ν / ν̄ Identification in a Liquid Scintillator Detector

Towards a novel decay-at-rest-based neutrino CPV framework

M. Grassi [APC/CNRS (Paris FR)], **F. Pessina** [PUC (Rio de Janeiro BR)]

A. Cabrera [APC/CNRS (Paris FR) & LNCA (Chooz FR)], **S. Dusini** [INFN (Padova IT)], **H. Nunokawa** [PUC (Rio de Janeiro BR)], **F. Suekane** [Tohoku U. (Sendai JP)]

Introduction

Establishing leptonic CP violation pivotal to better understand matter-antimatter asymmetry in Universe

Why yet another CPV Experimental Framework?

Achieve **better systematics uncertainties** by detecting both ν and ν̄ produced via decay-at-rest π and μ using a **liquid scintillator** detector

Charged-current interactions entirely in **quasi-elastic scattering** regime (E(ν) < 53 MeV)

In-vacuum oscillation (no matter effects)

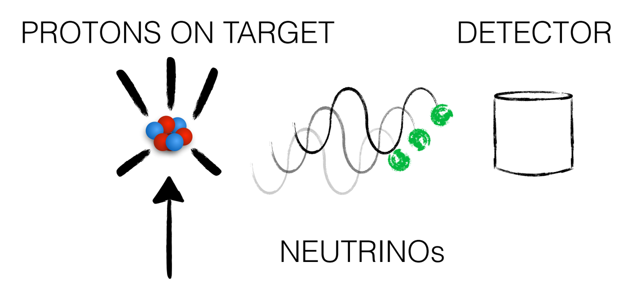
ν̄/ν emission is fully correlated & isotropic

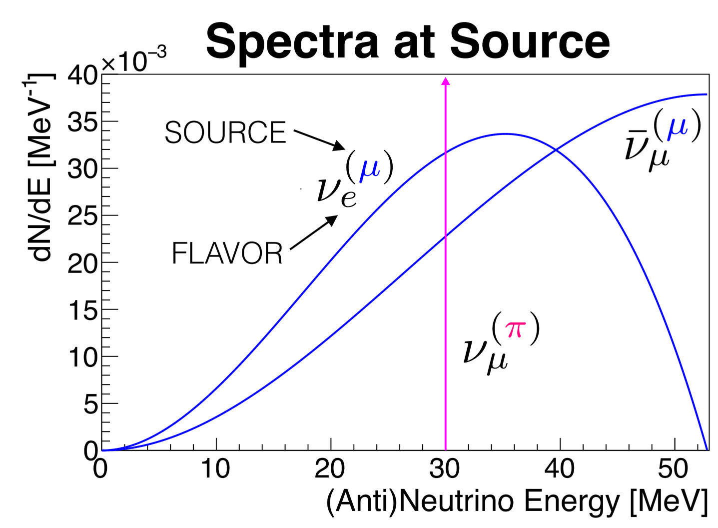
Negligible uncertainty arising from **beam profile**

