Evidence For Higgs Boson Decay to Muons

Adish Vartak

University of California San Diego

On behalf of the CMS Collaboration

Characterizing the Higgs Boson

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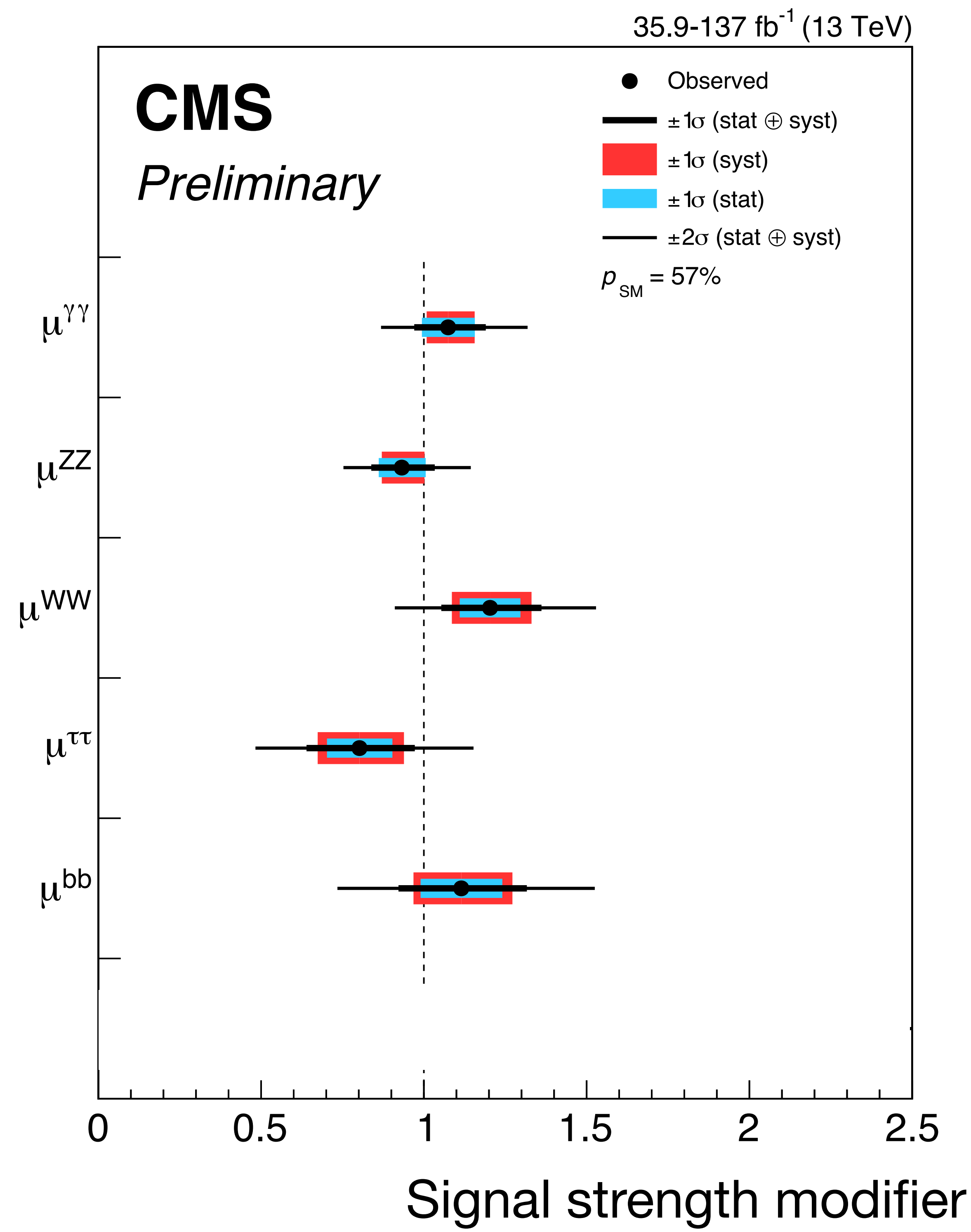

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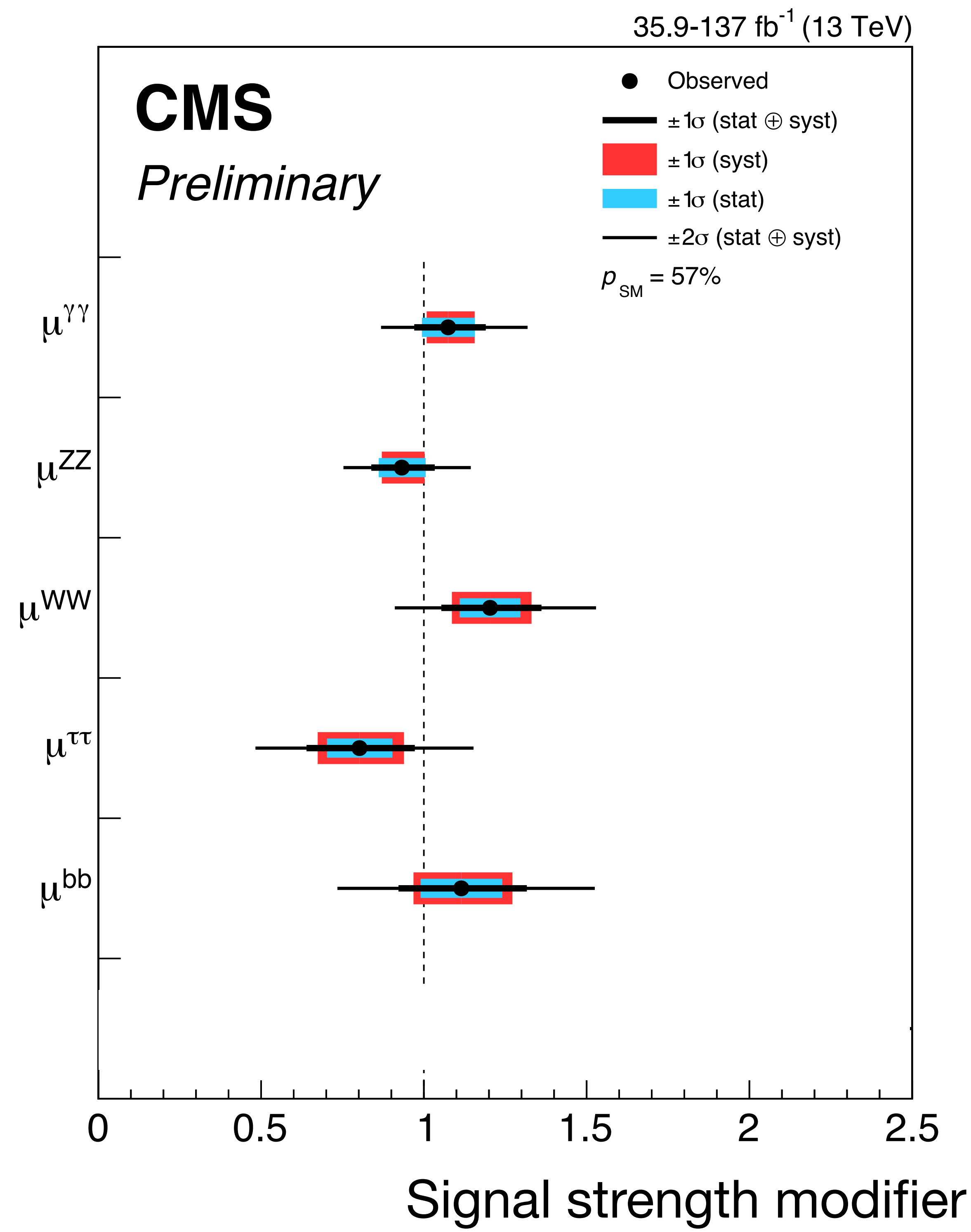
- The ***next frontier*** is to probe the Higgs boson interaction with ***2nd generation fermions***
  - ➡ H→ff coupling proportional to m_f
  - ➡ Small BR(H→ff) for 1st, 2nd gen. fermions



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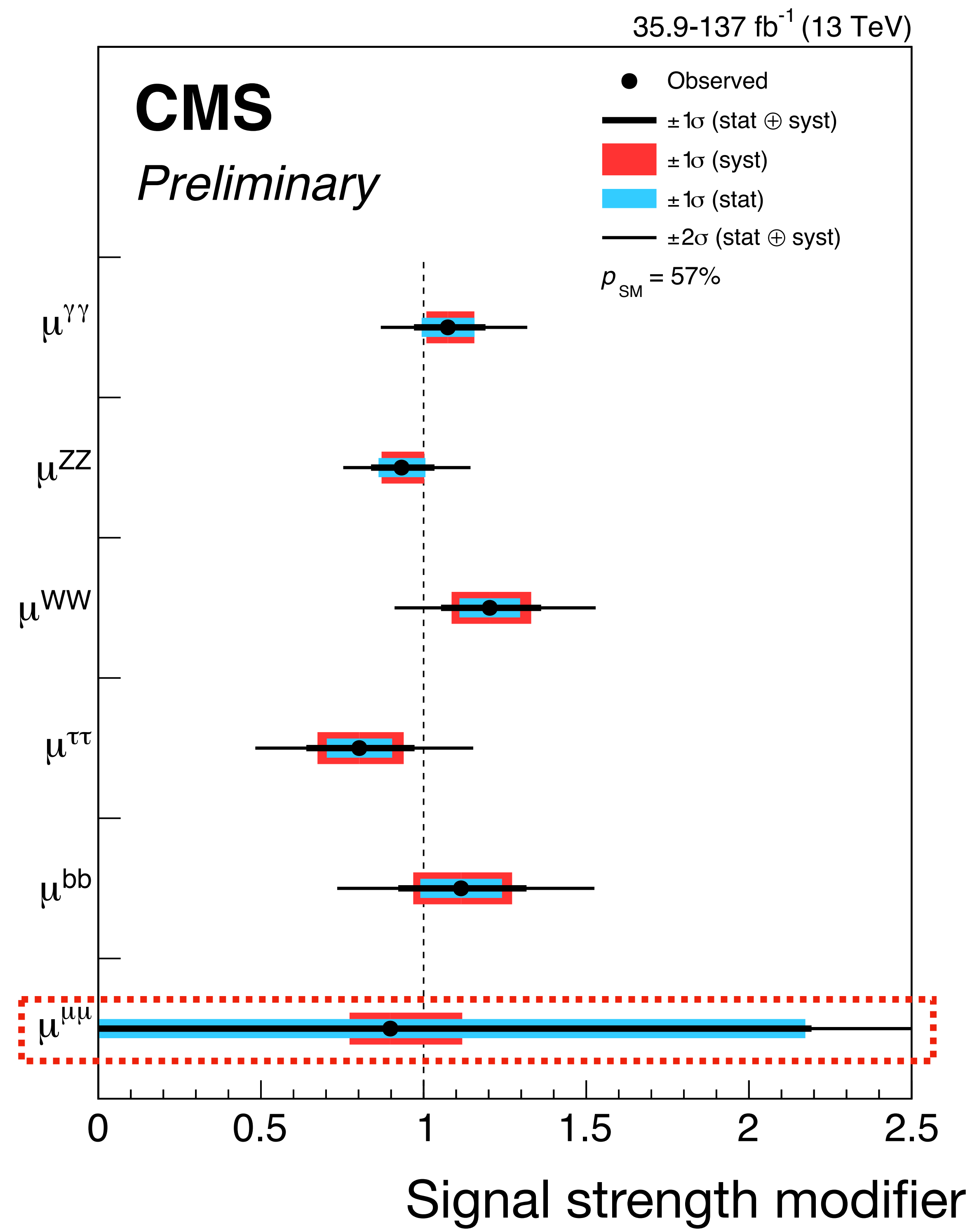
  - Found to be consistent with SM *HIG-19-005*
- The ***next frontier*** is to probe the Higgs boson interaction with ***2nd generation fermions***
  - ➡ $H \rightarrow ff$ coupling proportional to m_f
  - ➡ Small $BR(H \rightarrow ff)$ for 1st, 2nd gen. fermions
- **$H \rightarrow \mu\mu$ is probably the only accessible 2nd or 1st generation interaction at LHC**
- Observed (expected) limit set by previous CMS search: 2.9 (2.2) x SM prediction *PRL 122, 021801 (2019)*

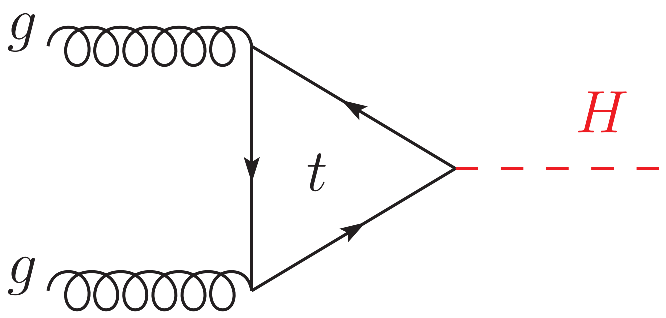


The H→μμ Search

- Look for a narrow dimuon mass peak at the Higgs mass
- Search hampered by:
  - ➡ Small signal rate : BR(H→μμ) = 2.1×10^{-4}
  - ➡ Large background : Dominant Drell-Yan background ~10^3 times larger than signal
- ***We maximize sensitivity by individually targeting the 4 main Higgs production modes***
- 4 analyses tailored to exploit the unique topologies of **gluon fusion, VBF, VH, ttH**

Higgs Production Modes

ggH



- ***87% of total H cross section***
- Low signal purity : 0.2-2%
- Large DY background

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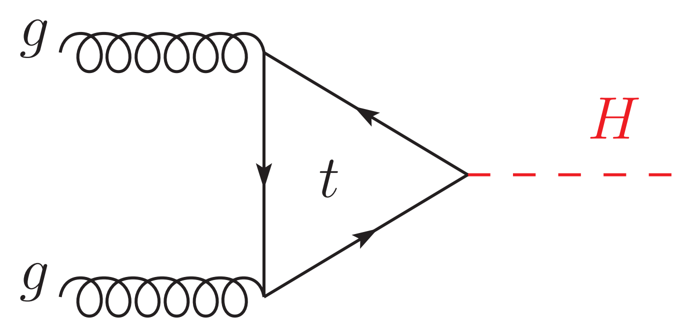

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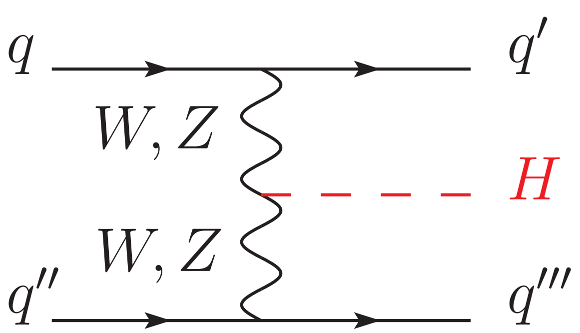
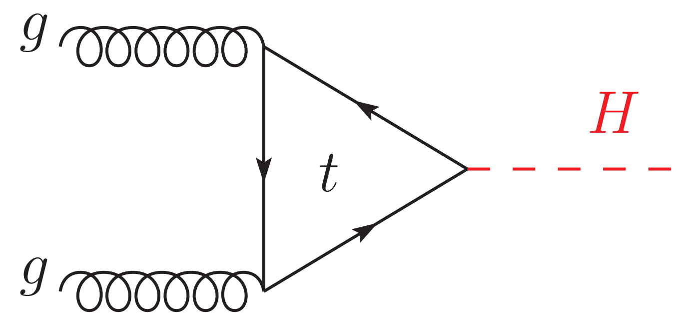
VBF



- ***7% of total H cross section***
- Two jets with large η-gap, m_{jj}
- Main backgrounds : DY, EWK Z+jj

Higgs Production Modes

ggH



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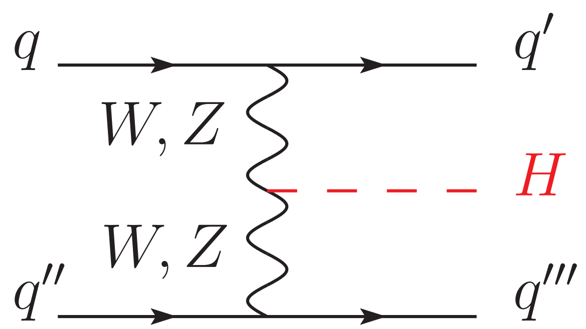

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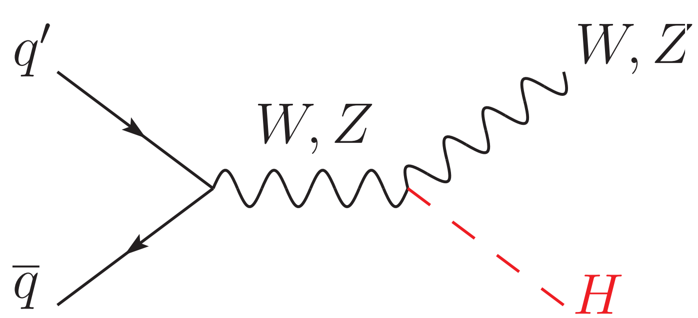
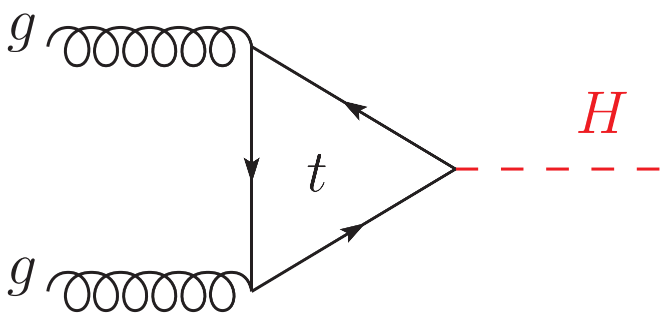


- ***4% of total H cross section***
- Additional e, μ in the event from leptonic decays of W, Z
- Main backgrounds : ZZ, WZ

Higgs Production Modes

ggH



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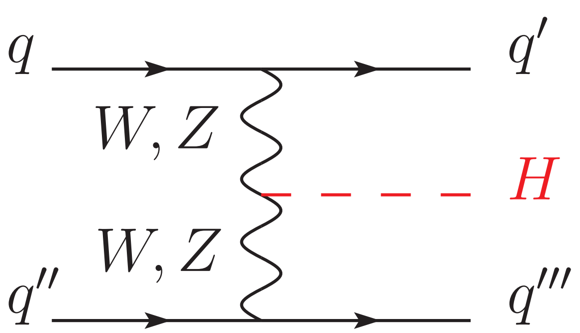
VBF



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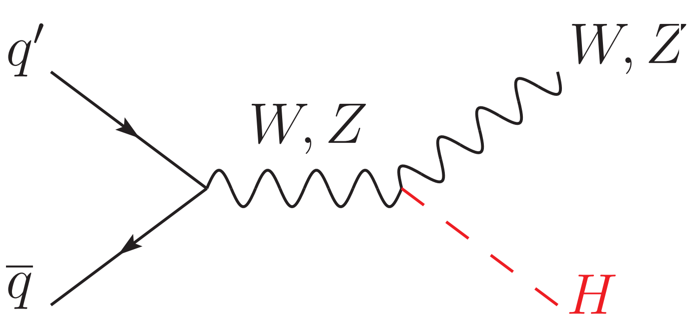
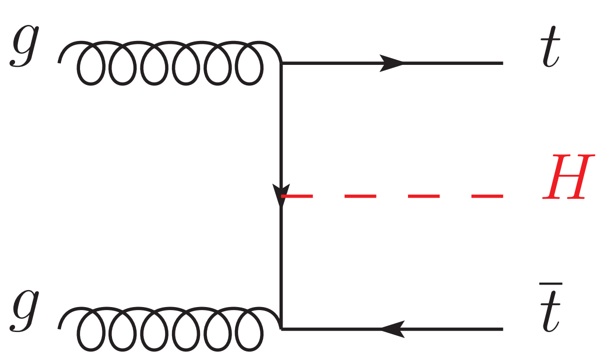
VH



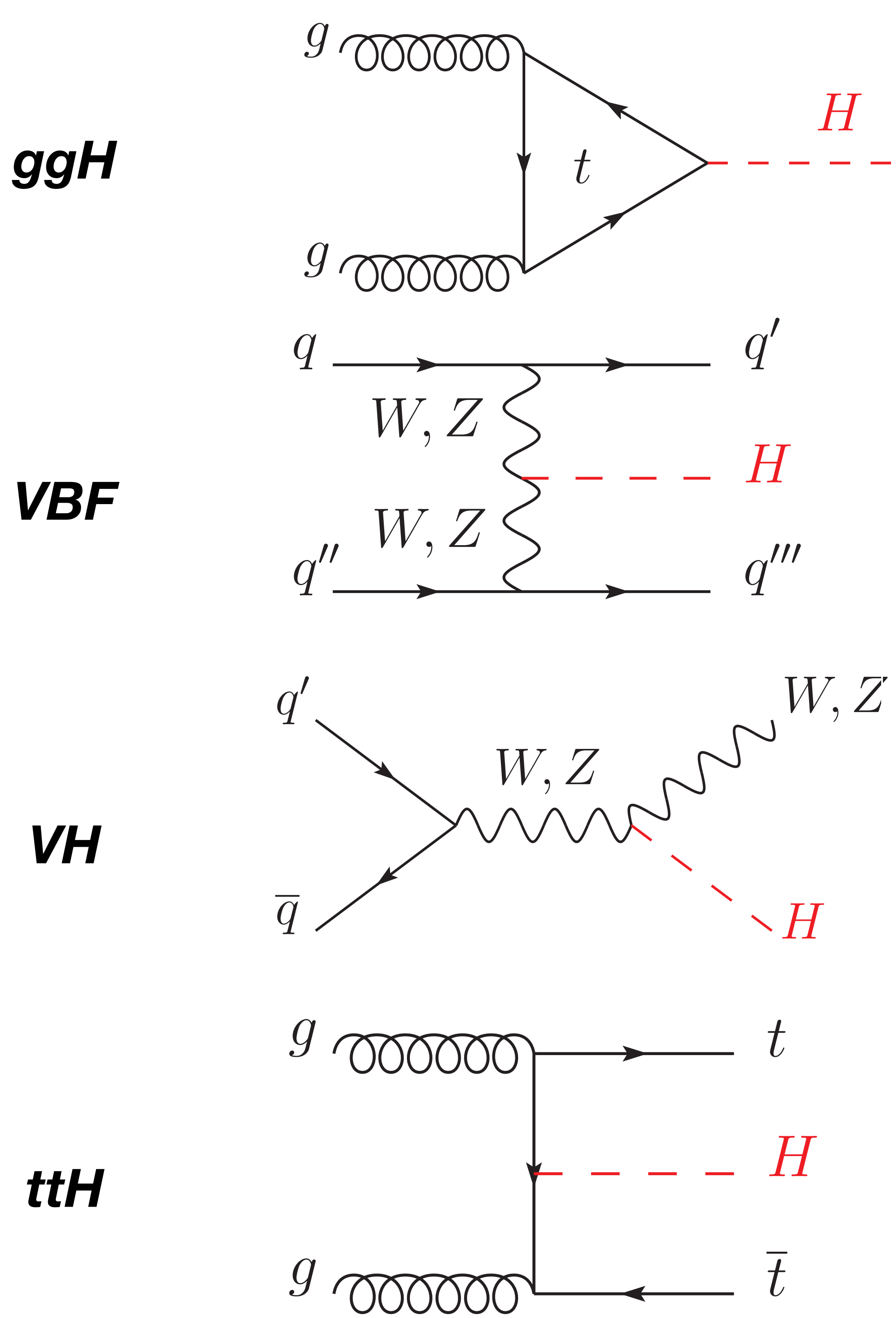
- ***4% of total H cross section***
- Additional e, μ in the event from leptonic decays of W, Z
- Main backgrounds : ZZ, WZ

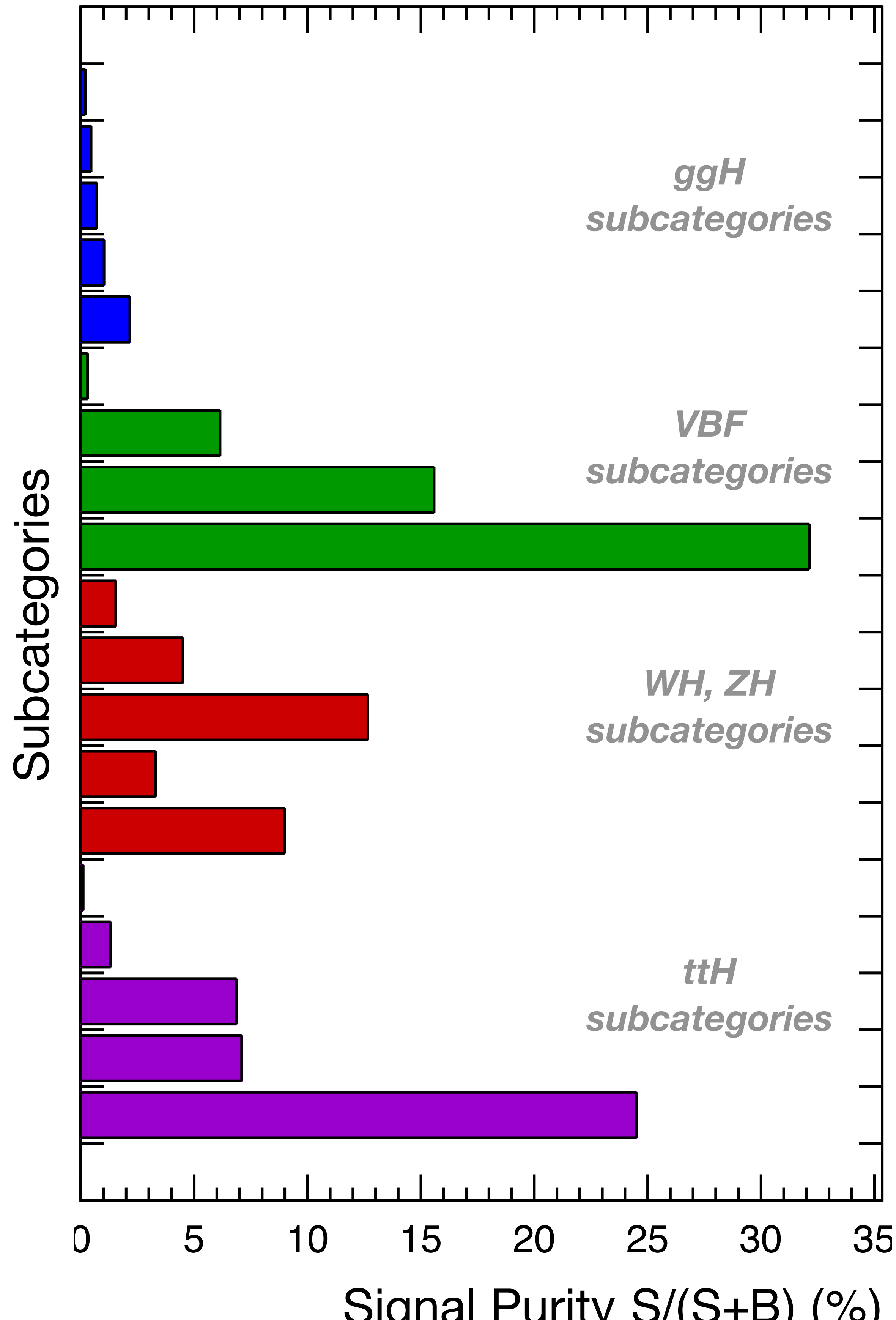
ttH



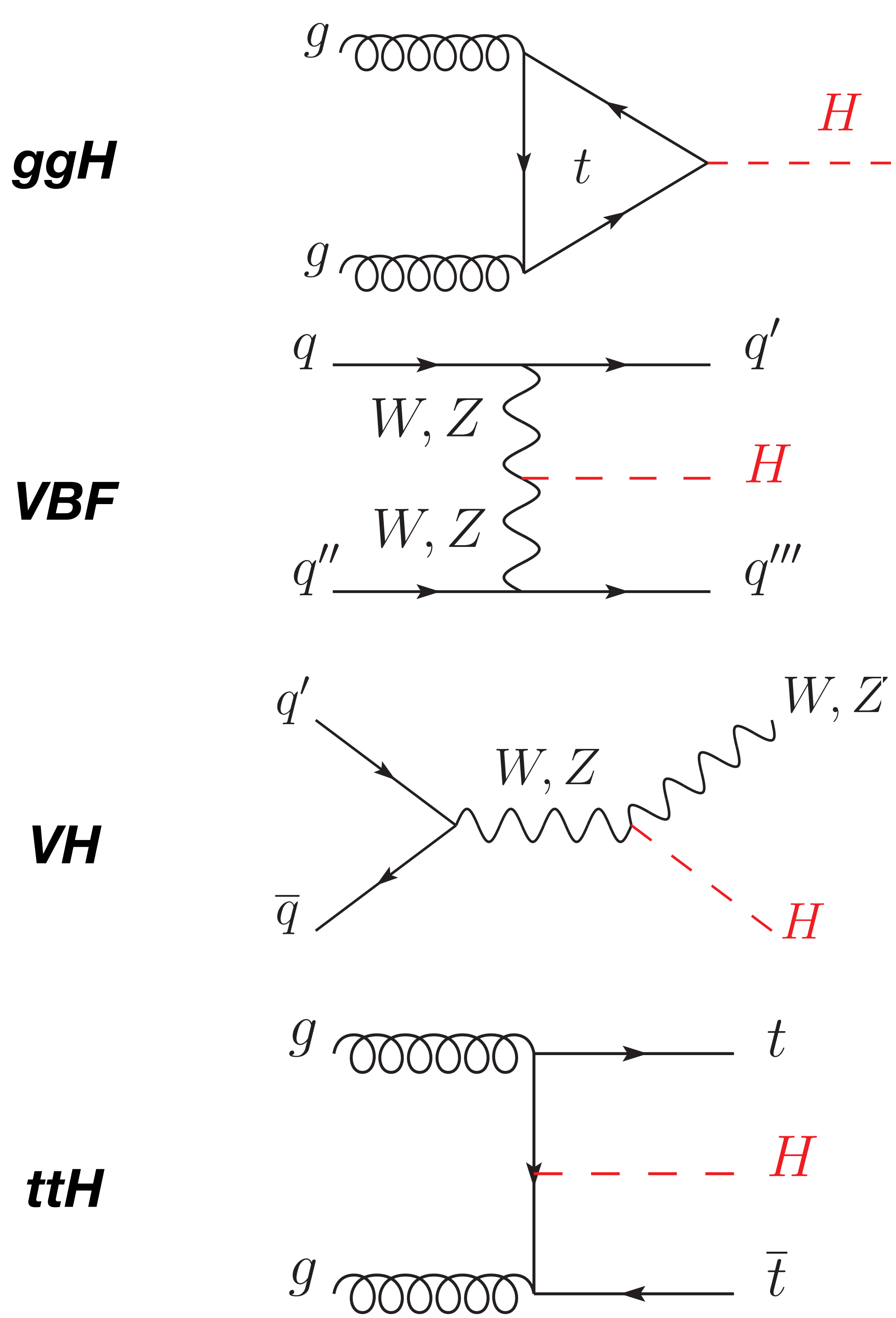
- ***1% of total H cross section***
- Additional jets, b-jets, leptons in the event from top decays
- Main backgrounds : tt, ttZ

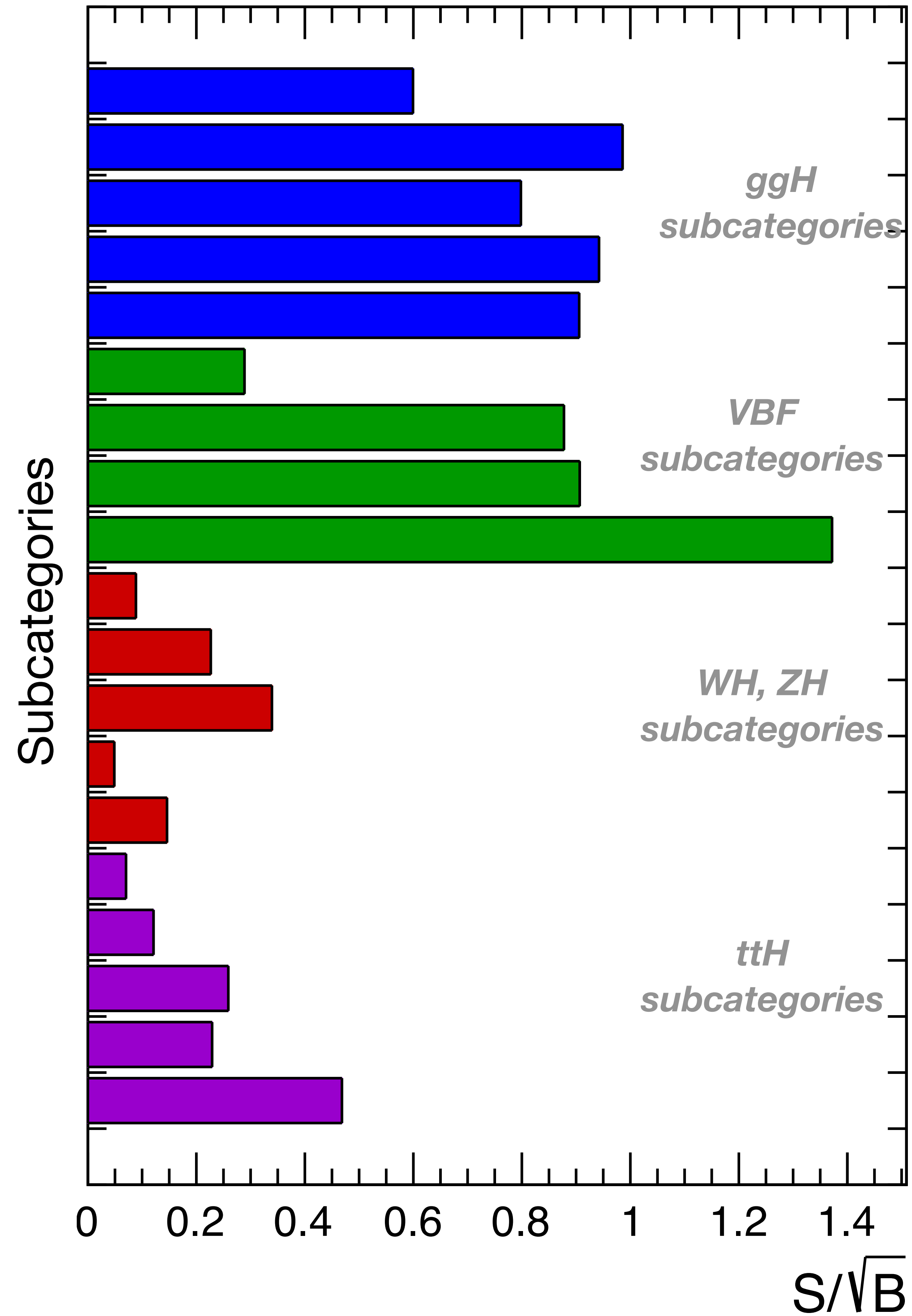
Higgs Production Modes: Purity





Higgs Production Modes: Sensitivity

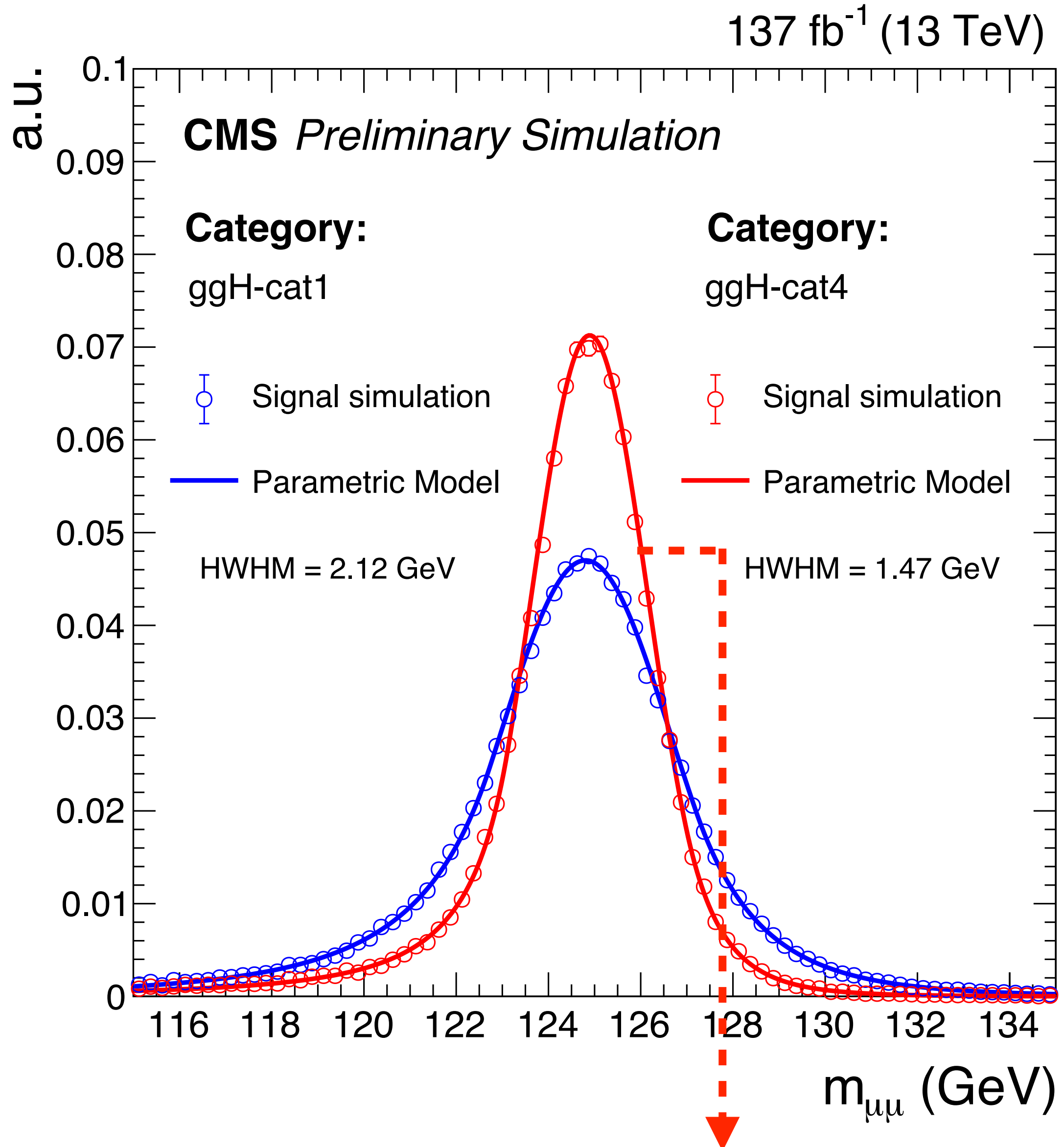




H→μμ Decay

Signal characterized by a sharp dimuon mass peak at 125 GeV
$m_{\mu\mu}$ resolution plays a defining role in determining analysis sensitivity

