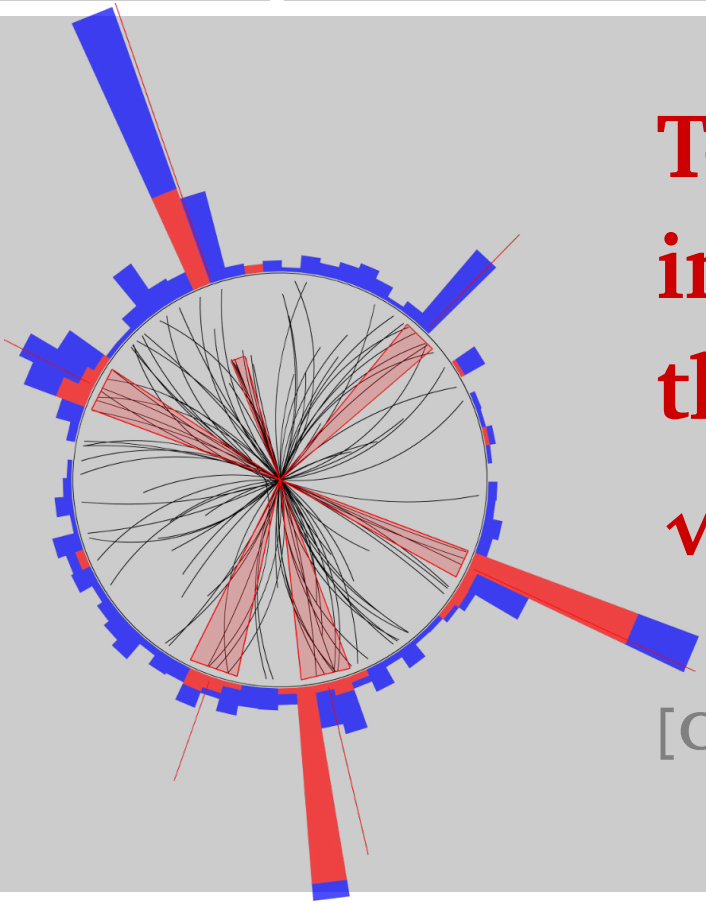
11th International Workshop on Top Quark Physics
Bad Neuenahr, Germany

Tuesday 18th September, 2018



Top quark mass measurement in the $t\bar{t}$ all-jets final state with the CMS experiment at $\sqrt{s} = 13\,\text{TeV}$

[CMS-PAS-TOP-17-008]

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on behalf of the CMS Collaboration

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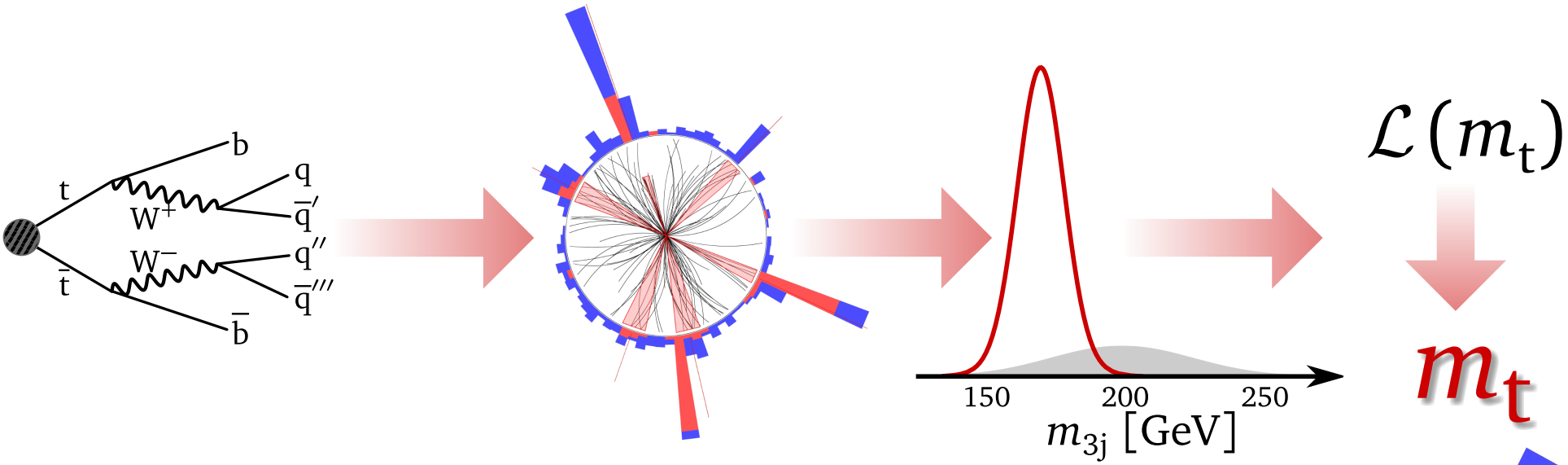
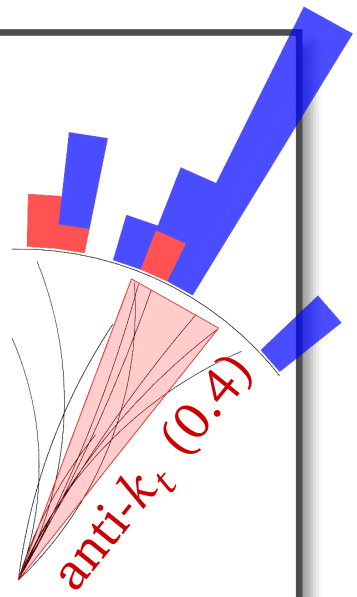
Overview, event selection

