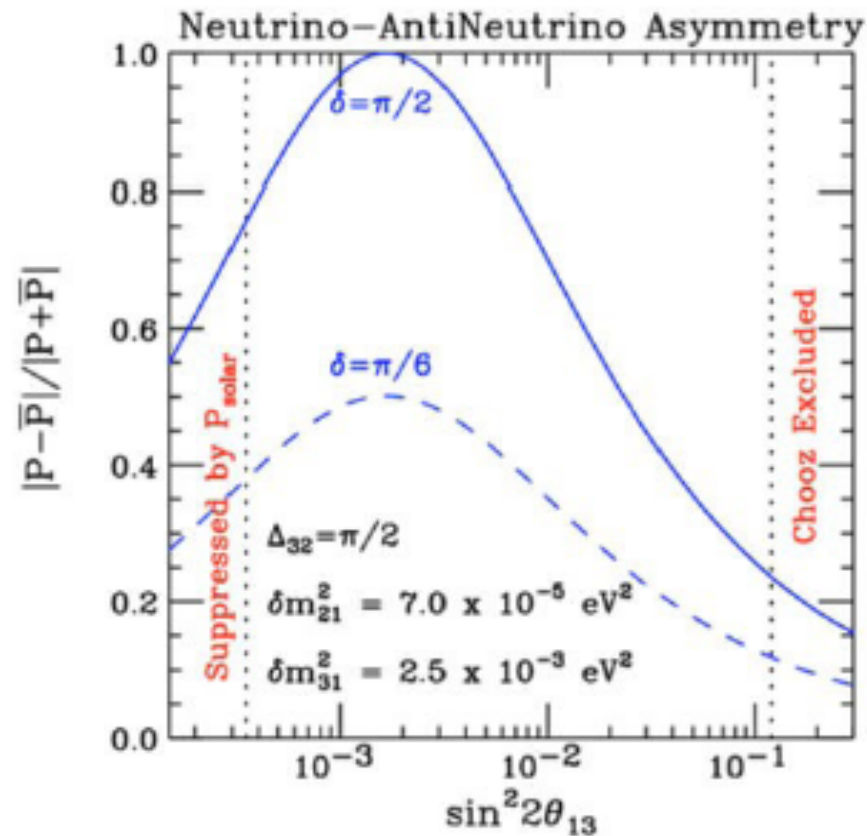

Systematics and Measuring CP-Violation In the Neutrino Sector

Intensity Frontier: Neutrino Physics Workshop
24 October, 2011

Jorge G. Morfin, Fermilab

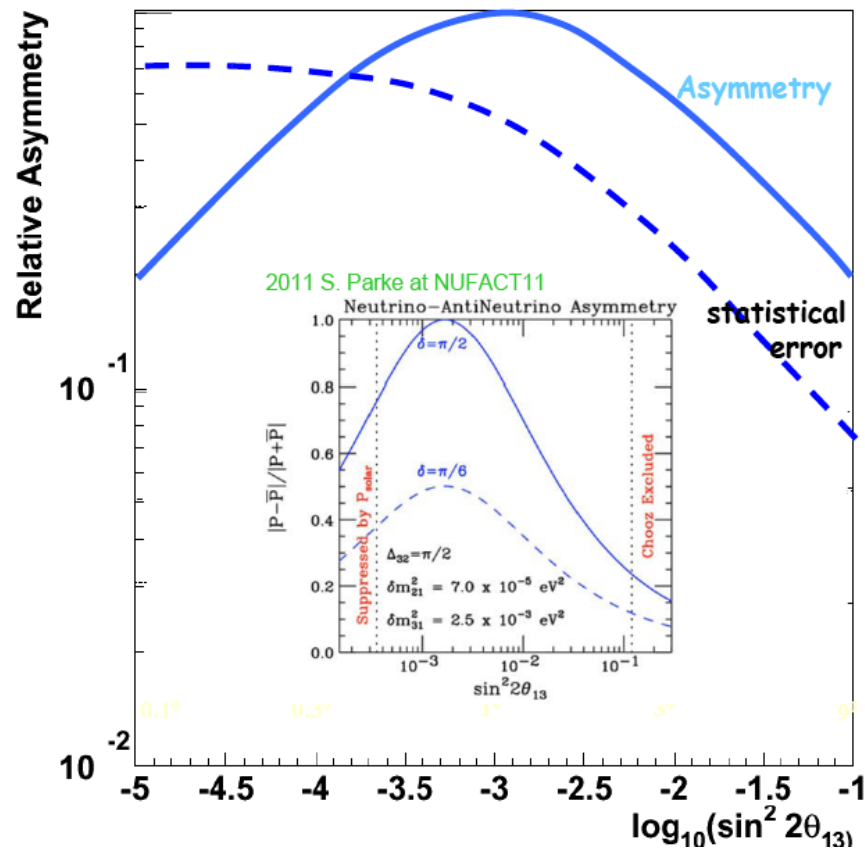
Experimental Measurement of CP Violation

