PROSPECTS FOR A HIGH PRECISION MEASUREMENT OF THE W MASS WITH THE CMS DETECTOR

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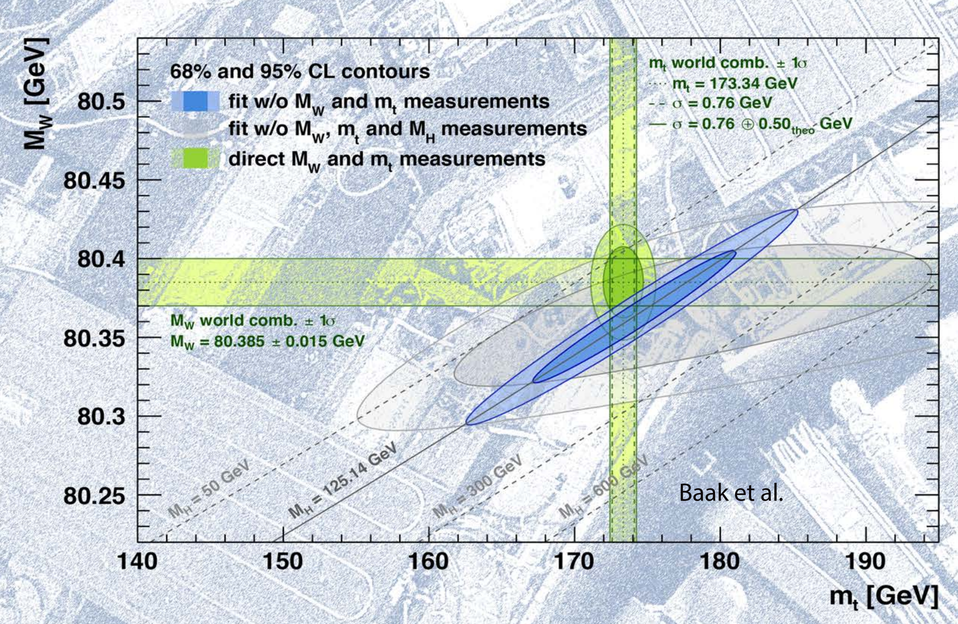
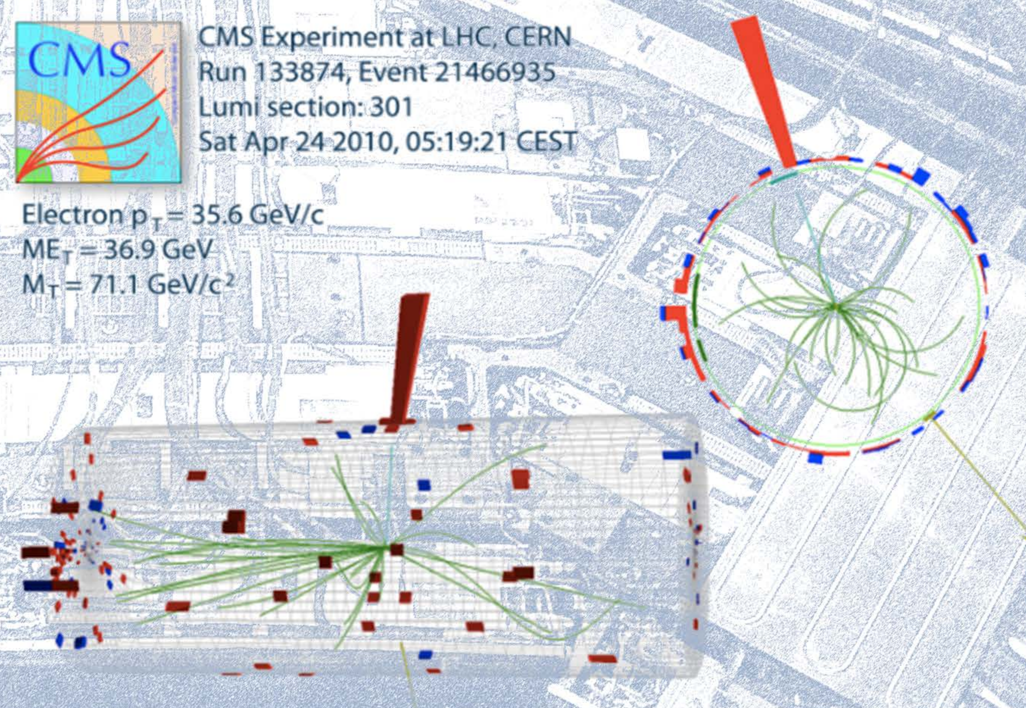
Testing the Standard Model at a new level of precision

