(Some) Results from ICHEP 2014

João Firmino da Costa
Séminaire SPP 15 Septembre 2014

Overview

Conference held in Valencia, 2-9 July 2014
Over **350** contributions across various fields !

Brout-Englert-Higgs Physics: link
Beyond the Standard Model: link
Flavour Physics: link
Neutrino Physics: link
Heavy Ions: link
Astroparticle Physics and Cosmology: link
Strong Interactions and Hadron Physics: link
Lepton Flavour Violation: link
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Top Quark and ElectroWeak Physics: link
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Lattice QCD: link
Formal Theory Developments: link

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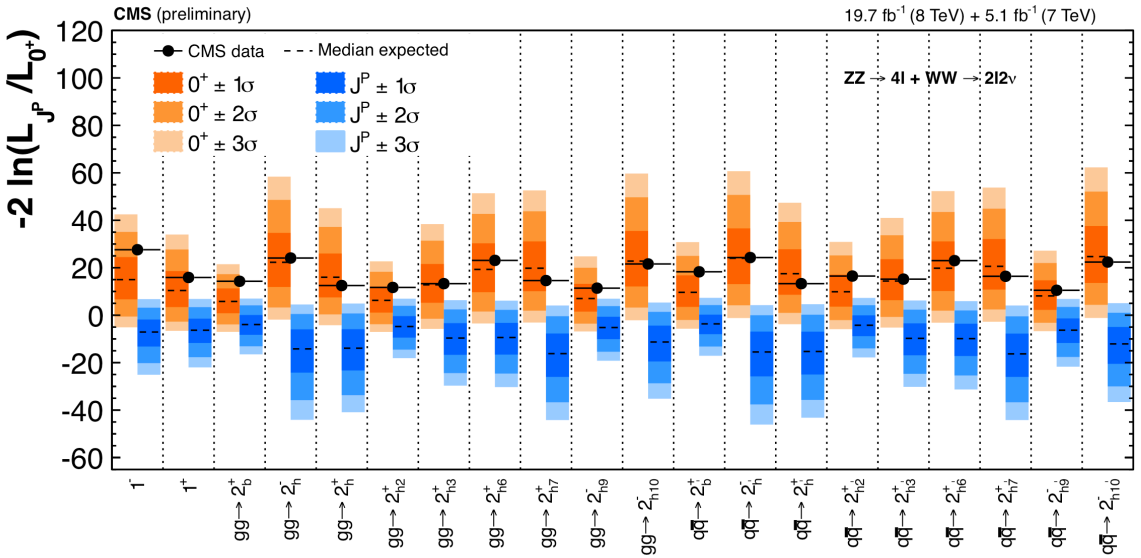
I will focus on results from

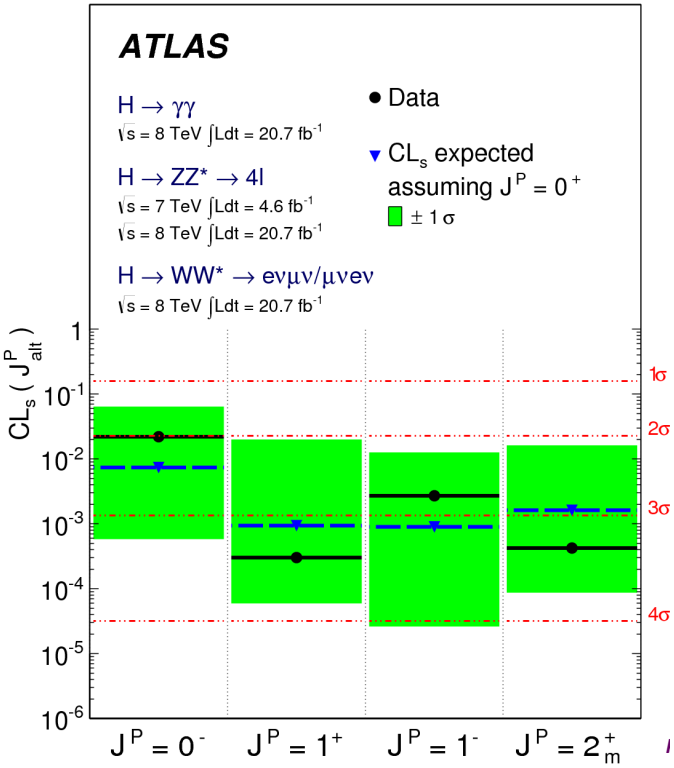
Higgs
Electroweak Physics
BSM
Flavour Physics

Statement of interests
I've worked in BaBar and am a member of ATLAS

Higgs spin-CP

SM predicts $J^{CP} = 0^{++}$
h→ gamma gamma disfavors spin-1 from theory
NP with extended Higgs sector allow for CP-mixing
Spin-CP probed via hypothesis testing using kinematic observables





Higgs spin-CP hypotheses tested
Both ATLAS/CMS exclude J = 1,2 essentially above 99.9 % CL for ensemble of tested models

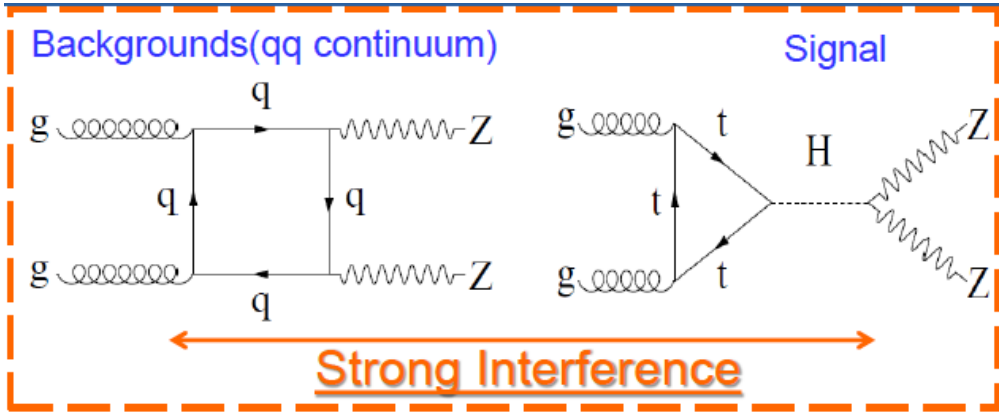
Higgs (125) off-shell width limits

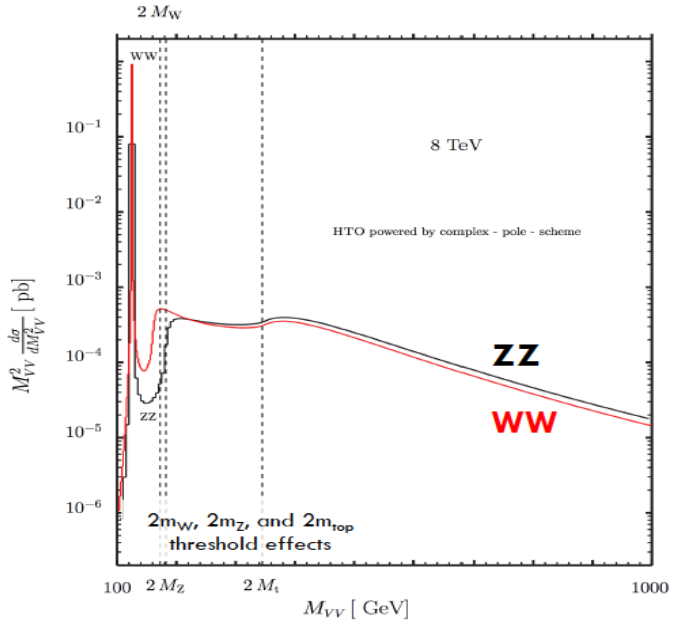
Width determination via events in high mass tails

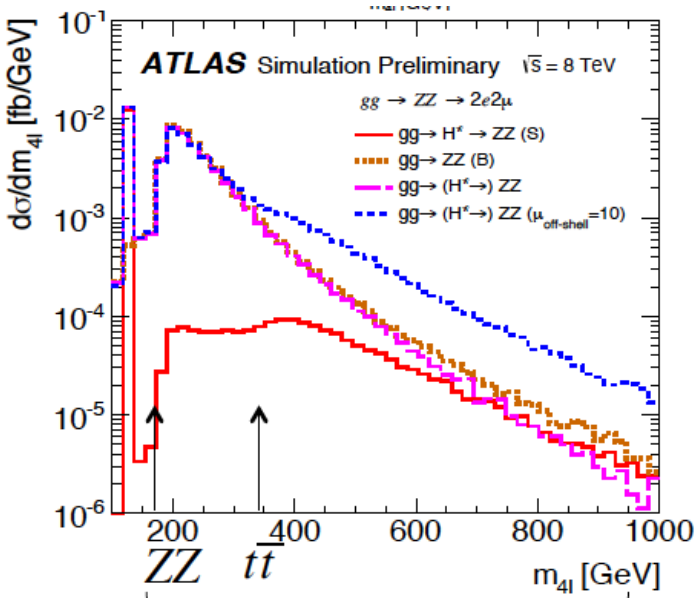
$$\sigma^{\text{on-shell}}_{gg\to H\to ZZ} \sim \frac{g^2_{ggH} g^2_{HZZ}}{m_H \Gamma_H}$$

$$\sigma^{\text{off-shell}}_{gg\to H\to ZZ} \sim \frac{g^2_{ggH} g^2_{HZZ}}{(2m_Z)^2}$$

