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Phase-2 L1 Trigger Menu

This page is intended to document useful information for Phase-2 L1 Trigger Menu. To help assess the performance of a designed Phase2 Menu, we need an overview of the ongoing future physics analyses.

Phase2 L1T Menu versions:

- v2 - slides 5 and 6 of the presentation.
Future analyses

In this subsection we list descriptions of current physics analysis for Phase-2. Namely, for each FTR analysis we list:

- FTR-XX-YYY
  - Title
  - Analysis selection: current objects and thresholds
  - Selection motivation: HLT limited or offline. This question means what was it that drove the selection: (a) current Run2 trigger thresholds? (b) offline reconstruction efficiency? (c) absolute signal efficiency? (d) optimized sensitivity of analysis? (e) else.
  - Ideal selection: objects and thresholds. This question means what would be the analysis cuts if CMS would operate in the triggerless mode (i.e. there were no cuts at L1T or HLT).

FTR-18-001

- Interested in trigger studies
- Title: Searches for light higgsino-like charginos and neutralinos at the HL-LHC with the Phase-2 CMS detector
- Contact: Basil Schneider
- Analysis Selection:
  - Two oppositely charged, soft \((5 < p_T < 30 \text{ GeV})\) leptons
  - \(dR (l_1, l_2) < 2.0\)
  - \(Nb = 0\)
  - \(Njet < 4.5\)
  - \(\text{Leading jet } p_T > 200 \text{ GeV}\)
  - \(MET > 250 \text{ GeV}\)
  - \(dPhi (MET, \text{leading jet}) > 2.0\)
  - \(m_{ll} \in [5, 40] \text{ GeV}\)
- Selection motivation: Target small mass splittings; signal recoils against ISR jet
- Ideal selection: Simply said: The smaller the lepton \(p_T\), the better. Our signal has arbitrary mass splitting, but theoretically motivated, and experimentally not excluded, is signal with small mass splittings. In an ideal selection, we would go lower in lepton \(p_T\)'s, as long as we are not drowning in background. Lowering MET might be beneficial as well to a certain degree. The MET mostly stems from the recoil against the ISR jet. The smaller the recoil, the higher the signal yield. In Run-2 we currently use the pure MET trigger and a dedicated MET plus 2 muon triggers for the low MET regions. The electron version of this trigger does not exist, since the L1 rate of soft electrons explodes due to hot towers in the ECAL. In my opinion, the most interesting question concerning triggering in Phase-2 for this analysis, is if we can control the electron trigger rate. Coinciding tracker information with the one from calorimetry at L1 could make this possible in Phase-2.

FTR-18-002

- Title: Search Sensitivity for Displaced Muons at HL-LHC
- Analysis Selection:
  - Two oppositely charged displaced muons (dedicated displaced standalone reco algo) in \(|\eta| < 2.8\)
  - \(p_T(\text{leading displ muon}) > 20 \text{ GeV}\), \(p_T(\text{subleading displ muon}) > 15 \text{ GeV}\), \(p_{T\text{miss}} > 50 \text{ GeV}\), \(m_{ll} \in [5, 40] \text{ GeV}\)
- Good quality track: chi^2/ndof < 2, 17 (|\eta| < 2.4) and 6 (2.4 <= |\eta| < 2.8) valid muon hits
Rejection of cosmics by back-to-back cut

ΔR (μ1, μ2) > 0.05 (duplication)

Selection motivation: The 20 GeV cut on the leading displaced muons comes from displaced muon L1 trigger studies (single muon) for Phase-2. This can be found in CMS-TDR-016 (Fig.1.22).

Ideal selection: Has been optimized with respect to recent displaced muon Phase-2 trigger studies. Could be optimized potentially by studying double-muon trigger thresholds.

FTR-18-003 (FNP)

- Potentially interested in trigger studies, if personpower available
  - Title: Search for vector boson fusion production of a massive resonance decaying to a pair of Higgs bosons in the four b quark final state at the HL-LHC using the CMS Phase 2 detector
  - Analysis Selection:
    - Number of AK8 jets == 2:
      - \(p_T > 300\) GeV and \(|\eta| < 3\)
      - \(90 < \text{soft-drop mass} < 140\) GeV
      - \(\text{N-subjettiness} \ 2/1 < 0.6\)
      - At least one soft-dropped subjet passing DeepCSV medium working point.
    - Number of AK4 jets \(\leq 2\)
      - \(p_T > 50\) GeV and \(|\eta| < 5\)
      - \(\Delta R (AK4, AK8) > 1.2\)
      - At least one pair of AK4 jets having invariant mass \( > 300\) GeV
      - The same pair should lie in opposite hemispheres in the detector: \(j_1^* j_2 < 0\).
  - Selection motivation: Central high mass resonance X decaying to Lorentz-boosted HH, with both Higgs bosons decaying to \(b\)b. Forward jets from VBF production.
  - Ideal selection: B-tagging, substructure, and VBF jets at trigger level to reduce backgrounds. Optimizing H jet mass window.

