update of ννHH @ 1 TeV

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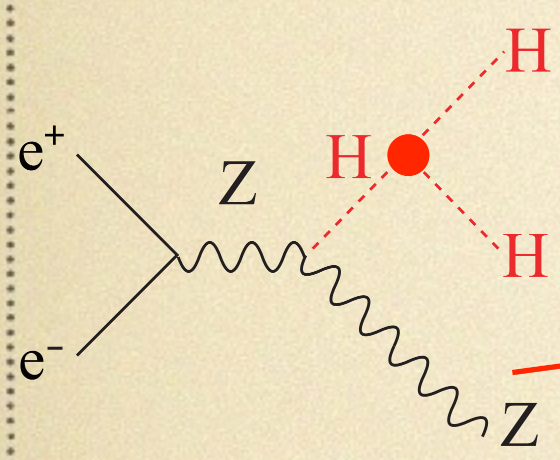
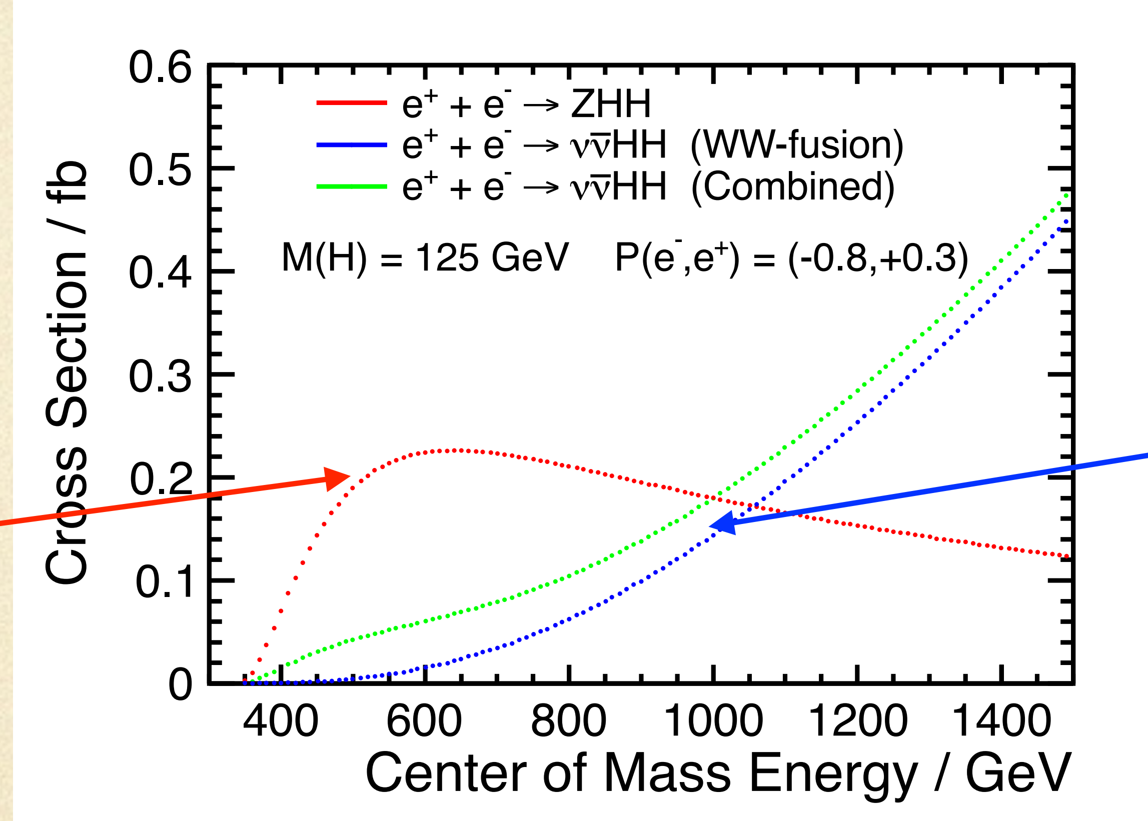
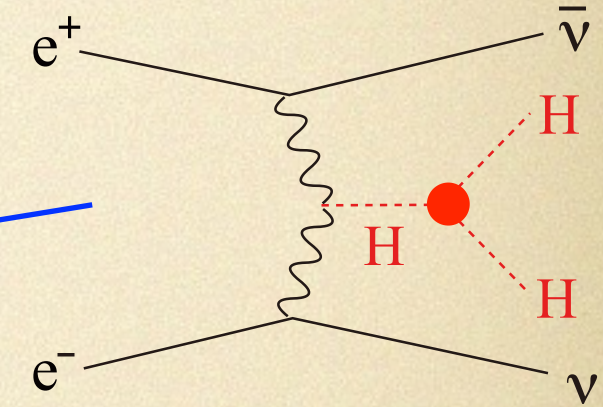
ILD Analysis & Software Meeting, Feb. 18, 2015

recent poster at HPNP 2015: http://jodo.sci.u-toyama.ac.jp/theory/HPNP2015/Slides/HPNP2015Poster1/Tian_20150212.pdf

status of Higgs self-coupling analysis







- ZHH—>Z(bb)(bb) @ 500 GeV: Claude —- kinematic fitting, matrix element method, etc.
- HH—>bb(WW*): Masakazu —- flavor tagging, PID, etc.
- ννHH—>νν(bb)(bb) @ 1 TeV: Junping —- updating analysis with mH=125GeV and overlay (today's topic)

$\Delta\lambda_{HHH}/\lambda_{HHH}$	500 GeV	+ 1 TeV
Baseline	83%	21%
LumiUP	46%	13%

500 GeV: 500 (1600) fb^{-1}
1 TeV: 1000 (2500) fb^{-1}

including HH—>bbbb and HH—>bbWW*

LC-REP-2013-003 J. Tian @ LCWS14 C. Dürig @ AWLC14 M. Kurata @ ECFA2013

update with H(125): identical analysis strategy

(cross section reduced by 12%; branching ratio reduced by 20%)

P(e-,e+) = (-0.8,+0.2); Ecm = 1 TeV; w/o overlay

$\int L = 2\ \mathrm{ab}^{-1}$

mH = 125 GeV

	ννHH -WWF (ννbbbb)	BG
#expected	240	7.86E+05
after selection	24.8(24.0)	23.9
significance	3.6σ	

(3.6σ)

mH = 120 GeV

ννHH -WWF (ννbbbb)	BG
272	7.86E+05
35.7	33.7
4.3σ	

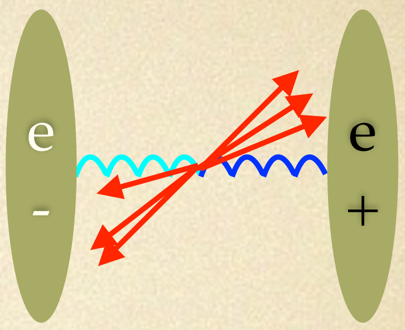
(preliminary)

