Pi0 reconstruction toward flavor tagging improvement

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INTRODUCTION

- For flavor tagging improvement
  - Vertex mass is the key to separate heavy/light flavor vertex
  - Many pi0s will escape from B/D vertex → checked that using MC truth
  - Mass resolution will be degrade due to escaping neutrals
  - Is there possibility to recover pi0s which escape from vertices?

- Towards pi0 attachment to vertices – Studying pi0 reconstruction
  - Gamma finder – using shower profile in calorimeters
  - π^0 finder – solving gamma pairing

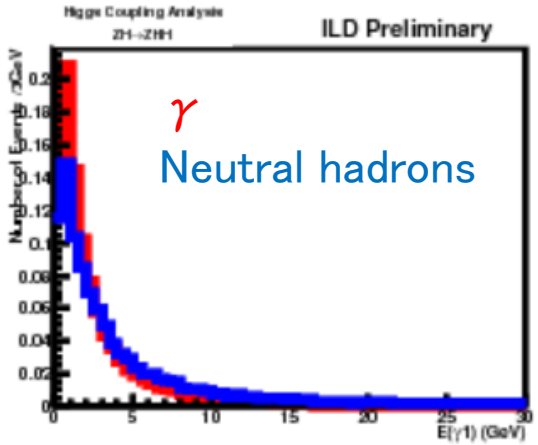
- First step is to find gammas – distinguish from neutral hadrons
  - Similar to lepton ID
  - Basically same method as lepton ID – Bayesian approach
- Second step is to reconstruct pi0s – pairing of 2 gammas
  - Similar to jet pairing
  - Using Bayesian approach(naïve Bayes)

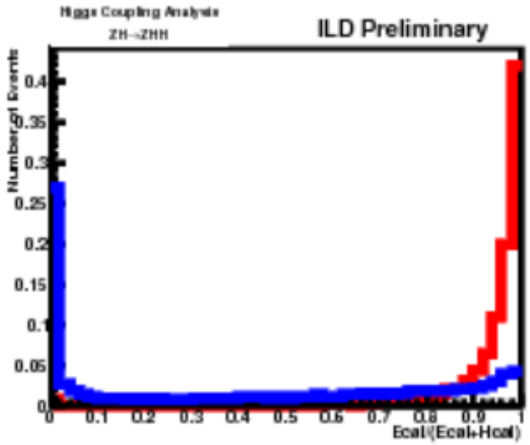
Gamma ID

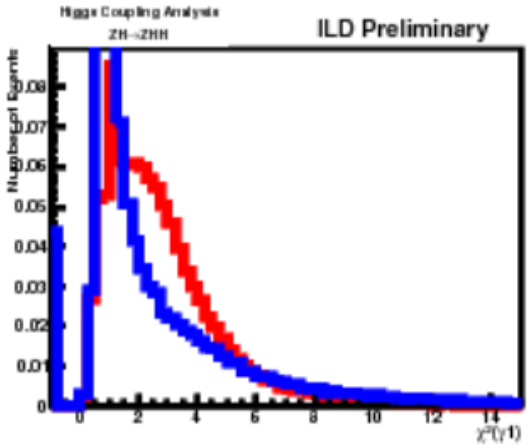
- Using naïve Bayes
  - Posterior probability: $P(\gamma|x) = \frac{P(x|\gamma)\cdot P(\gamma)}{P(x)} = \frac{P(x|\gamma)\cdot P(\gamma)}{P(x|\gamma)\cdot P(\gamma)+P(x|had)\cdot P(had)}$
  - Identify as gamma with $P(\gamma|x)$>threshold (need to optimize)
- Specific for this study:
  - Check 2 gammas at the same time because of correlation between 2 gammas
  - Preparing P.D.F.s for 1st gamma(large energy) and 2nd gamma(small energy)
  - Choosing pi0s from primary vertex(L_{decay} from IP < 0.3mm)
- Key Issues:
  - Using shower profile in calorimeters – Same as Lepton ID
    - e.g.) my talks@AWLC14
  - Using traditional variables – E(γ), Ecal/(Ecal+Hcal)
  - Can't use cone energy because not isolated

