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Particle level objects and pseudo-top-quark definitions

This page summarises the definition of objects at particle level to which ATLAS and CMS should unfold their differential distributions to. The ultimate purpose for these guidelines is to make an LHC combination on differential observables possible. Also, this helps in the definition of common cross-section acceptances where both experiments may consider to quote a fiducial cross-section. The combination of a cross section in a common, observable, acceptance minimises the impact of MC extrapolation by the individual experiments. This page describes the definition of simple objects like isolated leptons or jets, as well as complex objects such as top quarks (which need to be defined with operative procedures to be applied at particle level). By "particle level" definition we imply a collection of stable particles from full ME+parton shower generators (including therefore QCD+EWK FSR effects), without any simulation of the interaction of these particles with the detector components or any additional proton-proton interactions. These definitions have the advantage that theory uncertainties have a reduced impact on the final results. In the following discussion, when unfolded differential distributions are discussed, they must be intended as background-subtracted and not include additional proton-proton interactions.

Object construction

The objects considered in the event record are stable particles (mean lifetime > 0.3×10^{-10}s) within the observable pseudorapidity range.

- **Photons**: photons used for final state definitions and for the definition of leptons (electron & muon) should not be from hadron decays. These removes the dependency on the underlying event.

- **Electron**: define 4-momentum from photons and electron within an anti-k_t R=0.1, where leptons (electron & muons) are considered for jet clustering. No isolation condition is imposed. In order to choose prompt leptons from W/Z decay in a way safe for all generators currently under consideration, the parent of the electron is required not to be a hadron or quark (u-b). (Expect that future sanitisation of generator record will remove the need for the quark requirement.)

- **Muon**: define 4-momentum from photons and muon within an anti-k_t R=0.1, where leptons (electron & muons) and photons are considered for jet clustering. No isolation condition is imposed. In order to choose prompt leptons from W/Z decay in a way safe for all generators currently under consideration, the parent of the muon is required not to be a hadron or quark (u-b). (Expect that future sanitisation of generator record will remove the need for the quark requirement.)

- **ETmiss/Neutrinos**: As an event level variable the missing transverse energy is calculated as the 4-vector sum of neutrinos from W/Z-−boson decays. Tau decays are included. A neutrino is treated as a detectable particle and is selected for consideration in the same way as electrons or muons, i.e. the parent is required not to be a hadron or quark (u-b). (Expect that future sanitisation of generator record will remove the need for the quark requirement.)

- **Jets**: define with anti-k_t algorithm. Loop over all stable particles excluding the electrons, muons, neutrinos, and photons used in the definition of the selected leptons. This includes non-prompt muons and neutrinos for a proper b-jet energy scale. Use specific R parameter chosen by experiment: R=0.4 for ATLAS and R=0.5 for CMS.

- **b-jets**: A jet is a b-jet if any rescaled B-hadron is included in the jet. A rescaled B-hadron is treated as a stable B-hadron (that does not oscillate or decay to another B-hadron) for which the 4-momentum is scaled down by to the limit of floating point precision and added to the list of particles for jet-clustering as described above. Only B-hadrons with an initial p_T > 5 GeV are considered. This prescription provides an unambiguous way to associate a single jet with a B-hadron.

- **Further cuts in the event**: overlap removal, such as applied to reconstructed objects, does not make sense when the selected leptons are not included within jets. Instead, events where the leptons overlap with the selected jets should be discarded. For example, for a anti-k_t radius parameter of 0.4, events with dR(jet,el/mu) < 0.4 should be discarded.

Proposed common event selections

The following proposal attempts to match the event selection for particle-level objects with reconstructed objects. The electron and muon channels are synchronised to allow combinations within the selected kinematic range.

- **Single lepton channels (electron, muon)**:
    - Exactly one selected electron or muon with |eta| < 2.4 and p_T > 30 GeV
    - Not any other lepton (electron or muon) with |eta| < 2.5 and p_T > 15 GeV
    - Neutrino sum pt > 30 GeV
    - mT(W), defined as sqrt(2*pt(l)*pt(v)*(1-cos(phi(l)-phi(v)))), > 30 GeV
    - At least two b-tagged jets in the region |eta| < 2.4 and p_T > 30 GeV
    - At least four jets in the region |eta| < 2.4 and p_T > 30 GeV

- **Dilepton channels (electron, muon)**:
    - At least two selected leptons (e-e, e-mu, mu-mu) with |eta| < 2.4 and p_T > 30 GeV
    - For same-flavour channels neutrino sum pt > 60 GeV
    - At least two b-tagged jets in the region |eta| < 2.4 and p_T > 30 GeV

The requirement of at least two b-tagging jets is for the study of pseudo-top-quark. Other analyses that study more inclusive kinematics may be more suited to require at least one b-tagged jet.

