$e^+e^- \to \tau^+\tau^-$

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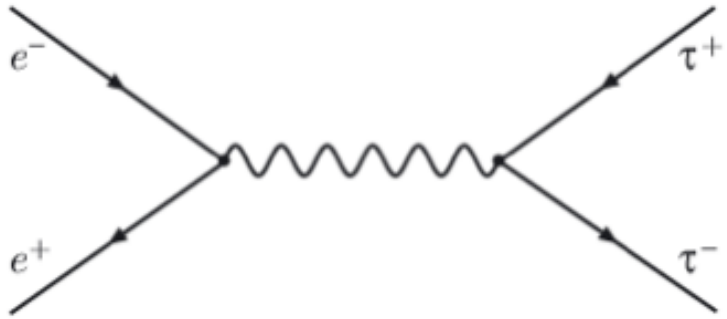
Introduction

Collision of e^+ and e^- generates tau lepton pair in ILC



Tau-lepton is the heaviest lepton

$$m_\tau = 1776.86 \pm 0.12 MeV$$

This process can be used to search for new interactions, also making use of our ability to measure the tau polarization

motivation

Correct reconstruction of tau decay mode is important for the tau polarization measurement.

the simulation for the purpose of reconstruction of events including hadronic decay of tau lepton pair generated in ILC

- Event selection
- Reduction of backgrounds
- ID of tau decay mode

  $\tau \to \pi\nu$

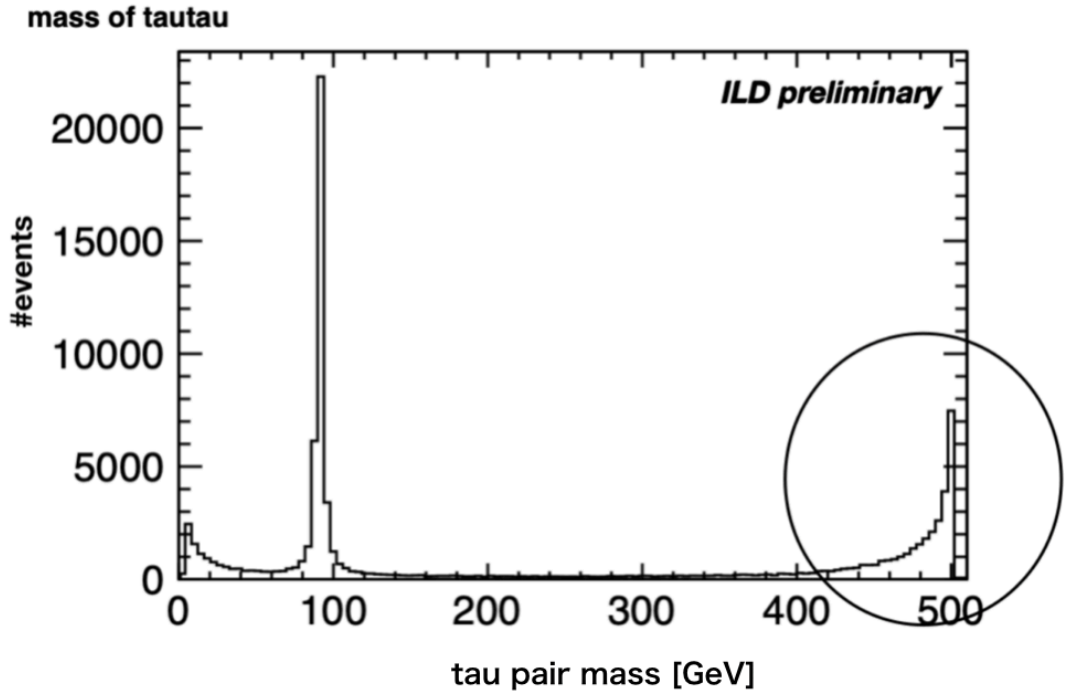
  $\tau \to \rho\nu$

  $\tau \to a_1\nu$
- Extraction of the tau's polarization

Simulation setup

Signal: $e^+e^- \to \tau^+\tau^-$

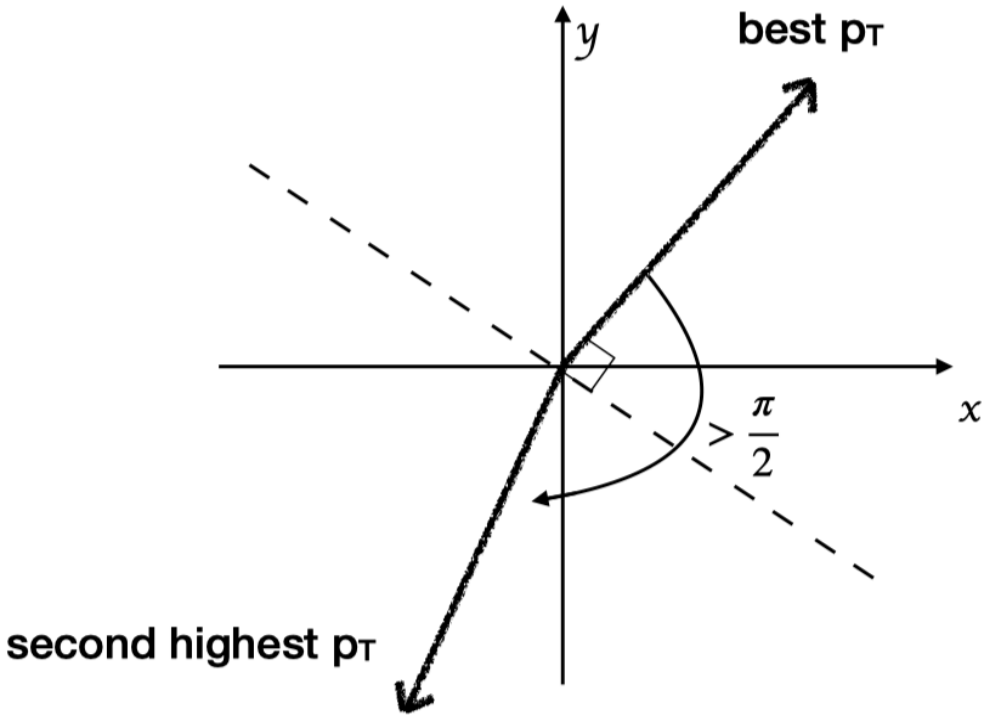
- High mass $\tau\tau$: m($\tau\tau$)>480 [GeV]
- Low mass $\tau\tau$: m($\tau\tau$)<480 [GeV]



Method

1:Find first&second τ seed

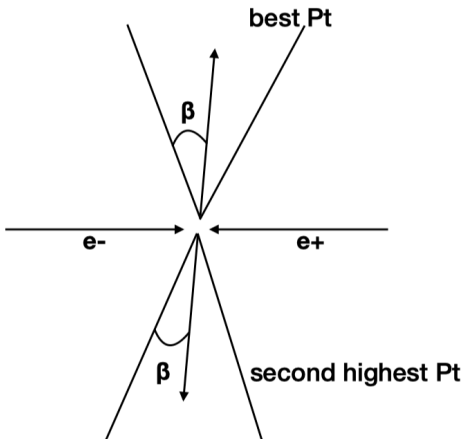
- charged PFO with first&second highest p_T and $\delta\phi > \pi/2$

