Higgs self-coupling analysis with H→WW*

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Status

- Doing some studies
  - Kinematic fitter for ZHH→(bb)(bb)(WW*)→(bb)(bb)(l ν jj) process
  - Vertex mass recovery in LCFIPlus
  - Both topics have some progress after LCWS14
  - And, some extra studies
- Unfortunately, I can't attend next general physics meeting… So today I'll talk about what I would want to talk at general meeting (It takes some time)

Kinematic Fitter

Trying Kinematic Fitter

- Determining the kinematics globally in the events
  - Distort the event kinematics to meet the constraint in specific process
  - Estimate how much is a event likely to the specific process?
  - Mass resolution will be improved by using χ^2 minimization

- First trial: ZHH→(bb)(bb)(WW*)→(bb)(bb)(l ν jj) kinematic fitter
  - Constraints:

$$m(bb) = m_Z$$

$$Max\big(m(l\nu), m(jj)\big) = m_W$$

$$m(bb) = m(l\nu jj)$$

$$E(H) + E(Z) + E(jj) + E(l\nu) = \sqrt{s}$$

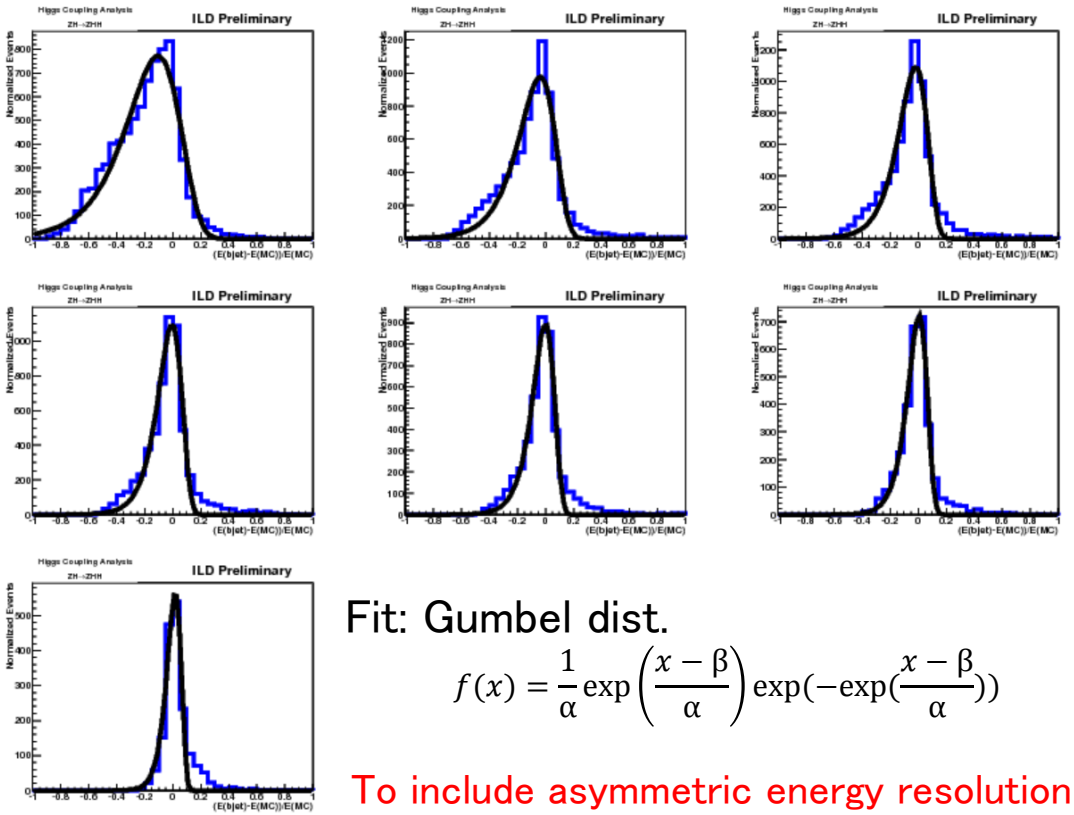
$$\overrightarrow{p_H} + \overrightarrow{p_Z} + \overrightarrow{p_{jj}} + \overrightarrow{p_{l\nu}} = \vec{0}$$