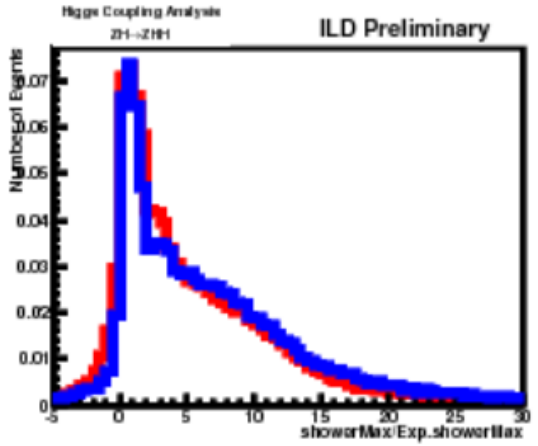
VARIABLES TO BE USED

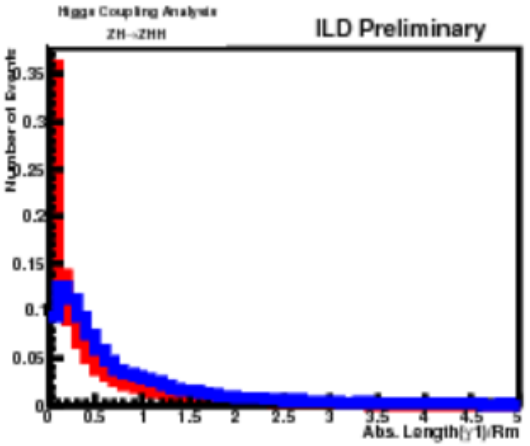
- For 1st gamma finding
- Signal: gamma with large energy from pi0(come from primary vertex)
- Background: neutral hadrons

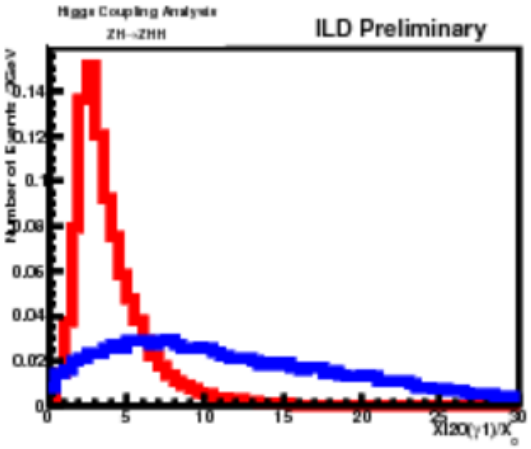










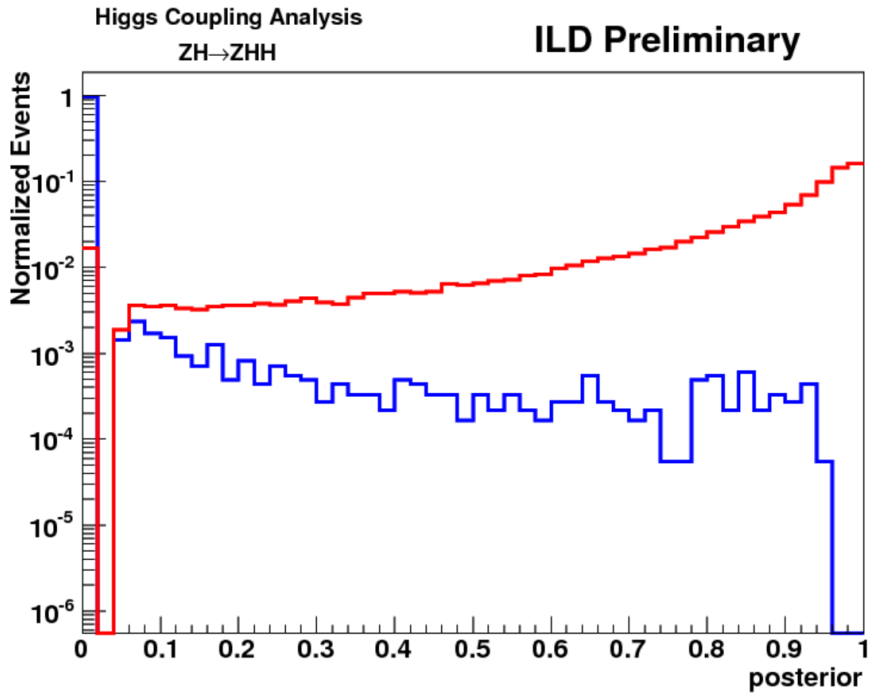


RESULTS

- Gamma ID eff. & background suppression eff.

sample	Signal	background
First γ eff. (%)	98.4±0.3	2.3±0.1
Second γ eff.(%)	98.9±0.3	2.4±0.1
γ pair eff. (%)	97.3±0.3	2.0±0.1