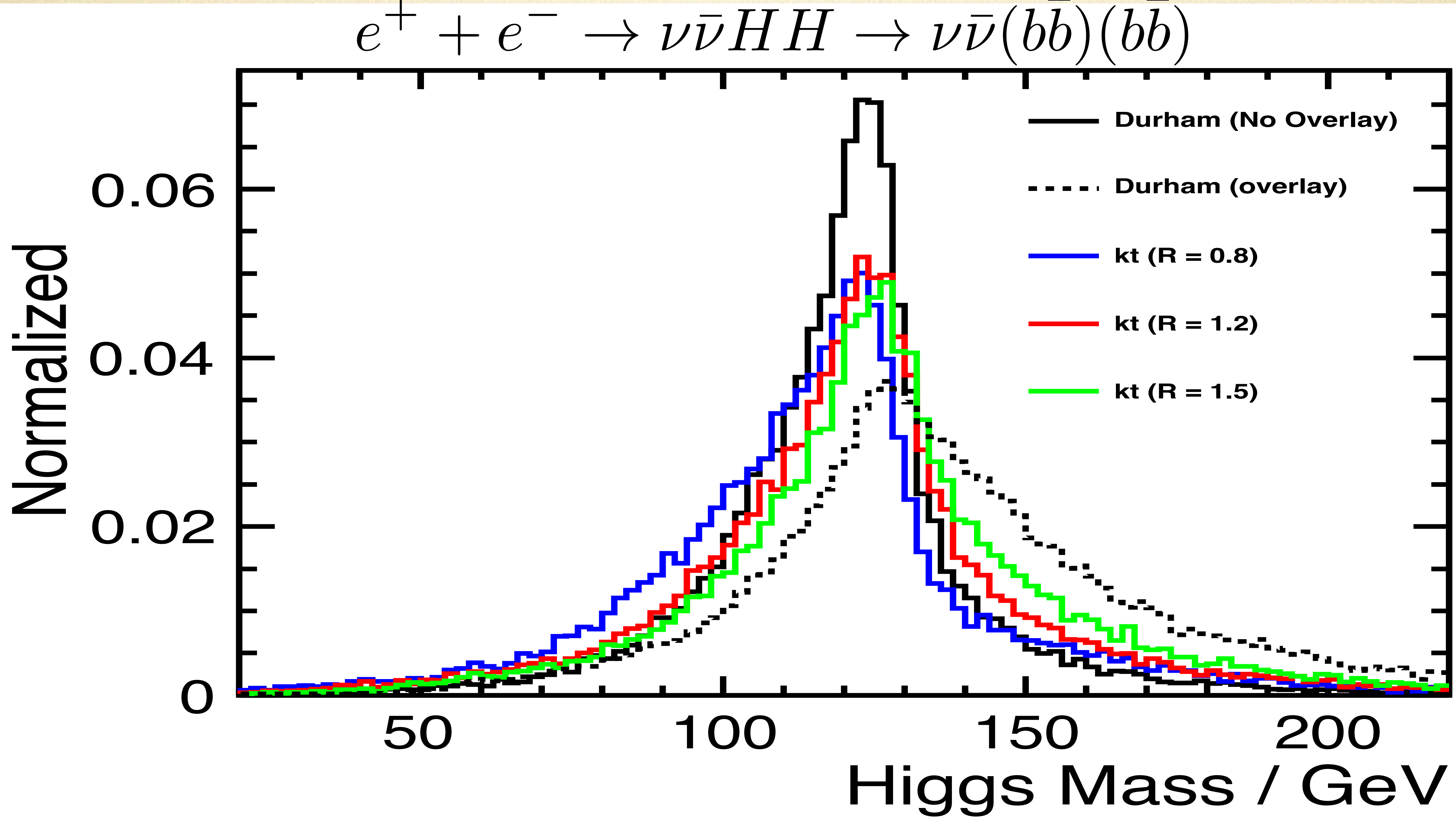
(by extrapolation x $\sqrt{(1-12\%)(1-20\%)}$)

including overlay: γγ—>hadrons

- exclusive kt algorithm.
- optimization: R-value and Njets

<N> = 4.1 @ 1 TeV





apparently a lot worse

including overlay: full analysis

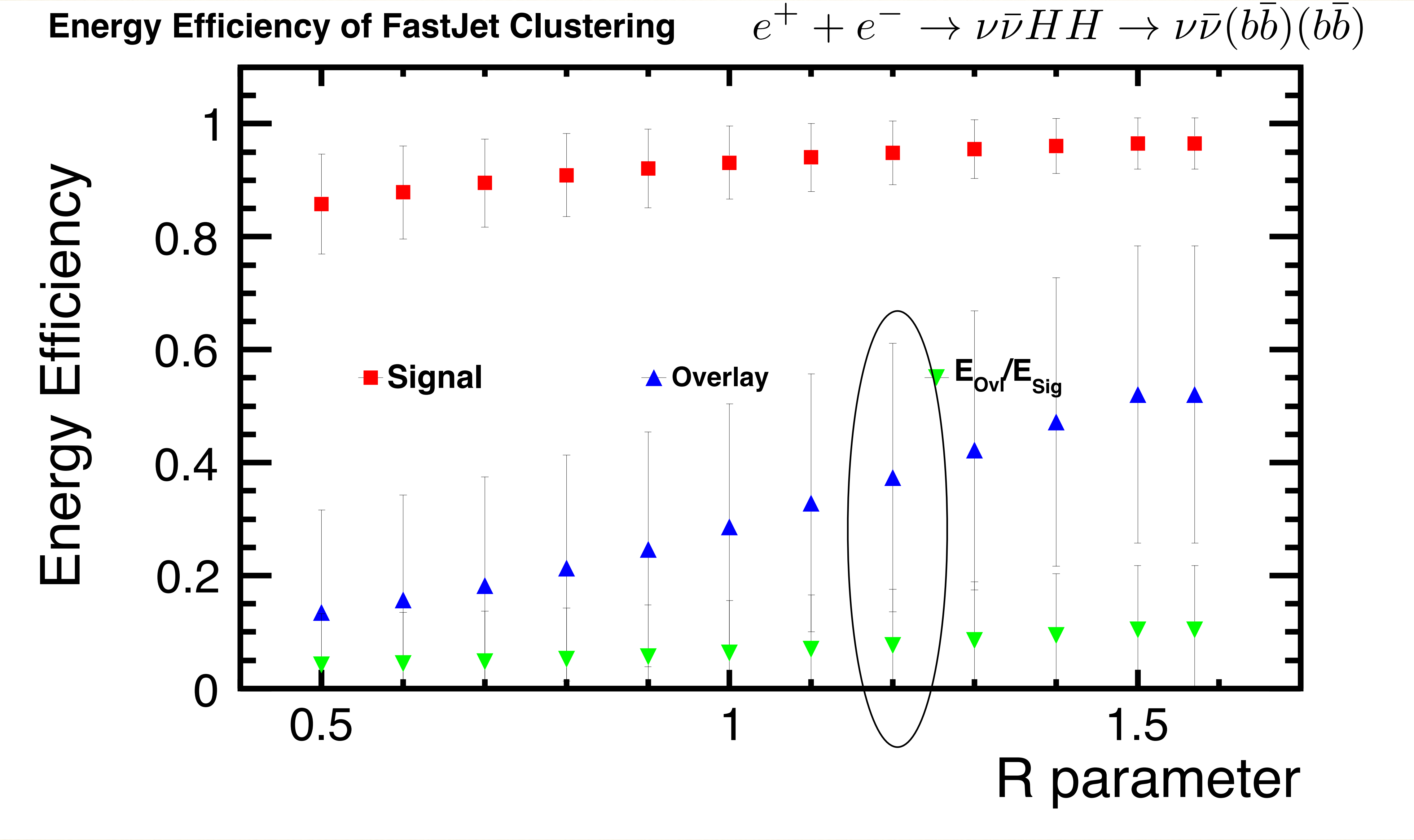
P(e-,e+) = (-0.8,+0.2); Ecm = 1 TeV; mH = 125 GeV; w/ overlay $\int L = 2\ ab^{-1}$

