# Les Houches 2009 MC & related tools

# Intro, suggestions etc…

**Jonathan Butterworth**

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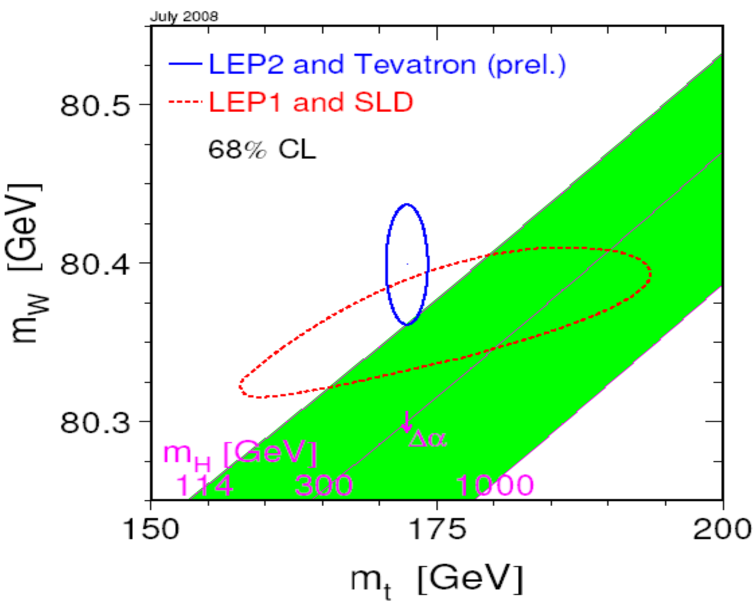
# Overview/motivation

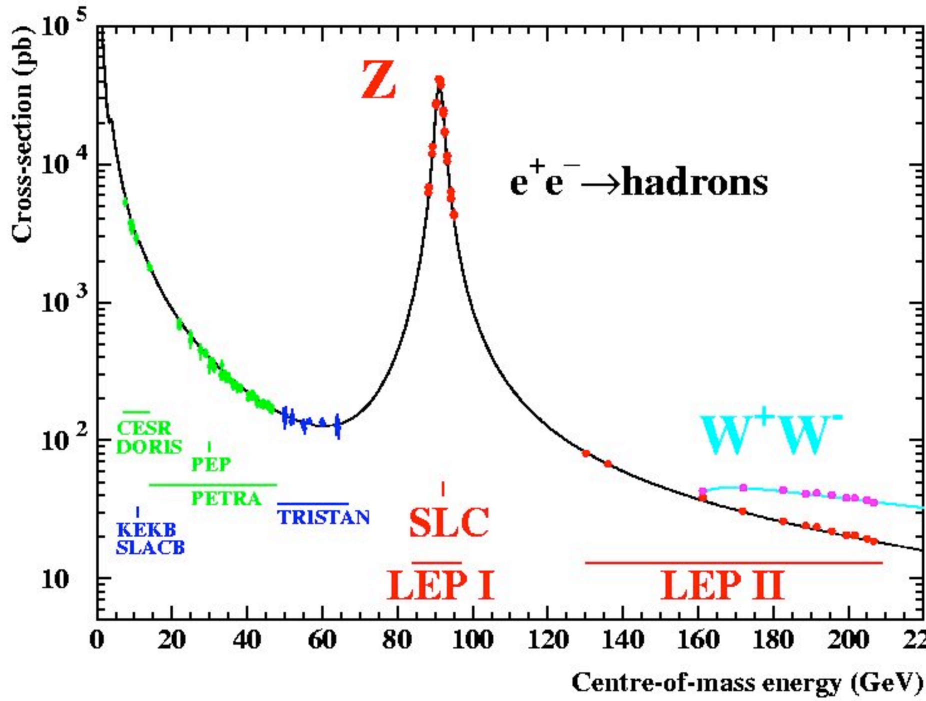
- Choices which are made by experimentalists have an impact on the usefulness of the data for phenomenological analysis.
- Seemingly arbitrary choices can sometimes dramatically affect the shelf-life and impact of a measurement.
- Ability to accurately compare and communicate results is likely to be a critical factor in how much physics we get from the LHC
- Some examples & explanation, then suggest the working topics

- Fundamental or observable?
- Corrections, corrections
  - Leptons and photons
  - Inclusive or exclusive
- Monte Carlos and tuning (Peter)
- Detector Simulation
- Jets and Jet Algorithms

# Fundamental or Observable

"Fundamental" things (top, W, H masses, couplings etc) are often only defined within the theory, and so are often rather model dependent, whereas "observable" things (proton mass, charged particle multiplicity, inclusive lepton cross section etc) are well defined but difficult to interpret.



