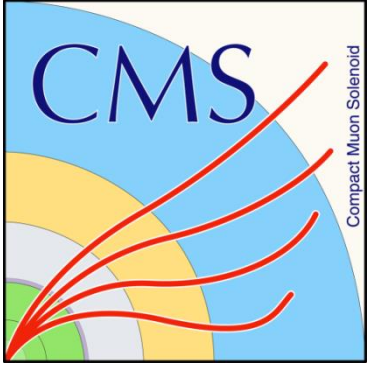
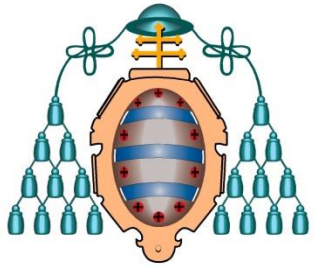




UNIVERSIDAD DE OVIEDO

Top pair cross section measurements in CMS and related searches for new physics

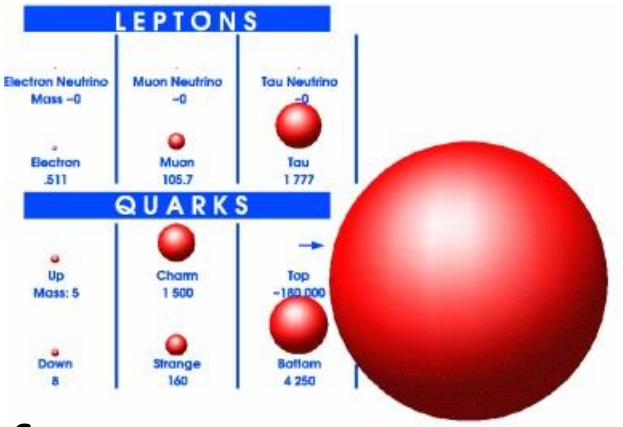
Juan R. González Fernández

TAE2016 - Benasque

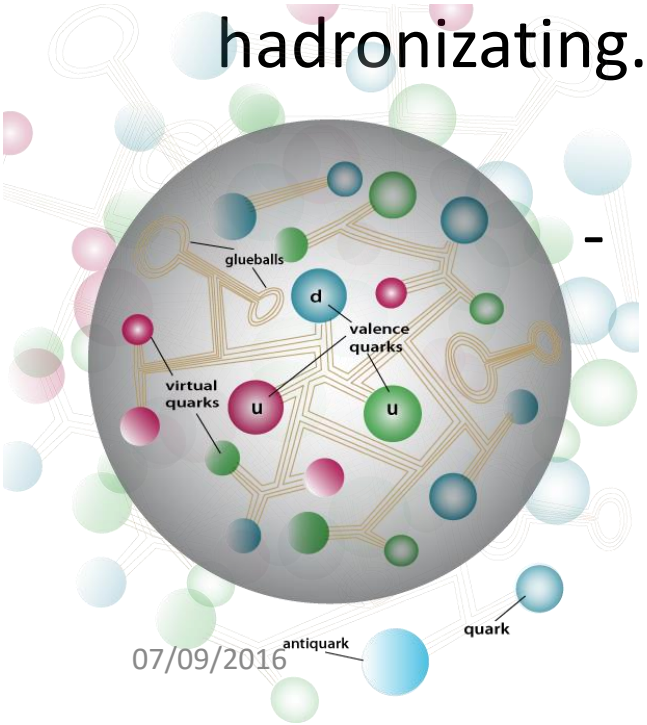
07/09/2016

Why is $t\bar{t}$ cross section important?

- Top quark: the most massive particle in the SM (largest coupling to the **higgs boson**!)



