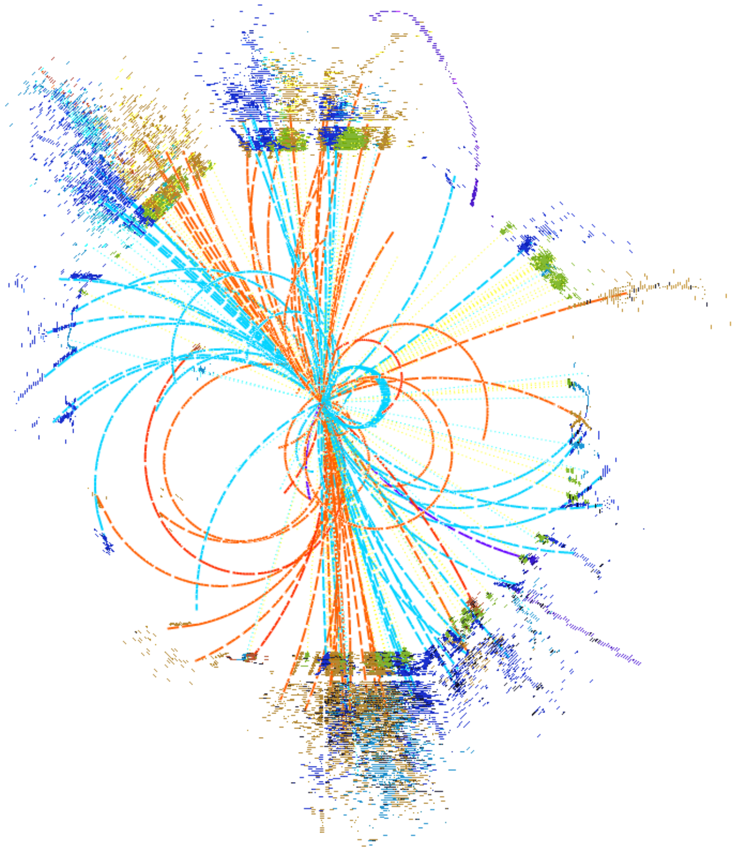
SiD benchmarking status

Philipp Roloff (CERN)



ECFA LC2013, 30/05/2013, DESY Hamburg

Overview

- Reconstruction aspects

- DBD benchmark analyses

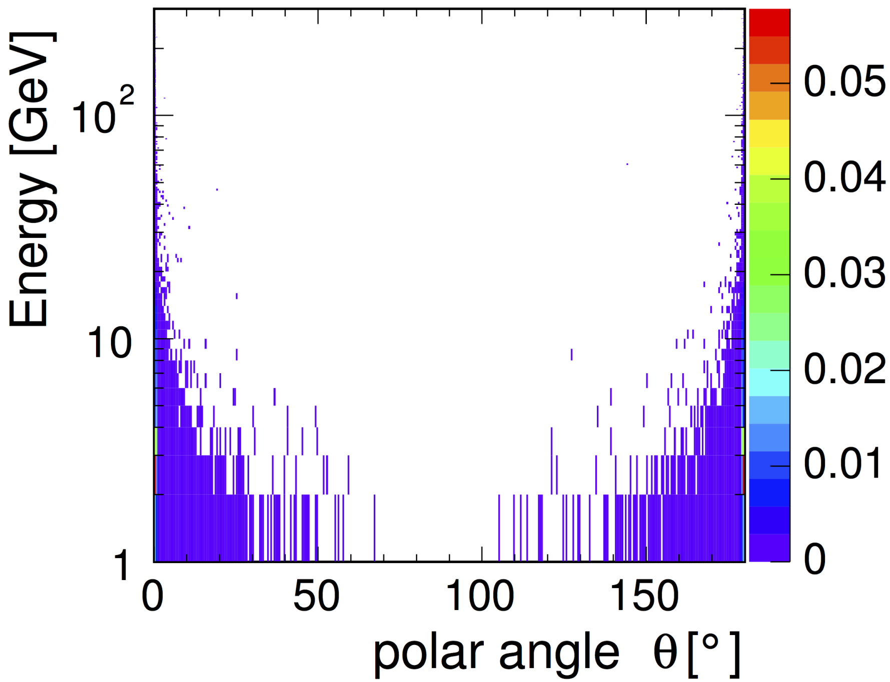
  - Top Yukawa coupling
  - Higgs branching fractions
  - Beam polarisation from WW pairs
  - Top cross section and FB-asymmetry

