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" Future Neutrino Beams"

- **Introduction**
- **Super Beams**
- **Beta Beams**
- **Neutrino Factory**

Supported by the European Network BENE (http://bene.web.cern.ch/bene/):
Beams for European Neutrino Experiments

Introduction

Near future neutrino oscillations experiments: T2K, Double Chooz and perhaps Noνa and Daya Bay, will not be enough to complete the exploration of neutrino oscillations: they will be unable to unambiguously measure θ_{13} , whatever its value is, the mass hierarchy and leptonic CP violation.

A new generation of neutrino oscillation experiments will be needed. It could be based again on conventional neutrino beams (SuperBeams) or on neutrino beams of new concept: Beta Beams and/or Neutrino Factories.

While Europe hasn't next generation long baseline experiments, it could be the site of second generation experiments.

So I will concentrate on possible second generation long baseline neutrino oscillation experiments in Europe.

Most of the neutrino oscillation parameters are waiting to be measured

δm^2_{12} ✓ SOLARS+KAMLAND $\delta m^2_{12} = (7.9 \pm 0.7)\, 10^{-5}\, eV^2$

θ_{12} ✓ SOLARS+KAMLAND $\sin^2(2\theta_{12}) = 0.82 \pm 0.055$

Addressed by a SuperBeam/Nufact experiment

δm^2_{23} ✓ ATMOSPHERICS $\delta m^2_{23} = (2.4 \pm 0.4)\, 10^{-3}\, eV^2$

θ_{23} ✓ ATMOSPHERICS $\sin^2(2\theta_{23}) > 0.95$

θ_{13} CHOOZ LIMIT $\sin^2 2\theta_{13} < 14^0$

LSND/Steriles

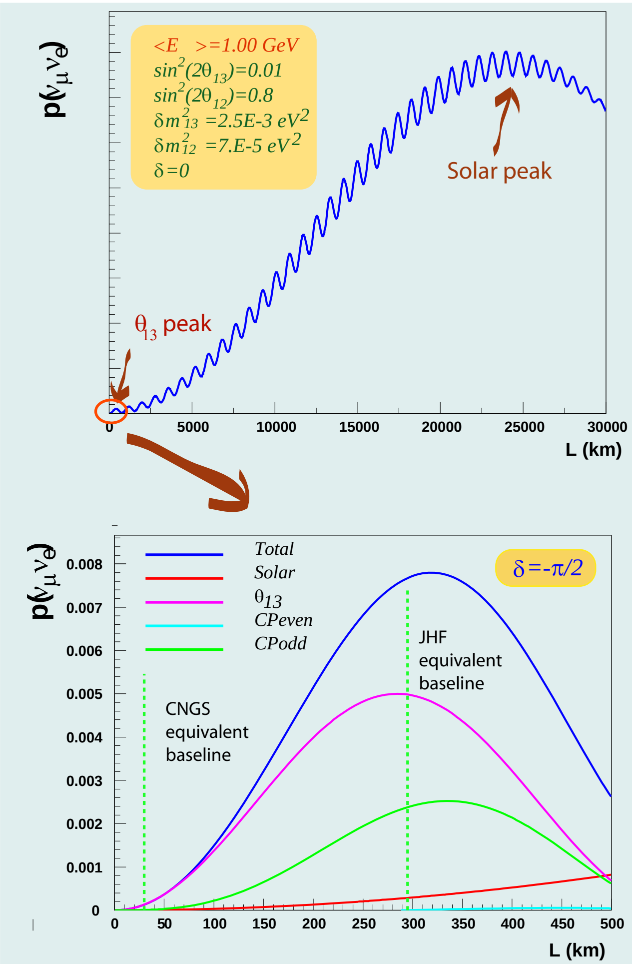
δ_{CP}

Mass hierarchy

Σm_ν BETA DECAY END POINT $\Sigma m_\nu < 6.6$ eV

Dirac/Majorana

Sub leading $\nu_\mu - \nu_e$ oscillations



$$p(\nu_\mu \to \nu_e) = 4c_{13}^2 s_{13}^2 s_{23}^2 \sin^2 \frac{\Delta m_{13}^2 L}{4E} \times \left[1 \pm \frac{2a}{\Delta m_{13}^2}(1-2s_{13}^2)\right] \quad \theta_{13} \text{ driven}$$

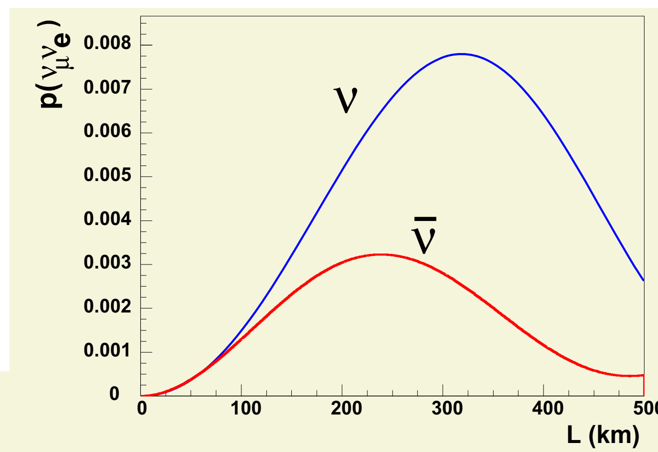
$$+ 8c_{13}^2 s_{12} s_{13} s_{23}(c_{12}c_{23}cos\delta - s_{12}s_{13}s_{23}) \cos \frac{\Delta m_{23}^2 L}{4E} \sin \frac{\Delta m_{13}^2 L}{4E} \sin \frac{\Delta m_{12}^2 L}{4E} \text{CPeven}$$

$$\mp 8c_{13}^2 c_{12} c_{23} s_{12} s_{13} s_{23} \sin\delta \sin \frac{\Delta m_{23}^2 L}{4E} \sin \frac{\Delta m_{13}^2 L}{4E} \sin \frac{\Delta m_{12}^2 L}{4E} \quad \text{CPodd}$$

$$+ 4s_{12}^2 c_{13}^2 \{c_{13}^2 c_{23}^2 + s_{12}^2 s_{23}^2 s_{13}^2 - 2c_{12}c_{23}s_{12}s_{23}s_{13}cos\delta\} \sin \frac{\Delta m_{12}^2 L}{4E} \quad \text{solar driven}$$

$$\mp 8c_{12}^2 s_{13}^2 s_{23}^2 \cos \frac{\Delta m_{23}^2 L}{4E} \sin \frac{\Delta m_{13}^2 L}{4E} \frac{aL}{4E}(1-2s_{13}^2) \quad \text{matter effect (CP odd)}$$

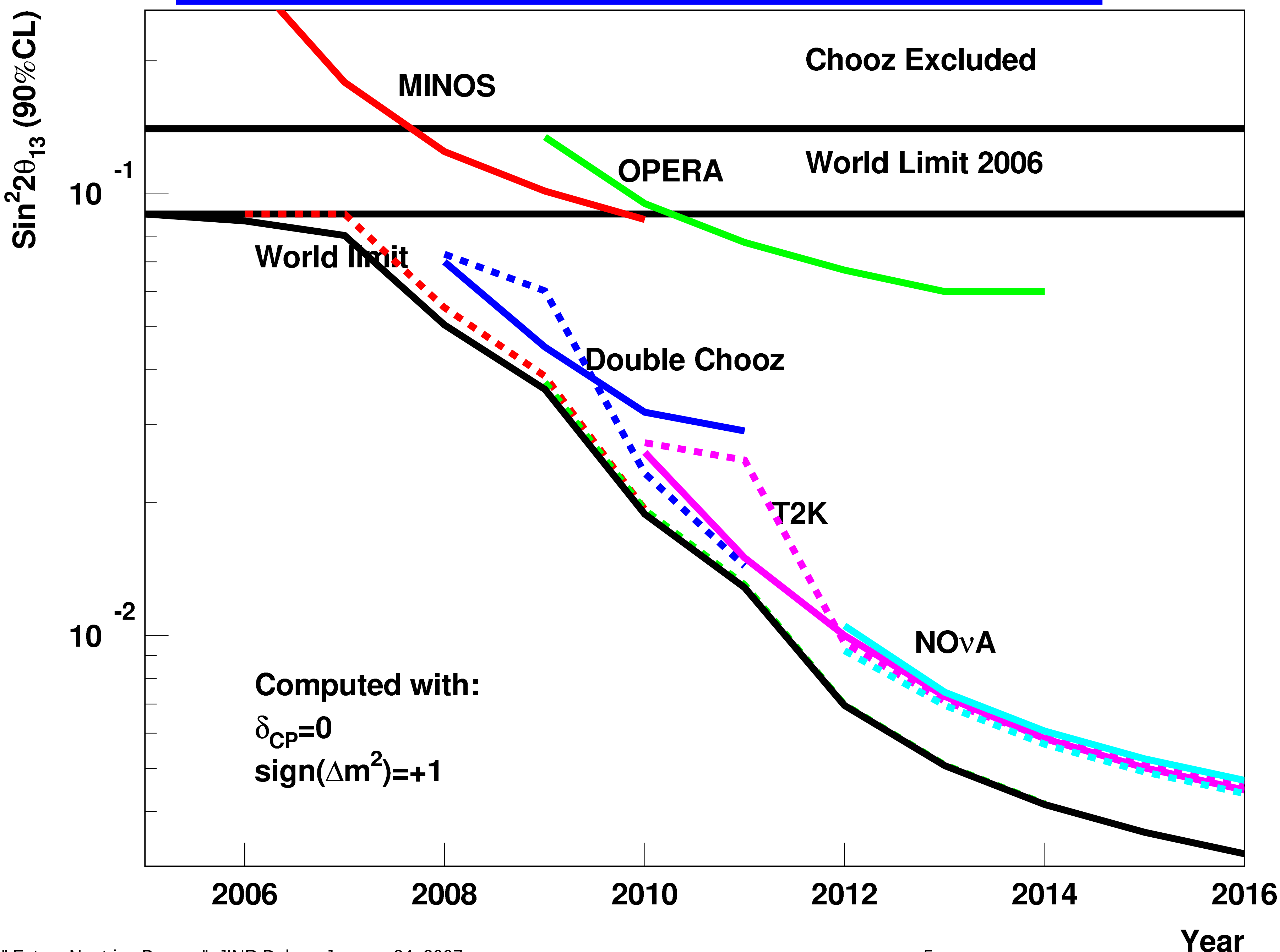
θ_{13} discovery requires total probability ($\propto \sin^2 2\theta_{13}$) greater than solar driven probability



Leptonic CP discovery requires

$$A_{CP} = \frac{P(\nu_\mu \to \nu_e) - P(\bar{\nu}_\mu \to \bar{\nu}_e)}{P(\nu_\mu \to \nu_e) + P(\bar{\nu}_\mu \to \bar{\nu}_e)} \neq 0$$

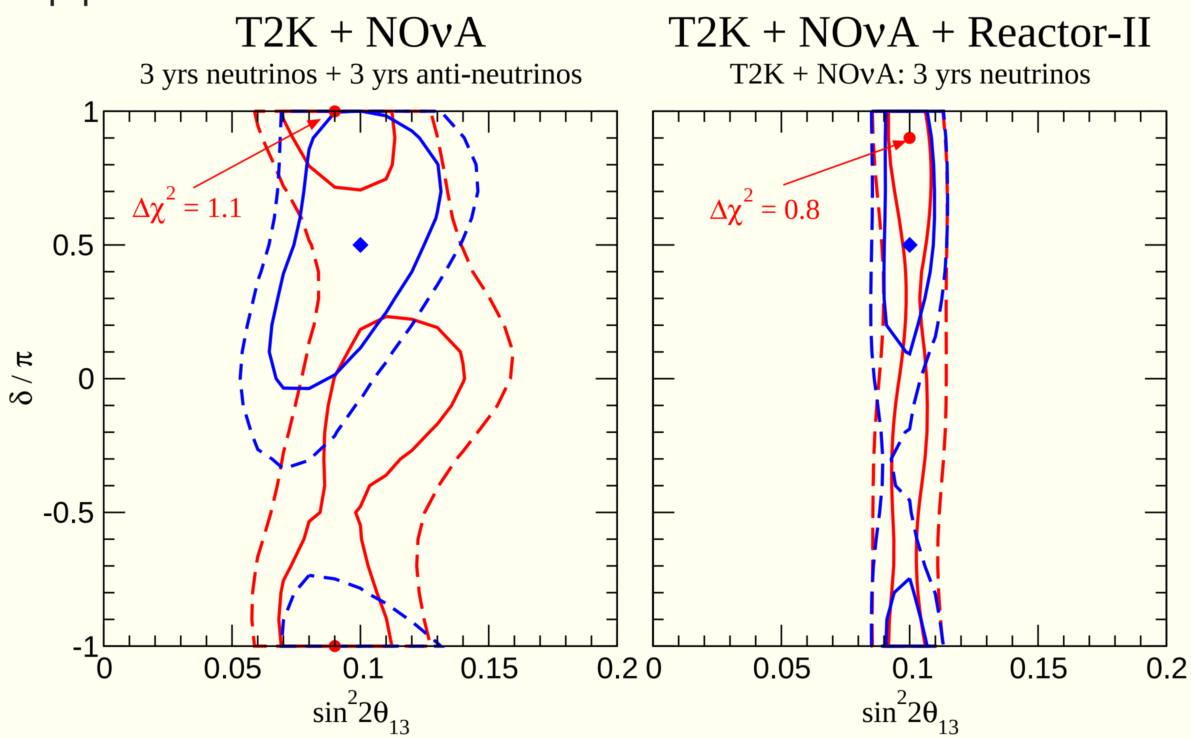
Status after the first and second generation: θ_{13}



Status after the first and second generation: δ_{CP}

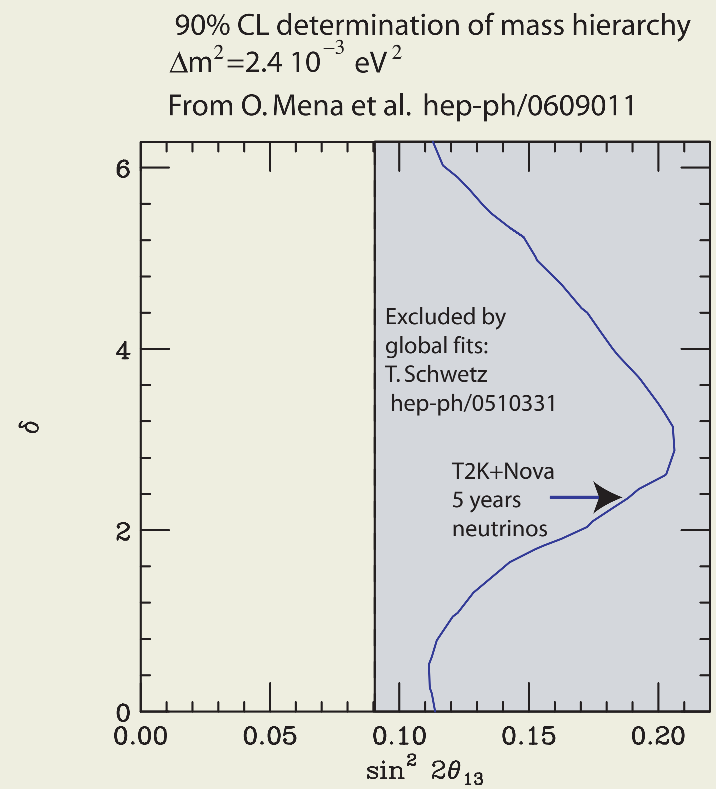
No hope to see any CP signal at 3σ

From P. Huber, M. Lindner, M. Rolinec, T. Schwetz and W. Winter, hep-ph/0412133.



