Reflections on Searching for New Physics with CMS

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Disclaimer

- Opinions expressed herein are my own.
- What CMS will actually do with the 2010/11 data remains to be seen.

References

- All public results are available via CERN Document System
- A collection of references by topic can be found here:

  https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResults
- I will refer in my slides to the CMS document numbers, and encourage you to read up on the details as you see fit.

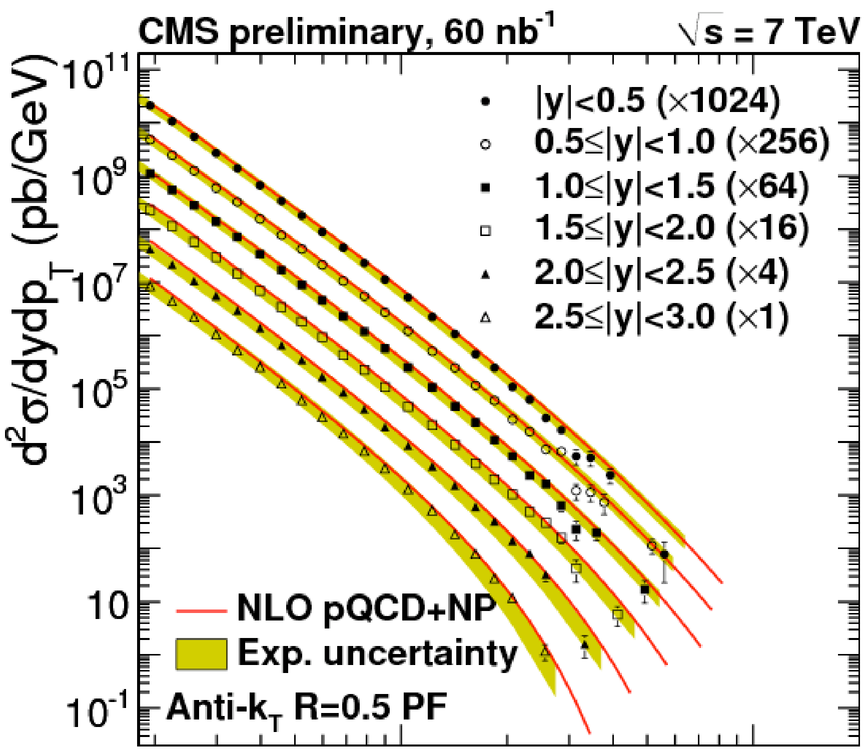
Physics Objects

Jets & MET & b-tags
Leptonic decays of Ws and Zs

Jet cross section: QCD-10-011
Jet reconstruction performance: JME-10-003
MET performance: JME-10-004 and DP2010-014
b-tag performance: BVT-10-001
Ws and Zs: EWK-10-002 and
https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsEWK

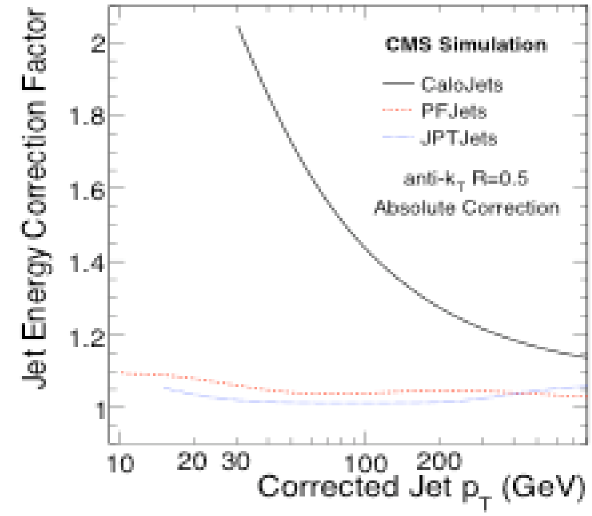
jets

Comparison of data vs theory



PF Jets

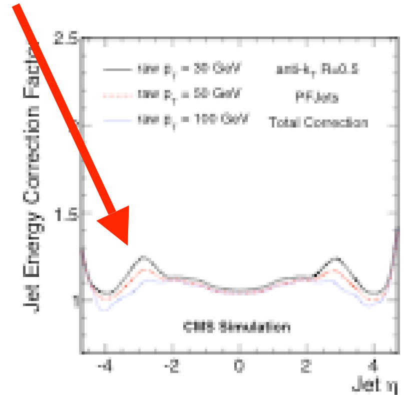
QCD-10-011



CMS uses 3 different jet reconstructions:
-> calorimeter only (Calo Jets)
-> calo & tracking (JPT Jets)
-> particle flow (PF Jets)
The JEC for two of them are ~10%