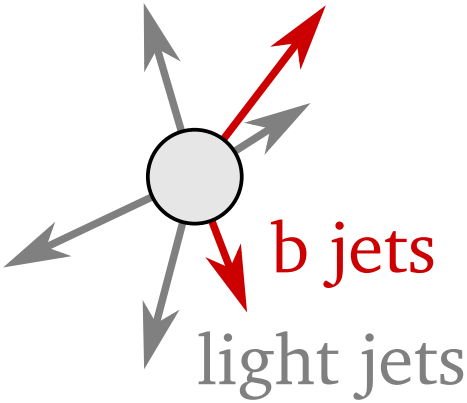


Event selection

- 2016 dataset:
  $\sqrt{s} = 13\,\text{TeV}$, $\mathcal{L} \approx 35.9\,\text{fb}^{-1}$
- trigger: six jets, one b tag
- $H_T = \sum_{\text{jets}} p_T > 450\,\text{GeV}$
- six jets, $p_T > 40\,\text{GeV}$
- two b tags
- $\Delta R(b\bar{b}) > 2.0$
- MC: POWHEG v2 + PYTHIA8, CUETP8M2T4



Kinematic fit



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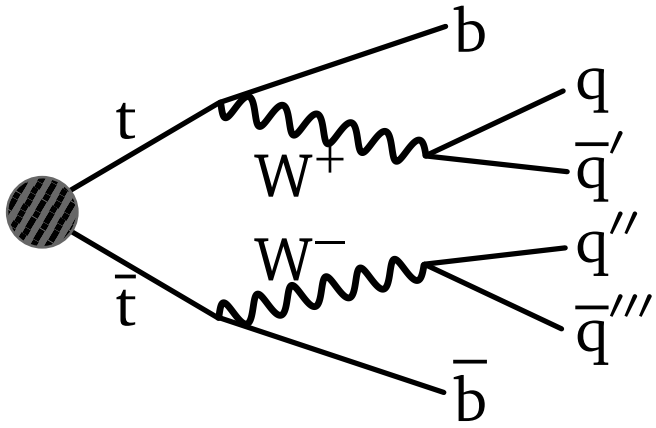
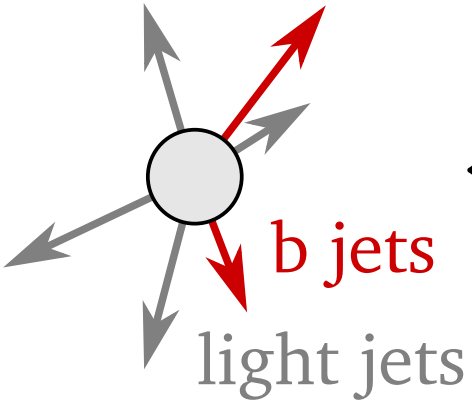