(very preliminary)

	ννHH -WWF (ννbbbb)	BG
#expected	240	7.86E+05
after selection	12.6(12.2)	12.0
significance	2.7σ	

a significant impact by overlay: 25% degradation

look into the remained particles after overly removal



by traditional kt algorithm to remove overlay, for R=1.2, there are still ~40% (energy) of overlay remained, and having ~5-15% of remained signal particles' total energy

→ a big trouble for jet-clustering

impact of overlay: a bit more detailed comparison

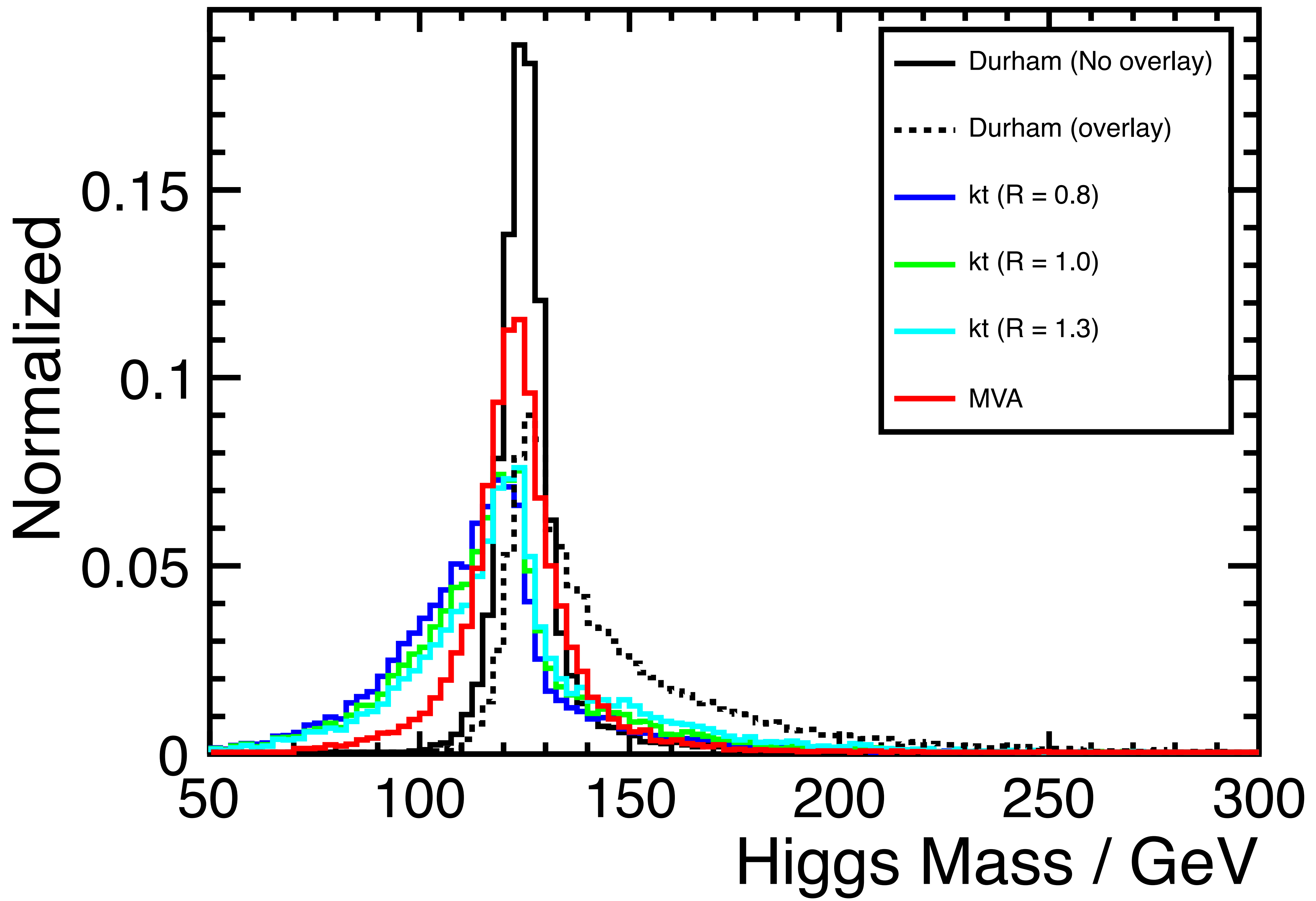
- found by looking into the components of each jet: in ~18% of all events, there are jets which are dominated by overlay particles.
- this immediately lead two signal efficiencies drop: cut on #particles in each jet; cut on smallest b-likeness
- then caused wider Higgs mass —> again signal efficiency drop by mass cut to keep similar level of background

a better strategy than kt algorithm is needed to remove overlay, in particular for t-channel signal processes

there was an alternative algorithm

(particle-by-particle tagging using MVA, based on d0, z0, pt, etc.; see my talk @ LCWS13)

$$e^+ + e^- \to \nu\bar{\nu}H \to \nu\bar{\nu}(WW^*) \to \nu\bar{\nu}qqqq$$ @ 500 GeV



