Razor boost analysis using adl2tnm and CutLang ADLs

(CutLang/adl2tnm hands-on exercise)

H. Prosper, S. Sekmen, G. Unel

ADLs4LHC workshop
Fermılab LPC, 6-8 May 2019

```
info analysis
# Details about experiment
  experiment CMS
  id SUS-16-050
  publication Phys.Rev. D97 (2018) no.1, 012007
  sqrtS 13.0
  lumi 35.9
  arXiv 1710.11188
  hepdata https://www.hepdata.net/record/ins1633588
  doi 10.1103/PhysRevD.97.012007

```

adl2tnm

```
### OBJECT SELECTIONS

# AK4 jets
object AK4jets
  take Jet
  select pt > 30
  select |eta| < 2.4

# AK8 jets
object AK8jets
  take FatJet
  select pt > 200
  select |eta| < 2.4

# b-tagged jets - loose
object bjetsLoose
  take AK4jets
  select btagDeepB > 0.152

# b-tagged jets - medium
object bjetsMedium
  take AK4jets
  select btagDeepB > 0.4941

# b-tagged jets - tight
object bjetsTight
  take AK4jets
  select btagDeepB > 0.8001
```

cutlang

```
### OBJECT SELECTIONS

# AK4 jets
object AK4jets : JET
  select {JET_}Pt > 30
  select {JET_}AbsEta < 2.4

# AK8 jets
object AK8jets : FJET
  select {FJET_}Pt > 200
  select {FJET_}Eta < 2.4

# b-tagged jets - loose
object bjetsLoose : AK4jets
  select {AK4jets_}btagDeepB > 0.152

# b-tagged jets - medium
object bjetsMedium : AK4jets
  select {AK4jets_ }btagDeepB > 0.4941

# b-tagged jets - tight
object bjetsTight : AK4jets
  select {AK4jets_}btagDeepB > 0.8001
```

adl2tnm

```
# W jets - mass-tagged
object WjetsMasstag
  take AK8jets
  select msoftdrop [] 65 105

# W jets - W-tagged
object Wjets
  take WjetsMasstag
  select tau2 / tau1 <= 0.4

# W jets - anti-tagged
object WjetsAntitag
  take WjetsMasstag
  select tau2 / tau1 > 0.4

# top jets - mass-tagged
object topjetsMasstag
  take AK8jets
  select pt > 400
  select msoftdrop [] 105 210

# top jets - mass-tagged, subjet b-antitagg
object topjetsMasstag0b
  take topjetsMasstag
  select btagDeepB < 0.1522

# top jets - top-tagged, subjet b-tagged
object topjets
  take topjetsMasstag
  select btagDeepB >= 0.1522
  select tau3 / tau2 < 0.46

# top jets - anti-tagged
object topjetsAntitag
  take topjetsMasstag
  select btagDeepB < 0.1522
```

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```
# W jets - mass-tagged
object WjetsMasstag : AK8jets
  select {AK8jets_}msoftdrop [] 65 105

# W jets - W-tagged
object Wjets : WjetsMasstag
  select {WjetsMasstag_}tau2 / {WjetsMasstag_}tau1 <= 0.4

# W jets - anti-tagged
object WjetsAntitag : WjetsMasstag
  select {WjetsMasstag_}tau2 / {WjetsMasstag_}tau1 > 0.4

# top jets - mass-tagged
object topjetsMasstag : AK8jets
  select {AK8jets_}Pt > 400
  select {AK8jets_}msoftdrop [] 105 210

# top jets - mass-tagged, subjet b-antitagged
object topjetsMasstag0b : topjetsMasstag
  select {topjetsMasstag_ }btagDeepB < 0.1522

# top jets - top-tagged, subjet b-tagged
object topjets : topjetsMasstag
  select {topjetsMasstag_}btagDeepB >= 0.1522
  select {topjetsMasstag_}tau3 / {topjetsMasstag_}tau2 < 0.46