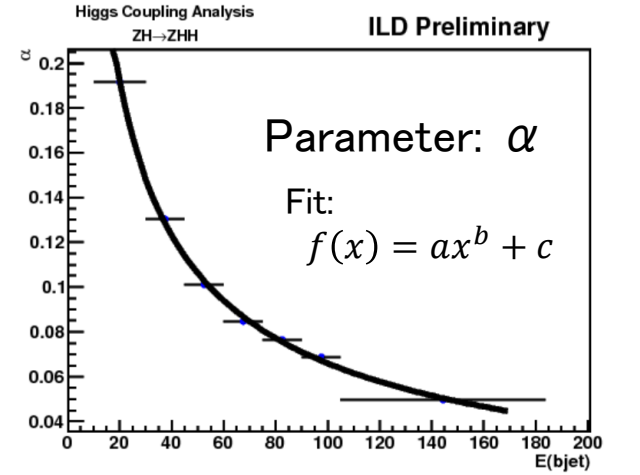
$$p_\nu = E_\nu$$

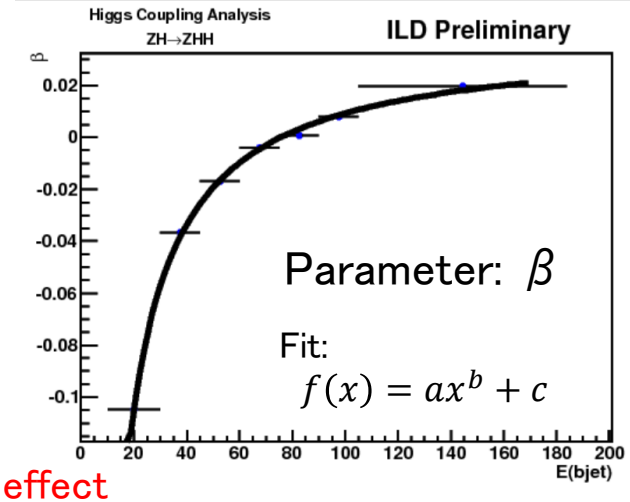
  - There was bug in code – fix it

Jet energy resolution – b jet

- Most critical factor which degrades mass resolution is jet energy resolution
  - So it is necessary to include this effect into Kinematic fitter
  - Jet energy resolution itself has energy dependence of jets
    - Parameterize fit parameters with jet energy







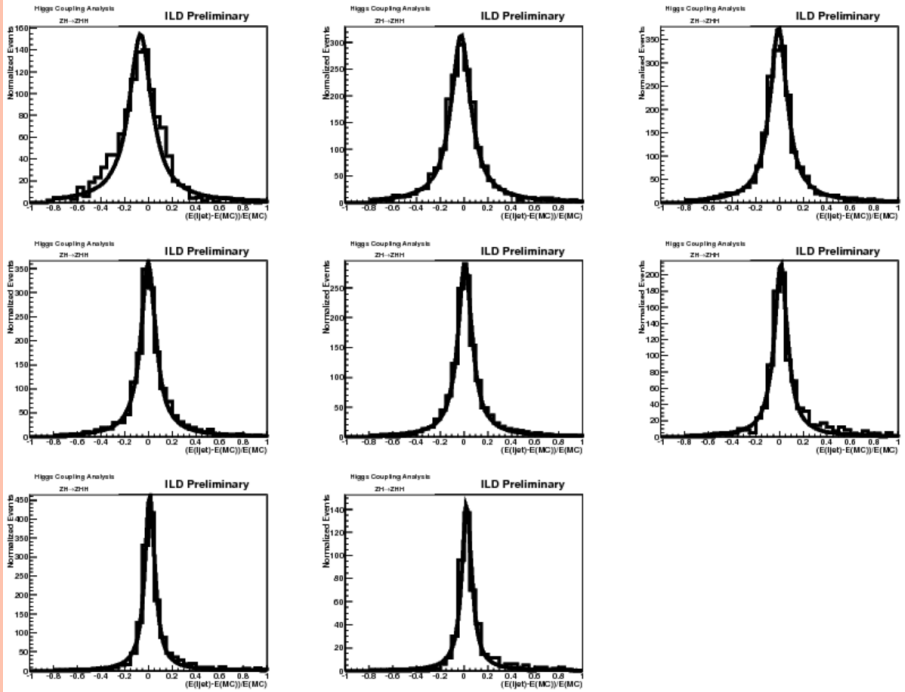
Fit: Gumbel dist.

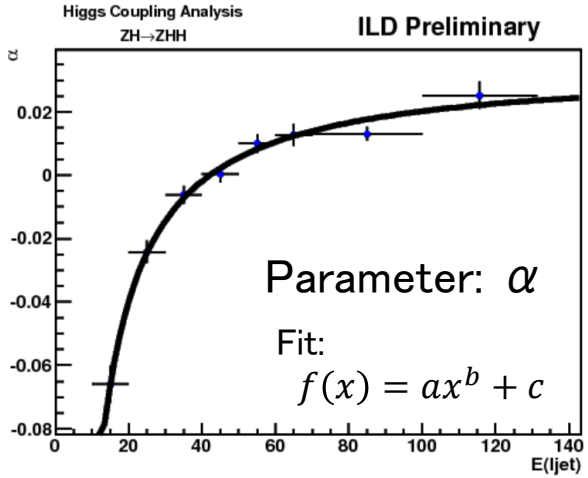
$$f(x) = \frac{1}{\alpha}\exp\left(\frac{x-\beta}{\alpha}\right)\exp(-\exp(\frac{x-\beta}{\alpha}))$$

