Particle ID study for Analysis Improvement

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For analysis improvement

- All the analyses are saturated within the present framework
  - Needs new idea
- Fundamental new variables might provide improvements of analysis tools
  - dE/dx in TPC
  - Shower profiles in the calorimeters
- Those variables have already boosted lepton ID efficiency
  - ～30% improvement can be obtained
  - Show that later

- Will those variables give improvements to other analysis components?
  - Particle ID will be available using those variables
  - Energy correction
  - Flavor tagging?
  - Hope for jet clustering?

  →it is necessary to study them

dE/dx

- For improvement, using dE/dx is one of the powerful tools
  - Particle ID for each track will give a large impact to the analysis
  - Application to general analysis component is very wide
    - Lepton ID
    - Track energy correction
    - B-tagging?
    - Jet clustering?
- Important factor to use dE/dx is: fluctuation
  - TDR: measurement resolution is **5%**
  - So, fluctuation from simulation is within 5% without detector effect

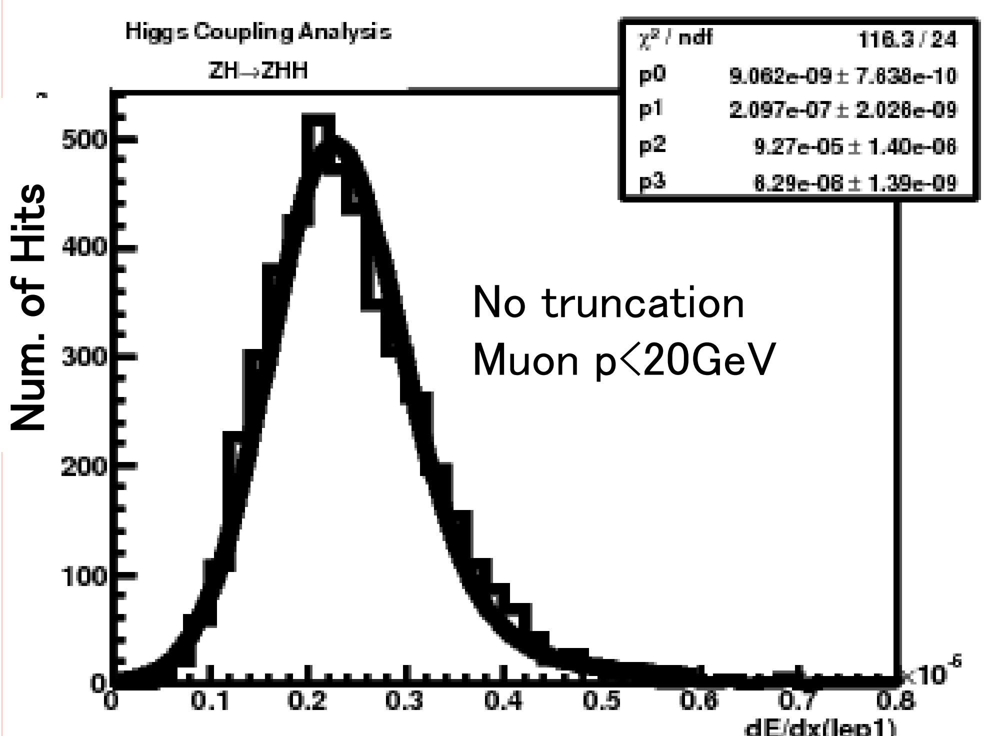
- dE/dx definition:
  - $\frac{dE}{dx} = \frac{energy\ deposit}{flight\ path\ in\ the\ hit(TPC)}$
  - dE/dx can be calculated at any hit point
  - Truncated mean is calculated as track dE/dx

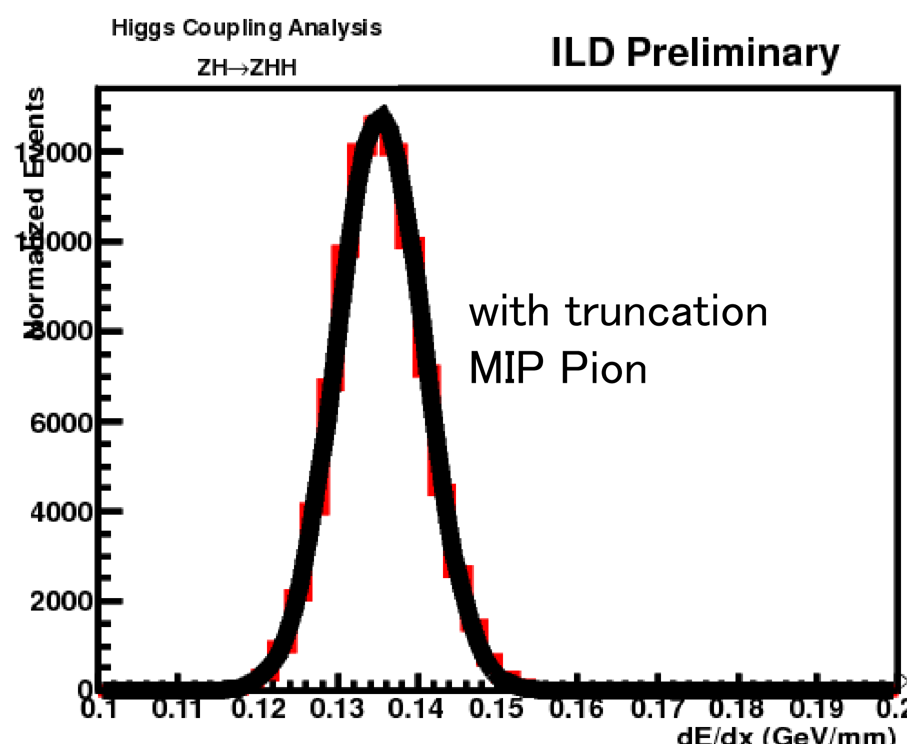
    $\left\langle \frac{dE}{dx} \right\rangle = \frac{1}{n} \sum_i^n \frac{dE_i}{dx_i}$ upper 30%, lower 8%(important!) hits are discarded to avoid Landau tail(next slide)

    →optimization is necessary

EFFECT OF LANDAU TAIL

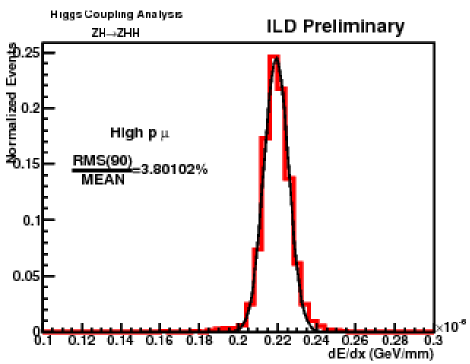
- Landau tail effect – muon tracks
  - dE/dx distribution of track hits
  - fitting – convolution of Gaussian and Landau
  - Tail can be seen in the case of no truncation
- Truncated mean distribution – MIP pion(0.3GeV/c<p<0.6GeV/c)
  - Good Gaussian shape