(dotted lines, solid are 90%CL)

. . . and mass hierarchy



To address leptonic CP violation: improve of at least one order of magnitude the sensitivity of $\sin^2 2\theta_{13}$; two order of magnitudes more neutrinos !!!

The SuperBeam way

Proposals based on upgrades of existing facilities:

- T2K $\Rightarrow$ T2HK or T2KK
- Noνa $\Rightarrow$ Super Noνa
- CNGS $\Rightarrow$ off-axis CNGS fired on a gigantic liquid argon detector
- AGS Brookhaven $\Rightarrow$ wide band beam fired on a gigantic water Cerenkov detector.

Proposals based on new facilities

- CERN-SPL SuperBeam

SuperBeams - J-PARC phase 2 (T2HK)

Upgrade the proton driver from 0.75 MW to 4 MW

Upgrade SuperKamiokande by a factor $\sim 20 \Longrightarrow$ HyperKamiokande

Both upgrades are necessary to address leptonic CP searches.

The detector would have valuable physics potential in proton decay, SN neutrinos, solar neutrinos.

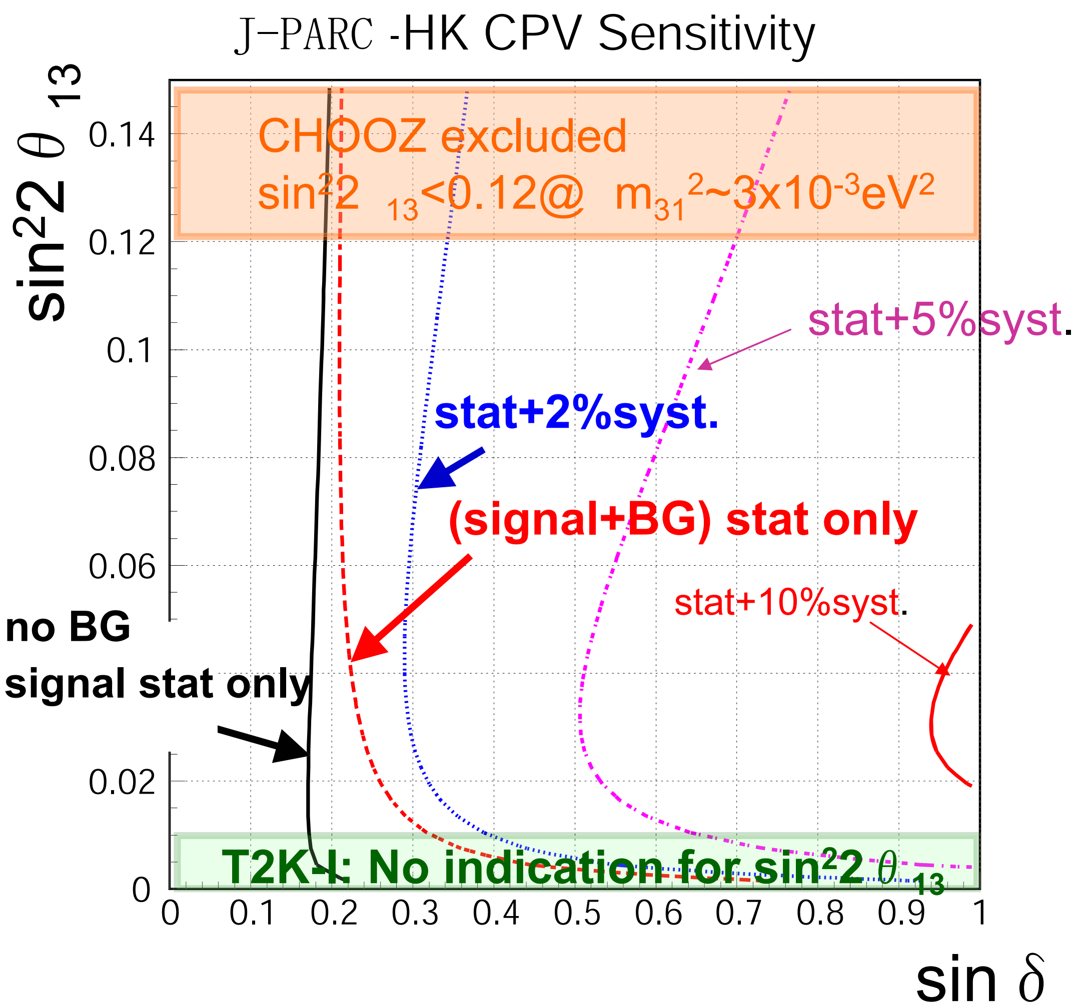
Its cost: ~ 0.5 G$

Systematics at 2% are difficult

4 MW at 50 GeV/c are difficult

Targetry and optics at 4 MW are difficult and will probably require some compromise

T. Kobayashi, J.Phys.G29:1493(2003)



Off-Axis CNGS

CNGS is optimized for tau appearance searches, with small sensitivity on θ_{13} .

First proposal: CN2GT: CNGS with a different optics, lower energy, fired off-axis to a PMT array deployed deep undersea in the Gulf of Taranto: A. Ball et al. CERN-PH-EP-2006-002. Expected sensitivity similar to T2K (phase I). From SPSC Villars review:“ *The C2GT concept (long base-line: CERN to the Gulf of Taranto) is an interesting idea which would require substantial technical development before its feasibility could be demonstrated. It also requires modifications to the CNGS beam-line. No such modifications should be made until CERNs existing commitment to the CNGS programme has been met. The question of C2GTs competitiveness at that time would have to be addressed*

Very recent proposal: A. Meregaglia and A. Rubbia, JHEP **0611** (2006) 032

- Have 8 times more p.o.t. Lower CNGS energy to about 10 GeV.
- Dig a new cavern, shallow depth, in an appropriate off-axis location close to LNGS.
- Install a 100 kton, monolithic liquid argon detector.
- In case build two 50 kton detectors and place one to the first oscillation maximum and the other to the second oscillation max.
- Final sensitivity in between T2K phase I and II.

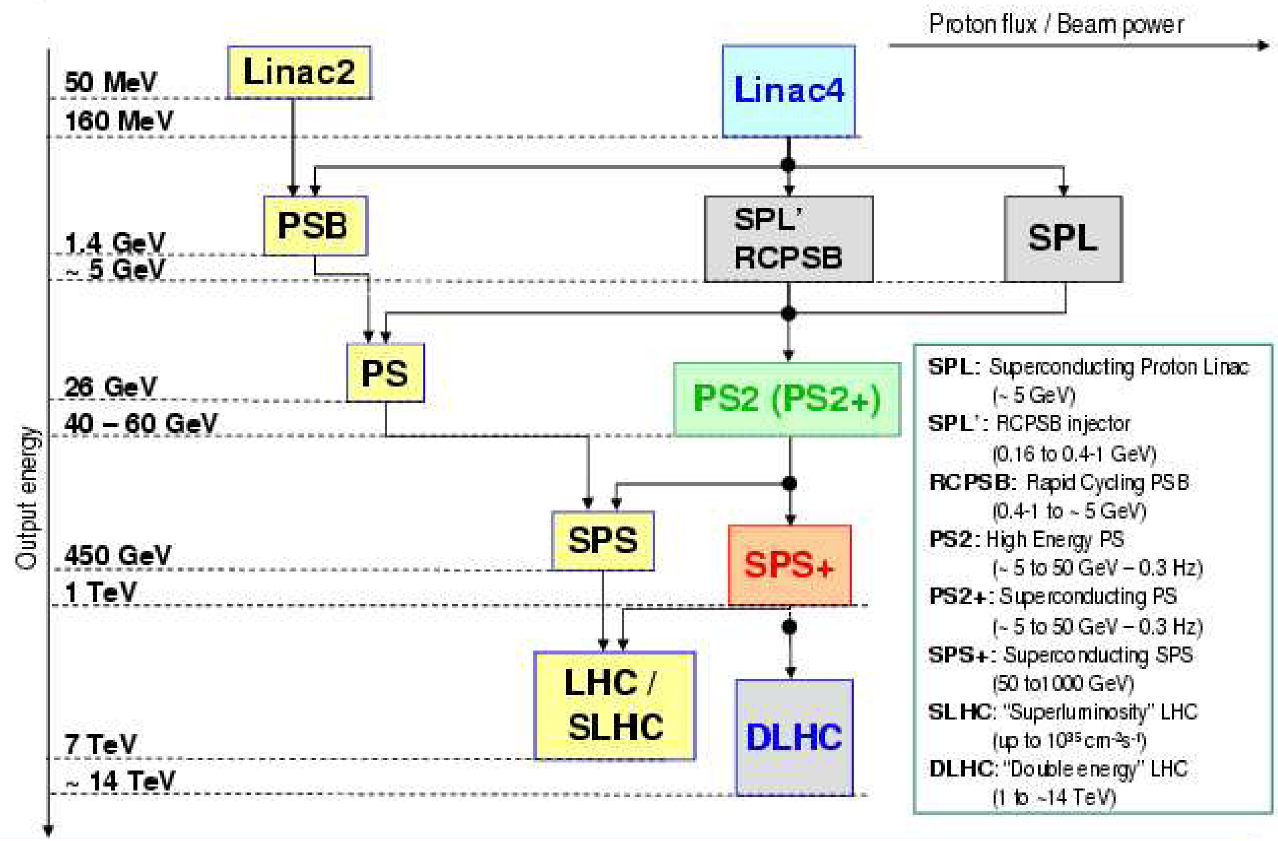
The ICARUS collaboration is going to make public a similar LoI (4 detectors of 5 kton each).

Main question: how far the SPSC intensity can be improved?

The following two slides are taken from E. Shaposhnikova talk at the BENE meeting of November 14, 2006: http://bene.web.cern.ch/bene/061113BENE06Slides/TuePhysics/Shaposhnikova.pdf

Future upgrade of accelerators

Scenarios for the CERN accelerator complex (*R. Garoby et al., CERN PAF, 2006*)



Future upgrade of accelerators
SPS

CNGS/FT beam

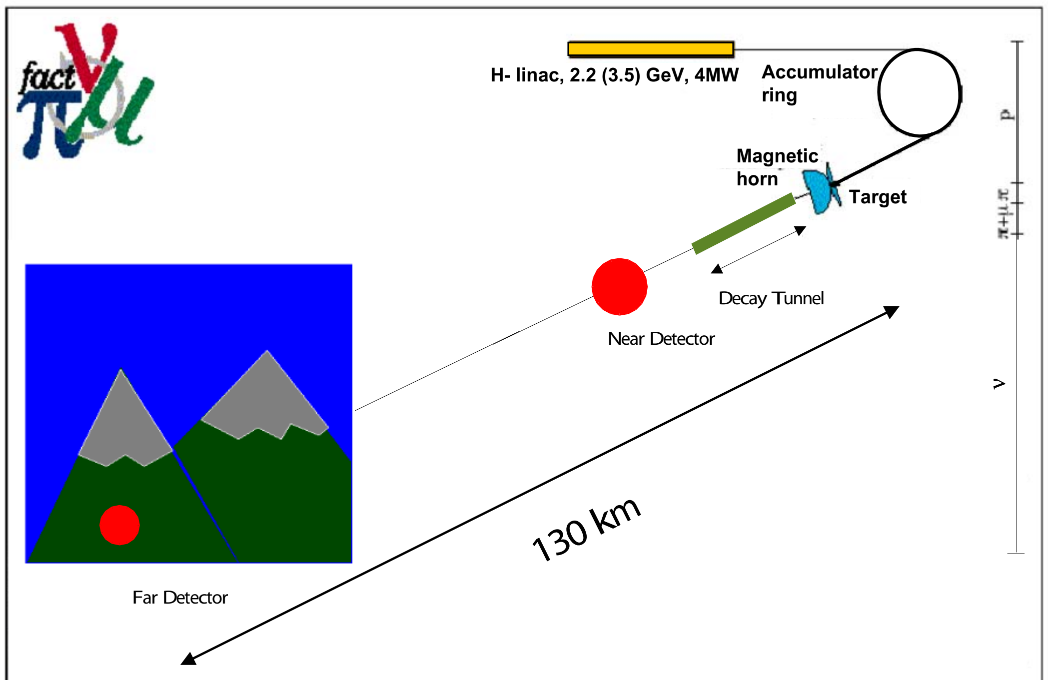
- total maximum intensity from PS2: 1.2×10^{14}
  4200 bunches with 3×10^{10} /bunch
  (ultimate LHC: 288 bunches with 1.7×10^{11} /bunch)
- 1 batch injection ? shorter acceleration cycle (by 1.2 s)
- no transition crossing (transition energy 21.4 GeV) ? less losses

⊖ But... old ring (impedance, e-cloud, RF systems, power...)

