HWW, ZHH, IsoLep, Overlay, GFit, MEM: Status and Plan

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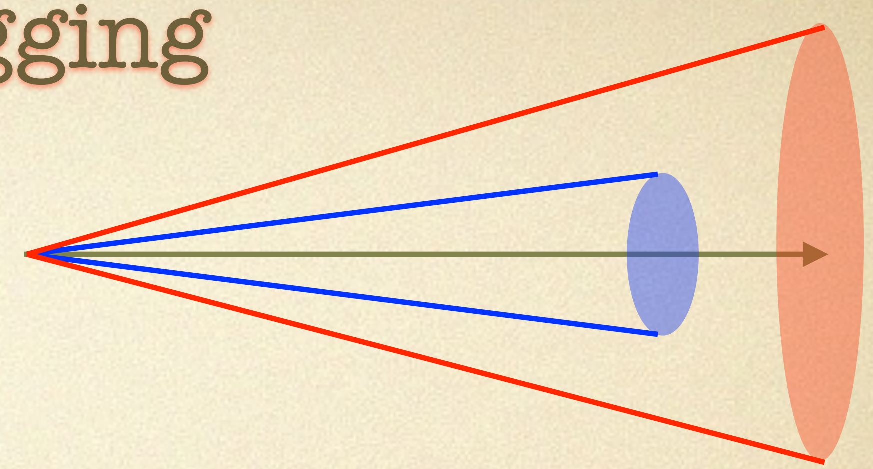
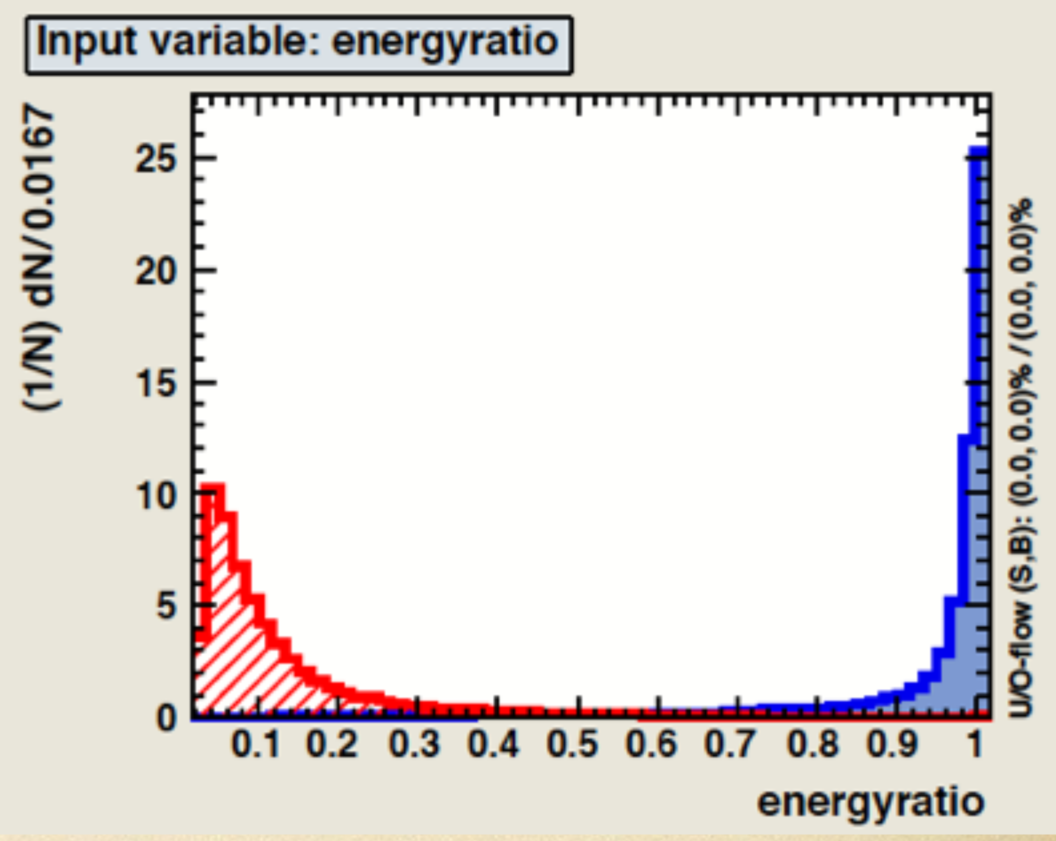
Isolated Lepton Tagging



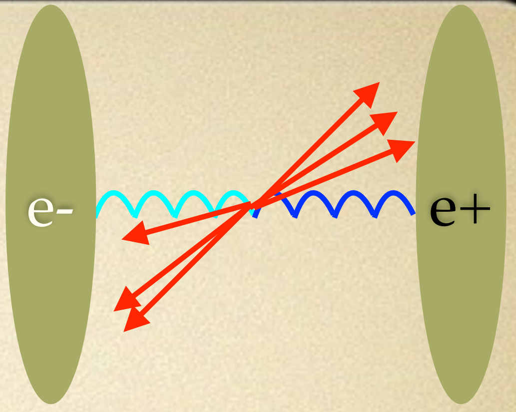
- ☑ general lepton identification: different fractions of energy deposited in ECAL, HCAL and Yoke.
- ☑ isolation requirement: effect of neighbor particles (now defined by two cones, one small, one large); from primary vertex.
- ☑ multivariate method is used to get the best efficiency / purity; output classifier (tagging) is kept for following optimization.
- ☐ shower shape not yet used (start point, lateral distribution), helpful for charged pion suppression.
- ☐ isolation still not ultimately optimized: infinity layers of cones (energy ratio .vs. cone angle).

