VBFH H→XX→4b

Short lifetimes

Long-lived internal Meeting

06. July 2020

Melanie Eich, Lisa Benato, Gregor Kasieczka, Karla Peña, Jörg Schindler

melanie.eich@desy.de

Universität Hamburg
DER FORSCHUNG | DER LEHRE | DER BILDUNG

EXZELLENZCLUSTER
QUANTUM UNIVERSE

GEFÖRDERT VOM
Bundesministerium
für Bildung
und Forschung

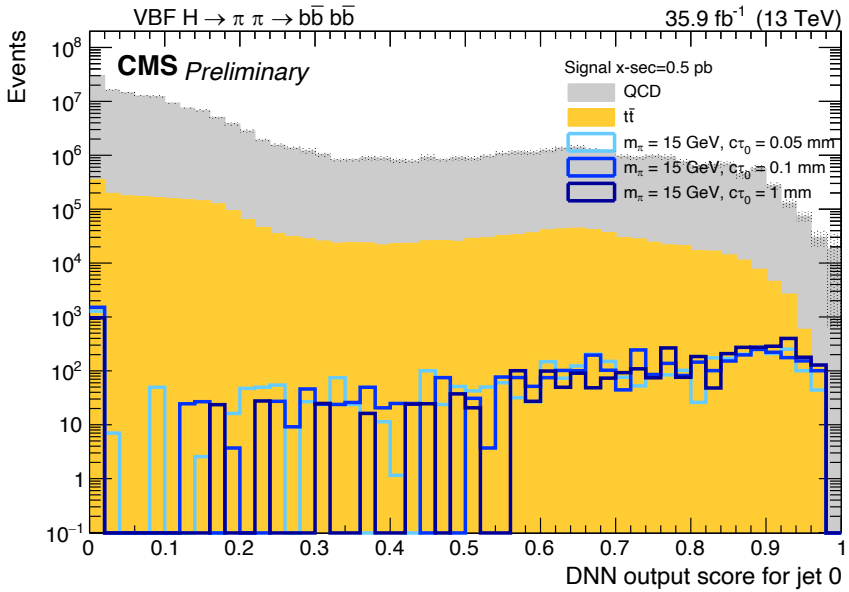
Emmy
Noether-
Programm
DFG Deutsche Forschungsgemeinschaft

News

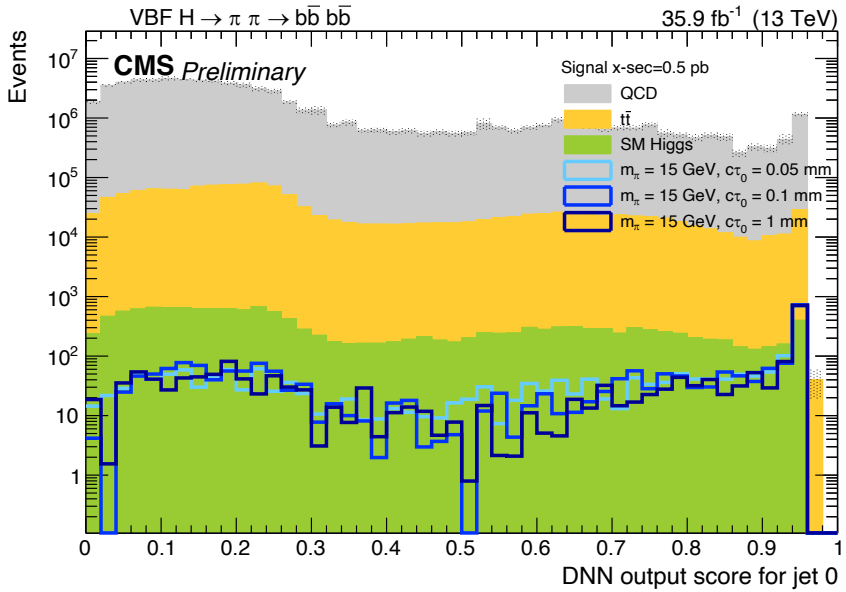
- Run over 2016 data → submitted RunH (no HIP effect etc.)
- First check for background estimation
- Problems with simple dnn

Simple DNN

Result with previous run:

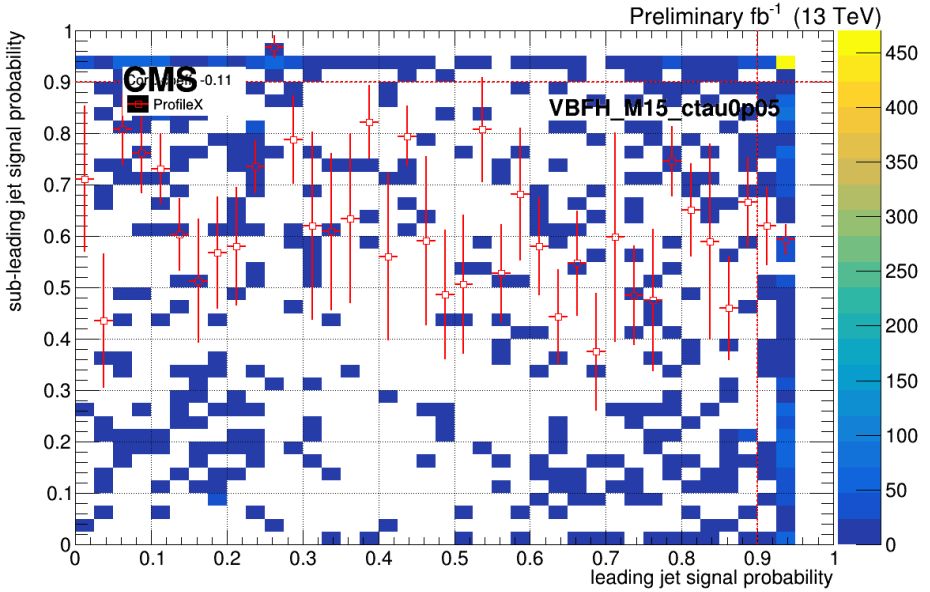


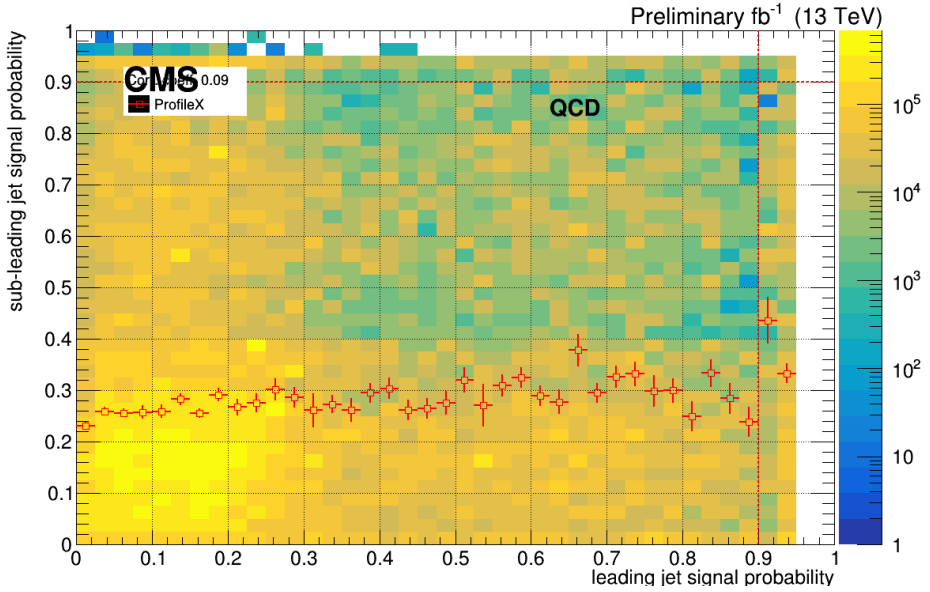
Result with current run:

