Performance Comparisons

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Outline

- Experimental strategies without NF or β-beam
  - T2KK
  - NOνA* (aka SNUMI)
    see also talk by N. Saoulidou
  - WBB
    see also talk by M. Bishai
- Large θ_{13} – new developments
  see also talk by S. Pascoli
- Outlook

T2KK

- $4\,\mathrm{MW}$ protons from Tokai (JAERI)
- decay pipe fixed (same as for T2K)
- 2(!) water Cherenkov (WC) detectors with $m_{\mathrm{fiducial}} = 270\,\mathrm{kt}$
- 2 baselines $L_1 = 295\,\mathrm{km}$ and $L_2 = 1050\,\mathrm{km}$
- same off-axis angle of 2°
- 4 years ν and 4 years $\bar{\nu}$
- performance as in T2K
- π^0 rejection as in T2K

M. Ishitsuka *et al.*, PRD **72** 033003 (2005).
K. Hagiwara *et al.*, PLB **637** 266 (2006).
T. Kajita *et al.*, hep-ph/0609286.

Upgrades of NOνA

- $1.13\,\mathrm{MW}$ from Main Injector at Fermilab (corresponding to 10^{21} pot in $1.7 \times 10^{7}\,\mathrm{s}$ at 120 GeV)
- decay pipe fixed (same as for MINOS and NOνA)
- $100\,\mathrm{kt}$ liquid Argon time projection chamber (LArTPC)
- 3 years ν and 3 years $\bar{\nu}$ of $25\,\mathrm{kt}$ (TASD) NOνA at Ash River
- plus 3 years ν and 3 years $\bar{\nu}$ of both

Liquid Argon

Any upgrade of NOνA needs a detector that

- delivers high statistics
- has very low NC backgrounds
- works on surface (or close to it)

Liquid Argon

- 80% efficiency
- 0 NC background
- $5\%/\sqrt{E}$ energy resolution for QE events
- $20\%/\sqrt{E}$ energy resolution for non-QE events

B. Fleming, private communication

WBB

aka 'the BNL proposal' – originally proposed to be hosted by BNL, using $28\,\mathrm{GeV}$ protons from the AGS.

- 1 (ν) or 2 ($\bar{\nu}$) MW at 28 GeV
- 300 kt Water Cherenkov detector
- baseline of 1300 km, on-axis
- 5 years ν and 5 years $\bar{\nu}$
- performance based on full detector MC
  C. Yanagisawa
- improved π^0 rejection

Exposure

Everyone has different assumptions about

- seconds in a year
- number of years
- detector size
- beam power (or pot)

Therefore we introduce the concept of exposure

$$\mathrm{detector\,mass}\,[\mathrm{Mt}] \times \mathrm{target\,power}\,[\mathrm{MW}] \times \mathrm{running\,time}\,[10^7\,\mathrm{s}]\,.$$

Setups

Setup	t_ν [yr]	$t_{\bar\nu}$ [yr]	$P_{\rm Target}$ [MW]	L [km]	Detector technology	$m_{\rm Det}$ [kt]	$\mathcal{L}$
NOνA*	3	3	1.13 ($\nu/\bar\nu$)	810	Liquid Argon TPC	100	1.15
$\mathrm{WBB}-120_\mathrm{S}$	5	5	1 (ν) +2($\bar\nu$)	1290	Liquid Argon TPC	100	2.55
T2KK	4	4	4 ($\nu/\bar\nu$)	295+1050	Water Cherenkov	270+270	17.28
β-beam	4	4	n/a	730	Water Cherenkov	500	n/a
NuFact	4	4	4 ($\nu/\bar\nu$)	3000+7500	Magn. iron calor.	50+50	n/a

