# *ZZ* aTGC Combination Progress

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## Updates Since Last Meeting

- ATLAS framework:
  - Can now track systematics and backgrounds separately
  - Can now use nuisance parameters to all orders instead of just to first order

$$N_{\text{exp}}^i(\theta_i) = N_{\text{exp}}^i(1 + \sum_k \sigma_{ik}\theta_k) \ 1^{\text{st}} \text{ order} \qquad (1)$$

$$N_{\text{exp}}^i(\theta_i) = N_{\text{exp}}^i \prod_k (1 + \sigma_{ik}\theta_k) \text{ all orders} \qquad (2)$$

  - Can now select which systematics have log-normal constraints and which are truncated Gaussian
- CMS framework can now use truncated Gaussians as constraints
- Calculated expected limits with Asimov dataset

# Comparing Observed Results - Log-normal

| 1D deltaNLL limit CMS inputs | $f_4^\gamma$ | | $f_4^Z$ | |
| --- | --- | --- | --- | --- |
| | ATLAS | CMS | ATLAS | CMS |
| $4\ell$ | [-0.0122, 0.0133] | [0.0122, 0.0134] | [-0.0104, 0.0111] | [0.0104, 0.0111] |
| 1D deltaNLL limit | $f_5^\gamma$ | | $f_5^Z$ | |
| $4\ell$ | [-0.0128, 0.0125] | [0.0129, 0.0126] | [-0.0107, 0.0109] | [0.0107, 0.0109] |

Table : CMS input intervals within 0.8%

| 1D deltaNLL limit ATLAS inputs | $f_4^\gamma$ | | $f_4^Z$ | |
| --- | --- | --- | --- | --- |
| | ATLAS | CMS | ATLAS | CMS |
| $4\ell$ | [-0.0184, 0.0184] | [0.0180, 0.0180] | [-0.0157, 0.0157] | [0.0154, 0.0154] |
| $2\ell2\nu$ | [-0.0184, 0.0183] | [0.0185, 0.0184] | [-0.0155, 0.0155] | [0.0156, 0.0156] |
| $4\ell + 2\ell2\nu$ | [-0.0147, 0.0146] | [0.0145, 0.0144] | [-0.0124, 0.0124] | [0.0123, 0.0123] |
| 1D deltaNLL limit | $f_5^\gamma$ | | $f_5^Z$ | |
| $4\ell$ | [-0.0186, 0.0186] | [-0.0182, 0.0182] | [-0.0159, 0.0159] | [0.0156, 0.0156] |
| $2\ell2\nu$ | [-0.0193, 0.0180] | [0.0195, 0.0182] | [-0.0163, 0.0152] | [0.0164, 0.0153] |
| $4\ell + 2\ell2\nu$ | [-0.0152, 0.0145] | [0.0151, 0.0143] | [-0.0129, 0.0123] | [0.0128, 0.0121] |

Table : ATLAS input intervals within 2.2%

## Comparing Observed Results - Gaussian

| 1D deltaNLL limit CMS inputs | $f_4^\gamma$ | | $f_4^Z$ | |
| --- | --- | --- | --- | --- |
| | ATLAS | CMS | ATLAS | CMS |
| $4\ell$ | [-0.0122, 0.0133] | [0.0122, 0.0133] | [-0.0104, 0.0111] | [0.0104, 0.0111] |
| 1D deltaNLL limit | $f_5^\gamma$ | | $f_5^Z$ | |
| $4\ell$ | [-0.0128, 0.0125] | [0.0129, 0.0126] | [-0.0107, 0.0109] | [0.0107, 0.0109] |