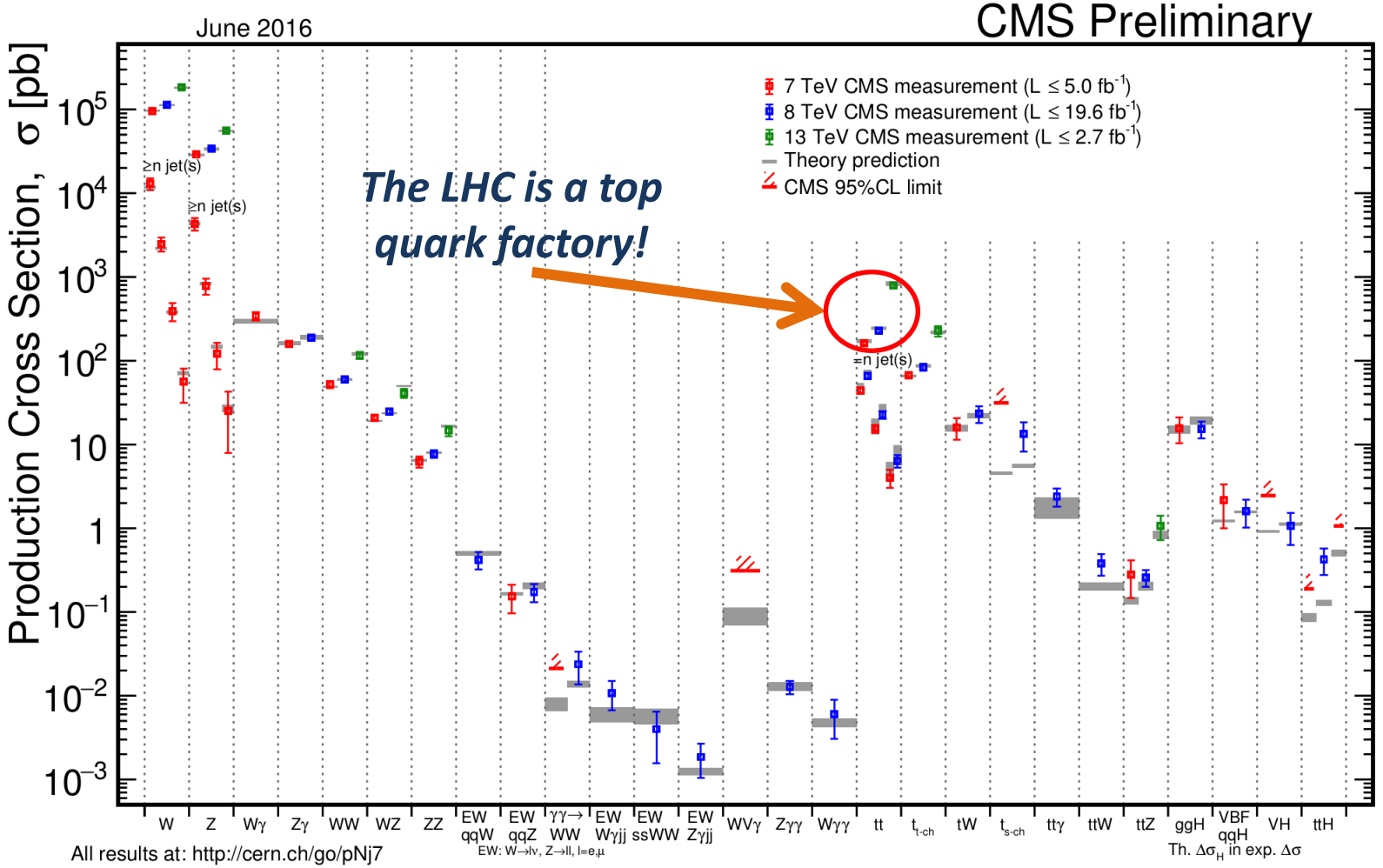
- It's the only quark that decays before hadronizating... Perfect to check **qcd predictions**!



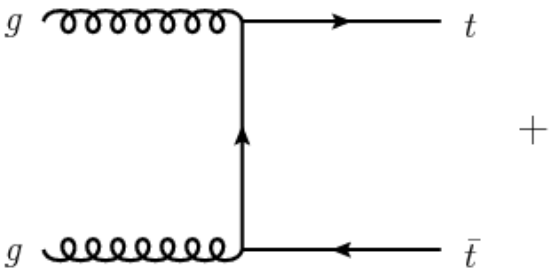
- The measurement of this cross section can **constrain** the proton **PDFs**, the value of α_s and a lot of processes in **new physics** scenarios

Why is $t\bar{t}$ cross section important?

- In experimental physics: **main background in most measurements and searches**



How is it produced?



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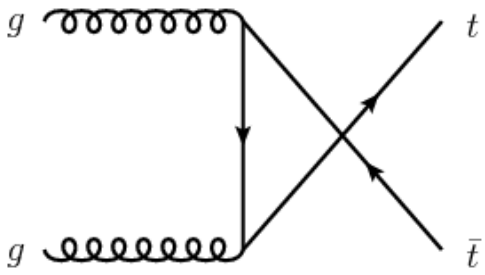

