DPS and the Higgs signal strength at the LHC

The principal purpose of this talk is to ask questions to the DPS-expert community, rather than to provide answers…

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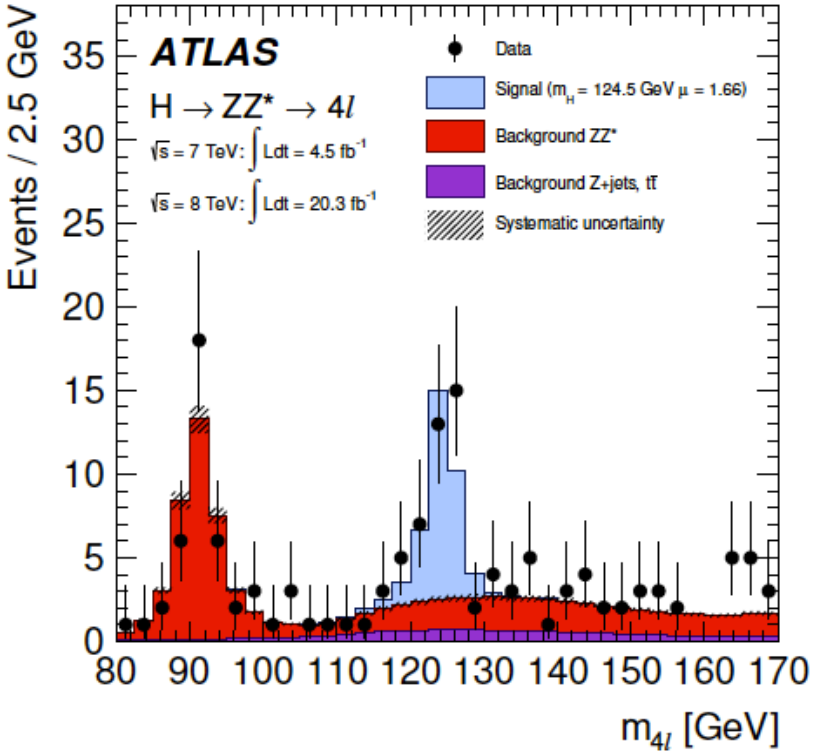
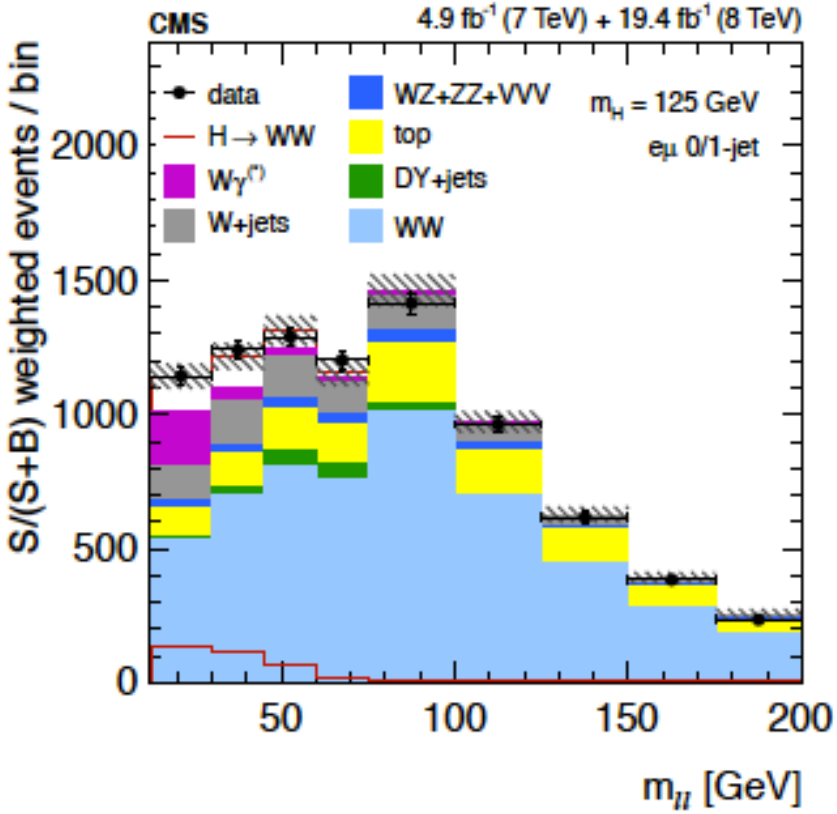
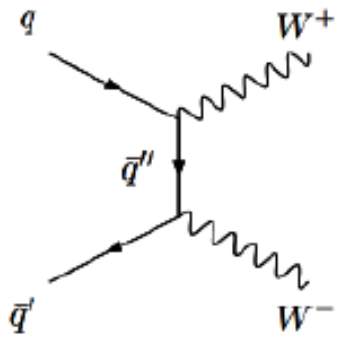
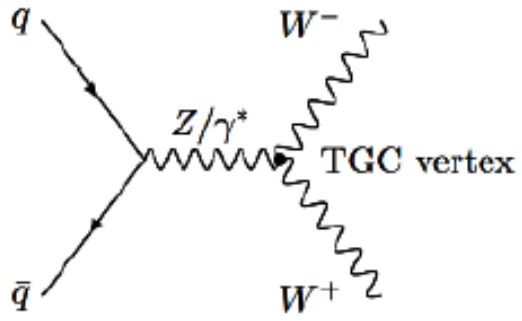
Background to Higgs searches in the VV* channel (ZZ*, WW*)

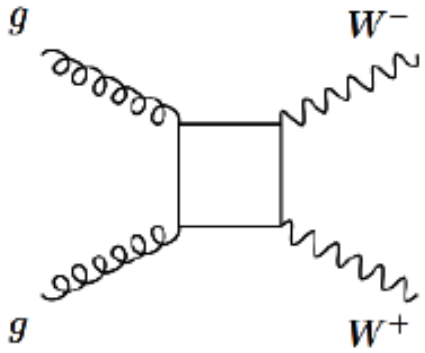




Irreducible background (not controlled experimentally within the present analysis methods)







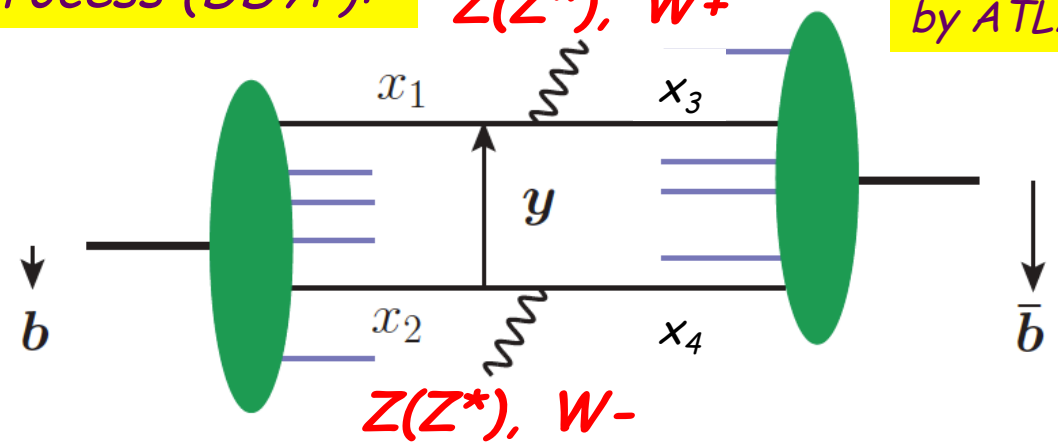
Quark-antiquark annihilation : NLO MCs available: dominant contribution to the WW and ZZ* background*

Gluon-gluon collision, (LO MCs available: contribution for $\mu = M_W$ at the level of couple of % (cut dep.)

Is there any other irreducible background source which needs to be considered?