“Upgrade" CNGS intensity needs RF upgrade and impedance reduction

Significantly more? ? SPS+ (SC, 50 ? 1000 GeV)

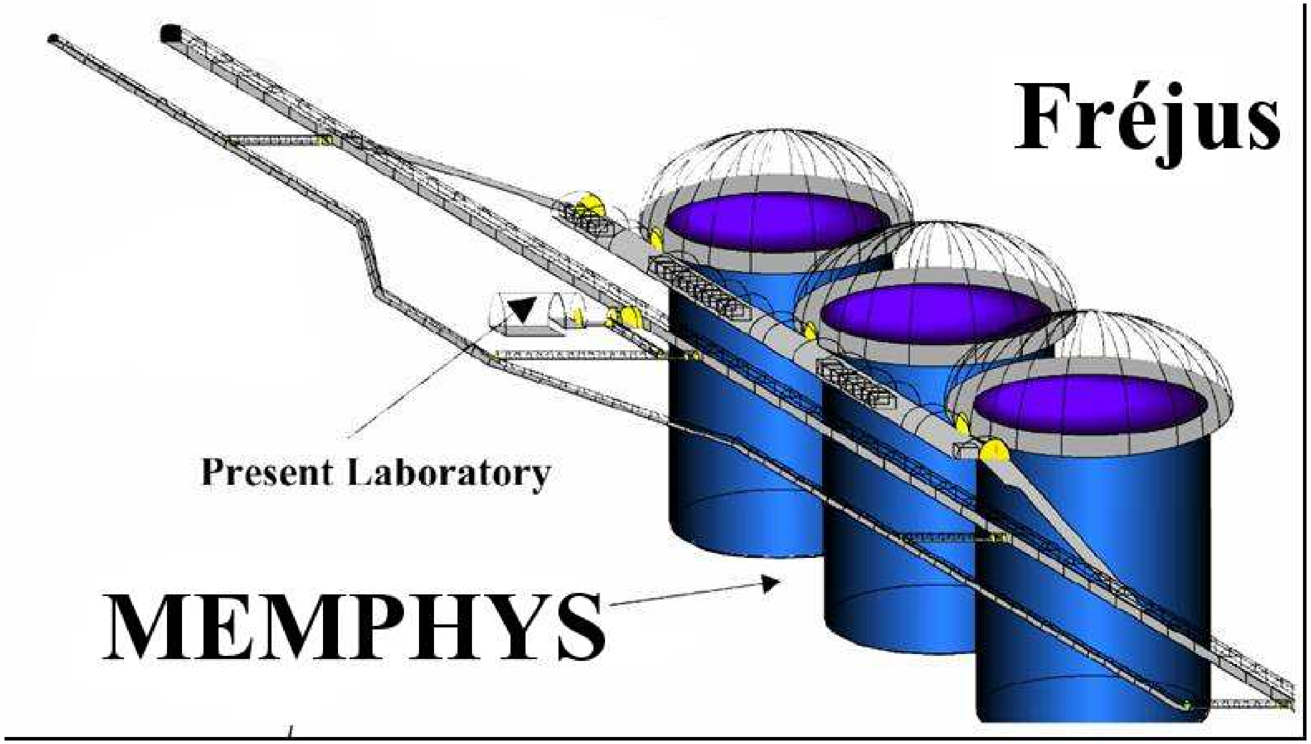
SuperBeams - SPL ν beam at CERN



Possible Low Energy Super Beam Layout

- A 3.5 GeV, 4MW Linac: the SPL.
- A liquid mercury target station capable to manage the 4 MW proton beam. R&D required.
- A conventional neutrino beam optics capable to survive to the beam power, the radiation and the mercury. Already prototyped.
- Up to here is the first stage of a neutrino factory complex.
- A sophisticated close detector to measure at 2% signal and backgrounds.
- A megaton class detector under the Frejus, L=130 km: Memphys.

The Memphys detector (hep-ex/0607026)

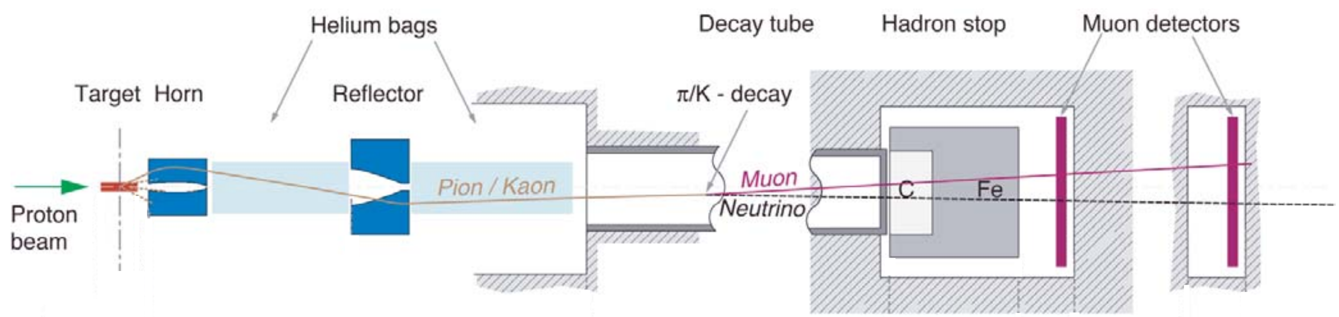


In the middle of the Frejus tunnel at a depth of 4800 m.w.e a preliminary investigation shows the feasibility to excavate up to five shafts of about 250,000 m^3 each ($\Phi = 65\,m$, full height=80 m).

Fiducial of 3 shafts: 440 kton.

30% coverage by using 12“ PMT’s from Photonis, 81k per shaft (with the same photostatistics of SuperKamiokande with 40% coverage)

Conventional neutrino beams are going to hit their ultimate limitations.



In a **conventional neutrino beam**, neutrinos are produced SECONDARY particle decays (mostly pions and kaons). Given the short life time of the pions ($2.6 \cdot 10^{-8}$s), they can only be focused (and charge selected) by means of magnetic horns. Then they are let to decay in a decay tunnel, short enough to prevent most of the muon decays.

- Besides the main component (ν_μ) at least 3 other neutrino flavors are present ($\overline{\nu}_\mu$, ν_e, $\overline{\nu}_e$), generated by wrong sign pions, kaons and muon decays. $\nu_e$contamination is a background for θ_{13} and δ, $\overline{\nu}_\mu$contamination dilutes any CP asymmetry.
- Hard to predict the details of the neutrino beam starting from the primary proton beam, the problems being on the secondary particle production side.
- Difficult to tune the energy of the beam in case of ongoing optimizations.

All these limitations are overcome if secondary particles become primary

Collect, focus and accelerate the neutrino parents at a given energy. This is impossible within the pion lifetime, but can be tempted within the muon lifetime **(Neutrino Factories)** or within some radioactive ion lifetime **(Beta Beams)**:

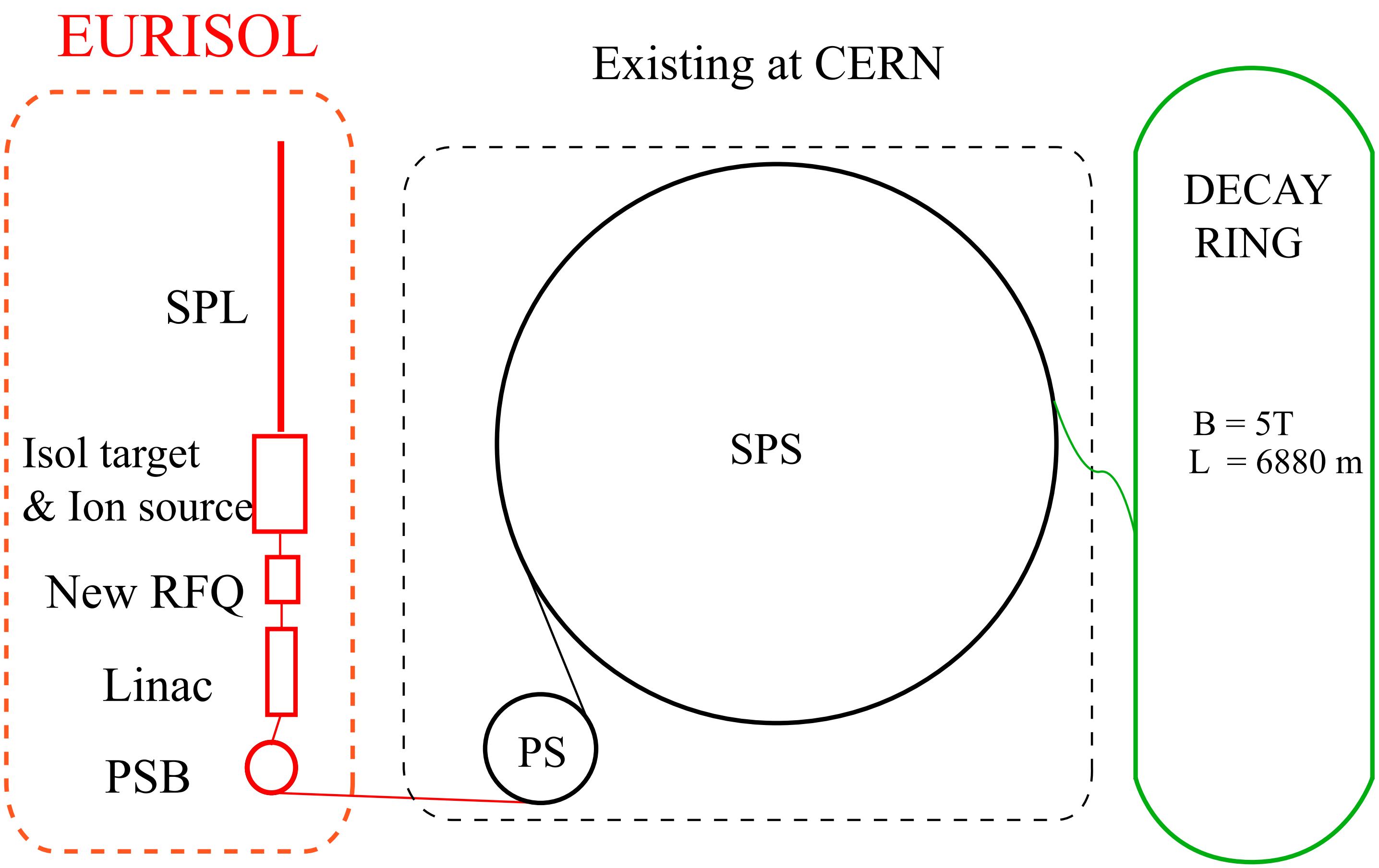
- Just one flavor in the beam
- Energy shape defined by just two parameters: the endpoint energy of the beta decay and the γ of the parent ion.
- Flux normalization given by the number of ions circulating in the decay ring.
- Beam divergence given by γ.

The full ^{6}He flux MonteCarlo code

```
Function Flux(E)
Data Endp/3.5078/
Data Decays /2.9E18/
ye=me/EndP
c ...For ge(ye) see hep-ph0312068
ge=0.0300615
2gE0=2*gamma*EndP
c ...  Kinematical Limits
If(E.gt.(1-ye)*2gE0)THEN
   Flux=0.
   Return
Endif
c ...Here is the Flux
Flux=Decays*gamma**2/(pi*L**2*ge)*(E**2*(2gE0-E))/
+ 2gE0**4*Sqrt((1-E/2gE0)**2-ye**2)
Return
```

Beta Beam (P. Zucchelli: Phys. Lett. B532:166, 2002)

M. Lindroos et al., see http://beta-beam.web.ch/beta-beam



- 1 ISOL target to produce He^6, 100 μA, $\Rightarrow 5.8 \cdot 10^{18}$ ion decays/straight session/year. $\Rightarrow \overline{\nu}_e$.
- 3 ISOL targets to produce Ne^{18}, 100 μA, $\Rightarrow 2.4 \cdot 10^{18}$ ion decays/straight session/year. $\Rightarrow \nu_e$.
- These fluxes apply if the two ions are run separately