- Require 2 opposite sign muons in the event
  - ➡ p_T > 20 GeV; $|\eta|$ < 2.4
- At least one muon with p_T > 26 (29) GeV in 2016, 2018 (2017) data
  - ➡ Consistency with single muon trigger thresholds
- Muon p_T resolution:
  - ➡ 1.5-2% in barrel region ($|\eta|$ < 0.9)
  - ➡ 2-4% in endcaps ($|\eta|$ > 1.2)
- FSR photon recovery:
  - ➡ 3% improvement in mass resolution
  - ➡ 2% increase in signal efficiency (otherwise spoiled by the photon in isolation region)



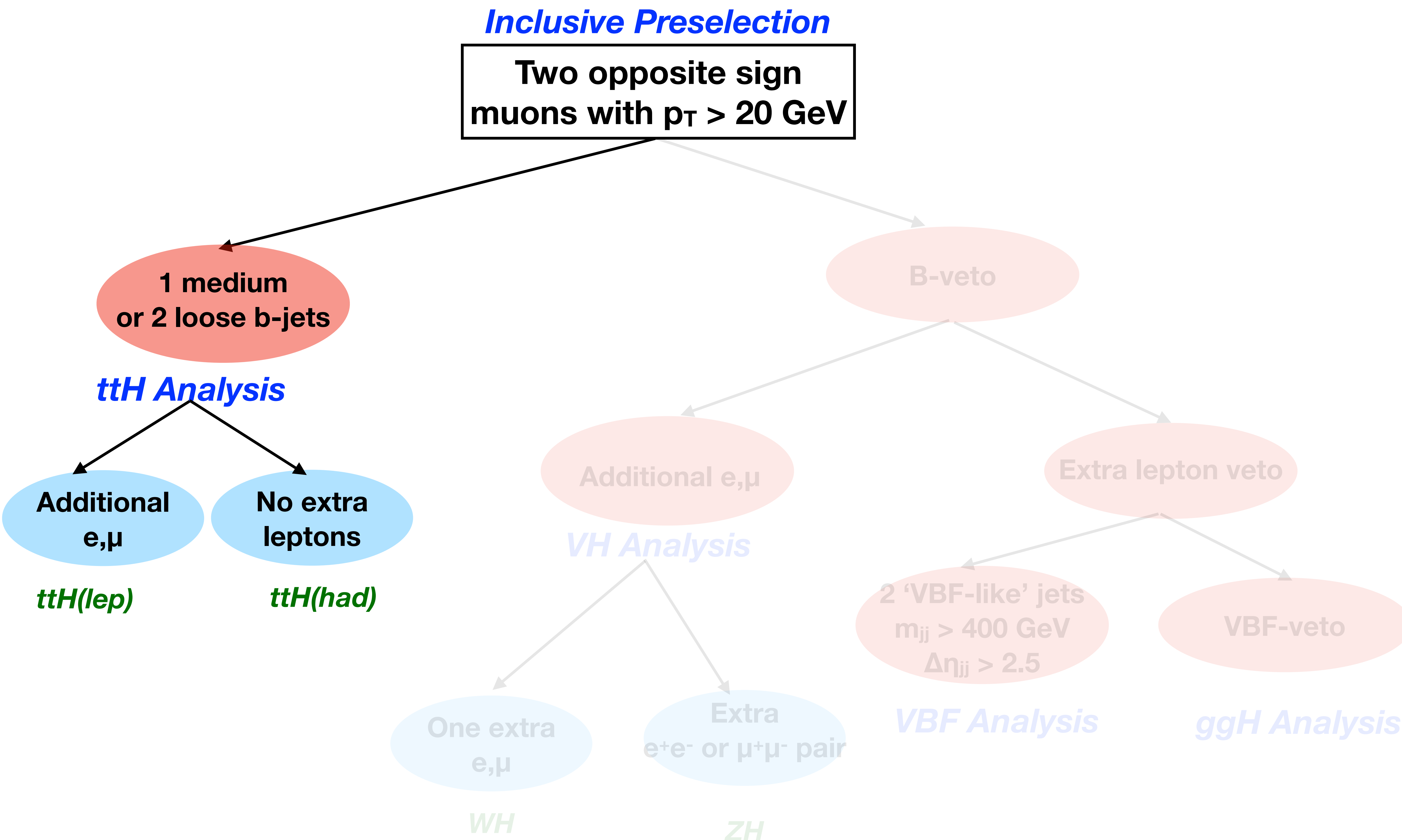
Events with high dimuon mass resolution (~1%)
Typically both muons in barrel

H→μμ Search Categories

Inclusive Preselection

Two opposite sign muons with p_T > 20 GeV

H→μμ Search Categories



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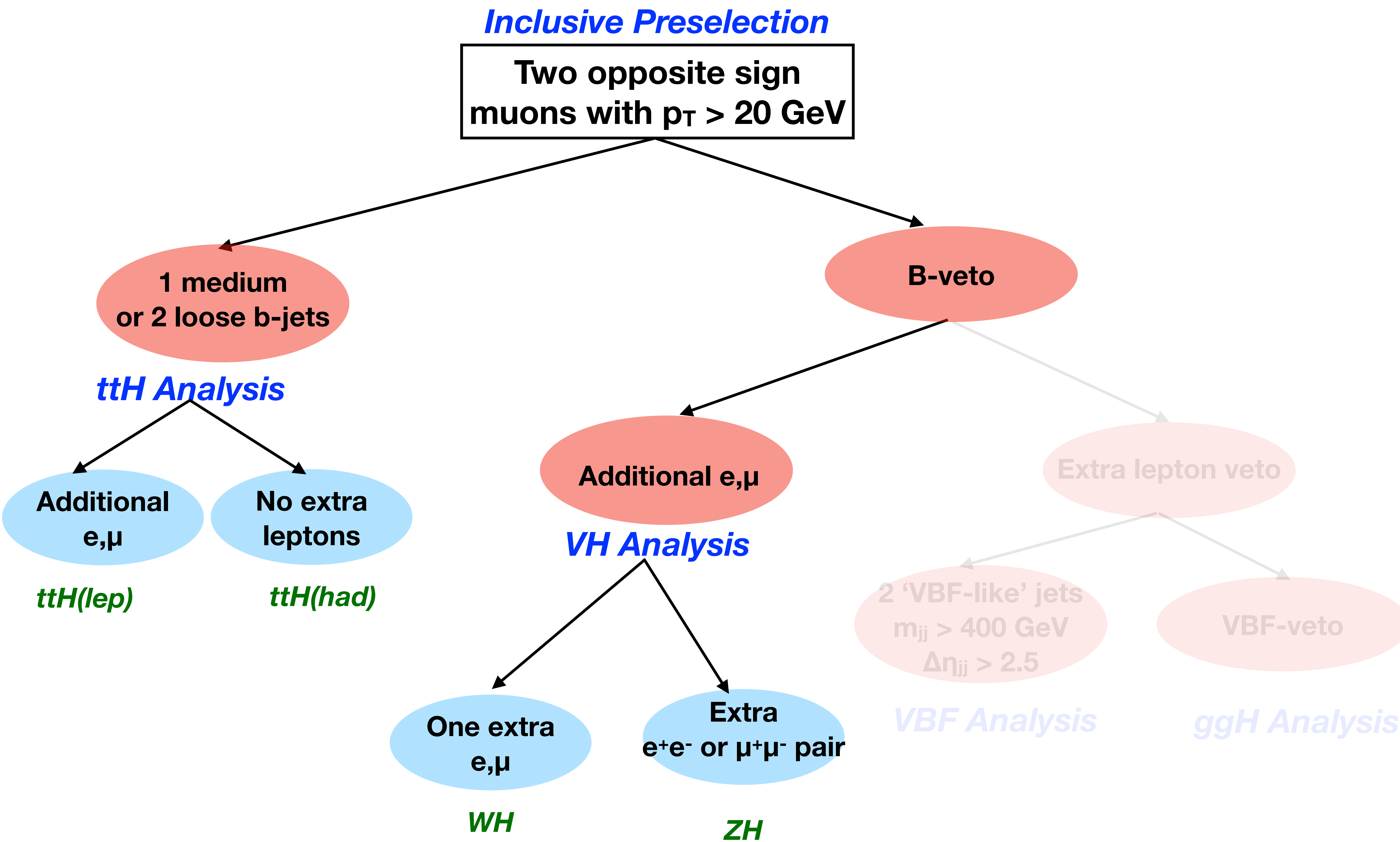

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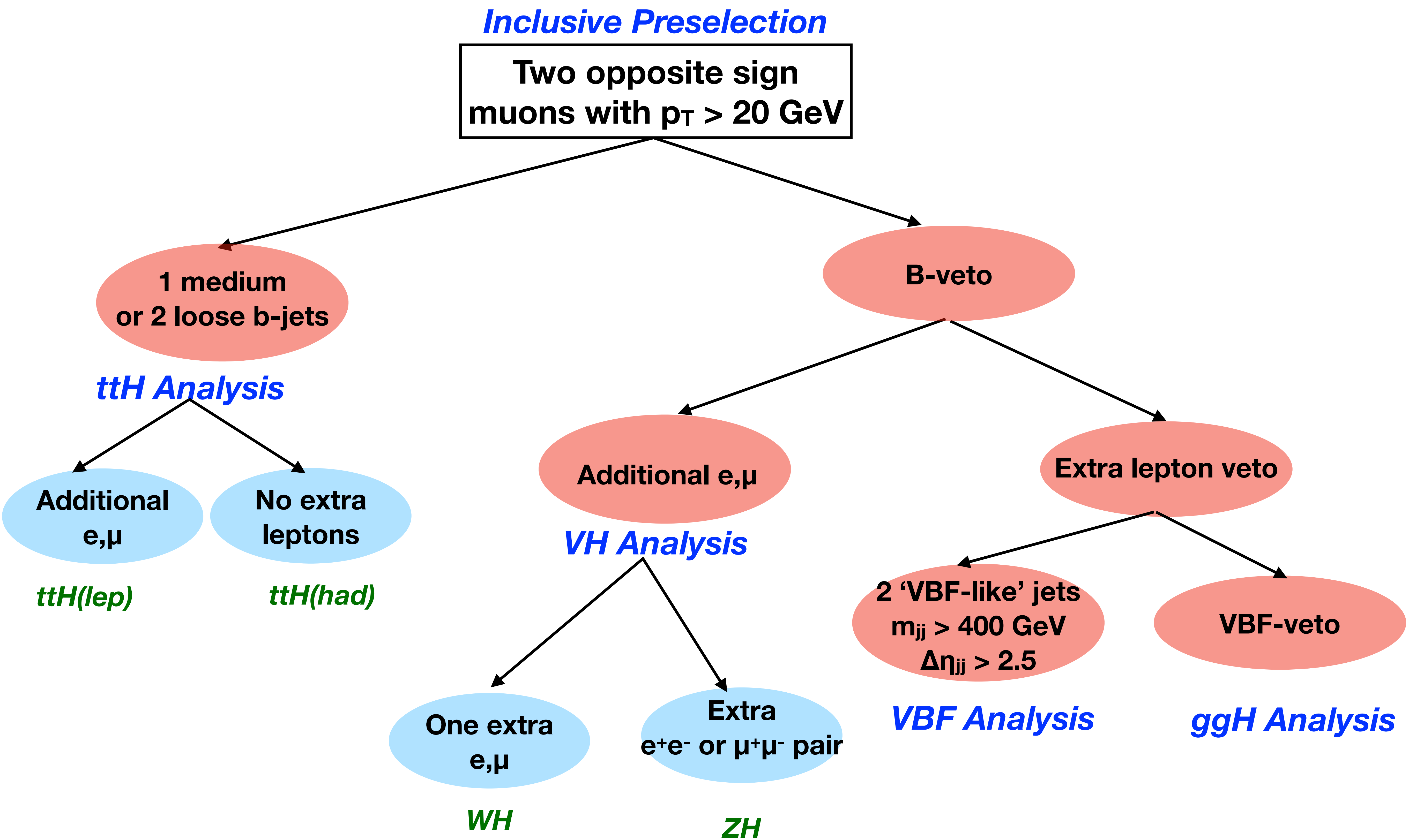
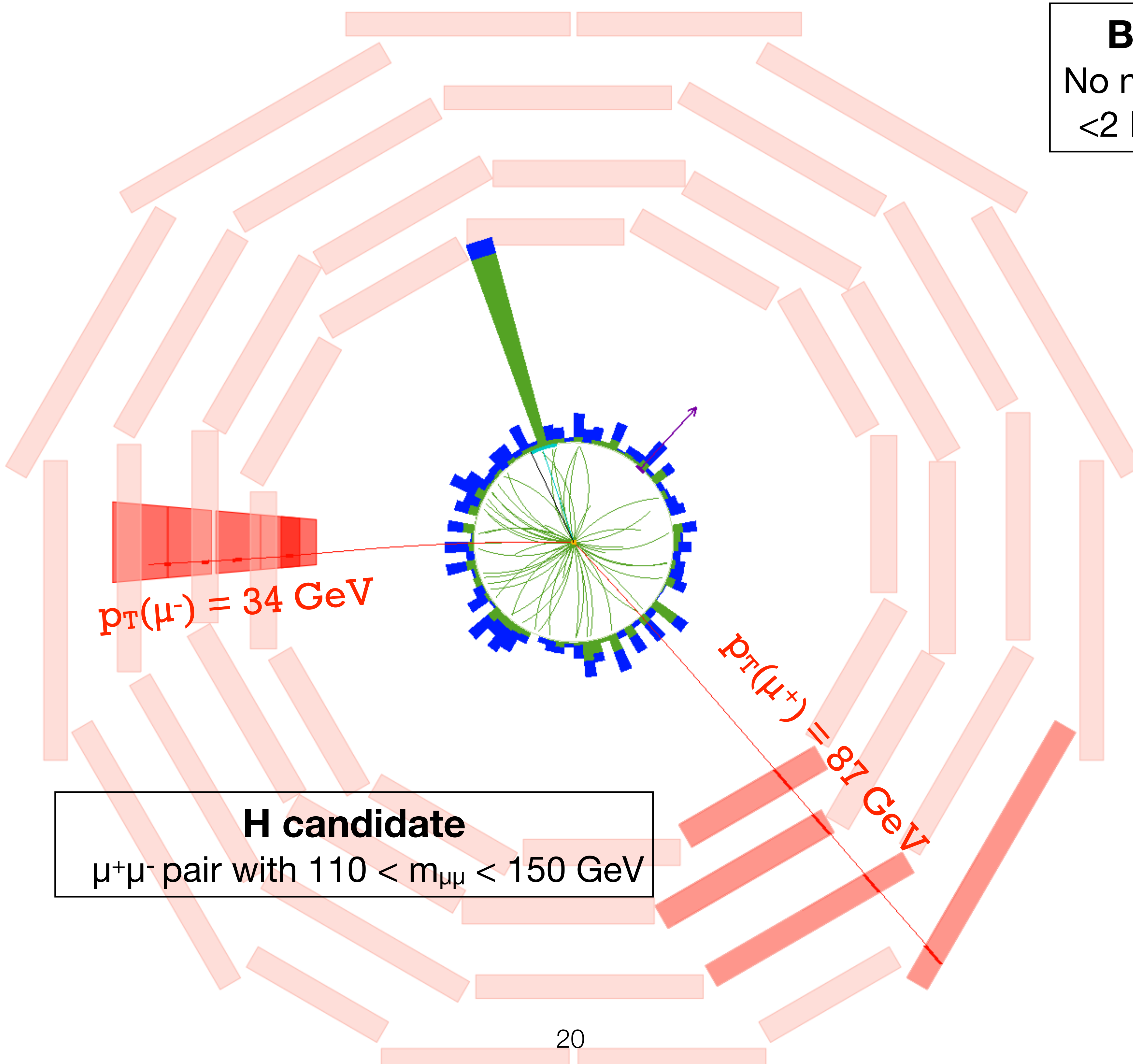


VH Analysis

WH Event

B-jet veto
No medium b-jet
<2 loose b-jets



H candidate
$\mu^+\mu^-$ pair with $110 < m_{\mu\mu} < 150$ GeV

20

WH Event

B-jet veto
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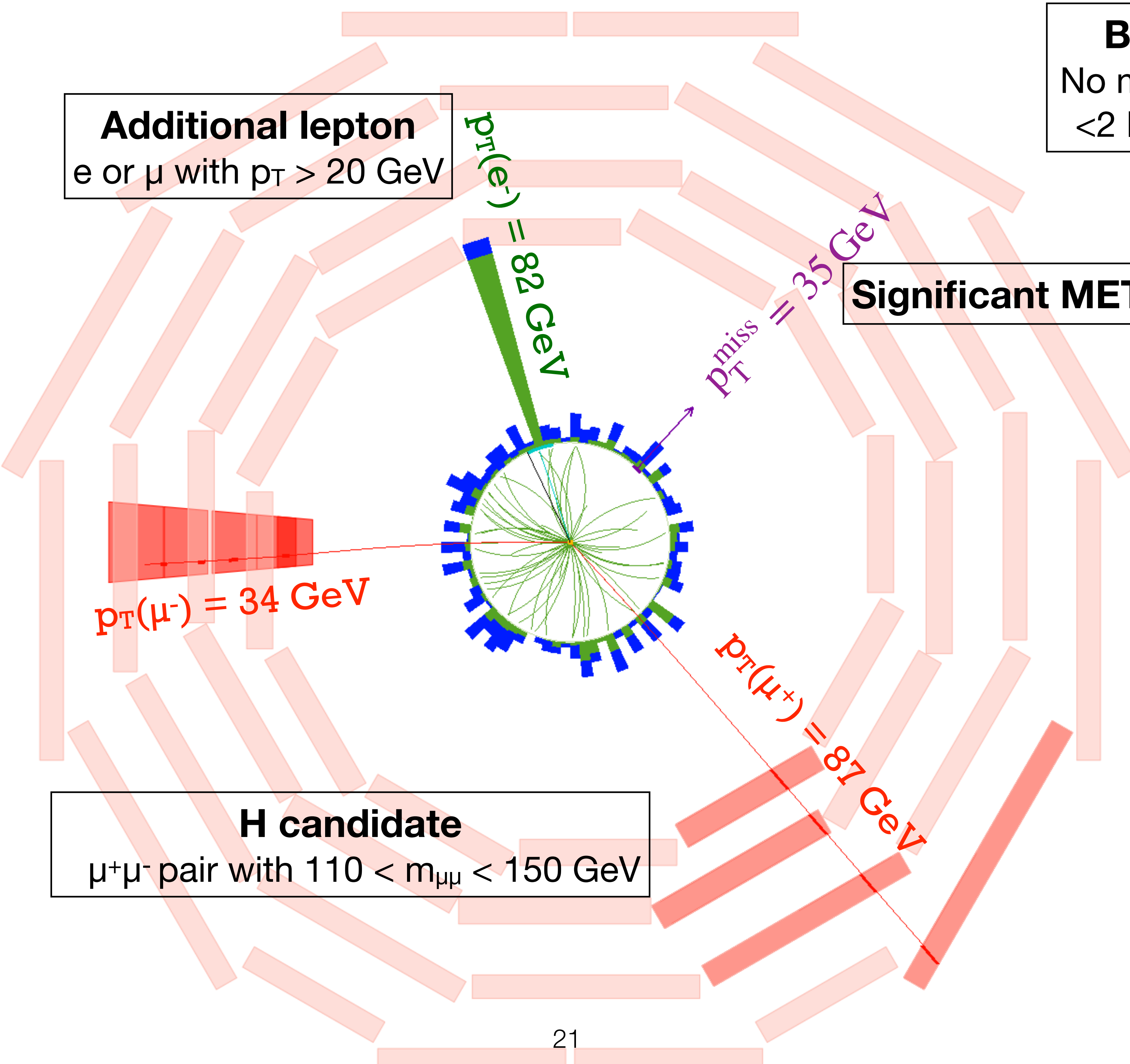
Additional lepton
e or μ with $p_T > 20$ GeV

Significant MET or MHT



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21

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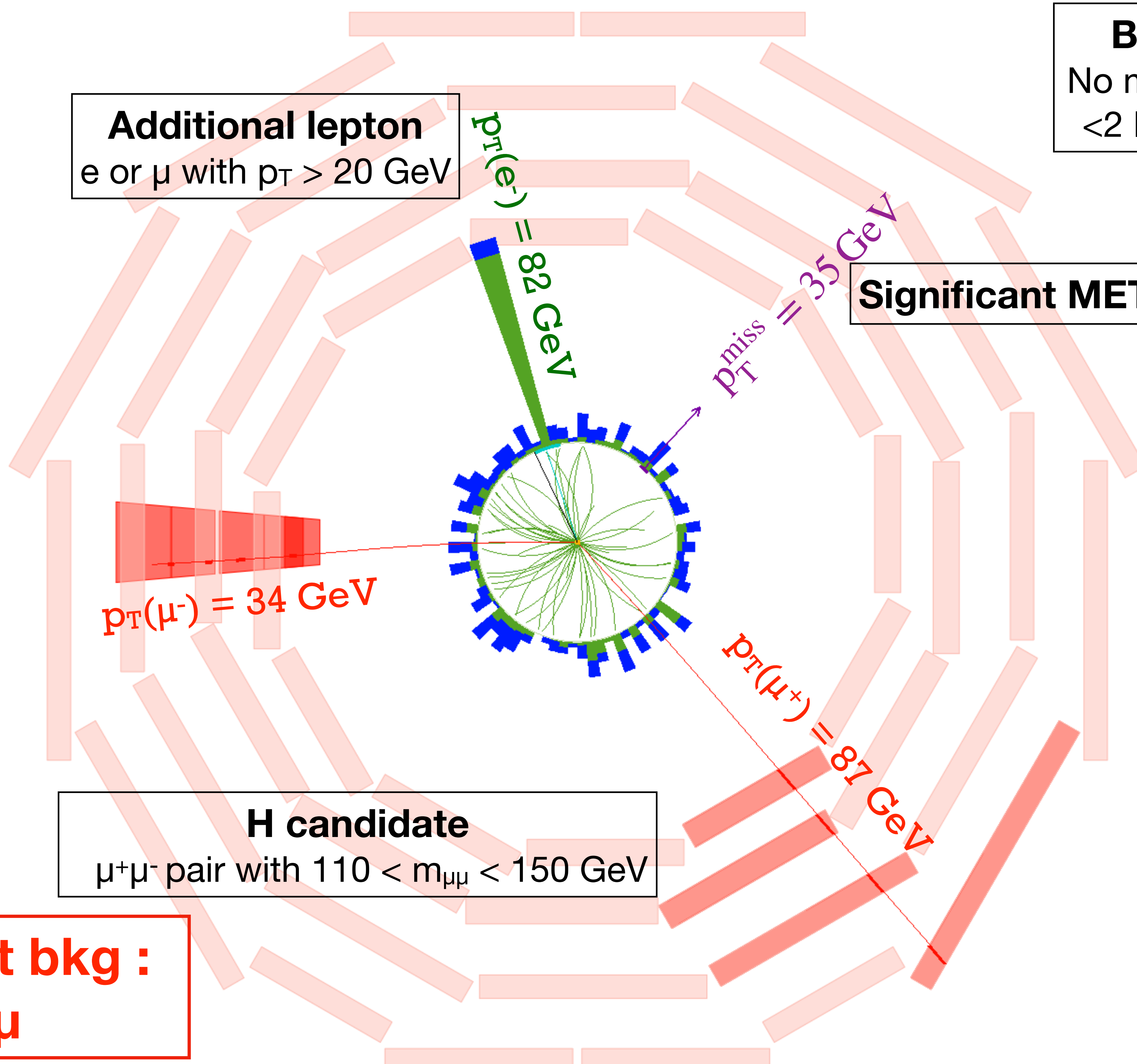

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Dominant bkg :
$WZ \rightarrow \ell\nu 2\mu$

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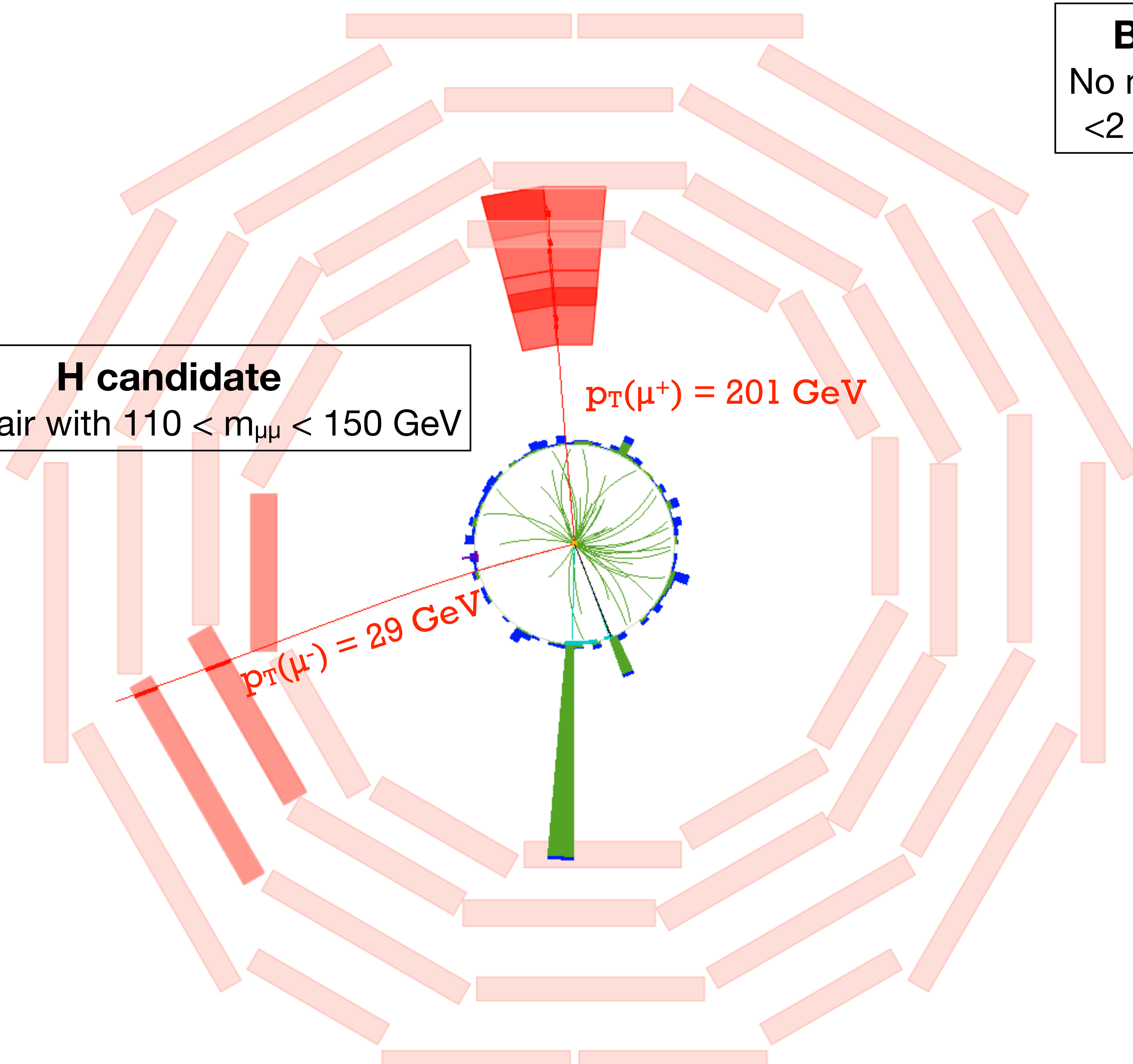

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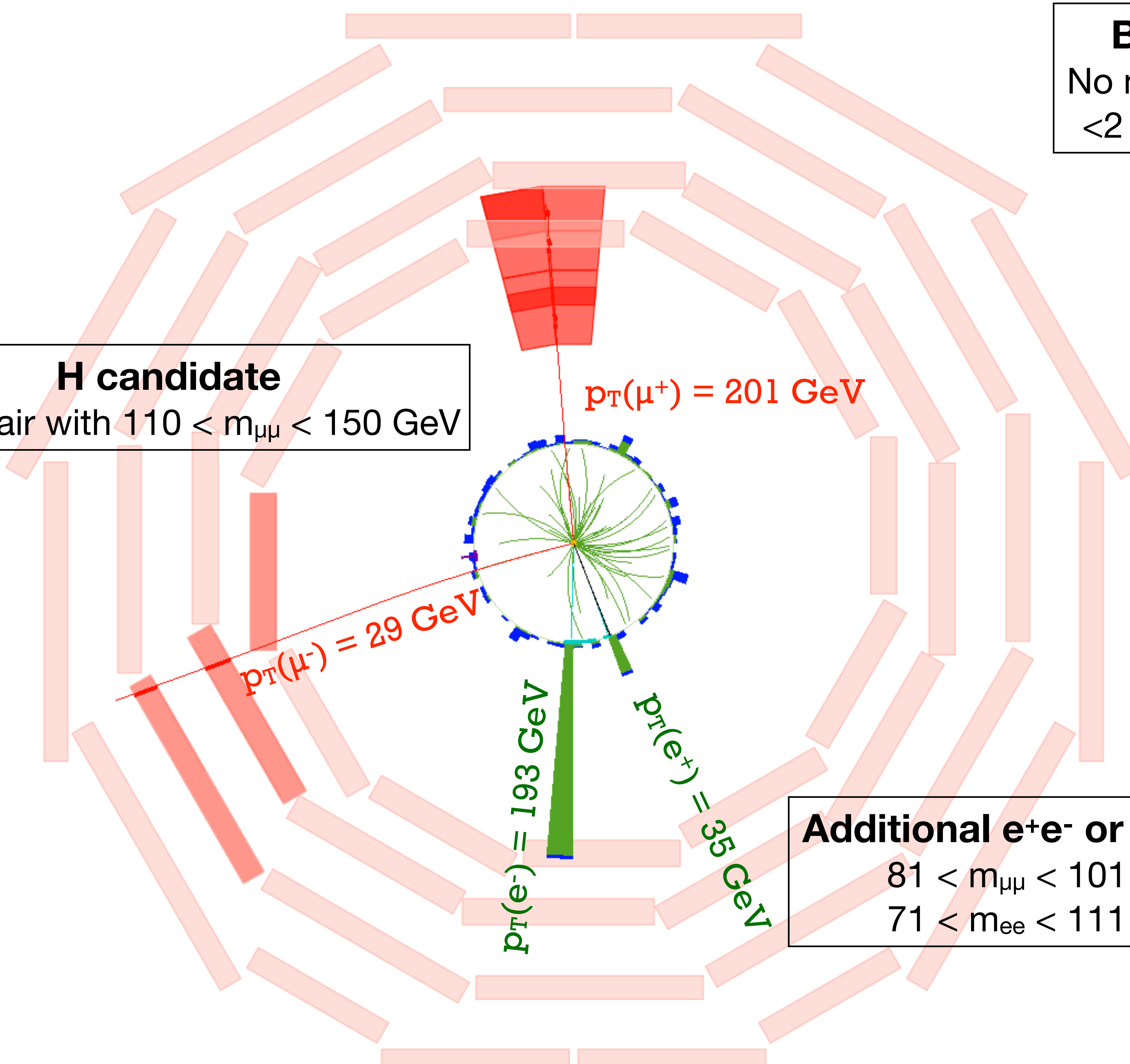

Additional e^+e^- or $\mu^+\mu^-$ pair
$81 < m_{\mu\mu} < 101$ GeV
$71 < m_{ee} < 111$ GeV