DPS background to Higgs searches

Double DY Process (DDYP):



Considered as negligible by ATLAS and CMS

Conventional picture of DDYP:

$$\sigma^{\mathrm{DDYP}}(p_1,p_2,p_3,p_4) = \frac{\sigma^{\mathrm{SDYP}}(p_1,p_2)\,\sigma^{\mathrm{SDYP}}(p_3,p_4)}{S_{qq}},$$

S_{qq} - σ_{eff} for qqbar

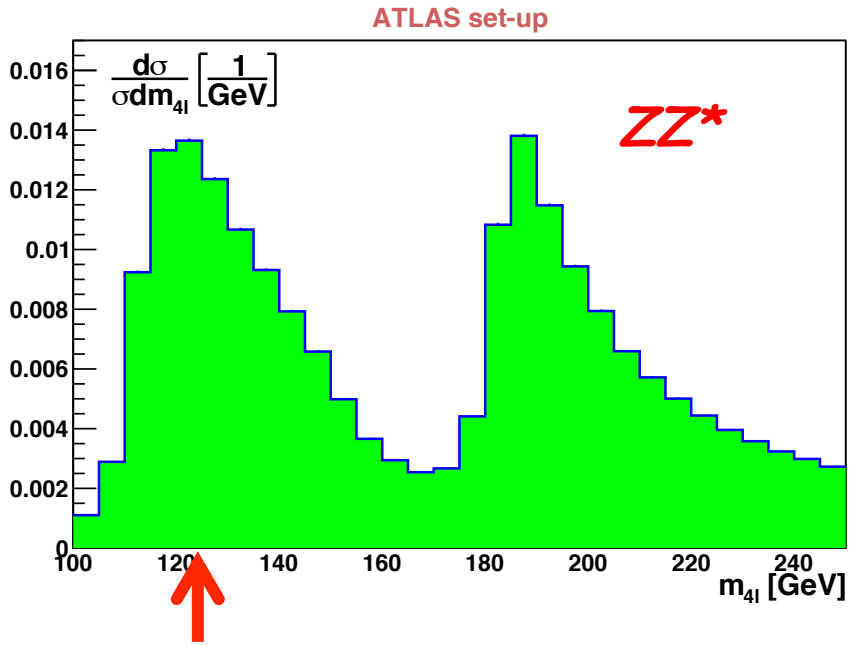
$$D_q(x_1,x_2,m_1^2,m_2^2)D_q(x_3,x_4,m_1^2,m_2^2) = q(x_1,m_1^2)q(x_3,m_1^2)q(x_2,m_2^2)q(x_4,m_2^2)$$

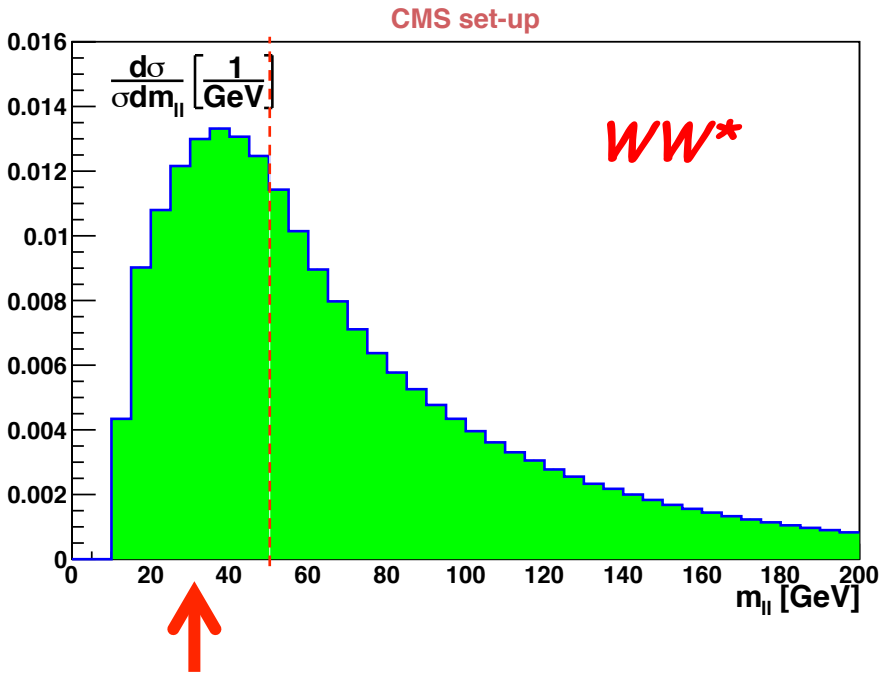
Neglected: *amplitude formalism and interferences, colour, spin and flavour correlations, correlations between the longitudinal momenta of participants, beyond the momentum conservation constraints*

Why bothering?

The DDYP mimics the "Higgs-like" signals!

Mass spectra (kinematical cuts implemented) – WINHAC generator



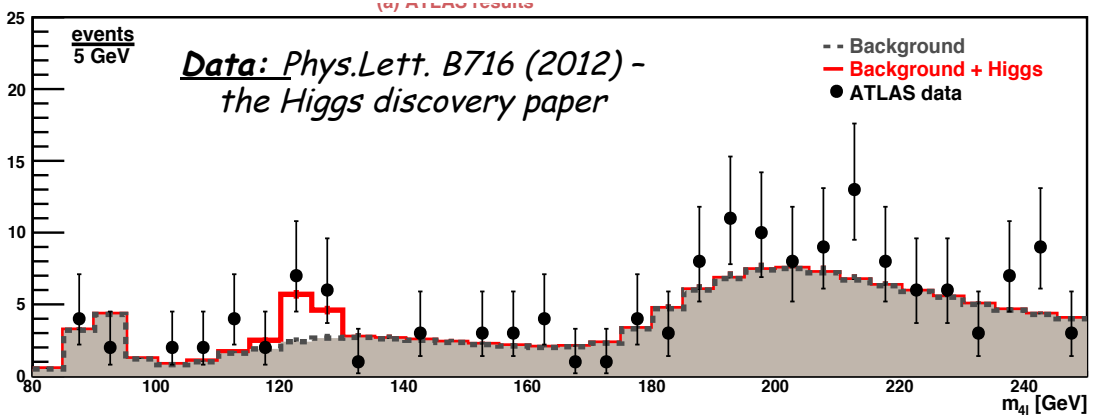


A peaking behaviour of the 4l mass spectrum (a peak at ~ 125 GeV) – interplay of kin. cuts and dynamics.

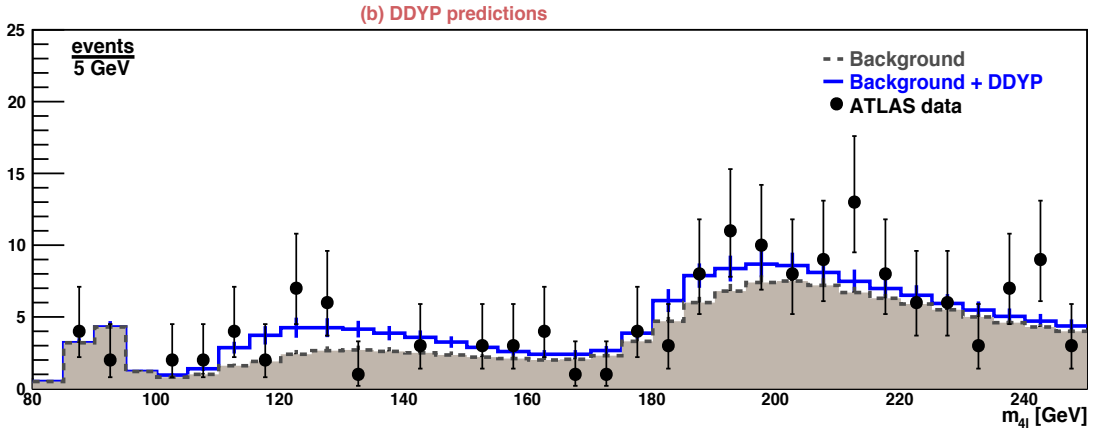
A dominant contribution in the region of small m_{ll} where the Higgs signal is expected to appear

Indeed, comparable fit quality for the Higgs and the DDYP hypotheses?

(M.W.K and W.P, Acta Phys.Polon. B45 (2014) 1, 71-87)



$$\chi^2/\mathrm{dof} = 1.14$$
$$p_0 = 0.25$$



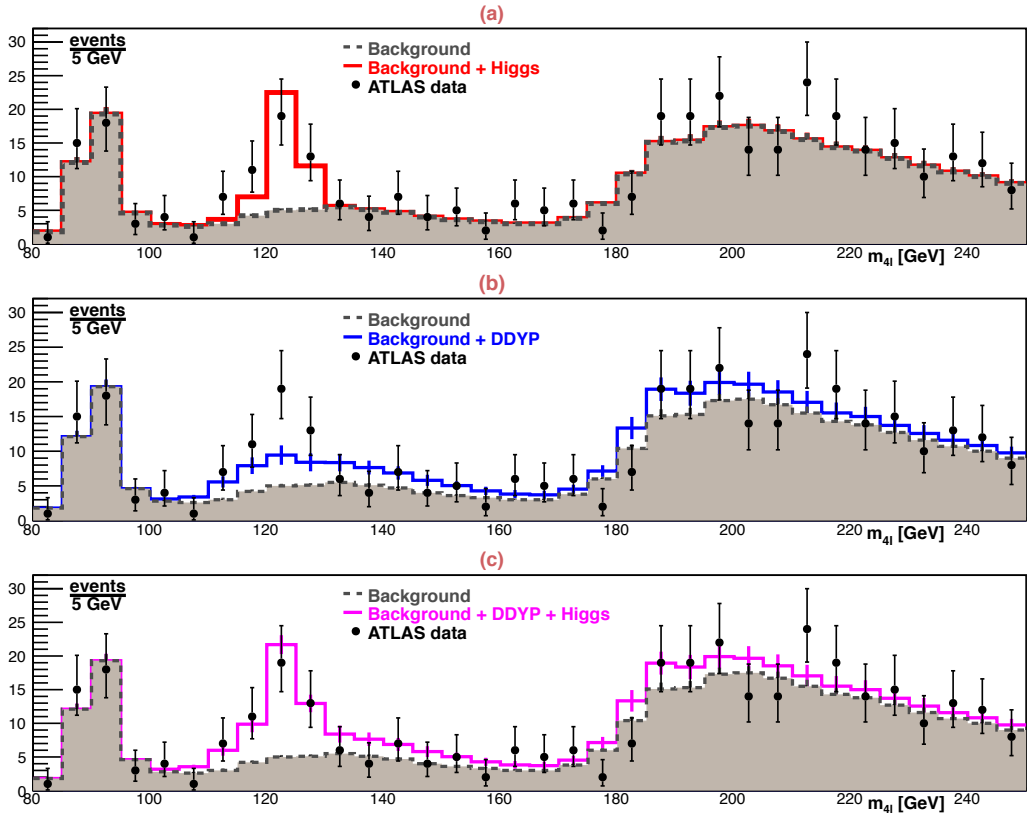
$$\chi^2/\mathrm{dof} = 1.04$$
$$p_0 = 0.41$$

$$S^{ZZ}_{q\bar{q}} = 0.14 \pm 0.07\ \mathrm{mb}$$

DDYP – parameter free prediction ! *… once the normalisation in the monitoring region: m_{4l} = 170-240 GeV is constrained*

