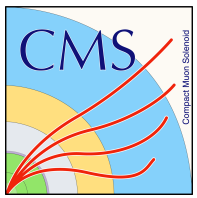
Search for W'$\rightarrow$ l ν production at 13 TeV in CMS

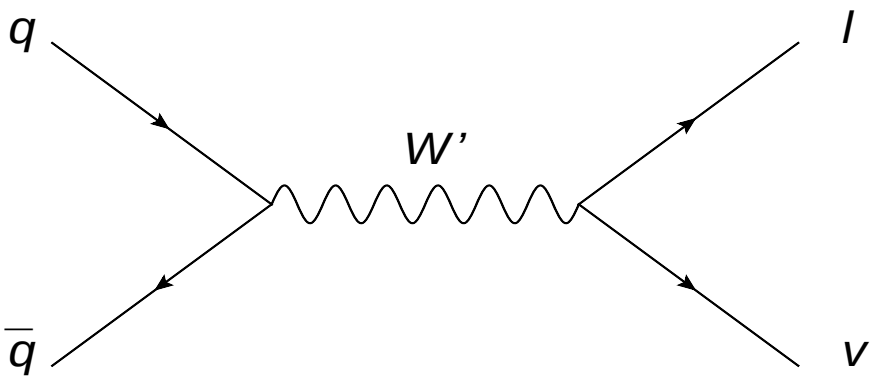
La Thuile 2016, Rencontres de Physique de la Vallée d'Aoste.

Alberto Escalante del Valle on behalf of the CMS Collaboration
CIEMAT



From a theoretical point of view...

Analysis that aims to discover, if exist, a heavy charged object decaying into a lepton+X, where X is something undetected in CMS (neutrino?).

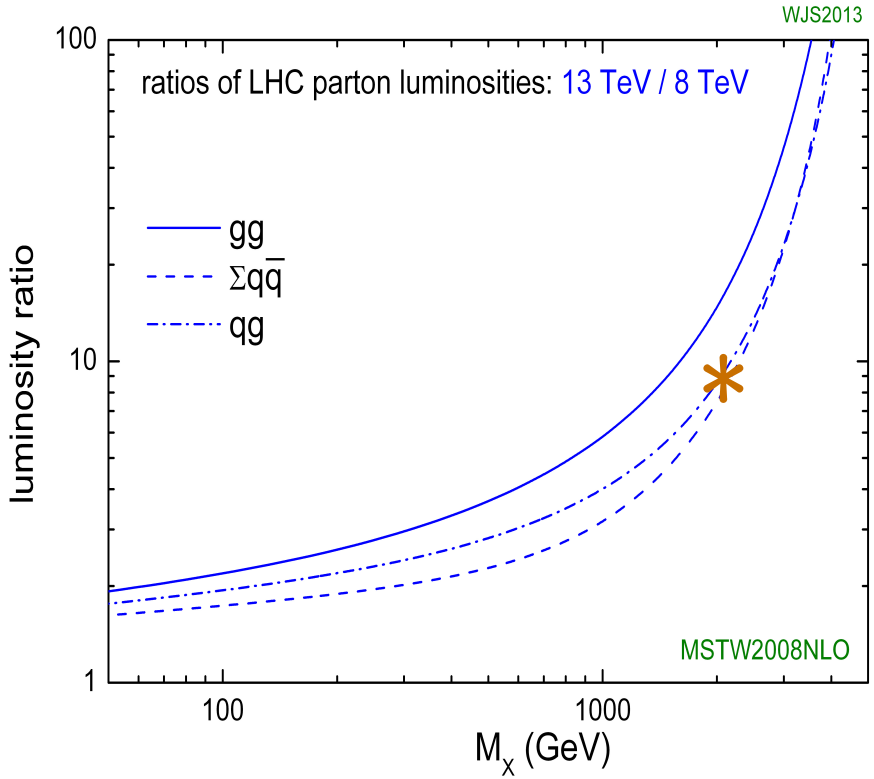


- Many extensions of the SM predict the existence of **additional charged vector bosons**, often called W' bosons.

Final state also sensitive to non-resonant topologies: Contact interaction, dark-matter production or extra-dimensions...

Check out 8 TeV paper: 10.1103/PhysRevD.91.092005

What we could expect with 2.2fb^{-1} at 13 TeV...



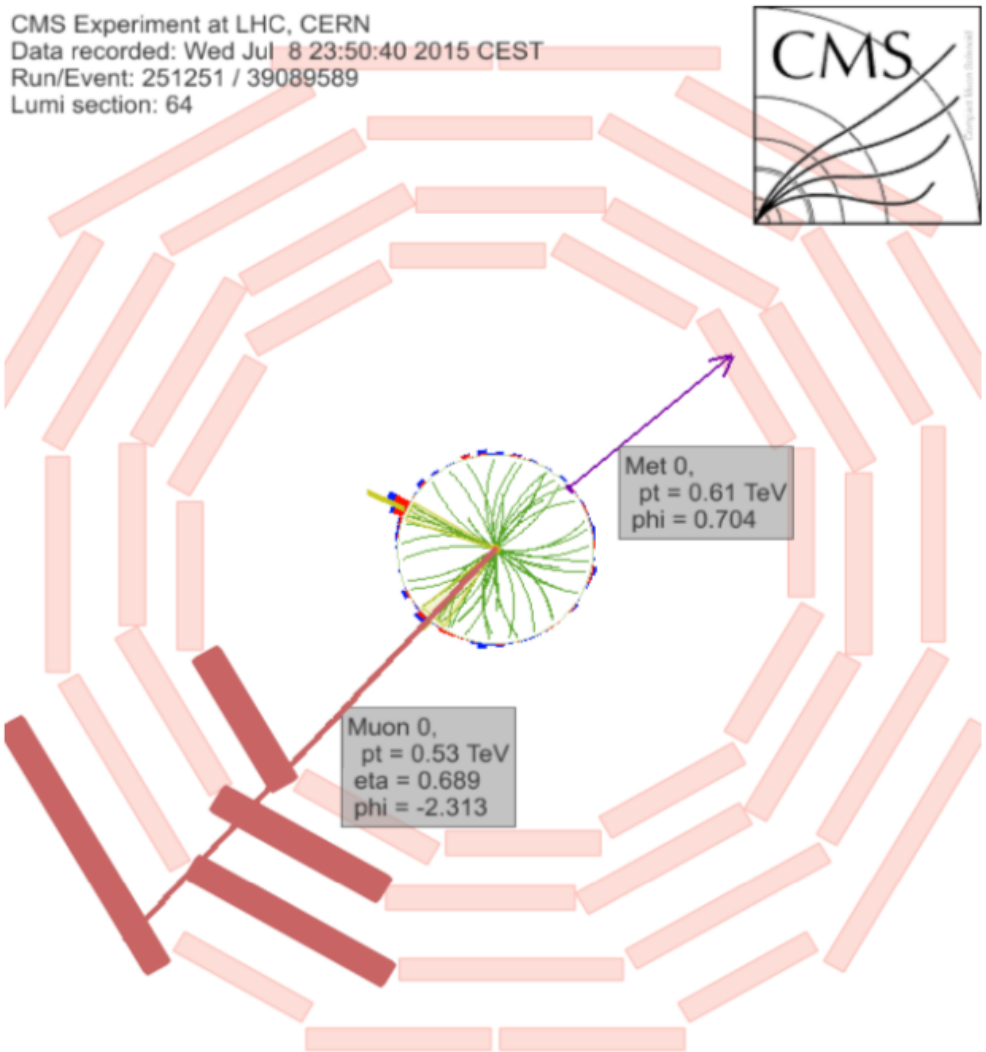
$2.2\ \text{fb}^{-1}$ at 13 TeV vs
$19.7\ \text{fb}^{-1}$ at 8 TeV.

