

# WP6 Status and plans

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# WP6

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- Two main nodes contributing to WP6:
  - **UAM Madrid:** EFM (Coordinator), Toshi Ota (new postdoc started 1/10/2018), Salvador Rosauo
  - **KTH Stockholm:** Mattias Blennow (Co-coordinator), Tommy Ohlsson, Monojit Ghosh (to join next year)
- Other nodes interested in collaborating: INFN, Durham, Uppsala and Athens.

# WP6 Deliverables

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- **D6.1: Physics Performance** according to initial parameters, **month 12**.
- **D6.2: Physics Performance** after **first optimizations** and recommendation for the baseline, **month 24**.
- **D6.3: Physics Performance** and comparison with other proposals, after a **second optimization**, **month 32**.
- **D6.4: Final Physics Performance**, **month 42**.

# WP6 progress towards milestones

- Collaboration between **UAM Madrid** (Salvador Rosauero, Toshi Ota and EFM) and **KTH Stockholm** (Mattias Blennow)
- Initial parameters:

6. Equipment	Parameter	Nominal value	Comments
Detector	Fiducial volume	500	
Beam	Proton energy	2.5	
Location	Baseline	540	
Beam	Total running time	10	$1.7 \cdot 10^7$ s per year assumed
Beam	Neutrino/Antineutrino runs	2/8	To be optimized
Detector	Expected performance for signal and background components		Migration matrices and efficiencies from EUROnu study <a href="https://arxiv.org/abs/1206.6665">https://arxiv.org/abs/1206.6665</a>

# WP6 progress towards milestones

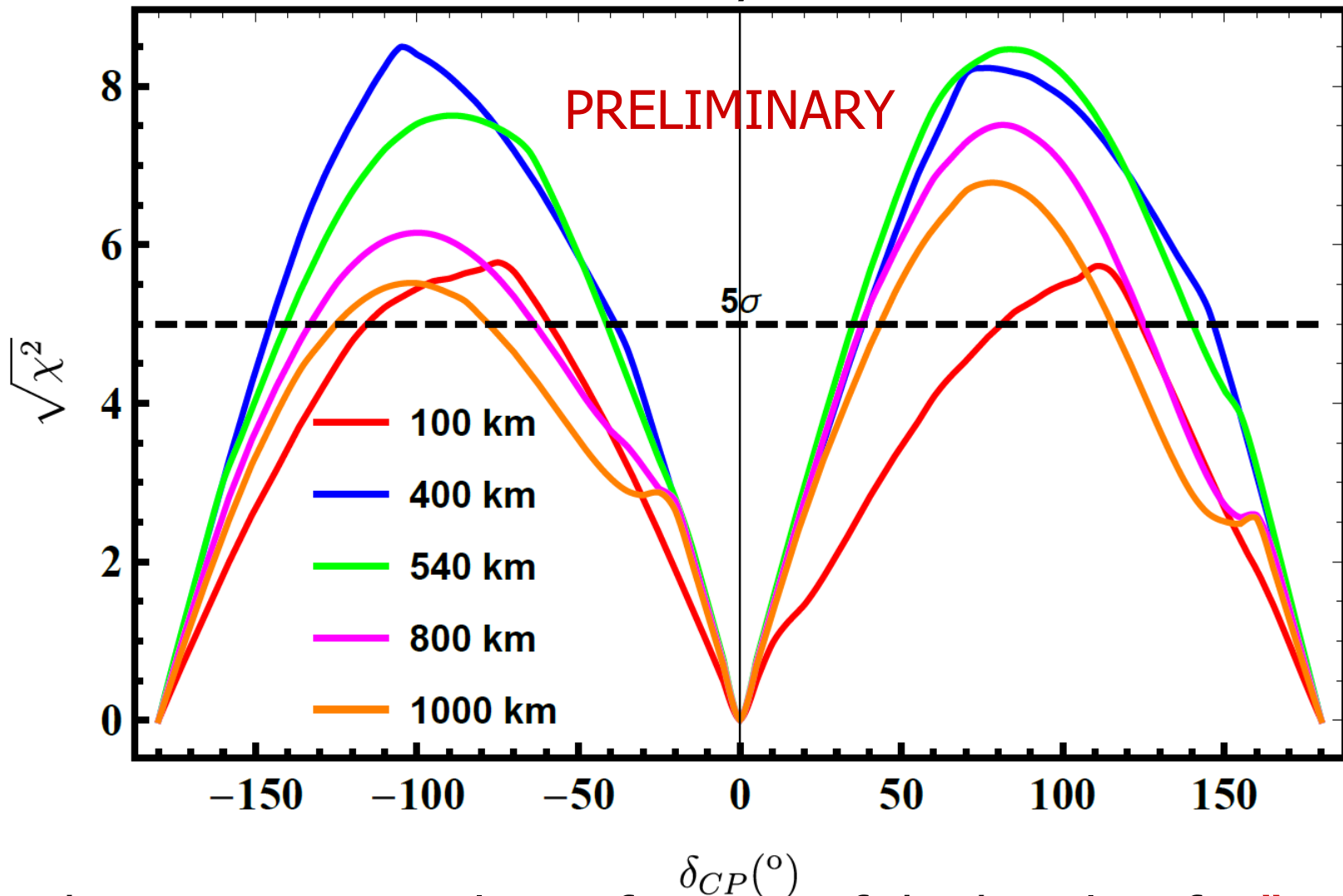
- First step prepare file to simulate **correlated systematics** between near and far detectors with **GLOBES**.

Systematics	SB		
	Opt.	Def.	Cons.
Fiducial volume ND	0.2%	0.5%	1%
Fiducial volume FD (incl. near-far extrap.)	1%	2.5%	5%
Flux error signal $\nu$	5%	7.5%	10%
Flux error background $\nu$	10%	15%	20%
Flux error signal $\bar{\nu}$	10%	15%	20%
Flux error background $\bar{\nu}$	20%	30%	40%
Background uncertainty	5%	7.5%	10%
Cross secs $\times$ eff. QE <sup>†</sup>	10%	15%	20%
Cross secs $\times$ eff. RES <sup>†</sup>	10%	15%	20%
Cross secs $\times$ eff. DIS <sup>†</sup>	5%	7.5%	10%
Effec. ratio $\nu_e/\nu_\mu$ QE <sup>*</sup>	3.5%	11%	—
Effec. ratio $\nu_e/\nu_\mu$ RES <sup>*</sup>	2.7%	5.4%	—
Effec. ratio $\nu_e/\nu_\mu$ DIS <sup>*</sup>	2.5%	5.1%	—
Matter density	1%	2%	5%

**T2HK** assumes that with the better photocoverage from reduced detector volume a **3.3/3.9%** overall systematic in  $\nu/\bar{\nu}$  is reachable **after** cancellation between near and far detectors

