TeV4LHC Higgs – 12/14/2004

Z→ bb and how to use it

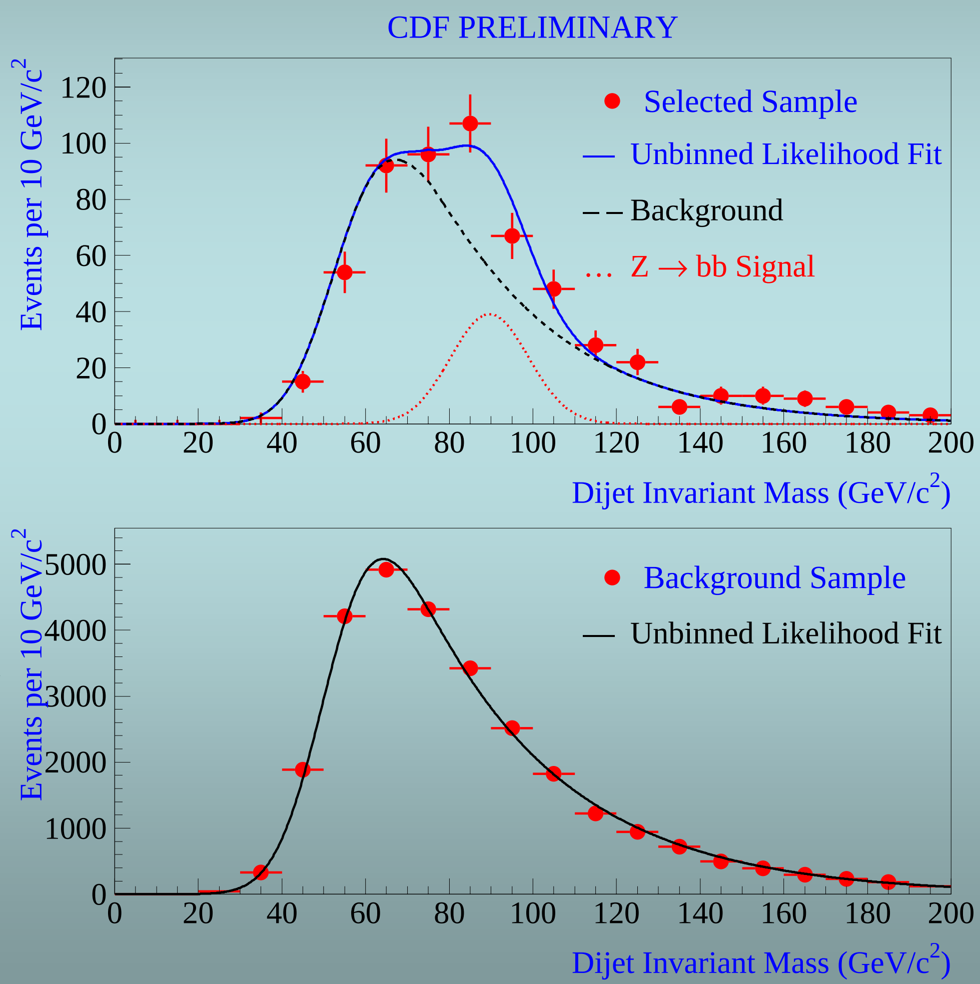
Tommaso Dorigo

University of Padova and INFN

- Introduction
- The Z→bb trigger at CDF II
- Resolution issues
- B-jet scale issues
- Other ideas

Introduction

- In Run I, CDF extracted a small signal of Z decays to bb pairs
- The signal was extracted from events collected by a low-Pt muon trigger
- Nice, but cannot be easily exploited for b-jet scale determinations