- If they show up at the TeV scale, the increase in cross section at 13 TeV makes their search **already sensitive with the first inverse femtobarn of collected pp collisions...**
- Run I limits at $M_{W'} < 3$ TeV

Searching a heavy cousin of the W ...

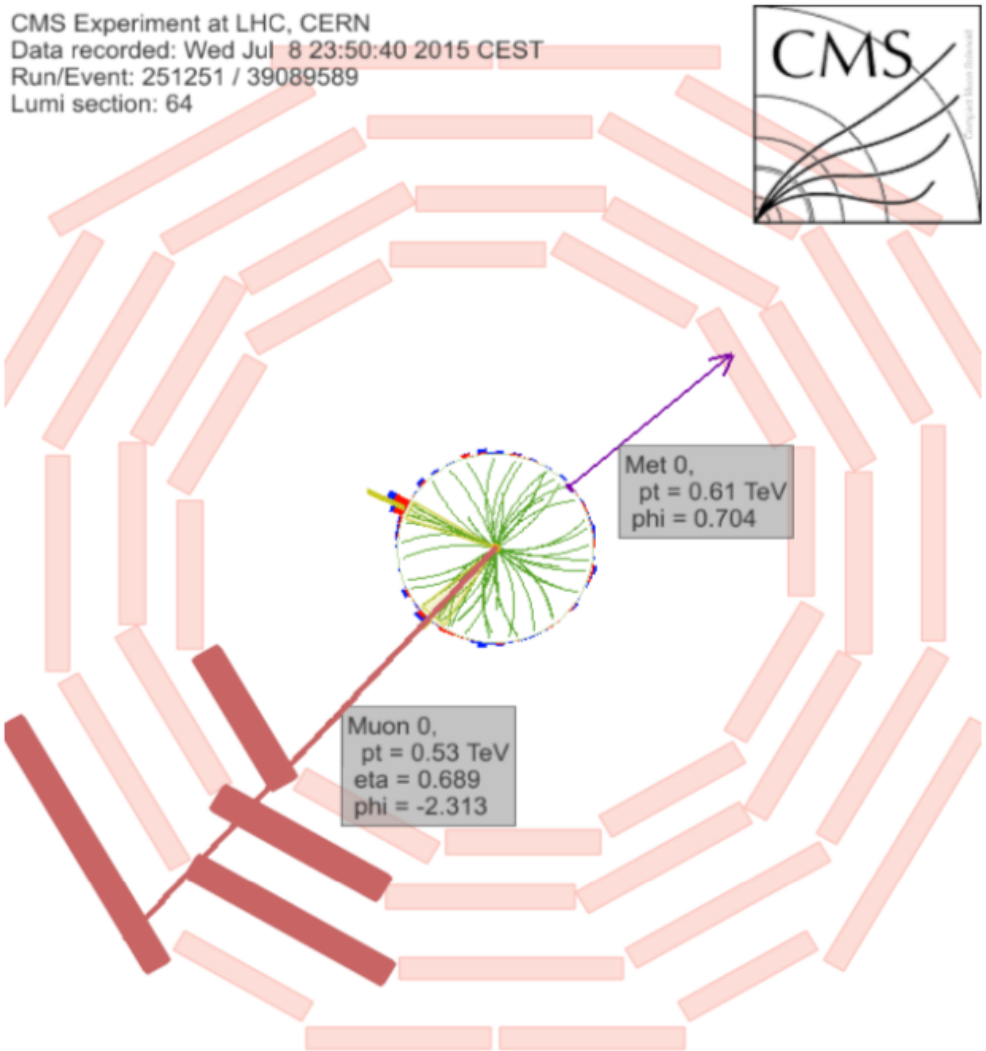
- Signal is a Sequential Standard Model W' (SSM W') from Pythia8.
- W' is a carbon copy of the SM W with same couplings.
- Open up decay to tb but WZ decay suppressed: Br $(W' \to l\nu) = 8\%$.

... From an experimental point of view



Experimentally it is an **extremely clean signature** with just a very high p_T lepton recoiling against "nothing" ($\overrightarrow{E}_T^{miss}$).