- γ pair eff. for background is the case when both of the gamma candidates are fake



Posterior distribution for γ 1

γ

Neutral hadrons

Gamma Pairing to reconstruct pi0s

- Using naïve Bayes
  - Posterior probability:

$$P(\pi^0|x) = \frac{P(x|\pi^0)\cdot P(\pi^0)}{P(x)} = \frac{P(x|\pi^0)\cdot P(\pi^0)}{P(x|\pi^0)\cdot P(\pi^0) + P(x|wrong)\cdot P(wrong)}$$

  - Identify as gamma pair from pi0 with $P(\pi^0|x)$>threshold (need to optimize)

- Key point: pi0 decay kinematics

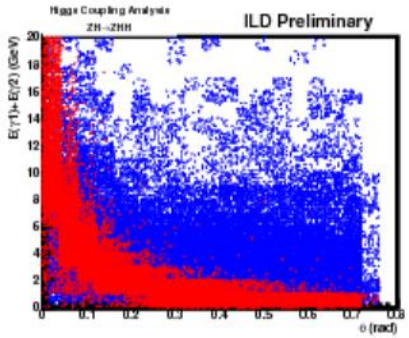
$$m_{\pi^0}^2 = 2E_{\gamma 1}E_{\gamma 2}(1-\cos\theta)$$

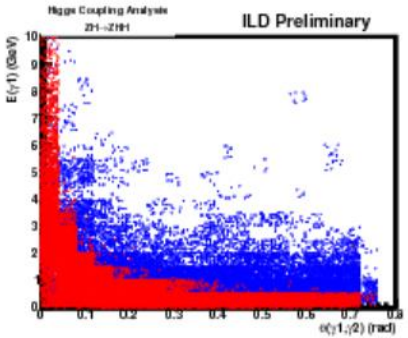
  - So, 2gammas' variables are highly correlated

- Avoid mis-pairing when many gammas jam in very small area
  - In many case, pi0s are flying in same direction!
  - So far, no very nice idea…

For this analysis

- Introducing 2D-likelihood to include correlation effect
  - E(γ 1)+E(γ 2) v.s. θ & E(γ 2) v.s. θ
  - p.d.f.s from these distributions

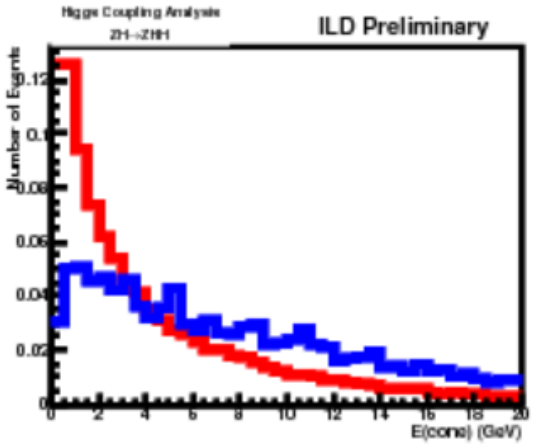


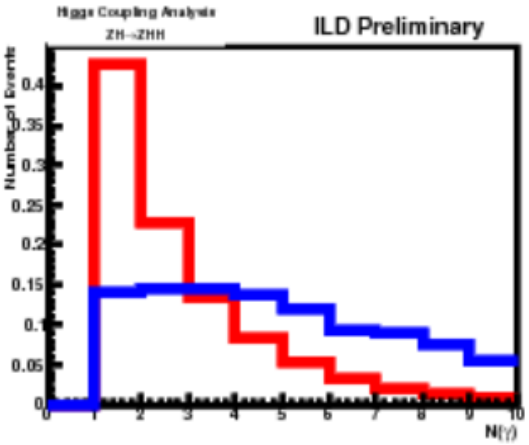


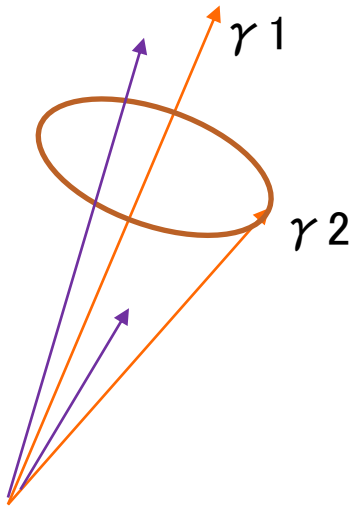
Pi0

Wrong pair

- Distribution of other gammas inside the cone of decay angle
  - To avoid mis-pairing of gammas located in small area







