Long Baseline Experiments in Europe within LAGUNA

P. Coloma

Based on a collaboration with Tracey Li and Silvia Pascoli

NuFact'11, Geneva

August 1st - 6th 2011

Long Baseline Experiments SuperBeams in Europe within LAGUNA

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Outline

- Introduction to LAGUNA sites and detectors
- Fluxes and statistics
- Simulation details
- Comparative results
- Robustness of the results
- Conclusions

LAGUNA sites and detectors

- Main goals of LAGUNA:

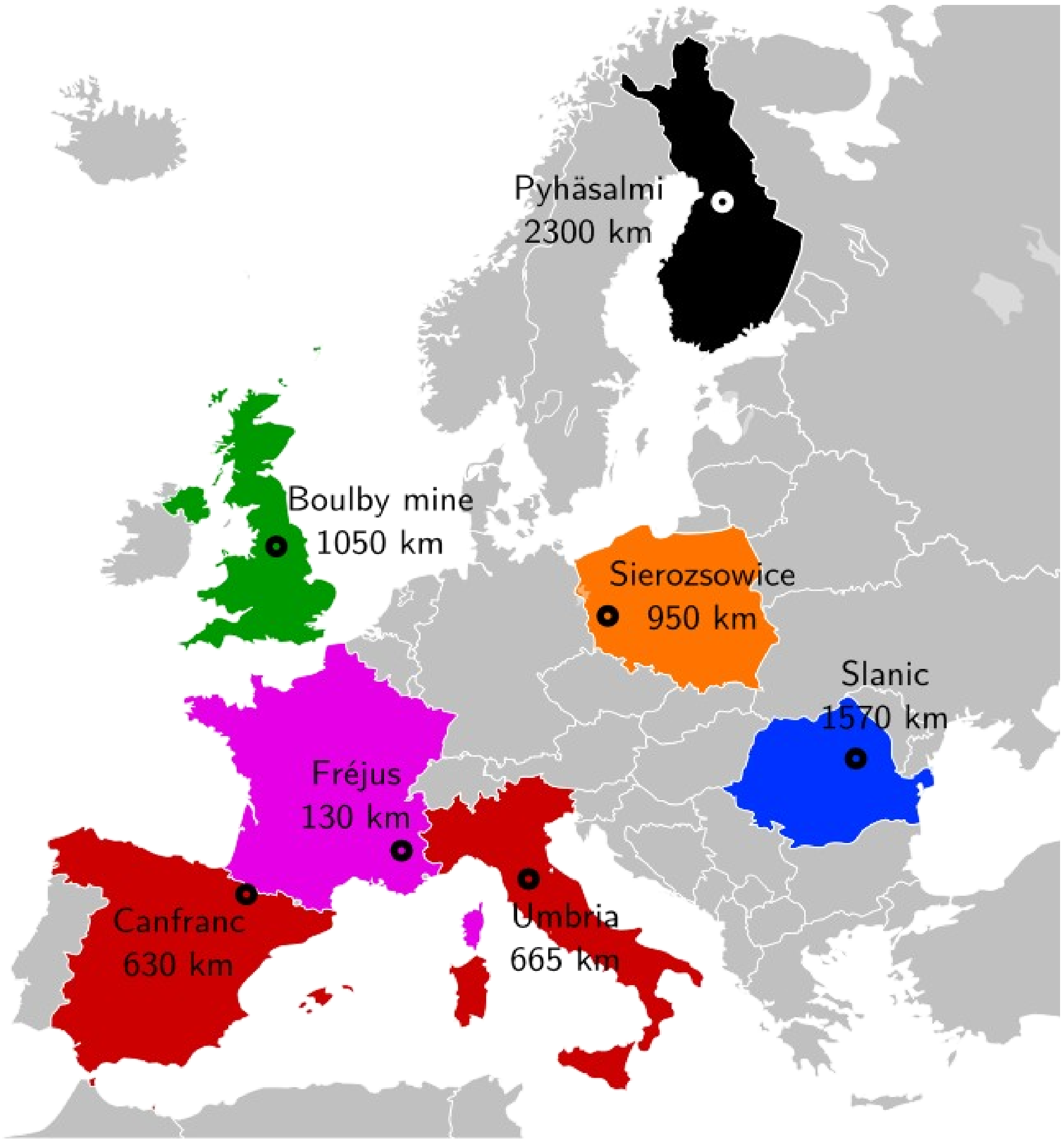
D. Angus et al, 1001.0077 [physics.ins-det]

  - Proton decay
  - Supernovae neutrinos
  - Terrestrial (geo- ,reactor), solar and atmospheric ν's

- LAGUNA needs a multi-purpose (very massive) underground detector. Considered technologies are:
  - **GLACIER**: 100 kton LAr — A. Rubbia, 0908.1286 [hep-ph]
  - **LENA**: 50 kton Liqu. Scintillator — M. Wurm, 1104.5620 [astro-ph.IM]
  - **MEMPHYS**: 440 kton WC — A. de Bellefon et al, hep-ex/0607026

LAGUNA sites and detectors

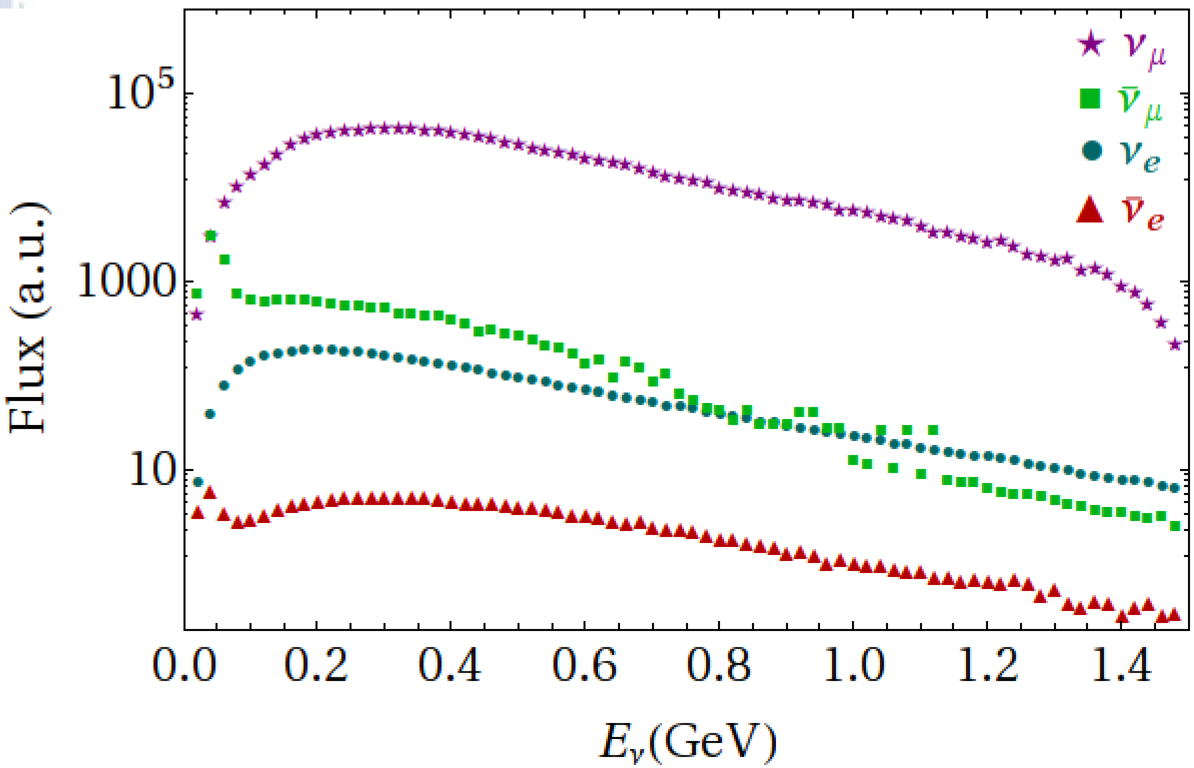
7 possible underground sites capable of hosting a very massive neutrino detector in Europe



Statistics and fluxes

Optimized fluxes for a good sensitivity to θ_{13}

L/E matching 1st peak



$$L = 130 \text{ km}$$
$$(4 \text{ MW})$$
$$0.56 \times 10^{23} \text{PoT yr}^{-1}$$
$$E_p = 4.5 \text{GeV}$$
$$10^7 \text{sec yr}^{-1}$$

(provided by A. Longhin)
1106.1096 [physics.acc-ph]

