Benchmark Analysis
Study of Higgs→invisible at $\sqrt{s}$ = 500 GeV

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Status

- Apply cheating; w/o ISR, BS, Overlay, Z->bb/cc
- Check di-jet mass & recoil mass distribution of signal
- Get result of l5/s5 w/ cheat
- Fit signal/bkg distribution
- Understand how ΔMrec and ΔEjj are related

$$\Delta M_{rec} \sim \frac{\sqrt{s} - (1-\beta^2)E_{jj}}{M_{rec}} \Delta E_{jj}$$
$$\sim 4\Delta E_{jj}\ (when\ \sqrt{s} = 500\ \mathrm{GeV})$$

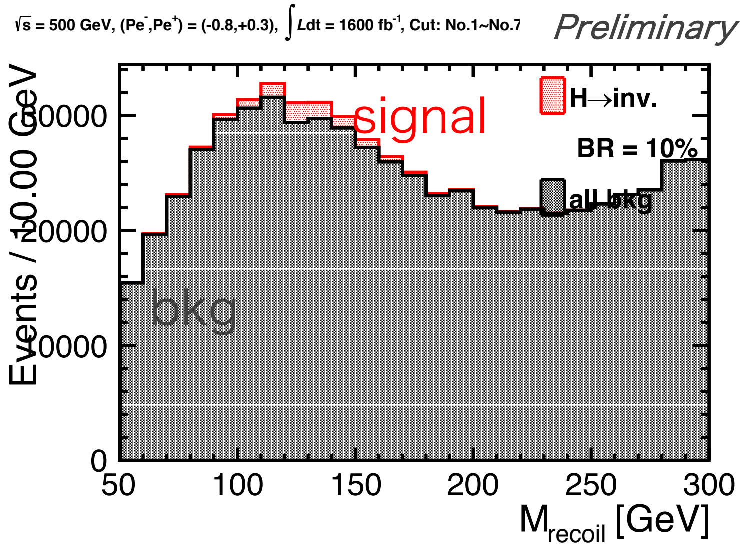
- Understand why Mrec can't be fitted by single Gaussian
  - Mrec consisted of multiple Gaussian overlaps because of energy dependence of JER
- Considering how to relate ΔMrec and JER

Preliminary

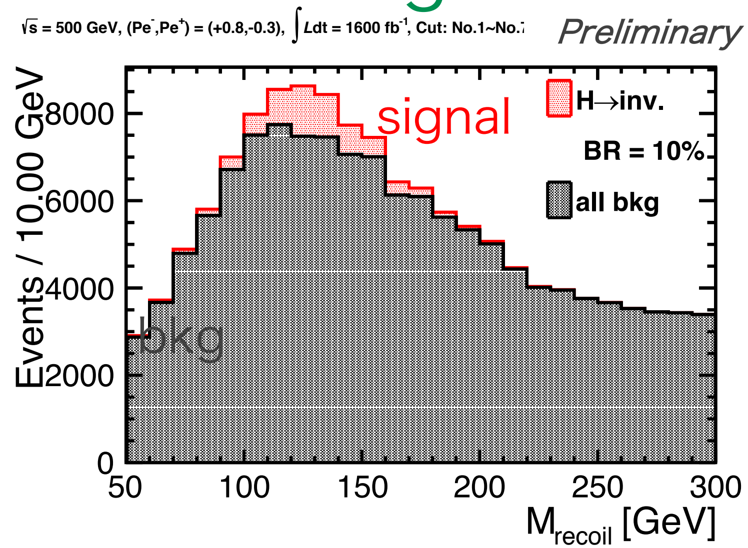
ILD_l5_o1_v02

Result w/ cheat [√s = 500 GeV, 1600 fb^{-1},BR(H->inv.)=10%]

Left



Right



signal w/o ISR, BS, Overlay

ILD_l5_o1_v02 w/ cheat [√s = 500 GeV, 1600 fb^{-1}]	$(P_{e^-}, P_{e^+}) = (-0.8, +0.3)$	$(P_{e^-}, P_{e^+}) = (+0.8, -0.3)$	combined
significance assuming BR(H->inv.)=10%	17.127	22.334	28.145
UL on BR (95% C.L.)	0.963 %	0.739 %	0.586 %
Full Sim Result (l5)	1.569 %	1.156 %	0.931 %

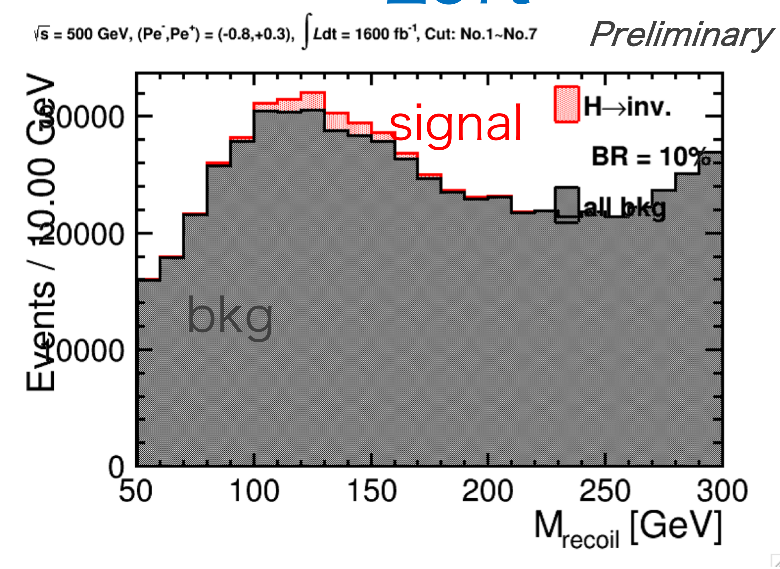
Preliminary

Preliminary

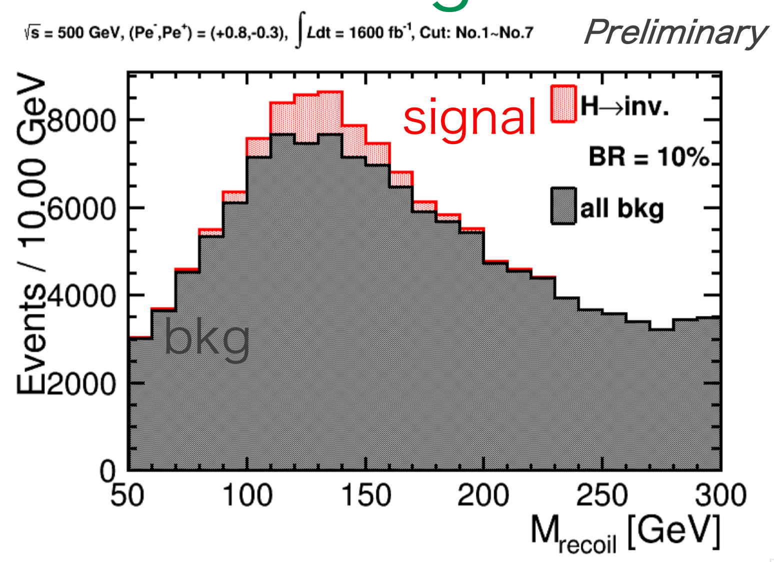
ILD_s5_o1_v02

Result w/ cheat [√s = 500 GeV, 1600 fb^{-1},BR(H->inv.)=10%]

