

REVIEW OF BETA-BEAM SETUPS

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MOTIVATION

One of WWP6 milestones for 2010

More in general, there is urgent need to define a minimal set of baseline scenarios for Beta-Beams, to compare with the Neutrino Factory

MOTIVATION

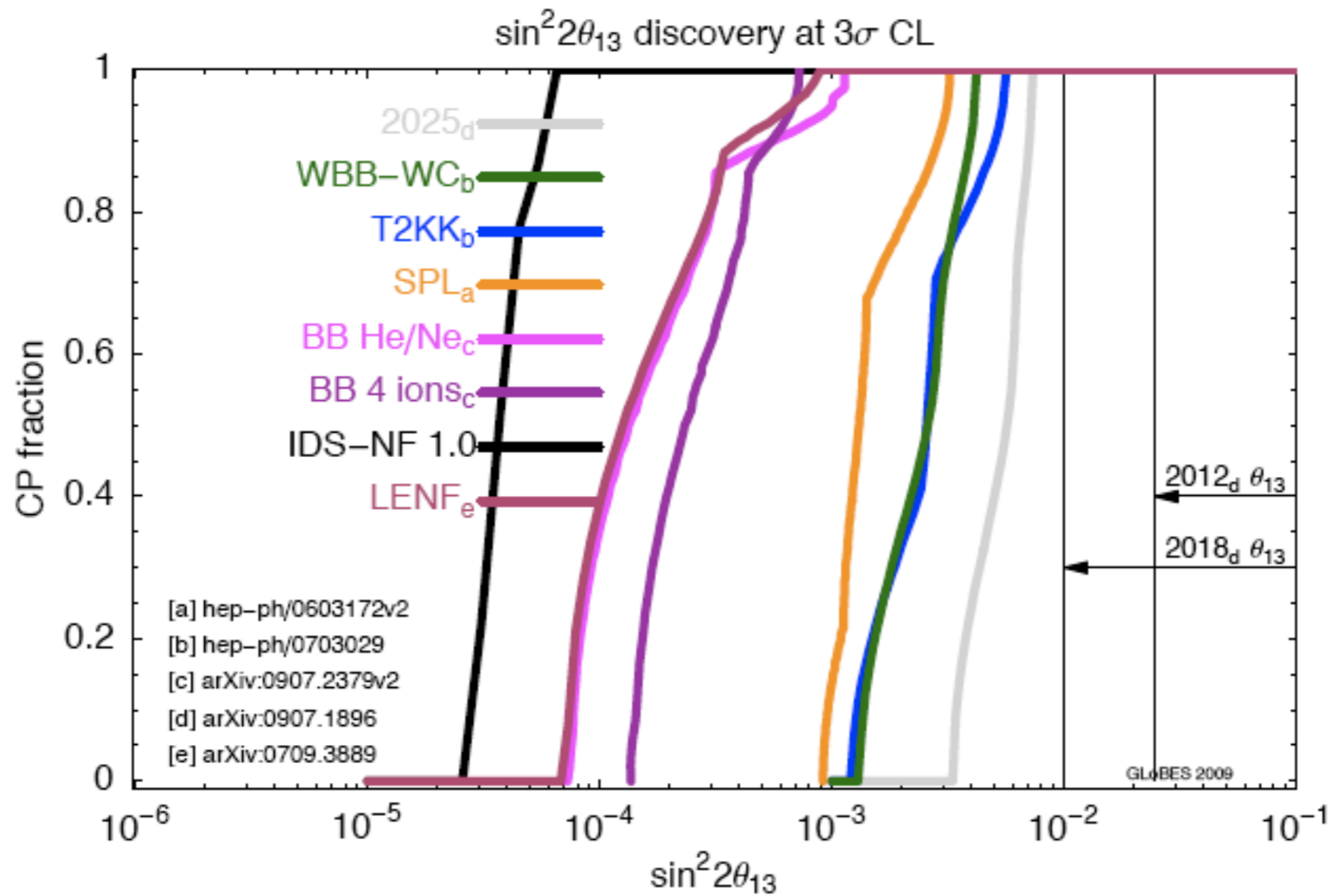
One of WWP6 milestones for 2010

Scenarios for Li and B beta-beams (feb 2010!)

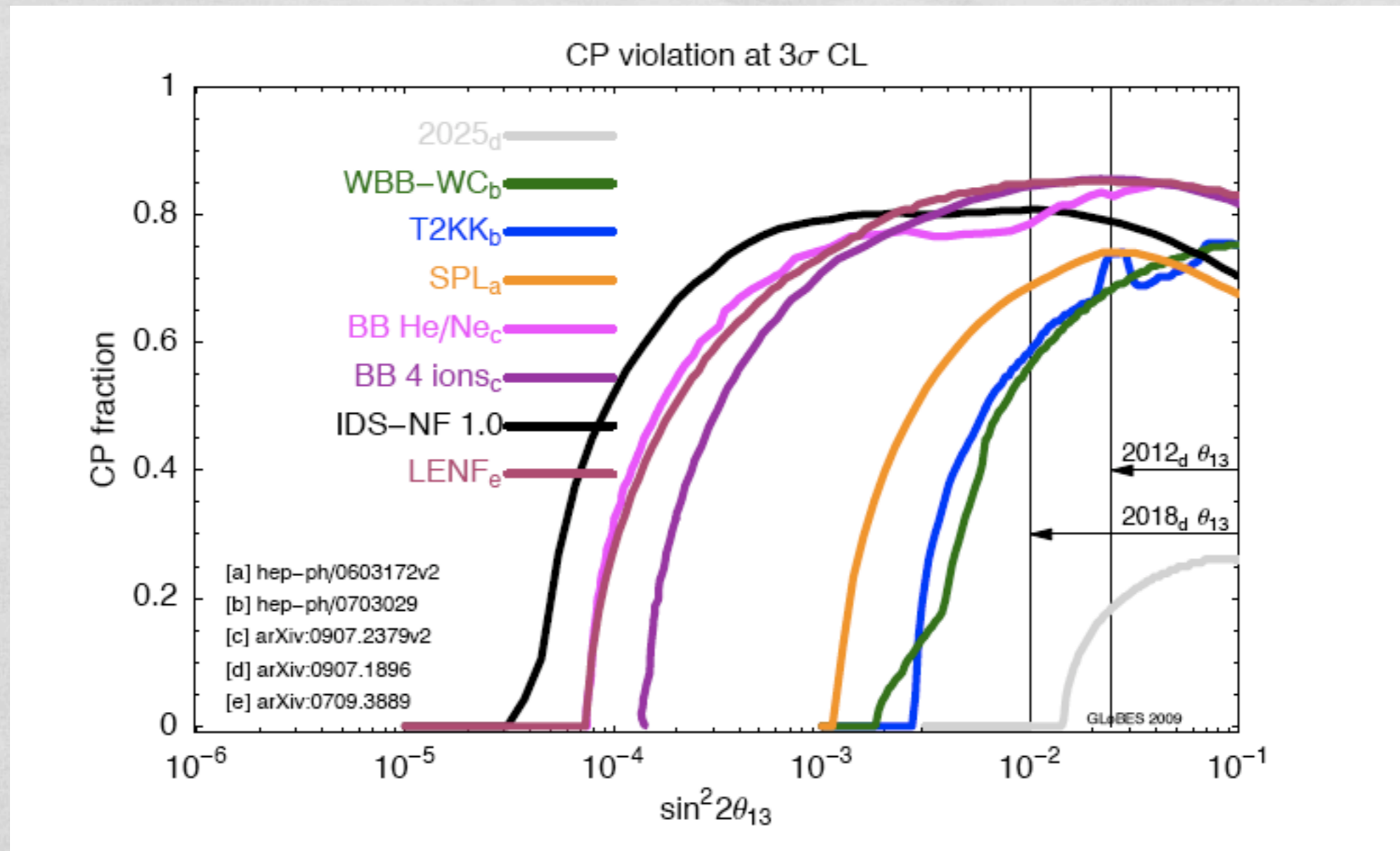
taken contact with WWP4 at this meeting on this point;
the hope is to get some “realistic” inputs for Li and B fluxes, to replace the present educated guesses on the amount of storable ions

