Extrapolation uncertainties from single top generators and calculation of R_t predictions

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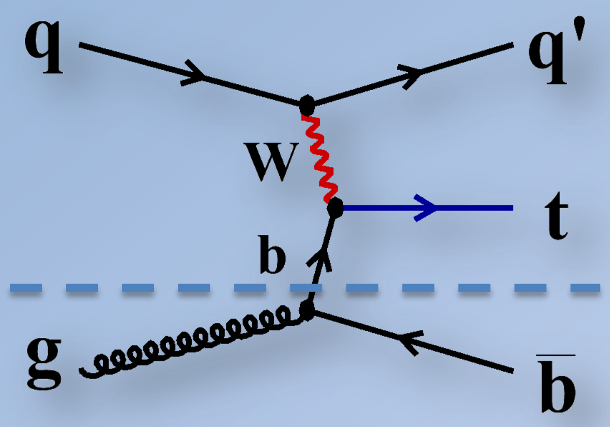
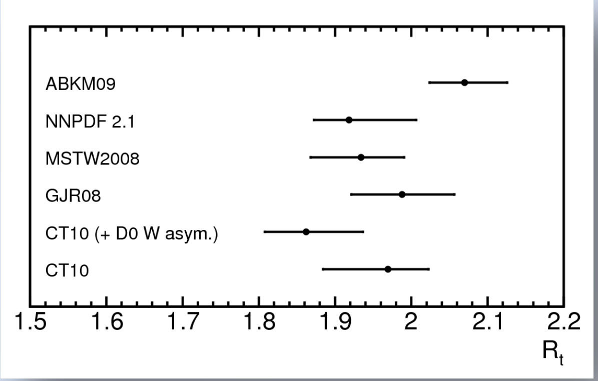
Outline



Extrapolation uncertainty on signal modeling

Prediction for cross section ratio @ NLO



Motivation

ATLAS-CONF-2012-132

Source	$\Delta\sigma_t/\sigma_t$ [%]
Data statistics	± 2.4
MC statistics	± 2.9
Background normalisation	± 1.5
QCD multijet normalisation	± 3.1
Jet energy scale	± 7.7
Jet energy resolution	± 3.0
Jet reconstruction	± 0.5
Jet vertex fraction	± 1.6
Mistag modeling	± 0.3
c-tagging efficiency	± 0.4
b-tagging efficiency	± 8.5
E_T^{miss}	± 2.3
Lepton efficiencies	± 4.1
Lepton energy resolution	± 2.2
Lepton energy scale	± 2.1
PDF	± 2.8
W+jets shape variation	± 0.3
W+jets extrapolation	± 0.6
t-channel generator	± 7.1
$t\bar{t}$ generator	± 3.3
ISR / FSR	± 9.1
Parton shower	± 0.8
Luminosity	± 3.6
Total systematic	± 18.8
Total	± 19.0

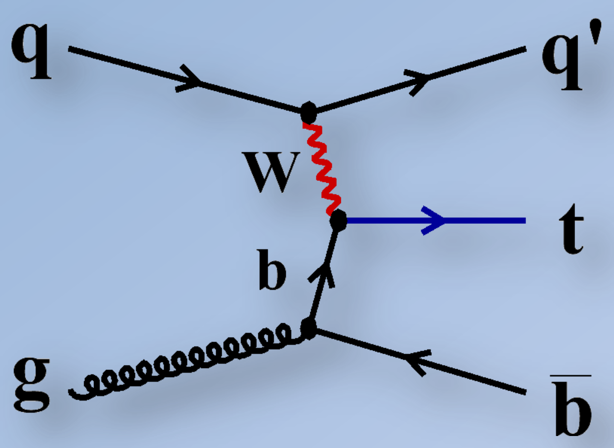
CMS PAS TOP-12-11

Uncertainty source	in pb	relative
Statistical	±5.7	±7.2 %
W+jets and $t\bar{t}$modeling	±3.6	± 4.5 %
JES	− 6.2 / + 4.7	− 7.8 / + 5.8 %
JER	− 0.8 / + 0.3	− 1.0 / + 0.4 %
Unclustered $\not\!E_T$	− 0.8 / + 0.7	− 1.0 / + 0.9 %
Pileup	− 0.5 / + 0.3	− 0.6 / + 0.4 %
Muon trigger + reconstruction	− 4.1 / + 4.0	− 5.1 / + 5.1 %
Q^2	±2.5	±3.1 %
$t\bar{t}$, rate	− 1.5 / + 1.7	− 1.9 / + 2.1 %
QCD, rate	±0.7	±0.9 %
$t-$channel generator	±4.4	±5.5 %
Other backgrounds, rate	±0.5	±0.6 %
b-tagging	±3.7	±4.6 %
PDF	± 3.7	±4.6 %
Simulation statistics	±1.8	±2.2 %
Total systematics	±11.0	±13.7 %
Luminosity uncertainty	±4.0	±5.0 %
Total	±13.0	±16.3%

t-channel generator uncertainty among the most contributing systematic uncertainties.

t-channel single top quark production

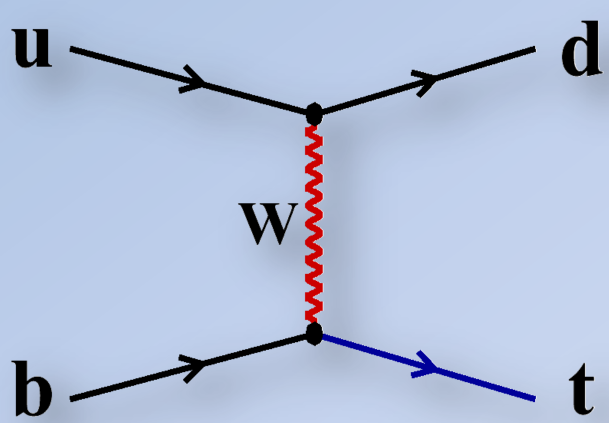
light quark jet



second b-quark / spectator b

$2 \rightarrow 3$:

- Production in the 4 flavour scheme
- Massive b quarks in the final state

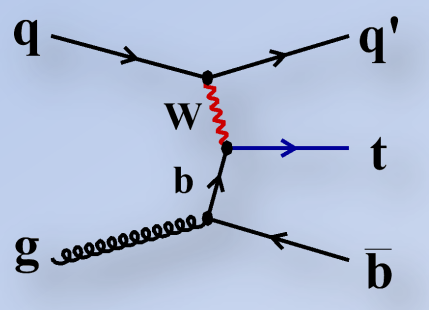


$2 \rightarrow 2$:

