Optimization of Overlay removal for Higgs→invisible at $\sqrt{s}$ = 500 GeV

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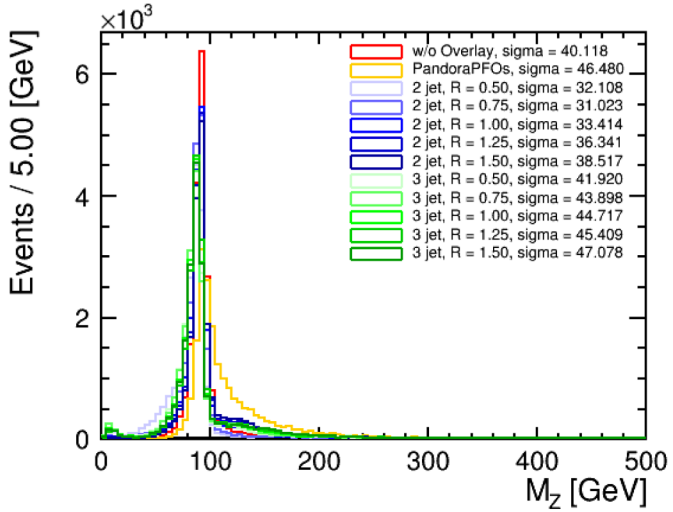
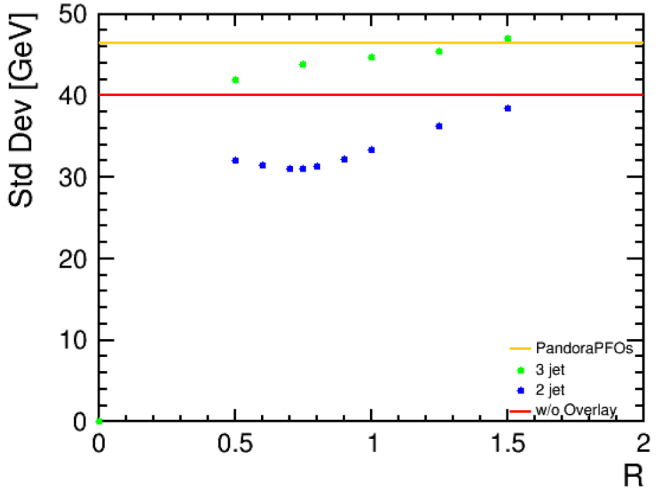
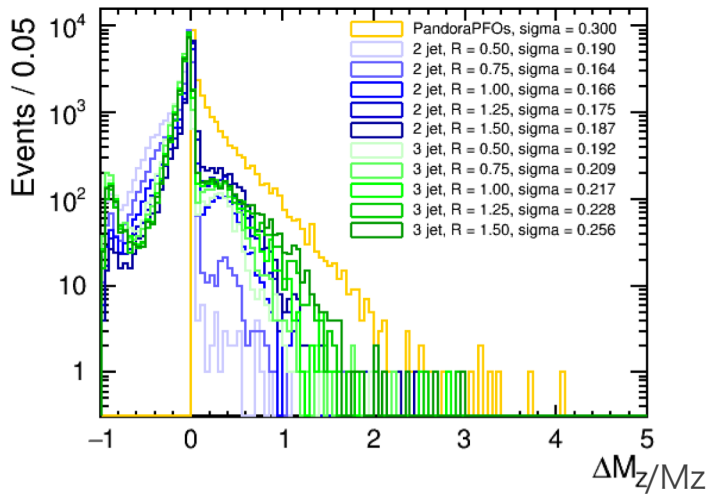
Status

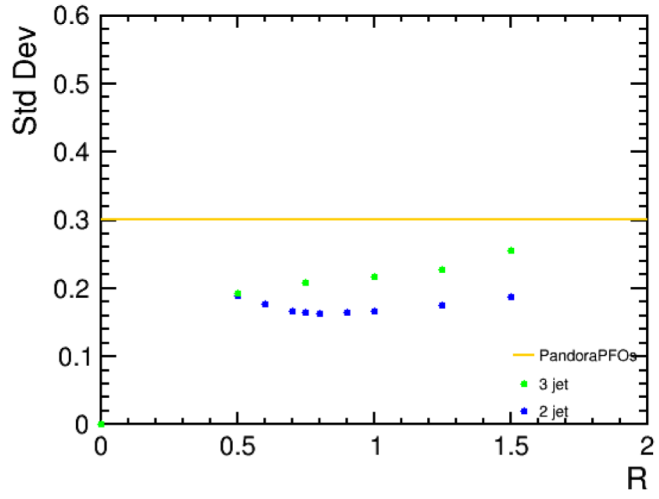
- So far kt algorithm was used for overlay removal.
- However those parameter was not optimized for $\sqrt{s}$ = 500 GeV.
  - {Njet = 2, R = 1.5} was used which is same as for $\sqrt{s}$ = 250 GeV case.
- I compared overlay removal performance of following algorithms and parameters. The benchmarks are Mz & ΔMz/Mz.
  - kt
    - Njet = {2, 3}, R = 0.5 ~ 1.5
  - anti-kt
    - Njet = {2, 3}, R = 0.5 ~ 1.5
  - Durham
    - Njet = {2, 3}, α = {0.5, 1.0, 3.0, 5.0, 7.0}

kt: {Njet=2, R=0.75} seems to be the best.