Statistics and fluxes

Optimized fluxes for a good sensitivity to θ_{13}

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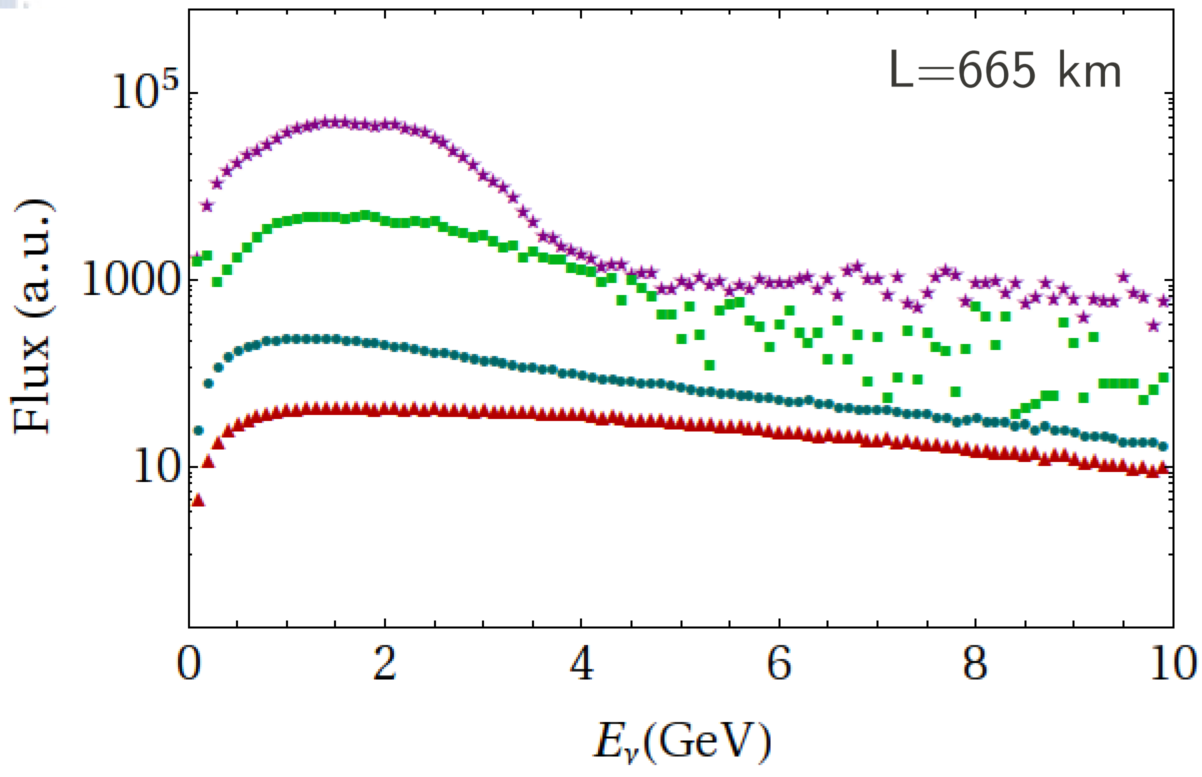


$$L > 130 \text{ km}$$

(2.4 MW)

$$3 \times 10^{21} \mathrm{PoT\,yr}^{-1}$$
$$E_p = 50 \mathrm{GeV}$$
$$10^7 \mathrm{sec\,yr}^{-1}$$

(provided by A. Longhin)
1106.1096 [physics.acc-ph]

Simulation details

General details

- All simulations using GLoBES 3.0 software hep-ph/0701187
- Marginalization over:
  - solar (4%) and atmospheric (10%) parameters
  - over matter density (2%) hep-ph/0305042
- Best-fit values according to Schwetz *et al*, 1103.0734 [hep-ph]
- Running times:
  - 2+8 for L=130 km;
  - 3+7 for longer baselines

Backgrounds & Systematics

- Intrinsic backgrounds (we assume a $\sim$50% may pass detector cuts). Ways out:
  - off-axis $\rightarrow$ not good for very long baselines
  - near detector
- Systematics of 5% on signal and background
  - may be further reduced with a near detector
- NC background (?) $\rightarrow$ naive guessing

Detector details

Detector	M (kton)	ϵ_{CC}	ϵ_{QE}	NC backgr.	$\sigma(E)$
GLACIER	100	90%	80%	0.5%	Migr. Matr.
LENA	50	90%	70% (e) 85% (μ)	$[0.5, 5]\,\%$	$0.05E$
WC ($L = 130$) WC ($L > 130$)	440	$\sim 70\%$ 40%	$\sim 70\%$ 40%	$[0.065 - 0.25]\,\%$ Rej. Effs.	Migr. Matr. Migr. Matr.

Campagne et al, hep-ph/0603172

Barger et al, 0705.4396 [hep-ph]

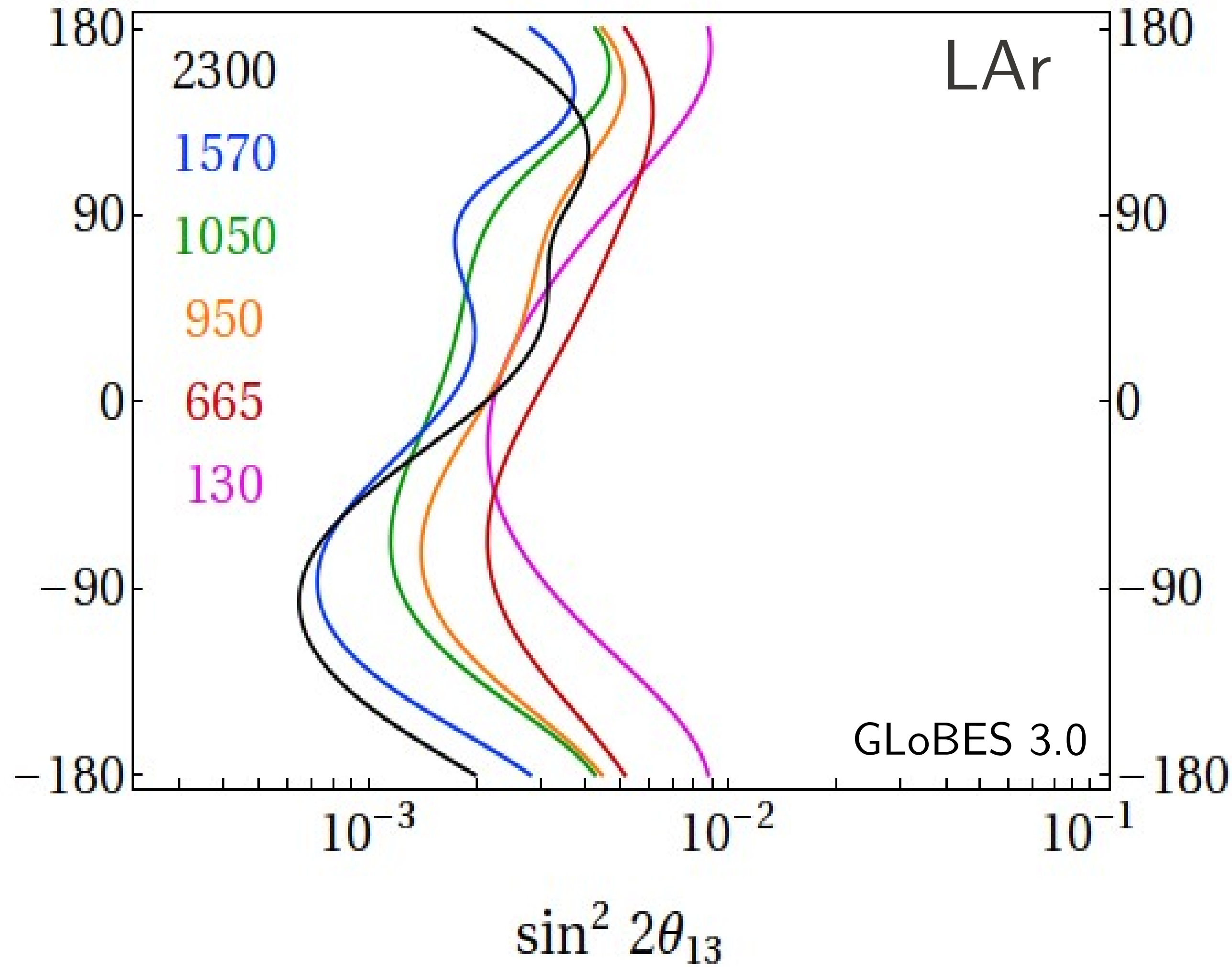
Info from: A. Rubbia, L. Esposito, J. Peltoniemi, R. Mollënberg, M. Wurm, L. Whitehead, B. Choudhary, N. Vassilopoulos...

Comparative results
(baselines and detectors)