After the discovery of the Higgs boson all the parameters of the Standard Model have been measured and therefore it is possible to exploit the predictive power of the theory to set more stringent limits to known observables.
The precision with which the W mass is predicted (8 MeV) almost doubles the precision on the world averaged measured value (15 MeV). For this reason, a measurement of the W mass with an accuracy of 10 MeV provides a crucial test of internal consistency of the Standard Model.

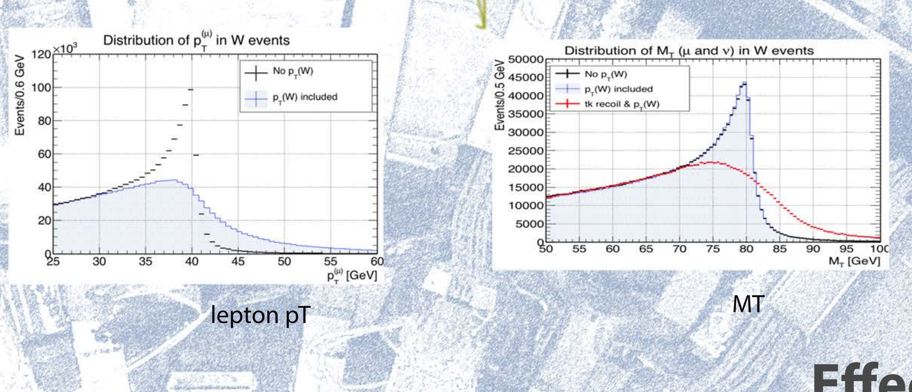
The plot below shows a scan of the confidence level profile of the W mass vs the top mass for the scenario where the Higgs mass is included in the fit (blue) or not (grey). Both contours agree with the direct measurement (green bands and ellipse) but it is clear that a shrinkage of the error band of the W mass could reveal a slight disagreement.





In CMS a W boson is produced through the annihilation of a quark and an anti-quark from proton-proton collisions.
Among all produced Ws, we select those decaying to a lepton and its associated neutrino.

This event display shows an example of a W event that we analyse. The lepton leaves a clear signature in the detector while the neutrino can not be detected: the kynematics of these events can not be closed and the analysis must be performed using templates of observables in the transverse plane for different mass hypotheses produced with the Montecarlo simulation.

