Background Estimation for Flavor Physics

Flavor White Paper Discussion
2021/09/15

Dan YU

Plan

- Earlier estimations & predictions
- Physics background and surviving rate for
  - LFV channels
  - Hadronic Z decays
  - Radiative Z decays
- A sketchy using the FullSim

Current estimations

- LFV: Mogens Dam (arxiv:1811.09408)
- Z hadronic decays: Shan Cher Qin Qin and Fu-Sheng YU
- Section 8.3

Decay	Present bound	FCC-ee sensitivity
$Z \to \mu e$	0.75×10^{-6}	10^{-10}–10^{-8}
$Z \to \tau \mu$	12×10^{-6}	10^{-9}
$Z \to \tau e$	9.8×10^{-6}	10^{-9}
$\tau \to \mu\gamma$	4.4×10^{-8}	2×10^{-9}
$\tau \to 3\mu$	2.1×10^{-8}	10^{-10}

Decay mode	Branching ratio	CEPC Uncertainty
$Z \to J/\psi\gamma$	8.02×10^{-8} [29]	$\sim 1.8\%$
$Z \to \Upsilon(1S)\gamma$	5.39×10^{-8} [29]	$\sim 3.4\%$
$Z \to \rho^0\gamma$	4.19×10^{-9} [29]	$\sim 1.8\%$
$Z \to \omega\gamma$	2.82×10^{-8} [29]	$\sim 0.8\%$
$Z \to \phi\gamma$	1.04×10^{-8} [29]	$\sim 1.6\%$
$Z \to \pi^0\gamma$	9.80×10^{-12} [29]	$< 3.4 \times 10^{-8}$
$Z \to \eta\gamma$	$0.1 - 1.7 \times 10^{-10}$ [30]	$\sim 12\% - 50\%$
$Z \to \eta'\gamma$	$3.1 - 4.8 \times 10^{-9}$ [30]	$\sim 2.7 - 3.4\%$

Decay mode	Branching ratio	CEPC Uncertainty
$Z \to \pi^{\pm}W^{\mp}$	1.5×10^{-10}	$\sim 20\%$
$Z \to \rho^{\pm}W^{\mp}$	4.0×10^{-10}	$\sim 13\%$
$Z \to K^{\pm}W^{\mp}$	1.2×10^{-11}	$\sim 70\%$
$Z \to K^{*\pm}W^{\mp}$	2.0×10^{-11}	$\sim 59\%$
$Z \to D_s^{\pm}W^{\mp}$	6.0×10^{-10}	$\sim 75\%$
$Z \to D^{\pm}W^{\mp}$	2.0×10^{-11}	$< 3 \times 10^{-10}$

Samples

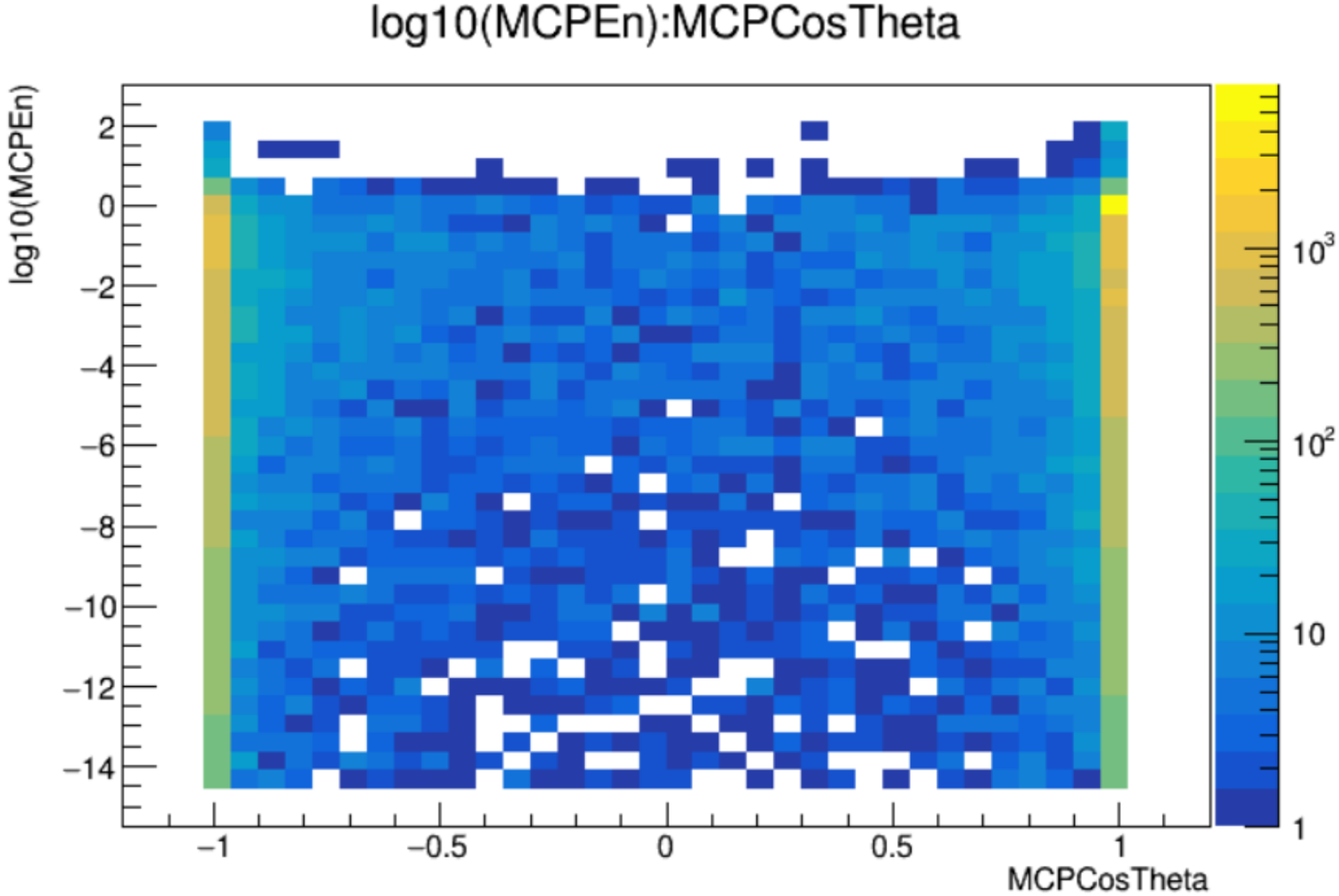
- CEPC Zpole: 10^{12} Z bosons ~ 3.36×10^{10} ττ, 6.99×10^{11} qq
- Current samples: Truth ~ 4×10^{-4} SM; Reco ~ 4×10^{-5} SM

Table 1: CEPC91.2GeV

Channel		Generator		FullSim		DstDate	
		size (GB)	yield (Million)	size (GB)	yield (Million)	size (GB)	yield (Million)
wo_isr	bb	3713	376	-	-	-	-
	cc	2610	294	-	-	-	-
	uu	2419	295	-	-	-	-
	e3e3	137	851	-	-	-	-
wi_isr	bhabha	49	33	619	1.1	19	1.1
	e2e2	151	120	105	1.6	9	1.6
	e3e3	25	13	355	1.6	25	1.6
	n1n1	22	24	-	-	-	-
	n2n2	23	25	-	-	-	-
	n3n3	22	24	-	-	-	-
	nn	67	73	-	-	-	-
	uu	365	42	5918	8.1	687	8.1
	dd	470	55	5931	8.1	678	8.1
	ss	467	55	5731	8.1	678	8.1
	bb	559	54	6332	8.1	775	8.1
	cc	404	43	6057	8.1	725	8.1
	qq	2234	253	-	-	-	-