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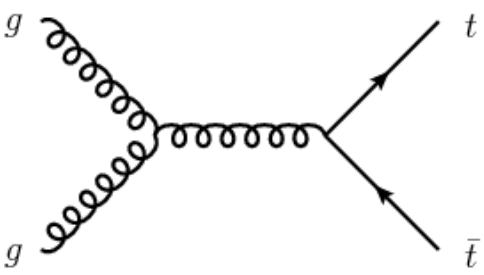
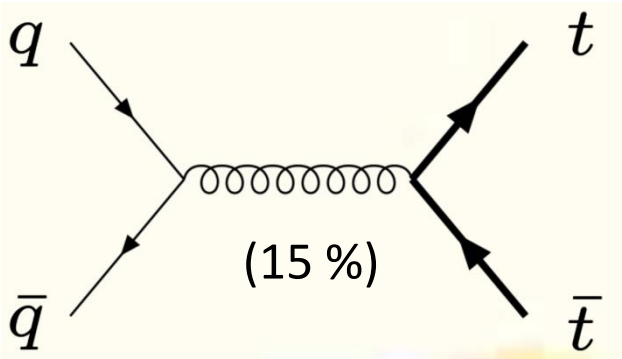
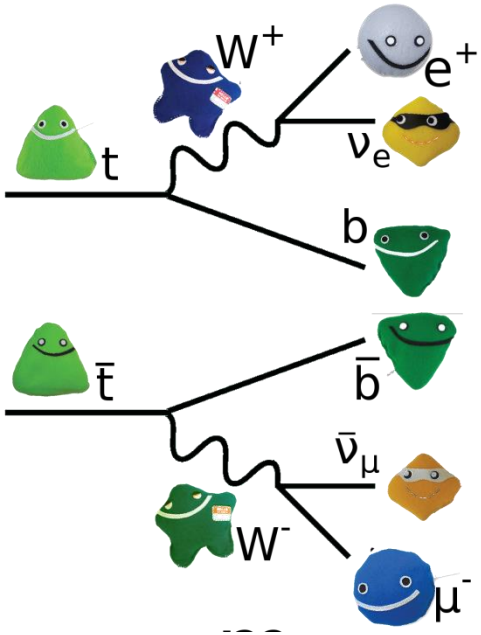


(85 %)



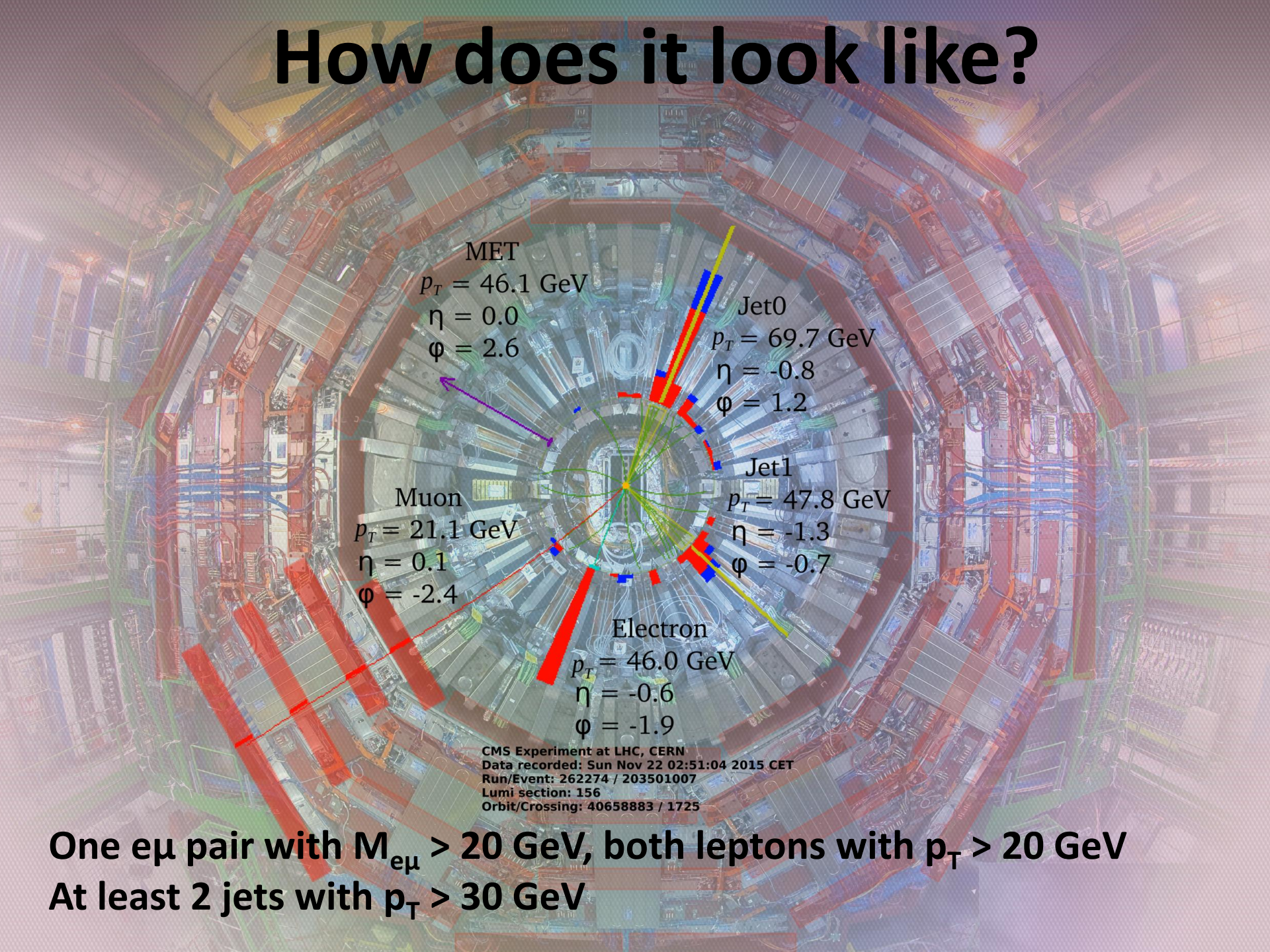
How does it decay?

