# Recent PFA Performance and Higgs Study using Kinematical Fit

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On behalf of GLD Colleagues

# *Introduction*

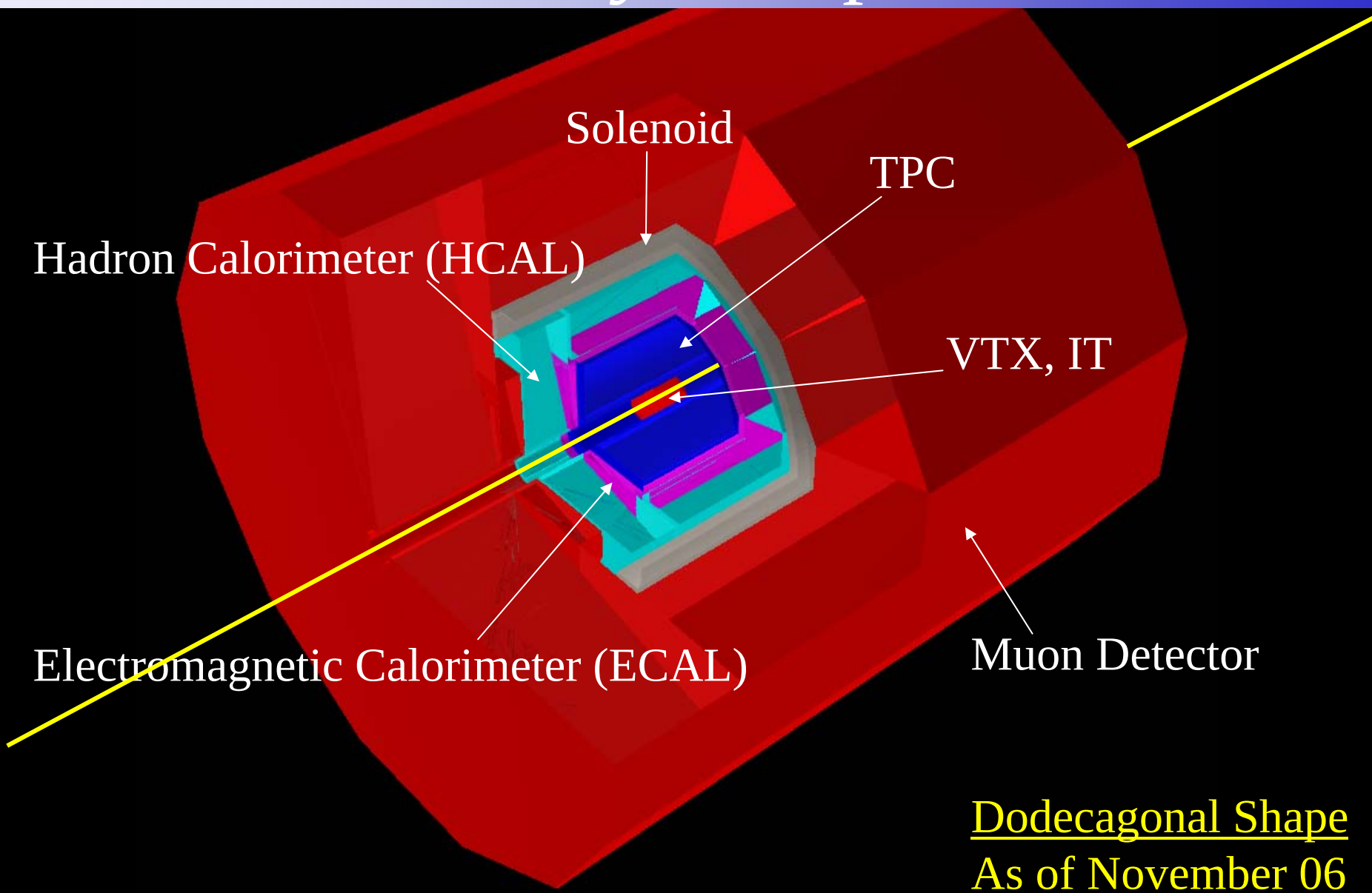
- Most of the important physics processes to be studied in the ILC experiment have multi-jets in the final state.
  → **Jet energy resolution is the key in the ILC physics.**

- The best energy resolution is obtained by reconstructing momenta of individual particles avoiding double counting among Trackers and Calorimeters.
  - Charged particles (~60%) measured by Tracker.
  - Photons (~30%) by electromagnetic CAL (ECAL).
  - Neutral hadrons (~10%) by ECAL + hadron CAL (HCAL).

  → ***Particle Flow Algorithm (PFA)***

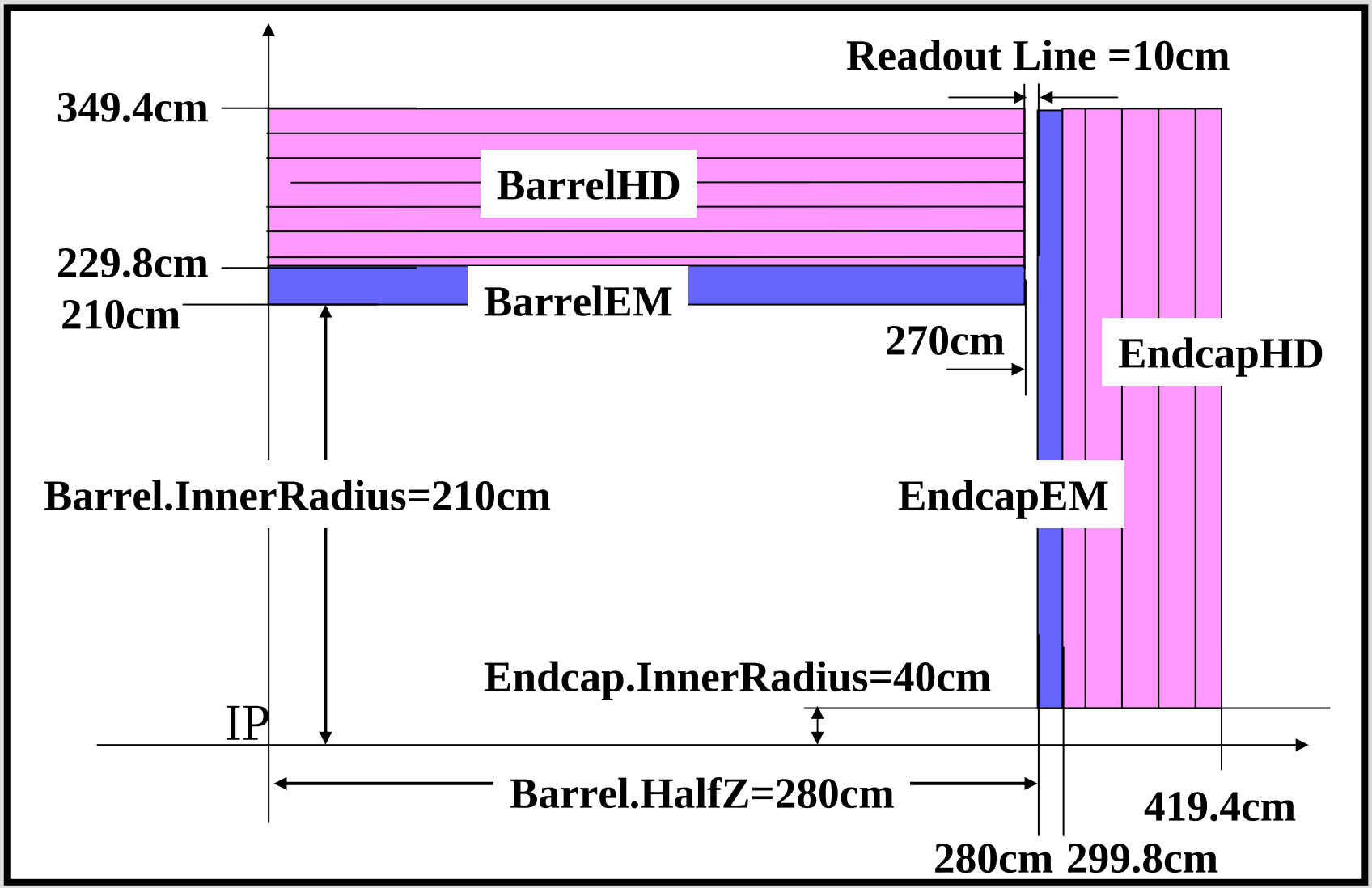
- In this talk, general scheme and performance of the GLD-PFA, using the GEANT4-based full simulator (Jupiter), will be presented.