ZH Event

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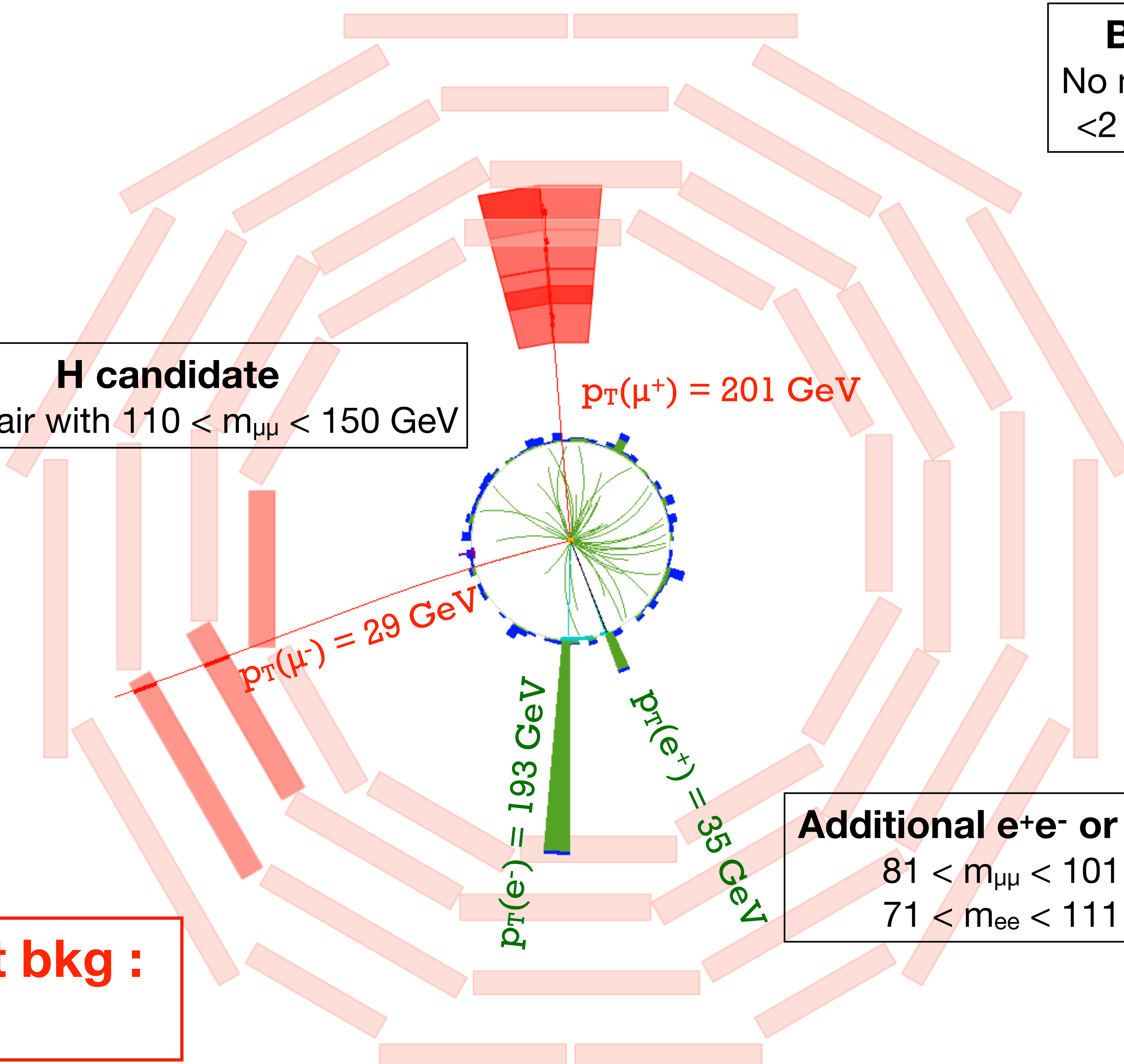

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Dominant bkg :
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Divide-n-Fit

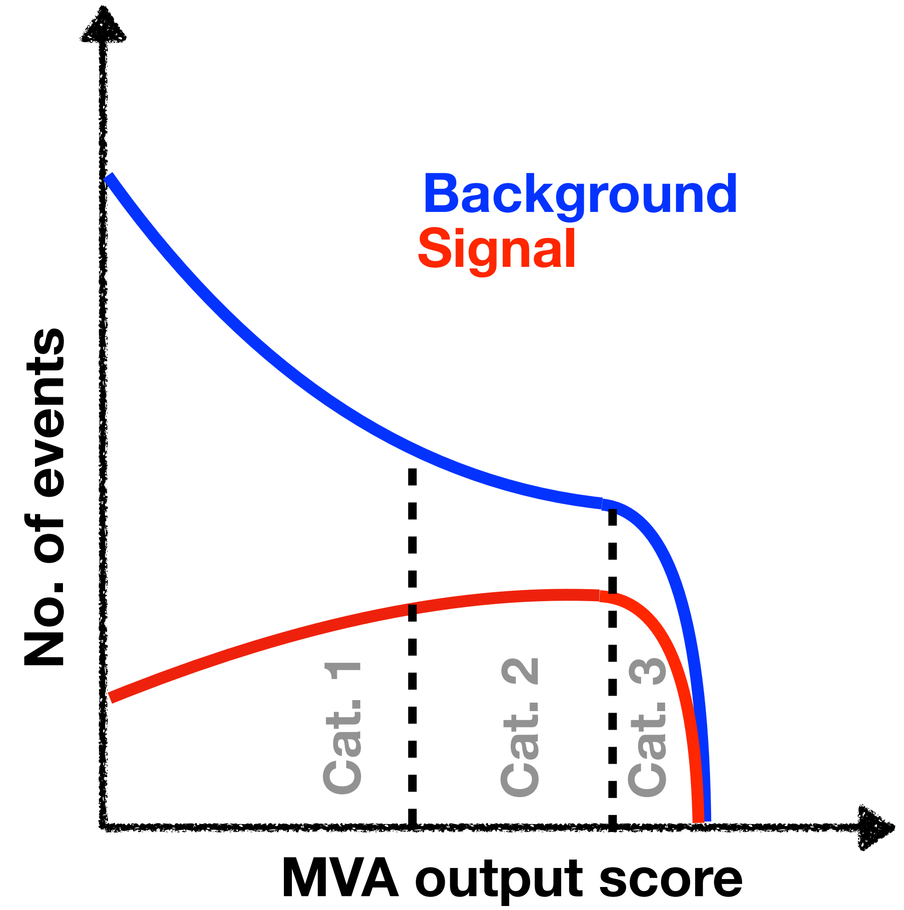
Use the divide-n-fit strategy to enhance analysis performance

Train signal v/s bkg. multivariate (BDT) classifier

- Exploit full kinematic information of the event
- Input variables chosen to be uncorrelated with H candidate mass
- Signal events weighted by $1/\sigma_m$ to give high resolution events more signal-like MVA score

Divide events into categories based on the classifier output

- Several subcategories with varying signal purity



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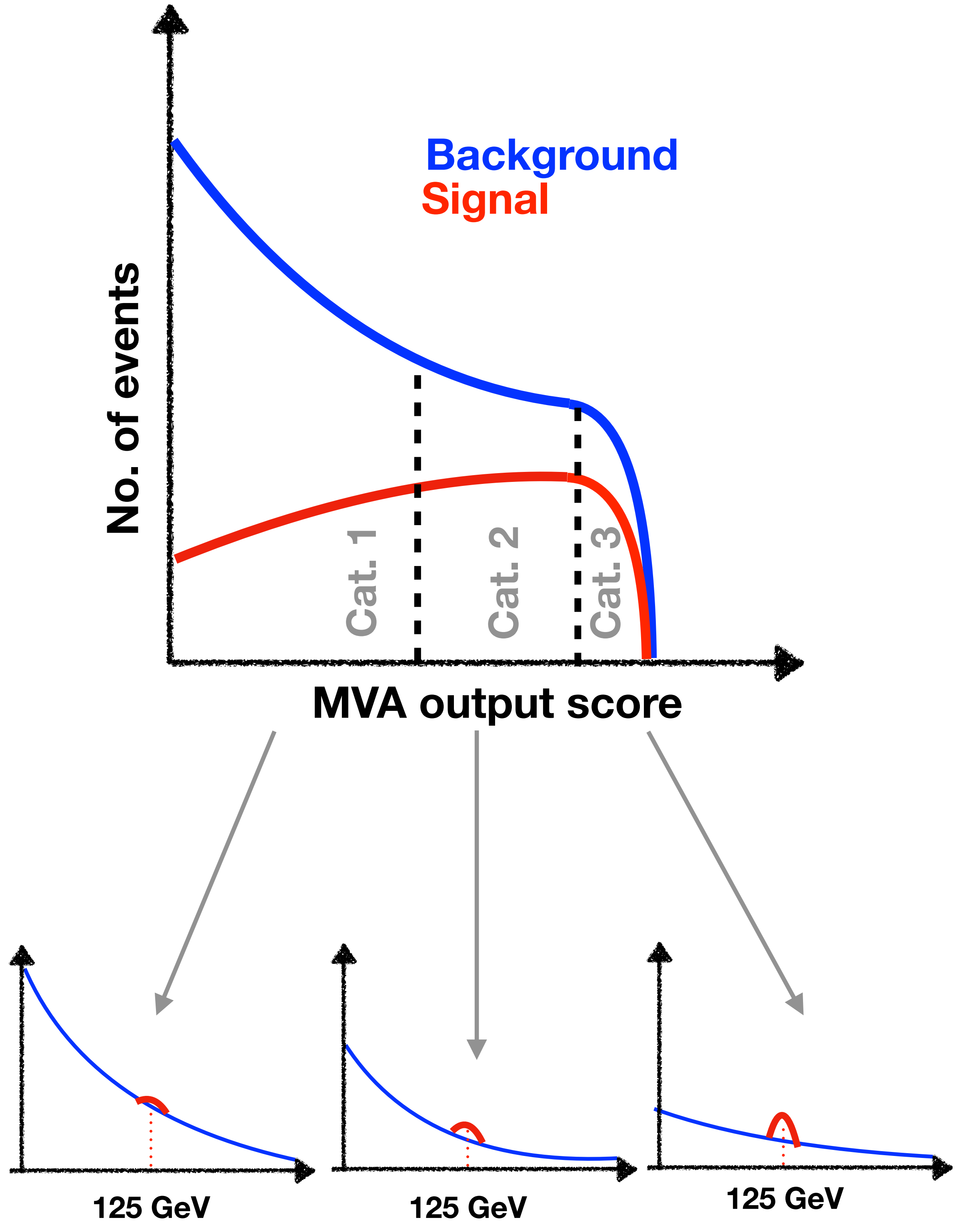
Fit the dimuon mass distribution in each subcategory to extract the signal

- Signal and background modeled using parametric functions
- Completely data-driven background prediction

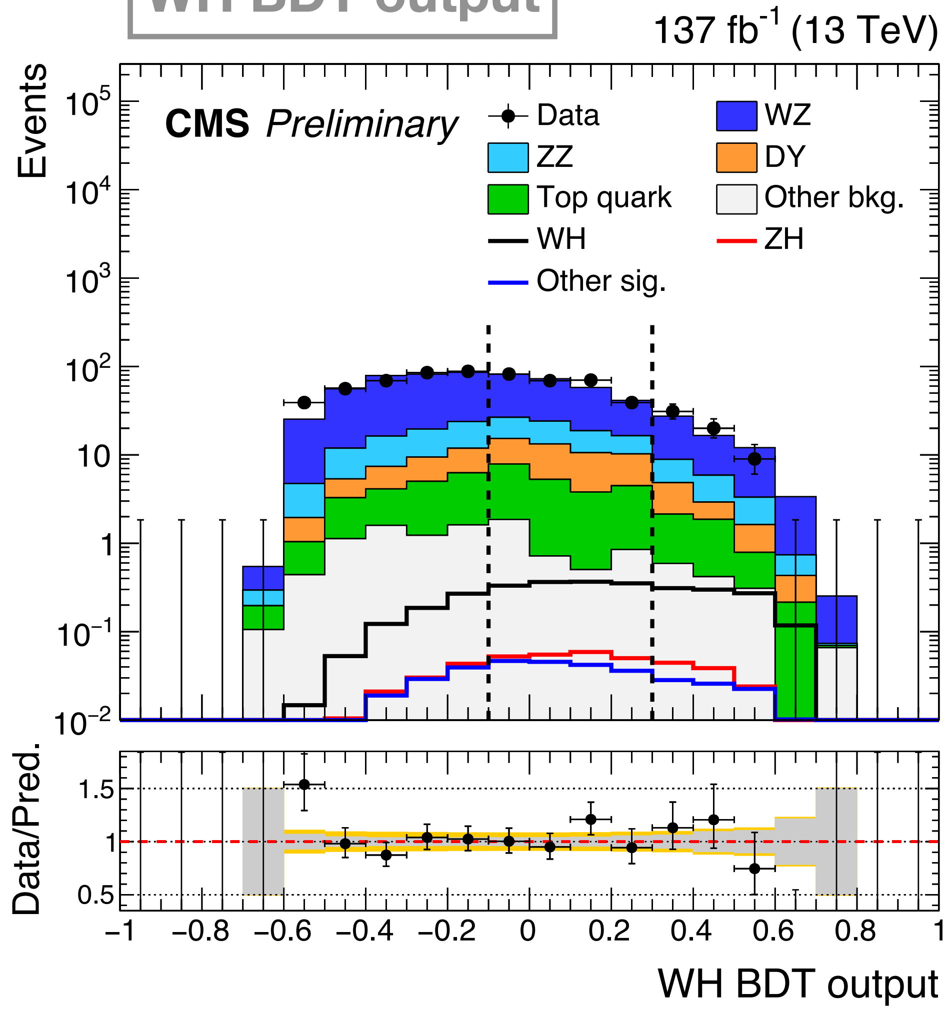


VH Analysis

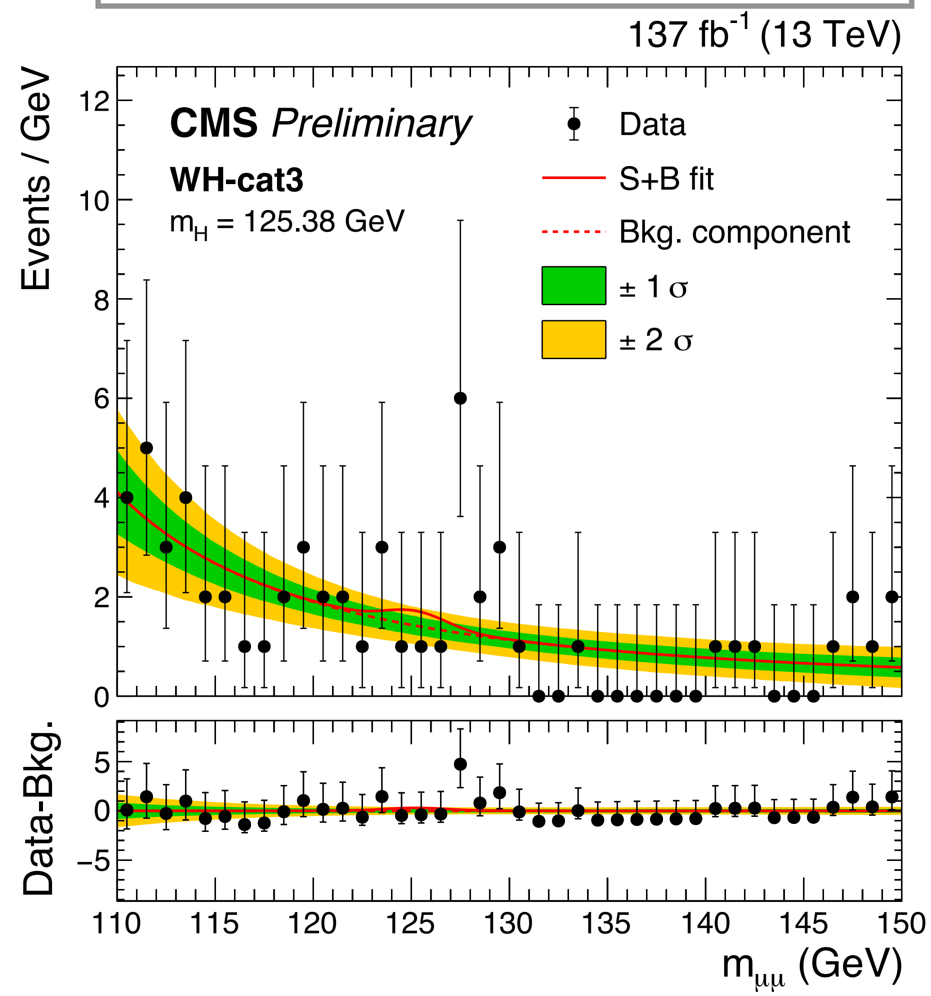
Inputs to WH and ZH BDT classifiers

- H candidate kinematics : Dimuon p_T, η, Δϕ(μμ), …
- WH kinematics : $p_T(\ell_W)$, $\Delta\eta(\ell_W,H)$, $\Delta\phi(\ell_W,H)$, $M_T(\ell_W,MHT)$, …
- ZH kinematics : Z p_T, η, m_Z, Δη(Z,H), Δϕ(Z,H), cosθ*(Z,H), …

WH BDT output



highest purity WH subcategory

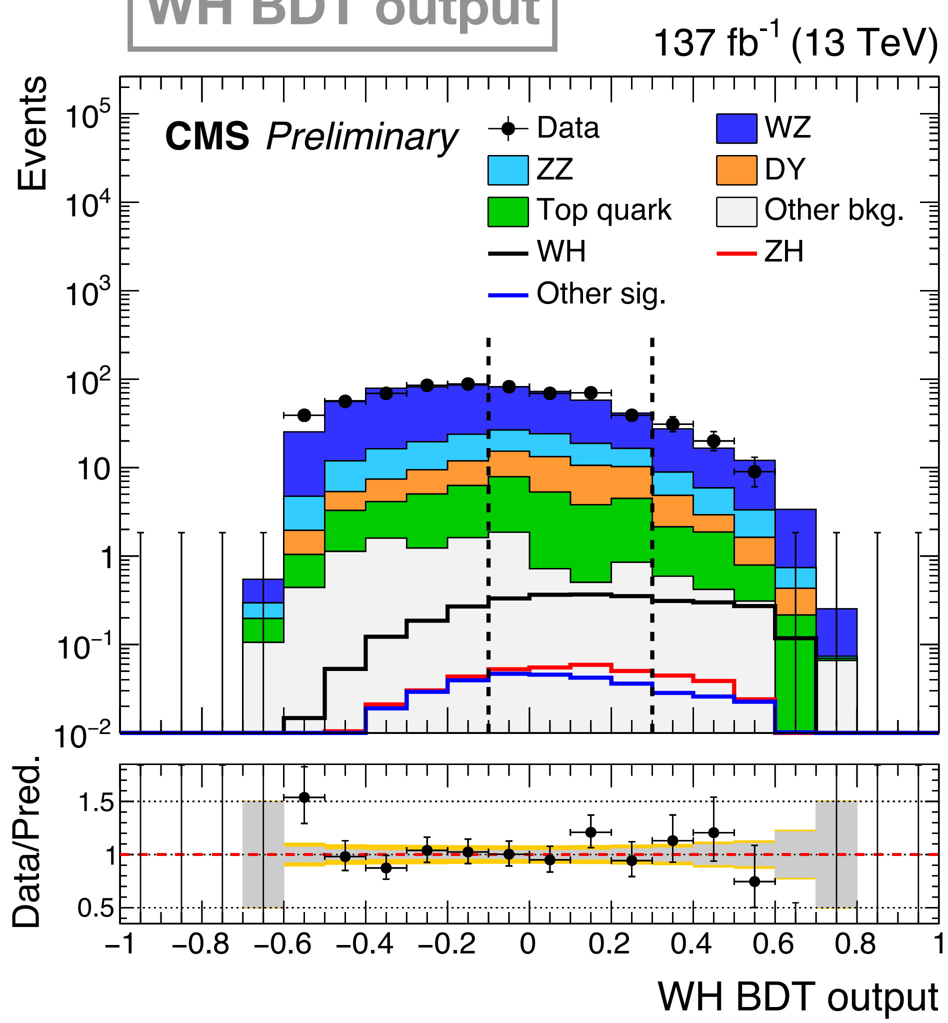


VH Analysis

Inputs to WH and ZH BDT classifiers

- H candidate kinematics : Dimuon p_T, η, $\Delta\phi(\mu\mu)$, …
- WH kinematics : $p_T(\ell_W)$, $\Delta\eta(\ell_W,H)$, $\Delta\phi(\ell_W,H)$, $M_T(\ell_W,MHT)$, …
- ZH kinematics : Z p_T, η, m_Z, $\Delta\eta(Z,H)$, $\Delta\phi(Z,H)$, $\cos\theta^*(Z,H)$, …

WH BDT output



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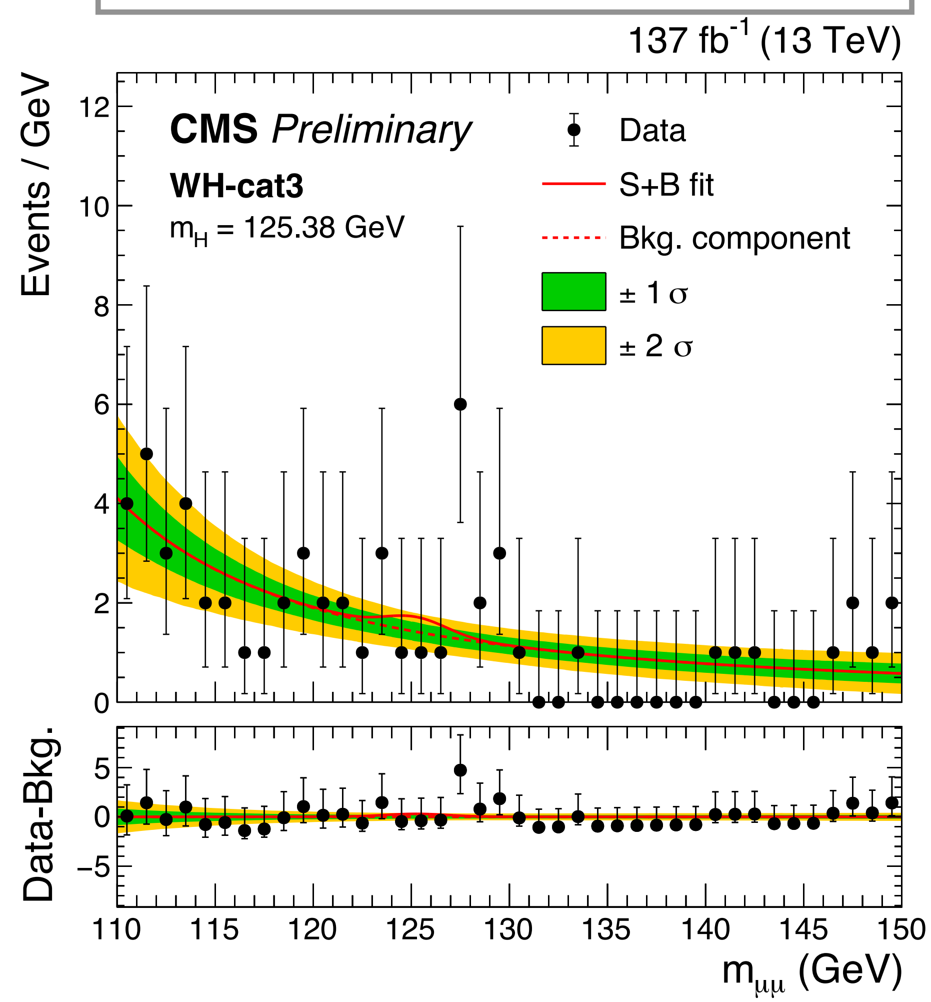
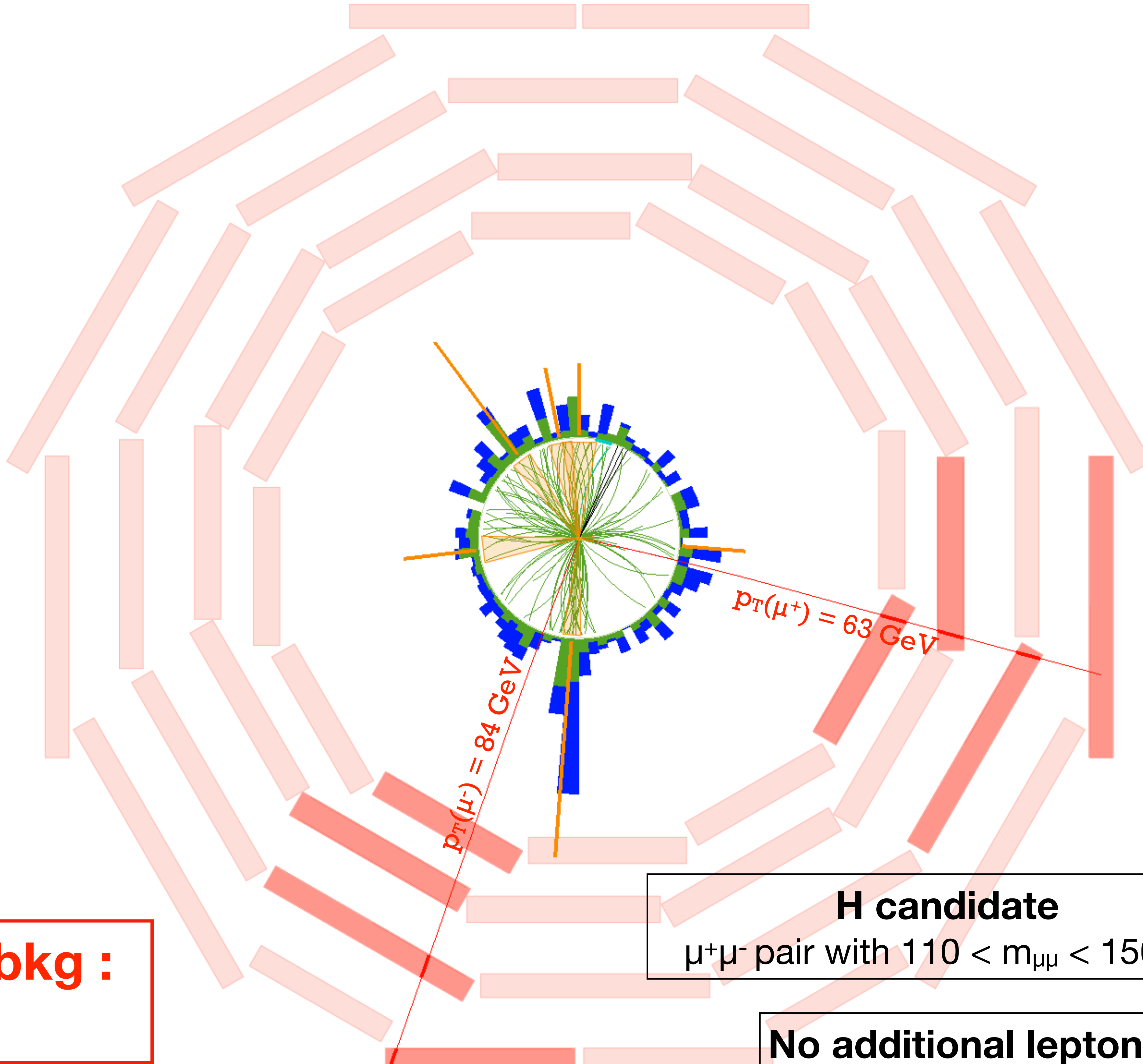


Combined WH & ZH results → **Obs (exp) significance : 2.0 (0.4)σ**

Signal Strength $\mu = 5.48^{+3.10}_{-2.83}$

ttH Analysis

ttH (Hadronic)



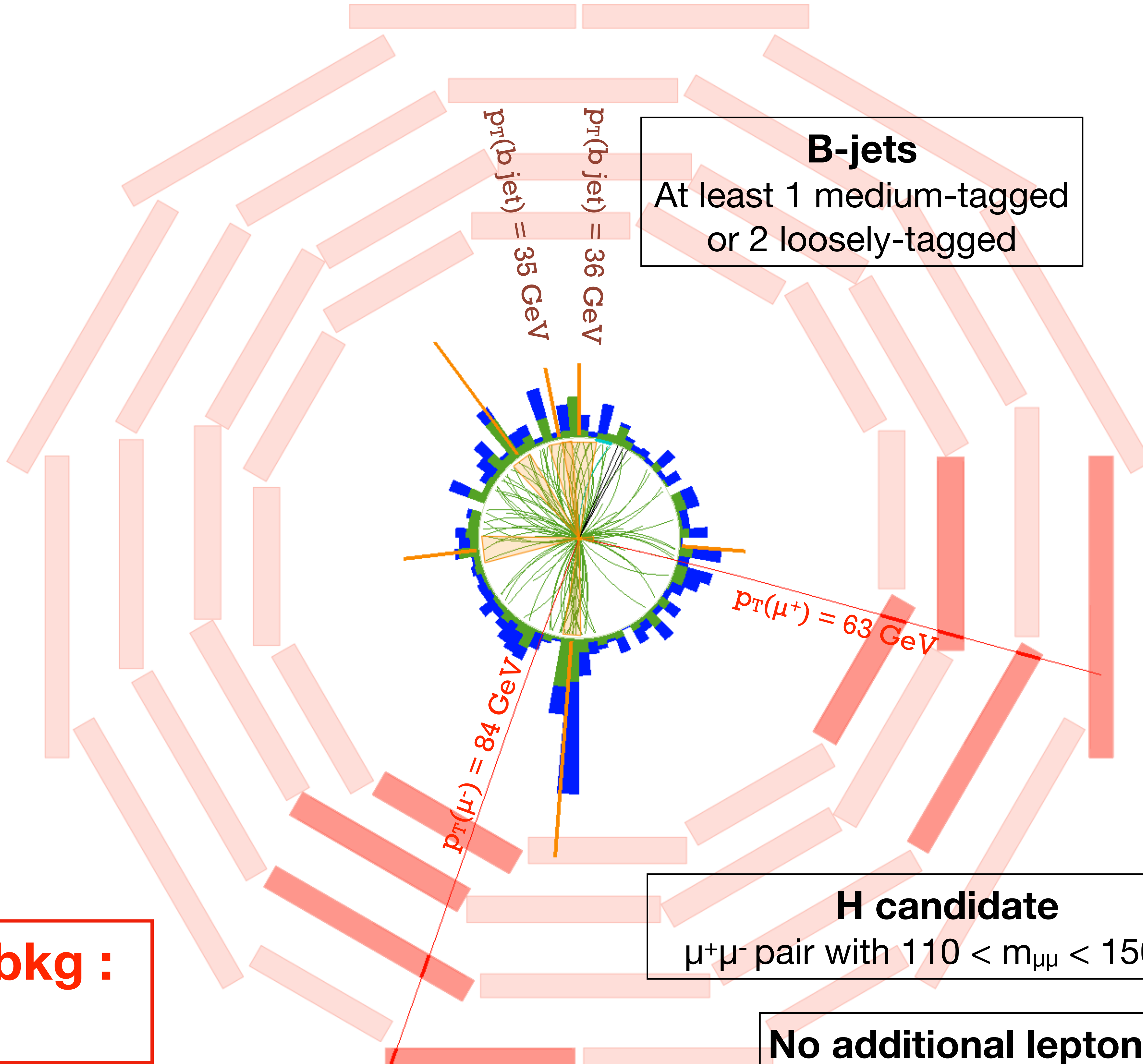
H candidate

$\mu^+\mu^-$ pair with $110 < m_{\mu\mu} < 150$ GeV

No additional leptons

Dominant bkg : tt+jets

ttH (Hadronic)



B-jets
At least 1 medium-tagged or 2 loosely-tagged

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No additional leptons

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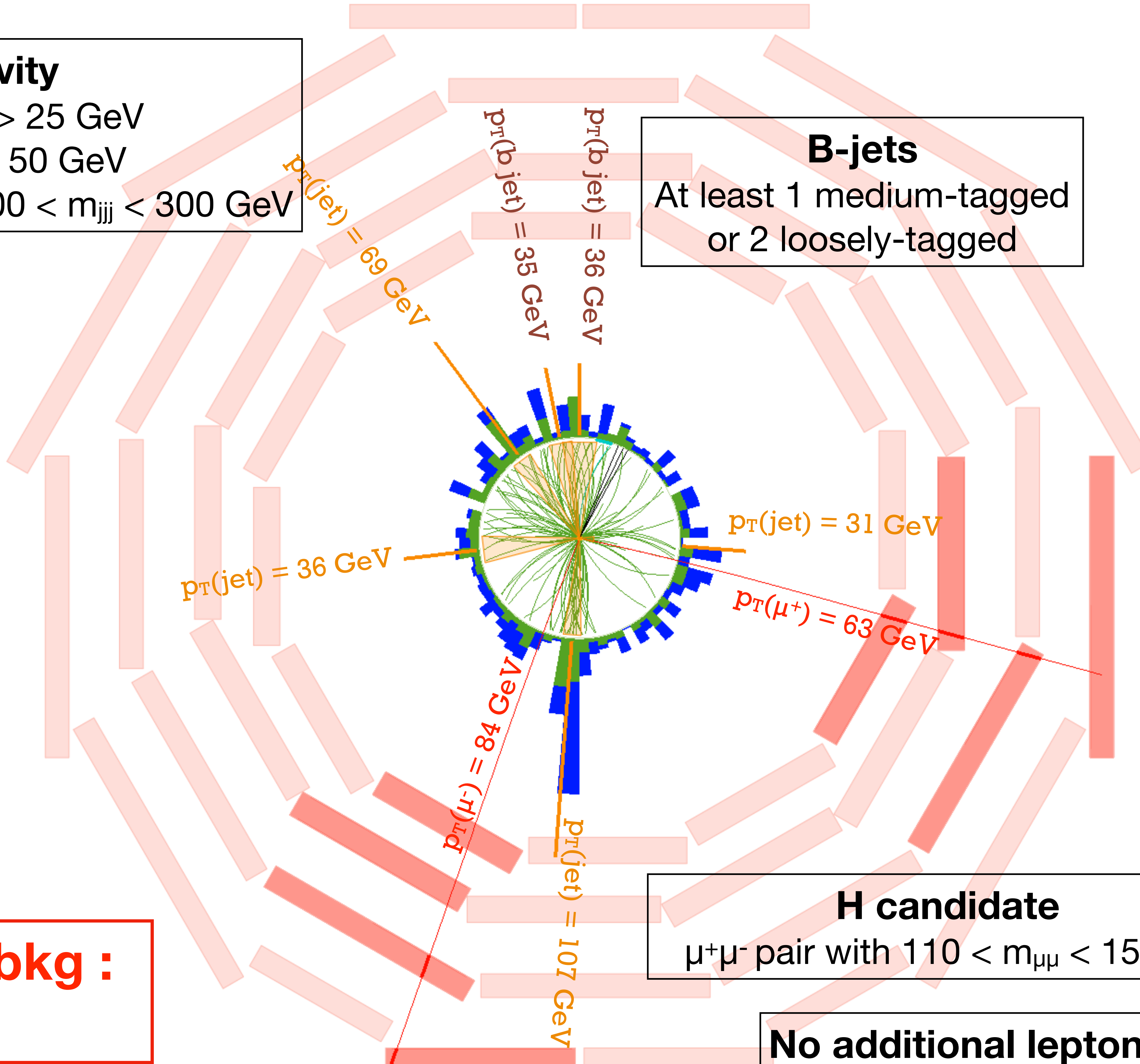
ttH (Hadronic)

Hadronic activity
≥ 3 jets with p_T > 25 GeV
Leading jet p_T > 50 GeV
≥ 1 jet triplet: 100 < m_{jjj} < 300 GeV

