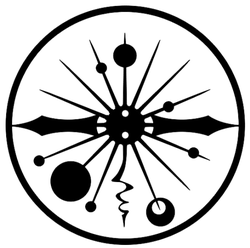
arXiv:1912.08403
arXiv:2203.07668

Measuring the tau polarisation at the ILC



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Today’s topic

First result using PFO for impact parameter method

look at

- Method efficiency
- Polarimeter

compared with MC

Motivation

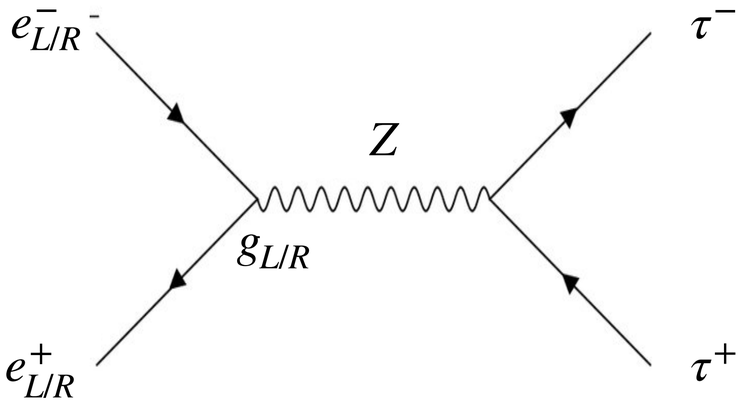
At the ILC, forward-backward asymmetry $A_{FB} = \frac{3}{4} A_e \cdot A_f$ can be measured

Thanks to ILC's polarised beams, A_e can be measured $\Rightarrow$ A_f can be extracted from A_{FB}

By measuring A_{FB} precisely and looking for deviations from SM predictions,
it is possible to search for new physics, such as heavy gauge boson Z'

We can also directly measure A_τ by using tau polarisation $P(\tau)$

$$\frac{dP(\tau)}{d\cos\theta} = \frac{3}{8} A_\tau (1 + \cos^2\theta) + \frac{3}{4} \left(\frac{A_e - P_e}{1 - A_e P_e} \right) \cos\theta$$



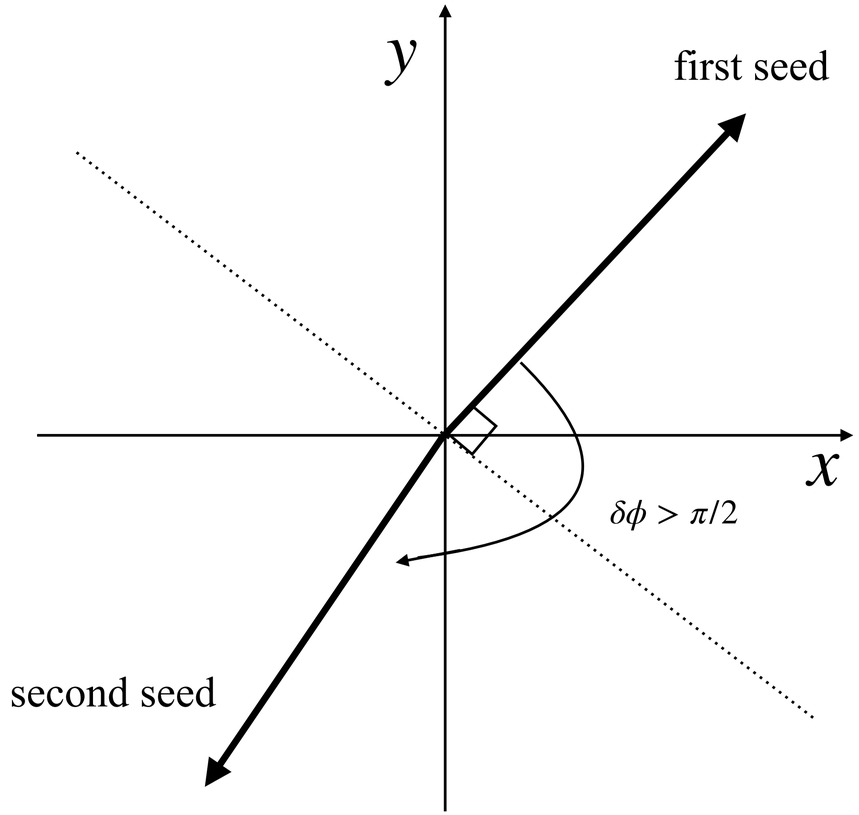
The aim of this study

The reconstruction of tau spin orientation (“**Polarimeter**”)
in order to measure polarisation to investigate new physics.

Tau jet reconstruction

1:Look for two seed direction to build tau jet candidates

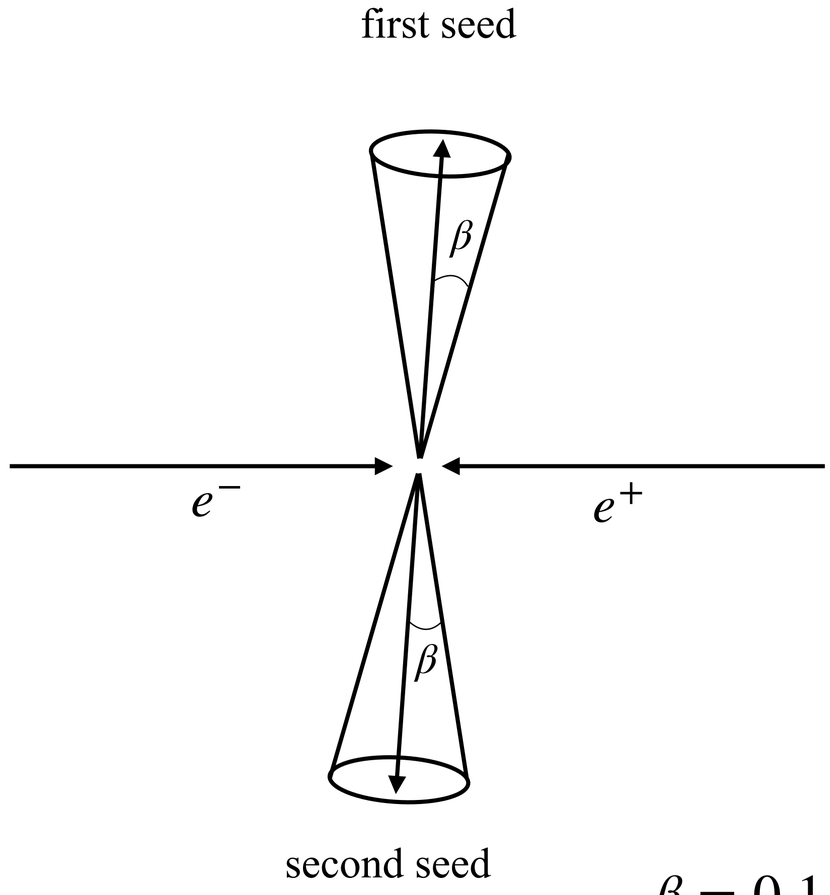
first seed : the highest momentum charged PFO



second seed : the highest momentum charged PFO

(separated from the first seed by at least π/2 in the x−y plane (δφ))

2:Make two cones



$\beta = 0.1$ rad

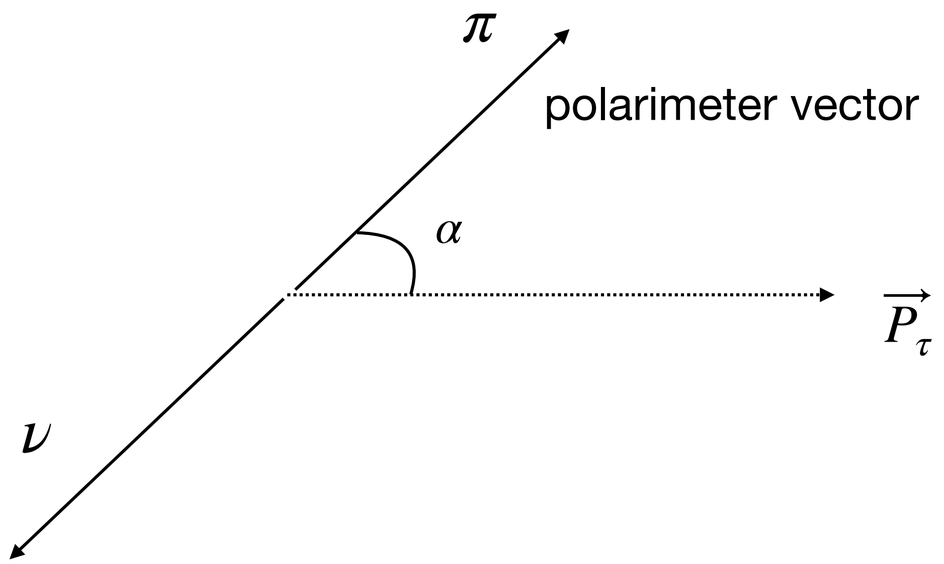
(need to tune)

Polarimeter

Reconstruction of tau polarisation $P(\tau)$ depends on tau decay mode.

