Asian Physics and Software meeting 2021.6.4

- Status reports:
  - Kinematic Fitter
  - Process for tuning
    - ZH->μμbb at 250 GeV -> 71st ILC General meeting
    - ZH->qqbb at 250 GeV
  - Target process: ZH->μμφφ->μμbbbb at 250 GeV
    - Sample generation

Our approach for non-Gaussian distributions

- The basic method assumes that the measured parameters would have Gaussian error against the true value.
- In order to treat arbitrary error distributions, the chi-square term is re-defined as the log-likelihood function;

$$\chi^2(\boldsymbol{\eta}, \boldsymbol{\xi}, \boldsymbol{\lambda}) = -2\ln L_{fo}(\boldsymbol{\eta}) - 2\boldsymbol{\lambda}^T \boldsymbol{h}(\boldsymbol{\eta}, \boldsymbol{\xi}) - 2\ln L_{sc}(\boldsymbol{\eta}, \boldsymbol{\xi})$$

$$L_{fo}(\boldsymbol{\eta}) = \prod_{i=1}^{n} f_i(y_i; \eta_i) \qquad L_{sc}(\boldsymbol{\eta}, \boldsymbol{\xi}) = \prod_{i=1}^{m} s_i(\boldsymbol{\eta}, \boldsymbol{\xi})$$

f_i : error distributions s_i : soft constraint distributions

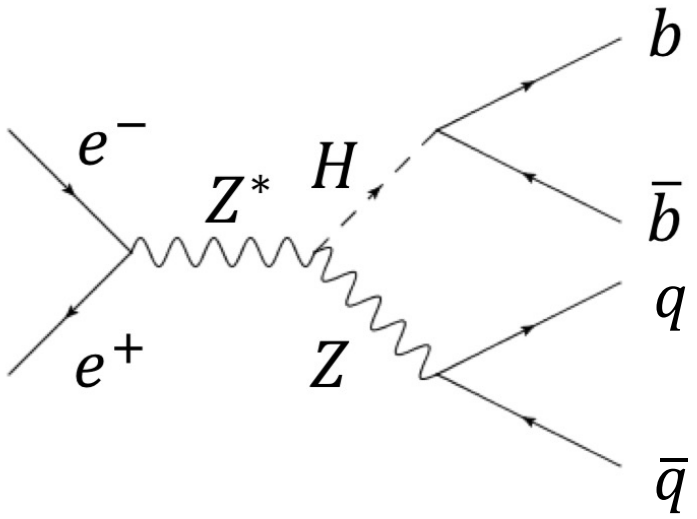
Note:

- The error distributions are normalized as the peak position returns 1.
- The soft constraint term is applied optionally.

- In the case of Gaussian distributions, the basic method is reproduced.

Test process: e^+e^- -> ZH -> qqbb

- This process is selected for technical study of our kinematic fitter.



Simulation setup

- $\sqrt{s}$ = 250 GeV
- (P_{e^-}, P_{e^+}) = (-1, +1)
- ILD DBD sample, ~10k event
- Main background: 4f_ZZ(WW)_hadronic

Event reconstruction

1. Particle reconstruction: PandoraPFA
2. Muon selection: IsolatedLeptonTaggingProcessor
3. Jet clustering & Flavor tagging : LCFIPlus
   Durham (forced to 4 jets)
4. Jet pairing:

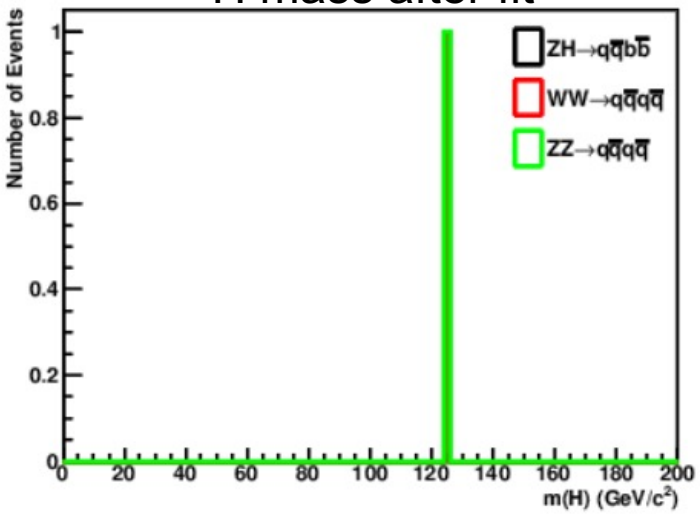
$$\chi 2_{pair} \equiv \frac{(M_{12} - M_Z)^2}{\sigma_Z^2} + \frac{(M_{34} - M_H)^2}{\sigma_H^2}$$

Kinematic Fit

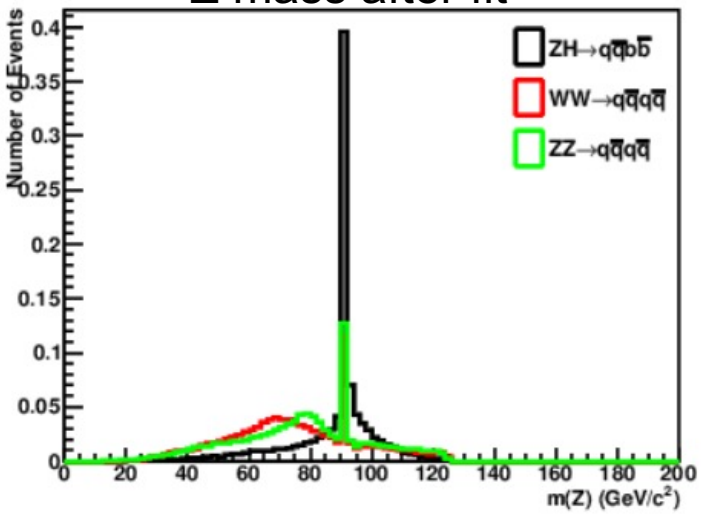
- FitObject
  - 4 JetFitObject + 1 ISRPhotonFitObject
  - Jet resolution: b-jet pair
- Constraint
  - Total Energy/Px/Py/Pz for all FOs
  - Higgs mass = 125 GeV for bb
  - Z mass w/ Breit-Wigner for qq (SoftConstraint)