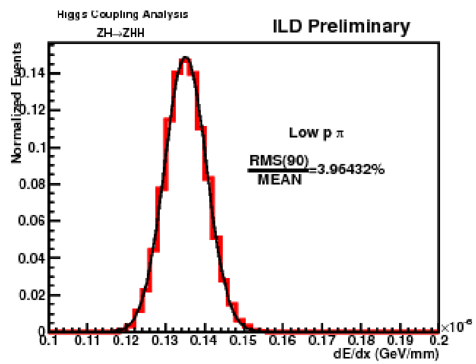


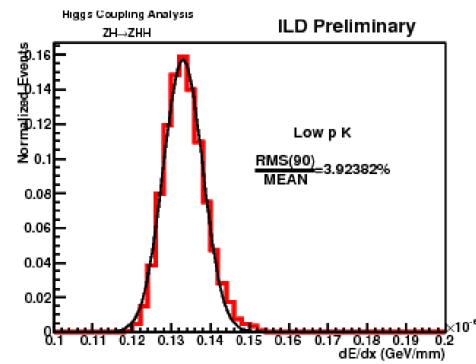


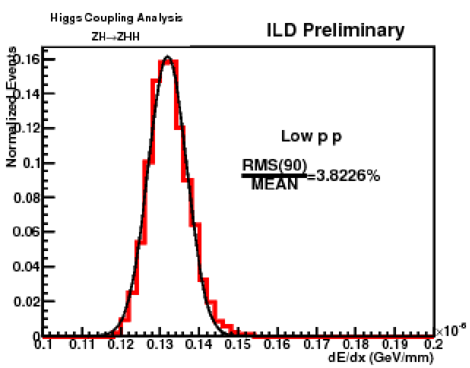
dE/dx FLUCTUATION

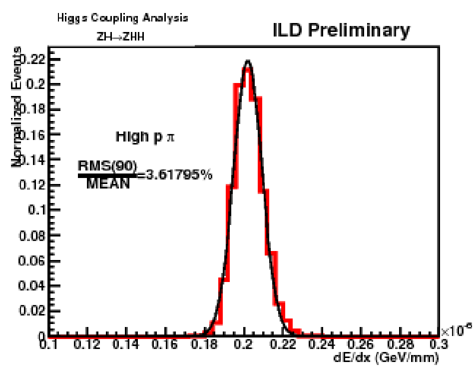
- Fluctuation of dE/dx using various type of tracks
  - Estimation of RMS(90)/MEAN

