Simultaneous extraction of m_t and α_s from differential $t\bar{t}$ distributions

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Work in progress—results preliminary

Simultaneous extraction of m_t and α_s from differential $t\bar{t}$ distributions

- 8 TeV data from ATLAS and CMS collected in Run 1
- Differential distributions of tops reconstructed from lepton+jets analyses, common binning
- Transverse momentum p_t^T, invariant mass $M_{t\bar{t}}$, single and pair rapidities y_t,$y_{t\bar{t}}$
- Absolute and normalised distributions—separate data sets from ATLAS, only normalised from CMS (absolute inferred)

Fit methodology

Least squares extraction for normalised and absolute distributions

$$\zeta_i = \zeta_i^{\text{data}} - \zeta_i^{\text{theory}}$$

$$\chi^2_{\text{norm}} = \frac{1}{(N_{\text{data}} - 1)} \sum_{i,j=1}^{N_{\text{data}}-1} \zeta_i C_{ij}^{-1} \zeta_j + \frac{(\sigma_{\text{NNLO}} - \sigma_{\text{data}})^2}{\delta\sigma^2_{\text{data}}}$$

$$\chi^2_{\text{abs}} = \frac{1}{N_{\text{data}}} \sum_{i,j=1}^{N_{\text{data}}} \zeta_i C_{ij}^{-1} \zeta_j$$

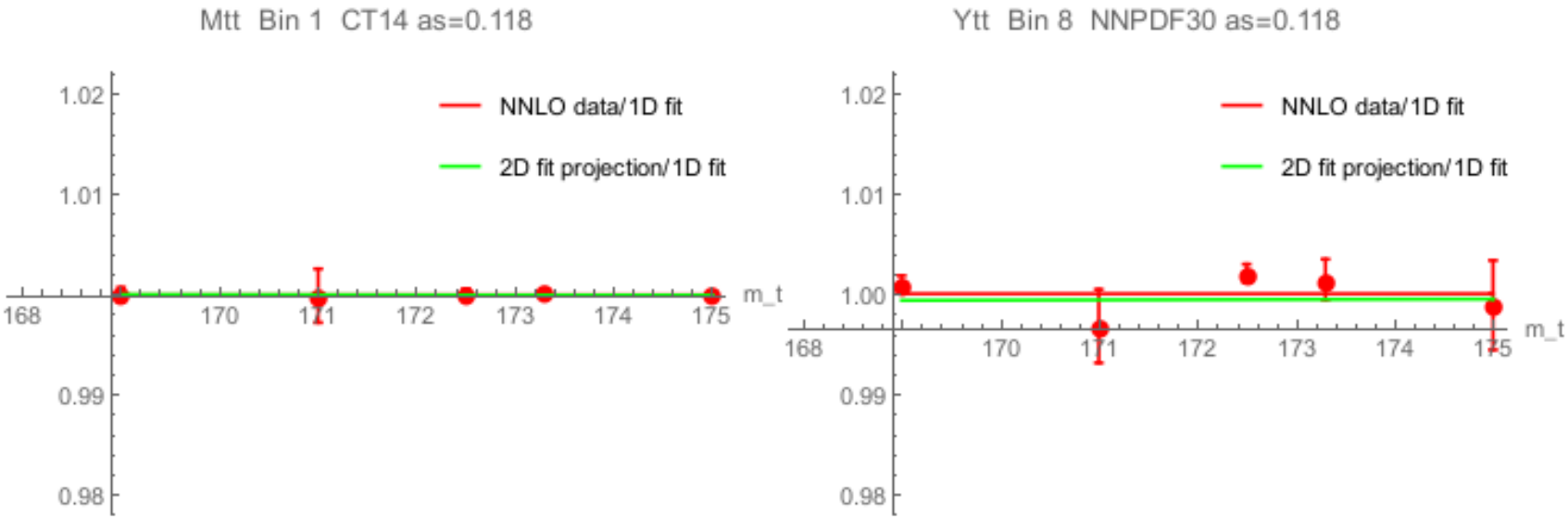
- Measured values of $\sigma_{t\bar{t}}$ taken from separate 8 TeV ATLAS/CMS measurements [1]
- Theory values of $\sigma_{t\bar{t}}$ calculated using `top++2.0` at NNLO with NNLL resummation of soft gluons

[1] 1406.5375,1603.02303

Theory input

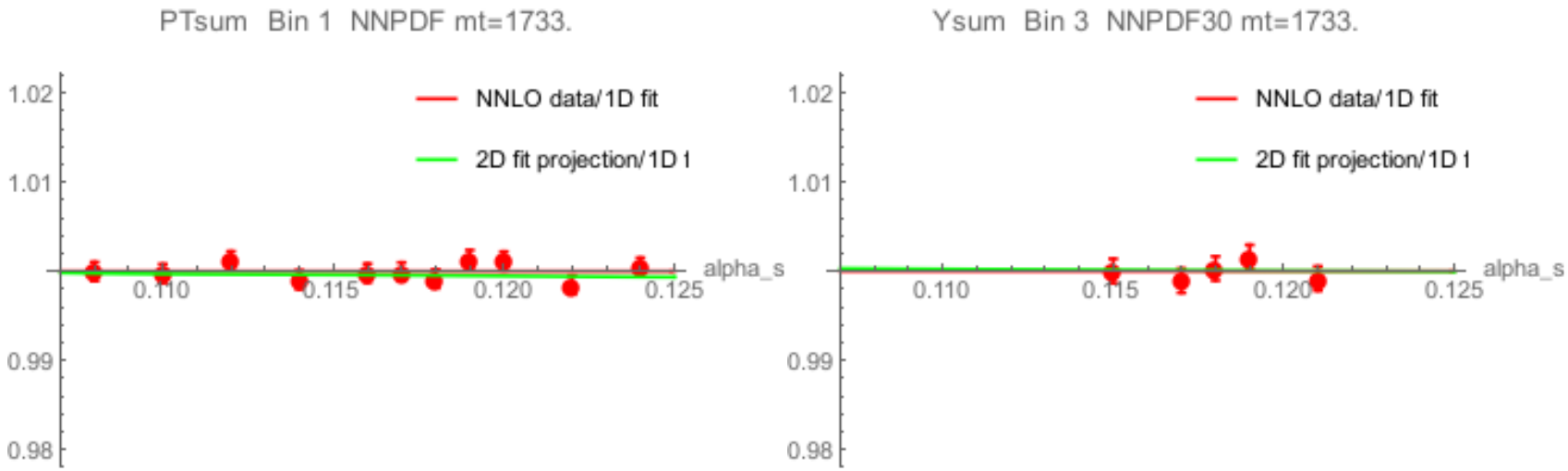
- For each distribution, need differential cross section in each bin as a function of α_s, m_t
- Precompute each bin weight on a grid of α_s, m_t and interpolate parameter dependence
- α_s dependence determined by PDF set, so procedure needs to be done for each choice
- Possible through use of FastNLO tables for values of $m_t = \{169.0, 171.0, 172.5, 173.3, 175.0\}$ GeV
- 3 sets chosen, NNPDF3.0, NNPDF3.1, CT14
- Different parametrisations chosen for each distribution, PDF choice

Assessing fit quality



- Factorised form taken for 2D parametrisation, $f(\alpha_s, m_t) = g(\alpha_s)h(m_t)$
- Points removed and fit redone to ensure no overfitting

