



CEPC

Prospect for $\tau\bar{\tau}$ Pair Production in CEPC with $\sqrt{s} = 240$ and 360 GeV

Feng LU

CEPC Joint Workshop 2022
23-25 May 2022, Shanghai, China



中国科学院高能物理研究所
Institute of High Energy Physics
Chinese Academy of Sciences

◆ Introduction

- ✓ *SUSY*

- ✓ *Smuon search at CEPC*

- ✓ *240GeV 5.05ab⁻¹ 5% sys. result*

◆ 360GeV anaysis & 1ab⁻¹ 5% sys. results

- ✓ *Variables distributions*

- ✓ *Final selection*

- ✓ *N-1 plots*

- ✓ *Results: yields & Zn map*

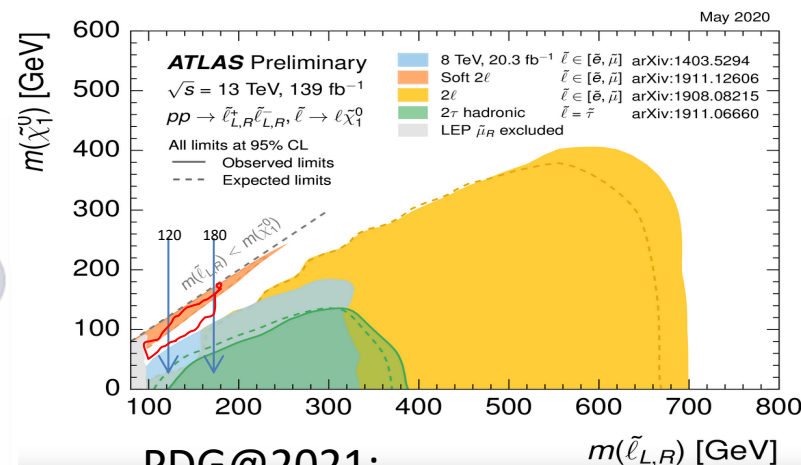
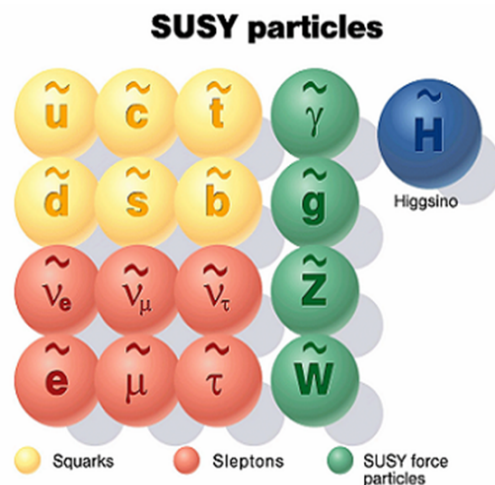
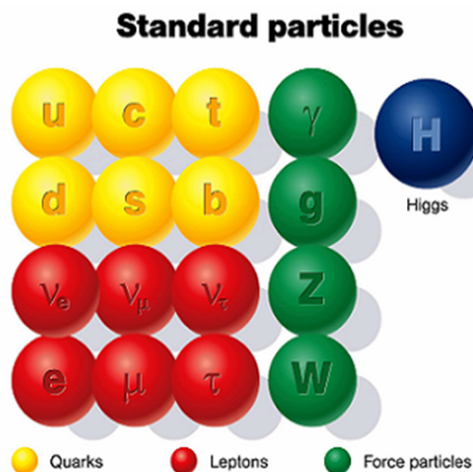
◆ Summary

SUSY reveals an unique symmetry between fermions and bosons:

- ✓ Try to solve Dark matter ; hierarchy problem; gravity and gauge theory unification ...
- ✓ May also for muon $g-2@2021$ 4.2σ ; W mass@2022 7σ to SM predictions

Muon is unique lepton: mass not light and life not short, its SUSY partner: smuon, may plays an essential role in SUSY sleptons search

CEPC provides good place to hunt it !



PDG@2021:

smuon mass > 94 GeV, CL=95%
 (CMSSM, $1 < \tan\beta < 40$, $m_{\text{smu}} - m_{\text{LSP}} > 10 \text{ GeV}$)

Smuon search at CEPC



- Signal sample designed in smuon $\tilde{\mu}$ and LSP mass phase space;
- $\tilde{\mu}$ mass is bounded by LEP/CEPC limit; LSP is bounded by the $\tilde{\mu}$ mass
- $\tilde{\mu}$ decays into a muon and a LSP with 100% BR
- Signal cross-section (LO) :

240GeV: $M_{\tilde{\mu}} = 115\text{GeV}$ 23.6 fb

360GeV: $M_{\tilde{\mu}} = 110\text{GeV}$ 217.5 fb

$= 120\text{GeV}$ 181.7 fb

$= 160\text{GeV}$ 42.5 fb

$= 170\text{GeV}$ 15.7 fb

$= 175\text{GeV}$ 5.7 fb

$= 179\text{GeV}$ 0.5 fb

- Main BKG at 360GeV :

$\mu\mu (Z)$ 2430.34 $\pm$ 22.60 fb

$WW \rightarrow ll$ 281.05 $\pm$ 0.29 fb

$ZZ \text{ or } WW \rightarrow \mu\mu\nu\nu$ 150.87 $\pm$ 0.17 fb

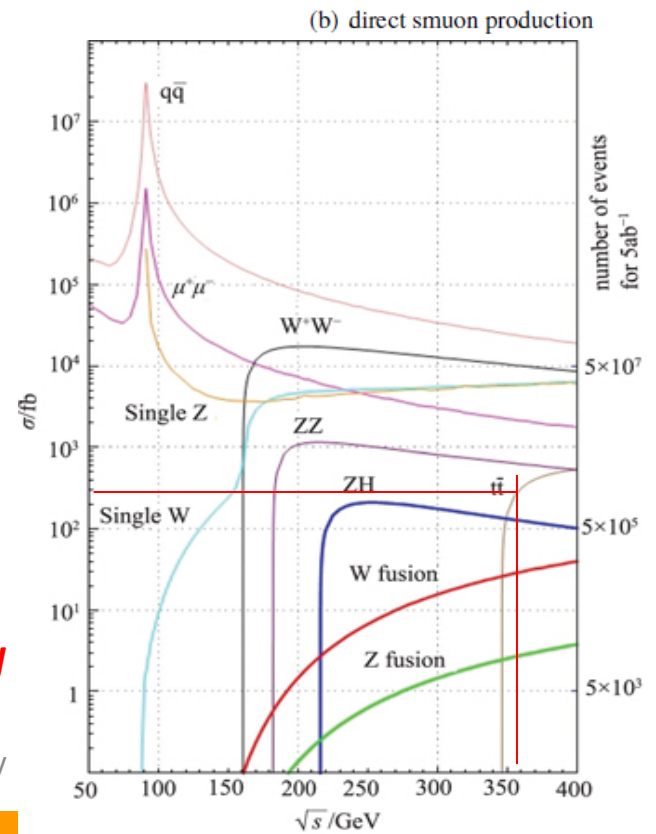
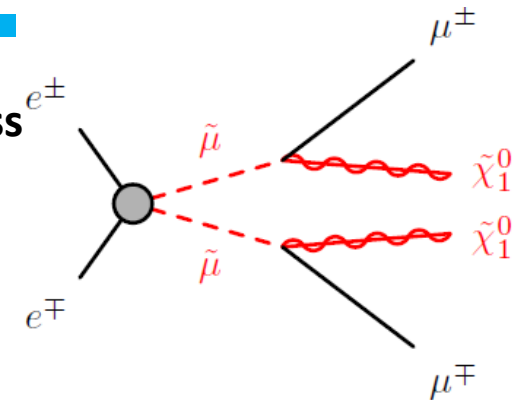
$\nu Z, Z \rightarrow \mu\mu$ 45.63 $\pm$ 0.13 fb