FTR-18-004 (FSM)

- Title: FCNC t q gluon
  - Contact: Lev Dudko et al: available
  - Analysis selection: 1 isolated muon, 2-3 jets (signal region: 1 b-tagged + 1 non-b-tagged jet)
    - \(p_T (\text{lepton}) > 25\)
    - \(|\eta(\text{lepton})| < 2.8\)
    - \(p_T (\text{jet}) > 30\)
    - \(|\eta(\text{jet})| < 4.7\)
  - MC datasets
  - Selection motivation: mostly online (single lepton trigger)
  - Ideal selection: Could be optimized by studying single lepton triggers

FTR-18-005 (FSM)

- Title: Study of Vector Boson Scattering at High Luminosity LHC via same sign dileptons
  - Contact: Kajari Mazumdar, interested to contribute
  - Analysis selection: 2 same sign leptons (isolation delta R > 0.3) + 2 jets (p\(T\) > 50 GeV, \(|\eta| < 4.7\))
    - \(p_T (\text{lepton}) > 20/20\)
    - \(|\eta(\text{lepton})| < 3\)
  - Selection motivation: Run-II analysis under the assumption that same-sign dilepton triggers are efficient for the offline selection. No dedicated trigger study was done.
Ideal selection: Could be optimized by studying same-sign double-muon triggers.

**FTR-18-006**

- **Title**: Search for heavy composite Majorana neutrinos at the High-Luminosity and the High-Energy LHC
- **Analysis selection**:
  - 2 same-flavour leptons (electrons or muons) in $|\eta|<2.4$,
  - $p_T$ (leading lepton) $> 110$ GeV,
  - $p_T$ (second leading lepton) $> 40$ GeV,
  - $M(l,l)$ $> 300$ GeV,
  - at least 1 Fat Jet (AK8 PUPPI jet) in $|\eta|<2.4$
- **Selection motivation**: signal expected in the high-mass and high-pt region
- **Ideal selection**: close to the present one - due to two possible decay topologies (depending on the parameters of the model), a possible improvement could be the definition of two signal regions: one for resolved jets, one for boosted case (present case).

**FTR-18-007**

- **Title**: Projection of the Mono-Z search for dark matter to the HL-LHC
- **Analysis selection**:
  - Single and double lepton triggers
  - Offline:
    - Two OSSF electrons/muons from Z decay
    - Electron $p_T > 25, 20$ GeV
    - Muon $p_T > 20, 20$ GeV
    - MET $> 100-200$ GeV (A 100 GeV MET cut was used in Run-II, while 200 GeV was used for the projection study based on a conservative estimate of MET performance. Hopefully, the final cut in the Phase-II analysis will lie closer to 100 GeV than 200 GeV.)
- **Selection motivation**: Mostly offline. Lepton thresholds chosen are chosen as close to HLT as possible, but the real limitation arises from the MET cut. After applying the MET cut, almost all events have at least one lepton with $p_T>50$ GeV, so the leading lepton is not a problem. If we could lower the trailing lepton $p_T$, that may give us a little more acceptance at low mass, but nothing dramatic. Unless there is significant improvement in the MET performance compared to Run-II, lower thresholds are not a priority.
- **Ideal selection**: see above.

**FTR-18-008**

- **Title**: Projection of searches for pair production of scalar leptoquarks decaying to a top quark and a charged lepton at the HL-LHC
- **Analysis selection**: Exactly as in B2G -16-027:
  - HLT Iso(Tk)Mu24
  - $>= 2$ muons (pt $> 30$ GeV, abs(eta) $< 2.4$, relIso $< 0.15$),
  - $>= 2$ AK4CHS jets (pt $> 30$ GeV, abs(eta) $< 2.4$),
  - $M_{\mu\mu}$ $> 111$ GeV
  - $>= 1$ b-tagged AK4CHS jet (CSVv2 loose WP)
  - $S_T > 350$ GeV
  - $S_T^{lep}$ (scalar sum of charged lepton pt) $> 200$ GeV
  - $2$ event categories based on number of electrons (pt $> 30$ GeV, abs(eta) $< 2.4$) and muons
Selection motivation: Muon-pt of > 30 GeV is essentially HLT-driven, all other cuts optimize the signal significance and suppress SM background. We could profit from a lower muon HLT pt threshold for our lowest mass points (MLQ = 200 - 300 GeV), but beyond that (400 GeV - 2000 GeV), the current thresholds are sufficiently efficient.

Ideal selection: We would profit from a lower isolated muon trigger threshold for our lowest mass points (MLQ = 200 - 300 GeV). Double muon triggers could maybe also recover efficiency.

