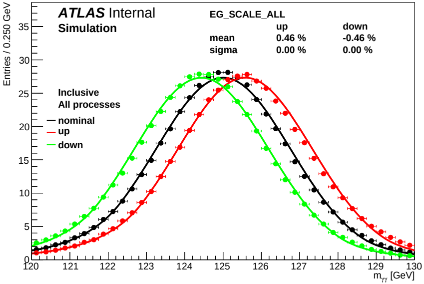
Methodology

For a given systematic source :

- Create distributions of $m_{\gamma\gamma}^{nom}$, $m_{\gamma\gamma}^{up}$, $m_{\gamma\gamma}^{down}$
- Fit main parameter of the systematic with DSCB :
  - Fit $m_{\gamma\gamma}$
  - Free parameter(s) of interest
  - Fixing $X = \hat{X}^{nom}$
- Systematic variation : $\delta_X = \frac{X^{fluct}}{X^{nom}} - 1,\ X \in \{\mu, \sigma\}$



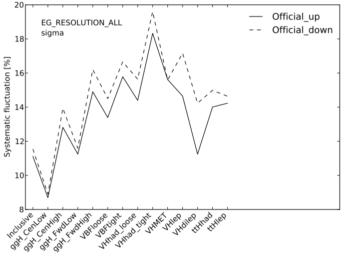
$$CB(m_{\gamma\gamma}) = \begin{cases} e^{-t^2/2} & \text{if } -\alpha_{low} \le t \le \alpha_{high} \\ \dfrac{e^{-\frac{1}{2}\alpha_{low}^2}}{\left[\frac{1}{R_{low}}\left(R_{low}-\alpha_{low}-t\right)\right]^{n_{low}}} & \text{if } t < -\alpha_{low} \\ \dfrac{e^{-\frac{1}{2}\alpha_{high}^2}}{\left[\frac{1}{R_{high}}\left(R_{high}-\alpha_{high}+t\right)\right]^{n_{high}}} & \text{if } t > \alpha_{high} \\ t = (m_{\gamma\gamma} - \mu)/\sigma,\ R_{low} = \frac{\alpha_{low}}{n_{low}},\ R_{high} = \frac{\alpha_{high}}{n_{high}} \end{cases} \tag{1}$$

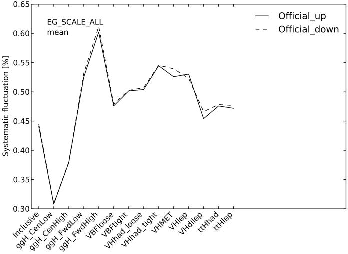
ICHEP Results

ICHEP results were obtained with only 2 nuisance parameters.

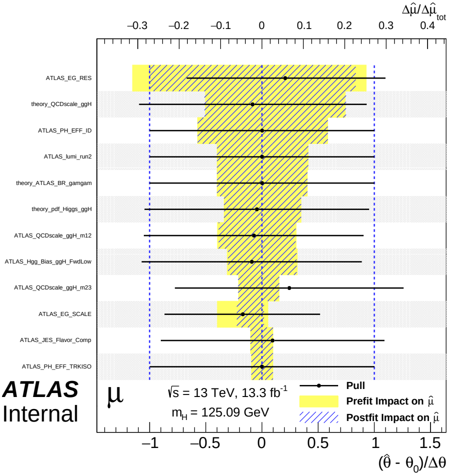
In stat framework, systematic only affects a single dedicated parameter (width or mass).

Photon Calibration Uncertainties (%)								
Category	EG_RESOLUTION_ALL				EG_SCALE_ALL			
	mean		sigma		mean		sigma	
	Up	Down	Up	Down	Up	Down	Up	Down
Inclusive	-0.01	0.01	11.11	-11.54	0.44	-0.44	2.30	0.31
ggH_CenLow	-0.01	0.01	8.69	-8.91	0.31	-0.31	0.66	-0.41
ggH_CenHigh	-0.00	0.01	12.81	-13.94	0.38	-0.38	0.56	-0.17
ggH_FwdLow	-0.02	0.02	11.24	-11.59	0.52	-0.53	2.64	0.62
ggH_FwdHigh	-0.01	0.01	14.90	-16.20	0.60	-0.61	3.51	1.92
VBFloose	-0.02	0.02	13.39	-14.50	0.48	-0.48	2.50	0.32
VBFtight	-0.01	0.01	15.78	-16.66	0.50	-0.50	3.27	1.16
VHhad_loose	-0.01	0.00	14.40	-15.64	0.50	-0.51	2.67	1.62
VHhad_tight	-0.01	0.01	18.32	-19.60	0.55	-0.54	5.96	-0.41
VHMET	0.01	-0.01	15.62	-15.59	0.53	-0.54	1.00	0.95
VHlep	-0.00	0.02	14.65	-17.17	0.53	-0.52	1.46	2.11
VHdilep	0.00	-0.01	11.24	-14.23	0.45	-0.47	1.98	0.83
ttHhad	-0.01	0.01	14.01	-14.99	0.48	-0.48	2.37	0.88
ttHlep	-0.01	0.01	14.23	-14.64	0.47	-0.48	2.45	1.44