Table : CMS input intervals within 0.8%

| 1D deltaNLL limit ATLAS inputs | $f_4^\gamma$ | | $f_4^Z$ | |
| --- | --- | --- | --- | --- |
| | ATLAS | CMS | ATLAS | CMS |
| $4\ell$ | [-0.0184, 0.0184] | [0.0180, 0.0180] | [-0.0157, 0.0157] | [0.0154, 0.0154] |
| $2\ell2\nu$ | [-0.0188, 0.0187] | [0.0191, 0.0191] | [-0.0158, 0.0158] | [0.0162, 0.0161] |
| $4\ell + 2\ell2\nu$ | [-0.0148, 0.0147] | [0.0147, 0.0146] | [-0.0126, 0.0126] | [0.0124, 0.0125] |
| 1D deltaNLL limit | $f_5^\gamma$ | | $f_5^Z$ | |
| $4\ell$ | [-0.0187, 0.0186] | [-0.0182, 0.0182] | [ -0.0159, 0.0159 ] | [0.0155, 0.0156] |
| $2\ell2\nu$ | [-0.0197, 0.0184] | [0.0200, 0.0188] | [ -0.0166, 0.0155] | [0.0169, 0.0158] |
| $4\ell + 2\ell2\nu$ | [-0.0154, 0.0146] | [0.0150, 0.0145] | [ -0.0130, 0.0124] | [0.0129, 0.0123] |

Table : ATLAS input intervals within 2.6%

# Comparing Expected Results - log-Normal

| 1D deltaNLL limit | $f_4^\gamma$ | | $f_4^Z$ | |
|---|---|---|---|---|
| | ATLAS | CMS | ATLAS | CMS |
| $4\ell$ | [-0.0159, 0.0170] | [0.0161, 0.0173] | [-0.0136, 0.0141] | [0.0140, 0.0145] |
| 1D deltaNLL limit | $f_5^\gamma$ | | $f_5^Z$ | |
| $4\ell$ | [-0.0166, 0.0163] | [0.0169, 0.0167] | [-0.0139, 0.0142] | [0.0141, 0.0144] |

Table : CMS input intervals within 2.9%

| 1D deltaNLL limit | $f_4^\gamma$ | | $f_4^Z$ | |
|---|---|---|---|---|
| | ATLAS | CMS | ATLAS | CMS |
| $4\ell$ | [-0.0173, 0.0173] | [0.0175, 0.0175] | [-0.0148, 0.0148] | [0.0150, 0.0150] |
| $2\ell2\nu$ | [-0.0174, 0.0173] | [0.0174, 0.0173] | [-0.0146, 0.0146] | [0.0147, 0.0147] |
| $4\ell + 2\ell2\nu$ | [-0.0141, 0.0141] | [0.0143, 0.0142] | [-0.0120, 0.0120] | [0.0121, 0.0121] |
| 1D deltaNLL limit | $f_5^\gamma$ | | $f_5^Z$ | |
| $4\ell$ | [-0.0177, 0.0175] | [0.0179, 0.0177] | [-0.0150, 0.0150] | [0.0152, 0.0152] |
| $2\ell2\nu$ | [-0.0182, 0.0171] | [0.0183, 0.0171] | [-0.0153, 0.0143] | [0.0154, 0.0144] |
| $4\ell + 2\ell2\nu$ | [-0.0147, 0.0140] | [0.0148, 0.0141] | [-0.0126, 0.0119] | [0.0125, 0.0120] |

Table : ATLAS input intervals within 1.4%

# Comparing Expected Results - Gaussian

| 1D deltaNLL limit | $f_4^\gamma$ | | $f_4^Z$ | |
|---|---|---|---|---|
| | ATLAS | CMS | ATLAS | CMS |
| $4\ell$ | [-0.0159, 0.0170] | [0.0162, 0.0173] | [-0.0137, 0.0144] | [0.0140, 0.0145] |
| 1D deltaNLL limit | $f_5^\gamma$ | | $f_5^Z$ | |
| $4\ell$ | [-0.0167, 0.0163] | [0.0169, 0.0167] | [-0.0138, 0.0141] | [0.0142, 0.0144] |