More in general, there is urgent need to define a minimal set of baseline scenarios for Beta-Beams, to compare with the Neutrino Factory

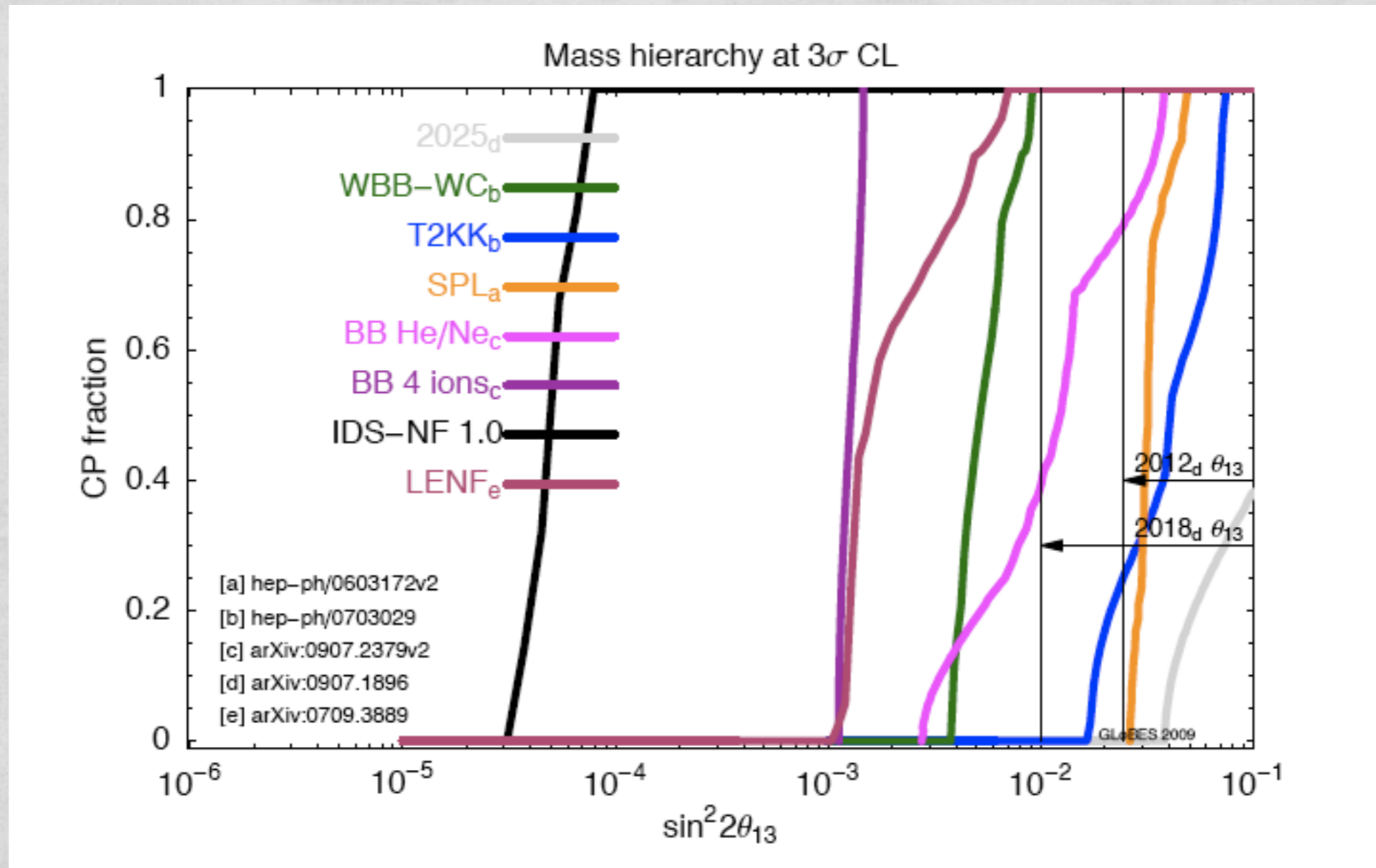
MIXING ANGLE



CP DISCOVERY POTENTIAL



MASS HIERARCHY



OUTLINE

- Review of classes of Beta-Beam setups
- Comparison of several Beta-Beam setups in terms of a few observables (requested by WWP4)
- Hopefully, this will help to determine the baseline scenario(s) for Beta-Beams

BETA-BEAM SETUPS, I

There are (too) many proposals in the market

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(1) Fixed the He/Ne CERN-Fréjus $\gamma=100$ proposal as a reference (setup 1)

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- (1) Fixed the He/Ne CERN-Fréjus $\gamma=100$ proposal as a reference (setup 1)
- (2) Fixed a small number of observables to compare

BETA-BEAM SETUPS,2

- Setup I will be compared with **three classes of alternative proposals** (huge tables shown in other talks will be splitted to explain the results)
 - Same γ , higher Q: Li and B, L ~ 700 Km (+cocktail)
 - Same ions, higher γ : He and Ne, L ~ 700 Km
 - Two baselines options (two ions or cocktail)

USED BIBLIOGRAPHY

- [1] E. Fernández Martínez, arXiv:0912.3804
- [2] A. Bandyopadhyay et al. (ISS Phys Rep), arXiv:0710.4947
- [3] P. Coloma et al., arXiv:0712.0796
- [4] S. Choubey et al., arXiv:0907.2379
- [5] S. Agarwalla et al., arXiv:0802.3621
- [6] S. Agarwalla et al., arXiv:0804.3007

REFERENCE: $\Gamma = 100$, $L = 130$ KM

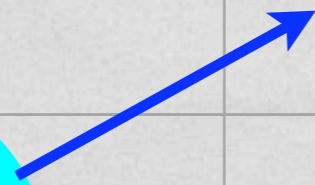
Ions	Fluxes/ 10^{18} x years	Minimal θ_{13}		
		Sensitivity	Disc. Potential	Hierarchy
${}^6\text{He}$ ${}^{18}\text{Ne}$	2.9×5 1.1×5	5×10^{-4}	5×10^{-4}	NO
${}^6\text{He}$ ${}^{18}\text{Ne}$	$(2.9 \times 2) \times 2$ $(1.1 / 2) \times 8$	6×10^{-4}	6×10^{-4}	NO
${}^6\text{He}$ ${}^{18}\text{Ne}$	$(2.9 \times 2) \times 2$ $(1.1 / 5) \times 8$	1×10^{-3}	1.2×10^{-3}	NO

440 Kton WWC, no atmo background

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		1×10^{-4}	6×10^{-4}	NO
${}^6\text{He}$ ${}^{18}\text{Ne}$	$(2.9 \times 2) \times 2$ $(1.1 / 5) \times 8$	1×10^{-3}	1.2×10^{-3}	NO