- 5% systematics for all setups

Comparison

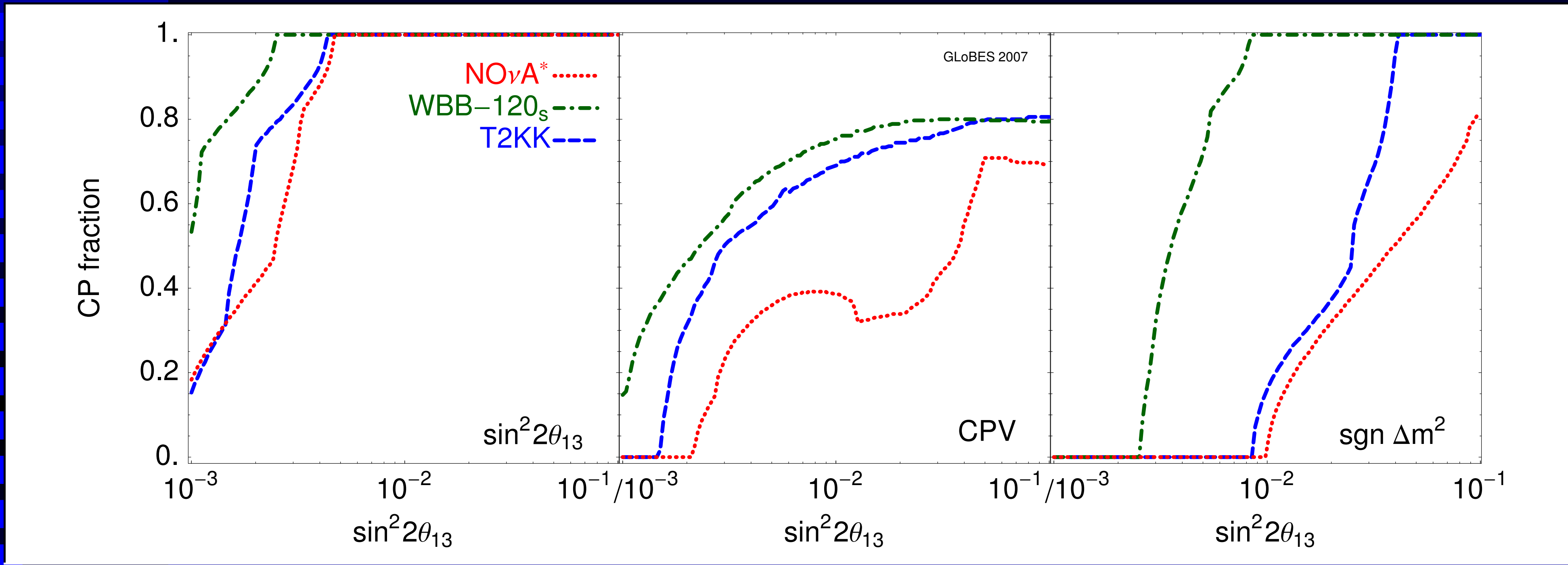
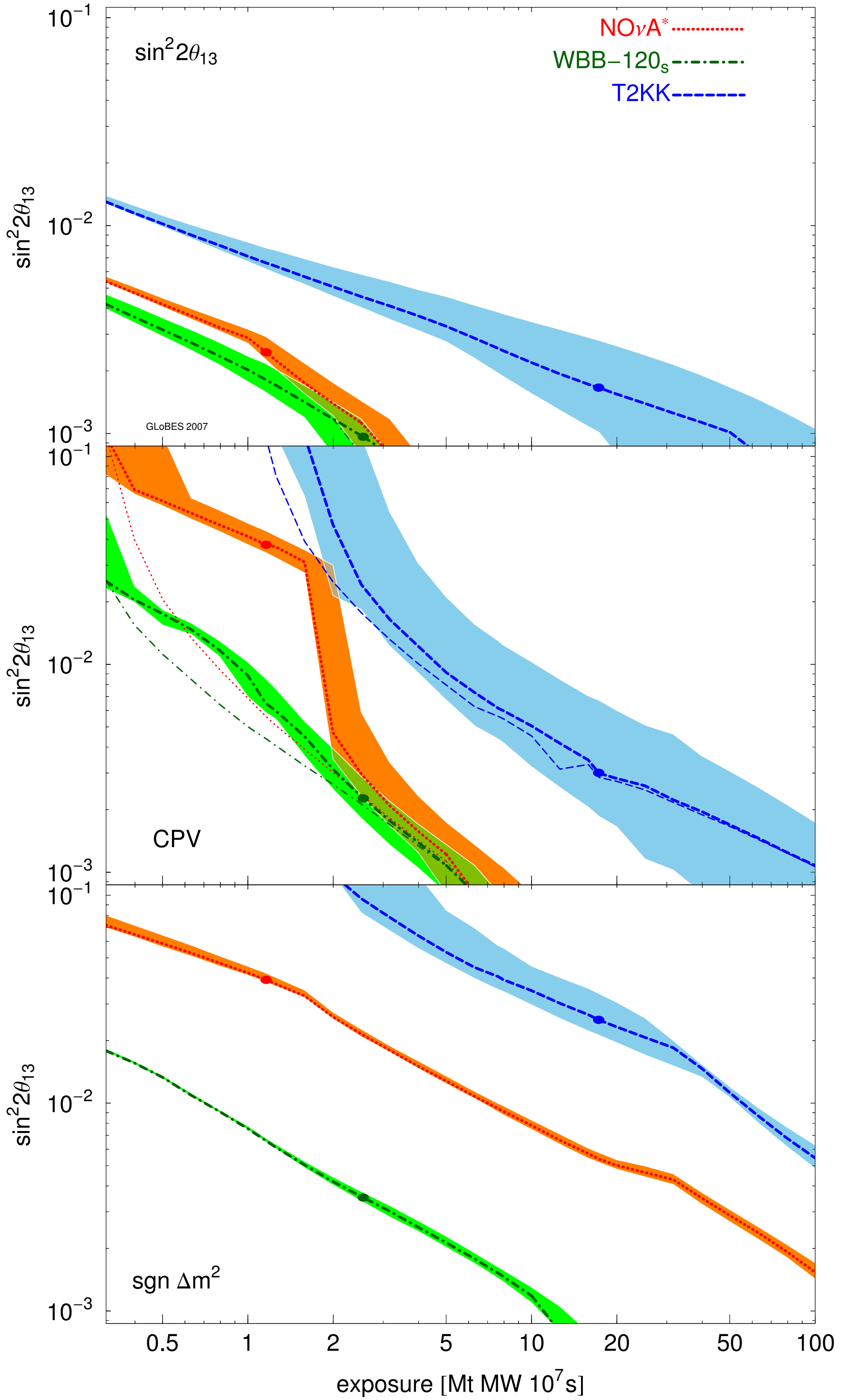


figure from Barger,PH,Marfatia,Winter hep-ph/0703029.