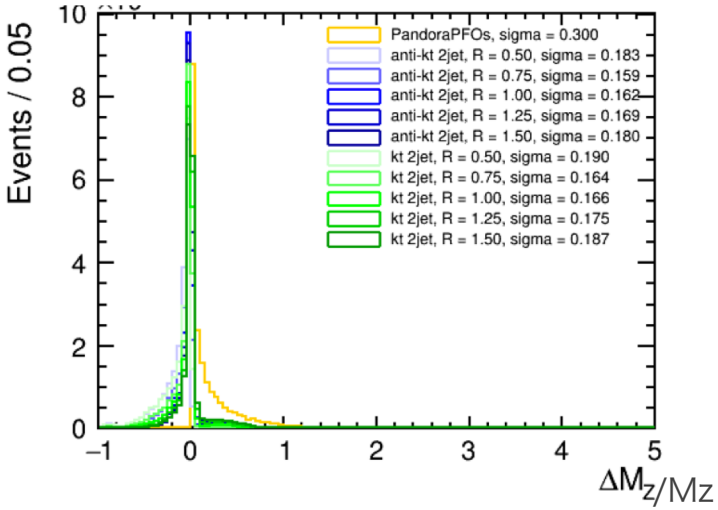


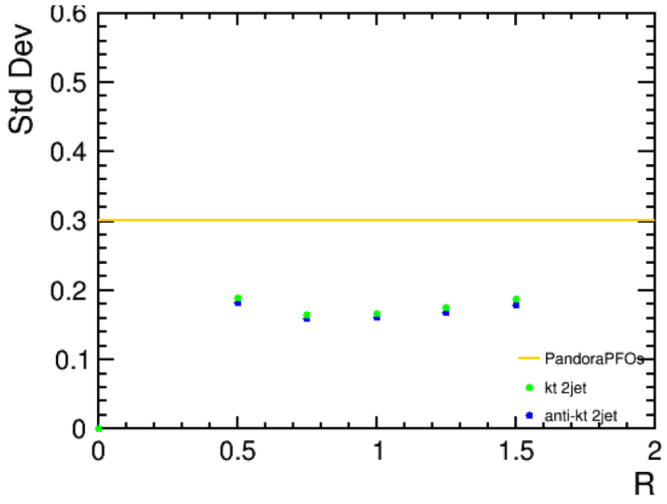


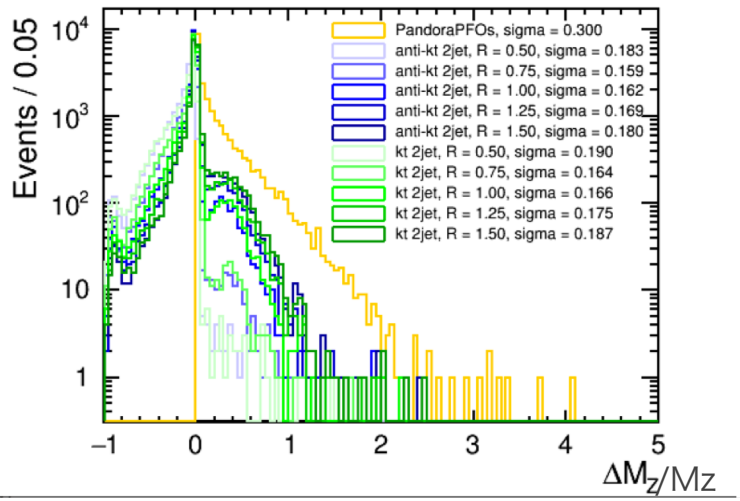




kt vs anti-kt


Events / 0.05
PandoraPFOs, sigma = 0.300
anti-kt 2jet, R = 0.50, sigma = 0.183
anti-kt 2jet, R = 0.75, sigma = 0.159
anti-kt 2jet, R = 1.00, sigma = 0.162
anti-kt 2jet, R = 1.25, sigma = 0.169
anti-kt 2jet, R = 1.50, sigma = 0.180
kt 2jet, R = 0.50, sigma = 0.190
kt 2jet, R = 0.75, sigma = 0.164
kt 2jet, R = 1.00, sigma = 0.166
kt 2jet, R = 1.25, sigma = 0.175
kt 2jet, R = 1.50, sigma = 0.187
ΔMz/Mz


Std Dev
PandoraPFOs
kt 2jet
anti-kt 2jet
R


Events / 0.05
PandoraPFOs, sigma = 0.300
anti-kt 2jet, R = 0.50, sigma = 0.183
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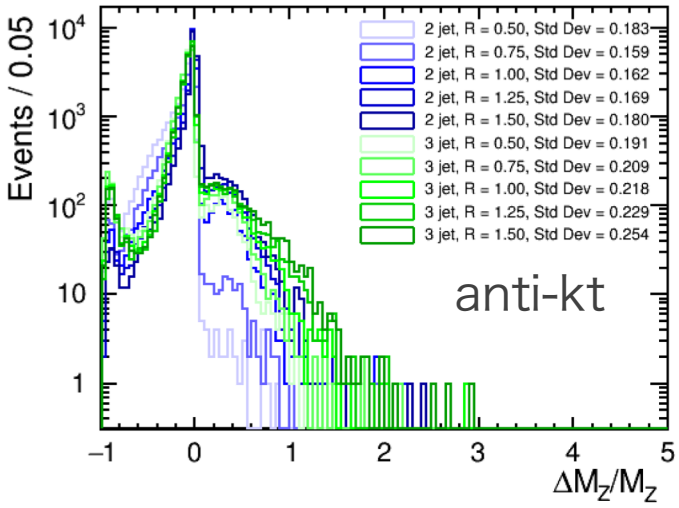
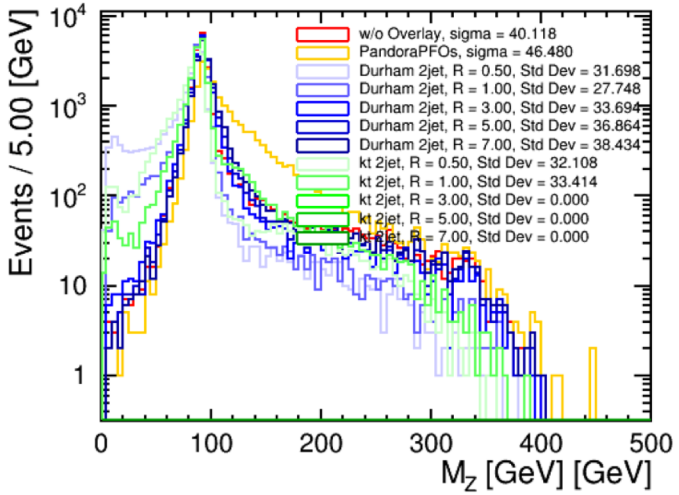
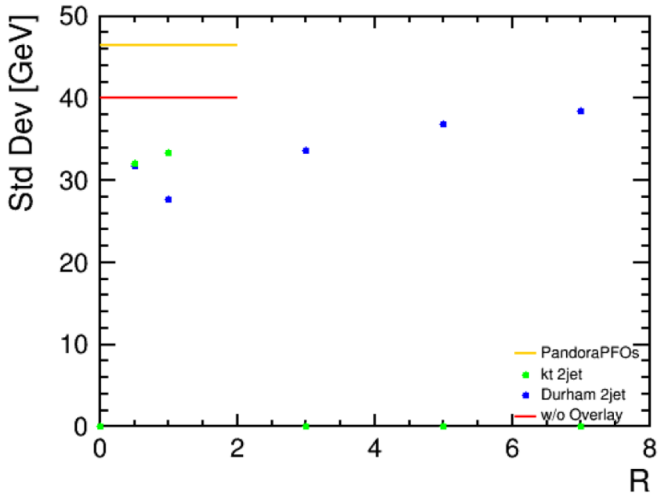
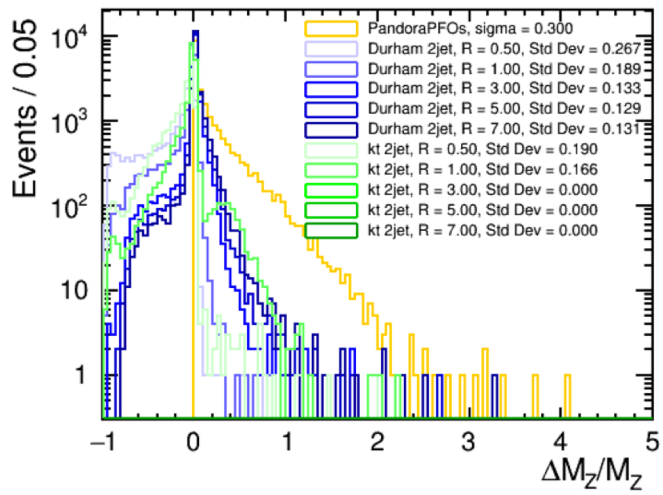
anti-kt 2jet, R = 1.00, sigma = 0.162
anti-kt 2jet, R = 1.25, sigma = 0.169
anti-kt 2jet, R = 1.50, sigma = 0.180
kt 2jet, R = 0.50, sigma = 0.190
kt 2jet, R = 0.75, sigma = 0.164
kt 2jet, R = 1.00, sigma = 0.166
kt 2jet, R = 1.25, sigma = 0.175
kt 2jet, R = 1.50, sigma = 0.187
ΔMz/Mz

