Impact of systematic errors on precision at future long baseline experiments

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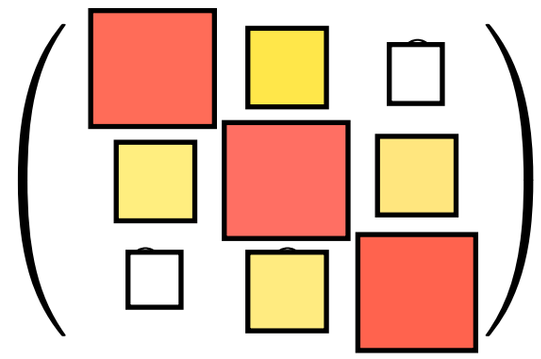
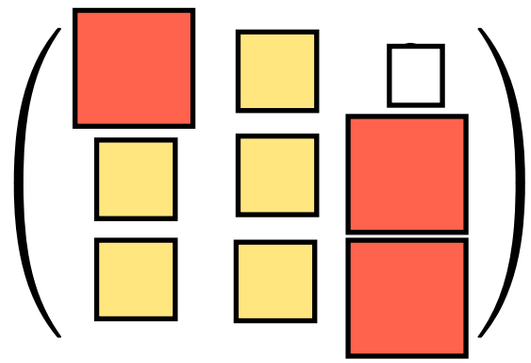
Outline

- Why precision?
- General landscape
- Simulation details and sources of systematics
- Effect of systematics on precision
  - General comparison
  - Effect of near detector
  - Effect of assumptions (opt, def, cons)
  - Identification of key systematics
- Summary and conclusions

Why precision?

$V_{CKM} \sim$ 

$U_{PMNS} \sim$ 

flavour symmetries?

Parameter	Value (neutrino PMNS matrix)	Value (quark CKM matrix)
θ_{12}	$34 \pm 1^\circ$	$13.04 \pm 0.05^\circ$
θ_{23}	$43 \pm 4^\circ$	$2.38 \pm 0.06^\circ$
θ_{13}	$9 \pm 1^\circ$	$0.201 \pm 0.011^\circ$
Δm^2_{21}	$+(7.58 \pm 0.22) \times 10^{-5}$ eV^2	
$\lvert\Delta m^2_{32}\rvert$	$(2.35 \pm 0.12) \times 10^{-3}$ eV^2	$m_3 >> m_2$
δ_{CP}	unknown	$67 \pm 5^\circ$

From M.Bishai's talk

The setups

- T2HK (1109.3262 [hep-ex]): 1.66 MW, 5 years (1.5+3.5), 560 kton WC simulated as in 0711.2950 [hep-ph], L=295 km
- LBNO (1001.0077 [physics.ins-det]): 800 kW, fluxes from PoS ICHEP2010 (2010) 325, 10 years (5+5), 100 kton LAr, L=2300 km
- BB350 (hep-ph/0312068, hep-ph/0503021): γ=350, 1.1(2.8)e18 useful Ne (He) ion decays per year, 10 years (5+5), 500 kton WC, L=650 km
- LENF (1012.1872 [hep-ph]): 10 GeV muons, 1.4e21 useful muon decays per year, 10 years (5+5), 100 kton MIND, L=2000 km
- LBNE (1110.6249 [hep-ex]): 700 kW, 10 years (5+5), 34 kton LAr, L=1290 km

General landscape

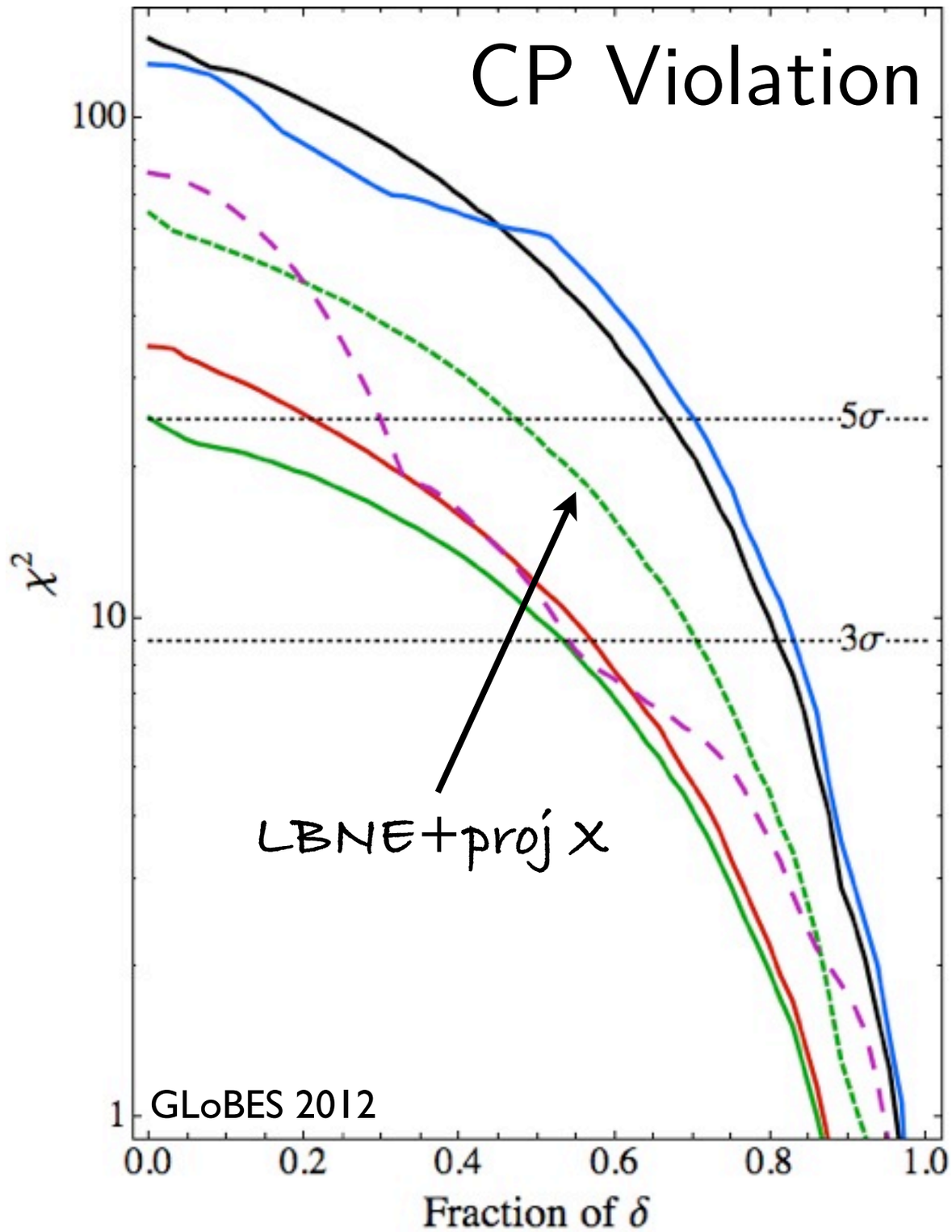
BB350:
hep-ph/0406132
hep-ph/0503021

T2HK: hep-ex/0106019

C2P:
1001.0077
[physics.ins-det]
hep-ex/0411062
1106.1096
[physics.acc-ph]

LENF: 1012.1872 [hep-ph]

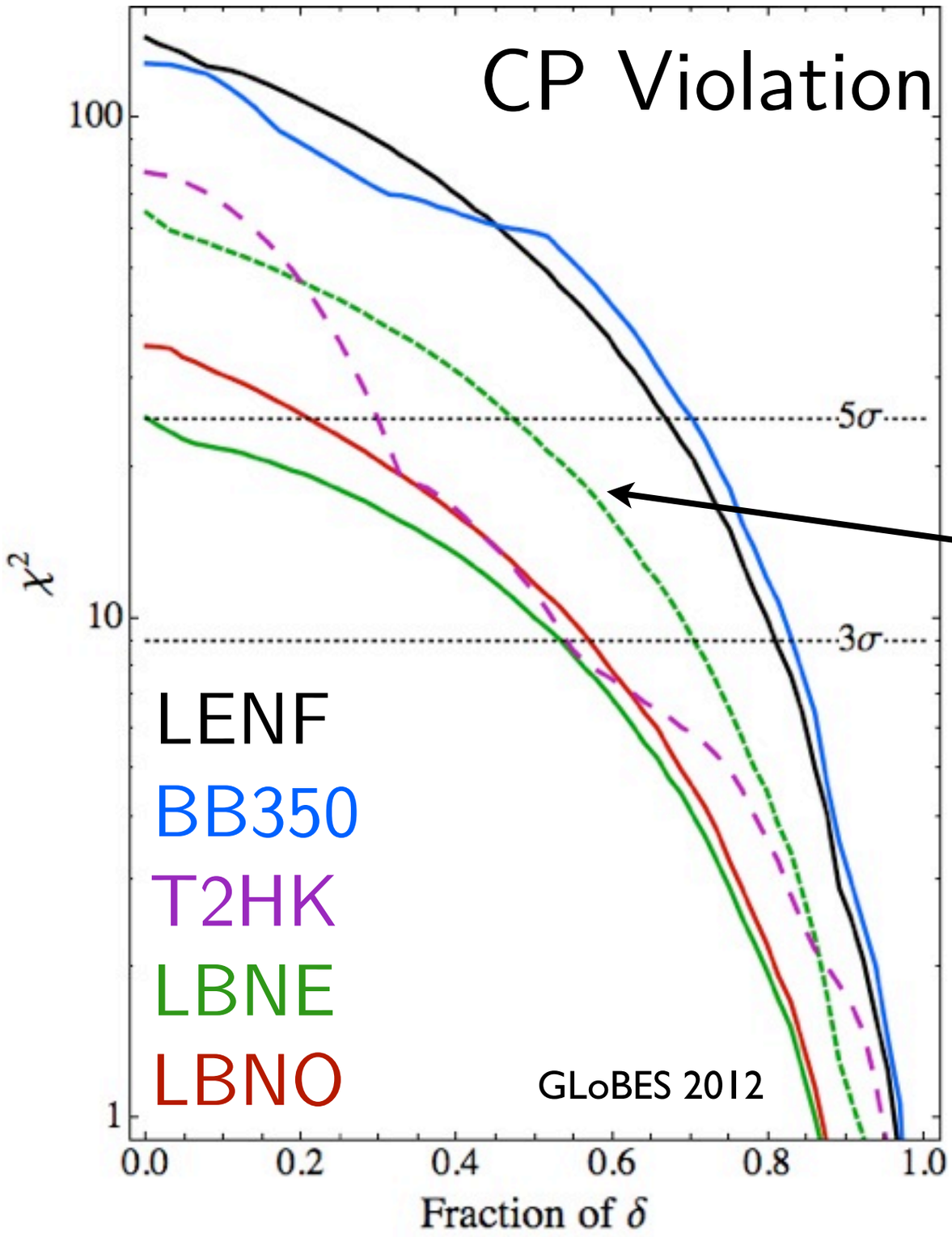
LBNE: 1110.6249 [hep-ex]