$$\frac{P(\nu_e \rightarrow \nu_\mu) - \overline{P}(\nu_e \rightarrow \nu_\mu)}{P(\nu_e \rightarrow \nu_\mu) + \overline{P}(\nu_e \rightarrow \nu_\mu)} = -A_{\text{CP}} \propto -\frac{\sin\delta \sin(\Delta m_{12}^2 L/4E) \sin\theta_{12} \sin\theta_{13}}{\sin^2\theta_{13} + \text{solar term...}}$$



Statistical Errors

$$\frac{P(\nu_e \rightarrow \nu_\mu) - \overline{P(\nu_e \rightarrow \nu_\mu)}}{P(\nu_e \rightarrow \nu_\mu) + \overline{P(\nu_e \rightarrow \nu_\mu)}} = -A_{CP} \propto -\frac{\sin\delta \sin(\Delta m_{12}^2 L/4E) \sin\theta_{12} \sin\theta_{13}}{\sin^2\theta_{13} + \text{solar term...}}$$



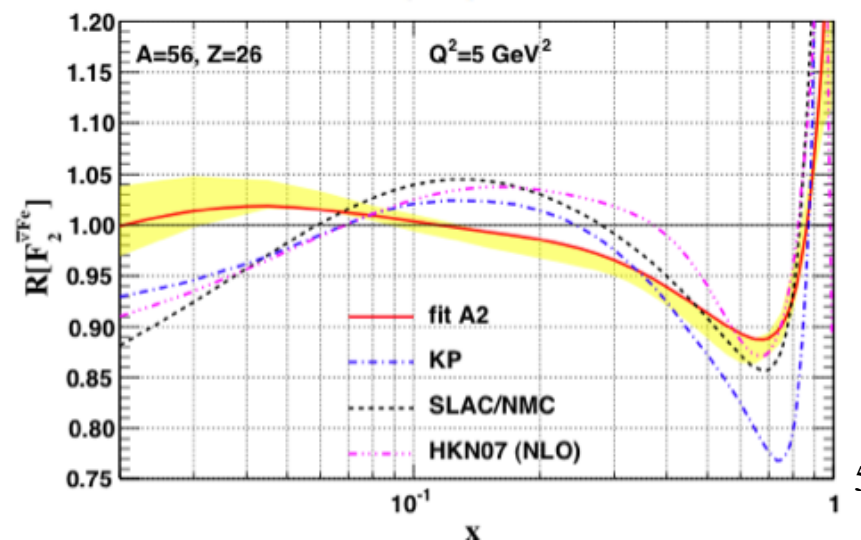
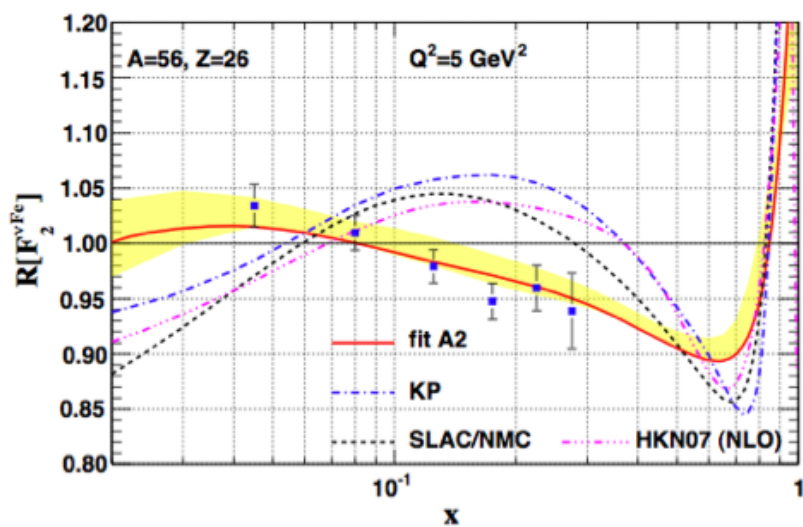
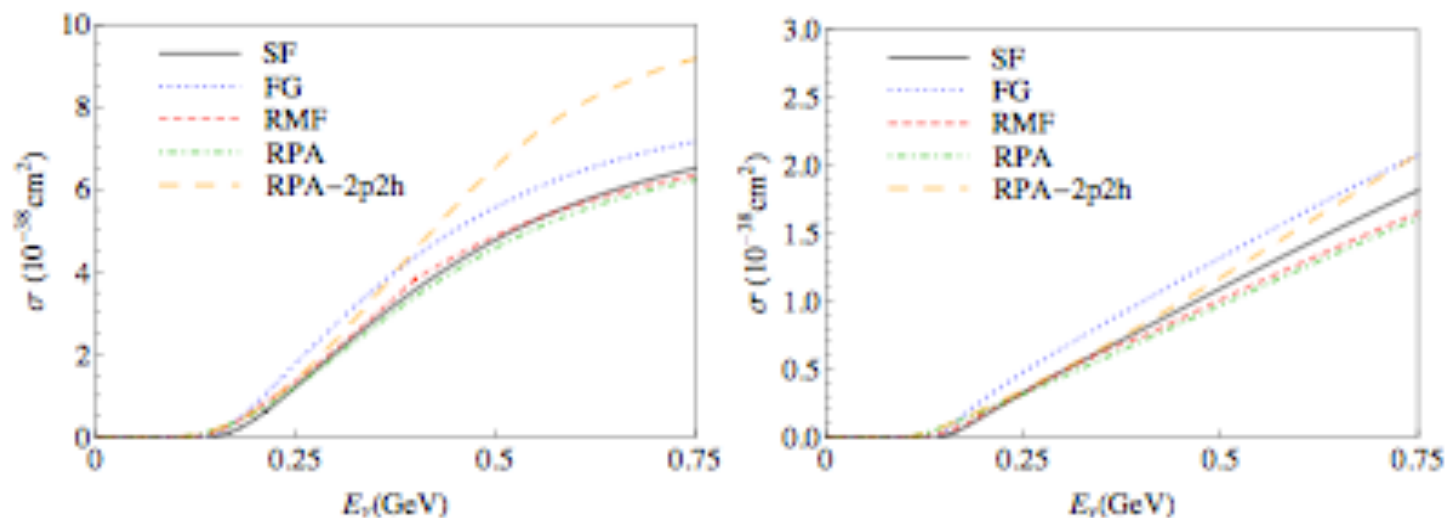
Systematic Errors in Measuring CP Violation

$$\frac{P(\nu_e \rightarrow \nu_\mu) - \overline{P}(\overline{\nu}_e \rightarrow \overline{\nu}_\mu)}{P(\nu_e \rightarrow \nu_\mu) + \overline{P}(\overline{\nu}_e \rightarrow \overline{\nu}_\mu)} = -A_{CP} \propto -\frac{\sin\delta \sin(\Delta m_{12}^2 L/4E) \sin\theta_{12} \sin\theta_{13}}{\sin^2\theta_{13} + \text{solar term...}}$$

