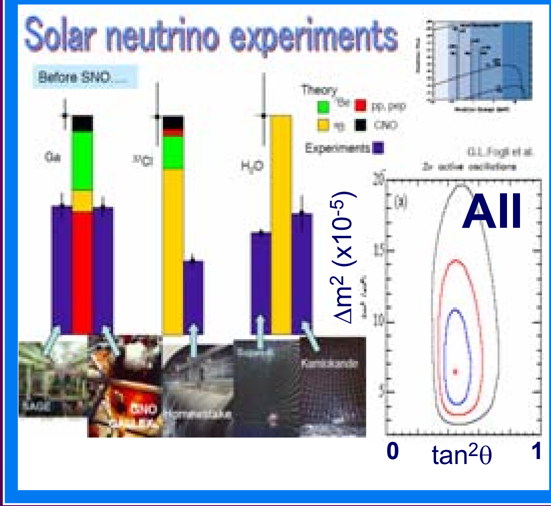
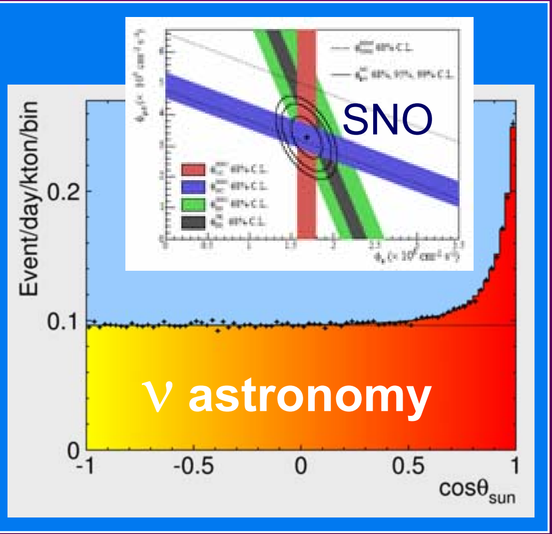
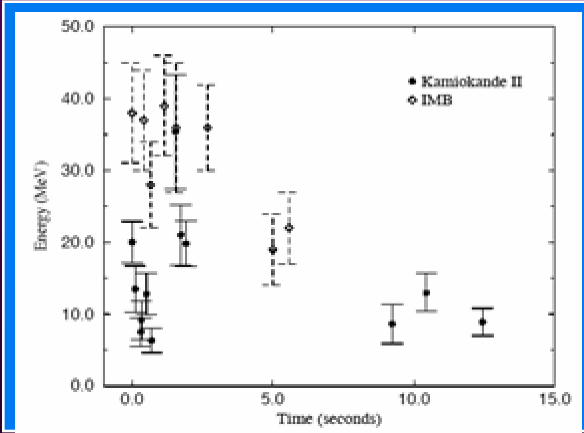
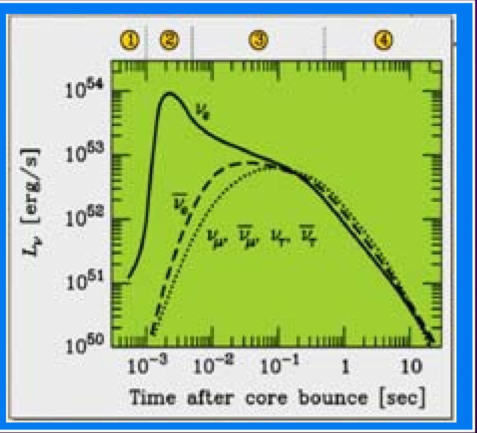
MEgaton Mass PHYSics

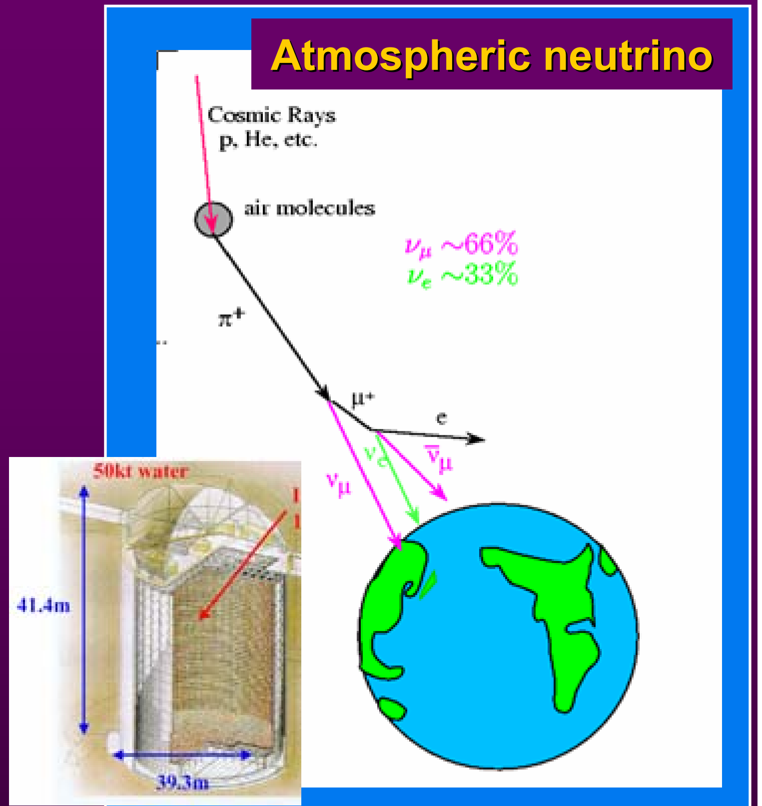
But past success of the field…

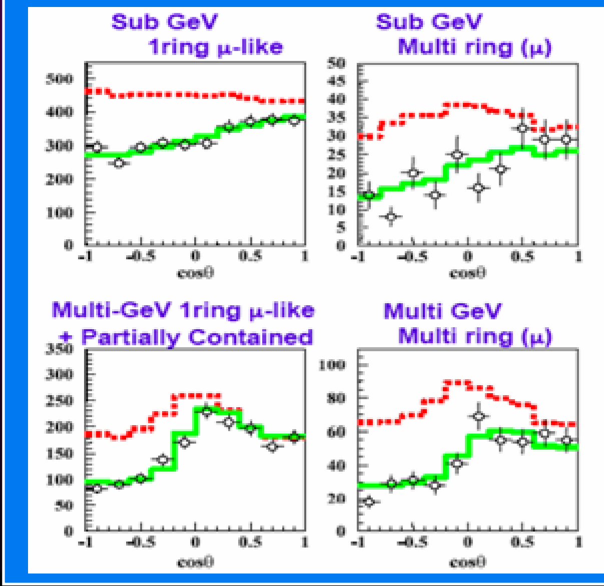












- Solar neutrino anomaly solved
- Detection of SN-1987A (Nobel Koshiba)
- Discovery of atm neutrino oscillations

The need for new generation experiments…

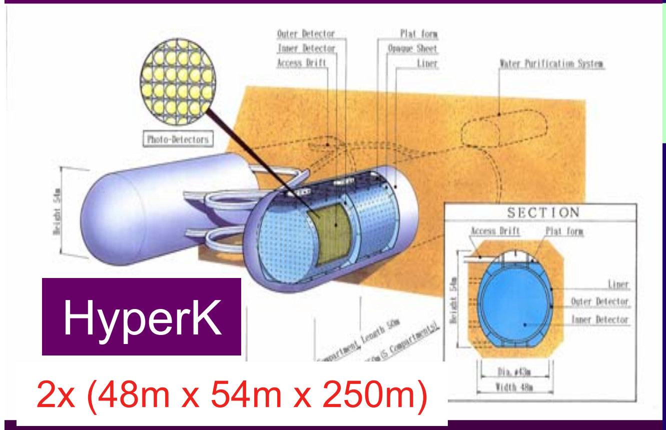
Still many important issues…

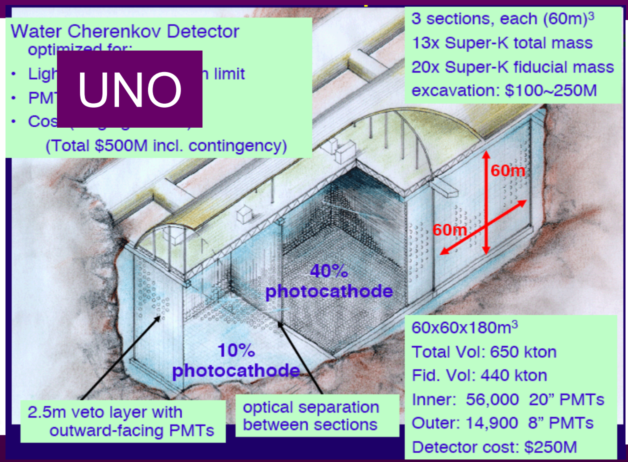
- **Baryon number violation** — **Proton decay**
- **Astroparticle physics**
  - **Understand gravitational collapse** — **Galactic SN ν**
  - **Star formation in the early universe** — **Diffuse SN ν**
  - **Explore violent phenomena in the universe** — **Trigger SN ν,**
  - **Dark matter and astrophysical sources** — **Incoming muons**
- **Neutrino properties** — **LBL - ν, Atm. - ν, SN - ν,**
- **Solar thermonuclear fusion processes** — **Solar - ν**
- **Geophysical models, Earth density profile** — **Geo - ν , U, Th - ν**

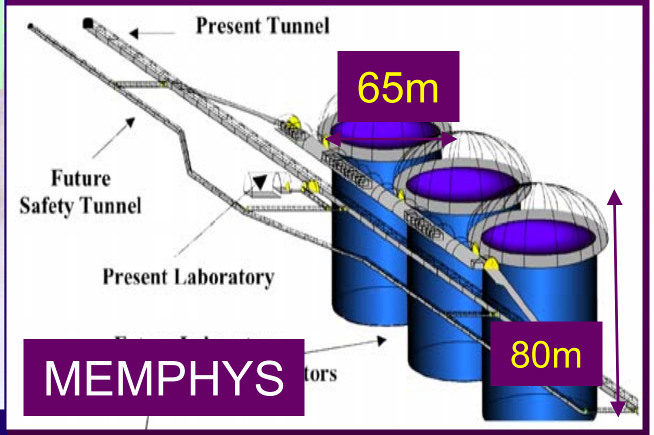
NNN Workshops

Aussois 05, Seatle 06, Hamamatsu 07

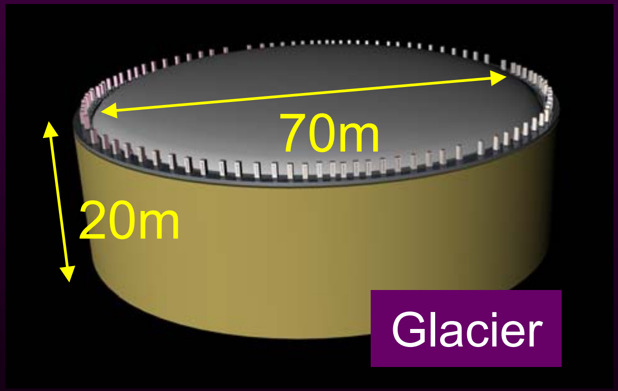
Water Cerenkov 500kT→1Mt



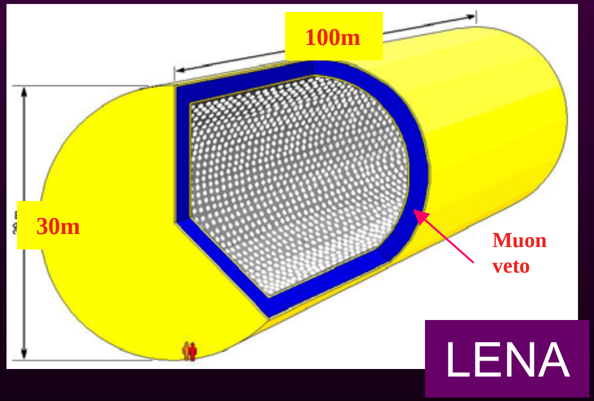




LAr →100kT



Liq. Scintillator →50kT



Mton Water Čerenkov

- Concept of a Mton water Cherenkov detector dates back to 1992
  - M. Koshiba: "DOUGHNUTS" Phys. Rep. 220 (1992) 229

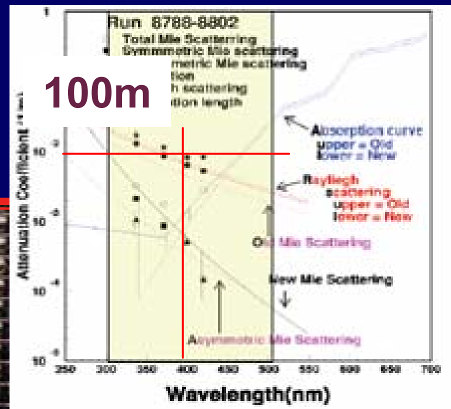
HyperK

- Concept of Hyper-Kamiokande was first presented at NNN99
  - K. Nakamura, Int. J. Mod. Phys. A18 (2003) 4053
- American concept UNO in NNN99:
  - **C.K. Jung, "Feasibility of a next generation underground water Cherenkov detector UNO", arXiv:hep-ex/0005046**
- Similar European project in 2005:
  - A. de Bellefon et al: "MEMPHYS a large scale water Cerenkov detector at Frejus", Contribution to the CERN Strategic Group

Well-proven technology (IMB, K, SK) for large scale however currently no wide expertise in Europe

Ex: MEMPHYS 1 shaft

About 170 γ/cm in 350 < λ < 500 nm
With 81,000 PMT (12'') 30% coverage, Q.E.≈24%, CE~70%
(⇔20''PMT 40% cov. ,Q.E.≈20%, CE~60%)
Relativistic particle produces
⇒≈14 p.e / cm
⇒≈6 p.e / MeV (SK-I)



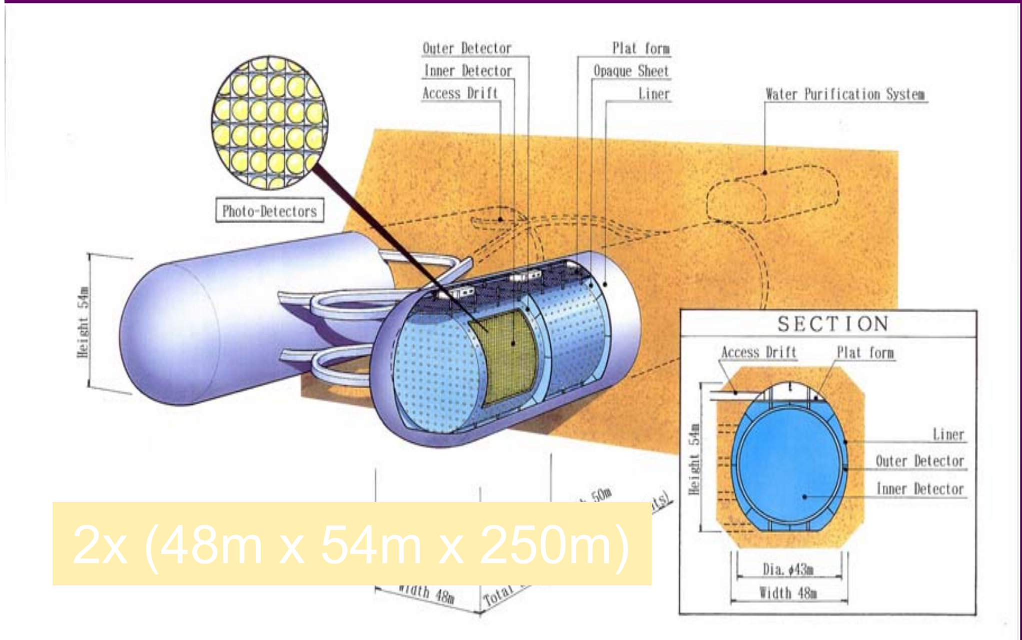
Volume total x4 SK
Fiduciel: 145kT
17535m^2 surface PMT