$ZZ \rightarrow \mu\mu\nu\nu$ 10.42 $\pm$ 0.02 fb

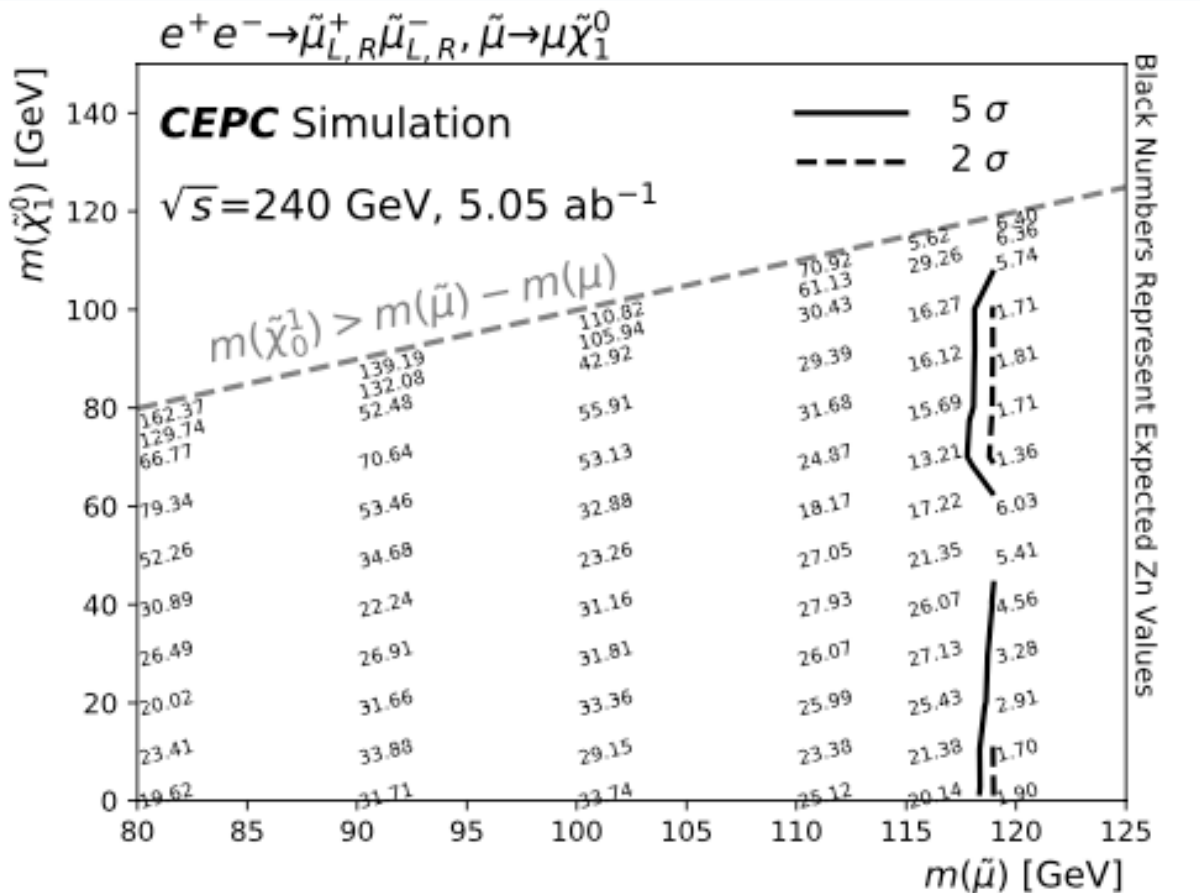
$\nu\nu H, H \rightarrow \text{anything}$ 53.62 $\pm$ 0.04 fb

$\tau\tau$ are
Channel
not listed

$t\bar{t}$ $\sim 300\text{fb}$, its $4j+2b \sim 202\text{fb}$, $\nu\nu\mu\mu + 2b \sim 3.4\text{fb}$, $t\bar{t}$ can be well suppressed in smuon search (now no generator yet!)



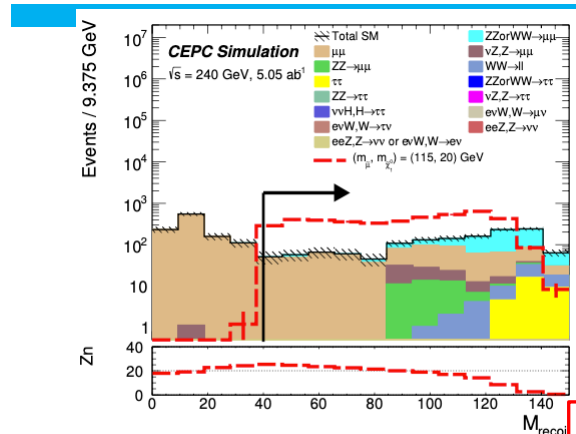
CEPC 240GeV 5.05ab⁻¹ (5% sys.) Results



SR-highDeltaM SR-midDeltaM SR-lowDeltaM

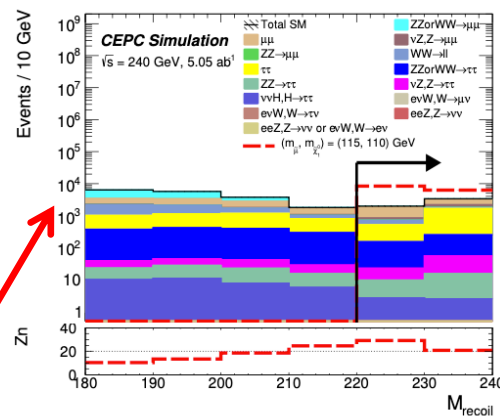
== 2 muons (OS, both energy >0.5 GeV)

$E_\mu > 40$ GeV	$9 \text{ GeV} < E_\mu < 48$ GeV	-
$\Delta R(\mu, recoil) < 2.9$	$1.5 < \Delta R(\mu, recoil) < 2.8$	-
$M_{\mu\mu} < 60$ GeV	$M_{\mu\mu} < 80$ GeV	-
$M_{recoil} > 40$ GeV	-	$M_{recoil} > 220$ GeV



(a) SR-highDeltaM: M_{recoil}

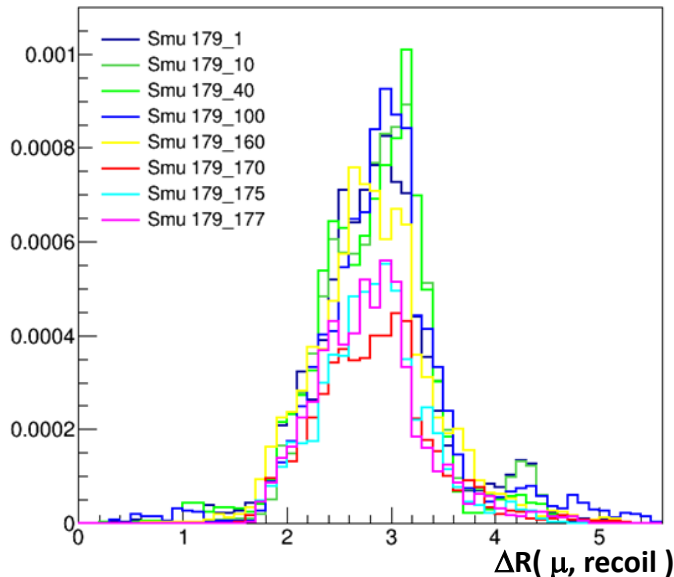
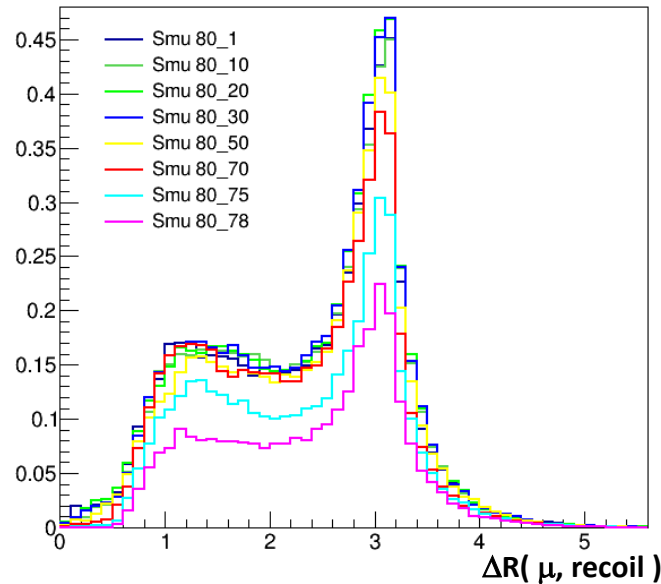
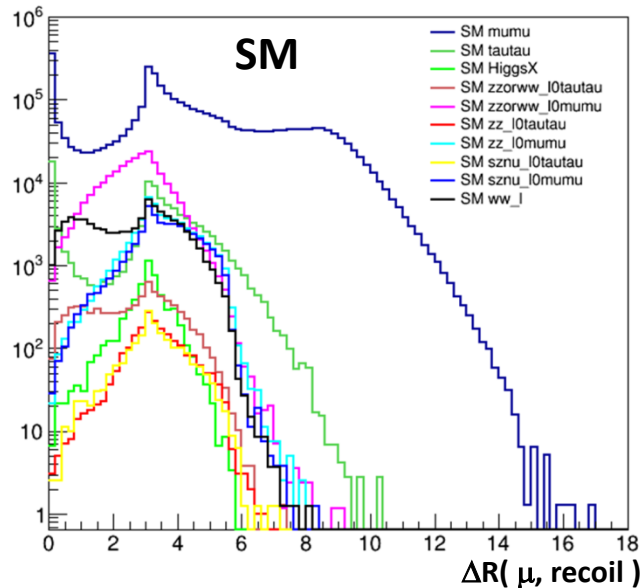
N-1 plot