Assessing fit quality



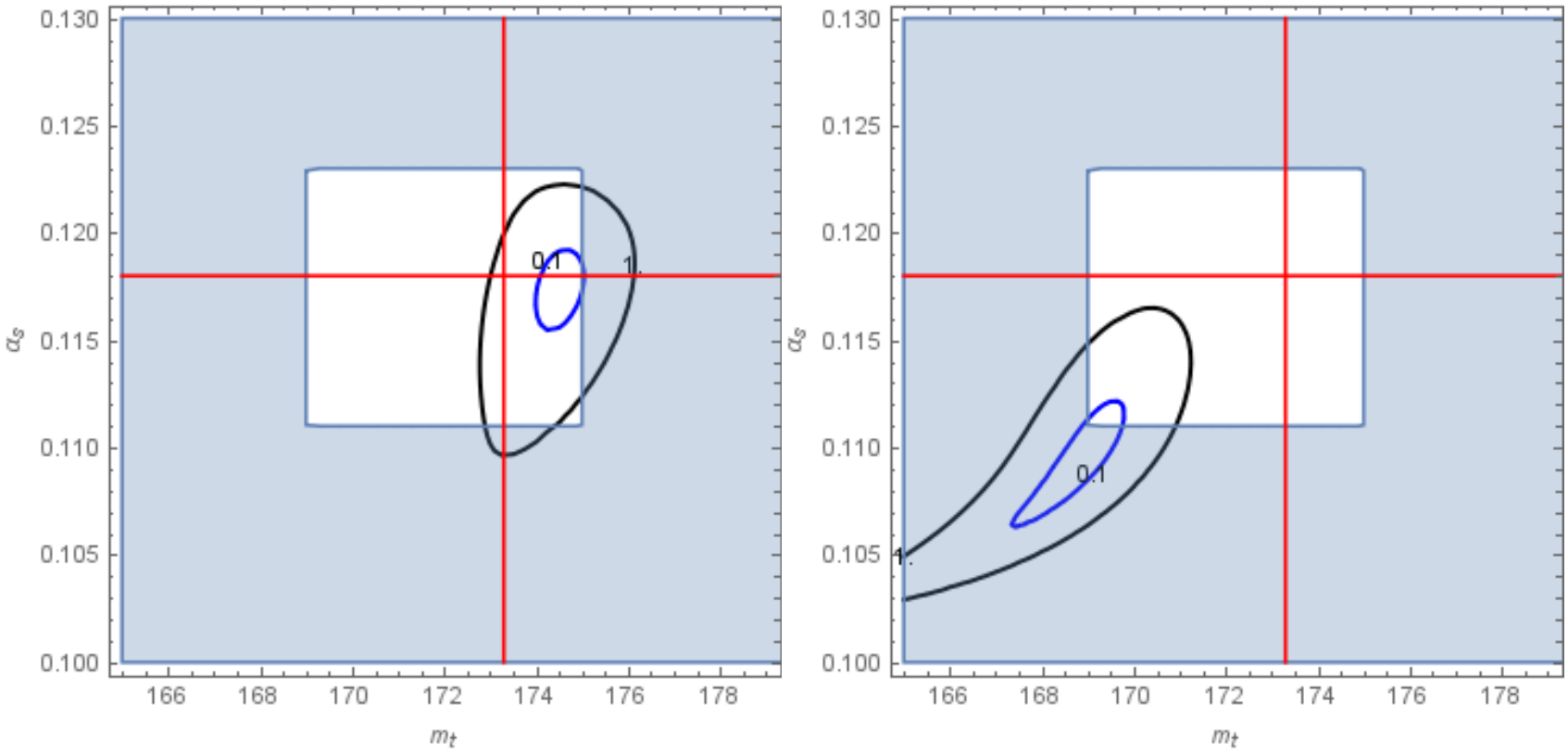
- Factorised form taken for 2D parametrisation, $f(\alpha_s, m_t) = g(\alpha_s)h(m_t)$
- Points removed and fit redone to ensure no overfitting

Results: p_t^T

CT14, normalised results

White region: interpolated, blue region: extrapolated

Blue line: $\Delta\chi^2 = 0.1$, black line: $\Delta\chi^2 = 1.0$



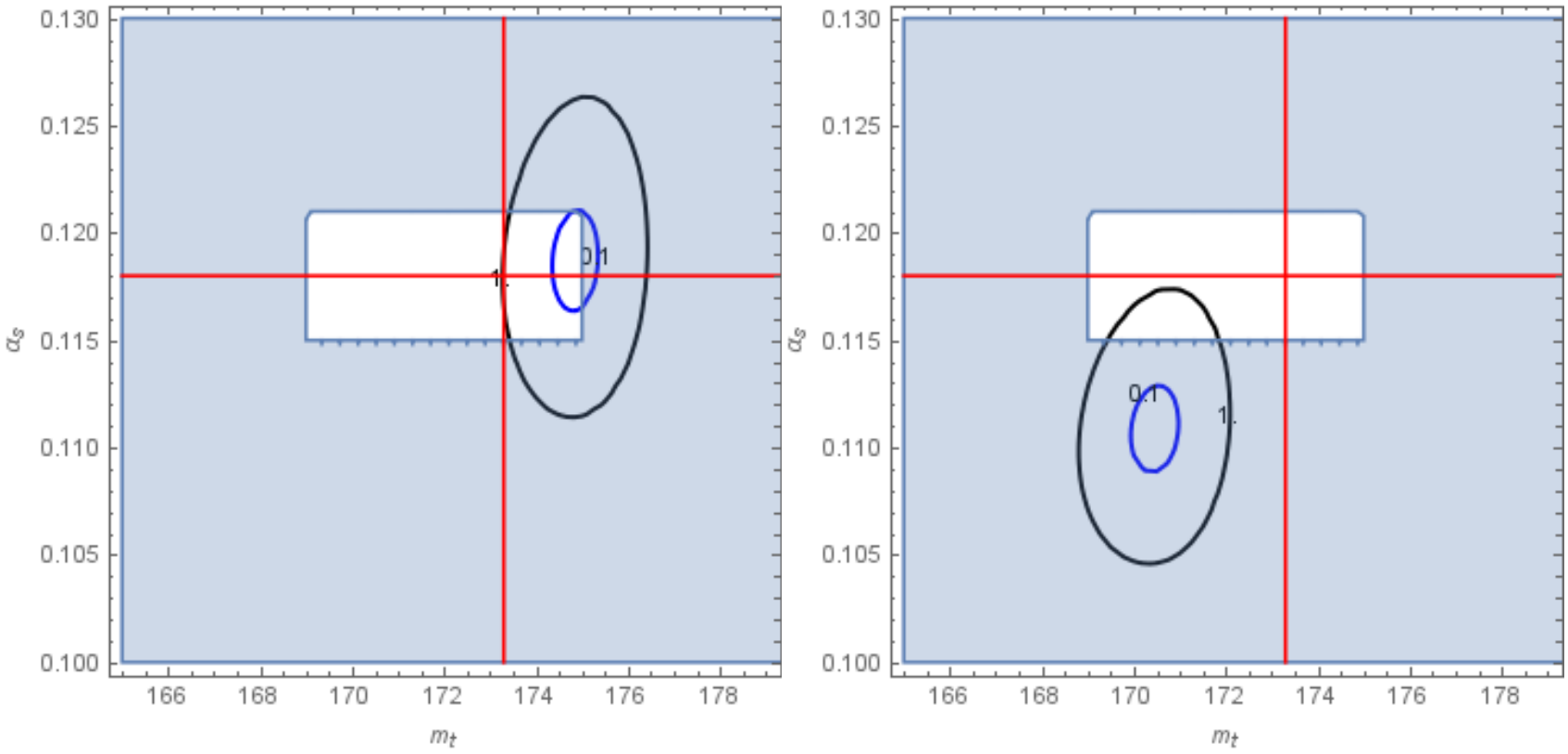
	ATLAS			CMS		
	α_s	m_t	$\chi^2_{\min}$	α_s	m_t	$\chi^2_{\min}$
p_T^t	0.1175	174.5	0.50	0.1096	168.9	0.71