- Ongoing studies using CLIC_SiD

Reconstruction aspects

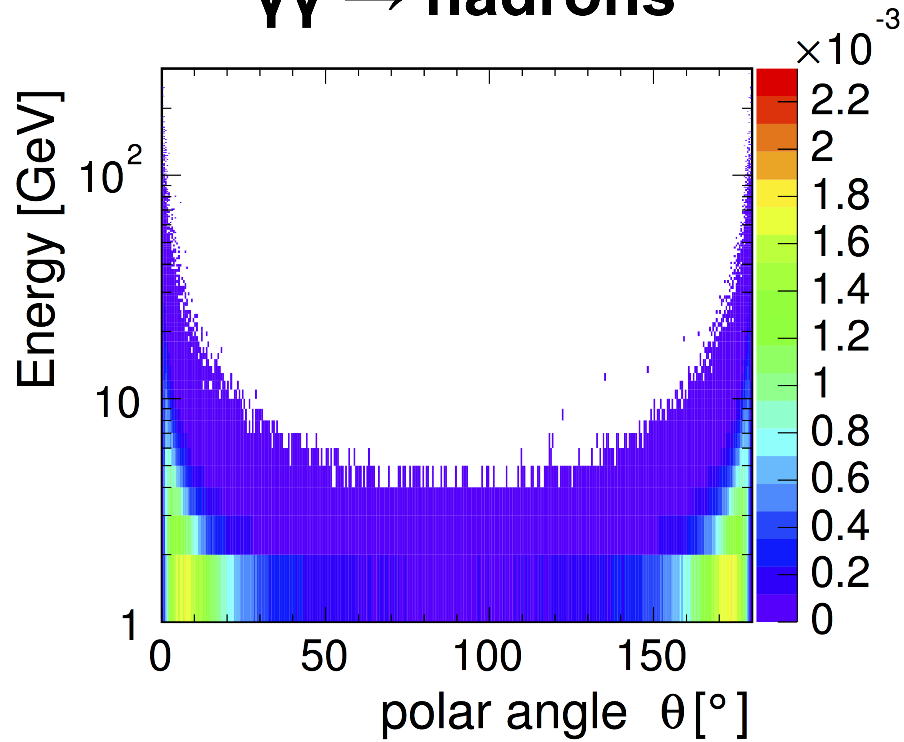
Beam-induced backgrounds

e^+e^- pairs



450000 particles per BX

γγ → hadrons

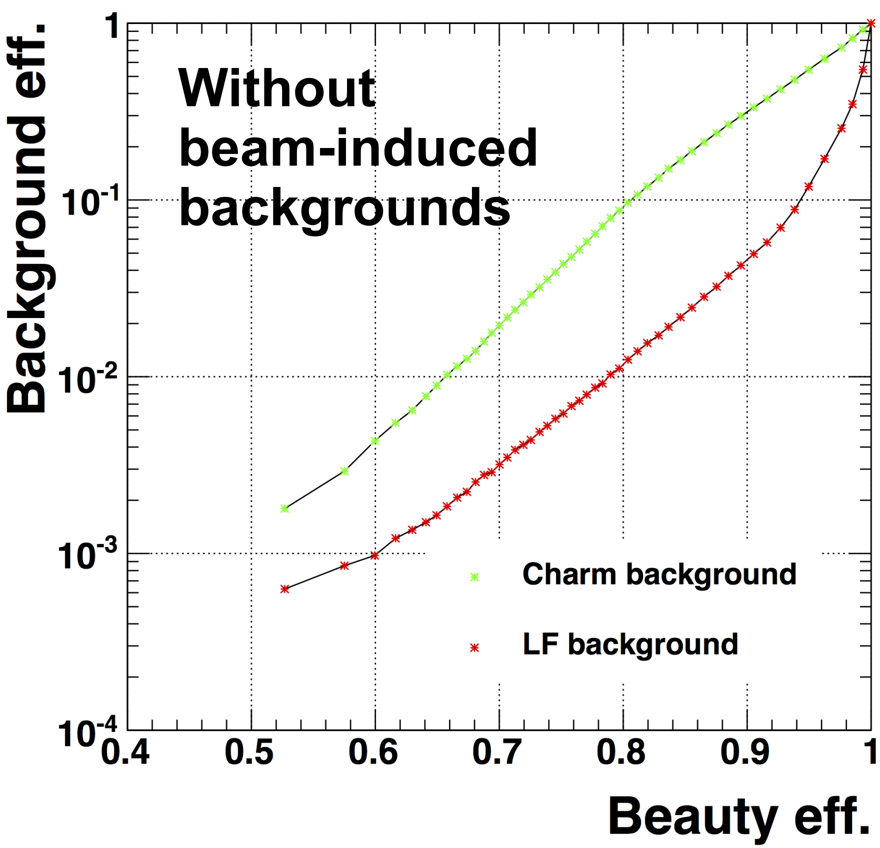


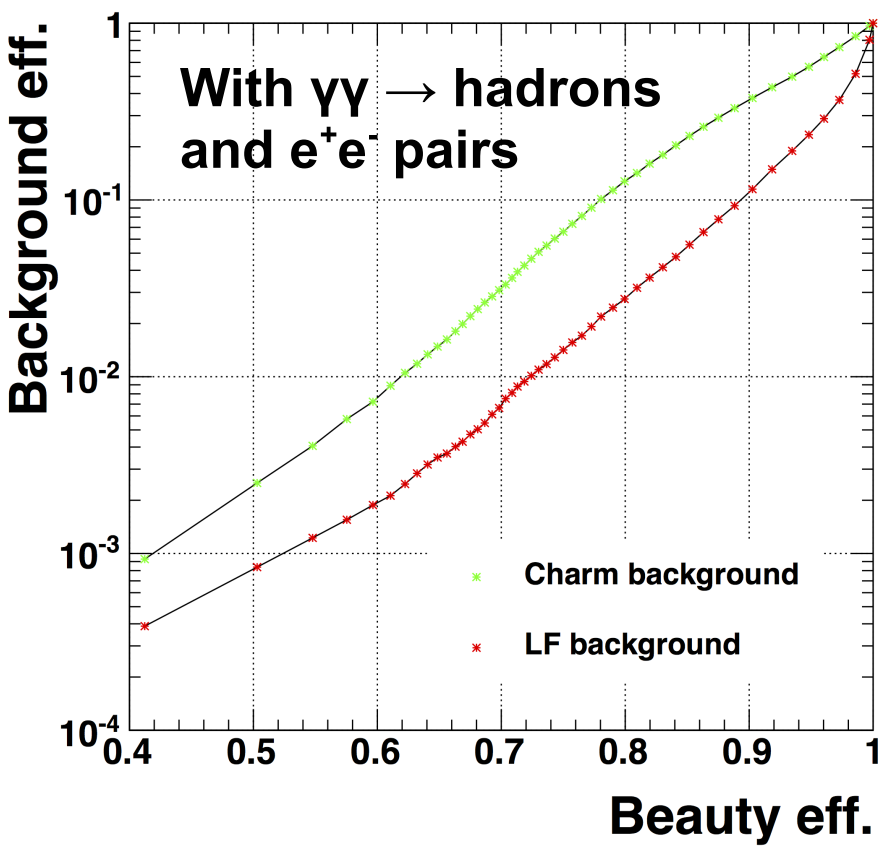
4.1 interactions per BX

→ The particles from beam-induced backgrounds processes peak in the forward direction

Beauty-jet tagging

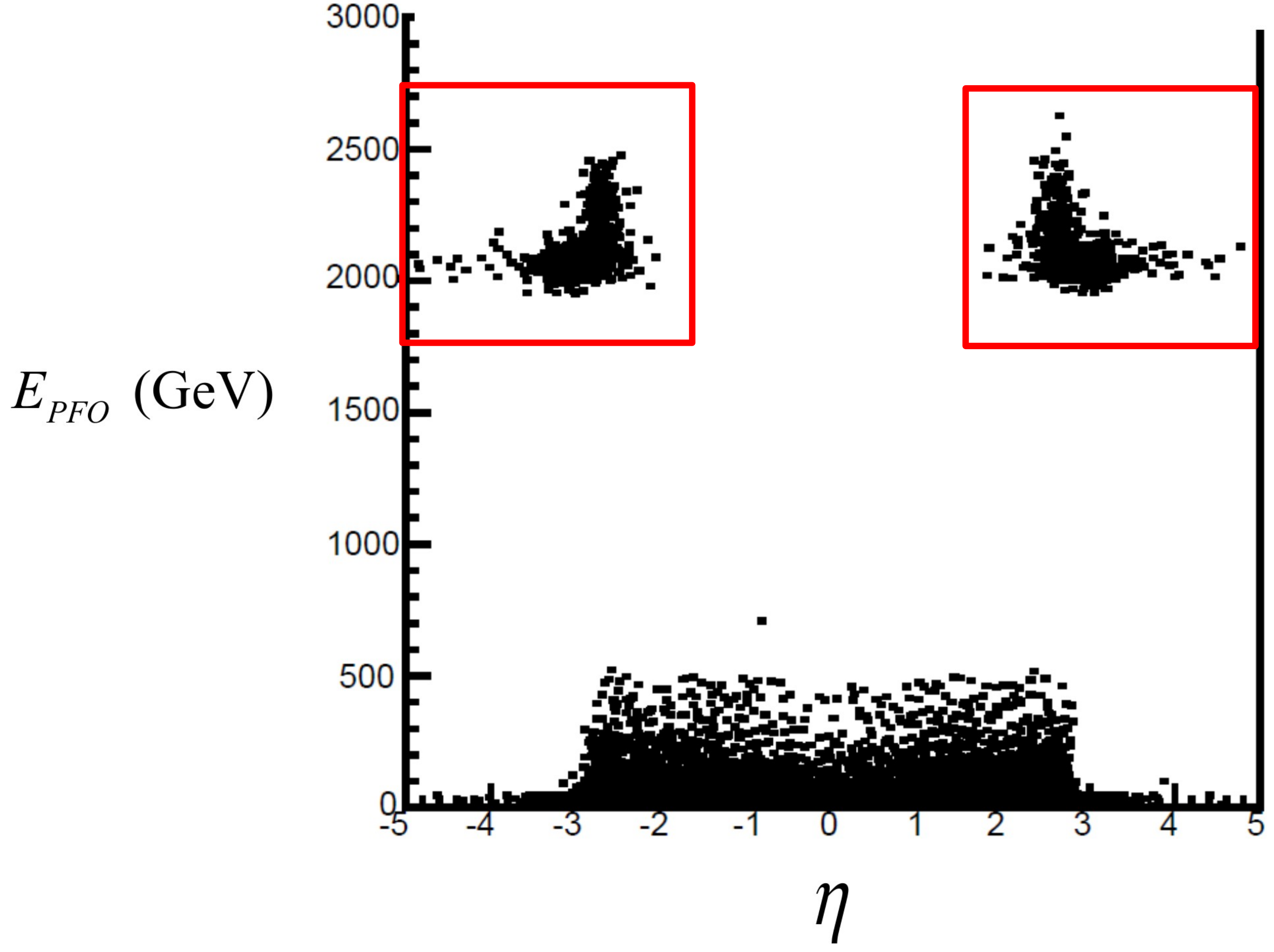
- Based on the LCFIPlus package
- Cuts adjusted for the SiD detector geometry





Test of the flavour tagging performance in $Z \to b\bar{b}$, $c\bar{c}$, $q\bar{q}$ events

Impact of e^+e^- pairs on the reconstruction



- Caused by mis-reconstruction of e^+e^- pairs
- Low angle electrons are combined with these PFOs
→ forward electron tagging difficult

DBD benchmark analysis

Overview of DBD benchmark studies

- Top Yukawa coupling, 1 TeV
(Ph. R., Jan Strube)

- Higgs branching fractions, 1 TeV
(Tim Barklow, Homer Neal)

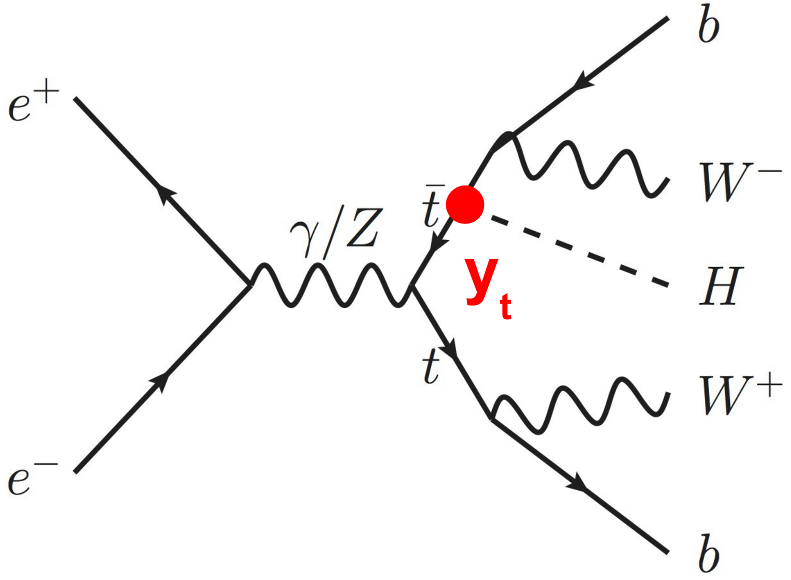
- Beam polarisation from WW pairs, 1 TeV
(Tim Barklow)