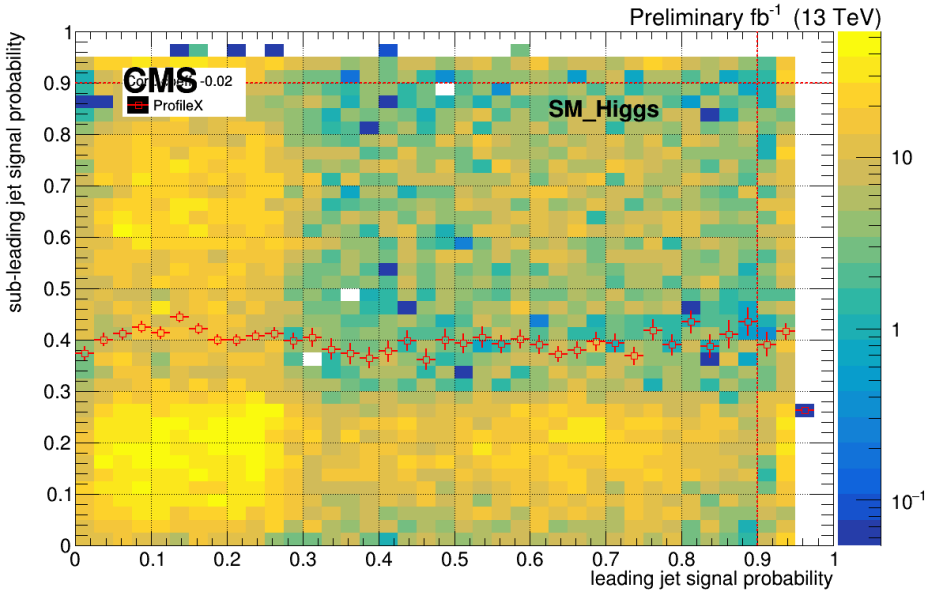


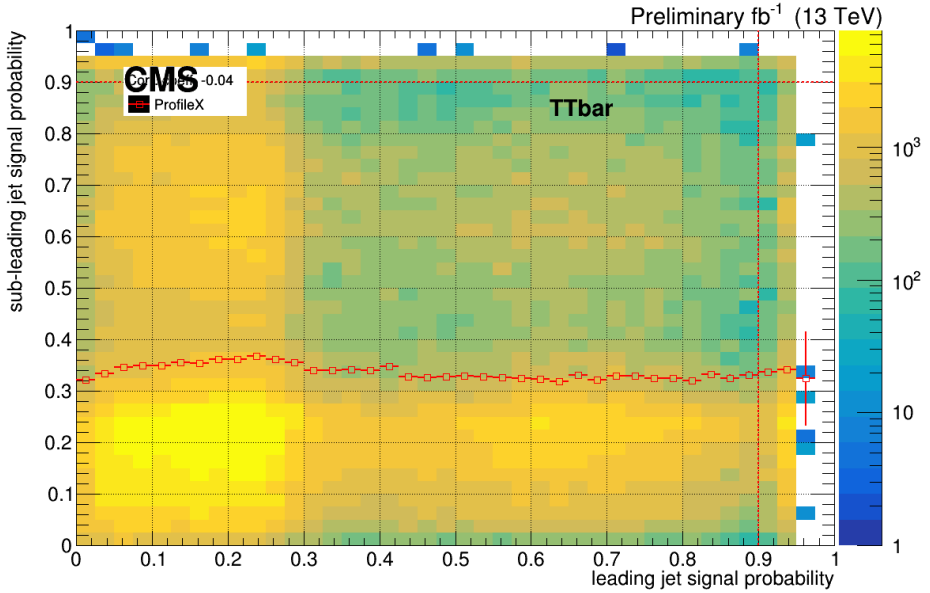
Trained with:	m=[15,20] GeV	m=15 GeV
Jets signal matched:	620k	350k
Background:	300M	235M
Batch size:	500	1024

First check background estimation – ABCD method









Talk for LLP meeting Friday

VBFH H→XX→4b

Short lifetimes

Long-lived Exotica WG Meeting

10. July 2020

Melanie Eich, Lisa Benato, Gregor Kasieczka, Karla Peña, Jörg Schindler

melanie.eich@desy.de

Universität Hamburg
DER FORSCHUNG | DER LEHRE | DER BILDUNG

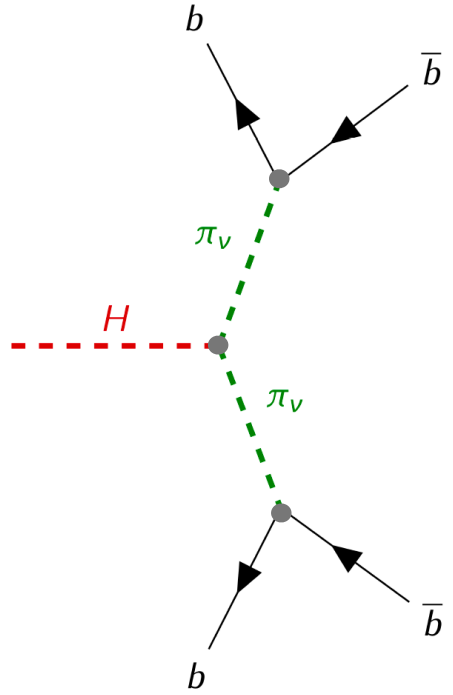
EXZELLENZCLUSTER
QUANTUM UNIVERSE

GEFÖRDERT VOM
Bundesministerium
für Bildung
und Forschung

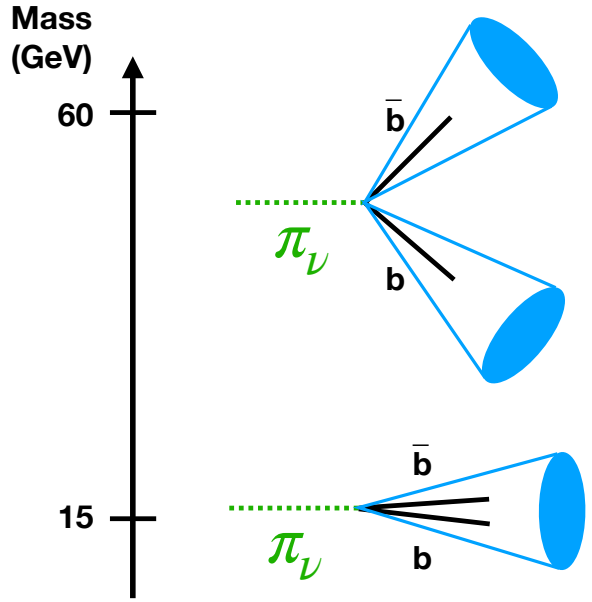
Emmy
Noether-
Programm
DFG Deutsche Forschungsgemeinschaft

Theoretical Overview

- Hierarchy problem of the SM solved by dark sector of **Twin Higgs** models
- Dark neutral scalars π_ν are long-lived, travel finite distance in CMS, decay to SM particles (dominantly $b\bar{b}$)
- Depending on $c\tau$ and $m_{\pi\nu}$ different experimental signatures



cτ	Signature
< 1 mm	b-quark like (Melanie)
1 mm – 1 m	displaced vertices (Karla)
1 m – 2 m	trackless jets (Lisa et al.)
up to 5m	muon chambers (Jörg et al.)



