Probing Source and Detector NSIs at ESSνSB

Sushant Raut

KTH Royal Institute of Technology, Stockholm

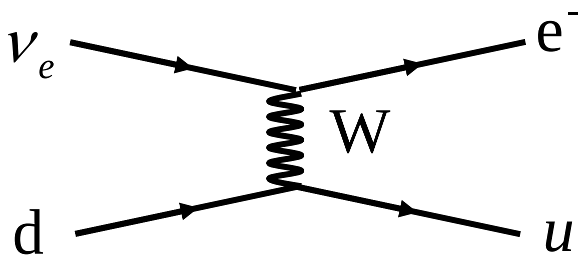
arXiv:1507.02868 - Mattias Blennow, Sandhya Choubey, Tommy Ohlsson, SR

Outline

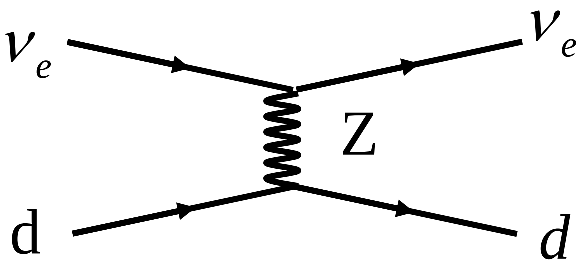
- Non-standard neutrino interactions: NSIs
- The proposed ESSνSB experiment
- Neutrino oscillations with NSIs
- Results of simulations
- Conclusions

Non-standard neutrino interactions: NSIs

- In the Standard Model,



$$\mathcal{L}_{CC} = (\overline{\ell_\alpha}\gamma^\mu P_L \nu_\alpha)(\bar{f}\gamma_\mu P_L f')$$



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Non-standard neutrino interactions: NSIs

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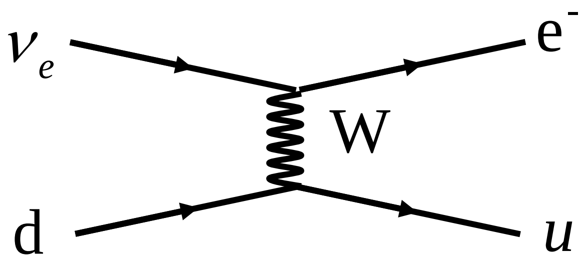

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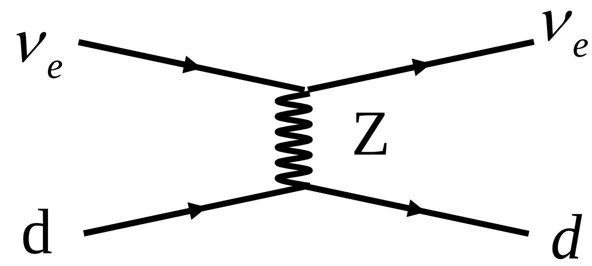

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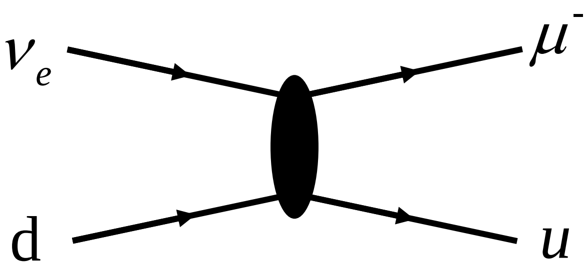
- With new physics, we could have

$$\mathcal{L}_{CC} = (\overline{\ell_\alpha} \gamma^\mu P_L \nu_\beta)(\bar{f} \gamma_\mu P_{L,R} f')$$



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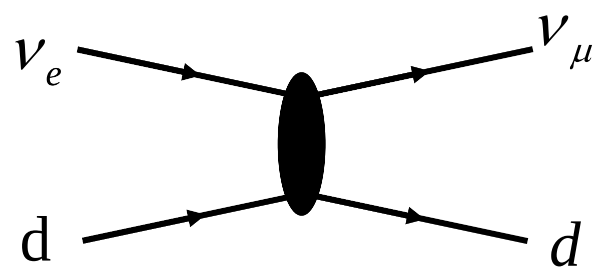

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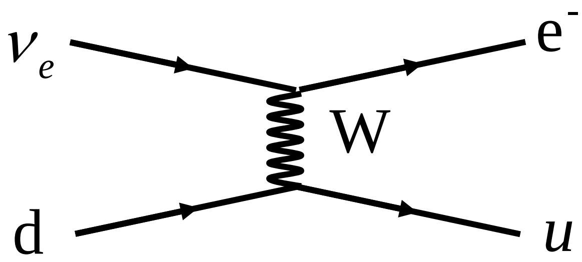

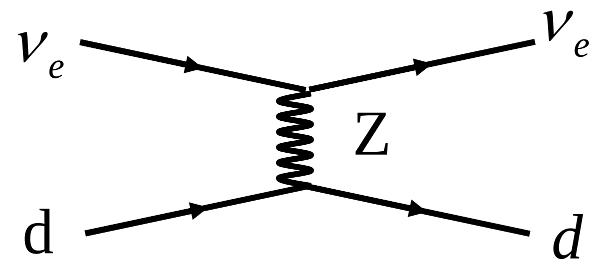

$$\mathcal{L}_{CC} = (\overline{\ell_{\alpha}}\gamma^{\mu} P_L \nu_{\alpha})(\bar{f}\gamma_{\mu} P_L f')$$

