Recent $t\bar{t}$ (inclusive and differential) cross sections results in CMS

ICHEP 2018

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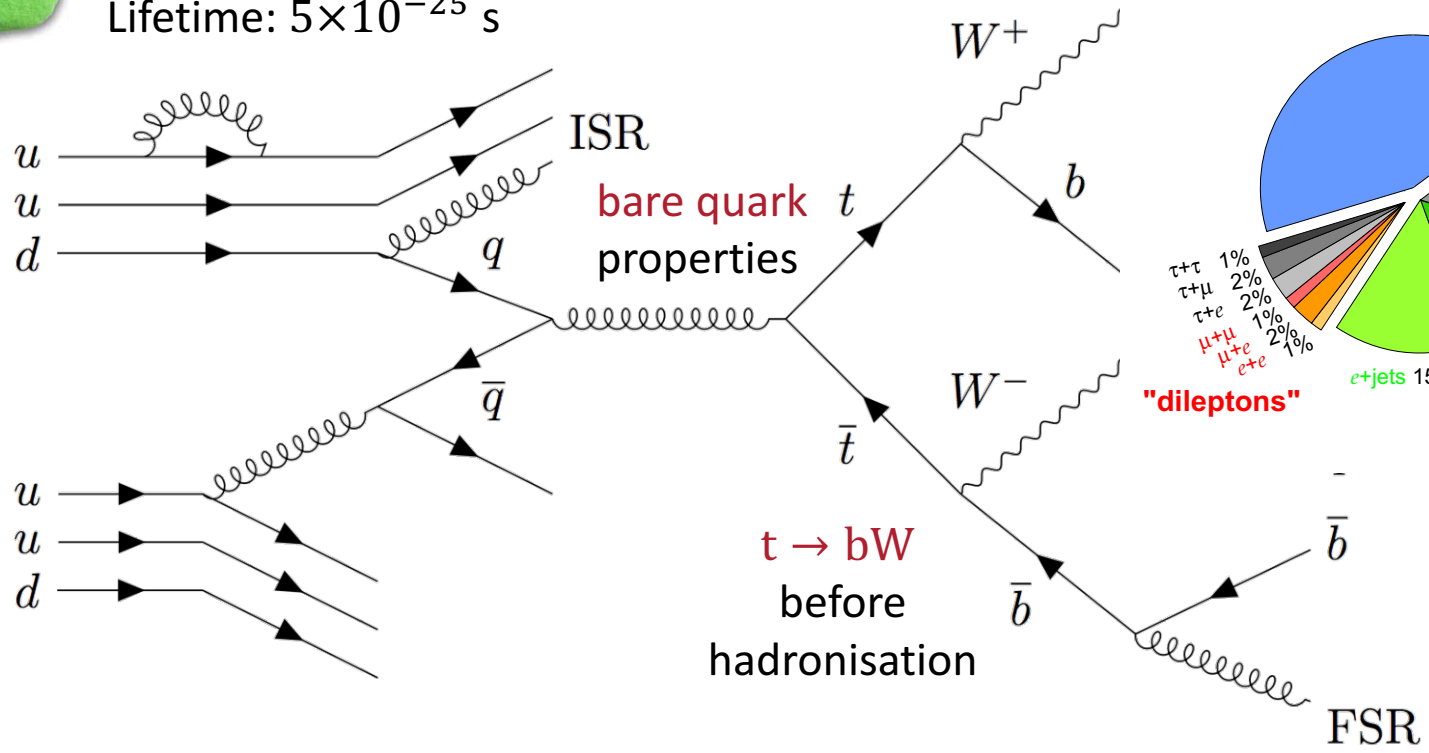
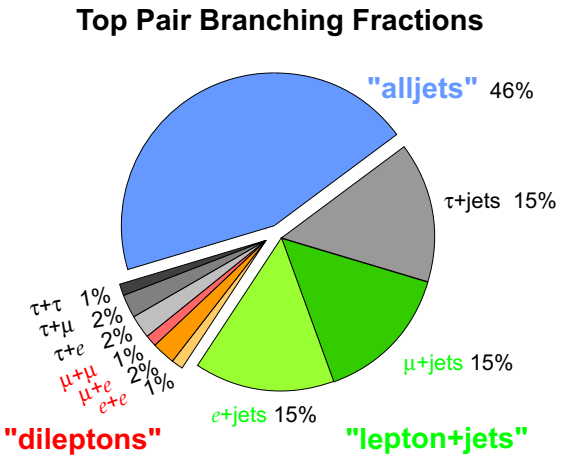
On behalf of the CMS collaboration

Production of $t\bar{t}$

Spin: 1/2
Charge: 2/3 e
Mass: 172.5 GeV
Lifetime: 5×10^{-25} s



Categorical final states



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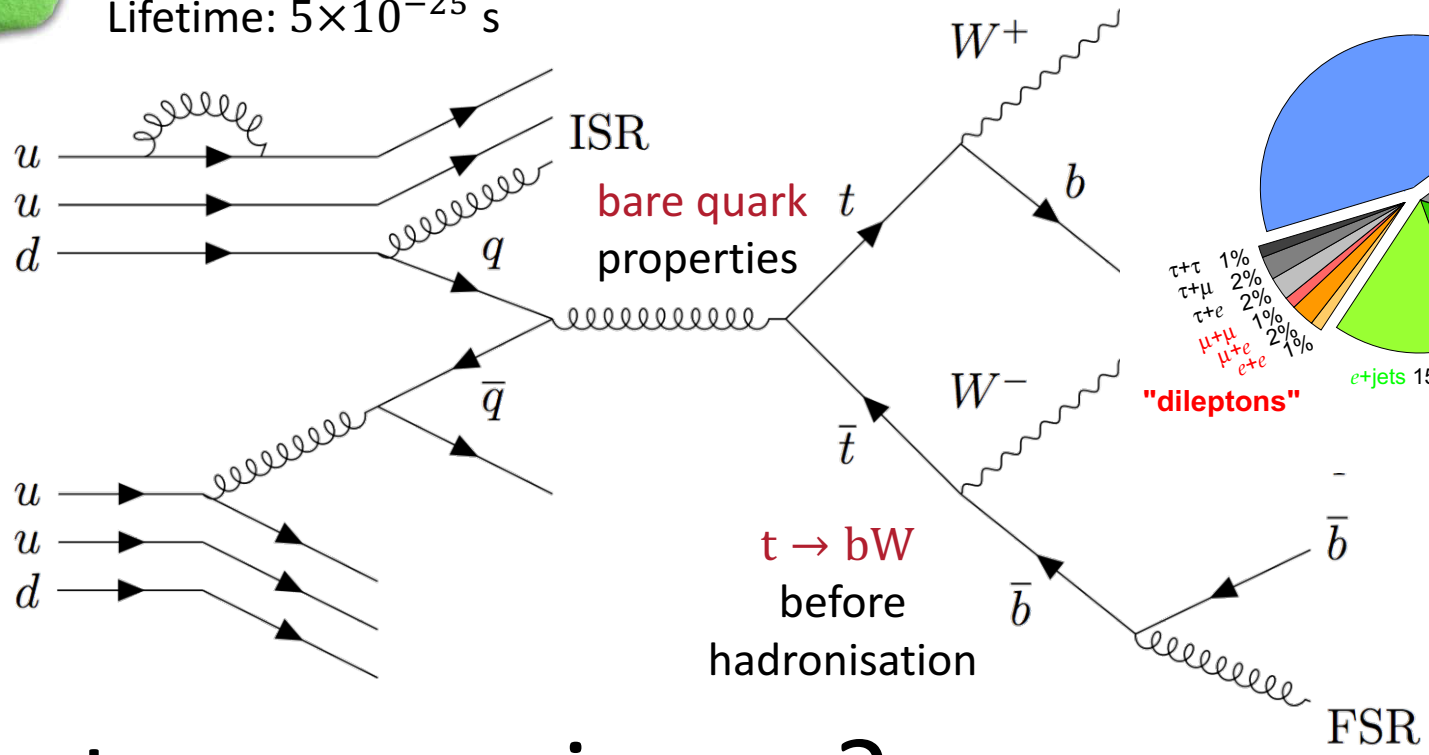