# WP6 progress towards milestones

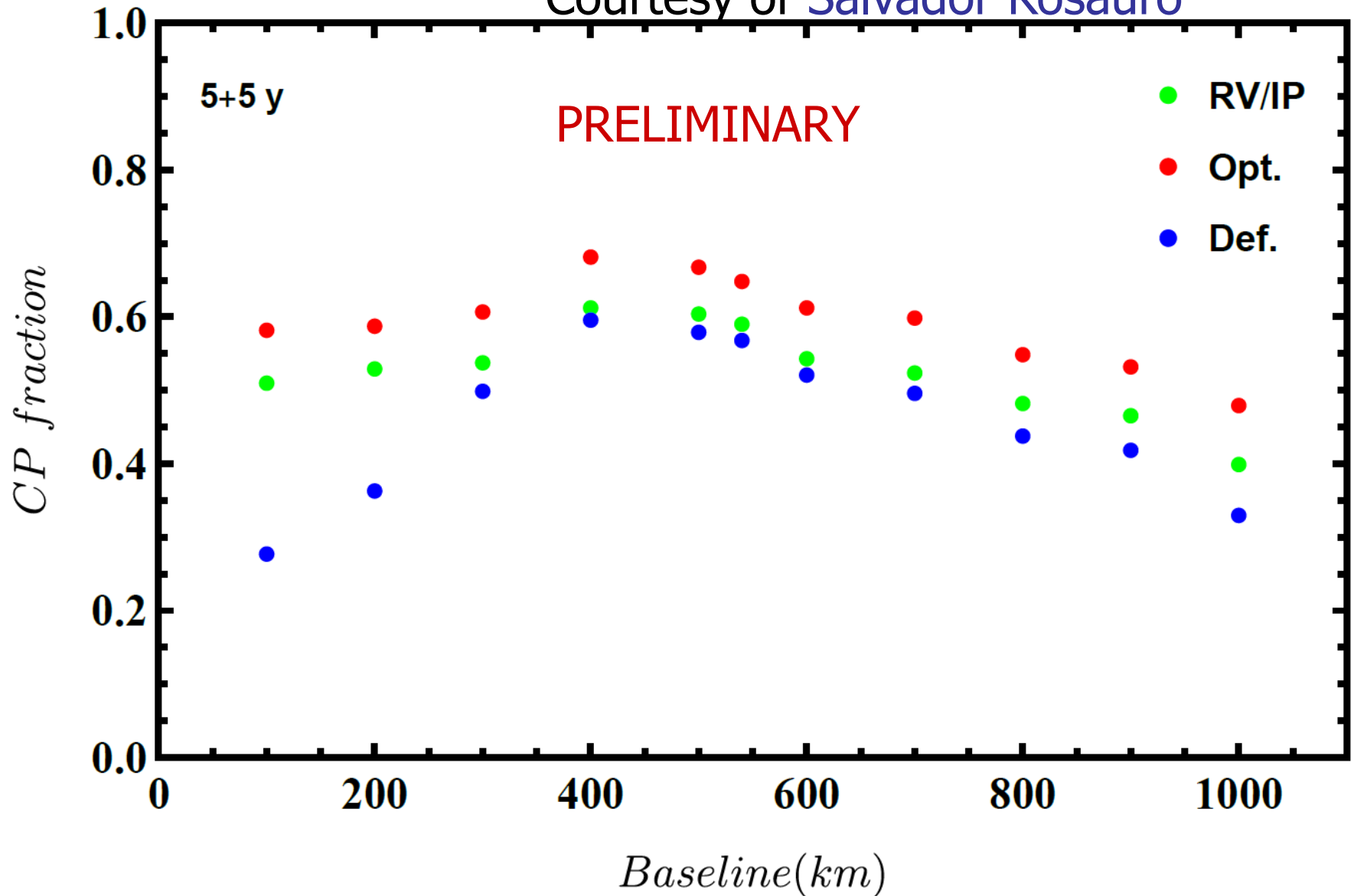
Courtesy of Salvador Rosauero



CPV discovery potential as a function of the baseline for "Def." sys

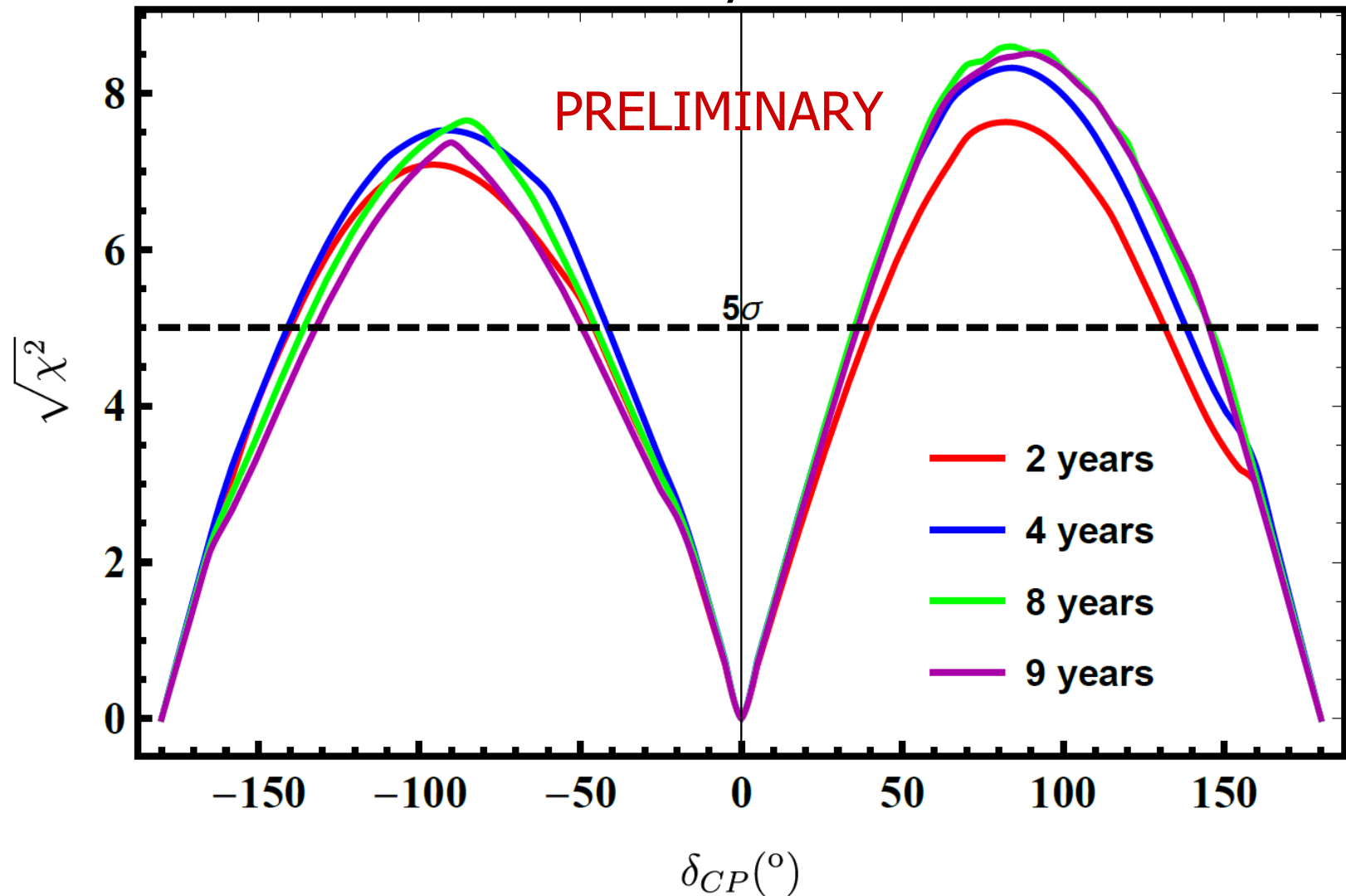
