Searches for Exotica in CMS

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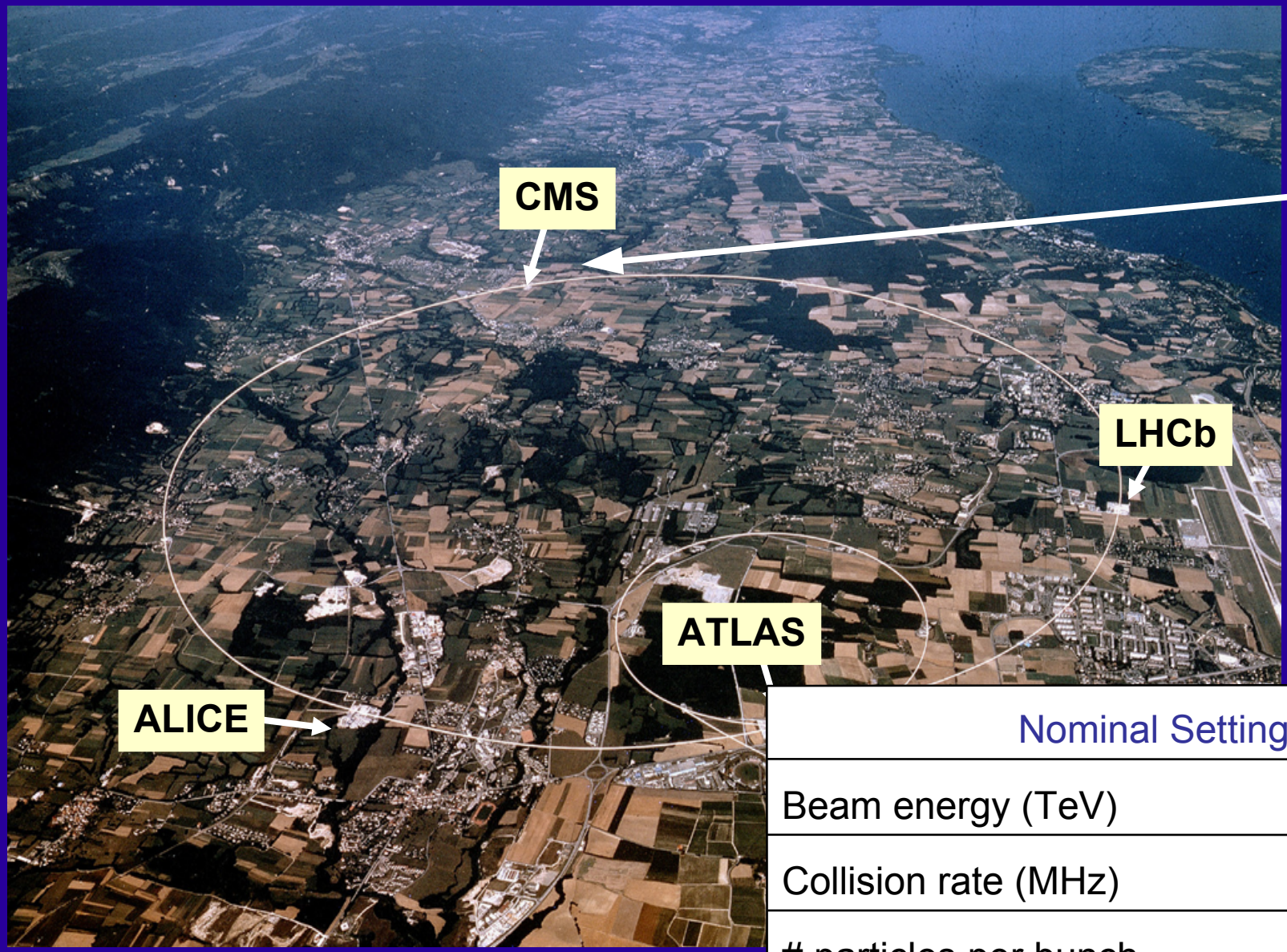
Motivation:

- The most exciting topics for the LHC, beyond the Standard Model physics. A lot of ground to cover though...
- Here, I'll hit a few selected topics:
  - W' and Z'
  - Dijet searches
  - HSCP
- And one general one: MUSiC

You've seen this...

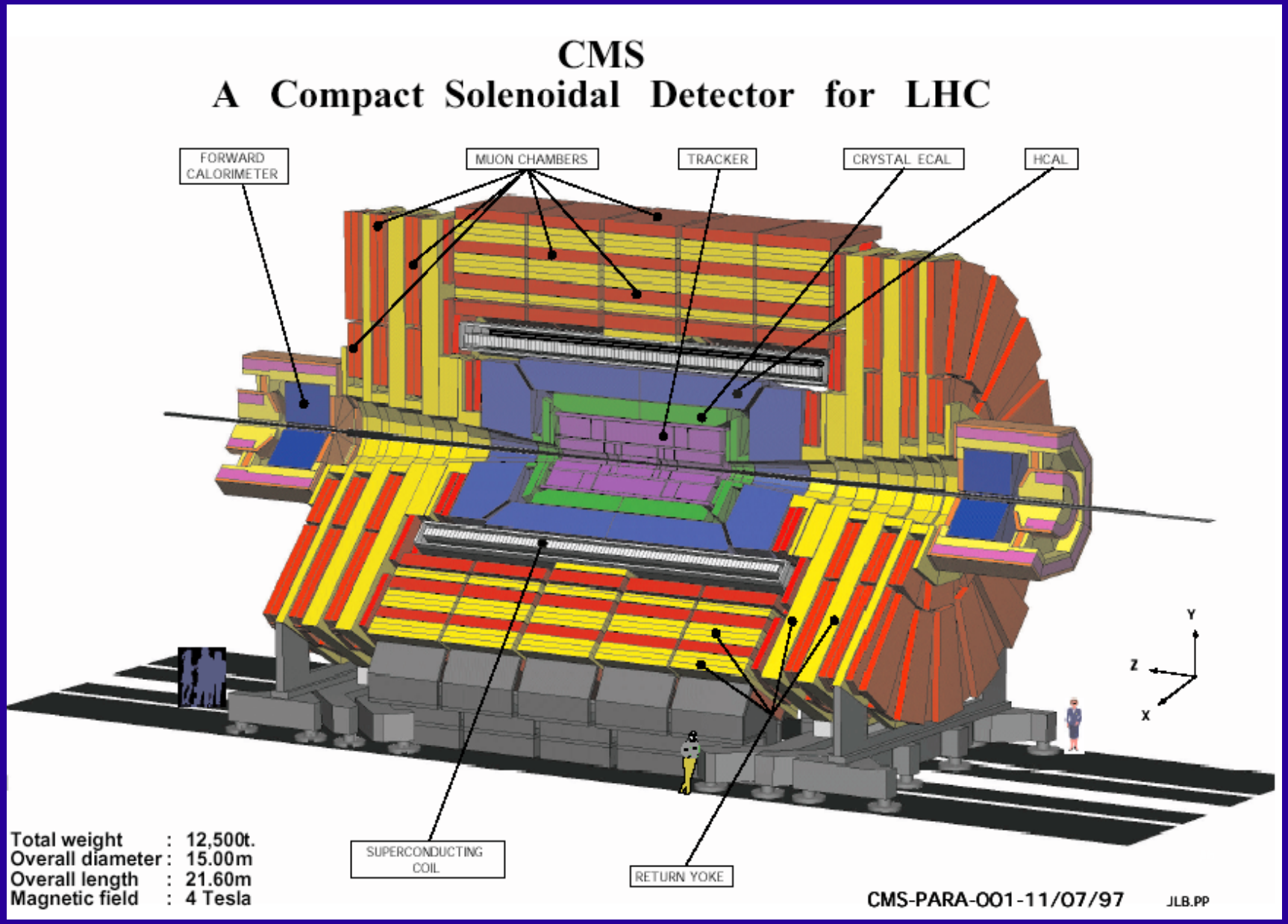


You are here.

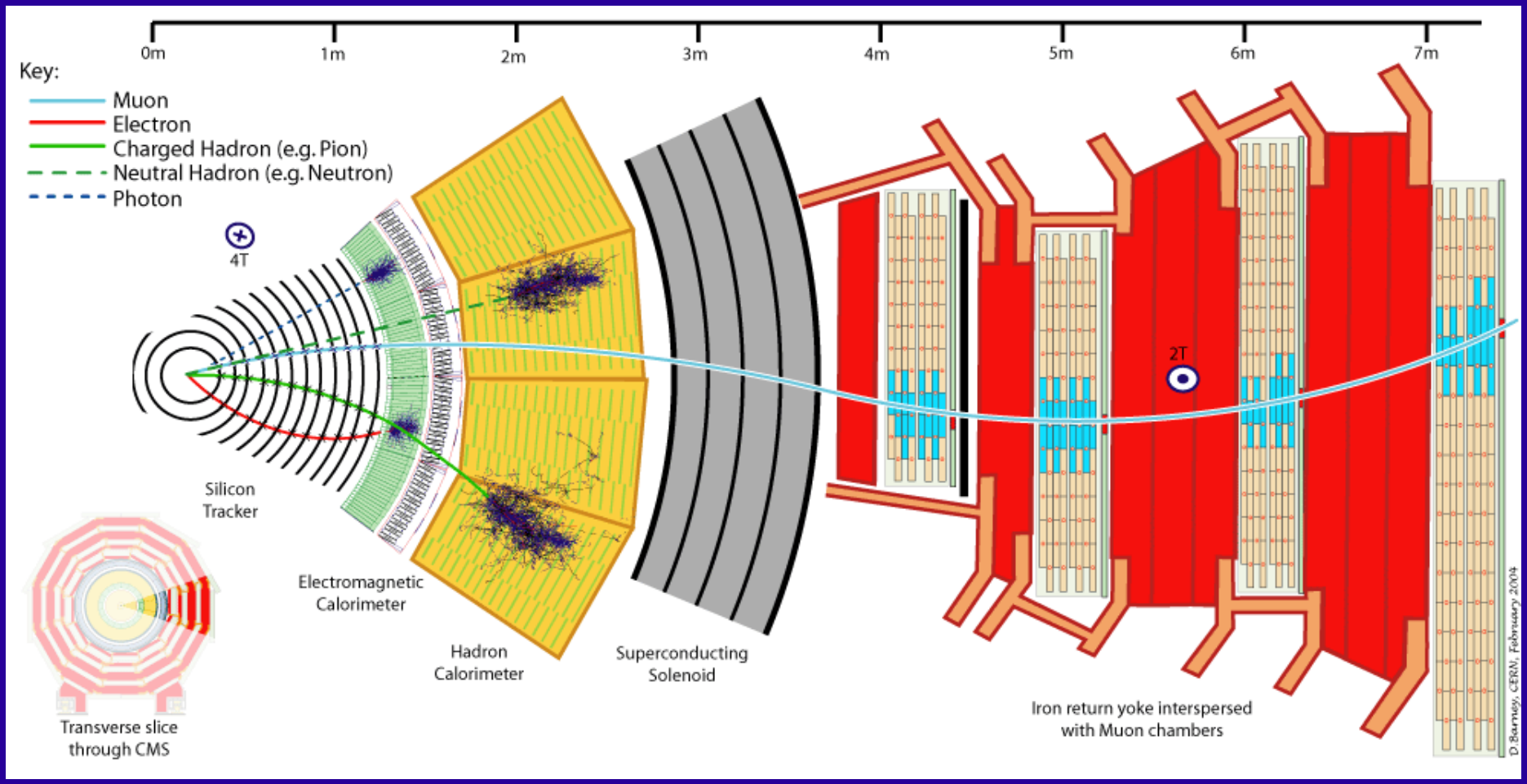
Nominal Settings	
Beam energy (TeV)	7
Collision rate (MHz)	40
# particles per bunch	1.15×10^{11}
Luminosity ($cm^{-2}\ s^{-1}$)	10^{34}
Stored energy per beam (MJ)	362

CMS Detector:

And of course, no talk is complete without the apparatus!