- Gd Cl_3 highly water soluble but acid
- Neutron capture on Gd emits a 8.0 MeV γ
- 100 tons of $GdCl_3$ in SK-III (0.2% by mass) would yield >90% neutron captures on Gd
- **Test currently on the K2K 1kT prototype**
- **A lot of Physics Potential depend from that!!!**

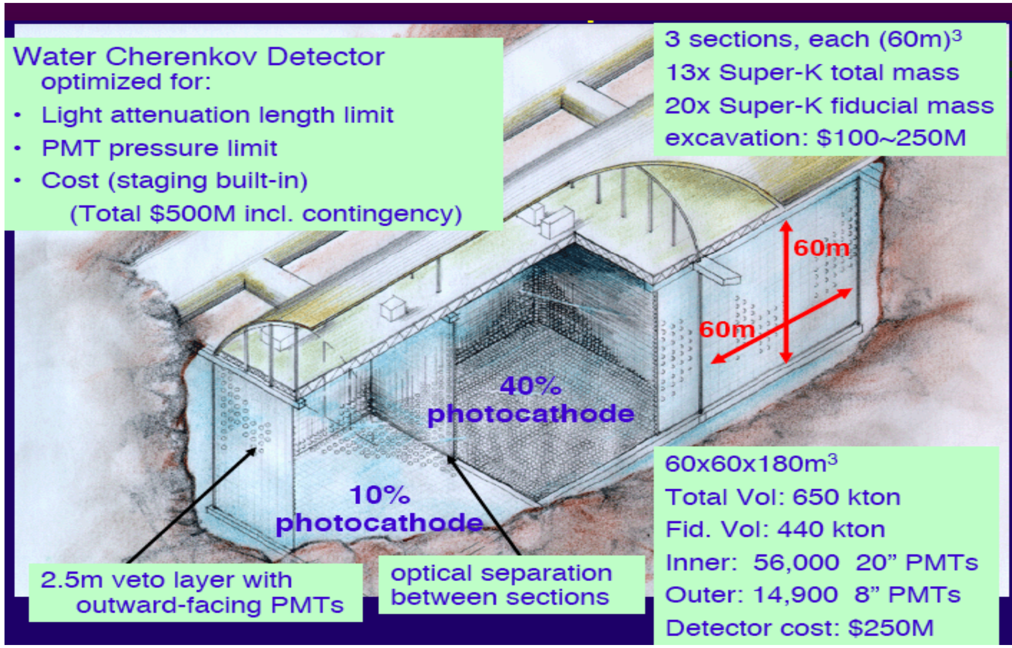
Beacom & Vagins Phys. Rev. Lett., **93**:171101, 2004

The Japanese and US projects: HK and UNO

(strong collaboration between the 3 WC projects in NNN and beyond)



- Toshibora Mine (900 mwe)
- FV 540 ktons
- Cavern study performed
- Photodetector R&D on-going
- Long baseline T2K superbeam (CP-violation)
- Decision following results from T2K-Phase 1 (2013-2022 ?)
- 2nd location in Korea ?

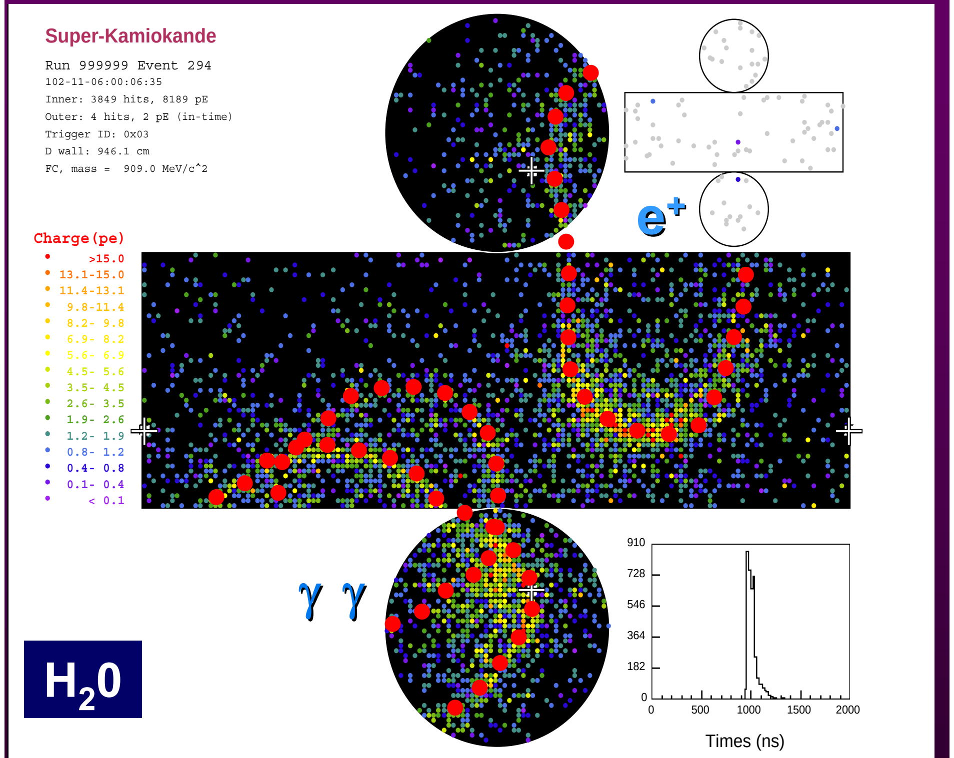


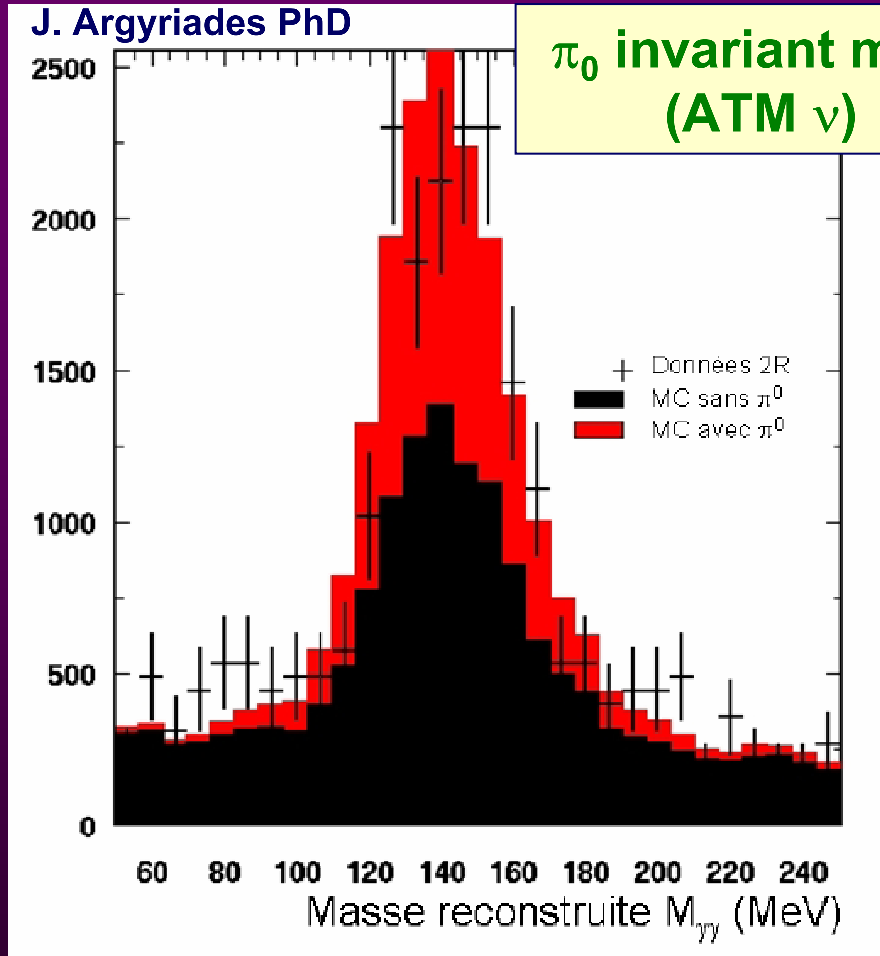
- Henderson Mine (4000 mwe, one of the 2 DUSEL sites)
- FV 440 ktons
- Cavern study to be done
- Photodetector R&D on-going
- Long baseline from BNL
- In the NSF process

Summary of WC in the world (LAL-06-22)

	UNO (USA)	HK (Japon)	MEMPHYS (EU)
Laboratory			
location	Henderson/Homestake	Tochibora	Fréjus
prof. Mwe	4500/4800	1500	4800
LBL(km)	1480÷2760/1280÷2530	290	130
Dimsensions			
type	3 cubes	2 tunnels de 5 compartments	3 to 5 shafts
dimension	$60 \times 60 \times 60 m^3$	ϕ:43m x L:50m	ϕ:65m x L:65m
M fid. Kt	440	550	440 à 730
Photodetectors			
type	20" PMT	20" H(A)PD	12" PMT
#	38000 (middle) 2 x 9500 (side)	20,000 per compartiment	81,000 per shaft
Couverage	40%/10% (middle/side)	40%	30%
Estimate Cost 50% excavation + 50% Photodetection			
	500M$	500 Oku ¥	161M€ x #shafts +100M€ infra.

Imaging capability…



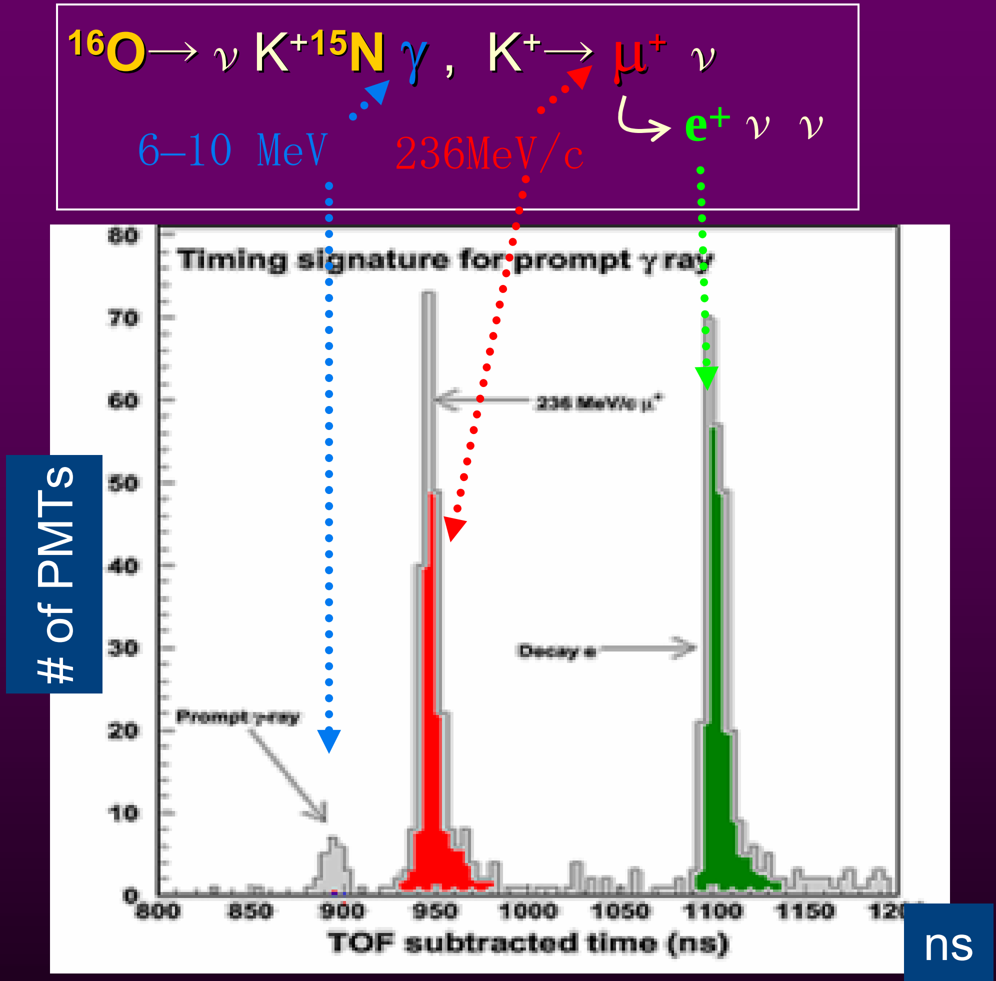


π_0 invariant mass (ATM ν)

1-ring vertex ~10cm
Ring-direction ~ 1°
σ_E ~10%/√E (45% Solar ν)
Absolute E scale @ 3%

Cerenkov threshold:
~1.07GeV:p, ~570MeV: $K^\pm$,
~120MeV:$\mu^\pm$,~0.6MeV:$e^\pm$
Lowest trigger threshold: 5MeV
(trig. rate x10 every MeV due to ambiant radioactivity)

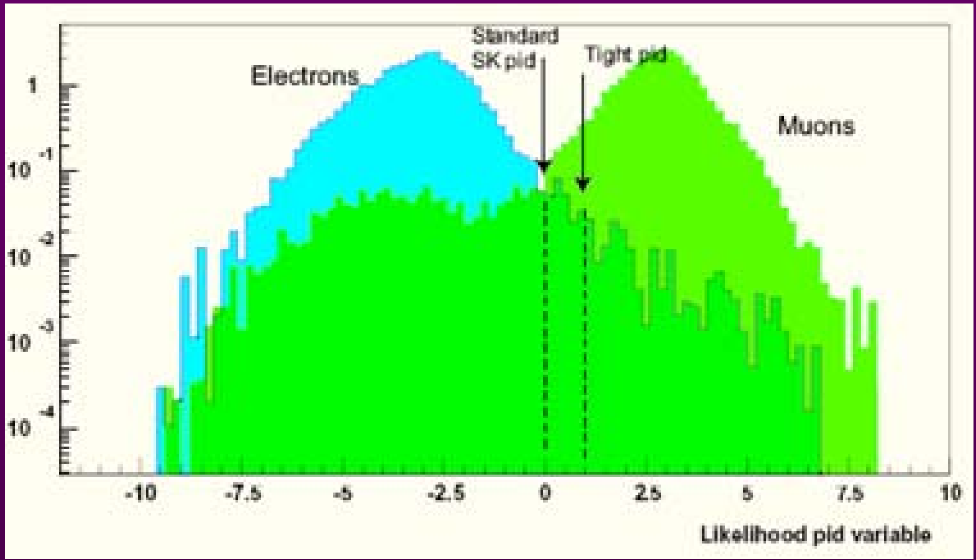
Timing capability: an example for $p \to K^+ \bar{\nu}$



Autotrigger capability

The first use of the PMT timing is the approximate vertex determination

Particle Id.



