Energy Flow Reconstruction:
Use Cases and Requirements

Dan Tovey, Mark Hodgkinson and Rob Duxfield

v1.1

1) Use Cases

U1: Jet Reconstruction

U1.1 Energy flow reconstruction takes list of CaloClusters (possibly from dedicated run with non-standard jobOptions), InDet TrackParticles, combined muon tracks and photon conversions.

U1.2 Energy flow code uses these objects to reconstruct 'energy flow objects' approximating 'stable' particles present in event final state (photons, electrons, muons, long-lived charged and neutral hadrons). Particles created far from primary vertex through interaction with material (brem photons, photon conversions etc.) are combined where possible into parent particles. Short-lived decays (tau-jets, b-jets, V0's etc.) are accounted for by their decay products.

U1.3 Output to TDS is list of calibrated (to appropriate energy scales) eflowObjects containing 4-vectors, perigee parameters and ID information, which are navigable back to parent TrackParticles, muon tracks and CaloClusters.

U1.4 User runs jet reconstruction algorithm directly on energy flow objects in TDS consistent with high-pT interaction point with no further calibration or correction. Definition of energy flow objects ensures effects of shower shapes of jet constituents are accounted for.

U2: ETmiss and Global Reconstruction

U2.1 Energy flow reconstruction takes list of CaloClusters (possibly from dedicated run with non-standard jobOptions), InDet TrackParticles, combined muon tracks and photon conversions.

U2.2 Energy flow code uses these objects to reconstruct 'energy flow objects' approximating 'stable' particles present in event final state (photons, electrons, muons, long-lived charged and neutral hadrons). Particles created far from primary vertex through interaction with material (brem photons, photon conversions etc.) are combined where possible into parent particles. Short-lived decays (tau-jets, b-jets, V0's etc.) are accounted for by their decay products.

U2.3 Output to TDS is list of calibrated (to appropriate energy scales) eflowObjects containing 4-vectors, perigee parameters and ID information, which are navigable back to parent TrackParticles, muon tracks and CaloClusters.

U2.4 Energy flow code loops over energy flow objects consistent with high-pT interaction point calculating ETmiss and global event shape properties (circularity, thrust, oblateness etc.), taking into account position of primary vertex, and records quantities in TDS.

U3 : Tau reconstruction

U3.1 Energy flow reconstruction takes list of CaloClusters (possibly from dedicated run with non-standard jobOptions), InDet TrackParticles, combined muon tracks and photon conversions.
U3.2 Energy flow code uses these objects to reconstruct ‘energy flow objects’ approximating ‘stable’ particles present in event final state (photons, electrons, muons, long-lived charged and neutral hadrons). Particles created far from primary vertex through interaction with material (brem photons, photon conversions etc.) are combined where possible into parent particles. Short-lived decays (tau-jets, b-jets, V0’s etc.) are accounted for by their decay products.
U3.3 Output to TDS is list of calibrated (to appropriate energy scales) eflowObjects containing 4-vectors, perigee parameters and ID information, which are navigable back to parent TrackParticles, muon tracks and CaloClusters.
U3.4 User runs jet reconstruction algorithm (possibly dedicated run with tuned jobOptions) directly on energy flow objects consistent with high-pT interaction point in TDS with no further calibration or correction. Definition of energy flow objects ensures effects of shower shapes of jet constituents are accounted for.
U3.5 User runs dedicated tau reconstruction code looping over found jets searching for jets comprising single charged hadron eflowObject + at least one neutral hadron eflowObject (one-prong) or three charged hadron eflowObjects of total charge +/-1 (three-prong).
U3.6 Dedicated code outputs list of tau candidates together with properties including invariant mass, charge etc.

U4 : b-tagging

U4.1 Energy flow reconstruction takes list of CaloClusters (possibly from dedicated run with non-standard jobOptions), InDet TrackParticles, combined muon tracks and photon conversions.
U4.2 Energy flow code uses these objects to reconstruct ‘energy flow objects’ approximating ‘stable’ particles present in event final state (photons, electrons, muons, long-lived charged and neutral hadrons). Particles created far from primary vertex through interaction with material (brem photons, photon conversions etc.) are combined where possible

into parent particles. Short-lived decays (tau-jets, b-jets, V0's etc.) are accounted for by their decay products.

U4.3 Output to TDS is list of calibrated (to appropriate energy scales) eflowObjects containing 4-vectors, perigee parameters and ID information, which are navigable back to parent TrackParticles, muon tracks and CaloClusters.

U4.4 User runs jet reconstruction algorithm (possibly dedicated run with tuned jobOptions) directly on energy flow objects consistent with high-pT interaction point in TDS with no further calibration or correction. Definition of energy flow objects ensures effects of shower shapes of jet constituents are accounted for.

U4.5 User runs dedicated b-tagging code looping over found jets searching for jets comprising charged eflowObjects with appropriate ID's (esp. electrons, muons).