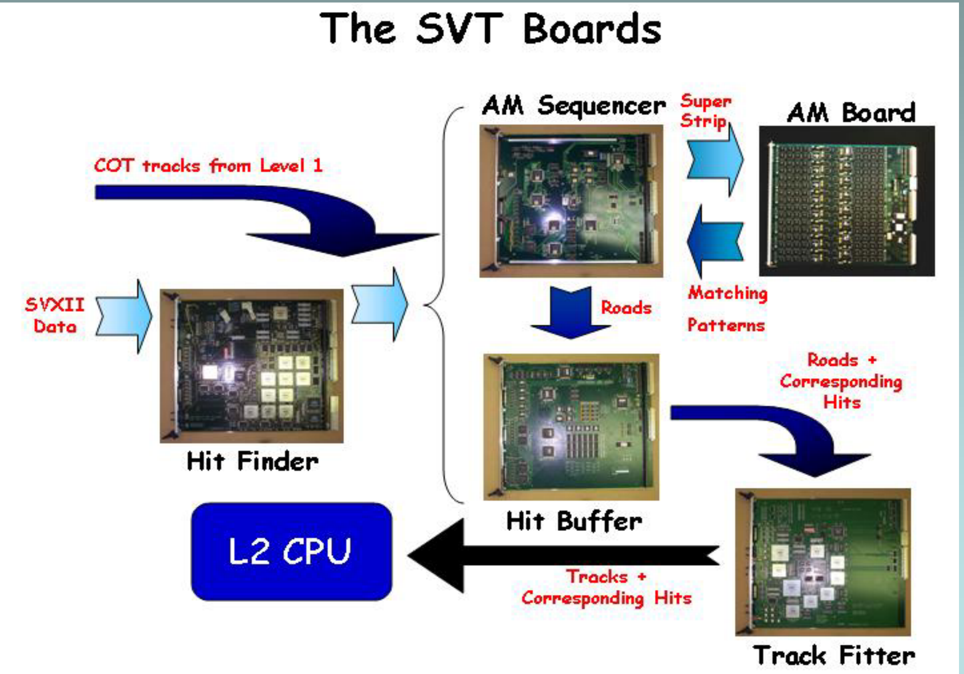


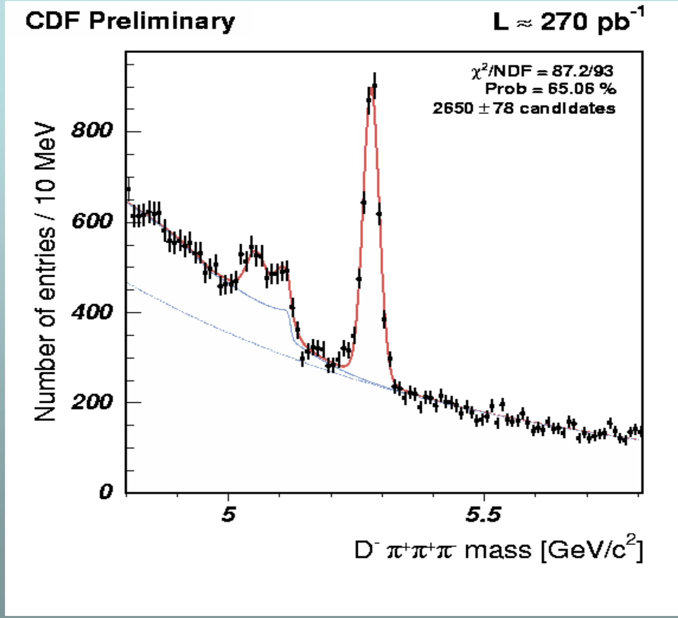
What could one do with a large sample of Z→ bb events

- A large-statistics resonance would be invaluable to extract the scale for b-jets, which cannot be easily determined otherwise and constitutes the largest single source of systematic uncertainty in all top mass measurements
- Once one sees a signal, one can then test improved algorithms that increase the mass resolution of a dijet decay
- This is of paramount importance for the Higgs search in low MH regime
- Finally, one cannot really claim one has a shot at finding the Higgs boson if one cannot see a 1000x cross section signal.

