NOW 2006

Comparison of the C2M* and T2HK LBL experiments

Thomas Schwetz

SISSA, Trieste

based on J.-E. Campagne, M. Maltoni, M. Mezzetto, T.S., hep-ph/0603172 (v2)

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*CERN-to-MEMPHYS

Introduction

Neutrino oscillation physics is entering the era of long-baseline experiments:

- **K2K** (finished)
- **MINOS**, **CNGS** (running)
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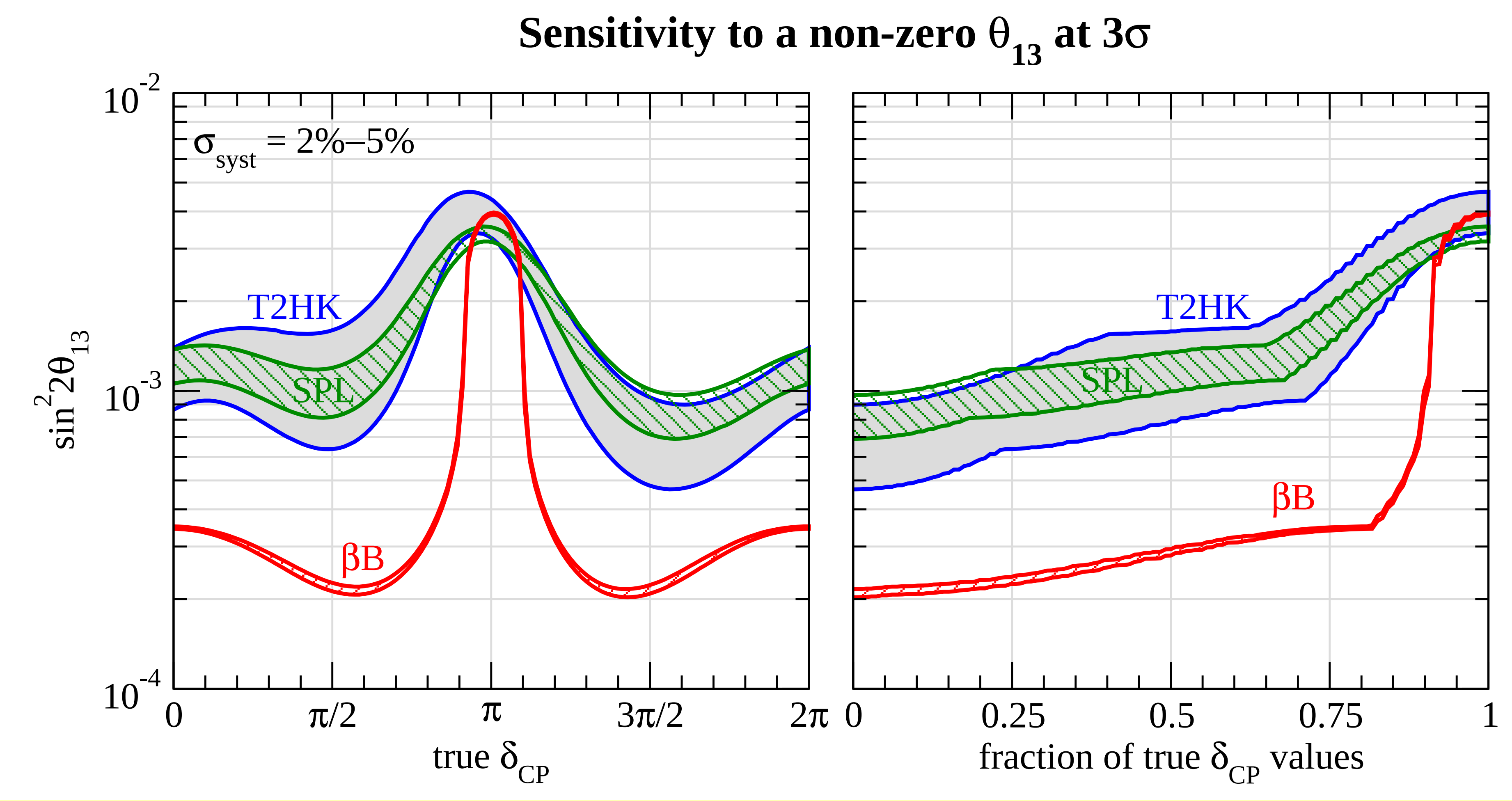
What will be the best option for the next step?

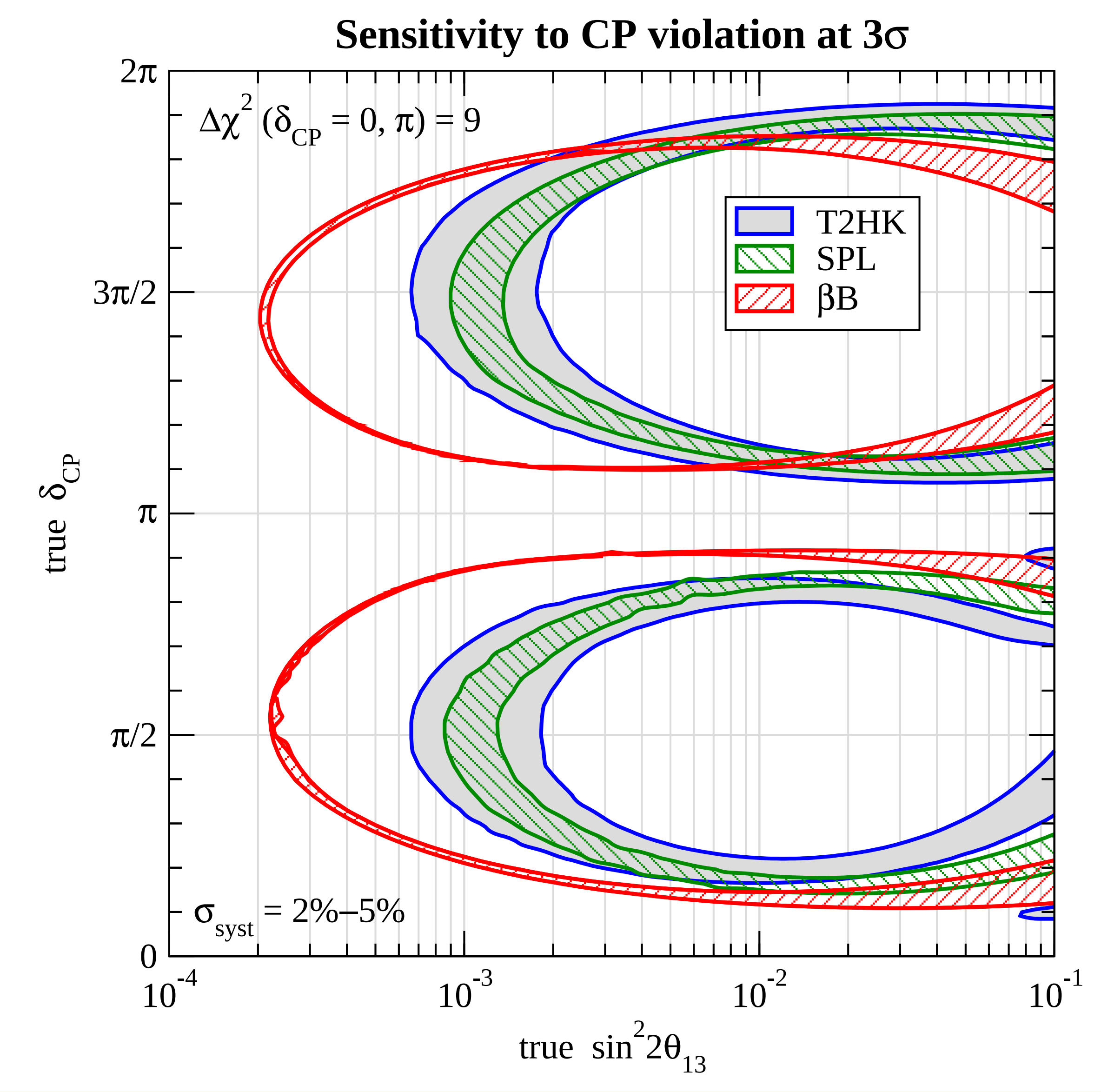
Three options for future LBL exps

	β**B**	**SPL**	**T2HK**
Baseline:	130 km (CERN-Frejus)		295 km (Tokai-Kamioka)
WC Detector:	MEMPHYS (440 kt)		Hyper-K (440 kt)
$\langle E_\nu \rangle$:	400 MeV	300 MeV	760 MeV
Channel:	$\overset{(-)}{\nu}_e \longrightarrow \overset{(-)}{\nu}_\mu$	$\overset{(-)}{\nu}_\mu \longrightarrow \overset{(-)}{\nu}_e$	
Time $(\nu + \bar{\nu})$:	5 + 5 y	2 + 8 y	
Beam:	$\begin{smallmatrix} 5.8 \\ 2.2 \end{smallmatrix}\ 10^{18}\ \begin{smallmatrix} \mathrm{He} \\ \mathrm{Ne} \end{smallmatrix}$ dcy/y	4 MW	
Systematics:	2%–5% uncertainty on signal & background		

Sensitivity to θ_{13}



CP violation



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The most relevant systematic is the uncertainty on the background:

$$\frac{\text{systematical}}{\text{statistical}} = \frac{\sigma_{\text{BG}} B}{\sqrt{B}} = \sigma_{\text{BG}} \sqrt{B}$$

experiment becomes systematics dominated for $\sigma_{\text{BG}} \gtrsim 1/\sqrt{B}$