1% 1-ring μ → e
10% 1-ring e → μ

$$\mathcal{P}^{angle}(e \text{ ou } \mu) = e^{-\frac{1}{2}\left(\frac{\theta^c - \theta^{att}(e \text{ ou } \mu)}{\delta\theta}\right)^2}$$

Compare the expected and measured Cerenkov angle

$$\mathcal{P}_n^{pattern}(e \text{ ou } \mu) = e^{-\frac{1}{2}\left(\frac{\chi^2(e \text{ ou } \mu) - \chi^2_{min}}{\sigma_{\chi^2_n}}\right)^2}$$

Compare the expected and measured charge of *i*th PMT from the *n*th ring

$$\mathcal{L}_n(e \text{ ou } \mu) = \prod_{\theta_i < 1{,}5\ \theta^c} \text{prob}\left[q_i^{obs}, q_{i,n}^{att}(e \text{ ou } \mu)) + \sum_{n' \neq n} q_{i,n'}^{att}\right]$$

Proton decay

An Upper Bound exists coming from the GAUGE sector (d=6)
Independant model I. Dorsner, P. F. Perez PLB 625 (05) 88

$$\tau_p^M \leq 6.0 \times 10^{39} \frac{(M_X/10^{16}\,\mathrm{GeV})^4}{\alpha_{GUT}^2} (0.003\,\mathrm{GeV}^3/\alpha)^2 \,\mathrm{years}$$

$$\tau_p^D \leq 1.4 \times 10^{37} \frac{(M_X/10^{16}\,\mathrm{GeV})^4}{\alpha_{GUT}^2} (0.003\,\mathrm{GeV}^3/\alpha)^2 \,\mathrm{years}$$

Specific model gives faster decay rates…

It is quite difficult and unnatural to set to 0 all the decay channels simultaneously

$\bar{\nu}$ + meson $\leftrightarrow$ charged lepton + meson

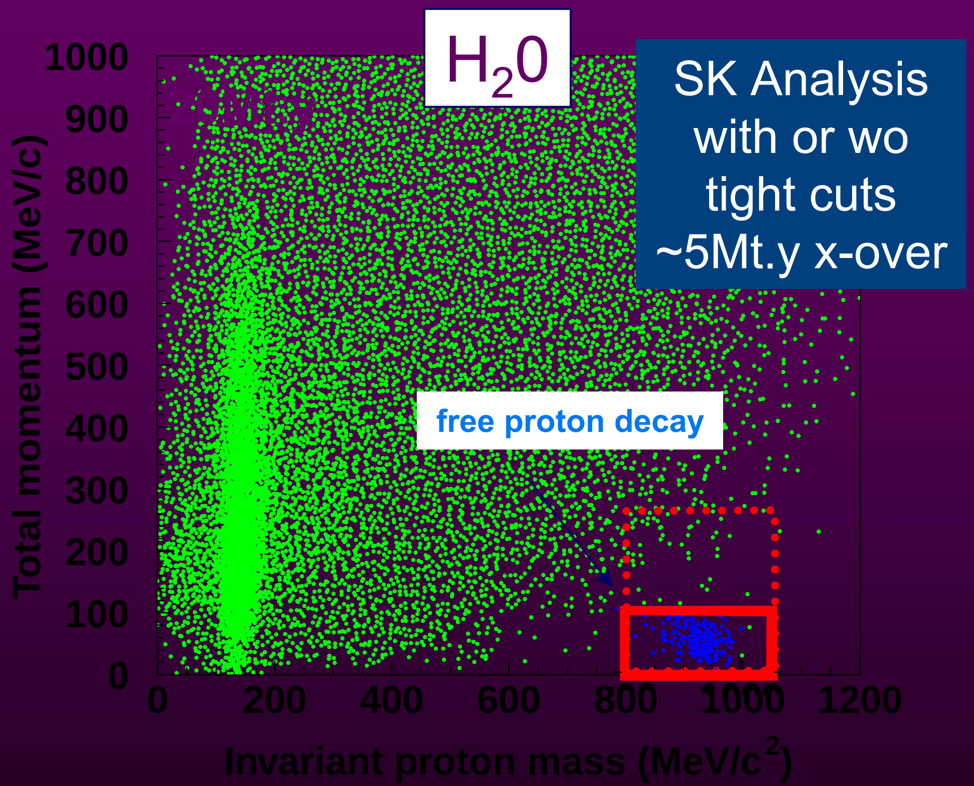
$$p \rightarrow K^+ \bar{\nu} \qquad p \rightarrow e^+ \pi^0$$

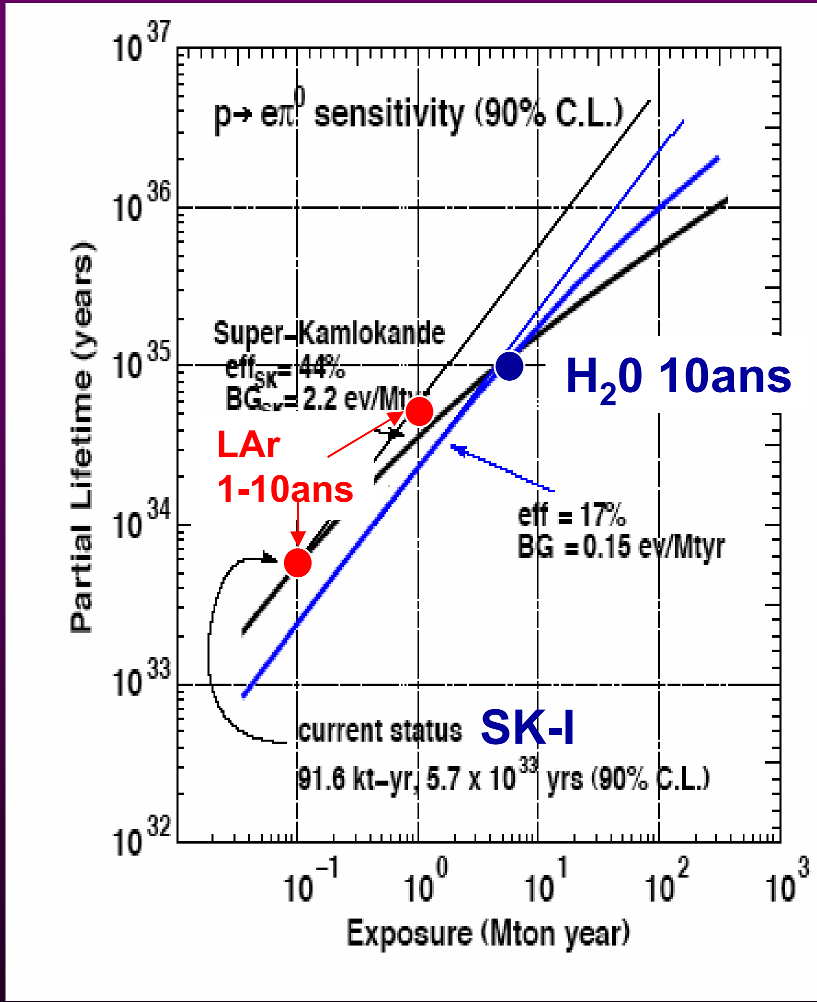
Some recent models predictions

Model	Decay modes	Prediction	References
Georgi-Glashow model	-	ruled out	[8]
Minimal realistic non-SUSY $SU(5)$	all channels	$\tau_p^{upper} = 1.4 \times 10^{36}$	[9]
Two Step Non-SUSY SO(10)	$p \to e^+\pi^0$	$\approx 10^{33-38}$	[10]
Minimal SUSY $SU(5)$	$p \to \bar{\nu}K^+$	$\approx 10^{32-34}$	[11]
SUSY $SO(10)$ with 10_H, and 126_H	$p \to \bar{\nu}K^+$	$\approx 10^{33-36}$	[12]
M-Theory(G_2)	$p \to e^+\pi^0$	$\approx 10^{33-37}$	[13]

P. F. Perez @ LPNHE 17/2/06

$p \rightarrow e^+ \pi^0$

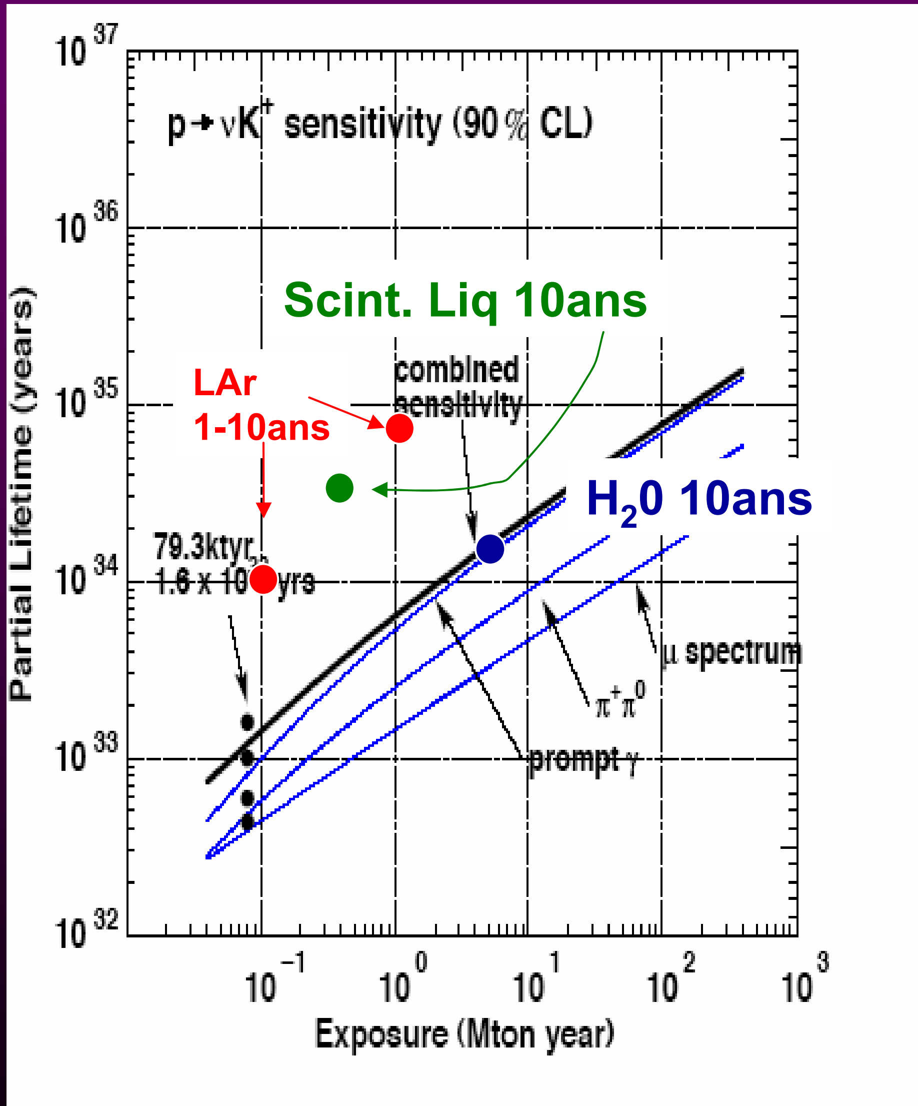




$p \to K^+ \bar{\nu}$

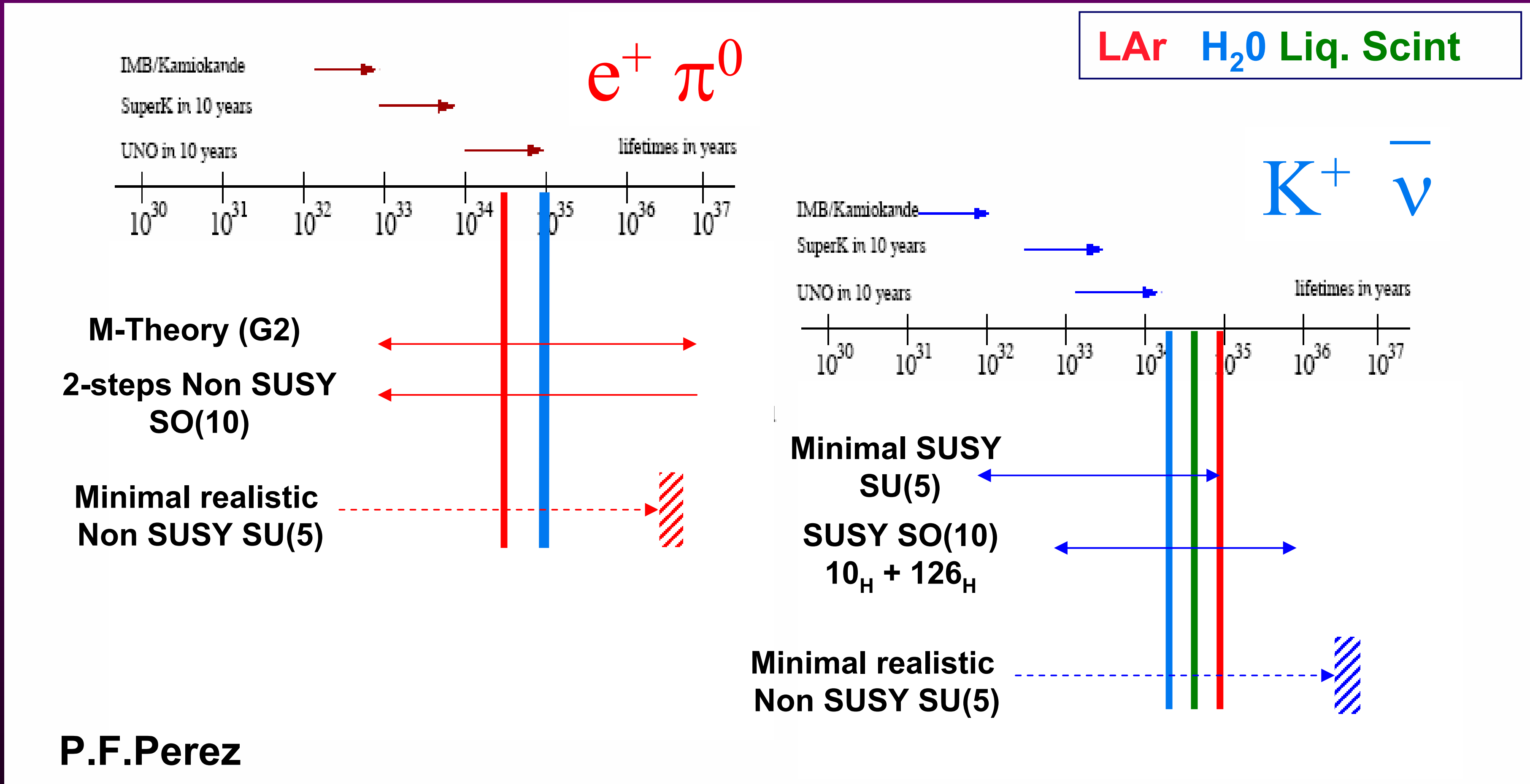
H_20: K⁺ below Č threshold
Imaging/Timing
$K^+ \to \pi^+\pi^0$; $\mu^+\nu$ avec ou sans ^{15}O
$\to {}^{15}N$ γ prompt (6MeV) tag