Not a good comparison parameter



440 Kton WWC, no atmo background

REFERENCE: $\Gamma = 100$, $L = 130$ KM

Ions	Fluxes/ 10^{18} x years	Minimal θ_{13}		
		Sensitivity	CP-fraction at 10^{-3}	Hierarchy
${}^6\text{He}$ ${}^{18}\text{Ne}$	2.9×5 1.1×5	5×10^{-4}	$\sim 50\%$	NO
${}^6\text{He}$ ${}^{18}\text{Ne}$	$(2.9 \times 2) \times 2$ $(1.1 / 2) \times 8$	6×10^{-4}	$\sim 45\%$	NO
${}^6\text{He}$ ${}^{18}\text{Ne}$	$(2.9 \times 2) \times 2$ $(1.1 / 5) \times 8$	1×10^{-3}	NO	NO

440 Kton WC, no atmo background

LI AND B: $\Gamma = 100$, $L = 650$ KM

Ions	Fluxes/ 10^{18} x years	Minimal θ_{13}		
		Sensitivity	CP-frac at 10^{-3}	Hierarchy
${}^8\text{Li}$ ${}^8\text{B}$	2.9×5 1.1×5	1.5×10^{-3}	NO	3×10^{-2}
${}^8\text{Li}$ ${}^8\text{B}$	$(2.9 \times 2) \times 5$ $(1.1 \times 2) \times 5$	7×10^{-4}	~25%	1.5×10^{-2}
${}^8\text{Li}$ ${}^8\text{B}$	$(2.9 \times 5) \times 5$ $(1.1 \times 5) \times 5$	2×10^{-4}	~60%	8×10^{-3}

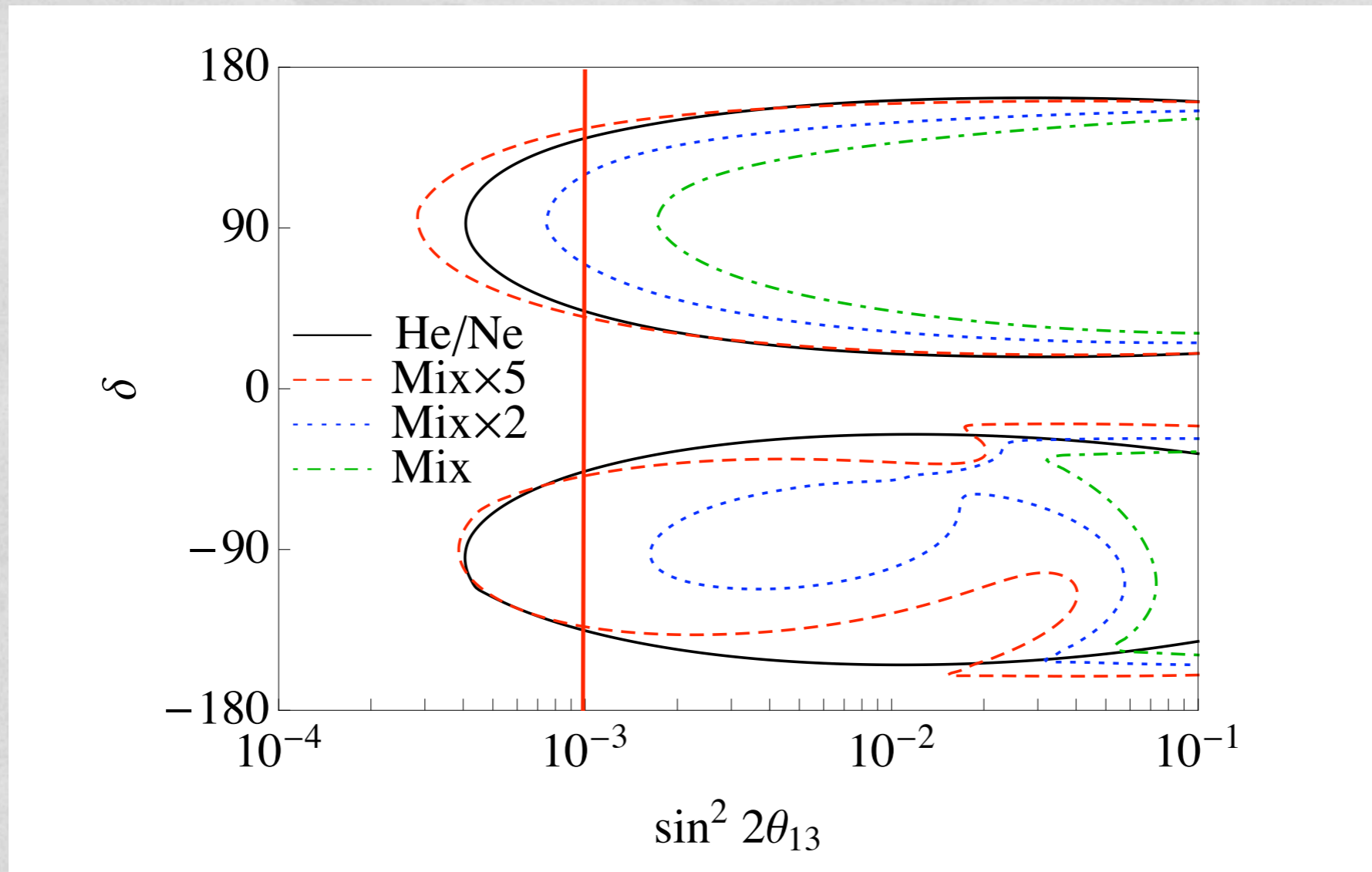
440 Kton WWC, no atmo background

COCKTAIL: $\Gamma = 100$, $L = 650$ KM

Ions	Fluxes/ 10^{18} x years	Minimal θ_{13}		
		Sensitivity	CP-fraction at 10^{-3}	Hierarchy
${}^8\text{Li}$ ${}^8\text{B}$ ${}^6\text{He}$	2.9×3 1.1×5 2.9×2	1.5×10^{-3}	NO	3×10^{-2}
${}^8\text{Li}$ ${}^8\text{B}$ ${}^6\text{He}$	$(2.9 \times 2) \times 3$ $(1.1 \times 2) \times 5$ $(2.9 \times 2) \times 2$	7×10^{-4}	~25%	1.5×10^{-2}
${}^8\text{Li}$ ${}^8\text{B}$ ${}^6\text{He}$	$(2.9 \times 5) \times 3$ $(1.1 \times 5) \times 5$ $(2.9 \times 5) \times 2$	3×10^{-4}	~60%	8×10^{-3}

