DAEδALUS

CP-violation and Beyond

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DAEδALUS Collaboration

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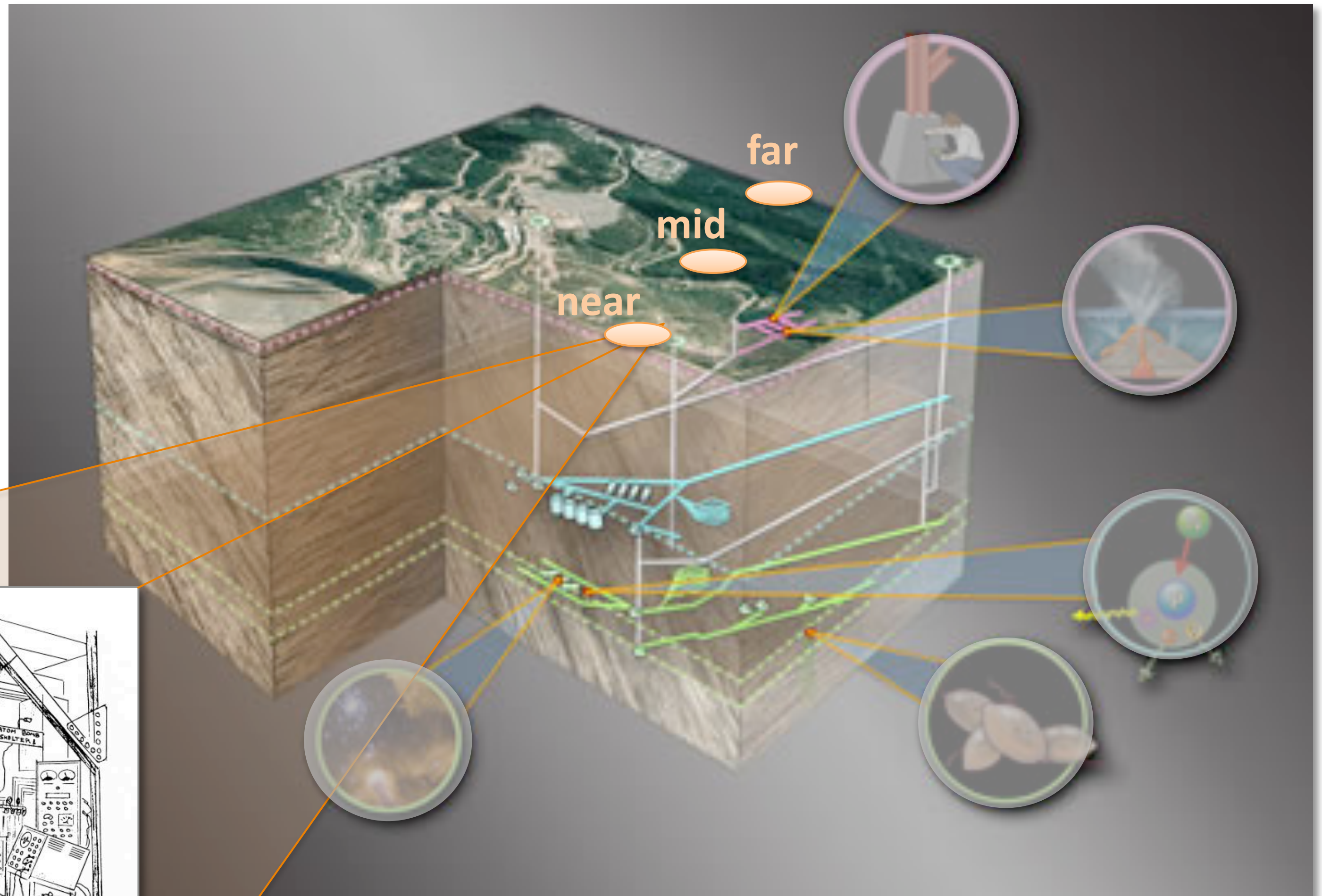
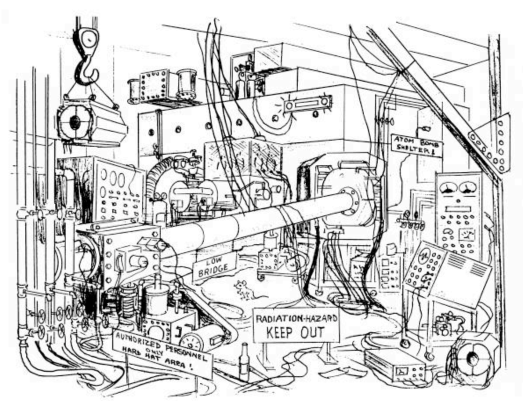
Decay
At rest
Experiment for
δ$_{CP}$ studies
At the
Laboratory for
Underground
Science

