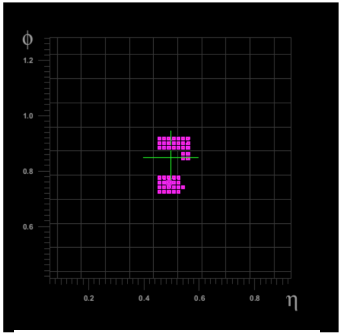
Update

Breno Orzari

SPRACE

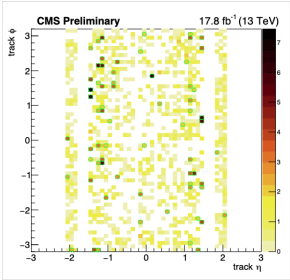
Background Estimation

- Charged leptons
  - Dominant source of high-p_T, isolated tracks from SM processes
  - Number of events estimated using the probability of the events to pass given selections
    - $N^{l}_{\text{est}} = N^{l}_{\text{ctrl}} P_{\text{veto}} P_{\text{offline}} P_{\text{trigger}}$
  - Determined using single lepton control regions
- Fake tracks
  - Missing associated calorimeter energy
  - Missing hits in muon chamber
  - Higher d_0
  - Estimated as:
    - $N^{\text{fake}}_{\text{est}} = P_{\text{fake}} N^{\text{basic}}_{\text{ctrl}}$
    - $P_{\text{fake}} = \zeta p^{\text{raw}}_{\text{fake}}$

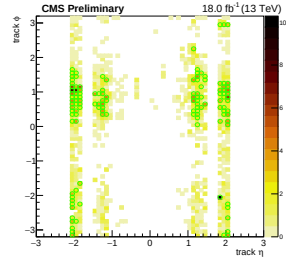


Background Estimation: Charged Leptons

- Use fiducial maps to reduce non-reconstructed lepton background
  - T&P lepton/track (selection in slide 11) used to identify regions in η/ϕ with higher number of non-lepton tracks
  - Ratio of tracks in T&P sample separated from veto (veto in slide 11) electrons and w/ opposite sign
  - Regions $> 2\sigma$ are considered inefficient (circled in green)
  - Veto any tracks falling in these inefficient regions



EGamma 2022F



Muon 2022F

Background Estimation: Charged Leptons

- $N^{l}_{\text{est}} = N^{l}_{\text{ctrl}} P_{\text{veto}} P_{\text{offline}} P_{\text{trigger}}$
  - N^{l}_{est}: estimated number of background events
  - N^{l}_{ctrl}: number of events in the single lepton control region (selection in slide 11)
  - P_{veto}: probability for events to pass lepton veto; defined as
    $$P_{\text{veto}} = \frac{N^{\text{veto}}_{\text{T\&P}} - N^{\text{veto}}_{\text{SS T\&P}}}{N_{\text{T\&P}} - N_{\text{SS T\&P}}}$$
  - P_{offline}: probability for event to pass offline missing p_T requirement
  - P_{trigger}: probability for event to pass missing p_T triggers; defined as
    $$P_{\text{trigger}} = \frac{\int_{120\ \text{GeV}}^{\infty} n(x)\epsilon(x)dx}{\int_{120\ \text{GeV}}^{\infty} n(x)}$$

2022 All MC Charged Leptons Background Estimation - 2022 Full Lumi

n_{layers}	flavor	N^l_{est}	N^l_{obs}	$\lvert N^l_{est}$ - $N^l_{obs}\rvert$
4	electron	0.10 ± 0.05	$0.004^{+0.06}_{-0.04}$	0.77σ
	muon	$0.01^{+0.02}_{-0.01}$	$0.04^{+0.06}_{-0.04}$	0.55σ
	tau	$0.04^{0.05}_{-0.04}$	0.68 ± 0.17	3.6σ
5	electron	$0.0^{+0.05}_{-0.0}$	$0.0^{+0.07}_{-0.0}$	0.0σ
	muon	$0.01^{+0.02}_{-0.01}$	$0.0^{+0.07}_{-0.0}$	0.16σ
	tau	$0.08^{0.12}_{-0.08}$	0.44 ± 0.14	1.96σ
≥ 6	electron	$0.0^{+0.10}_{-0.0}$	$0.0^{+0.07}_{-0.0}$	0.0σ
	muon	$0.0^{+0.08}_{-0.0}$	0.08 ± 0.07	0.75σ
	tau	0.05 ± 0.03	0.20 ± 0.10	1.44σ