# *Geometry in Jupiter*

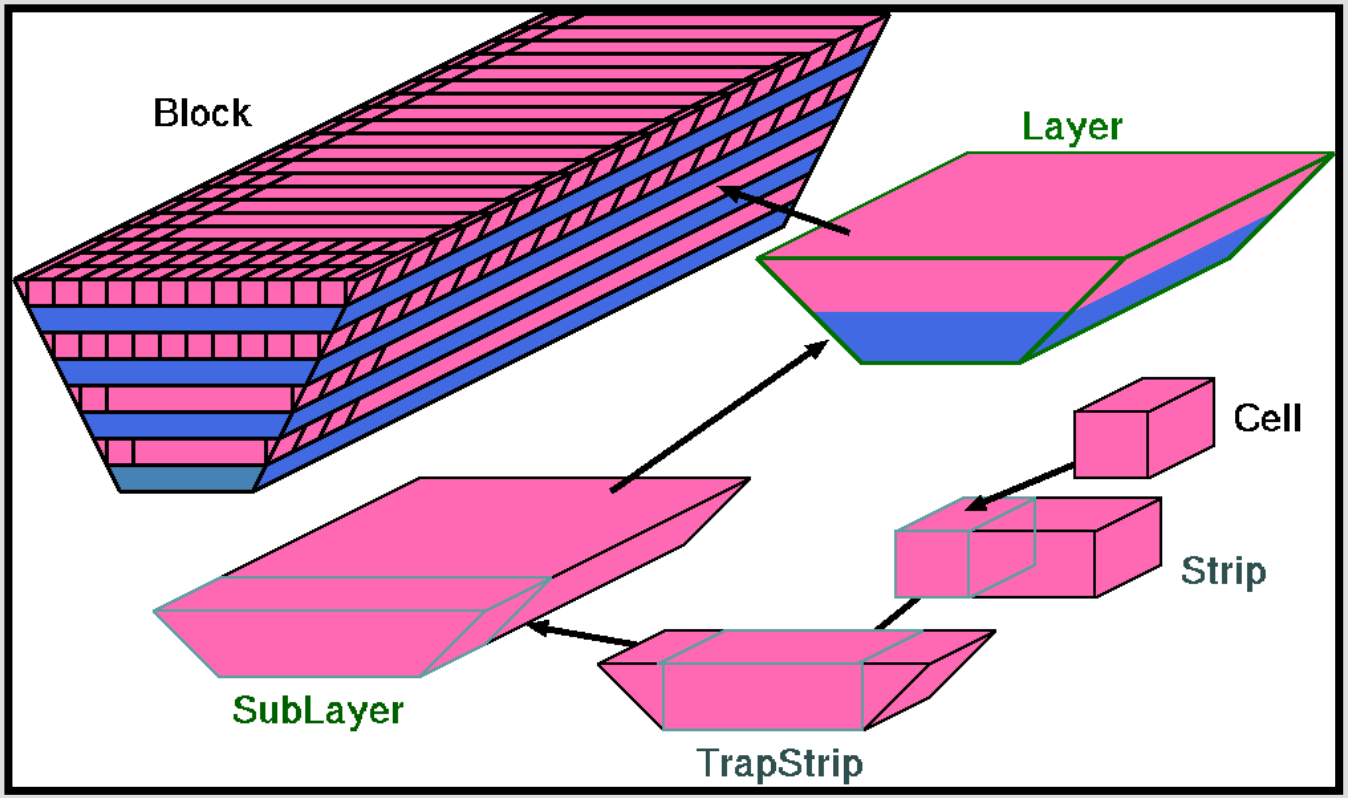



Dodecagonal Shape
As of November 06

# Calorimeter Geometry in Jupiter



# *Calorimeter Structure*




Active Layer

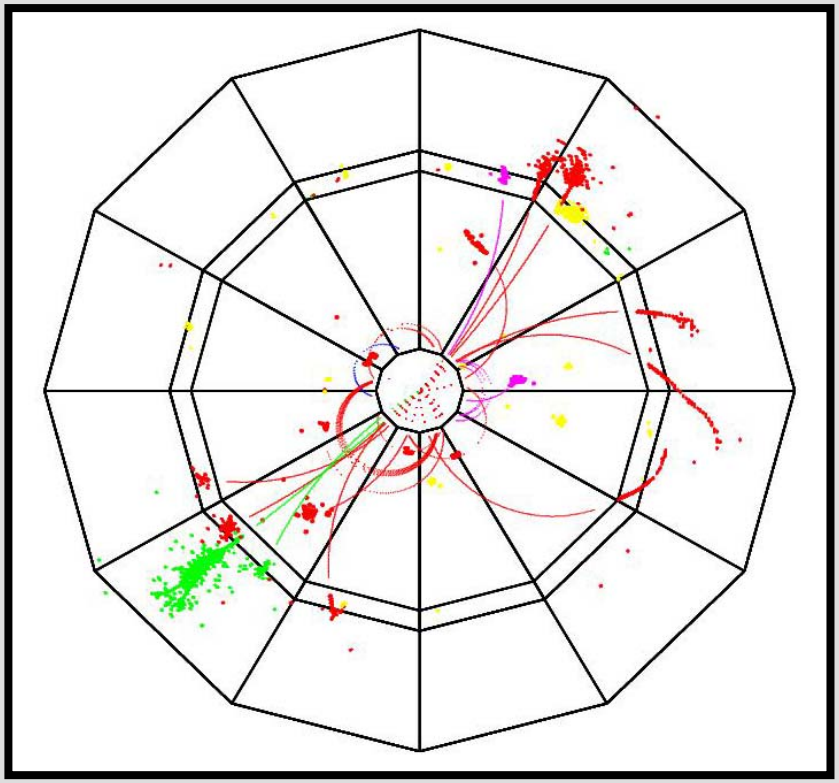
Absorber

**Current cell size : 2x2cm**
**Can be changed.**

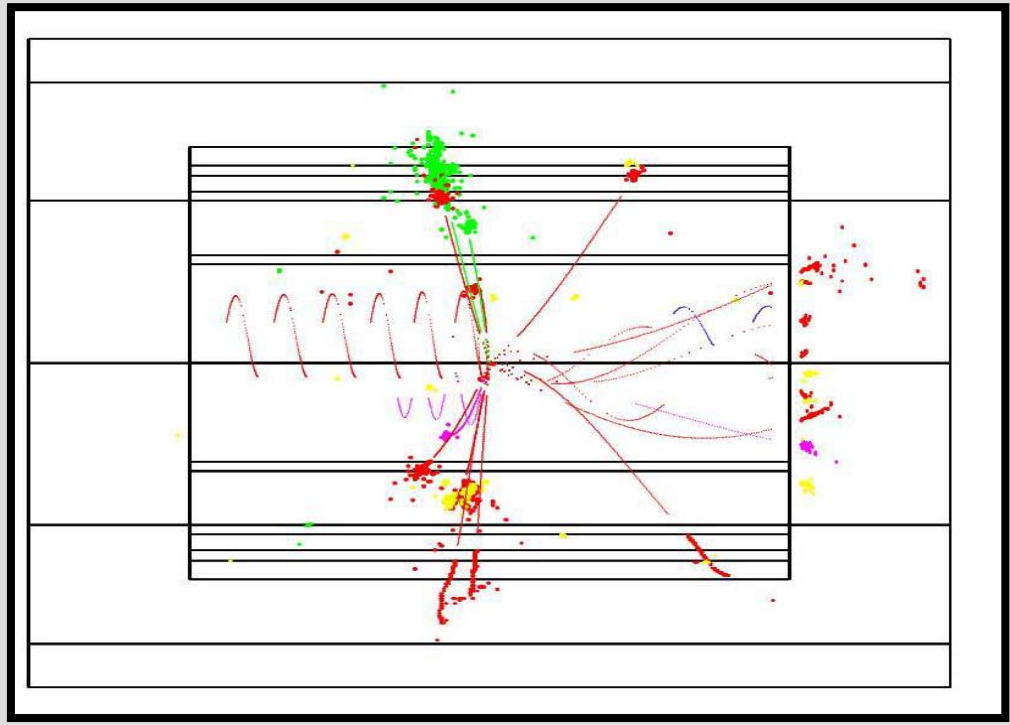
| ECAL | HCAL |
|---|---|
| W/Scinti./Gap | Fe/Scinti./Gap |
| 3/2/1 (mm) x 33 layers | 20/5/1 (mm) x 46 layers |

# *Particle Flow Algorithm*

# *Z-pole Event Display*



End View



Side View

- 2cm x 2cm tile (GLD backup solution) is used in this study.