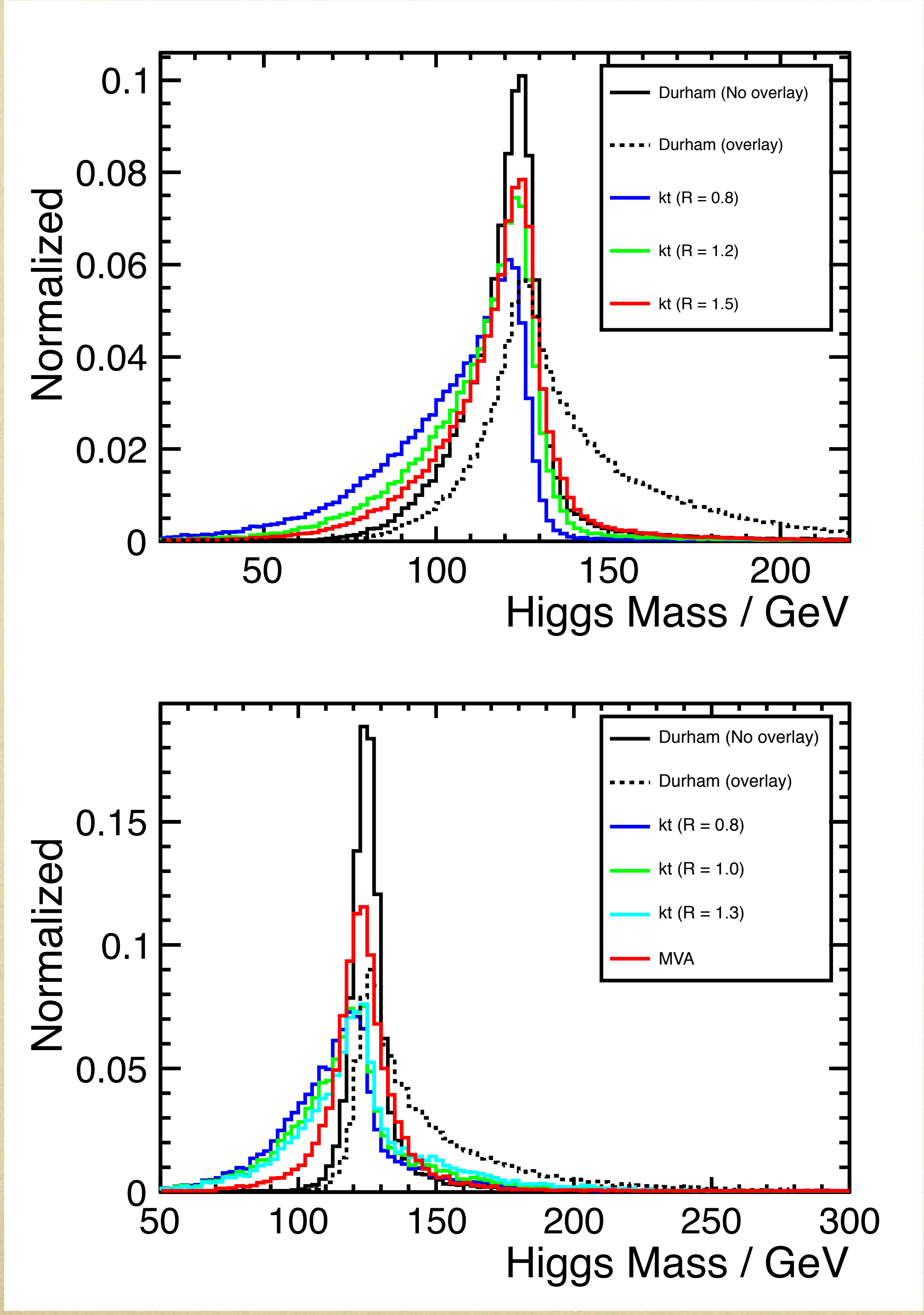


Eff (%)	eeHH	μμHH	bbbb	eνbbqq	μνbbqq
NEW	87.0	89.1	0.0017	0.32	0.020
DBD	85.7	88.4	0.028	1.44	0.10
LoI	81.9	85.4	0.43	2.71	1.94

not so trial to implement the last two, welcome to join if it's interesting to you!

overlay removal (beam-beam interaction)





- ☑ typically use kt jet-clustering algorithm to remove the forward and low-pt particles: need optimize NJet and R value.
- ☑ developed a new MVA method which identifies overlay particle-by-particle.
- ☐ kt works for H—>qq, MVA works for H—>WW*—>4q; however both are not satisfactory enough, still degrade significantly analysis performance particularly at higher energies.
- ☐ combine the pros of two methods looks promising: use MVA to find some most probable overlay particles (seeds), and then use clustering algorithm (jet,vertex,cone) to find others around those seeds.

but how exactly?