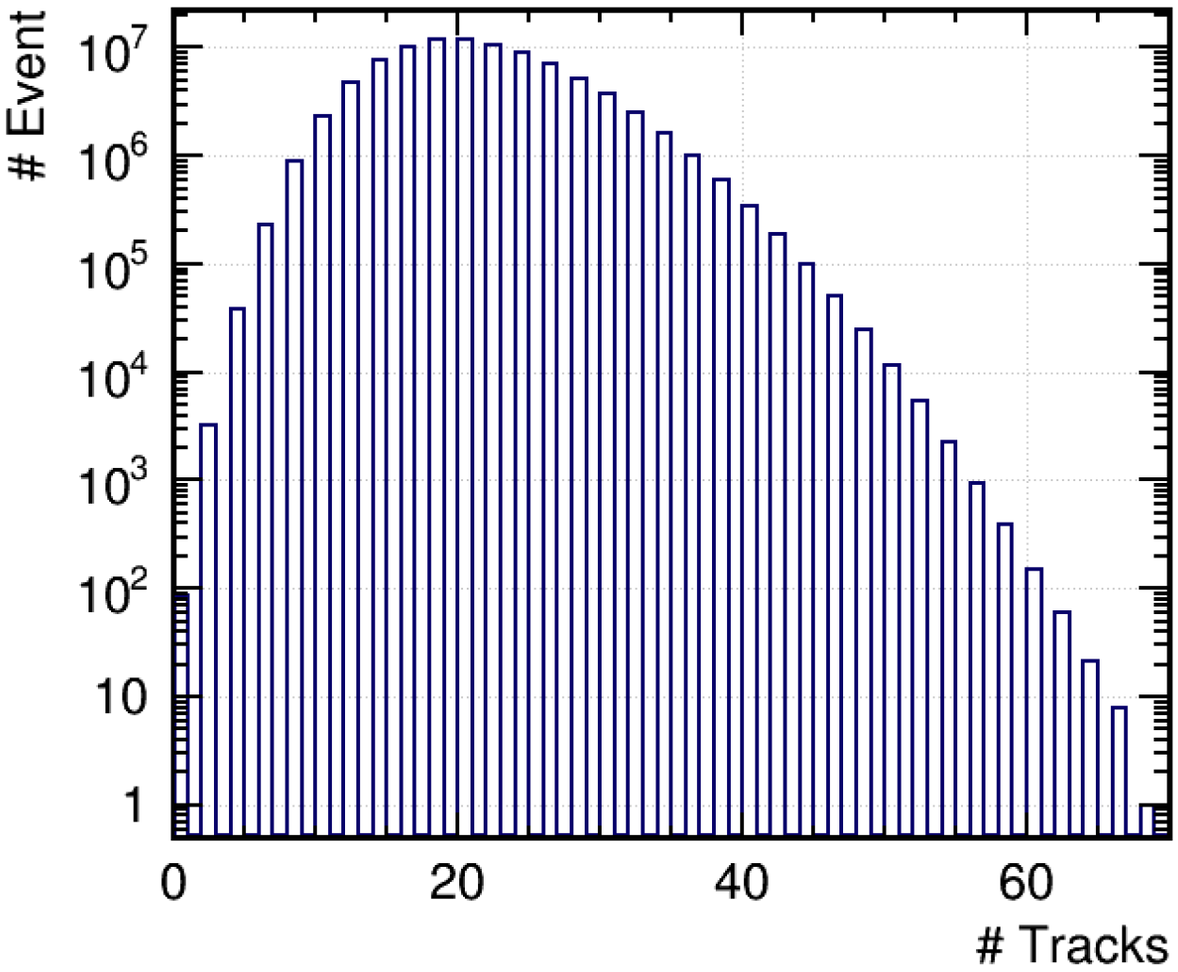
ISR

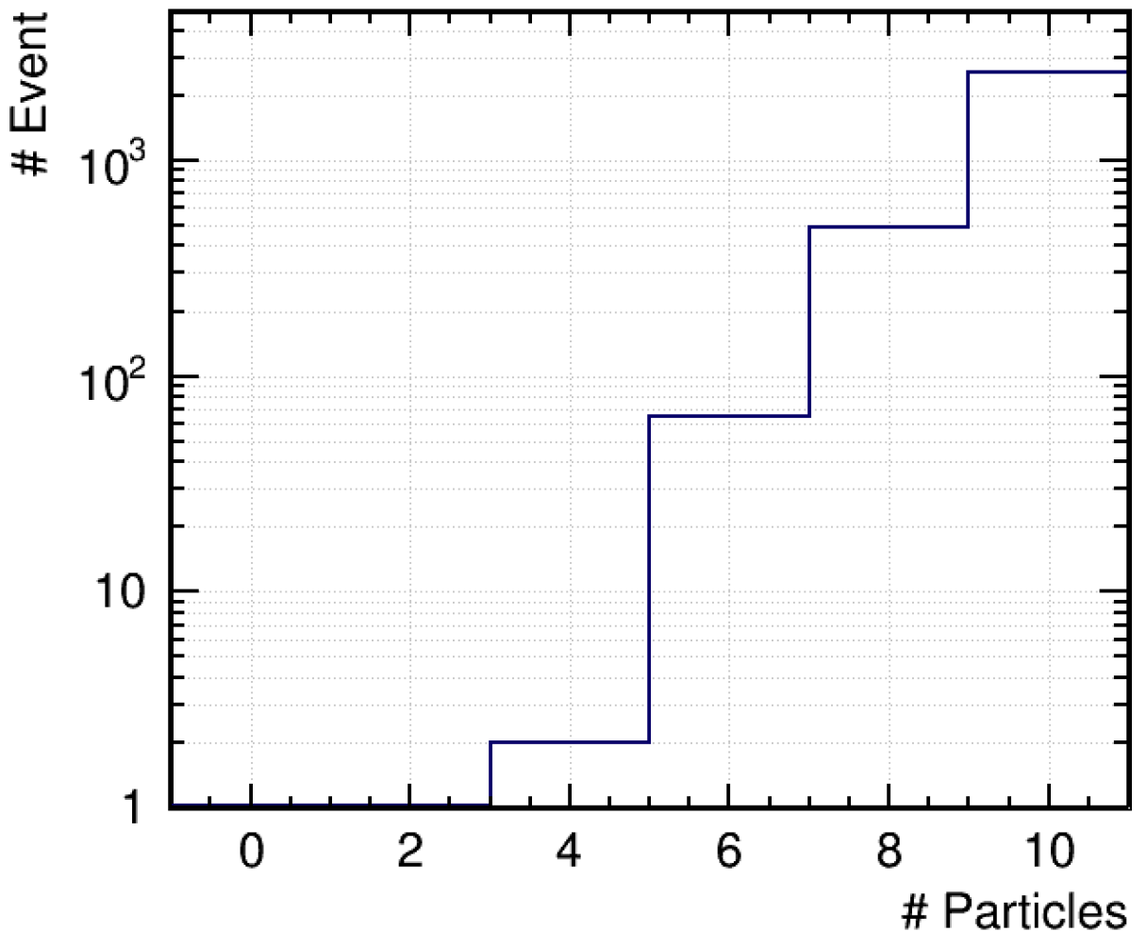
- Mostly to the forward region
- Energy < 1GeV



