Weak Boson Fusion Higgs boson production in CMS

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April 17, 2015

Outline

- A quick introduction
- The VBF topology
- VBF tagging in CMS
- CMS Result on VBF from run 1
- Conclusion

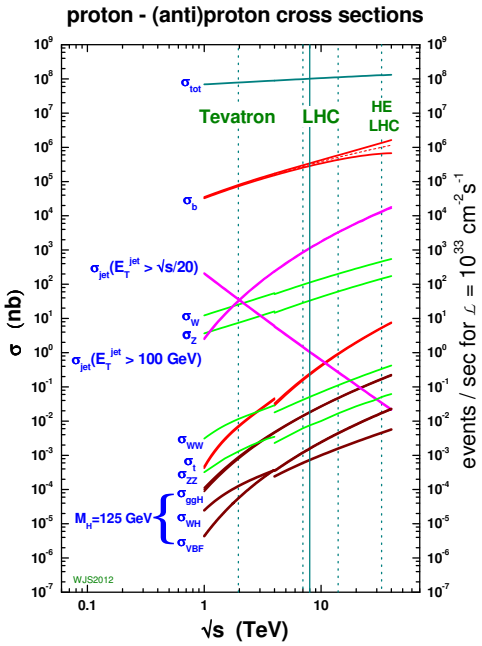
Section 1

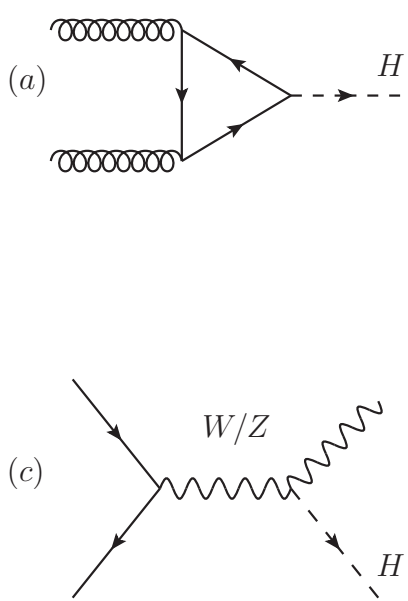
Introduction

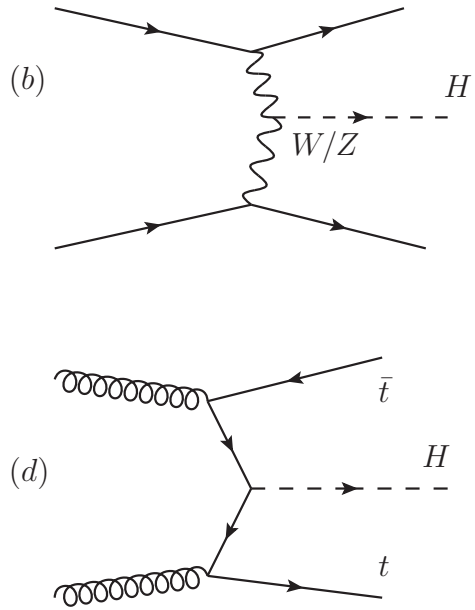
Outline

Higgs production at LHC

- The Higgs boson is produced at LHC trough 3 main production modes



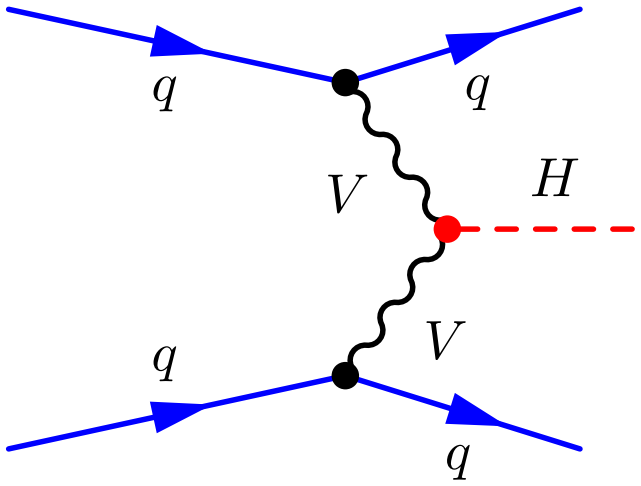




- The VBF production mode is second most common Higgs production mode at the LHC
- Which tools should we use to tag this topology ?