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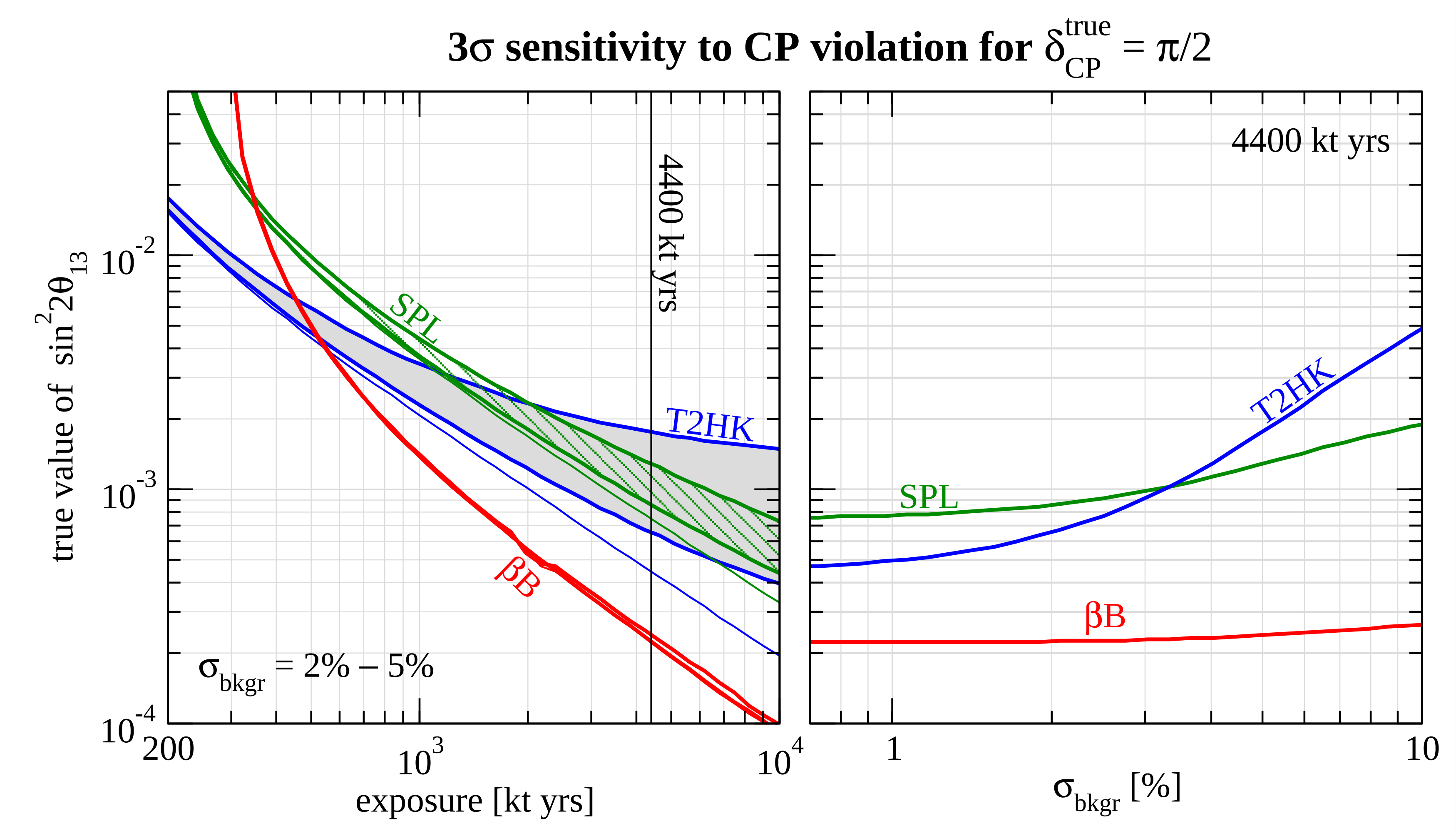
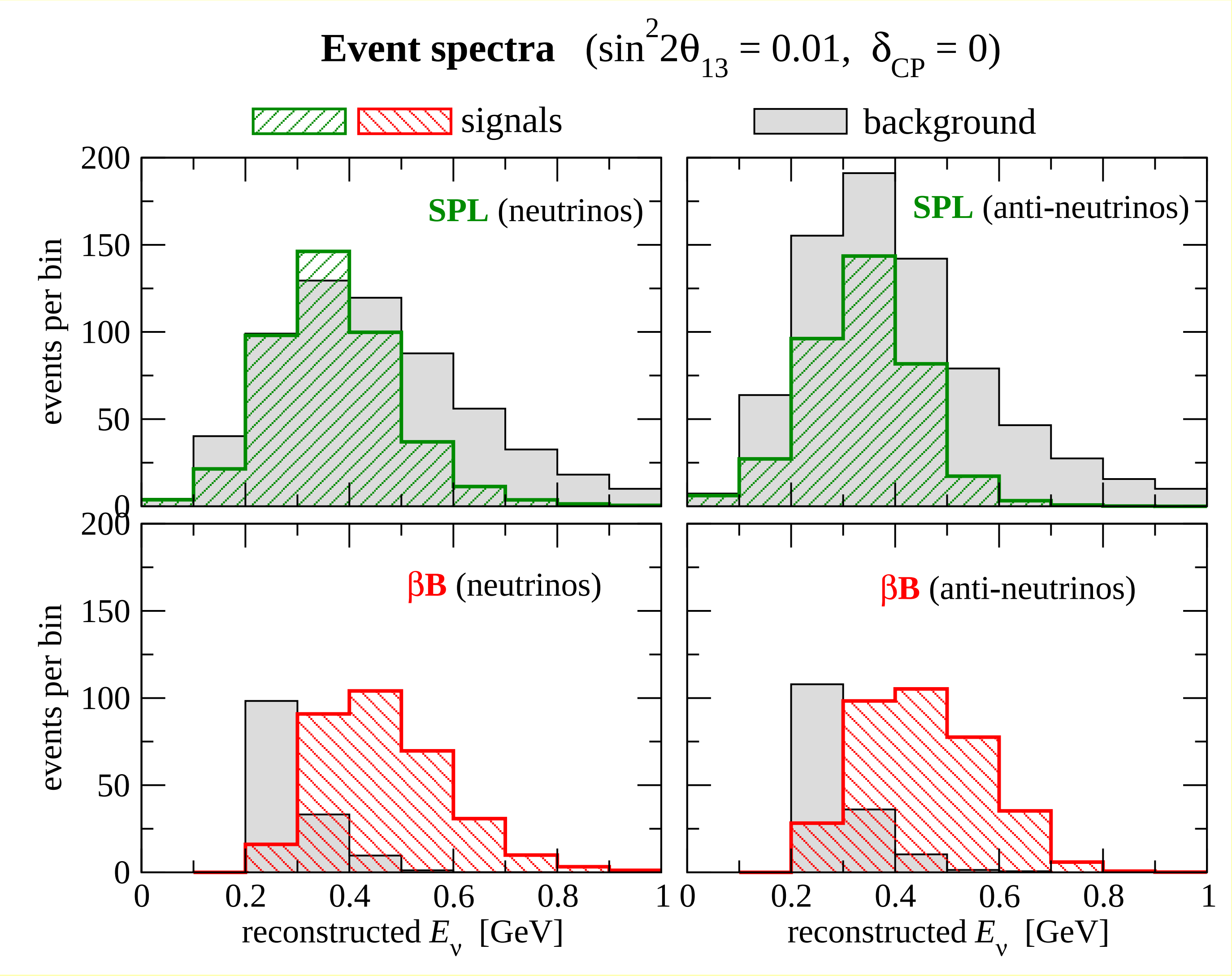
	β**B**	**SPL**	**T2HK**
$B\,(\nu + \bar{\nu})$	300	1260	2400
$1/\sqrt{B}$	6%	3%	2%

The impact of systematics

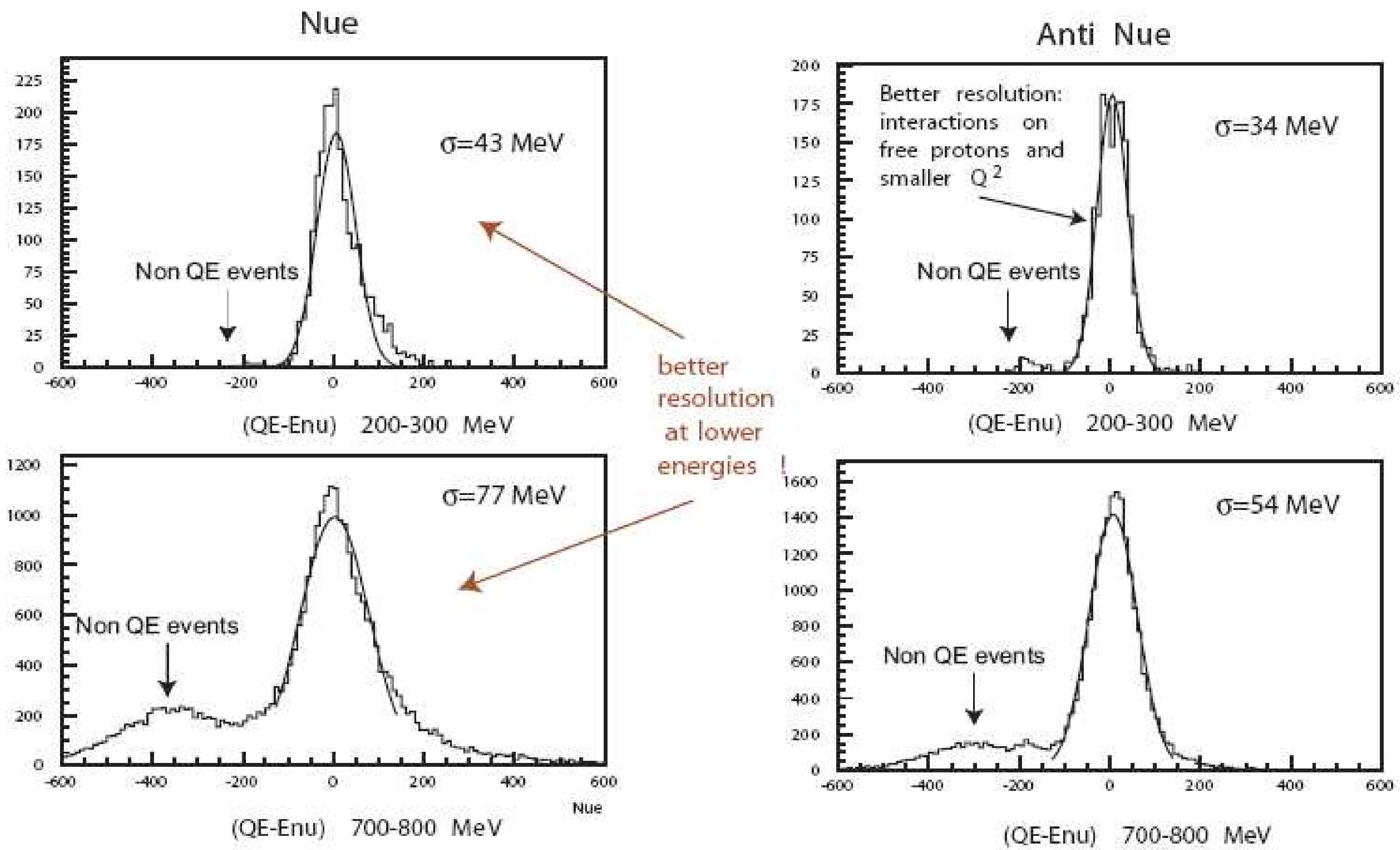


Energy shape is very important



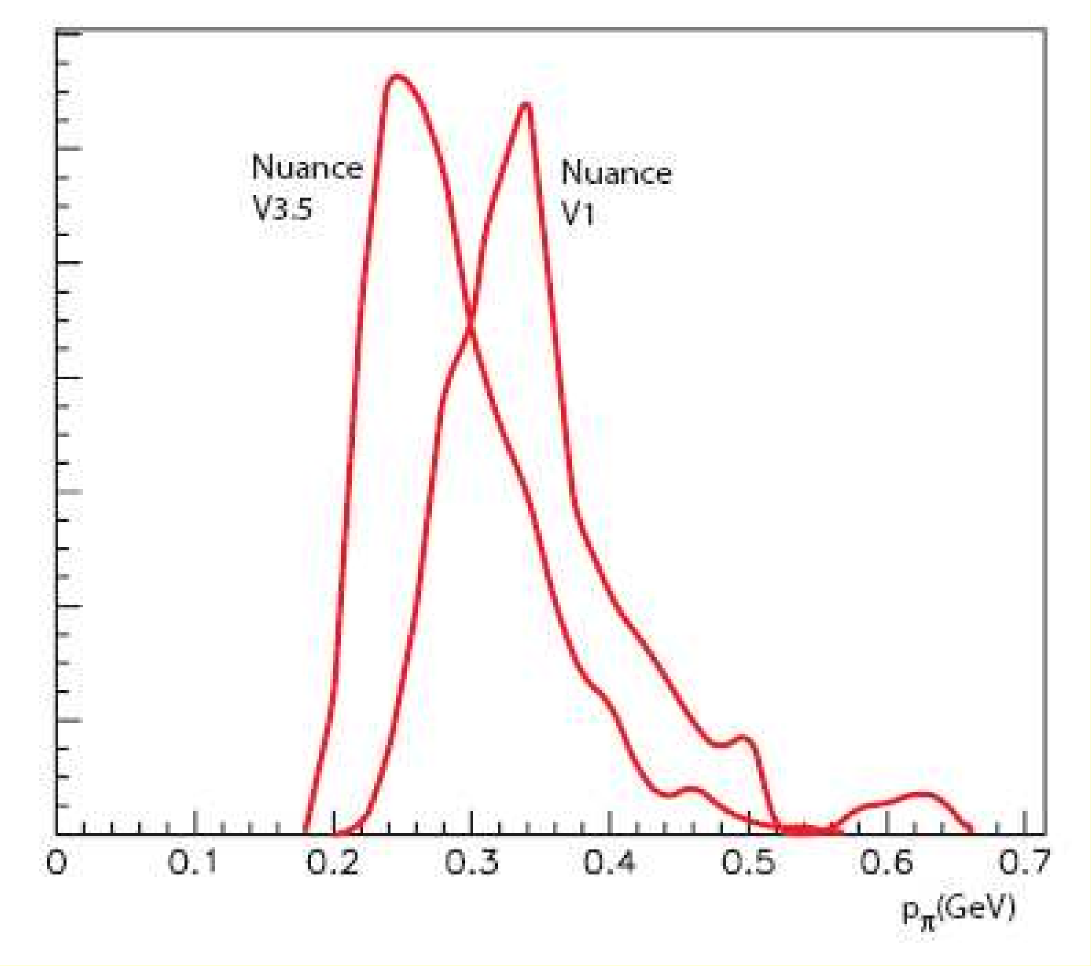
energy shape of BG is very different from signal for β**B**

Neutrino energy reconstruction (QE kinematics)



