Neutrino factory

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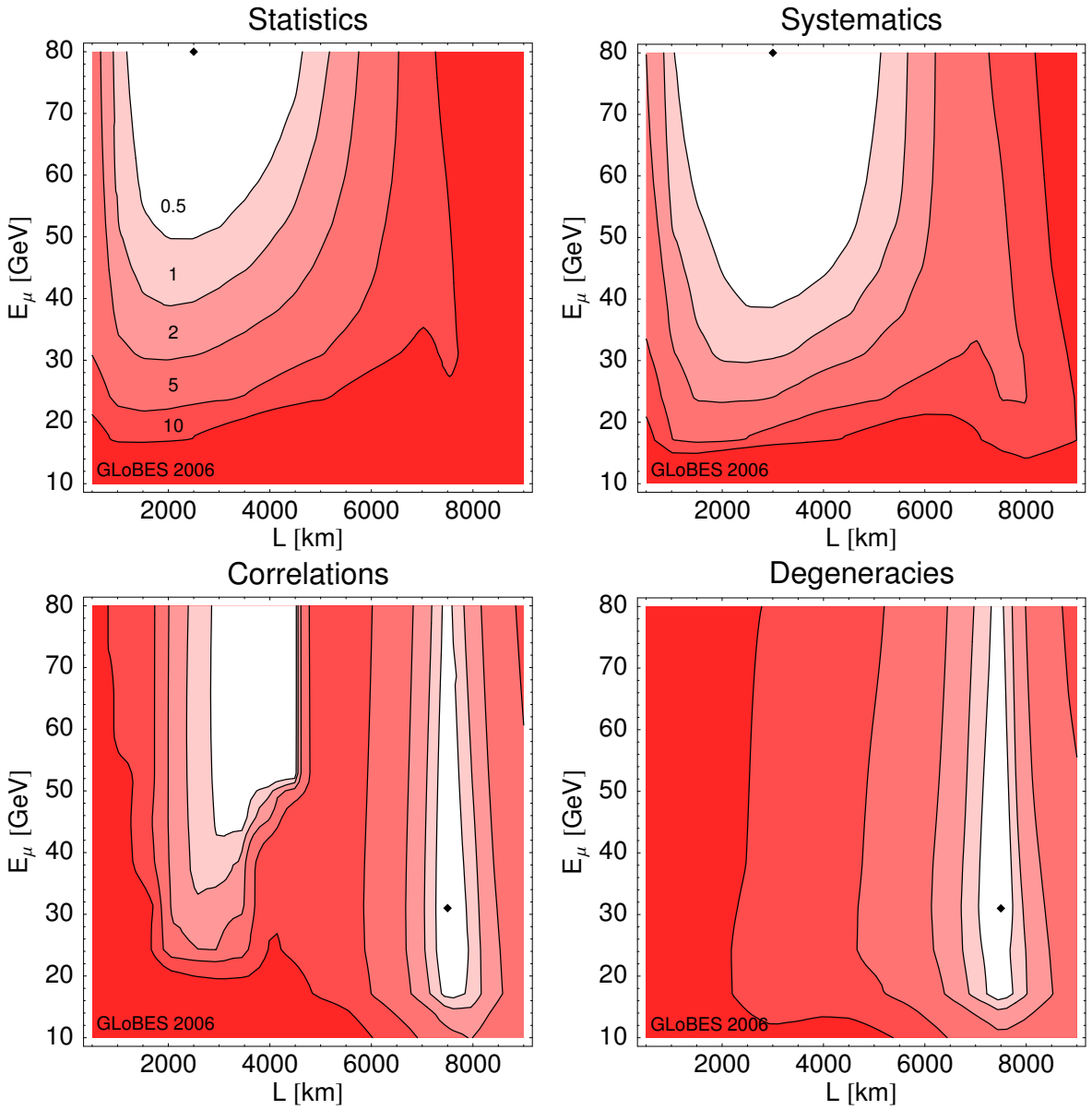
Outline

- take “existing” NF and repeat L-E optimization
- add a second baseline
- add new final states – silver and platinum
  - discuss improved detectors
  - for the golden channel
  - for the additional channels
- compare

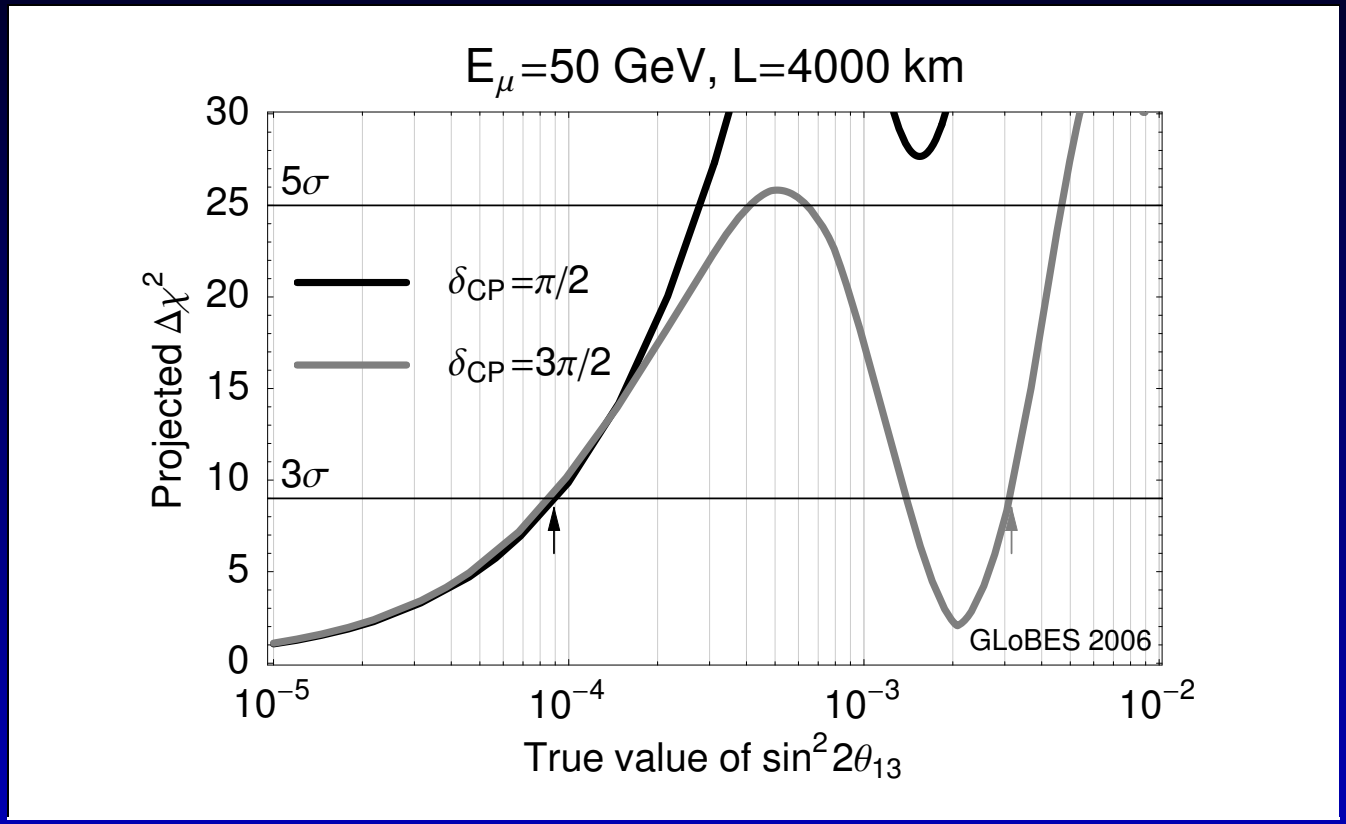
'Existing' NF

- 10^{21} muons per year
- $E_\mu = 50\,\mathrm{GeV}$
- 5 years μ^- and 5 years of μ^+ running
- $50\,\mathrm{kt}$ magnetized iron calorimeter
- efficiency for golden events rises linearly from 0 at $4\,\mathrm{GeV}$ to asymptotic value at $20\,\mathrm{GeV}$
- background $5 \cdot 10^{-5}$ of all NC events and $5 \cdot 10^{-5}$ of all right sign events
- for ν_μ disappearance we use a threshold of $1\,\mathrm{GeV}$ (no need for CID)
- energy resolution is $0.15 E_\nu$