(e) SR-lowDeltaM: M_{recoil}

With 5% flat systematic, the discovery sensitivity can reach up to 117 GeV in smuon mass [arXiv:2105.06135](https://arxiv.org/abs/2105.06135)

360GeV 1ab⁻¹ Analysis: Variables $\Delta R(\mu, \text{recoil})$



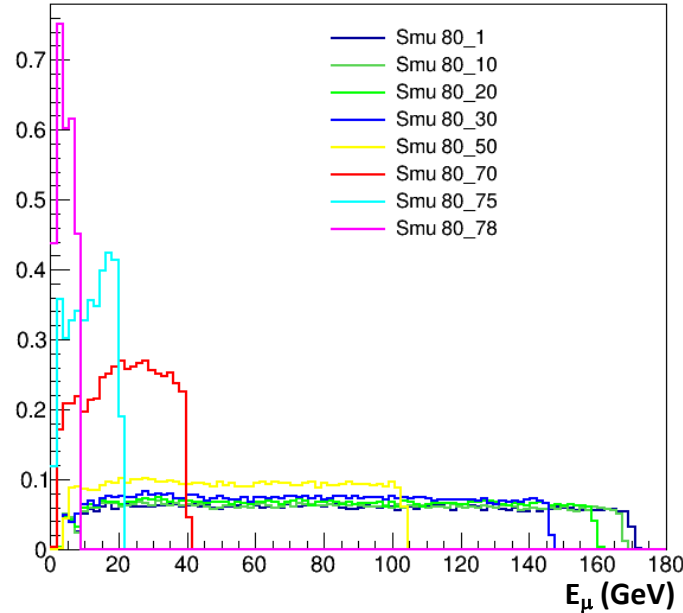
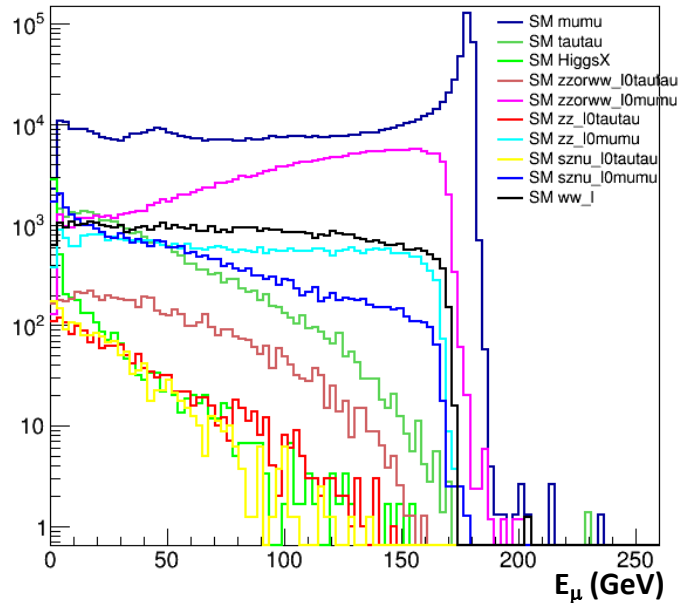
Preselection:

OSmuon==1 (OS 2 muons with $E_\mu > 0.5\text{GeV}$)

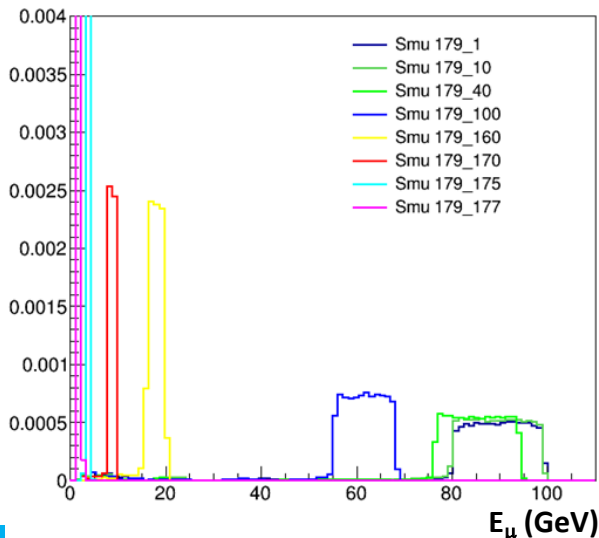
Signal $\Delta R(\mu, \text{recoil})$: 0.5 - 4.0

**Mean value slowly goes up as m_μ increases,
range is much narrower than SM BKG**

360GeV 1ab⁻¹ Analysis: Variables E_μ



$$\Delta M = m_{\tilde{\mu}} - m_{\text{LSP}}$$



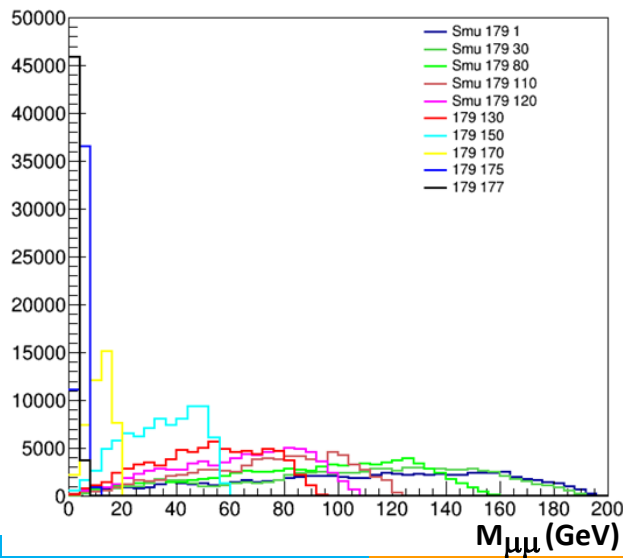
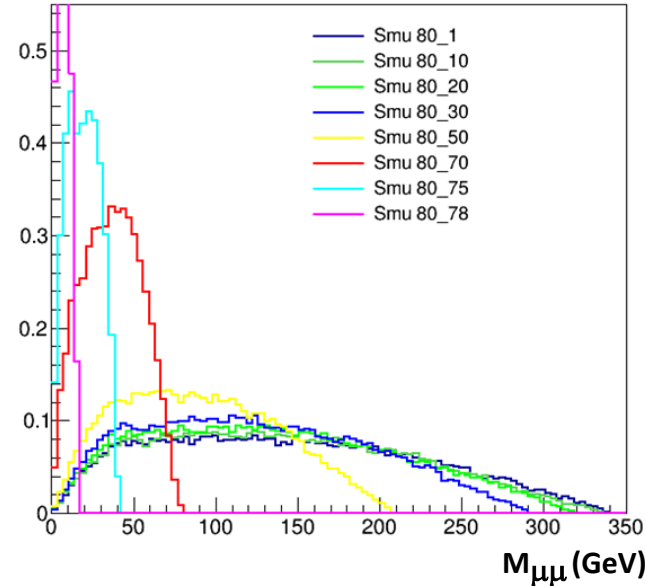
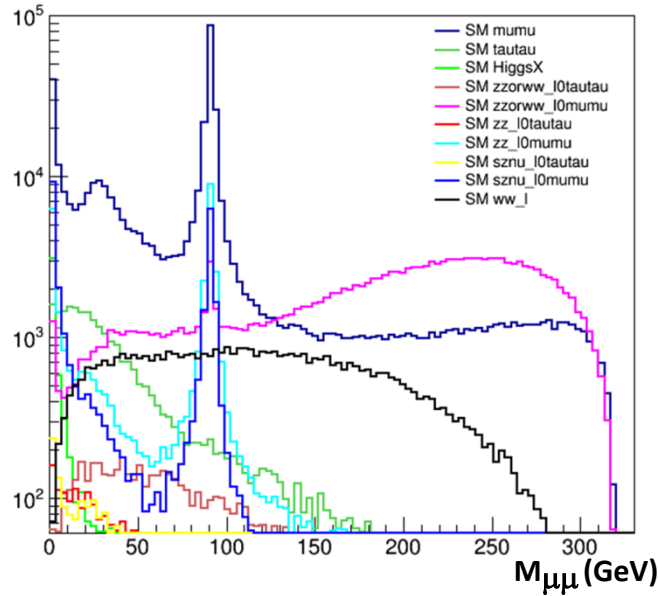
Preselection:

OSmuon==1 (OS 2 muons with $E_\mu > 0.5\text{GeV}$)

Signal E_μ : 0 – 170 GeV

Box-like distribution, sensitive to ΔM . Its range broader and mean value goes up as ΔM increase for fixed $m_{\tilde{\mu}}$; Range broader as $m_{\tilde{\mu}}$ reduce for fixed ΔM

360GeV@1ab⁻¹ Analysis: Variables $M_{\mu\mu}$



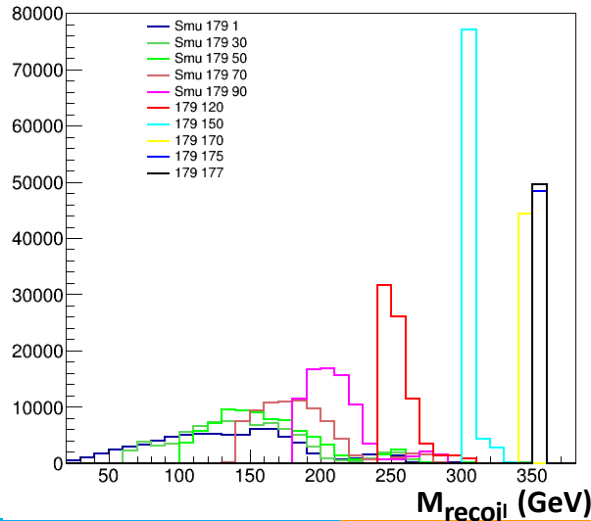
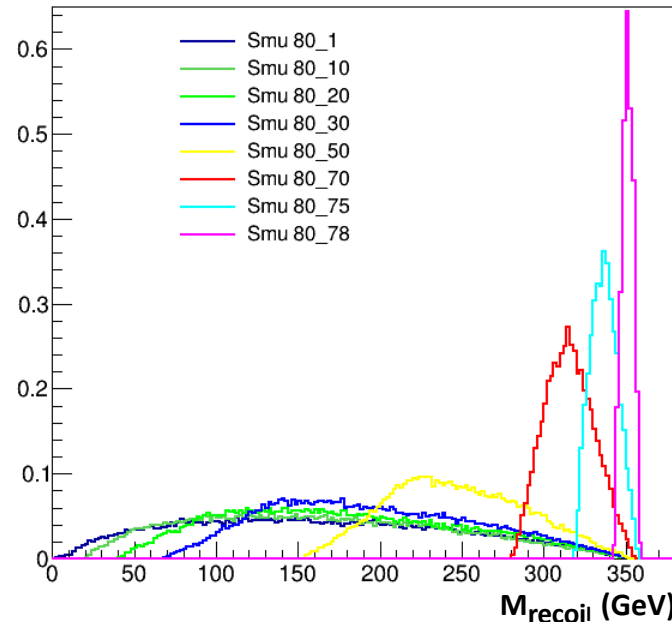
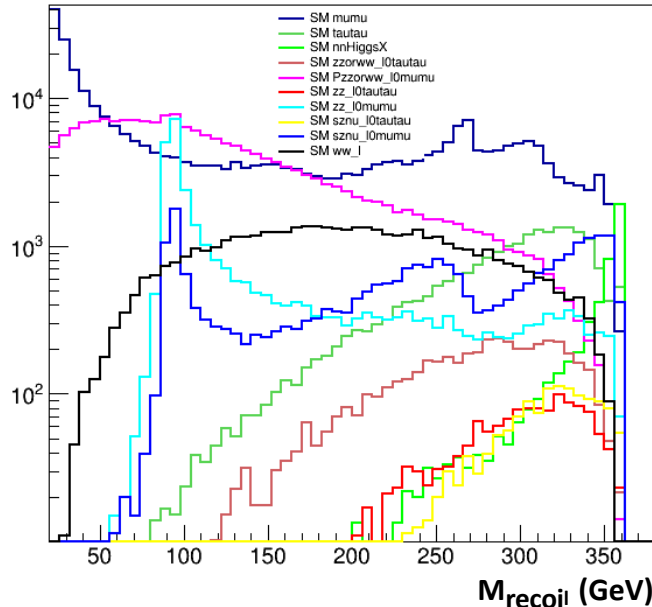
Preselection:

OSmuon==1 (OS 2 muons with $E_\mu > 0.5\text{GeV}$)

Signal $M_{\mu\mu}$: 0-330GeV

sensitive to ΔM . Its range broader and mean value goes up as ΔM increase for fixed $m_{\tilde{\mu}}$; Range broader as $m_{\tilde{\mu}}$ reduce for fixed ΔM . Changing tendency same as E_μ

360GeV@1ab⁻¹ Analysis: Variables M_{recoil}



Preselection:

$OS_{\text{muon}}=1$ (OS 2 muons with $E_{\mu} > 0.5\text{GeV}$)

Signal M_{recoil} : 0-355GeV

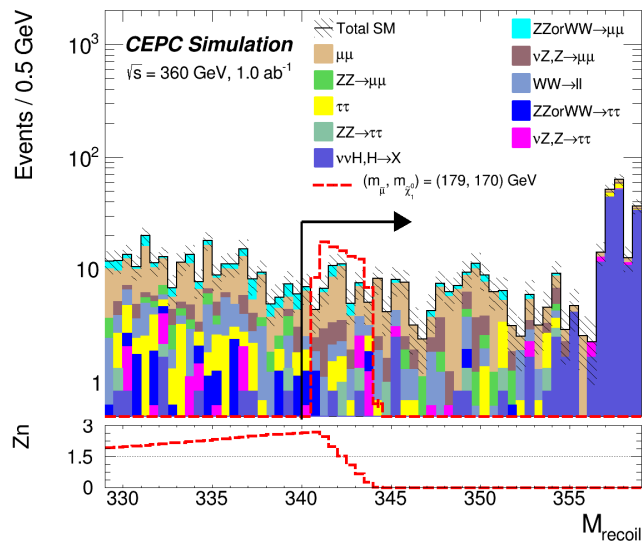
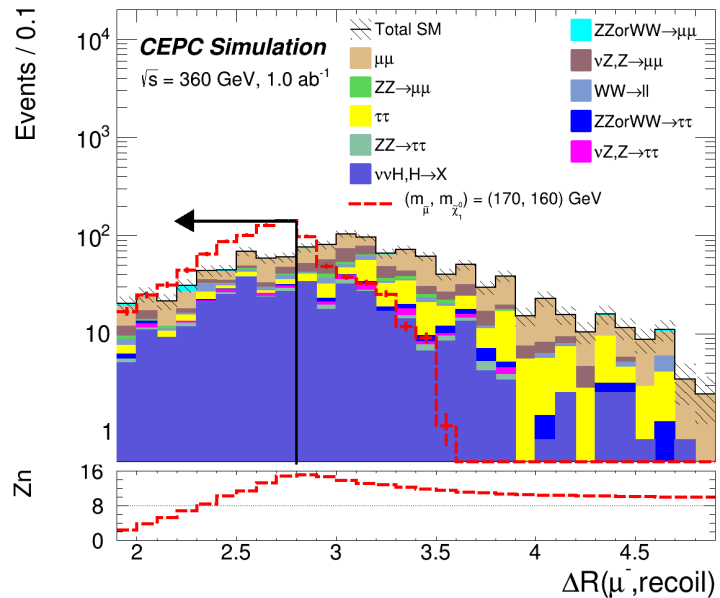
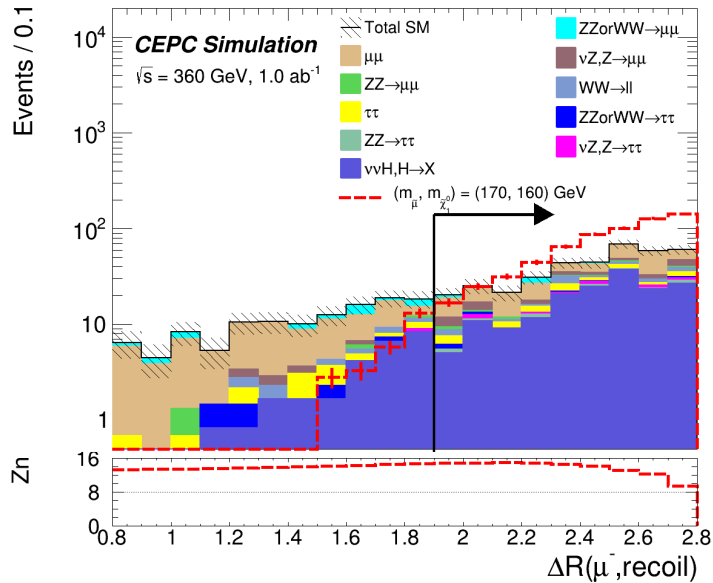
Sensitive to ΔM . Its range broader and mean value goes down as ΔM increase for fixed $m_{\tilde{\mu}}$; Range broader as $m_{\tilde{\mu}}$ reduce for fixed ΔM