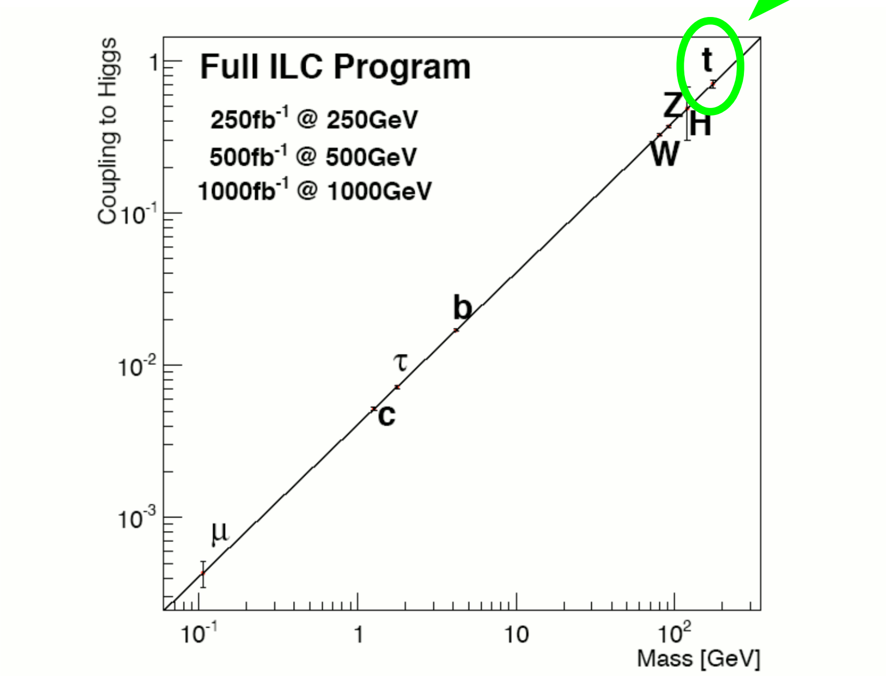
- Top cross section and FB-asymmetry, 500 GeV
(Malachi Schram)

$t\bar{t}H$: introduction

- **Final states:** - "6 jets": $t(\rightarrow qqb)\bar{t}(\rightarrow l\nu\bar{b})H(\rightarrow b\bar{b})$, m_H = 125 GeV
  - "8 jets": $t(\rightarrow qqb)\bar{t}(\rightarrow qq\bar{b})H(\rightarrow b\bar{b})$, m_H = 125 GeV

- **Motivation:** Cross section for $t\bar{t}H$ production is directly sensitive to the top Yukawa coupling, y_t:



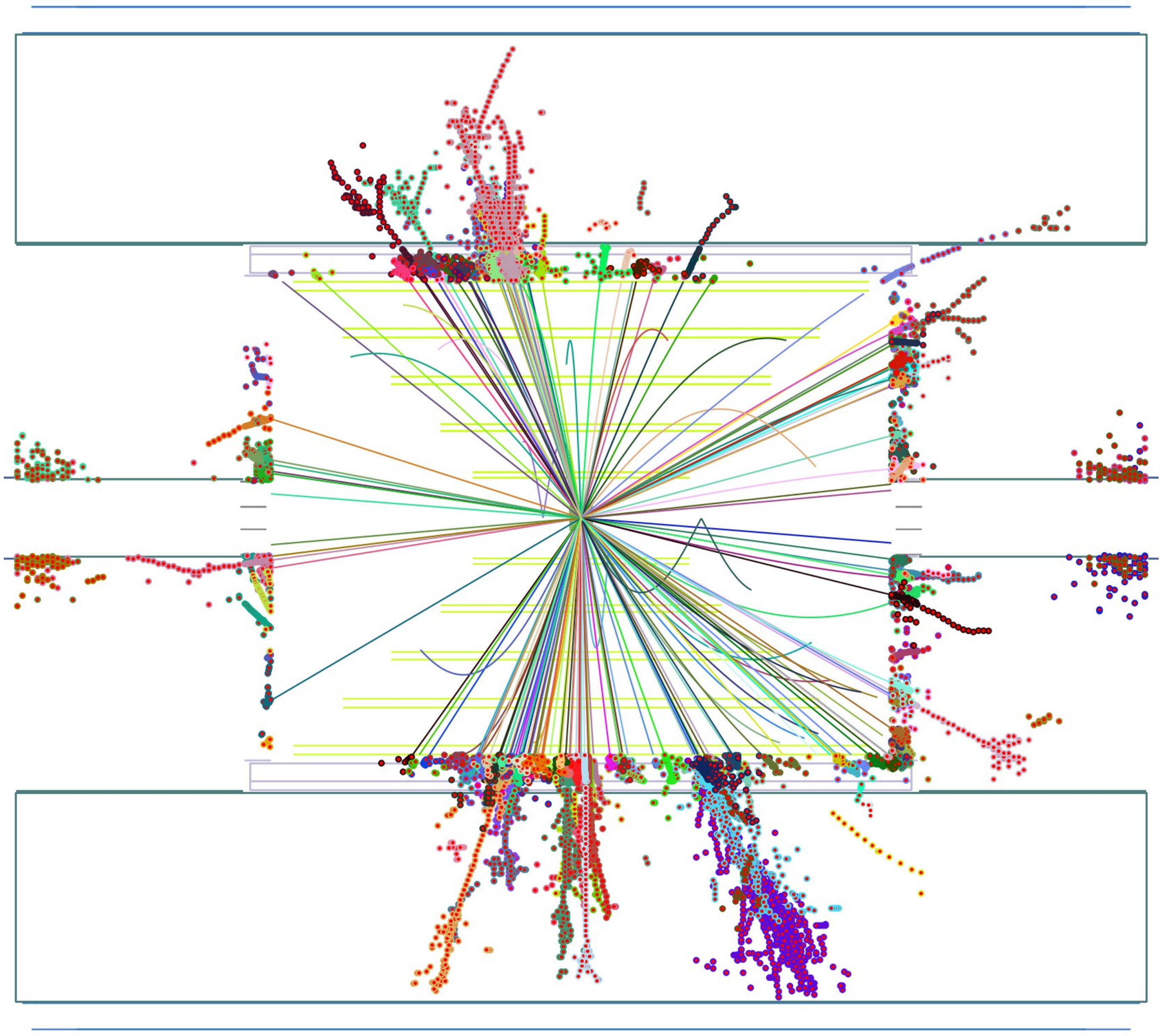


Event reconstruction I

1.) Remove all PFOs with:

- $p_T < 500$ MeV
- $\Theta < 20°$
- $\Theta > 160°$

2.) Remove identified isolated leptons from PFO list



8jet signal event

Event reconstruction II

3.) Perform jet clustering using the Durham algorithm in the exclusive mode with 6 or 8 jets

4.) Obtain b-tag value for each jet using LCFIPlus

5.) Group jets into $W^{\pm}$, H and top pairs by minimising:

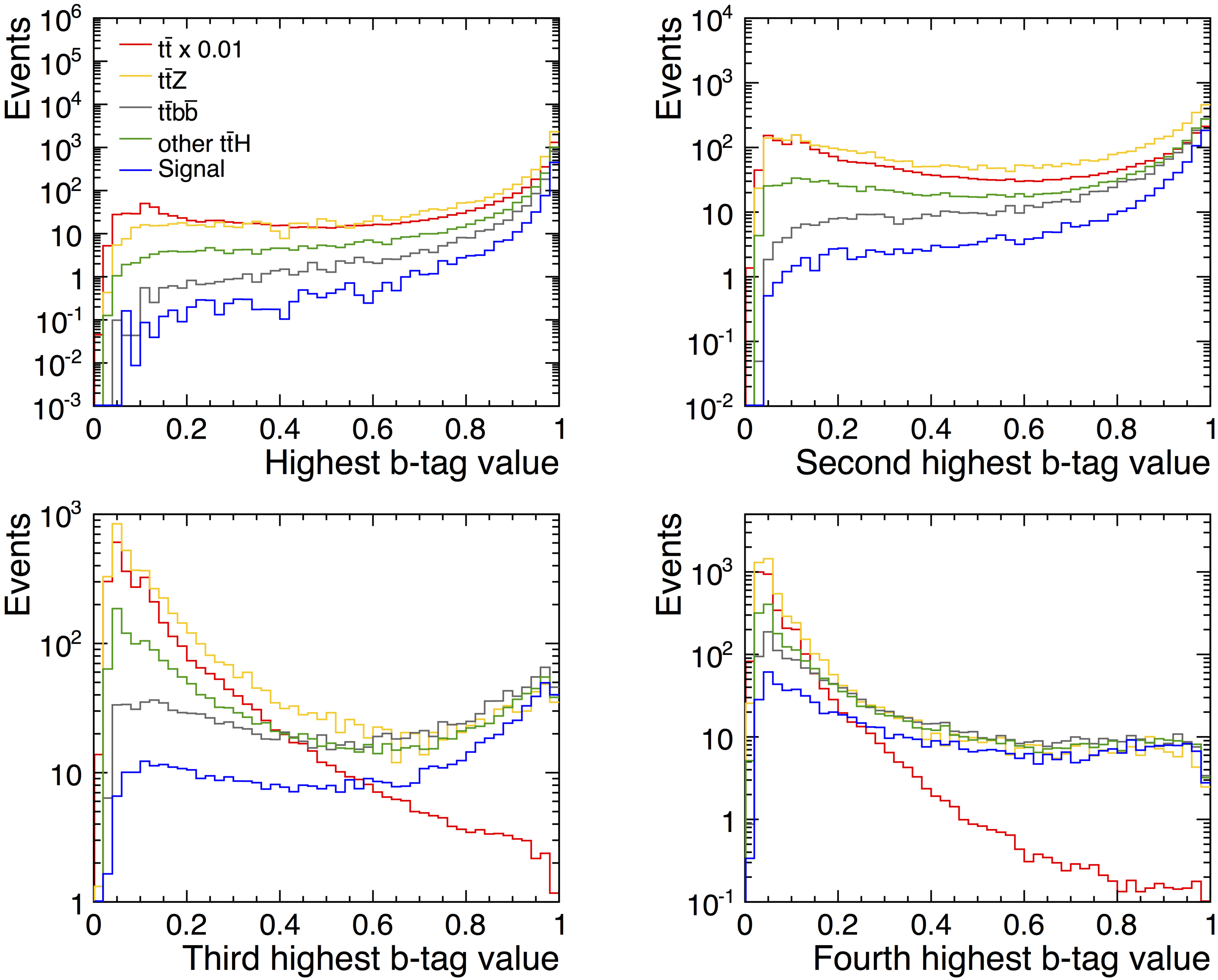
6jets:

$$\frac{(M_{12} - M_{W^\pm})^2}{\sigma^2_{W^\pm}} + \frac{(M_{123} - M_t)^2}{\sigma^2_t} + \frac{(M_{45} - M_H)^2}{\sigma^2_H}$$

8jets:

$$\frac{(M_{12} - M_{W^\pm})^2}{\sigma^2_{W^\pm}} + \frac{(M_{123} - M_t)^2}{\sigma^2_t} + \frac{(M_{45} - M_{W^\pm})^2}{\sigma^2_{W^\pm}} + \frac{(M_{456} - M_t)^2}{\sigma^2_t} + \frac{(M_{78} - M_H)^2}{\sigma^2_H}$$

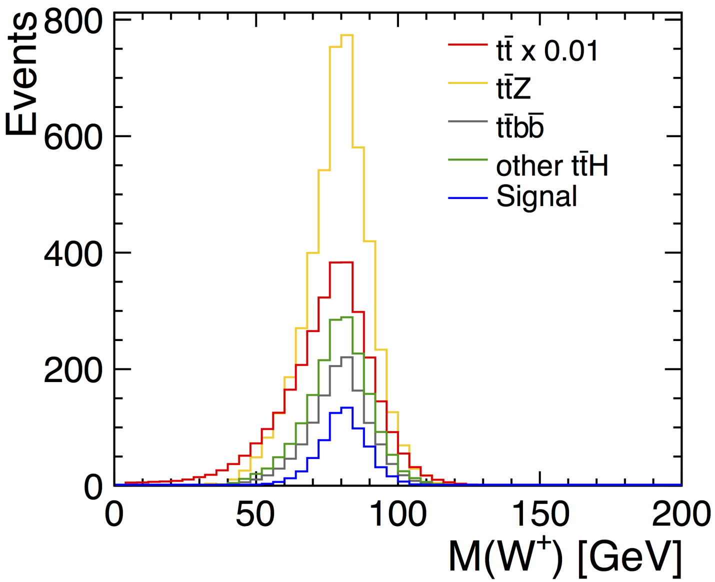
Top Yukawa coupling: b-tagging

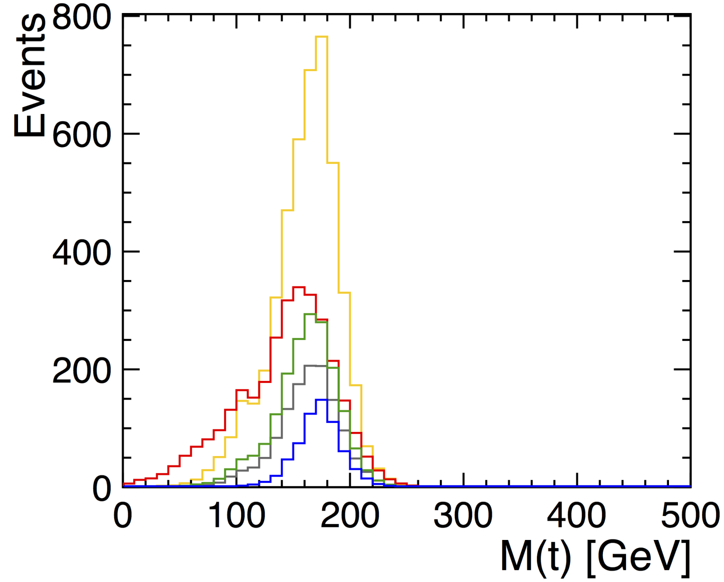


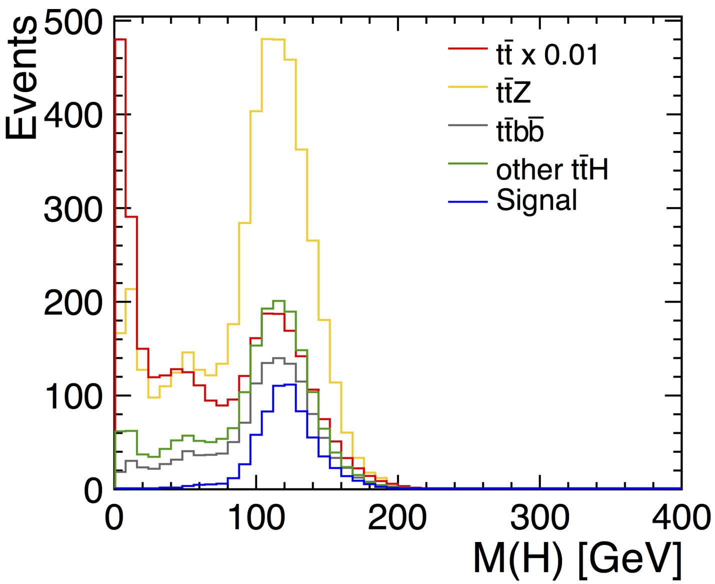
- Final state with six jets
- $t\bar{t}$ background scaled by 0.01
- Signal has 4 b-jets, part of the background samples contain only 2 b-jets