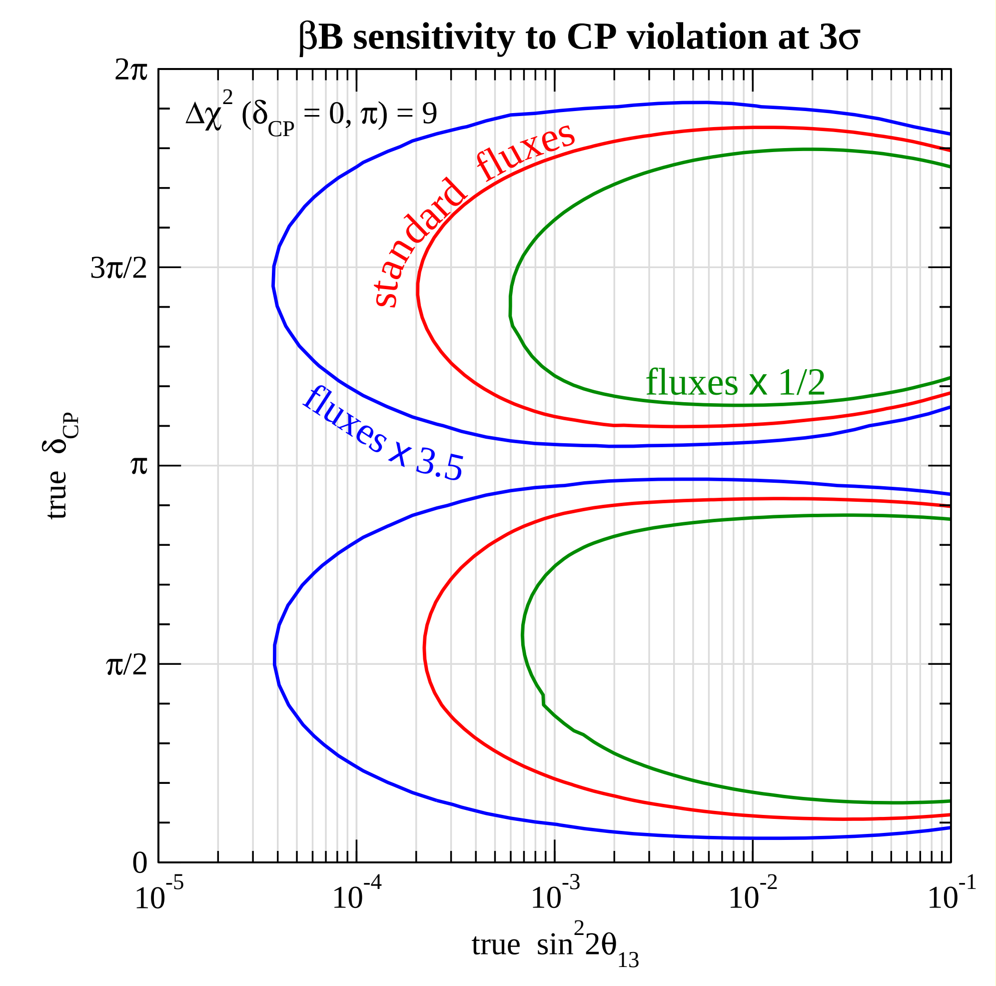
Below 0.5 GeV the energy resolution is optimal and the non QE contamination negligible.

Pion background in βB



makes a significant difference in the final sensitivity!!

βB-CPV sensitivity and number of ion decays

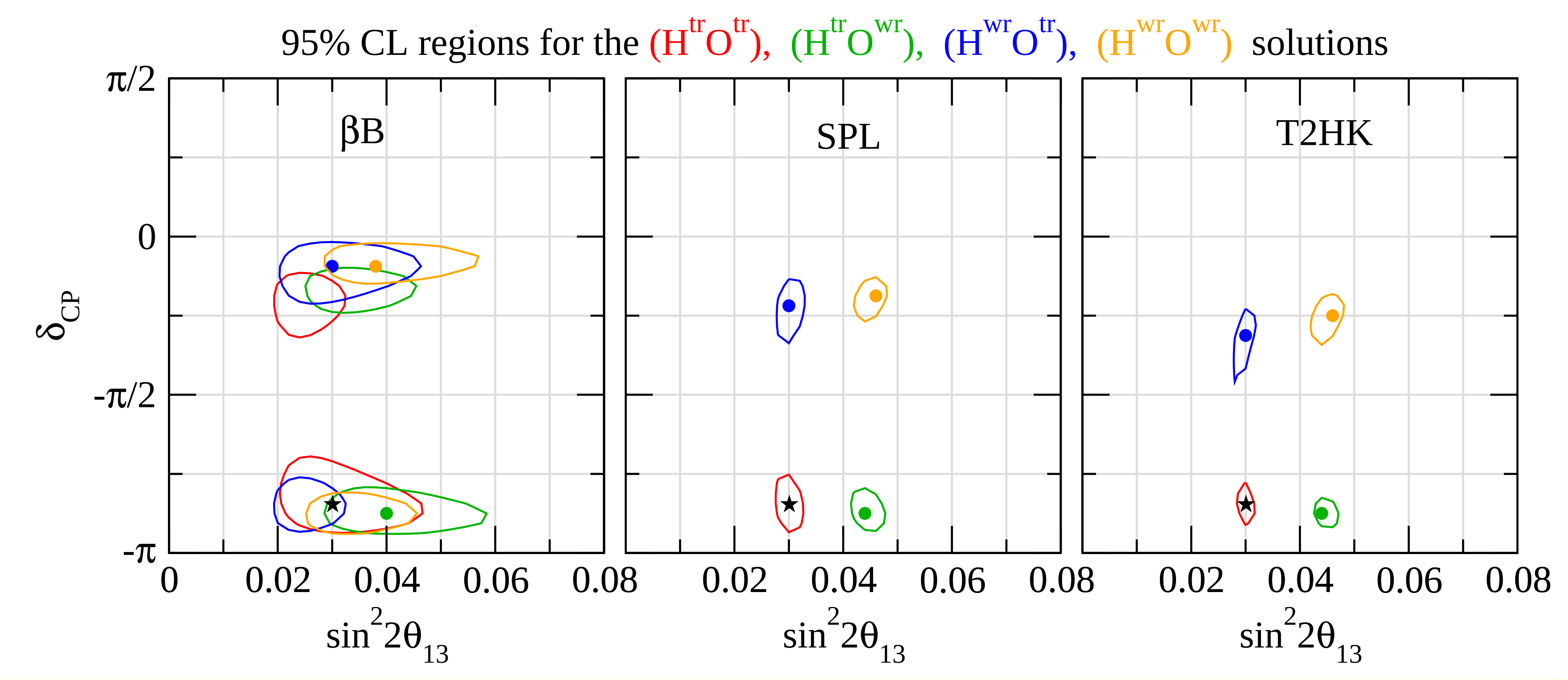


our "standard" fluxes: $5.8\,(2.2) \cdot 10^{18}$ He (Ne) dcys/yr

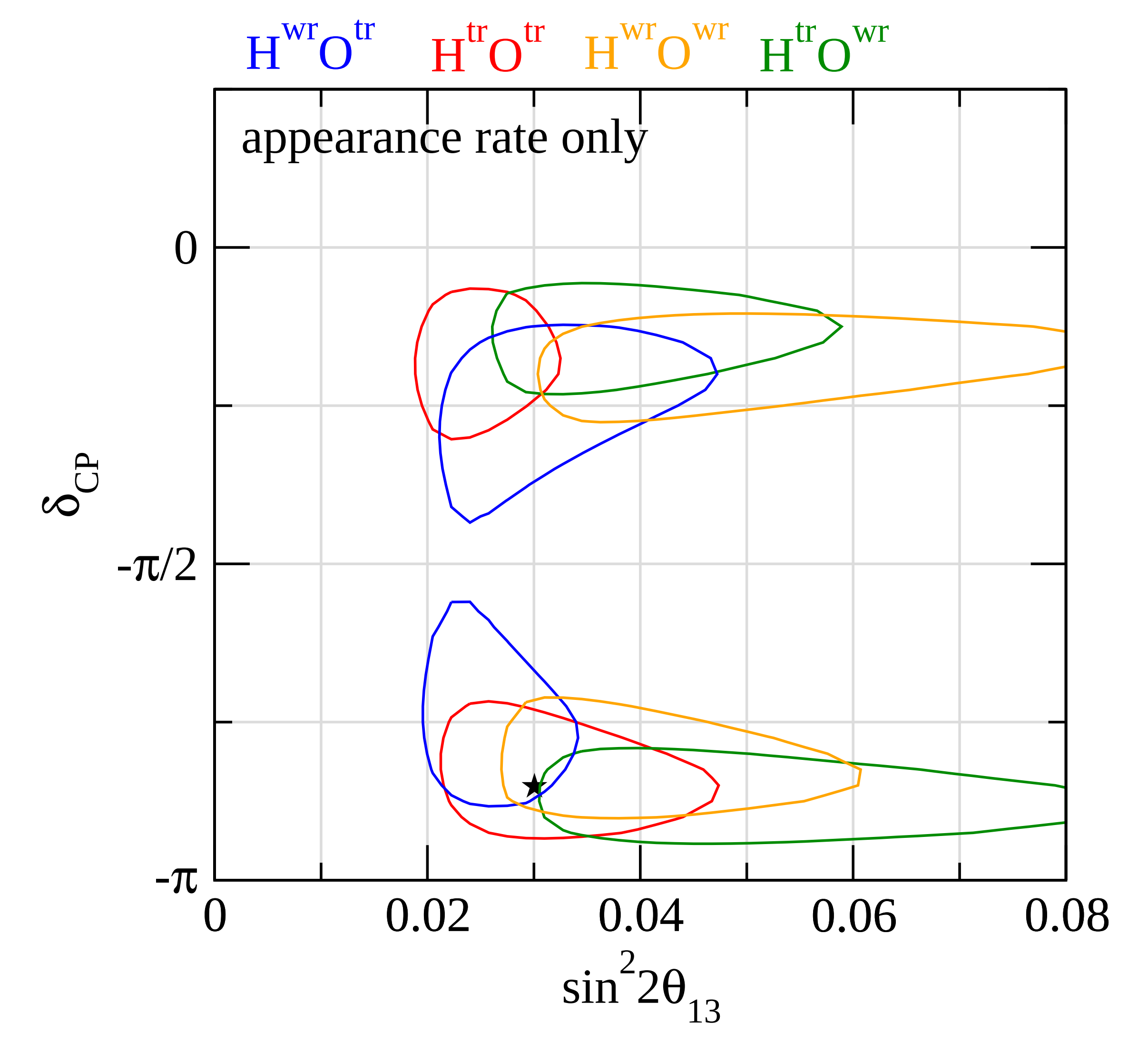
(twice the values of the EURISOL baseline design)