Full collected data – 4l channel

(ATLAS coll., Phys. Lett. B 726 (2013),88,)



Higgs: *chi-square/33 = 1.00908, p-value = 0.452683*

DDYP: *chi-square/33 = 1.16372, p-value = 0.237936*

DDYP+Higgs: *chi-square/33 = 0.76894 p-value = 0.826036*

! for mu_Higgs = 1

*…**a word of caution !** – the DDYP contribution is not corrected for the detector effects (unfolded data not published)*

The LHC W+W- cross-section puzzle

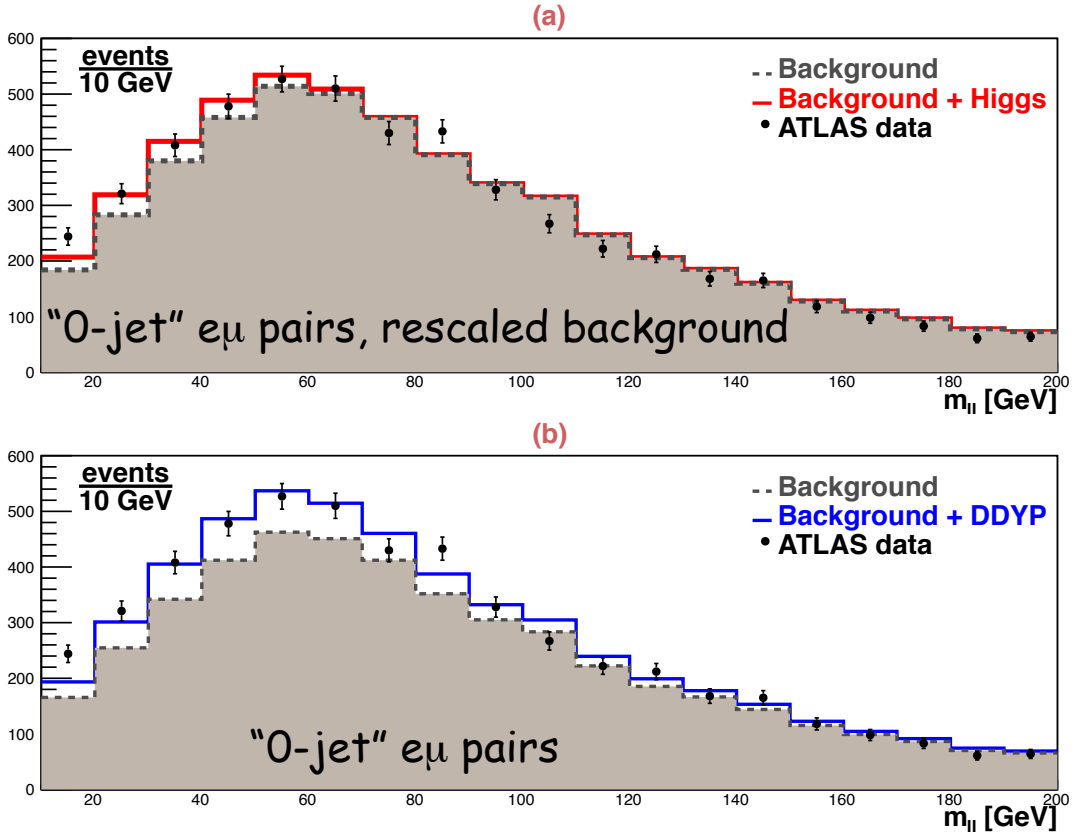
'The WW anomaly'

$\sqrt{s}$	ATLAS σ [pb]	CMS σ [pb]	Theory (MCFM) σ [pb]
7 TeV	$51.9^{+2.0+3.9+2.0}_{-2.0-3.9-2.0}$	$52.4^{+2.0+4.5+1.2}_{-2.0-4.5-1.2}$	$47.04^{+2.02+0.90}_{-1.51-0.66}$
8 TeV	$71.4^{+1.2+5.0+2.2}_{-1.2-4.4-2.1}$	$69.9^{+2.8+5.6+3.1}_{-2.8-5.6-3.1}$	$57.25^{+2.35+1.09}_{-1.60-0.80}$

Missing SM contribution at the level of ~14 pb (to be compared with the SM Higgs cross section of 4.6 +/- 1.1 pb. Necessity to rescale the background by ~20 % upwards.

Full collected data – 2l2ν channel

(Data: ATLAS coll., Phys. Lett. B 726 (2013),88,)



If DDYP-like process considered seriously…
→ parameter free prediction for the excess of events in the WW channel!. Background rescaling no longer needed!*

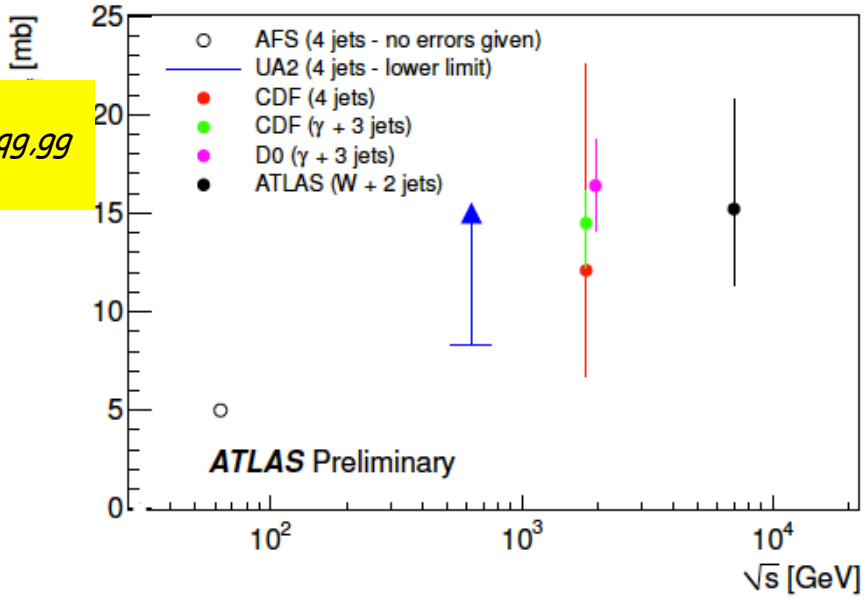
Solution of the W+W- cross-section puzzle?

Note: *The DDYP relates the excesses of the observed events in the ZZ and WW channels.*

…a word of caution! *– the DDYP contribution is not corrected for the detector effects (unfolded data not published)*

Why the background coming from the DDYP was not considered to be important by ATLAS and CMS?