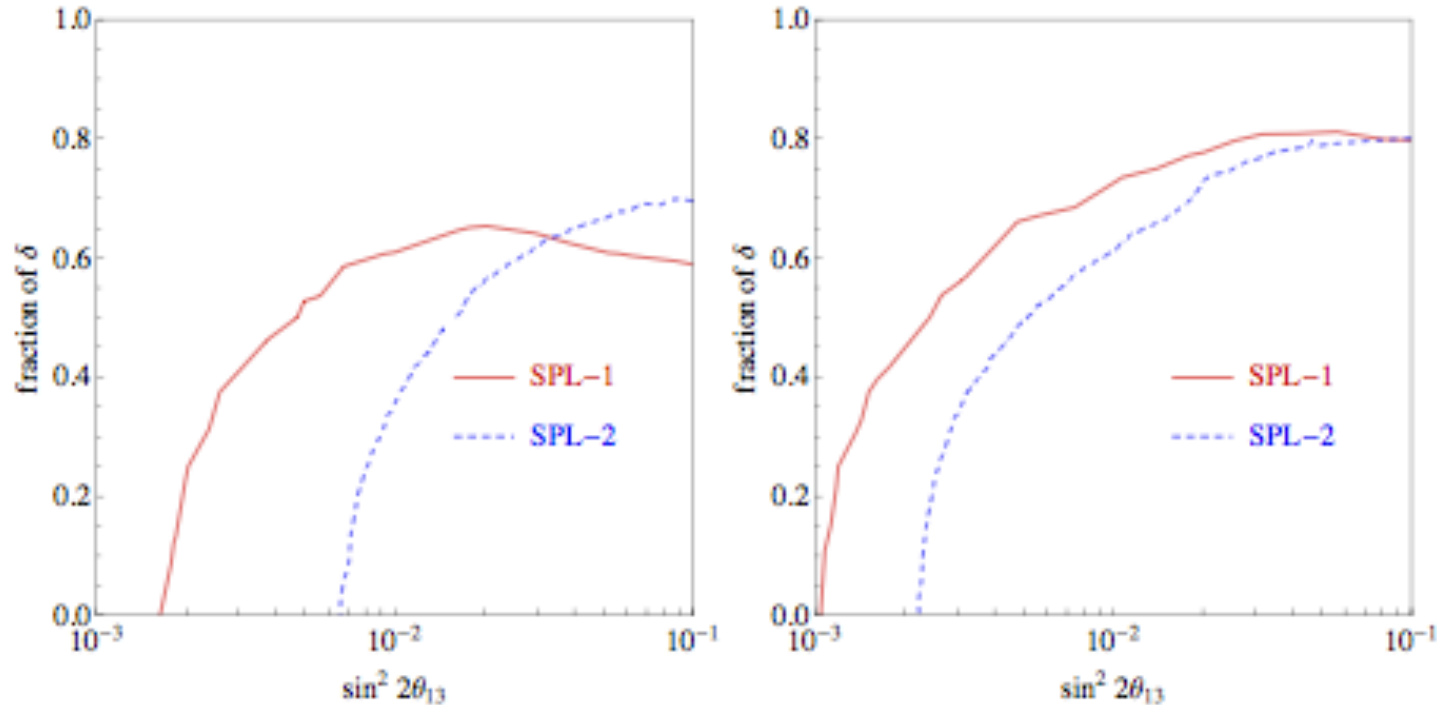
- ◆ We measure a convolution of energy dependent cross sections \otimes energy dependent nuclear effects.
- ◆ This convolution is different for neutrino and anti-neutrino and, since varying E_ν distributions near and far, different for near and far detectors.
- ◆ On top of this is the different relative flux between neutrino and antineutrino – near and far.
- ◆ For horn-beams:
 - ▼ large neutrino background in the antineutrino beam
 - ▼ background is from Neutral Current feed-down at higher E_ν .
- ◆ **There is a systematic error associated with each of these quantities/steps.**

Example: Unknown Nuclear Effects

QE cross section Dependence on Nuclear Model of Initial Nucleon Kinematics - D. Meloni