- Production in the 5 flavour scheme
- Second b produced through DGLAP backward evolution
  $\rightarrow$ second b quark massless

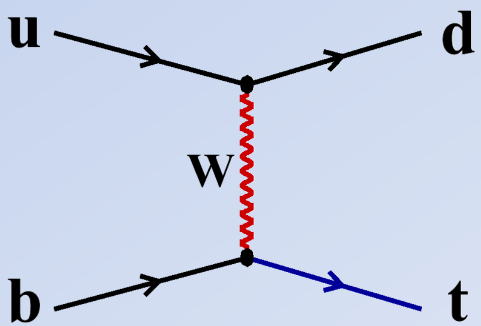
Overview / "Ranking"

1. 4 flavour (2 → 3) NLO
   - Not available with parton shower (Only without spin correlations in Powheg)



2. Matched samples for 2 → 2 and 2 → 3 process
   - Matching using p_T of second b (Comphep)
   - **ACOT method (AcerMC) → default in ATLAS**

3. 4 flavour (2 → 3) LO
   - Madgraph, Protos



4. 5 flavour (2 → 2) NLO
   - **Powheg → default in CMS**
   - MC@NLO (not usable due to bug in fHerwig)

5. 5 flavour (2 → 2) LO
   - Madgraph, Protos, Pythia (second b much too soft)

Calculation available for 2 →2 & 2 → 3 @ NLO with MCFM

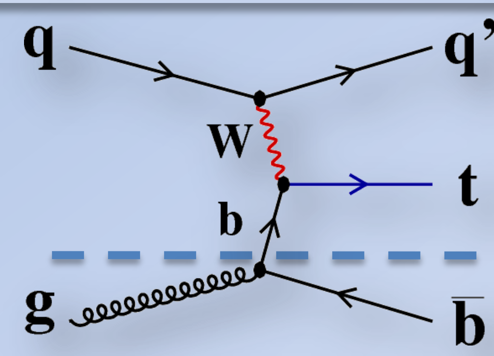
Matched generators

Idea:

- Use b-PDF , when second b is unimportant, otherwise keep b quark in the final state.

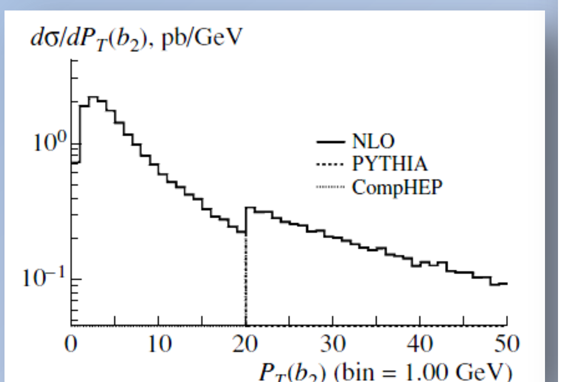
Two different approaches:

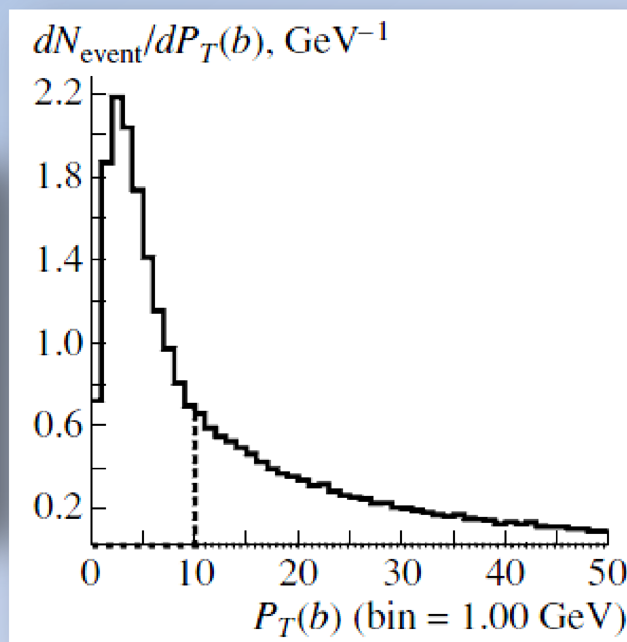
- Matching according to the second b p_T (CompHep)
- Subtraction of double counting ACOT (AcerMC)

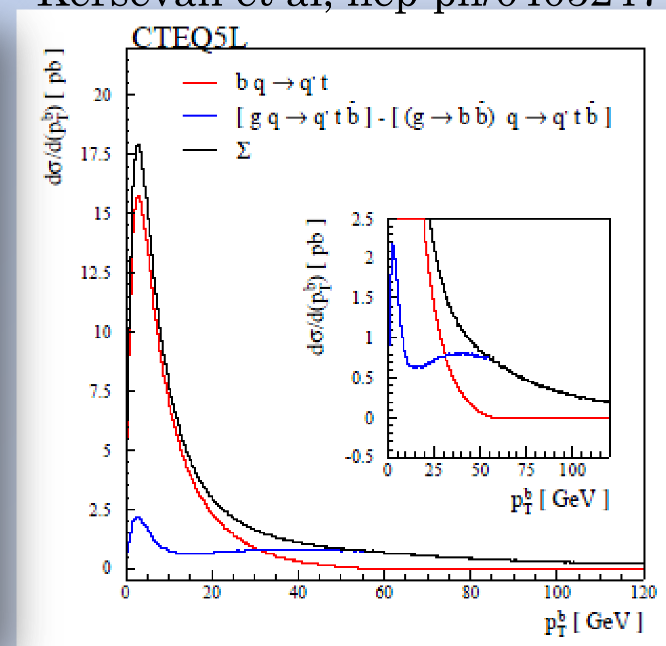


Boos et al.,Phys. At. Nucl.69, 1317 (2006)