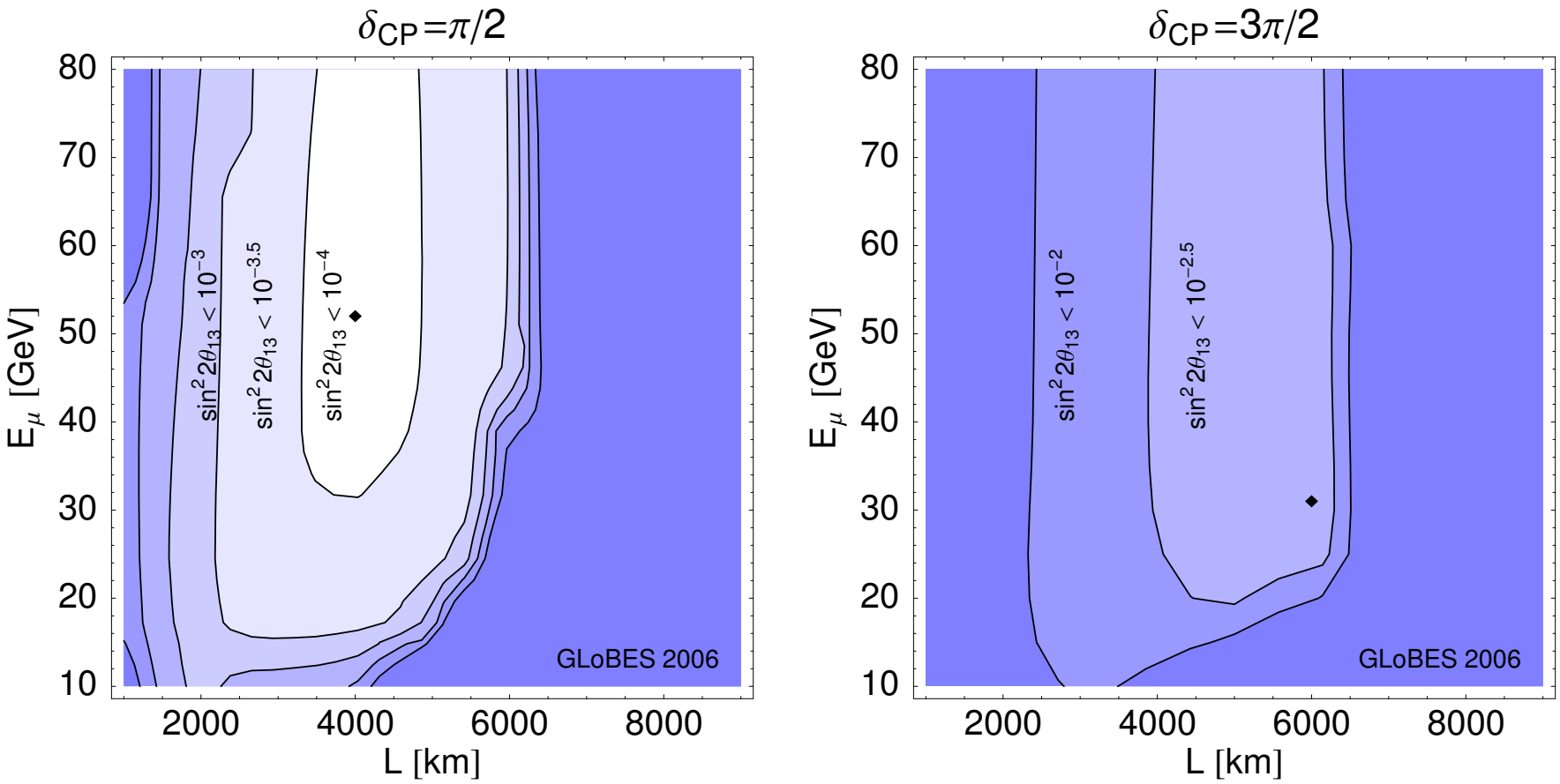
$\sin^2 2\theta_{13}$ sensitivity



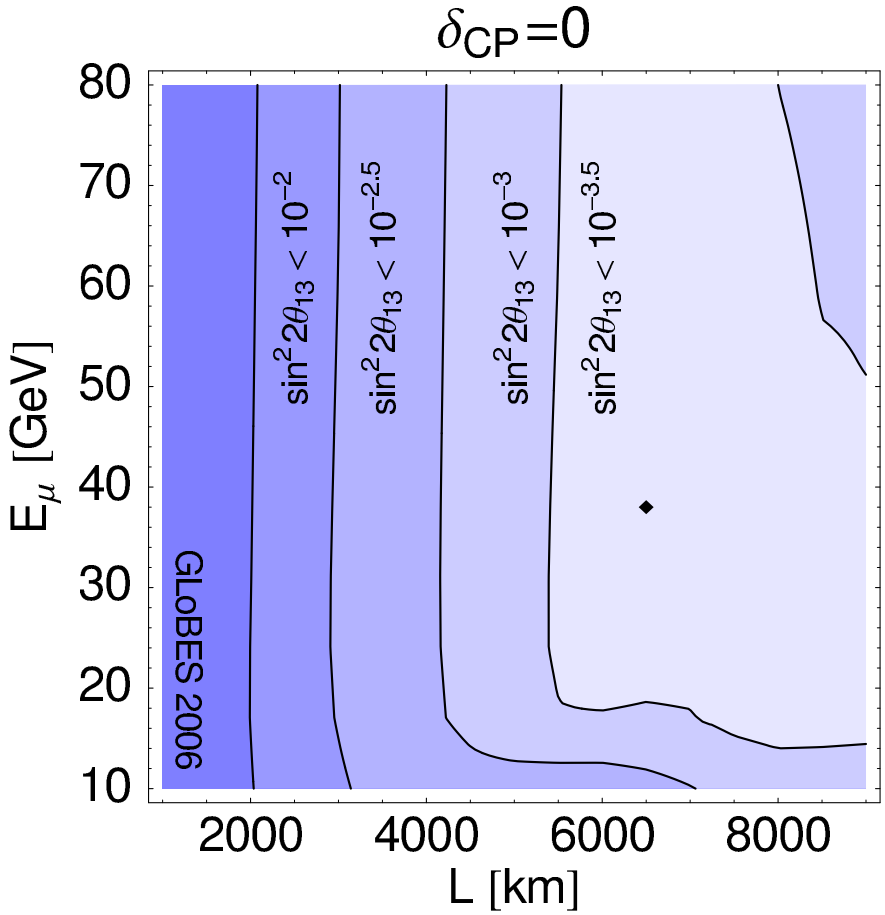
CP discovery reach

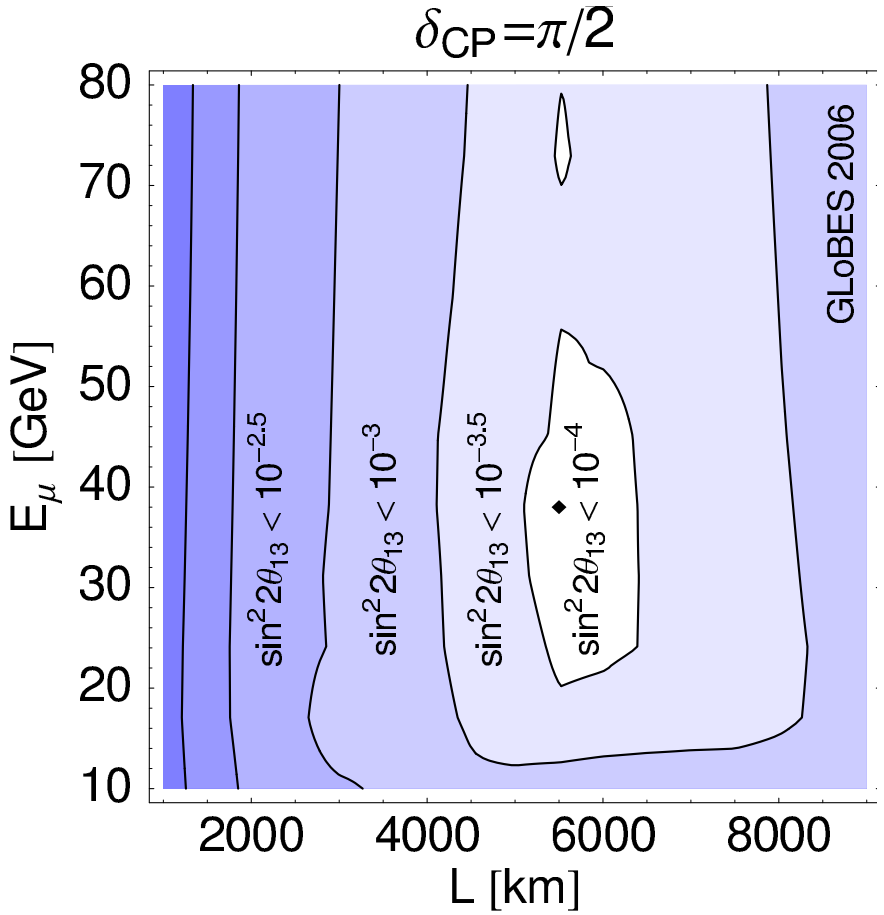


CP discovery reach – L vs E

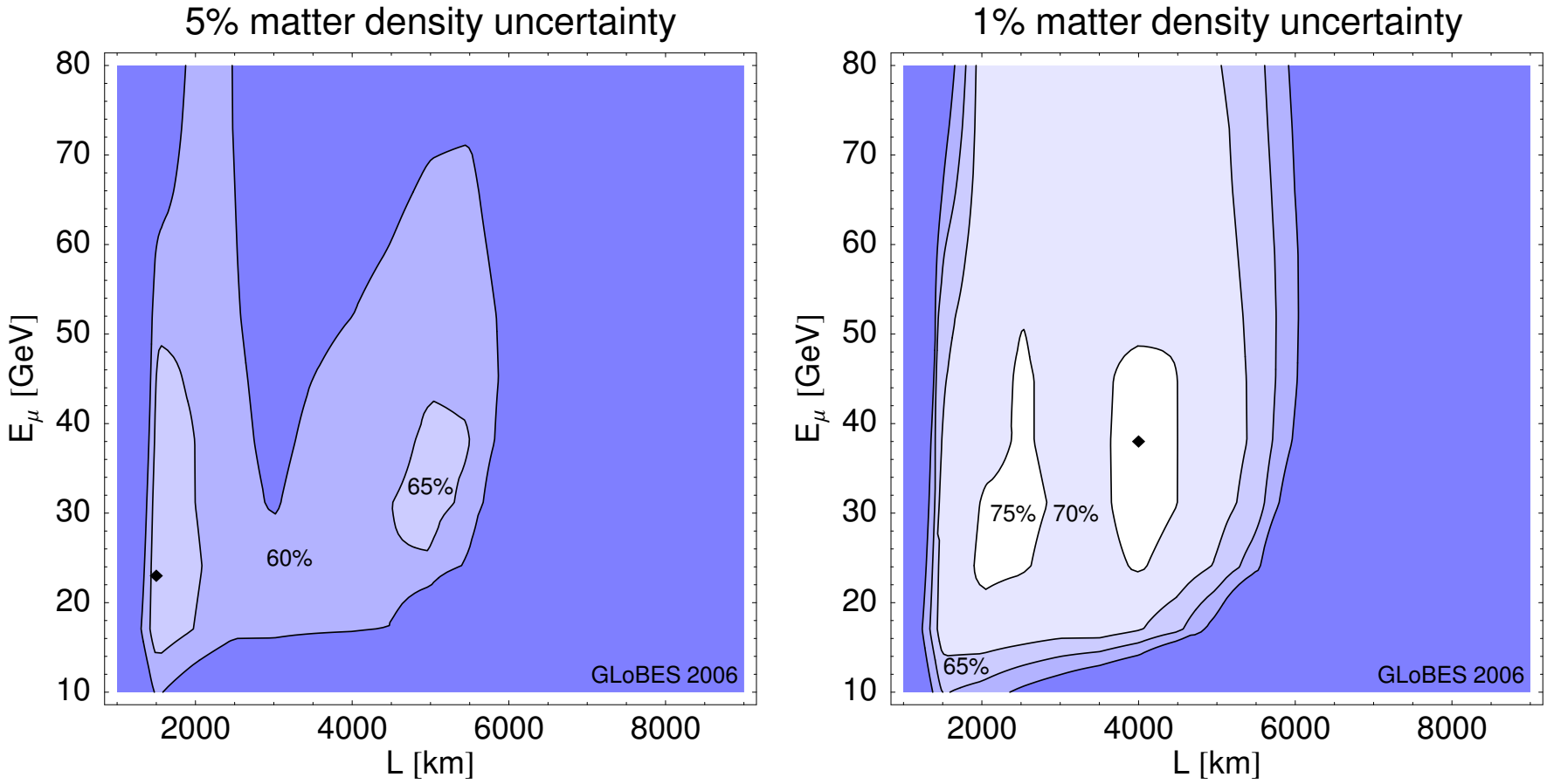


Mass hierarchy discovery reach





Large θ_{13} – L vs E



Summary – 'existing' NF

different L and E for different measurements

- $L \sim 2000 - 4000\,\mathrm{km}$, $E_\mu \simeq 30\,\mathrm{GeV}$ for CPV
- $L \sim 7500\,\mathrm{km}$, $E_\mu \simeq 20\,\mathrm{GeV}$ for θ_{13}
- $L \sim 7500\,\mathrm{km}$, $E_\mu \simeq 30\,\mathrm{GeV}$ for $\mathrm{sgn}\Delta m^2_{31}$

$E_\mu = 30\,\mathrm{GeV}$ and two baselines $4000\,\mathrm{km}$ and $7500\,\mathrm{km}$