FTR-18-009

- Title: Search for tt resonances at the HL-LHC with the CMS Phase II detector
- Analysis selection:
  - Semi-leptonic:
    - trigger: one medium electron pT>80, |eta|<3, non isolated
    - at least 2 AK4 jets, |eta|<4, leading pT>185(e)/150(mu), subleading pT>50
    - MET>120(e),50(mu)
    - 0 or 1 AK8 jets, pT>400, |eta|<4, 105<m_SD<210, tau32<0.65
    - 2D-cut for isolation: min[ΔR(lepton, jets)] > 0.4 or pTrel (lepton, jet) > 25 GeV
    - HTlep> 150
    - Chi2 discriminator
  - All-jets:
    - trigger (assumed): HT>1.2TeV
    - 2 AK8 jets, pT>400, |eta|<4, 105<m_SD<210, tau32<0.65
    - deltaPhi(jet,jet)>2.1
    -subjett b-tagging
- Selection motivation:
  - Semileptonic: lepton selection criteria are dictated by trigger. Due to the boosted nature of the search, un-isolated triggers had to be used. The remaining criteria are standard (boosted) ttbar criteria
  - All-jets: HT selection is dictated by the trigger and limits the low-boost reach of the analysis. The other criteria are usual boosted top selection criteria
- Ideal selection: while this analysis tries to probe for very high resonances (>3TeV), the low(er) mass resonances / large width remains interesting, and have actually gained interest recently as this search hits the "energy limit" of the LHC. With this in mind:
  - Semileptonic: lower unisolated, or mini-isolated lepton thresholds
  - All-jets: no HT cut (e.g. top/boosted btag/jet substructure trigger)

FTR-18-010

- Title: Search for supersymmetry with direct stau production at the HL-LHC with the CMS Phase-2 detector
- Contact: Isabell Melzer-Pellmann
- Analysis Selection:
  - Analysis with two hadronically decaying tau leptons: * Two opposite-charge hadronically decaying tau leptons with: * pt > 50 GeV * eta < 2.3 * pt (tau tau) > 50 GeV * dPhi (11, 12) > 1.5 * 0.3 < dR (11, 12) < 3.5 * Nb = 0 *
  - sumMT=MT(tau_1,MET)+MT(tau_2,MET) > 400 GeV (+ additional binning in sumMT) * MT2 > 50 GeV (+ additional binning in MT2) * Analysis with one hadronically decaying tau lepton and one muon or electron: * pt (tau) > 40 GeV * eta (tau) < 2.3 * pt (mu/el) > 30 GeV * eta (mu/el) < 2.4 / 1.6 * dPhi (11, 12) > 1.5 * 0.3 < dR (11, 12) < 3.5 * Nb = 0 * MT2 > 80 GeV (+ additional binning in MT2 and pt(tau))
- Selection motivation: Selection of two leptons, and rejection of Z+jets, W+jets, ttbar, VV events)
Ideal selection: Ideally would like to go a bit lower on tau pt, which is motivated by the current di-tau trigger. At least it would be great not to go higher in tau pt.

**FTR-18-011 (HFuture)**

- **Title**: Higgs properties measurements (HWW)
- **Contact**: Davide Di Croce
- **Analysis Selection**: Current offline requirements are:
  - 2 leptons with opposite charges
  - Leading/subleading lepton pt > 25/13
  - Third lepton veto (pt<10)
  - MET > 20
- **Selection motivation**: Mostly offline while using single and dilepton triggers
- **Ideal selection**: Going as low as possible with lepton pt thresholds

List of used triggers can be found: https://docs.google.com/spreadsheets/d/1F7-deG0NM0rhzx-diAseYIA-HYN15iMGXAcD0Ee7Y/edit#gid=0

- **Title**: Higgs properties measurements (HZZ)
- **Contact**: Toni Sculac
- **Analysis Selection**: 4 isolated + identified leptons
  - pt of 2 leading leptons has to be > 20, 10 GeV
  - These 4 leptons are used to build Opposite-Sign Same-Flavour pairs that are subject to additional cuts before being selected in our signal region
- **Selection motivation**: Designed to have as high efficiency as possible due to very small cross section but great signal to background ratio
- **Ideal selection**: Signal region is currently not limited by HLT at all, however with full Run II data our statistical and systematical uncertainties on the measurement of gluon fusion signal strength are of same magnitude. Main source of experimental systematics originates from uncertainty on efficiency measurements, specially in low pT region. We would thus profit significantly from prescaled low-mass resonance (J/Psi) HLT paths for electrons.

List of used triggers can be found: https://twiki.cern.ch/twiki/bin/view/CMS/HiggsZZ4lRunII#Trigger_paths
- **Summary**:
  - Need unprescaled EGamma, Muon and cross triggers to collect H->ZZ->4l events in all final states with efficiency as close as possible to 100%
  - Would profit from low pT tresholds since we select an offshell Z2 with mass around 40GeV
  - Would profit significantly from prescaled low-mass resonance (J/Psi) HLT paths for better understanding of leading systematic source.