Test process: e^+e^- -> ZH -> qqbb

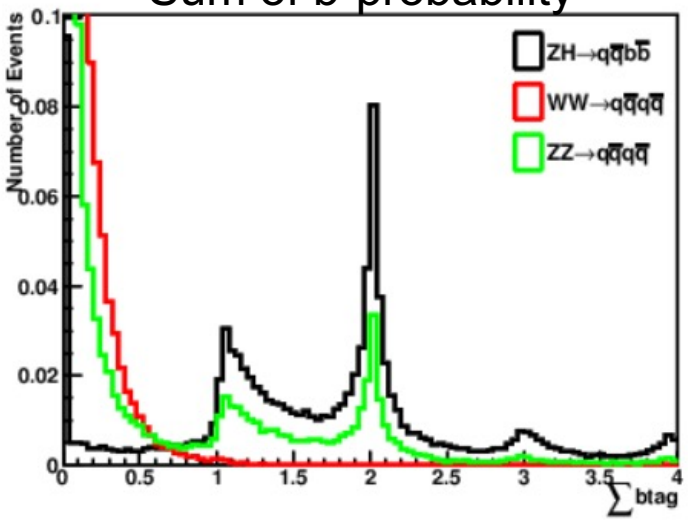
H mass after fit



Z mass after fit

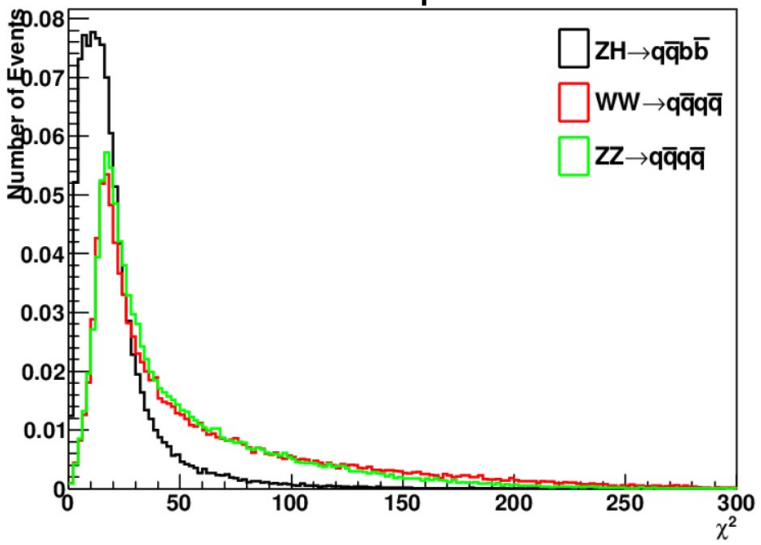


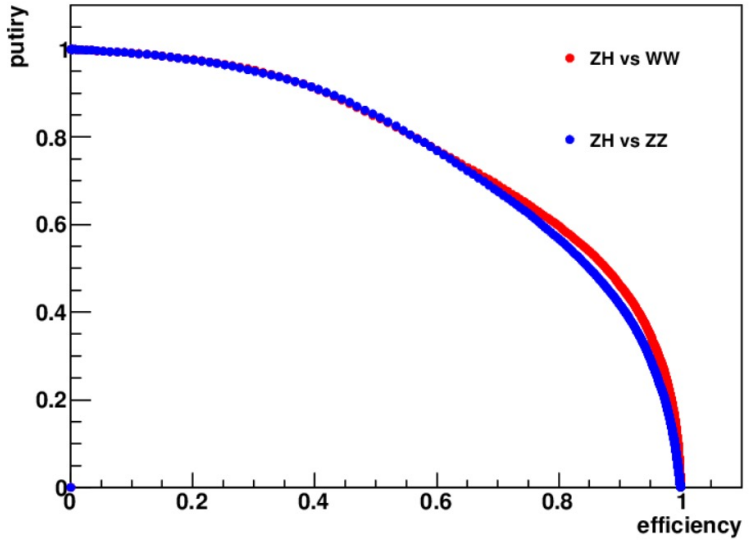
Sum of b-probability



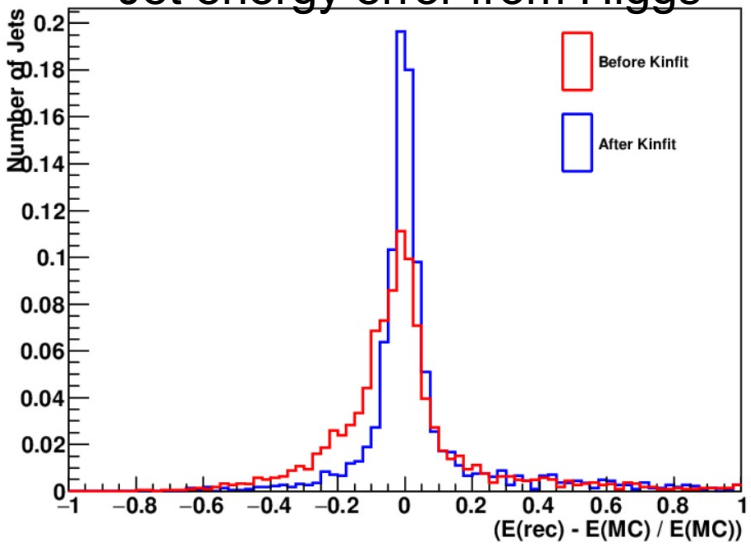
Test process: e^+e^- -> ZH -> qqbb

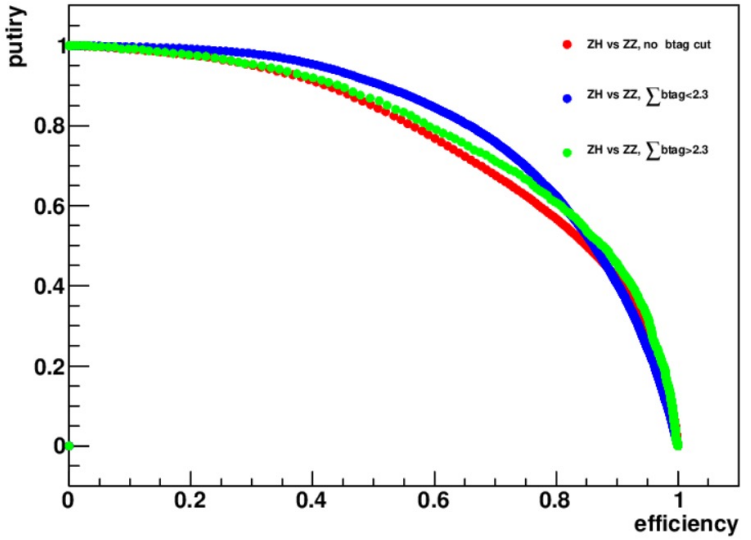
Chi-square





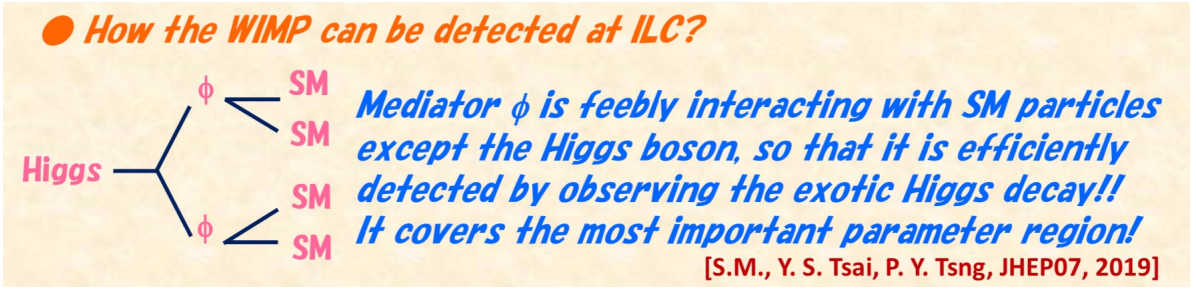
Jet energy error from Higgs



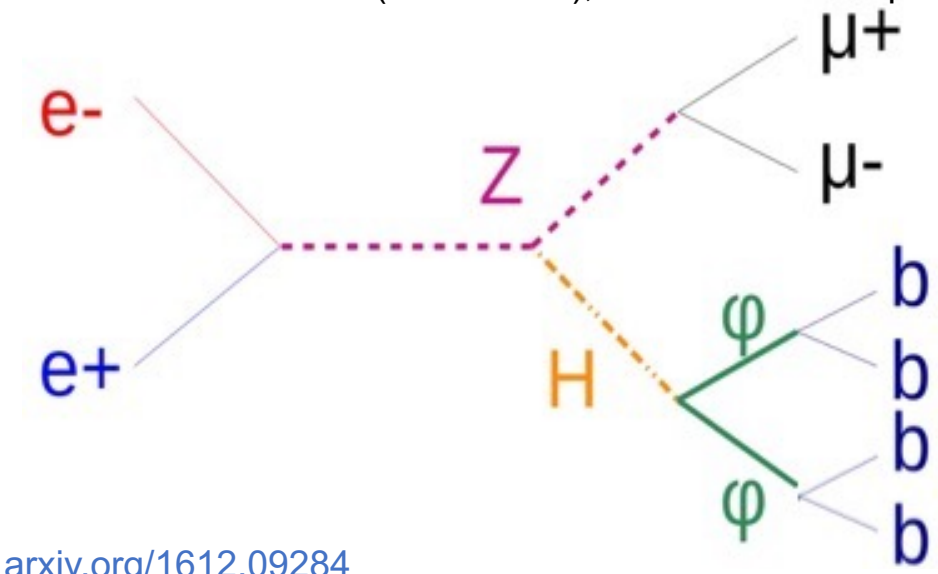


ZH->μμφφ->μμbbbb at 250 GeV

- Motivation:
  - Higgs exotic decay (H->φφ->bbbb)
  - To apply b-jet kinematic fitter
- Setup:
  - WHIZARD 2.8.5
  - mφ: 15, 20, 30, 40, 50, 60 [GeV]
  - 20,000 events for each mφ, polarization{ (-0.8,+0.3), (+0.8,-0.3) }
  - Official setting(mc-2020), √s = 250 GeV
- Status:
  - ✓ Sample preparation
    - Generate WHIZARD sample and some check at MC level
    - Simulate with DDSim, Reconstruct with MarlinStdReco
  - ☐ Fast analysis
    - IsolatedLeptonTagging, JetClustering (4-jet)
  - ☐ Test fitting
  - ☐ Detailed analysis



S. Matsumoto(Kavli IPMU), ILC summer camp 2020



arxiv.org/1612.09284

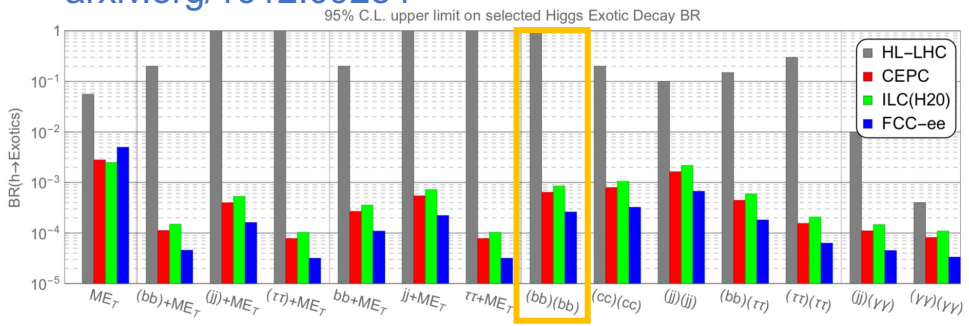


Fig. 12. The 95% C.L. upper limit on selected Higgs exotic decay branching fractions at HL-LHC, CEPC, ILC and FCC-*ee*. The benchmark parameter choices are the same as in Table 3. We put several vertical lines in this figure to divide different types of Higgs exotic decays.