# *Particle Flow Algorithm for GLD*

**Flow of GLD-PFA**

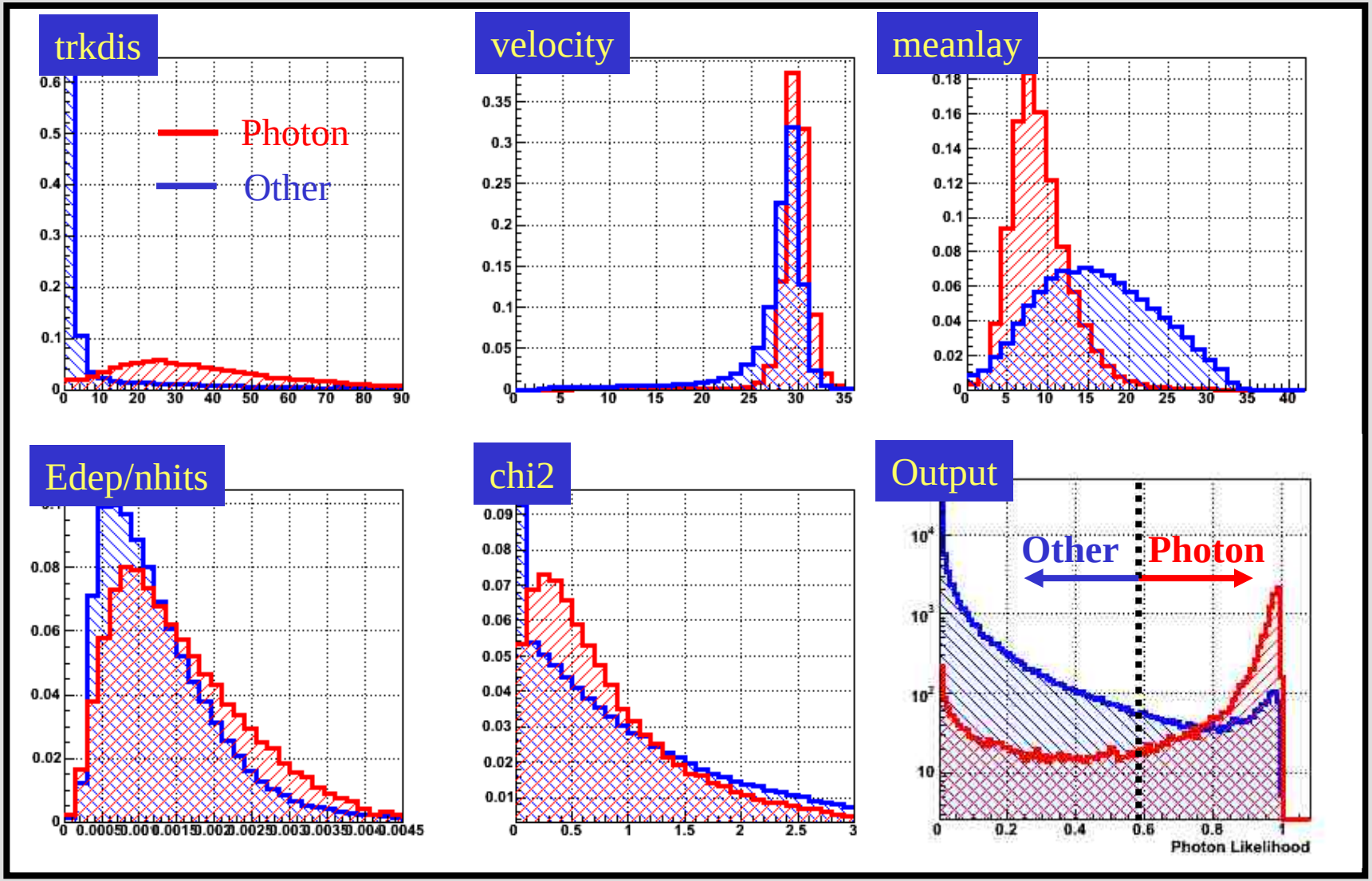
1. Photon Finding
2. Charged Hadron Finding
3. Neutral Hadron Finding
4. Satellite Hits Finding

*Satellite hits = calorimeter hit cell which does not belong to a cluster core

Note : Monte-Carlo truth information is used for muon and neutrino.

# *Photon Likelihood*

- Five variables are selected to form the photon likelihood function.



# *Particle Flow Algorithm for GLD*

**Flow of GLD-PFA**

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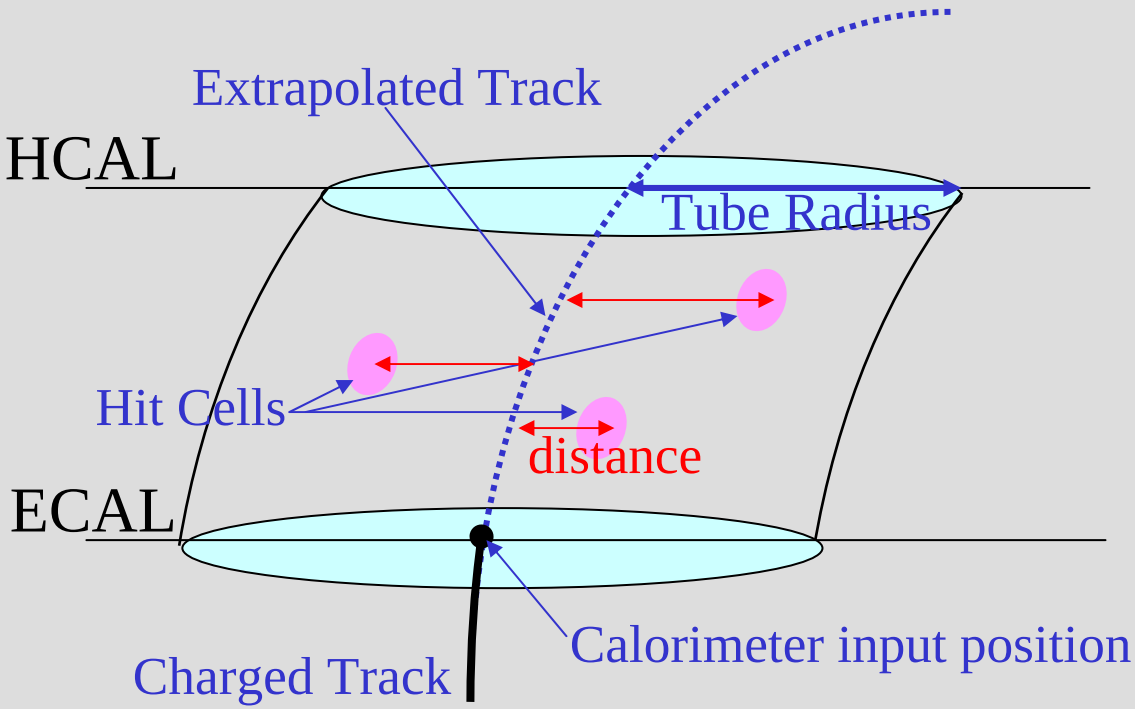
Note : Monte-Carlo truth information is used for muon and neutrino.