$S_{qq,gg}$



For the gluon-gluon and gluon-quark: $S_{qg,gg} \sim 15$ *mbarn*

To explain the "Higgs-like" excess partially (fully) one needs (within the canonical formalism) :

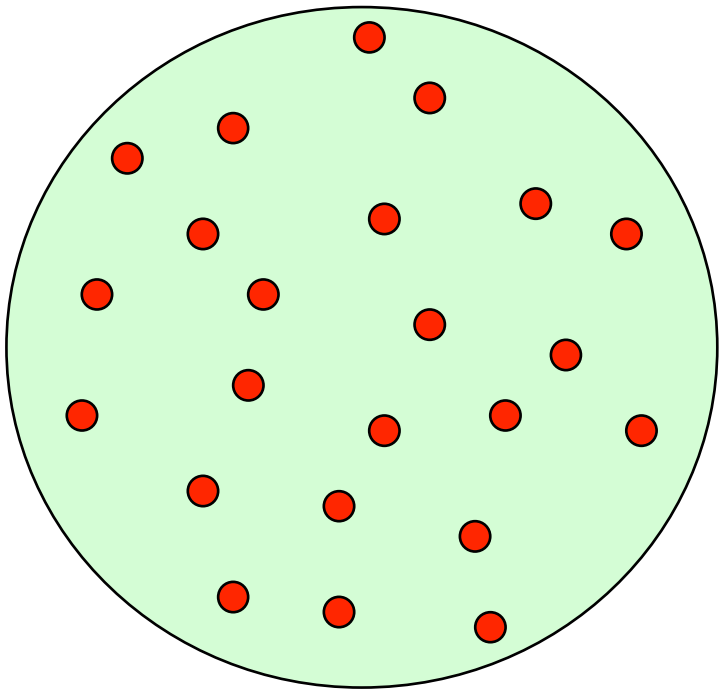
$$S_{qqbar} \sim 0.1\ (0.01)\ S_{qg,gg}$$

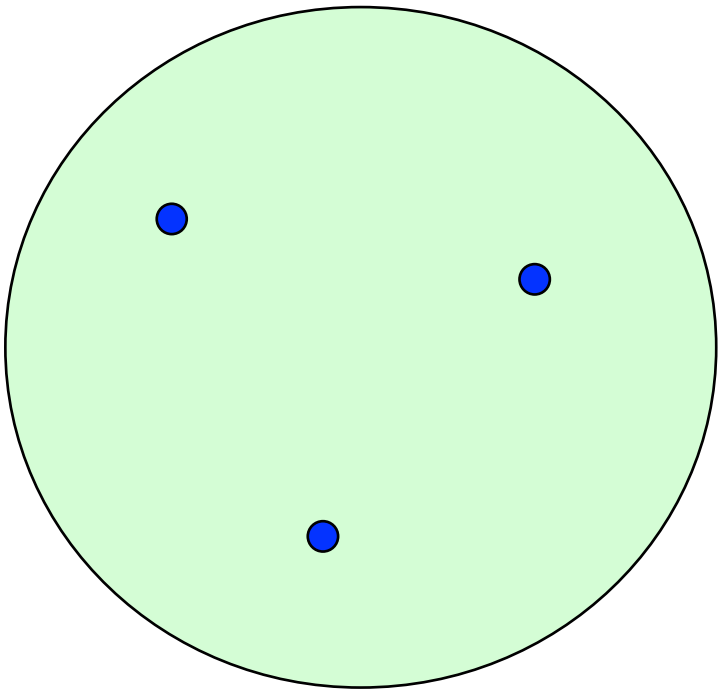
Can one reject a priori such, at first sight, unrealistic hypothesis (before measuring it) ???

The possible sources of enhancements of the DPI probability in the DDYP mimicking the Higgs signal:

- The transverse plane correlation length for the same flavour, opposite charge qqbar pairs
- Canonical PDFs, and PDFs assuring the local charge and flavour conservation
- Local spin conservation for qqbar pairs
- Less canonical mechanism of the electro-weak symmetry breaking, enhancing the VV cross-sections

The transverse-plane structure of the proton seen with the $1/M_Z$ transverse resolution

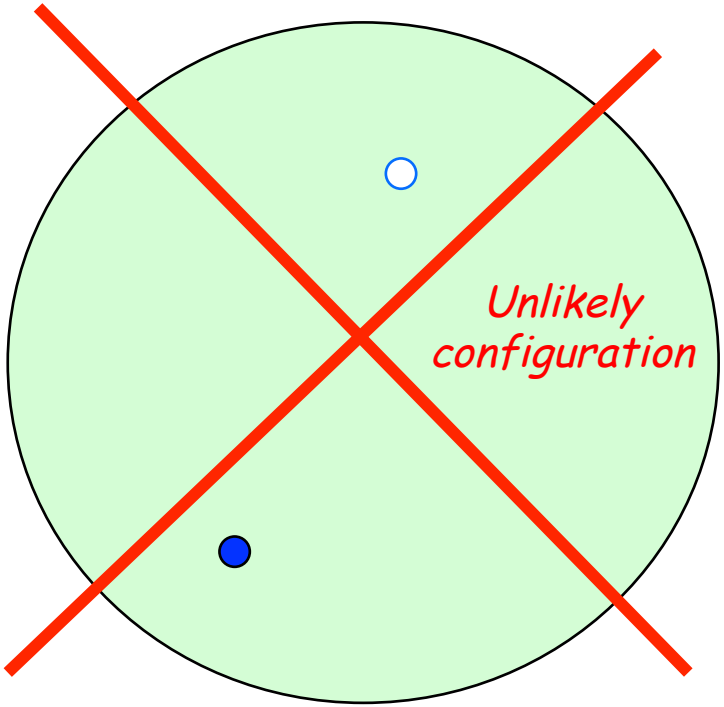


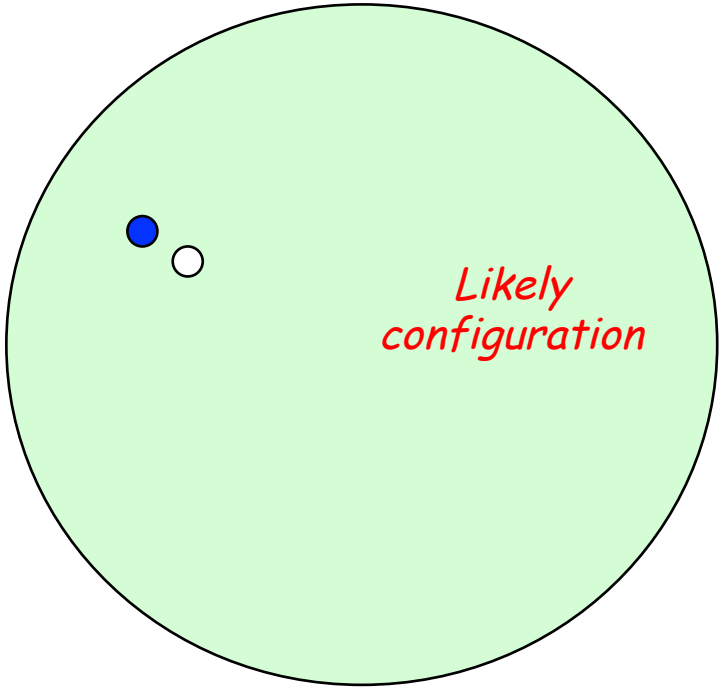


Gluonic structure of proton: *~ 20-30 gluons* ***(x ~0.02)*** *can produce Z bosons*

Valence quark structure of proton: *3 valence quarks can produce Z bosons*

The transverse cross-section of the proton seen with the $1/M_Z$ resolution

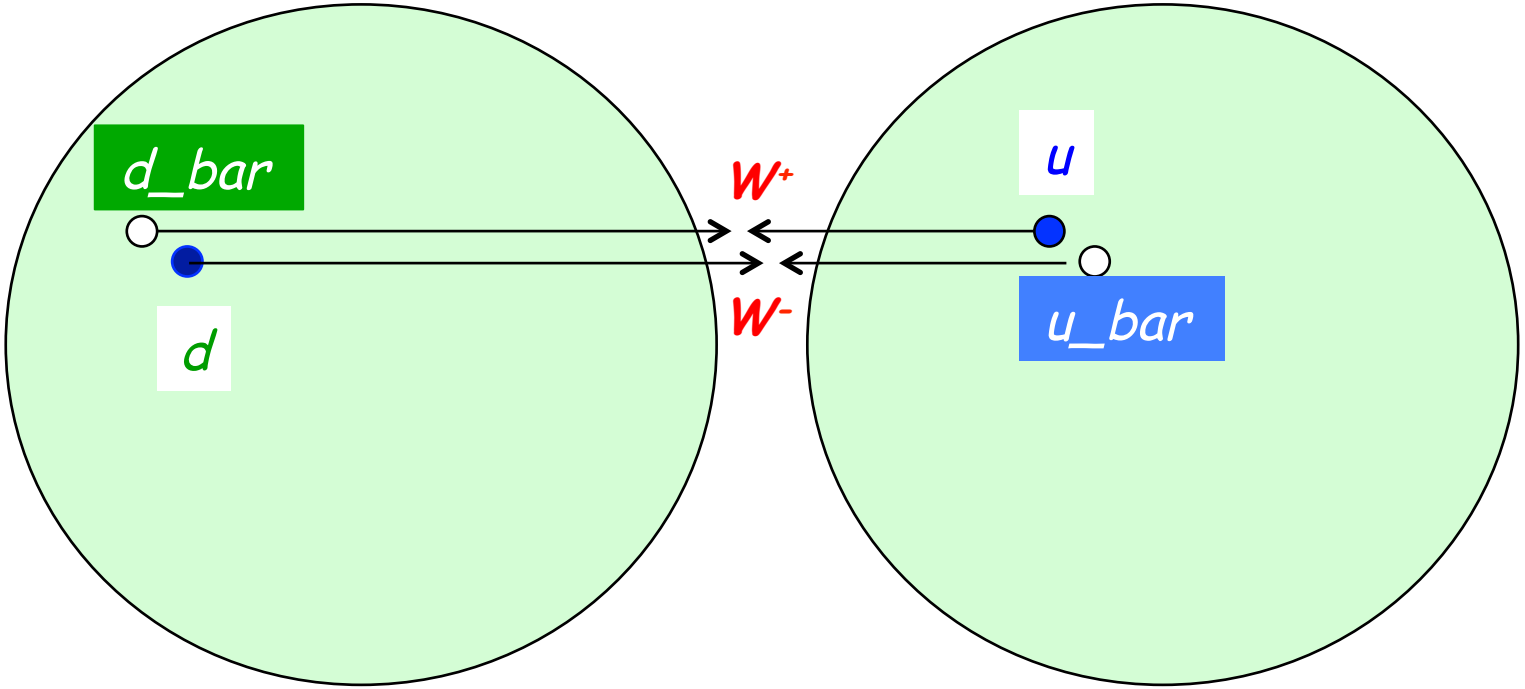




Sea structure of proton:
q- qbar excitation of the proton happen, in the x-region relevant to Higgs searches, with probability smaller than one!