Final selection



SR-highDeltaM $\Delta M > 100\text{GeV}$	SR-midDeltaM $100\text{GeV} \geq \Delta M > 10\text{GeV}$	SR-lowDeltaM $\Delta M \leq 10\text{GeV}$
==2 muons (OS, both energy > 0.5GeV)		
$\Delta R(\mu, \text{recoil}) < 2.8$	$1.9 < \Delta R(\mu, \text{recoil}) < 3.0$	$1.9 < \Delta R(\mu, \text{recoil}) < 2.8$
$E_\mu > 60\text{ GeV}$	$E_\mu < 80\text{ GeV}$	-----
$M_{\text{recoil}} > 100\text{ GeV}$	-----	$M_{\text{recoil}} > 340\text{ GeV}$
$87\text{ GeV} > M_{\mu\mu} \parallel$ $95\text{ GeV} < M_{\mu\mu} < 130\text{ GeV}$	$M_{\mu\mu} < 80\text{ GeV}$	-----

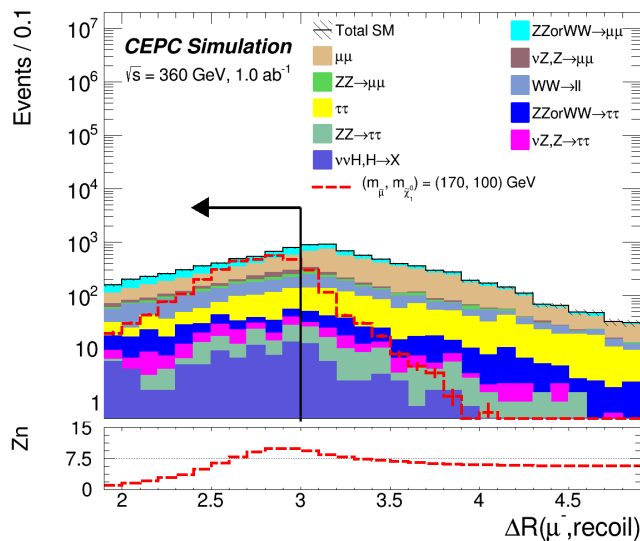
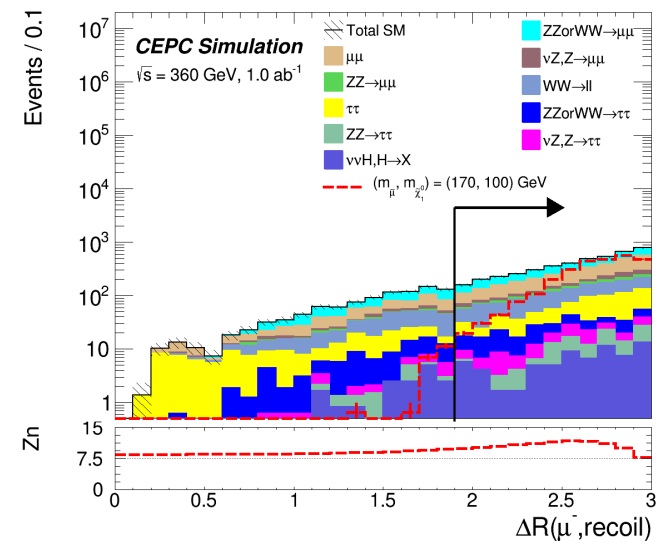
N-1 Plots: SR-LowDeltaM ($\Delta M \leq 10 \text{ GeV}$)



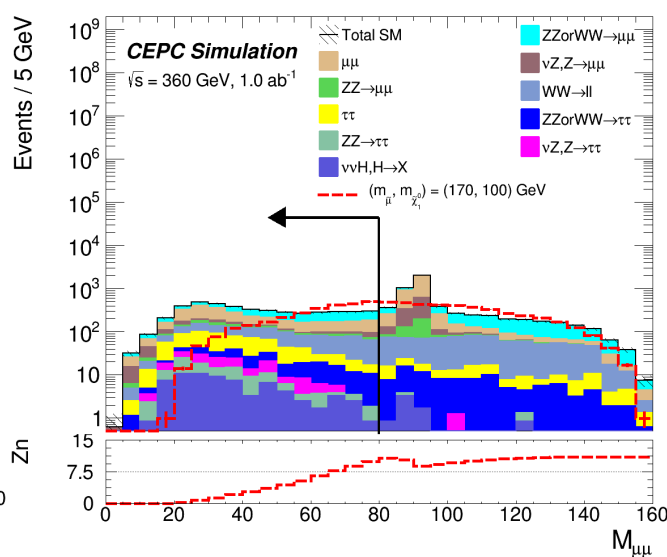
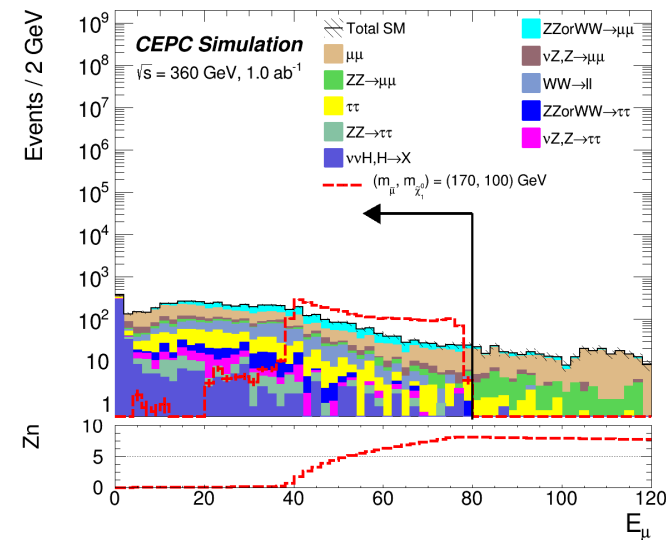
**OSmuon==1 &&
1.9 < ΔR(μ, recoil) < 2.8 &&
M_{recoil} > 340 GeV**

Good optimized !