# Fundamental or Observable

- So the biggest headline derived from a measurement is not the same thing as the measurement itself
  - It is often not even really a measurement.
- Ask ourselves: if
  - (e.g.) the LHC proves that the SM is wrong in some possibly bizarre way (no Higgs in loops, lots of KK particles in loops, low mass gluino or gravitino)
  - Or some theorist makes a much better calculation of my process

how does a given measurement need to be modified?

  - For a real measurement, the answer should be “it doesn’t” or at least “it doesn’t beyond the systematic uncertainties”.

# Corrections, corrections

- Many corrections are or may be applied by the experiment on the way to publishing a measurement;
  - Dead time, trigger acceptance, detector geometry, energy scale, dead material, pile-up, electroweak radiative corrections, $F_L$, "underlying event", "hadronisation"…
- If a correction requires intimate knowledge of the detector, then apply it.
  - After our experiment finishes, no-one is going to be able to (or want to!) correct for our trigger efficiencies, energy scale and resolution etc

# Corrections, corrections

- If a correction requires intimate knowledge of a developing theory, or a Monte Carlo model of some poorly-known physics, do not apply it!*
  - After your experiment finishes, if someone does a NNLO calculation, or really understands underlying events, hopefully your data remain useful!
- There's obviously a sliding scale, and a grey area…
  - Dead time, trigger acceptance, detector geometry, energy scale, dead material, pile-up, electroweak radiative corrections, $F_L$, "underlying event", "hadronisation"…

*or at very least, present the uncorrected version first!

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*although personally I don't think it's very big!

# Corrections, corrections

- So it is best to have *both* (e.g. HERA DIS: cross sections and PDFs), but if we are only going to have one it must be the observable!
- Few, if any, measurements are completely model-independent.
  - There will probably be some model dependence in our detector corrections (e.g different hadronisation models affect how we understand calorimeter response)
  - Minimise it and include in systematic error bars.
  - Where possible break down systematic contributions so they may be redone in future if knowledge improves

# Corrections, corrections

- E.g. W-asymmetry or lepton asymmetry at Tevatron
- W asymmetry has a more direct relationship to the distribution of particular partons
  - And it contains real extra information (from the missing $p_T$)
- BUT sensitivity to sea quarks is lost and replaced by a systematic error
  - Easier for PDF fitters to fit the lepton asymmetry.

