Large Apparatus for Grand Unification and Neutrino Astrophysics

GLACIER
LENA
MEMPHYS
groups

~60 physics & still Open

hep-project-laguna@cern.ch

- 22 institutes from CH, DE, ESP, FR, FIN, I, POL, UK
- University of Bern, CPPM, CUPP, University of Helsinki, University of Katowice, University of Krakow, IN2P3/CNRS-LAL, IN2P3/CNRS-LPNHE, University of Granada, University of Hamburg, Max-Planck-Institut für Kernphysik Heidelberg, University of Jyväskyla, Max-Planck-Institut für Physik München, Technische Universität München, University of Oulu, Institut de Physique Nucléaire Orsay, INFN/University of Padova, APC-Paris, DAPNIA/CEA-Saclay, University of Sheffield, ETH-Zürich
- New interest was raised at Valencia meeting

DRAFT ~30p

Large liquid detectors in Europe: Scientific Case

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(LAGUNA collaboration), *

Contents

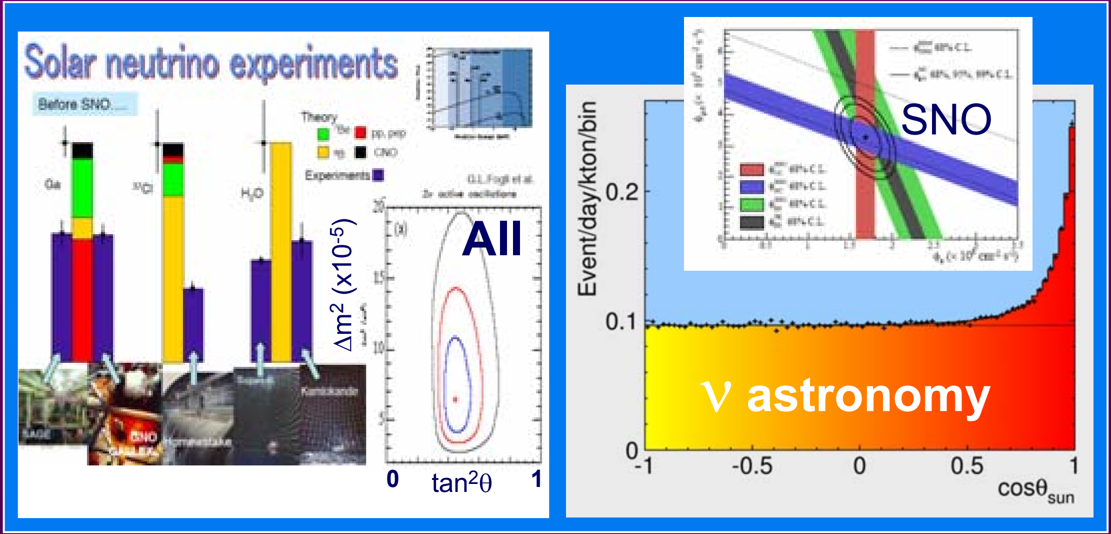
I. PHYSICS MOTIVATION

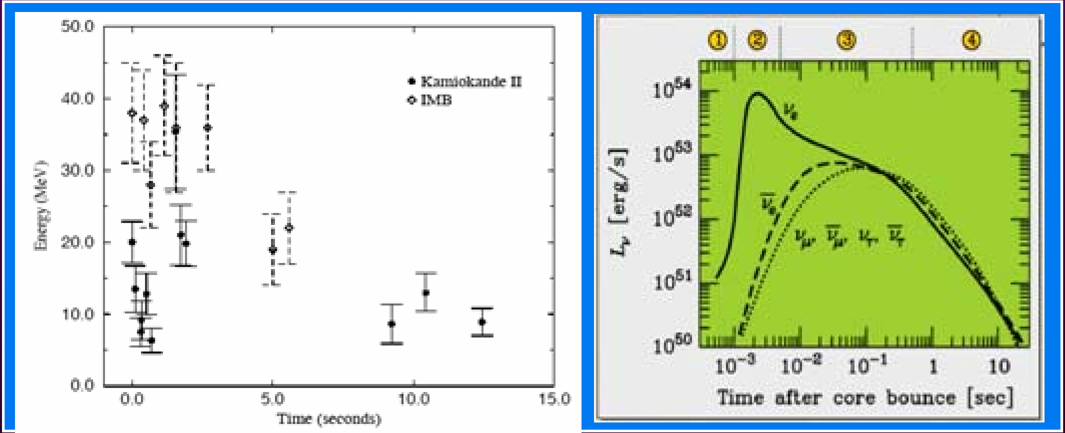
The decay of proton is the most exciting prediction of Grand Unified Theories (see (Nath and Perez, 2006)). Several experiments have been built to search for it, with no discovery yet. The window between predicted (in the simplest models typically below 10^{37} years) and excluded (Kobayashi *et al.*, 2005) ($O(10^{33})$ years, depending on the channel) lifetimes is, however, within our reach, and the demand to fill the gap grows. Also a negative result would be important to rule out certain models (like minimal SU(5) (Georgi and Glashow, 1974)) or constrain the parameter range. Identifying the proton decay and life time would set a firm scale for any unified theory, narrowing the scope for possible models and their parameters. This would be a mandatory step to go forward with the physics beyond the Standard Model, now partially stalled due to missing experimental data.

