Systematics at future LBL oscillation experiments

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Work in collaboration with
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(in preparation)

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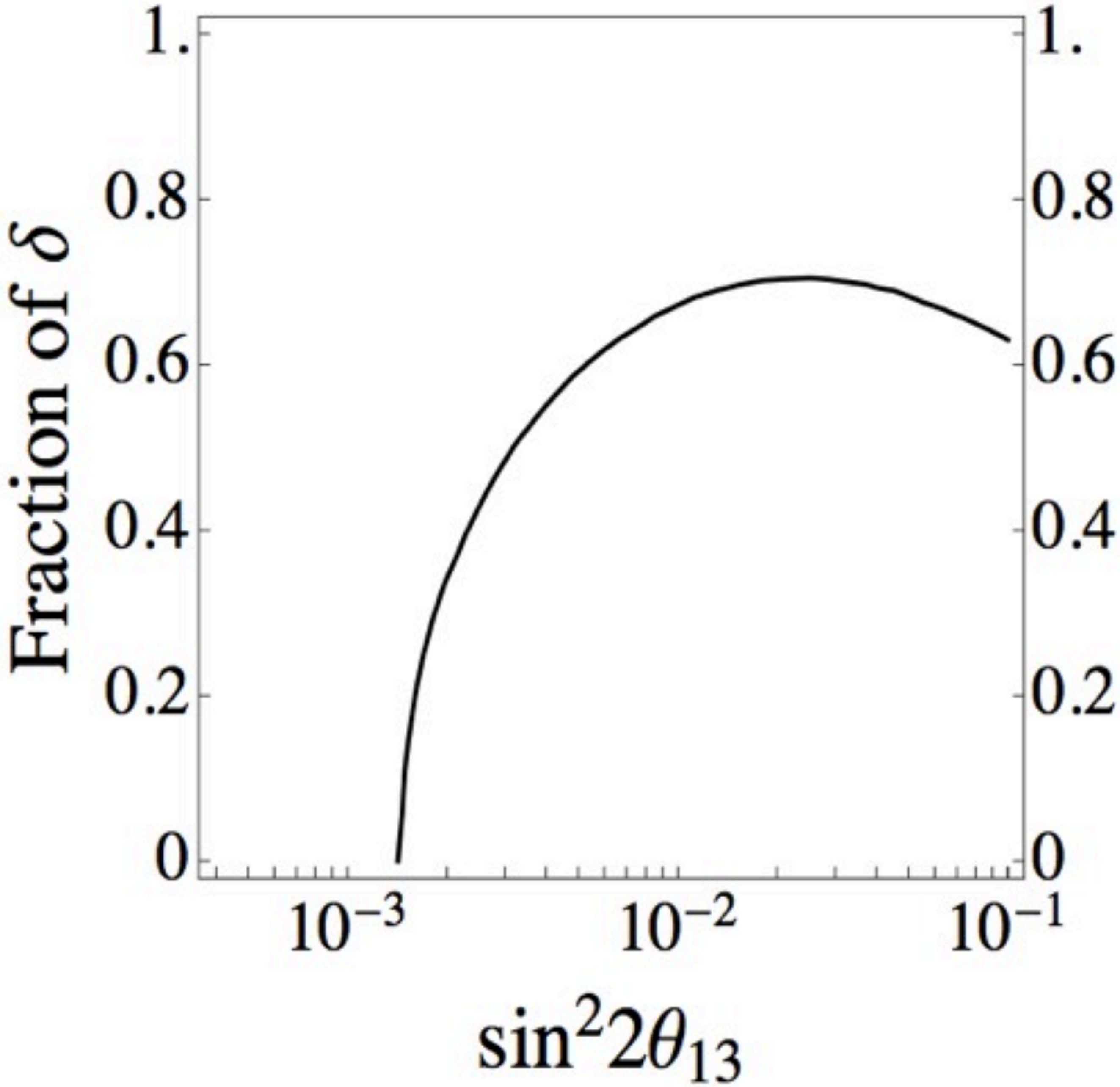
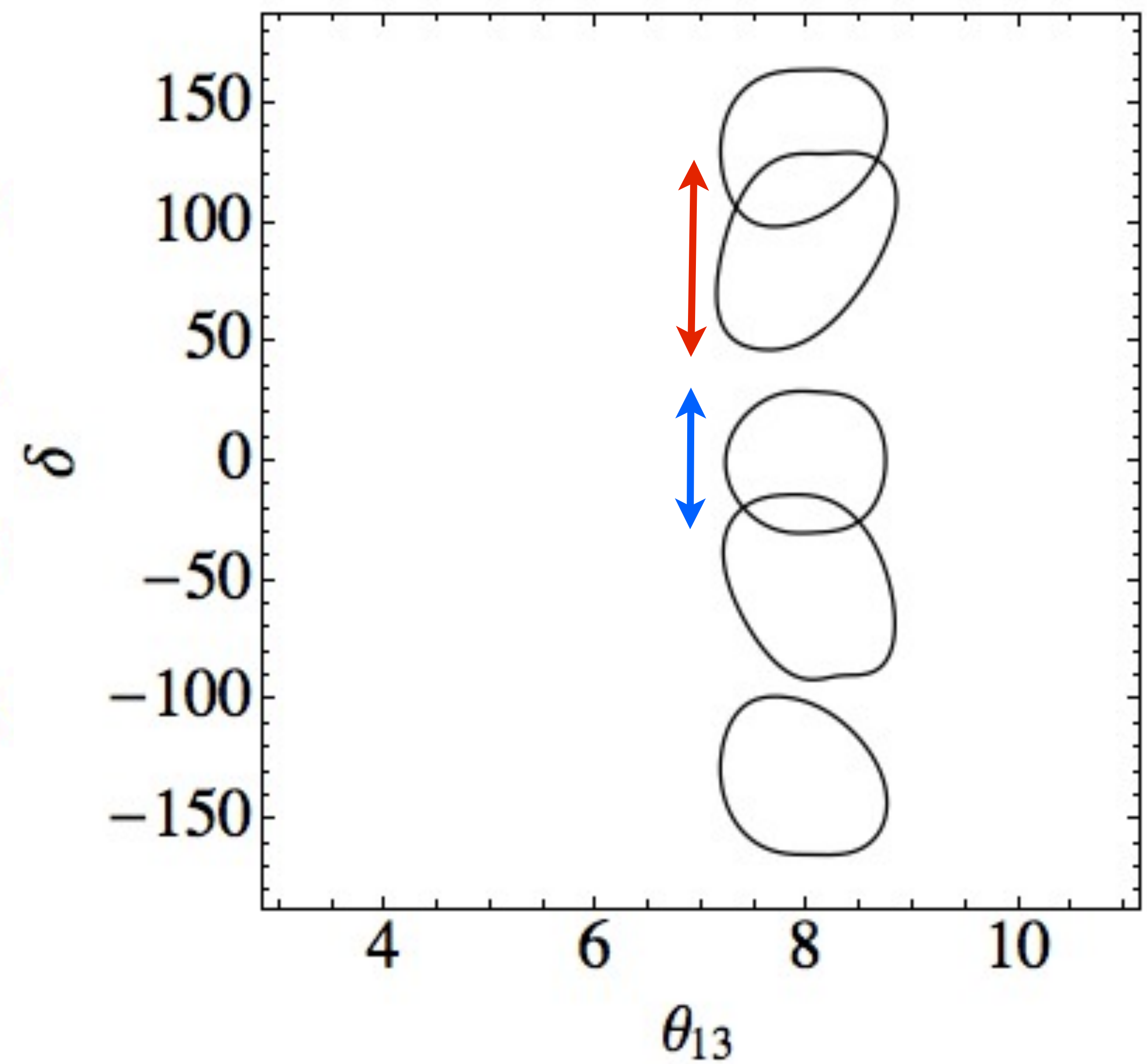
Outline

- Why precision?
- The importance of systematics
- Simulation details and sources of systematics
- Possible observables and CP fraction concept
- Effect of systematics on precision
    - General comparison
    - Effect of assumptions (opt, def, cons)
    - Exposure vs systematics
    - Identification of key systematics
- Summary and conclusions

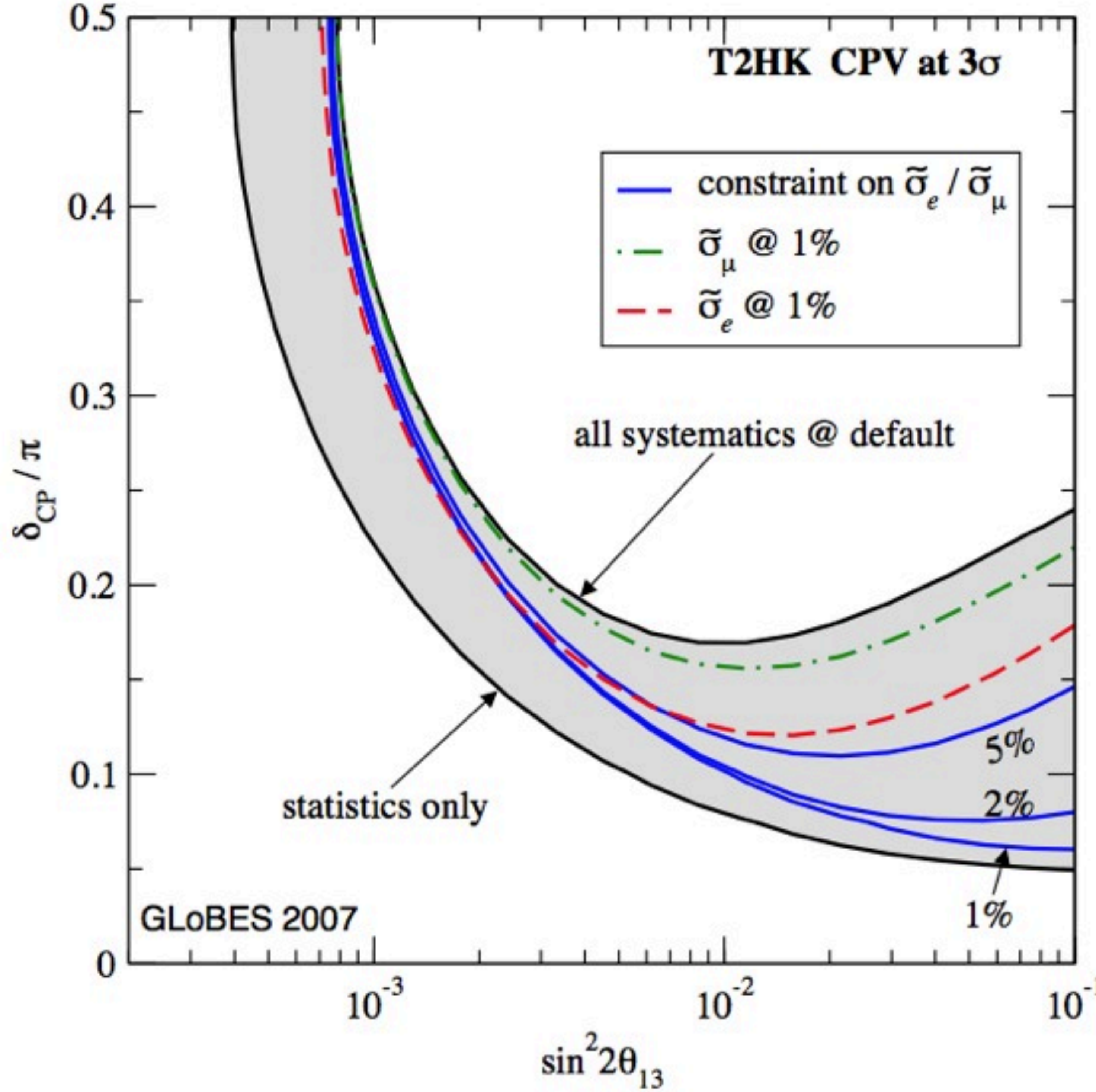
Why precision?