At nominal exposure

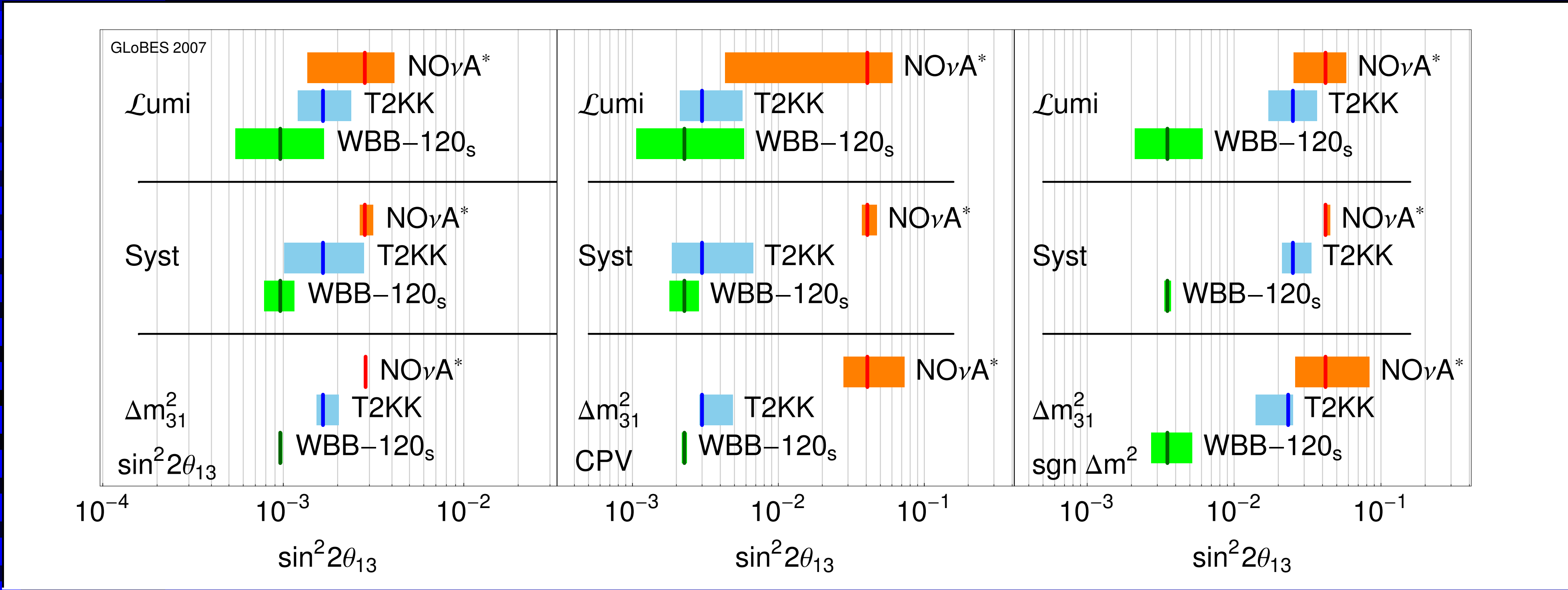
- $\mathrm{WBB} - 120_\mathrm{S}$ best performance
- T2KK close for CPV



- T2KK needs by far the largest exposure
- NOνA* does well for θ_{13} and CPV if the exposure is large enough > 2Mt MW 10^7s to resolve the $\mathrm{sgn}\Delta m$ degeneracy
- WBB-120_S performs best for any given exposure

Barger,PH,Marfatia,Winter hep-ph/0703029.

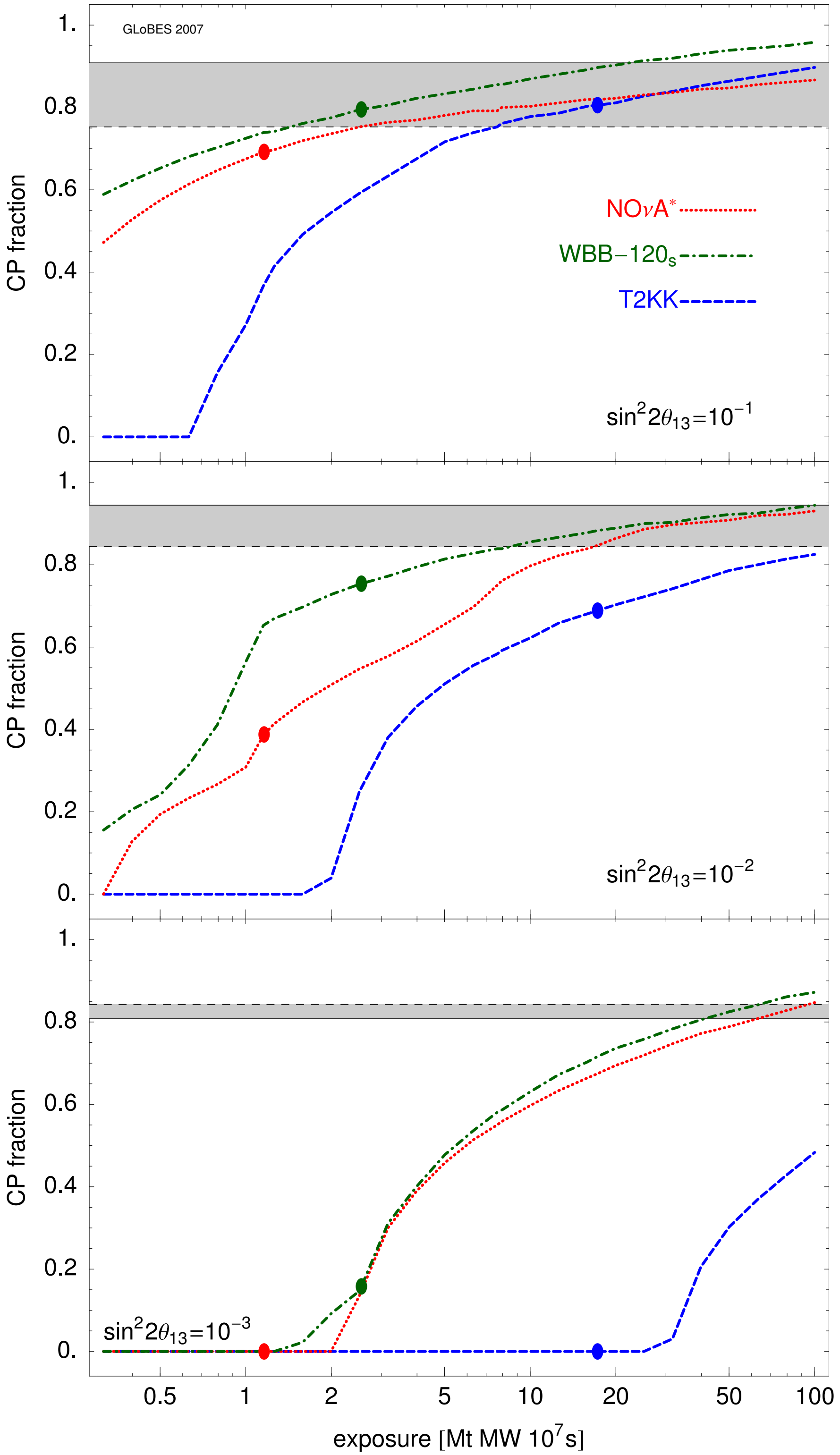
Robustness



Barger,PH,Marfatia,Winter hep-ph/0703029.