Monte-Carlo Samples and Reconstruction

Signal - central production:

- $m_{\pi\nu}$ = 15 , 40 and 55 GeV, $c\tau$ = 0mm – 5 mm
- Slightly more displaced b-quark as in SM process
- Vector-Boson Fusion (VBF) Higgs production

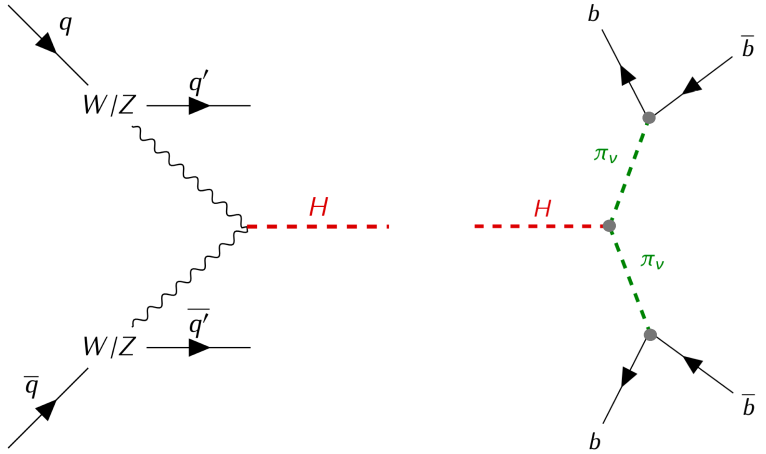
Background samples:

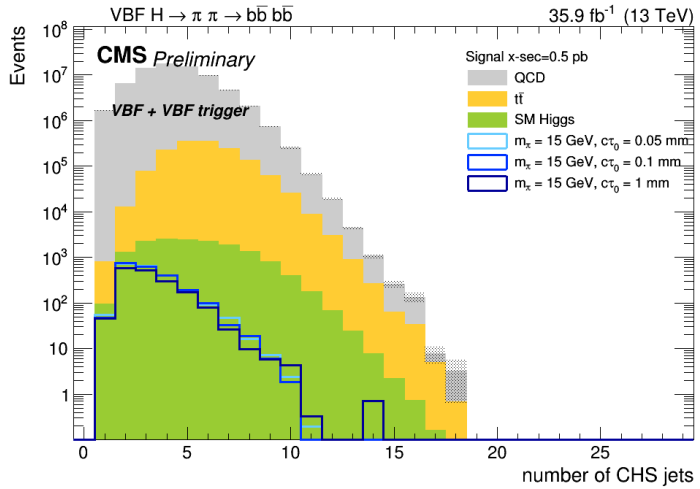
- QCD, $t\bar{t}$, SM Higgs

- 2016 MiniAODv3 Moriond17 campaign

Pre-Selection:

- Trigger: jets and b-tags (see backup)
- At least two AK4 CHS jets
  p_T > 20 GeV, $|\eta|$ < 2.4
- Identify VBF jets (m_{jj} > 400 GeV, $|\Delta\eta|$ > 3.0)
- H_T > 100 GeV