Discovery vs precision





Impact of systematics on CPV



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

The importance of systematics

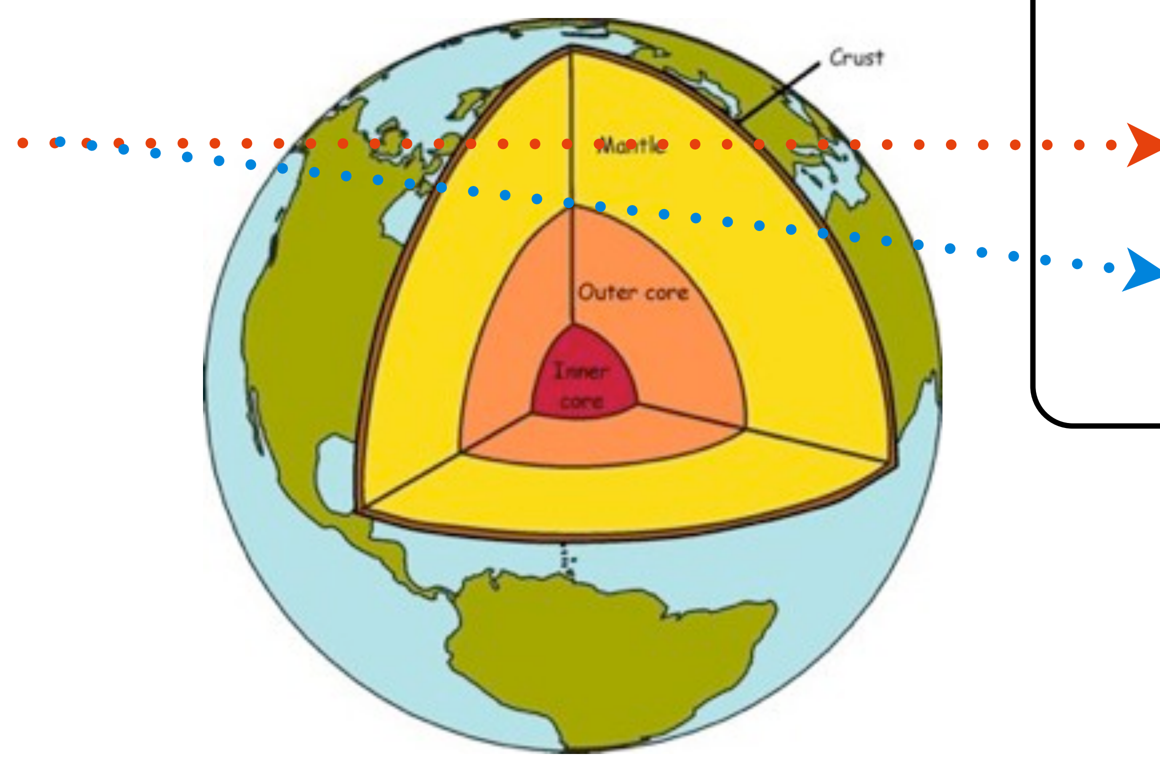
- Up to now, each facility has made its own assumptions about systematic uncertainties. Generally,
  - BB and NF are assumed to have low sys
  - SB are assumed to have high sys
- However, this may change if a near detector is included and correlations are considered carefully

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

An example

Signal:

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



CC interactions

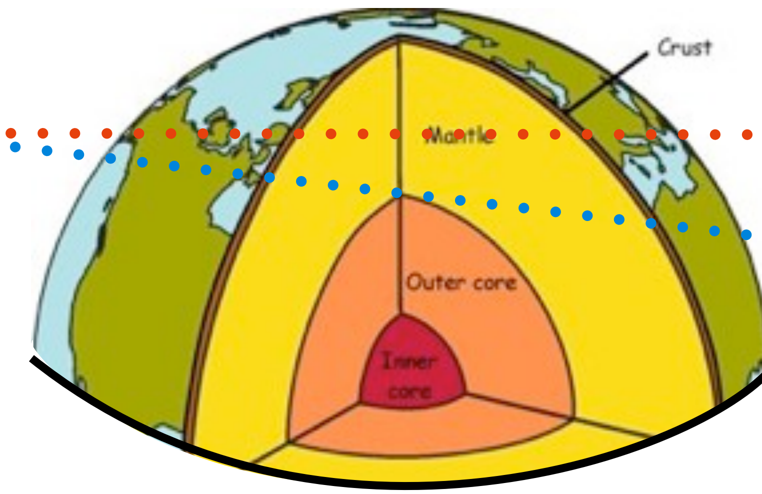
ν_e

ν_μ

An example

Signal:

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



CC interactions

ν_e

ν_μ

Backgrounds:

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

π^+ K^- K^+ $\longrightarrow$ $\bar{\nu}_e$ ν_e $\bar{\nu}_\mu$

ν_e $\bar{\nu}_e$

ν_μ $\bar{\nu}_\mu$

An example

Possible ways to reduce the effect of systematics:

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

2) measure intrinsic background at near detector

3) use data from disappearance channels at the far detector

Simulation details

PARENTAL

ADVISORY

EXPLICIT CONTENT

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%	–	3.5%	11%	–	3.5%	11%	–
Ratio ν_e/ν_μ RES*	2.7%	5.4%	–	2.7%	5.4%	–	2.7%	5.4%	–
Ratio ν_e/ν_μ DIS*	2.5%	5.1%	–	2.5%	5.1%	–	2.5%	5.1%	–
Matter density	1%	2%	5%	1%	2%	5%	1%	2%	5%

theoretical constraint

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

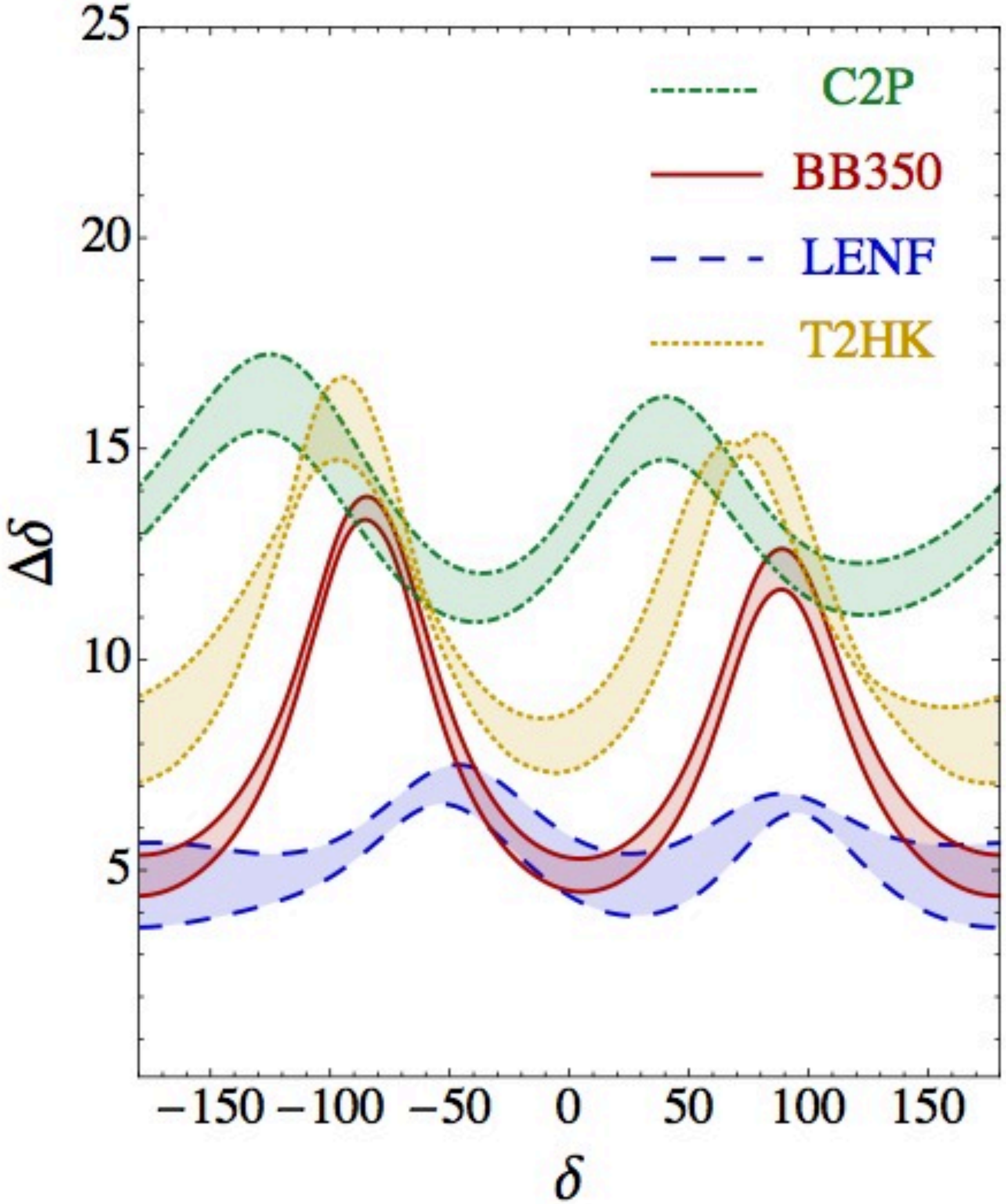
- GLoBES software used hep-ph/0407333, hep-ph/0701187
- Input values in agreement with best fits 1205.5254 [hep-ph], 1205.4018 [hep-ph]
- Marginalization over solar and atmospheric params performed assuming 1σ gaussian priors 1108.1376 [hep-ph]
- No degeneracies have been accounted for: atmospheric angle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

The setups

	Setup	L [km]	OA	Detector	kt	MW	Decays/yr	$(t_\nu, t_{\bar{\nu}})$
Benchmark	BB350	650	–	WC	500	–	$1.1(2.8) \times 10^{18}$	(5,5)
	IDS-3.0	2000	–	MIND	100	–	7×10^{20}	(10,10)
	WBB	2300	–	LAr	100	0.8	–	(5,5)
	T2HK	295	2.5°	WC	560	1.66	–	(1.5,3.5)
Alternative	BB100	130	–	WC	500	–	$1.1(2.8) \times 10^{18}$	(5,5)
	+ SPL		–			4	–	(2,8)
	LENF	1290	–	MIND	100	–	7×10^{20}	(10,10)
	$LBNE_{mini}$	1290	–	LAr	10	0.7	–	(5,5)
	$NOvA^{+}$	810	0.8°	LAr	30	0.7	–	(5,5)