Table : CMS input intervals within 3.5%

| 1D deltaNLL limit | $f_4^\gamma$ | | $f_4^Z$ | |
|---|---|---|---|---|
| | ATLAS | CMS | ATLAS | CMS |
| $4\ell$ | [-0.0173, 0.0173] | [0.0177, 0.0176] | [-0.0149, 0.0149] | [0.0151, 0.0151] |
| $2\ell2\nu$ | [-0.0177, 0.0176] | [0.0180, 0.0179] | [-0.0150, 0.0150] | [0.0152, 0.0152] |
| $4\ell + 2\ell2\nu$ | [-0.0145, 0.0145] | [0.0146, 0.0145] | [-0.0123, 0.0120] | [0.0124, 0.0124] |
| 1D deltaNLL limit | $f_5^\gamma$ | | $f_5^Z$ | |
| $4\ell$ | [-0.0176, 0.0175] | [0.0180, 0.0178] | [-0.0150, 0.0150] | [-0.0153, 0.0153] |
| $2\ell2\nu$ | [-0.0187, 0.0175] | [0.0189, 0.0177] | [-0.0157, 0.0147] | [0.0159, 0.0149] |
| $4\ell + 2\ell2\nu$ | [-0.0149, 0.0141] | [0.0150, 0.0145] | [-0.0126, 0.0122] | [0.0128, 0.0123] |

Table : ATLAS input intervals within 2.8%

# Combined aTGC Comparison

| Expected deltaNLL limit | $f_4^\gamma$ | | $f_4^Z$ | |
| --- | --- | --- | --- | --- |
| | ATLAS | CMS | ATLAS | CMS |
| Gaussian | [-0.0117, 0.0121] | [0.0120, 0.0125] | [-0.0101, 0.0103] | [-0.0103, 0.0105] |
| log-Normal | [-0.0117, 0.0121] | [0.0119, 0.0123] | [-0.00995, 0.0102] | [-0.0102, 0.0104] |
| Expected deltaNLL limit | $f_5^\gamma$ | | $f_5^Z$ | |
| Gaussian | [-0.0122, 0.0118] | [0.0126, 0.0121] | [-0.0103, 0.0101] | [0.0106, 0.0104] |
| log-Normal | [-0.0122, 0.0118] | [0.0125, 0.0120] | [-0.0103, 0.0101] | [0.0105, 0.0103] |
| Observed deltaNLL limit | $f_4^\gamma$ | | $f_4^Z$ | |
| | ATLAS | CMS | ATLAS | CMS |
| Gaussian | [-0.0103, 0.0108] | [0.0103, 0.0109] | [-0.00876, 0.00913] | [0.00874, 0.00913] |
| log-Normal | [-0.0102, 0.0108] | [0.0102, 0.0108] | [-0.00871, 0.00908] | [0.00871, 0.00909] |
| Observed deltaNLL limit | $f_5^\gamma$ | | $f_5^Z$ | |
| | ATLAS | CMS | ATLAS | CMS |
| Gaussian | [-0.0108, 0.0103] | [0.0108, 0.0104] | [-0.00908, 0.00892] | [0.00909, 0.00891] |
| log-Normal | [-0.0108, 0.0103] | [0.0108, 0.0103] | [-0.00903, 0.00886] | [0.00906, 0.00886] |

- Expected intervals within: Gaussian 3.2%, log-normal 2.4%
- Observed intervals within: Gaussian 1.0%, log-normal 0.3%

