Measurement of hadronic Higgs boson decays at FCC-ee

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Motivations

Measurement of **Higgs couplings** to quarks and gluons at FCC-ee

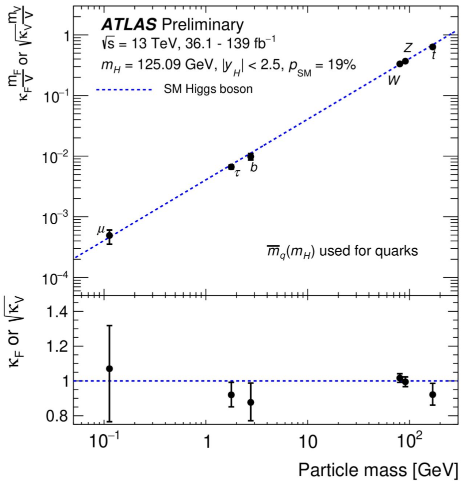
Yukawa coupling

$$m_f = v\frac{y_f}{\sqrt{2}}$$

Coupling-mass relation for fermions in the SM

Deviation from SM → Possible BSM physics

2022 (LHC)



~2040 (HL-LHC)

Coupling	HL-LHC
κ_W [%]	1.5*
κ_Z [%]	1.3*
κ_g [%]	2*
κ_γ [%]	1.6*
$\kappa_{Z\gamma}$ [%]	10*
κ_c [%]	–
κ_t [%]	3.2*
κ_b [%]	2.5*
κ_μ [%]	4.4*
κ_τ [%]	1.6*
BR_{inv} (<%, 95% CL)	1.9*
BR_{unt} (<%, 95% CL)	4*

Fully hadronic represents 80% of the Higgs decays

Higgs decay	H→bb	H→WW/ZZ	H→gg	H→cc	H→ss	(H→ττ)
BR	57.7%	11%	8.6%	2.9%	0.024%	(6.2%)

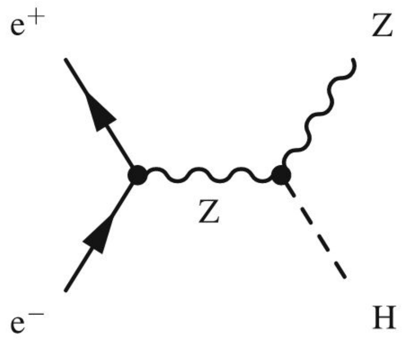
only one observed to this day

Observable at FCC-ee

Also possible future observation of **Flavour-violating** decays

Overview

ZH (Higgstrahlung)



Z decay channels

Z→ll, l = e,μ
Z→qq
Z→$\nu\nu$

√S & Luminosities (full program)

240 GeV ➔ 10.8ab-1
365 GeV ➔ 3.0ab-1

Samples IDEA (Delphes fast sim)

signals ZH@240 - H→bb/cc/gg/ss/WW/ZZ/ττ
ZH(+VBF)@365
N = 2 exclusive kT clustering for Z(ll/$\nu\nu$)**, N = 4 for Z(qq)

backgrounds WW, ZZ, Z/γ*, Zqq, ee, μμ, tt, $\nu\nu$Z, qqH

- **Orthogonal selection** to separate all **Z decay** channels (ll, qq, $\nu\nu$)
- S/B optimization with **cuts** on H dijets and Z decay pairs
  - cuts on E_{jets}, E_{miss}, $p_{leptons}$, $|\cos(\theta_{ll/qq})|$, $m_{ll/qq}$, ...
- **Categorization** of events in relation to their tagged Higgs decay *(b,c,g,s,W,Z,τ)*
  - categorization using Jet Tagger scores + jet properties
- **Simultaneous fit** on all categories assuming tagging efficiencies

** We also force reconstruction of H(WW/ZZ) to be 2 jets (rather than the expected 4)

Outline

Analysis I

ZH$\longrightarrow$**ll**jj/$\nu\nu$jj at **240** & **365** GeV (APC)

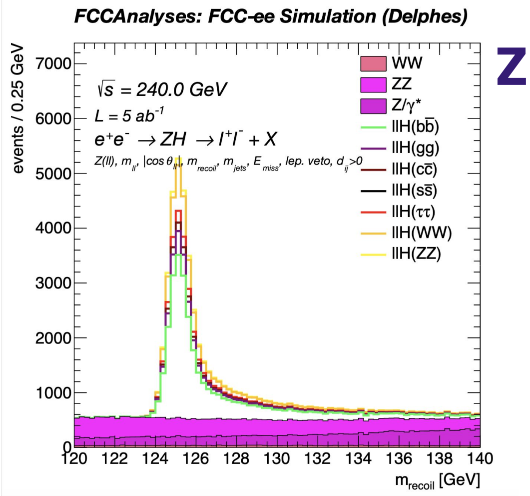
jj = bb,cc,gg,ss,WW,ZZ,ττ

Analysis II

ZH$\longrightarrow$**qq**jj/$\nu\nu$jj at **240** & **365** GeV (BNL)

Combination of the studies

ZH⟶lljj/$\nu\nu$jj at 240 GeV



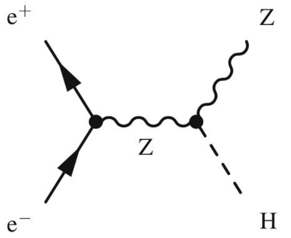
Z(ll)

Signals: Z(ll)H(bb/cc/gg/ss/WW/ZZ/ττ)

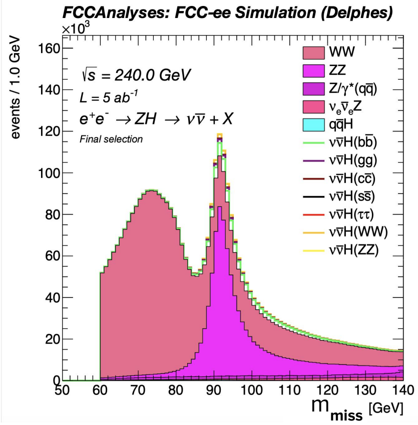
Backgrounds: WW, ZZ, Z/γ*, Zqq, ee, mumu

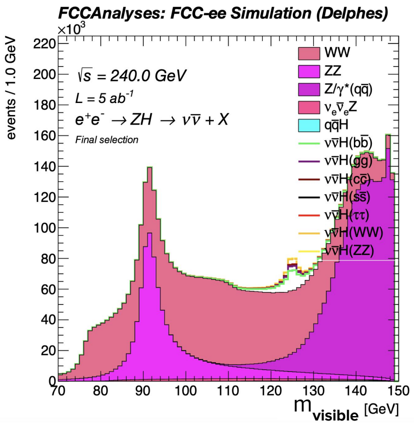
1D Study of the mass recoiling from the **Z**

$$(E_{ll} + E_H, \overrightarrow{p_{ll}} + \overrightarrow{p_H}) = (\sqrt{s}, \vec{0}) \Rightarrow M^2_{recoil} = s + m_Z^2 - 2E_{ll}\sqrt{s}$$



Z($\nu\nu$)





Signals: Z($\nu\nu$)H(bb/cc/gg/ss/WW/ZZ/ττ)

Backgrounds: WW, ZZ, $\nu\nu$Z, Zqq, qqH

2D Study of the mass recoiling from the **H** + visible mass from **H decay**

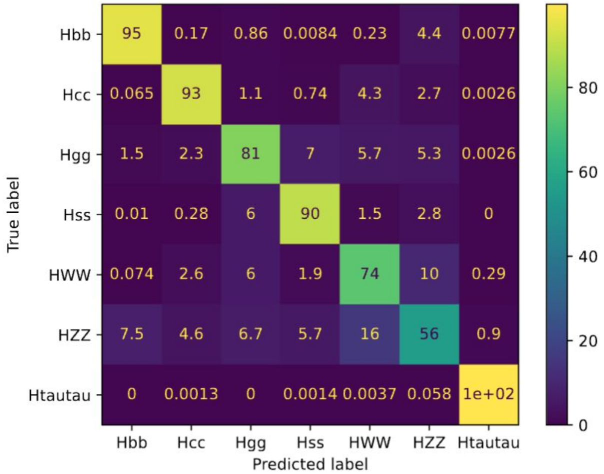
$m_{miss} (= m_{\nu\nu}) = m_{recoil}$

$m_{visible} = m_{jj}$

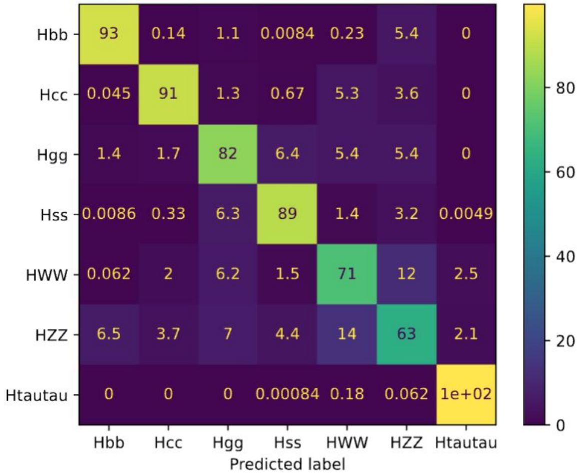
Events categorization - 240 GeV

We train a Neural Network to categorize the events in each signal channels

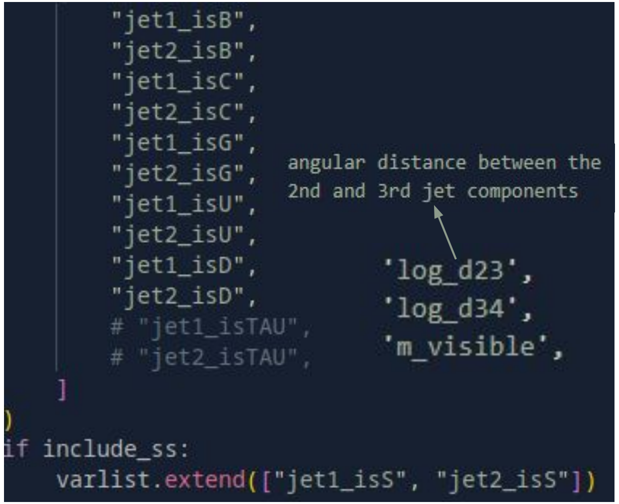
Z($\nu\nu$) Confusion Matrix



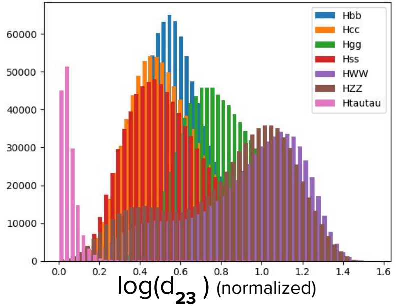
Z(ll) Confusion Matrix

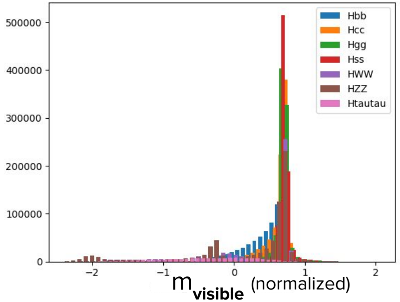


Training variables



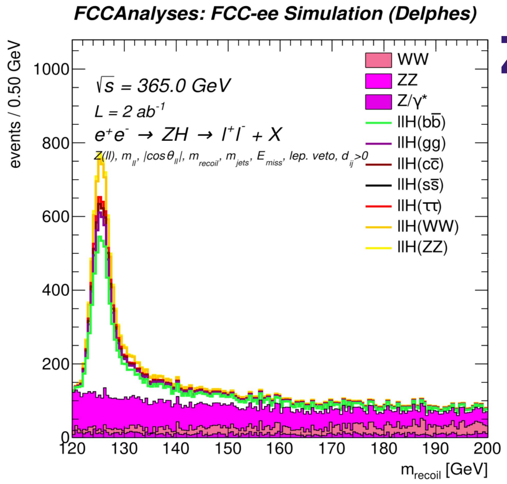
Training variables consist of output scores of a ParticleNet jet tagger which runs after reconstruction + some additional kinematic variables improving sensitivity in some channels