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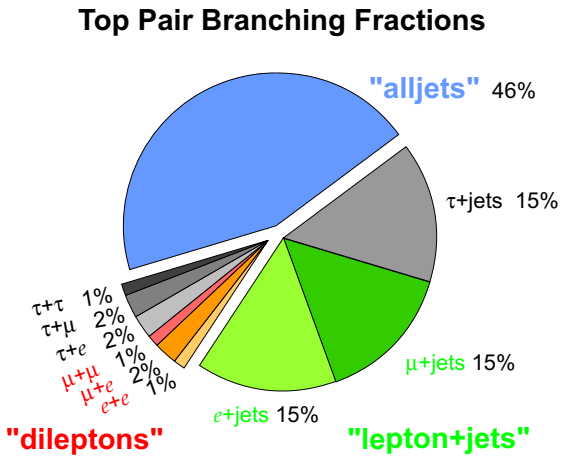
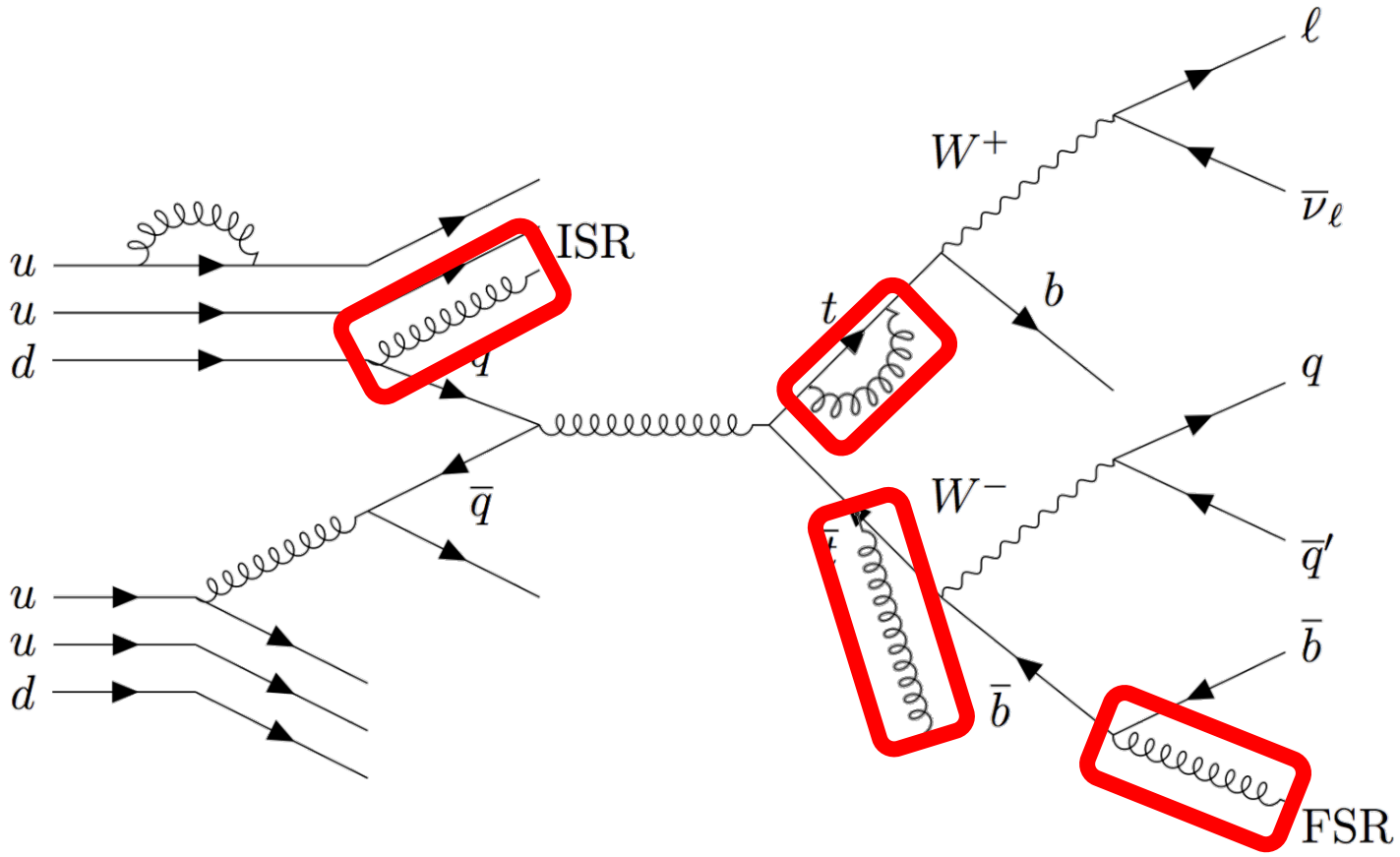


What can $\sigma_{t\bar{t}}$ give us?

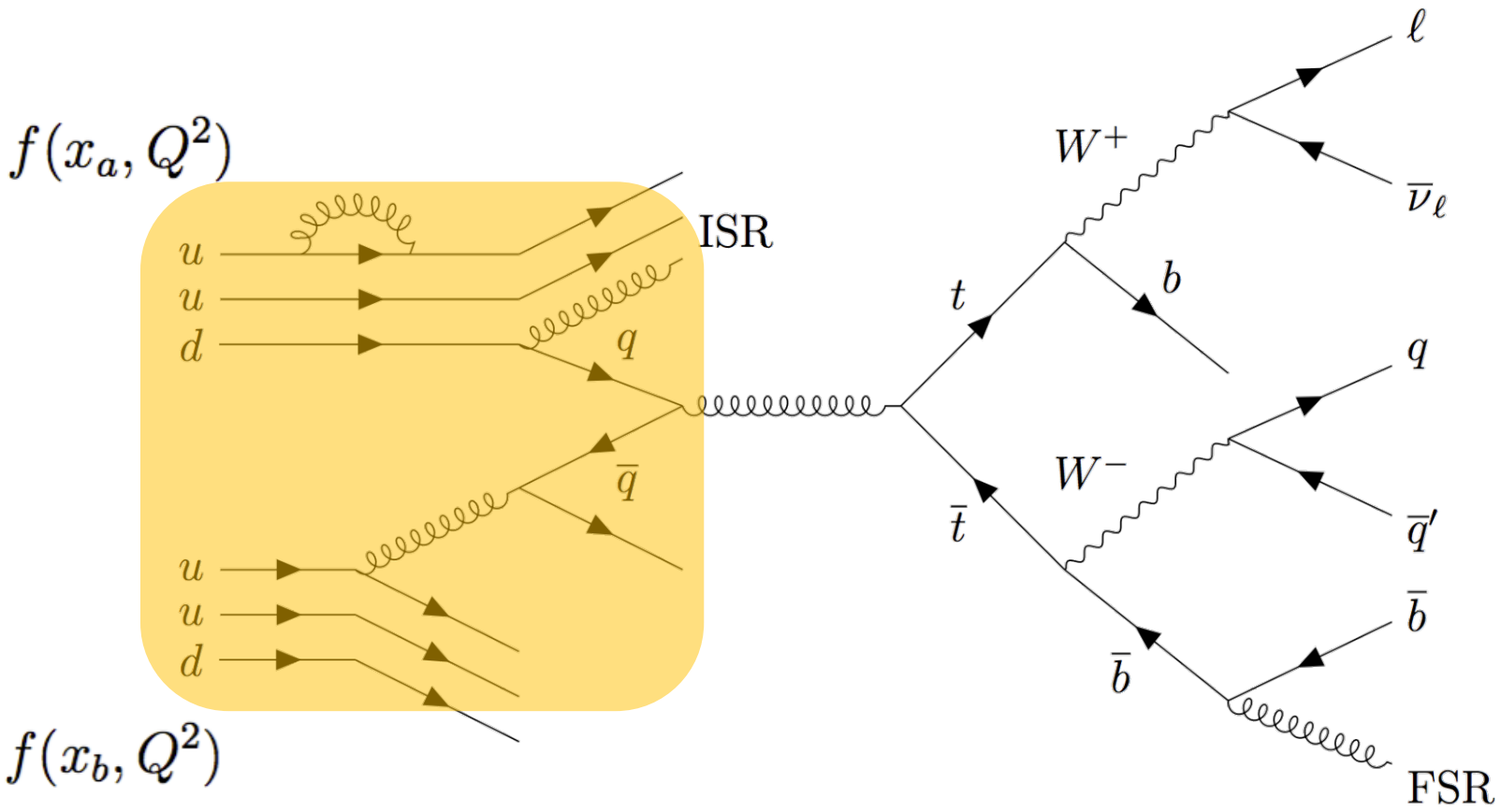
$$\sigma_{pp\to t\bar{t}} = \sum_{a,b} \int_0^1 f(x_a, Q^2)dx_a \cdot \int_0^1 f(x_b, Q^2)dx_b \cdot \hat{\sigma}_{ab\to t\bar{t}}$$