Vector Boson Fusion

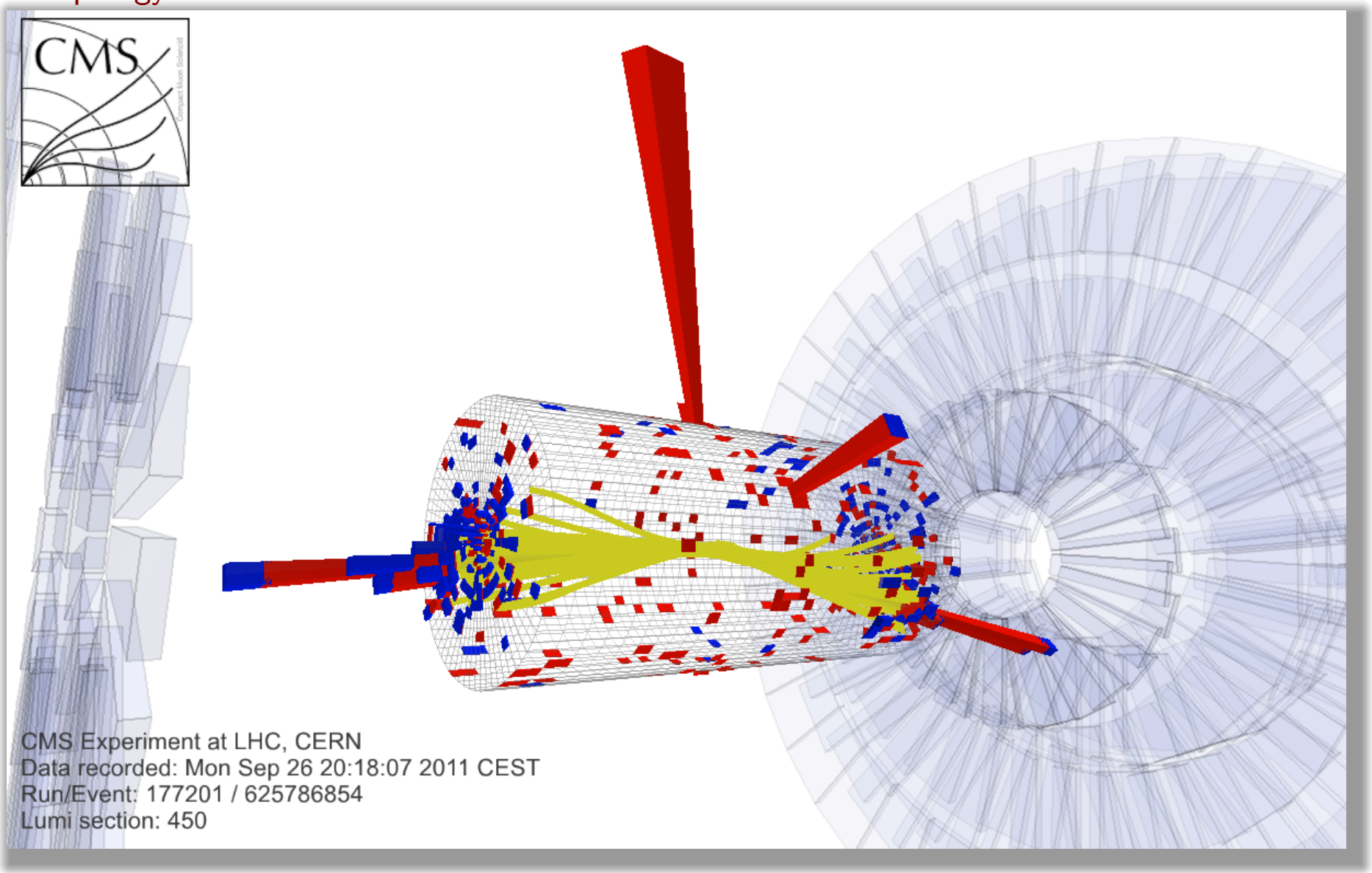
The topology



- The suppressed color exchange between quark lead to:
  - Very low hadronic activities in the central rapidity region
  - Two energetic **quark jets** with a large rapidity gap (from the scattered quarks)
- Jets are color connected with the proton remnant
- The Higgs boson product typically located in the central-rapidity region