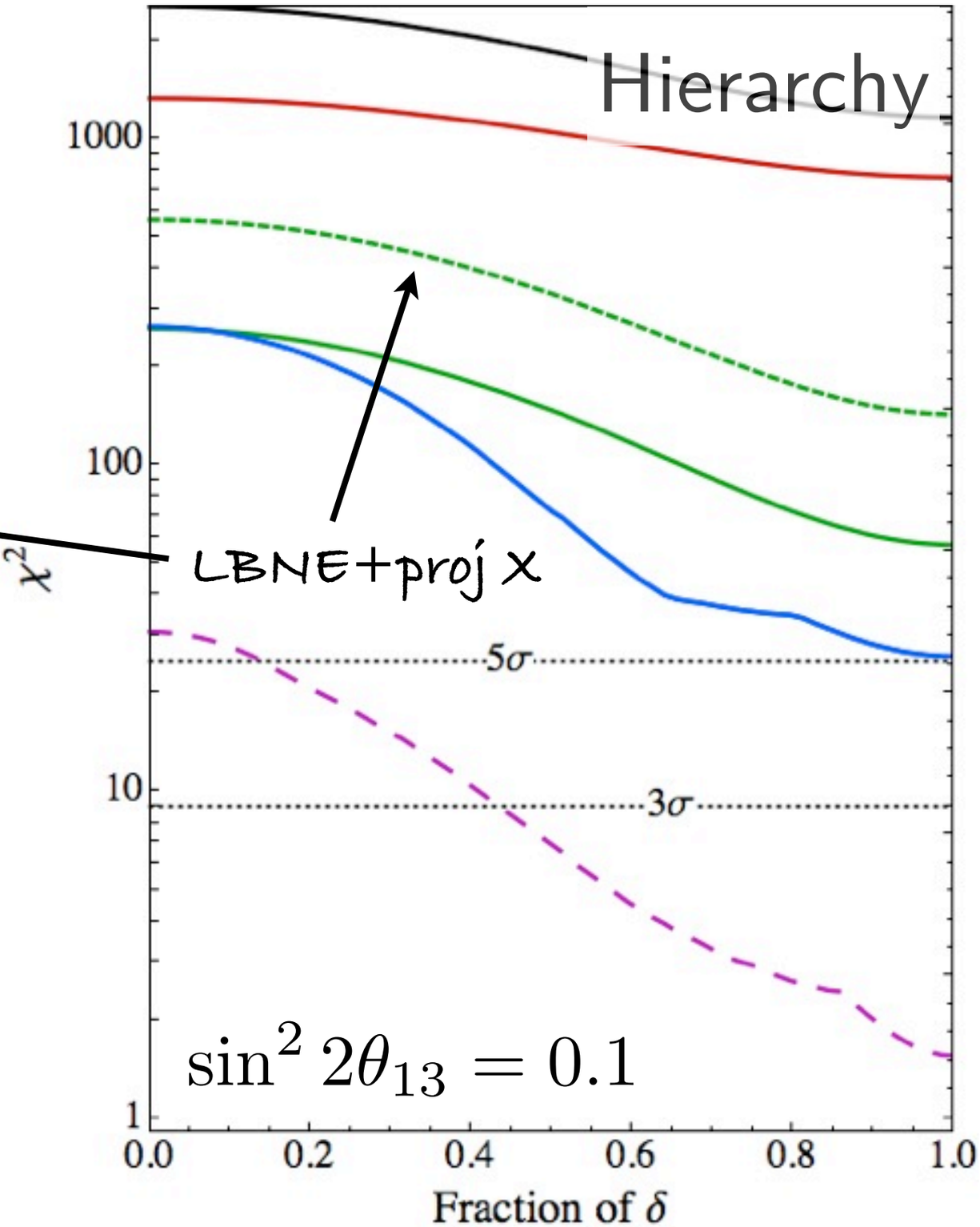


LENF
BB350
T2HK
LBNE
LBNO

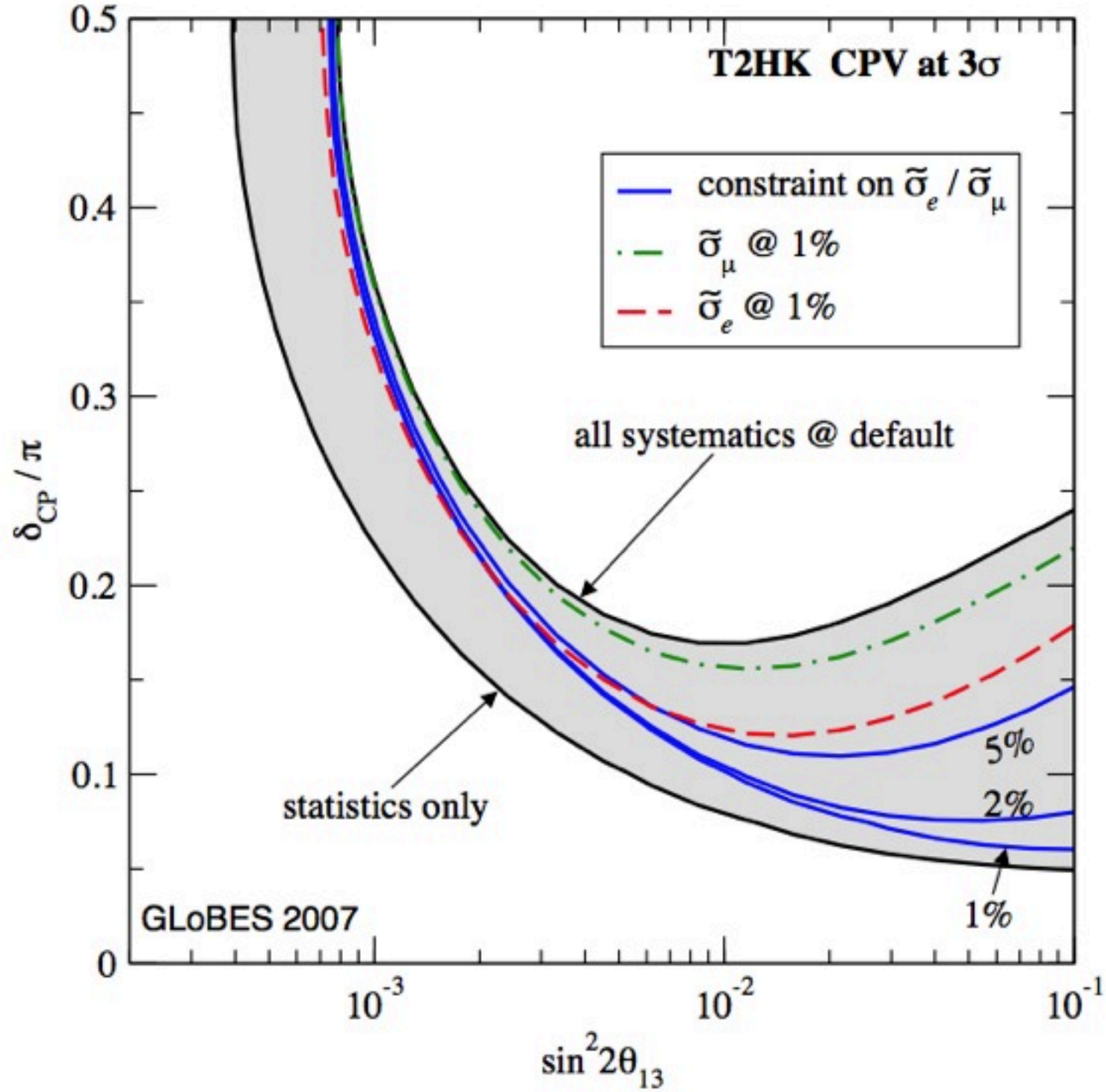
$\sin^2 2\theta_{13} = 0.1$

General landscape





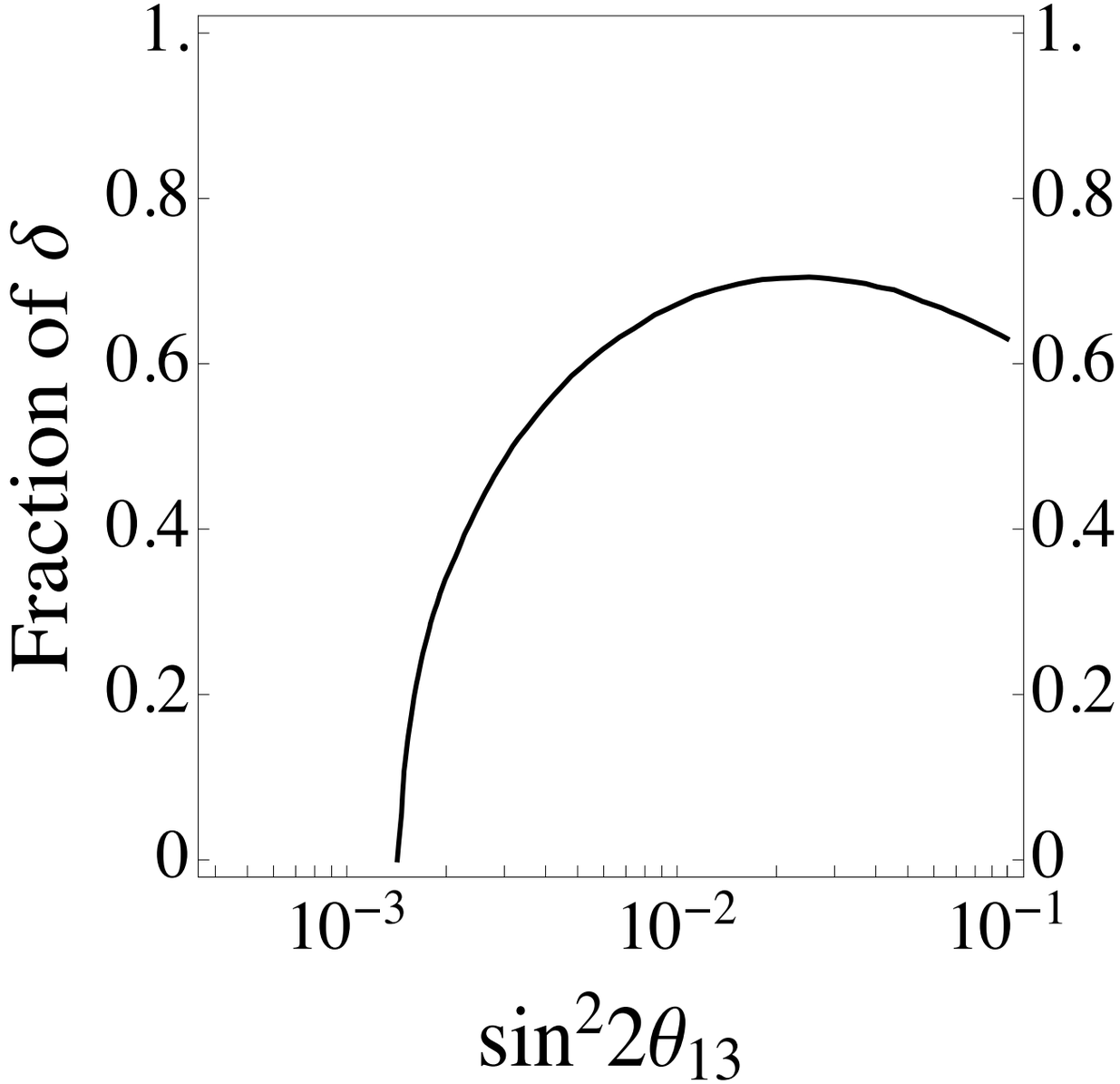
The impact of systematics

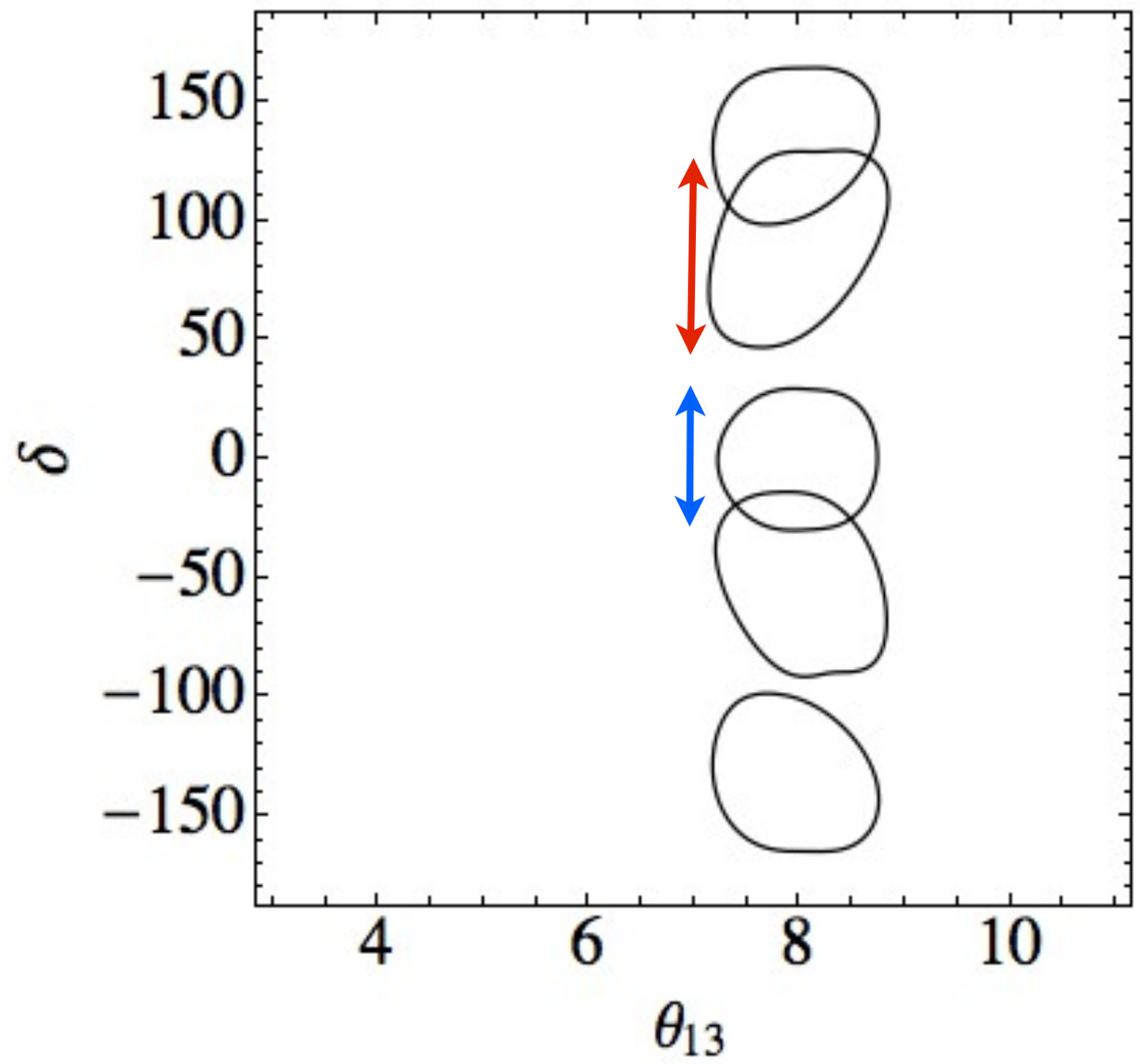


Huber, Mezzetto, Schwetz, 0711.2950 [hep-ph]

Why precision?

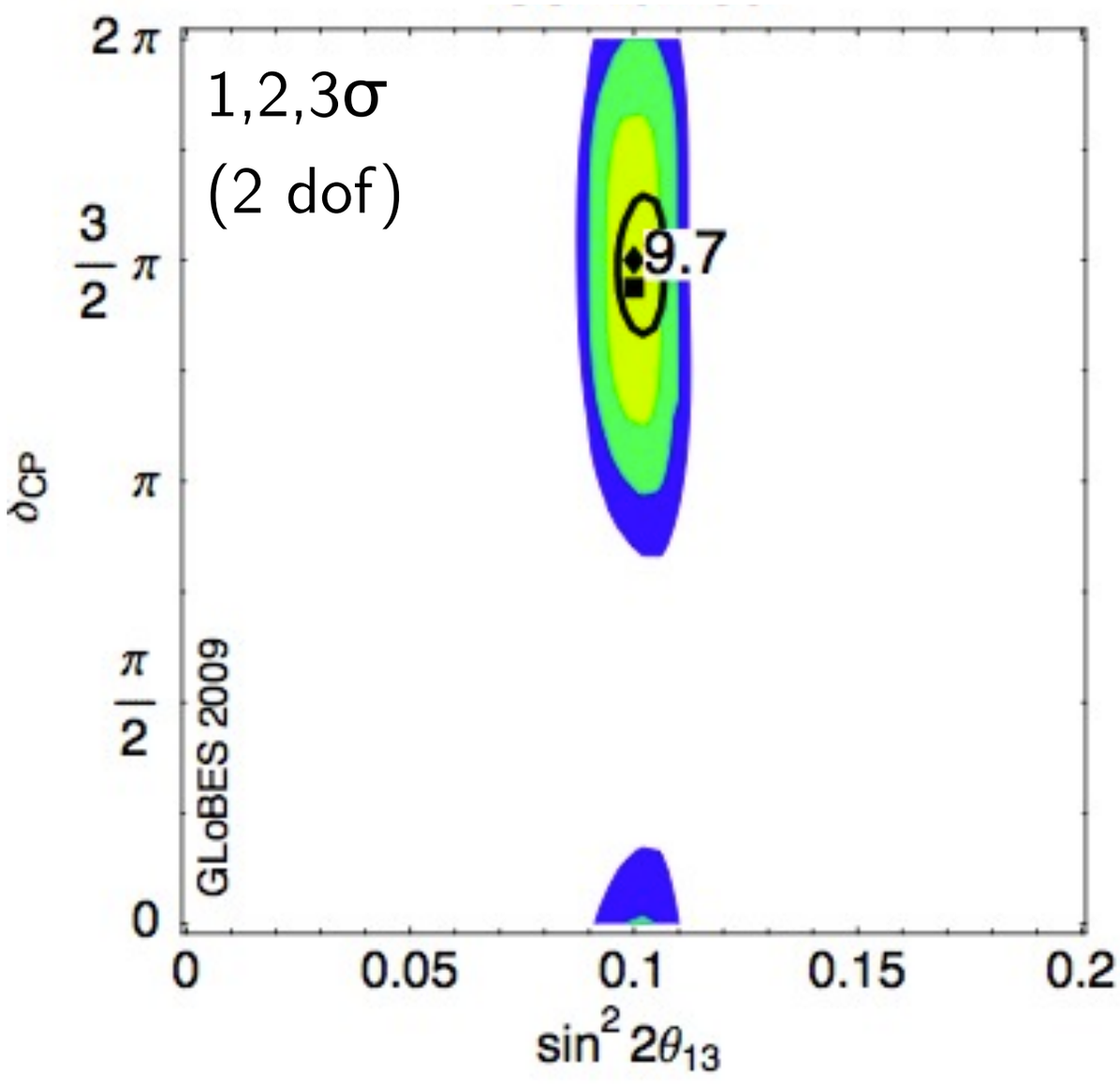
Discovery vs precision



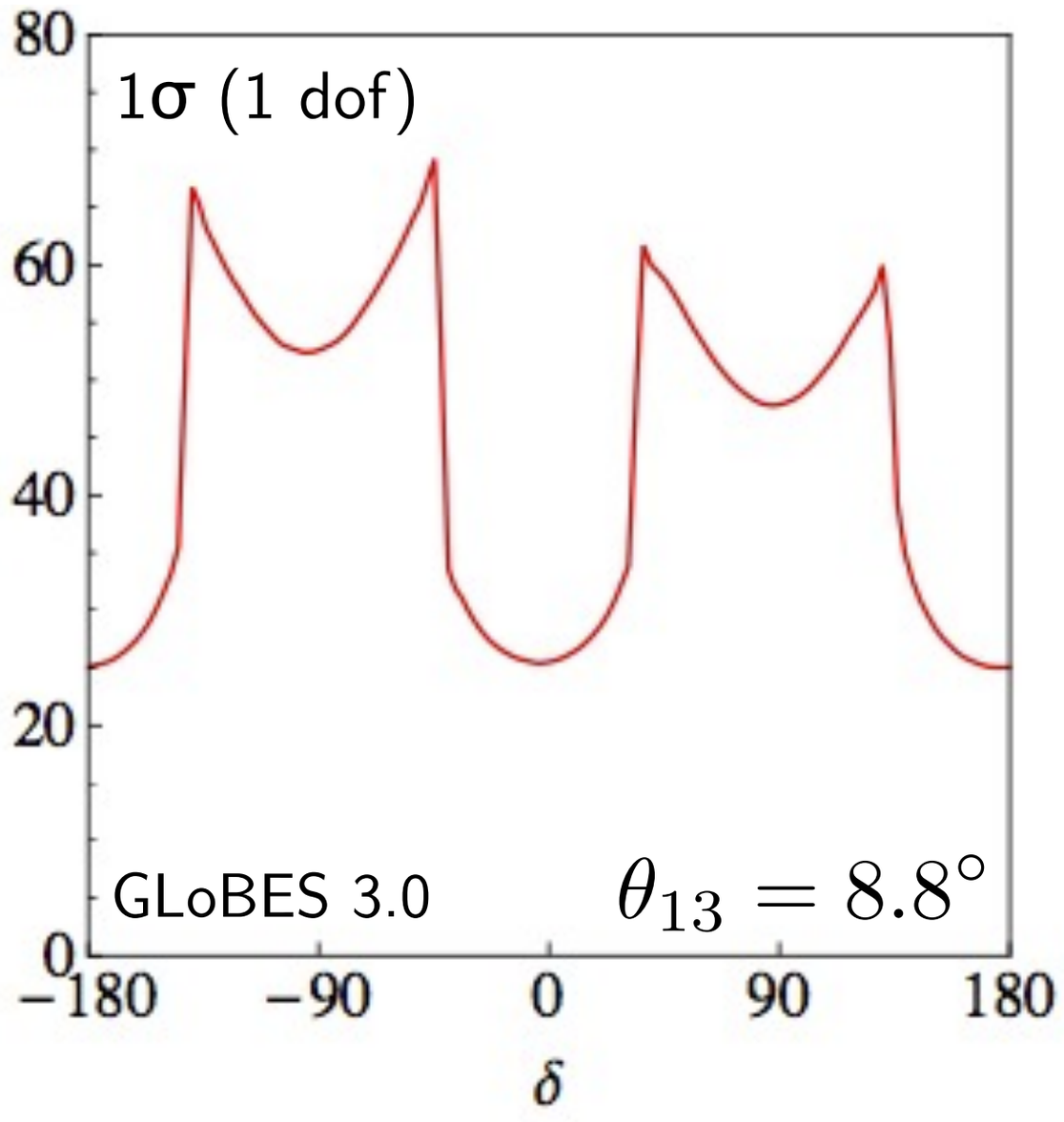


The starting point

NOvA+T2K+Daya Bay

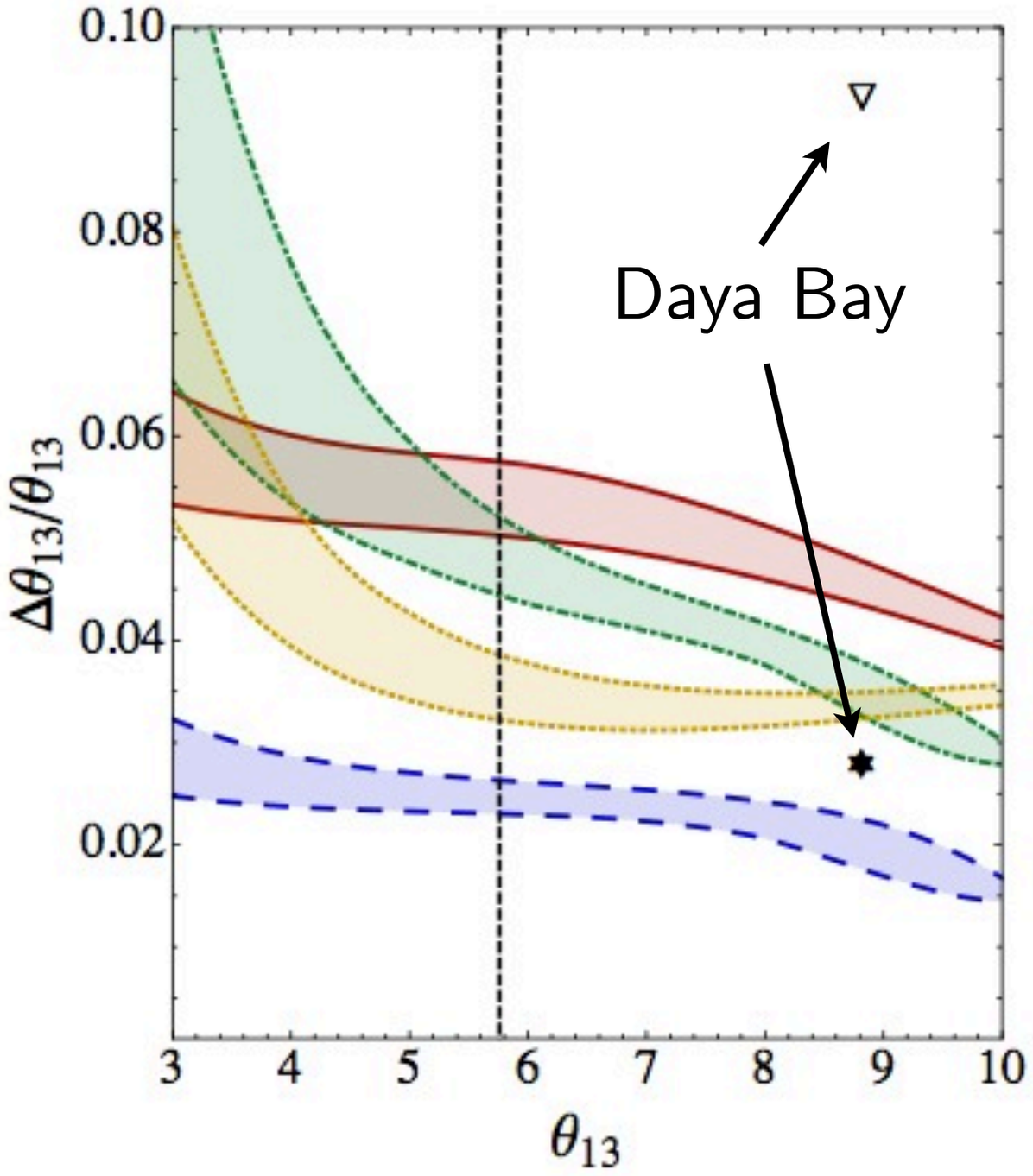


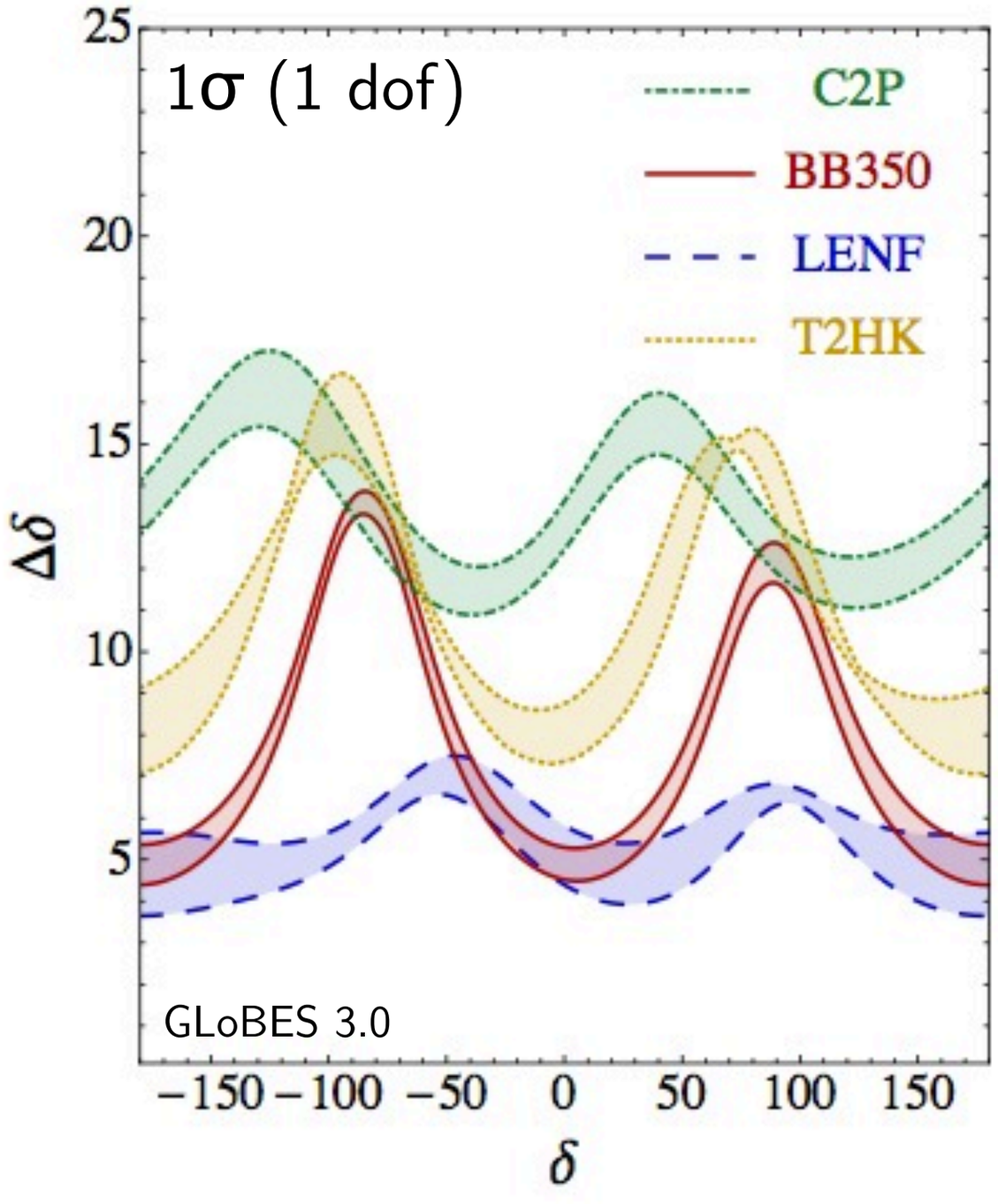
Huber, Lindner, Schwetz, Winter, 0907.1896 [hep-ph]