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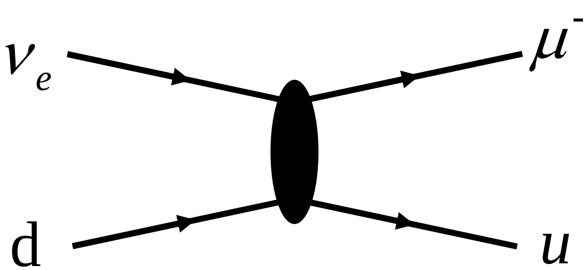
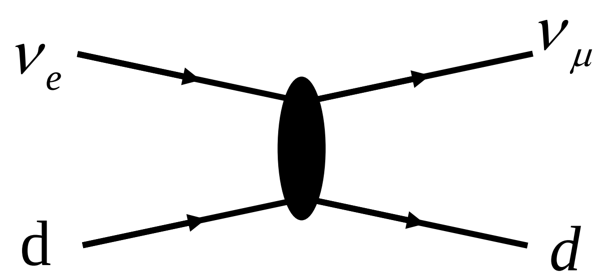




production, detection

propagation

The proposed ESSνSB experiment

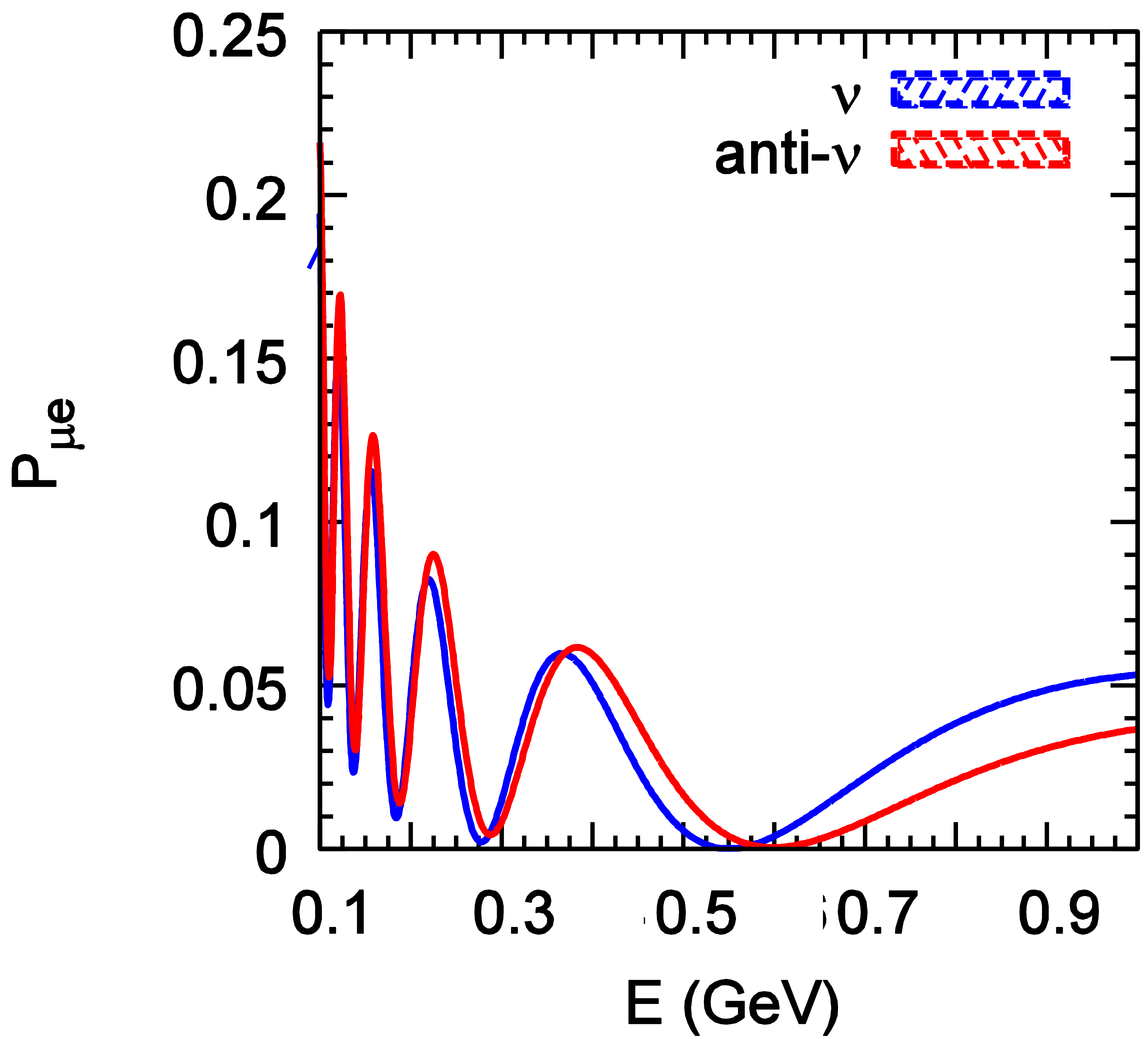
- European Spallation Source (ESS): under construction in Lund, Sweden
- Proposal to use the proton beam to produce a beam of neutrinos – peak energy 250 MeV
- Possible site for detector: mine in Garpenberg, Sweden – 540 km
- The mine can host a MEMPHYS-like Water Cerenkov detector

1309.7022: Baussan et al.