JEC vs eta for pflow @ 30GeV is less than 25% up to eta~4.5

Jet energy scale systematics ~ 5%



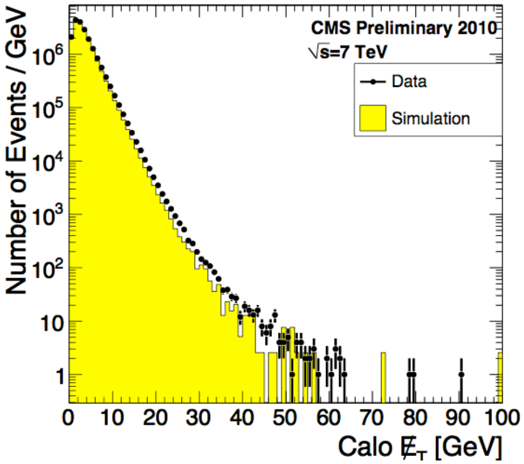
JME-10-003

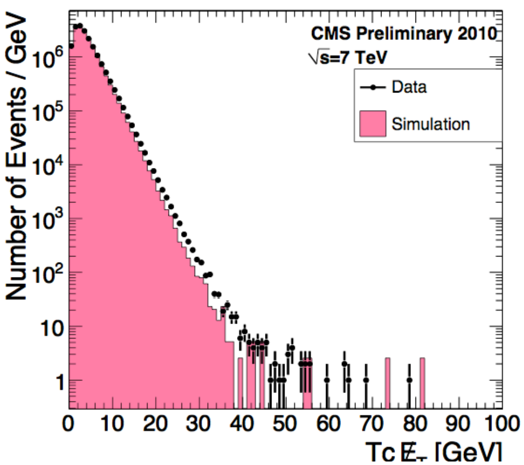
9/22/10

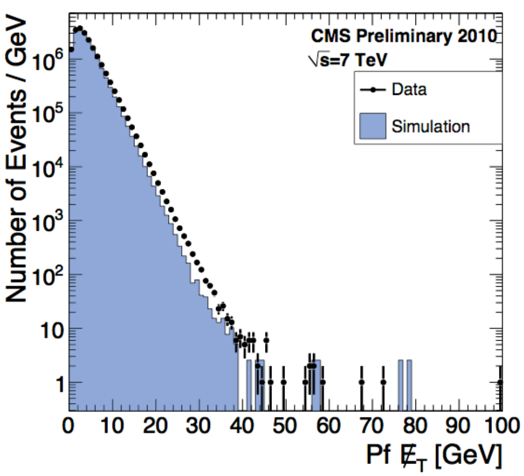
MET

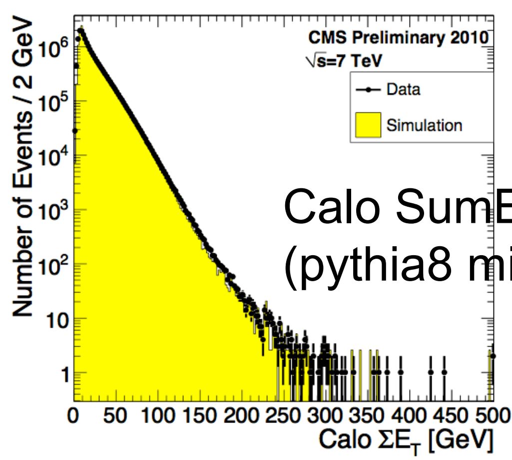
CMS uses 3 different MET reconstructions:
-> calorimeter only (Calo MET)
-> calo & tracking (tcMET)
-> particle flow (PFMET)

Data vs MC (Pythia8 minbias) agreement to within 1GeV shift over 10^7 in yield.



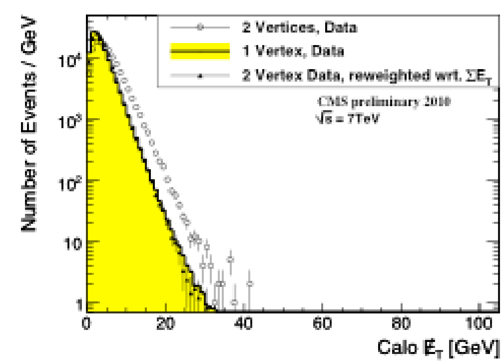






Calo SumET (pythia8 minbias)

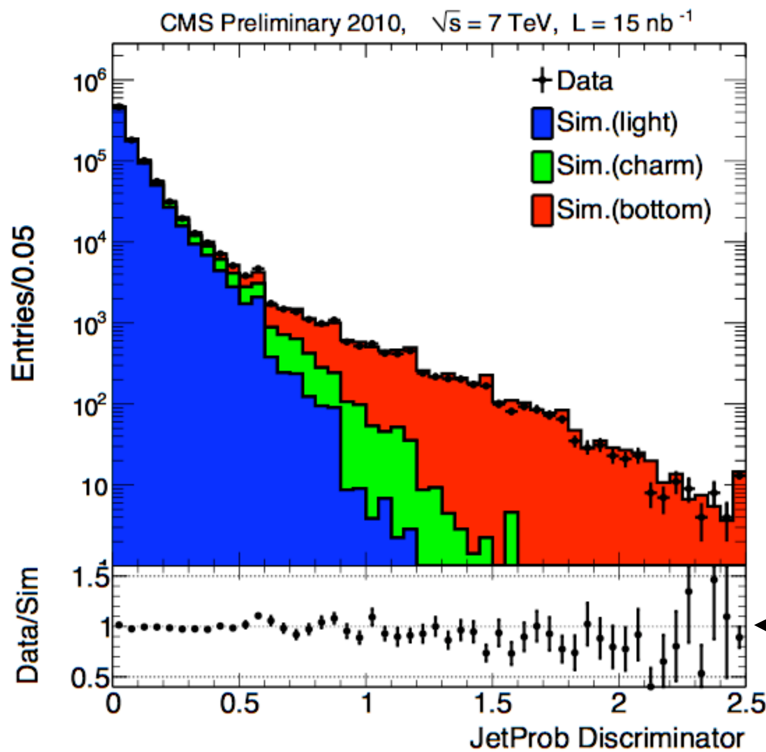
Effect of multiple interactions is understood in terms of increased sumET



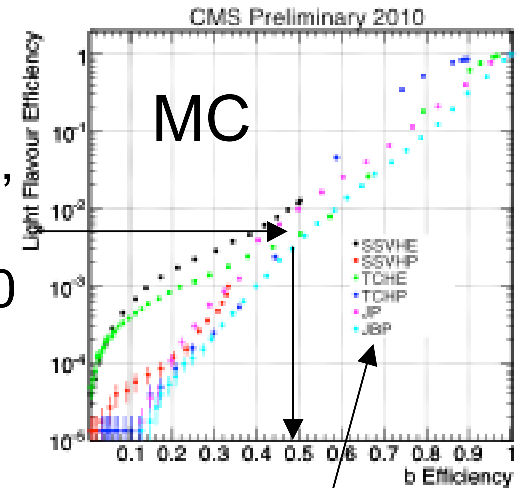
JME-10-004

b-tagging

BTV-10-001



For jets with pT>30GeV, b-tag eff. ~ 50% gives light flavor supp. ~ x 200

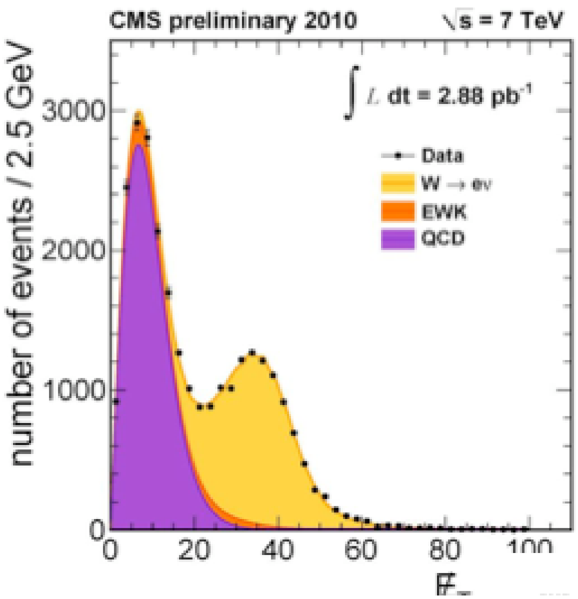


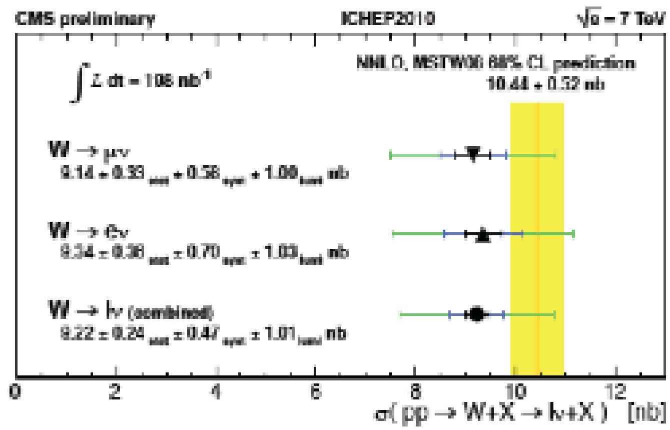
6 different tagging algorithms considered