Global Fit

$$\chi^2 = \sum_{i=1}^{i=33} (\frac{Y_i - Y_i'}{\Delta Y_i})^2 + (\frac{\xi_{ct}}{\Delta \xi_{ct}})^2 + (\frac{\xi_{\mu\tau}}{\Delta \xi_{\mu\tau}})^2 + (\frac{\xi_\Gamma}{\Delta \xi_\Gamma})^2$$

- ☑ model independent global fit: total width is a free parameter.
- ☑ model dependent global fit (7 parameters as @ LHC): total width is sum of partial width.
- ☐ how well we can identify all the decay modes?
- ☐ how much is the theoretical error on F_i (though believe to be small): loop induced; parametric errors.
- ☐ systematic errors in addition to ΔY_i.

$$Y_i' = F_i \cdot \frac{g^2_{HA_iA_i} \cdot g^2_{HB_iB_i}}{\Gamma_0}$$

$$\xi_\Gamma = \kappa_H - \sum_i \kappa_i^2 \mathrm{Br}_i|_{\mathrm{SM}}$$

$$\xi_{\mu\tau} = \kappa_\mu - \kappa_\tau \quad \xi_{ct} = \kappa_c - \kappa_t$$

$$\Delta\xi_\Gamma = 0.5\% \times 0.63$$

$$\Delta\xi_{ct} = \Delta\xi_{\mu\tau} = 0.5\%$$

$$\Delta_{\mathrm{Theory}} = 0 \; ; \; 0.1\% \; ; \; 0.5\%$$

$$\Delta Y_i^2 = \Delta Y_i^2(\mathrm{exp}) + (\Delta_{\mathrm{Theory}} Y_i')^2$$

	Baseline	LumiUP
luminosity	0.1%	0.05%
polarisation	0.1%	0.05%
b-tag efficiency *	0.3%	0.15%

(* only for H-->bb)

significant amount of work needed here, and probably challenging!