MC production: Whizard

- model: THDM_CKM

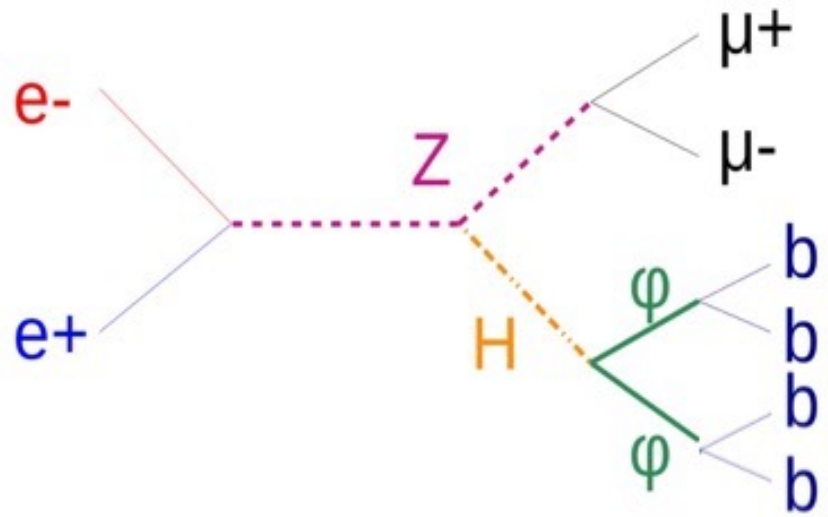
  Note: There are some bugs so MSSM_CKM may be better.

- process description:

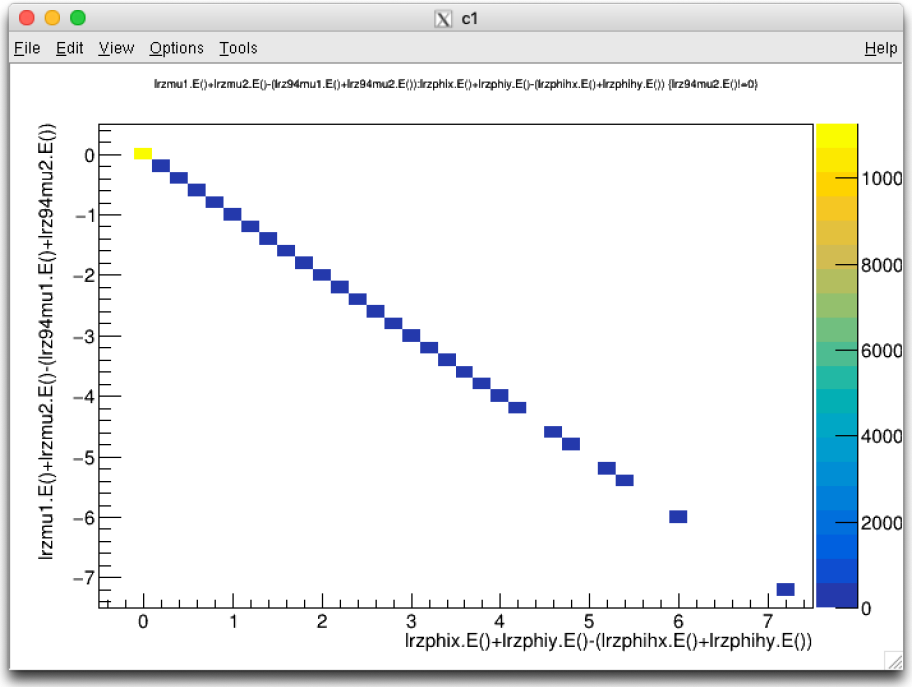
  "e-", "e+" => "mu+", "mu-", "h0" { $restrictions = "1+2~Z && 3+4~Z" },
  h0 => "H0", "H0" (unstable), H0 => b, "b~" (unstable)

- parameters
  - αs = 1.e-6
  - ms = mc = mb = 0 GeV
  - H0 = φ, mH0 = 30 GeV, wH0 = 4.1 MeV
  - Yd_33 = 1.0

- issues
  - There are some momentum exchanges between phis and muons.