# top jets - anti-tagged
object topjetsAntitag : topjetsMasstag
  select {topjetsMasstag_}btagDeepB < 0.1522
  select {topjetsMasstag_}tau3 / {topjetsMasstag_}tau2 >= 0.46
```

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```
# muons - veto
object muonsVeto
  take Muon
  select pt > 5
  select |eta| < 2.4
  select softId == 1
  select miniPFRelIso_all < 0.2
  select |dxy| < 0.2
  select |dz| < 0.5

# muons - select
object muonsSel
  take Muon
  select pt > 10
  select |eta| < 2.4
  select miniPFRelIso_all < 0.15
  select |dxy| < 0.05
  select |dz| < 0.1

# electrons - veto
object electronsVeto
  take Electron
  select pt > 5
  select |eta| < 2.5
  select miniPFRelIso_all < 0.1
  select |dxy| < 0.05
  select |dz| < 0.1

# electrons - select
object electronsSel
  take Electron
  select pt > 10
  select |eta| < 2.5
  select |eta| ][ 1.442 1.556
  select miniPFRelIso_all < 0.1
  select |dxy| < 0.05
  select |dz| < 0.1

# leptons - veto
object leptonsVeto
  take electronsVeto
  take muonsVeto

# leptons - select
object leptonsSel
  take electronsSel
  take muonsSel

# taus - veto
object tausVeto
  take Tau
  select pt > 18
  select |eta| < 2.5
  select idMVAnewDM2017v2 >= 4
```

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```
# muons - veto
object muonsVeto : MUO
  select {MUO_}Pt > 5
  select {MUO_}AbsEta < 2.4
  select {MUO_}softId == 1
  select {MUO_}miniPFRelIsoAll < 0.2
  select abs({MUO_}dxy) < 0.2
  select abs({MUO_}dz) < 0.5

# muons - select
object muonsSel : MUO
  select {MUO_}Pt > 10
  select {MUO_}AbsEta < 2.4
  select {MUO_}miniPFRelIsoAll < 0.15
  select abs({MUO_}dxy) < 0.05
  select abs({MUO_}dz) < 0.1

# electrons - veto
object electronsVeto : ELE
  select {ELE_}Pt > 5
  select {ELE_}AbsEta < 2.5
  select {ELE_}miniPFRelIsoAll < 0.1
  select abs({ELE_}dxy) < 0.05
  select abs({ELE_}dz) < 0.1

# electrons - select
object electronsSel : ELE
  select {ELE_}Pt > 10
  select {ELE_}AbsEta < 2.5
  select {ELE_}AbsEta  ][ 1.442 1.556
  select {ELE_}miniPFRelIsoAll < 0.1
  select abs({ELE_}dxy) < 0.05
  select abs({ELE_}dz) < 0.1

# taus - veto
object tausVeto : TAU
  select {Tau_}Pt > 18
  select {Tau_}AbsEta < 2.5
  select {Tau_}dMVAnewDM2017v2 >= 4
```

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```
# photons - select
object photons
  take Photon
  select pt > 80
  select |eta| < 2.5

# jets - no photon
object AK4jetsNopho
  take AK4jets j
  reject dR(j, photons) < 0.4 and photons.pt/j.pt [

# MET
object met
  take MET

# Megajets are 4-vectors, each consisting of multipl
# Each event with njets > 0 is partitioned into 2 me
object megajets
  take fmegajets(AK4jets)

object megajetsNopho
  take fmegajets(AK4jetsNopho)
```

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```
109  # photons - select
110  object photons : PHO
111    select {PHO_}Pt > 80
112    select {PHO_}AbsEta < 2.5
113
114  # jets - no photon
115  object AK4jetsNopho : AK4jets
116    select dR(AK4jets_, photons_ ) >=0.4 OR {photons_}Pt/{AK4jets_}Pt ][ 0.5 2.0
117  #  reject dR(AK4jets_, photons) < 0.4 AND photons.pt/j.pt [] 0.5 2.0
118
119  # Megajets are 4-vectors, each consisting of multiple jet.
120  # Each event with njets > 0 is partitioned into 2 megajets.
121  object megajets : AK4jets
122    select fmegajets(AK4jets) == 2
123
124  object megajetsNopho : AK4jetsNopho
125    select fmegajets(AK4jetsNopho) == 2
126
```

add2tnm