Local (transverse-plane) charge and flavour compensation !

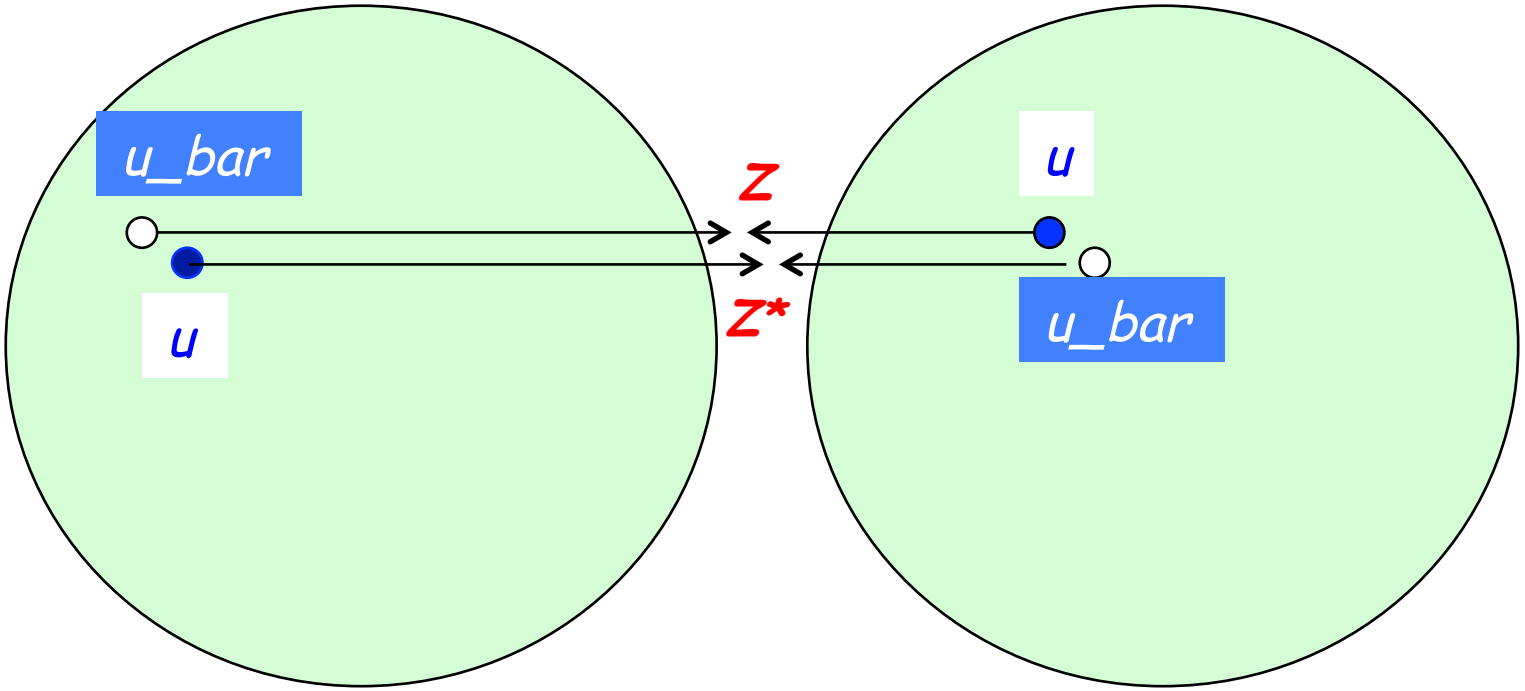
Enhanced W^+W^- production in DDYP



The presence of an antiquark enhances the probability of finding the same flavour quark nearby.

Note, no enhancement for the W^+W^+ and W^-W^- production

Enhanced ZZ (ZZ*) production in DDYP



The transverse plane correlation length of the uubar and ddbar pairs are the same (strong isospin symmetry) – the DDYP excess of ZZ and WW events is strongly correlated (mimicking the custodial symmetry)

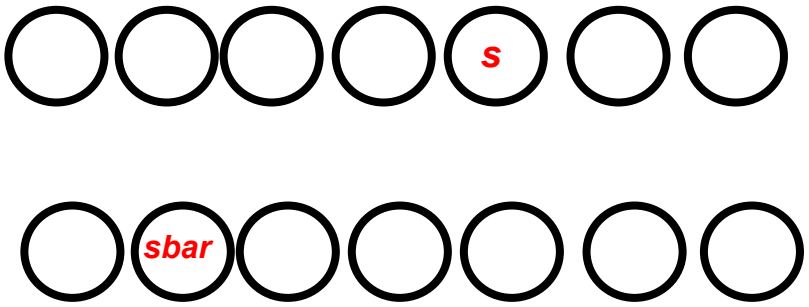
If qqbar excitations confined to the QCD lattice instanton size of 0.2 fm an enhancement of the DPS cross section by a factor of ~ 10

Canonical PDFs, and the PDFs assuring the local charge and flavour conservation *(frequent mis-interpretation of PDFs)*

Canonical approach

$q_i(x)\Delta x = qbar_i(x)\Delta x \sim \kappa$

$N_{qqbar\text{-}i}(x, x, \Delta x) \sim \kappa^2$



$P(DPI) \sim N_{ssbar} \sim (1/7)^2 = 1/49$

(for x ~ 0.01-0.02)

Local flavour conservation

$N_{qqbar\text{-}i}(x, \Delta x) \sim q_i(x)\Delta x \sim \kappa$

(the presence of a sea quark q_i in the proton Induces the presence of $qbar_i$ in the same proton)

$P(DPI) \sim N_{ssbar} \sim 1/7$

For small α (e.g. in the Higgs signal x-region) a significant underestimation of the probability of DPI involving the same flavour and opposite charge quarks and, as a consequence, a significant enhancement of the DPS background contribution –

only to the ZZ, Zγ*,W+W- final states!

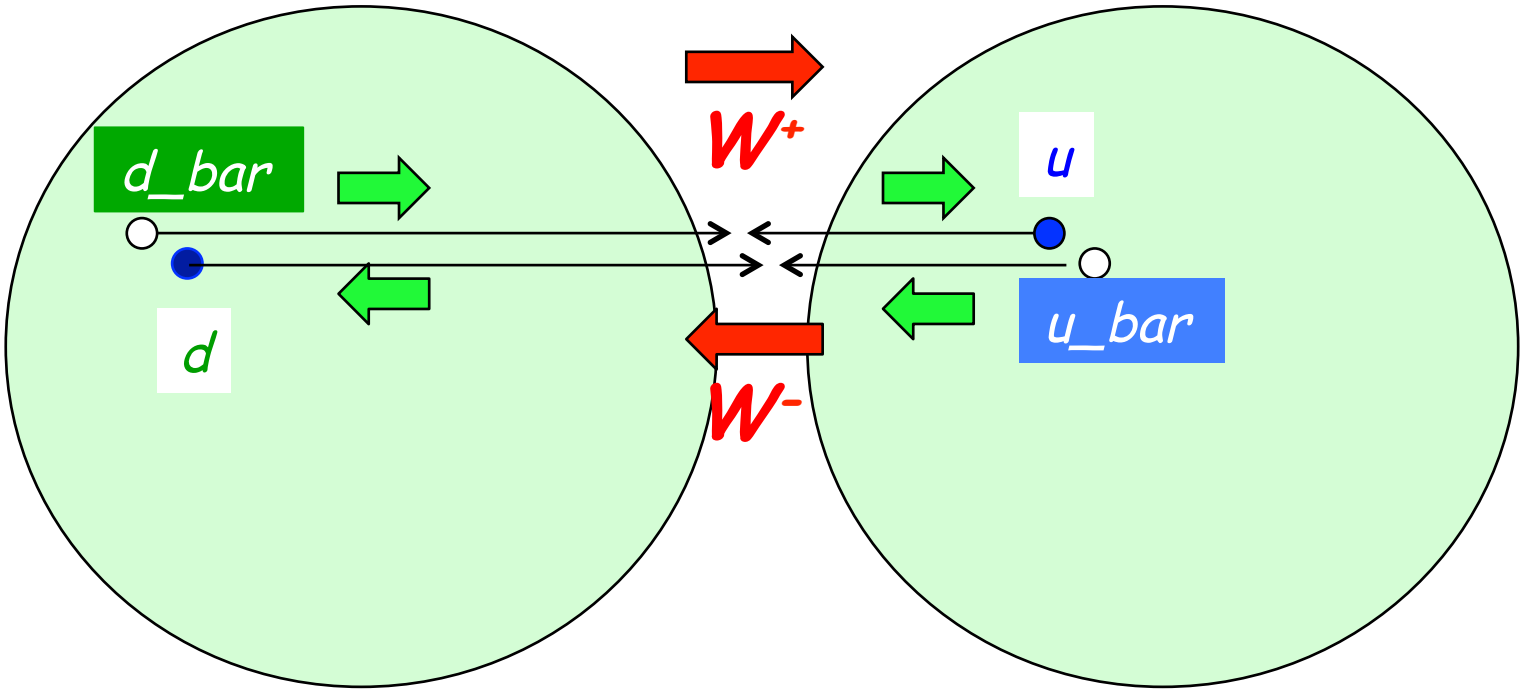
by a factor ~ $1/(N_{flavour} \times \kappa^2)$

