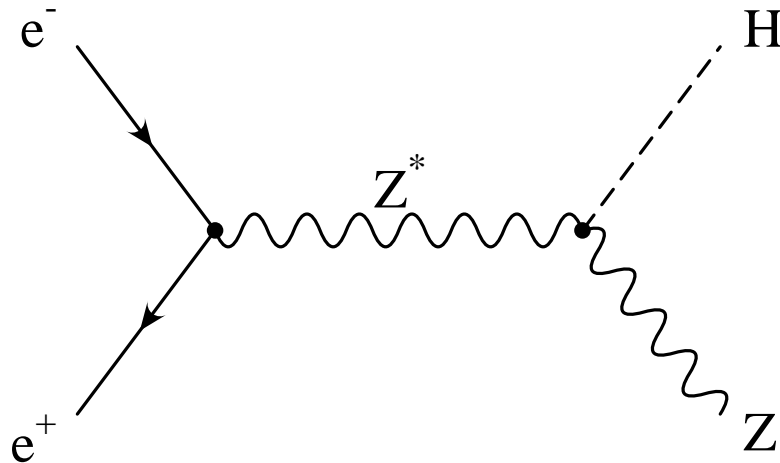


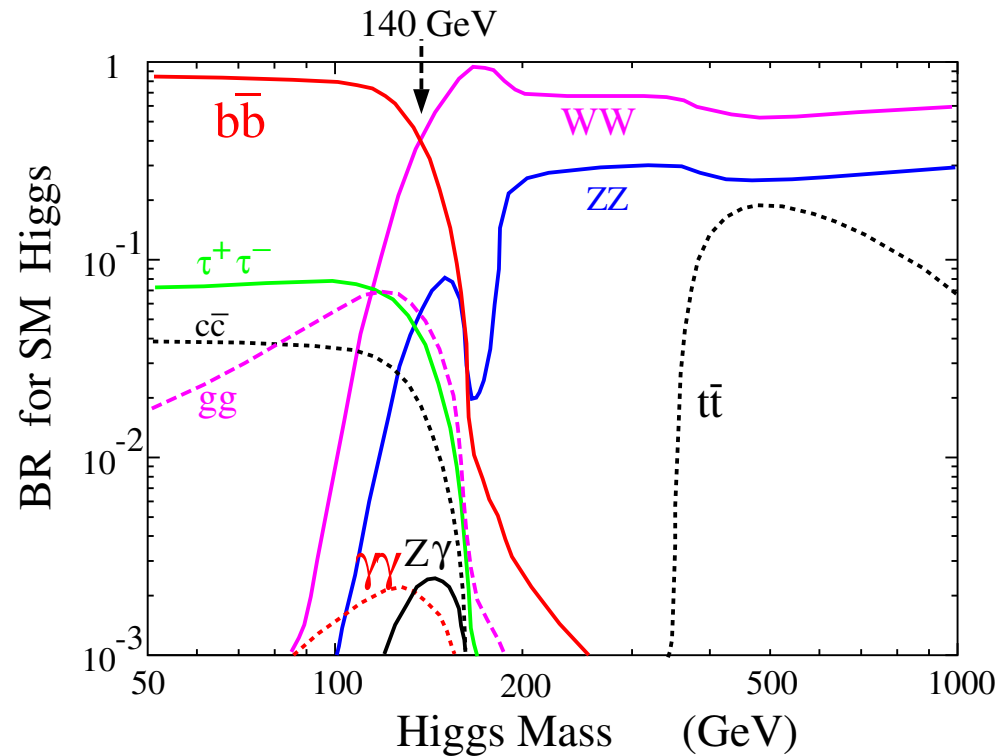
# $Br(H \rightarrow c\bar{c})$ at $ZH \rightarrow q\bar{q}c\bar{c}$ study

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- introduction
- jet resolution
- c-tag
- $ZH \rightarrow q\bar{q}c\bar{c}$  event selection
- $Br(H \rightarrow c\bar{c})$