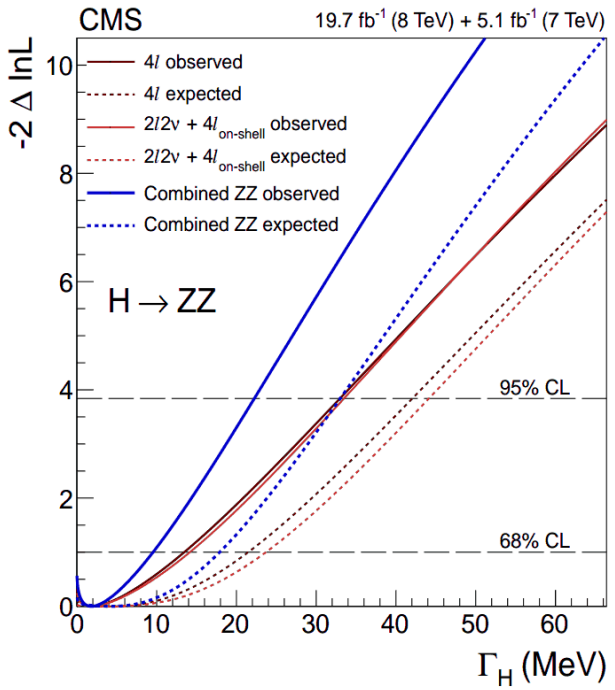
But you need to consider that gg → ZZ has 2 possible (and interfering paths)

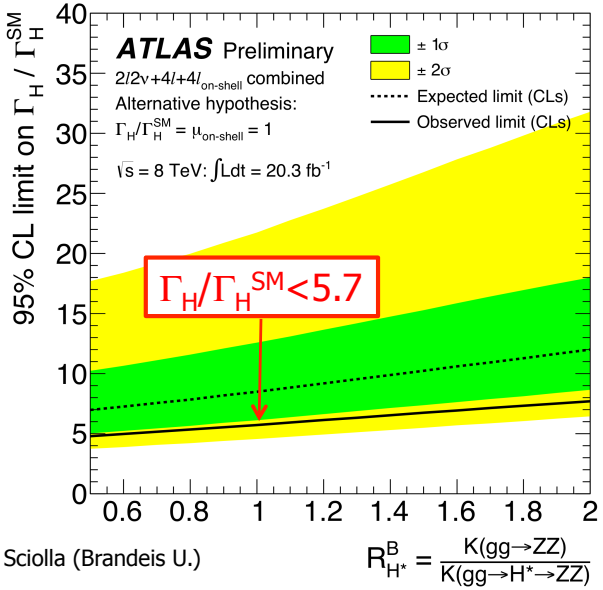






Higgs (125) off-shell width limits





G. Sciolla (Brandeis U.)

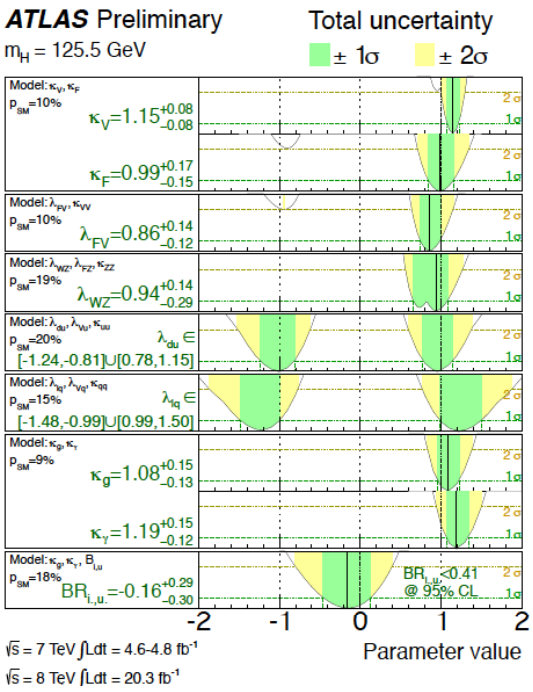
03/07/2014

Experiment	Limit on Γ_h/Γ_h^{SM} 95% CL obs(exp)
CMS	5.4 (8.0)
ATLAS	5.7 (8.5)

Clever method pionered by CMS to extract higgs width (with mild model dependence)
ATLAS & CMS corner the width to be lower than 22-24 MeV (SM predicts 4.2 MeV)

Higgs couplings

Summary of coupling measurements



ATLAS-CONF-2014-009

Higgs couplings ...

... to vector bosons, κ_V

... to fermions, κ_F

coupling ratio κ_F/κ_V

Custodial symmetry: κ_W/κ_Z

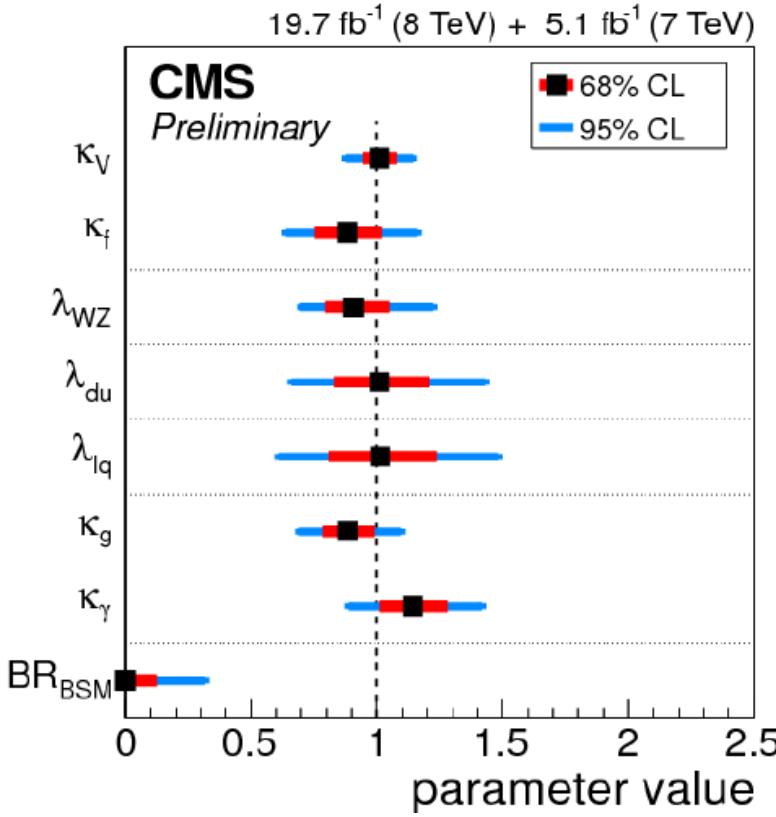
up vs down-type couplings

quark vs lepton couplings

sensitive to SUSY

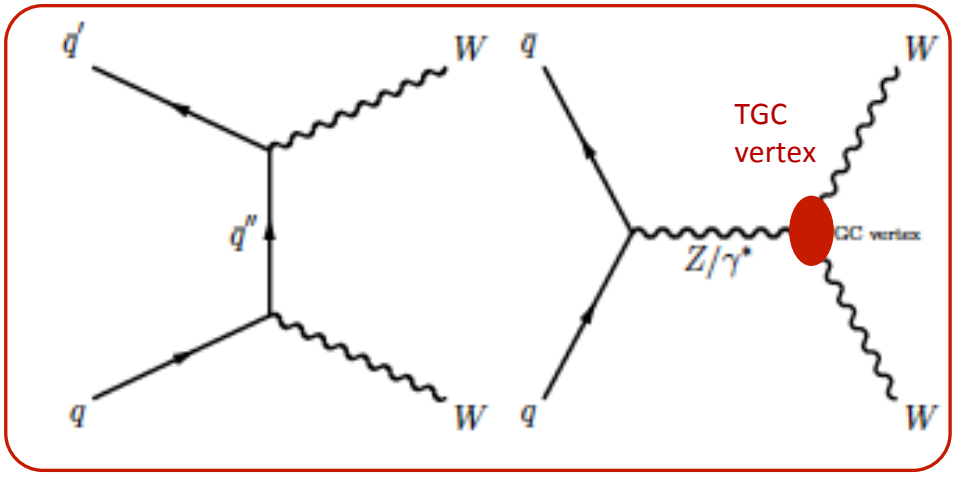
Additional particles in loops?
gg→H, H→γγ

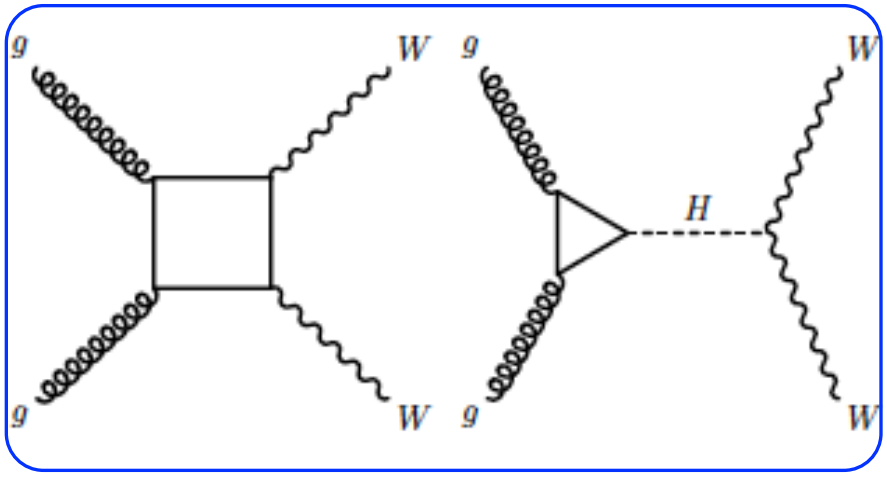
Unobserved or invisible particles



Higgs couplings thoroughly measured by LHC
All measurements consistent with the SM
→ Next step is to use Higgs to corner NP via couplings (eg. Higgs portal)

