Reconstruction & Calibration Needs of Focus Topics – Overview & Selected Topics

ECFA Higgs factory study

2nd Reconstruction WS

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Focus Topics: Overview

- ECFA Study defined 15 “Focus Topics” on which to trigger new, and in particular joined, across-project studies

HTOSS [HTE] $e^+e^- \to Zh$ with $h \to s\bar{s}$

ZHANG [HTE (GLOB)] $e^+e^- \to Zh$ and reconstruction of decay angles

HSELF [GLOB] Higgs self-coupling

WMASS [PREC] W mass from W^+W^- threshold and continuum

WWDIFF [GLOB] Studies of W^+W^- and $e\nu W$

TTTHRES [GLOB (HTE)] Top threshold scan

LUMI [PREC] Precision luminosity measurement

EXSCALAR [SRCH] New exotic scalars (typically $e^+e^- \to Z\phi$

LLPS [SRCH] Long-lived particles

EXTT [SRCH] Exotic top decays

CKMWW [FLAV] CKM matrix elements from W decays (V_{cs}, V_{cb} ...)

BKTAUTAU [FLAV] $B^0 \to K^{*0}\tau^+\tau^-$ (or similar)

TWOF [HTE] 2-fermion final states at $\sqrt{s} = M_Z$ and beyond: $b\bar{b}$, $c\bar{c}$, $s\bar{s}$, $\tau^+\tau^-$ ...

BCFRAG [FLAV (PREC)] b and c fragmentation functions

GSPLIT [PREC (FLAV)] Gluon splitting to $b\bar{b}$ and $c\bar{c}$, separating gluons from Higgs.

Focus Topics: Overview

- On each of these topics, “expert teams” have been formed, charged to develop a work plan:
  - 2-3 pages => to become public soon
    - Previous studies of relevance & available tools / samples
    - Target questions in terms of physics, analysis methods and detector optimization
    - Required developments in terms of theory, MC, **reconstruction algorithms, calibration methods (TODAY!)** and detector performance
- Basis of today’s discussion: detailed review of all topics at convener meeting 2 weeks ago

Focus Topics & Reconstruction

- LLPs: Timing, Displaced Things, Non-pointing Things, …
  => talk by Rebeca
- HtoSS: PID, RICH, V0s, ….
  => talk by Taikan

- b/c / tau tagging (EXscalar, Extt, TwoF, …)
- Jet clustering (Hself, WWdiff, …)
- Kinematic fit (Hself, WWdiff, Wmass, TTthres)
- Matrix elements…

Topic	input to RecoWS
HtoSS	PID / V0s / RICH
ZHang	
Hself	jet clustering
Wmass	acceptance precision (e-), tracker momentum scale, jet calibration, kin. fit
WWdiff	Kinfit, OO
TTthres	
LUMI	e/y sep
EXScalar	b, tau, ISR, jet reco
LLPs	Timing, non-pointing, in flight decays, ...
EXtt	low mass resonances
CKMWW	
BKtautau	
TwoF	
BCFrag/Gsplit	PID

- e/ gamma separation (LUMI, …)
- Electron reco (WWdiff, Wmas, LUMI, …)
- Calibration of energy / momentum scales (Wmass, …)
- Acceptances… (LUMI, Wmass, …)

} talk by Graham (Wednesday)

Two Fermions (TwoF, Adrian Irles & Fabio Maltoni)

- Signal processes: ee -> bb / cc / ss / uu / dd ; tautau / mumu
- Physics targets: total rates (R…), diff. cross-sections (A_FB), tau polarization
- Very nice recent talk by Adrian highlighting physics potential and reco needs
- Jet flavour tagging with high purity
  - bb/cc : solid basis LCFIPlus, ML developments
  - **double-tagging**: technique *measures* efficiencies
- Quark-Antiquark Tagging:
  - **Kaon charge**
    => PID talk by Uli &
    s-tag talk by Taikan
    => a lot ongoing!
  - **Vertex charge**
    => full vertex reco
    => can we do (even) better here than LCFIVertex? Learn from Belle2 ? …?
    => are vertex detectors of detector concepts optimised for this, also in the forward region?