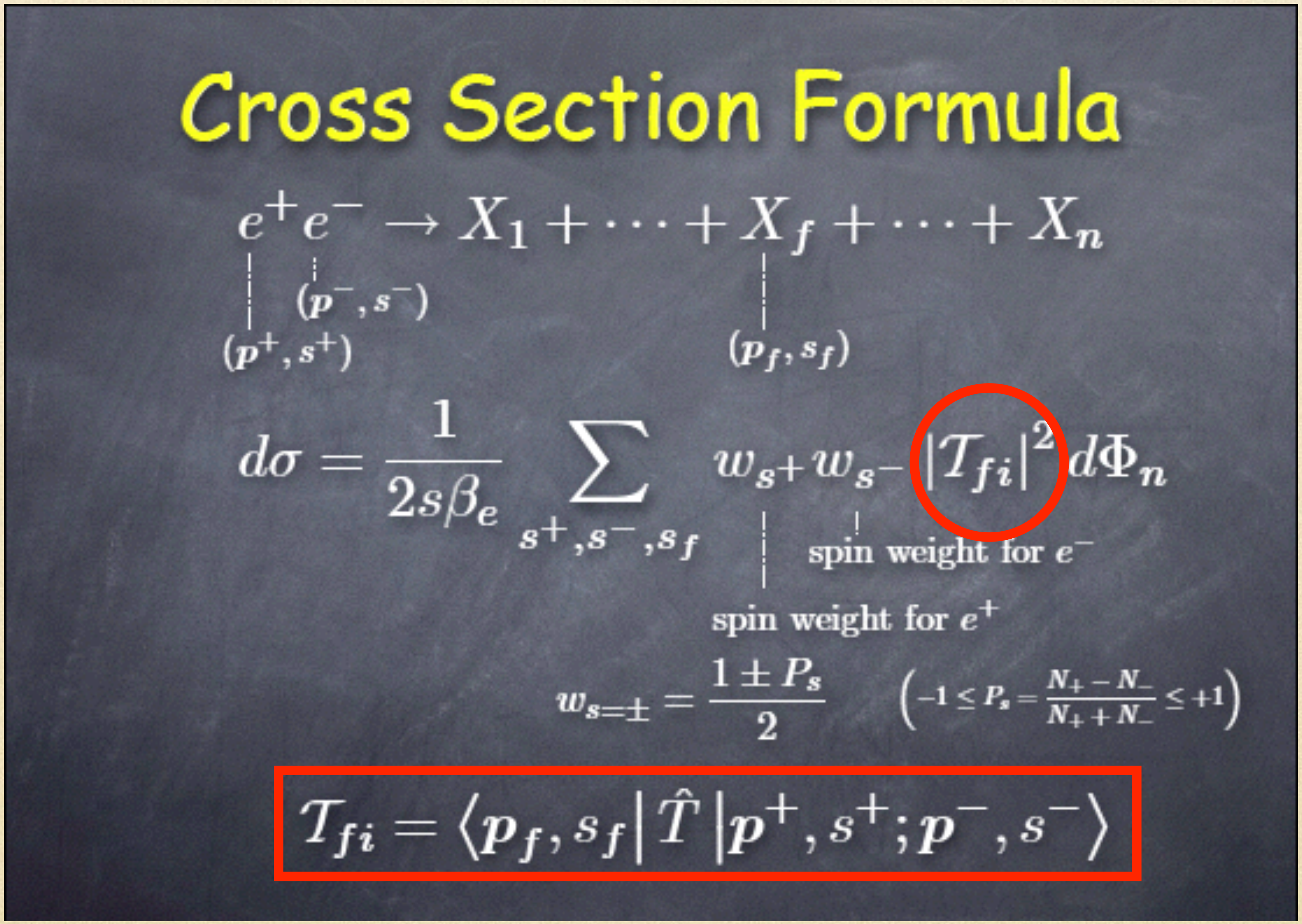
MEM: maximal use of event kinematics

(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

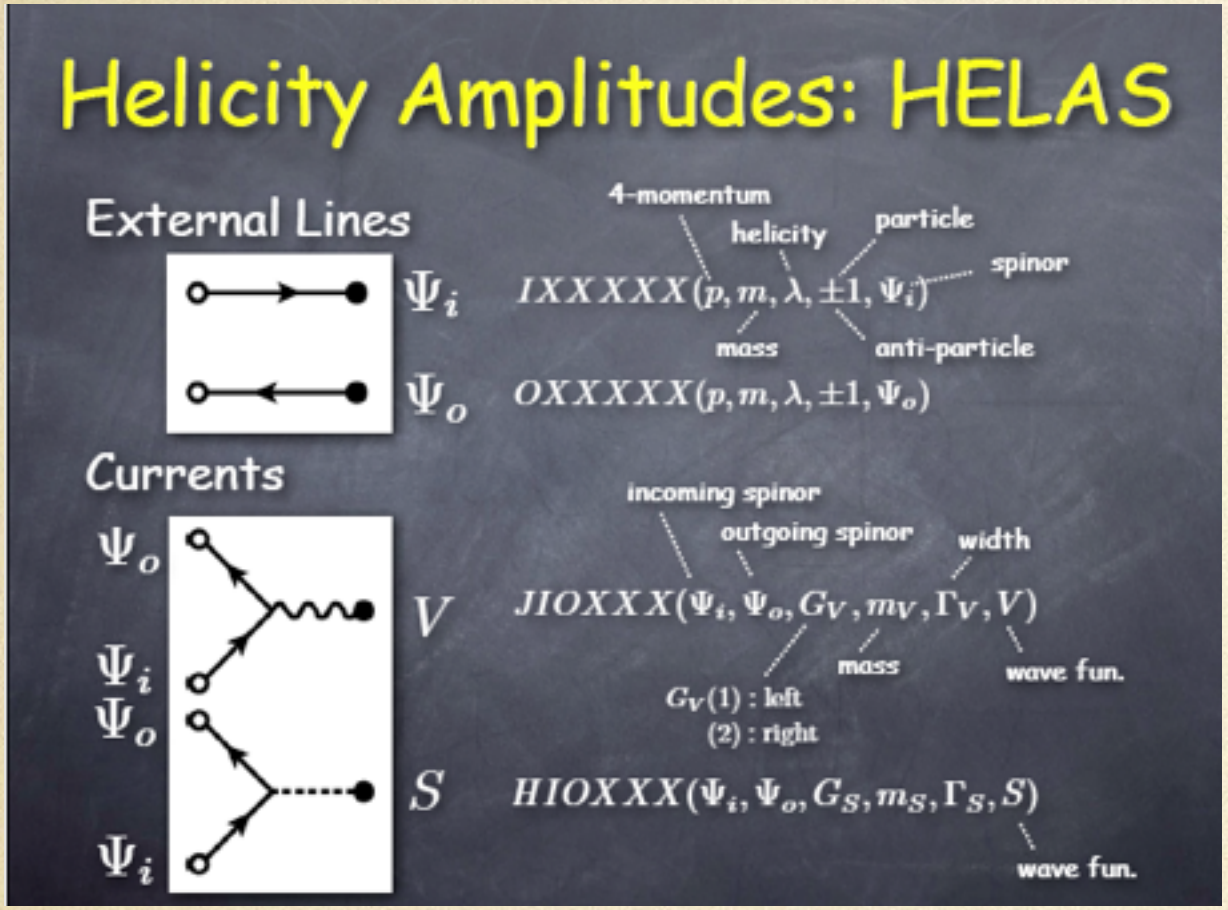
What is Matrix Element (Amplitude)