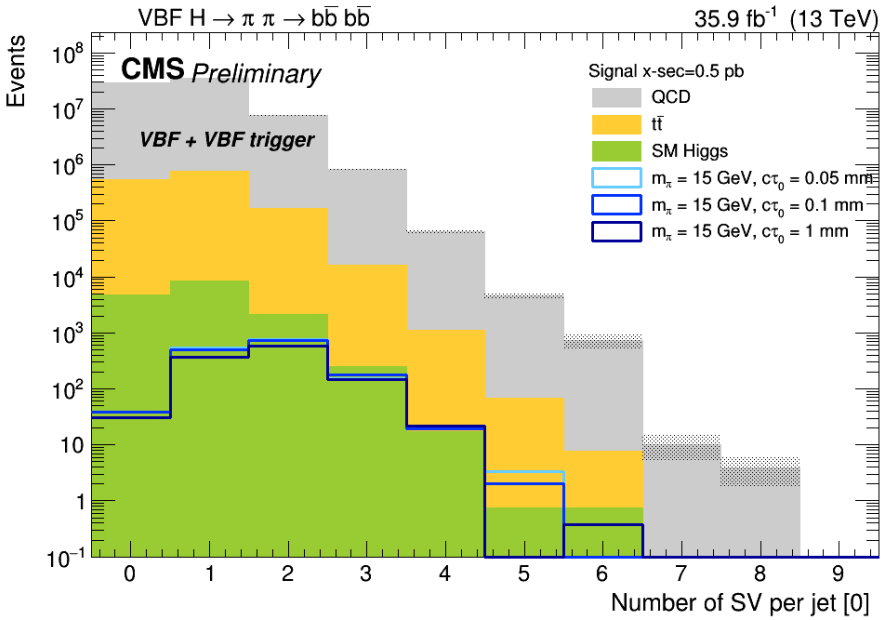


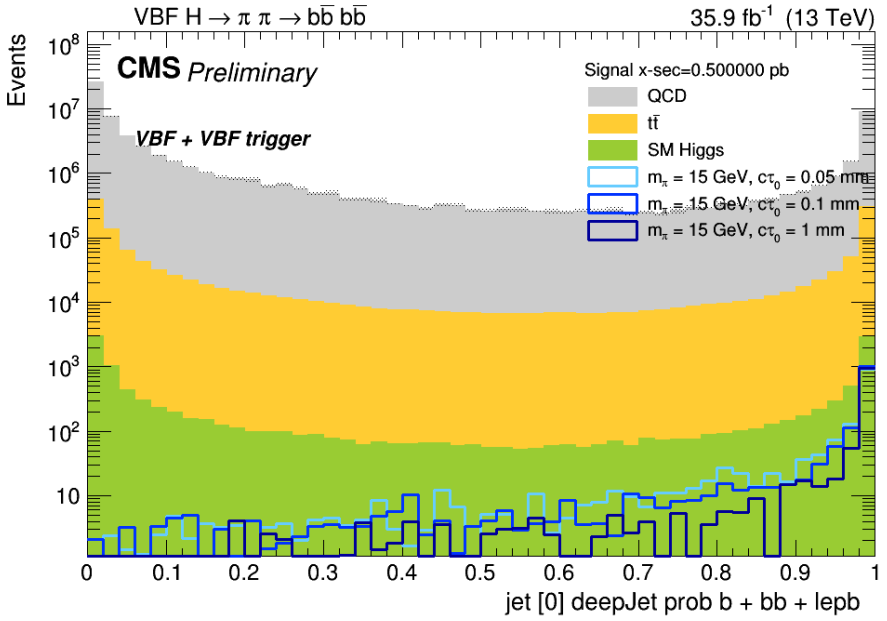


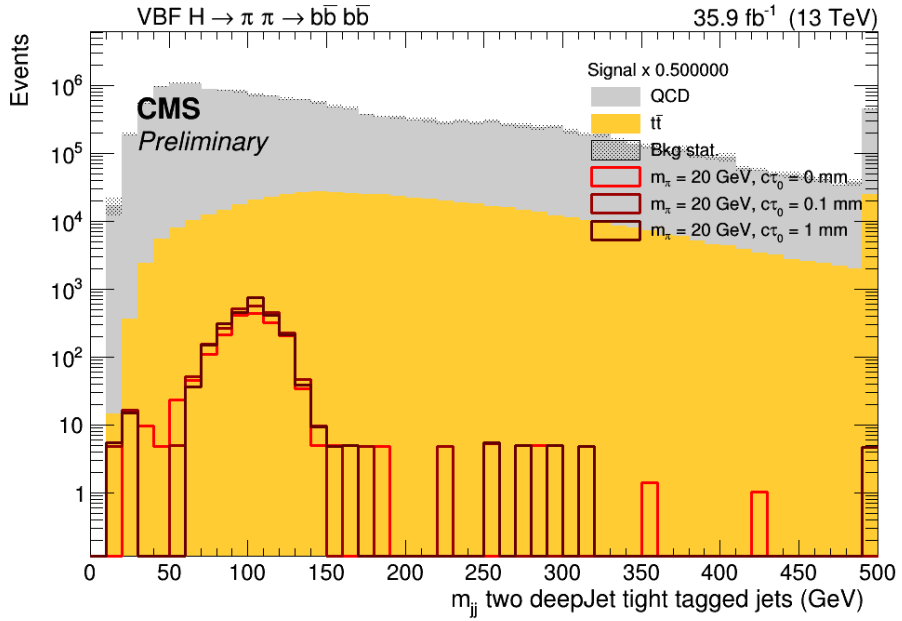
Difficulties

- Signal shows only slightly difference to background
- Only usage of standard b-tagger to calculate the invariant mass of tagged jets: too much background left

➪Not possible to perform a cut based analysis





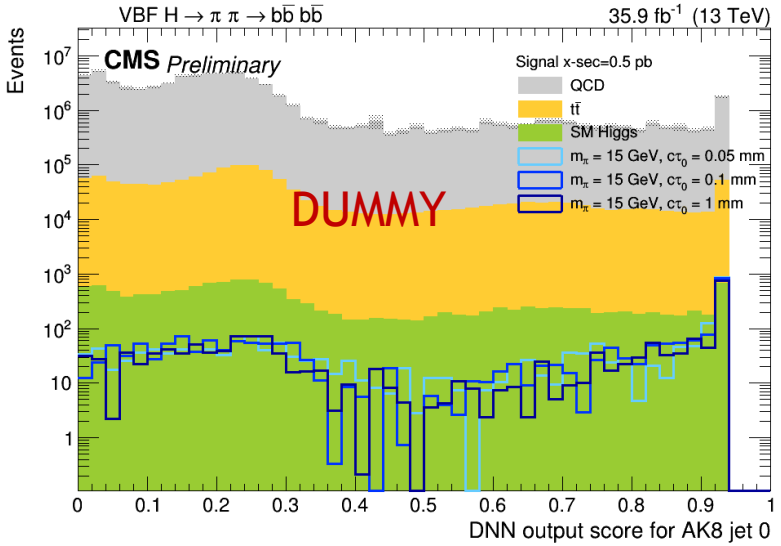


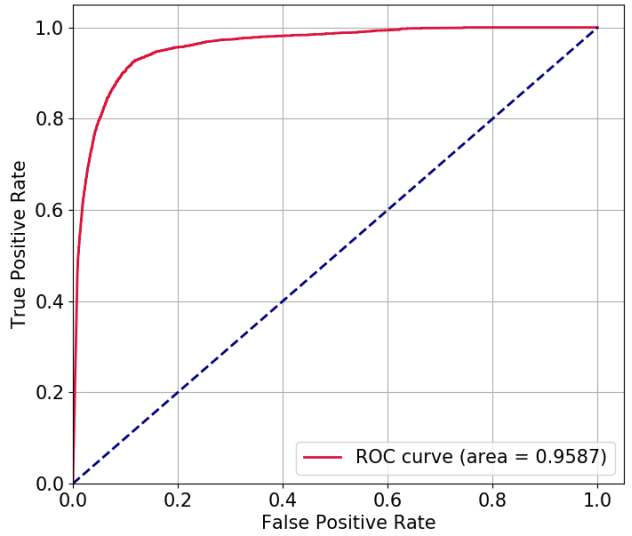
Fully connected Network - per jet tagger

- ~175k matched signal jets and ~200M inclusive background jets
- Input variables of leading four jets in p_T:
  - Kinematics:
    'Jet_pt', 'Jet_eta', 'Jet_phi', 'Jet_mass', 'Jet_energy',
  - b-tagger:
    'Jet_deepJet_probb', 'Jet_deepJet_probbb', 'Jet_deepJet_problepb',
    'Jet_deepJet_probuds', 'Jet_deepJet_probg', 'Jet_deepJet_probc',
  - Additional variables
    'Jet_nSV', 'Jet_nVertexTracks', 'Jet_flightDist2d', 'Jet_flightDist2dError',
    'Jet_flightDist3d', 'Jet_flightDist3dError', 'Jet_SV_mass', 'Jet_nTracksSV',
    'Jet_nConstituents', 'Jet_nTrackConstituents'

Layer (type)	Output Shape	Param #
dense (Dense)	(None, 128)	2944
dropout (Dropout)	(None, 128)	0
dense_1 (Dense)	(None, 128)	16512
dropout_1 (Dropout)	(None, 128)	0
dense_2 (Dense)	(None, 64)	8256
dense_3 (Dense)	(None, 2)	130

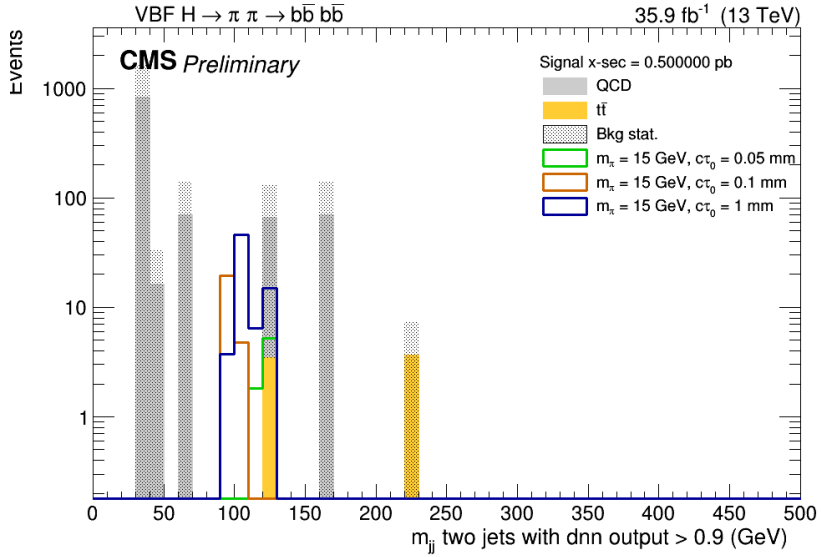
Total params: 27,842
Trainable params: 27,842
Non-trainable params: 0