Higher order corrections



Handle on perturbative QCD

Parton distribution

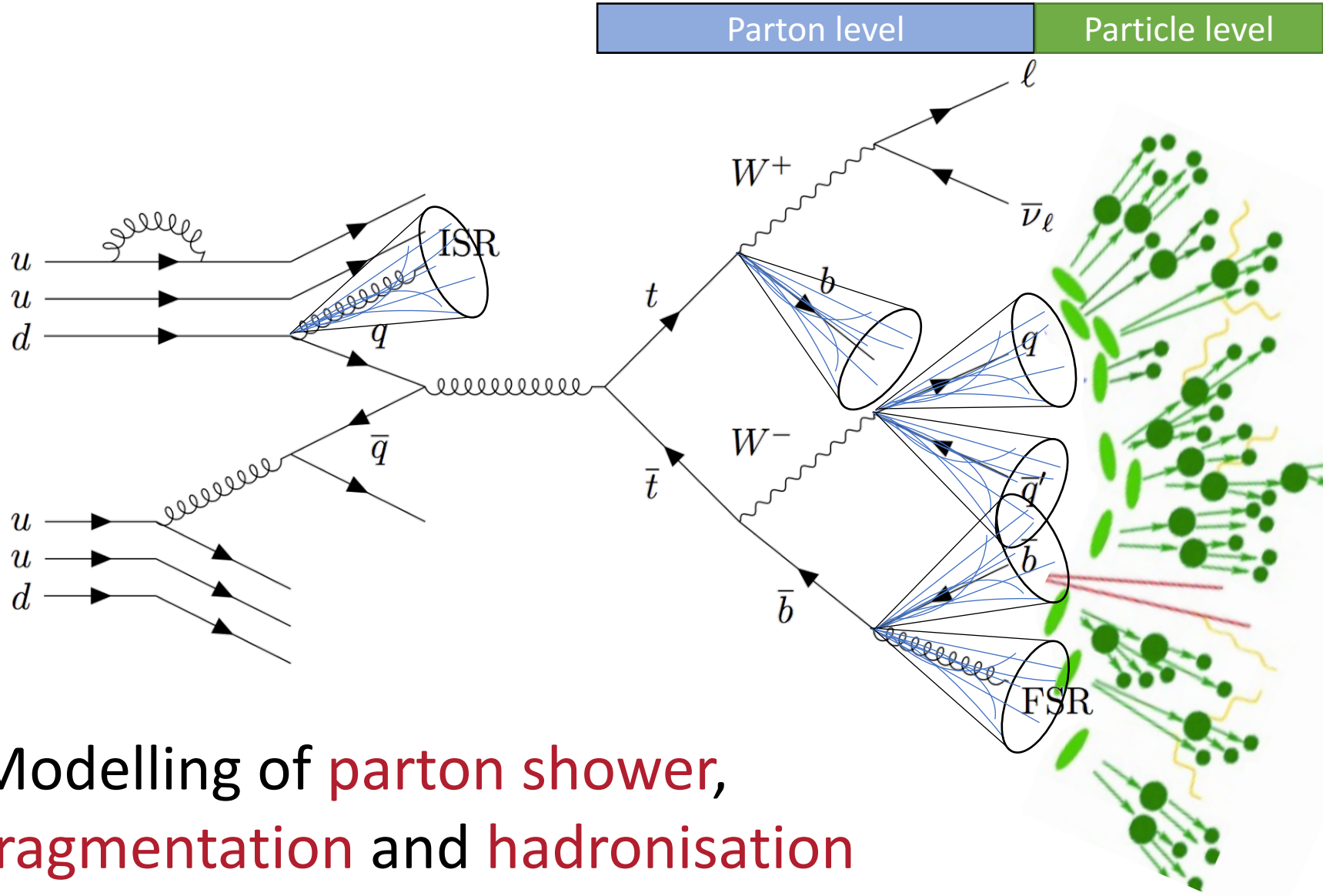


Constrain the gluon PDF

90% gluon-gluon collisions

Extract α_S, m_t

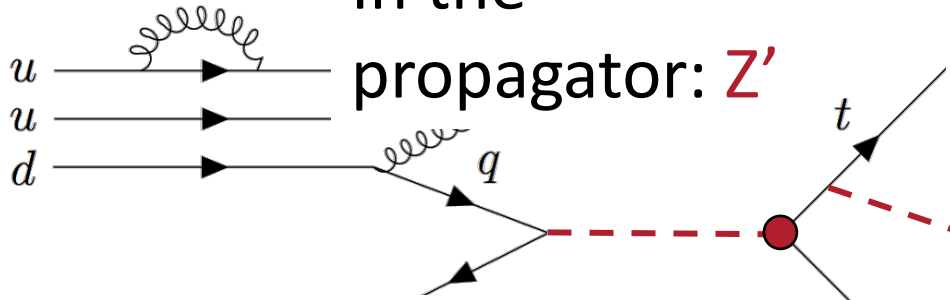
Lots of soft radiation



Modelling of parton shower, fragmentation and hadronisation

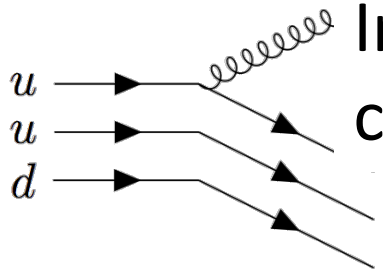
New physics and rare SM physics

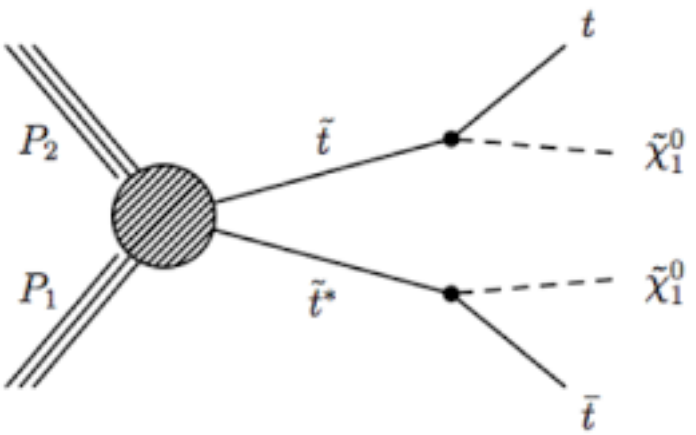
In the propagator: Z’



In the final state: $t\bar{t}X$

In the coupling: EFT

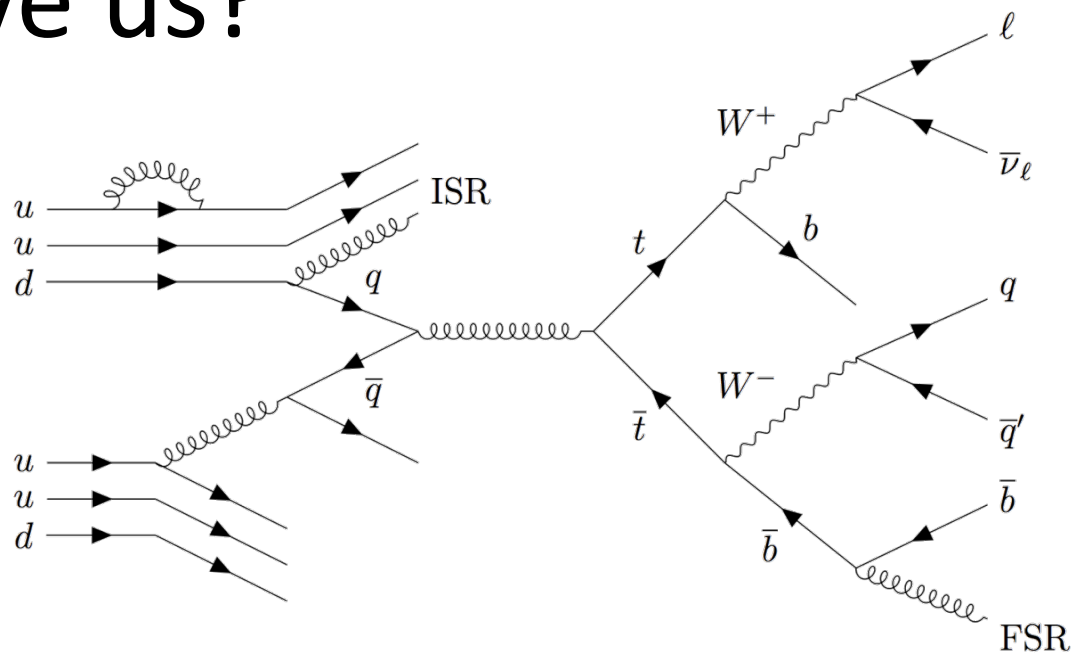




Large background to searches: SUSY, $t\bar{t}H$, $t\bar{t}t\bar{t}$

What can $\sigma_{t\bar{t}}$ give us?

A LOT!



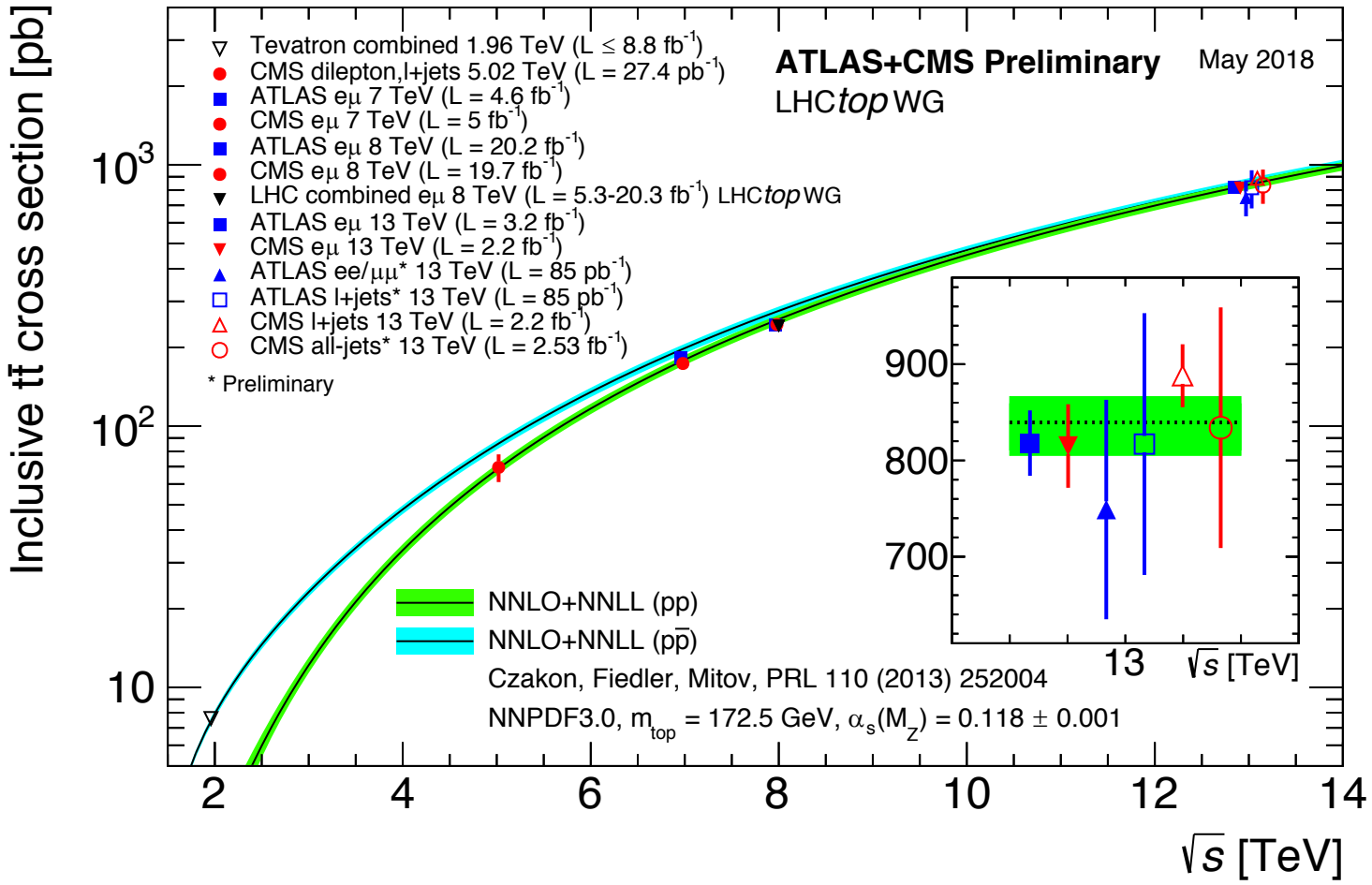
Important to:

the theoretical community

the experimental community

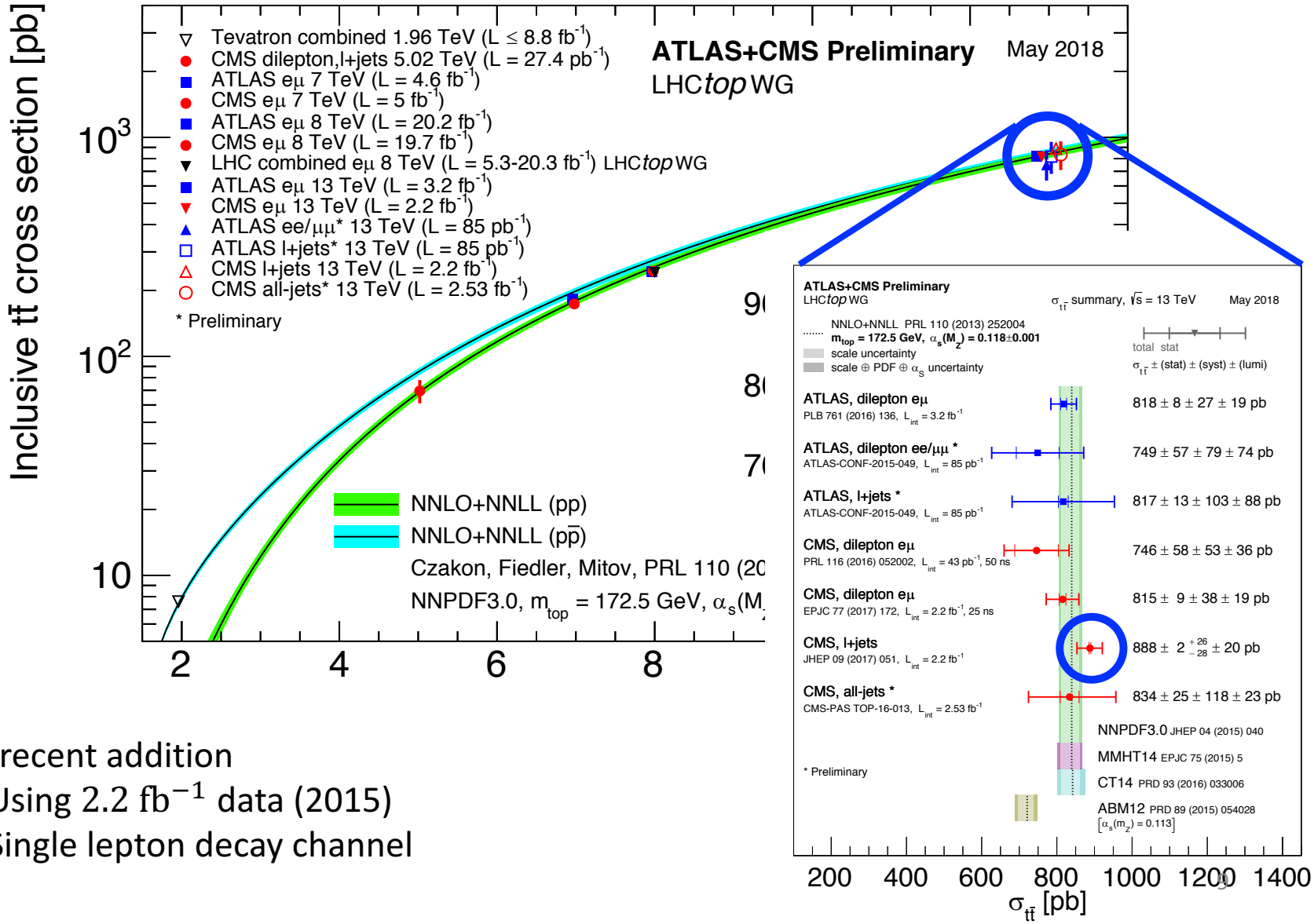
the simulation and tuning community

Inclusive $\sigma_{t\bar{t}}$



Inclusive $\sigma_{t\bar{t}}$ @ 13 TeV

JHEP 09 (2017) 051



Most recent addition

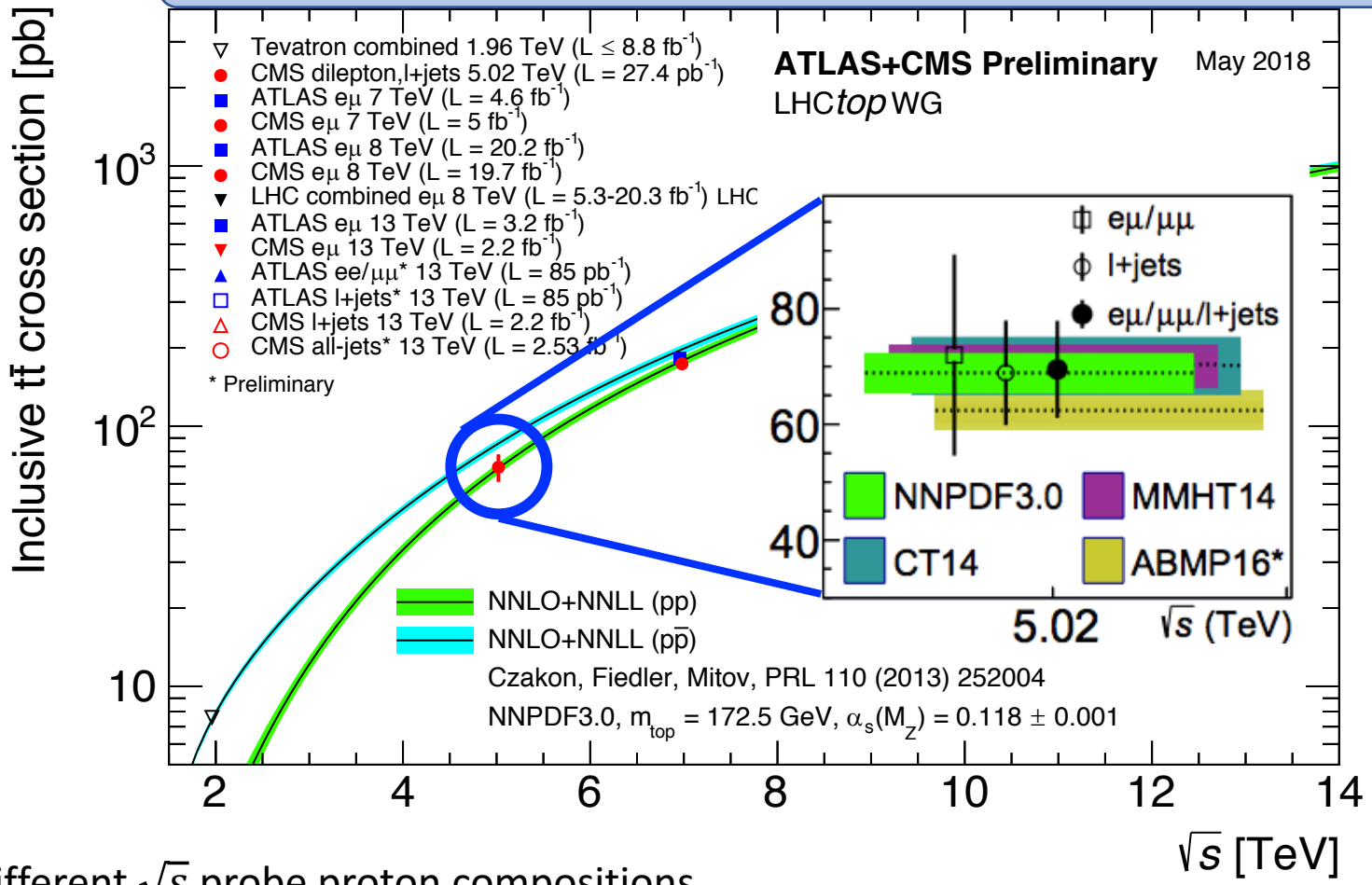
Using 2.2 fb^{-1} data (2015)

Single lepton decay channel

Inclusive $\sigma_{t\bar{t}}$ @ 5 TeV

JHEP 03 (2018) 115

$$\sigma_{t\bar{t}}^{5\ \mathrm{TeV}} = 69.5 \pm 6.1(\mathrm{stat}) \pm 5.6(\mathrm{syst}) \pm 1.6(\mathrm{lumi})\ \mathrm{pb}$$



$\sigma_{t\bar{t}}$ at different $\sqrt{s}$ probe proton compositions

- At least one lepton in final state
- Constrain gluon PDF

Inclusive $\sigma_{t\bar{t}}$ @ 5 TeV

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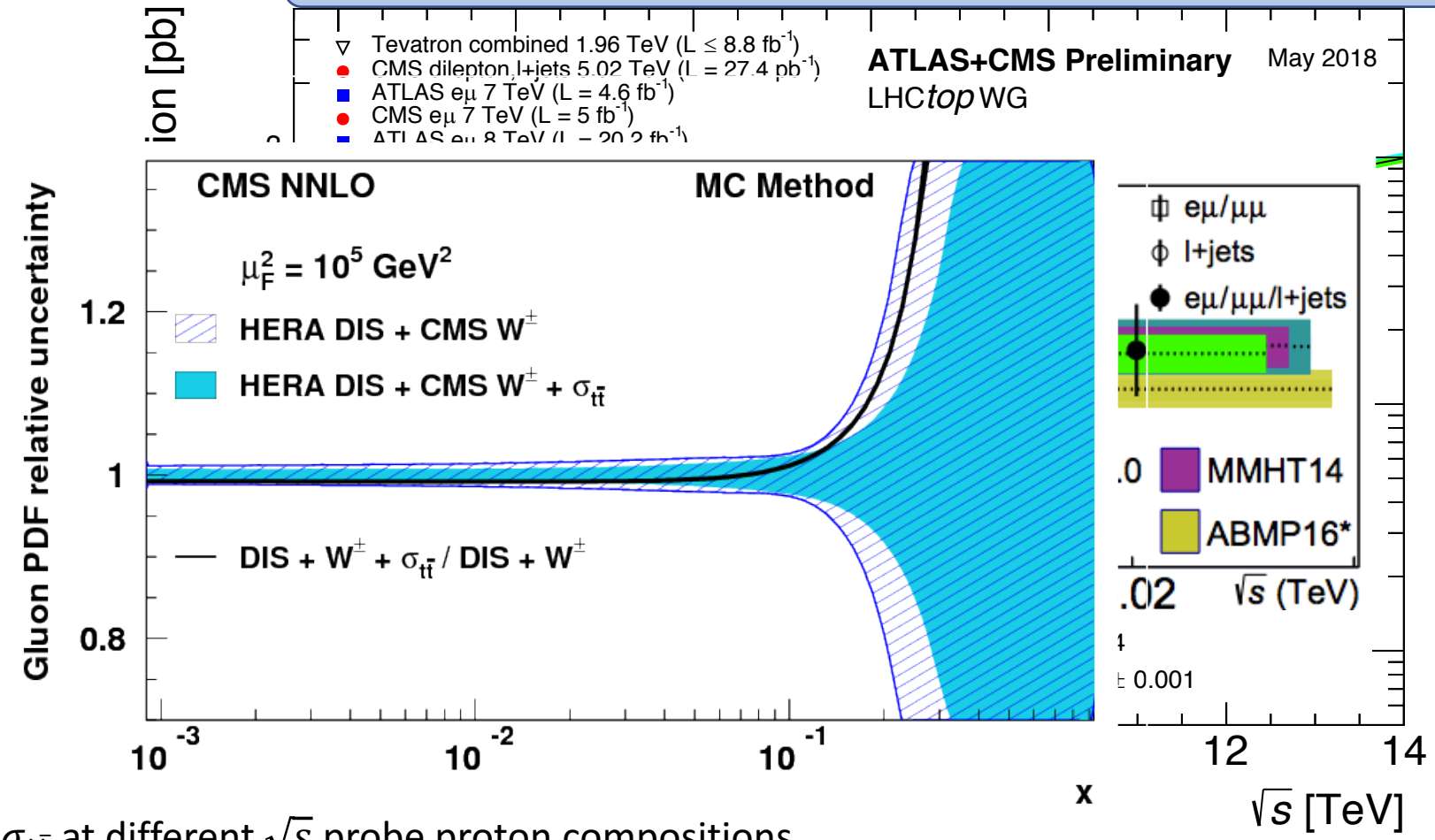