Left



Right

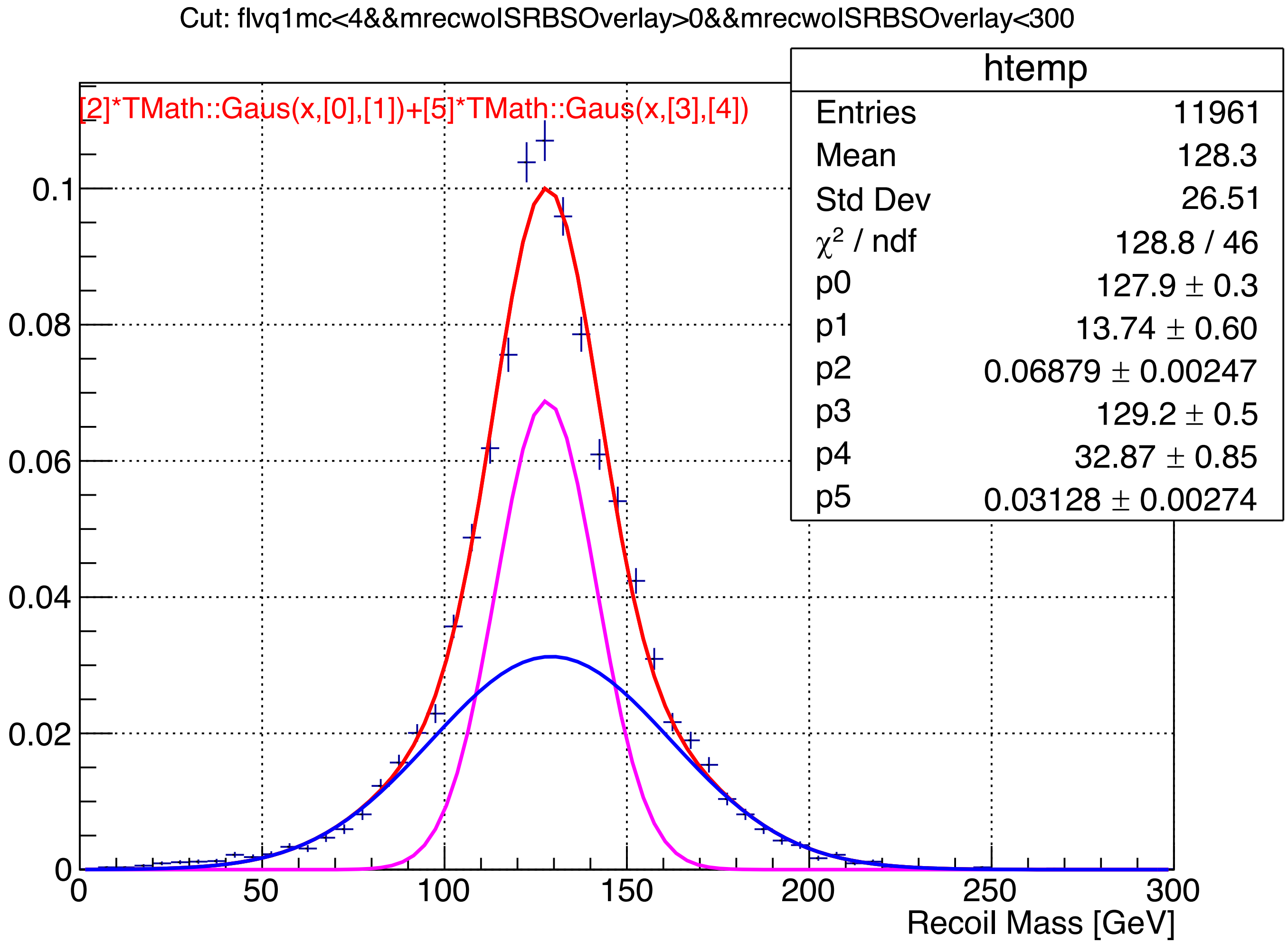


signal w/o ISR, BS, Overlay

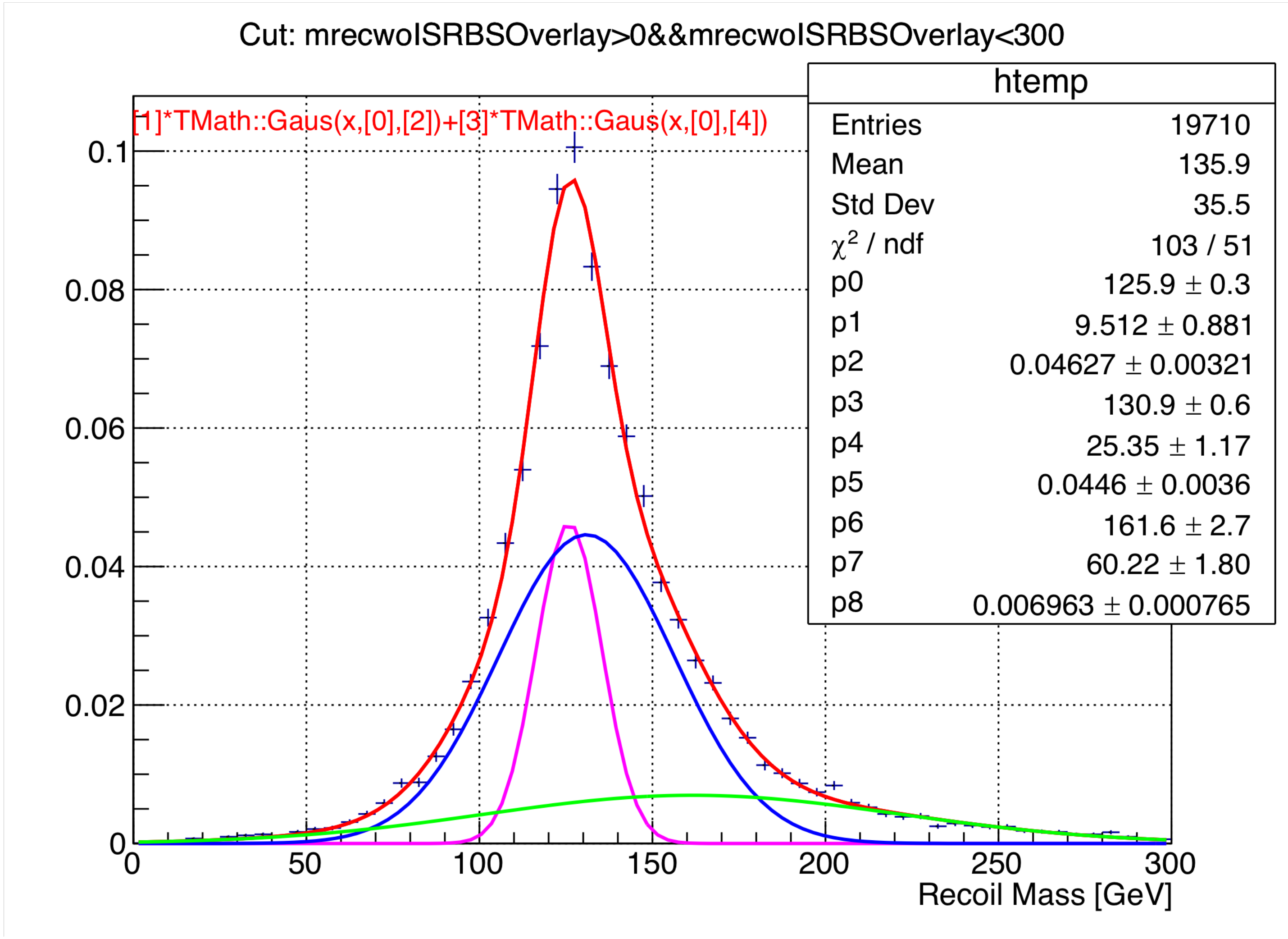
ILD_s5_o1_v02 w/ cheat [√s = 500 GeV, 1600 fb^{-1}]	$(P_{e^-}, P_{e^+}) = (-0.8, +0.3)$	$(P_{e^-}, P_{e^+}) = (+0.8, -0.3)$	combined
significance assuming BR(H->inv.)=10%	16.817	21.947	27.649
UL on BR (95% C.L.)	0.981 %	0.752 %	0.597 %
Full Sim Result (s5)	1.579 %	1.157 %	0.933 %

