Introduction to sub-groups
---Personal view on phenomenology---

Tokyo Metropolitan University

Osamu Yasuda

INTERNATIONAL NEUTRINO FACTORY AND SUPERBEAM SCOPING STUDY MEETING
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Possible works (a la Nagashima-san)

- Summarize SB, BB, NF → **Palladino, Hernandez, de Gouvea**
- Identify weakness of previous studies
- Physics performance as a function of E_ν and L
- Define a staged approach, phase 1,2,3
- Role of NF if θ_{13} is large
- Ultimate precision of parameters
- Describe the way of removing degeneracy etc
- Physics gain at NF of >1 far detectors
- Sensitivity to unitarity and physics beyond SM
- Comparison with other means
- Common tools (Globes etc) → **Huber**
- Impacts of NF on other fields

- Identify weakness of previous studies

  - Is the background fraction f_B really 10^{-5}?

  - What is the realistic or expected value for the threshold energy E_{th} ?
    (for NF **Huber-Lindner-Winter '02** assumed E_{th} =4GeV)

These factors f_B and E_{th} are crucial for estimation of sensitivity and optimization.
← Input from **Detector Subgroup** is important.

▶ Is uncertainty of the matter density really 5%?

Some works (e.g., **Huber et al.**) assume $\Delta\rho/\rho = 5\%$.

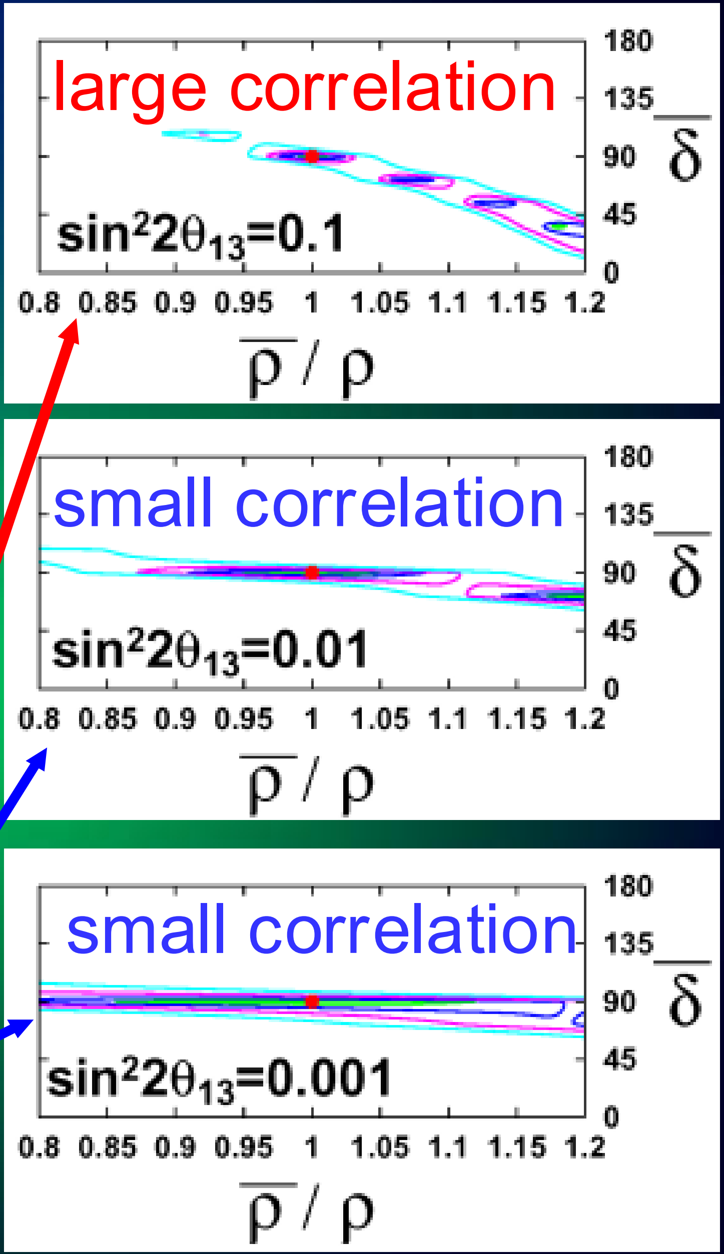
R. Geller @nufact01 + private communication

"The accuracy of estimates of the average density along the neutrino beam are almost certainly at worst +-10%, and are probably within +-5%." "But these are ballpark guesses anyway and the estimation of rigorous errors would be a tremendous work." "The point of our talk was to describe the nature of the errors rather than quoting figures (such as 5% or 10%)."