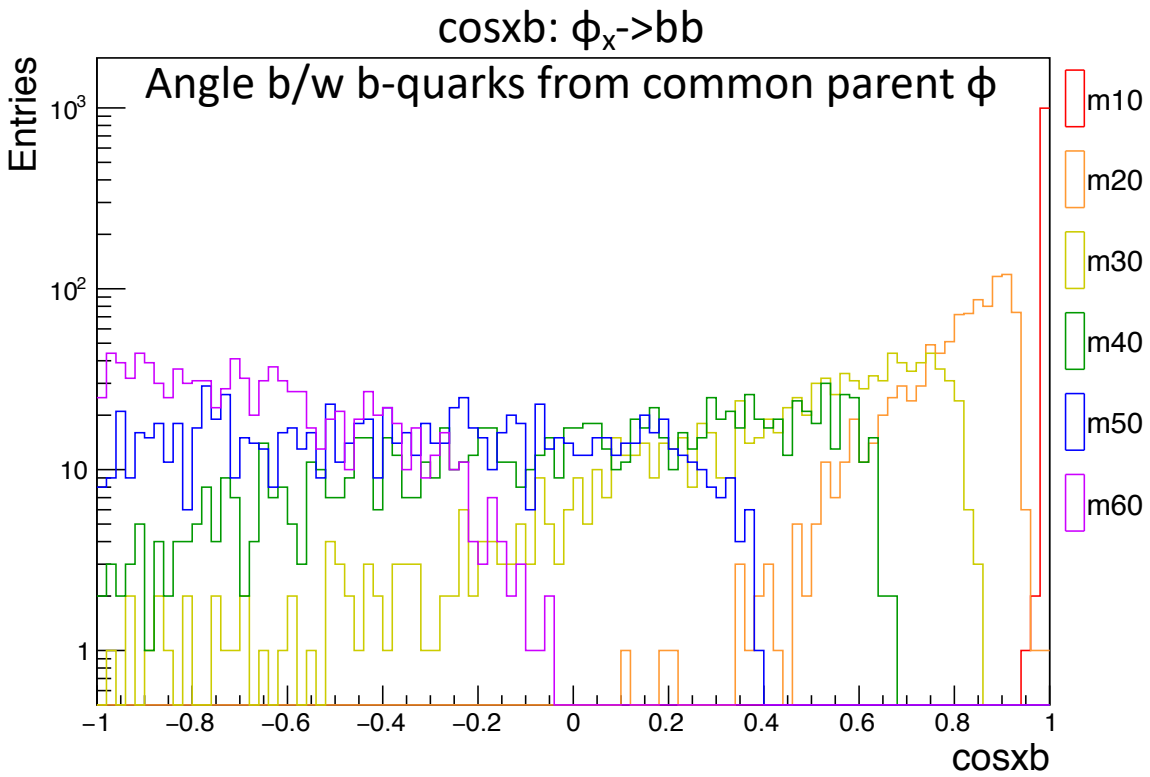


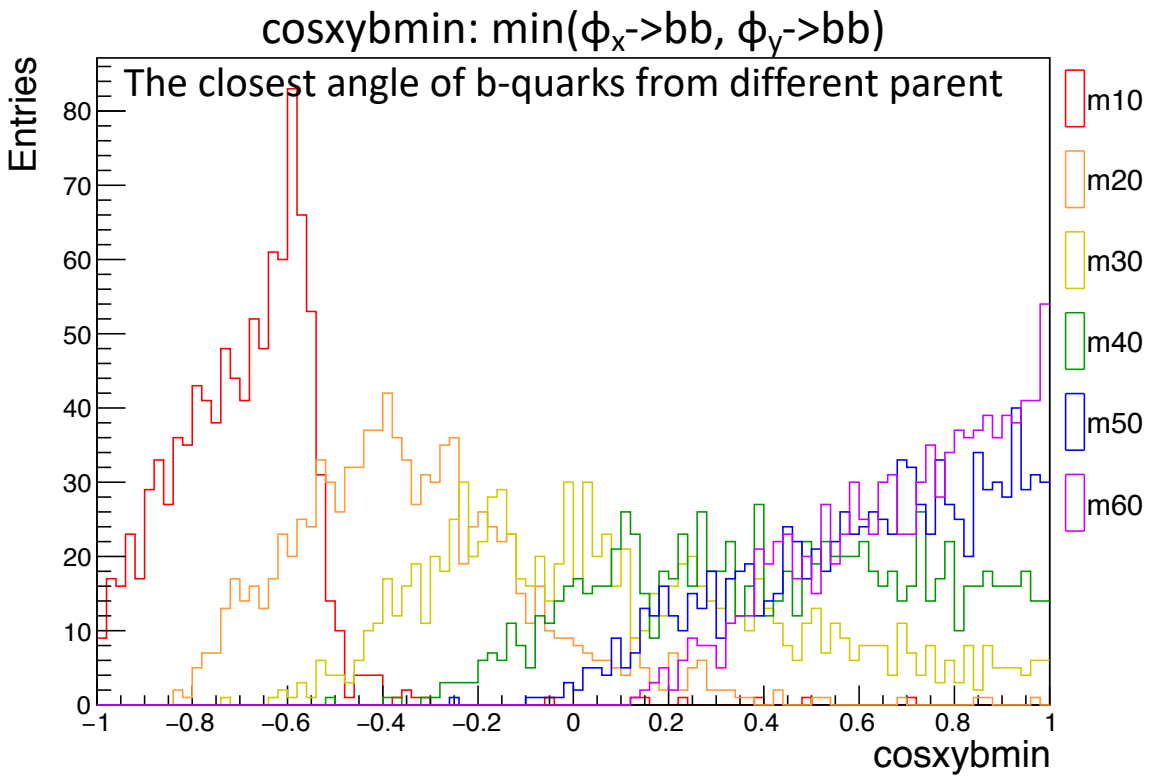
$\Delta E_{\mu s}$



$\Delta E_{\varphi s}$

MC-level check: b-quark angle

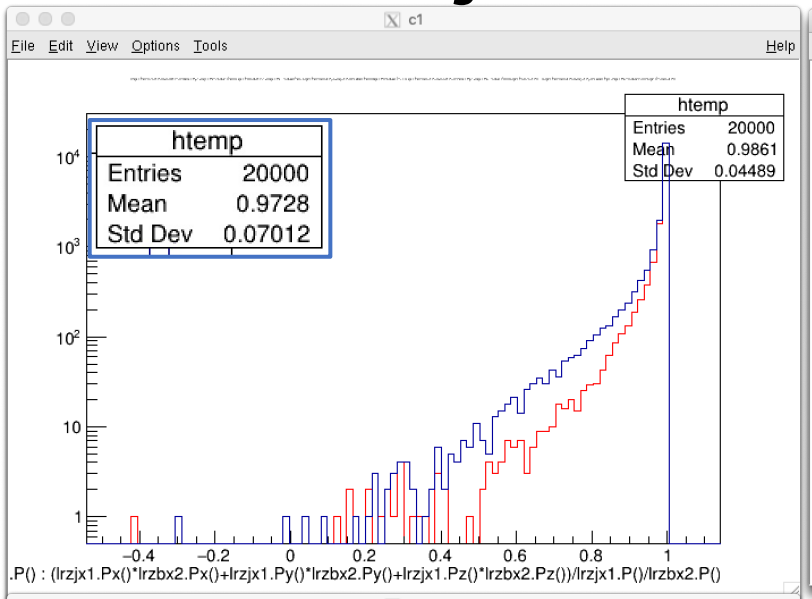


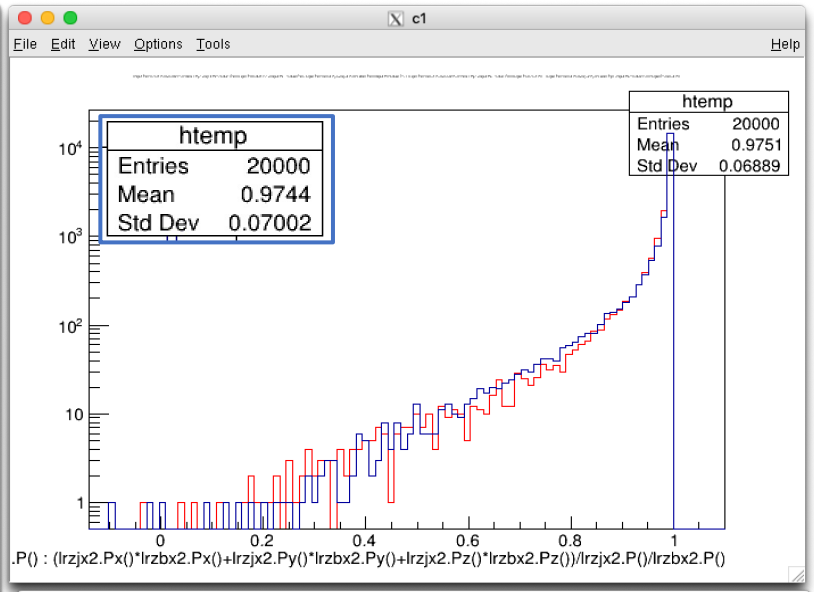


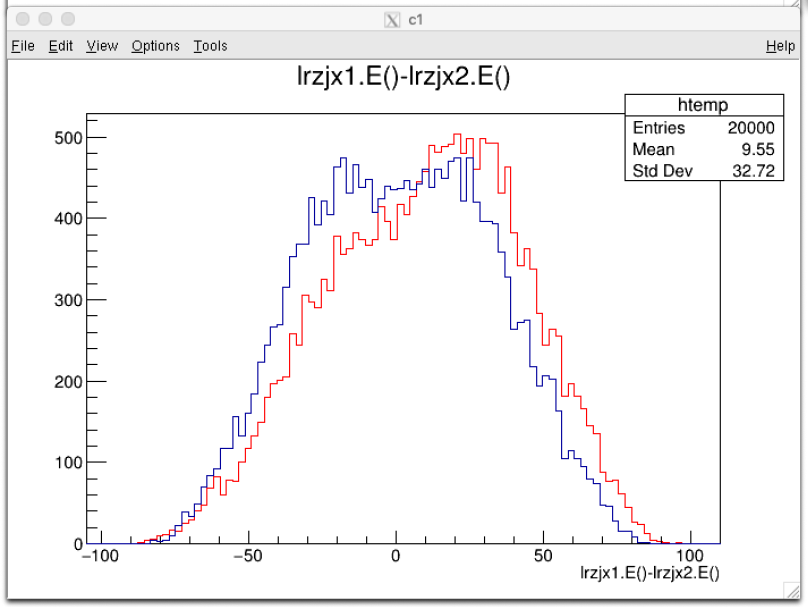
- The lighter mϕ, the easier to separate ϕs and the more difficult to separate b-quarks decayed from a common ϕ.
- We expect that the LCFIPlus vertexing is effective to separate the b-jets.
- Note: The case of m10 (i.e. mϕ = 10 GeV) is not enough to generate 4 B-hadrons.

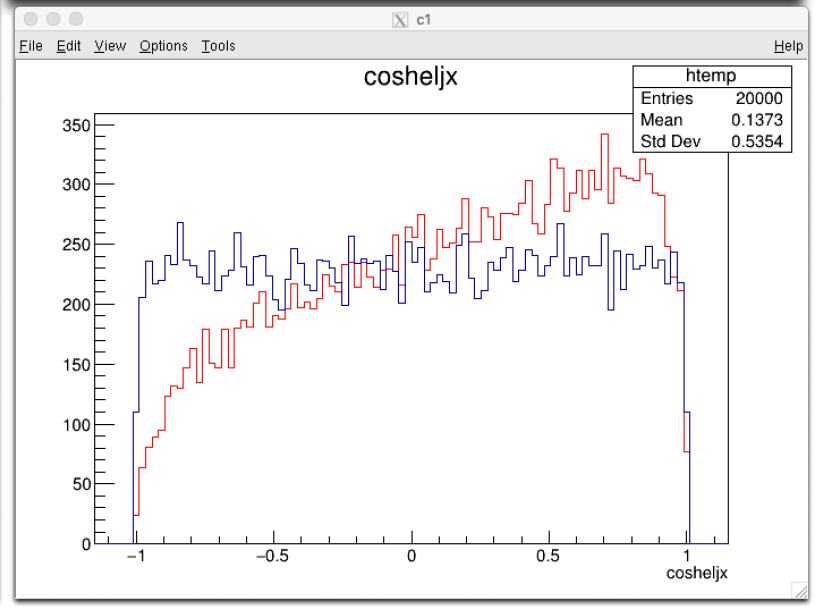
MC-level check: MC-jet

w/o Boost
w/ Boost
↖ $\cos\theta_{x1}$
↗ $\cos\theta_{x2}$
↙ E1 – E2
↘ $\cos\theta_{hel}$