Exciting new ideas about radioactive ion production

C. Rubbia et al., hep-ph/0602032

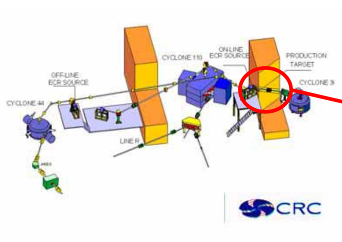
M. Lindroos at Nufact 05

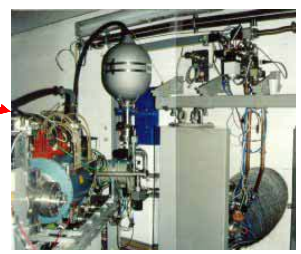
Producing 18Ne and 6He at 100 MeV

EURISOL Design Study

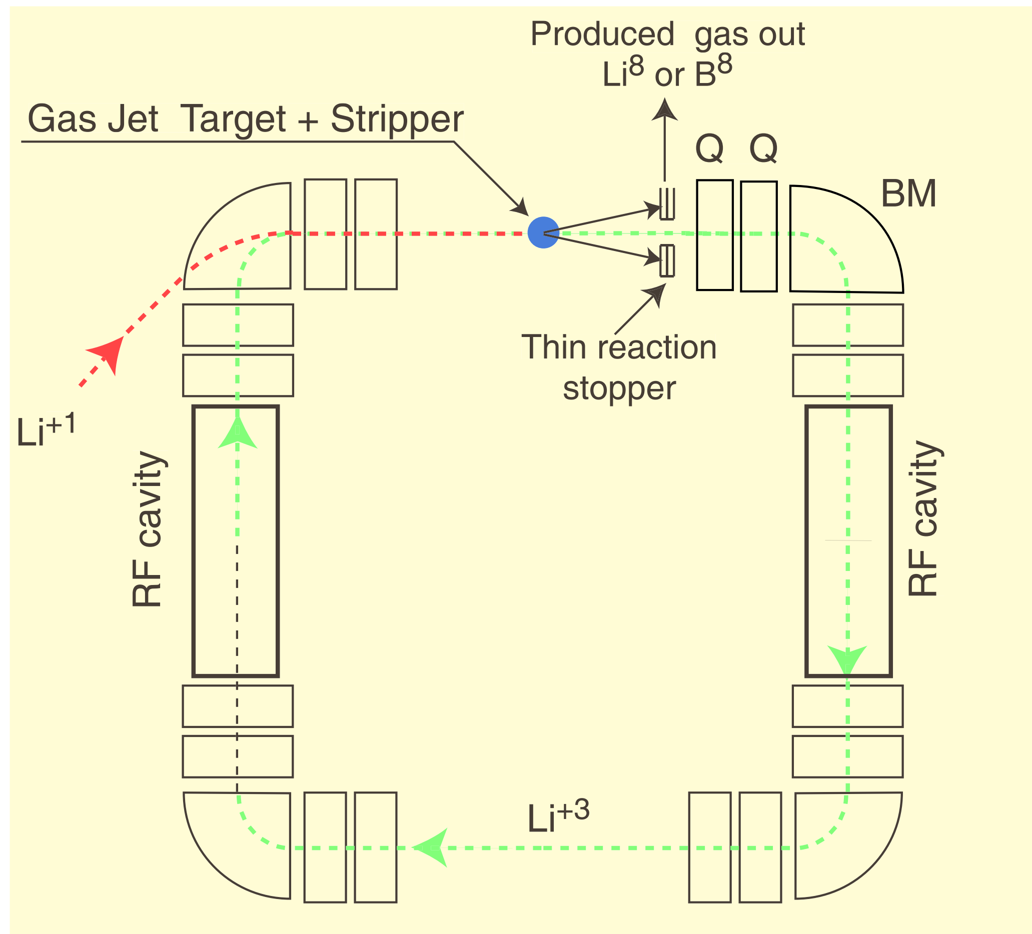
NuFact 05

- Work within EURISOL task 2 to investigate production rate with “medical cyclotron”
  - Louvain-La-Neuve, M. Loislet

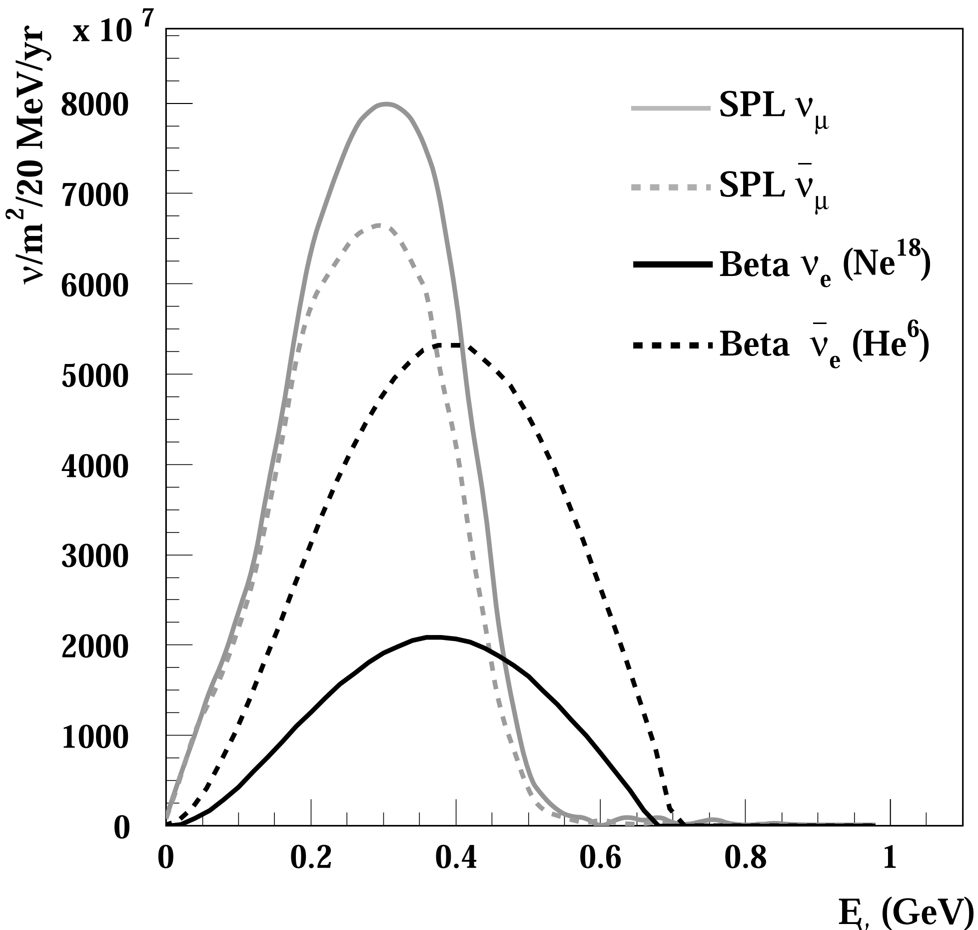




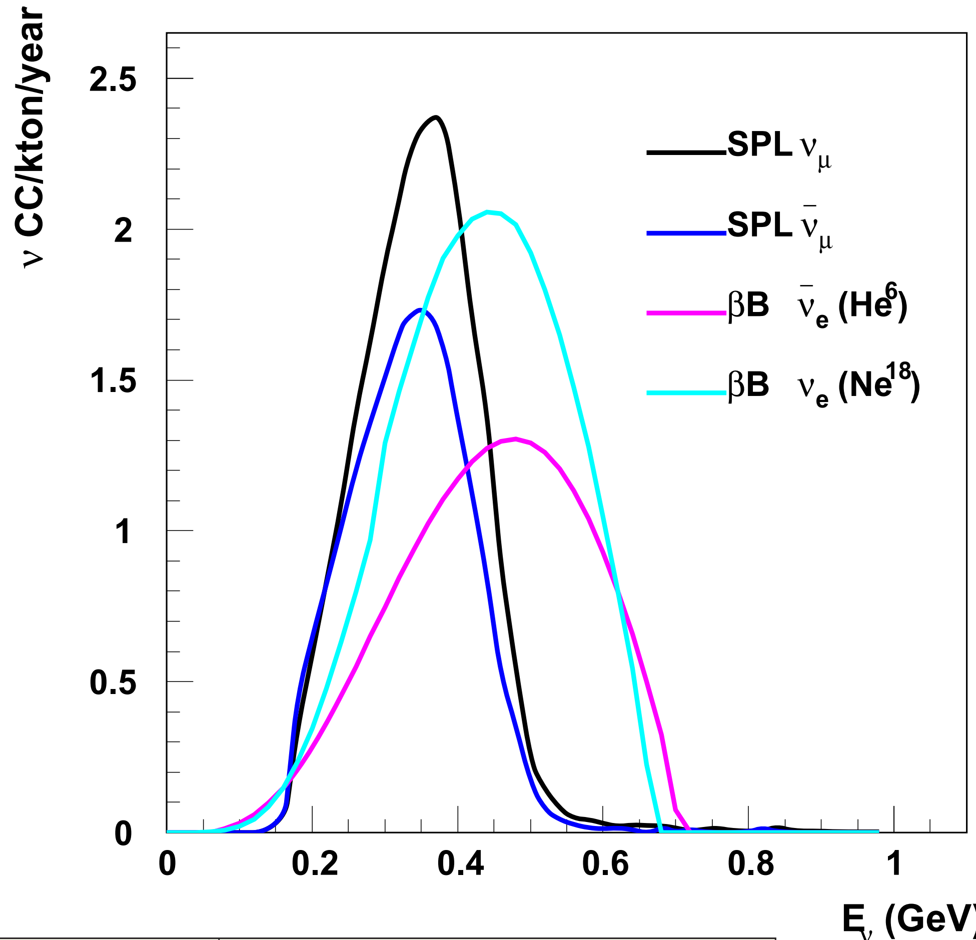
NUFACT05



Yearly Fluxes



Averaged yearly CC rates in a 10 years run for CP

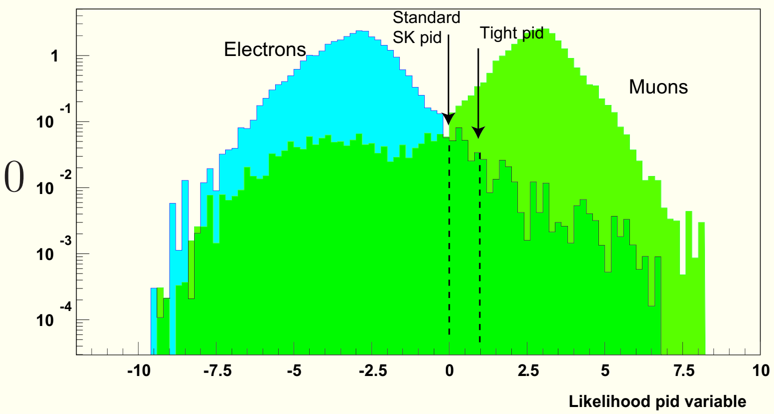


	Fluxes @ 130 km $\nu/m^2/yr$	$\langle E_\nu \rangle$ (GeV)	CC rate (no osc) events/kton/yr	$\langle E_\nu \rangle$ (GeV)	Years	Integrated events (440 kton $\times$ 10 years)
SPL Super Beam						
ν_μ	$11.80 \cdot 10^{11}$	0.29	121.7	0.36	2	107127
$\overline{\nu}_\mu$	$9.66 \cdot 10^{11}$	0.28	23.1	0.35	8	81164
Beta Beam						
$\overline{\nu}_e(\gamma = 100)$	$10.92 \cdot 10^{11}$	0.40	46.0	0.46	5	101262
$\nu_e(\gamma = 100)$	$4.06 \cdot 10^{11}$	0.38	65.4	0.44	5	143887

Particle identification and signal efficiency

Electron/muon misidentification must be suppressed much more than in standard SK analysis to guarantee a negligible background level.

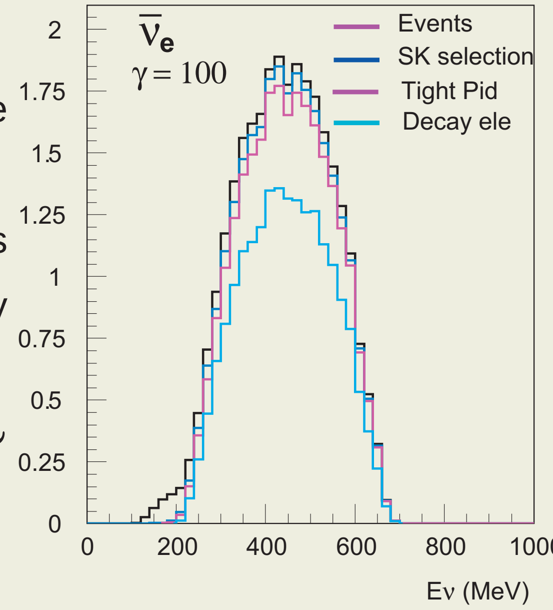
Pid in SK is performed through a Likelihood, $Pid > 0$ identifies muons. Use $Pid > 1$

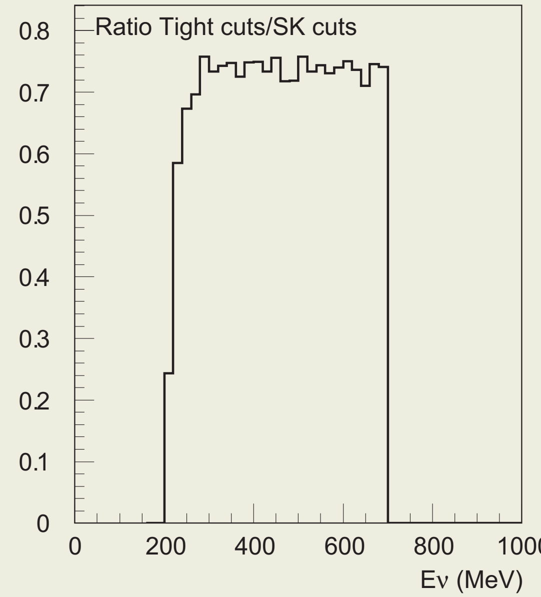


To further suppress electron background ask for the signal of the Michel electron from μ decay.

Final efficiency for positive muons. Negative muons have an efficiency smaller by $\sim 22\%$ because they can be absorbed before decaying.