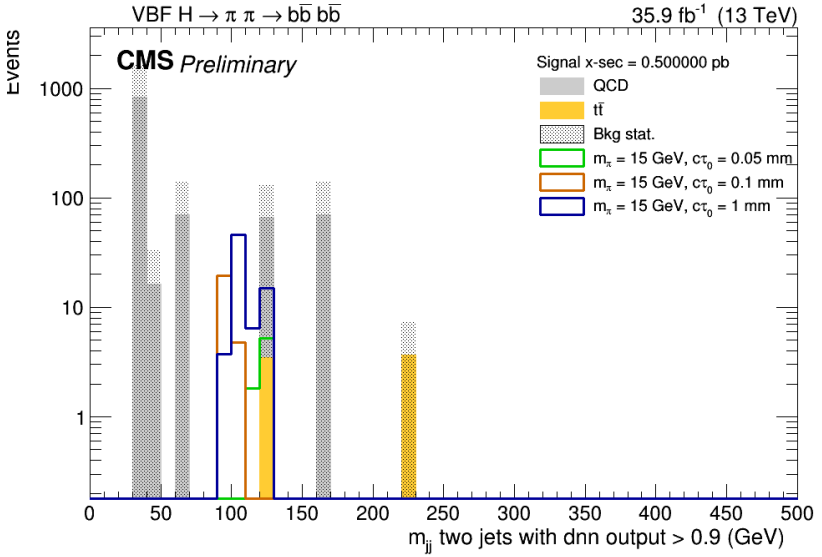
Background Efficiency check

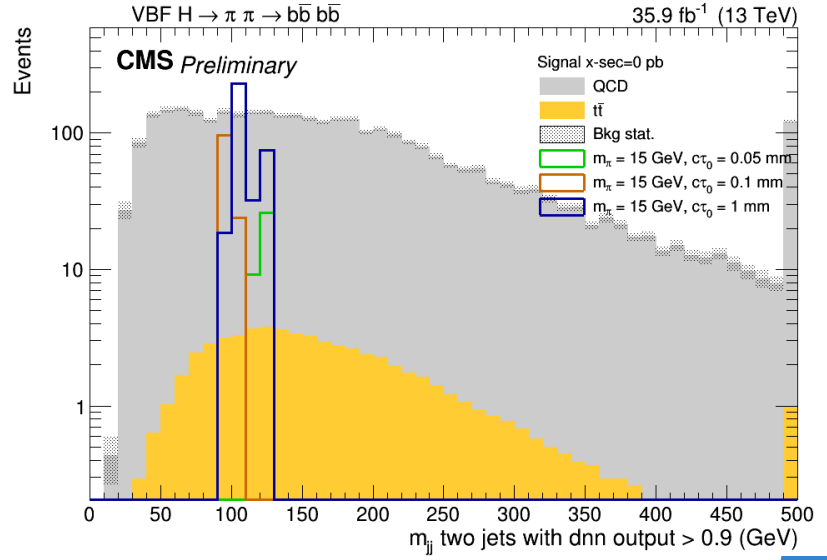
- Calculate invariant mass for leading two jets passing FCN discriminator > 0.9
- Too few background events left
- Perform data driven background estimation for full analysis



Background Efficiency check

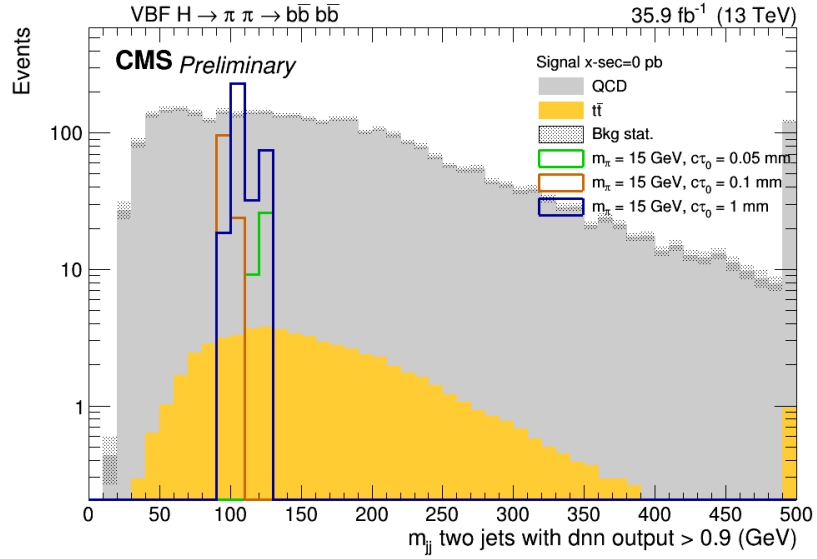
- Calculate invariant mass for leading two jets passing FCN discriminator > 0.9
- Too few background events left
- Perform data driven background estimation for full analysis
- For now:
  - Instead of cut background at discriminator value, use an efficiency factor
  - Calculated for each background in leading and sub-leading jet individually
  - Error of p_T binned efficiency is used to estimate an uncertainty on the efficiency
- Instead of few background events with high weights, smooth background distribution → Combine can deal with