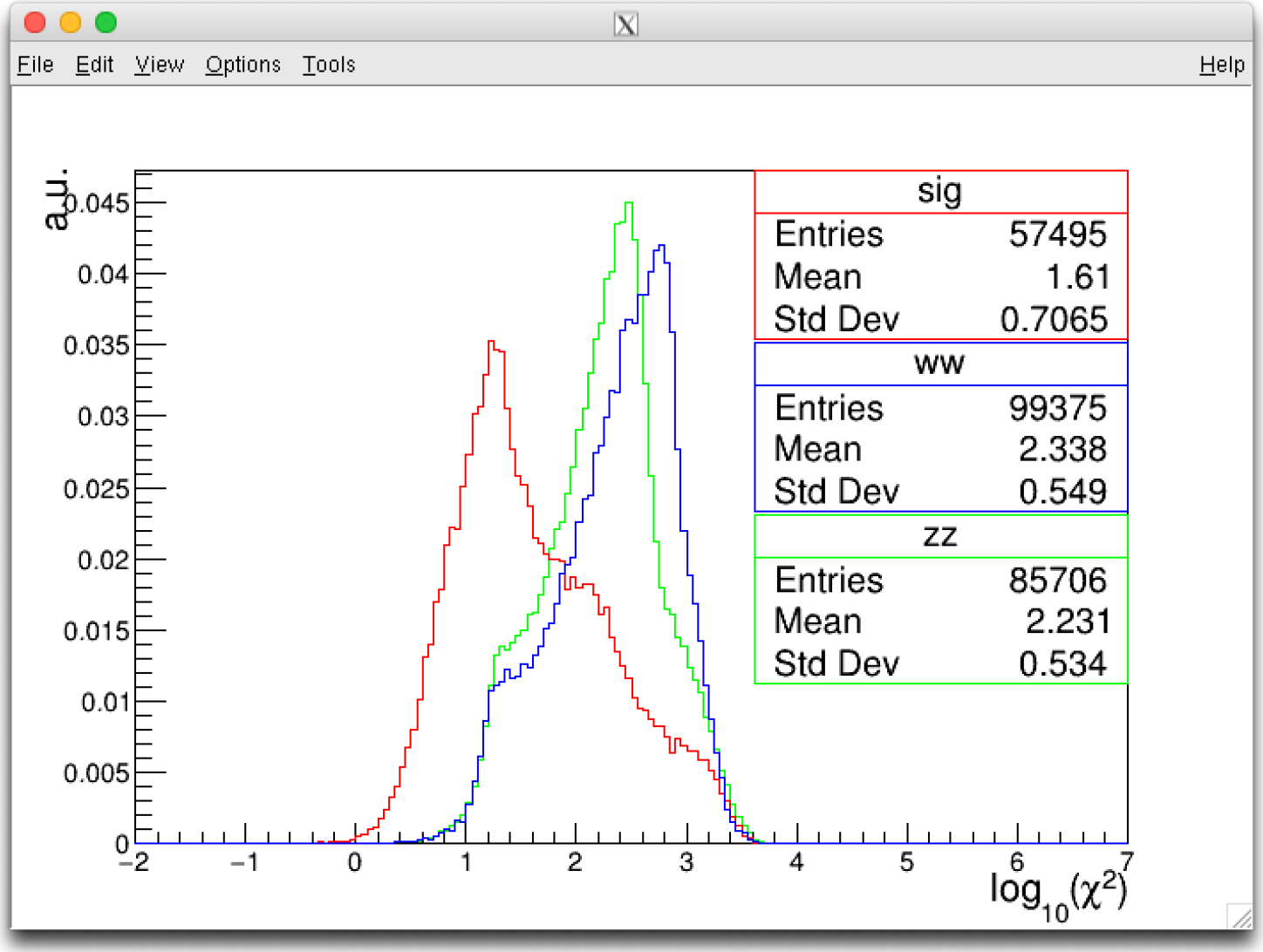


Summary and Plans

- ZH->qqbb at 250 GeV
  - Fast test of fitting is performed.
  - To use flavor information and resolutions
  - To optimize high level reconstruction
    - IsoLep, Overlay removal
  - We may need some cheating.
- Target process: ZH->μμφφ->μμbbbb at 250 GeV
  - Sample generation has almost done.
  - Alternative model MSSM_CKM will be tested.
  - Next step: Full analysis without kinematic fit.

backup

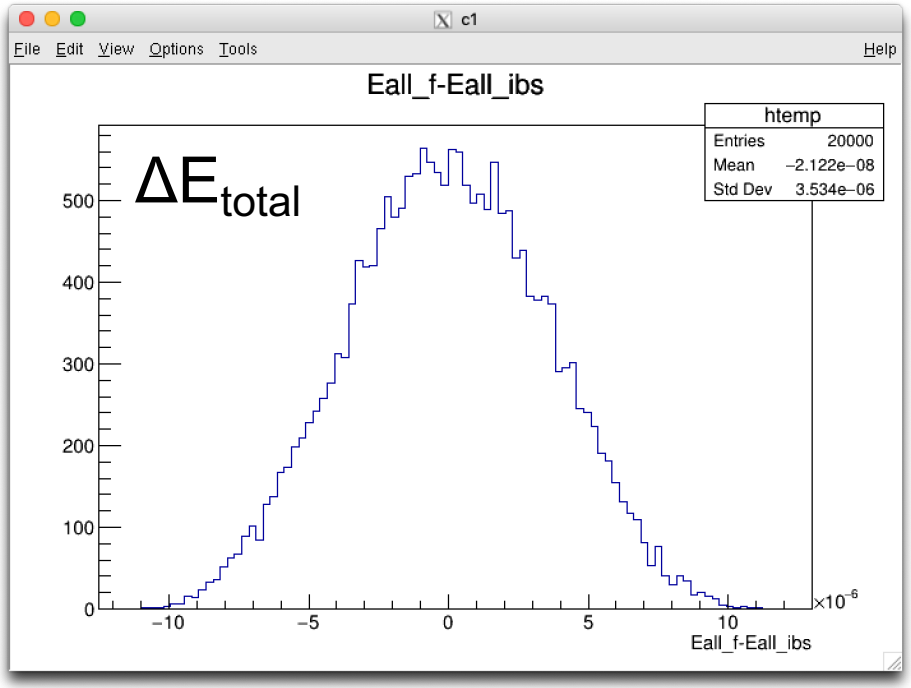
ZH->qqbb



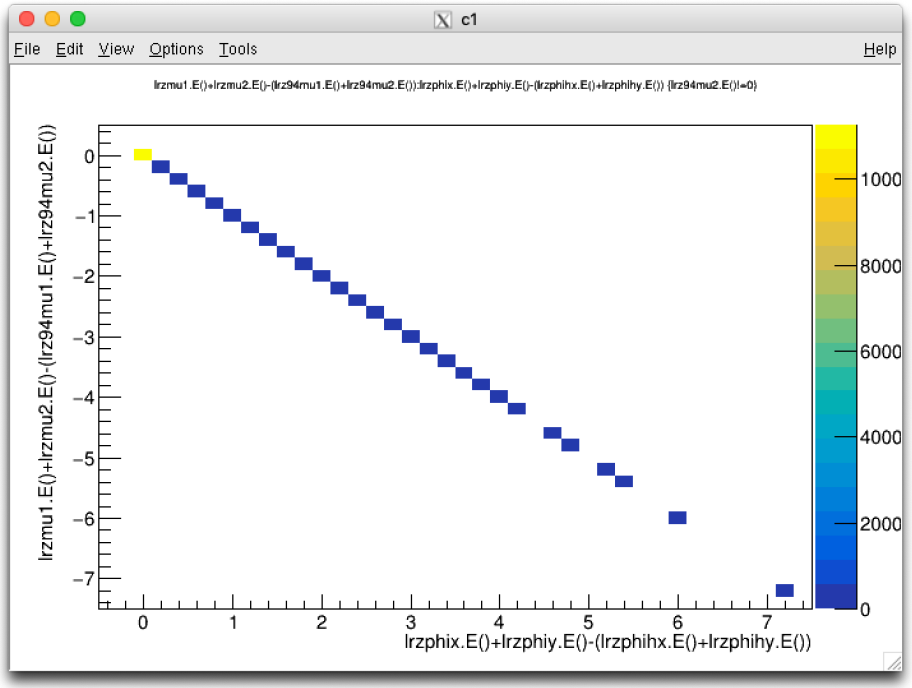
- sig: ZH->qqbb
- ww/zz: 4f_ww/zz_h
- Resolution: all b-jet
- TO DO:
  - Sig: chi2 vs mZ
  - flavor ごとに resolution を変える
  - 実際の生成数にスケール
  - All bkg
  - Clustering flag で確認
    - Pair 正否
    - Pairing は先にやるべき？
      - Marlinkinfit は fitter でやっている
  - higgsHC 外したら？
  - MC との紐付け
  - ルーティン処理した後 lcio でもらう
    - MC処理、変数用意は加藤
  - Overlay removal
  - 最終目標は？
    - 物理？ KF のベンチマーク？