Preliminary

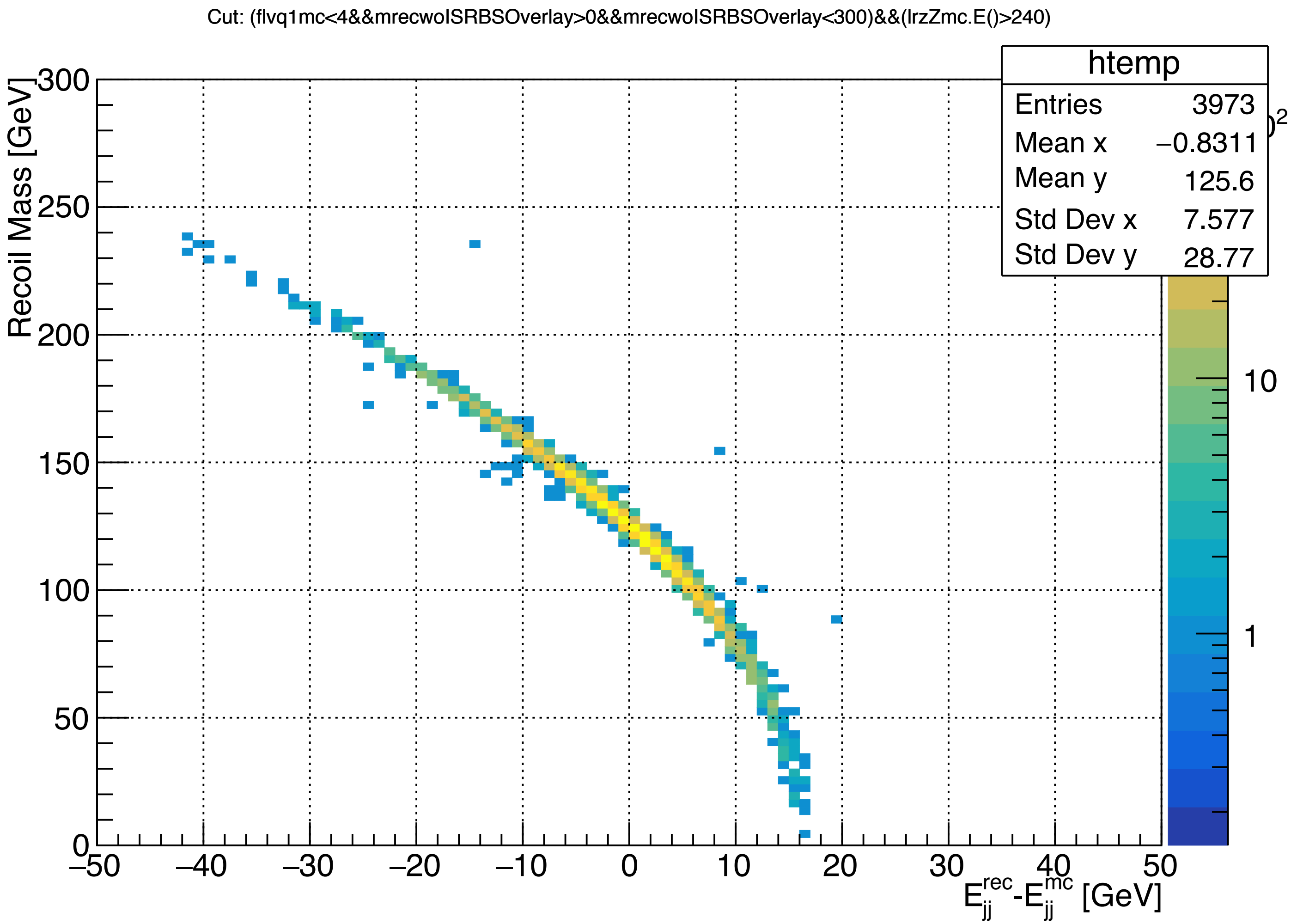
double-Gaussian fit w/o Z->bb/cc



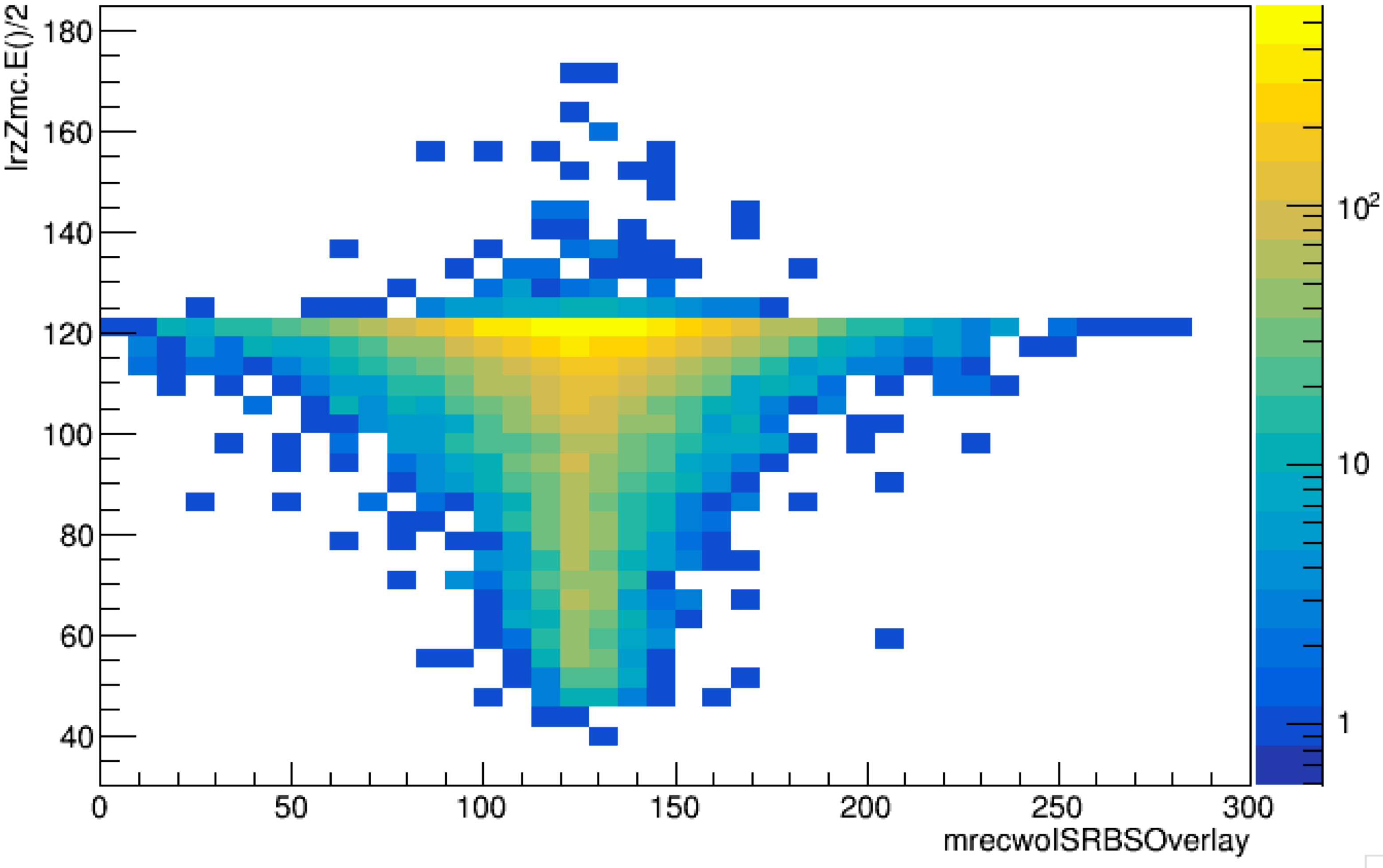
triple-Gaussian fit w/ Z->bb/cc



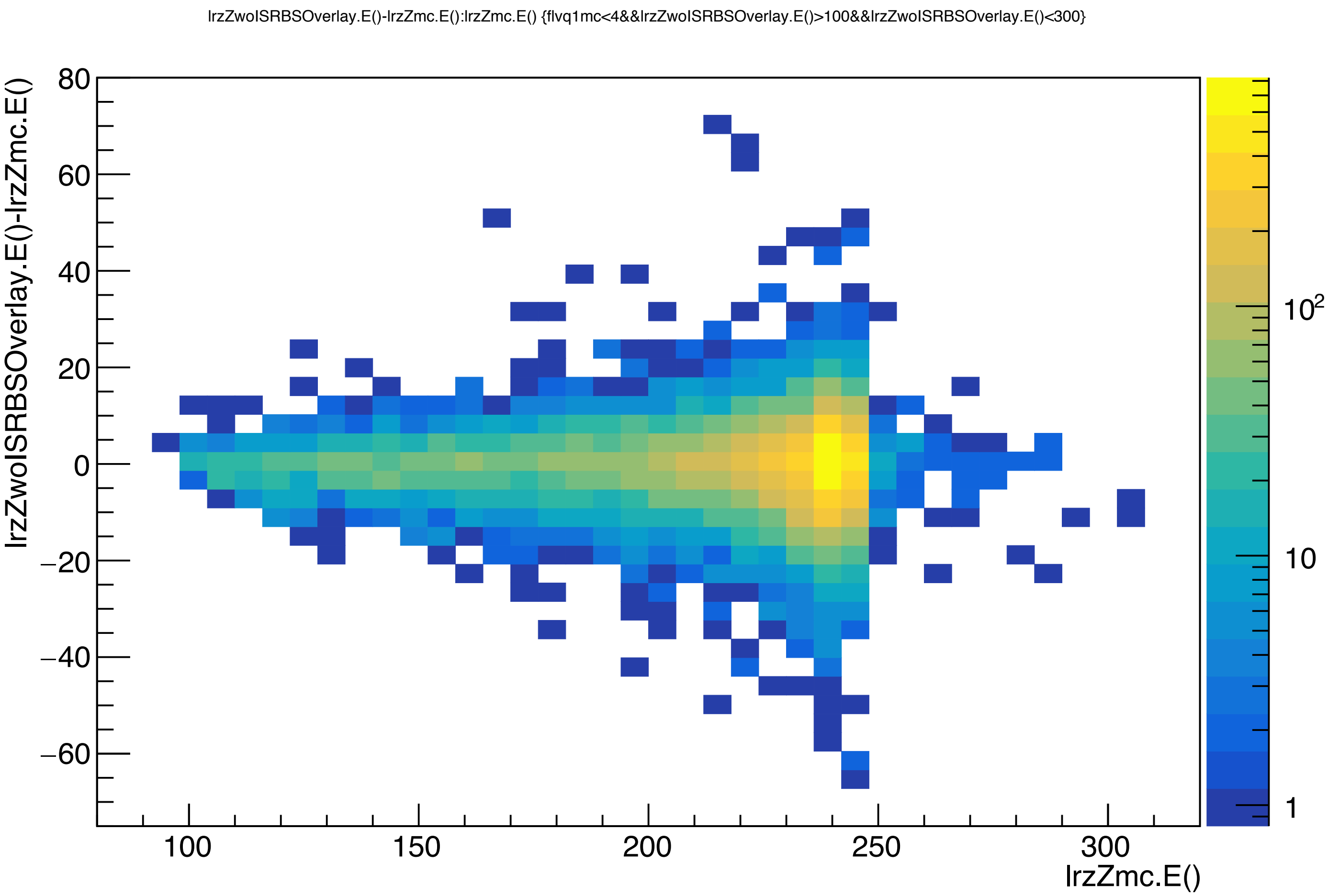
ΔEjj vs ΔMrec



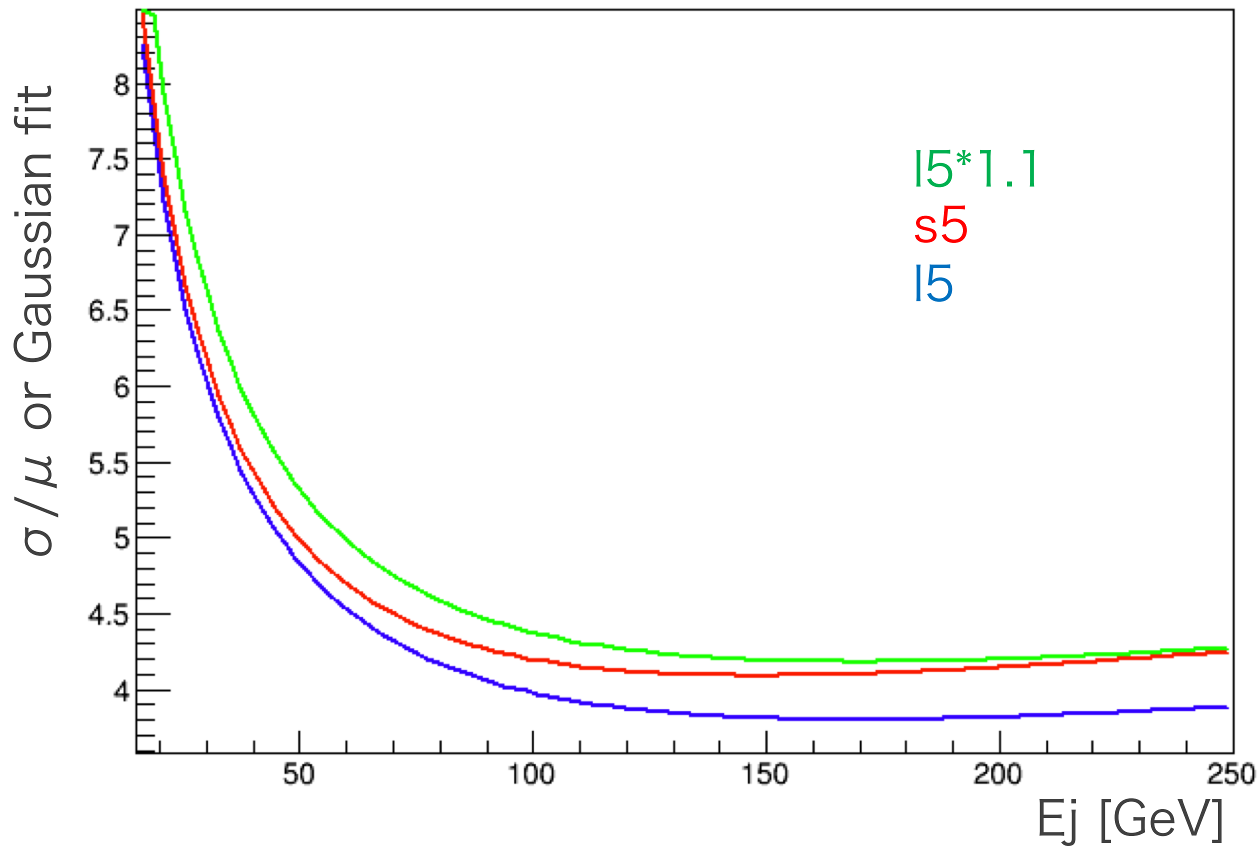
ΔMrec vs Ej^{mc}

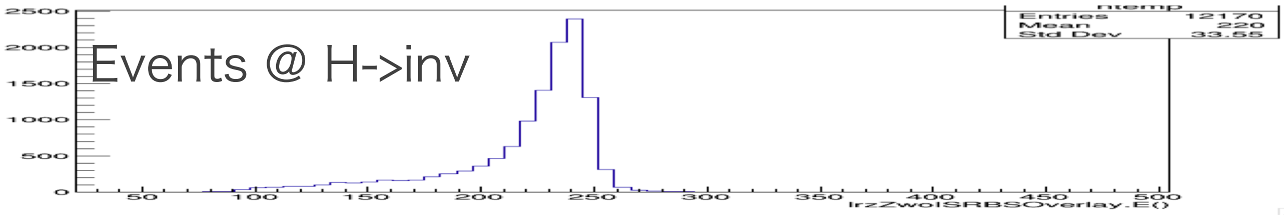


Ejj^{mc} vs ΔEjj



How should I relate ΔMrec and JER…?



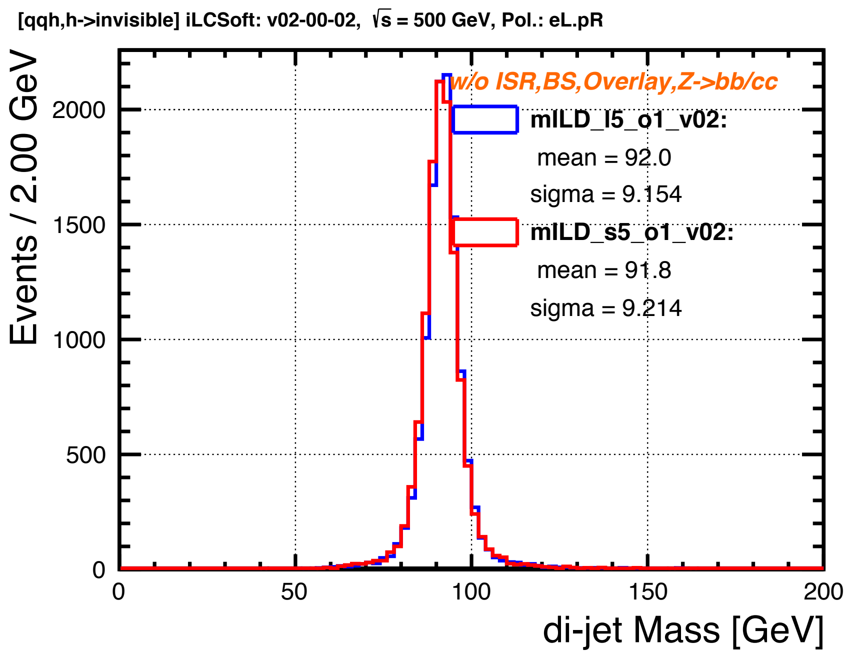


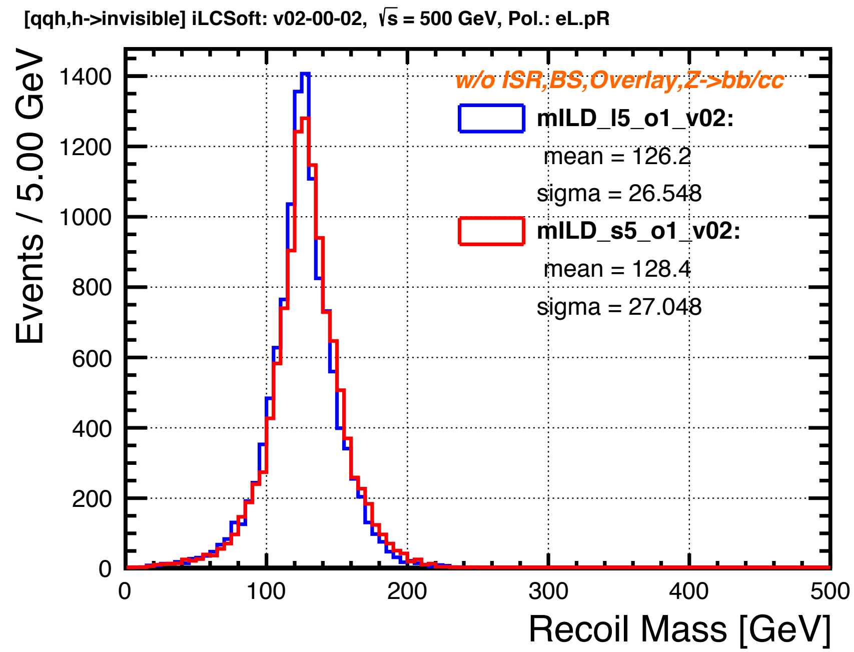
To do