Parameter degeneracies

Degeneracies



Resolving degeneracies with SPL



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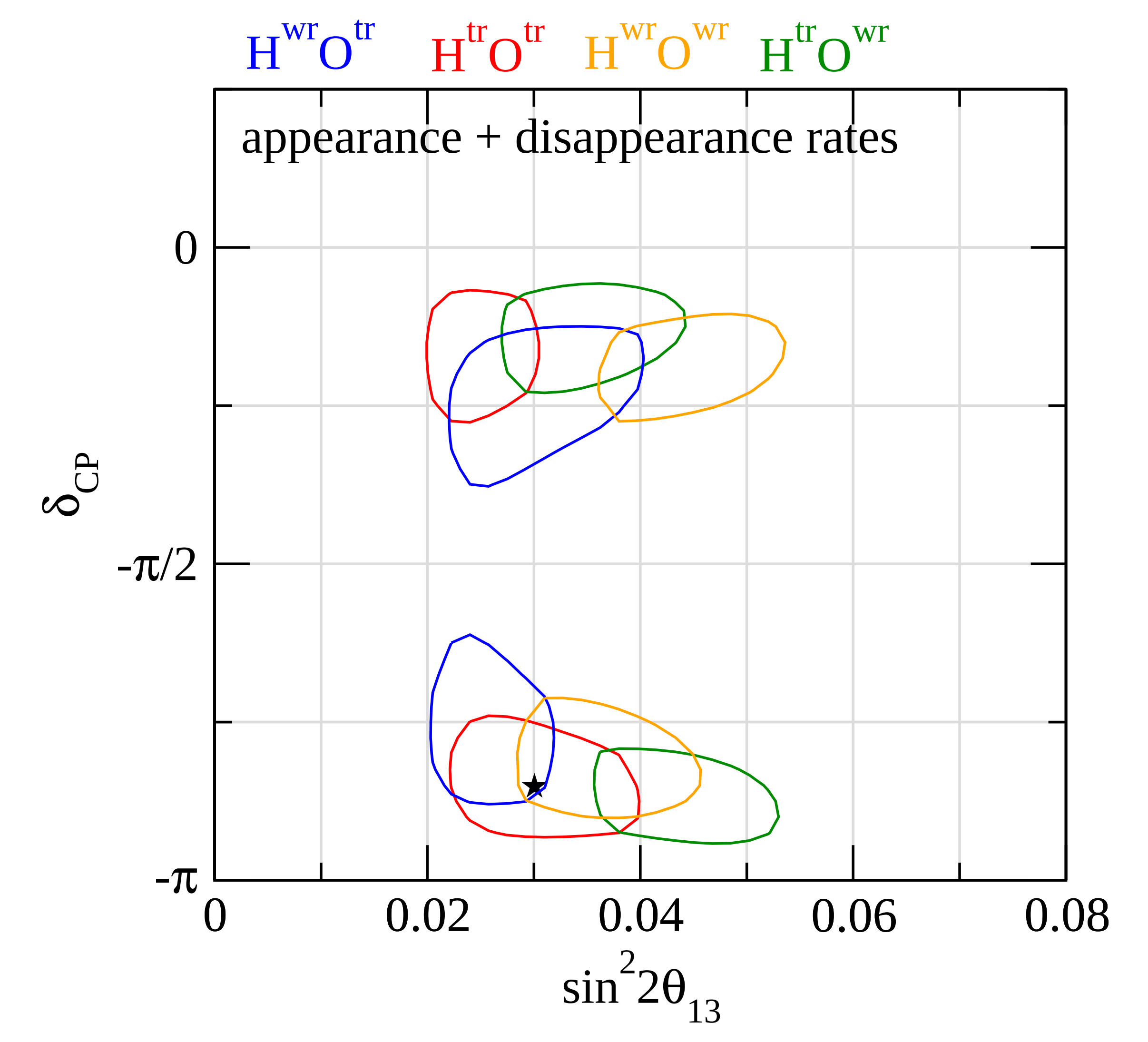

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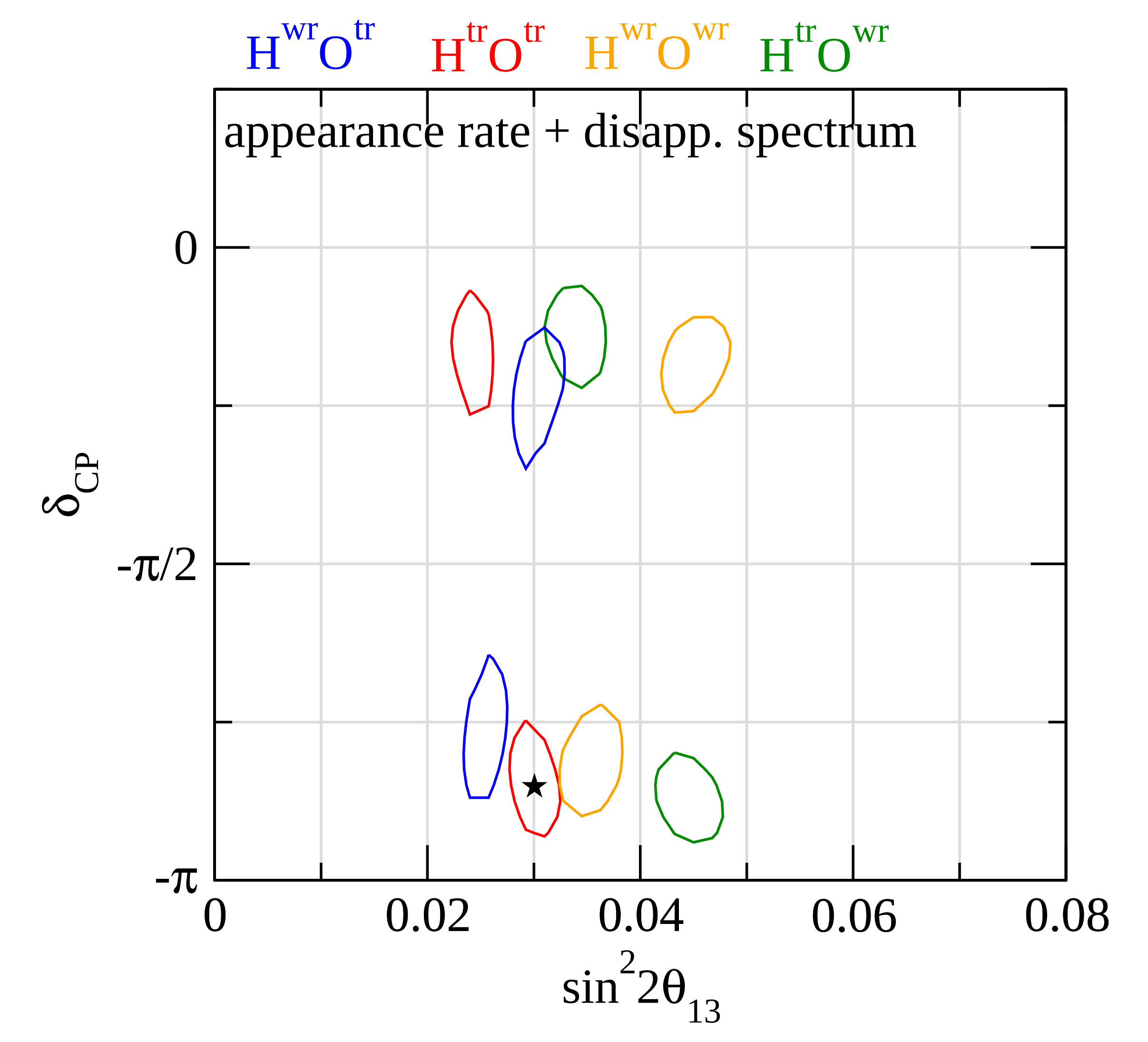

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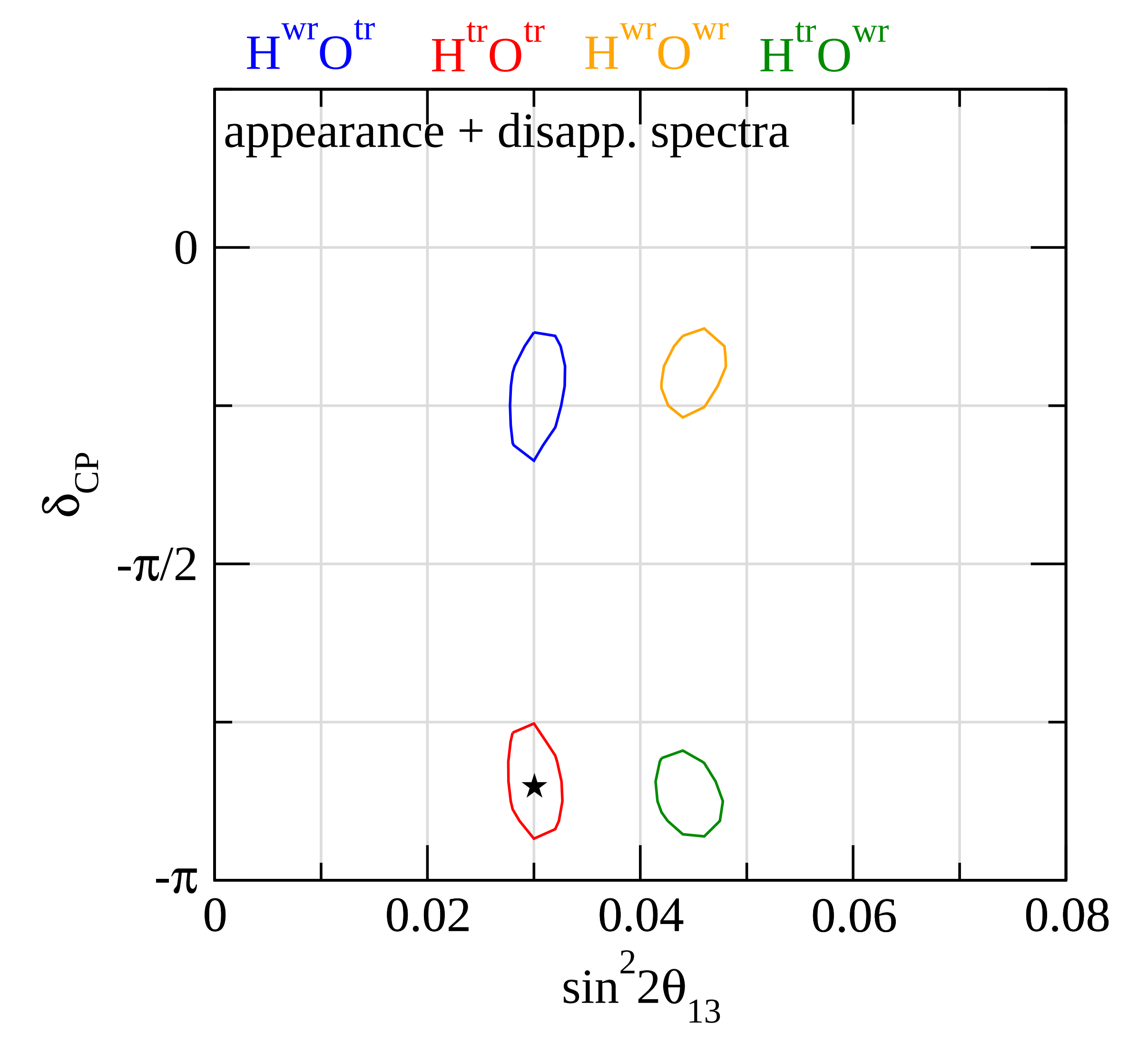