Kinematic fit



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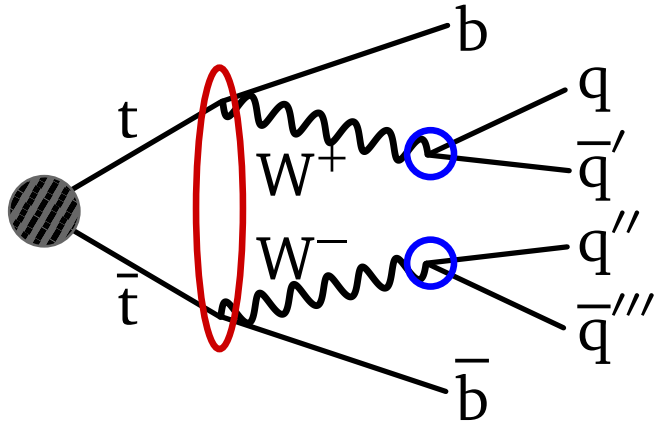
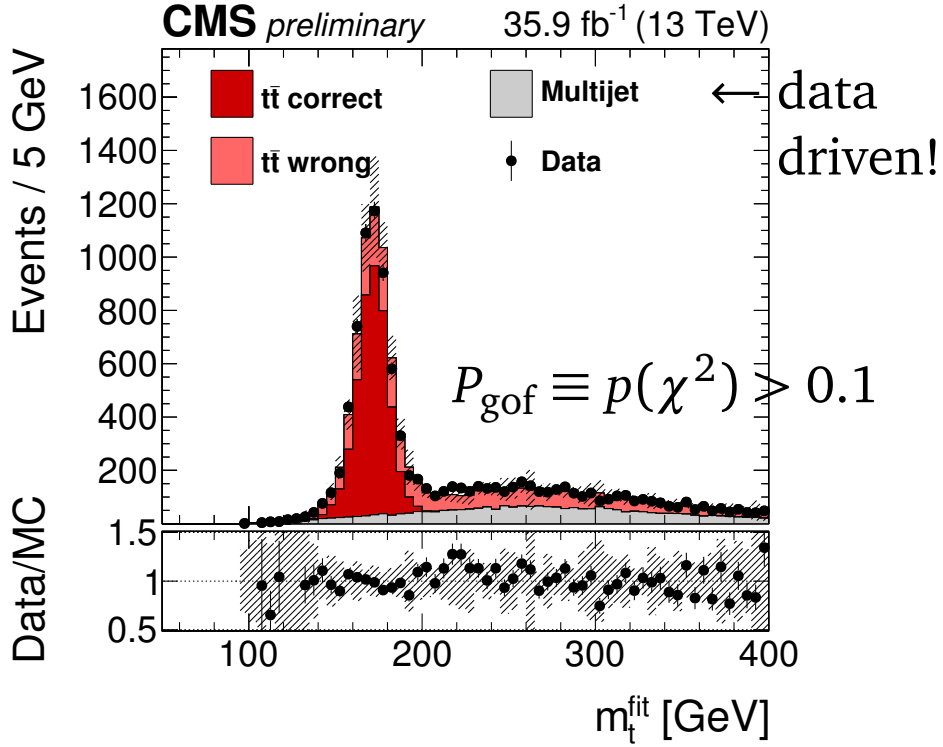


Minimize

$$\chi^2 = \sum_{j \in \text{jets}} \left[\frac{\left(p_{\mathrm{T}\,j}^{\text{reco}} - p_{\mathrm{T}\,j}^{\text{fit}}\right)^2}{\sigma^2_{p_{\mathrm{T}\,j}}} + \frac{\left(\eta_j^{\text{reco}} - \eta_j^{\text{fit}}\right)^2}{\sigma^2_{\eta_j}} + \frac{\left(\phi_j^{\text{reco}} - \phi_j^{\text{fit}}\right)^2}{\sigma^2_{\phi_j}} \right]$$

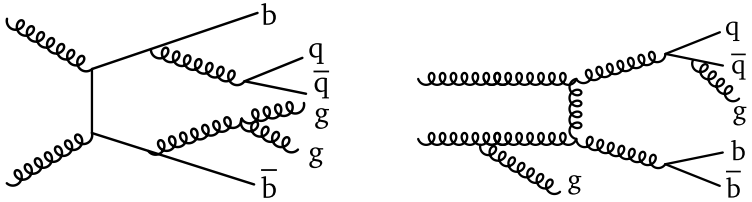
with constraints:

$m_{\mathrm{W}^+} = m_{\mathrm{W}^-} = 80.4\,\mathrm{GeV}, m_{\mathrm{t}} = m_{\bar{\mathrm{t}}}$