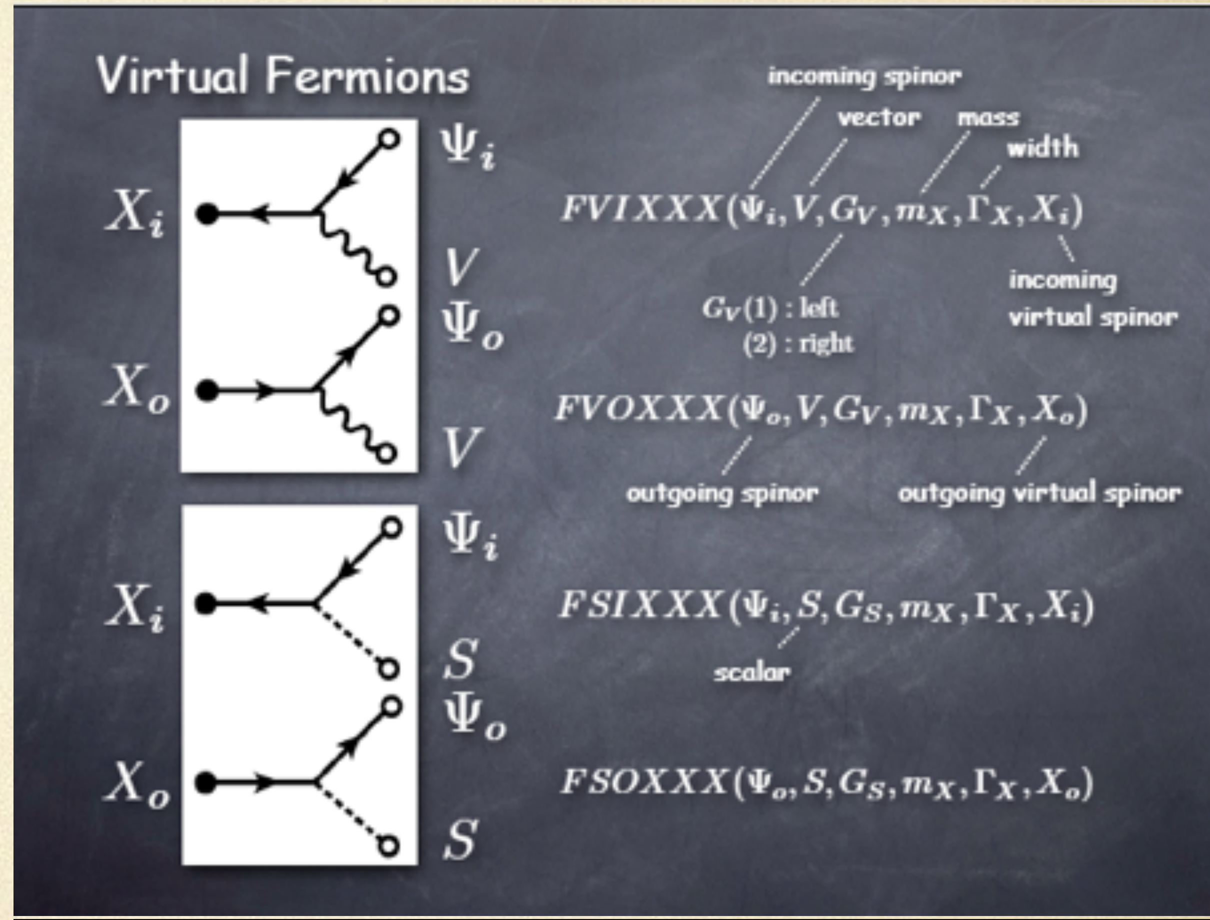
(squared ~ differential cross section)

