Search for long lived particles: calo lifetimes
Updates

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Signal signature - introduction

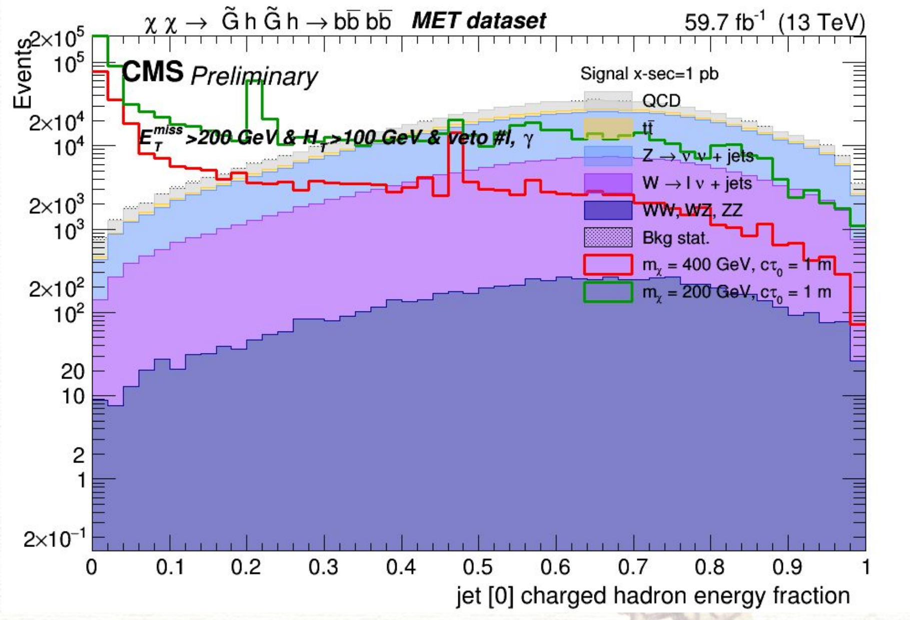
- Looking for neutral LLPs decaying in the CMS calorimeter (decay length ~ 1 m)
- Due to trigger limitations, we can only trigger on MET → 1 particle decays outside the detector (or in the muon chambers)
- Models:
  - GMSB SUSY pair production of neutralino → gravitino + SM Higgs→ bb
    This model includes true MET due to gravitino
  - Heavy version of the Higgs, can be related to various portal models (see ATLAS publication here) H2 → SS → bb bb
    MET when one S decays past the calorimeters
- Given that low-pT jets are an overwhelming background, we require some boost
  - AK4 CHS jets with pT>30 GeV
  - we look at barrel region to take advantage of ECAL crystals properties (time and rec hits multiplicities) → we observe some delay w.r.t. prompt jets
  - not sensitive to Twin Higgs models (SM Higgs @ 125 GeV does not provide enough boost to pass trigger and preselections)

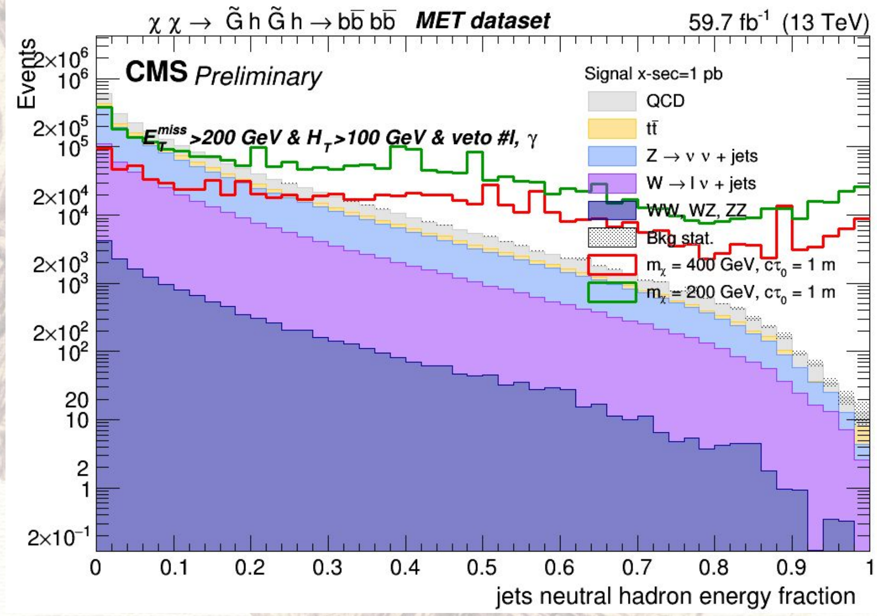
Analysis workflow

- So far: AOD (2018 MC), signal privately produced
- Preselections: PFMETNoMU120 trigger, MET>200 GeV, veto leptons/photons/taus
- Discriminating variables:
  - jet composition (charged/neutral energy fractions, provided by default in pat jets)
  - ECAL rec hits in the jet cone (average time, energy and multiplicity), plus rec hits shapes and fragmentation function
  - general tracks to build variables similar to EXO-20-003 (alpha/beta/gamma max, track pT, dR between tracks and jet) ⟶ not available in miniAOD
- We build a trackless jet tagger using a fully connected neural network
  - signal used for training: jets associated to a LLP decay between the last layers of tracker and HCAL
- Signal region: at least 2 trackless jets (high output score of the NN, working point optimized in order to get $4*10^{-4}$ background rejection ⟶ decision based on a cut based approach, see this presentation by JiaJing)

