Combined Higgs model at ATLAS

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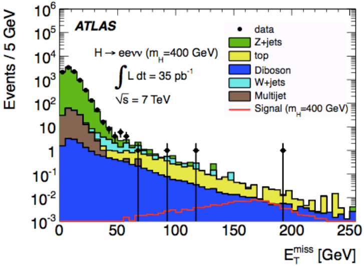
Individual channels

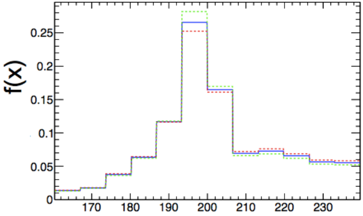
Higgs Boson Decay	Subsequent Decay	Sub-Channels	$\int L\,dt$ [fb^{-1}]	Ref.
2011 $\sqrt{s}$ =7 TeV				
$H \to ZZ^{(*)}$	4ℓ	$\{4e, 2e2\mu, 2\mu2e, 4\mu\}$	4.6	[1]
$H \to \gamma\gamma$	–	10 categories $\{p_{\mathrm{Tt}} \otimes \eta_\gamma \otimes \mathrm{conversion}\} \oplus \{\text{2-jet VBF}\} \oplus \{\ell\text{-tag, 2-jet VH}\}$	4.8	[5]
$H \to \tau\tau$	$\tau_{\mathrm{lep}}\tau_{\mathrm{lep}}$	$\{e\mu\} \otimes \{\text{0-jet}\} \oplus \{\ell\ell\} \otimes \{\text{1-jet, 2-jet}, p_{\mathrm{T},\tau\tau} > 100\ \mathrm{GeV}, VH\}$	4.6	[7]
	$\tau_{\mathrm{lep}}\tau_{\mathrm{had}}$	$\{e, \mu\} \otimes \{\text{0-jet, 1-jet}, p_{\mathrm{T},\tau\tau} > 100\ \mathrm{GeV}, \text{2-jet}\}$	4.6	
	$\tau_{\mathrm{had}}\tau_{\mathrm{had}}$	$\{\text{1-jet, 2-jet}\}$	4.6	
$VH \to Vbb$	$Z \to \nu\nu$	$E_{\mathrm{T}}^{\mathrm{miss}} \in \{120-160, 160-200, \geq 200\ \mathrm{GeV}\} \otimes \{\text{2-jet, 3-jet}\}$	4.6	[8]
	$W \to \ell\nu$	$p_{\mathrm{T}}^{W} \in \{< 50, 50-100, 100-150, 150-200, \geq 200\ \mathrm{GeV}\}$	4.7	
	$Z \to \ell\ell$	$p_{\mathrm{T}}^{Z} \in \{< 50, 50-100, 100-150, 150-200, \geq 200\ \mathrm{GeV}\}$	4.7	
2012 $\sqrt{s}$ =8 TeV				
$H \to ZZ^{(*)}$	4ℓ	$\{4e, 2e2\mu, 2\mu2e, 4\mu\}$	13	[6]
$H \to \gamma\gamma$	–	12 categories $\{p_{\mathrm{Tt}} \otimes \eta_\gamma \otimes \mathrm{conversion}\} \oplus \{\text{2-jet VBF}\} \oplus \{\ell\text{-tag, 2-jet VH}\}$	13	[5]
$H \to WW^{(*)}$	$e\nu\mu\nu$	$\{e\mu, \mu e\} \otimes \{\text{0-jet, 1-jet}\}$	13	[9]
$H \to \tau\tau$	$\tau_{\mathrm{lep}}\tau_{\mathrm{lep}}$	$\{\ell\ell\} \otimes \{\text{1-jet, 2-jet}, p_{\mathrm{T},\tau\tau} > 100\ \mathrm{GeV}, VH\}$	13	[7]
	$\tau_{\mathrm{lep}}\tau_{\mathrm{had}}$	$\{e, \mu\} \otimes \{\text{0-jet, 1-jet}, p_{\mathrm{T},\tau\tau} > 100\ \mathrm{GeV}, \text{2-jet}\}$	13	
	$\tau_{\mathrm{had}}\tau_{\mathrm{had}}$	$\{\text{1-jet, 2-jet}\}$	13	
$VH \to Vbb$	$Z \to \nu\nu$	$E_{\mathrm{T}}^{\mathrm{miss}} \in \{120-160, 160-200, \geq 200\ \mathrm{GeV}\} \otimes \{\text{2-jet, 3-jet}\}$	13	[8]
	$W \to \ell\nu$	$p_{\mathrm{T}}^{W} \in \{< 50, 50-100, 100-150, 150-200, \geq 200\ \mathrm{GeV}\}$	13	
	$Z \to \ell\ell$	$p_{\mathrm{T}}^{Z} \in \{< 50, 50-100, 100-150, 150-200, \geq 200\ \mathrm{GeV}\}$	13	