A trigger for $Z \rightarrow bb$ in CDF II

- To get its hands on a unbiased set of $Z \rightarrow bb$ decays, CDF relies on the SVT to trigger on low-Et dijet events from b-quarks.
- The SVT is a hardware device which is able to measure Pt and impact parameter (to within 50 um) of charged tracks in less than 20 us. It is implemented in the Level 2 of CDF, and it has proven crucial for most of CDF II's B physics program





The Z→ bb trigger at CDF II

- The CDF trigger system has 3 levels. The Z→bb trigger exploits most of its functionalities.

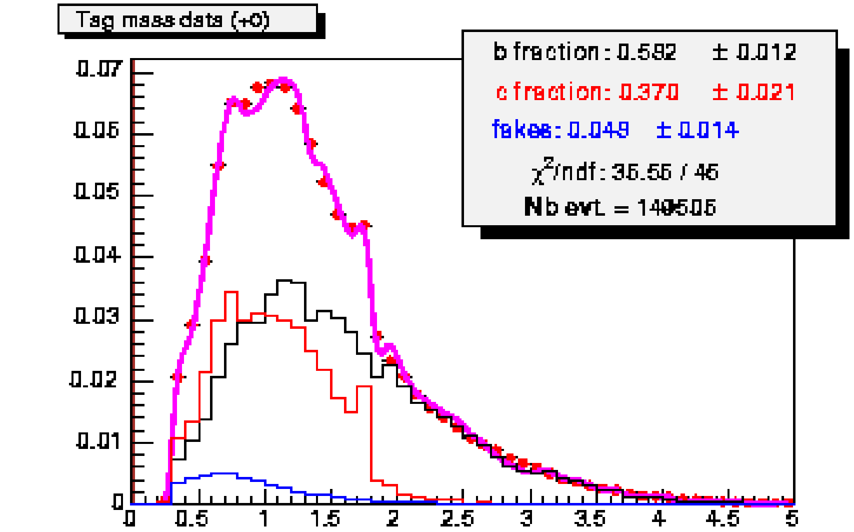
- At L1, dijet events with charged tracks are collected by requiring 1 5-GeV calorimeter tower, plus two 2 GeV charged tracks (thanks to the XFT, an eXtremely Fast Tracker).
- At L2, the SVT is used to ask for two tracks with IP>160 um and two energy clusters with Et>5 GeV.
- At L3, a full speed-optimized reconstruction is done. Events with two Et>10 GeV jets containing hints of lifetime are selected.

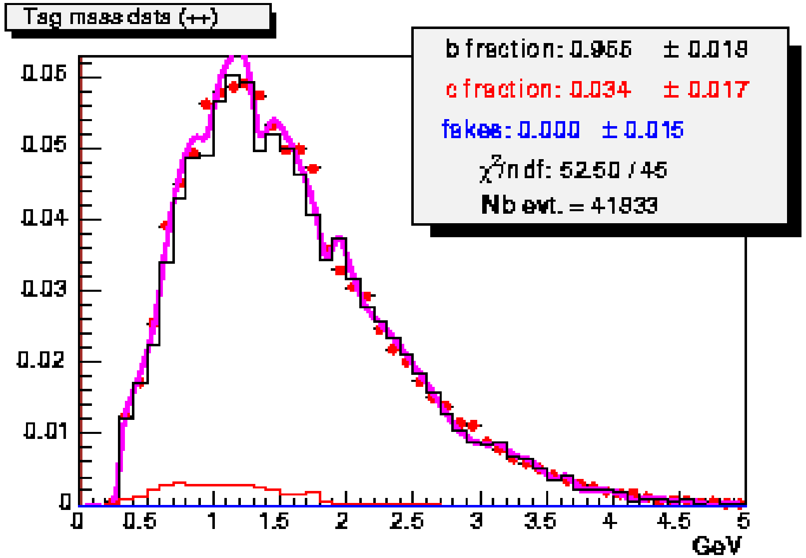
- The cross section (70 nb @L2) is largish for a calibration trigger. We are constantly fighting with rate increase with L…

- The overall efficiency on Z→bb is a mere 4-5%, but still much better than that of lepton triggers (<1%) which are however biasing the jet Et measurement.