Vector Boson Fusion

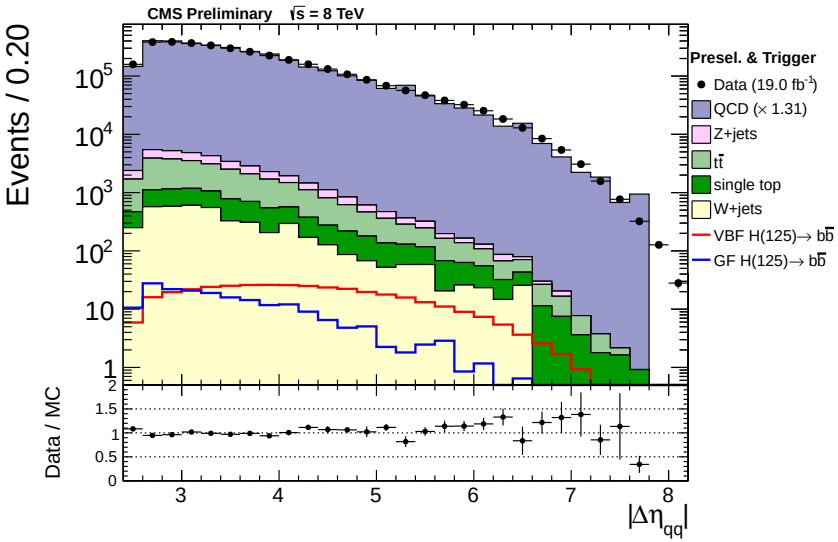
The topology

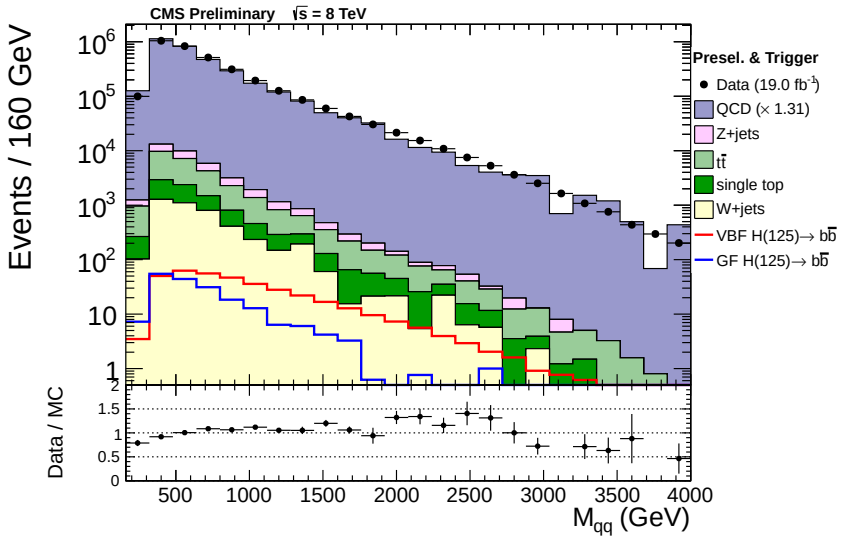


Tagging jets

Identifying the signature

- The forward-backward jets signature is mostly exploited by :
  - with A large rapidity separation
  - and A large invariant di-jet mass

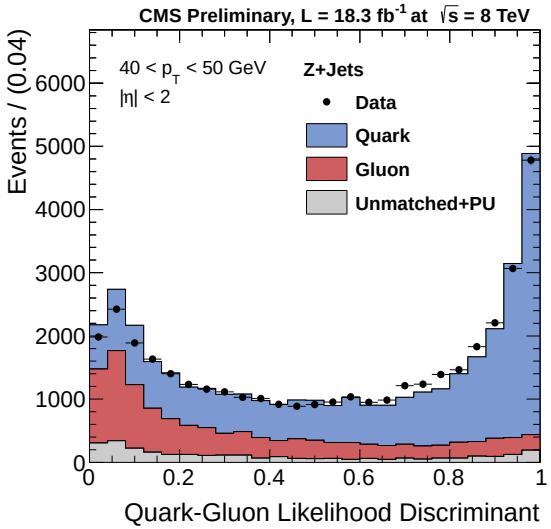


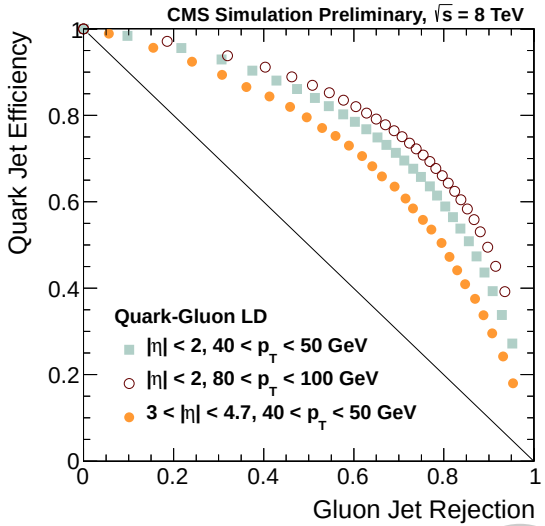


Tagging jets

Quark-Gluon discriminator

- Quark and Gluon have a different color interaction (different showering)
- This will mirror in the hadronisation process
- At a given energy a gluon jet will "on average"
  - Have a higher multiplicity
  - A wider angularity
  - Have a more uniform energy fragmentation
- These information are exploited by implementing a Likelihood based discrimination using the jet constituents
- Tree main discriminating variables
  - Angular spread in the (η, ϕ) plane
  - Jet multiplicities: $(n_{charged}, n_{neutral})$
  - momentum distribution among particles