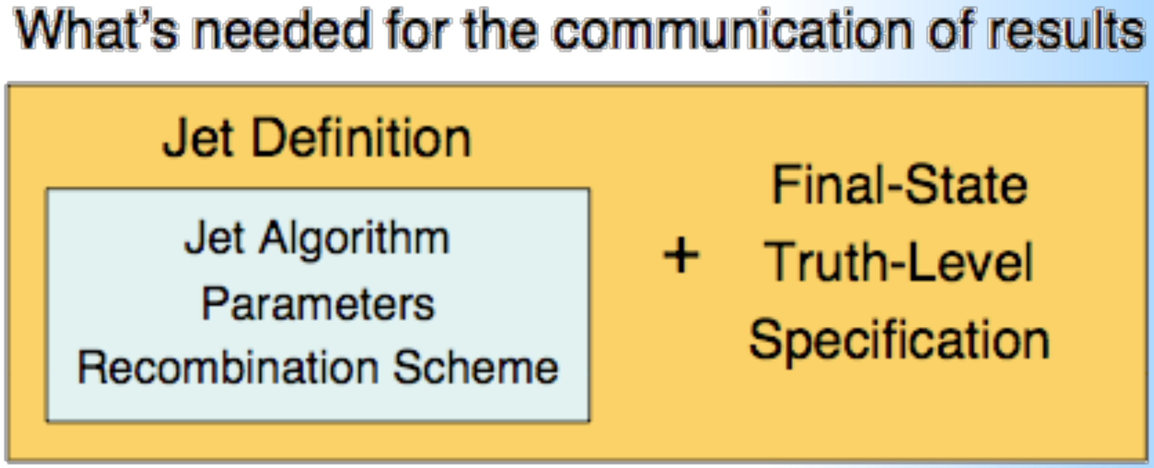
# Jets

- One key area in the data/theory comparison business
- Jets are not just less-well-measured leptons or "smeared" partons.
  - Hard radiation interference at amplitude level
  - Matching at high scales with Matrix element
  - Matching at low scales with parton densities and hadronisation model
  - potentially useful information in the internal jet structure, and in particle/energy flow between the jets
- Jets have **no existence independent of the algorithm**
  - even if the "algorithm" = event display + physicist

# Jets

- We want to connect what we measure back to the fundamental degrees of freedom of our (Standard) model, so we can publish for example:
  - Parton densities
  - Top, W, (Higgs?) masses
  - Deviations from the Standard Model (or limits derived from their absence)
- (Usually) requires comparison to state-of-the-art theory, so our jet finding procedure had better be something the theory/model can replicate
  - Clear separation between detector corrections (model independent) and interpretation (model dependent).
- "Truth" is algorithm+final state, not the calorimeter and not "partons"

# What is a Jet?




- One good place to look: Les Houches 2007 accords (arXiv: 0803.0678)
- Jet definition specifies all details of the procedure by which an arbitrary set of four-momenta is mapped into a set of jets. Composed of:
  - Jet algorithm (e.g inclusive, longitudinally boost-invariant $k_T$).
  - All the parameters of the jet algorithm (e.g. R=0.7)
  - The recombination scheme (e.g four-vector recombination, or E-scheme, or…)

# What is a Jet?

What's needed for the communication of results

**Jet Definition**

- Jet Algorithm
- Parameters
- Recombination Scheme

\+ Final-State Truth-Level Specification

- One good place to look: Les Houches 2007 accords (arXiv: 0803.0678)
- Final-state truth-level specification
  - What is the input (at the truth level). e.g. all final state particles with lifetimes longer than some cut…
  - Theory and experiment can correct to this level, within some controlled systematic error.

# Jets for different applications

- If you are doing simple searches at high $p_T$, jets are obvious
  - …maybe
  - Certainly even the “event display + physicist” algorithm should be pretty reproducible for counting ~1 TeV jets at LHC
    - (really? How precise is that 1 TeV cut?)
- If you are making precision measurements of jet cross sections (energy scale ~1%) then you will need to compare at least to NLO QCD.
  - In this case it is mandatory to have a jet definition which can also be applied to NLO QCD
- **Consequence:** This means a detector-independent, infrared & collinear safe algorithm