← Data/MC track beautifully

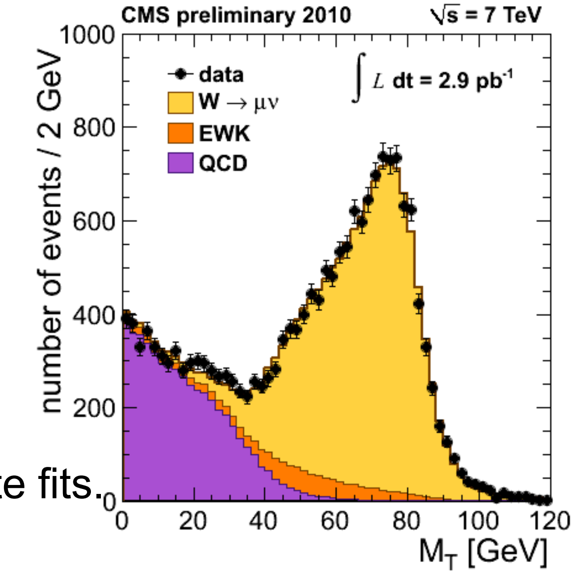
Tagging efficiency is then measured in data and MC using pT_{rel} template method to obtain a data/MC scale factor. Scale factors consistent with 1 to within 10-20%.

Leptonic W decays





Signal yields determined from template fits.



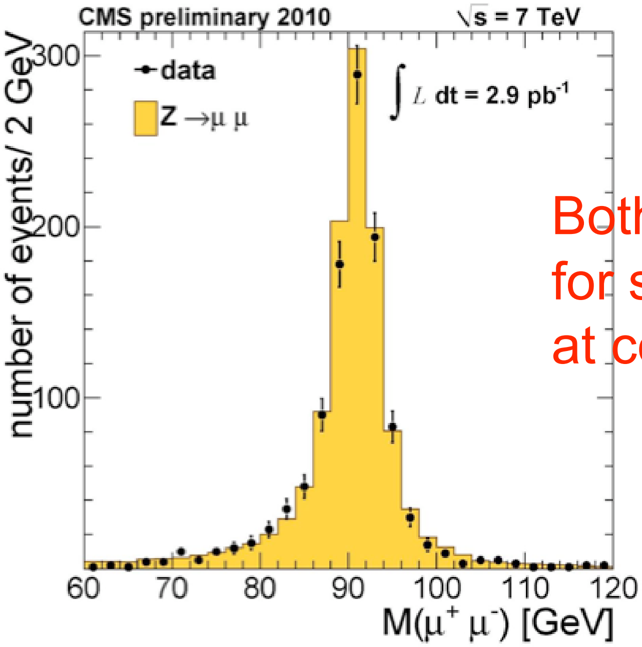
Average Cross Section

9.22 +- 0.24 +- 0.47 +- 1.01 nb

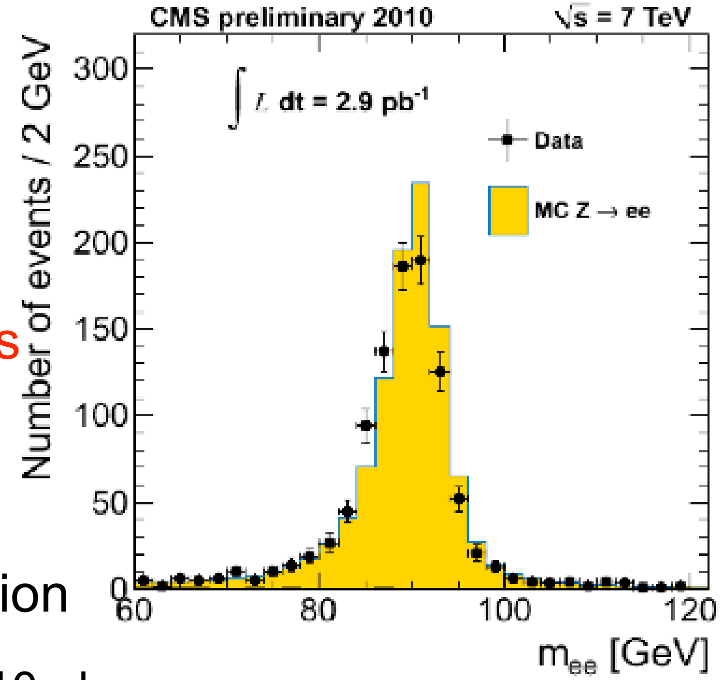
stat syst lumi

Both eν and μν allow for clean W signals at comparable efficiencies

Leptonic Z decays

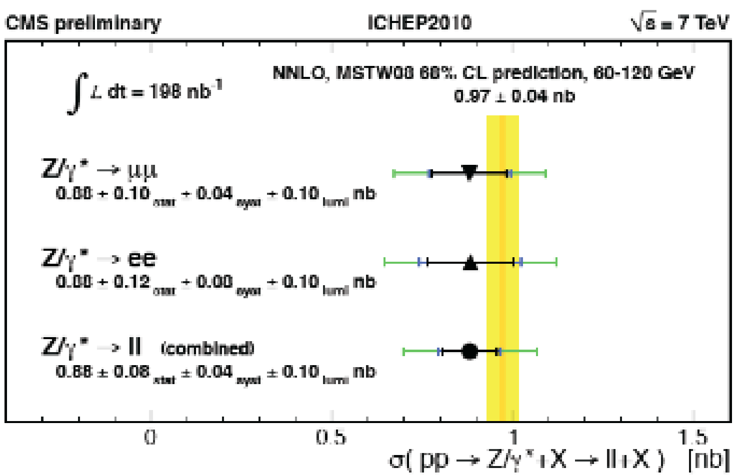


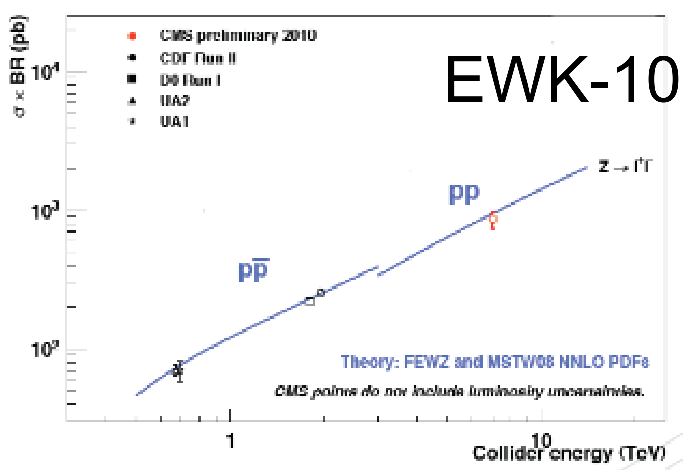
Both ee and μμ allow
for superclean Z signals
at comparable efficiencies