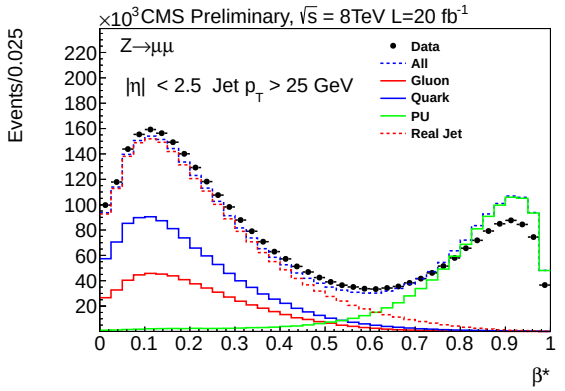


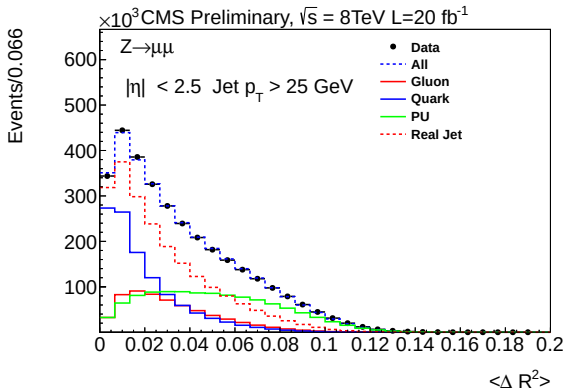


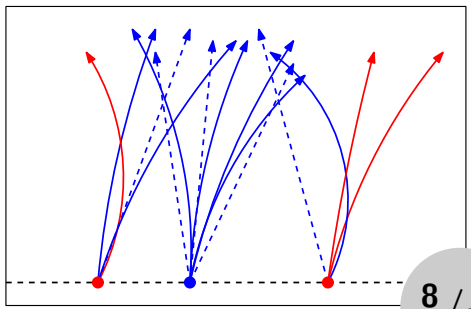
Tagging Jets

Pileup removal

- Pile up constitutes one of the most challenges for the analysis at the LHC
- The goal: reconstruct jets whose properties reflect the true jets arising from stable particles in the primary collision
- How we might do this ?
  - Extract jet momentum based on jet area and the average density from pileup in the event
  - Remove the jets which are more likely composed by the tracks from pile
    - Track based variables. ex: β^* : ratio of the energy carried by charged track from another PV in the jet over the energy of the all the track in jet
    - Shape based variable. ex: $\langle \Delta R^2 \rangle = \sum \Delta R^2 p_t / \sum p_t$
- remove the charged hadron tracks before jet clustering: Charged hadron subtraction (CHS)
  - Identify and remove all the tracks attached to pile-up vertices







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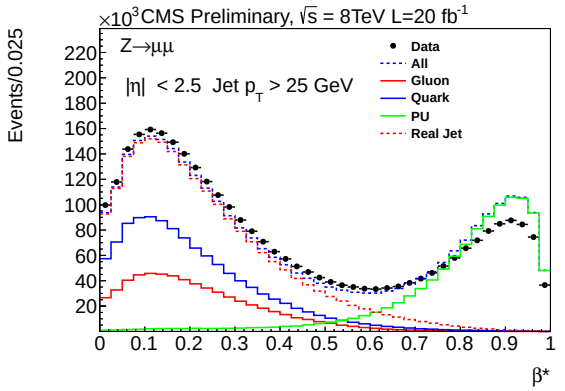

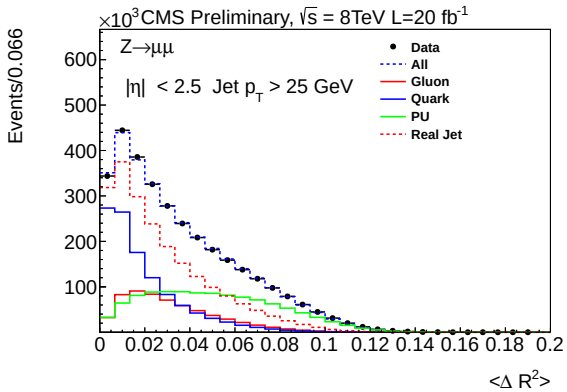

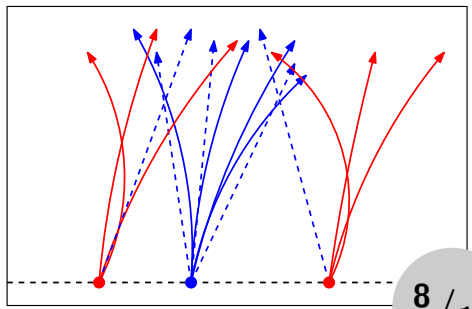

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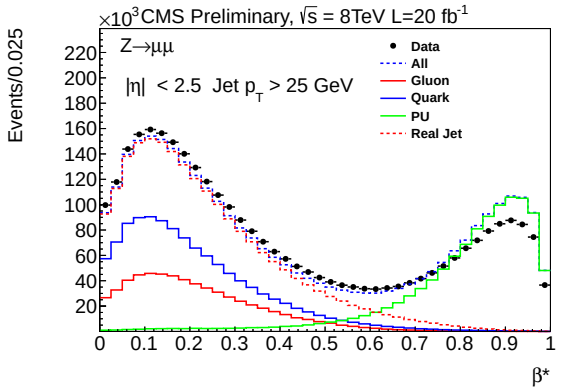