Kersevan et al, hep-ph/0405247







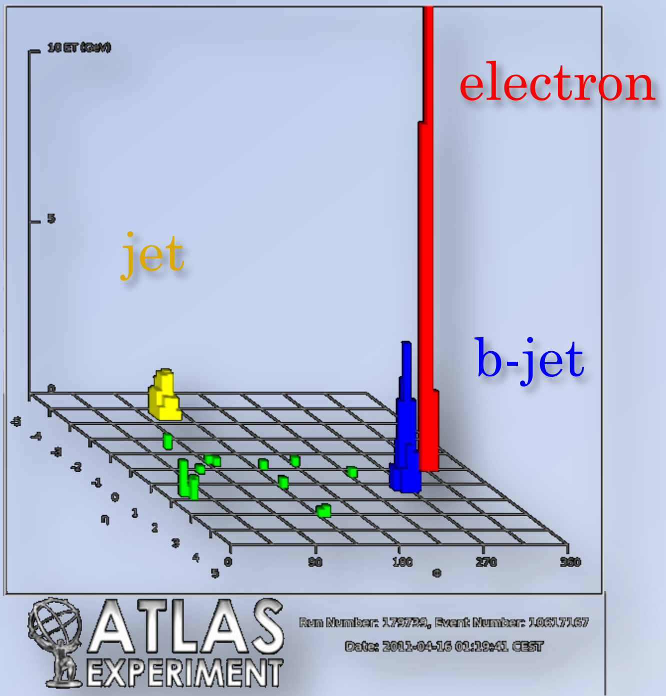
Comphep – Matching of second b pT
Matching parameter: find smooth distribution

AcerMC – ACOT method

Event selection for 8 TeV analyses

- Lepton selection (electron / muon):
  - p_T > 25 / 30 GeV, |η| < 2.5
  - Isolated
- Jets
  - Anti-k_T algorithm ΔR = 0.4 / 0.5
  - |η| < 4.5
  - Identification of b-quark jets using secondary vertex information
  - Number of jets: 2-4 for signal and control regions
- Missing transverse energy
  - E_T^{miss} > 50 GeV
- QCD multijet veto

t – channel event



Signal extraction:
CMS: exactly 2 jets and 1 tag
ATLAS: 2 or 3 jets and 1 tag
→ second b enters only in the acceptance

Systematic uncertainty

Method used in ATLAS

- Default generator:
  AcerMC + Pythia (matched 2 → 2 & 2 → 3 LO)
- Systematic:
  p_T of second b – AcerMC + Pythia vs. MCFM 2 → 3 NLO

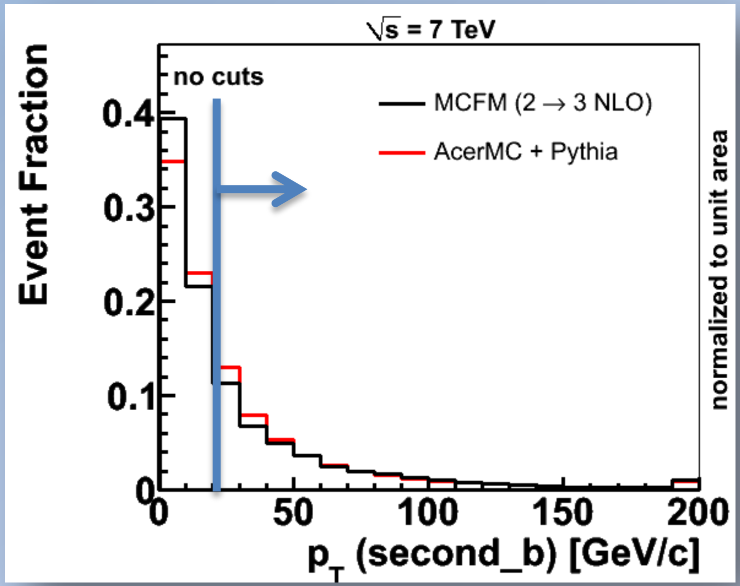
→ Use acceptance difference from truth distributions
More details next slide

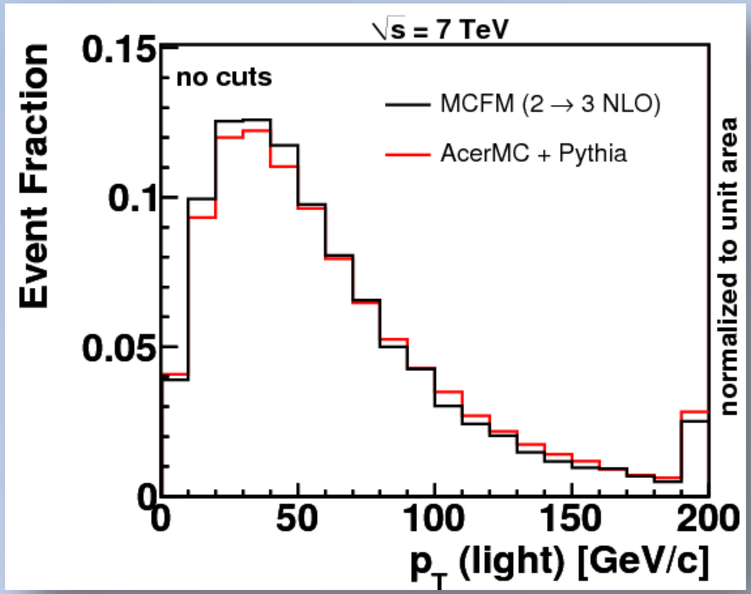
Method used in CMS

- Default generator:
  Powheg 2 → 2 NLO
- Alternative generator:
  Comphep (matched 2 → 2 & 2 → 3 LO)
  → Acceptance difference after complete event selection
  Using half of the difference as systematic variation
  (Since comparisons between 4-flavour and 5-flavour scheme are always smaller)

Method used in ATLAS

Comparison between AcerMC and MCMF 2 → 3 NLO:
→ compared distribution of quarks.





