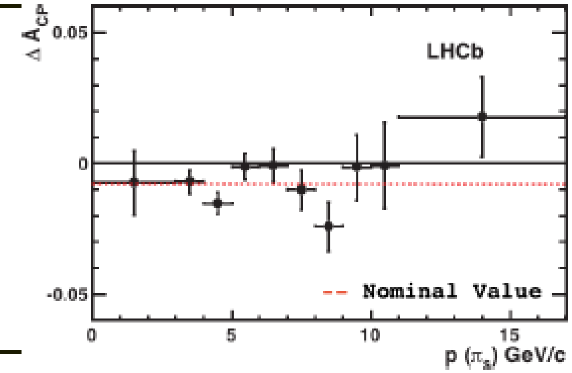
Flavor Physics

Direct CPV in $D^0 \to K^+K^-$ and $\pi^+\pi^-$

Garra Tico
Tonelli
Ko

$\Delta A_{cp} = A_{cp}(D^0 \to K^+K^-) - A_{cp}(D^0 \to \pi^+\pi^-)$ [%]

LHCb	$-0.82 \pm 0.21 \pm 0.11$	PRL2012
CDF	$-0.62 \pm 0.21 \pm 0.10$	charm2012
BaBar	(see below)	PRD2011
Belle	$-0.87 \pm 0.41 \pm 0.06$	ICHEP2012
WA	-0.678 ± 0.147 (>4σ)	HFAG2012



CDF ($p\bar{p}$): $A_{raw}(f) = A_{cp}(f) + A_D(\pi_s)$ [slow pion detection]

LHCb (pp): $A_{raw}(f) = A_{cp}(f) + A_D(\pi_s) + A_P(D^{*+})$ [production]

Belle (e^+e^-): $A_{raw}(f) = A_{cp}(f) + A_D(\pi_s) + A_{FB}(D)$ [forward-backward]

($B \to D$ has to be removed to avoid CPV in B decays in many analysis)

Individual A_{CP} are not significant

	$A_{cp}(D^0 \to K^+K^-)$ [%]	$A_{cp}(D^0 \to \pi^+\pi^-)$ [%]
CDF	$-0.24 \pm 0.22 \pm 0.09$	$+0.22 \pm 0.24 \pm 0.11$
BaBar	$0.00 \pm 0.34 \pm 0.13$	$-0.24 \pm 0.52 \pm 0.22$
Belle	$-0.32 \pm 0.21 \pm 0.09$	$+0.55 \pm 0.36 \pm 0.09$

Need to search for A_{CP} in other modes

Flavor Physics

Evidence for an excess of $\overline{B} \to D^{(*)}\tau^-\overline{\nu}_\tau$ decays

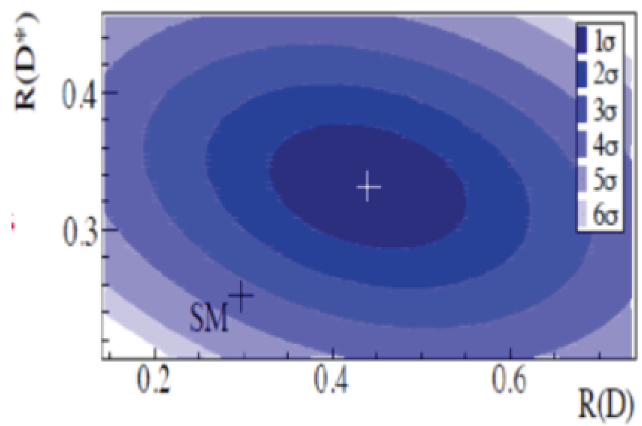
M.Nakao

A very recent flavour "problem"

Stone

	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

De Nardo

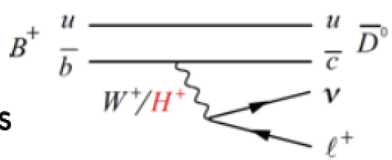


Combinination yields
χ^2 / n.d.o.f. = 14.6/2
(probability: 6.9 × 10^{-4})
3.4σ away from SM

Note:

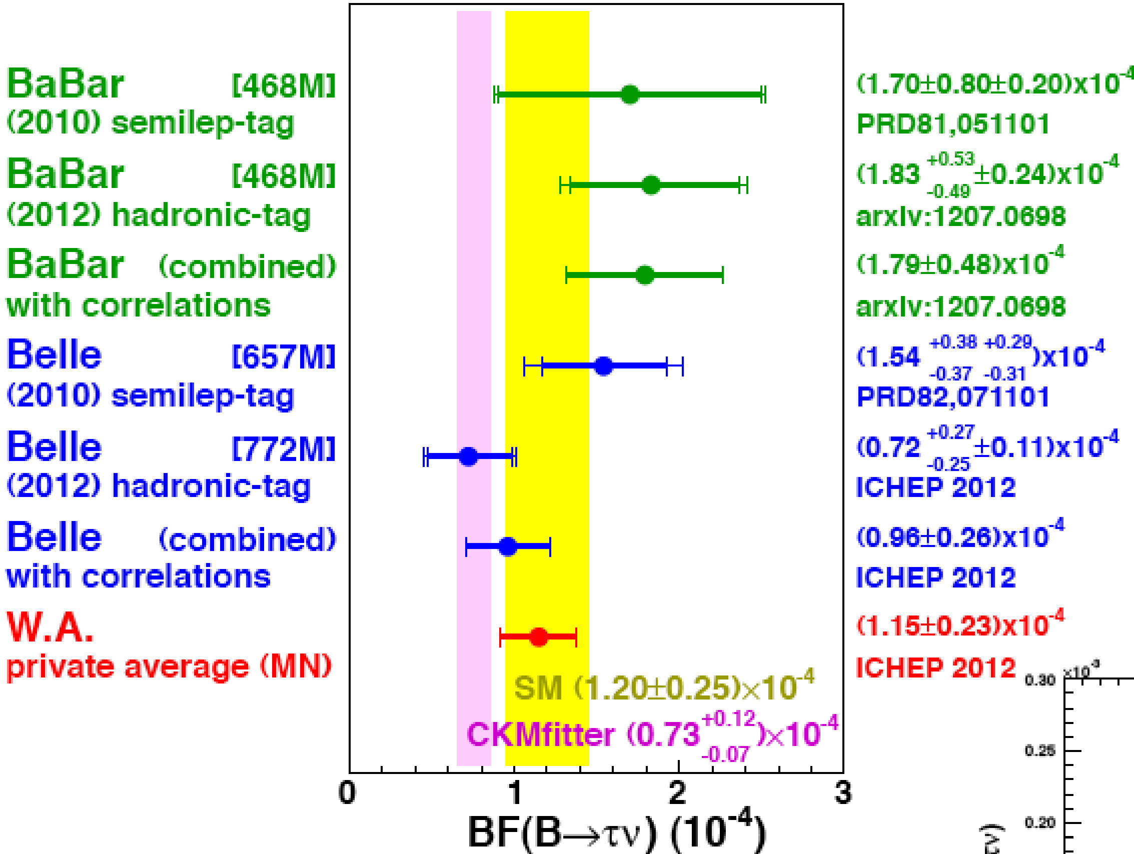
Errors of $\mathcal{R}_{\tau/l}$, $\mathcal{R}^*_{\tau/l}$ experimentally dominated