Coloma, Donini, Fernández-Martínez, Hernández, 1203.5651 [hep-ph]

Precision





Coloma, Donini, Fernández-Martínez, Hernández, 1203.5651 [hep-ph]

The importance of systematics

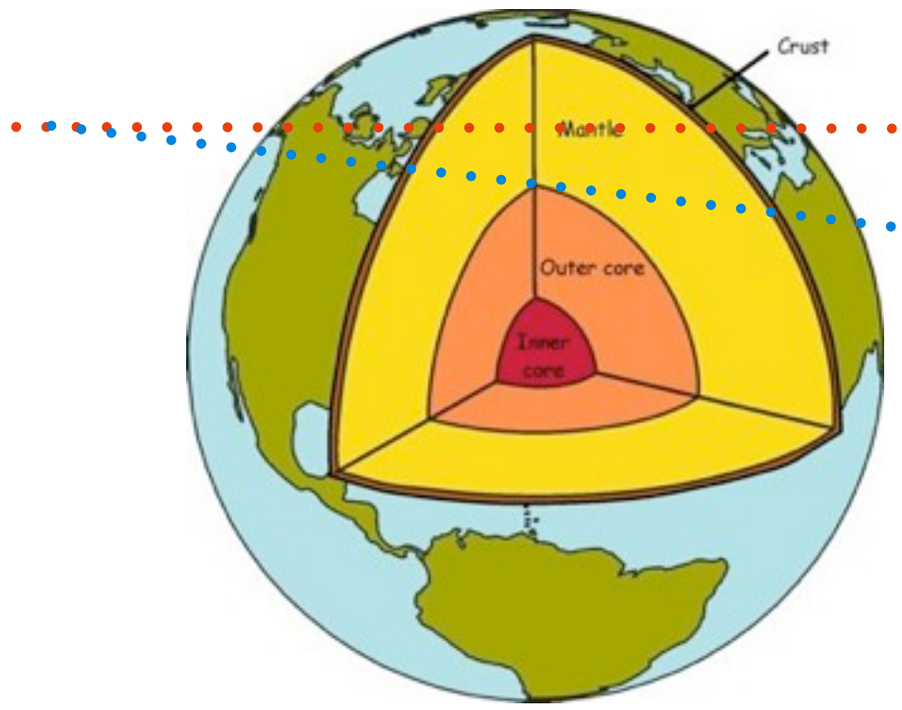
- Up to now, each facility has made its own assumptions about systematic uncertainties. Generally,
  - BB and NF are assumed to have low sys
  - SB are assumed to have high sys
- However, this may change if a near detector is included and correlations are considered carefully

  (For instance, if final flavour cross sections could be measured at the ND)

An example

Signal:

$$\pi^- \to \mu^- + \nu_\mu$$



CC interactions

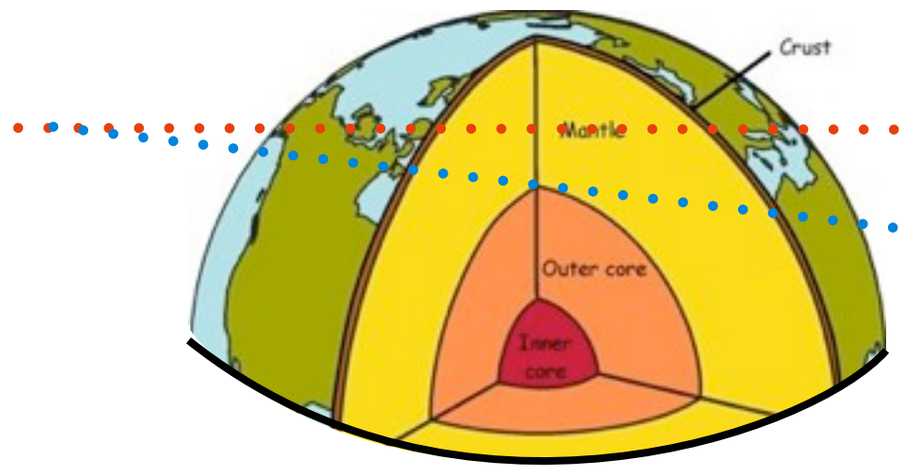
ν_e

ν_μ

An example

Signal:

$$\pi^- \rightarrow \mu^- + \nu_\mu$$



CC interactions

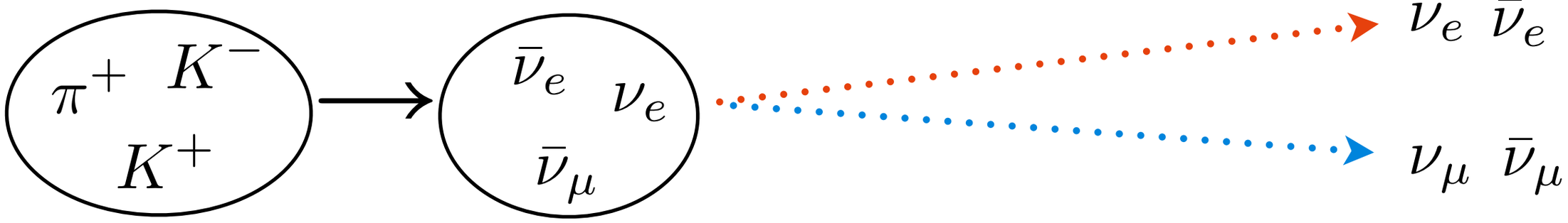
ν_e

ν_μ

Backgrounds:

NC interactions

$$\begin{cases} \pi^\pm \rightarrow \mu^\pm + E_{miss} \\ \pi^0 \rightarrow \gamma\gamma \end{cases}$$



An example

Possible ways to reduce the effect of systematics:

1) measure final flavour cross sections at a near detector. If this cannot be done, put constraints on ratios between cross sections for different flavours

2) measure intrinsic background at near detector

3) use data from disappearance channels at the far detector

Simulation details

Systematics	SB Opt.	SB Def.	SB Cons.	BB Opt.	BB Def.	BB Cons.	NF Opt.	NF Def.	NF Cons.
Fiducial volume ND	0.2%	0.5%	1%	0.2%	0.5%	1%	0.2%	0.5%	1%
Fiducial volume FD (incl. near-far extrap.)	1%	2.5%	5%	1%	2.5%	5%	1%	2.5%	5%
Flux error signal ν	5%	7.5%	10%	1%	2%	2.5%	0.1%	0.5%	1%
Flux error background ν	10%	15%	20%	correlated			correlated		
Flux error signal $\bar{\nu}$	10%	15%	20%	1%	2%	2.5%	0.1%	0.5%	1%
Flux error background $\bar{\nu}$	20%	30%	40%	correlated			correlated		
Background uncertainty	5%	7.5%	10%	5%	7.5%	10%	10%	15%	20%
Cross secs × eff. QE	10%	15%	20%	10%	15%	20%	10%	15%	20%
Cross secs × eff. RES	10%	15%	20%	10%	15%	20%	10%	15%	20%
Cross secs × eff. DIS	5%	7.5%	10%	5%	7.5%	10%	5%	7.5%	10%
Ratio ν_e/ν_μ QE	3.5%	11%	32%	3.5%	11%	32%	3.5%	11%	32%
Ratio ν_e/ν_μ RES	2.7%	5.4%	11%	2.7%	5.4%	11%	2.7%	5.4%	11%
Ratio ν_e/ν_μ DIS	2.5%	5.1%	10%	2.5%	5.1%	10%	2.5%	5.1%	10%
Matter density	1%	2%	5%	1%	2%	5%	1%	2%	5%

Simulation details

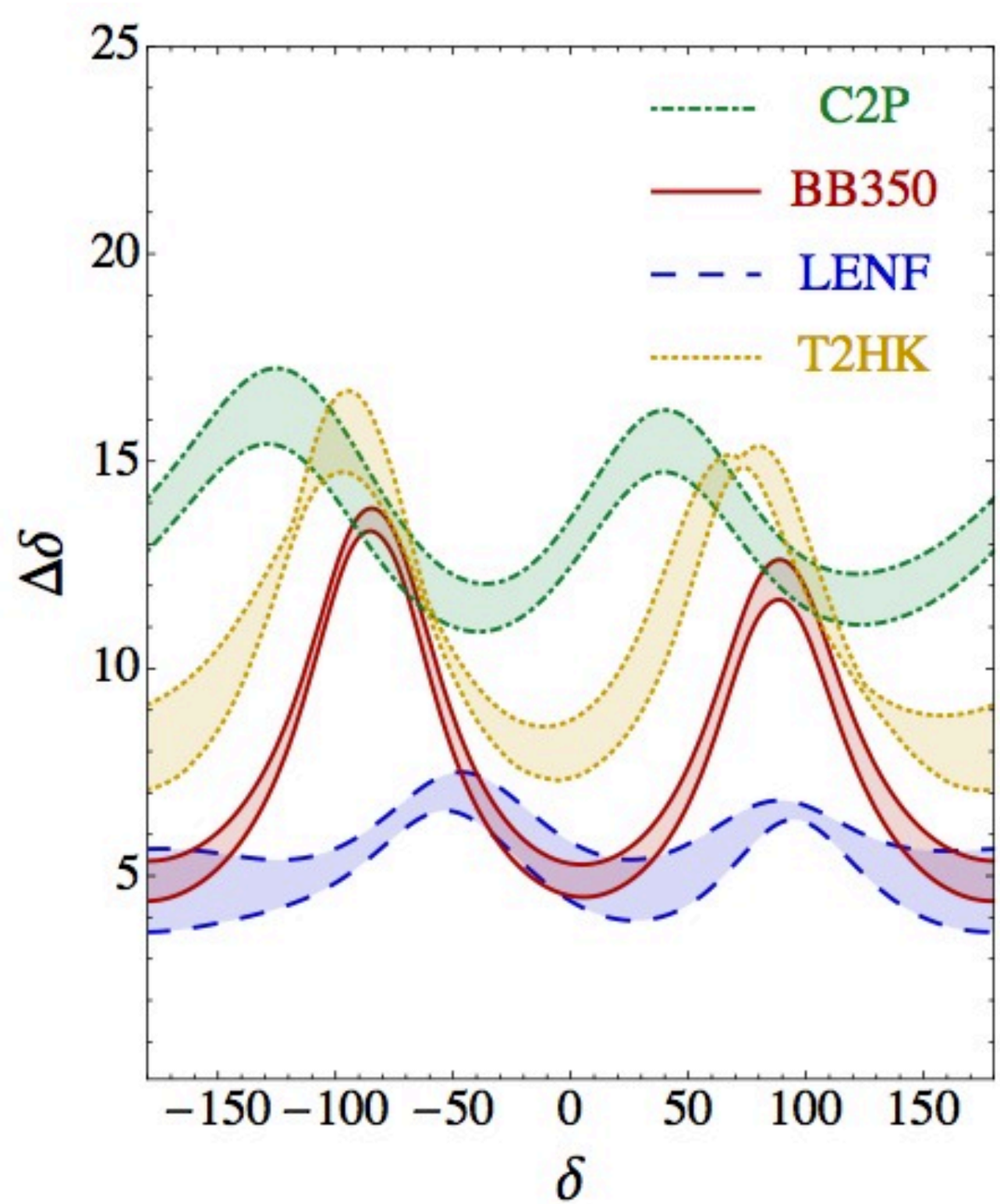
$$\chi^2 = \sum_{D,C,i} \frac{\left[(1+\xi_{D,C,i})N_{D,C,i} - \overline{N}_{D,C,i}\right]^2}{\overline{N}_{D,C,i}} + \sum_k \left(\frac{\xi_k}{\sigma_k}\right)^2$$

nuisance parameters

- GLoBES software used hep-ph/0407333, hep-ph/0701187
- Input values in agreement with best fits 1205.5254 [hep-ph], 1205.4018 [hep-ph]
- Marginalization over solar and atmospheric params performed assuming 1σ gaussian priors 1108.1376 [hep-ph]
- No degeneracies have been accounted for: atmospheric angle set to maximal, normal hierarchy
- $\sin^2 2\theta_{13} = 0.1$
- 1σ (1 dof) unless stated otherwise

Possible observables and precision

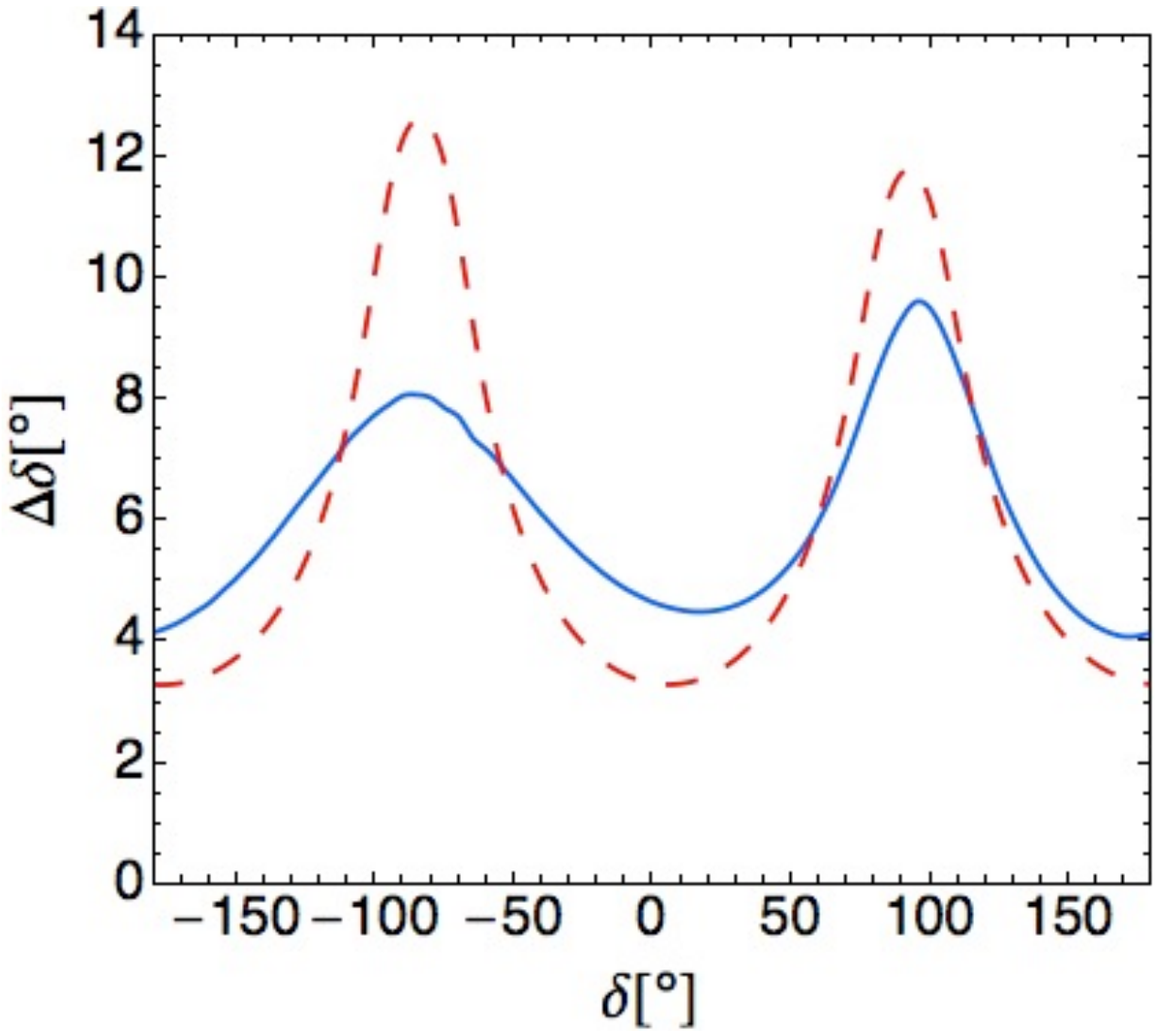
Precision



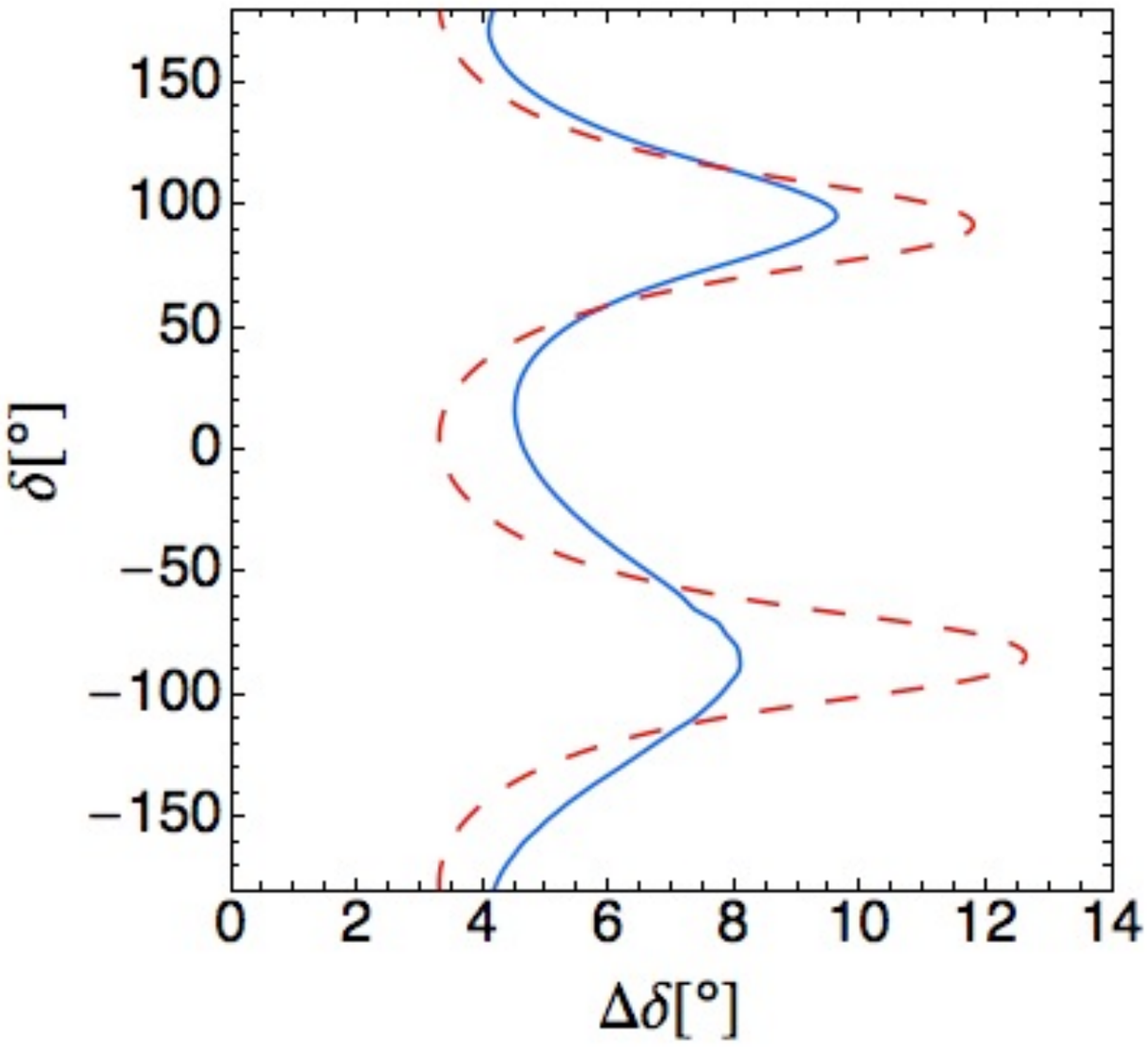
very different behaviour for all facilities

Coloma, Donini, Fernández-Martínez, Hernández, 1203.5651 [hep-ph]