Sensitivity to θ_{13}: LAr

Key factor here: statistics

Results almost δ independent from detector technology



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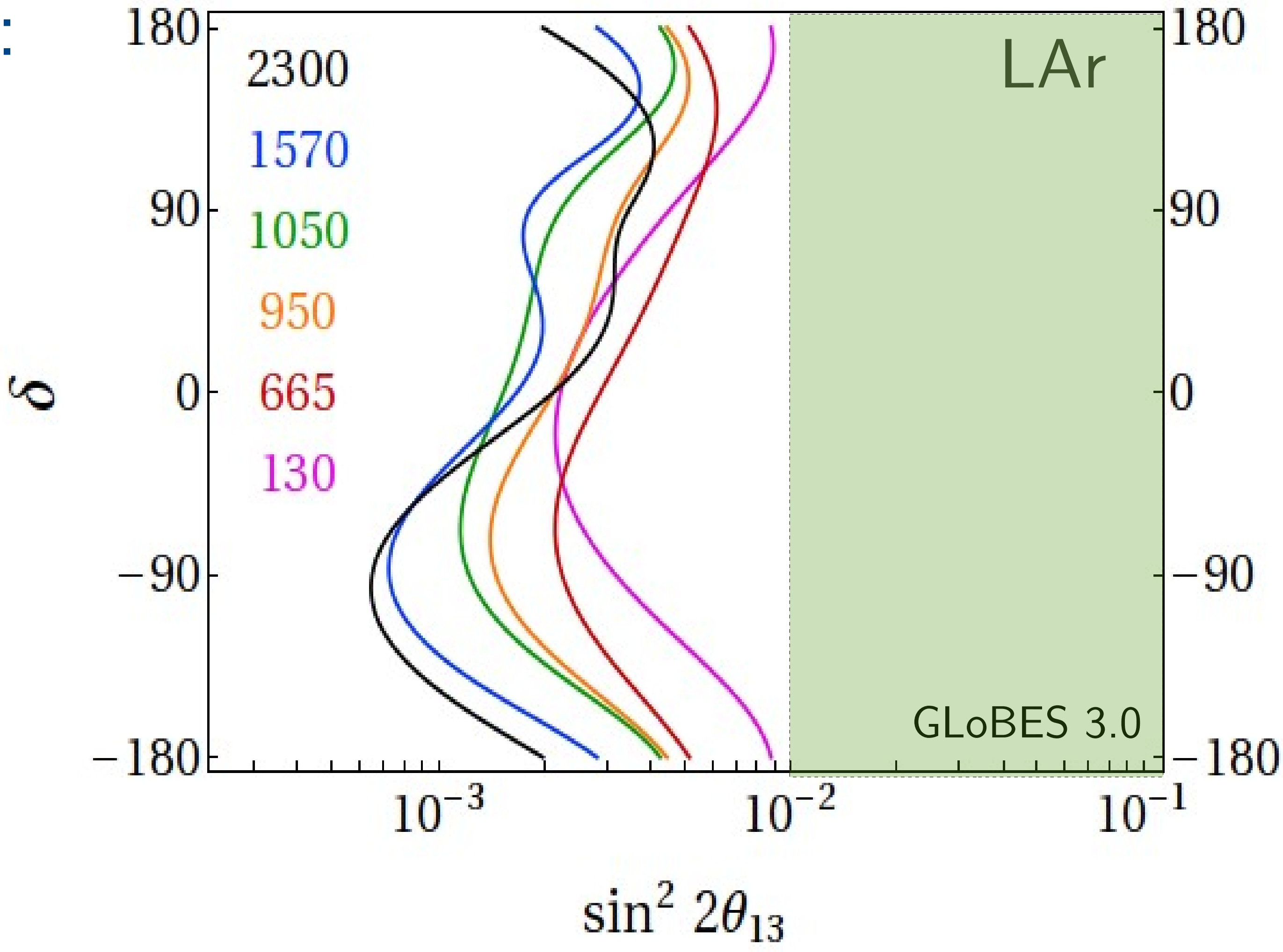
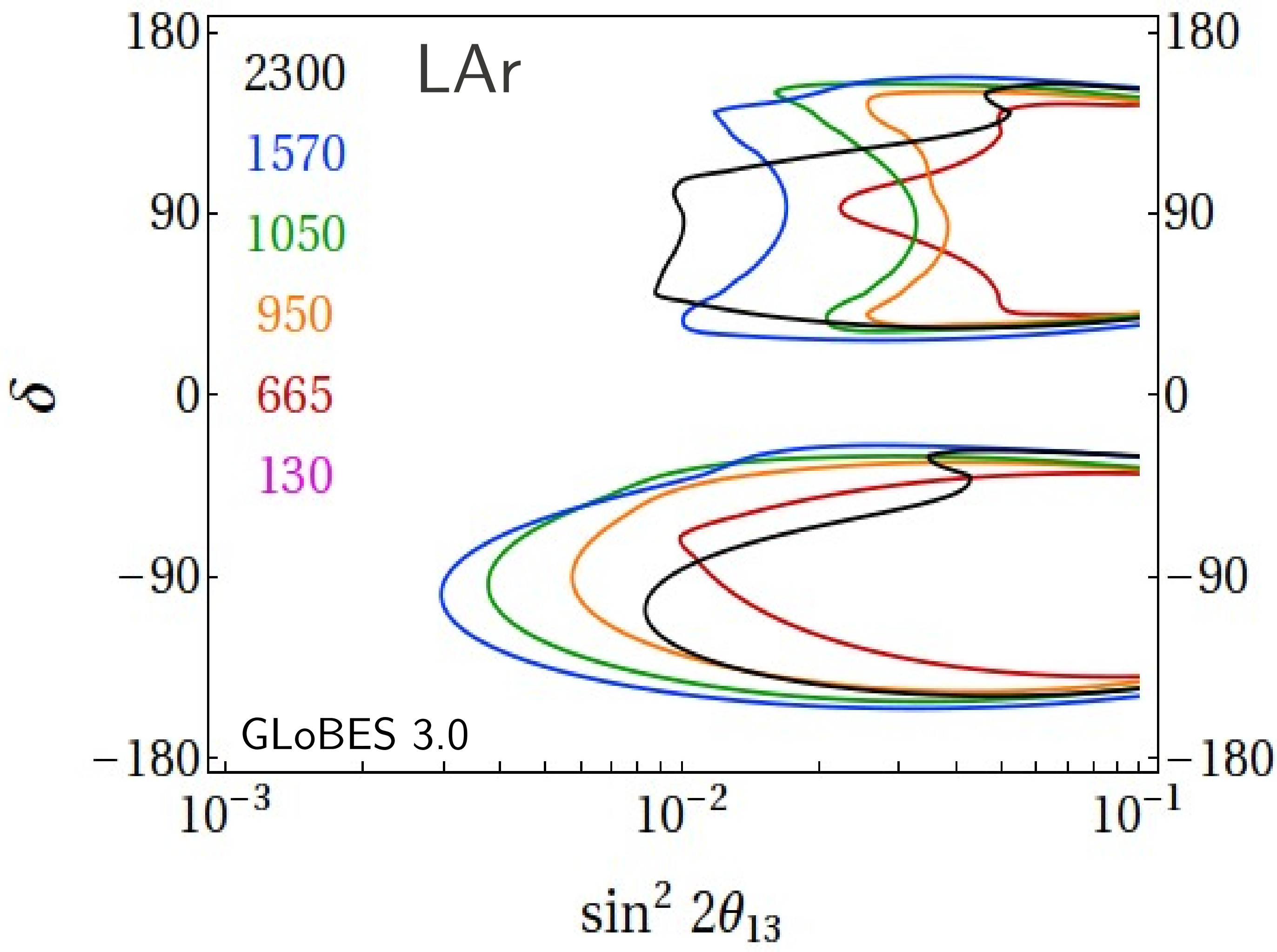