# WP6 progress towards milestones

Courtesy of Salvador Rosauero



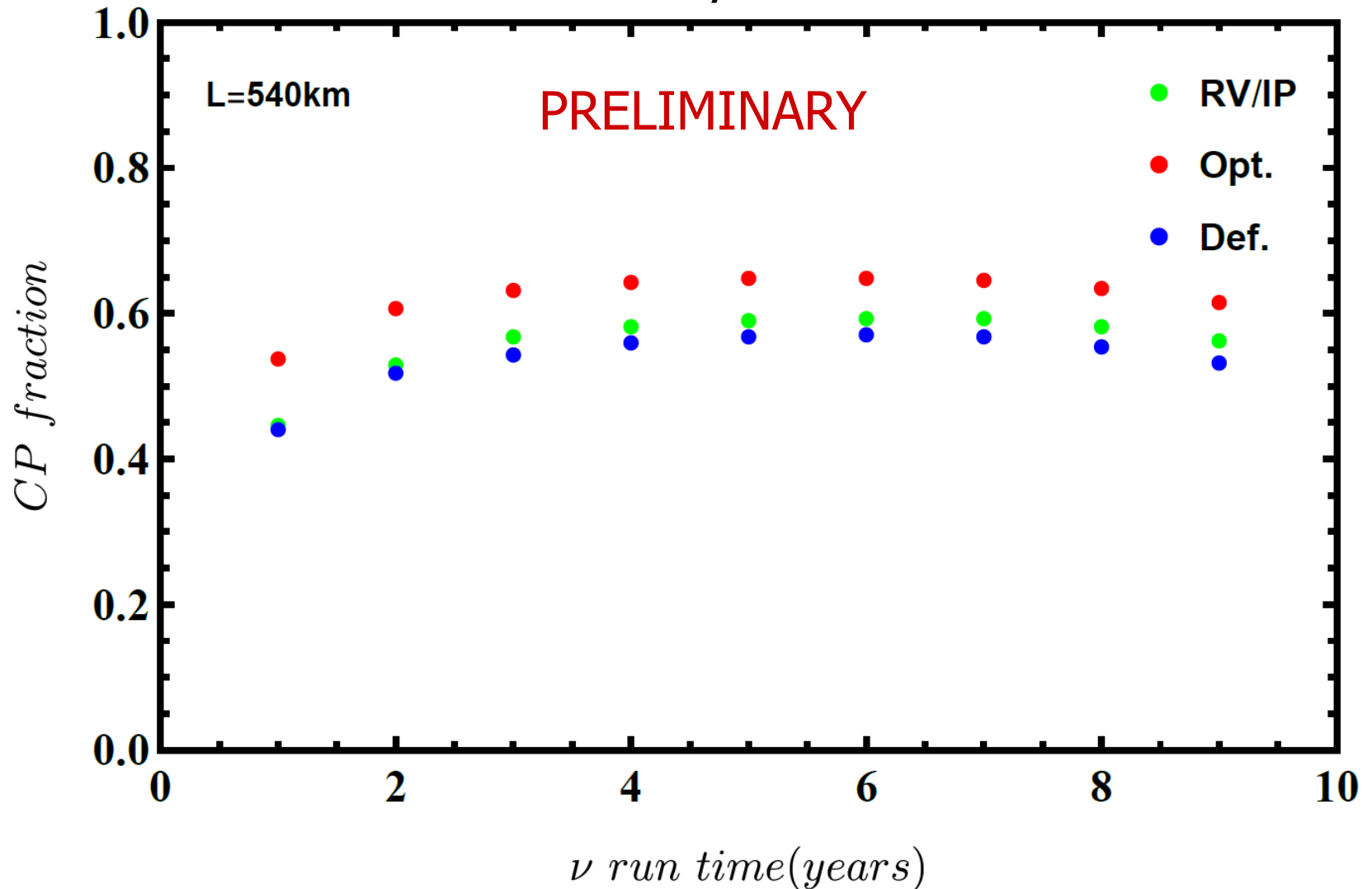
# WP6 progress towards milestones

Courtesy of Salvador Rosauero



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