Cleanest channel: dilepton different flavour (eμ)



Less DY background contamination!

How does it look like?

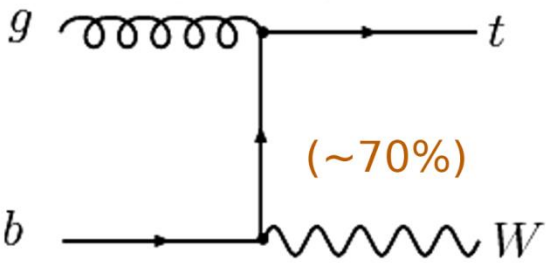


One eμ pair with $M_{e\mu}$ > 20 GeV, both leptons with p_T > 20 GeV

At least 2 jets with p_T > 30 GeV

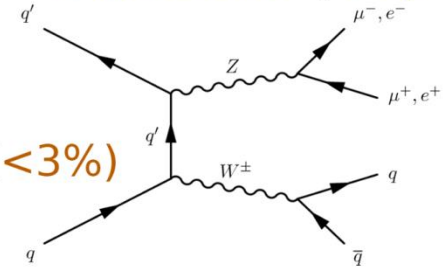
Main backgrounds

· Single top (tW)



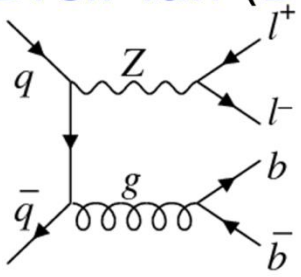
(~70%)

· Dibosons (VV)



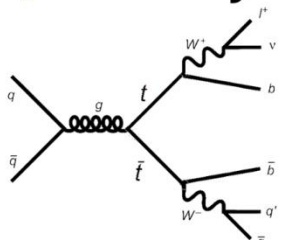
(<3%)

· Drell Yan (DY)

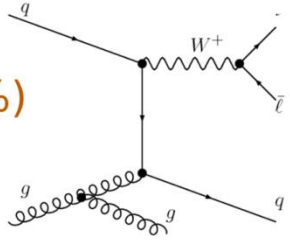


(~10%)

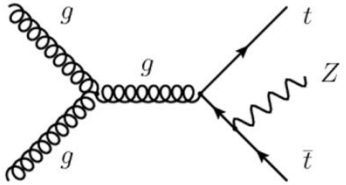
·"NonW/Z": W+Jets or tt̄ into one lepon



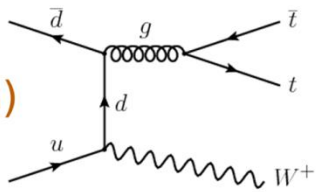
(~10%)



· "ttV": ttW, ttZ



(~5%)



- Non W/Z and DY calculated from **data driven** techniques
- MC simulation for tW, dibosons, ttW and ttZ