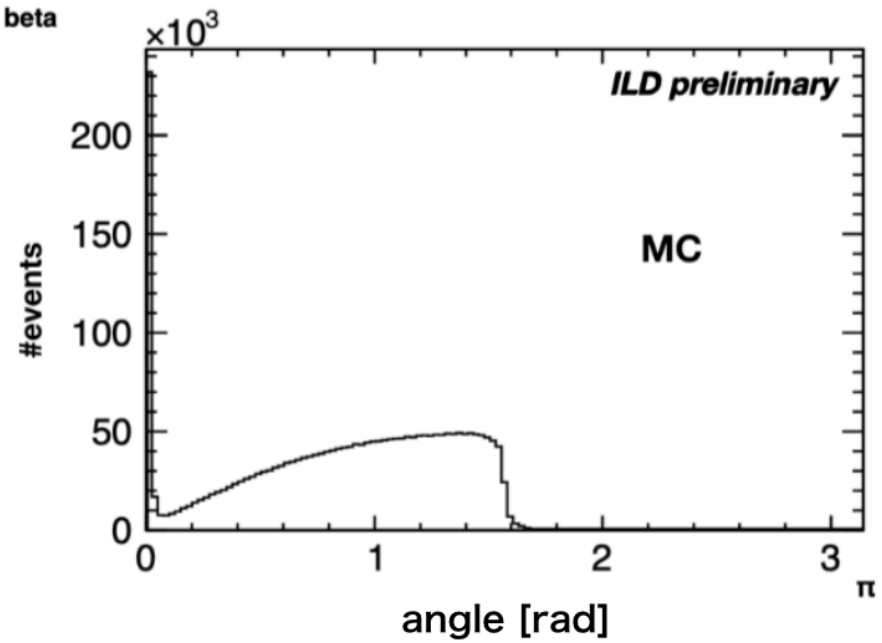


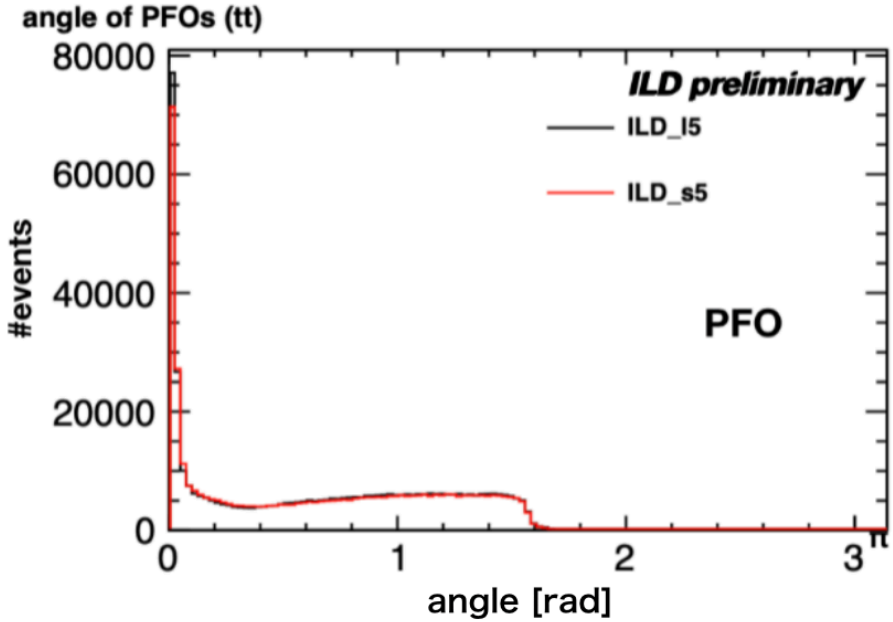
Method

2:Make cones

- Make cones to find τ jets







most particles are in a range of $\beta < 0.1\ [rad]$

event selection

- Cut 1:visible τ jet mass $<$ 2.5 [GeV]
- Cut2:acolineality between τ jet seed tracks $<$ 0.15 [rad]
- Cut3:energy sum of pfos outside cones $<$ 40 [GeV]
  p_T sum of pfos outside cones $<$ 20 [GeV]
- Cut4:Cone 1 particle's charge $\times$ Cone 2 particle's charge = -1
- Cut5:High energy $\mu^+\mu^-$& e^+e^- cut
- Cut6:visible mass of 2 τjet system $<$ 400 GeV
- Cut7:angle between τjet axes $>$ 3.05 [rad]
- Cut8:total number of PFOs $<$ 12

Last General meeting

I'm mainly working on tau decay mode identification

Starting to work on TMVA to identify tau decay mode

- Understanding what is TMVA and how to use it
- Comparison between previous result and TMVA result

progress from last General meeting

Previous result

MC truth	unk	pi	rho	a11p	a13p	e	mu
pi	1.83	83.93	11.24	0.56	0.39	1.15	0.89
rho	4.82	2.30	82.65	8.94	1.21	0.07	0.02
a11p	7.29	1.39	19.51	68.81	2.94	0.05	0.02
a13p	9.44	2.78	1.62	0.62	85.48	0.03	0.03
e	5.00	37.93	40.10	1.33	0.02	15.47	0.14
mu	0.98	11.75	0.64	0.00	0.02	0.00	86.62
other	12.66	10.57	14.70	14.98	46.91	0.09	0.10

reconstructed tau decay mode

Efficiency: $\frac{\text{each reconstructed decay mode}}{\text{sum of all entries for each MC Truth decay mode}}$

progress from last General meeting

Result (using IsolatedLeptonTagging)

MC truth	unk	pi	rho	a11p	a13p	e	mu
pi	1.80	82.34	12.11	0.39	0.37	1.84	1.15
rho	4.99	1.01	79.92	7.40	0.96	5.15	0.58
a11p	8.47	0.87	16.75	64.31	2.16	6.78	0.66
a13p	10.37	2.48	1.87	0.43	84.75	0.05	0.05
e	2.08	0.04	0.38	0.11	0.02	97.10	0.27
mu	0.98	0.64	0.10	0.00	0.02	0.67	97.59
other	21.19	9.95	14.43	13.50	38.99	1.57	0.37

reconstructed tau decay mode

Efficiency: $\frac{\text{each reconstructed decay mode}}{\text{sum of all entries for each MC Truth decay mode}}$

progress from last General meeting

MC truth	unk	pi	rho	a11p	a13p	e	mu
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a11p	8.47	0.87	16.75	64.31	2.16	6.78	0.66
a13p	10.37	2.48	1.87	0.43	84.75	0.05	0.05
e	2.08	0.04	0.38	0.11	0.02	97.10	0.27
mu	0.98	0.64	0.10	0.00	0.02	0.67	97.59
other	21.19	9.95	14.43	13.50	38.99	1.57	0.37

reconstructed tau decay mode

Starting to work on TMVA to identify tau decay mode better

progress from last General meeting

MC truth	unk	pi	rho	a11p	a13p	e	mu
pi	1.80	82.34	12.11	0.39	0.37	1.84	1.15
rho	4.99	1.01	79.92	7.40	0.96	5.15	0.58
a11p	8.47	0.87	16.75	64.31	2.16	6.78	0.66
a13p	10.37	2.48	1.87	0.43	84.75	0.05	0.05
e	2.08	0.04	0.38	0.11	0.02	97.10	0.27
mu	0.98	0.64	0.10	0.00	0.02	0.67	97.59
other	21.19	9.95	14.43	13.50	38.99	1.57	0.37

reconstructed tau decay mode

First, concentrate on π, ρ, a_1 decay mode identification

TMVA Setup

Input parameter

① NG: Number of Gamma inside cone

② MG: Mass of Gamma [GeV]

③ PGM: Mass of charged pion and Gamma [GeV]

④ MMax

⑤ MMin

⑥ MinAng1

⑦ MinAng2

⑧ GEMax

HiddenLayers = N+5,5

TestRate = 5

EstimatorType = Mean Square Estimator

MVA type = Boosted Decision Trees

NeuronType = tanh

NCycles = 1000

TMVA Setup

Input parameter

① NG: Number of Gamma inside cone

② MG: Mass of Gamma [GeV]

③ PGM: Mass of charged pion and Gamma [GeV]

④ MMax

⑤ MMin

⑥ MinAng1

⑦ MinAng2

⑧ GEMax

the 2-prong masses

charge : +/-

TMVA Setup

Input parameter

① NG: Number of Gamma inside cone

② MG: Mass of Gamma [GeV]

③ PGM: Mass of charged pion and Gamma [GeV]