...*in the simpleminded case of the flavour symmetry of the sea*

(realistically, a factor 5-10 expected for the lepton detection acceptance region of the LHC detectors)

Local spin compensation for qqbar pairs

(mimicking Higgs-like, spin 0, W^+W^- or ZZ* configurations)



The sea excitations carry a very small fraction of the proton spin

Consequence: ***local spin compensation:*** ***spin of DDYP W^+W^- = 0***

(further enhancement in the "Higgs kinematical region")

Can one resolve experimentally, at the LHC, the DDYP with respect to the Higgs boson decay signal?

Model independent test of DDYP.vs.Higgs

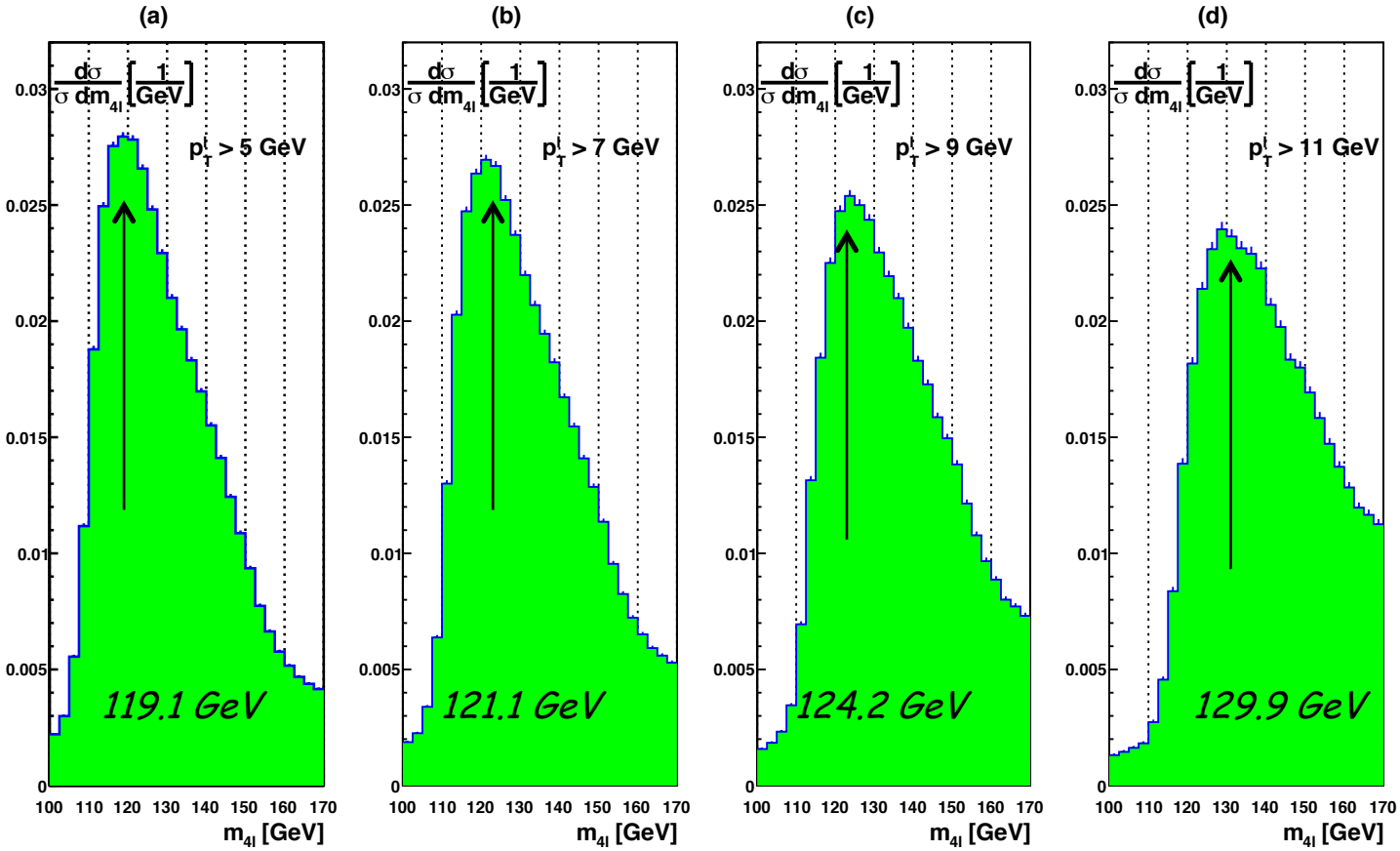
Similarities (ZZ* case) :

- *Mass peaks*
- *ZZ (WW) spin*
- *Custodial symmetry*

Differences (ZZ* case)

- *Invariance/variance of the peak position with exp. cuts*
- *Excess in the ~125 GeV region accompanied by the excess close to the $2M_Z$ region*
- *The peak width*
- *The p_T spectra of Z, Z* bosons*