Sample composition studies

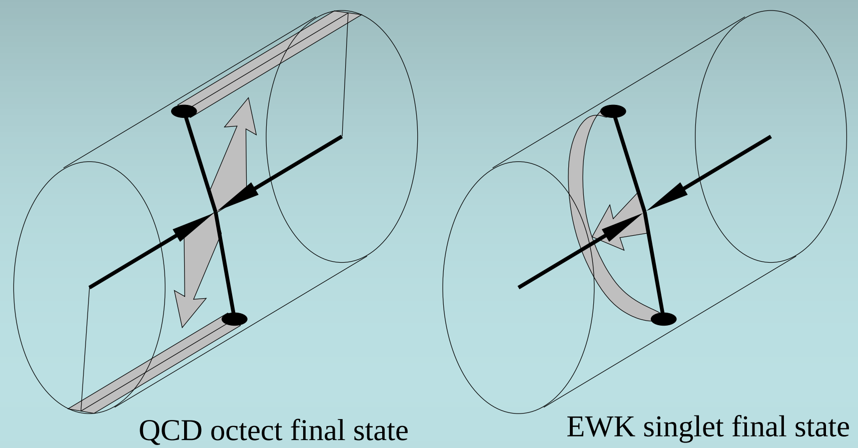
- Once data is collected, one still has lots of light quark and gluon jets in the sample, as a measurement reveals
- One thus has to select events with lifetime information in both jets (double SecVtX tags) to enhance as much as possible the S/N ratio
- The fraction of bb is then higher than 95%.

