Kinematic fitting for ParticleFlow Detectors at Future Higgs Factories

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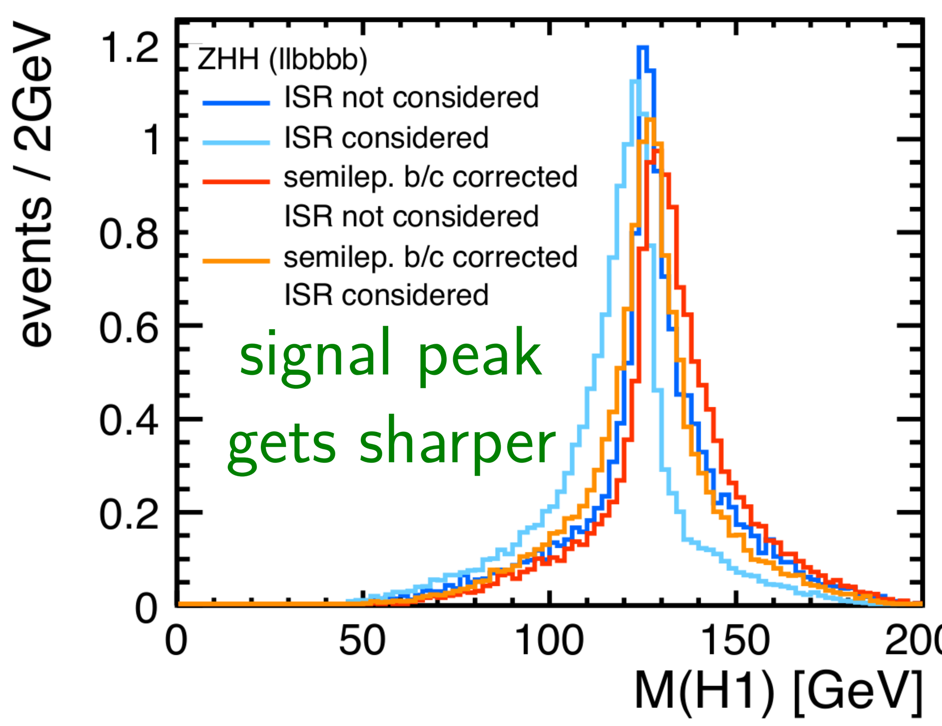
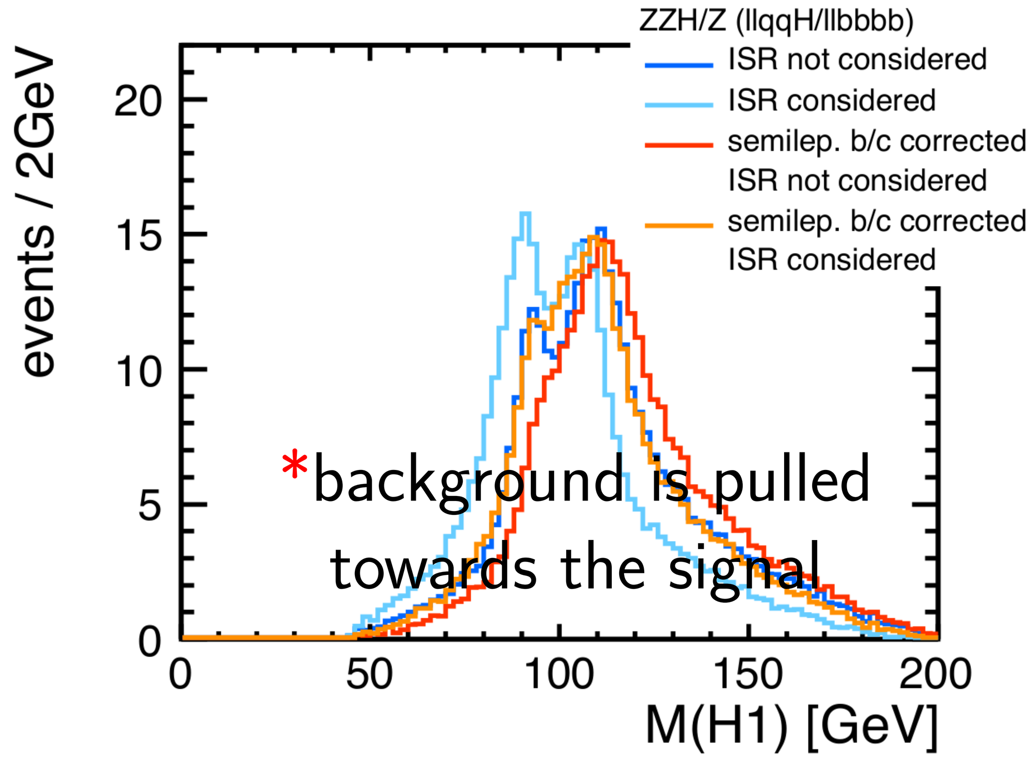
1- Motivation