Example: Resolving DDYP peak with respect to the Higgs peak

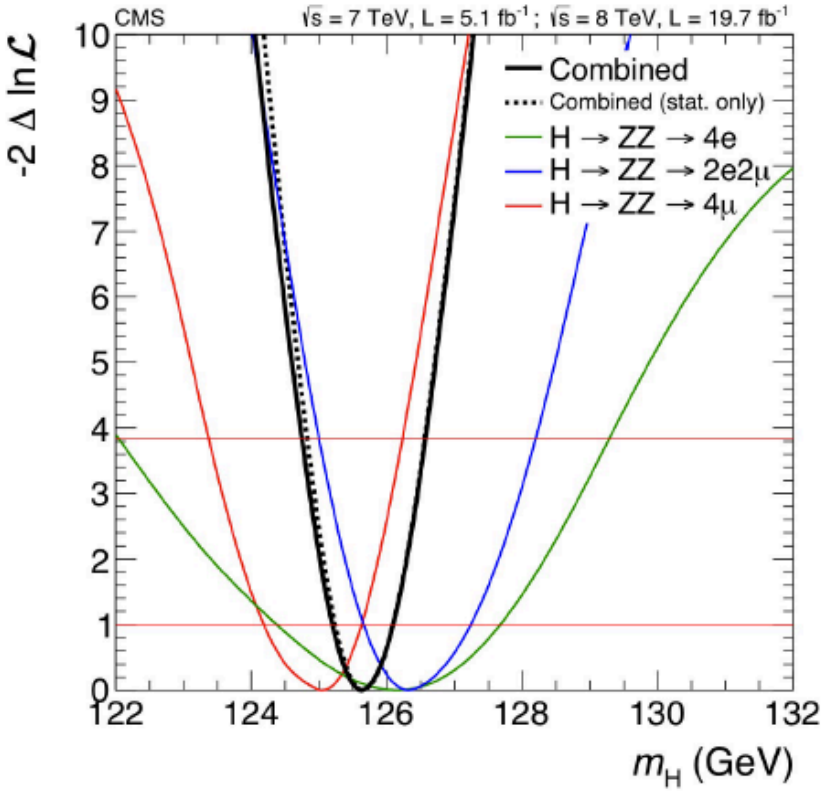


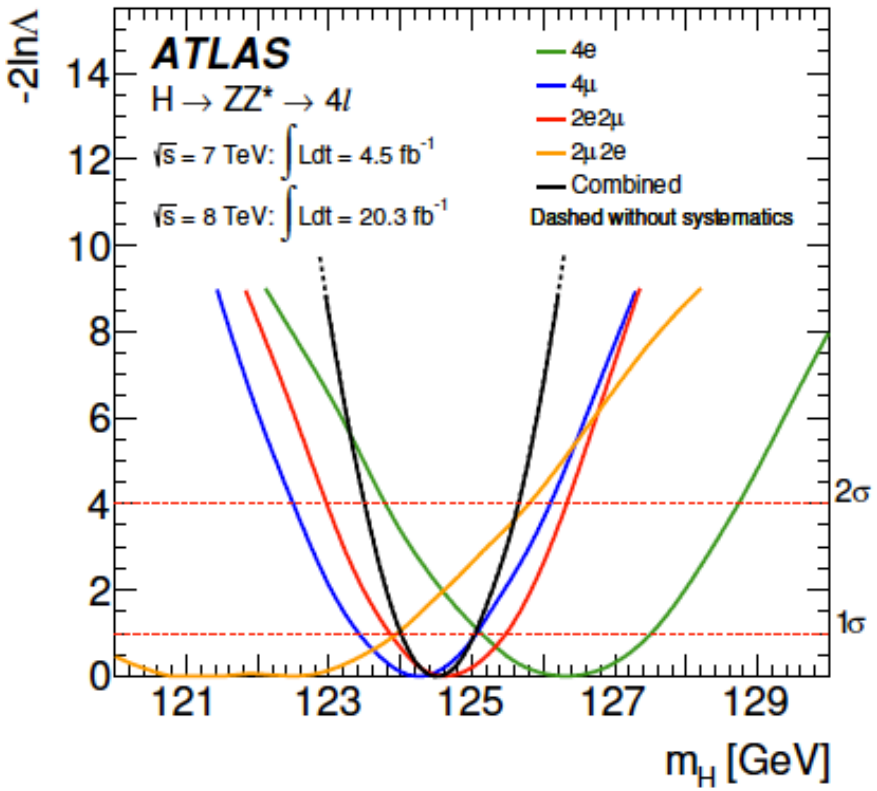
Contrary to the Higgs peak, the DDYP peak moves as a function of the p_T^l cut:

(explanation of the M_{4e}- $M_{4\mu}$?)

Indirect hint: Both ATLAS and CMS have higher p_T^l cuts for electrons than for muons

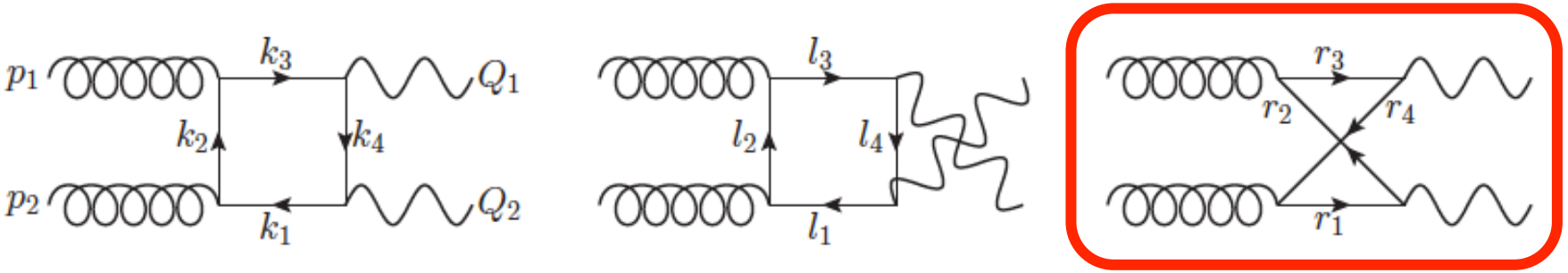
Is this reflected in the shift of the peak position upwards fro the 4e channel?





The ***leading twist***, LO, ***perturbative*** QCD picture of the qqbar excitation of the protons ending up in VV production

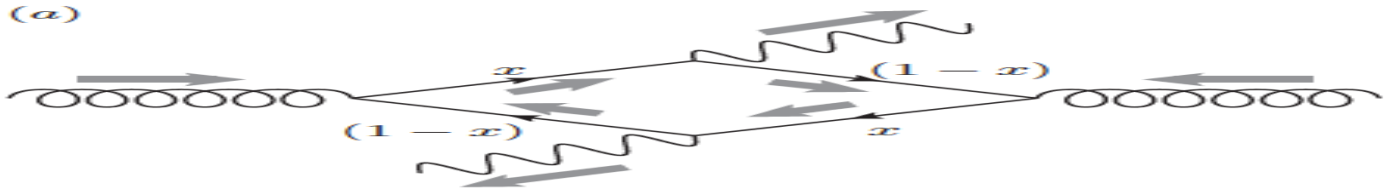
The relationship of the DDYP and "boxes", addressed already by: J.R. Gaunt, W.J. Stirling, A.M. Snigirev, M Diehl, A. Scheafer,….



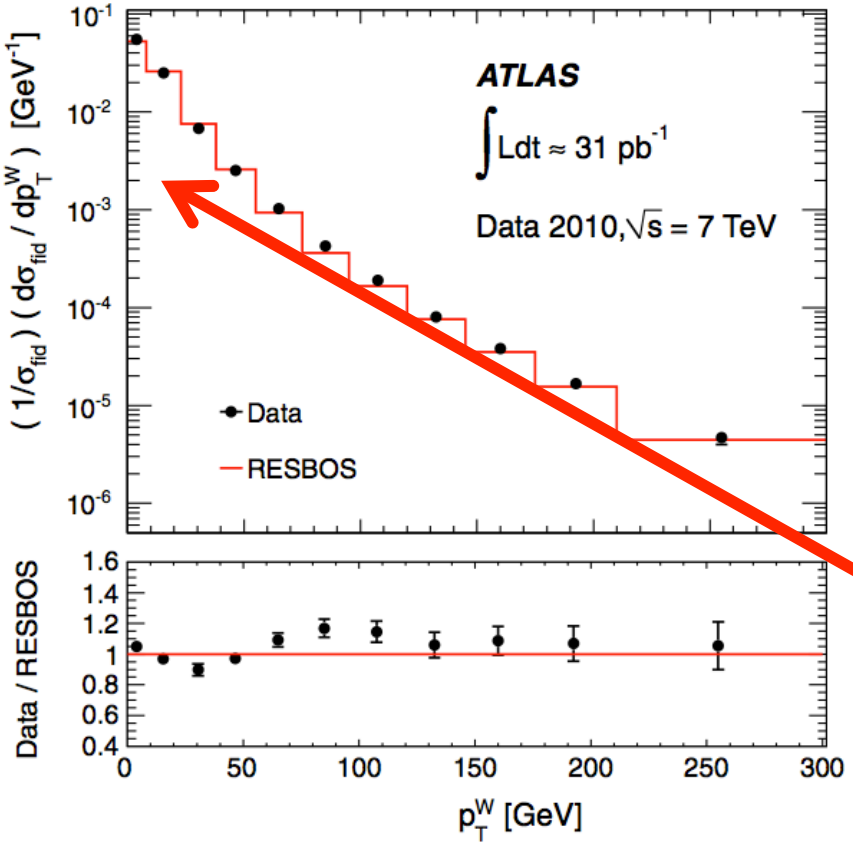
The basic question?

Is the "enhanced" DDYP contribution already "taken care" the gg box diagrams ?

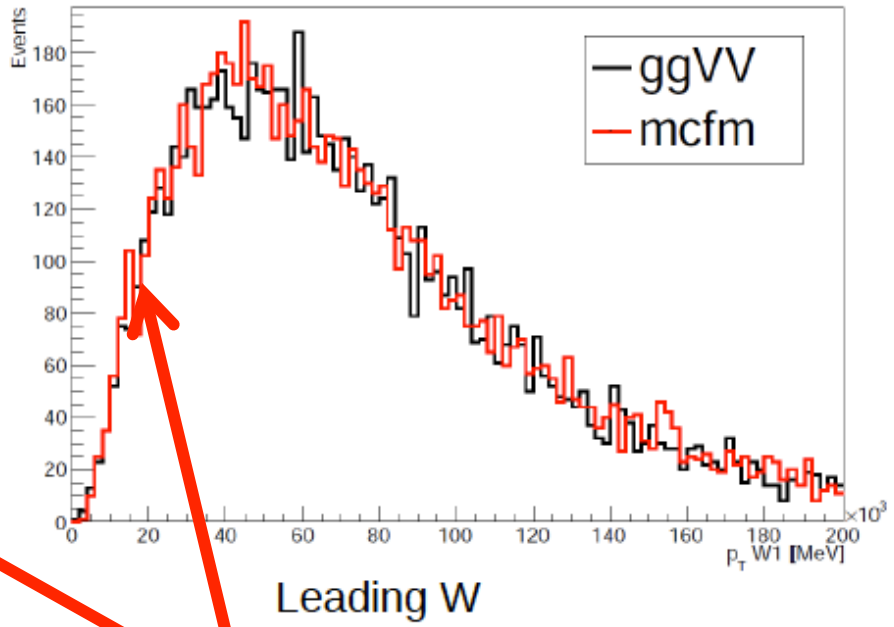
If, yes: Is there any manifestation of the collinear singularity of the conversion of gluons to qqbar in the Monte Carlos used in the Higgs background estimation by ATLAS and CMS?



Inclusive W p_T spectrum



W p_T spectrum for WW events



No sign of collinear enhancement???
An artefact confined to the LT, perturbative, LO picture ???