	10 GeV	20 GeV	30 GeV
AcerMC	65.1 %	42.1 %	29.1 %
MCFM	60.6 %	39.1 %	27.9 %
rel. diff.	-6.9 %	-7.1 %	-4.1%

	10 GeV	20 GeV	30 GeV
AcerMC	95.9 %	86.6 %	74.6 %
MCFM	96.1 %	86.2 %	73.6 %
rel. diff.	0.2 %	-0.5 %	-1.3 %

Cut on p_T of second b of 20 GeV gives acceptance difference of 7.1%

Input from theory

Frederix et al, arXiv:1207.5391

Comparison of NLO calculations using Powheg and aMC@NLO

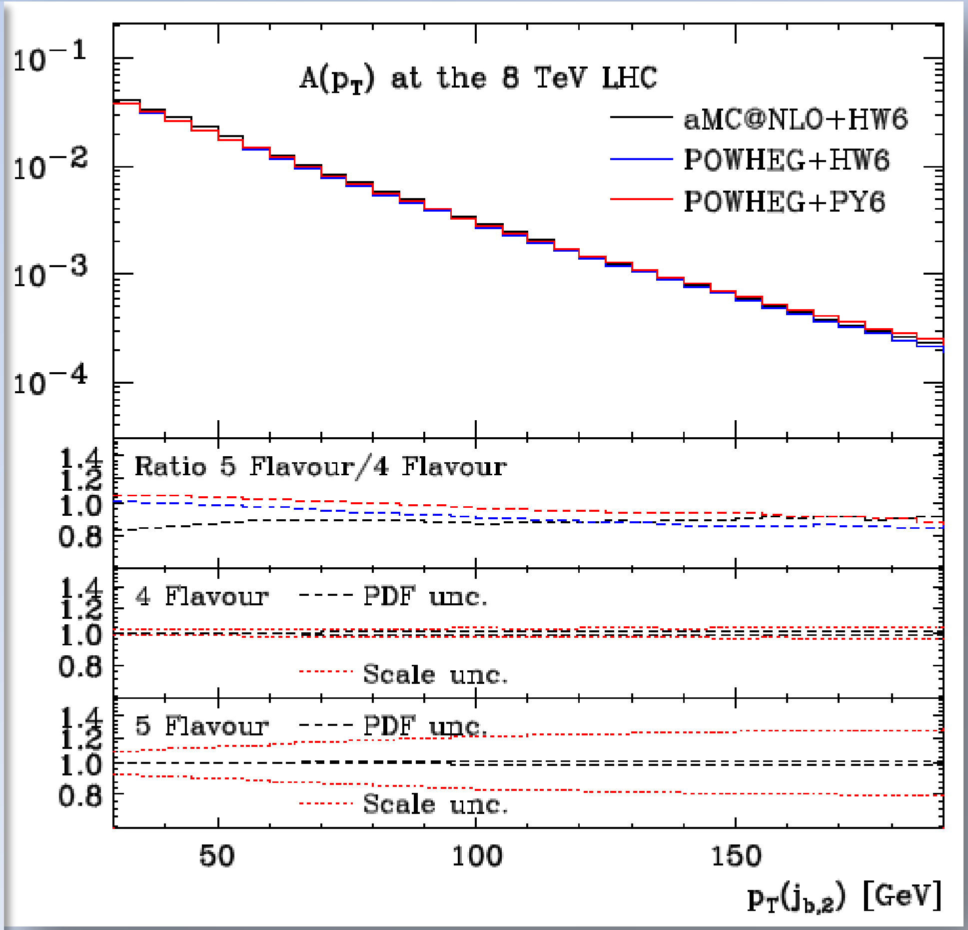
aMC@NLO and Powheg very similar for 2→ 3 NLO

Ratios given for

- 5-flavour / 4-flavour
  → uncertainty around 5% for lower p_T range

- PDF uncertainties
  → rather small for this observable

- Scale uncertainties
  2 →3 : very tiny
  2 →2 : > 10% over full p_T range!



Potential double counting

Generator related uncertainties in ATLAS

- ISR/FSR
  - Pythia parameter variation , based on $t\bar{t}$ jet gap fraction analysis
    → changes also distribution of second b-quark jet

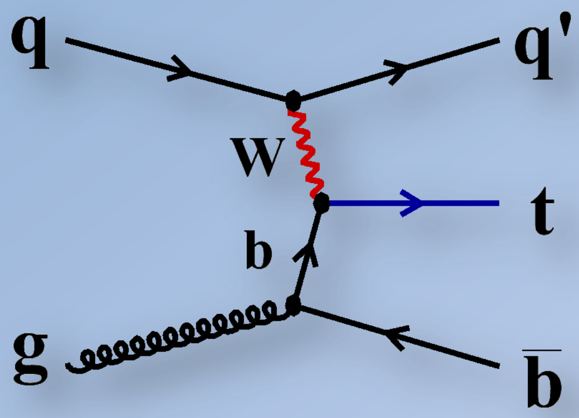
- PDF
  - AcerMC used MRSTLO**, MCFM used CTEQ6m

Generator related uncertainties in CMS

- Scale variation
  → scales varied by factor of ½ and 2

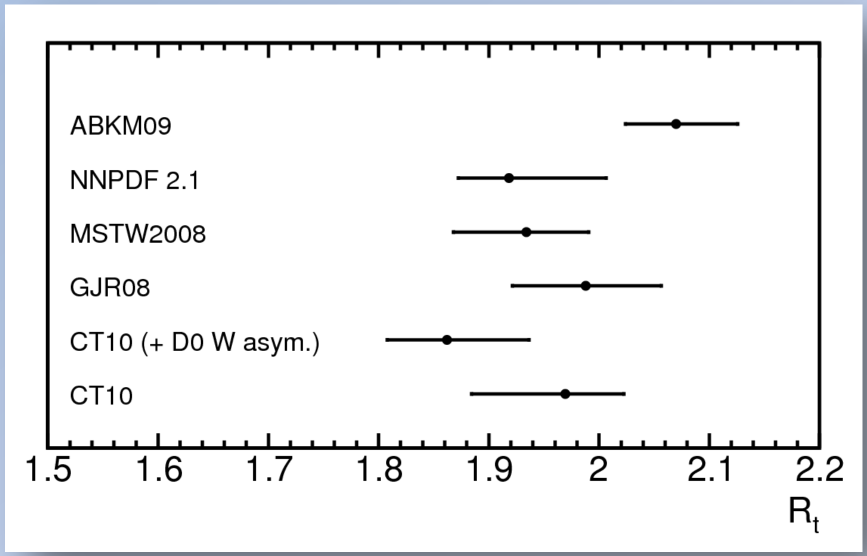
→ hard to determine overlap

t-channel cross section ratio

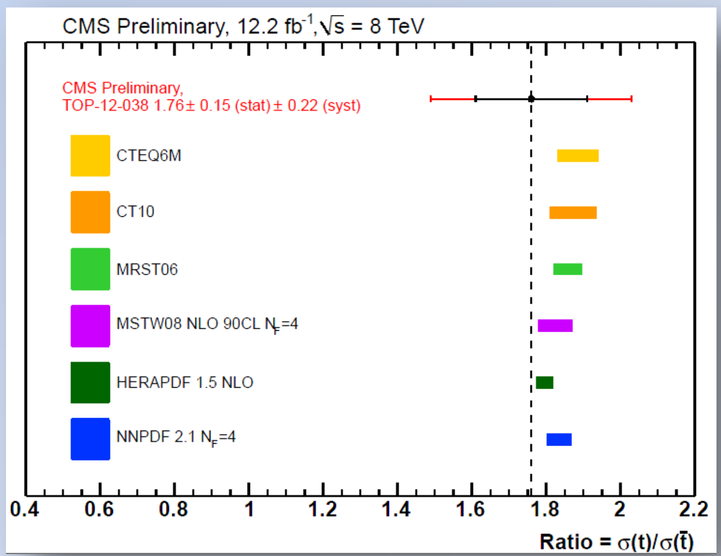


The charge of the top quark is connected to the type of the incoming light-flavour quark
→ Measure cross-section ratio top-quark/top-antiquark production is sensitive to d/u-quark ratio

Prediction for cross section ratio @ NLO for different PDF sets needed.