Possible observables

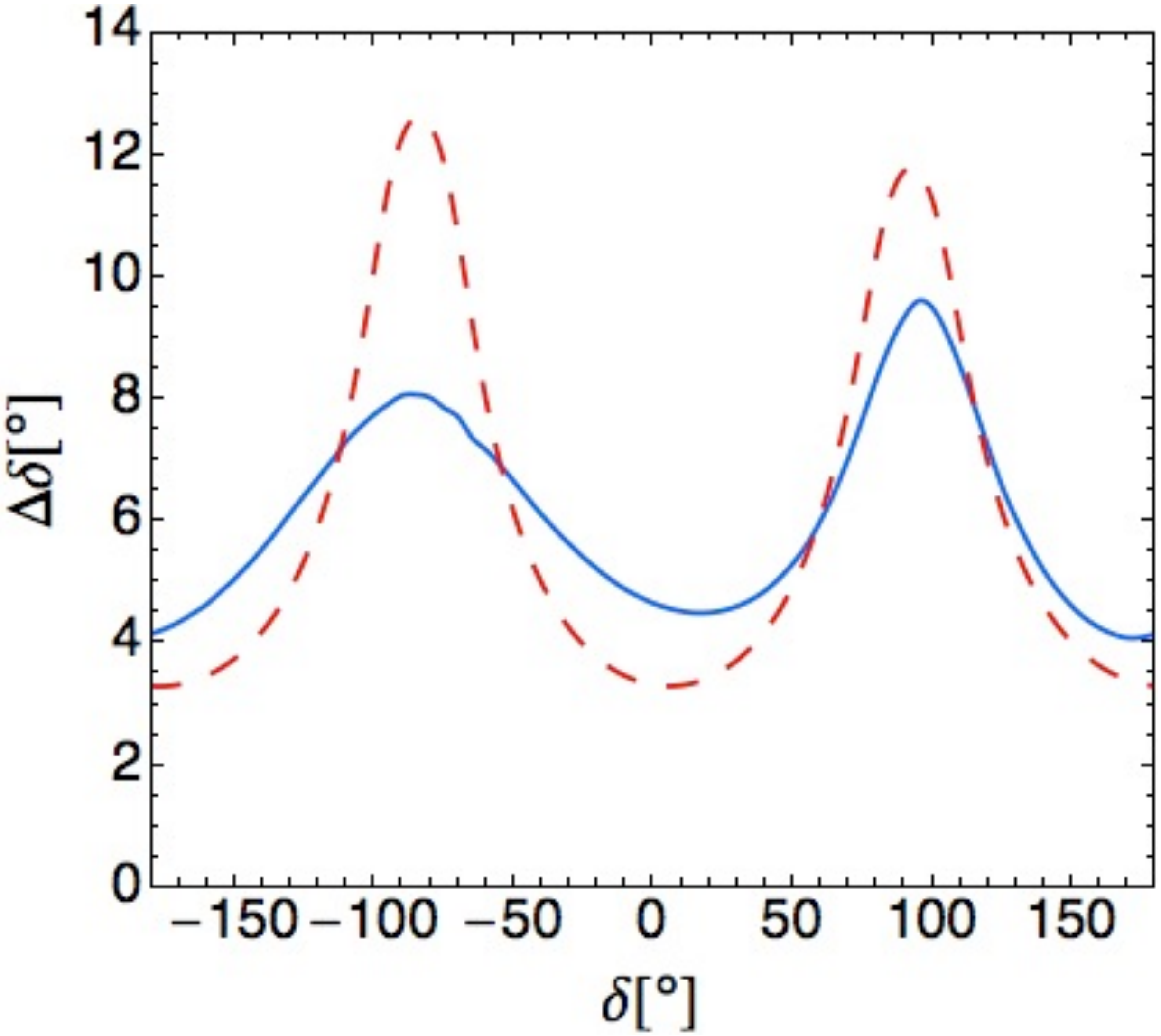
Precision



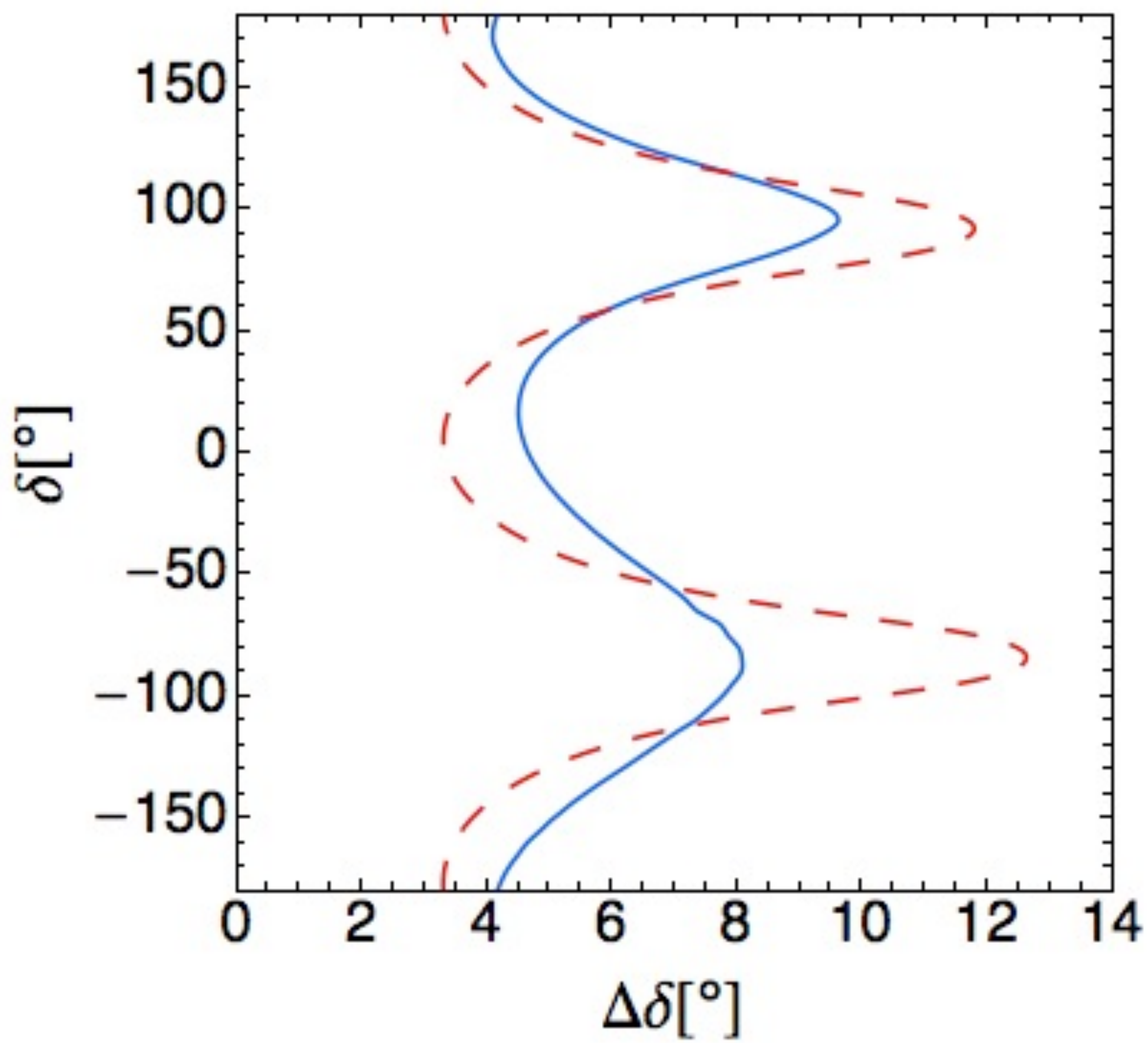
very different behaviour for all facilities