		N_{SLD}^{B}		
		0	1	2
N_{SLD}^{C}	0	34%	24%	4%
	1	18%	12%	2%
	2	3%	2%	0%

$\frac{2}{3}$ of $H \to b\bar{b}/c\bar{c}$ events have at least one semi-leptonic b- or c-decay

⇒ degrade the invariant di-jet mass (important to separate ZH/ZZ and ZHH/ZZH) [1]

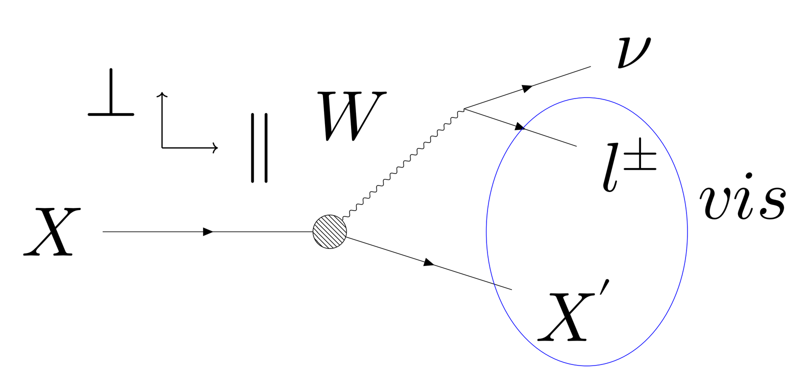


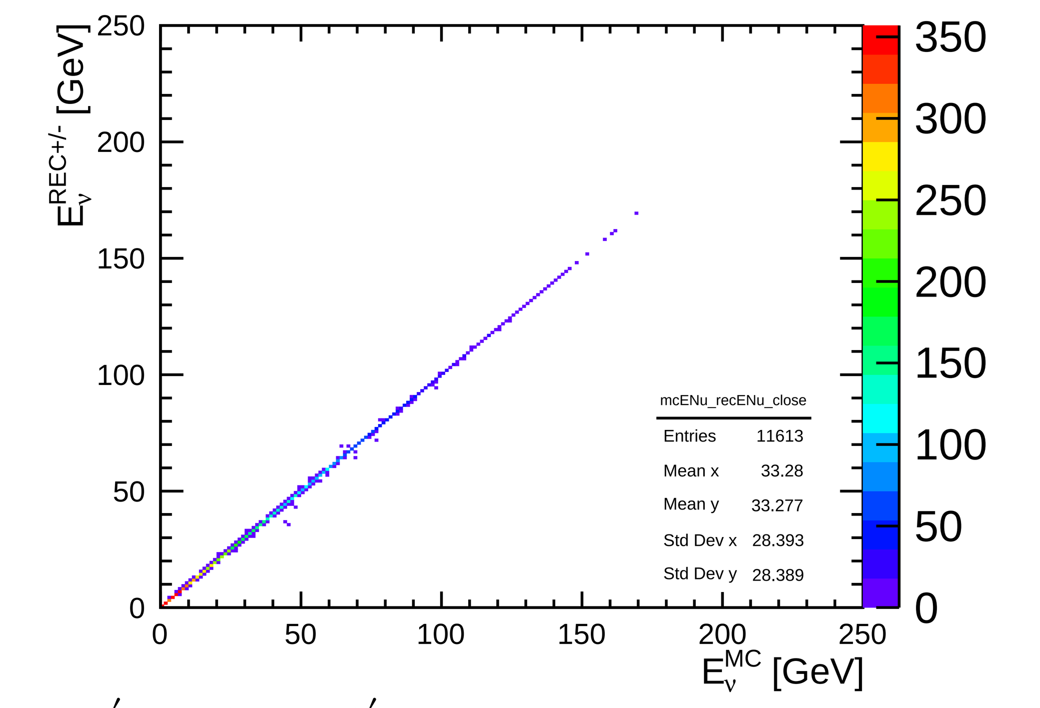


*avoid by:
- a better neutrino correction
- a better parametrisation of the jet uncertainties