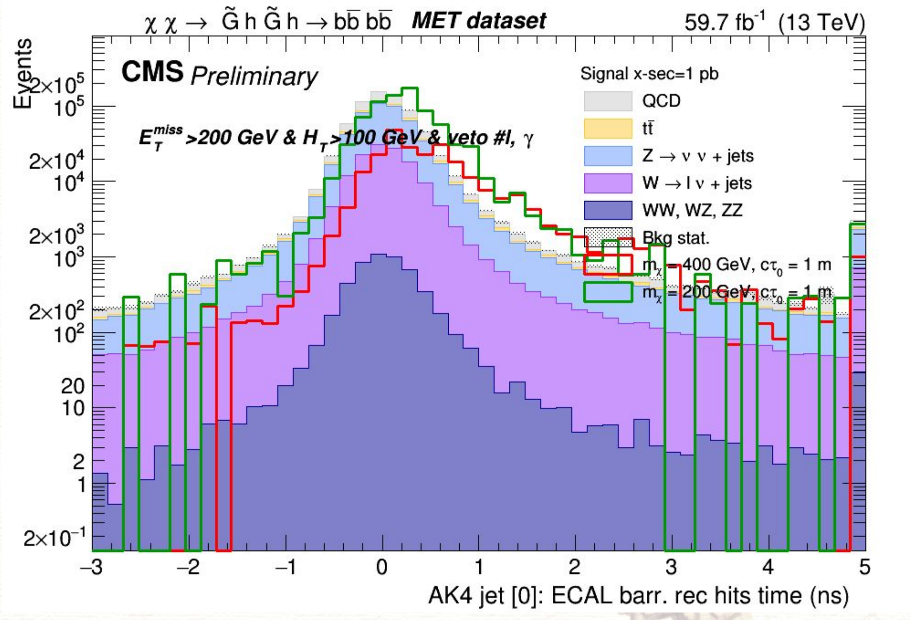
Discriminating variables

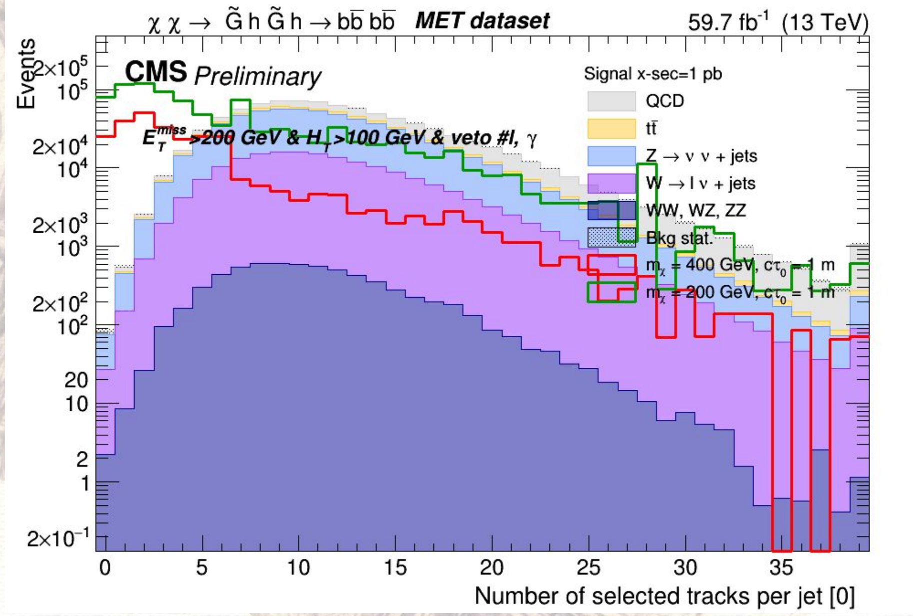
focus on GMSB SUSY signal



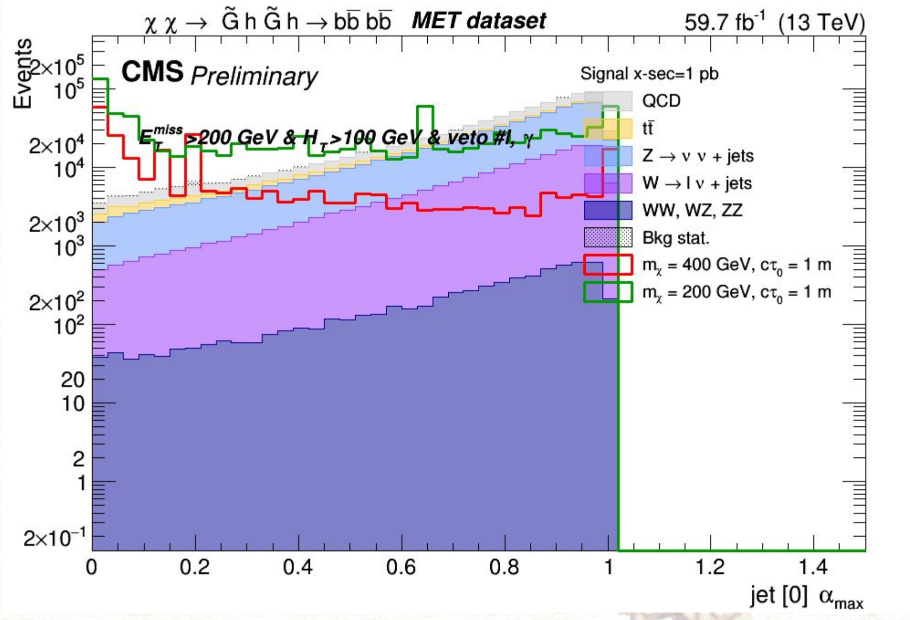


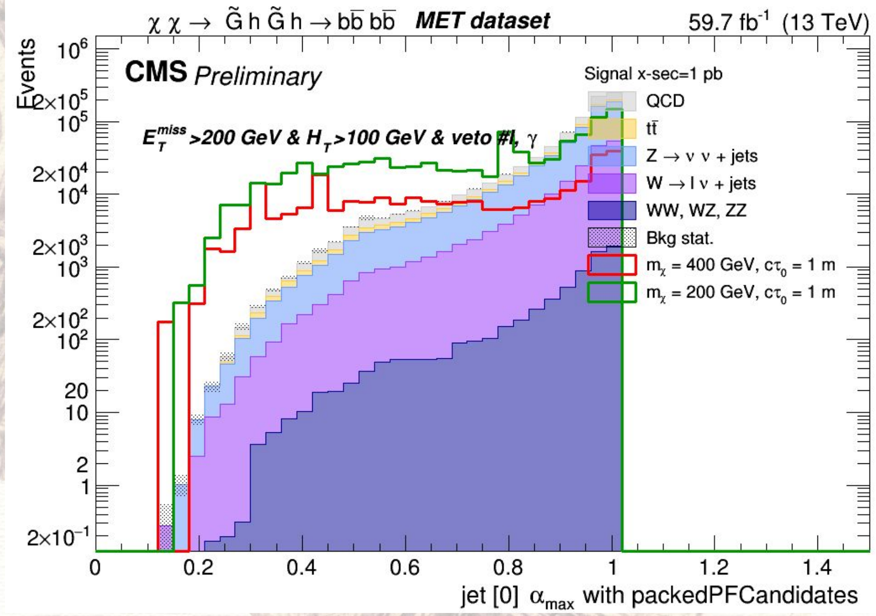
Discriminating variables