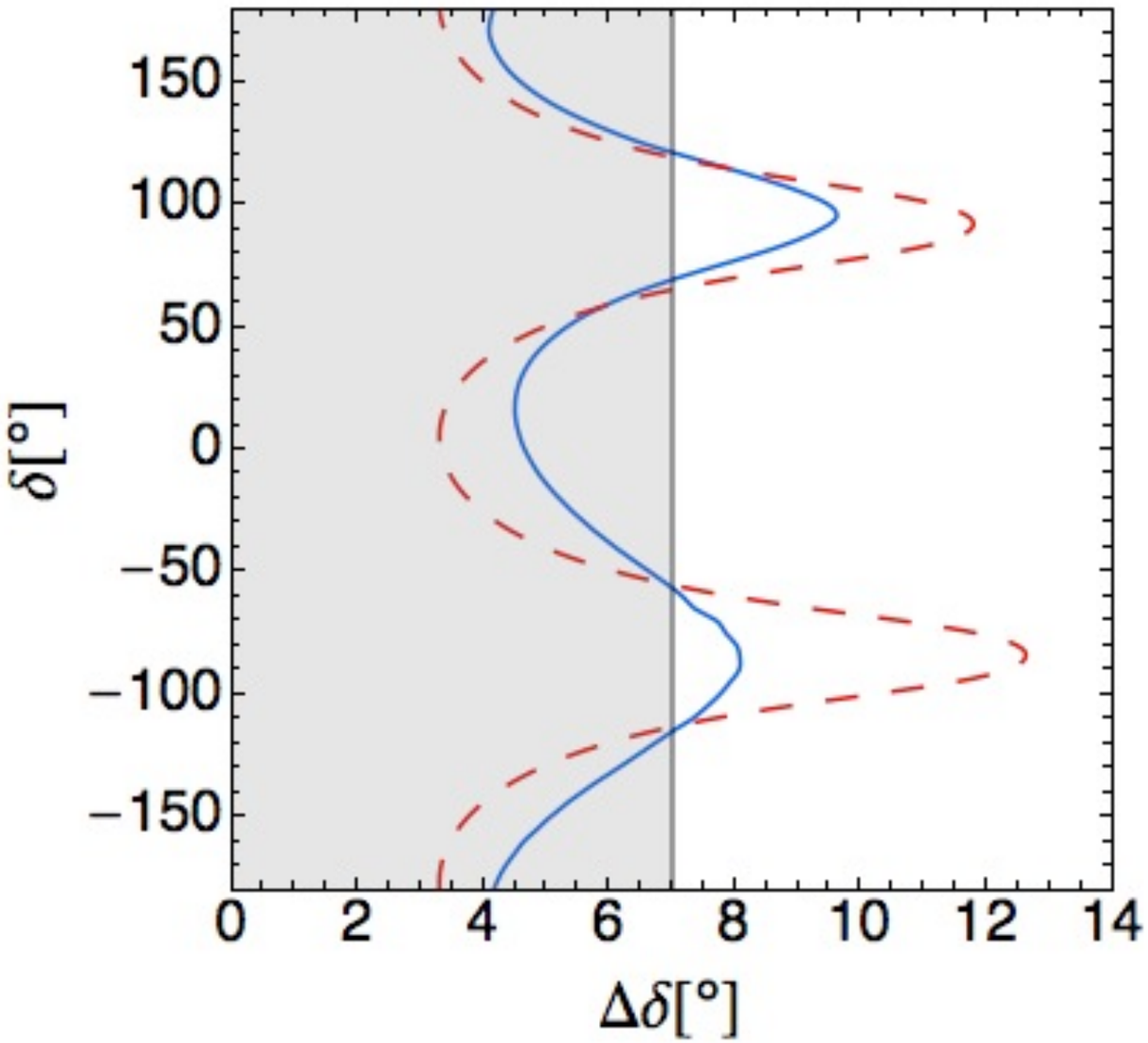
Precision and CP fraction



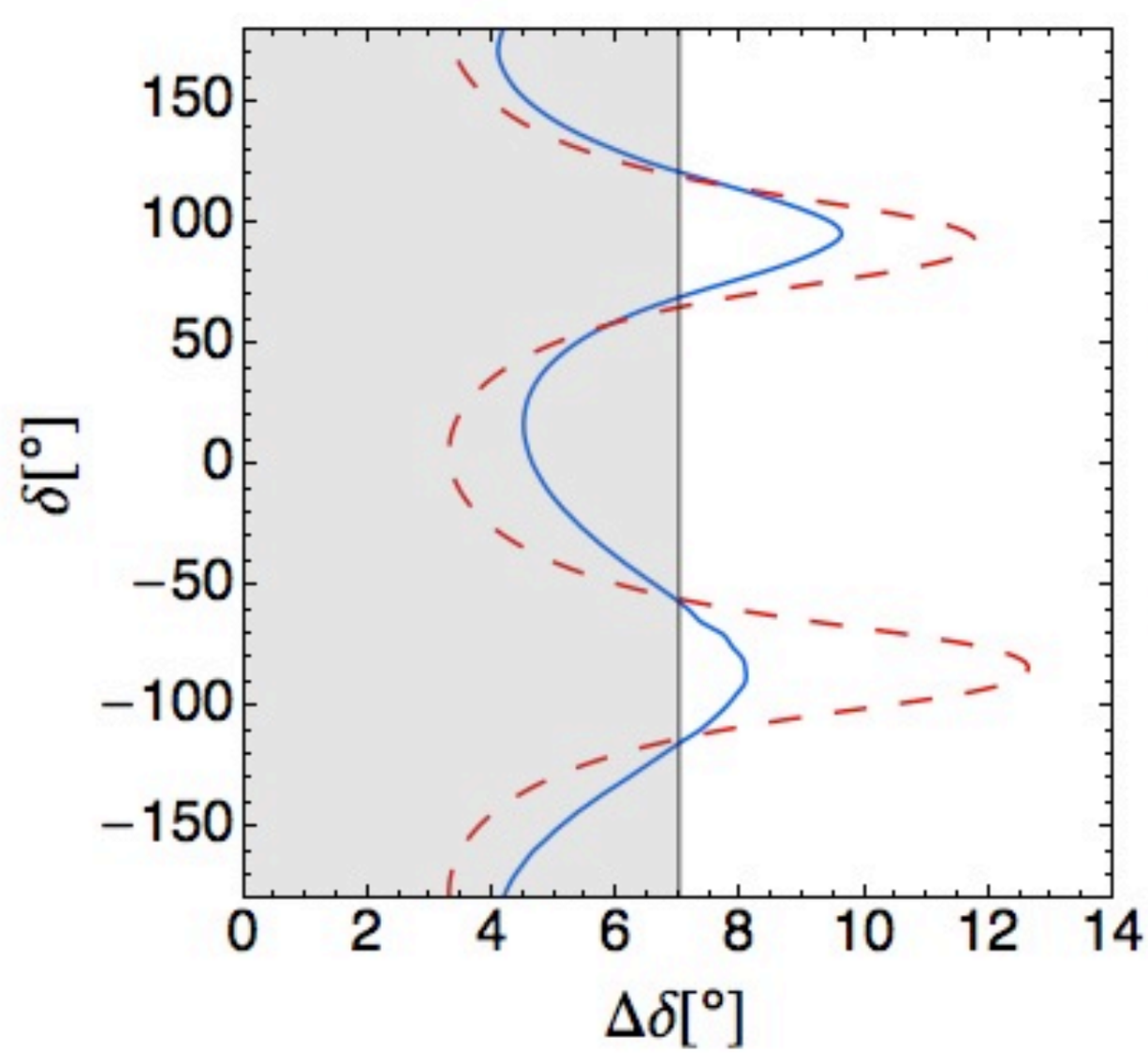
Precision and CP fraction

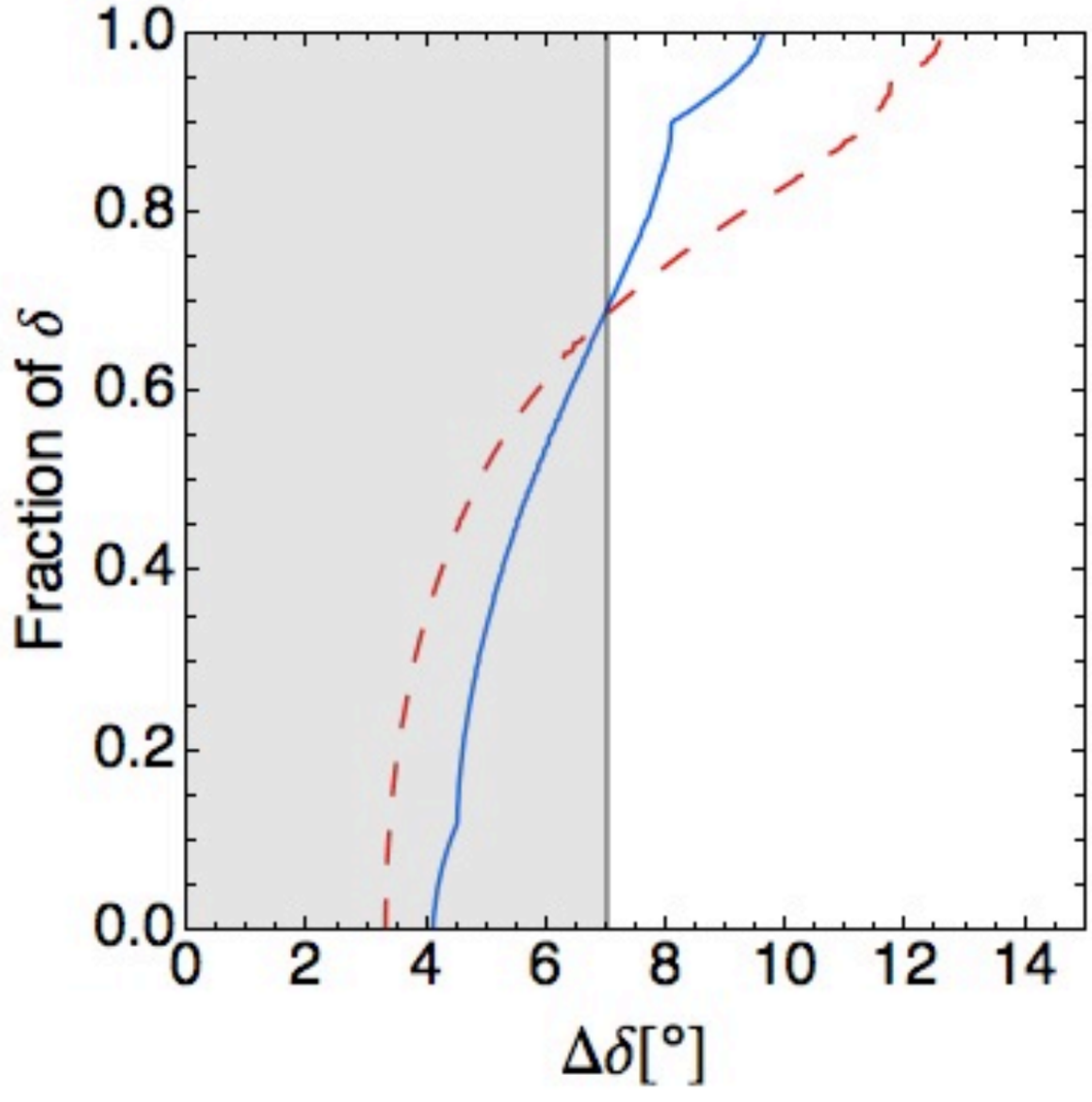


Precision and CP fraction



Precision and CP fraction

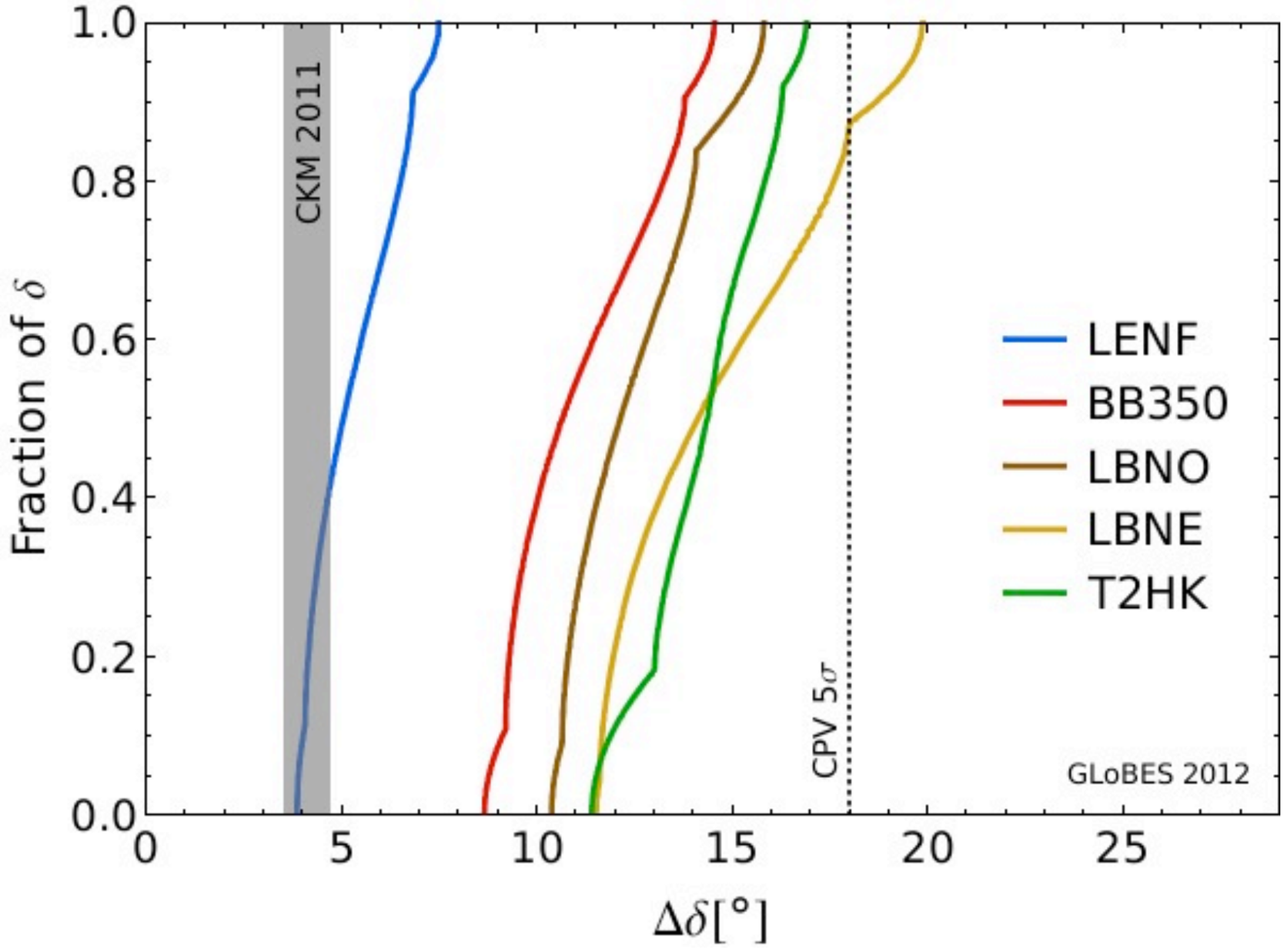




Results

General comparison

How far do we want to get?



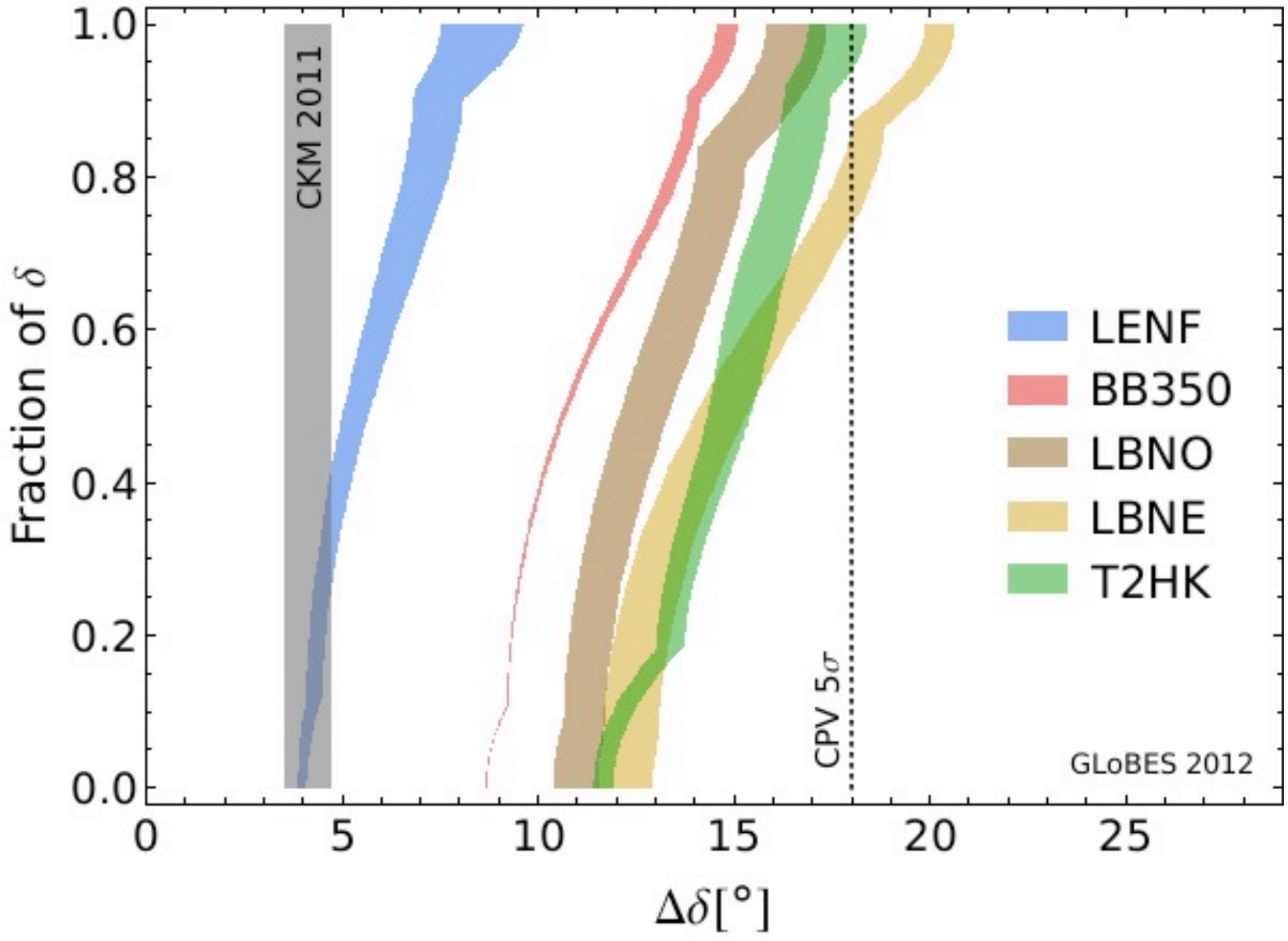
Coloma, Huber, Kopp, Winter, In preparation

Impact of near detector

Difference between 1 detector and 2 detectors (optimistic case):