Polarimeter vectors of $\tau \to \pi\nu$ in τ rest frame

$$h(\tau^{\pm} \to \pi^{\pm}\nu) \propto p_{\pi^{\pm}}$$



Polarimeter vectors of $\tau \to \rho\nu$ in τ rest frame

$$h(\tau^{\pm} \to \pi^{\pm}\pi^{0}\nu) \propto m_{\tau}(E_{\pi^{\pm}} - E_{\pi^{0}})(p_{\pi^{\pm}} - p_{\pi^{0}}) + \frac{1}{2}(p_{\pi^{\pm}} + p_{\pi^{0}})^{2}p_{\nu}$$

"**Polarimeter**"

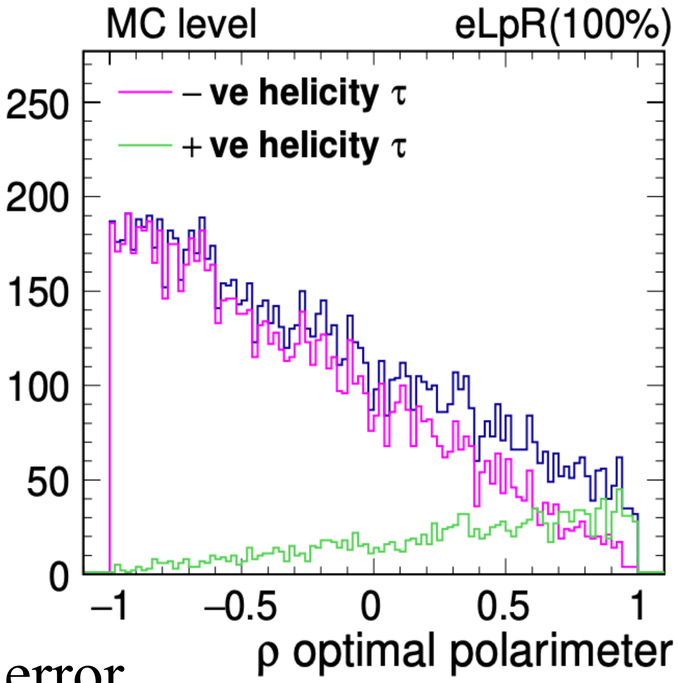
The cosine of the angle this polarimeter vector makes to the tau flight direction

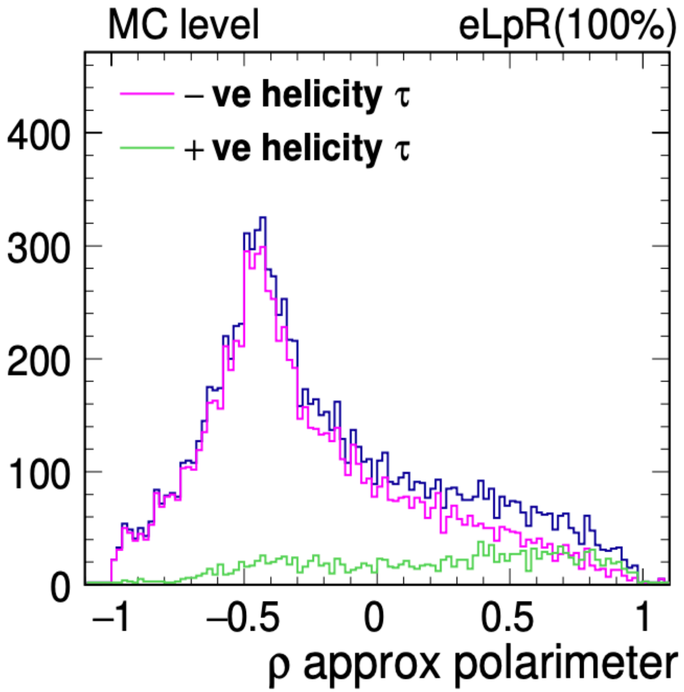
Previous study

Extract polarimeter without using neutrino information

"Approximate" polarimeters based only on the momenta of visible tau decay products

"Optimal" polarimeters including the neutrino component





mean statistical error on tau polarisation

($E_{\mathrm{CM}} = 500$ GeV, $\mathscr{L} = 1.6$ ab^{-1})

0.30 %

0.40 %

In this talk: reconstruct neutrino momentum → optimal polarimeters

Simulation setup

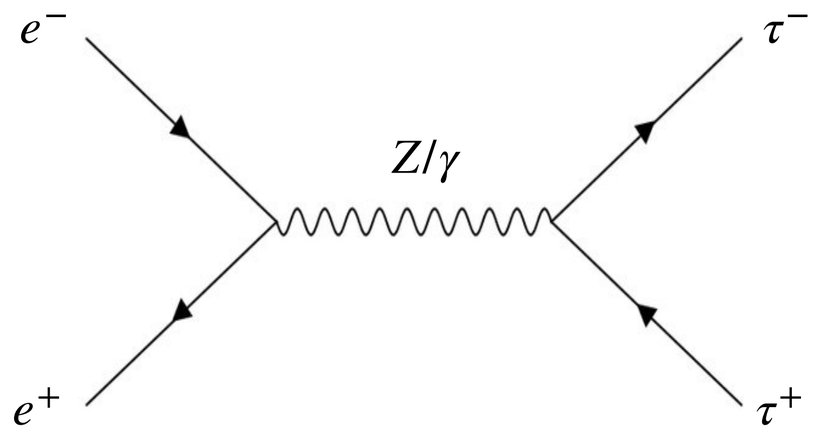
- Signal event sample with 100 % $e_L^- e_R^+$ beam polarisations were generated using WHIZARD ver 2.8.5.
- The decay of the polarised tau was done using TAUOLA.
- MC truth information was used.

currently

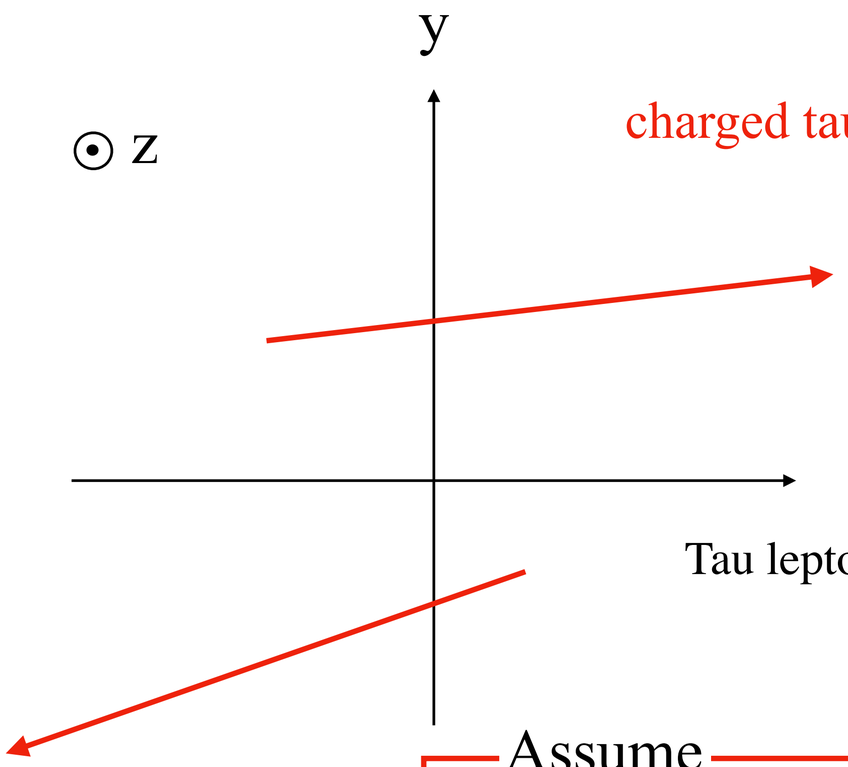
- only look at

  $\tau \to \pi\nu$ (BR ~ 10 %)

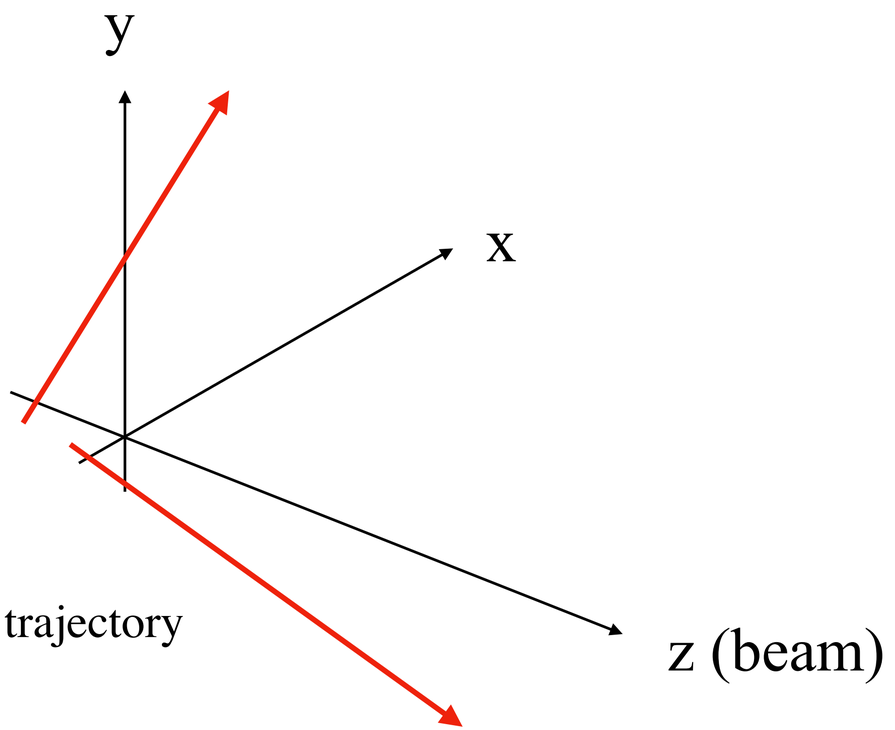
  $\tau \to \rho\nu$ (BR ~ 26 %)



