PINGU receiving accelerator neutrinos

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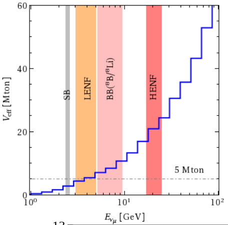
In collaboration with Walter Winter.
Thanks all in PINGU collaboration, especially Jason Koskinen.

Reference: Jian Tang and Walter Winter, "Requirements for a New Detector at the South Pole Reiceiving an Accelerator Neutrino Beam", to appear soon.

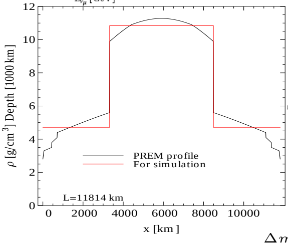
Outline

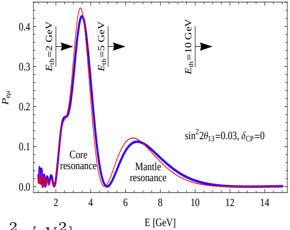
PINGU-I detector with unprecedented fiducial volume

The realistic $V_{\rm eff}$ by MC from Jason Koskinen. See descriptions in Carsten Rott's talk.



- SuperBeam: $E_{\rm peak}$: 2.5 GeV (ν_μ or $\bar{\nu}_\mu$)
- Beta Beam: $E_{\rm peak}$: 9.5 GeV (ν_e), 5.2 GeV ($\bar{\nu}_e$)
- Low Energy Neutrino Factory: $E_{\rm peak}$: 3 GeV (ν_e), 5 GeV (ν_μ)
- High Energy Neutrino Factory: $E_{\rm peak}$: 17 GeV (ν_e), 25 GeV (ν_μ)





$$E_{\rm res} \simeq 13200\ \cos 2\theta_{13}\ \frac{\Delta m^2_{31}\ [{\rm eV}^2]}{\rho\ [{\rm g\ cm}^{-3}]}$$ with $L = 11814$ km

For ρ of the Earth's mantle, $E_{\rm res} \simeq 7$ GeV. For ρ of the Earth's (outer) core, $E_{\rm res} \simeq 3$ GeV.

Proposals for future's accelerator neutrino experiment

Beta beam experiment:

$$\nu_\mu \text{ appearance: } \nu_e \longrightarrow \boxed{\nu_\mu} \text{ for } {}^{18}\text{Ne or } {}^{8}\text{B stored},$$

$$\bar{\nu}_\mu \text{ appearance: } \bar{\nu}_e \longrightarrow \boxed{\bar{\nu}_\mu} \text{ for } {}^{18}\text{He or } {}^{8}\text{Li stored}.$$

♠ ^{18}Ne and ^{6}He accelerated to $\gamma = 350$ with a 500 kton WC detector at a baseline of 650 km
♠ ^{8}B and ^{8}Li accelerated to $\gamma = 656$ and $\gamma = 390$, respectively. Maximal gamma allowed by the upgraded SPS at CERN? Detector at 7000 km. ref: 0907.2379 [hep-ph]

Neutrino factory experiment:

$$\nu_\mu \text{ appearance: } \nu_e \longrightarrow \boxed{\nu_\mu} \text{ for } \mu^+ \text{ stored } (-),$$

$$\bar{\nu}_\mu \text{ disappearance: } \bar{\nu}_\mu \longrightarrow \boxed{\bar{\nu}_\mu} \text{ for } \mu^+ \text{ stored } (-).$$

♠A two-baseline HENF: $E_\mu = 25\,\text{GeV}$ with a $L_1 \simeq 4000\,\text{km}$ and a $L_2 \simeq 7500\,\text{km}$ baseline.
♠A one-baseline LENF: $E_\mu = 10\,\text{GeV}$ with a baseline of $L \simeq 2200\,\text{km}$.