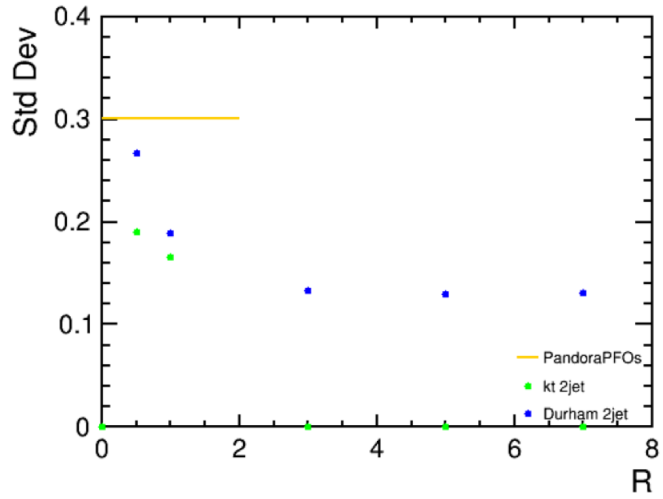

Events / 0.05
2 jet, R = 0.50, Std Dev = 0.183
2 jet, R = 0.75, Std Dev = 0.159
2 jet, R = 1.00, Std Dev = 0.162
2 jet, R = 1.25, Std Dev = 0.169
2 jet, R = 1.50, Std Dev = 0.180
3 jet, R = 0.50, Std Dev = 0.191
3 jet, R = 0.75, Std Dev = 0.209
3 jet, R = 1.00, Std Dev = 0.218
3 jet, R = 1.25, Std Dev = 0.229
3 jet, R = 1.50, Std Dev = 0.254
anti-kt
ΔMz/Mz

kt vs Durham

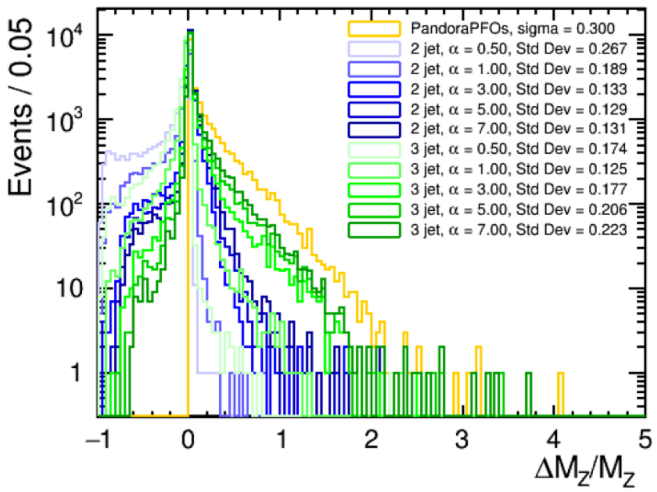

w/o Overlay, sigma = 40.118
PandoraPFOs, sigma = 46.480
Durham 2jet, R = 0.50, Std Dev = 31.698
Durham 2jet, R = 1.00, Std Dev = 27.748
Durham 2jet, R = 3.00, Std Dev = 33.694
Durham 2jet, R = 5.00, Std Dev = 36.864
Durham 2jet, R = 7.00, Std Dev = 38.434
kt 2jet, R = 0.50, Std Dev = 32.108
kt 2jet, R = 1.00, Std Dev = 33.414
kt 2jet, R = 3.00, Std Dev = 0.000
kt 2jet, R = 5.00, Std Dev = 0.000
kt 2jet, R = 7.00, Std Dev = 0.000
Events / 5.00 [GeV]
M_Z [GeV] [GeV]