MC production: check of momentum exchange

process c



ΔE_μs

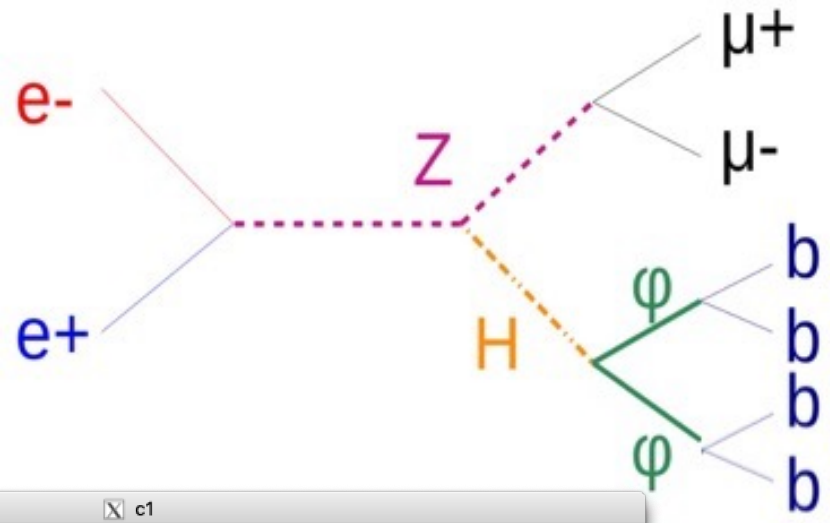


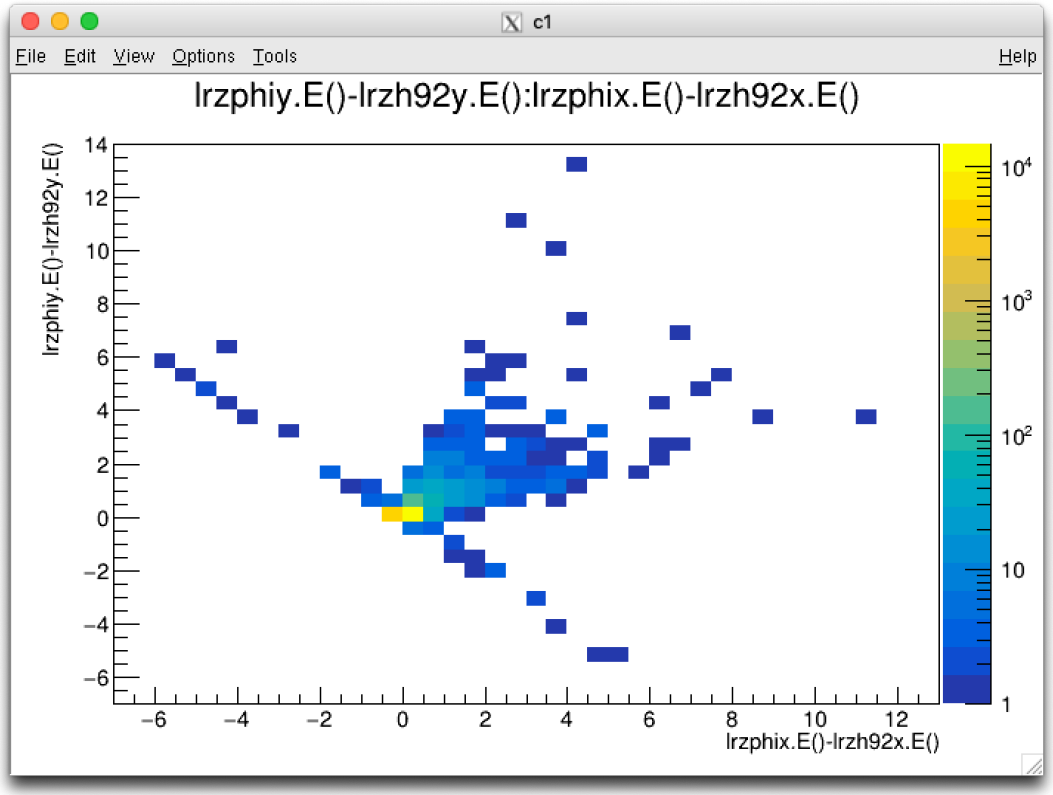
ΔE_φs

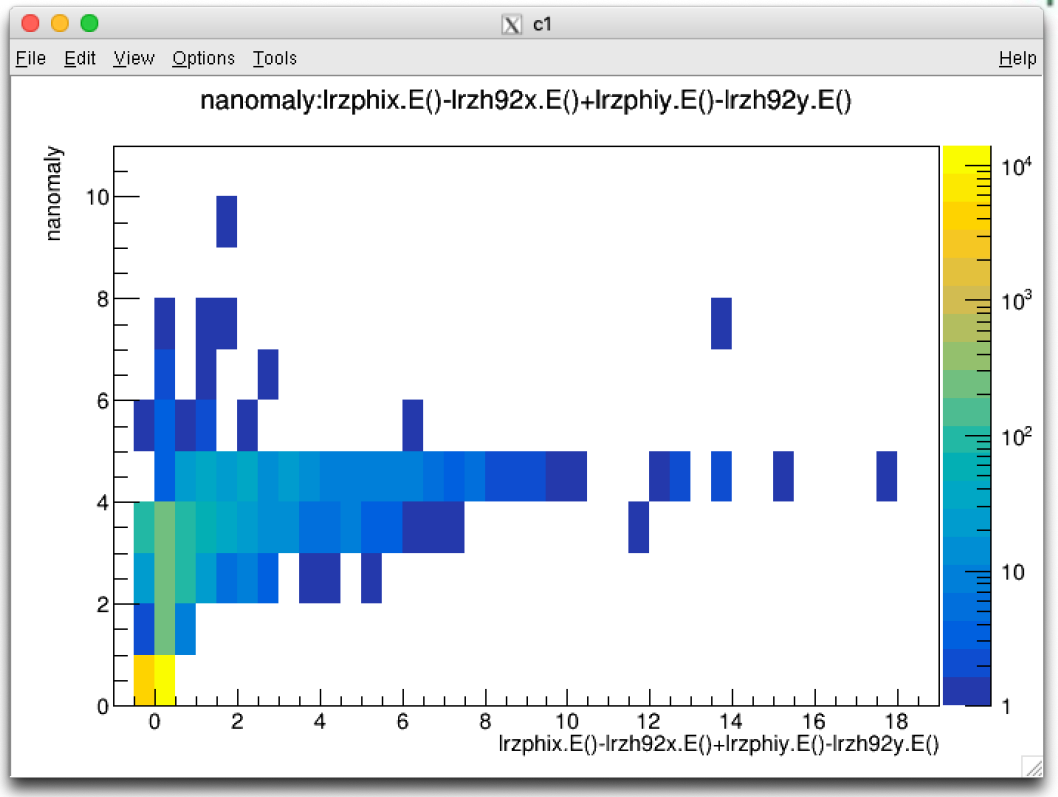
Note: There are a few events where a gluon has no daughter and I ignored them.

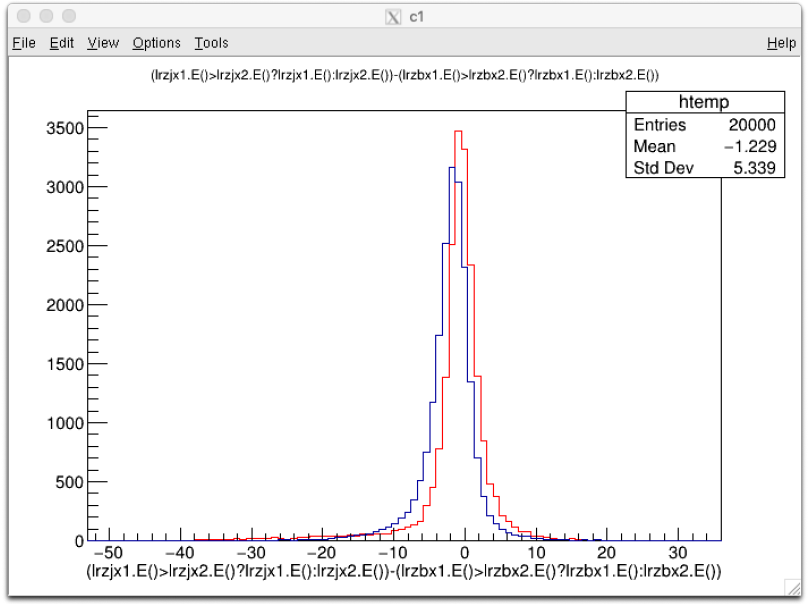
Check of MCPs for MC jet

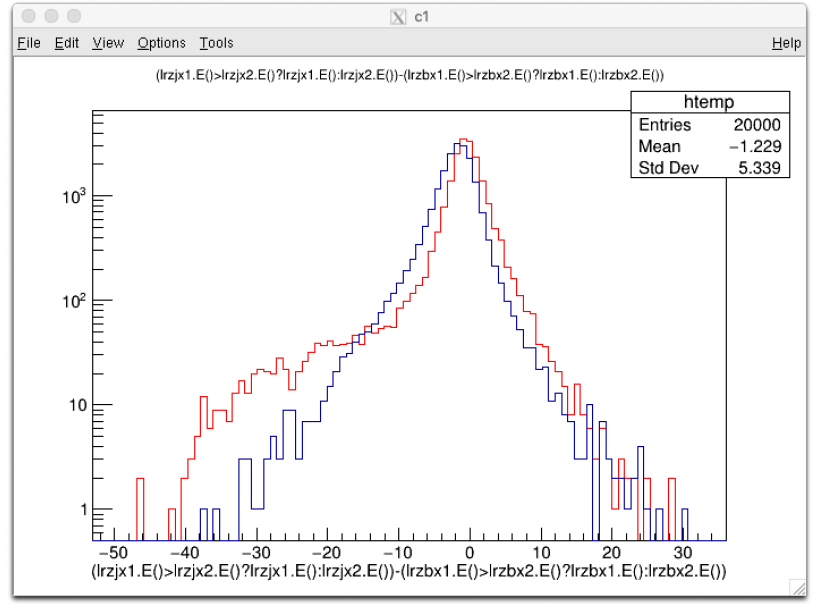
- phi{x, y} : parton level
- h92{x, y} : sum of hadrons
- anomaly : number of violation of energy conservation