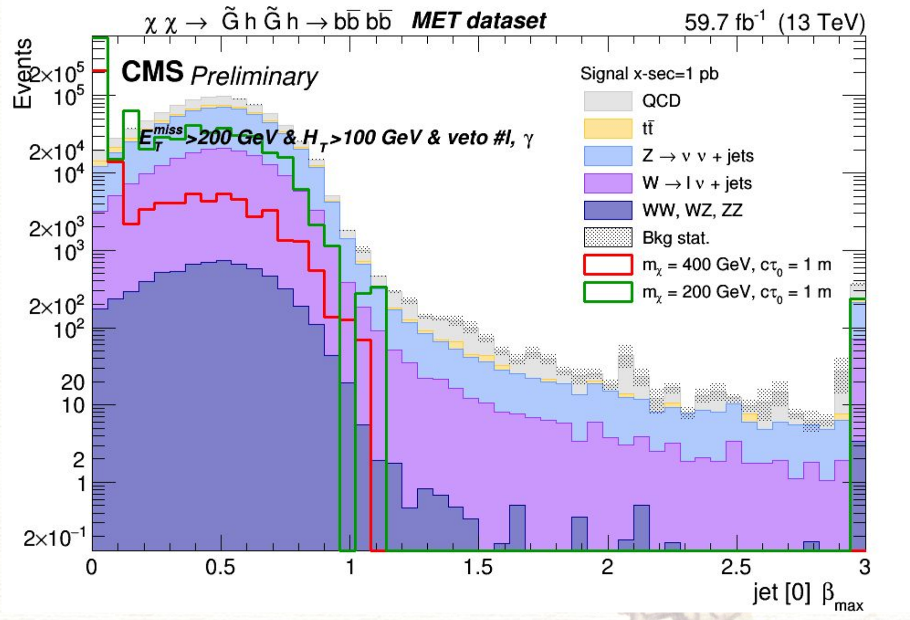
AOD only variables

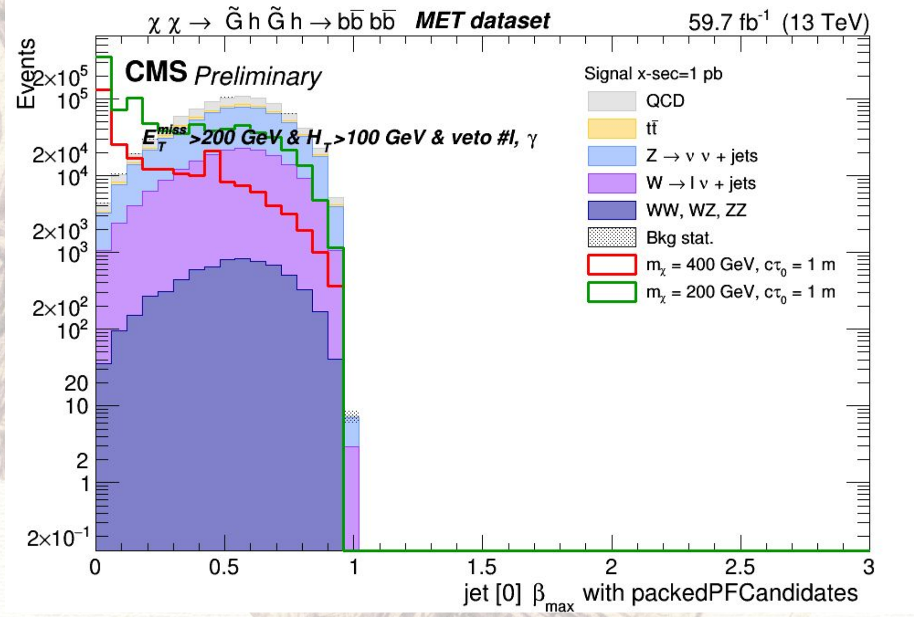




attempt at recasting the variable with packedPFCandidates

AOD only variables





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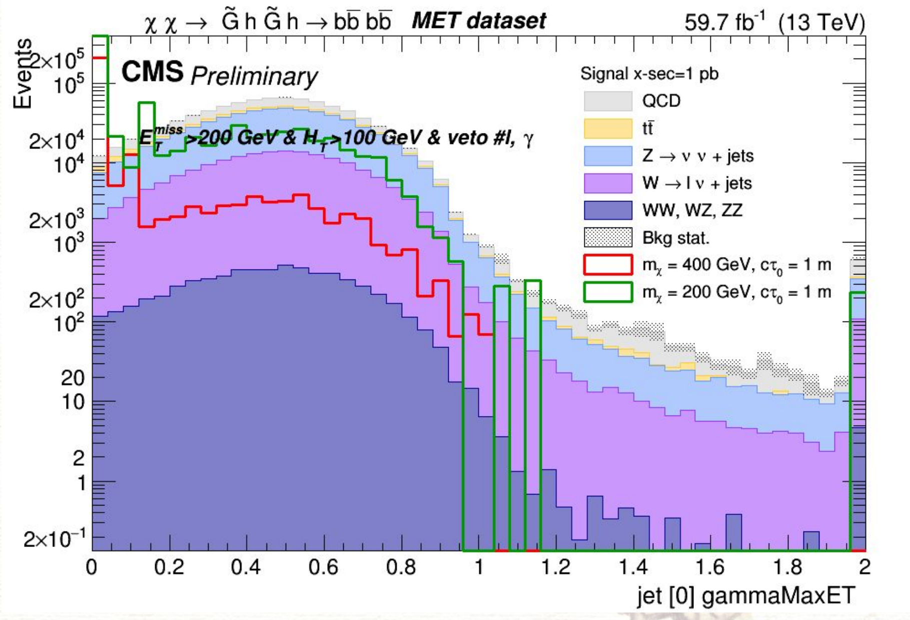