# *Charged Hadron Finding*

- ***Basic Concept*** :
  Extrapolate the charged track and calculate a distance between a calorimeter hit cell and the extrapolated track. Connect the cell that in a certain tube radius (clustering).




- Calculate the distance for any track/calorimeter cell combination.

- Tube radius for ECAL and HCAL can be changed separately.

# *Particle Flow Algorithm for GLD*

**Flow of GLD-PFA**

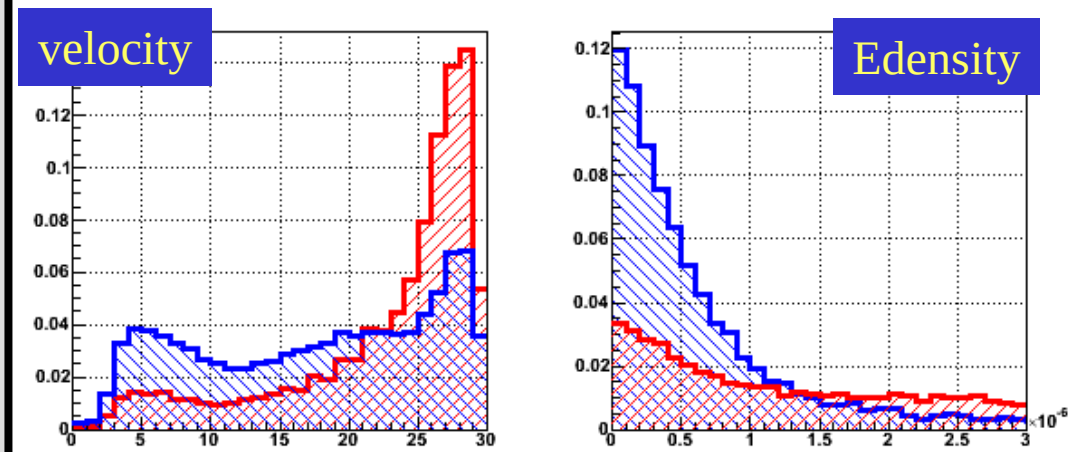
1. Photon Finding
2. Charged Hadron Finding
3. Neutral Hadron Finding
4. Satellite Hits Finding

*Satellite hits = calorimeter hit cell which does not belong to a cluster core

Note : Monte-Carlo truth information is used for muon and neutrino.

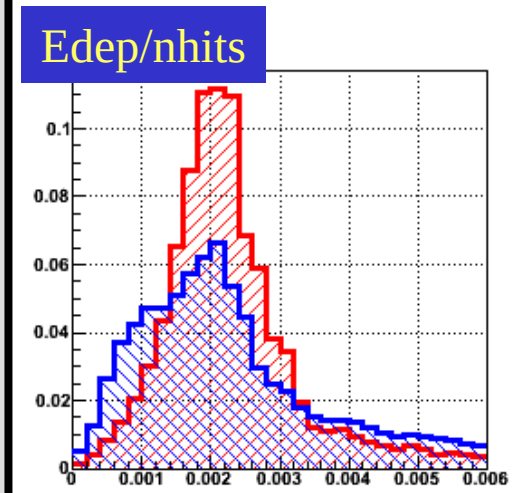
# *Neutral Hadron Likelihood*

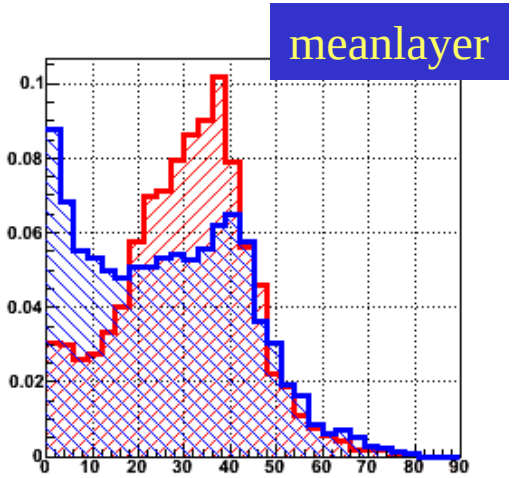
- Four variables are selected to form the NHD likelihood function.