$L_{ND} \sim 1 - 2$ km

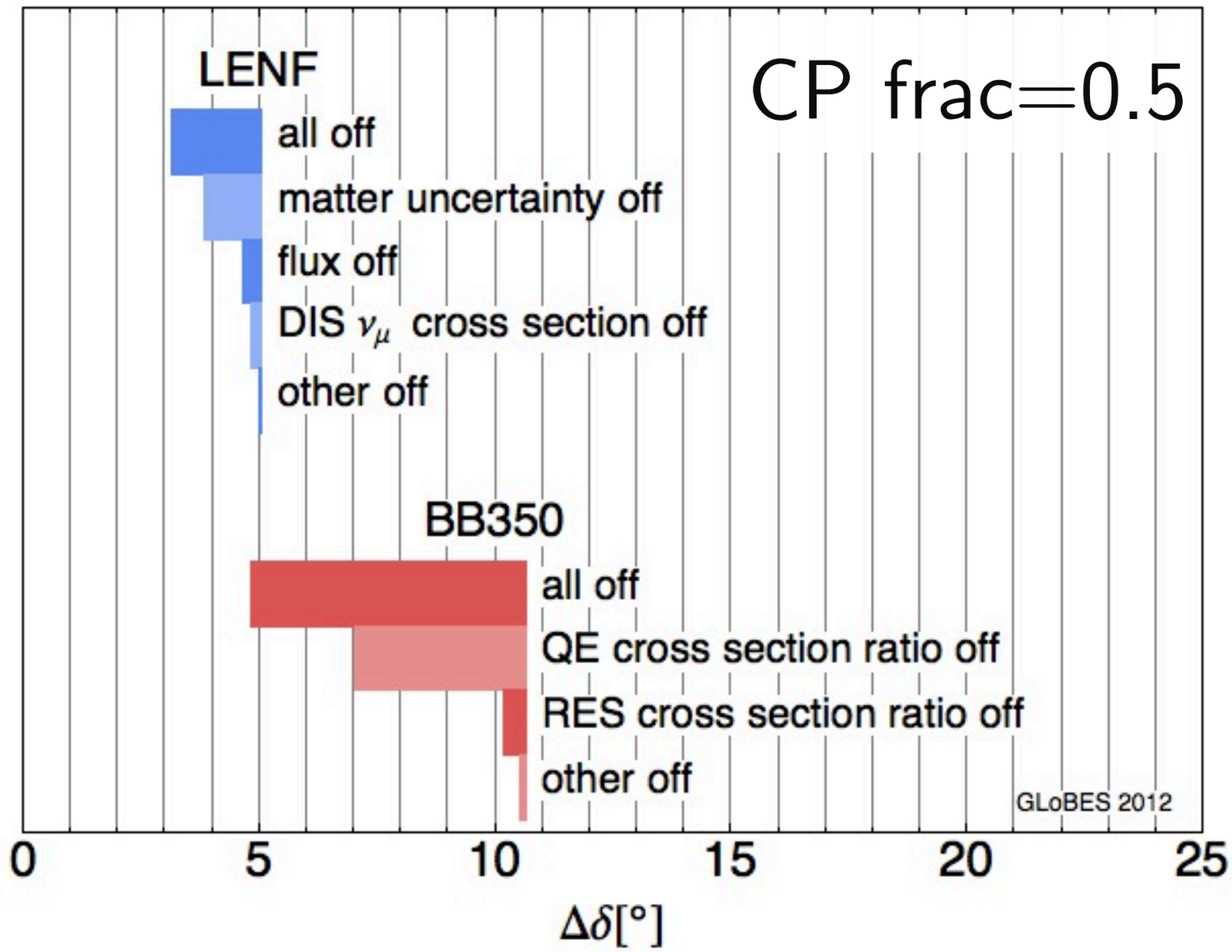
$M_{ND} \sim 25 - 100$ tons



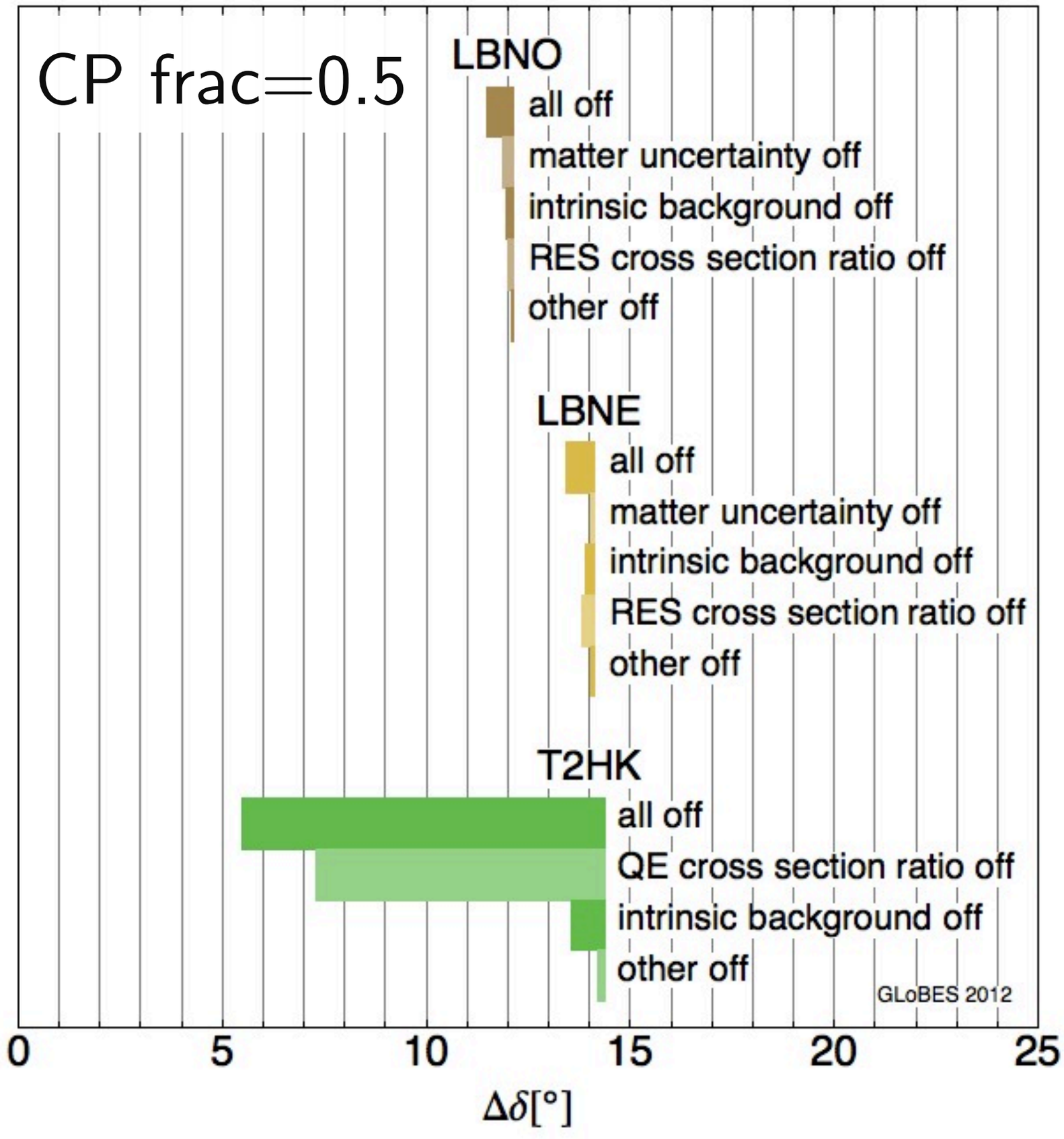
Coloma, Huber, Kopp, Winter, In preparation

Impact of systematics

Which sources are most relevant in each case?

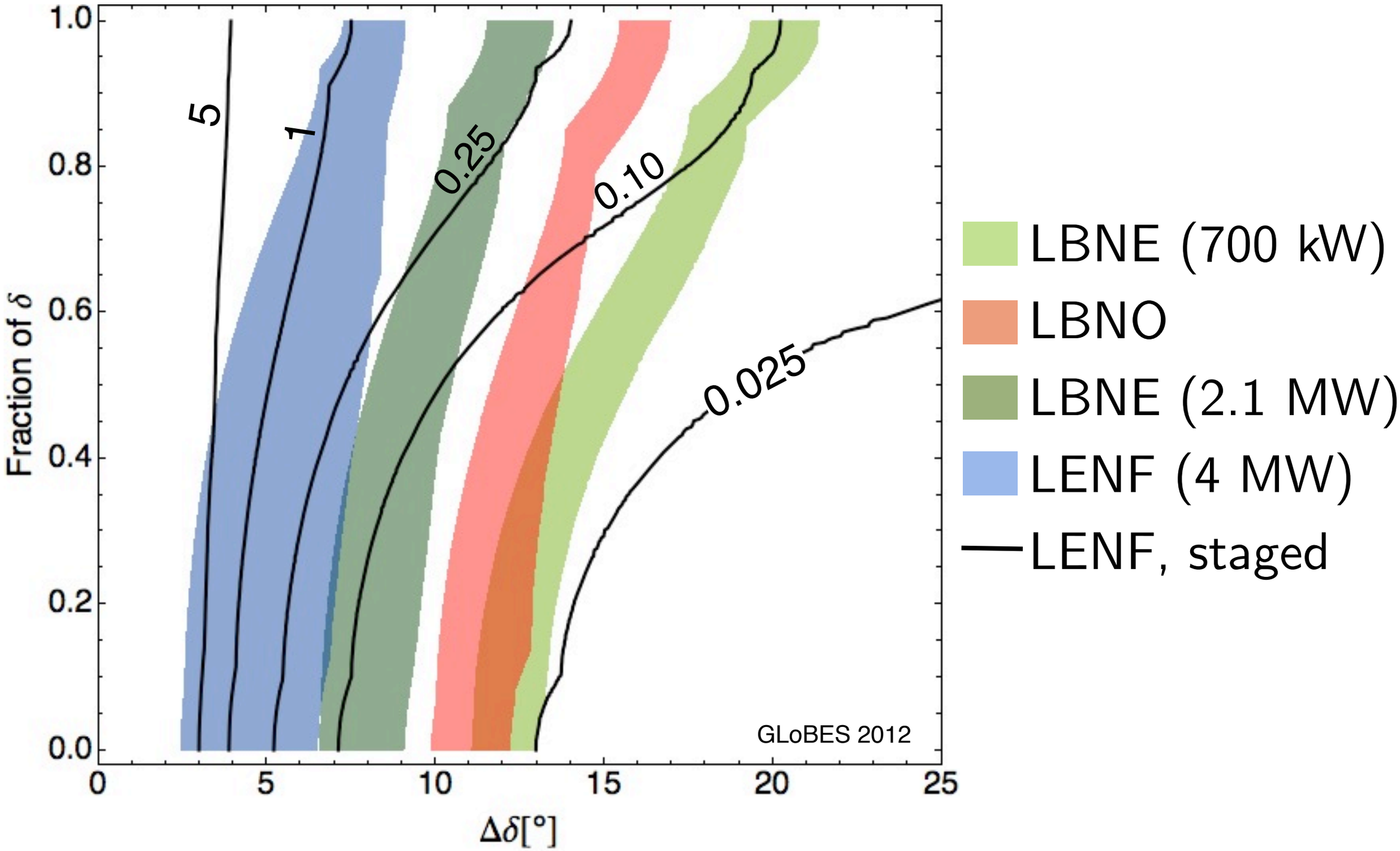


Coloma, Huber, Kopp, Winter, In preparation



Coloma, Huber, Kopp, Winter, In preparation

Staged approach for a NF



Summary

- We have done a comparison on equal footing between the most relevant setups in the literature for long baseline oscillation experiments.
  - we have included a ND for all setups, and several sources of sys
  - we have done a comparison on equal footing
  - we have tested how the specific values impact our results
  - we have found out the most relevant sources of sys in each case

Conclusions

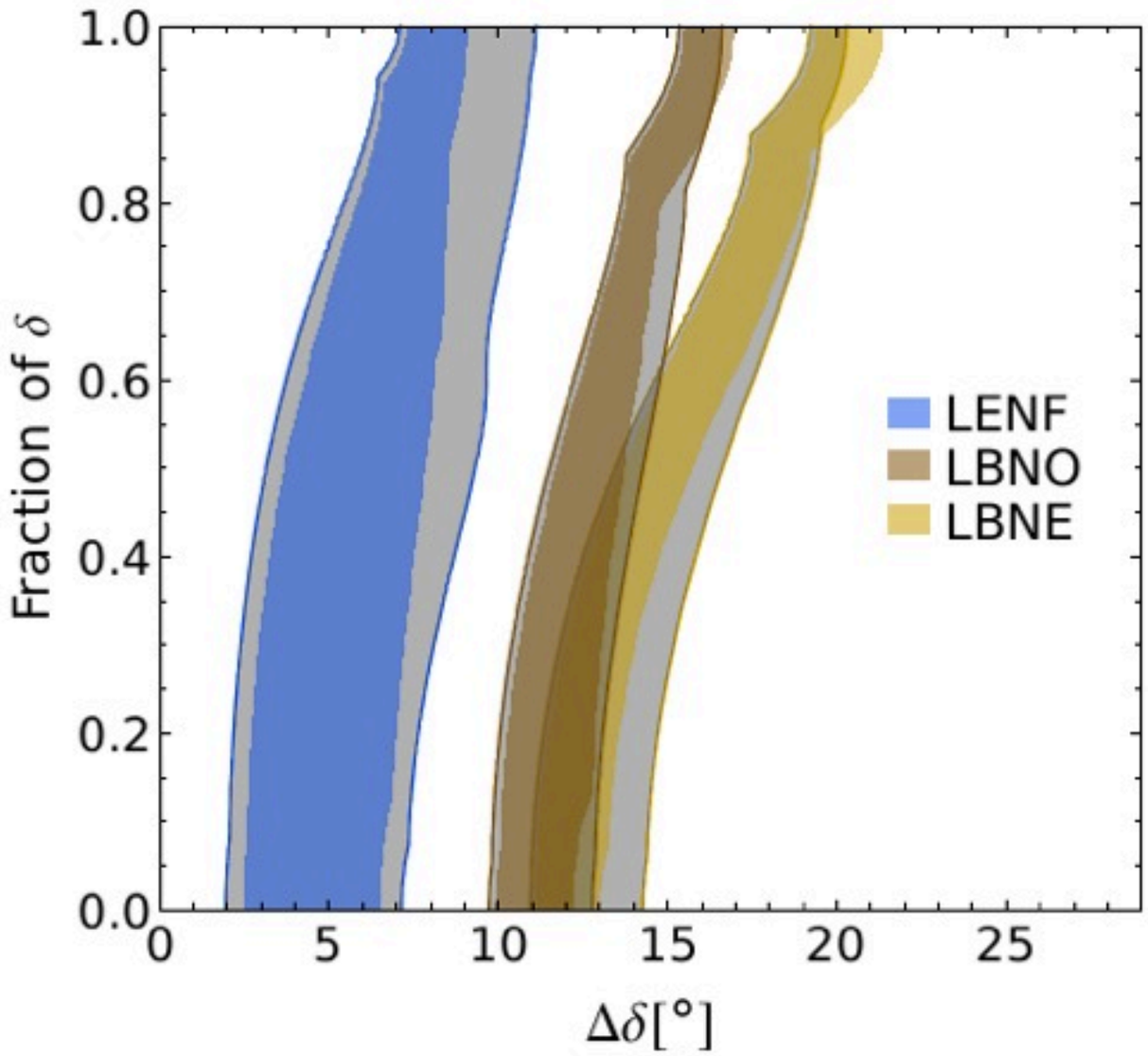
- The impact of a ND does not seem so relevant if data from disappearance at the FD is used
- Low energy setups are more affected by systematics
- Matter uncertainty has a large effect for LENF and LBNO

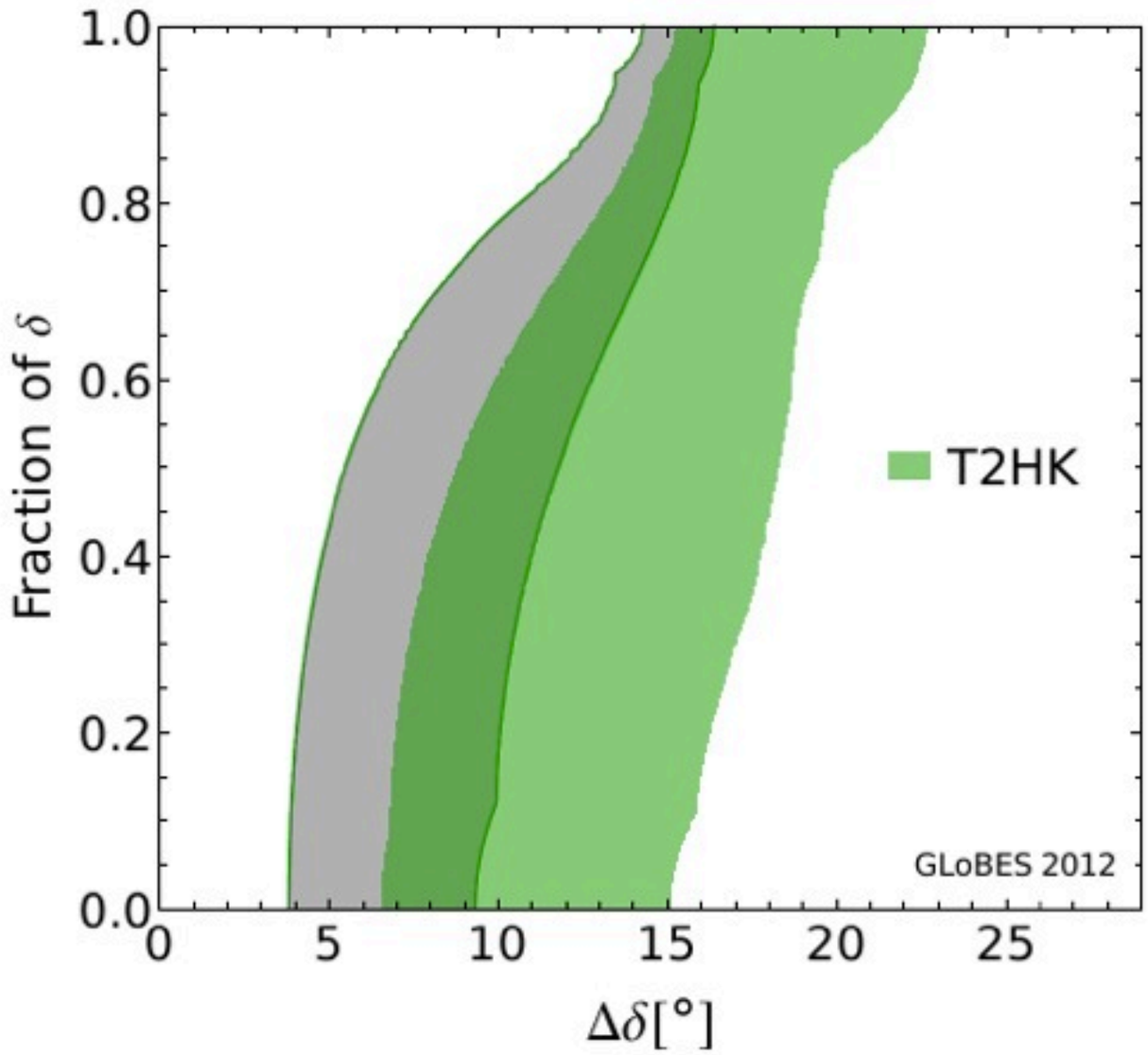
All results shown here are still preliminary:
any input/feedback is very welcome!