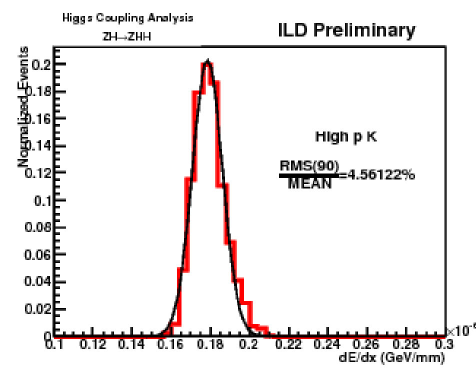


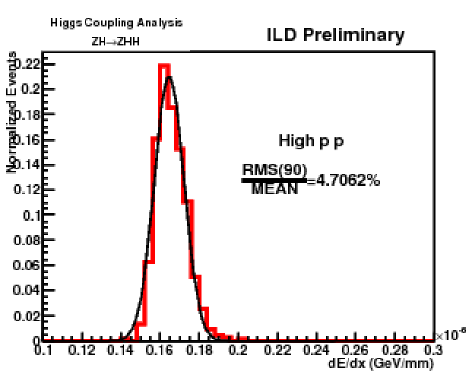












High: p >20GeV/c

Low: π 0.3GeV/c<p<0.6GeV/c

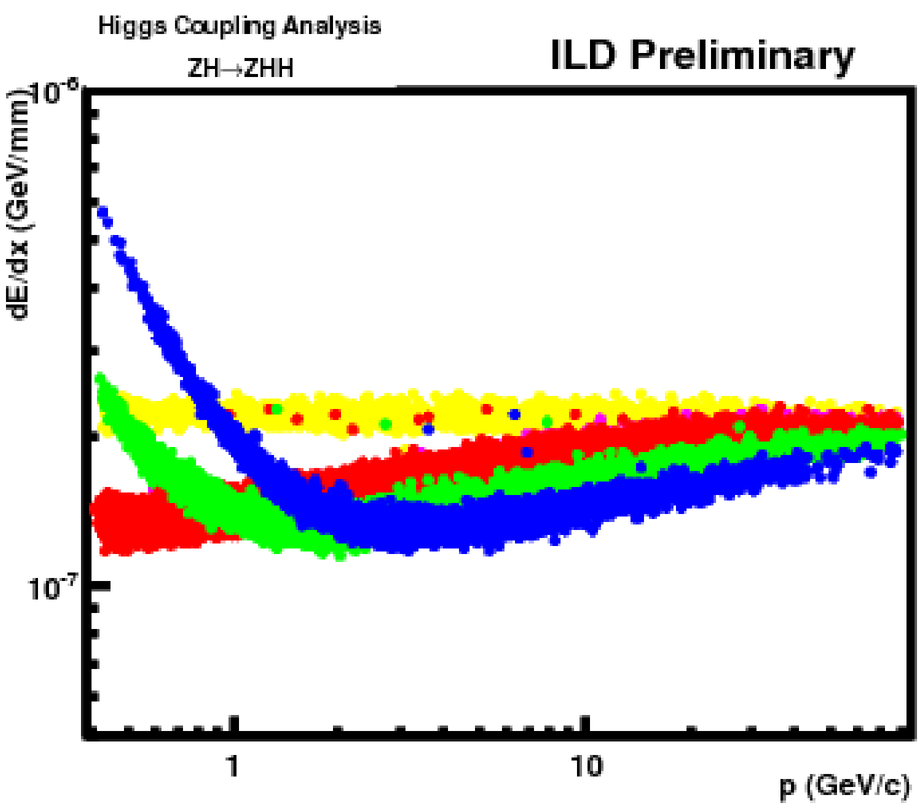
K 1.0GeV/c <p<3.0GeV/c

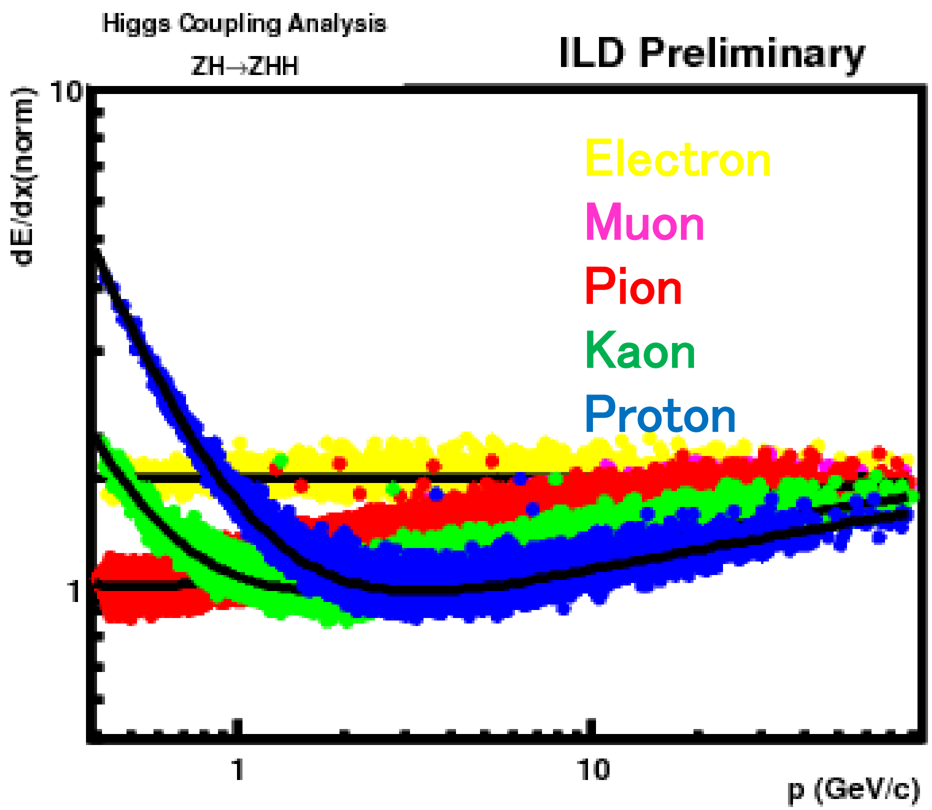
p 2.0GeV/c<p<4.0GeV/c

- Fluctuations of each particle/each momentum rage
  3 – (<5)%!!

dE/dx distribution

- For each particle
  - Polar angle dependence corrected
  - Num. of Hits dependence corrected
  - Scale to $\left\langle \frac{dE}{dx} \right\rangle = 1.0$ for MIP pion





Shower profile

- Shower shapes in the calorimeter are different between electron/photon/muon/hadrons
  - So characters of the clusters will be a good tool to distinguish tracks
  - Especially, electromagnetic shower shape is well known
  - Grabbing those information will boost leptonID efficiency/fake rejection efficiency

- Information extraction is based on the fitting:
  - Well-known EM shower profile

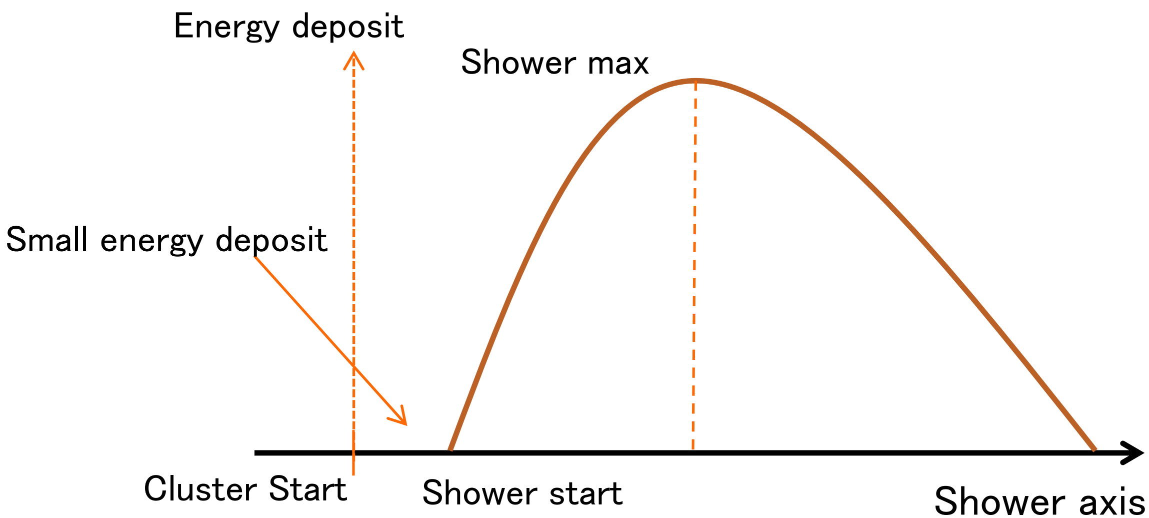
$$f(x_l, x_t) = ac\frac{(c(x - x_{l0}))^{b-1} \cdot \exp(-c(x - x_{l0})) \cdot \exp(-dx_t)}{\Gamma(b)}$$

- In addition, hit based variable is introduced to identify shower start
  - Xl20 – length from cluster start to 20% of total energy deposit

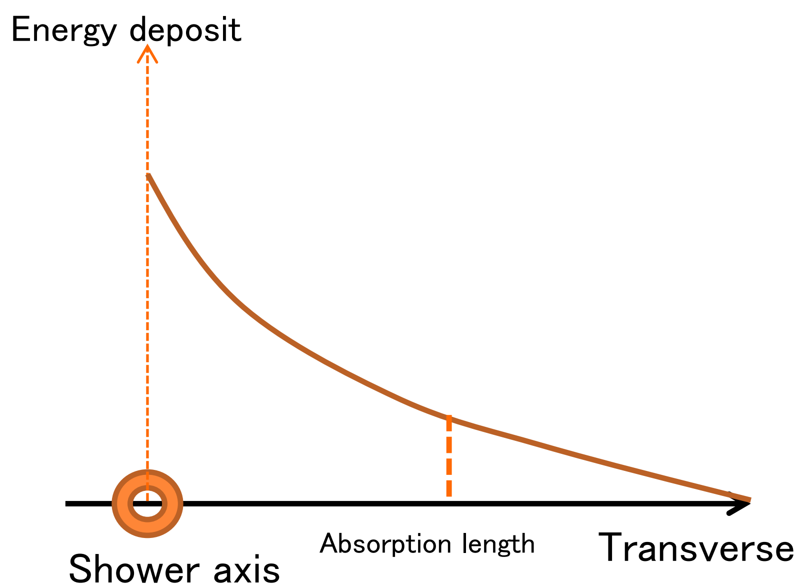
Shower profile –structure in the cluster