What happens to optimized (E_μ , L) if $\Delta\rho/\rho$ = 10%?

The case of $\Delta\rho/\rho$ = 10% should be also examined, or ask for opinions from more geologists on $\Delta\rho$.

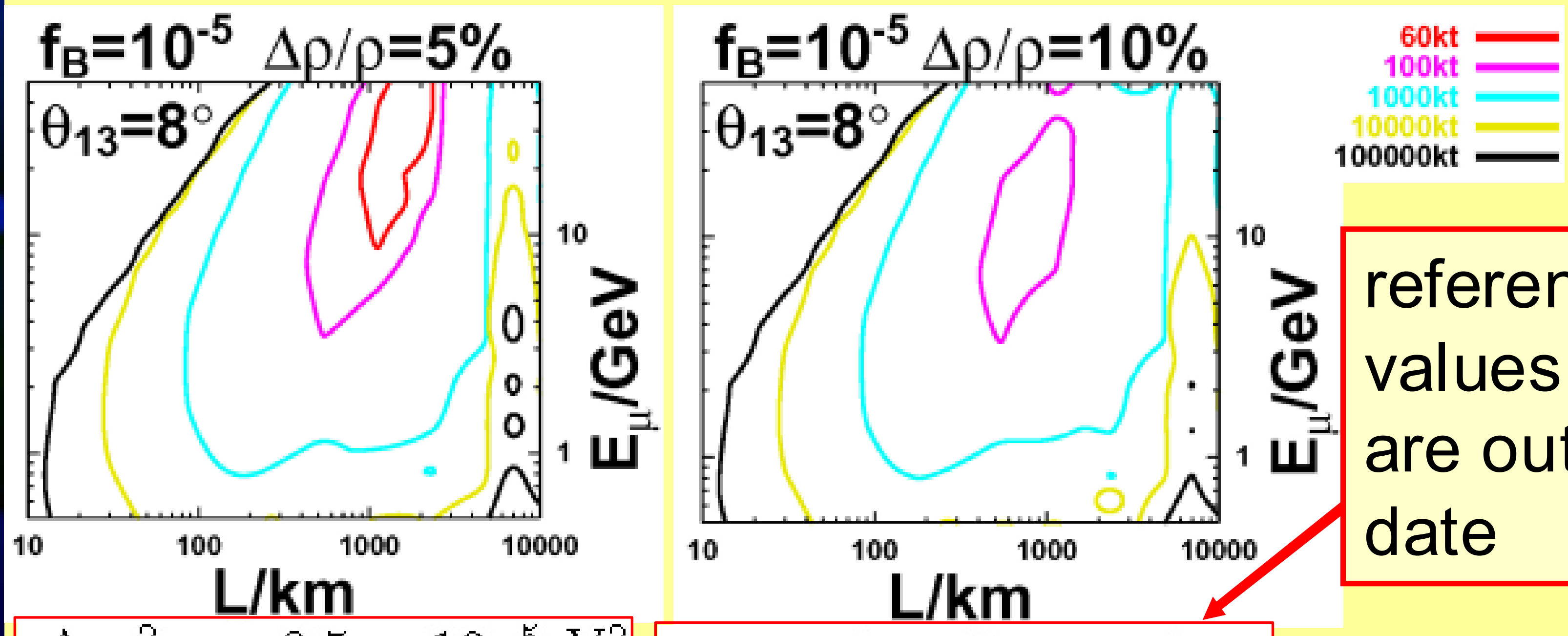
The problem may not be so serious, though, because correlation of errors in ρ and δ is not so large for $\sin^2 2\theta_{13} < 10^{-2}$.



Physics performance as a function of E_ν and L

▶ In most of the works, the sensitivity contour plot in the (E_ν, L) or (E_μ, L) plane has not been given. To make optimization easier to see, this kind of plot is useful.

(example) NF with $10^{21}\mu$ **Pinney-OY '01**



$\Delta m^2_{32} = 3.5 \times 10^{-5}\mathrm{eV}^2$

$\Delta m^2_{21} = 1.8 \times 10^{-5}\mathrm{eV}^2$

reference values are out of date

- Define a staged approach, phase 1,2,3

→ Describe the optimal way after the affirmative (or negative) signal is found for each case.