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

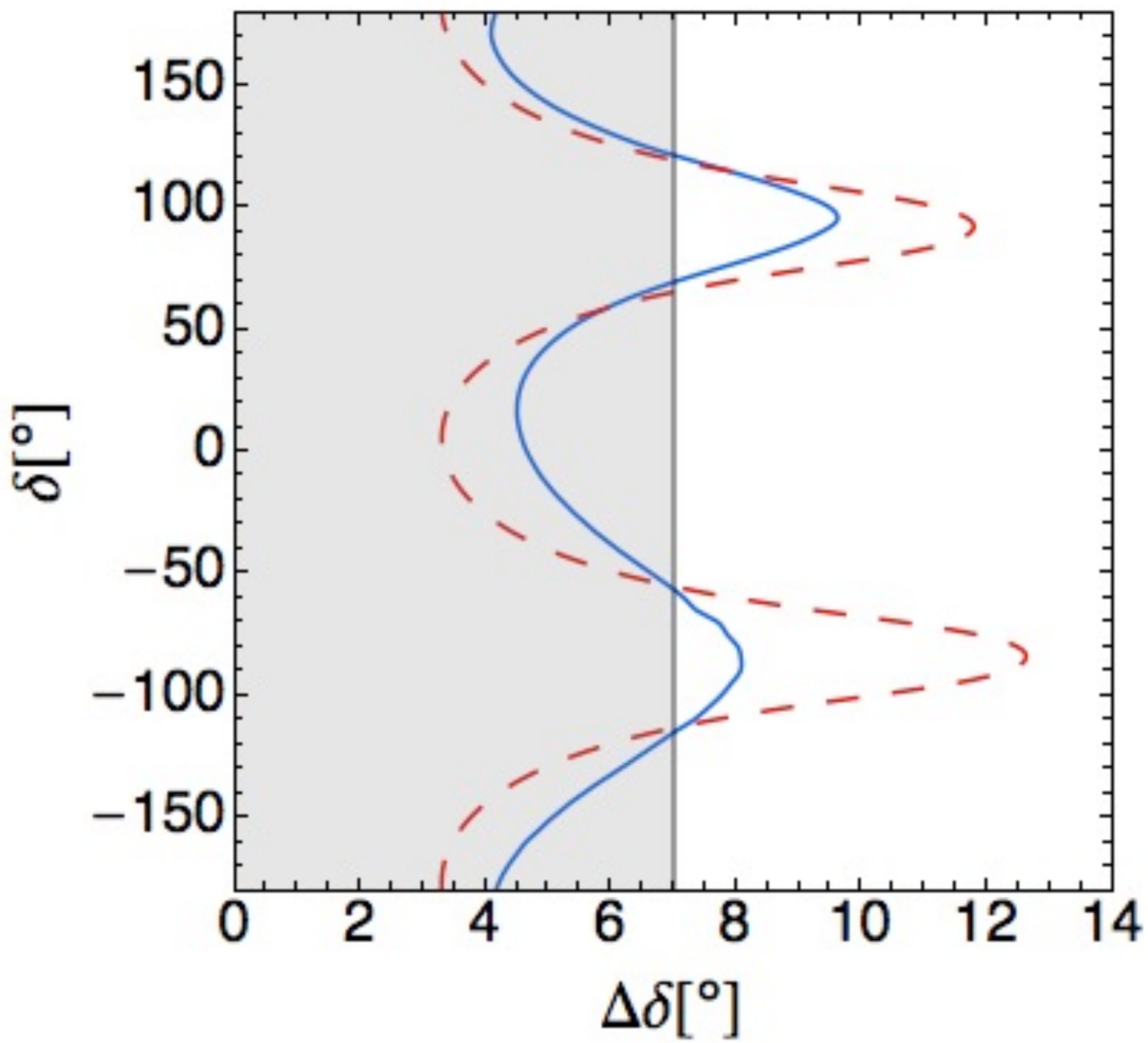
Precision and CP fraction



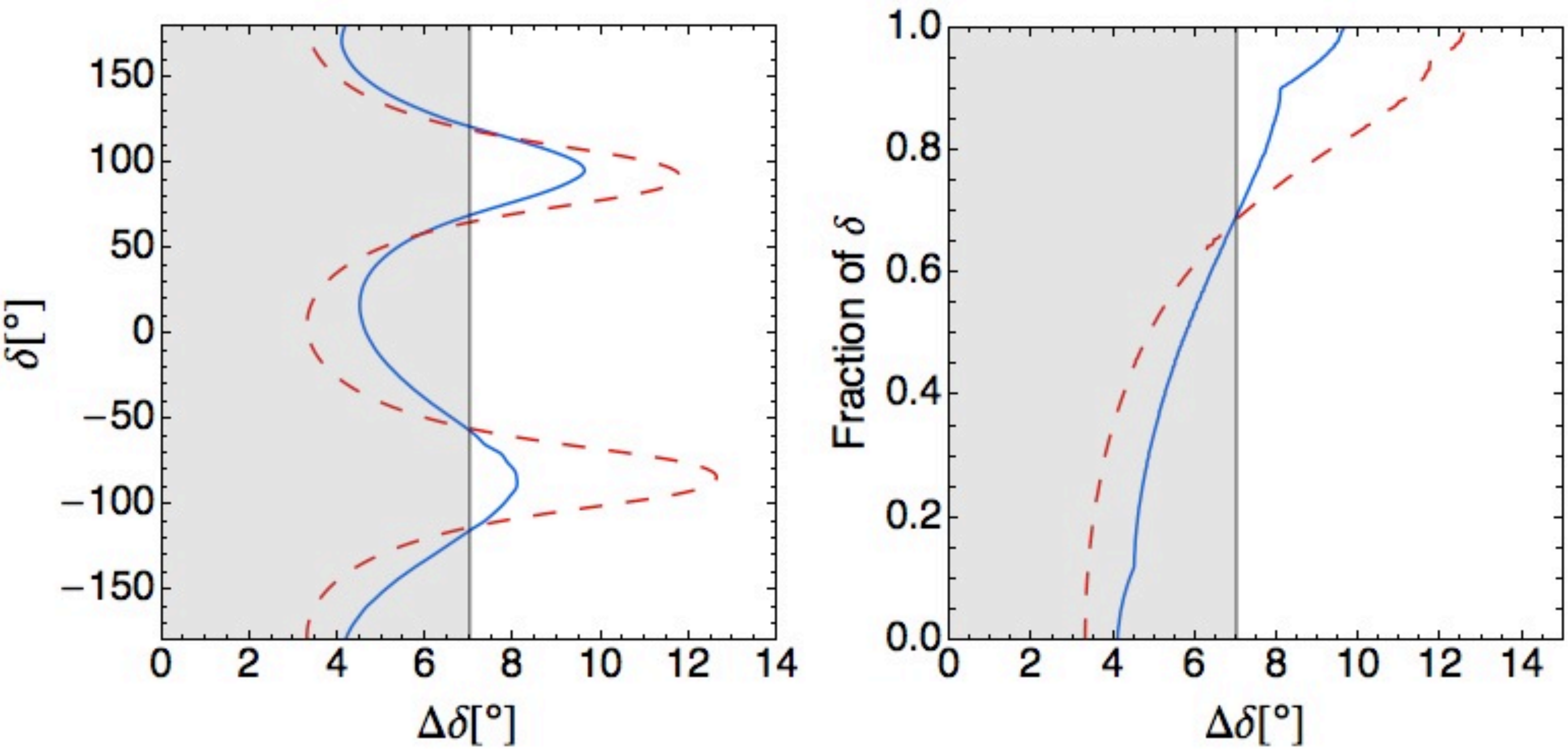
Precision and CP fraction



Precision and CP fraction



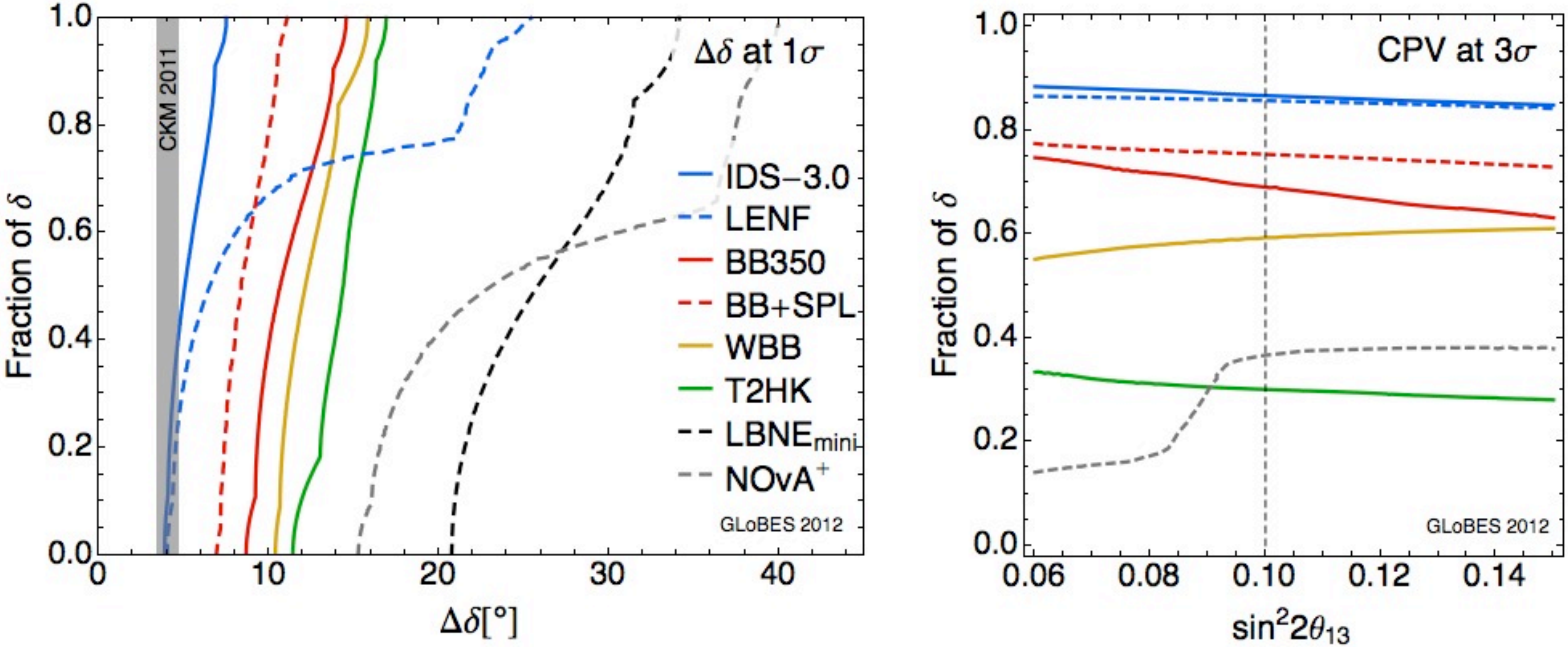
Precision and CP fraction



Results

General comparison

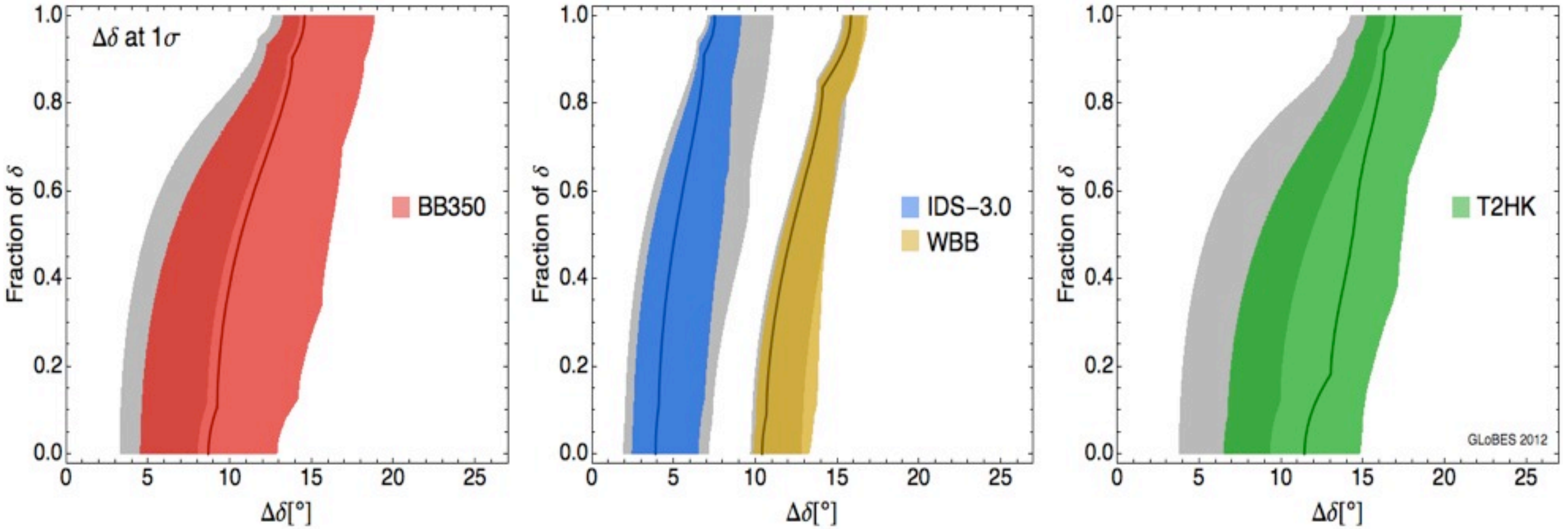
How far do we want to get?



Coloma, Huber, Kopp, Winter, In preparation

Impact of systematics

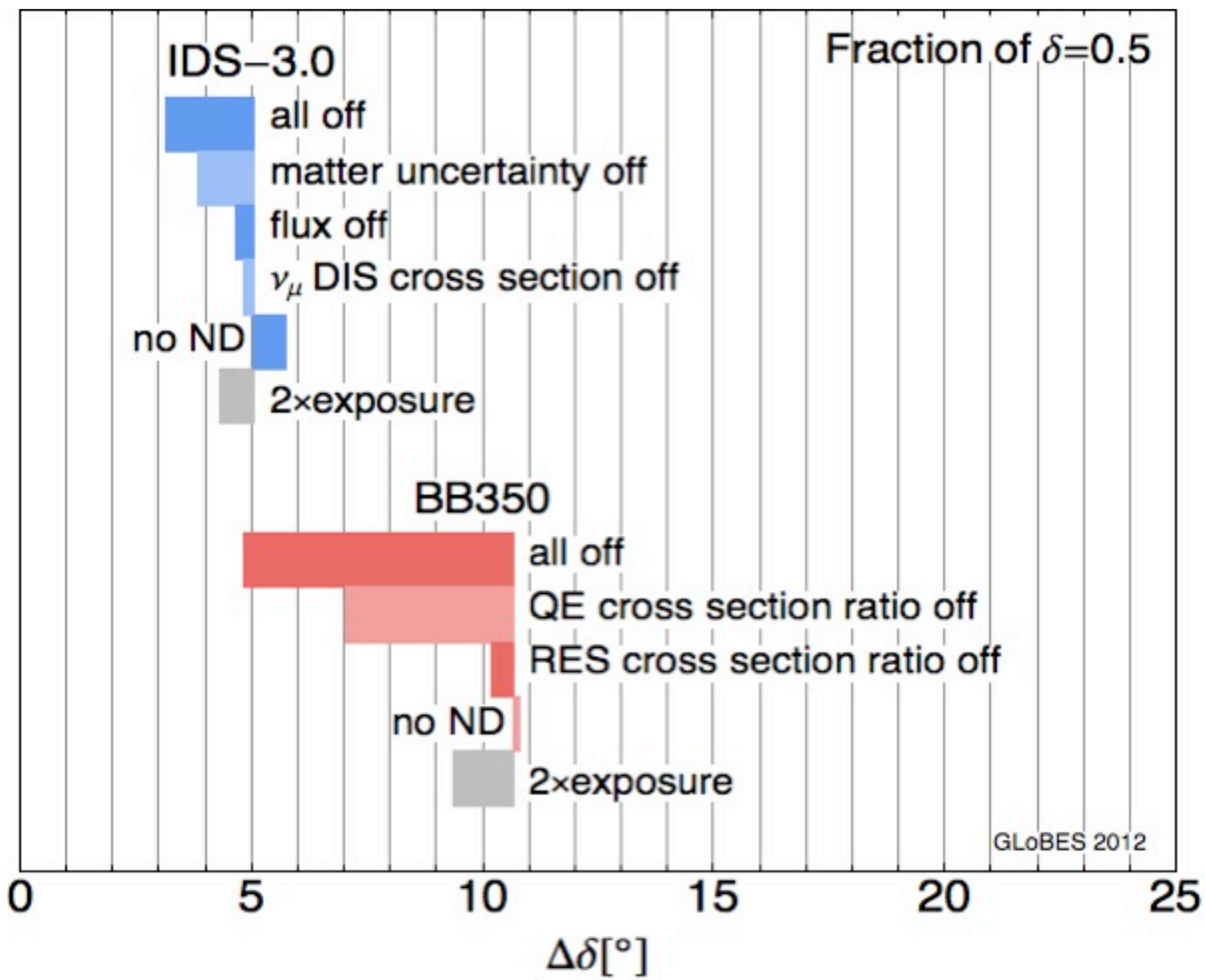
Variation between optimistic and conservative assumptions:



Coloma, Huber, Kopp, Winter, In preparation

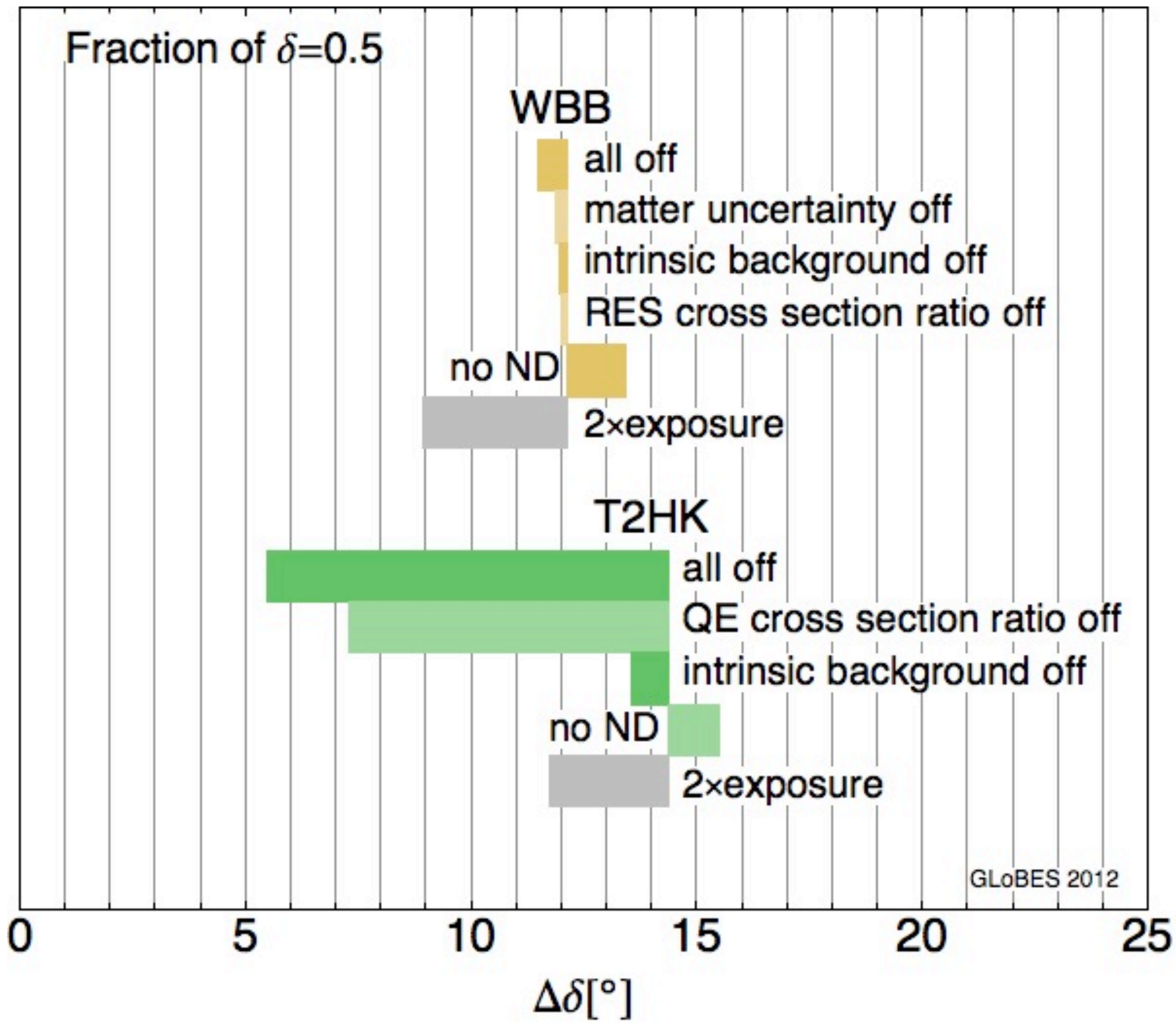
Key systematics

Which sources are most relevant in each case?