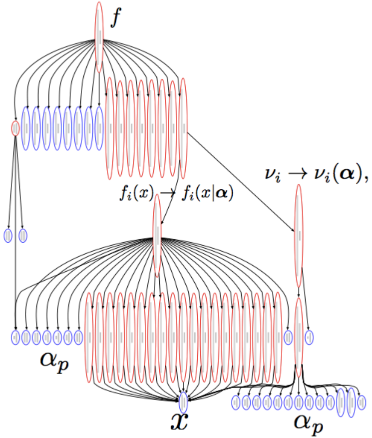
Individual channels

Higgs Boson Decay	Subsequent Decay	Modeling tools	$\int L\,dt$ [fb^{-1}]	Ref.
		2011 $\sqrt{s}$ =7 TeV		
$H \to ZZ^{(*)}$	4ℓ	histfactory + parametrized pdf	4.6	[1]
$H \to \gamma\gamma$	–	parametrized pdf	4.8	[5]
$H \to \tau\tau$	$\tau_{lep}\tau_{lep}$	histfactory	4.6	[7]
	$\tau_{lep}\tau_{had}$		4.6	
	$\tau_{had}\tau_{had}$		4.6	
$VH \to Vbb$	$Z \to \nu\nu$	histfactory	4.6	[8]
	$W \to \ell\nu$		4.7	
	$Z \to \ell\ell$		4.7	
		2012 $\sqrt{s}$ =8 TeV		
$H \to ZZ^{(*)}$	4ℓ	histfactory + parametrized pdf	13	[6]
$H \to \gamma\gamma$	–	parametrized pdf	13	[5]
$H \to WW^{(*)}$	$e\nu\mu\nu$	histfactory	13	[9]
$H \to \tau\tau$	$\tau_{lep}\tau_{lep}$	histfactory	13	[7]
	$\tau_{lep}\tau_{had}$		13	
	$\tau_{had}\tau_{had}$		13	
$VH \to Vbb$	$Z \to \nu\nu$	histfactory	13	[8]
	$W \to \ell\nu$		13	
	$Z \to \ell\ell$		13	

Individual channels







Individual channels

- Individual channels provide their own workspaces in the form of workspaces.
  1. $H \rightarrow \gamma\gamma$ and $H \rightarrow ZZ^{(*)} \rightarrow 4\ell$ provide mass parametrized models to facilitate mass combination
  2. Other channels provide fixed-mass models
- Embed handles for coupling study.
  1. mu_XS_* will scale the production XS
  2. mu_BR_* will scale the decay BR
  3. They will be re-parametrized for coupling study

Outline

Modeling

- A poisson model, where $f(x)$ describes the probability density for the observable x for a single event

$$\mathbf{f}(\mathcal{D}|\nu,\boldsymbol{\alpha}) = \mathrm{Pois}(n|\nu)\prod_{e=1}^{n} f(x_e|\boldsymbol{\alpha}) \;, \tag{1}$$

- A combined model:

$$\mathbf{f}_{\mathrm{sim}}(\mathcal{D}_{\mathrm{sim}}|\boldsymbol{\alpha}) = \prod_{c\in\mathrm{cats}}\left[\mathrm{Pois}(n_c|\nu(\boldsymbol{\alpha}))\prod_{e=1}^{n_c} f_c(x_{ce}|\boldsymbol{\alpha})\right] \;, \tag{2}$$

- Including the constraint terms:

$$\mathbf{f}_{\mathrm{tot}}(\mathcal{D}_{\mathrm{sim}},\mathcal{G}|\boldsymbol{\alpha}) = \prod_{c\in\mathrm{cats}}\left[\mathrm{Pois}(n_c|\nu_c(\boldsymbol{\alpha}))\prod_{e=1}^{n_c} f_c(x_{ce}|\boldsymbol{\alpha})\right]\cdot\prod_{p\in\mathbb{S}} f_p(a_p|\alpha_p \tag{3}$$

Modeling

- $$\mathbf{f}_{\mathrm{tot}}(\mathcal{D}_{\mathrm{sim}},\mathcal{G}|\boldsymbol{\alpha}) = \prod_{c\in \mathrm{cats}}\left[\mathrm{Pois}(n_c|\nu_c(\boldsymbol{\alpha}))\prod_{e=1}^{n_c} f_c(x_{ce}|\boldsymbol{\alpha})\right]\prod_{p\in\mathbb{S}} f_p(a_p|\alpha_p)$$

  pdf of Observables

  Auxiliary "measurement"

- The *likelihood function* $L(\boldsymbol{\alpha})$ is numerically equivalent to $f(x|\boldsymbol{\alpha})$ with x fixed – or $\mathbf{f}(\mathcal{D}|\boldsymbol{\alpha})$ with $\mathcal{D}$ fixed. It is common to work with the log-likelihood (or negative log-likelihood) function.