N-1 Plots: SR-MiddleDeltaM ($10\text{GeV} < \Delta M \leq 100\text{GeV}$)

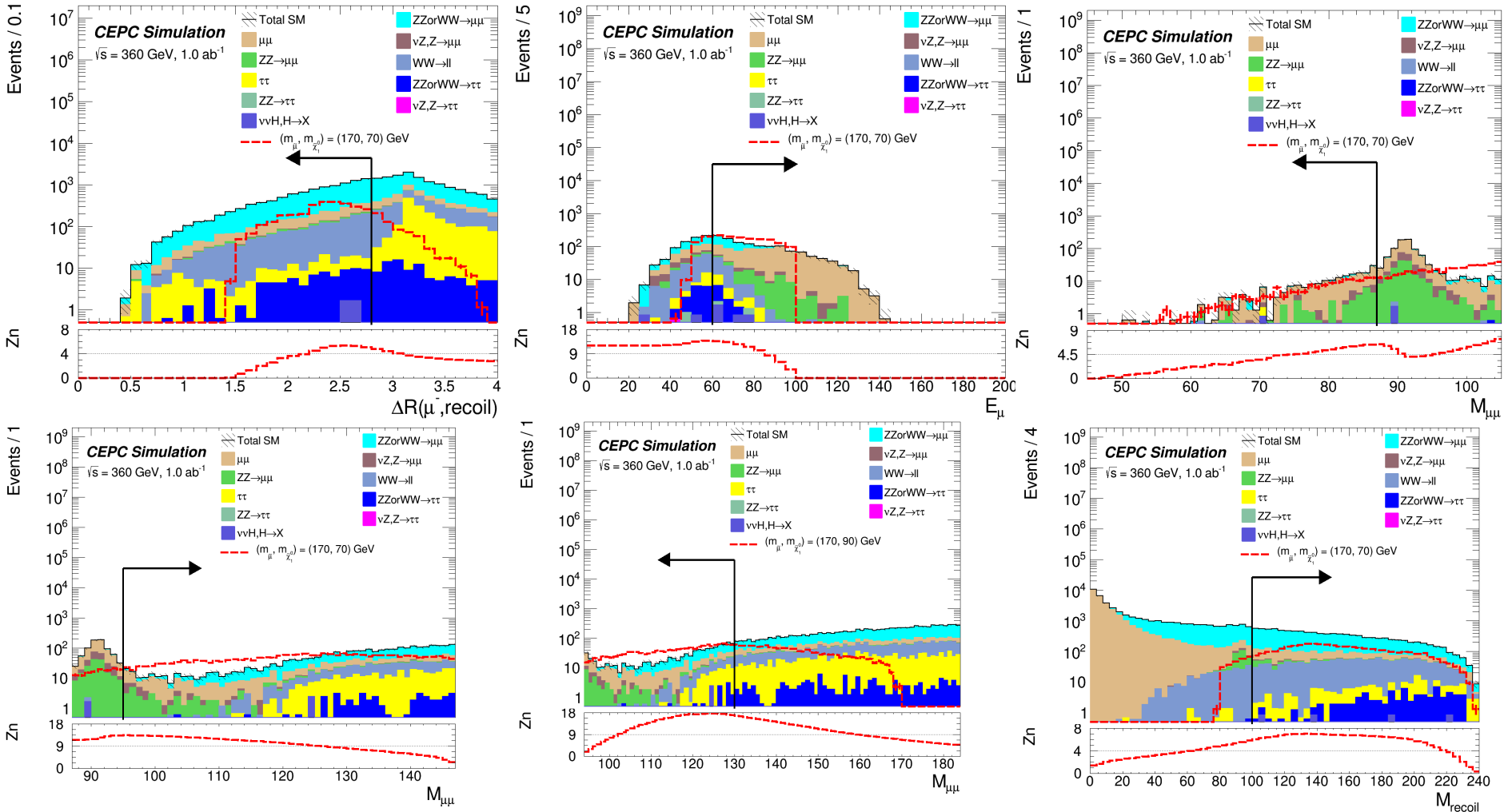


OSmuon==1 &&
 $1.9 < dR(\mu, \text{recoil}) < 3.0$ &&
 $E_\mu < 80\text{GeV}$ &&
 $M_{\mu\mu} < 80\text{GeV}$



Good optimized !

N-1 Plots: SR-HighDeltaM (dM>100GeV)



OSmuon==1 && $\Delta R(\mu, \text{recoil}) < 2.8$ && $E_{\mu} > 60$ && $(M_{\mu\mu} < 87.0 \text{ || } 95 < M_{\mu\mu} < 130)$ && $M_{\text{recoil}} > 100$

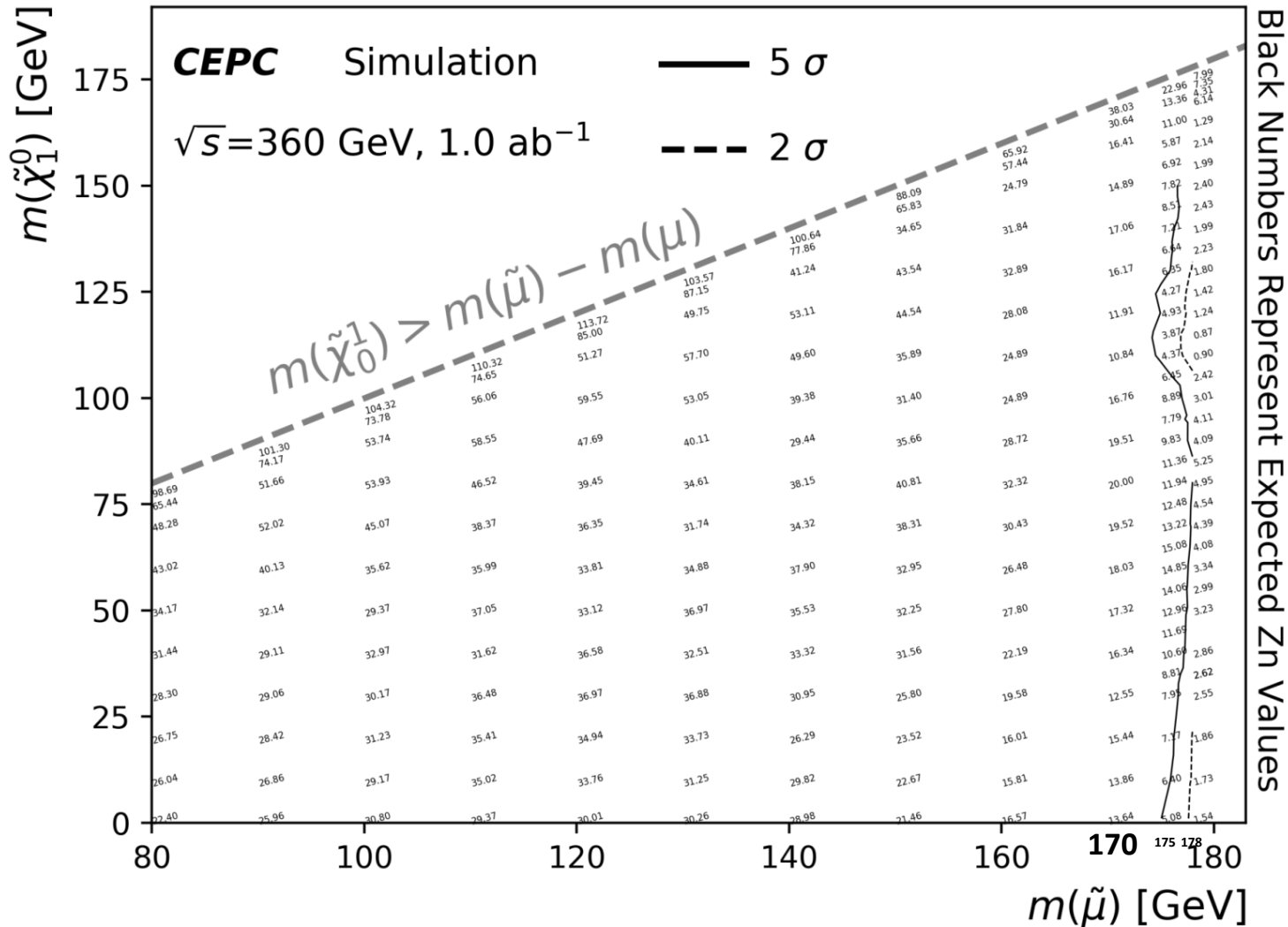
Good optimized!