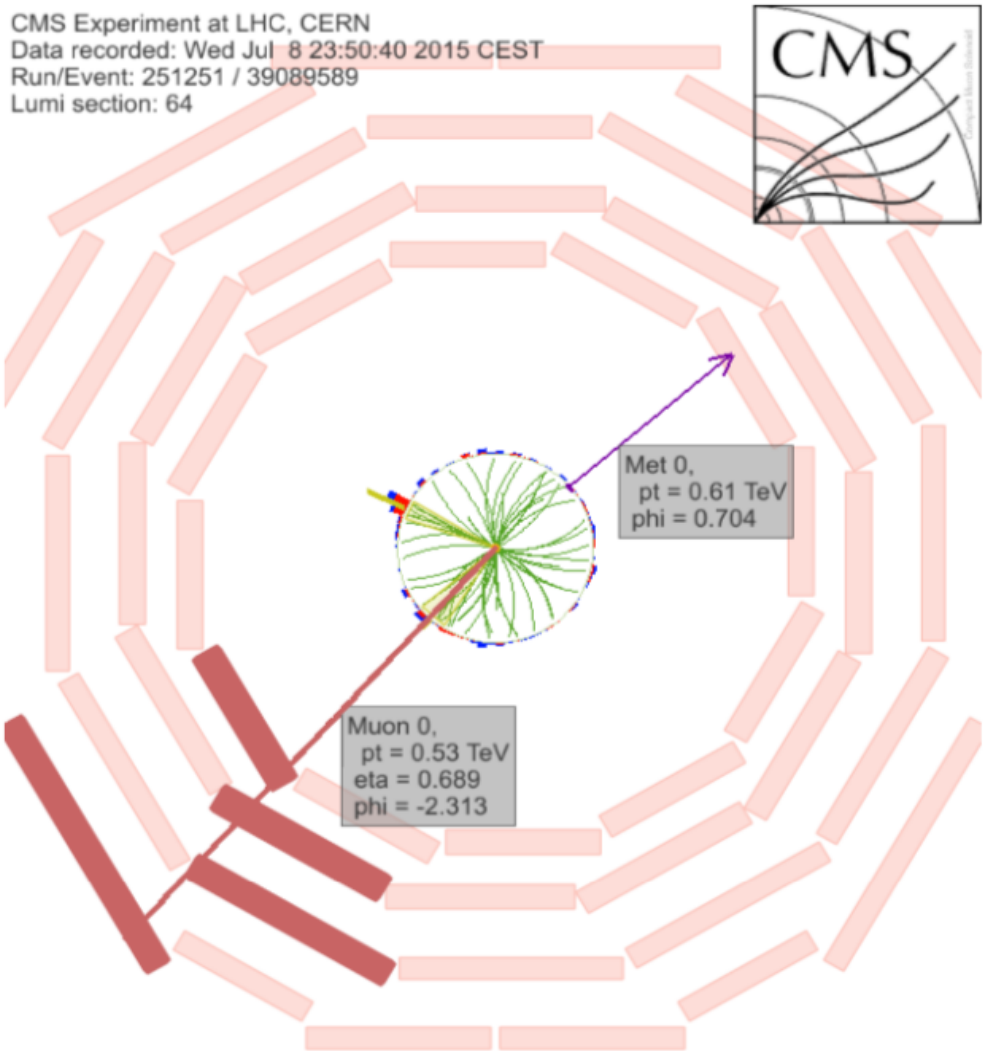
... From an experimental point of view



$\overrightarrow{E}_T^{miss} = -\sum \overrightarrow{p}_T$ sum of all the reconstructed particles in transverse plane...

... At high mass, the $\overrightarrow{E}_T^{miss}$ **is dominated by the lepton "itself"**, $\overrightarrow{E}_T^{miss} \sim -\overrightarrow{p}_T^{l}$.

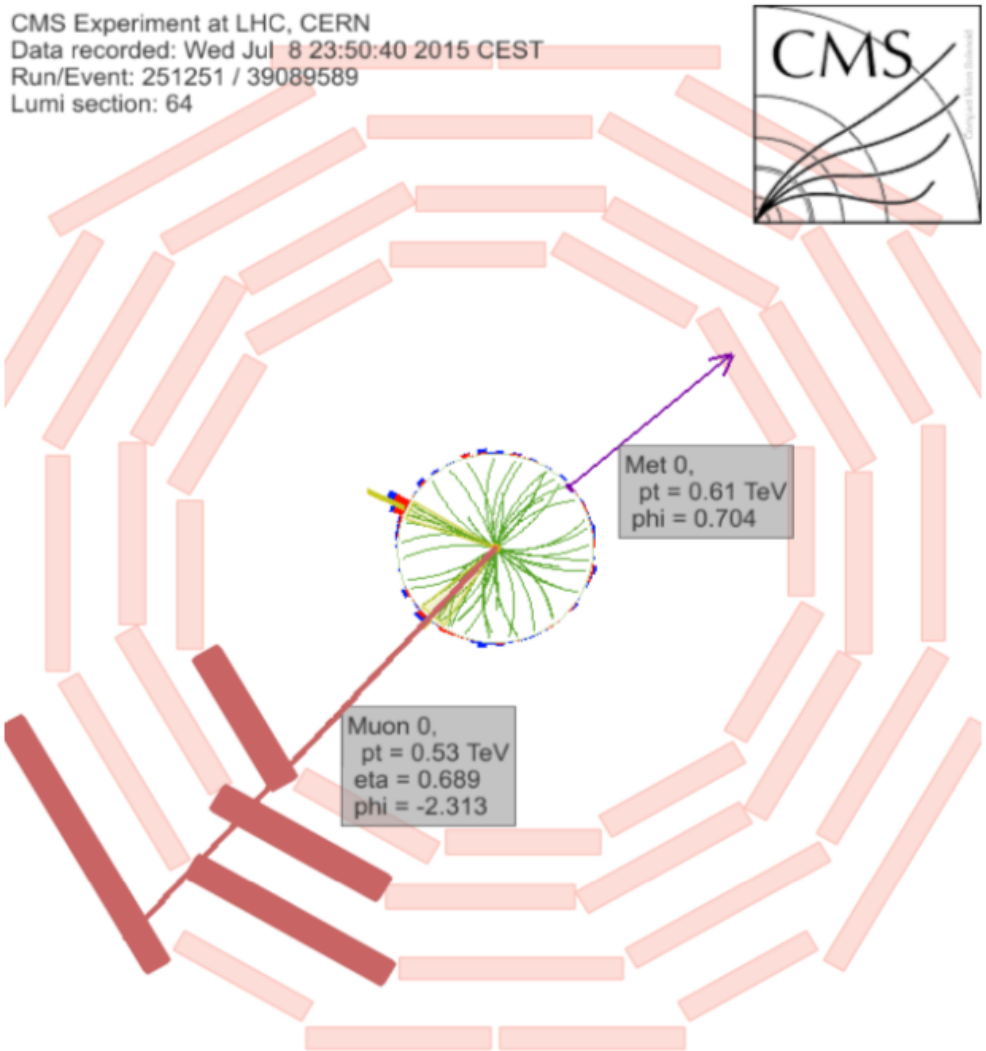
... From an experimental point of view



Unfortunately, **no candle (Z, J/ψ..) at the "TeV" scale where to calibrate the leptons**.

At the TeV scale, it is essentially a **background "free" search....**.

... From an experimental point of view



Some of the highest p_T leptons in CMS!

This makes W' search an excellent analysis to probe the performance of TeV leptons in CMS.

Analysis strategy in a nutshell

Electrons

- Dedicated High E_T identification.
- Electron $E_T > 130$ GeV.
- $|\eta| < 1.444$ or $1.566 < |\eta| < 2.5$

Muons

- Dedicated High p_T identification.
- Muon $p_T > 53$ GeV.
- $|\eta| < 2.0$

High p_t lepton reconstructed and identified in the acceptance.