▶ Compare samples with 1 tag vs 2 tags (after preselection)

$$f_{1b} = \varepsilon_c \overline{R_b} + \widetilde{\varepsilon_c} \overline{R_c} + \widetilde{\varepsilon_{uds}} \left(1 - \overline{R_b} - \overline{R_c}\right)$$

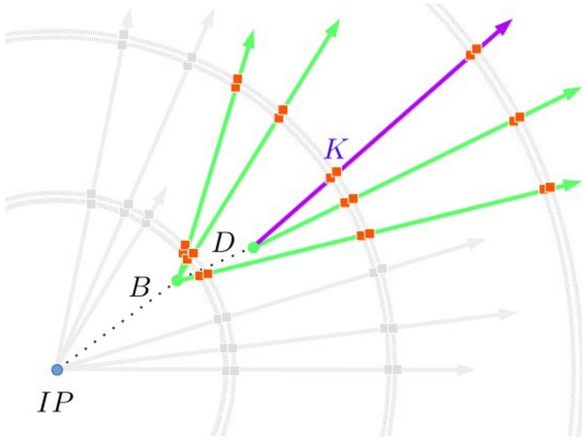
$$f_{2b} = \varepsilon_b^2 (1+\rho) R_b + \widetilde{\varepsilon_c}^2 R_c + \widetilde{\varepsilon_{uds}}^2 \left(1 - R_b - R_c\right)$$

Measured observables

PHYSICS! Indirect observables

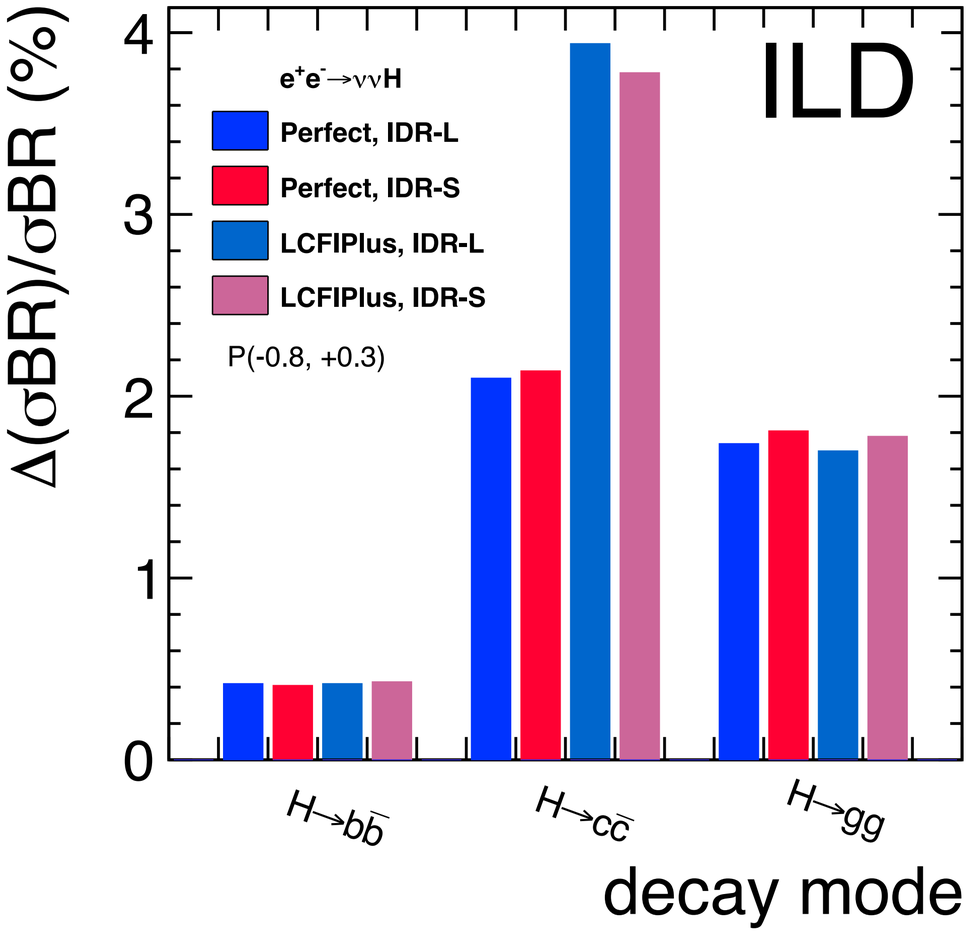
Inputs (MC or independent measurements)