τ reconstruction method



charged tau daughter trajectory



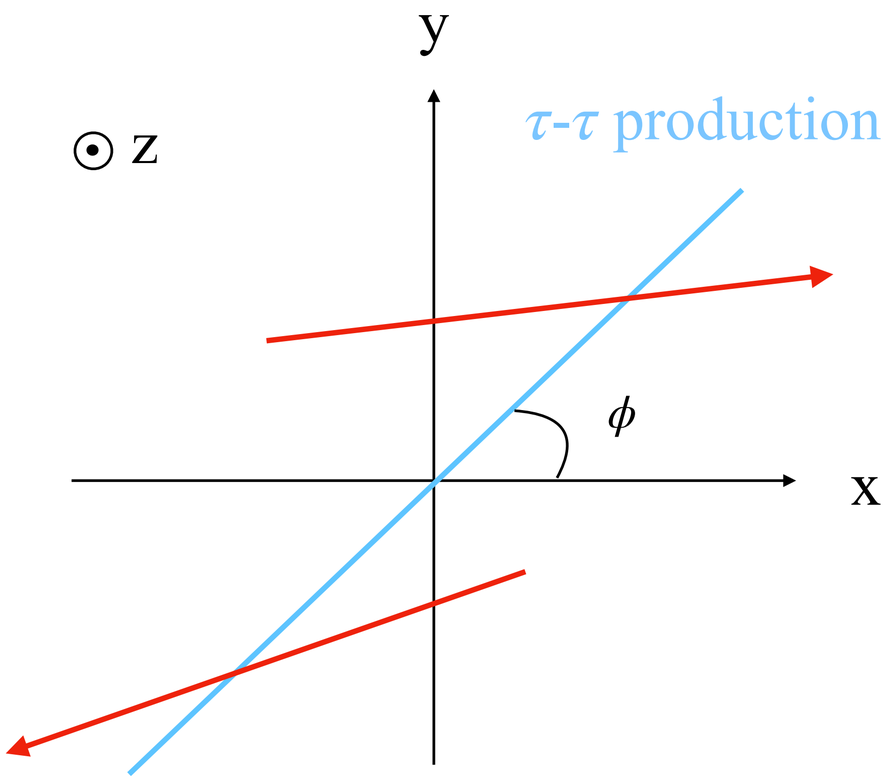
Tau lepton decayed somewhere along this trajectory

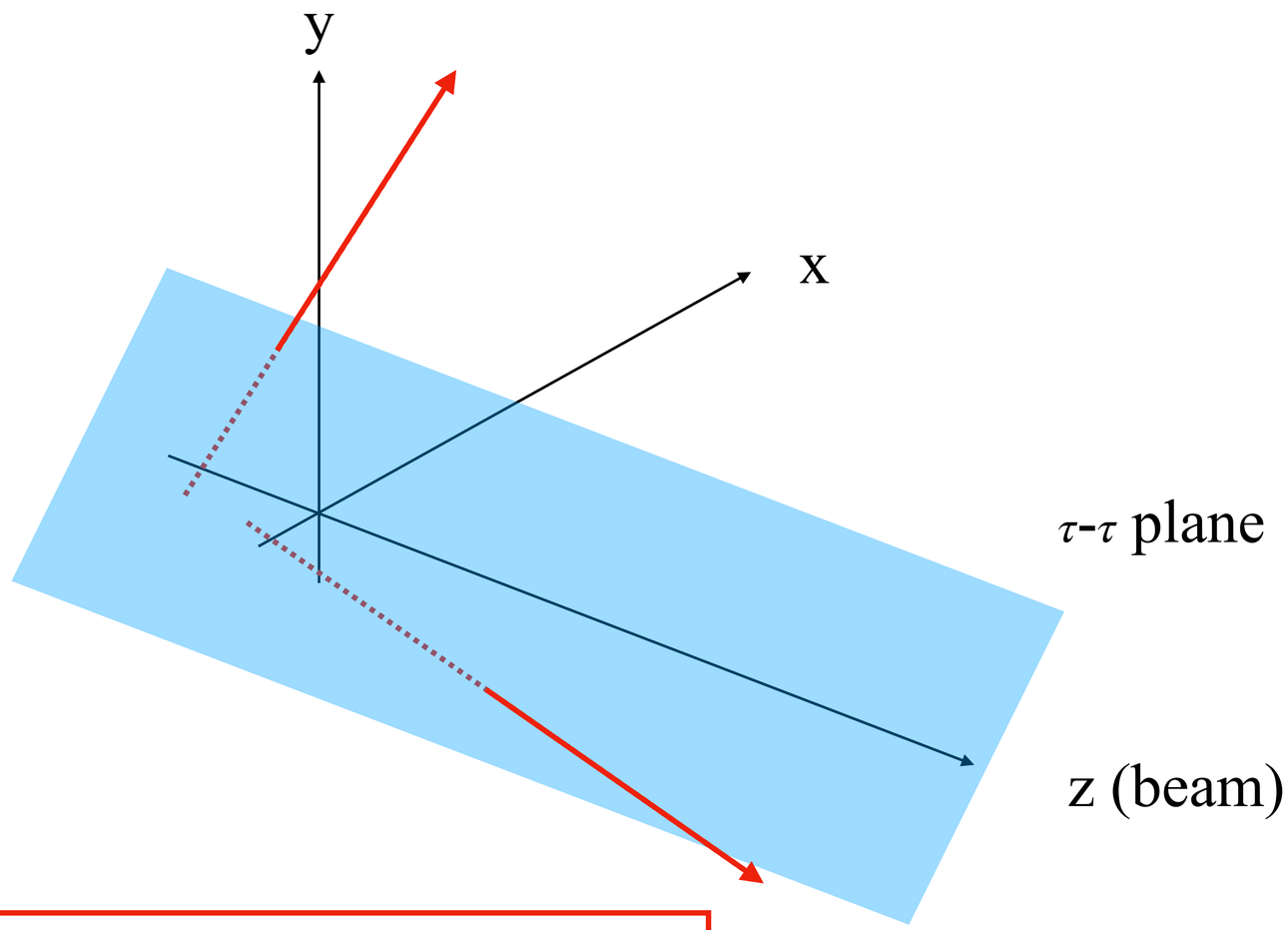
Assume

- Two taus are produced along the beam line($x = y = 0$),
- Two taus are back-to-back in x-y plane,

  — any ISR photons have negligible p_T
- Charged particle travels approximately in a straight line near IP.