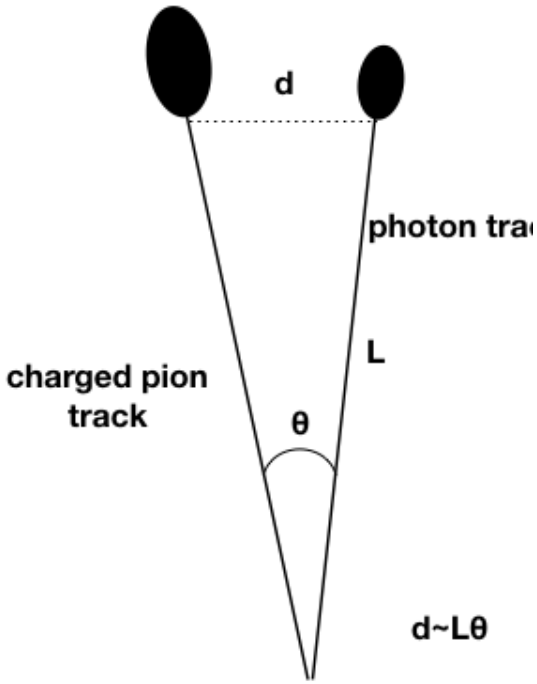
④ MMax

⑤ MMin

⑥ MinAng1

⑦ MinAng2

⑧ GEMax



TMVA Setup

Input parameter

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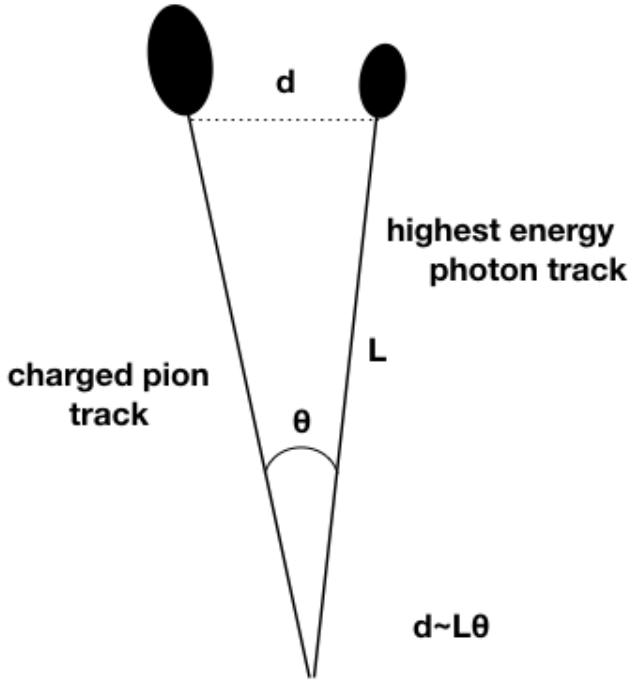


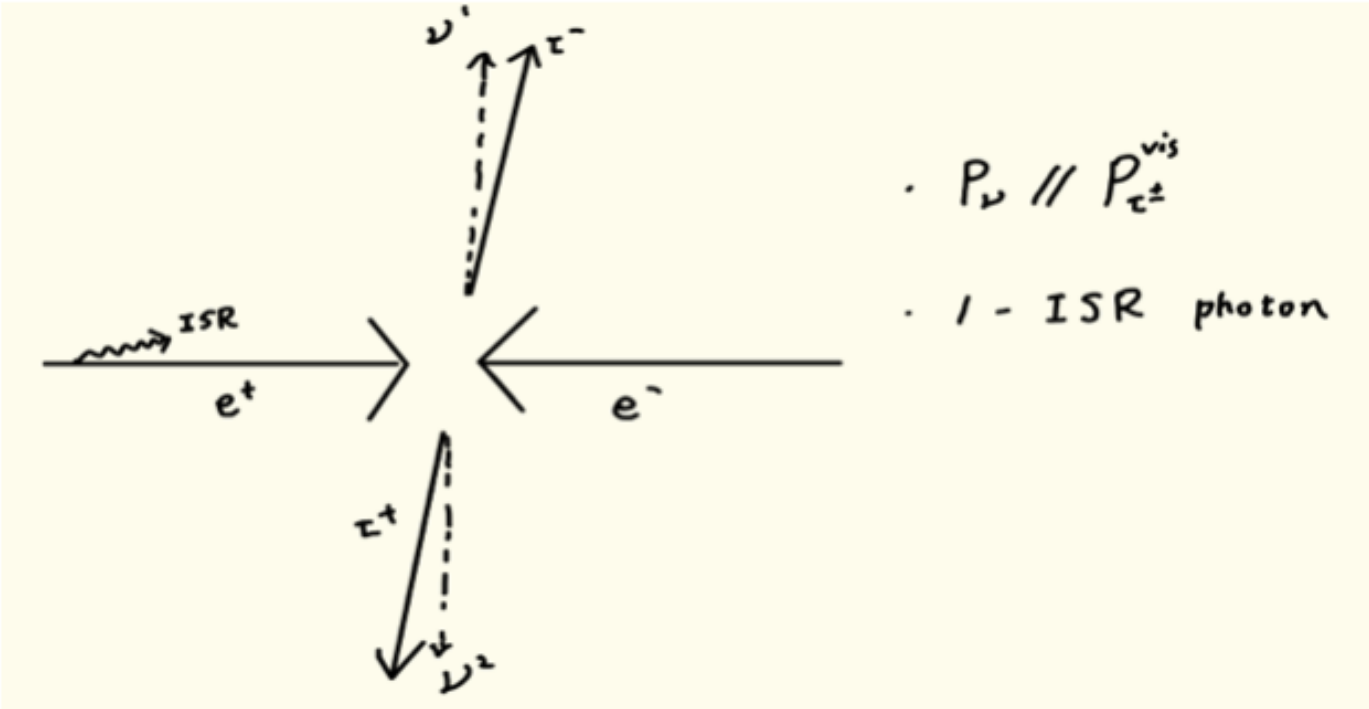
Previous result

MC truth	reconstructed tau decay mode			
pi	1.80	82.34	12.11	0.39
rho	4.99	1.01	79.92	7.40
a11p	8.47	0.87	16.75	64.31
	unk	pi	rho	a11p

TMVA result

MC truth	reconstructed tau decay mode			
pi	2.03	91.51	2.79	0.68
rho	8.71	3.45	72.56	9.55
a11p	14.00	1.29	10.00	67.26
	unk	pi	rho	a11p

Neutrino energy calculation



$$\Sigma E = E^1_\nu + E^2_\nu + E^{vis}_{\tau^+} + E^{vis}_{\tau^-} + E_{ISR} = 500$$
$$\Sigma P_x = P^{vis}_{\tau^- x} + P^{vis}_{\tau^+ x} + P^1_{\nu x} + P^2_{\nu x} = 0$$
$$\Sigma P_y = P^{vis}_{\tau^- y} + P^{vis}_{\tau^+ y} + P^1_{\nu y} + P^2_{\nu y} = 0$$
$$\Sigma P_z = P^{ISR}_z + P^{vis}_{\tau^+} + P^{vis}_{\tau^-} + P^1_{\nu z} + P^2_{\nu z} = 0$$

Neutrino energy calculation

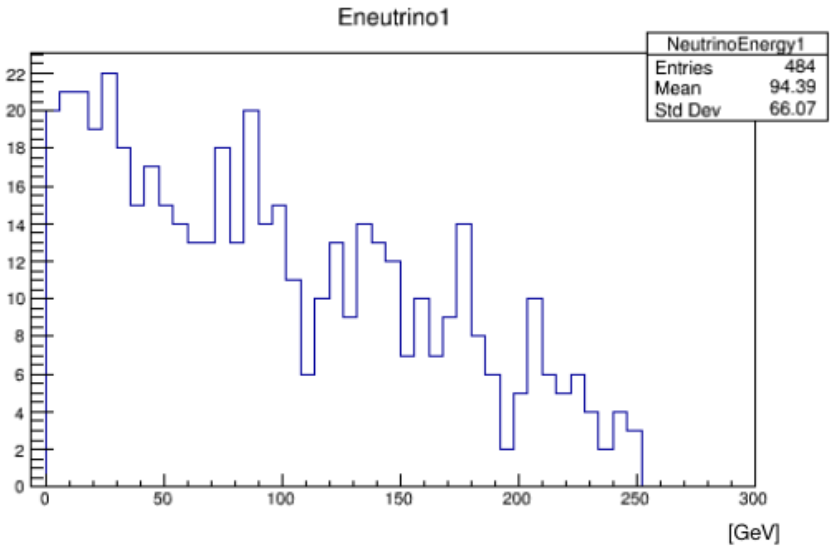
$$\Sigma E = E^1_\nu + E^2_\nu + E^{vis}_{\tau^+} + E^{vis}_{\tau^-} + E_{ISR} = 500$$
$$\Sigma P_x = P^{vis}_{\tau^- x} + P^{vis}_{\tau^+ x} + P^1_{\nu x} + P^2_{\nu x} = 0$$
$$\Sigma P_y = P^{vis}_{\tau^- y} + P^{vis}_{\tau^+ y} + P^1_{\nu y} + P^2_{\nu y} = 0$$
$$\Sigma P_z = P^{ISR}_z + P^{vis}_{\tau^+} + P^{vis}_{\tau^-} + P^1_{\nu z} + P^2_{\nu z} = 0$$

