Object (Truth) Definition in ATLAS and CMS

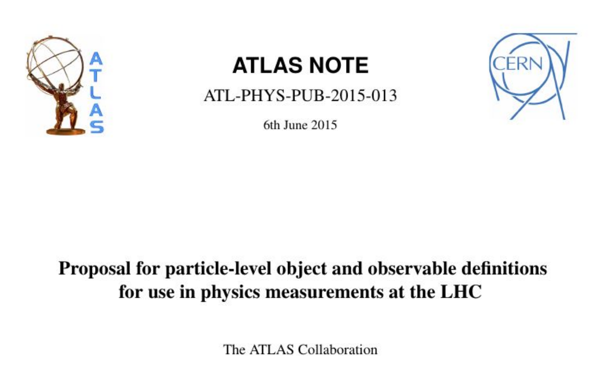
LHC EWWG Multiboson

Introduction: Motivation

- Is a cross section measurement from ATLAS/CMS the really the *same* ?
- Or are there subtle (and not so subtle) differences?

- This even applies to truth event selections
    - How are jets built: with/without neutrinos, muons, invisible particles, pileup?
    - How are leptons defined? with/without bremsstrahlung photons?
    - How do you distinguish jets from leptons?
      → overlap removal: muons inside jets? electrons inside jets
      → when is this a electron or a jet or a muon?
    - How are b-jets defined?
    - How are bosons defined/selected (mass cuts, matching to generator mothers)?

ATLAS public documents



ATLAS NOTE

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Proposal for particle-level object and observable definitions for use in physics measurements at the LHC

The ATLAS Collaboration

- A public document from ATLAS side exist https://cds.cern.ch/record/2022743

- Motivation: More precise measurements and theory predictions -- use observables that allow:
  - Accurate comparison of theoretical and experimental results
  - Unambiguous comparison to future measurements possible
  - Minimal knowledge of experimental or model-dependent definitions of the final state objects.

- Based on the stable particles that enter in the detector and their physical parents
- Minimal extrapolation but simple and streamlined fiducial region (i.e. same η-range for electrons and muons)

General definitions

- **Stable particles**
  - Lifetime $ct_0 > 10$ mm → Equivalent: HepMC record -> status ==1
- **Prompt or lepton-associated photons**
  - pdgID=22, not from hadrons or taus*, final state (i.e. stable) particles
- **Prompt leptons**
  - abs(pdgID) = 11-16, not from hadrons, final state (stable) particles
- **Physical particle**
  - "Reliably" measurable: on-mass-shall, lab-frame, lepton, photons, decayed hadrons, i.e. status code 1 (or 2) → no intermediate gluons, quarks, clusters (not always accessible..!)
- **Heavy flavour hadron:**
  - A heavy flavour (HF) hadron contains a valence c or b quark (weakly decaying HF hadron are experimentally taggable by displaced secondary

*Not from hadron/tau: defined as coming from decays of such particles, needs to be checked recursively

Jet definitions

- ATLAS usually uses anti-k_t with R=0.6 (collects radiation) or 0.4 (for jet counting)
- What is clustered in the jet?
  - 1. Collect all stable particles in the event record.
  - 2. Identify electrons, muons & neutrinos not from hadrons.
  - 3. Dress electrons & muons with photons not from hadrons.
  - 4. Cluster all stable particles, excluding the particles found in (2) and (3).
- Model-dependence enters in Pile-up corrections and calibration
  $\rightarrow$ needs to be studied, if large effect to pick least model-dependent.

Jet flavour

- **Ghost association:**
    - HF hadrons do not fullfill lifetime criterium for stable particles → excluded from jet finding
    - Can be *included* nonetheless as infinitifely small momentum particles (i.e. do not change pT)
    - Can then be associated to a jet → ghost-association
    - HF jet is:
        - A b-jet if contains at least 1 ghost-associated b-hadron
        - A c-jet if contains at least 1 ghost-associated c-hadron but no b-hadron

- How is this implemented in e.g. Rivet?

Missing transverse momentum

- **Should be built including all invisible particles**
  - Sum of these invisible particles → neutrinos / neutralinos

- Invisible particles not from hadron / HF decays

Lepton definition

- Use promt leptons → no association to W, Z.. mother particles needed
- Definition using mother particles are equivalent (where information is available) but *not model-independent → **use prompt leptons**

- What about QED Final state radiation (FSR)? → leads to different leptons
  - **Born leptons:** leptons prior to FSR - defined by LO diagram in α_{QED}
    Not strictly physical, neglect interference between initial and final state QED radiation in W/Z
  - **Bare leptons:** leptons "after QED FSR", depend on technical details of implementation of QED radiation on MC generators
  - **Dressed leptons:** using a cone of $dR<0.1$ around bare lepton and adding all prompt photons to lepton can remedy model-dependence of final state leptons, negligible impact of ISR photons
    Dressed lepton measurements can be directly combined! (difference electron-muon $< 0.1\%$)

Isolation/Overlapp removals

- Apply same procedures as on detector level
  - e.g remove overlapping electrons (even if both are prompt -- cannot resolve on detector level)
  - Remove overlapping electron/muons/photons
  - Remove overlapping electrons/jets → usually remove jet (assumed to be clustered from the electron on detector level)
  - Remove overlapping muons/jets → usually remove muon (as on detector level assumed to be HF, but could also be defined threshold dependent)

Definition of Bosons

- Use algorithmic approach to associate leptons to boson,
  I.e. two leptons within Z mass window

- Example: WZ final state
  - Can use Z mass as constraint but not W
  - For same flavour final states: ambiguity which lepton is from W, which from Z
  - Using *closest* pair to Z mass can introduce bias
  - → *will probably hear more ideas next week*

Procedure to reconstruct event topology

1. Select the stable particles.
2. Select prompt leptons (e, νe , μ, ν μ) and associate photons (not from hadrons) to electrons and muons to define dressed-level charged leptons.
3. Define particle-level jets by clustering all stable particles excluding the particles found in step (2).
4. Assign the jet flavour based on heavy-flavour hadrons ghost-matched to jets.
5. Sum all prompt neutrinos defined in (2) to form the missing transverse momentum.
6. Resolve lepton-lepton and jet-lepton overlap following a procedure close to that used at the detector level.
7. Define other particle-level observables in complex event topologies based on the particle-level objects defined above → e.g. W,Z bosons, top

Conclusions

- Well defined definitions *independent* of generator implementation needed
- Can be achieved with a few restrictions (prompt leptons, dressing...)
- *Should* be implemented for most Multiboson measurements from ATLAS
- More on the CMS perspective next week
  (though most definitions should not be outrageously different)