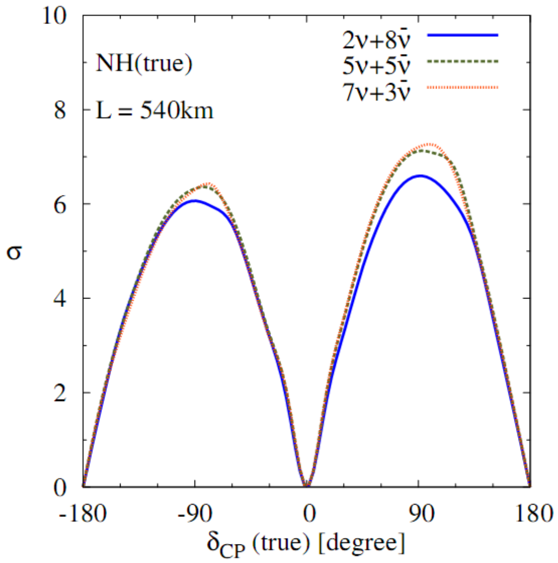
ESSνSB

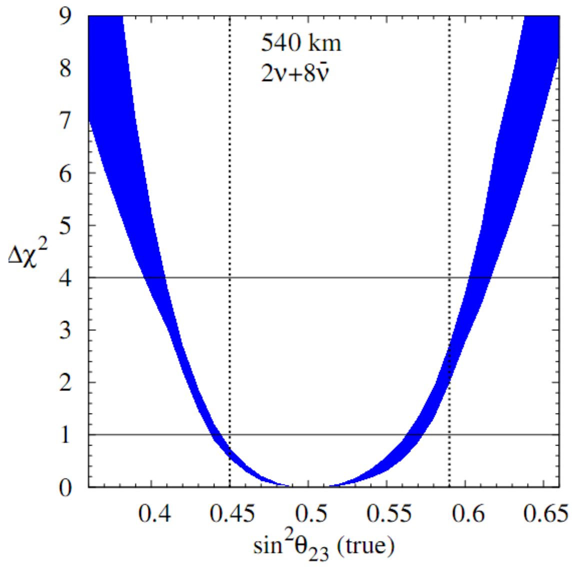
- For a 540 km baseline, the second oscillation maximum (which is sensitive to δ) is at 400 MeV

- The peak energy of the ESSνSB unoscillated spectrum lies at this energy, giving this experiment good sensitivity to δ