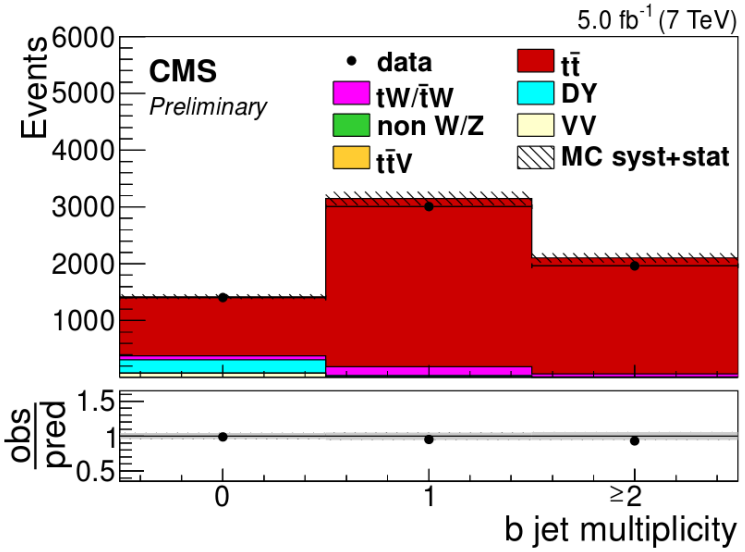
Cross section measurement

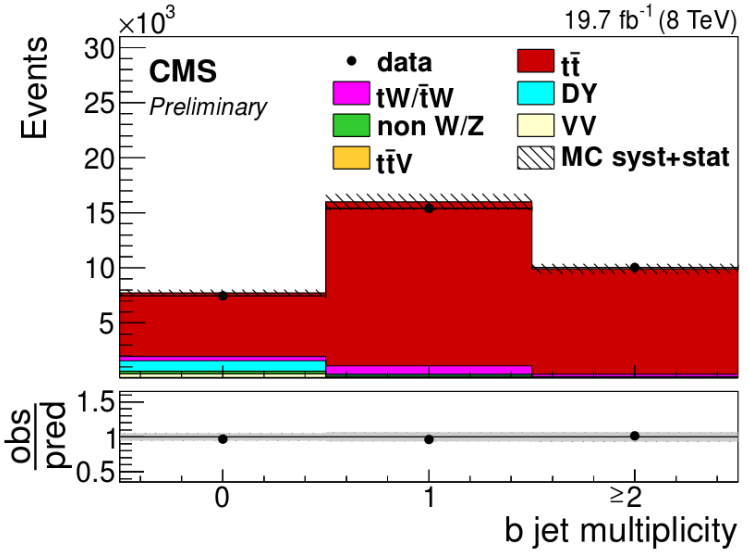
$$\sigma_{t\bar{t}} = \frac{N_{data} - N_{bkg}}{\varepsilon \cdot \mathcal{A} \cdot BR \cdot \int \mathcal{L} dt}$$

- $BR(t\bar{t} \rightarrow e\mu) = 0.03263$
- $\int \mathcal{L} dt$: Total integrated luminosity
- N_{data}: number of observed events
- N_{bkg}: Estimated background events
- ε: Reconstraction efficiency
- $\mathcal{A}$: acceptance (detector + selection)

Last results at 7 and 8 TeV

JHEP 2016:29, [arXiv:1613.02303] (19.7 fb^{-1} at 8 TeV, 5,0 fb^{-1} at 7 TeV)





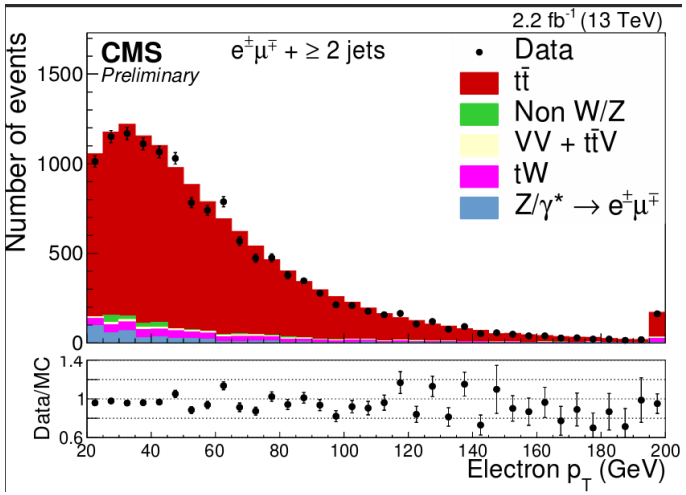
Source	Number of $e^{\pm}\mu^{\mp}$ events	
	7 TeV	8 TeV
DY	$22.1 \pm 3.1 \pm 3.3$	$173.3 \pm 25.1 \pm 26.0$
Non-W/Z	$51.0 \pm 0.7 \pm 15.3$	$145.9 \pm 14.8 \pm 43.8$
Single top quark (tW)	$204.0 \pm 3.1 \pm 61.2$	$1033.6 \pm 2.9 \pm 313.8$
VV	$6.9 \pm 0.6 \pm 2.1$	$35.4 \pm 1.9 \pm 11.1$
Rare ($t\bar{t}V$)	$--$	$83.6 \pm 1.3 \pm 25.5$
Total background	$284.0 \pm 16.0 \pm 63.2$	$1471.7 \pm 46.7 \pm 319.1$
$t\bar{t}$ dilepton signal	$5008.2 \pm 15.4 \pm 188.0$	$24439.6 \pm 43.6 \pm 956.4$
Data	4970	25441

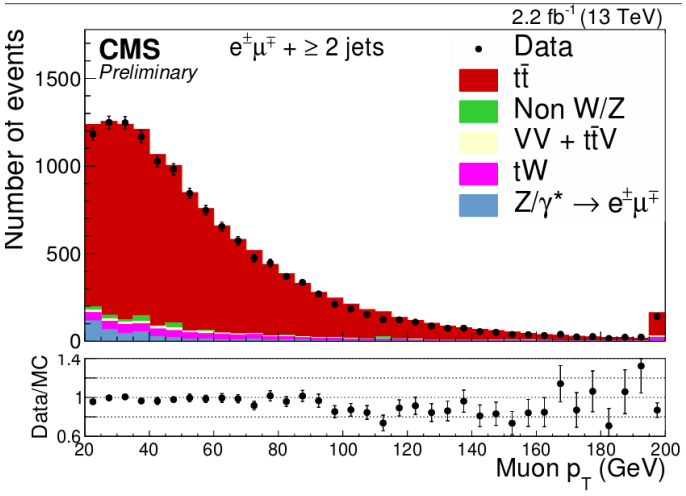
At least one b-jet is required

Last results at 13 TeV

Phys. Rev. Lett. 116, 052002, [arXiv:1510.05302] (42 pb^{-1})
CMS-PAS-TOP-16-005 , cds.cern.ch/record/2141738 (2.2 fb^{-1})