τ reconstruction method



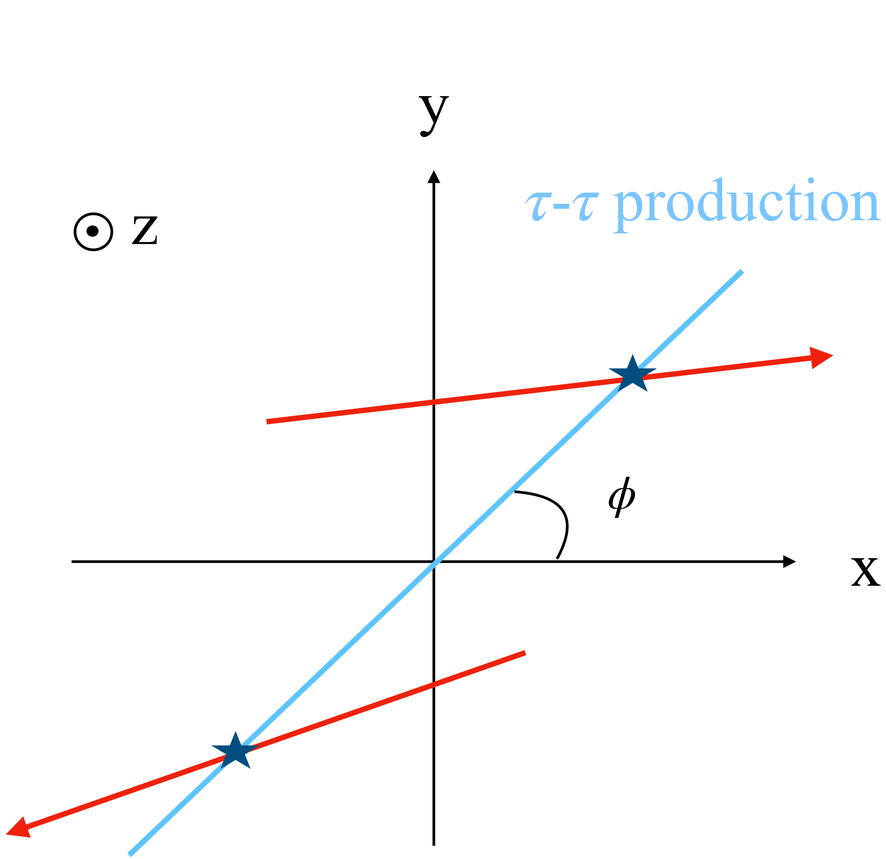


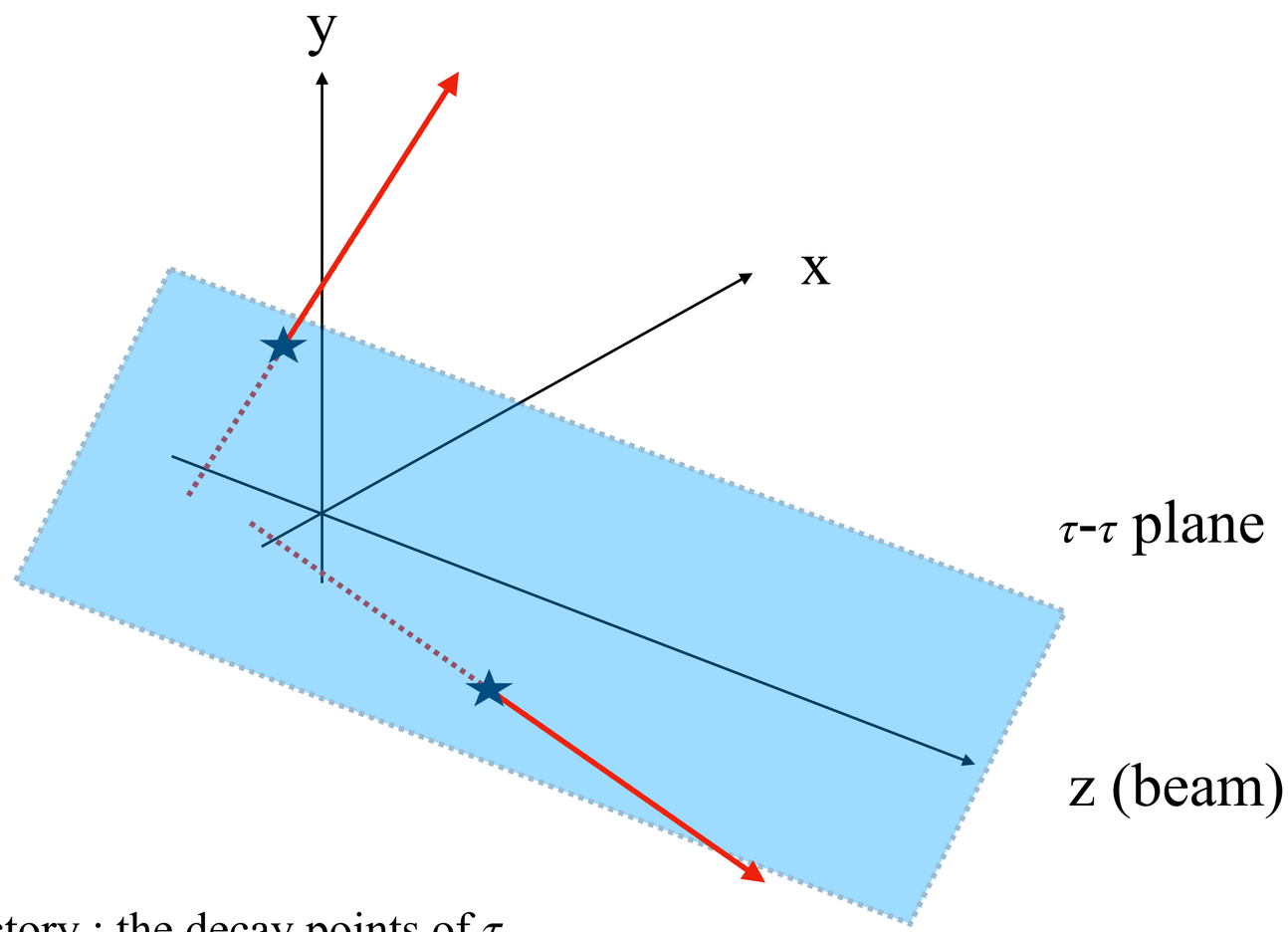
Assume

- Primary interaction occurs along the beam line($x = y = 0$),
- Two taus are back-to-back in x-y plane,
- Charged particle travels approximately in a straight line near IP.