$\sigma_{t\bar{t}}$ at different $\sqrt{s}$ probe proton compositions

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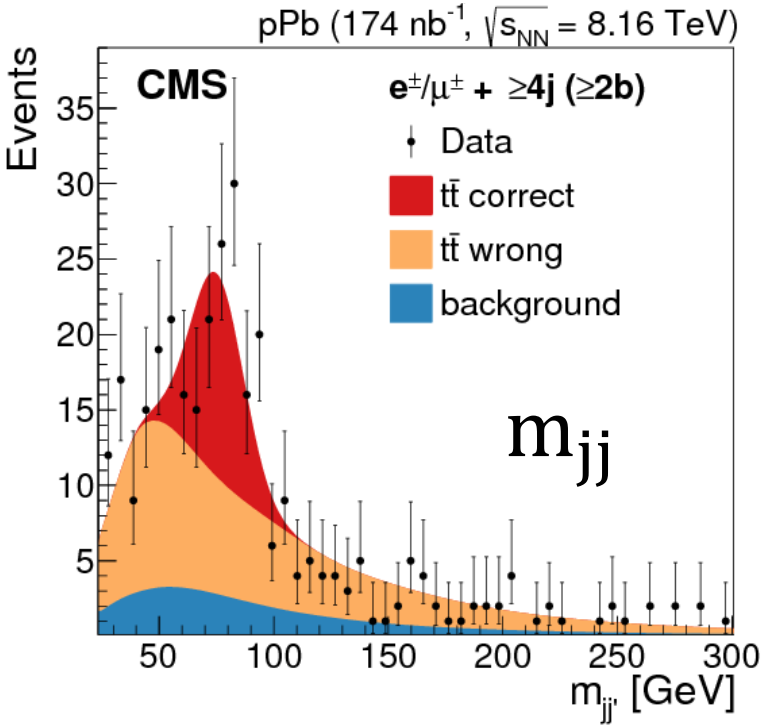
Moderate improvement in gluon PDF uncertainty at high x

Inclusive $\sigma_{t\bar{t}}$ @ 8.16 TeV p-Pb

PRL. 119, 242001 (2017)



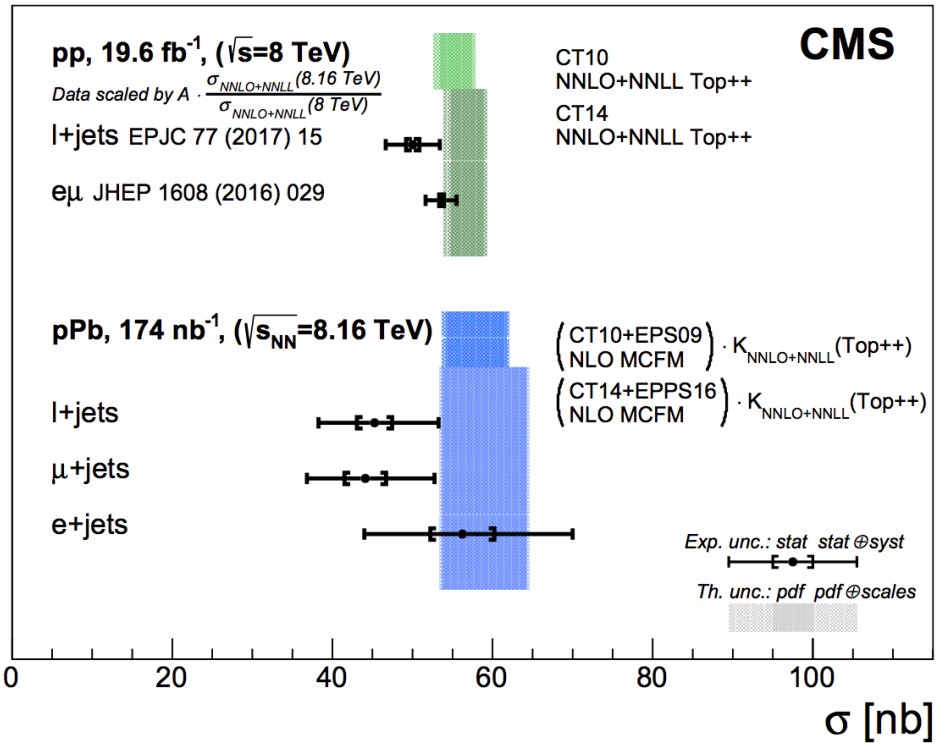
Lepton+jets channel

Extract $\sigma_{t\bar{t}}$ using simultaneous combined likelihood fit

- m_{jj} of W candidate
- Verify with m_t
- Background only rejected at $> 5\sigma$

Consistent with pQCD predictions

$$\sigma^{8.16\ \mathrm{TeV}}_{\mathrm{pPb}\to t\bar{t}} = 45 \pm 8\ \mathrm{nb}$$



First observation of the top quark in p-Pb collisions!

Inclusive $\sigma_{t\bar{t}}$ @ 8.16 TeV p-Pb

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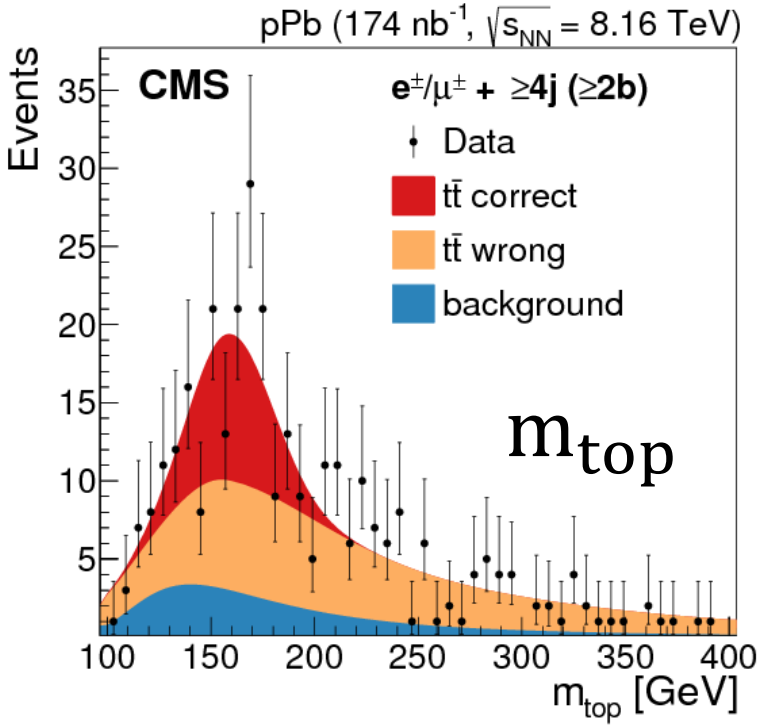

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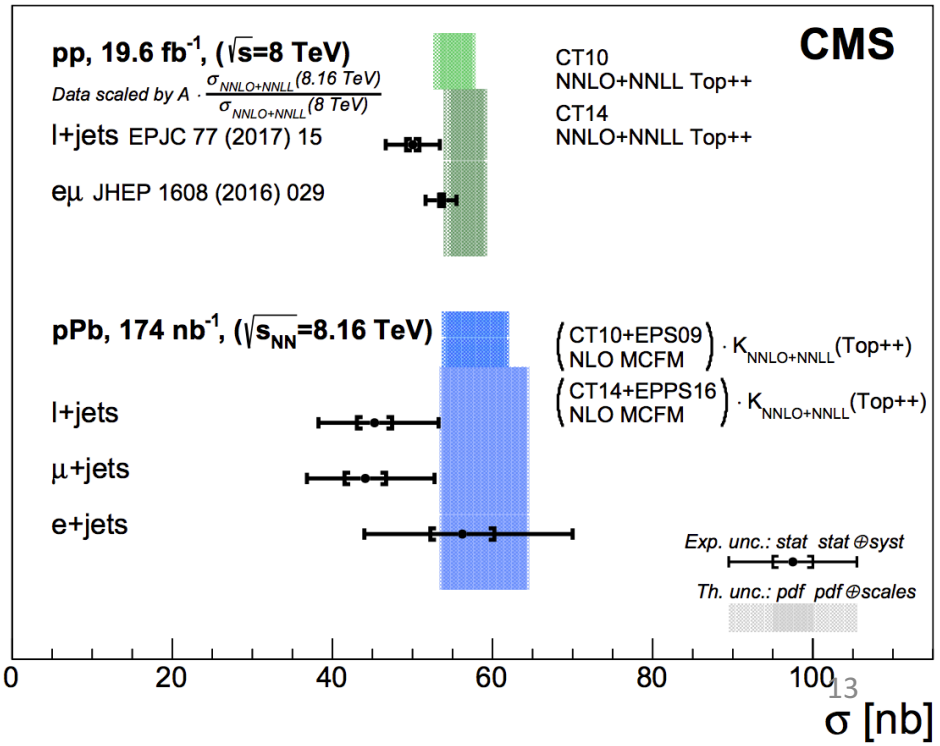
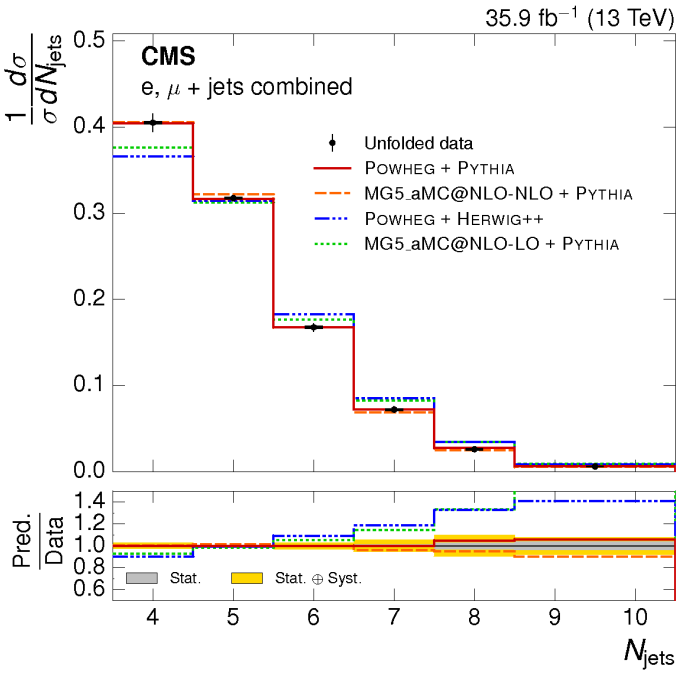