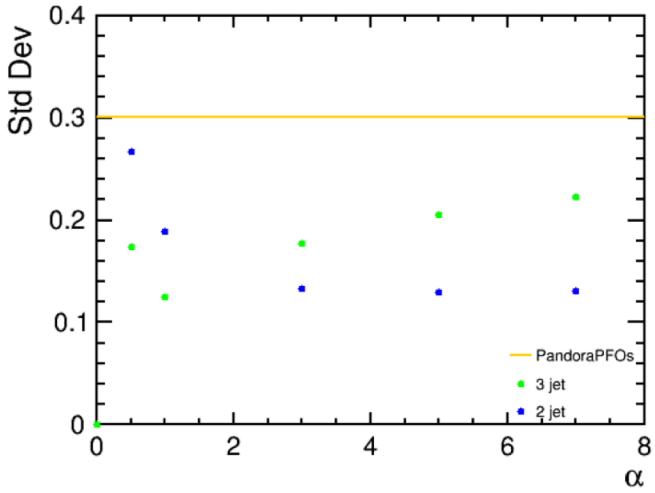

Std Dev [GeV]
PandoraPFOs
kt 2jet
Durham 2jet
w/o Overlay
R

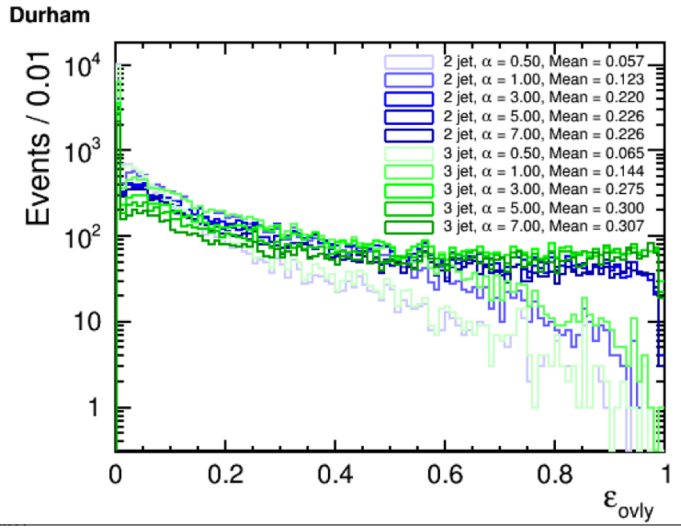

PandoraPFOs, sigma = 0.300
Durham 2jet, R = 0.50, Std Dev = 0.267
Durham 2jet, R = 1.00, Std Dev = 0.189
Durham 2jet, R = 3.00, Std Dev = 0.133
Durham 2jet, R = 5.00, Std Dev = 0.129
Durham 2jet, R = 7.00, Std Dev = 0.131
kt 2jet, R = 0.50, Std Dev = 0.190
kt 2jet, R = 1.00, Std Dev = 0.166
kt 2jet, R = 3.00, Std Dev = 0.000
kt 2jet, R = 5.00, Std Dev = 0.000
kt 2jet, R = 7.00, Std Dev = 0.000
Events / 0.05
ΔM_Z/M_Z

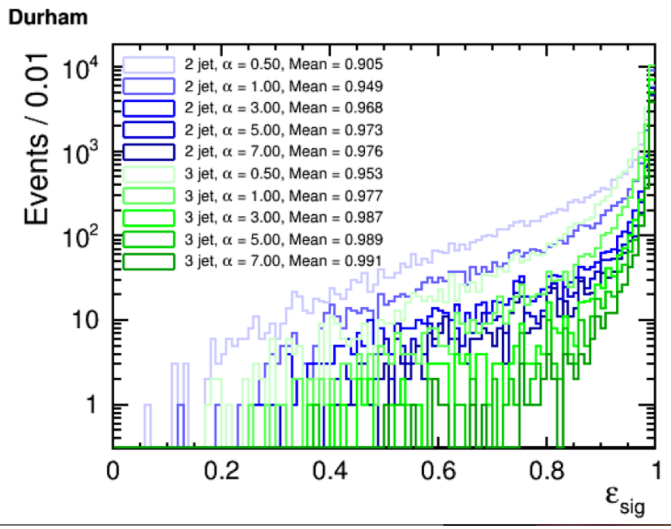

Std Dev
PandoraPFOs
kt 2jet
Durham 2jet
R

Durham : {Njet=2, α=5.0} seems to be the best.