# Higgs decay

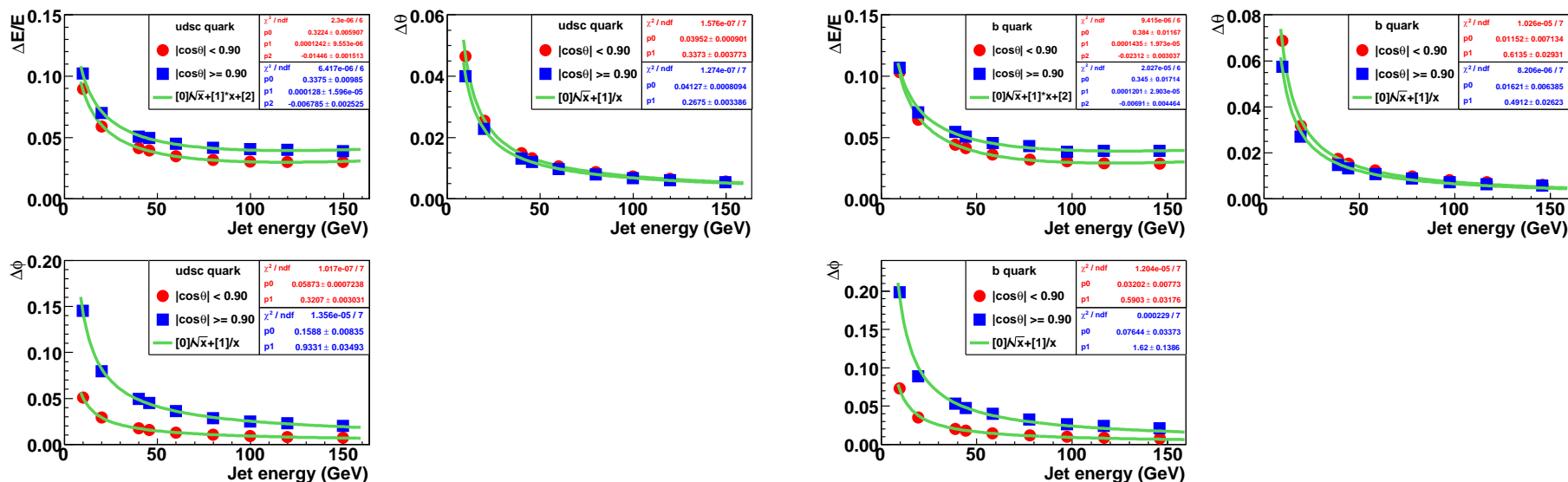


- Higgs branching ratio  $\text{Br}(h \rightarrow c\bar{c})$  @  $M_h = 120$  GeV
- extract  $\frac{\Delta\sigma(ZH \rightarrow qq\bar{c}\bar{c})}{\sigma(ZH \rightarrow qq\bar{c}\bar{c})}$  and  $\frac{\Delta\text{Br}(H \rightarrow c\bar{c})}{\text{Br}(H \rightarrow c\bar{c})}$

# MC data samples @ 250 GeV

- signal events  $q\bar{q}H \rightarrow q\bar{q}c\bar{c}$  and background events  $q\bar{q}$  and  $q\bar{q}q\bar{q}$ 
  - DESY DST files:  $(e^+, e^-)$  polarization; (1.0, -1.0) and (-1.0, 1.0)
  - combine it for polarization (0.3, -0.8)
    - \*  $qq$ :  $3.35 \text{ fb}^{-1}$   $q\bar{q}(q = u, d, s, c, b)$  samples
    - \*  $qqqq\_01$ :  $25.0 \text{ fb}^{-1}$  csdu, uddu, cssc, udsc samples
    - \*  $qqqq\_02$ :  $900.0 \text{ fb}^{-1}$  remaining  $qqqq$  samples
    - \*  $qqh$  1709  $\text{fb}^{-1}$   $qqh$  samples
- detector model ILD00 and event reconstruction ilcinstall v01-06
- kinematic fitting MarlinKinfite @ analysis  $\rightarrow$  jet resolution
  - $q\bar{q}$  at 20/40/80/91.2/120/160/200/240/300 GeV
  - $q = u, d, s, c$ : 20K;  $q = b$ : 10K

