Top quarks and tau leptons

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LIP, CMS

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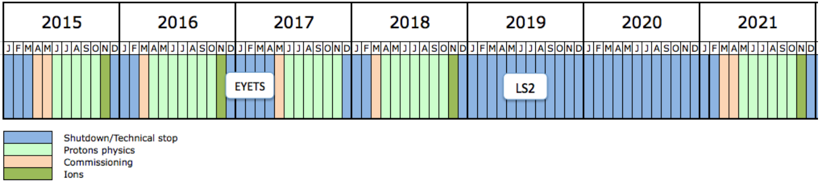
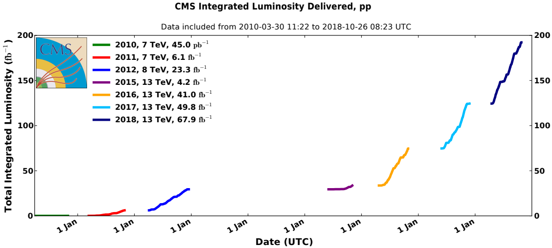
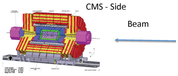
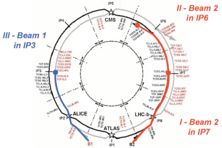
CMS detector, available data



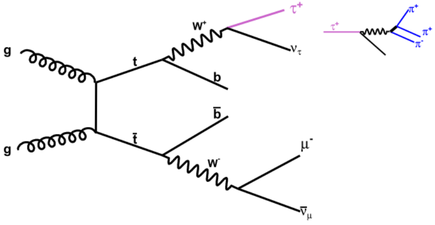






The LHC schedule and the data collected by CMS in Run1 (30 fb^{-1}) and Run2 (162 fb^{-1}).

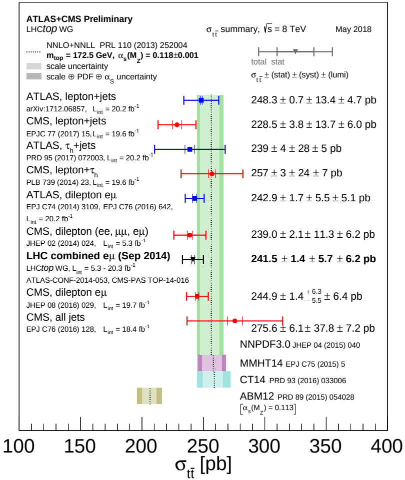
Top quark pair production in lepton+tau final state



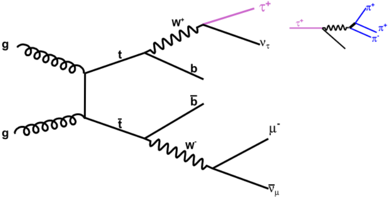
Motivation:

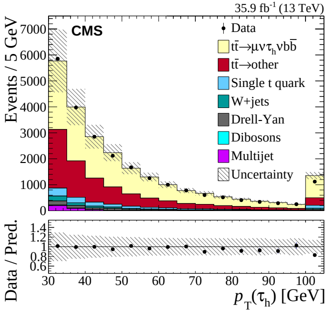
- a measurement in $t\bar{t} \to b\bar{b}l\tau$ channel at 13TeV
- improved systematic uncertainties
- a spin-off measurement with the ratio to dilepton channel

This work comprises my PhD thesis, to be submitted at the end of March.



Features of $t\bar{t} \to b\bar{b}\ell\tau\nu_\ell\nu_\tau$ channel, measurement method





Many particular final products:

- 2 b-jets (displaced vertex of jet)
- 1 lepton (muon or electron)
- 2 neutrinos
- 1 hadronicaly decaying tau lepton

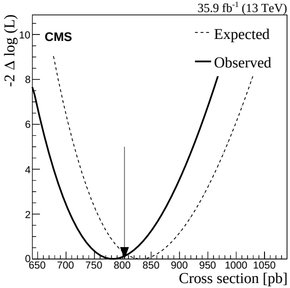
- select events with ID algorithms for all the final state objects
- the main background is from the misidentified τ_h in $t\bar{t} \to b\bar{b}\ell\nu_\ell q\bar{q}$