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

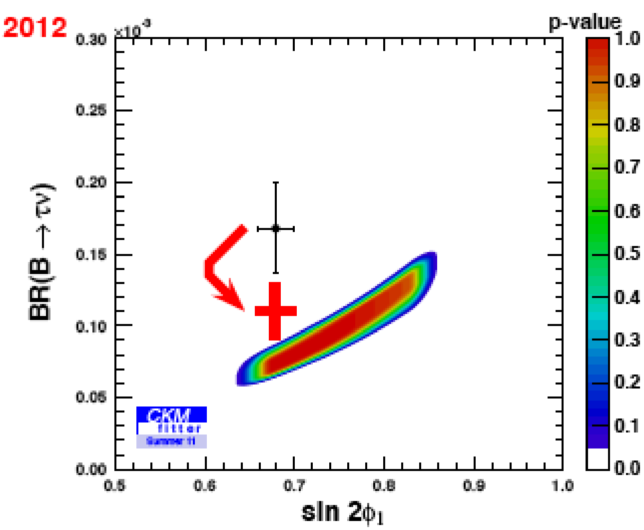


Relevant eg for H+ search, but it seems difficult to explain this effect

Flavor Physics



New Belle Result

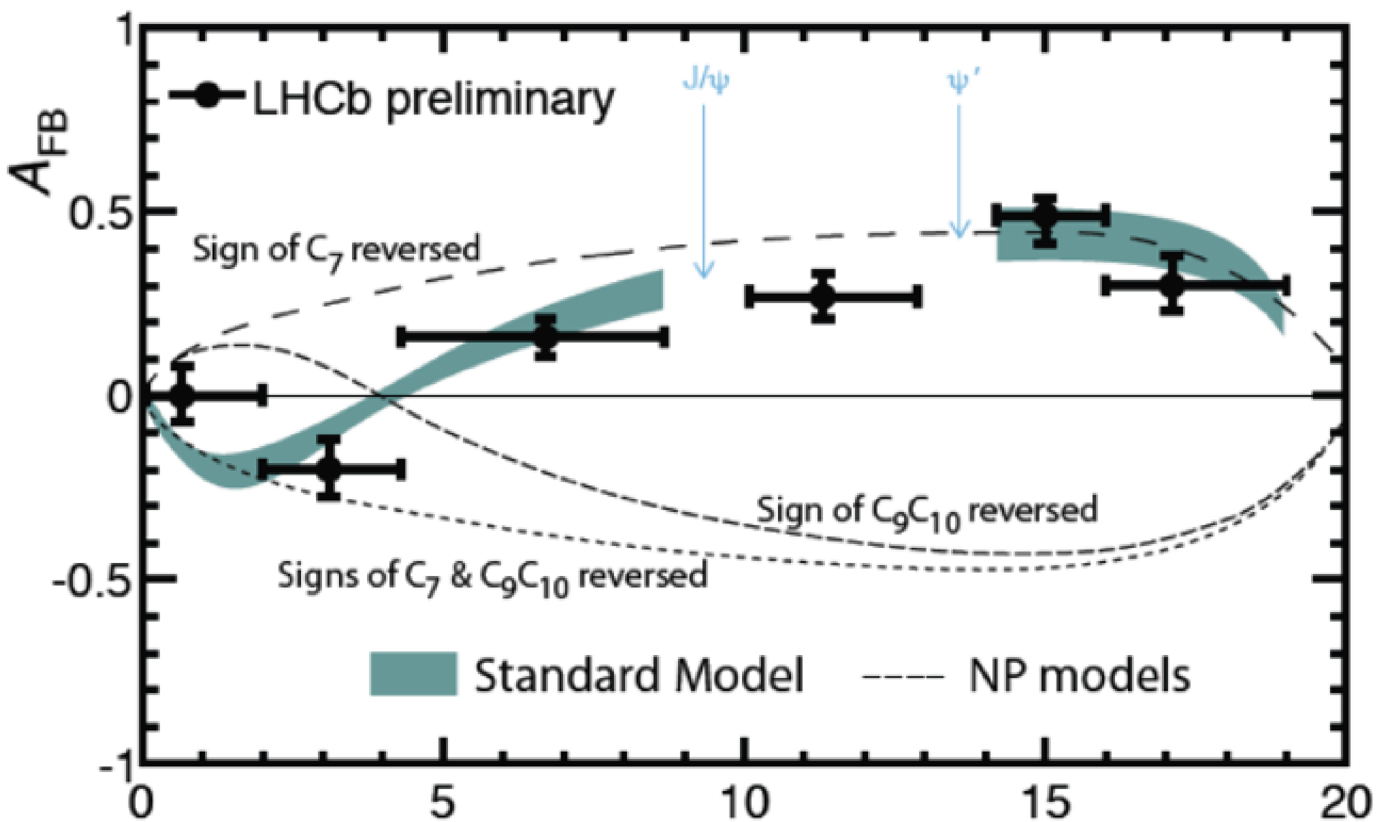


Tension between $B^+ \to \tau^+ \nu$ world average and CKM fit becomes much smaller