Backup

Impact of systematics

Differences with the old implementation:

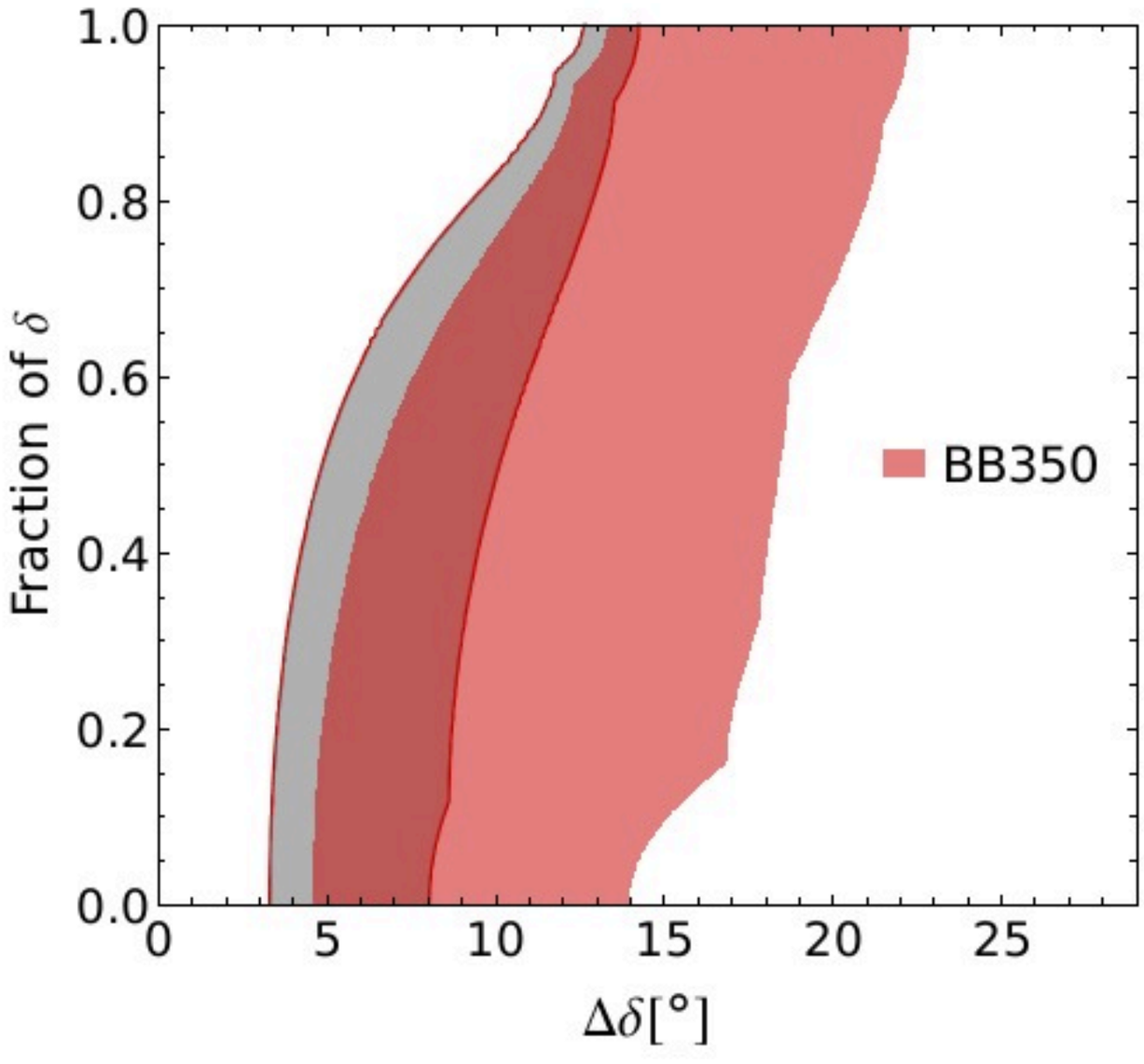




Coloma, Huber, Kopp, Winter, In preparation

Impact of systematics

Differences with the old implementation:



Coloma, Huber, Kopp, Winter, In preparation

Currently Open Documents
cp_MH.c
ids-nf-3.0beta_...
ids-nf-3.0beta-...

Recent Documents
ids-nf-3.0beta-fd.inc
ids-nf-3.0beta_opt...
cp_MH.c

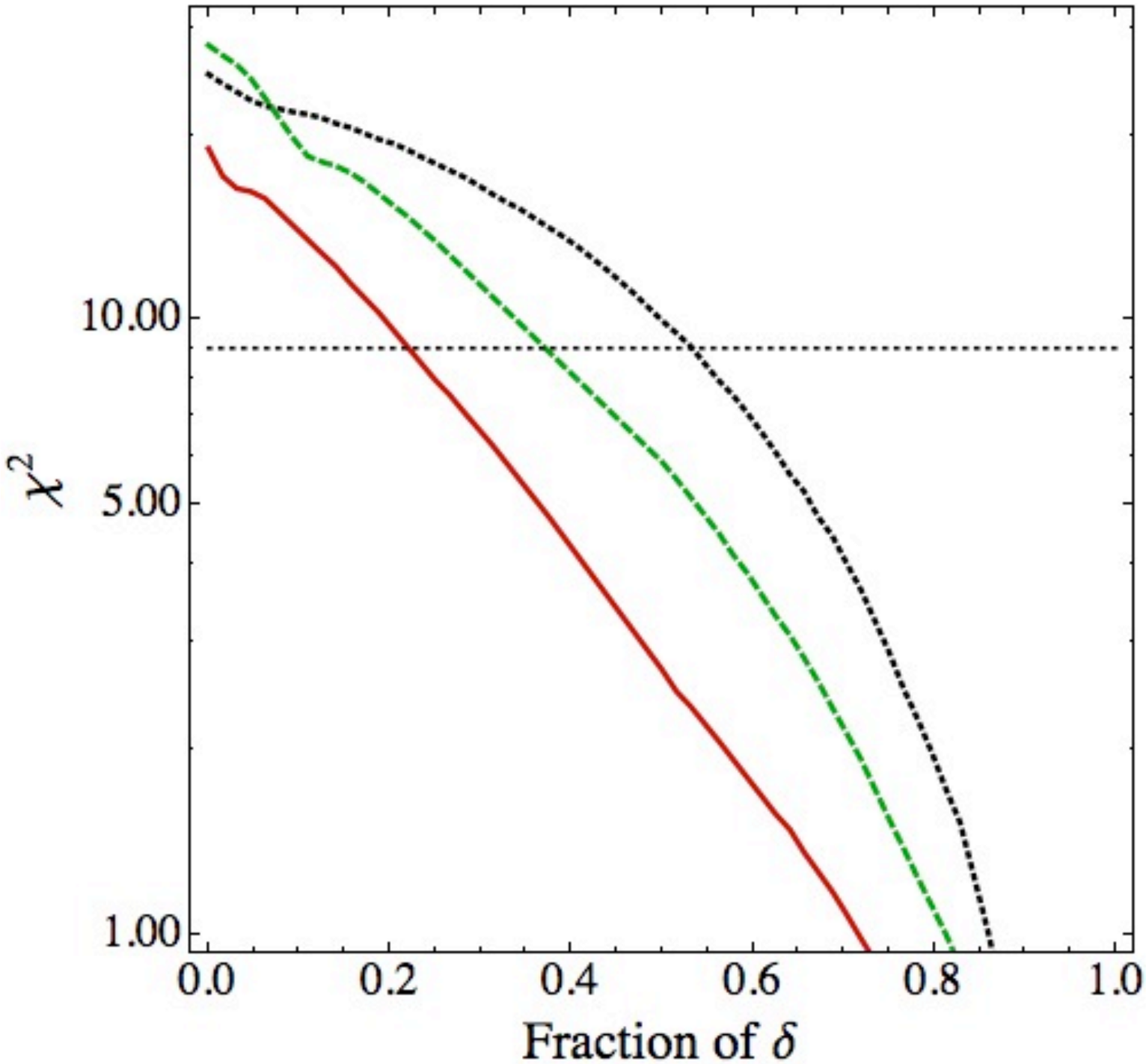
Last Saved: 5/30/12 12:41:35 PM
File Path ▾ : ~/Dropbox/systematics/newsys/LENF/ids-nf-3.0beta-fd.inc

ids-nf-3.0beta-fd.inc

```
>

// \mu^- running: appearance
rule(#Nu_Mu_Bar_Appearance)<
  @signal                    = 1.0@#nu_mu_bar_appQE : 1.0@#nu_mu_bar_appRES : 1.0@#nu_mu_bar_appDIS
  @sys_on_multiex_errors_sig = { #MassFar, #FluxMuMinus, #XmbQE } :
                               { #MassFar, #FluxMuMinus, #XmbRES } :
                               { #MassFar, #FluxMuMinus, #XmbDIS }

  @background                = 1@#nu_NC_bckg : 1@#nu_mu_misCID
  @sys_on_multiex_errors_bg  = { #MassFar, #FluxMuMinus, #NCBG_mb } :
                               { #MassFar, #FluxMuMinus, #BGm  }

  @sys_on_function  = "chiMultiExp"
  @sys_off_function = "chiNoSysSpectrum"
  @energy_window = 0.1 : 10
>


// \mu^+ running: disappearance
rule(#Nu_Mu_Bar_Disappearance)<
  @signal                    = 1.0@#nu_mu_bar_disQE : 1.0@#nu_mu_bar_disRES : 1.0@#nu_mu_bar_disDIS
  @sys_on_multiex_errors_sig = { #MassFar, #FluxMuPlus, #XmbQE  } :
                               { #MassFar, #FluxMuPlus, #XmbRES } :
                               { #MassFar, #FluxMuPlus, #XmbDIS }

  @background                = 1@#nu_bar_NC_bckg
  @sys_on_multiex_errors_bg  = { #MassFar, #FluxMuPlus, #NCBG_mb }

  @sys_on_function  = "chiMultiExp"
  @sys_off_function = "chiNoSysSpectrum"
  @energy_window = 0.1 : 10
>
```

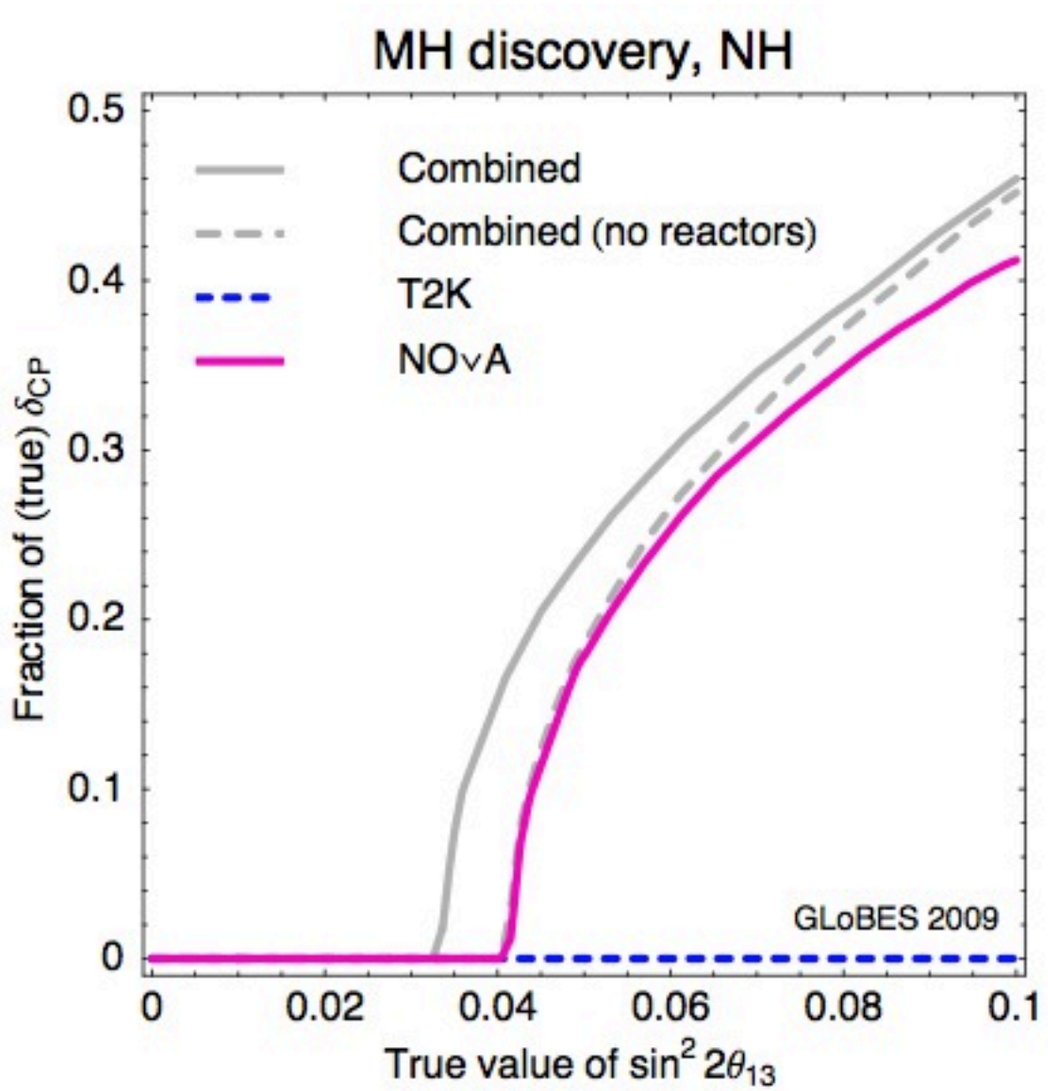
260 26 (none) Unicode (UTF-8) Unix (LF) 8,130 / 660 / 290

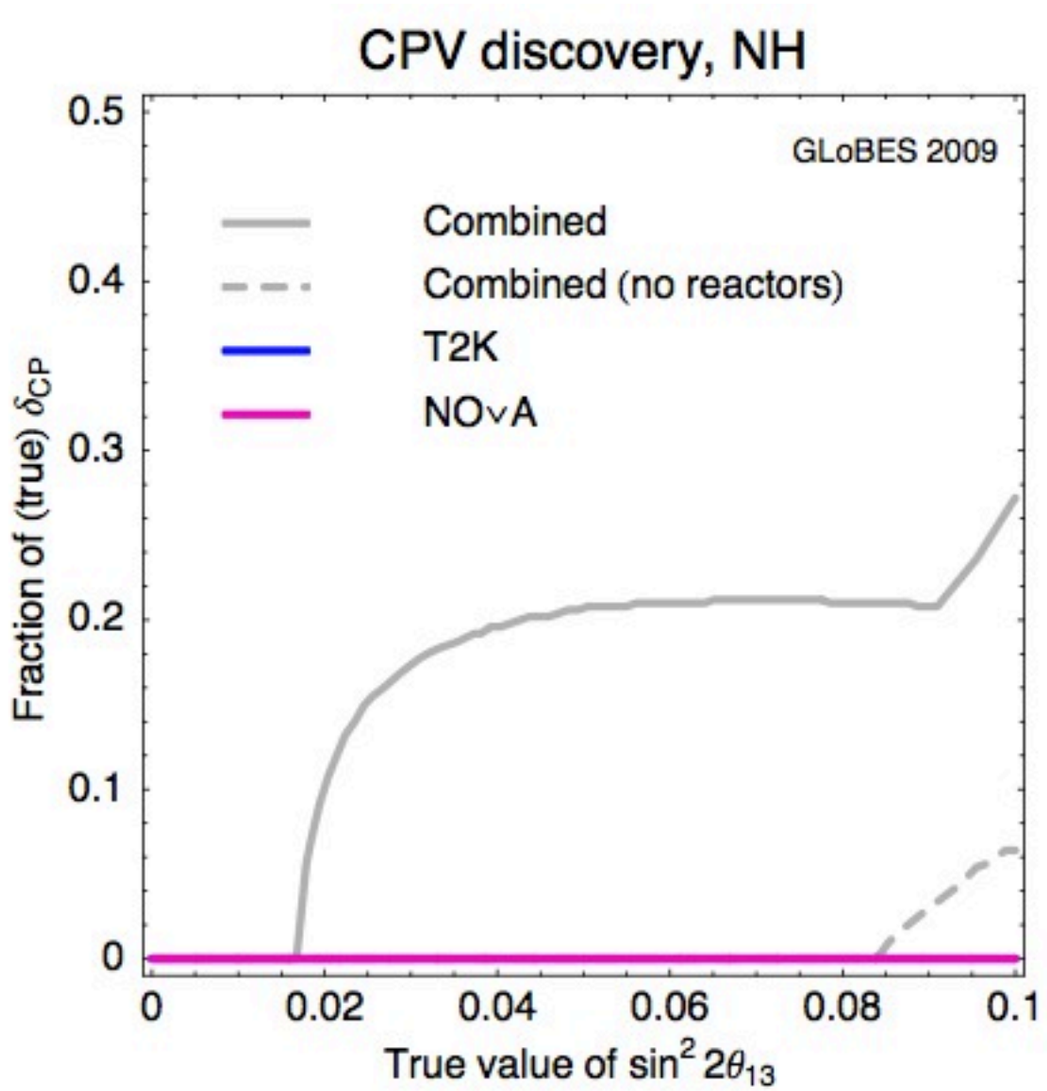
Effect of th13 prior on CPV



Present oscillation facilities

Discovery potential at the 90% CL



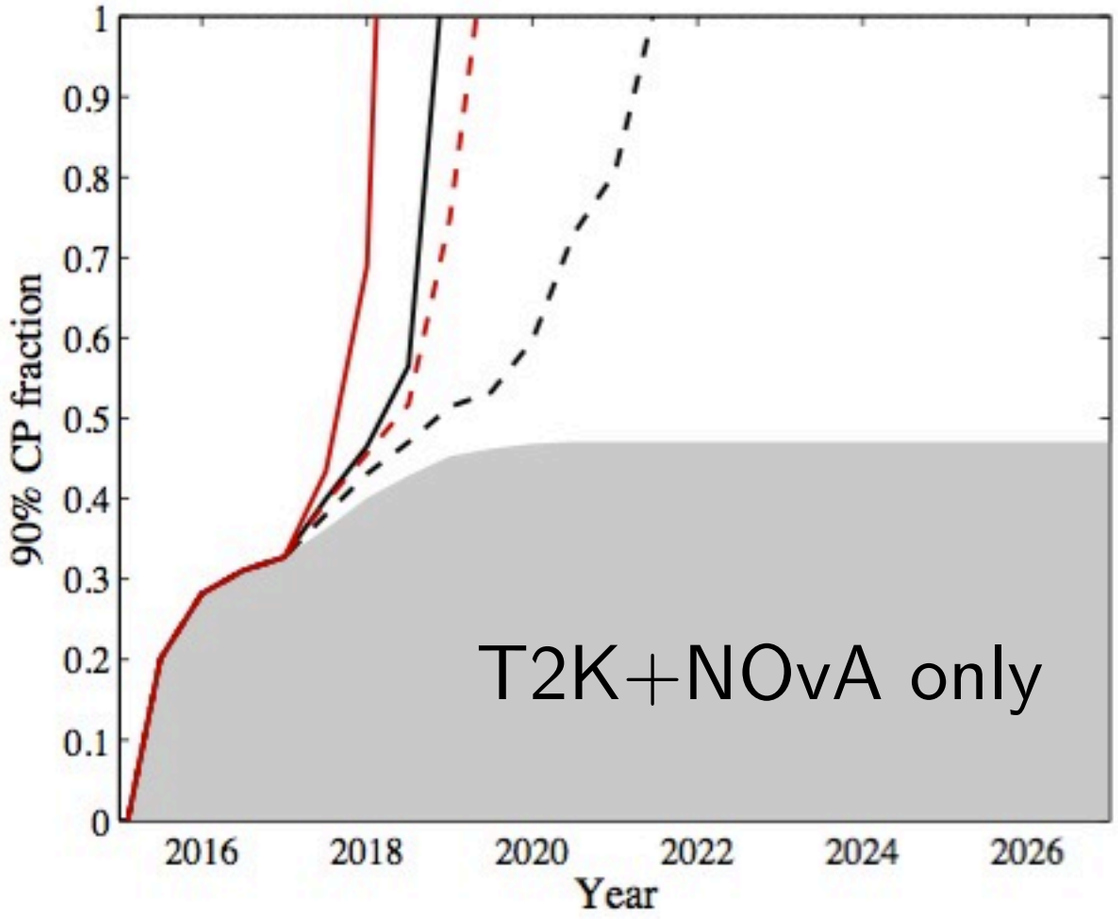


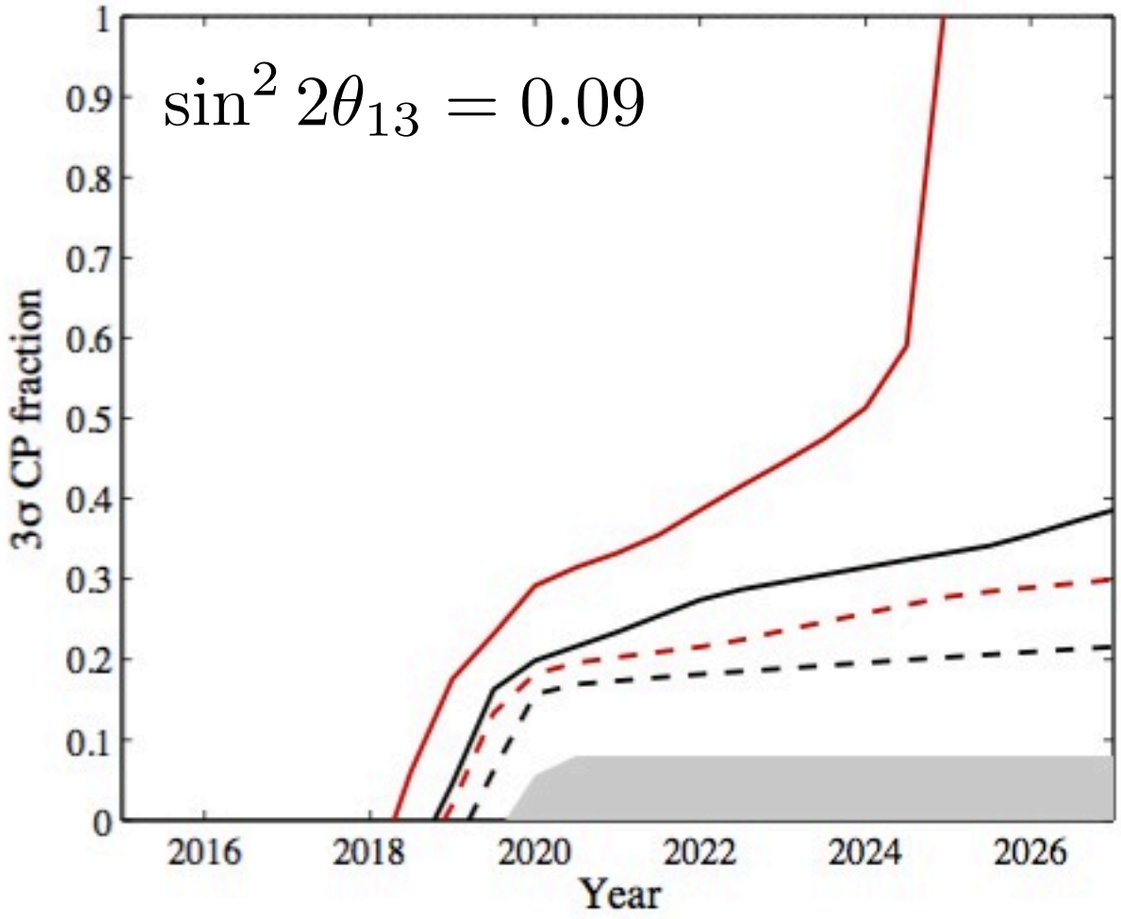
Huber, Lindner, Schwetz, Winter, 0907.1896 [hep-ph]