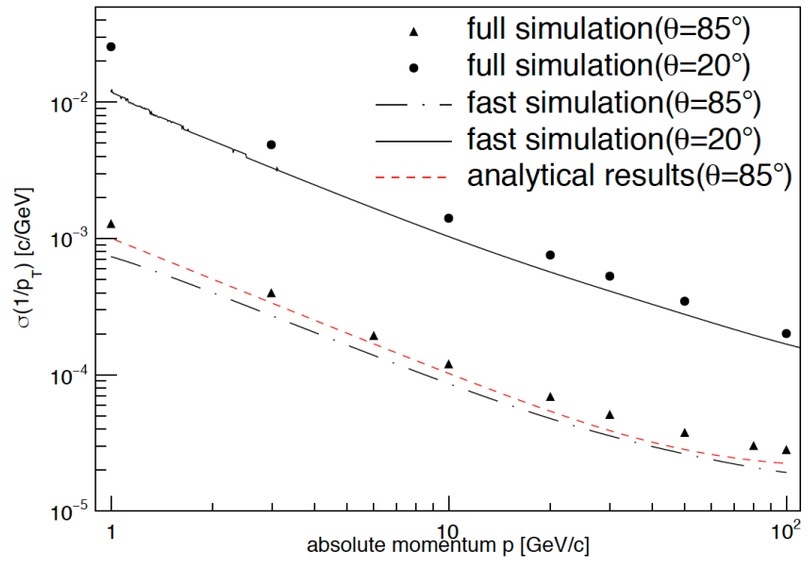
Jet multiplicity

- Jets are not likely to be mixed with leptonic events

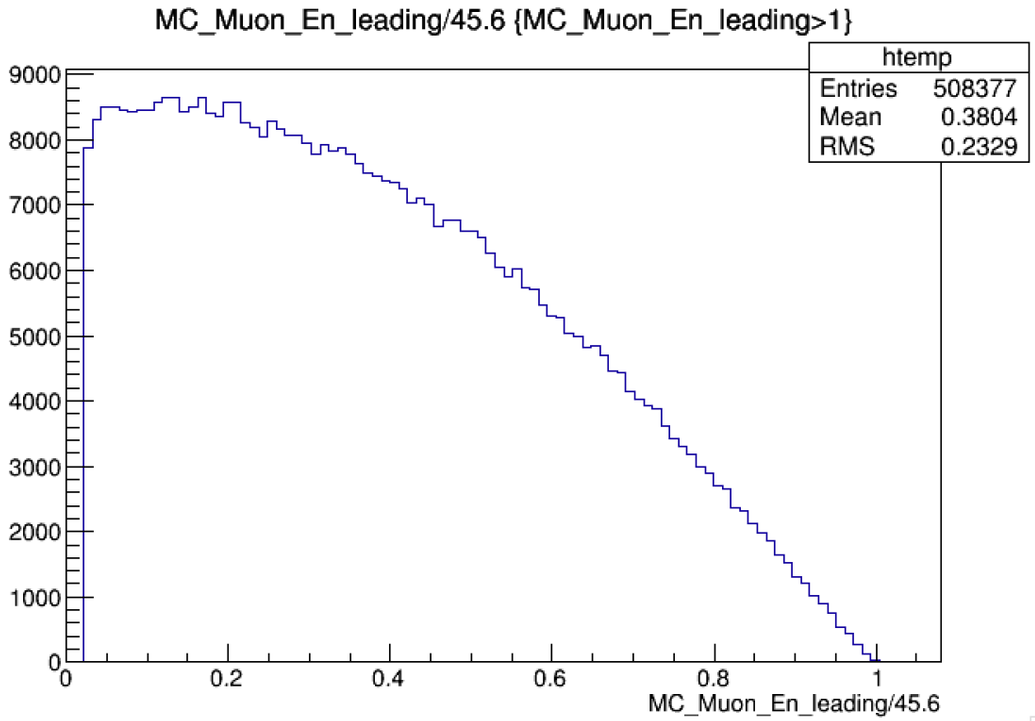


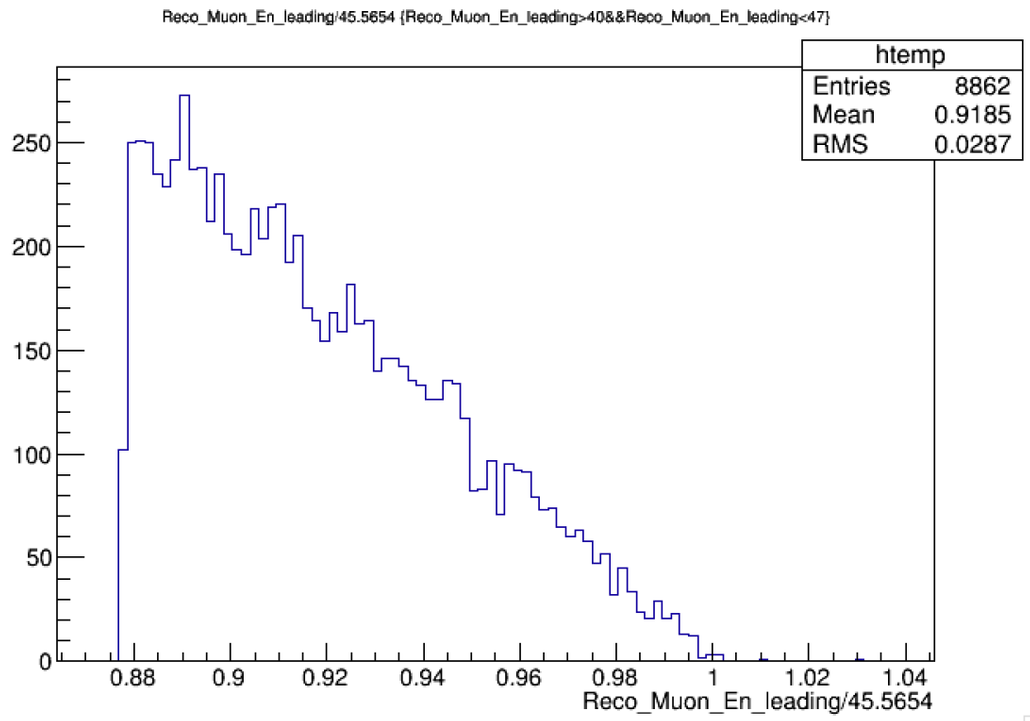


LFV — $Z \to \tau\mu$



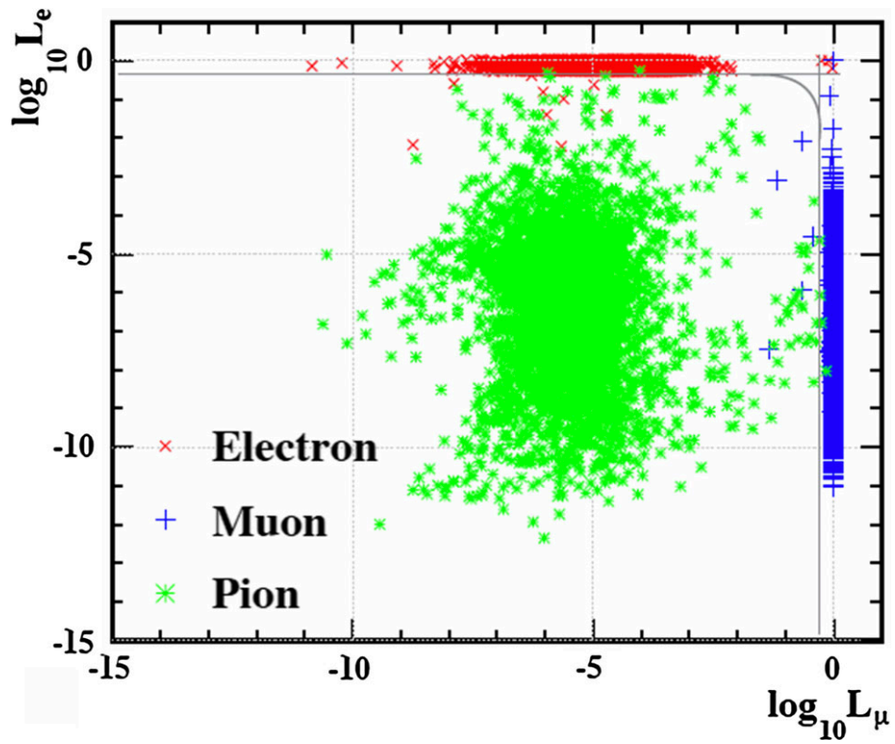
- Main background $Z \to \tau\tau$, $\tau \to \mu\nu\nu$
- Current sensitivity: $1.2*10^{-5}$ (LEP) FCC-ee estimation: 10^{-9}
- Key distribution ($P_\mu/P_{beam}>1$):
  - Signal accuracy depend on the momentum resolution ($\delta p/p \sim 10^{-3}$), signal window: (0.998, 1.002)
  - Background surviving Nbkg: 5*ScaleFactor ~ $3.36*10^5$
- Sensitivity estimated: $1.1*10^{-9}$