```
160  ### EVENT VARIABLES
161  # All functions used here are taken from Razorfunc.h
162
163  define MR = fMR(megajets)
164  define Rsq = sqrt(fMTR(megajets, met) / MR)
165  define dphimegajets = dPhi(megajets[0], megajets[1])
166  define dphimegajetsNopho = dPhi(megajetsNopho[0], megajetsNopho[1])
167
168  define METl = met + leptonsVeto[0]
169  define METll = met + leptonsVeto[0] + leptonsVeto[1]
170  define METpho = met + photons[0]
171
172  define Rsql = sqrt(fMTR(megajets, METl) / MR)
173  define Rsqll = sqrt(fMTR(megajets, METll) / MR)
174  define MRNopho = fMR(megajetsNopho)
175  define Rsqpho = sqrt(fMTR(megajetsNopho, METpho) / MRNopho)
176  define MT = fMT(leptonsVeto[0], met)
177  define Mll = fMll(leptonsSel[0], leptonsSel[1])
178
```

```
127  ### EVENT VARIABLES
128  define MR : fMR(megajets)
129  define Rsq : (fMTR(megajets, MET) / MR )^0.5
130  define dphimegajets : dPhi(megajets[0], megajets[1])
131  define dphimegajetsNopho : dPhi(megajetsNopho[0], megajetsNopho[1])
132
133  define METLVe   : METLV_0 electronsVeto_0
134  define METLVm   : METLV_0 muonsVeto_0
135  define METLVee  : METLV_0 electronsVeto_0  electronsVeto_1
136  define METLVmm  : METLV_0 muonsVeto_0  muonsVeto_1
137  define METLVpho : METLV_0 photons[0]
138
139  define Rsqe : (fMTR(megajets, METLVe) / MR)^0.5
140  define Rsqm : (fMTR(megajets, METLVm) / MR)^0.5
141  define Rsqee : sqrt(fMTR(megajets, METLVee) / MR)
142  define Rsqmm : sqrt(fMTR(megajets, METLVmm) / MR)
143  define MRNopho : fMR(megajetsNopho)
144  define Rsqpho : sqrt(fMTR(megajetsNopho, METLVpho) / MRNopho)
145  define MTe : sqrt( 2*{electronsVeto_0}Pt *MET*(1-cos( {METLV_0}Phi - {electronsVeto_0}Phi )))
146  define MTm : sqrt( 2*{muonsVeto_0}Pt *MET*(1-cos( {METLV_0}Phi - {muonsVeto_0}Phi )))
147  define mZ : 91.187
148
```

adl2tnm

```
# EVENT SELECTION
# Boosted categories

# Boost pre-selection cuts
region preselection
  # weight HTMETtrig(HT, met) # way to apply event weights
  select AK4jets.size >= 3
  select AK8jets.size >= 1
  select MR > 800
  select Rsq > 0.08

# W category signal and control regions
region WcategorySR
  select preselection
  select leptonsVeto.size == 0
  select tausVeto.size == 0
  select bjetsMedium.size >= 1
  select Wjets.size >= 1
  select dphimegajets < 2.8

region WcategoryCRQ
  select preselection
  select leptonsVeto.size == 0
  select tausVeto.size == 0
  select WjetsAntitag.size >= 1
  select bjetsLoose.size == 0
  select dphimegajets >= 2.8

region WcategoryCRT
  select preselection
  select leptonsVeto.size == 1
  select Wjets.size >= 1
  select dphimegajets < 2.8
  select MT < 100
  # or select fMT(leptonsVeto[0], met) < 100
  select bjetsMedium.size >= 1
```

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```
# EVENT SELECTION
# Boosted categories

# Boost pre-selection cuts
region preselection
  select ALL   # This is only to see the initial event count
  select Size(AK4jets) >= 3
  select Size(AK8jets) >= 1
  select Size(megajets) == 2
  select MR > 800
  select Rsq > 0.08

region WcategorySR
  preselection
  select Size(electronsVeto) + Size(muonsVeto) == 0
  select Size(tausVeto) == 0
  select Size(bjetsMedium) >= 1
  select Size(Wjets) >= 1
  #histo hWjPT, "Wjets Pt GeV", 10, 0, 500, {Wjets_0}Pt
  select dphimegajets < 2.8

region WcategoryCRQ
  preselection
  select Size(electronsVeto) + Size(muonsVeto) == 0
  select Size(tausVeto) == 0
  select Size(WjetsAntitag) >= 1
  select Size(bjetsLoose) == 0
  select dphimegajets >= 2.8

region WcategoryCRT
  preselection
  select Size(electronsVeto) + Size(muonsVeto) == 1
  select Size(Wjets) >= 1
  select dphimegajets < 2.8
  select Size(muonsVeto) == 1 ? MTm < 100 : MTe < 100
  select Size(bjetsMedium) >= 1
```