Average cross section

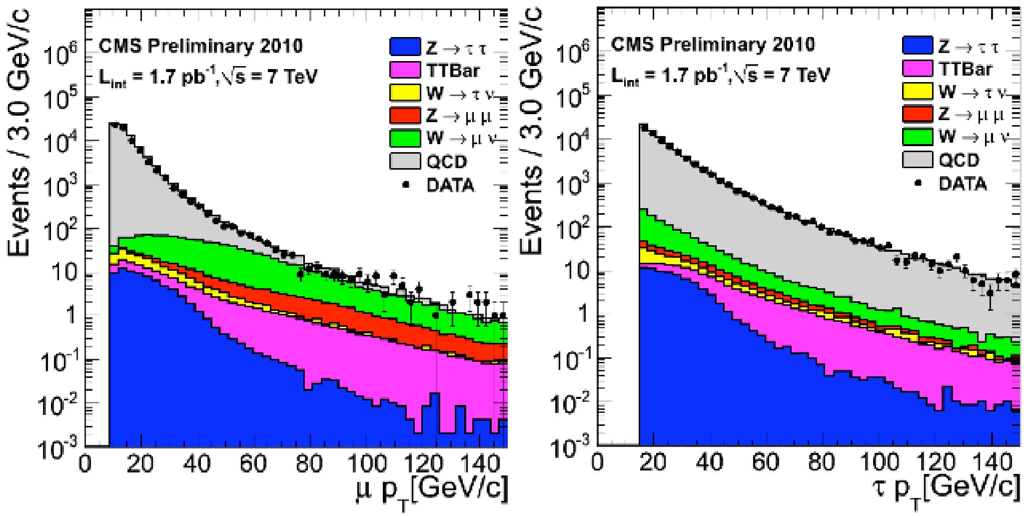
0.88 +- 0.08 +- 0.04 +- 0.10 nb
stat syst lumi





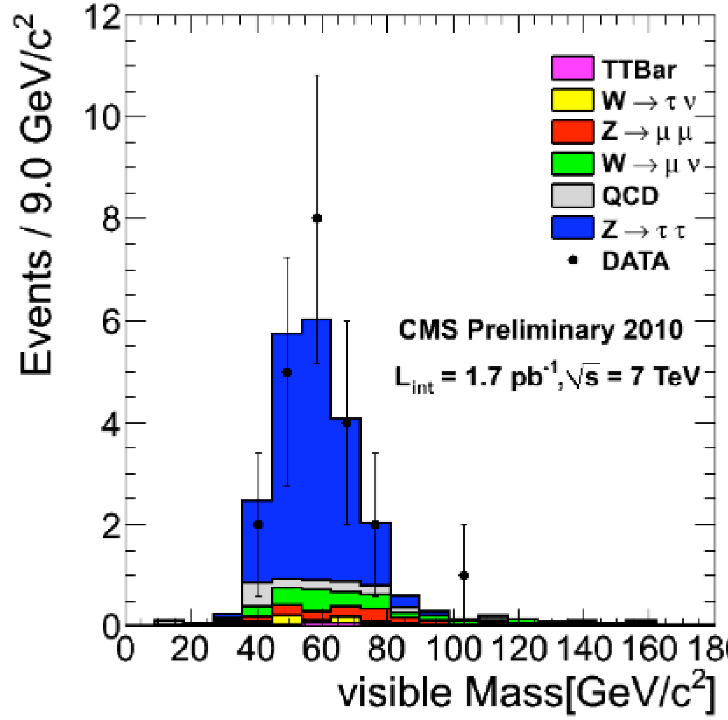
EWK-10-002

Muons are clearly cleaner than taus
(no isolation applied yet)



Z to $\tau^+\tau^-$

PFT-10-004
(updated with more stats)



A clean Z to $\tau^+\tau^-$ signal is achieved in the muon + hadronic tau channel.

(mu pt>15, tau pT>20, both isolated)

Searching for new physics

Let's start with some pedagogy

Search Ingredients

1. Design the event selection
2. Measure
   1. Estimated bkg yields
   2. Measured yield of signal candidates
3. Determine selection efficiency
4. Calculate cross section

1. & 2. can be done (fairly) model independent.

$\Rightarrow$ We should strive to cover corners of SM phase space for as many combinations of signatures as possible.

3. Is very difficult to do completely model independent.

And thus 4. tends to be somewhat model dependent.

Search for stopped gluinos
-- A case study --

- Idea:
  - a colored object is produced
  - Hadronizes and travels through the detector as "R-hadron"
  - Gets stopped in the detector material
  - Decays at some later point while there are no beams colliding
- Signature:
  - At least one jet with ET > 50GeV at a time with no colliding beams

EXO-10-003

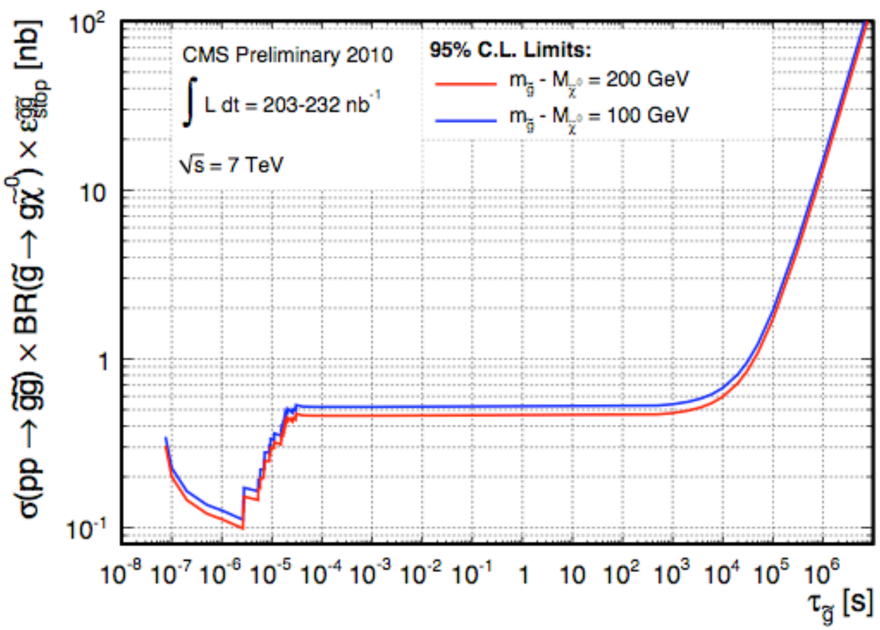
Model Independent measurement

Lifetime [s]	Expected Background ($\pm$ stat $\pm$ syst)	Observed
1e-07	$0.15 \pm 0.04 \pm 0.05$	0
1e-06	$1.8 \pm 0.5 \pm 0.5$	0
1e-05	$11.7 \pm 3.2 \pm 3.5$	8
1e-04	$28.3 \pm 7.8 \pm 8.5$	19
1e-03	$28.3 \pm 7.8 \pm 8.5$	19
1e+03	$28.3 \pm 7.8 \pm 8.5$	19
1e+04	$28.3 \pm 7.8 \pm 8.5$	19
1e+05	$28.3 \pm 7.8 \pm 8.5$	19
1e+06	$28.3 \pm 7.8 \pm 8.5$	19

- The signature is generic.
- The bkg estimate and observed yield is generic.