- **Title**: Higgs properties measurements (Hττ)
- **Contact**: Tyler Ruggles
- **Selection motivation**: Sensitive to trigger thresholds, any increase harms the analysis
- If the lepton+tau cross triggers are to be adjusted for Run-III, the general interest would be in lower light lepton thresholds, with higher tau_h thresholds. For the 2016 SM HTT analysis analysts used asymmetric thresholds on the tau_h (pt>40/50 GeV) while 40/40 would be allowed based on HLT thresholds. Unfortunately, while an asymmetric doubleTau trigger would work for SM Higgs, this would prove to be difficult for all tau analyses.
List of used triggers and additional selection definitions can be found:
https://twiki.cern.ch/twiki/bin/viewauth/CMS/HiggsToTauTauWorking2017#Trigger_Information

Summary:

- Triggers already cut into the phase space quite a bit and any increase of thresholds will lead to a loss of acceptance and thus sensitivity -- however if there are reasons other than the trigger to increase offline thresholds, then thresholds could be increased accordingly without harm. This is the situation for the bulk SM signal: signatures with lower-pt objects (e.g. \( h \rightarrow aa \rightarrow \)) are of course more affected, signatures with higher-pt hardly at all (e.g. MSSM).

- **Title**: Higgs properties measurements (\( H \rightarrow \gamma\gamma \))
- **Contact**: Linda Finco
- **Selection motivation**:
  - At the beginning of Run II there was a need to add a mass cut at 90GeV (not present in Run I).
  - The unseeded leg pt threshold was increased from 18GeV to 22GeV in order to follow bandwidth limitation requirements (between 2016 and 2017).
  - The offline pt selection requirements are 35/25 GeV for the leading/subleading photon.
    - Online pt requirements above 32/22 GeV would cause problems for the analysis as the would be too close to offline requirements and they would modify the shape of background distributions, thus worsening the background fit. At this moment, this situation is not affection the analysis.
    - This is not the case for the low-mass path, where there is great limitation coming from the online pt cuts at 30 and 18 GeV, given that in this case, the main goal is to explore a lower mass region.

List of used triggers and additional selection definitions can be found:
https://twiki.cern.ch/twiki/bin/view/CMS/Higgs2G

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**FTR-18-013 (FSM)**

- **Title**: Measurement of rare B \( \mu^+\mu^- \) decays with the Phase-2 upgraded CMS detector at the HL-LHC
- **currenty no availability for trigger studies**
- **Analysis Selection**: opposite sign \( \mu \) global muons, \( p_T(mumu) > 4 \) GeV, \( |\eta| < 1.4 \), \( 4.5 < m(mumu) < 6.5 \) GeV, \( p_T(mumu) > 6.5 \) GeV
- **Selection motivation**: limited by detector acceptance and trigger rate
- **Ideal selection**: as low as possible muon pt thresholds

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**FTR-18-014 (FSM)**

- **Title**: Sensitivity projection for VBS ZZ and longitudinal scattering at HL-LHC
- **Contact**: Claude Charlot (availability being checked)
- **Analysis selection**: similar to CMS-SMP-16-001: 2 Z candidates from 2 pairs of OS SF leptons (4 leptons in total), \( \geq 2 \) jets
  - \( p_T(\text{lepton}) > 20/12/7/7 \) (electron), 20/10/5/5 (muon)
  - \( |\eta(\text{lepton})| < 2.8 \)
  - \( p_T(\text{jet}) > 30 \) GeV, \( m(jj) > 100 \) GeV
  - \( |\eta(\text{jet})| < 4.7 \)
  - \( Z \) window of +/- 30 GeV
- **Selection motivation**: mostly offline (dilepton and trilepton triggers)
- **Ideal selection**: Could be optimized by studying triple-lepton (or quad lepton?) triggers

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FTR-18-011 (HFuture)
FTR-18-015 (FSM)

- **Title**: ttbar differential cross sections and PDF constraints at the HL-LHC
- **Contact**: Otto Hindrich (available)
- **Analysis selection**: 1 lepton, 4 jets (2 b-tagged)
  - $pt$ (lepton) > 30 GeV,
  - $|\eta|$(lepton) < 2.8
  - $pt$ (j) > 30 GeV,
  - $|\eta|$(jet) < 4 (3.8 for b-tagged)
- **Selection motivation**: HLT limited-> dependent on the lepton $pt$ threshold at the trigger level
- **Ideal selection**: esp. electron channel could be optimized for single electron + multi jet cross triggers, for muons retain lowest possible single muon threshold

FTR-18-016 (HFuture)