A **new neutrino (multi-)source** for a large Gd-doped water cherenkov at DUSEL





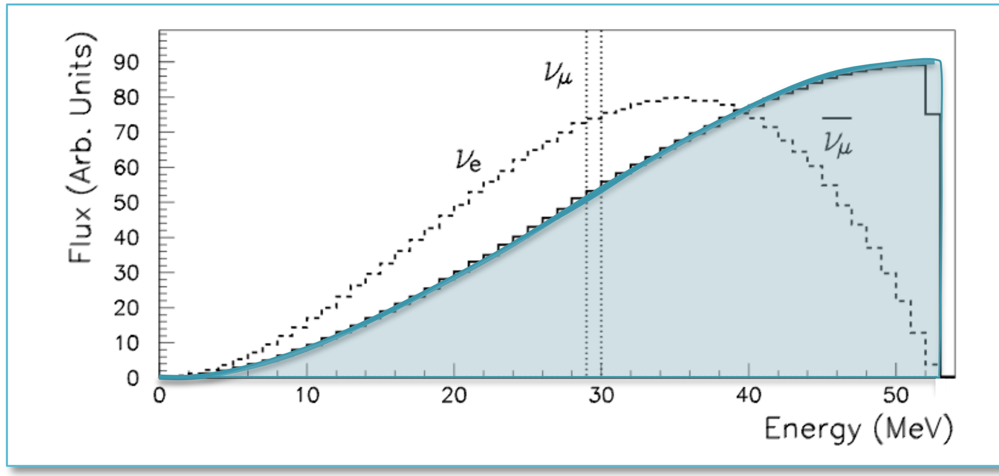
The cyclotron as seen by... the visitor.

[LBNL Image Library]

See previous talk by J. Alonso
on high-power cyclotrons for DAEδALUS

Goal: Independent measurement of θ_{13} and δ_{CP}

Antineutrino beam…



+ 3 separate L/E…

(vacuum appearance probability:)

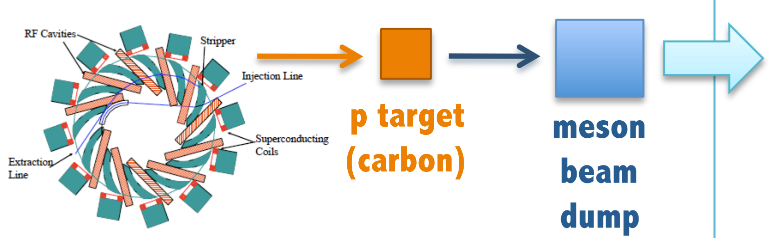
$$
\begin{aligned}
P(\overline{\nu}_\mu \rightarrow \overline{\nu}_e) = & \quad \sin^2\theta_{23}\, \mathbf{\sin^2\theta_{13}} \quad \sin^2\Delta_{31} \\
& - \mathbf{\sin\delta} \quad \mathbf{\sin 2\theta_{13}}\, \sin 2\theta_{23}\, \sin 2\theta_{12} \quad \sin^2\Delta_{31} \sin\Delta_{21} \\
& + \mathbf{\cos\delta} \quad \mathbf{\sin 2\theta_{13}}\, \sin 2\theta_{23}\, \sin 2\theta_{12} \quad \sin\Delta_{31}\, \cos\Delta_{31}\, \sin\Delta_{21} \\
& + \quad \cos^2\theta_{23}\, \sin^2\theta_{12} \quad \sin^2\Delta_{21}
\end{aligned}
$$

+ no matter effects!