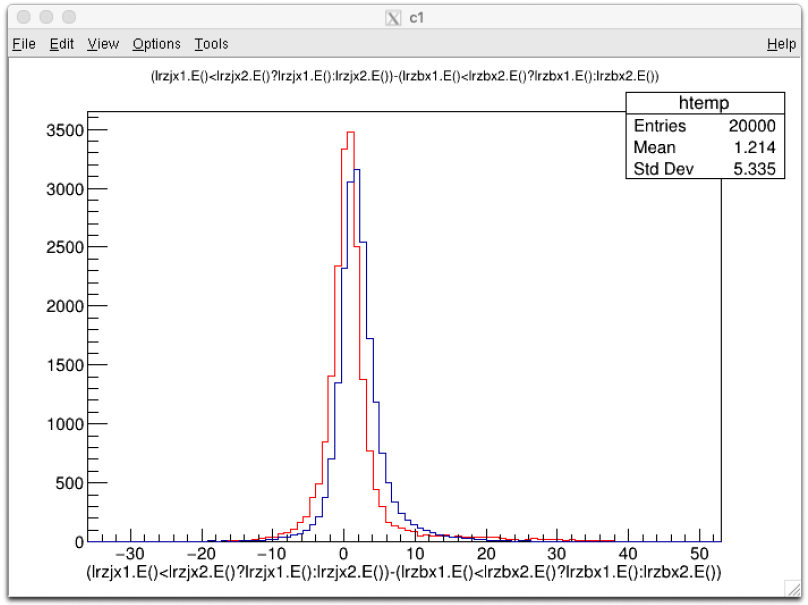


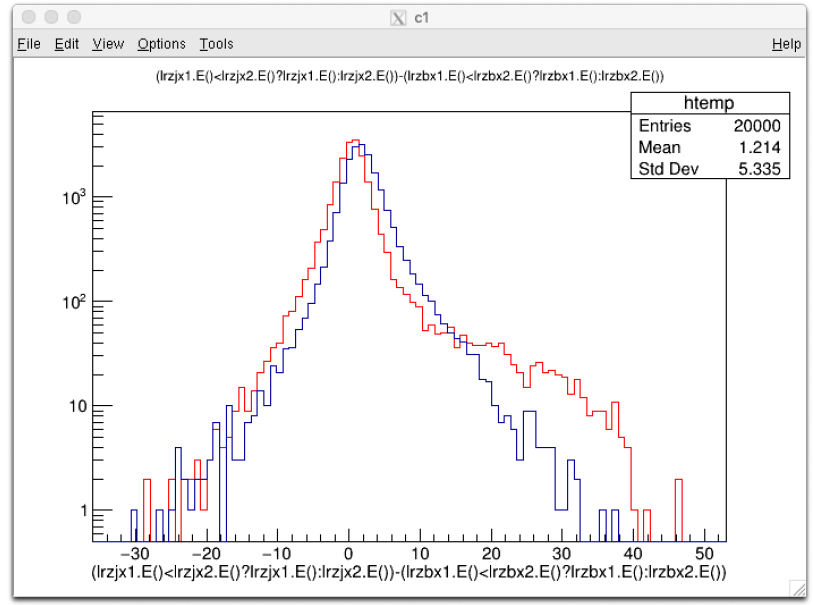










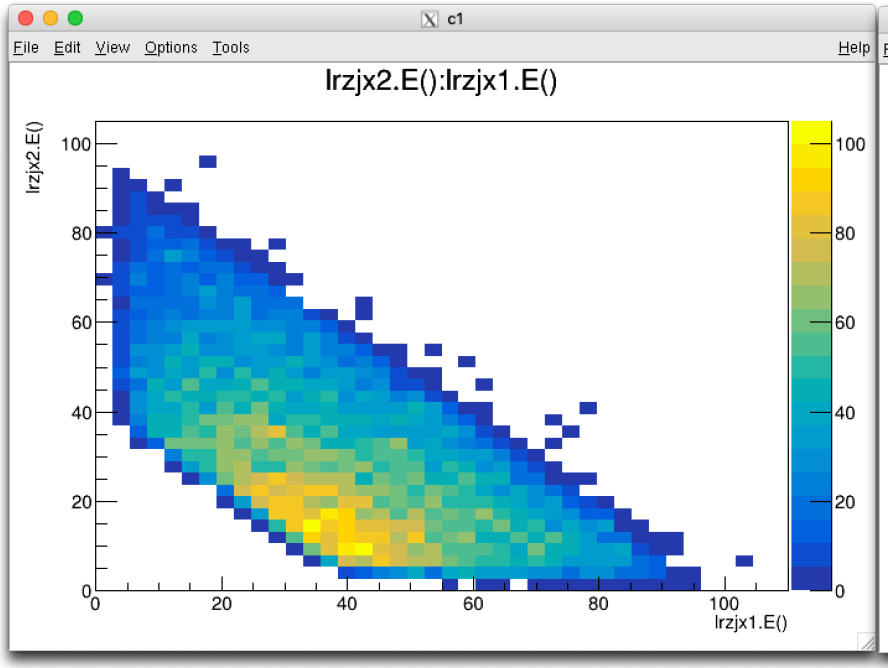


w/o Boost

w/ Boost

↑ Ej大 – Eq大

↓ Ej小 – Eq小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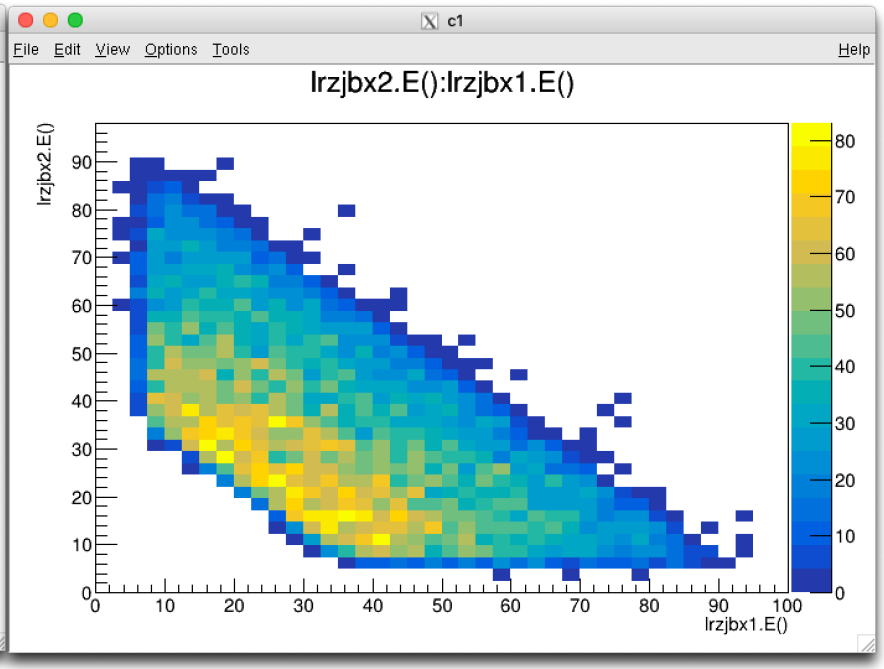
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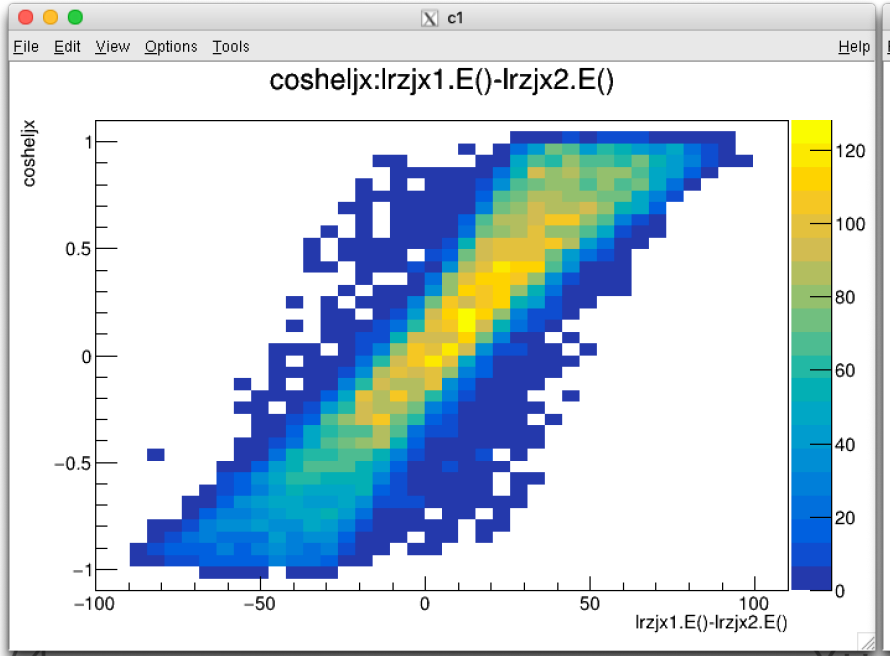