A Quick Word About Object ID:



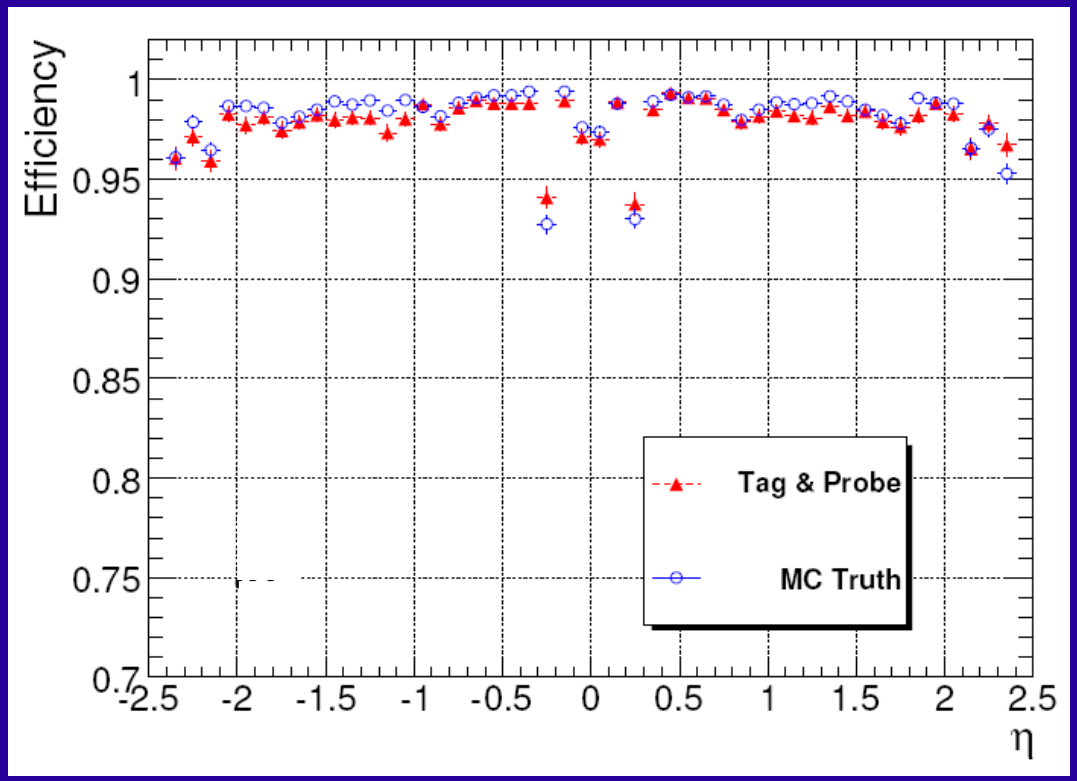
Extra Gauge Bosons:

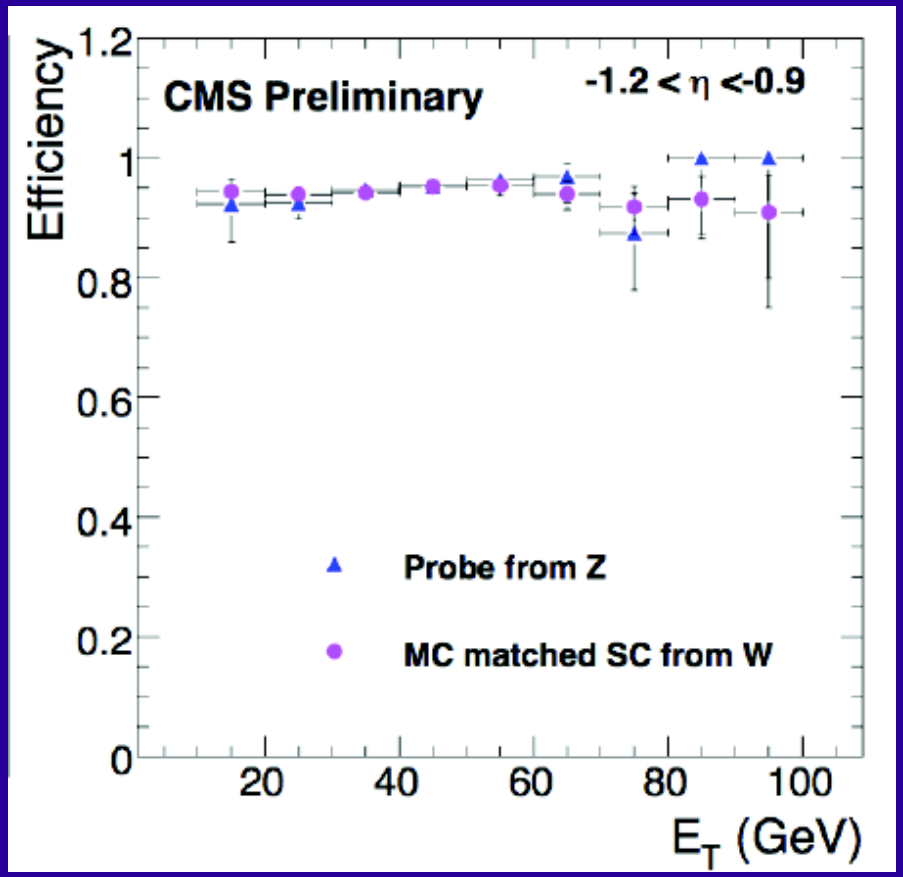
- Typically used for a benchmark, searching for a heavier partner to one of the standard gauge bosons.
- Representative of unexpected resonances, or lepton+missing E_T signals, and generalize well.
- In each case, the emphasis has been put on early data, and data-based efficiencies and background estimates (channel dependent).

Tag and Probe:

- Typically to measure the efficiency of leptons in data one resorts to the "Tag and Probe" method:
  - Try to identify a Z->ll decay using very tight requirements on one lepton (Tag), while using as loose as possible on the other (Probe).
  - Form the invariant mass to control backgrounds.
  - Check that the selection cuts on the "Tag" lepton do not bias the efficiency calculated with the "Probe" (typically correlated things like isolation).

Tag and Probe (2):



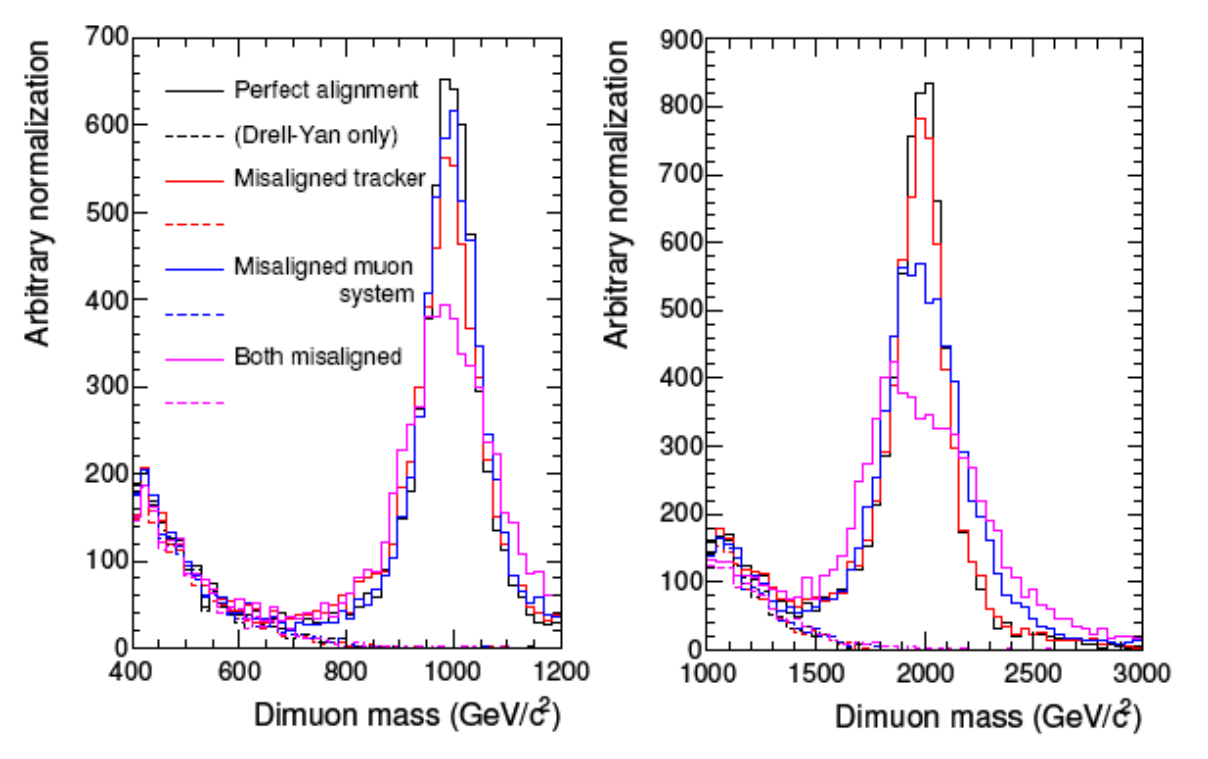


Global Muon Reconstruction, tag and probe method and MC truth.