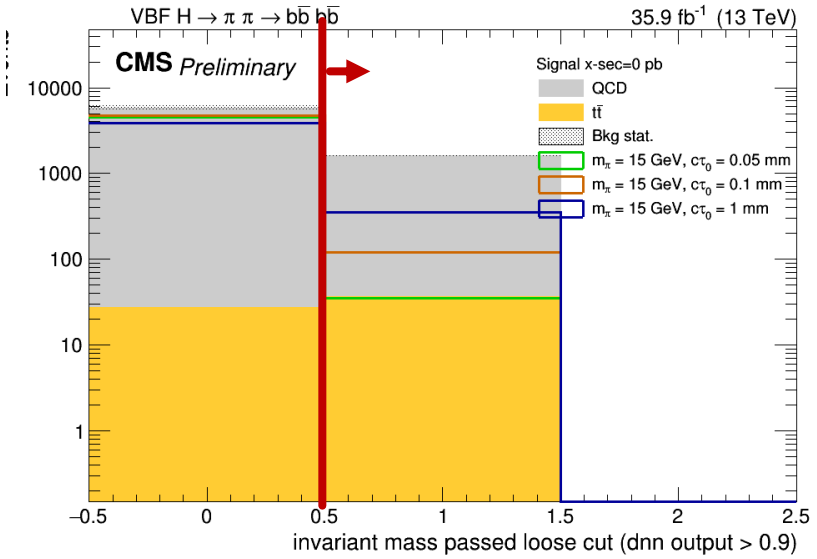


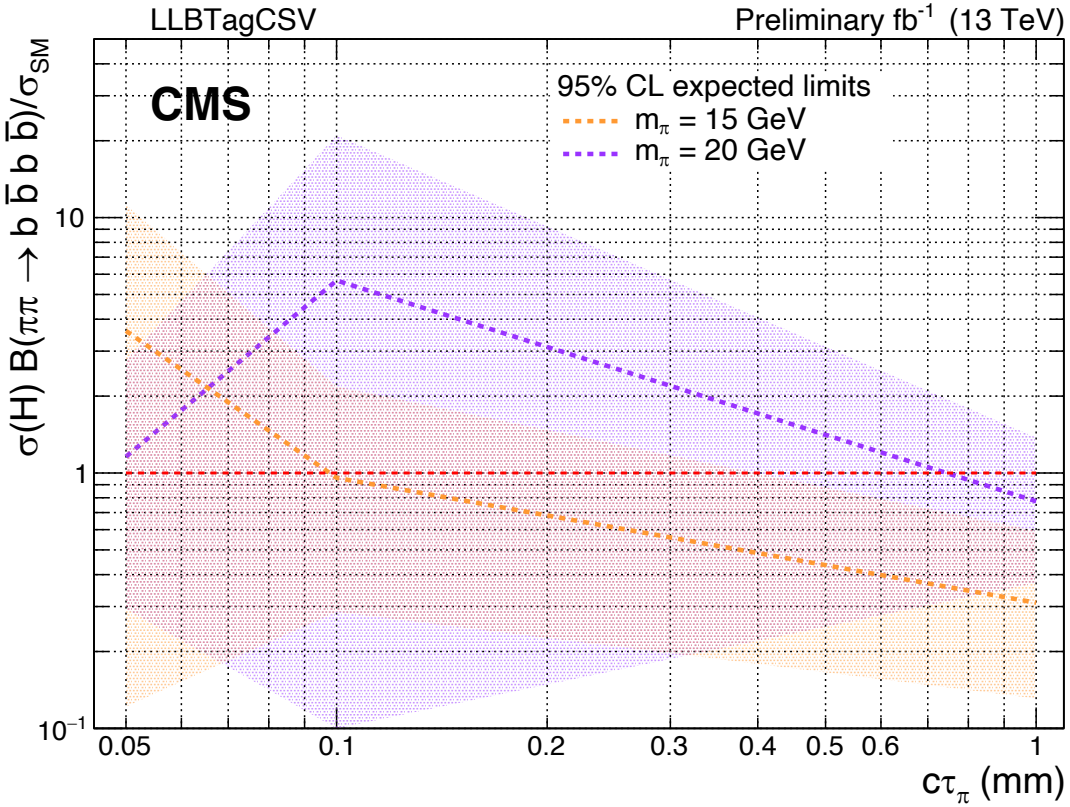


Sensitivity

Calculate invariant mass for leading two jets passing FCN discriminator > 0.9







Limit shows that this could be the right direction for the full analysis

→

Conclusion and Next Steps

- Short lifetime behaves only slightly different than background does
- Not enough to perform a cut based analysis
- Simple FCN shows good performance
- Limits with efficiency study looks promising

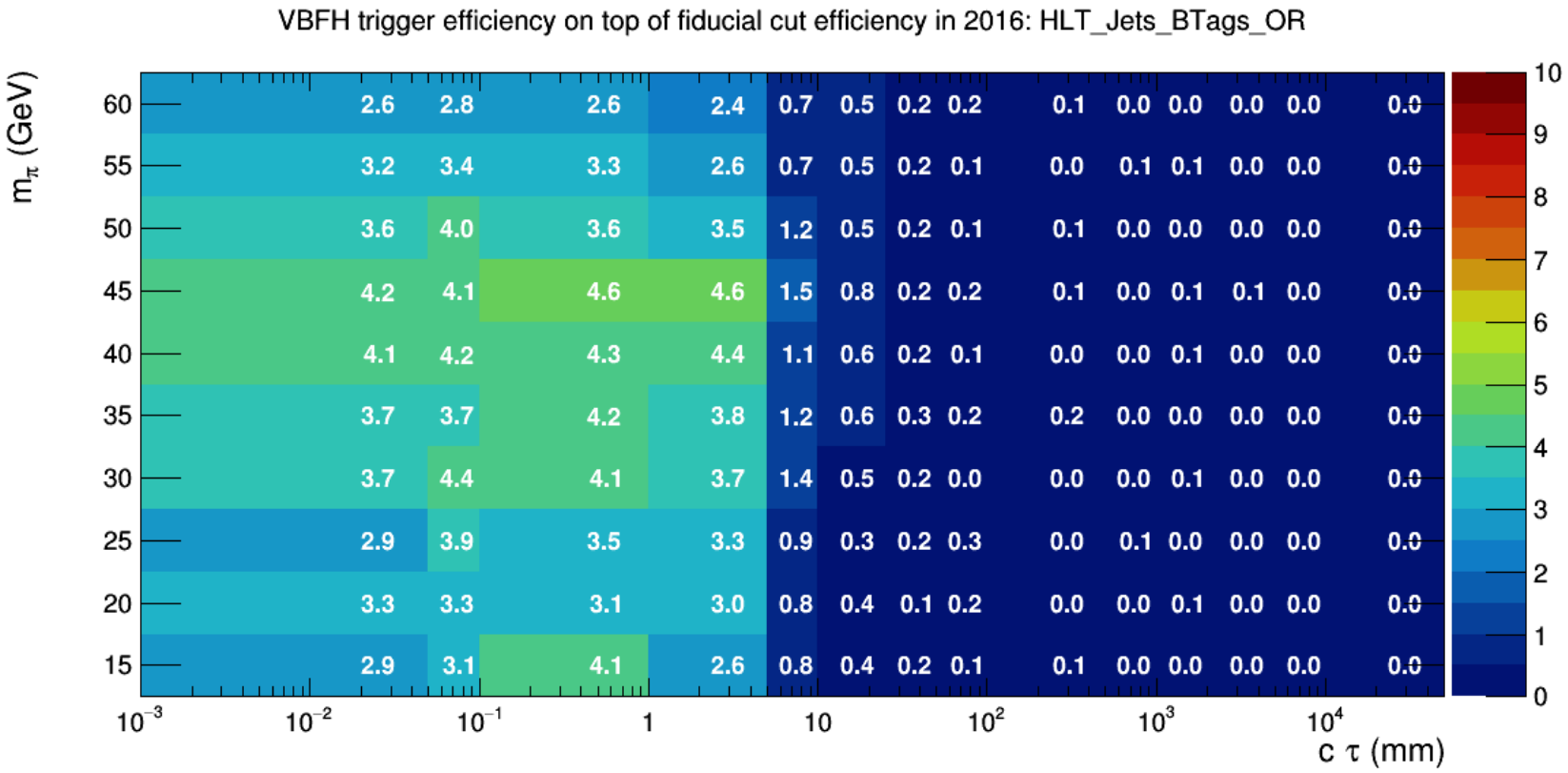
- Do proper background estimation
- Have a first look at data and check data/MC agreement in control region