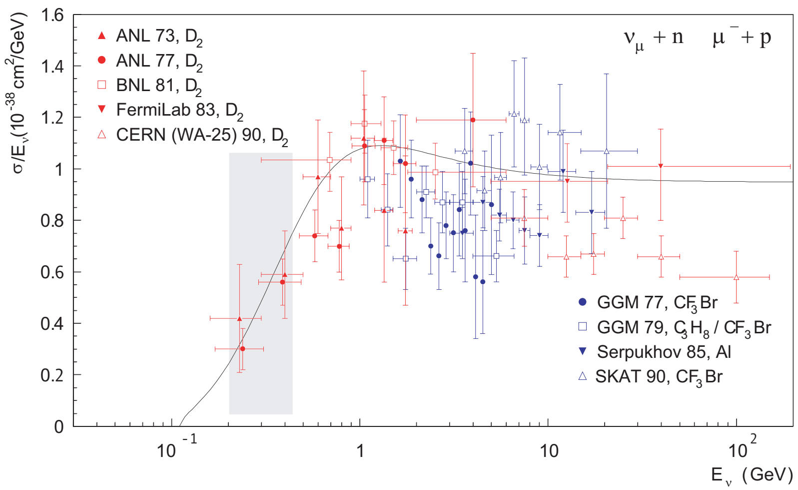
Electron mis-identification suppressed to $\sim 10^{-5}$.

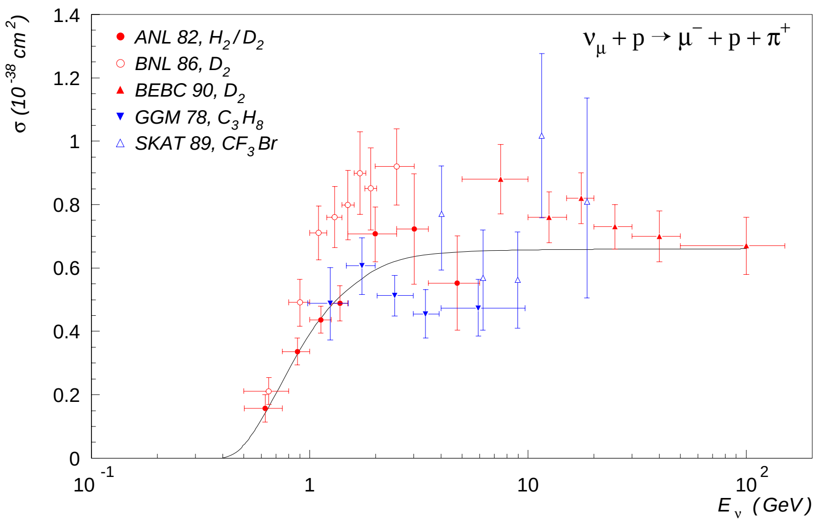




The cross sections problem

V.V. Lyubushkin et al., internal NOMAD memo





Neutrino cross-sections are poorly measured around 300 MeV.

Nuclear effects are very important at these energies.

No surprise that different MonteCarlo codes predict rates with a 50% spread.

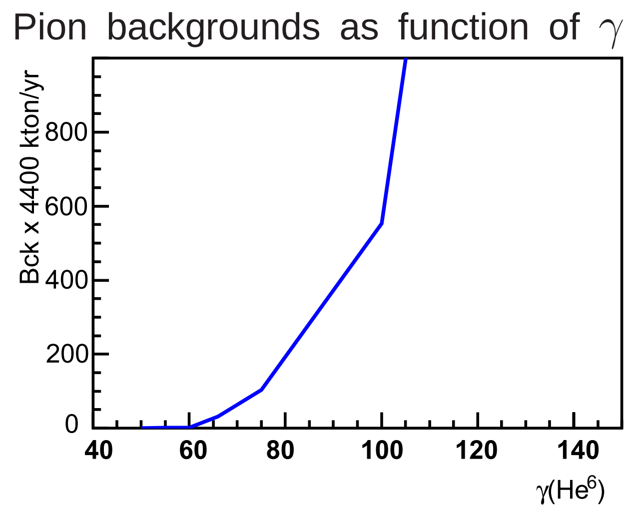
On the other hand: Beta Beam is the ideal place where to measure neutrino cross sections

- Neutrino flux and spectrum are completely defined by the parent ion characteristics and by the Lorentz boost γ.
- Just one neutrino flavour in the beam.
- You can scan different γ values starting from below the Δ production threshold.
- A close detector can then measure neutrino cross sections with unprecedent precision.

A 2% systematic error both in signal and backgrounds is used in the following

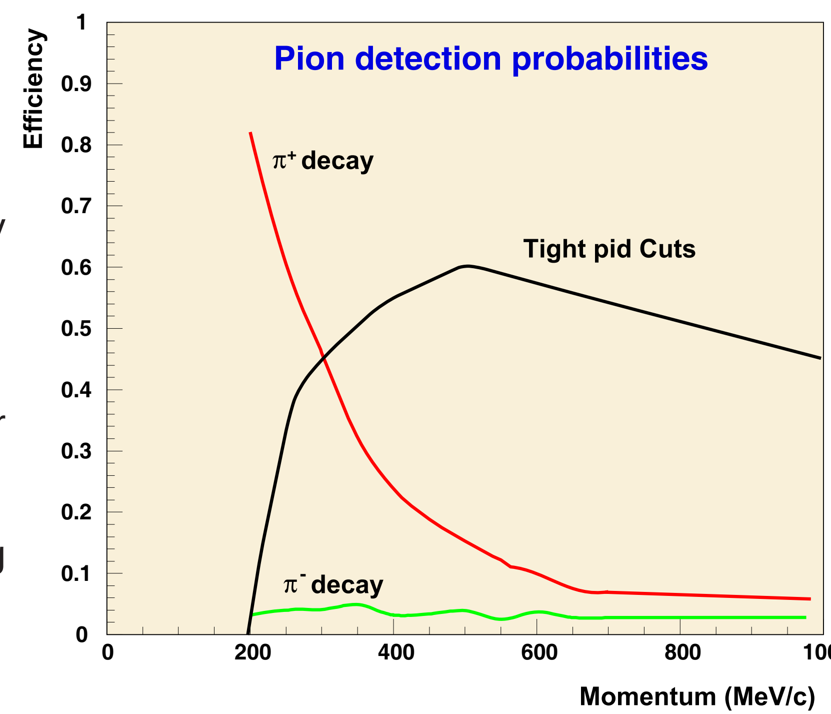
The pion background

The pions generated in NC events can fake the muon signal.
They are the main concern.

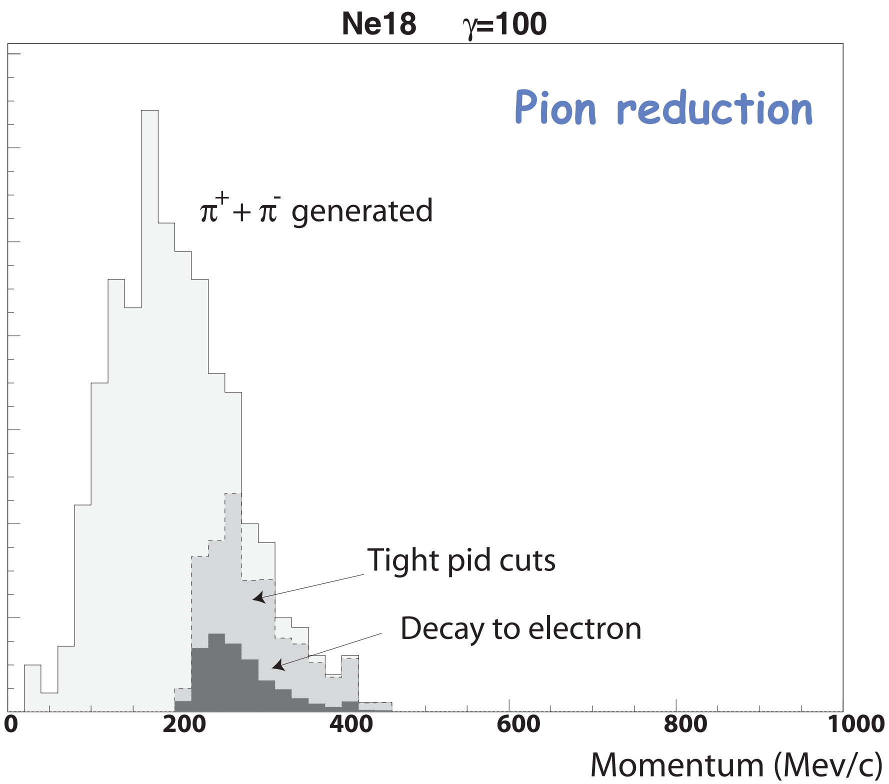


To estimate these backgrounds

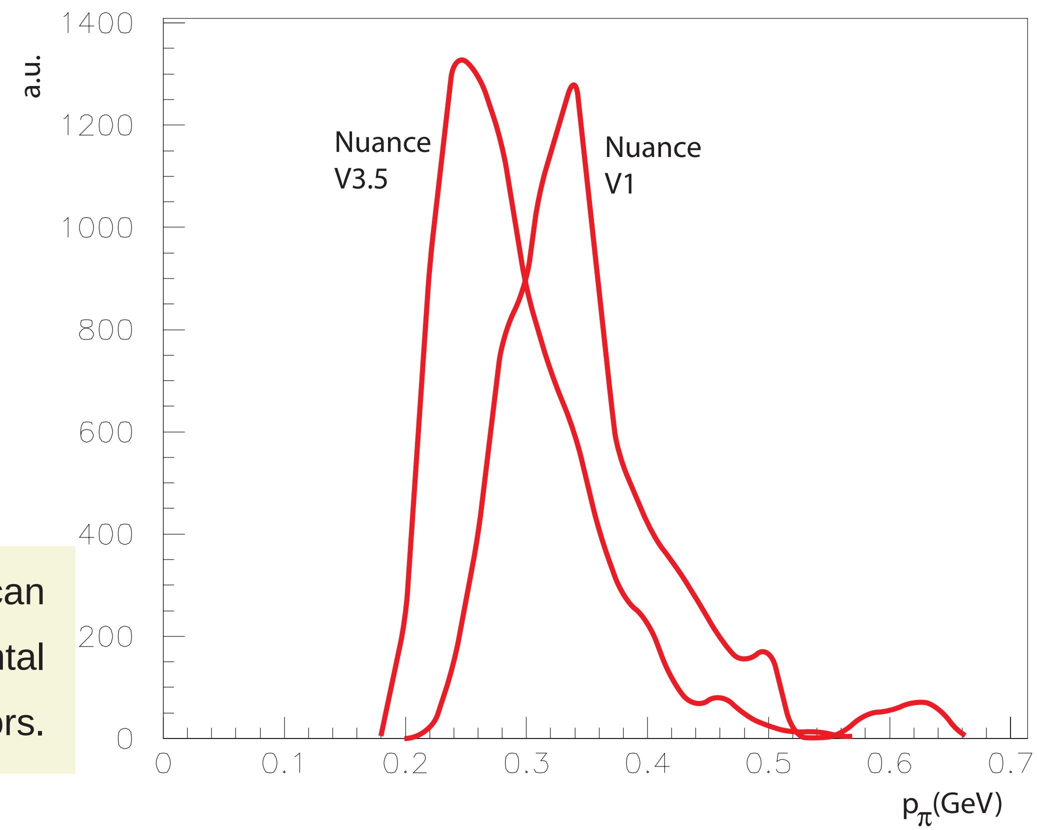
- Generate CC and NC events with Nuance
- Count events with a pion and no other track above the Čerenkov threshold (single ring events)
- Apply the particle identification cuts of SuperKamiokande
- Follow pions in water (Geant 3.21) to compute the probability for $\pi \longrightarrow \mu \longrightarrow e$.
- Reconstruct the neutrino energy from the survived pions treating them as the signal muons



The pion background (cont.)



	Ne18			He6		
	ν_μ	π^+	π^-	$\overline{\nu}_\mu$	π^+	π^-
generated	133078	560	334	113631	673	400
pid	105923	202	102	83419	241	119
decay	67888	106	8	67727	121	7



Pion production cross sections and nuclear effects can heavily change these numbers and the overall experimental sensitivity. Potentially the worst source of systematic errors.

Atmospheric neutrino background

- Generate with Nuance atmospheric neutrinos in the Memphys fiducial
- Apply the tight particle identification cuts.
- Reconstruct them with the QE algorithm assuming they are coming from CERN.
- Accept them in the energy and direction window of the BB events:
- Apply the baseline BB duty cycle: $2.2 \cdot 10^{-3}$

The final rate is 5 background events/year (in a solar year, Beta Beam should run about 1/3 of this period)

Considering that the pion background is of the order of 20 events/year, the duty cycle of the Beta Beam can be raised by a factor 5 at least without sizable losses in the overall sensitivities.