Profile Likelihood Ratio

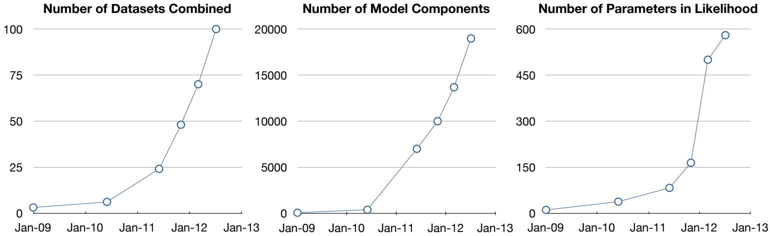
- Measure μ:

$$\Lambda(\boldsymbol{\mu}) = \frac{L\big(\boldsymbol{\mu}, \hat{\hat{\boldsymbol{\theta}}}(\boldsymbol{\mu})\big)}{L(\hat{\boldsymbol{\mu}}, \hat{\boldsymbol{\theta}})} \;, \tag{1}$$

- Coupling determination:

$$\Lambda(\boldsymbol{\kappa}) = \frac{L\big(\boldsymbol{\kappa}, \hat{\hat{\boldsymbol{\theta}}}(\boldsymbol{\kappa})\big)}{L(\hat{\boldsymbol{\kappa}}, \hat{\boldsymbol{\theta}})} \;, \tag{2}$$

Model



- The model has become much bigger along with higgs searches
- more than 100 categories, more than 1000 nuisance parameters, around 700 of them are mc-stat ones

Outline

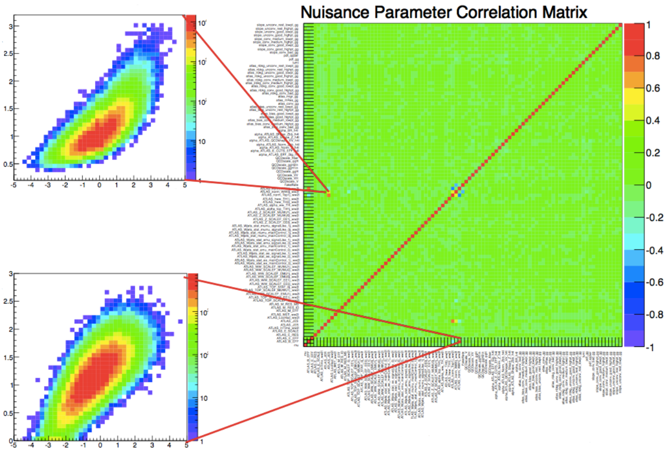
Treatment of systematics

- Systematics are becoming increasingly important, as they dominate sensitivity as the dataset grows.
  - Being conservative is not acceptable, as the main goal is to reduce the total uncertainty
  - Different treatment of systematics can potentially change the results
- All sources of uncertainties are taken to be either 100%-correlated (positively or negatively) or uncorrelated (independent)
  - Likelihood can be written in a clean factorized form
  - May need break-down of the systematics into different sources

Treatment of systematics

- Decision to correlate or not those parameters are taken based on physics judgement.
  - Jet Energy scale uncertainty is splitted into different sub-ones, each originating from a different source: ATLAS_JES_BASE, ATLAS_JES_BJET, ATLAS_JES_CLOSEBY, ATLAS_JES_FLAV, ATLAS_JES_FWD, ATLAS_JES_MU, ATLAS_JES_NPV
- In some cases, the source of several uncertainties could be the same, but the event kinematics, flavor composition, etc could be different, thus need uncorrelate them

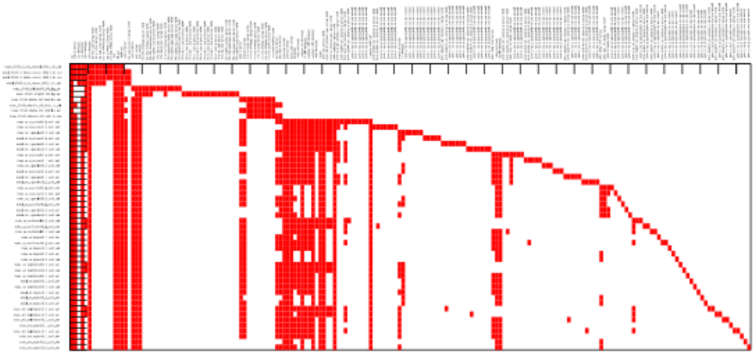
Treatment of systematics



- A suite of standard RooStats tool perfoming these checks.

Treatment of systematics

- Systematics in each category



Outline

1. Combination inputs
2. Combination model
   - Combination model
   - Systematics
3. Model Construction
   - Combination tool
   - μ/rate combination
   - Mass combination
   - Coupling measurements

Combination tool

- Our model has become more complicated along with the higgs search
- Better care must be taken to correlate parameters and perform other operations, with all the information documented. Using xml file is one good choice.
  1. Easy to add/remove individual channels
  2. Clear to see the structure of each input
  3. Remapping of the nuisance parameters can be done easily and transparently
  4. Most of the common operations can be done without touching the source code