ZH⟶lljj at 365 GeV

changes compared to 240 GeV



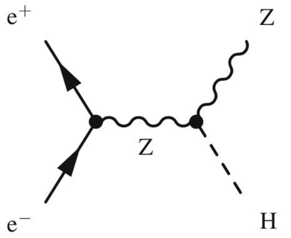
Z(ll)

Signals: Z(ll)H(bb/cc/gg/ss/WW/ZZ/$\tau\tau$)

Backgrounds: WW, ZZ, Z/γ*, ~~Zqq~~, ee, mumu, tt

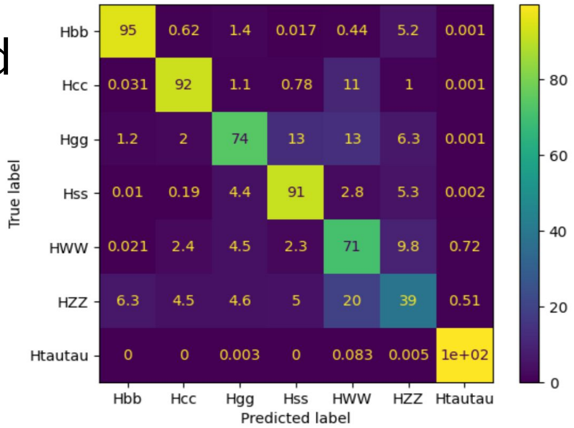
1D Study of the mass recoiling from the **Z**

$$\left(E_{ll} + E_H, \overrightarrow{p_{ll}} + \overrightarrow{p_H}\right) = \left(\sqrt{s}, \vec{0}\right) \Rightarrow M^2_{recoil} = s + m_Z^2 - 2E_{ll}\sqrt{s}$$



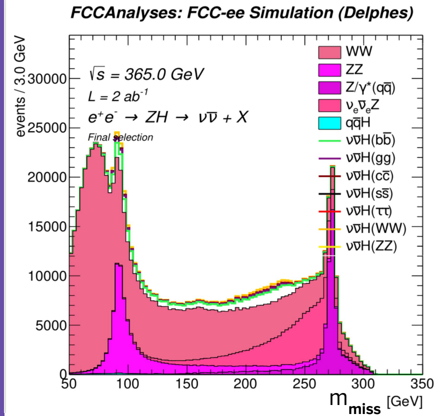
Same training variables and strategy as for 240GeV

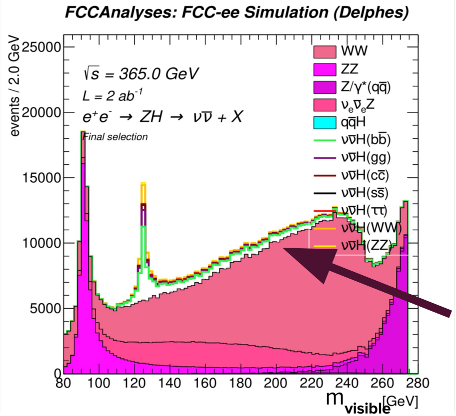
Z(ll) Confusion Matrix



$\nu\nu$jj at 365 GeV - Separate ZH and VBF

$\nu\nu$jj





Backgrounds: WW, ZZ, $\nu\nu$Z, Zqq, qqH, tt

2D Study of the mass recoiling from the **H** + visible mass from **H decay**

Contribution from **VBF** non-negligible at 365 GeV

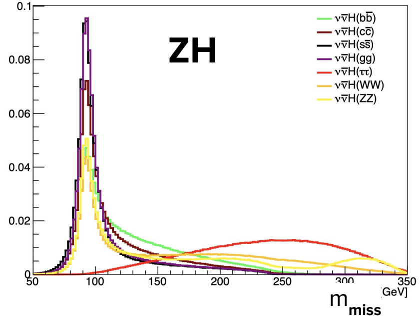
$m_{miss} (= m_{\nu\nu}) = m_{recoil}$ $\quad$ $m_{visible} = m_{jj}$

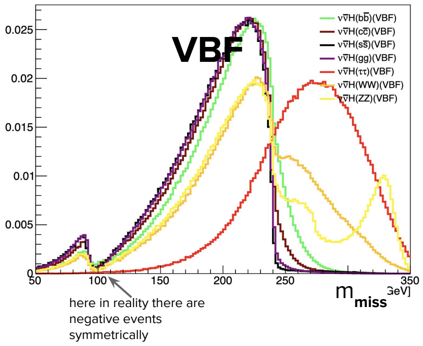
ZH/VBF separation

Signals: ZH - ***$nu_{mu}nu_{mu}H$ * 3***

VBF - ***$nu_e nu_e H$ - $nu_{mu}nu_{mu}H$***

Same could also be considered for 240GeV in later studies





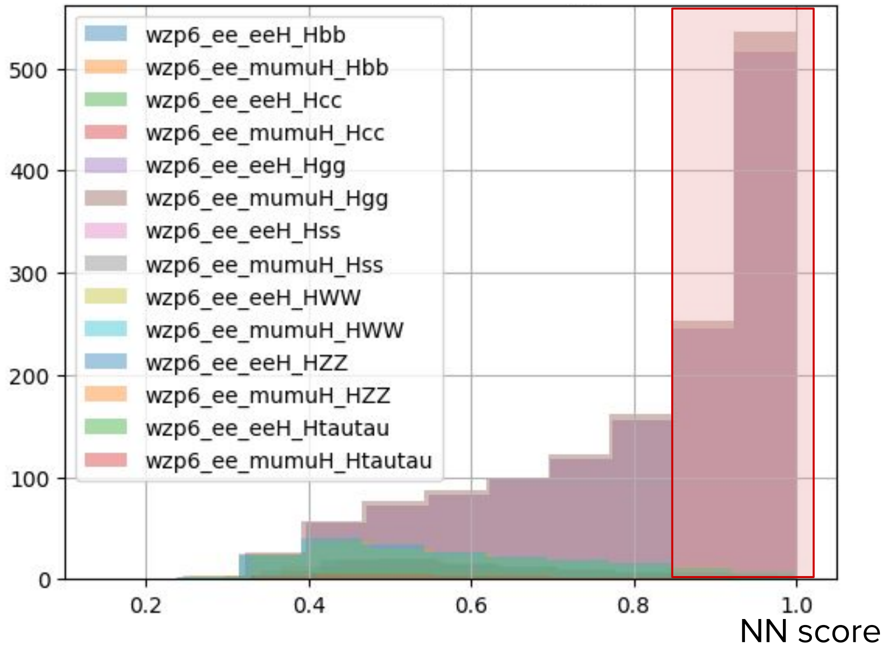
The number of POIs in the fit is now 14 = 7*(vbf+zh) $\quad$ *7 = len(bb/cc/gg/ss/WW/ZZ/ττ)*

We then categorize events as before for both ZH and VBF

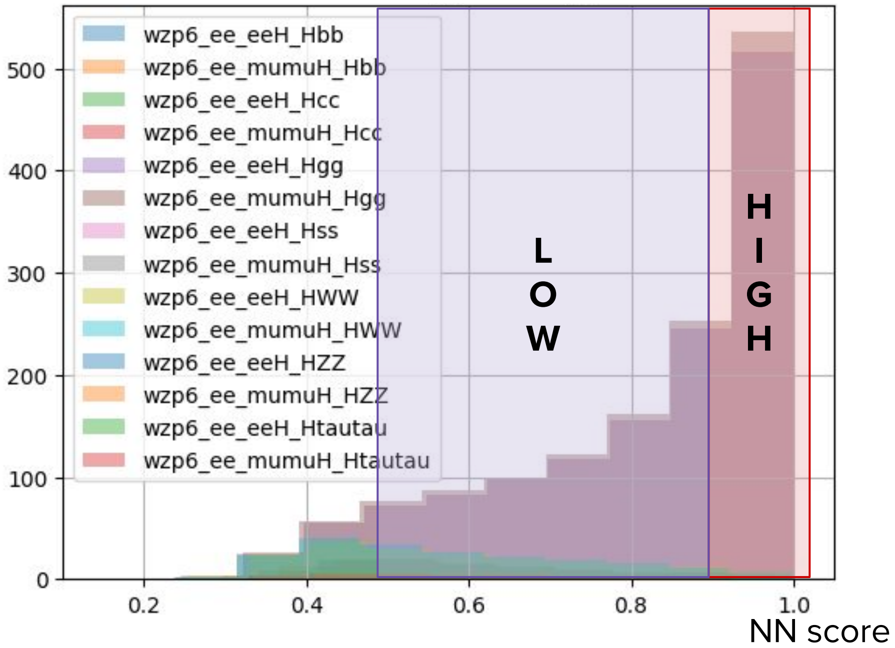
Purity categorization - 240 & 365 GeV

Goal : increase analysis sensitivity by including purity categories in the samples

before



after



We considered a maximum of **3 purity categories (high, mid, low)**

$\nu\nu$jj at 240 & 365 GeV (BNL)

240

Signals: Z($\nu\nu$)H(bb/cc/gg/ss/WW/ZZ/ττ)

365

Signals: ZH - $\boldsymbol{nu_{mu}nu_{mu}H * 3}$

VBF - $\boldsymbol{nu_{e}nu_{e}H}$ - $\boldsymbol{nu_{mu}nu_{mu}H}$

(same strategy as in page 8)

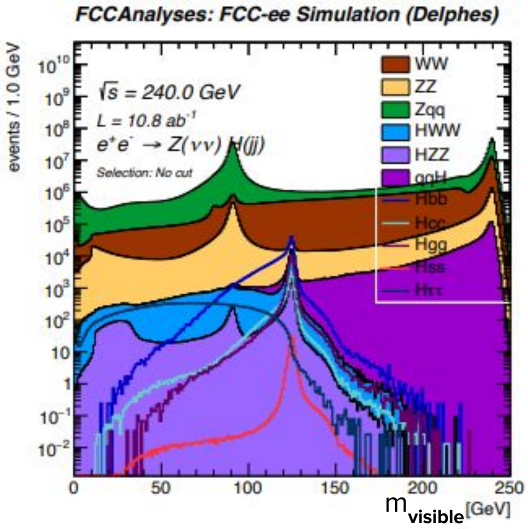
Backgrounds: WW, ZZ, Z/γ*, Zqq, $\nu\nu$Z