- Two tau momenta lie in a plane containing z-axis, at some azimuthal angle ϕ

τ reconstruction method

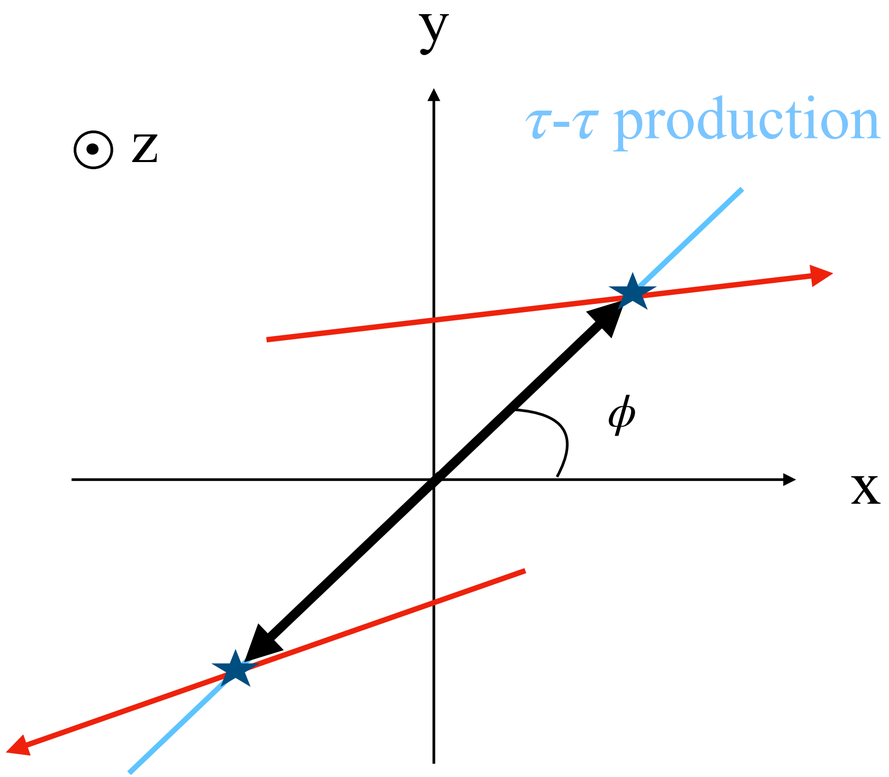


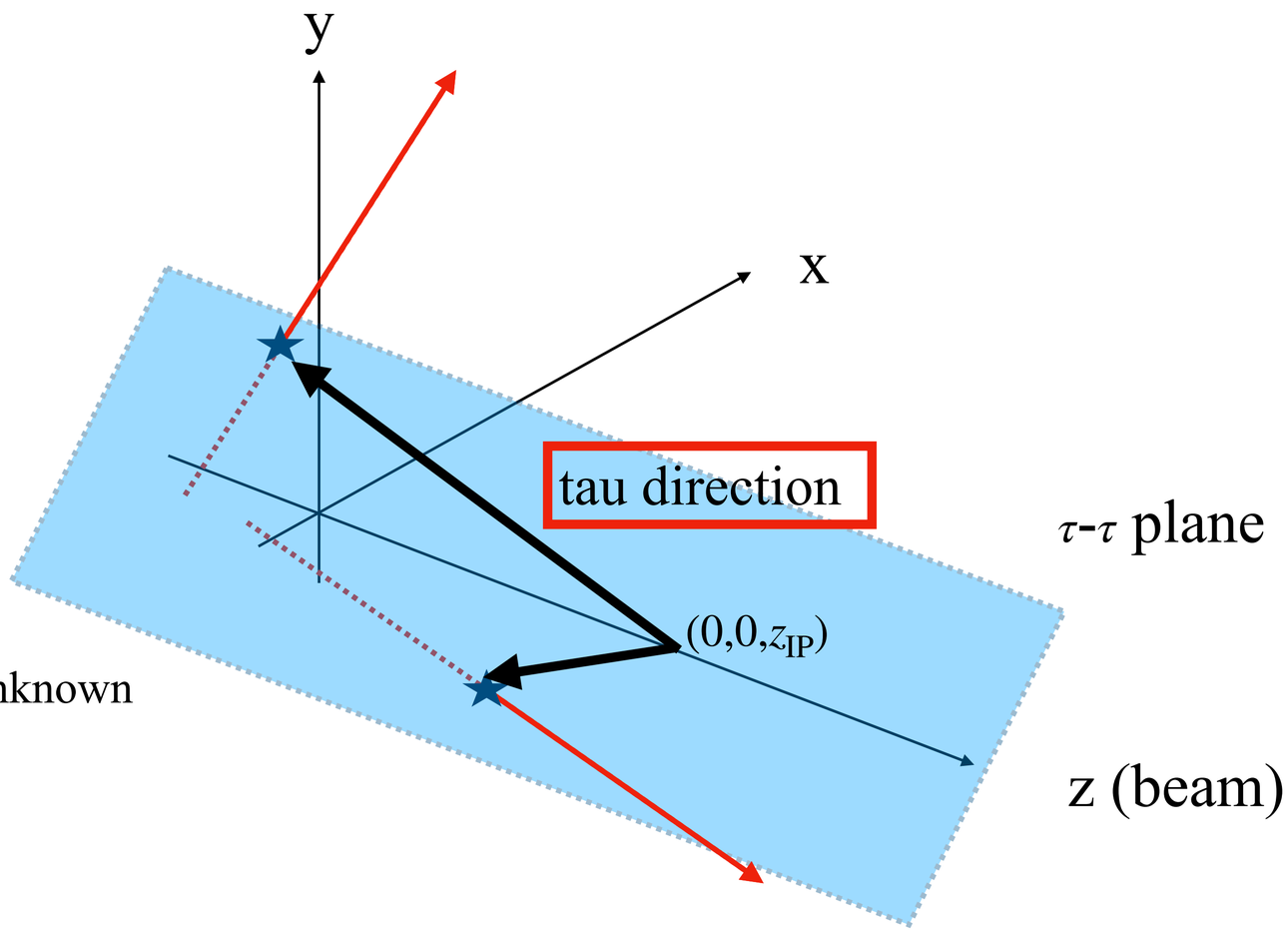


★ The intersection between plane and trajectory : the decay points of τ

For a plane with azimuthal angle ϕ,
the intersection of trajectories with this plane can be calculated.

τ reconstruction method





(ϕ, z_{IP}) : unknown

then choice of z_{IP} gives direction of tau momenta

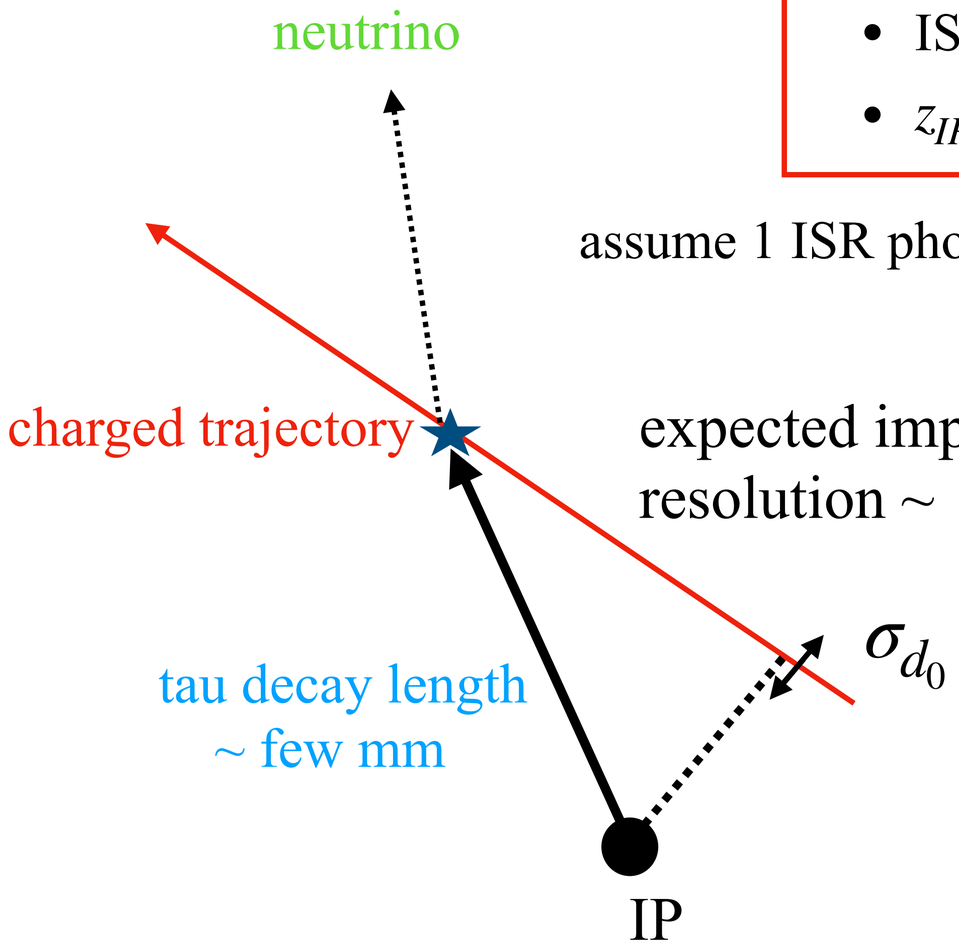
⇒How can we choose ϕ, z_{IP} ?

τ reconstruction method

Unknown
- neutrino 3-momentum $\times 2$
- ISR momentum
- z_{IP}

Constraints
- 4-momentum conservation
- tau mass $\times 2$
- Decay point on trajectory $\times 2$