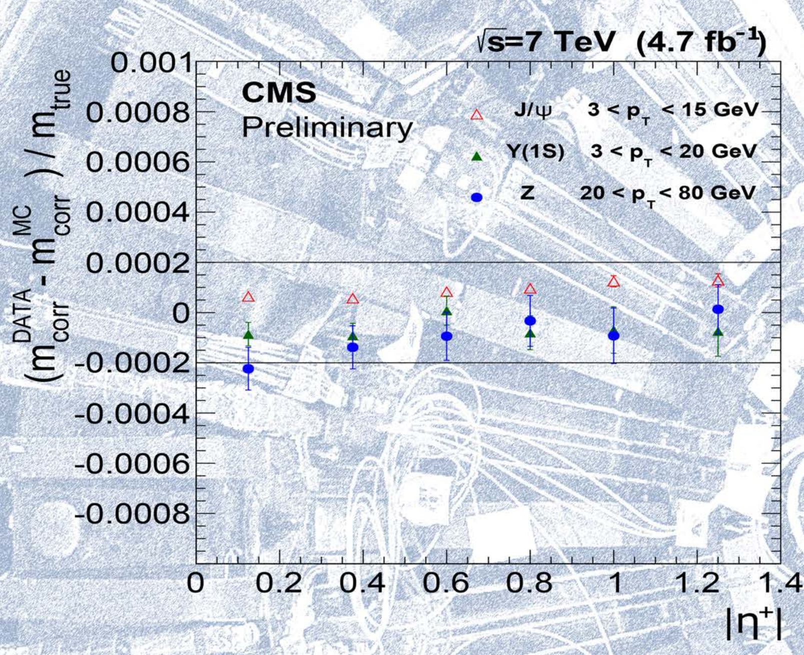


The templates are fitted to the data with a likelihood scan in the mass value. To obtain a measurement of the W mass at a precision of 10 MeV, the templates must be measured at a level of 0.1 per mil. This implies an accurate control of the theoretical and experimental systematics.

Pushing the detector to the edge of its limits

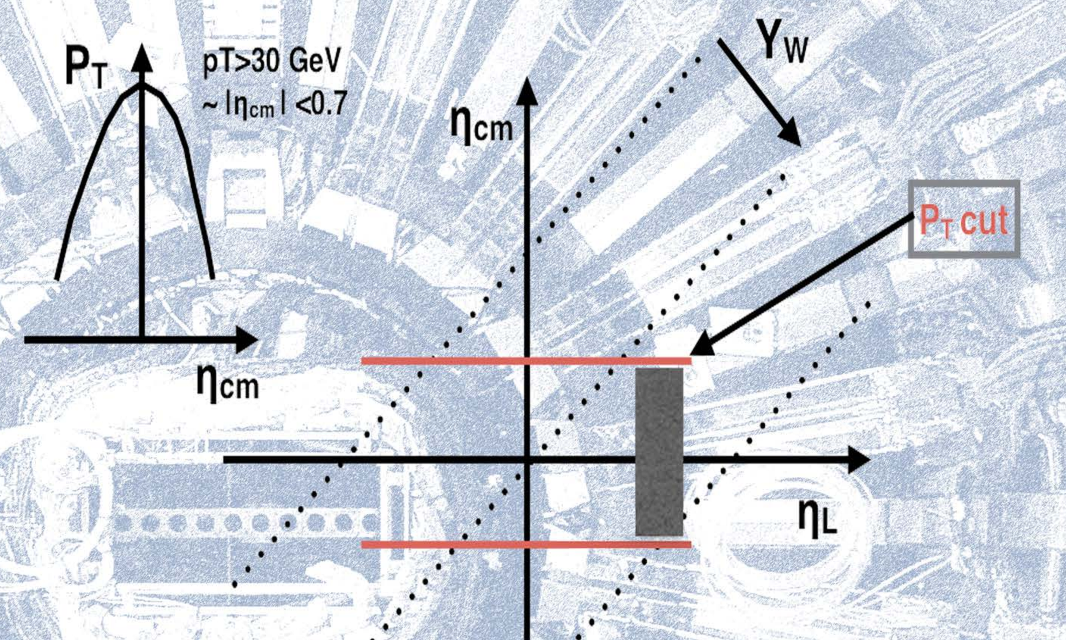
The key experimental ingredient for the measurement is the precise lepton momentum scale calibration. In the past years CMS has started an effort to measure the muon momentum scale to the level of 0.1 per mil.

This implies an outstanding understanding of the tracking system and in particular the magnetic field, the alignment of the silicon modules and the material of the detector.
Another important quantity to control is the muon momentum resolution, which is currently measured in CMS at the percent level.



The muon scale calibration in CMS is currently at the level of 0.2 per mil, which propagates to the W mass as 10 MeV.