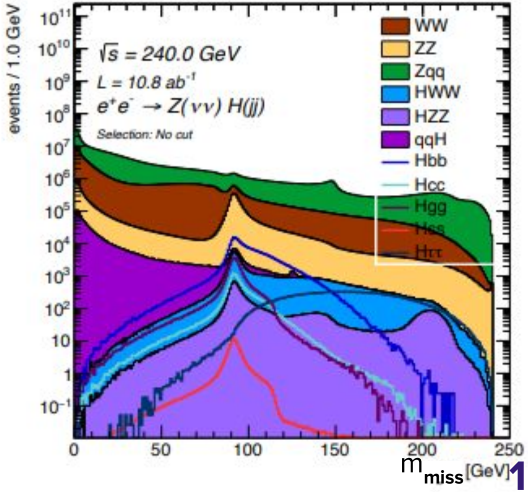
2D Study of the mass recoiling from the **H** + visible mass from **H decay**

$m_{miss}(= m_{\nu\nu}) = m_{recoil}$ $m_{visible} = m_{jj}$

Categorization of jets using the same ParticleNet jet tagger scores as previous analysis (different method)

Events selection orthogonal to Zll analysis





ZH⟶qqjj at 240 & 365 GeV

Signals: Z(qq)H(bb/cc/gg/ss/WW/ZZ/ττ)

Backgrounds: WW, ZZ, Z/γ*, Zqq, $\nu\nu$Z

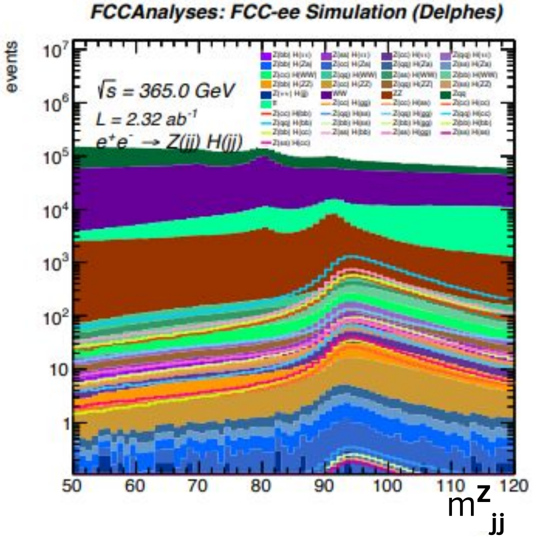
2D Study of the both hadronic masses from the **H** and **Z**

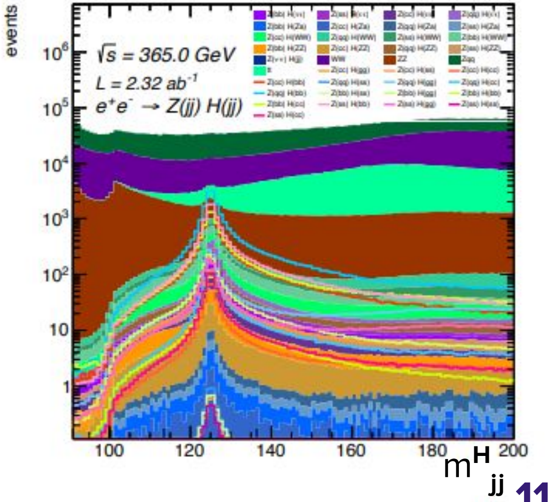
$m_H = m^H_{jj}$ $m_Z = m^Z_{jj}$

Categorization of jets using the same ParticleNet jet tagger scores as previous analysis (different method)

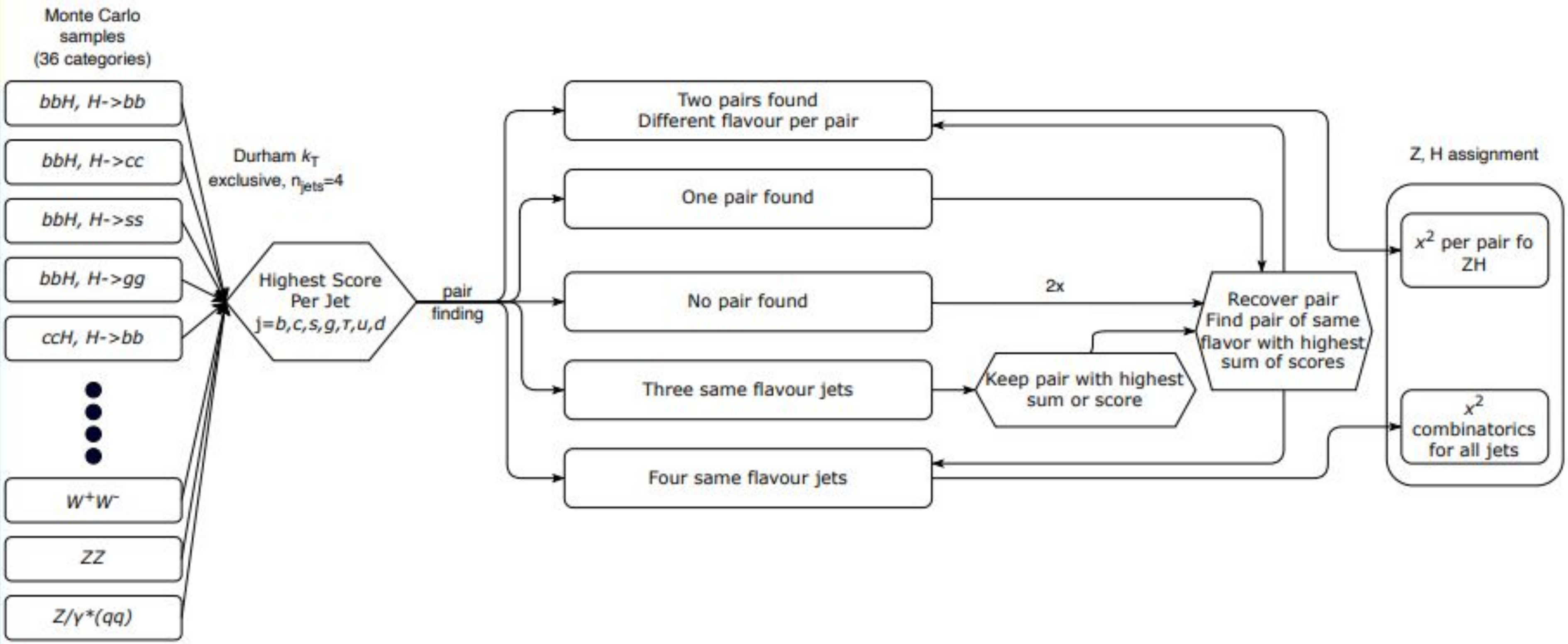
Events selection orthogonal to Z(ll)/Z($\nu\nu$) analysis

Jet Pairing based on tagger scores & combinatorics





Jet pairs reconstruction for Z(qq)H(jj)



Categorization for Z(qq) and Z($\nu\nu$) - Score Map

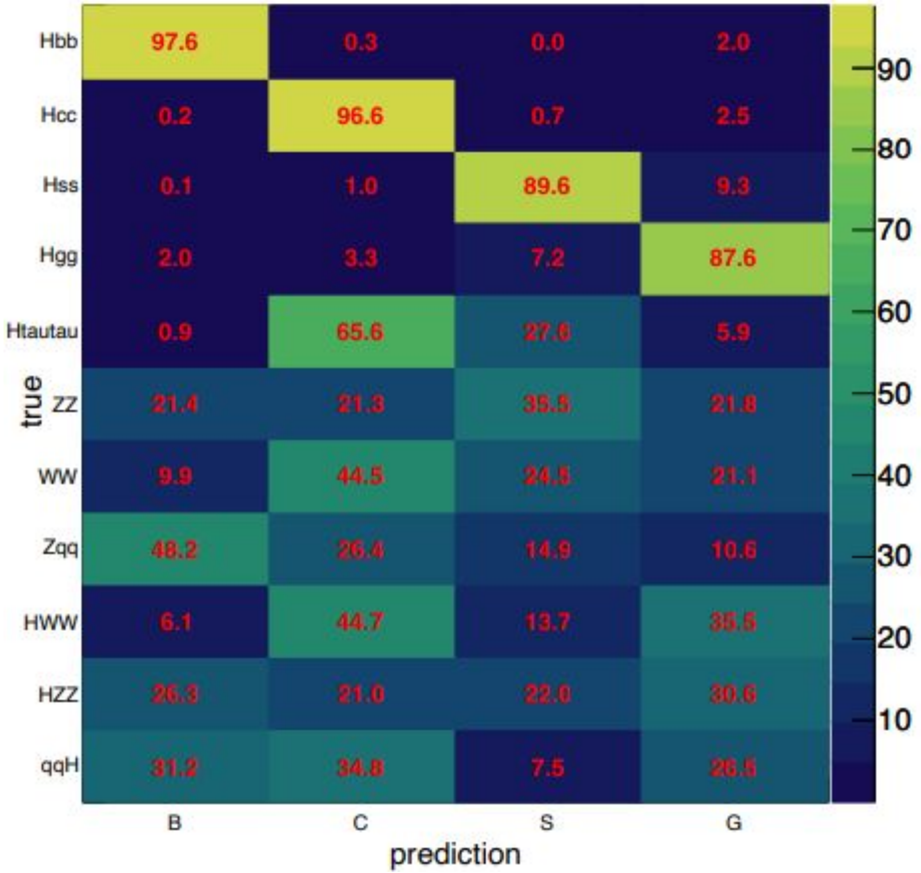
Events are categorised from the sum of the two jets score

$$\forall \text{ event: } J_{12}^{score} = J_1^{score} + J_2^{score}, J = b, c, s, g$$

$$\text{eg. if: } J_1^{score} = b \;\&\; J_2^{score} = b \implies B_{like}^{score}$$

$$\text{if } B_{like}^{score} > C_{like}^{score} > S_{like}^{score} G_{like}^{score} \implies B_{like}^{event}$$

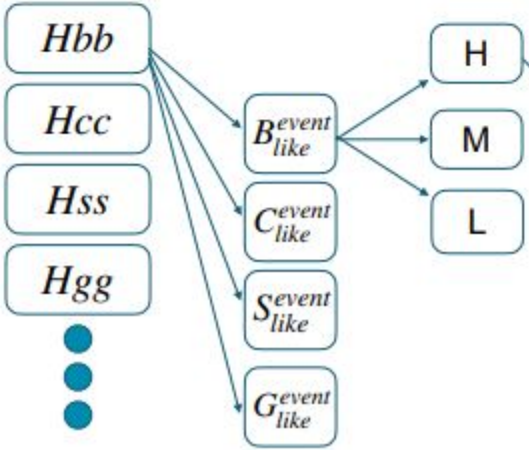
Events are further divided in 3 categories based on their *Score Like* value