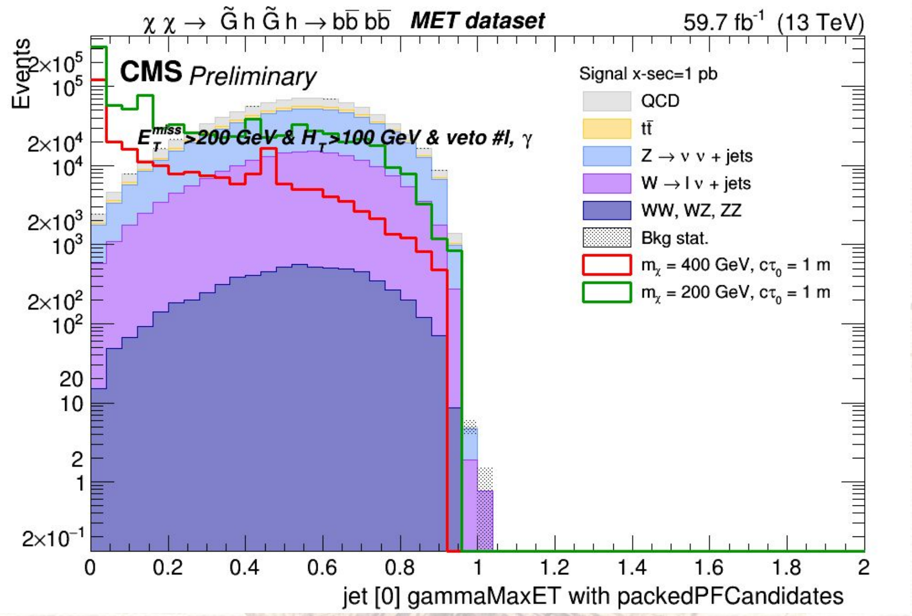

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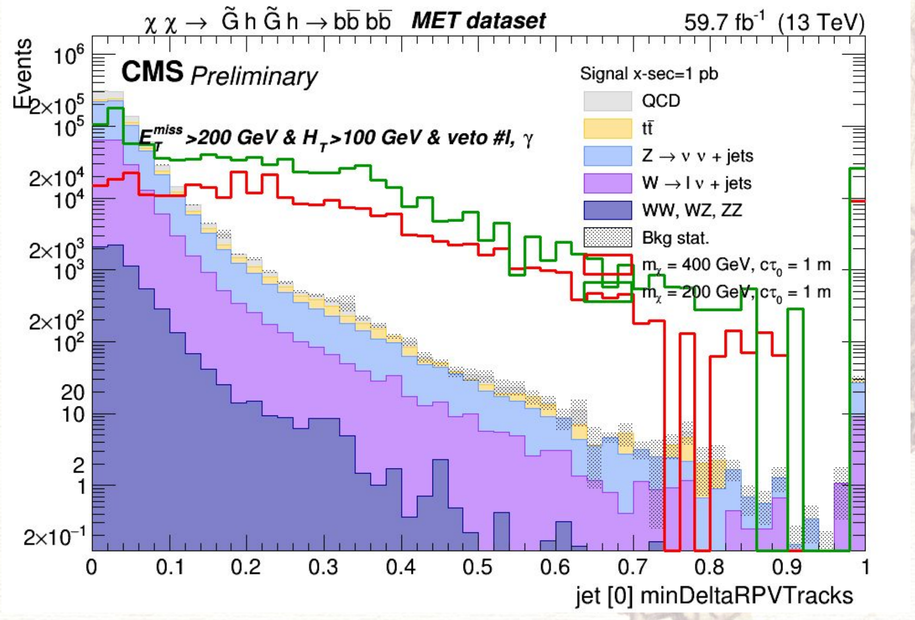


with packedPFCandidates: not informative (endpoint at jet radius 0.4, signal overlaps background)

Full list of variables for training (I)

also in miniAOD

- nTrackConstituents
- cHadEFrac
- nHadEFrac
- eleEFrac
- photonEFrac
- nSelectedTracks → from tagInfo, used as input for b-tagging
- timeRecHitsEB
- eFracRecHitsEB → normalized by jet energy
- nRecHitsEB
- sig1EB, sig2EB → major/minor axes of jet shapes (see backup) obtained from ECAL rec hits
- ptDEB → fragmentation function JME-13-002
  pTD= sqrt(∑ET^2) / ∑ET,
  pTD→1 for jets made of only one rec hits that carries all of its energy, and pTD→0 for a jet made of an infinite number of rec hits

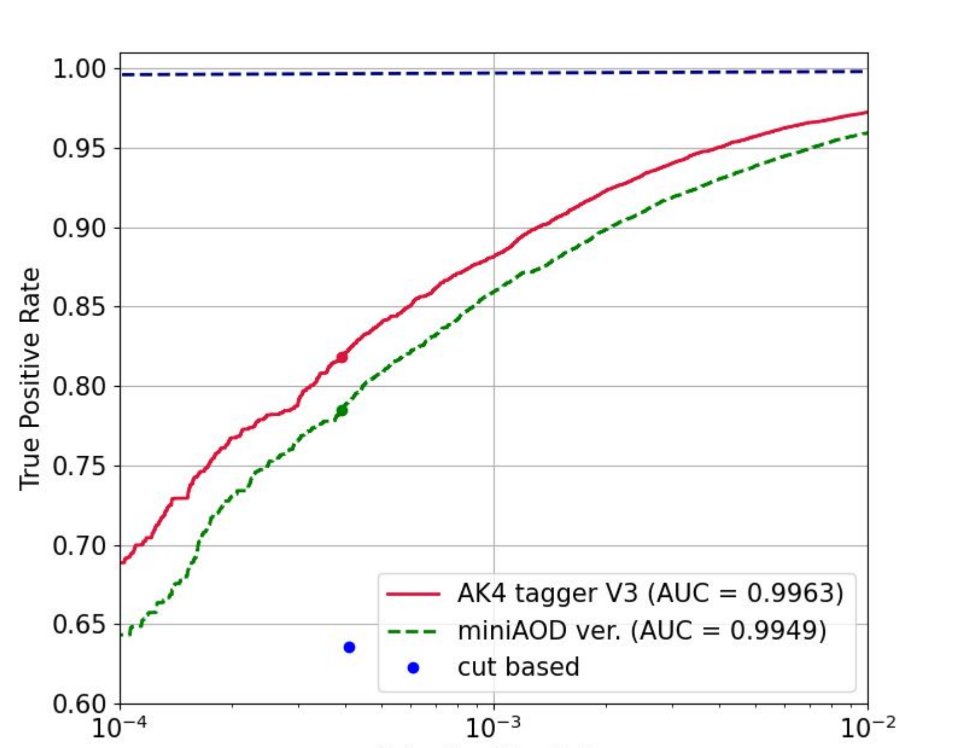
Full list of variables for training (II)

AOD only

- ptAllTracks → pT sum of tracks inside jet cone
- ptAllPVTracks → pT sum of tracks from a PV inside jet cone
- alphaMax → max track pT from a PV / pT sum of tracks inside jet cone
- betaMax → max track pT from a PV / jet pT
- gammaMax → max track pT from a PV / jet energy
- gammaMaxEM → max track pT from a PV / jet EM energy
- gammaMaxHadronic → max track pT from a PV / jet hadronic energy
- gammaMaxET → max track pT from a PV / jet transverse energy
- minDeltaRAllTracks → min dR tracks/jet
- minDeltaRPVTracks → min dR tracks from PV/jet