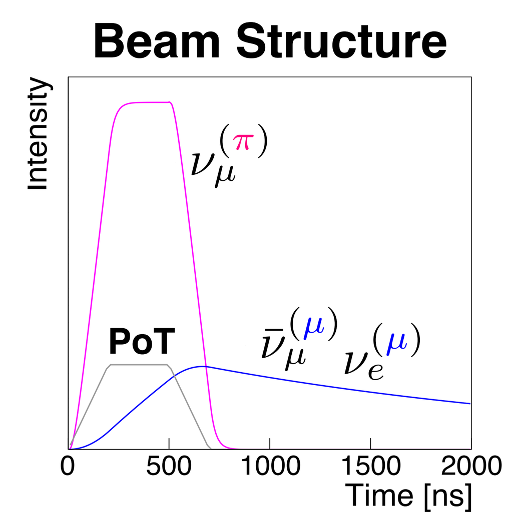
Neutrino Production & Oscillation

$$\pi^+ \to \mu^+ + \nu_\mu^{(\pi)}$$

$$\mu^+ \to e^+ + \nu_e^{(\mu)} + \bar{\nu}_\mu^{(\mu)}$$

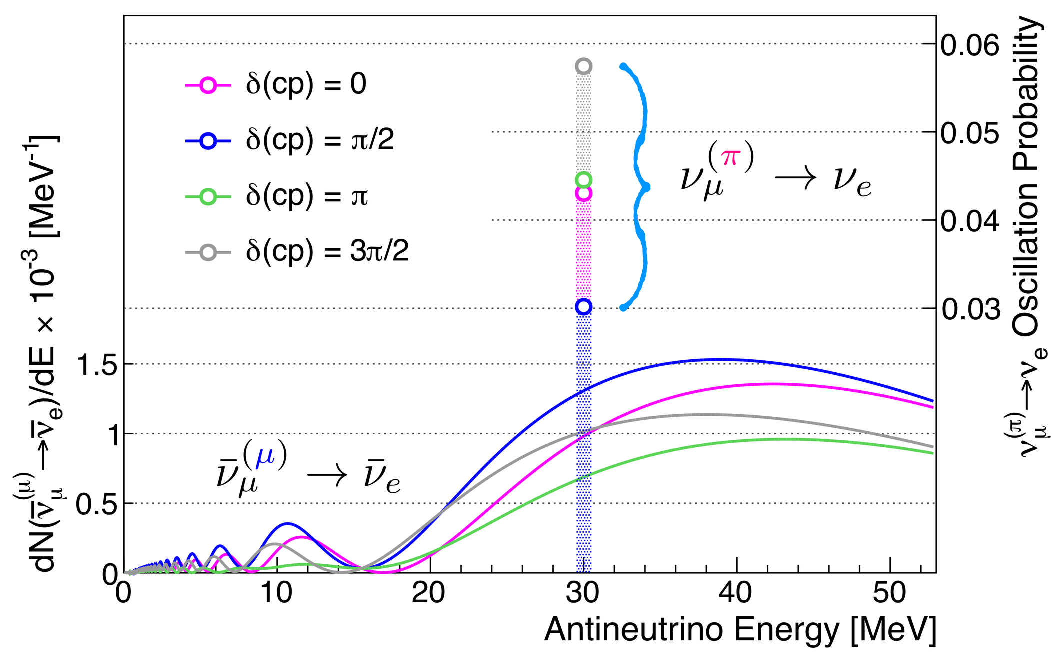






Determine δ_{CP} by comparing neutrino and antineutrino oscillation probabilities

Oscillated Neutrino Spectra (L = 16km)



Neutrino Detection

Exploit Charged-Current Quasi-Elastic interactions yielding positrons and electrons in the final state