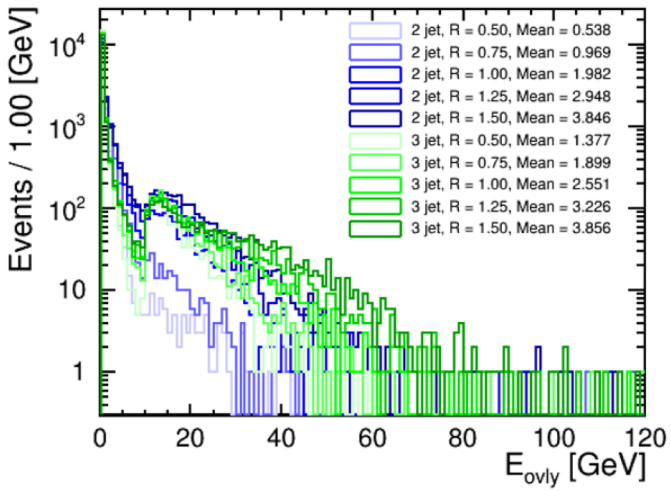


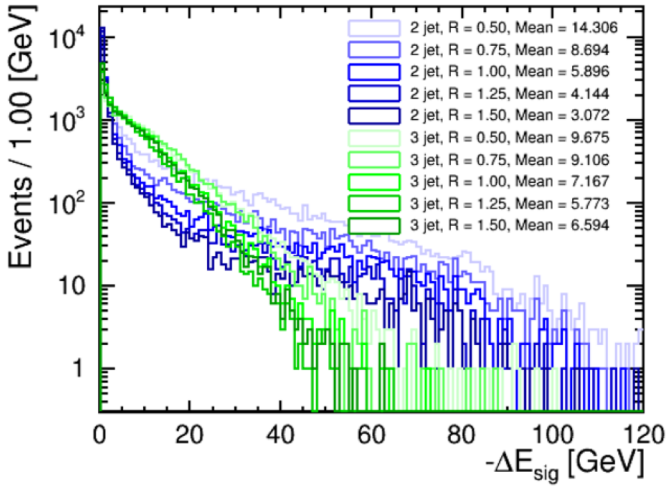
Conclusion

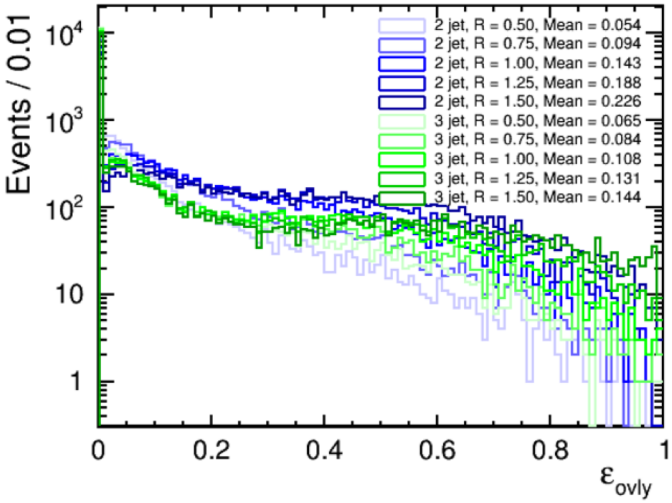
- I compared overlay removal performance of following algorithms and parameters.
  - kt
    - Njet = {2, 3}, R = 0.5 ~ 1.5
  - anti-kt
    - Njet = {2, 3}, R = 0.5 ~ 1.5
  - Durham
    - Njet = {2, 3}, α = {0.5, 1.0, 3.0, 5.0, 7.0}
- I decided to use Durham with {Njet = 2, α = 5.0}.

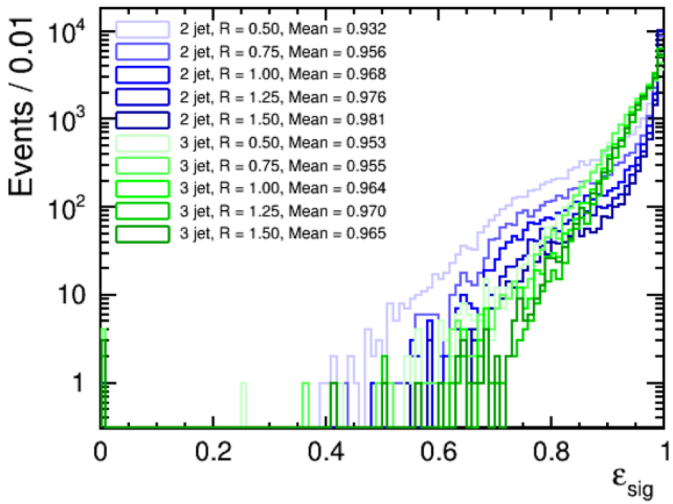
backup

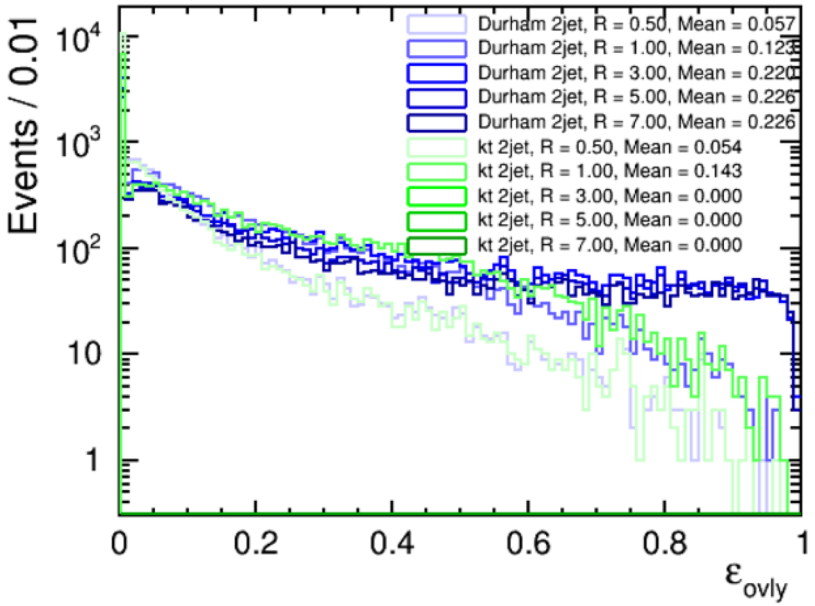
kt : {Njet=2, R=0.75} seems to be the best.