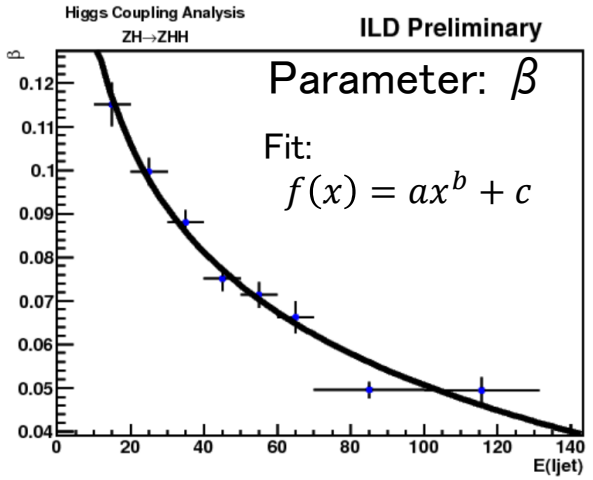
To include asymmetric energy resolution effect

Jet energy resolution – jet from W boson

- Most critical factor which degrades mass resolution is jet energy resolution
  - So it is necessary to include this effect into Kinematic fitter
  - Jet energy resolution itself has energy dependence of jets
    - Parameterize fit parameters with jet energy







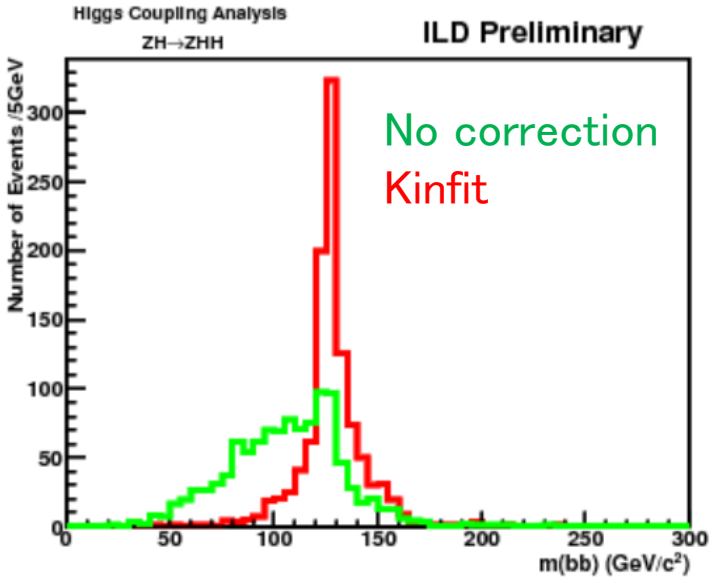
Fit: Cauchy dist.(Breit–Wigner)

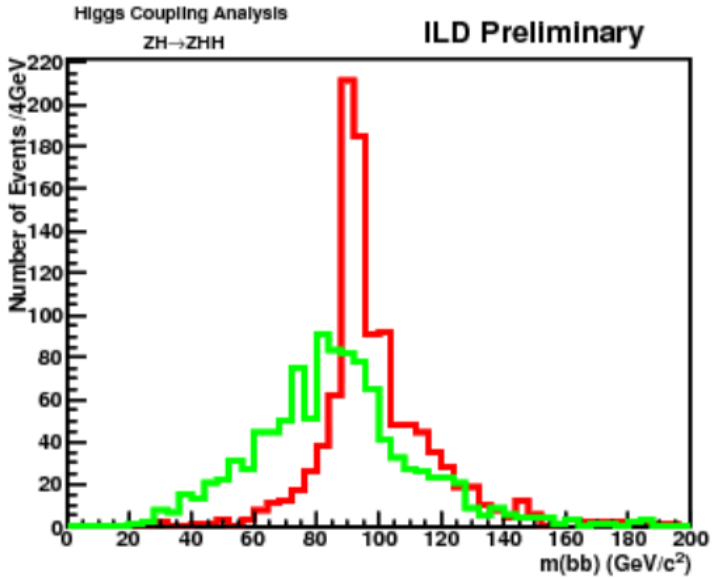
$$f(x) = \frac{1}{\pi}\frac{\beta}{(x-\alpha)^2+\beta^2}$$