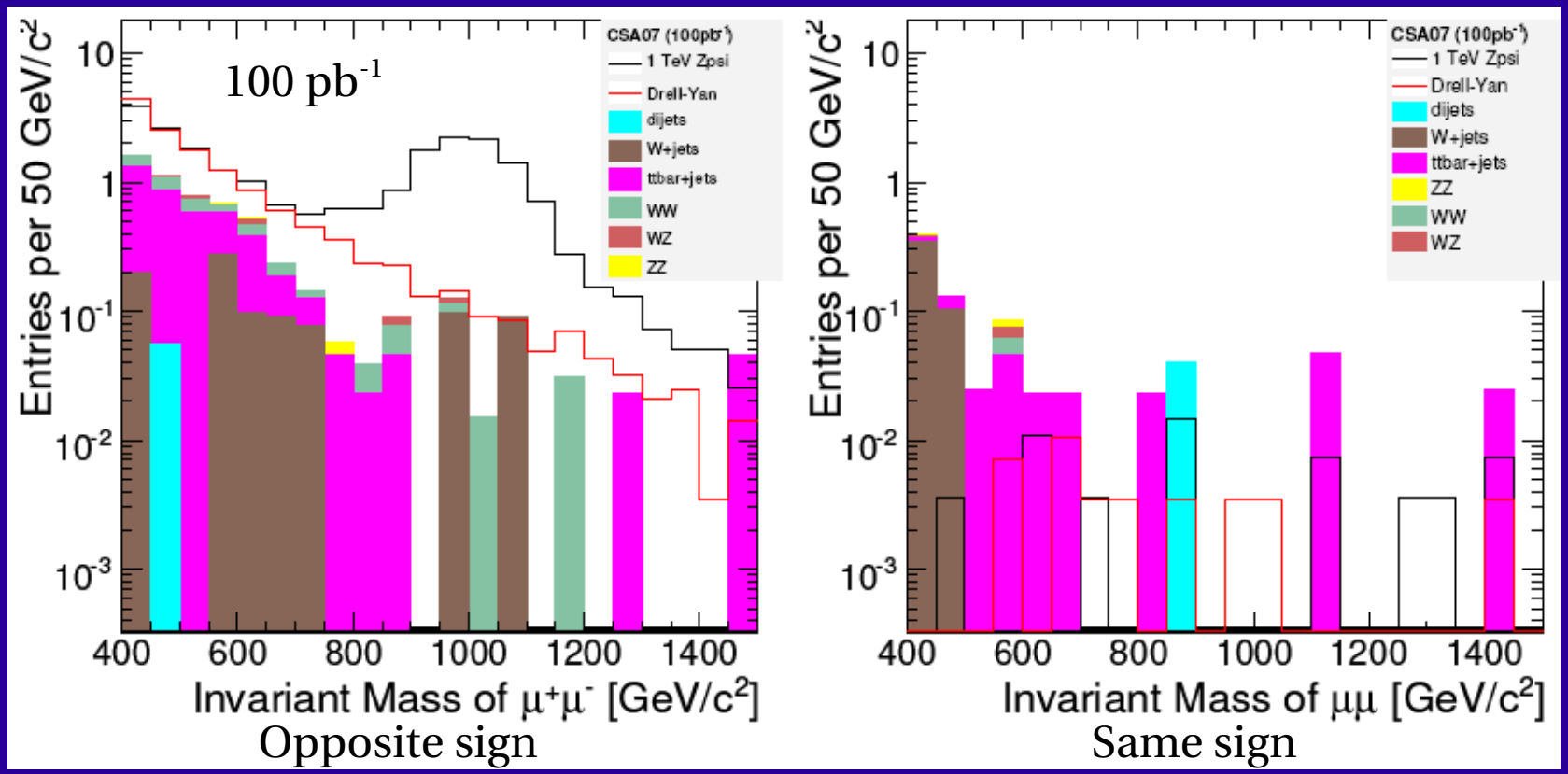
Electron Cluster-Track matching efficiency as a function of E_T, tag and probe, and MC truth.

Z'->μμ:

- Well identified, separate momentum measurements, very low backgrounds from QCD (via isolation requirements).
- Plots shown display loss of resolution due to possible startup misalignment.

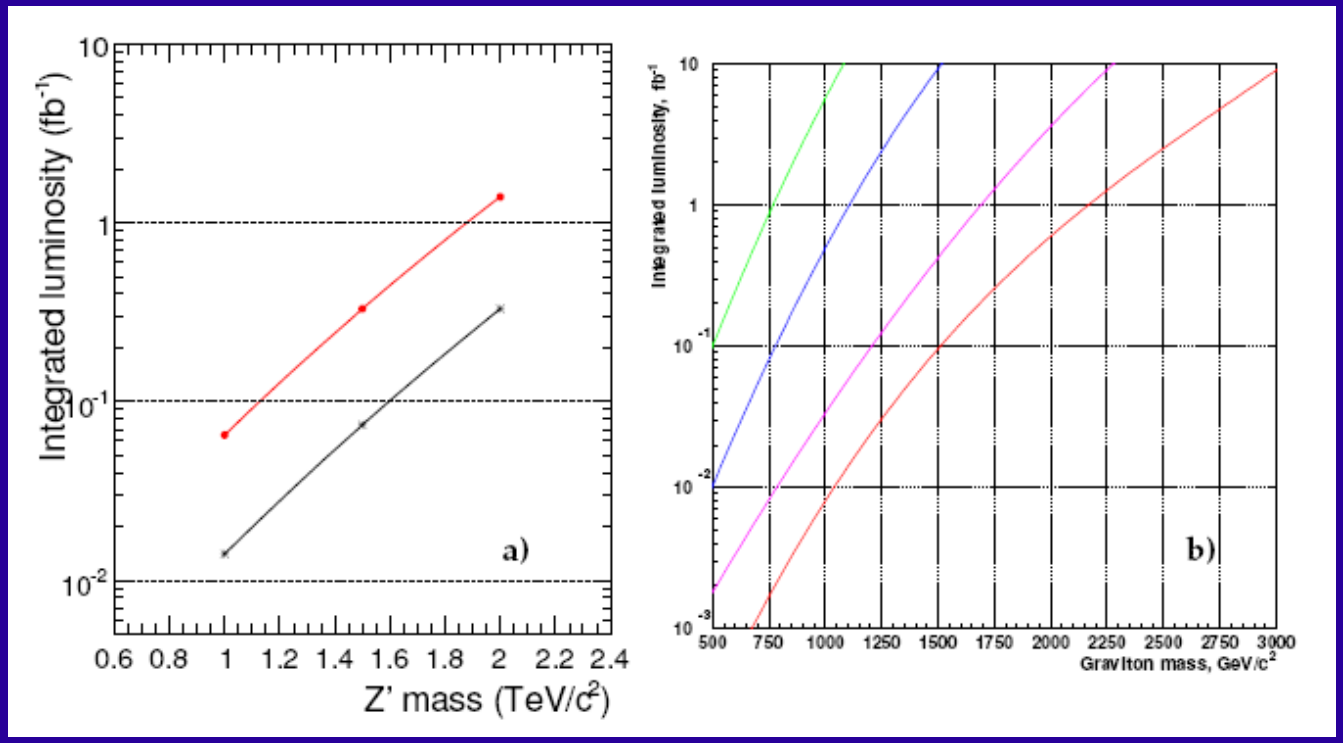


Z'->μμ:



- Expected signal and backgrounds for 100 pb^{-1}, for a 1 TeV Z', and control region (same sign muons). Main background is simply DY μμ.

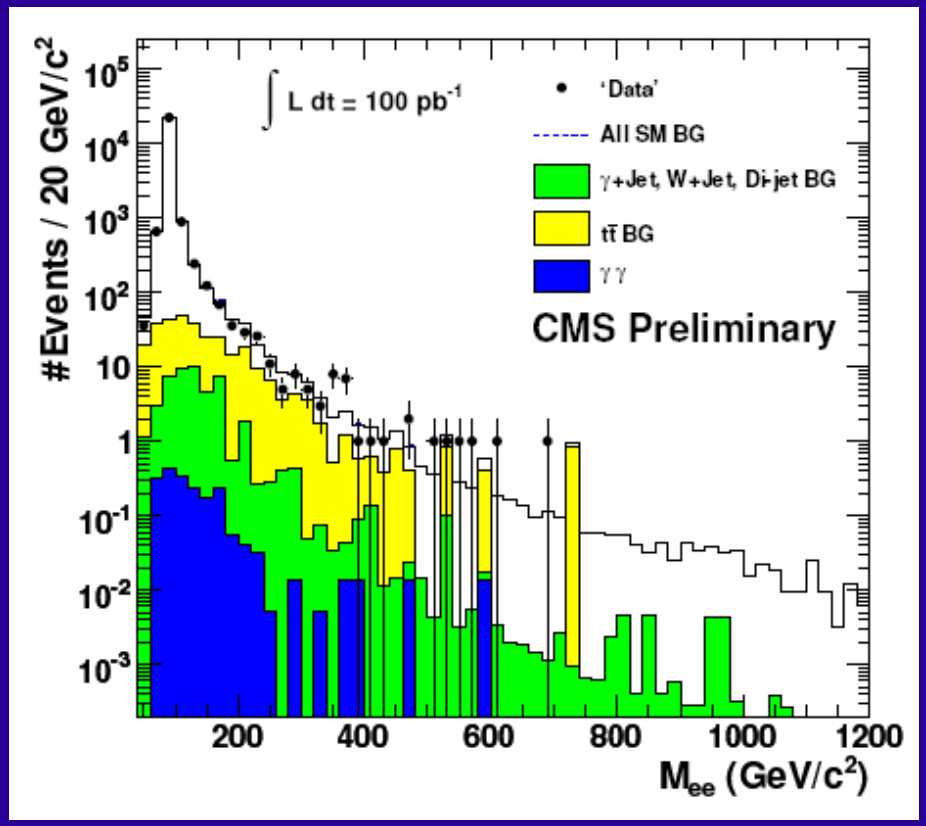
Z'->μμ reach:



- Discovery reach for Z' search (two separate models (left)), and G->μμ (different couplings c (right)).