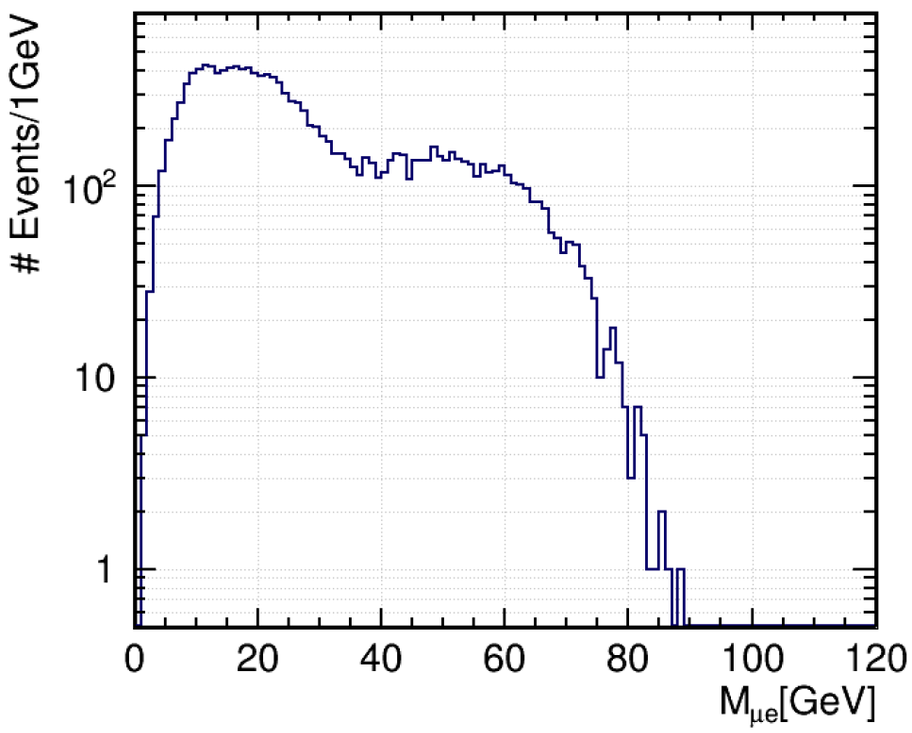




LFV — Z → μe

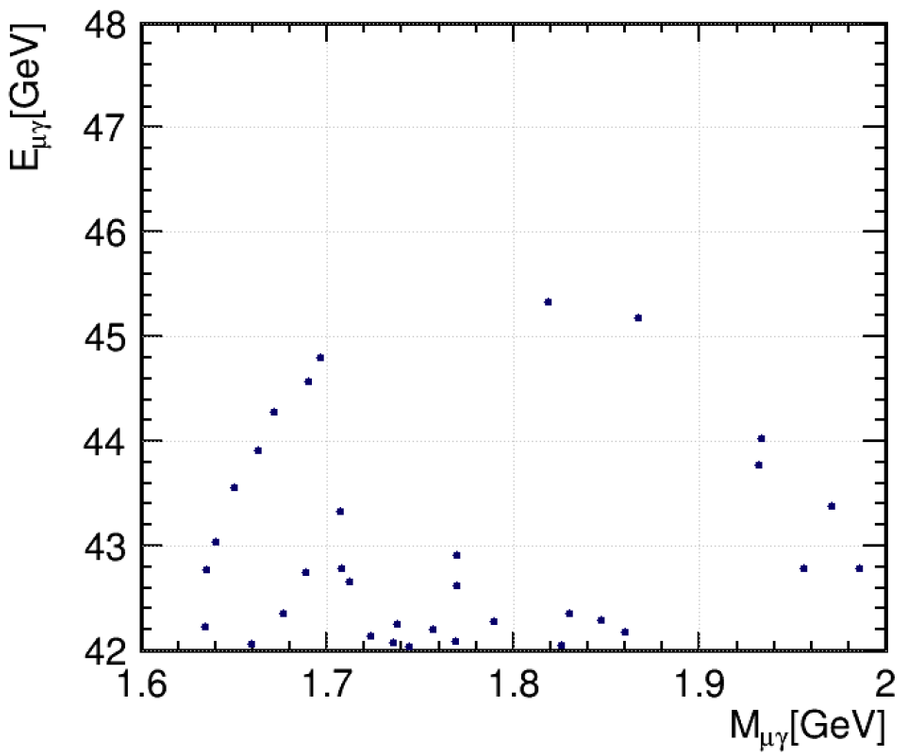
- Physics background: Z→bhabha/μμ/ττ
- Current bound: 7.5*10^{-7} (ATLAS)
  - FCC-ee estimation: 10^{-9}
- Key distribution:
  - μ/e mis-id rate: by sacrificing the id efficiency, barely bhabha/μμ surviving (FCC-ee estimation: 10^{-7})
  - Invariant mass: no ττ surviving
- Sensitivity ~ 10^{-10}