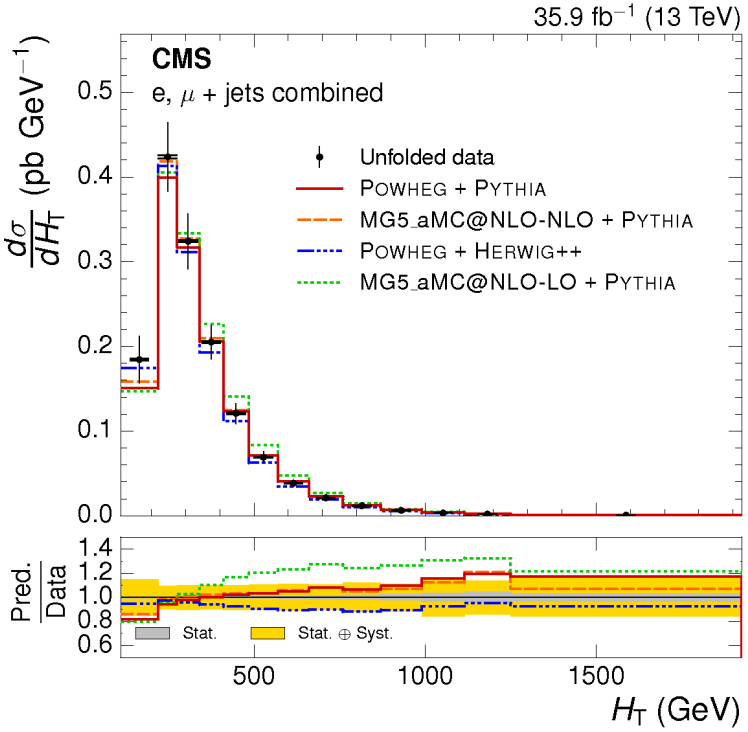
First observation of the top quark in p-Pb collisions!

Differential $\sigma_{t\bar{t}}$

JHEP 06 (2018) 002

- Function of kinematic event variables
  - No top reconstruction
- Using 35.9 fb^{-1} of data (2016)
- Absolute and normalised $\sigma_{t\bar{t}}$
  - Lepton+jets channel
  - Particle level in fiducial phase space
- LO and NLO MC generator comparisons
  - Public RIVET plugin
- Presented in poster session





	POWHEG+PYTHIA		With MC theoretical uncertainties	
	χ^2/ndf	p-value	χ^2/ndf	p-value
N_{jets}	2 / 5	0.84	1.8 / 5	0.88
H_T	28 / 12	<0.01	4.9 / 12	0.96
S_T	22 / 12	0.04	4.2 / 12	0.98
p_T^{miss}	11 / 5	0.06	2.9 / 5	0.72
p_T^W	16 / 6	0.01	2.5 / 6	0.87
p_T^ℓ	25 / 16	0.08	14 / 16	0.60
$\lvert\eta^\ell\rvert$	19 / 7	<0.01	15 / 7	0.03

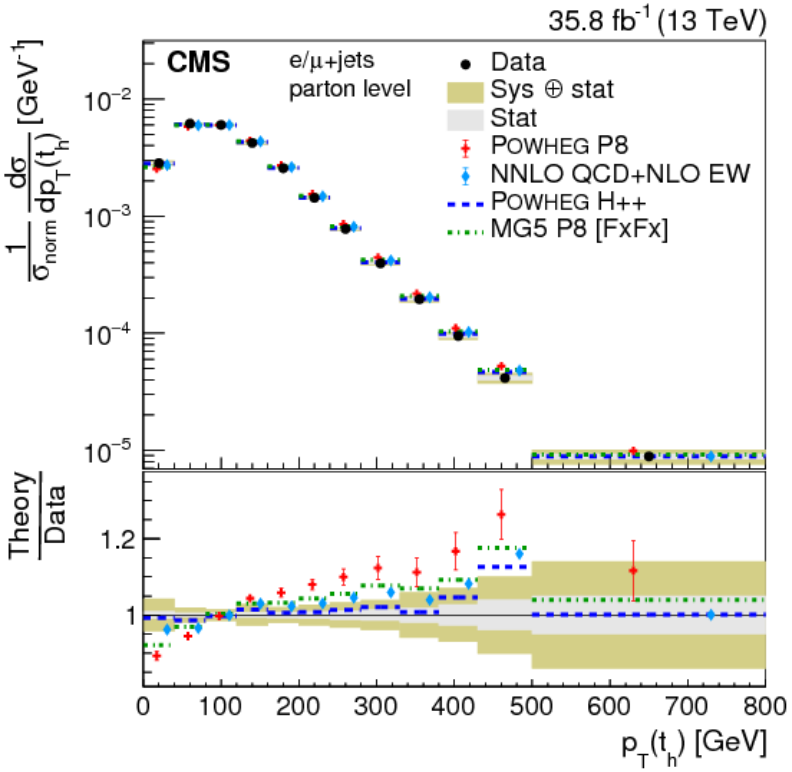
- Powheg+Pythia generally consistent with data
  - Differences covered by theoretical uncertainties
- Other NLO models also consistent
- LO MG5_aMC@NLO is not consistent

Differential $\sigma_{t\bar{t}}$

PRD 97, 112003 (2018)

Absolute and normalised $\sigma_{t\bar{t}}$

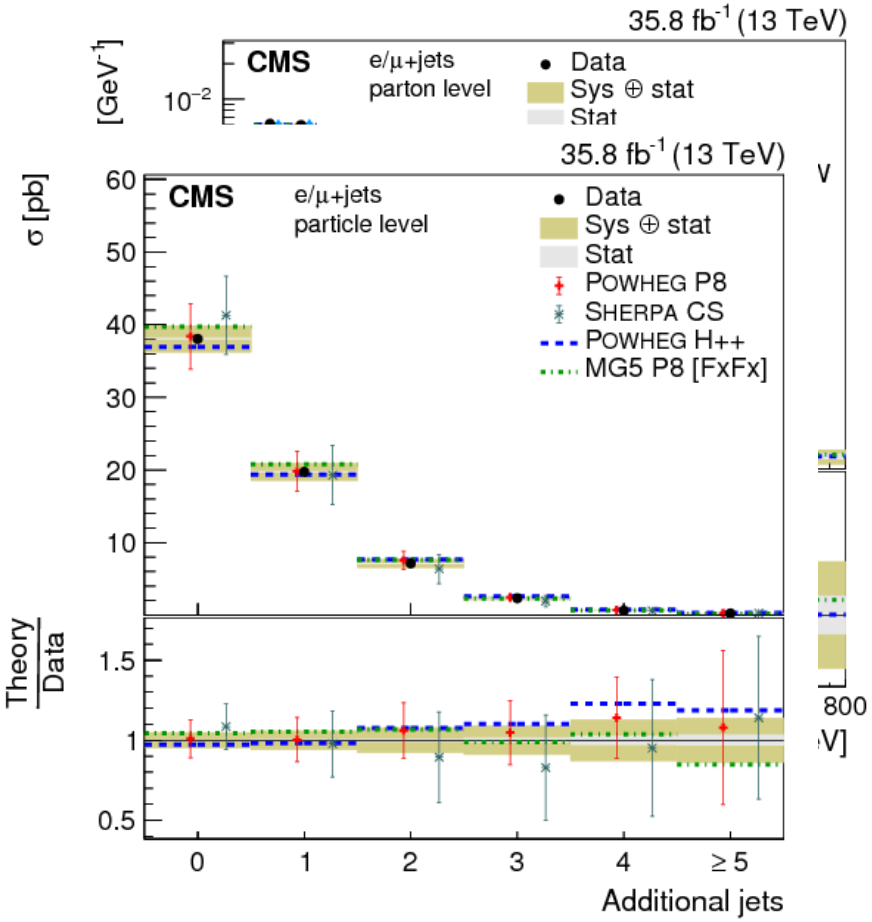
- Lepton+jets channel
- Particle level in fiducial phase space
- Parton level in full phase space



Differential $\sigma_{t\bar{t}}$

PRD 97, 112003 (2018)

- Absolute and normalised $\sigma_{t\bar{t}}$
  - Lepton+jets channel
  - Particle level in fiducial phase space
  - Parton level in full phase space
- Additional jet measurements
  - Kinematic properties
  - Additional jets
  - Gap fraction