U4.6 Dedicated code outputs list of b candidates together with properties including likelihood, invariant mass, charge etc.

2) Requirements

Inputs

R1. The energy flow code shall take as input list(s) of TrackParticles.

R2. The energy flow code shall take as input list(s) of CaloClusters formed from nearest neighbour clustering (e.g. from CaloTopoClusterMaker). The energy flow package shall contain a tuned set of jobOptions for optimally reconstructing CaloClusters associated with showers inside jets.

R3. The energy flow code shall take as input list(s) of combined muon tracks (e.g. from MuonIdentification).

R4. The energy flow code should take as input Conversion objects.

Algorithm

R5. The energy flow code shall run as a standard Athena top algorithm.

R6. The energy flow code shall be broken down wherever possible into sub-algorithms/AlgTools which can be specified at run-time in jobOptions.

R7. The energy flow code shall contain no hard-coded parameters.

R8. The energy flow code shall not modify existing objects in the TDS.

R9. The energy flow code should modify copies of objects in the TDS.

R10. The energy flow code may permit the user to specify whether to calculate ETmiss and global event shape properties (circularity, thrust, oblateness etc.) at run-time via jobOptions.

R11. The energy flow code and CaloCluster reconstruction jobOptions shall be tuned to deliver optimum performance for particles in low pT jets.

R12. The energy flow code shall substitute TrackParticles with corresponding combined muon tracks.

R13. The energy flow code shall use standard TrackParticle extrapolation tools to extrapolate charged tracks to the calorimeter face (e.g. TrackToCalo).

R14. The energy flow code shall match CaloClusters to TrackParticles at the calorimeter face.

R15. The energy flow code should reconstruct topologically connected TrackParticles and CaloClusters (eflowCaloObjects) prior to reconstructing eflowObjects in order to simplify/speed-up the algorithm.

R16. The energy flow code should merge eflowCaloObjects when a topological link appears subsequently (e.g. a photon conversion).

R17. The energy flow code shall use TRT information (No. high threshold hits) as input to identification of charged tracks.

R18. The energy flow code shall use shower shape information when available as input to identification of CaloClusters.

R19. The energy flow code may use a likelihood technique to combine ID information from charged TrackParticles and matched CaloClusters.

R20. The energy flow code shall permit the user to specify alternative expected shower subtraction schemes at run-time via jobOptions.

R21. The energy flow code shall determine the expected means and standard deviations of the energy deposits of charged particles in the calorimeter at appropriate granularity.

R22. The energy flow code shall provide options (set in jobOptions) for calculating and subtracting expected energy deposits at least at the CaloCell and CaloCluster levels.

R23. The energy flow code shall provide options (set in jobOptions) for calibrating the energies of neutral hadrons at least at the

- CaloCell level (with H1 E/V hadronic calibration with standard tools)
- CaloCluster level (with dedicated pT-dependent hadronic calibration of clusters).

R24. The energy flow code should measure the pT of eflowObjects using the most appropriate estimator for the assumed ID, shower isolation and approximate pT. This may be the pT of the TrackParticle or the matched CaloCluster.

R25. If specified by jobOptions, ETmiss and global event shape properties shall be calculated from eflowObjects consistent with high-pT interaction, with a cut (specified in jobOptions) on e.g. z-position of perigee of charged eflowObjects relative to e.g. pT-weighted mean z position of all charged eflowObjects. Neutral eflowObjects shall be corrected for this assumed IP position.

Outputs

R26. The energy flow code shall output into the TDS a list of eflowObjects providing information on the perigee parameters, 4-vectors, charges and particle ID codes of energy flow objects representing all ‘stable’ final state particles.

R27. eflowObjects shall inherit from INavigable4Momentum.

R28. eflowObjects shall be persistified with ElementLink.

R29. 4-vectors returned by eflowObjects shall be accessible in either of the (px, py, pz, E) or (eta, phi, pT, m) bases.

R30. 4-vectors returned by eflowObjects shall be specified at the perigee having been corrected for the effects of magnetic field and material where appropriate/possible.

R31. The energy flow ID code should classify eflowObjects according to the following scheme (used in conjunction with assumed charge):

- EM objects inside InDet (photons/electrons specified by charge)
- Hadrons inside InDet (charged/neutral specified by charge)
- Muons inside muon spectrometer coverage
- Unidentified TrackParticles inside InDet (charged/neutral specified by charge)
- EM objects inside LArEM (ID from shower shape only)
- Hadrons inside LArEM (ID from shower shape only)
- Objects outside LArEM (no further ID)

An eflowObject should possess only one such ID. This ID will be obtained from the first of the above criteria to be satisfied in the above order.

R32. If calculated, ETmiss and global properties shall be output in the eflowObjectContainer alongside the DataVector of eflowObjects.