CP discovery potential: LAr

Matter effects spoil our CP discovery potential for $\delta>0$



CP discovery potential: LAr

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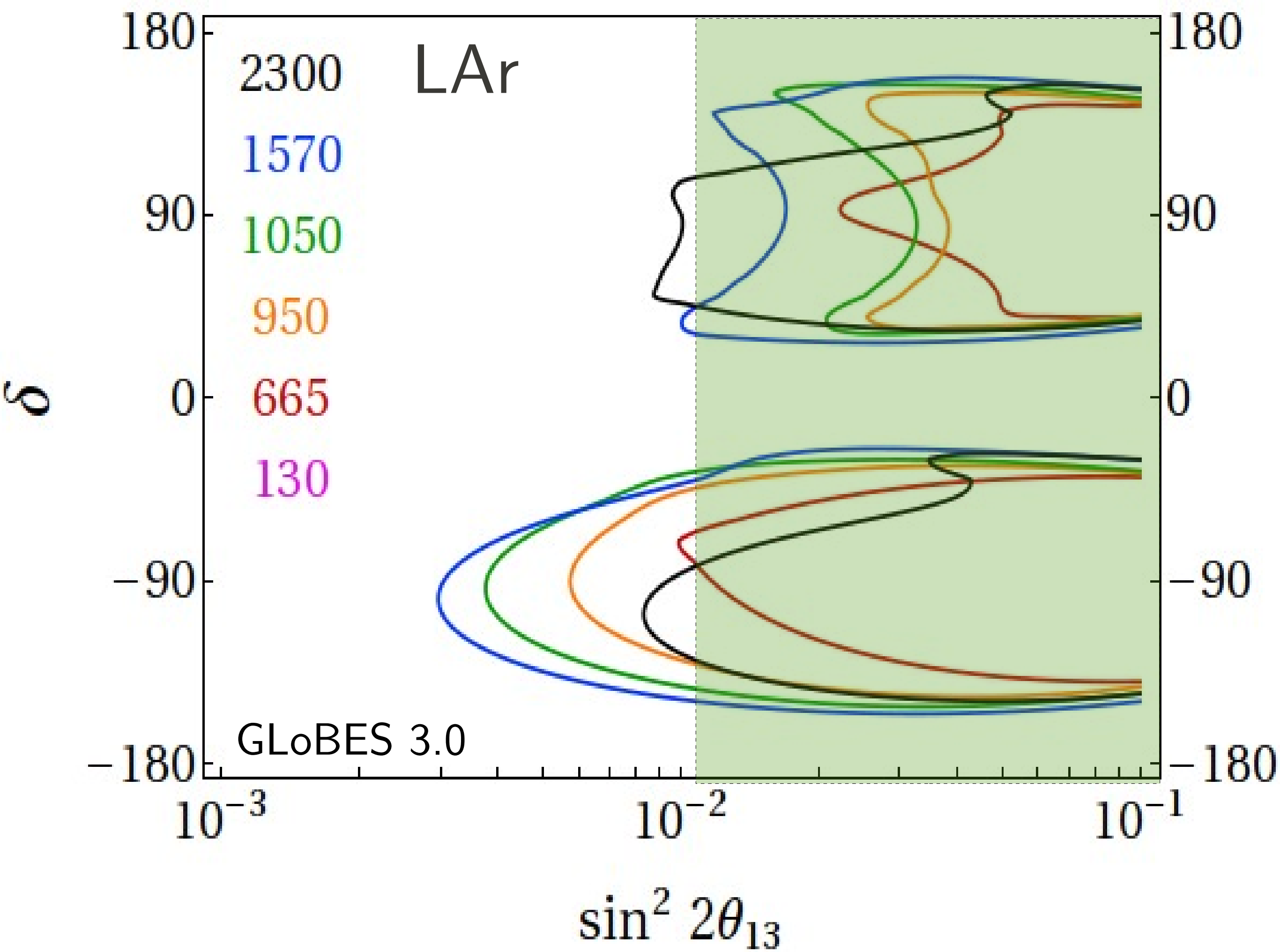
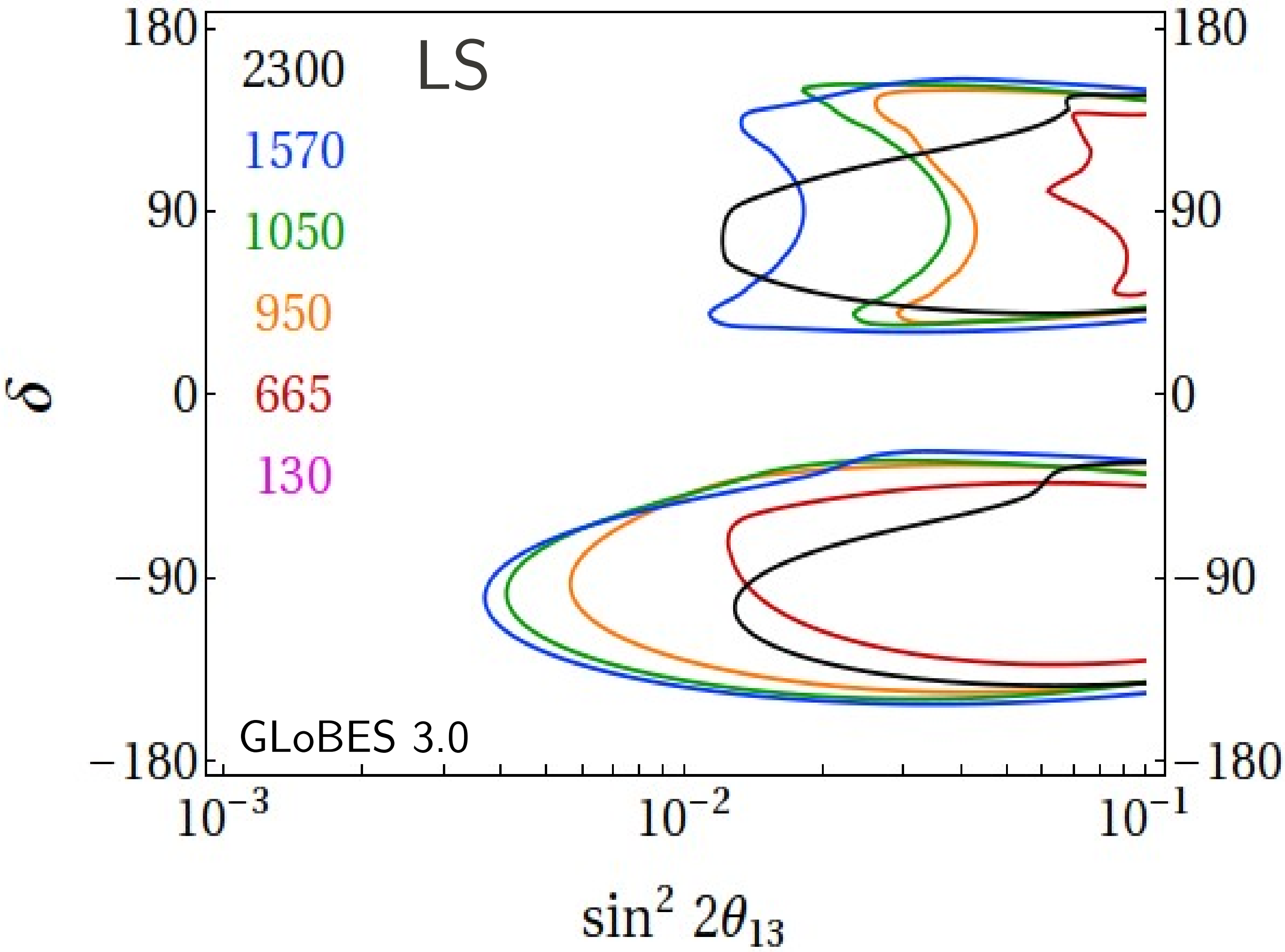