- **Title**: Search for VBF Higgs to invisible at the HL-LHC
- **Contact**: Anne-Marie Magnan
- **Analysis Selection**: baseline selection (cut&count) strategy from HIG-17-023, re-optimised for 14 TeV 3000 fb-1.
  - Signal region (SR): VBF dijet + MET final state, no other object (veto on electrons, muons, taus, bjets, photons)
    - dijet pair: two highest-$pt$ jets after PU rejection, with jet1 $pt>$80 GeV, lowest possible threshold on jet2 $pt$ (40 GeV).
    - dijet mass > 1.5--2.5 TeV (or 300-500 GeV for shape analysis), dijet $\Delta$eta > 4 (2 for shape analysis), dijet $\Delta$phi < 1.8
    - lowest possible threshold on MET ($\sim$170--220 GeV -- was 250 GeV for trigger reasons in run2).
    - $\Delta$mindphi(jets $pt>$30 GeV, MET) > 0.5 to kill QCD
  - Control regions (CR): W/Z with one or two isolated tight electrons/muons $pt>$20 (20,10) GeV, QCD multijets with $\Delta$mindphi(jet,MET)<0.5. To have muon CR with same trigger as SR: L1/HLT/offline MET calculated without muons.
  - Triggers in run 2: two approaches, one pure VBF dijet at L1, dijet+MET at HLT. Other pure MET at L1 and HLT (METMHT trigger). SingleElectron trigger for electron CR.
- **Selection motivation**: optimised on 95% CL limit on BR(inv) with YR18 systematics included, for 14 TeV with 300, 1000 and 3000 fb-1. Shape analysis more powerful but would require lower threshold on $\Delta$tetaj and Mjj. Compromise between S/B, systematics impact, and statistics in control regions. Have been assuming trigger thresholds can be below analysis thresholds such that $>$95% efficiency after offline selection, by combining VBF dijet+MET criteria at L1.
- **Ideal selection**:
  - for signal trigger: lowest possible threshold on jet2 $pt$, lowest possible threshold on MET(noMuons) >150 GeV: dijet+METnoMu at L1, with dijet_dphi and $\Delta$mindphi(jet,METnoMu) requirements to kill QCD and lower rates. Need control trigger without dphi requirements, prescaled, for QCD background CR.
  - for electron CR: lowest possible threshold on single electron trigger (considered 40 GeV like for run 2)
  - lowest $pt$ thresholds and highest $\eta$ acceptance possible for vetoes on elec/mu/tau/bjets/photons.
FTR-18-017 (HF.future)

- **Title**: Projection of the Run 2 MSSM H->tautau limits for the High-Luminosity LHC
- **Contact**: Martin Flechl
- **Analysis Selection**: Projection of HIG-17-020, selection taken from there
  - Require two tau decays (e,mu, or tau-had)
  - pt cuts:
    - emu: 13/10 for first/second lepton
    - etau: 26-e, 30-tau
    - mutau: 23-mu, 30-tau
    - tautau: 40/40
  - categories with/without b-tag
  - some additional cuts based on final state (mt, dzeta)
- **Selection motivation**: pt/eta thresholds of objects (e, mu, tau-had) chosen according to trigger thresholds, but in the - for HL-LHC - interesting high-mass region the analysis is not limited by trigger requirements
- **Ideal selection**: Similar to now, not a problem if trigger thresholds rise moderately.

FTR-18-018 (HF.future)

- **Title**: First Level Track Jet Trigger for Displaced Jets at High Luminosity LHC
  - **Contact**: Rishi Patel
  - **Analysis Selection**: L1 Track Jet selection based on HT and displaced tracks (scan thresholds and show rate and signal efficiency)
  - **Selection motivation**: Use HT + Displaced trigger for Exotic higgs decays to jets, and show improvement in the HT threshold
    - Track Jets made from Track pT>2GeV
    - L1 HT Computed with Track Jet pT >5GeV
    - Track Jets with pT>50 (100) have to have at least 2 tracks (3 tracks)
    - Track Selection criteria for prompt tracks based on Chi2 and pT, for displaced tracks it is based on d0, chi2, nstubs
    - **Ideal selection**: The PAS shows the rates and thresholds at L1 given a displaced track +prompt track trigger algorithm, where the most ideal is at the lowest L1 HT threshold with still fully turned on signal efficiency for exotic higgs decays.

FTR-18-019 (HF.future)

- **Title**: Prospects for HH measurements at the HL-LHC
- **summary**: this analysis studies and combines five HH decay channels, each having a different trigger strategy and challenges. The information for each channel is listed separately below

- **Channel**: bb
  - **Contact**: Fabio Monti
  - **Analysis Selection**: Two photons and two jets
    - photons: abs(eta) < 2.5, pt > 30/20 GeV (lead/sublead), pT/m(gg) > 1/3 , 1/4, 100 < m(gg) , 180 GeV
Selection motivation: Central photons and jets are chosen to maximise the S/B ratio (the signal is mostly central)

Ideal selection:

- Thresholds as low as possible help to access the low mHH spectrum and consequently improve the determination of the trilinear coupling

- Channel: bb
  - Contact: Giles Strong
  - Analysis Selection: Three tautau decay channels (e tauh, mu tauh, tauh tauh) + two jets
  - e tauh:
    - electron: abs(eta) < 2.1, pt > 27 GeV, isolated
    - tauh: abs(eta) < 2.3, pt > 20 GeV, isolated
  - mu tauh:
    - electron: abs(eta) < 2.1, pt > 23 GeV, isolated
    - tauh: abs(eta) < 2.3, pt > 20 GeV, isolated
  - tauh tauh:
    - both tauh: abs(eta) < 2.1, pt > 45 GeV, isolated
  - jets: pt > 30 GeV, abs(eta) < 2.4, b tag WP medium

Selection motivation: thresholds determined by the corresponding trigger thresholds (same values as Run II assumed)

Ideal selection:

- Thresholds as low as possible, especially in the tauhtauh channel that is the most sensitive. Phase 2 trigger may also exploit the additional H->bb presence and/or the invariant mass of the objects