2- ν-correction

1. identify b- or c- jets → flavour tagging
2. find the semi-leptonic decay(s) in the jet → find and tag leptons in jets
3. estimate neutrino momentum from kinematic of the semi-leptonic decay





$$E_\nu = E_X - E_{vis} = \frac{E_{vis}E'_{vis} - \vec{p}_{vis\parallel}\cdot\vec{p}'_{vis\parallel}}{m^2_{vis}+\vec{p}^2_{vis\perp}} m_X - E_{vis}$$

$$E'_{vis} = \frac{m^2_X + m^2_{vis}}{2m_X} \qquad \vec{p}'_{vis\parallel} = \pm\sqrt{\left(\frac{m^2_X - m^2_{vis}}{2m_X}\right)^2 - \vec{p}^2_{vis\perp}}$$

2-fold ambiguity in the solution for neutrino energy (momentum)!

Use kinematic fit to decide!

As proof of principle: cheat input to ν-correction

3- Kinematic fitting

Mathematical tool that adjusts measured quantities within their uncertainties to fulfill certain constraints [2] [3]

- E & $\vec{p}$ conservation: clean collision environment at lepton colliders
- Invariant mass of known particles (e.g. m_Z) as soft constraint
- Minimize χ^2:

$$\chi^2(\boldsymbol{a},\boldsymbol{\xi},\boldsymbol{f}) = (\boldsymbol{\eta}-\boldsymbol{a})^T V^{-1}(\boldsymbol{\eta}-\boldsymbol{a}) - 2\lambda^T \boldsymbol{f}(\boldsymbol{a},\boldsymbol{\xi})$$

$\boldsymbol{\eta}$: vector of measured kinematic variables — V: **covariance matrix**

$\boldsymbol{a}$: vector of fitted quantities — λ: Lagrange multipliers

$\boldsymbol{\xi}$: vector of unmeasured kinematic variables — $\boldsymbol{f}(\boldsymbol{a},\boldsymbol{\xi})$: vector of constraints

References

[1] Claude F. Duerig. PhD thesis. DESY, 2016. DOI: 10.3204/PUBDB-2016-04283.

[2] R. J. Barlow. Chichester: John Wiley & Sons, 1989. ISBN: 9781118723234.

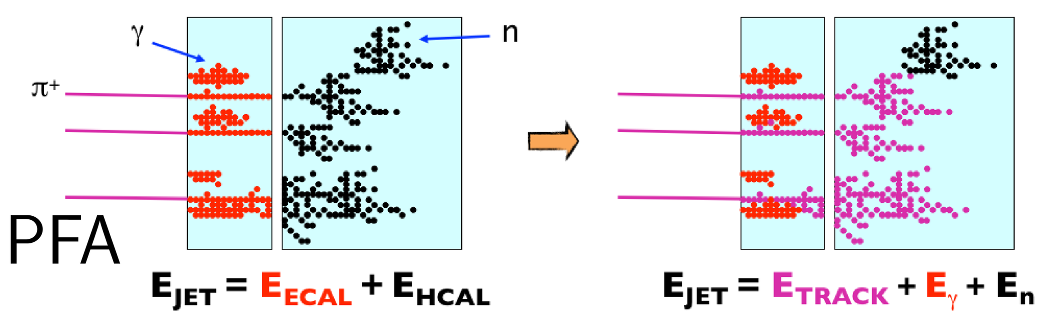
[3] B. List and J. List. In: *LC Notes* (2009). URL: https://t1p.de/a20z.