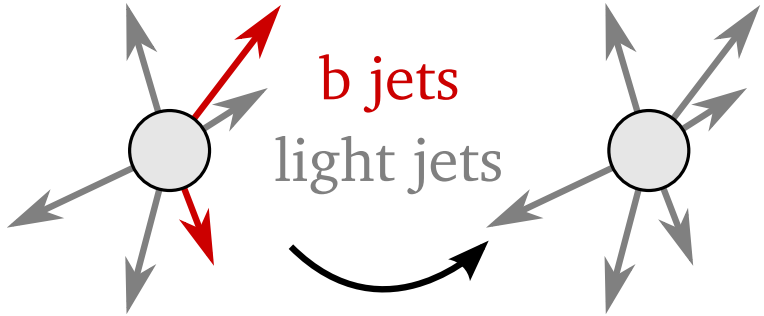
Background estimation

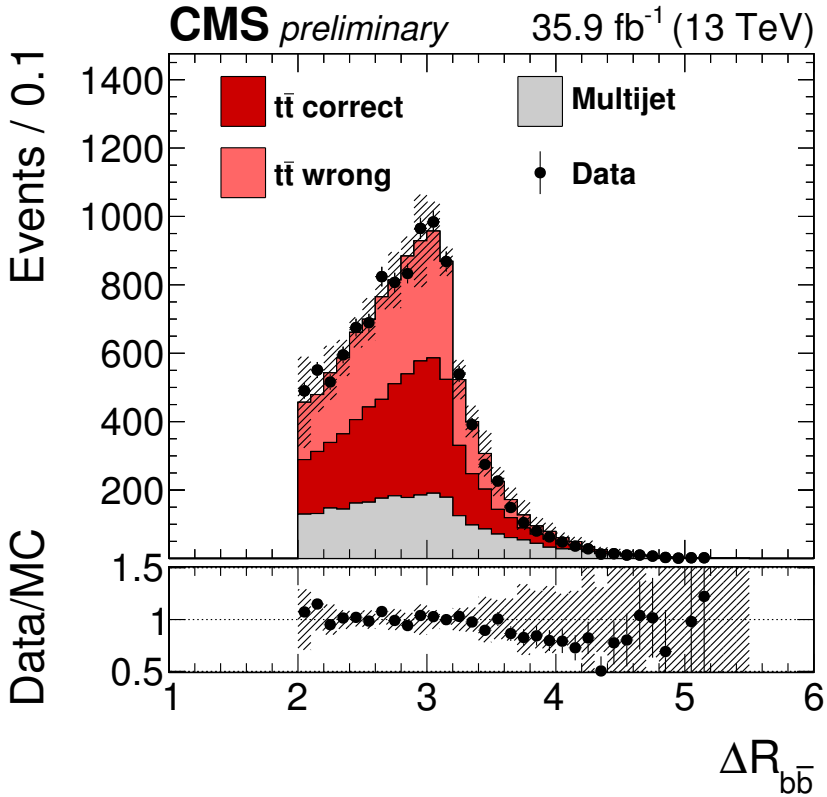
QCD multijet production

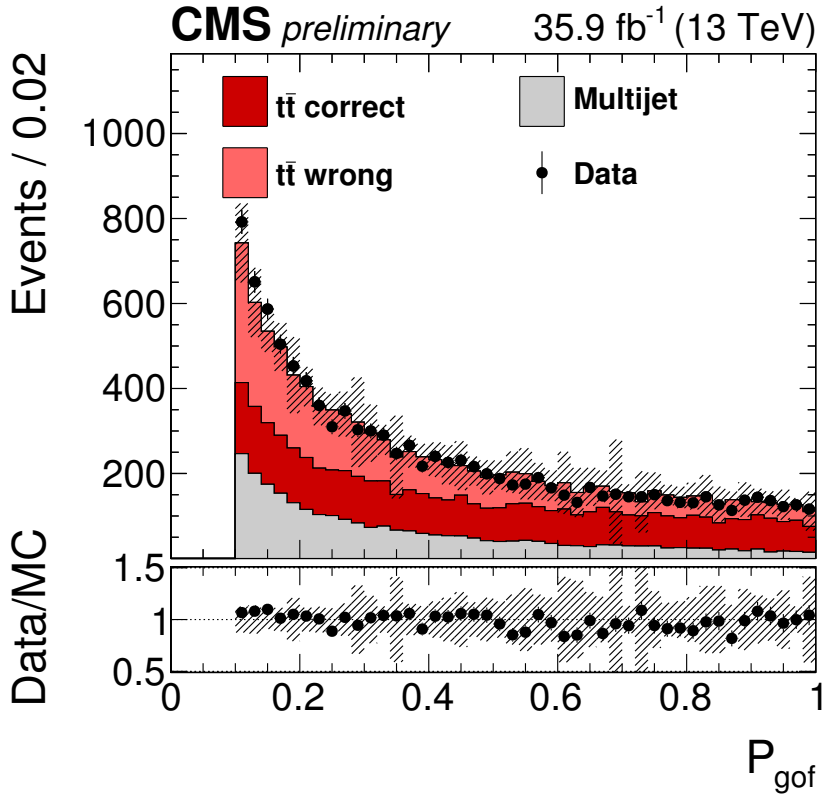


purely combinatorial

estimate from data in **0-b-tag region**





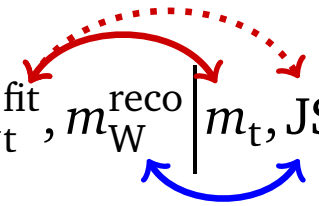


Mass extraction: ideogram method

Estimate m_t and additional jet scale factor (JSF)