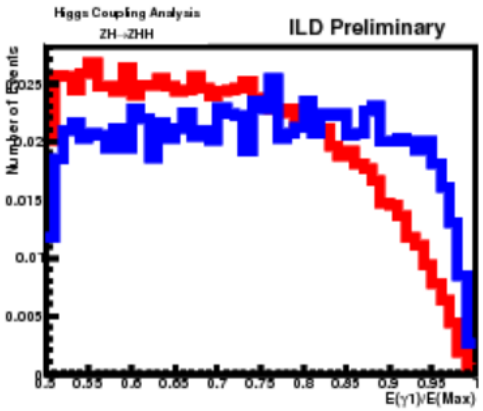
Energy expectation of 2 gammas

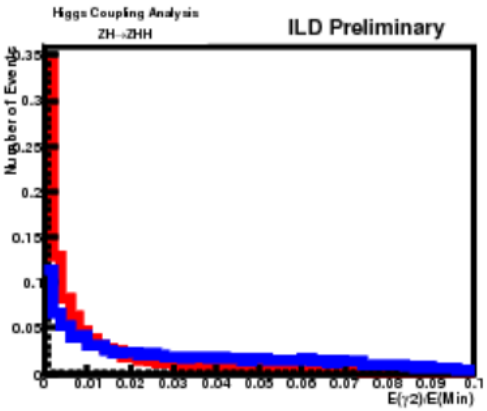
- In 2-body decay, energy range of 2 daughters can be predicted:

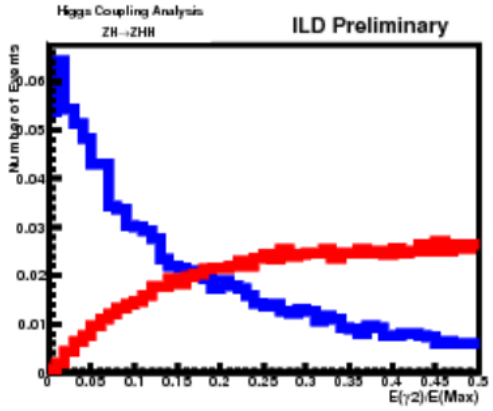
  →allowed energy range of gammas is:

$$\frac{E_{\pi 0}}{2}(1-\beta_{\pi 0}) \leq E_{\gamma} \leq \frac{E_{\pi 0}}{2}(1+\beta_{\pi 0})$$

- How are 2 gamma energies given from pi0 decay?
  - Check energy ratios: $\frac{E_{\gamma 1}}{E_{max}}, \frac{E_{min}}{E_{\gamma 2}}, \frac{E_{\gamma 2}}{E_{max}}$
  - Distributions are quite different between correct pairs and wrong pairs!