ATLAS-CONF-2012-056

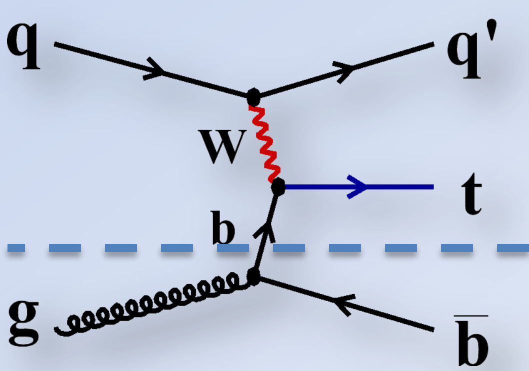


CMS PAS TOP-12-11

Available calculations

Author	Order	Scheme	PDF	Free parameters
Kidonakis (only values, no code)	NLO+NNLL	5-flavour	MSTW2008	m_{top}, $\sqrt{s}$
Hathor (private version)	NLO	5-flavour	LHAPDF	scales, $\sqrt{s}$
MCFM (publically available)	NLO	4- / 5- flavour	LHAPDF	All

Strategy:
- Sanity checks:
  - Compare MCFM with Hathor
  - Compare MCFM/Hathor with Kidonakis
- Produce all PDF variations with Hathor/MCFM
  - Calculate uncertainties using Hathor
  - Calculate dependencies on $\sqrt{s}$, α_s etc. using Hathor



Settings for MCFM

Used Version
- 6.5

Processes:
- $2 \rightarrow 2$: 161 / 166
- $2 \rightarrow 3$: 231 / 236

Used settings
- $\sqrt{s} = 7$ TeV
- Quark masses
  - $m_{top} = 172.5$ GeV,
  - $2 \rightarrow 2$: $m_b = 0$ GeV
  - $2 \rightarrow 3$: $m_b = 4.7$ GeV
- No cuts on jets
- All others: default settings

Fac. / Renorm scales
- $2 \rightarrow 2$: m_{top}
- $2 \rightarrow 3$: Light quark line: $m_{top}/2$
  Heavy quark line: $m_{top}/4$

Choice from:
J. M. Campbell et. al Phys. Rev. Lett. 102 (2009) 182003

Stat. Uncertainty:
- $2 \rightarrow 2$: 0.1%
- $2 \rightarrow 3$: 0.3%

Better precision would just mean more CPU …

Values from MCFM

PDF	$\sigma(t)$ [pb]	$\sigma(\bar{t})$ [pb]	R_t	$\sigma(t)$ [pb]	$\sigma(\bar{t})$ [pb]	R_t
	$2 \rightarrow 2$			$2 \rightarrow 3$		
CT10	41.0	21.3	1.93	39.3	20.4	1.93
CT10f4				41.2	21.6	1.91
CT10nlo	41.0	21.3	1.92	39.2	20.4	1.92
CT10w	40.4	21.8	1.86	38.8	20.9	1.86
CT10wf4				40.7	22.0	1.85
MSTW2008nlo68cl	42.3	22.4	1.89	40.1	21.2	1.89
MSTW2008nlo68cl_nf4				40.1	21.3	1.88
abm11_5n_nlo	45.2	22.0	2.06	39.6	19.1	2.07
abm11_4n_nlo				39.6	19.2	2.07
GJR08VFnloE	42.2	22.5	1.87	38.3	20.4	1.88
GJR08FFnloE				40.5	20.6	1.96
HERAPDF15NLO	42.0	21.2	1.98	40.3	20.4	1.98
NNPDF23_nlo_as_0119	42.4	22.7	1.87	40.2	21.6	1.86

Comparison between MCFM & Hathor ($2 \rightarrow 2$)

PDF	$\sigma(t)$ [pb]	$\sigma(\bar{t})$ [pb]	R_t	$\sigma(t)$ [pb]	$\sigma(\bar{t})$ [pb]	R_t
	MCFM			Hathor		
CT10	41.0	21.3	1.93	41.0	21.3	1.93
CT10nlo	41.0	21.3	1.92	41.0	21.4	1.92
CT10w	40.4	21.8	1.86	40.4	21.9	1.85
MSTW2008nlo68cl	**42.3**	**22.4**	**1.89**	**42.3**	**22.4**	**1.89**
NNPDF22_nlo_100	42.6	22.6	1.89	42.6	22.7	1.88
abm11_5n_nlo	45.2	22.0	2.06	45.3	22.0	2.06
GJR08VFnloE	42.2	22.5	1.87	42.2	22.5	1.87
HERAPDF15NLO	42.0	21.2	1.98	41.8	21.1	1.98

Kidonakis (MSTW2008nnlo):