Hit points in the cal. are converted from (x,y,z) to (xl, xt)

longitudinal



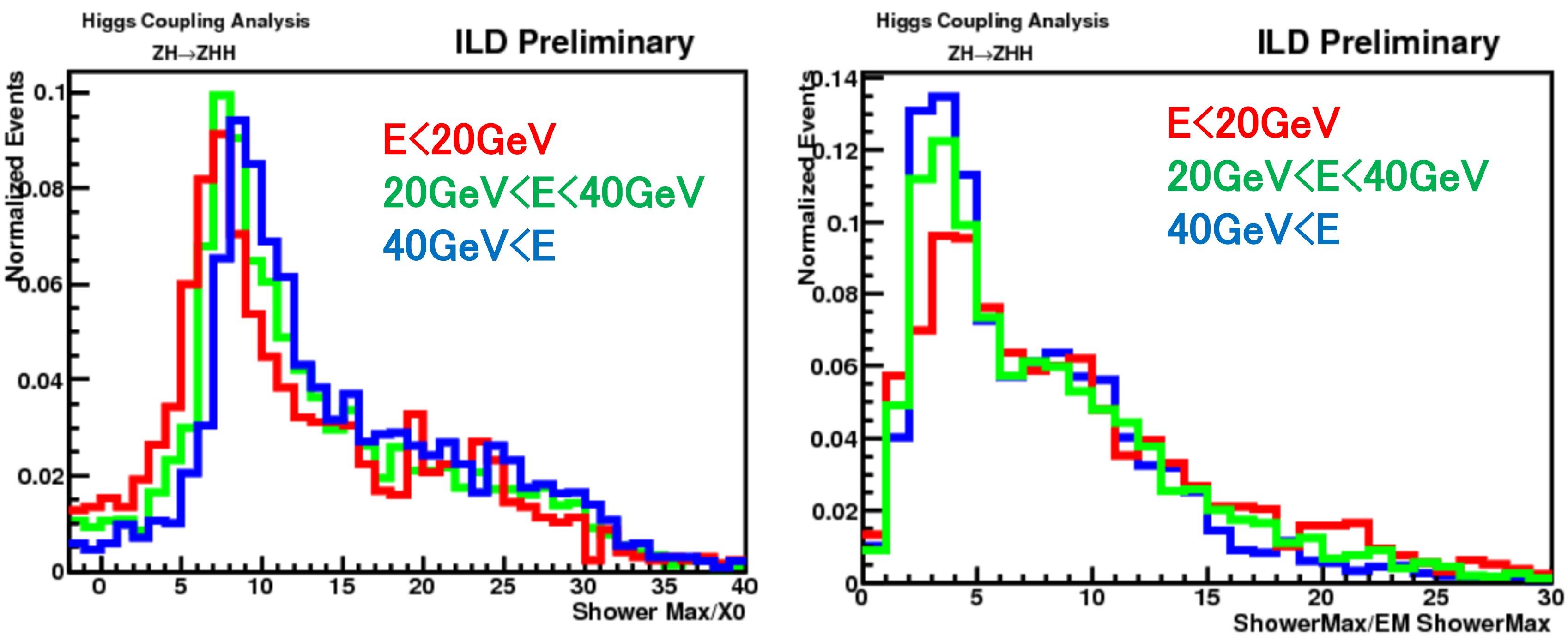
transverse



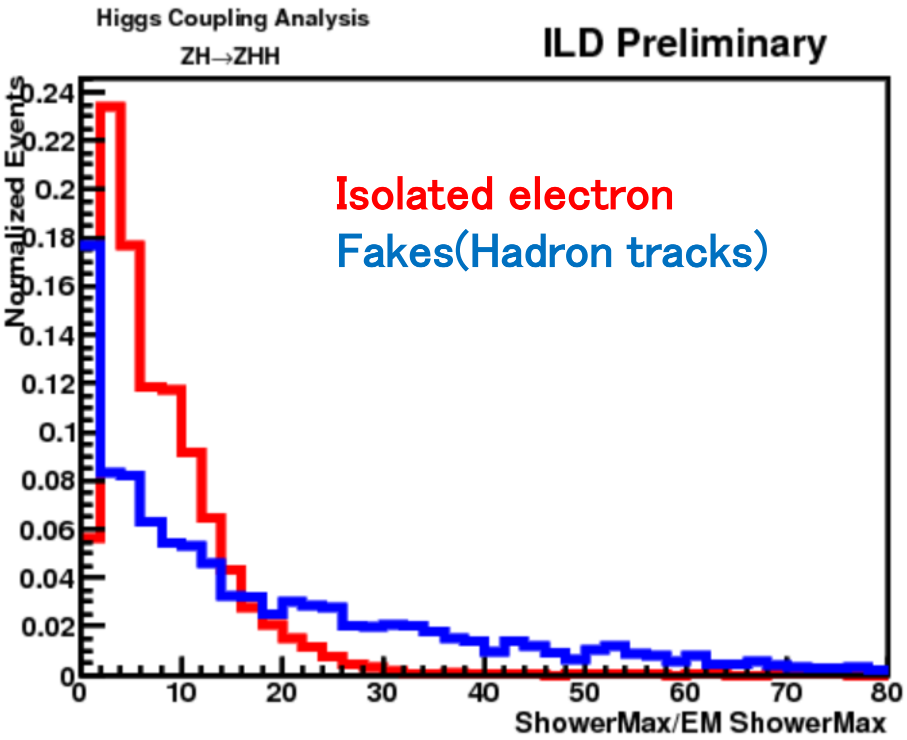
Longitudinal information

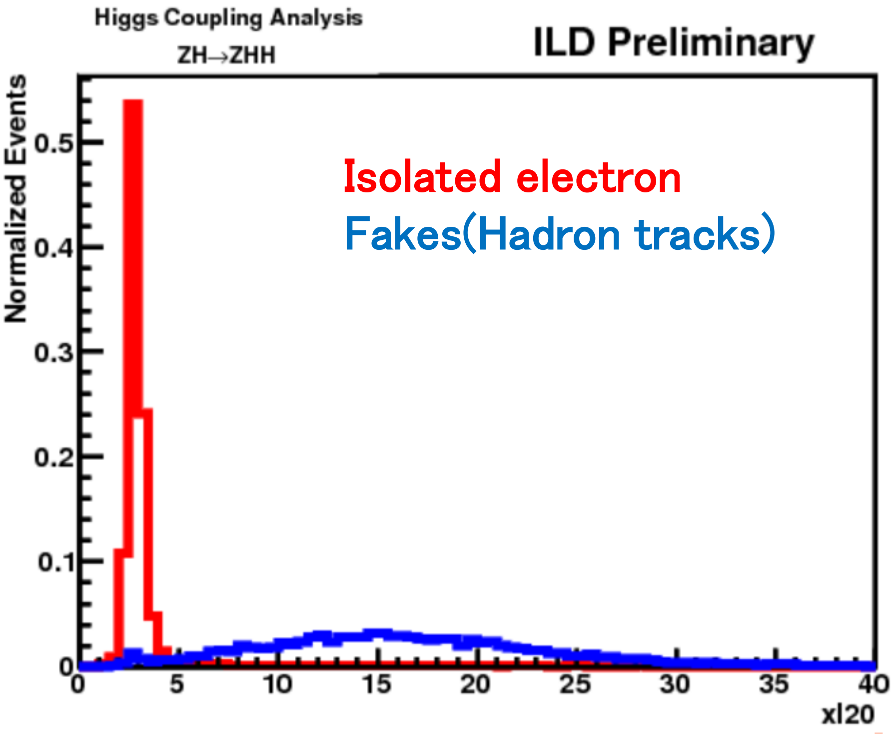
- Length from calorimeter surface to the point which has maximum energy deposit
  - Of course, there is an energy dependence
  - But, the dependence is logarithmic
  - Taking ratio with Expected shower Max

$$\text{Exp. Shower Max} = 1.0\left(\log\frac{E_0}{E_c} - 0.5\right), \quad E_c = 0.021\frac{X_o}{Rm}\text{GeV}$$