# Checking Each Uncertainty

| Systematic | $f_5^\gamma$ ATLAS | $f_5^\gamma$ CMS | $f_5^Z$ ATLAS | $f_5^Z$ CMS |
|---|---|---|---|---|
| No Systematics | [-0.0116, 0.0111] | [-0.0116,0.0111] | [-0.00972, 0.00955] | [-0.00974,0.00954] |
| Full Systematics | [-0.0108, 0.0104] | [-0.0108,0.0104] | [-0.00909, 0.00893] | [-0.00909,0.00891] |
| ATLAS Mcbkgstat | [-0.0116, 0.0111] | [-0.0116,0.0112] | [-0.00972, 0.00956] | [-0.00975,0.00955] |
| ATLAS Ddbkgstat | [-0.0116, 0.0112] | [-0.0116,0.0111] | [-0.00977, 0.00963] | [-0.00974,0.00954] |
| ATLAS ZZstat | [-0.0116, 0.0111] | [-0.0116,0.0111] | [-0.00972, 0.00955] | [-0.00974,0.00955] |
| Combined ZZ theory | [-0.0109, 0.0104] | [-0.0109,0.0104] | [-0.00914, 0.00896] | [-0.00916,0.00895] |
| CMS DdbkgUnc mmmm eemm eeee | [-0.0116, 0.0111] | [-0.0116,0.0111] | [-0.00972, 0.00955] | [-0.00974,0.00954] |
| ATLAS Mcbkgsys | [-0.0116, 0.0111] | [-0.0116,0.0111] | [-0.00972, 0.00955] | [-0.00974,0.00954] |
| ATLAS DDbkgsys1 sys2 | [-0.0116, 0.0111] | [-0.0116,0.0111] | [-0.00971, 0.00955] | [-0.00973,0.00954] |
| Lumi Combined | [-0.0114, 0.0109] | [-0.0114,0.0109] | [-0.00955, 0.00937] | [-0.00957,0.00936] |
| ATLAS Mcsyst | [-0.0115, 0.0110] | [-0.0115,0.0110] | [-0.00960, 0.00943] | [-0.00964,0.00943] |
| CMS ZZ other | [-0.0114, 0.0109] | [-0.0115,0.0110] | [-0.00959, 0.00943] | [-0.00961,0.00942] |

- Using truncated Gaussian constraints
- ATLAS intervals only using 1$^{st}$ order nuisance parameters, but systematics tracked separately

# Still to Do

- Need to understand why adding uncertainies decrease interval size
  - May have to do with normalization (uncertainty) vs shape (aTGC)
- Determine if Asimov datasets are appropriate for extracting expected intervals

# Back Ups

# Raw Systematic Values

```
MCbkgstat MCbkgATLAS UCOR ABS 0 0 0 0 0.78 0.74 0.66 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
DDbkgstat DDbkgATLAS UCOR ABS 0.75 0.24 0.10 0.01 4.38 2.69 1.70 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
ZZstat Signal UCOR ABS 0.24 0.17 0.14 0.06 0.22 0.28 0.14 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
ZZuncCMS Signal CORR REL 0 0 0 0 0 0 0 0.1342 0.1342 0.1342 0.1342 0.1342 0.1342 0.1342 0.1342
0.1342 0.1342 0.1342 0.1342 0.1342 0.1342 0.1342
ZZtheory Signal CORR REL 0.064088793 0.071086808 0.08512931 0.161290323 0.095202952 0.104725415
0.133136095 0.04 0.04 0.04 0.04 0.04 0.04 0.04 0.04 0.04 0.04 0.04 0.04 0.04 0.04 0.04
DdbkgUncmmmm DdbkgCMS CORR REL 0 0 0 0 0 0 0 0.3 0.3 0.3 0.3 0.3 0.3 0 0 0 0 0 0 0 0 0 0
DdbkgUnceemm DdbkgCMS CORR REL 0 0 0 0 0 0 0 0 0 0 0 0 0 0.3 0.3 0.3 0.3 0.3 0.3 0 0 0 0
DdbkgUnceeee DdbkgCMS CORR REL 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0.3 0.3 0.3 0.3 0.3
MCbkgsys MCbkgATLAS CORR REL 0 0 0 0 0.022 0.023 0.022 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
DDbkgsys1 DDbkgATLAS CORR ABS 0.48 0 0.07 0 1.12 0 0.19 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
DDbkgsys2 DDbkgATLAS CORR ABS 0.15 0 0.008 0 0.68 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
LumiCombined CORR REL 0.039 0.039 0.039 0.039 0.039 0.039 0.039 0.022 0.022 0.022 0.022 0.022
0.022 0.022 0.022 0.022 0.022 0.022 0.022 0.022 0.022 0.022

MCsyst CORR ABS 0.97 0.55 0.37 0.07 0.27 0.48 0.40 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
```

- First is the uncertainty name
- If a second name follows the uncertainty, it is the background (or signal) it applies to
- CORR means correlated across the bins, UCOR is uncorrelated
- REL means it's a relative error ABS means the error is given as a number of events