B-jets
At least 1 medium-tagged or 2 loosely-tagged



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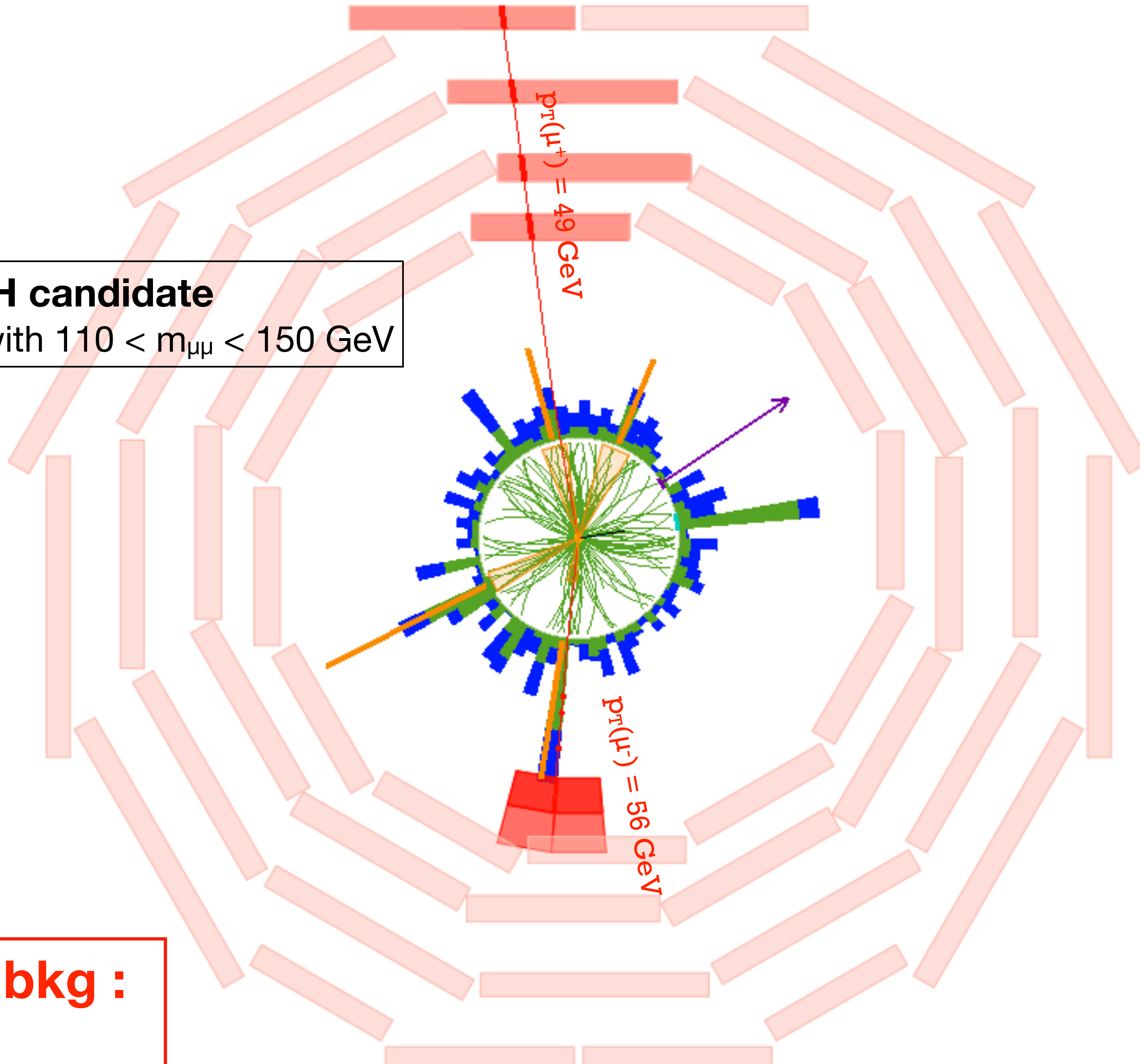
ttH (Leptonic)



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Dominant bkg : tt, ttZ

ttH (Leptonic)

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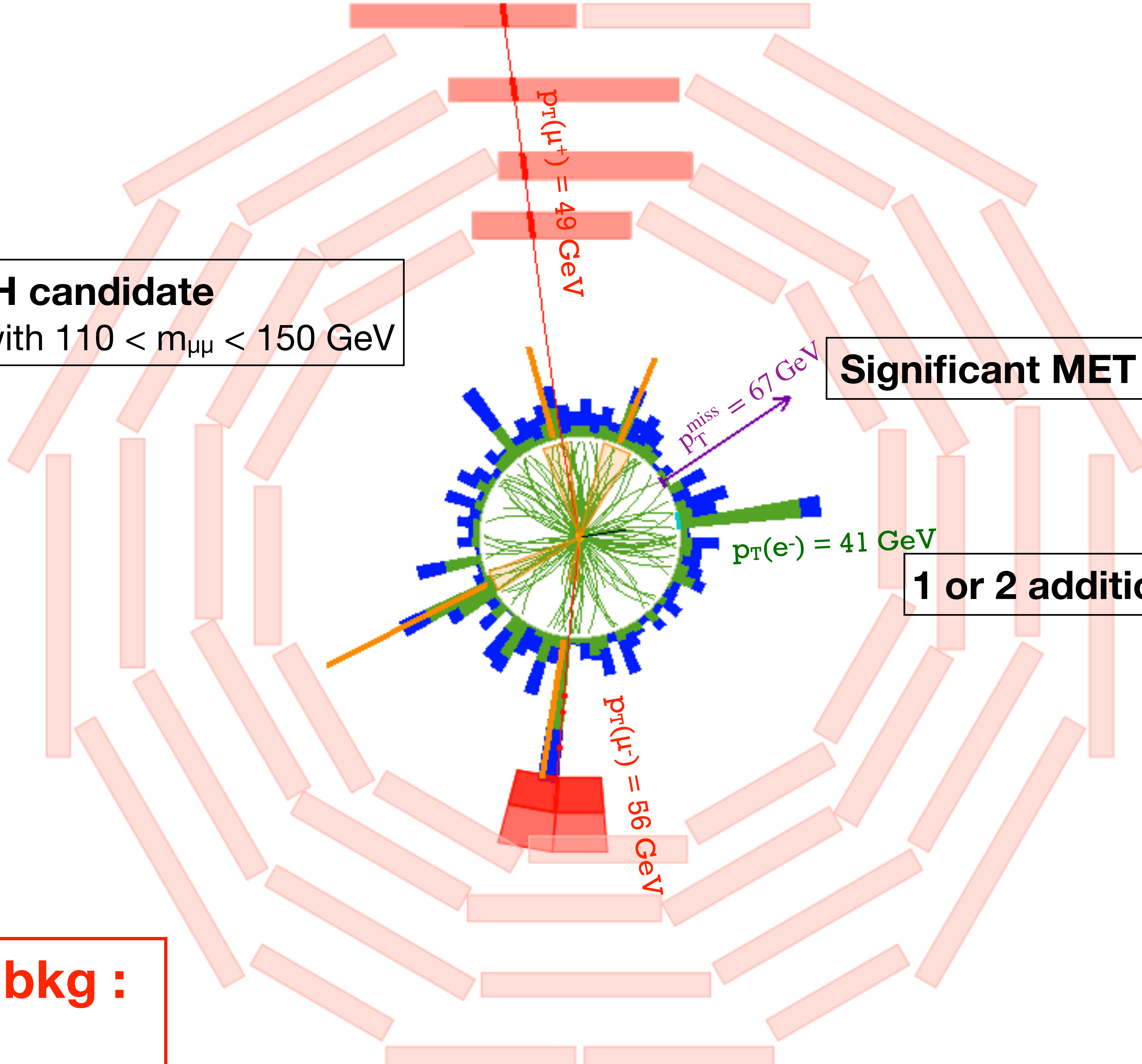
Significant MET

1 or 2 additional e,μ



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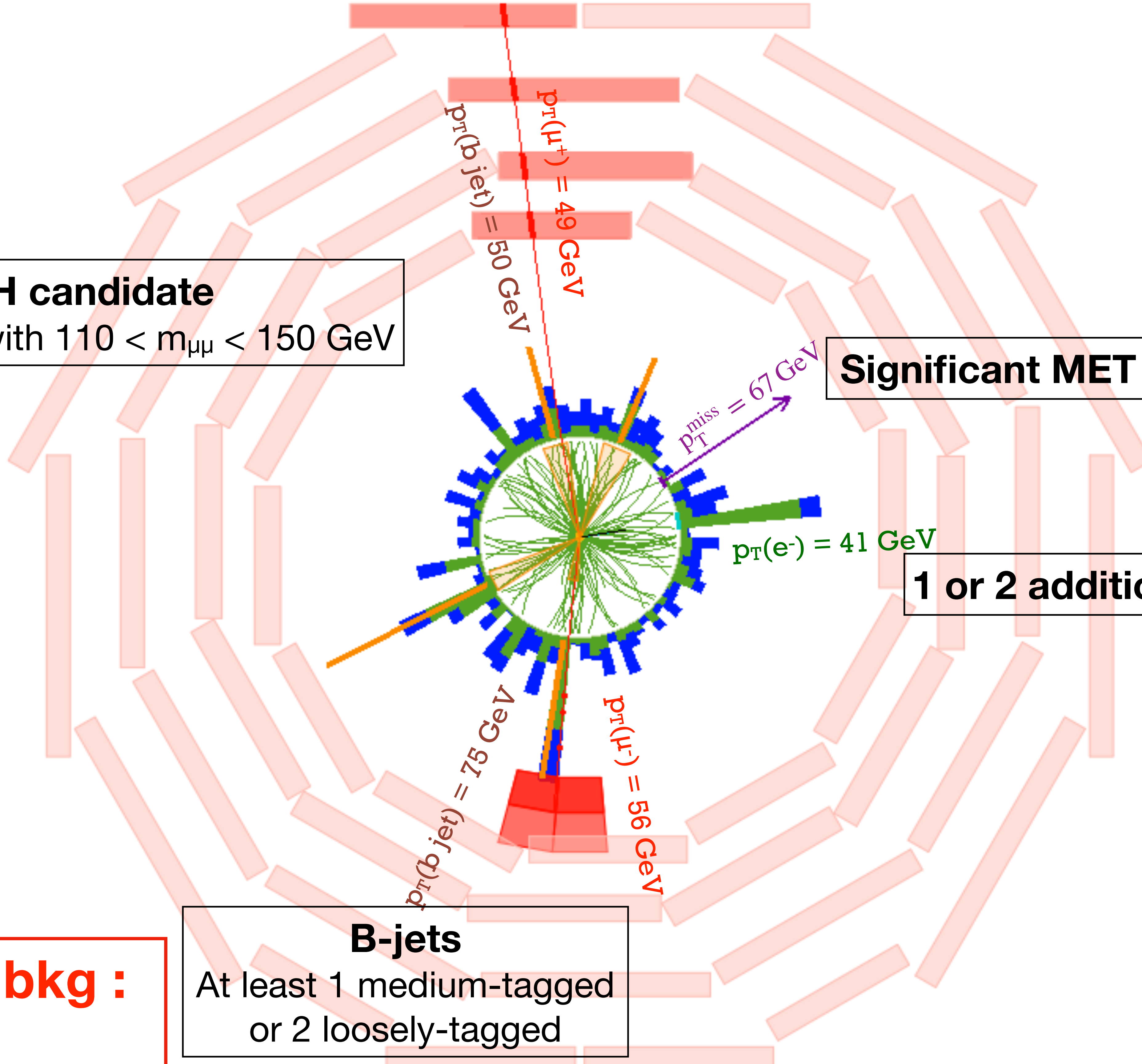

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B-jets
At least 1 medium-tagged
or 2 loosely-tagged

Dominant bkg :
tt, ttZ

ttH (Leptonic)

Hadronic activity
≥ 2 jets with p_T > 25 GeV

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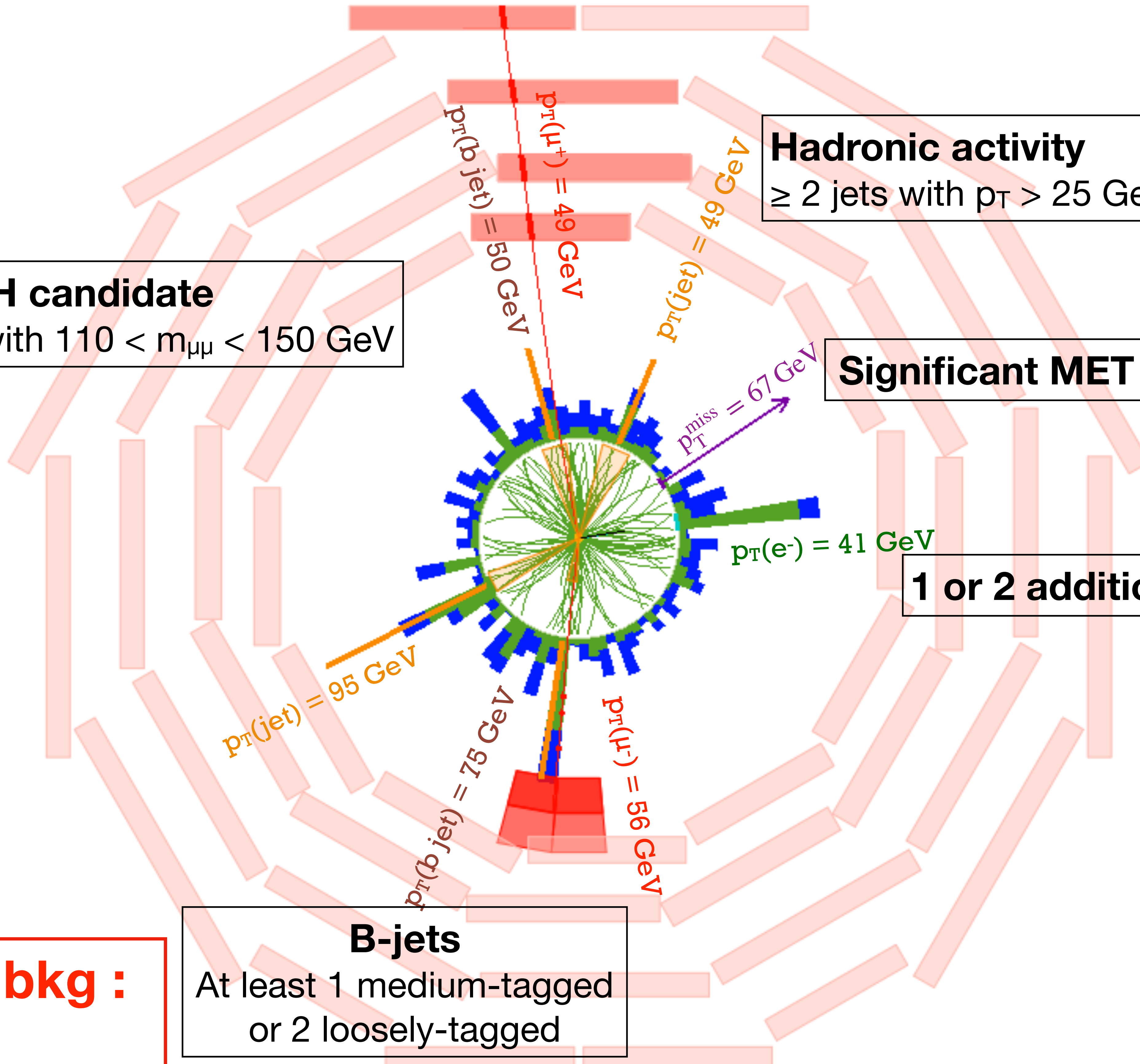


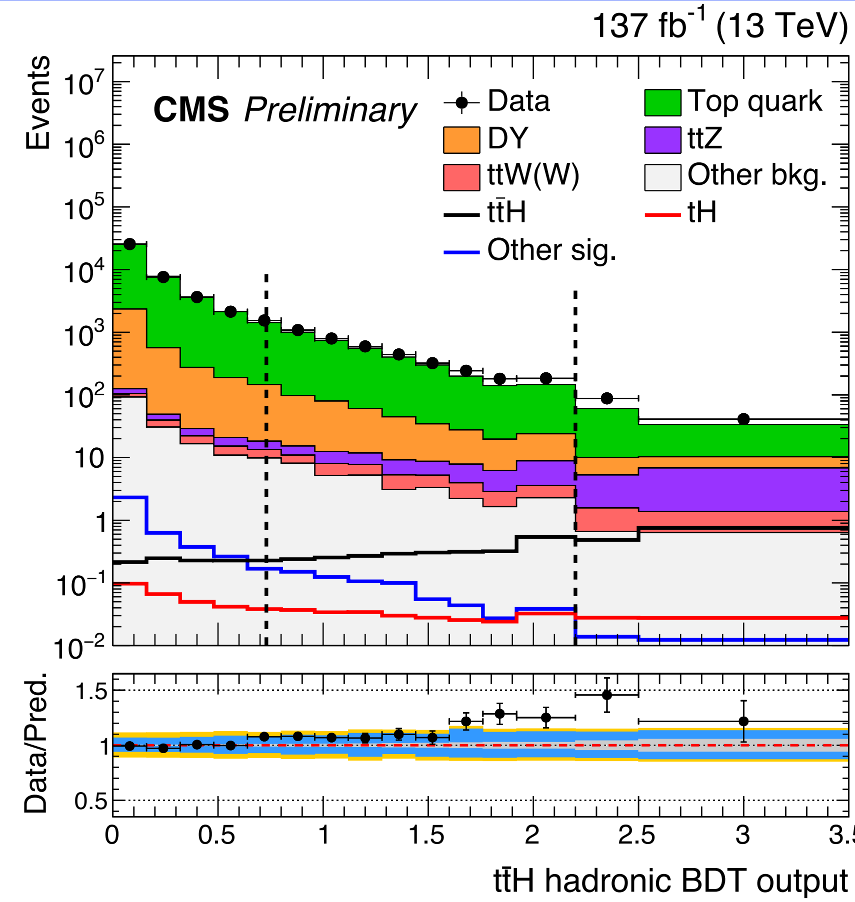
B-jets
At least 1 medium-tagged
or 2 loosely-tagged

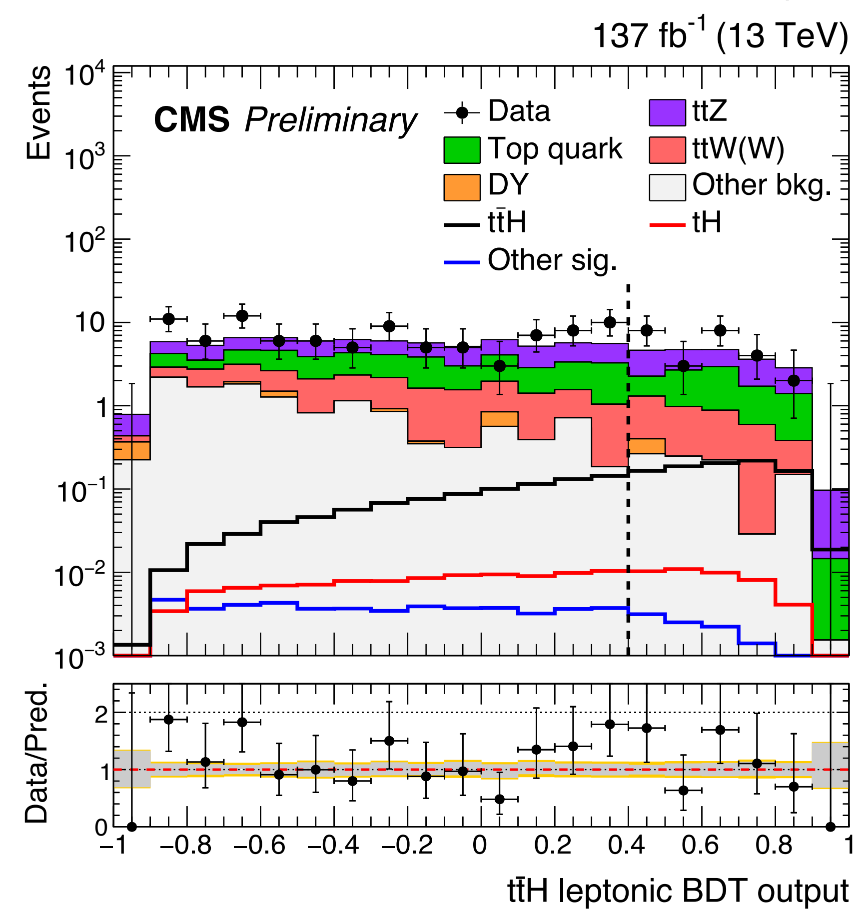
Dominant bkg :
tt, ttZ

ttH BDT Classifiers

Adopt the divide-n-fit strategy

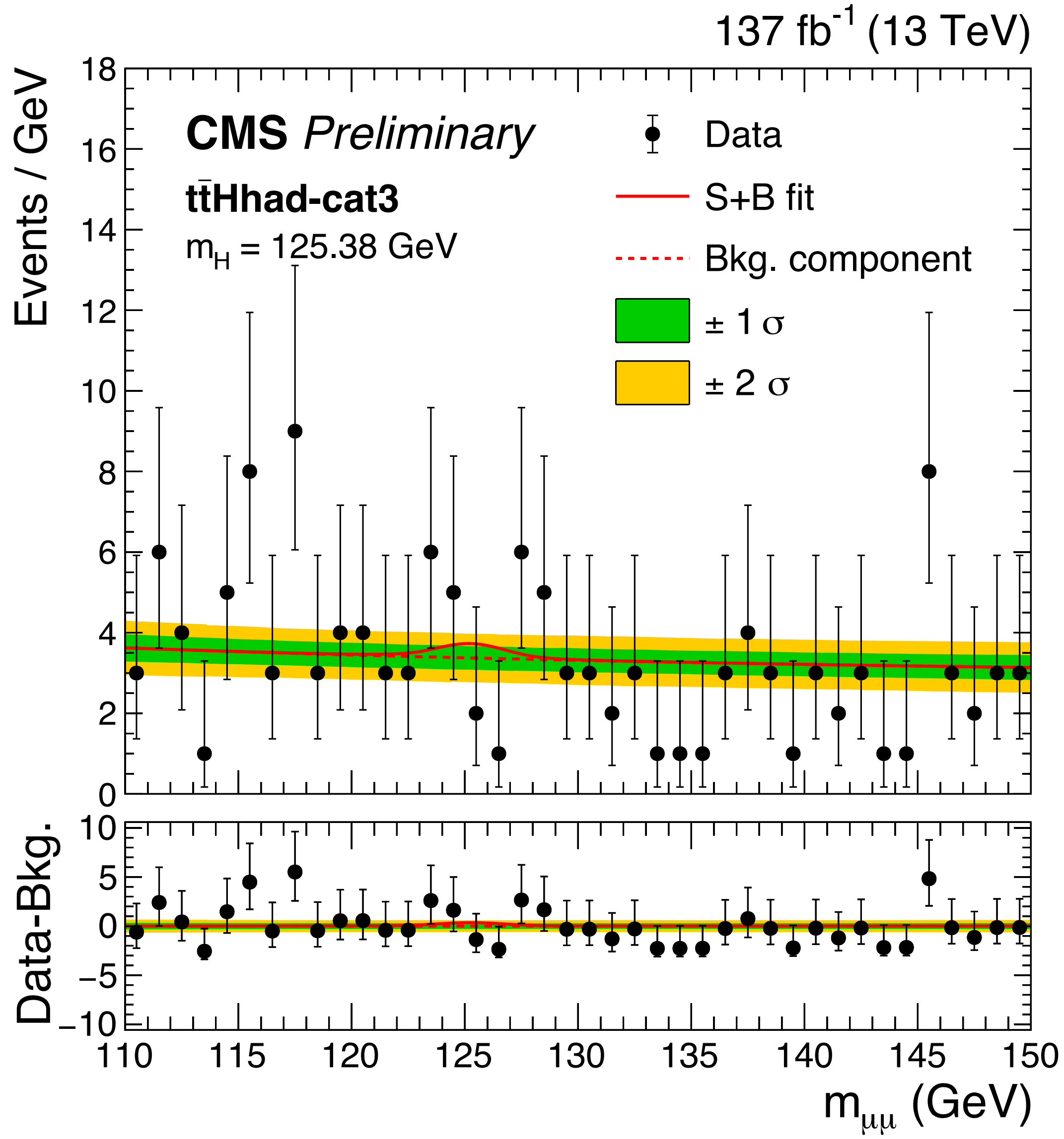
- **Common inputs to BDT classifiers:**
  - ➡ Dimuon p_T & rapidity, decay angles ϕ_{CS}, $\cos\theta_{CS}$, ….
  - ➡ MET, H_T, numbers of jets ….
- **Inputs specific to ttH (hadronic)**
  - ➡ p_T, η of the three leading jets
  - ➡ Top candidate (T): Jet triplet having max. Resolved Hadronic Top Tagger (RHTT) score
    - T p_T, RHTT, p_T balance(H, T) …
- **Inputs specific to ttH (leptonic)**
  - ➡ ℓ^T: Highest p_T additional lepton
  - ➡ $\Delta\phi$(H, ℓ^T), mass(b, ℓ^T), transverse mass (MET, ℓ^T) ….

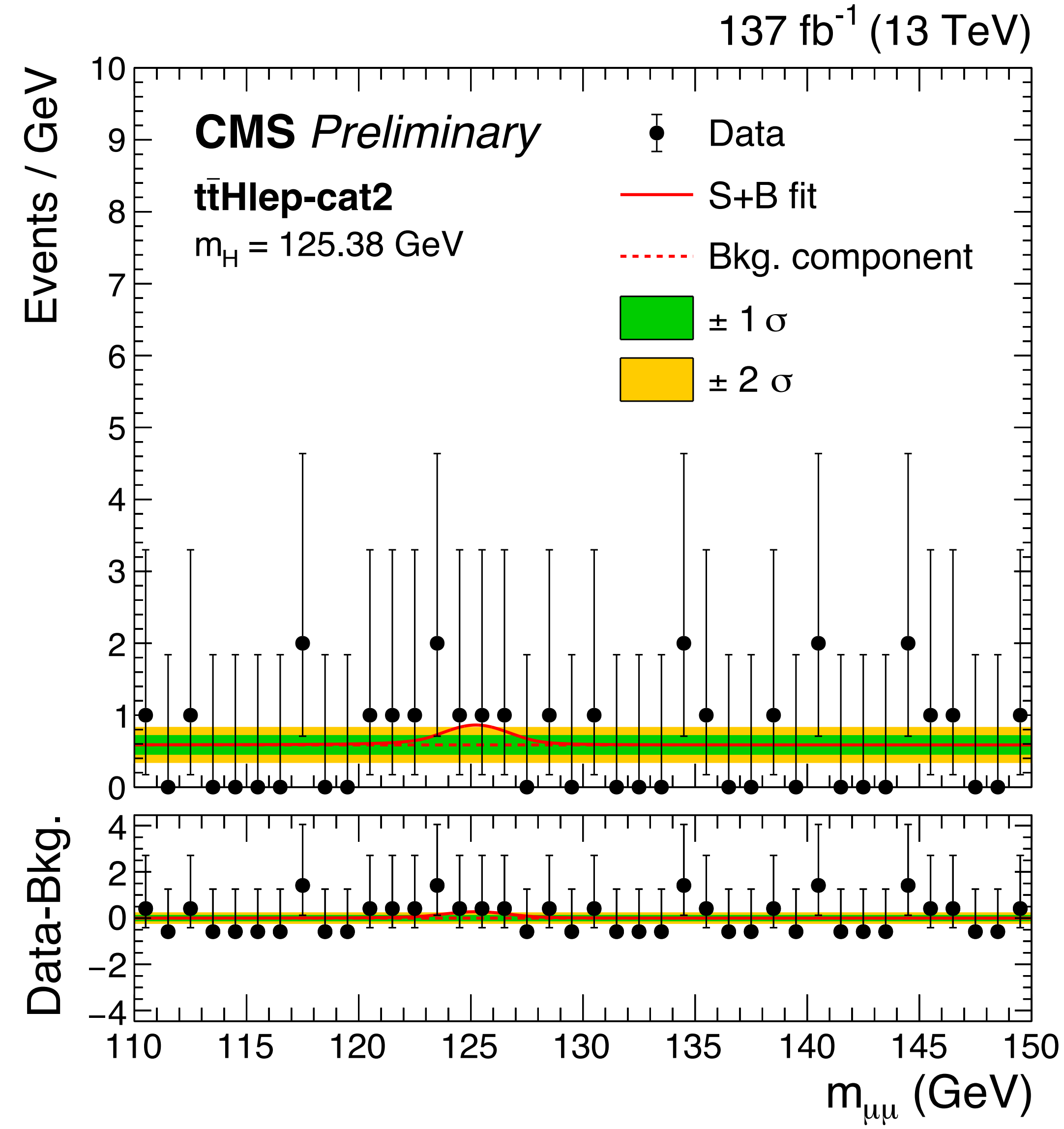




ttH Results

$m_{\mu\mu}$ distributions in the highest purity ttH(had) & ttH(lep) subcategories





Combined ttH results → **Obs (exp) significance : 1.2 (0.5)σ**

Signal Strength $\mu = 2.32^{+2.27}_{-1.95}$

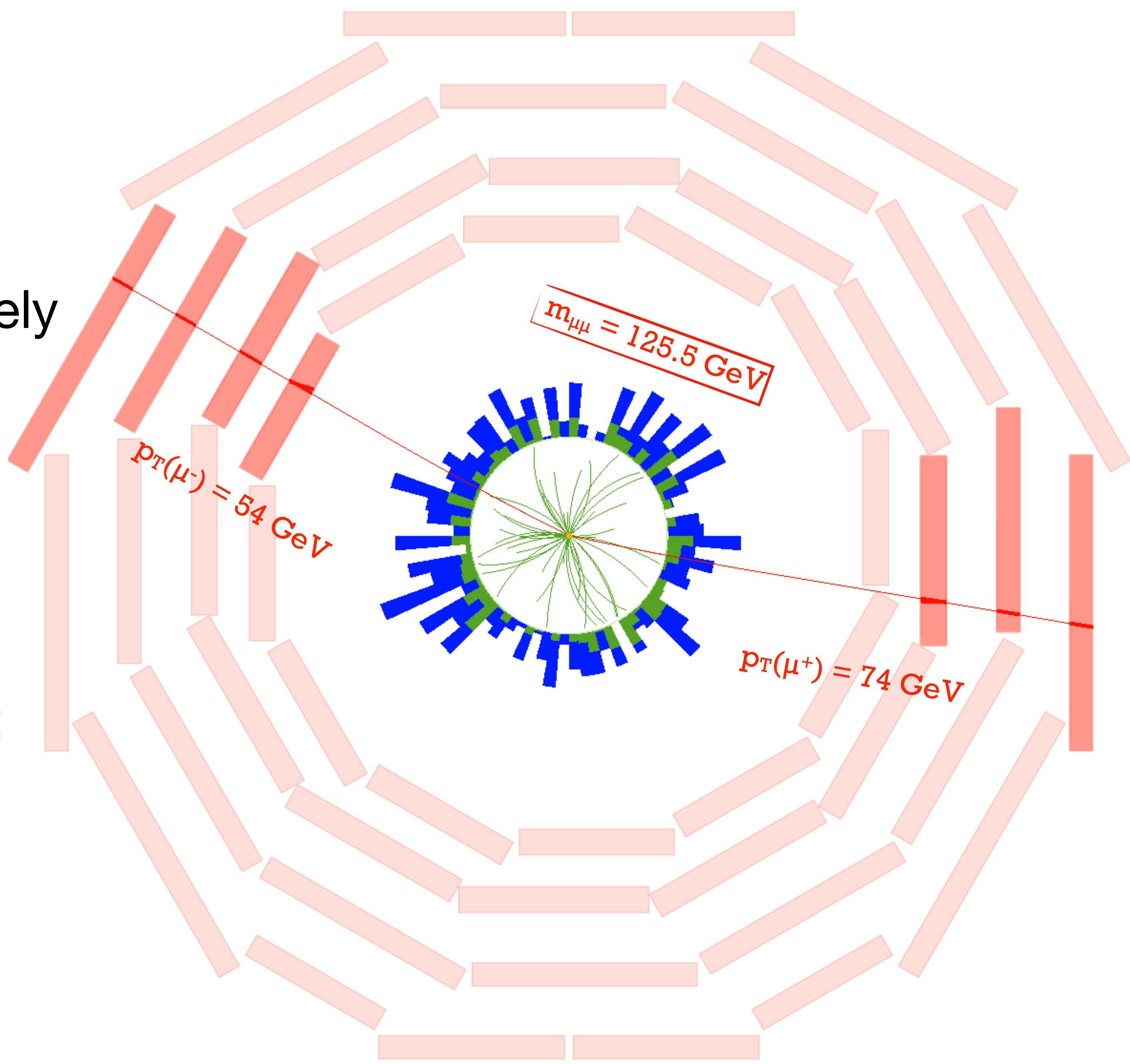
ggH Analysis

Gluon Fusion Category

- Higgs candidate:
  - ➡ Exactly two opposite-sign muons in the event
  - ➡ $\mu^+\mu^-$ pair with $110 < m_{\mu\mu} < 150$ GeV
- ttH veto : No event with 1 medium or 2 loosely tagged b jets
- VH veto : No additional e, μ in the event
- For events with 2 or more jets ($p_T > 25$ GeV)
  - ➡ $m_{jj} < 400$ GeV or $|\Delta\eta_{jj}| < 2.5$ or leading jet $p_T < 35$ GeV