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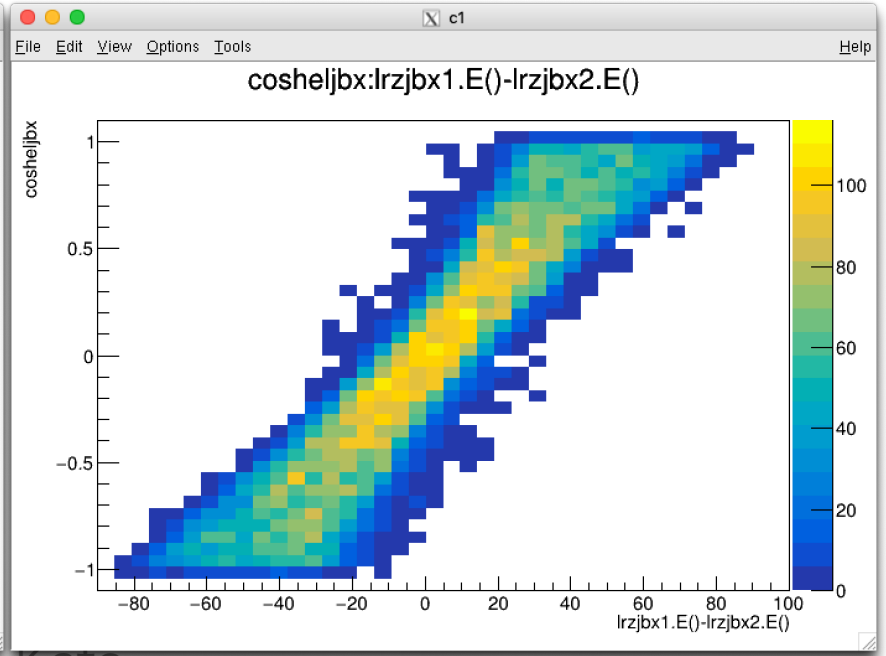
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cosheljbx
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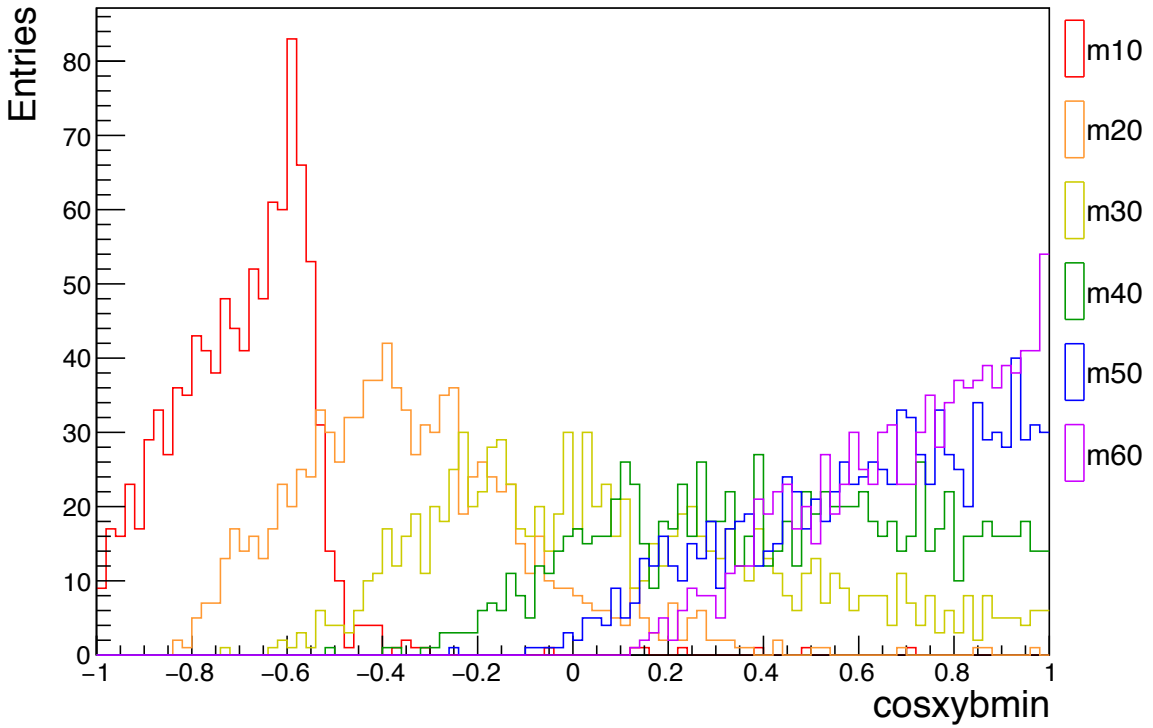
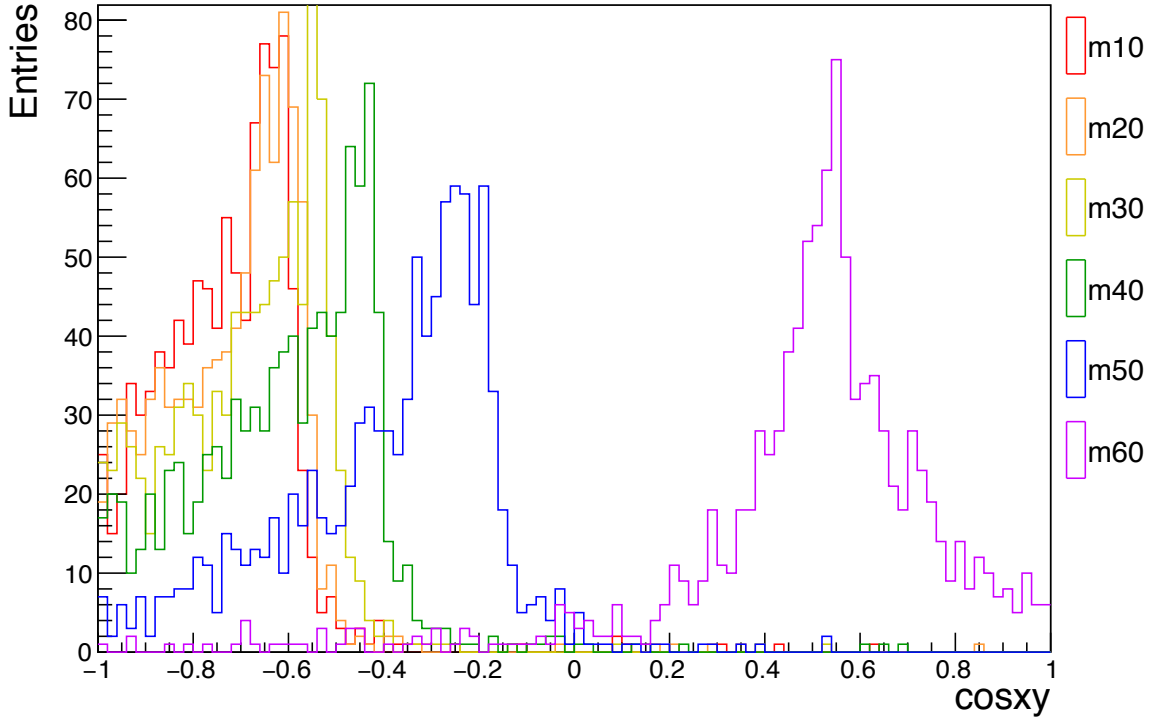
MC-level check: b-quark angle

cosxybmin: 親が異なるbのペアで角度が最小のもの



(参考) cosxy: ϕ(35), ϕ(36) の間の角度



- m60 でも LCFIPlus による分離が期待できる