SM BKG & Signal yields

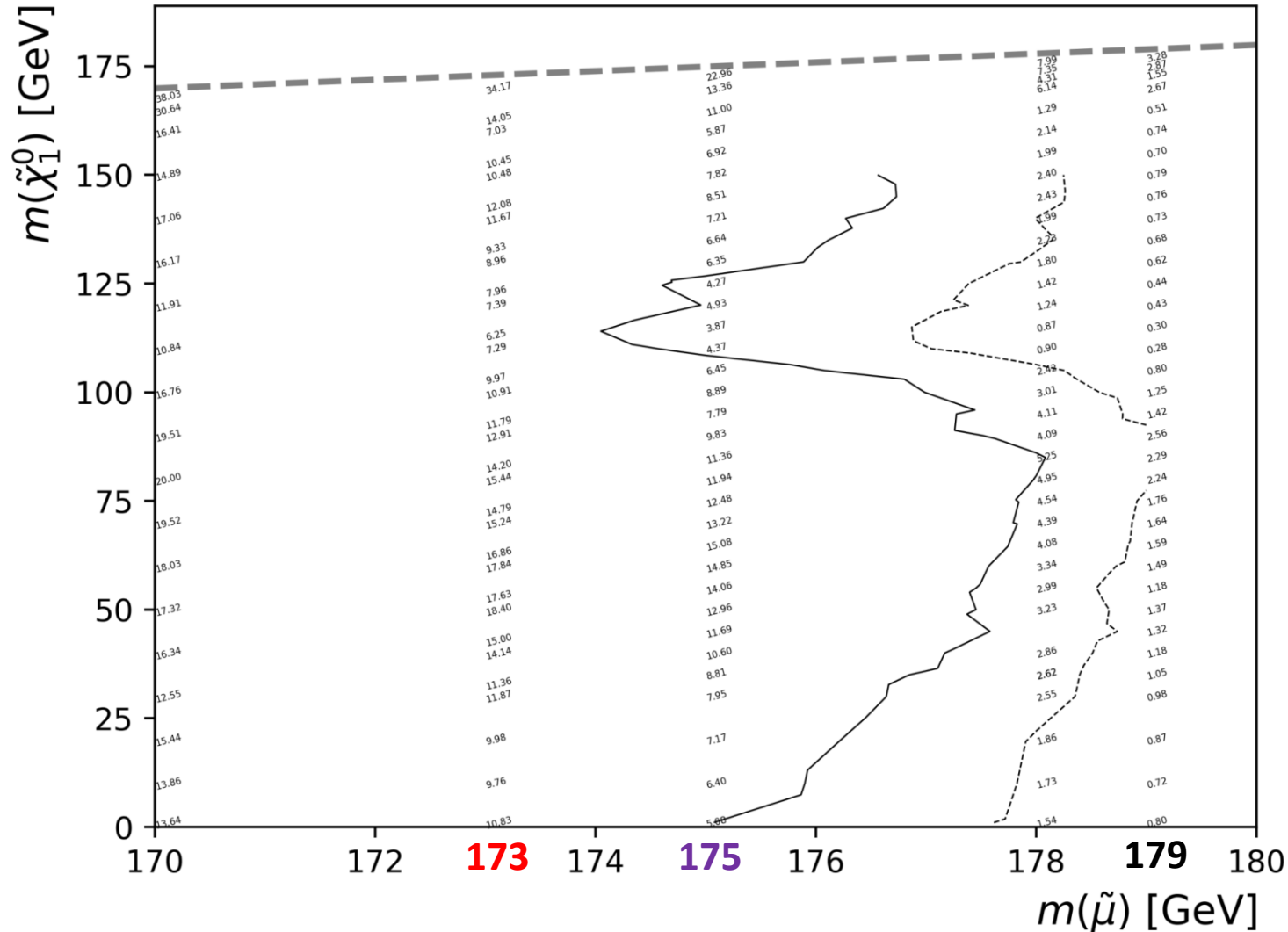
Process	Preselection	SR-highDeltaM	SR-midDeltaM	SR-lowDeltaM
$\mu\mu$	$1.59 \text{ E6} \pm 1015$	218.6 ± 11.9	1743 ± 33.6	107.1 ± 8.3
$ZZ \text{ or } WW \rightarrow \mu\mu\nu\nu$	116669 ± 262	332.5 ± 14.0	1335 ± 28.0	14.10 ± 2.88
$\nu Z, Z \rightarrow \mu\mu$	22705 ± 119	21.3 ± 3.6	383.7 ± 15.5	25.66 ± 4.01
$ZZ \rightarrow \mu\mu\nu\nu$	27213 ± 130	45.0 ± 5.3	191.9 ± 11.0	5.63 ± 1.88
$WW \rightarrow ll$	39268 ± 155	67.4 ± 6.4	678.1 ± 20.4	18.38 ± 3.35
$ZZ \text{ or } WW \rightarrow \tau\tau\nu\nu$	3751 ± 49	7.57 ± 2.18	148.9 ± 9.7	3.79 ± 1.55
$\tau\tau$	48579 ± 183	13.1 ± 3.0	540.5 ± 19.3	21.4 ± 3.8
$\nu Z, Z \rightarrow \tau\tau$	1001 ± 25	0.0 ± 0.0	98.2 ± 7.8	8.76 ± 2.34
$ZZ \rightarrow \tau\tau\nu\nu$	1068 ± 23	1.00 ± 0.71	83.1 ± 6.5	6.01 ± 1.73
$\nu\nu H, H \rightarrow \text{anything}$	2776 ± 48	3.34 ± 1.67	419.1 ± 18.7	170.3 ± 11.9
SM Total BKG	$1.86 \text{ E6} \pm 1092$	710 ± 21	5622 ± 60	381.0 ± 16.6
Signal 175_10	5145.6 ± 17.5	354.5 ± 4.6	-----	-----
Signal 175_65	6157.1 ± 17.6	972.2 ± 7.6	-----	-----
Signal 170_120	13426 ± 47	-----	4290 ± 27	-----
Signal 175_155	4382 ± 16	-----	383.7 ± 15.5	-----
Signal 173_163	5137.2 ± 22	-----	-----	600.6 ± 7.7
Signal 173_170	6307.4 ± 24	-----	-----	2048.3 ± 14.2

Final Zn plot

3 Region Best $e^+e^- \rightarrow \tilde{\mu}_{L,R}^+ \tilde{\mu}_{L,R}^-, \tilde{\mu} \rightarrow \mu \tilde{\chi}_1^0$



Enlarged Zn plot with all points (+ 173, 179GeV)