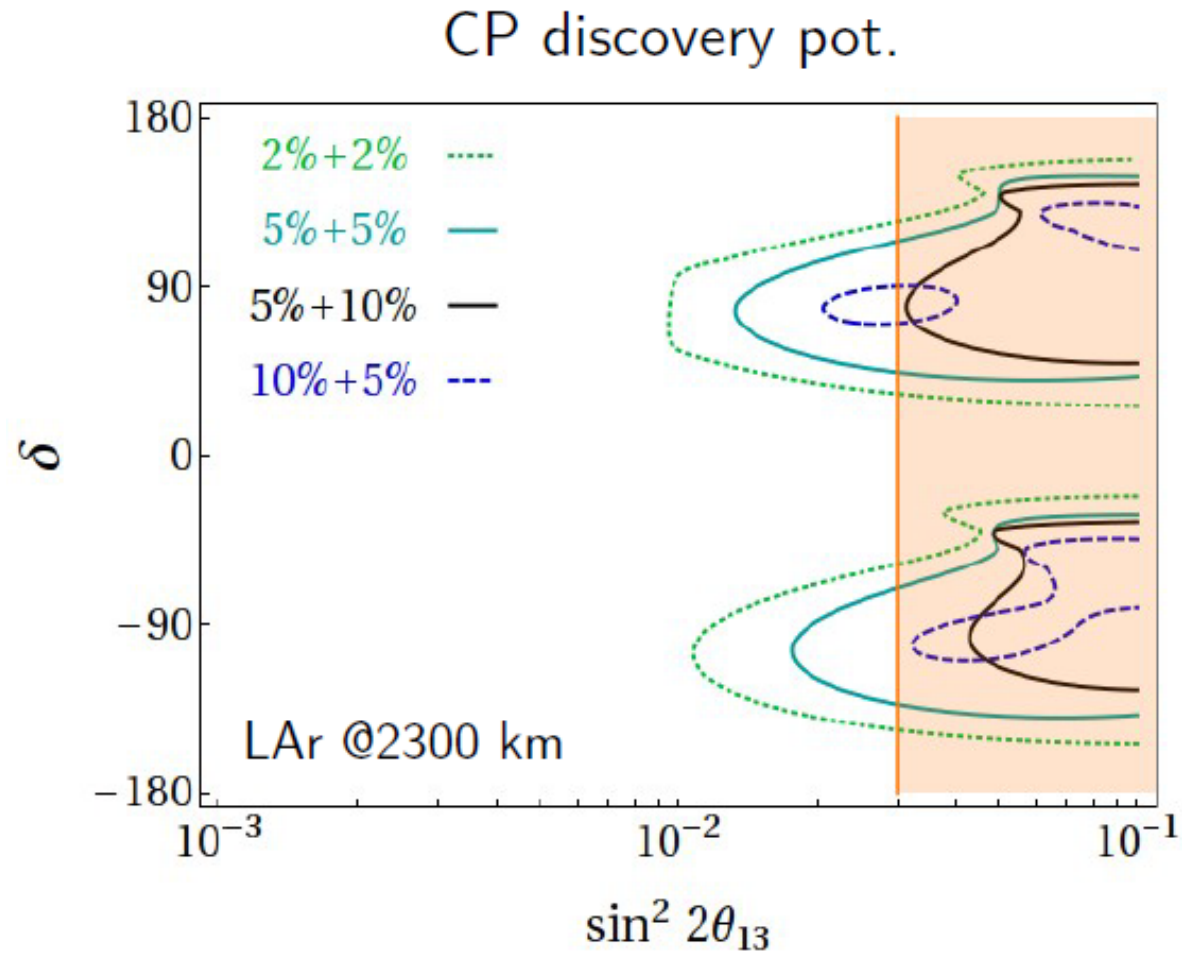
Effect of Systematic Errors on CP Discovery