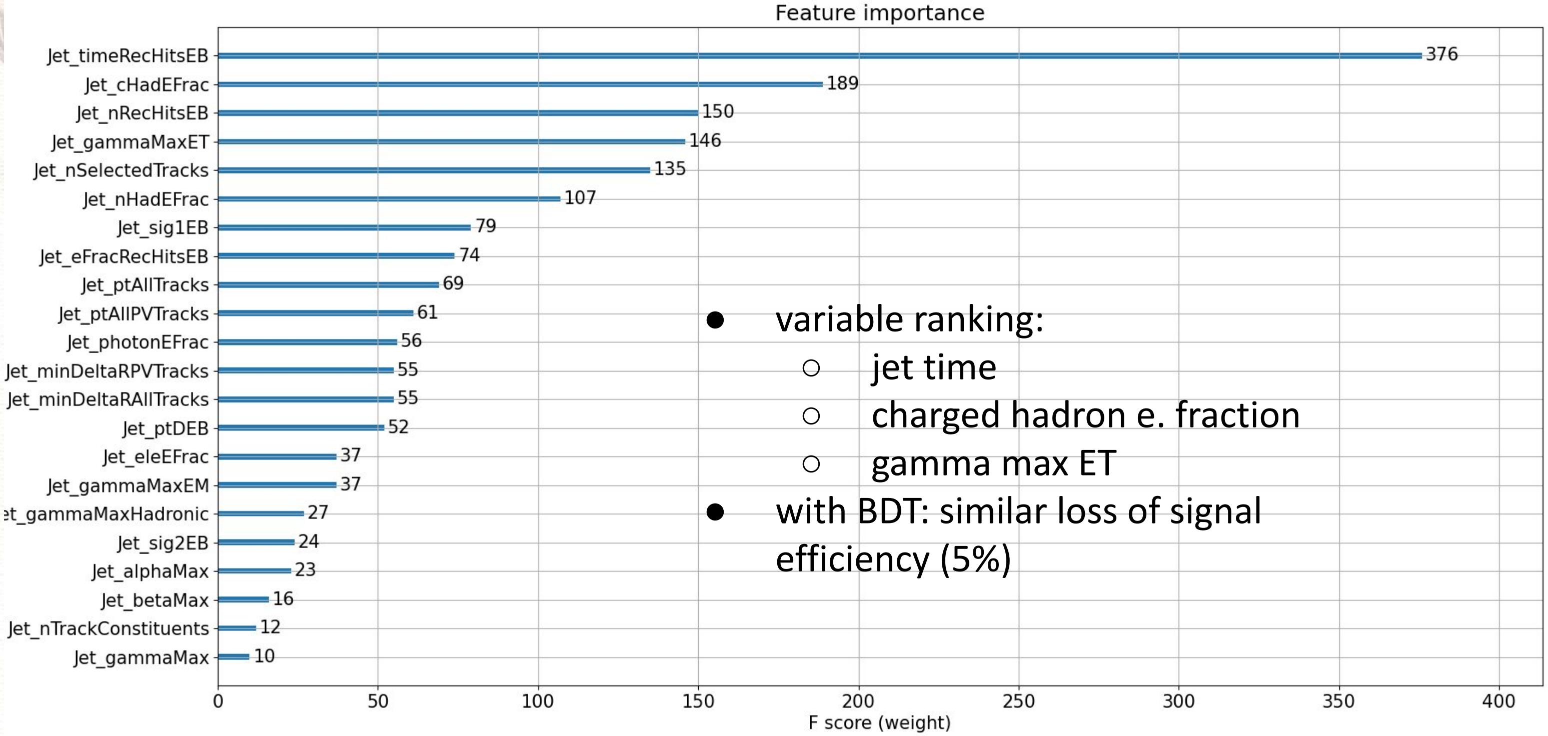
These are calculated with general tracks → removed from the trackles jet tagger and re-trained

AOD vs miniAOD: tagger performances



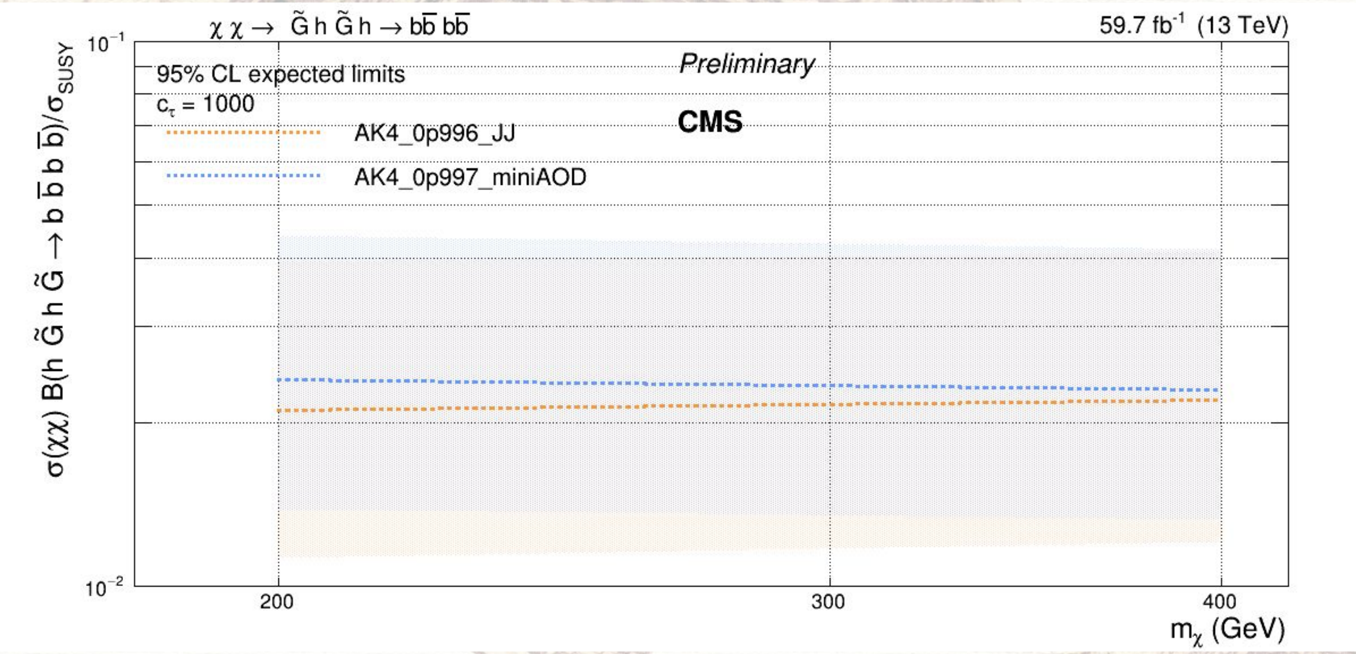
- miniAOD: removed all variables obtained with generalTracks (slide 11)
- training signal: SUSY
- retrained the tagger, same architecture, same n. epochs
- @ same background rejection → 5% signal efficiency loss