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```
region WcategoryCRW
  select preselection
  select leptonsVeto.size == 1
  select WjetsMasstag.size >= 1
  select dphimegajets < 2.8
  select MT [] 30 100
  #or select fMT(leptonsVeto[0], met) [] 30 100
  select bjetsLoose.size == 0

region WcategoryCRL
  select AK4jets.size >= 3
  select AK8jets.size >= 1
  select MR > 800
  select leptonsVeto.size == 1
  select Rsql > 0.08
  # or select sqrt(fMTR(megajets, METl) / MR) > 0.08
  select WjetsMasstag.size >= 1
  select dphimegajets < 2.8
  select MT [] 30 100
  # or 30 < MT < 100
  # or select fMT(leptonsVeto[0], MET) [] 30 100
  # or select 30 < fMT(leptonsVeto[0], MET) < 100
  select bjetsLoose.size == 0

region WcategoryCRG
  select photons.size == 1
  select AK4jetsNopho.size >= 3
  select AK8jets.size >= 1
  select leptonsVeto.size == 0
  select tausVeto.size == 0
  select MRNopho > 800
  select Rsqpho > 0.08
  select WjetsMasstag.size >= 1
  select dphimegajetsNopho < 2.8
```

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```
region WcategoryCRW
  preselection
  select Size(muonsVeto) + Size(electronsVeto) == 1
  select Size(WjetsMasstag) >= 1
  select dphimegajets < 2.8
  select Size(muonsVeto) == 1 ? MTm [] 30 100 : MTe [] 30 100
  select Size(bjetsLoose) == 0

region WcategoryCRL
  select Size(AK4jets) >= 3
  select Size(AK8jets) >= 1
  select Size(megajets) == 2
  select MR > 800
  select Size(muonsVeto) + Size(electronsVeto) == 1
  select Size(muonsVeto) == 1 ? Rsqm > 0.08 : Rsqe > 0.08
  select Size(WjetsMasstag) >= 1
  select dphimegajets < 2.10
  select Size(muonsVeto) == 1 ? MTm [] 30 100 : MTe [] 30 100
  select Size(bjetsLoose) == 0

region WcategoryCRG
  select Size(photons) == 1
  select Size(AK4jetsNopho) >= 3
  select Size(AK8jets) >= 1
  select Size(electronsVeto) + Size(muonsVeto) == 0
  select Size(tausVeto) == 0
  select Size(megajetsNopho) == 2
  select MRNopho > 800
  select Rsqpho > 0.08
  select Size(WjetsMasstag) >= 1
  select dphimegajetsNopho < 2.8
```

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```
region WcategoryCRZ
  select AK4jets.size >= 3
  select AK8jets.size >= 1
  select MR > 800
  select (muonsSel.size == 2 and electronsVeto.size == 0) or
         (electronsSel.size == 2 and muonsVeto.size == 0)
  select leptonsSel[0].charge + leptonsSel[1].charge == 0
  select fMll(leptonsSel[0], leptonsSel[1]) < 10
  select Rsqll > 0.08
  select WjetsMasstag.size >= 1
  select dphimegajets < 2.8
```

cutlang

```
region WcategoryCRZ
  select Size(AK4jets) >= 3
  select Size(AK8jets) >= 1
  select Size(megajets) == 2
  select MR > 800
  select (Size(muonsSel) == 2 AND Size(electronsVeto) == 0) OR (Size(electronsSel) == 2 AND Size(muonsVeto) == 0)
  select Size(muonsSel) == 2 ? {muonsSel[0]}q + {muonsSel[1]}q == 0 : {electronsSel[0]}q + {electronsSel[1]}q == 0
  select Size(muonsSel) == 2 ? Abs({muonsSel[0] muonsSel[1]}m - mZ) < 10 : Abs({electronsSel[0] electronsSel[1]}m - mZ) < 10
  select Size(muonsSel) == 2 ? Rsqmm > 0.08 : Rsqee > 0.08
  select Size(WjetsMasstag) >= 1
  select dphimegajets < 2.8
```