σ x BR x efficiency to stop in detector

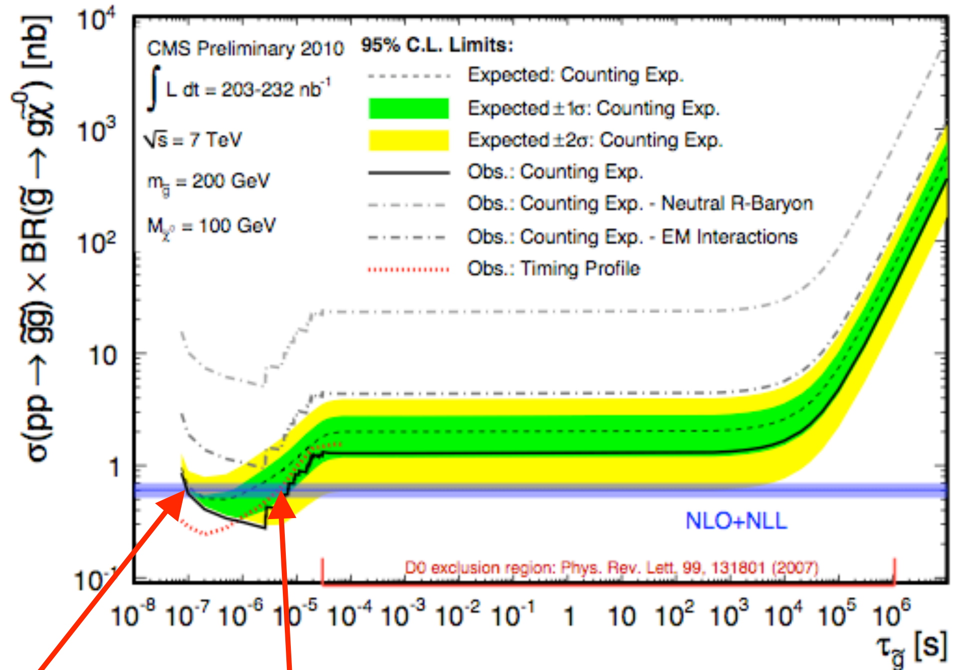
- Mildly model dependent as it must assume a production mechanism, gluino mass, and decay kinematics.



95% C.L. limits for two different mass differences between gluino and LSP.

More significant model dependence enters via probability for gluino to stop in detector.

- Exclude gluino with lifetimes ranging from 75ns to 6μs for mass = 200GeV as long as gluino - LSP mass difference is > 100GeV, 100% BR, and “cloud model” of R-hadron interaction.



EXO-10-003

Result probes new territory!

Lessons Learned

- As experimentalists, we will try to present our results in different ways, ranging from the most model independent, raw data, to the model dependent cross section limits.
- As theorists, you can help by
  - Pointing out how we can be more generic in presenting our results.
  - Providing guidance with models that motivate signatures we may have forgotten to present.

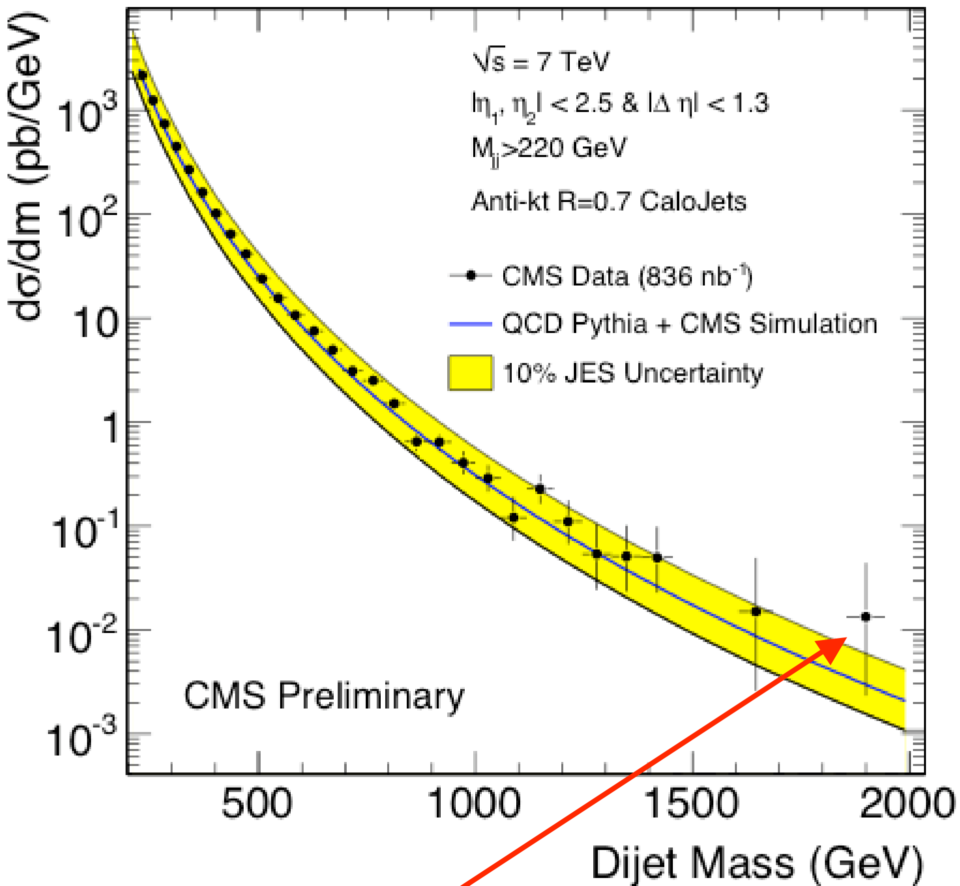
  => Just because we have not shown it does not mean we have not looked!