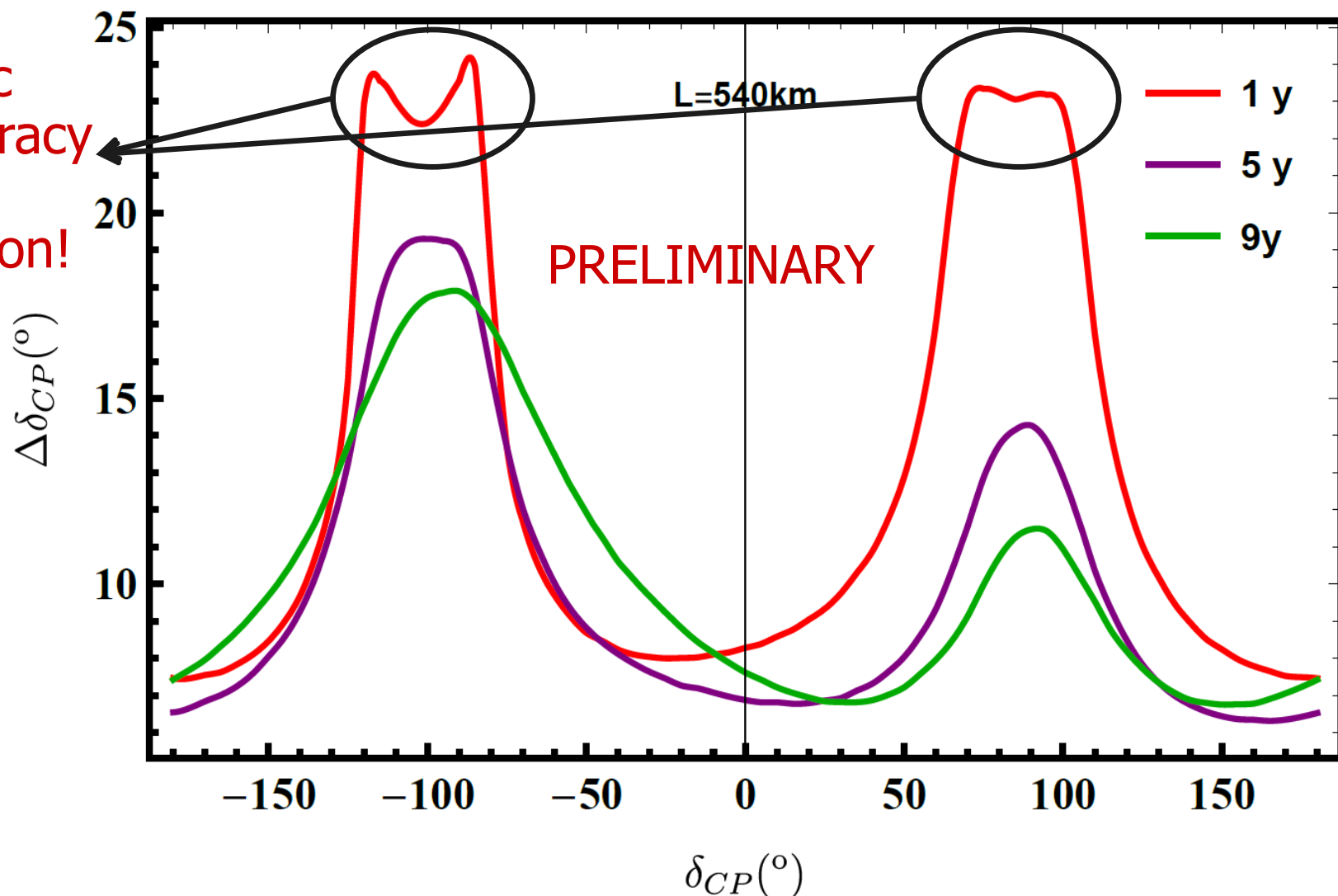
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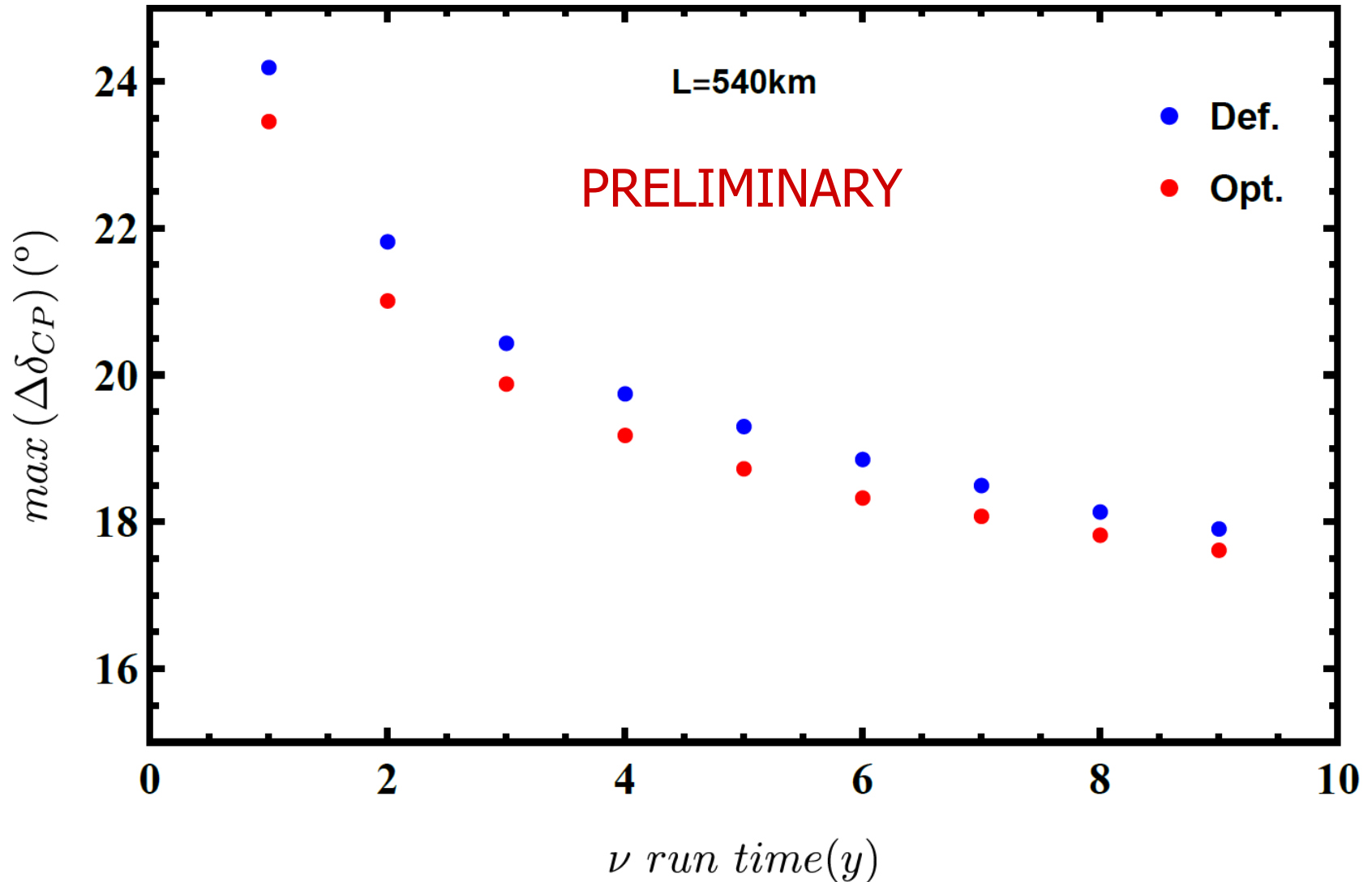
Courtesy of Salvador Rosauo

Intrinsic  
degeneracy  
spoils  
precision!