Dominant background : Drell-Yan

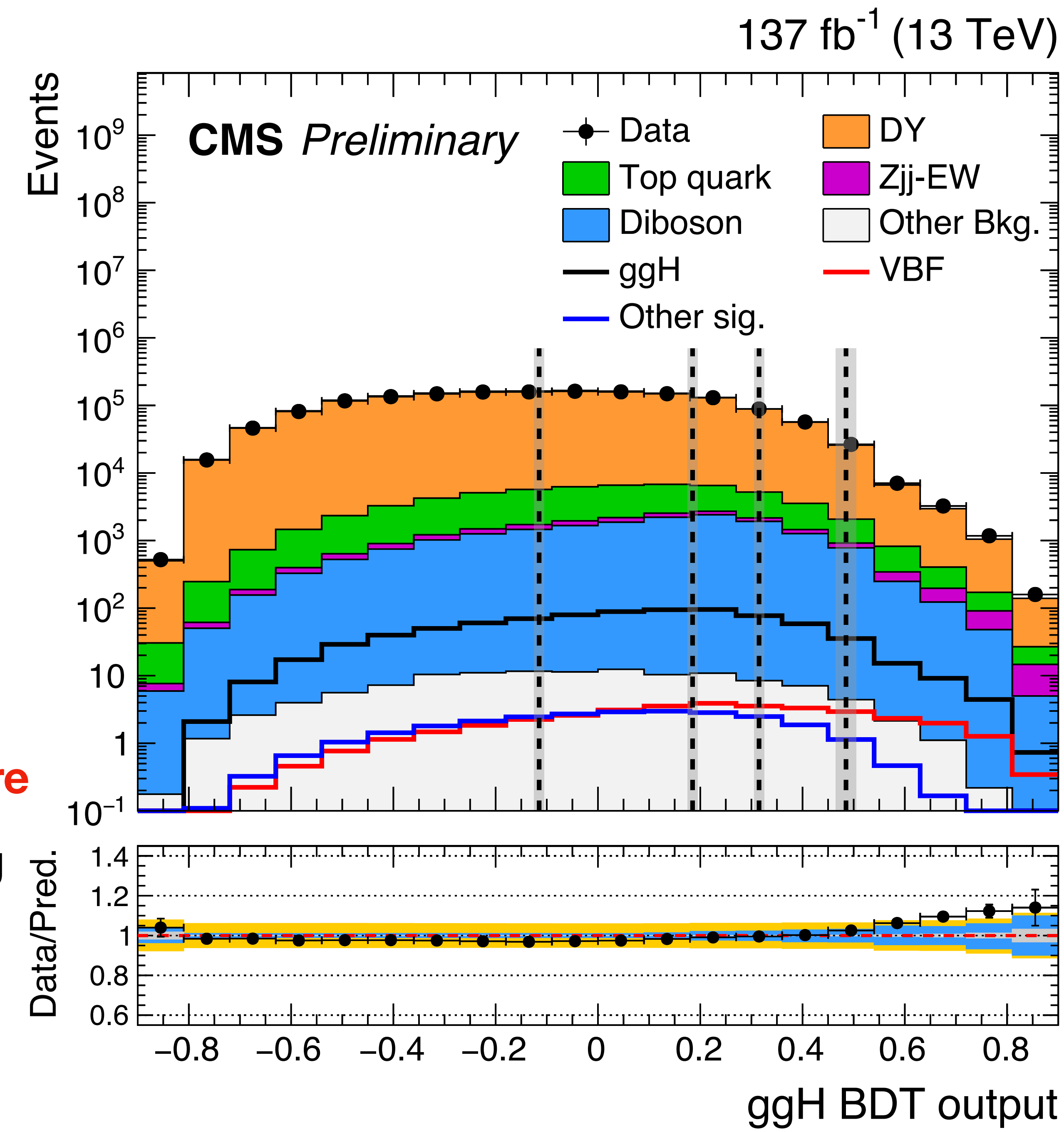
ggH Signal Event



ggH BDT Classifier

- **BDT inputs related to H candidate kinematics**
  - ➡ Dimuon p_T & rapidity, decay angles ϕ_{CS}, $\cos\theta_{CS}$,
  - ➡ $\eta(\mu)$, $p_T(\mu)/m_{\mu\mu}$ ….
- **BDT inputs related to ISR jet activity**
  - ➡ p_T, η of the leading jet
  - ➡ For events with one jet : $\Delta\eta(H, j)$, $\Delta\phi(H, j)$
  - ➡ For events with 2 or more jets :
    - min-$\Delta\eta(H, j)$, min-$\Delta\phi(H, j)$, m_{jj}, $\Delta\eta_{jj}$, $\Delta\phi_{jj}$
- **Events with high $m_{\mu\mu}$ resolution pushed to high score**
  - ➡ Due to $1/\sigma_m$ weight applied to signal during training

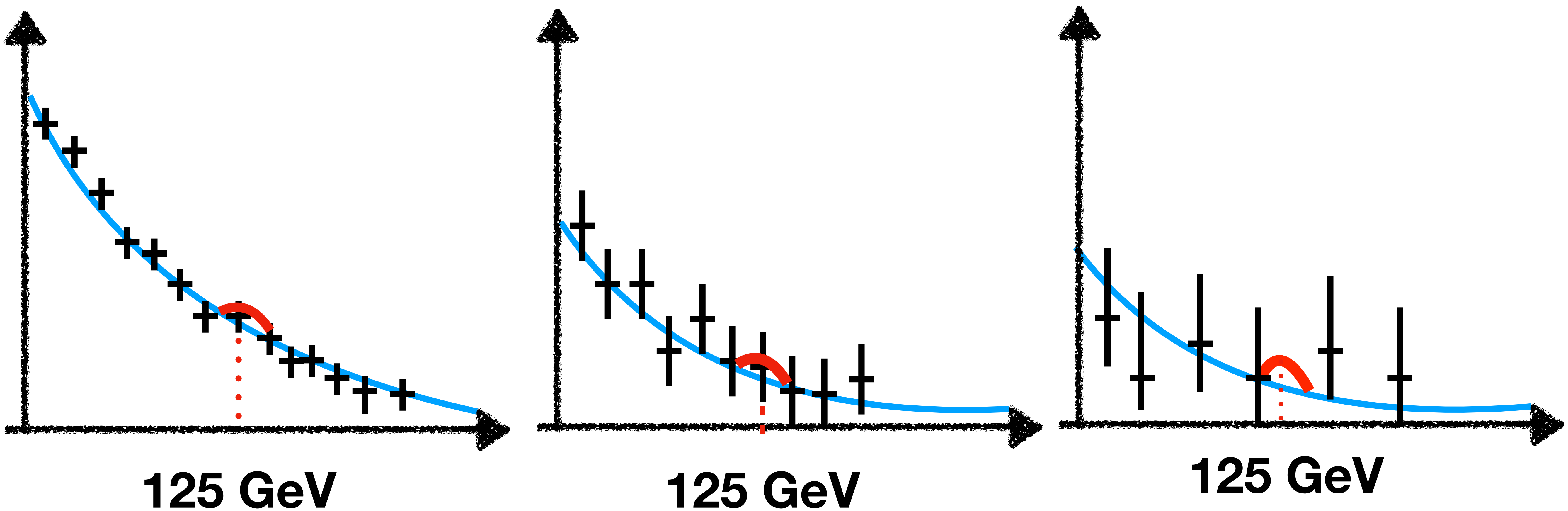
Event category	HWHM (GeV)
ggH-cat1	2.12
ggH-cat2	1.75
ggH-cat3	1.60
ggH-cat4	1.47
ggH-cat5	1.50



Adopt the divide-n-fit strategy
- ***5 ggH subcategories***

Background Fitting Strategy

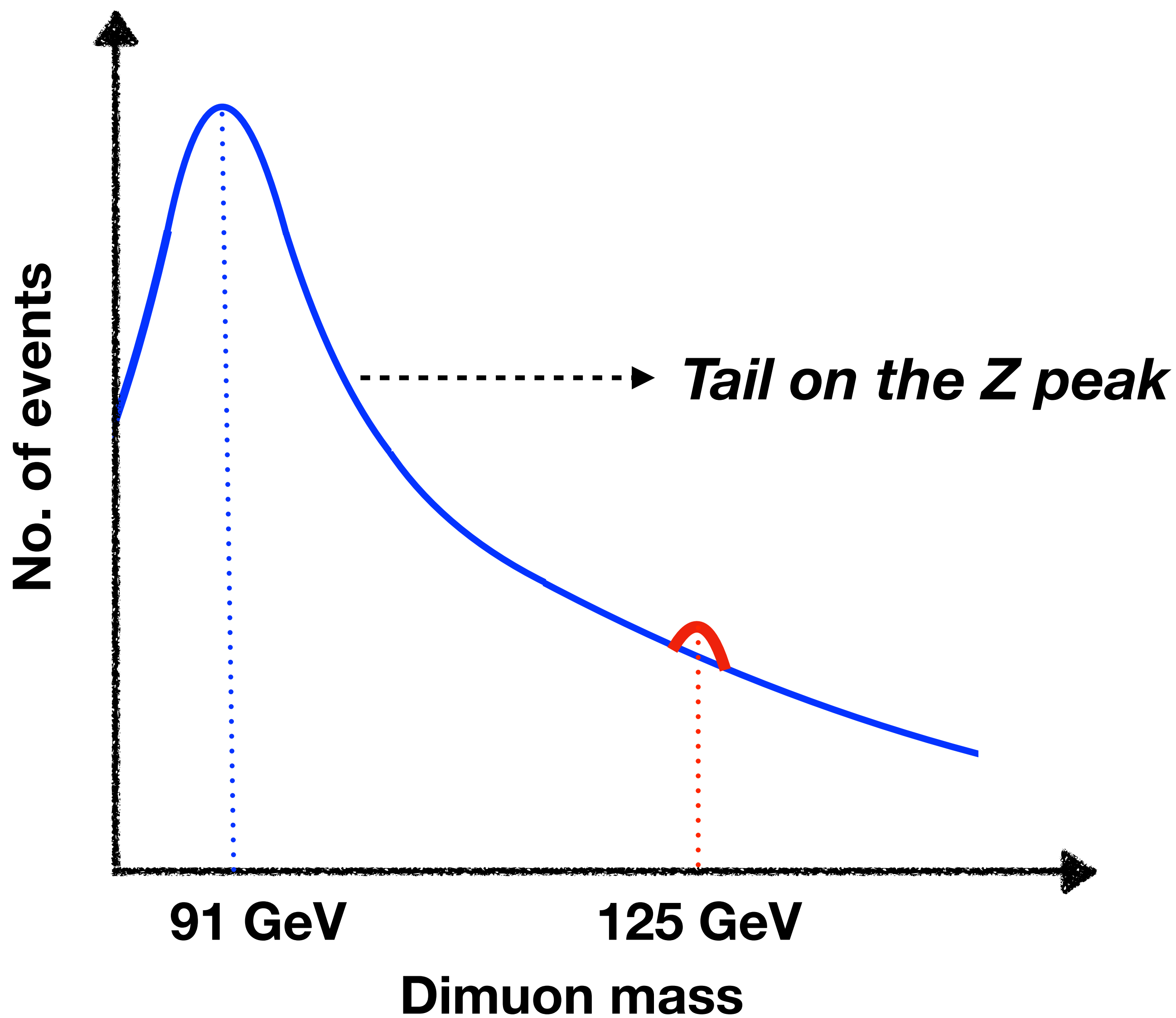
- Typical approach is to fit $m_{\mu\mu}$ distribution in each subcategory independently
- Fit in one subcategory not influenced by shape of background in other subcategories



Background shape parameters uncorrelated across subcategories

Background Fitting Strategy

- Background shape in each subcategory driven by the tail of the Z peak
- Background shape expected to be similar across various subcategories
- Minor variations due to differences in dimuon kinematics



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Bkg. model in a subcategory = **Correlated "Core" shape**

Common shape for all categories

Shape parameters correlated across categories

Shape parameters constrained by data in all categories

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Bkg. model in a subcategory = **Correlated "Core" shape** X **Per-category shape modulation**

Correlated "Core" shape	Per-category shape modulation
Common shape for all categories	2nd or 3rd order Chebyshev polynomial
Shape parameters correlated across categories	Parameters uncorrelated across subcategories
Shape parameters constrained by data in all categories	Account for variations across categories

Background Fitting Strategy

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Correlated "Core" shape:

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2nd or 3rd order Chebyshev polynomial

Parameters uncorrelated across subcategories

Account for variations across categories

N_{bkg} (Bkg. yield):

Uncorrelated across subcategories

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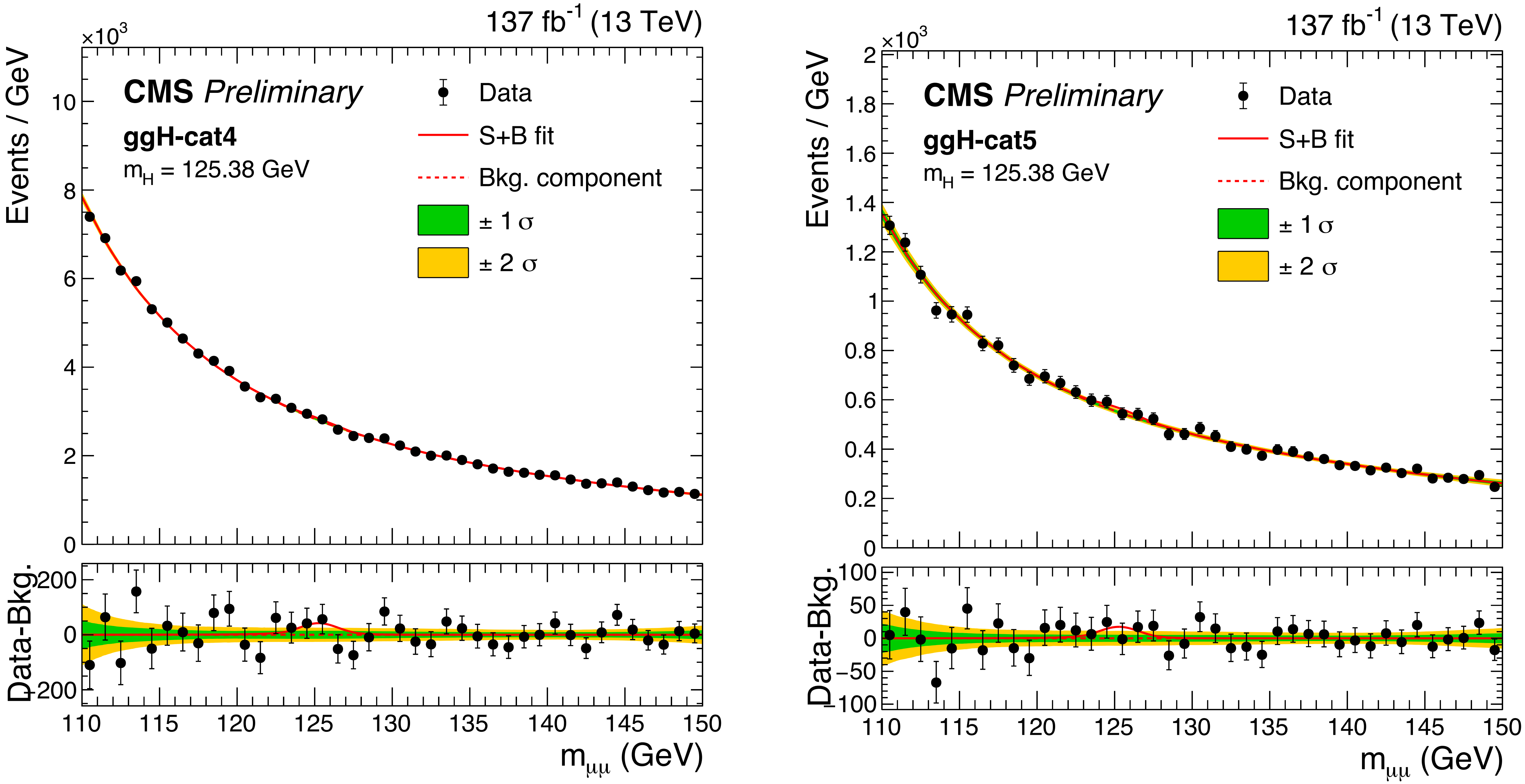
Bkg. model in a subcategory = **Correlated "Core" shape** X **Per-category shape modulation** X **N_{bkg} (Bkg. yield)**

Correlated "Core" shape	Per-category shape modulation	N_{bkg} (Bkg. yield)
Common shape for all categories	2nd or 3rd order Chebyshev polynomial	Uncorrelated across subcategories
Shape parameters correlated across categories	Parameters uncorrelated across subcategories	
Shape parameters constrained by data in all categories	Account for variations across categories	

Fewer background shape parameters; ~10% improvement w.r.t. keeping all subcategories uncorrelated

ggH Results

$m_{\mu\mu}$ distributions in the 2 most sensitive subcategories



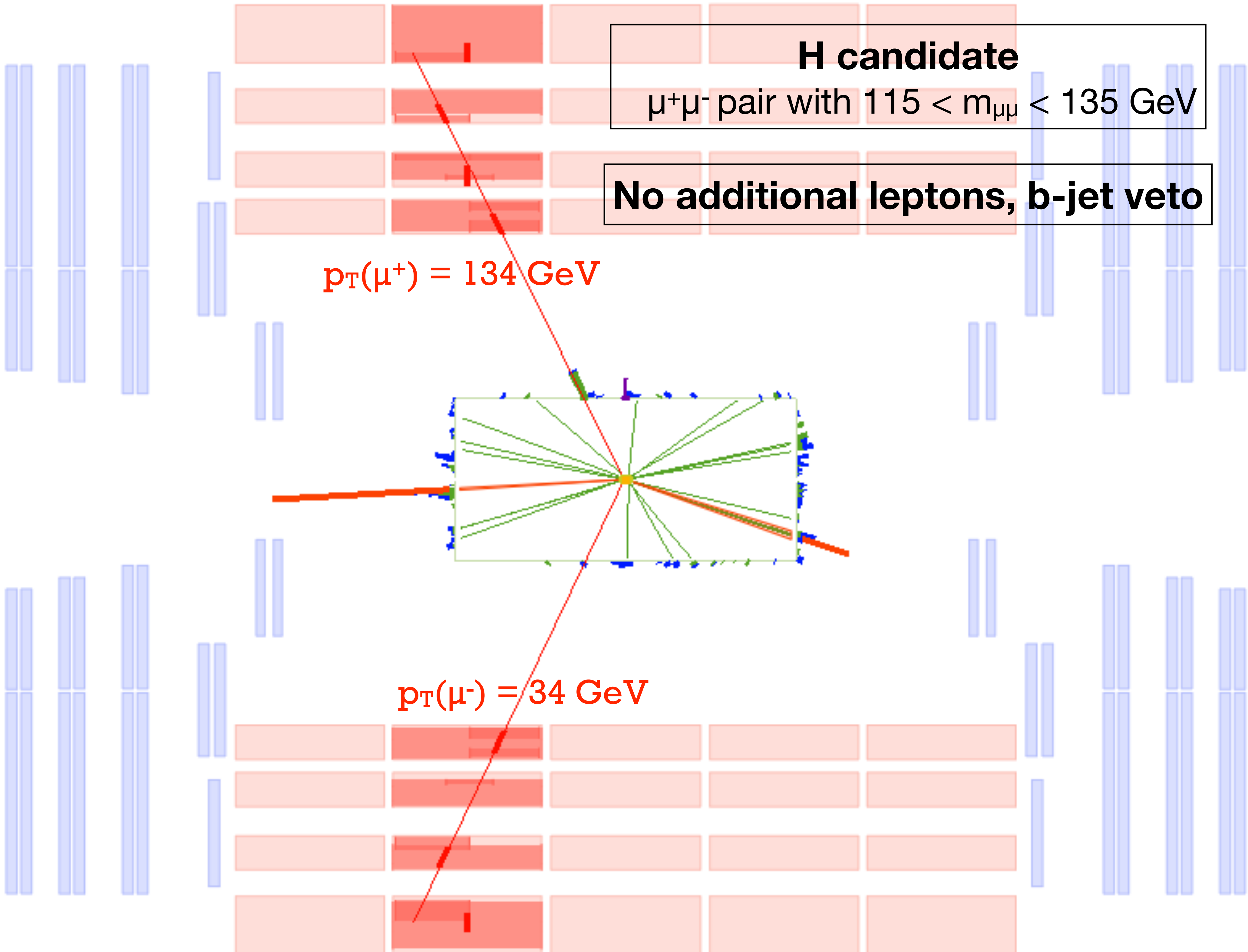
Combined ggH results →

Obs (exp) significance : 1.0 (1.6)σ

Signal Strength $\mu = 0.63^{+0.65}_{-0.64}$

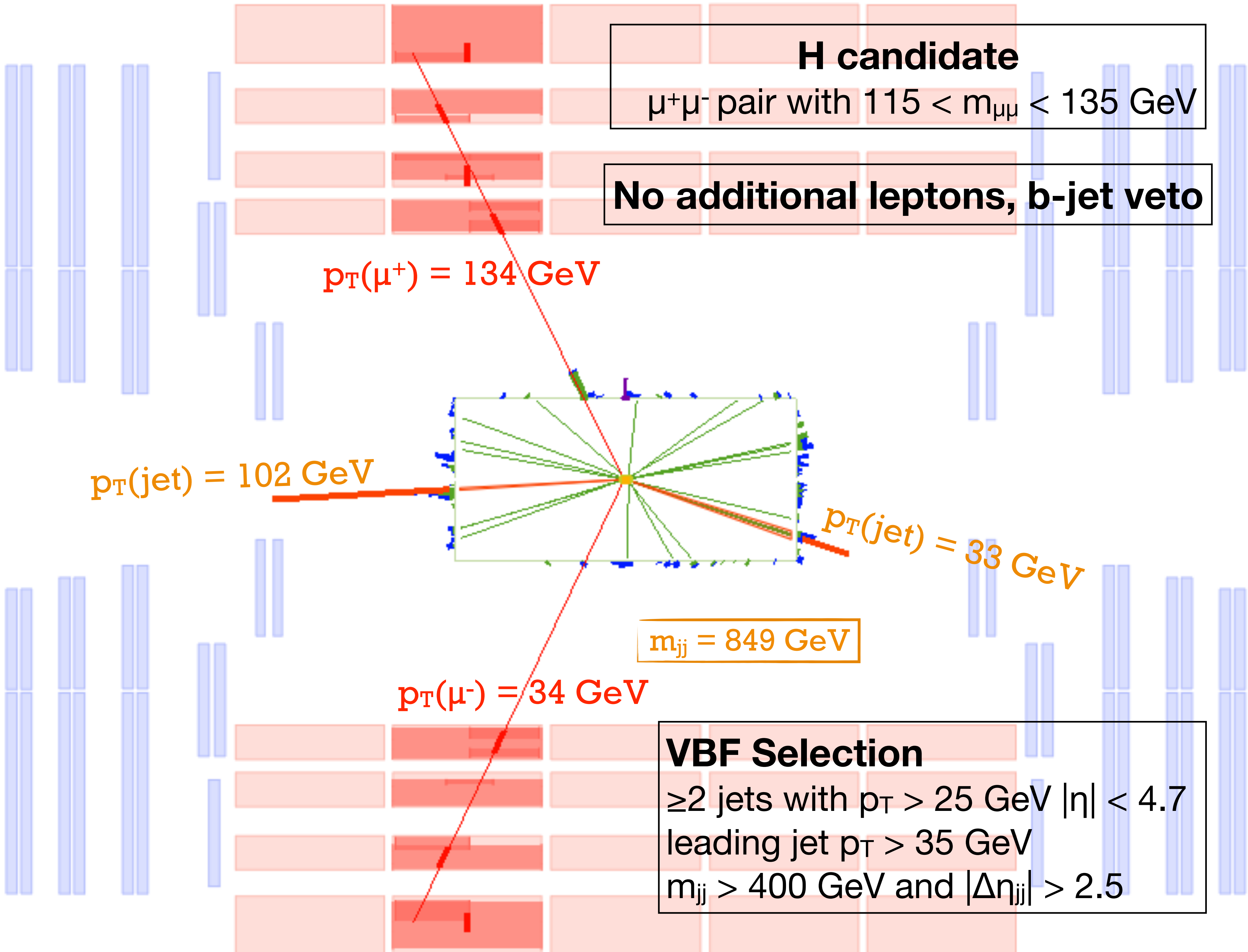
VBF Analysis

VBF Signal



H candidate
$\mu^+\mu^-$ pair with $115 < m_{\mu\mu} < 135$ GeV
No additional leptons, b-jet veto
$p_T(\mu^+)$ = 134 GeV
$p_T(\mu^-)$ = 34 GeV

VBF Signal



H candidate

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No additional leptons, b-jet veto

VBF Selection

≥2 jets with $p_T > 25$ GeV $|\eta| < 4.7$

leading jet $p_T > 35$ GeV

$m_{jj} > 400$ GeV and $|\Delta\eta_{jj}| > 2.5$

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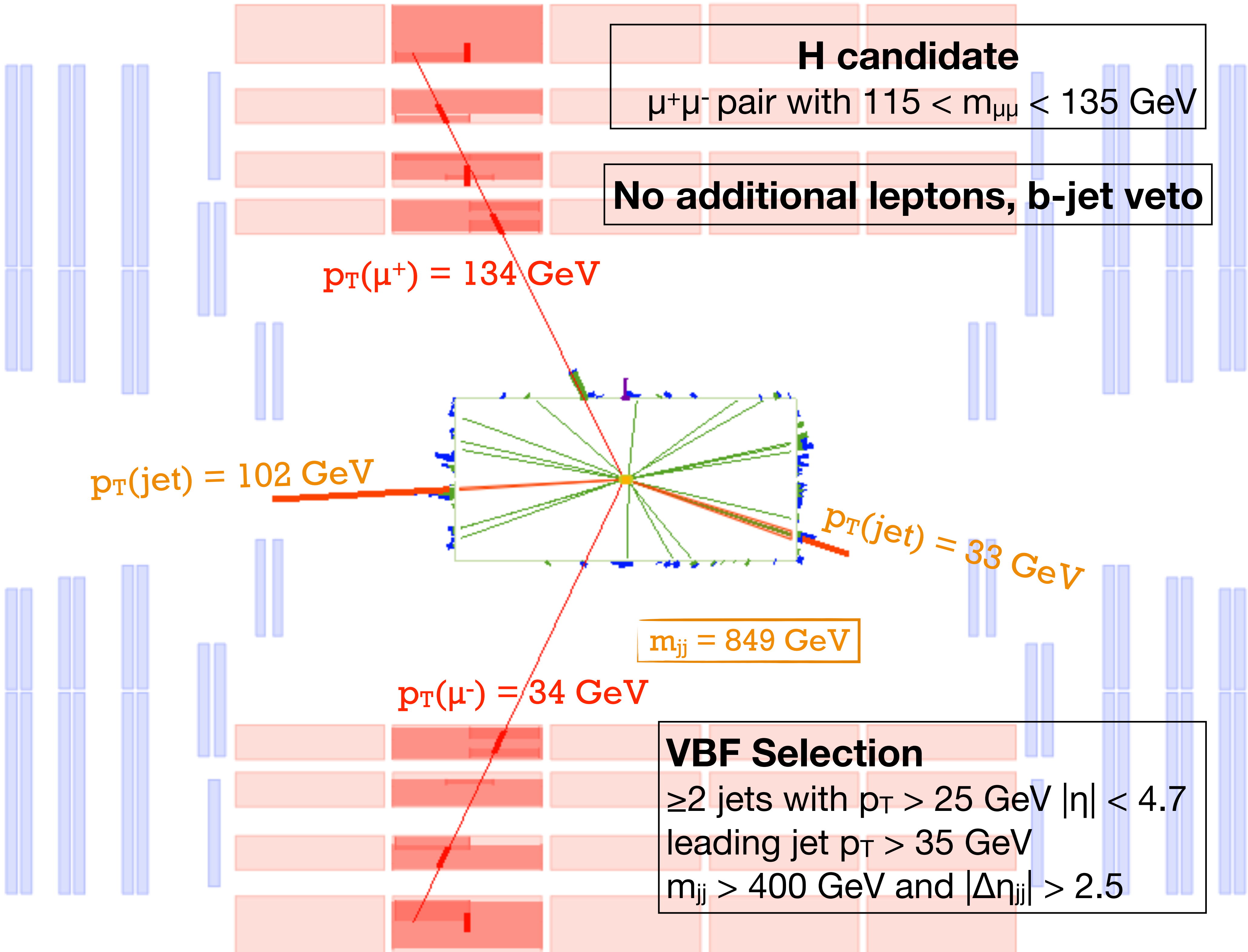


VBF Selection

$\geq$2 jets with $p_T > 25$ GeV $|\eta| < 4.7$

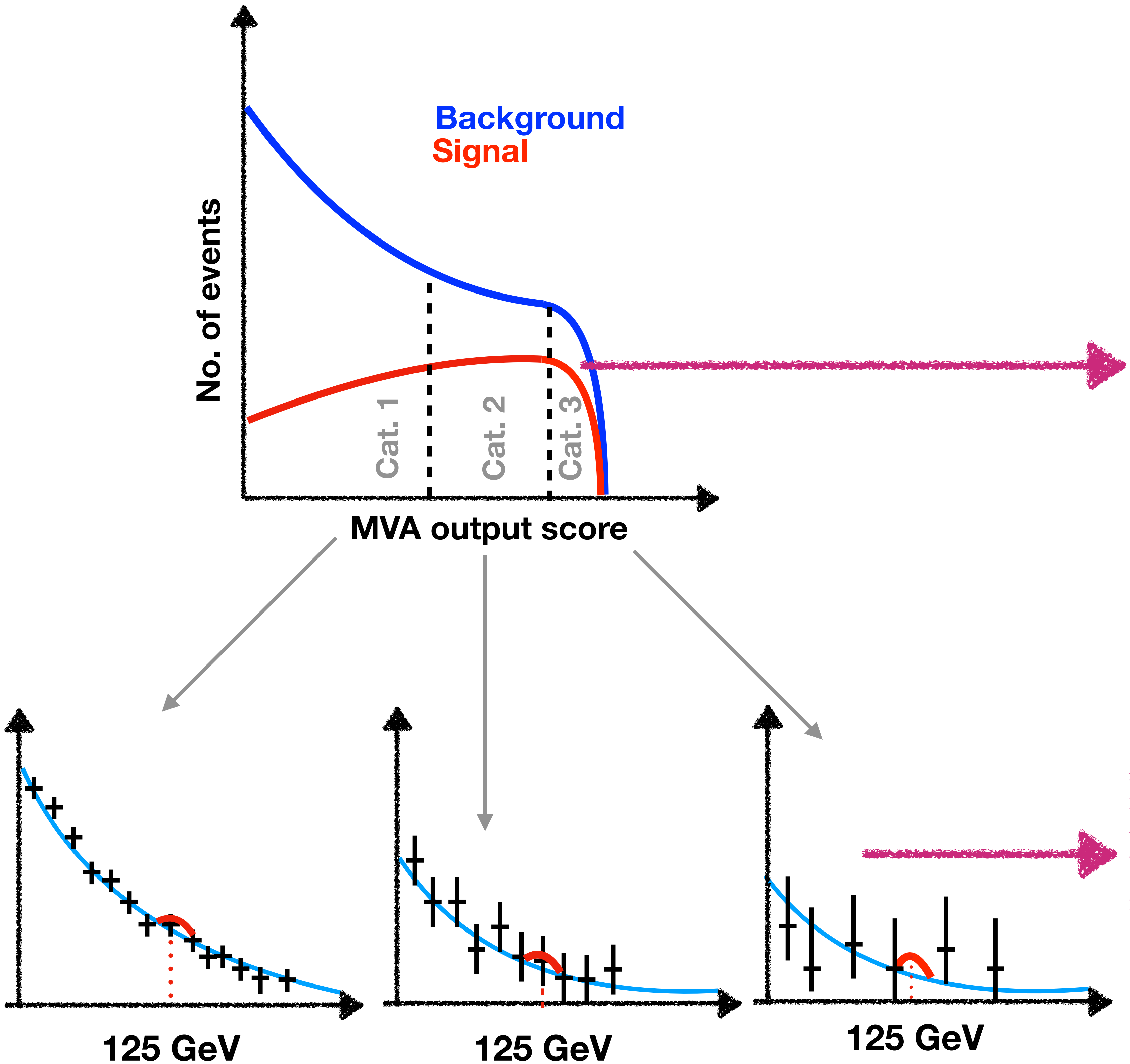
leading jet $p_T > 35$ GeV

$m_{jj} > 400$ GeV and $|\Delta\eta_{jj}| > 2.5$

Dominant bkg: DY+jets, EWK Z+jets

VBF Analysis Strategy

Lets recap the divide-n-fit strategy



There is a trade-off in defining the MVA categories

Add categories with higher purity to suppress background

Large background uncertainty due to small no. of events in sidebands limits sensitivity

VBF Analysis Strategy

- Possible to get 30-40% purity in certain VBF search regions
- Few events (10 or less) in the Higgs mass sidebands (SB) to constrain background with a parametric fit
- Statistical uncertainty in SB translates to ~30-50% uncertainty on the predicted background under the Higgs peak

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Try a different approach :

- Include the $m_{\mu\mu}$ directly in the MVA classifier
- Perform a binned fit of the MVA classifier output
- Take background estimate from simulation

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★ CMS has performed ***detailed measurements of DY and EWK Z+jets processes*** *EPJC 78 (2018) 589*

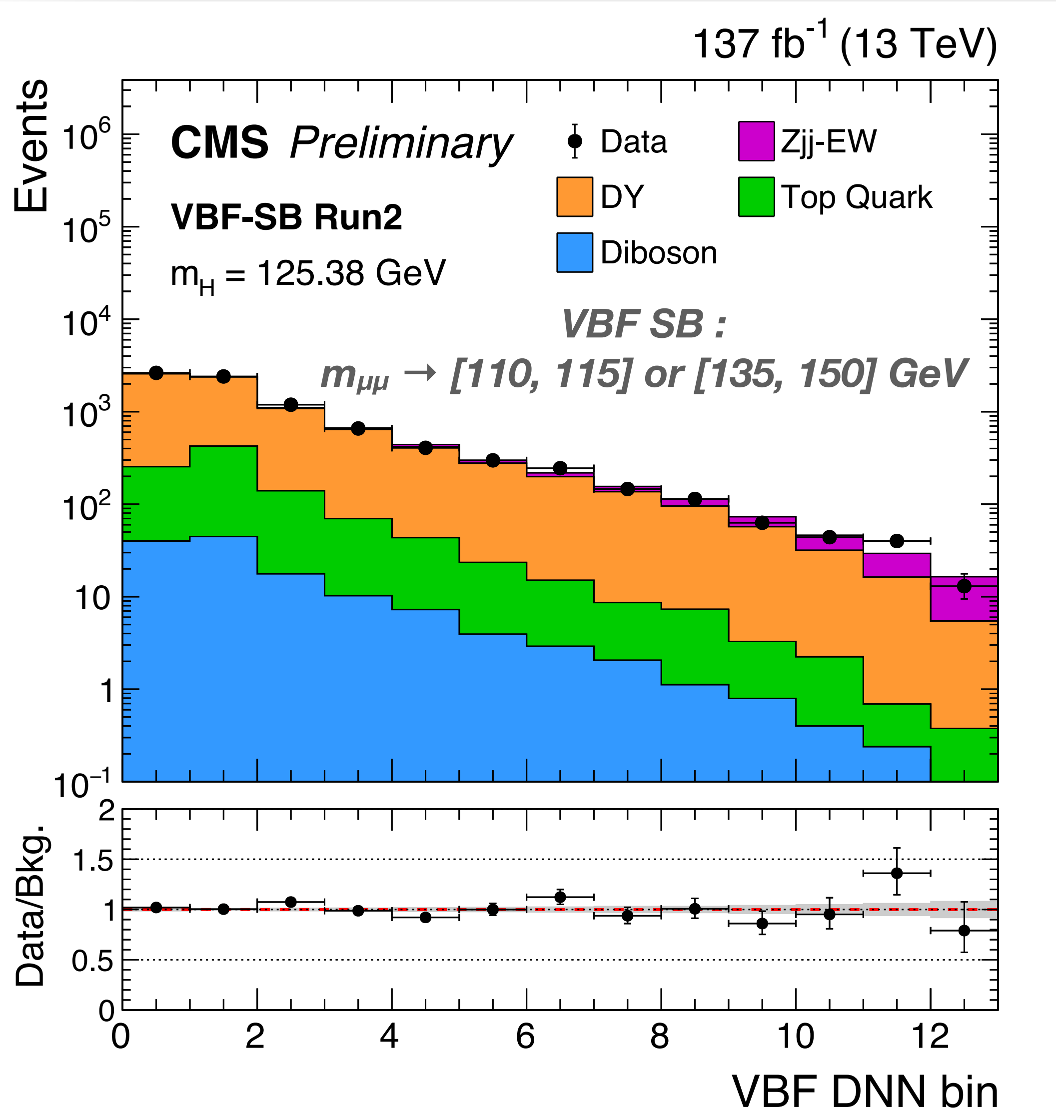
★ We can rely on simulation to predict bkg. with ***better precision compared to parametric fit***