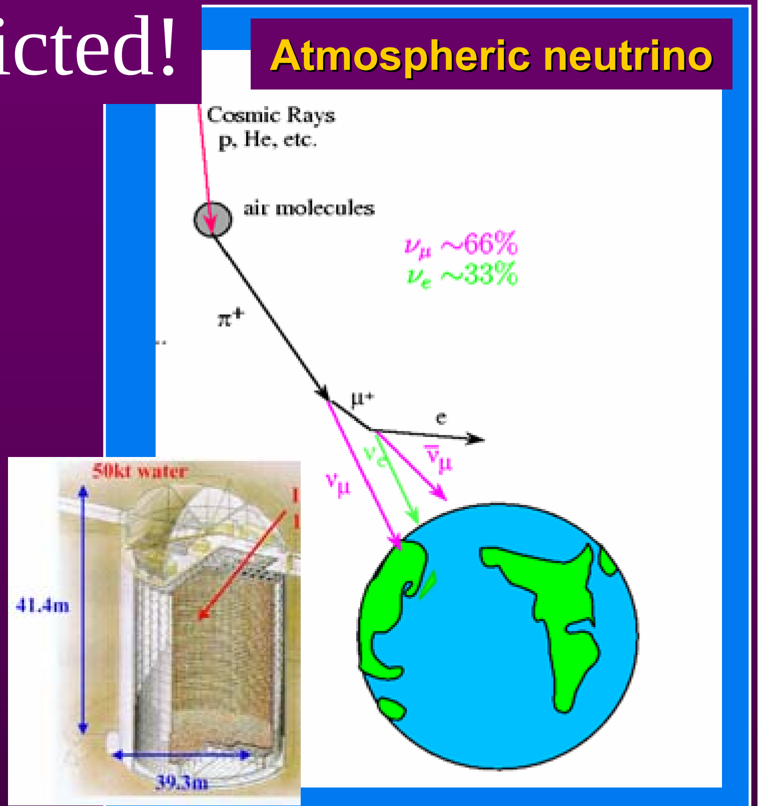
The interior of the Earth is known unbelievably ill. We know much better what happens inside the Sun than inside our own planet. There are very few messengers that can give information from below the reach of drill-holes, and mere therory is not sufficient for building a credible model for the Earth. However, there is a new unexploited window to the Earth interior, by observing neutrinos produced in the radioactive decays of heavy elements in the matter. Until now only KamLand experiment (Araki *et al.*, 2005a) has been able to study geoneutrinos, but its event rate does not allow significant conclusions.

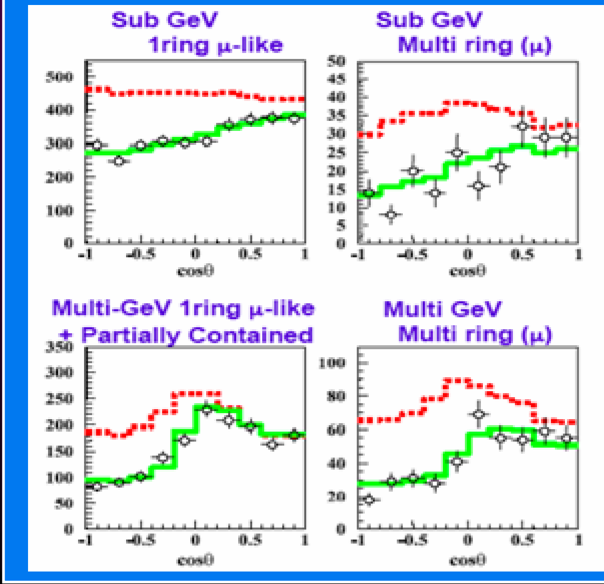
Neutrinos are important messengers from stars. Indeed, neutrino astronomy has a glorious history, from the detection of solar neutrinos (Abdurashitov *et al.*, 1994; Aharmim *et al.*, 2005; Altmann *et al.*, 2005; Anselmann *et al.*, 1992; Davis *et al.*, 1968; Hirata *et al.*, 1989; Smy, 2003) to the observation of neutrinos from a supernova (Bionta *et al.*, 1987; Hirata *et al.*, 1987), acknowledged by Nobel Prizes for Koshiba and Ray Davis. These ob-

Past success of the field not predicted!