2022EE MC Charged Leptons Background Estimation - 2022EFG Lumi

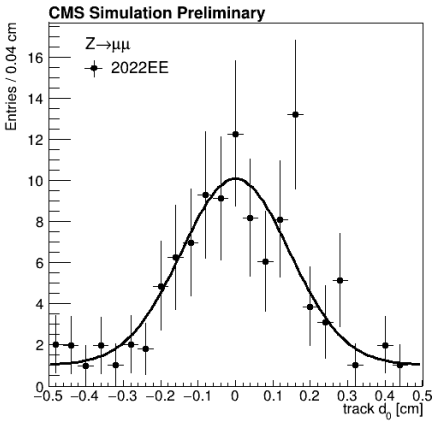
n_{layers}	flavor	N^l_{est}	N^l_{obs}	$\lvert N^l_{est}$ - $N^l_{obs}\rvert$
4	electron	0.06 ± 0.04	$0.0^{+0.05}_{-0.0}$	0.95σ
	muon	0.01 ± 0.01	0.04 ± 0.04	0.85σ
	tau	$0.0^{0.002}_{-0.0}$	$0.0^{+0.05}_{-0.0}$	0.0σ
5	electron	$0.0^{+0.04}_{-0.0}$	$0.0^{+0.05}_{-0.0}$	0.0σ
	muon	$0.01^{+0.02}_{-0.01}$	$0.0^{+0.05}_{-0.0}$	0.23σ
	tau	$0.0^{0.002}_{-0.0}$	$0.0^{+0.05}_{-0.0}$	0.0σ
≥ 6	electron	$0.0^{+0.08}_{-0.0}$	$0.0^{+0.05}_{-0.0}$	0.0σ
	muon	$0.0^{+0.05}_{-0.0}$	0.08 ± 0.06	1.06σ
	tau	0.05 ± 0.01	$0.0^{+0.05}_{-0.0}$	1.01σ

2022 MC Charged Leptons Background Estimation - 2022CD Lumi

n_{layers}	flavor	N^l_{est}	N^l_{obs}	$\lvert N^l_{est}$ - $N^l_{obs}\rvert$
4	electron	0.04 ± 0.03	0.04 ± 0.04	0.05σ
	muon	$0.0^{+0.01}_{-0.0}$	$0.0^{0.05}_{-0.0}$	0.0σ
	tau	$0.04^{0.05}_{-0.04}$	0.69 ± 0.17	3.7σ
5	electron	$0.0^{+0.03}_{-0.0}$	$0.0^{+0.05}_{-0.0}$	0.0σ
	muon	$0.0^{+0.02}_{-0.0}$	$0.0^{+0.05}_{-0.0}$	0.0σ
	tau	$0.08^{0.12}_{-0.08}$	0.44 ± 0.13	2.03σ
≥ 6	electron	$0.0^{+0.06}_{-0.0}$	$0.0^{+0.05}_{-0.0}$	0.0σ
	muon	$0.0^{+0.06}_{-0.0}$	$0.0^{+0.05}_{-0.0}$	0.0σ
	tau	$0.0^{+0.03}_{-0.0}$	0.20 ± 0.09	2.11σ

Background Estimation: Fake Tracks

- $N_{\text{est}}^{\text{fake}} = N_{\text{ctrl}}^{\text{basic}} P_{\text{fake}}^{\text{raw}} \zeta$
  - $N_{\text{est}}^{\text{fake}}$: estimated number of background events
  - $N_{\text{ctrl}}^{\text{basic}}$: number of events in the basic selection control region
  - $P_{\text{fake}}^{\text{raw}}$: probability for events to have a fake track calculated with $Z \to ll$ CRs (selection in slide 12); defined as
    $$P_{\text{fake}}^{\text{raw}} = \frac{N(\geq \text{ 1 dis. trk. in sideband} \mid \text{control region})}{N(\text{control region})}$$
  - ζ: transfer factor for CRs with more than 4 layers, due to low statistics, extracted from $n_{\text{layers}} = 4$; defined as
    $$\zeta = \frac{\int_0^{0.02\text{ cm}} \text{fit d}(|d_0|)}{\int_{0.05\text{ cm}}^{0.50\text{ cm}} \text{fit d}(|d_0|)}$$



2022EE MC Fake Tracks Background Estimation

n_{layers}	N^l_{est}	N^l_{obs}	$\lvert N^l_{est}$ - $N^l_{obs}\rvert$
4	0.09 ± 0.02	0.28 ± 0.09	2.2σ
5	0.03 ± 0.01	0.02 ± 0.02	0.5σ
≥ 6	insufficient statistics		