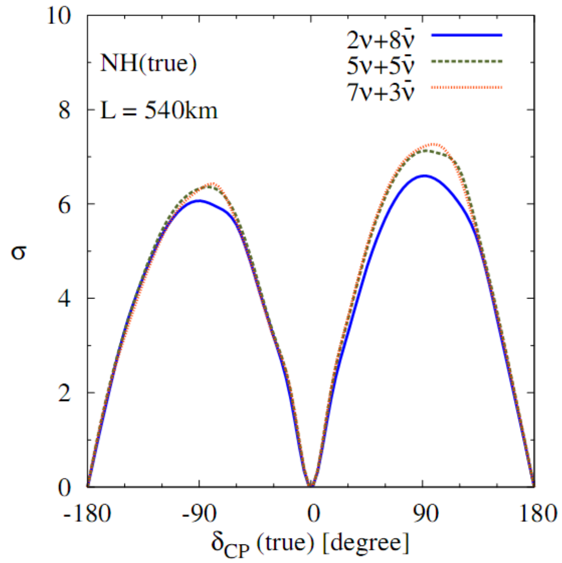
ESSνSB

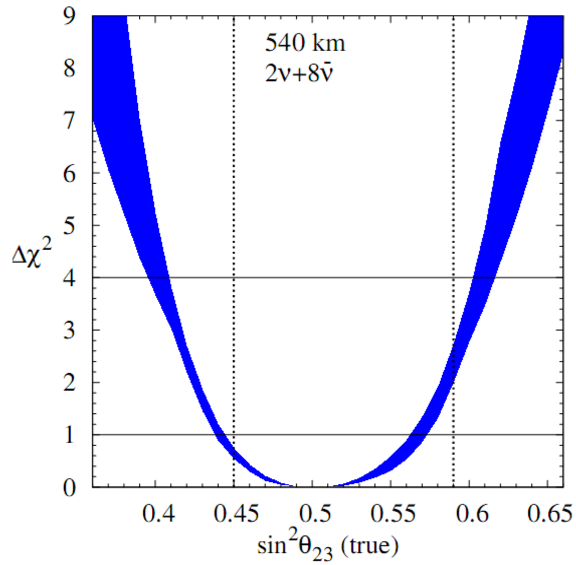




1406.2219: Agarwalla, Choubey, Prakash

ESSνSB





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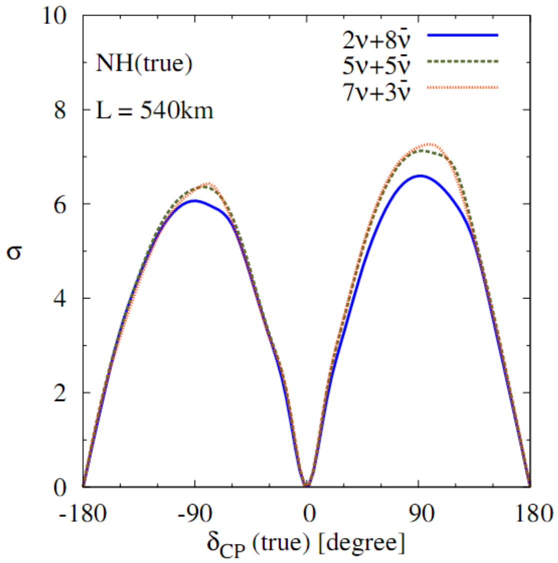
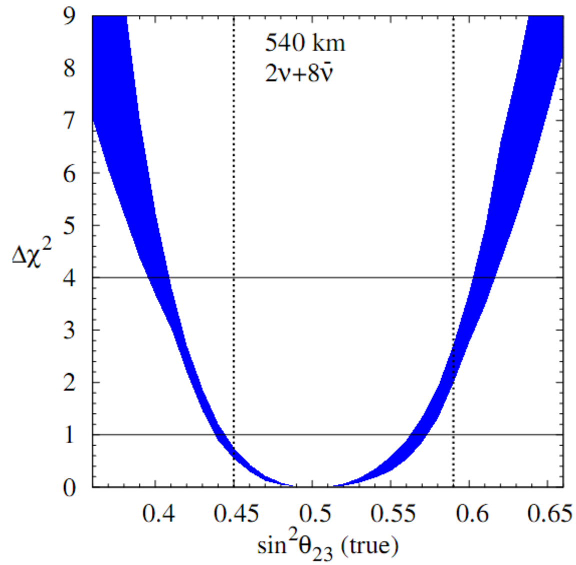
- Question 1: How will these results be affected by NSIs?
- Question 2: Can we use ESSνSB to measure NSIs?

ESSνSB





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- Question 1: How will these results be affected by NSIs?
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- We have written a GLoBES-compatible probability engine and used it in conjunction with MonteCUBES to simulate this experiment

Neutrino oscillations with NSIs

- Propagation NSIs are only relevant for large matter effects and high energy. Therefore we only consider source and detector NSIs here.

$$|\nu_\alpha^s\rangle = |\nu_\alpha\rangle + \sum_{\gamma=e,\mu,\tau} \varepsilon_{\alpha\gamma}^s |\nu_\gamma\rangle \quad ; \quad \langle\nu_\beta^d| = \langle\nu_\beta| + \sum_{\gamma=e,\mu,\tau} \varepsilon_{\beta\gamma}^d \langle\nu_\gamma|$$

- Since ESSνSB will only observe $\nu_\mu \rightarrow \nu_\mu$ and $\nu_\mu \rightarrow \nu_e$ channels, the relevant NSI parameters are

$$\begin{pmatrix} \varepsilon_{ee}^s & \varepsilon_{e\mu}^s & \varepsilon_{e\tau}^s \\ \varepsilon_{\mu e}^s & \varepsilon_{\mu\mu}^s & \varepsilon_{\mu\tau}^s \\ \varepsilon_{\tau e}^s & \varepsilon_{\tau\mu}^s & \varepsilon_{\tau\tau}^s \end{pmatrix} \quad ; \quad \begin{pmatrix} \varepsilon_{ee}^d & \varepsilon_{e\mu}^d & \varepsilon_{e\tau}^d \\ \varepsilon_{\mu e}^d & \varepsilon_{\mu\mu}^d & \varepsilon_{\mu\tau}^d \\ \varepsilon_{\tau e}^d & \varepsilon_{\tau\mu}^d & \varepsilon_{\tau\tau}^d \end{pmatrix}$$

Existing knowledge

$$|\varepsilon^{s}_{\mu e}| < 0.026 \quad , \quad |\varepsilon^{s}_{\mu\mu}| < 0.078 \quad , \quad |\varepsilon^{s}_{\mu\tau}| < 0.013$$

$$|\varepsilon^{d}_{ee}| < 0.041 \quad , \quad |\varepsilon^{d}_{\mu e}| < 0.025 \quad , \quad |\varepsilon^{d}_{\tau e}| < 0.041$$