Calibration uncertainties contributions



ATL-COM-PHYS-2016-222

- Resolution systematic dominant
- Consequent other experimental contribution
- Energy scale has small contribution

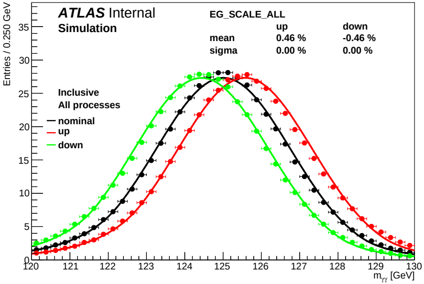
Scale factors interpretation

Assume the up fluctuation (red) as data and nominal distribution (black) as MC in the template method. One has

$$m_H^{up} = m_H^{nom}(1+\alpha)$$

Hence

$$\delta_{m_H} = \alpha$$



Furthermore :

$$\sigma_H^{up} = \sigma_H^{nom} \oplus cE$$

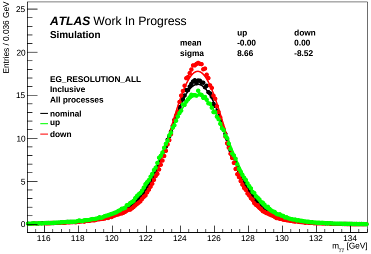
Hence

$$\delta_{\sigma_H} = \sqrt{1 + \frac{c^2E^2}{\sigma_H^2}} - 1$$

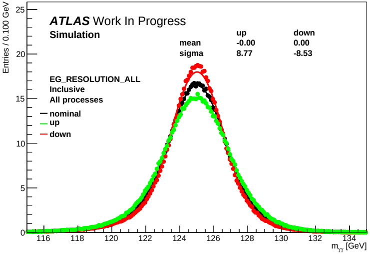
One has to be carefull with resolution uncertainty as the template method is weak to measure small differences.

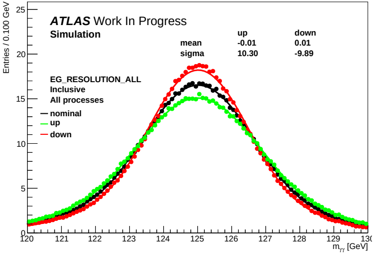
Method comparison

4 different fitting methods are compared : fitting in 3 different ranges and template method cross-check within $[122, 128]$GeV. Methods compared on h013 simplified model (2NP).

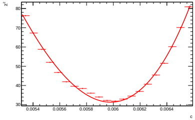


$\leftarrow$ $[105, 160]$ $\rightarrow$ $[115, 135]$





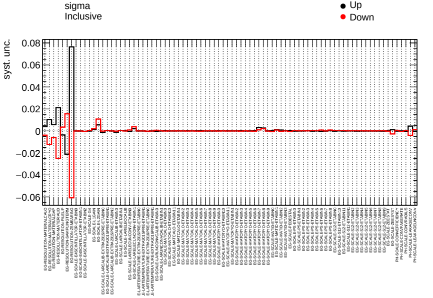
$\leftarrow$ $[120, 130]$ $\rightarrow$ $[122, 128]$



$$c = (0.598 \pm 0.009)\%$$
$$\rightarrow \delta_{\sigma_H} = (8.82 \pm 0.25)\%$$

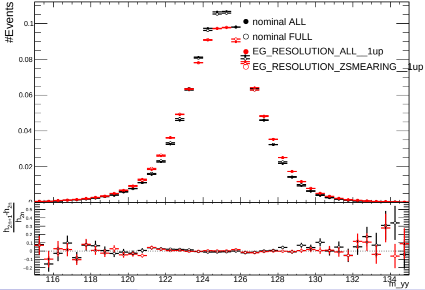
Calibration systematics model discrepancies

- RESOLUTION_ZSMEARING should be identical to RESOLUTION_ALL.
- Distributions agree but not fits
- Will look into fit procedure.