Antineutrino: Inverse beta decay (IBD) on H

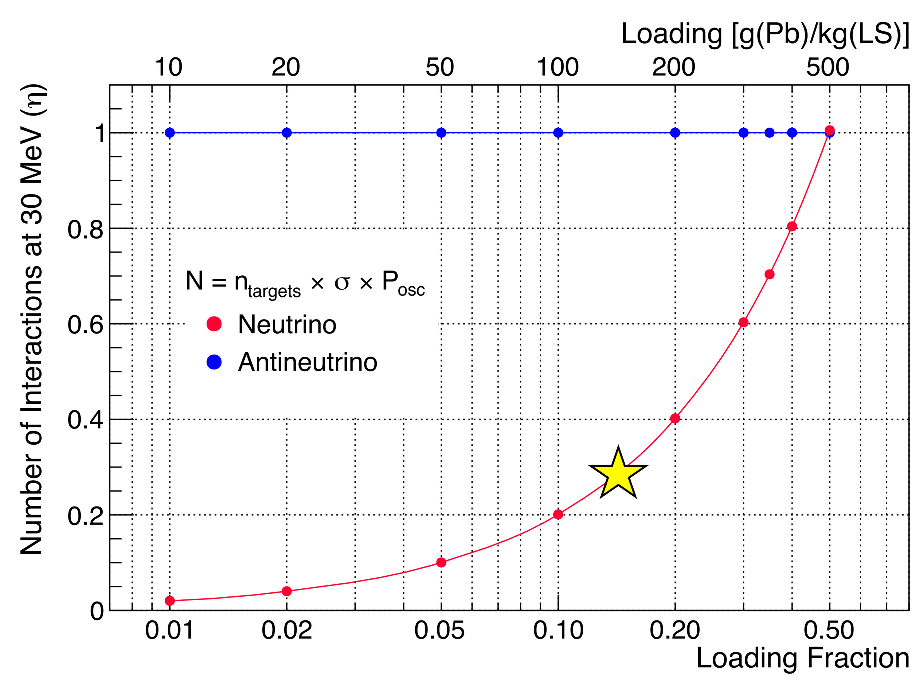
$$\bar{\nu}_e + p \to e^+ + n$$

Neutrino: element with cross-section larger than IBD to be **loaded** into liquid scintillator. Eg Pb

$$\nu_e + {}^{208}\mathrm{Pb} \to {}^{208}\mathrm{Bi}^* + e^-$$

$$^{208}\mathrm{Bi}^* \to {}^{208-\mathrm{Y}}\mathrm{Bi} + \mathrm{X}\gamma + \mathrm{Y}n$$

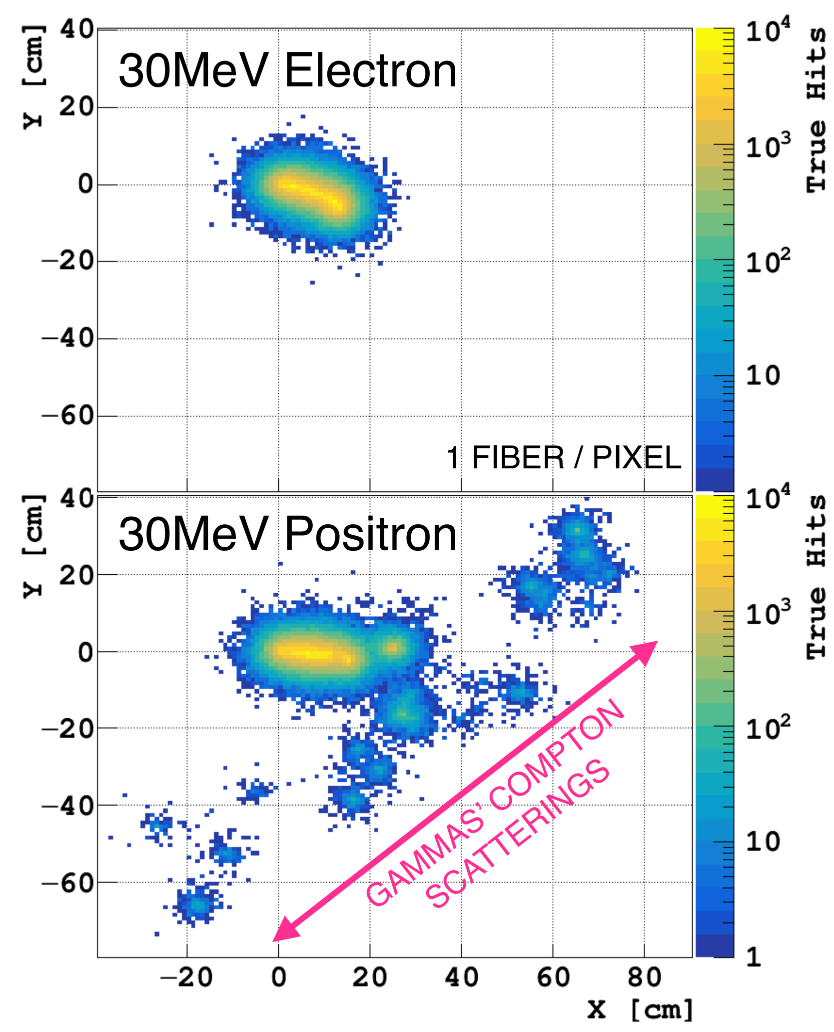
Loading expressed as **η** = N(Pb interactions)/N(IBD)