Cross-check with BDT



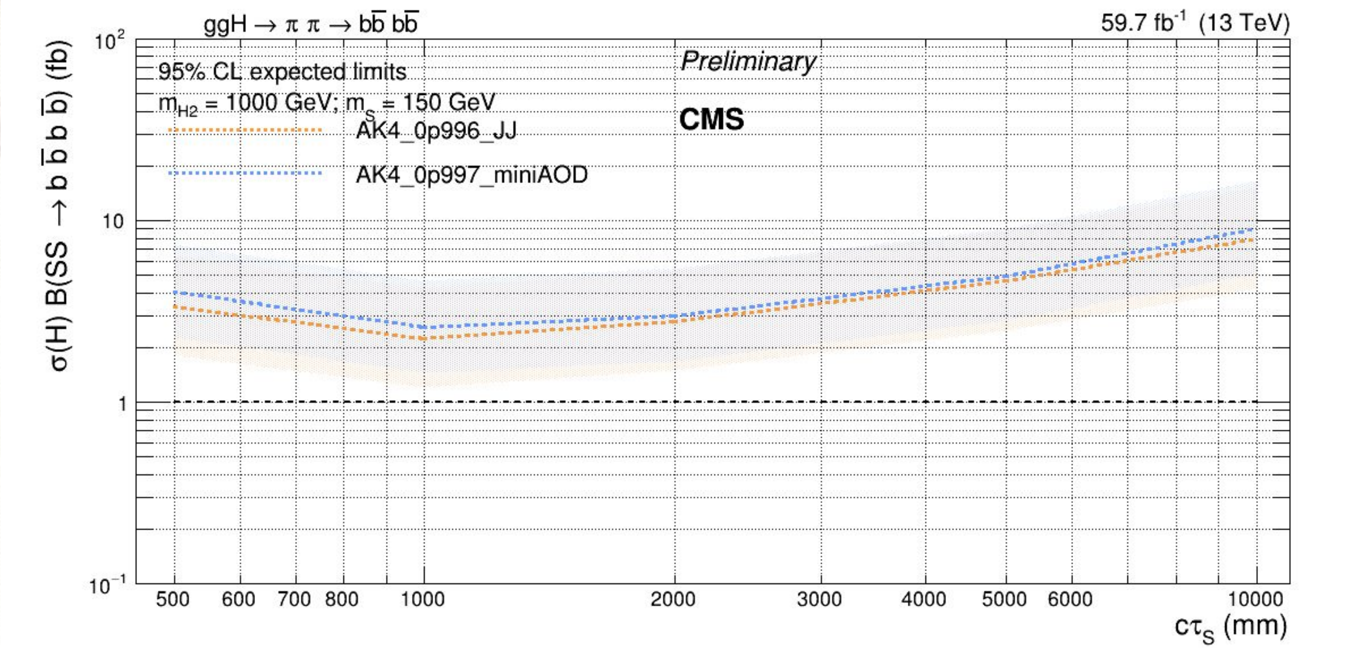
- variable ranking:
  - jet time
  - charged hadron e. fraction
  - gamma max ET
- with BDT: similar loss of signal efficiency (5%)

AOD vs miniAOD: limits



- GMSB SUSY
- MC based limits (counting experiment, only stat. + lumi uncertainties)
- sensitivity decreased by 20%

AOD vs miniAOD: limits



- Heavy Higgs signal
- sensitivity decreased by 20-25%

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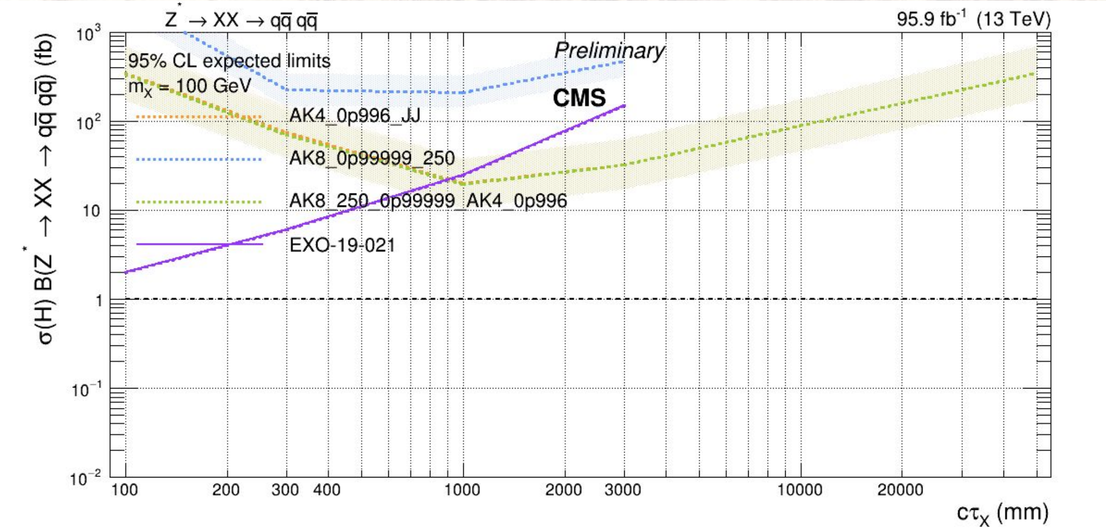
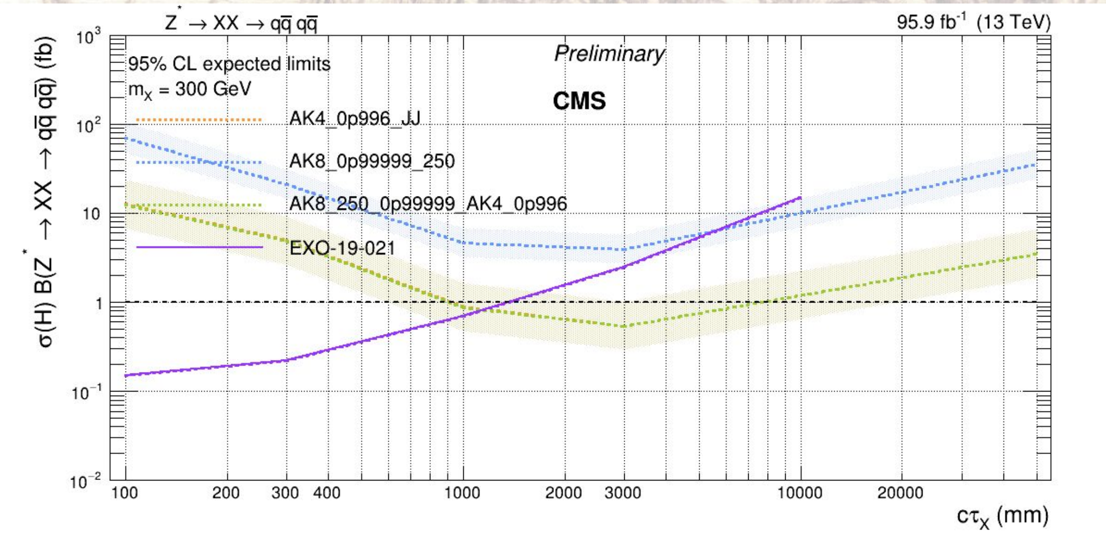
Comparison with other analyses