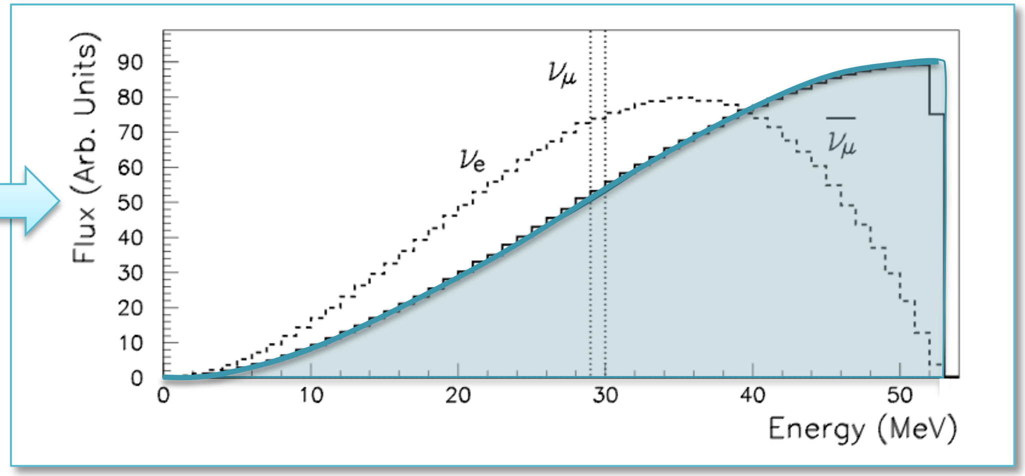
Goal: Independent measurement of θ_{13} and δ_{CP}

Antineutrino beam:

$\pi^+ \rightarrow \mu^+$ decay-at-rest:



800 MeV proton source, e.g. H2+ accelerator



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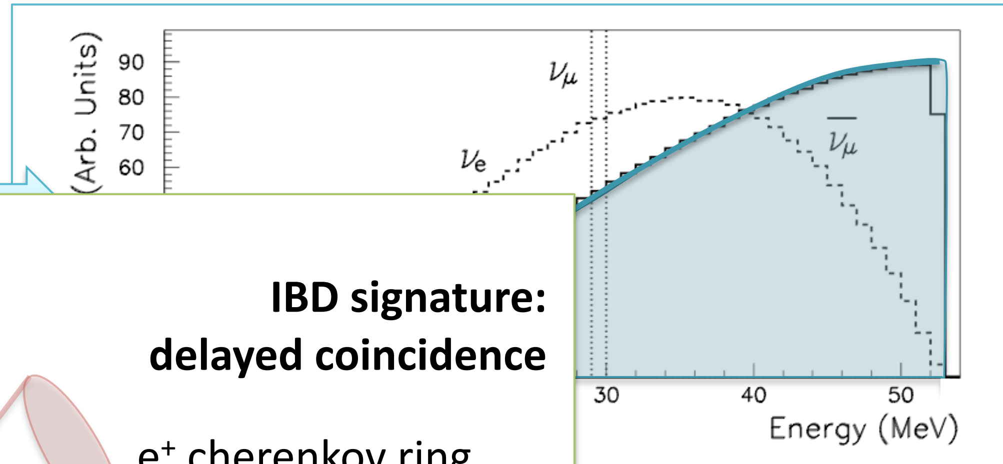
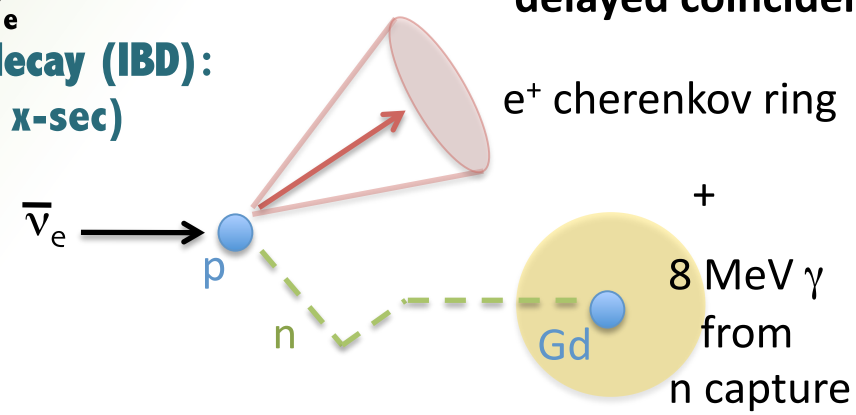