# Scales in the experiment

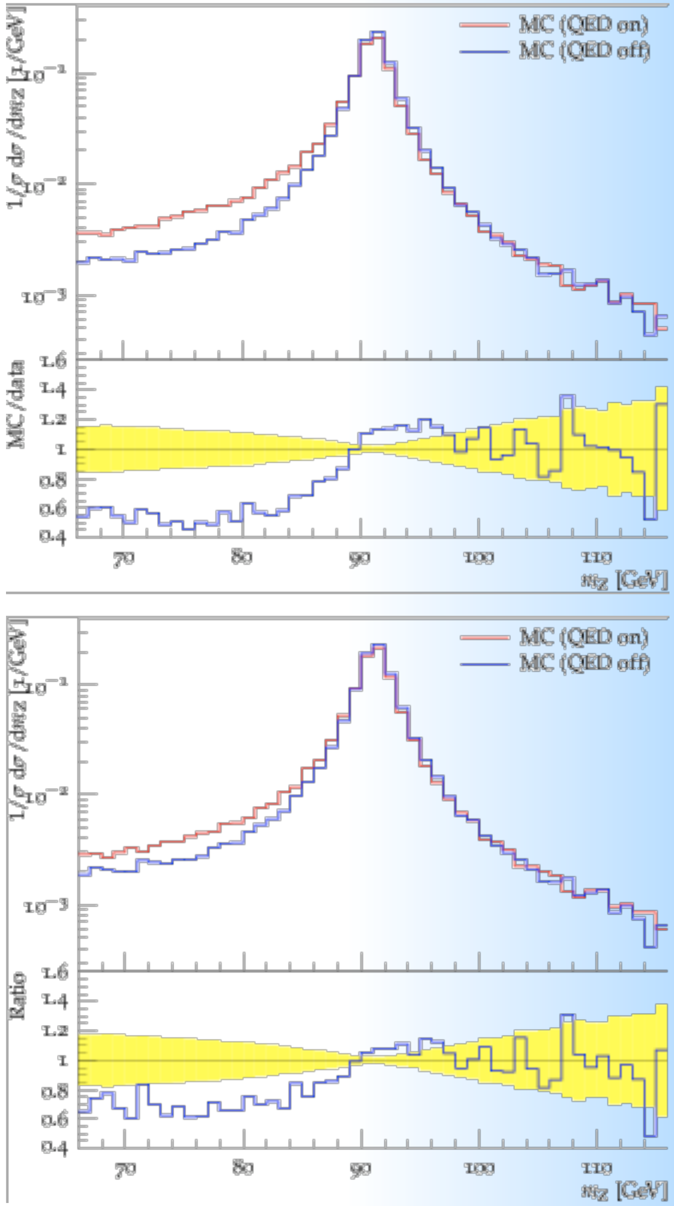
- (1) Proton mass / becomes possible to accurately calculate using perturbative QCD
  - around 1 - 5 GeV.
- (2) W, Z mass / electroweak symmetry-breaking scale / Higgs mass if it exists
  - around 50-300 GeV
- (3) LHC scale O(10 TeV).
- Because of (3) the LHC is the first machine to produce copious highly-boosted particles with masses at scale 2, or very high multiplicities of jets each at scale 2.

# Leptons and Photons

- Some issues similar to jets
  - Isolation from hadronic activity: define “activity”
  - Electrons in $e^+e^-$/DIS: QED initial state radiation
    - “Radiative return” to the Z peak.
  - Electrons anywhere: QED final state radiation
    - How photons were radiated?
    - Were they included in the electron object?
    - Best not to have an implicit cut based on your calorimeter geometry.

# Leptons and Photons

- In a MC comparison, take the "true" electron
  - Large sensitivity to FSR
- Include photons within dR<0.2 of the electron
  - Reduced sensitivity
- But what does the measurement correspond to?

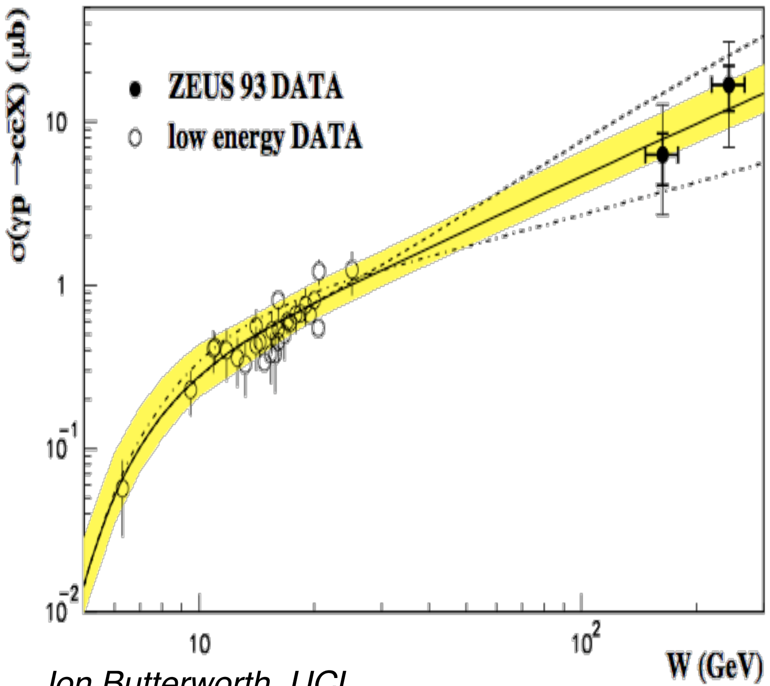


# Inclusive or exclusive

- An inclusive "measurement" is often easy for the theorist, but misleading
- More exclusive observables are harder to calculate predictions for but experimentally honest
- In general, avoid integrating into "different" regions where you have zero sensitivity (i.e. Φ is generally ok but not $p_T$)