# Jet resolution



- kinematic fitting → jet resolution
- $e^+e^- \rightarrow q\bar{q}$  events without ISR
- jets finding at hadron level: MC stable particles without neutrinos
- jets finding at detector level

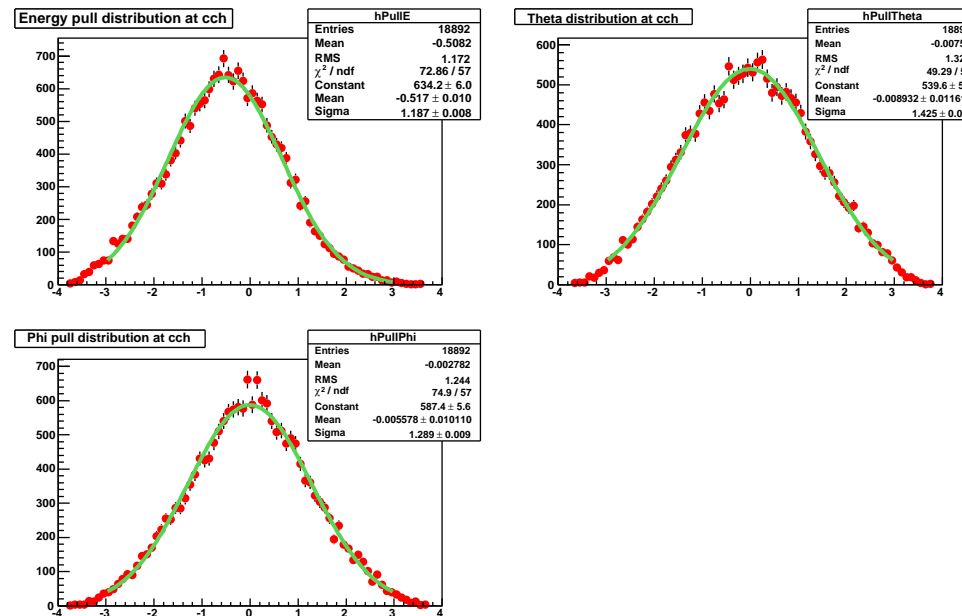
# jet resolution @ $c\bar{c}h$ events

- kinematic fitting

- energy-momentum conservation and two jets from  $Z^0$ :  $M_{j_1j_2} = M_Z$

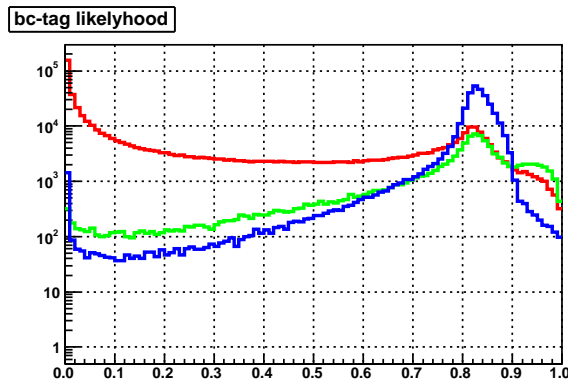
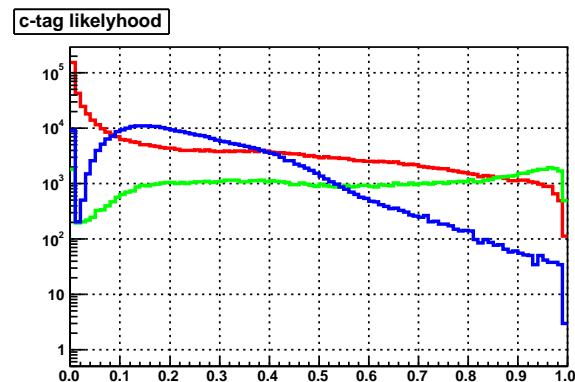
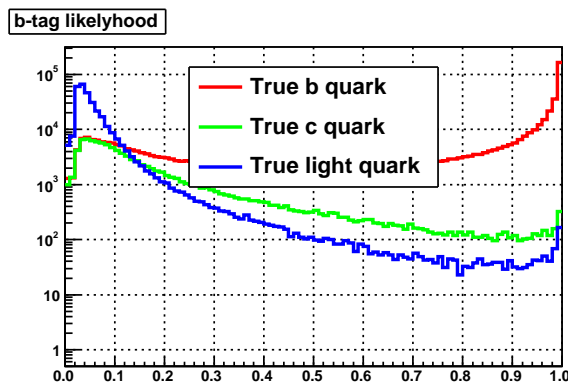
- check jet resolution by pull variables