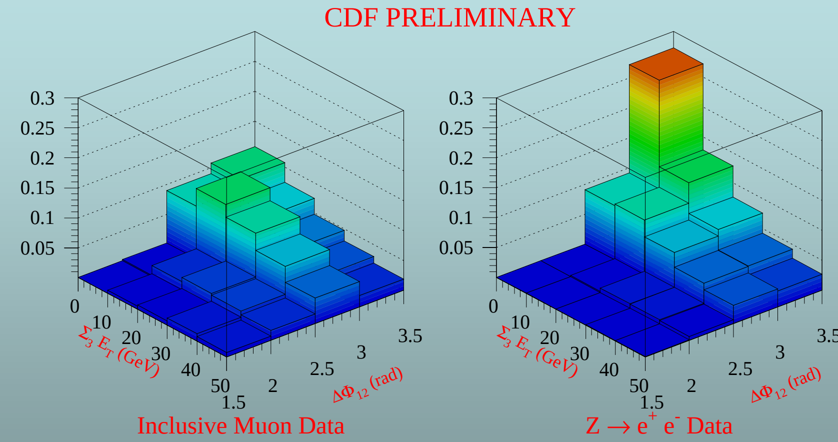




Other handles to boost the S/N

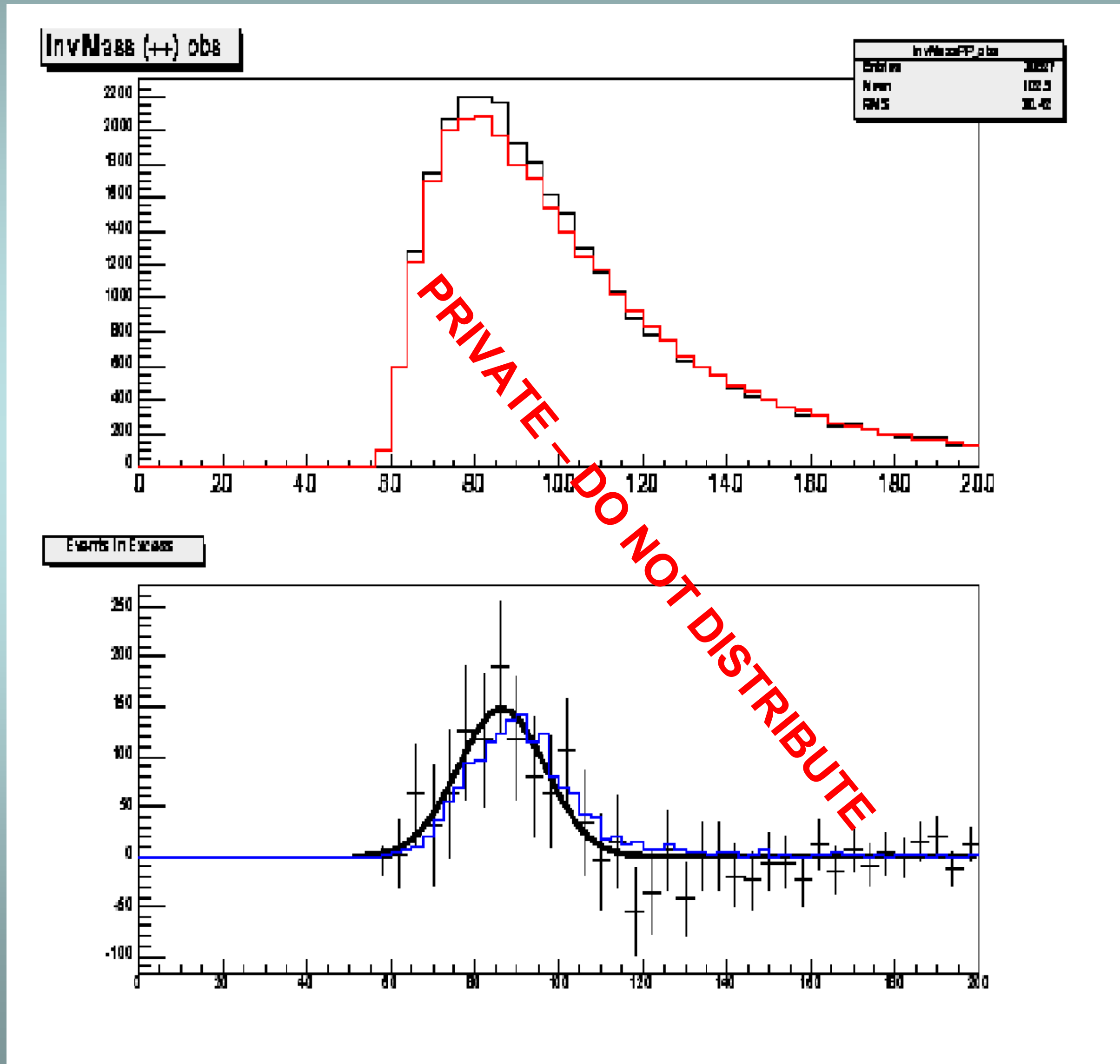
- The topology of Z decay is a clean one: one expects two jets with little radiation from QCD
- Initial state is in fact quarks, while bb from QCD are 90% gluons
- Color flow is absent from IS to FS in signal events
- Overall, the most sensitive variable is the sum of clusterized energy besides the two leading jets
- Back-to-backness also good discriminant (but somehow trigger-biased in our case