	ε	Bkgd
H_20 (*)	8.6%	3/Mt.y
Scint. Liq.	65%	<1/Mt.y
LAr	97%	<1/Mt.y



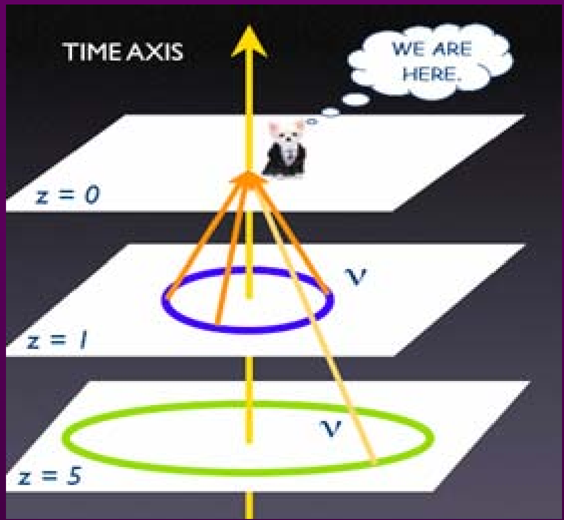
*: SK analysis

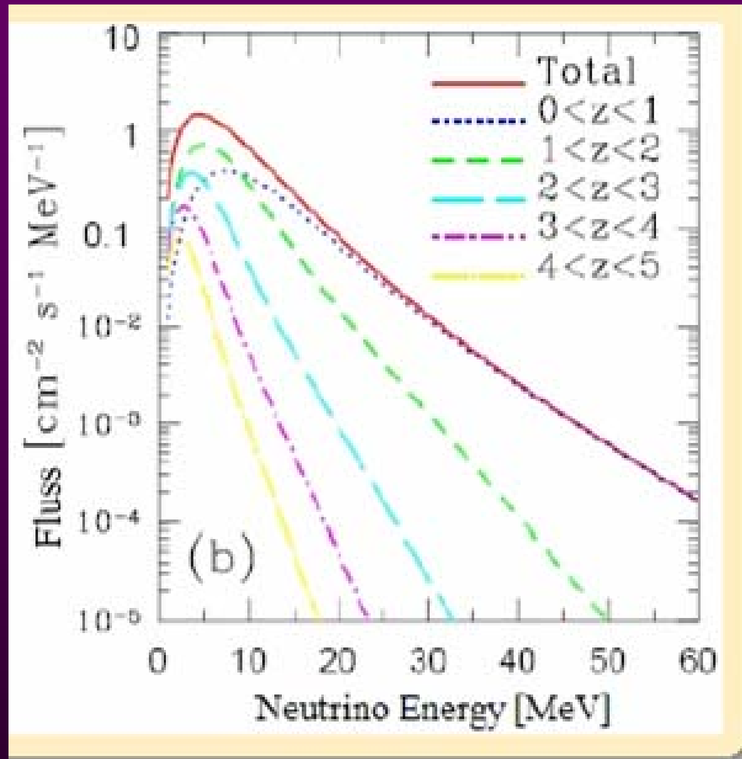
Summary of proton decay



Definitively not exhaustive neither p channels nor n decay…

Diffuse SN

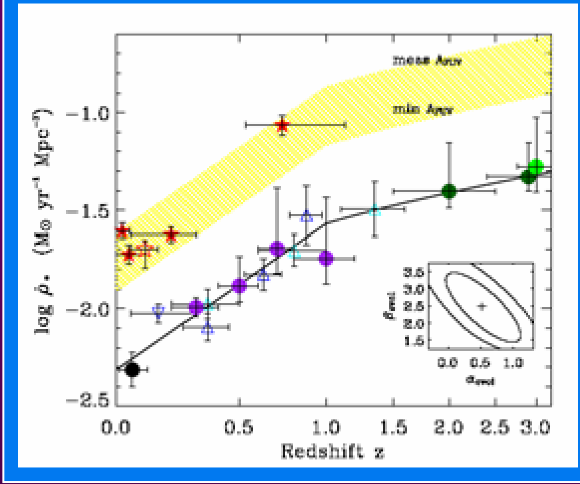




Detection of SNν with z ≲ 1

Flux ∝ **all SN(z) in particular those which produce a Black hole**

Current limit close to a detection?



Star Formation
GALEX
$(1+z)^{2.5}$ z<1
$(1+Z)^{0.5}$ z>1

Astrophys.J. 619 (2005) L47

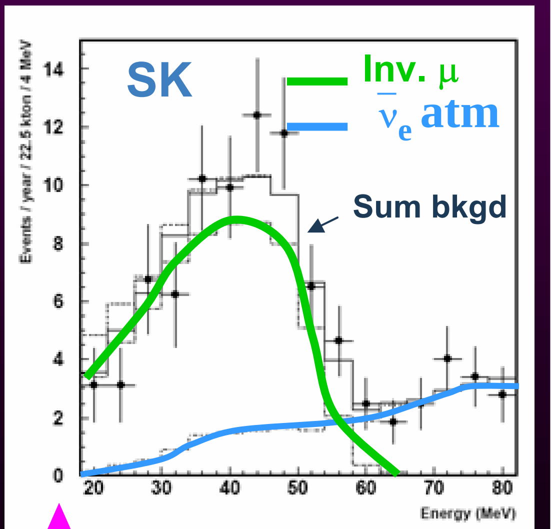
Supernova

$$\frac{dN_\nu}{dE_\nu} \propto \frac{E_\nu^2}{\exp(E_\nu/T_\nu - \eta)+1},$$
$$T_{\nu_e} = 3 \text{ MeV},$$
$$T_{\bar{\nu}_e} = 5 \text{ MeV},$$
$$T_{\nu_x} = 8 \text{ MeV}$$

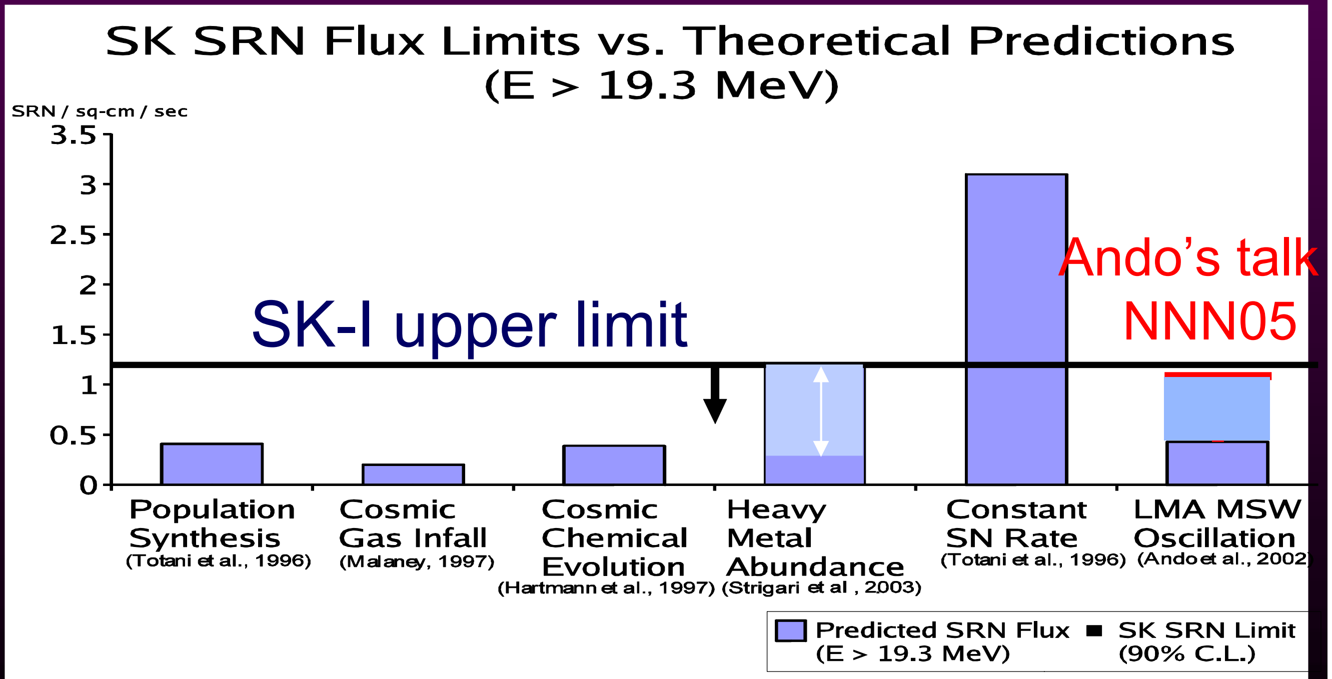
E_ν > 11.3 MeV	E_ν > 19.3MeV
5.1 $cm^{-2}s^{-1}$	1.2 $cm^{-2}s^{-1}$

The oscillations (LMA) tend to increase the flux above E>30MeV

Phys. Rev. Lett 90, 061101 (2003)



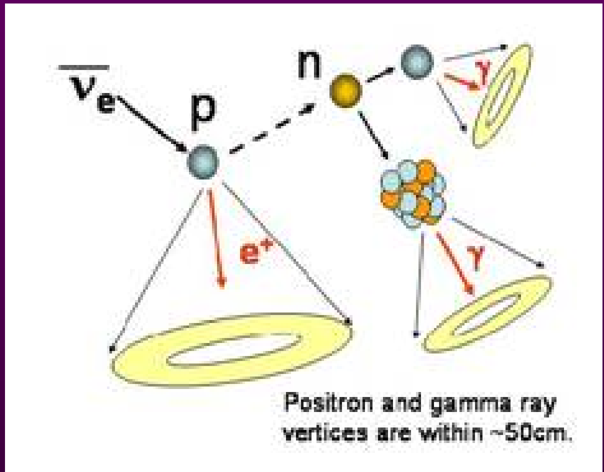
Reacteur + Sun



Futur: $\bar{\nu}_e$ & ν_e complementarity

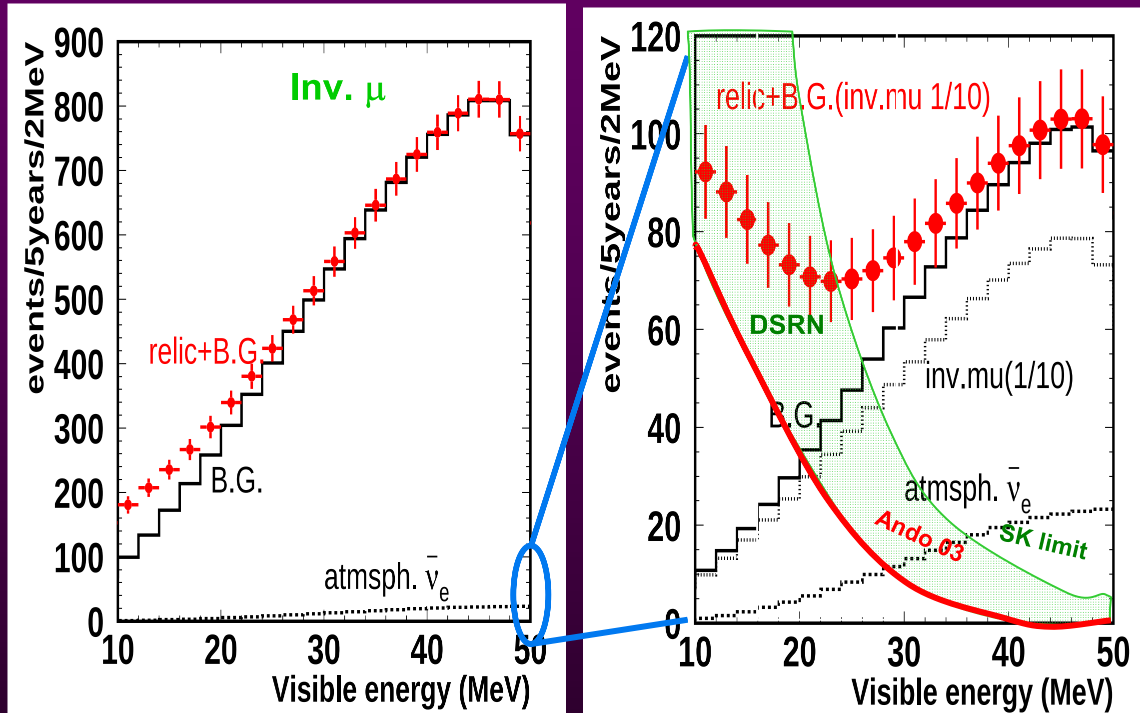
$\bar{\nu}_e$

H_20 + neutron capture
30% PMT coverage



ΔT(p: 2MeV γ) = ~ 200 μs
ΔT(**Gd**: 8MeV γ) = few 10^{th} μs

No n-tagging | **With n-tagging**



Nakahata+Vagins @ NNN05

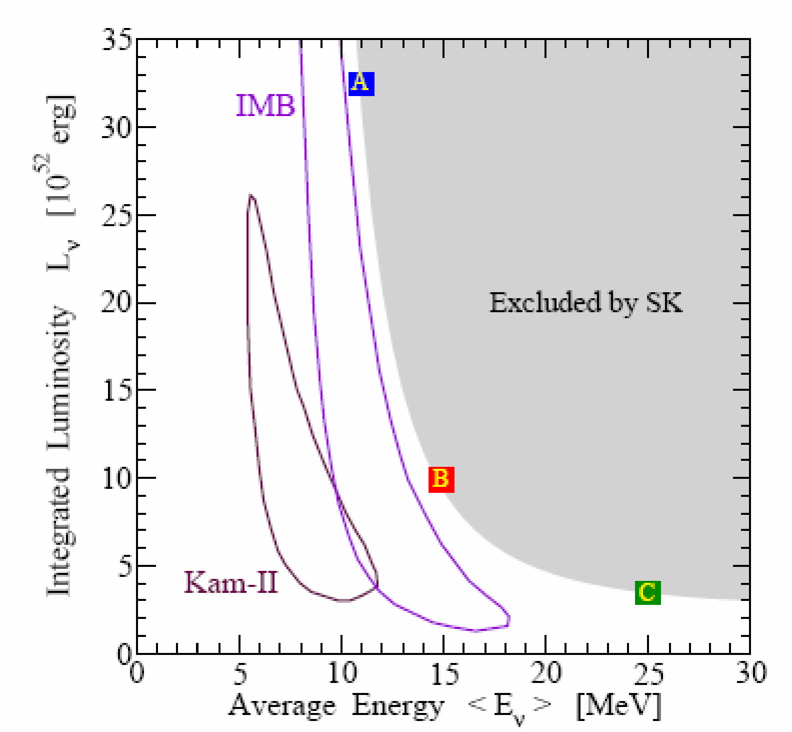
MEMPHYS: 60-150* Sig/65 BG [15-30]MeV 2yrs (1Mt.y)

$\nu_e + {}^{40}Ar \rightarrow {}^{40}K^* + e^-$ **(see GLACIER)**

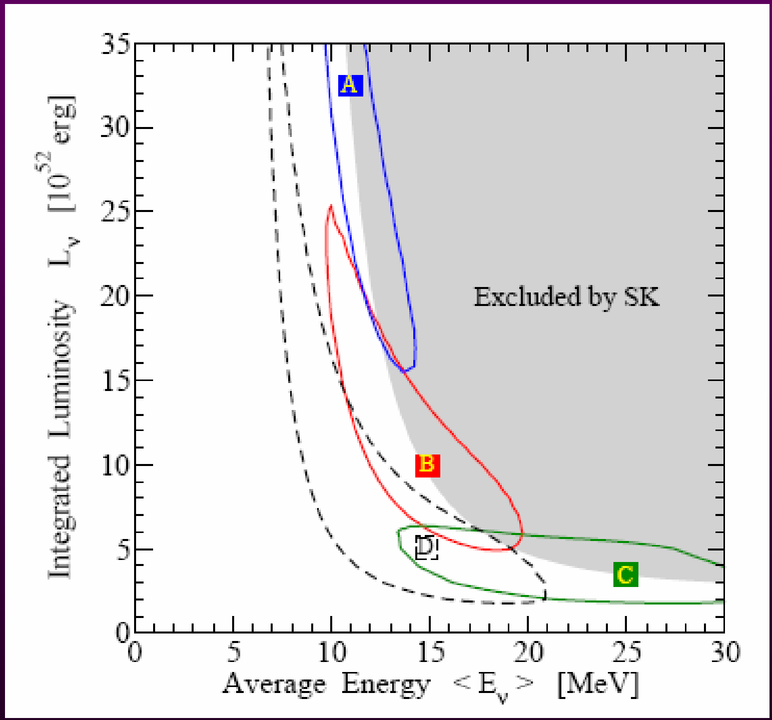
***: at SK limit**

SN parameter measurements

SN 1987A (KAM-II,IMB)
DSN (SK)