Superbeam experiment:

$$\nu_e \text{ appearance: } \nu_\mu \longrightarrow \boxed{\nu_e} \text{ for } \pi^+ \text{ decays},$$

$$\nu_\mu \text{ disappearance: } \nu_\mu \longrightarrow \boxed{\nu_\mu} \text{ for } \pi^+ \text{ decays}.$$

♠Take the 120 GeV configuration of LBNE as an example.

♠200 kton WC detector at 1300 km.

Requirements of PINGU-I for accelerator neutrino experiments

Beta beam experiment (replace the magic baseline by PINGU):

- ☺ Good ν_μ flavor identification and $(\nu_e\,, \nu_\tau)$ "misID"$\lesssim 1\%$
- ☺ Energy threshold $E_{\rm th} \lesssim 5$ GeV.
- ☺ Energy resolution better than $50\% \cdot E$.
- ☺ Effective fiducial volume $V_{\rm eff} \gtrsim 1$ Mton

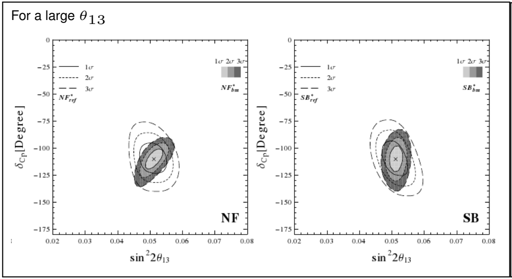
Neutrino factory experiment (replace the magic baseline by PINGU or use a single baseline LENF by PINGU):

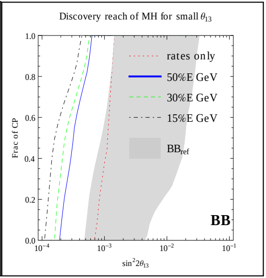
- ☺ Good ν_μ flavor identification and $(\nu_e\,, \nu_\tau)$ "misID"$\lesssim 1\%$
- ☺ Energy threshold $E_{\rm th} \lesssim 2$ GeV.
- ☹ Energy resolution better than $10\% \cdot E$ (No CID!).
- ☺ Effective fiducial volume $V_{\rm eff} \gtrsim 5$ Mton

Superbeam experiment (with a single baseline PINGU):

- ☹ Good ν_e flavor identification and $(\nu_\mu\,, \nu_\tau)$ "misID"$\lesssim 1\%$ (*HARD!*)
- ☺ Energy threshold $E_{\rm th} \lesssim 2$ GeV.
- ☺ Energy resolution better than $50\% \cdot E$.
- ☺ Effective fiducial volume $V_{\rm eff} \gtrsim 5$ Mton

Summary



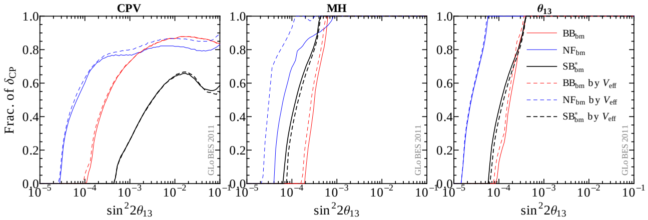


- if θ_{13} is large, θ_{13} and δ_{CP} can, under optimistic assumptions, be measured with a single baseline to PINGU-I detector.
- if θ_{13} is small, PINGU-I may replace the long baseline for the mass hierarchy measurement or degeneracy resolutions at BB (ROBUST)
  or apply to NF with a good energy resolution.

Backup

Values used in the previous slides.

Experiment	Setups	misID	misIDtracks	$E_{\rm th}$	Energy res.	Fid. mass
Beta beam	$\mathrm{BB_{bm}}$, $\mathrm{BB^*_{bm}}$	0.001	n/a	2 GeV	$50\% \cdot E$	5 Mt
Neutrino factory	$\mathrm{NF_{bm}}$, $\mathrm{NF^*_{bm}}$	0.001	n/a	2 GeV	$10\% \cdot E$	5 Mt
Superbeam	$\mathrm{SB^*_{bm}}$	0.01	0.01	2 GeV	$20\% \cdot E$	5 Mt



LENF with PINGU-I (L^{3}NF yet to be tested)