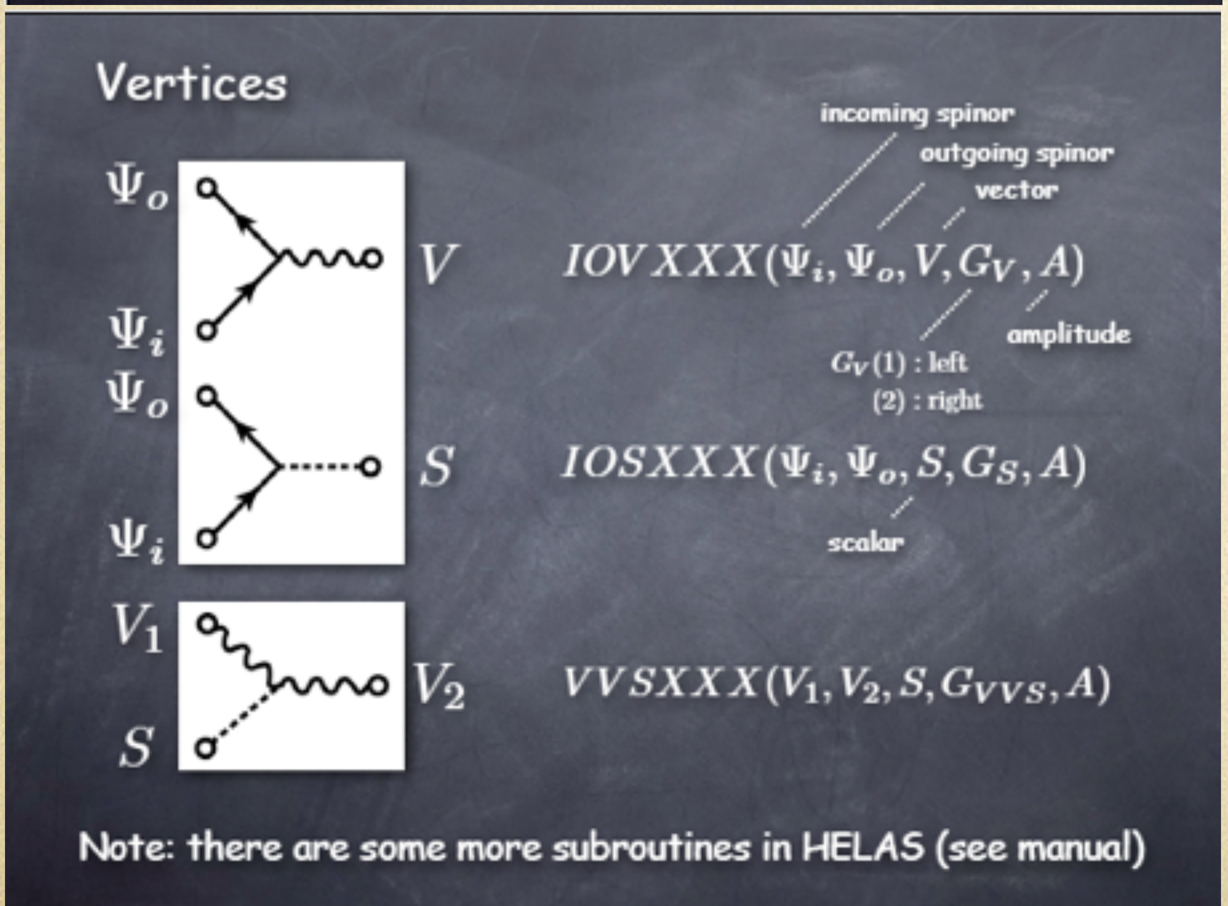


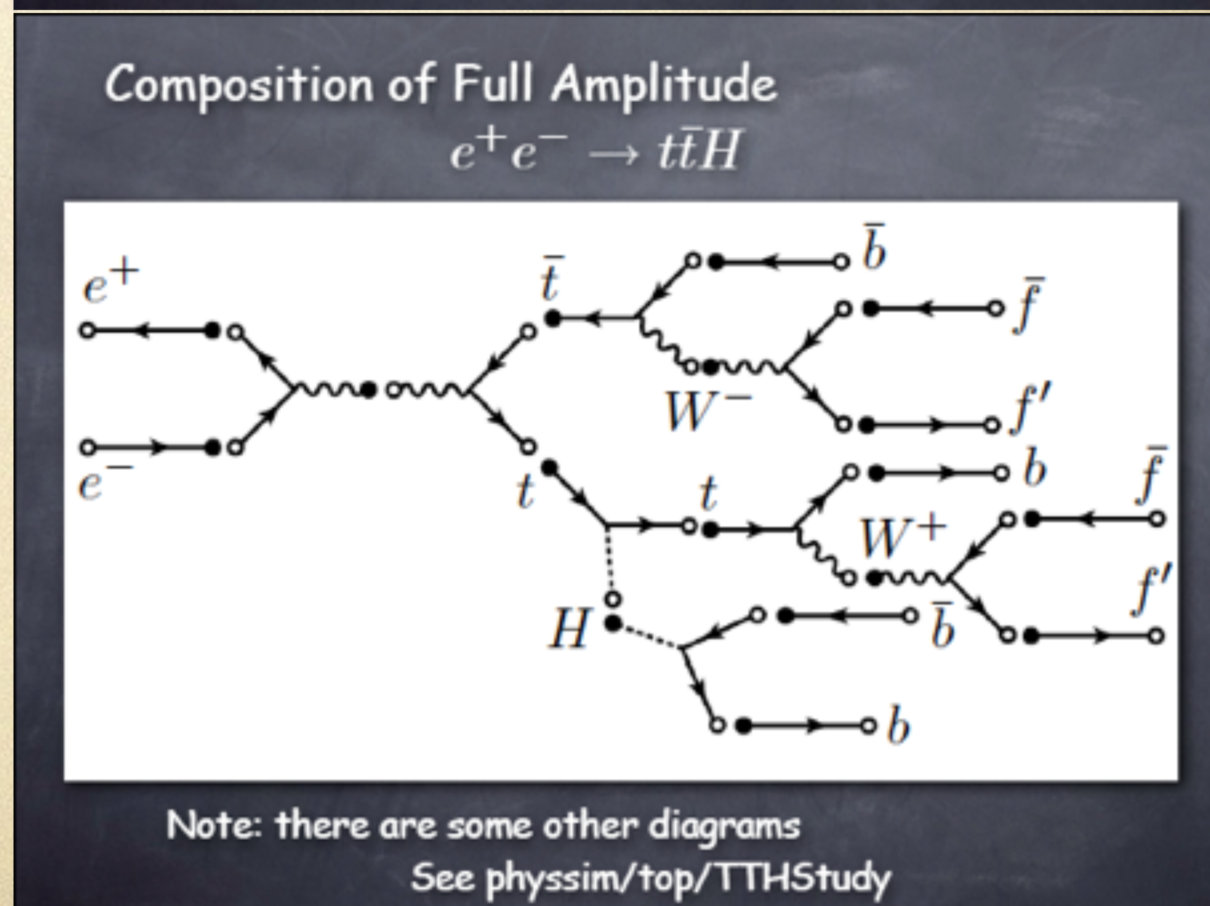
(technically, ME2 is the weight of each phase space point)

tools to calculate ME (thank Fujii-san!)