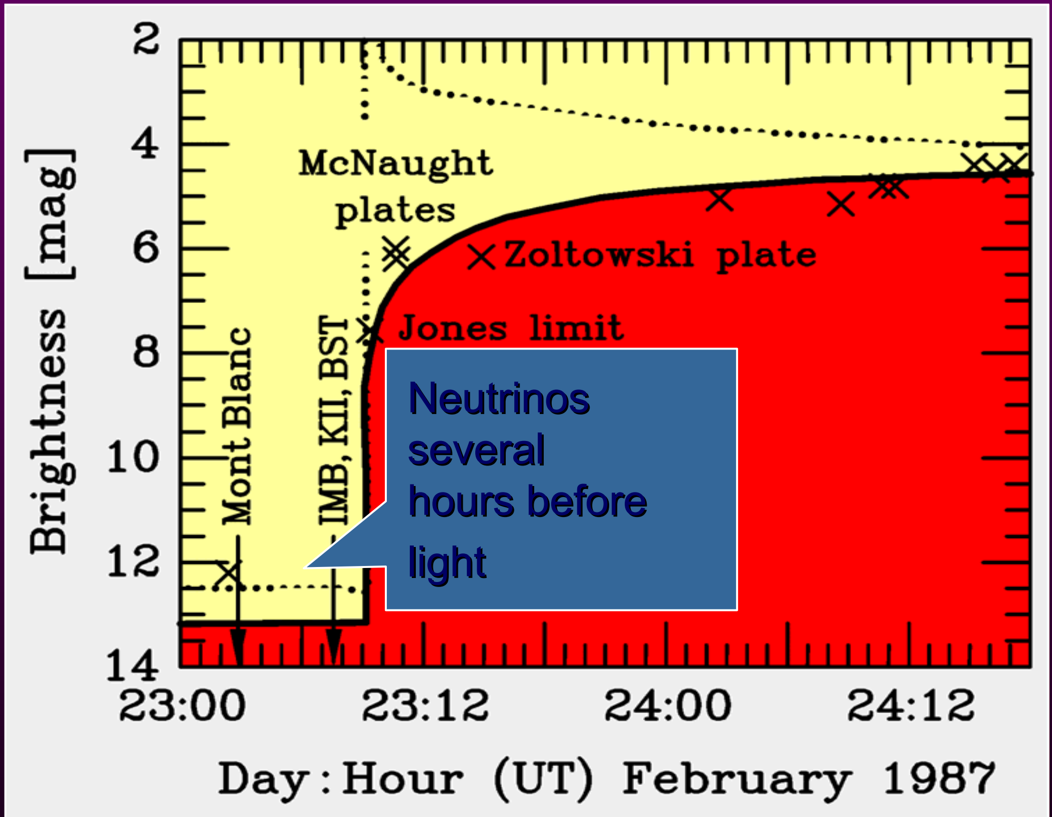
DSN
5yrs SK-Gd
⇔1yr MEMPHYS-1shaft-Gd



Yukse, Ando Beacom astro-ph/0509297

SN II Explosion

Early light curve of SN1987A



As for the SUN in the past…

In case of signal:
- **astrophysical subject?**
- **neutrino physics subject?**

It will depend of the respective knowledge at the time of detection

Counting rates

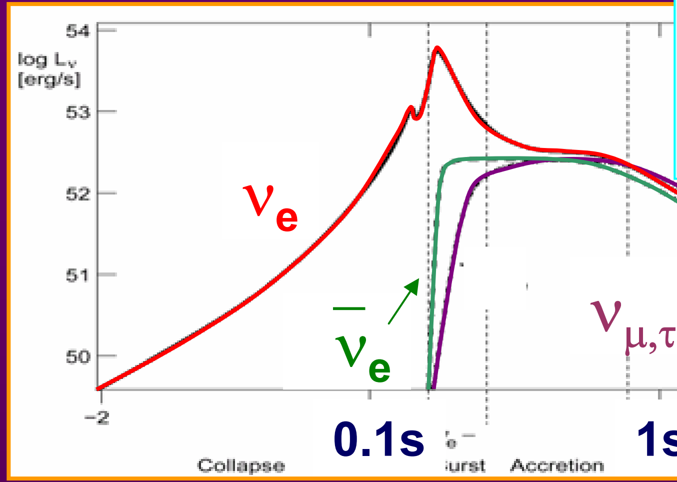
Mixture of initial fluxes:

$$F_{\nu_e} = pF^0_{\nu_e} + (1-p)F^0_{\nu_x}\,,$$
$$F_{\bar\nu_e} = \bar pF^0_{\bar\nu_e} + (1-\bar p)F^0_{\nu_x}\,,$$
$$4F_{\nu_x} = (1-p)F^0_{\nu_e} + (1-\bar p)F^0_{\bar\nu_e} + (2+p+\bar p)F^0_{\nu_x}\,.$$

Survival probabilities in different scenarios:

Case	Hierarchy	$\sin^2\Theta_{13}$	p	$\bar p$
A	Normal	Large	0	$\cos^2\Theta_\odot$
B	Inverted	Large	$\sin^2\Theta_\odot$	0
C	Any	Small	$\sin^2\Theta_\odot$	$\cos^2\Theta_\odot$

- "Small": $\sin^2\Theta_{13} \lesssim 10^{-5}$, "Large": $\sin^2\Theta_{13} \gtrsim 10^{-3}$.



$\langle E_e \rangle \approx 9-12$ MeV
$\langle E_{\bar e} \rangle \approx 14-17$ MeV
$\langle E_x \rangle \approx 18-22$ MeV

$8M_\odot$ 10kpc	Si burn	ν_e burst	ν_e cc	$\bar\nu_e$ cc	$\overset{(-)}{\nu}_x$ e ES	$\overset{(-)}{\nu}_x$ ~~e ES~~
H_2O 0.4Mt	2-10 With Gd	15	100 p >>^{16}O		3	-
Sci Liq 50kt	85			9 p >>^{12}C	0,6	10 p >>^{12}C
LAr 100kt		380	24-31	1-2	1,3	30

$\times 10^3$

What to do with this SNν ?

- SN trigger
  - GALEX + SN formation ⇒ 1 SN/y D<10 Mpc
    - H20 450kT [18-30MeV]: $4.5/(Mpc)^2$ and 0.4BG/day
    - H20+Gd 240kT [12-38MeV]: $4.5/(Mpc)^2$ et 0.3BG/day
  - However 9 SN with D<10 Mpc in 3 years (x3 the expected rate)…
    - 2 events $\Delta t < 10s$ (no BG) ⇒ SN Alarm
    - SN via Optic ⇒ if $\Delta t < 10s$ 1 event ⇒ Alarm confirmed
  - *In coïncidence with GW, if possible(???)⇒ sensitivity $m_\nu \sim 1eV$*
- Si → Fer burning if D<2kpc : n-capture requested
- Neutronization burst : possible but better with GLACIER
- SN direction:
  - ES e- 2°→0.6° (H_20 + Gd)

Time evolution of the energy spectrum: Burst + Shock Wave +Earth θ_{13} parameter + mass Hierarchy

Hierarchy	$\sin^2\theta_{13}$	ν_e neutronization peak	Shock wave	Earth effect
Normal	$\gtrsim 10^{-3}$	Absent	ν_e	$\bar{\nu}_e$ ν_e (delayed)
Inverted	$\gtrsim 10^{-3}$	Present	$\bar{\nu}_e$	ν_e $\bar{\nu}_e$ (delayed)
Any	$\lesssim 10^{-5}$	Present	———	ν_e $\bar{\nu}_e$

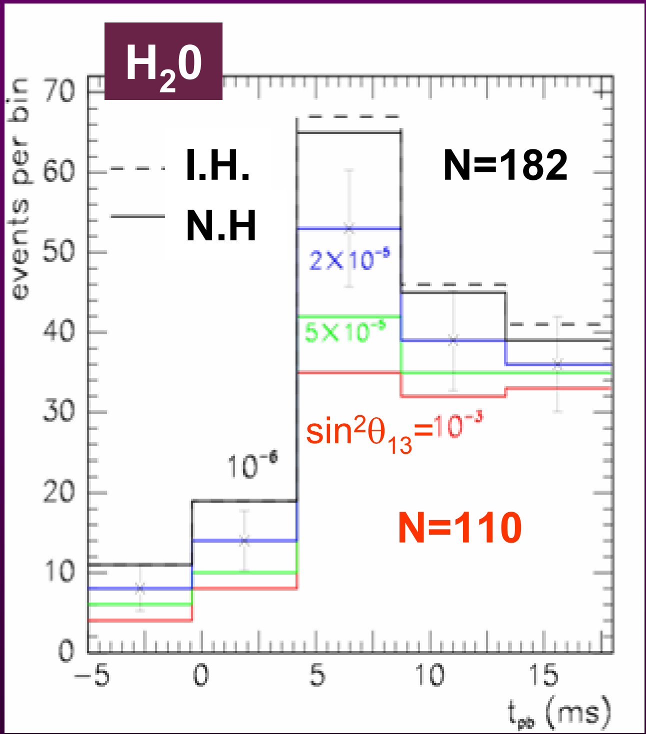
A. Mirizzi @ LPNHE 17/2/06

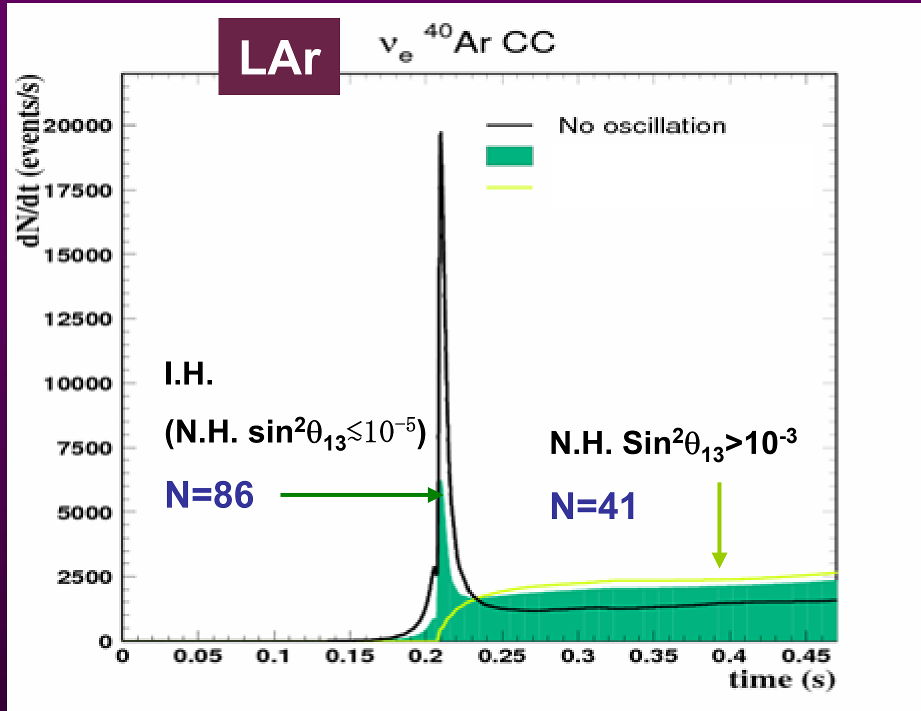
Exploiting these complementary signatures, one could extract useful information on the neutrino mass hierarchy and on θ_{13}

($\nu_{\mu\tau}$ + p NC measurement of independant fraction of the binding energy)

Neutronization burst (~ 25 ms, after the bounce)

Robust feature of the SN simulation





$\nu_{e,x}\, e^- \rightarrow \nu_{e,x}\, e^-$ (ES)

$\nu_e\, Ar \rightarrow e^- K^*$ (CC) **+ NC**

Possibility to probe non standard physics

Resonant Spin Flavor transitions [E.Akhmedov et al., hep-ph/0310119]

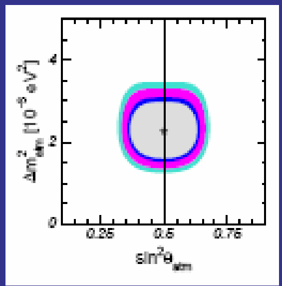
Neutrino Decay [S.Ando, hep-ph/0405200]

→ **Possibility to look for non standard $\bar{\nu}_e$ fraction (H$_2$0)**

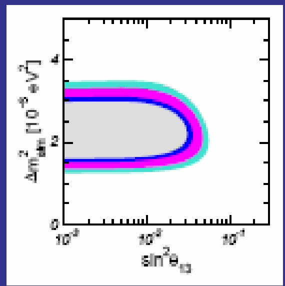
Man made Oscillations...

Non couvert ici par ex.: échelle de masse, Majorana vs Dirac, ν stérile…

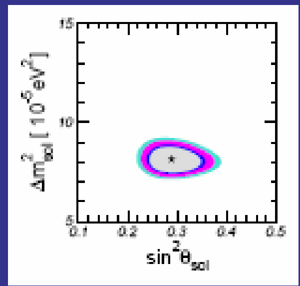
$$U = \begin{pmatrix} 1 & 0 & 0 \\ 0 & c_{23} & s_{23} \\ 0 & -s_{23} & c_{23} \end{pmatrix} \begin{pmatrix} c_{13} & 0 & e^{-i\delta} s_{13} \\ 0 & 1 & 0 \\ -e^{i\delta} s_{13} & 0 & c_{13} \end{pmatrix} \begin{pmatrix} c_{12} & s_{12} & 0 \\ -s_{12} & c_{12} & 0 \\ 0 & 0 & 1 \end{pmatrix}$$



atmospheric + K2K



CHOOZ

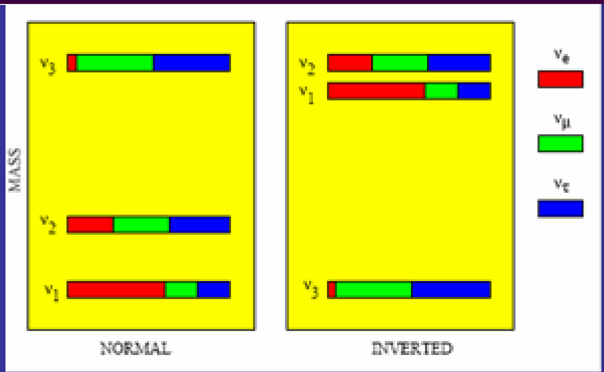


solar + KamLAND

		1σ
$\sin^2\theta_{12}$	$0.31^{+0.02}_{-0.03}$	9%
$\sin^2\theta_{23}$	$0.50^{+0.06}_{-0.05}$	11%

Δm^2_{21} [10^{-5}eV^2]	7.9 ± 0.3	4%
$\lvert\Delta m^2_{31}\rvert$ [10^{-3}eV^2]	$2.2^{+0.37}_{-0.27}$	14%

Échelle de masse



$\Delta m^2_{31} > 0$ $\Delta m^2_{31} < 0$

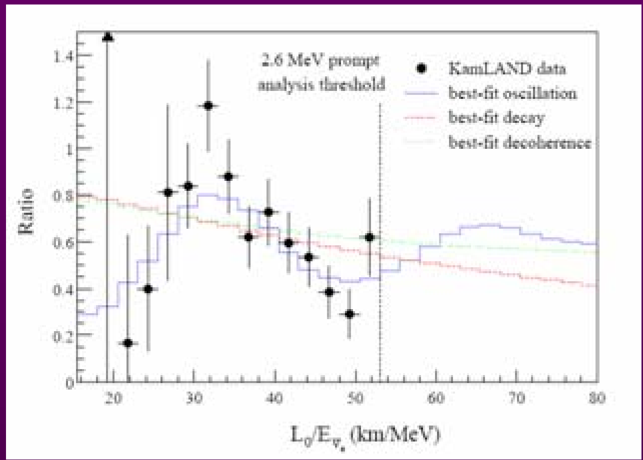
Octant de θ_{23}

θ_{13}

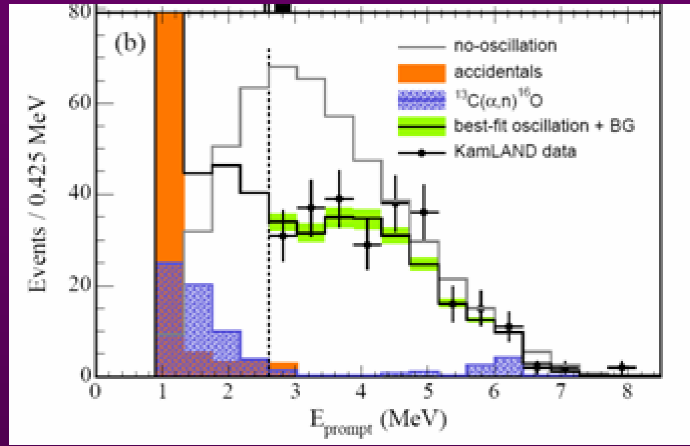
δ_{CP}

?

