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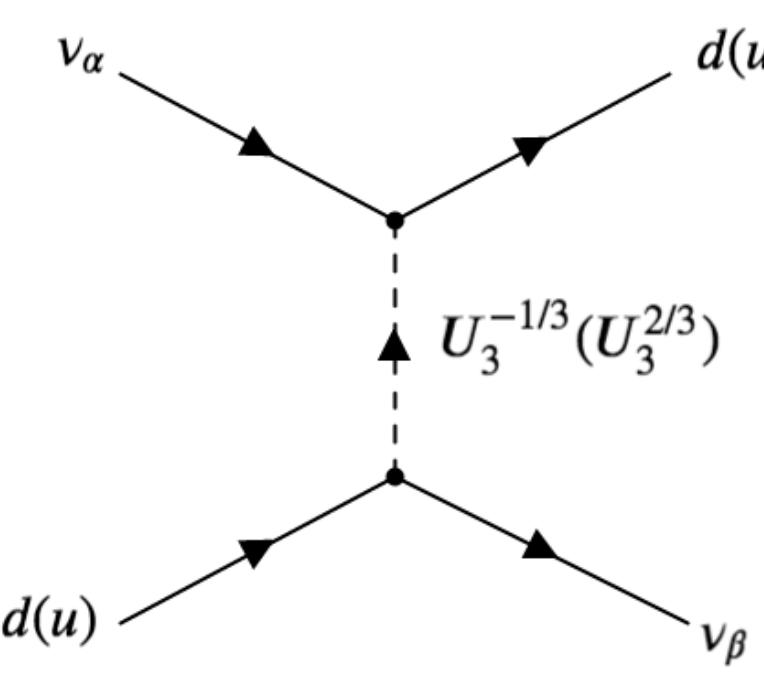
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## Abstract

- Vector leptoquark  $U_3$ , which can induce interactions between the propagating neutrinos and the nucleons within the earth.
- Such interactions provide a relatively large values of NSI parameter  $\epsilon_{e\mu}$  and  $\epsilon_{e\tau}$ .
- The NSI parameter  $\epsilon_{e\mu}$ , which can successfully explain the current discrepancy between the observed results of T2K and NOvA.
- Also one can constrain the neutrino oscillation parameters in the context of currently running long baseline experiments.

## Theoretical Framework

- We have consider an additional vector leptoquark  $U_3$  to the standard model.
- $U_3$  transform as  $(\bar{3}, 3, 2/3)$  under the gauge group  $SU(3)_C \times SU(2)_L \times U(1)_Y$ .
- The three charge states are  $U_3^{5/3}$ ,  $U_3^{2/3}$ ,  $U_3^{-1/3}$ .
- During the propagation, neutrinos interact with the nucleons ( $u$  and  $d$  quarks) of earth matter through the exchange of leptoquark.



- Effective Lagrangian for the interaction between the neutrinos and up or down-type quarks.

$$\mathcal{L}_{\text{eff}}^{\text{down}} = -\frac{2}{m_{LQ}^2} \lambda_{j\beta}^{LL} \lambda_{i\alpha}^{LL*} (\bar{d}_L^i \gamma_\mu P_L d_L^j) (\bar{\nu}_\alpha \gamma^\mu P_L \nu_\beta) \quad (1)$$

$$\mathcal{L}_{\text{eff}}^{\text{up}} = -\frac{2}{m_{LQ}^2} \lambda_{j\beta}^{LL} \lambda_{i\alpha}^{LL*} (\bar{u}_L^i \gamma_\mu P_L u_L^j) (\bar{\nu}_\alpha \gamma^\mu P_L \nu_\beta) \quad (2)$$