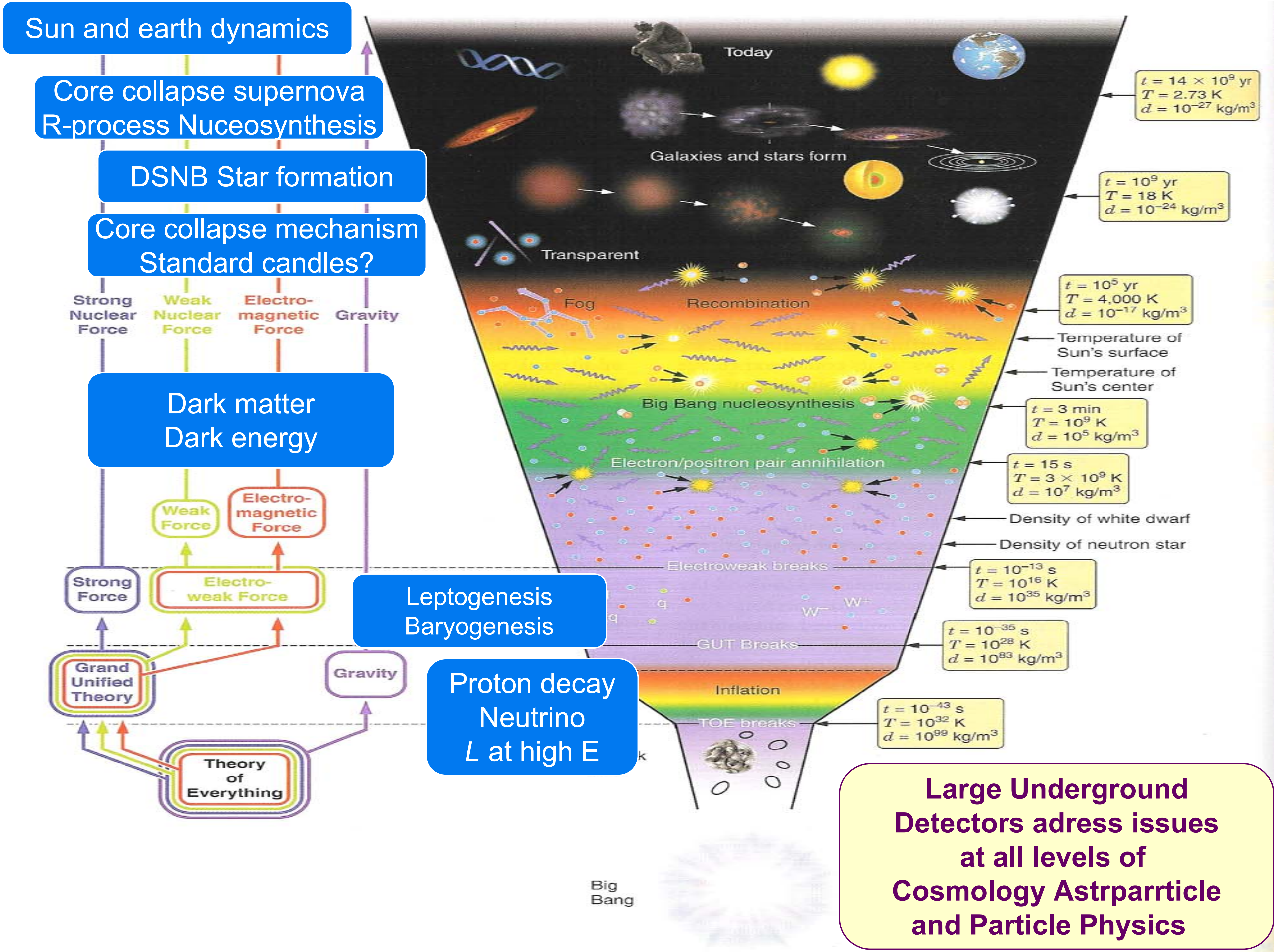








- •Solar neutrino anomaly solved
- •Detection of SN-1987A (Nobel Koshiba)
- •Discovery of atm neutrino oscillations



Sun and earth dynamics
Core collapse supernova
R-process Nuceosynthesis
DSNB Star formation
Core collapse mechanism
Standard candles?
Strong Nuclear Force
Weak Nuclear Force
Electro-magnetic Force
Gravity
Dark matter
Dark energy
Weak Force
Electro-magnetic Force
Strong Force
Electro-weak Force
Leptogenesis
Baryogenesis
Grand Unified Theory
Gravity
Proton decay
Neutrino
L at high E
Theory of Everything
Today
Galaxies and stars form
Transparent
Fog
Recombination
Big Bang nucleosynthesis
Electron/positron pair annihilation
Electroweak breaks
W−
W+
q
GUT Breaks
Inflation
TOE breaks
Big Bang
t = 14 × 10^9 yr
T = 2.73 K
d = 10^−27 kg/m^3
t = 10^9 yr
T = 18 K
d = 10^−24 kg/m^3
t = 10^5 yr
T = 4,000 K
d = 10^−17 kg/m^3
Temperature of Sun's surface
Temperature of Sun's center
t = 3 min
T = 10^9 K
d = 10^5 kg/m^3
t = 15 s
T = 3 × 10^9 K
d = 10^7 kg/m^3
Density of white dwarf
Density of neutron star
t = 10^−13 s
T = 10^16 K
d = 10^35 kg/m^3
t = 10^−35 s
T = 10^28 K
d = 10^83 kg/m^3
t = 10^−43 s
T = 10^32 K
d = 10^99 kg/m^3
Large Underground
Detectors adress issues
at all levels of
Cosmology Astrparrticle
and Particle Physics

Where?

IUS

Institute of Underground Science in Boulby mine, UK

LSM

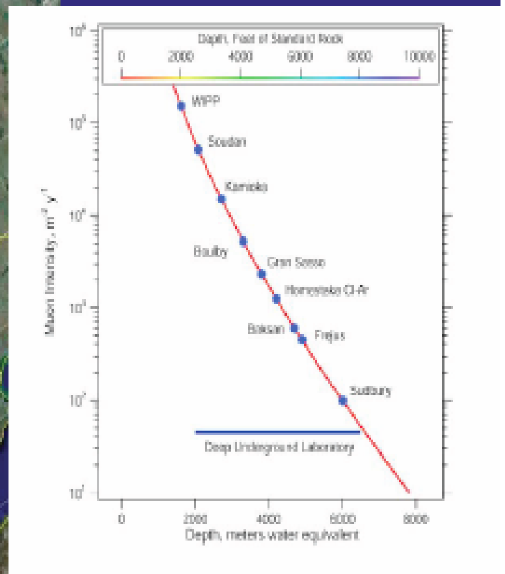
Laboratoire Souterrain de Modane, France

Centre for Underground Physics in Pyhäsalmi mine

Currently there is no available sight to host very large scale detectors in Europe!

- New facilities will have to be excavated or old one extended
- What depth?
- What other synergies? (beamline distance)
- What is the distance from reactors?