W^+W^-

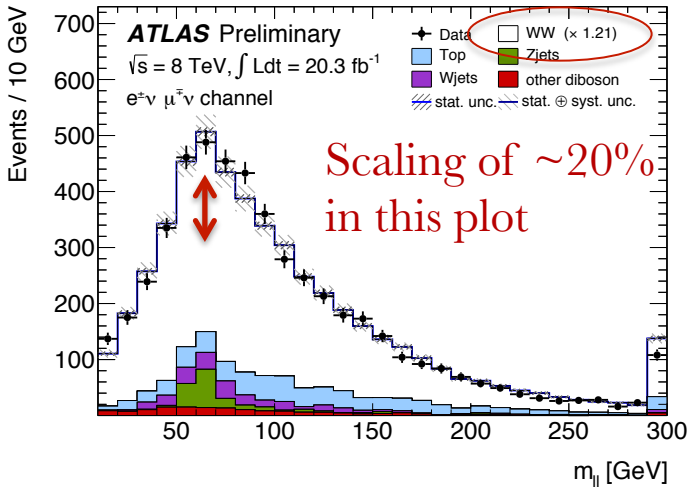


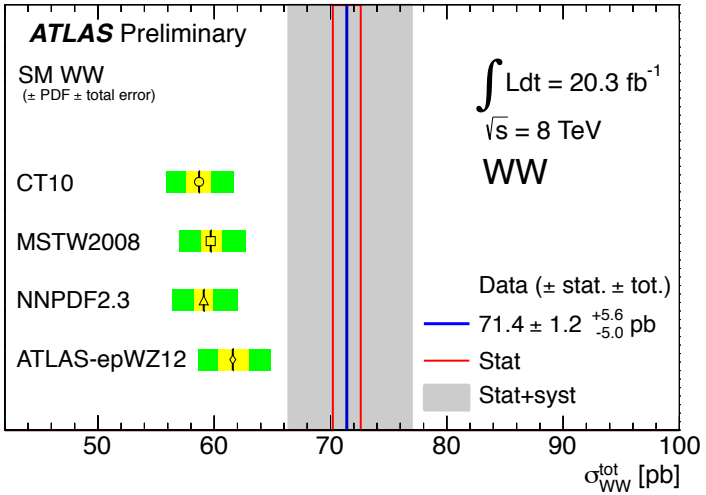


91% **2%** **7%**

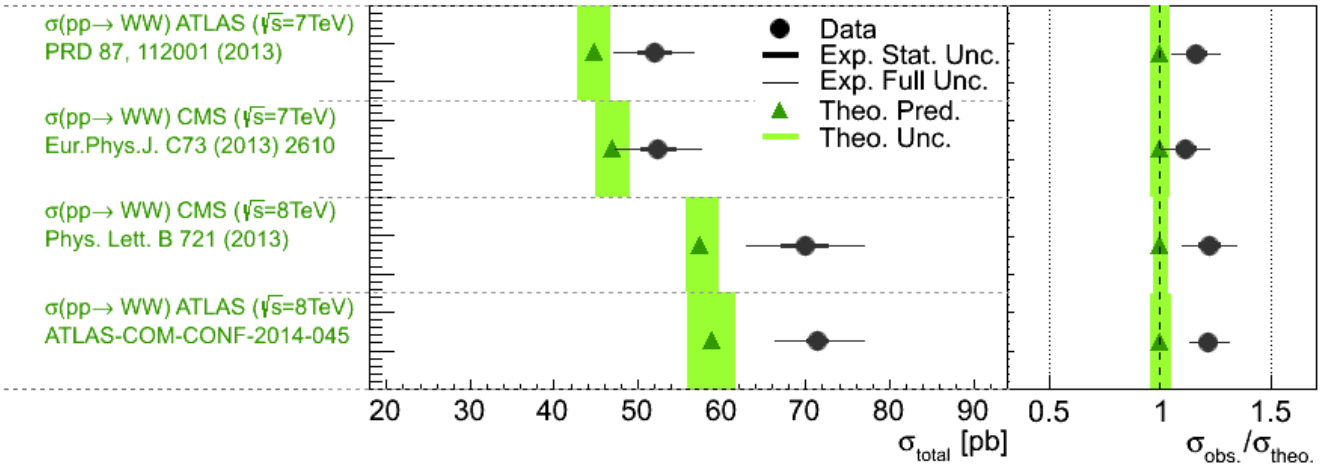
$\sigma^{tot} = 71.4 \pm 1.2(stat)\ ^{+5.0}_{-4.4}(syst)\ ^{+2.2}_{-2.1}(lumi)pb$

$\sigma^{theo} = 58.7^{+3}_{-2.7}\ pb$





W^+W^-



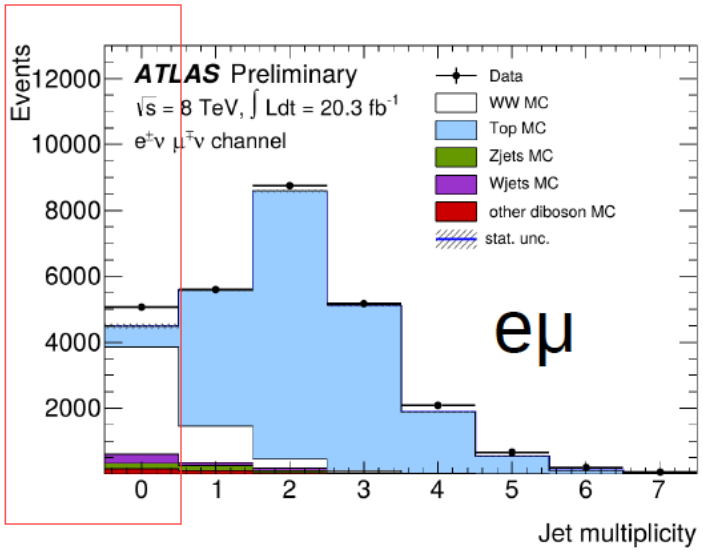
Significance

1.4 σ

1.0 σ

1.7 σ

2.1 σ



Possible extra effects to take into account	variation in Cross Section
Choice of PDF	2.9 pb
qq→WW (NLO→NNLO+NNLL k-factor)	1.6 pb
qq→WW(NLO EW correction)	- 0.5 pb
gg→WW (LO→NNLO+NNLL k-factor)	2.8 pb

Consistently higher measured cross section than expectations,
Flat excess versus the usual variables (pTll, etc…), where NP is expected
Theory corrections + new PDF pushes the 2.1 sigma effect to below 1.5 sigma

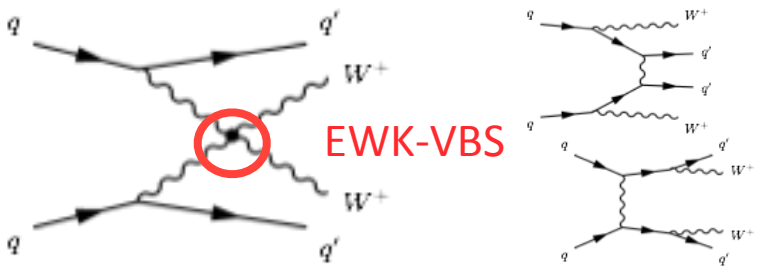
$W^{+/-}W^{+/-}$ scattering

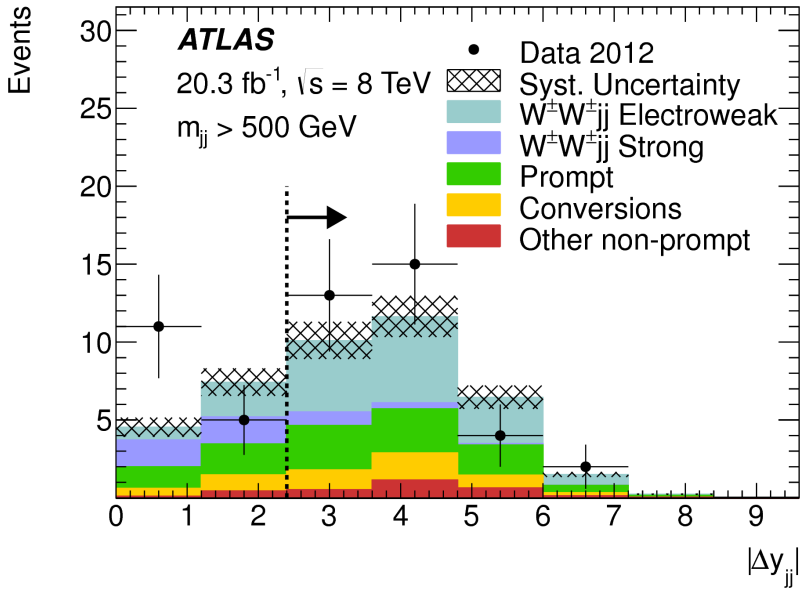
(Very) rare SM process

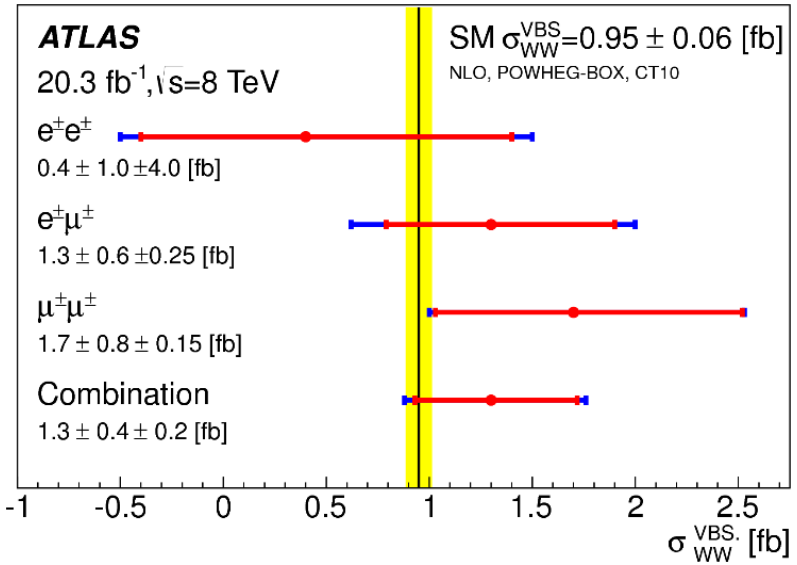
Can be used as probe for NP (EFT)

No previous evidence of VVVV vertex

Quite challenging due to dominant WW QCD production







ATLAS : 3.6/2.8 sigmas (observed/expected)
CMS : 2.0/3.1 sigmas (observed/expected)

First evidence for vector boson scattering
Paves the way for other quartic gauge coupling measurements

UCSD

Summary & Conclusions

Frank Wuerthwein's clear summary

- We looked all over the place ….
  - Singly produced resonances up to ~ 5 TeV
  - Pair produced new particles up to ~ 1.5 TeV
  - Vast diversity of signatures
- No new physics found anywhere we looked.
  - Devil's in the details => many places left to hide!
- Let's do it all over again next few years at higher energy and larger luminosity !!!