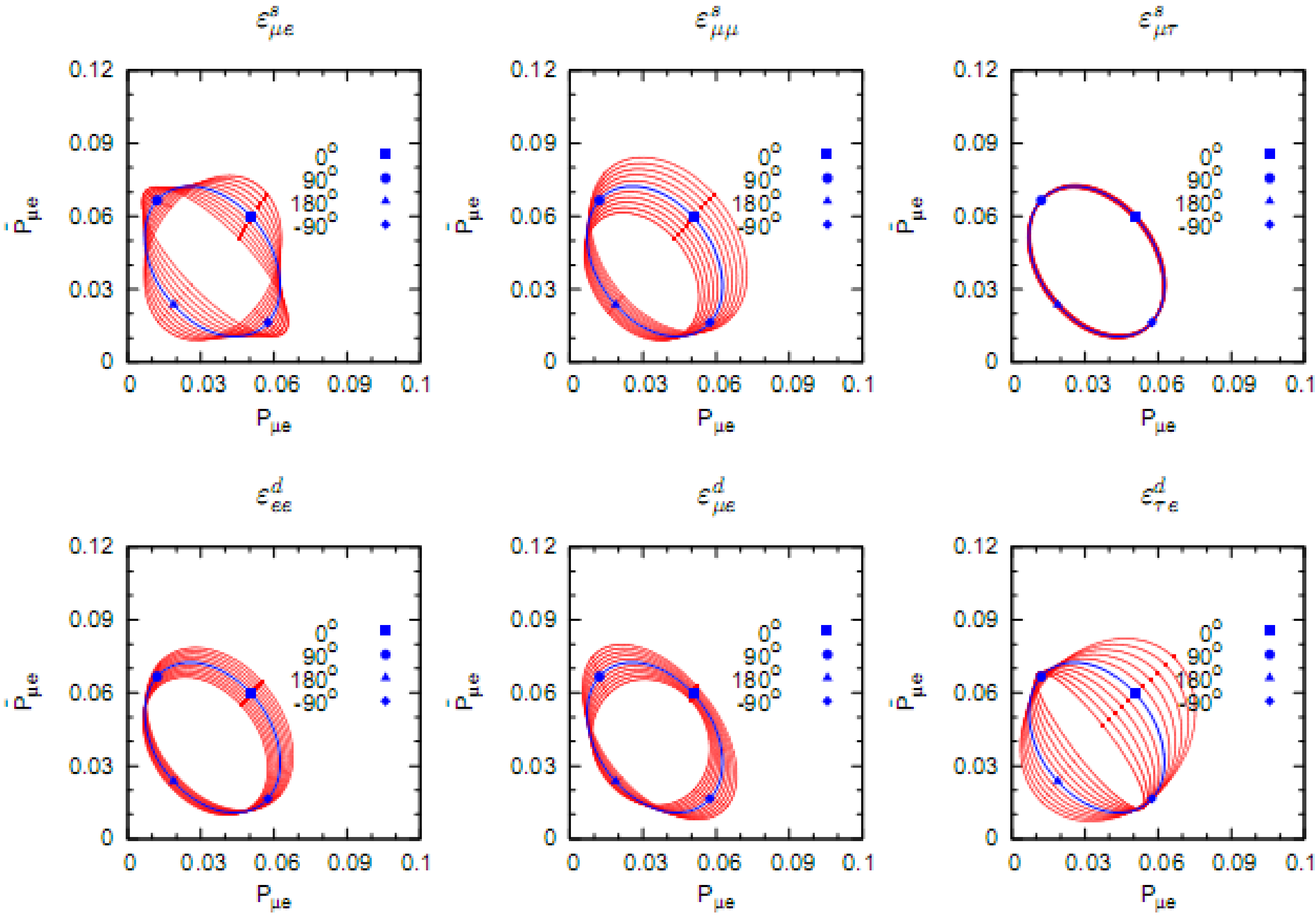
$$|\varepsilon^{d}_{e\mu}| < 0.026 \quad , \quad |\varepsilon^{d}_{\mu\mu}| < 0.078 \quad , \quad |\varepsilon^{d}_{\tau\mu}| < 0.013$$