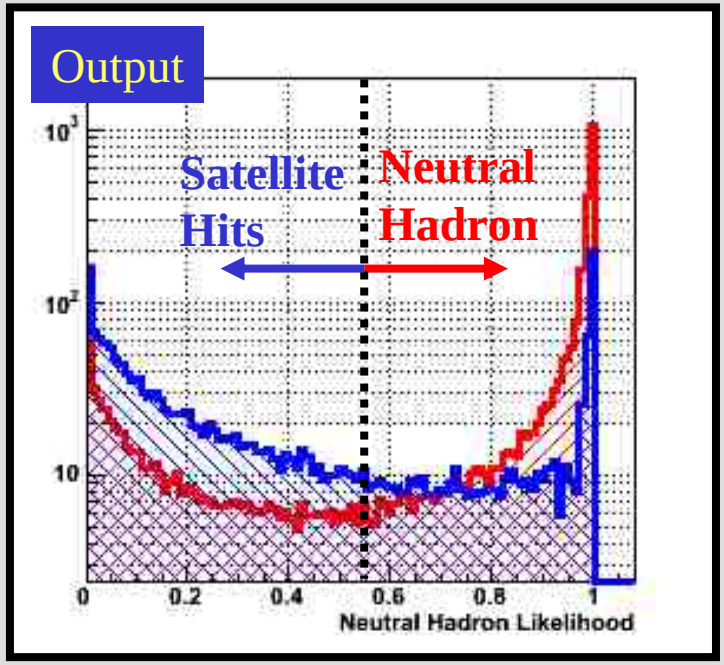








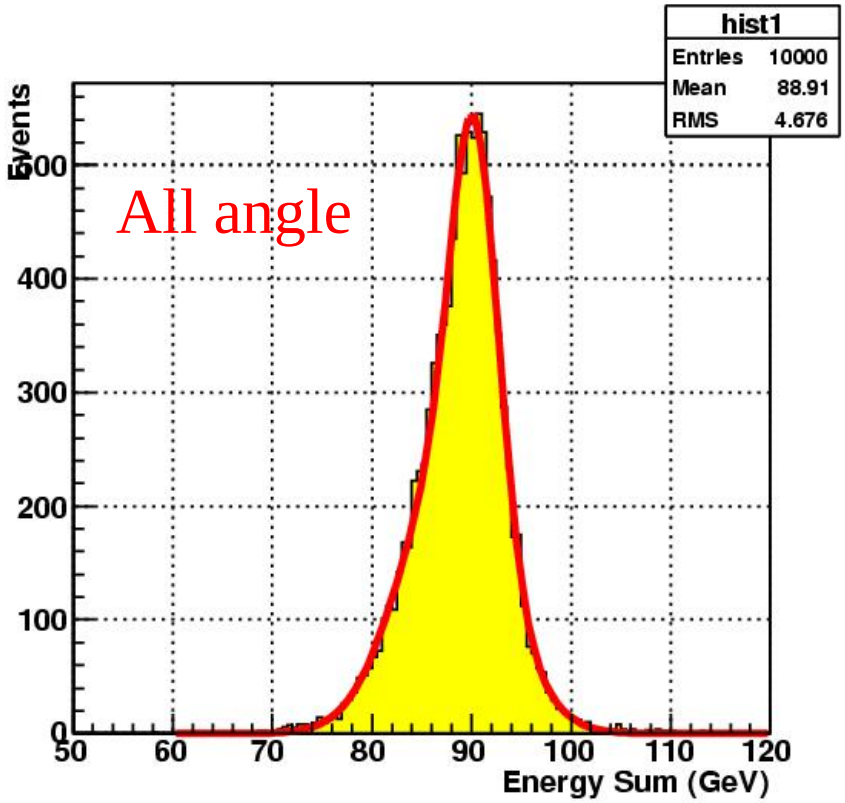



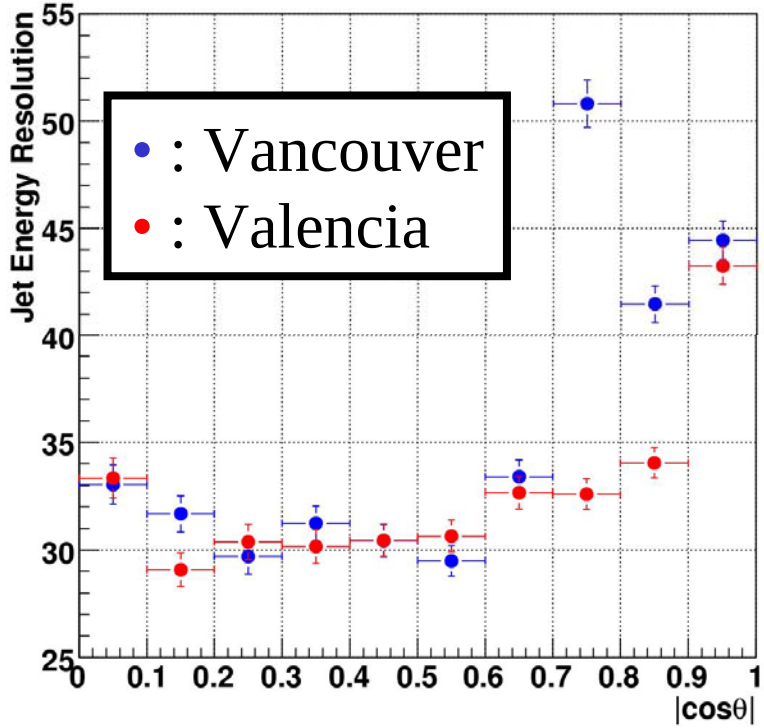

Neutral Hadron

Satellite Hits

# *Jet Energy Resolution (Z-pole)*

- Z → uds @ 91.2GeV, tile calorimeter, 2cm x 2cm tile size

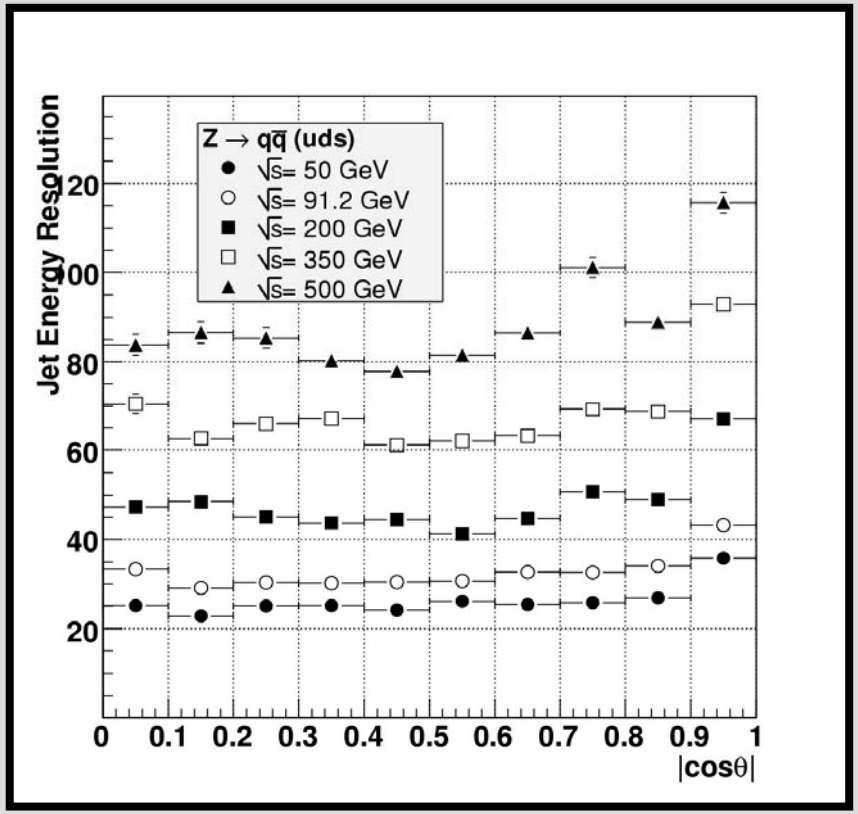


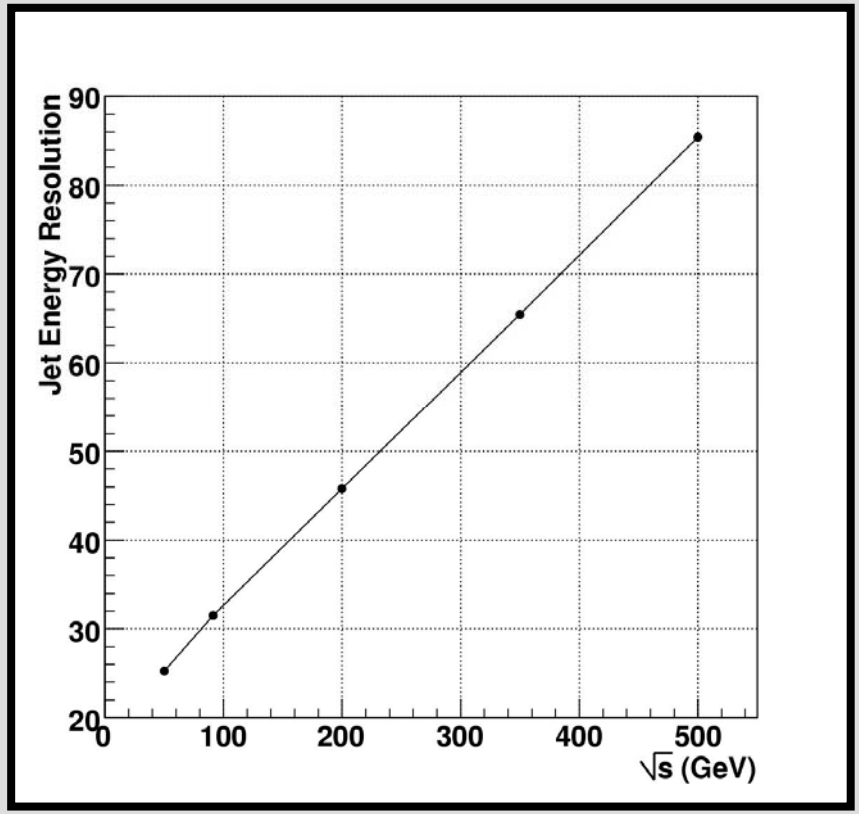




- Performance in the EndCap region is remarkably improved recently.
- Almost no angular dependence : 31%/√E for |cosθ|<0.9.