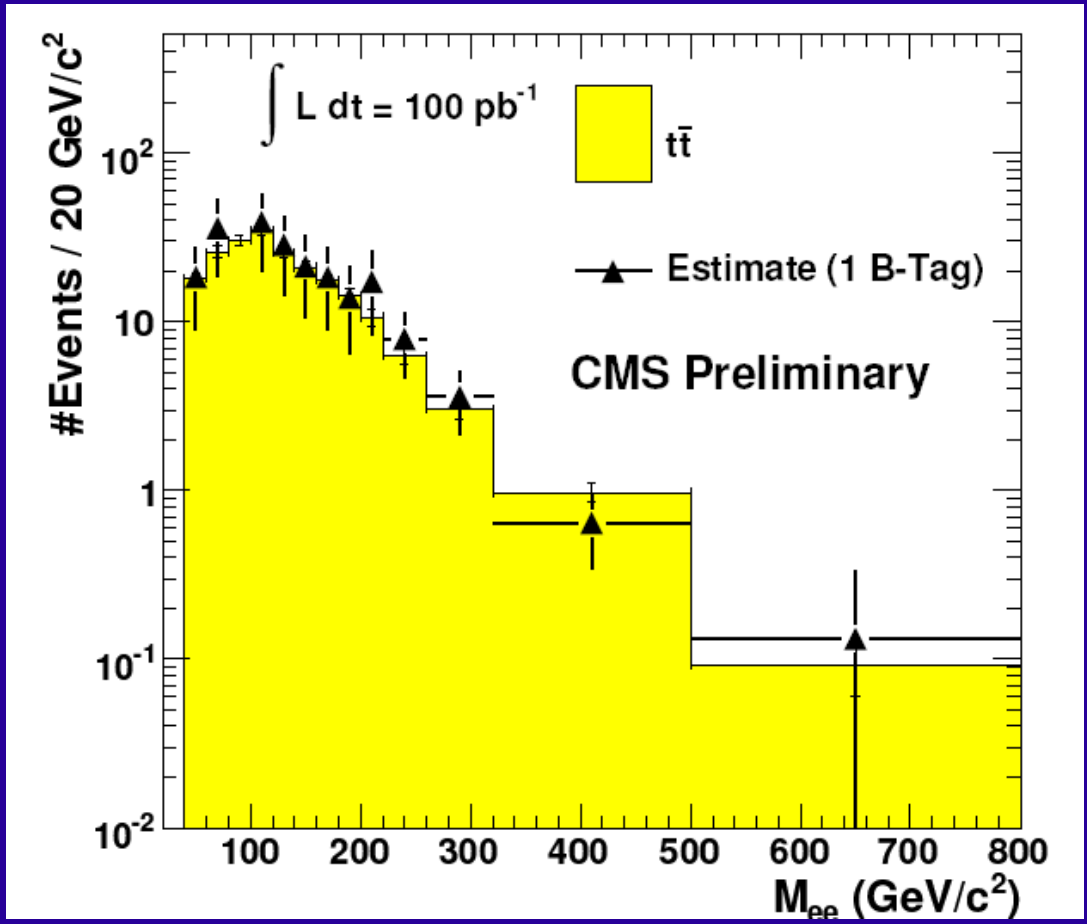
Z'->ee

- Slightly different than Z->μμ, more backgrounds from misidentification.
  - QCD backgrounds minimized via shower shape and isolation, and tight track η-ϕ match.
  - Top estimated from data.



Z'->ee: Top Background

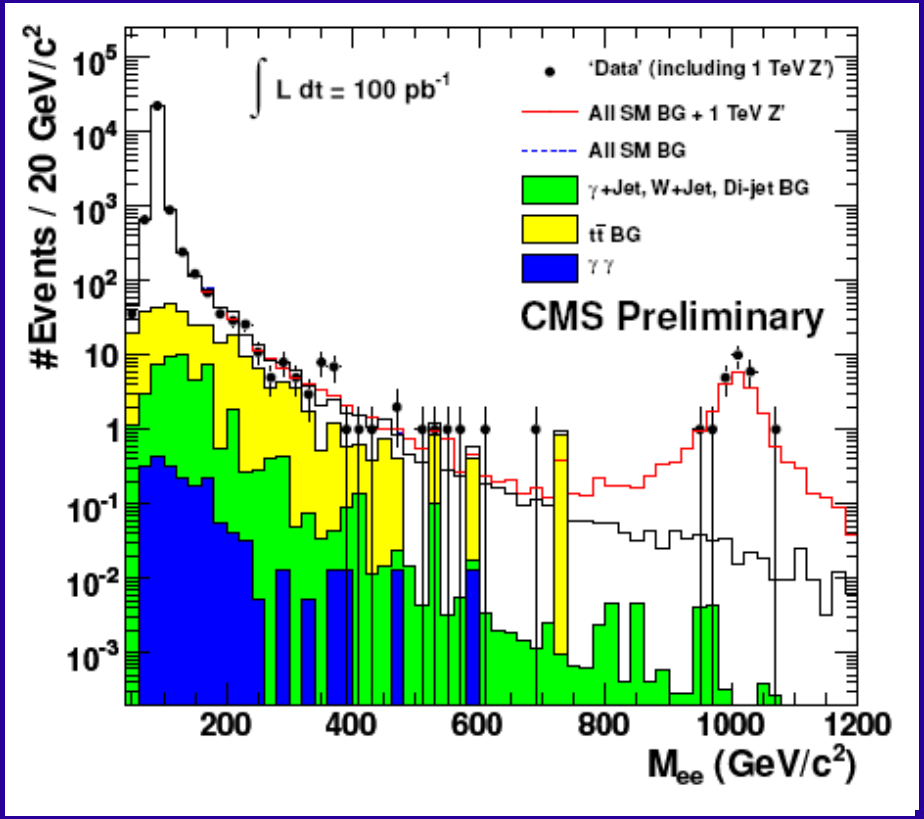
- Di-top production, estimate the b-tag efficiency from the 2-tag to 1-tag ratio, as well as the total number of di-top.
- Since this doesn't affect the invariant mass (as shown), this gives a semi-data based method to estimate the background



Invariant mass in top events, and using 1- and 2- btags.

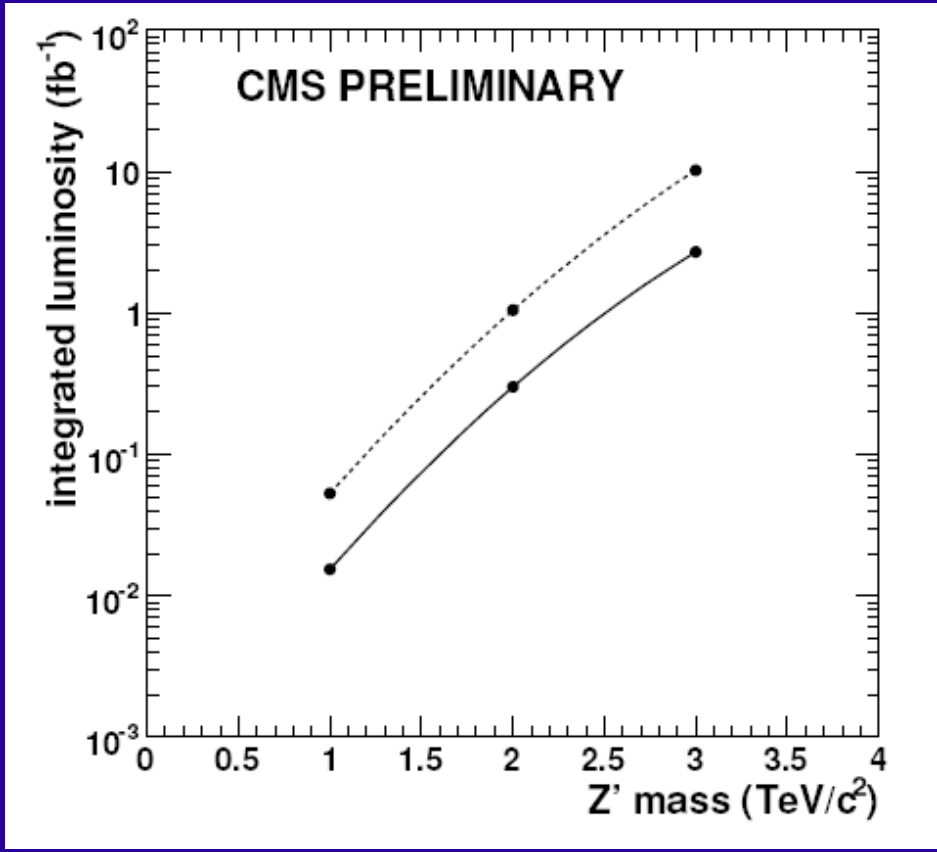
Z'->ee

- Hey look, there's a Z' there!
  - This is the case where signal was mixed in with the calculated (SSM) Z' cross section.
  - Very clear signal above the continuum background!



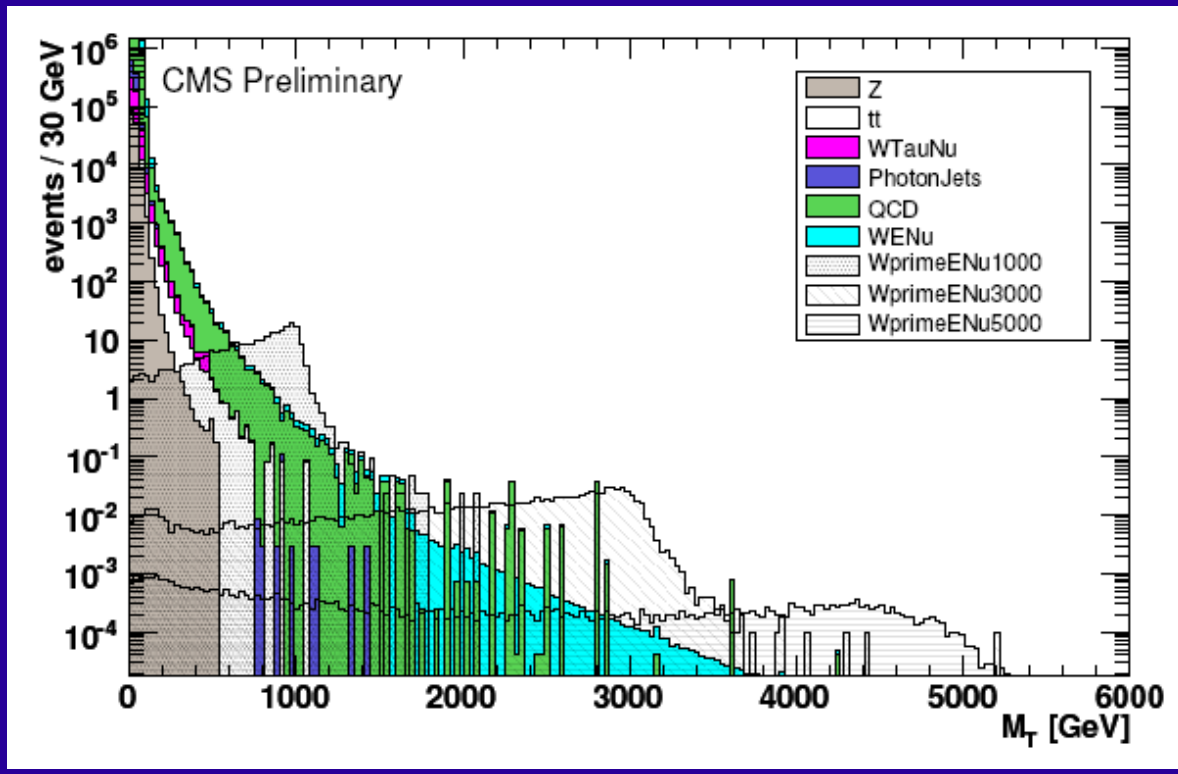
Z'->ee reach:

- Again, integrated luminosity, for our data based techniques needed for 5σ observation of two separate Z' models.