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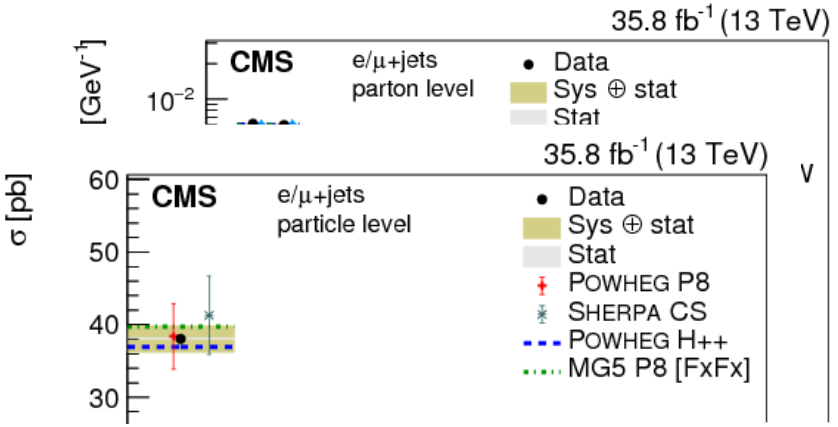
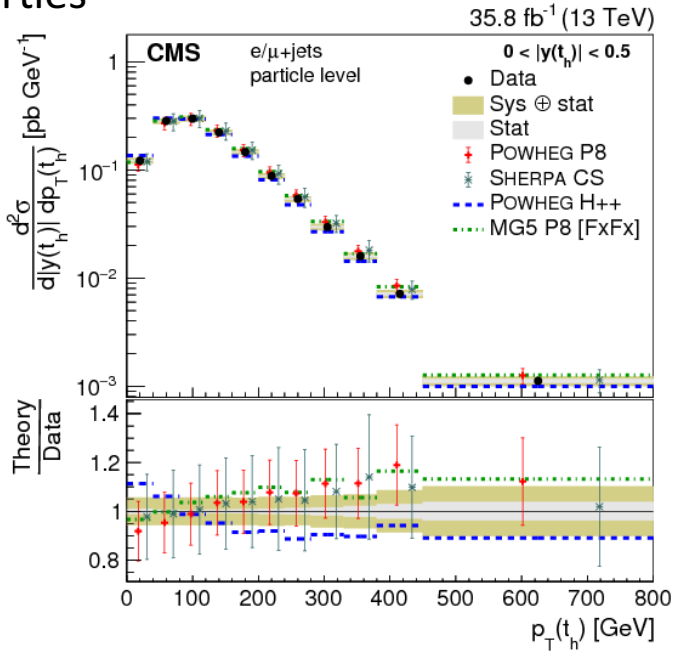
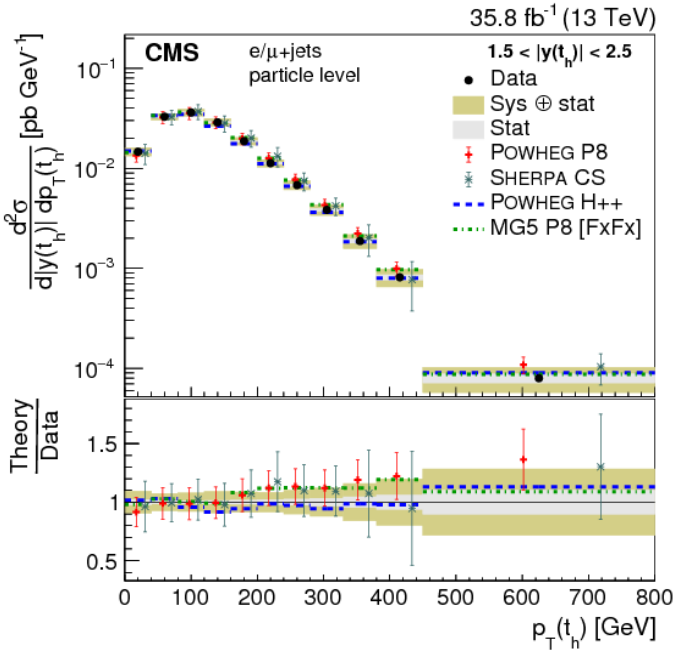
- Additional jet measurements
  - Kinematic properties
  - Additional jets
  - Gap fraction
- 2D measurements
  - $|y(t_h)|$vs $p_T(t_h)$
  - $M(t\bar{t})$ vs $|y(t\bar{t})|$
  - $p_T(t_h)$ vs $M(t\bar{t})$
- Public RIVET plugin







- Powheg+Pythia generally consistent
  - Observed trend in $p_T(t)$
- Sherpa generally not consistent
  - Using current tuning

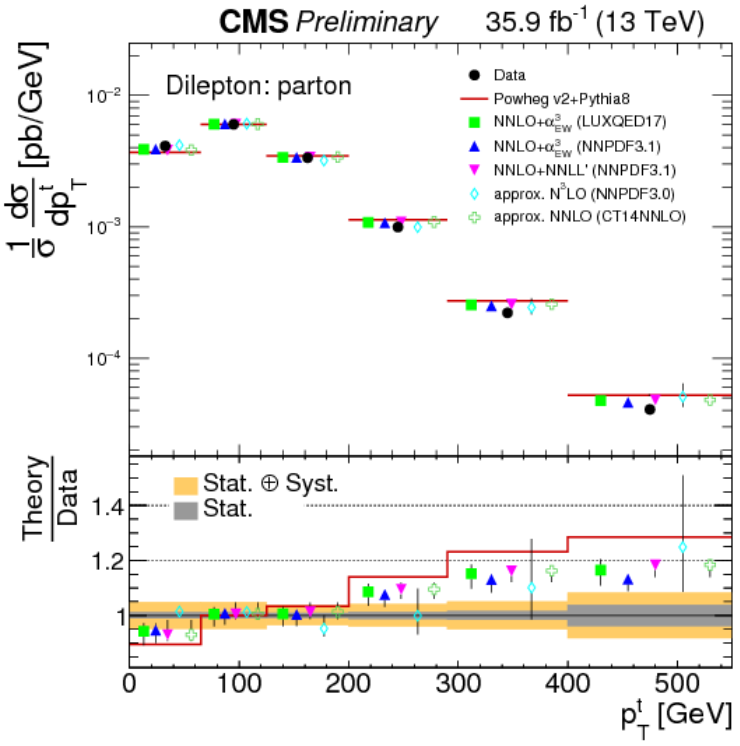
- Low p-values
  - neglecting theory uncertainty in models
  - $p_T(t)$ related distributions
  - Additional jet multiplicities

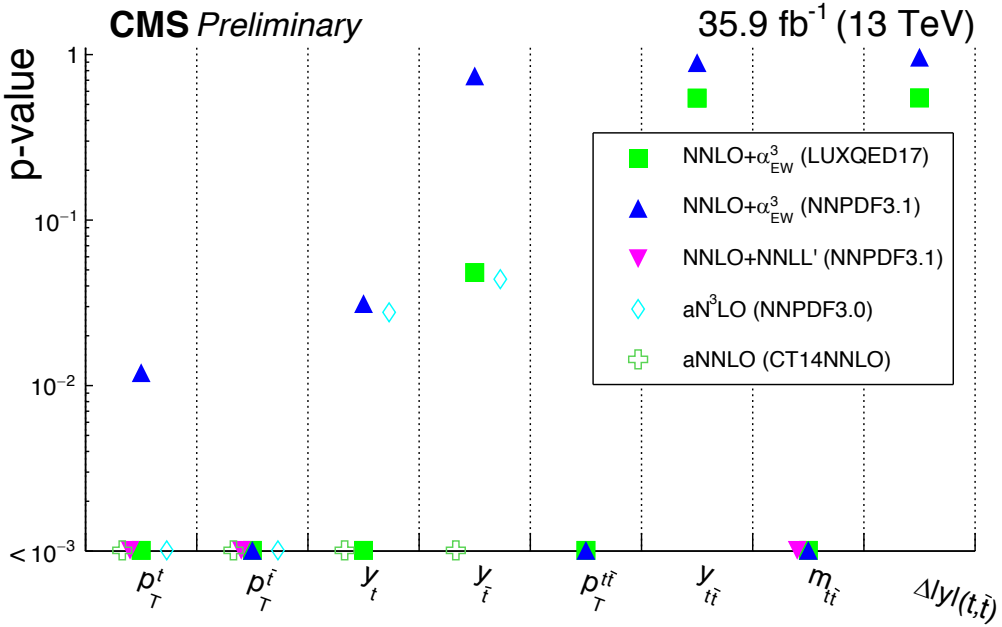
Differential $\sigma_{t\bar{t}}$

CMS-PAS-TOP-17-014

Absolute and normalised $\sigma_{t\bar{t}}$

- Dilepton channel
- Particle level in fiducial phase space
- Parton level in full phase space
- Comprehensive set of top quark kinematics