Coloma, Huber, Kopp, Winter, In preparation

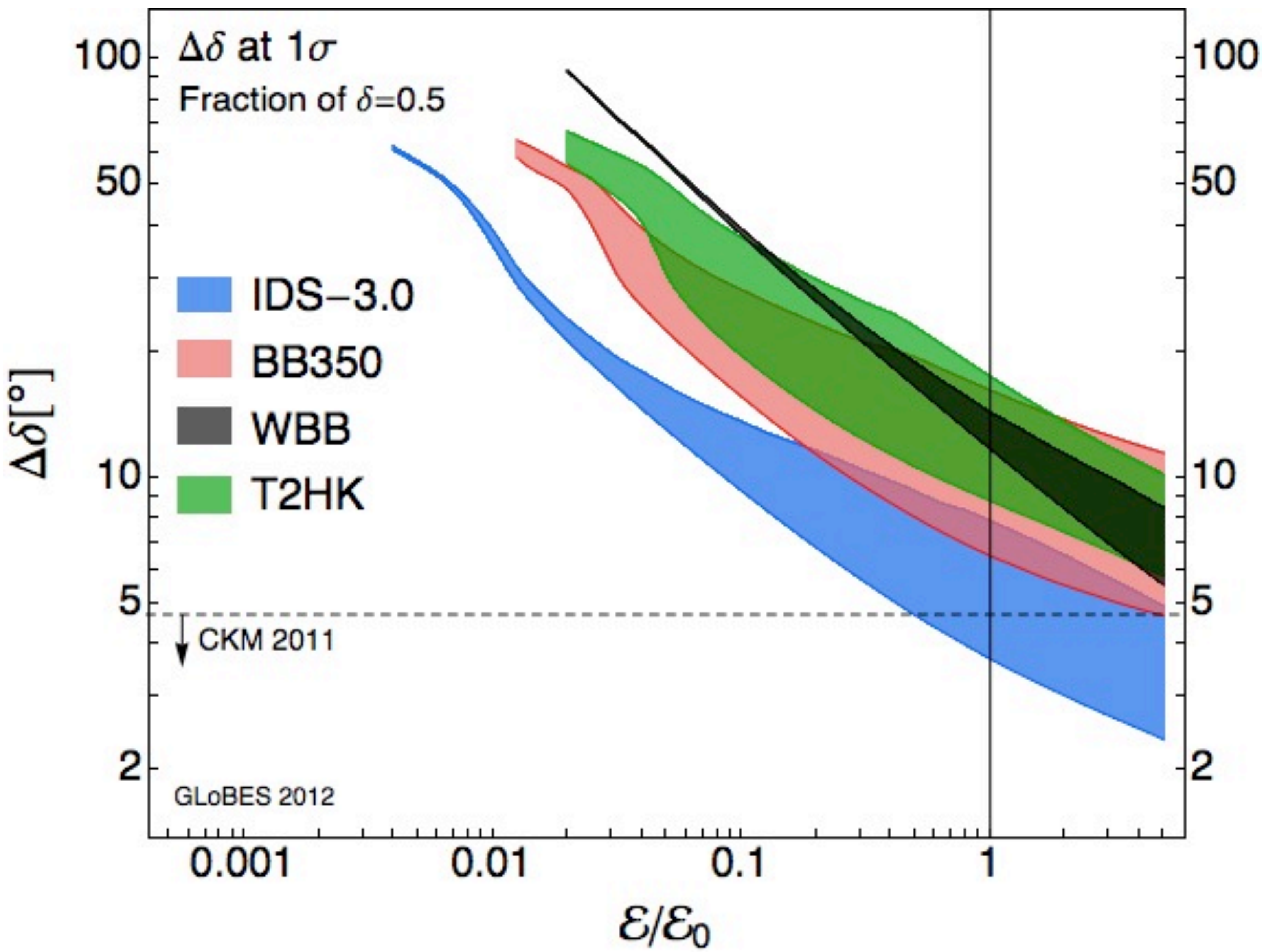
Key systematics



Coloma, Huber, Kopp, Winter, In preparation

Exposure vs systematics

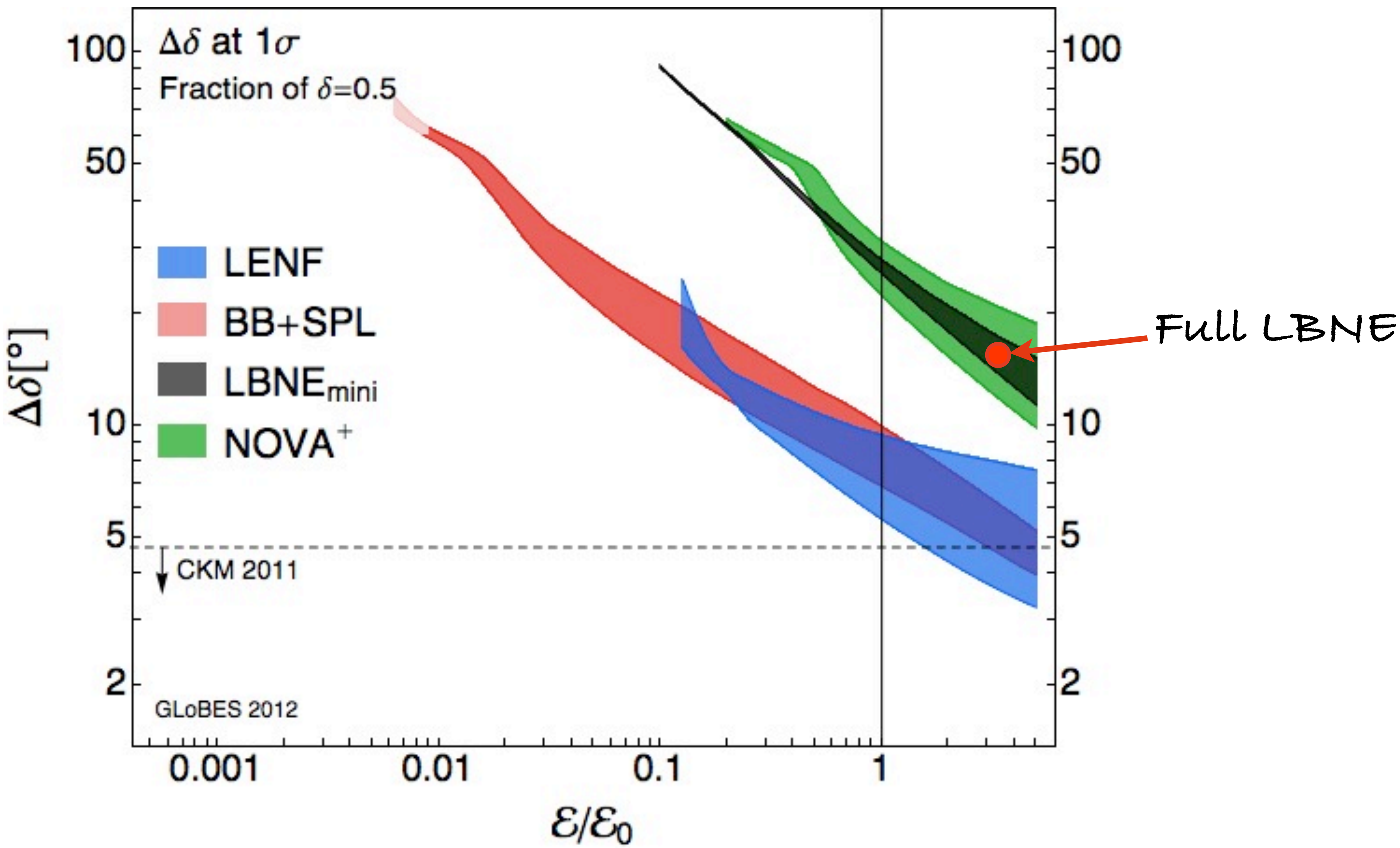
Variation between optimistic and conservative assumptions:



Coloma, Huber, Kopp, Winter, In preparation

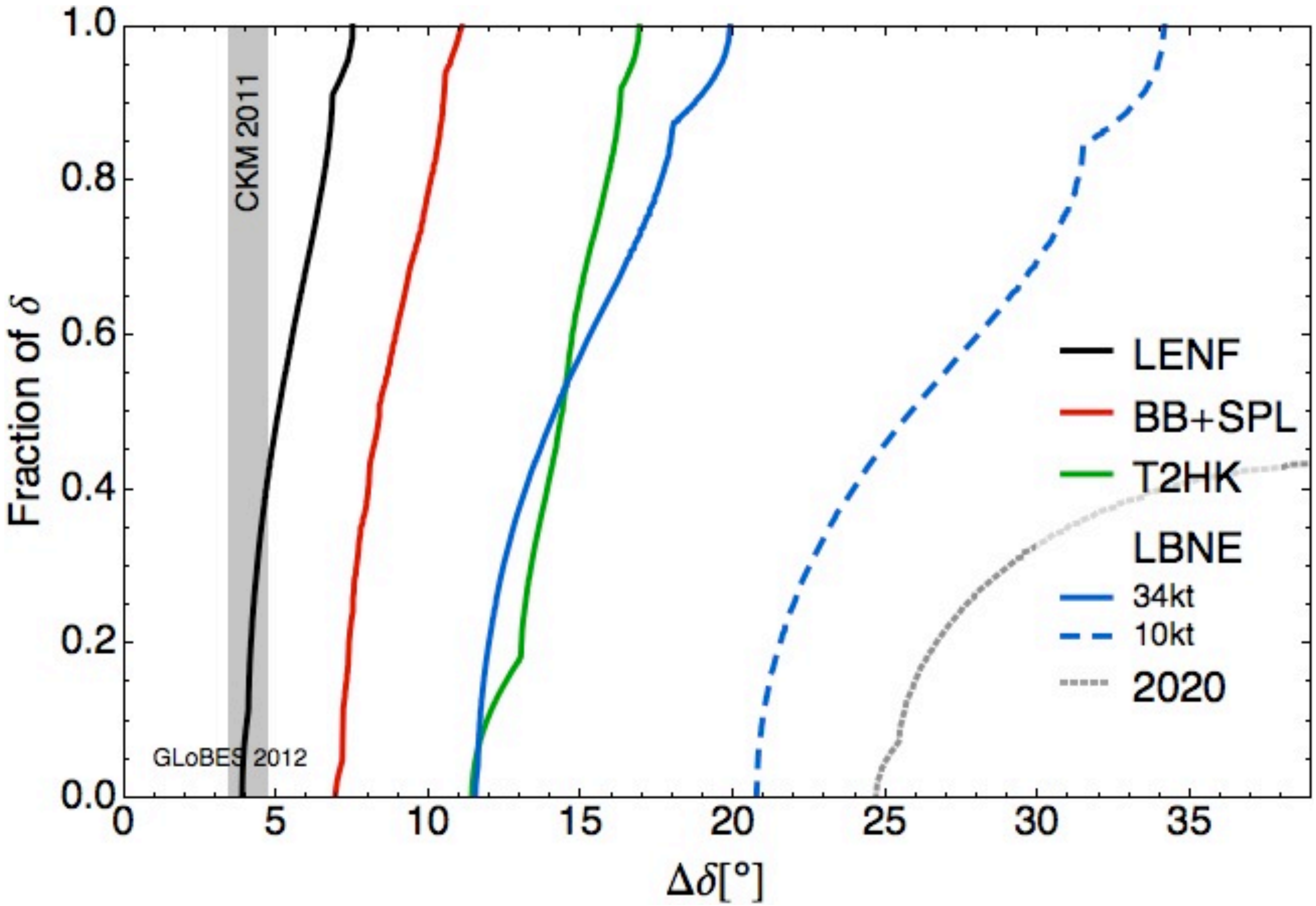
Exposure vs systematics

Variation between optimistic and conservative assumptions:

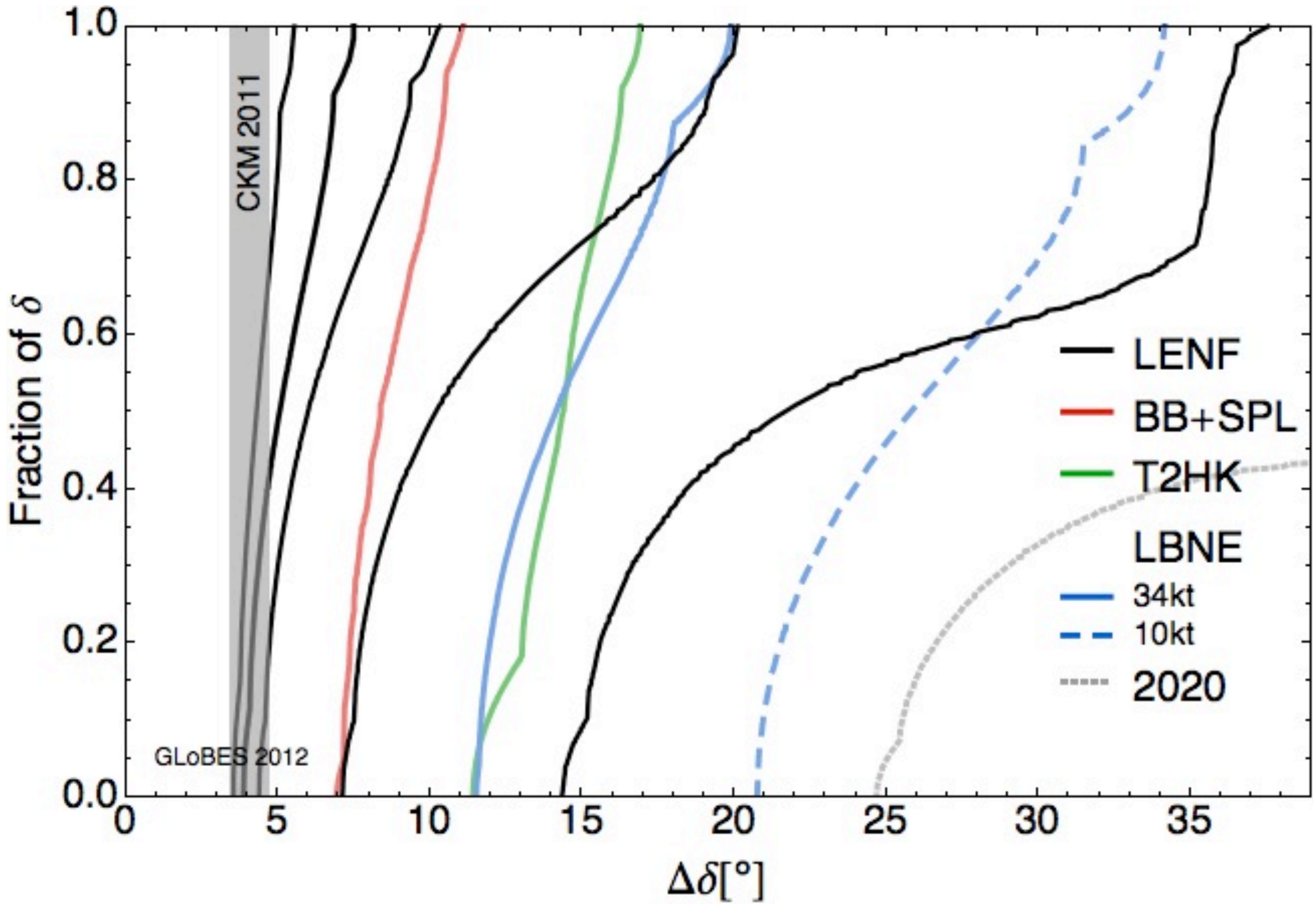


Coloma, Huber, Kopp, Winter, In preparation

Staged approach for a NF



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

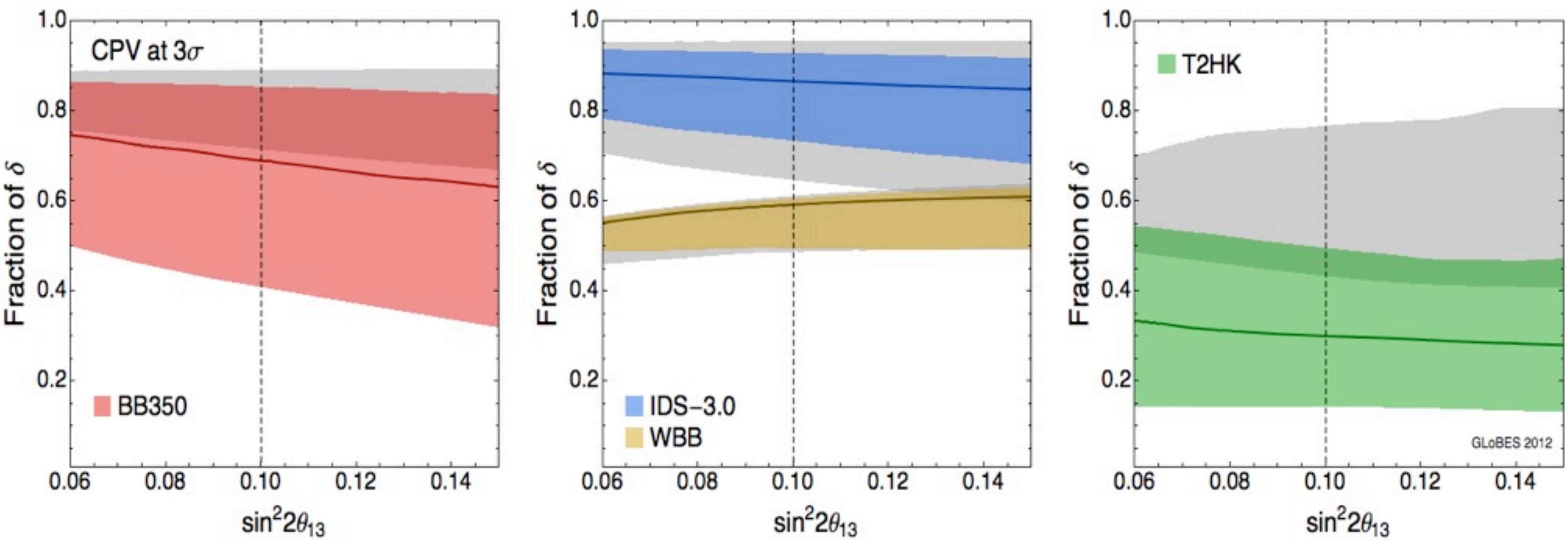
Conclusions

- The impact of a ND does not seem so relevant if data from disappearance at the FD is used
- Low energy setups are generally more affected by systematics
  - Theoretical assumptions on cross section ratios are critical
  - EXCEPTION: BB+SPL
- Matter uncertainty has a large effect for LENF
- In some cases, it may a be better path to increase statistics than reduce systematics...

Backup

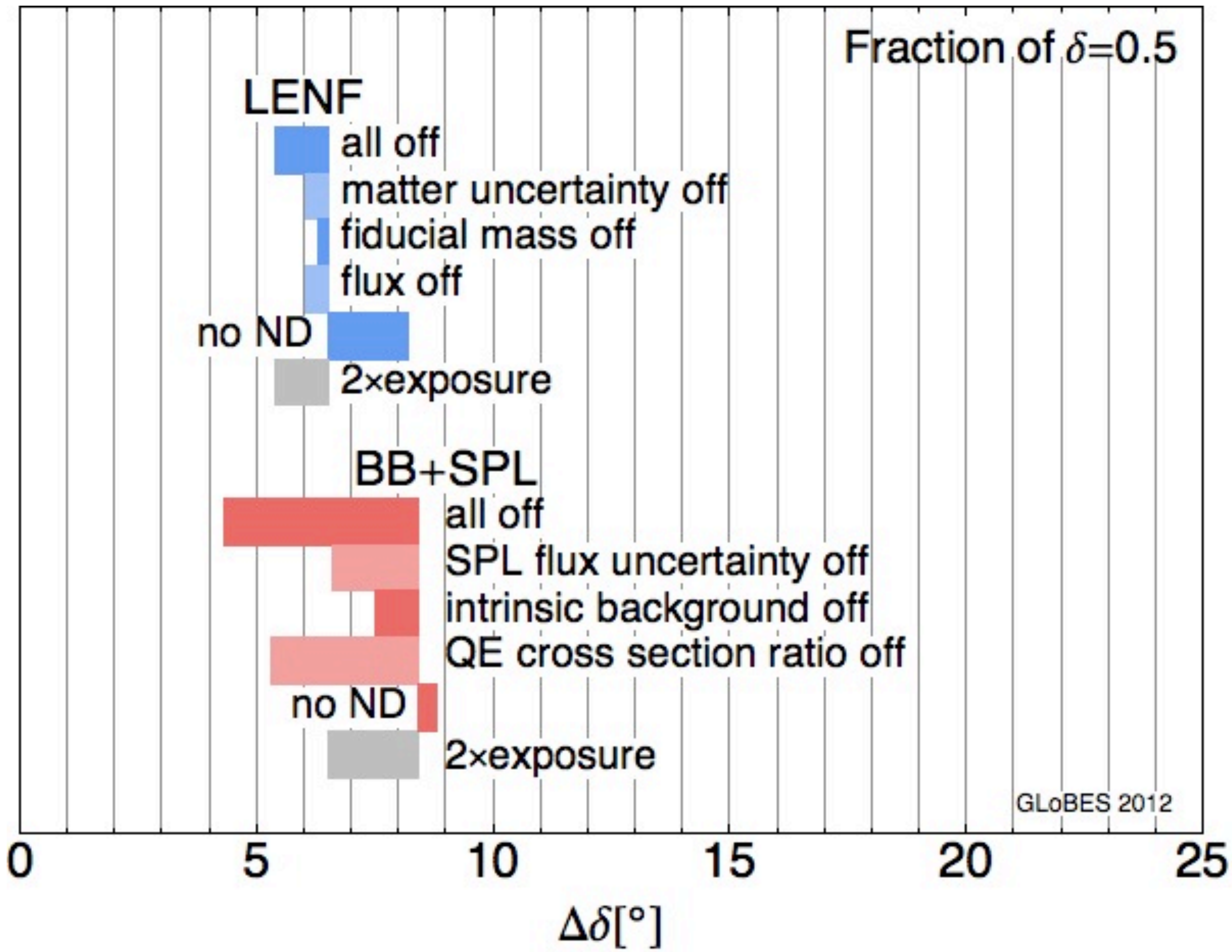
Impact of systematics

Variation between optimistic and conservative assumptions:



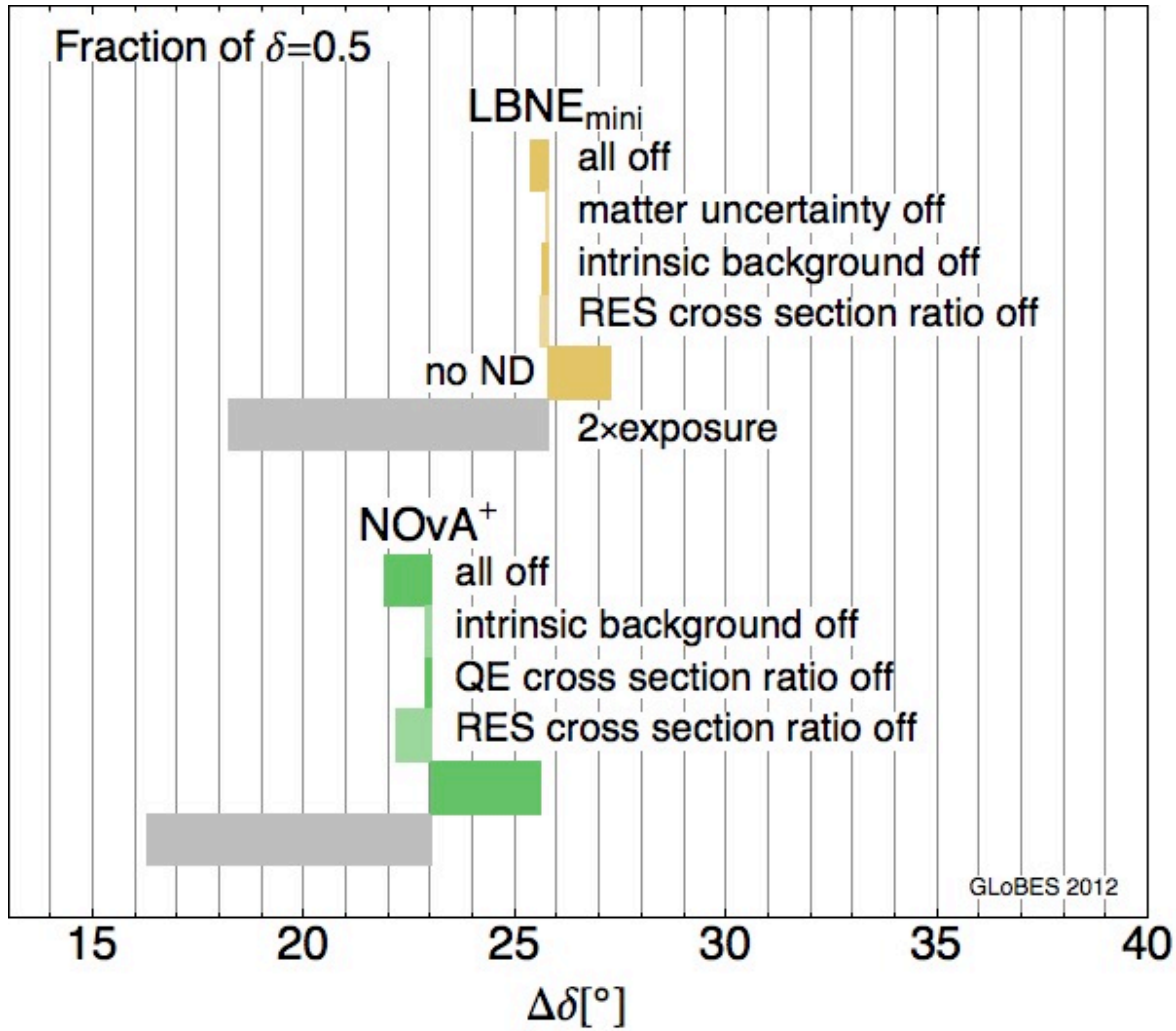
Coloma, Huber, Kopp, Winter, In preparation

Key systematics



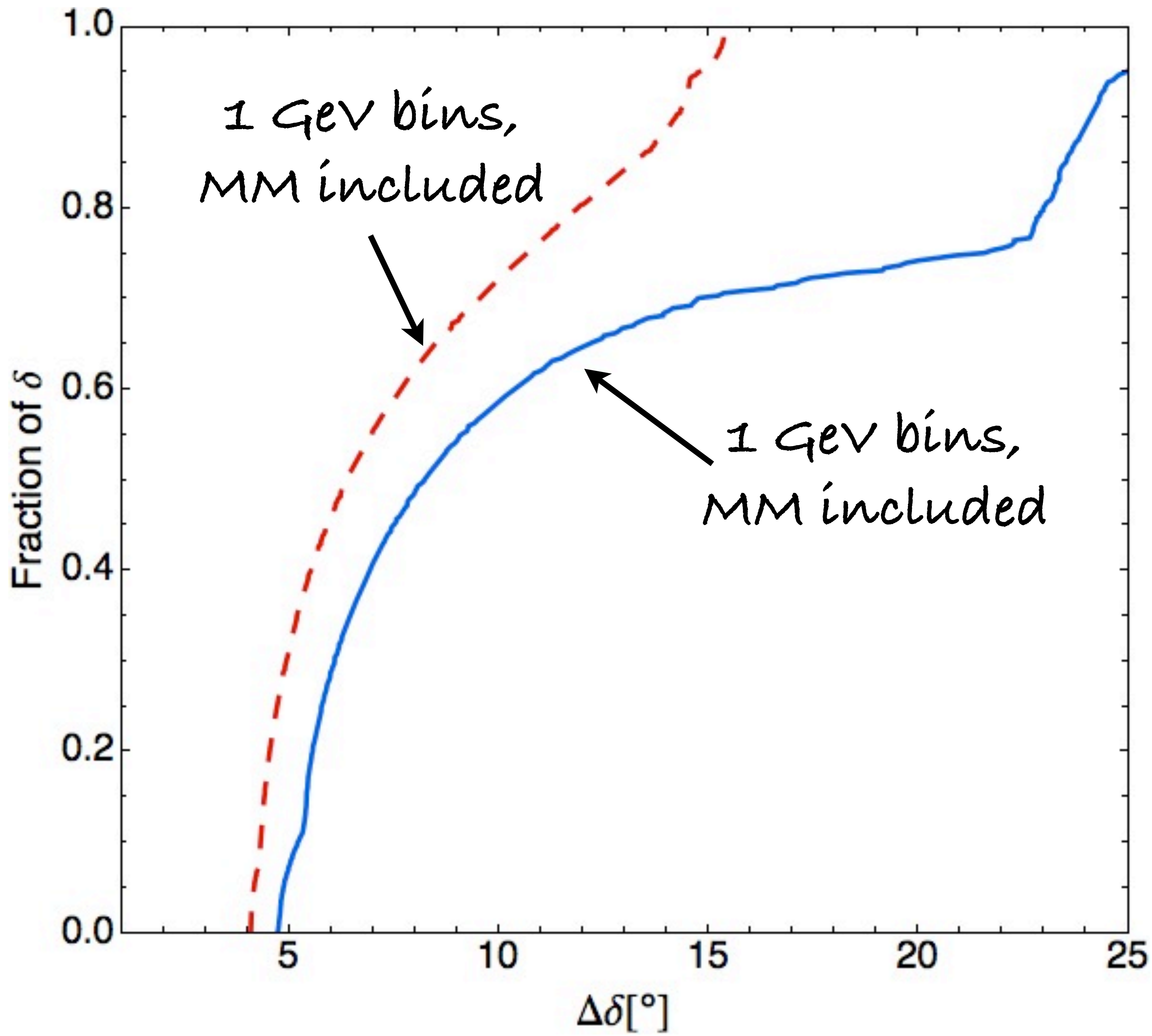
Coloma, Huber, Kopp, Winter, In preparation