Effects due to the production mechanism



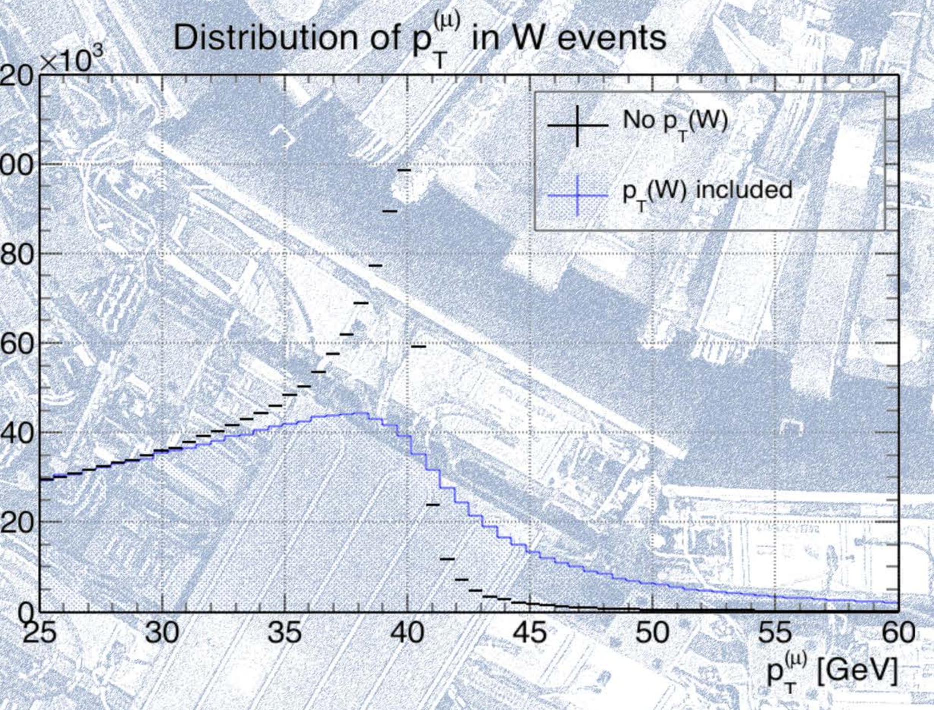
The pT and MT spectra are sensitive to the parton distribution functions of the colliding quarks through the acceptance cut on the lepton pseudorapidity. This cut can not be avoided since the CMS detector does not cover the full solid angle.

The sketch on the left shows this concept. When cutting in the acceptance, we lose a certain amount of events that depend on the unknown rapidity distribution and on the unknown W polarisation. This causes the mean value of the pT spectrum to depend on the production mechanism.
This effect can be mitigated adjusting the fitting range or exploiting new fitting procedures.

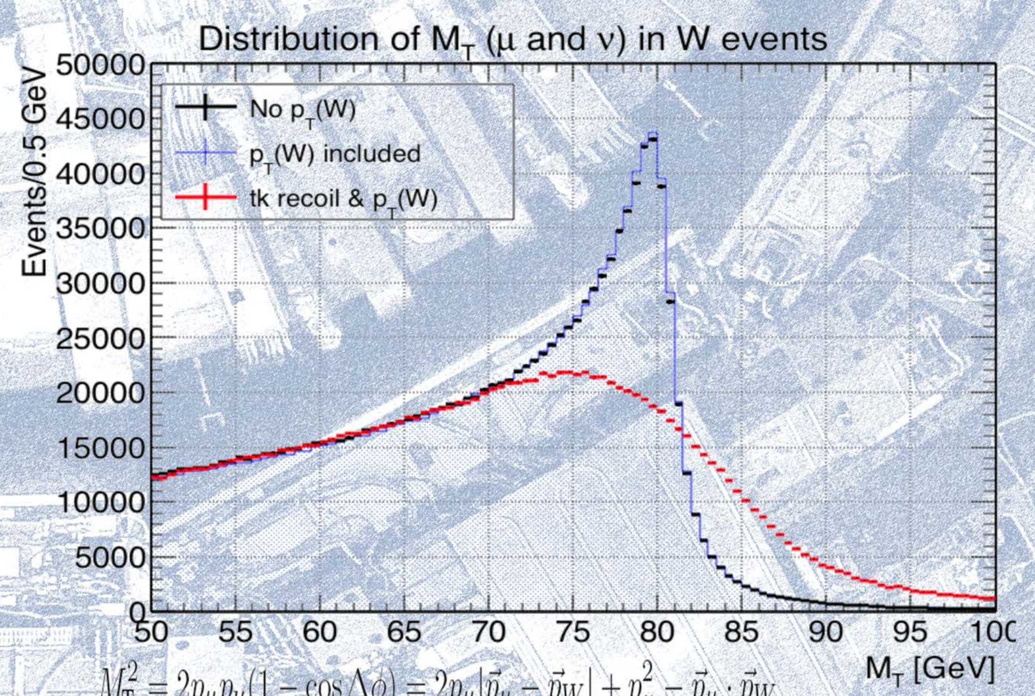
Which template to fit: an interplay of theoretical and experimental inputs