L_{int} = 1 ab^{-1}

W^+/top/Higgs masses





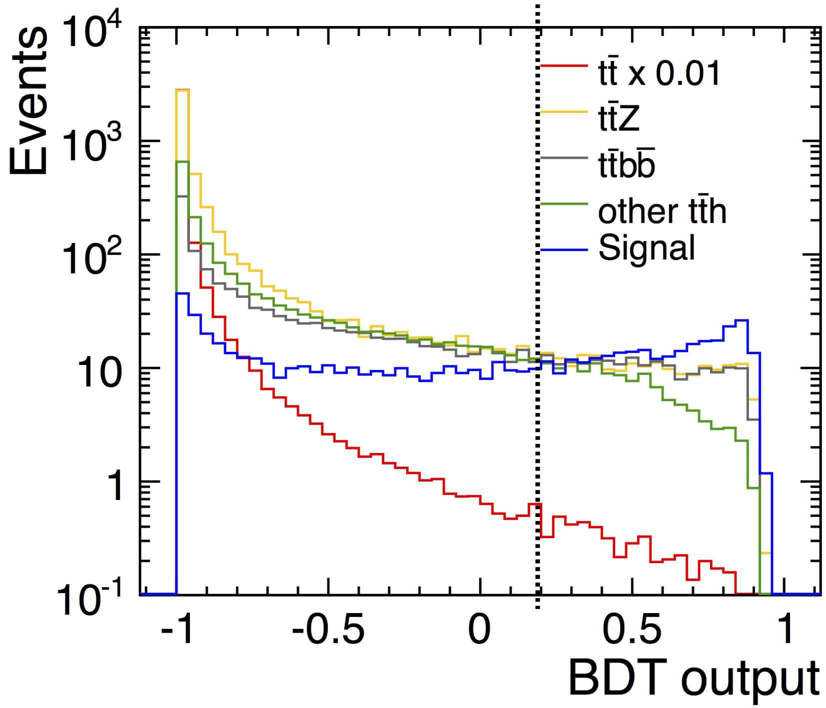


- Final state with eight jets
- $t\bar{t}$ background scaled by 0.01
- The background distributions are broader than the signal peaks

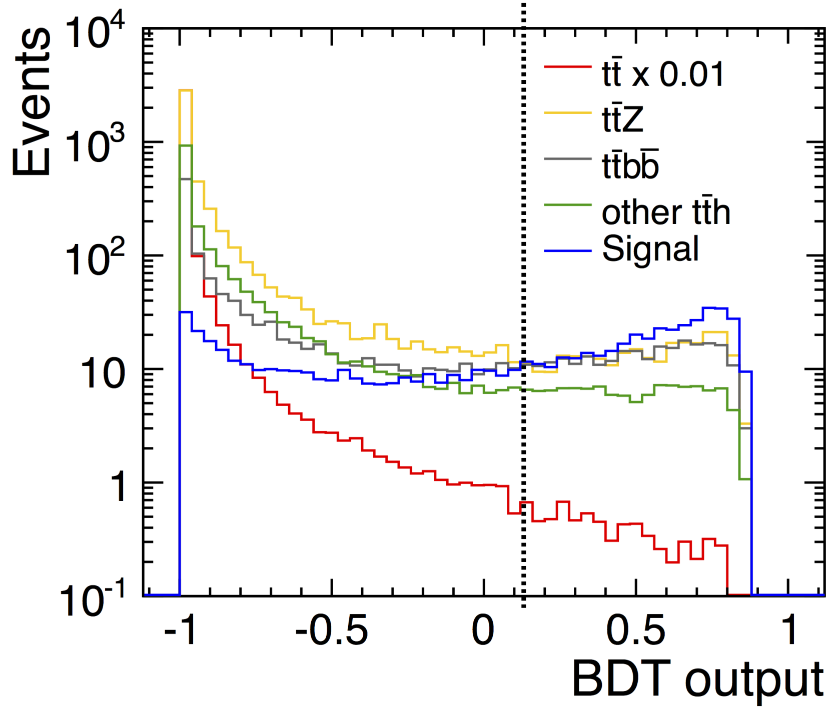
L_{int} = 1 ab^{-1}

Top Yukawa coupling: results

6 jets: BDT > 0.1978



8 jets: BDT > 0.1248



Using cut on BDT output with best significance: $\mathbf{L_{int} = 1\ ab^{-1}}$

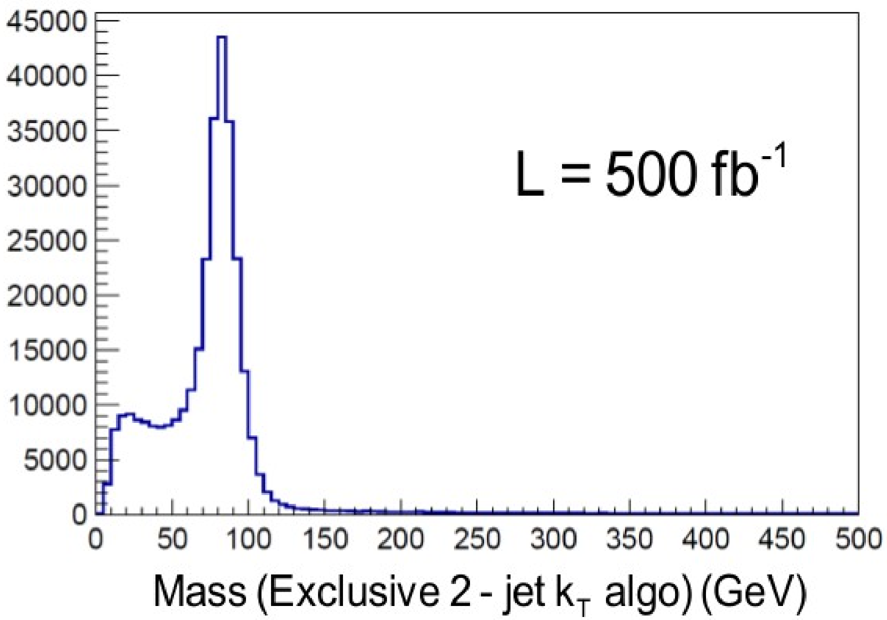
$\Delta\sigma / \sigma = 13.2\% \rightarrow \Delta y_t / y \approx 6.9\%$	$\Delta\sigma / \sigma = 11.5\% \rightarrow \Delta y_t / y \approx 6.0\%$

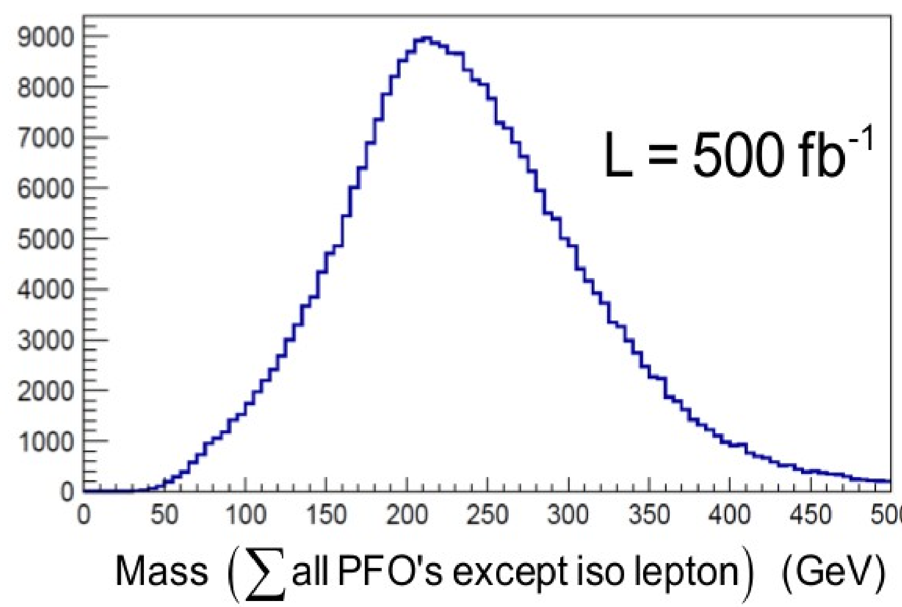
Combined: $\Delta y_t / y \approx 4.5\%$ (4.0% for only $P(e^-) = -0.8$ and $P(e^+) = +0.2$)

Beam polarisation from W^+W^-: introduction

- The measurement uses semileptonic and fully hadronic events events
- Using hadron-collider type k_t algorithm with R = 0.7 in the exclusive mode with 2 or 4 jets