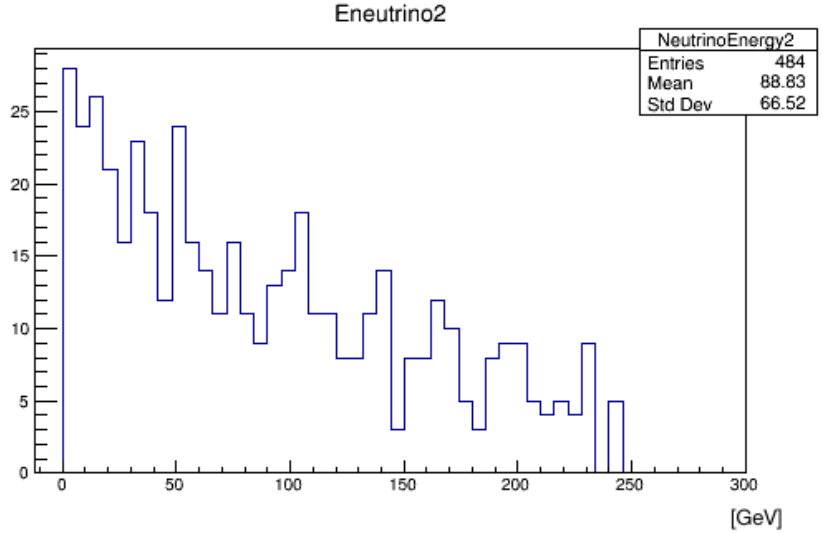
$$E^1_\nu = \frac{P^{vis}_{\tau^- y} + P^{vis}_{\tau^+ y}}{P^{-x}P^{+y} - P^{-y}P^{+x}} P^{+x} - \frac{P^{vis}_{\tau^- x} + P^{vis}_{\tau^+ x}}{P^{-x}P^{+y} - P^{-y}P^{+x}} P^{+y}$$

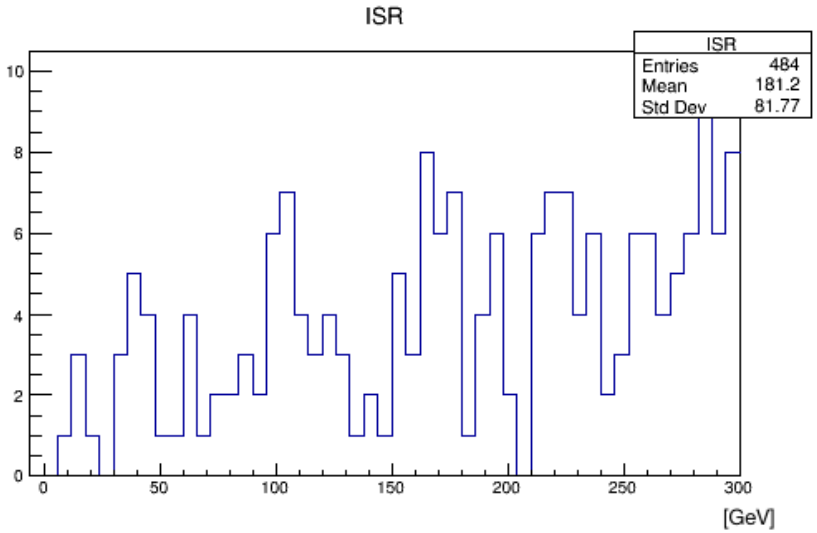
$$E^2_\nu = \frac{P^{vis}_{\tau^- x} + P^{vis}_{\tau^+ x}}{P^{-x}P^{+y} - P^{-y}P^{+x}} P^{-y} - \frac{P^{vis}_{\tau^- y} + P^{vis}_{\tau^+ y}}{P^{-x}P^{+y} - P^{-y}P^{+x}} P^{-x}$$

$$E_{ISR} = 500 - E^1_\nu - E^2_\nu - E^{vis}_{\tau^+} - E^{vis}_{\tau^-}$$

$$P^{\pm i} = \frac{P^{vis}_{\tau^\pm i}}{P^{vis}_{\tau^\pm}} \quad i = (x, y)$$



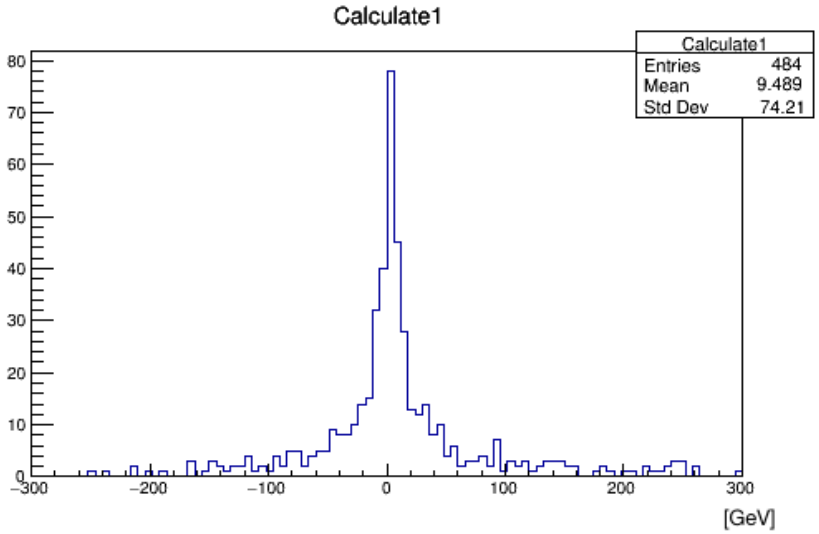


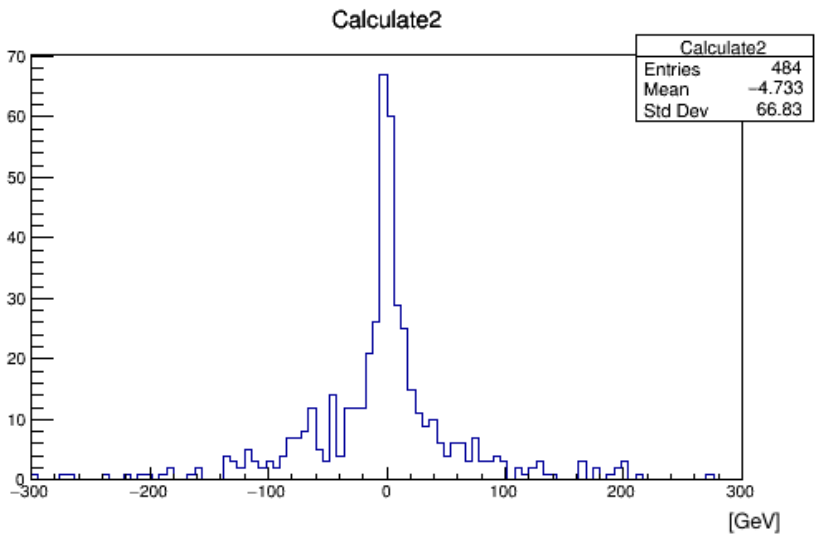


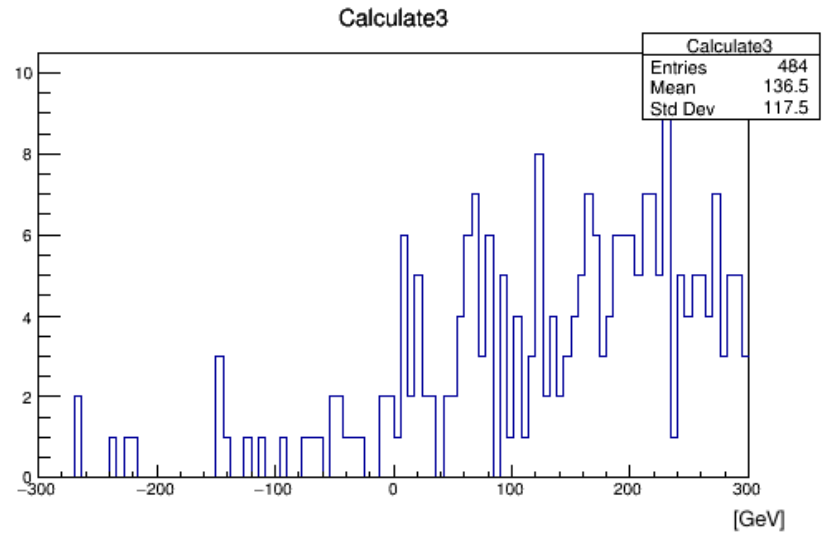
$$E_\nu^1 = \frac{P^{vis}_{\tau^- y} + P^{vis}_{\tau^+ y}}{P^{-x}P^{+y} - P^{-y}P^{+x}} P^{+x} - \frac{P^{vis}_{\tau^- x} + P^{vis}_{\tau^+ x}}{P^{-x}P^{+y} - P^{-y}P^{+x}} P^{+y}$$