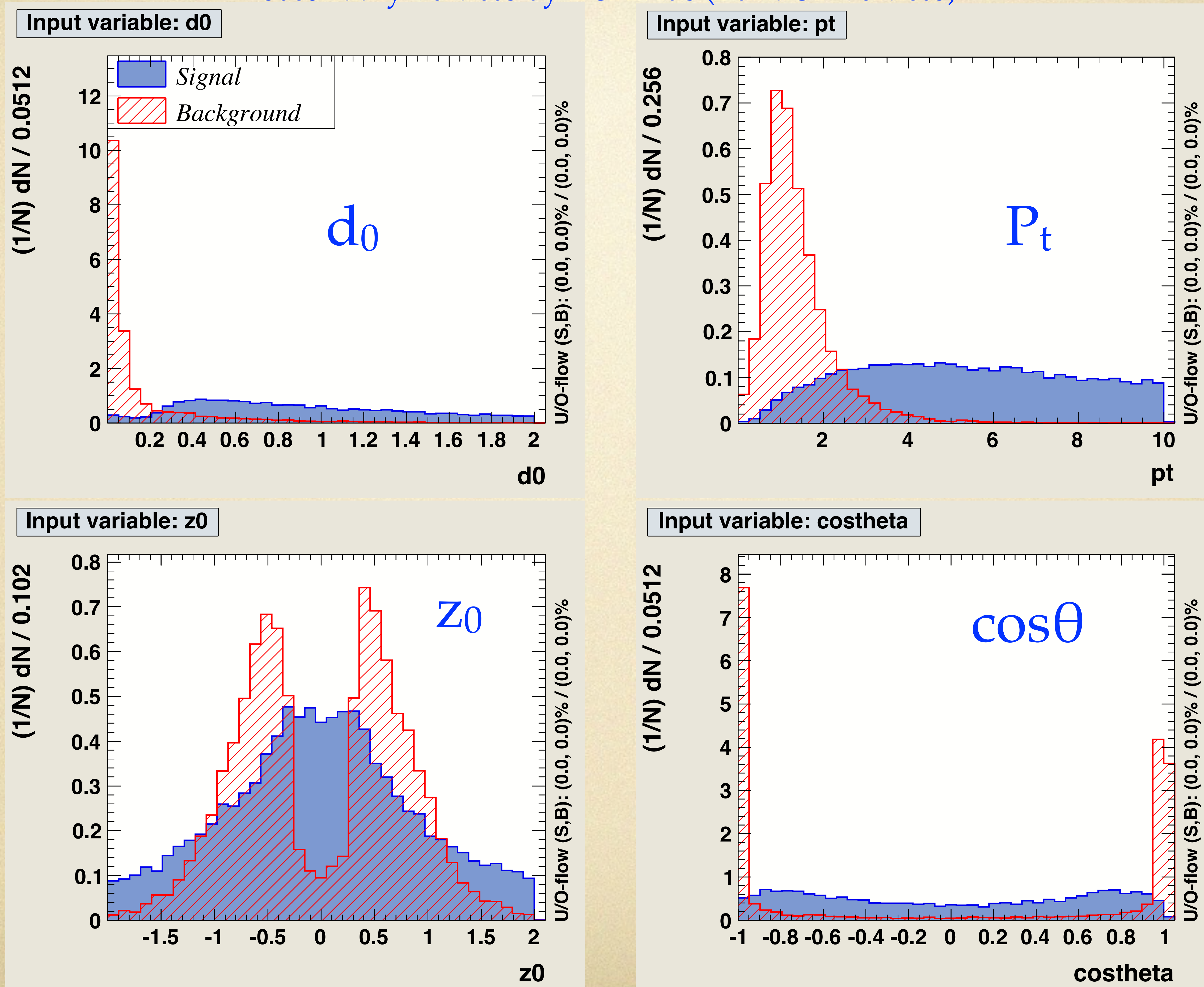
works much better in some cases, but not all; one caveat of this algorithm is that overlay particles from primary vertex are not well identified

a new strategy under investigation

- at first, identify some seed particles from both overlay and signal process (MVA)
- then based on those seed particles, apply certain clustering algorithm (cone or kt or any jet algorithm) to find other overlay particles around those seed particles
- good candidates of seed particles can be those from secondary vertices (if reconstructed), or those with shifted z0 but non-shifted d0

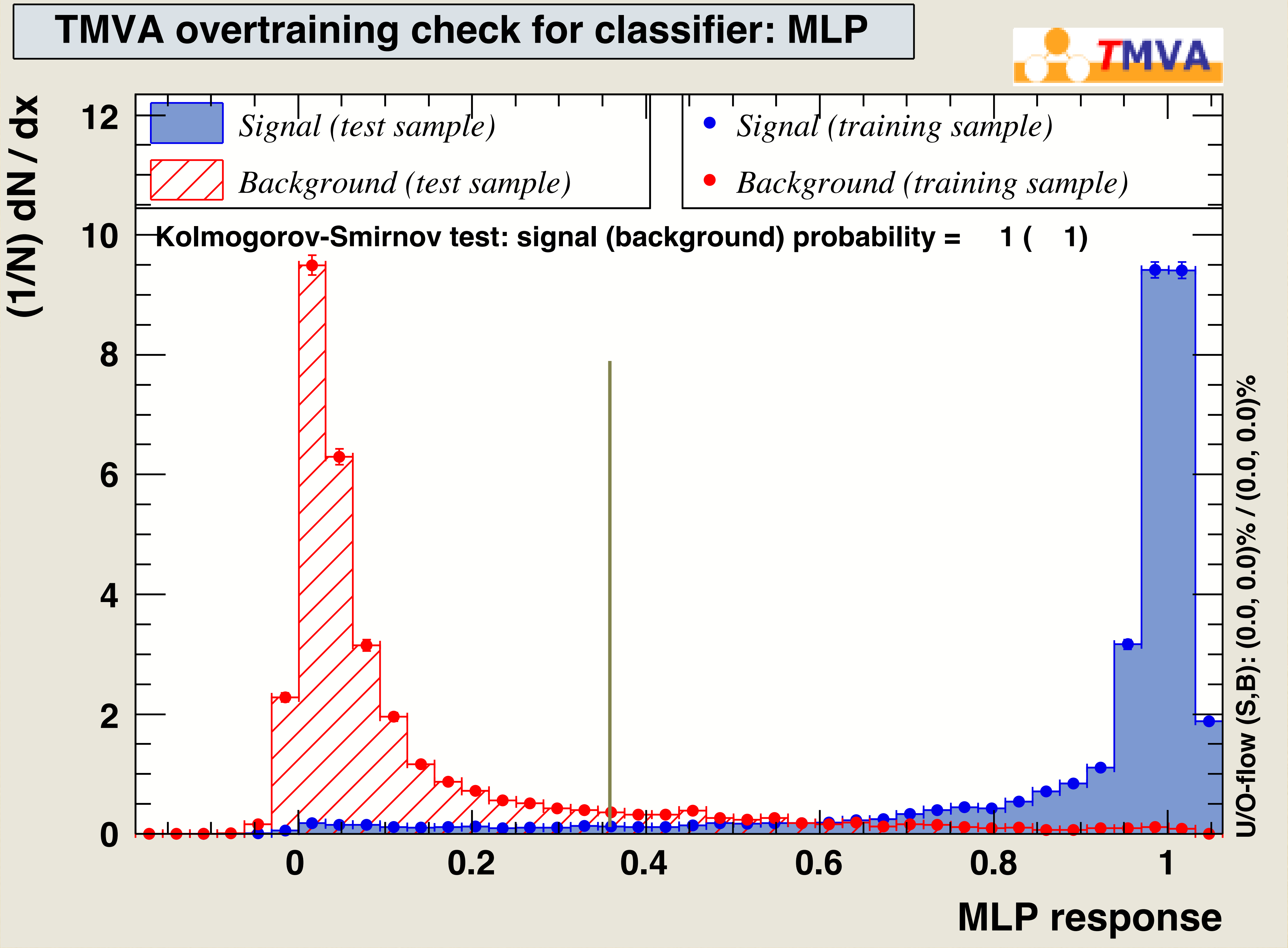
characteristics of vertices from signal and overlay

secondary vertices by LCFIPlus (BuildUP vertices)



MVA to separate vertices from signal and overlay

(since z0 is highly correlated with cosθ and d0, not used)



mva_out > 0.37: Eff_signal ~ 99.7%; Eff_overlay ~10%

but…

- the vertex reconstruction efficiencies for overlay are rather row (only 20% of all events, there are overlay vertices reconstructed by LCFIPlus).
- to improve, change minimum Pt, minimum # of TPC Hits…
- not so successful yet, try to do vertex finder only for forward low-pt particles.
- nevertheless, it would not be a big issue, since we will rely one others seeds which are just single particle based.
- ongoing…