Combination tool

```xml
<!DOCTYPE Combination  SYSTEM '/xdata10/hji/condor_args/Combination.dtd'>
<Combination>
  <Channel Name="combined" IsCombined="true" Mass="125"> <!-- is combined file -->
      <File Name="/xdata10/hji/autumn/ccl2/output/ccl2_test3/125_ccl2_test3.xml_125.root"/>
      <Workspace Name="combWS"/>
      <ModelConfig  Name="ModelConfig"/>
      <ModelData Name="combData"/>
      <ModelPOI Name="mu(1~0~5)*mu_7(1-1),mu_XS7_ggF[1-1],mu_XS7_VBF[1-1],mu_XS7_WH[1-1],mu_XS7_ZH[1-1],mu_XS7_ttH[1-1],mu_BR_gamgam[1-1],mu_BR_WW[1-1],mu
  </Channel>
  <Channel Name="llll_1112">
      <File Name="/xdata10/hji/autumn/ccl2/input//llll_1112/llll_1112.root"/>
      <Workspace Name="combined"/>
      <ModelConfig Name="ModelConfig"/>
      <ModelPOI Name="mu,mu_XS7_ggF,mu_XS7_VBF,mu_XS7_WH,mu_XS7_ZH,dummy,dummy,dummy,mu_BR_ZZ,dummy,dummy,mu,mu_XS8_ggF,mu_XS8_VBF,mu_XS8_WH,mu_XS8_ZH,dum
      <ModelData Name="obsData"/>
      <RenameMap>
        <Syst OldName=             "alpha_ATLAS_BR_VV" ,,.NewName=        "ATLAS_BR_VV"/>
        <Syst OldName=           "alpha_ATLAS_EFF_Sig" ,,.NewName=  "ATLAS_H4l_EL_EFF"/>
        <Syst OldName=            "alpha_ATLAS_EL_EFF" ,,.NewName=       "ATLAS_EL_EFF"/>
        <Syst OldName=           "alpha_ATLAS_EL_TRIG" ,,.NewName=      "ATLAS_EL_TRIG"/>
        <Syst OldName=           "alpha_ATLAS_EM_ES_Z" ,,.NewName=      "ATLAS_EM_ES_Z"/>
        <Syst OldName=         "alpha_ATLAS_LUMI_2011" ,,.NewName=    "ATLAS_LUMI_2011"/>
        <Syst OldName=         "alpha_ATLAS_LUMI_2012" ,,.NewName=    "ATLAS_LUMI_2012"/>
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        <Syst OldName=        "alpha_ATLAS_llll_EL_EFF" ,,.NewName=  "ATLAS_H4l_EL_EFF"/>
        <Syst OldName=     "alpha_ATLAS_norm_SF_llee_Bkg" ,,.NewName="ATLAS_SF_H4l_llee_Bkg_2012"/>
        <Syst OldName= "alpha_ATLAS_norm_SF_llll_Z_2mu2e_2011" ,,.NewName="ATLAS_SF_H4l_2mu2e_Z_2011"/>
        <Syst OldName= "alpha_ATLAS_norm_SF_llll_Z_2mu2e_2012" ,,.NewName="ATLAS_SF_H4l_2mu2e_Z_2012"/>
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        <Syst OldName=   "alpha_ATLAS_norm_SF_llll_Z_4e_2012" ,,.NewName="ATLAS_SF_H4l_4e_Z_2012"/>
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        <Syst OldName="alpha_ATLAS_norm_SF_llll_ttbar_2e2mu_2011" ,.,.NewName="ATLAS_SF_H4l_2e2mu_ttbar_2011"/>
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        <Syst OldName="alpha_ATLAS_norm_SF_llll_ttbar_4mu_2011" ,.,.NewName="ATLAS_SF_H4l_4mu_ttbar_2011"/>
test.xml                                                              unix | utf-8 | xml
```

Combined model

Individual model

Rename Nuisance Parameters

Connecting the variables

- Renaming of nuisance parameters

```
<Syst OldName="atlas_nui_EM_ES_Z_unconv_good_lowpt
    (atlas_EM_ES_Z, RNDM_atlas_EM_ES_Z)"
    NewName="ATLAS_EM_ES_Z"/>
```

1. Nuisance Parameter: atlas_EM_ES_Z → ATLAS_EM_ES_Z
2. Global Observable: RNDM_atlas_EM_ES_Z → ATLAS_EM_ES_Z_In
3. Pdf: atlas_nui_EM_ES_Z_unconv_good_lowpt→ ATLAS_EM_ES_Z_Pdf

- Assume default naming convention in input workspaces:

```
<Syst OldName="alpha_ATLAS_BR_VV"  NewName="ATLAS_BR_VV"/>
```

