Study of kinematic fit for Higgs->inv.

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kinematic fit

- We want to improve recoil mass resolution of Higgs->inv. analysis.

$$e^{-}e^{+} \to ZH, Z \to qq, H \to invisible$$

$$M_{rec}^2 = (\sqrt{s} - E_Z)^2 - |\vec{p}_Z|^2$$

- Apply kinematic fit

  minimize χ^2 under constraints => method of Lagrange multipliers

$$\chi^2 = \left(\vec{\eta}_{fit} - \vec{\eta}_{meas}\right)^T V^{-1}\left(\vec{\eta}_{fit} - \vec{\eta}_{meas}\right) + 2\vec{\lambda}^T \cdot \vec{f}$$

  - measured parameters $\vec{\eta}$: $E_{j1}, \theta_{\mathrm{j}1}, \phi_{j1}, E_{j2}, \theta_{\mathrm{j}2}, \phi_{j2}$
  - constraint function $\vec{f}$: $m_{j1,j2} = m_Z = 91.2\ \mathrm{GeV}$, ($\beta_{j1} = |p_{j1}|/E_{j1},\ \beta_{j2} = |p_{j2}|/E_{j2}$)
  - covariance matrix V : $\sigma_E = 40\% \cdot \sqrt{E},\ \sigma_\theta = 0.1rad,\ \sigma_\phi = 0.1rad$

- Use MarlinKinfit

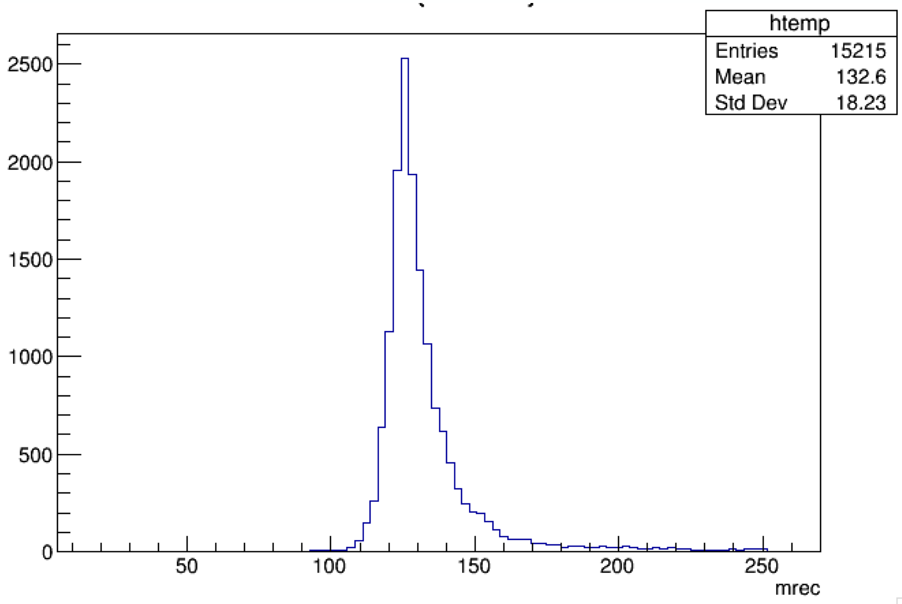
  fitter engine : NewtonFitter

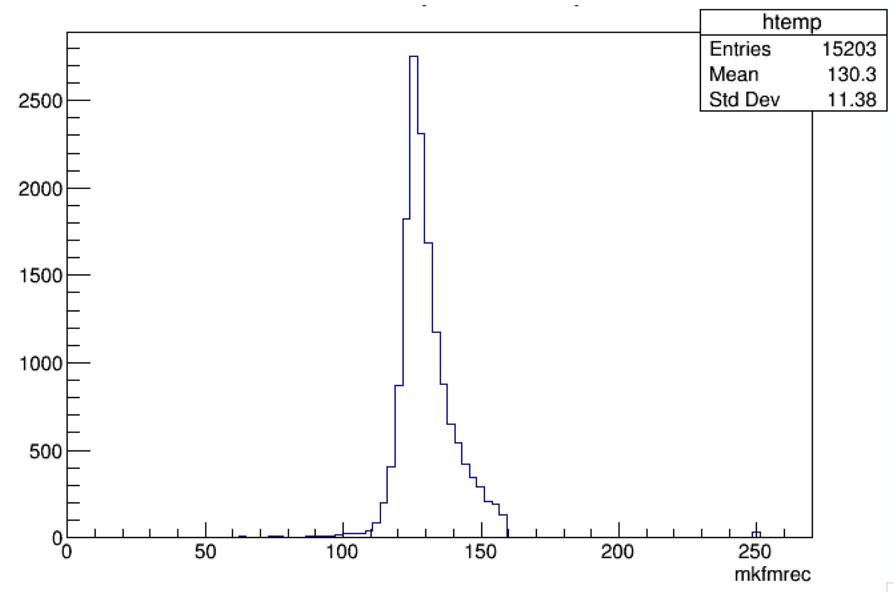
  samples : ffH_ZZ_4n { ILD_l4_v02, ILD_s4_v02, (ILD_o1_v05) }