Detector:

Look for $\bar{\nu}_\mu \rightarrow \bar{\nu}_e$
via inverse beta decay (IBD):
(well known x-sec)

IBD signature:
delayed coincidence



Assumes (proposed) 300 kton H_2O cherenkov detector (Gd-doped)

Goal: Independent measurement of θ_{13} and δ_{CP}

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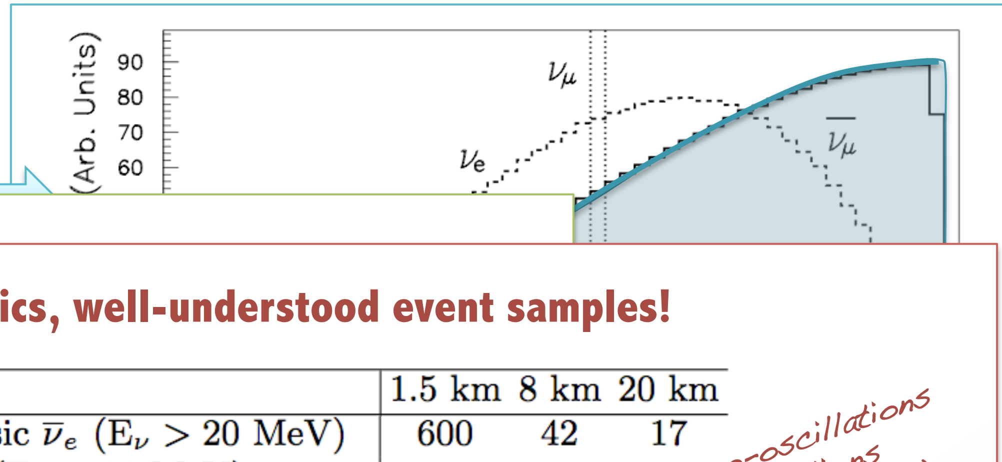

Detector:

Look for $\overline{\nu}_\mu \rightarrow \overline{\nu}_e$
via inverse beta de
(well known x

Assumes (proposed

→ High-statistics, well-understood event samples!

Event Type	1.5 km	8 km	20 km
IBD from Intrinsic $\overline{\nu}_e$ ($E_\nu > 20$ MeV)	600	42	17
IBD Non-Beam ($E_\nu > 20$ MeV)			
atmospheric $\nu_\mu p$ "invisible muons"	270	270	270
atmospheric IBD	55	55	55
diffuse SN neutrinos	23	23	23
ν_e−e Elastic ($E_\nu > 10$ MeV)	16750	1178	470
ν_e−Oxygen ($E_\nu > 20$ MeV)	101218	7116	2840

no-oscillations predictions (backgrounds)

Absolute flux and relative normalization of each source is constrained by ν-e elastic scattering (~20k events, very forward, near detector) and ν_e-O events, respectively.

Goal: Independent measurement of θ_{13} and δ_{CP}

Antineutrino beam:

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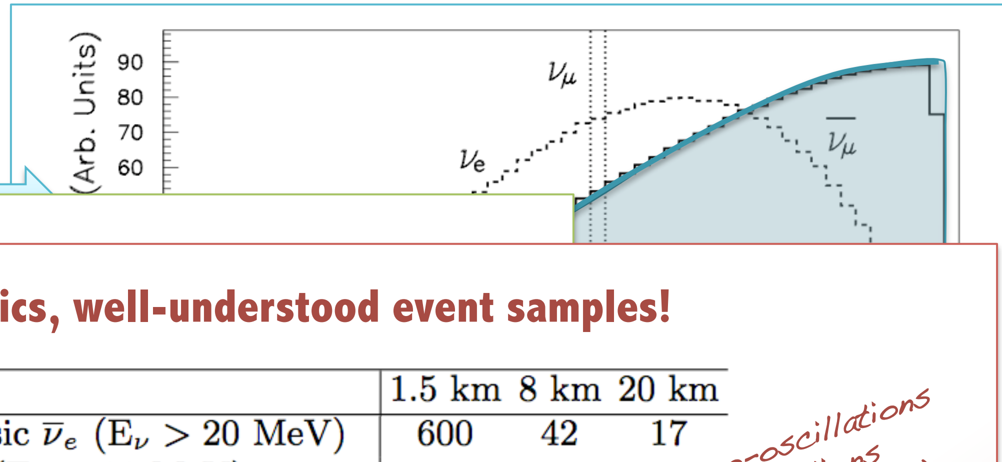

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IBD Oscillation Events ($E_\nu > 20$ MeV)			
$\delta_{CP} = 0^0$, Normal Hierarchy	763	1270	1215
" , Inverted Hierarchy	452	820	1179
$\delta_{CP} = 90^0$, Normal Hierarchy	628	1220	1625
" , Inverted Hierarchy	628	1220	1642
$\delta_{CP} = 180^0$, Normal Hierarchy	452	818	1169
" , Inverted Hierarchy	764	1272	1225
$\delta_{CP} = 270^0$, Normal Hierarchy	588	870	756
" , Inverted Hierarchy	588	870	766

no-oscillations predictions (backgrounds)

expected oscillation signal ($\sin^2 2\theta_{13} = 0.05$)

Advantages of the DAEδALUS design:

• Nature forces the neutrino flux energy distribution to be the same; allows for **flux normalization constraint**

• The important neutrino **cross sections are very well known** (IBD, ν-e; <1% error)

• The **detector systematics are identical** for all baselines (single detector)

• The backgrounds are expected to be very low and will be **measured** directly.

Measurement is
statistics- rather than systematics-limited
+
not sensitive to matter effects (low E)
+
not sensitive to mass hierarchy

Complementary to LBNE:

LBNE has matter effects

DAEδALUS does not

LBNE is mainly a ν experiment (low antineutrino statistics)

DAEδALUS is entirely $\bar{\nu}$ (high antineutrino statistics)

LBNE is a high energy experiment (300 MeV - 10 GeV)