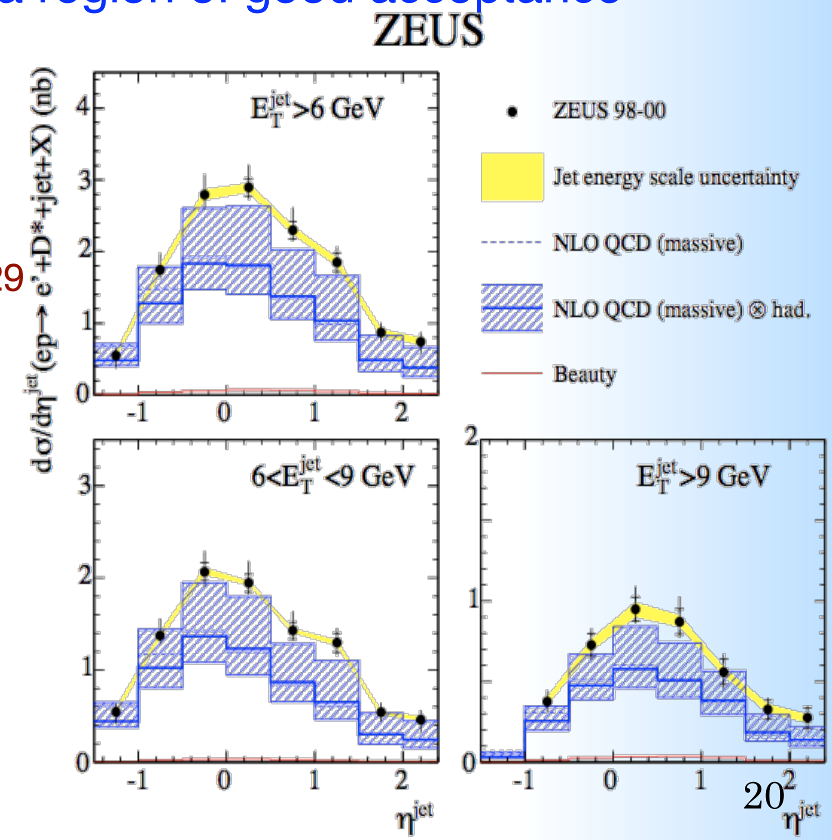
# Inclusive or exclusive

- Many examples where errors new measurement just about bracket the theory uncertainties: because they are the SAME THING!
  - e.g. early ZEUS D* measurement extrapolated to high y and low $p_T$
  - Or measured with jets, differential, in a region of good acceptance




Nucl.Phys.B729:492-525,2005

NLO from Frixione, Mangano, Nason, Ridolfi



# Rivet, robustness and tuning

- Rivet: "Robust Independent Validation of Experiment at Theory"
- Carry out exact replica of experimental analysis on 4-vector final state level.
- If you can't write a Rivet Analysis class for it, it's probably not a measurement.

# Detector Simulation

- Some modelling of detector effects outside of the experimental collaboration is sometimes desirable
  - Some key “measurements” are uncorrected.
  - Allows model builders to evaluate potential more realistically
  - Some products on the market already (see wiki)

# Detector Simulation

- Issues for discussion
  - I/O. Input = HepMC? Output = ?
    - (e.g. objects/events for input to rivet?)
  - What are the requirements?
    - b-tagging, jet calibration, magnetic field, granularity…
  - Comparison/validation against in-house fast simulations?

# *Beginning…*

As Peter said, points for discussion, programme of work to be defined in the *brainstorms*:

- 14:00 Today: Matching
- 16:00 Today: NLM&MC
- 17:00 Today PDFs/NLM
- 9:00 Tomorrow: Tuning
- 11:00 Tomorrow: Data/Theory comp
- 14:00 Tomorrow: Jets (& Subjets)
- 16:00 Tomorrow: PDFs/Matching overspill

All in the auditorium except matching (library)

We will set up wiki pages for each active group, with names.

Evolve into work plan & proceedings.