Flavor Physics

A remarkable measurement/constraint

Stone

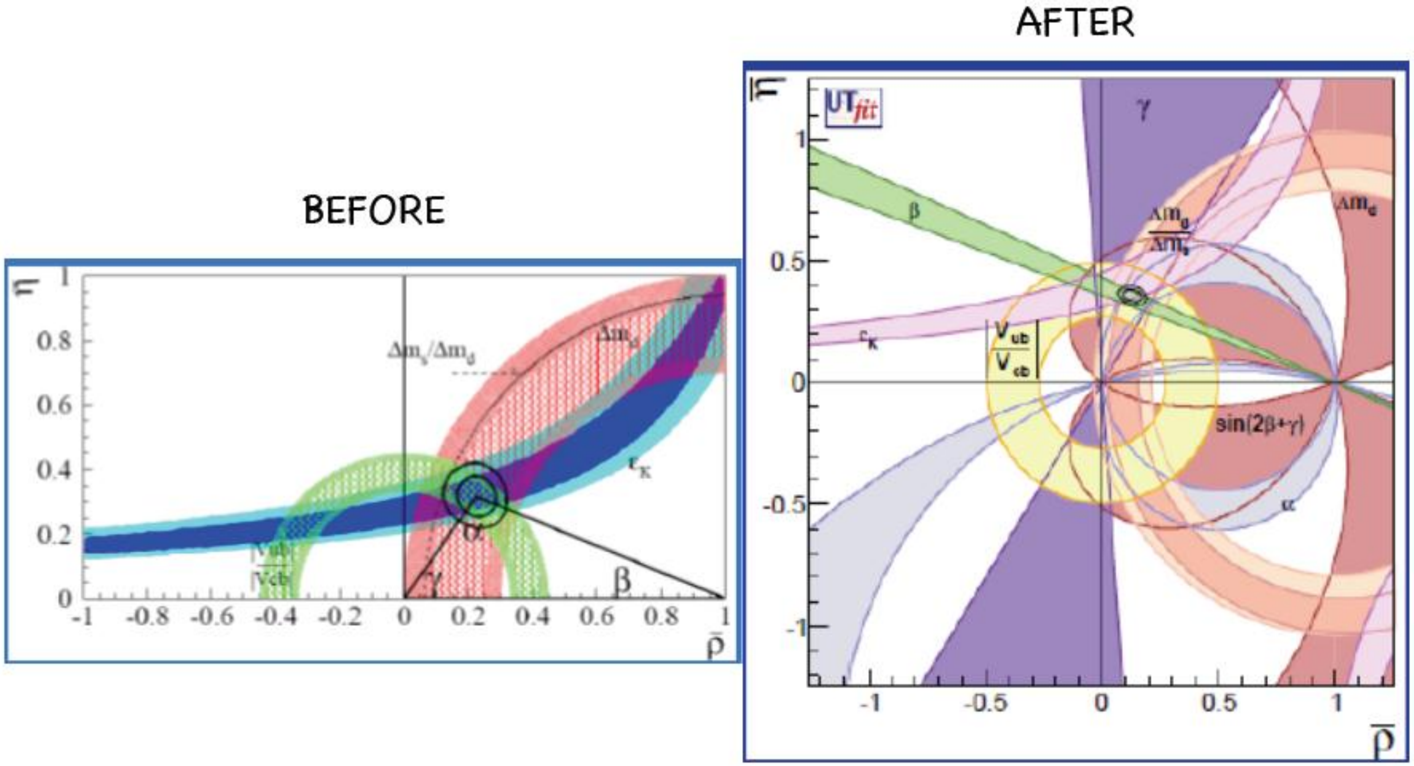


Forward-backward B-asymmetry in $B \to K^* l^+ l^-$

Flavor Physics

The progress of flavour in a popular figure

Tarantino



actually a gross underestimate of the real evolution

Are we seeing the unitarity triangle closing at ~10% accuracy, or is it just a coincidence?

CKM/CPV Summary

CKM / CPV status TODAY

- **CKM unitarity triangle**
  - $\phi_1 = (21.4 \pm 0.8)^\circ$ — done ☺
  - $\phi_2 = (88.7\,^{+4.6}_{-4.2})^\circ$, still more to come from Belle and BaBar (and LHCb)
  - $\phi_3 = (66 \pm 12)^\circ$, LHCb opening new door on $B \to DK$
  - V_{ub} and V_{cb} — new results still flowing in
- **$B^+ \to \tau^+\nu$ and CKM — one of the most interesting tensions**
  - Tension decreased with new Belle result (!)
- **More CP violation**
  - CPV in B decays is not so rare any more (many new results skipped!)
  - CPV searches in D and τ are reaching the sensitivity to produce some interesting results (e.g. ΔA_{cp})

Rare Decays

R. Mizuk

$D^0 \to \mu^+\mu^-$

from
M. Bonivento's talk
K. Ulmer's talk [634]

LHCb

$\mathcal{B}(D^0 \to \mu^+\mu^-) < 1.3\ (1.1) \cdot 10^{-8}$ at 95 (90)%CL

Preliminary (LHCb-CONF 2012-005)

0.9 fb^{-1} data

CMS

$B(D^0 \to \mu^+\mu^-) \leq 5.4 \times 10^{-7} (90\%\ \mathrm{CL})$.