- Neutral current non-standard interaction Lagrangian is,

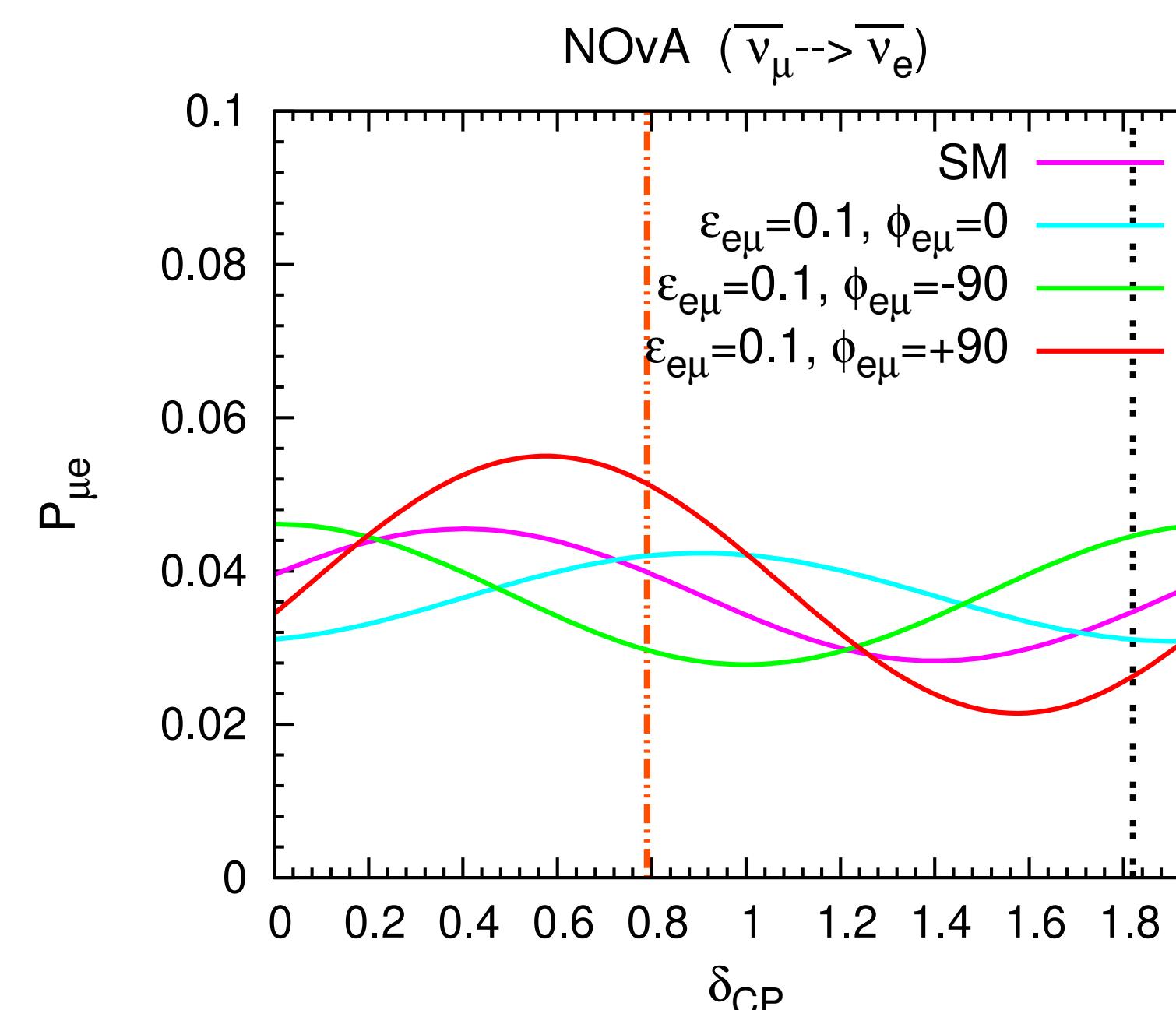
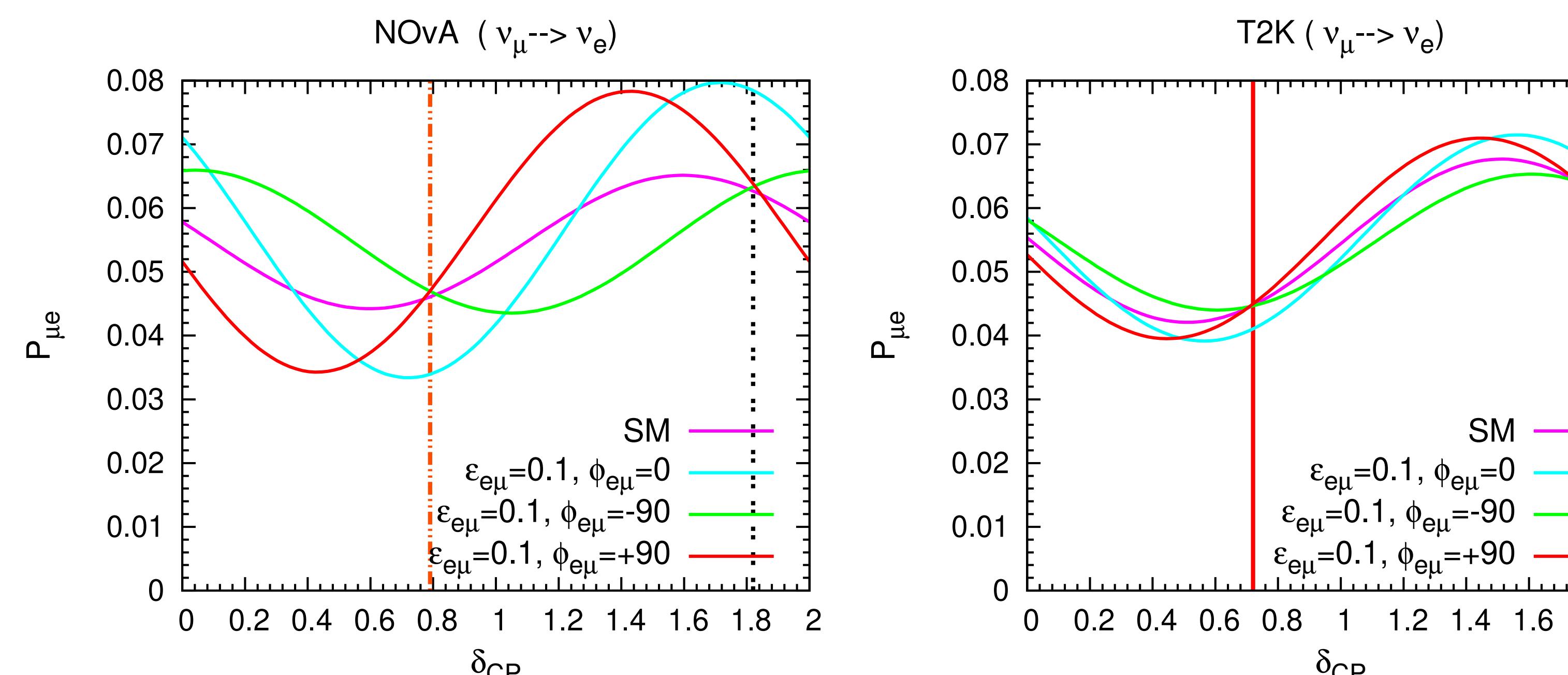
$$\mathcal{L}_{\text{NSI}} = -2\sqrt{2} G_F \epsilon_{\alpha\beta}^{\text{fC}} (\bar{\nu}_\alpha \gamma^\mu L \nu_\beta) (\bar{f} \gamma_\mu P_C f), \quad (3)$$

