[Snowmass LOI: Forward 3≤η≤6 Lepton-Photon-Jet System]

Instrumentation Frontier Topical Groups: (check all that apply □/■)

□ (IF1) Quantum Sensors
■ (IF2) Photon Detectors
■ (IF3) Solid State Detectors and Tracking
□ (IF4) Trigger and DAQ
□ (IF5) Micro Pattern Gas Detectors (MPGDs)
■ (IF6) Calorimetry
□ (IF7) Electronics/ASICs
□ (IF8) Noble Elements
■ (IF9) Cross Cutting and Systems Integration

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Introduction: At the present time, the Forward Region 3<η<6 has emerged as more favorable for new physics activity, in kinematics of signals, the need for high statistics, and fuller understanding of underlying events and the initial parton distribution functions(PDFs):

*a) Light Higgs:*the SM Higgs is produced over a larger range of η and better studied with increased η lepton coverage, including the 4 lepton final states, spin-parity measurements, direct H->μμ, and the investigation of unitary in VV scattering.

b) SUSY: the absence of a significant fraction of predicted SUSY particles at ~sub-TeV masses; missing E_T becomes crucial; as an example, a 1 TeV muon at η=3 has ~100 GeV E_T.

c) DM: indications of dark matter <10 GeV, in underground experiments indicate that lowering the missing E_T threshold is crucial (see above).

d) $B_d \to K^*\mu\mu$, $B_s \to \mu\mu$: the dimuon decays of the neutral B as a test of physics beyond the standard model, and constrain SUSY. LHCb covers 2< η <4.5. Extending coverage would both enable a far larger sample set, and also a more direct comparison with LHCb.

e) A_{FB}: *Muon Pair Front/Back Asymmetries*: A_{FB} tests V-A; deviations imply BSM.

Forward (|η|>2.4) Physics Processes

Physics benefitting from Forward Leptons & photons and an improved Forward HCal:

1) Muon Pair F/B Asymmetries - $A_{FB} = \frac{\sigma_F - \sigma_B}{\sigma_F + \sigma_B}$;$\sigma_{F,B}$ is the differential cross-section of qq–>μμ, integrated over each hemisphere. 3<η<6: 50% more events, x2 smaller error, 4% larger A_{FBi}

2) Low Mass Higgs Properties: Production, Decays, and Spin-Parity**:** A 125 GeV Higgs makes the acceptance for leptons and jets (VBF jet tags) in the forward region more important. The channel H-> ZZ* -> 4 leptons results in about 40% of the Higgs decays throwing *at least* one lepton into the region 2.4<η<6. Higgs *direct decays to muons* ie H–>μμ is about 0.25% of the BR of a 125 GeV Higgs, but requires >100 fB^{-1}; the width of the Higgs and the absolute cross-section can be measured well - but is only accessible at very high lumi, and thus benefits from the nearly 20% of such muons lost without a forward lepton system.

3) Vector Boson Fusion*:* VBF/Scattering is an important process for Higgs production and other heavier objects, requiring high statistics for both the jet and leptonic decays of WW, WZ, ZZ. Since color is not exchanged between the colliding protons, forward jet tagging enhances VBF signals. The highest S/N is for jets at η~ 3.1, and a rapidity difference between tagging jets $\Delta\eta_{jj} > 5$ for cleanest signal/noise. The 125 GeV Higgs enhances activity in the forward region. Information on the CP properties of the Higgs produced by VBF can be obtained from the azimuthal angular difference $\Delta\phi_{jj}$ of the 2 tagging jets. The dip structures at 0/180° or 90° depend only on the tensor structure of the HVV coupling.

4) EW Symmetry Breaking (EWSB) and Vector-Vector Scattering: It is essential to show that the s-wave scattering amplitude of WW, WZ, ZZ is damped by the Higgs, protecting unitarity; ~500 fb^{-1}. Because the scattering is forward peaked in the light Higgs case, ~15% of leptons from H-> WW –> $l_1 l_2$ have one lepton within the tagging jet cone. The cross-section for $\Delta\phi_{ll}$ of the 2 leptons > 170° is ~50% higher than the no-Higgs case.

5) SUSY: If the LSP is <50 GeV, then missing energy cuts must be lowered. As an example of holes in the detector, a 500 GeV muon at □=3 carries away ~50 GeV in E_T, and at present does even carry a muon ID tag. At 14 TeV, forward muons and mismeasured jets carry away E_T.

6) *B_d->K*μμ, B_s -> μμ:* Dimuon decays of neutral B's test physics beyond the standard model, including and strongly constrain SUSY parameter space. CMS covers |η|<2, while LHCb covers 2< η <4.5. Tracker information must find 0.5 mm displaced B-decay secondary vertices.

7) Standard Model Z, W Production (QCD-EW) and PDF's - Z or W (QCD-EW) production results in 15-20% of vector boson decay leptons to fall into the region 3<η<6. Measuring W, Z and other Drell-Yan light processes, such as low pT resonance production of J/Ψ and Υ out to the highest η are sensitive to measuring and constraining the PDF's at low x, important for unfolding most of the production processes, as CMS transitions to 14 TeV.

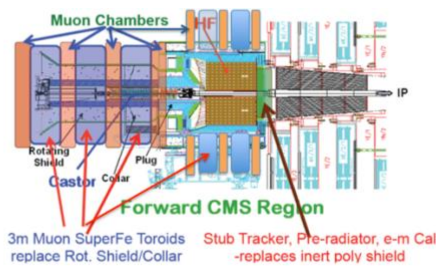
8) Double Parton Scattering: The correlation in x amongst quarks/partons is interesting; if we knew $F_2(x_1, x_2,..x_n)$, and Fourier transformed it, we would have the proton.

9) Single Top QCD-EW Production: t-channel single top production (t-bbar/b-tbar production via W+b+gluon in the t-channel) is about ¼ of all ttbar production, but is tagged by a single forward jet; for tag-jets at rapidities η>3, the S:B exceeds 2.5:1, and growing with η. An important issue for such jets is overlapping events requiring fine-segmentation e-m front end.

10) Exotica:…… Heavy resonances, Z'/W', heavy quasi-stable charged particle precision timing. Forward leptons+jets increase the physics reach.

A Forward Lepton-Photon-Jet System – 3≤η≤6

We propose forward regions of LHC detectors with stub-tracker/pre-radiator/e-m calorimeter, and a superferric iron-toroid combined calorimeter/muon system. As an example, CMS could replace the Forward region with: 1. 20-24 quartz tile and direct multi-anode PMT-sensors and W-absorbers layers, arranged with progressive thickness absorbers as combined ½ Lrad layers for a stub-tracker/e-m pre-shower and followed by 1 Lrad e-m calorimeter absorber-detectors at $1cm^2$ transverse segmentation. 2. The e-m/stub-tracker is followed by a combined hadron calorimeter and muon spectrometer formed by ½ Lint thick superferric iron toroid matrices, instrumented as stub quartz fiber calorimeters, read by compact quartz window rad-hard metal envelope PMT, alternating with 6 layers of Si Trackers +/- 0.05 mrad resolution per stack ~25 μm x-y resolution muon "chambers") to cover muons from η~3 to 5.5 (σ_p/p < 15% at 1.5 TeV)



Cartoons (not fully to scales) of Lepton-Photon systems for the the CMS Forward Region only as an example: Passive regions that could be replaced with active devices