Polkowice-Sieroszowice



LSC

Laboratorio Subterraneo de Canfranc, Spain

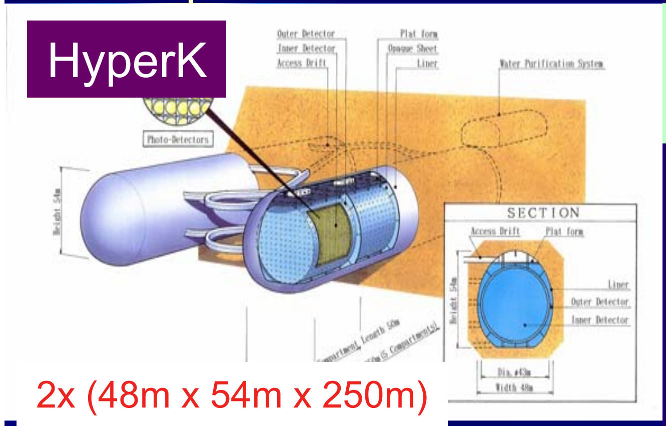
LNGS

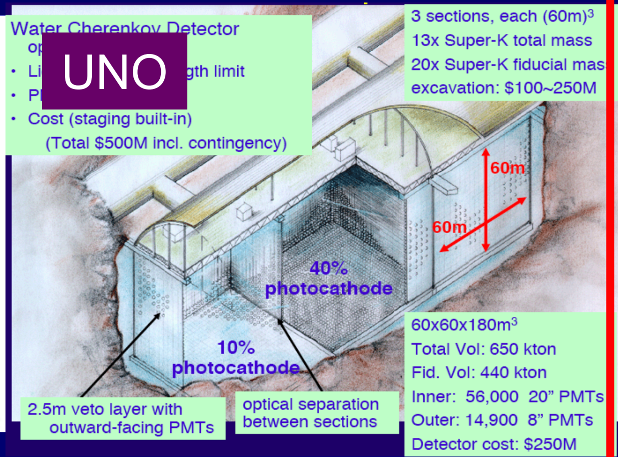
Laboratori Nazionali del Gran Sasso, Italy

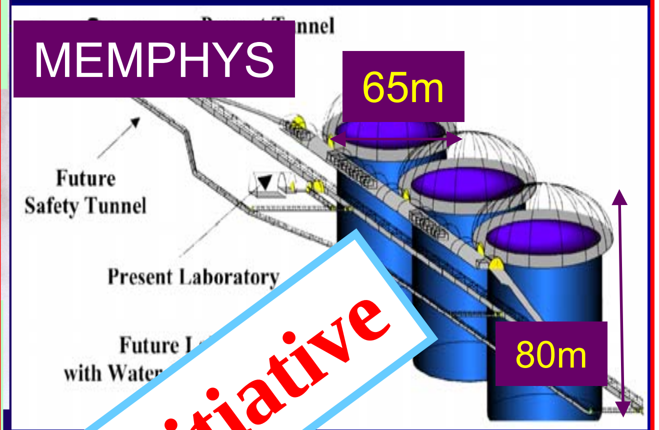
Some detectors presented at NNN Workshops