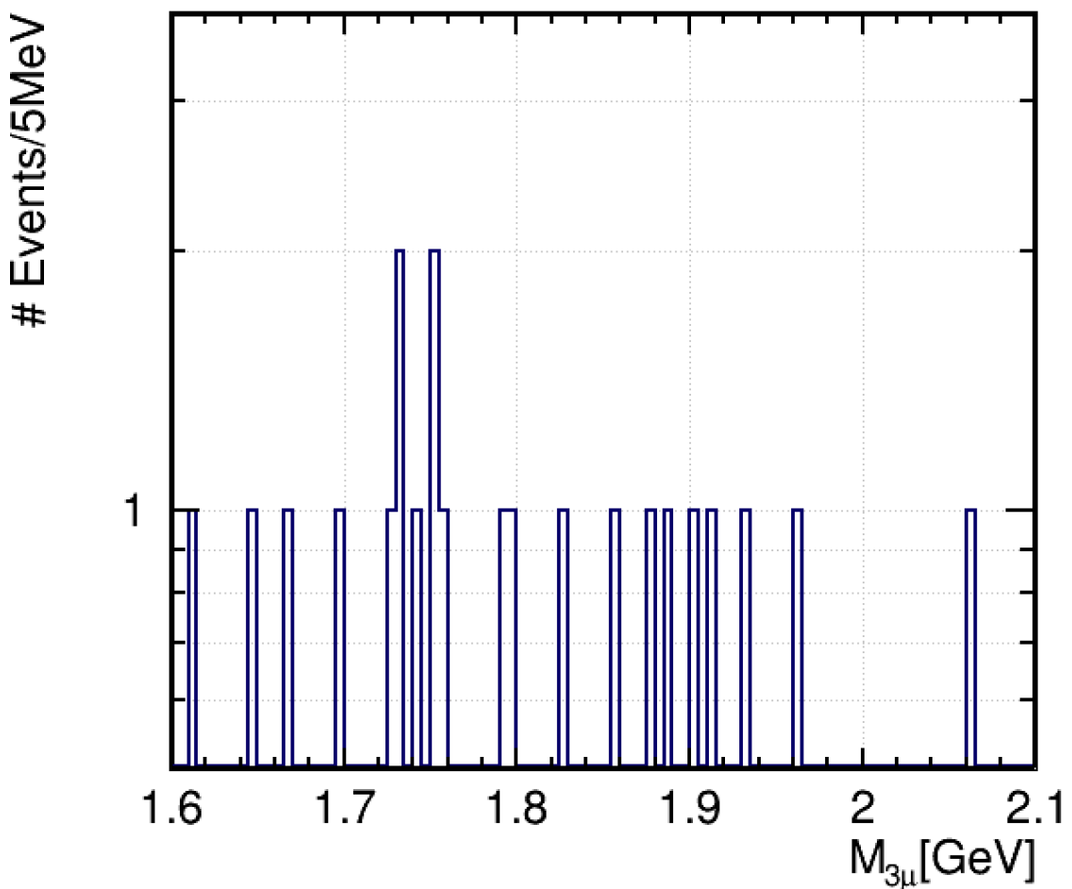
LFV — $\tau \rightarrow \mu(e)\gamma$

- Physics background: $Z \rightarrow \tau\tau\gamma$, $\tau \rightarrow \mu\nu\nu$
- Current bound: $2.7*10^{-8}$ (Babar) FCC-ee estimation: $2*10^{-9}$
- Key distribution: $M(\mu\gamma)$, $E(\mu\gamma)$
  - Signal resolution: $\sigma(m)$ = 26 MeV, $\sigma(E)$=850MeV (Ecal energy resolution ⊕ Track momentum resolution ⊕ Position resolution, from Mogens' paper)
  - Background surviving: 1*SF ~ 10k
- Sensitivity: 10^{-10}



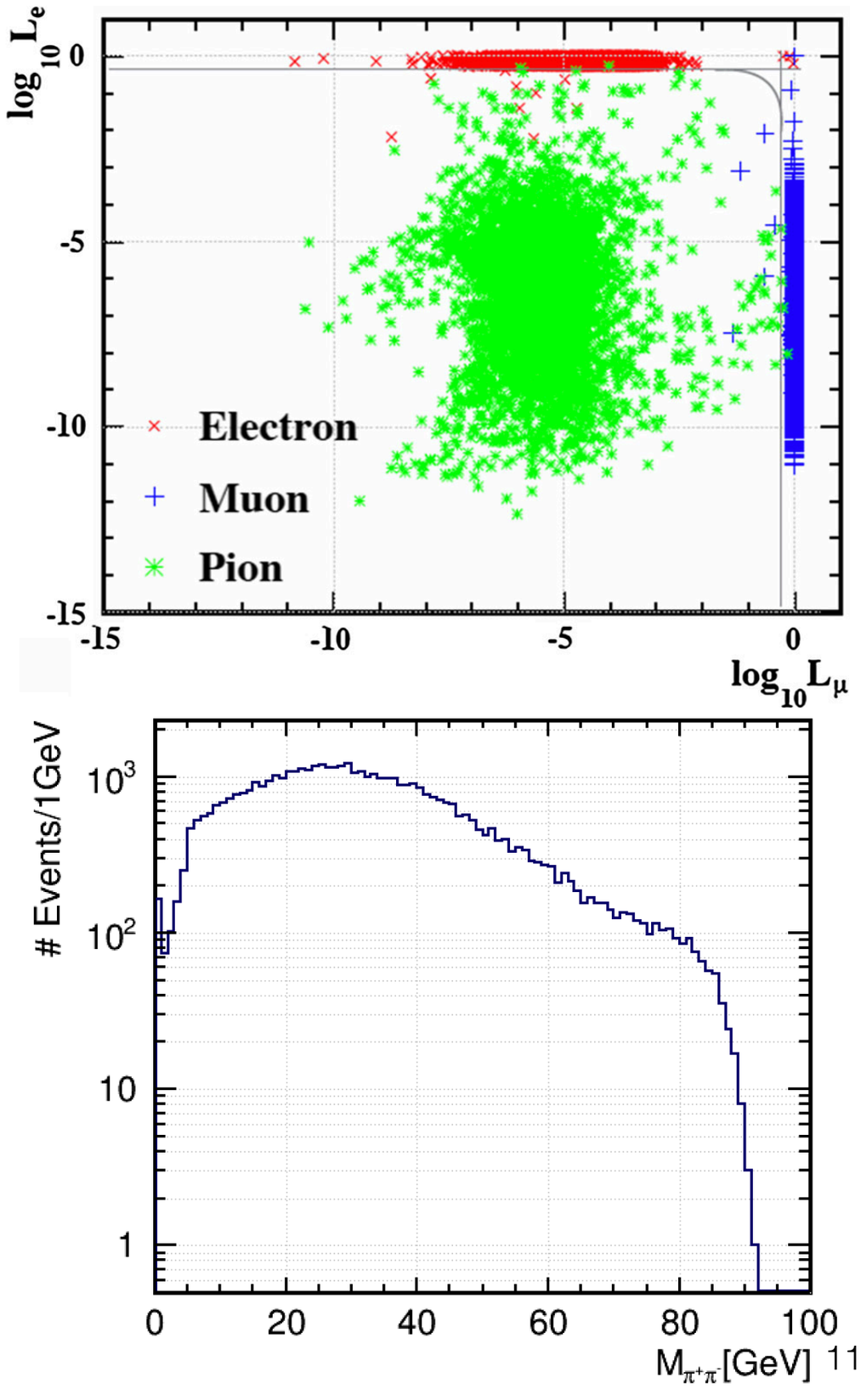
LFV — $\tau \rightarrow 3\mu$

- Main background: free
- Current bound: $2.1*10^{-8}$ (Belle) FCC-ee estimation: 10^{-10}
- Key distribution: invariant mass
  - Signal resolution: track momentum resolution $\delta p/p \sim 10^{-3}$, Window: (1.756GeV,1.796GeV)
  - Background surviving: 2*SF ~ 20k
- Sensitivity: 10^{-10}