- Exposure from 2 to 0.5 times nominal value
- Systematics from 2% to 10%
- Δm^2_{31} from $2.0 - 3.0 \times 10^{-3}\,\mathrm{eV}^2$

Large θ_{13}



At large θ_{13} any of the three setups can have the same performance as a NuFact or β-beam.

These large values would be certainly discovered by Double Chooz, Daya Bay, T2K and NOνA!

$\Rightarrow$ decision on next generation facility should wait at least for the first reactor data

Barger,PH,Marfatia,Winter hep-ph/0703029.

Neutrino factory superbeam

$$\pi^- \longrightarrow \mu^- + \underbrace{\bar{\nu}_\mu}_{???} \longrightarrow e^- + \underbrace{\bar{\nu}_e + \nu_\mu}_{NF}$$

Why not use the neutrinos produced during muon production?

- allows to study ν_e appearance w/o electron CID
- lots of events at low energies
- no additional accelerators/target required
- possibly only one detector needed, in that case fully correlated matter effects
  $\longrightarrow$ subject of further study

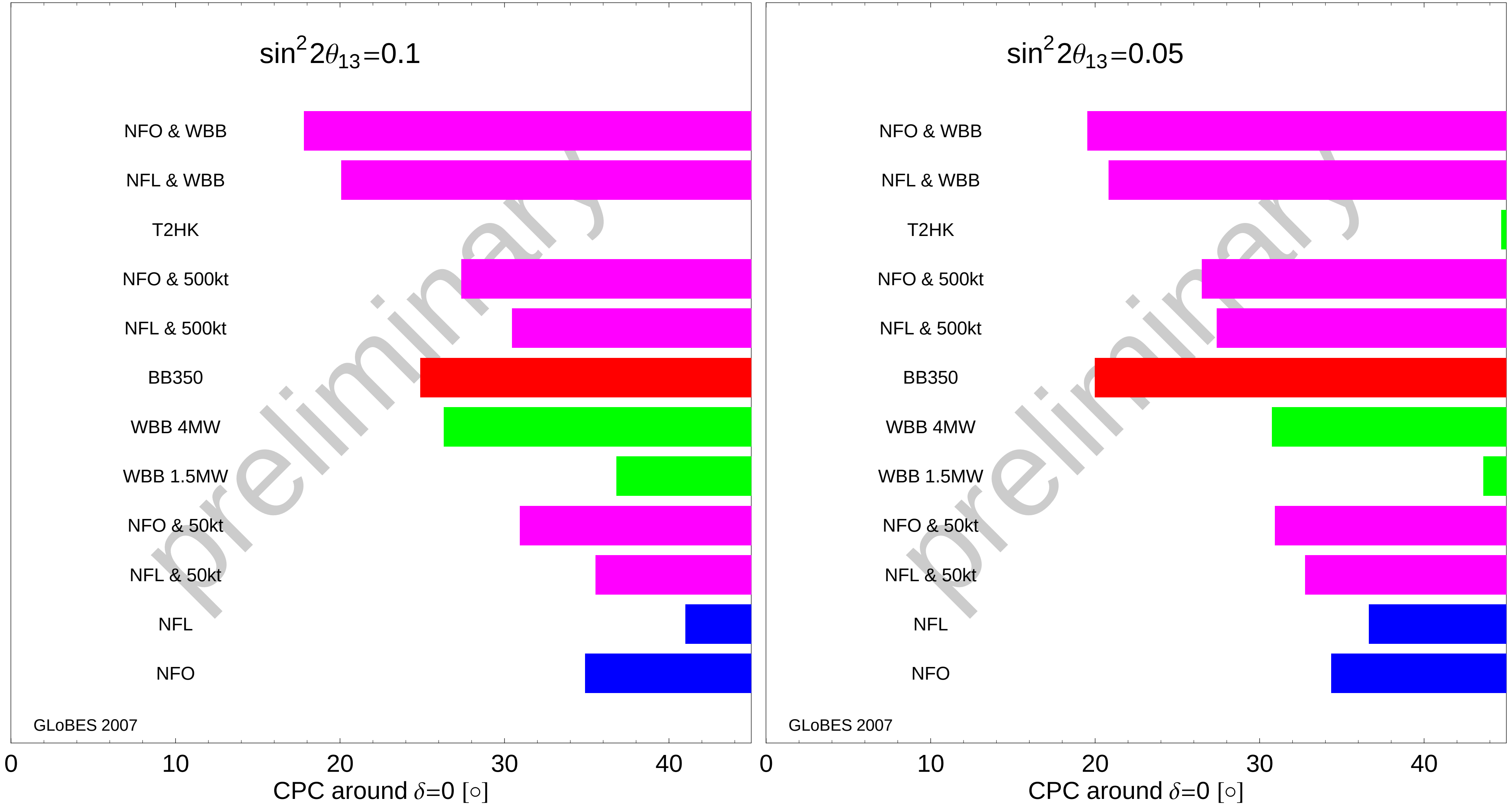
work in progress, together with W. Winter

Possible Setups

- for E_p of a few GeV, we use MiniBOONE beam and performance, *i.e.* we assume a Cherenkov detector – labeled ’50kt’ and ’500kt’
- for E_p of a few 10 GeV, we use WBB beam and performance, *i.e.* water Cherenkov detector with 300 kt fiducial mass – labeled ’WBB’

’NFL’ is a low energy neutrino factory with $E_\mu = 5\,\mathrm{GeV}$, Geer, Mena, Pascoli, hep-ph/0701258.
’NFO’ is the optimal neutrino factory with $E_\mu = 20\,\mathrm{GeV}$ and two baselines, PH, Lindner, Rolinec, Winter, hep-ph/0606119.