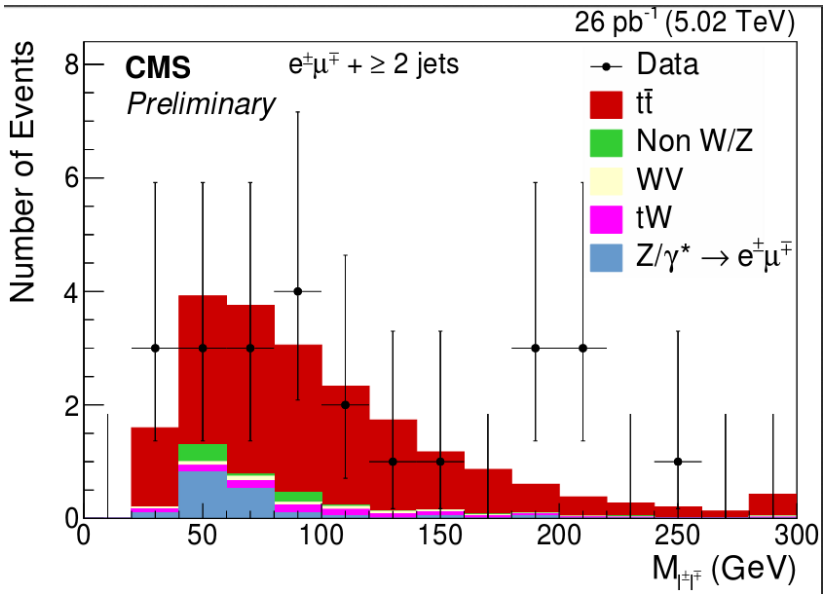
Source	$\Delta\sigma_{t\bar{t}}$ (pb)	$\Delta\sigma_{t\bar{t}}/\sigma_{t\bar{t}}$ (%)
Data statistics	8.3	1.0
Trigger efficiencies	9.7	1.2
Lepton efficiencies	18.4	2.3
Lepton energy scale	0.3	0.04
Jet energy scale	17.0	2.2
Jet energy resolution	0.8	0.1
b tagging	11.0	1.4
Mistagging	0.5	0.06
Pileup	1.5	0.2
Single top quark	11.8	1.5
VV	0.4	0.06
Drell–Yan	0.3	0.04
Non-W/Z leptons	2.7	0.3
$t\bar{t}$ V	0.8	0.1
PDF	4.8	0.6
Scale (μ_F and μ_R)	0.8	0.1
Parton shower scale	6.4	0.8
$t\bar{t}$ NLO generator	16.8	2.1
$t\bar{t}$ hadronization	10.2	1.3
Total systematic (no integrated luminosity)	38.0	4.8
Integrated luminosity	21.4	2.7
Total	44.4	5.6