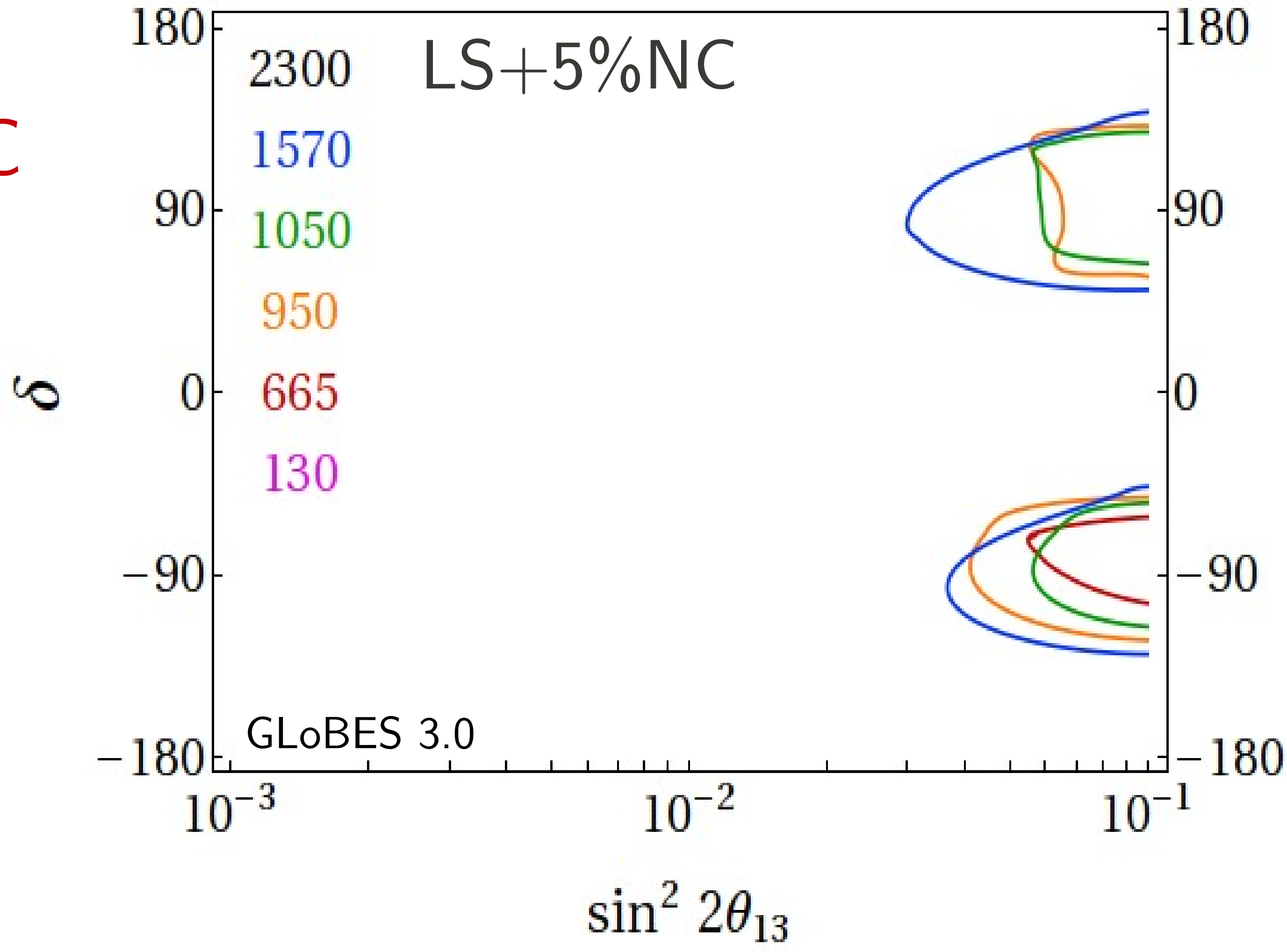
CP disc. pot.: Liquid Scintillator

LENA results also quite good even though only 50 kton



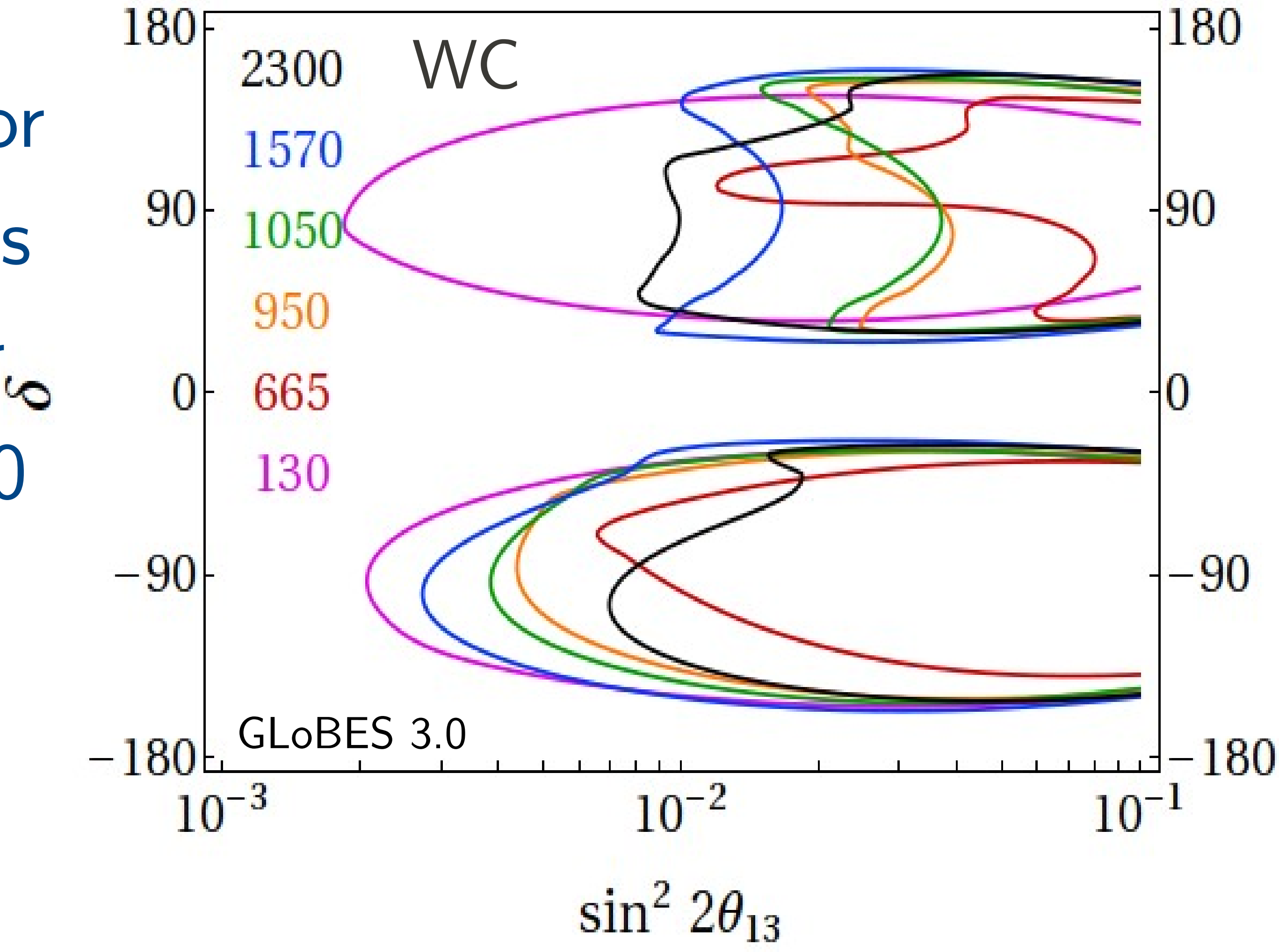
CP disc. pot.: Liquid Scintillator

But with 5%NC background, results get <u>much worse!!</u>



CP discovery potential: WC

WC is optimal for very low energies → much better results at L=130 km



CP discovery potential: WC

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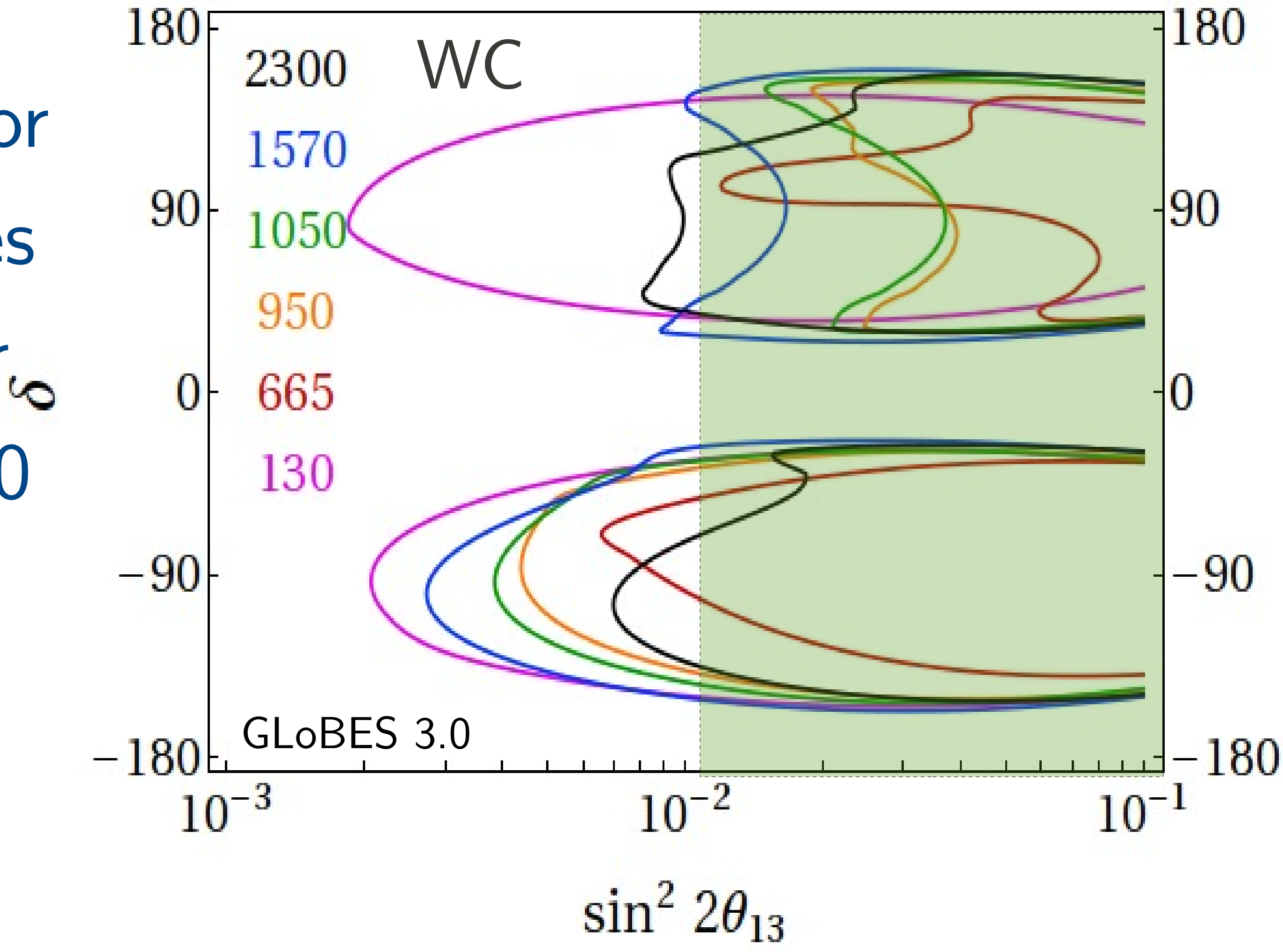
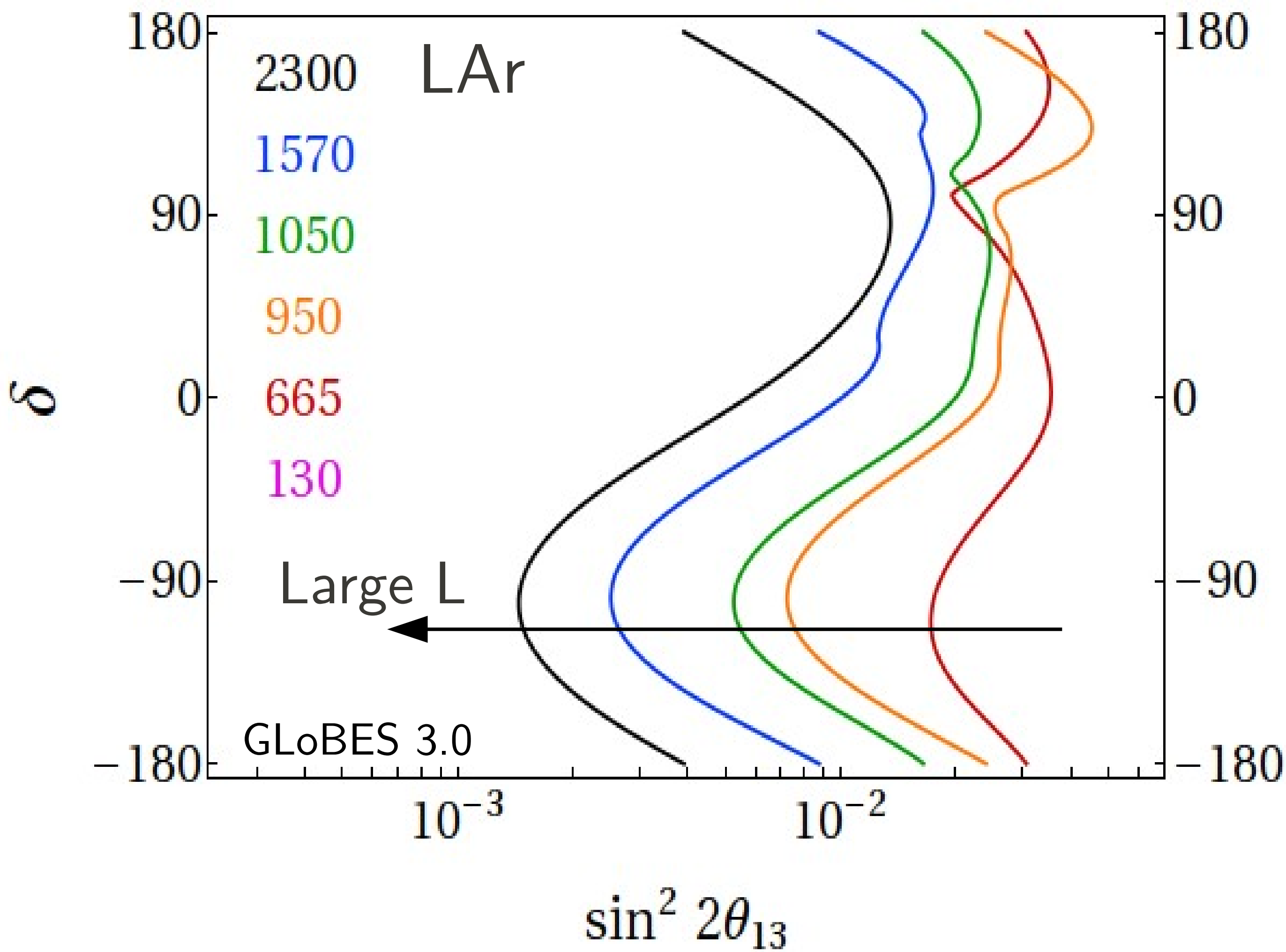