Similar set of equations for the c-quark solved simultaneously



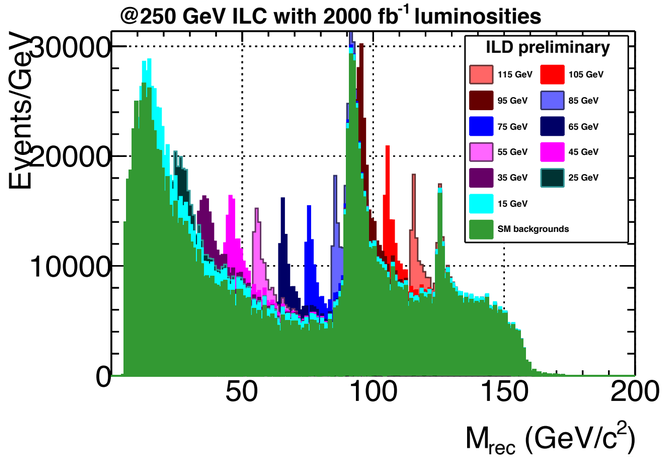
Interlude: where to improve flavour tagging for Higgs

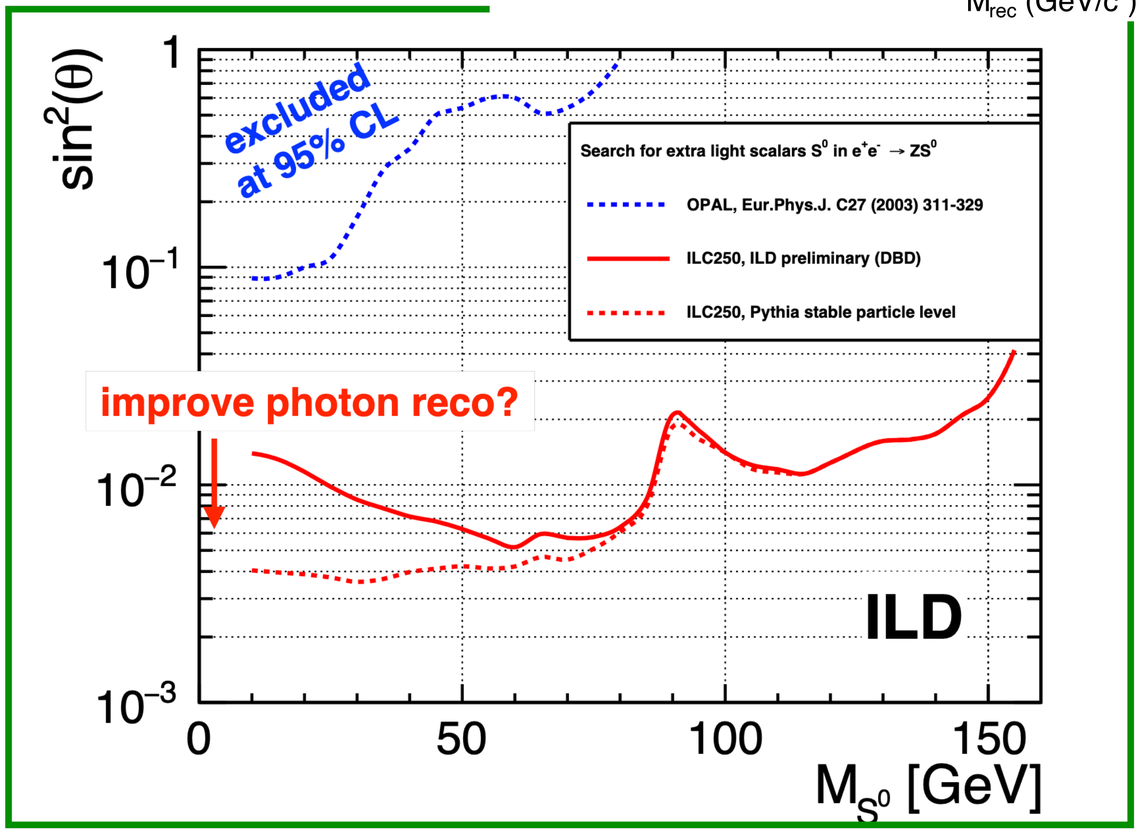
- Study for ILD Interim Design Report on H->bb/cc/gg (M. Kurata)
- Compared
  - Actual LCFIPlus performance
  - Perfect flavour tagging
- σxBR(cc) shows a lot (!) of room for improvement !