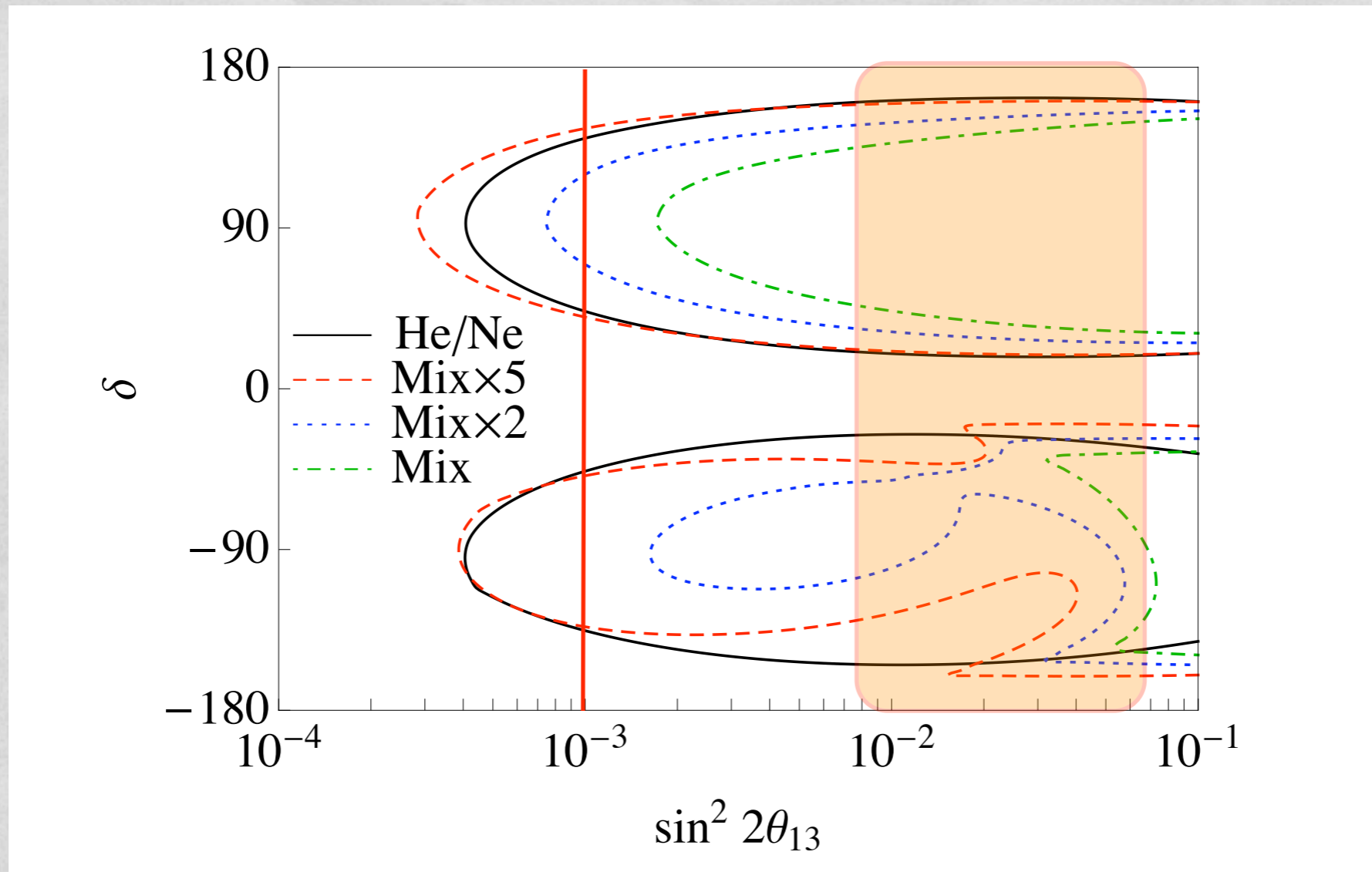
440 Kton WWC, no atmo background

WHY TO MIX IONS?



From Ref. [1]

WHY TO MIX IONS?



Perhaps, adding ^{18}Ne we can solve the problem at 10^{-2}

From Ref. [1]

HIGH- Γ : $\Gamma=350$, $L = 700$ KM

Ions	Fluxes/ 10^{18} x years	Minimal θ_{13}		
		Sensitivity	CP-fraction at 10^{-3}	Hierarchy
${}^6\text{He}$ ${}^{18}\text{Ne}$ 500 Kton WC	2.9×5 1.1×5	8×10^{-5}	~75%	2×10^{-3}
${}^6\text{He}$ ${}^{18}\text{Ne}$ 50 Kton T ASD	2.9×5 1.1×5	5×10^{-4}	~50%	1.5×10^{-2}

no atmo background

TWO BASELINES WITH $\Gamma=350$

50 Kton MIND @ 2000 Km and 7000 Km

Ions	Fluxes/ 10^{18} x years	Minimal θ_{13}		
		Sensitivity	CP-fraction at 10^{-3}	Hierarchy
${}^8\text{Li}$ ${}^8\text{B}$	2×5 2×5	1×10^{-3}	-	6×10^{-4}
${}^8\text{Li}$ ${}^8\text{B}$	5×5 5×5	3×10^{-4}	-	3×10^{-4}
${}^8\text{Li}$ ${}^8\text{B}$	10×5 10×5	1.5×10^{-4}	$\sim 35\%$	2×10^{-4}

no atmo background

TWO BASELINES COCKTAILS

50 Kton MIND @ 7000 Km

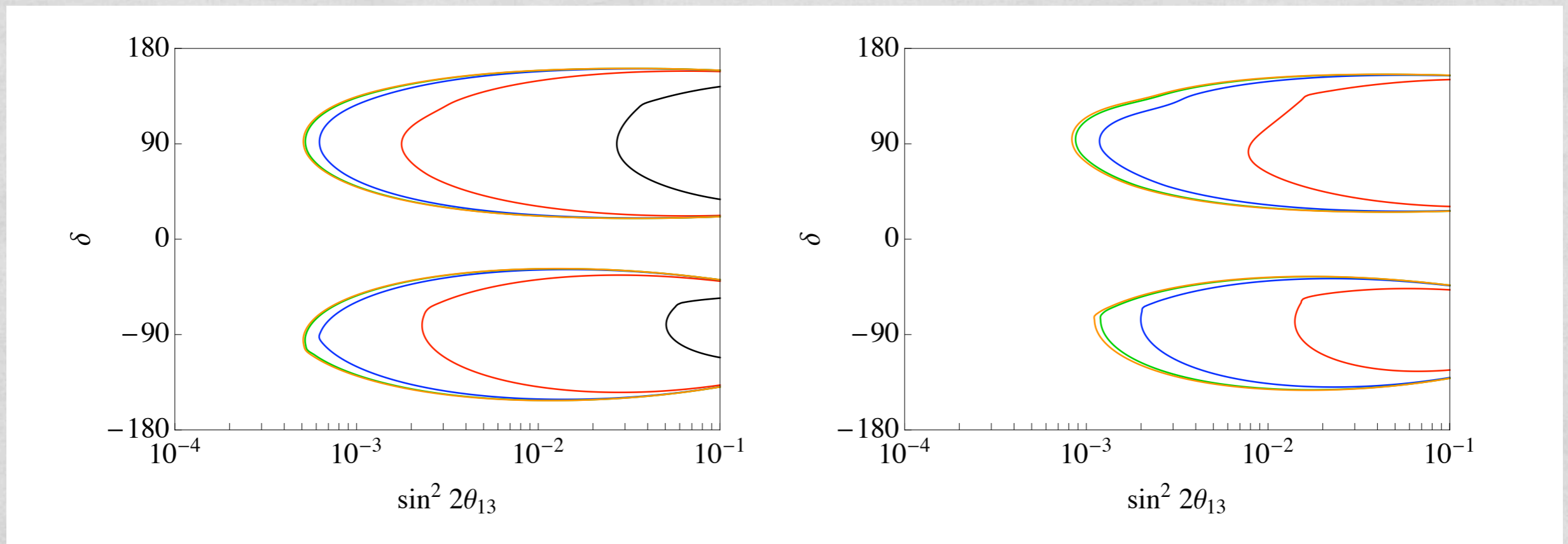
$L_2 = 650$ Km

	Ions	γ	Fluxes/ 10^{18} x years	Minimal θ_{13}		
				Sensitivity	CP-fraction at 10^{-3}	Hierarchy
(1)	${}^8\text{Li}$ ${}^8\text{B}$ ${}^6\text{He}$ ${}^{18}\text{Ne}$	390 656 350 350	10×2.5 for all ions	1.8×10^{-4}	$\sim 70\%$	1×10^{-3}
(2)	${}^8\text{Li}$ ${}^8\text{B}$ ${}^6\text{He}$ ${}^{18}\text{Ne}$	656 656 575 575	10×2.5 for all ions	5×10^{-4}	$\sim 45\%$	6×10^{-4}