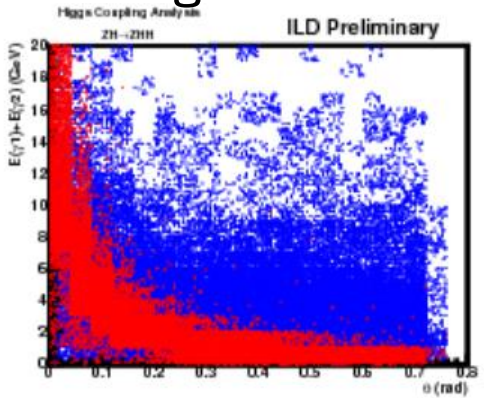


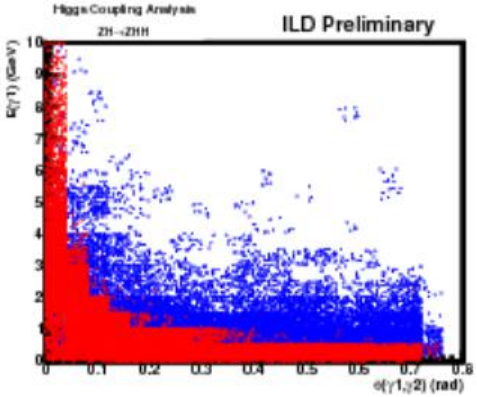
Pi0

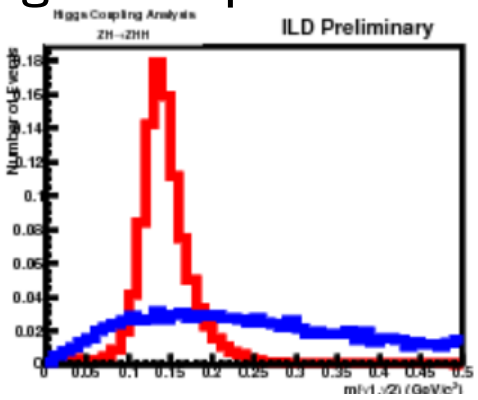
Wrong pair

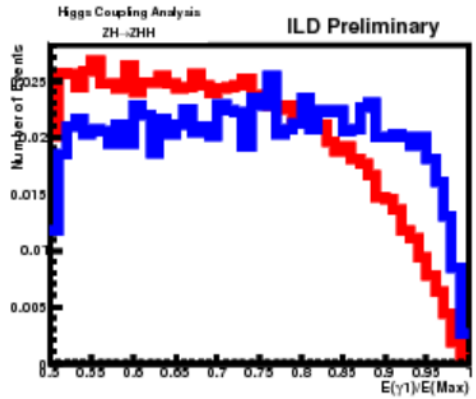
VARIABLES TO BE USED

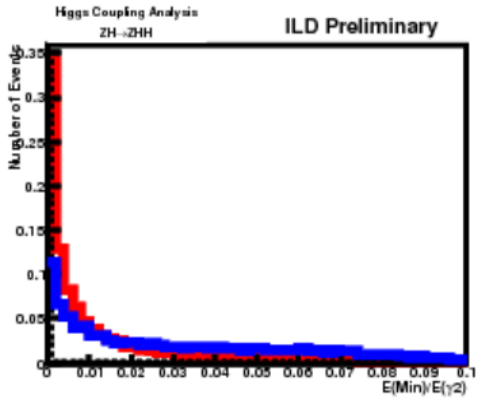
- Signal: pi0s from primary vertex(L_{decay} from IP < 0.3mm)
- Background: all the combinations of wrong gamma pairs

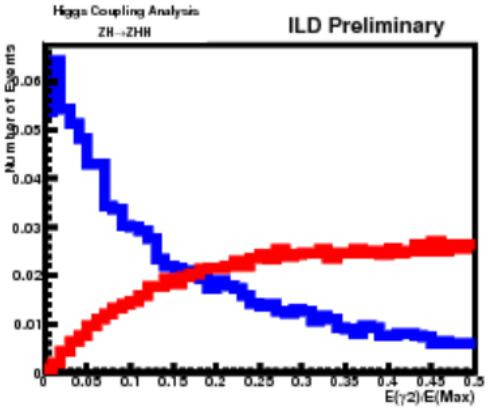


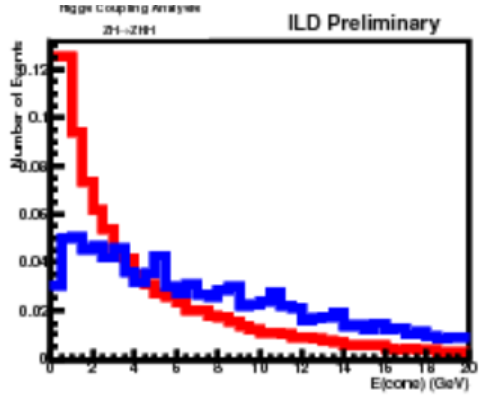


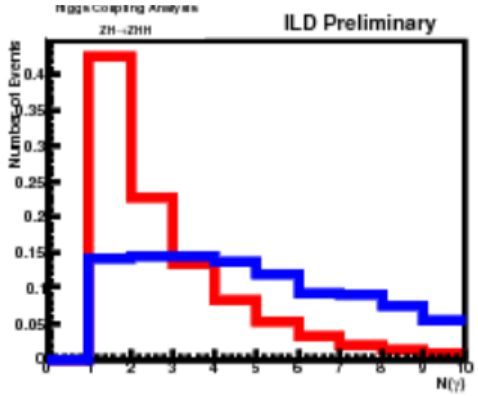












Pi0

Wrong pair

Problem of pi0 reconstruction in the events

- Pi0 reconstruction: maximize likelihood(minimize χ^2) globally in the event
- If, num. of pi0s in the event is known, it is very easy!
- Big problem: **num. of pi0s in the event is a free parameter!!!**
- **So, trivial answer to meet the condition(maximum likelihood) IS:**
  →no pi0s in the event!! (Log likelihood is of course 0(max)!)