Extra (higgs-like) Scalars (EXScalar, F.Zarnecki)

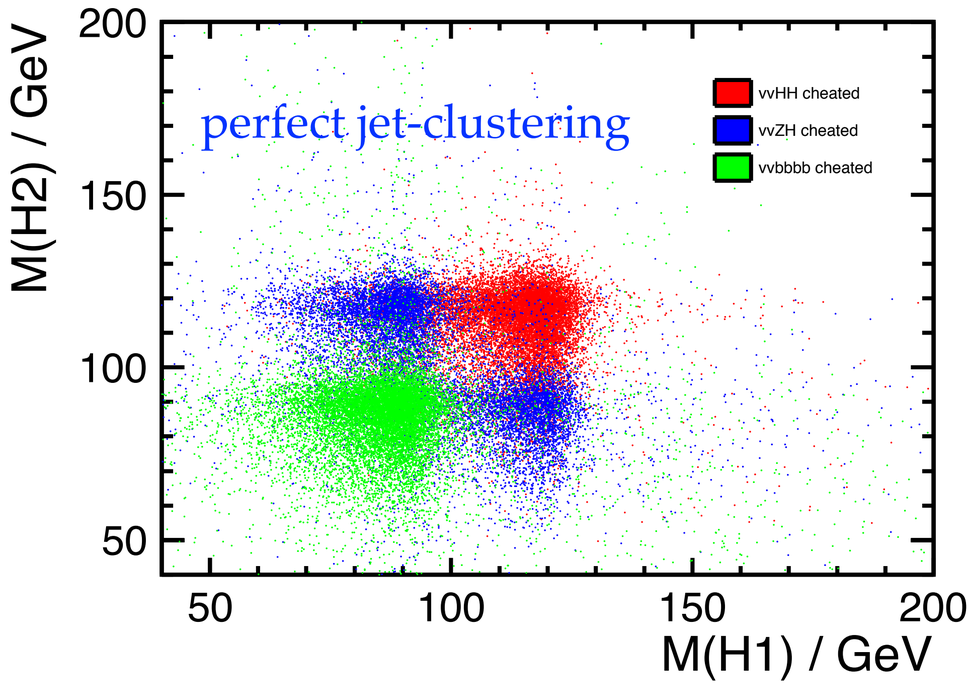
- Focus on Higgs-strahlung production of extra scalars
  - Inclusive search via recoil method
  - Exclusive searches in all kinds of decay modes:
    bb, cc, tautau, partially invisible, …
    => so far only done on theory-level!
- Specifica wrt object tagging for low mass scalars
  - Small mass => boost
    => decay products with small opening angle
    => very different from back-to-back topology
  - ISR reconstruction and identification important,
    even limiting for recoil method