(1) 500 Kton WWC; (2) 50 Kton T ASD no atmo background

DUTY CYCLES AT $\Gamma = 100$

Setup: ${}^6\text{He}$ and ${}^{18}\text{Ne}$ at Fréjus, $\phi_{\text{He}} [10^{18}] = 2.9 \times 2$



$$\phi_{\text{Ne}} [10^{18}] = 1.1 / 2$$

$$\phi_{\text{Ne}} [10^{18}] = 1.1 / 5$$

$$\text{SF} = 10^{-\infty}, 10^{-4}, 10^{-3}, 10^{-2}, 10^{-1}$$

From Ref. [1]

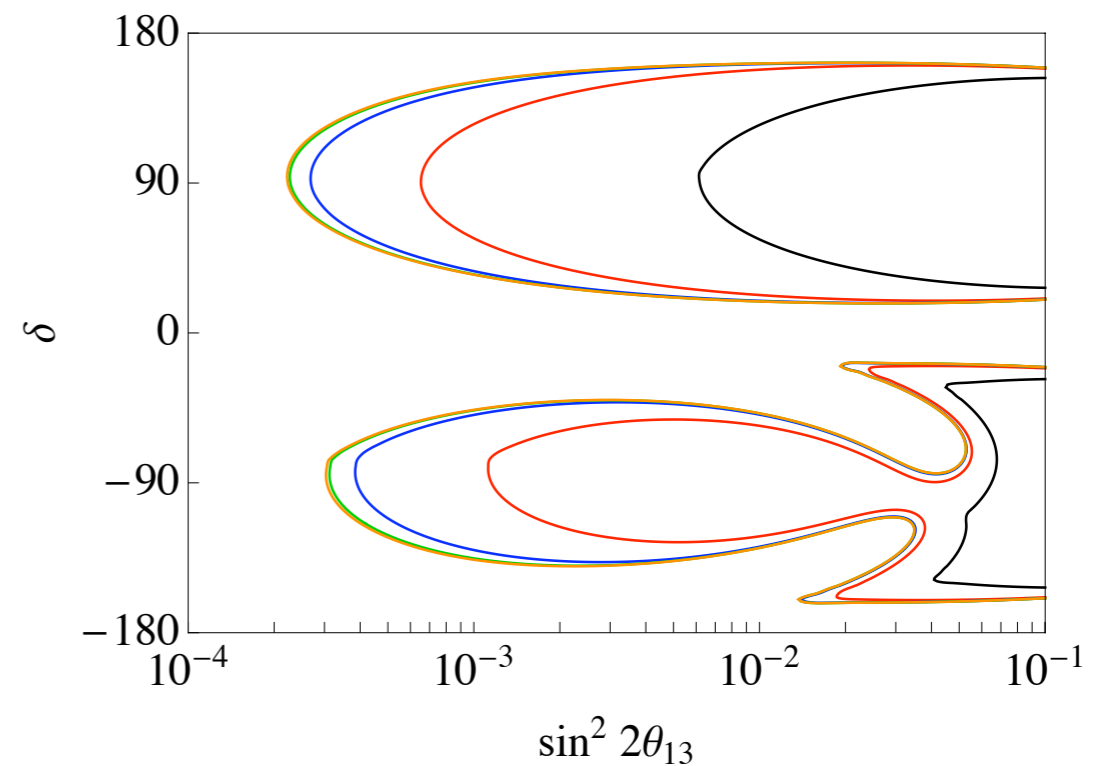
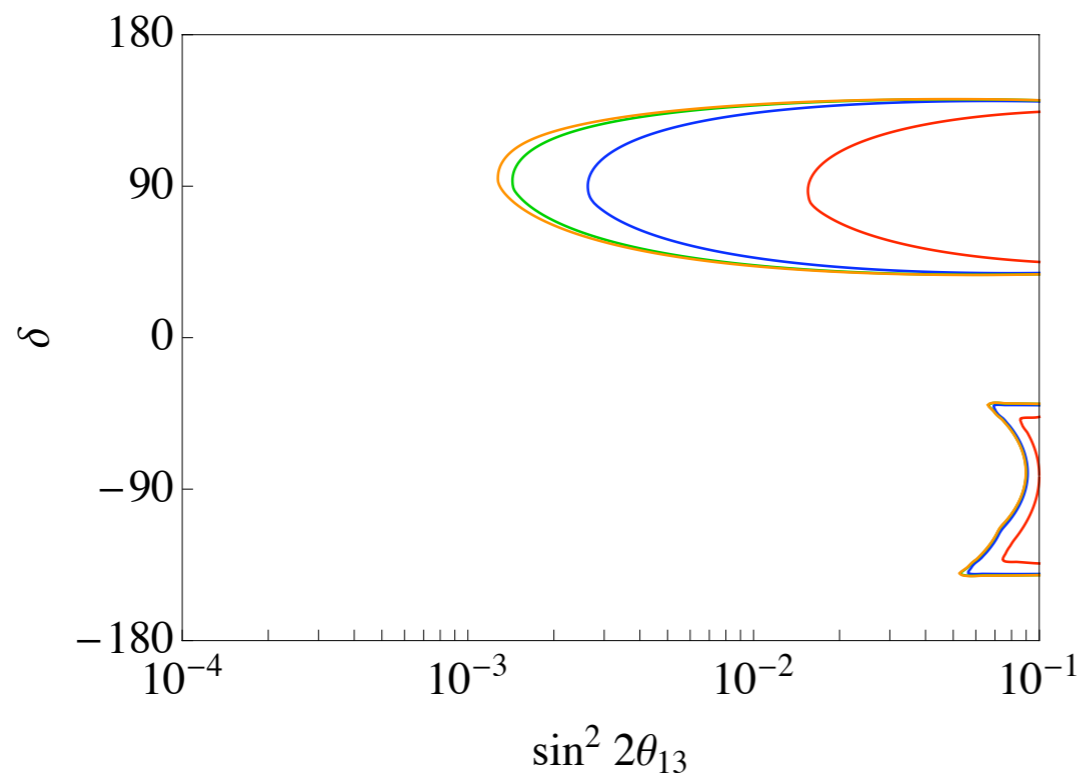
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${}^6\text{He}$ ${}^{18}\text{Ne}$	$(2.9 \times 2) \times 2$ $(1.1 / 2) \times 8$	6×10^{-4} ↓ 2×10^{-3}	NO	NO
${}^6\text{He}$ ${}^{18}\text{Ne}$	$(2.9 \times 2) \times 2$ $(1.1 / 5) \times 8$	1×10^{-3} ↓ 1×10^{-2}	NO	NO