Sensitivity to mass hierarchy

Key factor here:

matter effects

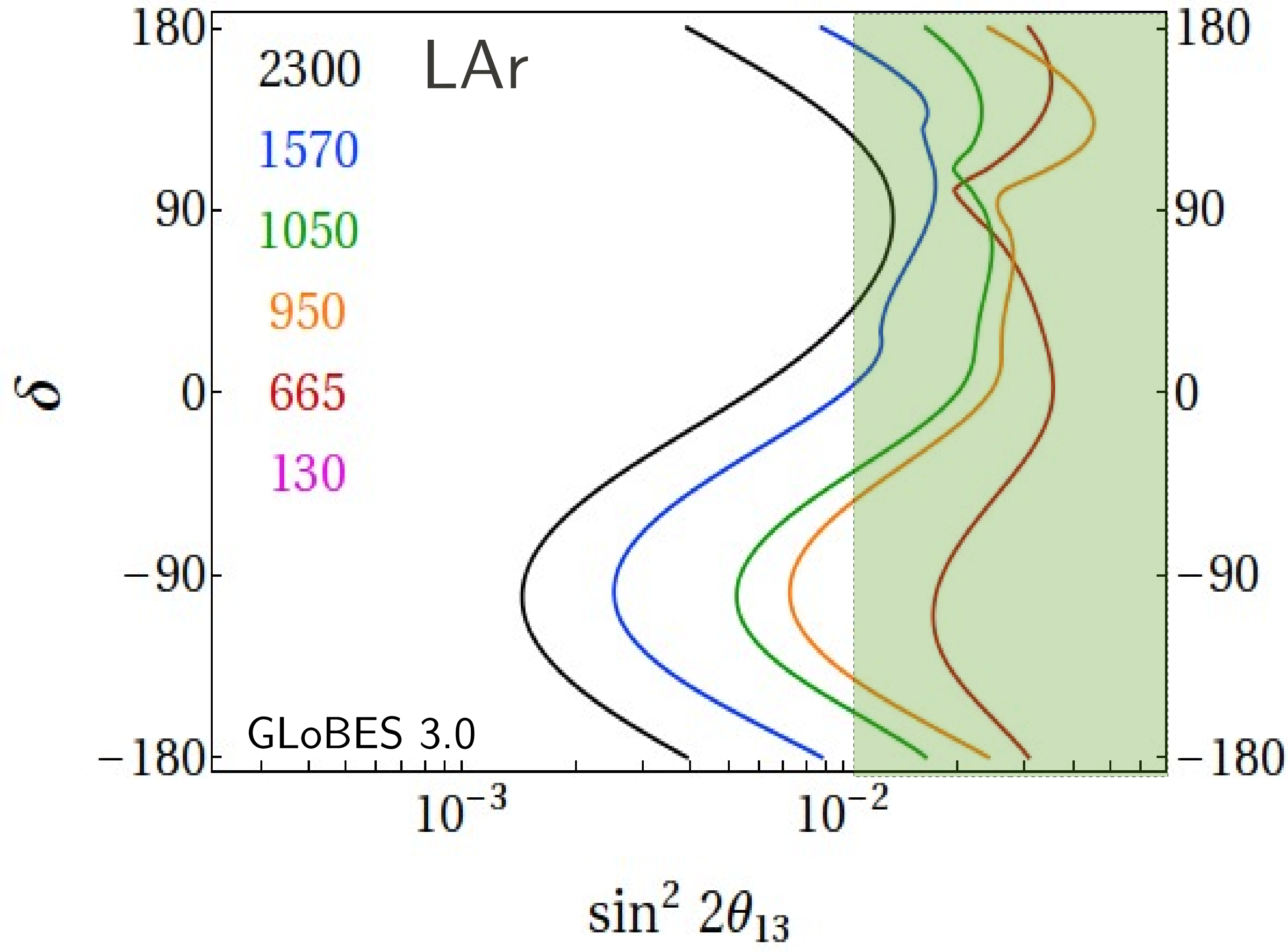
Results almost independent from detector technology



Sensitivity to mass hierarchy

Key factor here: matter effects

Results almost independent from detector technology



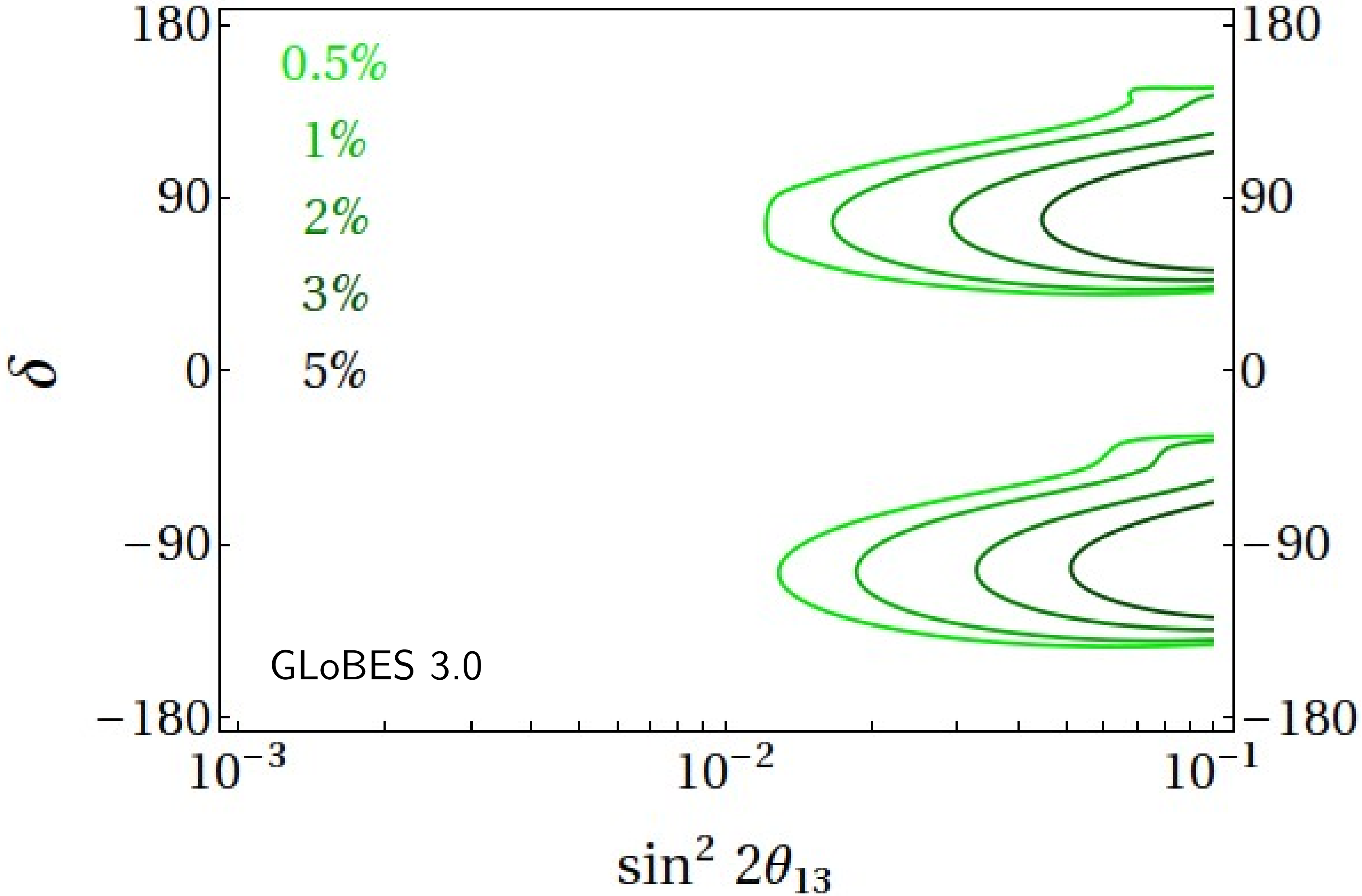
Influence of specific simulation details in our results