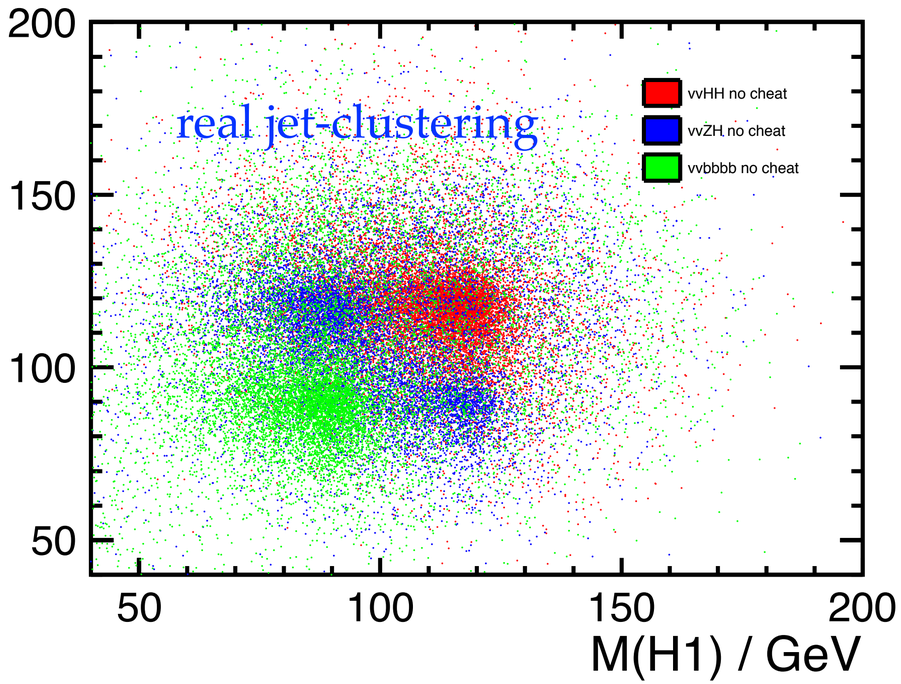




Multi-jet processes (WW, ZH(H), tt, …): Jet Clustering

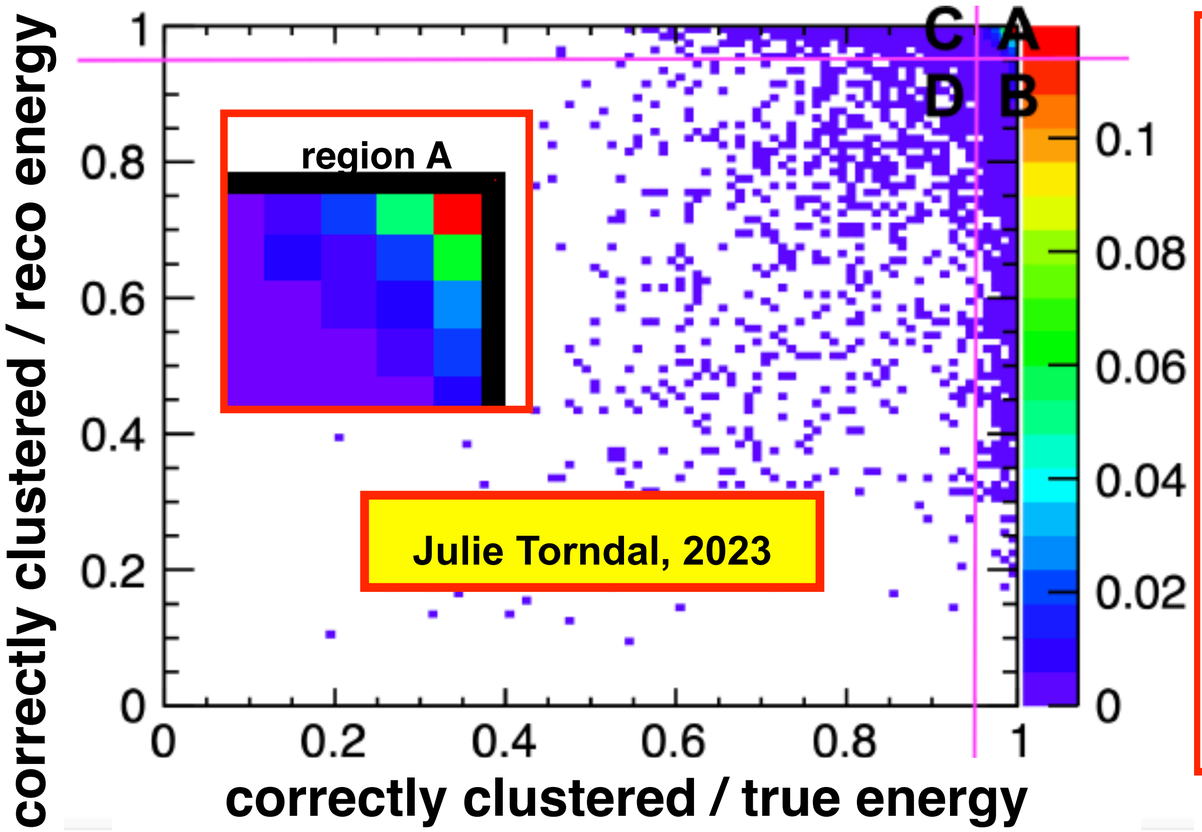
- Jet clustering in e+e- projections mostly from LEP times: Durham & Co
- Exception: Valencia algorithm, mainly to suppress forward background from overlay at linear colliders
- With the “gold-plated” detector concepts proposed, jet clustering errors dominate jet energy resolution for any process with > 2 jets !
- Can we do better?
- Cf talk by Julie later!