where  $\alpha, \beta = e, \mu, \tau$  and  $f = e, u, d$

- Comparing these equations, bounds on the NSI parameter  $\epsilon_{e\mu} = \epsilon_{e\mu}^e + 3\epsilon_{e\mu}^u + 3\epsilon_{e\mu}^d$  will be  $\epsilon_{e\mu} \leq 0.9$ . In this work we use a more stringent bound  $\epsilon_{e\mu} \approx 0.15$ .

## a) Effect of NSI parameters at probability level.

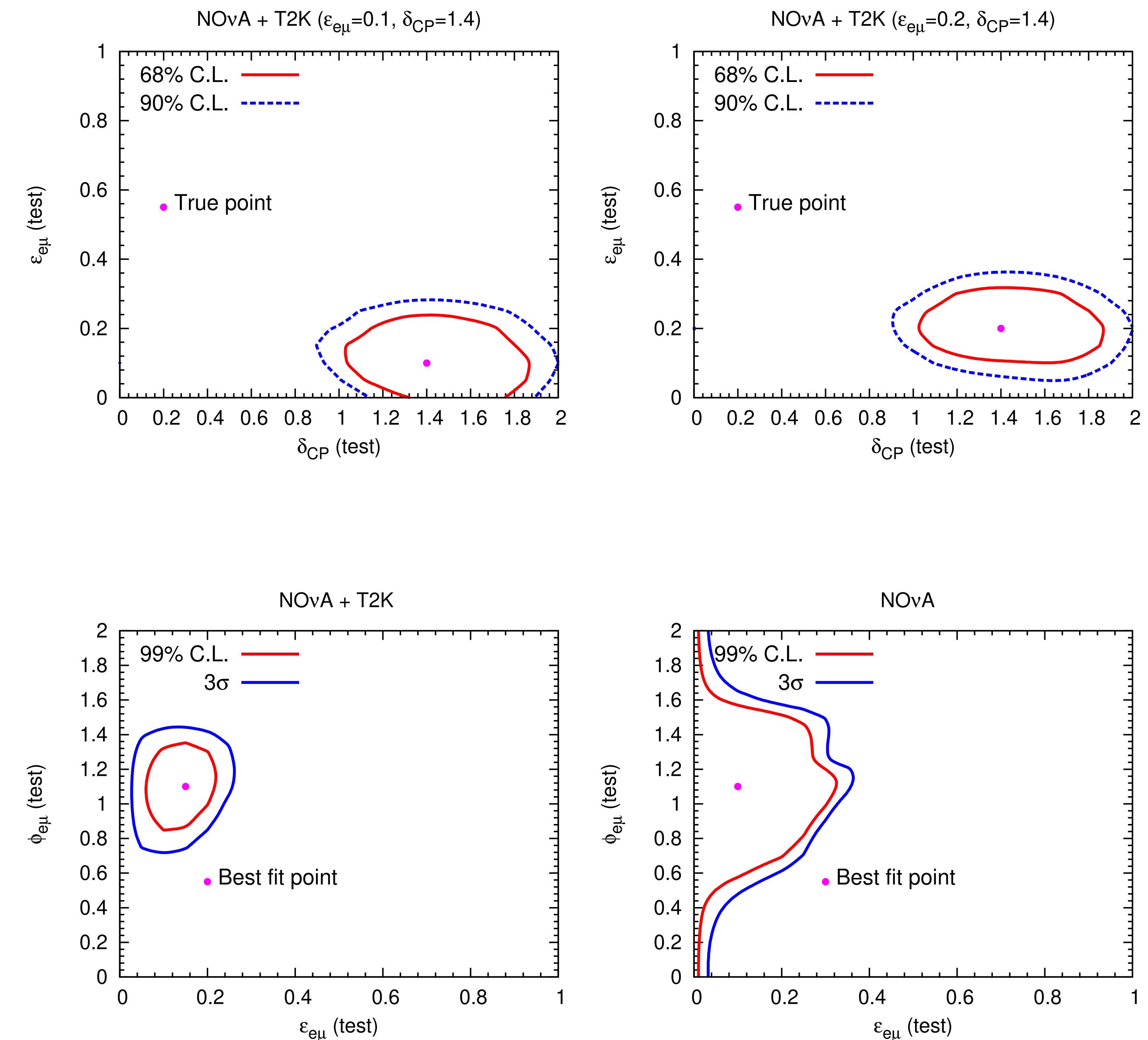
Appearance probability with respect to  $\delta_{CP}$  for  $\epsilon_{e\mu} \approx 0.1$  and  $\phi_{e\mu} = 0, -90^\circ, 90^\circ$ .



## Results

### b) Effect at sensitivity levels

Allowed parameter regions of  $\epsilon_{e\mu}$ ,  $\delta_{CP}$  obtained for the combination of NOvA and T2K.



Allowed parameter regions of  $\epsilon_{e\mu}$ ,  $\phi_{e\mu}$  for combination of NOvA and T2K.

## Conclusions

- From the model we obtained bounds on the neutral current NSI parameter  $\epsilon_{e\mu} \leq 0.9$ .
- At a probability level we found that  $P_{\mu e}(\text{SM}, \delta_{CP} \sim 0.8\pi, \text{NH}) = P_{\mu e}(\text{NSI}(\epsilon_{e\mu} = 0.15, \phi_{e\mu} = \pm\pi/2), \delta_{CP} = 0.8\pi, \text{NH})$ .
- Also we have seen that there exists degeneracy between  $P_{\mu e}$  and  $\epsilon_{e\mu}$  for  $\epsilon_{e\mu} \in [0, 0.2]$  for NOvA and  $\phi_{e\mu} = \pm\pi/2$ .
- From the sensitivity plots the degeneracy can be explained for NSI parameter value as  $\epsilon_{e\mu} \in [0.1, 0.15]$  and  $\phi_{e\mu} \simeq 1.1\pi$
- Vector Leptoquark  $U_3$  is a possible candidate to explain NOvA, T2K tension in  $\delta_{CP}$ .

## References

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