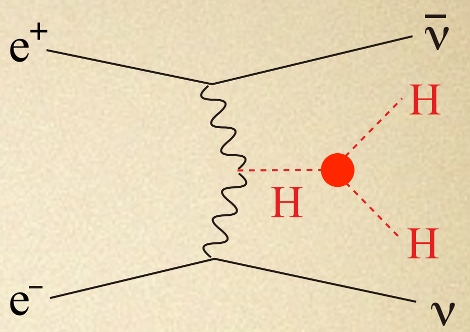
Happy Chinese New Year of Sheep

— year of good luck

Backup

$$e^+ + e^- \to \nu\bar{\nu}HH \to \nu\bar{\nu}(b\bar{b})(b\bar{b})$$

(full simulation @ 1 TeV, mH = 125 GeV;
without γγ—>hadrons overlay case)



pre-selection:

- reject events with isolated lepton (done with MVA based IsolatedLeptonTagging processor)
- cluster all particles to four jets (Durham), each with at least 7 particles, 3rd Btagging > 0.2 (done within LCFIPlus processors); pair those four jets to two Higgs by minimising χ2 defined by two pair masses.

final-selection:

- Visible energy < 900 GeV; Missing Mass > 0 (cut1)
- tt-bar suppression (MVA): MLP_lvbbqq > 0.67 (cut2)
- vvZZ and vvZH suppression (MVA): MLP_vvbbbb > 0.45 (cut3)
- B-tagging: Bmax3 + Bmax4 > 0.71 (cut4)

signal and backgrounds (reduction table)

P(e-,e+) = (-0.8,+0.2); Ecm = 1 TeV; mH = 125 GeV; w/o overlay $\int L = 2\ ab^{-1}$

(preliminary)

	ννHH - WWF (ννbbbb)	ννHH (ZHH)	ννZH	ννZZ	tt-bar	BG	significance
#expected	240	72.2	3.33E+03	1.72E+03	7.81E+05	7.86E+05	0.27
pre-selection	77.1(66)	23.3	472	781	2.97E+04	3.1E+04	0.44
cut1	75.2(64.4)	16	447	749	1.09E+04	1.21E+04	0.68
cut2	57.9(50.8)	5.48	260	227	397	890	1.9
cut3	33.5(29.4)	2.1	20.8	6.6	128	157	2.4
cut4	24.8(24.0)	1.57	12.1	3.34	6.86	23.9	3.6

nS = 24.8, nB = 23.9 ~ 3.6σ

(3.6σ by previous extrapolation)

signal and backgrounds (reduction table)

P(e-,e+) = (-0.8,+0.2); Ecm = 1 TeV; mH = 125 GeV; w/ overlay $\int L = 2\ ab^{-1}$

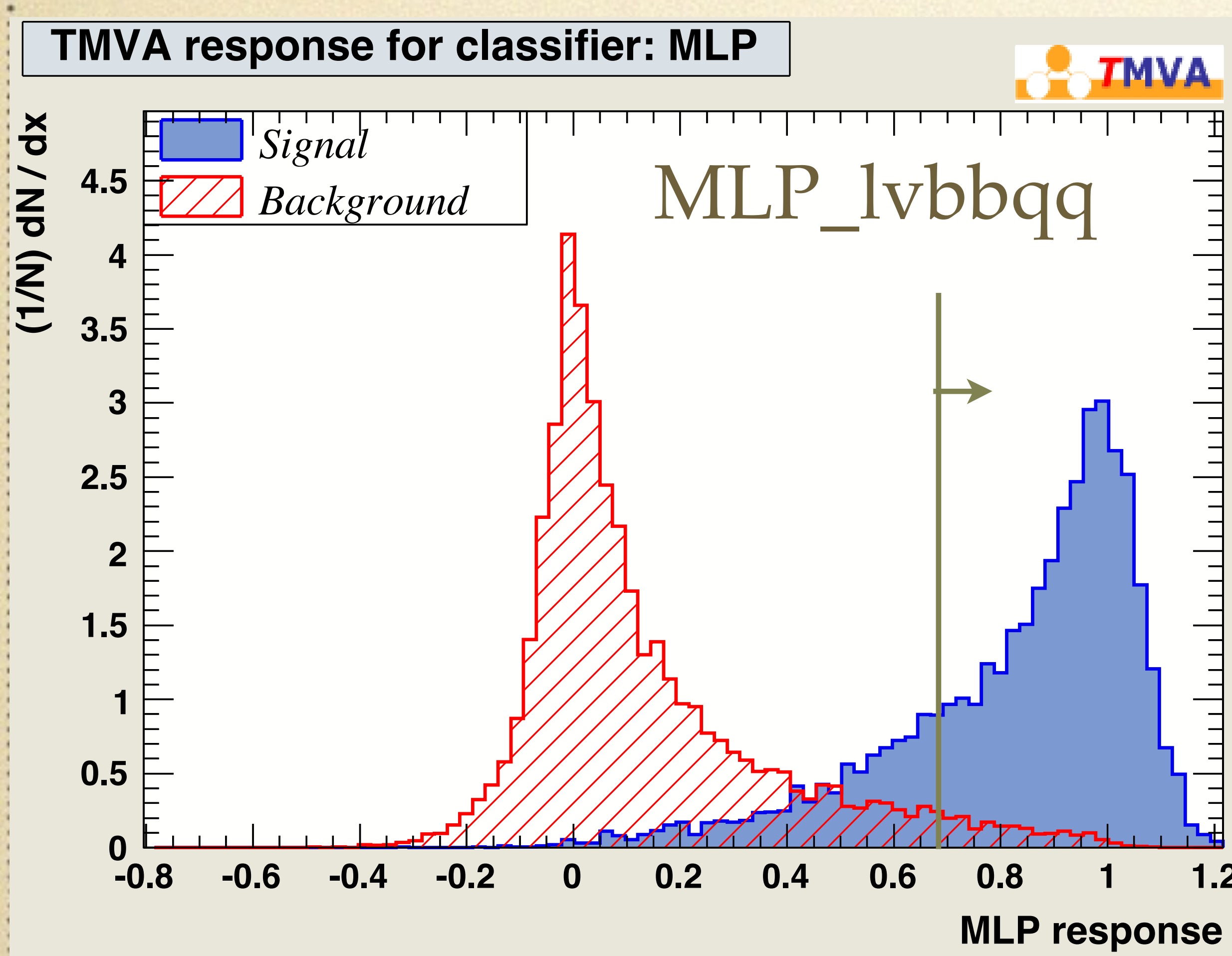
(very preliminary)