Results: p_t^T

NNPDF3.0, normalised results

White region: interpolated, blue region: extrapolated

Blue line: $\Delta\chi^2 = 0.1$, black line: $\Delta\chi^2 = 1.0$



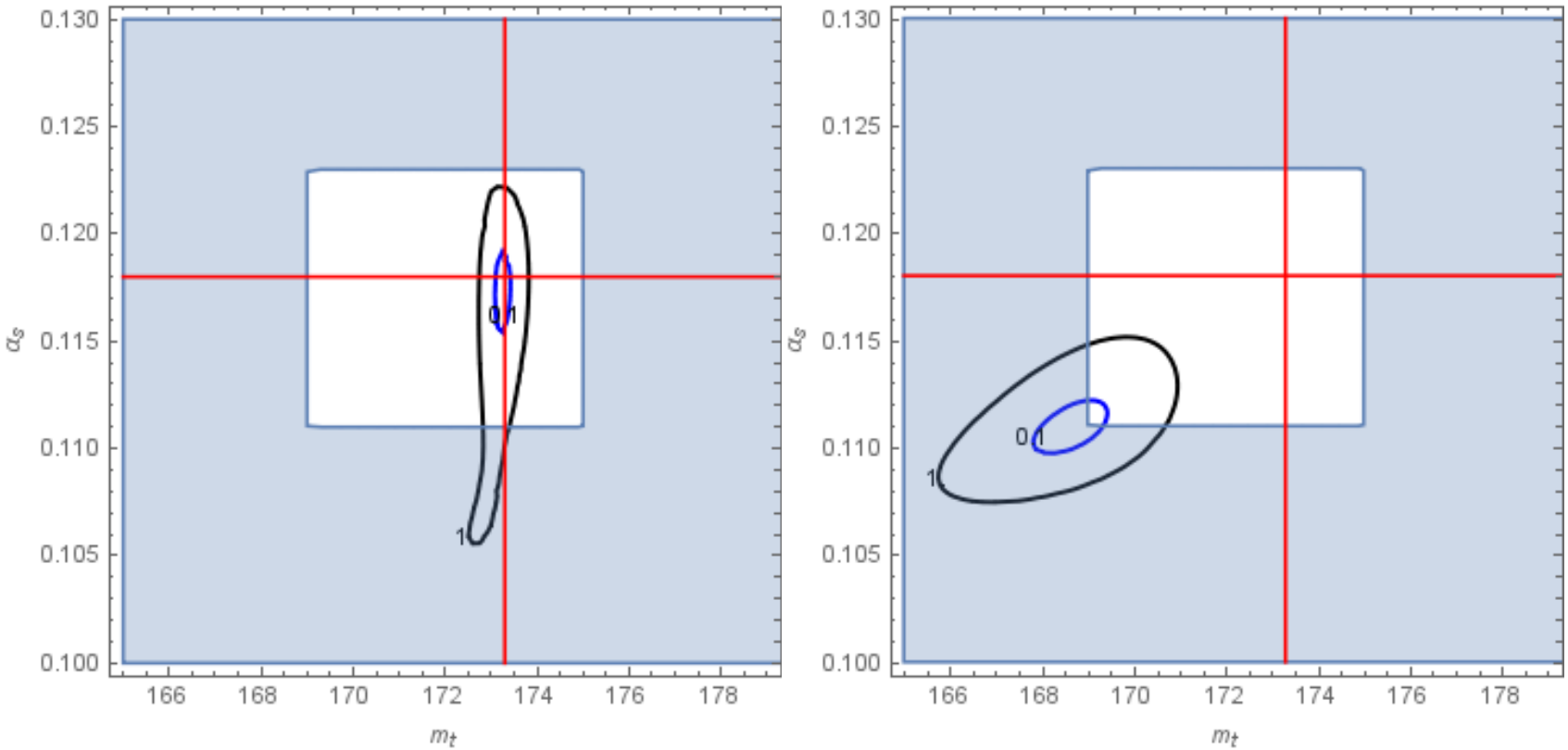
	ATLAS			CMS		
	α_s	m_t	$\chi^2_{\min}$	α_s	m_t	$\chi^2_{\min}$
p_T^t	0.1187	174.9	0.46	0.1108	170.5	0.68