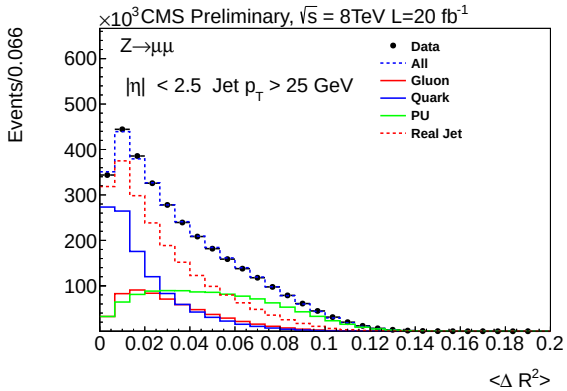

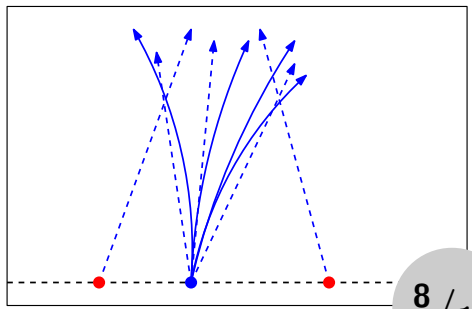

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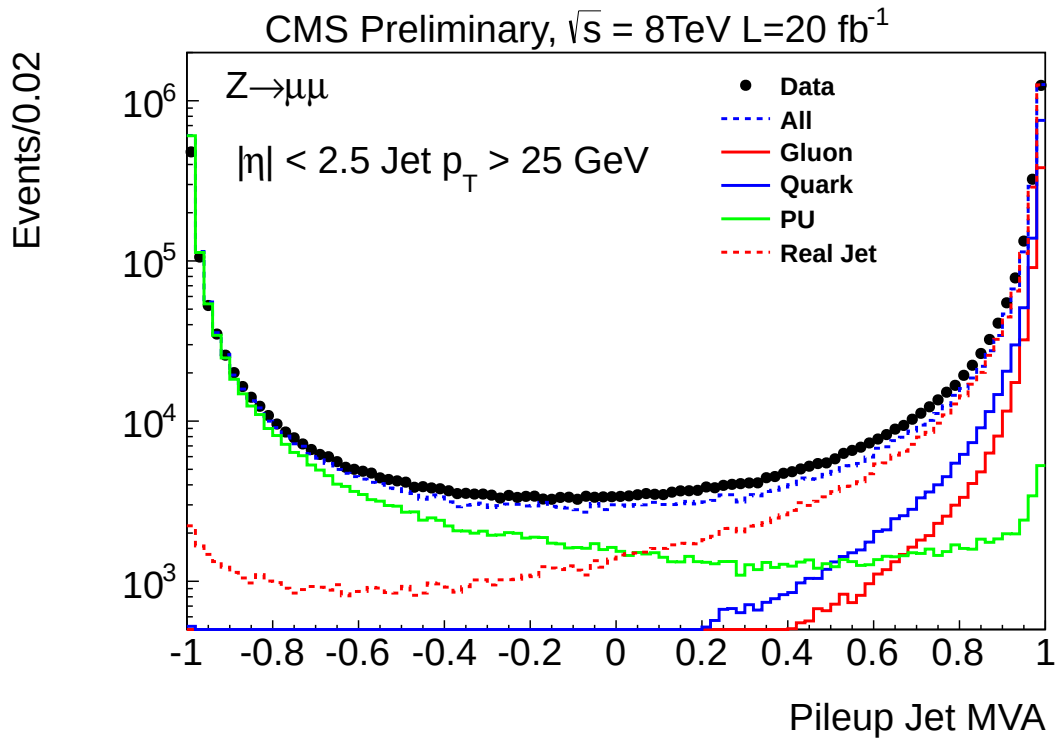