- [case 1] $10^{-2}<\sin^2 2\theta_{13}$

Reactor and/or SB-I will see the affirmative signal.

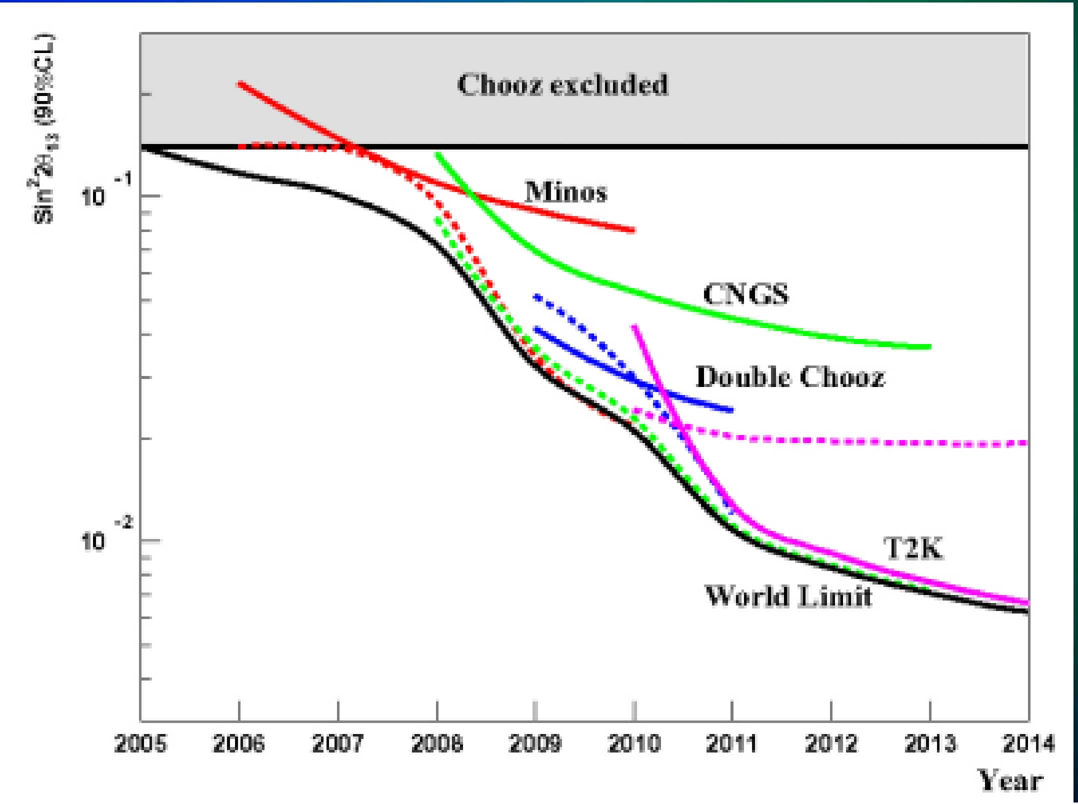
- [case 2] $10^{-3}<\sin^2 2\theta_{13}<10^{-2}$

SB-II and/or BB will see the affirmative signal.

- [case 3] $\sin^2 2\theta_{13}<10^{-3}$

NF (+maybe high γ BB) will be the experiments which have potential to see the affirmative signal.

▶ It is useful to plot the expected sensitivity to $\sin^2 2\theta_{13}$ as a function of time and discuss the strategy depending on whether each experiment gives affirmative/negative results.