→ crucial for suppression of beam-induced backgrounds



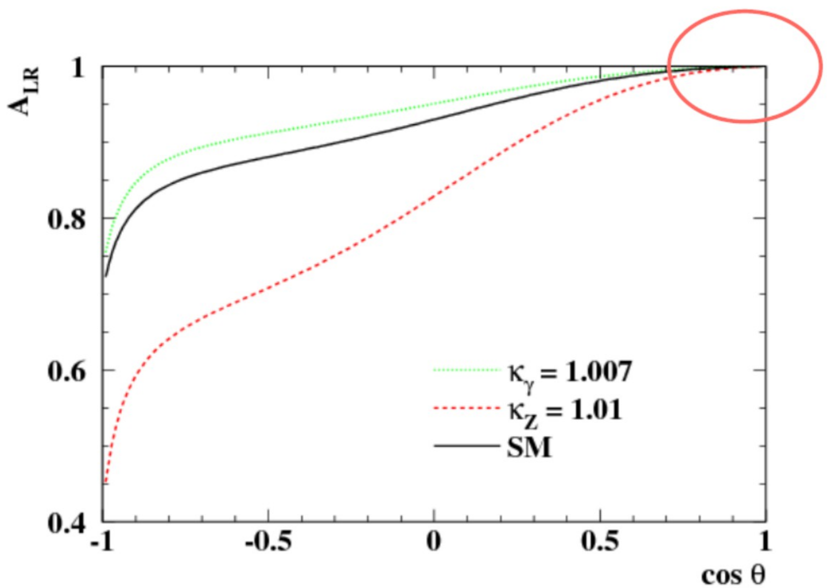


semileptonic events

Beam polarisation from W^+W^-: results

$\cos\Theta$ range	P_{e-}, P_{e+}	$\Delta P_{e-}(L)_{\text{eff}}$	$\Delta P_{e-}(R)_{\text{eff}}$	ΔP_{e-}	ΔP_{e+}
$0.8 < \cos\Theta < 1$	-0.8,+0.2	0.0011	0.022	0.13	0.087
$0.8 < \cos\Theta < 1$	+0.8,-0.2	0.00036	0.0096	0.0050	0.024
$-1 < \cos\Theta < 1$	-0.8,+0.2	0.0011	0.0104	0.062	0.041
$-1 < \cos\Theta < 1$	+0.8,-0.2	0.00036	0.0077	0.0045	0.020

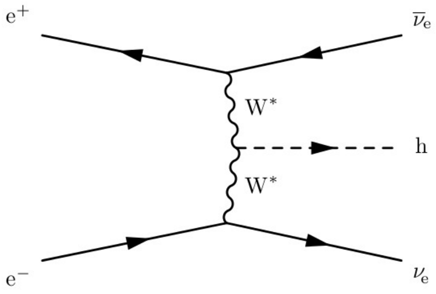
$\cos\Theta$ range	P_{e-}, P_{e+}	$\Delta\alpha$	$\Delta\beta$	$\Delta\lvert P_{e-}\rvert$	$\Delta\lvert P_{e+}\rvert$
$-1 < \cos\Theta < 1$	sum	0.0010	0.00032	0.0020	0.0029



Θ: W production angle (polar angle of the W^- in W^+W^- rest frame)

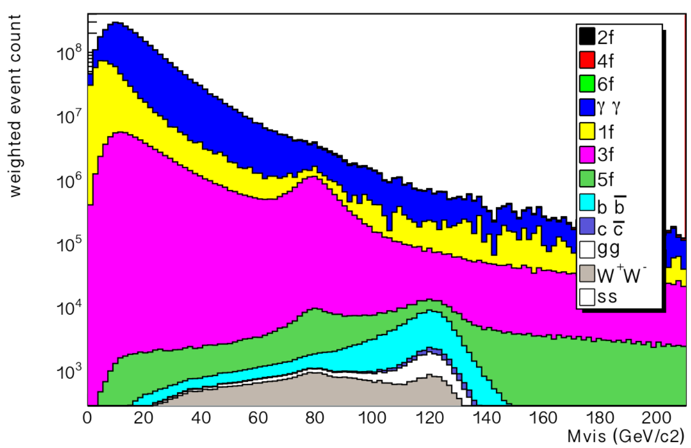
$\nu\bar{\nu}H$, H → $b\bar{b}/c\bar{c}/W^+W^-/gg$: selection

- Cut-based preselection + Fisher discriminant for each final state

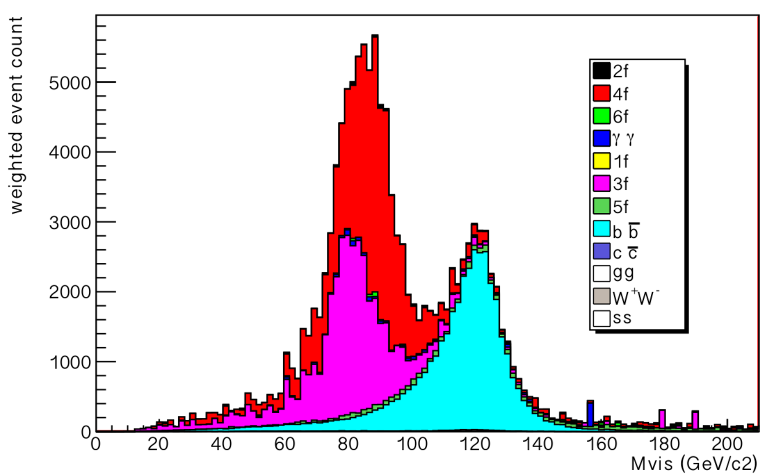


	h → $b\bar{b}$ (%)	h → $c\bar{c}$ (%)	h → gg (%)	h → W^+W^- (%)
$e^+e^- \to$ 2 fermions	0.14	0.40	0.14	0.00
$e^+e^- \to$ 4 fermions	6.41	22.3	19.6	20.0
$e^+e^- \to$ 6 fermions	0.23	2.30	2.38	2.64
$\gamma\gamma \to X$	1.19	8.11	11.0	11.9
$\gamma e^+ \to X$	3.03	15.3	18.1	19.3
$e^-\gamma \to X$	3.80	23.5	28.5	28.3
h → $b\bar{b}$	83.7	7.00	0.36	0.96
h → $c\bar{c}$	0.28	12.6	0.45	0.65
h → gg	0.50	1.42	15.2	2.81
h → WW^*	0.17	6.03	3.8	12.3

- Backgrounds from electron-photon interactions important



before selection



after selection for H → $b\bar{b}$ (not using M_{vis})

- Exclusive k_t algorithm with 2 jets, R = 1.5

$\nu\bar{\nu}H$, $H \to b\bar{b}/c\bar{c}/W^+W^-/gg$: DBD results

	$\mathcal{L} = 500\ \mathrm{fb}^{-1}$		$\mathcal{L} = 1\ \mathrm{ab}^{-1}$
	$P(e^-)$ = -80% $P(e^+)$ = +20%	$P(e^-)$ = +80% $P(e^+)$ = -20%	$P(e^-)$ = -80% $P(e^+)$ = +20%
$h \to b\bar{b}$	0.0067	0.046	0.0047
$h \to c\bar{c}$	0.108	0.843	0.076
$h \to gg$	0.044	0.294	0.031
$h \to W^+W^-$	0.047	0.346	0.033

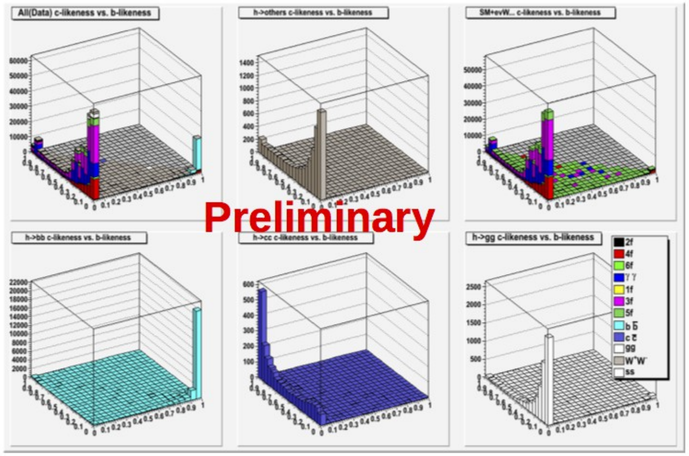
Analysis is still ongoing, results will improve

Current Activities of the SiD ffH 1TeV BR Study

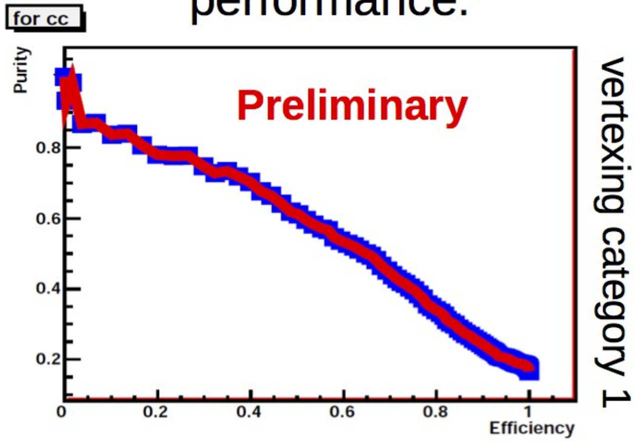
500/fb -80/+20	SiD DBD	SID now
$H \rightarrow c\bar{c}$	0.108	0.088 **Preliminary**