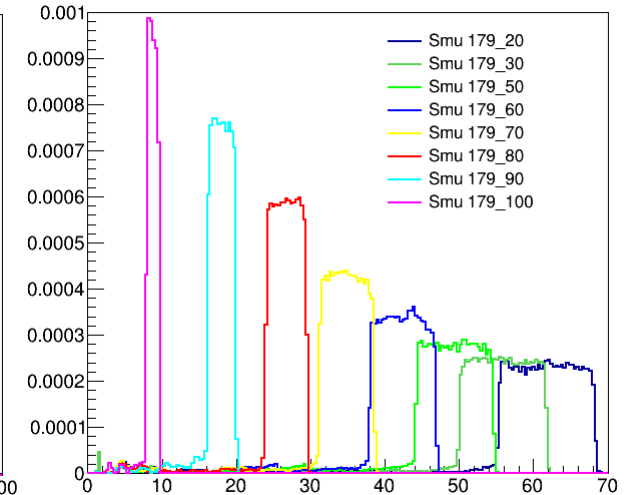
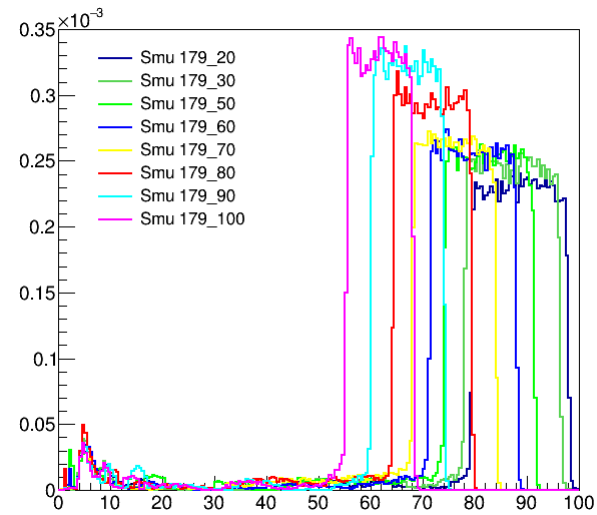
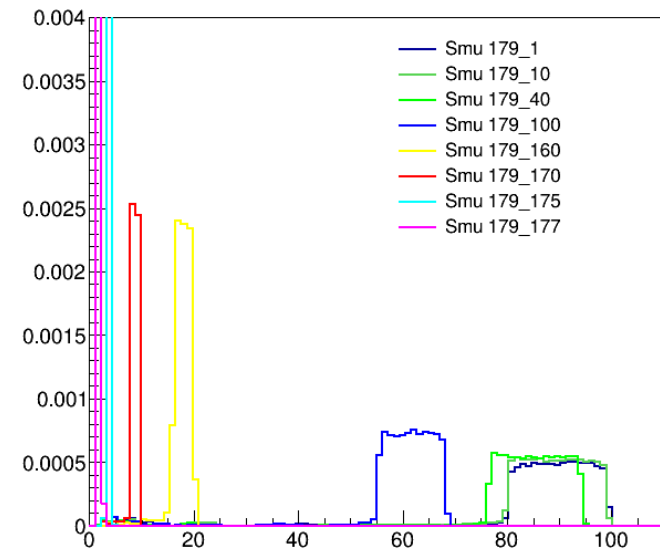
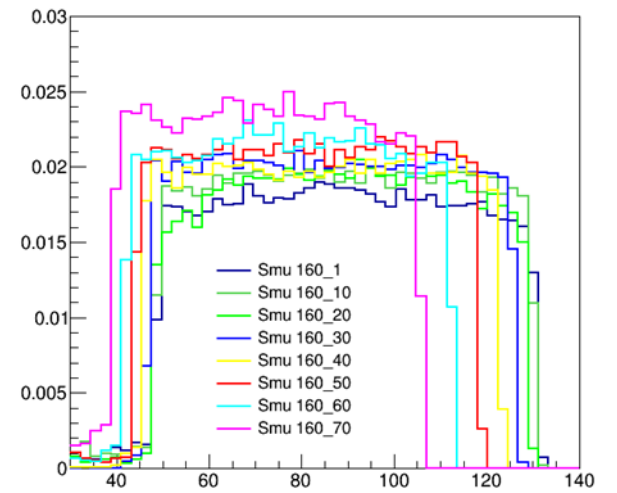
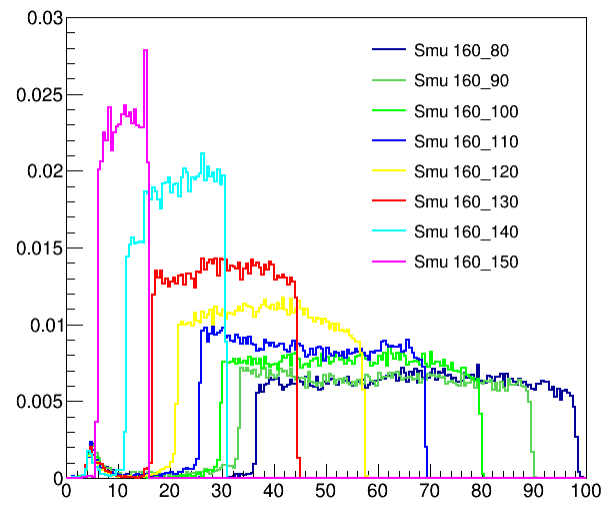
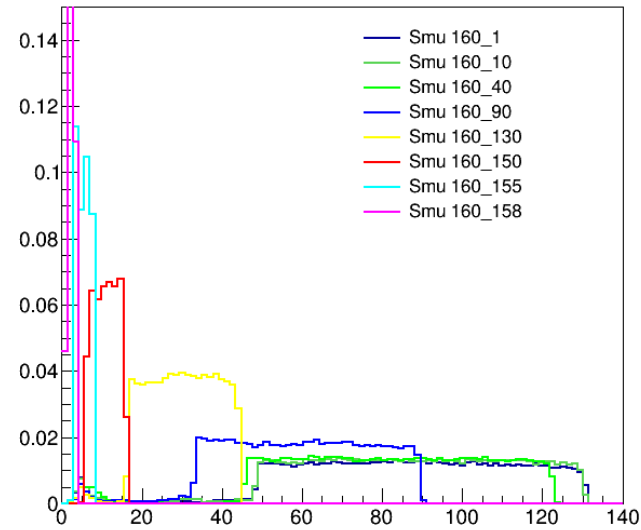


- **smuon search at 360GeV CEPC with 1ab^{-1} is investigated**
- **With 5% flat systematic, the discovery sensitivity with 360GeV 1ab^{-1} can reach up to 173GeV and most of LSP values of 175GeV in smuon mass, our analysis greatly enlarges smuon discovery range, become one of important motivation to raise CEPC CME to 360GeV**
- **Will continue to investigate Zn performance of smuon 174GeV LSP points, and further optimize this search**

Thanks a lot !

Backup

smu pair Signal E_μ dstrubution ($0.5 < \Delta R(\mu, \text{recoil}) < 4.2$ && $O_{\text{Smuon}} == 1$)



360GeV 1ab Analysis: Three key tools



FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

FileEditViewFormatTools

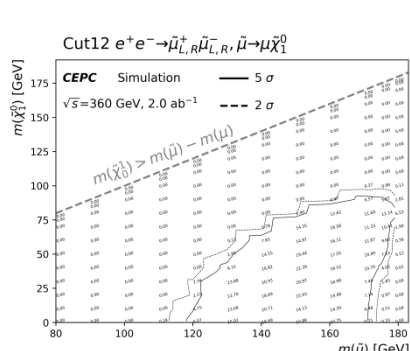
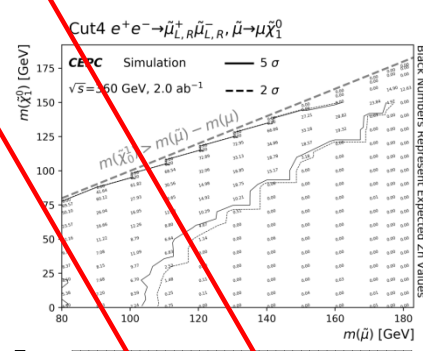
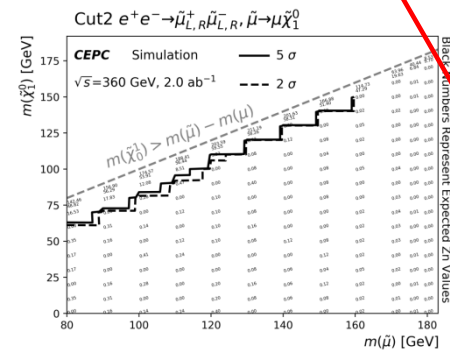
FileEditViewFormatTools

FileEditViewFormatTools

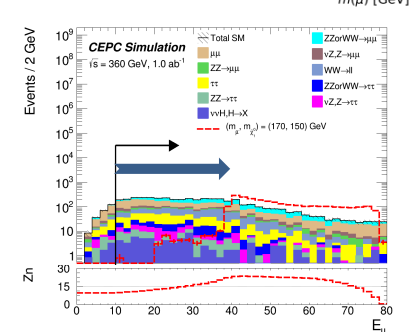
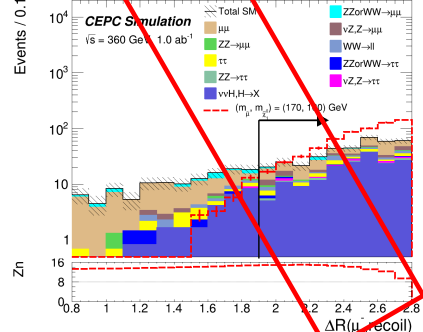
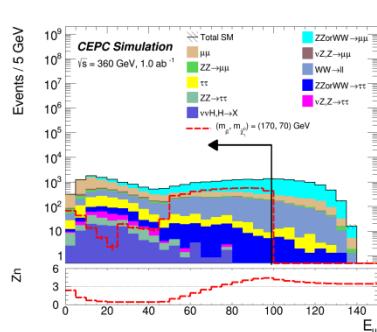
FileEditViewFormatTools

Sensitivity values Excel created by several ten thousands of combinations of $\Delta R(\mu, \text{recoil})$, E_μ , $M^{\mu\mu}$ and M_{recoil}

Sorting & finding Better



Zn plot
~200 Global comparing
& finding larger contour



N-1 plot
~100 Final check
& best selection