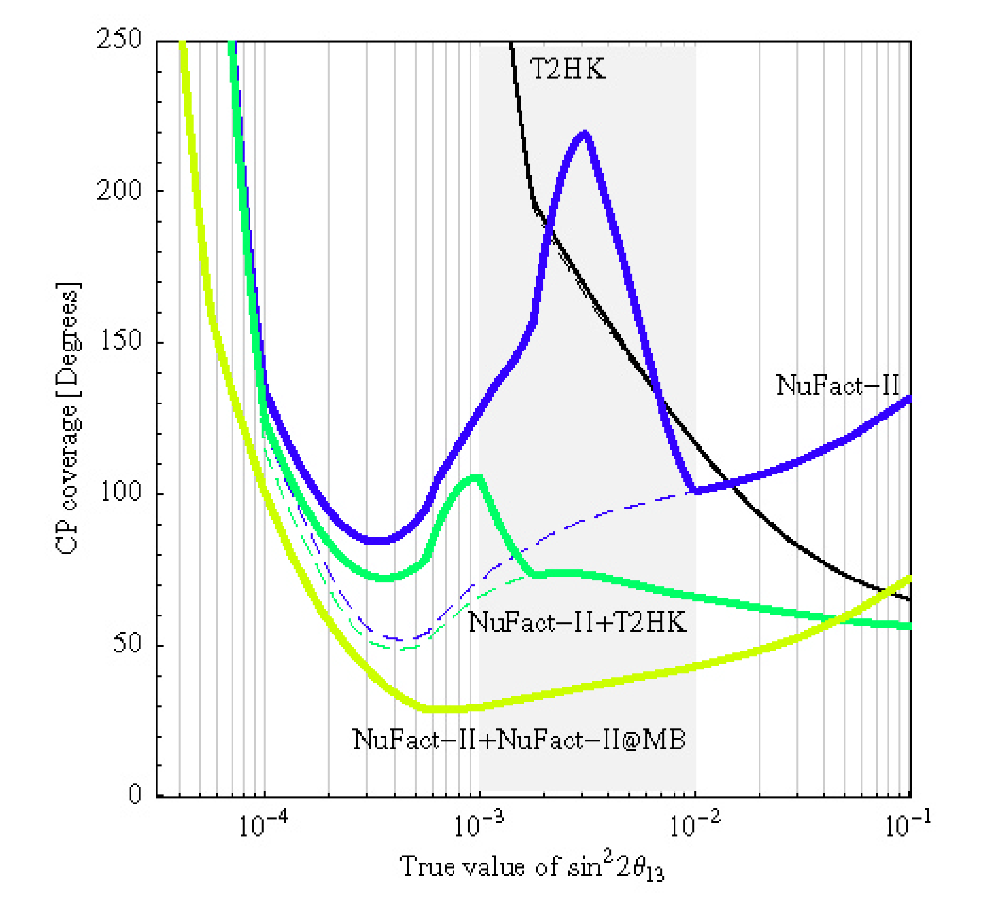
Guglielmi, Mezzetto, Migliozzi , Terranova, hep-ph/0508034

● Role of NF if θ_{13} is large

For $\sin^2 2\theta_{13} > 10^{-2}$ NF seems to be inferior to other experiments.

⬇

▶ Look for some application of NF in this case (if any).



Huber-Lindner-Winter '05

Ultimate precision of parameters

Due to correlations and degeneracies each experiment can't have its full ability.
→ Any way to improve?

Usually we optimize the (E_ν , L) or (E_μ , L) for each experiment (SB, BB, NF):

$$\Delta\chi^2_{total} = \min_{E_\nu, L} \Delta\chi^2_{SB}(E_\nu, L) + \min_{E_\mu, L'} \Delta\chi^2_{NF}(E_\mu, L')$$

However, since the probabilities in each $\Delta\chi^2$ are correlated due to degeneracies, we may be able to optimize further by taking:

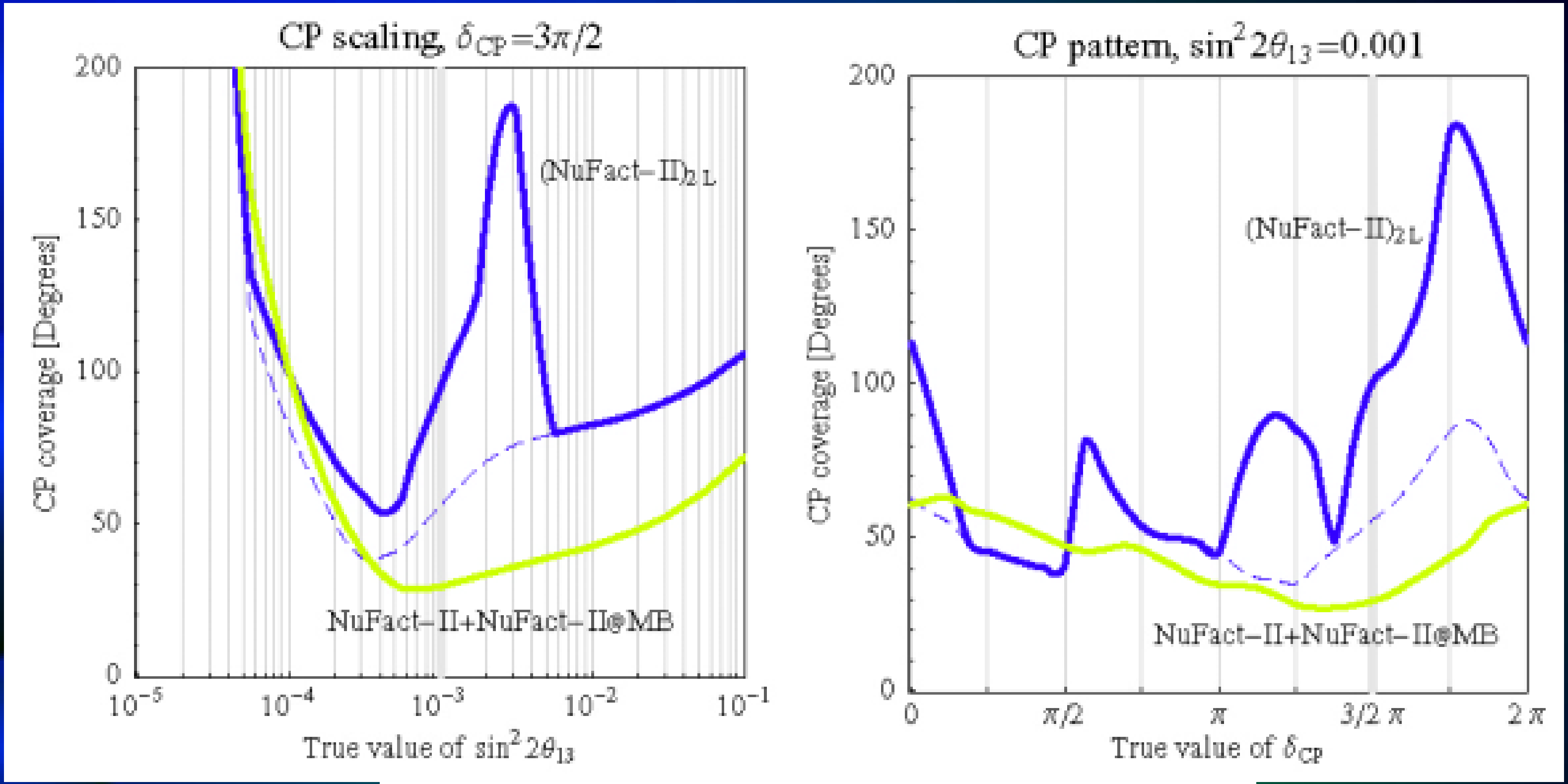
$$\Delta\chi^2_{total} = \min_{E_\nu, L, E_\mu, L'} \left[\Delta\chi^2_{SB}(E_\nu, L) + \Delta\chi^2_{NF}(E_\mu, L')\right]$$

- Describe the way of removing degeneracy etc

▶ Systematic demonstration of eliminating fake solutions due to the eight-fold degeneracy should be given for all the range of the oscillation parameters which are allowed at present.

▶ Find out the way to resolve the eight-fold degeneracy for $\sin^2 2\theta_{13} < 10^{-2}$.

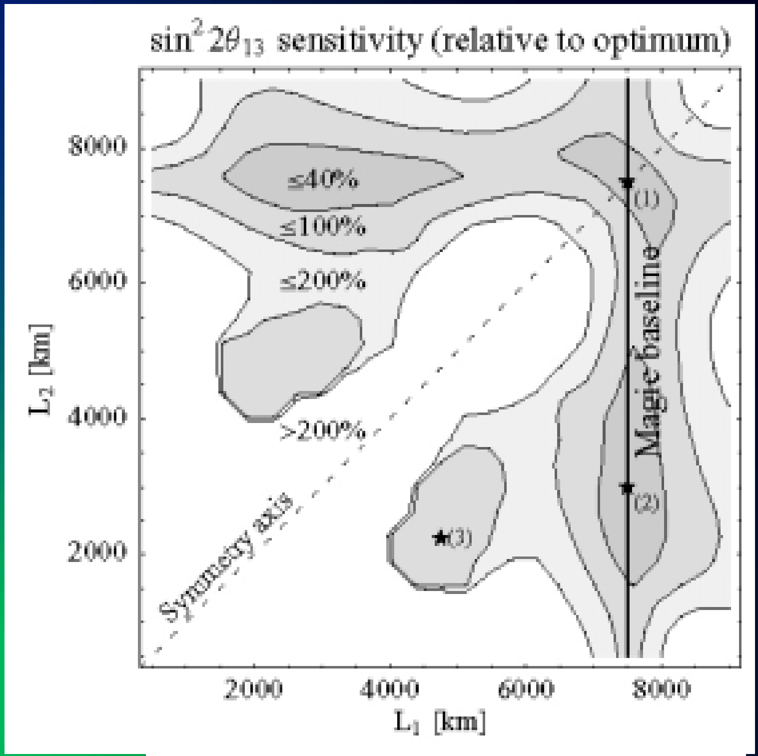
- Physics gain at NF of >1 far detectors