Results: $M_{t\bar{t}}$

CT14, normalised results

White region: interpolated, blue region: extrapolated

Blue line: $\Delta\chi^2 = 0.1$, black line: $\Delta\chi^2 = 1.0$



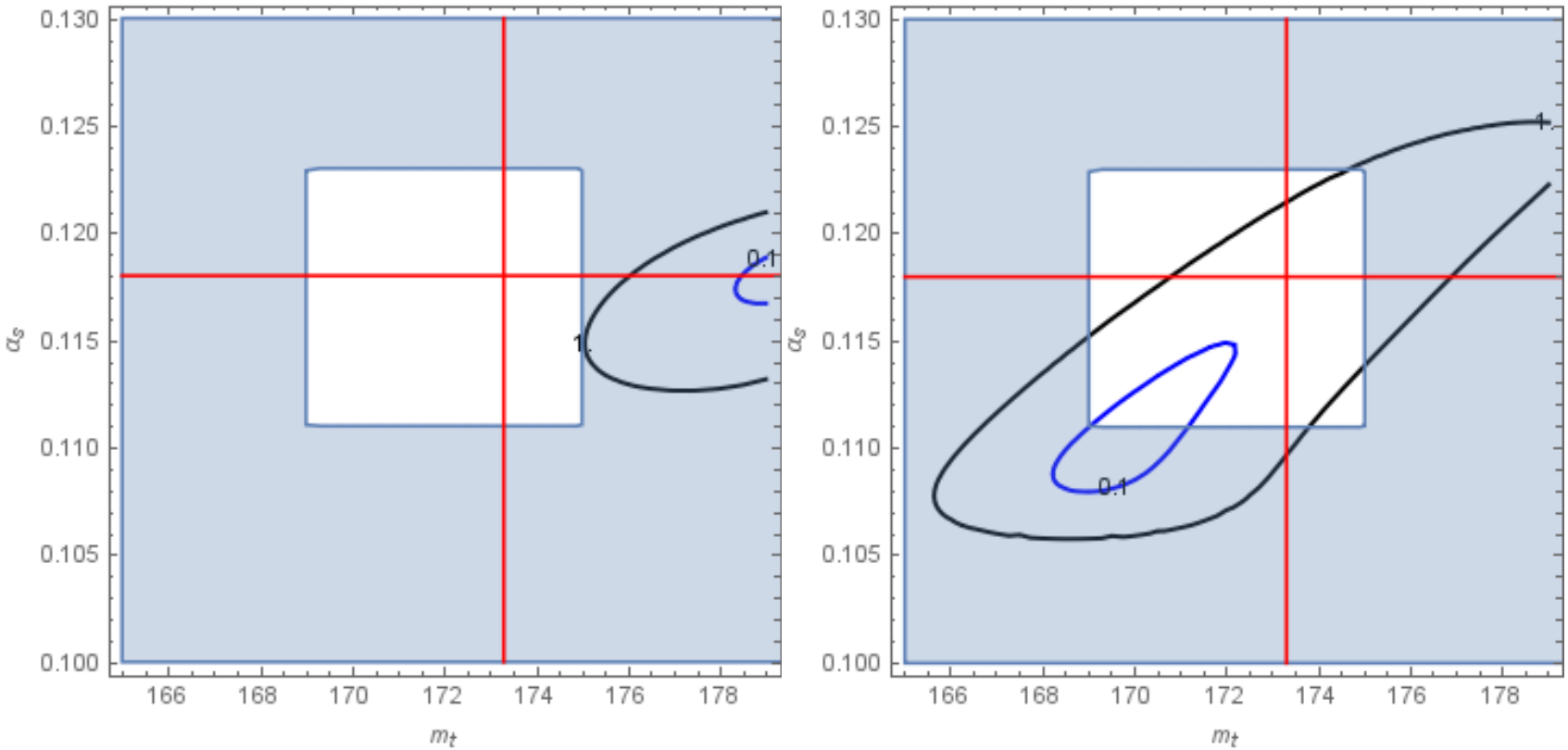
	ATLAS			CMS		
	α_s	m_t	χ^2_{min}	α_s	m_t	χ^2_{min}
$M_{t\bar{t}}$	0.1174	173.2	1.23	0.1109	168.7	4.77

Results: y_t

CT14, normalised results

White region: interpolated, blue region: extrapolated

Blue line: $\Delta\chi^2 = 0.1$, black line: $\Delta\chi^2 = 1.0$



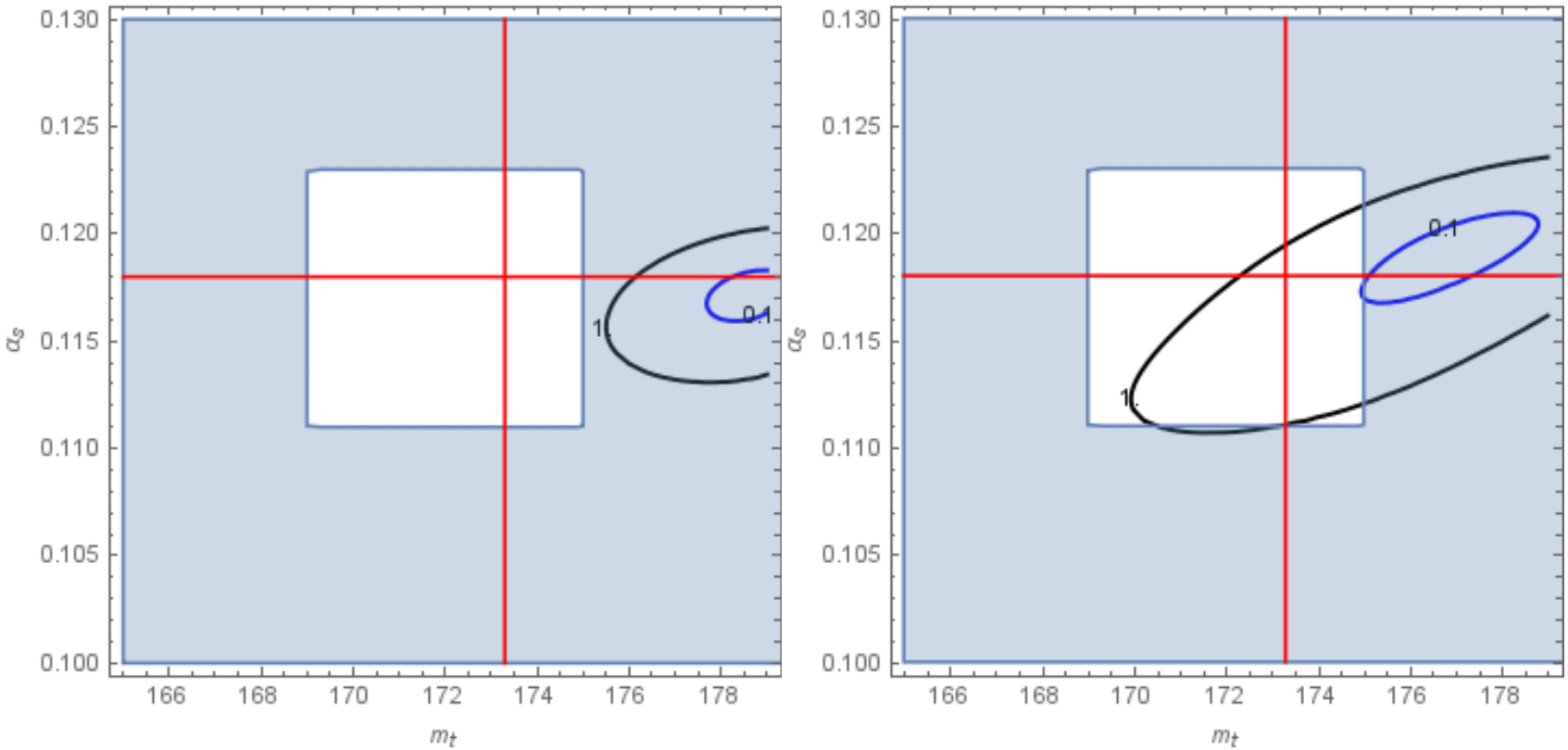
	ATLAS			CMS		
	α_s	m_t	$\chi^2_{\min}$	α_s	m_t	$\chi^2_{\min}$
y_t	0.1183	179.6	3.35	0.1100	169.6	2.26

Results: $y_{t\bar{t}}$

CT14, normalised results

White region: interpolated, blue region: extrapolated

Blue line: $\Delta\chi^2 = 0.1$, black line: $\Delta\chi^2 = 1.0$



	ATLAS			CMS		
	α_s	m_t	$\chi^2_{\min}$	α_s	m_t	$\chi^2_{\min}$
$y_{t\bar{t}}$	0.1172	178.6	8.35	0.1191	177.0	1.85

$M_{t\bar{t}}$ distribution fits

- Sensitivity to mass dependence in $M_{t\bar{t}}$ concentrated in first bin
  - Calculations with different m_t will show majority of variation here with tail largely unaffected
- Experimental binning begins at 345 GeV which is above threshold for $m_t < 172.5$ GeV. Leads to missed events for $m_t < 172.5$ GeV.
- MC mass 172.5 assumed in published measurements
  - For consistent mass extraction, extrapolations with different vales of m_t needed in MC.
- In our calculations, binning is consistent with experimental binning for all values of m_t (i.e. missed events not included).