Common to both channels

- Balanced kinematics:
  - $\Delta\phi(\overrightarrow{p}^{l}_{T}, \overrightarrow{E}^{miss}_{T}) > 2.5\ (0.8\pi)$
  - $0.4 < \frac{p^{l}_{T}}{E^{miss}_{T}} < 1.5$
- Veto events with an additional second lepton.

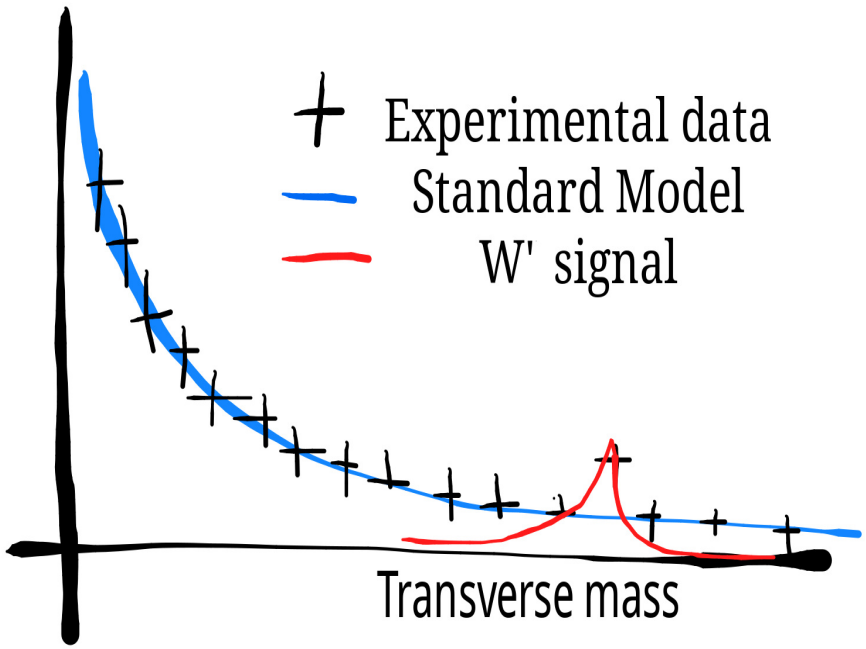
Clean and balanced kinematics in the event

Analysis strategy in a nutshell

After selection, the discriminant variable for the search is the Transverse Mass, M_T that is directly sensitive to the $M_{W'}$.

$$M_T = \sqrt{2p_T^l E_T^{miss}(1 - cos[\Delta\phi(\overrightarrow{p}_T^{\,l}, \overrightarrow{E}_T^{\,miss})])}$$

$\mu + E_T^{miss}$: $M_T > 120$ GeV
$e + E_T^{miss}$: $M_T > 200$ GeV

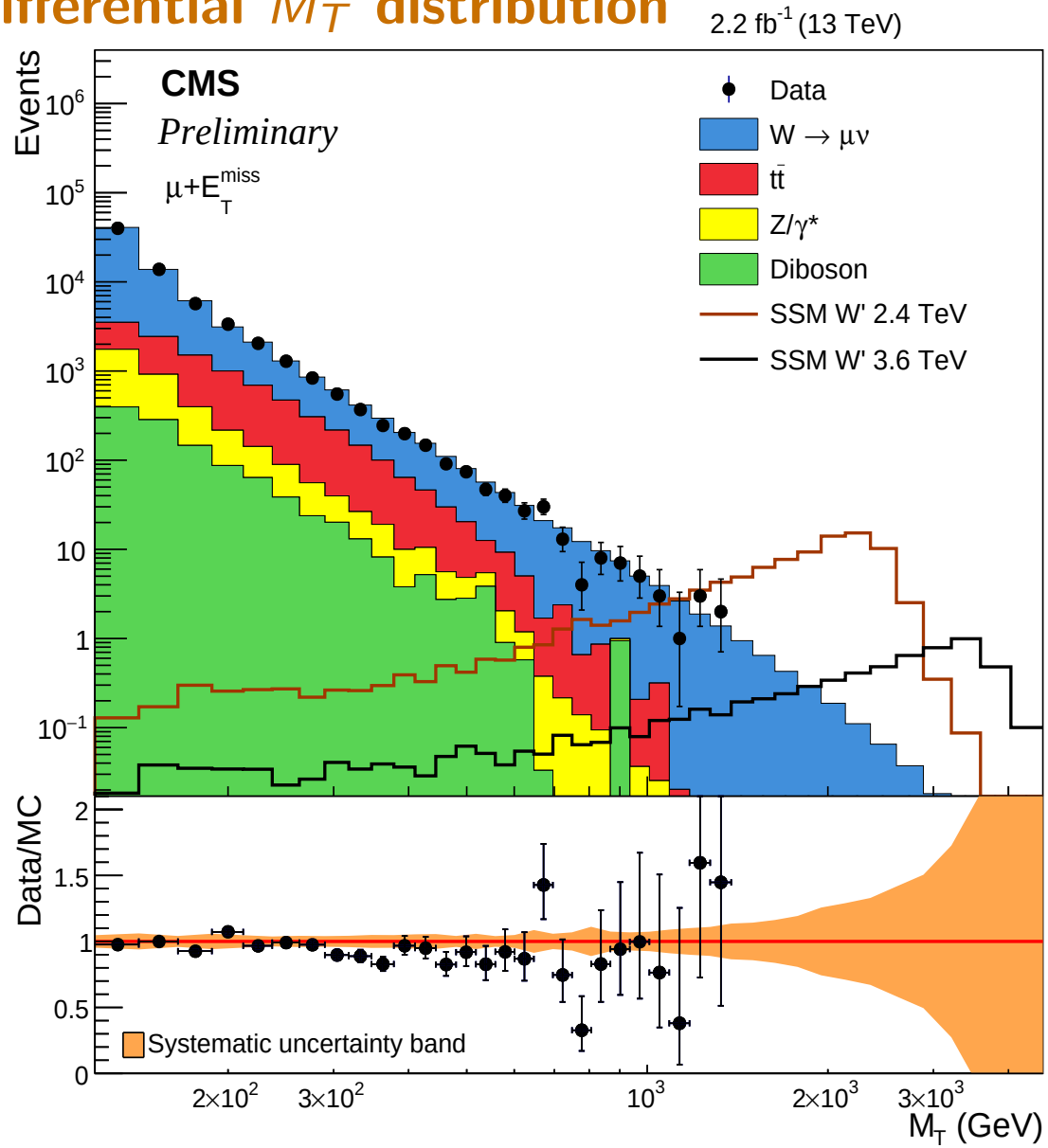


Acceptance x efficiency $\sim 75\%$ for $W' \to l\nu$ of 3 TeV.