Signal

Visualize interactions: opaque liquid scintillator readout by a dense lattice of wavelength shifting fibers

➤ $\nu_e/\bar{\nu}_e$ tagging capabilities (G4 Sim)



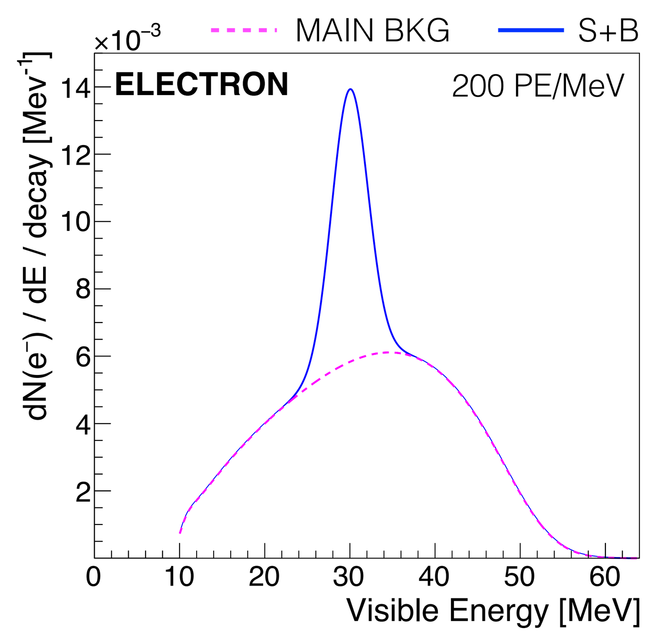
Backgrounds

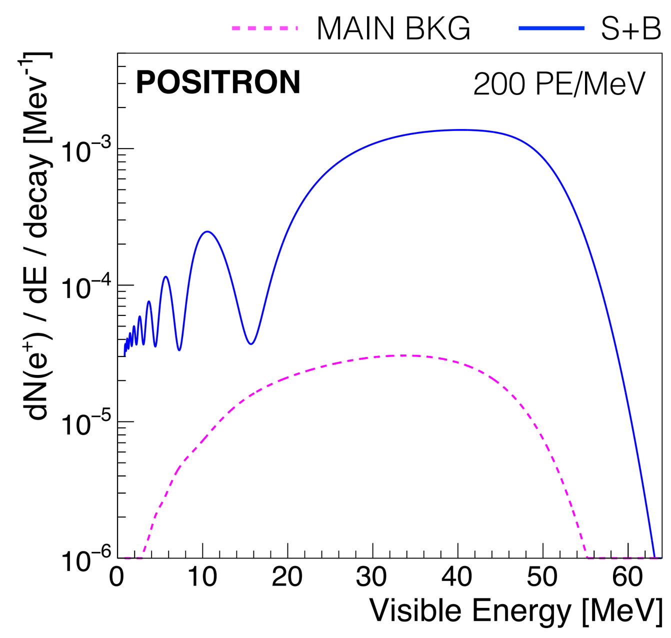
Natural radioactivity negligible above 5MeV

Beam-off backgrounds: statistical subtraction (beam-off data)