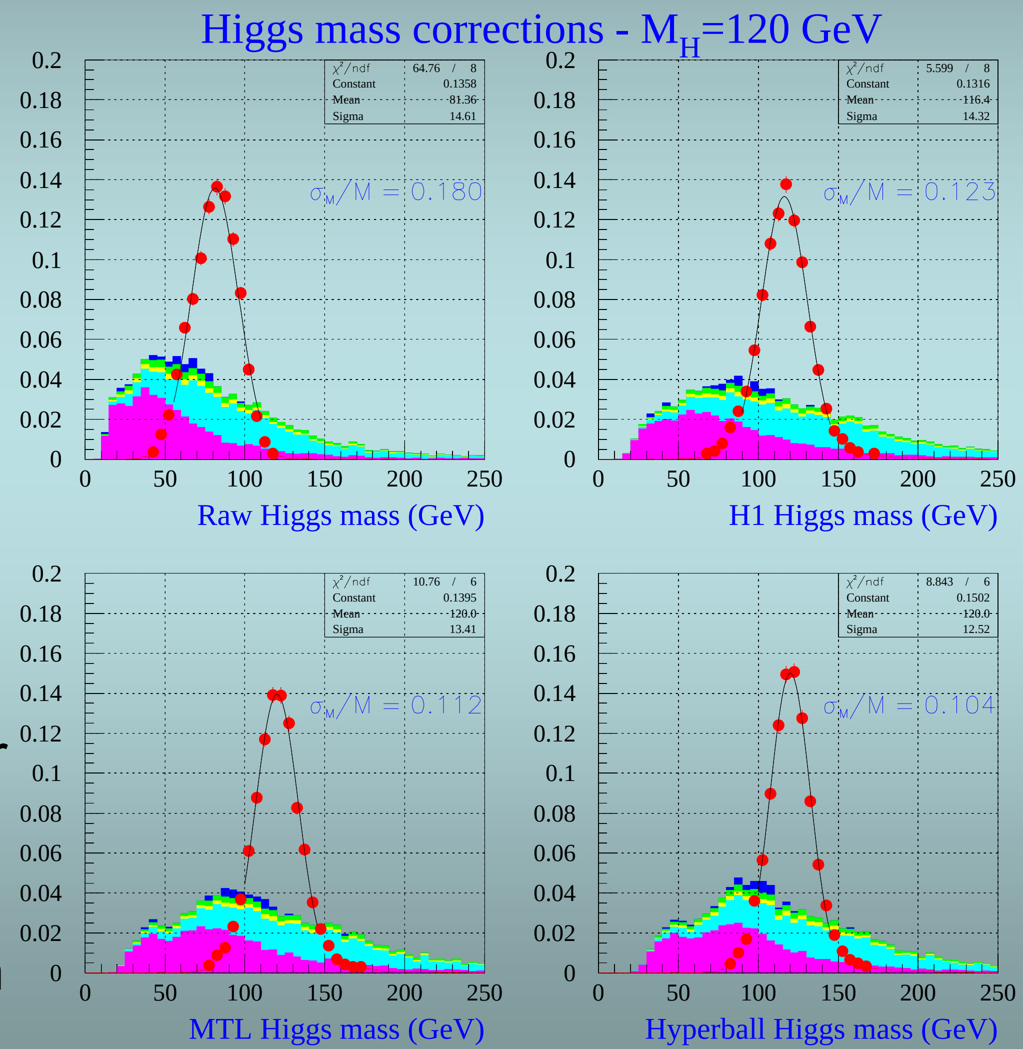
What we expect to get

- With 2 fb-1, we expect to obtain about 10,000 signal events on top of a background 10-15 times larger
- This should be enough for a determination of the b-jet scale to within 1%, and for detailed studies of resolution optimization algorithms



Resolution optimization issues

- A 10,000 Z→ bb signal would be very nice to test and support our claims of a 10% sigma(M)/M resolution for bb systems – and to allow us to get even further (but less than 8-9% is forbidden by fundamental laws)
- In the HSWG, we showed that we could obtain a 10% resolution on H→bb decay on WH/ZH events
- That has a big impact on the Tevatron's chances for light Higgs boson discovery
- If we KNOW our resolution, things are even better.



Jet energy scale issues

- While studying and finding the Z→bb is cool, there are other avenues to a determination of the b-jet scale
- CDF is studying gamma-b events, which have a not-so-insignificant cross section and would be a perfect tool – the same thoroghly used for generic jets
- At the LHC, things are not so rosy. People is thinking about Z→bb+jet events… I have a better idea

Z→bb + jet ?