New ideas



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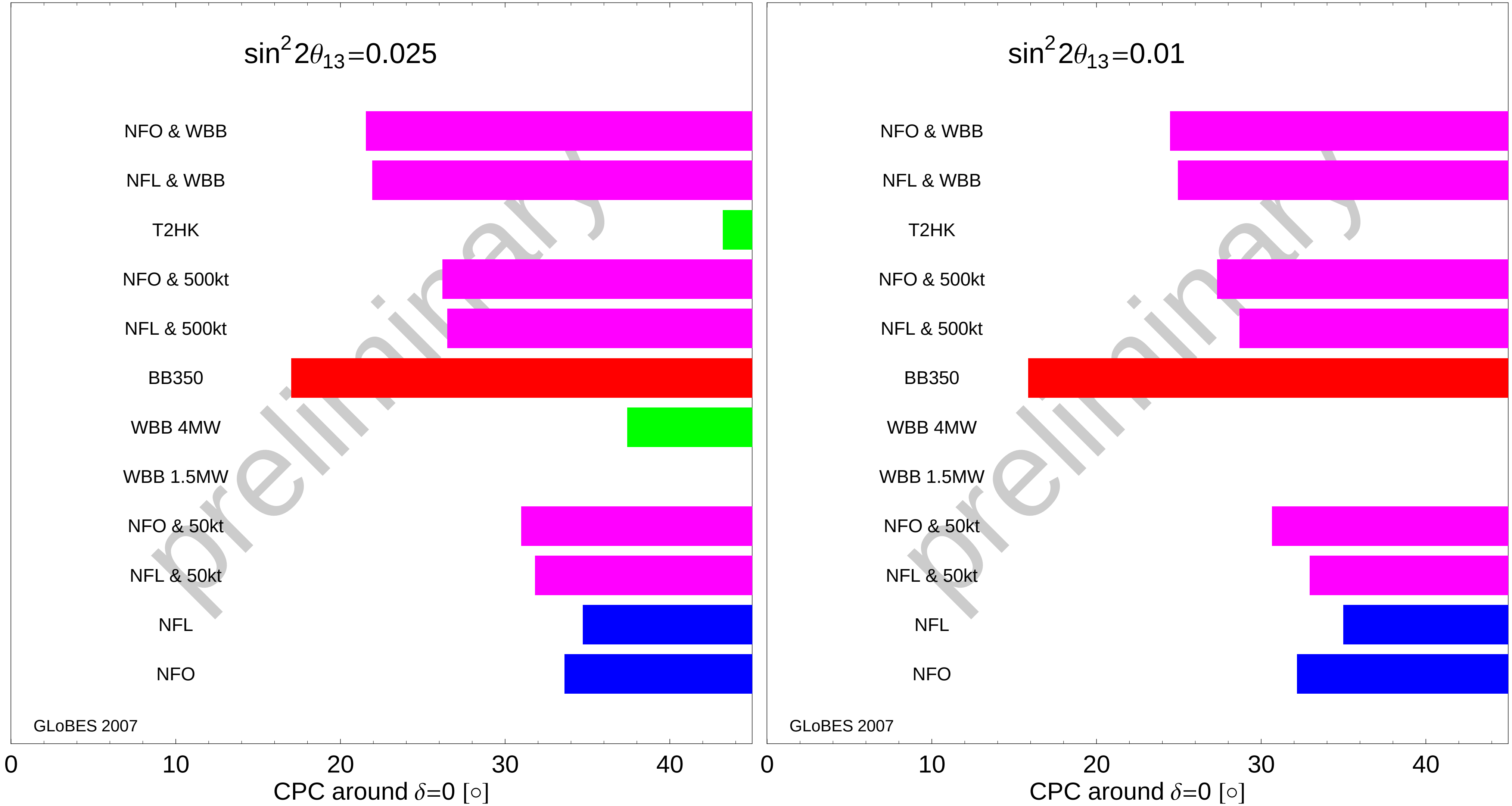
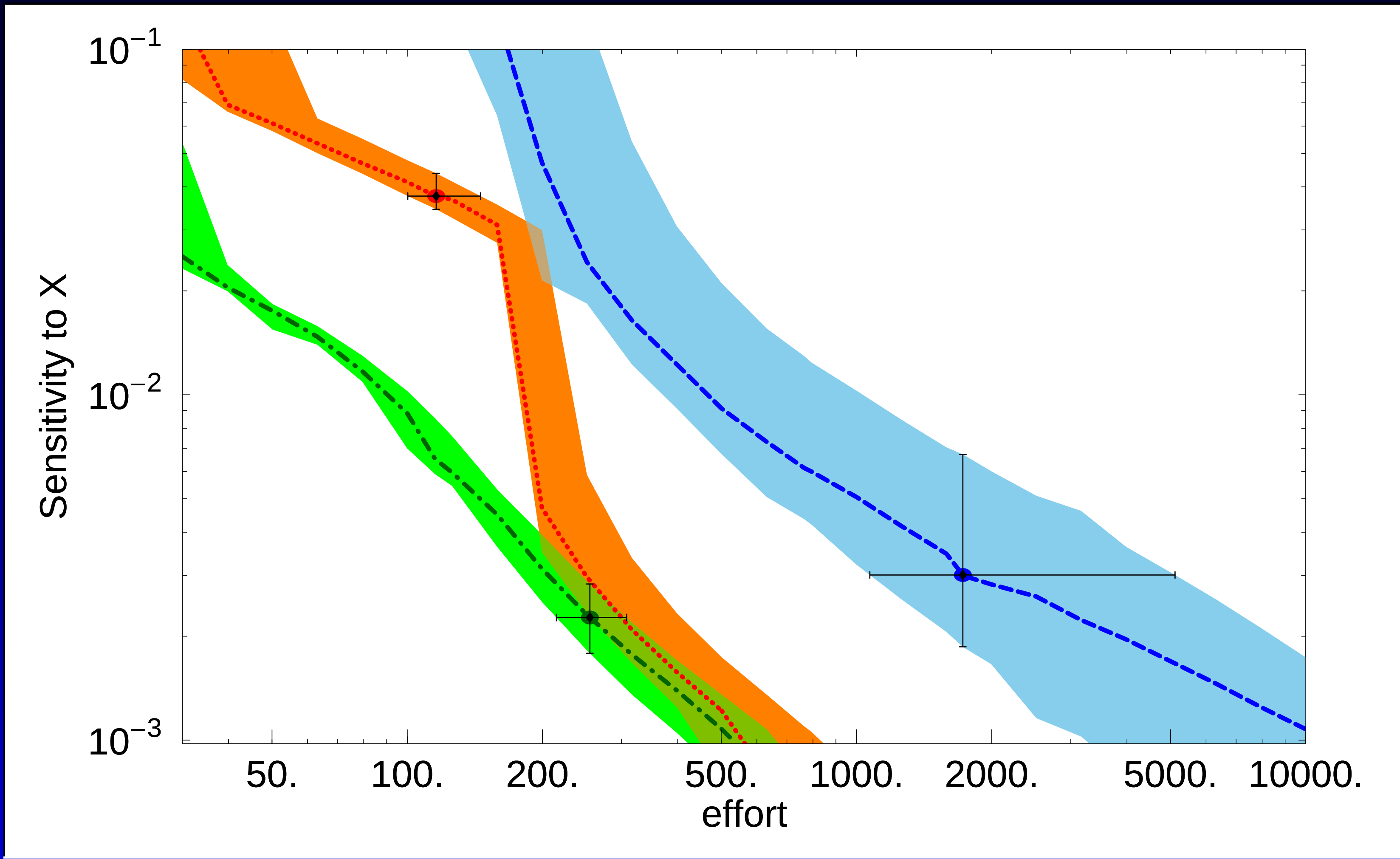
New ideas