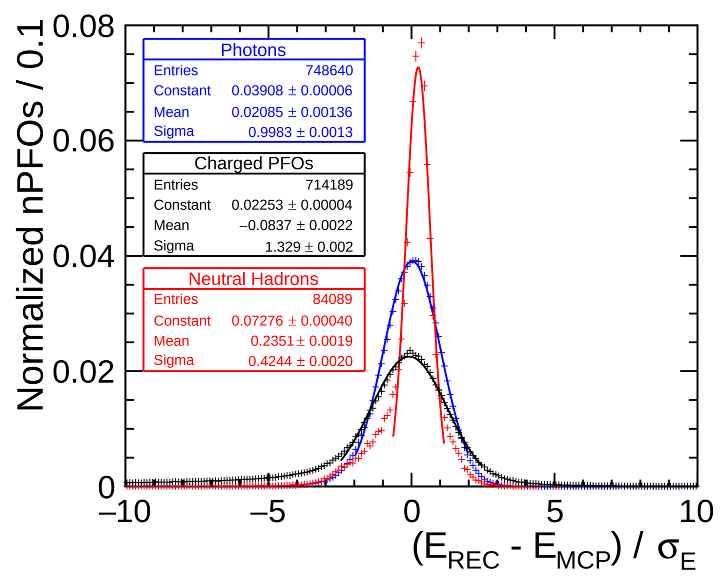
[4] Aliakbar Ebrahimi. PhD thesis. DESY, 2017. DOI: 10.3204/PUBDB-2017-11891.

4- PFA paradigm and jet error parametrization

ErrorFlow [4]

1. σ_{det}: detector resolution
2. σ_{conf}: effects of confusion in the PFA
3. σ_{clus}: mistakes in the jet clustering
4. $\sigma_{overlay}$: uncertainties of $\gamma\gamma \to$lowp_T hadron overlay removal
5. σ_ν: uncertainties of ν-correction for semi-leptonic b- and c-decays

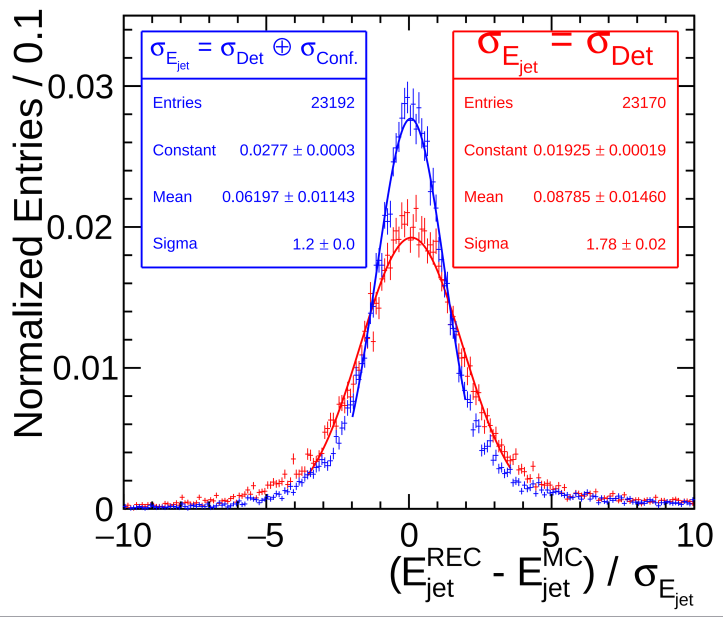




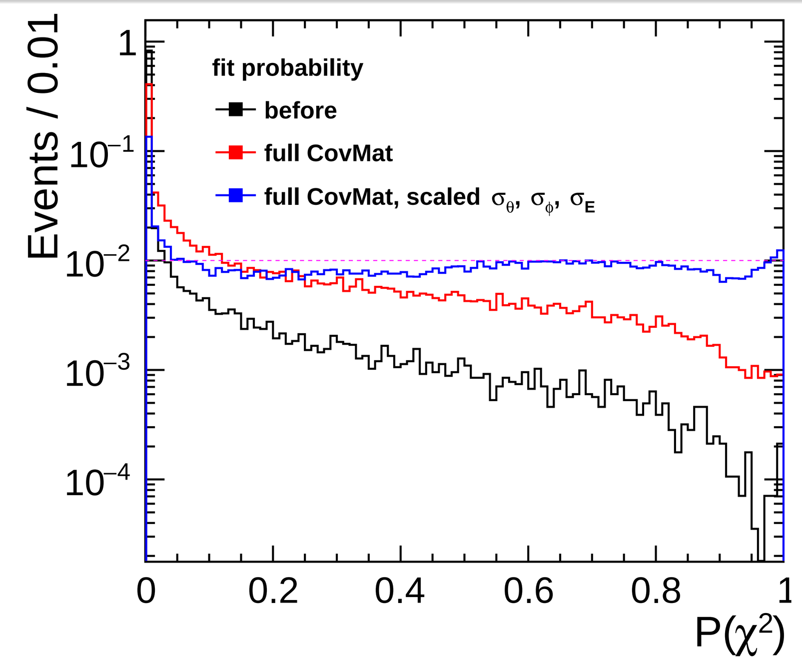
1. get CovMat of each PFO
2. Add up all PFOs CovMat
3. Add confusion σ_{conf}
4. transform to $\sigma_{E,\theta,\phi}$