assume 1 ISR photon collinear with beam and each other



expected impact parameter resolution ~ few um

For choice of z_{IP}, ϕ

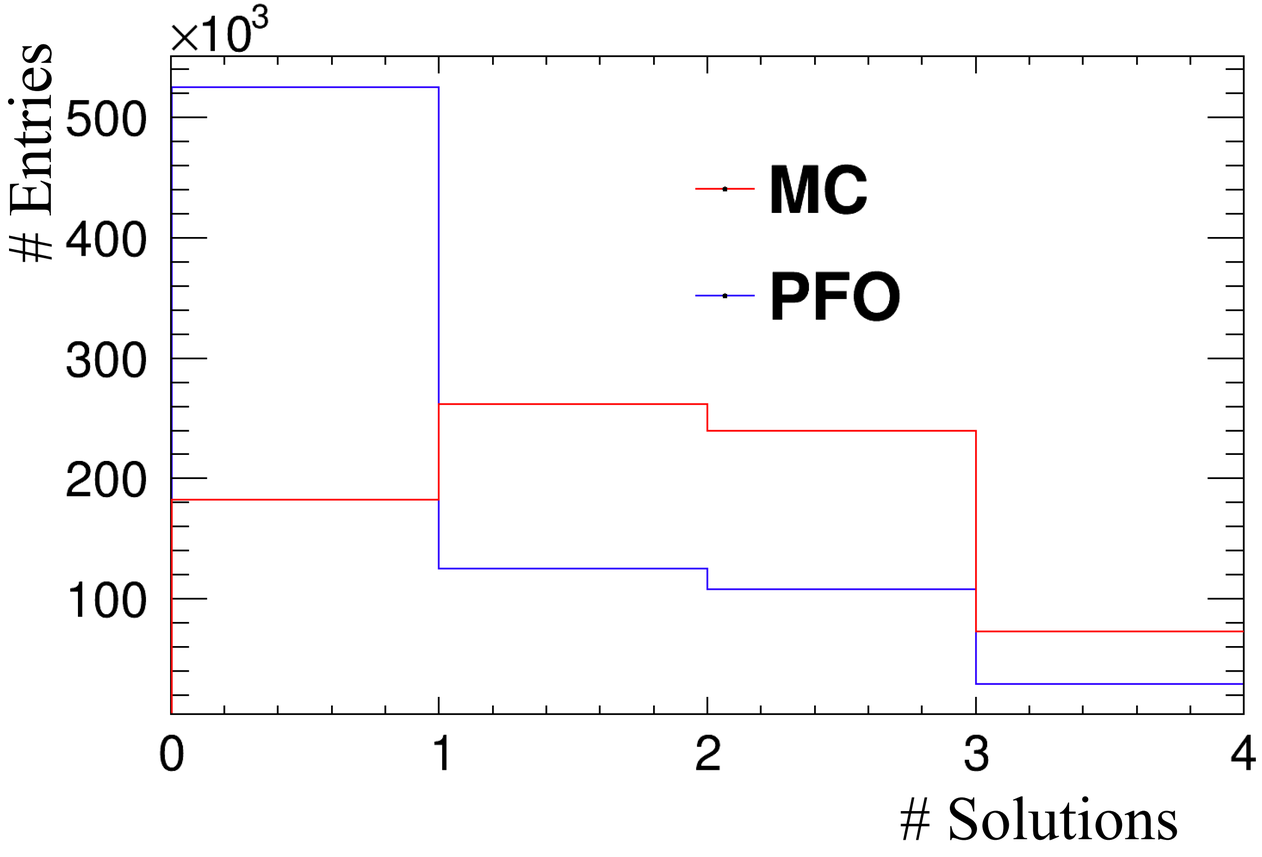
we can calculate tau 4-momenta P_τ

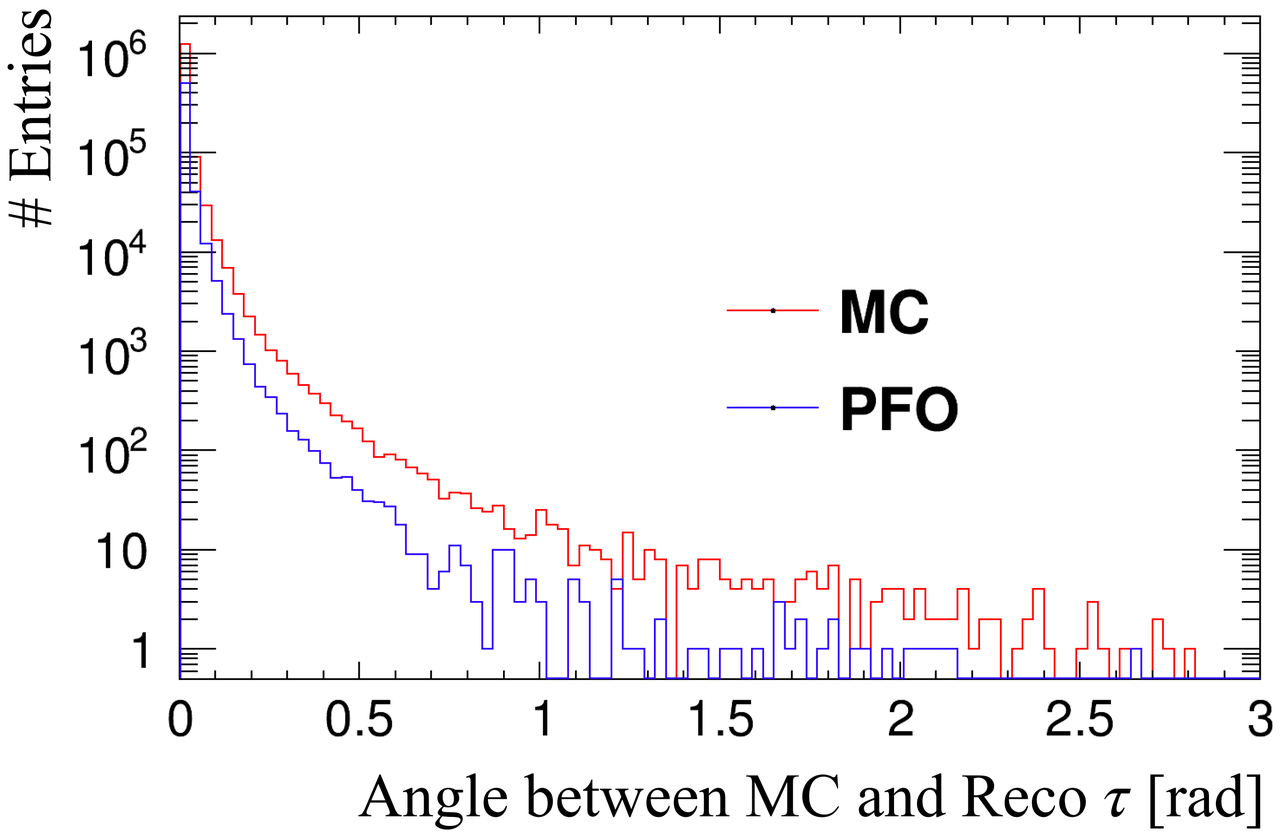
the invariant mass of the missing (neutrino) momentum for each tau can be calculated