Event in signal region = 23, predicted BG = 23

BELLE

Belle $< 1.4 \times 10^{-7}$ PRD, 81 091102

best published result

No news on $B_s \to \mu\mu$ and the MEG box is still closed

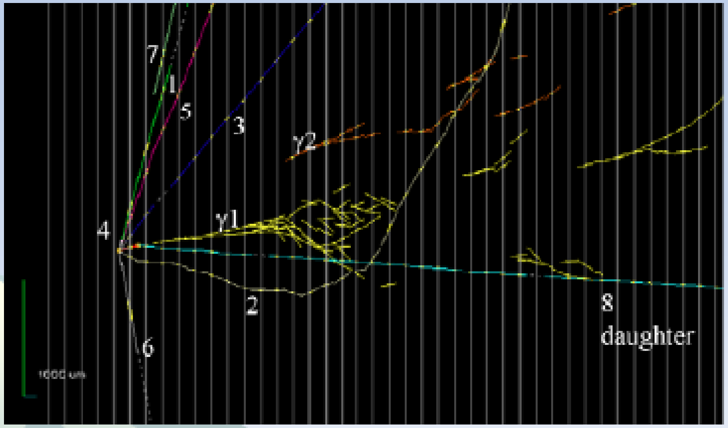
Neutrinos: ν_τ Appearance

T. Kobayashi

OPERA ν_τ appearance

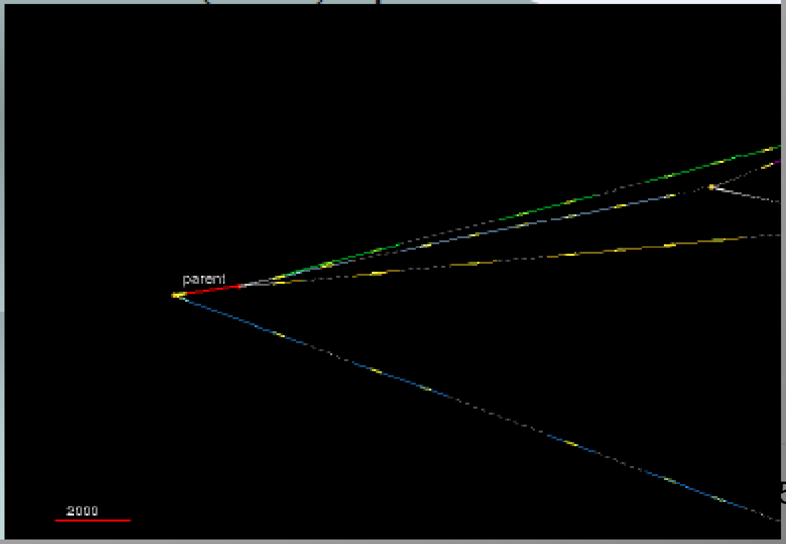
- Status of the analysis
  - 2 candidate events so far (expected 2.1 with 0.2 background events)
  - A few more events are under study.
  - Progress in estimating detection efficiency and BG.

First cand. ($\tau \rightarrow$1had kink) reported in 2010



Years	Status	# of events for Decay search	Expected ν_τ (Preliminary)	Observed ν_τ Candidate Events	Expected BG for ν_τ (Preliminary)
2008-2009	Finished	2783		1	
2010-2011	In analysis	1343		1	
2012	Started				
Total		4126	2.1	2	0.2

2[nd] Cand ($\tau \rightarrow$3h) reported in June 2012



Neutrinos at the speed of light ? Yes…

S.Bertolucci @ Nu2012

After the OPERA result in September 2011

All the big experiments al Gran Sasso set up a campaign to repeat the measurement with:

- Improved timing resolution
- Reduction of systematics
- Real time monitoring of the time stamp
- Redundant systems
- Independent clock synchronization and geodesy
- Better structure of the CNGS beam

MINOS measurement (Giles Barr)