$\sigma^{PFO} \longrightarrow \sigma^{jet}$

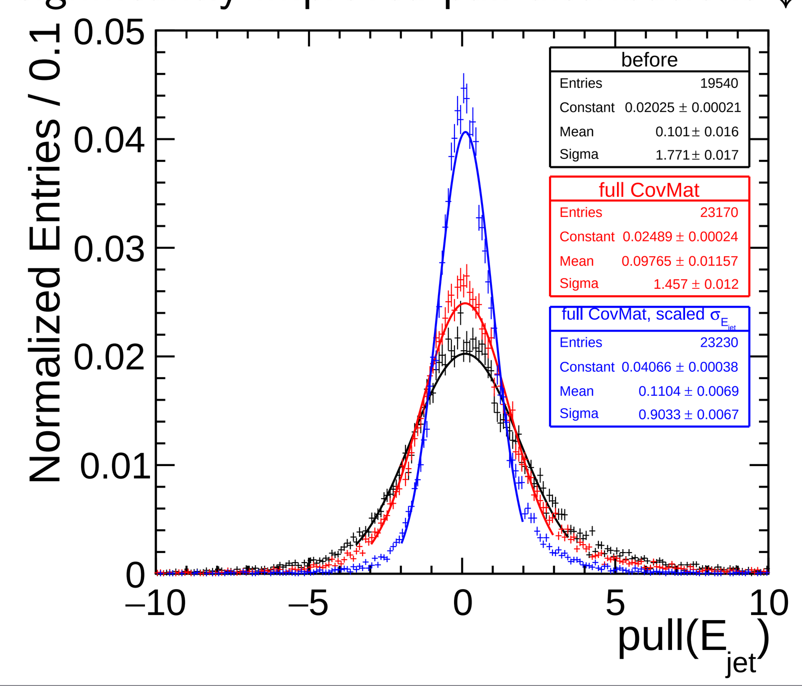
scale up σ_E by 20%



5- Fit performance



↑ flat-most fit probability ever seen!
and
significantly improved pull distributions ↓