$$P\left(m_t, \mathrm{JSF} | \mathrm{sample}\right) \propto P(\mathrm{JSF}) \cdot \mathcal{L}\left(\mathrm{sample} | m_t, \mathrm{JSF}\right)$$

$$\mathcal{L}\left(\mathrm{sample} | m_t, \mathrm{JSF}\right) = \prod_{\mathrm{events}} P\left(\mathrm{event} | m_t, \mathrm{JSF}\right) = \prod_{\mathrm{events}} P\left(m_t^{\mathrm{fit}}, m_W^{\mathrm{reco}} \middle| m_t, \mathrm{JSF}\right)$$



Mass extraction: ideogram method

Estimate m_t and additional jet scale factor (JSF)

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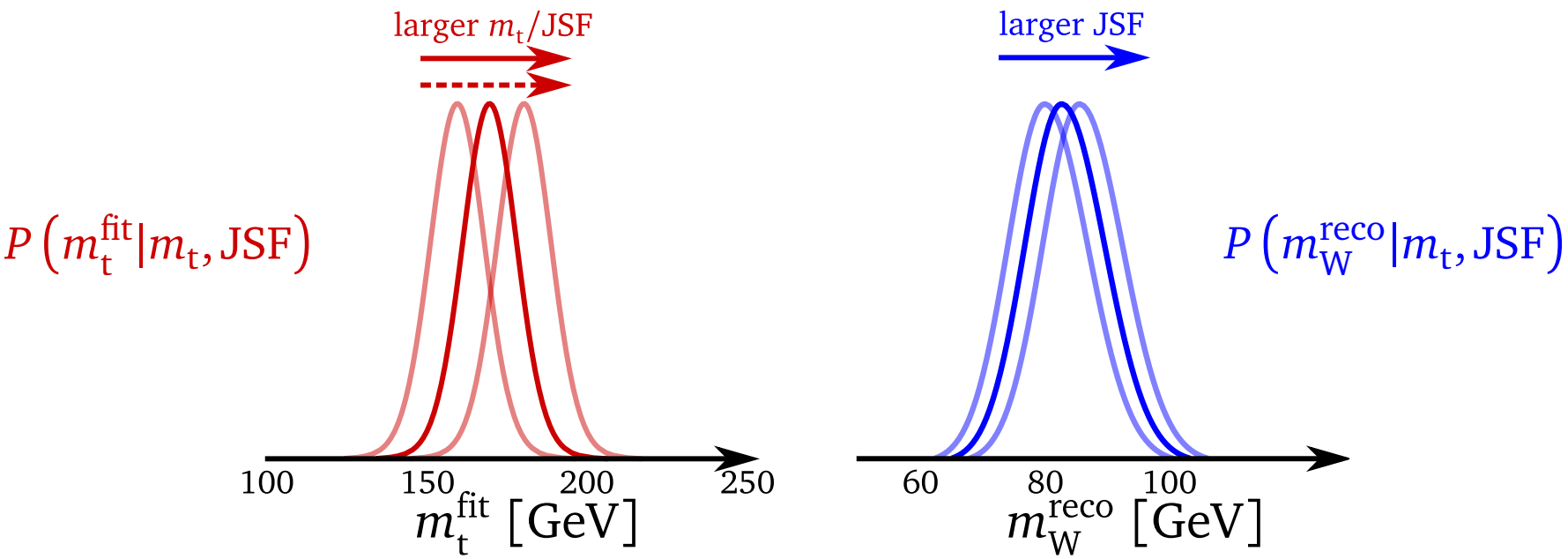