W'->eν:

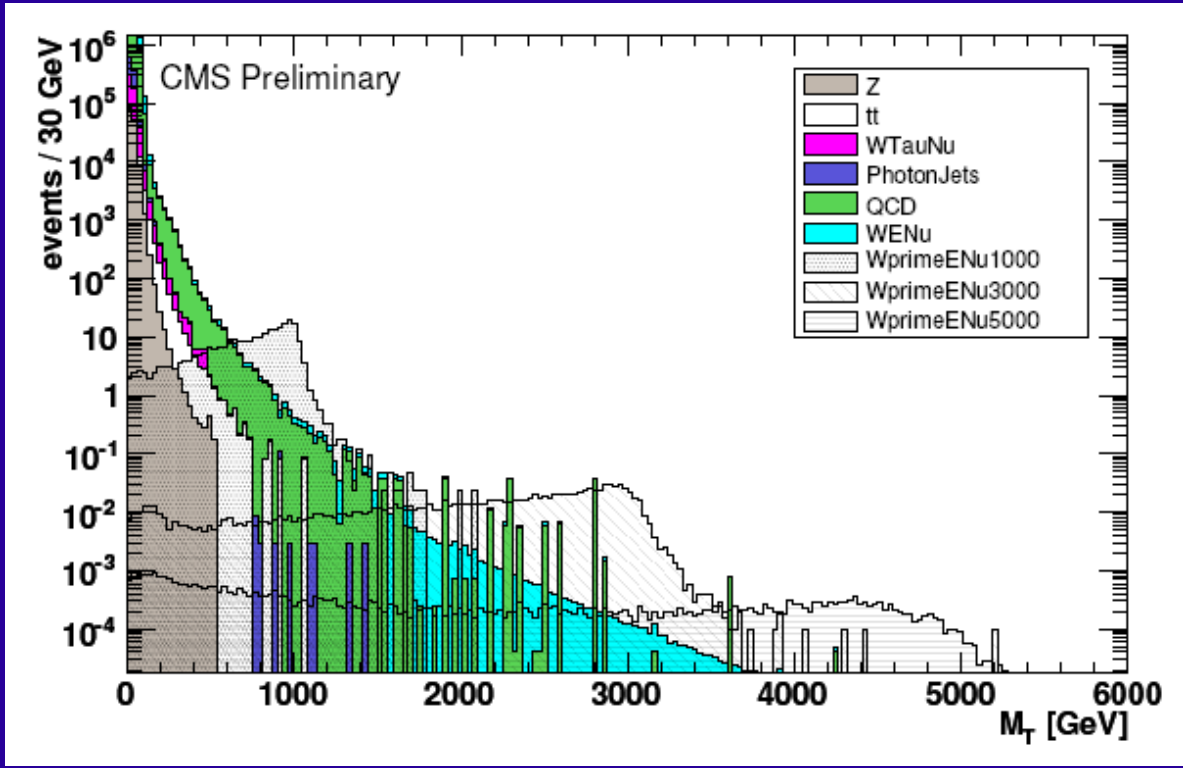
- Typically used for a benchmark, and understanding missing E_T for more complicated topologies.
- Have the SM W transverse mass as a check to begin with.



Transverse mass distributions for three separate W' masses, and SM backgrounds.

W'->eν:

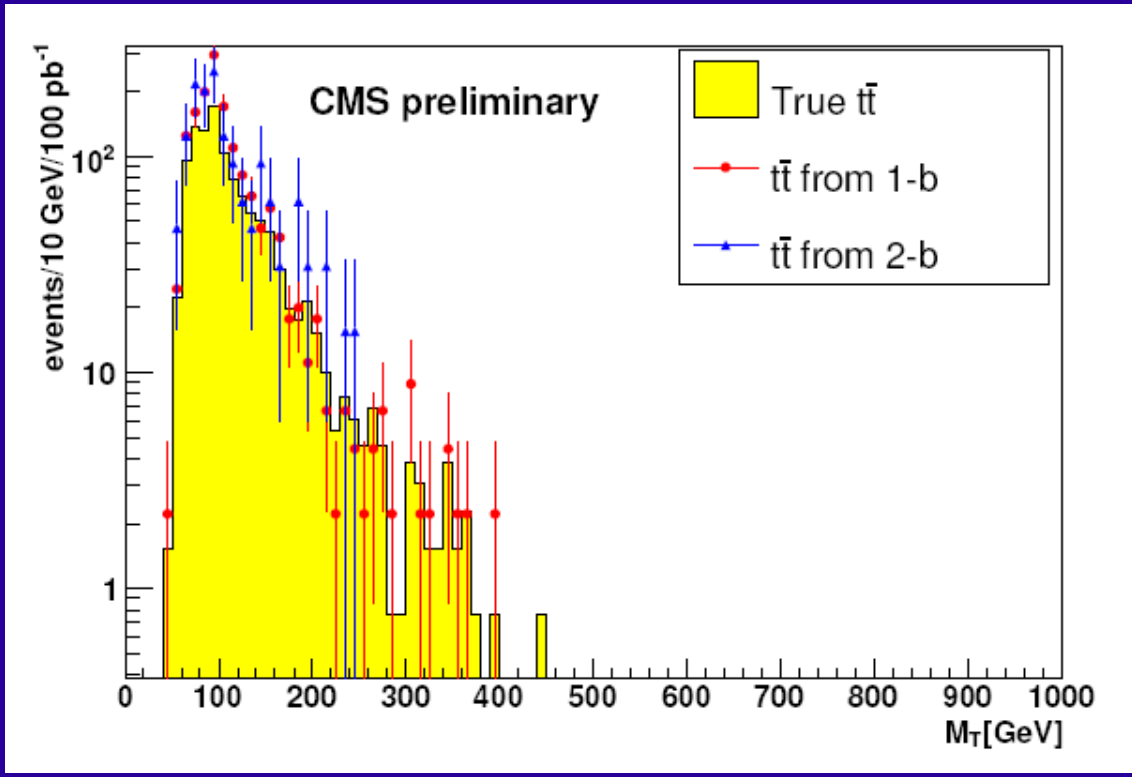
- QCD Multijets: Normalize to low M_T region, take shape from inverted quality cuts.
- SM W->eν: Indistinguishable, but rare (can normalize to SM peak).



Transverse mass distributions for three separate W' masses, and SM backgrounds.

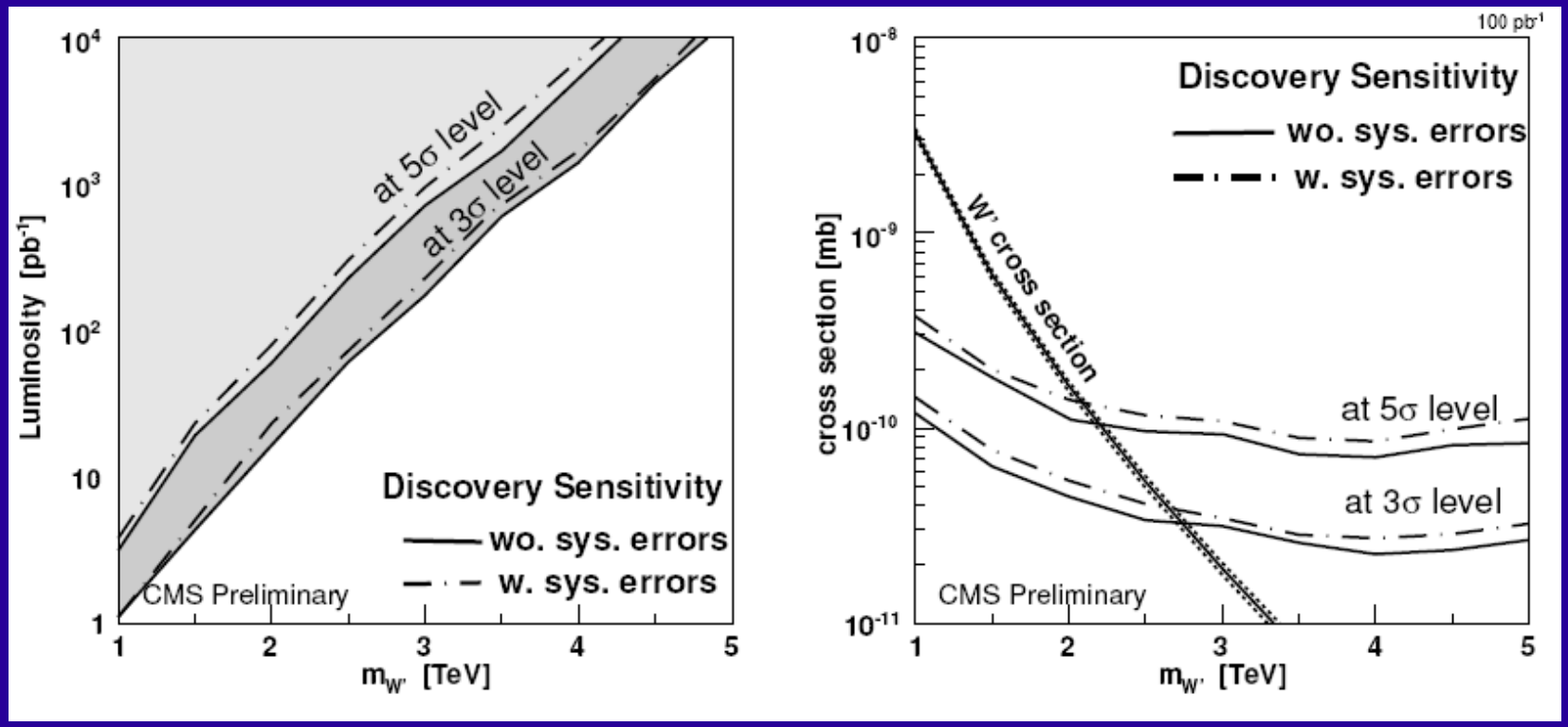
W'->eν:

- As previously discussed for Z'->ee, one does a similar estimate for di-top production for W':
  - In this case of course, it's the transverse mass that we're concerned with.
  - But still no bias from the b-tagging.



Transverse mass in top events, and using 1- and 2- btags.

W'->eν:



- Sensitivity for 100 pb^{-1} of startup data, using the data based techniques described. Worth noting that with only 40 pb^{-1}, one reaches current best from Tevatron.