- Channel: bbbb
  - Contact: Luca Cadamuro (resolved), Devdatta Majumder (booster)
  - Analysis Selection: four b jets (resolved) or two AK8 jets (boosted). The resolved analysis drives the sensitivity for SM HH and trilinear coupling measurement
  - resolved: four jets: pt > 45 GeV, abs(eta) < 3.5, b tag WP medium, circular region around mH1, mH2 with radius 40 GeV
  - boosted: two AK8 jets with pt > 300 GeV, abs(eta) < 3 + softdrop andsubjettiness requirements

Selection motivation: thresholds determined by the corresponding trigger thresholds (same values as Run II assumed)

Ideal selection:

- Thresholds as low as possible to maintain significant acceptance to the HH signal. The loss in significance vs the pt threshold increase has been studies (fig. 3a of the PAS). -10% (30%) significance if the minimal jet threshold is raised to 55 (80) GeV

- Channel: bbWW
  - Contact: Martin Delcourt
  - Analysis Selection: three WW decay channels (ee, mumu, emu) + two jets
  - e e:
    - electron: abs(eta) < 2.8, isolated
  - mu mu:
    - muon: abs(eta) < 2.8, isolated
  - e mu:
    - electron: pt > 25, mu pt > 10 GeV, abs(eta) < 2.8, isolated
  - mu e:
    - muon: pt > 25, e pt > 20 GeV, abs(eta) < 2.8, isolated
  - jets:
    - jet: pt > 20 GeV, abs(eta) < 2.8, b tag medium WP

Selection motivation: thresholds determined by the corresponding trigger thresholds

Ideal selection:

- Thresholds as low as possible to maintain significant acceptance to the HH signal
• **Channel**: bbZZ
• **Contact**: Lisa Borgonovi
• **Analysis Selection**: four lepton final state considered (4mu, 4e, 2e2mu)
  ◊ at least for leptons with pt > 5 (7) GeV for muons (electrons), abs(eta) < 2.8. Event must contain a leading and subleading lepton with pt > 20 and 10 GeV. Mass requirements 50 < m(z1) < 100 GeV, 12 < m(z2) < 60, 120 < m(4l) < 30 GeV
  ◊ jets : pt > 20 Gev, b tag medium WP
• **Selection motivation**: thresholds determined by the corresponding trigger thresholds
• **Ideal selection**: ◊ Very low branching fraction channel, low pt thresholds needed for high acceptance and minimum signal yield

**FTR-18-020 (HFuture)**

• **Title**: Constraints on the Higgs boson self-coupling from ttH+tH, H to gamma gamma differential measurements at the HL-LHC.
• **Analysis selection**: 2 photons with usual H->gg (diphoton) selection + 1-bjet (up to |eta|<4.) -> 2 categories, based on top decay : leptonic (>=1 lepton, >=2 jets) and hadronic (0 leptons, >=3 jets). We use medium working points for b-jets and tight WP for photons.
• **Selection motivation**: Motivated by requiring a good sample of ttH at low pT(H) with reduced backgrounds. Trigger is limited only by photon selection, but analysis selection requires m(gg)>100 GeV for fitting so essentially we already require pT>25 for sub-leading photon (i.e trigger can be lower than this but not much point below 20)
• **Ideal selection**: For the analysis, we would ideally have that the trigger is ~100% efficient for the photons but provided the isolation isn't an issue, pT thresholds of 20-25 are fine.

**FTR-18-021**

• **Interested in trigger studies**
• **Title**: Search for Vector-Like Fermions using missing transverse momentum and muons in a final state of pp-collisions in the HL-LHC and Phase-II CMS experiment
• **Analysis Selection**: Tight muons + puppi met and jets. Two channels: one or two muons
  ◊ muons pt greater than 3 GeV and smaller than 20 GeV,
  ◊ MET>70 GeV,
  ◊ Leading jet pt > 70 GeV,
  ◊ further criteria based on the relations among these variables.
• **Selection motivation**: HLT limited ----> Highly dependent on the muon pt threshold at the trigger level
• **Ideal selection**: Rely on oe or mutiple jet pt threshold, perhpas combined with a MET threshold to have as low as threshold as possible for muons pt.

**FTR-18-028**

• **Title**: Search for a leptoquark decaying into a tau lepton and a b quark
• **Analysis Selection**: ◊ The sensitivity is driven by pair LQ production, LQ (-> tau b) LQ (-> tau b), which subsequently decays into tau(h) tau(h), where tau(h) means hadronically decaying tau lepton.
  ◊ We require two tau(h)s with pT > 50 GeV and two jets with pT > 50 GeV, where one of them should be b-tagged
  ◊ Then, we search for the excess of events at the tail of scalar pT sum (:= 2 tau(h) pT + 2 jet pT)
• **Selection motivation**: offline
FTR-18-029