Start 99, recent Aussois 05**,** Seattle 06, future **Hamamatsu 07**, Paris 08

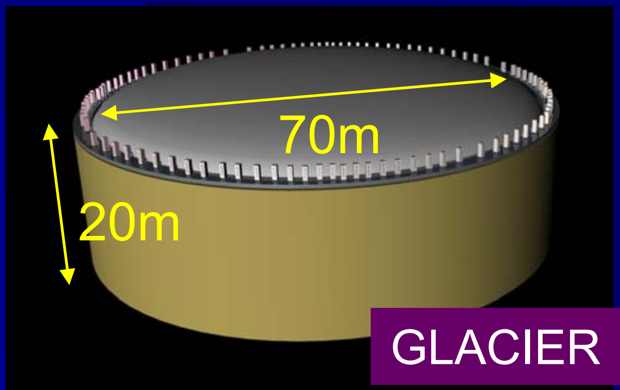
Water Čerenkov 500kT→1Mt





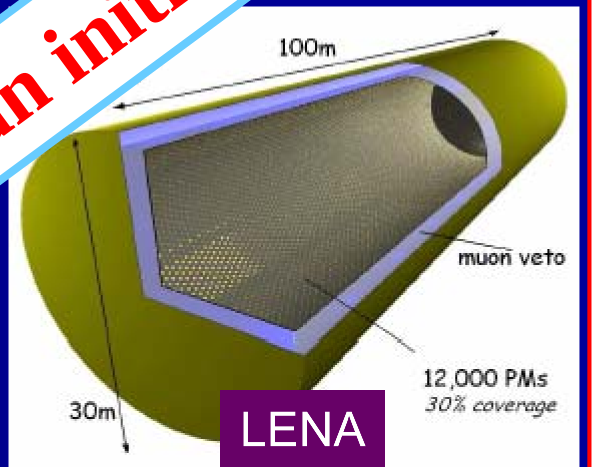


European initiative



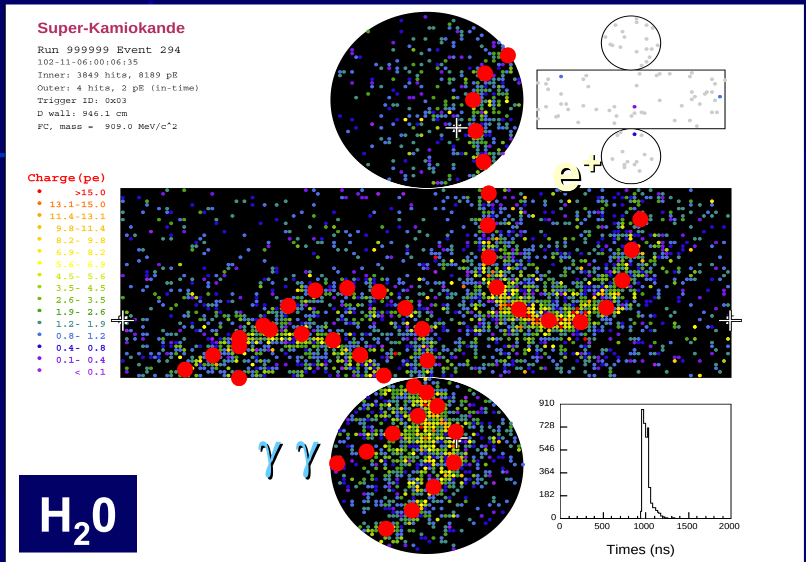
Liq. Argon →100kT

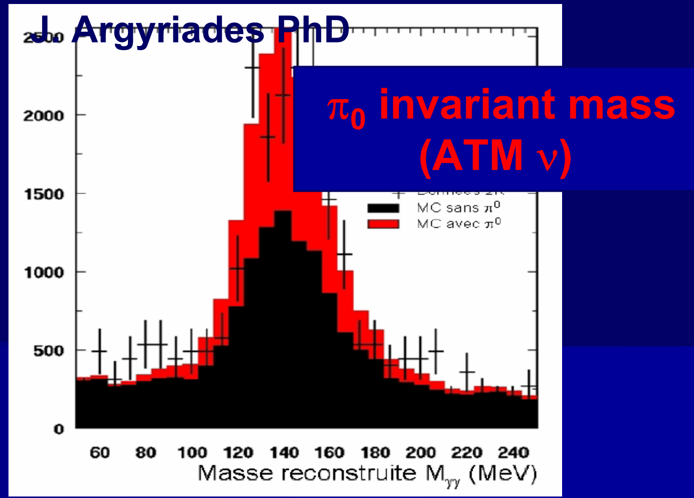
Liq. Scintillator →50kT



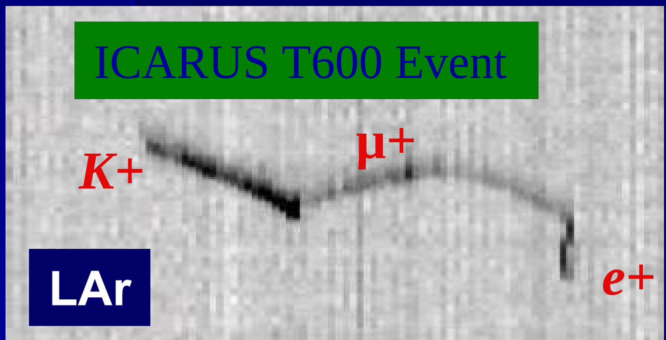
Large Apparati for Grand Unification and Neutrino Astrophysics : LAGUNA

Imaging...





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

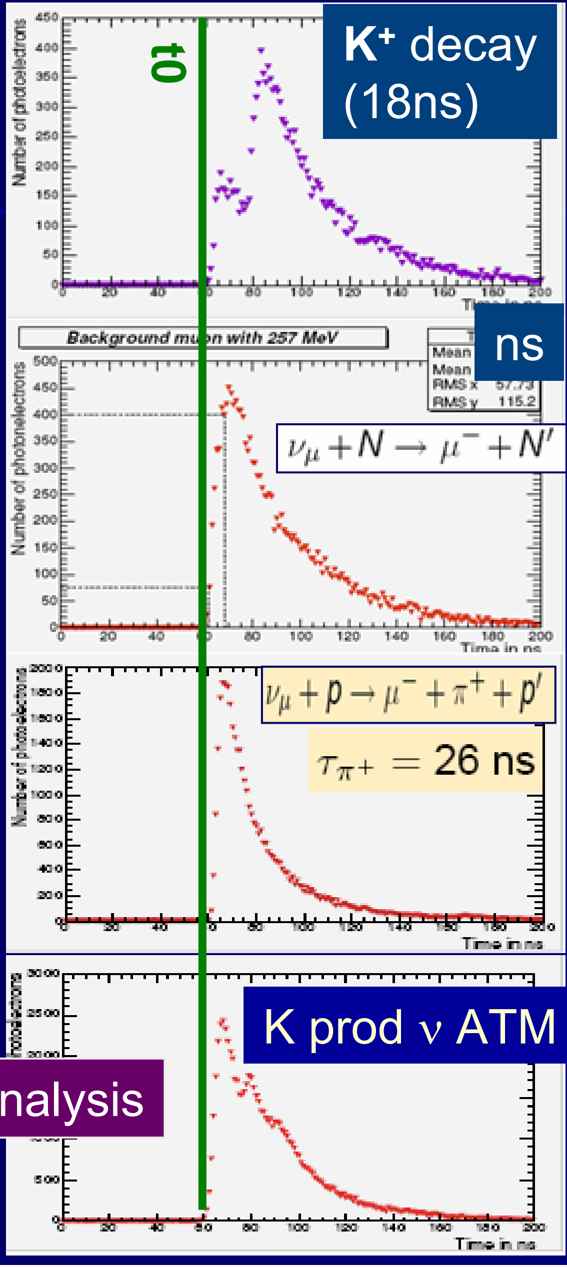


High granularity: Sampling = 0.02 X_0
"bubble" size ≈3×3×0.4 mm^3

Energy Threshold:
H$_2$0 seuil Č: ~1.07GeV:p, ~570MeV: K$^\pm$, ~120MeV:$\mu^\pm$,~0.6MeV:e$^\pm$
LENA ~(200÷300)keV (100pe/Mev)
LAr few 100 keV
Resolution: LENA/GLACIER better

Timing…

Scint.Liq.