$$E_\nu^2 = \frac{P^{vis}_{\tau^- x} + P^{vis}_{\tau^+ x}}{P^{-x}P^{+y} - P^{-y}P^{+x}} P^{-y} - \frac{P^{vis}_{\tau^- y} + P^{vis}_{\tau^+ y}}{P^{-x}P^{+y} - P^{-y}P^{+x}} P^{-x}$$

$$E_{ISR} = 500 - E_\nu^1 - E_\nu^2 - E^{vis}_{\tau^+} - E^{vis}_{\tau^-}$$







$$\Sigma E = E^1_\nu + E^2_\nu + E^{vis}_{\tau^+} + E^{vis}_{\tau^-} + E_{ISR} = 500$$

$$\Sigma P_x = P^{vis}_{\tau^- x} + P^{vis}_{\tau^+ x} + P^1_{\nu x} + P^2_{\nu x} = 0$$

$$\Sigma P_y = P^{vis}_{\tau^- y} + P^{vis}_{\tau^+ y} + P^1_{\nu y} + P^2_{\nu y} = 0$$

Plan

- For a1-1p decay, some improvement are needed
  - some more input parameters

    $m_{\gamma\gamma}$

    $m_{\gamma\gamma\pi}$

    $m_{\gamma\pi}$

    E_{γ}^{max}

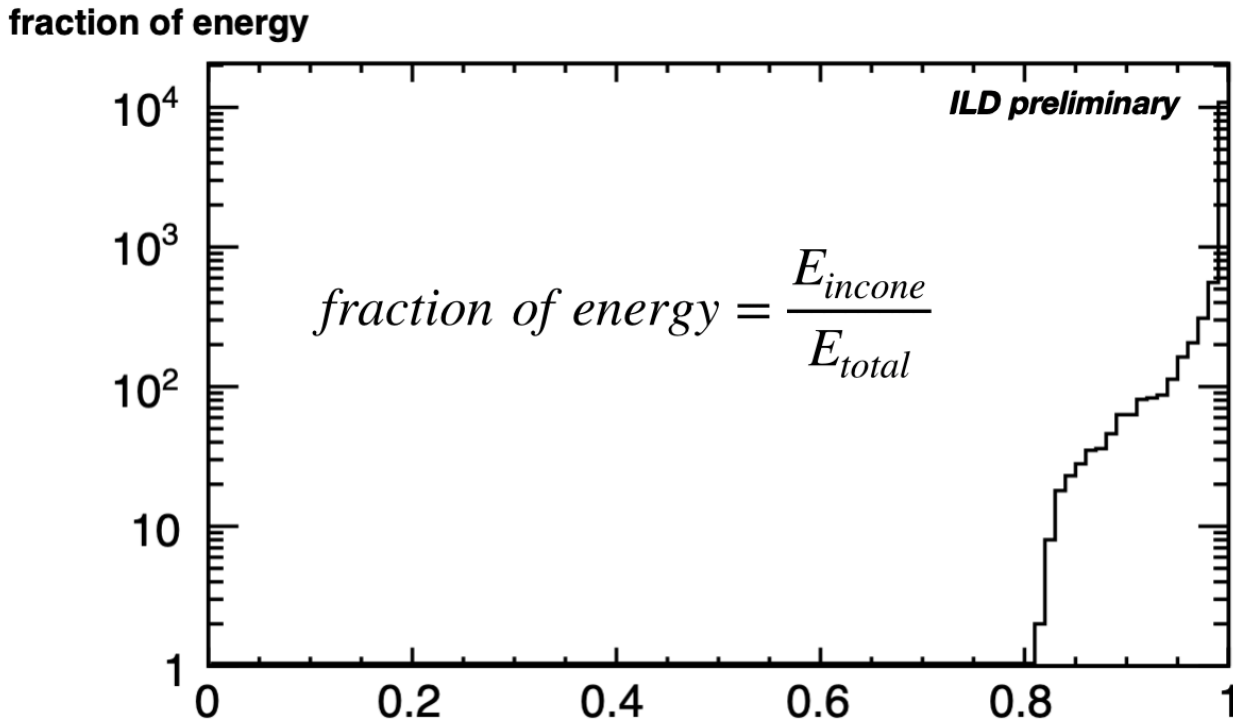
    E_{γ}^{min}
- For calculating the neutrino energy

  There is some mistake somewhere

Summary

- I simulated $e^+e^- \to \tau^+\tau^-$ and found jets in the process
- About 99% of energy is inside cone
  - Inside cone
    - all charged tau daughters are inside best cone
    - neutral tau daughters are mostly photon and sometimes neutral tau daughters are outside cone
- Cut table including major backgrounds were made.
- After including all cuts, most of the backgrounds and Low mass $\tau\tau$ are rejected
- Need some improvement to include TMVA output