Combining distributions and experiments

- Would ideally like to combine distributions within experiments, but correlations not currently available
- Combine distributions from ATLAS and CMS assuming no correlations (luminosity?)

$$\chi^2_{\text{norm}} = \frac{1}{(N_{\text{ATLAS}} + N_{\text{CMS}} - 2)} \left(\sum_{i,j=1}^{N_{\text{ATLAS}}-1} \zeta_{i,\text{ATLAS}} C^{-1}_{ij,\text{ATLAS}} \zeta_{j,\text{ATLAS}} + \sum_{i,j=1}^{N_{\text{CMS}}-1} \zeta_{i,\text{CMS}} C^{-1}_{ij,\text{CMS}} \zeta_{j,\text{CMS}} \right)$$

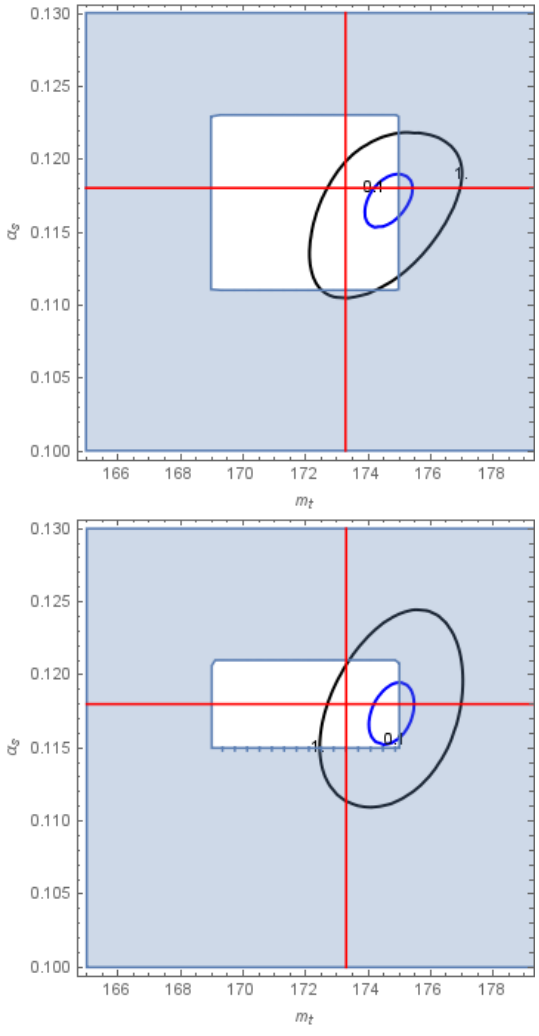
$$+ \frac{(\sigma_{\text{NNLO}} - \sigma_{\text{ATLAS}})^2}{\delta\sigma^2_{\text{ATLAS}}} + \frac{(\sigma_{\text{NNLO}} - \sigma_{\text{CMS}})^2}{\delta\sigma^2_{\text{CMS}}}$$

$$\chi^2_{\text{abs}} = \frac{1}{(N_{\text{ATLAS}} + N_{\text{CMS}})} \left(\sum_{i,j=1}^{N_{\text{ATLAS}}} \zeta_{i,\text{ATLAS}} C^{-1}_{ij,\text{ATLAS}} \zeta_{j,\text{ATLAS}} + \sum_{i,j=1}^{N_{\text{CMS}}} \zeta_{i,\text{CMS}} C^{-1}_{ij,\text{CMS}} \zeta_{j,\text{CMS}} \right)$$

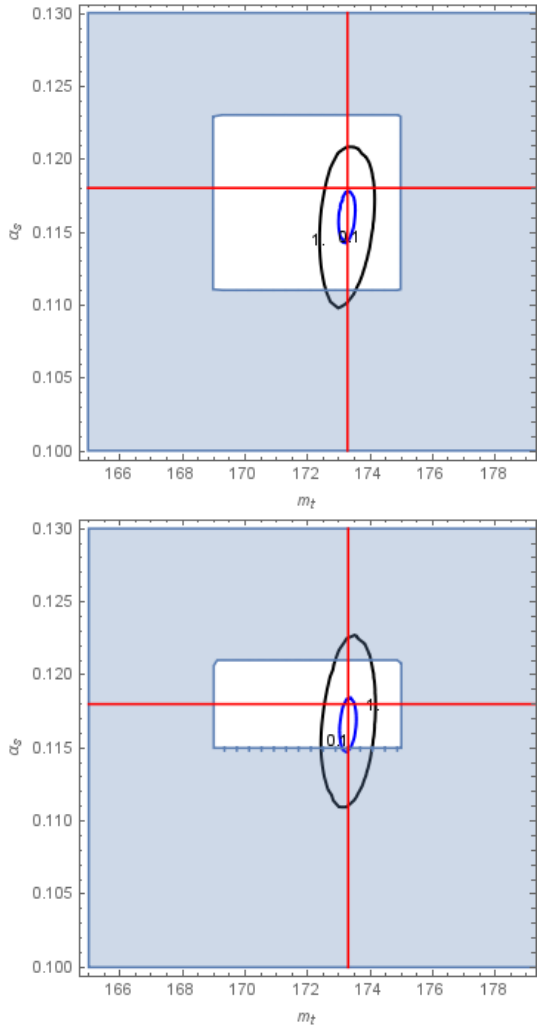
CT14

NNPDF3.0

ATLAS p_t^T, CMS $y_{t\bar{t}}$



ATLAS $M_{t\bar{t}}$, CMS $y_{t\bar{t}}$



Best fit values

In light of differences, consider best quality results satisfying

- Fit quality requirement $\chi^2 \leq 1.8$
- Restrict $0.115 \leq \alpha_s \leq 0.120$ and $170.0 \leq m_t \leq 175.0$ GeV ($\pm \sim 3\sigma$ around world average)

		CT14			NNPDF3.0		
ATLAS	CMS	α_s	m_t	χ^2_{min}	α_s	m_t	χ^2_{min}
p_T^t	$y_{t\bar{t}}$	$0.1172^{+0.0044}_{-0.0058}$	$174.7^{+2.2}_{-2.2}$	1.33	$0.1173^{+0.0066}_{-0.0061}$	$174.7^{+2.2}_{-2.1}$	0.78
$M_{t\bar{t}}$	$y_{t\bar{t}}$	$0.1161^{+0.0048}_{-0.0060}$	$173.3^{+0.9}_{-0.8}$	1.80	$0.1166^{+0.0060}_{-0.0056}$	$173.3^{+0.9}_{-0.8}$	1.36

Conclusions

- 8 TeV ATLAS, CMS data compared to NNLO theory to extract α_s, m_t simultaneously
- Find noticeable differences between
  - ATLAS and CMS
  - Different PDF choices
  - Different distributions

  indicating large sensitivity to all factors—data, PDF and kinematics
- In order to perform extraction,
  - Impose a cut-off of acceptable χ^2 values at 1.8
  - Restrict $0.115 \leq \alpha_s \leq 0.120$ and $170.0 \leq m_t \leq 175.0$ GeV ($\pm \sim 3\sigma$ around world average)

Conclusions

- Combining ATLAS and CMS generally results in better χ^2, less variation between PDFs
- Absolute distributions give better χ^2 but larger errors
- Find consistency between PDFs for ATLAS p_t^T or $M_{t\bar{t}}$ combined with CMS $y_{t\bar{t}}$
- Need correlations for best extraction
- Results available publically with paper or on request