Results shown for the Phyasalmi baseline, but similar dependence expected for the rest of baselines

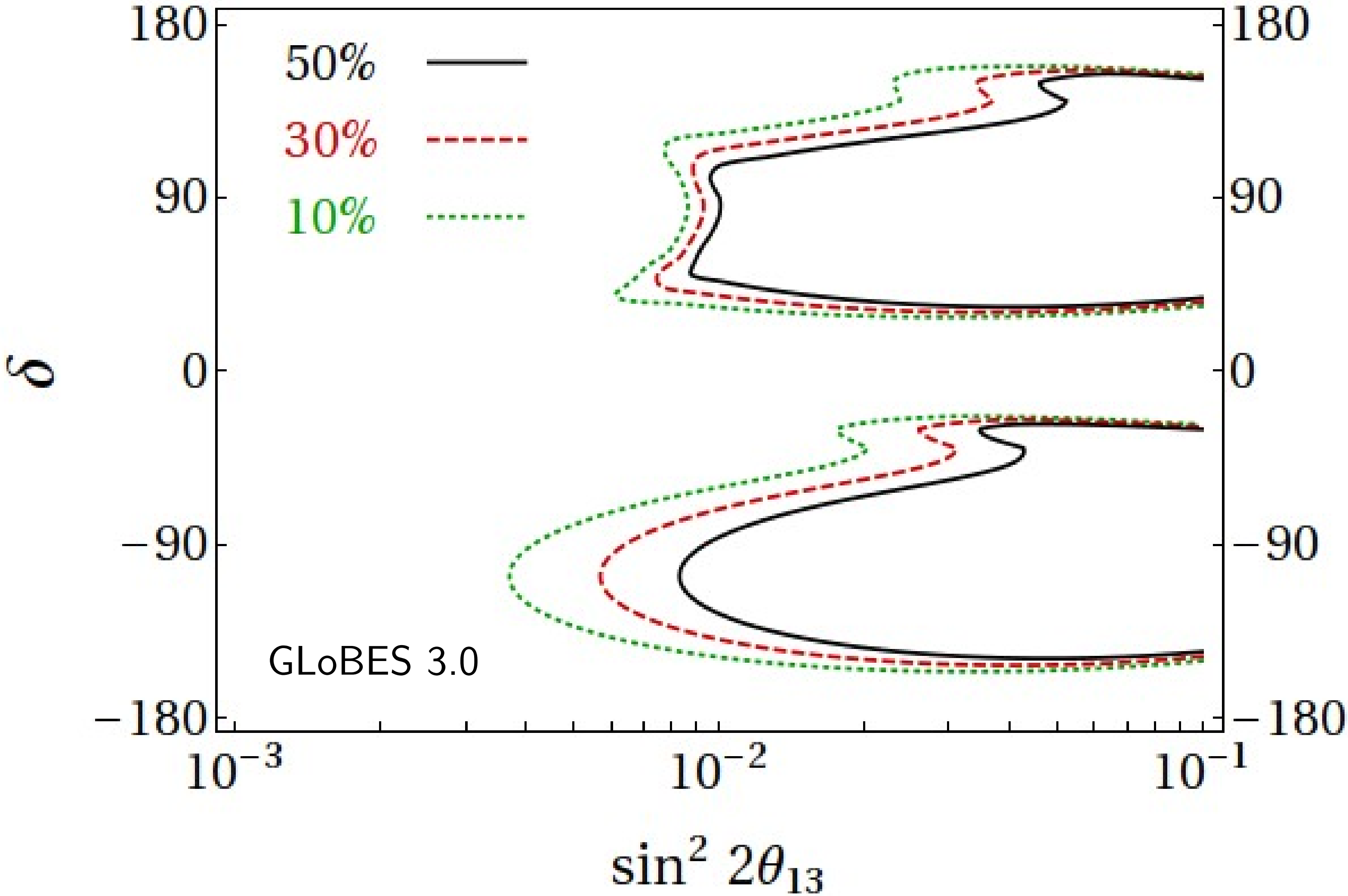
Small vs large θ_{13}

- Relevant factors if θ_{13} is small:
  - beam background levels
  - background systematics
- Relevant factors if θ_{13} is large:
  - QE event sample
  - signal systematics
- Always relevant:
  - NC backgrounds