Resolution is very symmetric

Performance check

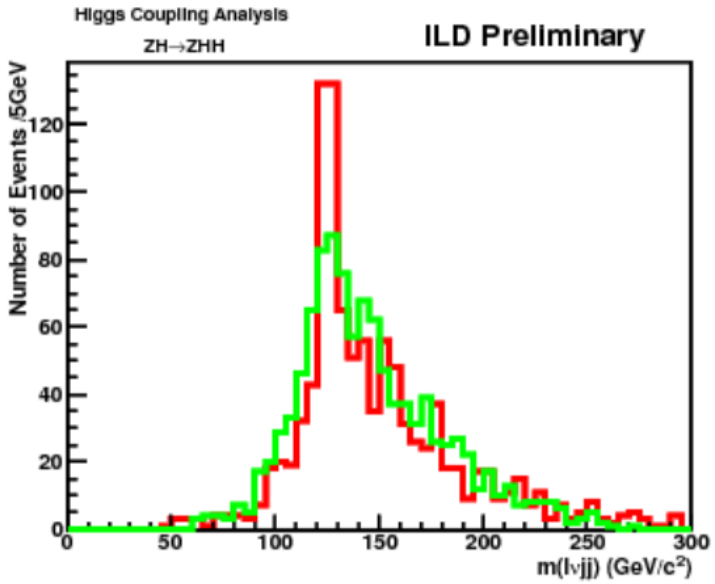
- Higgs mass(H→bb) & Z mass distribution
  - Mass resolution is going better! →promising





- Higgs(H→WW*→l ν jj)
  - Better than previous result!

  →this resolution improvement is enough?



PROSPECTS

- All the mass resolutions become better using Kinematic fitter
  - So far, Kinematic fitter is working good
  - But, m(l ν jj) resolution improvement is enough?
  - Neutrino energy correction is the key for m(l ν jj) resolution

- All the neutrinos in the event should be checked for better m(l ν jj) resolution
  - Soft neutrinos affect on angular resolution of jets and missing momentum itself?
  - If so, it is necessary to include angular resolution effect into Kinematic fitter
  - It is possible, but very hard work…

- Need to check using background processes
  - Especially, comparison to ZZH is important

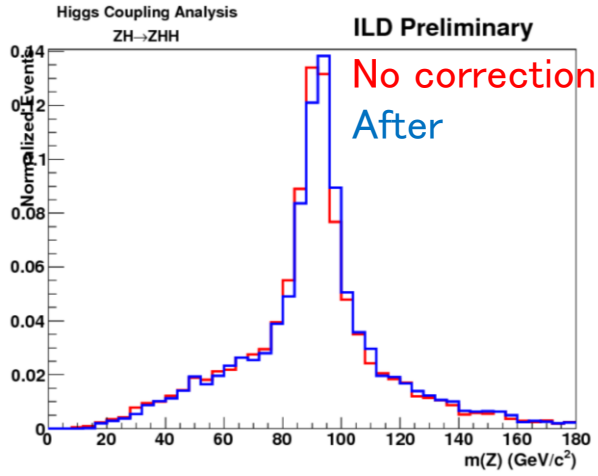
- Kinfit for ZHH→(bb)(bb)(WW*)→(bb)(bb)(jjjj) process

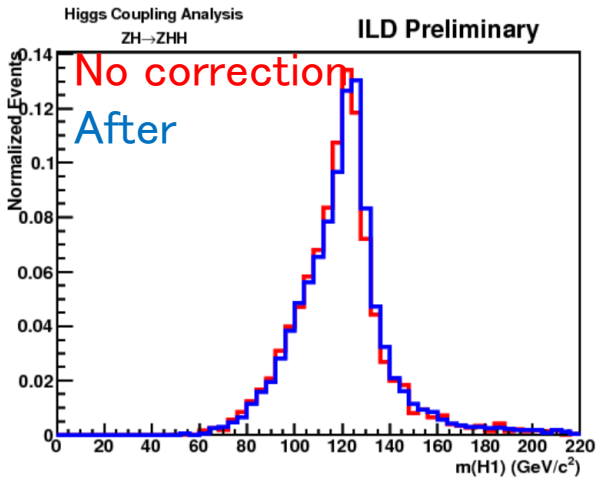
In LCFIPlus

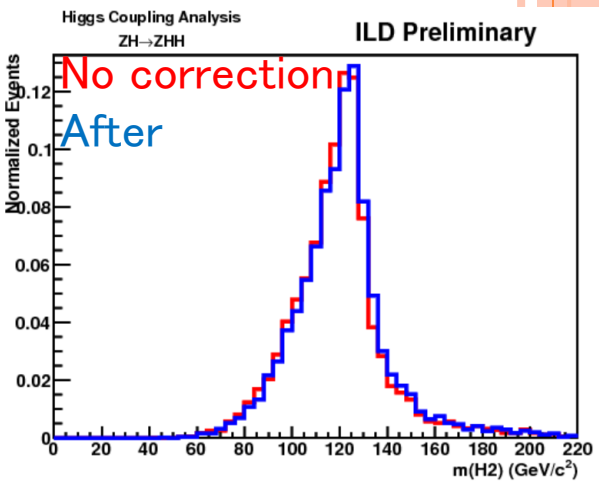
Track energy correction

- Track energies are corrected before jet clustering
  - Energy correction using ParticleID
  - Method: Durham
  - Corrected energy is used when calculating y value
  - Clustering will be changed slightly, especially low momentum track clustering → how is the invariant mass?
  - Sample: qqHH→(qq)(bb)(bb)

  - Looks almost same as previous result – effect is small, but going to good direction!