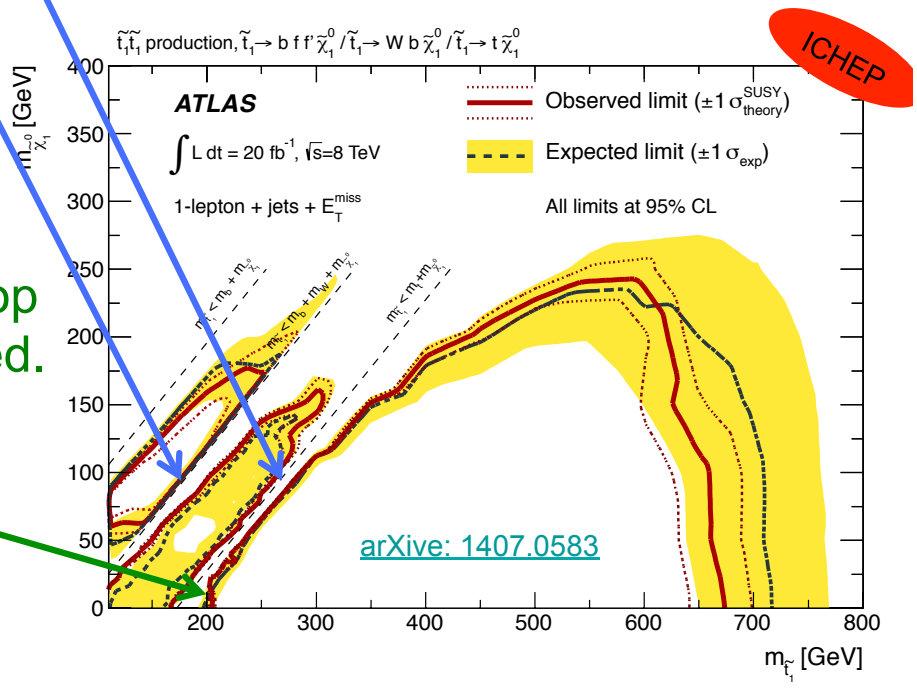
Example of places left to hide

Frank Wuerthwein's

"Closing the gaps"

At larger m_{DM} ,
ISR boost and increased luminosity will close the gap.

Near m_{DM} ~ 0 precision top measurements are needed.
(e.g. arXive: 1406.5375)



7/7/14

$B^0 \rightarrow K^{*0} \mu\mu$

b → s l^+l^- tests structure of interaction

Angular analysis (4D) allows full description of all possible polarizations states.

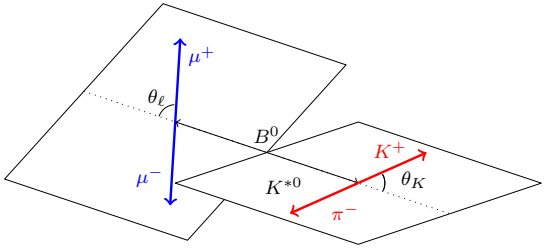
Each state means SM QCD-EW predictions
→ Form Factors (F.F.)
→ + NP terms !

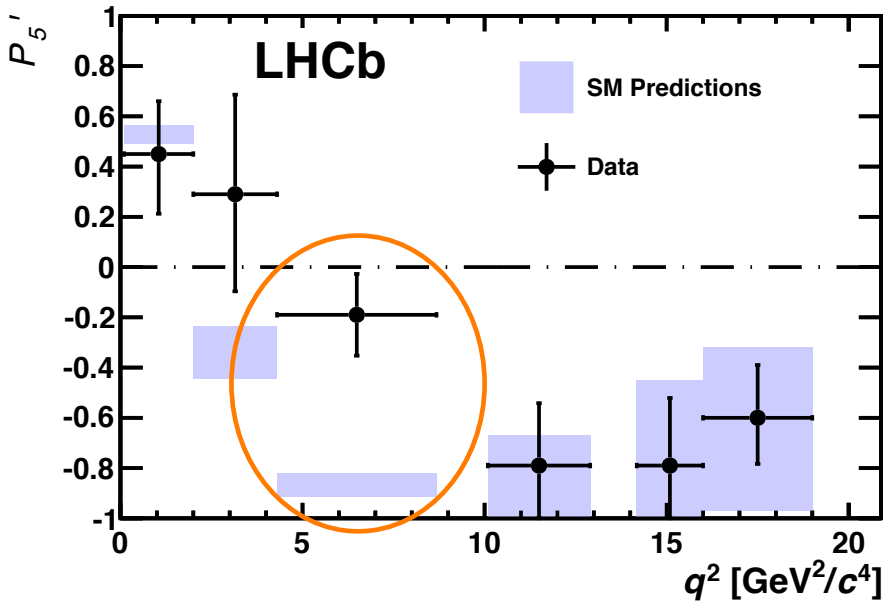
Projecting data as function of certain angles allows enhancement of states.

Ratio of projections allows to cancel F.F

$$P'_{4,5} = S_{4,5} / F_L (1 - F_L)$$

3.7 sigma effect in P'_5





Theory uncertainties are underestimated ?
Difficult to explain with SUSY and consistent with a Z' of ~ 7 TeV

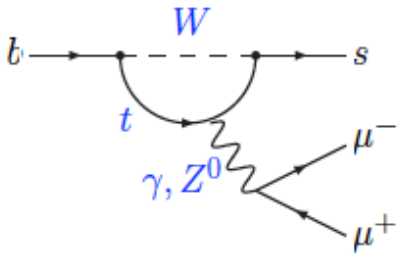
Lepton Universality

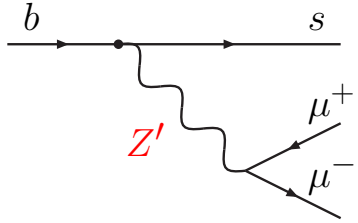
Probe for anomalous coupling in case of NP.

Theoretical uncertainties for processes
Br(B -> K ll) are of O(30%)

Largely cancel for ratio of branching fractions
fo B → K mumu and B → K ee

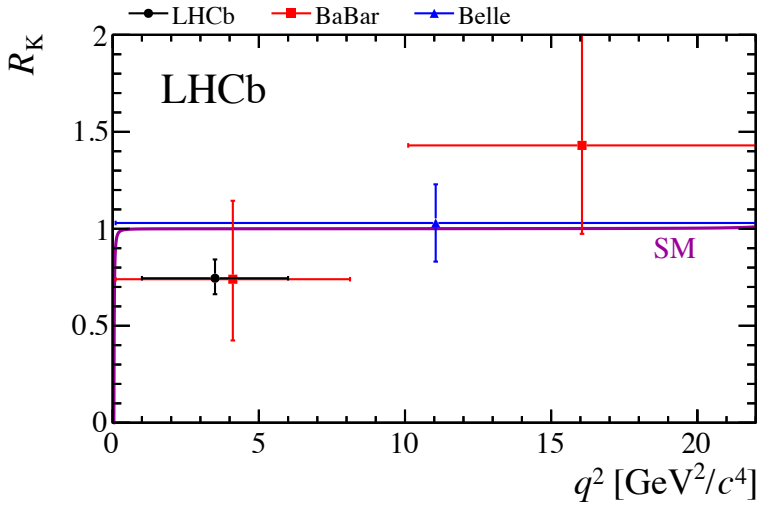
Sensitive to new (pseudo)scalar interactions





Challenge in analysis :
Control bremstrahlung emission from electrons

$$R_K = 0.745^{+0.090}_{-0.074}(\text{stat})^{+0.036}_{-0.036}(\text{syst})$$



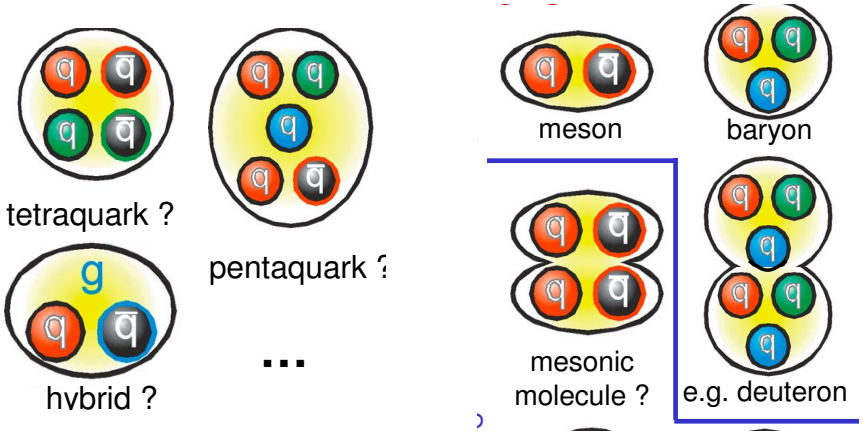
Intriguing hints of NP (though a fluctuation is not impossible).
More data is needed to clear what's going on

Exotic mesons

Why it's interesting ? Well ... because they are exotic ... new particles !