DAEδALUS is a low energy experiment

LBNE varies beam energy

DAEδALUS varies beam distance

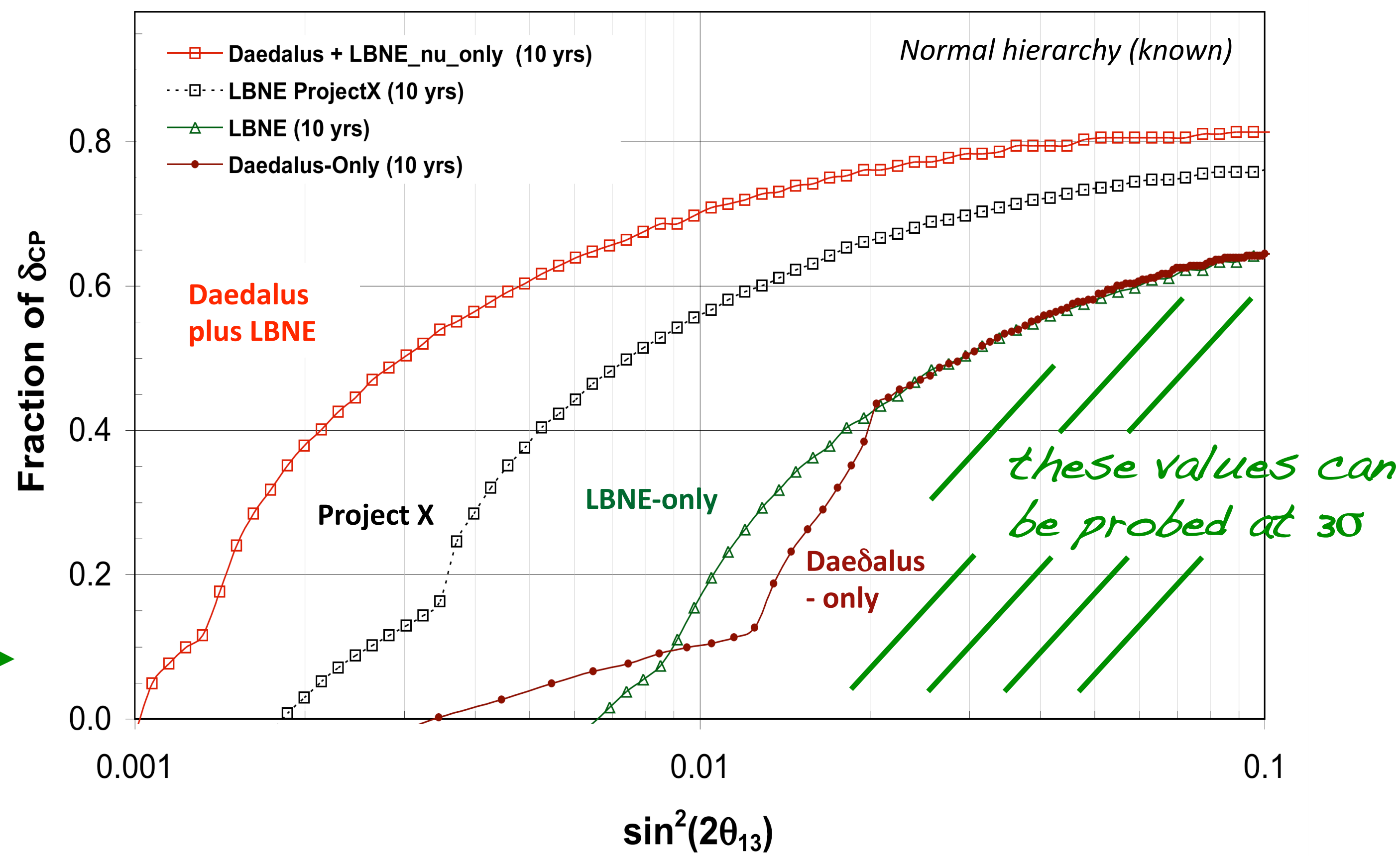
What happens when we combine the two?

Complementary to LBNE:

Quantifying measure:

Fraction of δ_{CP} space where δ_{CP}=0 or 180° (no CP violation) can be excluded at 3σ