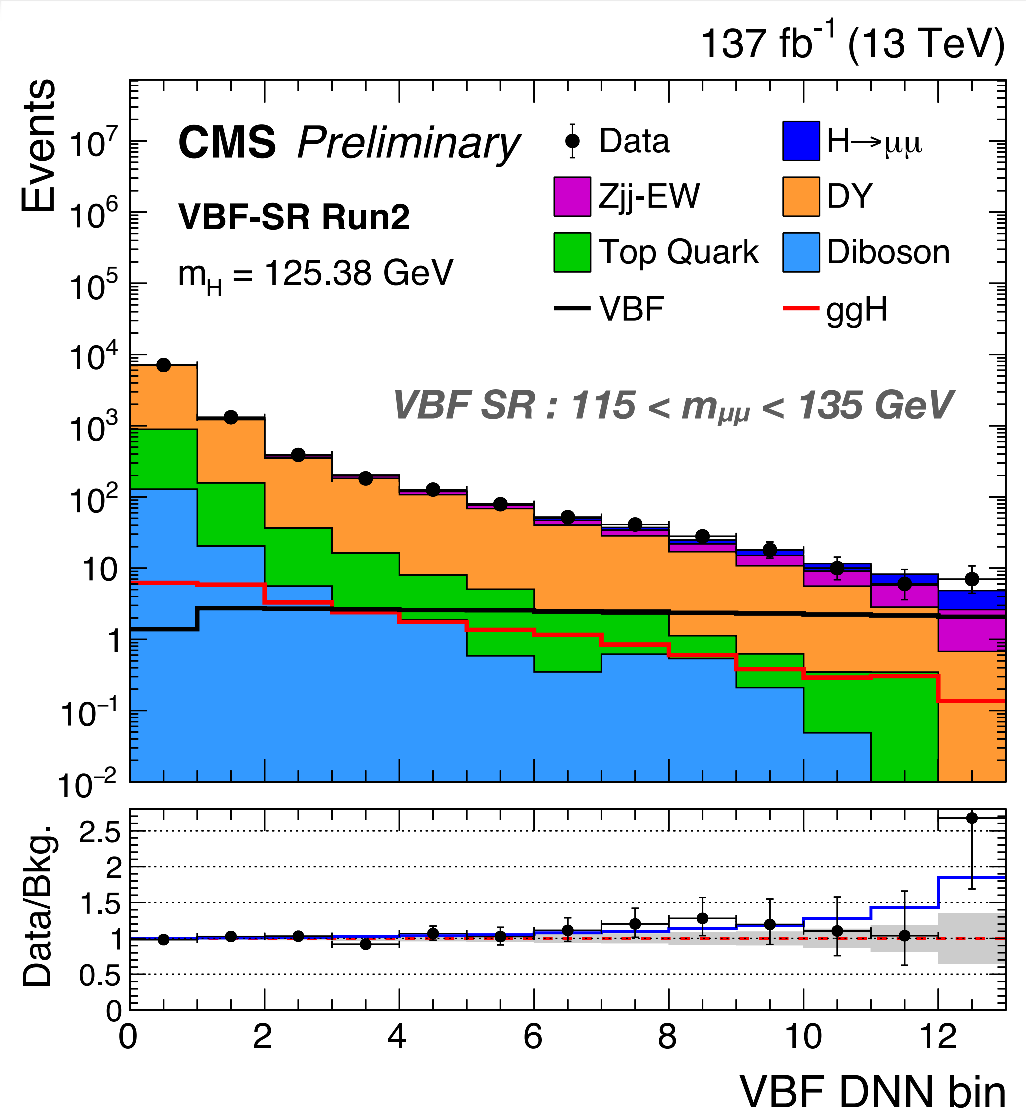
★ **Use data in the Higgs SB [110-115], [135-150] GeV to validate, constrain bkg. prediction**

★ **About 20% improvement in expected significance w.r.t. divide-n-fit strategy**

VBF Analysis : DNN Classifier

- **Inputs (H kinematics)**
  - ➡ $m_{\mu\mu}$, dimuon p_T & rapidity, decay angles ϕ_{CS}, $\cos\theta_{CS}$, …
- **Inputs (VBF jet kinematics)**
  - ➡ m_{jj}, $\Delta\eta_{jj}$, $\Delta\phi_{jj}$, min-$\Delta\eta$(H, j) , min-$\Delta\phi$(H, j), Zeppenfeld variable, p_T-balance(H, jj)
- **Low hadronic activity in η-gap**
  - ➡ Soft jets (p_T > 5 GeV) : Reconstructed from tracks associated with the PV
  - ➡ Number & H_T of soft jets used as DNN inputs

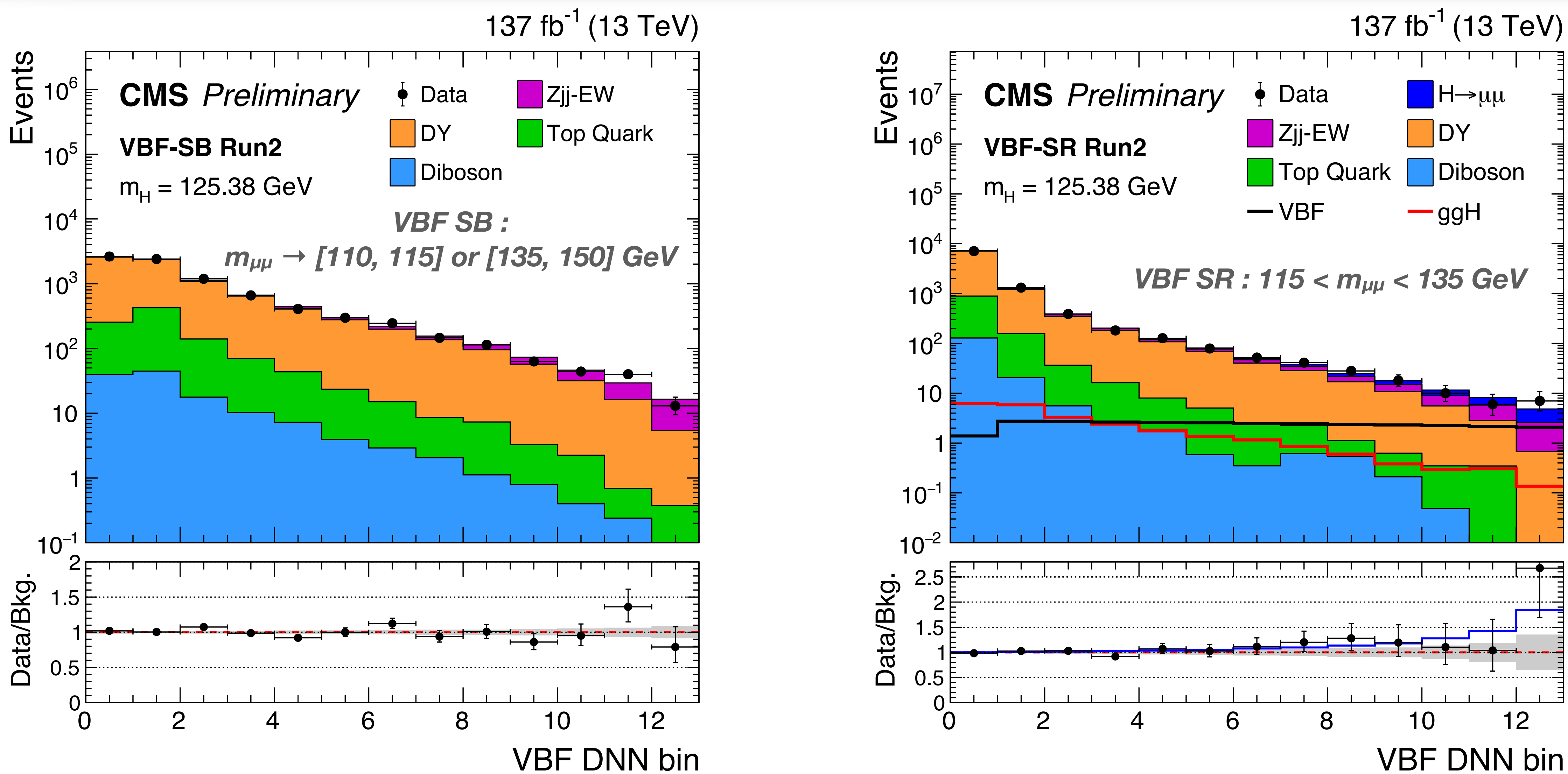




VBF Analysis : Systematics

Main sources of background systematics

- Parton shower modeling : HERWIG (nominal choice) v/s PYTHIA (dipole-shower) difference
- Jet energy scale and resolution
- DY bkg. contribution due VBF jets unmatched at ME-level (e.g. jets from pileup) : Constrained from data
- MC statistical uncertainty
- Theory uncertainty : Missing higher order corrections, choice of PDFs, etc.
- ***Overall impact of the systematic uncertainties is small (less than 5%)***

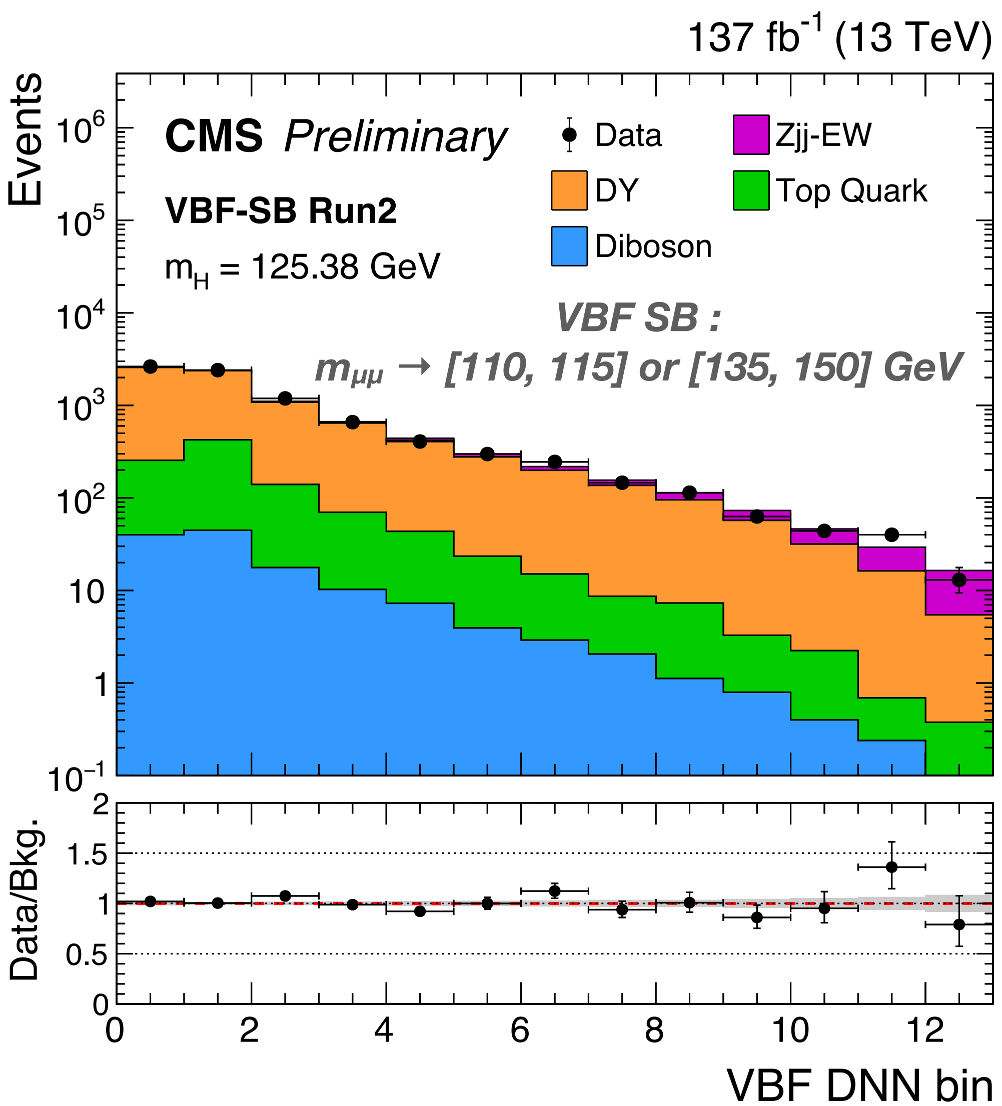


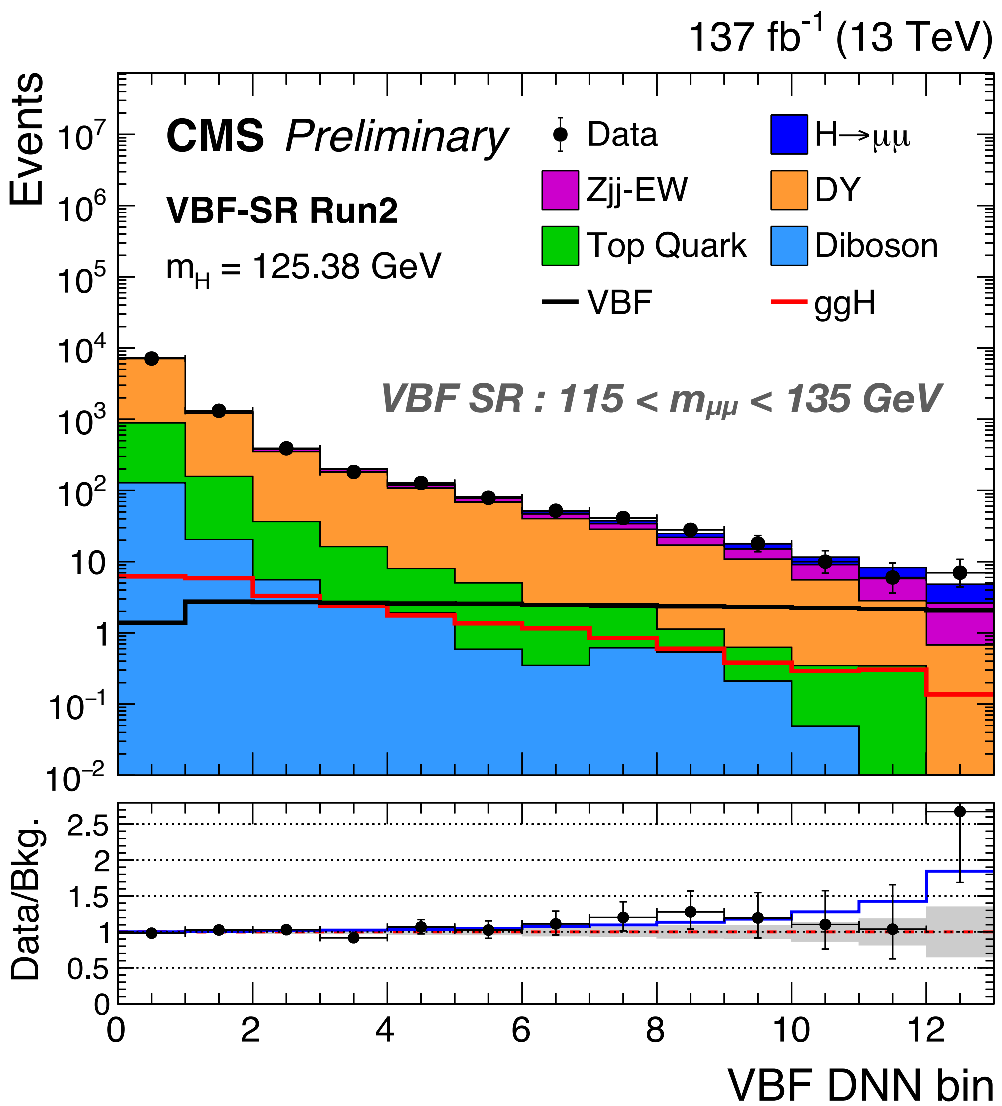
VBF Analysis : Results

Perform a simultaneous fit of the DNN output in VBF SB and SR

Obs (exp) significance : 2.4 (1.8)σ

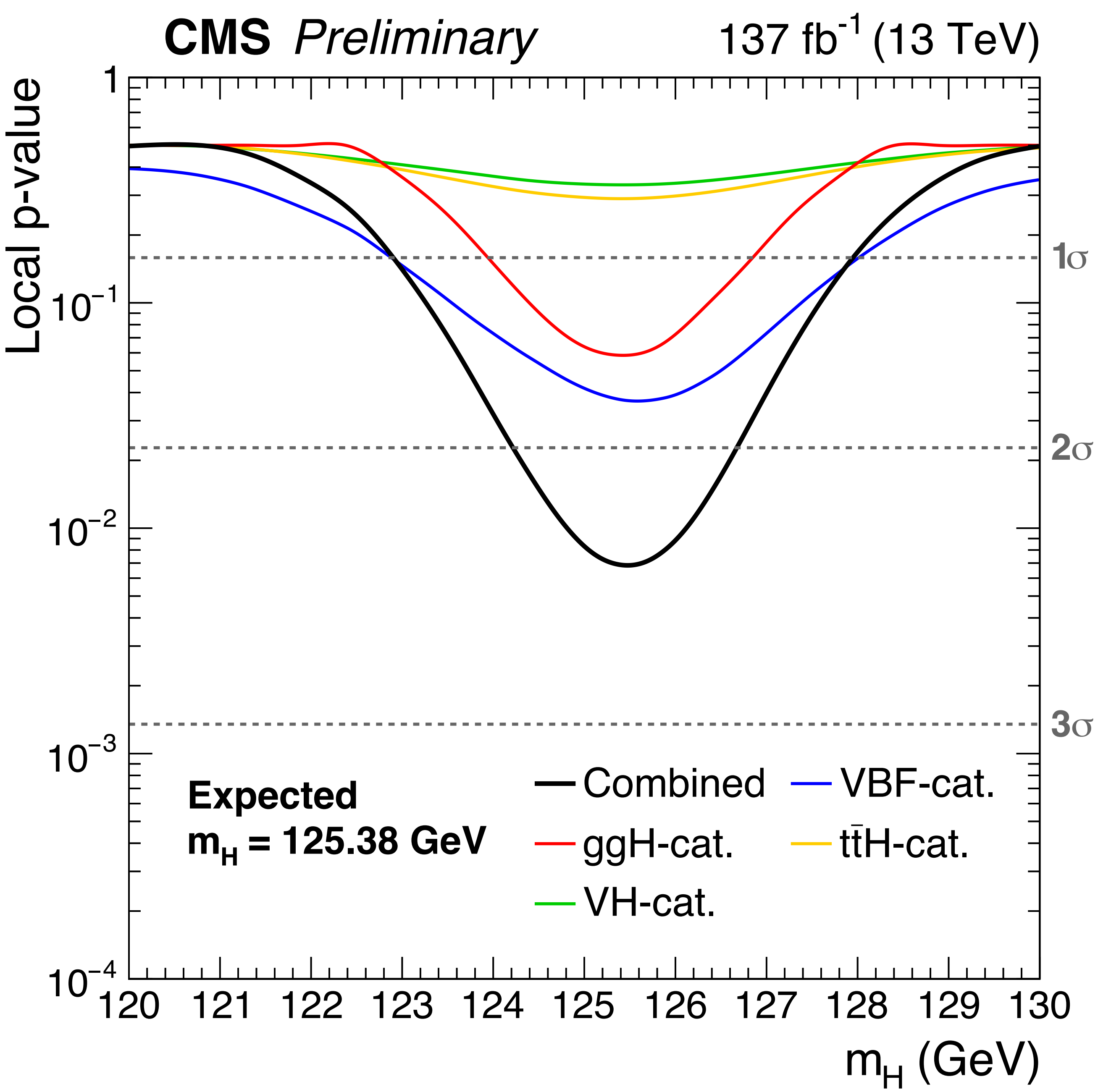
Signal Strength $\mu = 1.36^{+0.69}_{-0.61}$





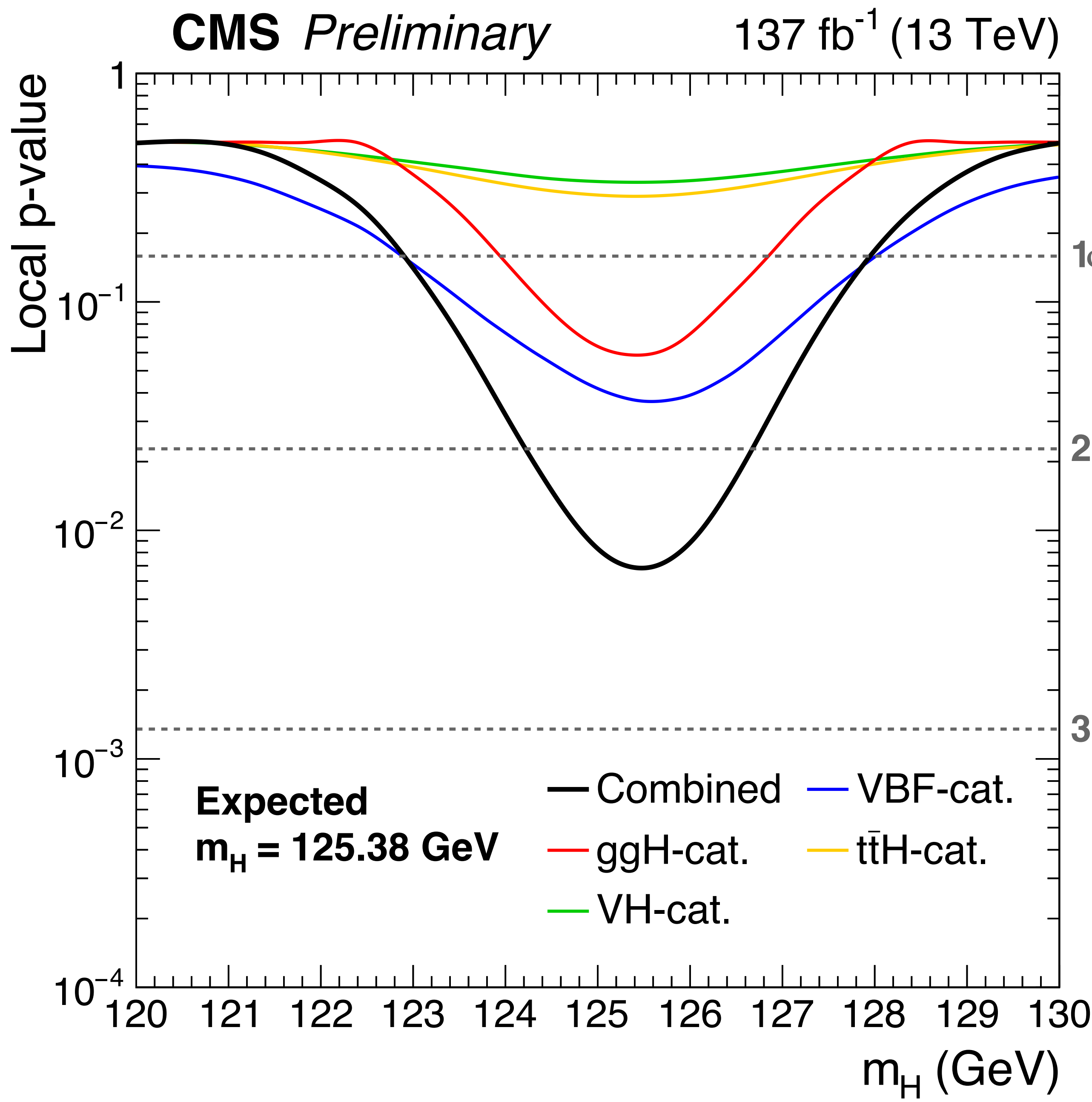
H→ μμ Results

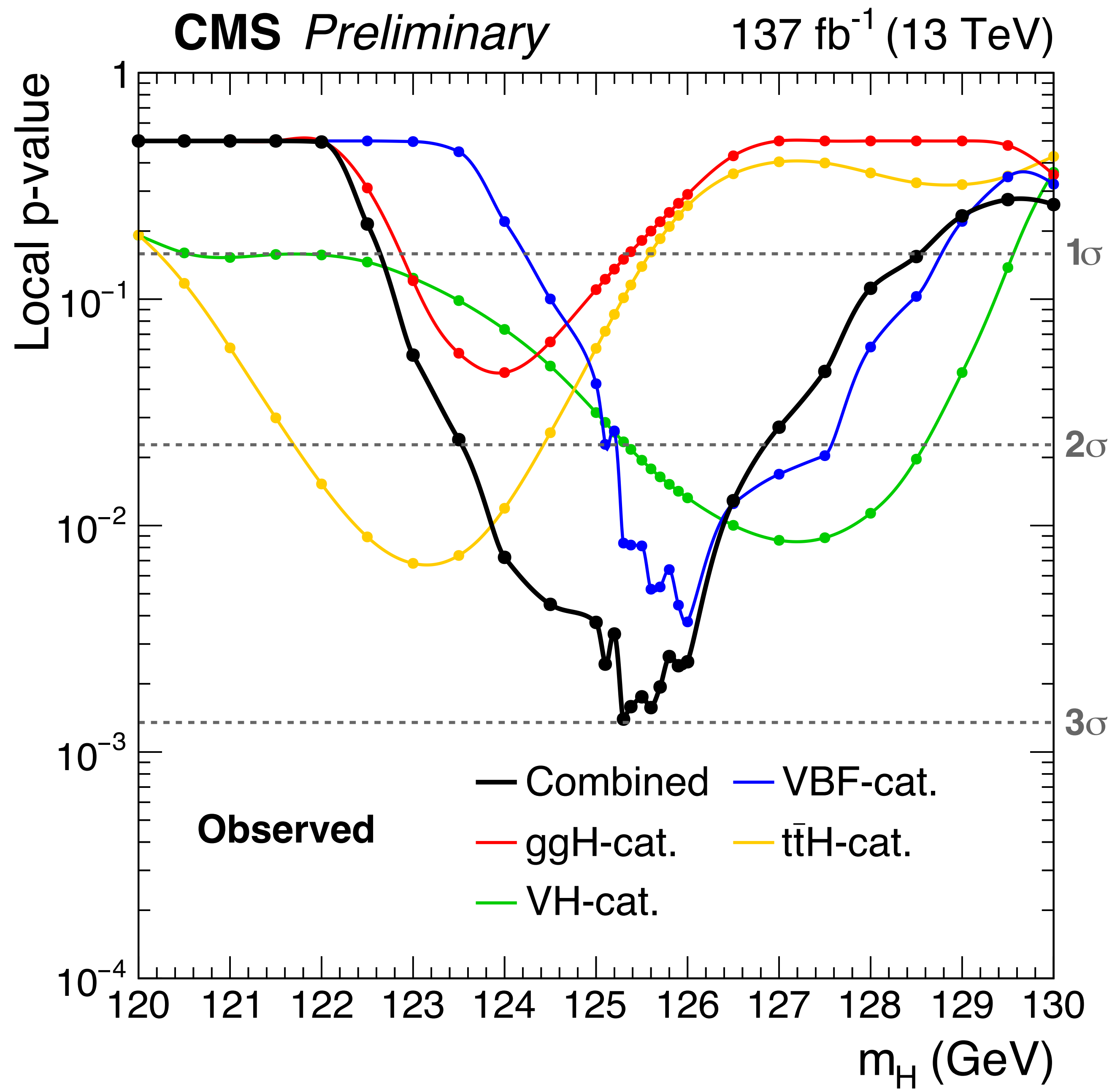
p-value of Excess



Exp. Significance at m_H = 125.38 GeV :
2.5σ

p-value of Excess

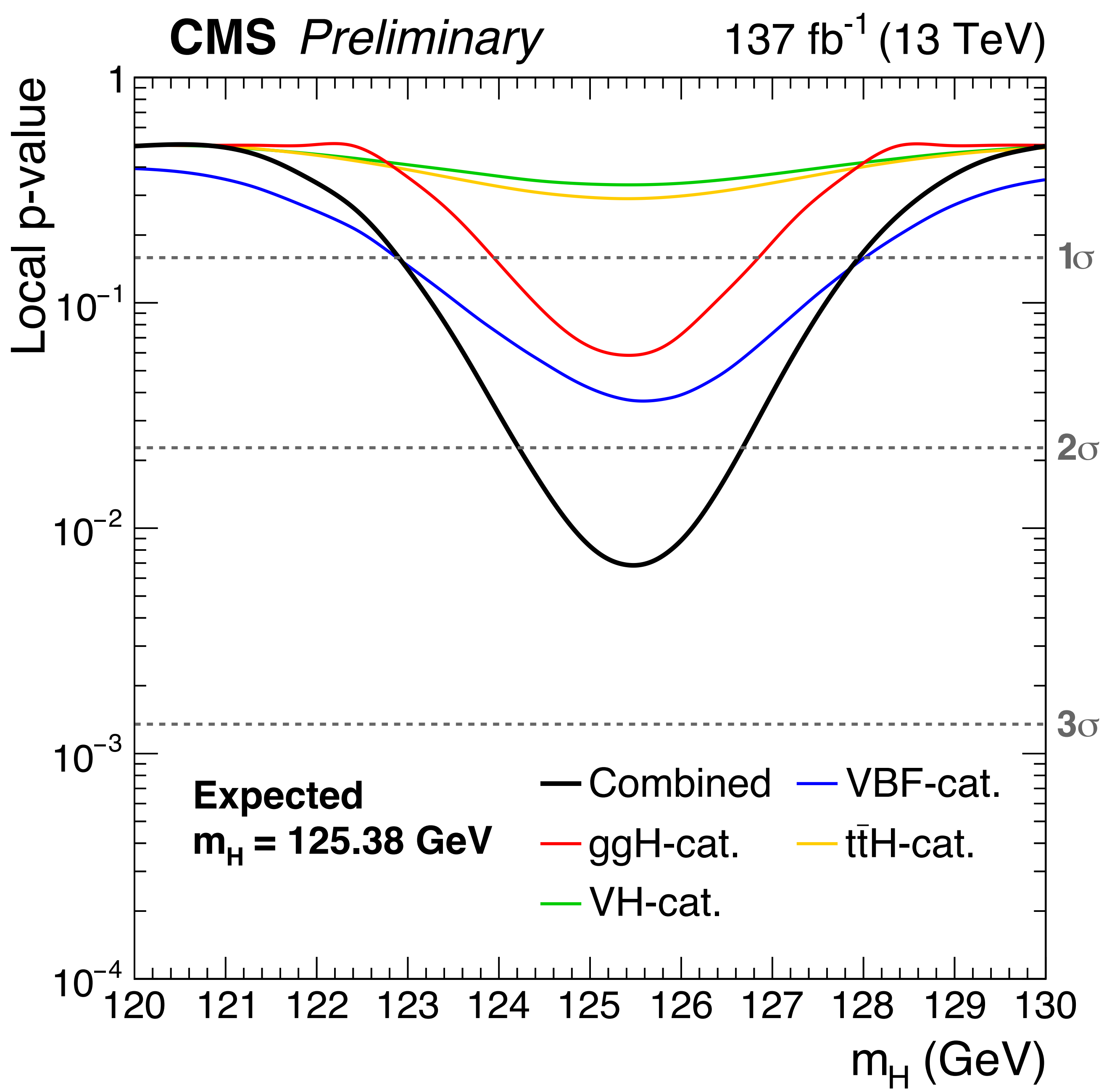


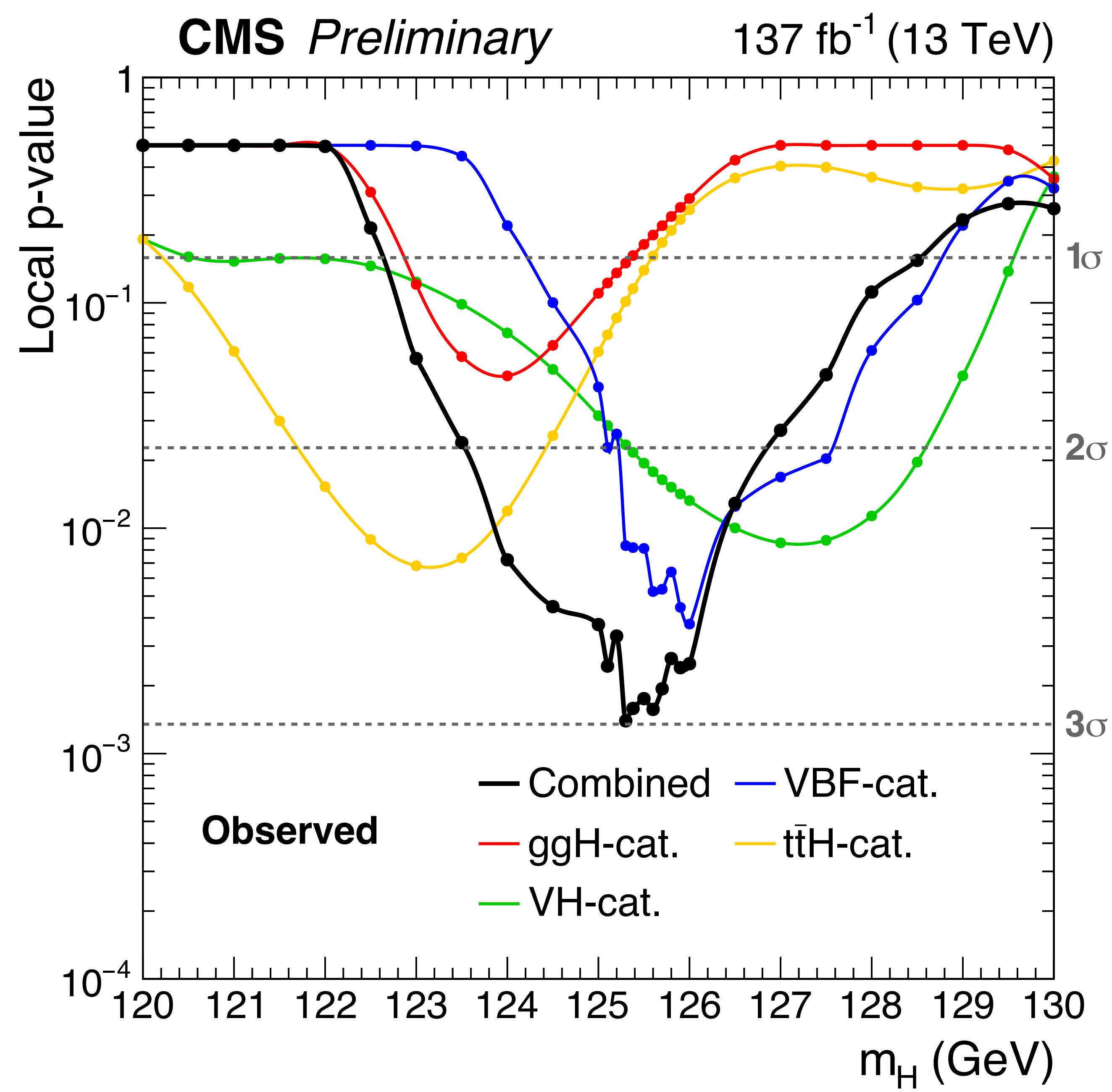


Exp. Significance at m_H = 125.38 GeV :
2.5σ

Obs. Significance at m_H = 125.38 GeV :
3.0σ

p-value of Excess





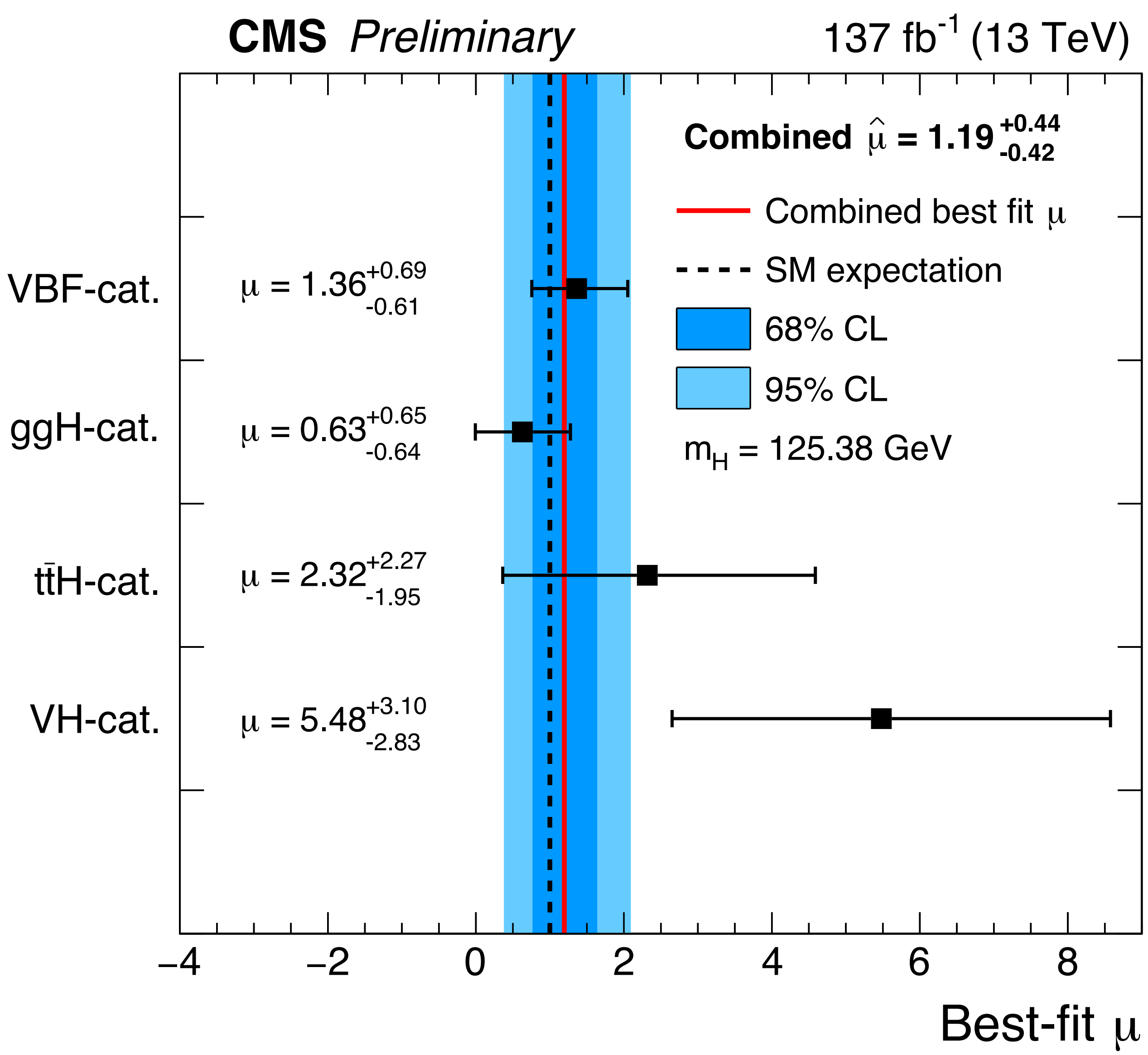
Exp. Significance at m_H = 125.38 GeV :
2.5σ