- $PULL(x) = (x_{meas} - x_{fit}) / (\sqrt{\sigma_{meas}^2 - \sigma_{fit}^2})$



# b-tag/c-tag at ZH 250GeV

- b-tag, c-tag and bc-tag from LCFIvertex package
- $ZH \rightarrow q\bar{q}H$  events with  $(e^+, e^-)$  polarization (1.0, -1.0)

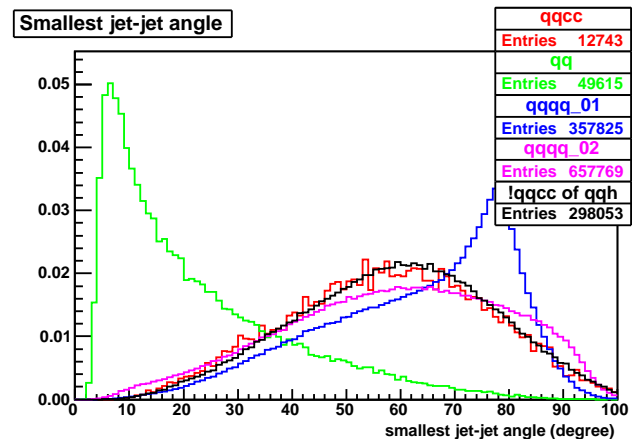
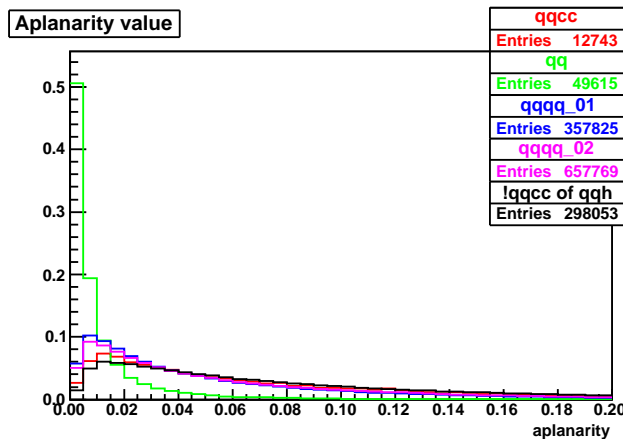
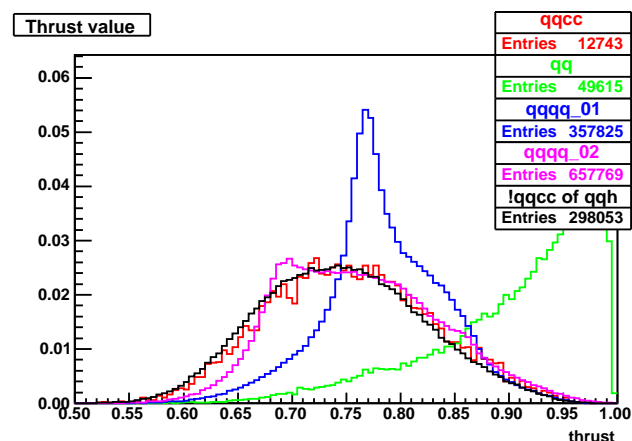
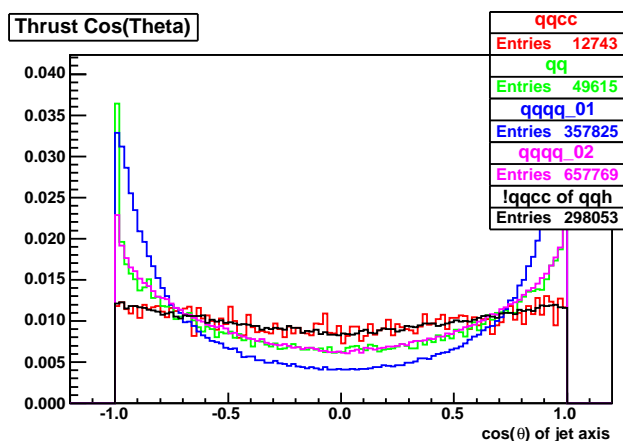