Nbre de PMTs

Pulse shape analysis

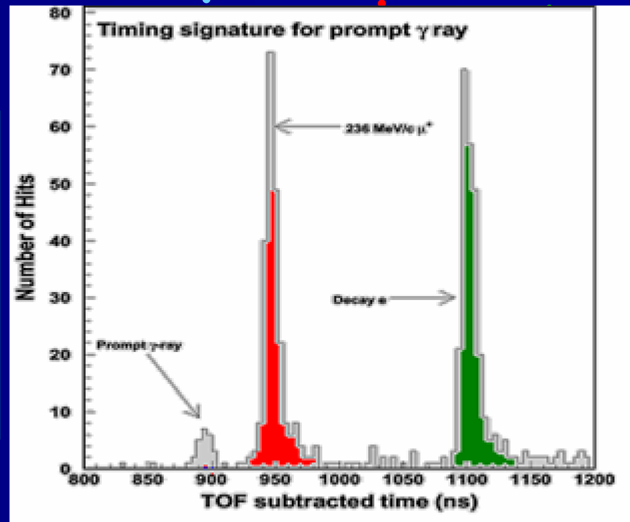
H_20

$^{16}O \rightarrow \nu K^{+} {}^{15}N\ \gamma$, $K^+ \rightarrow \mu^+ \nu$

$\hookrightarrow e^+ \nu\nu$

6–10 MeV

236MeV/c



Nbre de PMTs

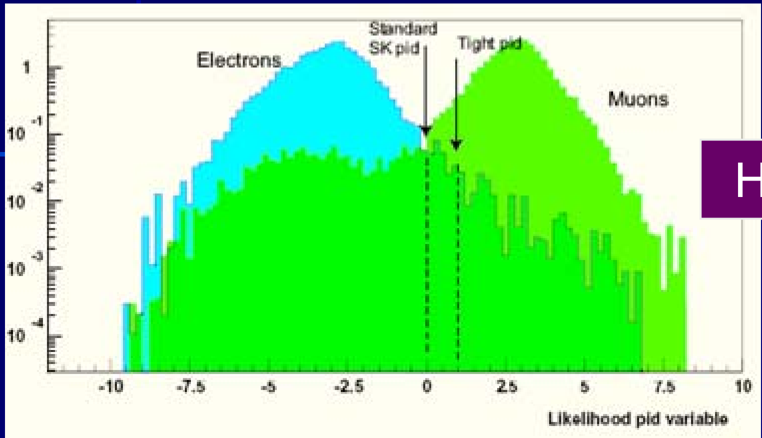
ns

All: Autotrigger capability

No possibility for Glacier (1μs)

PId

Particle ID : 99% 1-ring μ, e



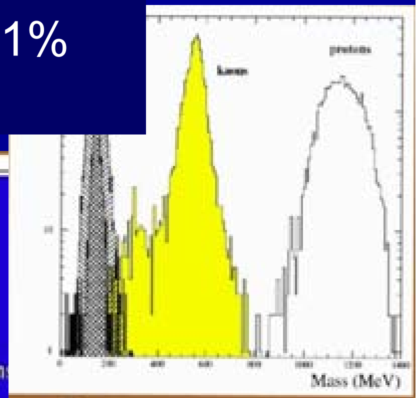
H$_2$0

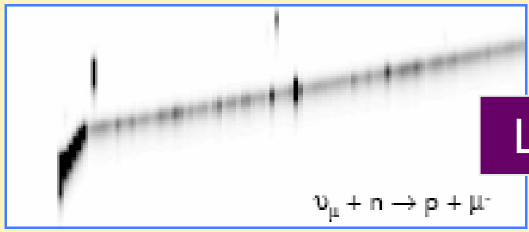
Seuil Cerenkov

Scin. Liq.

Timing μ decay (e/μ sep.)
e/α/p recul à basse énergie
n Id via capture γ
TOF pour « point like event »

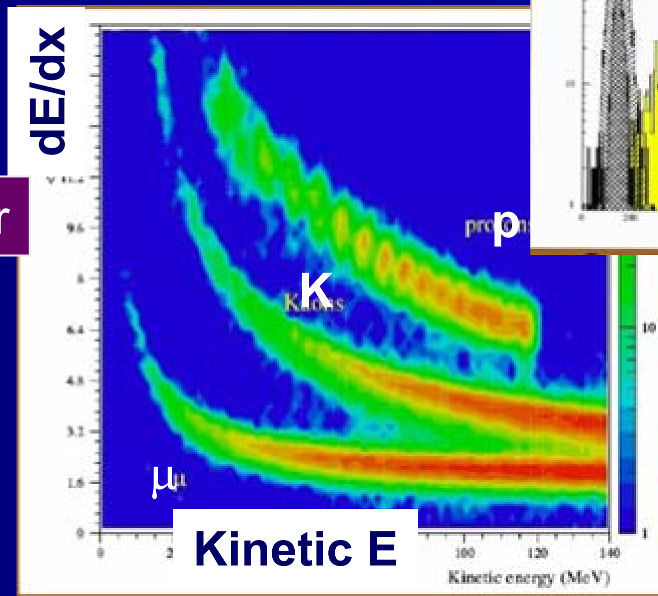
Neural Net: dEdx + Length
Protons efficiency >99%
Kaons mis-id as protons <1%
Pions/muons cc 1%





MC QE event.
Proton momentum = 490 MeV/c

LAr



See track below Cerenkov thres.
Ex. proton recoil QEν (T2K–2km)