15 ± 11 (stat.) ± 29 (syst.) ns

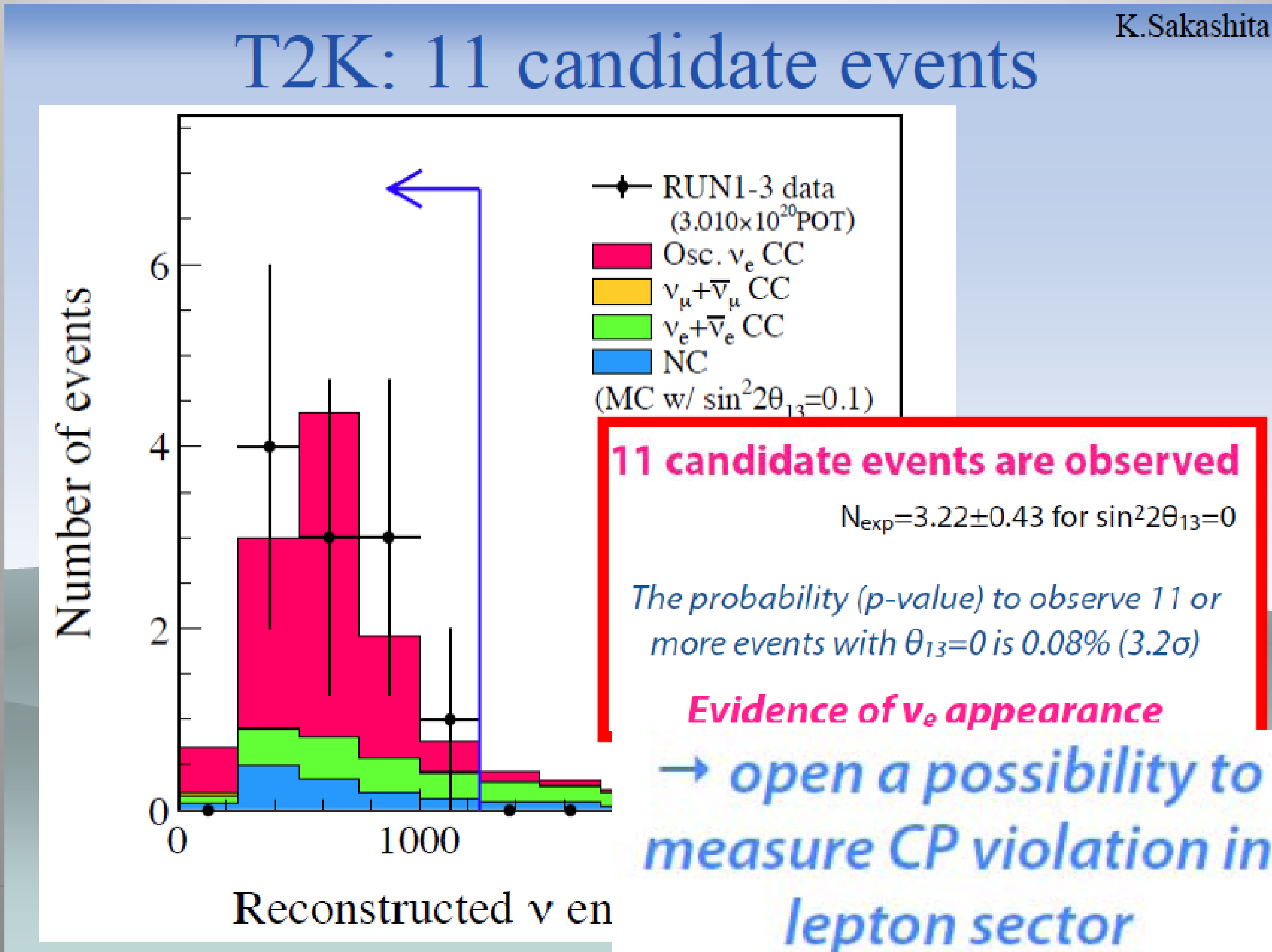
which is consistent with v=c

To summarize S.Bertolucci @ Nu2012

- All experiments consistent with no measurable deviation from the speed of light for neutrinos:
  - **Borexino**: $\delta t = 2.7 \pm 1.2$ (stat) ± 3(sys) ns
  - **ICARUS**: $\delta t = 5.1 \pm 1.1$(stat) ± 5.5(sys) ns
  - **LVD**: $\delta t = 2.9 \pm 0.6$(stat) ± 3(sys) ns
  - **OPERA**: $\delta t = 1.6 \pm 1.1$(stat) [+ 6.1, -3.7](sys) ns
- Very preliminary analyses, more refinements to be expected soon
- A paradigmatic example of collaboration and competition!

All consistent w/ c

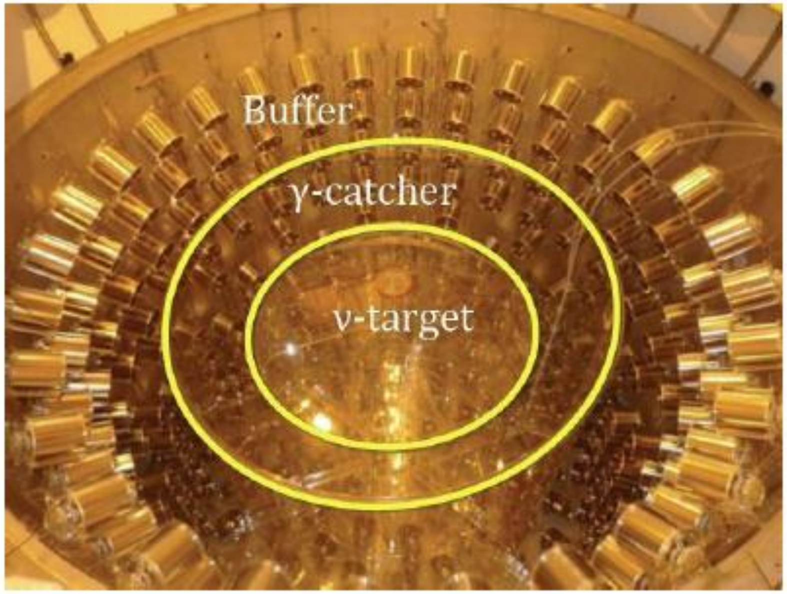
T2K Update 2012: more events



Neutrinos: Reactor based

Double Chooz Results

J. Cao



- Far detector starts data taking at the beginning of 2011
- First results in Nov. 2011 based on 85.6 days of data

$\sin^2 2\theta_{13}$=0.086±0.041(Stat)±0.030(Syst), 1.7σ for non-zero θ_{13}

- Updated results on Jun.4, 2012, based on 228 days of data

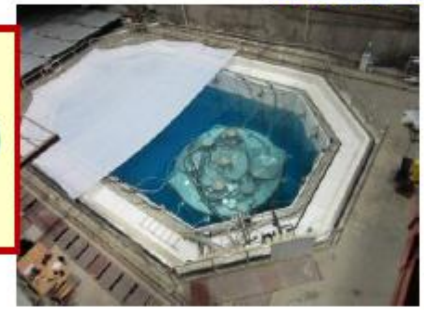
$\sin^2 2\theta_{13}$=0.109±0.030(Stat)±0.025(Syst), 3.1σ for non-zero θ_{13}

Neutrinos: Reactor based

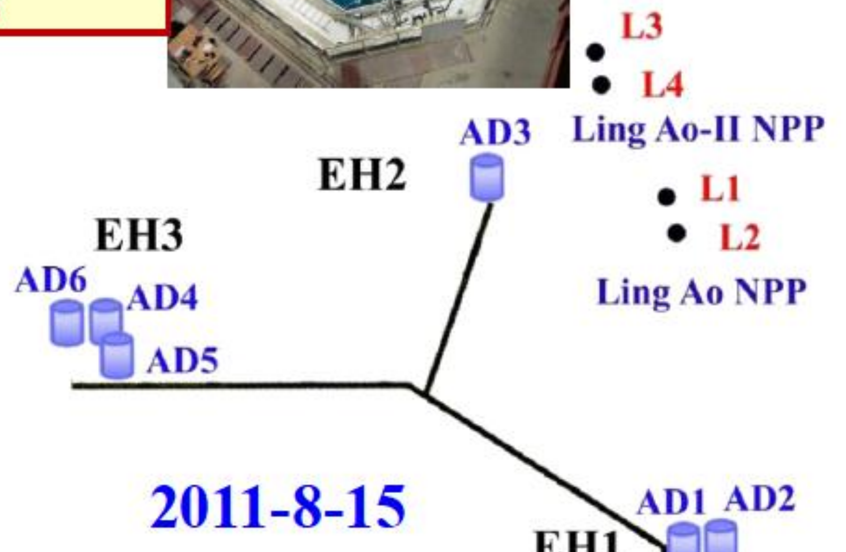
Daya Bay Results

Mar.8, 2012, with 55 day data
$\sin^2 2\theta_{13}$=0.092±0.016(stat)±0.005(syst)
5.2 σ for non-zero θ_{13}