# $ZH \rightarrow q\bar{q}c\bar{c}$ event selection

- (0) Preselection: total visible energy  $E_{visible} > 150$  GeV; four good jets: jet energy  $E_{jet} > 10.0$  GeV; jets contain at least six particle flow objects; jets contain at least two charged tracks
- (1) thrust  $T \leq 0.80$
- (2) angle of thrust axis  $|\cos \theta_T| \leq 0.80$
- (3) aplanarity  $A \geq 0.01$
- (4) minimum jet-jet angle  $\theta \geq 40$
- (5)  $\chi^2$  probability of kinematic fitting ( $4C \otimes M_{j_1j_2} = 91.20$  GeV)  $> 0.01$
- (6)  $\chi^2$  probability of kinematic fitting ( $4C \otimes M_{j_1j_2} = M_{j_3j_4}$  GeV)  $< 0.0001$
- (7) fitted Higgs boson mass  $M_H^{fit}$  with  $115\text{GeV} < M_H^{fit} < 125\text{GeV}$
- (8) two jets from Higgs boson with c-tag  $> 0.50$ , and c-likeness of two jets from Higgs boson with c-likeness  $> 0.80$

# Event selection: signal vs. background events

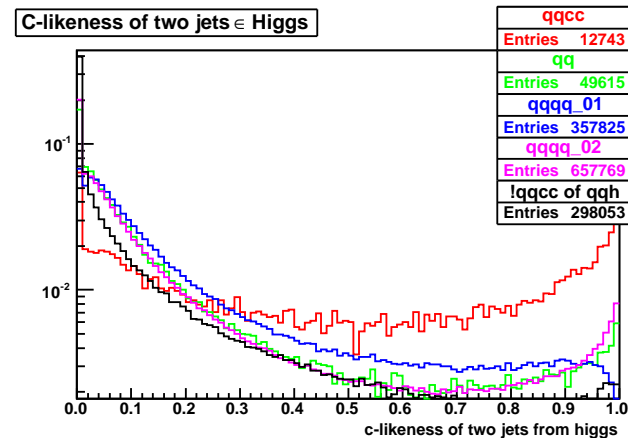
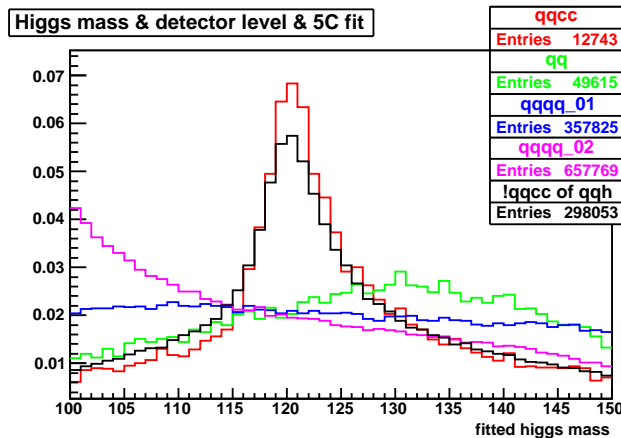
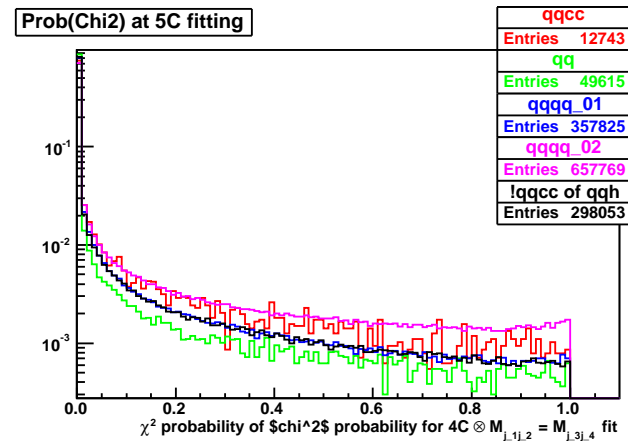
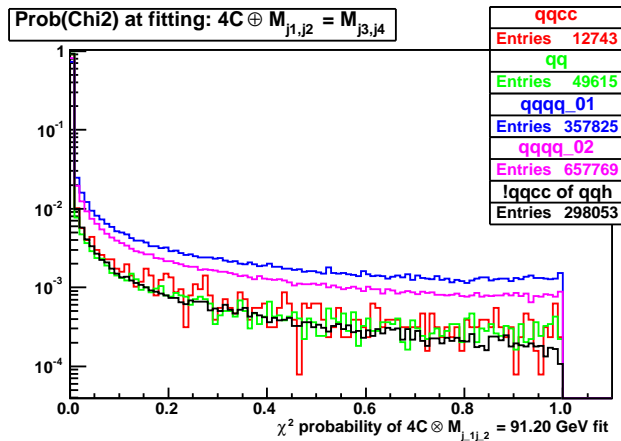
- All events after pre-selection





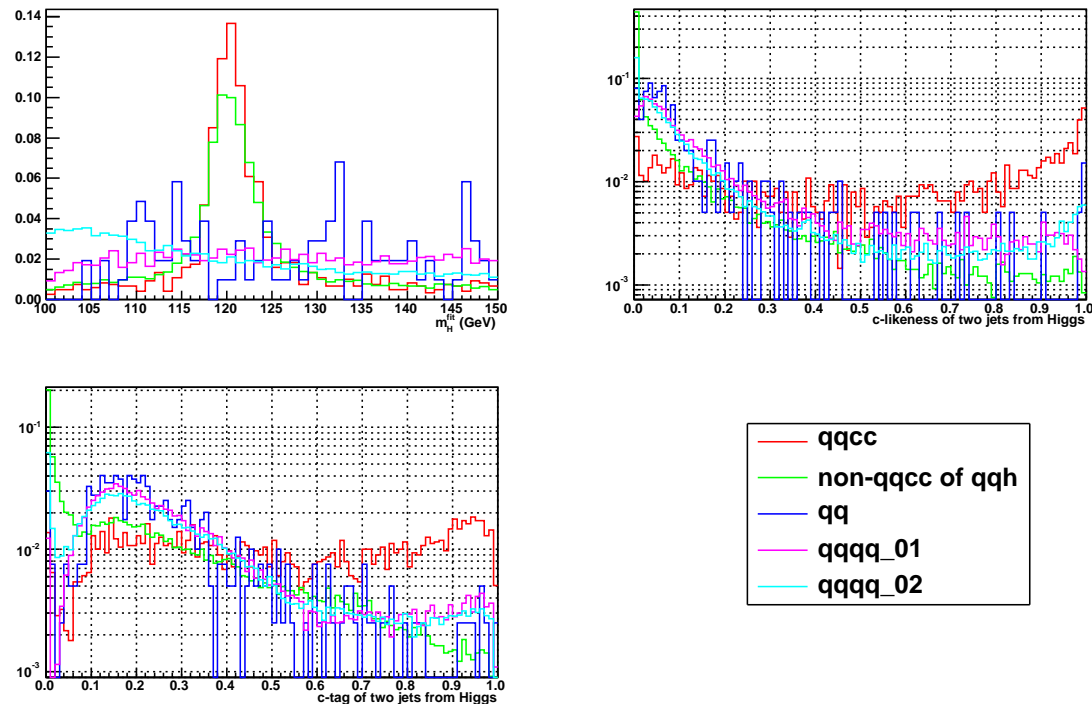
# Event selection: signal vs. background events