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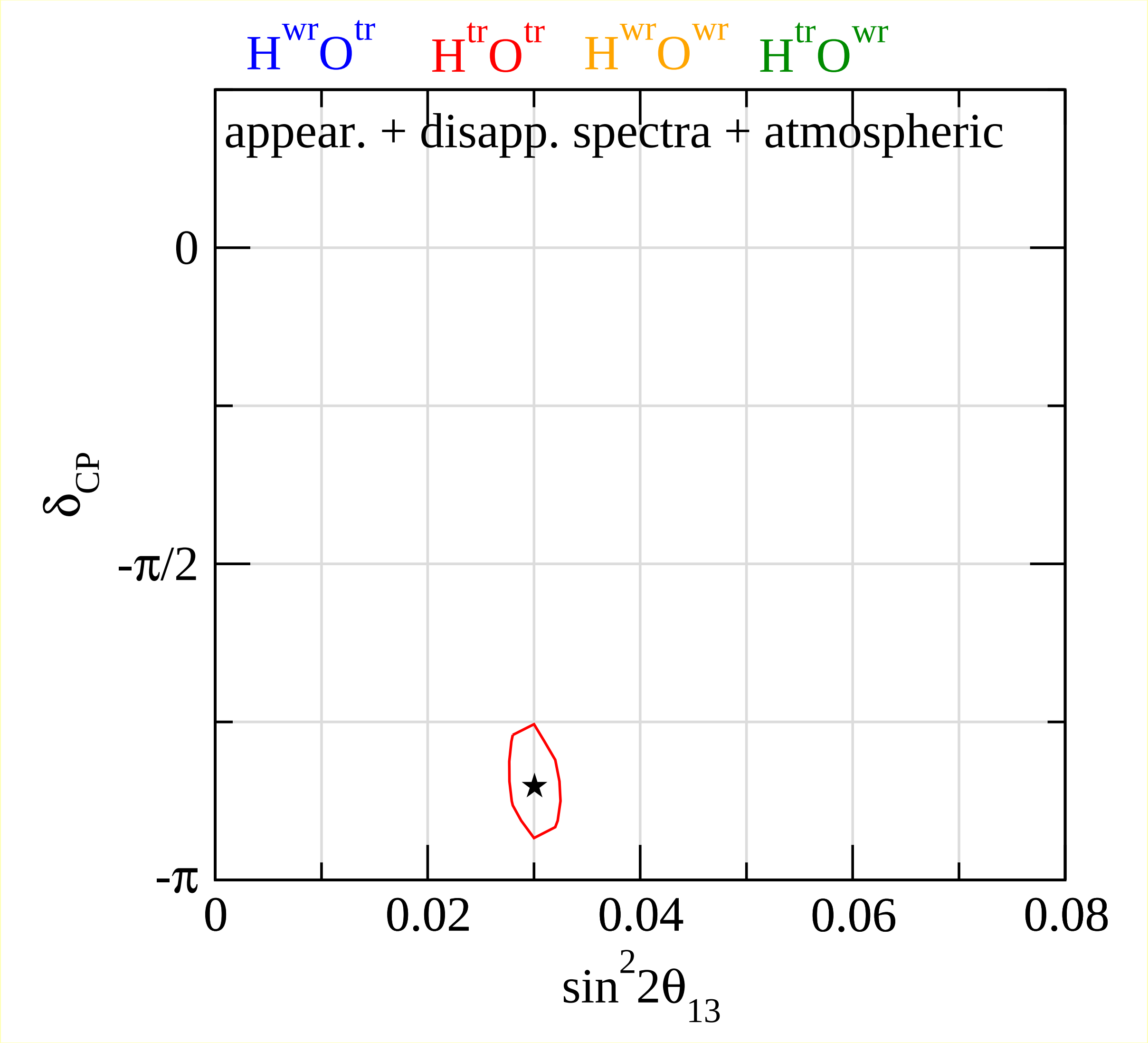
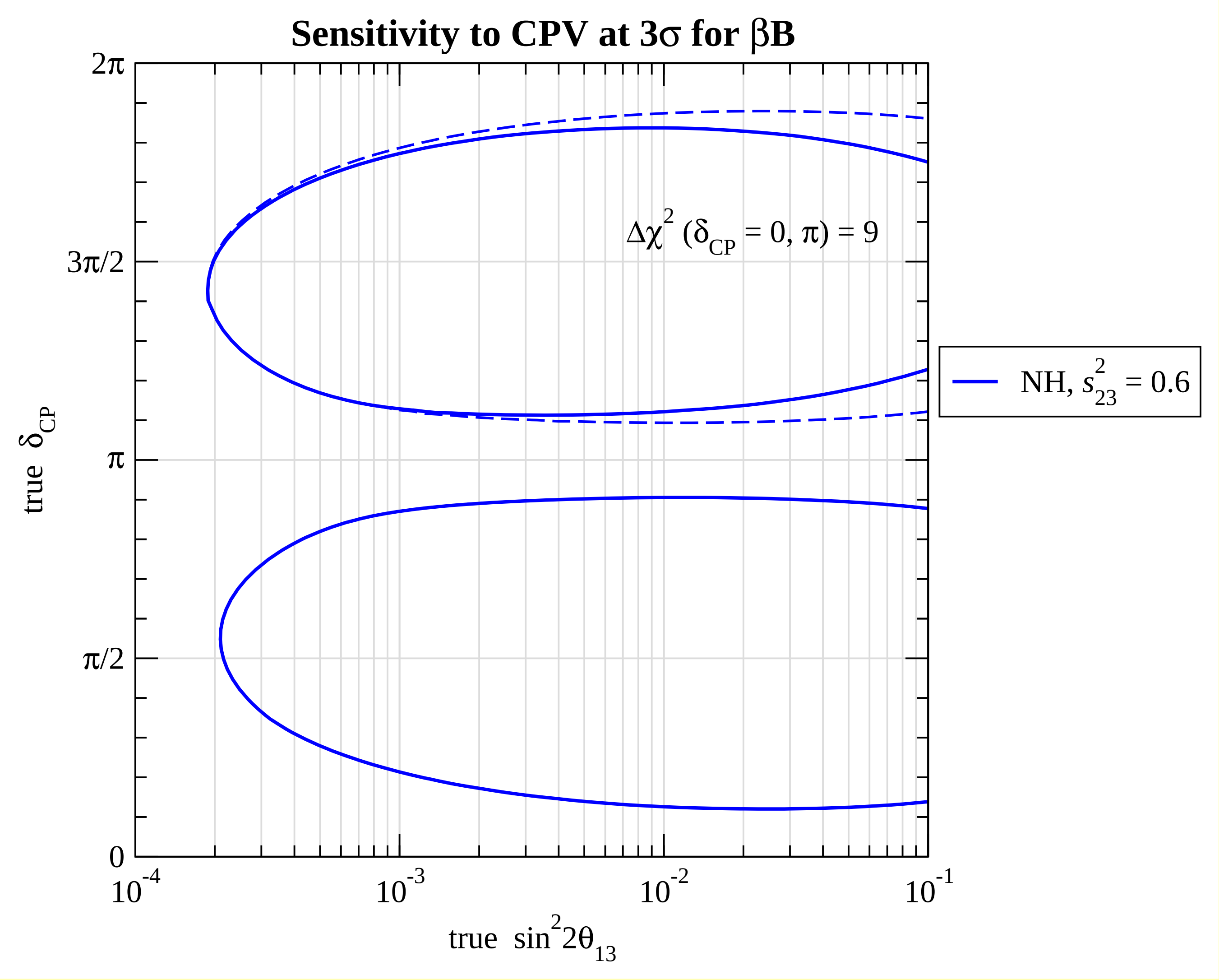
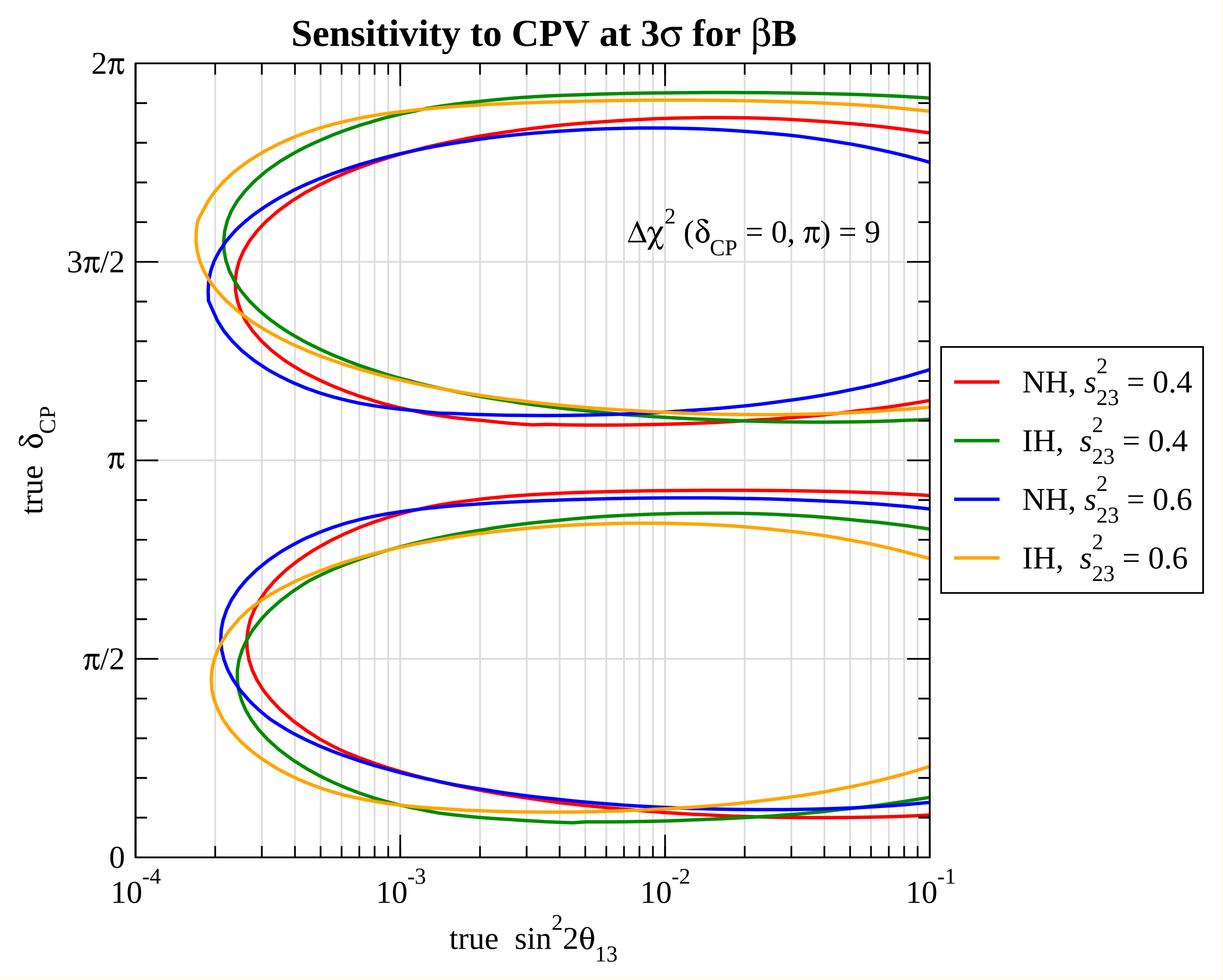


Fortunately degeneracies have a rather small impact on the CPV sensitivity . . .

Degeneracies and CPV at βB



Impact of the true values



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use atmospheric neutrino data in your Mt detector!

P. Huber, M. Maltoni, T.S., Phys. Rev. D71, 053006 (2005) [hep-ph/0501037]

Three-flavour effects in atmospheric ν

Thanks to the huge statistics there is sensitivity to sub-leading three flavour effects in ATM data:

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- $\theta_{13} > 0$ leads to resonant matter effect for core-crossing neutrinos (multi-GeV energies) sensitivity to the mass hierarchy