2011-11-5



2011-12-24



2011-8-15

Jun.4, 2012, with 139 day data
$\sin^2 2\theta_{13}$=0.089±0.010(stat)±0.005(syst)
7.7 σ for non-zero θ_{13}

16

Neutrinos: Reactor based

RENO

- **Data taking started on Aug. 11, 2011**
- **First physics results based on 228 days data taking (up to Mar. 25, 2012) released on April 3, 2012, revised on April 8, 2012:**

$\sin^2 2\theta_{13}$=0.113±0.013(Stat)±0.019(Syst), 4. 9σ for non-zero θ_{13}

Neutrinos

R. Barbieri

θ_{13} now known

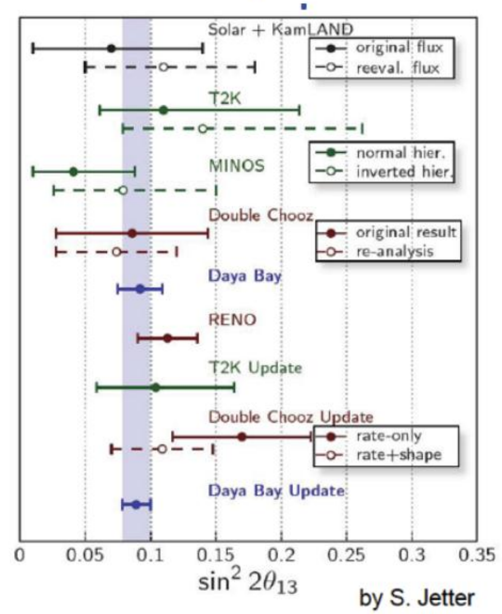
Sakashita
Novella

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}



Neutrinos

Summary of neutrino parameters

R. Barbieri

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

(Normal Hierarchy)

Kobayashi
Cao
Gonzales-Garcia

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

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

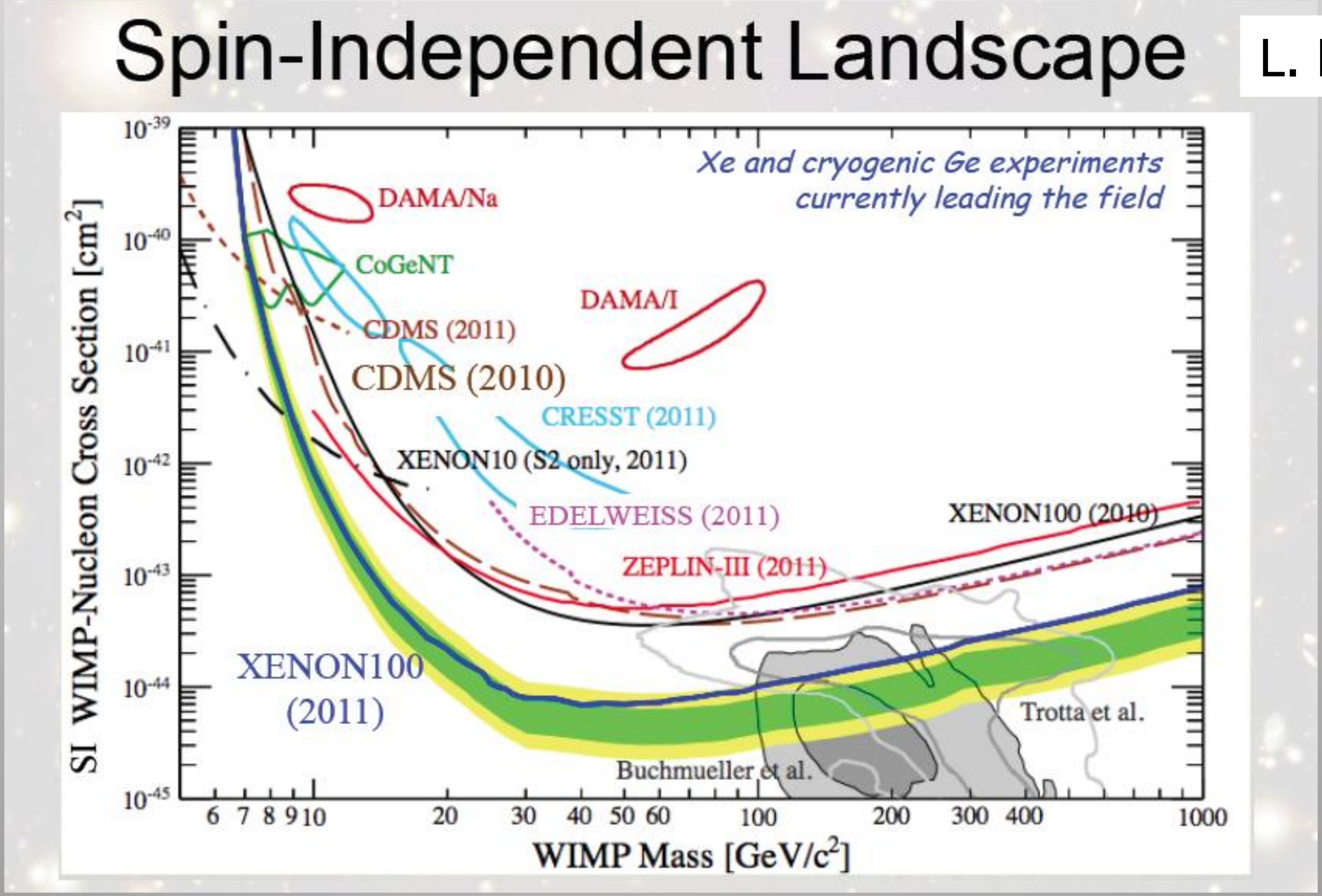
$$\sin^2\theta_{12} = 0.307^{+0.018}_{-0.016}$$

$$\sin^2\theta_{23} = 0.398^{+0.030}_{-0.026}$$ ← 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 $\cos\delta < 0$