- fit signal/bkg distribution and get p.d.f.
  - signal distribution w/ cheat is fitted by double-Gaussian
- adjust width of signal (recoil mass dist.) which will scale with JER and do toyMC using this signal shape
- evaluate each results and make performance plot
  - how should I define JER reference value...?
- check dependence of opening angle of Z->2jet

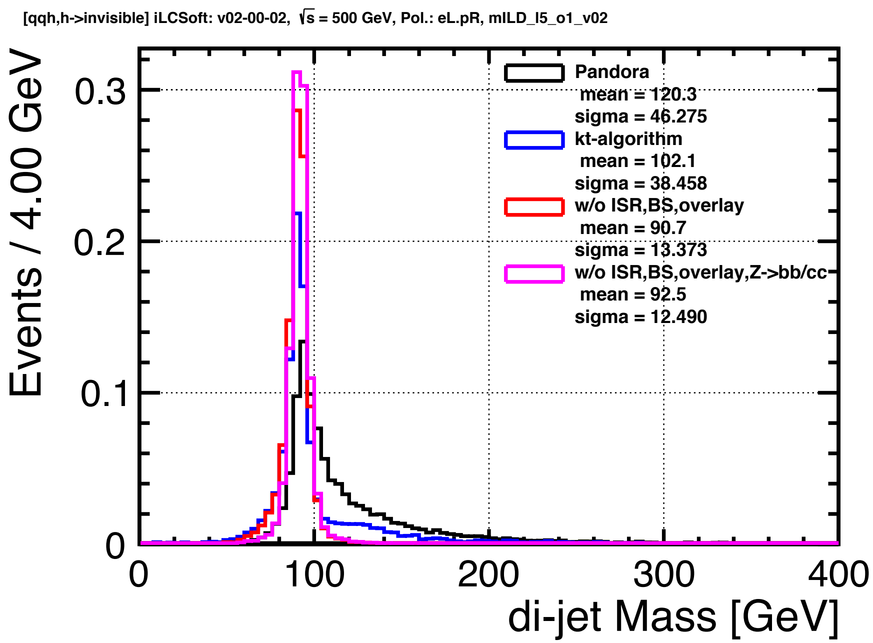
backup

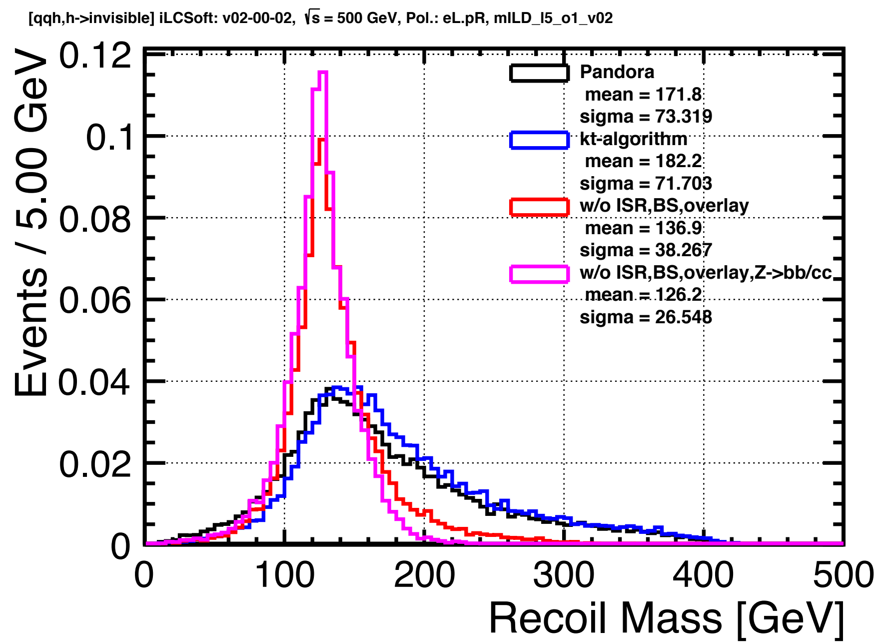
Comparison Large/Small w/o ISR, BS, Overlay, Z->bb/cc