Backup

T&P, lepton veto and single lepton CR selections

T&P

quantity	object	selection
	event passes `SingleElectron/EGamma` triggers	
≥ 1	electrons	$p_T > 35\,\text{GeV}$ ($> 32\,\text{GeV}$ in 2018)
≥ 1	electrons	$\lvert\eta\rvert < 2.1$
≥ 1	electrons	passing tight electron ID
	exactly one passing electron chosen randomly	
≥ 1	tracks	$p_T > 30\,\text{GeV}$
≥ 1	tracks	$\lvert\eta\rvert < 2.1$
≥ 1	tracks	$\lvert\eta\rvert < 0.15$ OR $\lvert\eta\rvert > 0.35$
≥ 1	tracks	$\lvert\eta\rvert < 1.42$ OR $\lvert\eta\rvert > 1.65$
≥ 1	tracks	$\lvert\eta\rvert < 1.55$ OR $\lvert\eta\rvert > 1.85$
≥ 1	tracks	$\min \Delta R_{\text{track,noisy/dead ECAL ch.}} > 0.05$
≥ 1	tracks	$\lvert d_z\rvert > 0.5\,\text{cm}$ OR $\lvert\lambda\rvert > 10^{-3}$
≥ 1	tracks	$\eta < 0$ OR $\eta > 1.42$ OR $\phi < 2.7$
≥ 1	tracks	number of pixel hits ≥ 4
≥ 1	tracks	missing inner hits $= 0$
≥ 1	tracks	missing middle hits $= 0$
≥ 1	tracks	rel. track-based iso. < 0.05
≥ 1	tracks	$\lvert d_{xy}\rvert < 0.02\,\text{cm}$
≥ 1	tracks	$\lvert d_z\rvert < 0.5\,\text{cm}$
≥ 1	track-jet pairs	$\Delta R_{\text{track,jet}} > 0.5$
≥ 1	track-electron pairs	$M_{\text{track,electron}} > 10\,\text{GeV}$
≥ 1	tracks	$\min \Delta R_{\text{track,muon}} > 0.15$
≥ 1	tracks	$\min \Delta R_{\text{track,had. tau}} > 0.15$
	exactly one passing track chosen randomly	
$= 1$	track-electron pairs	$\lvert M_{\text{track,electron}} - M_Z\rvert < 10\,\text{GeV}$
$= 1$	track-electron pairs	$q_{\text{track}} \cdot q_{\text{electron}} < 0$
≥ 1	track	$n_{\text{layers}} \geq 4$ (three signal region bins)

Lepton veto

flavor	quantity	object	selection
electron	≥ 1	tracks	$\min \Delta R_{\text{track,electron}} > 0.15$
	≥ 1	tracks	$E_{\text{calo}}^{\Delta R<0.5} < 10\,\text{GeV}$
	≥ 1	tracks	missing outer hits ≥ 3
muon	≥ 1	tracks	$\min \Delta R_{\text{track,muon}} > 0.15$
	≥ 1	tracks	missing outer hits ≥ 3
tau	≥ 1	tracks	$\min \Delta R_{\text{track,had. tau}} > 0.15$
	≥ 1	track-jet pairs	$\Delta R_{\text{track,jet}} > 0.5$
	≥ 1	tracks	$E_{\text{calo}}^{\Delta R<0.5} < 10\,\text{GeV}$
	≥ 1	tracks	missing outer hits ≥ 3

Single lepton CR

quantity	object	selection
	event passes `SingleElectron/EGamma` triggers	
≥ 1	electrons	$p_T > 35\,\text{GeV}$ ($> 32\,\text{GeV}$ in 2018)
≥ 1	electrons	$\lvert\eta\rvert < 2.1$
≥ 1	electrons	passes tight electron ID
	exactly one passing electron chosen randomly	
	event passes jet criteria of *basic selection*	
	event passes track criteria of *isolated track selection*	
track selected in *isolated track selection* matched to selected electron within $\Delta R < 0.1$		

Double lepton CR selection

$$Z \to \mu\mu$$

quantity	object	selection
	event passes `SingleMuon` triggers	
$= 2$	muons	$p_{\mathrm{T}} > 29\,\mathrm{GeV}$ ($> 26\,\mathrm{GeV}$ in 2018)
$= 2$	muons	$\lvert\eta\rvert < 2.1$
$= 2$	muons	passes tight muon ID
$= 1$	muon pairs	$q_{\mathrm{muon}} \cdot q_{\mathrm{muon}} < 0$
$= 1$	muon pairs	$\lvert M_{\mathrm{muon,muon}} - M_{\mathrm{Z}}\rvert < 10\,\mathrm{GeV}$