Background is SM $W \to l\nu$ taken from simulation

Muon analysis

Differential M_T distribution

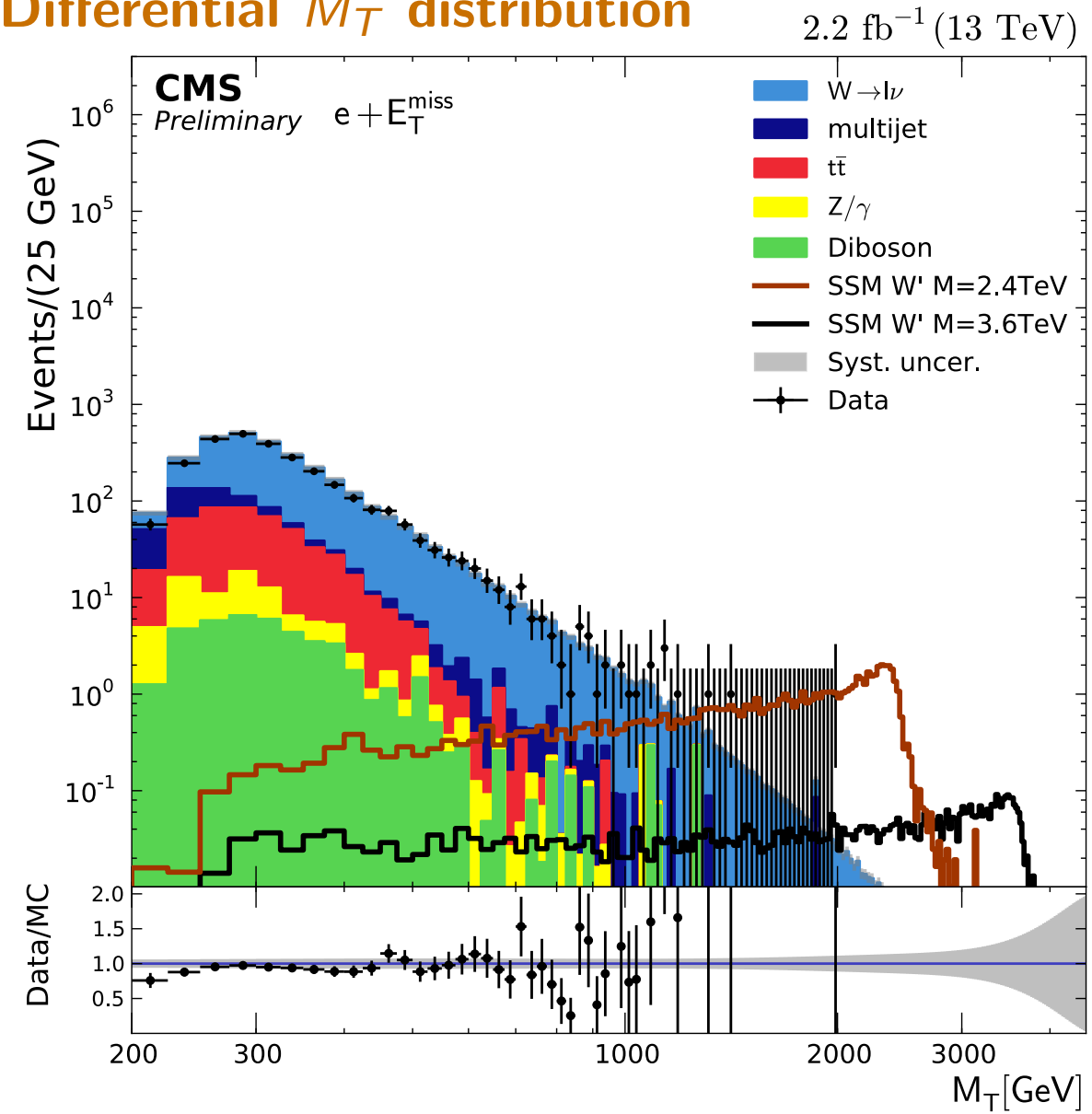


Key points

- Improved muon resolution at high p_T achieved **combining tracker and muon detectors** information.
- Main **systematics are muon scale and resolution evaluated with cosmic muon** that rely on a good detector alignment.

Electron analysis

Differential M_T distribution



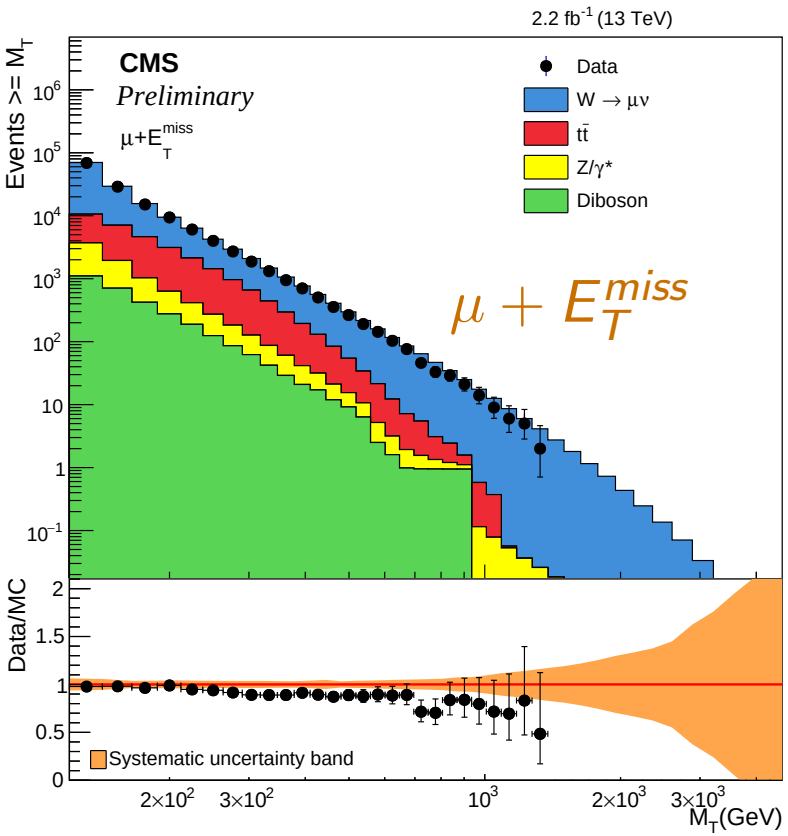
Key points

- **Electron energy measurement driven by calorimeter, great performance at high E_T.**
- **Dominant systematics** concern the modelling of the W background: **PDF uncertainties and higher order corrections.**