Δm^2_{21} et $\sin^2\theta_{12}$ « *solar parameters* »



KamLAND



0.77kT.y

Reacteurs ν

Background for Supernova ν

S. Choubey, S.T. Petcov, hep-ph/0404103

99% CL Data set	range $\Delta m^2_{21}/10^{-5}$eV²	spread Δm^2_{21}	range $\sin^2\theta_{12}$	spread $\sin^2\theta_{12}$
only solar	$3.2 - 14.9$	65%	$0.22 - 0.37$	25%
solar+1 kTy KL	$6.5 - 8.0$	10%	$0.23 - 0.37$	23%
solar+2.6 kTy KL	$6.7 - 7.7$	7%	$0.23 - 0.36$	22%
3 yrs SK-Gd	$7.0 - 7.4$	3%	$0.25 - 0.37$	19%
5 yrs SK-Gd	$7.0 - 7.3$	2%	$0.26 - 0.35$	15%

A possible « Roadmap » (inspired by A. Cervera @ CSG-Orsay06)

1st step: present era *Ongoing:* 2005-2010

- Improve the precision on the atmospheric parameters looking at ν_μ disappearance
- Confirm (atm. osc)=($\nu_\mu \rightarrow \nu_\tau$) and first look at $\nu_\mu \rightarrow \nu_e$

2nd step: prospective era *Approved/Proposed:* 2009-2015

- Demonstrate visibility of sub-leading transitions:

  $\nu_\mu \rightarrow \nu_e$, $\nu_e \rightarrow \nu_e$
- Explore θ_{13} down to 2^0 (today $<10^0$)

3rd step: deep search era *Discussed:* 2015-2025

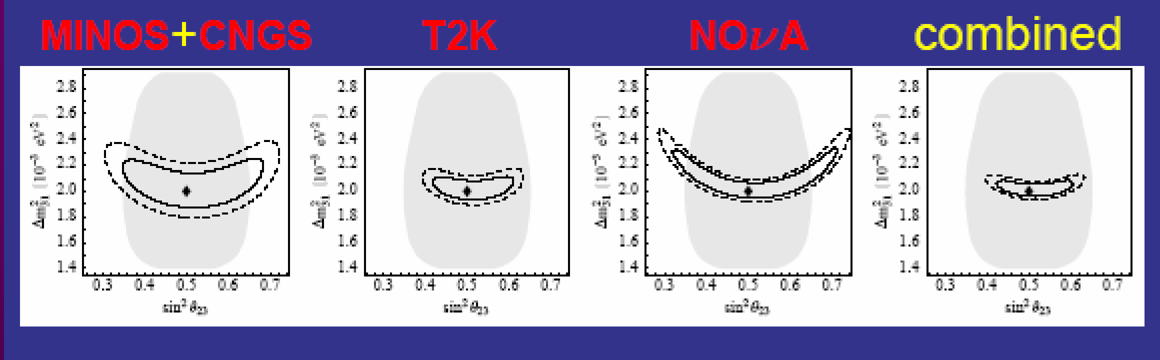
$\theta_{13} > 3^0$ —— Known by 2011 —— $\theta_{13} < 3^0$

$\theta_{13} > 3^0$	$\theta_{13} < 3^0$
• Existing facilities could reach it • ... but with very small sensitivity to δ_{CP} and mass hierarchy	• No access for ongoing experiments at that time

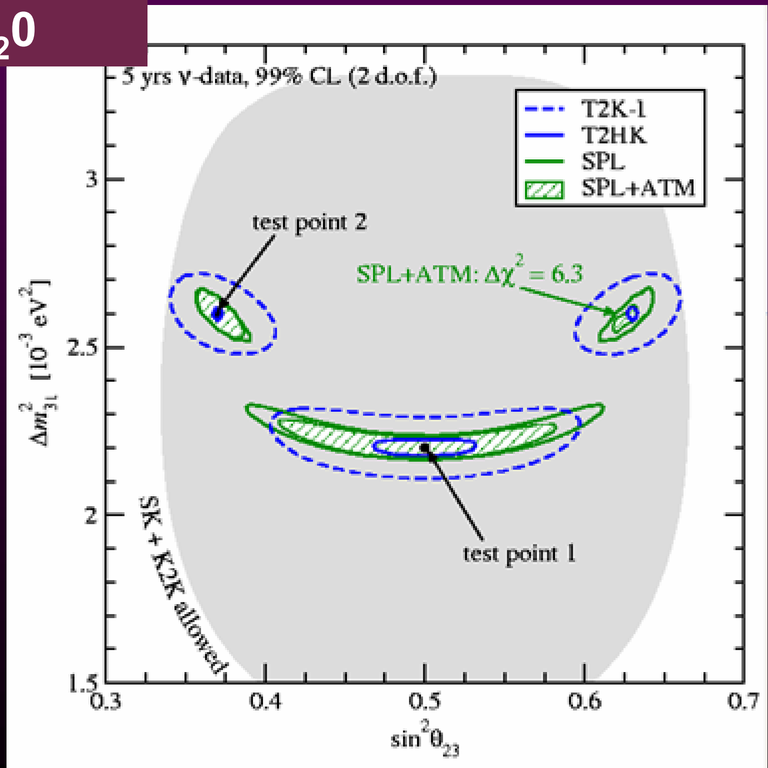
Cleaner and more intense beams + bigger detectors

$|\Delta m^2_{31}|$ et $\sin^2\theta_{23}$ « *atmospheric parameters* »

Huber, Lindner, Rolinec, Schwetz, Winter, hep-ph/0403068



H_20



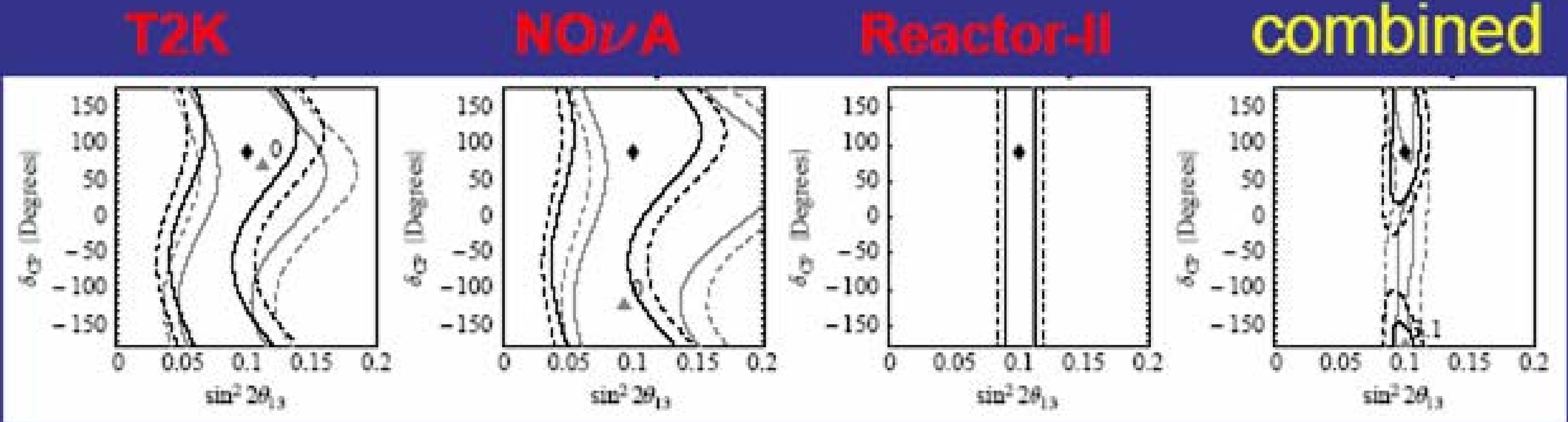
precision area!

T2HK E_ν~ 750MeV
SPL E_ν ~ 300MeV
(Fermi motion limitation)

JECampagne, M. Maltoni, M.Mezzetto, Th. Schwetz
hep-ph/0603172

CP-phase and hierarchy within ten years

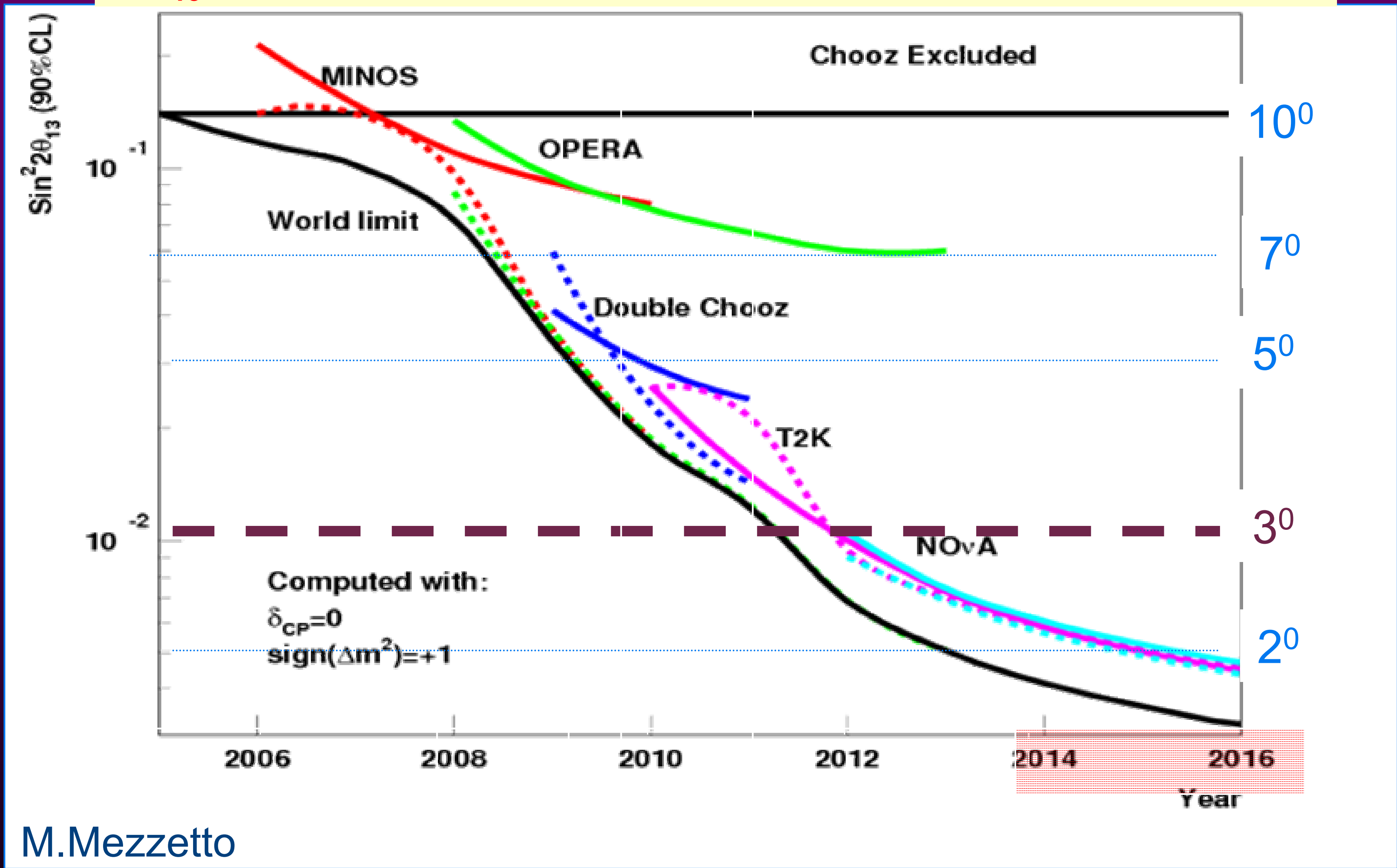
assume $\sin^2 2\theta_{13} = 0.1$



Huber, Lindner, Rolinec, Schwetz, Winter, hep-ph/0403068

θ_{13} : sensitivity time evolution (take care…)

If θ_{13} is found on the road the priority will have to be adapted



Weak sensitivity to CP

Limit of the exp.

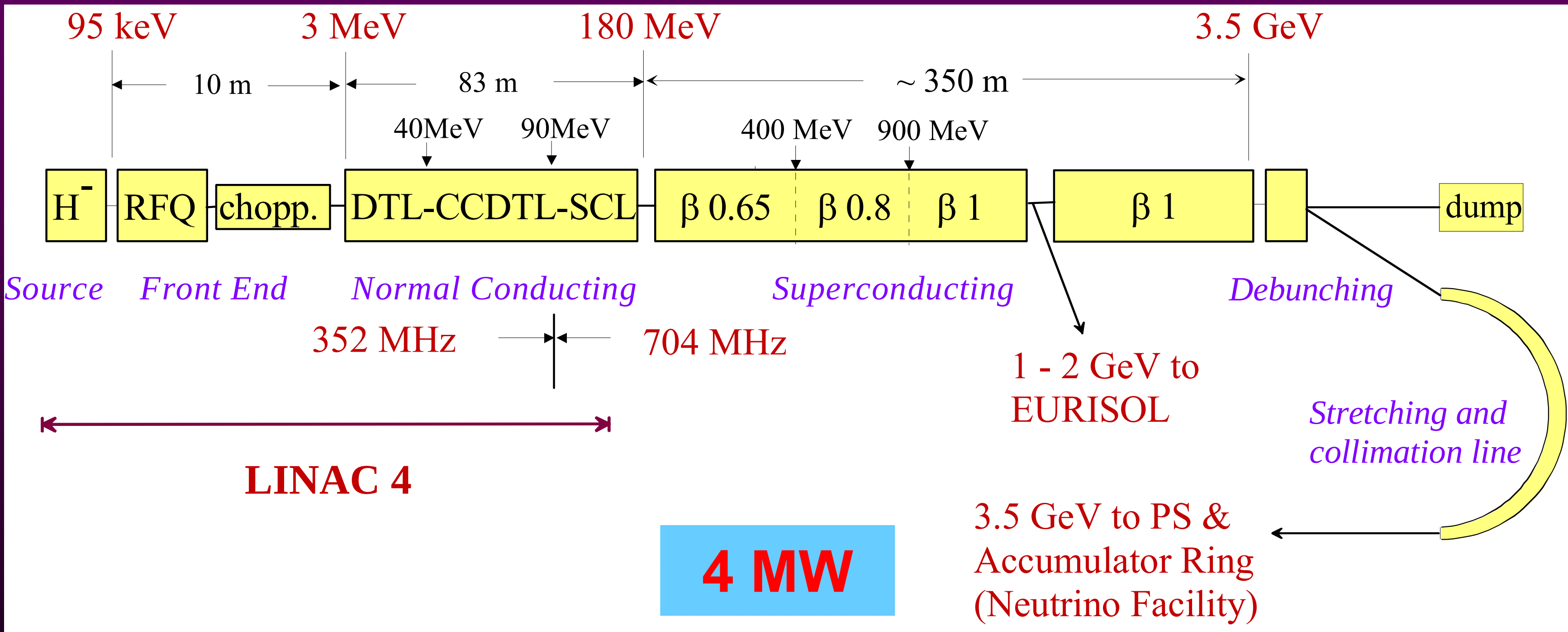
Word Limit wo the exp.