Silver channel

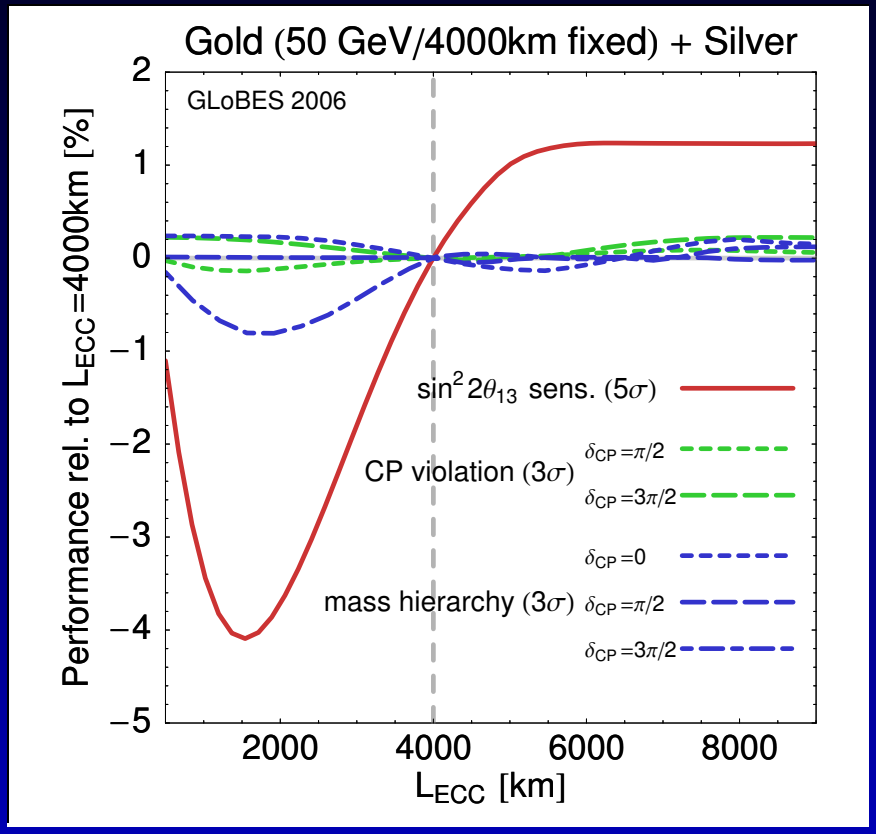
Silver

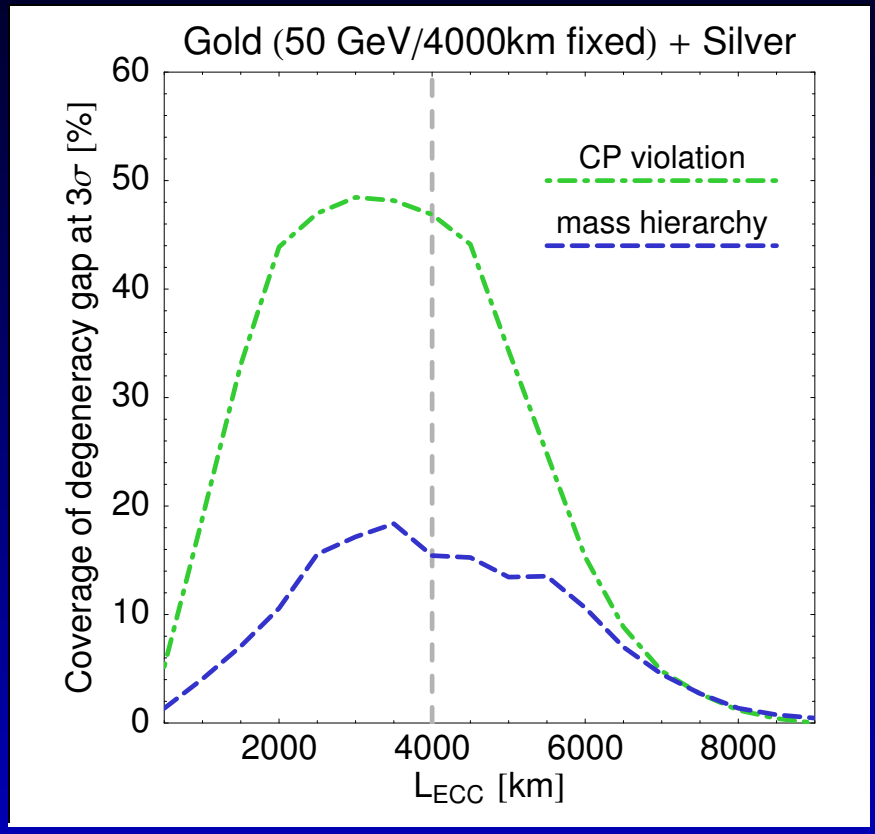
- $5\,\mathrm{kt}$ ECC
- OPERA-like performance (Auterio *et al.*)

Silver*

- $10\,\mathrm{kt}$ ECC
- 5 times as efficient as Silver
- 3 times the background

Which baseline for Silver?





Platinum channel

Platinum

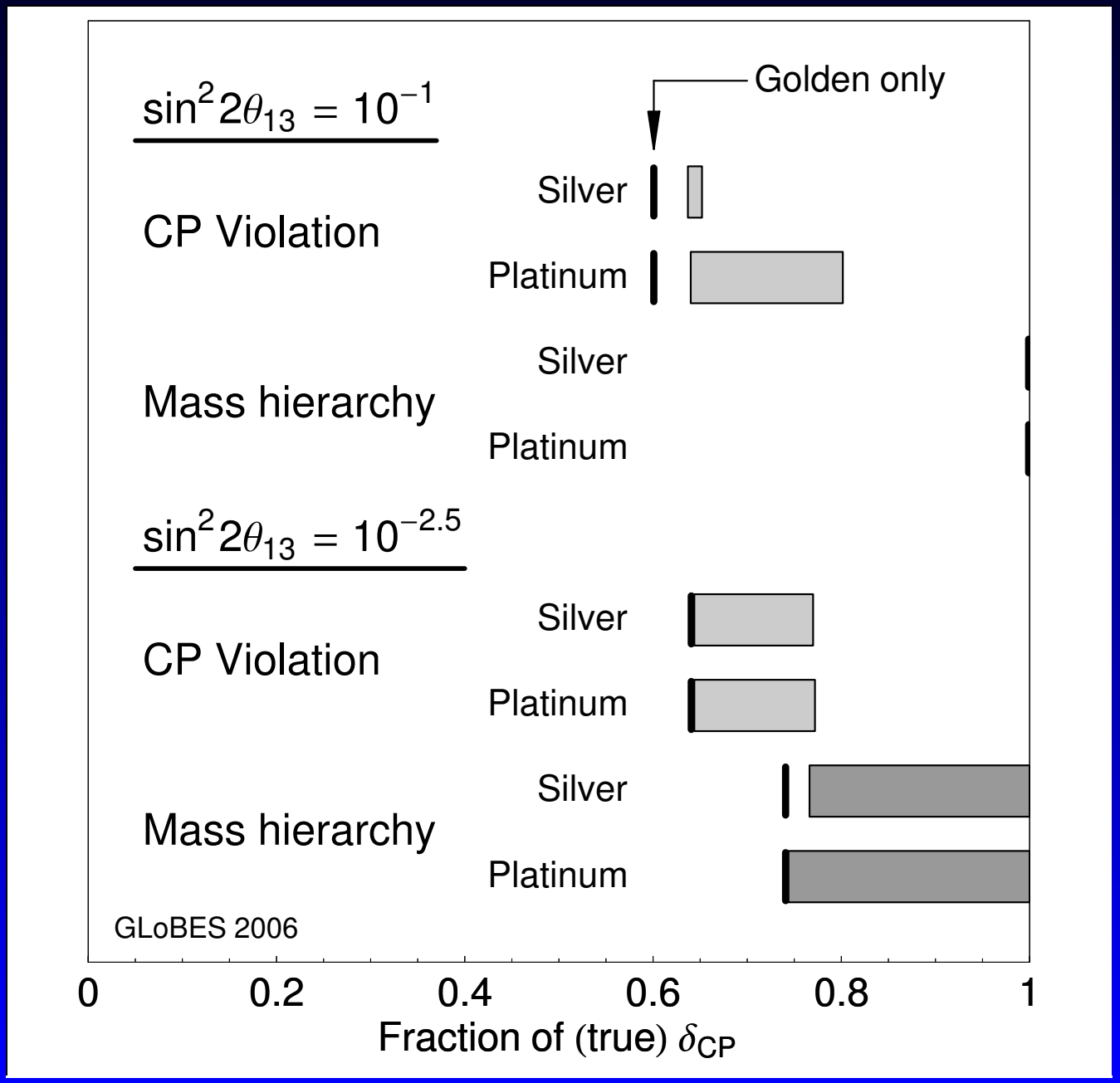
- $15\,\mathrm{kt}$ LAr TPC
- 20% signal efficiency
- 1% charge confusion
- CID up to $7.5\,\mathrm{GeV}$