$\boldsymbol{\sigma(t)}$ = 42.1 pb

$\boldsymbol{\sigma(\bar{t})}$ = 22.4 pb

$\boldsymbol{R_t}$ = 1.88

Calculation of uncertainties

Statistical uncertainty
- from integration → 0.2% for R_t

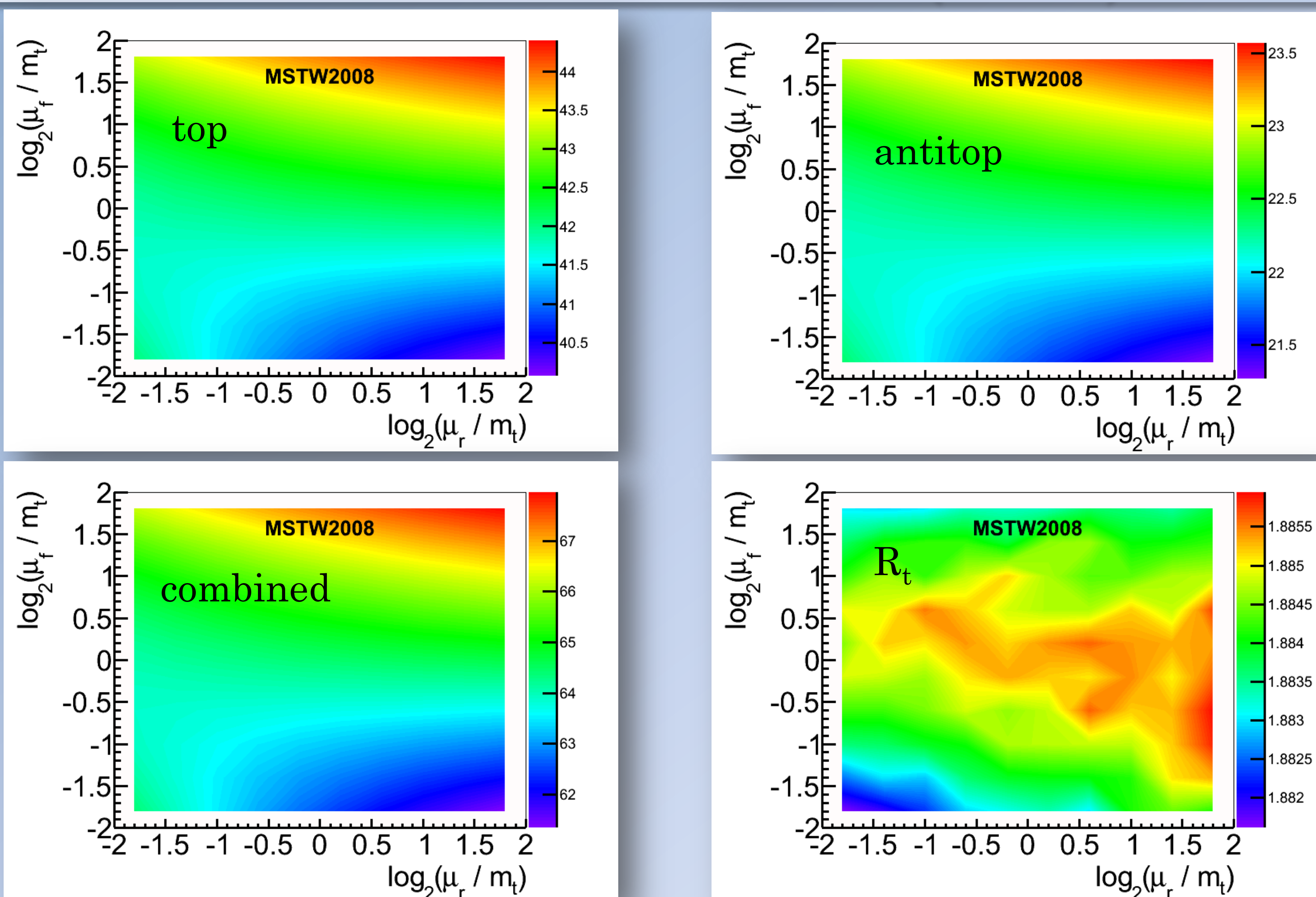
Scale uncertainty
- Following Olness et el. arXiv:0907.5052
- Scan μ_r,μ_f plane between ¼ and 4 x nominal
- Use difference between min and max to nominal, respectively.

$2 \rightarrow 2$ vs. $2 \rightarrow 3$
- Use difference between the two calculations

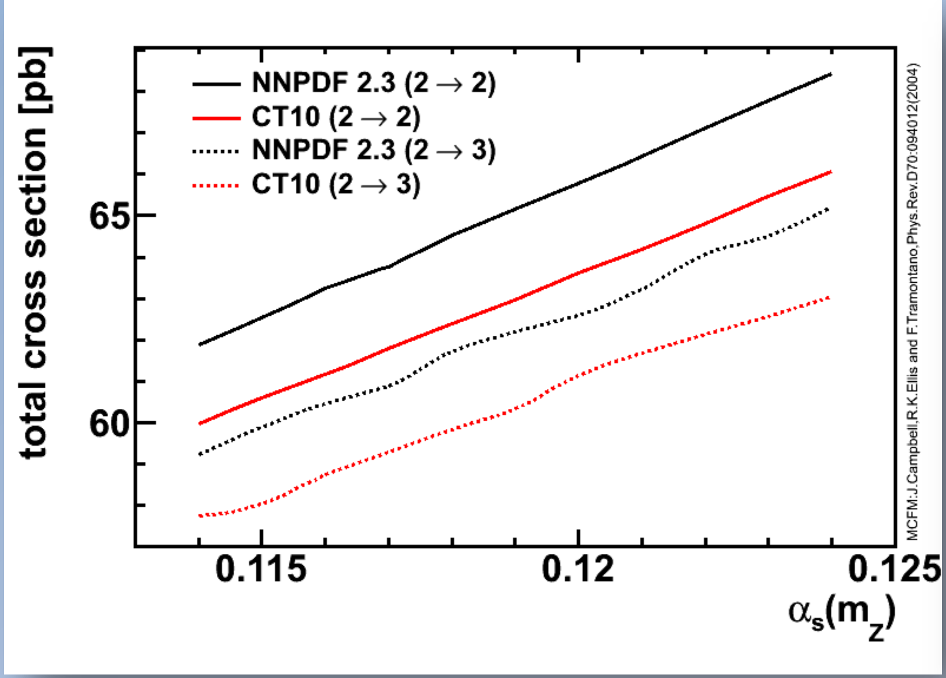
PDF internal uncertainties
- Calculations are done according to respective recommendations
  - NNPDFs: Use RMS of replicas
  - All others use symmetric or asymmetric Hessian approach

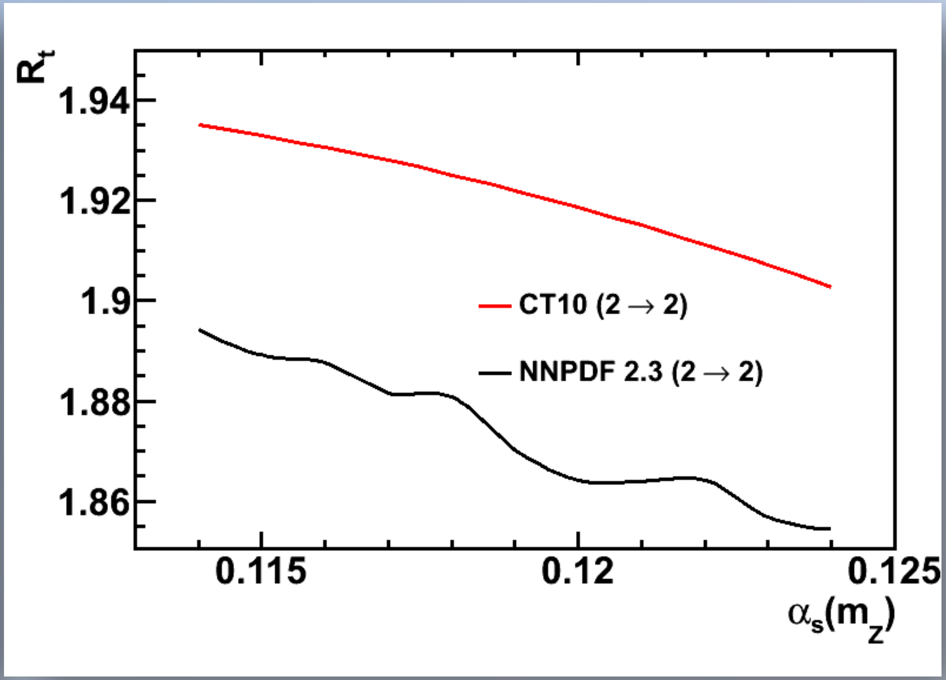
Not yet included - to be discussed:
- Uncertainty on α_s
- Uncertainty due to top quark mass