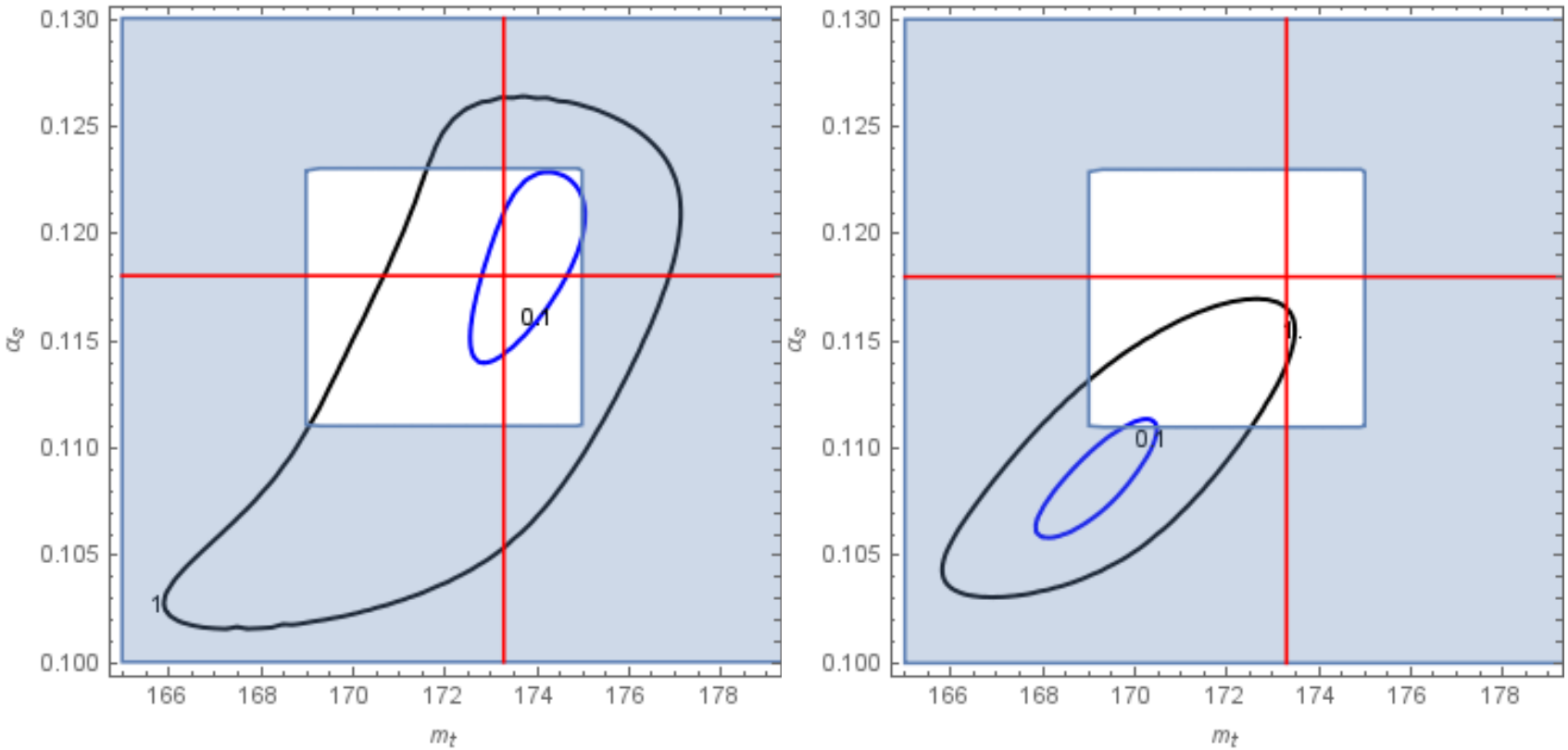
Back-up slides

Results: p_t^T

CT14, absolute results

White region: interpolated, blue region: extrapolated

Blue line: $\Delta\chi^2 = 0.1$, black line: $\Delta\chi^2 = 1.0$