0907.0097: Biggio, Blennow, Fernandez-Martinez

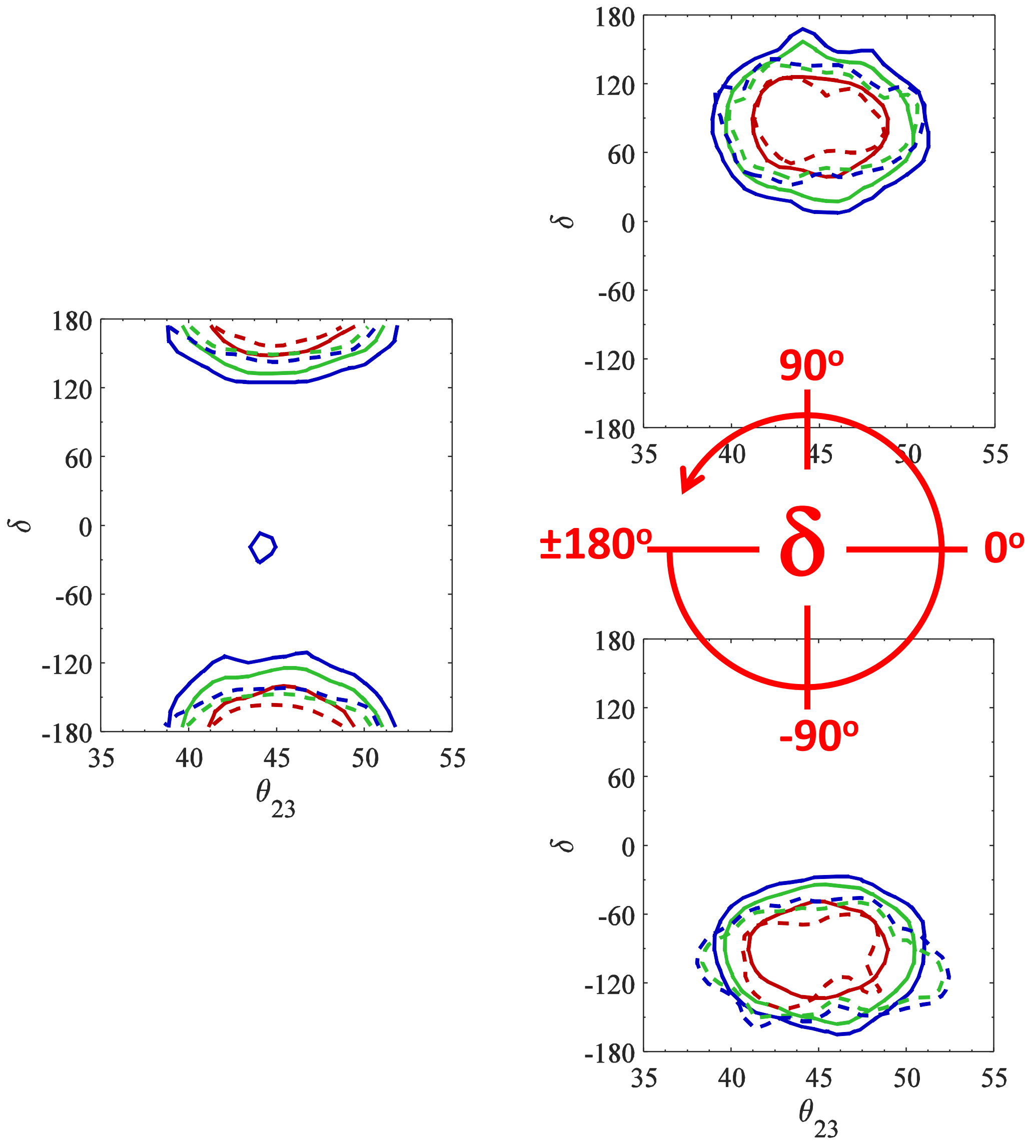
For a physical understanding of the oscillations, we refer to the analytical expressions in the presence of NSIs