STATUS

- Construction of vertex mass recovery module in LCFIPlus is completed
  - Need debug
  - Start to look at the recovered vertex mass distribution
  - Will be able to show some plots in next meeting…

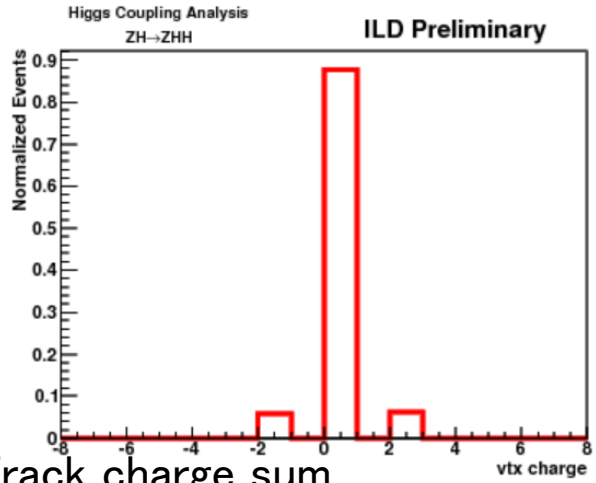
First trial of vertex charge study

Vertex charge study

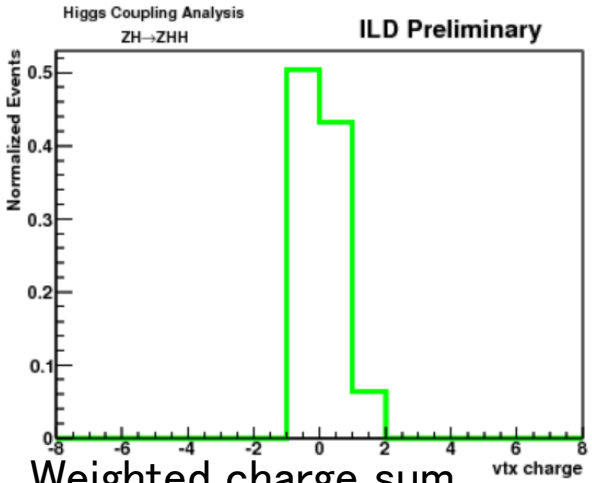
- First check of vertex charge
  - Using b vtx: 1vtx in bjet
  - Calculate simple track charge sum and track energy weighted charge sum
  - Check how much the vertex charge agrees with its original b quark charge
  - So far, using vertices with at least 1 Kaon track → tag particles using particle ID
- To be honest, I have no idea about the strategy. So please help!