Combination Tools

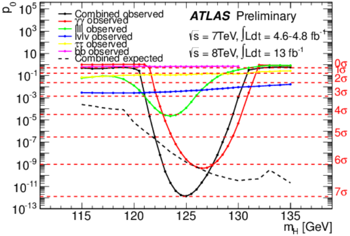
- Connecting the parameters of interest

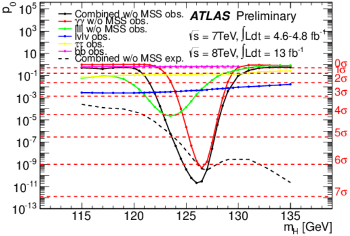
```
combined model:
<ModelPOI Name="mu(1~0~5),
mu_XS7_ggF[1-1], mu_XS7_VBF[1-1],
mu_XS7_WH[1-1], mu_XS7_ZH[1-1],
mu_XS7_ttH[1-1], mu_BR_gamgam[1-1],
mu_BR_WW[1-1], mu_BR_ZZ[1-1],
mu_BR_bb[1-1], mu_BR_tautau[1-1]"/>

individual model:
<ModelPOI Name="mu,
mu_ggF,mu_VBF,mu_WH,mu_ZH,mu_ttH,
mu_BR_gg,dummy,dummy,dummy,dummy"/>
```

Outline

Significance





- The local probability p0 for a background-only experiment to be more signal-like than the observation.
- Mass scale systematics(MSS) are included in the left plot, but NOT in the right plot
- MSS can be pulled so that the excess can be described by the model in a wilder range, thus forming a broader curve.

Outline

Mass combination

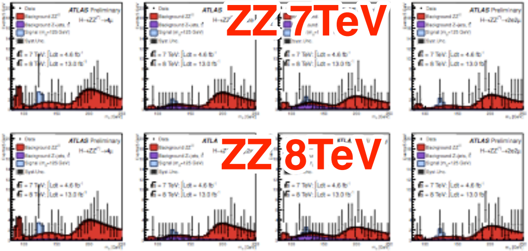
- Use high mass-resolution channels, $H \to \gamma\gamma$ and $H \to \ell\ell\ell\ell$
- Model is parametrized in terms of mass
- Estimate the mass:

$$\Lambda(m_H) = \frac{L(m_H\,,\,\hat{\hat{\mu}}_{\gamma\gamma}(m_H)\,,\,\hat{\hat{\mu}}_{4\ell}(m_H)\,,\,\hat{\hat{\boldsymbol{\theta}}}(m_H))}{L(\hat{m}_H\,,\hat{\mu}_{\gamma\gamma}\,,\hat{\mu}_{4\ell}\,,\hat{\boldsymbol{\theta}})}\;. \qquad (3)$$

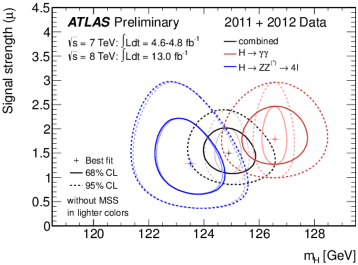
- Directly quantify the consistency between the measurements of $m_H^{\gamma\gamma}$ and $m_H^{4\ell}$:

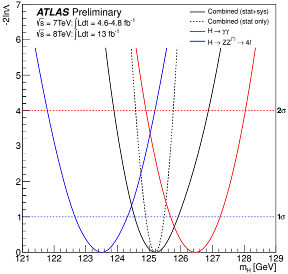
$$\Lambda(\Delta m_H) = \frac{L(\Delta m_H\,,\,\hat{\hat{\mu}}_{\gamma\gamma}(\Delta m_H)\,,\,\hat{\hat{\mu}}_{4\ell}(\Delta m_H)\,,\,\hat{\hat{m}}_H(\Delta m_H)\,,\,\hat{\hat{\boldsymbol{\theta}}}(\Delta m_H))}{L(\hat{\Delta m}_H\,,\hat{\mu}_{\gamma\gamma}\,,\hat{\mu}_{4\ell}\,,\hat{m}_H\,,\hat{\boldsymbol{\theta}})}\;. \qquad (4)$$

Mass combination



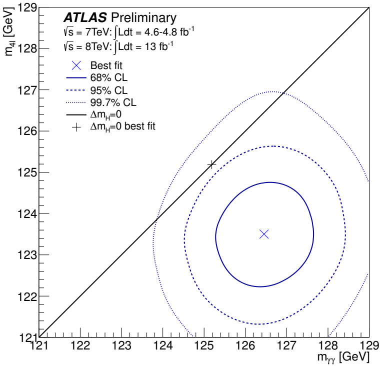
Mass combination

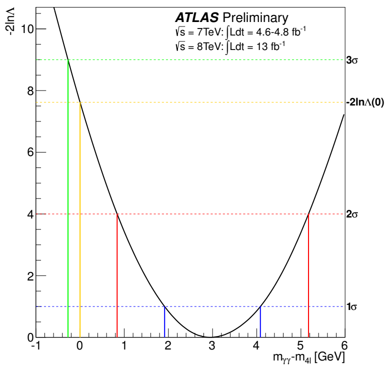




- Left: Likelihood contours on the (μ, m_H) plane
- Right: The profile likelihood ratio -2ln$\Lambda(m_H)$

Mass combination





- Left: Likelihood contours on the $(m_H^{\gamma\gamma}, m_H^{llll})$ plane
- Right: The profile likelihood ratio -2ln$\Lambda(m_H^{\gamma\gamma} - m_H^{llll})$