0708.0152: Kopp, Lindner, Ota, Sato

Interplay of NSI parameters with δ



Results

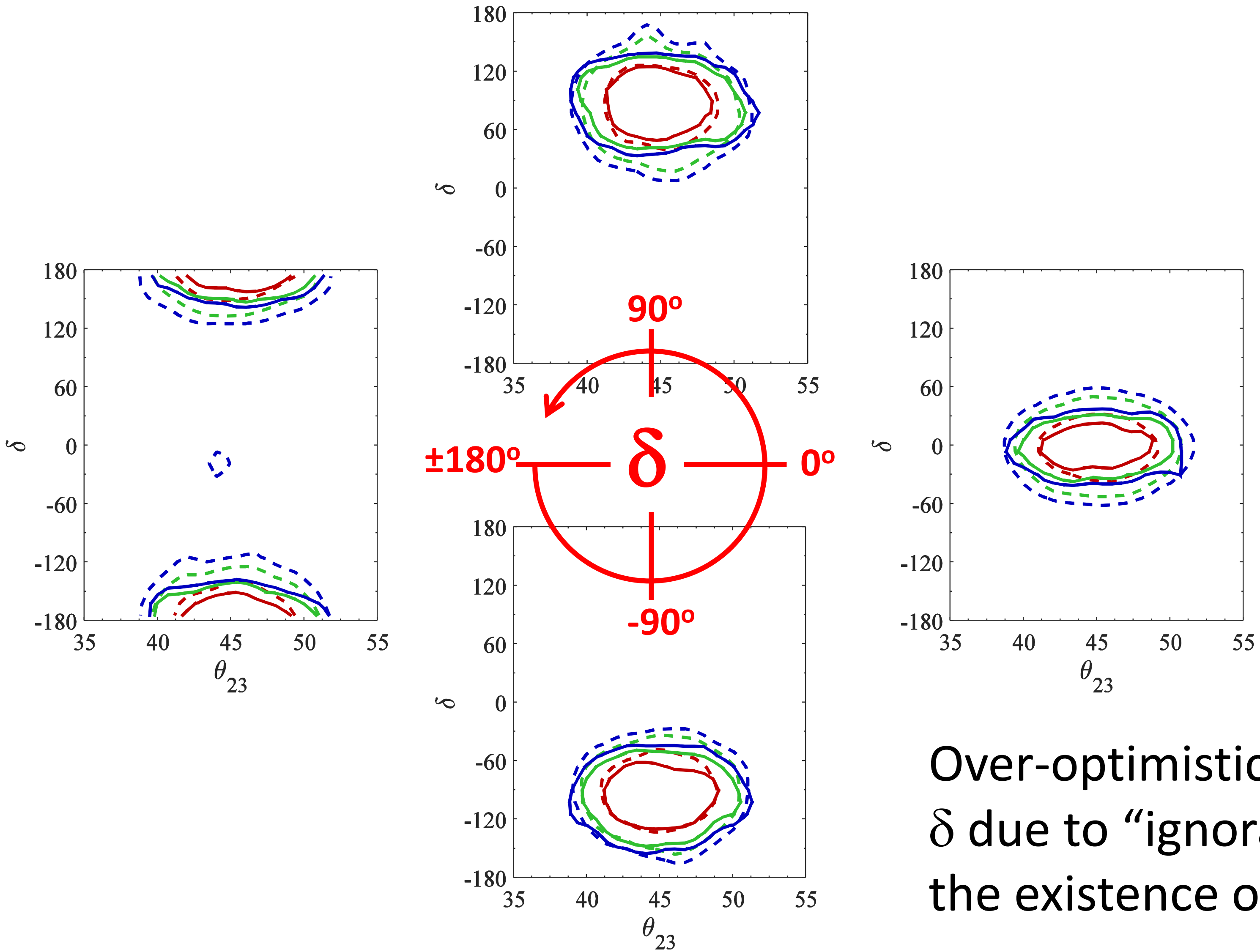


Worsening of δ-precision because of NSIs

Results

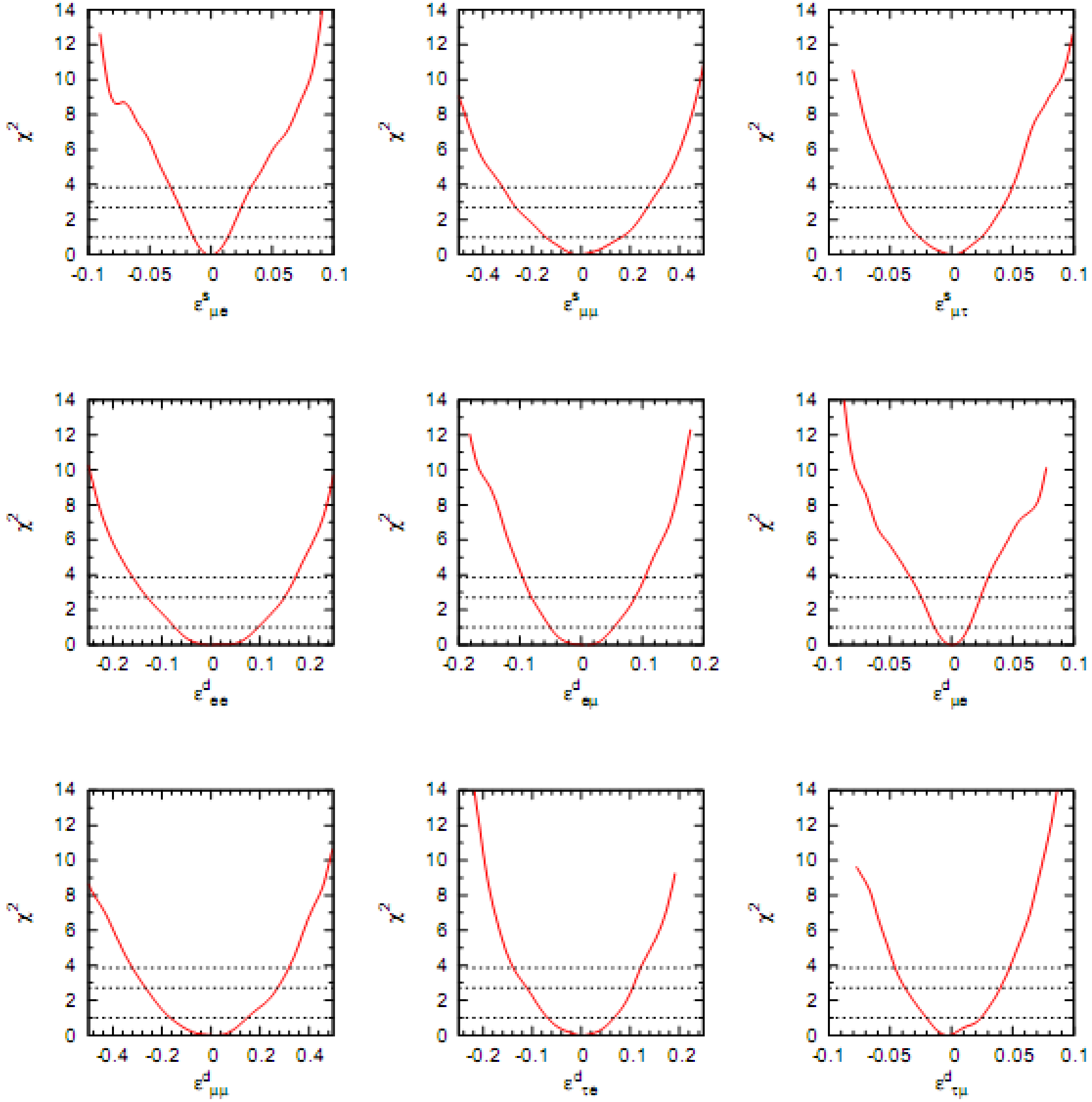
- Salient features:
  - Same features seen across all θ_{23}
  - θ_{23}-precision is largely unaffected by NSIs
  - Worsening of δ -precision is most for δ =180
  - Worsening of precision is at most twice as bad: The measurement of δ at ESSνSB is quite robust against NSIs