440 Kton WWC, $SF = 10^{-2}$

DUTY CYCLES AT $\Gamma = 100$

Setup: ${}^8\text{Li}$ and ${}^8\text{B}$ at $L = 650$



$$\phi_{\text{Li}} [10^{18}] = 2.9$$

$$\phi_{\text{B}} [10^{18}] = 1.1$$

$$\phi_{\text{Li}} [10^{18}] = 2.9 \times 5$$

$$\phi_{\text{B}} [10^{18}] = 1.1 \times 5$$

$$\text{SF} = 10^{-\infty}, 10^{-4}, 10^{-3}, 10^{-2}, 10^{-1}$$

From Ref. [1]

LI AND B: $\Gamma = 100$, $L = 650$ KM

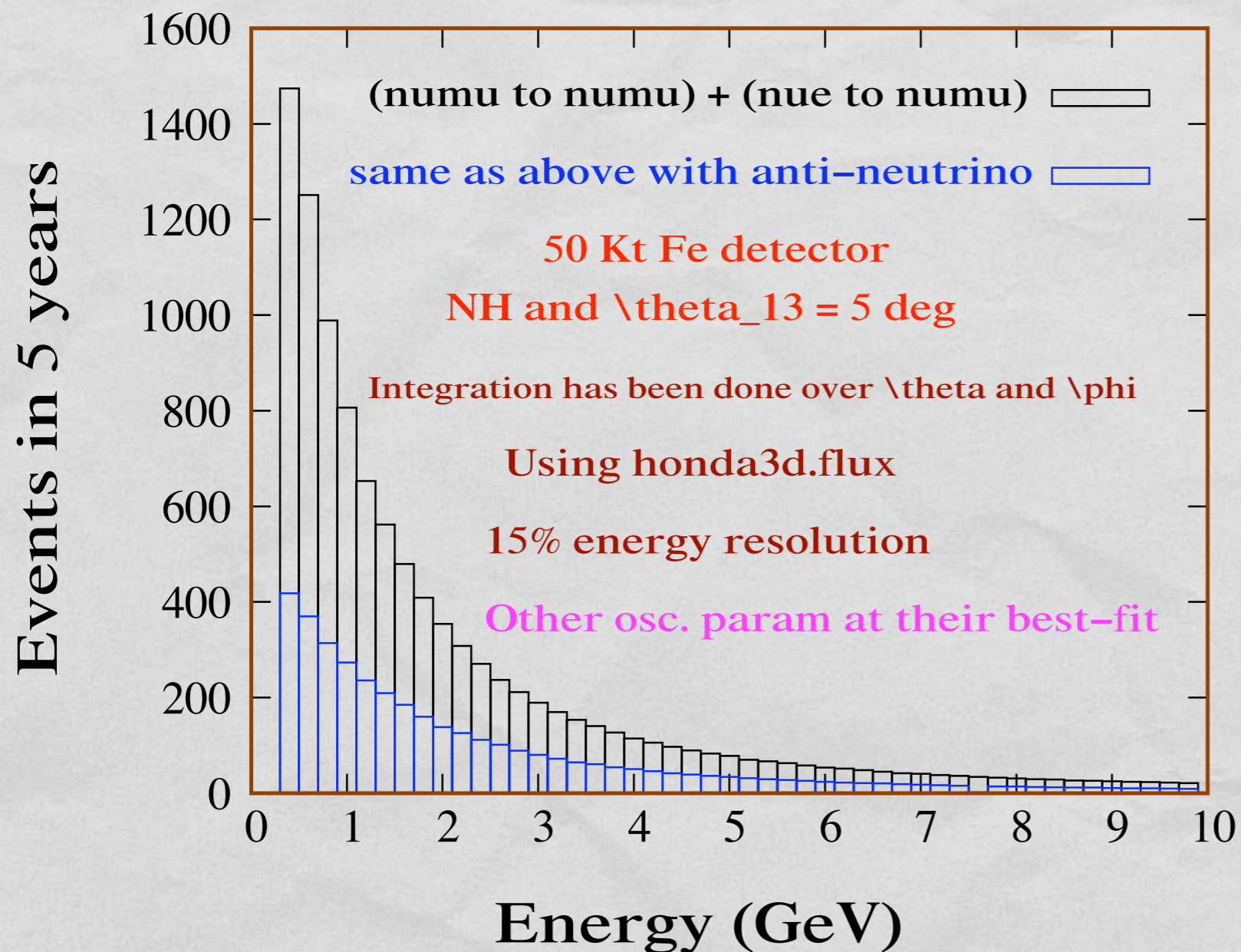
Ions	Fluxes/ 10^{18} x years	Minimal θ_{13}		
		Sensitivity	CP-frac at 10^{-3}	Hierarchy
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${}^8\text{Li}$ ${}^8\text{B}$	$(2.9 \times 2) \times 5$ $(1.1 \times 2) \times 5$	-	-	-
${}^8\text{Li}$ ${}^8\text{B}$	$(2.9 \times 5) \times 5$ $(1.1 \times 5) \times 5$	2×10^{-4} ↓ 7×10^{-4}	~25%	1×10^{-2}