Coloma, Fernandez-Martinez

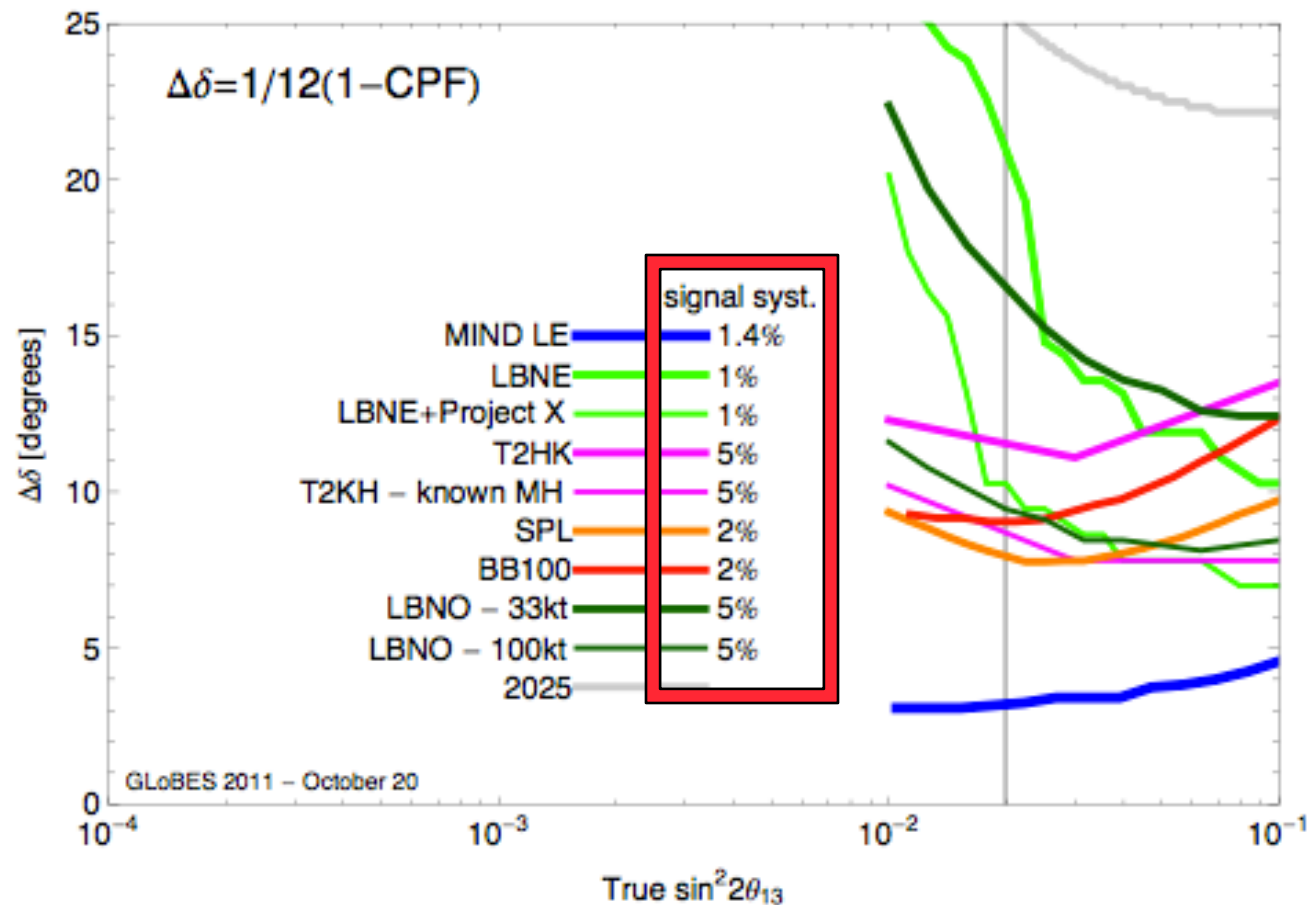
FIG. 4: Effect of the systematic errors on the CP discovery potential of the SPL Super-Beam at a 130 km (solid red lines) and 650 km (dashed blue lines) baseline. The left panel assumes “large” systematic errors of 10% and 20% for the signal and background respectively while the right panel assumes “small” systematics of 2.5% and 5% for signal and background. Fig. 3 corresponds to an intermediate case of 5% and 10% for signal and background.

Effect of Systematic Errors on CP Discovery



Comparing Systematic Errors

- ◆ How do the proponents arrive at these quoted systematic errors?



Proposal: Intensity Frontier (Neutrino) Systematic Error Working Group

- ◆ Proposing to spend \$ Billion(s) on new facilities.
- ◆ Need to have thorough understanding of capabilities of facilities.
- ◆ Particularly for larger θ_{13} , systematics are extremely important.
- ◆ Many of the types of systematics are similar for different facilities / detectors.
- ◆ **Join forces to bring collective skills and knowledge to focus on the challenge of estimating systematics.**
- ◆ Goal is to construct full covariant error matrix for each experiment based on same input to understand, for example, which errors factor out in the measurement of A_{CP} .