Results



Over-optimistic precision in δ due to "ignorance" about the existence of NSIs

Results

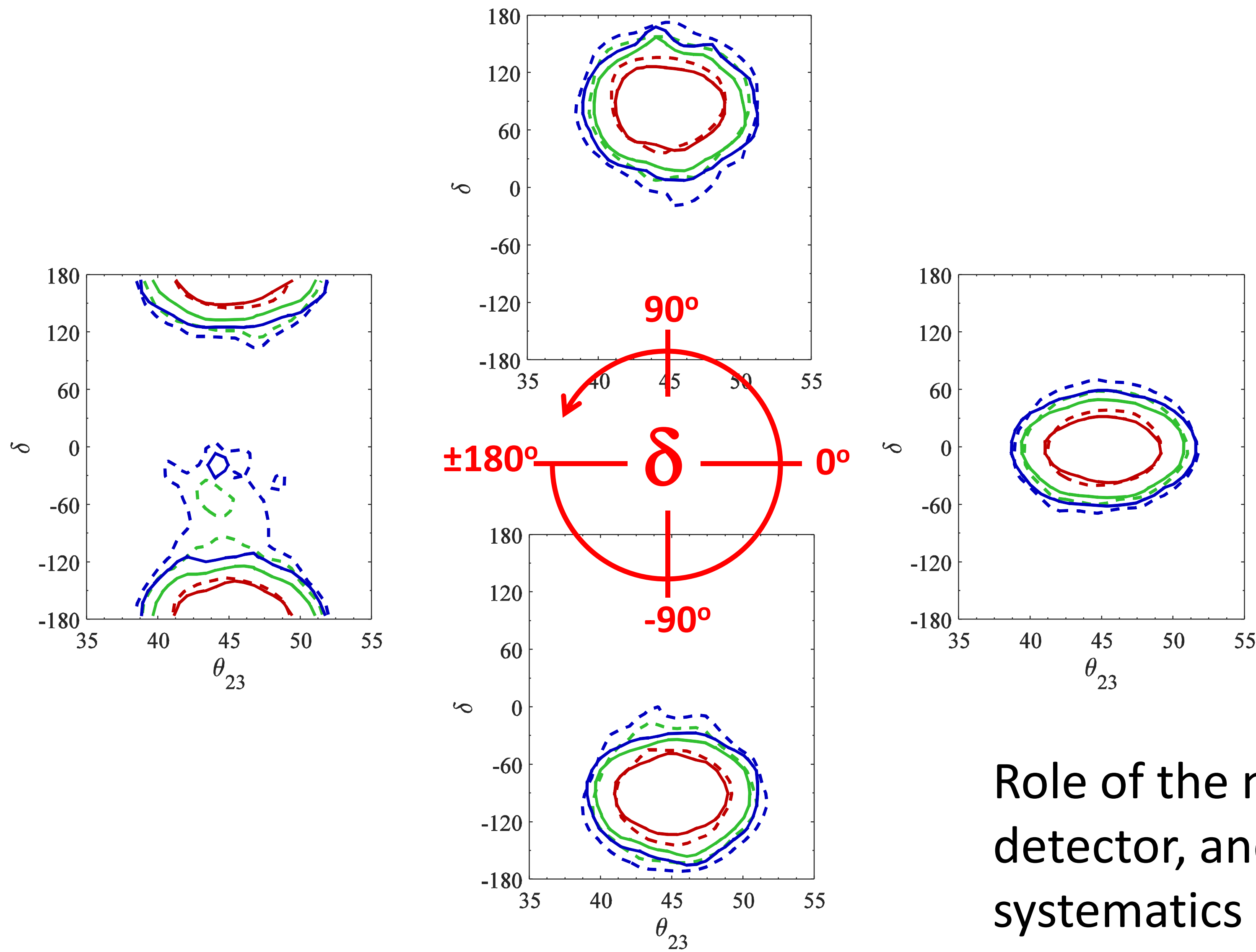


Limits on NSI parameters from ESSνSB

Results

Parameter	Realistic limits	Optimistic limits	Existing limits
$\varepsilon^{s}_{\mu e}$	(-0.024,0.025)	(-0.014,0.013)	0.026
$\varepsilon^{s}_{\mu\mu}$	(-0.27,0.27)	(-0.25,0.27)	0.078
$\varepsilon^{s}_{\mu\tau}$	(-0.040,0.040)	(-0.040,0.037)	0.013
ε^{d}_{ee}	(-0.13,0.15)	(-0.13,0.15)	0.041
$\varepsilon^{d}_{e\mu}$	(-0.080,0.087)	(-0.082,0.082)	0.026
$\varepsilon^{d}_{\mu e}$	(-0.025,0.024)	(-0.014,0.013)	0.025
$\varepsilon^{d}_{\mu\mu}$	(-0.27,0.28)	(-0.27,0.25)	0.078
$\varepsilon^{d}_{\tau e}$	(-0.11,0.10)	(-0.11,0.12)	0.041
$\varepsilon^{d}_{\tau\mu}$	(-0.038,0.040)	(-0.033,0.029)	0.013

Results



Role of the near detector, and systematics

Conclusions

- Worsening of precision in δ due to presence of NSIs is at most by a factor of 2, i.e. The measurement of δ at ESSνSB is rather robust to the presence of NSIs
- Not accounting for NSIs gives a slightly over-optimistic precision in δ
- ESSνSB can impose strong bounds on $\varepsilon^{s}_{\mu e}$ and $\varepsilon^{d}_{\mu e}$, which are stronger than current bounds
- Using the near detector improves the precision in δ