Backup

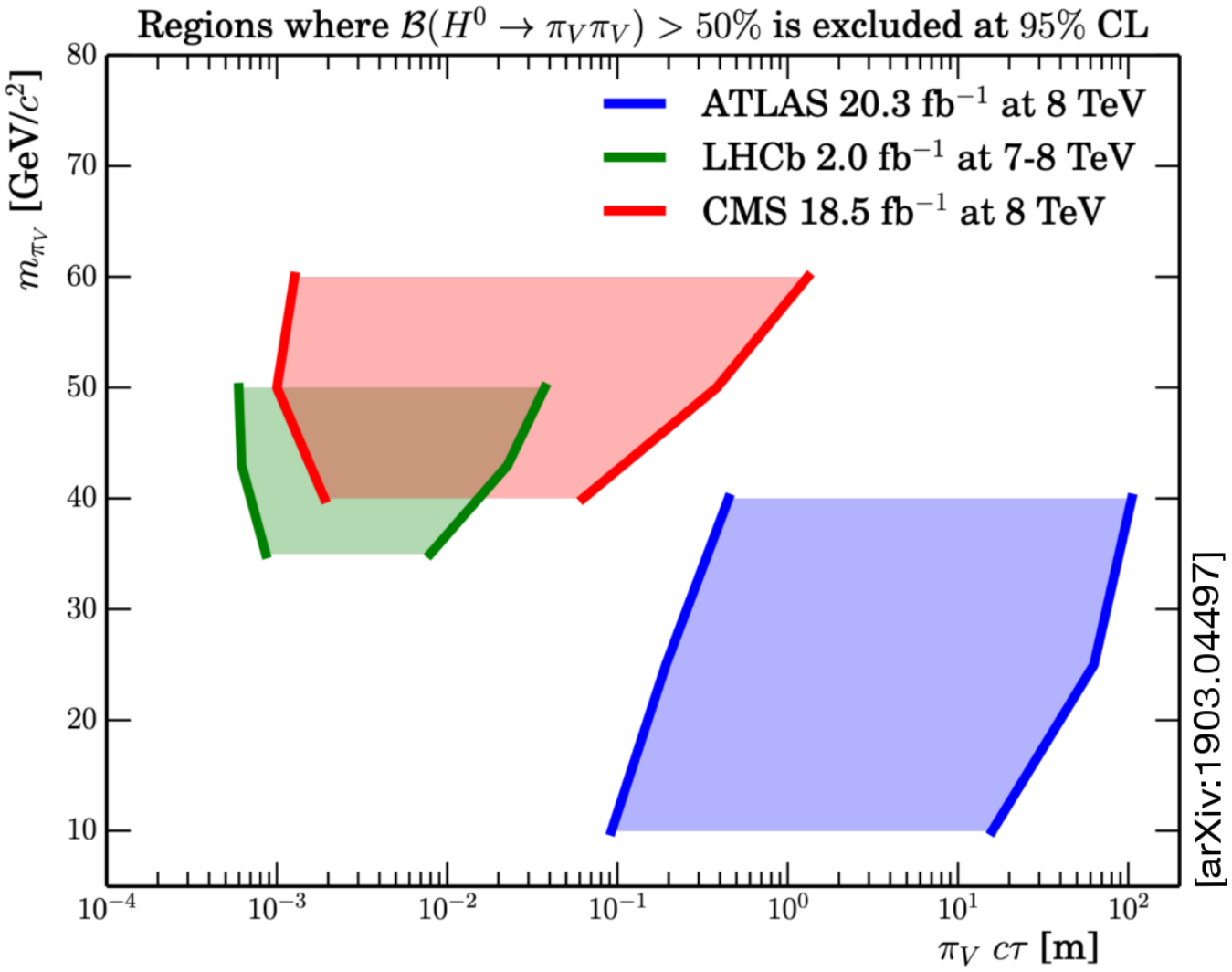
Trigger

Generator b-quarks in acceptance: $p_T > 15$ GeV, $|\eta| < 2.4$

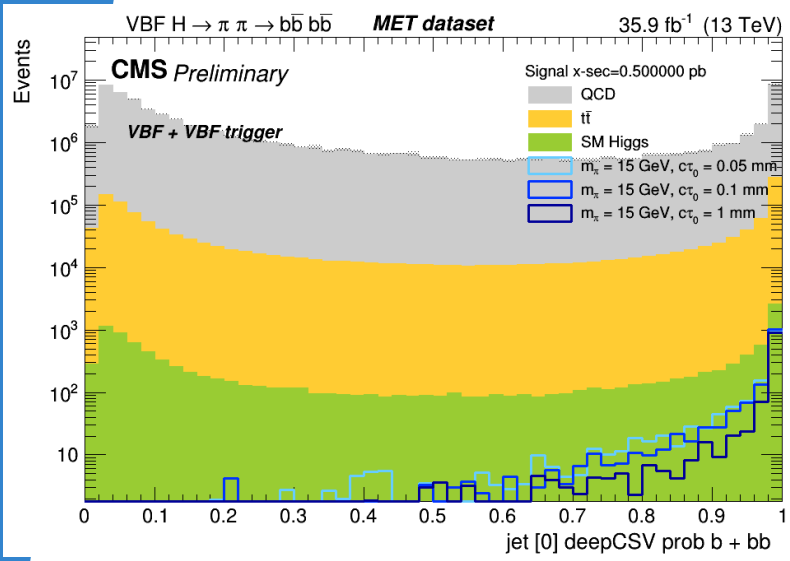
'HLT_DoubleJet90_Double30_TripleBTagCSV_p087_v' ||
'HLT_QuadJet45_TripleBTagCSV_p087_v' ||
'HLT_DoubleJetsC112_DoubleBTagCSV_p014_DoublePFJetsC112MaxDeta1p6_v' ||
'HLT_DoubleJetsC112_DoubleBTagCSV_p026_DoublePFJetsC172_v'