- Status
  - there may be some bugs .....

- Plan
  - adjust jet energy resolution for each event
  - apply BW mass constraint
  - consider ISR effect (include aa_lowpt overlay)
  - make my own kinematic fitter

MarlinKinfit result





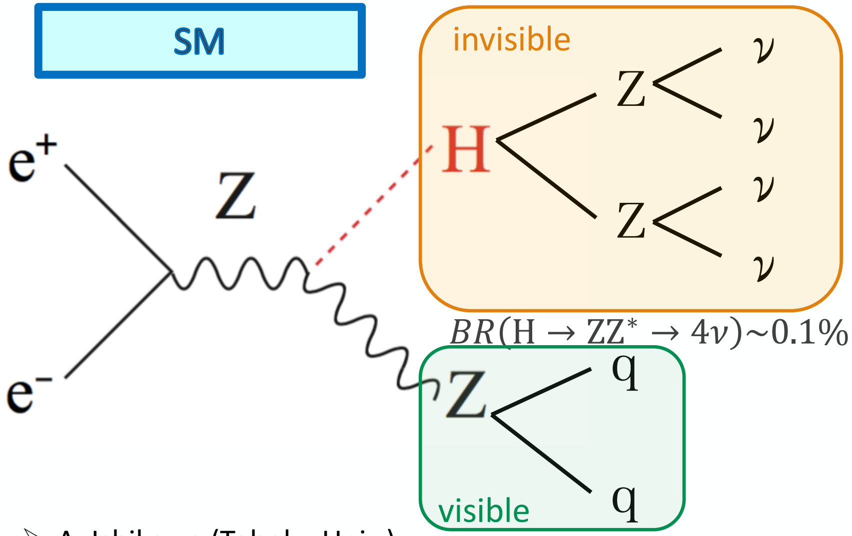
backup

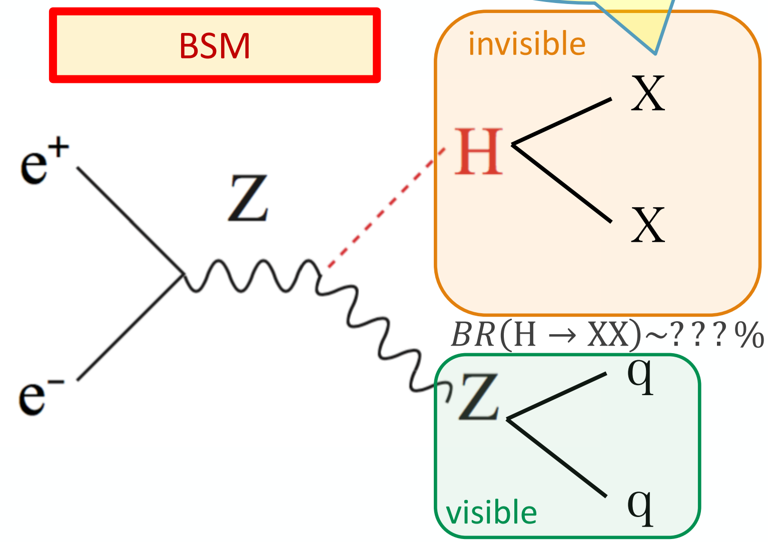
Motivation

- In SM, Higgs decays invisibly through
  $H \to ZZ^* \to 4\nu$ (BR($H \to inv.$)~0.1%)
- If BR($H \to inv.$) exceeds SM prediction ,
  it signifies new physics beyond SM (BSM)
- We estimate SM upper limit of BR($H \to inv.$)
- Compare between left & right polarization at the ILC

LHC CMS result (95% CL)
observed (expected)
24% (23%)