Method

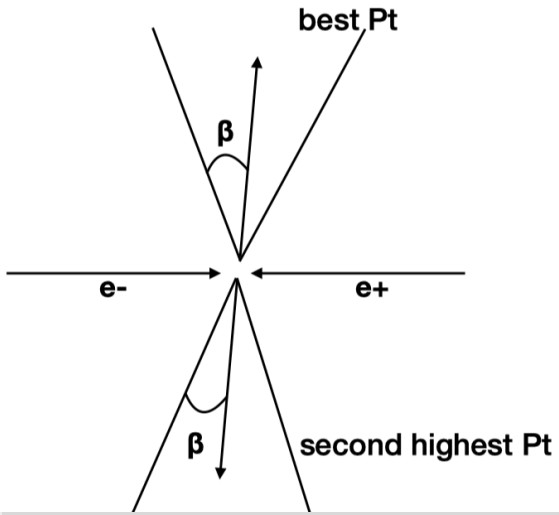


E_{incone} :sum of tau daughter's energy inside cone

E_{total} :sum of tau daughter's energy inside and outside cone

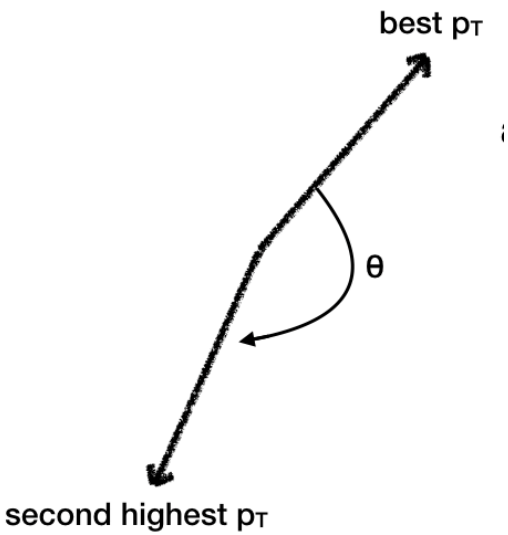
about 99% of energy
is inside cone

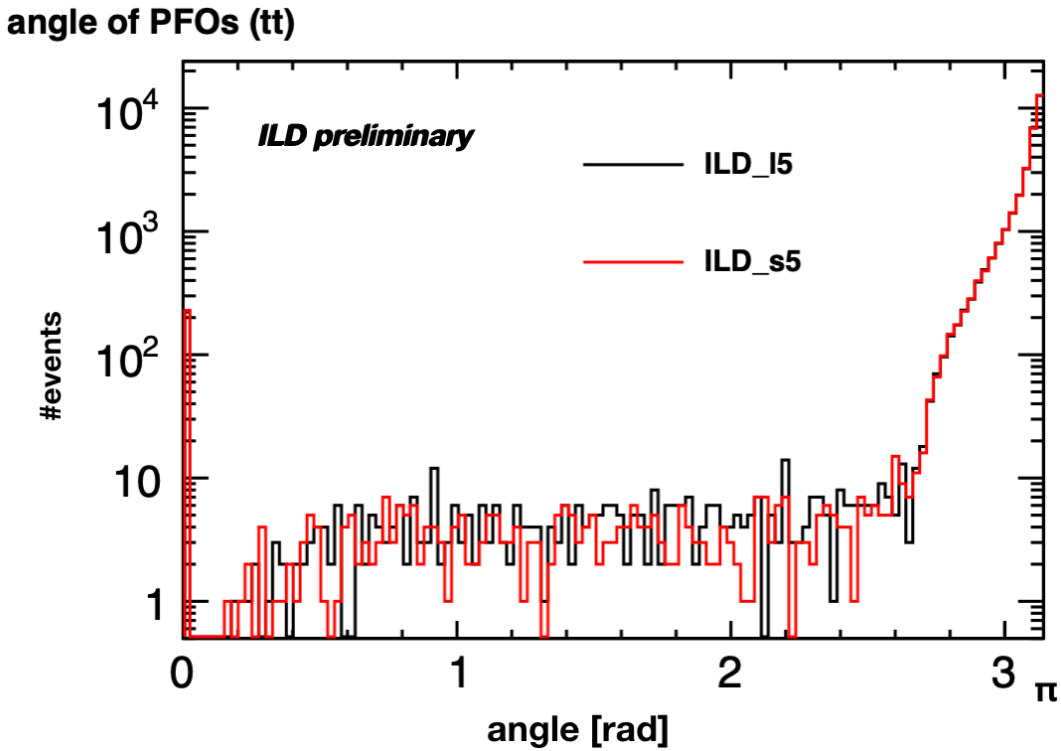
how much energy
is inside cone



Method

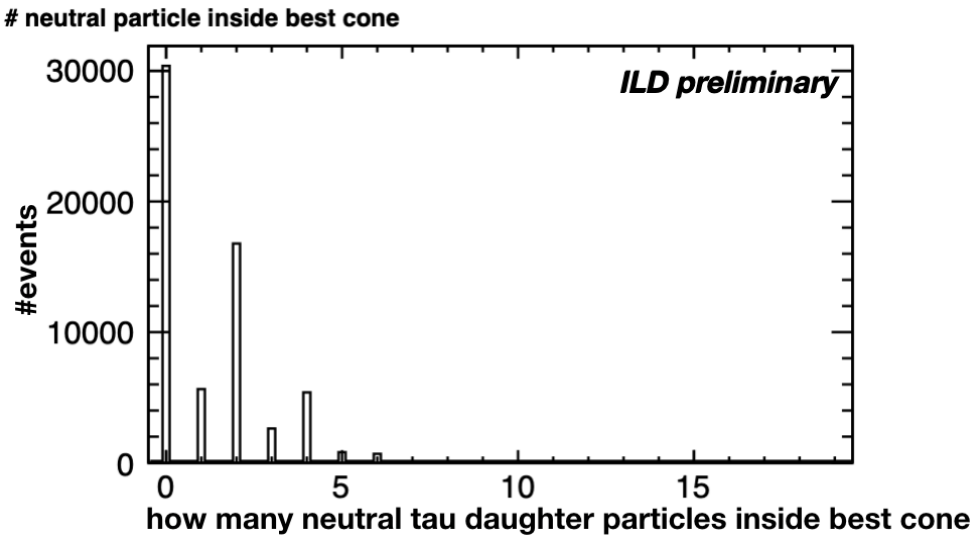
- angle θ formed by first τ seed and second τ seed