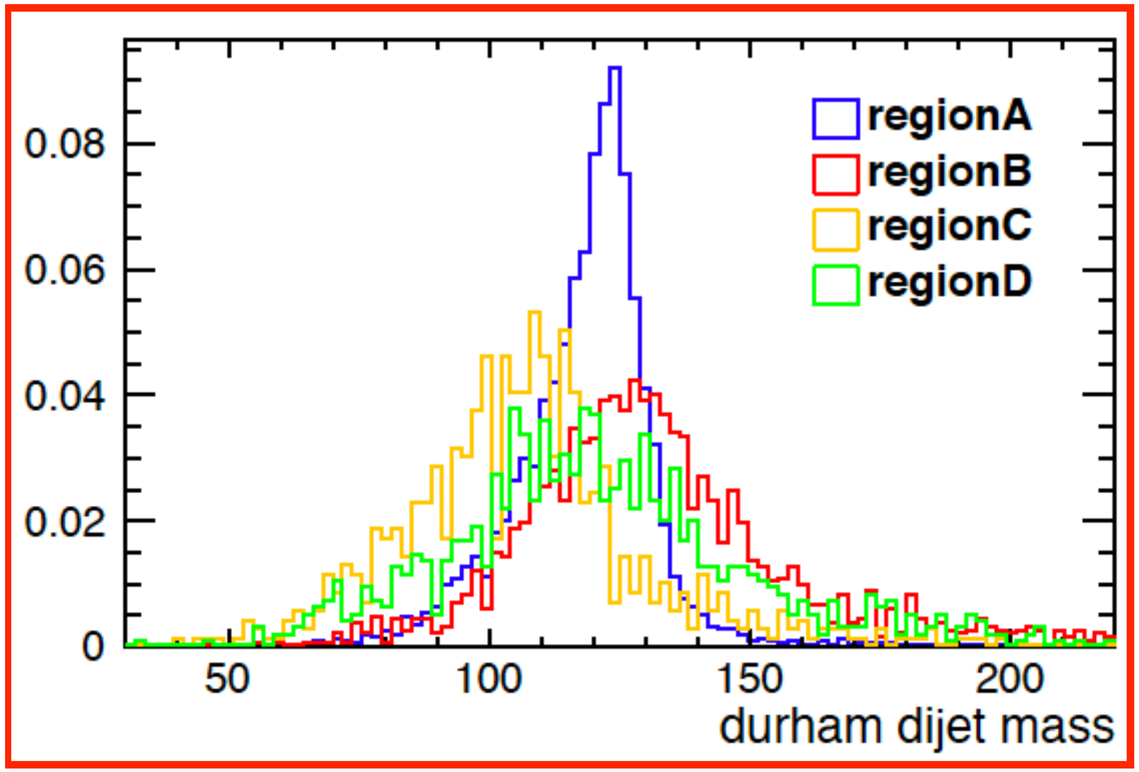




Urgently wanted: modern jet clustering

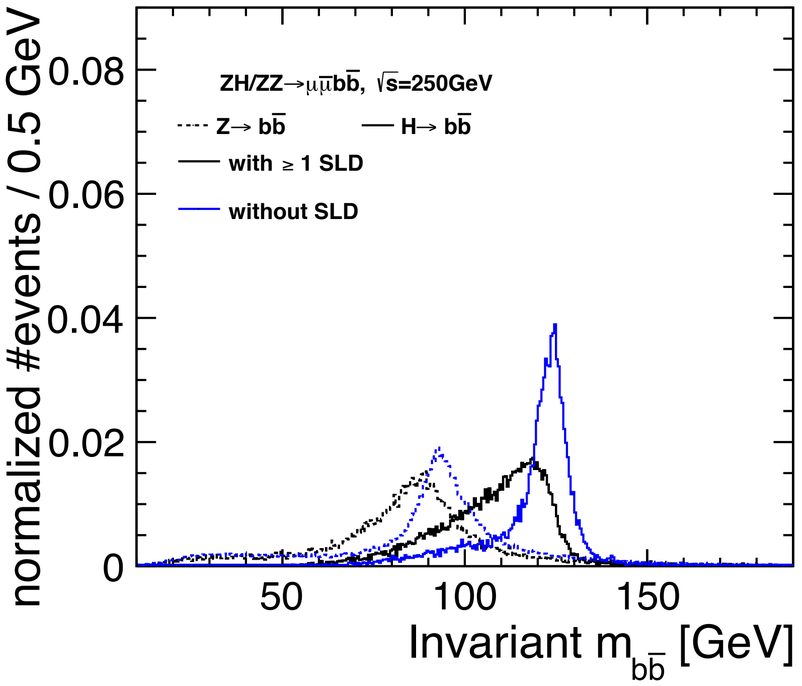
… bottle-neck for Higgs self-coupling precision