Key systematics

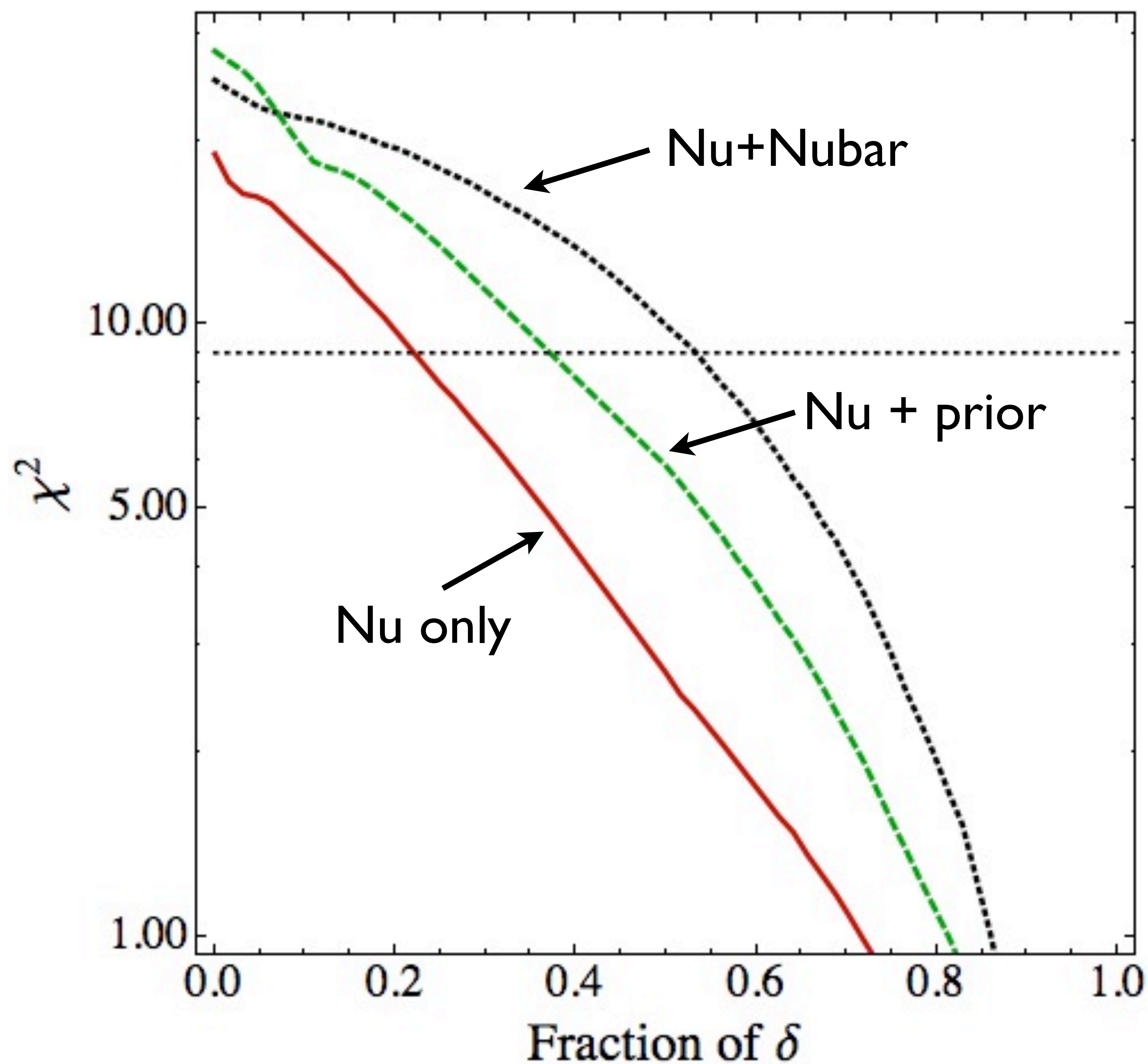


Coloma, Huber, Kopp, Winter, In preparation

Binning for the LENF

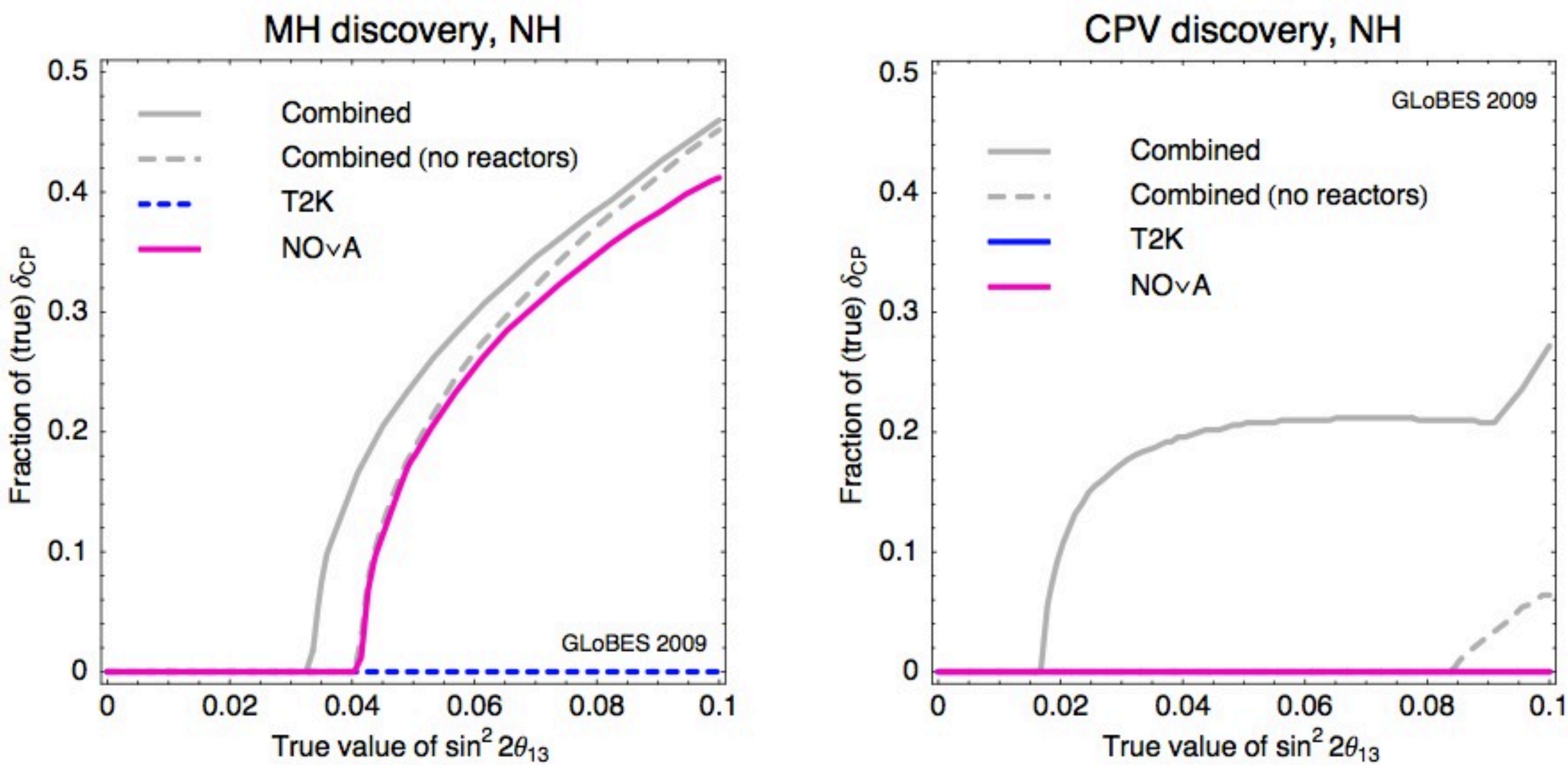


Effect of th13 prior on CPV



Present oscillation facilities

Discovery potential at the 90% CL

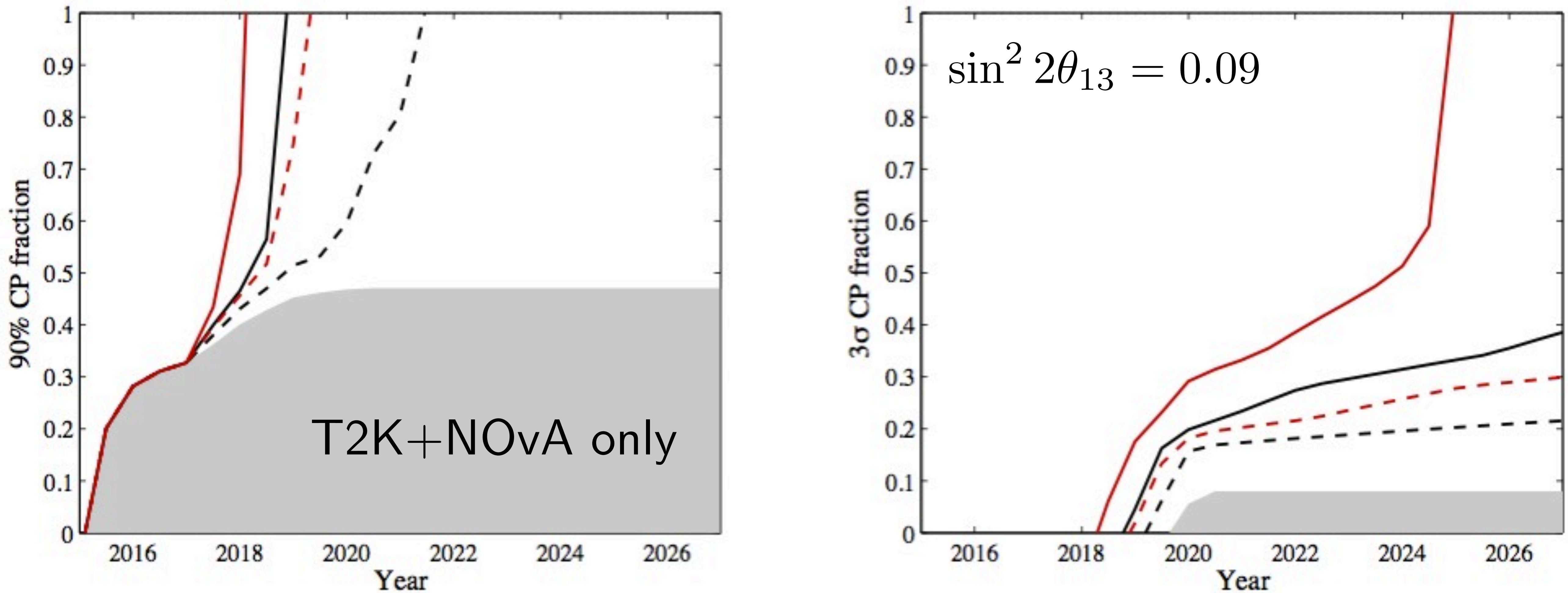


Huber, Lindner, Schwetz, Winter, 0907.1896 [hep-ph]

Present oscillation facilities

T2K+NOvA+INO

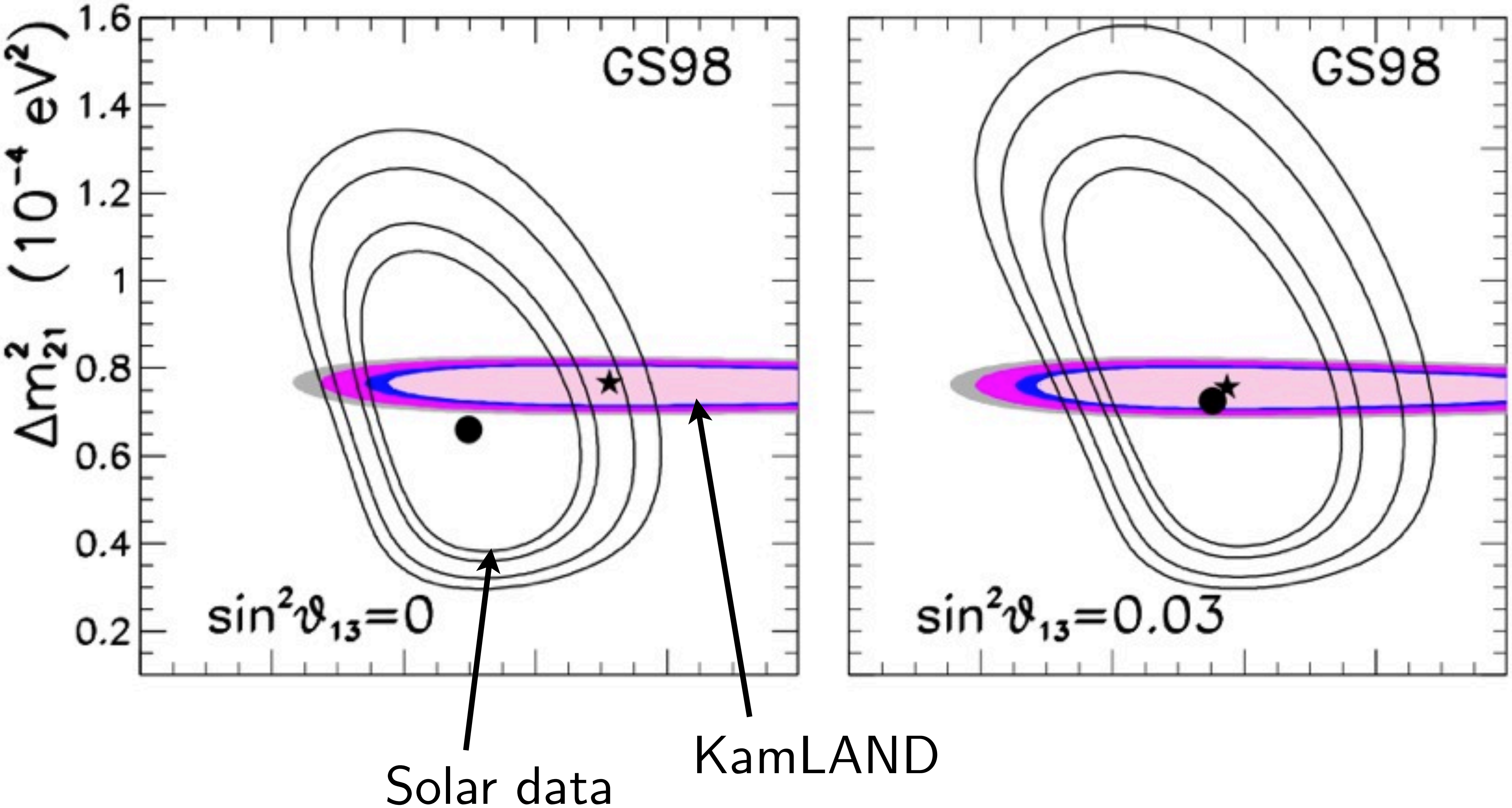
(50kt/100kt; low/high res)