Z(4430) observed by Belle at 5.2 sigmas
It is the 2nd charged 4-quark candidate

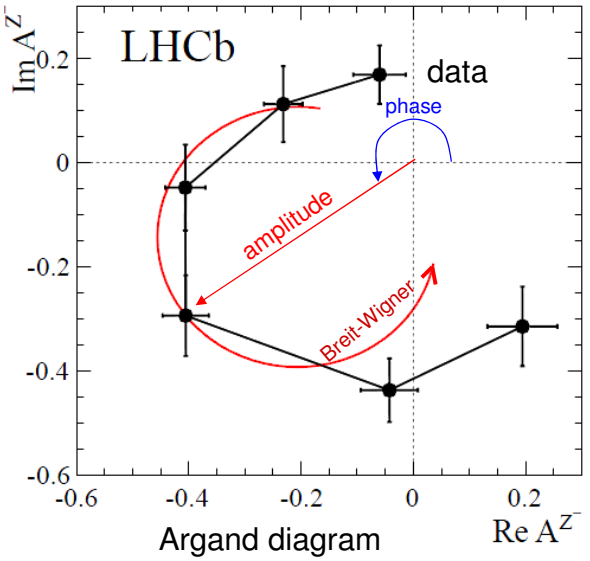
Properties roughly determined.
LHCb adds 10x times more statistics :



Including systematic variations:

	Rejection level relative to 1^+	
Disfavored J^P	LHCb	Belle
0-	9.7σ	3.4σ
1-	15.8σ	3.7σ
2+	16.1σ	5.1σ
2-	14.6σ	4.7σ

- $J^P=1^+$ now established beyond any doubt



The only other confirmed charged four-quark candidate $Z(3900)^-$ observed by BES-III and Belle in 2013 could be a $\overline{D}D^*$ threshold effect

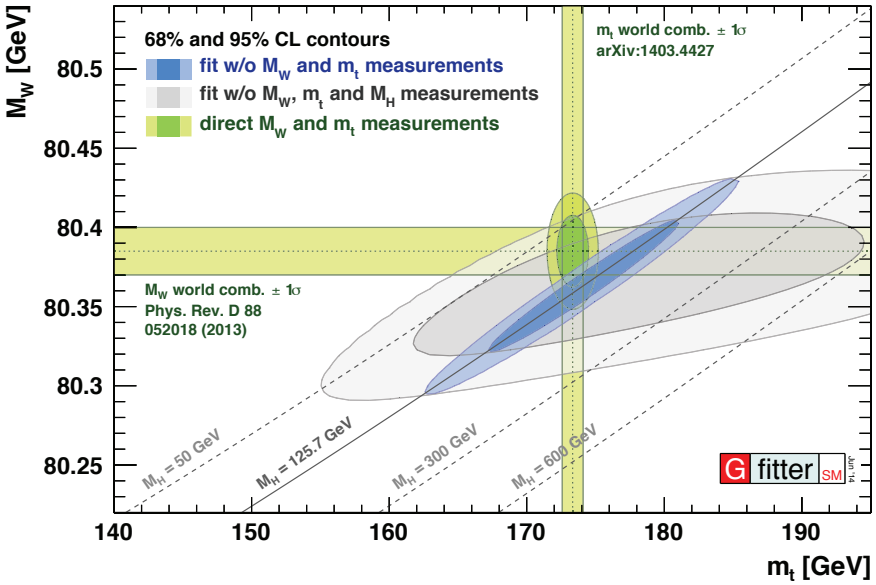
LHCb's T. Swanicki

LHC R(o)un(d) 1 summary plots

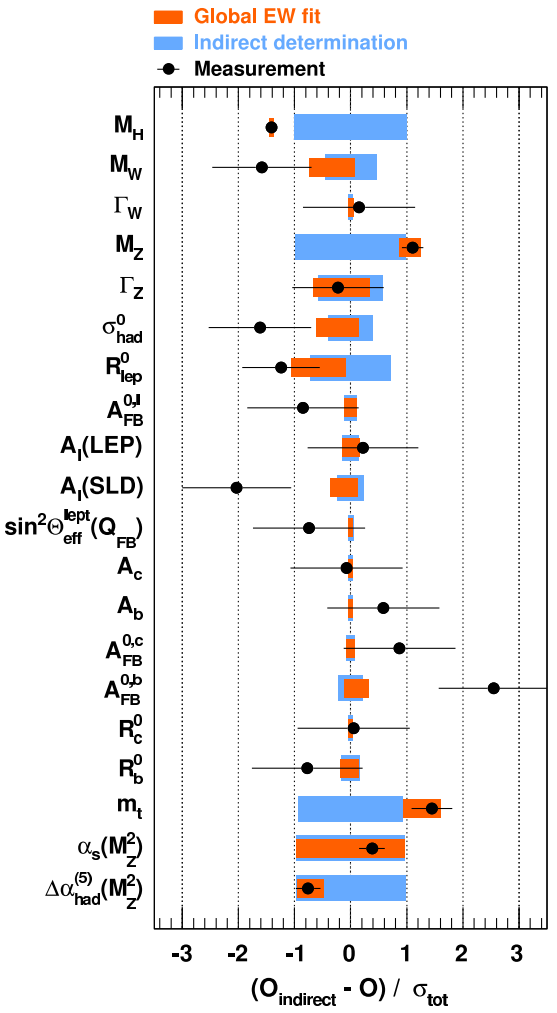
Very good agreement between **indirect** and **direct** determinations