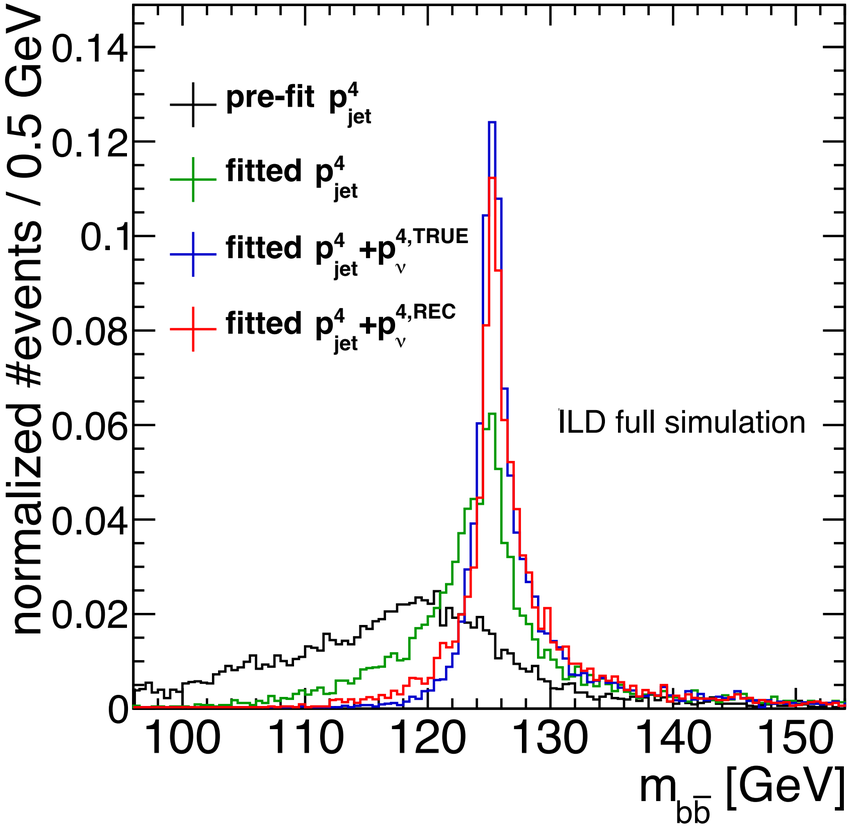




Multi-jet processes & Heavy flavour jets: Semi-leptonic decays!

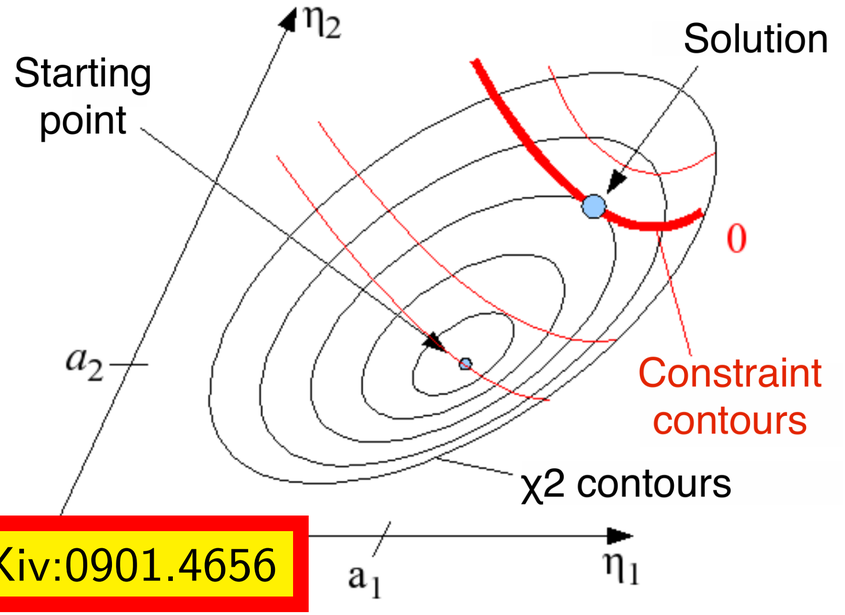
- PFA performance usually done on light jets only…
- Most interesting physics is involving b / c jets!
- Recent development (Yasser Radkhorrami) will be available in net release: **recover neutrino 4-momentum from semi-leptonic decays**
- Requires:
  - Lepton ID in jets => talk by Leonhard
  - **Kinematic fitting with jet-by-jet covariance matrix**
  - Excellent vertexing, individual PFOs





Multi-jet processes (WW, ZH(H), tt, …): Kinematic fitting

- Kinematic fit: adjustment of measured quantities under certain kinematic constraints:
  - Energy and momentum conservation
  - Invariant masses of particles



arXiv:0901.4656

Exploit well-known initial state in e^+e^- colliders

⇒ **need error parametrization, in particular for jets**

- Minimize χ^2:

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

$\boldsymbol{\eta}$: vector of measured kinematic variables (x)