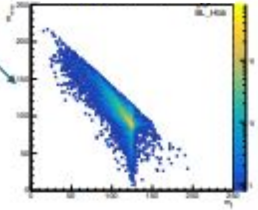
Categorization for Z(qq) and Z($\nu\nu$) - Purity categories

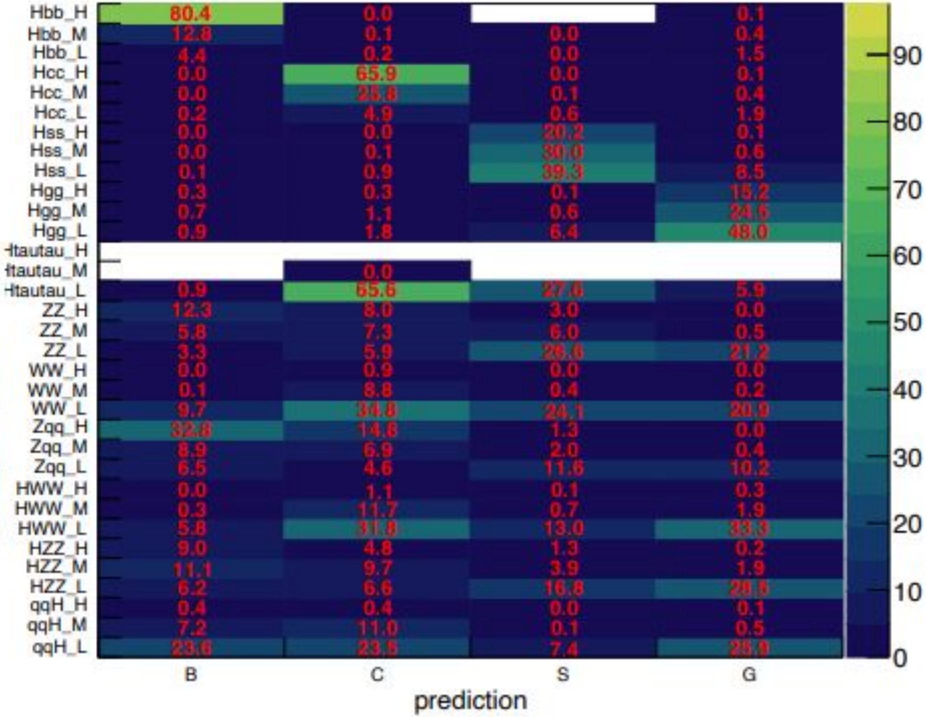
- Split the J^{score}_{like} in three bins of purity: Low, Medium, High

	B	C	S	G
L	< 1.1	< 1.0	< 1.1	< 1.2
M	$\in [1.1, 1.9]$	$\in [1.0, 1.8]$	$\in [1.1, 1.7]$	$\in [1.2, 1.5]$
H	> 1.9	> 1.8	> 1.7	> 1.5



m_{miss}(vs) $m_{visible}$





Results - Combination at 240 GeV

Fitting using **CMS** tool **CombineTF** to extract σ.BR in each category

Monte Carlo stats uncertainties

Backgrounds are let fully floating

Expected sensitivity (%) of σ(ZH).BR(H⟶jj) at 68% CL **L = 10.8ab-1**

240 GeV	H⟶bb	H⟶cc	H⟶gg	H⟶ss	H⟶ZZ	H⟶WW	H⟶ττ
Z⟶ll	0.68	4.02	2.18	234	13.66	1.78	4.08
Z⟶qq	0.32	3.52	3.07	408.55	52.08	8.74	110.73
Z⟶$\nu\nu$ (BNL)	0.33	2.27	0.94	137	19.84	1.89	21.76
Z⟶$\nu\nu$ (APC)	0.36	2.18	1.10	151	15.29	1.51	11
Combined (BNL)	0.21	1.66	0.8	104.99	10.07	1.16	3.97
Combined (APC)	0.22	1.65	0.93	121	9.56	1.11	3.79

Results - Combination at 365 GeV

Fitting using **CMS** tool **CombineTF** to extract σ.BR in each category

Monte Carlo stats uncertainties

Backgrounds are let fully floating

Expected sensitivity (%) of σ.BR(H⟶jj) at 68% CL L = 3.0ab-1

365 GeV		H⟶bb	H⟶cc	H⟶gg	H⟶ss	H⟶ZZ	H⟶WW	H⟶ττ
ZH⟶llH		1.74	11.29	5.74	1169	44	5.61	13.15
$\nu\nu$H	**ZH**	0.69	4.24	2.82	413.5	36.8	3.60	13.1
	VBF	0.68	3.99	2.64	295.2	43.4	5.43	30.6
ZH⟶qqH		0.51	3.87	3.05	564	55.7	5.73	259
Combined	**ZH**	0.41	3.13	2.21	356.12	26.01	3.18	10.97
	VBF	0.67	3.49	2.66	290	37.12	5.36	24.2

Conclusion & prospects

Promising results at **% level** in some categories

Achieved full combination at **240 GeV** and **365 GeV**.

Expected sensitivity (%) of σ.BR(H⟶jj) at 68% CL   L = 10.8ab-1

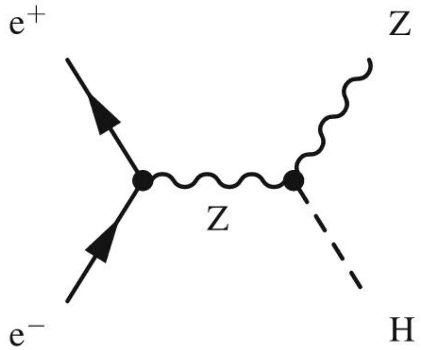
240 GeV		**H⟶bb**	**H⟶cc**	**H⟶gg**	**H⟶ss**	**H⟶ZZ**	**H⟶WW**	**H⟶ττ**
Combined (BNL)		0.21	1.66	0.8	104.99	10.07	1.16	3.97
Combined (APC)		0.22	1.65	0.93	121	9.56	1.11	3.79
365 GeV		**H⟶bb**	**H⟶cc**	**H⟶gg**	**H⟶ss**	**H⟶ZZ**	**H⟶WW**	**H⟶ττ**
Combined	**ZH**	0.41	3.13	2.21	356.12	26.01	3.18	10.97
	VBF	0.67	3.49	2.66	290	37.12	5.36	24.2

Thank you

Big thanks to : George Iakovidis
and Giovanni Marchiori, Jan Eysermans and Michele Selvaggi

(ZH) Higgstrahlung process - Recoil Mass

- $e^{+} + e^{-} \rightarrow Z + H$



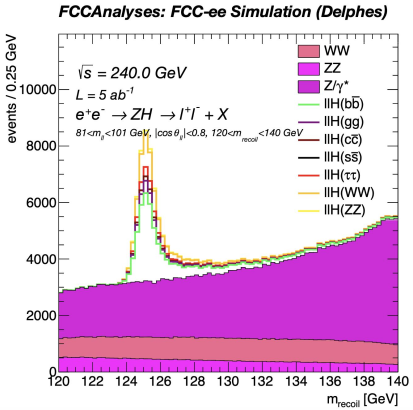
Recoil Mass :

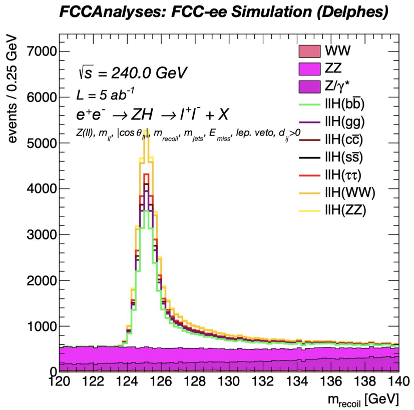
$$(E_{ll} + E_H, \overrightarrow{p_{ll}} + \overrightarrow{p_H}) = (\sqrt{s}, \vec{0}) \Rightarrow M^2_{recoil} = s + m^2_Z - 2E_{ll}\sqrt{s}$$

- Allows model independent measurement of the total Higgs Cross-section
- Unusable in the LHC due to the composite nature of protons

Cutflows - 240 GeV

S/B optimized with **selections** on leptons and jets kinematic properties





Zll

Cut	ZHbb		ZHcc		ZHgg		ZHss		ZHWW		ZHZZ		ZHtautau		ZZ		WW		Zll		Zqq	
	Yield	Eff	Yield	Eff	Yield	Eff	Yield	Eff	Yield	Eff	Yield	Eff	Yield	Eff	Yield	Eff	Yield	Eff	Yield	Eff	Yield	Eff
No cuts	40[illegible]55	-	2013	-	5700	-	17	-	14985	-	1838	-	4367	-	6794950	-	82192500	-	67965000	-	263269500	-
one Z->ll candidate	36448	90	1808	90	5119	90	15	90	13571	91	1664	91	3956	91	566449	8	772157	1	13389259	20	141045	0
m(ll) 81-101 GeV	32793	90	1627	90	4605	90	14	90	12151	90	1502	90	3547	90	363333	64	190171	25	5677860	42	7530	5
|cos(theta_ll)|<0.8	26694	81	1327	82	3746	81	11	81	9889	81	1223	81	2884	81	227312	63	145268	76	906114	16	5550	74
m(recoil) 120-140 GeV	25497	96	1268	96	3580	96	11	96	9408	95	1154	94	2743	95	32182	14	61912	43	206164	23	1079	19
max p(extra lep) < 25 GeV	24318	95	1256	99	3577	100	11	100	6912	73	1040	90	2031	74	28850	90	61825	100	206163	100	977	91
l=e	11950	-	616	-	1754	-	5	-	3386	-	510	-	998	-	14481	-	31880	-	171906	-	466	-
l=mu	12368	-	640	-	1823	-	5	-	3526	-	530	-	1033	-	14369	-	29945	-	34258	-	511	-

Zνν

Cut	vvHbb		vvHcc		vvHgg		vvHss		vvHWW		vvHZZ		vvHtautau		qqH		nuenueZ		Zqq		WW		ZZ	
	Yield	Eff	Yield	Eff	Yield	Eff	Yield	Eff	Yield	Eff	Yield	Eff	Yield	Eff	Yield	Eff	Yield	Eff	Yield	Eff	Yield	Eff	Yield	Eff
No cuts	134500	-	6675	-	18910	-	55	-	49700	-	6100	-	14485	-	681520	-	166370	-	263269500	-	82192500	-	6794950	-
No leptons with p>20 GeV	123364	92	6531	98	18877	100	55	100	34142	69	5335	87	9824	68	580210	85	152109	91	254437693	97	49001192	60	5299230	78
15<E_j1<105, 10<E_j2<70 GeV	122075	99	6439	99	18501	98	54	98	32873	96	4922	92	7801	79	16777	3	147609	97	109466219	43	6515777	13	1811708	34
|cos(theta_jj)|<0.9	110401	90	5824	90	16754	91	49	90	29563	90	4226	86	6496	83	14859	89	92878	63	2556074	2	4698934	72	1312817	72
cos(th_j1+th_j2)>0.5	110014	100	5806	100	16648	99	49	100	28351	96	4025	95	6441	99	14725	99	80799	87	2508454	98	3787830	81	1035917	79
cos(phi_j1-phi_j2)<0.999	106539	97	5623	97	16165	97	48	97	27633	97	3919	97	6200	96	14169	96	78719	97	2045260	82	3698506	98	1014048	98
70<mvis<150, 60<mmiss<220 GeV	105661	99	5555	99	15955	99	47	99	27094	98	3792	97	6165	99	13083	92	77045	98	2039752	100	2846585	77	974735	96
d23>0, d34>0	105661	100	5555	100	15955	100	47	100	27078	100	3787	100	5896	96	13083	100	76961	100	2039516	100	2829867	99	973642	100
All cuts	105661	100	5555	100	15955	100	47	100	27078	100	3787	100	5896	100	13083	100	76961	100	2039516	100	2829867	100	973642	100