Total Inclusive Uncertainty :

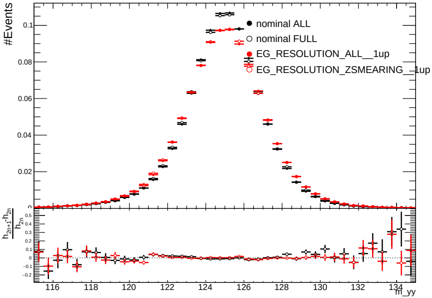
%	Scale	Resolution
Full	0.26	7.03
Reduced	0.44	11.11



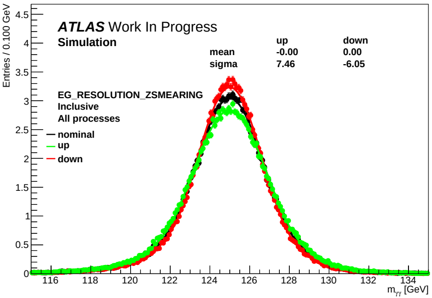
Method impact on values

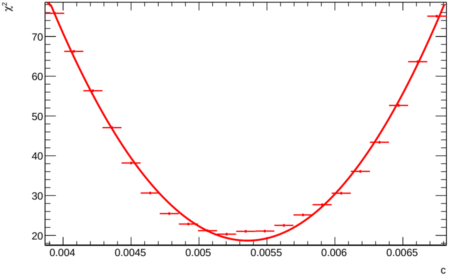
FULL and ALL models are compared with a fit within $[115, 135]$.

NP	cat	mean	sigma	alphaHi	alphaLow	nHi	nLow
nominal ALL	0	125.014	1.7421	1.48071	1.34134	19.9948	7.91861
nominal FULL	0	124.998	1.77225	1.47488	1.37898	19.9071	7.56628
Difference (%)			1.7	2.8		4.4	
EG_RESOLUTION_ALL__1up	0	125.009	1.89485	1.48071	1.34134	19.9948	7.91861
EG_RESOLUTION_ZSMEARING__1up	0	124.993	1.90455	1.47488	1.37898	19.9071	7.56628
Difference (%)			0.5				



Comparison with ZSMEARING





$$c = (0.536 \pm 0.019)\%$$

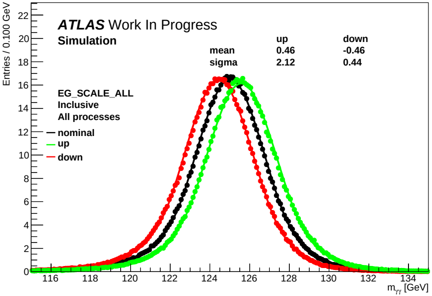
$$\sigma_H = (1.77 \pm 0.37)\%$$

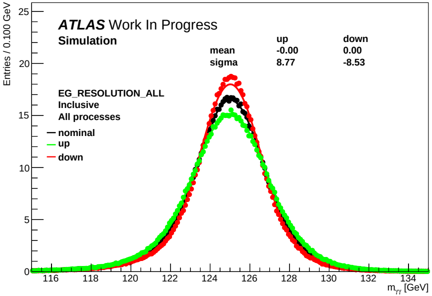
$$\rightarrow \delta_{\sigma_H} = (6.90 \pm 0.47)\%$$

$(\pm 0.5)\%$	Fit [115, 135]	Template [122, 128]
RESOLUTION_ALL	8.77	8.82
RESOLUTION_ZSMEARING	7.46	6.9

Simplified model

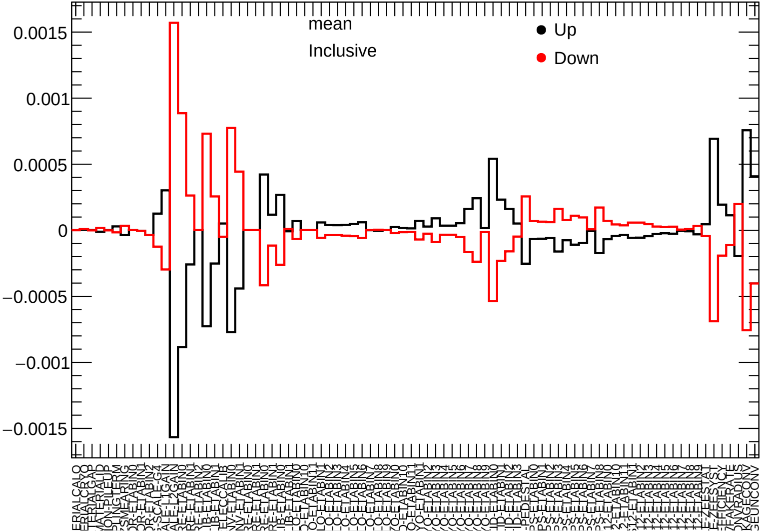
The simplified model sum in quadrature respectively all systematic sources into respectively a single nuisance parameter for scale and resolution. The fit between $[115, 135]$ is used as closest to the signal model tool default behaviour.