The background of misidentified τ_h

- distinguish misidentified τ_h per the physical process of origin
- use tau-independent parameters:
  - the m_W and m_t constraint in the kinematics of jets
  - the shape of $m_\mathrm{T}(\vec{p}^{\ell}, \vec{p}_\mathrm{T}^{miss}) = \sqrt{2|\vec{p}_\mathrm{T}^{\ell}||\vec{p}_\mathrm{T}^{miss}|(1 - \cos\Delta\varphi)}$ distribution
- both methods constrain the background and cross-check each other

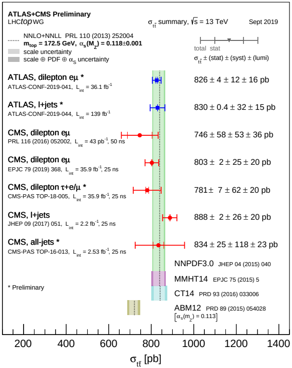
then:

- template distributions from the simulation and a data-driven estimation of QCD
- a Profile Likelihood Ratio fit is performed to the binned distributions



Results

- measured values:
  the production cross section and the partial width of the $t \to b\tau\nu_\tau$ decay
- first measurement in this channel @13TeV
- improved precision over Run1 and other measurements ($10\% \to 7\%$)
- the remaining uncertainty is mainly due to τ_h ID — a further improvement requires a different analysis strategy, with different goals (next slides)
- the paper has been accepted by JHEP (1911.13204)



$$\sigma_{t\bar{t}}(\ell\tau) = 781 \pm 7 \pm 62 \pm 20\mathrm{pb}$$

Lepton universality in W decays, motivation

$\Gamma(\tau^+\nu)/\Gamma(e^+\nu)$ Γ_4/Γ_2

VALUE	EVTS	DOCUMENT ID		TECN	COMMENT
1.043±0.024 OUR AVERAGE					
1.063±0.027		SCHAEL	13A	LEP	E^{ee}_{cm}= 130–209 GeV
0.961±0.061	980	[1] ABBOTT	00D	D0	$E^{p\bar{p}}_{cm}$= 1.8 TeV
0.94 ±0.14	179	[2] ABE	92E	CDF	$E^{p\bar{p}}_{cm}$= 1.8 TeV
1.04 ±0.08 ±0.08	754	[3] ALITTI	92F	UA2	$E^{p\bar{p}}_{cm}$= 630 GeV
1.02 ±0.20 ±0.12	32	ALBAJAR	89	UA1	$E^{p\bar{p}}_{cm}$= 546,630 GeV

$W \to e\nu$	(10.75 ± 0.13) %
$W \to \mu\nu$	(10.57 ± 0.15) %
$W \to \tau\nu$	(11.25 ± 0.20) %

- excess of about 2.5σ in current measurements:
    - performed at LEP in virtual WW channel (not enough energy)
    - relative uncertainty $\approx 2\%$
- similar excess in B physics, in processes with $b \to c\ell^-\overline{\nu}_\ell$ transition
- at LHC:
    - enough energy for on-shell dibosons and $t\bar{t}$
    - current similar measurements lack precision (about 6-10%)
    - with the amount of luminosity we can use a tight selection
- 1910.11783 estimation from ATLAS' S. Dysch and T. R. Wyatt

A feasibility study for lepton universality

- $\frac{\mathcal{B}(W\to\tau)}{\mathcal{B}(W\to\mu)}$ in $t\bar{t}$ final states:
  $\frac{\sigma(\mu\tau_h)}{\sigma(\mu\mu)} = \frac{\mathcal{B}(W\to\tau\to\tau_h)}{\mathcal{B}(W\to\mu)+\mathcal{B}(W\to\tau\to\mu)} = \frac{\frac{\mathcal{B}(W\to\tau)}{\mathcal{B}(W\to\mu)}\mathcal{B}(\tau\to\tau_h)}{1+\frac{\mathcal{B}(W\to\tau)}{\mathcal{B}(W\to\mu)}\mathcal{B}(\tau\to\mu)}$
- constrain τ_{h} ID uncertainty in a double ratio with DY:
  $\frac{t\bar{t}\to\ell\tau_{\mathrm{h}}}{t\bar{t}\to\ell\ell}\frac{DY\to\ell\ell}{DY\to\tau_\ell\tau_{\mathrm{h}}}$
- make a tight cut on τ_{h} ID to select a clean DY and $t\bar{t}$ samples
- current study shows about 3% overall uncertainty in full Run2 dataset with only 1 flavour of leptons
- but it is statistically bound
- a number of optimizations to enhance statistics are being studied

Questions