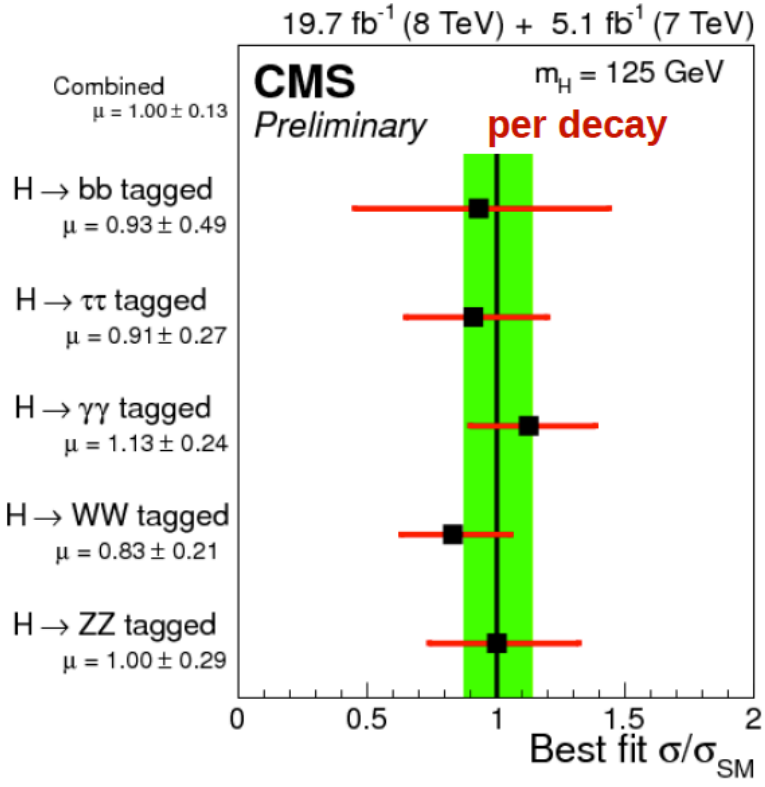
Summary :

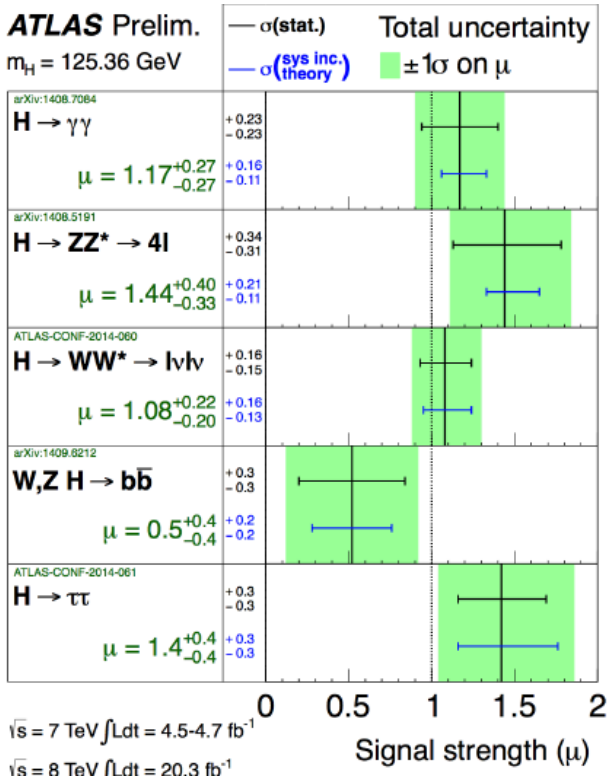
- *The Double Drell Yan Process contribution to the Higgs background was assumed by the ATLAS and CMS collaboration to be negligible*
- *This is indeed the case for the simpleminded model lacking flavour, longitudinal momentum, transverse momentum and spin correlations between colliding partons*
- *In our view the above conclusion is premature and needs further investigation – several reasons of the enhancement of the DDYP cross-sections were presented in this talk*
- *The main purpose of this talk is to attract the attention of the DPS community to the importance of the DDYP process, both in the context of the Higgs searches but also in the context of the investigation of the proton structure (partonic space/momentum, spin and flavour correlations)*
- *…but also to encourage the experimentalists to investigate the "Higgs-like excesses of events" in a more open context…*

Extra transparencies

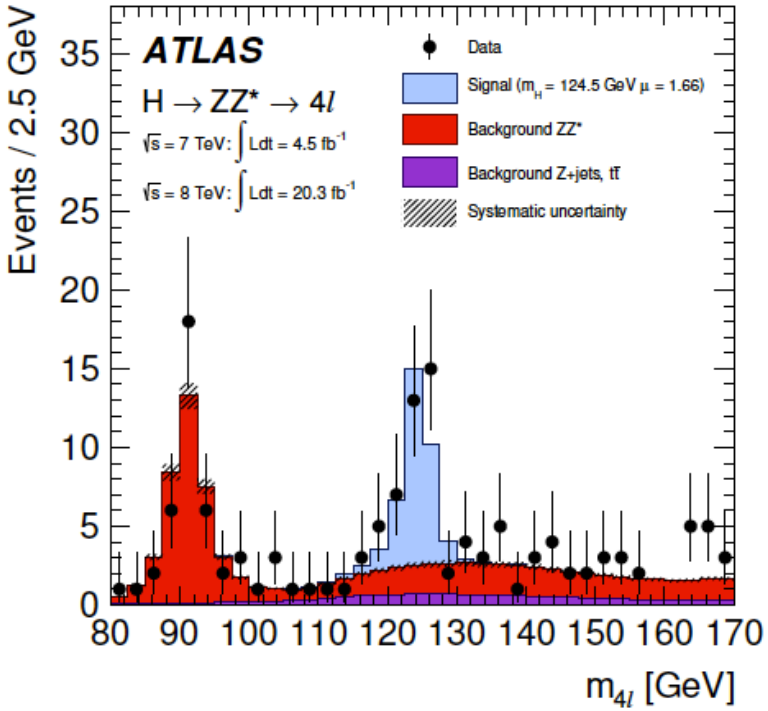
Higgs signal strength - October 2014

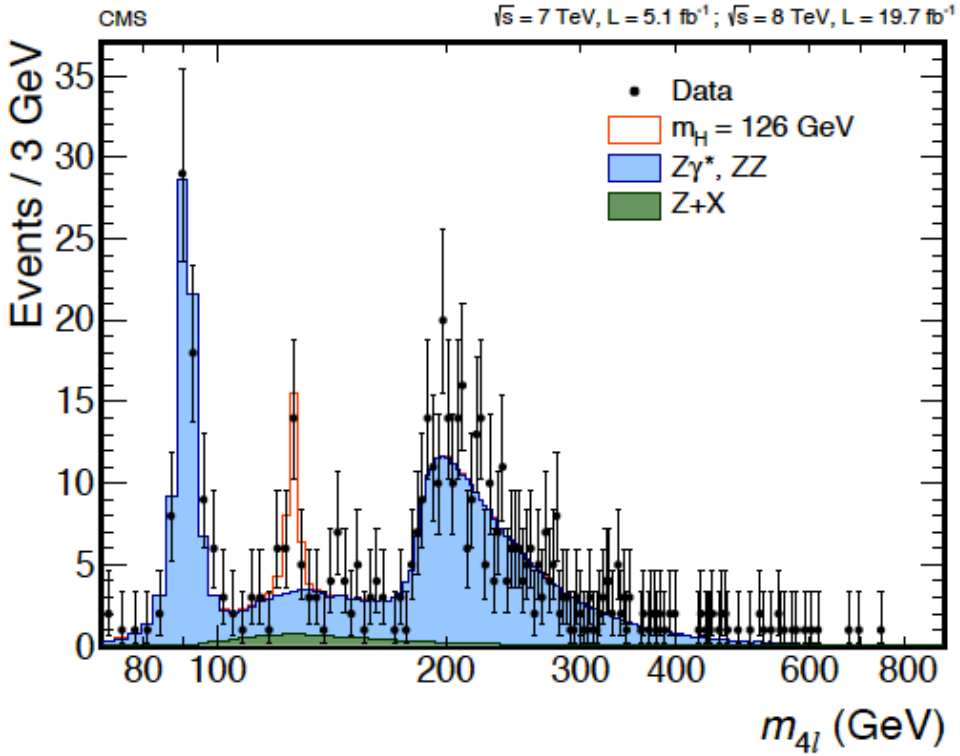
SM Branching ratio at 125.4 GeV						
bb	WW	ττ	ZZ	γγ	Zγ	μμ
57%	22%	6.3%	2.7%	0.23%	0.15%	0.02%





Higgs evidence in the 4l channel





Why the background coming from the DDYP was not considered to be important by ATLAS and CMS?

…because no distinction was made, for the DPS involving the gluon-gluon, gluon-quark and quark-antiquark pairs… and no distinction of the, colour, flavour, charge and spin of the DPS collision products…

Higgs evidence in the 2l2ν channel