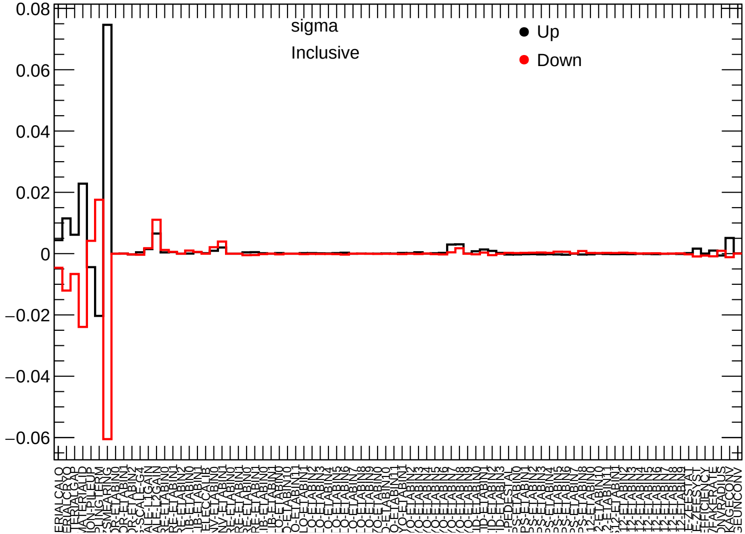
Model FULL_v1 : mass uncertainty

The full model (83 NP) is used instead of simplified 3NP model.



Model FULL_v1 : resolution uncertainty

The full model (83 NP) is used instead of simplified 3NP model.



Model Comparison

Total Inclusive Uncertainty :

%	Scale	Resolution
Full	0.27	8.26
Reduced	0.46	9.02
Reduced (Templates)	0.43	8.82

Systematics in statistical framework

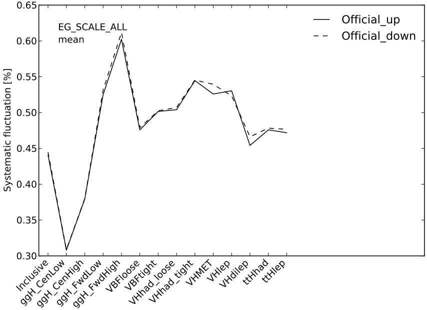
Changing an energy correction factor (by systematic fluctuation) affects several parameters. For current results, it is assumed that **only the parameter X targetted by the systematic (POI) is affected** (hence fixing the others).
Only the parametrization of X will contain the measured uncertainty δ_X :

$$X \to X(1 + \delta_X \theta)$$

with θ a gaussian constrained free parameter.

In the framework, the pulling of the nuisance parameters only affects the main parameter of the systematic

Typical plot

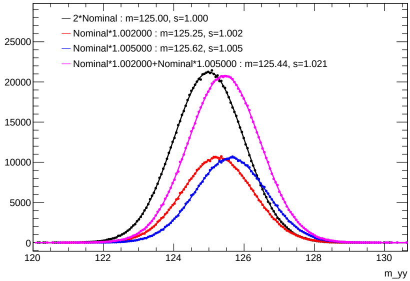


For a given fitted variable (here mean) :

- Full line : $\frac{\mu_{up} - \mu_{nominal}}{\mu_{nominal}}$
- Dashed line : $-\frac{\mu_{down} - \mu_{nominal}}{\mu_{nominal}}$

Both lines should be superimposed in case of symmetric systematics.

Scale impact on width

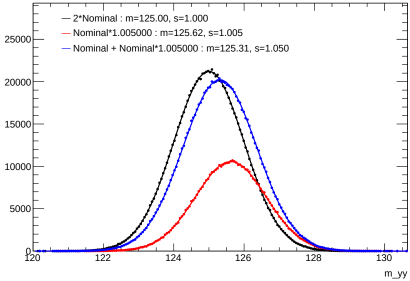


1M random numbers generated on a Gaussian($\mu = 125, \sigma = 1$).