$$P_\nu = P_\tau - P_{vis}$$

We choose the values of z and ϕ which result in neutrino masses closest to zero

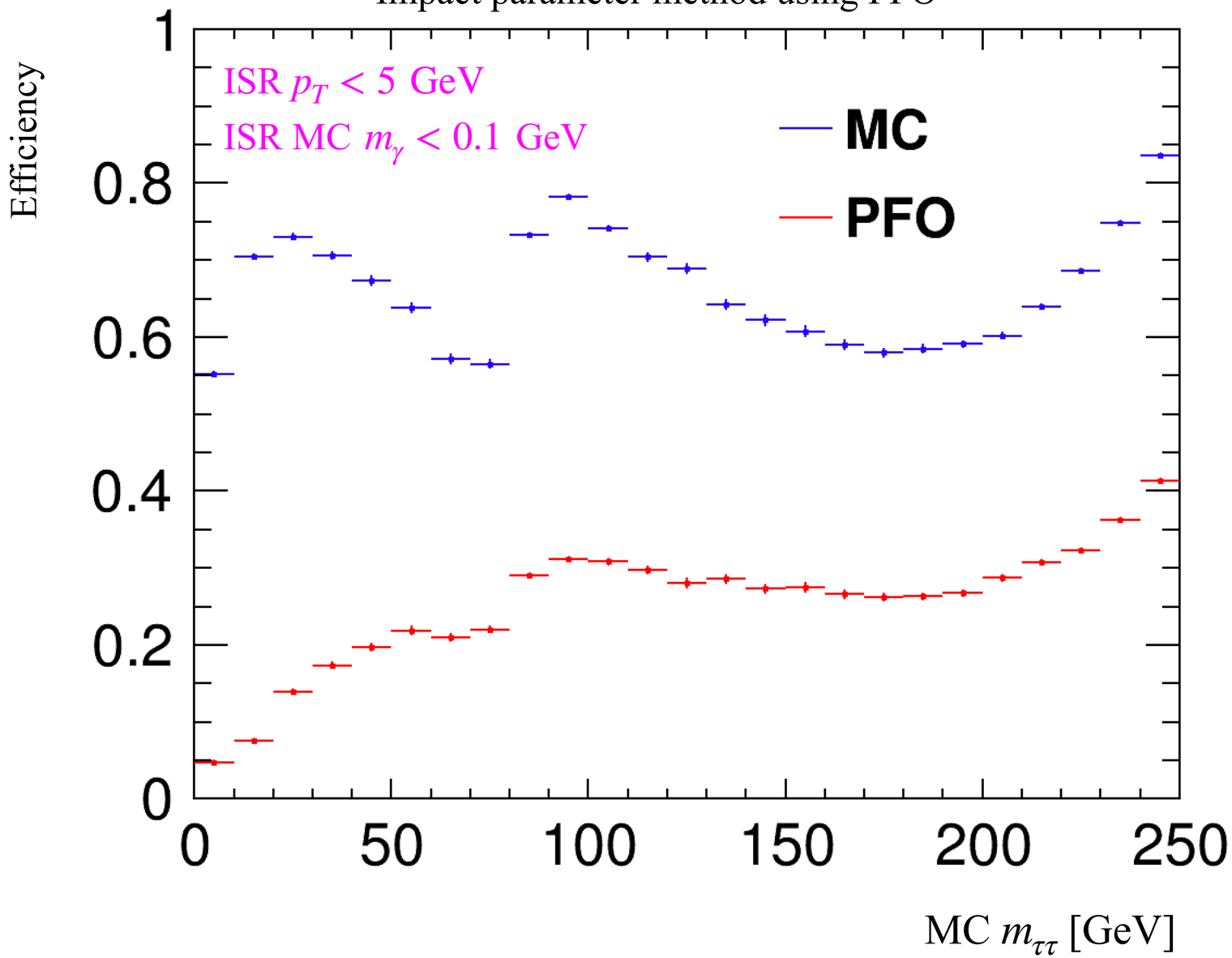
Solutions





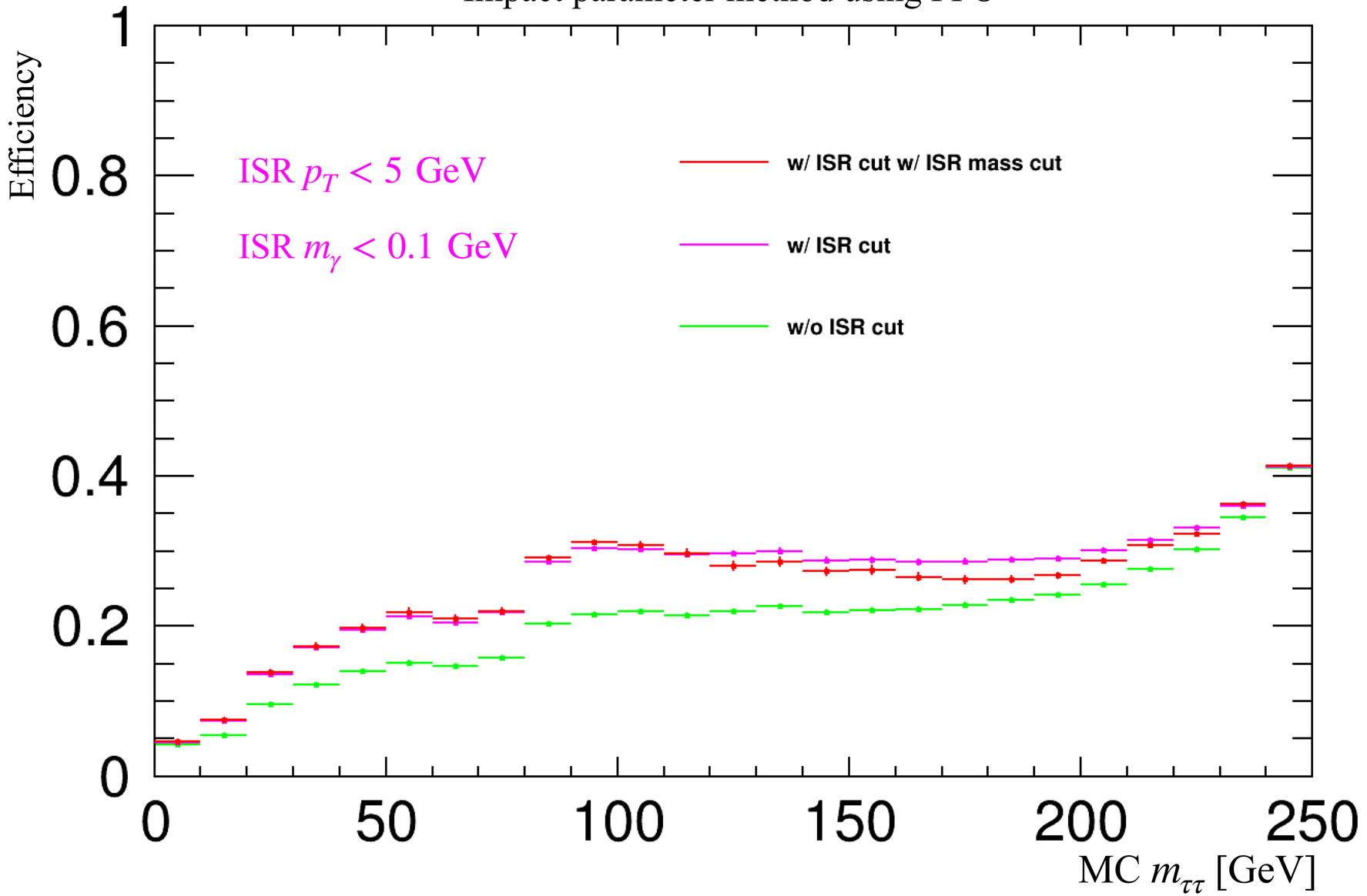
The distance to MC tau is close and the number of solutions is small because of cone size $\beta = 0.1$ rad ?