Dark Matter…
SUSY…





- A. Ishikawa (Tohoku Univ.),
”Search for Invisible Higgs Decays at the ILC” LCWS2014@Belgrade
- M. A. Thomson (Univ. of Cambridge), arXiv: 1509.02853 (2015)

The Mathematics of the NewtonFitter

N parameters a_i, $i = 1...N$ Measured values $\vec{y}$, covarianve matrix V

K constraint funtions $\vec{f}(\vec{a})$

The total χ^2: $\chi_T^2(\vec{a}, \vec{\lambda}) = \chi^2(\vec{a}, \vec{y}) + \vec{\lambda}^T \cdot \vec{f}(\vec{a}).$

Seek stationary point, where all derivatives vanish:

$$
\begin{aligned}
\nabla_a \chi_T^2 &= \nabla_a \chi^2 + \vec{\lambda}^T \cdot \nabla_a \vec{f}(\vec{a}) = \vec{0}, \qquad (N \text{ equations}) \\
\nabla_\lambda \chi_T^2 &= \vec{f}(\vec{a}) = \vec{0}, \qquad (K \text{ equations})
\end{aligned}
\qquad
\begin{pmatrix} 0 \\ 0 \end{pmatrix} = \begin{pmatrix} \frac{\partial \chi_T^2}{\partial \vec{a}} \\ \frac{\partial \chi_T^2}{\partial \vec{\lambda}} \end{pmatrix} = \begin{pmatrix} \frac{\partial \chi^2}{\partial a_i} + \sum_k \lambda_k \cdot \frac{\partial f_k}{\partial a_i} \\ f_k \end{pmatrix}
$$

Newton-Raphson iterative method to solve *y*(*x*)=0:

$$x^{\nu+1} = x^\nu - \frac{y(x^\nu)}{y'(x^\nu)} \quad \text{=> solve} \quad y'(x^\nu) \cdot (x^\nu - x^{\nu+1}) = y(x^\nu)$$

Here: Solve this system of equations in each step:

$$
\left(\begin{array}{ccc|ccc}
\frac{\partial^2 \chi^2}{\partial a_1 \partial a_1} + \lambda_k \cdot \frac{\partial^2 f_k}{\partial a_1 \partial a_1} & \cdots & \frac{\partial^2 \chi^2}{\partial a_1 \partial a_N} + \lambda_k \cdot \frac{\partial^2 f_k}{\partial a_1 \partial a_N} & \frac{\partial f_1}{\partial a_1} & \cdots & \frac{\partial f_K}{\partial a_1} \\
\cdots & & \cdots & \cdots & & \cdots \\
\frac{\partial \chi^2}{\partial a_N \partial a_1} + \lambda_k \cdot \frac{\partial^2 f_k}{\partial a_N \partial a_1} & \cdots & \frac{\partial^2 \chi^2}{\partial a_N \partial a_N} + \lambda_k \cdot \frac{\partial^2 f_k}{\partial a_N \partial a_N} & \frac{\partial f_1}{\partial a_N} & \cdots & \frac{\partial f_K}{\partial a_N} \\
\hline
\frac{\partial f_1}{\partial a_1} & \cdots & \frac{\partial f_1}{\partial a_N} & 0 & \cdots & 0 \\
\cdots & & \cdots & \cdots & & \cdots \\
\frac{\partial f_K}{\partial a_1} & \cdots & \frac{\partial f_K}{\partial a_N} & 0 & \cdots & 0
\end{array}\right)
\cdot
\left(\begin{array}{c}
a_1^\nu - a_1^{\nu+1} \\ \cdots \\ a_N^\nu - a_N^{\nu+1} \\ \hline \lambda_1^\nu - \lambda_1^{\nu+1} \\ \cdots \\ \lambda_K^\nu - \lambda_K^{\nu+1}
\end{array}\right)
=
\left(\begin{array}{c}
\frac{\partial \chi^2}{\partial a_1} + \lambda_k^\nu \cdot \frac{\partial f_k}{\partial a_1} \\ \cdots \\ \frac{\partial \chi^2}{\partial a_N} + \lambda_k^\nu \cdot \frac{\partial f_k}{\partial a_N} \\ \hline f_1 \\ \cdots \\ f_K
\end{array}\right)
$$

B. List 20.2.2008 (Marlin)Kinfit: Kinematic Fitting for the ILC Page 12

Jet energy resolution study