Comparison Pandora/kt-algorithm/cheat

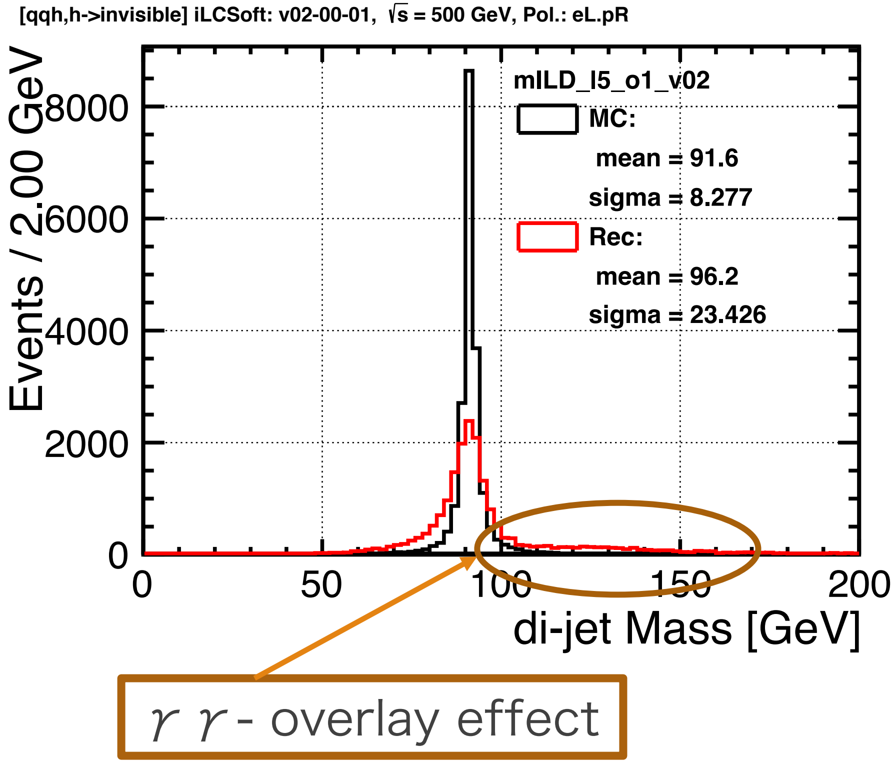


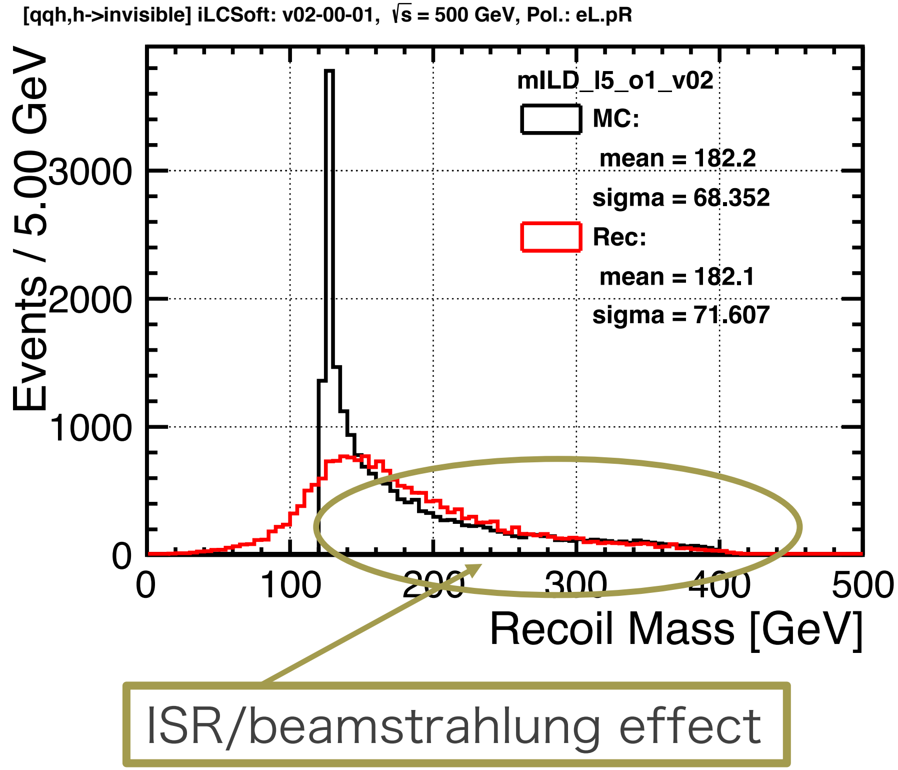


use MCTruth information

Distribution di-jet mass/Recoil mass

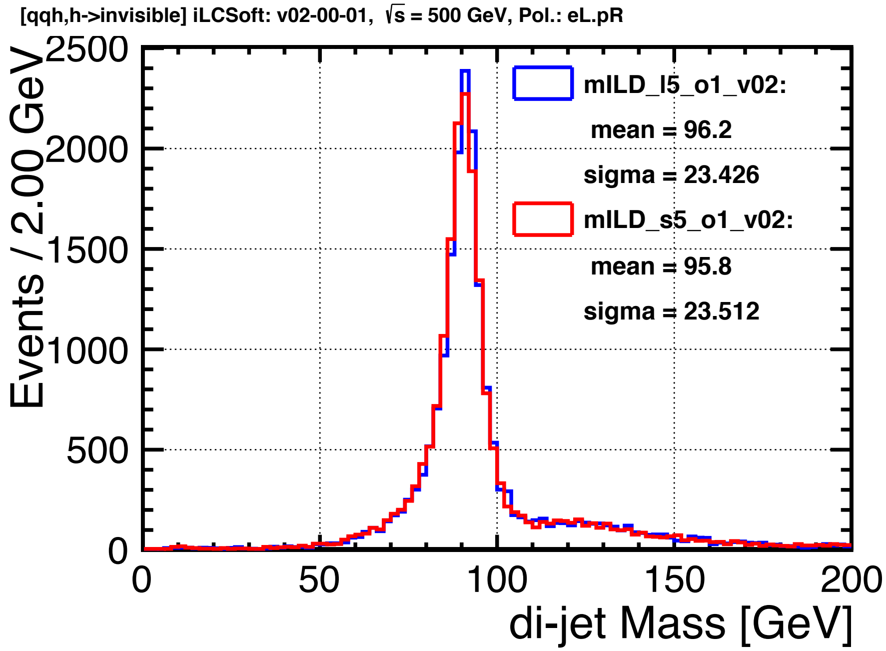
As a first step, I checked signal distribution.

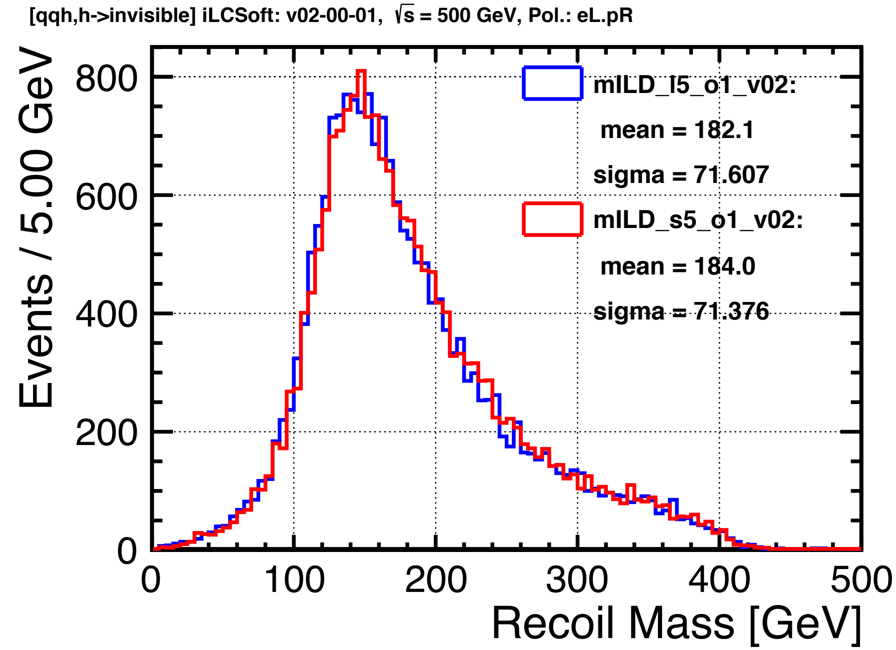




※Any event selection are not applied.

Comparison Large/Small





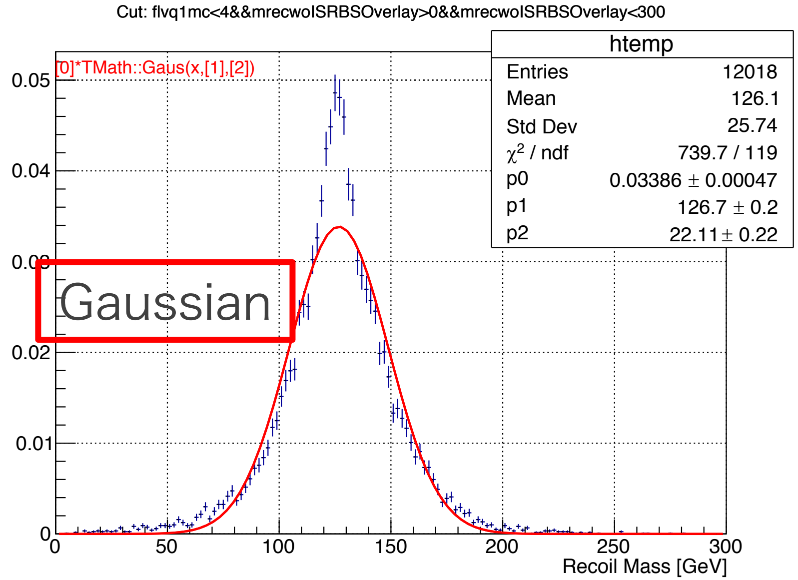
- There seems to be no big difference… why?
  →The effect other than detectors may be too large.
  ISR, beam effect, $\gamma\gamma$- overlay, Z->bb/cc, etc…
- We need cheating!