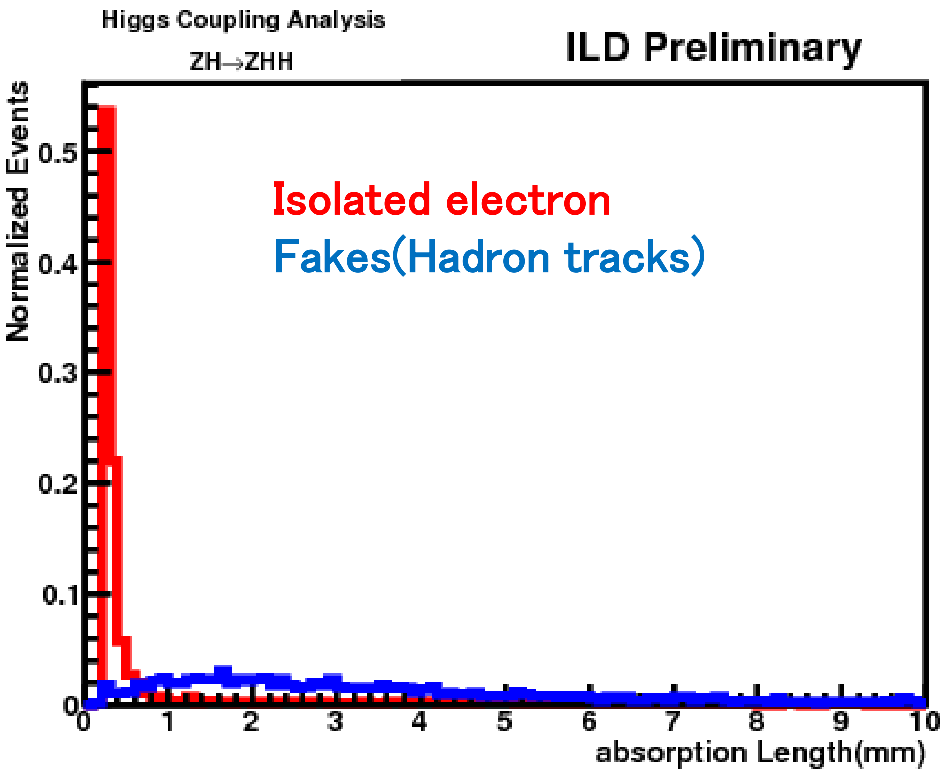
Difference between electron/Fakes

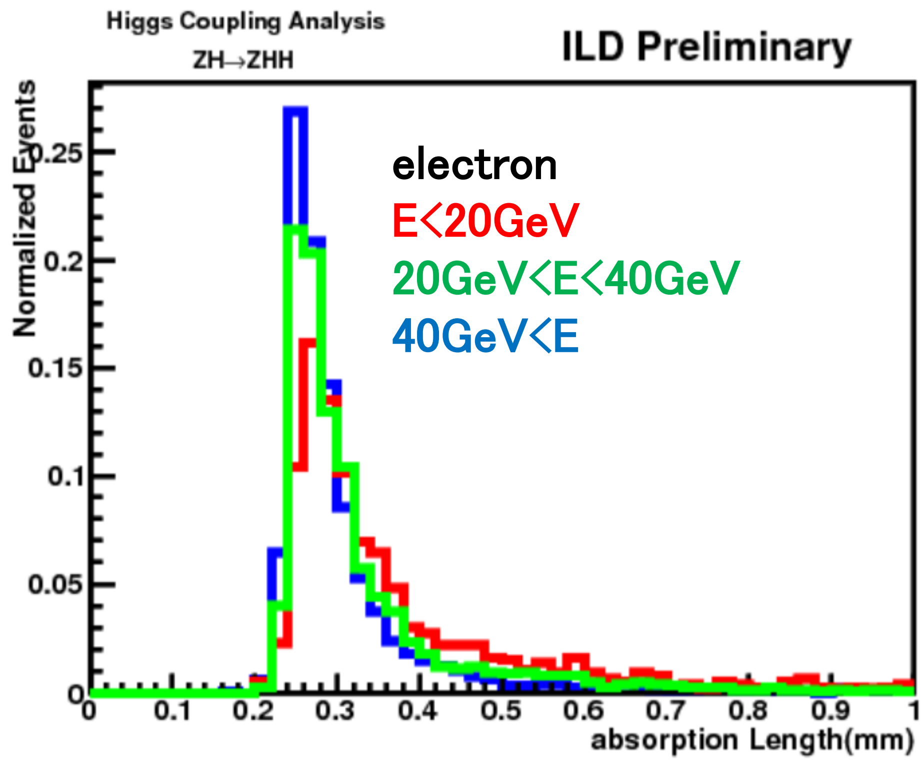




Transverse information

- Transverse shower profile is characterized by absorption length
  - EM shower spread is very small – 90% energy within Moliere Radius
  - Hadron shower spread is wide
  - There is an energy dependence of course, but the effect is small in the case of electron





Application – Lepton ID

- Lepton ID for single lepton – using likelihood method
  - Lepton likeliness: $L = \frac{\prod s}{\prod s + \prod b}$,
- Signal detection efficiency – set almost same efficiency
- Signal is HH→(bb)(WW*)→(bb)(l ν jj)