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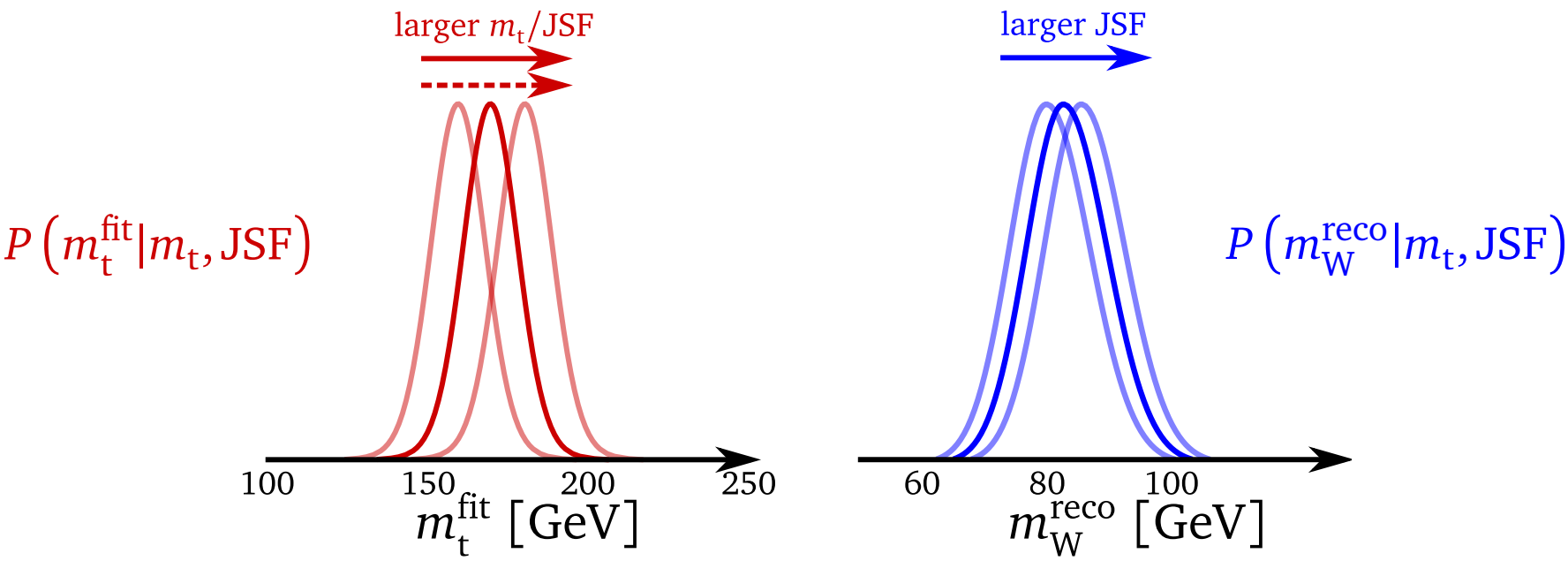


Three versions of ideogram fit:

- only m_t free (1D)
- m_t and JSF free (2D)
- Gaussian JSF constraint (hybrid)

Results

	δm_t^{hyb} [GeV]	δJSF^{hyb} [%]
Experimental uncertainties		
Method calibration	0.06	0.2
JEC (quad. sum)	0.15	0.2
- Intercalibration	−0.04	−0.1
- MPFInSitu	+0.08	+0.1
- Uncorrelated	+0.12	+0.2
Jet energy resolution	−0.03	+0.3
b tagging	0.02	0.0
Pileup	−0.04	+0.1
Background	0.07	0.1
Trigger	+0.02	−0.1
Modeling uncertainties		
JEC Flavor (linear sum)	−0.34	+0.0
- light quarks (uds)	+0.07	−0.1
- charm	+0.02	−0.0
- bottom	−0.29	−0.0
- gluon	−0.13	+0.2
b jet modeling (quad. sum)	0.09	0.0
- b frag. Bowler-Lund	−0.07	+0.0
- b frag. Peterson	−0.05	+0.0
- semi-leptonic B decays	−0.03	−0.0
PDF	0.01	0.0
Ren. and fact. scale	0.04	0.0
ME/PS matching	+0.24±0.18	−0.2
ME generator	+0.31±0.30	+0.1
ISR PS scale	+0.12±0.14	−0.1
FSR PS scale	+0.18±0.11	−0.1
Top quark p_T	+0.03	−0.0
Underlying event	+0.10±0.17	−0.2
Early resonance decays	+0.13±0.24	+0.3
CR modeling (max. shift)	−0.36±0.25	−0.3
- "gluon move" (ERD on)	+0.32±0.25	−0.3
- "QCD inspired" (ERD on)	−0.36±0.25	−0.1
Total systematic	**0.76**	**0.7**
Statistical (expected)	0.20	0.1
Total (expected)	**0.79**	**0.7**