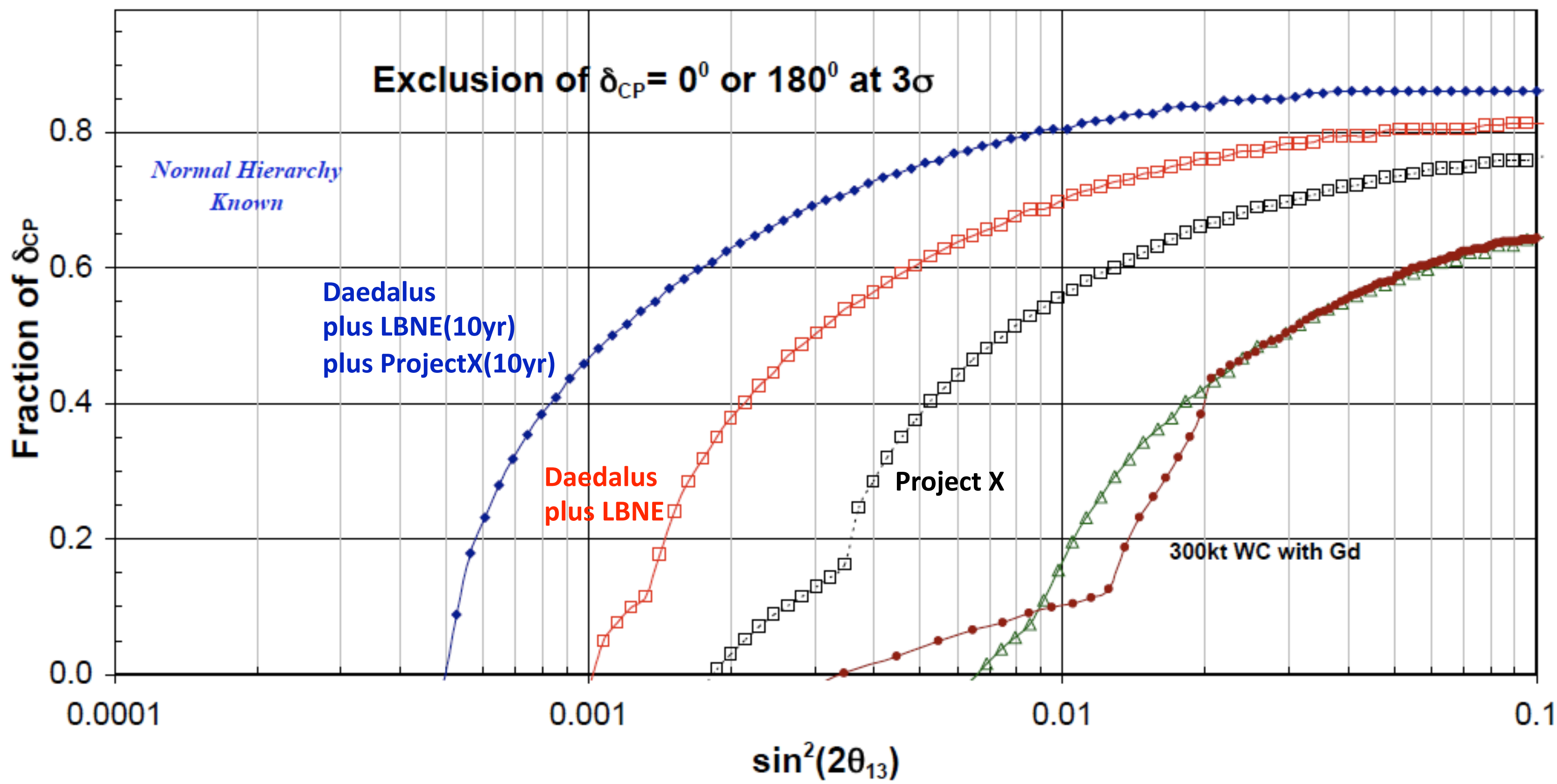
Excellent δ_{CP} sensitivity down to small $\sin^2 2\theta_{13}$ values



DAEδALUS + LBNE → an improvement of x5 over LBNE alone

Complementary to LBNE:

Running longer (+10 yr) with Project-X → another factor of 2 sensitivity gain

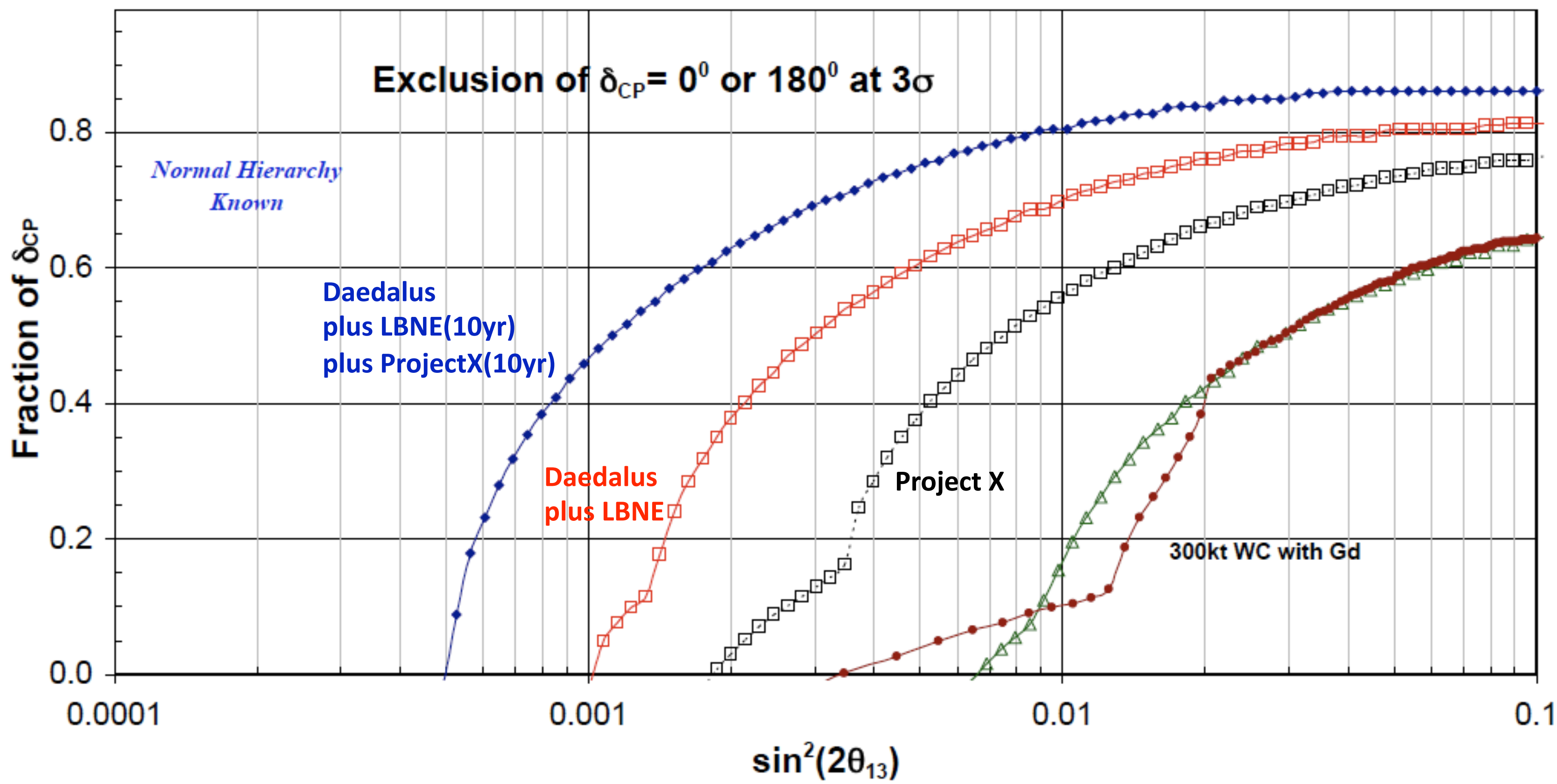


DAEδALUS + LBNE → an improvement of x5 over LBNE alone

DAEδALUS + LBNE + Project-X → gains another x3 factor (x15 total)

Complementary to LBNE:

Running longer (+10 yr) with Project-X → another factor of 2 sensitivity gain



If $\sin^2(2\theta_{13}) < 0.01$, one will need data samples beyond LBNE, such as DAEδALUS, to make CP violation measurements.

Even with Project-X, the sensitivity reach is much better if a DAEδALUS sample is included.

The case for DAEδALUS:

Even though DAEδALUS can make neutrino oscillation measurements as a standalone experiment,

independent confirmation of θ_{13} and δ_{CP}

the real **strength comes from combining** the high-statistics, low-systematics DAEδALUS antineutrino sample with a high-statistics neutrino sample from LBNE and/or Project-X.

+ enhanced sensitivity to θ_{13} and δ_{CP}

The case for DAEδALUS:

+ more physics!

By construction, detector requirements overlap with <100 MeV physics searches: supernova relic neutrinos, proton decay,…

A new accelerator facility (near), and neutrino (multi-)source at DUSEL provides opportunities for new experiments and enhancement of the DUSEL neutrino program:

Other, contributed ideas:

- Coherent neutrino-nucleus scattering
- Searches for non-standard neutrino interactions
- $\sin^2\theta_w$ measurement
- High-Δm^2 oscillation searches
- Axion searches
- Etc…

LBNE + large detector at DUSEL + DAEδALUS