Proton decay

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

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

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

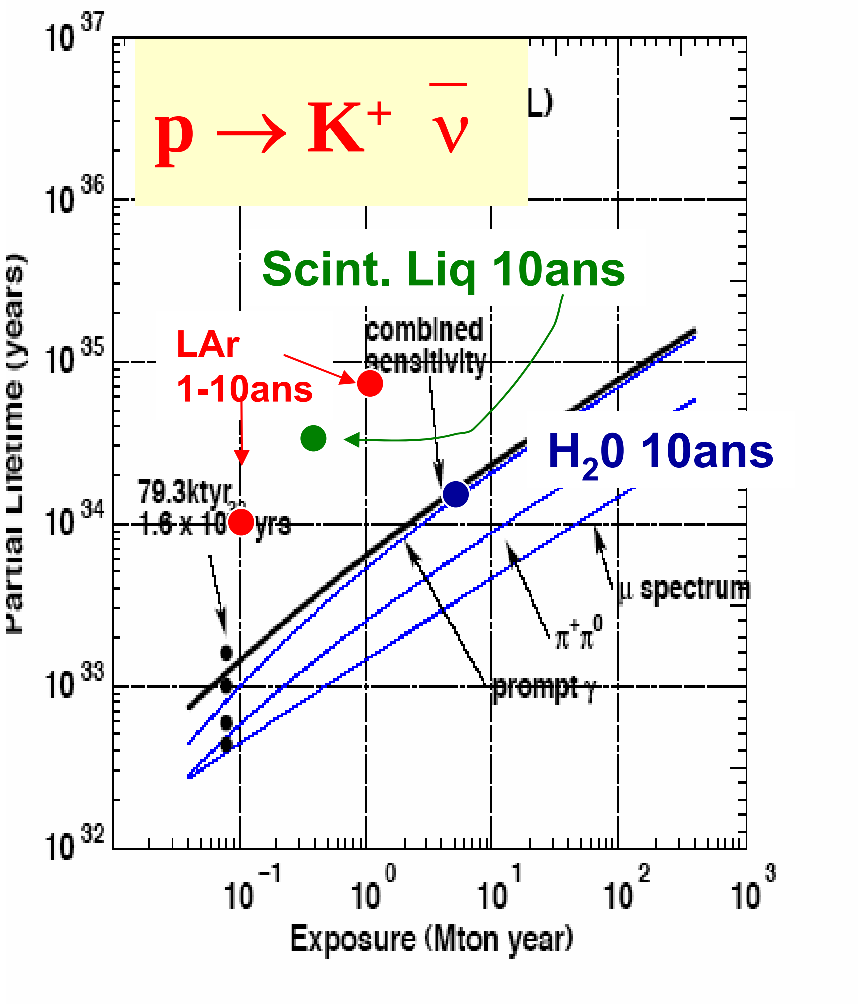
Specific model gives faster decay rates…

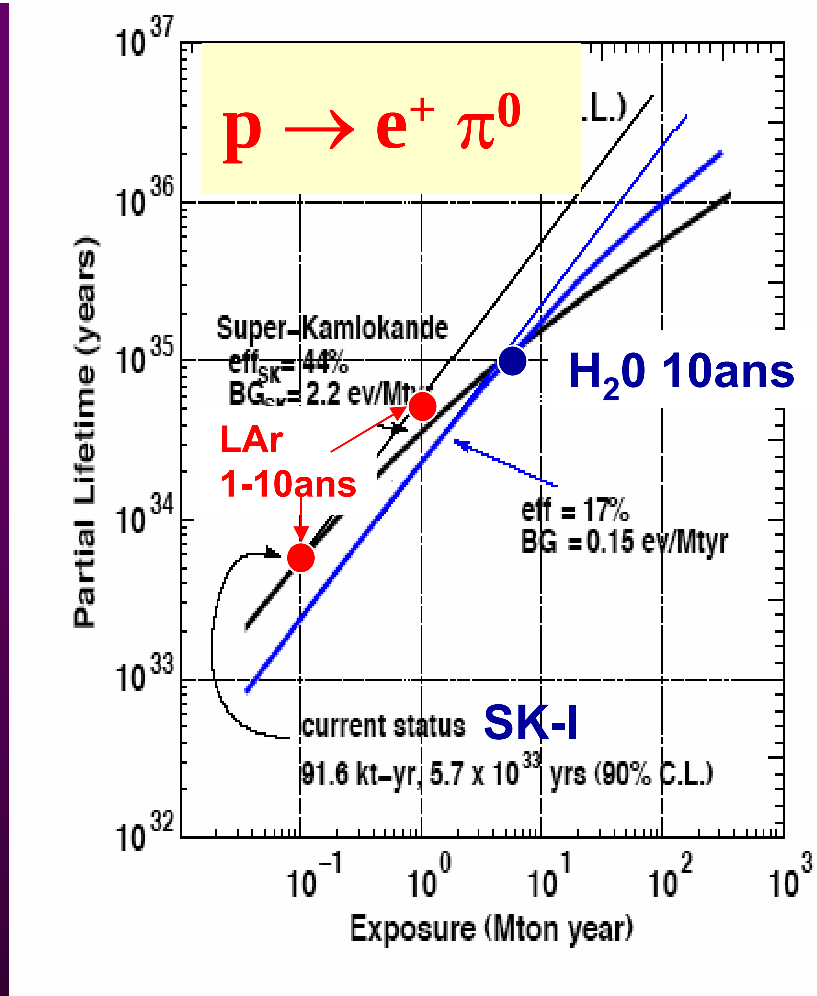
It is quite diffical and unatural to set to 0 all the decay channels simultaneously

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

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

(generic channels)

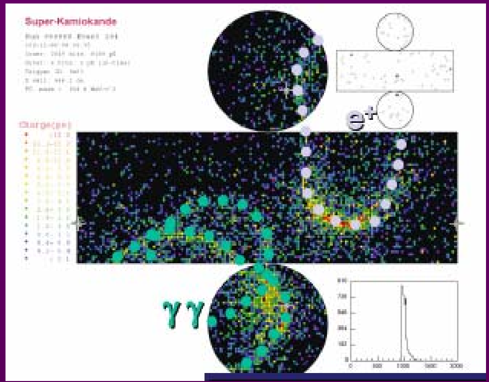




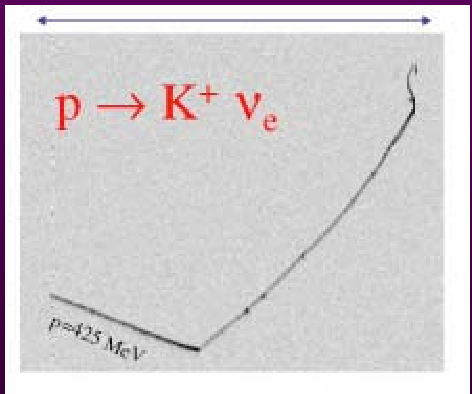
SUSY SU(5), SO(10) , 5dim op, susy spectrum τ_p= 3x10^{33}- 3x10^{34}y.