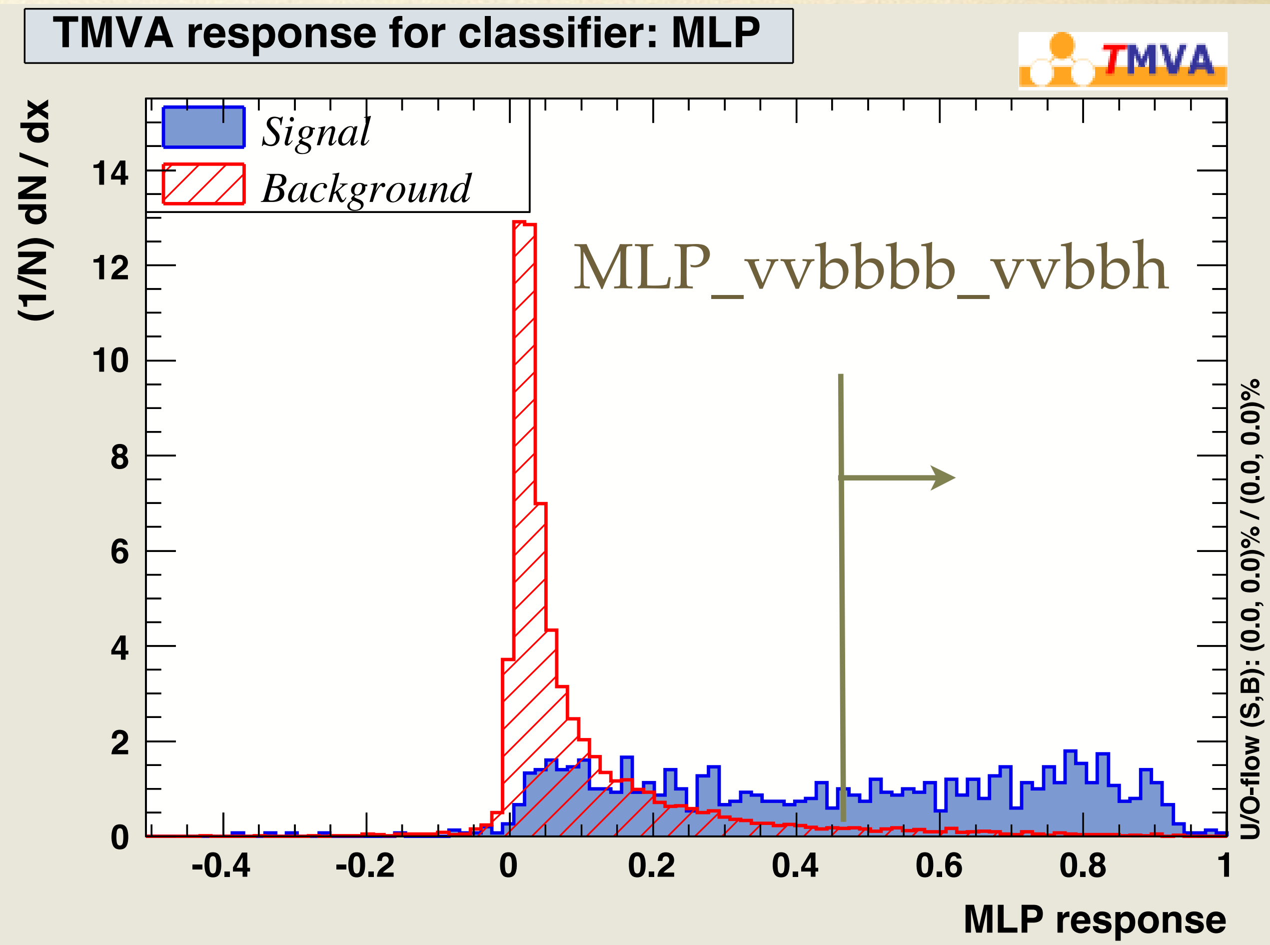
	ννHH - WWF (ννbbbb)	ννHH (ZHH)	ννZH	ννZZ	tt-bar	BG	significance
#expected	240	72.2	3.33E+03	1.72E+03	7.81E+05	7.86E+05	0.27
pre-selection	69.1(54.5)	19	473	600	2.94E+04	3.05E+04	0.4
cut1	66.2(52.4)	12.2	438	570	5.51E+03	6.53E+03	0.82
cut2	54.4(44.1)	4.09	322	392	759	1.48E+03	1.4
cut3	19.6(16.5)	0.445	19	6	109	134	1.6
cut4	12.6(12.2)	0.299	7.51	2.24	1.97	12.0	2.7

nS = 12.6, nB = 12.0 ~ 2.7σ

(25% degradation than case w/o overlay!)

MVA output





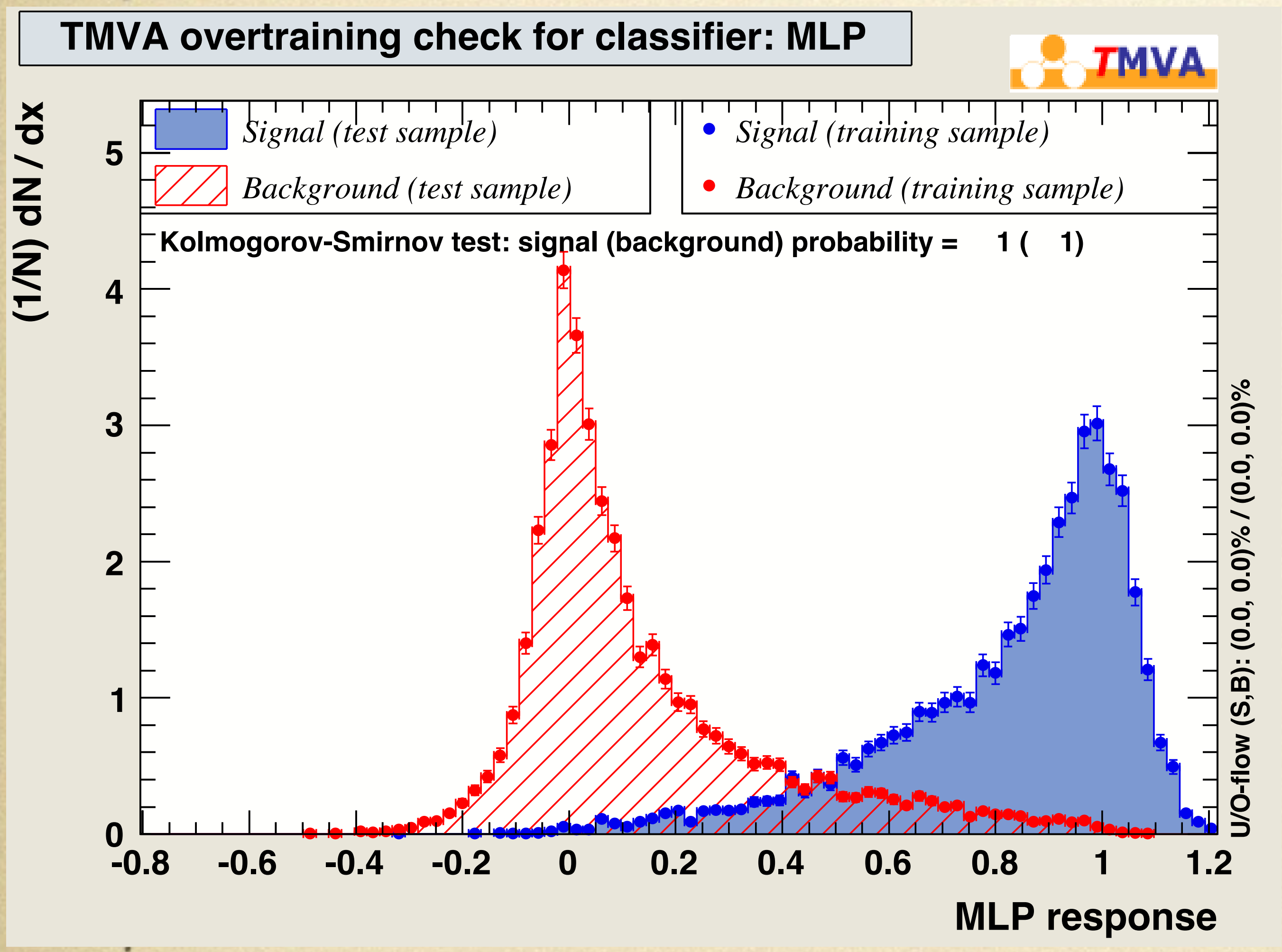
inputs:

- Evis, MissPt, MissMass
- W mass case of tt4j and tt5j reconstruction
- tau mass in case of tt5j
- Pmax and Econe of leptons
- M(H1), M(H2)
- $Y_{5\to4}$

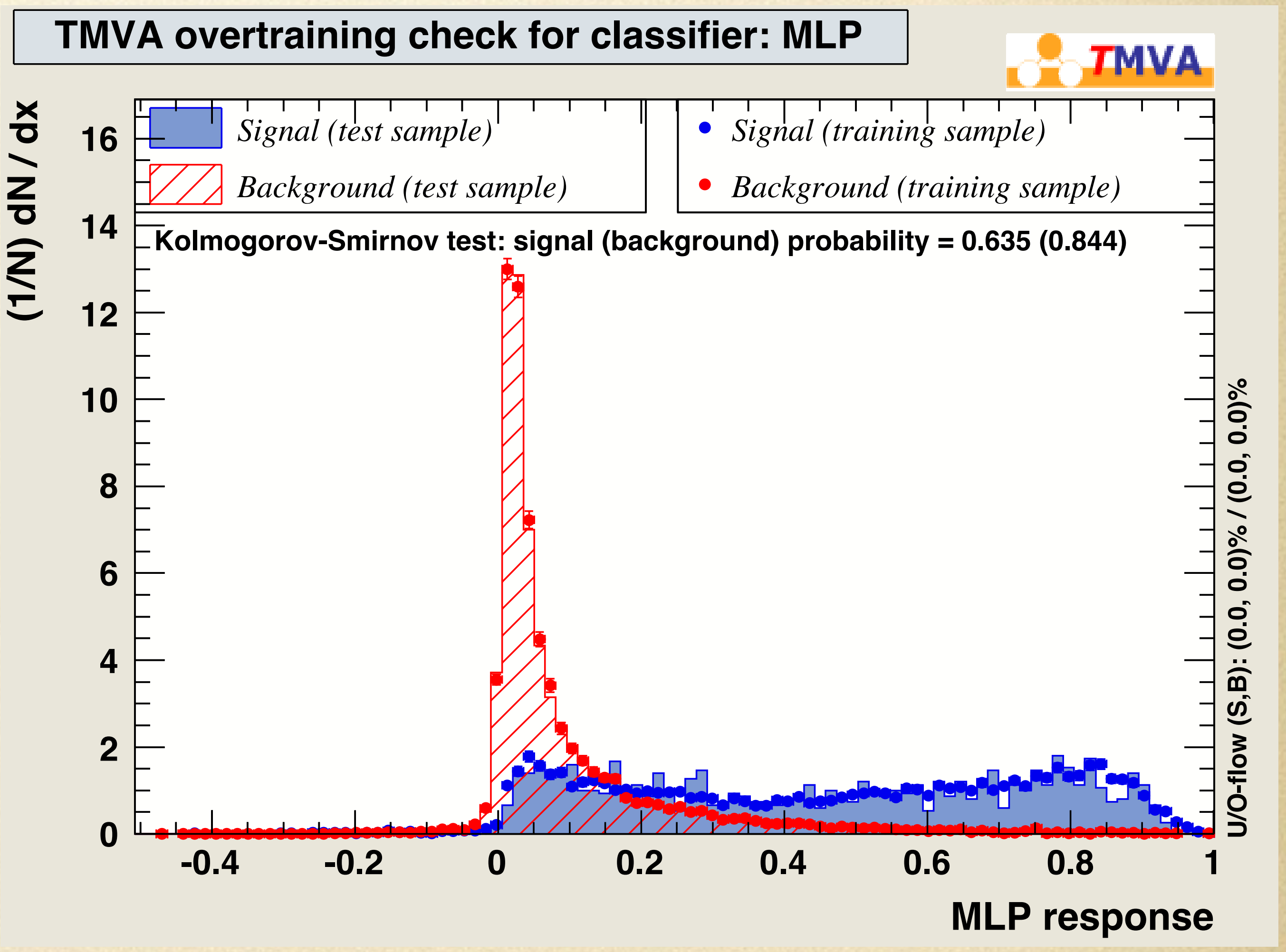
- two Z masses in case of ννZZ reconstruction
- Z and Higgs masses in case of ννZH reconstruction
- M(H1), M(H2)