work in progress, together with W. Winter

Physics vs Effort



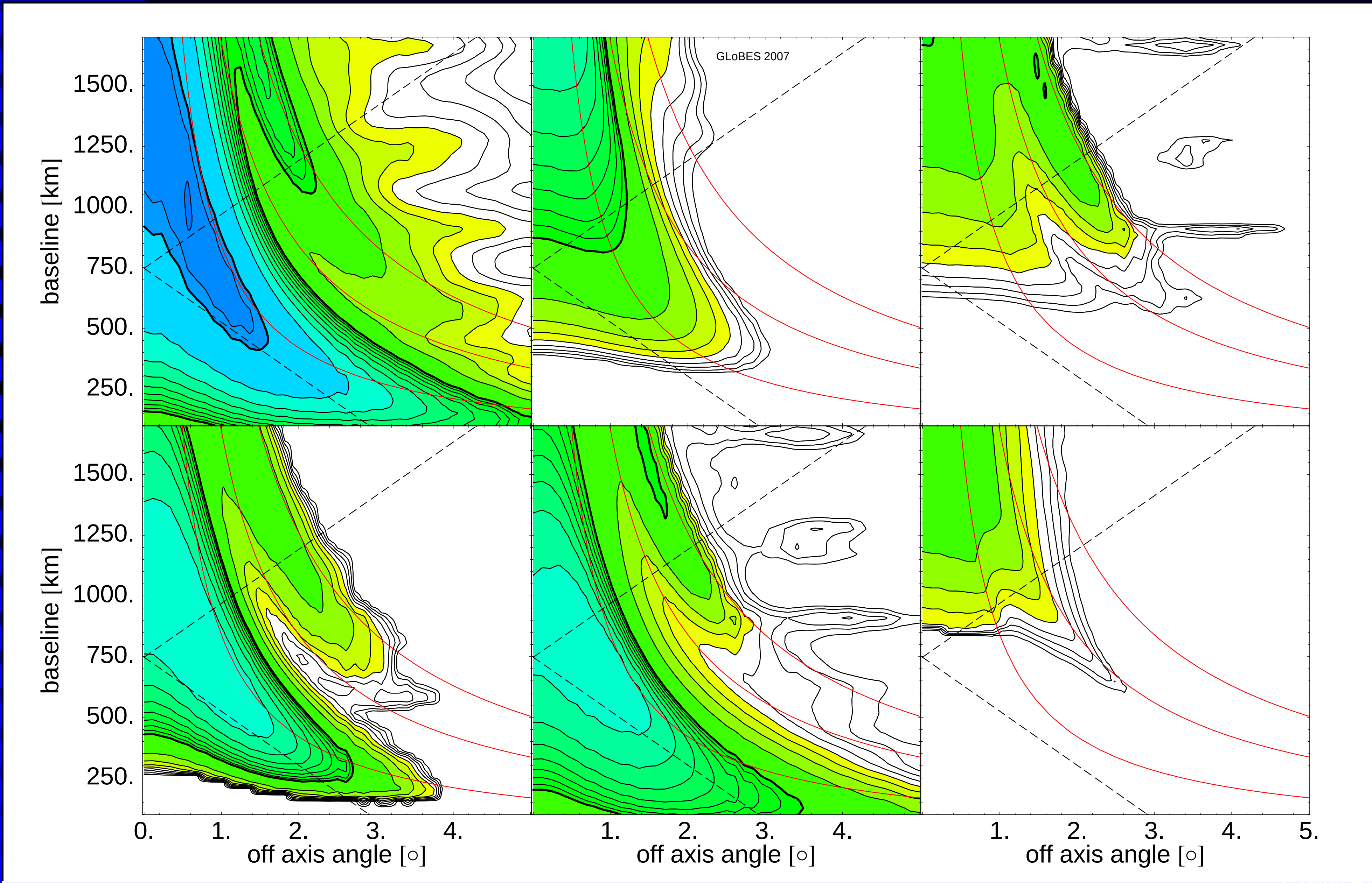
Knowing how expensive an option is and how its performance changes as function of the effort is crucial!