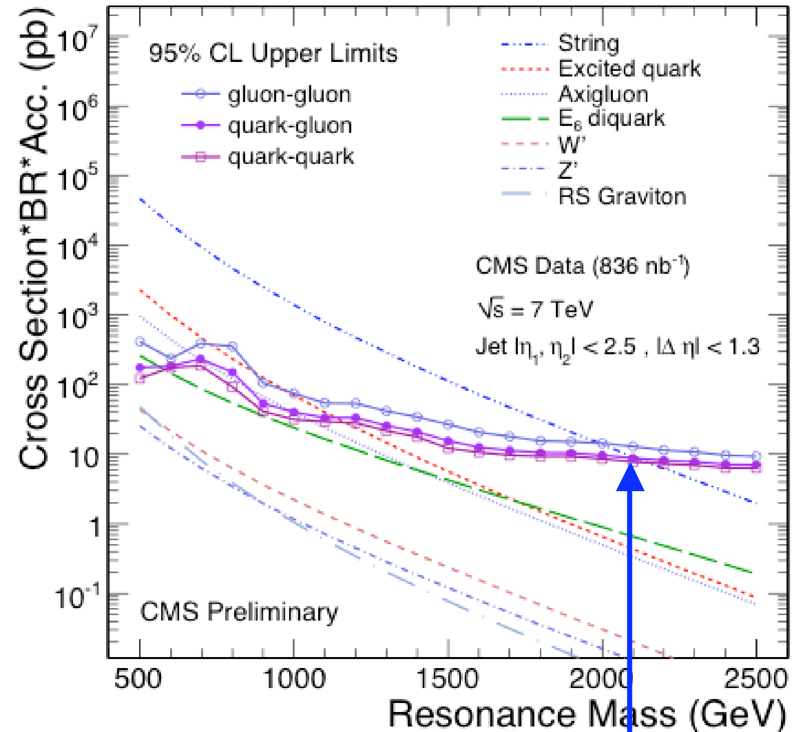
Searches for Resonances

CMS will search for many di-object resonances, including:

Jet jet, ee, $\mu\mu$, $\tau\tau$, $\gamma\gamma$, $e\gamma$, $\mu\gamma$, $e\nu$, $\mu\nu$, WZ, …

Search for Dijet Resonances





Highest observed dijet mass = 1.92TeV

Exclude string resonances with mass < 2.10 TeV

Probes New Territory with 836+-92 nb^{-1} !

SUSY inspired searches

CMS Objective:

Cover the usual models (mSUGRA, GMSB, …)

Cover as many "SM free" regions as possible

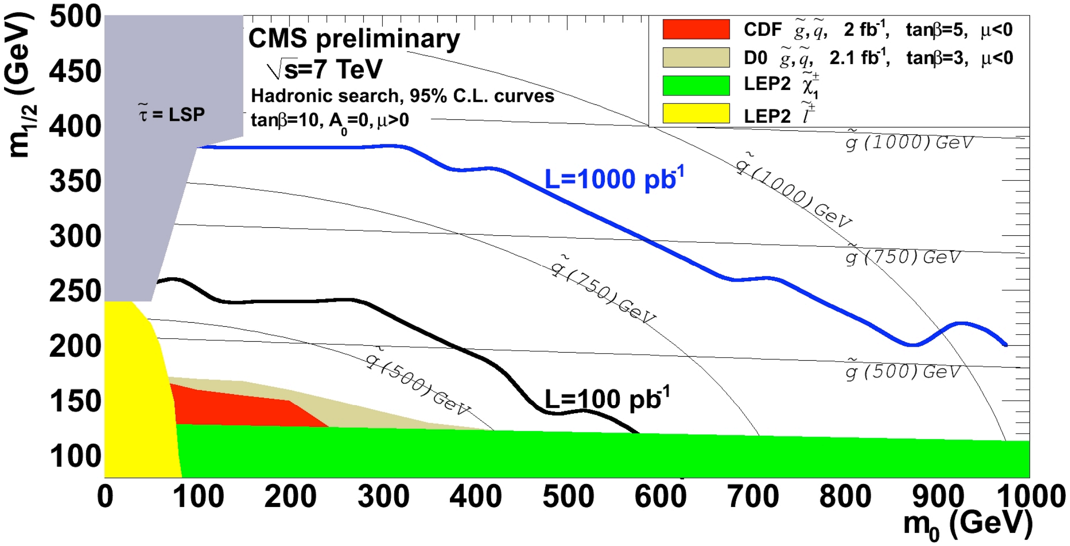
Ordering Principle

- Order by lepton (or photon) count
  - 0 leptons
  - 1 lepton
  - 2 leptons
    - Same sign
    - Opposite sign
  - More than 2 leptons

- 2 photons
- 1 photon + 1 lepton
- multiple photons/leptons

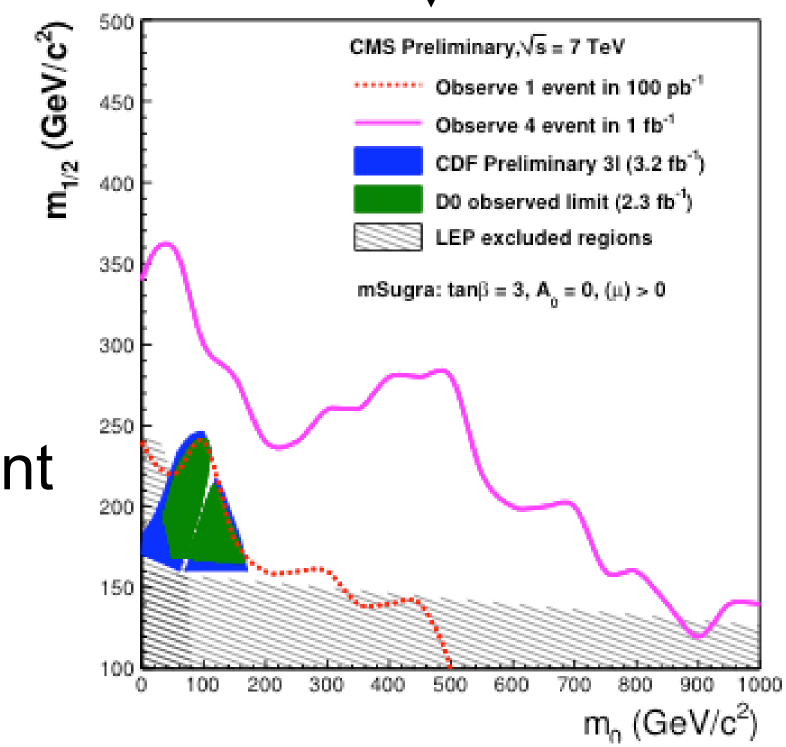
- All analyses require MET & HT
  - Details depend on what's required to suppress SM
  - The more leptons/photons the less MET & HT required