Obs. Significance at m_H = 125.38 GeV :
3.0σ

Combination with Run-1 H→μμ analysis improves significance by ~1%

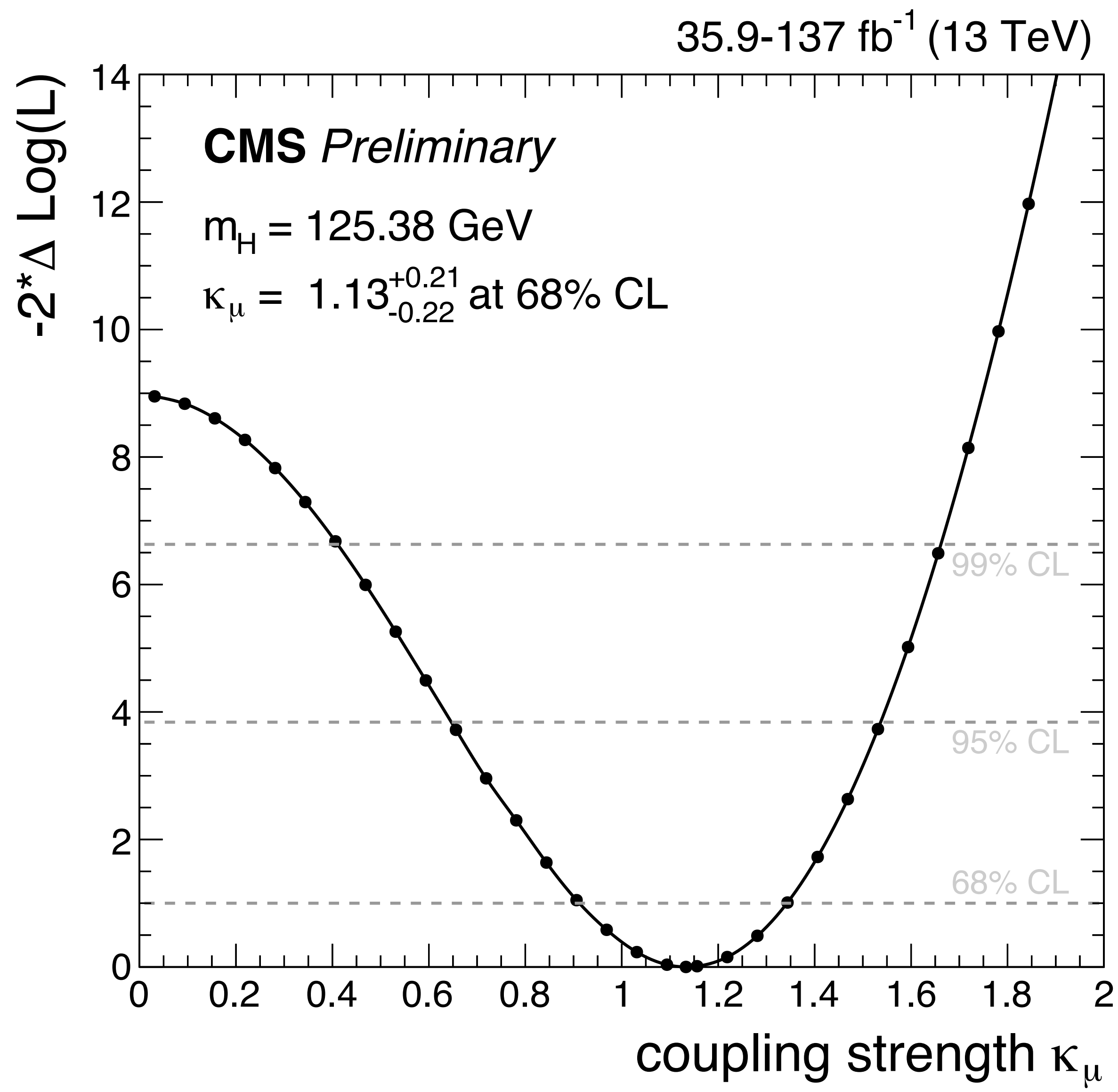
H→μμ Signal

Signal strength in 4 analysis categories



H→μμ coupling strength

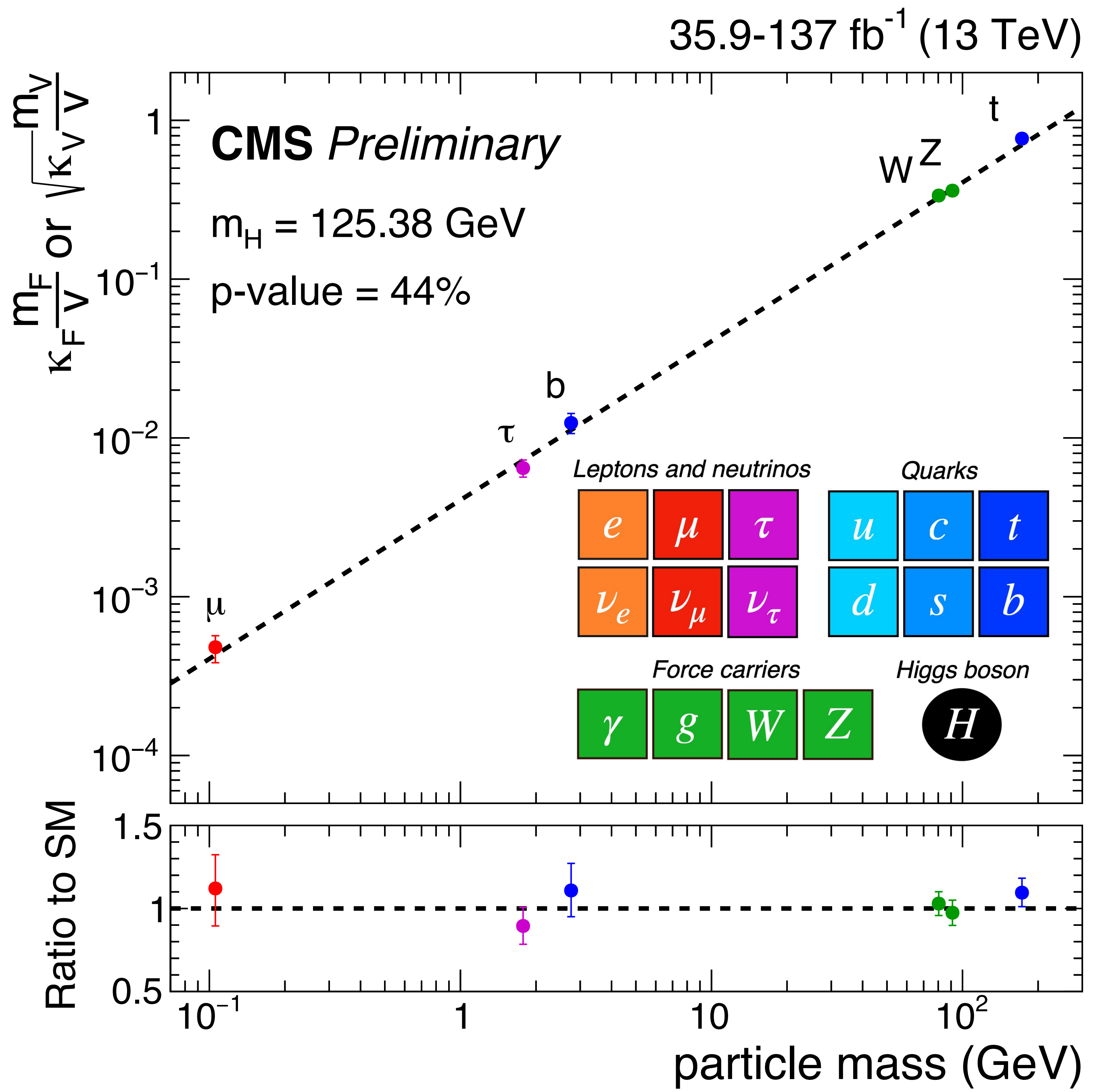
Combination with other Higgs modes *(HIG-19-005)*



Observed signal is compatible with the standard model prediction

Summary

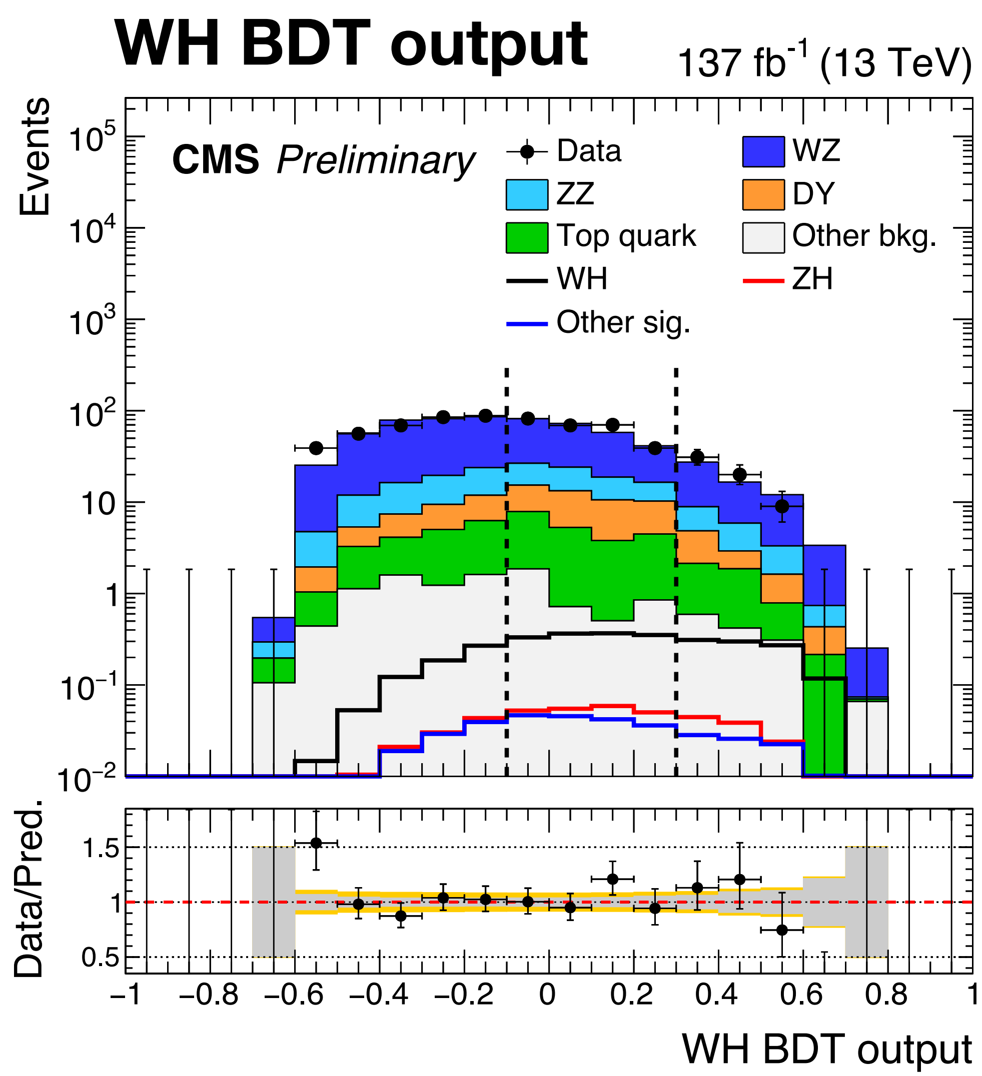
- $H \rightarrow \mu\mu$ measurement performed with the full Run-2 data set
- Observed (expected) significance : 3.0 (2.5)σ
- First evidence of $H \rightarrow \mu\mu$ signal
- First evidence of Higgs interaction with a 2nd generation fermion
- Measured signal strength $\hat{\mu}$ **= 1.19** $^{+0.44}_{-0.42}$
- ***Remarkable success of the standard model continues!!***

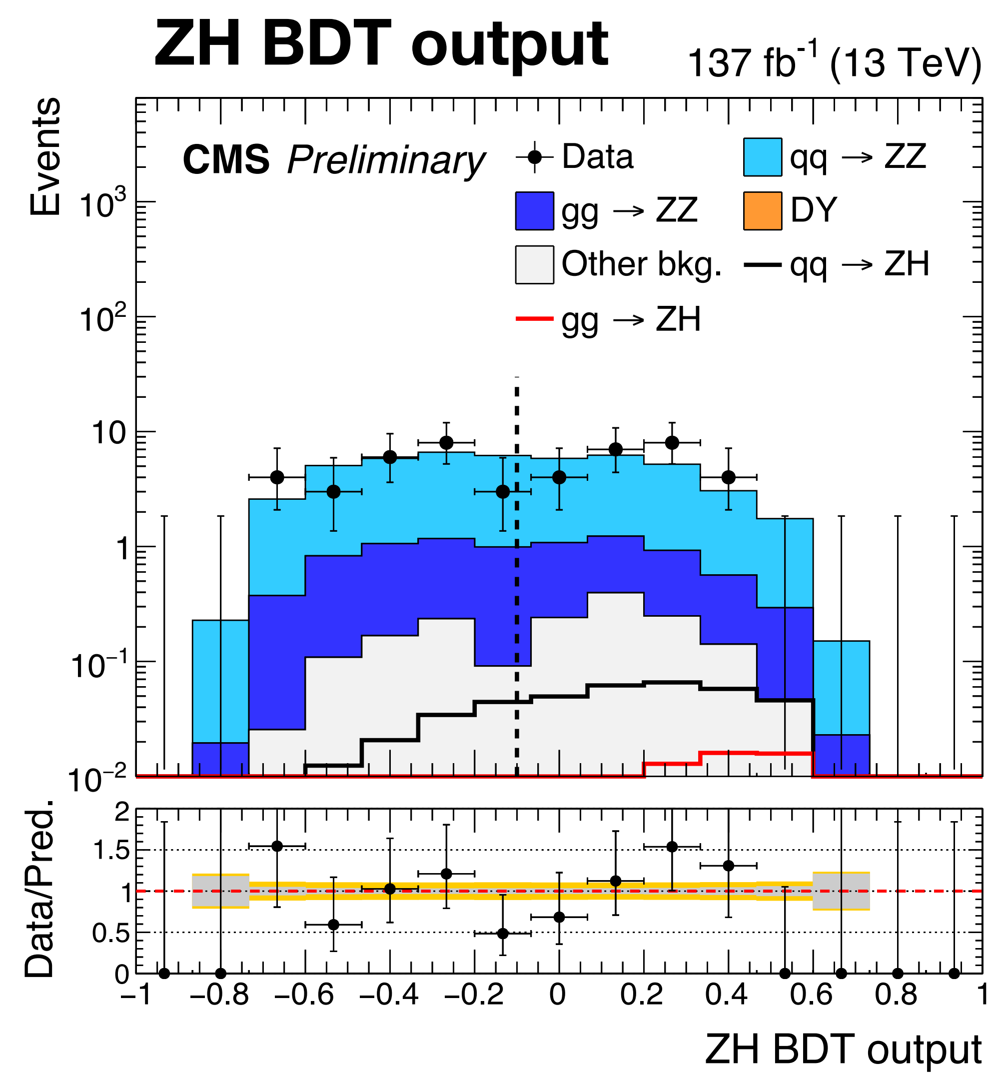


Spares

WH & ZH Analysis

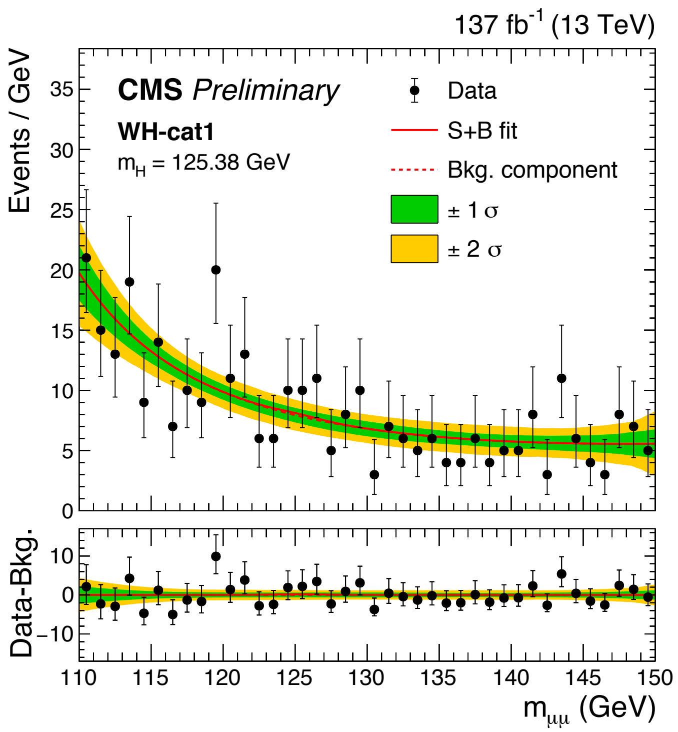
Selection	WH leptonic		ZH leptonic	
	$\mu\mu\mu$	$\mu\mu$e	4μ	2μ2e
Number of loose (medium) b-tagged jets	≤ 1 (0)	≤ 1 (0)	≤ 1 (0)	≤ 1 (0)
N(μ) passing id.+iso.	3	2	4	2
N(e) passing id.+iso.	0	1	0	2
Lepton charge	$\sum q(\ell) = \pm 1$		$\sum q(\ell) = 0$	
Low mass resonance veto	$m_{\ell\ell} > 12\,\mathrm{GeV}$			
N($\mu^+\mu^-$) pairs with $110 < m_{\mu\mu} < 150\,\mathrm{GeV}$	≥ 1	1	≥ 1	1
N($\mu^+\mu^-$) pairs with $\lvert m_{\mu\mu} - m_Z\rvert < 10\,\mathrm{GeV}\rvert$	0	0	1	0
N(e$^+$e$^-$) pairs with $\lvert m_{ee} - m_Z\rvert < 20\,\mathrm{GeV}\rvert$	0	0	0	1

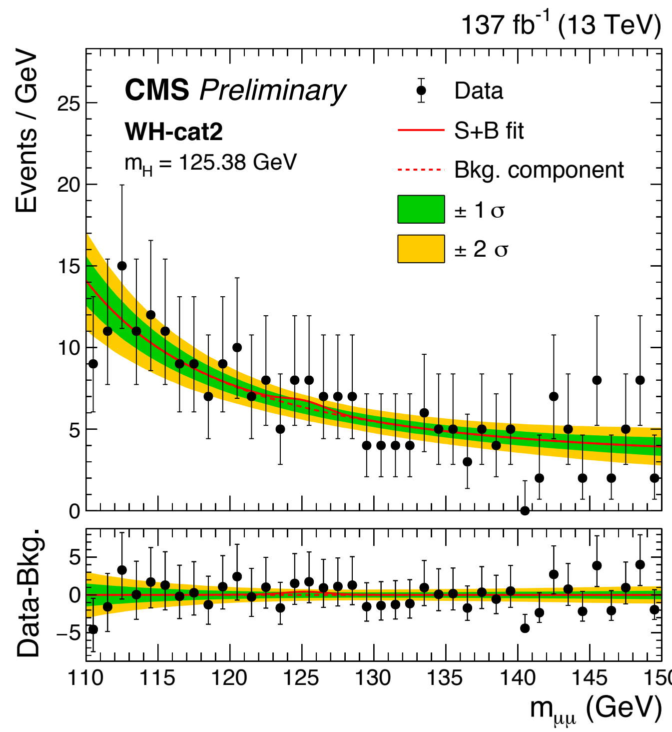


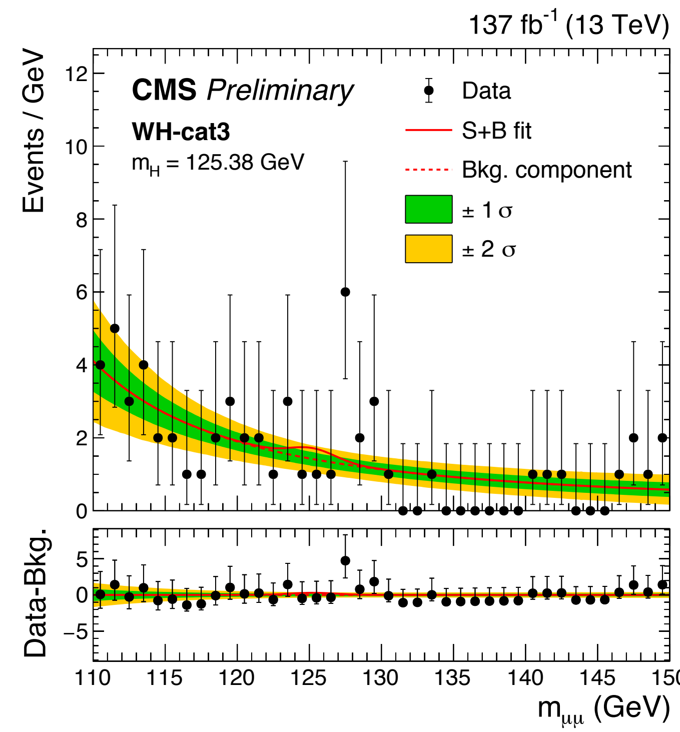


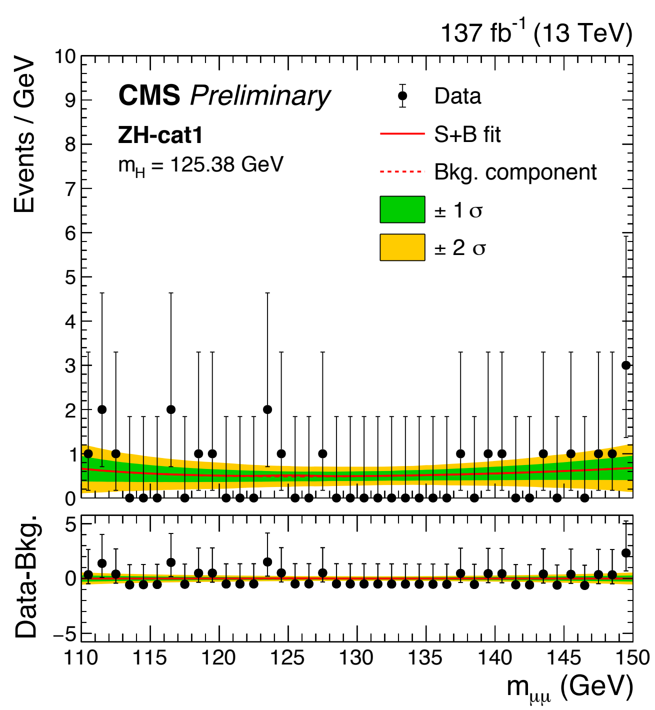
WH & ZH Analysis

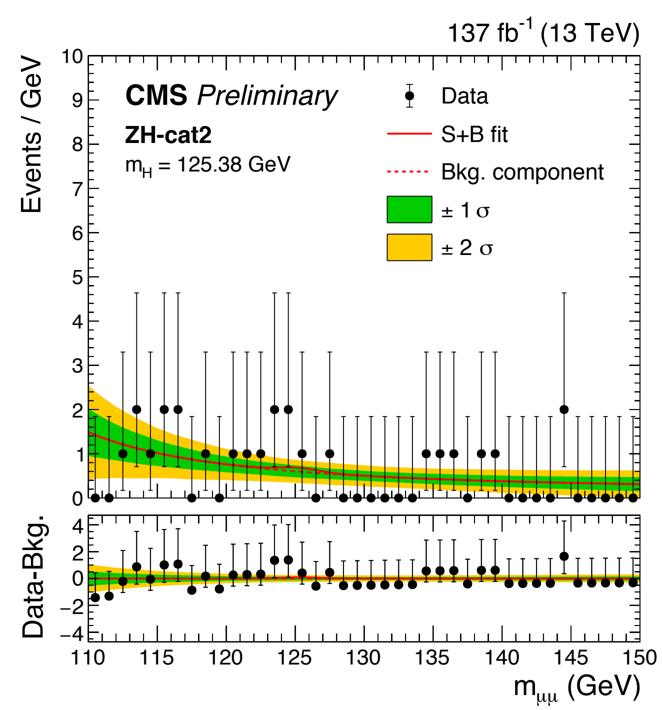
Category	Sig.	WH (%)	qqZH (%)	ggZH (%)	$t\bar{t}H + tH$ (%)	HWHM (GeV)	Bkg. in HWHM	S/(S+B) (%) in HWHM	$S/\sqrt{B}$ in HWHM	Data in HWHM
WH-cat1	0.82	76.2	9.6	1.6	12.6	2.00	32.0	1.54	0.09	34
WH-cat2	1.72	80.1	9.1	1.5	9.3	1.80	23.1	4.50	0.23	27
WH-cat3	1.14	85.7	6.7	1.8	4.8	1.90	5.48	12.6	0.35	4
ZH-cat1	0.11	—	82.8	17.2	—	2.07	2.05	3.29	0.05	4
ZH-cat2	0.31	—	79.6	20.4	—	1.80	2.19	8.98	0.14	4











Background shapes used to fit background

BWZ

$$\frac{\Gamma_Z e^{a m_{\mu\mu}}}{(m_{\mu\mu} - m_Z)^2 + (\Gamma_Z/2)^2}$$

BWZGamma

$$f \times \mathrm{BWZ}(m_{\mu\mu}; a, m_Z, \Gamma_Z) + (1 - f) \times \frac{e^{a m_{\mu\mu}}}{m_{\mu\mu}^2}$$

ttH Analysis Details

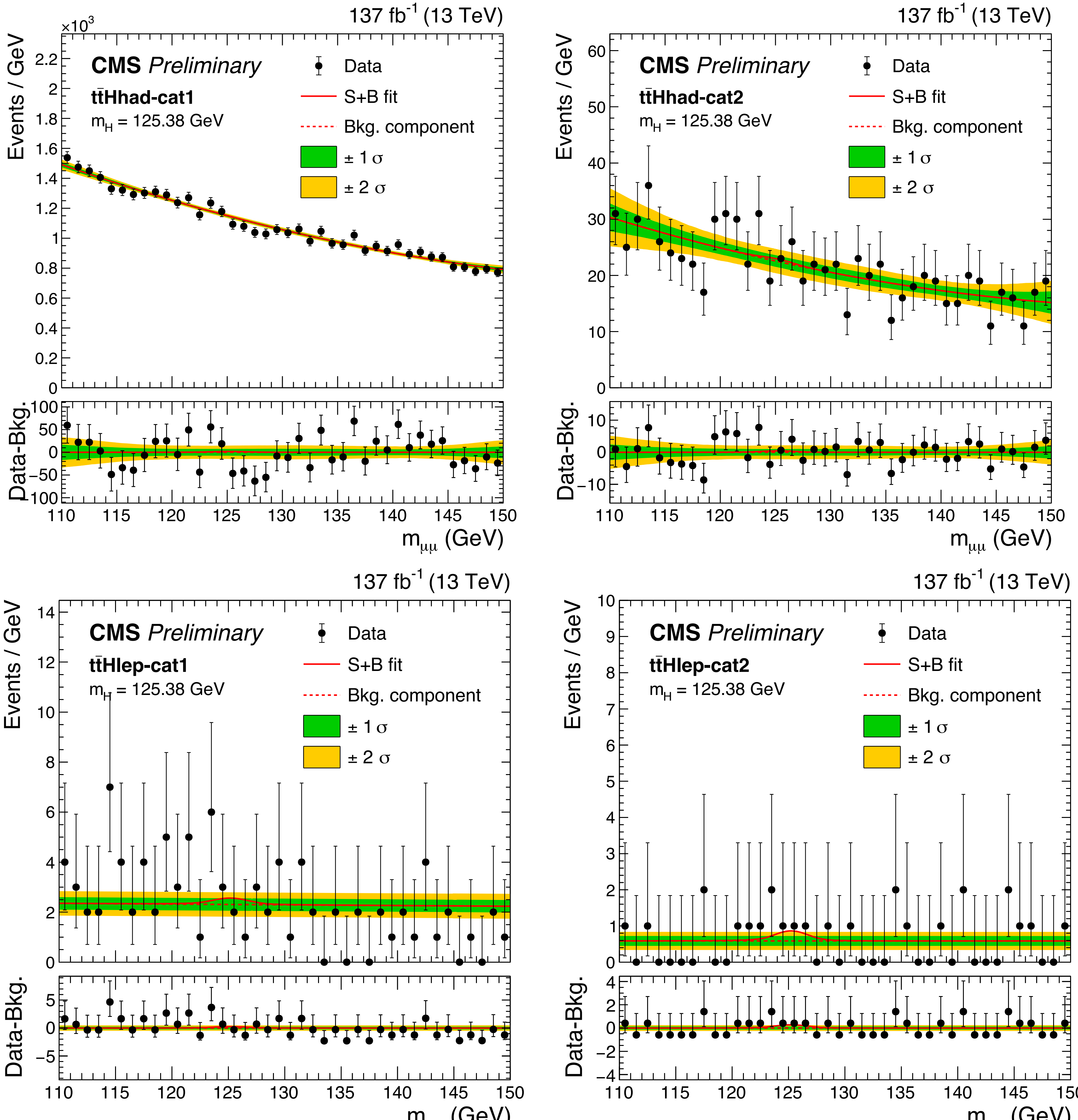
Event Selection

Selection	$t\bar{t}H$ hadronic	$t\bar{t}H$ leptonic
Number of b quark jets	>0 medium or >1 loose b-tagged jets	
Number of leptons	2	3 or 4
Lepton charge	$\sum q(\ell)=0$	$N(\ell)=3\ (4) \rightarrow \sum q(\ell)=\pm 1\ (0)$
Jet multiplicity ($p_T > 25\,\mathrm{GeV}$, $\lvert\eta\rvert < 4.7$)	≥ 3	≥ 2
Leading jet p_T	$> 50\,\mathrm{GeV}$	$> 35\,\mathrm{GeV}$
Jet triplet mass	$100 < m_{jjj} < 300\,\mathrm{GeV}$	—
Z mass veto	—	$\lvert m_{\ell\ell} - m_Z\rvert > 10\,\mathrm{GeV}$
Low mass resonance veto	—	$m_{\ell\ell} > 12\,\mathrm{GeV}$

Summary of various subcategories

Category	Sig.	$t\bar{t}H$ (%)	ggH (%)	VH (%)	tH (%)	VBF+$b\bar{b}$H (%)	HWHM (GeV)	Bkg. in HWHM	$S/(S+B)$ (%) in HWHM	$S/\sqrt{B}$ in HWHM	Data in HWHM
$t\bar{t}$Hhad-cat1	6.87	32.3	40.3	17.2	6.2	4.0	1.85	4298	1.07	0.07	4251
$t\bar{t}$Hhad-cat2	1.62	84.3	3.8	5.6	6.2	—	1.81	82.0	1.32	0.12	89
$t\bar{t}$Hhad-cat3	1.33	94.0	0.3	1.3	4.2	0.2	1.80	12.3	6.87	0.26	12
$t\bar{t}$Hlep-cat1	1.06	85.8	—	4.7	9.5	—	1.92	9.00	7.09	0.22	13
$t\bar{t}$Hlep-cat2	0.99	94.7	—	1.0	4.3	—	1.75	2.08	24.5	0.47	4

ttH Mass Distributions



Background Shapes

ttH(had)

- 2nd order Bernstein pol.
- Sum of 2 exponentials

ttH(lep)

- Exponential

ggH Analysis

Summary of various subcategories

Category	Sig.	ggH (%)	VBF (%)	VH + $t\bar{t}$H (%)	HWHM (GeV)	Bkg. in HWHM	S/(S+B) (%) in HWHM	$S/\sqrt{B}$ in HWHM	Data in HWHM
ggH-cat1	267.6	93.7	2.9	3.4	2.12	86359	0.20	0.60	86632
ggH-cat2	311.5	93.5	3.4	3.1	1.75	46347	0.46	0.98	46393
ggH-cat3	131.4	93.2	4.0	2.8	1.60	12655	0.70	0.80	12738
ggH-cat4	125.6	91.5	5.5	3.0	1.47	8259	1.03	0.96	8377
ggH-cat5	53.8	83.5	14.3	2.2	1.50	1678	2.16	0.91	1711