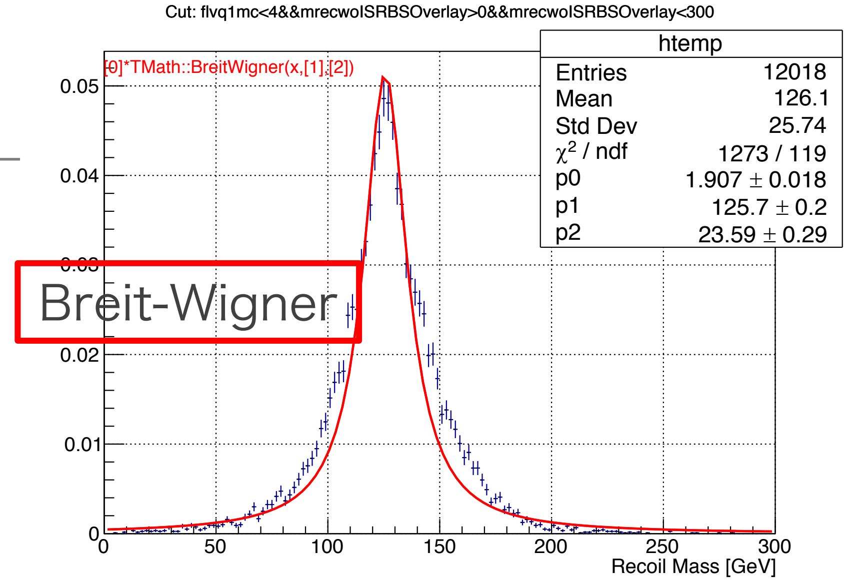
Results

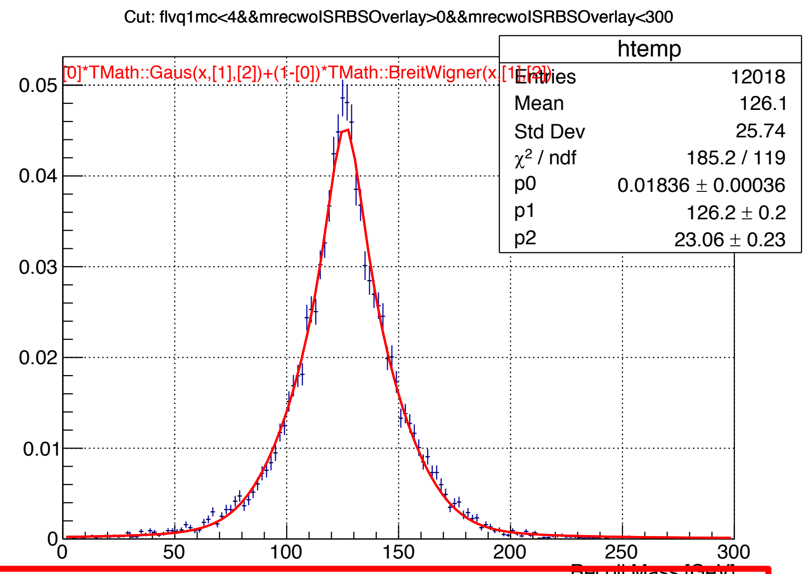
DBD [$\sqrt{s}$ = 250 GeV, 900 fb^{-1}]	$(P_{e^-}, P_{e^+}) = (-0.8, +0.3)$	$(P_{e^-}, P_{e^+}) = (+0.8, -0.3)$	combined
UL on BR (95% C.L.)	0.44 %	0.31 %	0.25 %
ILD_l5_o1_v02 [$\sqrt{s}$ = 500 GeV, 1600 fb^{-1}]	$(P_{e^-}, P_{e^+}) = (-0.8, +0.3)$	$(P_{e^-}, P_{e^+}) = (+0.8, -0.3)$	combined
significance assuming BR(H->inv.)=10%	10.516	14.272	17.728
UL on BR (95% C.L.)	1.569 %	1.156 %	0.931 %
ILD_s5_o1_v02 [$\sqrt{s}$ = 500 GeV, 1600 fb^{-1}]	$(P_{e^-}, P_{e^+}) = (-0.8, +0.3)$	$(P_{e^-}, P_{e^+}) = (+0.8, -0.3)$	combined
significance assuming BR(H->inv.)=10%	10.451	14.257	17.677
UL on BR (95% C.L.)	1.579 %	1.157 %	0.933 %

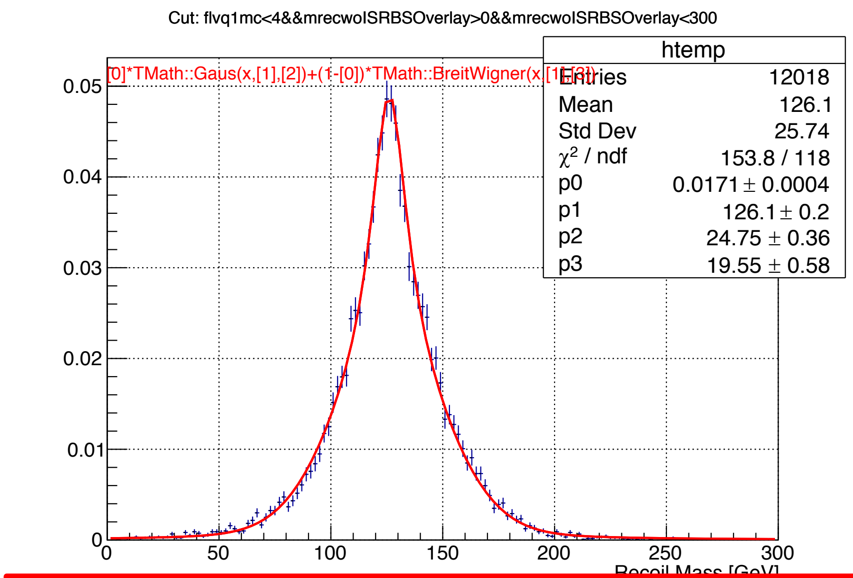
Preliminary

Preliminary









p0×Gaus+(1-p0)×BW same sigma

p0×Gaus+(1-p0)×BW different sigma

Motivation

Physics Motivation

Higgs can decay invisibly into final states
as candidate dark matter particles ($m_{DM} < m_H/2$),
if there is *a hidden sector which couples to Higgs field.*

Search Channel

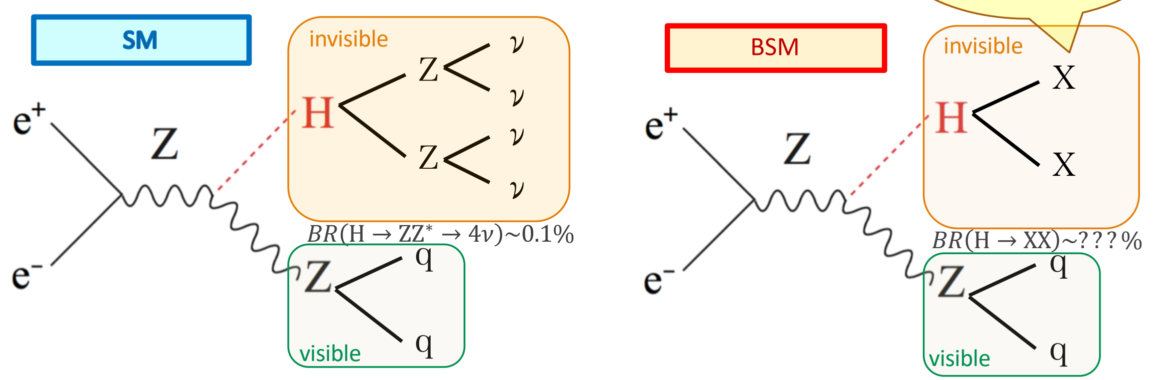
$e^+e^- \rightarrow ZH$, $Z \rightarrow qq$, $H \rightarrow$ invisible, at $\sqrt{s}$ = 500 GeV

Final Observable

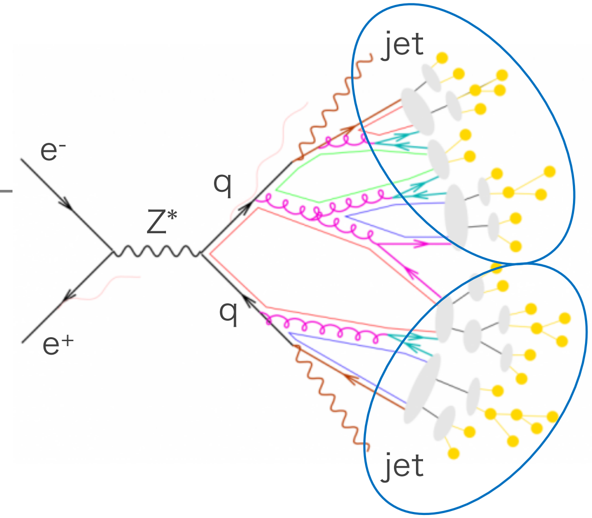
95% C.L. upper limit on Branching Ratio of $H \rightarrow$ invisible.