Results: $M_{t\bar{t}}$

CT14, absolute results

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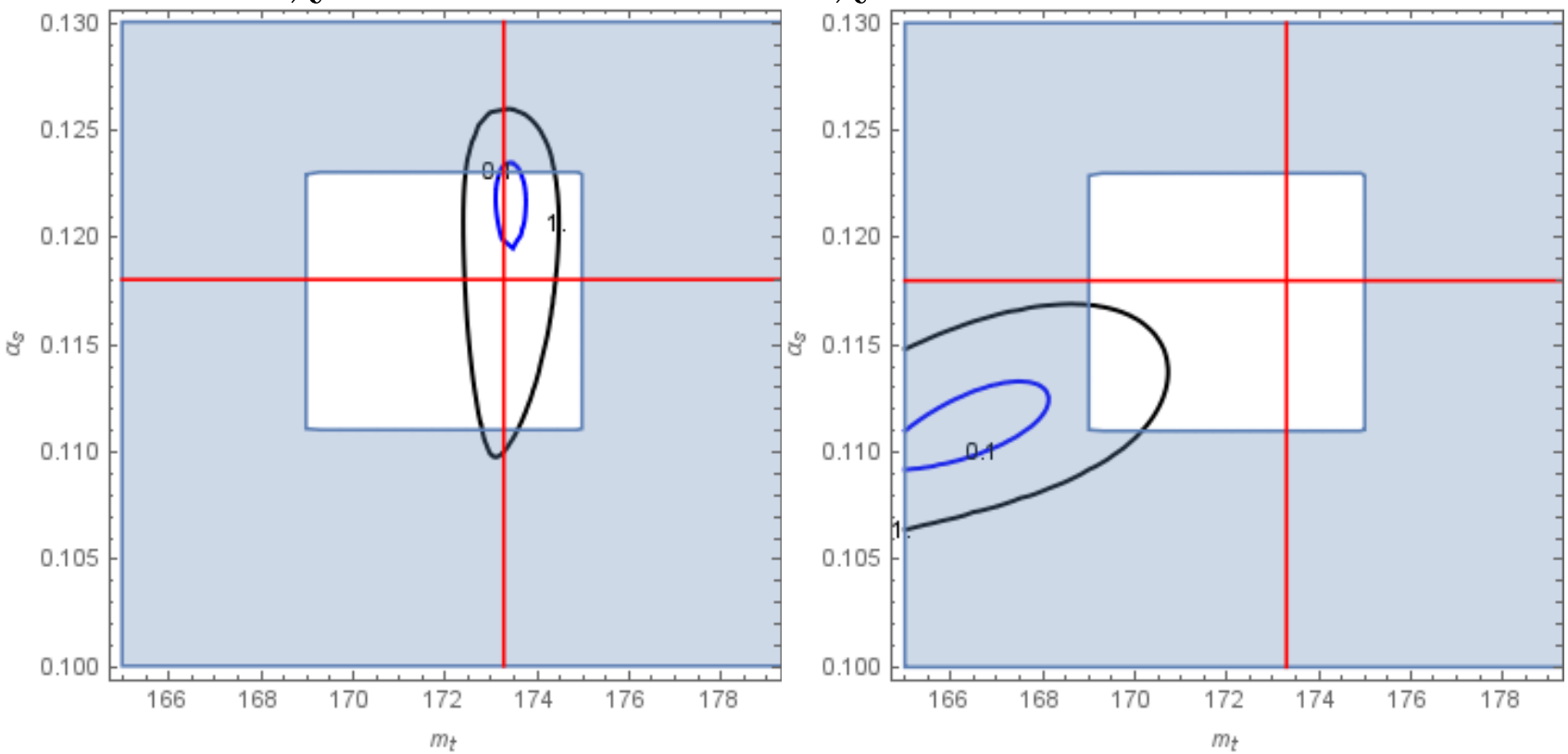
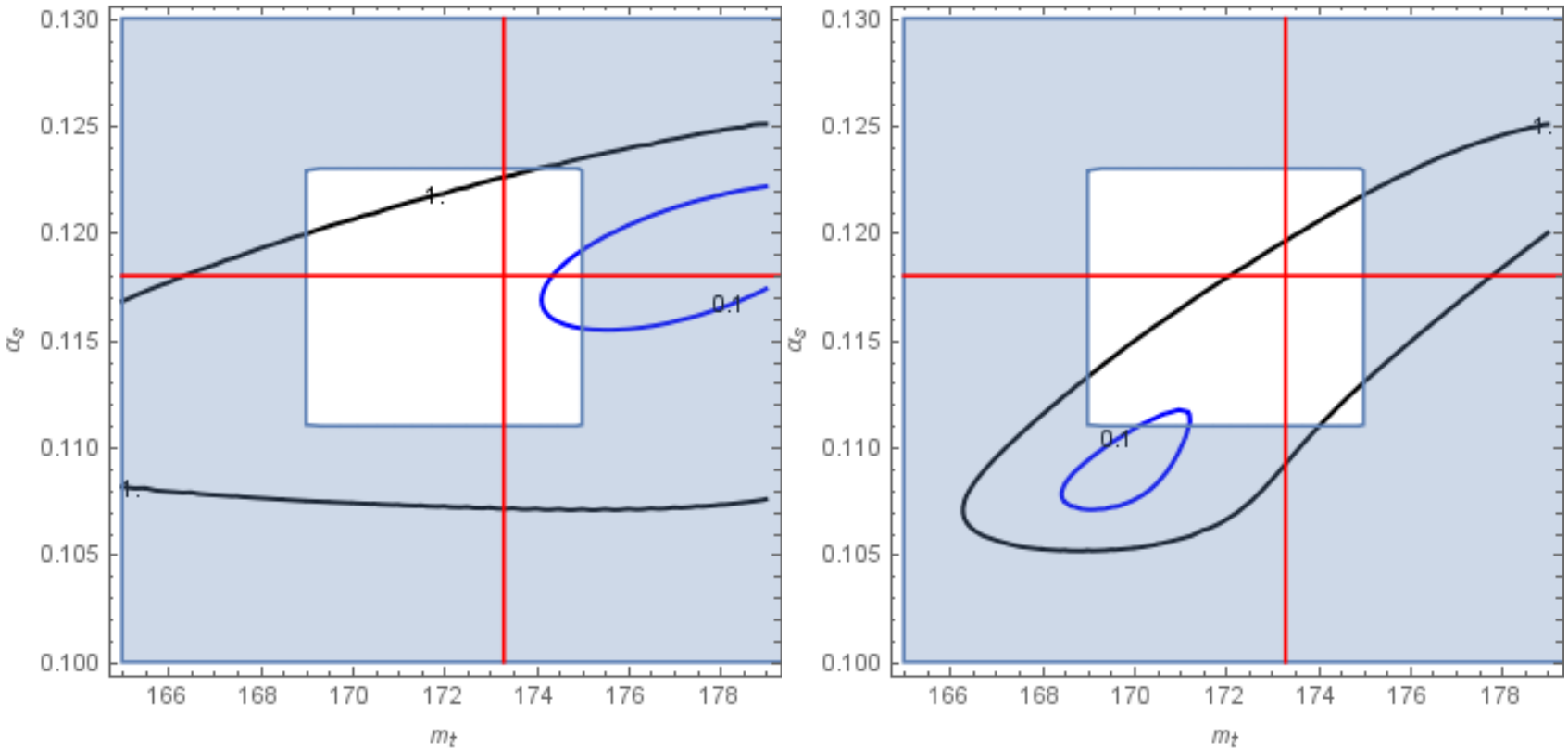