Platinum*

- $50\,\mathrm{kt}$ (maybe same than improved golden detector)
- CID up to $50\,\mathrm{GeV}$

same baseline as golden detector

How useful are those channels?



Summary for channels

Within a 3 flavor oscillation only framework

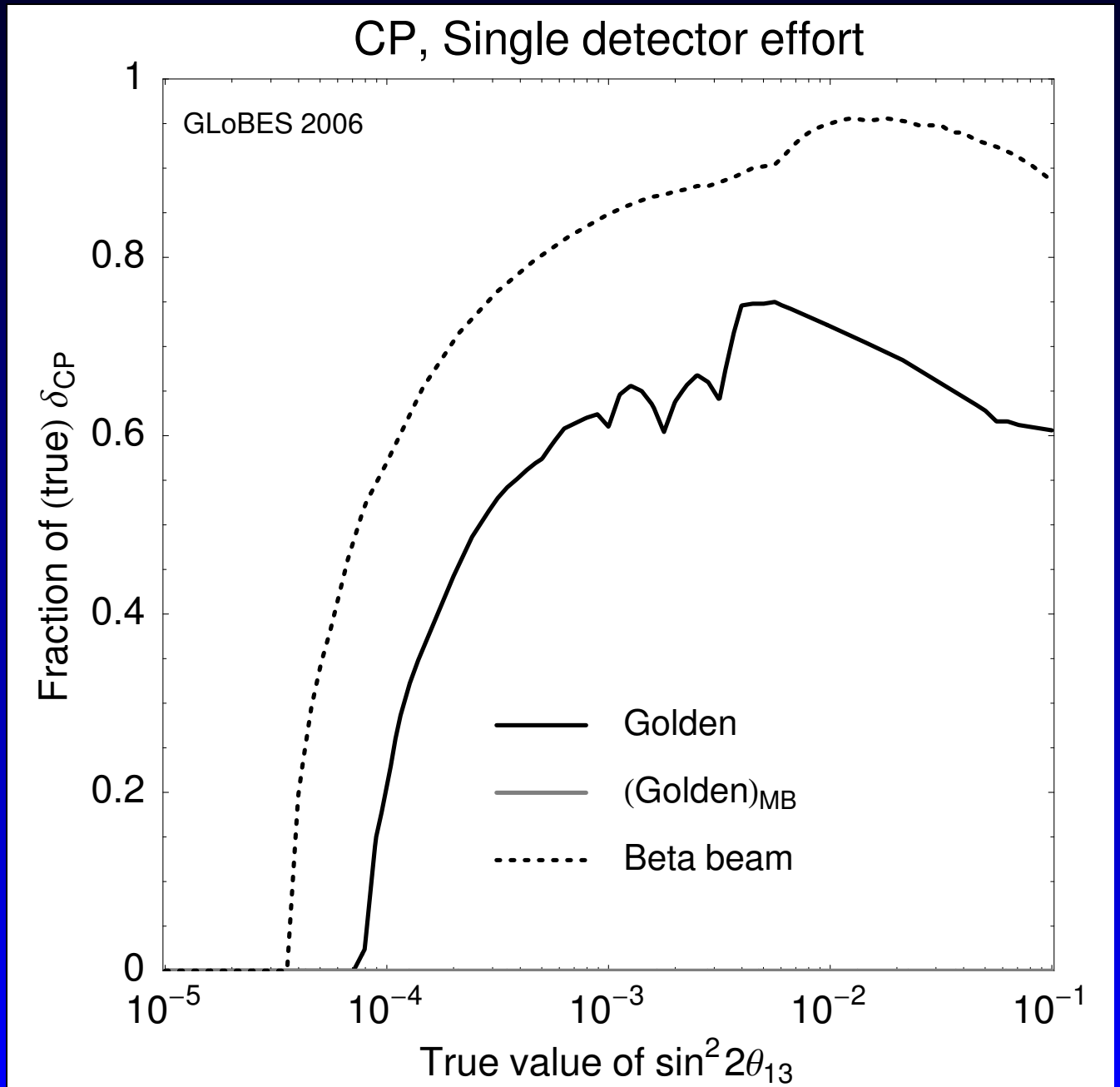
- Channels are of limited use
- at large θ_{13}: reduce correlation
- at intermediate θ_{13}: reduction of intrinsic degeneracy

Second baseline works better (even relative to channel*)!