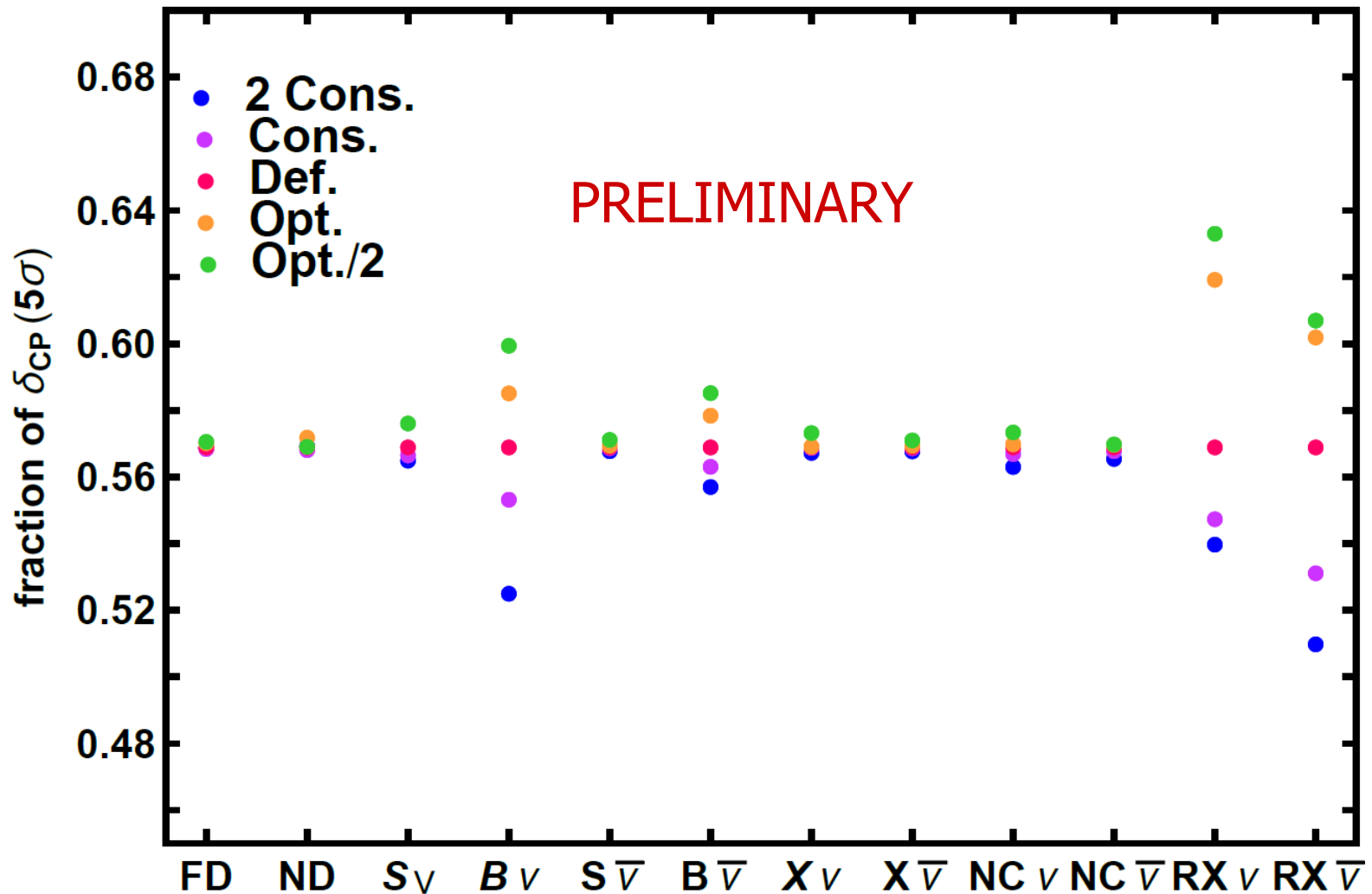
# WP6 progress towards milestones

Courtesy of Salvador Rosauero



# WP6 progress towards milestones

Courtesy of Salvador Rosauero



Biggest impact from the **cross sect.** Ratio between **ND** and **FD**

# WP6 progress towards milestones

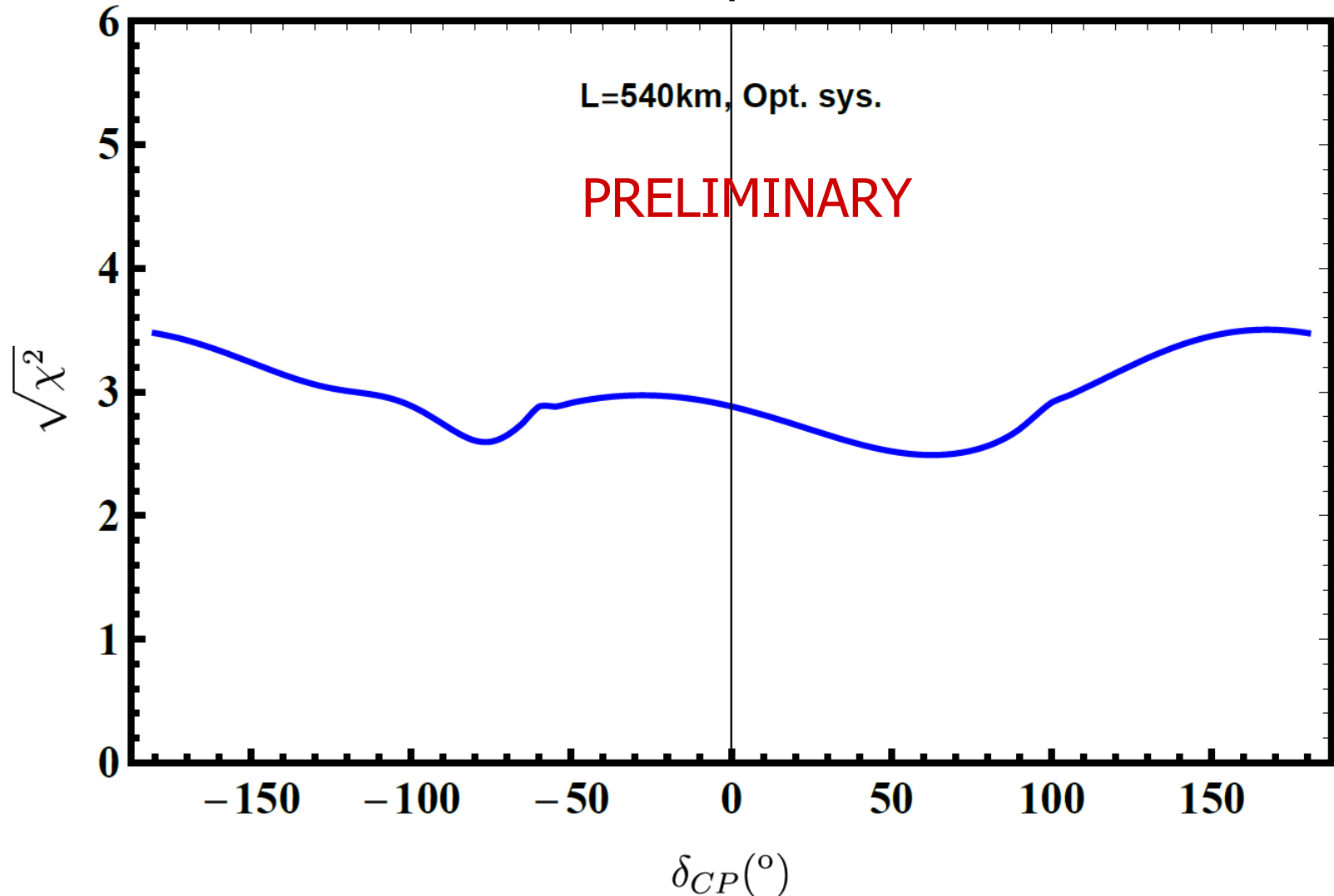
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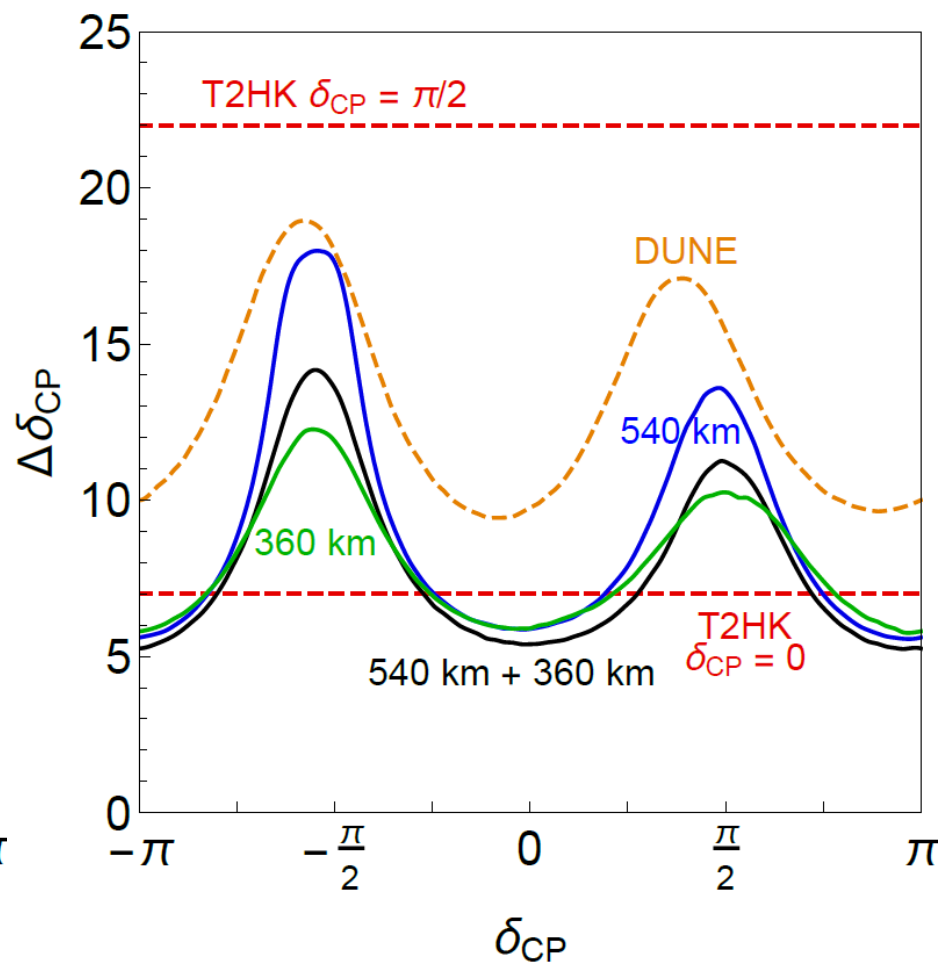
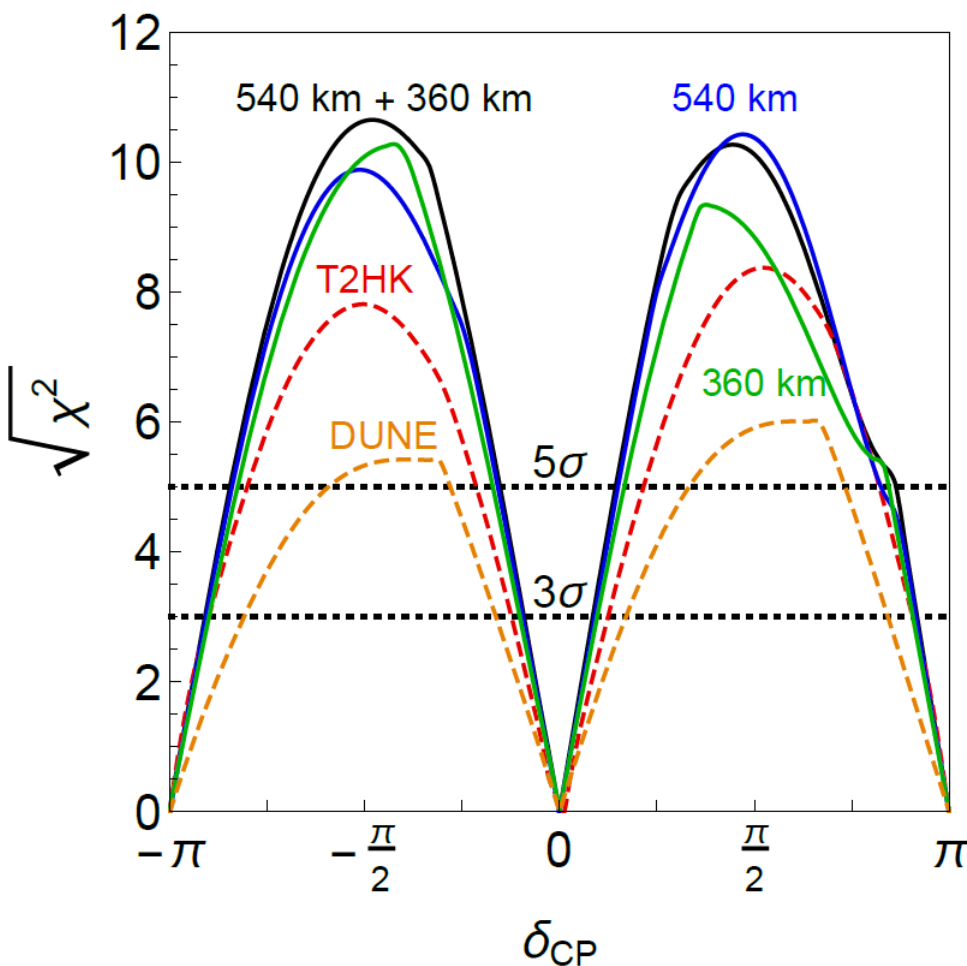
# WP6 progress towards milestones

Courtesy of Salvador Rosauero



Mass hierarchy sensitivity from ESSnuSB alone  $\sim 3\sigma$ .

# Comparison with other facilities



For  $\sin^2 2\theta_{13} = 0.1$  and 3% overall systematics

# Summary and future plans

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- We have the **software** ready to perform all simulations to update the **physics reach** with new input from other **WPs**.
- We have **preliminary results** for the **physics reach** according to **initial parameters**. Ready to deliver the **first milestone**.
- We have also performed some **optimizations** both in **baseline** and **running time** and have identified the most relevant **systematic uncertainties**.
- We plan to add **atmospheric neutrino oscillation data** in future analyses. This comes for **free** in our detector and should improve sensitivities and **solve degeneracies**.