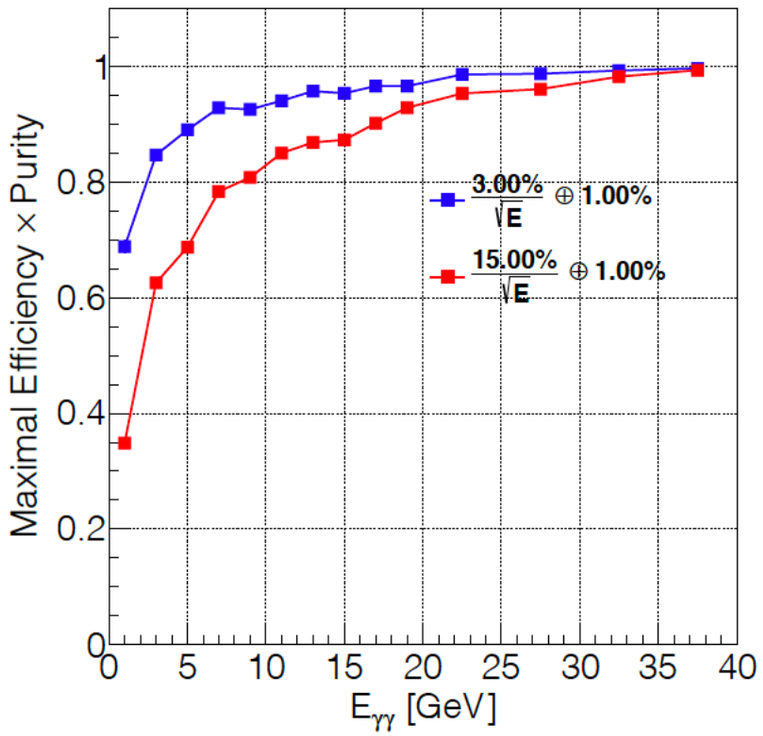
Hadronic Z decays — $Z \to \pi\pi$

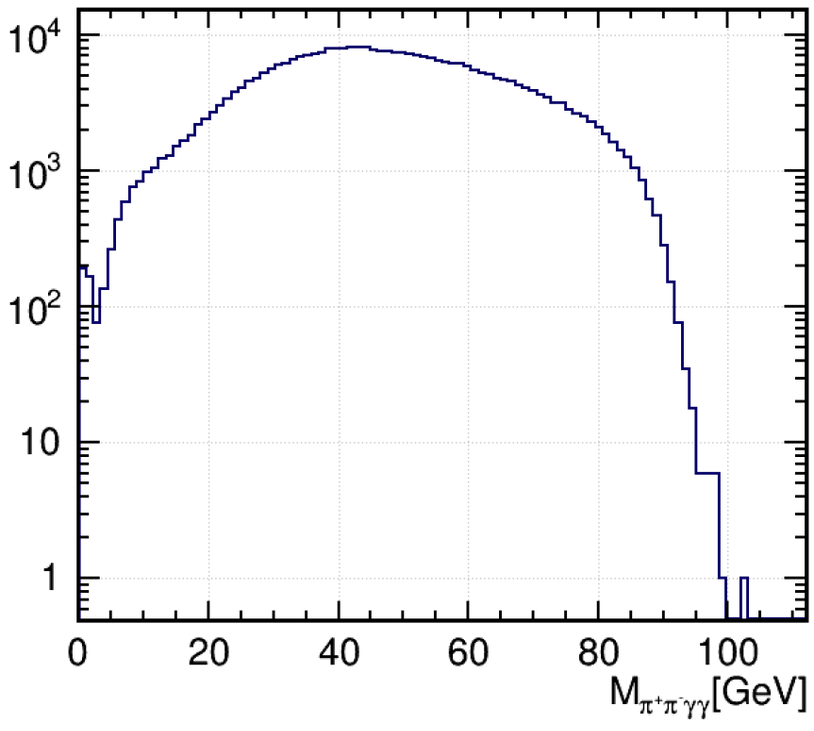
- Physics background: $Z \to \mu\mu$, $Z \to \tau\tau$
- Key distribution:
  - invariant mass
    - Signal resolution: track
    - $Z \to \tau\tau$ surviving: 1*SF
  - mis-id rate:
    - Muon mis-id rate ~ 0
- Sensitivity: 10^{-10}

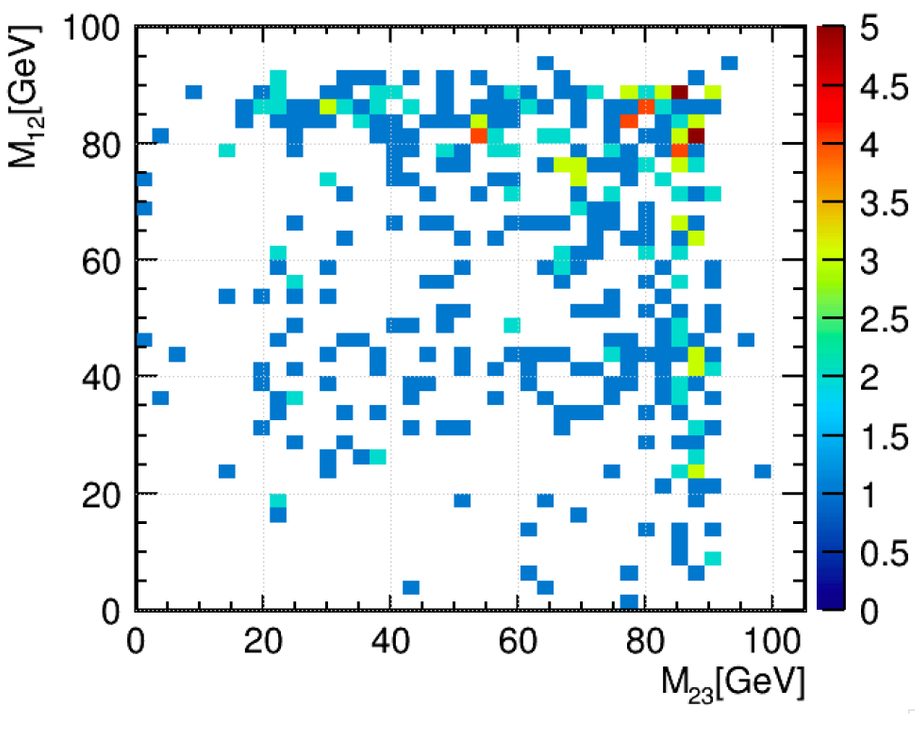


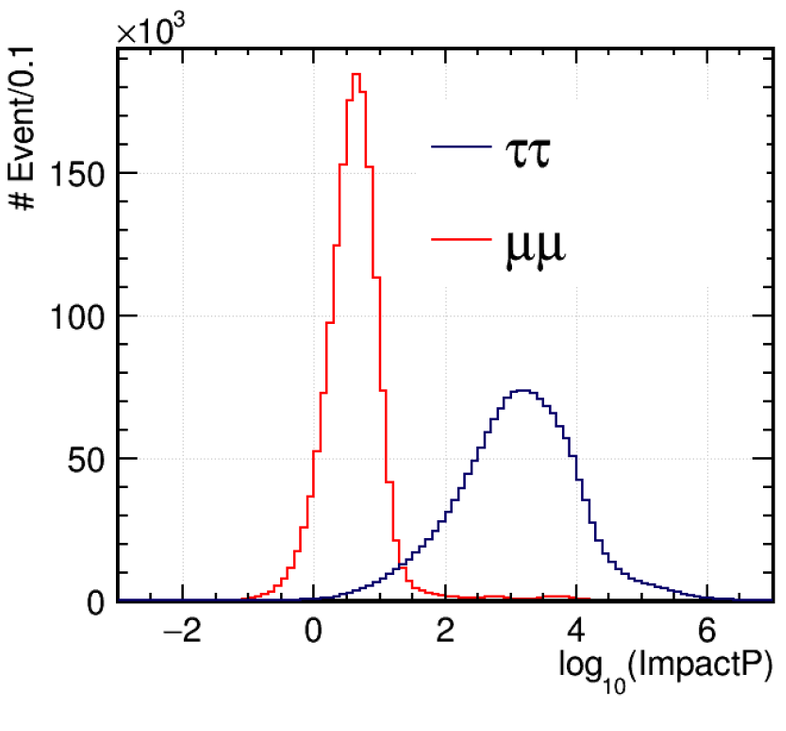
Hadronic Z decay — $Z \to \pi^+\pi^-\pi^0$

- Main background: $Z \to \tau\tau$
- Key distribution:
  - InvM:
    - Signal resolution: $\sigma(m)$ ~ sub MeV
    - Background reduced to 10^{-4}
  - Impact parameter: reduce 10%
    - M_{12} & M_{23} (M>Mtau): bkg reduced to 10^{-7} ~ 100k
- Sensitivity: 10^{-9}