First trial of 2 track case

- K+π candidates – vertices are almost neutral!
  - Vertex charge

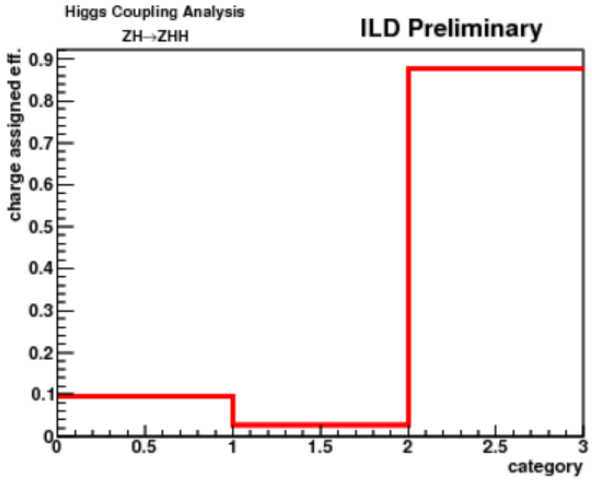


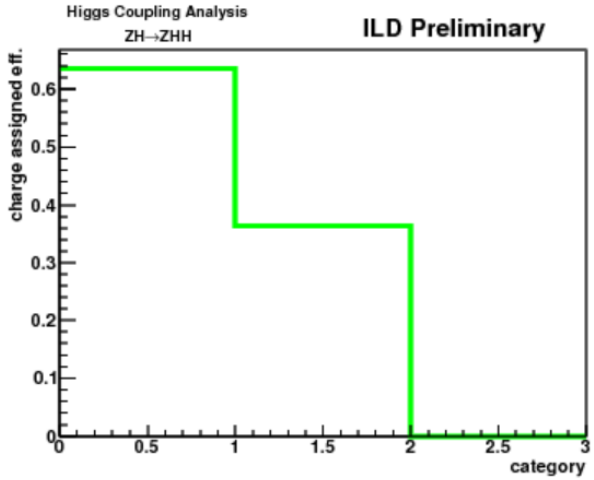
Track charge sum



Weighted charge sum

  - Efficiency

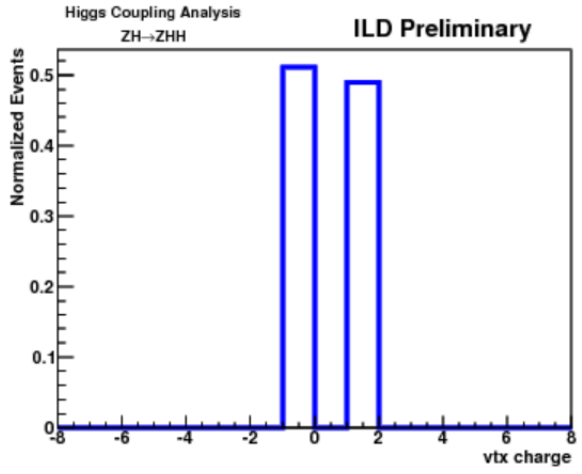




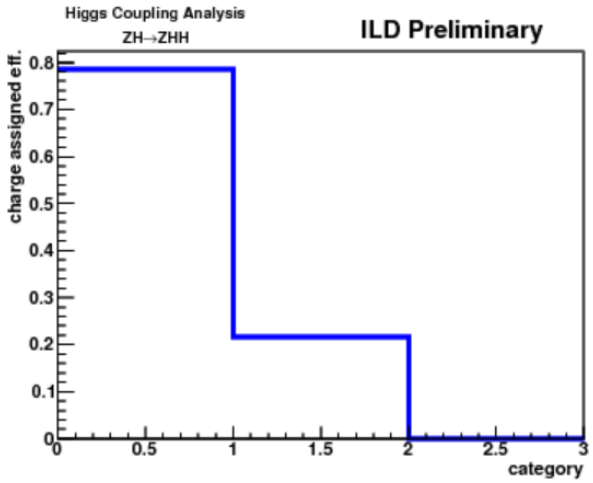
  - It is not enough…

Advantage of particle ID

- In K+π case, does Kaon carry b quark charge?
  - Try to check the relation between Kaon charge and b quark charge
  - Kaon charge