# The Golden channel in matter

$$P(\bar{\nu}_e \rightarrow \bar{\nu}_\mu) = s_{23}^2 \sin^2 2\theta_{13} \left( \frac{\Delta_{atm}}{\tilde{B}_\mp} \right)^2 \sin^2 \left( \frac{\tilde{B}_\mp L}{2} \right) \quad \text{"atmospheric"}$$

$$+ c_{23}^2 \sin^2 2\theta_{12} \left( \frac{\Delta_{sol}}{A} \right)^2 \sin^2 \left( \frac{AL}{2} \right) \quad \text{"solar"}$$

$$\text{"interference"} + \tilde{J} \frac{\Delta_{sol}}{A} \frac{\Delta_{atm}}{\tilde{B}_\mp} \sin \left( \frac{AL}{2} \right) \sin \left( \frac{\tilde{B}_\mp L}{2} \right) \cos \left( \pm \delta - \frac{\Delta_{atm} L}{2} \right)$$

Expanded in

$$\sin 2\theta_{13} \sim 0.3 \quad \left( \frac{\Delta_{sol} L}{2} \right) \cong 0.05$$

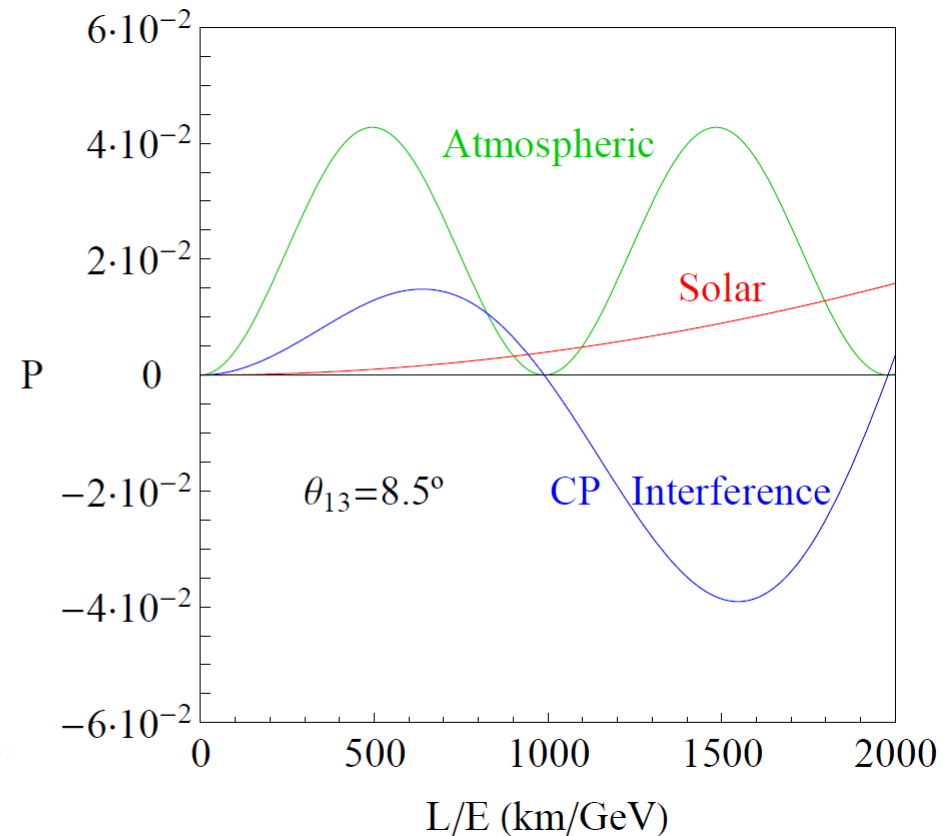
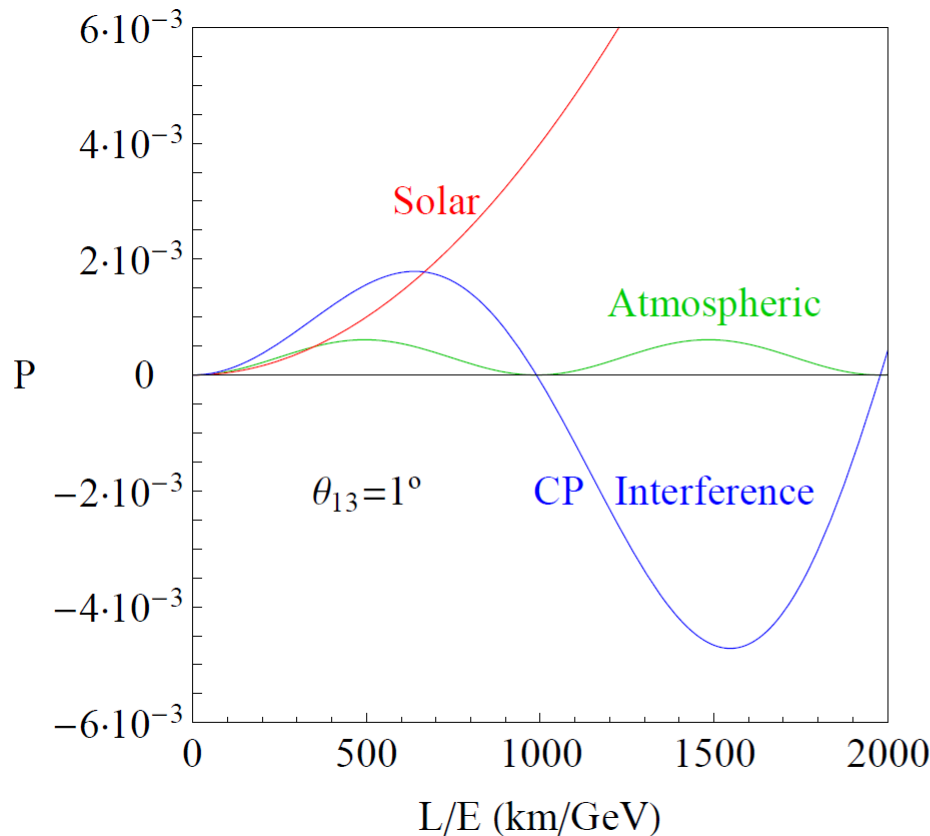
where

$$\tilde{J} = \cos \theta_{13} \sin 2\theta_{13} \sin 2\theta_{12} \sin 2\theta_{23} \quad \Delta_{atm} = \frac{\Delta m_{23}^2}{2E} \quad \Delta_{sol} = \frac{\Delta m_{12}^2}{2E}$$