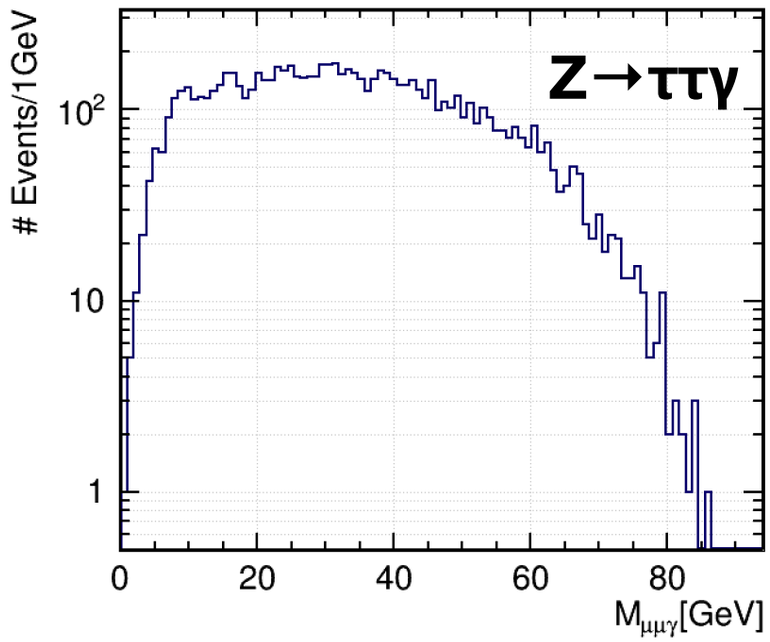


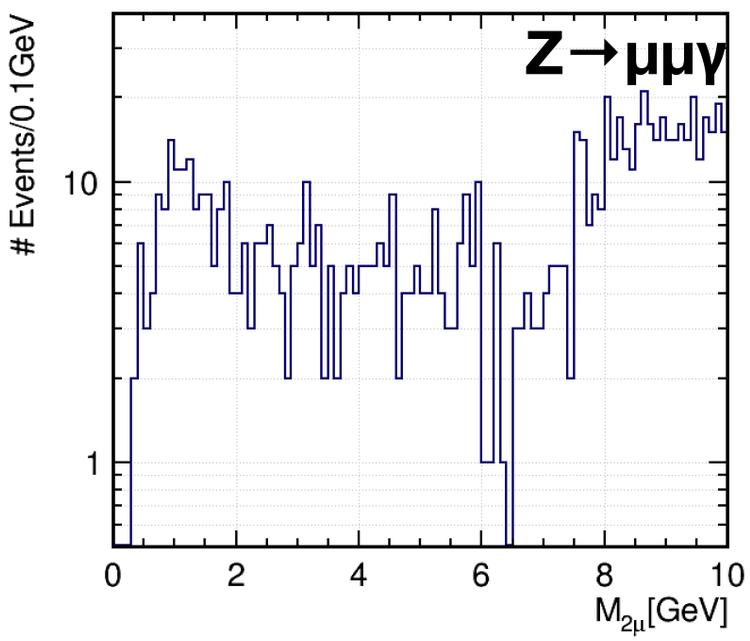




Radiative Z decay
— Z→J/ψ γ, J/ψ→μ+μ-

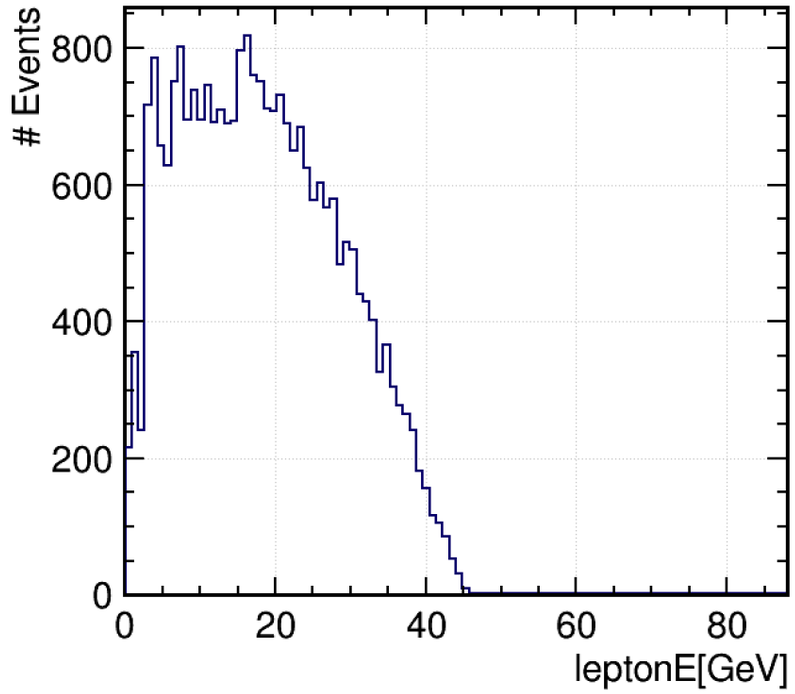
- Main background: Z→ττγ, μμγ
- Current bound: 2.6*10^{-6}(ATLAS)
  White paper prediction: 8*10^{-8}
- Key distribution:
  - total invariant mass:
    - 1*SF Z→ττγ surviving
  - di-muon invariant mass:
    - 3*SF Z→ μμγ surviving
  - impact parameter:
    - reduce10%
- Sensitivity: 10^{-9}

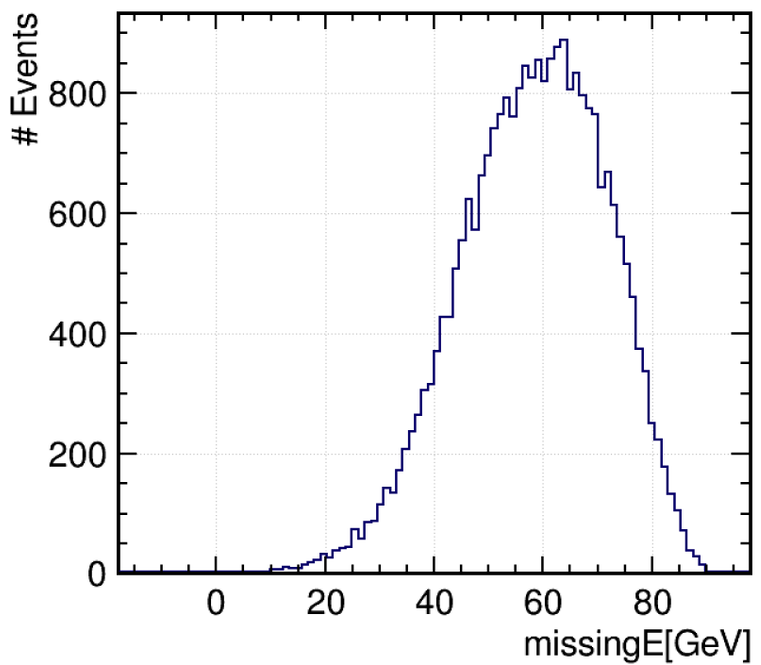




Weak Radiative Z decay — $Z \to \pi^{+/-} W^{-/+}$ (leptonic)

- Main background: $Z \to \tau\tau$, one $\tau \to \pi\nu$, the other $\tau \to l\nu\nu$
- Current bound: $7.0*10^{-5}$(LEP)
  White paper prediction: 10^{-10}
- Key distribution:
  - Acoplanarity, Missing E, lepton E: assuming bkg reduce rate same order as LEP
  - impact parameter: reduce 10%, ~10k bkg surviving
- Sensitivity: 10^{-10}