Background Model Used across ggH subcategories

Correlated "Core" shape X **Per-category shape modulation**

Envelope of 3 functions

2nd or 3rd order Chebyshev polynomials

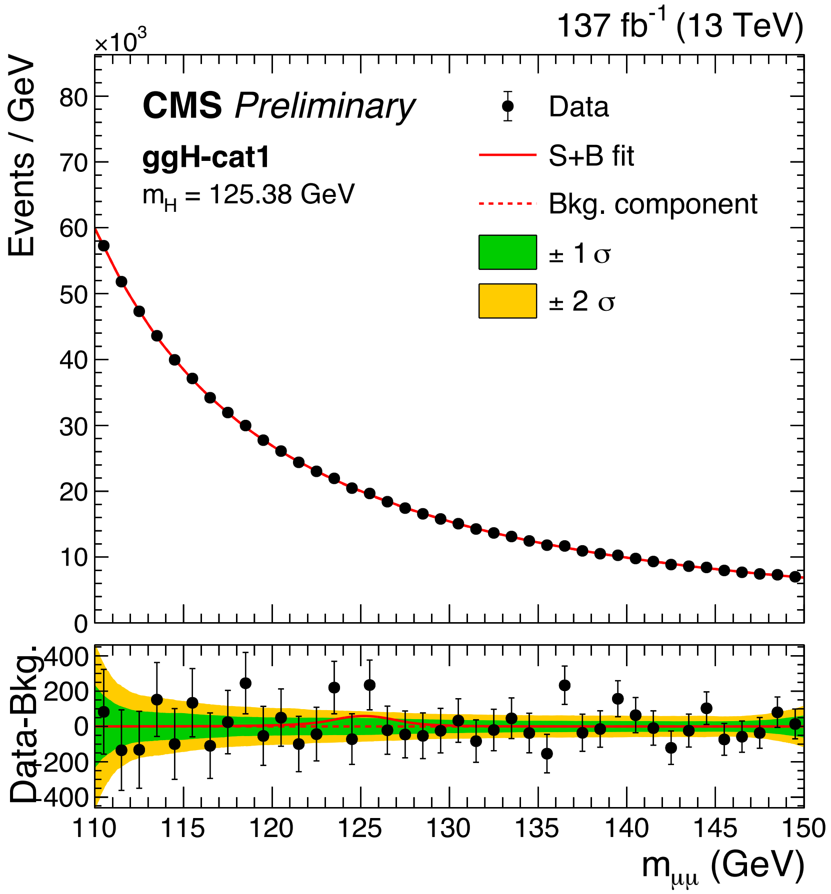
(1) Modified Breit Wigner

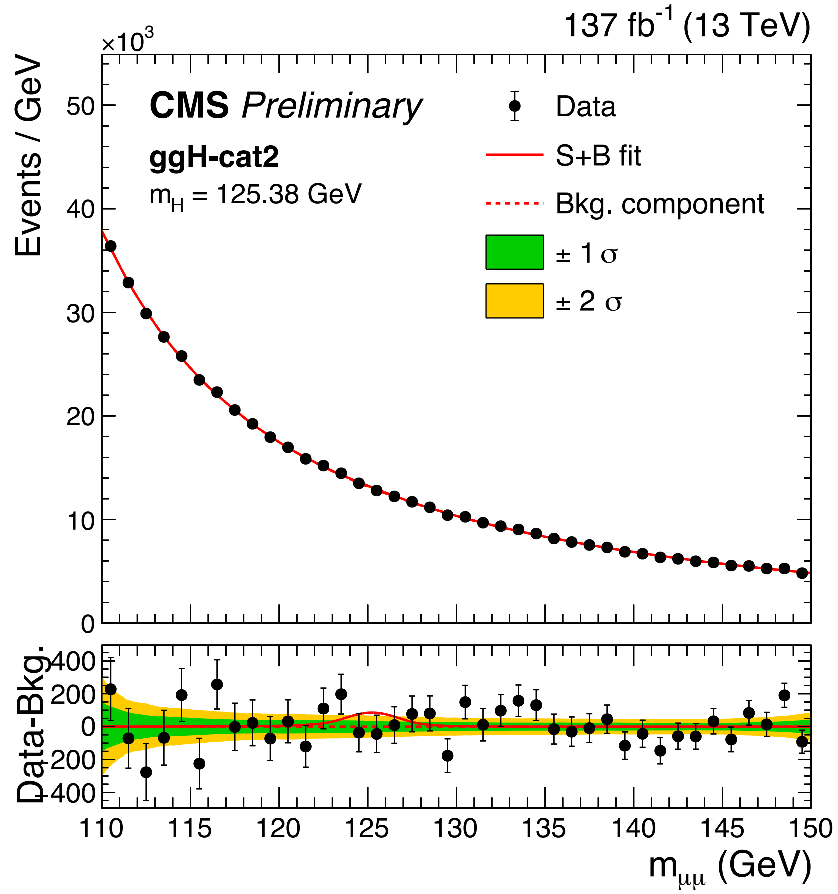
$$\frac{e^{a_2 m_{\mu\mu} + a_3 m_{\mu\mu}^2}}{(m_{\mu\mu} - m_Z)^{a_1} + (\Gamma_Z/2)^{a_1}}$$

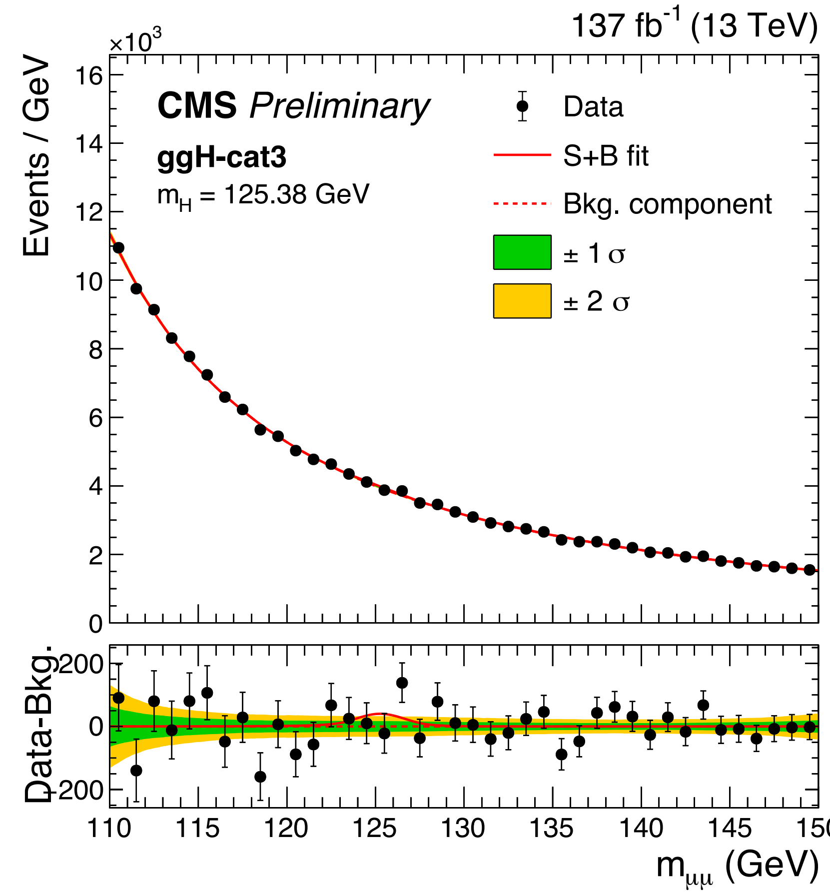
(2) Sum of exponentials

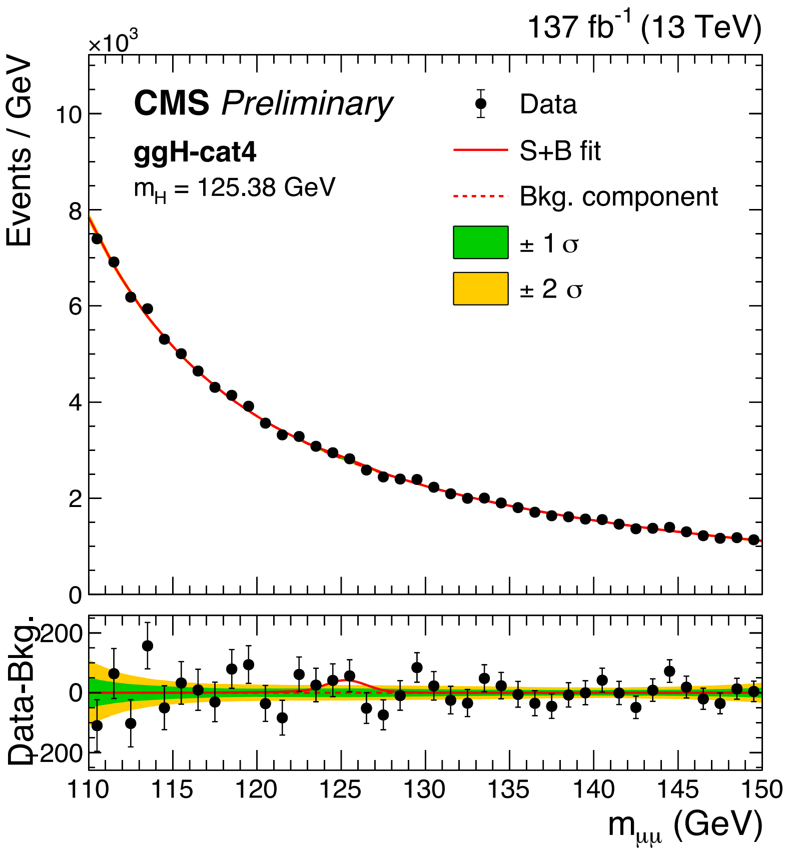
(3) Non-parametric shape from spline interpolation of FEWZ prediction

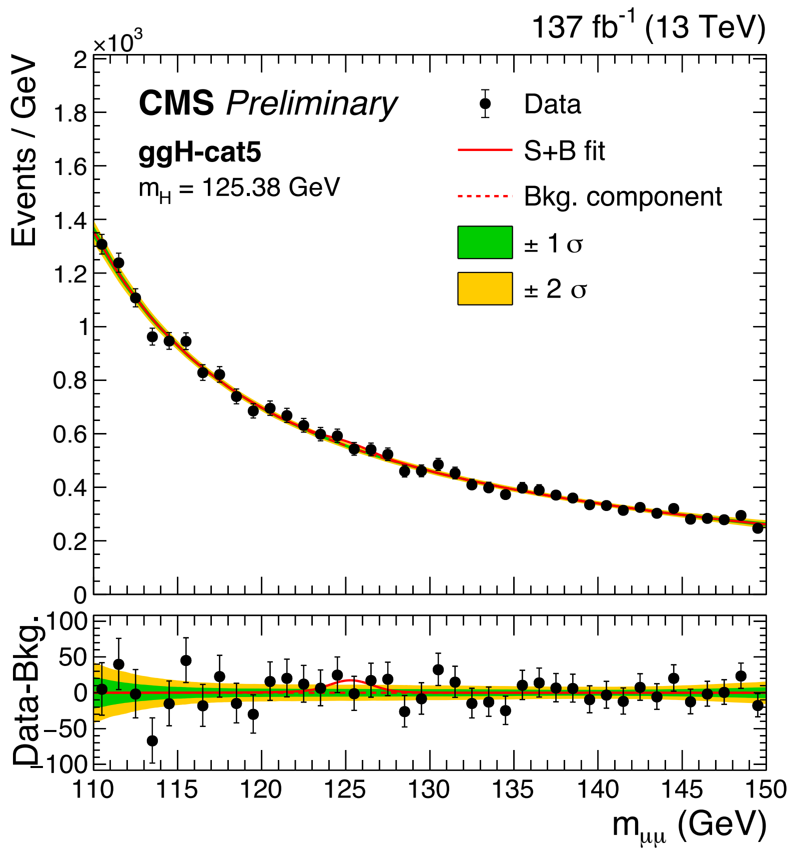
ggH Mass Distributions



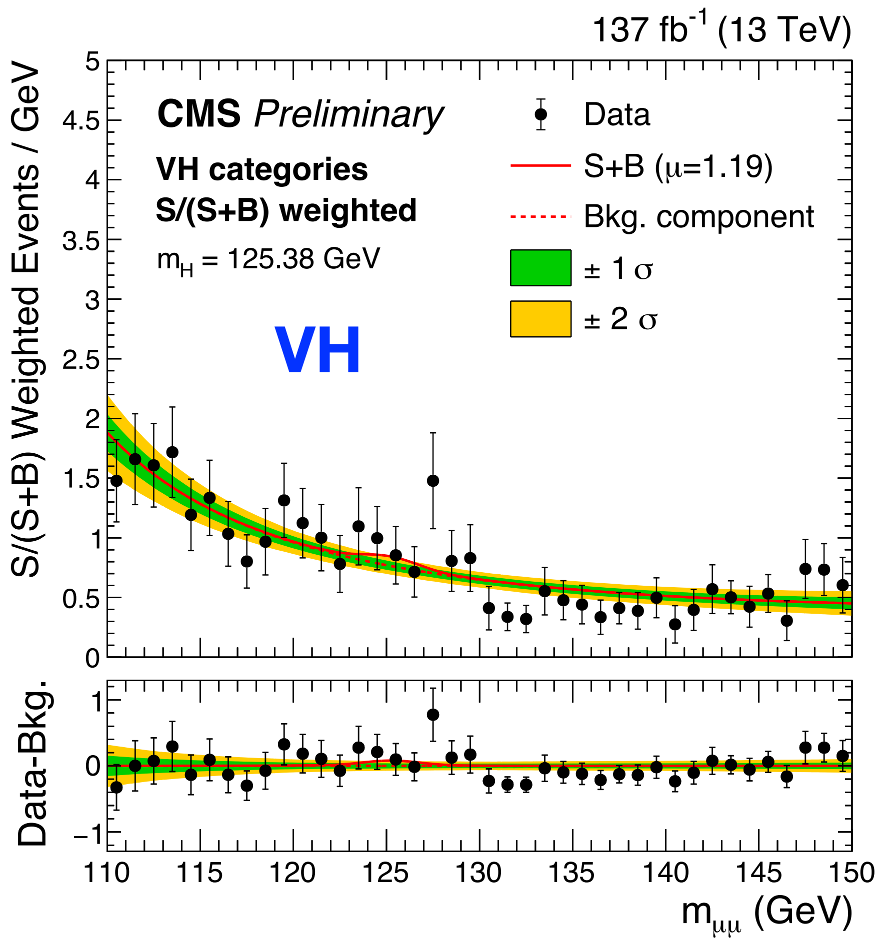


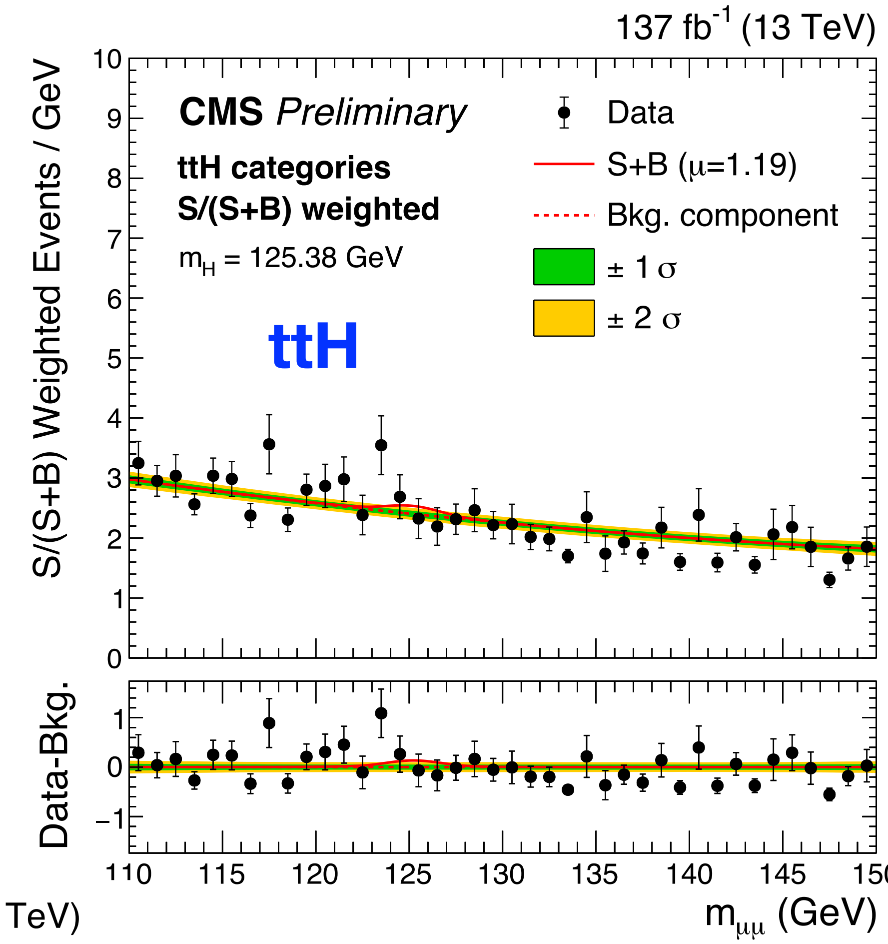


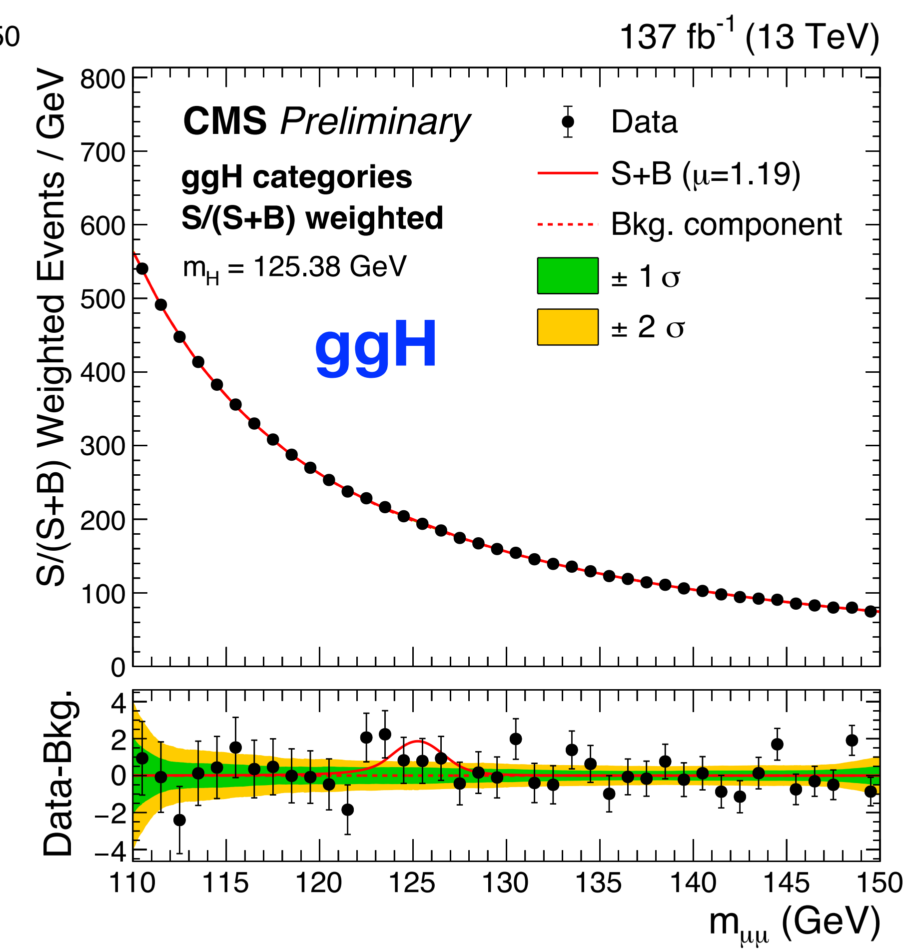




S/(S+B) Weighted Mass Distributions

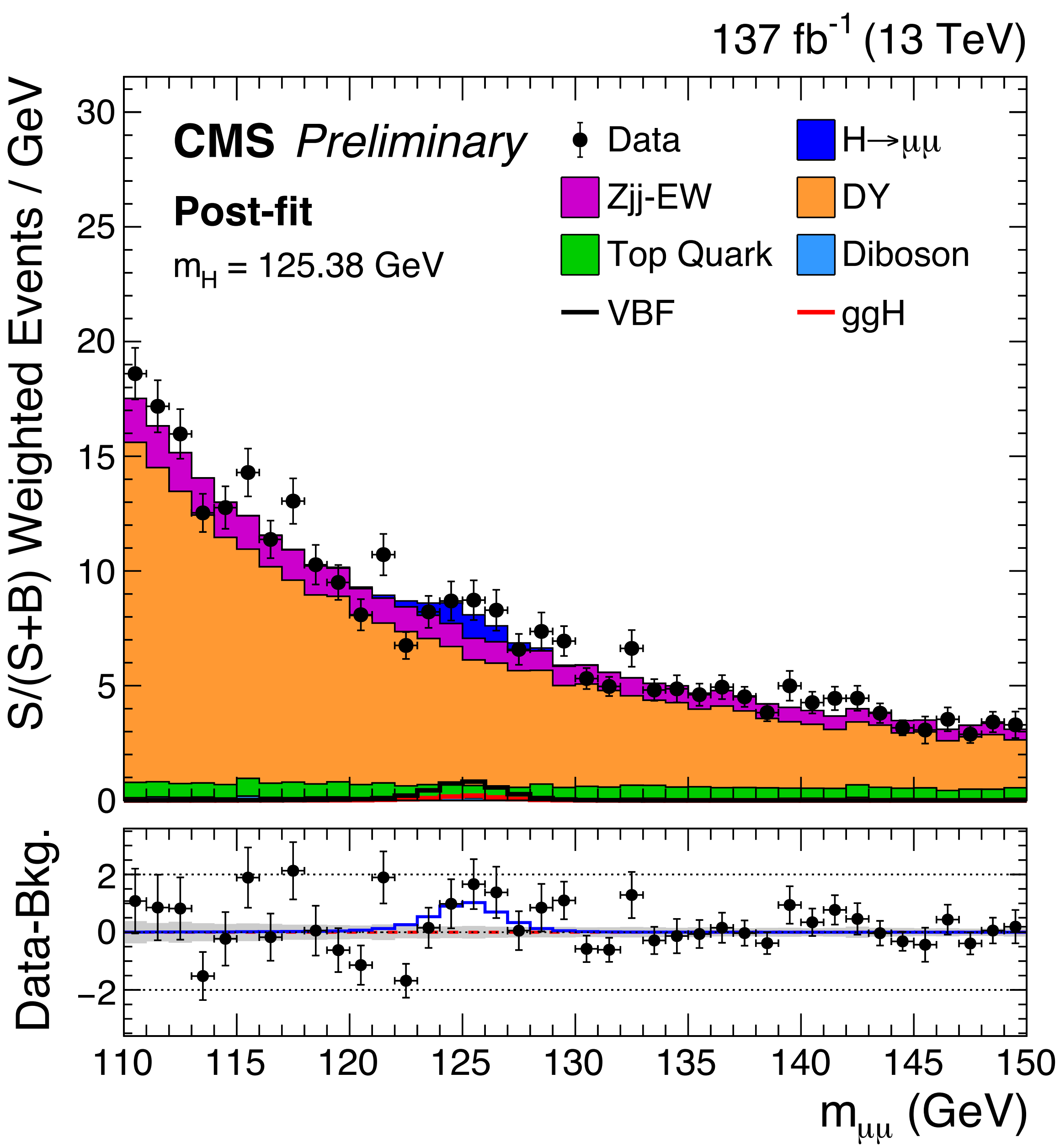




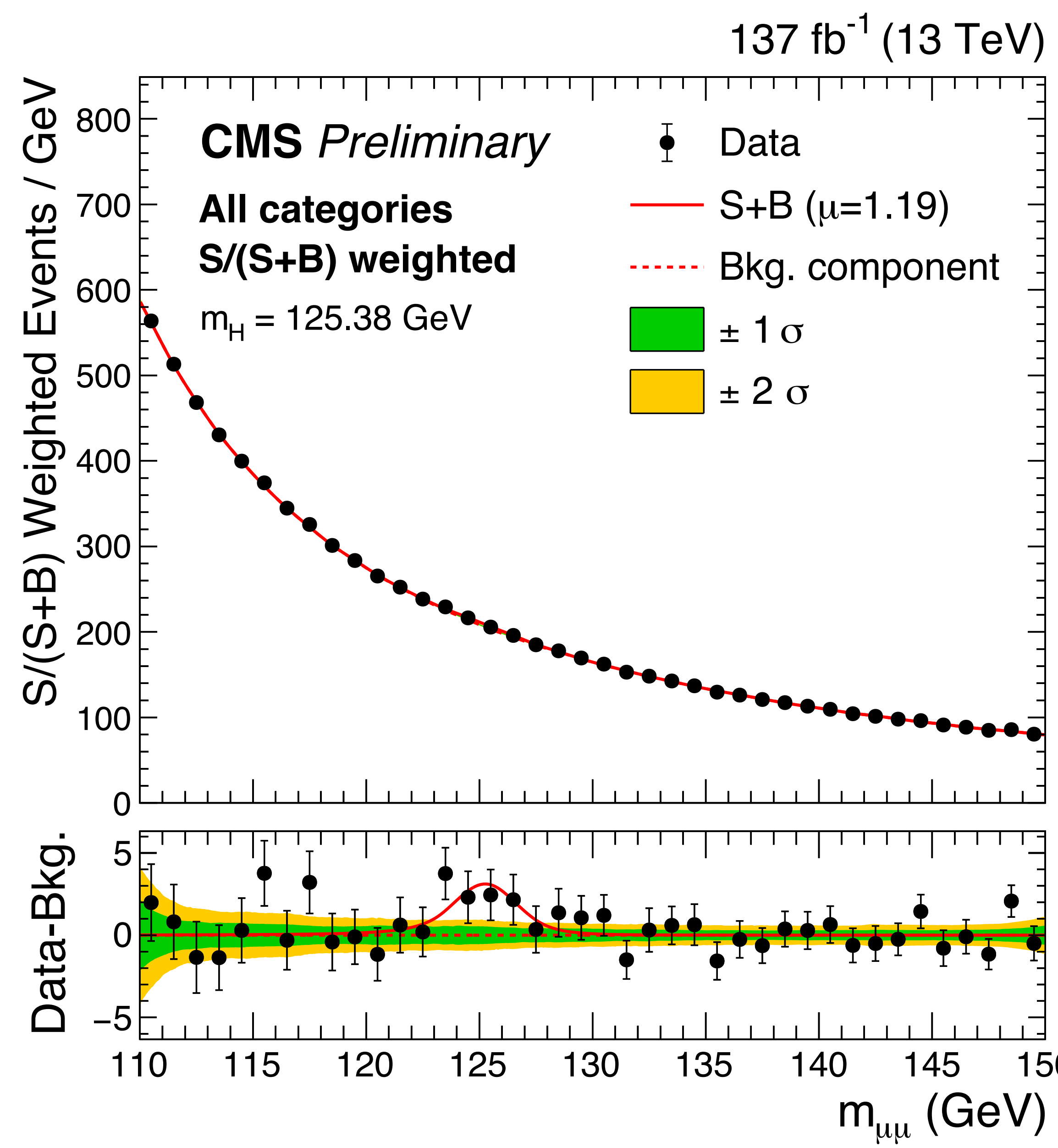


S/(S+B) Weighted Mass Distributions

VBF Analysis

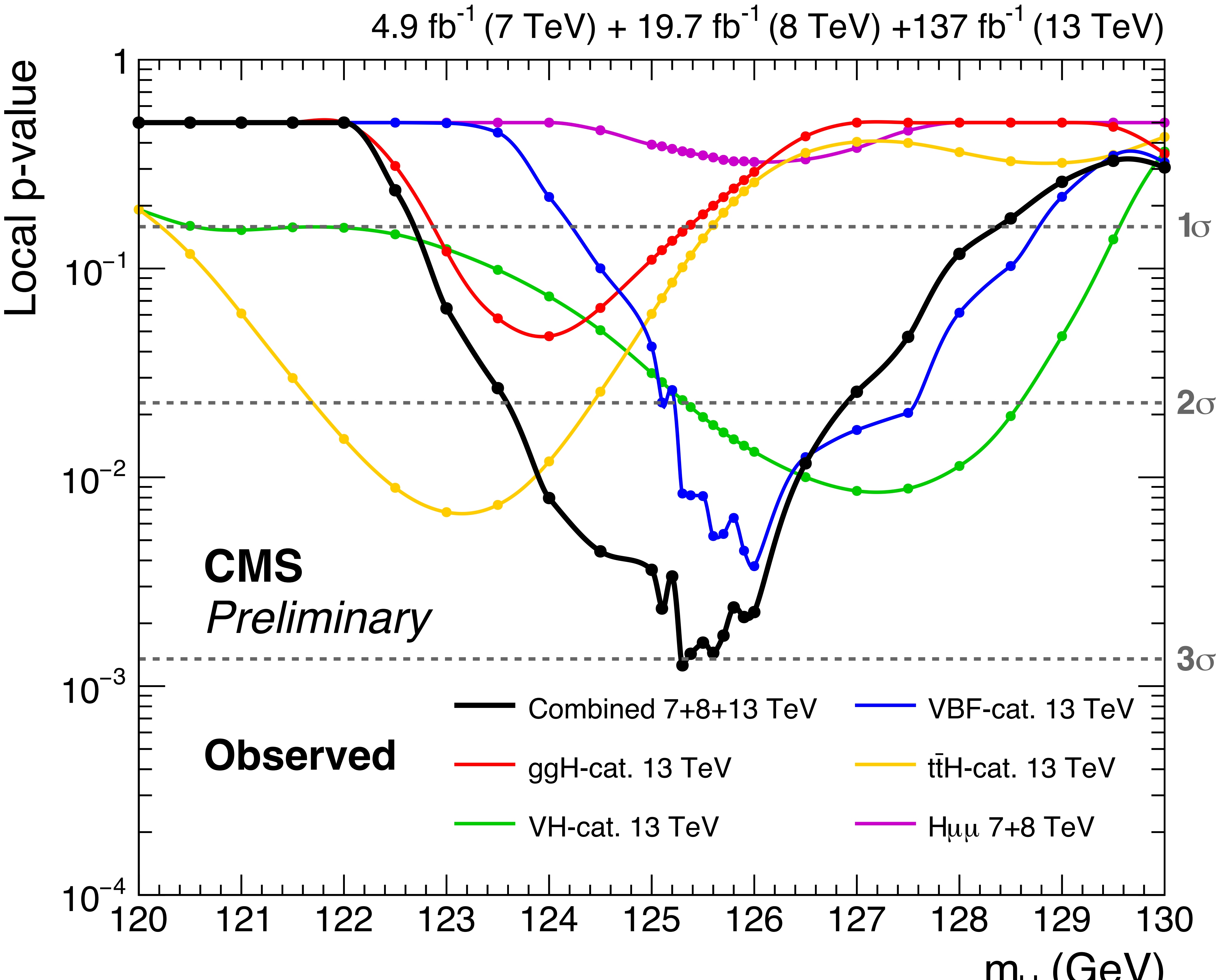


All 4 channels combined

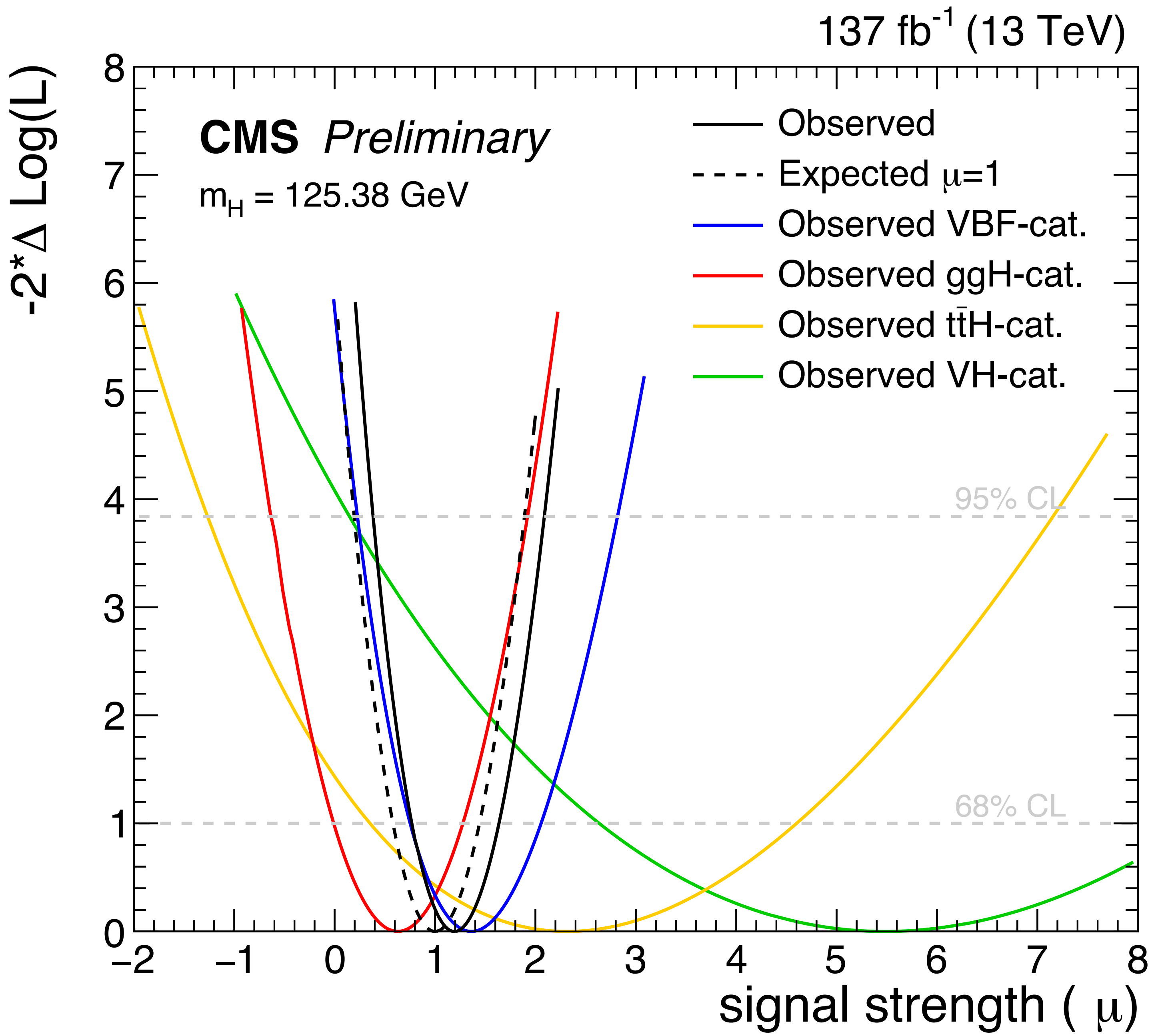


Events weighted by S/(S+B) of the corresponding bin for a *mass-decorrelated DNN* ($m_{\mu\mu}$ fixed to 125 GeV)

Run-1 + Run-2 Combination



H→μμ Signal



$$\hat{\mu} = 1.19^{+0.44}_{-0.42}$$

Uncertainty source	$\Delta\mu$	
Total uncertainty	+0.44	−0.42
Statistical uncertainty	+0.41	−0.39
Total systematic uncertainty	+0.17	−0.16
Size of simulated samples	+0.07	−0.06
Total experimental uncertainty	+0.12	−0.10
Total theoretical uncertainty	+0.10	−0.11