Matrix Element Method for ILC Physics Analysis

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http://ilcphys.kek.jp/meeting/physics/archives/2009-05-19/GGGuide.pdf

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MEM: maximal use of event kinematics

(approach the true likelihood of each event)

- one of the Multivariate methods
- first used for precision top mass measurement at D0
- recently used for the H—>ZZ*—>4l analysis in Higgs discovery by CMS
- not being widely used comparing to BDT, MVA, but to me MEM is even more interesting

What is Matrix Element (Amplitude)

(squared ~ differential cross section)

Cross Section Formula

$$e^+e^- \to X_1 + \cdots + X_f + \cdots + X_n$$

(p^-, s^-) (p^+, s^+) (p_f, s_f)

$$d\sigma = \frac{1}{2s\beta_e} \sum_{s^+, s^-, s_f} w_{s^+} w_{s^-} |\mathcal{T}_{fi}|^2 d\Phi_n$$

spin weight for e^-

spin weight for e^+

$$w_{s=\pm} = \frac{1 \pm P_s}{2} \qquad \left(-1 \le P_s = \frac{N_+ - N_-}{N_+ + N_-} \le +1\right)$$

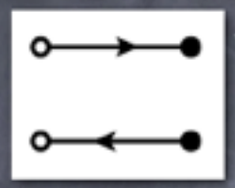
$$\mathcal{T}_{fi} = \langle p_f, s_f | \hat{T} | p^+, s^+; p^-, s^- \rangle$$

(technically, ME2 is the weight of each phase space point)

tools to calculate ME (thank Fujii-san!)

Helicity Amplitudes: HELAS

External Lines

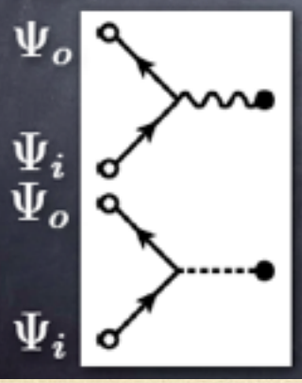


4-momentum, helicity, particle, spinor, mass, anti-particle

$IXXXXX(p, m, \lambda, \pm 1, \Psi_i)$

$OXXXXX(p, m, \lambda, \pm 1, \Psi_o)$

Currents



incoming spinor, outgoing spinor, width, mass, wave fun.

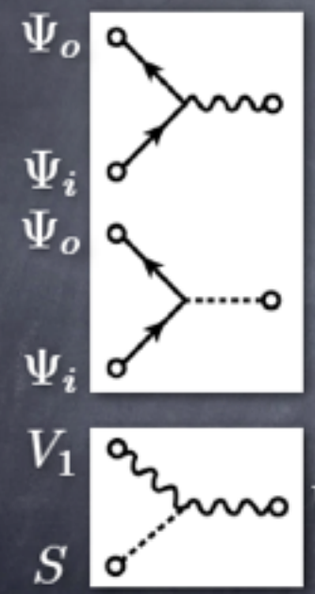
$JIOXXX(\Psi_i, \Psi_o, G_V, m_V, \Gamma_V, V)$

$G_V(1)$: left, (2) : right

$HIOXXX(\Psi_i, \Psi_o, G_S, m_S, \Gamma_S, S)$

wave fun.

Vertices



incoming spinor, outgoing spinor, vector, amplitude

$IOVXXX(\Psi_i, \Psi_o, V, G_V, A)$

$G_V(1)$: left, (2) : right

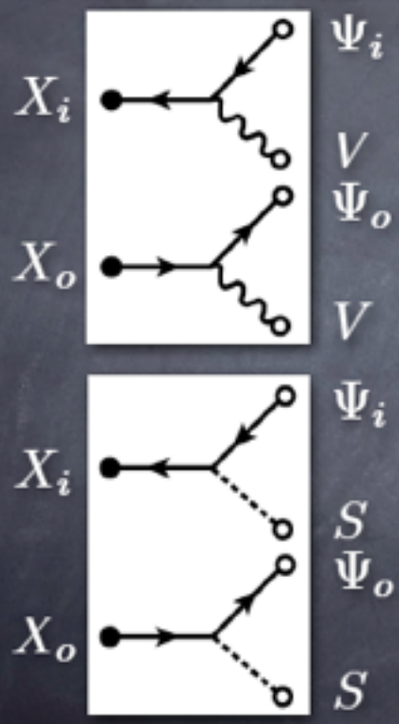
$IOSXXX(\Psi_i, \Psi_o, S, G_S, A)$

scalar

$VVSXXX(V_1, V_2, S, G_{VVS}, A)$

Note: there are some more subroutines in HELAS (see manual)