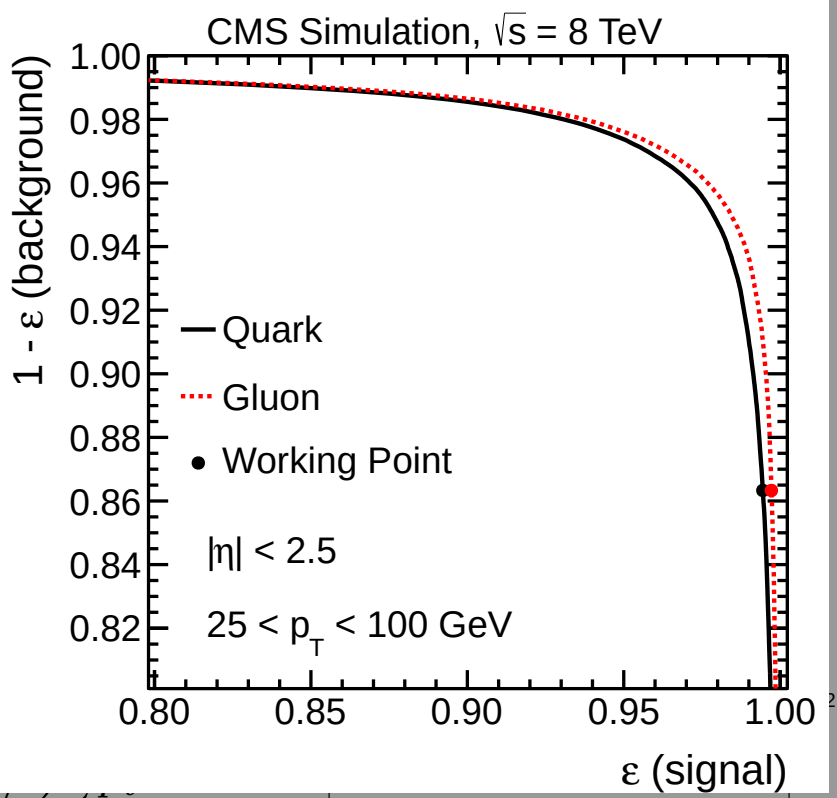

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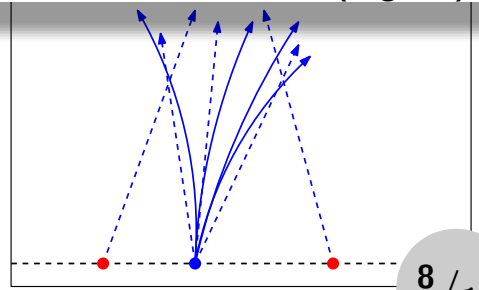
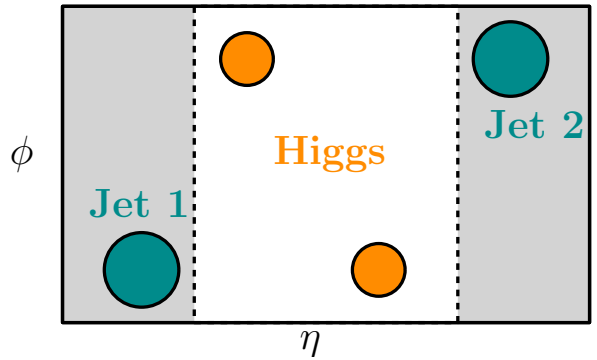


Section 2

Tagging the VBF Topology

VBF tagging

- Since the we are expecting almost no hadronic activity in the central region between the two tagged jets → veto can be introduced



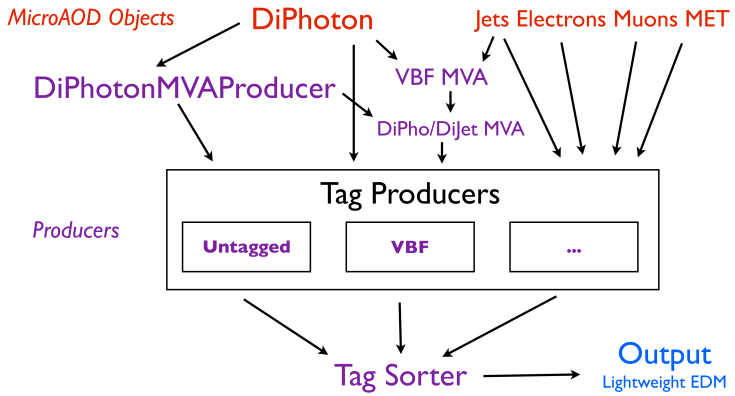
  - This approach is widely used in $H \to WW$ and $H \to \tau\tau$ channels
  - Typically a central jet veto of 30 GeV was applied during run I
- The VBF topology is also reflected in the Zeppenfeld variable $Z = \eta|_{obs} - (\eta_{j_1} + \eta_{j_2})/2$
  - The Higgs candidate, $\eta|_{obs} = \eta(H)$ for the VBF signal will be strongly peaked around 0 for the background: This is exploited with VBF ($H \to \gamma\gamma$) analysis with a cut of $Z < 2.6$
  - A 3rd jet in the event, The VBF signal will show a double peak, contrasting with the peak around 0 in the background
- The VBF($H \to \gamma\gamma$) uses as well the azimutal angle between the di-jets and di-photon system: $\Delta_{\gamma\gamma-jj}$
  - This variable is also sensitive to remove event with additional ISR or PU jets

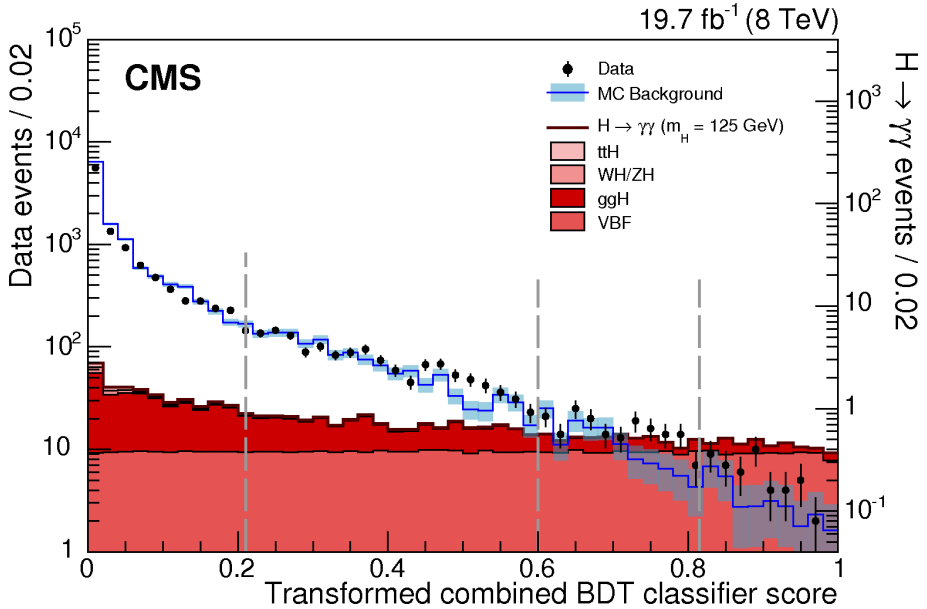
Section 3

results from the run I

The VBF Higgs signature with $H \to \gamma\gamma$

- VBF signature tagging done in two steps
- Dijet kinemtics BDT
  - Trained with VBF as signal and ggH included as part of background
  - Use diphoton and dijet kinematic variables to exploit VBF topology
- Combined dijet-diphoton BDT
  - Use output of both diphoton BDT and dijet BDT, along with $p_T^{\gamma\gamma}/m_{\gamma\gamma}$ to exploit correlation, as input
  - Train with VBF as signal against background to exploit VBF like kinematics AND good diphoton pairs (resolution, photon quality)