Outline

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2. Combination model
    - Combination model
    - Systematics
3. Model Construction
    - Combination tool
    - μ/rate combination
    - Mass combination
    - Coupling measurements

Coupling model

- For each production mode i, a signal strength factor μ_i defined by $\mu_i = \frac{\sigma_i}{\sigma_{i,SM}}$ is introduced
- For each decay final state f, a factor $\mu_f = \frac{B_f}{B_{f,SM}}$ is introduced
- For each analysis category k the number of signal events (n^k_{signal}) is parametrized as:
  $n^k_{signal} = (\Sigma\mu_i\sigma_{i,SM} \times A^k_i \times \epsilon^k_i) \times \mu_f \times B_{f,SM} \times \mathcal{L}^k$

Coupling model

- Only modifications of couplings strengths, are taken into account: the observed state is assumed to be a CP-even scalar as in the SM.
- The signals observed in the different search channels originate from a single narrow resonance.
- The width of the Higgs boson with a mass of 126 GeV is assumed to be negligible. Hence:
  $\sigma \times BR(ii \to H \to ff) = \frac{\sigma_{ii} \times \Gamma_{ff}}{\Gamma_H}$

Coupling model

- The leading order (LO) motivated scale factors κ_i are defined in such a way that the cross sections σ_{ii} and the partial decay widths Γ_{ff} associated with the SM particle i scale with the factor κ_i^2 when compared to the corresponding SM prediction.

Production modes

$$\frac{\sigma_{\mathrm{ggH}}}{\sigma_{\mathrm{ggH}}^{\mathrm{SM}}} = \begin{cases} \kappa_g^2(\kappa_b, \kappa_t, m_H) \\ \kappa_g^2 \end{cases}$$

$$\frac{\sigma_{\mathrm{VBF}}}{\sigma_{\mathrm{VBF}}^{\mathrm{SM}}} = \kappa_{\mathrm{VBF}}^2(\kappa_W, \kappa_Z, m_H)$$

$$\frac{\sigma_{\mathrm{WH}}}{\sigma_{\mathrm{WH}}^{\mathrm{SM}}} = \kappa_W^2$$

$$\frac{\sigma_{\mathrm{ZH}}}{\sigma_{\mathrm{ZH}}^{\mathrm{SM}}} = \kappa_Z^2$$

$$\frac{\sigma_{t\bar{t}H}}{\sigma_{t\bar{t}H}^{\mathrm{SM}}} = \kappa_t^2$$

Detectable decay modes

$$\frac{\Gamma_{WW^{(*)}}}{\Gamma_{WW^{(*)}}^{\mathrm{SM}}} = \kappa_W^2$$

$$\frac{\Gamma_{ZZ^{(*)}}}{\Gamma_{ZZ^{(*)}}^{\mathrm{SM}}} = \kappa_Z^2$$

$$\frac{\Gamma_{b\bar{b}}}{\Gamma_{b\bar{b}}^{\mathrm{SM}}} = \kappa_b^2$$

$$\frac{\Gamma_{\tau^-\tau^+}}{\Gamma_{\tau^-\tau^+}^{\mathrm{SM}}} = \kappa_\tau^2$$

$$\frac{\Gamma_{\gamma\gamma}}{\Gamma_{\gamma\gamma}^{\mathrm{SM}}} = \begin{cases} \kappa_\gamma^2(\kappa_b, \kappa_t, \kappa_\tau, \kappa_W, m_H) \\ \kappa_\gamma^2 \end{cases}$$

$$\frac{\Gamma_{Z\gamma}}{\Gamma_{Z\gamma}^{\mathrm{SM}}} = \begin{cases} \kappa_{(Z\gamma)}^2(\kappa_b, \kappa_t, \kappa_\tau, \kappa_W, m_H) \\ \kappa_{(Z\gamma)}^2 \end{cases}$$