SPL current design

SPL main goals:

- increase the performance of the CERN high energy accelerators (PS, SPS & LHC)

- address the needs of future experiments with neutrinos and radio-active ion beams



The present R&D programme concentrates on low-energy (Linac4) items, wherever possible in collaboration with other laboratories.

From R.Garoby

How to overcome Super Beam limitations ?

Main problem :

SPL protons produce less negative pions, so less antineutrinos

antineutrino cross-section ~ 5 times smaller than neutrinos

So 10 SPL years have to be shared as ~ 2 neutrino + 8 antineutrino years

A solution :

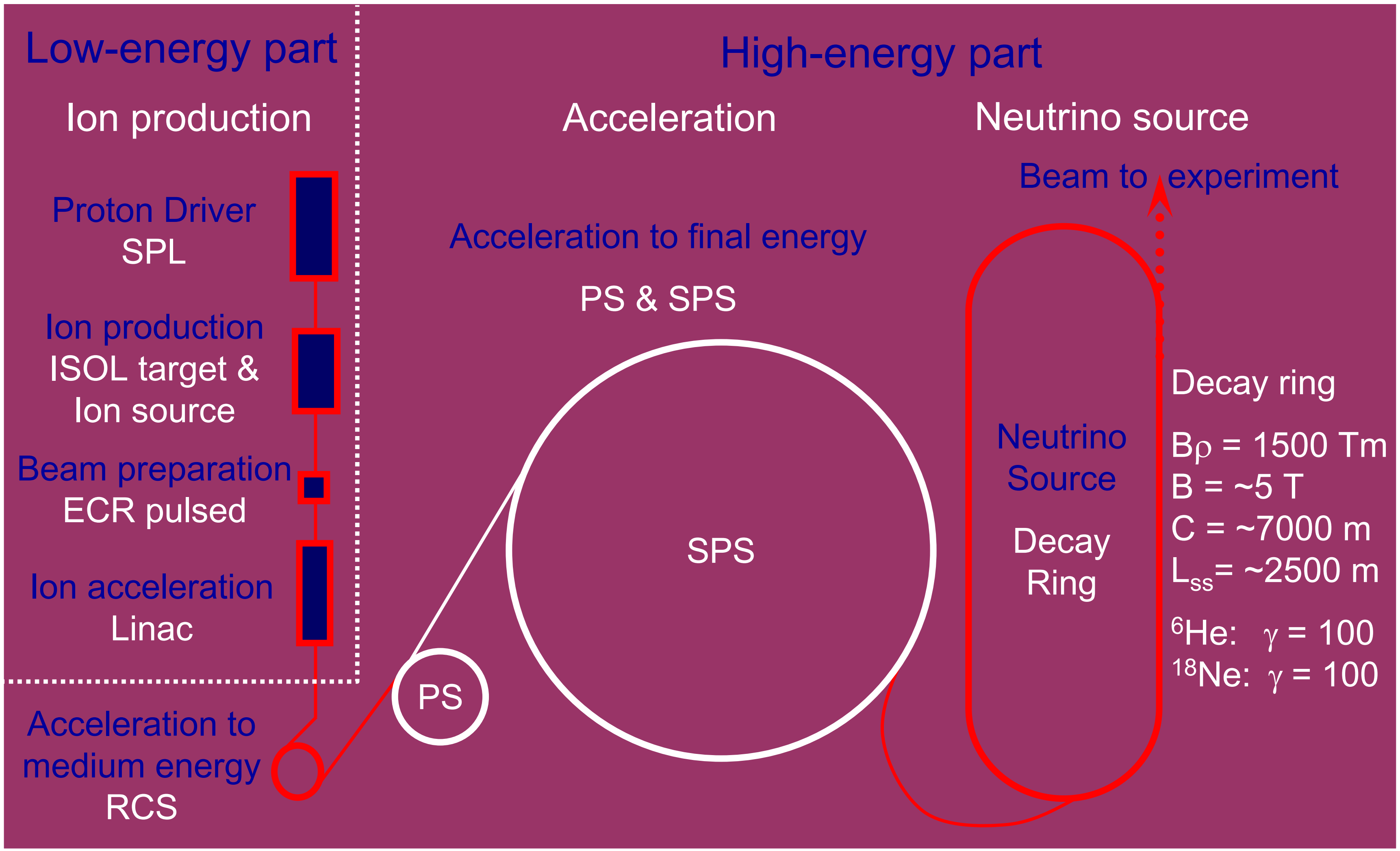
Produce a ν_e beam to study $\nu_e \rightarrow \nu_\mu$ oscillation and run it SIMULTANEOUSLY

with ν_μ beam from SPL

Compare $\nu_\mu \rightarrow \nu_e$ and $\nu_e \rightarrow \nu_\mu$ (T asymetry, equivalent to CP asymetry)

THIS WAS THE INITIAL MOTIVATION FOR A BETA BEAM

Beta-beam baseline design



Super Beam + β Beam + MEMPHYS

JECampagne, M. Maltoni, M.Mezzetto, Th. Schwetz hep-ph/0603172

2 beams

1 detector

SUPERBEAM

4 ν flavours + K

$2 \rightarrow 5$yrs $\nu_\mu \rightarrow \nu_e$

π^+/π^-

8yrs $\bar{\nu}_\mu \rightarrow \bar{\nu}_e$

BETABEAM

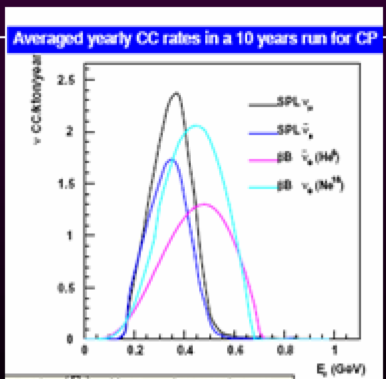
pure

$\nu_e \rightarrow \nu_\mu$ 5yrs

^{18}Nd

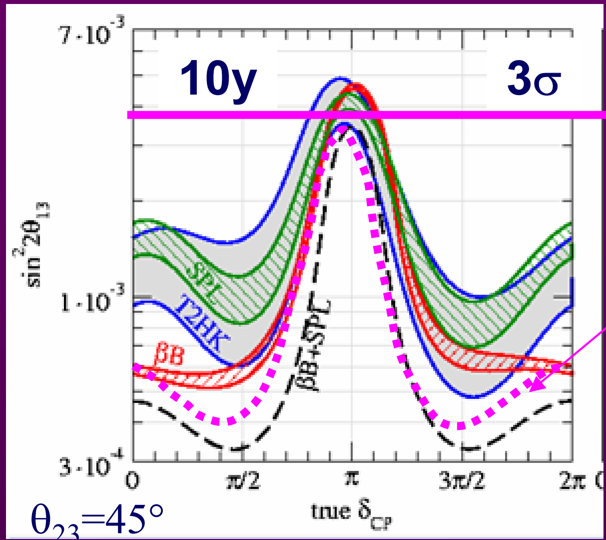
^{6}He

$\bar{\nu}_e \rightarrow \bar{\nu}_\mu$ 5yrs



2 ways of testing CP, T and CPT : redundancy and check of systematics

$\bar{\nu}_\mu$	107k	$\bar{\nu}_e$ (γ =100)	101k	
ν_μ	81k	ν_e(γ =100)	144k	4Mt.y



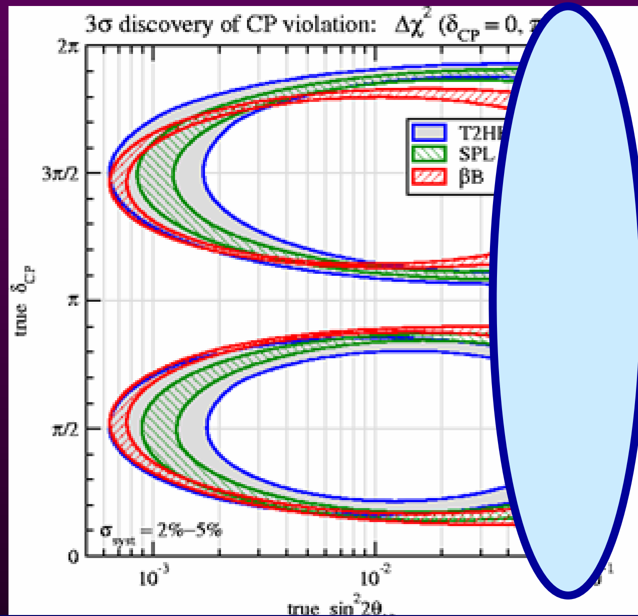
$\sin^2 2\theta_{13} < 4\ 10^{-3}$ in 10 y

or 5y combining SPL (ν_μ) + BB(ν_e)

$\theta_{13} \neq 0$

Test

CP̸



Study inside the ISS/BENE WG

Systematics dominant
SB: beam contents
SB et BB: x-section, eff./Bgd
(NF: matter profile, eff./Bgd)

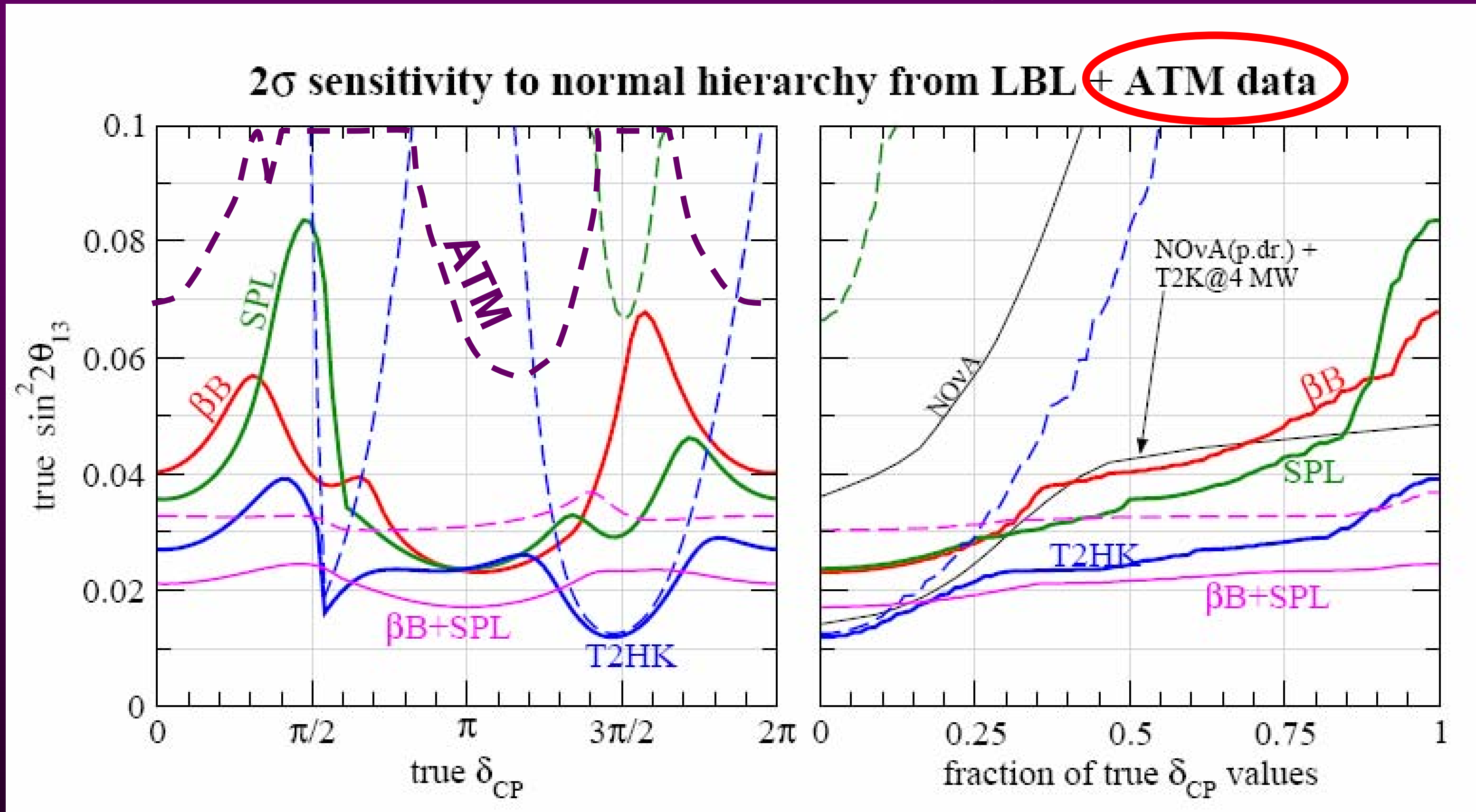
Band: 2%→5% syst
BB: 5+5y
SPL: 2+8y
T2HK: 2+8y
all: 440kT fid. mass

JECampagne, M. Maltoni, M.Mezzetto, Th. Schwetz hep-ph/0603172

Mass hierarchy: Synergy βB & SPL, and also ATM

Contrary to Donini et al. statement

JECampagne, M. Maltoni, M.Mezzetto, Th. Schwetz



ATM: ν atmosph. 4.4Mt.y

– – –: LBL alone

____: LBL + ATM

Notice βB+SPL vs T2HK !!!

Not yet included in the paper

Degeneracies

$$P_{\mu e} \simeq \sin^2 2\theta_{13} \sin^2 \theta_{23} \sin^2 \Delta_{31} + \alpha^2 \sin^2 2\theta_{12} \cos^2 \theta_{23} \Delta_{31}^2$$
$$+ \alpha \sin 2\theta_{12} \sin 2\theta_{13} \sin 2\theta_{23} \Delta_{31} \sin \Delta_{31} \cos(\Delta_{31} \pm \delta_{CP})$$

several possibilities to resolve the degeneracies are known:

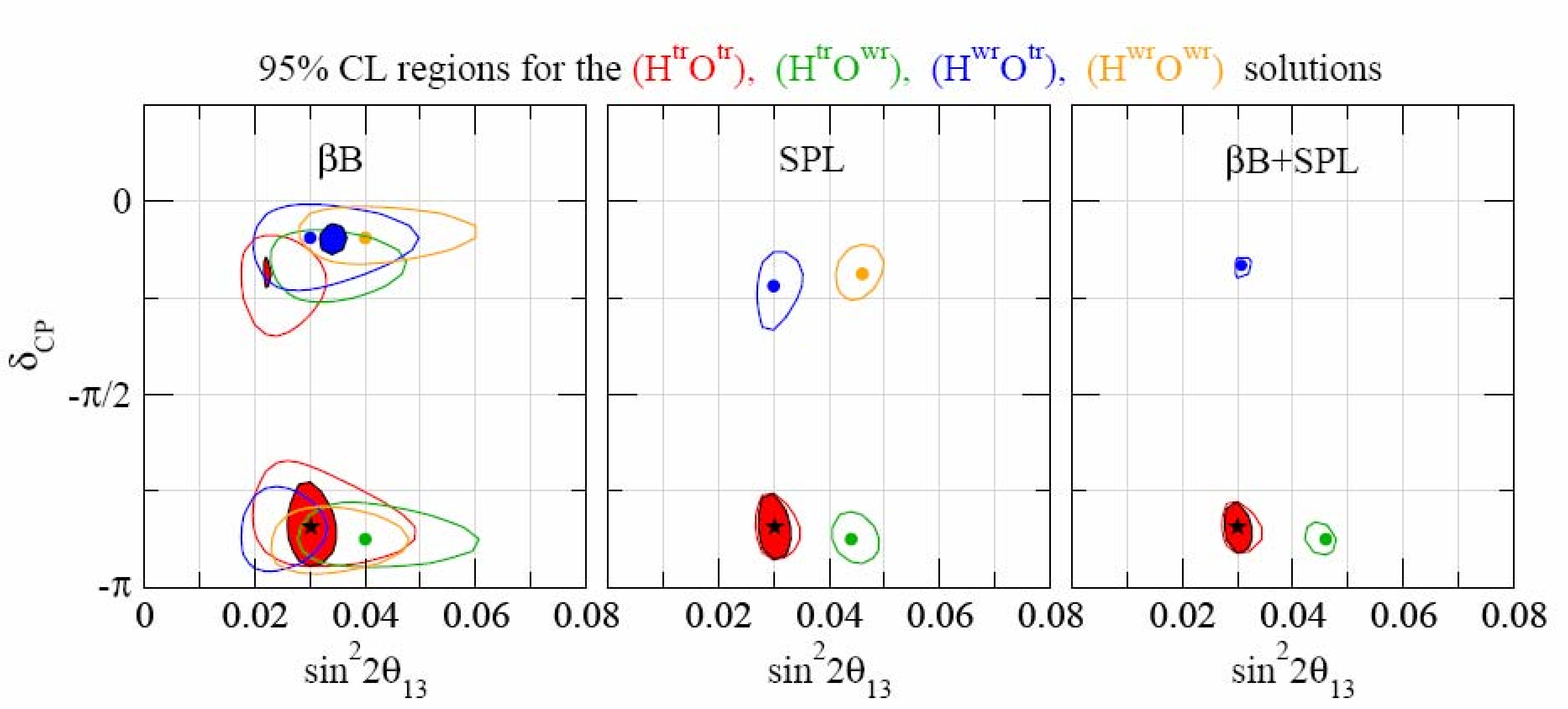
- combining information from detectors at different baselines and/or energies
  e.g., second osc. maximum, different off-axis angle
- using additional oscillation chanels ($\nu_e \to \nu_\tau$)
- spectral information (broadband beam)
- adding information on θ_{13} from a reactor experiment
- combing data from LBL and atmospheric neutrino experiments

Th. Schwetz

MEMPHYS+ SPL+BB+ ATM

O: θ_{23}Octant   H: sign $|\Delta m^2_{31}|$

$\sin^2\theta_{23}$=0.6



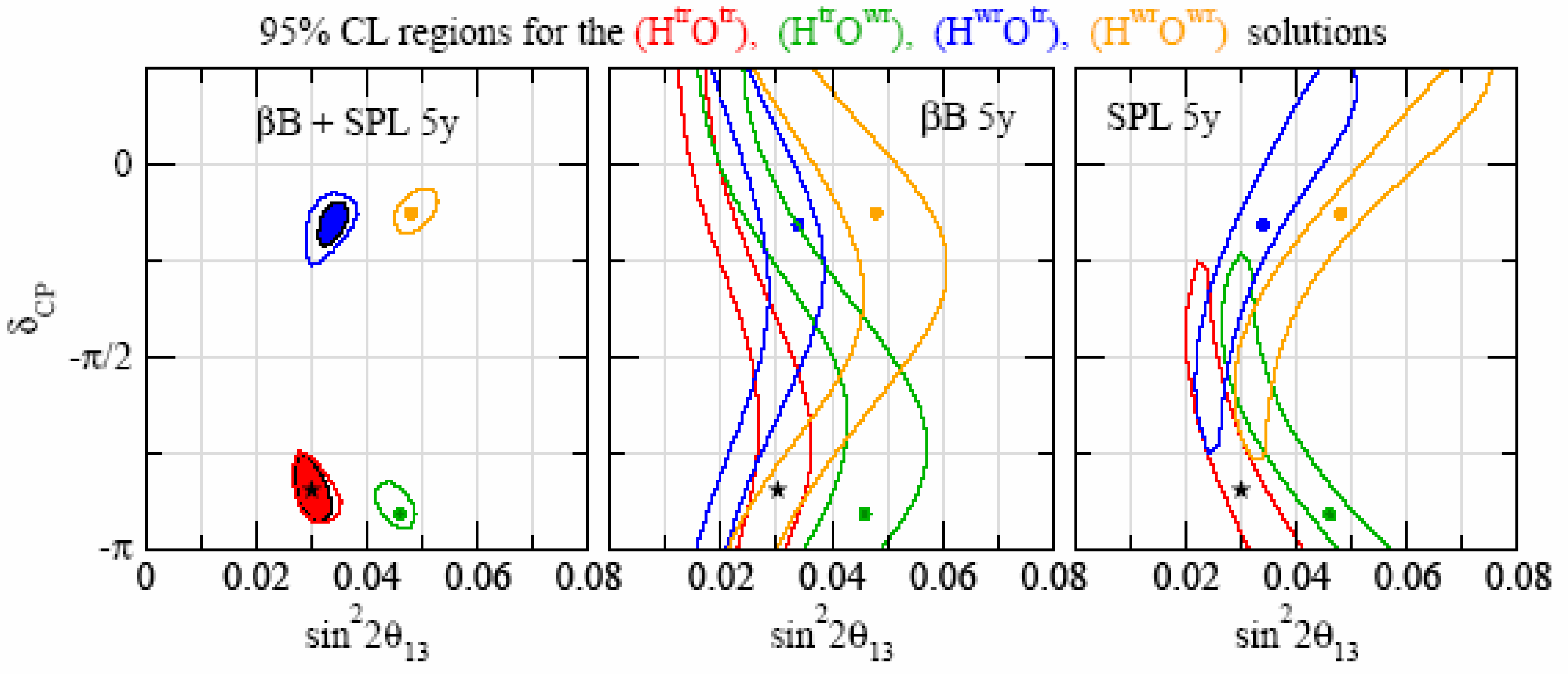
BB: 5+5y
SPL: 2+8y
440kT fid. mass

ATM can solve degeneracies!!!

JECampagne, M. Maltoni, M.Mezzetto, Th. Schwetz hep-ph/0603172

Other way to solve the degeneracies: use ν_e and ν_μ

BB: 5y (ν_e)
SPL: 5y (ν_μ)
ATM: 5y
MEMPHYS 440kT fid. mass



Still a wrong hierarchy clone with χ^2=3.3

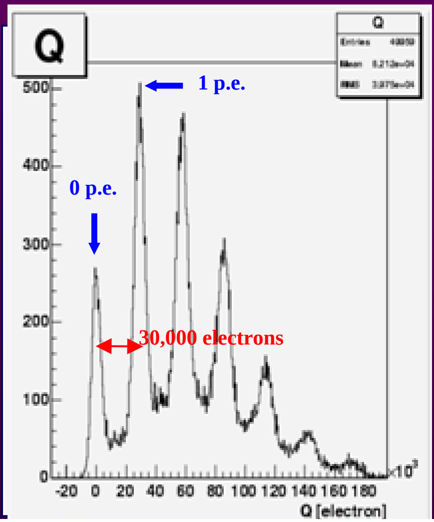
R&D Photodetecteurs

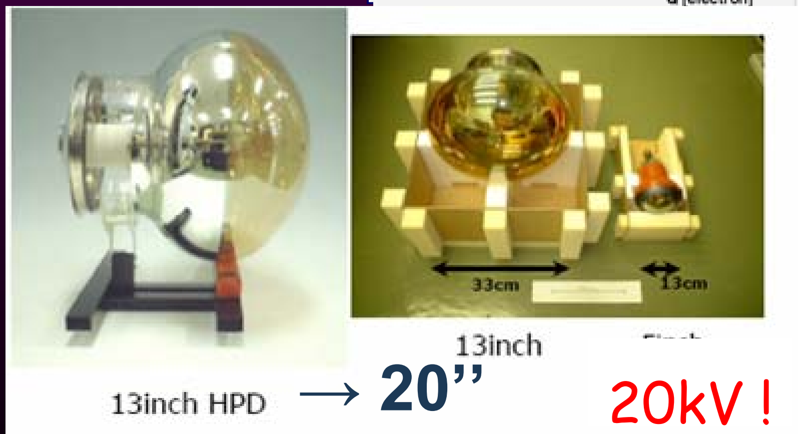
•Diameter	20“	<=>	12“
•projected area	1660		615 cm²
•QE(typ)	20		24 %
•CE	60		70 %
•Cost	2500		800 €
•Cost/p.e/cm	13		8 €

PMT Photonis@NNN05

Hamamatsu R&D

HPD





Summary

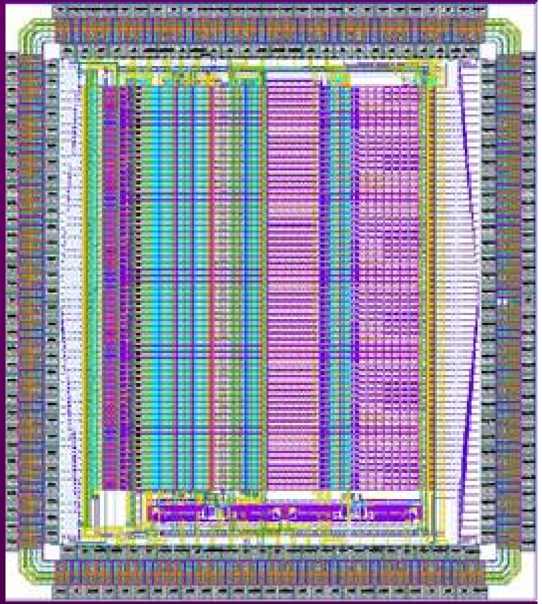
- R&D for a large format hybrid photo detector has started.
- Initial study shows excellent performance:
  - ✓ Single photon sensitivity
  - ✓ Wide dynamic range (up to the readout limit)
  - ✓ Good time resolution (better than 1ns)
  - ✓ Good uniformity (over a large photocathode)
- Promising

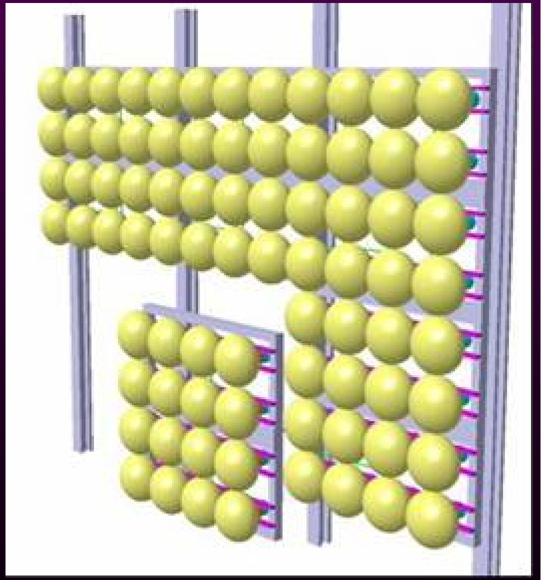
H. Aihara @ NNN05

Needs low noise electronics

R&D Electronique

- Integrated readout : "digital PM (bits out)"
  - Charge measurement (12bits)
  - Time measurement (1ns)
  - Single photoelectron sensitivity
- High counting rate capability (target 100 MHz)
- Large area pixellised PM :
  - 16 low cost PMs
  - Centralized ASIC for DAQ
  - Variable gain to have only one HV
- Multichannel readout
  - Gain adjustment
  - Subsequent versions of OPERA_ROC ASICs
- Network
  - Wireless?





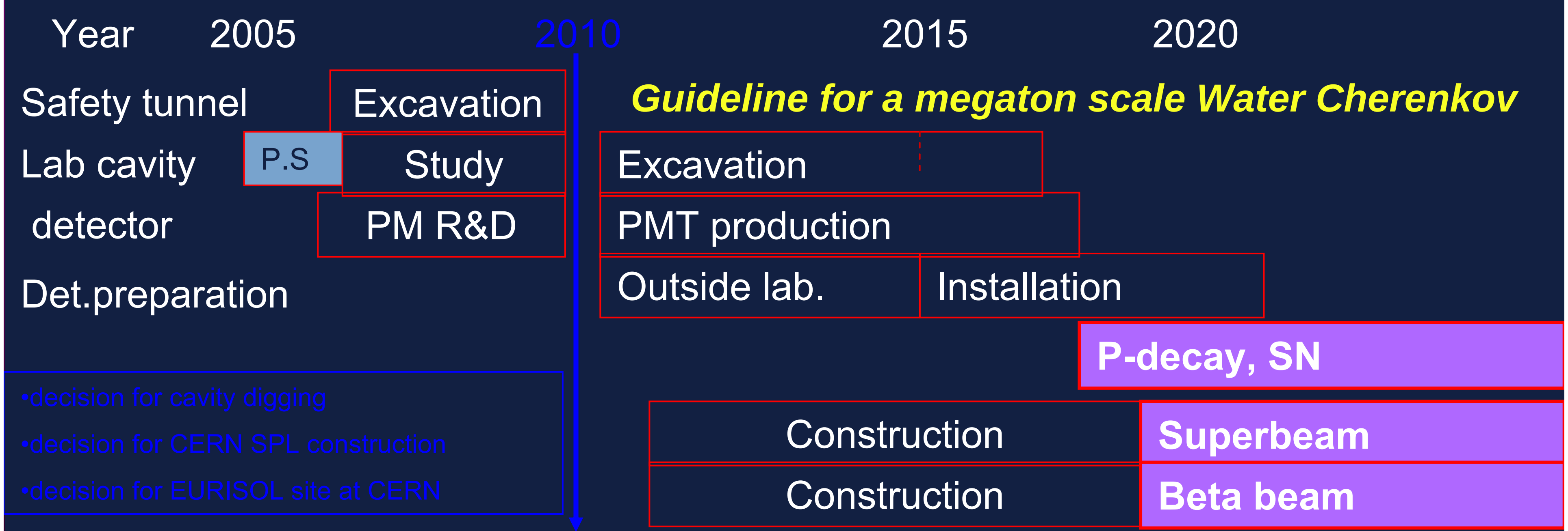
IPNO-LAL-LAPP

French funding agency
(ANR ≠ CNRS/IN2P3 and CEA)

- Request for a Joint R&D :
  - LAL-IPNO-LAPP
  - Photonis Co.
  - 3years, 400k€, 1FTE physicist, 5FTE Engineers
- LAL: electonics: 100k€ + 1 post-doc
- IPNO: photodetector tests + mechanics: 180k€
- LAPP: Data network: 53k€
- Photonis: PMTs provider: 64k€

Expected answer in July 06

When?



Year
2005
2010
2015
2020
Safety tunnel
Excavation
Guideline for a megaton scale Water Cherenkov
Lab cavity
P.S
Study
Excavation
detector
PM R&D
PMT production
Det.preparation
Outside lab.
Installation
P-decay, SN
•decision for cavity digging
•decision for CERN SPL construction
•decision for EURISOL site at CERN
Construction
Superbeam
Construction
Beta beam

The 3 technologies have complementarity Physics and common R&D

- **Networking activities**
- A1) Physics potential of Large Deep Underground experiments in both non- accelerator and accelerator sectors, interdisciplinary aspects (geoneutrinos)
- A2) Underground Laboratories for very large detectors : best strategies for excavation, access and equipments (ventilation, air-conditioning, power supply, low background environment, etc.),
- A3) Safety optimisation in Very Large Underground Facilities
- A4) Interdisciplinary aspects of the facility
- **Joint Research Activities**
- B1) Development of low-cost photo-sensors for Cerenkov and scintillation processes in optical and DUV regions, of different types (vacuum or gaseous, in connection with industry)
- B2) Development of solutions for low-cost readout electronic for a large number of channels
- B3) Development of large scale liquid production and purification systems
- B4) Technical feasibility and safety of large underground liquid containers (tanker)
- B5) Site definition and local studies for large scale caverns with large underground apparatuses (rock/salt quality, access requirements, ventilation systems, power supply, ...)

Start structure for FP7, connection with ILIAS…