mSUGRA MC exercises



All hadronic

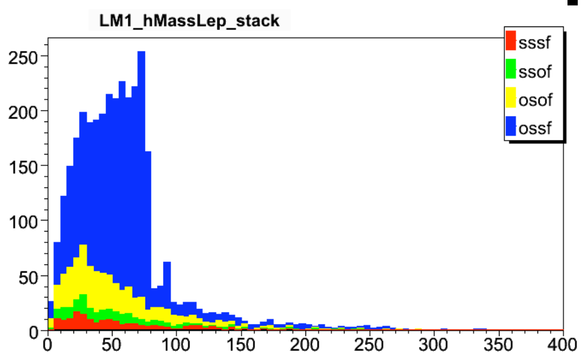
Same sign dileptons



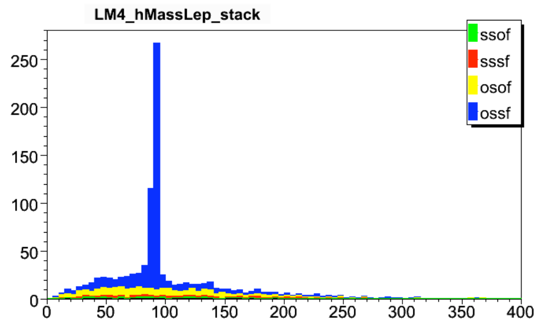
For details see:
CMS Note 2010/008

Both of these are MC projections, predicting that ~ 100 pb^{-1} is sufficient to probe new territory in mSUGRA.

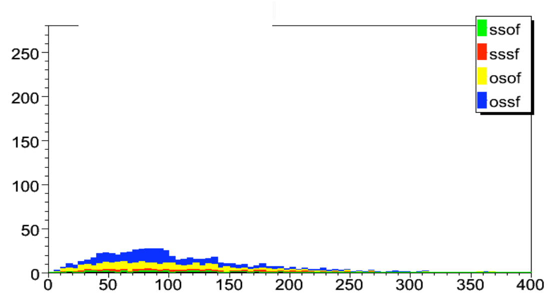
Reflection on Opposite sign dileptons + MET + jets



Dilepton mass edge is self-calibrating



Z peak will require data driven study to rule out misunderstood Z bkg



Featureless will require data driven study to rule out misunderstood top bkg.

Note: Plots are merely cartoons !

Data Driven Techniques

Unless a signal is “self-calibrating”,

we need to have a data driven way to prove that it’s not a poorly understood SM effect.

Data Driven Techniques

- “fake leptons” (e, μ, and τ)
  - Use extrapolations in isolation and/or Id
- “fake MET”
  - Use templates from QCD multi-jet events
- “real MET” from ttbar and Wjets
  - Use (di-)lepton pT to model MET tail from neutrinos

SUSY-10-001
PRD81 2010 035005

One more final thought

- For every signature with MET + HT, we ought to also think about constructing searches with only MET or only HT.
- … and finally MUSiC (EXO-08-005)

Abstract

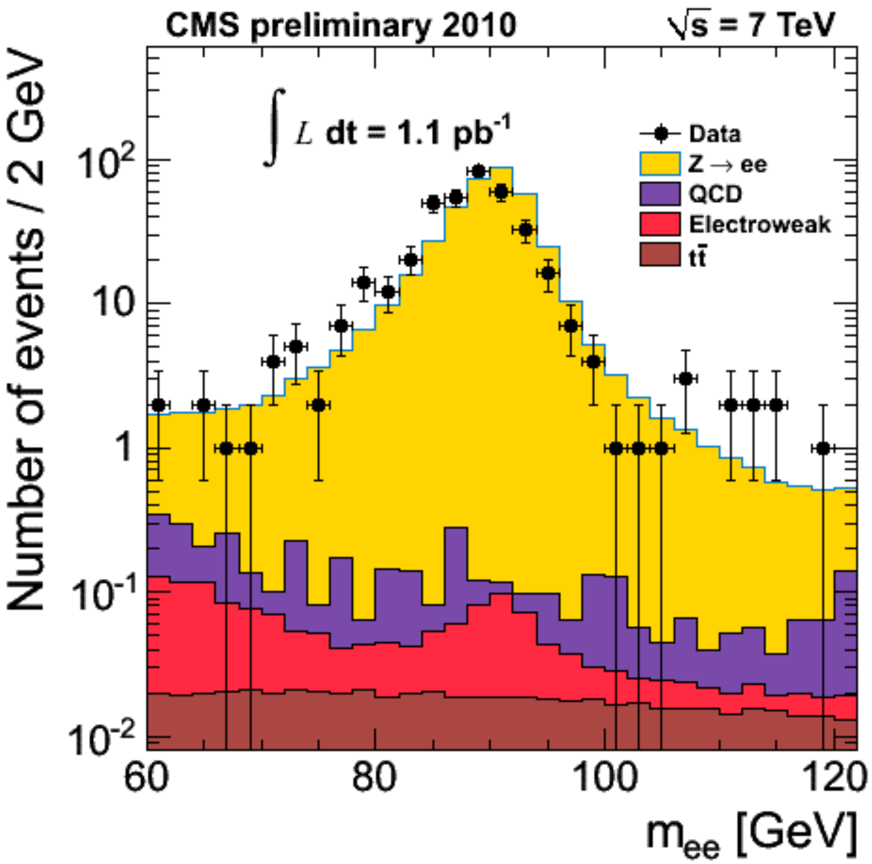
We present a model independent analysis approach, systematically scanning the data for deviations from the Monte Carlo expectation. Such an analysis can contribute to the understanding of the detector and the tuning of the event generators. Due to the minimal theoretical bias this approach is sensitive to a variety of models, including those not yet thought of. Events are classified into event classes according to their particle content (muons, electrons, photons, jets and missing transverse energy). A broad scan of various distributions is performed, identifying significant deviations from the Monte Carlo simulation. We outline the importance of systematic uncertainties, which are taken into account rigorously within the algorithm. Possible detector effects and generator issues, as well as models involving supersymmetry and new heavy gauge bosons have been used as an input to the search algorithm.