Detector Benchmark

main variables: *di-jet (Z) mass, recoil mass*
influential detector performance: *jet energy resolution*



Setting of Evaluation JER



ILCSoft & ILDConfig: v02-00-01

ILD models: ILD_{l5,s5}_{o1,o2}_v02

Samples:

mc-opt-3

uds samples: Z→di-jet, no bkg

$\sqrt{s}$ = { 30, 40, 60 ,91, 120, 160, 200, 250, 300, 350, 400, 500 } GeV

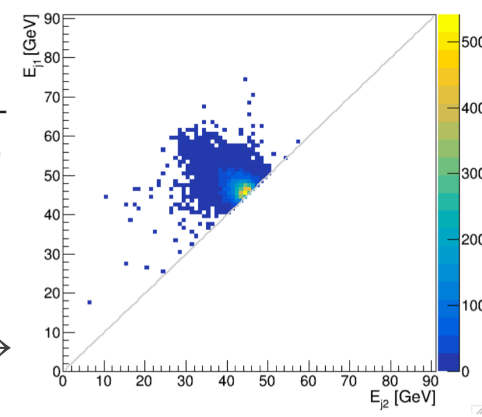
10,000 evts in each $\sqrt{s}$ & models

Jet resolution definition:

[Total energy method] ※assuming $E_{j1} = E_{j2}$

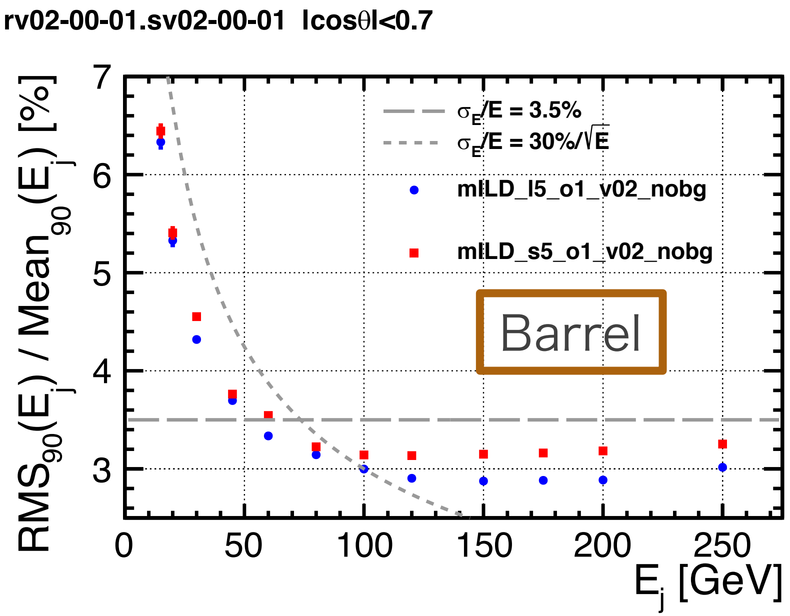
$$\frac{\sigma_{E_j}}{E_j} = \frac{\mathrm{RMS}_{90}(E_j)}{mean_{90}(E_j)} = \sqrt{2}\frac{\mathrm{RMS}_{90}(E_{jj})}{mean_{90}(E_{jj})}$$

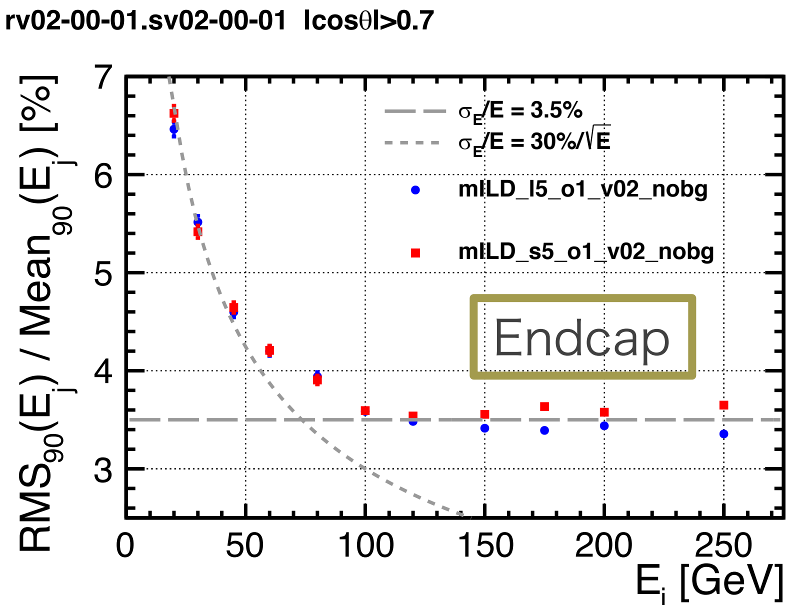
In realistic case, Ejet is not strictly same. →



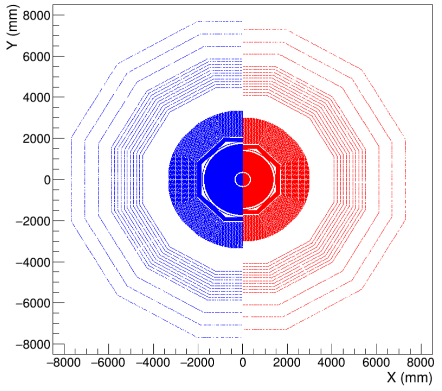
JER: Comparison Large/Small

The two detector models (large/small) were evaluated for comparison.





There are just a little, but significant difference.



Analysis Setup

- <u>Simulation</u>
  - ILCSoft: v02-00-01
  - Samples: new optimization samples @ 500 GeV
  - Detector: ILD full simulation (ILD_{l5,s5}_o1_v02)
  - $\sqrt{s}$ = 500 GeV, $\int Ldt$ = 1600 fb^{-1} , $(P_{e^-}, P_{e^+}) = (-0.8, +0.3), (+0.8, -0.3)$
    "Left" "Right"
- <u>Flow of analysis</u>

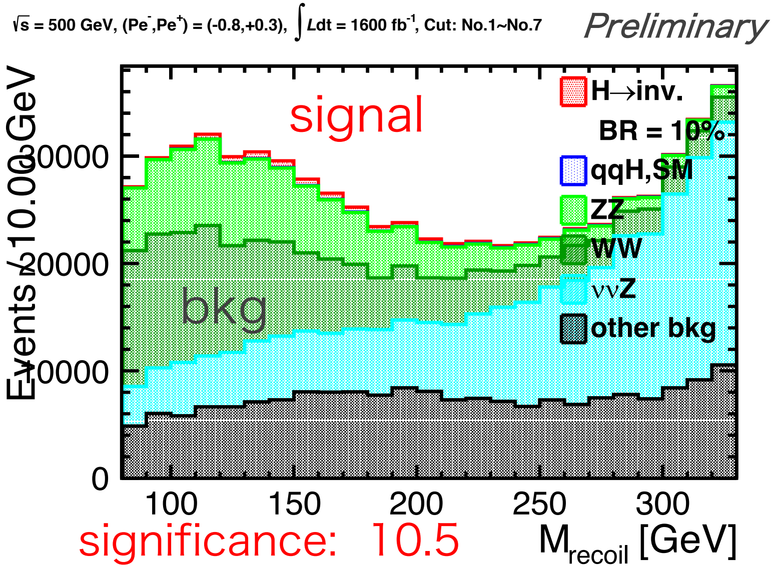
1. **Particle flow reconstruction** (PandoraPFA)
2. **Isolated lepton tagging**: to remove in stage of Eve. Sel.
3. **Remove $\gamma\gamma$-overlay:** using kt_algorithm (FastJet)
4. **Durham jet finder**: forced 2 jets clustering
5. **Event selection**
   - Optimized assuming signal BR(H→invisible) = 10%
6. **Estimate upper limit(UL) of BR (95% C.L.)**

$$UL(\%) \equiv \frac{10(\%)}{N_S(10\%)} \times 1.65\sqrt{N_B}$$

ILD_l5_o1_v02

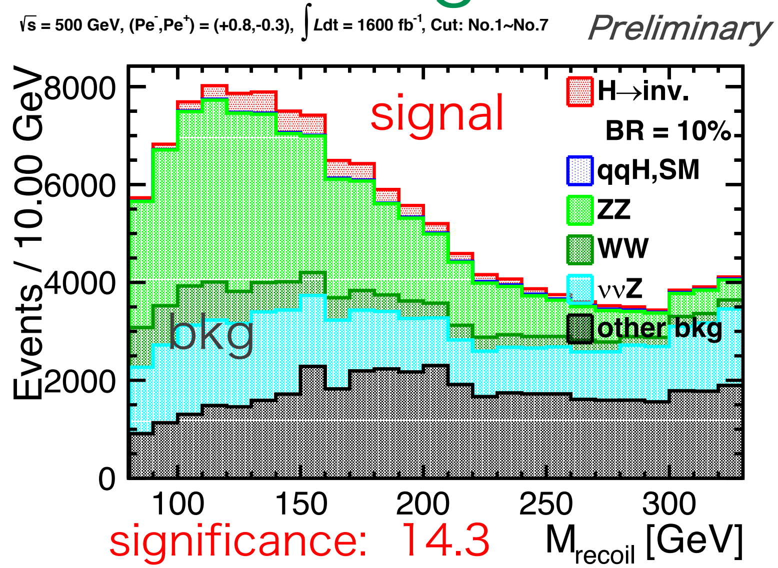
Full simulation [√s = 500 GeV, 1600 fb^{-1},BR(H->inv.)=10%]