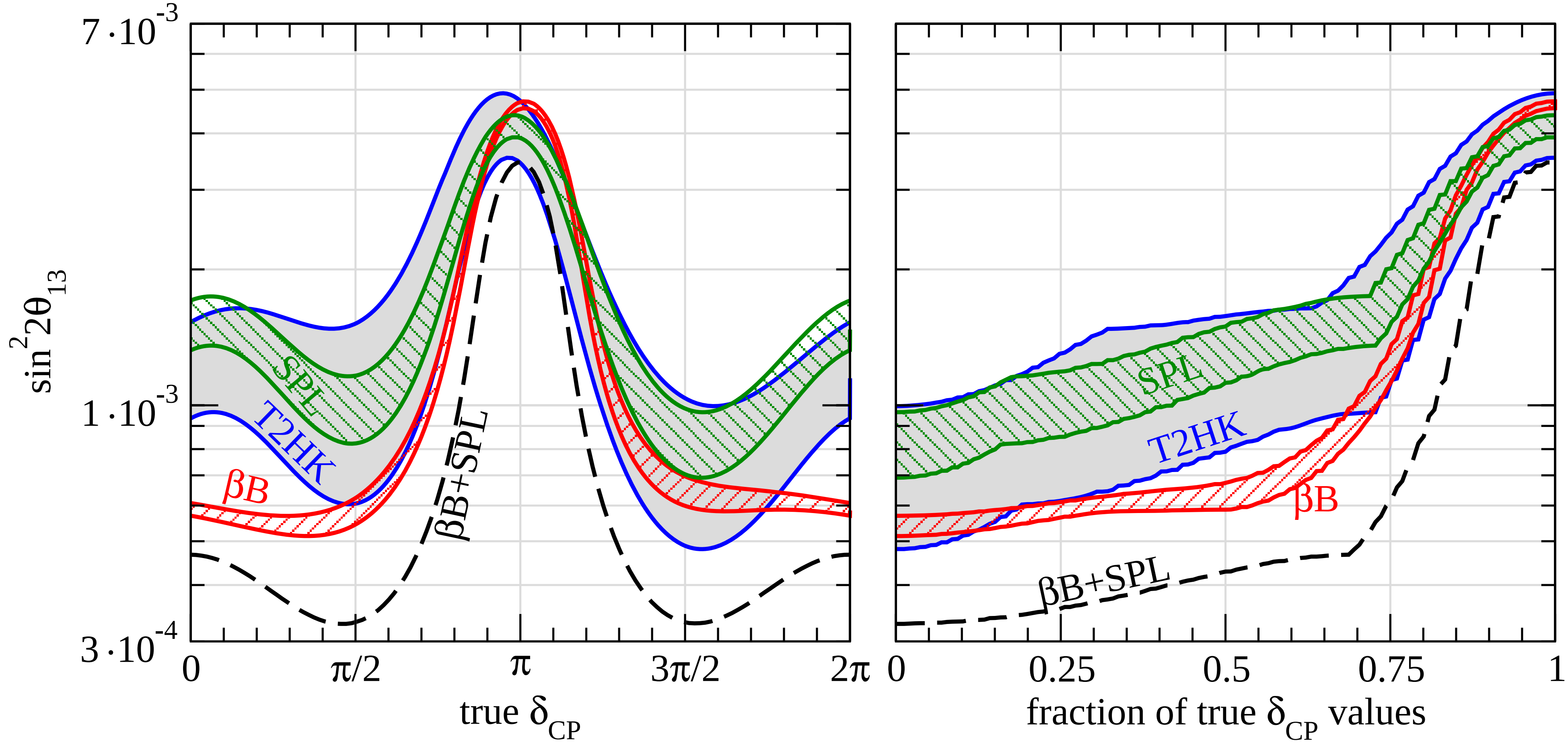
Oscillation signals

From J.E.Campagne, M. Maltoni, M.M., T.Schwetz, hep-ph/0603172.

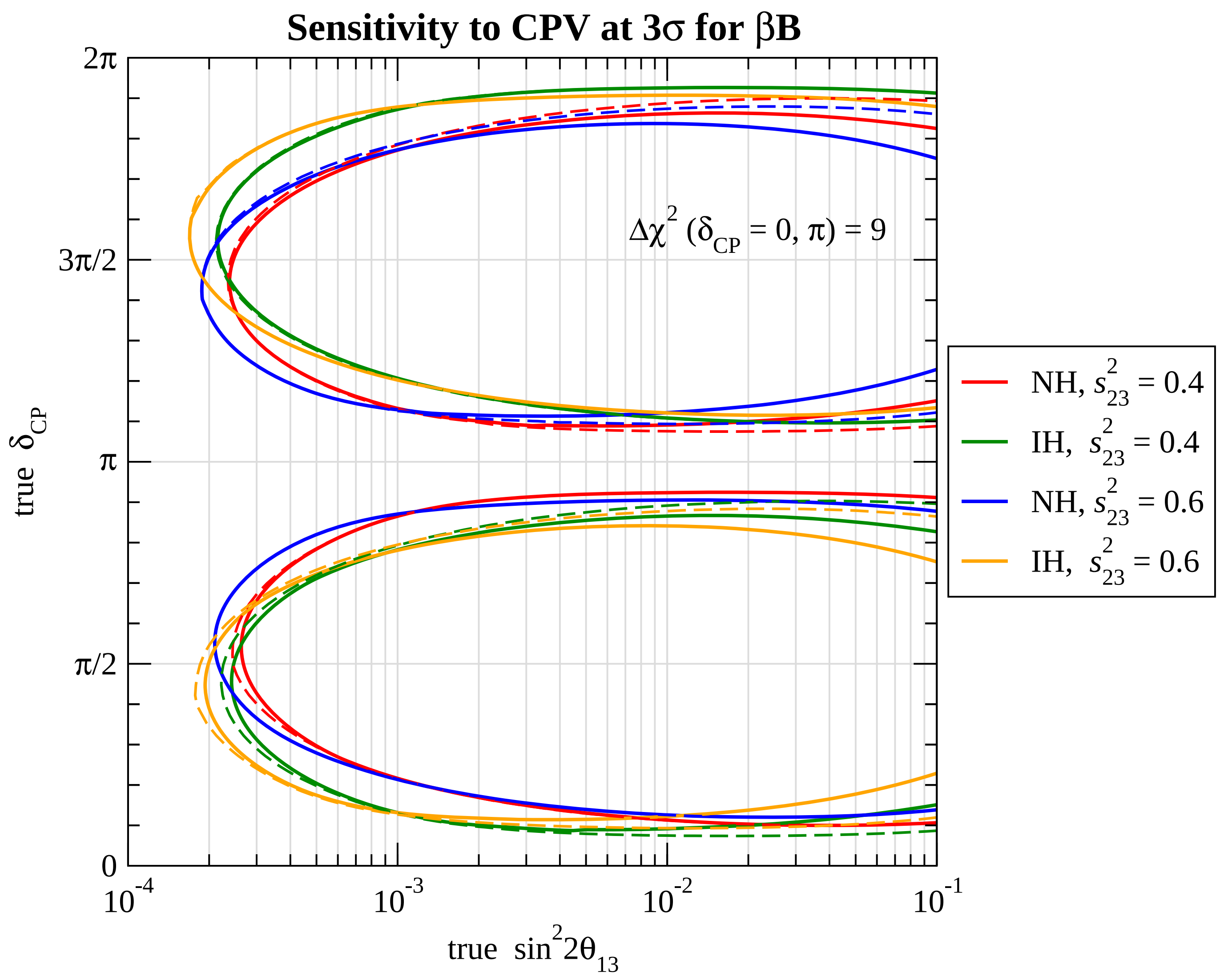
	βB		SPL		T2HK	
	$\delta_{CP} = 0$	$\delta_{CP} = \pi/2$	$\delta_{CP} = 0$	$\delta_{CP} = \pi/2$	$\delta_{CP} = 0$	$\delta_{CP} = \pi/2$
appearance ν						
background	143		600		1017	
$\sin^2 2\theta_{13} = 0$	25		41		84	
$\sin^2 2\theta_{13} = 10^{-3}$	72	81	93	10	181	18
$\sin^2 2\theta_{13} = 10^{-2}$	310	339	387	126	754	240
appearance $\bar{\nu}$						
background	157		500		1428	
$\sin^2 2\theta_{13} = 0$	30		36		90	
$\sin^2 2\theta_{13} = 10^{-3}$	82	12	74	104	188	261
$\sin^2 2\theta_{13} = 10^{-2}$	346	125	297	390	746	977

Computed with $\Delta m^2_{31} = +2.4 \times 10^{-3}\ \mathrm{eV}^2$, $\sin^2\theta_{23} = 0.5$, $\Delta m^2_{21} = 7.9 \times 10^{-5}\ \mathrm{eV}^2$, $\sin^2\theta_{12} = 0.3$. with an accuracy of 10% for θ_{12}, θ_{23}, Δm^2_{31}, and 4% for Δm^2_{21} at 1σ.

3σ discovery of a non-zero θ_{13}



Line width: 2% and 5% systematic errors.

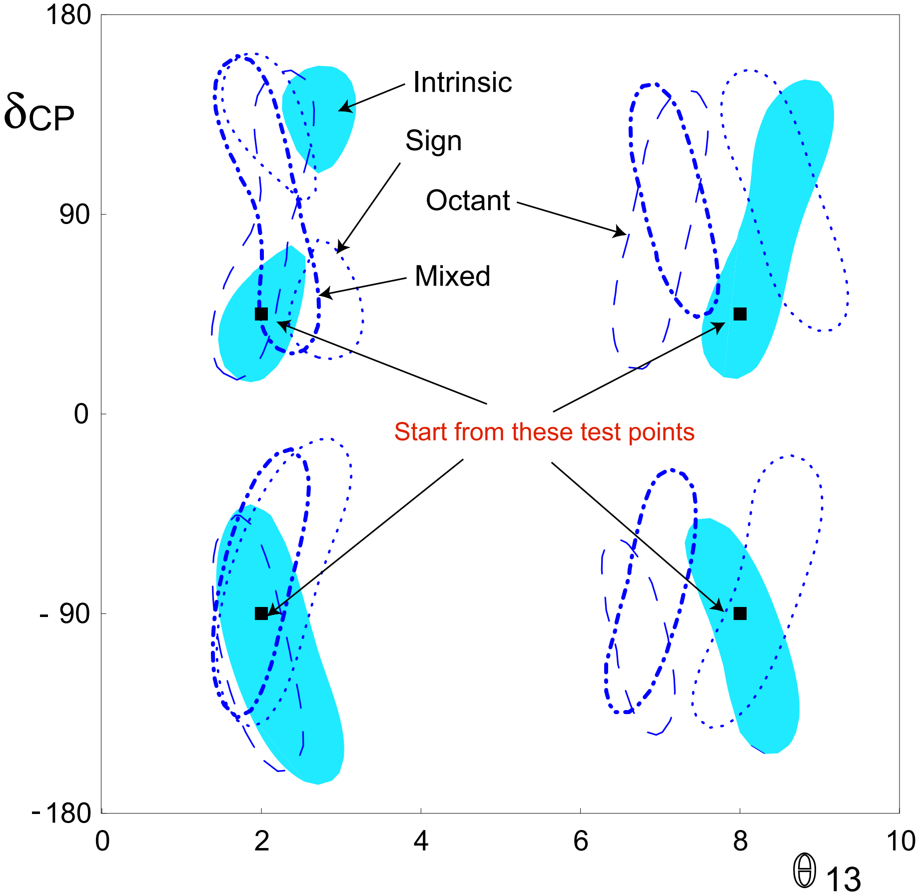


Computed for all the possible combinations of the unknown octant and $\text{sign}(\Delta m^2)$. Dashed curves are sensitivities computed not taking into account degeneracies.

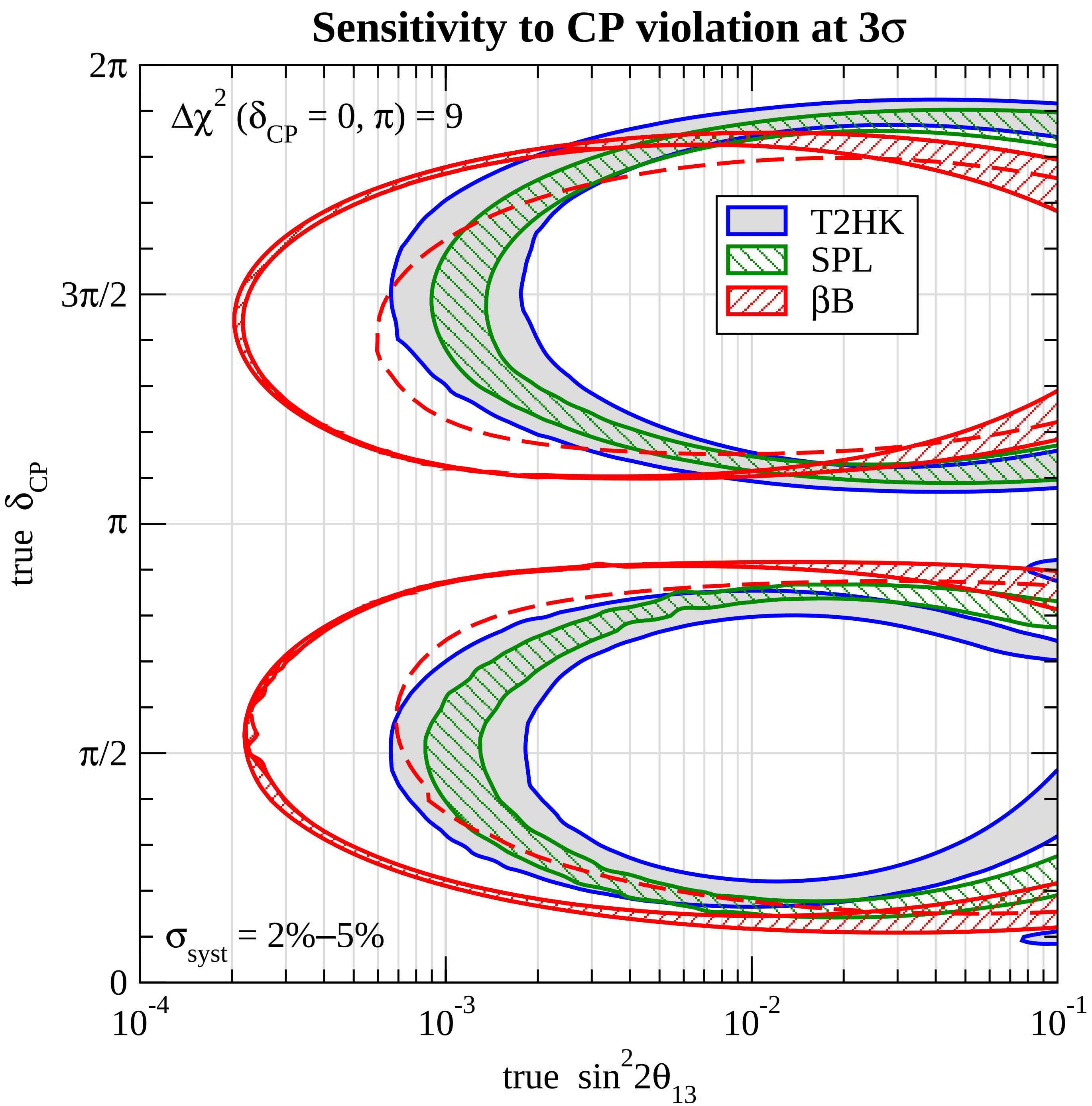
The degeneracy problem

The sub-leading $\nu_\mu \longrightarrow \nu_e$formula leaves room for clone solutions of the fit to θ_{13} and $\delta_{\rm CP}$. The eightfold degeneracies arise from

- $\mathbf{sign(\Delta m^2)}$. Changing $\mathrm{sign}(\Delta m^2)$ the $P(\nu_\mu \rightarrow \nu_e)$terms $\propto \sin(\Delta m^2_{23})$ change sign. Two separate solutions can be created by $(\theta_{13}\,, \delta_{\rm CP}\,, \mathrm{sign}(\Delta m^2)\ )$ and by $(\theta_{13}{}', \delta_{\rm CP}{}', -\mathrm{sign}(\Delta m^2)\ )$.
- $\boldsymbol{\pi/2 - \theta_{23}}$ (octant) . ν_μ disappearance measures $\sin^2 2\theta_{23}$ but some terms in the oscillation formula depend from $\sin\theta_{23}$ .At present the experimental best fit is $\sin^2 2\theta_{23} = 1$ allowing no ambiguity, but the experimental not excluded values smaller than unity allow for a twofold $\pi/2 - \theta_{23}$ ambiguity.
- **Mixed** The product of the above two



These eightfold discrete degeneracies (or twofold in case $\sin^2 2\theta_{23} \simeq 1$) can be solved by combining information of different experiments running at different energies or looking to different processes (i.e. combining $\nu_\mu \rightarrow \nu_e$ transitions with $\nu_e$disappearance or with $\nu_e \rightarrow \nu_\tau$ transitions). A single experiment cannot solve all these degeneracies by itself.