Dijets:

- Specifically, dijets plus missing transverse energy, a common SUSY signature.
- However, the missing E_T is not going to be known well at startup.
  - Neither will the Jet E_T for that matter.
- Need to be clever with what information we DO have, thus…

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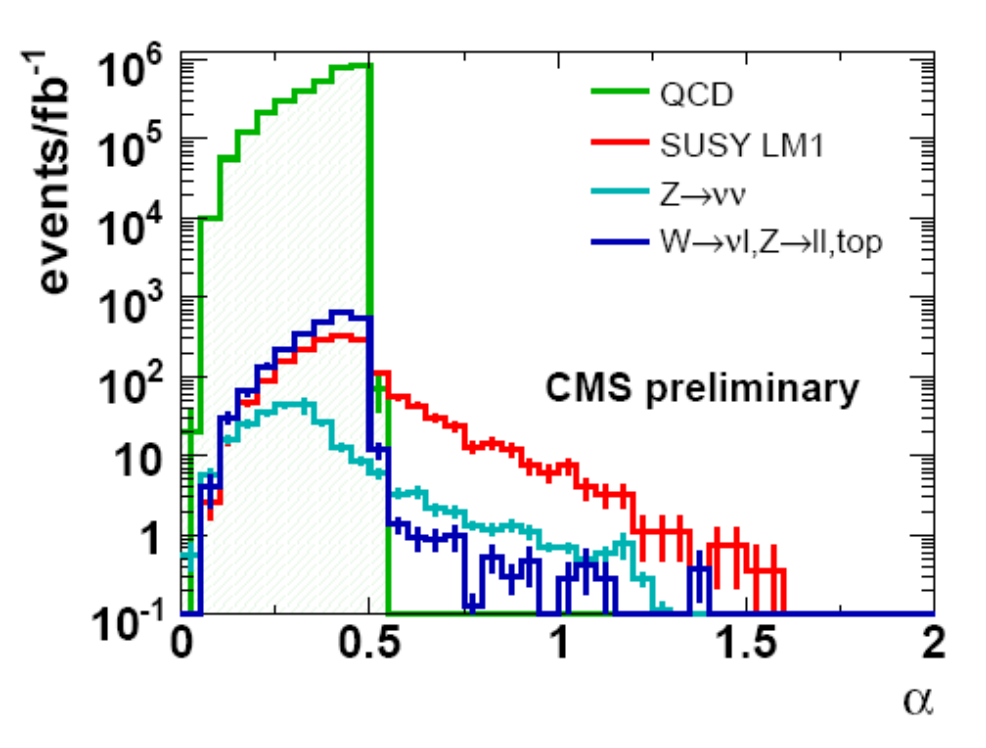
$$\alpha = \frac{E_T^{j2}}{\sqrt{2E^{j1}E^{j2}(1-\cos\Theta)}}$$



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$$\alpha_T = \frac{E_T^{j2}}{\sqrt{2E_T^{j1}E_T^{j2}(1-\cos\Delta\phi)}} = \frac{\sqrt{E_T^{j2}/E_T^{j1}}}{\sqrt{2(1-\cos\Delta\phi)}}$$

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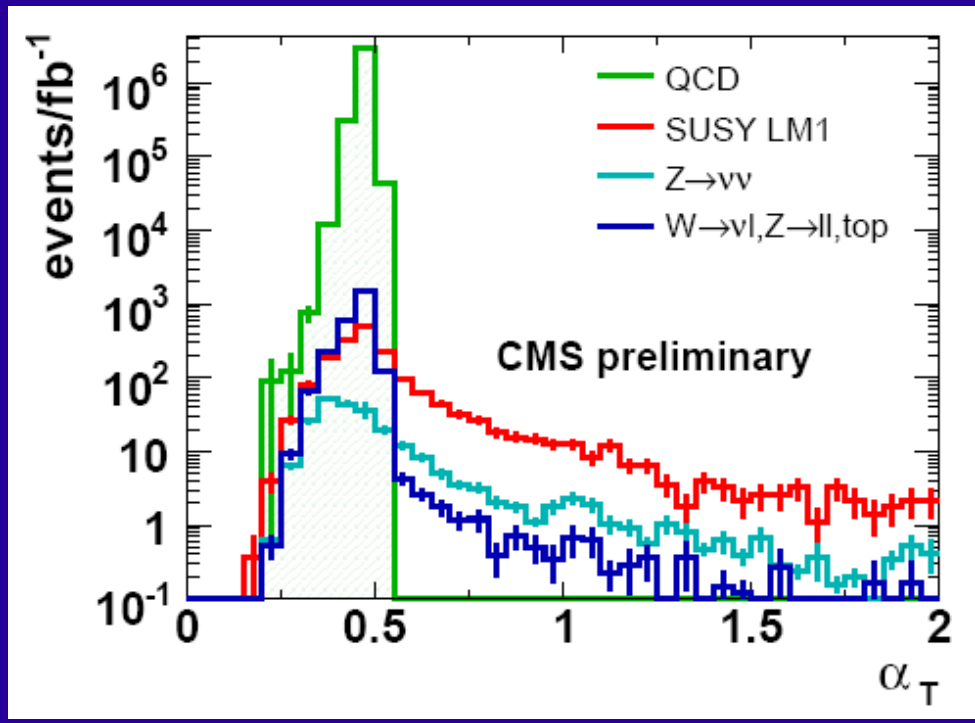
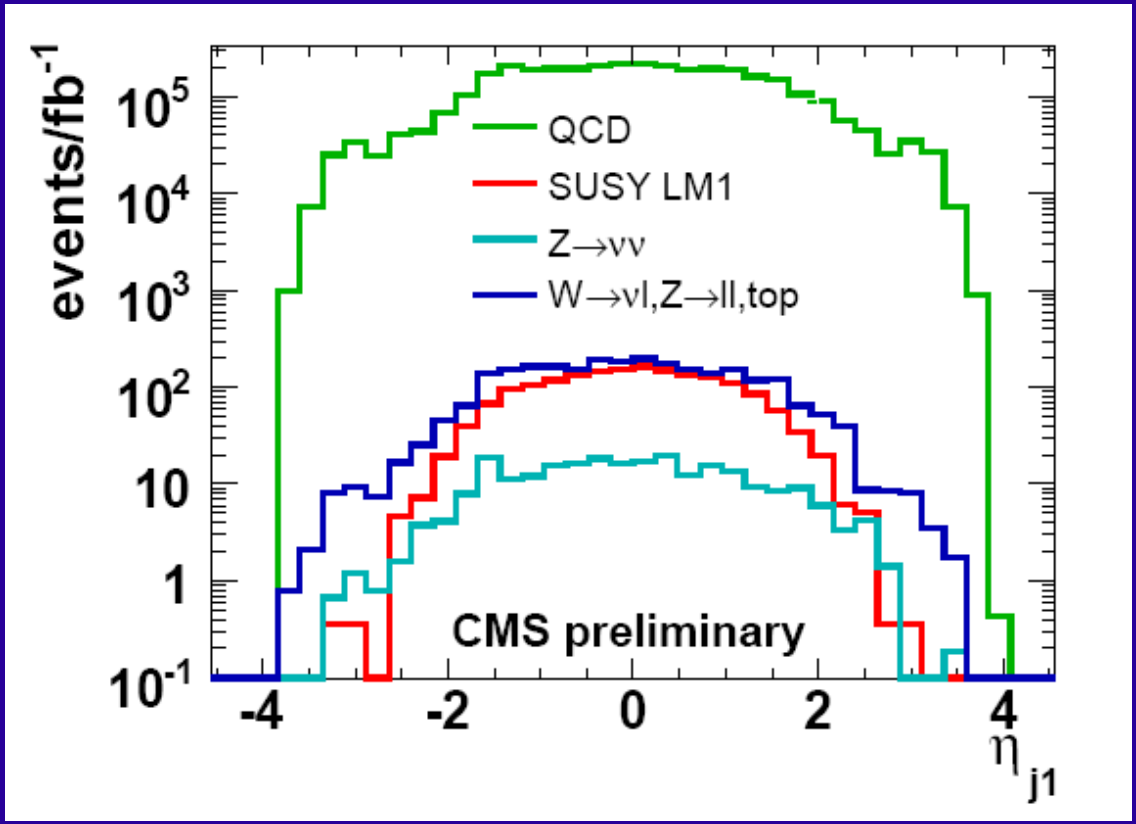


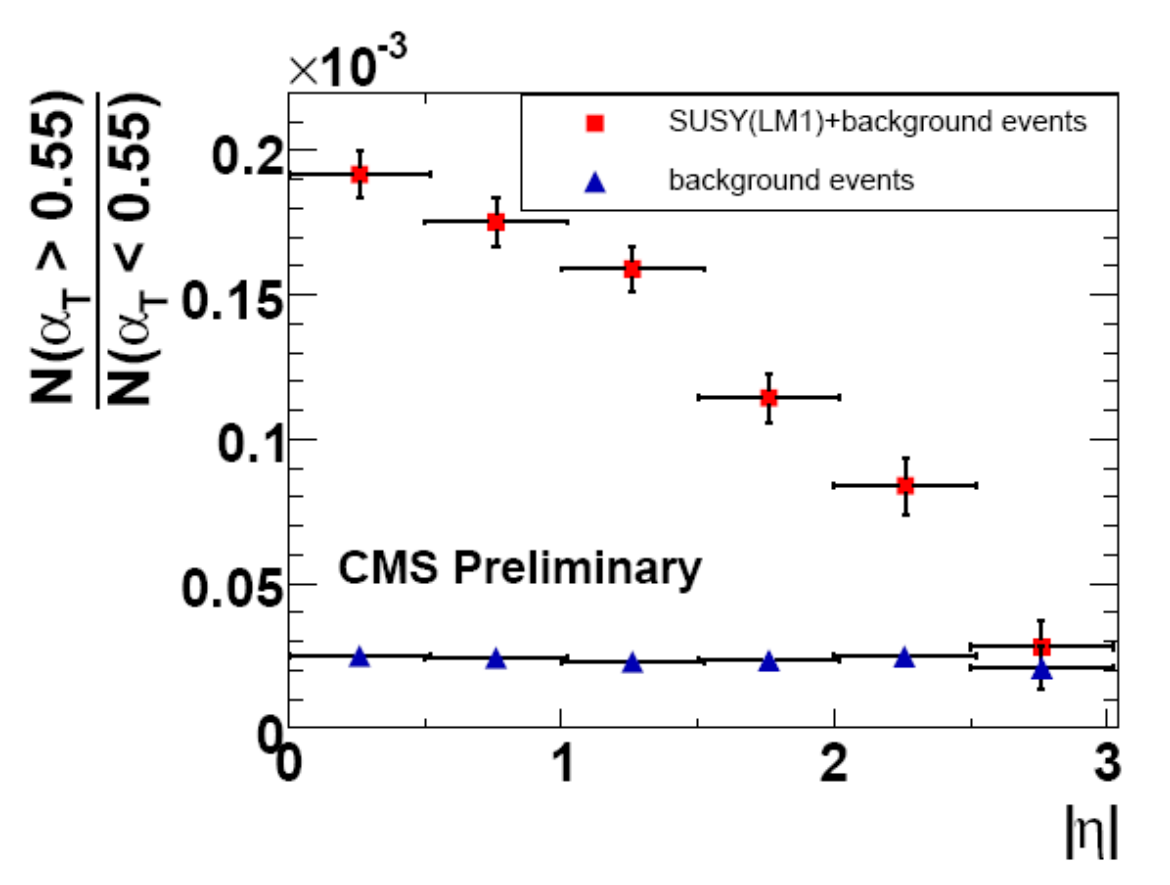
Background Estimation

- Finding background from data:
  - Define a region without signal.