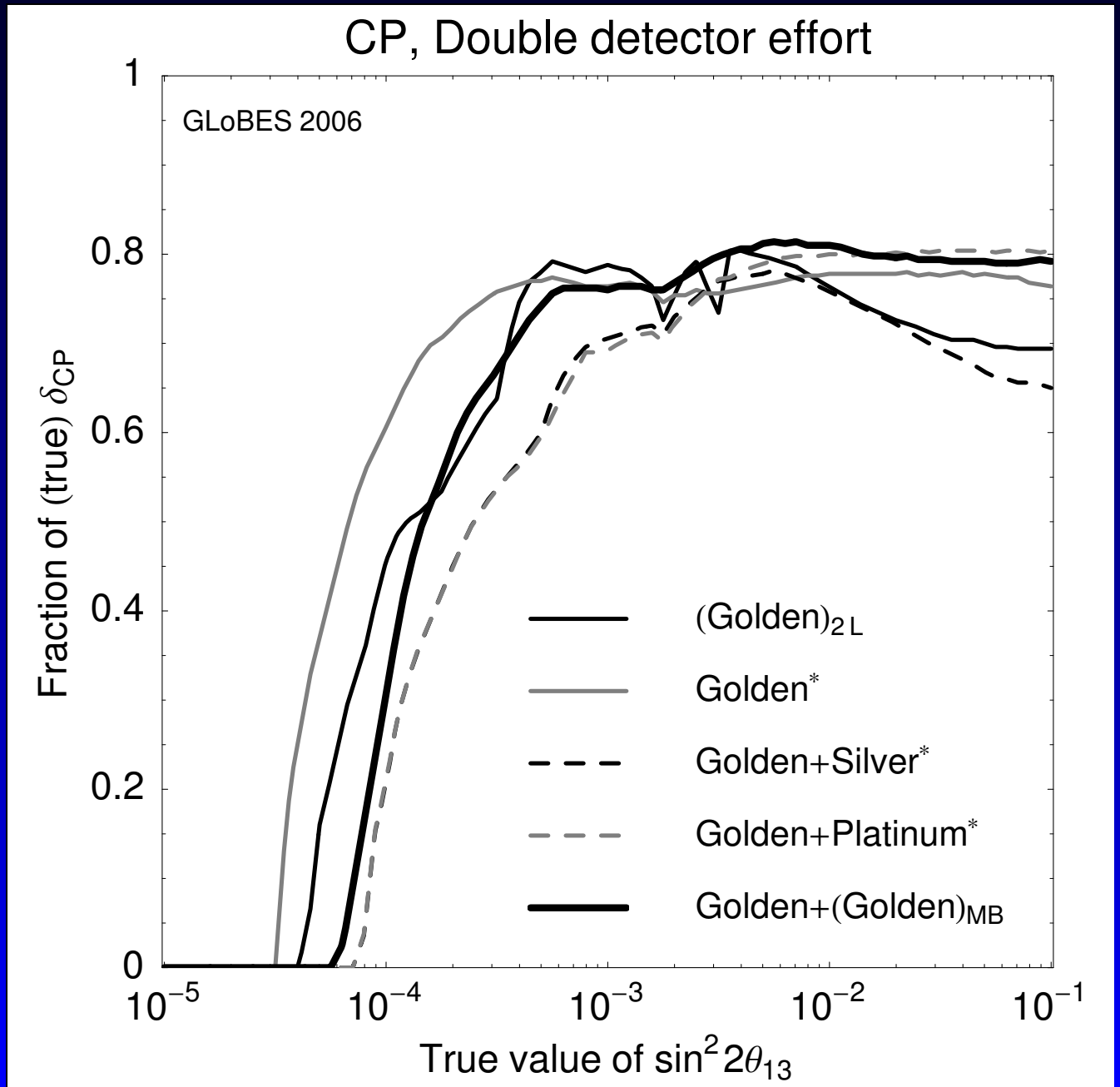
Improved golden channel

- $50\,\mathrm{kt}$
- 50% efficiency at $1(3), \mathrm{GeV}$
- $10^{-3}(E_\nu\,[\mathrm{GeV}])^{-2}$ of all NC events as background (factor 10 more is no problem)
- $10^{-3}(E_\nu\,[\mathrm{GeV}])^{-2}$ of all right sign events as background (factor 10 more is no problem)
- Energy resolution $0.15\sqrt{(E)} + 0.085$

Comparison


CP, Single detector effort
GLoBES 2006
Fraction of (true) δ_{CP}
True value of $\sin^2 2\theta_{13}$
1
0.8
0.6
0.4
0.2
0
10^{-5}
10^{-4}
10^{-3}
10^{-2}
10^{-1}
Golden
(Golden)$_{MB}$
Beta beam

Comparison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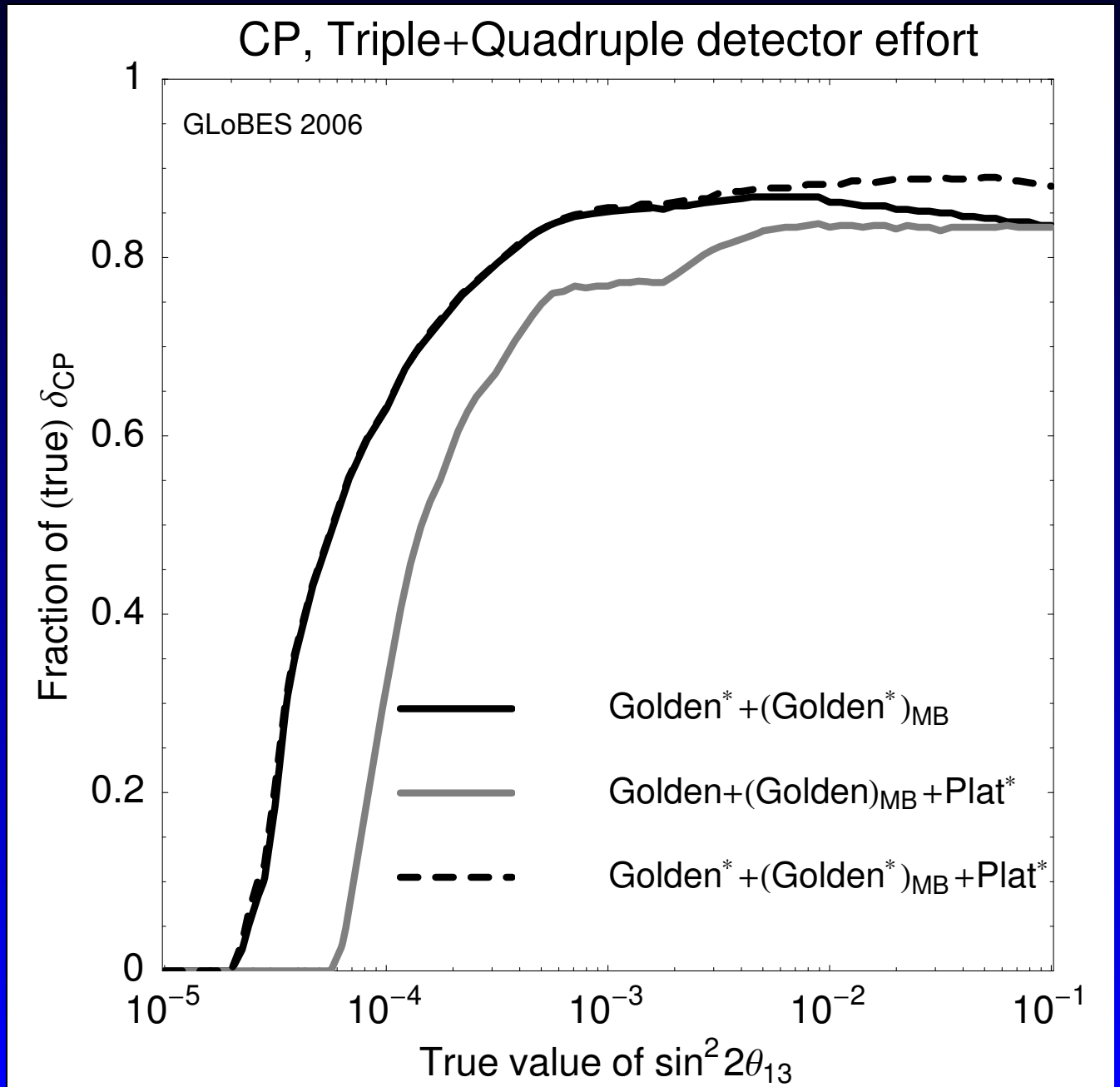
0.8
0.6
0.4
0.2
0
10^{-5}
10^{-4}
10^{-3}
10^{-2}
10^{-1}
$(\text{Golden})_{2\,\text{L}}$
Golden*
Golden+Silver*
Golden+Platinum*
Golden+$(\text{Golden})_{\text{MB}}$