# *Jet Energy Resolution*

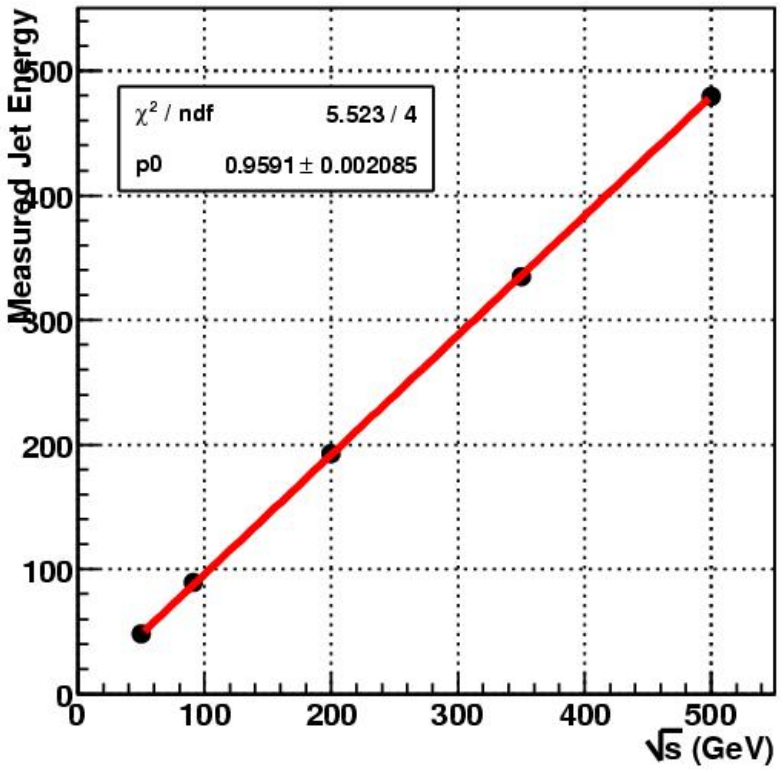
- Energy dependence of jet energy resolution.

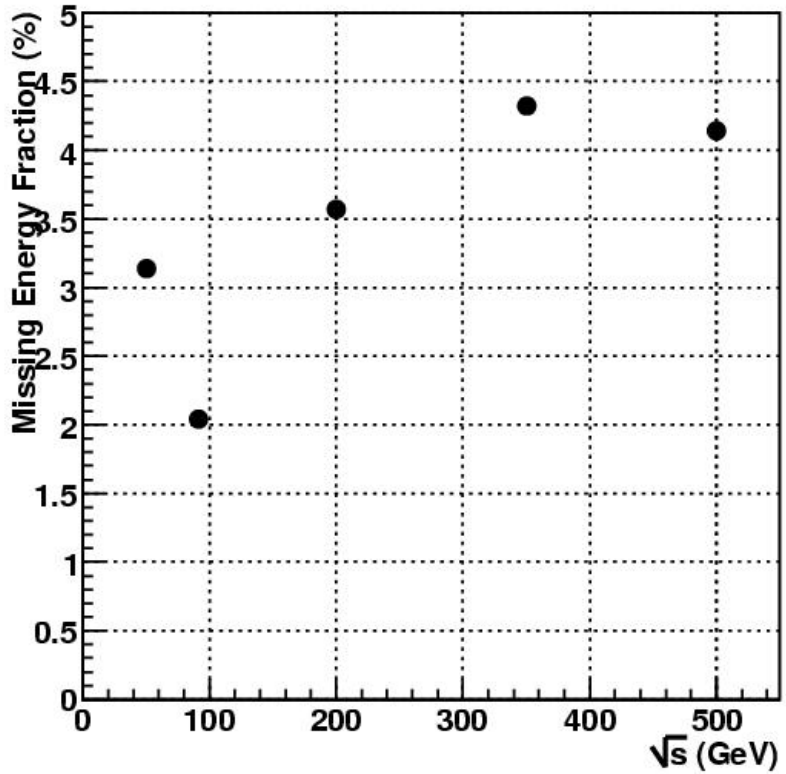



- Jet energy resolution linearly degrades. (Fitting region : $|\cos\theta|<0.9$)