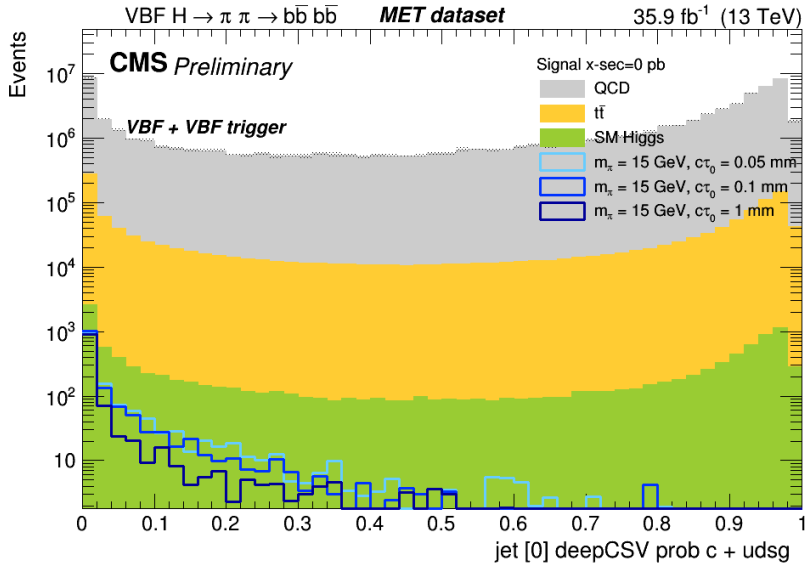


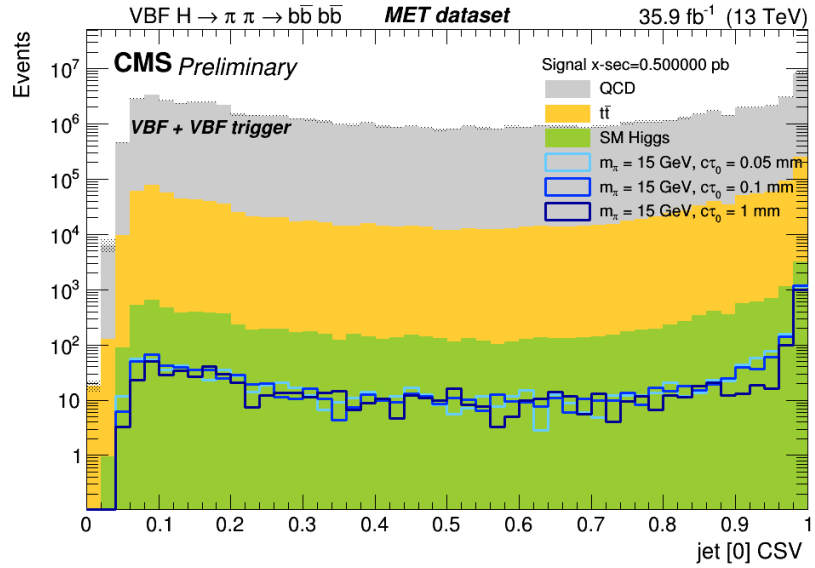
Previous Analyses

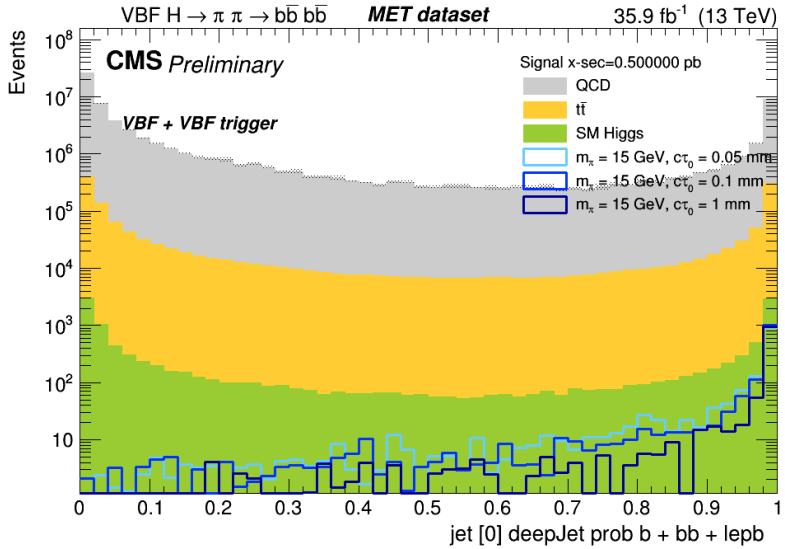


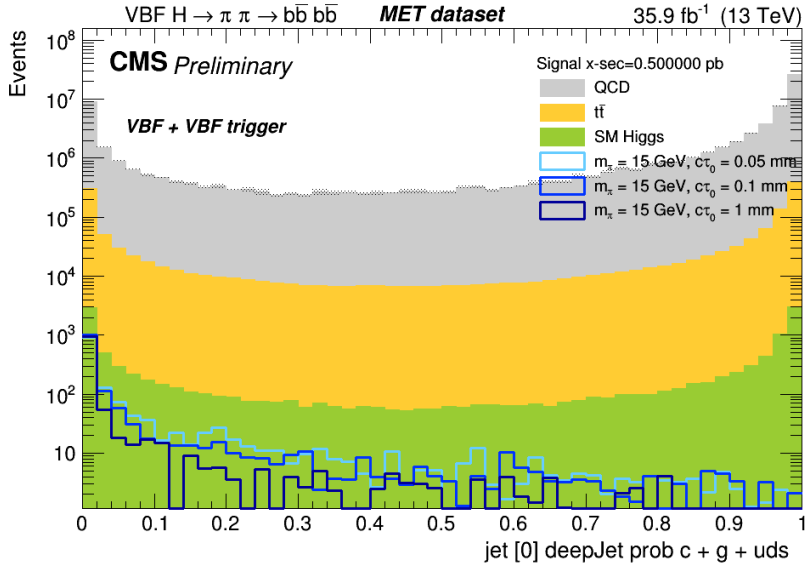
Performance of different tagger

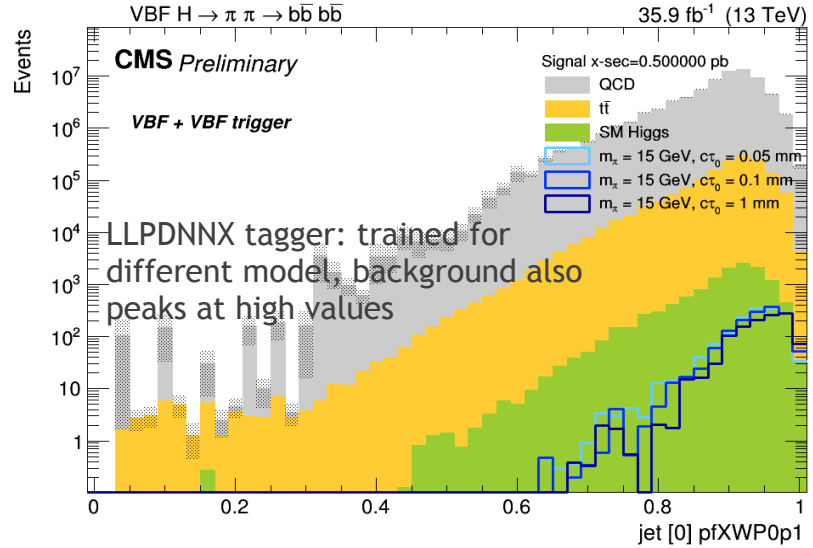












LLPDNNX tagger: trained for different model, background also peaks at high values

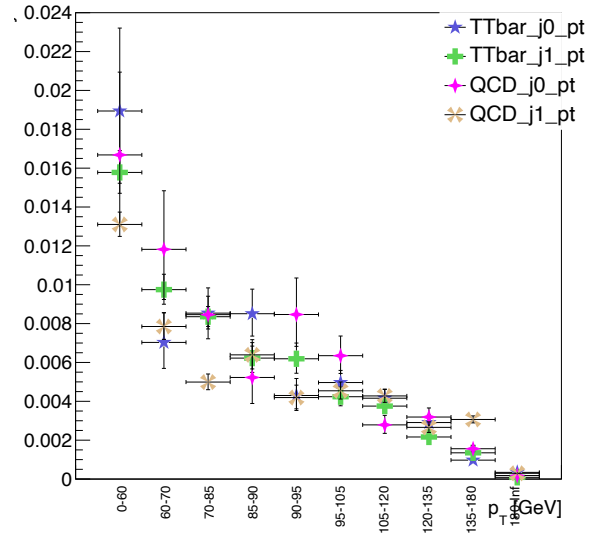
Efficiency

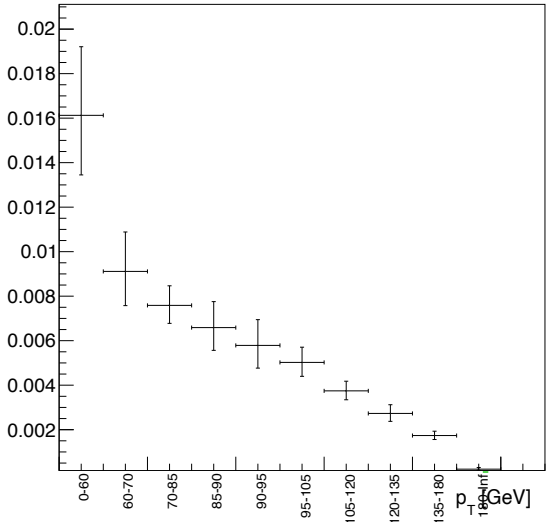
- Too low statistics in background!
  Workaround for this study:
- Calculate background efficiency for j0 (j1) which passes dnn output cut for different p_T bins

  Calculations:
  - n1:# jets pass dnn cut per p_T bin and add error as sqrt of value
  - n2:# jets total per p_T bin and add error as sqrt of value
  - Efficiency: $eff_{jX,pT} = \frac{n1}{n2} = \frac{\varepsilon}{1-\varepsilon}$
  - Asymmetric errors: $\Delta\tau_{low/up} = \frac{1}{(1-\varepsilon)^2}\Delta\varepsilon_{low/up}$

  Combine all efficiencies to one overall p_T binned efficiency; do error propagation to combine the assymetric errors
- Cut signal at dnn output cut
- Calculate invariant mass of leading 2 jets (signal passes dnn output cut)
- Scale background with

$$\boldsymbol{Eff = eff_{j0} * eff_{j1}}$$





Efficiency Uncertainty

- Scale background with

$$\boldsymbol{Eff = eff_{j0} * eff_{j1}}$$

- Take integral of scaled histogram as central value ($I_{central}$)

- Scale histogram up and down with using the efficiency for each jet:

$$Eff_{up} = \left(eff_{j0} + error_{up_{eff,j0}}\right) * \left(eff_{j1} + error_{up_{eff,j1}}\right)$$
$$Eff_{down} = \left(eff_{j0} - error_{down_{eff,j0}}\right) * \left(eff_{j1} - error_{down_{eff,j1}}\right)$$

  and get integrals (I_{up}, I_{down})

- Calculate uncertainty as:

$$Uncertainty = \frac{I_{up} + I_{down}}{2 * I_{central}}$$