Comparison

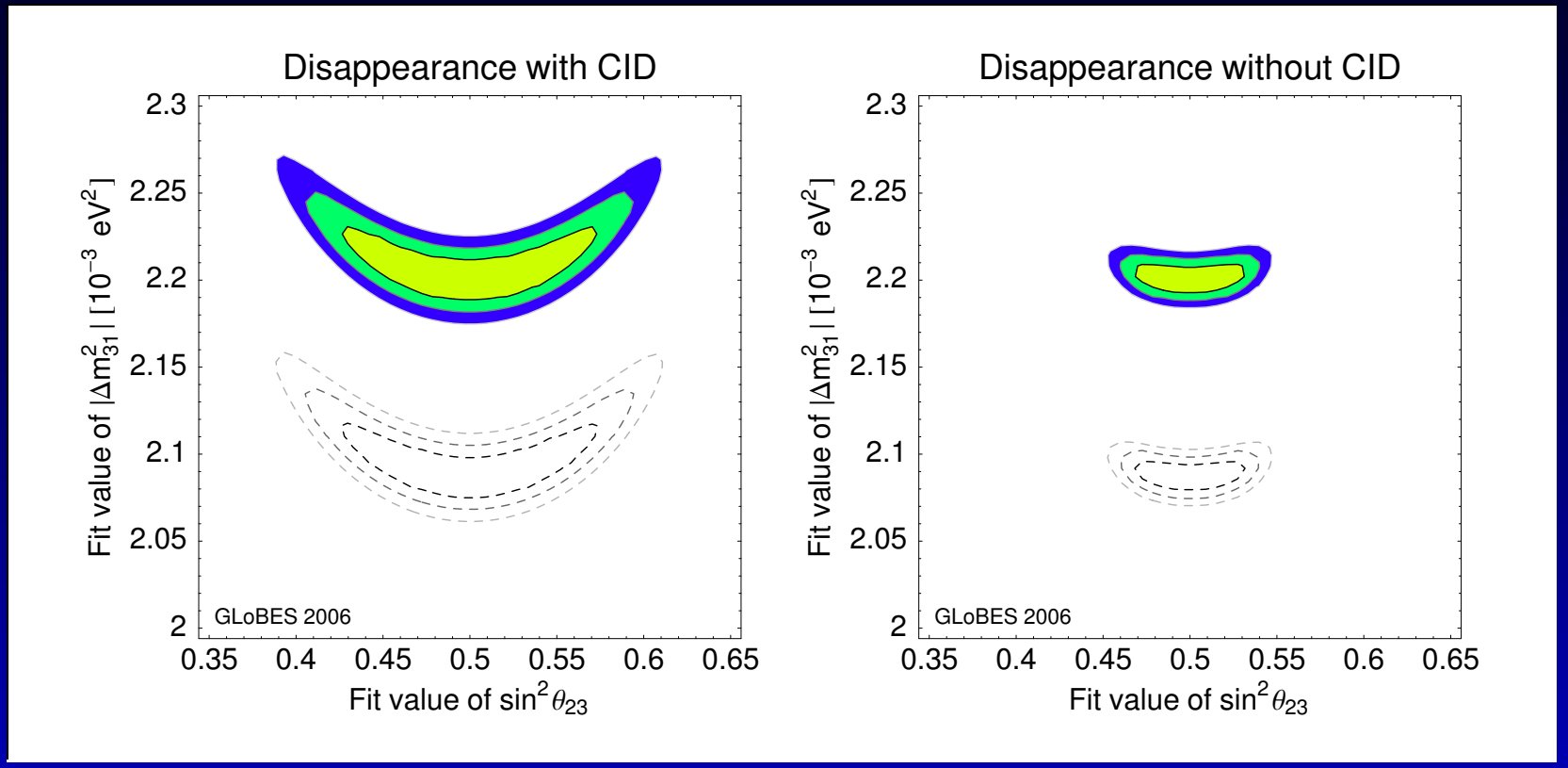

CP, Triple+Quadruple detector effort
GLoBES 2006
Fraction of (true) δ_{CP}
True value of $\sin^2 2\theta_{13}$
1
0.8
0.6
0.4
0.2
0
10^{-5}
10^{-4}
10^{-3}
10^{-2}
10^{-1}
Golden* +(Golden*)$_{MB}$
Golden+(Golden)$_{MB}$ +Plat*
Golden* +(Golden*)$_{MB}$ +Plat*

Conclusion

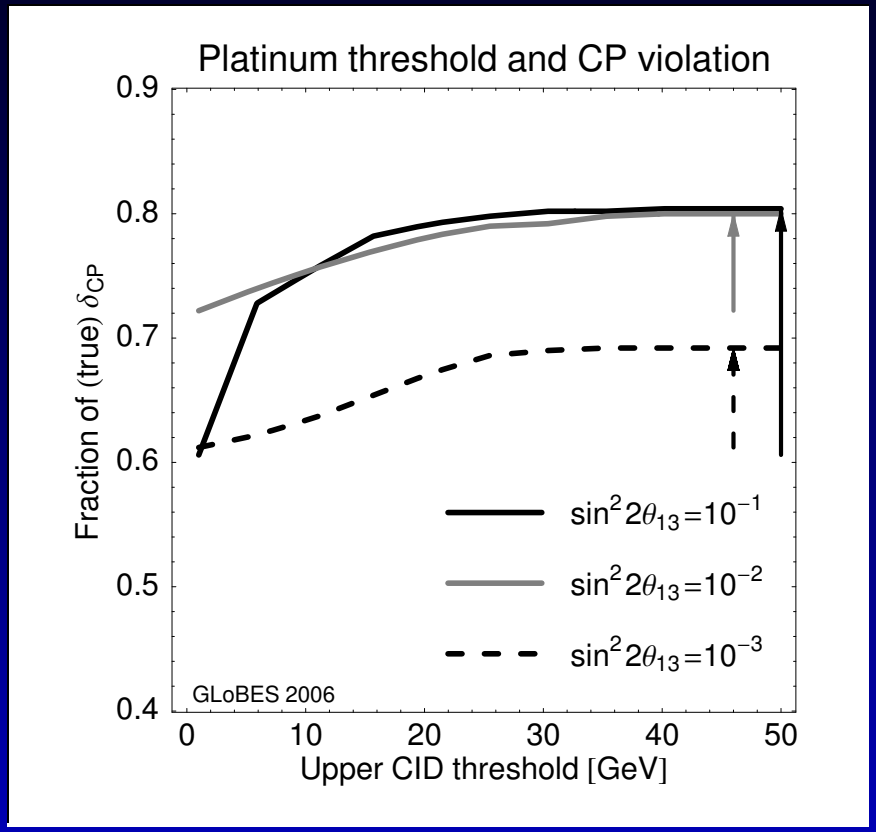
- lower muon energy possible $30\,\mathrm{GeV}$ – oscillation physics
- lower threshold for golden channel
  - $E_\mu = 20\,\mathrm{GeV}$
  - vastly increased performance
  - detector cost?
- two baselines – correlations and degeneracies