The spectrum of the lepton transverse momentum and of the transverse mass are both sensitive to the W mass through the jacobian edge.
However, in both cases the peak is smeared for reasons of different nature:

The edge of the lepton transverse momentum spectrum is smeared by the transverse momentum of the W boson.
This can not be measured because the neutrino is undetected and it must be predicted theoretically. However this is a very difficult task since it involves effects of non-perturbative QCD.



theoretically more difficult



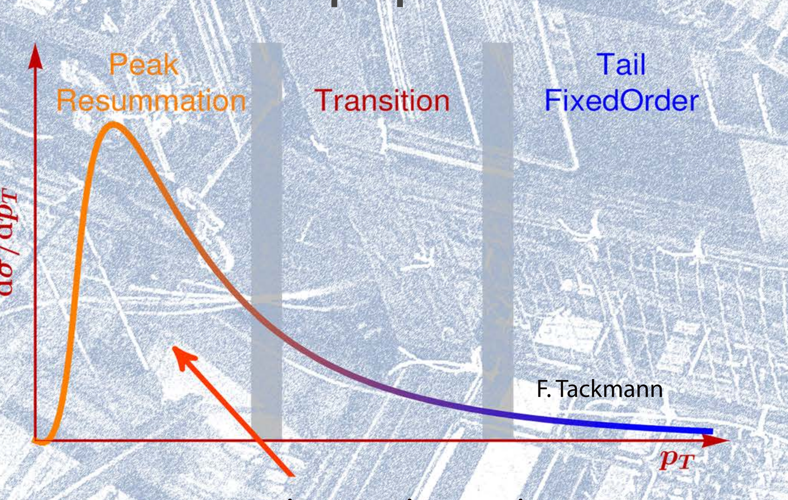
$$M_T^2 = 2p_\mu p_\nu(1-\cos\Delta\phi) = 2p_\mu|\vec{p}_\mu - \vec{p}_W| + p_\mu^2 - \vec{p}_\mu \cdot \vec{p}_W$$

The transverse mass spectrum is robust under boosts in the transverse plane, but the edge is smeared by the resolution whith which the hadronic recoil to the W boson is measured.

It is necessary to perform an accurate calibration of the recoil in order to increase the sensitivity of the template to the W mass.

experimentally more difficult

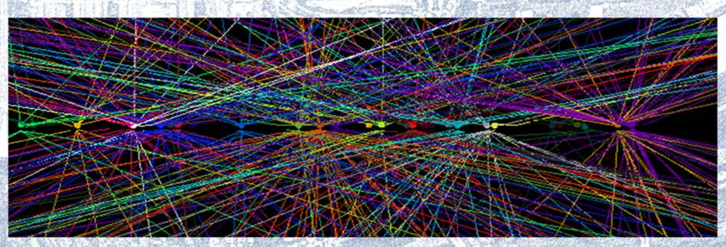
sketch of W pT spectrum



The prediction of the W pT can be obtained using parton shower Montecarlo simulation (i.e. Pythia) or tools that perform analythic resummation of the large logarithms (i.e. DYRes, ResBos...).

The procedure is usually validated to Z data since the Z pT can be measured accurately and the phase space is similar to W decays.

The resolution of the hadronic recoil is mostly affected by the pile-up (~30 reconstructed vertices)



In CMS the hadronic recoil is measured using only the charged tracks, requiring that the vertex of the selected track is near to the lepton vertex. In this way **the recoil is insensitive to pile-up, as shown in the plot on the right.**

However, this kind of recoil has a reduced response (~40%). In order to fully profit of the MT invariance under transverse boosts it is necessary to recover the full response.
This effort is still on-going.