Coupling model

```
<!DOCTYPE Orgnization  SYSTEM 'Orgnization.dtd'>
<Orgnization InFile="/xdata10/hji/autumn/ccl2/output/ccl2_test3/125.root"
  OutFile="/xdata10/hji/autumn/ccl2/output/ccl2_test3/CVCF/125.root" ModelName="CVCF" POINames="CV,CF">
    <Item Name="CV[0,0,2]"/>
    <Item Name="CF[1,-3,3]"/>
    <Item Name="one[1]"/>

    <!-- PRODUCTION -->
    <!-- gluglu->H, 7TeV -->
    <Item Name="expr::C2_GlGlH_7TeV('(@0*@0)*@2  + (@1*@1)*@3 + (@0*@1)*@4', CF, CF, sigma_tt_o_sigma_ggH_GlGlH_7TeV[1.0592],sigma_bb_o_sigma_ggH_GlGlH_7TeV[0.0070],sigm
    <!-- gluglu->H, 8TeV -->
    <Item Name="expr::C2_GlGlH_8TeV('(@0*@0)*@2  + (@1*@1)*@3 + (@0*@1)*@4', CF, CF, sigma_tt_o_sigma_ggH_GlGlH_8TeV[1.0580],sigma_bb_o_sigma_ggH_GlGlH_8TeV[0.0070],sigm
    <!-- VBF->H -->
    <Item Name="expr::CV2_VBF('@0*@0',CV)"/>
    <Item Name="expr::CV2_WH('@0*@0',CV)"/>
    <Item Name="expr::CV2_ZH('@0*@0',CV)"/>
    <Item Name="expr::CF2_ttH('@0*@0',CF)"/>

    <!-- DECAY -->
    <!-- H->gamgam -->
    <Item Name="expr::C2_HGaGa('(@0*@0)*@4 + (@1*@1)*@5 + (@2*@2)*@6 + (@0*@1)*@7 + (@0*@2)*@8 + (@1*@2)*@9 + (@3*@3)*@10 + (@0*@3)*@11 + (@1*@3)*@12 + (@2*@3)*@13',CF,C
    <!-- H->Zgam -->
    <Item Name="expr::C2_HZGa('(@0*@0)*@4 + (@1*@1)*@5 + (@2*@2)*@6 + (@0*@1)*@7 + (@0*@2)*@8 + (@1*@2)*@9 + (@3*@3)*@10 + (@0*@3)*@11 + (@1*@3)*@12 + (@2*@3)*@13',CF,CF,
    <!-- H->gluglu -->
    <Item Name="expr::C2_HGlGl('(@0*@0)*@2  + (@1*@1)*@3 + (@0*@1)*@4', CF, CF, G_tt_o_G_gg_HGlGl[1.1114],G_bb_o_G_gg_HGlGl[0.0116],G_tb_o_G_gg_HGlGl[-0.1229])"/>
    <Item Name="expr::CV2_WW('@0*@0',CV)"/>
    <Item Name="expr::CV2_ZZ('@0*@0',CV)"/>
    <Item Name="expr::CF2_tautau('@0*@0',CF)"/>
    <Item Name="expr::CF2_bb('@0*@0',CF)"/>
    <!-- total width -->
    <Item Name="expr::invC2H('1/(@0*@11 + @1*@12 + @2*@13 + @3*@14 + @4*@15 + @5*@16 + @6*@17 + @7*@17 + @8*@16 + @9*@18 + @10*@18)', BR_H_gluglu_SM[0.0855],BR_H_gamgam_

    <!-- PDF -->
    <Item Name="EDIT::NEWPDF(OLDPDF,
          mu_XS7_ggF=C2_GlGlH_7TeV, mu_XS7_VBF=CV2_VBF, mu_XS7_WH=CV2_WH, mu_XS7_ZH=CV2_ZH, mu_XS7_ttH=CF2_ttH,
          mu_BR_gamgam=C2_HGaGa, mu_BR_WW=CV2_WW, mu_BR_ZZ=CV2_ZZ, mu_BR_tautau=CF2_tautau, mu_BR_bb=CF2_bb,
          mu_7=one,
          mu_XS8_ggF=C2_GlGlH_8TeV, mu_XS8_VBF=CV2_VBF, mu_XS8_WH=CV2_WH, mu_XS8_ZH=CV2_ZH, mu_XS8_ttH=CF2_ttH,
          mu_8=one,
          mu=invC2H)"/>
</Orgnization>
```

Production

Decay

Total width

Replace those mu "handles"

Parametrization

- gluon fusion

```
mH_GeV   sigma_ggH_pb   sigma_tt/sigma_ggH  sigma_bb/sigma_ggH  sigma_tb/sigma_g
126.0    1.332933e+01   1.058802e+00        6.860053e-03        -6.566210e-02
```

```
<Item Name="expr::C2_GlGlH_7TeV('(@0*@0)*@2  + (@1*@1)*@3 + (@0*@1)*@4',
CF, CF, sigma_tt_o_sigma_ggH_GlGlH_7TeV[1.0592],sigma_bb_o_sigma_ggH_GlGlH_
sigma_tb_o_sigma_ggH_GlGlH_7TeV[-0.0662])"/>
```

- $H\rightarrow\gamma\gamma$

```
M_H      G_gaga     G_tt/G_gaga  G_bb/G_gaga  G_WW/G_gaga  G_tb/G_gaga  G_tW/G_g
126.   0.95959E-05  0.70904E-01  0.18760E-04   1.5863     -0.17319E-02 -0.67074
```

```
<!-- H->gamgam -->
<Item Name="expr::C2_HGaGa('(@0*@0)*@4 + (@1*@1)*@5 + (@2*@2)*@6 + (@0*@1)*
(@0*@2)*@8 + (@1*@2)*@9 + (@3*@3)*@10 + (@0*@3)*@11 + (@1*@3)*@12 + (@2*@3)
CF,CF,CV,CF,G_tt_o_G_HGaGa[0.0715],G_bb_o_G_HGaGa[0.0000],G_WW_o_G_HGaGa[1.
G_tb_o_G_HGaGa[-0.0018],G_tW_o_G_HGaGa[-0.6740],G_bW_o_G_HGaGa[0.0083],G_ll
G_tl_o_G_HGaGa[-0.0019],G_bl_o_G_HGaGa[0.0000],G_lW_o_G_HGaGa[0.0090])"/>
```