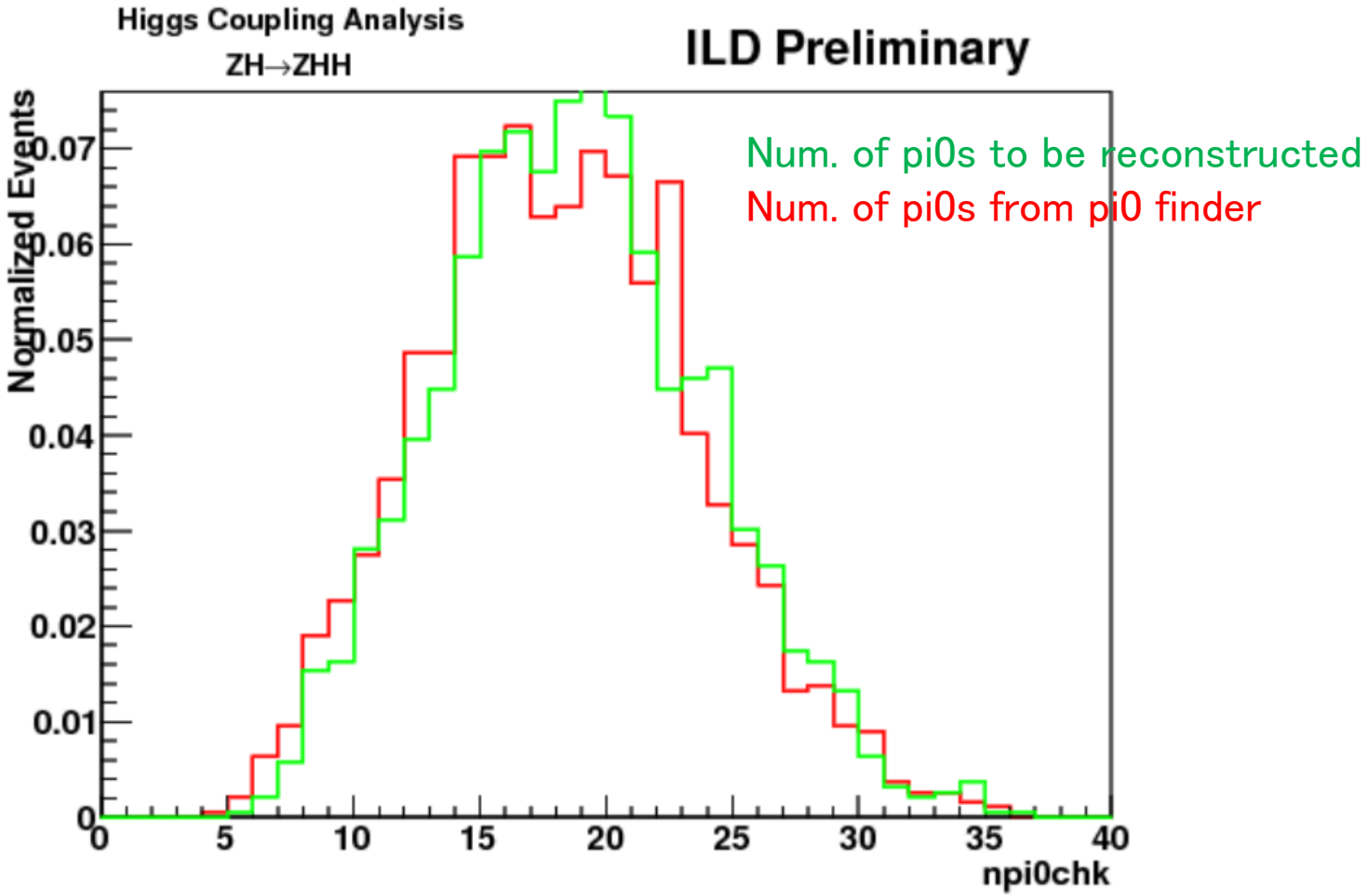
- To avoid it: impose a penalty for unpaired gammas
- So define the information criterion:

$$IC = -2\sum \log L(\pi^0) + k \cdot N(unpaired\ \gamma)$$

- Gamma pairing is performed according to IC:
  →minimize IC
- If k(>0.0) is large, pairing of gammas is boosted
  →it is necessary to optimize k!