440 Kton WWC, $SF = 10^{-2}$

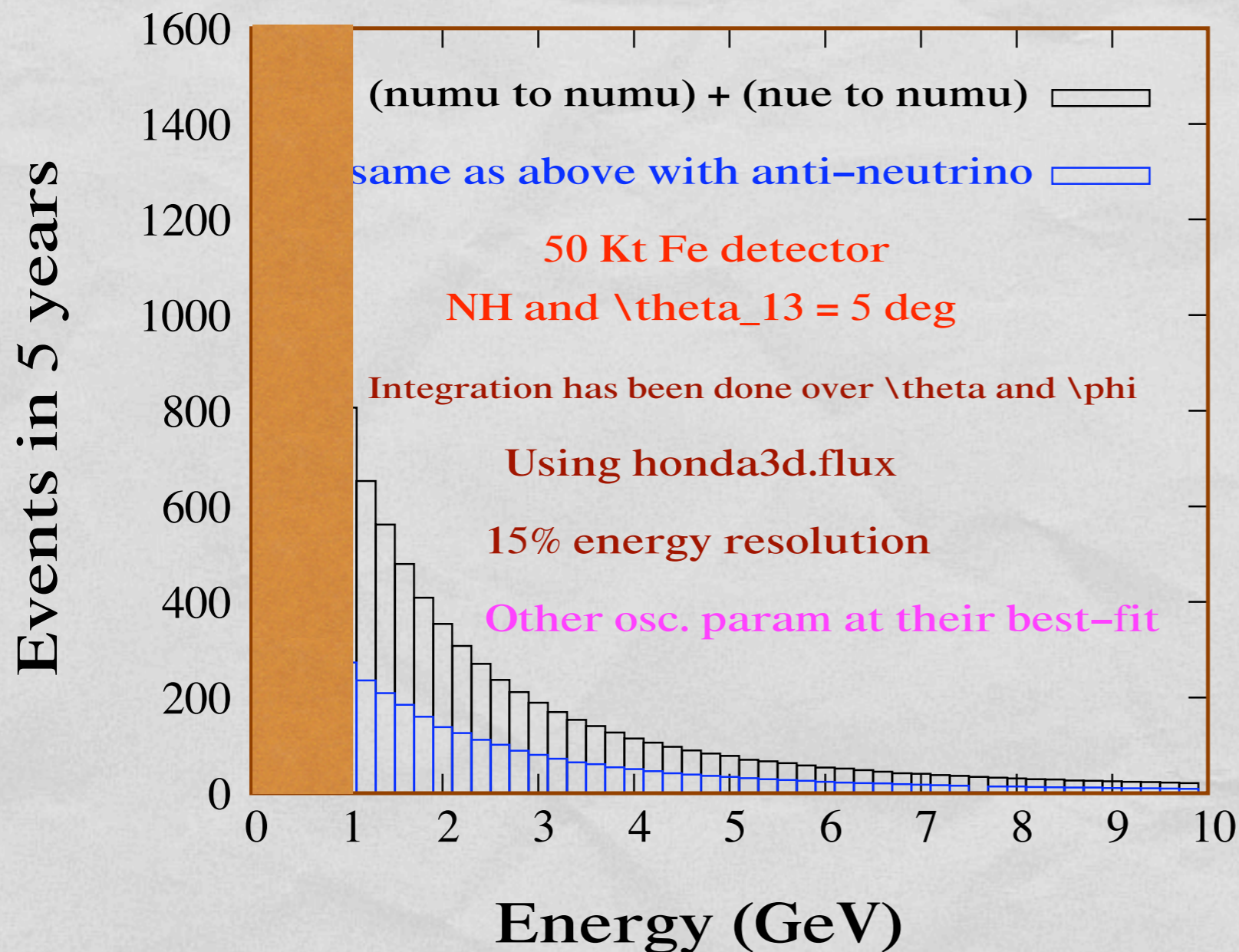
DUTY CYCLES AT $\Gamma = 350$

- It is expected that the SF needed to kill atmosphericics can be significantly relaxed
- Unfortunately, we have not yet a full comparison of the performances of different setups as a function of SF, as it is the case at $\gamma = 100$
- We are working on that