- When looking for a discrimination between Z→bb and gluon→bb, one is struck by the scarcity of handles
- QCD radiation and color flow are virtually the only ones if you cannot determine the b charge
- S/N is largest when no other jets are present… Obvious: ISR is stronger from gg collisions than from qqbar
- So when one searches for Z→bb+jet vs g→bb+jet, one pays the price of a further reduced S/N… Sure, if one cannot trigger on bb alone that's the best one can do. Or is it ?

Z→bb + gamma !?

- As a matter of fact, why not looking for Z→bb recoiling against a photon ?

Advantages:

  - Automatically selects qq initial state, boosting the S/N by an order of magnitude at typical TeVatron energy, surely more at LHC
  - The recoiling gamma is WELL MEASURED! Much more than a jet anyway
  - Can fully exploit dedicated detectors for H→gammagamma…
  - Resolution is so good, one can determine b-jet scale by just looking at jet-jet ANGLE!

Disadvantages:

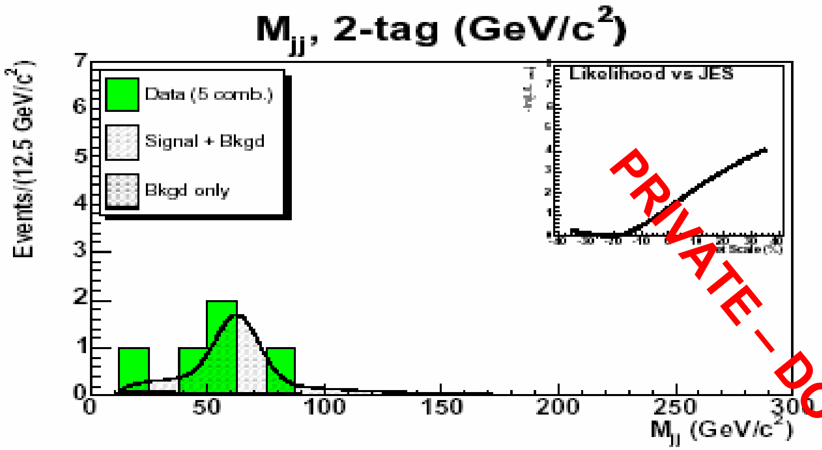
  - Much fewer events of course
  - Not much else

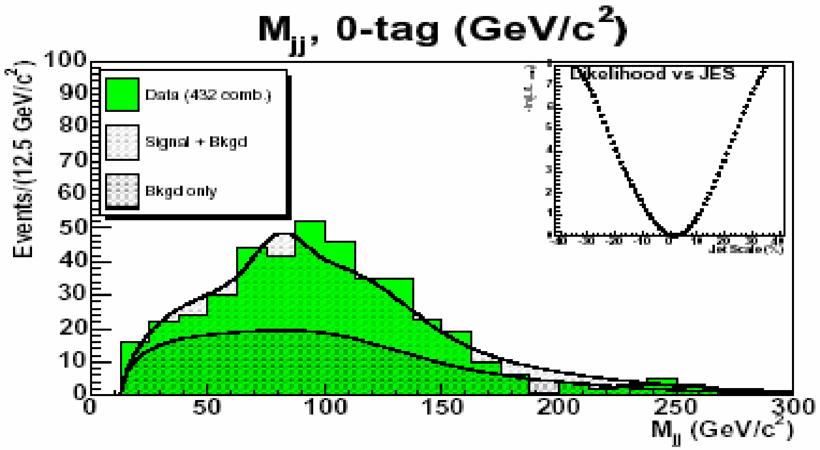
- Have a CMS student working on this… Expect results soon!