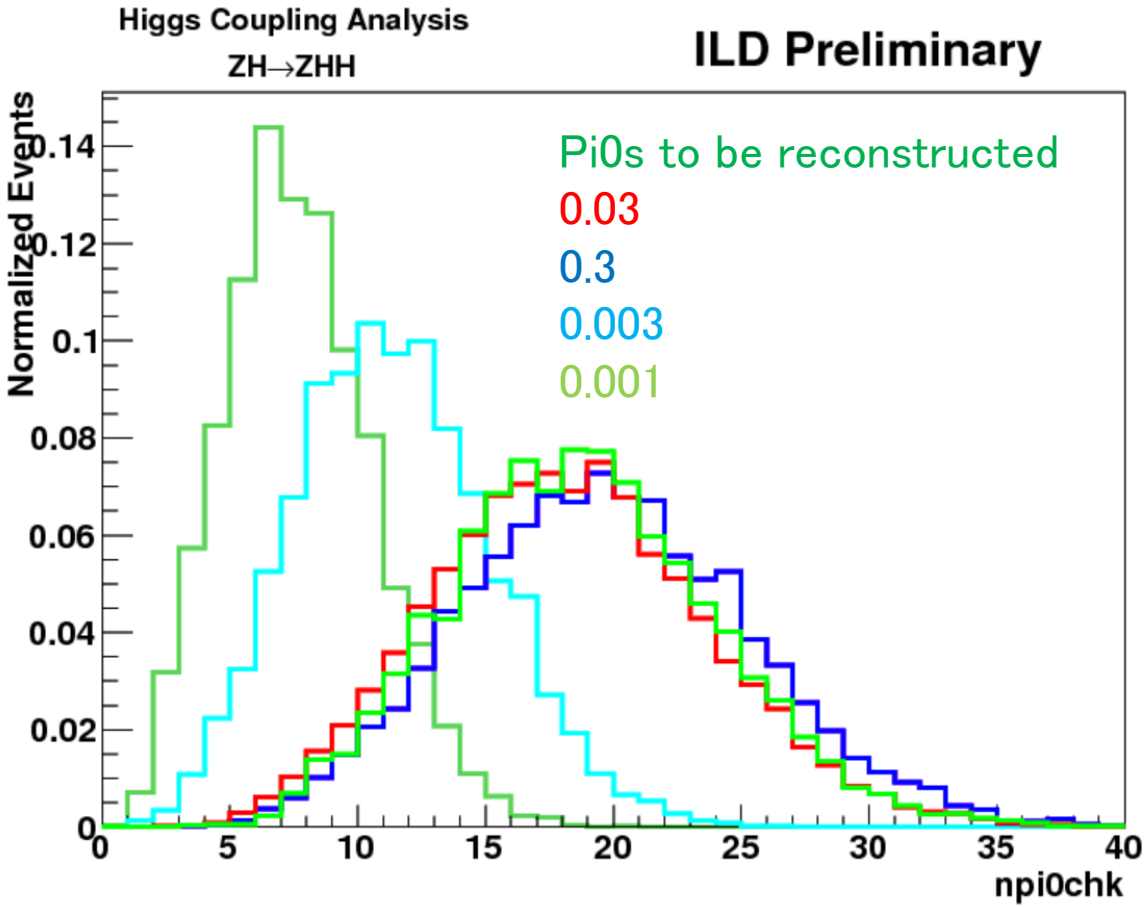
K OPTIMIZATION SO FAR

- K will be set at the point where num. of pi0s are almost same as the capacity of pi0 reconstruction matched with MC truth
- Set $k = 0.03 \cdot \log N(\gamma)$



K PARAMETER EFFECT

- How k parameter works?
  - $k = \alpha \cdot \log N(\gamma)$
  - Change α to each value
  - Saturation @large α is due to gamma pairing posterior threshold effect



RESULTS

- Good pairing eff. & mis-pairing eff.

	Correct pair	Wrong pair
eff. (%)	46.0±0.3	54.0±0.4

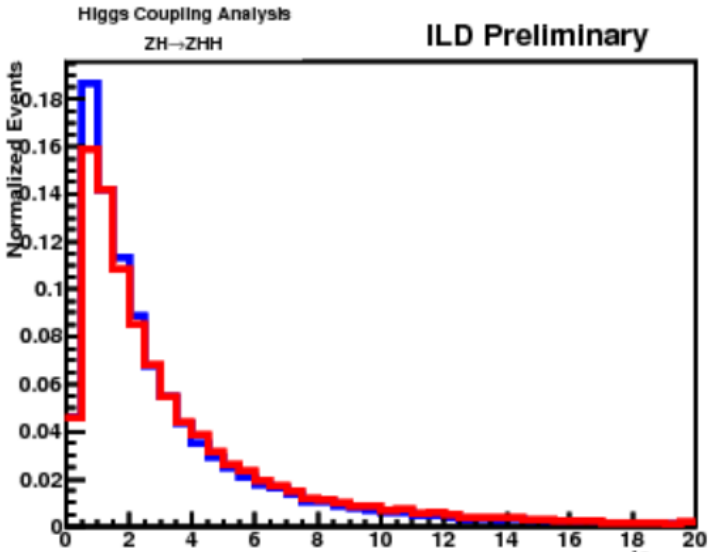
  - Just counting the num. of good pairing pi0s in the reconstructed pi0s
  - Definition of the efficiency is difficult…