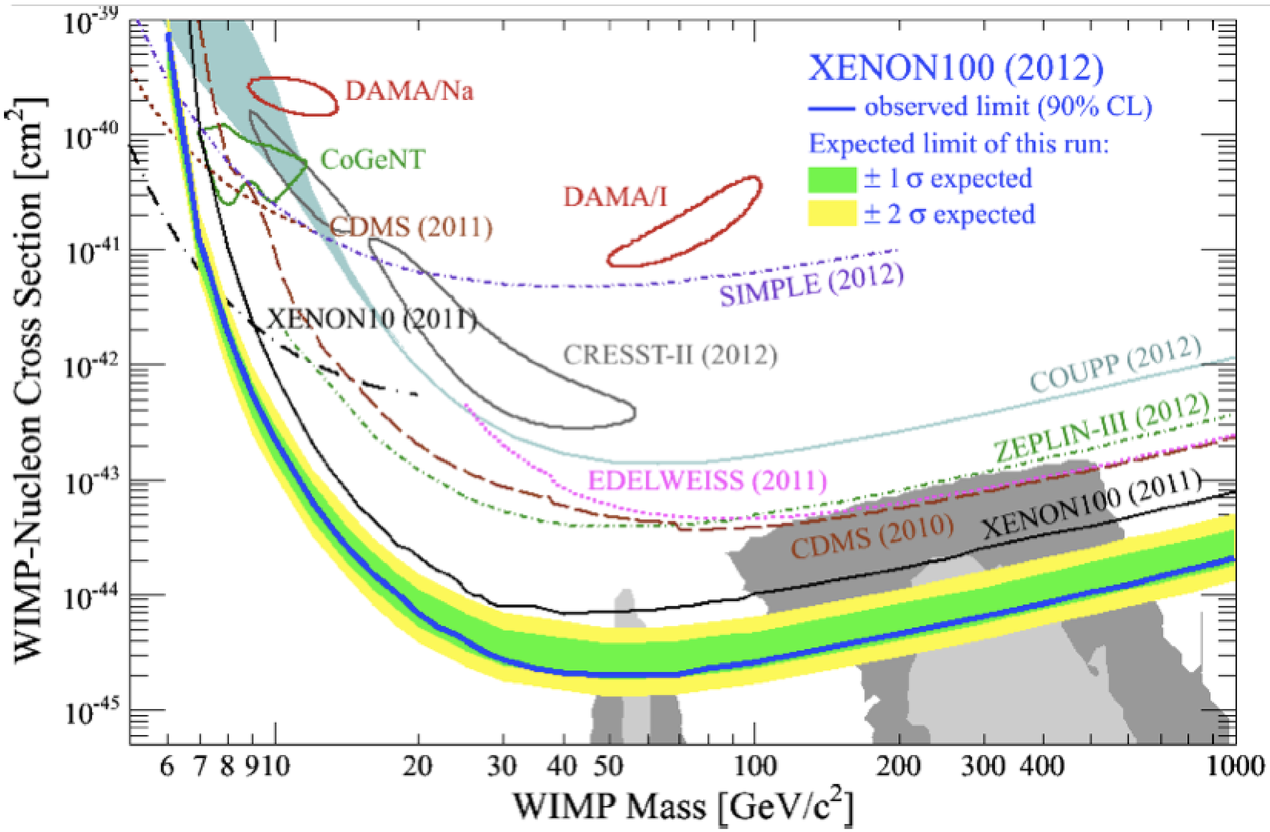
Dark Matter



Wednesday this week: New Result from XENON100 (@ "Dark Attack")
-> 1 event expected/2 observed
Improve limits: new limit 90%CL is 2x10E-45 for 55 GeV

Dark Matter (post Melbourne)

XENON100: New Spin-Independent Results



Upper Limit (90% C.L.) is 2 x 10^{-45} cm^2 for 55 GeV/c^2 WIMP

Wednesday this week: New Result from XENON100 (@ “Dark Attack”)
-> 1 event expected/2 observed
Improve limits: new limit 90%CL is 2x10E-45 for 55 GeV