# *Linearity*

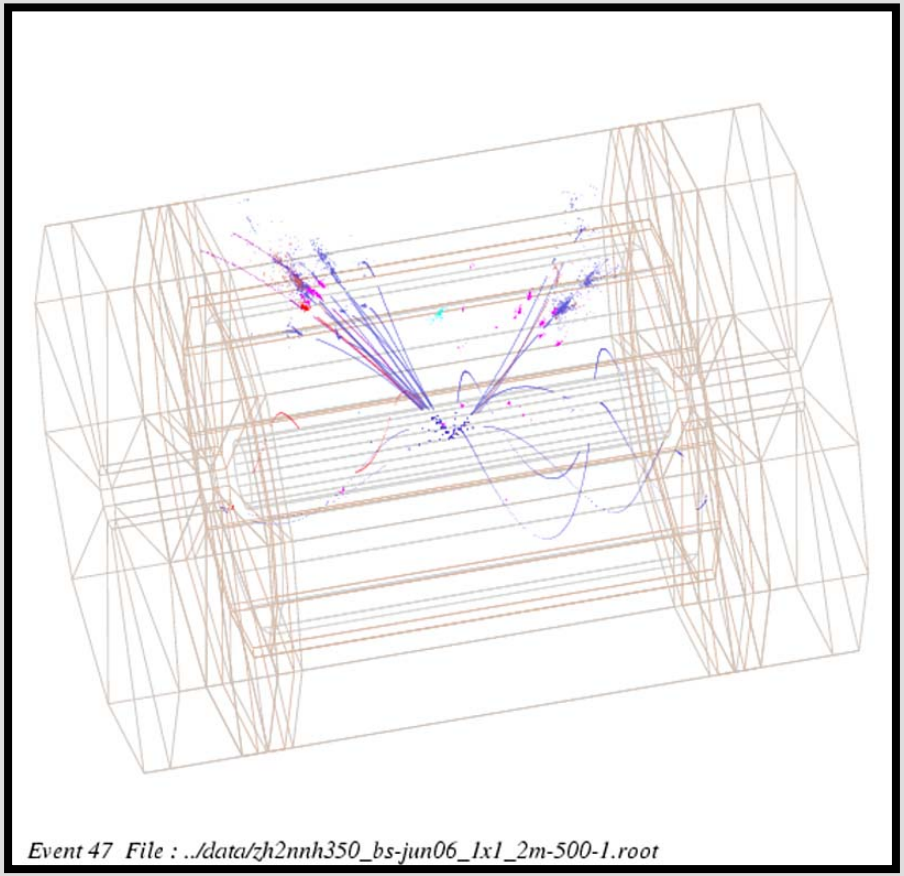


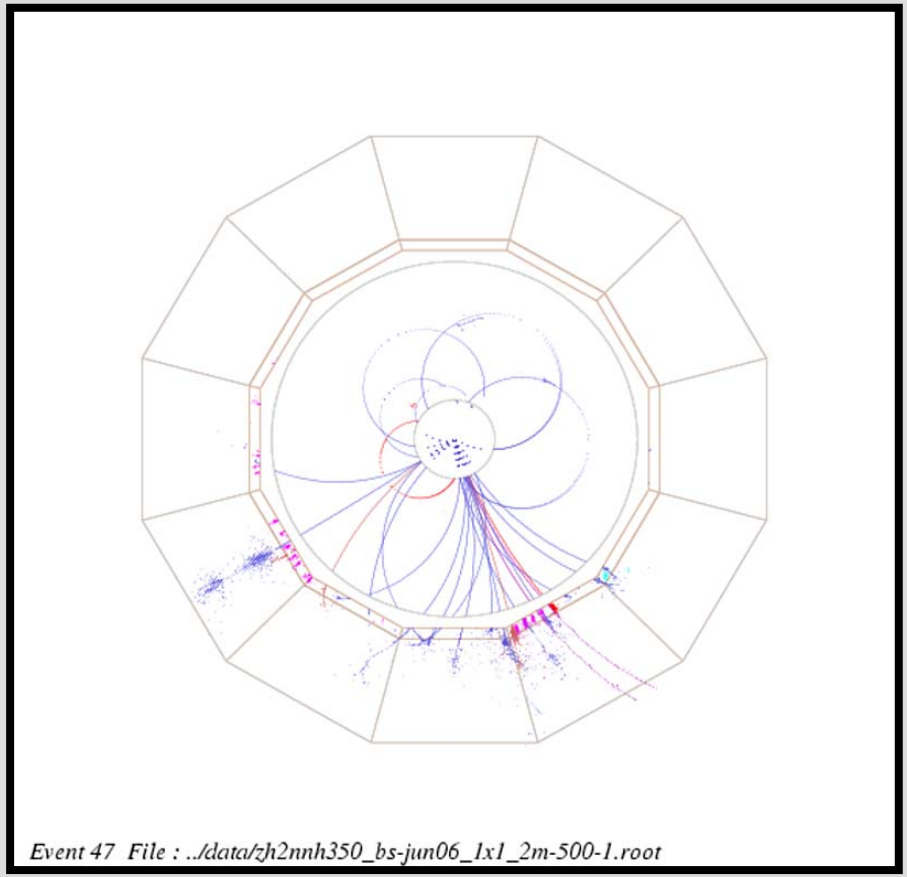




- Good linearity. Jet energy can be corrected.

# *Zh Study*

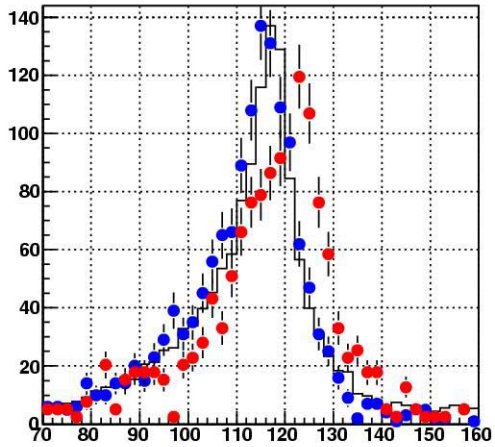
# *Typical Event Display*



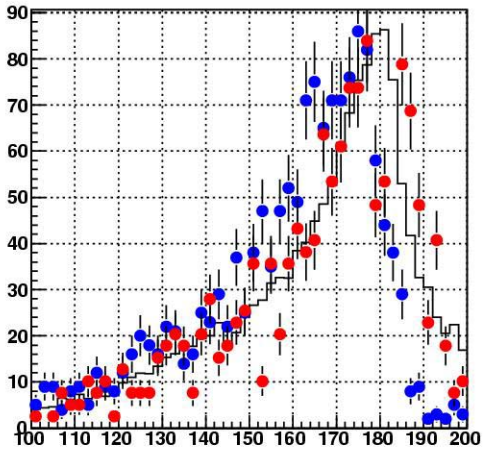




- $ZH \rightarrow \nu\nu h$ : Two jets from Higgs can be seen.

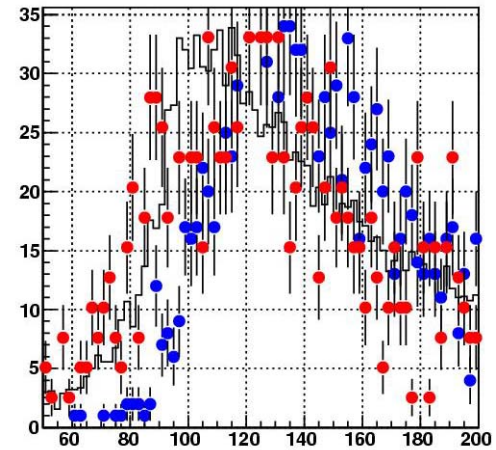
# $Zh \rightarrow \nu\nu h$ @ 350GeV



Higgs Mass



Visible Energy



Missing Mass

- Fast MC
- w/o correction
- w/ correction

- Jet energy is corrected by an empirical formula obtained by Z → qqbar studies.
- Selection Criteria
  - 90 < Evis < 200 GeV
  - pt >20 GeV/c

# *Kinematical Fit (2jet)*

- 6 Measured Variables

  Jet1 : $E_{j1}$, $\theta_{j1}$, $\varphi_{j1}$

  Jet2 : $E_{j2}$, $\theta_{j2}$, $\varphi_{j2}$ (Note : $E_{j1} > E_{j2}$)