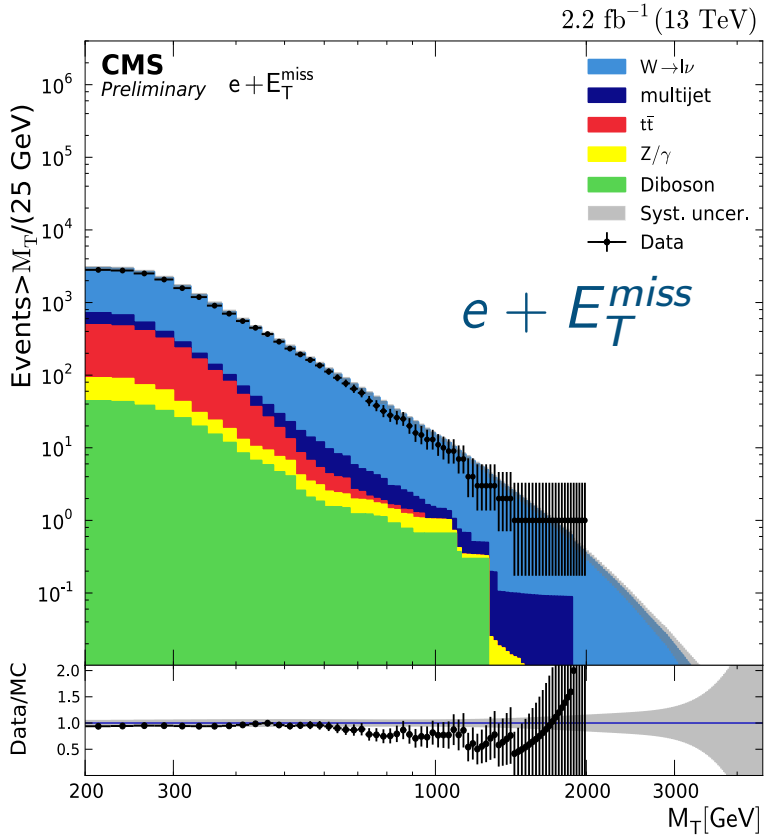
Cumulative distributions: Events >= M_T

M_T[GeV]	>1000	>1500
Data	10	0
SM	13.0±1.2	1.8±0.3

M_T[GeV]	>1000	>1500
Data	11	1
SM	14.3±1.2	1.9±0.2



$\mu + E_T^{miss}$



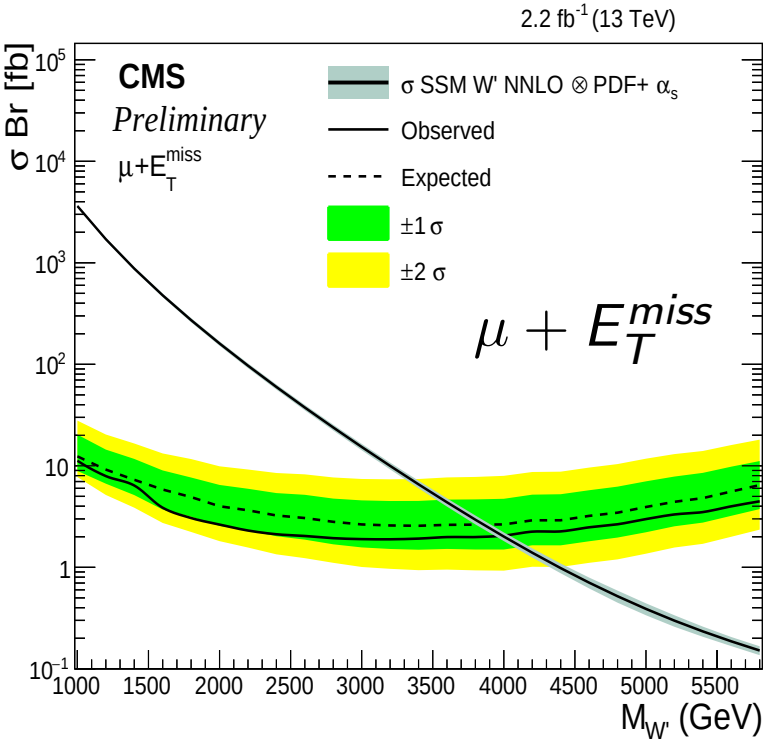
$e + E_T^{miss}$

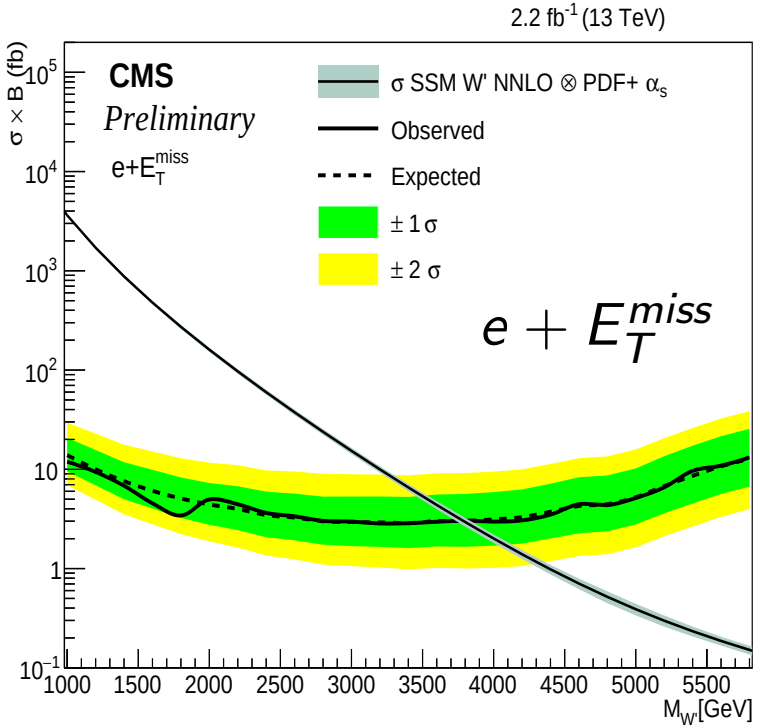
Highest event at M_T = 1.3 TeV.

Highest event at M_T = 2 TeV.

Results at 13 TeV

In the absence of significant deviations with respect to the SM... Upper limits are set to $\sigma_{W'} Br(W' \to l\nu)$ in the context of SSM W'.