Present oscillation facilities

T2K+NOvA+INO

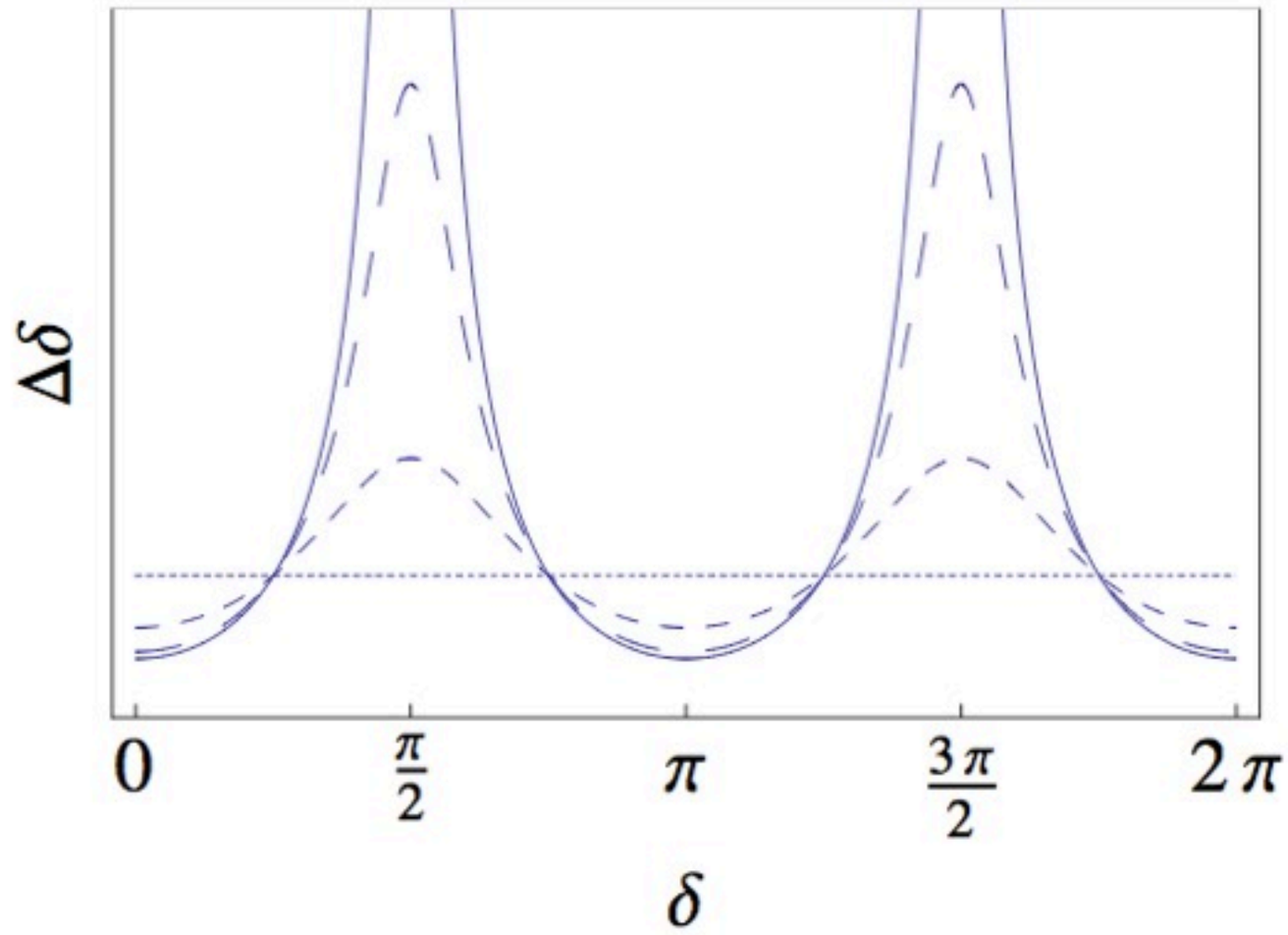
(50kt/100kt; low/high res)





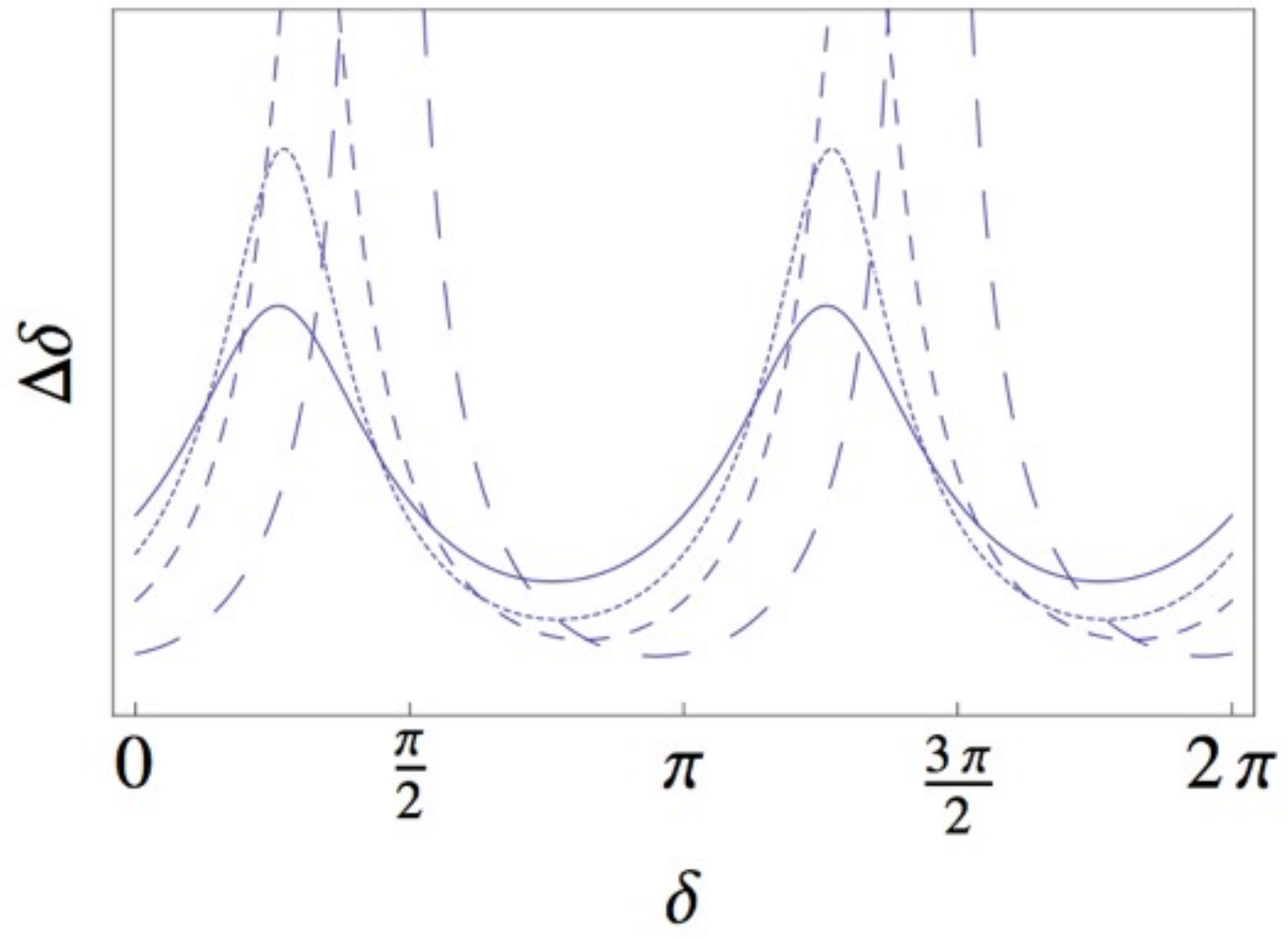
Blennow, Schwetz, 1203.3388 [hep-ph]

On/Off peak (vacuum)



$$(\Delta\delta)_{\pm} \propto \frac{1}{\sin\left(\frac{\pi}{2} \mp \delta\right)}$$

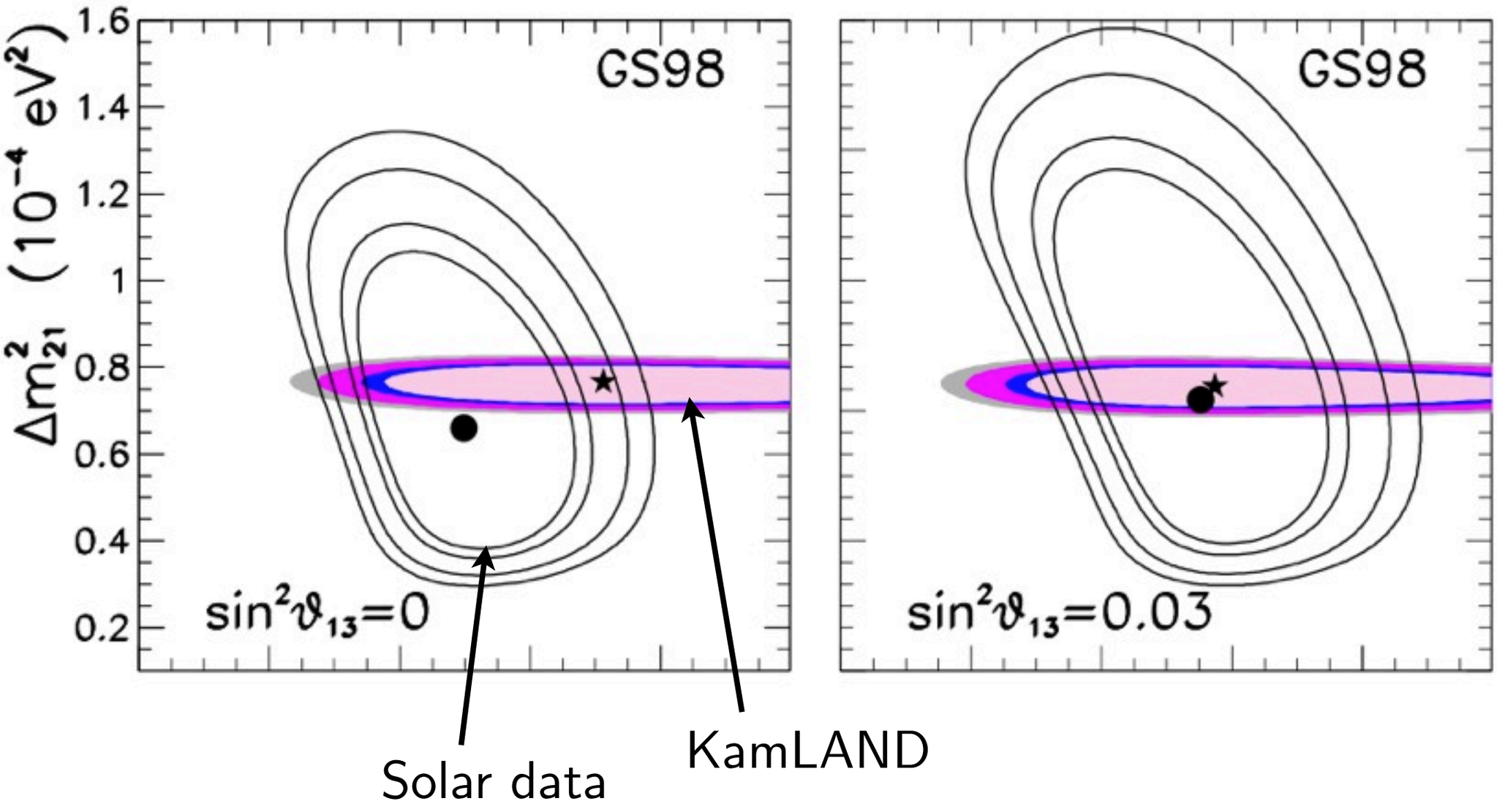
Importance of matter effects



$$(\Delta\delta)_{\pm} \propto \frac{1}{\sin\left(\frac{\pi}{2}\frac{1}{(1\mp\hat{A})} \mp \delta\right)} \qquad \left(\hat{A} \equiv \frac{\sqrt{2}G_F n_e L}{2\Delta}\right)$$

Previous hints on θ_{13}

Previous hints from global fits pointed to nonzero θ_{13}...



González-García, Maltoni,Salvado, 1001.4524 [hep-ph]

General landscape

BB100,BB350:
hep-ph/0406132
hep-ph/0503021

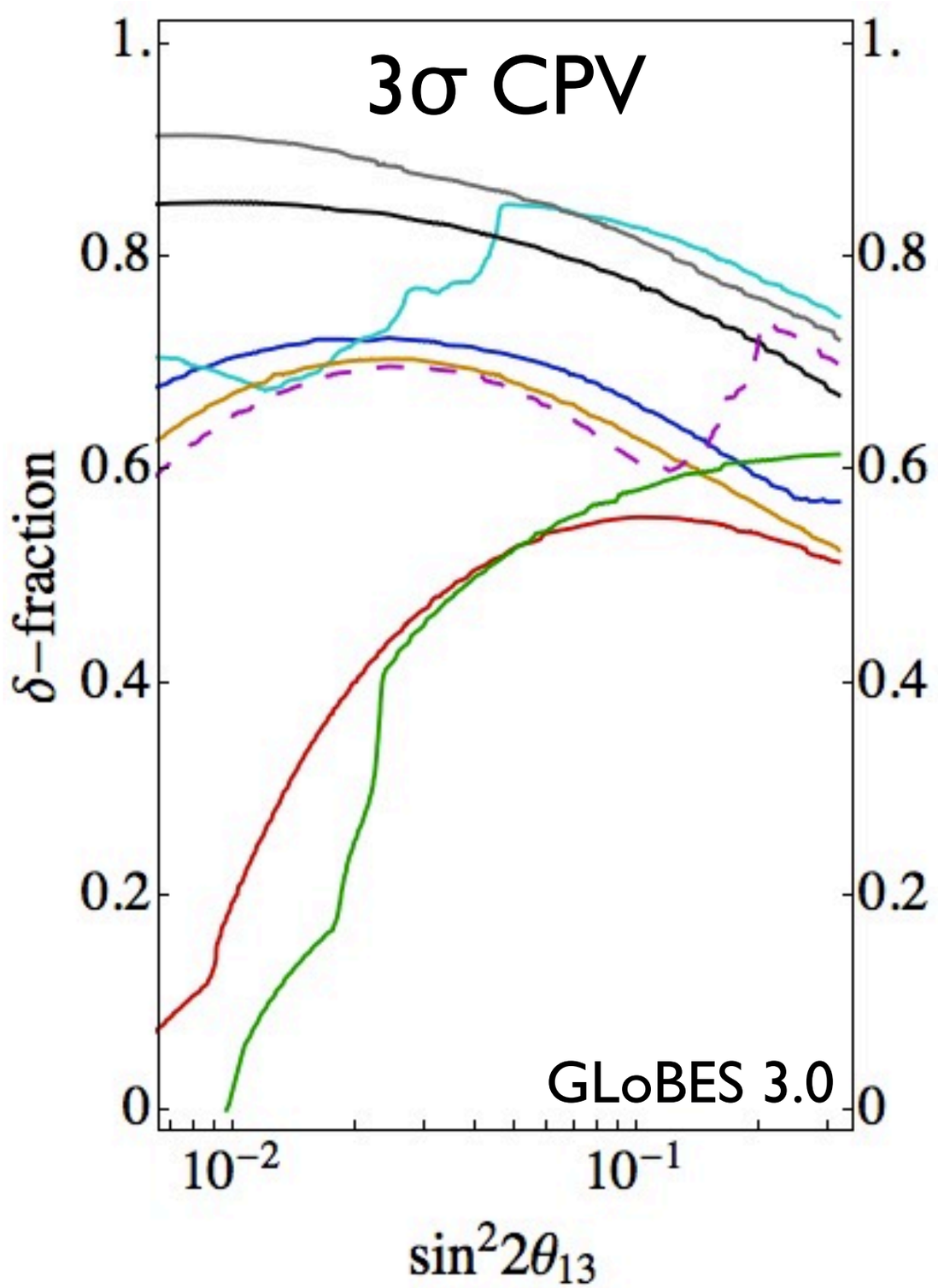
T2HK: hep-ex/0106019

C2P, SPL:
1001.0077 [physics.ins-det]
hep-ex/0411062
1106.1096 [physics.acc-ph]

LENF: 1012.1872 [hep-ph]

LBNE: 1110.6249 [hep-ex]

IDS: 1112.2853 [hep-ex]



LENF
IDS-NF
BB350
T2HK
BB100
SPL
LBNE
C2P

An example

Signal:

$$\pi^- \rightarrow \mu^- + \nu_\mu$$

CC interactions

ν_e

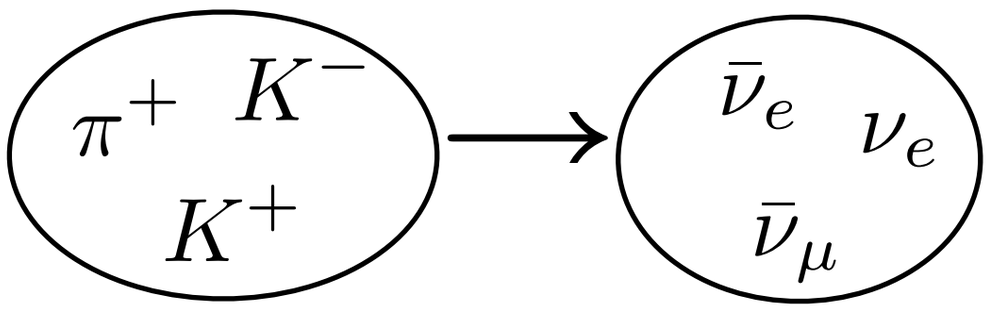
ν_μ

Backgrounds:

NC interactions

$\pi^\pm \rightarrow \mu^\pm + E_{miss}$

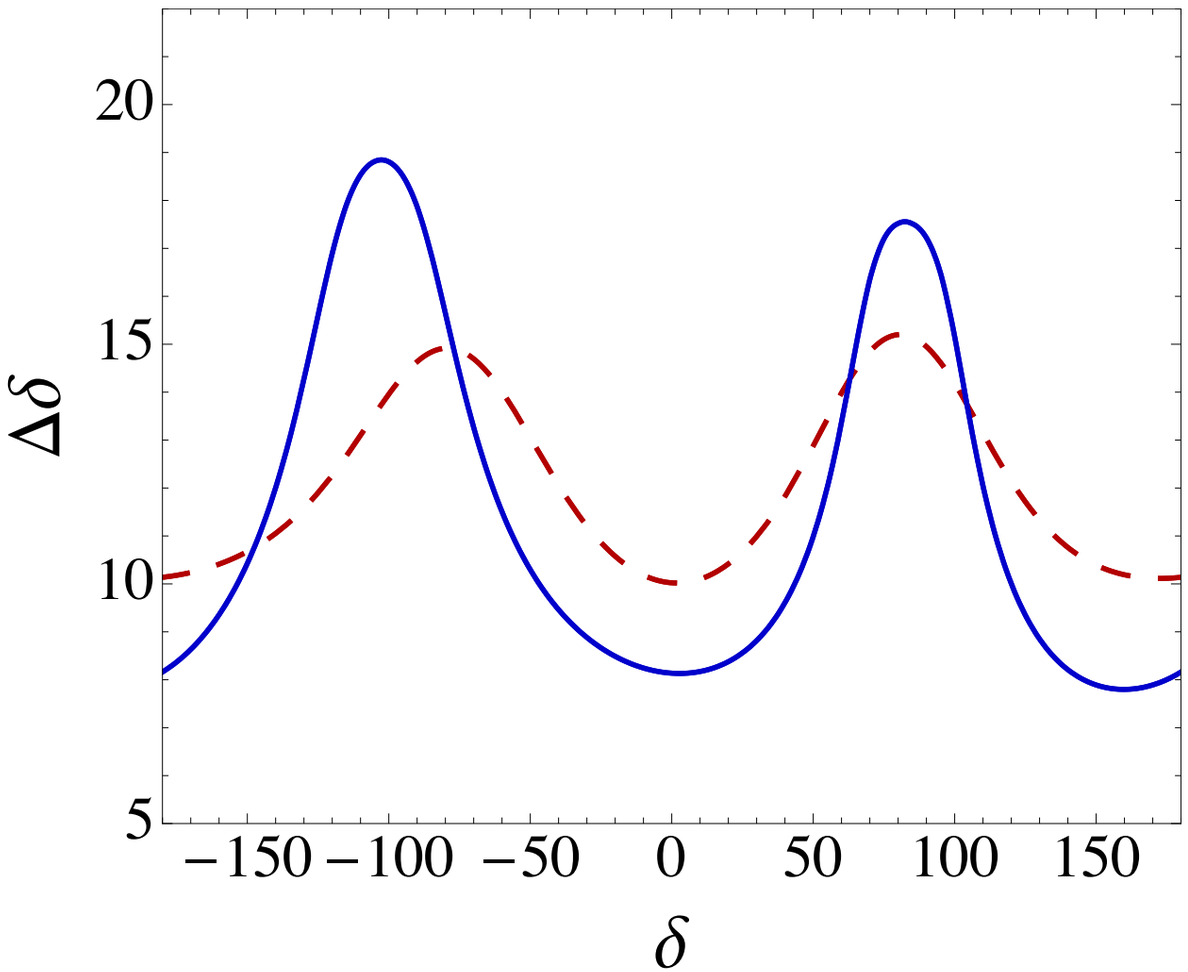
$\pi^0 \rightarrow \gamma\gamma$



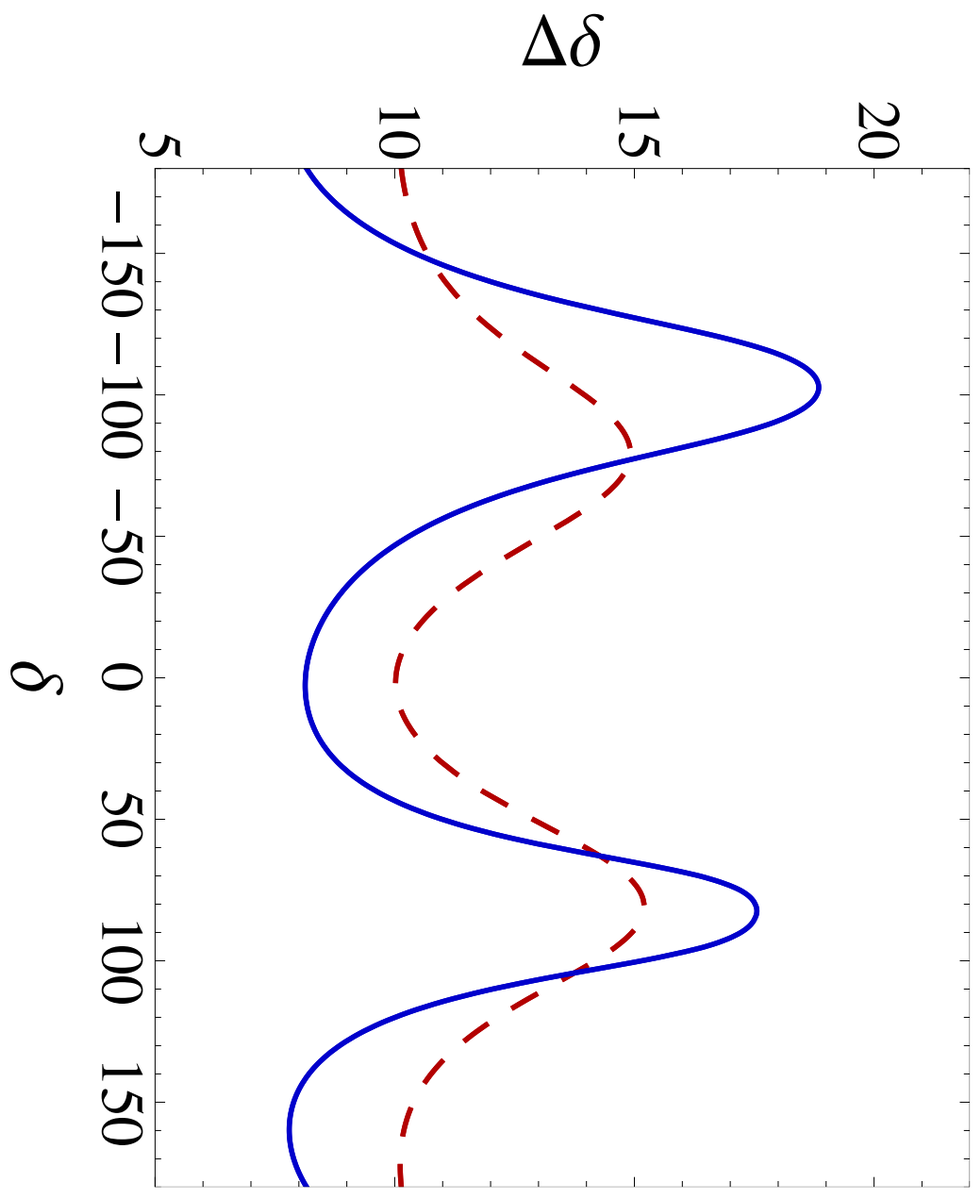
$\nu_e\ \bar{\nu}_e$

$\nu_\mu\ \bar{\nu}_\mu$

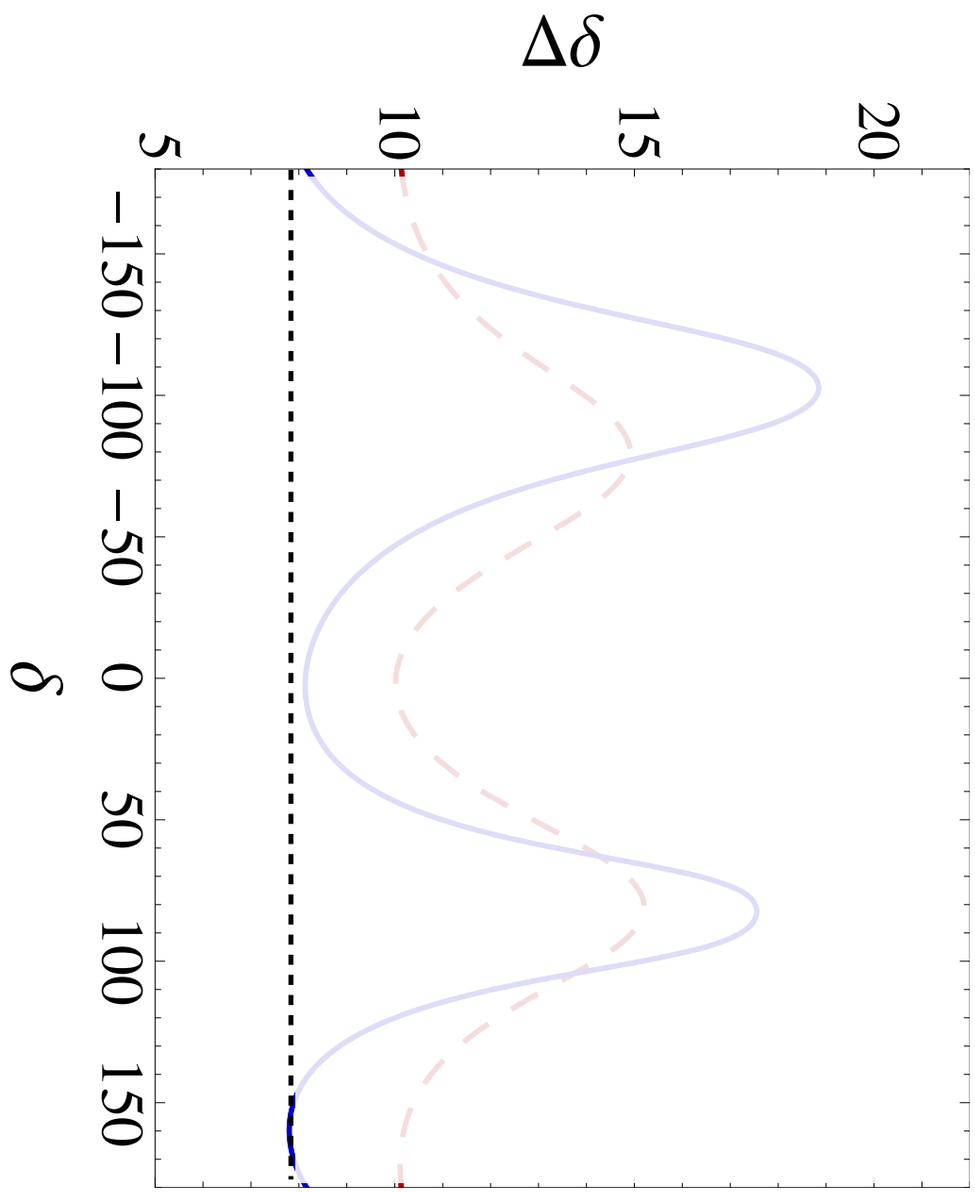
Precision and CP fraction

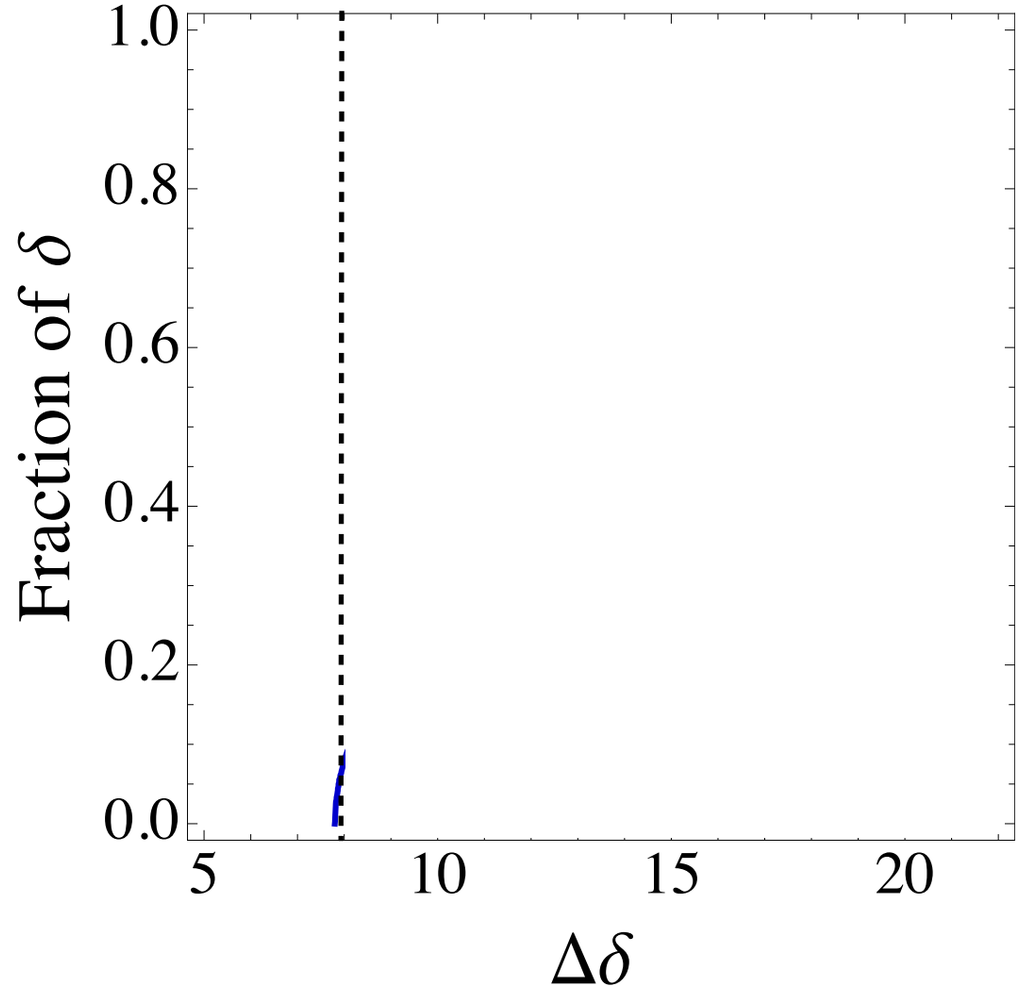


Precision and CP fraction

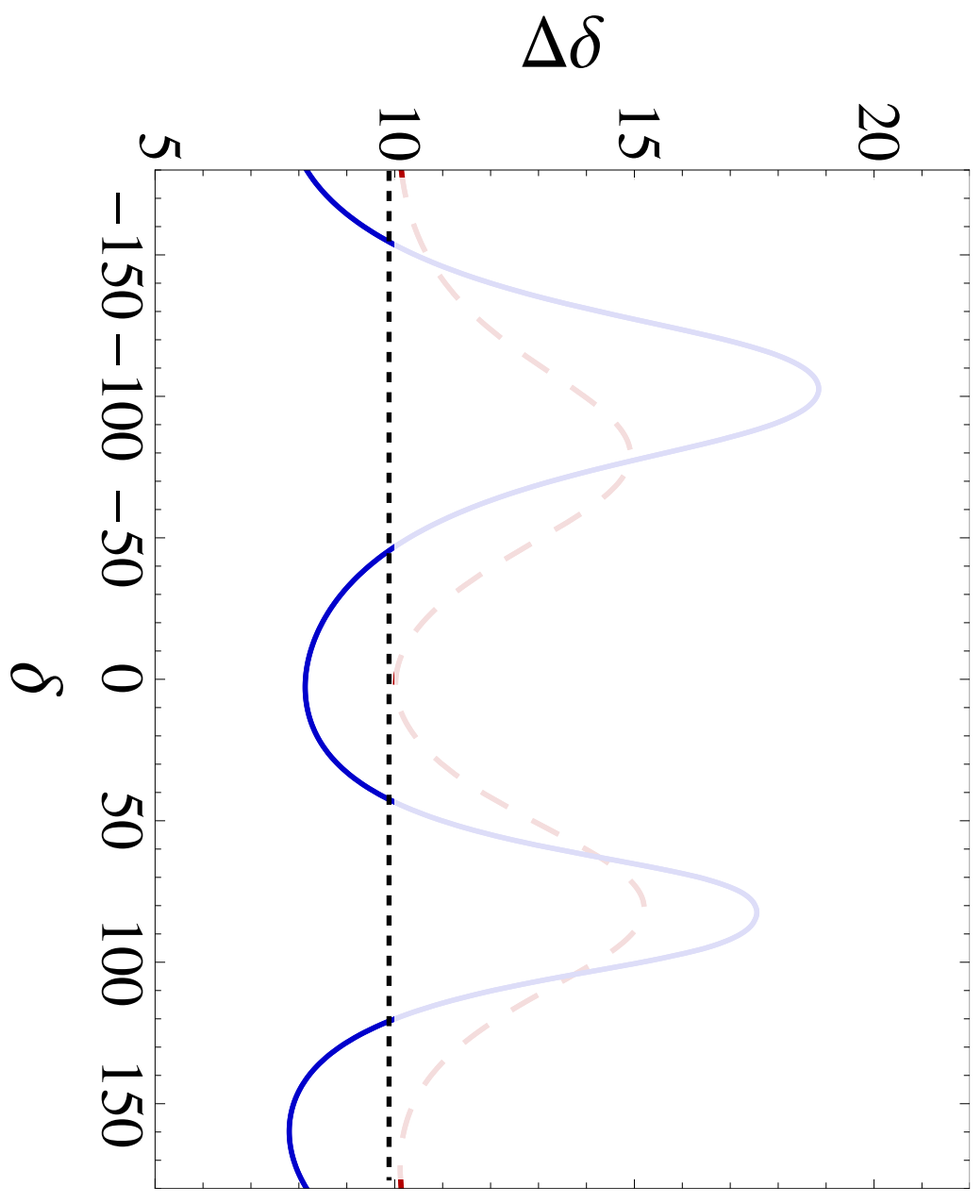


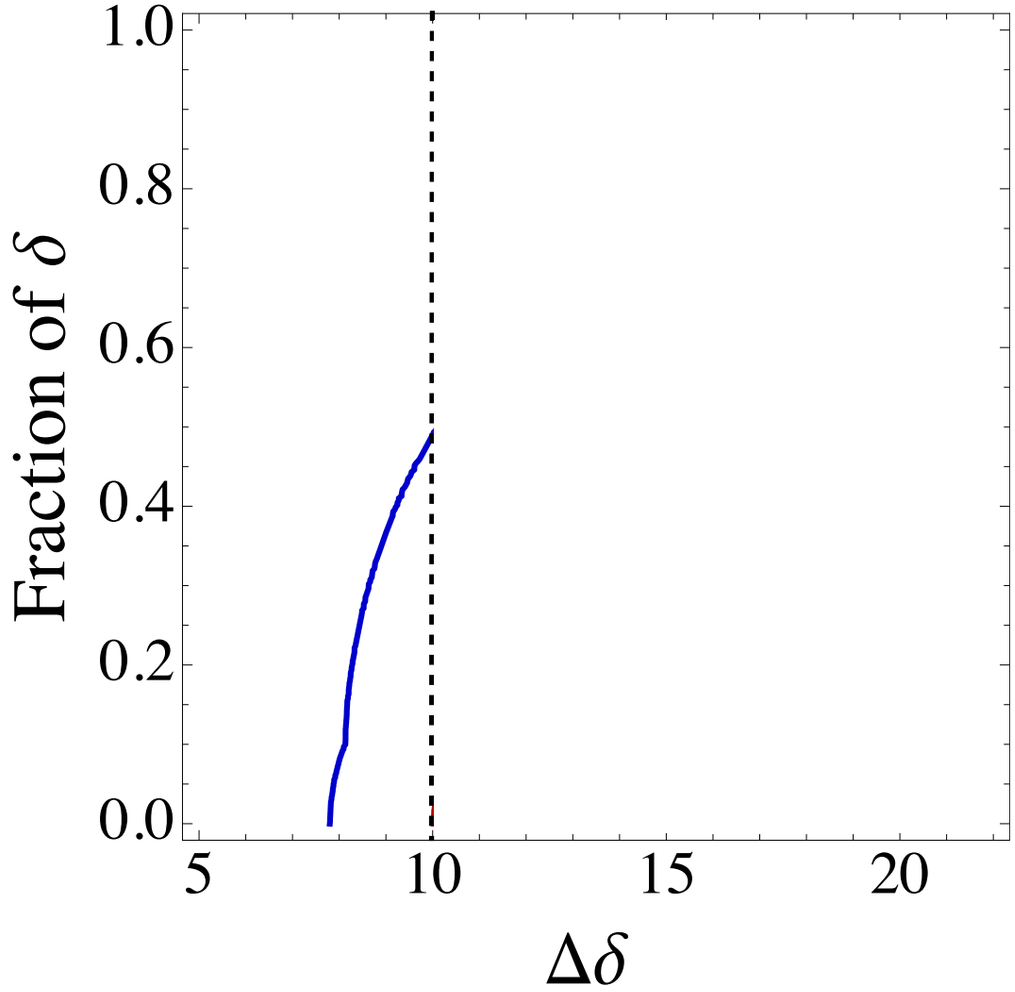
Precision and CP fraction





Precision and CP fraction





Precision and CP fraction