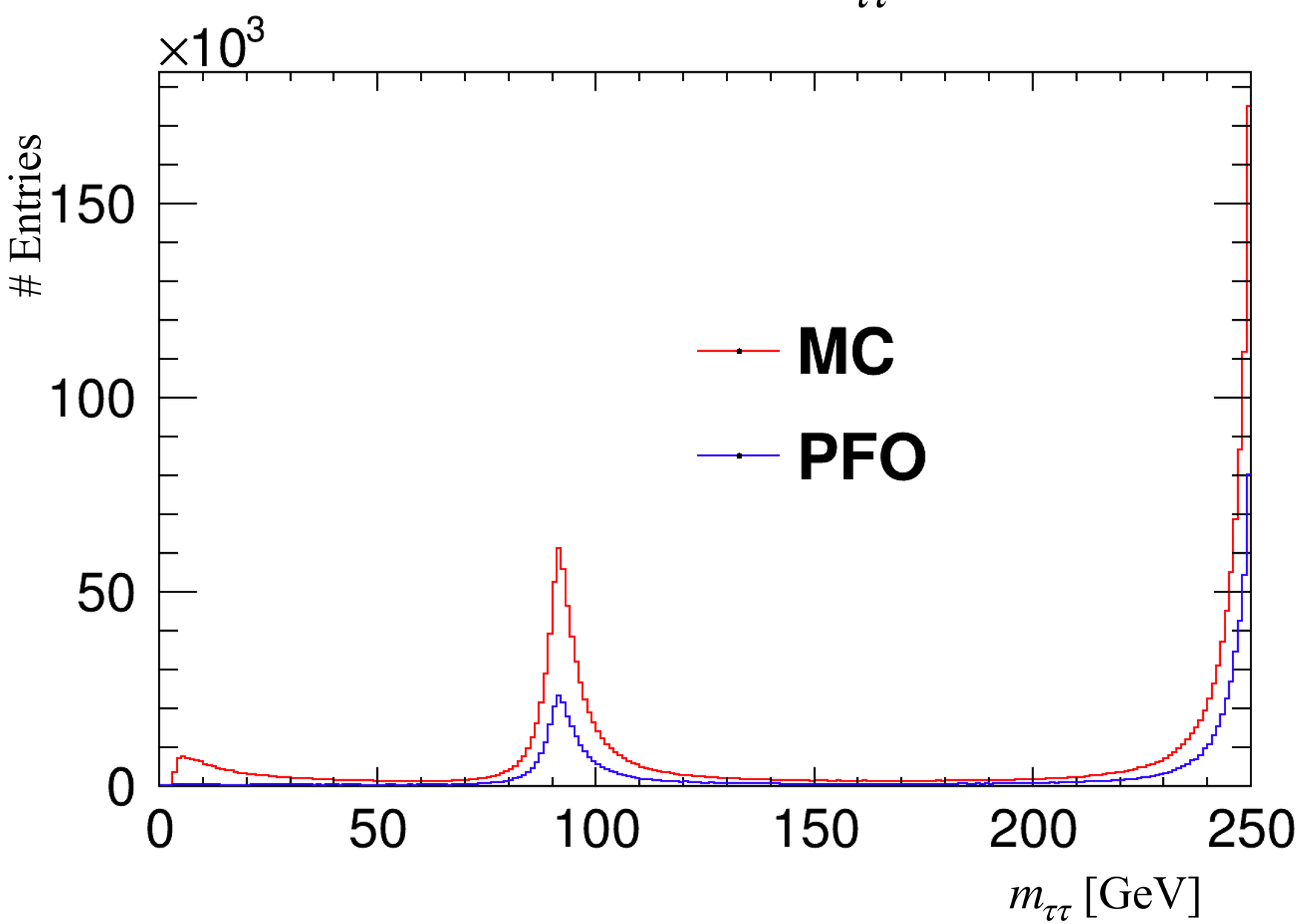
Method efficiency



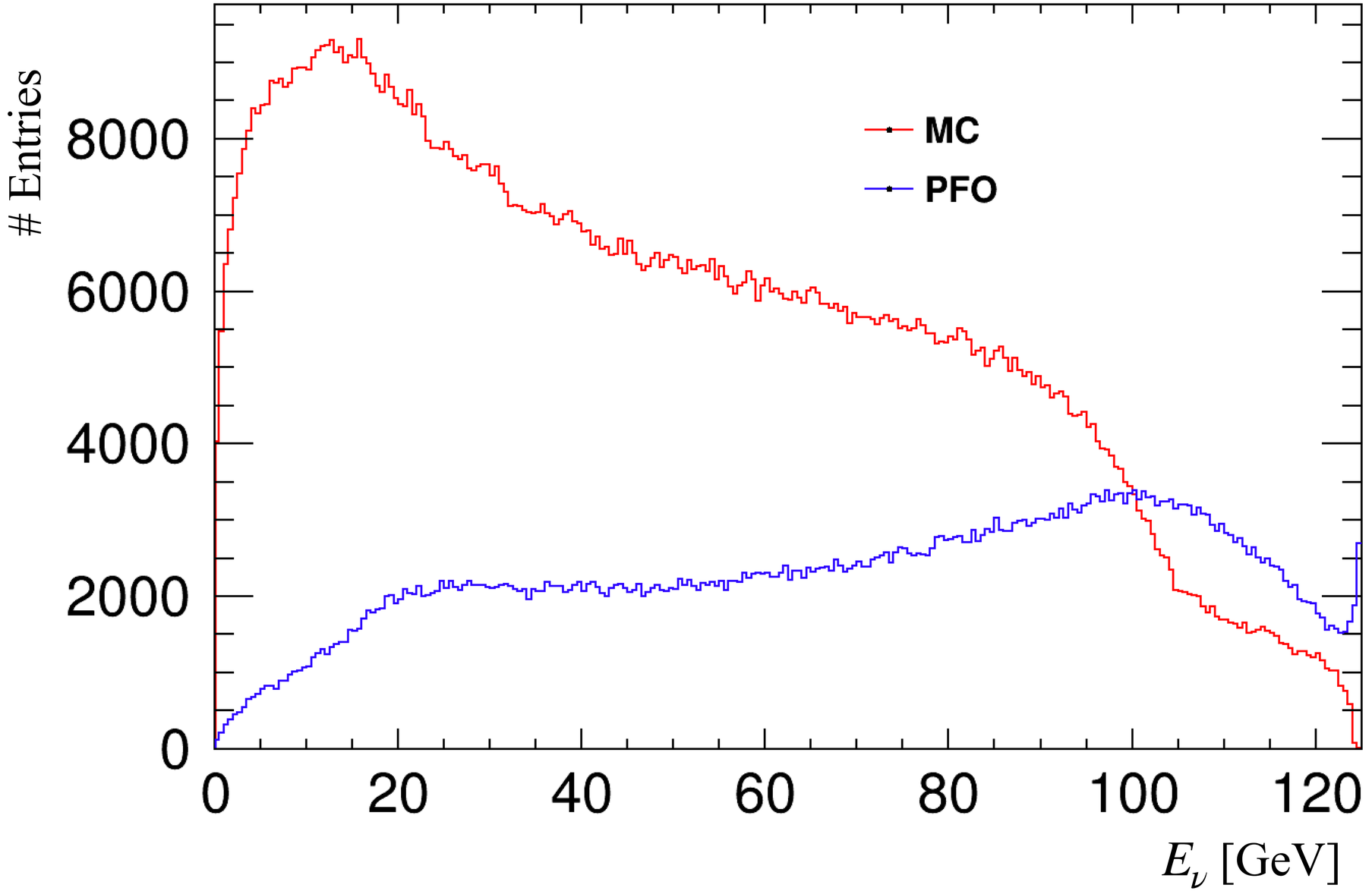
Method efficiency

Impact parameter method using PFO



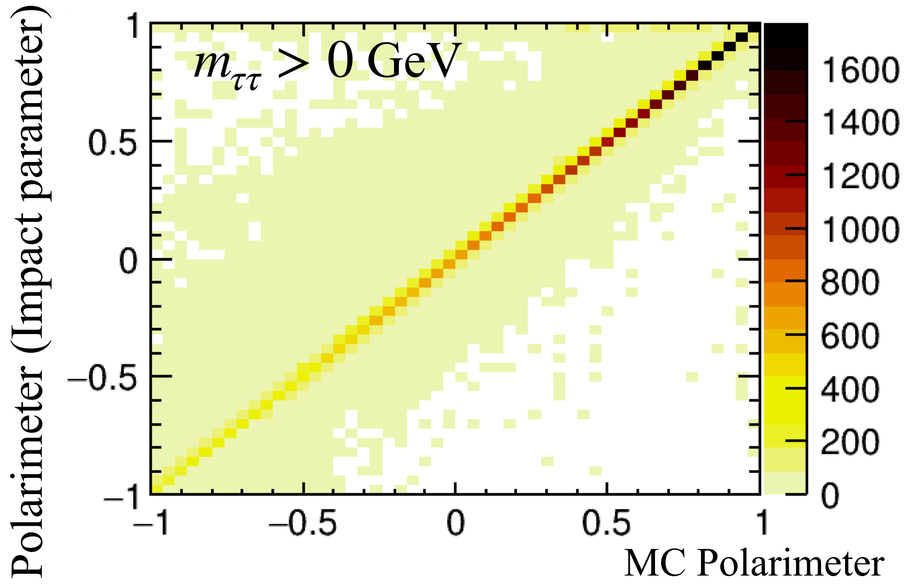

Reconstructed $m_{\tau\tau}$
$\times 10^3$
Entries
150
100
50
0
MC
PFO
0
50
100
150
200
250
$m_{\tau\tau}$ [GeV]

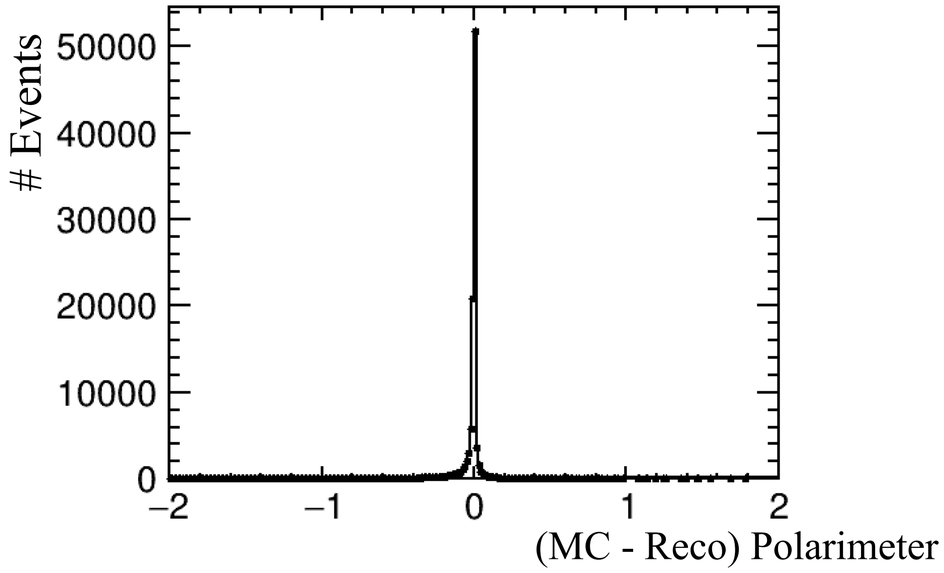
Reconstructed neutrino energy



PFO

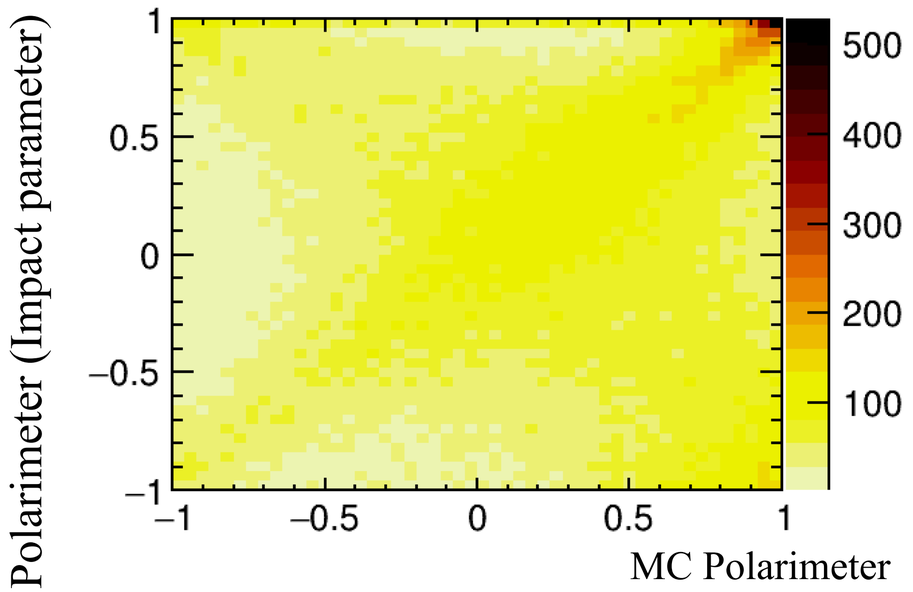
$\tau \to \pi\nu$ Impact parameter method vs MC eLpR(100%)

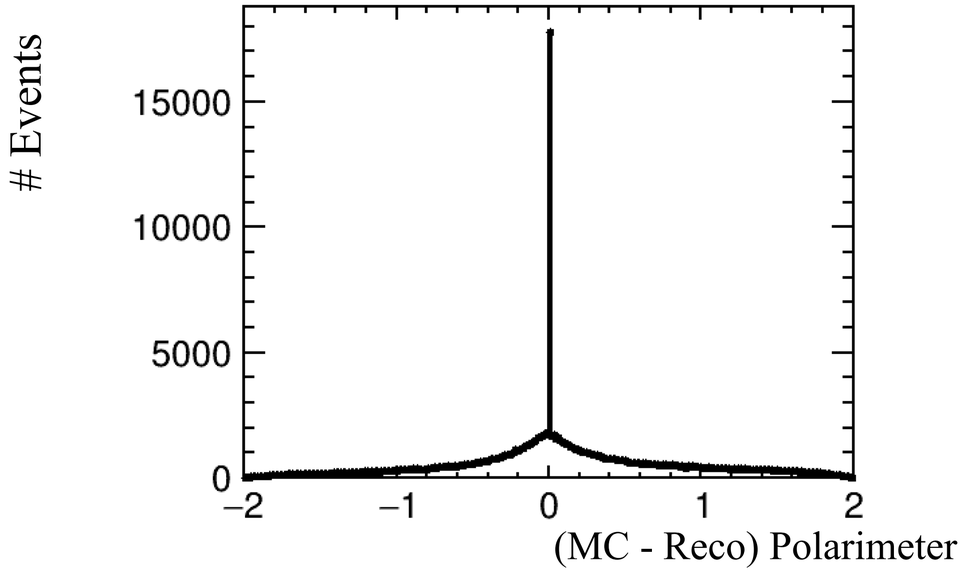




Polarimeter

$\tau \to \rho\nu$ Impact parameter method vs MC eLpR(100%)





Summary

- First result using PFO for Impact parameter method was investigated
- The efficiency also has a strange distribution at Z-pole as in the case of MC.
- The results of using PFO for the impact parameter show that the efficiency is still not very good.

Future plan

- Quantify the precision with which the tau polarisation can be measured at ILC-250.
- Investigate search for new physics by using the tau polarisation.