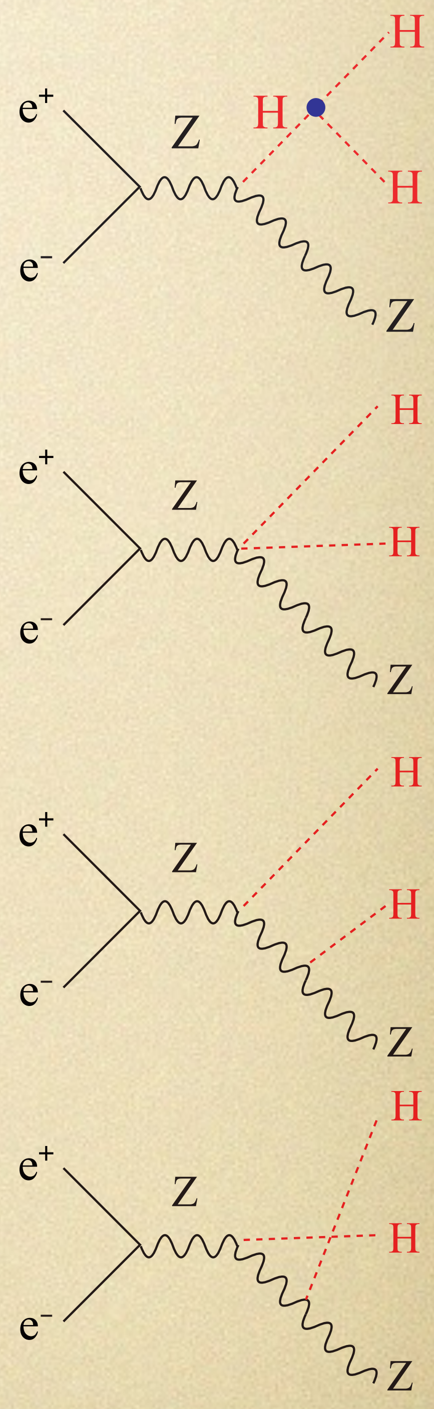






example core code to calculate matrix element

```
//---------------------------
// Higgs Production Amplitude
//---------------------------
HELVector zs(em, ep, glze, grze, kM_z, gamz);

Double_t v     = 2.*kM_w/kGw;
Double_t ghhh  = -TMath::Power(fMass,2)/v*3.;
Double_t gzzh  = kGz*kM_z;
Double_t gzzhh = kGz*kGz/2.;

HELScalar hh(h1, h2, ghhh, fMass, 0.);
HELVertex amp1(zs, zf, hh, gzzh);         // HHH self-coupling

HELVertex amp2(zs, zf, h1, h2, gzzhh);    // ZZHH 4-point

HELVector vz1(zf, h1, gzzh, kM_z, gamz);
HELVertex amp3(zs, vz1, h2, gzzh);        // double H-strahlung

HELVector vz2(zf, h2, gzzh, kM_z, gamz);
HELVertex amp4(zs, vz2, h1, gzzh);        // double H-strahlung

Complex_t amp  = amp1 + amp2 + amp3 + amp4;
```



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.

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

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

Higgs Self-coupling: status of ZHH (HH—>bbbb) analysis

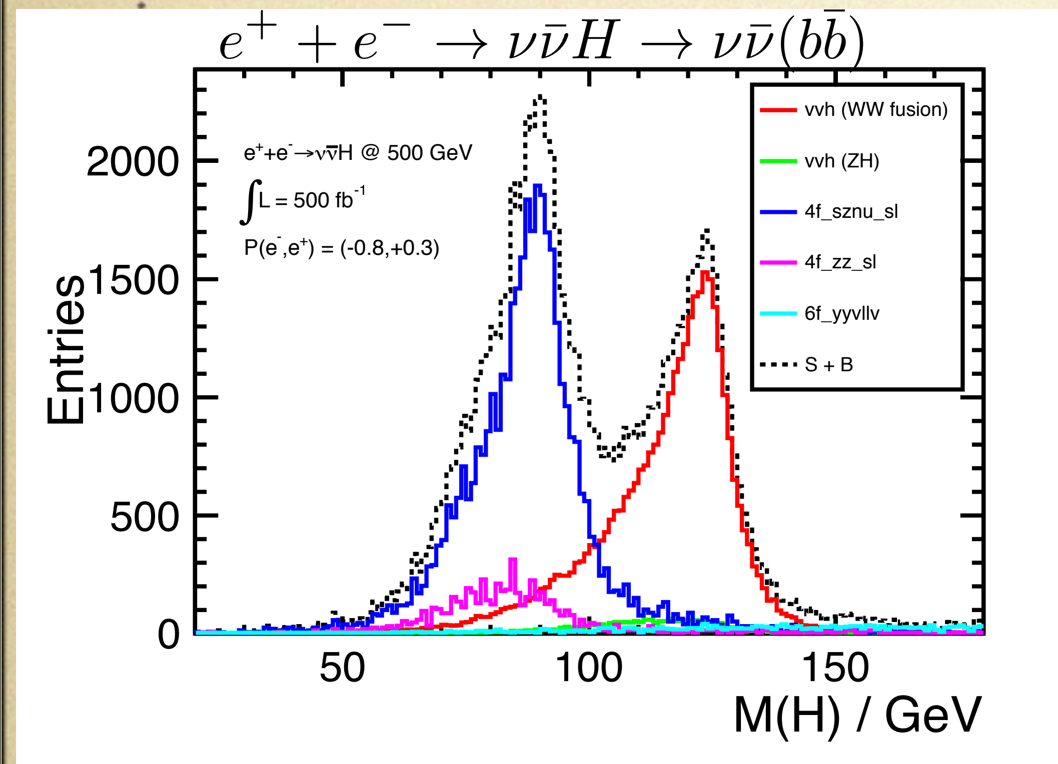
(see Claude's talk @ ILD Phys & Soft meeting, Jan. 15)