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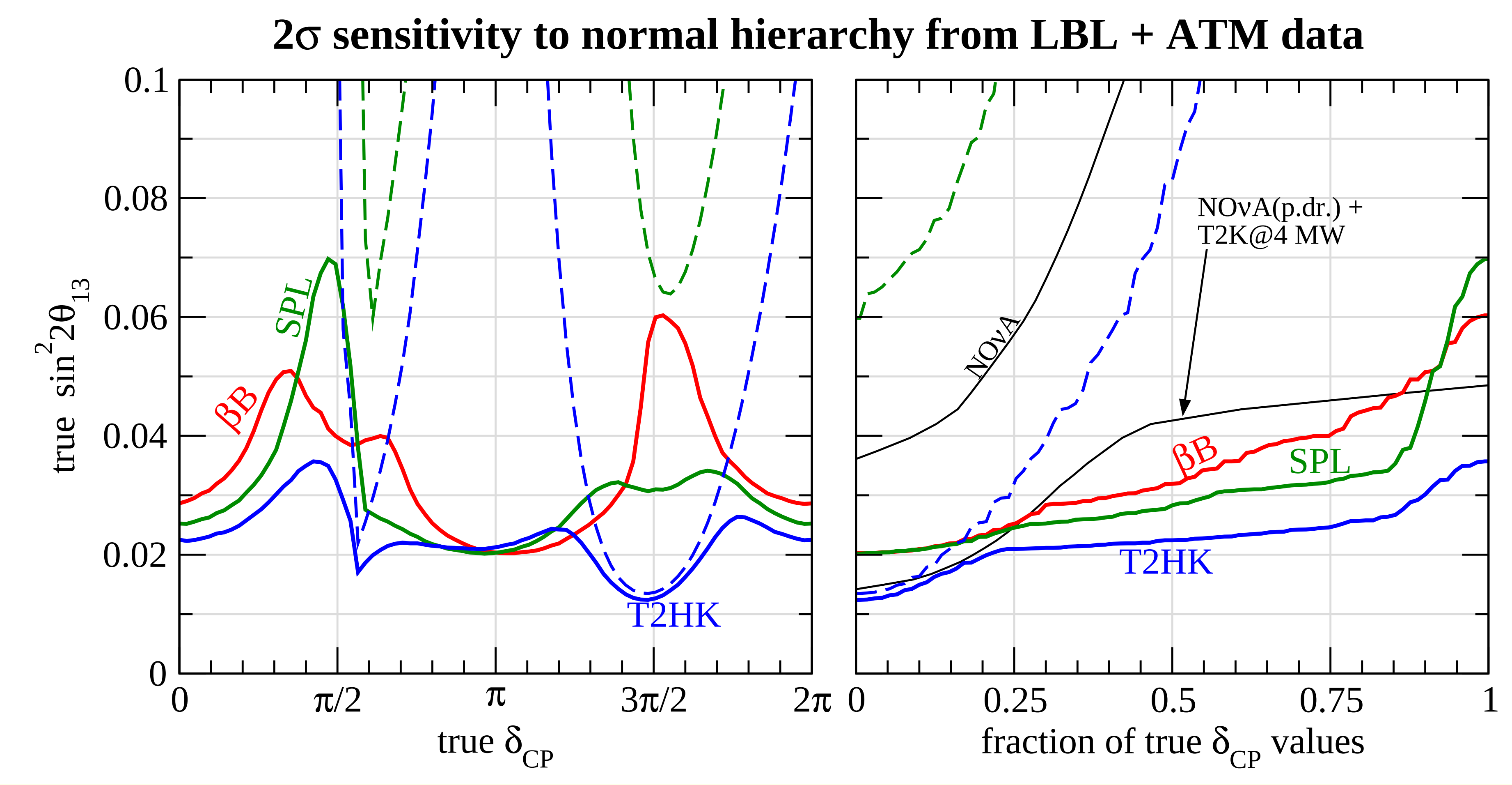
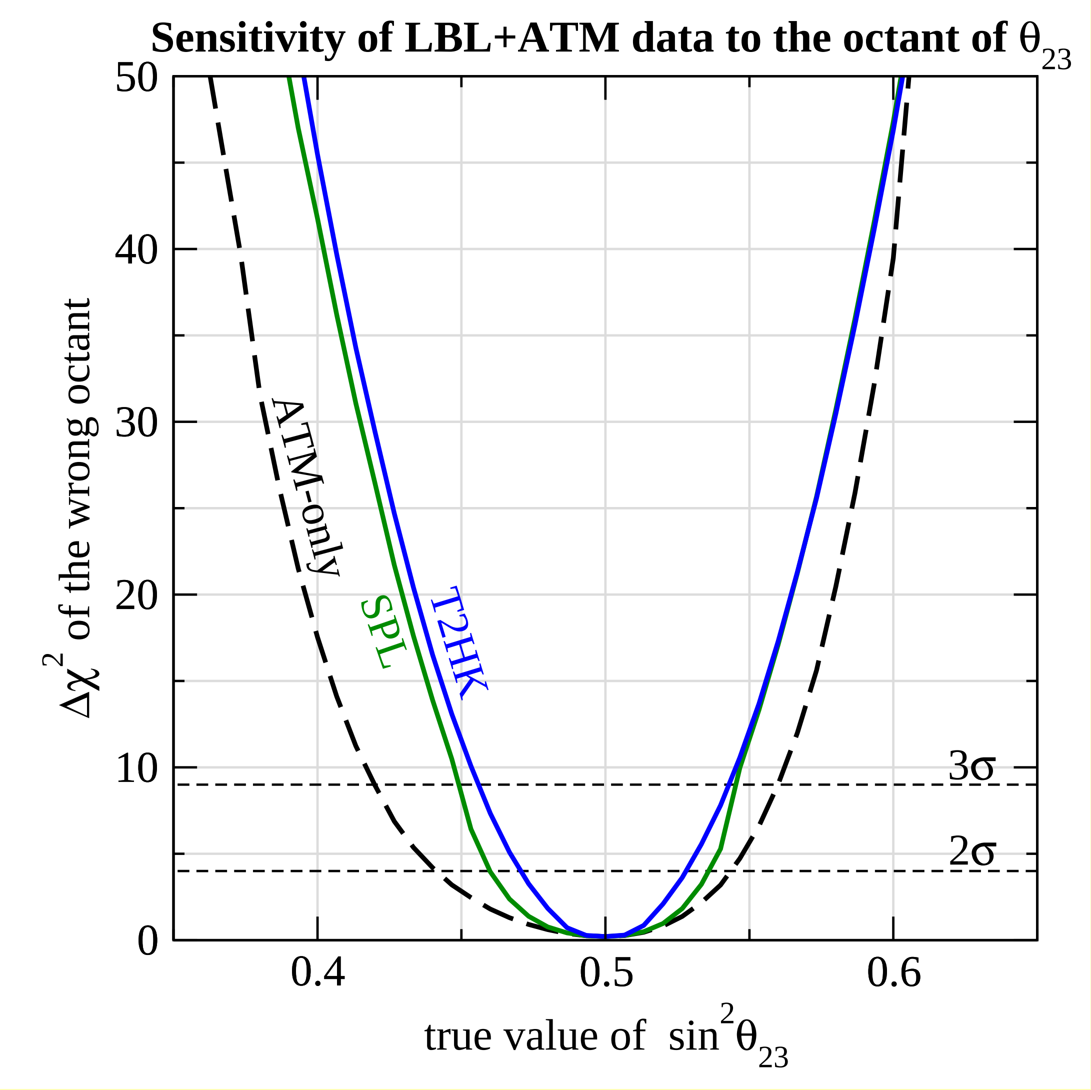
- $\theta_{13} > 0$ leads to resonant matter effect for core-crossing neutrinos (multi-GeV energies) sensitivity to the mass hierarchy
- effects of the solar Δm^2_{21} provides sensitivity to the octant of θ_{23} (sub-GeV)

Sensitivity to the mass hierarchy

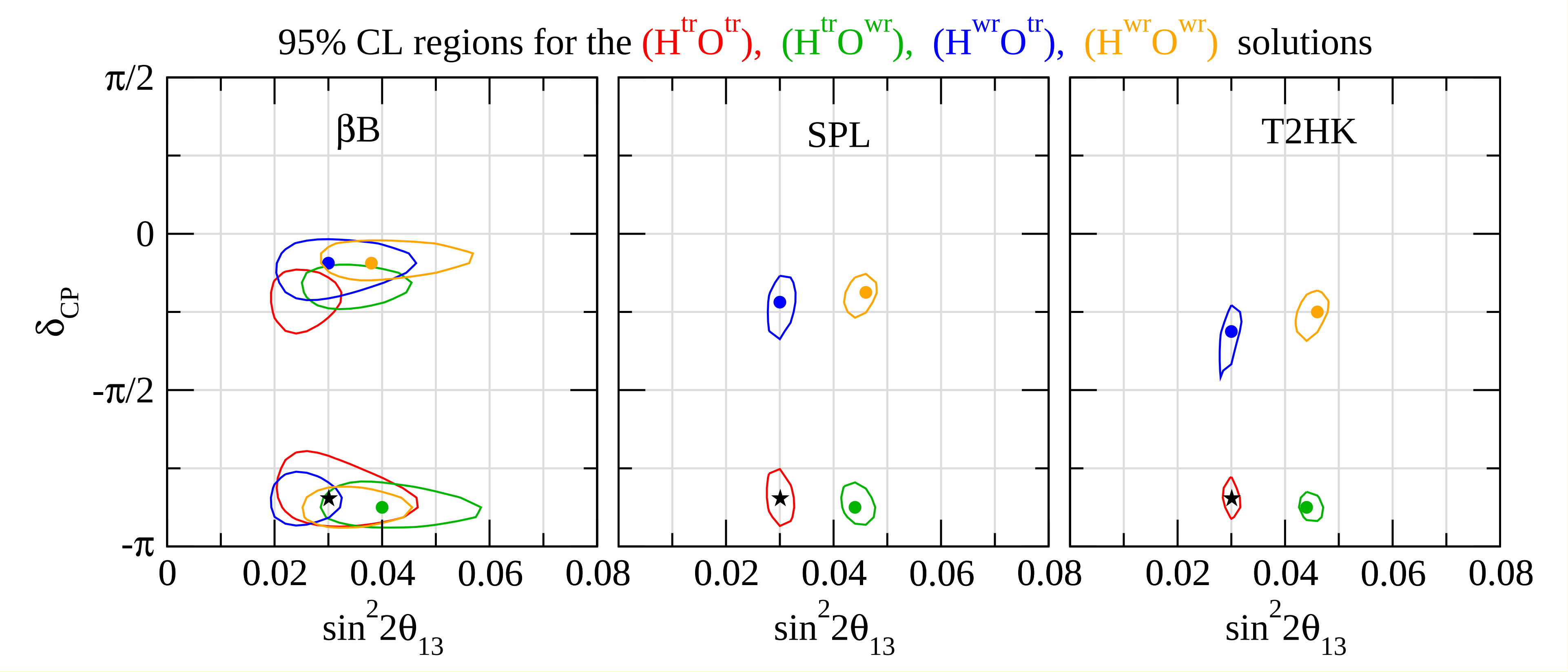


dashed: LBL only, solid: LBL+ATM

Sensitivity to the octant of θ_{23}



Resolving degeneracies



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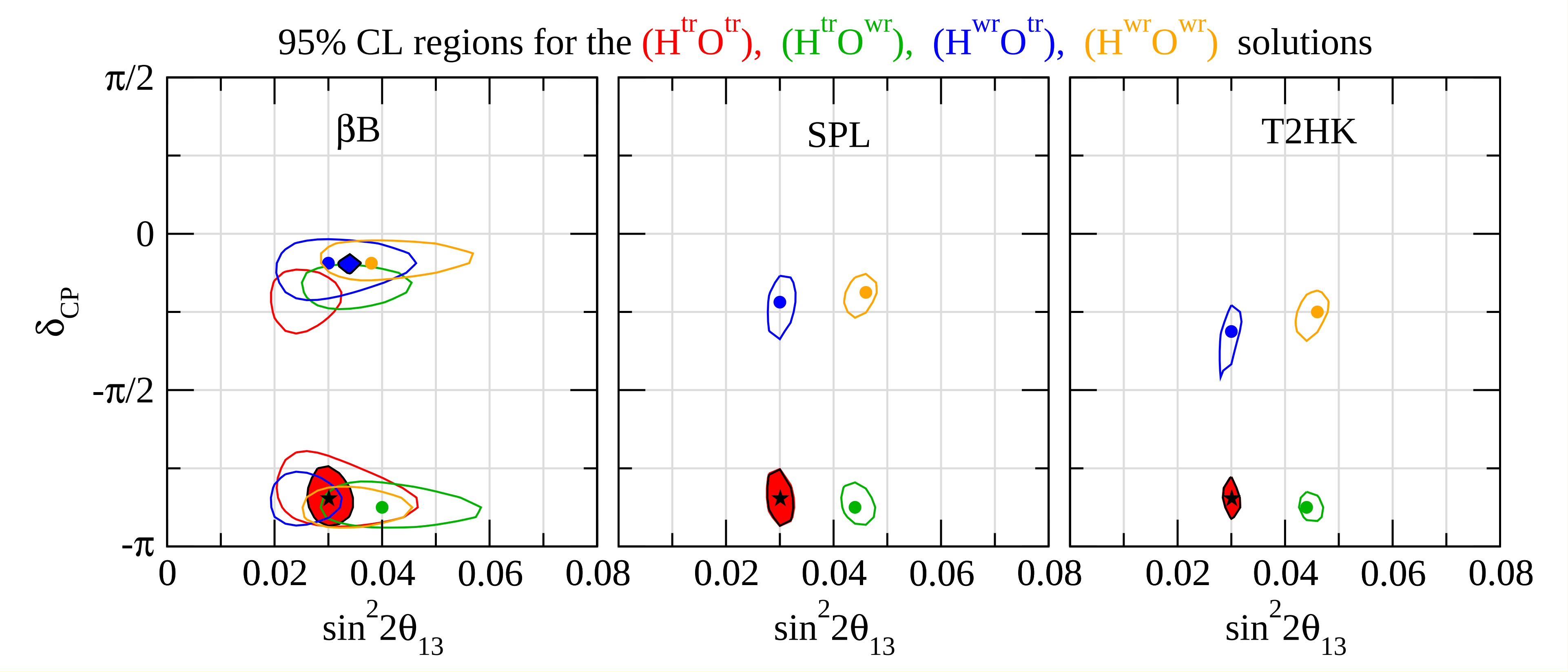
Resolving degeneracies



solid: LBL only, shaded: LBL+ATM

Synergies of βB and SPL

Synergies of β**B** *and* **SPL**

CPT invariance:

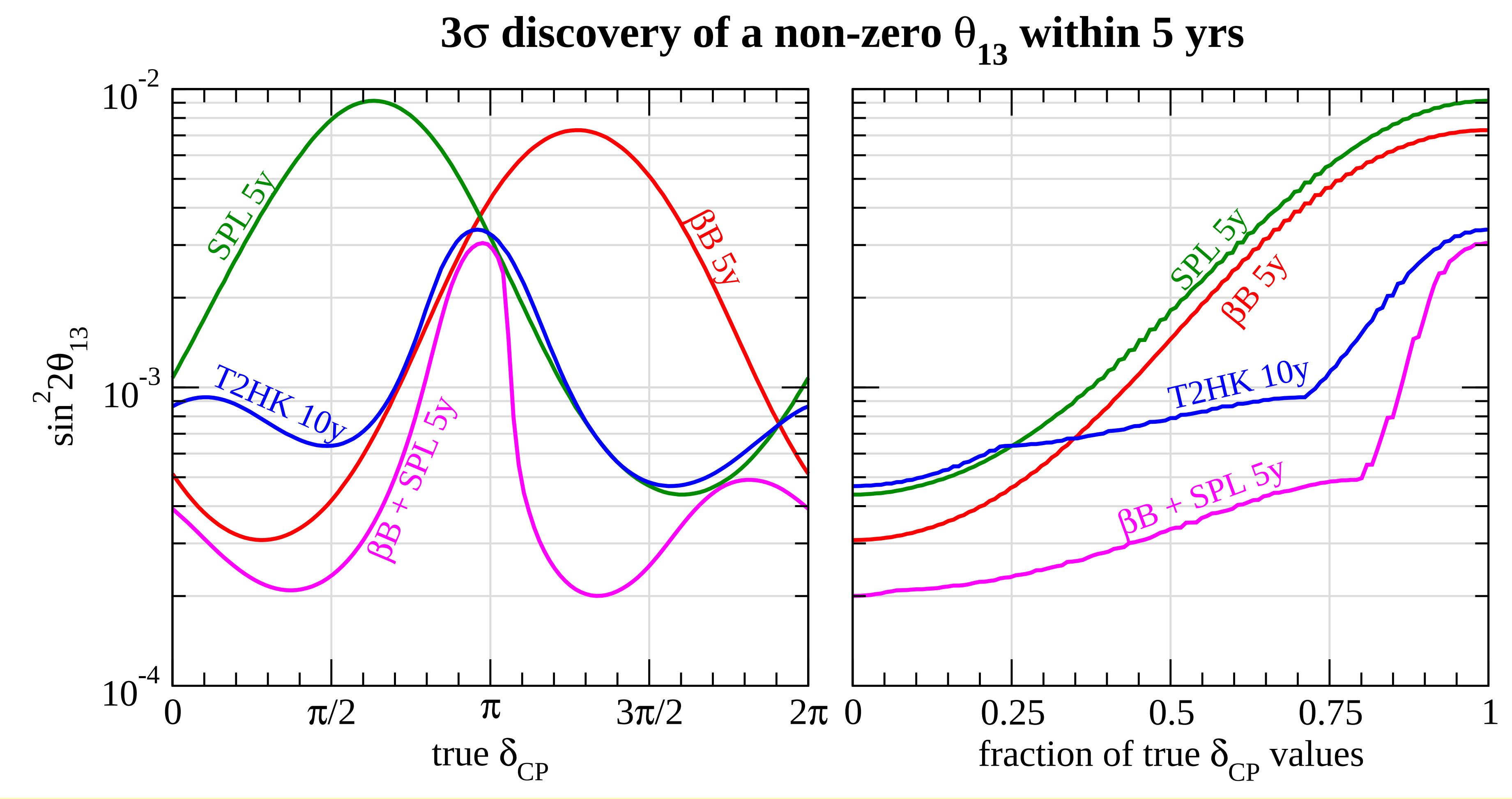
$$P_{\bar{\nu}_\mu \to \bar{\nu}_e} = P_{\nu_e \to \nu_\mu}$$

$\Rightarrow$ replace the anti-neutrinos from the superbeam with neutrinos from the β**B**

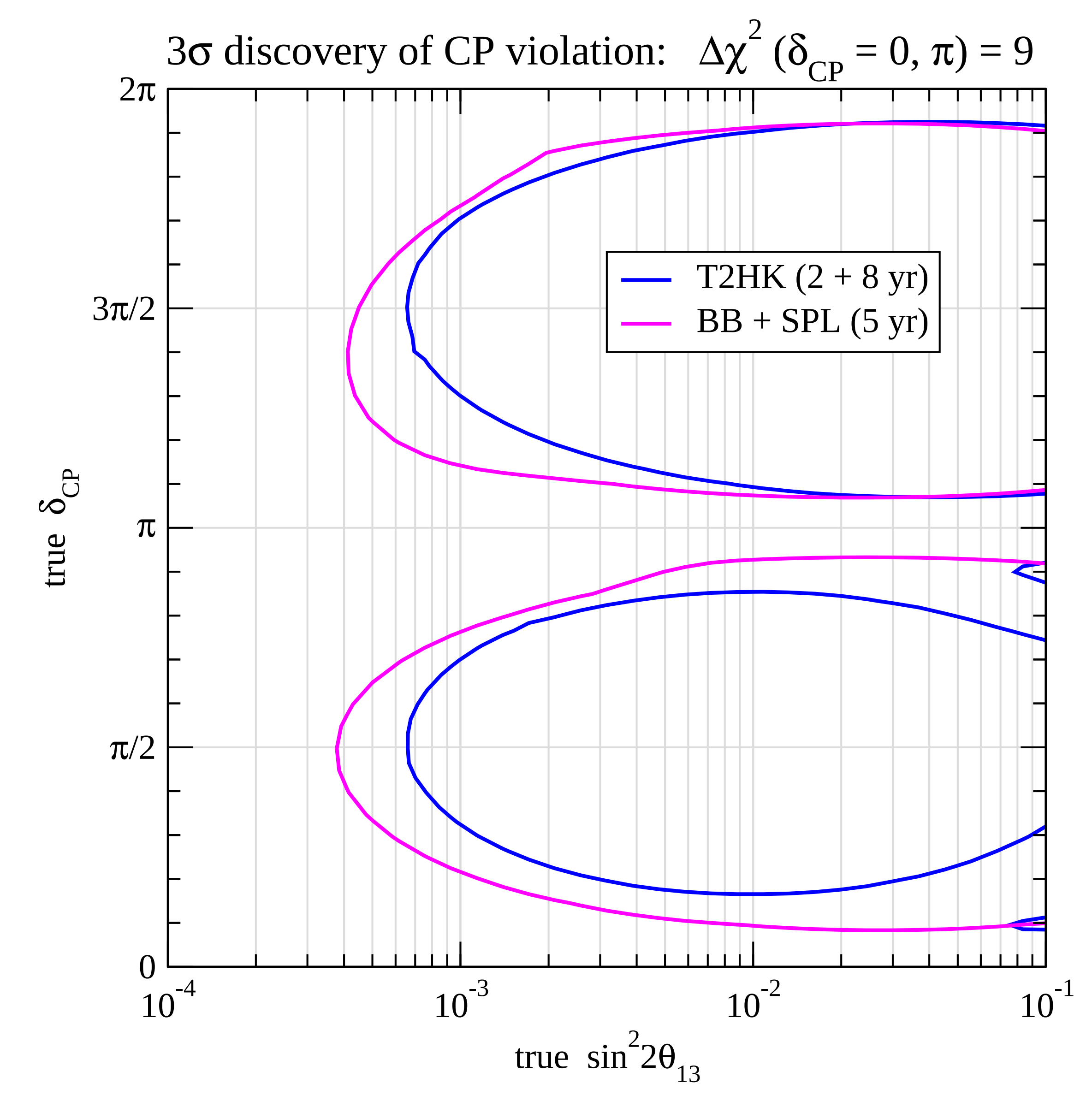
$\Rightarrow$ if β**B** and superbeam are available simultaneously anti-neutrino running is not needed

$\Rightarrow$ can do the same measurement in about half of the time

βB+SPL(ν only): θ_{13} sensitivity



βB+SPL(ν only): CP violation



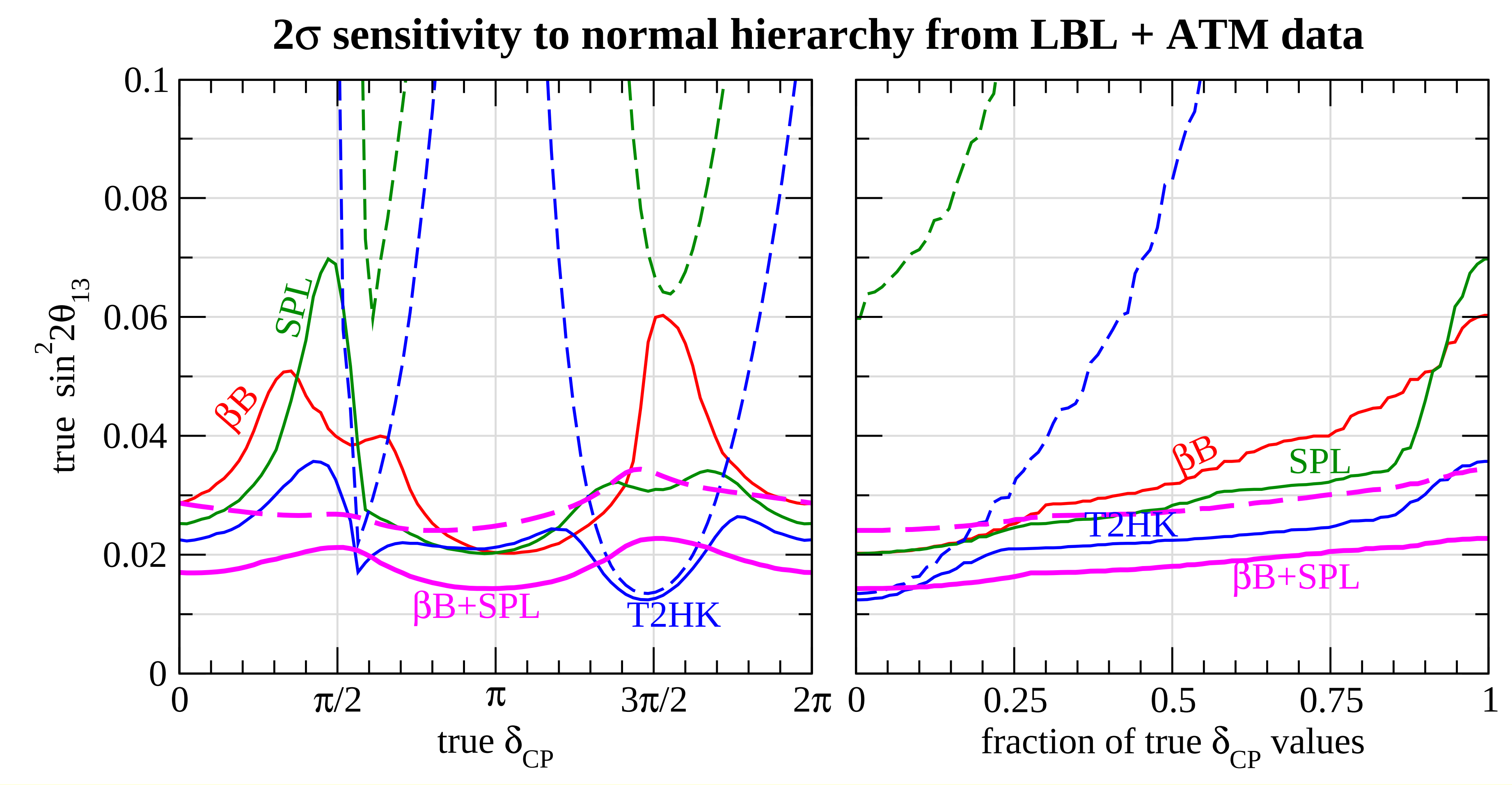
βB+SPL: *mass hierarchy*

If all four CP and T conjugated probabilities

SPL	(ν):	$P_{\nu_\mu \to \nu_e}$
SPL	$(\bar{\nu})$:	$P_{\bar{\nu}_\mu \to \bar{\nu}_e}$
β**B**	(ν):	$P_{\nu_e \to \nu_\mu}$
β**B**	$(\bar{\nu})$:	$P_{\bar{\nu}_e \to \bar{\nu}_\mu}$

are availble the tiny matter effect from CERN to MEMPHYS (130 km) provides sensitivity to the neutrino mass hierarchy.

βB+SPL: *mass hierarchy*



dashed: LBL only, solid: LBL+ATM

Before concluding. . .

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These results have been obtained with the

GLoBES software package:
http://www.ph.tum.de/$\sim$globes

BB.glb, SPL.glb, T2HK.glb files are availble.