Background Estimation

- Finding background from data:
  - Define a region without signal.
  - Measure ratio R.



Background Estimation

- Finding background from data:
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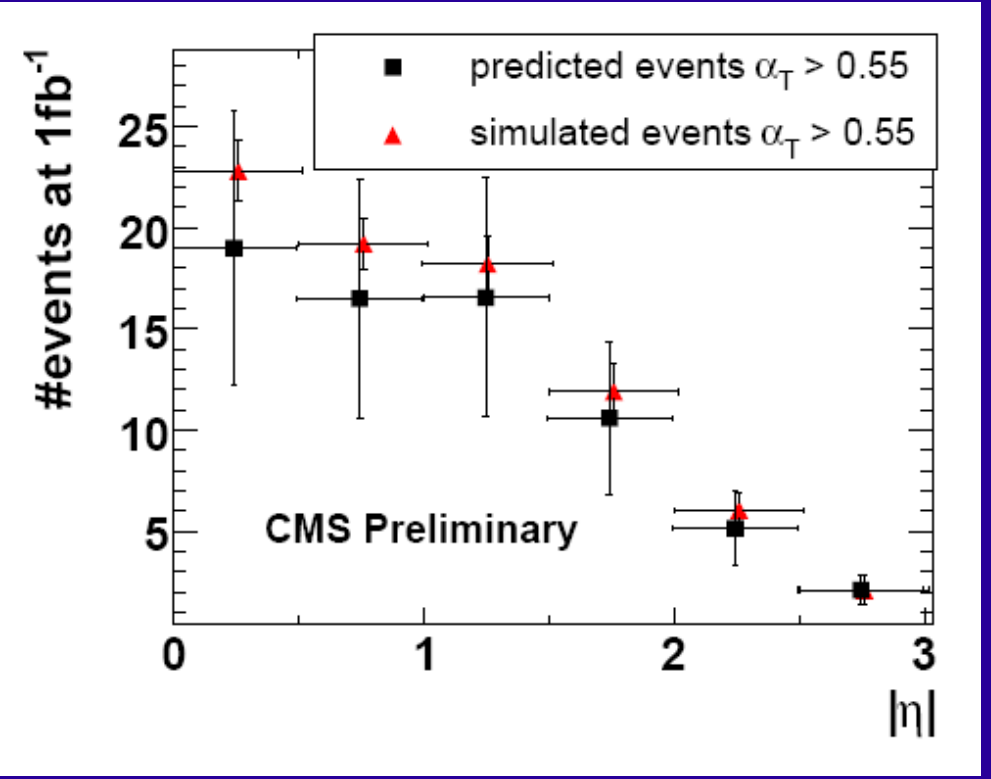
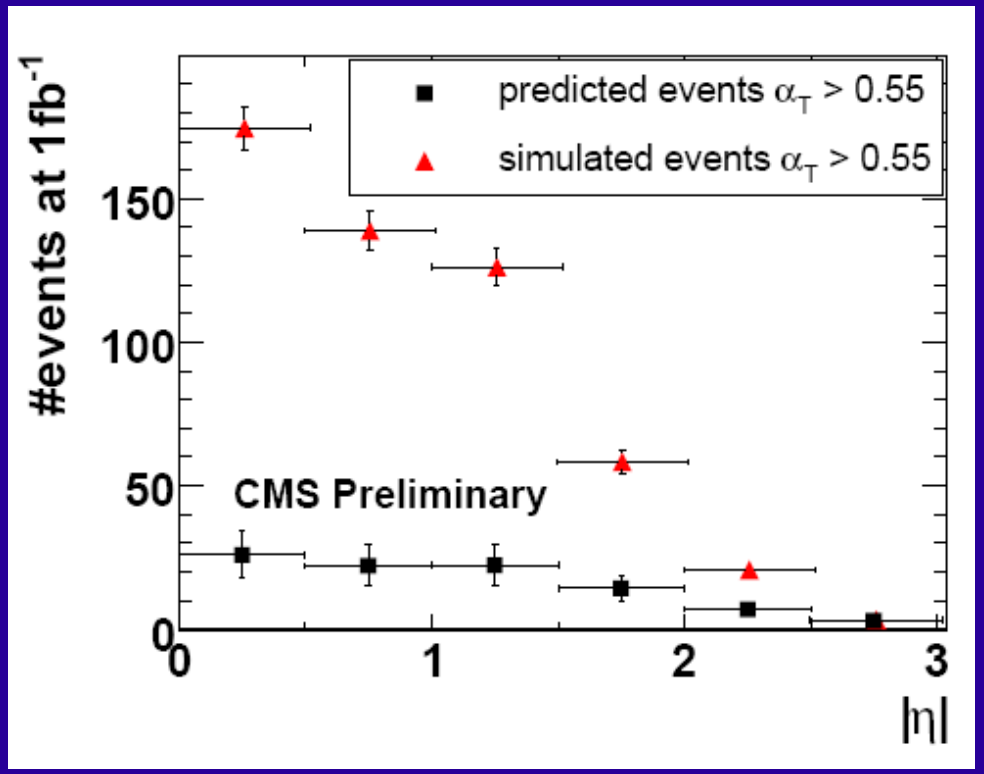
  - Measure ratio R.
  - Use R to extrapolate into region with signal.



Closure test, no signal present.

Background Estimation

- Finding background from data:
  - Define a region without signal.
  - Measure ratio R
  - Use R to extrapolate into region with signal.
  - Should generalize for any new central dijet + MET!



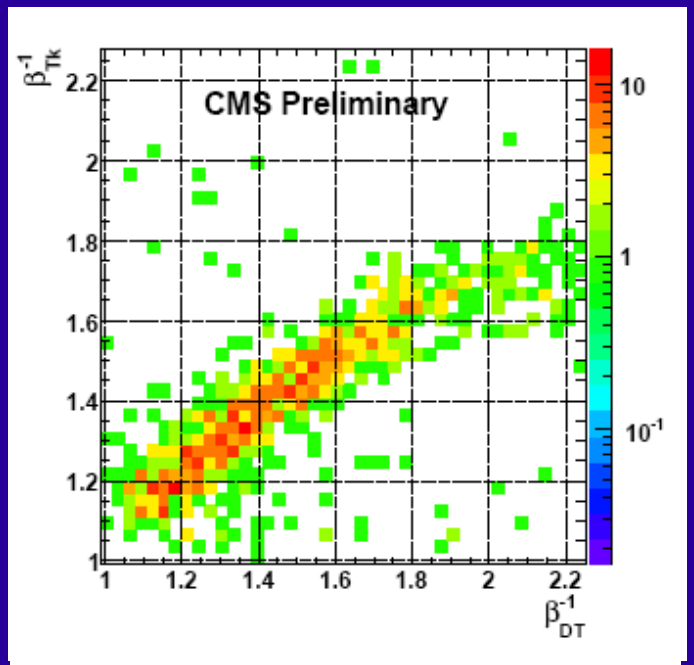
With signal present.

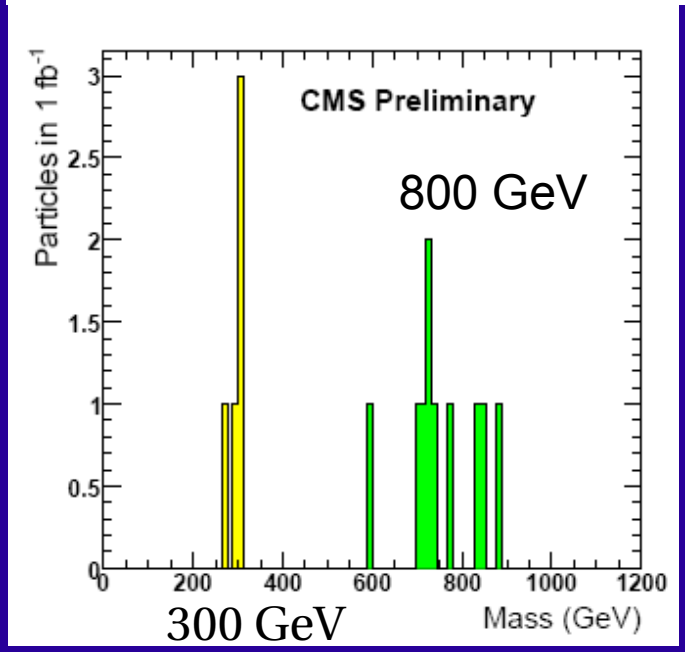
HSCP:

- For Universal Extra Dimensions, SM particles have KK partners, which can be pair produced.
- A Heavy, Stable, Charged Particle (HSCP), propagating through the detector can appear somewhat like a muon (if lepton-like), depending on the mass.
- So if it walks like a muon, and talks like a muon, and acts like a muon, how do we know it isn't a muon?

HSCP (2):

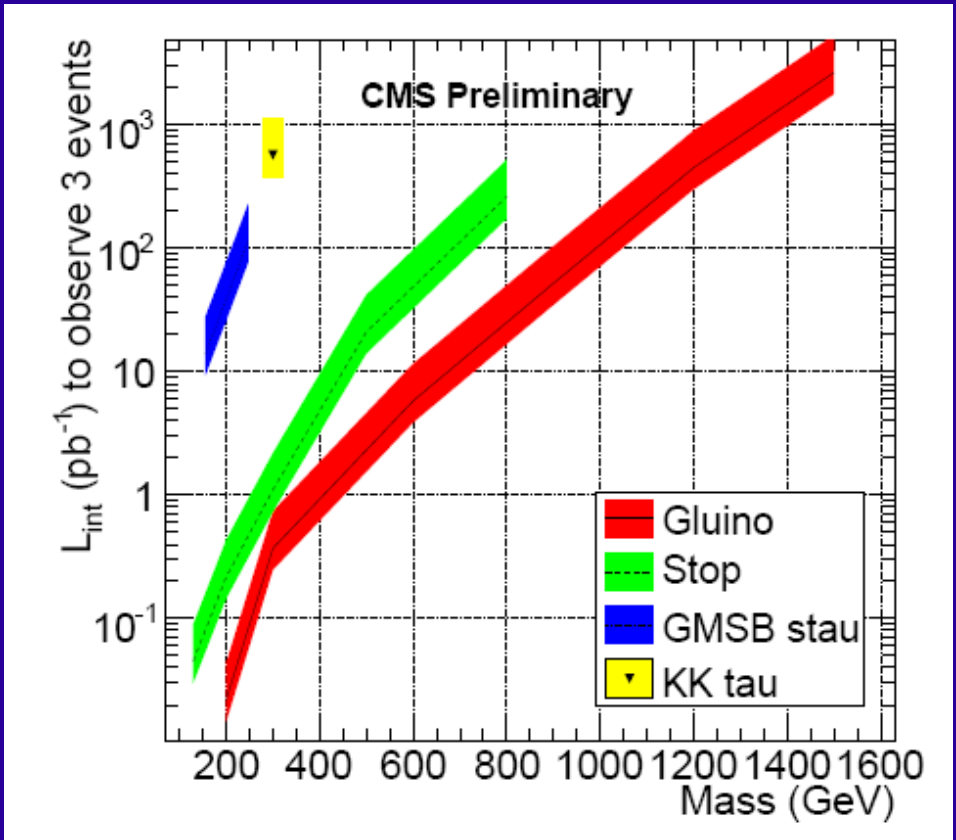
- CMS tracker can measure dE/dx for the particle passage, and thus measure β (and the mass from the measured momentum).
  - Can also correlate this to measurement from muon drift tubes.