$$A = \sqrt{2} G_F n_e \quad \tilde{B}_\mp = |A \mp \Delta_{atm}|$$

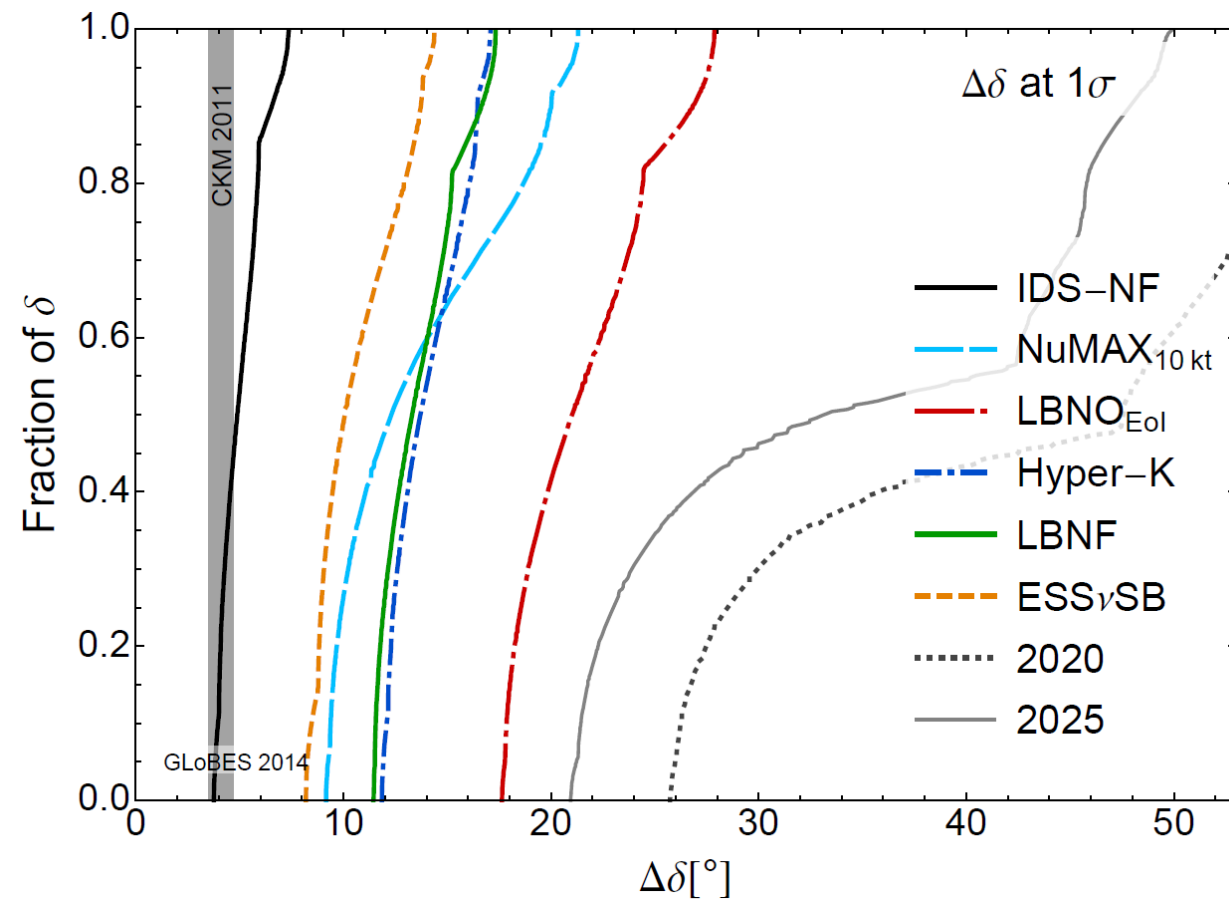
A. Cervera *et al.* hep-ph/0002108

# Optimization of facilities for large $\theta_{13}$



Signal systematics and not stats becomes the bottleneck for large  $\theta_{13}$ , explore second peak? P. Coloma and EFM 1110.4583

# Importance of cross sections sys



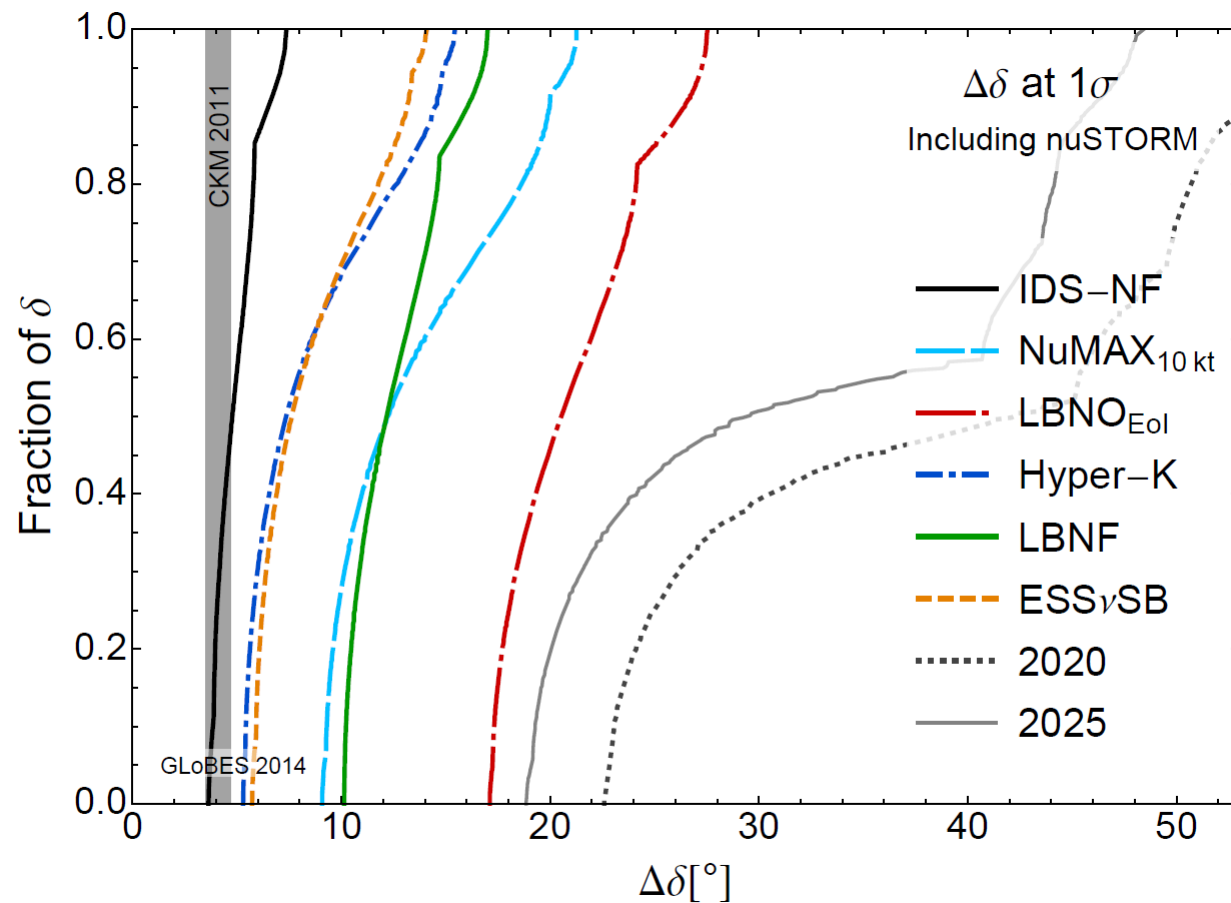
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Background uncertainty	7.5%
Cross secs $\times$ eff. $QE^\dagger$	15%
Cross secs $\times$ eff. $RES^\dagger$	15%
Cross secs $\times$ eff. $DIS^\dagger$	7.5%
Effec. ratio $\nu_e/\nu_\mu$ $QE^*$	11%
Effec. ratio $\nu_e/\nu_\mu$ $RES^*$	5.4%
Effec. ratio $\nu_e/\nu_\mu$ $DIS^*$	5.1%
Matter density	2%

Courtesy of P. Coloma

P. Coloma et al 1209.5973

# Importance of cross sections sys

+NuSTORM (1% uncorrelated errors on xsecs)



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