first τ seeds and second τ seeds are almost back-to-back

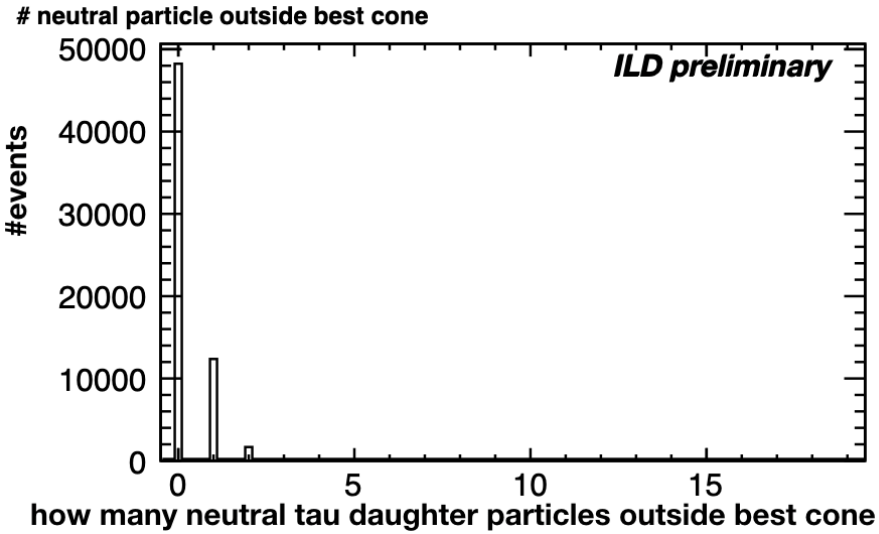
Result



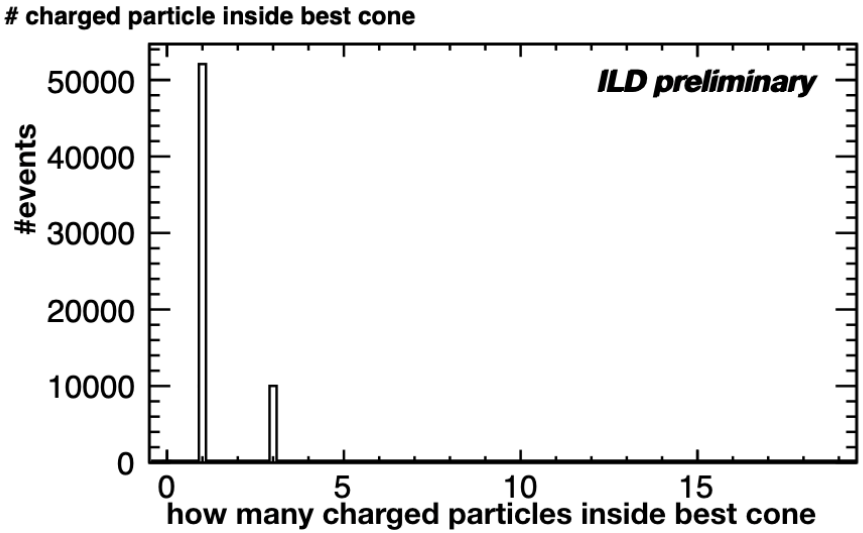
neutral tau daughters are mostly photon

sometimes neutral tau daughters

are outside cone

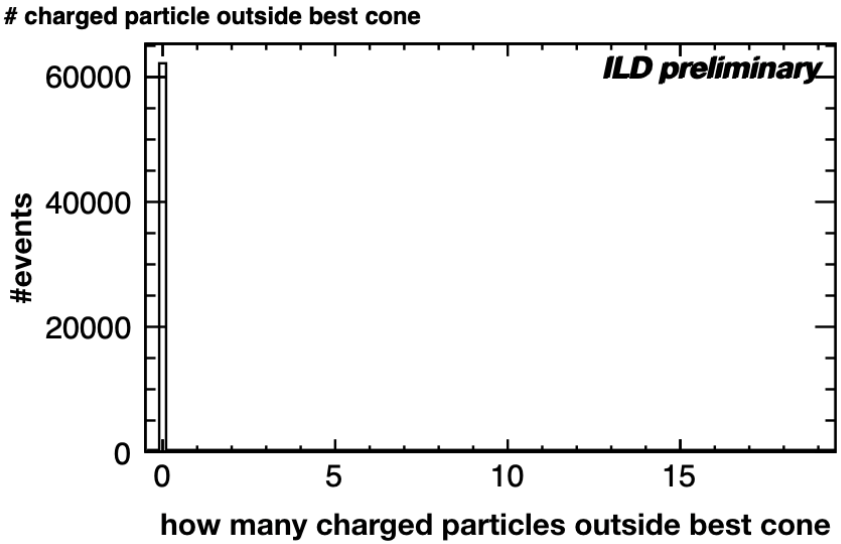


Result



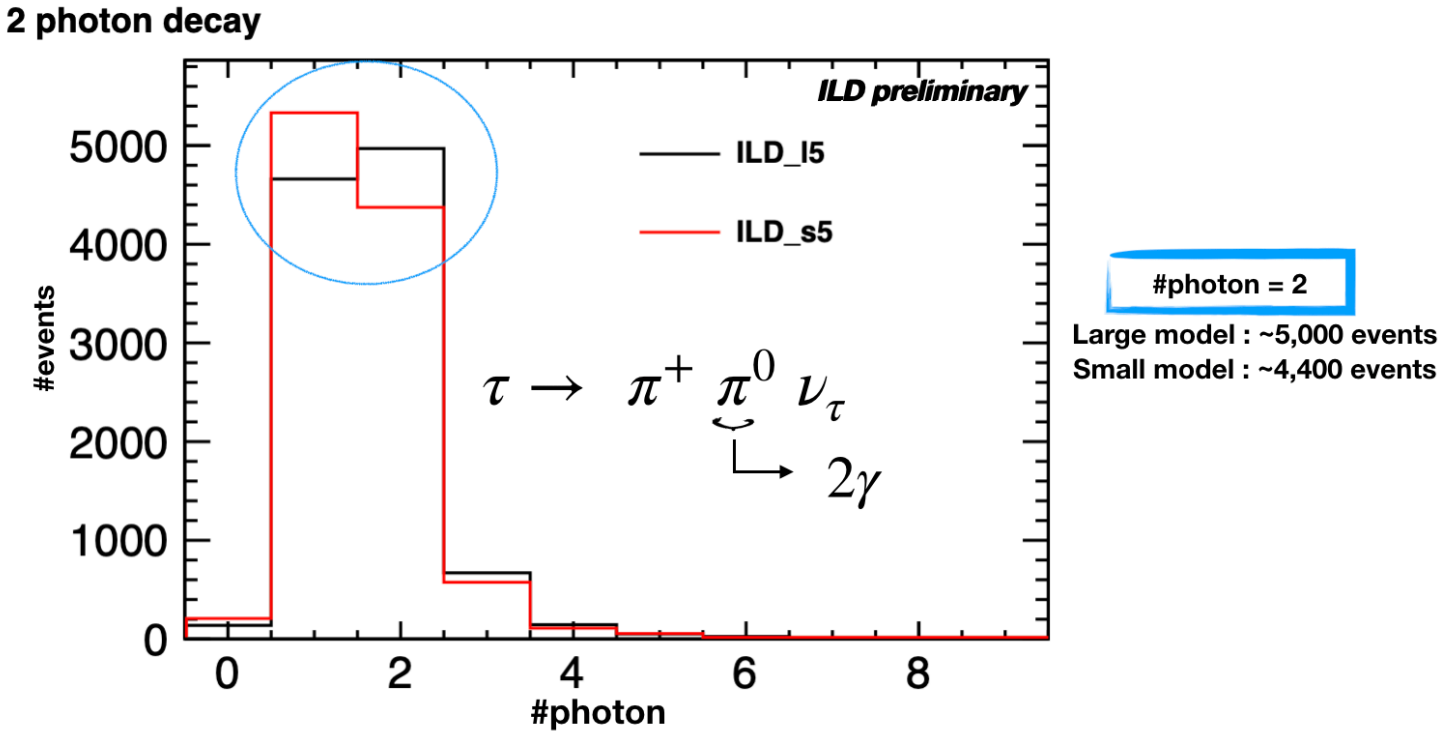
all charged tau daughters

are inside best cone



Result

- Comparison between Large and Small ILD model



Large model is better than small model to count photons

Cut table of Large detectors model

Preliminary

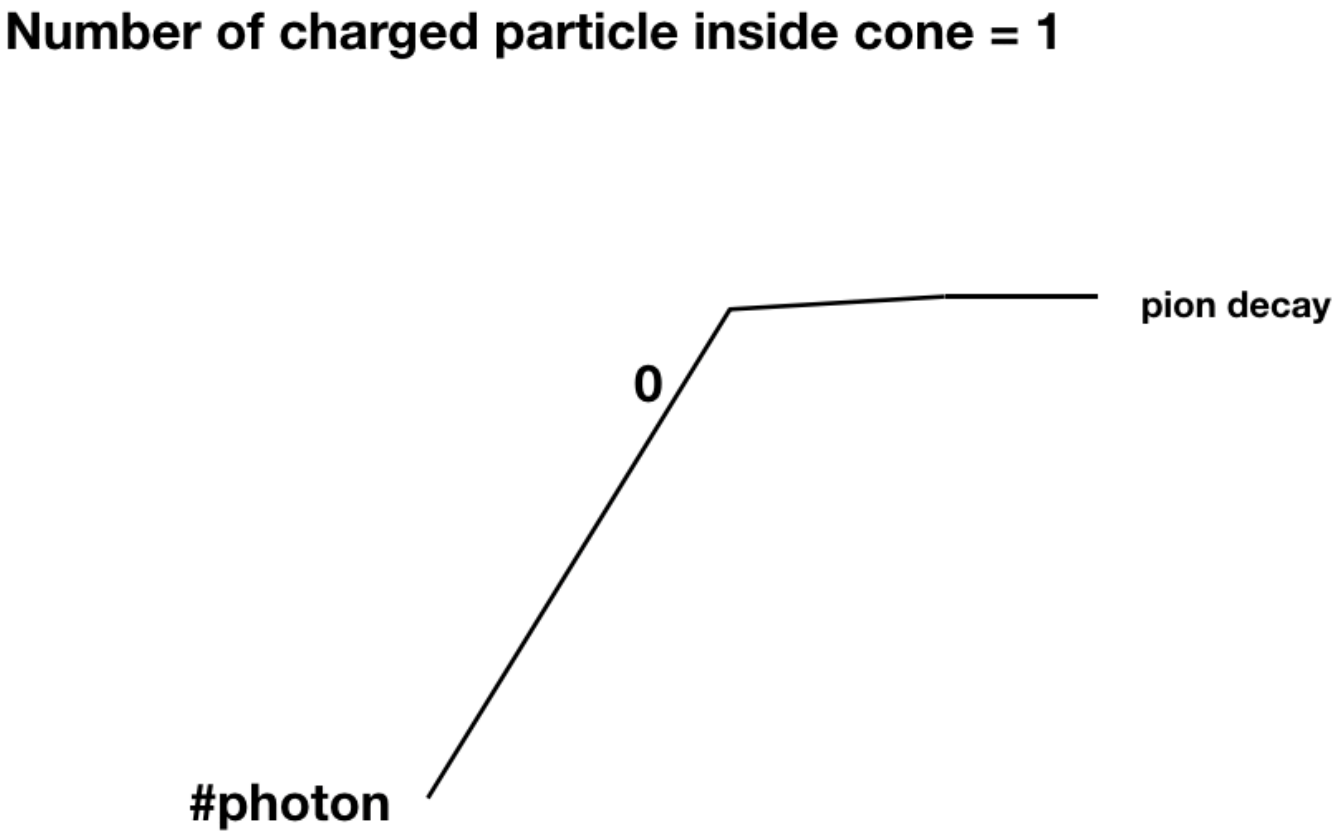
Beam Polarisation = (-80, +30),Integrated Lumi = 1600.0 selected events/1000

PROCESS	ttHiMass	ttLoMass	mumu	4f_ZZ_WW_Mix_l	4fZZleptonic
UNCUT	593.21	2310.53	3211.59	864.47	65.52
CUT 1	492.65	1787.35	2637.14	684.99	47.76
CUT 2	482.91	272.37	873.61	119.57	4.55
CUT 3	451.89	215.55	778.98	104.84	2.01
CUT 4	428.37	197.76	764.75	96.83	1.17
CUT 5	428.35	197.76	86.20	87.72	0.83
CUT 6	427.45	197.63	24.78	70.01	0.71
CUT 7	425.51	132.11	14.05	27.50	0.48
CUT 8	425.38	132.00	14.05	27.49	0.48

PROCESS	4fsingleZee	2fZhadronic	4f_sZ_sW_Mix_l	4fWWleptonic	4fsingleWleptonic	4fsingleZnunu
UNCUT	8090.16	35325.10	1066.31	832.88	2744.43	294.51
CUT 1	5164.76	5060.10	781.16	667.61	2071.75	184.71
CUT 2	355.88	73.24	74.44	115.51	263.39	4.39
CUT 3	159.89	8.54	59.45	101.09	221.57	3.38
CUT 4	112.08	0.73	53.05	92.18	201.93	1.72
CUT 5	104.91	0.73	50.76	92.08	201.93	1.72
CUT 6	73.81	0.73	37.21	91.06	162.92	1.71
CUT 7	48.69	0.71	14.71	37.81	65.97	0.76
CUT 8	48.69	0.71	14.71	37.81	65.97	0.76