see MVA details in LC-REP-2013-003

MVA overtraining test



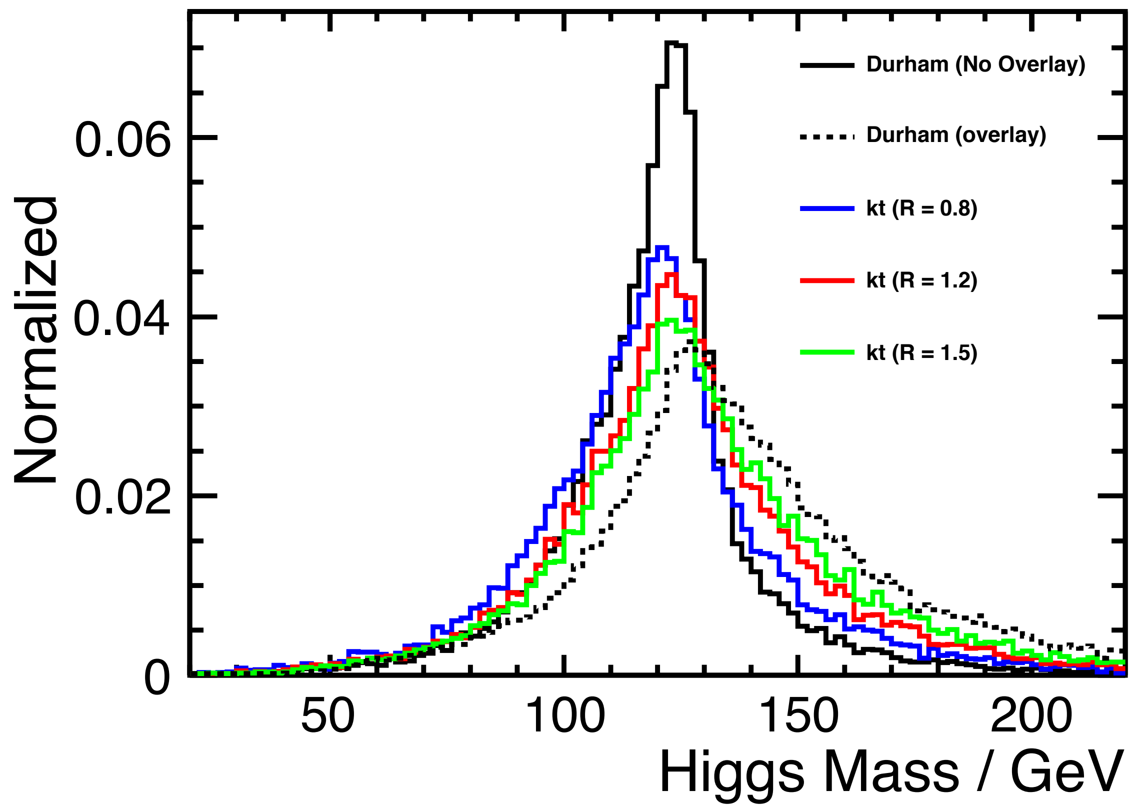
MLP_lvbbqq

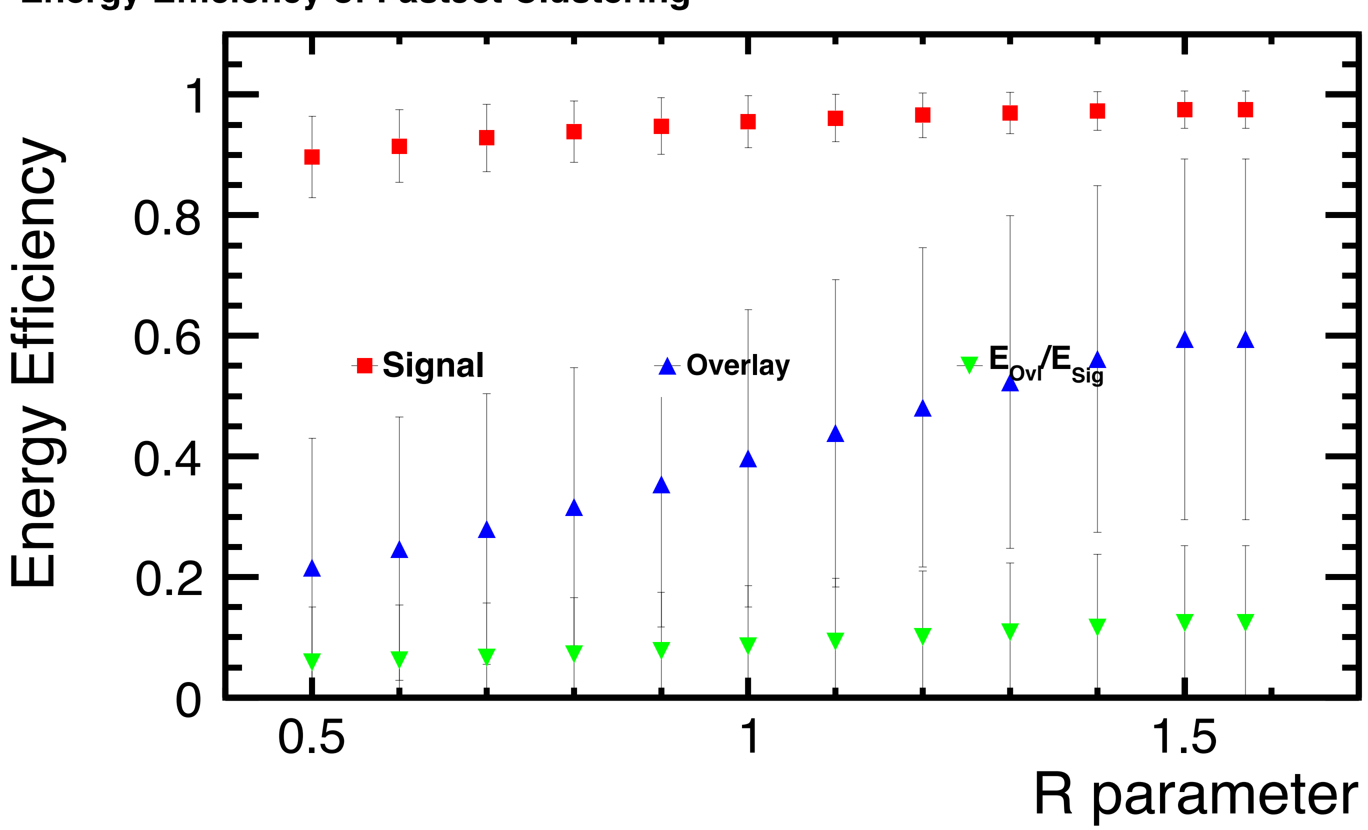


MLP_vvbbbb_vvbbh

including overlay: γγ—>hadrons

- exclusive kt algorithm (NJet = 5)





DBD full simulation

Higgs self-coupling @ 1 TeV

P(e-,e+)=(-0.8,+0.2) $e^+ + e^- \to \nu\bar{\nu}HH$ $M(H) = 120\text{GeV}$ $\int Ldt = 2\text{ab}^{-1}$

	Expected	After Cut
ννhh (WW F)	272	35.7
ννhh (ZHH)	74	3.88
BG (tt/ννZH)	7.86×10^5	33.7
significance	0.3	4.29

- better sensitive factor
- benefit more from beam polarisation
- BG tt x-section smaller
- more boosted b-jets

$$\frac{\Delta\sigma}{\sigma} \approx 23\% \qquad \frac{\Delta\lambda}{\lambda} \approx 18\%$$

Double Higgs excess significance: $> 7\sigma$

Higgs self-coupling significance: $> 5\sigma$

DBD analysis (no gam-gam overlay):

signal and backgrounds (reduction table)

Polarization: (e-,e+)=(-0.8,+0.2) $E_{\rm cm} = 1$ TeV, $M_H = 120$ GeV $\int L = 2\ \mathrm{ab}^{-1}$

	Expected	Generated	pre-selction	cut1	cut2	cut3	cut4
νvhh (WW F)	272	1.05×10^5	127	107	77.2	47.6	35.7
νvhh (ZHH)	74	2.85×10^5	32.7	19.7	6.68	4.88	3.88
ννbbbb	650	2.87×10^5	553	505	146	6.21	4.62
ννccbb	1070	1.76×10^5	269	242	63.3	2.69	0.19
yyxyyx	3.74×10^5	1.64×10^6	18951	4422	38.5	26.7	1.83
yyxyeν	1.50×10^5	6.21×10^5	812	424	44.4	11	0.73
yyxylν	2.57×10^5	1.17×10^6	13457	4975	202	84.5	4.86
ννZH	3125	7.56×10^4	522	467	257	30.6	17.6
BG	7.86×10^5		34597	11054	758	167	33.7
significance	0.3		0.68	1.01	2.67	3.25	4.29

$$\frac{\Delta\sigma}{\sigma} \approx 23\% \qquad \frac{\Delta\lambda}{\lambda} \approx 20\%$$ (18%)

(with weighting)

Double Higgs excess significance: 7.2σ