- BDTG (higher stats training eventually proved that this is better than Fisher, FisherG, and BDT)
- higher stats for decay mode selection training
- about 30% more ffh_nomu events
- addition of b & c likeness variables
- more 250GeV Z->$b\bar{b}$,$c\bar{c}$,$q\bar{q}$ used for flavor tagging training
- added event vertex category variables for incorporating different performance cuts depending on event category

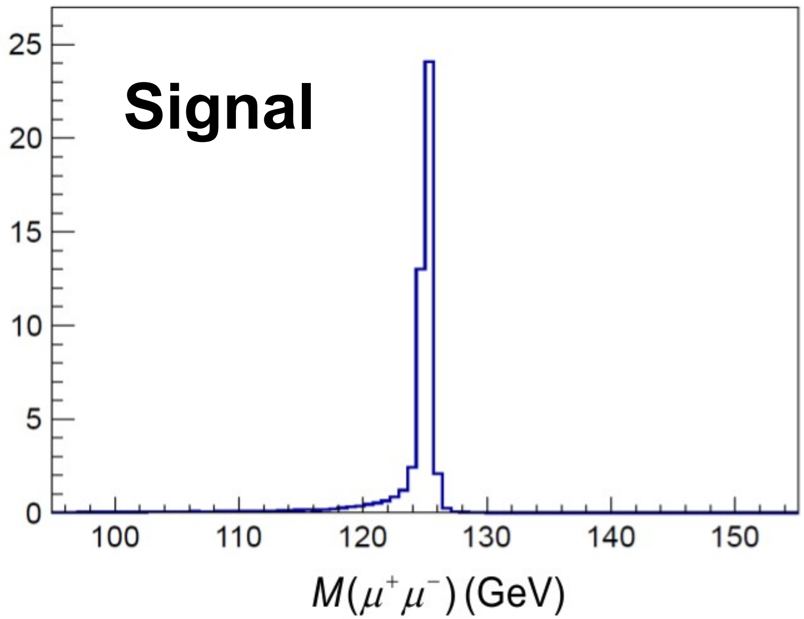
Investigating using the template method for SiD

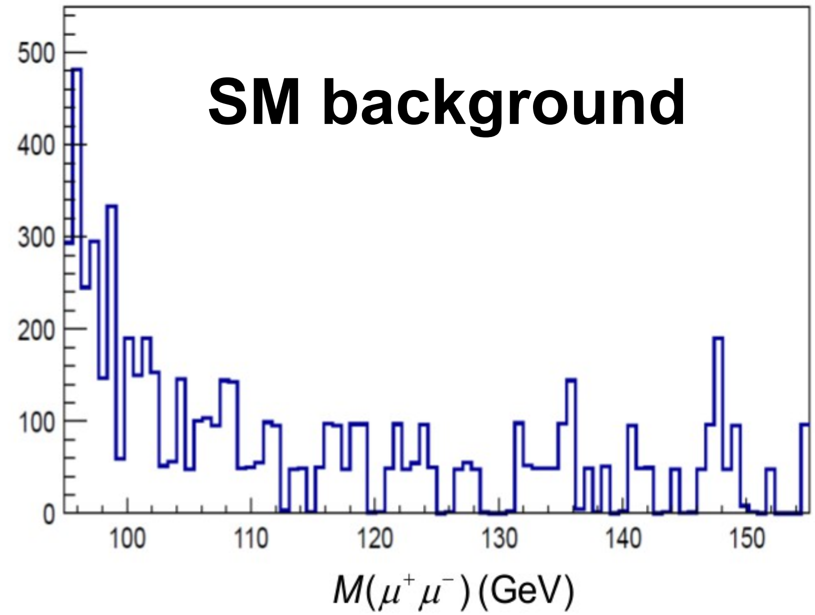


Investigating flavor tagging performance:



$\nu\bar{\nu}H$, $H \rightarrow \mu^+\mu^-$





Backgrounds assumed flat in the range $115 < M(\mu^+\mu^-) < 145$ GeV

Number of signal and background events in $124 < M(\mu^+\mu^-) < 126$ GeV

Process	N_{Events}
$e^+e^- \rightarrow \nu_e\bar{\nu}_e h \rightarrow \nu_e\bar{\nu}_e\mu^+\mu^-$	20.0 ± 0.1
$e^+e^- \rightarrow \nu_e\bar{\nu}_e\mu^+\mu^-$	17.4 ± 5.3
$e^+e^- \rightarrow \nu_\mu\bar{\nu}_\mu\mu^+\mu^-$	7.9 ± 3.5
$e^+e^- \rightarrow \nu_\tau\bar{\nu}_\tau\mu^+\mu^-$	1.6 ± 1.6
$e^+e^- \rightarrow t\bar{t} \rightarrow b\bar{b}\nu_\mu\bar{\nu}_\mu\mu^+\mu^-$	0.8 ± 0.2
$e^+e^- \rightarrow \nu_\tau\bar{\nu}_\mu\tau^+\mu^-$	0.2 ± 0.1
$\gamma\gamma \rightarrow \nu_\mu\bar{\nu}_\mu\mu^+\mu^-$	29.3 ± 6.7
$e^-\gamma \rightarrow e^-\nu_\mu\bar{\nu}_\mu\mu^+\mu^-$	4.8 ± 2.7
$e^-\gamma \rightarrow \nu_e\nu_\mu\bar{\nu}_\mu\mu^-\mu^+\mu^-$	1.6 ± 1.6
$e^-\gamma \rightarrow \nu_e\bar{\nu}_\mu\mu^-\mu^+\mu^-$	0.2 ± 0.2
$e^+e^- \rightarrow q\bar{q}\nu_\mu\bar{\nu}_\mu\mu^+\mu^-, q \neq b$	0.2 ± 0.1

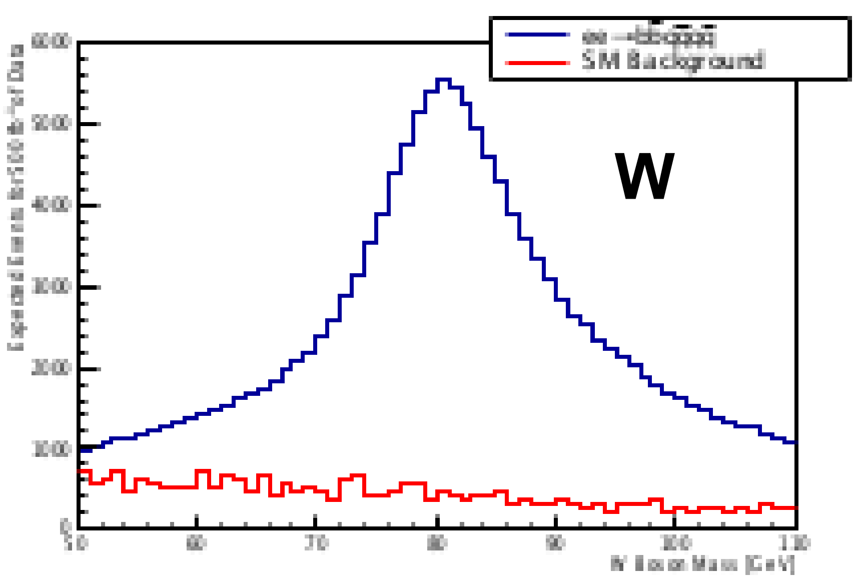
$\Delta(\sigma \times BR) \approx 32\%$

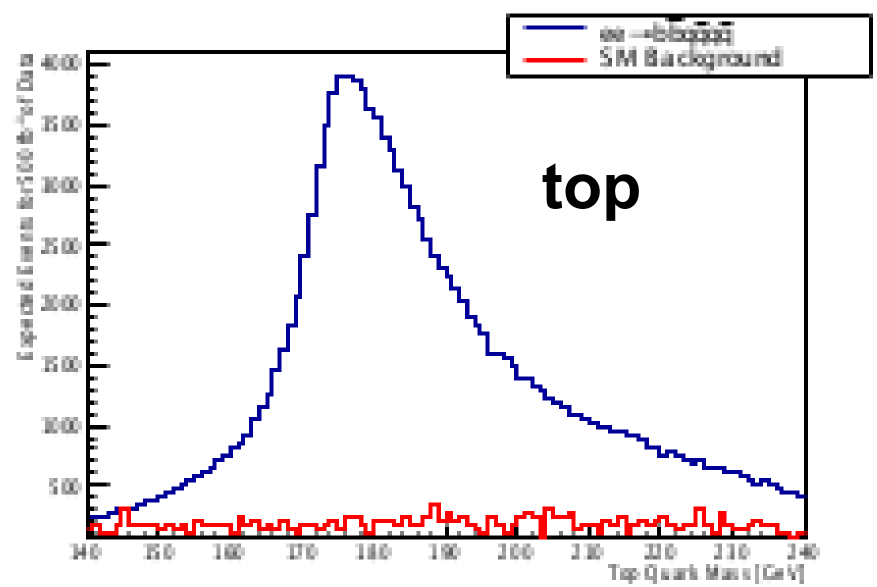
$L = 1$ ab^{-1}, only $P(e^-) = -0.8$ and $P(e^+) = +0.2$