Global p-value $\approx 20\%$

Gfitter coll. '14

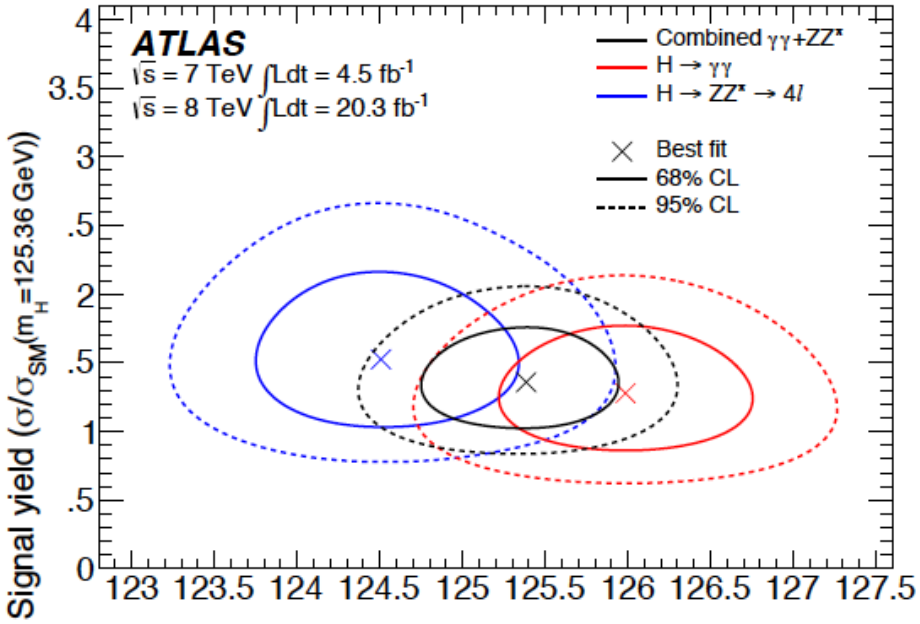


Freitas

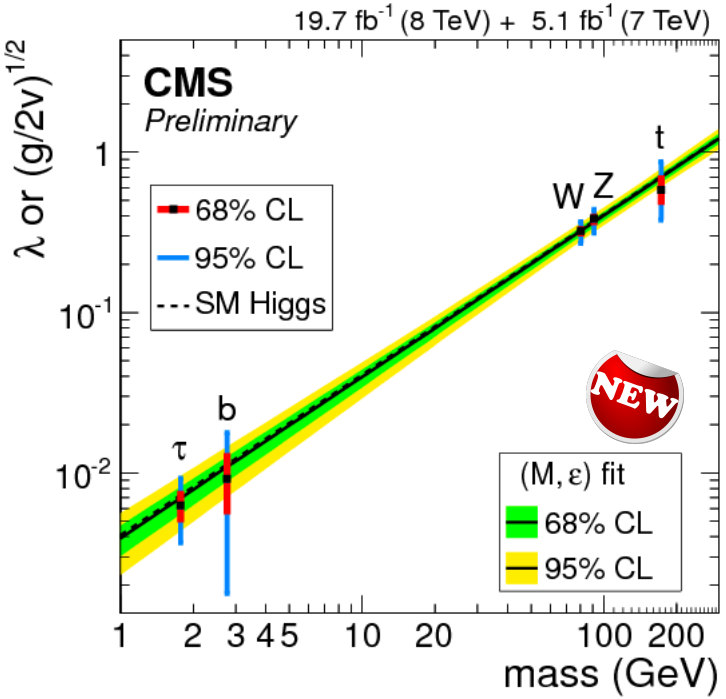


Electroweak sector of SM is still bullet-proof

LHC R(o)un(d) 1 summary plots

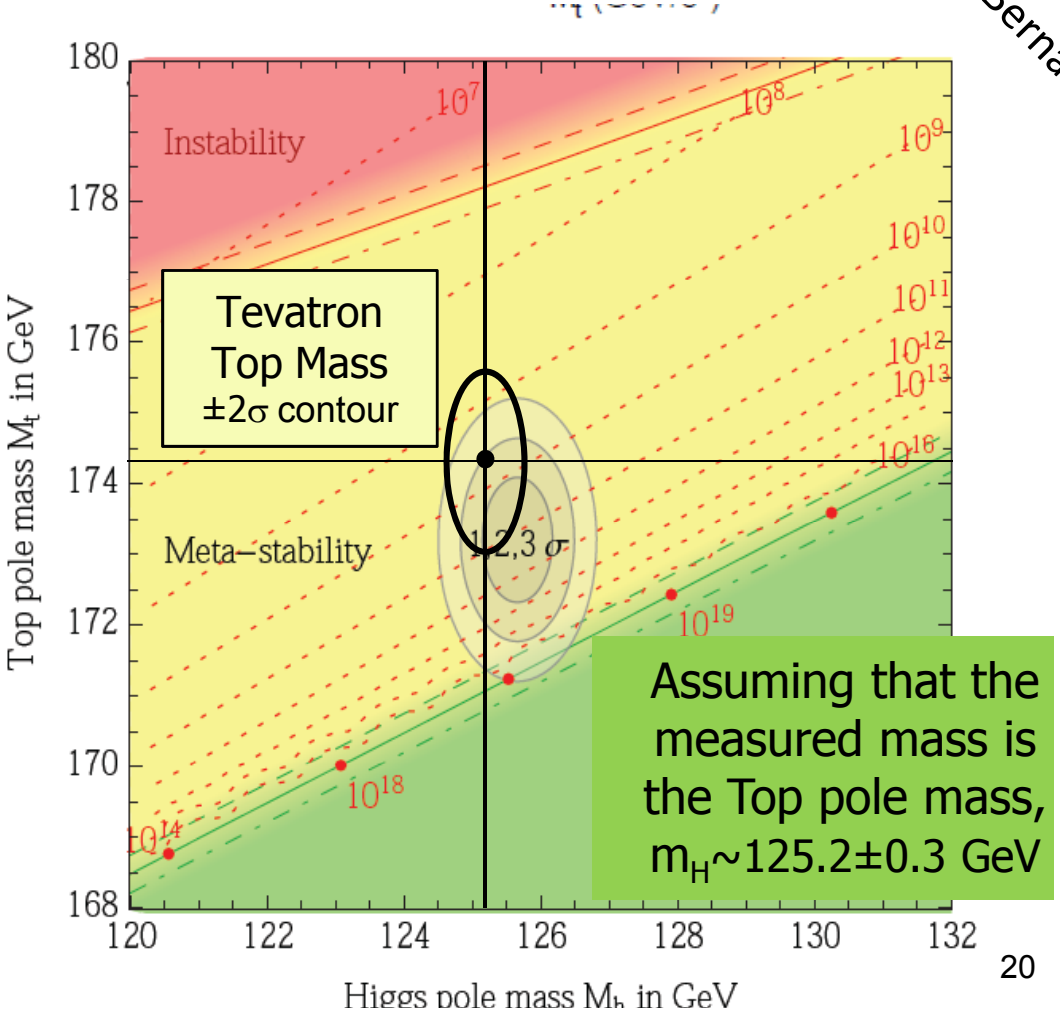


Experiment	mass value
ATLAS	125.4 +/- 0.4
CMS	125.0 +/- 0.3



Higgs coupling to elementary particles follows exactly SM predictions
spin-CP properties idem.
Particle is up to now fully compatible with SM Higgs boson

Should we worry about the universe's fate ?



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Hinting that universe-metastability is continent-dependent ....

non-physics results

Outreach

How to reach out to the ignorant ?

This is a **challenge** that cannot be addressed with exposing scientifc tools and methods even stronger

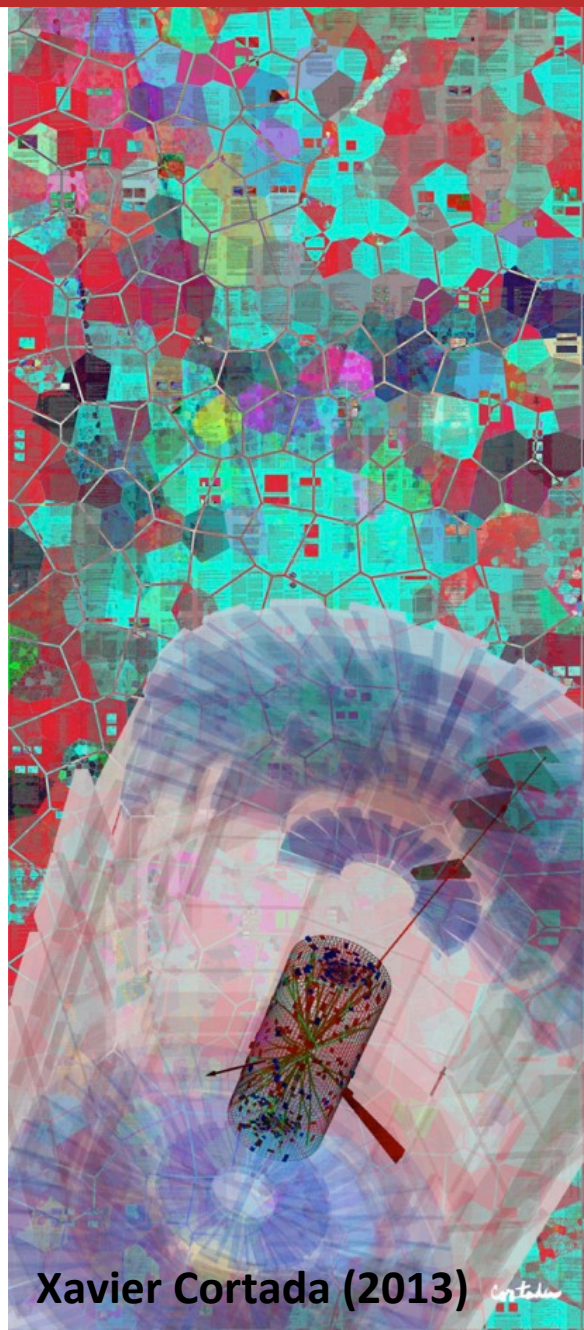
However, **different routes** can **share our enthusiasm** with a wider **audience**

Art projects involving science topics have a big potential to widen the audience

to share excitement

to trigger reflections inside peoples minds on the universe, on science, etc. that otherwise would never happen

And many (all?) of these art projects are even good and interesting for all of us to play, think, and wonder about!



Xavier Cortada (2013)

Outside of the meeting rooms

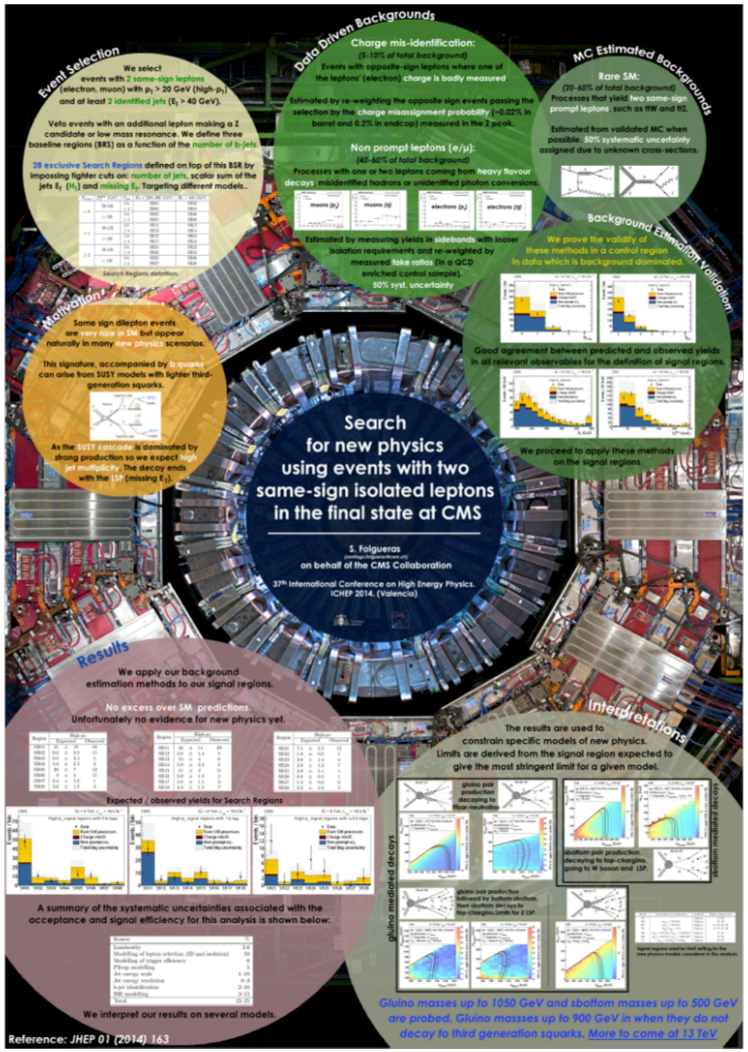
As usual there was a poster Session

~ 100 posters across all fields of the conference

Novelty this year (at least for me) :

Competition for « best » poster (?)

Prize for winner : 750 Euros



Spares

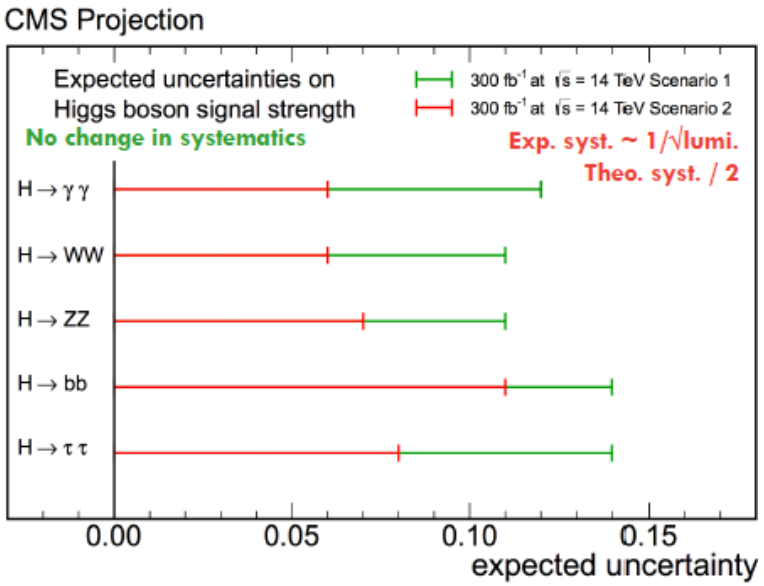
Prospects

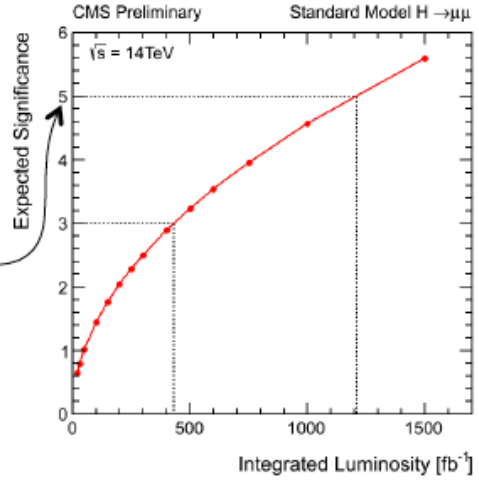
A. Adams
CMS

Looking ahead

96 [arXiv:1307.7135] [CMS-PAS-HIG-13-007]

- 300 fb^{-1} at 14 TeV:
  - Vast improvement over present datasets.
  - **Room for theory improvements.**
- For (HL-LHC) 3000 fb^{-1}:
  - **H→μμ at > 5σ.**
  - Can we get to the Higgs self-coupling?