The VBF Higgs signature with $H \to \gamma\gamma$

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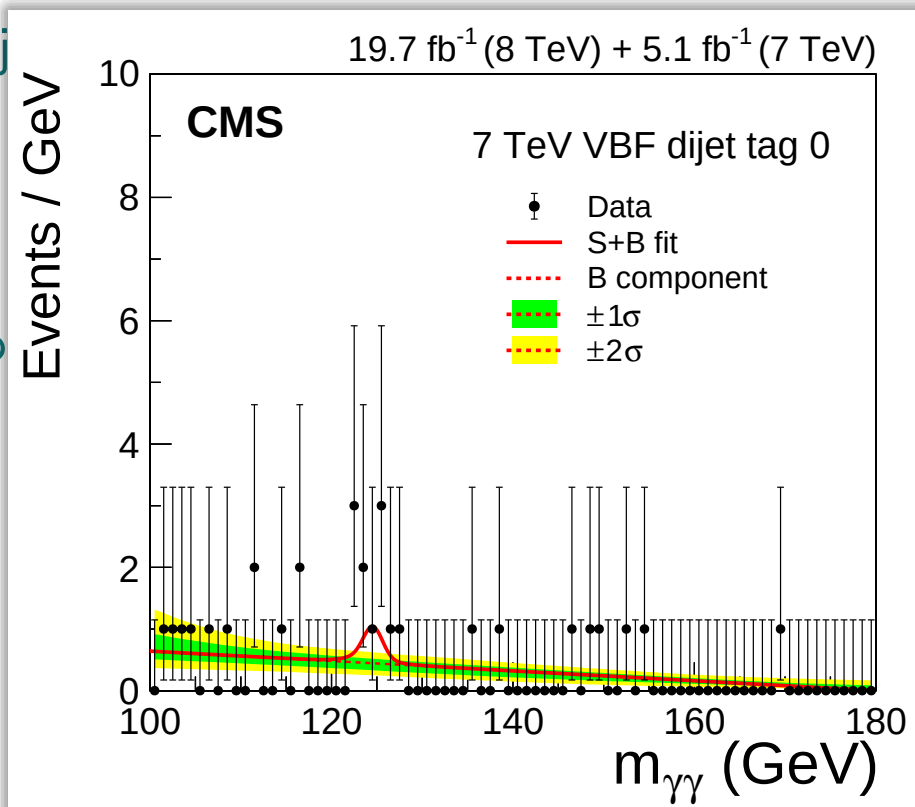
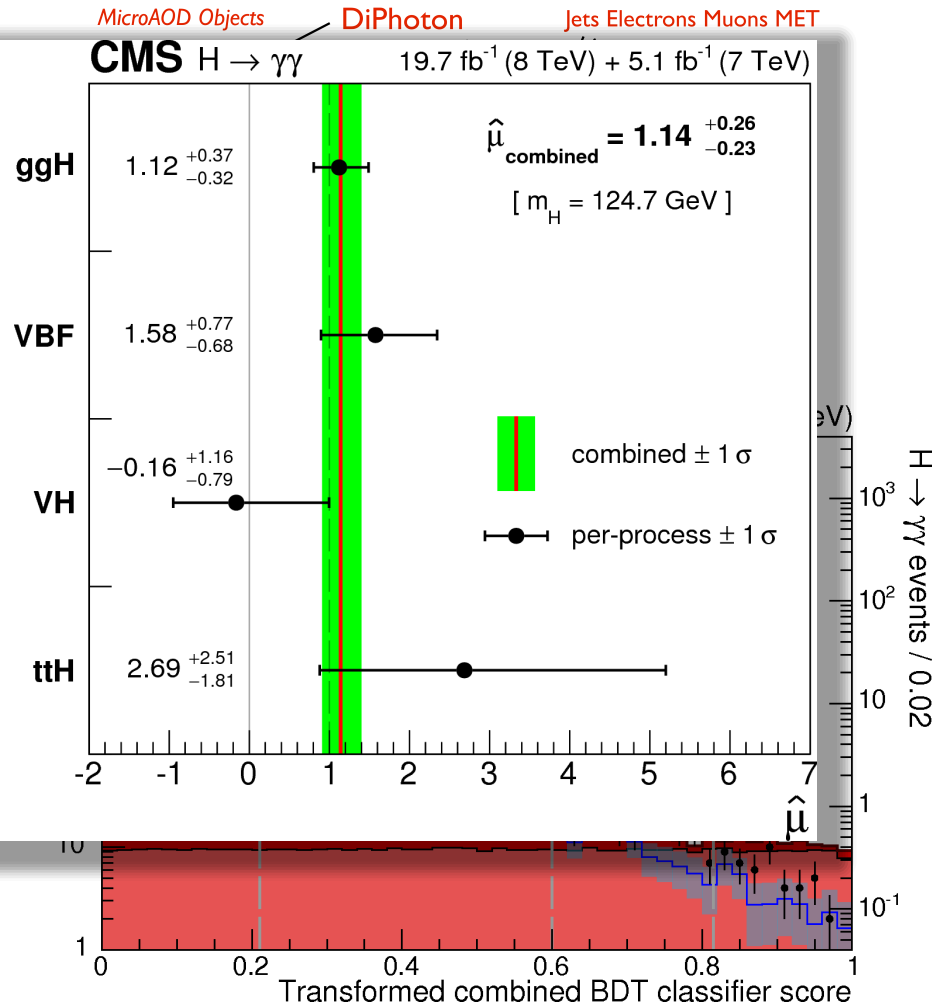
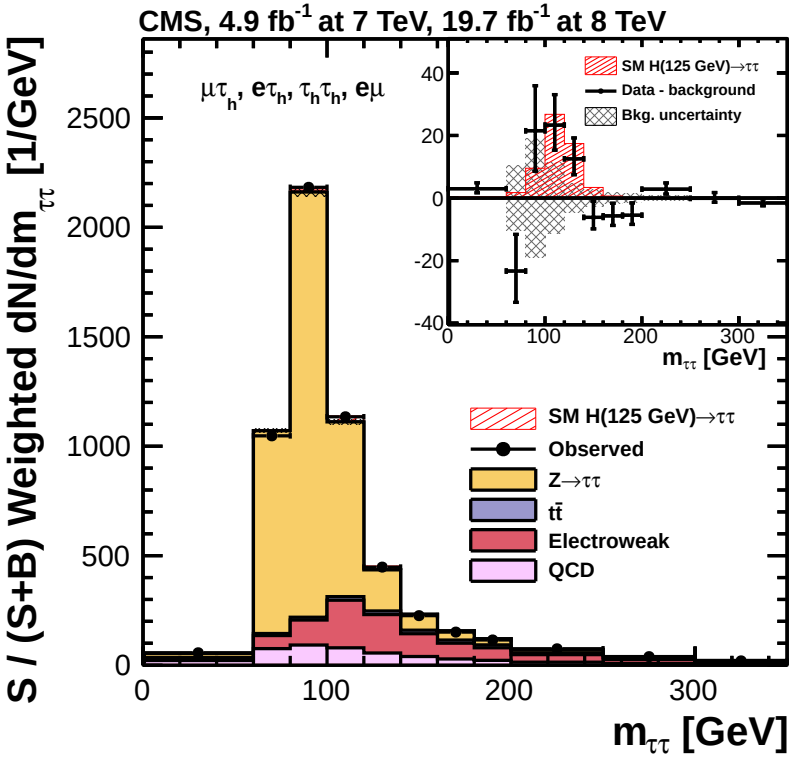