Outlook

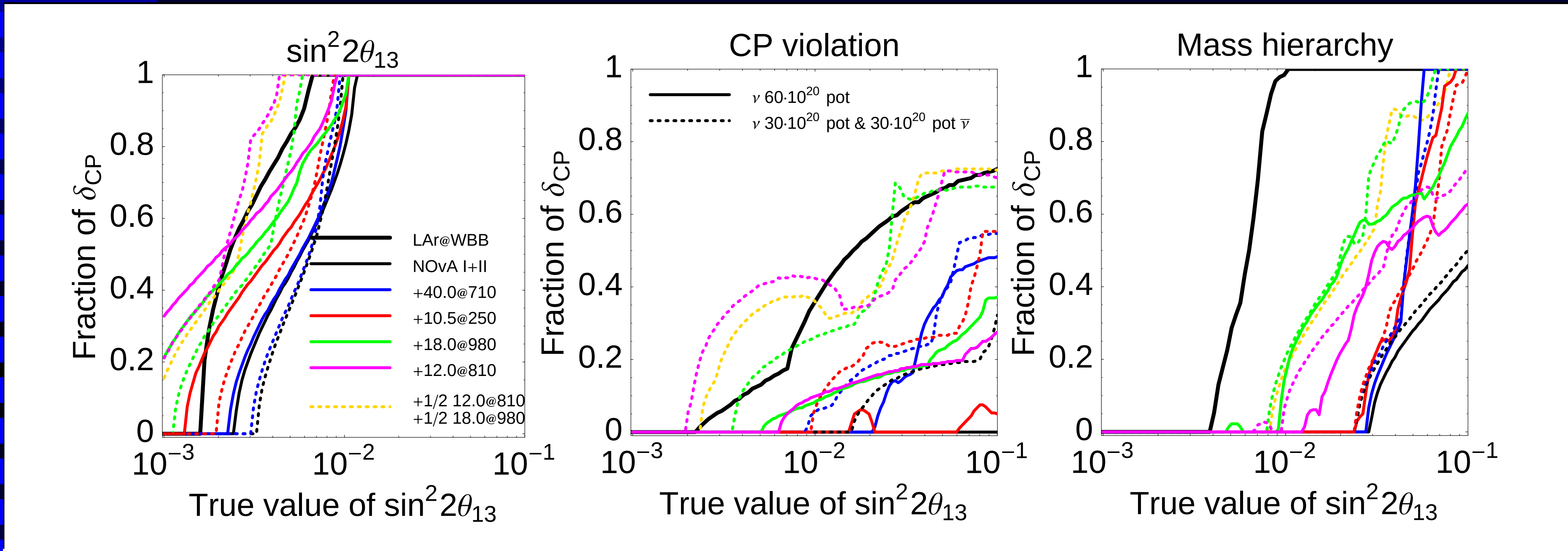
- Off vs On-axis decision requires careful analysis
- Short distances ($< 500\,\mathrm{km}$) are disfavored
- size of $\sin^2 2\theta_{13}$ is the key parameter
- for large $\sin^2 2\theta_{13} > 0.01$
  - physics vs cost will be crucial
  - we will know whether $\sin^2 2\theta_{13} > 0.03$ by 2012
  - we will know whether $\sin^2 2\theta_{13} > 0.01$ by ~ 2014