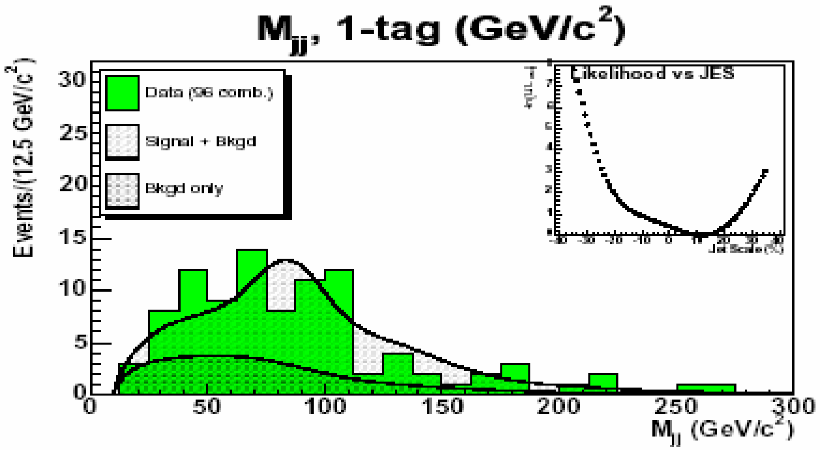
…But is the b-scale determination needed after all ?

- CDF and D0 are rapidly collecting large samples of tt decays in single lepton final states
- At the LHC, top events will be all over the place
- The W→jj signal in single-lepton tt events is prominent, will be used to get the scale of light quark jets
- B-jets are different… But are they different enough to create a problem ?

The auto-calibrating W→jj







Sample	Result JES
0-tag	$+1.7\ ^{+6.1}_{-6.2}$ (stat.)%
1-tag	$+10.9\ ^{+9.5}_{-13.4}$ (stat.)%
2-tag	$-22.1\ ^{+12.5}_{-16.4}$ (stat.)%

PRIVATE – DO NOT DISTRIBUTE!

This is very promising! Statistics-dominated, will improve with time.

Effect of b-scale uncertainty

- Let's take the winter '03-'04 measurement of Mtop from CDF
- Study how much of the JES systematics is due to b-scale alone
- Dominant in b-tagged events!

(From a study by JF Arguin, Toronto Univ.)

Motivation: Top Mass Measurement

The JES uncertainty is dominant for M_{top} measurement:

Example: Last template lepton +jets measurement:

1. Jet energy scale: $6.8 \text{ GeV}/c^2$
2. Statistics: $5.7 \text{ GeV}/c^2$
3. Other syst.: $2.0 \text{ GeV}/c^2$

In $t\bar{t}$ lepton+jets events: 2 b-jets and 2 jets from W (plus ISR/FSR jets)

Separate contribution of b-jets from others (shift in template mean):

Type	2-tag (GeV/c^2)	1-tag+4-jets (GeV/c^2)	0-tag (GeV/c^2)
All jets	5.9	6.6	7.4
Only b-jets	4.7	4.2	3.9
All non-b-jets	1.3	2.3	3.4

$\rightarrow$ W-jets are constrained to W mass, but no direct constraints on b-jets!

How much are b-jet different ?

- B-jets are different in many respects:
  - They have a different (harder) fragmentation than light quarks or gluons
  - They yield leptons in 23% of cases (and more from the subsequent charm decays)
  - They have a large mass
  - They are color-connected to the top quark (only relevant to differences with W→jj jets)
- These differences have however a limited impact on top mass determinations, if one sets their scale the same as that of W→jj decay products (CDF II study, JF Arguin (Toronto Univ.)):
  - vary fragmentation parametrizations and parameters → 0.3% error on top mass;
  - vary amount of SL decay →0.4% error on top mass
  - Estimate amount of b-jet energy coming from color flow in MC, vary MC parameters → 0.3% error on top mass
  - So total effect could be small, O(0.5%)…
- This is good news!... But a resonance is a resonance, we need it no less.

Concluding remarks

- CDF II is in good shape for determining the b-jet scale with Z→bb events
- However, this might prove unnecessary (but still fun!) as auto-calibrating techniques in top mass measurements are being refined
- The Z signal will be used to prove we weren't boasting in vain on dijet mass resolution in the HSWG report
- There are other ways to get the b-jet scale.
- Z→bb plus gamma is at the least to be explored more thoroughly, possibly a fine addition to any b-scale determination, maybe(just maybe) the real way to go.
- You may steal my idea, but please quote me! ☺