Superbeams

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IDS-NF plenary meeting

March, 2009

CERN

Outline

- What is super about these beams?
- Off-axis
- On-axis
- Projects
- Comparison
- Summary

Definition of 'super'

All super beam projects have in common

- Extrapolation from known technologies
- Proton beam power in excess of 1 MW
- Detector mass 100 kton or more
- Running time of a decade
- cost of $10^8 - 10^9$ (Euro/Dollar)

Off-axis

The off-axis technology is appealing because

- simple tuning of beam energy
- narrow beam – concentrates the events around the oscillation maximum and allows to do a "counting" experiment
- no high energy tail – high energy neutrinos produce lots of NC events which tend to be reconstructed at low energies
- low background – somewhat reduced ν_e contamination

Drawbacks

The off-axis technology has intrinsic limitations

- narrow beam – concentrates the events around the oscillation maximum and reduces to do a "counting" experiment
- background – ν_e contamination

Being a counting experiment implies that absolute event numbers are important, thus it is very demanding in terms of systematics. It also means that one can measure only two numbers n_ν and $n_{\bar{\nu}}$. Virtually impossible to resolve the degeneracies.

On-axis

One may consider an on-axis, wide band beam because

- higher energy (not always an advantage) – longer baseline, more matter effects
- higher on-axis flux
- broad spectrum – many values of L/E at the same time
- energy information to fight systematics

Drawbacks

- high energy – long baseline for the first maximum reduces flux
- high energy tail – NC feed down, puts stringent demands on the detector
- broad spectrum only useful if the energy resolution is sufficient

This puts the emphasis on the detector side: large mass to compensate distance, good energy resolution and NC rejection

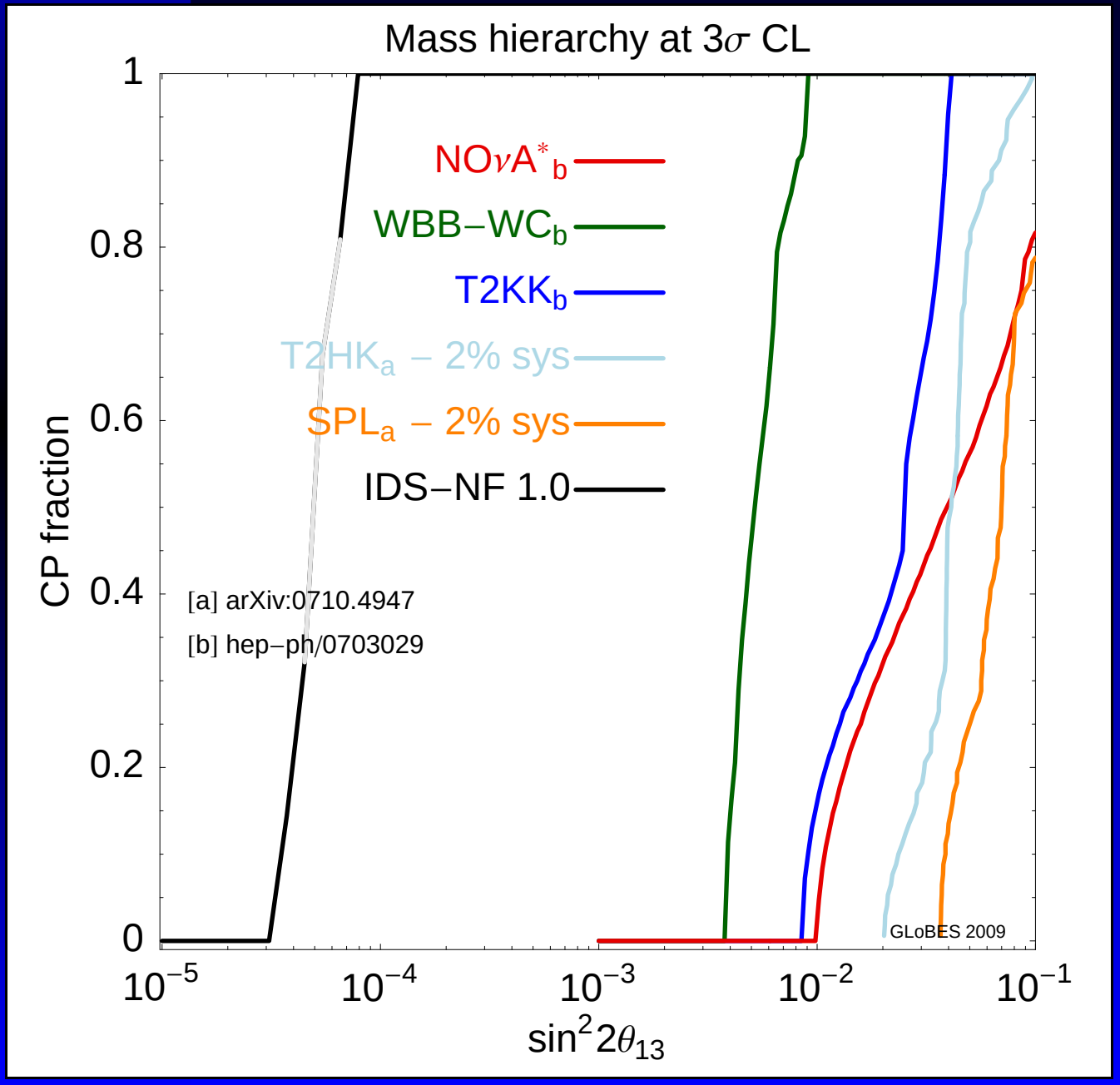
Projects

- SPL – beam from CERN, $P = 4\,\mathrm{MW}$, one water Cherenkov detector at $L = 130\,\mathrm{km}$ with a fiducial mass of $440\,\mathrm{kt}$, off-axis
- T2HK – beam from JAERI, $P = 4\,\mathrm{MW}$, one water Cherenkov detector at $L = 295\,\mathrm{km}$ with a fiducial mass of $540\,\mathrm{kt}$, off-axis
- T2KK – beam from JAERI, $P = 4\,\mathrm{MW}$, two water Cherenkov detectors at $L = 295\,\mathrm{km}$ and $L = 1050\,\mathrm{km}$ with a fiducial mass of $270\,\mathrm{kt}$, off-axis