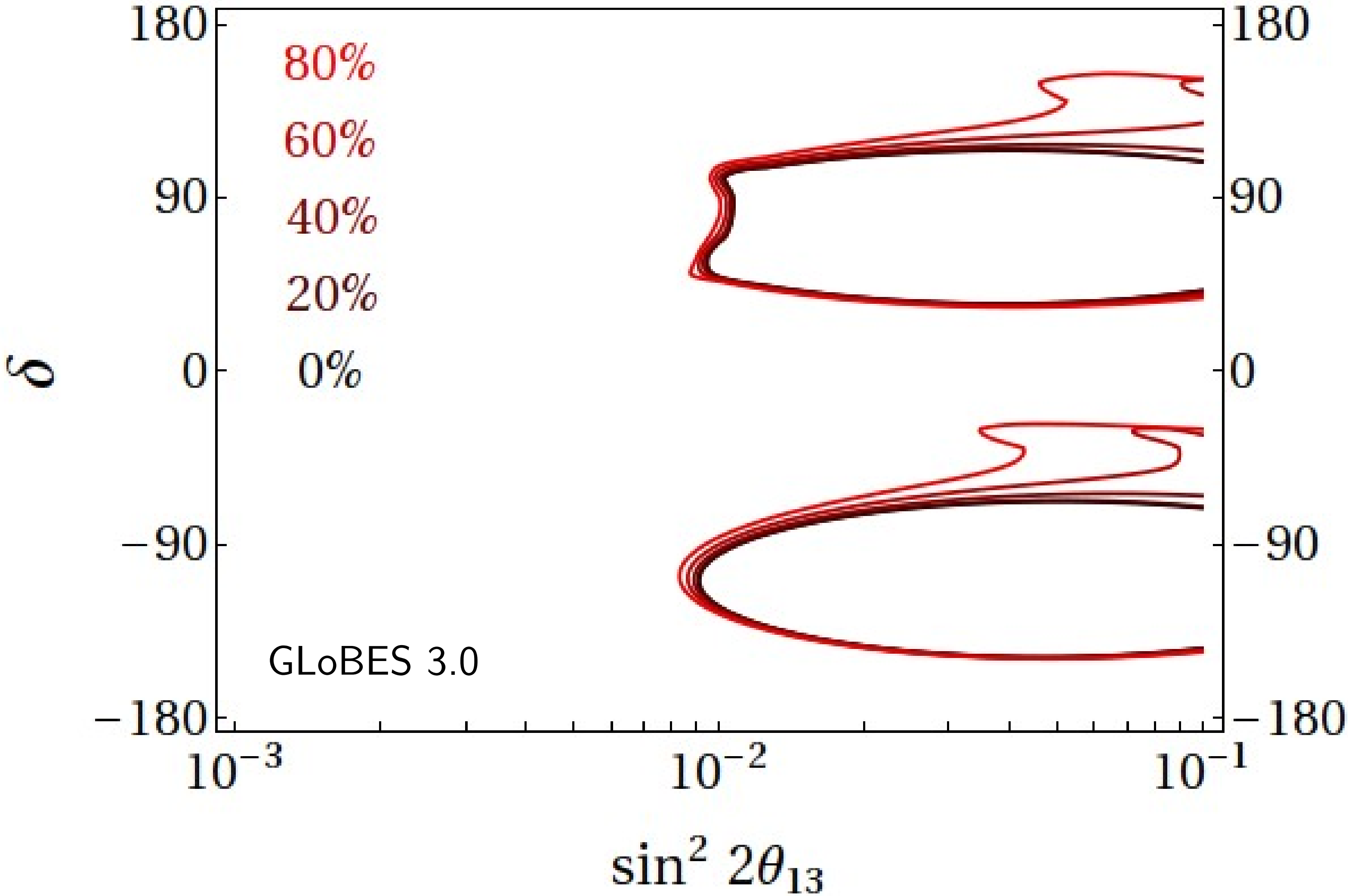
NC background in Liquid Scintillator



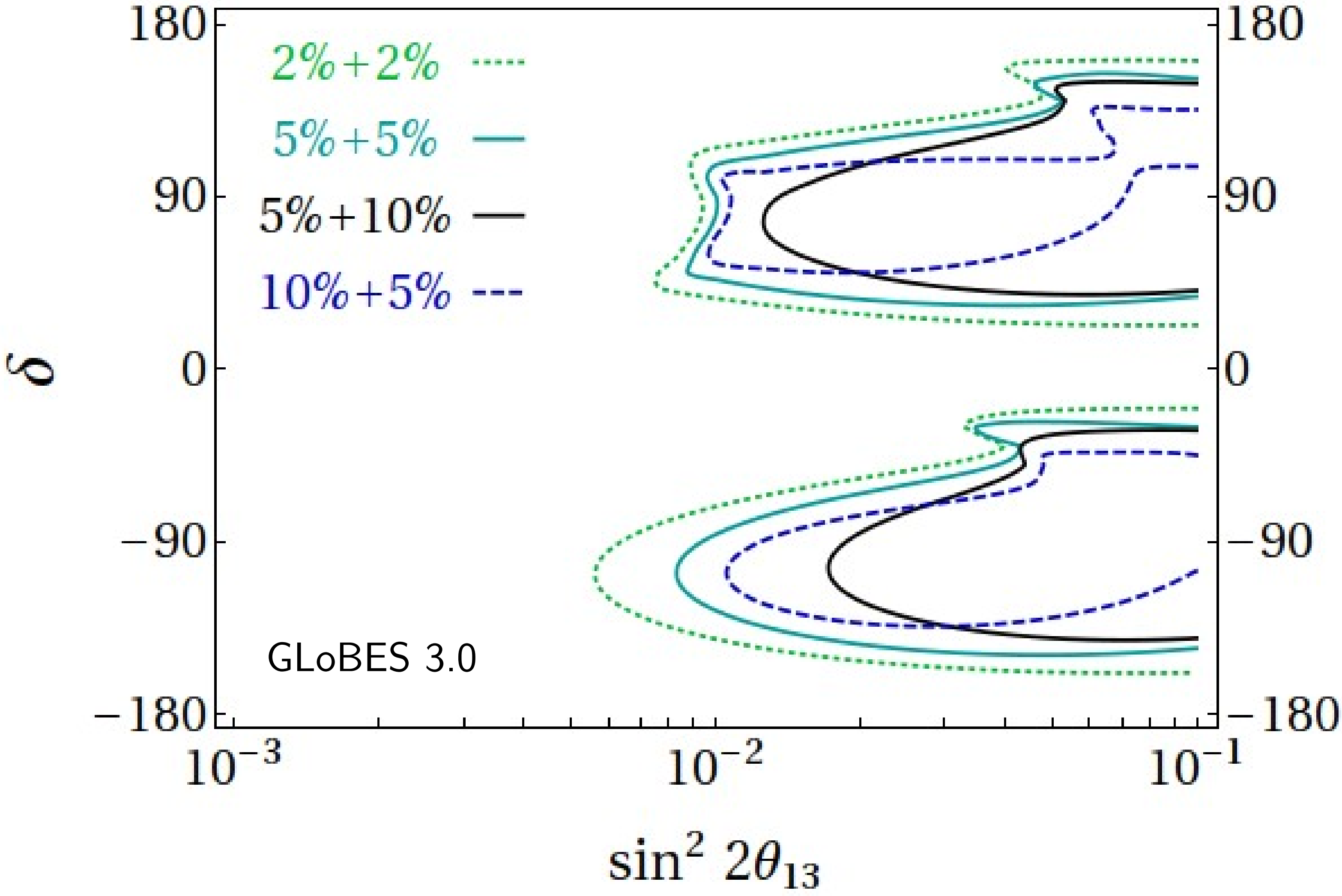
Intrinsic beam backgrounds in LAr



QE efficiencies in LAr



Systematic errors in LAr



Conclusions

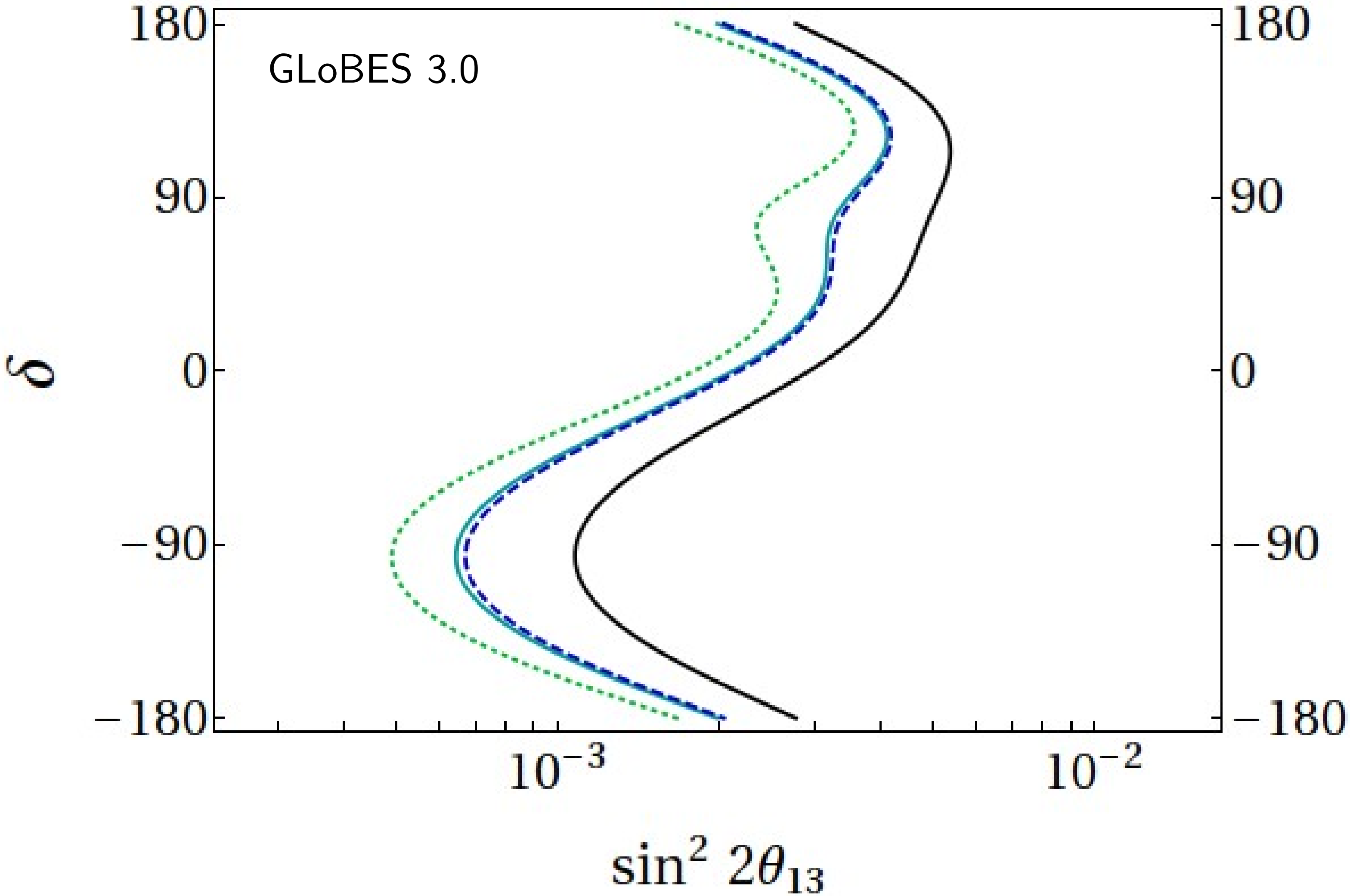
- We have studied 7 possible sites for a very massive neutrino detector in Europe and three different technologies:
  - In general, very good results for all detector technologies and observables
  - Mass hierarchy prefers longer baselines, though
  - LAr and WC show very good performance: is magnetization possible for LAr?
  - Liquid Scintillator:
    - statistically limited
    - NC background rejection capability is uncertain

Conclusions

- Strategy strongly depends on future results at T2K/MINOS
  - if θ_{13} very large, effort would have to be done to improve CP and and mass hierarchy discovery potential
- SuperBeams are very well-known but...
  - A detailed estimation of systematics is a priority at this point!!

BACKUP

Systematic errors in LAr



Detectors

- GLACIER (arXiv:0705.4396 [hep-ph])
  - 100 kton fiducial mass
  - Bin size: 0.15 – 0.25 GeV
  - Emin = 100 MeV
  - Migration matrices (L. Esposito & A. Rubbia)
  - 90% efficiency (80% for QE events)
  - 0.5% of unoscillated events $\rightarrow$ NC background

Detectors

- LENA (R. Mollënberg, J. Peltoniemi, M. Wurm)
  - 50 kton fiducial mass
  - Bin size: 0.05 – 0.25 GeV
  - Emin: 500 MeV
  - sigma(E) = 0.05*E
  - 90% efficiency (70% - 85% for QE events)
  - 0.5% - 5% unoscillated events as NC background

Detectors

- MEMPHYS (Fréjus) $\rightarrow$ as in hep-ph/0603172
- MEMPHYS (rest of baselines) (0705.4396 [hep-ph])
  - 440 kton fiducial mass
  - Bin size: 125 MeV
  - Emin: 500 MeV
  - Migration matrices from L. Whitehead
  - 40% efficiency. Rejection efficiencies for NC background from L. Whitehead too

Sensitivity to theta13: WC

Key factor here: statistics

Optimization of the detector also helps!