$t\bar{t}$: introduction and cross section

Investigated reaction: $e^+e^- \rightarrow t\bar{t} \rightarrow b\bar{b}q\bar{q}q\bar{q}$
$\sqrt{s}$ = 500 GeV, 500 fb^{-1}, $P(e^-) = \pm 80\%$, $P(e^-) = \pm 30\%$

- Event selection follows closely the LOI study
- Flavour tagging based on LCFIPlus, kinematic fit





$\Delta(\sigma) < 1\%$

For both polarisation configurations

$t\bar{t}$: A_{FB}

$$A_{FB} = \frac{\sigma(\theta < 90^o) - \sigma(\theta > 90^o)}{\sigma(\theta < 90^o) + \sigma(\theta > 90^o)}$$

Θ: angle to the reconstructed top quark

Beauty and top quark charge obtained from combination of vertex and jet charges:

$$Q = \frac{\sum_j p_j^k Q_j}{\sum_j p_j^k}$$

k = 0.3

$\Delta(A_{FB}) \approx 2\%$

For both polarisation configurations

→ In agreement in LOI results

Lessons learned

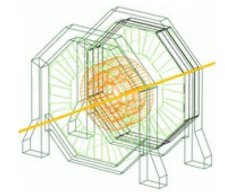
- Beam-induced backgrounds not negligible:

  - Impact on flavour tagging performance visible
  - Need to use hadron-collider type jet finding algorithms if the forward direction is relevant
  - Forward electron tagging needs work

- Comparison to and common meetings with ILD were very useful

- As always, more documentation desirable (some software tools, details of LOI analyses)

Instead of a summary...



Process $e^+e^- \rightarrow$	$\sqrt{s}$ (GeV)	$\mathcal{L}$ (fb^{-1})	SiD	Meas. Quant.	Unit	Result
$e^+e^-h/\mu^+\mu^-h$	250	250	LOI	m_H	GeV	$\pm$ 0.04
				σ	%	$\pm$ 2.7
$hZ^0 \rightarrow c\bar{c}q\bar{q}$	250	250	LOI	BR	%	$\pm$ 6.0
$hZ^0 \rightarrow c\bar{c}\nu\bar{\nu}$	250	250	LOI	BR	%	$\pm$ 11.0
$hZ^0 \rightarrow \mu^+\mu^-q\bar{q}$	250	250	LOI	σ	%	89.1
$\tau^+\tau^-$	500	500	LOI	$A^{\tau}{}_{FB}$	-	$\pm$ 0.0021/0.0024
				$< P_\tau >$	%	$\pm$ 1.7/2.3
$t\bar{t} \rightarrow$ 6 jets	500	500	LOI	m_{top}	GeV	173.92 $\pm$ 0.05
				σ	%	0.49
				$A^{t}{}_{FB}$	-	$\pm$ 0.008
$\tilde{\chi}^0_2\tilde{\chi}^0_2 \rightarrow \tilde{\chi}^0_1\tilde{\chi}^0_1Z^0Z^0$	500	500	LOI	$m_{\tilde{\chi}^0_1}$	GeV	$\pm$ 0.16
$\tilde{\chi}^0_2\tilde{\chi}^0_2 \rightarrow \tilde{\chi}^0_1\tilde{\chi}^0_1Z^0Z^0$	500	500	LOI	$m_{\tilde{\chi}^+_1}$	GeV	$\pm$ 0.45
$\tilde{\chi}^+_1\tilde{\chi}^-_1 \rightarrow \tilde{\chi}^0_1\tilde{\chi}^0_1W^+W^-$	500	500	LOI	$m_{\tilde{\chi}^0_1}$	GeV	$\pm$ 0.28
$\tilde{\chi}^+_1\tilde{\chi}^-_1 \rightarrow \tilde{\chi}^0_1\tilde{\chi}^0_1W^+W^-$	500	500	LOI	$m_{\tilde{\chi}^0_2}$	GeV	$\pm$ 0.49
$t\bar{t}h$ (6 jets)	1000	1000	DBD	σ	%	$\pm$ 13.2
$t\bar{t}h$ (8 jets)	1000	1000	DBD	σ	%	$\pm$ 11.5
$t\bar{t}h$ (combined)	1000	1000	DBD	σ	%	$\pm$ 8.7
$\nu_e\bar{\nu}_eh; h \rightarrow WW^*$	1000	1000	DBD	$\sigma \times$ BR	%	$\pm$ 3.3
$\nu_e\bar{\nu}_eh; h \rightarrow gg$	1000	1000	DBD	$\sigma \times$ BR	%	$\pm$ 3.1
$\nu_e\bar{\nu}_eh; h \rightarrow c\bar{c}$	1000	1000	DBD	$\sigma \times$ BR	%	$\pm$ 7.6
$\nu_e\bar{\nu}_eh; h \rightarrow b\bar{b}$	1000	1000	DBD	$\sigma \times$ BR	%	$\pm$ 0.47
$\nu_e\bar{\nu}_eh; h \rightarrow \mu^+\mu^-$	1000	1000	DBD	$\sigma \times$ BR	%	$\pm$ 32
W^+W^-	1000	1000	DBD	$P_{e^-}(L)_{\mathrm{eff}}$	%	$\pm$ 0.20/0.90
W^+W^-	1000	1000	DBD	$\lvert P_{e^-} \rvert$	%	$\pm$ 0.25
W^+W^-	1000	1000	DBD	$\lvert P_{e^+} \rvert$	%	$\pm$ 1.45
$t\bar{t} \rightarrow$ 6 jets	500	500	DBD	σ	%	$\pm$ 0.47/0.69
				$A^{t}{}_{FB}$	%	$\pm$ 2.0/2.5

The benchmark results illustrate the detector performance of the SiD detector for centre-of-mass energies of up to 1 TeV

Ongoing studies using CLIC_SiD

CLIC physics performance for the SM Higgs

Ongoing effort to investigate the full physics performance of CLIC for SM Higgs boson measurements at 350, 1400 and 3000 GeV:

350 GeV:

CLIC_SiD

- Model-independent mass and cross section from recoil method
- $H \rightarrow b\bar{b}$, $H \rightarrow c\bar{c}$, $H \rightarrow gg$, BR($H \rightarrow \tau^+\tau^-$), $H \rightarrow WW^*$

1.4 GeV:

- $H \rightarrow b\bar{b}$, $H \rightarrow c\bar{c}$, $H \rightarrow gg$, BR($H \rightarrow \tau^+\tau^-$), $H \rightarrow WW^*$, $H \rightarrow Z\gamma$, $H \rightarrow \gamma\gamma$, $H \rightarrow \mu^+\mu^-$
- top Yukawa coupling from the $t\bar{t}H$ cross section
- Higgs self-coupling from $HH\nu\bar{\nu}$ cross section (improvements by refined analysis expected)
- Higgs production in ZZ-fusion

3 TeV:

- $H \rightarrow b\bar{b}$, $H \rightarrow c\bar{c}$, $H \rightarrow gg$, $H \rightarrow WW^*$, $H \rightarrow \mu^+\mu^-$
- Higgs self-coupling from $HH\nu\bar{\nu}$ cross section (improvements by refined analysis expected)

In addition:

- Extraction of the Higgs width at all energies
- Extraction of the Higgs couplings from combined fit to all measurements

Expect full set of results in the summer

Presentations at this workshop

Tomas Lastovicka: Measurement of the Higgs couplings to b- and c-quarks and to gluons at 350 GeV, 1.4 TeV and 3 TeV CLIC

Eva Sicking: Measurement of the Higgs couplings to gauge bosons at CLIC

Astrid Münnich: Measurement of the Higgs boson decay to tau leptons at a CLIC collider operating at 350 and 1400 GeV

Ivanka Bozovic-Jelisavcic: Measurement of the Higgs boson decay to muons at a CLIC collider operating at 1.4 and 3 TeV

Sophie Redford: Measurement of the top Yukawa coupling at a 1.4 TeV CLIC collider

Jan Strube: Measurement of the Higgs self-coupling at 1.4 and 3 TeV

CLIC_SiD

Thanks for your attention!