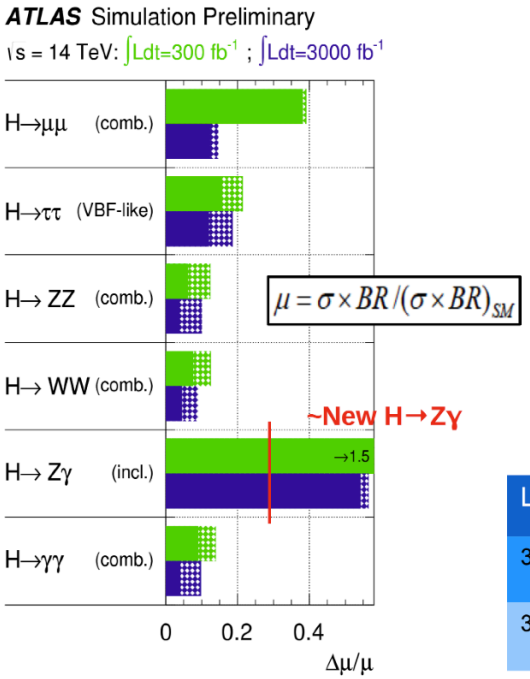
Prospects

R. Camacho
ATLAS

ATL-PHYS-PUB-2013-014

Signal strength

Can be measured for the main channels (WW, ZZ, γγ) within 5%(10%) with (without) theory uncertainties



Couplings

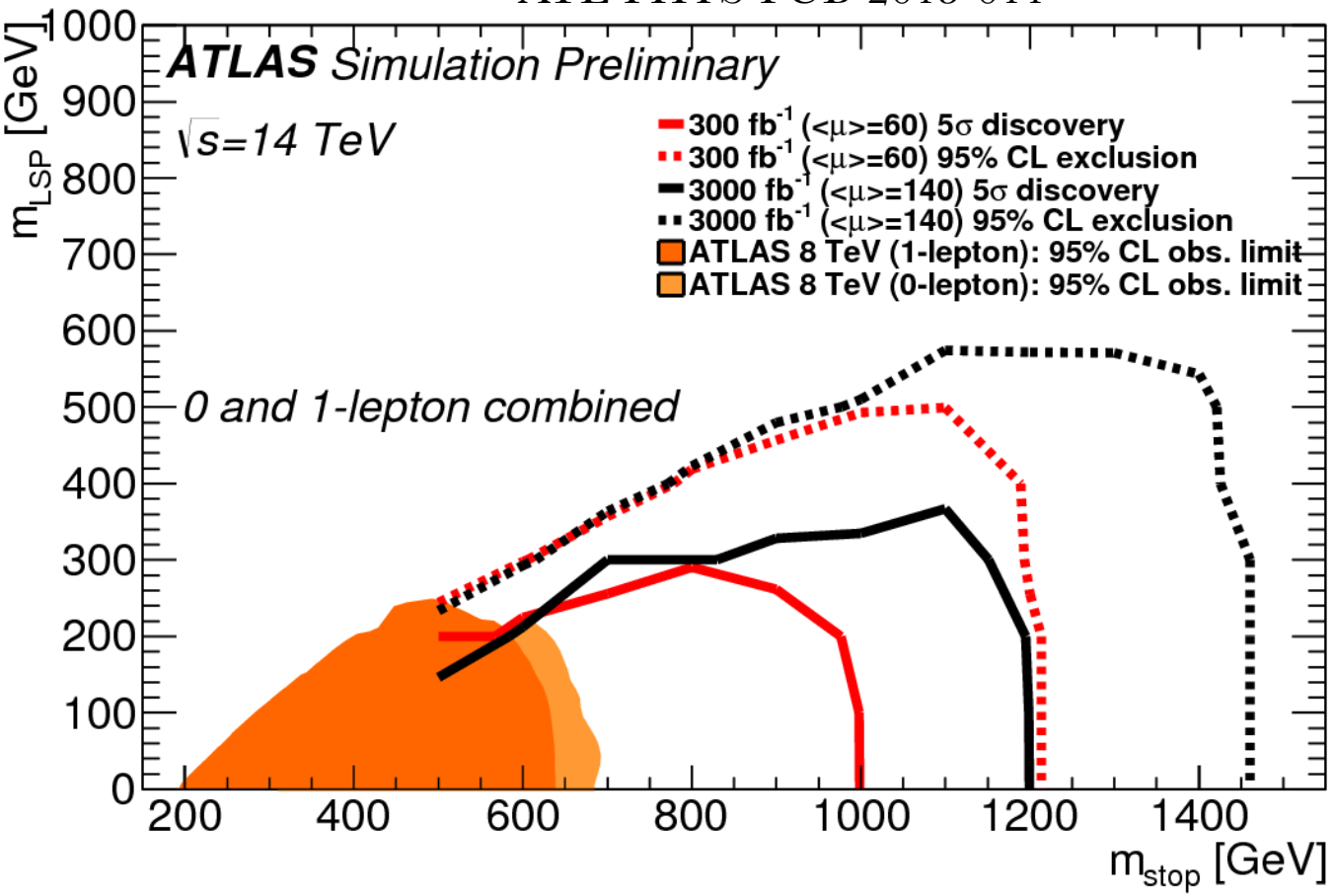
- Crucial information from bb decay channels presented earlier not yet used here: uses ττ to fix fermions
- Provides constraint on new physics in H→γγ loop at 5%
- Probes couplings of 2nd and 3rd generation at 25% precision
- About 10% (5%) precision in Higgs couplings to vector bosons reachable with 300 fb^{-1} (3000 fb^{-1})

L	K_γ,%	K_W	K_Z	K_g	K_b	K_t	K_τ	$K_{Z\gamma}$	K_μ
300 fb^{-1}	[8,13]	[7,8]	[7,8]	[9,11]	-	[20,22]	[13,18]	[78,79]	[21,23]
3000 fb^{-1}	[5,9]	[4,6]	[4,6]	[5,7]	-	[8,10]	[10,15]	[29,30]	[8,11]

New Zγ, γγ and bb information not included yet 16

Prospects

ATL-PHYS-PUB-2013-011



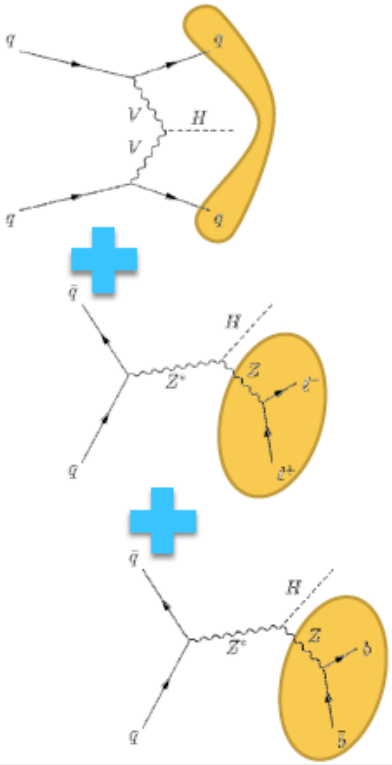
Higgs portal CMS

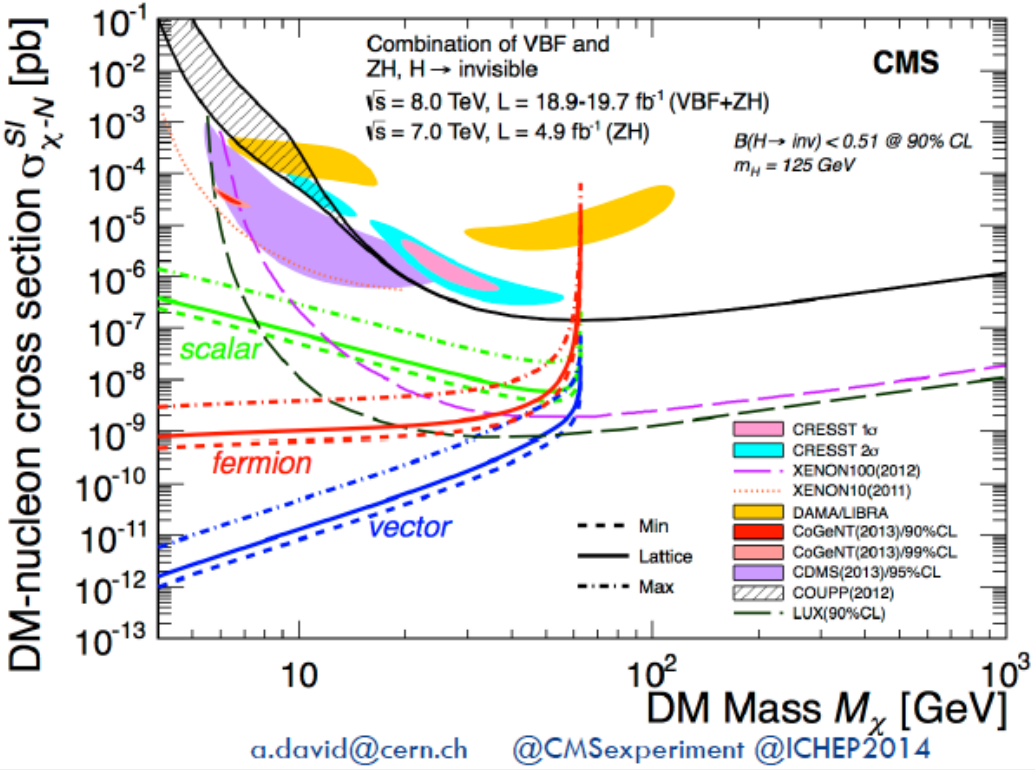
A. Adams

Invisible Higgs search combination

86 [arXiv:1404.1344, submitted to EPJC]