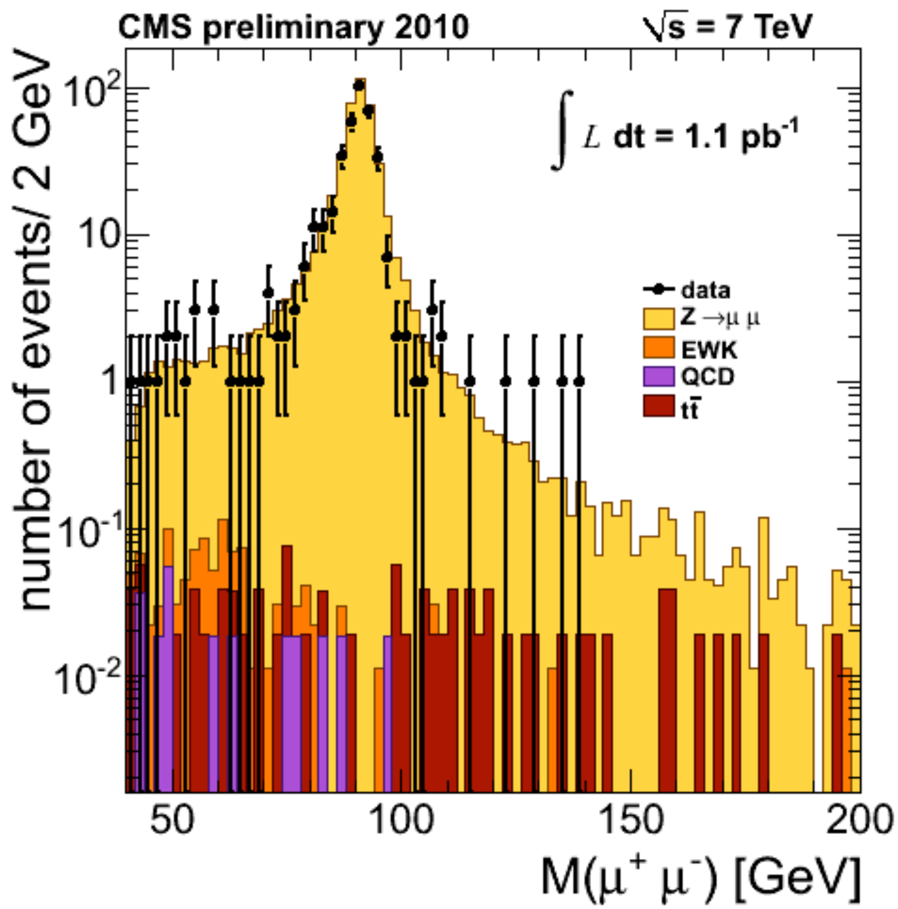
Take Home Messages

- Data and MC agreements are impressive on everything CMS has looked at so far.
- Nevertheless, CMS developed data driven techniques to account for all major bkg's in searches.
- CMS expects to pursue a balanced diet of:
  - Targeted searches for well motivated models
  - Generic searches based on signatures
- Your input on better ways of presenting search results is always appreciated.
- You can find CMS physics results organized by topic at: https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResults

Backup

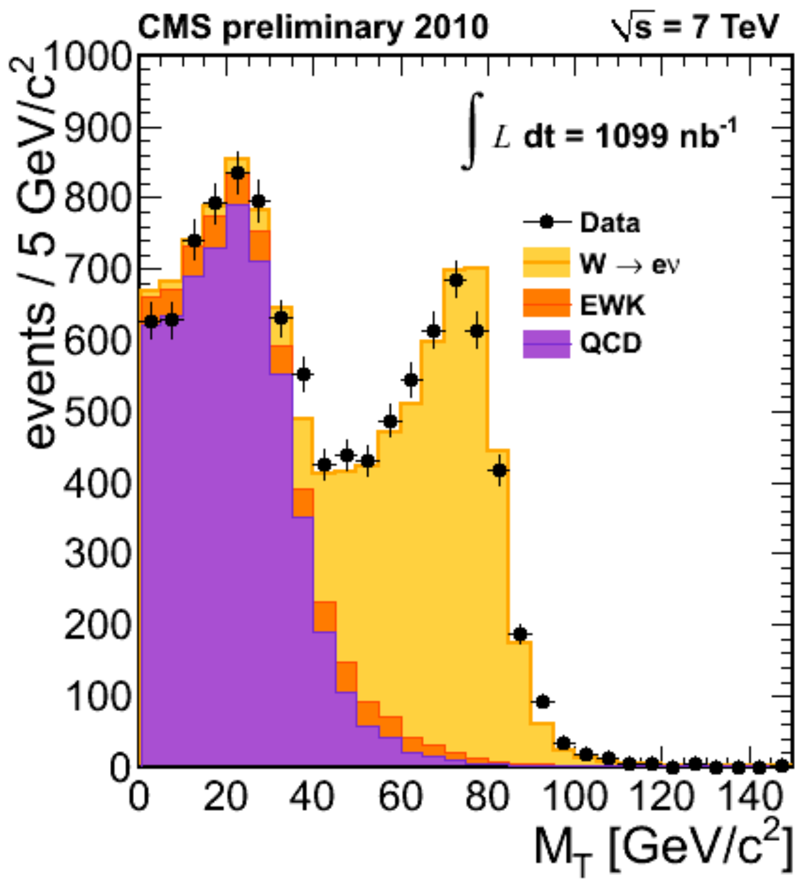
Leptonic Z decays

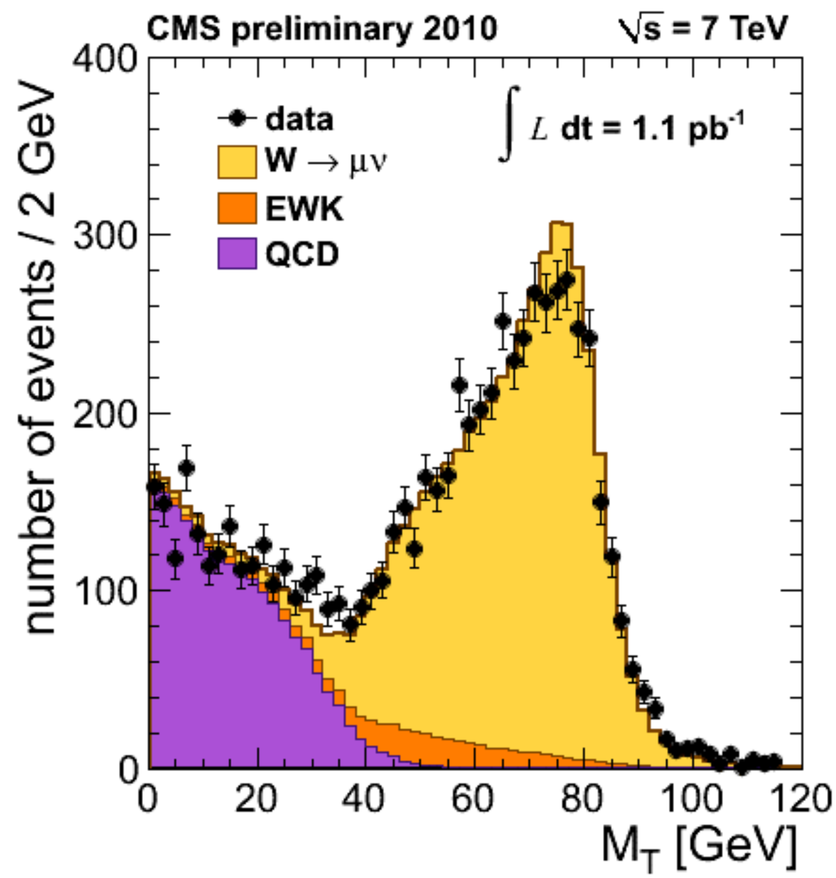




Both ee and μμ allow for superclean Z signals at comparable efficiencies

Leptonic W decays





Both eν and μν allow for clean W signals at comparable efficiencies