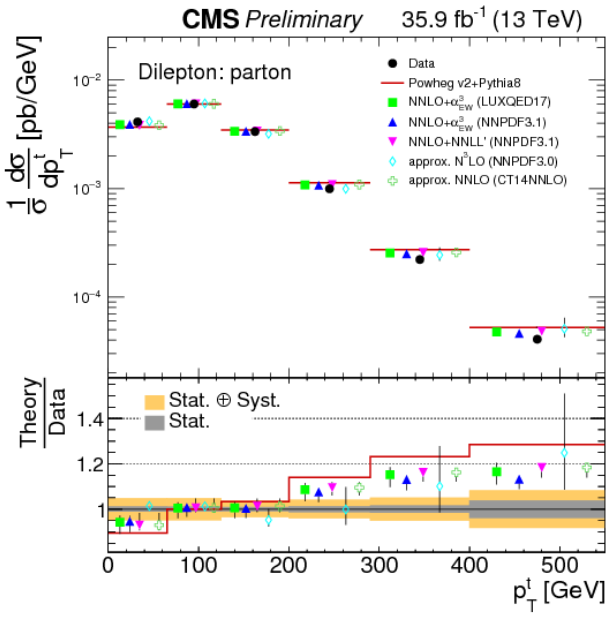
Electroweak corrections help

Higher order QCD helps

Differential $\sigma_{t\bar{t}}$

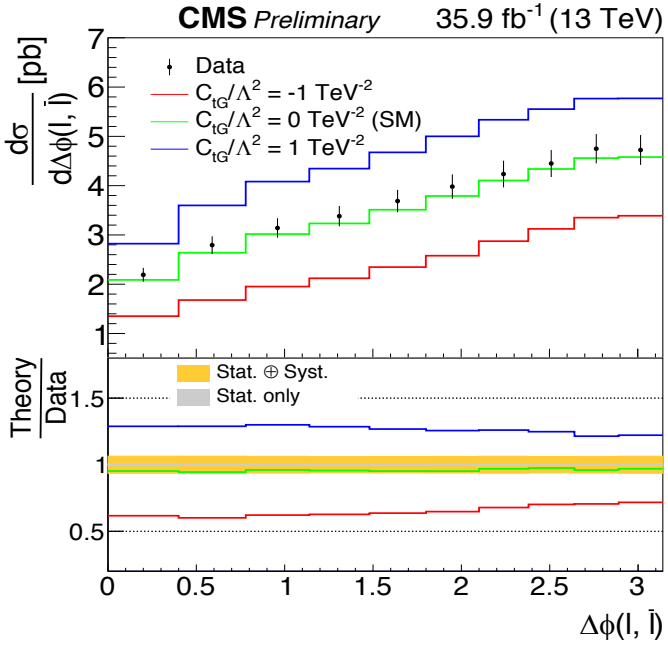
CMS-PAS-TOP-17-014

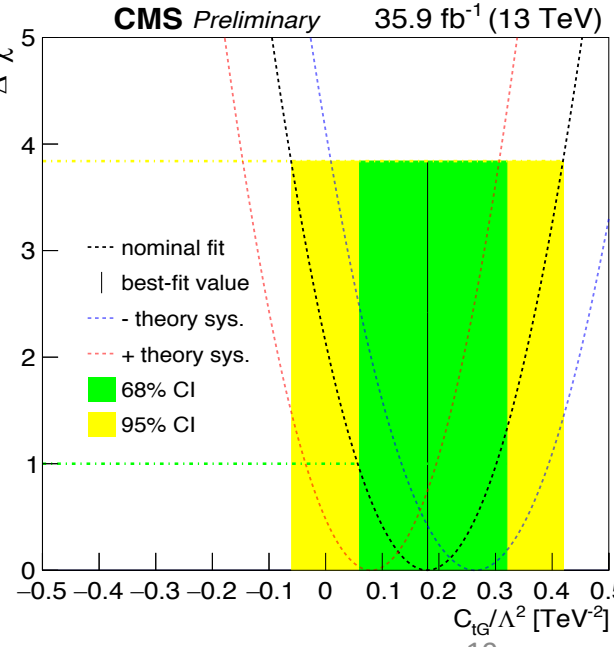
- Absolute and normalised $\sigma_{t\bar{t}}$
  - Dilepton channel
  - Particle level in fiducial phase space
  - Parton level in full phase space
  - Comprehensive set of top quark kinematics
- Constrain top quark chromomagnetic dipole moment
  - EFT operator O_{tG} parameterised by C_{tG}/Λ^2
  - Introduces $t\bar{t}gg$ vertex and modifies $t\bar{t}g$
  - Modified spin correlation - $\Delta\phi(l,\bar{l})$ sensitive



95% confidence interval
$-0.06 < C_{tG}/\Lambda^2 < 0.41$

Consistent with and improve upon previous measurements





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CMS-PAS-TOP-17-014

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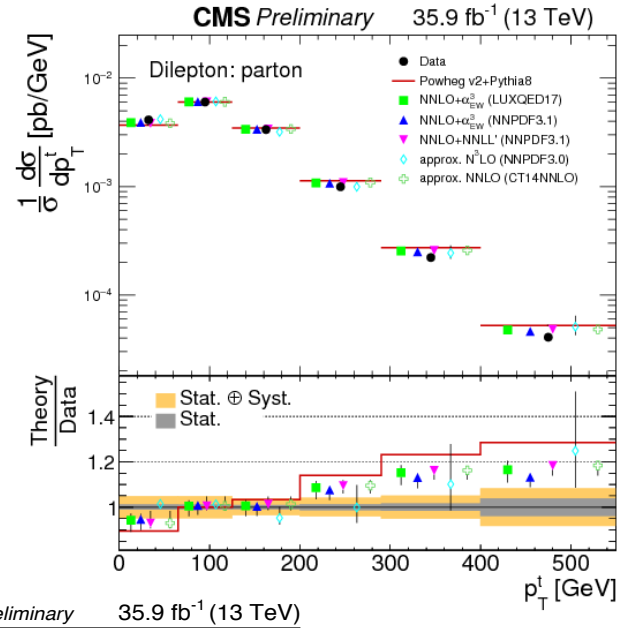
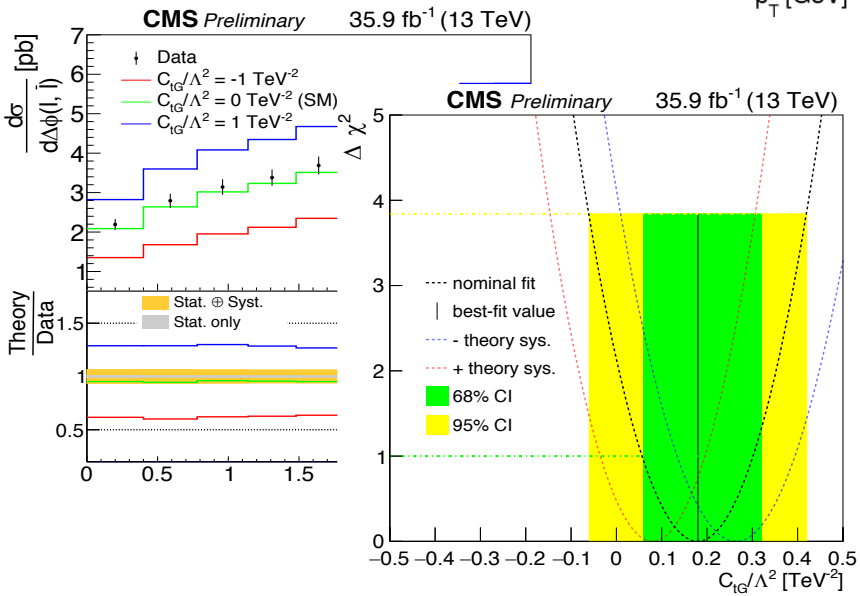
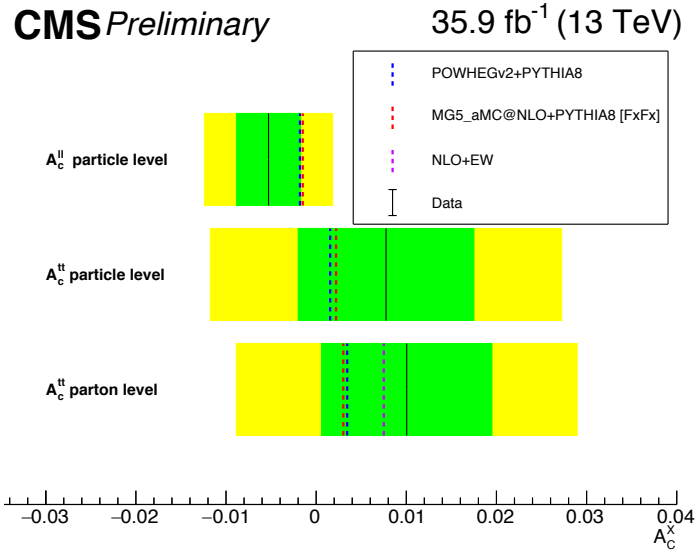
  - Comprehensive set of top quark kinematics
- Constrain top quark chromomagnetic dipole moment
  - EFT operator O_{tG} parameterised by C_{tG}/Λ^2
  - Introduces $t\bar{t}gg$ vertex and modifies $t\bar{t}g$
  - Modified spin correlation - $\Delta\phi(l,\bar{l})$ sensitive
- Extract charge asymmetries
  - $t\bar{t}$ and lepton
  - First measurement at 13 TeV

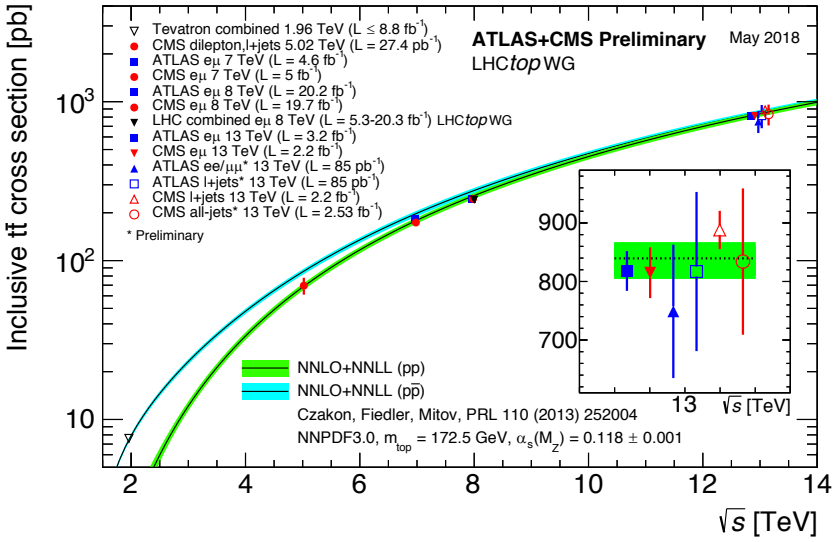


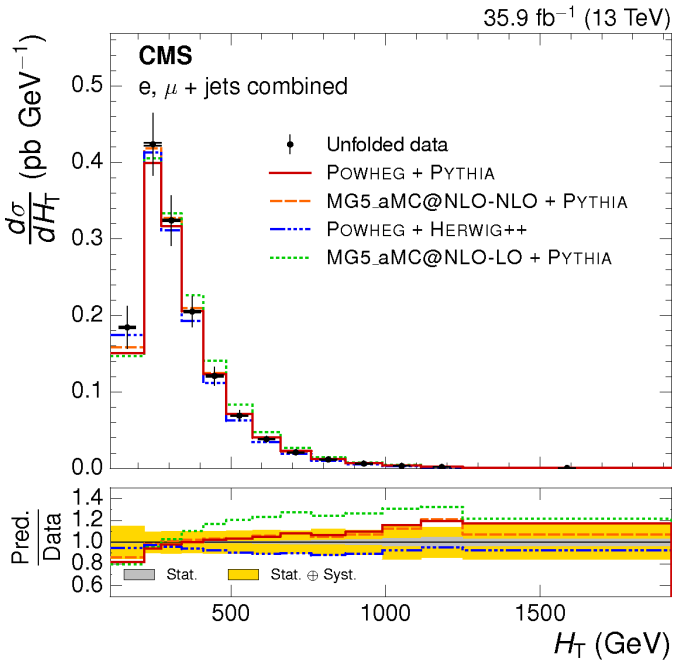




Good agreement with SM predictions

Summary





Wide range of inclusive cross sections

- @ 5, 8.16, 13 TeV
- Constraining PDFs

Observation of top in p-Pb collisions

Wide range of differential cross sections

- Precision measurements of the SM
- Tuning $t\bar{t}$ production models
- Constraining EFTs