- Combination of **VBF, Z(ℓℓ)H, and Z(b$\bar{b}$)H** searches: **BR(H→inv) < 0.58** (0.44 exp.) at 95% CL.
- **Competitive limits for low mass DM in "Higgs portal" models.**





a.david@cern.ch @CMSexperiment @ICHEP2014

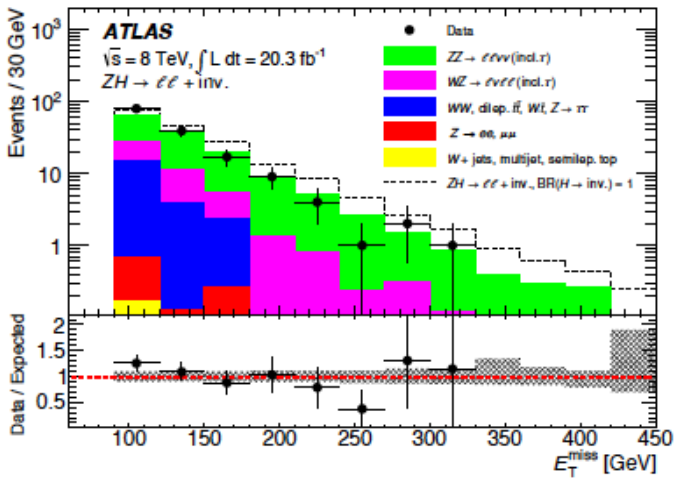
Higgs portal ATLAS

Directly probing invisible decays

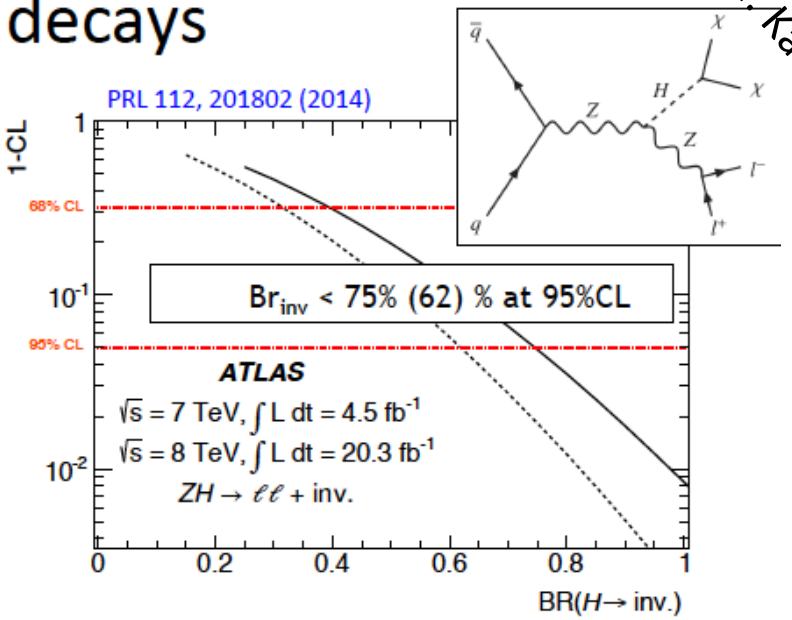
M. Kado

Highlight Analysis II

PRL 112, 201802 (2014)

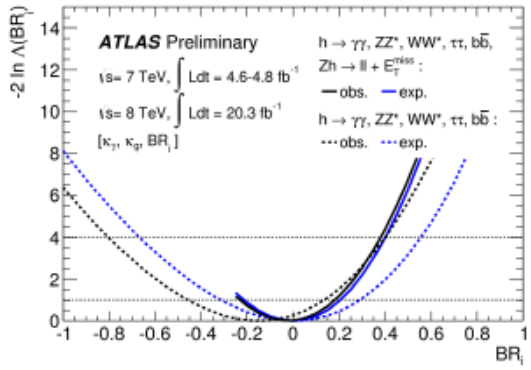


PRL 112, 201802 (2014)

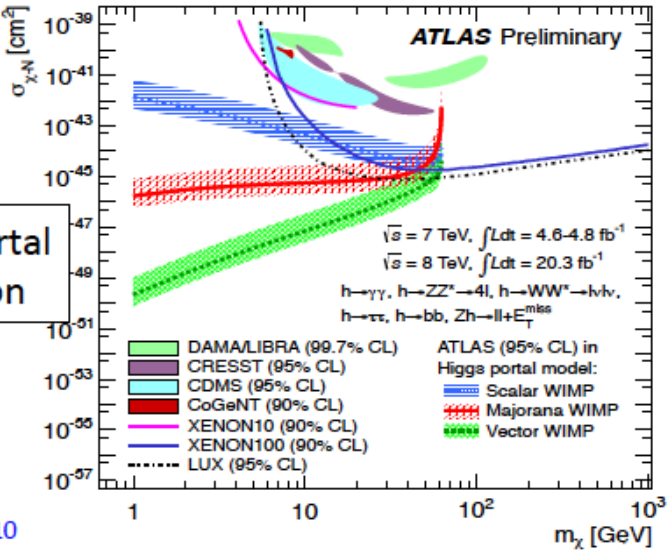


- Visible – Invisible combination
- Corresponding limit :

Br_{inv} < 37% (39) % at 95%CL



Pure Higgs portal interpretation



ATLAS-CONF-2014-010

$B^0 \rightarrow K^{*0} \mu\mu$

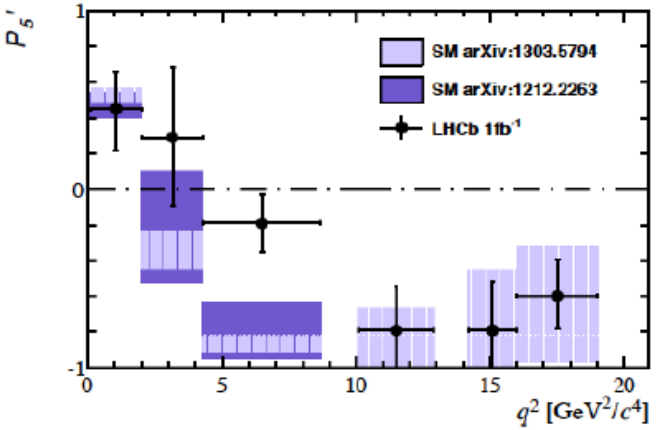
G. Isidori

- *The anomalies:*

I. The P_5' anomaly in $B \rightarrow K^{*0}\mu\mu$

3.7σ local discrepancy
vs. SM [Descotes-Genon et al. '13]

II. Overall smallness of the four
$BR(B \rightarrow H\mu\mu)$, $H=K^{*0}, K^{*+}, K^+, K^0$



Pro NP:

- Reduced tension with data in both cases with a unique fit of modified Wilson coefficients (mainly C_9)
- The corresponding effective NP scale is high (~10 TeV), not in contradiction with other data

Against NP:

- Main effect in P_5' not far from cc threshold
- Significance reduced with conservative estimates of non-factorizable corrections

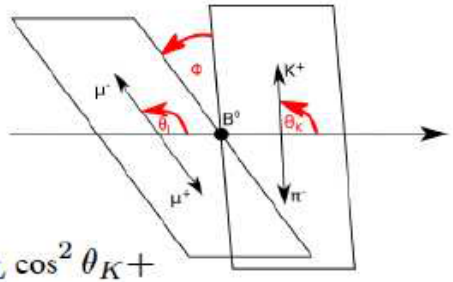
Jaeger *et al.* '12
Hambrock *et al.* '13
Hiller & Zwicky '13

$B^0 \rightarrow K^{*0} \mu\mu$

G. Isidori

▶ *What's* P_5' *?*

Angular analysis of $B^0 \to K^{*0}\mu^+\mu^-$

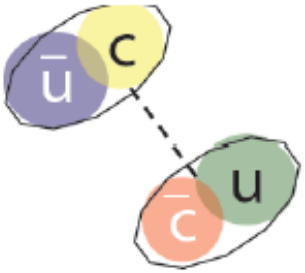


$$\frac{d^4(\Gamma+\bar{\Gamma})}{d\cos\theta_\ell\, d\cos\theta_K\, d\phi\, dq^2} = \frac{9}{32\pi}\Big[\frac{3}{4}(1-F_L)\sin^2\theta_K + F_L\cos^2\theta_K +$$
$$\frac{1}{4}(1-F_L)\sin^2\theta_K\cos 2\theta_\ell - F_L\cos^2\theta_K\cos 2\theta_\ell +$$
$$S_3\sin^2\theta_K\sin^2\theta_\ell\cos 2\phi + S_4\sin 2\theta_K\sin 2\theta_\ell\cos\phi +$$
$$S_5\sin 2\theta_K\sin\theta_\ell\cos\phi + S_6\sin^2\theta_K\cos\theta_\ell +$$
$$S_7\sin 2\theta_K\sin\theta_\ell\sin\phi +$$
$$S_8\sin 2\theta_K\sin 2\theta_\ell\sin\phi + S_9\sin^2\theta_K\sin^2\theta_\ell\sin 2\phi\Big]$$

$$P'_{4,5} = \frac{S_{4,5}}{\sqrt{F_L(1-F_L)}}$$

Exotics - spares

H. Peng

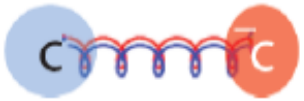


Molecular states :

- Loosely bound states of a pair of mesons,
- bound by the long-range color-singlet pion exchange,
- weakly bound, mesons tend to decay as if they were free.

Tetraquarks :

- bound states of four quarks,
- bound by colored-force between quarks,
- decay through rearrangement,
- many states with the same multiplet, some are with non-zero charge, or strangeness



Hybrid :

- bound states with a pair of quarks and one excited gluon
- Lattice and model predictions for lowest lying charmonium hybrid m~4200MeV