- **Title**: Search for excited leptons in $ll\gamma$ final states in proton-proton collisions at the HL-LHC
  - **Analysis Selection**: 
    - two electrons + a photon or two muons + a photon,
    - $p_T(e, \mu, \gamma) > 35$ GeV,
    - $|\eta(e, \gamma)| < 2.5$,
    - $|\eta(\mu)| < 2.4$
  - **Selection motivation**: offline (sufficiently high momentum mu, e and photon, so much higher $p_T$ threshold than trigger threshold)
  - **Ideal selection**: higher $p_T$ cut and tighter object selection do not affect significantly on the analysis

FTR-18-030

- **Title**: Sensitivity study for a heavy gauge boson $W'$ in the decay channel with a tau and a neutrino at the High-Luminosity LHC
  - **Analysis Selection**: 
    - selecting hadronic decay of the tau ($\tau_h$). Exactly one $\tau_h$ with $p_T > 80$ GeV
    - $\tau_h$ reco based on PUPPI jets with $p_T>30$ GeV and $\eta<2.7$
    - use "medium" WP32 for Delphes parametrization. With 45% efficiency. Note: no real tau reco in this upgrade study
    - $\text{MET} > 200$ GeV
    - veto electrons and muons with $p_T < 25$ GeV
    - $0.7 < p_T/\text{MET} < 1.3$ (from Run 2)
    - $\Delta_{\phi}(\tau, \text{MET}) > 2.4$ rad
  - **Selection motivation**: one tau and MET back-to-back and balanced in $p_T$ to reject background. Selection is driven by (from above) (c) absolute signal efficiency (d) optimized sensitivity of analysis.
  - **Ideal selection**: no big impact from trigger thresholds since we are searching for heavy objects.

FTR-18-031 (FSM)

- **Title**: Expected sensitivities for $ttt$ production at HL-LHC and HE-LHC
  - **Analysis Selection**: 
    - same-sign dilepton and multilepton final states
    - at least 5 jets of which at least 2 are b-jets,
    - $p_T(\text{lepton}) > 20$ GeV, $p_T(\text{b-jet (DeepCSV)}) > 25$ GeV, $p_T(\text{non-b-jet}) > 40$ GeV
    - veto against Z-bosons
  - **Selection motivation**: optimize $ttt$ signal over tt background
  - **Ideal selection**: signal is at high HT, however low trigger thresholds for multi-lepton final states are assumed.
FTR-18-032 (FSM)

- **Title:** High-pT jet measurements at the HL-LHC (jets: inclusive, b, W(Boosted) and top(Boosted))
- **Contact:** Jindrich Lidrych available for trigger studies
- **Analysis Selection:**
  - bb analysis: \( p_T(\text{leading jet}) > 400 \text{ GeV}, p_T(\text{2nd jet}) > 200 \text{ GeV} \)
  - tt(Boosted): fatjet (\( \delta R = 0.8 \)), \( p_T > 400 \text{ GeV}, 50 < m(\text{subjett}, \text{W candidate}) < 150 \text{ GeV}, \text{subjet-b-tagging, mSD} > 105 \text{ GeV}, \text{and tau3/tau2} < 0.68 \)
  - W(Boosted): fatjet (\( \delta R = 0.8 \)), \( p_T > 400 \text{ GeV}, 65 < m(\text{SD}) < 105 \text{ GeV}, \)
- **Selection motivation:** offline (can use prescaled triggers for lower pt jets)
- **Ideal selection:** maximum efficiency at large pt

FTR-18-033 (FSM)

- **Title:** \( P5' \) parameter in the \( B_0 \rightarrow K^* 0 \mu^+ \mu^- \) decays
- **Contact:** Sara Fiorendi (availability tba)
- **Analysis Selection:**
  - Trigger: Dimuon at L1 (in 2018 \( p_T > 4 \text{ when covering full eta} \)), displaced dimuon+track candidate \@ HLT
  - Offline: Two muons + 2 tracks from a common vertex, selection on the vertex quality and displacement from interaction region.
  - Muon \( p_T > 4 \text{ GeV}, \text{Track } p_T > 0.8/1.2 \text{ GeV} \): threshold driven by trigger selection.
- **Selection motivation:** driven by trigger thresholds and by signal significance optimization
- **Ideal selection:** two muons (or if possible electrons, cf. parking 2018, possible use of track trigger?) with as low as possible thresholds.

FTR-18-035 (HFuture)

- **Title:** \( H \rightarrow a a \rightarrow 2 b \tau \) and \( H \rightarrow a a \rightarrow 2 \mu \tau \)
- **Contact:** Cecile Caillol
- **Analysis Selection:**
  - emub final state: 1 electron + 1 muon + 1 bjet (triggered with muon + electron)
  - etaub final state: 1 electron + 1 tauh + 1 bjet (triggered with single electron)
  - mutaub final state: 1 muon + 1 tauh + 1 bjet (triggered with single muon)
  - mumu+emu final state: 3 muons + 1 electron (triggered with double muon)
  - mumu+etauh final state: 2 muons + 1 electron + 1 tauh (triggered with double muon)
  - mumu+mutauh final state: 3 muons + 1 tauh (triggered with double muon)
  - mumu+tauhtauh final state: 2 muons + 2 tauh (triggered with double muon)
- **Selection motivation:** signal acceptance very small at high lepton \( p_T \), signal concentrated at low invariant mass of the three objects
- **Ideal selection:** lower lepton \( p_T \), would be nice to trigger on low \( p_T \) double tauh