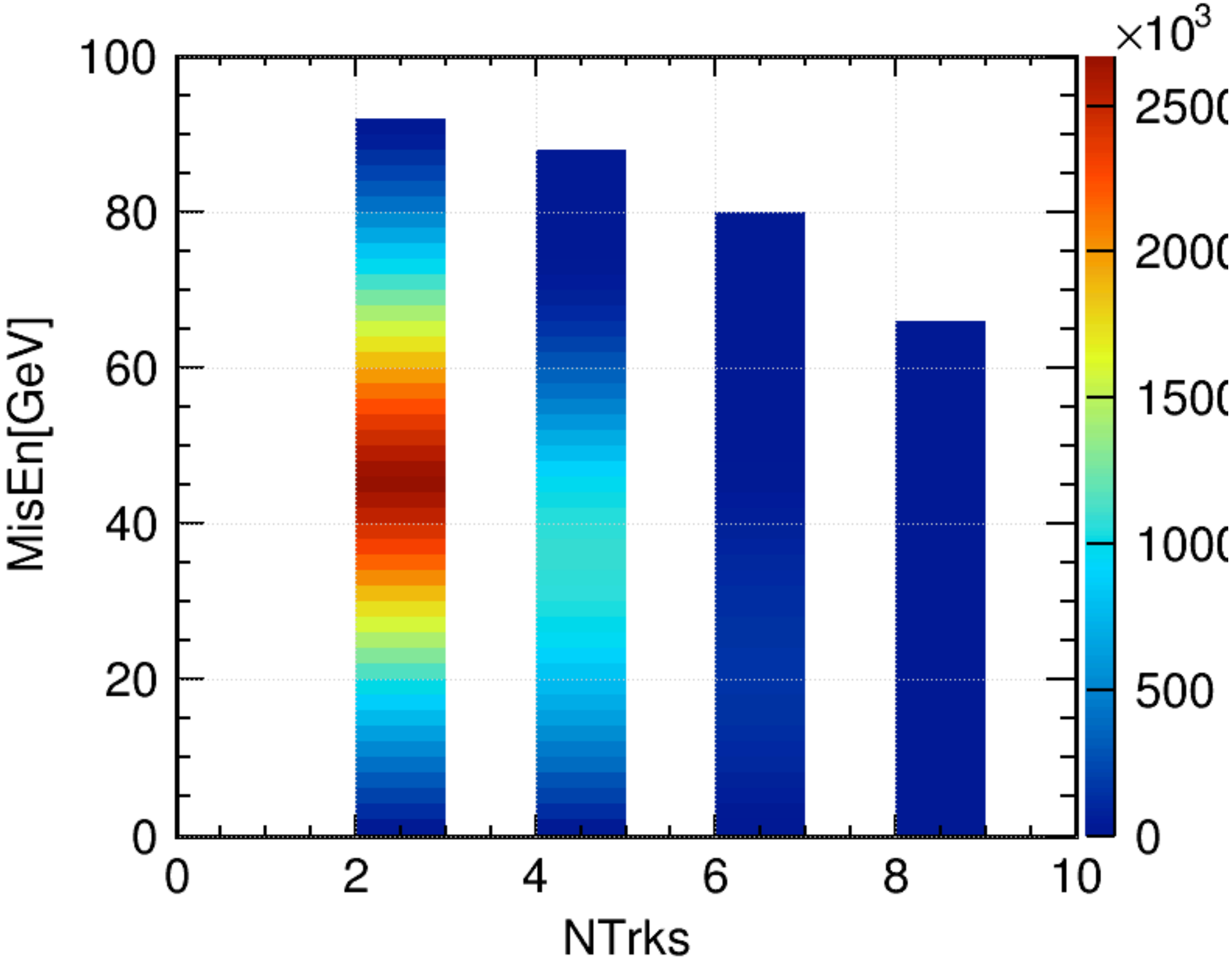


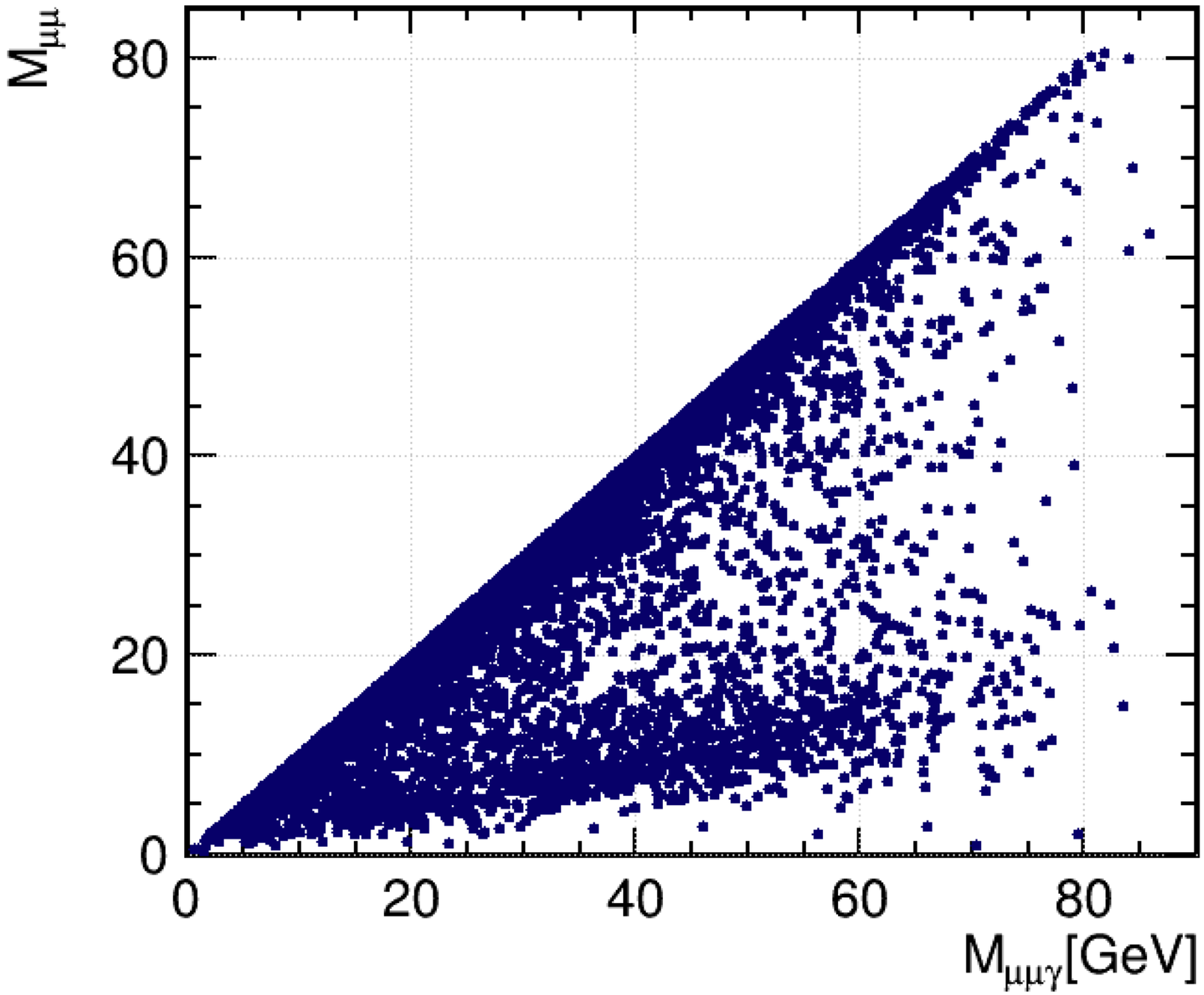


Summary

- There is considerable quantity of samples, both Truth & FullSim+Rec for the flavor physics study
  - Delphes card also available
- Some Zpole channels are analyzed as the background of flavor physics
  - FullSim result consistent with the earlier estimation
  - mostly background free
  - The ISR effects is not crucial
  - Photon confusion is the most catastrophic

Backup


MisEn[GeV]
NTrks
×10^3
0
20
40
60
80
100
0
2
4
6
8
10
0
500
1000
1500
2000
2500


$M_{\mu\mu}$
80
60
40
20
0
0
20
40
60
80
$M_{\mu\mu\gamma}$[GeV]