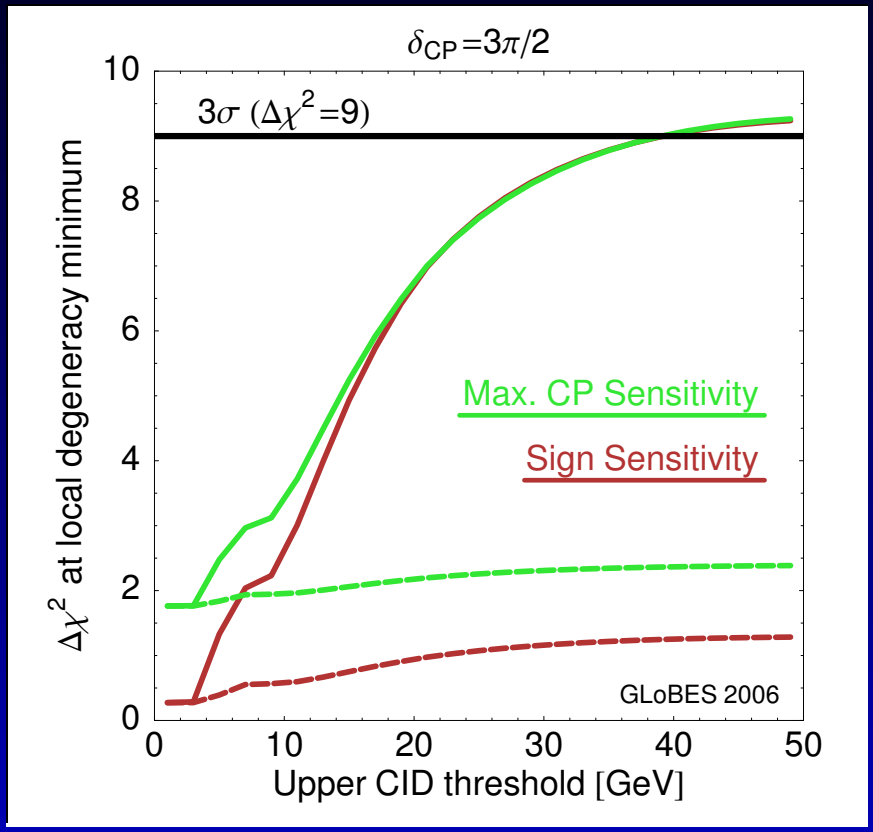
Backup slides

Atmospheric parameters



Impact of CID threshold





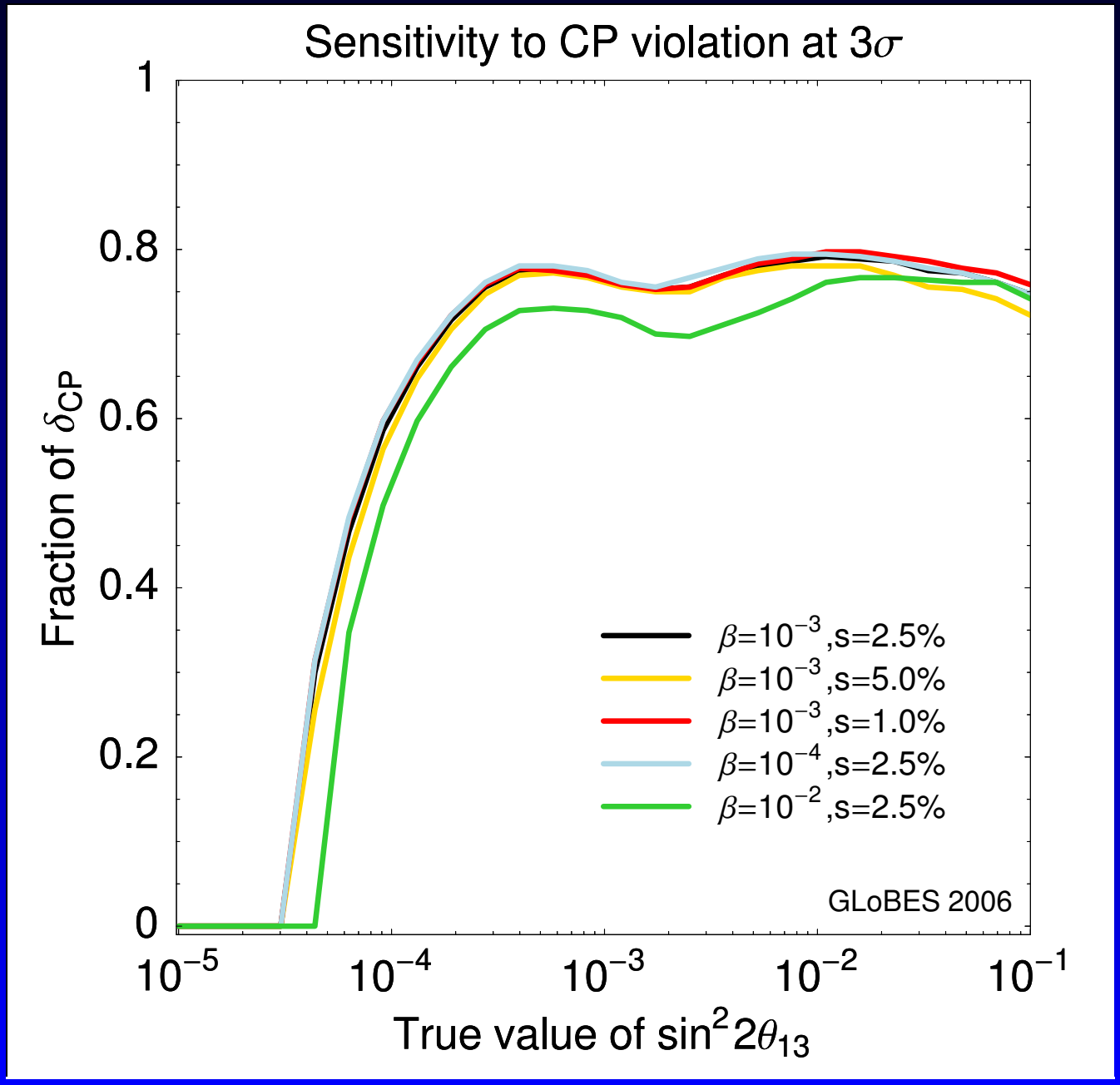
Rates – I

$\sin^2 2\theta_{13} = 10^{-1}$	Signal	Background	S/$\sqrt{\text{B}}$
Golden	31000 (6000)	39 (73)	5000 (700)
Silver	210 (–)	32 (–)	37 (–)
Silver@732km	260 (–)	110 (–)	25 (–)
Silver*	2100 (–)	190 (–)	150 (–)
Silver*@732km	2600 (–)	670 (–)	100 (–)
Platinum	4 (120)	140 (110)	0.3 (11)
Platinum*	6700 (27000)	190000 (160000)	15 (68)
$(\text{Golden})_{\text{MB}}$	5100 (340)	9 (17)	1700 (83)

Rates – II

$\sin^2 2\theta_{13} = 10^{-2.5}$	Signal	Background	$S/\sqrt{B}$
Golden	1900 (450)	39 (72)	300 (53)
Silver	3 (–)	33 (–)	0.5 (–)
Silver@732km	1.7 (–)	110 (–)	0.2 (–)
Silver*	29 (–)	200 (–)	2.1 (–)
Silver*@732km	17 (–)	680 (–)	0.7 (–)
Platinum	1 (5)	170 (110)	0.08 (0.5)
Platinum*	500 (1600)	190000 (160000)	1.1 (4)
$(\text{Golden})_{\text{MB}}$	200 (10)	9 (17)	67 (2.4)

Systematics & backgrounds



Threshold vs resolution