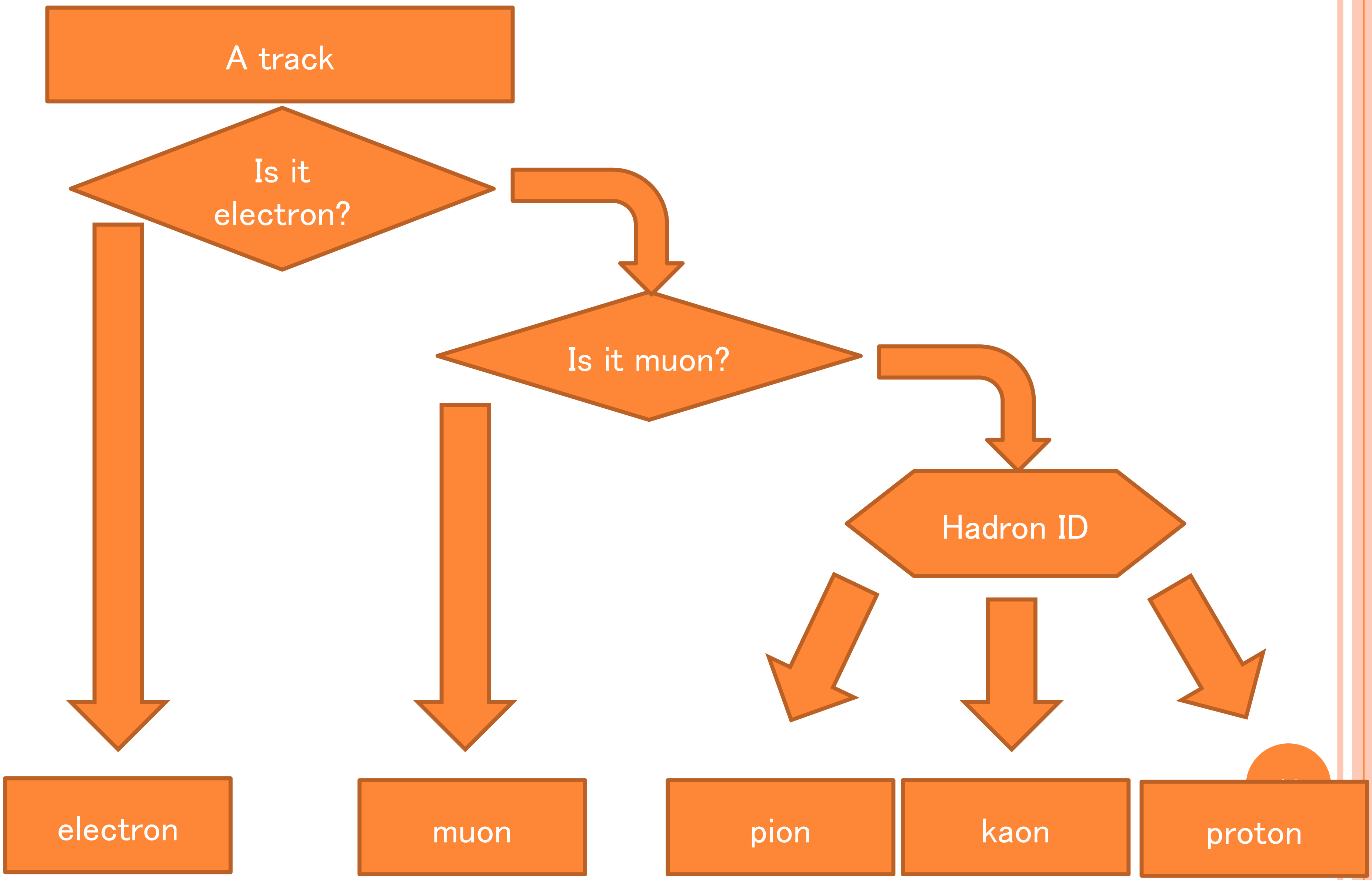
method	Cut based	Likelihood_old	Likelihood_new
Signal(%)	98.1	98.1	97.8

- Background rejection efficiency

method	Cut based	Likelihood_old	Likelihood_new
ttbar – lep+jets(%)	62.2	-	**62.4**
ttbar – allhad(%)	7.9	3.1	**2.3**
ttbar – dilepton(%)	47.2	-	**17.9**
HH→(bb)(bb) (%)	-	2.3	**1.0**

- Note: lepton energy threshold is loosened on likelihood_new
  - From E(lep)>15GeV → E(lep)>10GeV

Application – Particle ID strategy

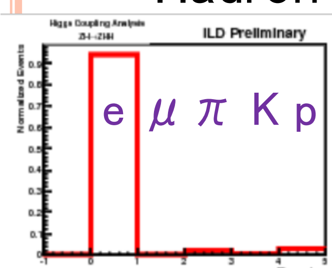


Particle ID

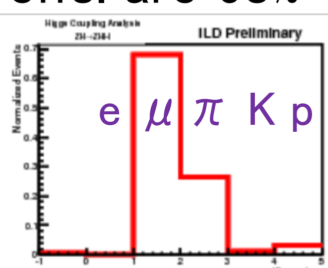
- ID efficiency for each basic particle type
  - How are particles identified as each particle type?

- Difference from first trial(AWLC14):
  - Changing MC matching method →matching eff. becomes 100%
  - So, very low momentum muon can't be distinguished from pion because such muons stop in the calorimeter

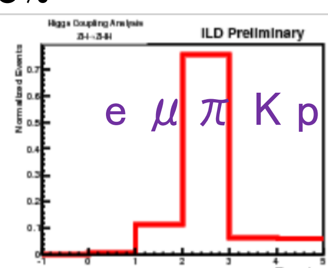
- ID efficiency:
  - Electron can be identified almost perfectly
  - Muon ID eff. reduces from 80% to ～70%
  - Hadron ID effs. are 68%～75%