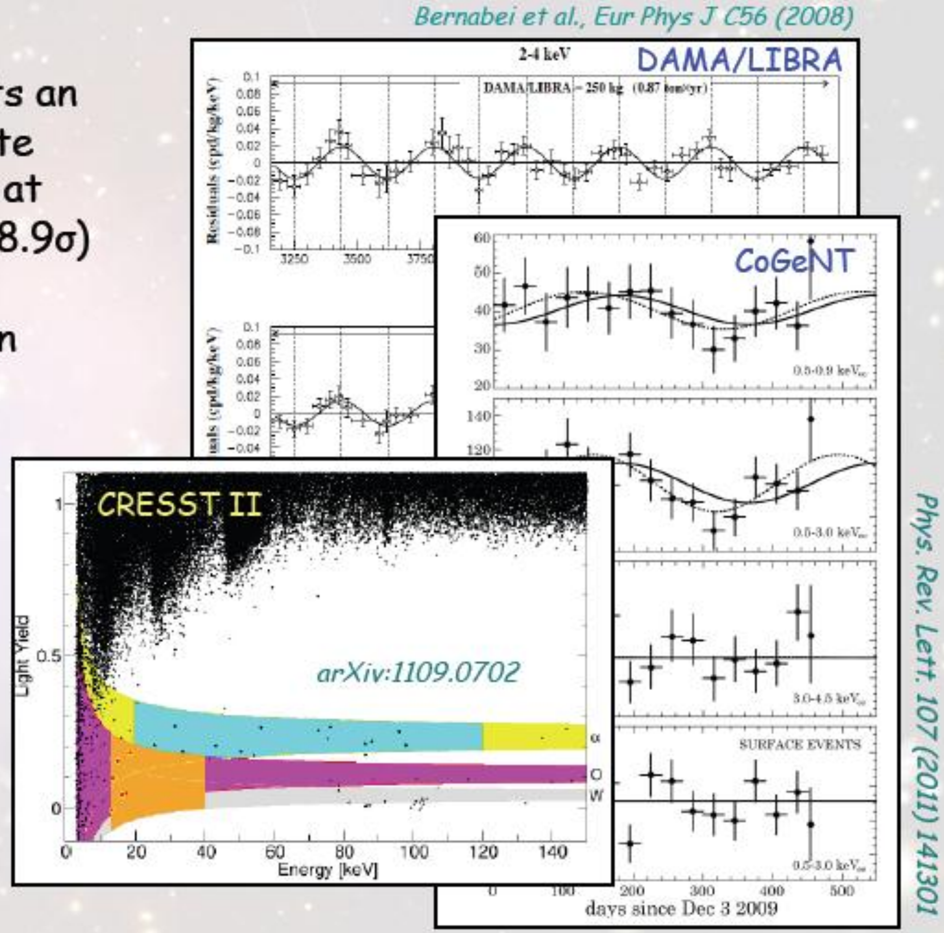
Dark Matter

Unexplained Events

2008: DAMA/LIBRA reports an annual modulation in event rate consistent with dark matter, at high statistical significance (8.9σ)

2010/11: CoGeNT reports an overall excess of low-energy events, and an annual modulation – albeit with only ~2σ significance

2012: CRESST-II reports a 4.2σ excess of low-energy events



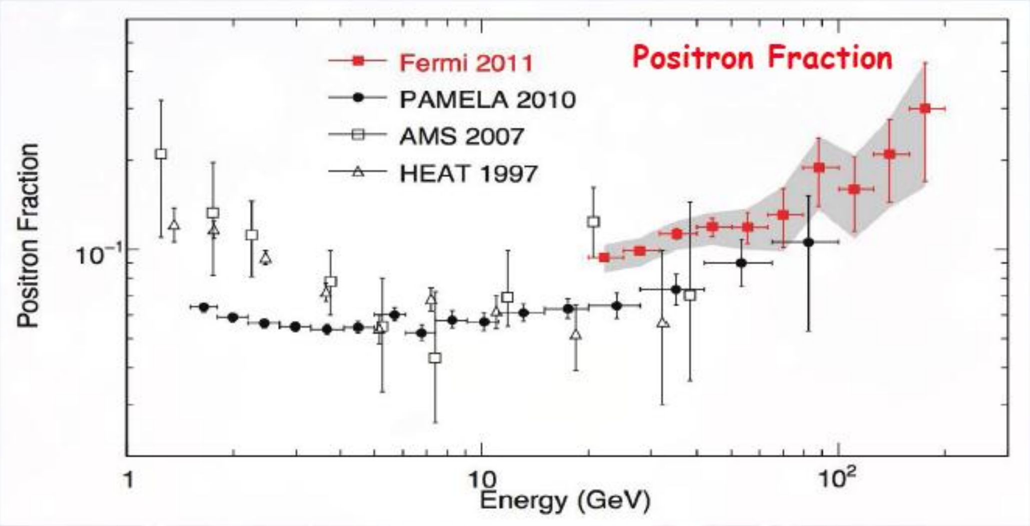
But null results in other experiments: No real new insight in this controversy

Indirect DM Detection

Pamela versus Fermi

N. Weiner

FERMI POSITRONS



Signal is confirmed

- Dark Matter Explanations for PAMELA are tough
  - Large rates
  - Large rates *into* e+e-
  - *Low* rates into antiprotons

- Pulsars remain the best explanation of the PAMELA/ Fermi excess (i.e., we know there are pulsars and they make e+e-)

Cosmology…

M. Trodden

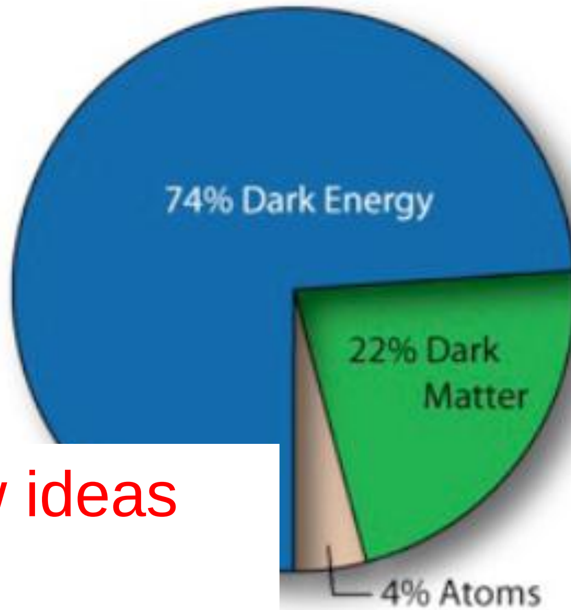
Why is the cosmological constant so small?

Is cosmic acceleration a signal of a breakdown of GR?

What is driving cosmic acceleration? (See Wali, MT Parallels)

Genesis:
- Why is the universe so flat?
- Why is the universe so homogeneous?
- Why … from
- Wha… singu…

(See A…



…re more …ntimatter? …arling, Parallels)

What is the nature of dark matter? (See Weiner, Hsu Plenaries. Dienes, Brooks, Foot, Neilson, Li, Hsu, Hill, Mahmoudi, Ahmad, Slatyer, Balazs, Morselli Parallels)

What laid down its primordial perturbations?

- A number of new ideas for dark Energy
  - Dynamic dark Energy
  - Modified gravity
  - Massive gravity
- Still far from a solution…

Conclusion

- Dynamic conference & well organized. A lot of outreach organized.
- A Higgs-like particle is with us
  - This opens a lot of prospects for new studies
  - Clearly timely for the ESG later this year
- No convincing sign of New Physics. Phase space systematically scanned
  - There are always a few new “signals”
- Many new experiments planned (dark matter, rare decays…). Not discussed here

Backup