Virtual Fermions



incoming spinor, vector, mass, width

$FVIXXX(\Psi_i, V, G_V, m_X, \Gamma_X, X_i)$

$G_V(1)$: left, (2) : right; incoming virtual spinor

$FVOXXX(\Psi_o, V, G_V, m_X, \Gamma_X, X_o)$

outgoing spinor; outgoing virtual spinor

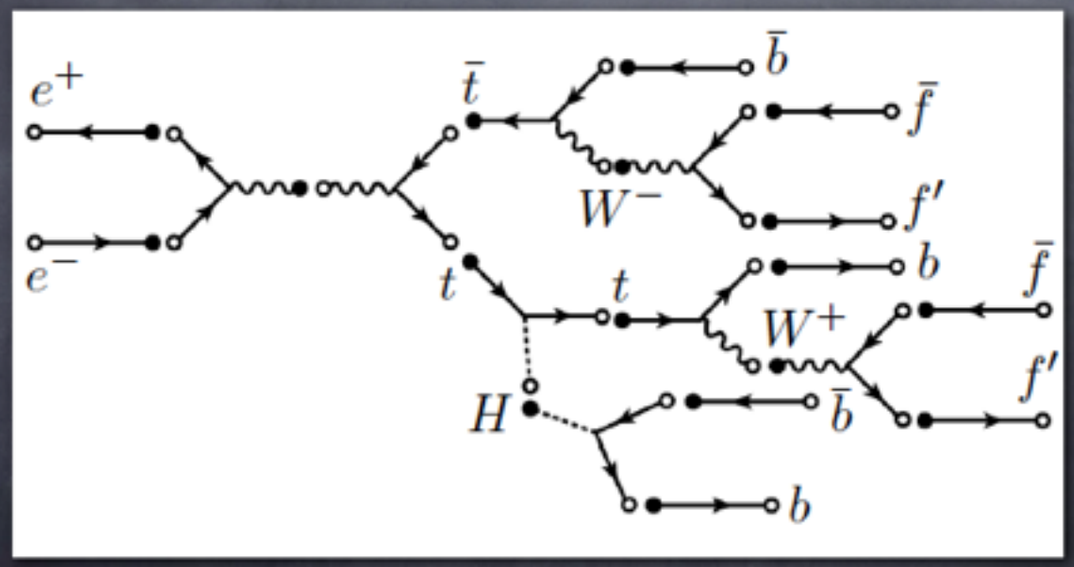
$FSIXXX(\Psi_i, S, G_S, m_X, \Gamma_X, X_i)$

scalar

$FSOXXX(\Psi_o, S, G_S, m_X, \Gamma_X, X_o)$

Composition of Full Amplitude

$e^+e^- \to t\bar{t}H$



Note: there are some other diagrams
See physsim/top/TTHStudy

how to calculate ME in our processors

- export physsim to ilcsoft (only HELLib, GENLib needed), done.
- simplify generator source code to provide ME, example of ZHHBases ready.
- the above libraries will be common as an independent package of ilcsoft (will include as many different processes as we need).
- in analysis processor, each event we only need provide four momentum of final states (parton level) to XXXBases class.

`login.cc.kek.jp:/home/ilc/tianjp/analysis/PostDBD/MEM/lib/libPhyssim.so`

`/home/ilc/tianjp/analysis/PostDBD/MEM/example/src/MEMExampleProcessor.cc`

(preliminary)

Detector Effect

- unfortunately, the four momentum we measured have resolution —> we need detector transfer function (jet-energy resolution, momentum resolution, etc.) and integrate all possible truth four momentum.

- and even worse, some four momentum can not be measured (missing neutrinos) —> integrate all possible truth four momentum.

$$L(\mathbf{p}_i^{\rm vis}|\mathbf{a}) = \frac{1}{\sigma_{\mathbf{a}}}[\prod_{j\in{\rm inv.}}\int\frac{d^3p_j}{(2\pi)^3 2E_j}][\prod_{k\in{\rm vis.}}\int\frac{d^3p_k}{(2\pi)^3 2E_k}W_i(\mathbf{p}_i^{\rm vis}|p_k,\mathbf{a})]|M(p_j,p_k;\mathbf{a})|^2$$

ongoing, lots of study needed, anyone interested in this study is very welcome to join the effort