Sensitivity to CP violation at 3σ
Δχ^2 (δ_CP = 0, π) = 9
T2HK
SPL
βB
σ_syst = 2%–5%
2π
3π/2
π
π/2
0
true δ_CP
10^-4
10^-3
10^-2
10^-1
true sin^2 2θ_13

The synergy with atmospheric neutrinos

P. Huber et al., hep-ph/0501037: Combining Long Baseline data with atmospheric neutrinos (that come for free in the megaton detector):

- Degeneracies can be canceled, allowing for better performances in θ_{13} and LCPV searches
- The neutrino mass hierarchy can be measured
- The θ_{23} octant can be determined.

The main reasons are:

- **Octant** e-like events in the Sub-GeV data is $\propto \cos^2\theta_{23}$
- **Sign** e-like events in the Multi-GeV data, thanks to matter effects, especially for zenith angles corresponding to neutrino trajectories crossing the mantle and core where a resonantly enhancement occurs.

NOTE: LBL and atmospherics are a true synergy. They add to each other much more that a simple gain in statistics. Atmospherics alone could not measure the hierarchy, the octant, θ_{13} and LCPV. While the Beta Beam at short baselines could not measure the hierarchy as well as the octant.

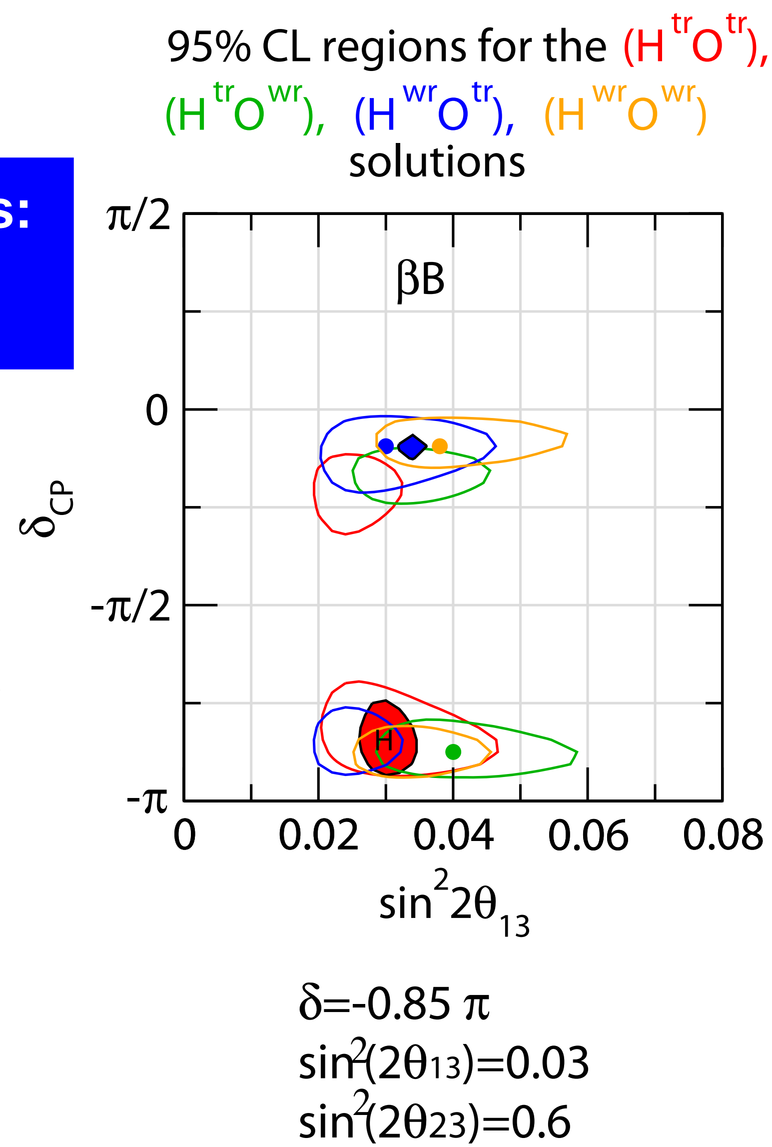
In the following sensitivities of the Beta Beam combined with the atmospherics are taken from J.E.Campagne, M.Maltoni, M.M., T.Schwetz, hep-ph/0603172 in its latest version, not yet released.

Beta Beam plus atmospherics: degeneracy removal

From: J.E.Campagne, M.Maltoni, M.M., T.Schwetz, hep-ph/0603172, revised

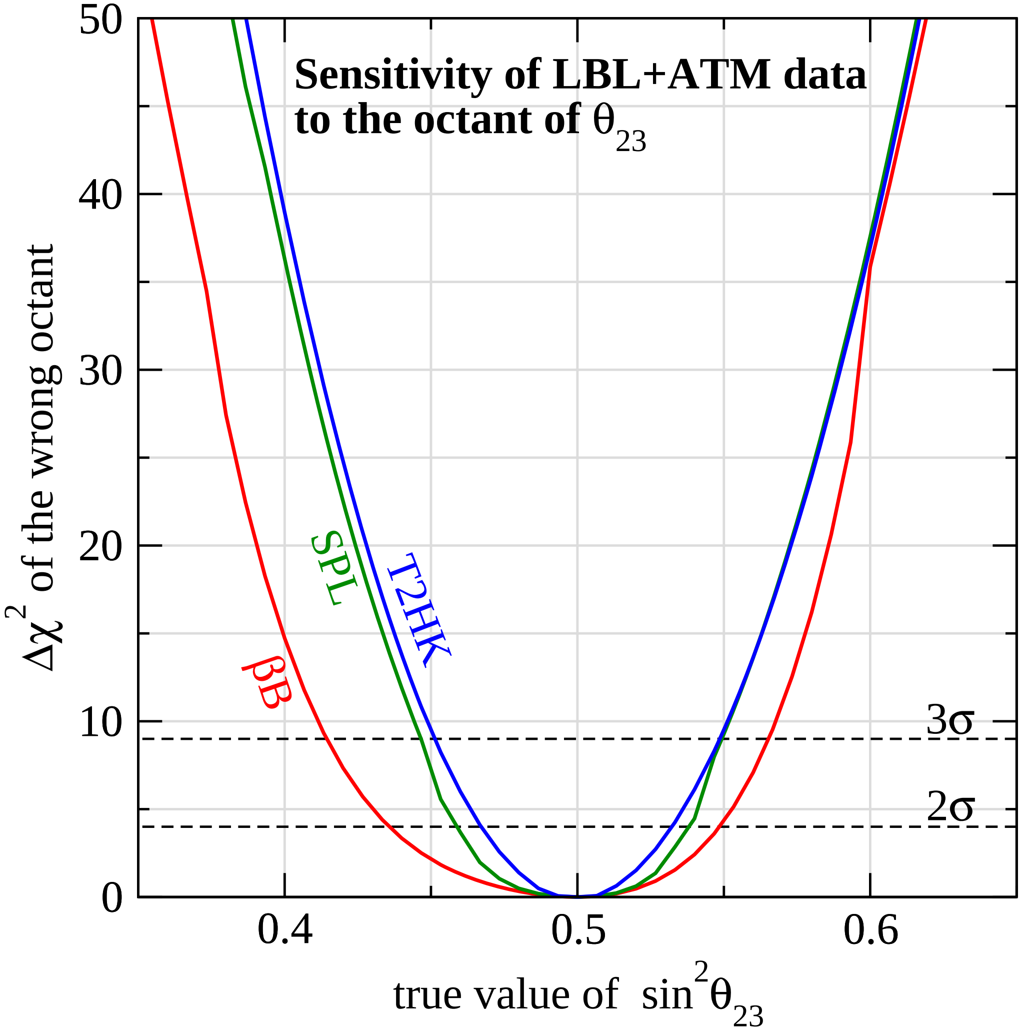
The red region is what is left after the atmospheric analysis.

Note how degeneracies were not influencing LCPV sensitivity too much.



Beta Beam plus atmospherics: determining the octant

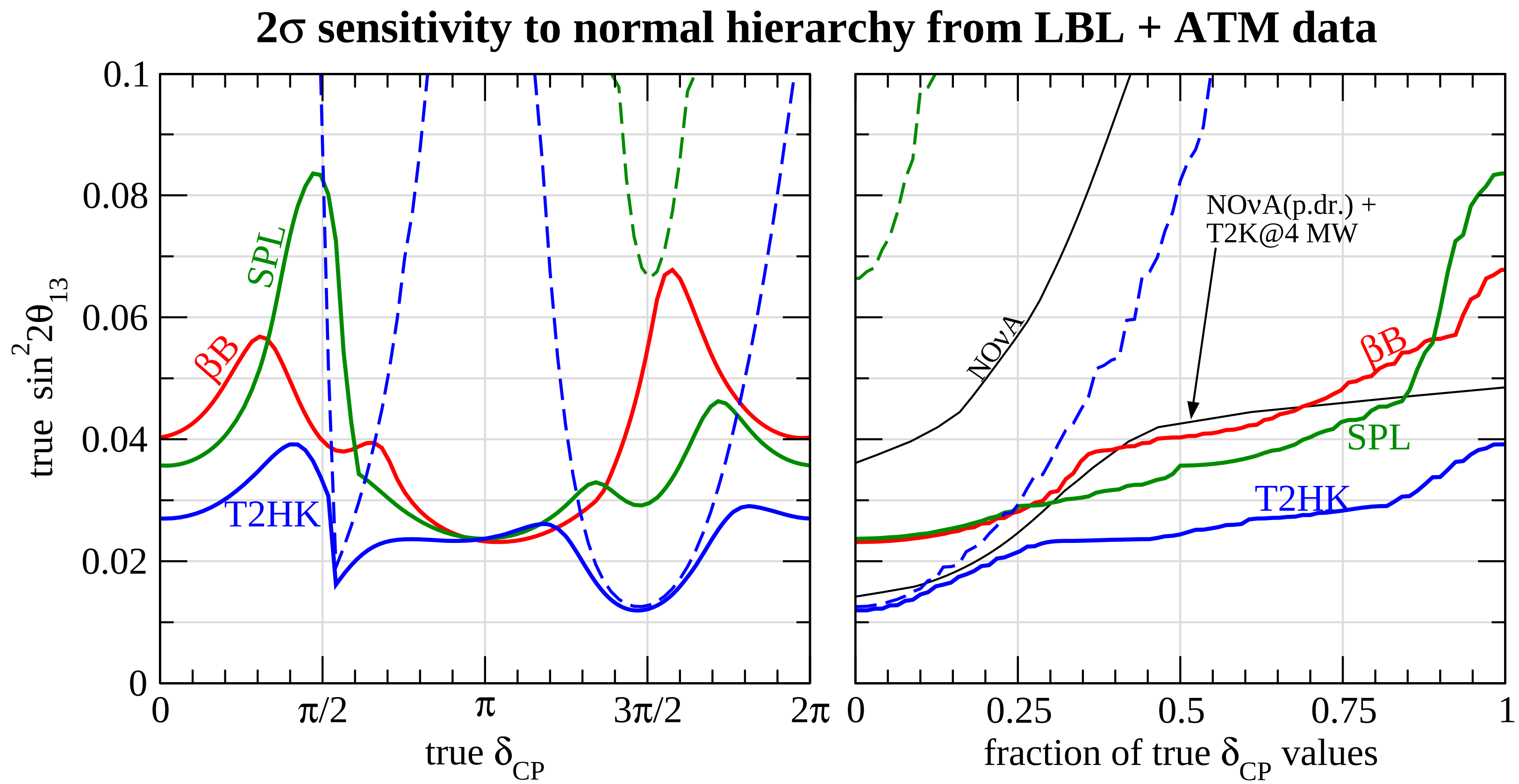
From: J.E.Campagne, M.Maltoni, M.M., T.Schwetz, hep-ph/0603172, revised



Computed for θ_{13} =0. Though the Beta Beam has practically no sensitivity to θ_{23} and the precision on θ_{23} from the Beta Beam is very poor, together with atmospheric data it can provide non-trivial information on the octant.