HSCP (3):

- Depending on the mass of the particle produced, it can take comparitively little luminosity to observe these events.
- Pair production and invariant mass allow control of minimal backgrounds.



MUSiC:

- Model Unspecific Search in CMS:
  - Akin to other model independent searches, casts a wide net and attempts to capture signals not specifically covered by other particular analyses. Currently considers the permutations of at least one lepton (e or μ), and γ, j, and missing E_T.
  - It is worth noting that one requires a detailed understanding of the detector to get a true signal out. But that's where MUSiC can help! It can point out to us the things that aren't properly modeled early on so that we can correct them.

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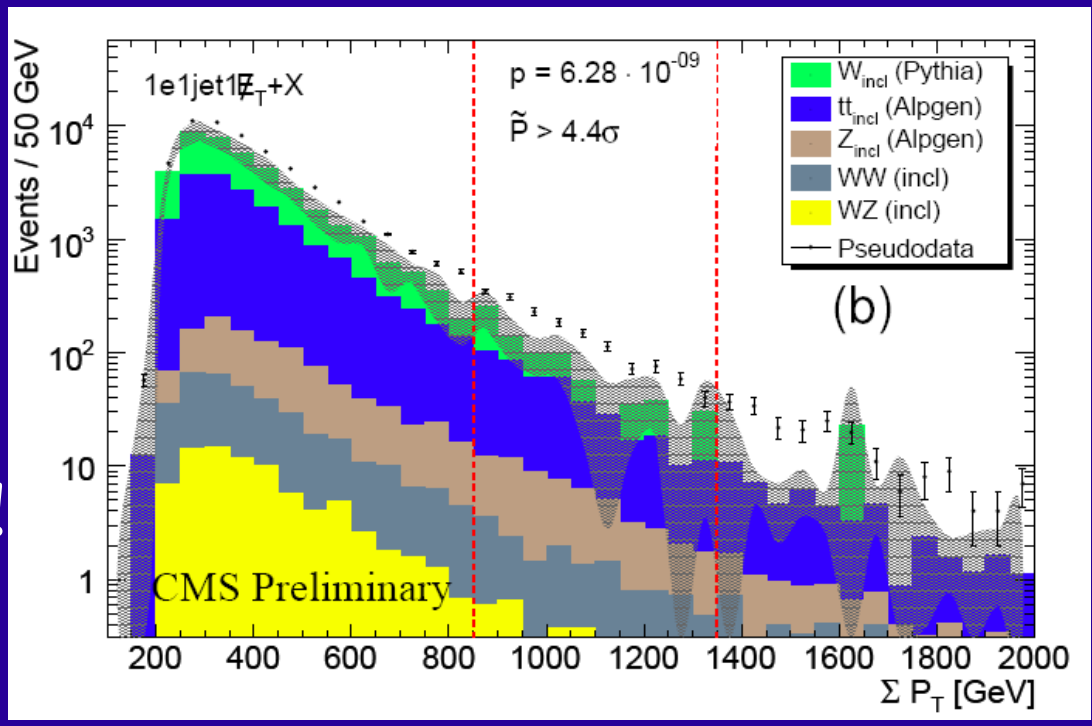


In this case it's telling us we modeled our W+jets background incorrectly.

Conclusions:

- Tuning up analyses using:
  - More reasonable startup integrated luminosities (everyone knows we won't get 5 fb^{-1} on Day 1).
  - Data based measurements for efficiencies and backgrounds.
  - Measures in place to identify problems and correct them.
- Ready for the rubber to hit the road!

Backups:

for your entertainment

Dijets (2):

- $p_T^{j1} > 50\,\mathrm{GeV}$, $p_T^{j2} > 50\,\mathrm{GeV}$
- $F_{em}^{j1} < 0.9$, $F_{em}^{j2} < 0.9$
- $|\eta_{j1}| < 2.5$
- $p_T^{j3} < 50\,\mathrm{GeV}$
- $\Delta\phi(\mathrm{j_i}, \mathrm{MHT}) < 0.3$ rad (i=1,2,3)
- $p_T^{e} < 10\,\mathrm{GeV}$, $p_T^{\mu} < 10\,\mathrm{GeV}$

MM scatter

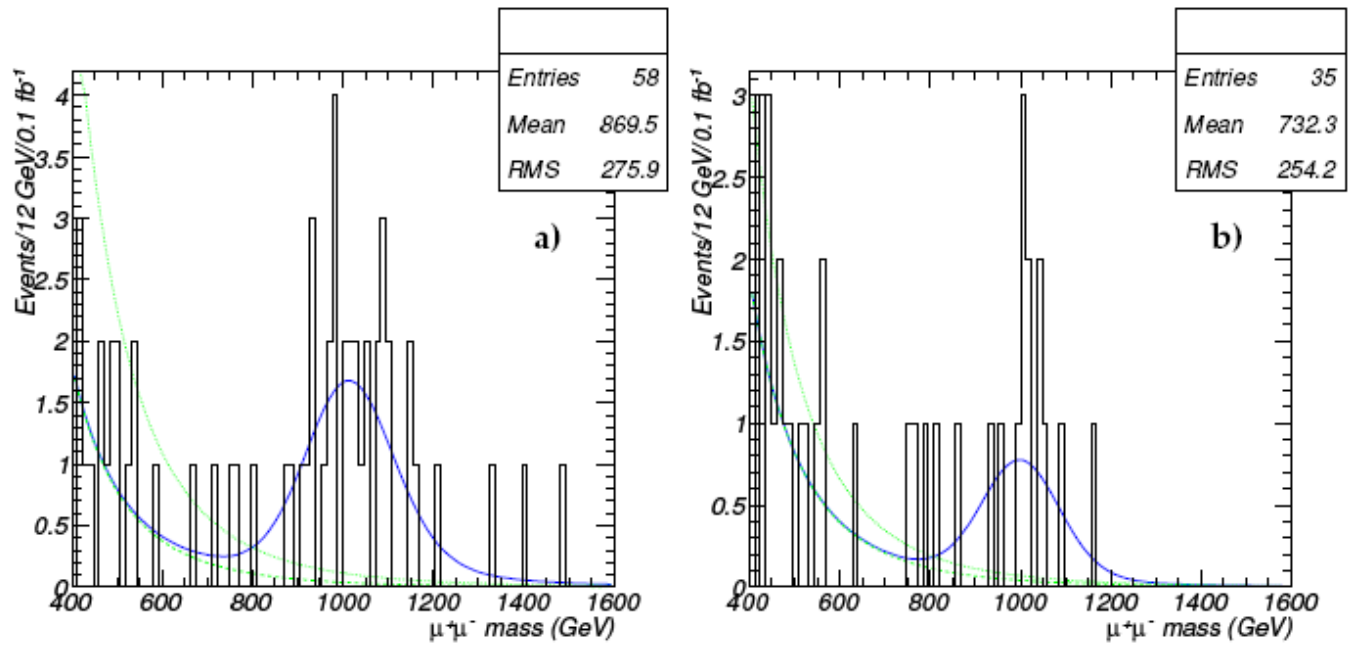
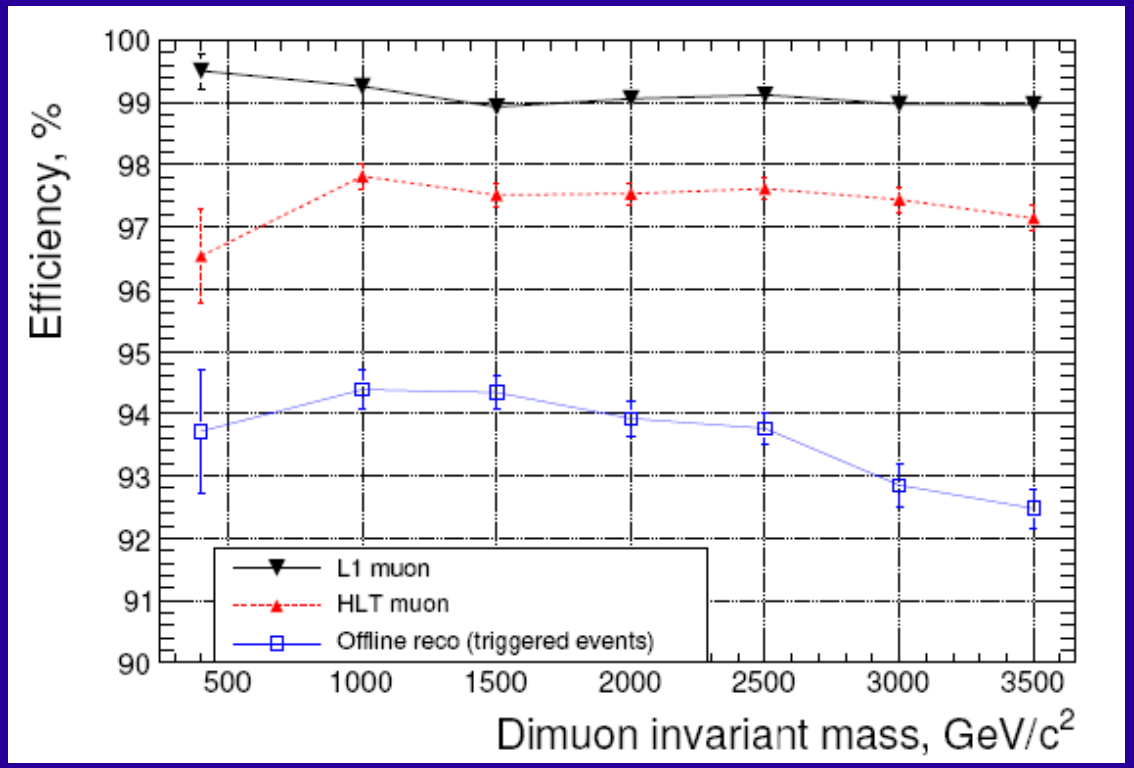


Figure 8: Histograms of $M_{\mu\mu}$ in two typical MC experiments, for a) a 1 TeV/c^2 Z_{SSM} plus background and b) a 1 TeV/c^2 Z_ψ plus background, for an integrated luminosity of 100 pb^{-1}. The solid blue line is the result of the full signal-plus-background fit to the mass distribution; the dashed green line shows the background component of the fit; the dotted green line is the result of the background-only fit. Data were binned only when plotted; all fits performed were unbinned.

Dileptons:mm