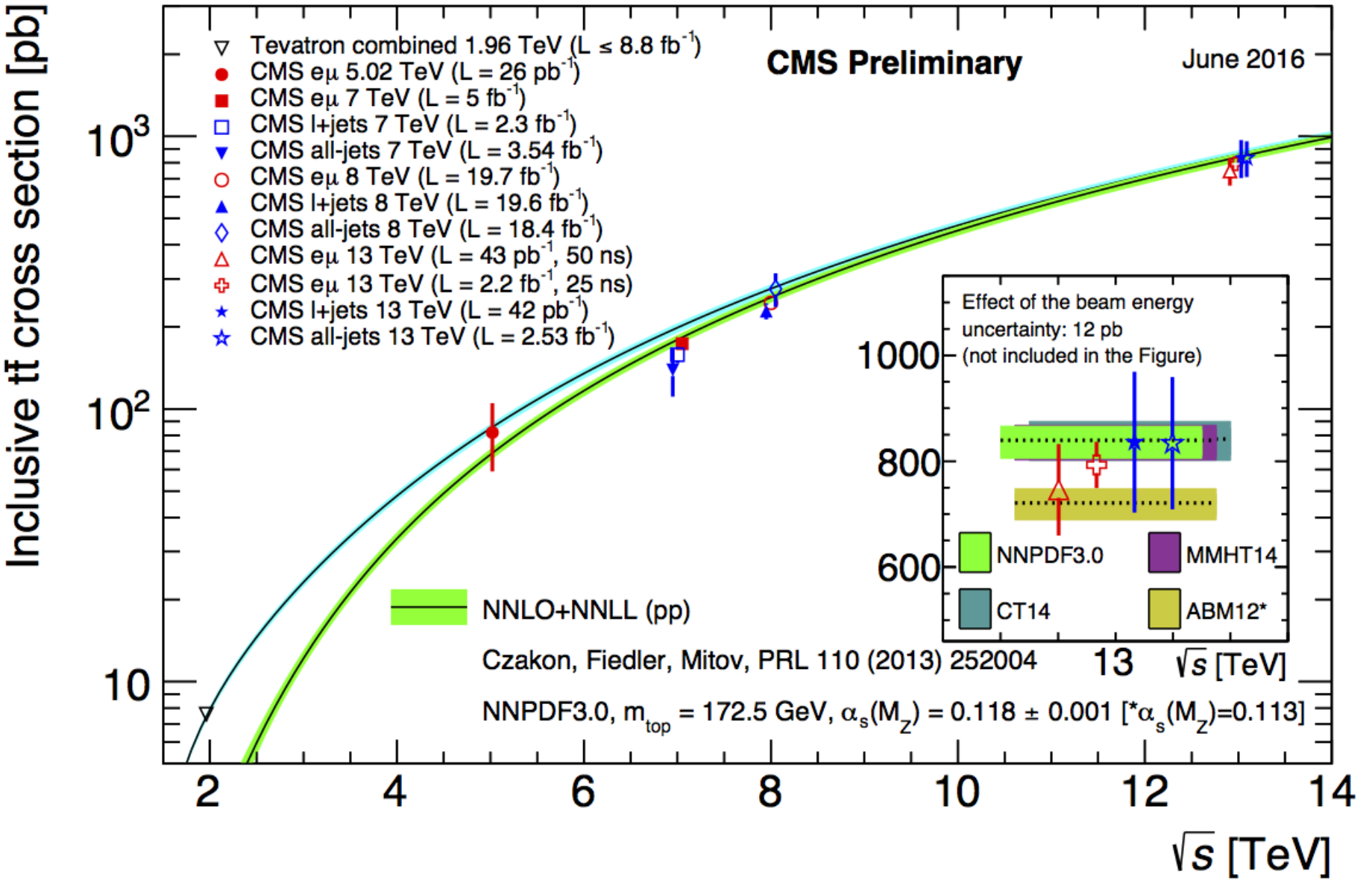


Last (and first) results at 5 TeV

CMS-PAS-TOP-16-015 , cds.cern.ch/record/2161499 (26 pb^{-1})

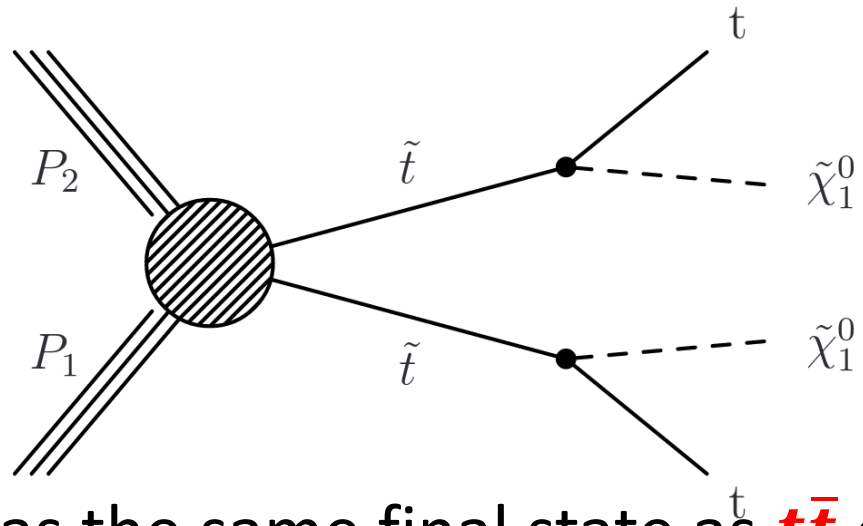


Source	$\Delta\sigma_{t\bar{t}}$ (pb)	$\Delta\sigma_{t\bar{t}}/\sigma_{t\bar{t}}$ (%)
Electron efficiencies	1.1	1.4
Muon efficiencies	2.4	3.0
Jet energy scale	1.1	1.3
Jet energy resolution	0.05	0.06
QCD scales of $t\bar{t}$ signal (PS)	1.0	1.2
QCD scales of $t\bar{t}$ signal (ME)	0.2	0.2
Hadronization model of $t\bar{t}$ signal	1.0	1.2
PDF	0.4	0.5
MC statistics	1.2	1.4
tW background	1.1	1.3
WV background	0.5	0.6
DY background	2.1	2.6
Non W/Z background	1.9	2.3
Total systematic (w/o luminosity)	4.6	5.6
Integrated luminosity	9.8	12
Statistical uncertainty	20	24
Total	23	28