ATMOSPHERICS AT INO

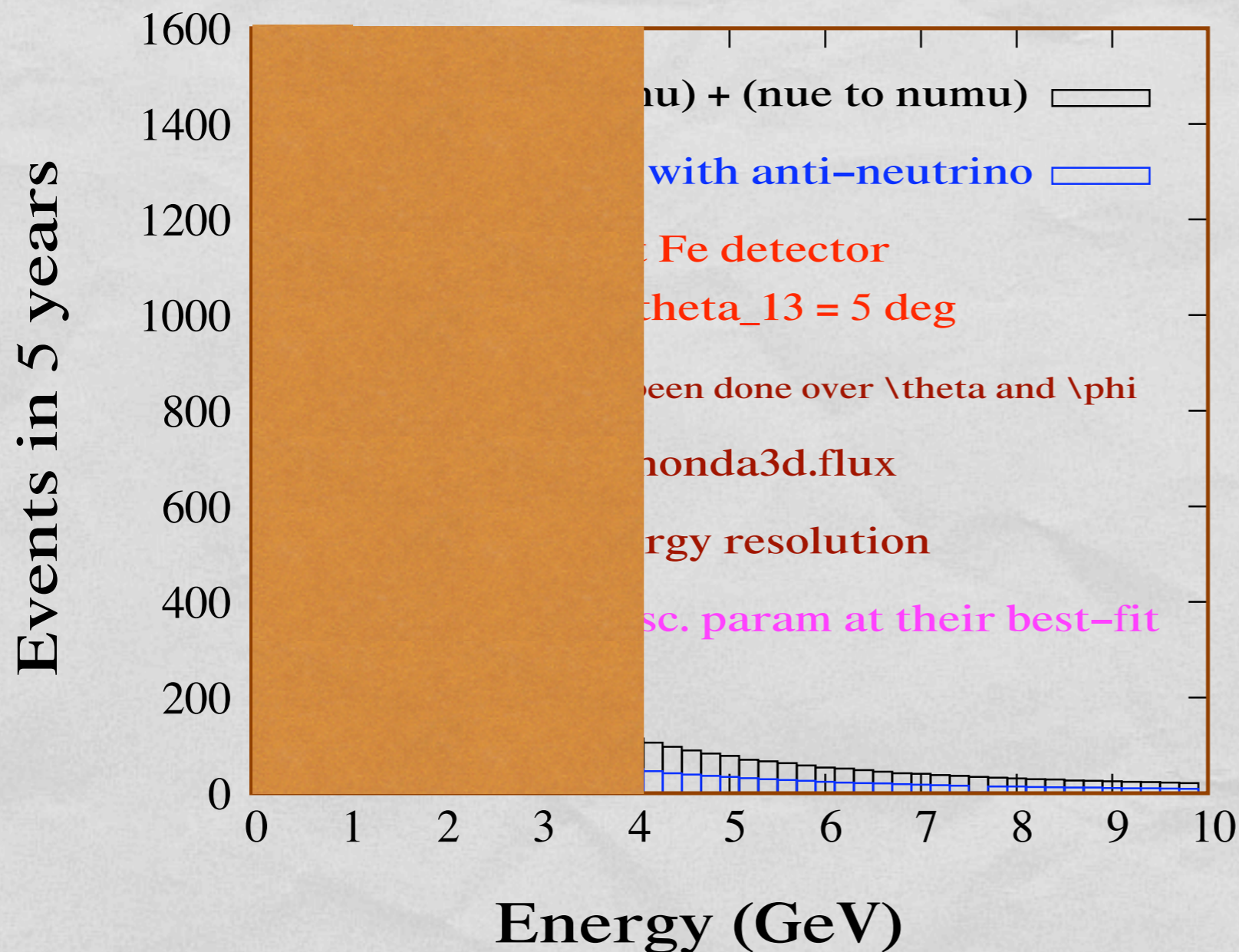


ATMOSPHERICS AT INO



Cut in energy

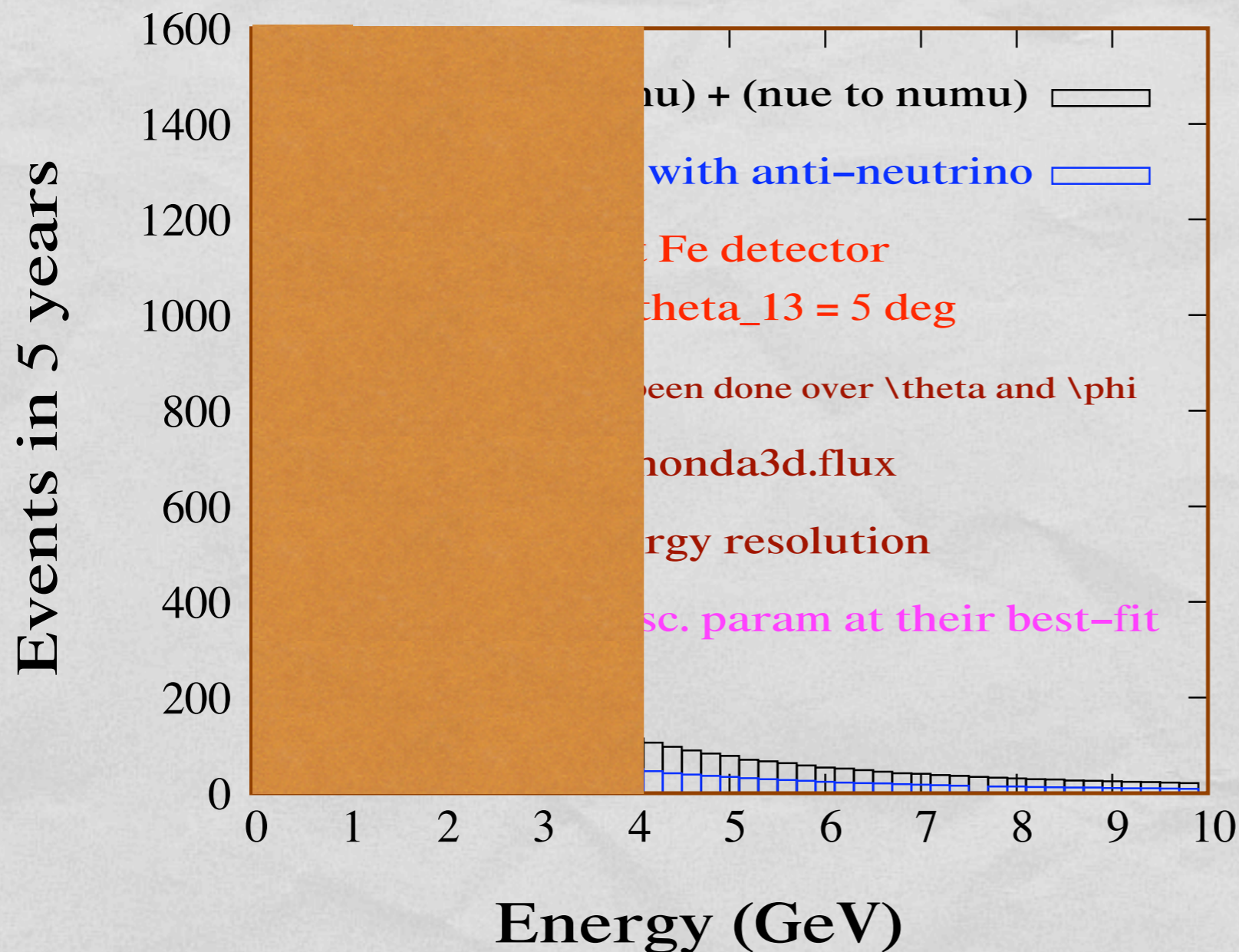
ATMOSPHERICS AT INO



Cut in energy

Going from 1 GeV
to 4 GeV you do not
lose any physics and
the bckd decreases a
lot

ATMOSPHERICS AT INO



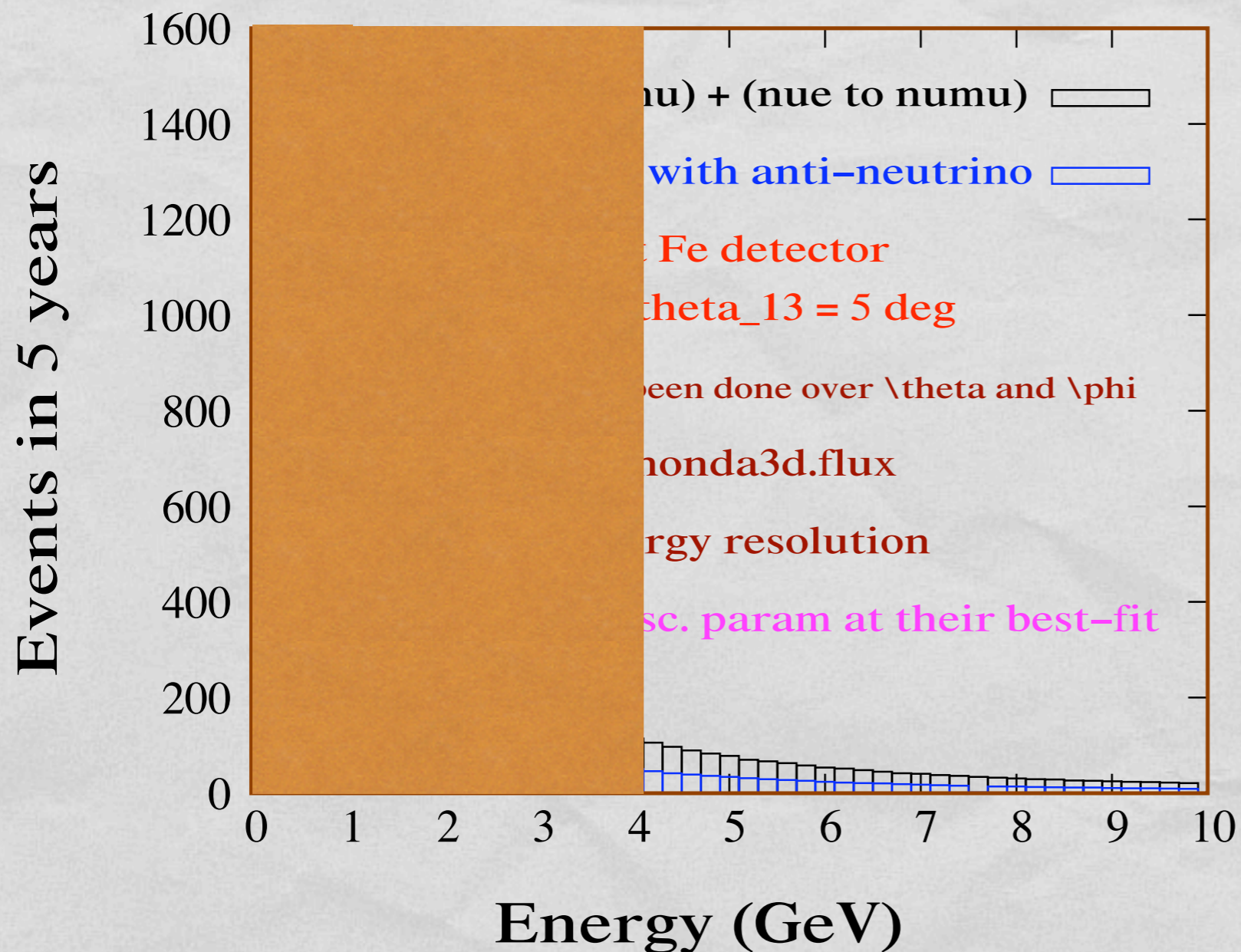
Cut in energy

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SF can be relaxed

Courtesy of S. Agarwalla

ATMOSPHERICS AT INO



Cut in energy

Going from 1 GeV
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lot

SF can be relaxed

Important for two baselines scenarios

Courtesy of S. Agarwalla

CONCLUSIONS, I

- Setup I:
 $\sin^2 2\theta_{13} > 5 \cdot 10^{-4}$, 50% CP-fraction at $\sin^2 2\theta_{13} = 10^{-3}$;
no sensitivity to the hierarchy
- Halving the Ne flux can be compensated by doubling the He flux with no loss in the physics
- High-Q ions with 5 times the nominal fluxes :
 $\sin^2 2\theta_{13} > 2 \cdot 10^{-4}$, 60% CP-fraction at $\sin^2 2\theta_{13} = 10^{-3}$;
can measure the hierarchy for $\sin^2 2\theta_{13} > 8 \cdot 10^{-3}$

CONCLUSIONS,2

- Setup I is overrun by High- γ options.
He/Ne beam at $\gamma = 350$ with nominal fluxes:
 $\sin^2 2\theta_{13} > 8 \cdot 10^{-5}$, 75% CP-fraction at $\sin^2 2\theta_{13} = 10^{-3}$;
can measure the hierarchy for $\sin^2 2\theta_{13} > 2 \cdot 10^{-3}$
- Two baselines scenarios do better on the hierarchy, in general. However, they usually are worse on CP
- Two baselines cocktail is the most interesting alternative to the He/Ne beam at $\gamma = 350$: similar performances but much better handle on the hierarchy

CONCLUSIONS,3

- Duty cycles studies performed for low- γ options
- Under study for the high- γ . We plan to include it in the 2010 WWP6 Yearly Report.