Princeton: XX model



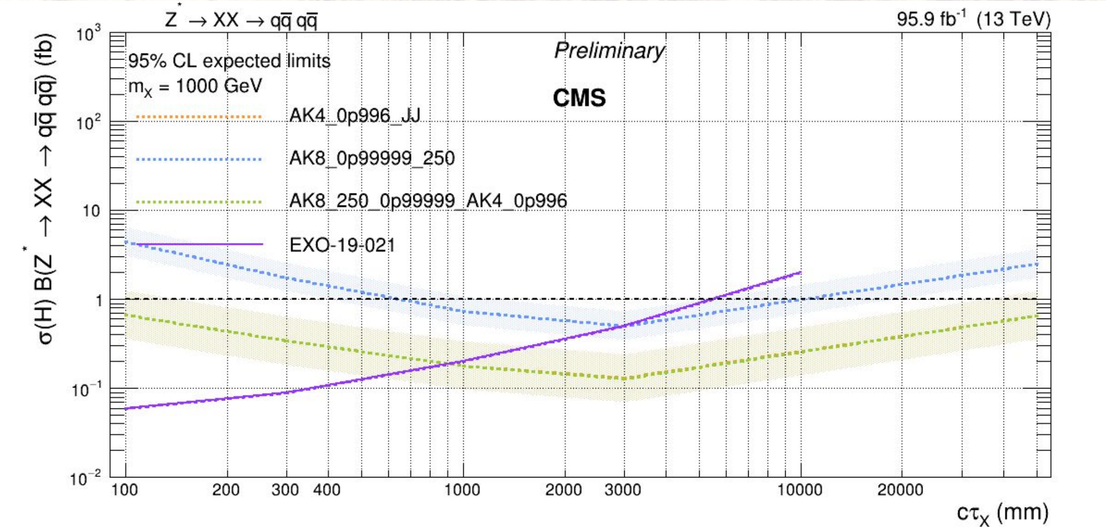
- same luminosity

Princeton: XX model



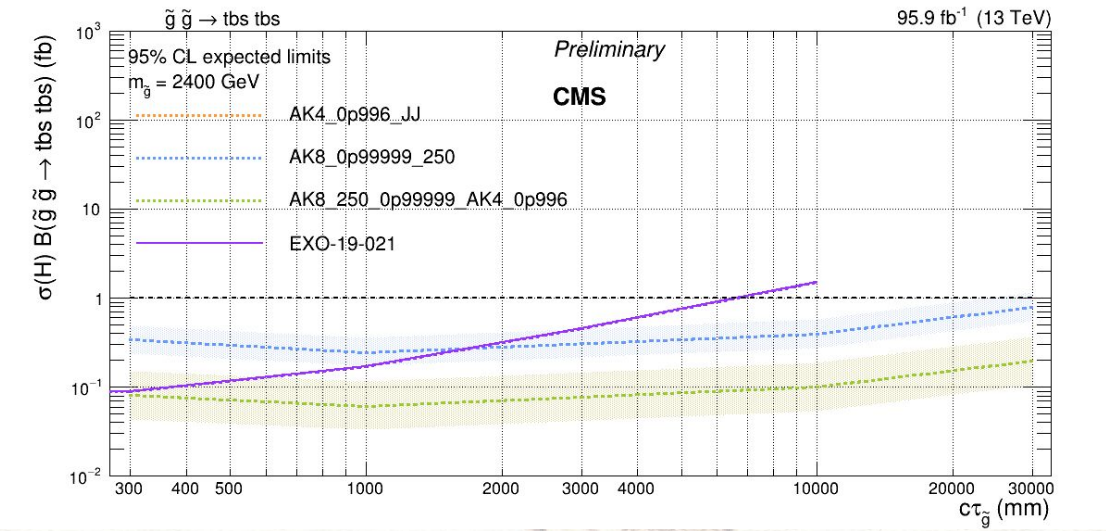
- same luminosity

Princeton: XX model



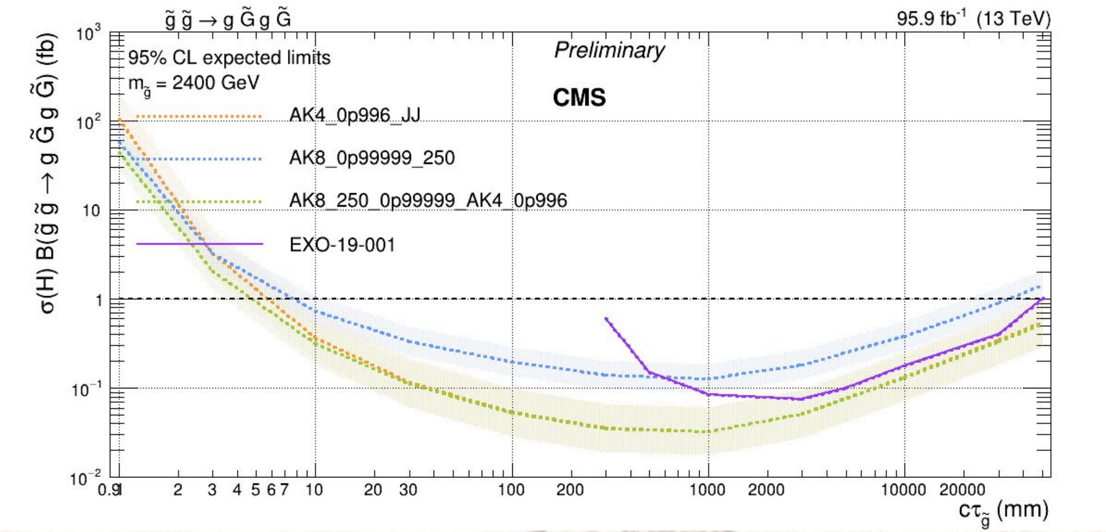
- same luminosity

Princeton: split SUSY



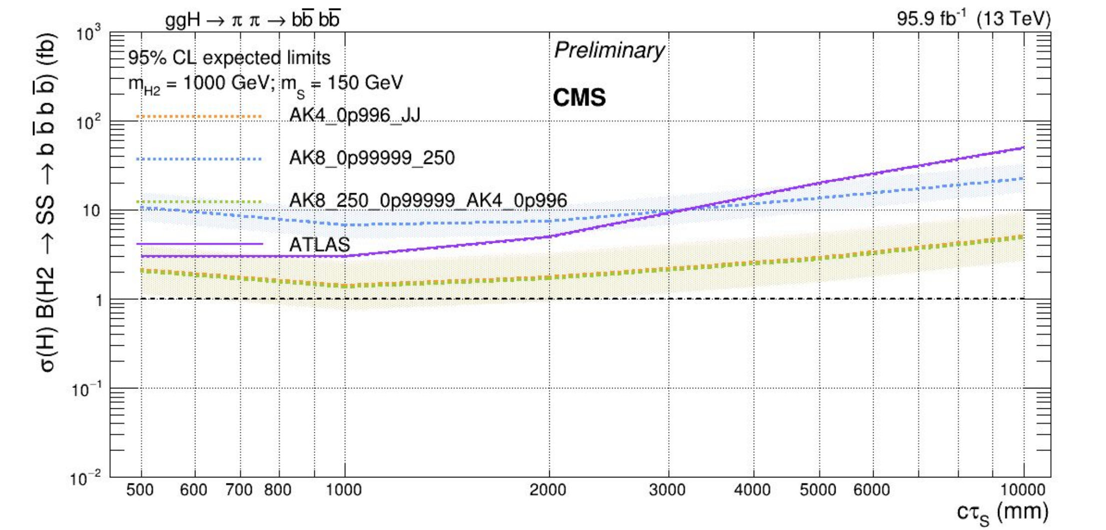
- same luminosity

Delayed jets: GMSB SUSY



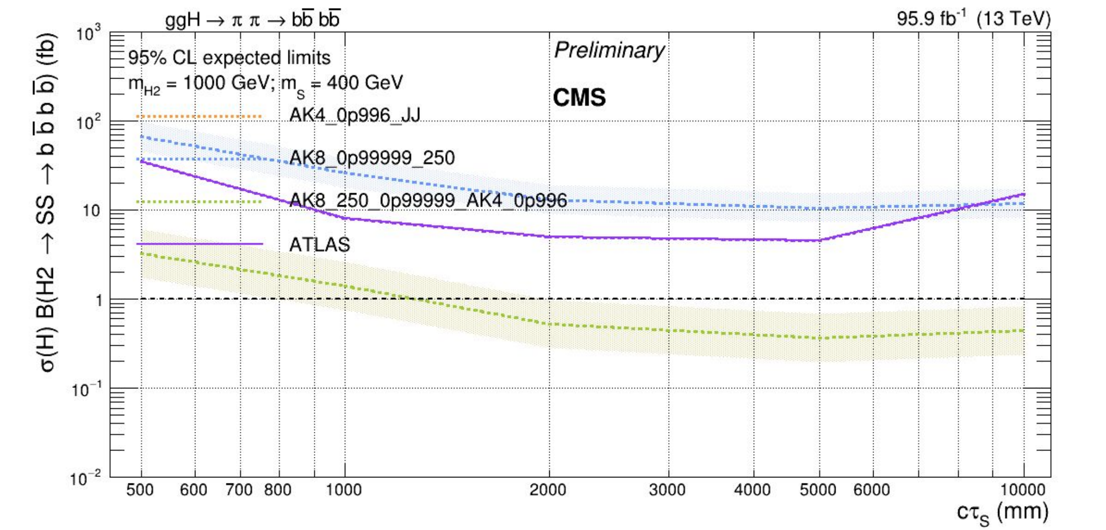
- EXO-19-001 quotes 137 /fb

ATLAS: Heavy Higgs



- ATLAS quotes 33 /fb

ATLAS: Heavy Higgs



- ATLAS quotes 33 /fb
- We seem capable to do a lot better with the resolved signal → need to re-read why

Concluding remarks

- Hard to justify AK8 analysis
- Very boosted signal seems very different w.r.t the mass point used for training the AK8 tagger → jets do not have a high DNN score