Efficiency (%)	vvHbb	vvHcc	vvHgg	vvHss	vvHWW	vvHZZ	vvHtautau	qqH	nuenueZ	Zqq	WW	ZZ
	78.56	83.23	84.38	84.52	54.48	62.09	40.70	1.92	46.26	0.77	3.44	14.33

Eff. in ZH(other) channels wrt had decays (%)	WW	ZZ	tautau
	83.65	82.51	77.83

Cutflows Zqq - 240 GeV

	Lepton cut	$M_{\text{vis}}, \theta_{\text{vis}}$	d_{ij}
$e^+e^- \to Z(cc)H(gg)$	98.7	88.3	87.2
$e^+e^- \to Z(cc)H(ss)$	99.0	88.4	86.3
$e^+e^- \to Z(cc)H(cc)$	96.6	88.1	86.1
$e^+e^- \to Z(cc)H(bb)$	89.7	83.5	81.2
$e^+e^- \to Z(qq)H(gg)$	99.8	86.2	85.2
$e^+e^- \to Z(qq)H(ss)$	99.9	86.6	84.6
$e^+e^- \to Z(qq)H(cc)$	97.8	87.1	85.2
$e^+e^- \to Z(qq)H(bb)$	91.4	83.8	81.7
$e^+e^- \to Z(bb)H(gg)$	94.6	87.0	85.9
$e^+e^- \to Z(bb)H(ss)$	95.0	87.3	85.1
$e^+e^- \to Z(bb)H(cc)$	92.1	85.7	83.4
$e^+e^- \to Z(bb)H(bb)$	84.4	79.8	77.3
$e^+e^- \to Z(ss)H(gg)$	99.8	87.0	85.9
$e^+e^- \to Z(ss)H(ss)$	99.9	87.2	85.2
$e^+e^- \to Z(ss)H(cc)$	97.8	87.7	85.7
$e^+e^- \to Z(ss)H(bb)$	91.3	84.1	82.0

	Lepton cut	$M_{\text{vis}}, \theta_{\text{vis}}$	d_{ij}
$e^+e^- \to Z(bb)H(\tau\tau)$	63.7	43.9	32.8
$e^+e^- \to Z(ss)H(\tau\tau)$	67.1	48.3	36.4
$e^+e^- \to Z(cc)H(\tau\tau)$	68.0	50.2	38.1
$e^+e^- \to Z(qq)H(\tau\tau)$	67.9	50.1	38.1
$e^+e^- \to Z(bb)H(Z\gamma)$	86.5	62.4	61.3
$e^+e^- \to Z(ss)H(Z\gamma)$	90.5	64.0	62.9
$e^+e^- \to Z(cc)H(Z\gamma)$	91.7	63.7	62.5
$e^+e^- \to Z(qq)H(Z\gamma)$	91.6	63.1	61.9
$e^+e^- \to Z(bb)H(WW)$	64.7	57.4	54.6
$e^+e^- \to Z(ss)H(WW)$	68.0	59.8	57.0
$e^+e^- \to Z(cc)H(WW)$	68.7	59.9	57.0
$e^+e^- \to Z(qq)H(WW)$	68.6	59.4	56.6
$e^+e^- \to Z(bb)H(ZZ)$	81.8	60.6	57.8
$e^+e^- \to Z(ss)H(ZZ)$	86.1	63.3	60.5
$e^+e^- \to Z(cc)H(ZZ)$	87.5	63.9	61.1
$e^+e^- \to Z(qq)H(ZZ)$	87.5	63.6	60.8
$e^+e^- \to Z(\nu\nu)H(jj)$	87.5	00.1	00.0
$e^+e^- \to W^+W^-$	64.1	45.1	37.9
$e^+e^- \to ZZ$	79.8	43.4	38.1
$e^+e^- \to Z/\gamma^*(q\bar{q})$	96.5	31.8	07.6

- Events (orthogonal to $ll, \nu\nu$ analysis)
  - $n_j = 4$ per event
  - Cuts on leptons
    - lepton (both e, μ) $p_l < 20\,\text{GeV}$ & $n_{e,\mu} \leq 2$ per event
  - Cuts on $m_{\text{vis}}, \theta_{\text{vis}}$
    - $m_{\text{vis}} > 150\,\text{GeV}$,
    - $0.15 < \theta_{\text{vis}} < 3$
  - Clustering merging parameter cut (d_{12}, d_{23}, d_{34})
  - χ^2 on the energy correction <30
- On the jet pairs
  - Pairs: Find minimum $(m_{j_1j_2} - m_Z)^2 + (m_{j_3j_4} - m_H)^2$ for all jet combination
    $\sqrt{(m_{z_{jj}} - m_W)^2 + (m_{H_{jj}} - m_W)^2} > 10$, $\sqrt{(m_{z_{jj}} - m_Z)^2 + (m_{H_{jj}} - m_Z)^2} > 10$, ZZ, WW rejection
  - $50 < m_{Z_{jj}} < 125\,\text{GeV}, m_{H_{jj}} > 91\,\text{GeV}$

Cutflows - 365 GeV
Zll

Cut	ZHbb		ZHcc		ZHgg		ZHss		ZHWW		ZHZZ		ZHtautau		ZZ		WW		tt		Zll		Zqq	
	Yield	Eff	Yield	Eff	Yield	Eff	Yield	Eff	Yield	Eff	Yield	Eff	Yield	Eff	Yield	Eff	Yield	Eff	Yield	Eff	Yield	Eff	Yield	Eff
No cuts	15504	-	770	-	2179	-	5	-	5729	-	703	-	1670	-	1478440	-	24647950	-	1840000	-	8769440	-	49254270	-
>0 iso-leptons with p>40 GeV	15267	98	758	98	2146	98	5	98	5656	99	693	99	1648	99	273844	19	9077163	37	467641	25	7187002	82	54598	0
one Z->ll candidate	14194	93	702	93	1986	93	5	93	5275	93	647	93	1539	93	200127	73	562743	6	69355	15	4590047	64	39609	73
m(ll) 81-101 GeV	9421	66	464	66	1309	66	3	66	3507	66	438	68	1027	67	123438	62	48867	9	9046	13	2165561	47	25	0
|cos(theta_ll)|<0.8	8028	85	397	86	1122	86	3	86	2981	85	373	85	871	85	54684	44	26214	54	7292	81	245000	11	0	0
m(recoil) 120-200 GeV	7276	91	362	91	1025	91	3	91	2688	90	328	88	783	90	13233	24	6635	25	323	4	33794	14	0	0
E(j2)>15 GeV	7255	100	361	100	1025	100	3	100	2555	95	299	91	597	76	12496	94	6173	93	320	99	24013	71	0	0
<=2 iso leptons	6685	92	357	99	1018	99	2	100	1618	63	244	82	307	51	11109	89	6138	99	297	93	24013	100	0	0
d23>0, d34>0	6685	100	357	100	1018	100	2	100	1616	100	232	95	296	97	9126	82	2992	49	297	100	1597	7	0	0
All cuts	6685	100	357	100	1018	100	2	100	1616	100	232	100	296	100	9126	100	2992	100	297	100	1597	100	0	0
l=e	3289	-	176	-	501	-	1	-	795	-	114	-	146	-	4699	-	1564	-	150	-	1201	-	0	-
l=mu	3396	-	182	-	518	-	1	-	821	-	118	-	150	-	4427	-	1428	-	147	-	396	-	0	-
H->had	6685	-	357	-	1018	-	2	-	1227	-	153	-	284	-	9126	-	2992	-	297	-	1597	-	0	-
H->oth	0	-	0	-	0	-	0	-	388	-	79	-	12	-	0	-	0	-	0	-	0	-	0	-

	ZHbb	ZHcc	ZHgg	ZHss	ZHWW	ZHZZ	ZHtautau	ZZ	WW	tt	Zll	Zqq
Efficiency (%)	43.11	46.41	46.73	46.93	28.21	33.07	17.73	0.62	0.01	0.02	0.02	0.00
Eff. in e channel (%)	33.23	35.75	35.98	36.12	21.73	25.49	13.73	0.50	0.01	0.01	0.02	0.00
Eff. in mu channel (%)	60.56	65.22	65.70	66.02	39.64	46.46	24.78	0.83	0.02	0.02	0.01	0.00

	WW	ZZ	tautau
Eff. in ZH(other) channels wrt had decays (%)	47.25	44.66	40.61

Cutflows Zqq - 365 GeV

	Lepton cut	$M_{\rm vis}, E_{\rm vis}, \theta_{\rm vis}$	$d_{\rm ij}$	χ^2
$e^+e^- \to Z(cc)H(gg)$	95.1	75.3	74.7	72.2
$e^+e^- \to Z(cc)H(ss)$	95.6	76.0	75.3	73.0
$e^+e^- \to Z(cc)H(cc)$	90.4	74.0	73.5	70.2
$e^+e^- \to Z(cc)H(bb)$	80.9	68.6	68.2	63.3
$e^+e^- \to Z(qq)H(gg)$	99.3	75.0	74.1	72.9
$e^+e^- \to Z(qq)H(ss)$	99.8	75.7	74.8	73.7
$e^+e^- \to Z(qq)H(cc)$	94.5	74.8	74.1	71.7
$e^+e^- \to Z(qq)H(bb)$	85.0	70.5	70.0	65.6
$e^+e^- \to Z(bb)H(gg)$	86.6	71.8	71.3	67.0
$e^+e^- \to Z(bb)H(ss)$	87.2	72.4	71.9	67.6
$e^+e^- \to Z(bb)H(cc)$	81.9	69.3	68.9	64.1
$e^+e^- \to Z(bb)H(bb)$	72.5	63.0	62.7	56.8
$e^+e^- \to Z(ss)H(gg)$	99.3	75.8	74.9	73.6
$e^+e^- \to Z(ss)H(ss)$	99.8	76.5	75.5	74.4
$e^+e^- \to Z(ss)H(cc)$	94.6	75.4	74.6	72.2
$e^+e^- \to Z(ss)H(bb)$	85.1	70.9	70.3	66.0