- Bad pairing eff. is the problem…
  - When gammas are located in small area
  - In many case, gammas tend to jam in small area

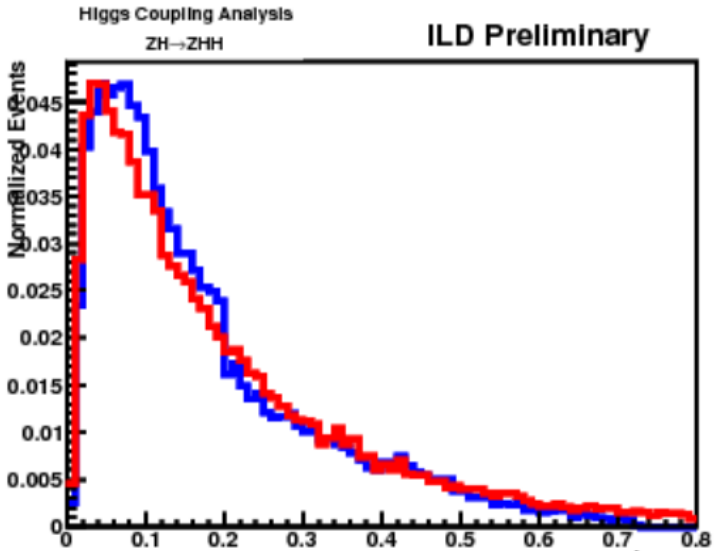
- Need to check the degradation when neutral hadrons are contaminated
  - But we have only to check the mis-pairing effect on vertex mass recovery!

Checking kinematics

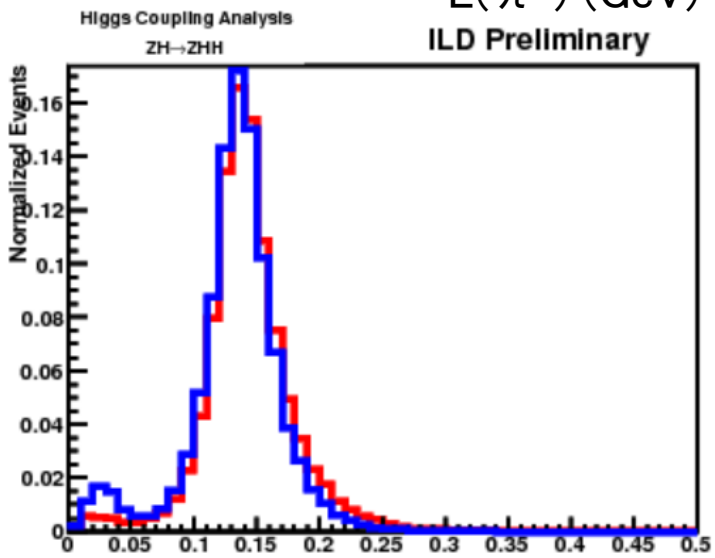
- Pi0 decay kinematics



E(π^0) (GeV)



θ (γ 1, γ 2) (rad)



m(π^0) (GeV/c^2)

MC truth

Pi0 finder

Summary and prospects

- Construct pi0 reconstruction tools for vertex mass recovery
  - Gamma mis-ID eff. is ～2.0% while gamma ID eff. is ～97%
  - Gamma pairing eff. is ～50%
  - Pi0 decay kinematics can reproduct well

- Problems
  - Gamma pairing eff. is too low due to gammas jamming in small area – Such gammas are important!
  - Decay kinematics can't identify good combination of 2 gammas – kinematics OK
  - Global IC minimization algorithm is not good!
    - Consuming too much CPU time – a few second/vertex(momentum correction of gamma is necessary on each vertex)
    - Is there good global minimization algorithm? – need help
  - Method to global minimization(maximization)
    - IC is really a good estimator?

- Prospects: How does pi0 reconstruction work on vertex mass recovery?
  - In my next talk!