- 3 Unmeasured Variables

  Z0 : $E_z$, $\theta_z$, $\varphi_z$

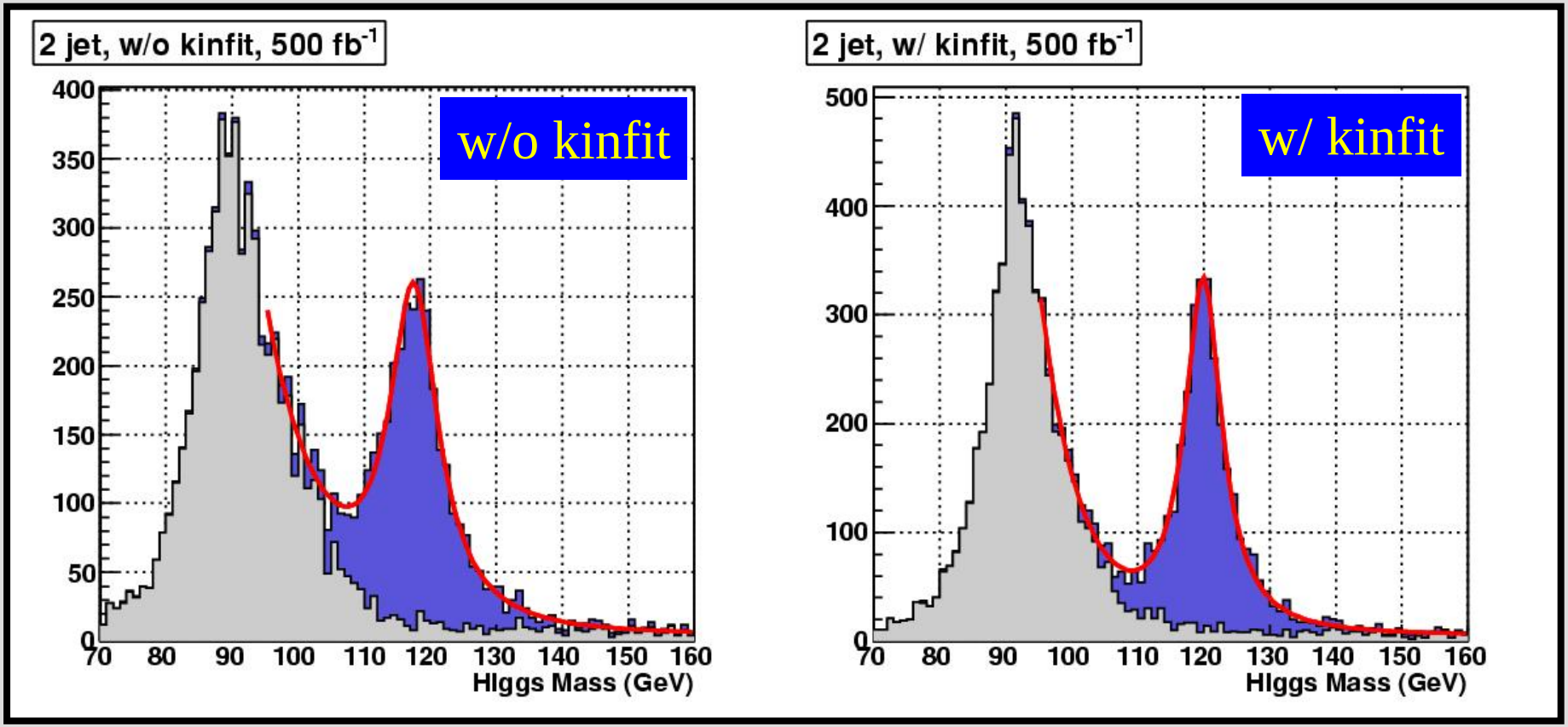
- 4 Constraints

$$p_{j1}\cos\varphi_{j1}\sin\theta_{j1} + p_{j2}\cos\varphi_{j2}\sin\theta_{j2} + p_Z\cos\varphi_Z\sin\theta_Z = 0$$
$$p_{j1}\sin\varphi_{j1}\sin\theta_{j1} + p_{j2}\sin\varphi_{j2}\sin\theta_{j2} + p_Z\sin\varphi_Z\sin\theta_Z = 0$$
$$p_{j1}\cos\theta_{j1} + p_{j2}\cos\theta_{j2} + p_Z\cos\theta_Z = 0$$
$$E_{j1} + E_{j2} + E_z - E_{cm} = 0$$

(Note: jet mass is fixed : $p_{fit} = \sqrt{\{E_{fit}^2 - (E_{meas}^2 - p_{meas}^2)\}}$ )

→ 1C-fit can be performed.

# *Fitted Results (2jet)*




| | δ(σ × Br(h→bb)) | Mh (GeV) | δMh (MeV) |
|---|---|---|---|
| w/o kinfit | 2.04% | 117.5 | 124.8 |
| w/ kinfit | 1.89% | 119.9 | 85.6 |

# *Kinematical Fit (4jet)*

- 12 Measured Variables

Jet1 : $E_{j1}$, $\theta_{j1}$, $\varphi_{j1}$, Jet2 : $E_{j2}$, $\theta_{j2}$, $\varphi_{j2}$ (Higgs pair)

Jet3 : $E_{j3}$, $\theta_{j3}$, $\varphi_{j3}$, Jet4 : $E_{j4}$, $\theta_{j4}$, $\varphi_{j4}$ (Z0 pair)

- 5 Constraints

$$p_{j1}\cos\varphi_{j1}\sin\theta_{j1} + p_{j2}\cos\varphi_{j2}\sin\theta_{j2} + p_{j3}\cos\varphi_{j3}\sin\theta_{j3} + p_{j4}\cos\varphi_{j4}\sin\theta_{j4} = 0$$

$$p_{j1}\sin\varphi_{j1}\sin\theta_{j1} + p_{j2}\sin\varphi_{j2}\sin\theta_{j2} + p_{j3}\sin\varphi_{j3}\sin\theta_{j3} + p_{j4}\sin\varphi_{j4}\sin\theta_{j4} = 0$$

$$p_{j1}\cos\theta_{j1} + p_{j2}\cos\theta_{j2} + p_{j3}\cos\theta_{j3} + p_{j4}\cos\theta_{j4} = 0$$

$$E_{j1} + E_{j2} + E_{j3} + E_{j4} - E_{cm} = 0$$

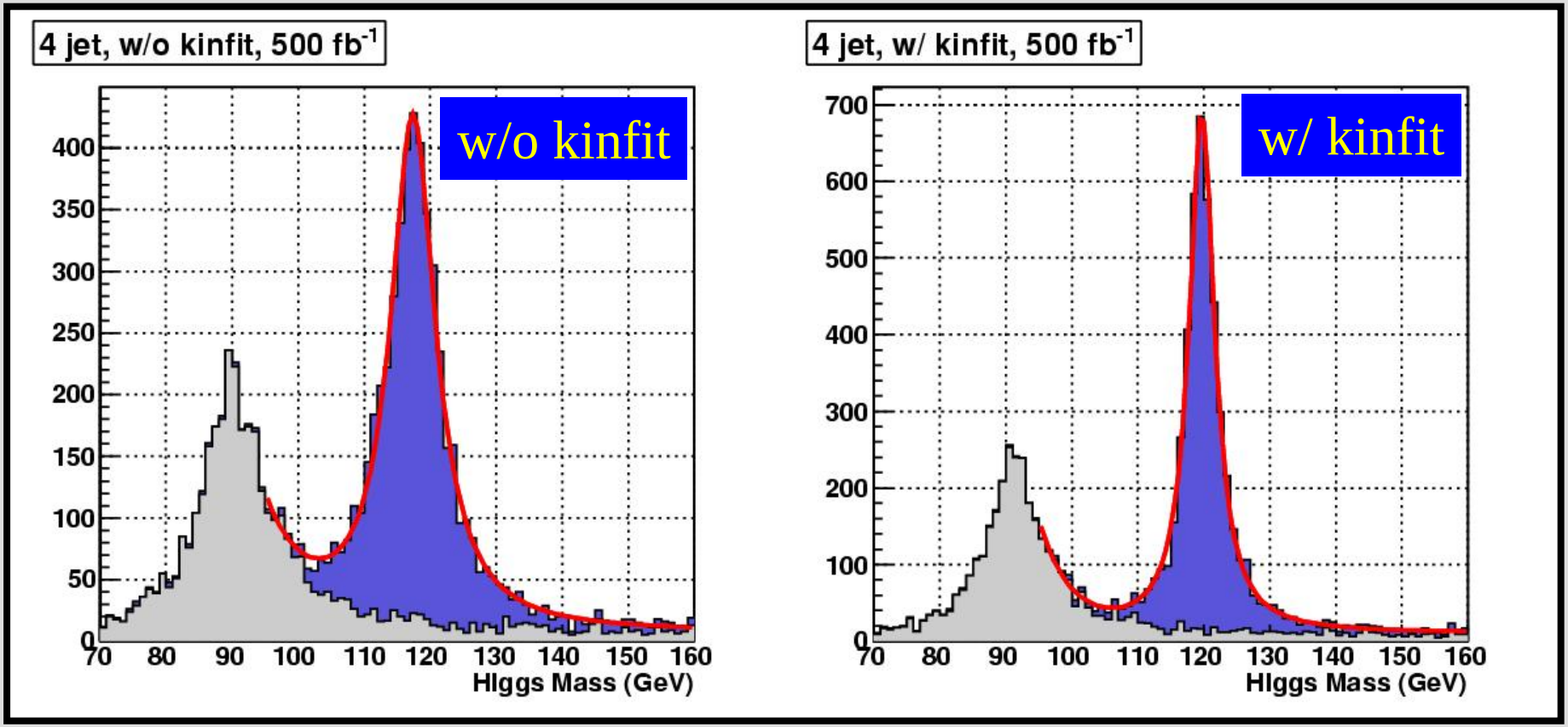
$$E_{j3} + E_{j4} - \sqrt{\{(p_{fit,j3} + p_{fit,j4})^2 + M_z^2\}} = 0$$

(Note: jet mass is fixed (OPAL method)

$$p_{fit} = \sqrt{\{E_{fit}^2 - (E_{meas}^2 - p_{meas}^2)\}}\ )$$

→ 5C-fit can be performed.

# *Fitted Results (4jet)*




| | $\delta(\sigma \times Br(h \rightarrow bb))$ | Mh (GeV) | $\delta$Mh (MeV) |
|---|---|---|---|
| w/o kinfit | 1.5% | 117.4 | 84.6 |
| w/ kinfit | 1.5% | 119.7 | 49.2 |

# *Summary*

- Realistic PFA has been developed using the GEANT-4 based full simulator of the GLD detector.
- Jet energy resolution is studied by using Z->qq events. ILC goal of 30% has been achieved for Z-pole events.
- ZH study based on current PFA performance is now ongoing. Kinematical fitting is employed to get a better performance.