- Initial numbers distribution.
- Half events multiplied by 1.002.
- Remaining events multiplied by 1.005.
- Combined distribution of red and blue.

Mean (m) and RMS (s) of a fitted gaussians are given in the legend. Interpretationof the curve in the next slides.

Uncertainty reduction



Lets assume a gaussian distributed energy distribution. Events are affected **either** by systematic A or B with same amplitude (0.3%).

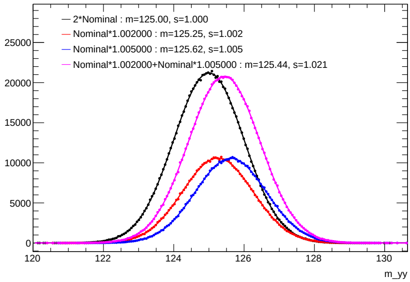
Summing quadratically the systematic gives $\delta E = 0.3\%$ for all event. Hence $\Delta M = 0.3\%$.
Applying independently systematics to events gives :

$$\Delta M_A = \Delta M_B = \delta E/2$$

Because only half events are effectively modified. Finally :

$$\Delta M = \Delta M_A \oplus \Delta M_B = \frac{\delta E}{\sqrt{2}}$$

μ/σ scale correlation



Lets assume a gaussian distributed energy distribution. Applying energy scale correction gives :

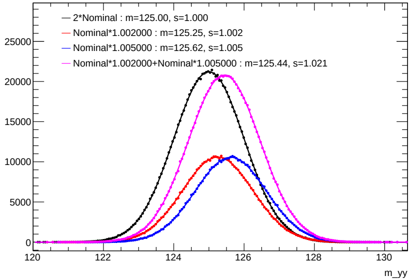
$$E \rightarrow E(1+a)$$

Hence the distribution will be changed to :

$$exp\left(-\frac{(E-\mu)^2}{2\sigma^2}\right) \rightarrow exp\left(-\frac{(\frac{E}{1+a}-\mu)^2}{2\sigma^2}\right) = exp\left(-\frac{(E-\mu(1+a))^2}{2\sigma^2(1+a)^2}\right) \quad (2)$$

The new distribution is a shifted gaussian with scaled RMS.
Given the medium shift of EG_SCALE_ALL, we expect $^{+0.4}_{-0.4}\%$ change in resolution.

Inhomegenous scale



The RMS of two points separated by d is $d/4$.
If d is the difference between two scale factors,

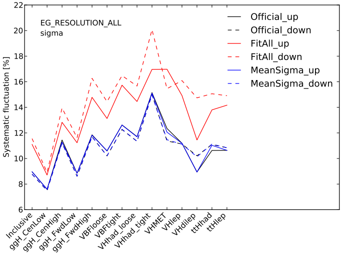
$$d \sim 3.10^{-3} \cdot E_\gamma = 0.18$$

$$\frac{\text{RMS}}{\text{Resolution}} = \frac{d/4}{1.5\text{GeV}} = 3\%$$

The inhomogeneity of the scale factors uncertainties changes the width of the distribution at the percent level. This effect will always increase the width.

Black and pink distribution show an illustration of this effect.

Fitting methods : σ fluctuation



- σ is sensitive to the change of scale.
- Two understood explanations :
  - μ/σ correlation when scaling energies.
  - Resolution loss due to inhomogenous scaling.
- Effect on resolution is small but I propose to add a width effect linked to EG_SCALE_ALL nuisance parameter.
  - Add a second nuisance parameter to the width to limit overconstraints.
  - Good hopes to reduce Zee resolution systematics (dominant in EG_RESOLUTION_ALL) within medium timescale.

Cross-check : template method

The template method is used to measure α and C simultaneously.

- Create distorded MC (templates) with test values of α and C.
- **Compute χ^2 between Z mass distribution of data and template**.
- **Fit the minimum of the χ^2 distribution** in the (α, C) plane.
- Fit performed in 2 steps of 1D fits :
  - fit $\chi^2 = f(\alpha)$ at constant C (lines) $\rightarrow (\alpha_{min}, \chi^2_{min})$.
  - fit $\chi^2_{min} = f(C) \rightarrow (C, \Delta C)$
  - project C in $\alpha_{min} = f(C)$, corresponding bin gives $(\alpha, \Delta\alpha)$.