Blennow, Schwetz, 1203.3388 [hep-ph]

Previous hints on θ_{13}

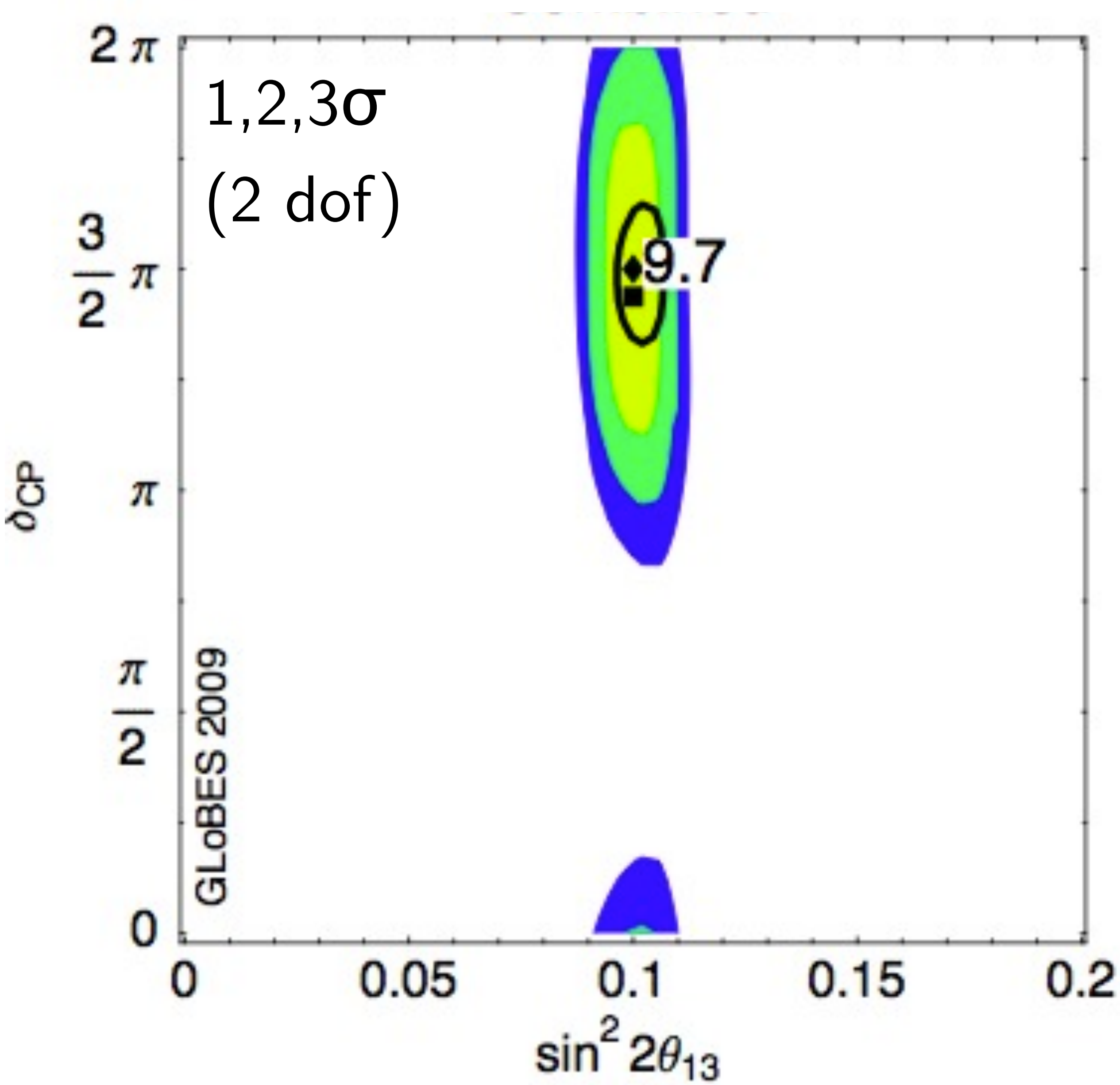
Previous hints from global fits pointed to nonzero θ_{13}...

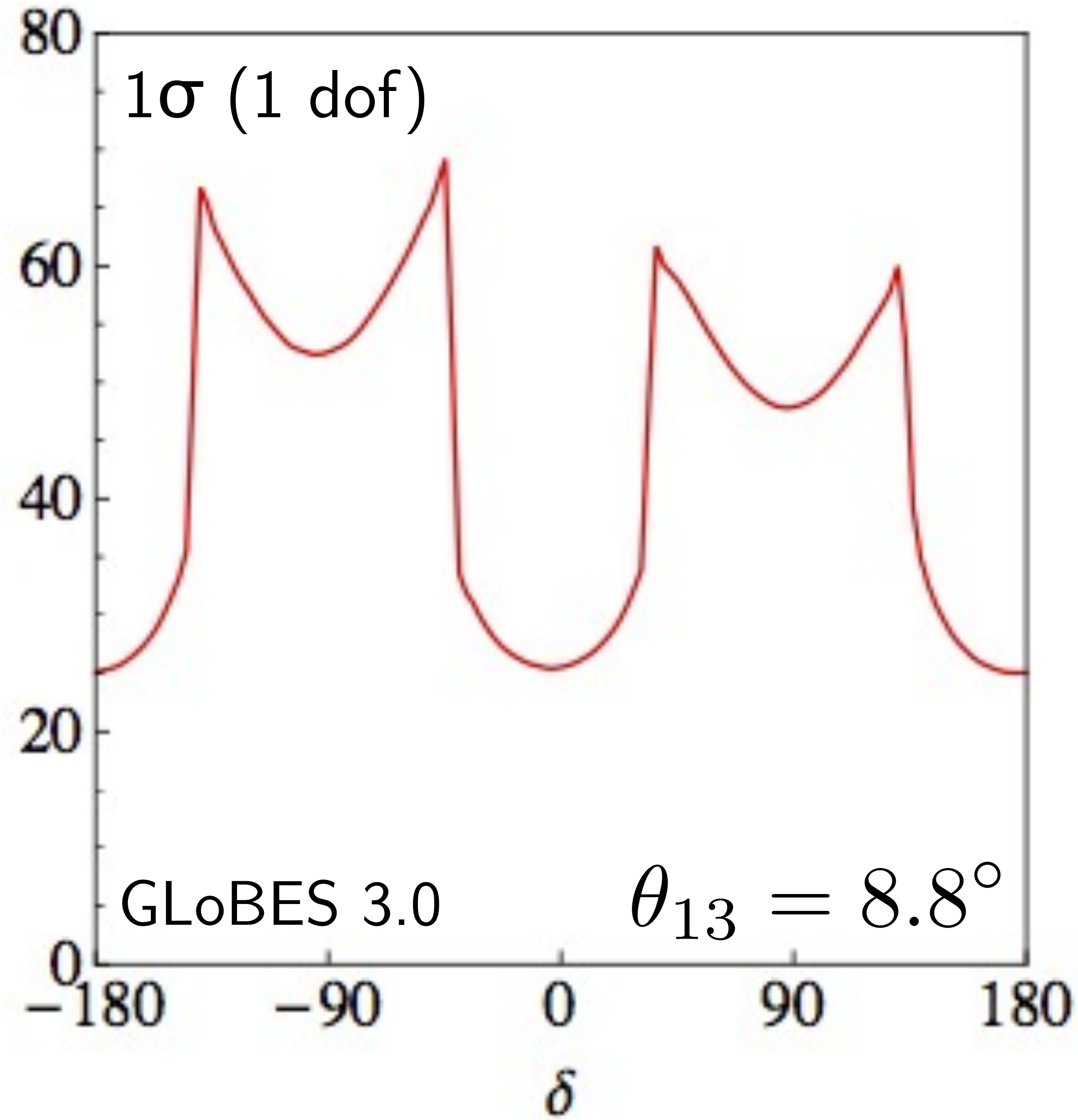


González-García, Maltoni,Salvado, 1001.4524 [hep-ph]

The starting point

NOvA+T2K+Daya Bay

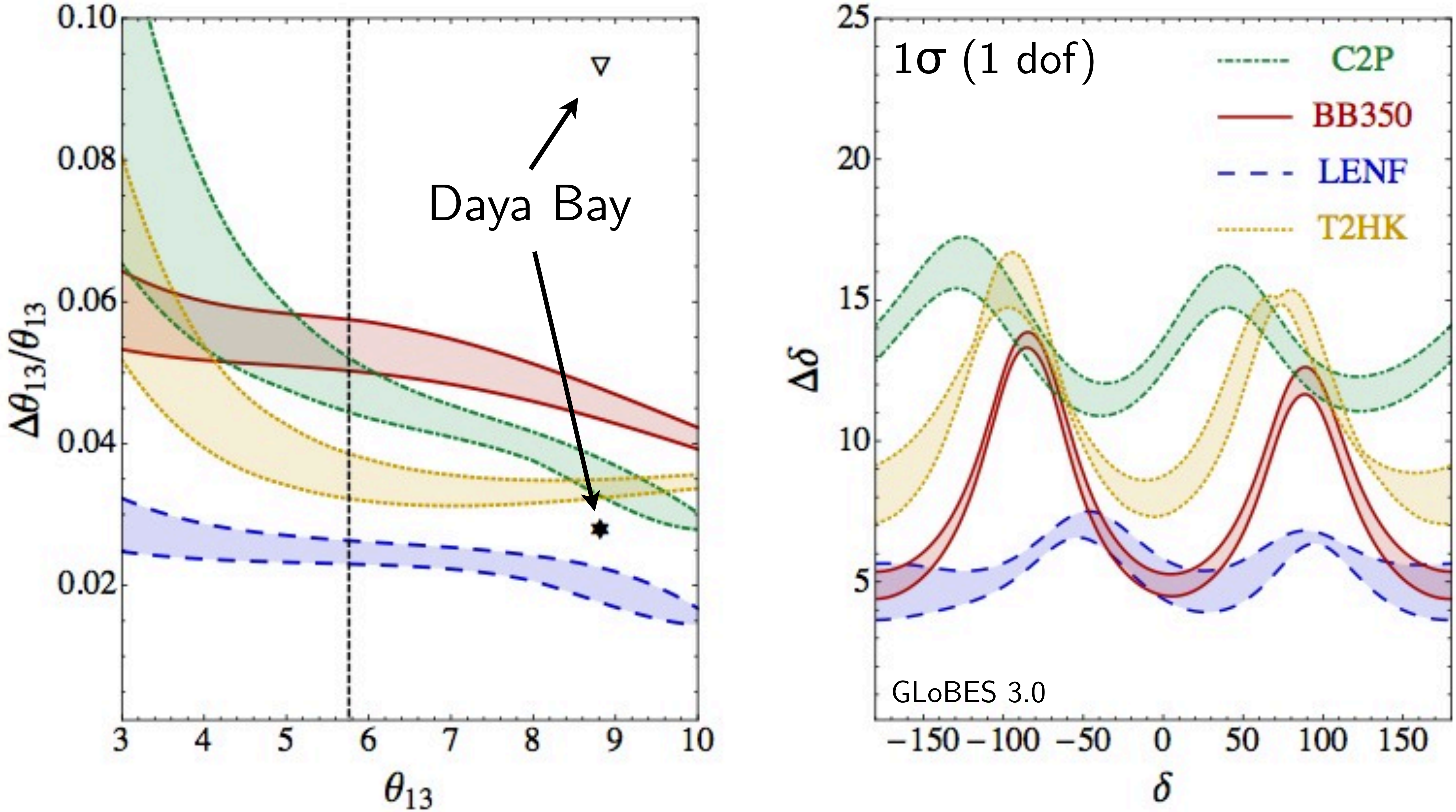




Huber, Lindner, Schwetz, Winter, 0907.1896 [hep-ph]

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

Precision



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

Currently Open Documents

- cp_MH.c
- ids-nf-3.0beta_...
- ids-nf-3.0beta-...

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
>
```

Recent Documents

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

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