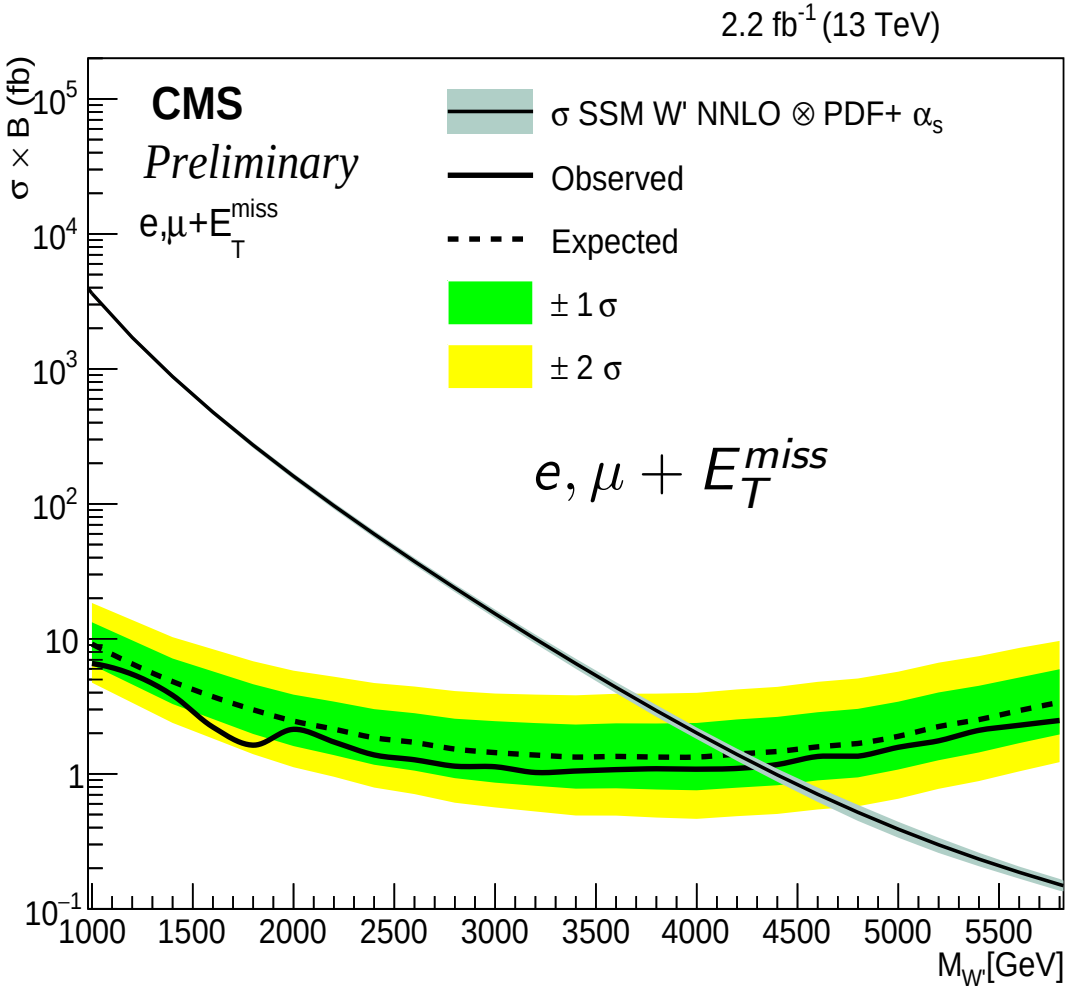


19.7fb^{-1} at 8 TeV vs 2.2fb^{-1} at 13 TeV

$\mu + E_T^{miss}$	Run I	Run II
Expected	3.09 TeV	3.8 TeV
Observed	2.99 TeV	4 TeV

$\mu + E_T^{miss}$	Run I	Run II
Expected	3.18 TeV	3.8 TeV
Observed	3.22 TeV	3.8 TeV

Results at 13 TeV



Combination:

19.7fb^{-1} at 8 TeV vs

2.2fb^{-1} at 13 TeV

$l + E_T^{miss}$	Run I	Run II
Expected	3.26 TeV	4.2 TeV
Observed	3.28 TeV	4.4 TeV

Conclusions

- **No presence of new physics has been found (yet)** in any of the two channels.
- When combined, the limits on the mass **exclusion extend up to 4.4 TeV (expected: 4.2 TeV).**
- These values significantly **improve the results obtained with Run I data.**

Conclusions

- **No presence of new physics has been found (yet)** in any of the two channels.
- When combined, the limits on the mass **exclusion extend up to 4.4 TeV (expected: 4.2 TeV).**
- These values significantly **improve the results obtained with Run I data.**

2015 was the warm up at 13 TeV, in 2016 we will collect enough data ($\sim$ x10) to significantly improve the sensitivity to find a W' on time for La Thuile 2017.

For more information about this analysis, check out:

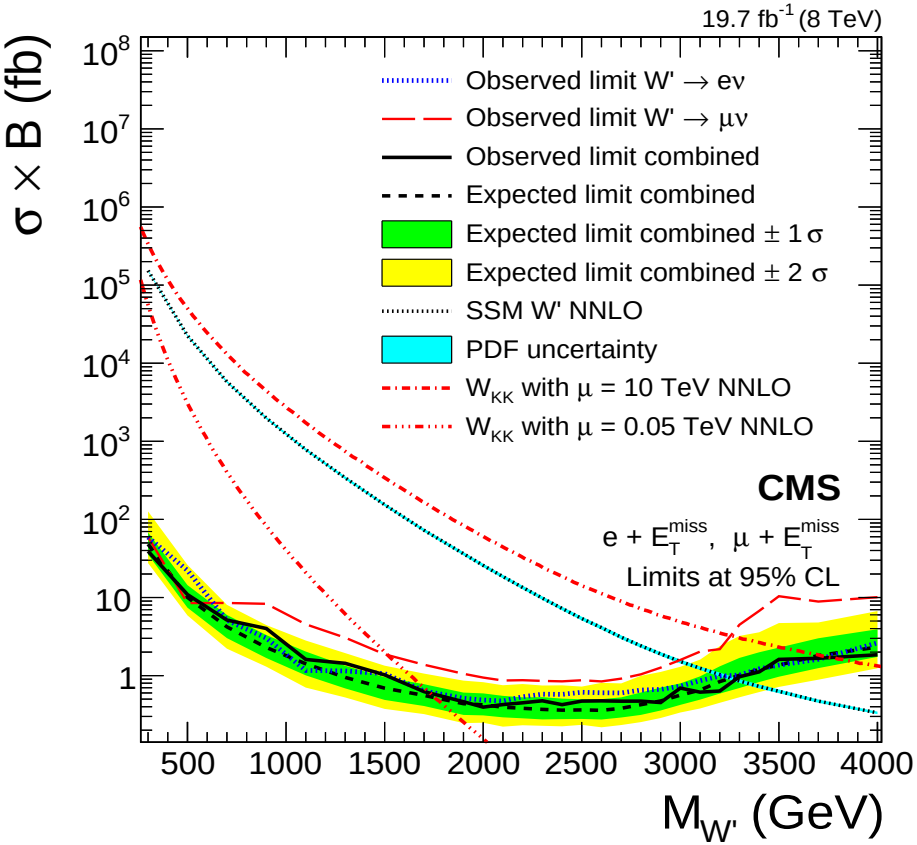
CMS Collaboration, Search for SSM W' production, in the lepton+MET final state at a center-of-mass energy of 13 TeV, **CMS-PAS-EXO-15-006.**