Pseudo-top-quark definition

The starting sample is ttbar without fully hadronic decays (the sample includes lepton and dilepton decays where the lepton is an electron or a muon or a tau)

- **Single lepton events**: All objects as defined above. The procedure is as follows:
    - Require exactly 1 electron or exactly 1 muon; no other leptons.
    - Require >=4 jets
    - Require >=2 b-jets
    - Select the two highest p_T b-jets as the b-jets to be used for the pseudo-top-quark definition.
    - Define the leptonic W by combining the lepton with the ETmiss and solving for pz assuming the W mass (highest pz from two-fold ambiguity)
    - Combine the b-jet closest to the lepton with the leptonic W, to form the leptonic pseudo-top-quark.
    - Define the hadronic W from the two highest p_T jets that are not the two selected b-jets.
    - Combine the remaining b-jet with the hadronic W, to form the hadronic pseudo-top-quark.

- **Dilepton events**: All objects as defined above. The procedure is as follows:
    - Require >=2 jets
    - Require >= 2 b-jets
    - Require exactly 2 opposite sign leptons (el, mu)
    - If leptons have the same flavor, require m(l+l-) > 20 GeV and | m(l+l-) - Mz | > 10GeV
    - Consider only the 2 leading pt selected neutrinos. Consider the 2 combinations (nu_1,lep_+)(nu_2,lep_-) or (nu_1,lep_-)(nu_2,lep_+) where _1 and _2 refer to pt ordering and _+ ,_-

refer to the lepton sign. The (nu,lep) pair that gives combined lepton-neutrino four momenta W1 and W2 with the minimal | m_W1 - M_W_PDG | + |m_W2-M_W_PDG |, where M_W_PDG is the mass of the W boson from the PDG, is considered the proper combination to make the pseudo-W+ and the pseudo-W- from the dilepton decay.
  - Consider the pairs (b-jet_1, W+), (b-jet_2, W-), and (b-jet_1, W-), (b-jet_2, W+), the pair where combined b-jet - W four momenta T1 and T2 are such that | m_T1 - M_top_PDG | + |m_T2-M_top_PDG | where M_top_PDG is the mass of the top quark from the PDG is considered the proper combination of bs and Ws to determine the pseudo-top-quarks.

To-do List

- One important point is to be able to study the correlation between experiments by using the very same events input to both reconstruction procedures. Since the distributions are ultimately background subtracted, this is achieved by sharing a common signal tt sample (with whatever generator+PS) in the two collaboration. The binary GenEvent format is proposed.

- To be discussed if needed: both experiments will unfold to their own jet definition with given R=0.4 and 0.5. Differences are determined by unfolding the same sample. Each experiment unfolds the same sample of events to both R=0.4 and R=0.5; so as to make comparisons within the given experiment and with the other experiment. Both experiments unfold to a common intermediate R parameter size of R= 0.45

- Discuss and synchronize unfolding technique. Currently different styles of regularized unfolding are used.

- For unfolding, determine the best way to match particle-level and reconstructed b-jets. Determine the best method to account for the possible switching of all objects between particle level and reconstruction (pT ordering, a deltaR criterion, recluster the generated rescaled B-Hadron in the reconstructed jet,...)

- Consider the possibility to place a cut on the reconstructed W mass and top mass i.e. reject events that do not fulfill |m_TX -M_top_PDG| < XX GeV or |m_WX -M_top_PDG| < XX GeV

- Study the possibility to correct the neutrino to give the W mass in the (nu, lep) pair after the pseudo-W boson assignment and before the pseudo-top-quark definition

- Choose whether the phase-space differences in the dilepton channel allow for combination of the three channels

-- RobertoChierici - 05-Apr-2012 -- WilliamBell - 24-Apr-2014

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