	Lepton cut	$M_{\rm vis}, \theta_{\rm vis}$	$d_{\rm ij}$	χ^2
$e^+e^- \to Z(bb)H(\tau\tau)$	55.2	49.5	42.5	19.6
$e^+e^- \to Z(ss)H(\tau\tau)$	61.1	55.6	47.4	22.4
$e^+e^- \to Z(cc)H(\tau\tau)$	63.8	58.5	49.9	23.6
$e^+e^- \to Z(qq)H(\tau\tau)$	63.8	58.5	49.9	23.6
$e^+e^- \to Z(bb)H(Z\gamma)$	78.5	62.4	55.0	46.7
$e^+e^- \to Z(ss)H(Z\gamma)$	86.3	67.3	58.4	50.7
$e^+e^- \to Z(cc)H(Z\gamma)$	90.3	69.1	59.4	52.0
$e^+e^- \to Z(qq)H(Z\gamma)$	90.1	68.6	58.9	51.6
$e^+e^- \to Z(bb)H(WW)$	57.8	49.8	48.1	36.6
$e^+e^- \to Z(ss)H(WW)$	63.8	53.7	51.6	40.2
$e^+e^- \to Z(cc)H(WW)$	66.8	55.0	52.6	41.2
$e^+e^- \to Z(qq)H(WW)$	66.7	54.6	52.3	40.8
$e^+e^- \to Z(bb)H(ZZ)$	73.0	60.4	53.8	39.6
$e^+e^- \to Z(ss)H(ZZ)$	80.8	65.2	58.5	43.7
$e^+e^- \to Z(cc)H(ZZ)$	84.7	67.7	60.4	45.4
$e^+e^- \to Z(qq)H(ZZ)$	84.7	67.3	60.0	45.0
$e^+e^- \to Z(\nu\nu)H(jj)$	84.5	1.8	0.8	0.0
$e^+e^- \to W^+W^-$	63.8	41.8	31.2	27.9
$e^+e^- \to ZZ$	76.8	37.7	32.7	29.9
$e^+e^- \to Z/\gamma^*(q\bar{q})$	99.6	31.2	15.9	15.4
$e^+e^- \to t\bar{t}$	53.6	50.5	49.5	37.9

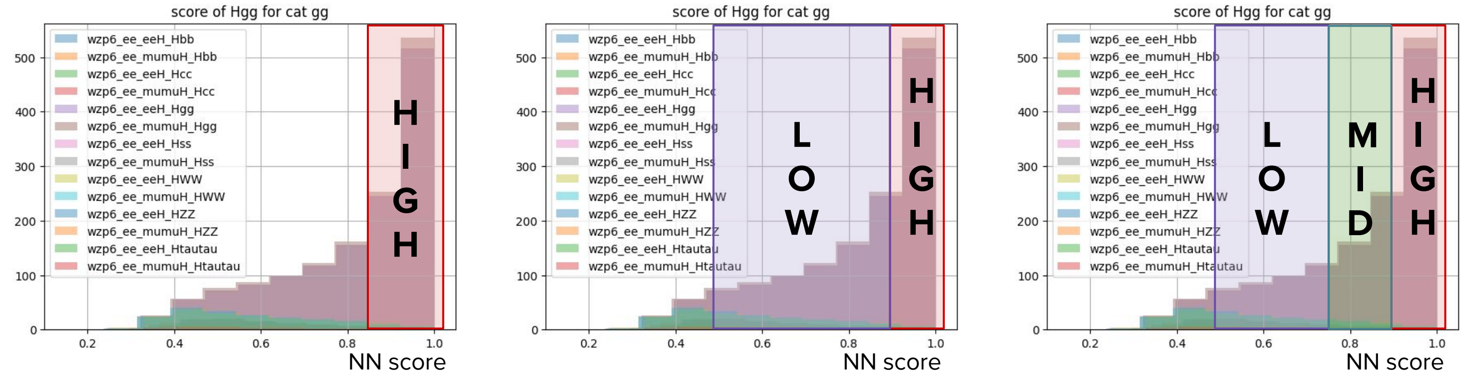
- Events (orthogonal to $ll, \nu\nu$ analysis)
  - $n_j = 4$ per event
  - Cuts on leptons
    - lepton (both e, μ) $p_l < 20\,\text{GeV}$ & $n_{e,\mu} \leq 2$ per event
  - Cuts on $m_{\rm vis}, \theta_{\rm vis}$
    - $m_{\rm vis} > 150\,\text{GeV}, E_{\rm vis} > 190\,\text{GeV}$
    - $0.15 < \theta_{\rm vis} < 3$
  - Clustering merging parameter cut (d_{12}, d_{23}, d_{34})
  - χ^2 on the energy correction <100
- On the jet pairs
  - Pairs: Find minimum $(m_{j_1j_2} - m_Z)^2 + (m_{j_3j_4} - m_H)^2$ for all jet combination
    $\sqrt{(m_{z_{jj}} - m_W)^2 + (m_{H_{jj}} - m_W)^2} > 10$, $\sqrt{(m_{z_{jj}} - m_Z)^2 + (m_{H_{jj}} - m_Z)^2} > 10$, ZZ, WW rejection
  - $50 < m_{Z_{jj}} < 125\,\text{GeV}, m_{H_{jj}} > 91\,\text{GeV}$

Selection - 240 GeV

		Before selection	Lepton cuts	$\lvert cos(\theta_{inv})\rvert < 0.85$	kinematics & d	efficiency(%)
Hbb	Yield(10^5)	2.91	2.67	2.28	2.28	78.4
	Sig.	10.59	10.34	16.01	54.0	
Hcc	Yield(10^4)	1.44	1.41	1.21	1.21	84.0
	Sig.	0.52	0.54	0.84	2.87	
Hgg	Yield(10^4)	3.59	3.59	3.08	3.07	85.5
	Sig.	1.30	1.39	2.16	7.27	
Hss	Yield	110	110	93.9	93.9	85.5
	Sig.	0.004	0.004	0.006	0.02	
$H\tau\tau$	Yield(10^4)	2.73	1.97	1.67	1.38	50.5
	Sig.	0.99	0.76	1.17	3.27	
HWW	Yield(10^4)	10.4	7.34	6.28	6.10	58.7
HZZ	Yield(10^4)	1.25	1.10	0.94	0.80	64.0
qqH	Yield(10^5)	14.7	12.6	8.86	0.56	3.8
WW	Yield(10^7)	17.3	10.6	6.35	1.26	7.3
ZZ	Yield(10^6)	14.0	11.0	6.93	2.60	18.6
Zqq	Yield(10^7)	56.6	54.7	13.1	0.22	0.4

$S/\sqrt{S+B}$

Backup - Purity categories



	bb	cc	gg	ss	zz	ww	tautau
Zll_npur1_240(MCst.)	0.68	4.17	2.29	309.73	14.21	1.75	3.62
Zll_npur2_240(MCst.)	0.67	3.98	2.17	234.47	12.77	1.70	3.74
Zll_npur3_240(MCst.)	0.67	3.93	2.16	229.23	12.52	1.70	3.73
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Zll_npur1_365(MCst.)	1.74	11.66	6.00	1545.43	57.32	5.60	12.88
Zll_npur2_365(MCst.)	1.72	11.09	5.80	1341.34	50.52	5.48	11.57
Zll_npur3_365(MCst.)	1.71	10.96	5.69	1117.70	41.84	5.37	12.59

For $Z\nu\nu$, all categories yield the best precision with 3 purity categories

Yields for Z(ll) at 240 GeV

Expected yields (significance s/√tot) for Zll at E = 240

	bb	cc	gg	ss	WW	ZZ	tautau	bkg	TOTAL
bb_low	8043.0 (76)	0.6 (0)	61.5 (1)	0.0 (0)	5.5 (0)	103.0 (1)	0.0 (0)	2895.1	11108.7
bb_mid	7330.8 (77)	0.2 (0)	13.9 (0)	0.0 (0)	1.1 (0)	16.2 (0)	0.0 (0)	1775.7	9137.9
bb_high	32970.0 (175)	0.0 (0)	3.8 (0)	0.0 (0)	0.2 (0)	4.1 (0)	0.0 (0)	2389.3	35367.4
cc_low	57.8 (1)	458.0 (7)	79.0 (1)	0.1 (0)	230.6 (4)	62.1 (1)	0.0 (0)	3342.0	4229.5
cc_mid	19.7 (0)	474.4 (10)	12.8 (0)	0.0 (0)	17.6 (0)	5.8 (0)	0.0 (0)	1693.6	2223.9
cc_high	5.0 (0)	1487.7 (27)	3.7 (0)	0.0 (0)	1.2 (0)	0.9 (0)	0.0 (0)	1632.5	3131.2
gg_low	418.6 (6)	16.3 (0)	1812.0 (26)	0.8 (0)	596.6 (9)	84.7 (1)	0.0 (0)	1970.2	4899.3
gg_mid	92.4 (2)	4.4 (0)	2525.4 (43)	0.3 (0)	170.1 (3)	23.5 (0)	0.0 (0)	712.1	3528.1
gg_high	9.2 (0)	0.7 (0)	1628.7 (39)	0.0 (0)	14.8 (0)	2.1 (0)	0.0 (0)	96.7	1752.1
ss_low	2.0 (0)	10.2 (0)	318.8 (5)	5.0 (0)	134.1 (2)	64.5 (1)	0.1 (0)	4241.1	4775.8
ss_mid	0.2 (0)	3.9 (0)	41.8 (1)	5.2 (0)	4.4 (0)	4.1 (0)	0.0 (0)	2207.7	2267.4
ss_high	0.0 (0)	1.0 (0)	7.1 (0)	9.4 (0)	0.1 (0)	0.1 (0)	0.0 (0)	1668.6	1686.4
WW_low	33.7 (0)	41.3 (1)	100.2 (1)	0.1 (0)	2132.6 (30)	94.6 (1)	4.0 (0)	2637.1	5043.5
WW_mid	14.5 (0)	15.7 (0)	30.7 (1)	0.0 (0)	1583.8 (30)	36.4 (1)	1.2 (0)	1051.2	2733.5
WW_high	16.8 (0)	14.5 (0)	26.1 (0)	0.0 (0)	5689.0 (65)	43.0 (0)	1.0 (0)	1855.4	7645.9
ZZ_low	2117.1 (19)	44.9 (0)	116.4 (1)	0.2 (0)	733.4 (7)	411.2 (4)	1.8 (0)	9017.1	12442.1
ZZ_mid	295.7 (4)	4.5 (0)	17.7 (0)	0.0 (0)	144.6 (2)	208.1 (3)	0.4 (0)	4087.8	4758.8
ZZ_high	75.8 (1)	0.9 (0)	4.2 (0)	0.0 (0)	109.4 (1)	524.1 (5)	0.1 (0)	10477.7	11192.2
tautau_high	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	262.6 (2)	29.1 (0)	3777.6 (26)	16444.0	20513.3
TOTAL	51502.2	2579.2	6803.8	21.1	11831.8	1717.6	3786.2		