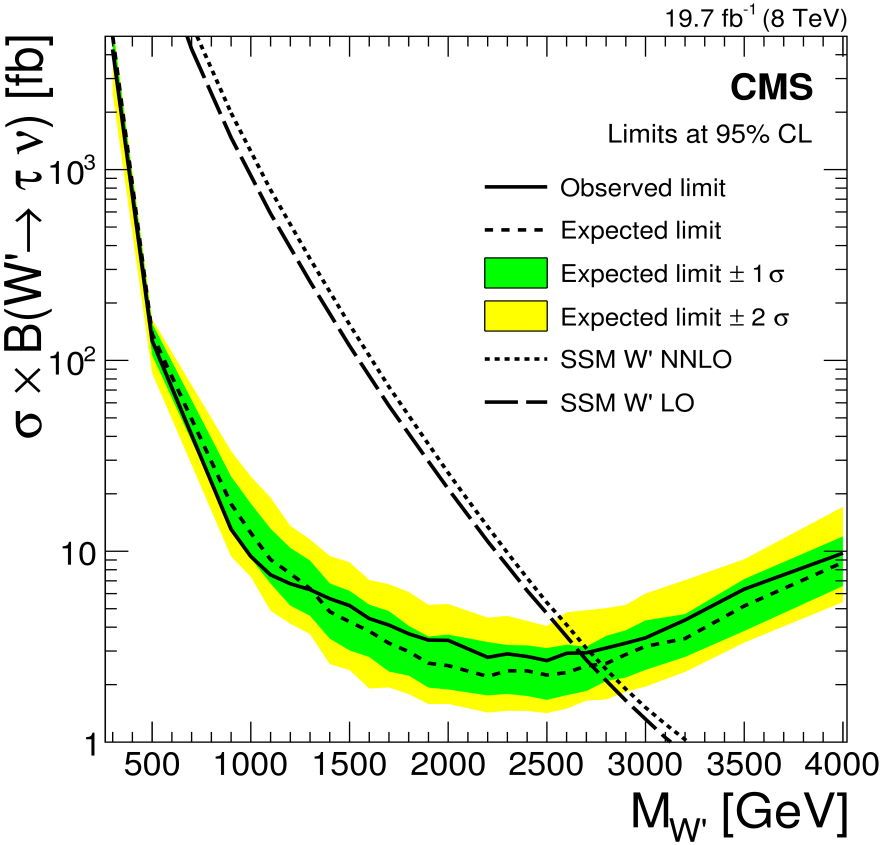
Other material

Additional material.

8 TeV results

From 8 TeV paper: 10.1103/PhysRevD.91.092005
and from : arxiv.org:1508.04308

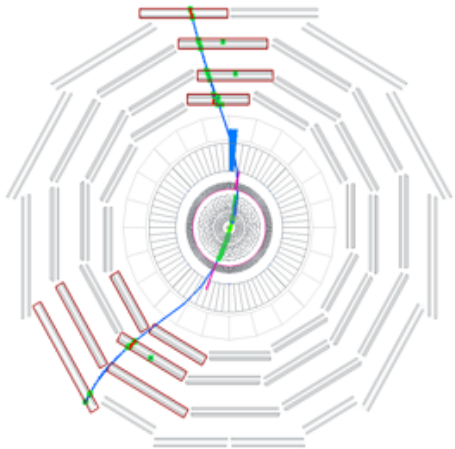




High p_T muons

- For the reconstruction, inner tracker and the outer muon system are used together.
- At least one hit in pixel detector, and at least four layers of strip tracker.
- Segments in two or more muon detector layers, this reduces hadronic punch-trough.
- To reduce cosmic background: $|d_{xy}| \leq 0.02cm$ and $d_z \leq 0.5cm$.
- $\frac{\sigma_{p_T}}{p_T} < 0.30$ to avoid muons with mismeasured p_T.
- Relative tracker isolation less than 10% with respect to muon p_T.
- Muon scale and resolution evaluated with cosmic muons and Drell-Yan events.

Note:
At high p_T the muon curvature is very small, making the alignment a crucial element in the TeV performance.



High E_T electrons (HEEP)

- Reconstructed from electromagnetic cluster in ECAL, matched to a track.
- In order to ensure that is an electron and not a photon, electron candidate has a well matched prompt-track $\eta - \phi$ which has no more that one hit missing in the inner portion of the tracker.
- Energy deposited in the ECAL to be consistent with that of an electron.
- Electron isolation in the tracker is ensured by requiring p_T sum all tracks in a ΔR =0.3 cone from the Primary Vertex to be less than 5 GeV.
- Sum of energy in the HCAL in a ΔR =0.15 cone centered in the electron candidate to be less that 5% of the electron energy.

Systematics (I)

Muons:

- Muon momentum scale, consider a possible scale bias of $0.1c/TeV$ in barrel and $0.2c/TeV$ in endcaps in simulation, those values are estimated from cosmic muons and Drell-Yan events.
- Muon momentum resolution, additional Gaussian smearing of 80% of the p_T resolution applied to the simulations.
- 3%-8% uncertainty in muon trigger, reconstruction, identification and isolation efficiencies in simulation, evaluated with the Tag and Probe method.

Systematics (II)

Electron:

- Electron energy scale, 2% uncertainty, evaluated with Drell-Yan events.
- Electron resolution, additional smearing of 2% is applied to the simulation.
- Uncertainties on the electron and positron identification efficiencies when extrapolated to high E_T are 4% (6%) in the barrel (endcaps).
- Uncertainties in the electron trigger are 0.2% (0.5%) for barrel (endcaps).

Systematics (III)

Common to both channels:

- Luminosity 4.6% uncertainty in the central value.
- 5% uncertainty in minimum bias cross section used in the pile up re weight in simulation.
- 5% due to higher order corrections in W simulation: NNLO QCD from FEWZ and NLO EW corrections from MCSANC.
- PDF uncertainties from latest PDF4LHC recommendation, 2% - 20%, depending on the mass.