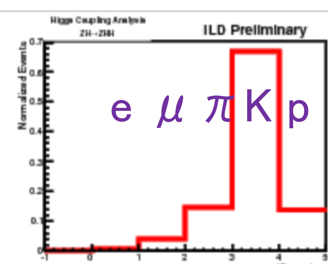
e



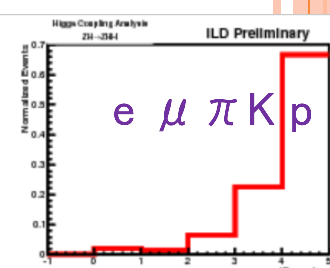
μ



π



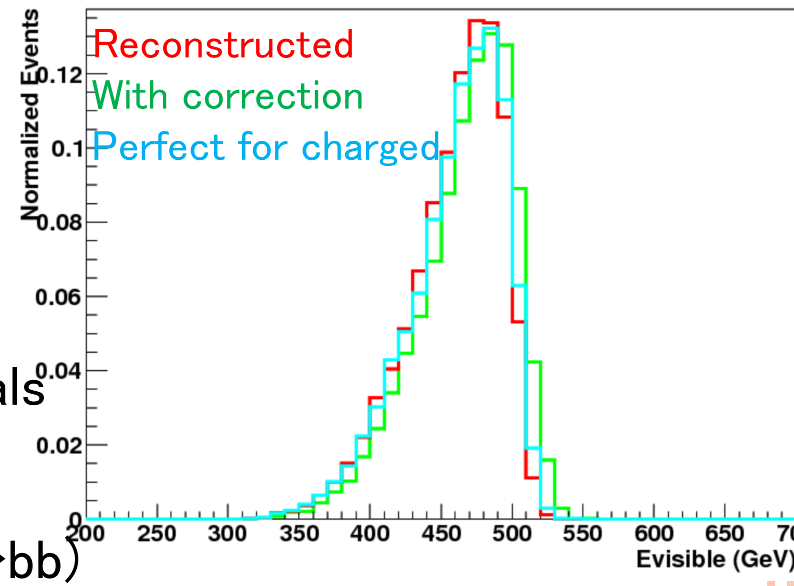
K

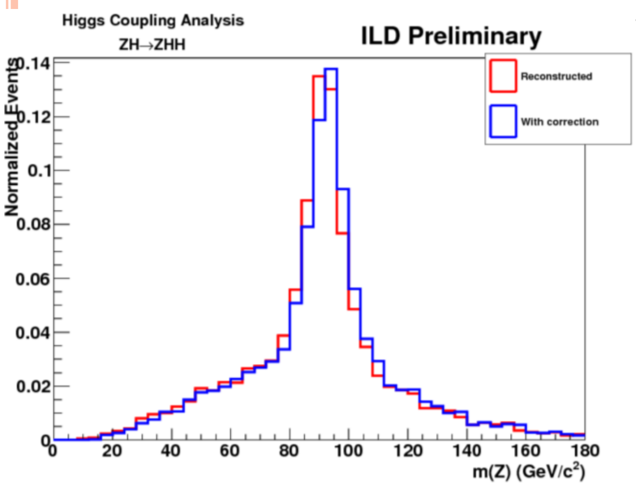


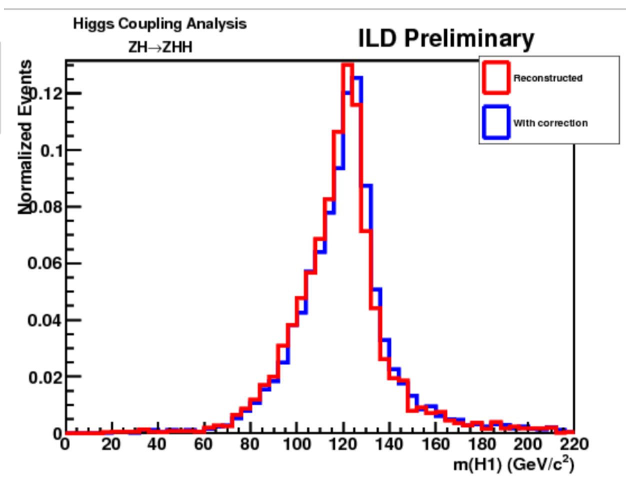
p

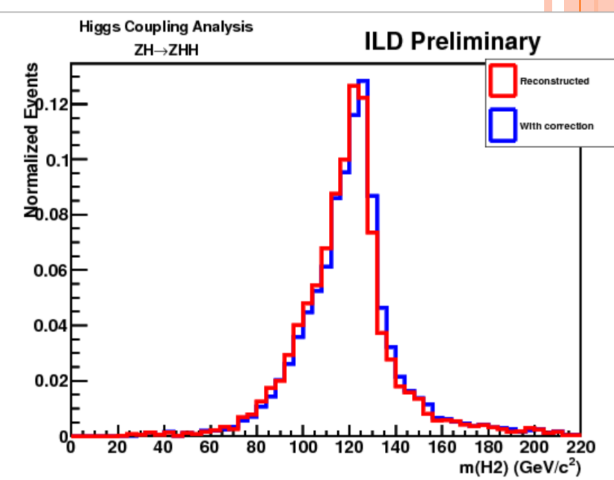
Track energy correction

- Track energies are corrected using momentum & mass
  - Using particle ID to identify tracks
- Visible energy
  - Using qqHH→qq(bb)(bb)
  - So far, overestimated due to misID
  - Correction effect is small due to neutrals
- Mass distribution
  - Checking Z(Z→qq, q is light) and H(H→bb)
  - Jet matching with MC truth is applied
  - Effect is small too due to neutrals



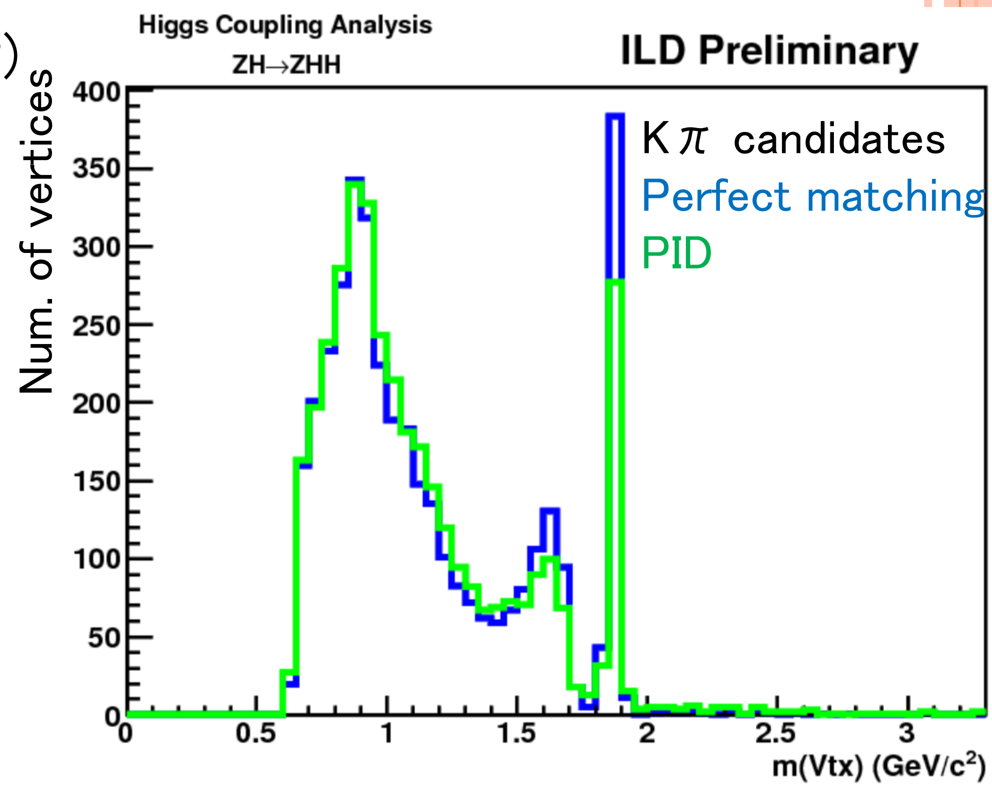






For future study

- Particle ID can be used for b–tagging improvement?
- First trial: vertex mass distribution
- Classifying vertices with particle type using particle ID
- Example: vertex mass with Kπ candidates
  - Vertex is from LCFIPlus
  - Choosing thirdary vertex in bjet(corresponds to Ddecay?)
  - Green–blue will become same if PID is perfect



Summary and Todo

- Explore some fundamental variables for analysis improvement
  - dE/dx in TPC and shower profile

- dE/dx and shower profile information provide ～30% improvement for Isolated lepton ID

- Studying particle ID:
  - Hadron ID eff. is 68%～75%
  - Energy correction effect is small, but going to good direction

- Todo:
  - Particle ID optimization
  - study of B and D decay for flavor tagging improvement
  - Pi0 is important for flavor tagging? → checking pi0 finder?