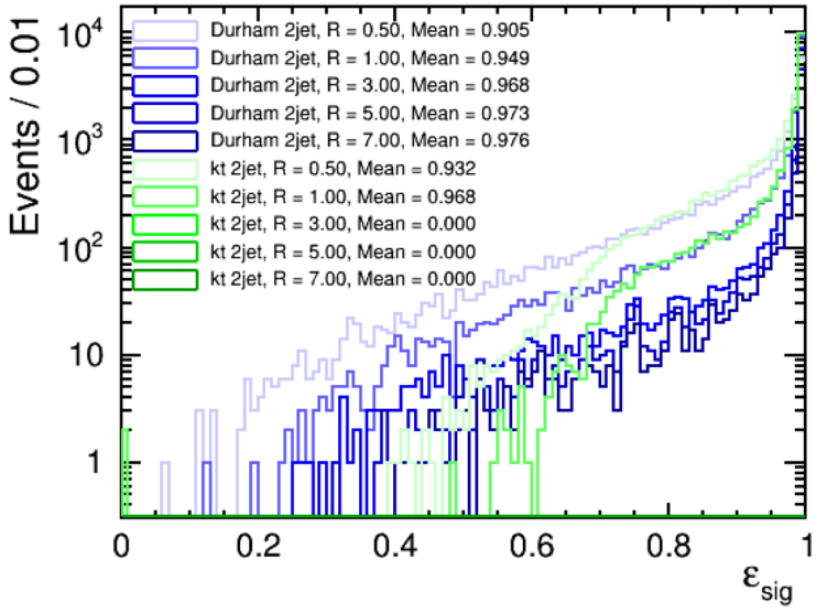




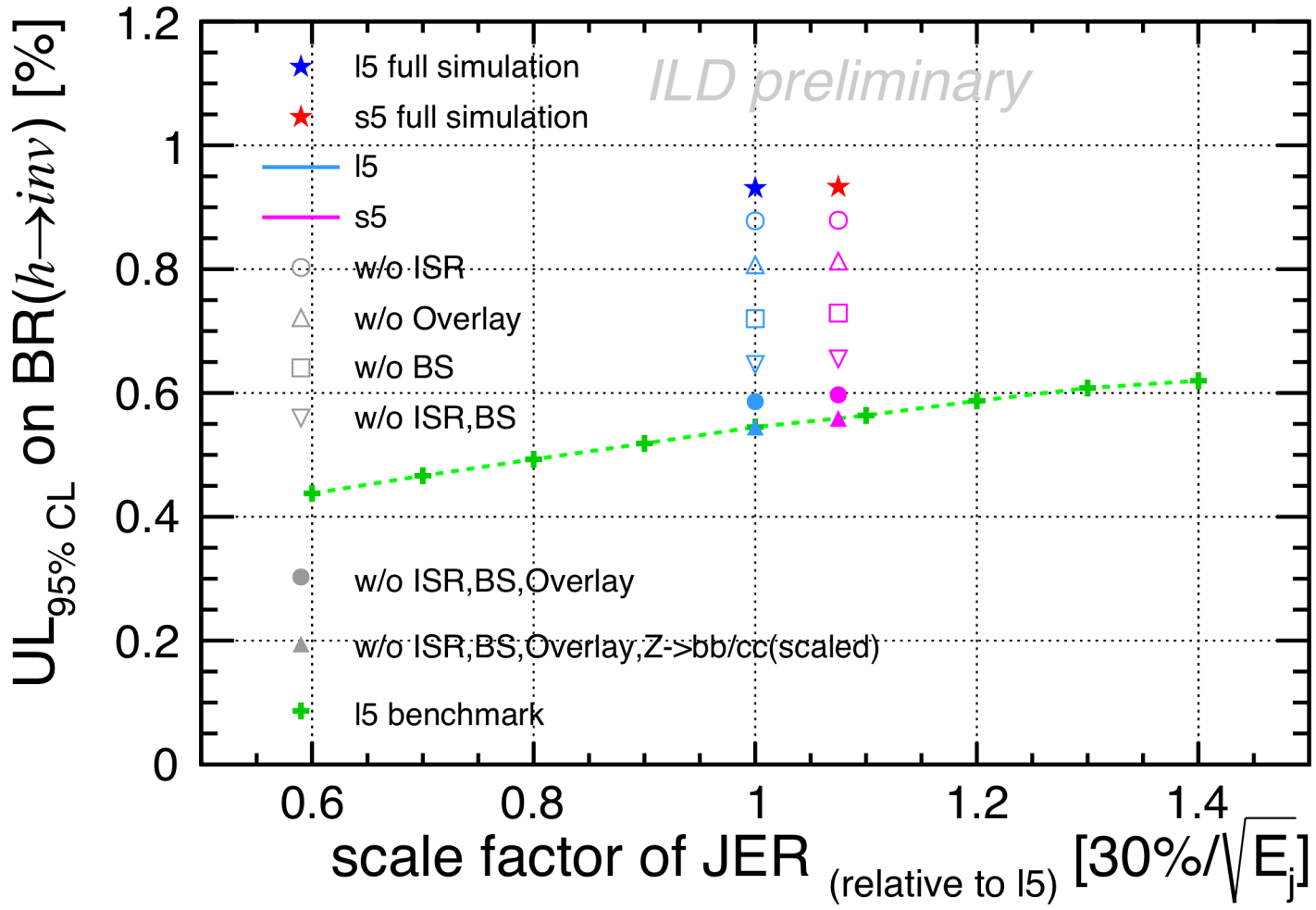





Events / 0.01
Durham 2jet, R = 0.50, Mean = 0.057
Durham 2jet, R = 1.00, Mean = 0.123
Durham 2jet, R = 3.00, Mean = 0.220
Durham 2jet, R = 5.00, Mean = 0.226
Durham 2jet, R = 7.00, Mean = 0.226
kt 2jet, R = 0.50, Mean = 0.054
kt 2jet, R = 1.00, Mean = 0.143
kt 2jet, R = 3.00, Mean = 0.000
kt 2jet, R = 5.00, Mean = 0.000
kt 2jet, R = 7.00, Mean = 0.000
ε_{ovly}


Events / 0.01
Durham 2jet, R = 0.50, Mean = 0.905
Durham 2jet, R = 1.00, Mean = 0.949
Durham 2jet, R = 3.00, Mean = 0.968
Durham 2jet, R = 5.00, Mean = 0.973
Durham 2jet, R = 7.00, Mean = 0.976
kt 2jet, R = 0.50, Mean = 0.932
kt 2jet, R = 1.00, Mean = 0.968
kt 2jet, R = 3.00, Mean = 0.000
kt 2jet, R = 5.00, Mean = 0.000
kt 2jet, R = 7.00, Mean = 0.000
ε_{sig}

Results (2018/1/8)



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

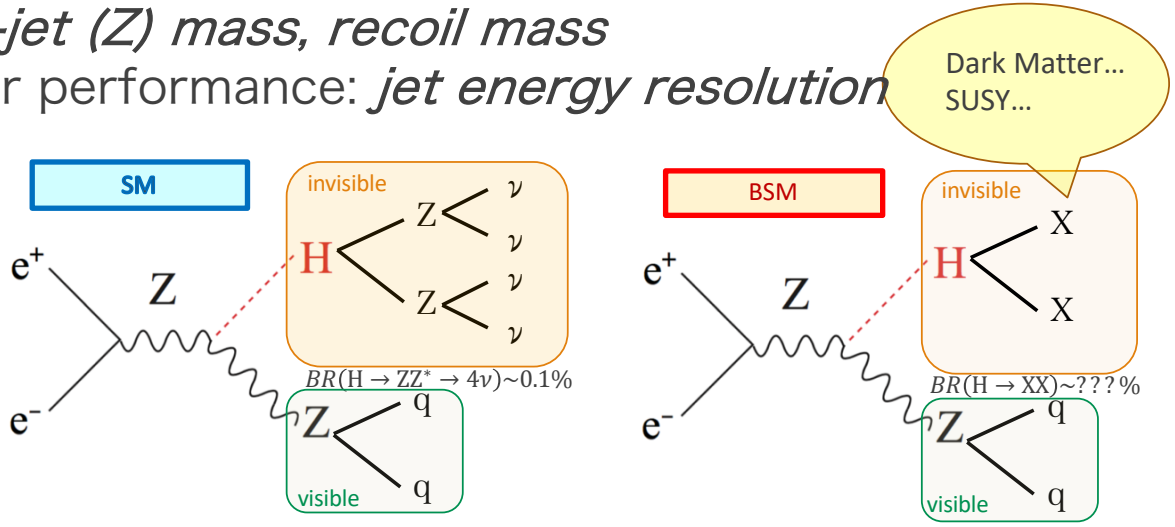
e+e- → ZH, Z→qq, H→invisible, at √s = 500 GeV