Scan of ren. / fac. Scales ($2 \rightarrow 2$)



α_s dependence

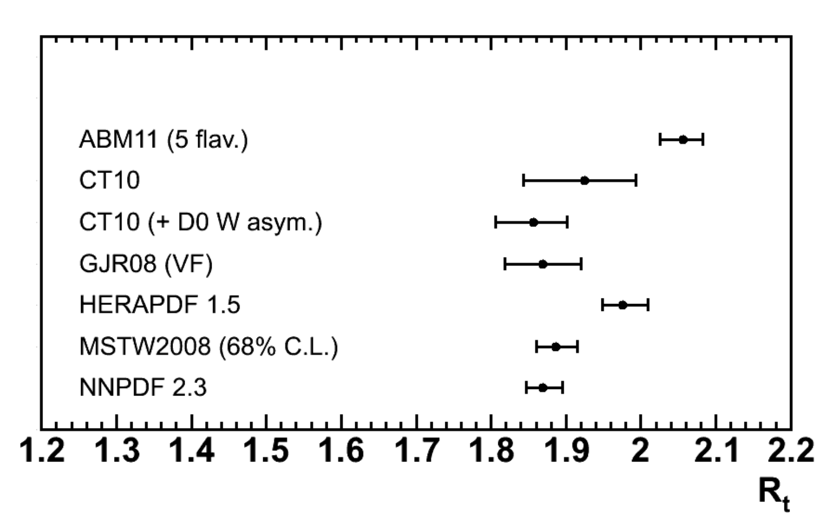




- Nice dependence on α_s
  - Total cross section has a stronger dependence then R_t
- Could quote also uncertainty on α_s

Summary of uncertainties for R_t

PDF	$\sigma(t)$ [pb]	$\sigma(\bar{t})$ [pb]	R_t	Scale		PDF		2→2 2→3
CT10	41.0	21.3	**1.93**	-1.1%	0.4%	-4.1%	3.5%	0.3%
CT10w	40.4	21.8	**1.86**	-0.7%	0.5%	-2.7%	2.3%	0.0%
MSTW2008nlo68cl	42.3	22.4	**1.89**	-0.8%	0.5%	-1.1%	1.4%	0.2%
NNPDF23_nlo	42.6	22.6	**1.89**	-0.4%	0.9%	-1.3%	1.3%	0.3%
HERAPDF15	42.0	21.2	**1.98**	-0.2%	0.9%	-1.3%	1.4%	0.2%
abm11_5n_nlo	45.2	22.0	**2.06**	-0.5%	0.7%	-1.2%	0.9%	0.7%
GJR08VFnloE	42.2	22.5	**1.87**	-1.0%	0.0%	-2.5%	2.7%	0.2%

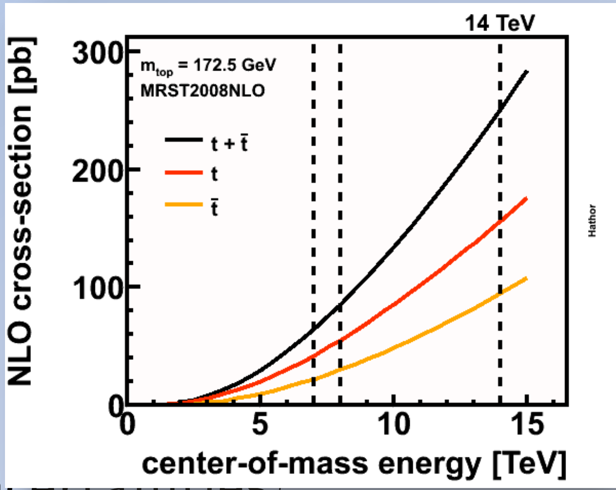


Calculations are for **7 TeV**!
Statistical uncertainty on R_t ±0.2%

Conclusion

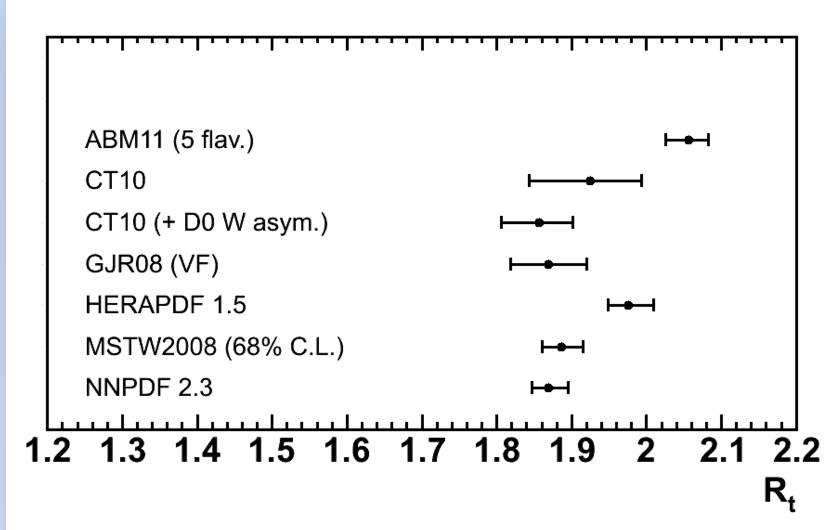
Extrapolation uncertainty for t-channel cross section measurement

- Getting one of the dominant uncertainties
- ATLAS and CMS uses quite different approach
- What should we quote as generator uncertainty
  - 4-flavour vs. 5-flavour?
  - scale uncertainty?
  - How to avoid overlap with other generator uncertainties?