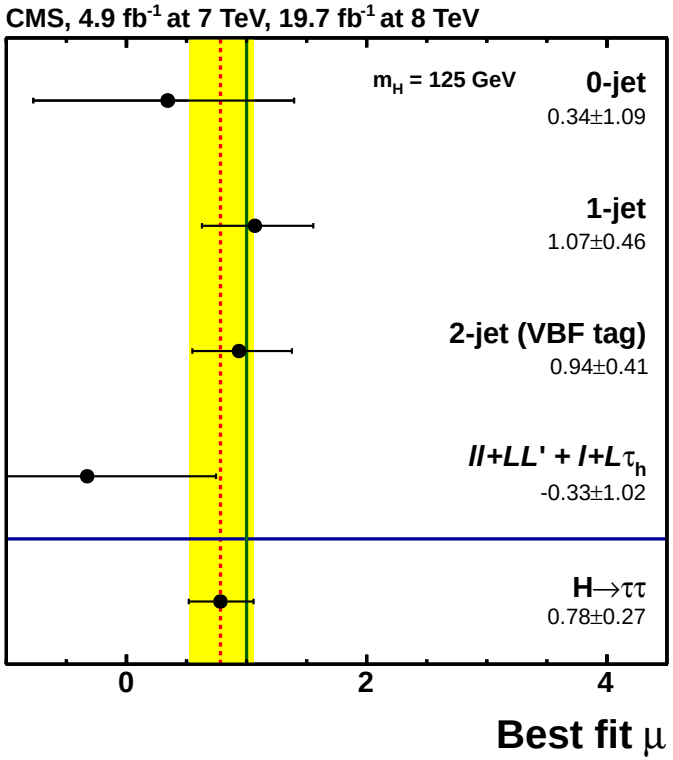


The VBF signature with $H \to \tau\tau$

- requires $\geq$ 2-jets
- $M_{jj} > 500GeV$, $\Delta\eta_{jj} > 3.5$
- Central jet veto

- Presence of secondary vertex in the tau decay + MET





Conclusion

- Introduction on the VBF tagging in CMS
- Method for VBF di-jets are shown
- As well as the techniques used (will be used) for the pile-up removal
- Few results on the Higgs research on the VBF production mode are shown

- Currently we are all engaged on preparation for the run II
  - Validation of tools and analyses
- The Goal will be the rediscovery of the Higgs boson first (to validate the discovery) and make prices measurement
- If we are lucky enough, we will discover new physics !!