BACKUPS

Basic idea

- Lepton ID using likelihood is introduced:
  - Lepton selection imposing just one cut
- Target is to find the leptons from W boson as Higgs daughter
  - In some case, lepton energy is so small
  - Form general lepton ID to make the analysis easier
    - Want to apply it to Z lepton finding too
- Likelihood definition:
  - Isolated lepton likeliness

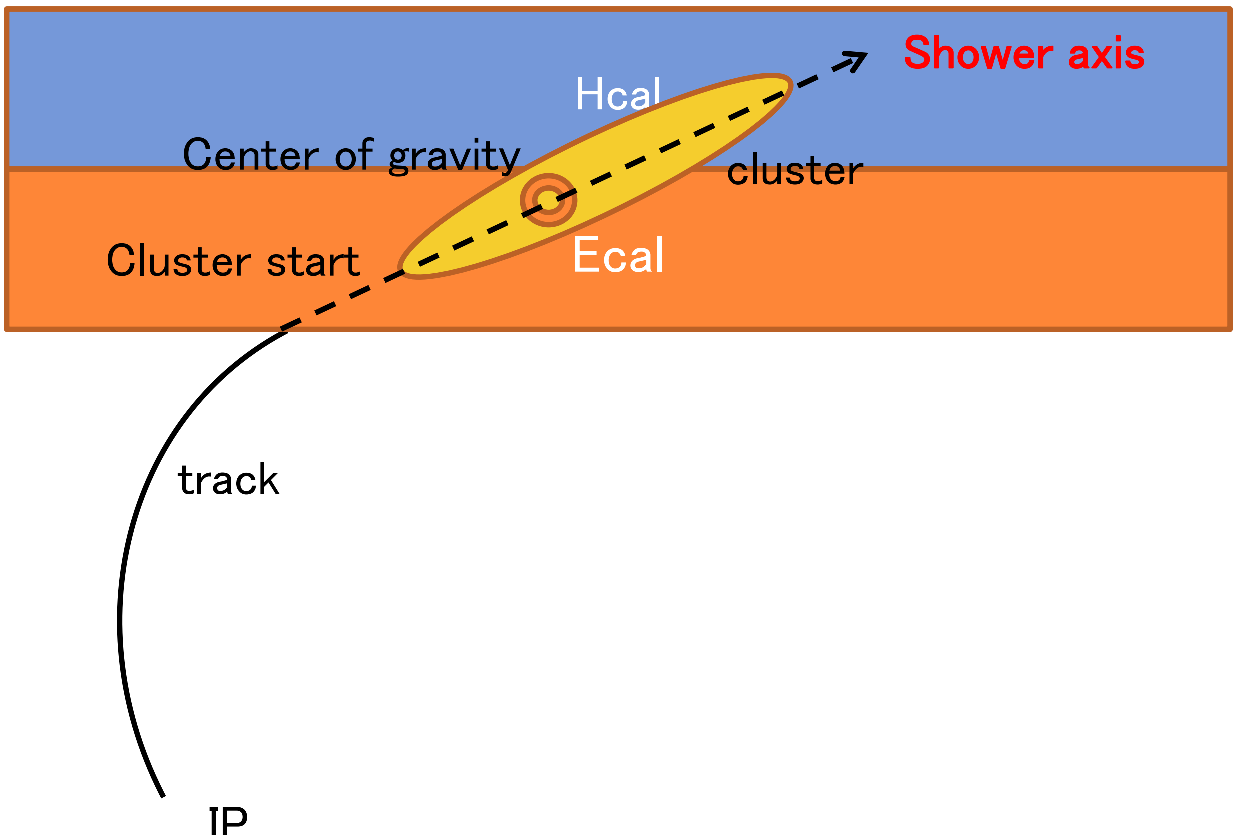
$$L = \frac{\prod s}{\prod s + \prod b},$$

s:pdfs of signal variables

b:pdfs of background variables

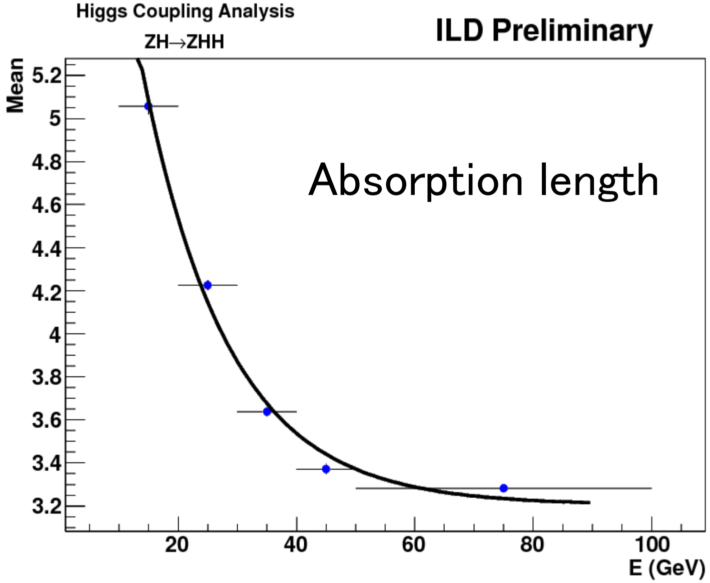
Definition of the shower axis

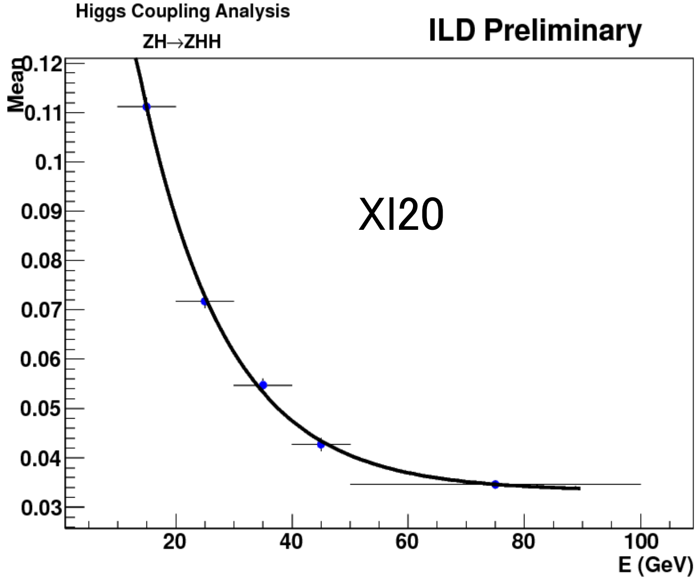
- Shower axis is the direction of the track intruding into calorimeter
  - This correction will change the shower start distribution from last talk
- All the hit points(x,y,z) are converted to longitudinal and transverse components along to the shower axis



CORRECTION

- Mean is corrected to reduce the momentum dependence





- After correction: much better. Dependence reduced