Left



significance: 10.5

Right



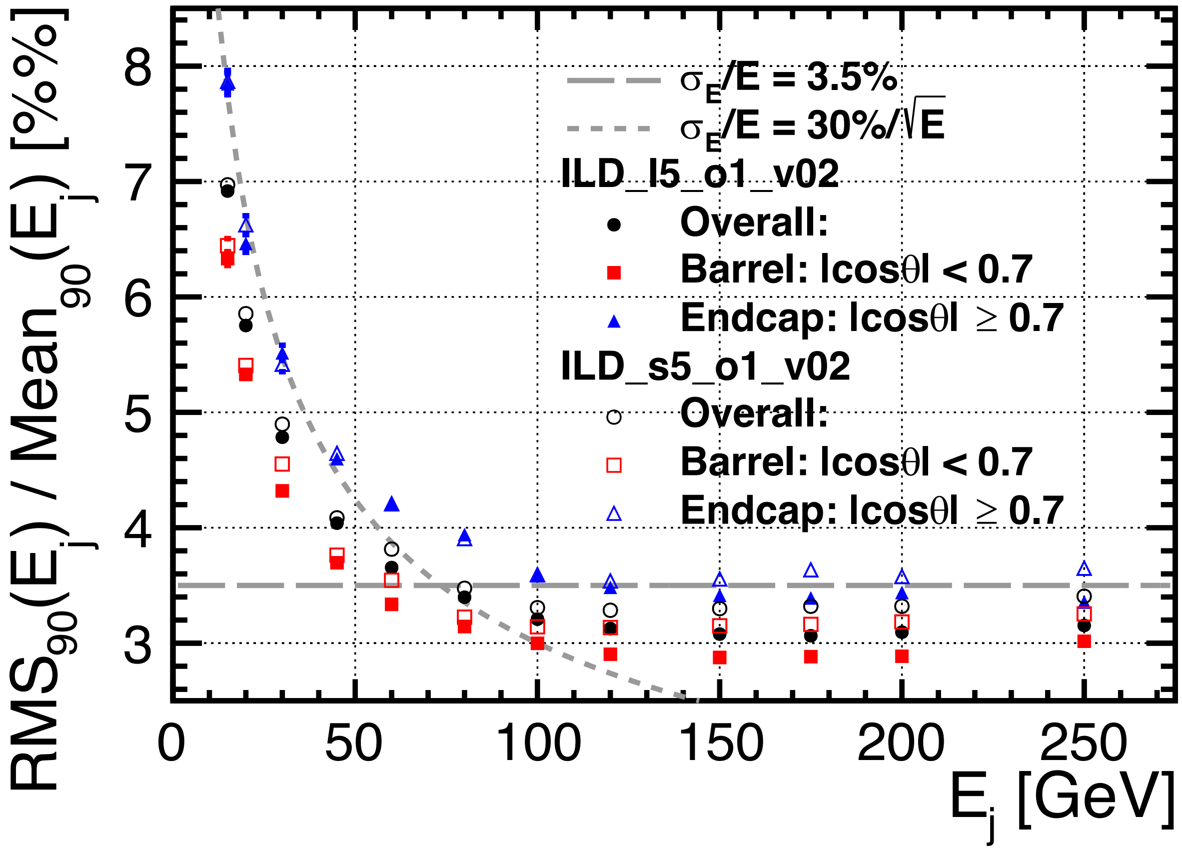
significance: 14.3

ILD_l5_o1_v02 [√s = 500 GeV, 1600 fb^{-1}]	$(P_{e^-}, P_{e^+}) = (-0.8, +0.3)$	$(P_{e^-}, P_{e^+}) = (+0.8, -0.3)$	combined
significance assuming BR(H->inv.)=10%	10.5	14.3	17.7
UL on BR (95% C.L.)	1.57 %	1.15 %	0.93 %
Previous Result by Ishikawa-san	1.77 %	1.29 %	1.04 %

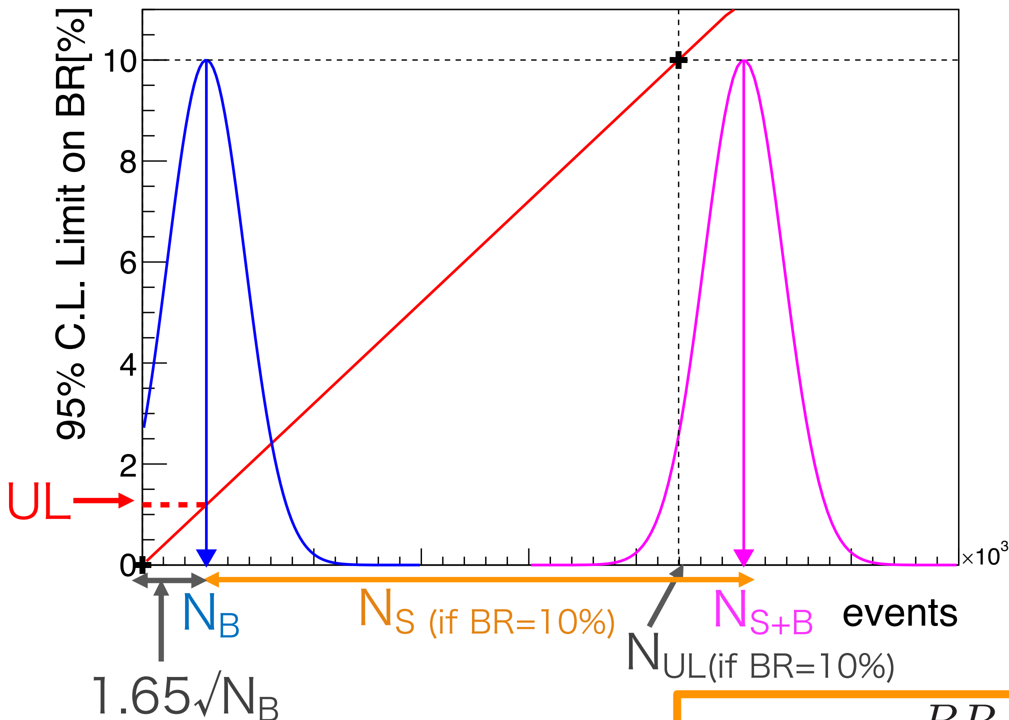
JER: Comparison Large/Small

The two detector models (large/small) were evaluated for comparison.

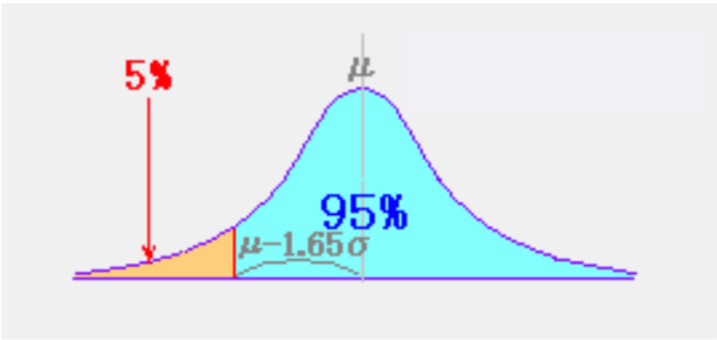
rv02-00-01.sv02-00-01



How to set Upper Limit



definition of 95% C.L.
(one-sided test)

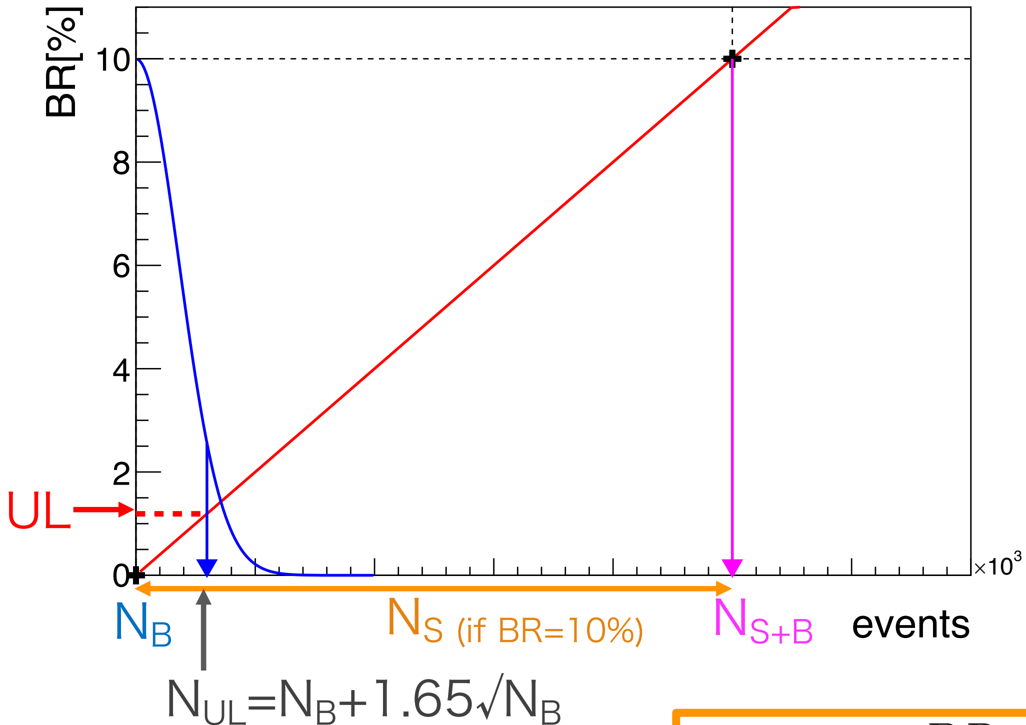


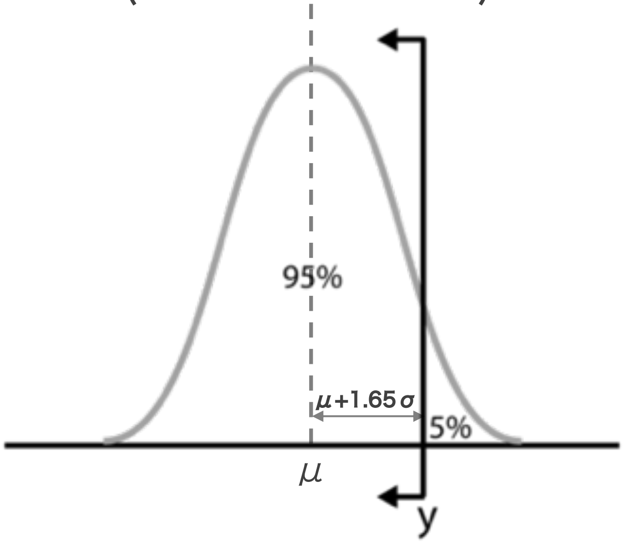
$$UL(\%) \equiv \frac{BR_{\text{assumed}}[\%]}{N_S(BR_{\text{assumed}})} \times \sigma(N_B, \text{CL})$$

$$\cong \frac{10[\%]}{N_S(BR = 10[\%])} \times 1.65\sqrt{N_B}\ (\text{CL} = 95\%)$$

$$\simeq \frac{10[\%] \times 1.65}{significance(BR = 10[\%])}$$

How to set Upper Limit





$$
\begin{aligned}
UL(\%) &\equiv \frac{BR_{\text{assumed}}[\%]}{N_S(BR_{\text{assumed}})} \times \sigma(N_B, \text{CL}) \\
&= \frac{10[\%]}{N_S(BR=10[\%])} \times 1.65\sqrt{N_B}\ (\text{CL}=95\%) \\
&\simeq \frac{10[\%] \times 1.65}{significance(BR=10[\%])}
\end{aligned}
$$

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