Beta Beam plus atmospherics: determining the mass hierarchy.

From: J.E.Campagne, M.Maltoni, M.M., T.Schwetz, hep-ph/0603172, revised



The high energy options

Several papers explored the physics potential of higher energy beta beams:

- J. Burguet-Castell et al., Nucl. Phys. B **695**, 217 (2004): $\gamma = 350$
- F. Terranova et al., Eur. Phys. J. C **38** (2004) 69: $\gamma = 2500$, $\gamma = 4158$
- J. Burguet-Castell et al., hep-ph/0503021: $\gamma = 150$
- P. Huber, M. Lindner, M. Rolinec and W. Winter, hep-ph/0506237 (with a discussion of fluxes vs. γ).

All these papers computed sensitivities assuming constant ion decay rates at higher gammas.

What can be kept constant indeed is the number of ions circulating in the decay ring, the decay rate will scale as $1/\gamma$.

In this way rates at the far detector at a first order CONSTANT with γ. Higher γ favour better energy reconstruction but they have higher background rates.

To be noted that the decay tunnel length is directly proportional to γ, for $\gamma = 150$ the decay tunnel length is $\simeq 7000$ m (36% useful straight session, 5 T magnets).

Electron capture beams

Radioactive ions can produce neutrinos also through electron capture.

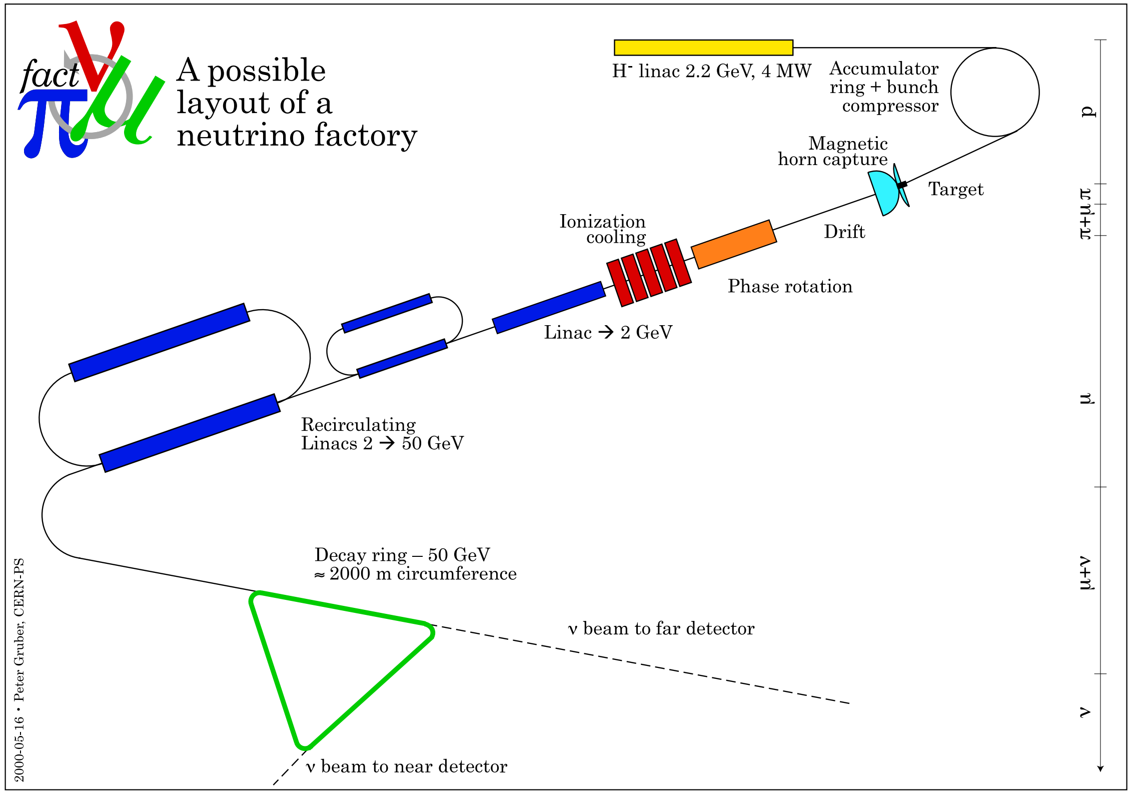
Monochromatic, single flavor neutrino beams!

- J. Bernabeu, J. Burguet-Castell, C. Espinoza and M. Lindroos, hep-ph/0505054
- J. Sato, hep-ph/0503144.

- The same complex could run either beta or electron capture beams.
- No way to have $\overline{\nu}_e$ beams.
- Ions should be partially (and not fully) stripped. Technologically challenging.
- Ion candidates are much heavier than beta candidates and have longer lifetimes (more difficult to stack them in the decay ring)

The basic concept of a neutrino factory (the CERN scheme)

- High power (4 MW) proton beam onto a liquid mercury target.
- System for collection of the produced pions and their decay products, the muons.
- Energy spread and transverse emittance have to be reduced: "phase rotation" and ionization cooling
- Acceleration of the muon beam with a LINAC and Recirculating Linear Accelerators.
- Muons are injected into a storage ring (decay ring), where they decay in long straight sections in order to deliver the desired neutrino beams.
- **GOAL:** $\geq 10^{20}$ μ **decays per straight section per year**



Oscillation signals at the neutrino factory

μ^- (μ^+) decay in (ν_μ , $\overline{\nu}_e$) (($\overline{\nu}_\mu$, ν_e)).

Golden channel: search for $\nu_e \longrightarrow \nu_\mu$ ($\overline{\nu}_e \longrightarrow \overline{\nu}_\mu$) transitions by detecting wrong sign muons.

Default detector: 40-100 kton iron magnetized calorimeter (Monolith like)

Silver channel: search for $\nu_e \longrightarrow \nu_\tau$ transitions by detecting ν_τ appearance.

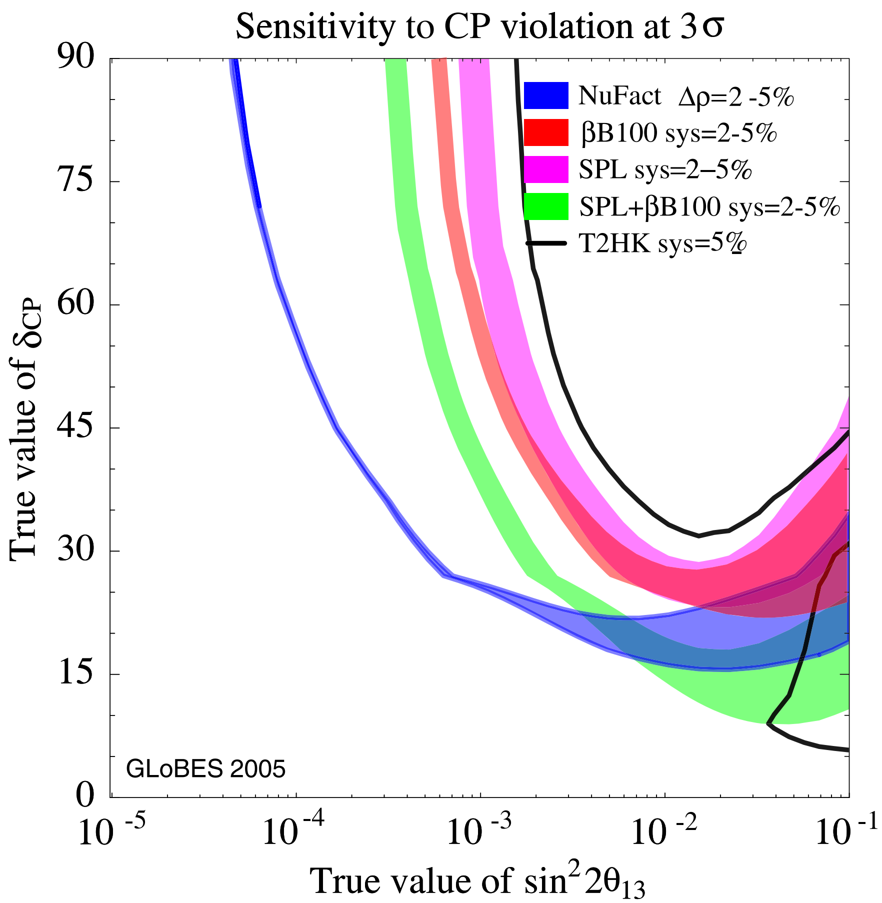
Ideal detectors: $4\times$ Opera or 10 Kton LAr detector.

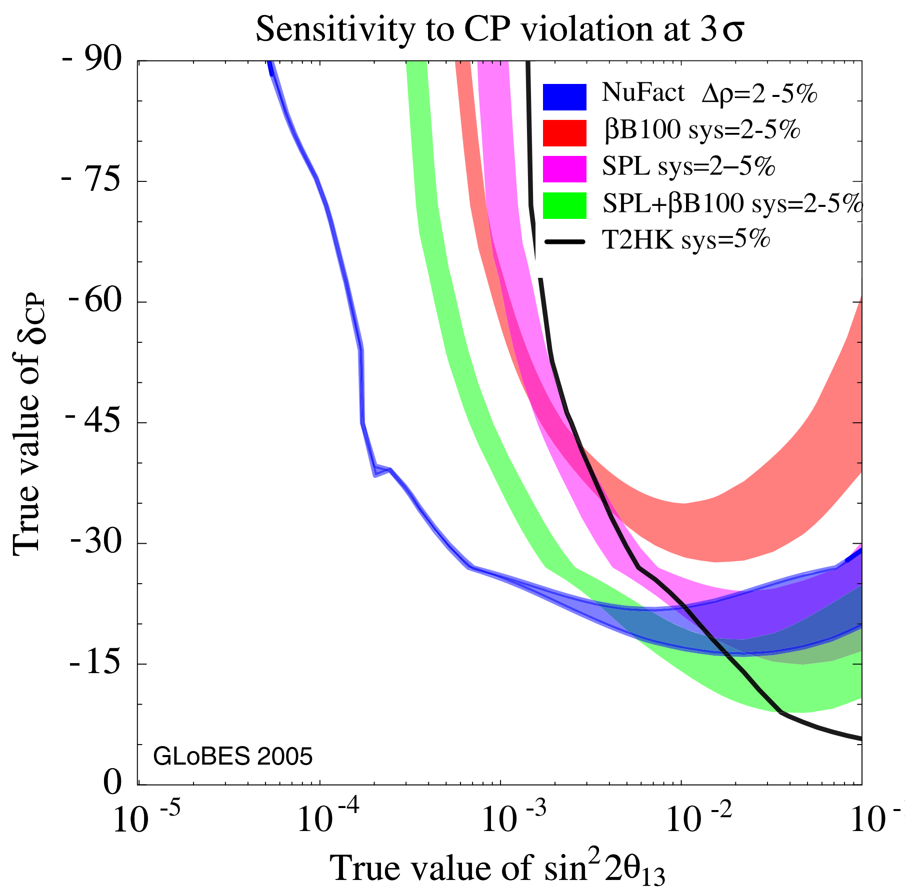
All these detectors can be accomodate at LNGS.

Ideal baseline for a 50 GeV Neutrino Factory is ~ 3000 km.

Leptonic CP violation discovery potential

From A.Blondel, A.Cervera-Villanueva, A.Donini, P.Huber, M.Mezzetto and P.Strolin, Acta Phys. Polon. B **37** (2006) 2077



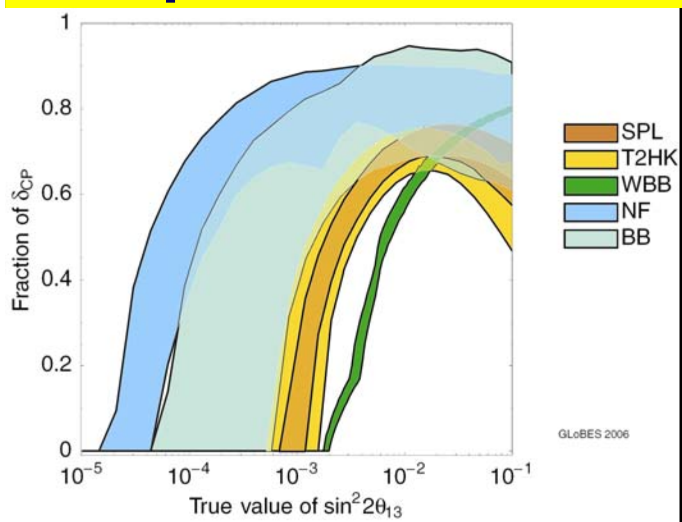


ISS and European design study.

ISS stands for International Scoping study, an international effort started about 2 years ago to fully establish the possibilities and the physics potential of future neutrino beam facilities. The final document will be ready soon .

This year will be a call for proposals from EU in the FP7 framework. The neutrino phyisics community is going to produce a request for a design study of a future neutrino beam facility.

Comparison: CP violation



SPL
Systematics: 2% – 5%

T2HK
Systematics: 2% – 5%

WBB
Systematics from proposal

Beta beam
= 100
500 kT H_2O Ç (130 km)
= 350
500 kT H_2O Ç (730 km)

Neutrino Factory
Golden, 4000,
E_μ = 50 GeV
Golden* (4000 km), Golden* (7500 km)
E_μ = 20 GeV

Conclusions

- It's not too early to discuss and study next generation neutrino beam experiments.
- New concepts and new ideas have raised great interest in the community and beyond. We are in the phase of their conceptual development and comparison of the different possibilities.
- CERN is not fully supporting future neutrino beams, and their development will have to be integrated inside the foreseen upgrades of LHC.
- Developments in this field are to now a bottom-up process, driven by the foundamental importance of neutrino oscillations and the enthusiasm of neutrino physicists.