- Preparing correct signal samples now (with clipping wings)
- Would like to have a look at the topology asap (Wed-Thu if possible)

Backup

Jet shapes

Second moment matrix:

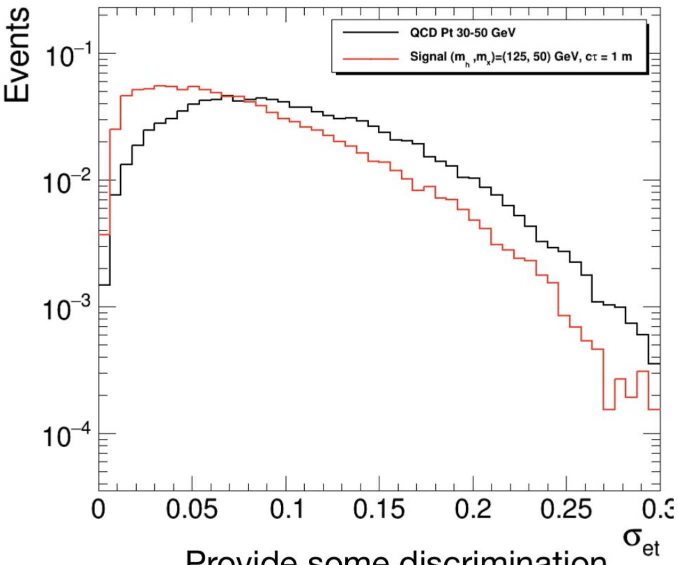
$$M_{11} = \sum_i E_{T,i}^2 \Delta\eta_i^2 \qquad M_{22} = \sum_i E_{T,i}^2 \Delta\phi_i^2$$

$$M_{12} = M_{21} = -\sum_i E_{T,i}^2 \Delta\phi_i \Delta\eta_i$$

Major (σ_1) and minor (σ_2) axis of the jet from Eigenvalues ($\lambda_{1,2}$):

$$\sigma_1 = \sqrt{\frac{\lambda_1}{\sum_i E_{T,i}^2}} \qquad \sigma_2 = \sqrt{\frac{\lambda_2}{\sum_i E_{T,i}^2}}$$

$$\sigma_{et} = \sqrt{\sigma_1^2 + \sigma_2^2}$$



Provide some discrimination between QCD and signal jets

*JME-13-002 (discriminate between light quark/gluon jet)

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