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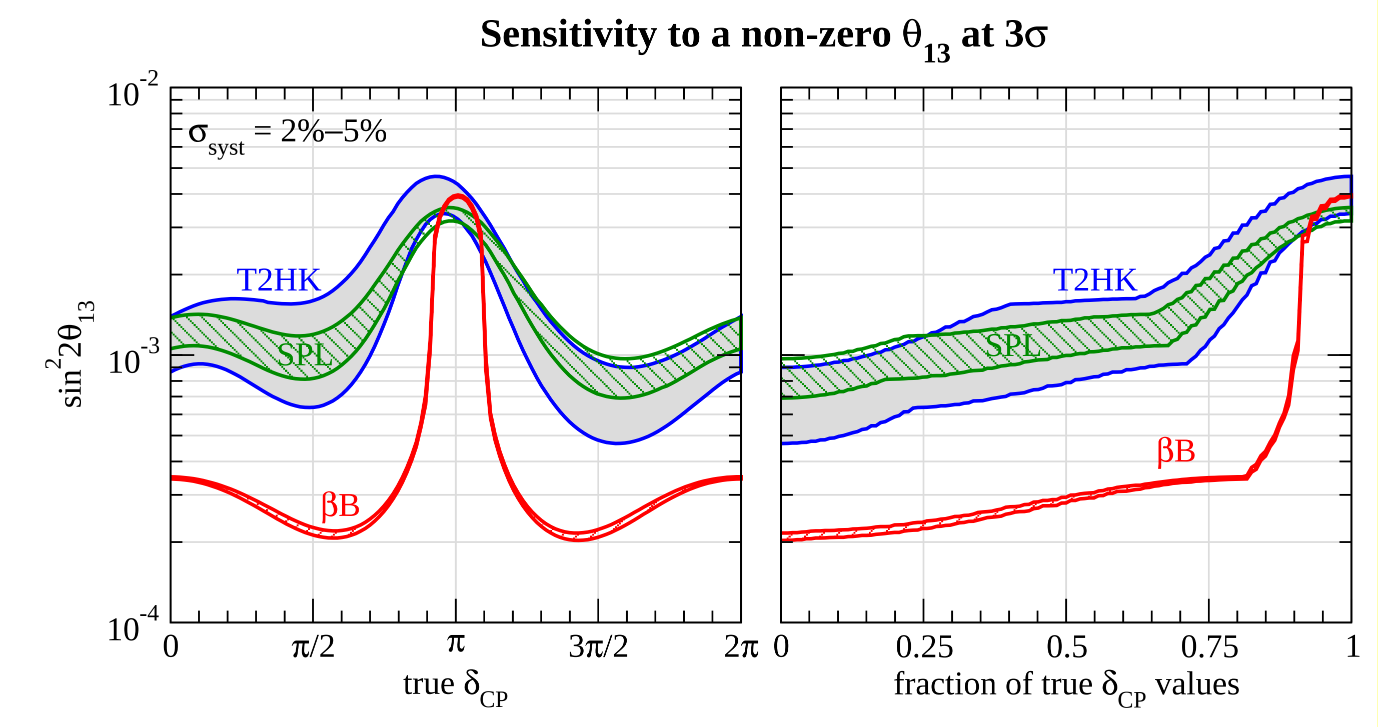

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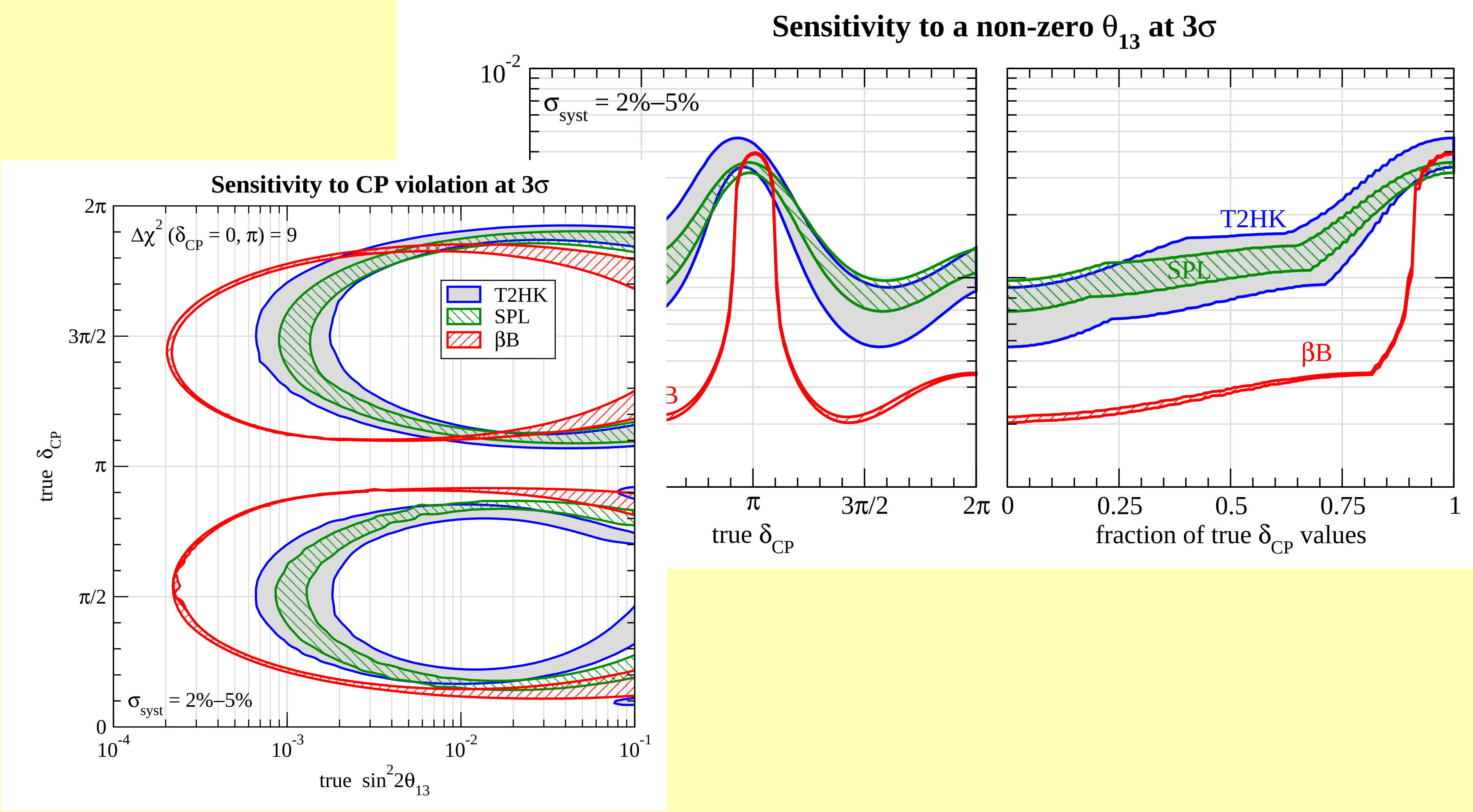
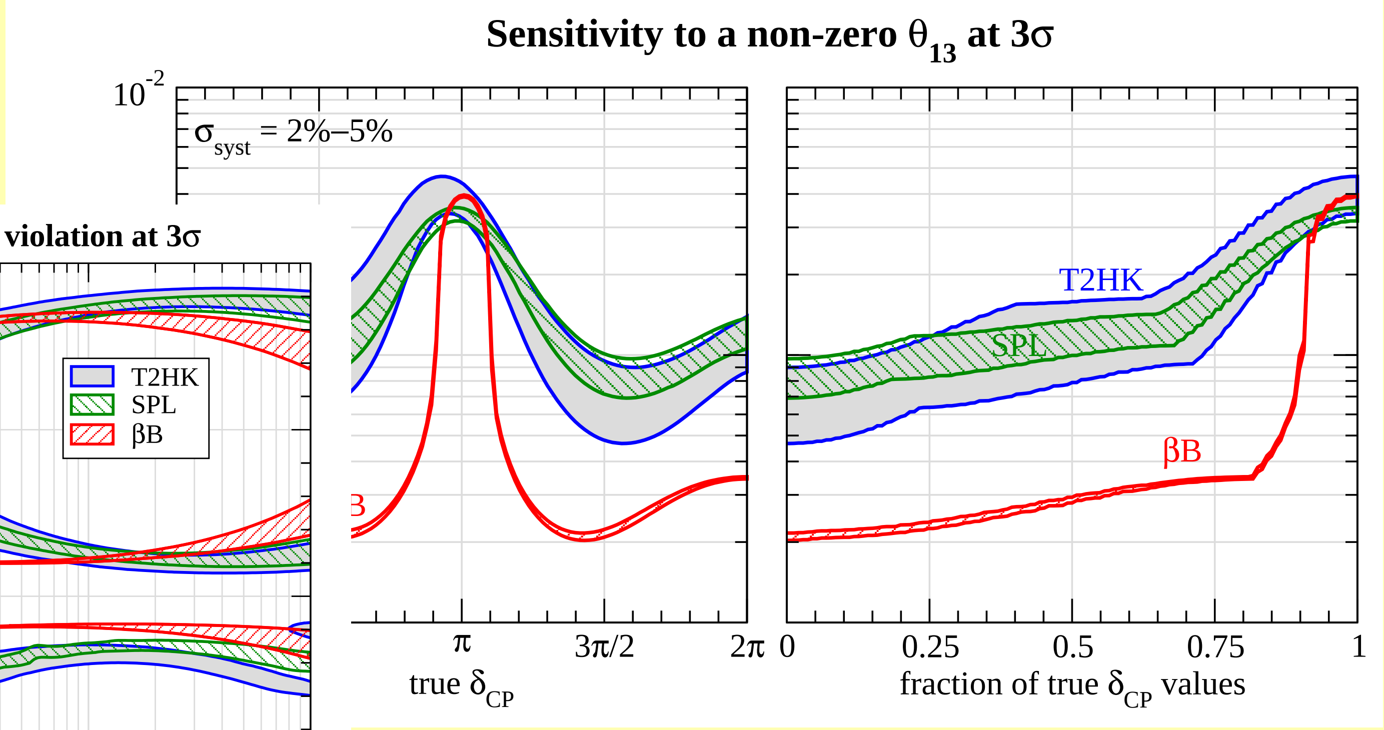
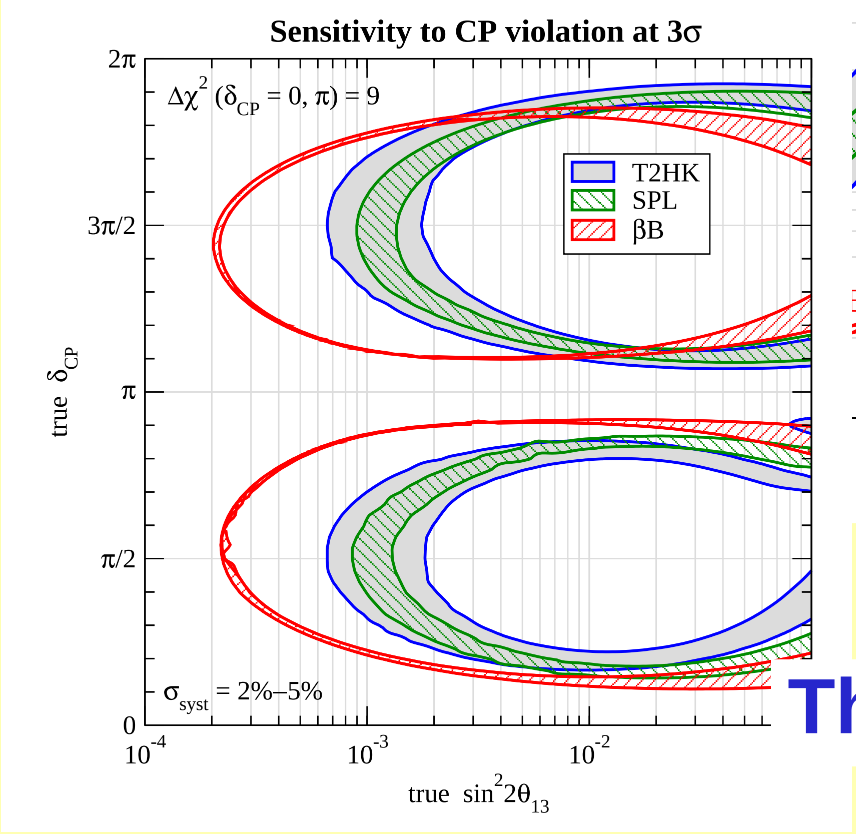


Instead of conclusions...





Thank you for your attention!