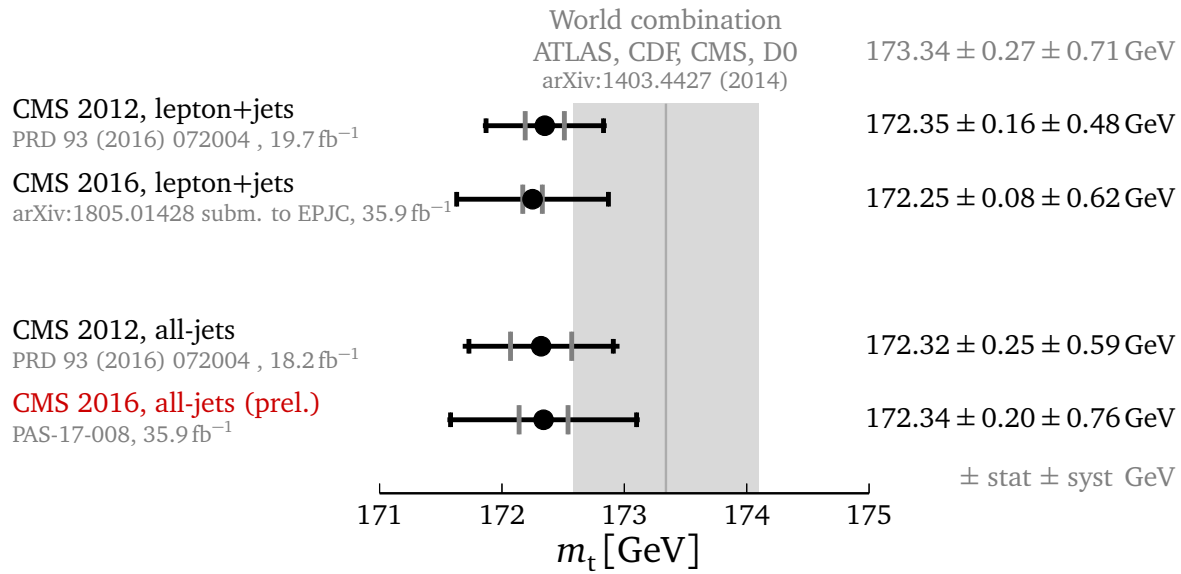
Result

$m_t = 172.34 \pm 0.20\,(\text{stat+JSF}) \pm 0.76\,(\text{syst})\ \text{GeV}$

Main uncertainties:

color reconnection modeling

flavor-dependent JEC



Summary

This talk.

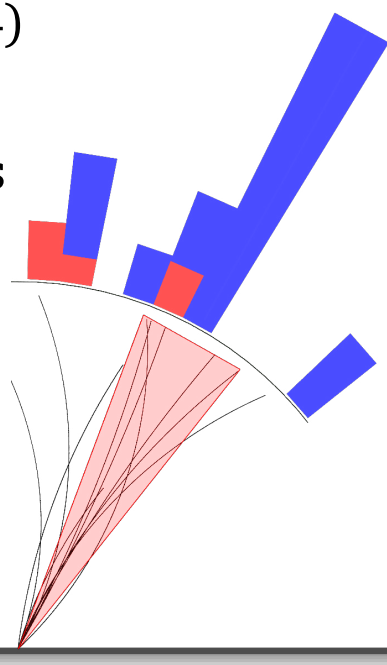
[For more details, see my poster]

BACKUP

Object definitions

Jets

- clustered with anti-k_t algorithm ($D = 0.4$) from particle flow objects
- pileup subtraction using charged hadrons
- $p_{\mathrm{T}} > 30\,\mathrm{GeV}$
- $|\eta| < 2.4$
- CSVv2 b tagger: tight WP
  - efficiency $\approx 49\,\%$
  - mistag rate $\approx 0.1\,\%$