Yields for Z($\nu\nu$) at 240 GeV

Expected yields (significance s/√tot) for Znunu at E = 240

	bb	cc	gg	ss	WW	ZZ	tautau	bkg	TOTAL
bb_low	37028.7 (72)	6.4 (0)	337.8 (1)	0.0 (0)	15.1 (0)	423.7 (1)	0.4 (0)	226228.0	264040.2
bb_mid	39730.1 (113)	1.7 (0)	40.8 (0)	0.0 (0)	1.4 (0)	61.9 (0)	0.1 (0)	83828.9	123664.9
bb_high	129708.7 (289)	0.3 (0)	10.1 (0)	0.0 (0)	0.1 (0)	8.7 (0)	0.1 (0)	71205.7	200933.7
cc_low	130.5 (0)	1776.9 (3)	343.7 (1)	0.1 (0)	812.4 (1)	261.4 (0)	0.1 (0)	332054.7	335379.7
cc_mid	47.5 (0)	1665.6 (5)	74.0 (0)	0.0 (0)	71.5 (0)	29.9 (0)	0.0 (0)	93776.2	95664.6
cc_high	24.2 (0)	7168.4 (27)	25.8 (0)	0.0 (0)	12.9 (0)	6.4 (0)	0.0 (0)	64817.7	72055.3
gg_low	744.0 (3)	44.1 (0)	4432.3 (16)	1.8 (0)	977.3 (4)	133.6 (0)	0.0 (0)	66351.5	72684.4
gg_mid	339.9 (2)	21.0 (0)	4754.8 (25)	0.9 (0)	472.2 (3)	65.4 (0)	0.0 (0)	29167.5	34821.6
gg_high	162.9 (1)	13.7 (0)	14473.8 (76)	0.7 (0)	368.8 (2)	48.2 (0)	0.0 (0)	21558.8	36627.0
ss_low	3.1 (0)	33.5 (0)	1045.4 (3)	7.3 (0)	460.5 (1)	199.7 (1)	0.0 (0)	131829.1	133578.8
ss_mid	1.0 (0)	11.9 (0)	283.9 (1)	4.0 (0)	98.5 (0)	54.4 (0)	0.0 (0)	44494.3	44948.0
ss_high	1.2 (0)	41.8 (0)	641.1 (2)	77.2 (0)	107.1 (0)	83.5 (0)	0.0 (0)	161135.3	162087.2
WW_low	170.9 (0)	186.5 (0)	756.6 (1)	0.4 (0)	9842.1 (11)	523.1 (1)	0.2 (0)	813993.5	825473.4
WW_mid	91.0 (0)	96.5 (0)	199.4 (0)	0.1 (0)	7634.3 (9)	164.0 (0)	0.1 (0)	788286.0	796471.4
WW_high	84.0 (0)	55.4 (0)	112.0 (0)	0.1 (0)	16290.3 (13)	130.0 (0)	0.2 (0)	1546240.7	1562912.7
ZZ_low	9765.6 (10)	203.9 (0)	738.2 (1)	1.1 (0)	2723.3 (3)	1678.1 (2)	1.9 (0)	970946.3	986058.3
ZZ_mid	1112.0 (1)	12.1 (0)	108.0 (0)	0.2 (0)	352.4 (0)	789.1 (1)	0.1 (0)	639893.7	642267.5
ZZ_high	57.4 (0)	0.7 (0)	10.1 (0)	0.0 (0)	80.9 (0)	453.4 (1)	0.0 (0)	652726.7	653329.3
tautau_low	1.2 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.7 (0)	2.5 (0)	29.3 (0)	14886.1	14919.8
tautau_mid	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.1 (0)	0.1 (0)	16.8 (0)	3182.0	3198.9
tautau_high	0.5 (0)	0.0 (0)	0.0 (0)	0.0 (0)	2.3 (0)	1.8 (0)	5358.7 (9)	328666.1	334029.3
TOTAL	270706.6	13919.7	35191.6	115.1	52155.9	6836.2	9194.2		

Yields for Z(ll) at 365 GeV

Expected yields (significance s/√tot) for Zll at E = 365

	bb	cc	gg	ss	WW	ZZ	tautau	bkg	TOTAL
bb_low	546.9 (18)	0.2 (0)	6.9 (0)	0.0 (0)	1.2 (0)	11.0 (0)	0.0 (0)	410.1	976.4
bb_mid	2117.2 (40)	0.3 (0)	8.7 (0)	0.0 (0)	0.8 (0)	10.9 (0)	0.0 (0)	710.9	2848.8
bb_high	5392.6 (69)	0.1 (0)	0.6 (0)	0.0 (0)	0.0 (0)	1.0 (0)	0.0 (0)	686.7	6081.1
cc_low	7.5 (0)	63.1 (2)	11.9 (0)	0.0 (0)	35.5 (1)	9.2 (0)	0.0 (0)	516.3	643.5
cc_mid	3.8 (0)	109.9 (4)	3.6 (0)	0.0 (0)	5.5 (0)	2.3 (0)	0.0 (0)	518.7	643.9
cc_high	1.0 (0)	234.4 (9)	0.6 (0)	0.0 (0)	0.4 (0)	0.2 (0)	0.0 (0)	468.2	704.6
gg_low	39.9 (1)	2.6 (0)	312.9 (11)	0.1 (0)	87.3 (3)	12.4 (0)	0.0 (0)	412.8	868.1
gg_mid	9.8 (0)	0.8 (0)	385.1 (16)	0.0 (0)	25.9 (1)	3.8 (0)	0.0 (0)	168.6	594.2
gg_high	0.6 (0)	0.2 (0)	248.5 (14)	0.0 (0)	3.1 (0)	0.5 (0)	0.0 (0)	70.8	323.7
ss_low	0.4 (0)	2.2 (0)	70.7 (2)	1.3 (0)	22.1 (1)	10.8 (0)	0.0 (0)	1733.8	1841.3
ss_mid	0.0 (0)	0.1 (0)	1.6 (0)	0.3 (0)	0.1 (0)	0.1 (0)	0.0 (0)	220.6	222.8
ss_high	0.0 (0)	0.1 (0)	1.2 (0)	1.2 (0)	0.1 (0)	0.1 (0)	0.0 (0)	490.2	492.8
WW_low	5.4 (0)	12.4 (0)	36.6 (1)	0.0 (0)	746.2 (17)	28.4 (1)	0.4 (0)	1071.7	1901.0
WW_mid	0.3 (0)	0.5 (0)	0.8 (0)	0.0 (0)	64.6 (5)	1.0 (0)	0.0 (0)	81.6	148.8
WW_high	0.8 (0)	1.5 (0)	2.4 (0)	0.0 (0)	468.0 (12)	3.8 (0)	0.0 (0)	1008.8	1485.2
ZZ_low	333.6 (7)	6.4 (0)	14.7 (0)	0.0 (0)	73.9 (2)	46.5 (1)	0.1 (0)	1753.1	2228.2
ZZ_mid	111.3 (2)	0.6 (0)	4.6 (0)	0.0 (0)	34.8 (1)	59.1 (1)	0.0 (0)	3604.8	3815.2
ZZ_high	1.5 (0)	0.0 (0)	0.1 (0)	0.0 (0)	2.2 (0)	22.3 (1)	0.0 (0)	493.8	520.0
tautau_low	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	8.6 (0)	1.1 (0)	140.4 (4)	1275.9	1426.1
tautau_high	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.2 (0)	0.2 (0)	244.4 (8)	813.0	1057.8
TOTAL	279279.4	14355.0	36303.2	118.0	53736.2	7060.9	9579.6		

Yields for Z($\nu\nu$) at 365 GeV

Expected yields (significance s/√tot) for Znunu at E = 365

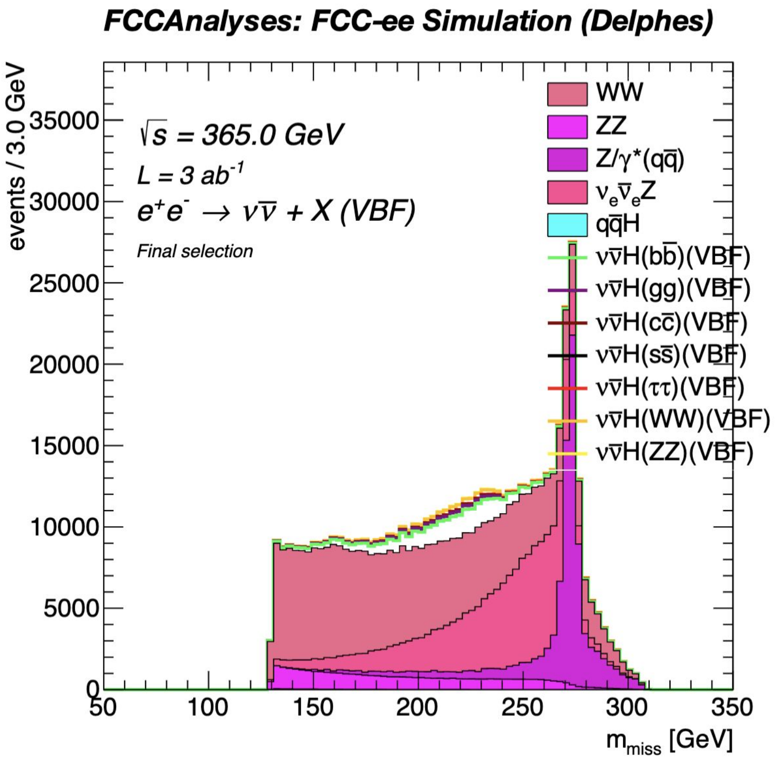
	bb	cc	gg	ss	WW	ZZ	tautau	bkg	TOTAL
bb_low	783.2 (14)	0.5 (0)	9.5 (0)	0.0 (0)	0.7 (0)	11.1 (0)	0.0 (0)	2231.8	3036.7
bb_mid	2103.7 (29)	0.6 (0)	13.7 (0)	0.0 (0)	0.6 (0)	11.1 (0)	0.0 (0)	3179.0	5308.7
bb_high	13285.7 (103)	0.2 (0)	3.3 (0)	0.0 (0)	0.1 (0)	4.1 (0)	0.0 (0)	3270.1	16563.4
cc_low	21.6 (0)	366.3 (3)	29.3 (0)	0.0 (0)	72.3 (1)	23.6 (0)	0.0 (0)	15539.2	16052.3
cc_mid	1.3 (0)	259.8 (6)	1.4 (0)	0.0 (0)	0.8 (0)	0.4 (0)	0.0 (0)	1487.3	1751.1
cc_high	0.1 (0)	364.3 (13)	0.3 (0)	0.0 (0)	0.1 (0)	0.0 (0)	0.0 (0)	389.2	754.0
gg_low	178.1 (2)	14.7 (0)	1351.5 (14)	0.8 (0)	473.0 (5)	65.7 (1)	0.0 (0)	7706.1	9789.8
gg_mid	6.3 (0)	1.1 (0)	603.5 (18)	0.1 (0)	33.9 (1)	4.7 (0)	0.0 (0)	449.3	1098.8
gg_high	1.4 (0)	0.7 (0)	792.7 (26)	0.0 (0)	12.4 (0)	1.7 (0)	0.0 (0)	135.5	944.4
ss_high	0.0 (0)	0.2 (0)	2.8 (0)	3.5 (0)	0.1 (0)	0.2 (0)	0.0 (0)	1057.2	1064.1
WW_low	2.5 (0)	20.3 (0)	45.9 (0)	0.0 (0)	1025.5 (6)	33.6 (0)	0.0 (0)	27146.2	28274.0
WW_mid	0.4 (0)	5.0 (0)	8.7 (0)	0.0 (0)	758.3 (7)	8.9 (0)	0.0 (0)	9647.0	10428.3
WW_high	0.0 (0)	0.5 (0)	0.7 (0)	0.0 (0)	257.3 (4)	1.2 (0)	0.0 (0)	3024.8	3284.5
ZZ_low	485.8 (1)	7.3 (0)	30.8 (0)	0.0 (0)	139.7 (0)	162.8 (1)	0.0 (0)	104380.1	105206.6
ZZ_mid	0.4 (0)	0.0 (0)	0.2 (0)	0.0 (0)	2.1 (0)	4.1 (0)	0.0 (0)	4068.9	4075.8
ZZ_high	2.0 (0)	0.0 (0)	0.6 (0)	0.0 (0)	9.7 (0)	54.5 (0)	0.0 (0)	69363.4	69430.3
tautau_low	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.1 (0)	12.0	12.2
tautau_mid	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	2.6 (0)	256.2	258.8
tautau_high	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	100.3 (4)	520.0	620.3
TOTAL	16872.4	1041.5	2894.9	4.4	2786.7	387.5	103.1		