Final Observable

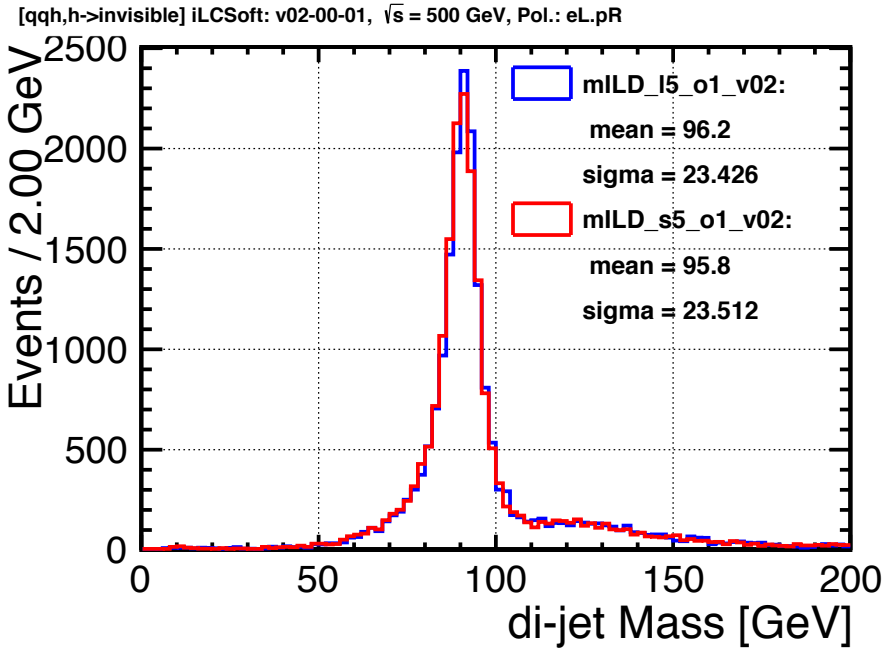
95% C.L. upper limit on Branching Ratio of H→invisible.

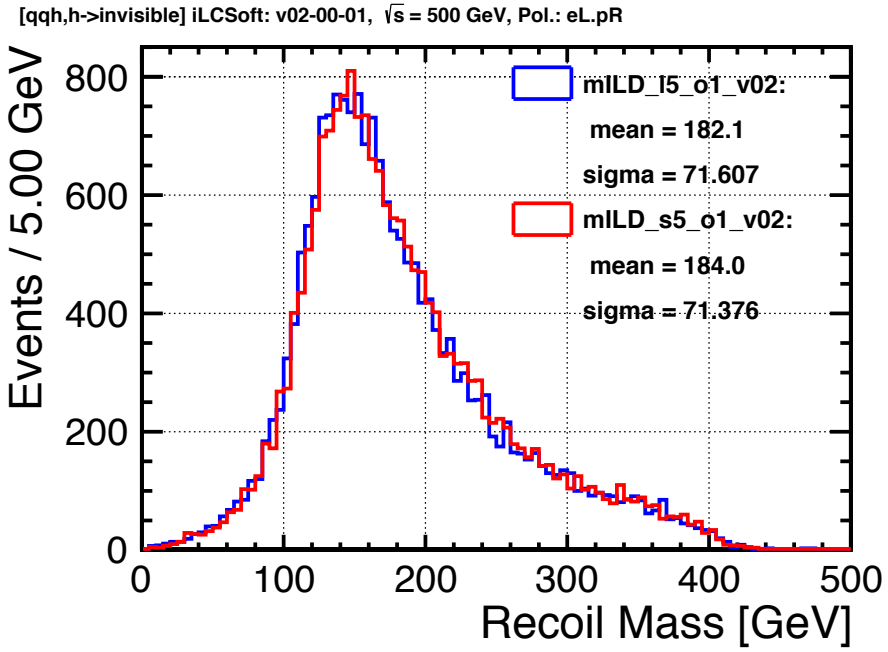
Detector Benchmark

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



Comparison Large/Small





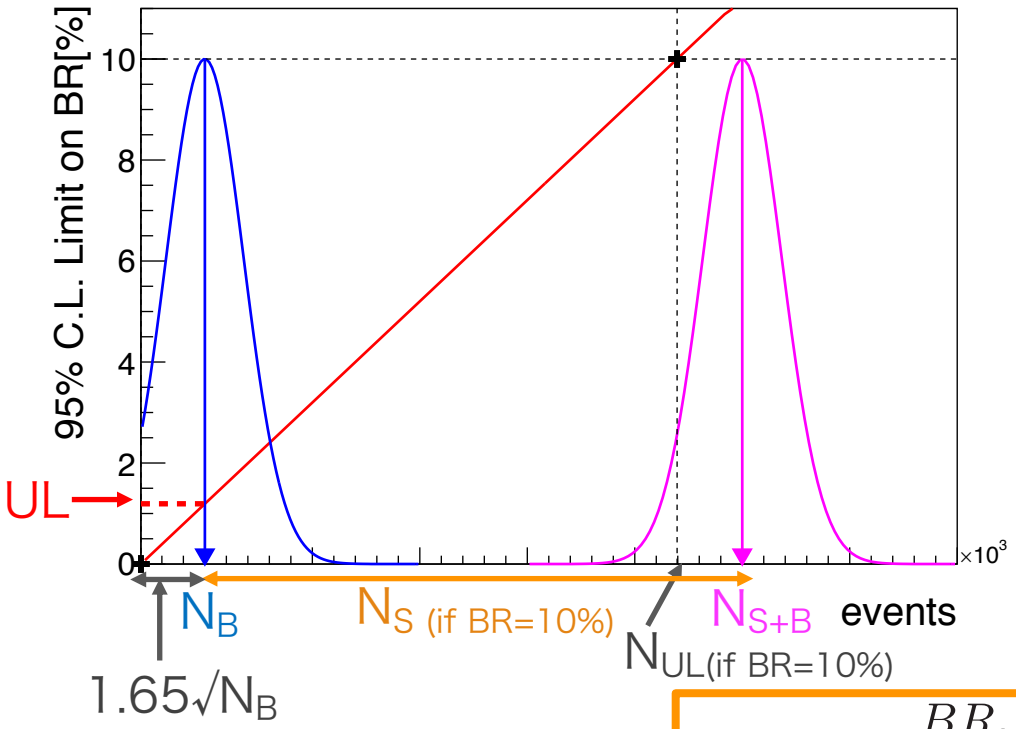
- There seems to be no big difference... why?
  - →The effect other than detectors may be too large.
    ISR, beam effect, $\gamma\gamma$ - overlay, Z->bb/cc, etc...
- Apply cheating to isolate these effects