Results: y_t

CT14, absolute results

White region: interpolated, blue region: extrapolated

Blue line: $\Delta\chi^2 = 0.1$, black line: $\Delta\chi^2 = 1.0$



Results: $y_{t\bar{t}}$

CT14, absolute results

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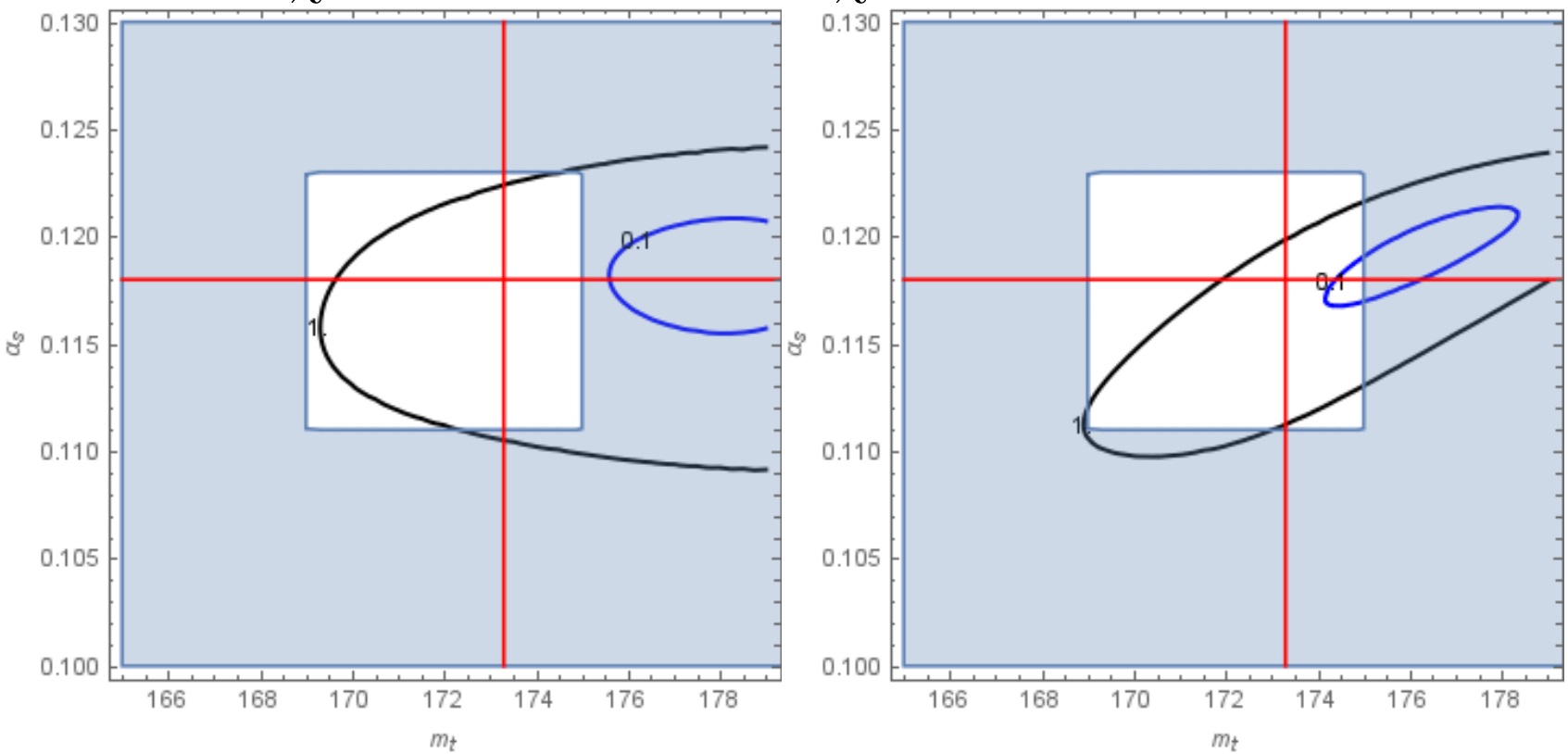
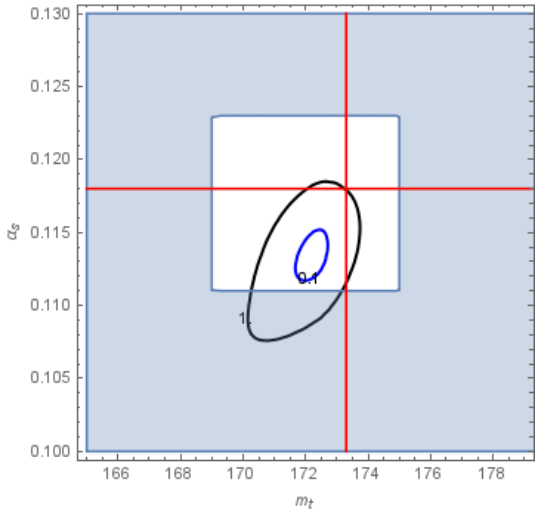
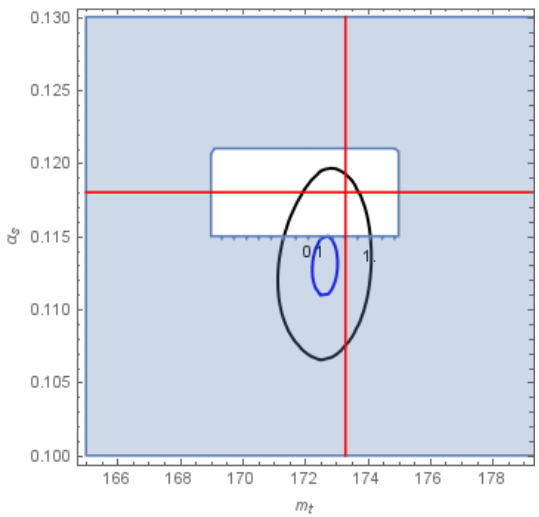


CT14

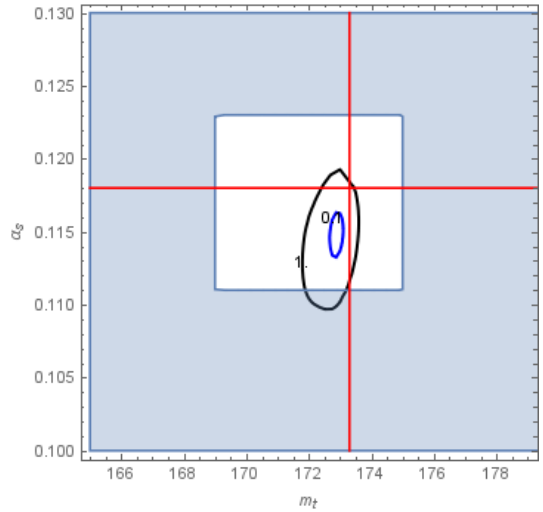
NNPDF3.0

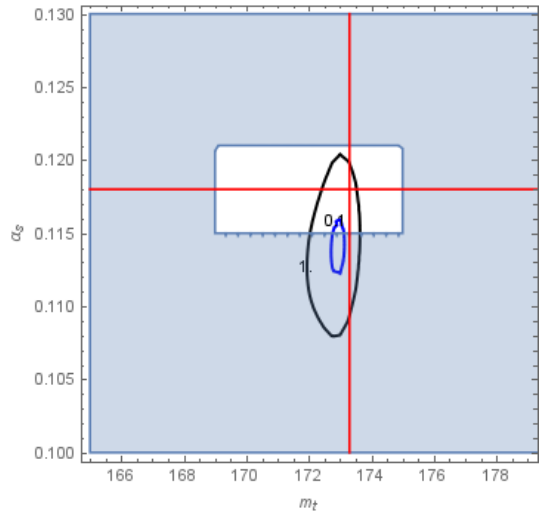
ATLAS p_t^T, CMS $M_{t\bar{t}}$





ATLAS $M_{t\bar{t}}$, CMS $M_{t\bar{t}}$

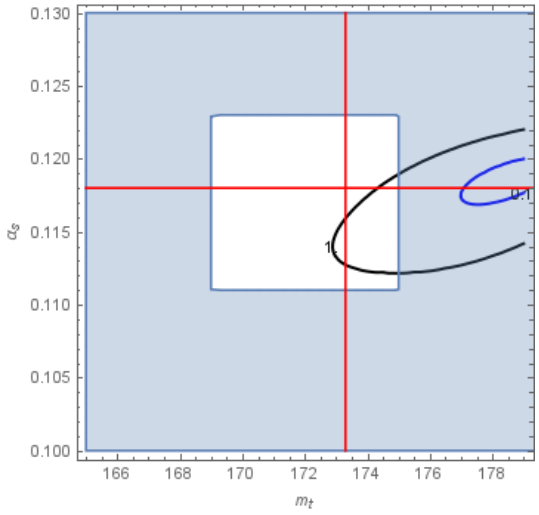


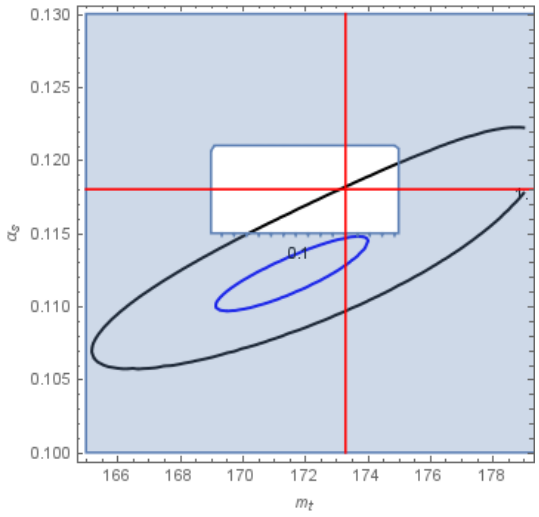


CT14

NNPDF3.0

ATLAS y_t, CMS $y_{t\bar{t}}$





ATLAS $y_{t\bar{t}}$, CMS $y_{t\bar{t}}$