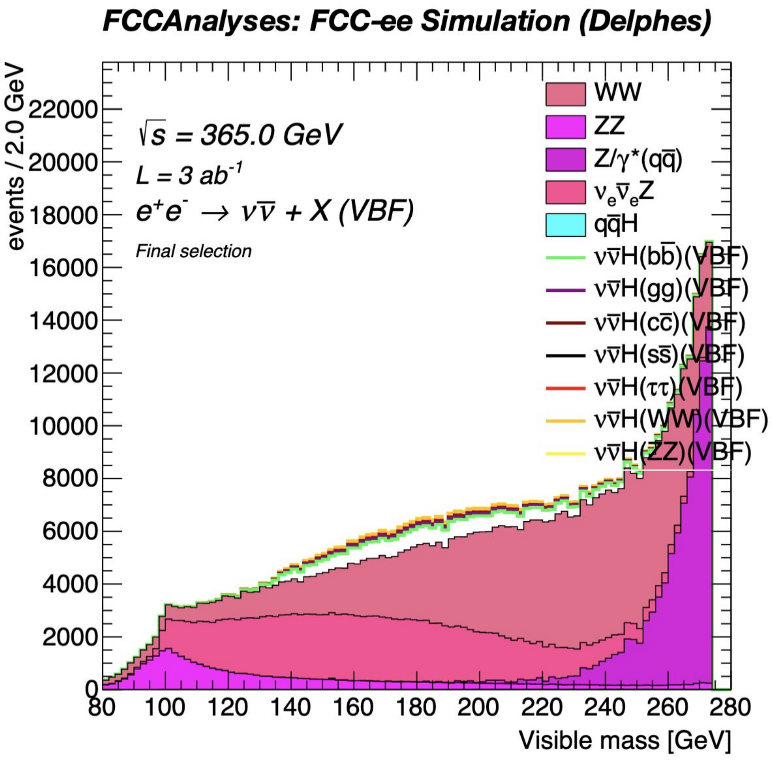
Yields for VBF at 365 GeV

Expected yields (significance s/√tot) for VBF at E = 365

	bb	cc	gg	ss	WW	ZZ	tautau	bkg	TOTAL
bb_low	4112.3 (21)	1.0 (0)	42.0 (0)	0.0 (0)	5.4 (0)	60.3 (0)	0.0 (0)	32961.7	37182.7
bb_mid	3428.1 (31)	0.2 (0)	6.1 (0)	0.0 (0)	0.8 (0)	12.8 (0)	0.0 (0)	8726.8	12174.8
bb_high	22055.8 (136)	0.2 (0)	3.7 (0)	0.0 (0)	0.1 (0)	5.7 (0)	0.0 (0)	4118.1	26183.7
cc_low	19.2 (0)	166.9 (1)	40.2 (0)	0.0 (0)	127.5 (1)	29.9 (0)	0.0 (0)	51806.8	52190.5
cc_mid	14.4 (0)	632.9 (4)	22.6 (0)	0.0 (0)	30.0 (0)	12.3 (0)	0.0 (0)	26585.4	27297.5
cc_high	1.3 (0)	725.2 (14)	1.0 (0)	0.0 (0)	0.4 (0)	0.1 (0)	0.0 (0)	2037.8	2765.8
gg_low	7.6 (0)	0.5 (0)	22.7 (1)	0.0 (0)	18.4 (0)	2.7 (0)	0.0 (0)	1350.4	1402.4
gg_mid	142.1 (1)	11.8 (0)	1369.2 (8)	0.8 (0)	441.4 (3)	66.2 (0)	0.0 (0)	28699.6	30731.1
gg_high	14.0 (0)	2.1 (0)	2350.7 (28)	0.2 (0)	88.7 (1)	13.6 (0)	0.0 (0)	4784.6	7253.9
ss_low	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0	0.0
ss_mid	0.3 (0)	0.7 (0)	48.9 (0)	0.2 (0)	21.1 (0)	8.0 (0)	0.0 (0)	14178.0	14257.2
ss_high	0.0 (0)	0.3 (0)	4.0 (0)	0.6 (0)	0.3 (0)	0.4 (0)	0.0 (0)	1630.8	1636.4
WW_low	0.9 (0)	1.3 (0)	4.5 (0)	0.0 (0)	65.4 (1)	3.5 (0)	0.0 (0)	3967.5	4043.2
WW_mid	17.6 (0)	28.2 (0)	70.2 (0)	0.0 (0)	3499.0 (11)	63.5 (0)	0.1 (0)	102060.2	105738.9
WW_high	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	26.4 (1)	0.0 (0)	0.0 (0)	291.5	317.9
ZZ_low	1436.9 (3)	39.9 (0)	85.4 (0)	0.1 (0)	452.8 (1)	310.3 (1)	0.1 (0)	241462.5	243788.0
ZZ_mid	3.7 (0)	0.1 (0)	0.4 (0)	0.0 (0)	3.2 (0)	8.3 (0)	0.0 (0)	7190.0	7205.6
ZZ_high	5.9 (0)	0.1 (0)	1.2 (0)	0.0 (0)	11.1 (0)	78.0 (0)	0.0 (0)	105630.5	105726.8
tautau_high	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	6.1 (0)	2.5 (0)	1265.2 (4)	91918.9	93192.8
TOTAL	48132.7	2652.9	6967.8	6.3	7584.6	1065.6	1368.5		

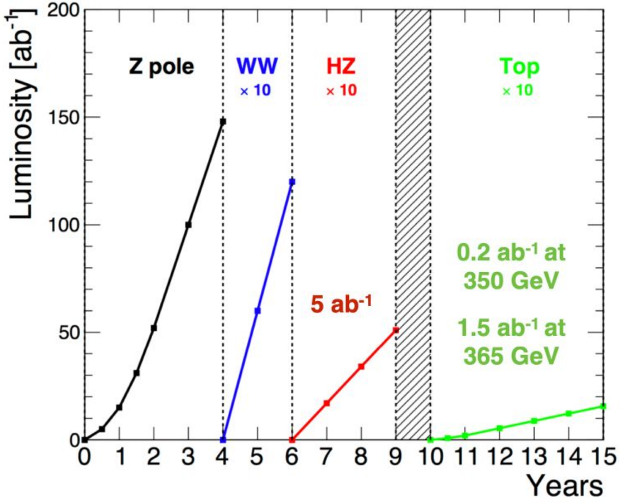
VBF 365 GeV - after selection

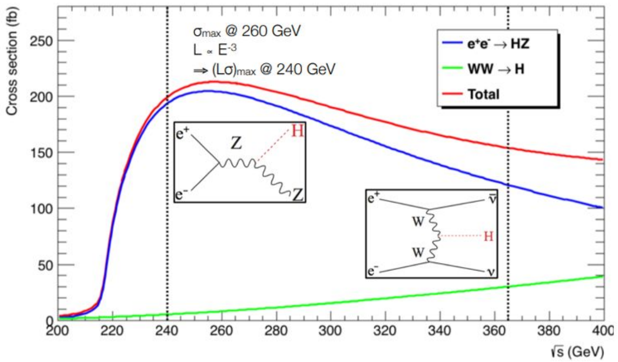




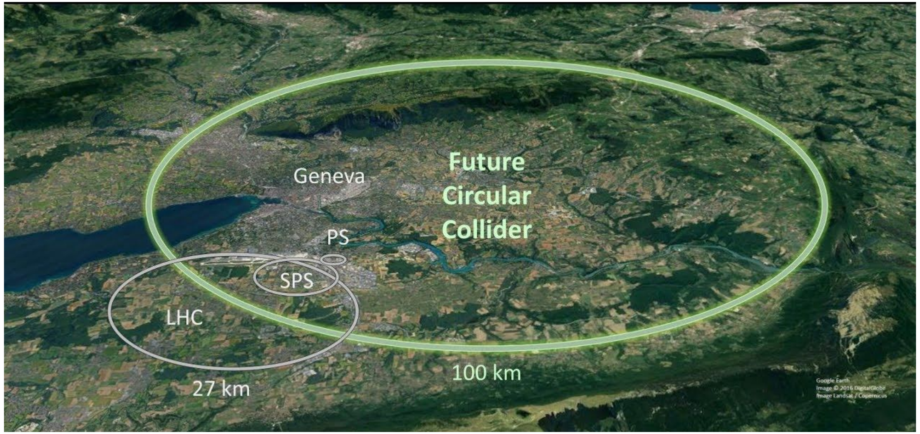
The FCC experiment - FCC-ee

FCC-ee functioning schedule





- **FCC** (Future Circular Collider)
  - ~90km circular collider project
  - Two periods on functioning : **FCC-ee** & FCC-hh



  - Great improvement on EW studies wrt **LEP**
  - Higgs factory

  - Great prospects for new physics (hh)

Fitting strategy for all channels

Fitting using **CMS** tool **CombineTF** to extract σ.BR in each category

7 POIs, Hbb, Hcc, Hss, Hgg, Hττ, HWW, HZZ (floating parameters)

Binning :

- **BNL :** 1 GeV bin width (projected in 5 GeV for the recoil mass)
- **APC :** custom binning *by-eye* (negligible/little improvement compared to 1 GeV width)

Empty categories removed from the fit

Rebinned such that :

- There is at least one **expected** (sum of sig+bkg) event in each bin
- Add 10-6 events in empty bins to help fit convergence, without implementing a bias

Monte Carlo stats uncertainties

- No systematics on the backgrounds