Systematic uncertainties

	2D		1D	hybrid	
	δm_t^{2D} [GeV]	δJSF^{2D} [%]	δm_t^{1D} [GeV]	δm_t^{hyb} [GeV]	δJSF^{hyb} [%]
Experimental uncertainties					
Method calibration	0.06	0.2	0.06	0.06	0.2
JEC (quad. sum)	0.18	0.3	0.73	0.15	0.2
- Intercalibration	−0.04	−0.1	+0.12	−0.04	−0.1
- MPFInSitu	−0.03	−0.0	+0.22	+0.08	+0.1
- Uncorrelated	−0.17	−0.3	+0.69	+0.12	+0.2
Jet energy resolution	−0.12	+0.4	+0.18	−0.03	+0.3
b tagging	0.02	0.0	0.01	0.02	0.0
Pileup	−0.06	+0.1	+0.00	−0.04	+0.1
Background	0.10	0.1	0.03	0.07	0.1
Trigger	+0.04	−0.1	−0.04	+0.02	−0.1
Modeling of hadronization					
JEC Flavor (linear sum)	−0.35	+0.1	−0.31	−0.34	+0.0
- light quarks (uds)	+0.10	−0.1	−0.01	+0.07	−0.1
- charm	+0.03	−0.0	−0.01	+0.02	−0.0
- bottom	−0.29	−0.0	−0.29	−0.29	−0.0
- gluon	−0.19	+0.2	+0.03	−0.13	+0.2
b jet modeling (quad. sum)	0.09	0.0	0.09	0.09	0.0
- b frag. Bowler-Lund	−0.07	+0.0	−0.07	−0.07	+0.0
- b frag. Peterson	−0.05	+0.0	−0.04	−0.05	+0.0
- semi-leptonic B decays	−0.03	−0.0	−0.03	−0.03	−0.0
Modeling of perturbative QCD					
PDF	0.01	0.0	0.01	0.01	0.0
Ren. and fact. scale	0.05	0.0	0.04	0.04	0.0
ME/PS matching	+0.32±0.20	−0.3	−0.05±0.14	+0.24±0.18	−0.2
ME generator	+0.29±0.34	+0.1	+0.36±0.24	+0.31±0.30	+0.1
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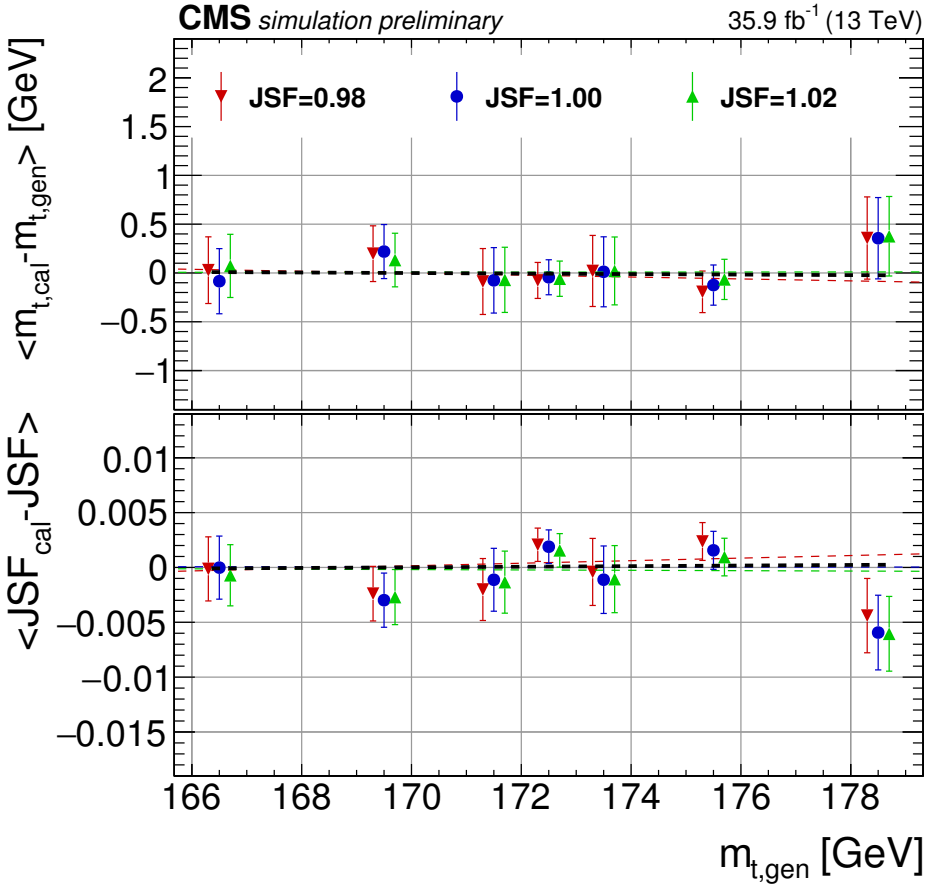
FSR PS scale	+0.22±0.12	−0.2	+0.11±0.08	+0.18±0.11	−0.1
Top quark p_T	+0.03	−0.0	+0.02	+0.03	−0.0
Modeling of soft QCD					
Underlying event	+0.16±0.19	−0.3	−0.07±0.14	+0.10±0.17	−0.2
Early resonance decays	+0.02±0.28	+0.4	+0.38±0.19	+0.13±0.24	+0.3
CR modeling (max. shift)	+0.41±0.29	−0.4	−0.43±0.20	−0.36±0.25	−0.3
- “gluon move” (ERD on)	+0.41±0.29	−0.4	+0.10±0.20	+0.32±0.25	−0.3
- “QCD inspired” (ERD on)	−0.32±0.29	−0.1	−0.43±0.20	−0.36±0.25	−0.1
Total systematic	**0.88**	**1.0**	**1.10**	**0.76**	**0.7**
Statistical (expected)	0.21	0.2	0.16	0.20	0.1
Total (expected)	**0.91**	**1.0**	**1.11**	**0.79**	**0.7**

Calibration



Color reconnection modeling

Color reconnection models with “early resonance decays” in PYTHIA8

- default setup
- string formation beyond leading color (“QCD inspired”) [JHEP **1508** (2015) 003]
- gluons can be moved to another string (“gluon move”) [JHEP **1411** (2014) 043]