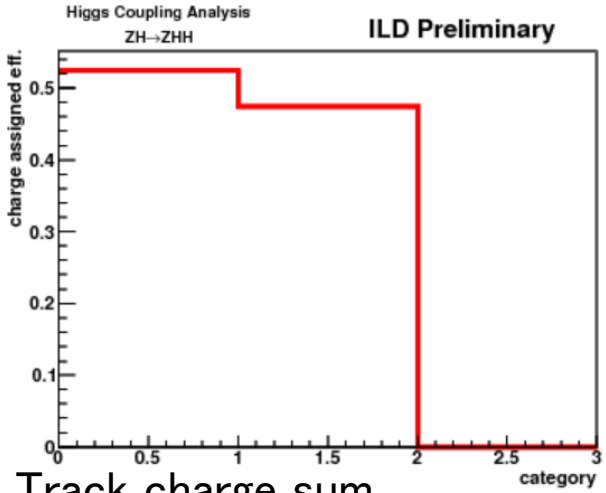
  - Efficiency



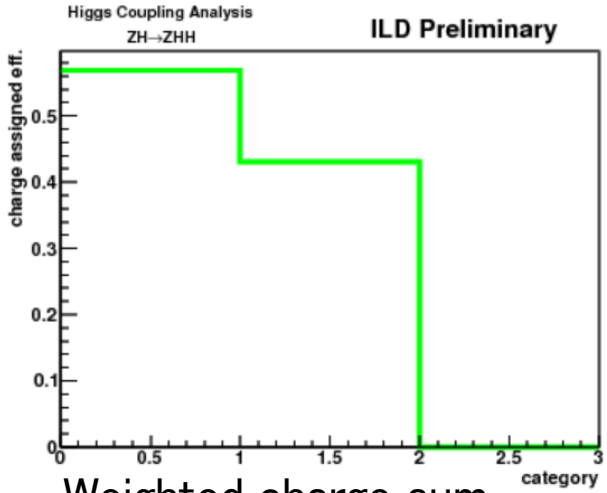
  - Better, but more idea is necessary

First trial of 3 track case – good case

- K+ π + π case: efficiency



Track charge sum

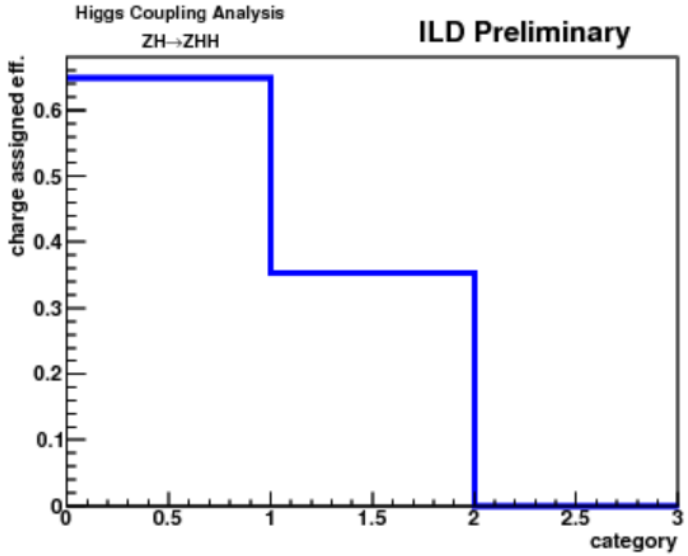


Weighted charge sum

- Using Kaon charge

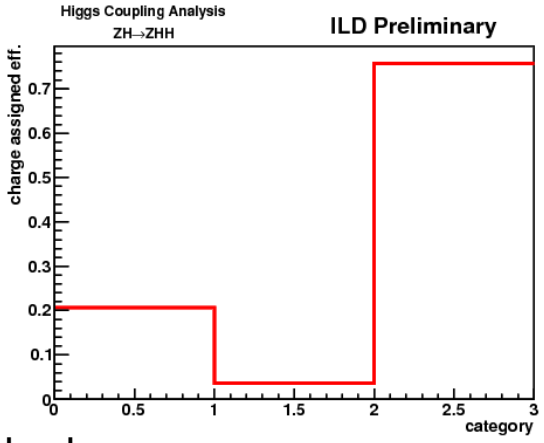
- Worse than

  K+ π case, but better

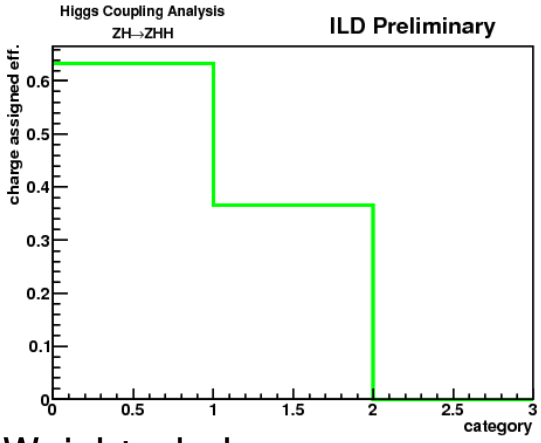


4 TRACK CASE – GOOD CASE

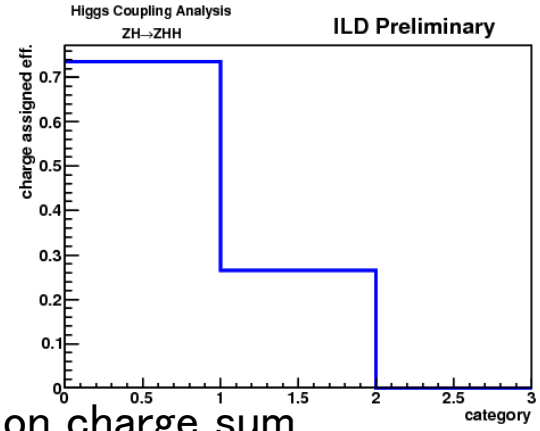
- K+ π + π + π : efficiency



Track charge sum



Weighted charge sum

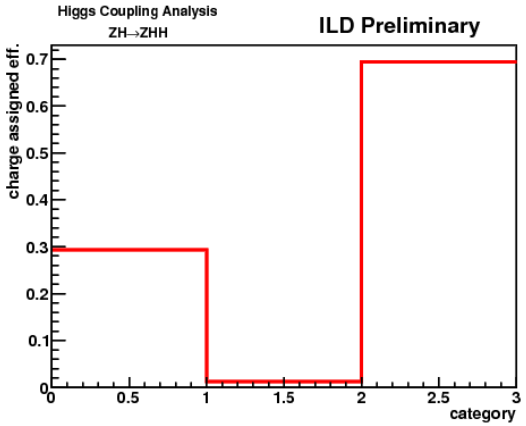


Kaon charge sum

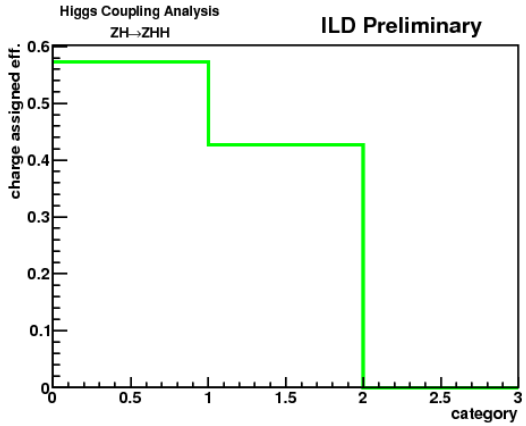
- Even num. of track case is better than odd num. of track case?