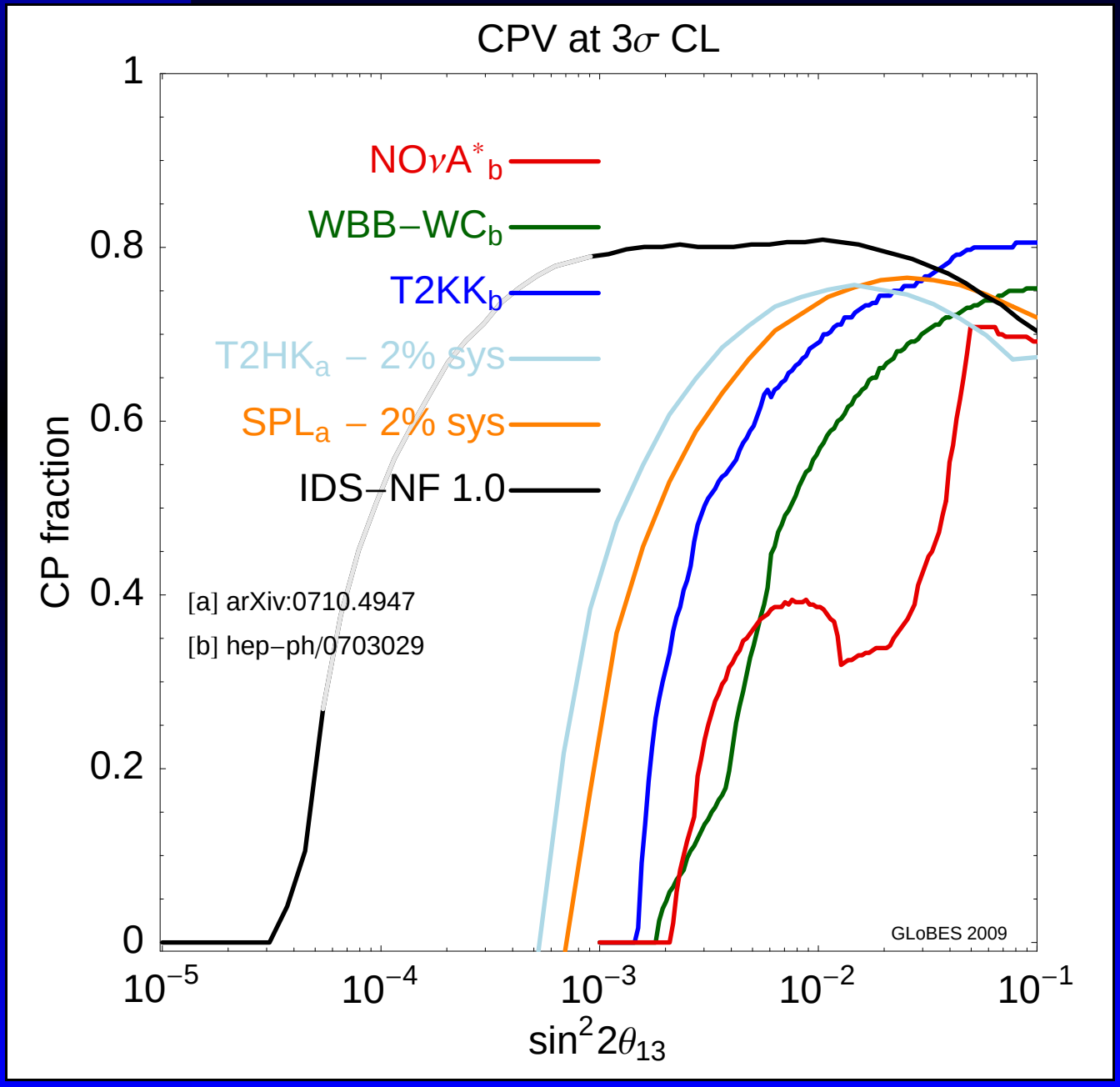
Projects – continued

- WBB – beam from FNAL, $P = 1.1\,\mathrm{MW}$, one water Cherenkov detector at $L = 1300\,\mathrm{km}$ with a fiducial mass of $300\,\mathrm{kt}$, on-axis
- NOνA* – beam from FNAL, $P = 1.1\,\mathrm{MW}$, one liquid Argon TPC at $L = 810\,\mathrm{km}$ with a fiducial mass of $100\,\mathrm{kt}$, off-axis

Mass Hierarchy



CPV


CPV at 3σ CL
NOνA*b
WBB–WCb
T2KKb
T2HKa – 2% sys
SPLa – 2% sys
IDS–NF 1.0
[a] arXiv:0710.4947
[b] hep–ph/0703029
GLoBES 2009
CP fraction
sin²2θ13
1
0.8
0.6
0.4
0.2
0
10⁻⁵
10⁻⁴
10⁻³
10⁻²
10⁻¹

Summary

- Large number of projects, they will need to converge at some point
- Superbeams are always site specific, and thus never fully optimized
- Crucial difference between proposal is target mass at distances larger than 1000 km (T2KK, WBB)
- Sensitivity to mass hierarchy does not go below $\sin^2 2\theta_{13} = 10^{-2}$
- CP sensitivity competitive at large θ_{13}
- Need to study precision