Inclusive tt̄ cross section [pb]
CMS Preliminary
June 2016
Tevatron combined 1.96 TeV (L ≤ 8.8 fb-1)
CMS eμ 5.02 TeV (L = 26 pb-1)
CMS eμ 7 TeV (L = 5 fb-1)
CMS l+jets 7 TeV (L = 2.3 fb-1)
CMS all-jets 7 TeV (L = 3.54 fb-1)
CMS eμ 8 TeV (L = 19.7 fb-1)
CMS l+jets 8 TeV (L = 19.6 fb-1)
CMS all-jets 8 TeV (L = 18.4 fb-1)
CMS eμ 13 TeV (L = 43 pb-1, 50 ns)
CMS eμ 13 TeV (L = 2.2 fb-1, 25 ns)
CMS l+jets 13 TeV (L = 42 pb-1)
CMS all-jets 13 TeV (L = 2.53 fb-1)
Effect of the beam energy uncertainty: 12 pb (not included in the Figure)
NNPDF3.0
MMHT14
CT14
ABM12*
NNLO+NNLL (pp)
Czakon, Fiedler, Mitov, PRL 110 (2013) 252004
NNPDF3.0, m_top = 172.5 GeV, α_s(M_Z) = 0.118 ± 0.001 [*α_s(M_Z)=0.113]
√s [TeV]

Indirect stop search

- In MSSM **top squarks** are produced in pairs and decay into a **top** and a **neutralino**

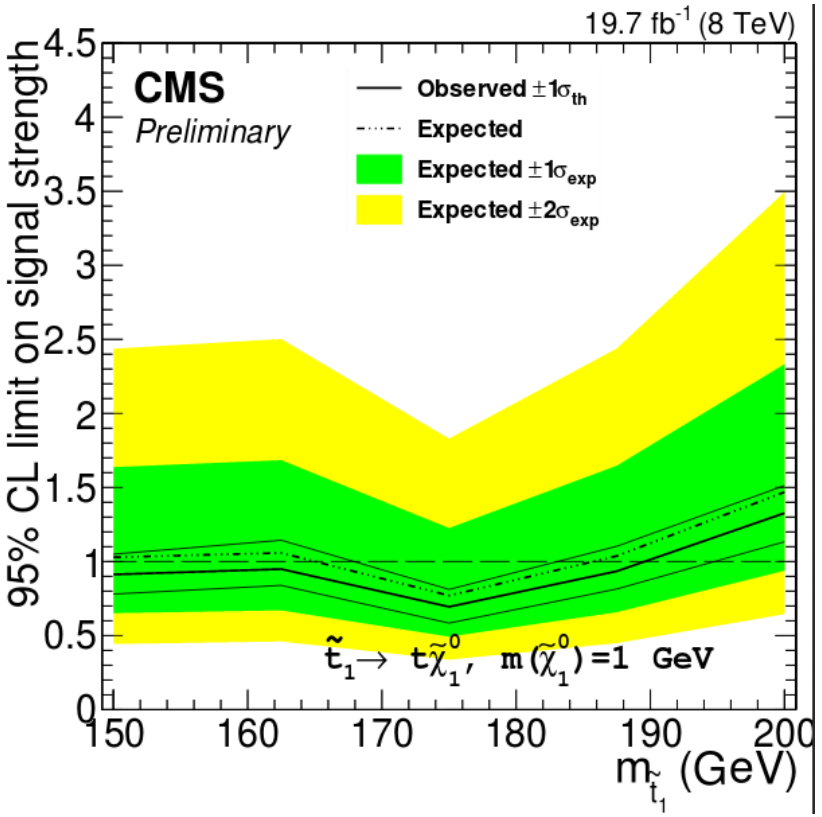


- This process has the same final state as $t\bar{t}$ except for the presence of the **neutralinos**
- The kinematics of the process depends on the difference between the **masses** of **stop** and **neutralino**

Indirect stop search

- When $M_{\tilde{t}} - M_{\tilde{\chi}_1^0} \simeq M_t$ the kinematics of **stop pair** production are very similar to $t\bar{t}$
- In this case, the supersymmetric process can only be detected as an excess in the $t\bar{t}$ cross section

- This indirect search was done at **8 TeV** and will be performed at **13 TeV** with a much larger integrated **luminosity**
- The **production cross sections are much higher** at 13 TeV: better sensitivity!



Summary

- Top pair production cross section will always be a fundamental process in LHC physics.
- The latest measurements at 5 and 13 TeV by CMS are going to be published soon (next weeks/months...).
- With more integrated lumi larger masses of SUSY particles will be tested in a region where other searches are not sensitive.

BACK UP

DY estimate

- **Distributions are taken from MC** and **normalized using data** inside the Z peak in same-flavour channels
- We calculate a normalizarion for ee and μμ channels and **extrapolate to the eμ channel**
- The scale factor is always near to 1

NonW/Z estimate

- We take the **events in the same sign (SS) region** in data and **substract** the estimate prompt SS events from MC (**WZ, ttW...)**
- We **extrapolate** that result **into the opposite sign (OS) region** by multiplying by the **ratio** between number of events with **fake leptons in OS and SS regions**, estimated from MC (mainly from W+Jets and semileptonic tt)