4 TRACK CASE – GOOD CASE

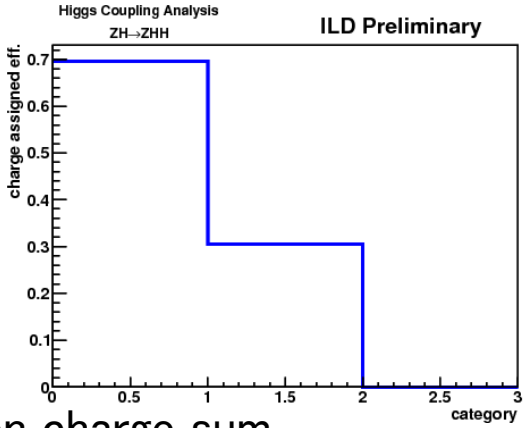
- K+K+K+ π : efficiency



Track charge sum



Weighted charge sum

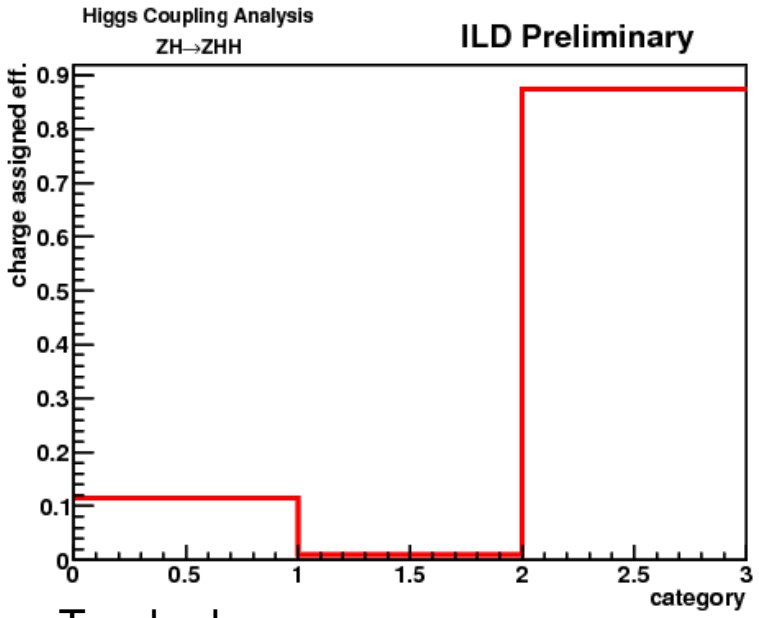


Kaon charge sum

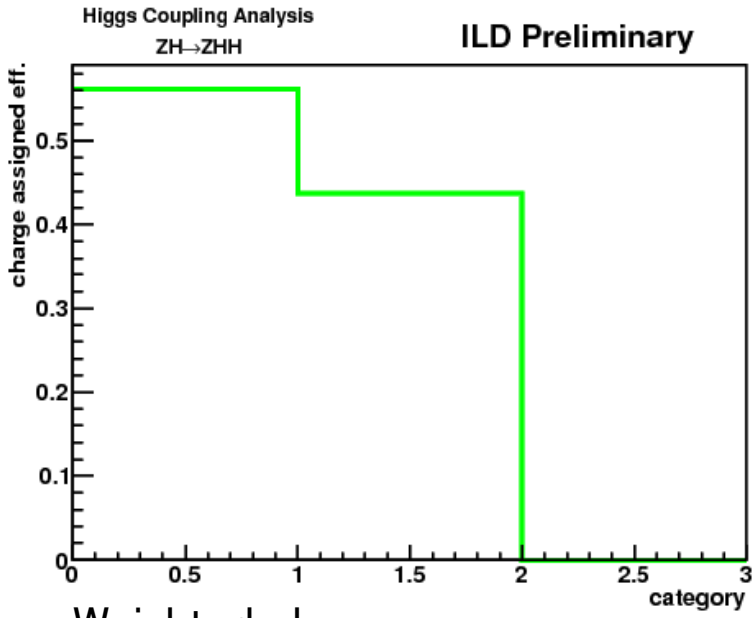
- If num. of Kaon is odd, Kaon charge sum looks good information

DIFFICULT?

- If num. of Kaons on vertices is even…
- K+K case: efficiency



Track charge sum



Weighted charge sum

- Looks hopeless…
- Good idea?

Problems and prospects

- In some cases, Kaon charge on vertex looks good information to identify original b quark charge
  - But, very specific – so far, seems just odd num. of Kaon on vertices
  - Even num. of tracks on vertices can identified b quark charge better than odd num. of tracks case – why?
  - How is the other case? e.g.) K+K, $\pi+\pi$, K+K+π etc.
  - But symmetric cases(e.g. K+K, K+K+$\pi+\pi$, K+K+K+K etc.) seem hopeless…
  - Efficiency is still not enough – need some idea
    - Track quality cut is necessary?
    - MVA will be necessary finally
- Of course, need to check other case
- What is next?
- Can the b quark charge estimator be constructed?
  - A lot of help necessary!