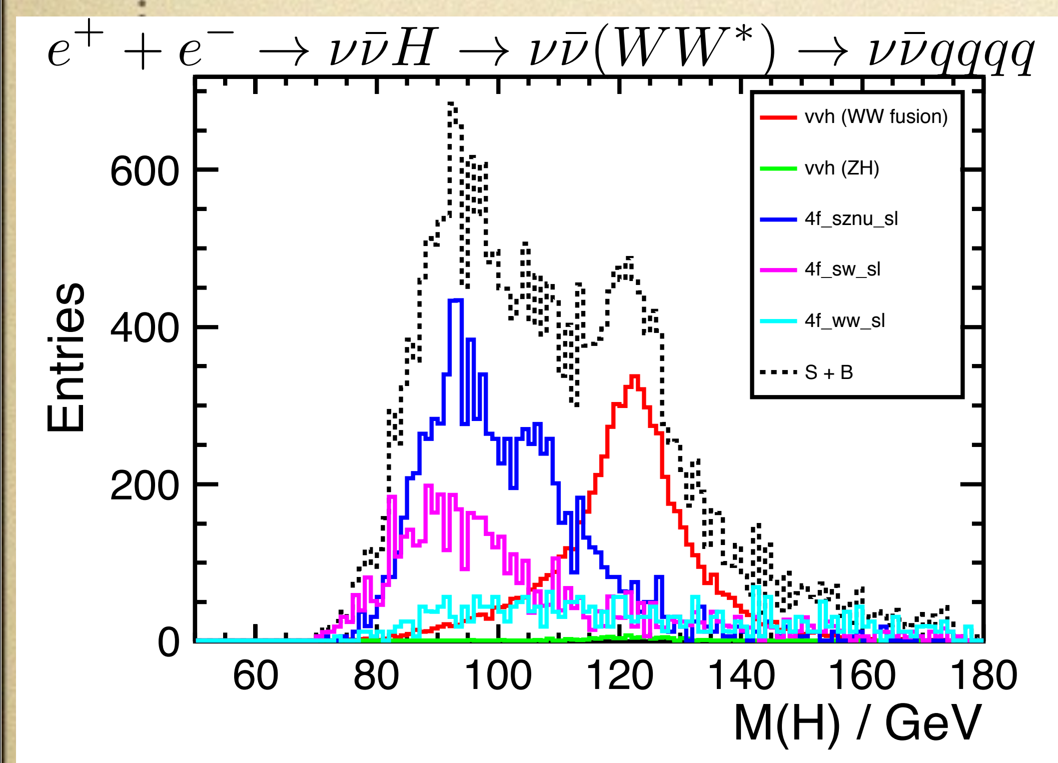
- [x] collaborating with DESY group, updating analysis with mH=125 GeV, both w/ overlay and w/o overlay.
- [x] llHH mode preliminarily done, consistent with our previous extrapolation.
- [x] vvHH mode ongoing, samples with overlay are ready, we will discuss current result later this month. .
- [ ] one short-term task is to publish new weighting method, mid-term plan is get three modes updated towards next American Workshop on LC.
- [ ] towards improvement, known issue is to optimize all cuts to maximize coupling sensitivity, instead of cross section.
- [ ] apply weighting method to full simulated samples.
- [ ] try to first improve jet pairing (currently only ~63% events are correctly paired!).
- [ ] investigate kinematic fitting and color-singlet jet-clustering eventually.

$$\frac{I+2S}{\sqrt{\sigma+B_r}} \qquad \frac{\sigma}{\sqrt{\sigma+B_r}} \qquad \sigma = B + I + S$$

HWW and Total Width: status of ννH analysis

(see my talk @ 34th General Physics Meeting)





- ☑ analysis ννH—>νν(bb): for extracting HWW coupling.
- ☑ analysis ννH—>νν(WW*), both full hadronic and semi-leptonic modes: for extracting Higgs total width.
- ☑ analysis ννH—>νν(ZZ*), only semi-leptonic mode done.
- ☐ only at 500 GeV done with DBD software, 250 GeV analysis still with LoI tools and with mH=126 GeV (by Claude); worth updating 250 GeV analysis probably with more advanced method, such as matrix element method.
- ☐ for 500 GeV analysis, some fitting method is needed to get result instead of simply by S/sqrt(S+B).
- ☐ full hadronic mode of ZZ* is also worth a try: to see how well we can separate WW* and ZZ*.

back up

Model-independent Global Fit for Couplings

33 σxBR measurements (Y_i) and σ_{ZH} ($Y_{34,35}$)

$$\chi^2 = \sum_{i=1}^{35} \left(\frac{Y_i - Y_i'}{\Delta Y_i} \right)$$

$$Y_i' = F_i \cdot \frac{g^2_{HA_iA_i} \cdot g^2_{HB_iB_i}}{\Gamma_0} \qquad (A_i = Z, W, t)$$

$$(B_i = b, c, \tau, \mu, g, \gamma, Z, W \, : \text{decay})$$

$$(i = 1, \cdots, 33)$$

$$F_i = S_i \, G_i$$

$$G_i = \left(\frac{\Gamma_i}{g_i^2} \right)$$

$$S_i = \left(\frac{\sigma_{ZH}}{g^2_{HZZ}} \right), \left(\frac{\sigma_{\nu\bar{\nu}H}}{g^2_{HWW}} \right), \text{ or } \left(\frac{\sigma_{t\bar{t}H}}{g^2_{Htt}} \right)$$

- The recoil mass measurement is the key to unlock the door to this completely model-independent analysis!
- Cross section calculations (S_i) do not involve QCD ISR.
- Partial width calculations (G_i) do not need quark mass as input.

We are confident that the total theory errors for S_i and G_i will be at the 0.1% level at the time of ILC running.