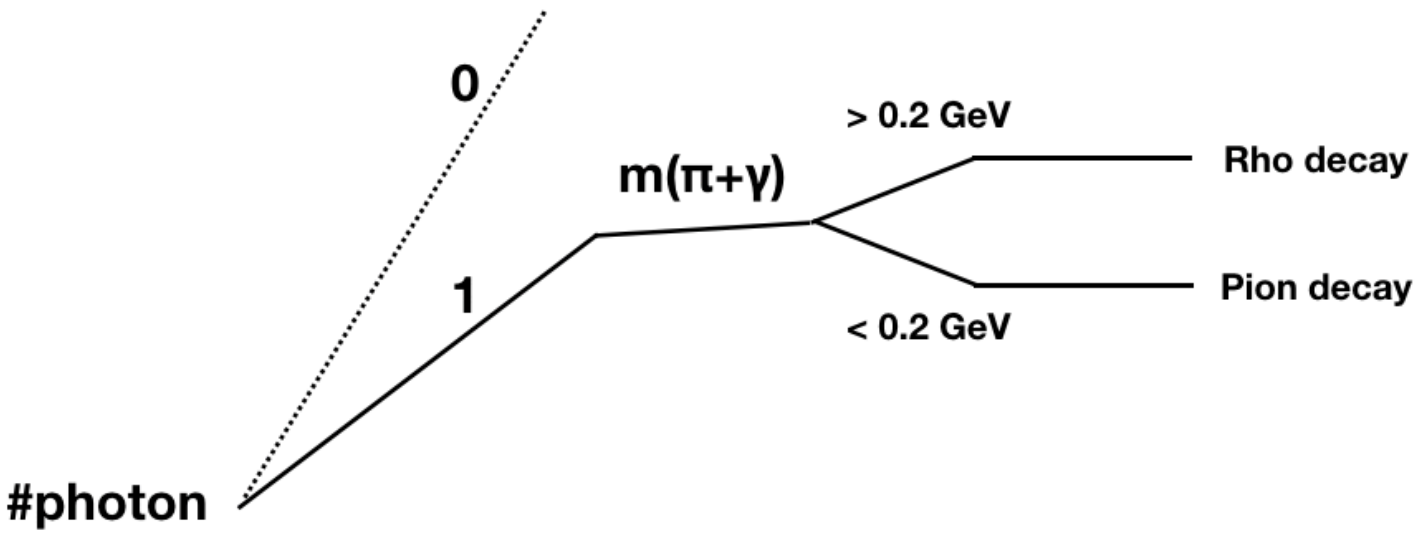
4f_ZZ_WW_Mix_l:4fZZWWMixleptonic 4f_sZ_sW_Mix_l:4fsingleZsingleWMixleptonic

τ decay mode ID



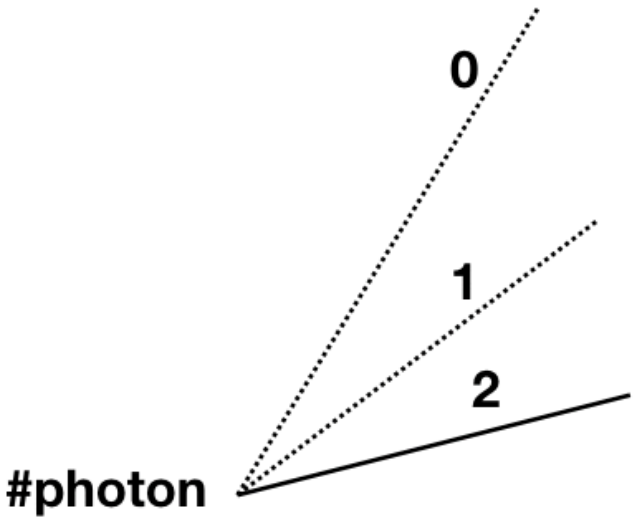
τ decay mode ID

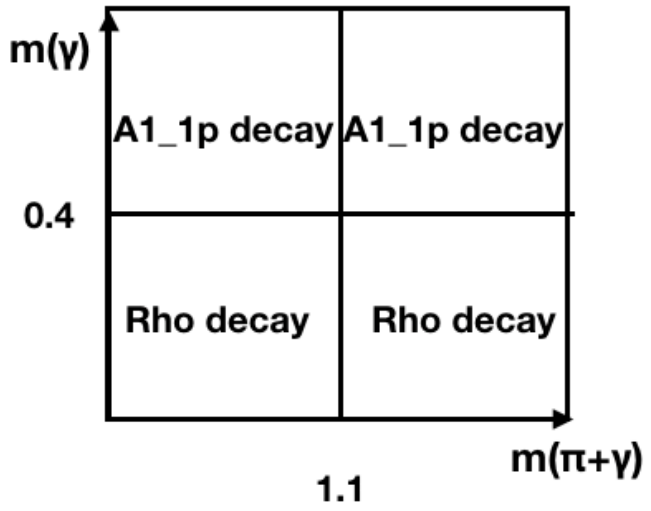
Number of charged particle inside cone = 1



τ decay mode ID

Number of charged particle inside cone = 1





τ decay mode ID

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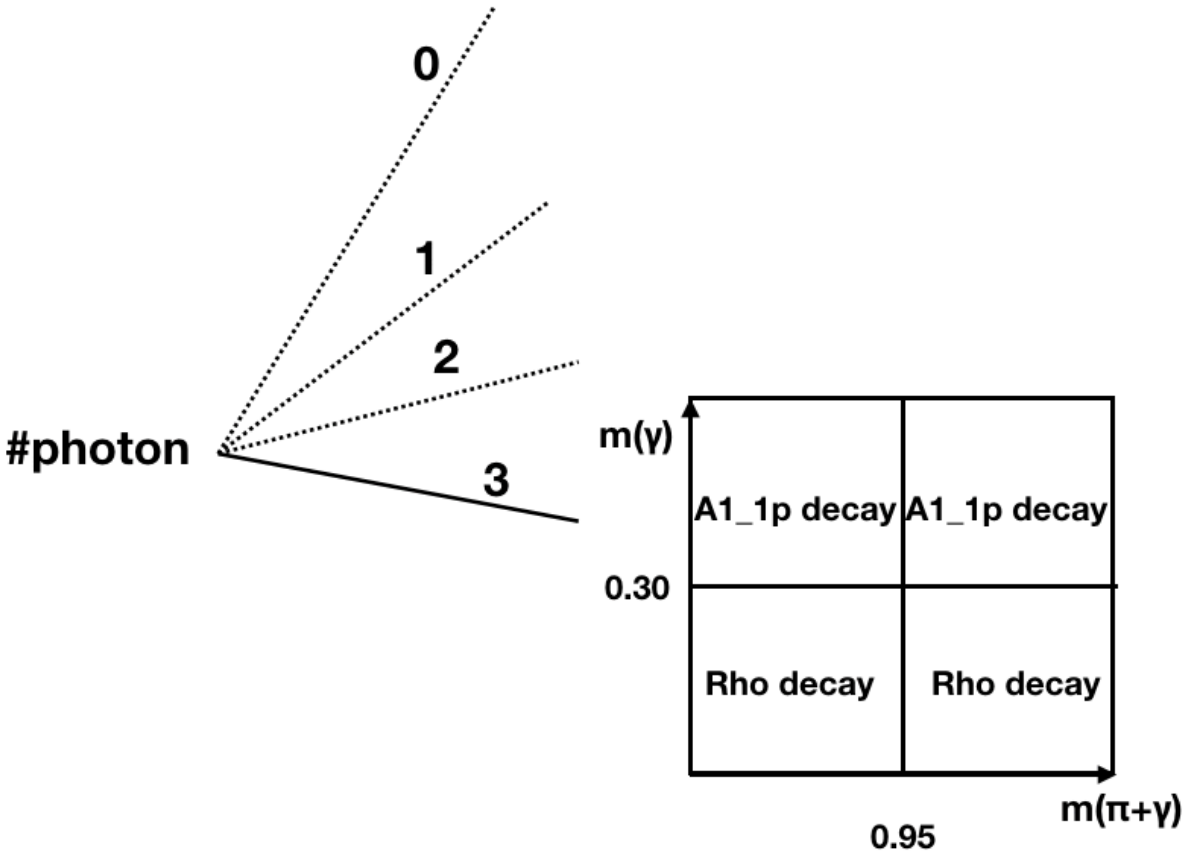

τ decay mode ID

Number of charged particle inside cone = 1