FTR-18-036 (FSM)

- **Title:** \( tt+Z \) BSM interpretation at HL-LHC
- **Contact:** Robert Schoefbeck (currently no availability for trigger studies)
- **Analysis selection:** 3 leptons + 3 jets (1 b-tagged)
  - \( p_T (\text{lepton}) > 40/20/10 \text{ GeV}, \)
  - \( \text{leta}(\text{lepton}) \) < 3
  - \( p_T (j) > 30 \text{ GeV}, \)
  - \( \text{leta}(\text{jet}) \) < 4
Z window of +/- 10 GeV

Selection motivation: Offline. The leading lepton is mostly > 40 GeV, the lower thresholds are kept as loose as possible (based on Run-II)

Ideal selection: Not much different, except a small benefit from lowering the trailing lepton pt cut (this increases high pT Z acceptance for Z's decaying with the leptons in the direction of motion which causes one lepton to be very soft)

FTR-18-037

- Title: HL-LHC and HE-LHC searches for new physics in hadronic final states with boosted W bosons or top quarks using razor variables
- Analysis selection: current objects and thresholds:
  - This was a projection study, where the samples and selection were directly taken from the Run2 search.
  - Inclusive hadronic final states with boosted Ws/tops: >=3 jets (>30GeV), either >= boosted W + >=b or >= boosted top, 0 lepton, razor variables MR (hadronic quantity reflecting heavy particle mass) > 800, R2 > 0.08 (transverse quantity dependent on MET).
- Selection motivation: HLT limited or offline: Offline. The analysis is about 70% efficient wrt HLT. We chose to take the physics-motivated selection and apply efficiency maps. This is a very central process with little gain from forward detector upgrades.
- Ideal selection: objects and thresholds: would stay the same (binning would be optimized).
  - We could benefit from lower threshold HT or razor triggers combined with efficient boosted object triggers.

FTR-18-038 (FSM)

- Title: Prospects for the measurement of electroweak and polarized WZ → 3lν production cross sections at the High-Luminosity LHC
- Contact: Sascha Savin (will try to contribute)
- Analysis selection: 3 leptons, 2 jets, b-tag veto, Z inv. mass window,
  - This was a projection study, where the samples and selection were directly taken from the Run2 search.
  - leptons: pt(l1(Z))>25 GeV, pt(l2(Z))>15 GeV, pt(l(W))>20, m(3l)>100 GeV, |eta(mu)| < 2.8, |eta(e)|<3.0
  - jets: |eta(jet)| < 4.7, pt (jet) > 30, mjj > 500 GeV, delta(eta) > 2.5
  - ptmiss > 30 GeV
- Selection motivation: Suppression of DY and ttbar background
- Ideal selection: offline motivated

FTR-18-040 (HFuture)

- Title: H->ZZ ->2l2q
- Contact: Meng Xiao
- Analysis selection: 2 leptons, 2 jets or 1 boost jet, Z inv mass window, Z pt > 150, rely on dilepton trigger
- Selection motivation: kill background in low mass region, retain signal efficiency in high mass region
- Ideal selection: offline motivated
FTR-18-041 (FSM)

- **Title**: CP-violation studies using $B_0$ decays to $J/\psi(1020)$
- **Contact**: Giacomo Fedi (availability tba)
- **Analysis Selection**:
  - Trigger: Dimuon at L1, displaced $J\psi$(mumu)+Tracks and $J\psi$+Muon at HLT
  - 2 muons $p_T>$3.5-4 GeV creating a $J\psi$ with mass within 150 MeV the PDG value
  - 2 track $p_T>$0.8-1.2 GeV creating a $\phi$ with mass within 10 MeV the PDG value
  - muons+tracks creating a common vertex and a $B_s$
  - offline proper decay time cut to remove either the turn on curve due to the one trigger ($L/\sigma>$3) or to remove the prompt $J\psi$ in case of unbiased trigger
- **Selection motivation**: trigger-thresholds and S/B optimization
- **Ideal selection**: two muons (or if possible electrons, cf. parking 2018, possible use of track trigger? GF: requiring trigger tracks with $p_T>$2 GeV reduces the signal rate, why instead don’t we exploit the PV to search for displaced $J\psi$?) with as low as possible thresholds.

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**Tau->3mu (already for muon TDR-17-003) (FSM)**

- **Title**: Tau->3mu
- **Contact**: Andrey Korytov, Vladimir Rekovic (available for trigger studies)
- **Analysis selection**: $\eta_{\text{mu}} < 2.8$
- **Selection motivation**: maximal eta coverage for 3 muons
- **Ideal selection**: loose trigger requirements for optimal efficiency in forward region (with additional hardware beyond eta 2.8)
Wishlist: analyses that would make sense but have not been done yet

I wish I were an analysis

• ...

-- VladimirRekovic - 2018-12-04