Parametrization

- total width

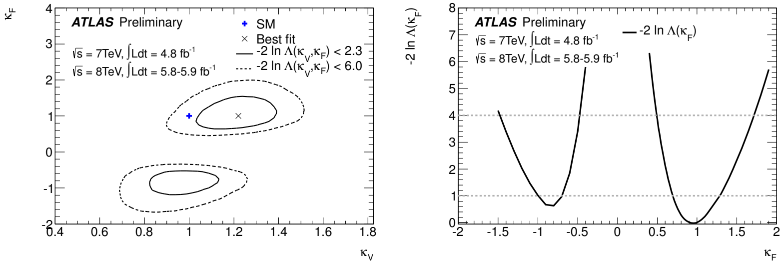
```
mH_GeV  H_gg      H_gamgam  H_Zgam      H_WW        H_ZZ      Total_Width_GeV
126.0   8.45E-02 2.29E-03  1.64E-03    2.33E-01   2.91E-02  4.18E-03
```

```
<!-- total width -->
<Item Name="expr::invC2H('1/(@0*@11 + @1*@12 + @2*@13 + @3*@14 + @4*@15 +
@5*@16 + @6*@17 + @7*@17 + @8*@16 + @9*@18 + @10*@18)',
BR_H_gluglu_SM[0.0855],BR_H_gamgam_SM[0.0023],BR_H_Zgam_SM[0.0015],
BR_H_WW_SM[0.2160],BR_H_ZZ_SM[0.0266],BR_H_bb_SM[0.5770],
BR_H_tautau_SM[0.0637],BR_H_mumu_SM[0.0002],BR_H_ssbar_SM[0.0004],
BR_H_ccbar_SM[0.0267],BR_H_ttbar_SM[0.0000], C2_HGlGl, C2_HGaGa, C2_HZGa, C
```

- Replace the handles

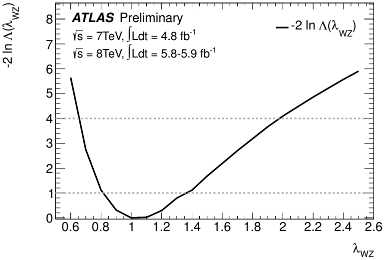
```
mu_XS7_ggF=C2_GlGlH_7TeV
mu_BR_gamgam=C2_HGaGa
mu=invC2H)
```

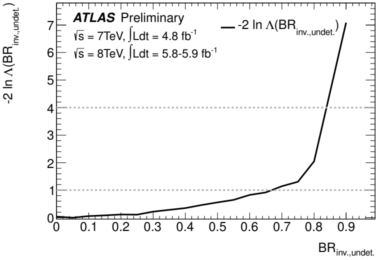
Coupling results



- κ_F and κ_V model, with assumption on total width

Coupling results

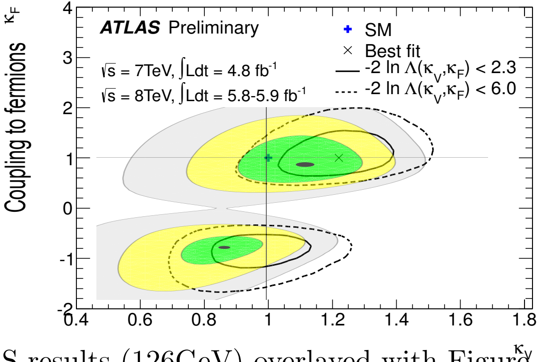




Left: model to probe custodial symmetry.

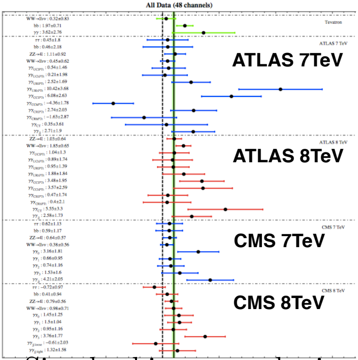
Right: model to probe invisible/undetected branching ratio

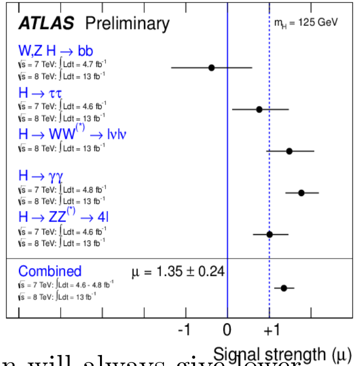
Coupling results



- ATLAS results (126GeV) overlayed with Figure 2 of arXiv:1207.1717, a back-of-envelop calculation
- We'll make public the results for each channel, in which case comparison would be easier

Coupling results





- Simple chisquare cobmination will always give lower strengths: neglecting the fact that the $\sigma_\mu^+ > \sigma_\mu^-$
- Provided a table of μ and it's SYMMETRIZED errors in ATLAS recently