$\boldsymbol{a}$: vector of fitted quantities

$\boldsymbol{\xi}$: vector of unmeasured kinematic variables

$\boldsymbol{V}$: **covariance matrix**

$\boldsymbol{\lambda}$: Lagrange multipliers

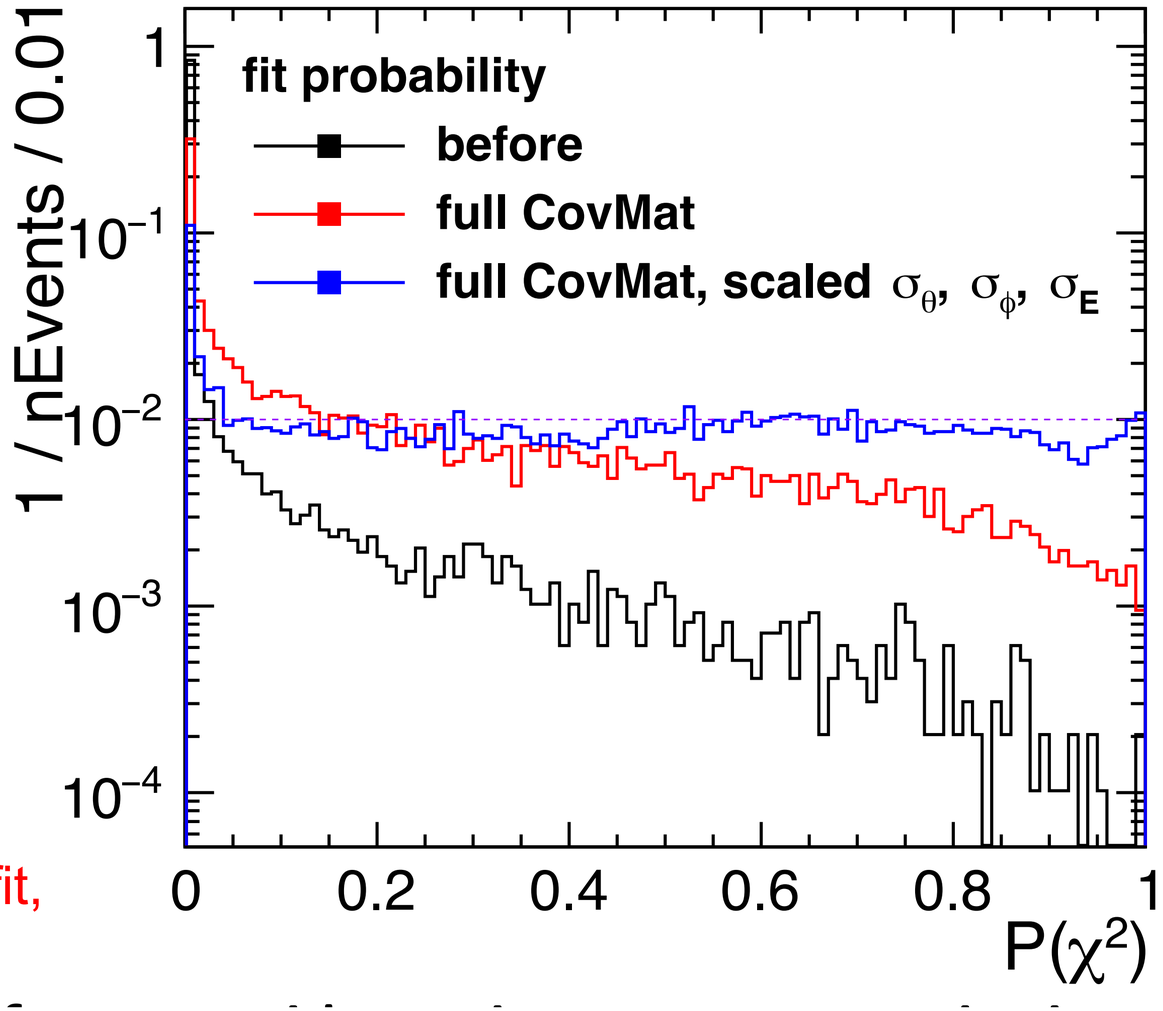
$\boldsymbol{f}(\boldsymbol{a}, \boldsymbol{\xi})$: vector of constraints

Multi-jet processes (WW, ZH(H), tt, …): Jet Covariances

- Very good error parametrisations for
  - detector resolution
  - PFA confusion
  - ISR treatment
  - Semi-leptonic decays
- Still missing
  - jet clustering errors
  - PS / fragmentation / hadronization

  ⇒ These require treatment of (anti-) correlated errors Between different jets

  ⇒ Technically clear how to implement in MarlinKinfit, needs time / person power…



Conclusion

- This was a tour-de-force ride through many, many aspects…
  … and much more to come in the following talks!

- **Reconstruction algorithms** of sufficient sophistication are essential to link detector performance and physics
  => many analyses do not yet exploit the full capabilities of the proposed detectors
  => be careful not to “optimize way” detector capabilities because reco / ana too simplistic!!!
- **Focus topics** contain a lot of interesting reconstruction and analysis method challenges
- They is an ideal area for a cross-detector and across-collider collaboration!
- Many promising developments ongoing
- But still many open issues **=> excellent opportunities to contribute new ideas!**