- All events after pre-selection



# Event selection: signal vs. background events

- The cuts on fitted Higgs boson mass, c-tag and c-likeness of two jets from Higgs boson are essential, these variables are shown for events after all other cuts.



# $\sigma(ZH \rightarrow q\bar{q}c\bar{c}) @ \text{ILD00}$

- $q\bar{q}c\bar{c}$  event selection

	$N_{event} @ 250 \text{ fb}^{-1}$
$ZH \rightarrow q\bar{q}c\bar{c}$	37.16
$qq$	0
$qqqq_{01}$	70
$qqqq_{02}$	26.94
non- $qqcc @ q\bar{q}H$	24.28

- $\Delta\sigma(ZH \rightarrow q\bar{q}c\bar{c})/\sigma(ZH \rightarrow q\bar{q}c\bar{c}) = \sqrt{s+b}/s = 29.6\%$

# $Br(H \rightarrow c\bar{c})$ @ ILD00

- Higgs branching ratio  $Br(H \rightarrow c\bar{c})$

$$Br(H \rightarrow c\bar{c}) = \frac{\sigma(e^+e^- \rightarrow ZH \rightarrow q\bar{q}c\bar{c})}{\sigma(e^+e^- \rightarrow ZH)}$$

- $\sigma(e^+e^- \rightarrow ZH)$  from ZH recoil-mass analysis
  - 5.3% for muon channel

- $\Delta Br(H \rightarrow c\bar{c})$

$$\begin{aligned} \frac{\Delta Br(H \rightarrow c\bar{c})}{Br(H \rightarrow c\bar{c})} &= \sqrt{\left(\frac{\Delta\sigma(e^+e^- \rightarrow ZH \rightarrow q\bar{q}c\bar{c})}{\sigma(e^+e^- \rightarrow ZH \rightarrow q\bar{q}c\bar{c})}\right)^2 + \left(\frac{\Delta\sigma(e^+e^- \rightarrow ZH)}{\sigma(e^+e^- \rightarrow ZH)}\right)^2} \\ &= 30\% \end{aligned}$$

# Summary

- $qqc\bar{c}$  @ 250GeV with ILD00 detector model
  - $\Delta\sigma(qqc\bar{c})/\sigma(qqc\bar{c}) = 29.6\%$
  - $\Delta Br(H \rightarrow c\bar{c})/Br(H \rightarrow c\bar{c}) = 30\%$
- Future work
  - use neural network for event selection
  - jet energy correction
  - Higgsstrahlungs matrix element and other variables for event selection
  - any suggestion

# Comparison

	$\Delta Br(H \rightarrow c\bar{c})/Br(H \rightarrow c\bar{c})$
$ZH \rightarrow q\bar{q}c\bar{c}$	$30 \oplus 5\%$
$ZH \rightarrow \nu\bar{\nu}H$	$19 \oplus 5\%$
$ZH \rightarrow l^+l^-q\bar{q}$	$28 \oplus 5\%$