6- Higgs mass reconstruction

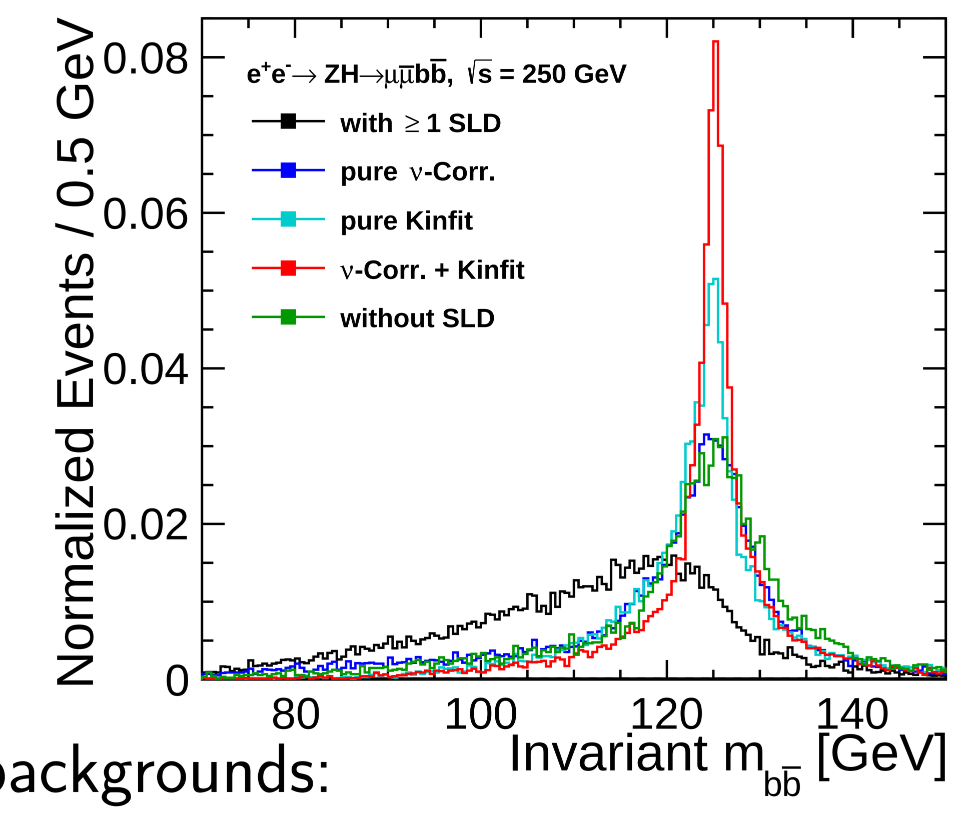
ISR and Beamstrahlung included

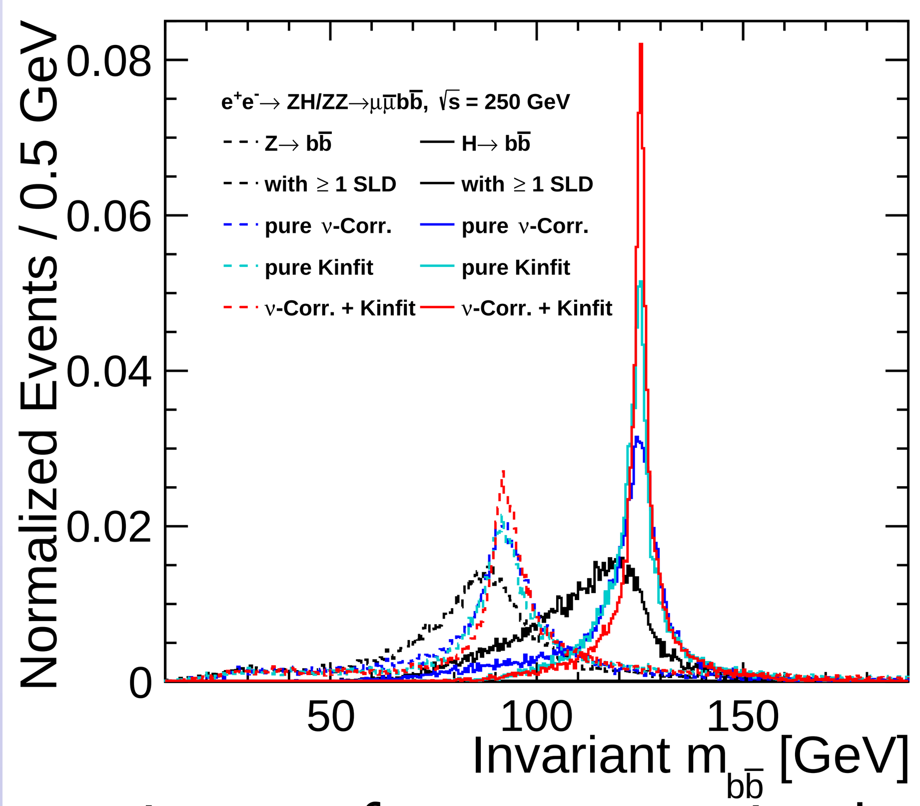
Fully cheated ν-correction

ErrorFlow: jet error estimation

Drastically improved reco. m_H:

ν correction + Kinfit ⇒ together





Add backgrounds:

$e^+e^- \to ZZ \to \mu\bar{\mu}$

$\gamma\gamma \to$ low p_T hadron overlay

$Z \to b\bar{b}$ and $H \to b\bar{b}$ well separated: background not pulled towards signal

potentially large improvement eg for Higgs self-coupling prospects

ongoing: perform ν-correction based on reconstructed information only