Backup Slides

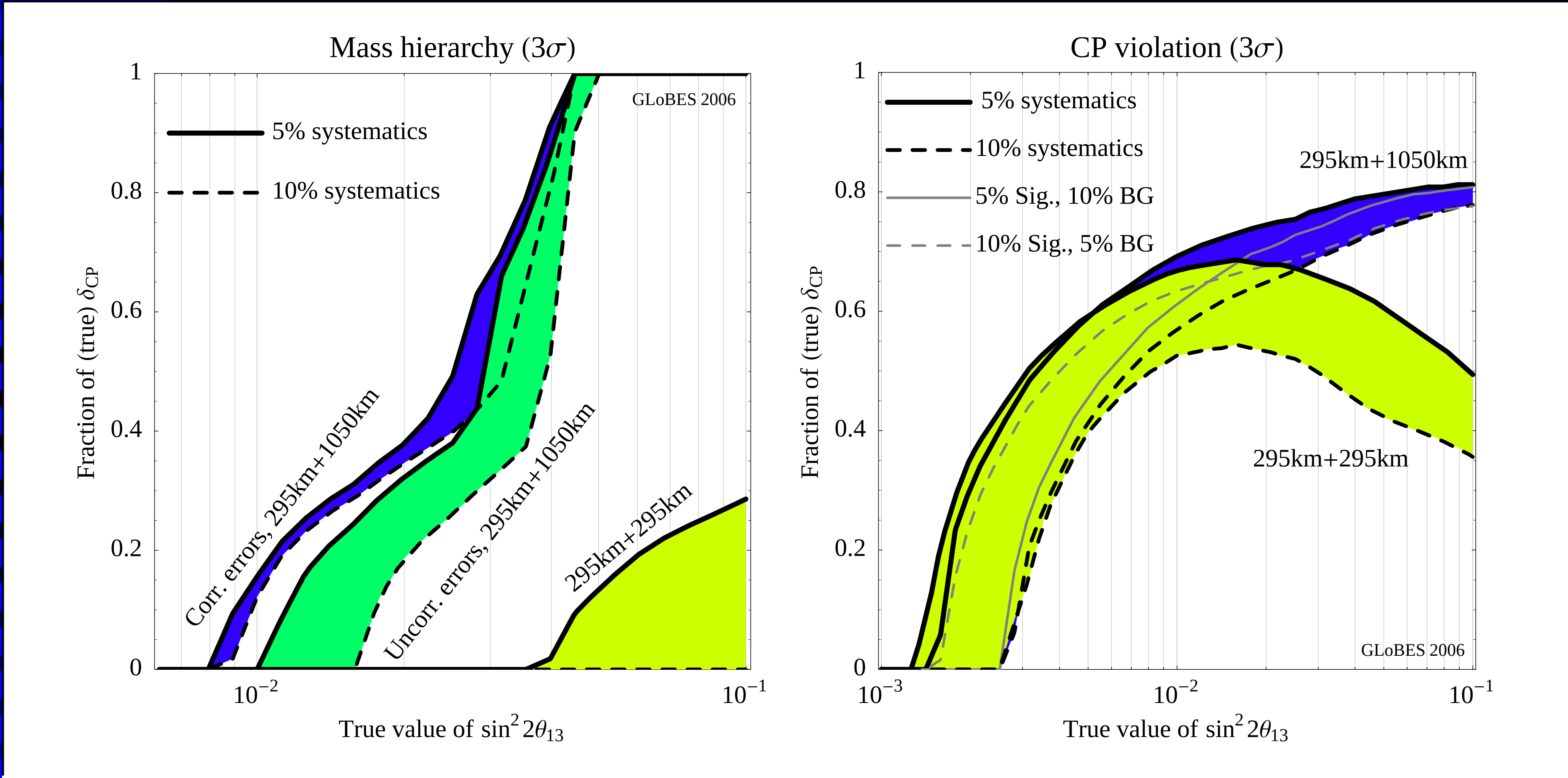
On vs off-axis



More NOνA options

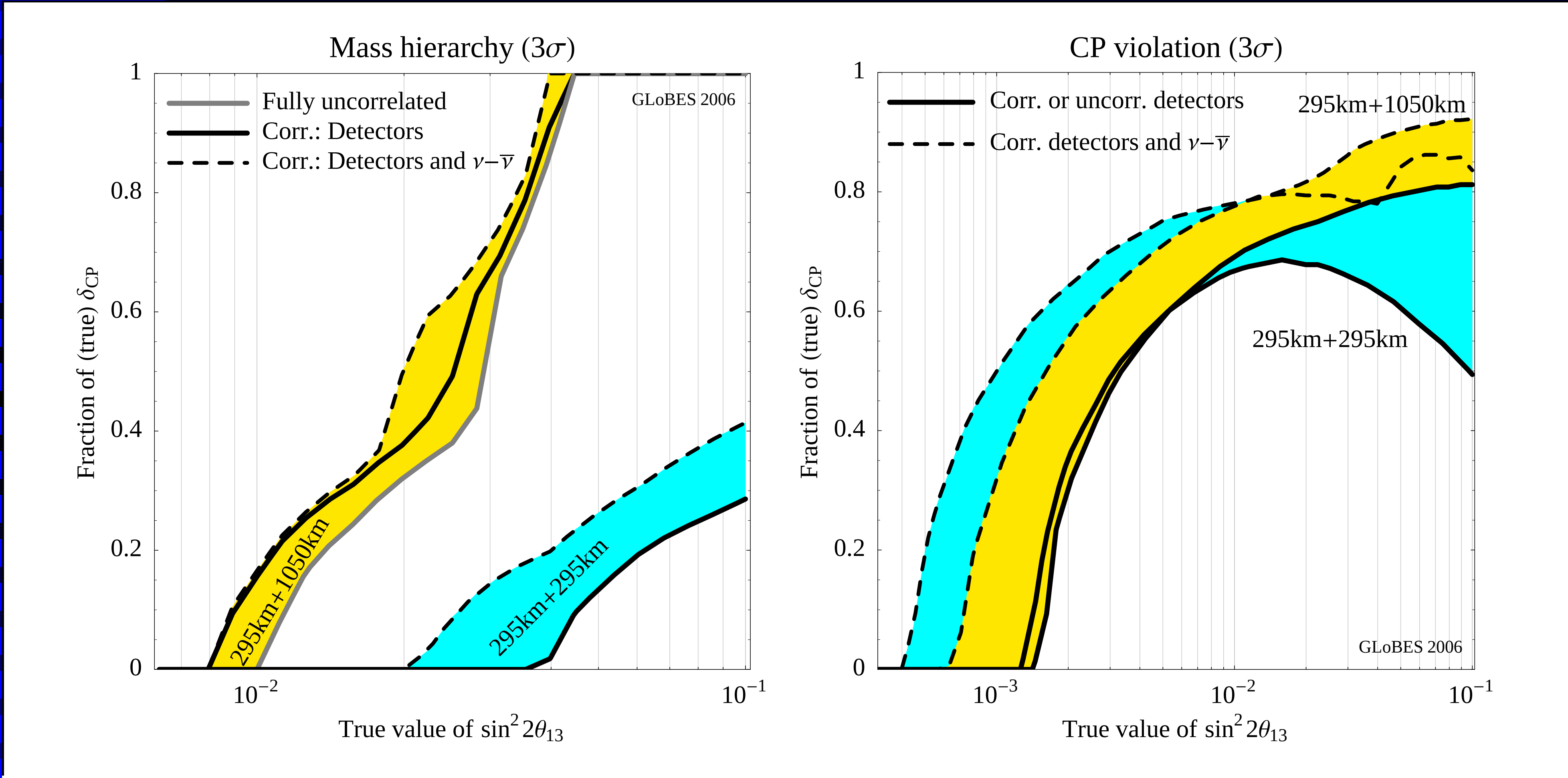


T2KK



- second baseline crucial for mass hierarchy
- also helps CPV at large θ_{13}

T2KK



- detectors errors for mass hierarchy important
- for CPV one needs to reduce the $\nu/\bar{\nu}$ errors