Beam-on backgrounds: reduction thanks to

Electron	*Positron*
μ^+: $\nu_e \to \nu_e$ (MAIN)	μ^-: $\bar{\nu}_e \to \bar{\nu}_e$ (MAIN)
Timing w.r.t. Beam	Capture in target
μ^-: $\nu_\mu \to \nu_e$	π^-: $\bar{\nu}_\mu \to \bar{\nu}_e$
Capture + oscillation + timing	Capture + oscillation + timing



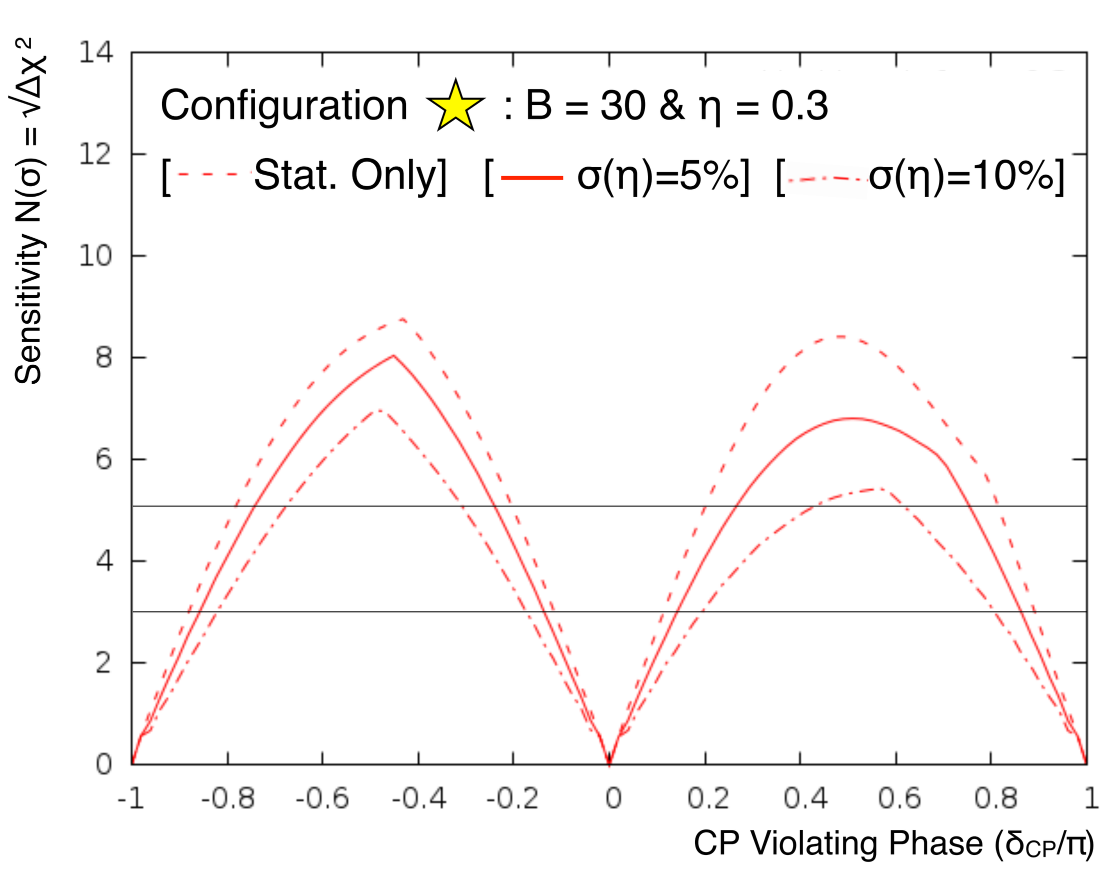


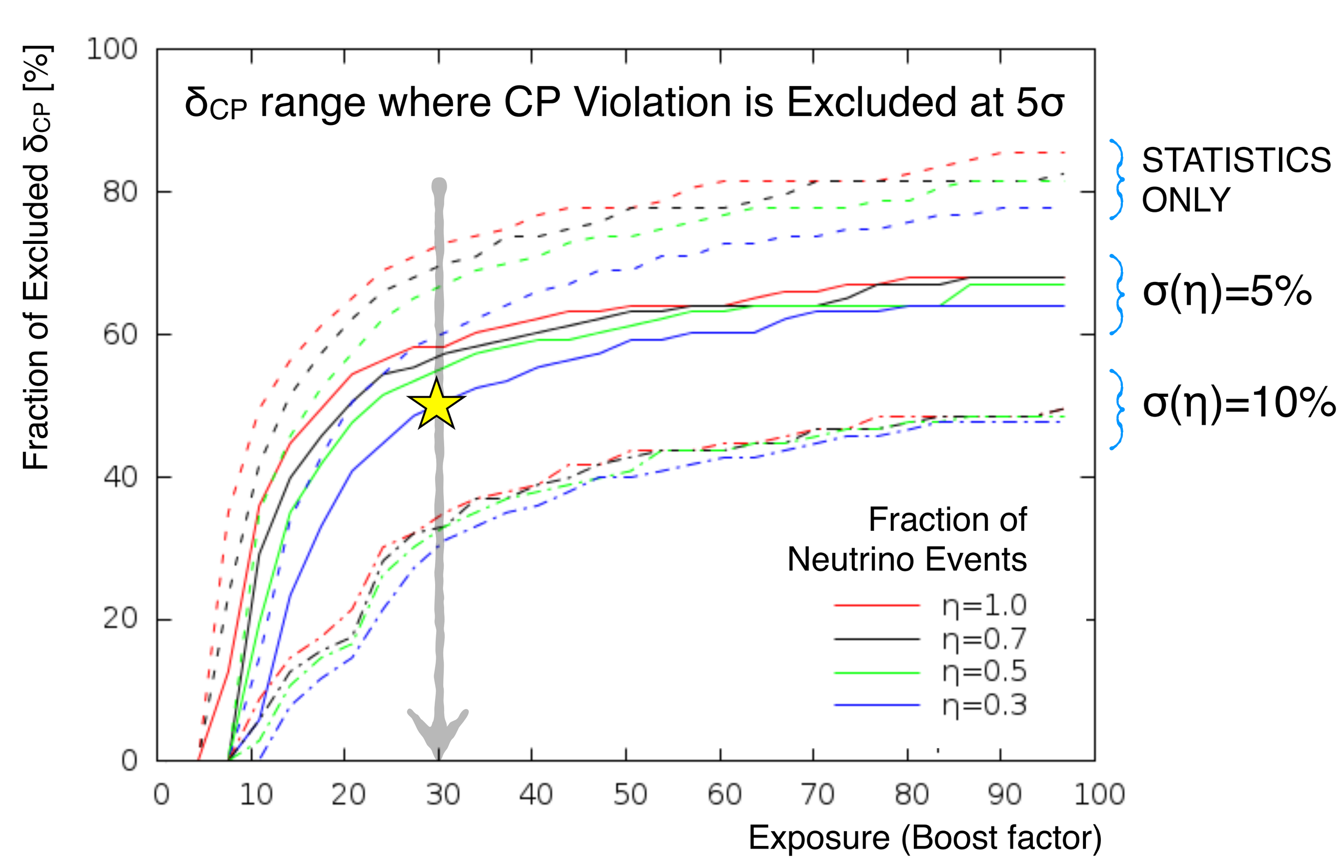
Results: Sensitivity to CP Violation

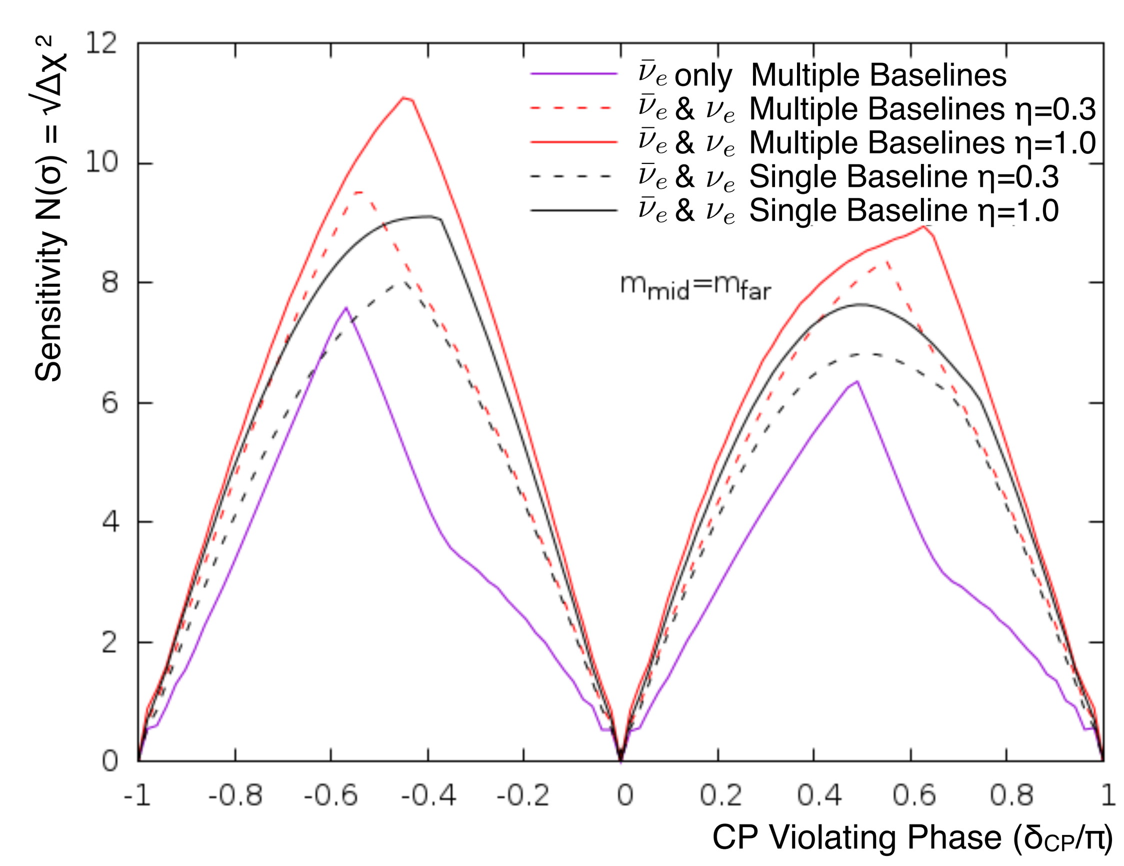
Sensitivity via **χ² analysis** ✻ Main external uncertainty: $\sin^2(\theta_{23})$ = 0.5 ± 0.04 [Capozzi 2017] ✻ Main **systematic uncertainty**: cross section of loaded element (η)

Exposure modeled through **scale factor B** ✻ Normalization: **B1** ≡ 100 kton detector × 5 years × 1MW beam × 10% proton fraction

Experimental configuration (☆) implies liquid scintillator loading < 20% & results in 10 years at a 5 MW beam facility (eg. European Spallation Source)







Past proposals: exploit oscillation-induced distortions in the $\bar{\nu}_e$ appearance spectrum at **multiple baselines** [Minakata 1997, Conrad 2010] disregarding ν_e.

Using same exposure, our approach yields **better sensitivity using a single-baseline** configuration by detecting $\bar{\nu}_e$ and ν_e at the same time (rightmost panel).

This technique can be clearly implemented in a multiple-baseline configuration, resulting in additional sensitivity (rightmost panel).

Email: mgrassi@in2p3.fr

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