Analysis Setup

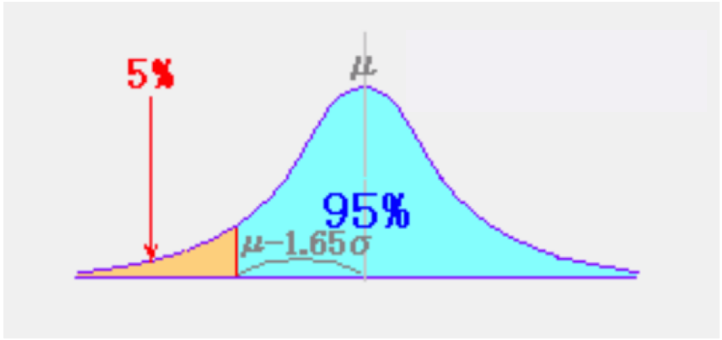
- Simulation
  - ILCSoft: v02-00-01
  - Samples: new optimization samples @ 500 GeV
  - Detector: ILD full simulation (ILD_{l5,s5}_o1_v02)
  - $\sqrt{s}$ = 500 GeV, $\int Ldt$ = 1600 fb^{-1} , $(P_{e^-}, P_{e^+}) = (-0.8, +0.3), (+0.8, -0.3)$ “Left” “Right”
- Flow of analysis
  1. **Particle flow reconstruction**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

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

How to set Upper Limit



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

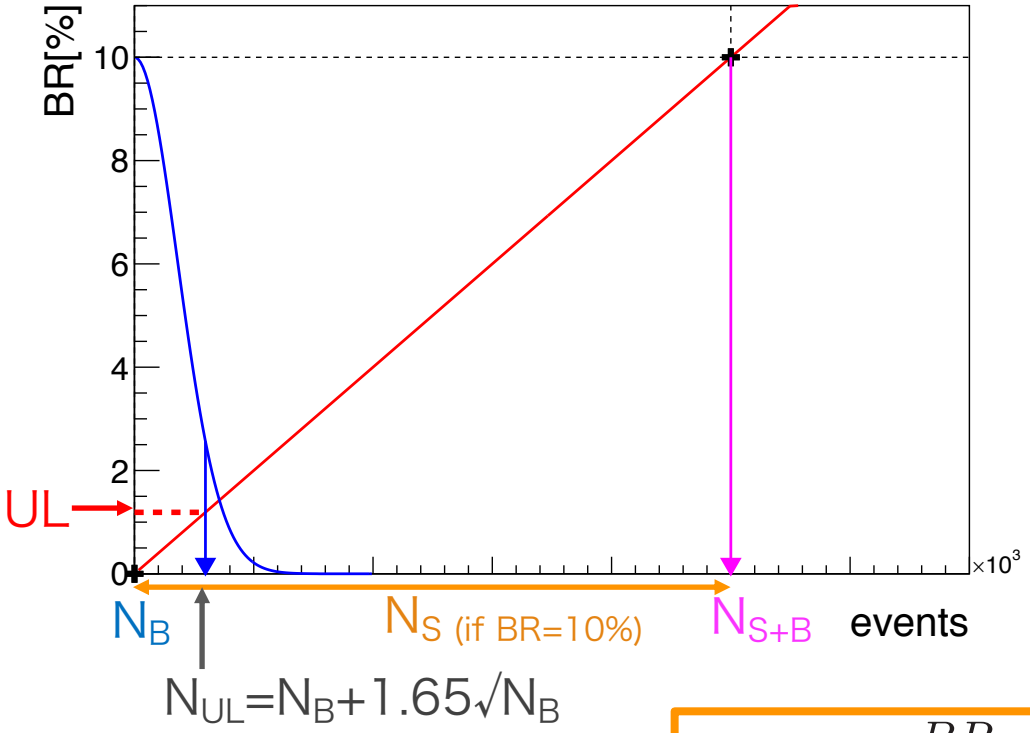


$$UL(\%) \equiv \frac{BR_{\mathrm{assumed}}[\%]}{N_S(BR_{\mathrm{assumed}})} \times \sigma(N_B, \mathrm{CL})$$

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

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

How to set Upper Limit



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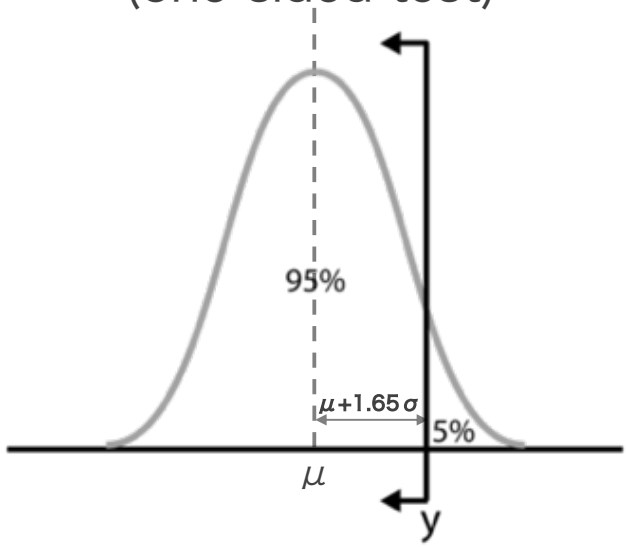

$$UL(\%) \equiv \frac{BR_{\mathrm{assumed}}[\%]}{N_S(BR_{\mathrm{assumed}})} \times \sigma(N_B, \mathrm{CL})$$
$$= \frac{10[\%]}{N_S(BR = 10[\%])} \times 1.65\sqrt{N_B}\ (\mathrm{CL} = 95\%)$$
$$\simeq \frac{10[\%] \times 1.65}{significance(BR = 10[\%])}$$