Huber-Lindner-Winter '05

Combination with measurements at the Magic Baseline L ≅ 7500km helps resolving degeneracies.

The guess $\Delta\rho/\rho$ = 5%–10% is for baselines L < 3000km or so, and for L>7000km the error is probably larger.



Huber-Winter '03

▶ Estimation of the sensitivity should be re-examined with larger error of the density.

Comparison with NF+BB etc should be done.

Sensitivity to unitarity and physics beyond SM

Standard scenario assumes three flavors and vanishing off-diagonal elements of the matter term:

$$U\begin{pmatrix} E_1 & 0 & 0 \\ 0 & E_2 & 0 \\ 0 & 0 & E_3 \end{pmatrix}U^{-1}+\begin{pmatrix} A & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{pmatrix}$$

Possible source of violation of unitarity:

- scenario 1: existence of sterile neutrinos
- scenario 2: existence of flavor changing ν int.

▶ scenario 1: existence of sterile neutrinos (ν_s)

Until the LSND result is dismissed by MiniBOONE the most promising scenario for the moment is the (3+2)-scheme (**Sorel-Conrad-Shaevitz '04**) .

⇨ Work out how much precision is required in SB, BB and NF to see violation of unitarity.

If the LSND result is dismissed by MiniBOONE, one could still construct schemes which have no conflict with the existing data.

⇨ Construct all possible ν_s schemes and work out how much precision is required to see violation of unitarity.

▶ scenario 2: existence of flavor changing neutrino interactions (probe of physics beyond SM)

$$U\begin{pmatrix} E_1 & 0 & 0 \\ 0 & E_2 & 0 \\ 0 & 0 & E_3 \end{pmatrix}U^{-1}+\begin{pmatrix} A+\varepsilon_{ee} & \varepsilon_{e\mu} & \varepsilon_{e\tau} \\ \varepsilon^*_{e\mu} & \varepsilon_{\mu\mu} & \varepsilon_{\tau\mu} \\ \varepsilon^*_{e\tau} & \varepsilon^*_{\tau\mu} & \varepsilon_{\tau\tau} \end{pmatrix}$$

⇨ Construct all possible models explicitly with $\mathrm{Im}(\varepsilon_{\alpha\beta}) \neq 0$ and work out how much precision is required to see violation of unitarity.

Scenario 2 may favor shorter baselines & lower energies.

Comparison with other means

NF has a unique feature: $\mu^{\mp}$ can be polarized

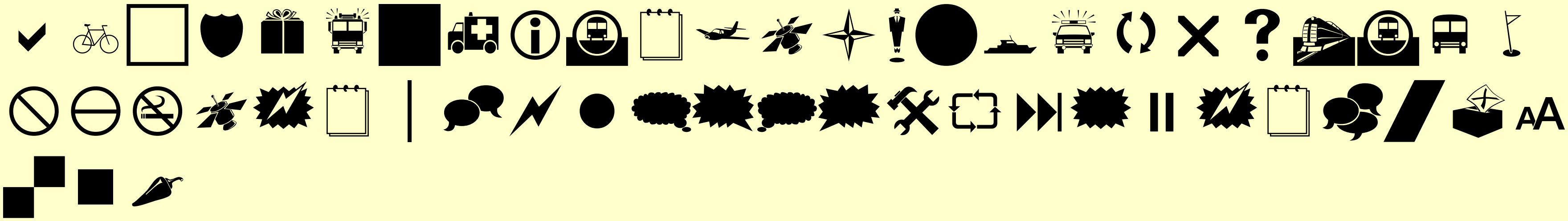
(Examples)

- T violation **Ota-Sato-Kuno '01**
- Possible resolution of degeneracy **Ota@nufact05**

⇒ Look for more applications of NF with polarized μ (if any).

Summary

We have 11 months to complete the study and all the phenomenologists are invited to start working along the lines suggested in the Physics working group plan.



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