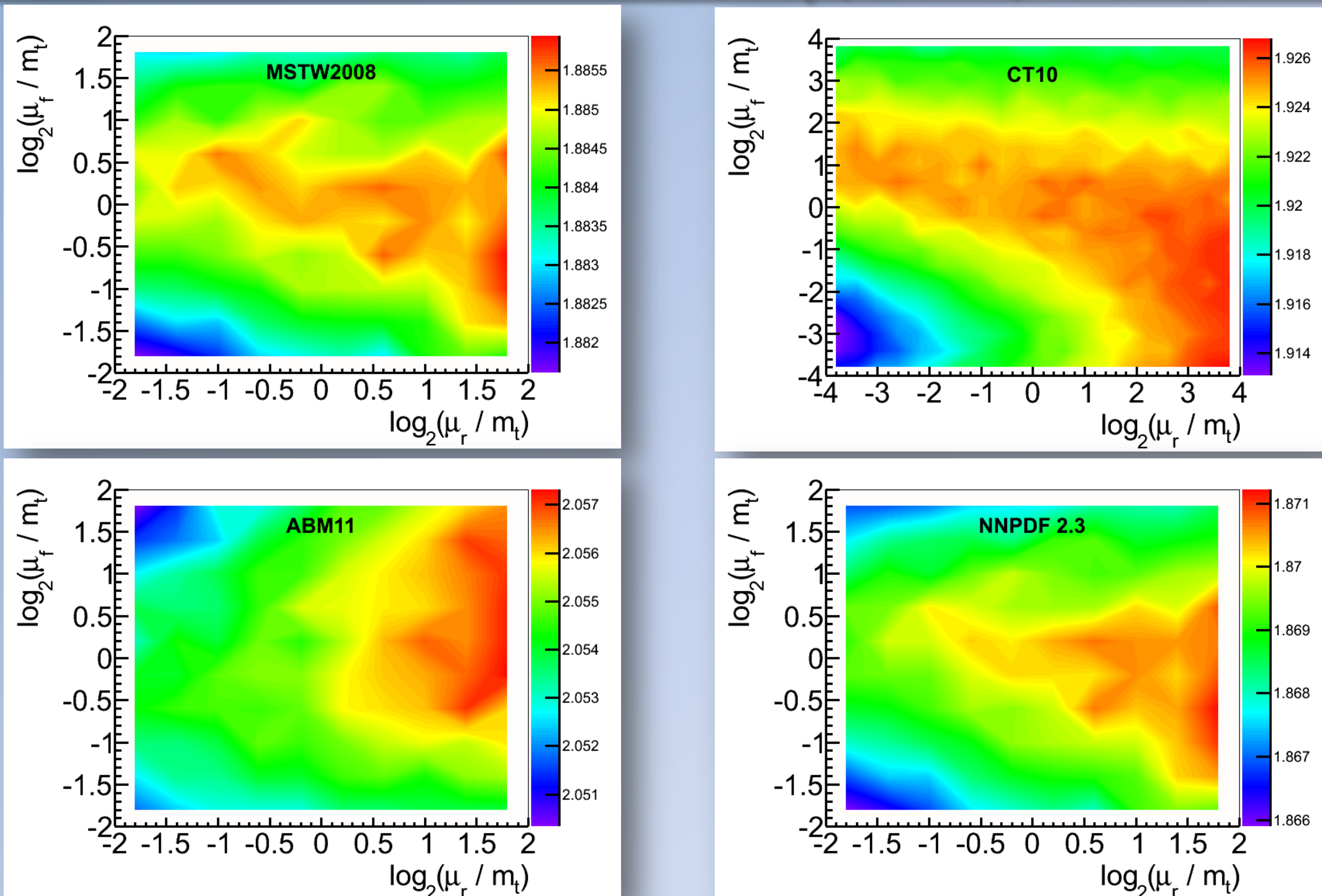
Cross section predictions for R_t

- Quite different choice how to compare with predictions for different PDF sets
- Harmonize presentation ?
  - Choice of PDF sets
  - Choice of parameters (m_t, …)
  - Choice of quoted uncertainties
  - Estimation of uncertainties



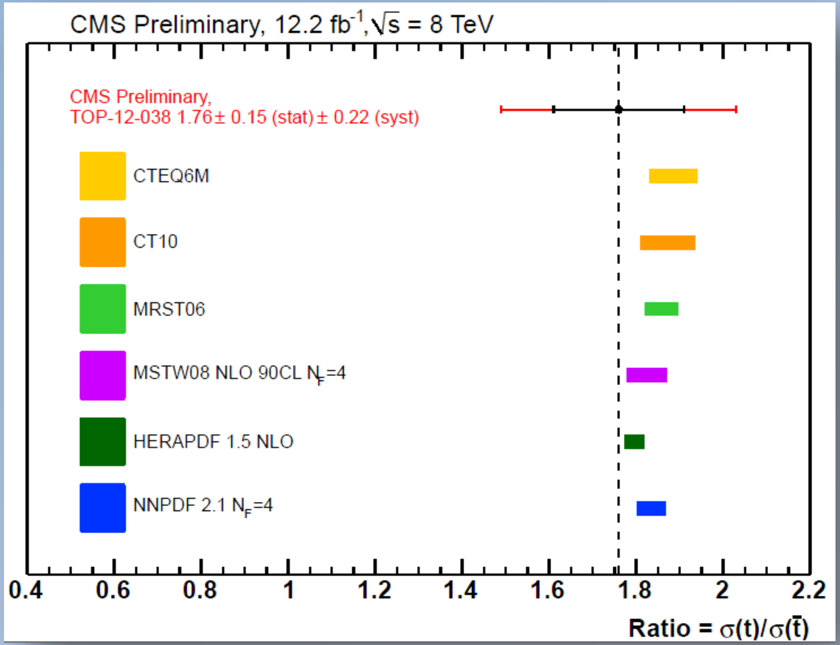
Backup

Scale scans for R_t ($2 \rightarrow 2$)



Rt calcualtions from CMS

CMS PAS TOP-12-38



Calculation done with Powheg using reweighting @ 8 TeV

For fixed four-flavour PDFs : 2 → 3 NLO

Variable flavour PDFs : 2 → 2 NLO

Parameters:

- m_t = 173 GeV

Uncertainties

- Scale uncertainty: factor of 2 and ½ simultaneously varied
- Statistical uncertainty
- Top mass: 172 GeV and 174 GeV