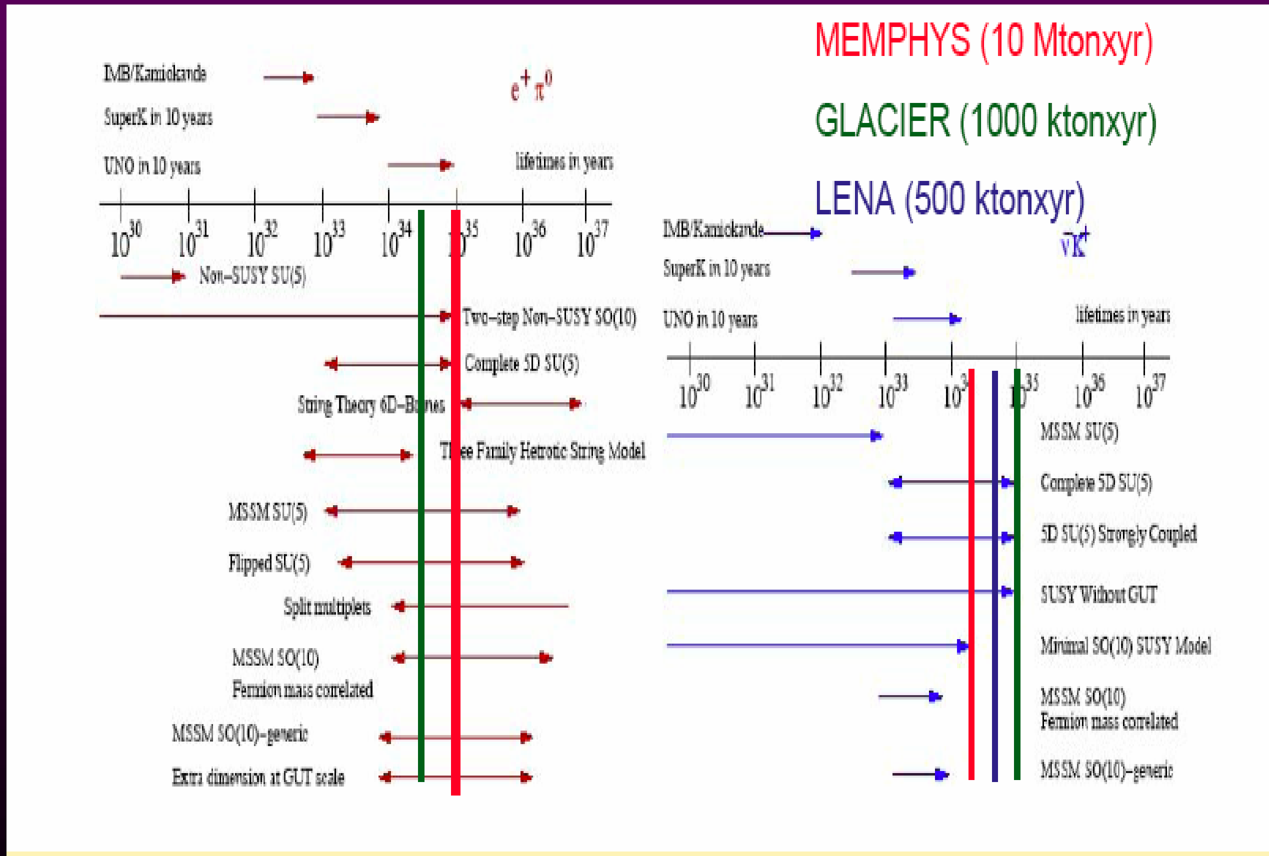
SUSY SU(5), SO(10) , 6dim op, model independent τ_p=10^{34}-10^{36}y

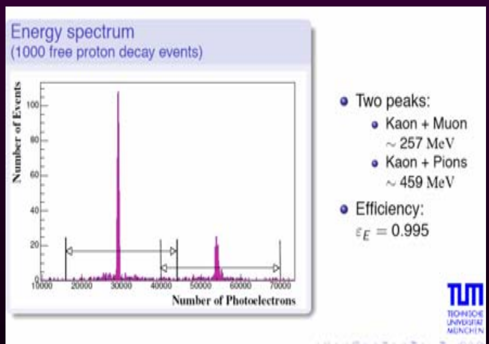
Awaiting important results from LHC



	GLACIER	LENA	MEMPHYS
$e^+\pi^0$			
$\epsilon(\%)/\mathrm{Bkgd(Mt.y)}$	45/1	-	43/2.25
τ_p/B (90% C.L., 10 yrs)	0.5×10^{35}	-	1.0×10^{35}
$\bar{\nu}K^+$			
$\epsilon(\%)/\mathrm{Bkgd(Mt.y)}$	97/1	65/1	8.8/3
τ_p/B (90% C.L., 10 yrs)	1.1×10^{35}	0.4×10^{35}	0.2×10^{35}

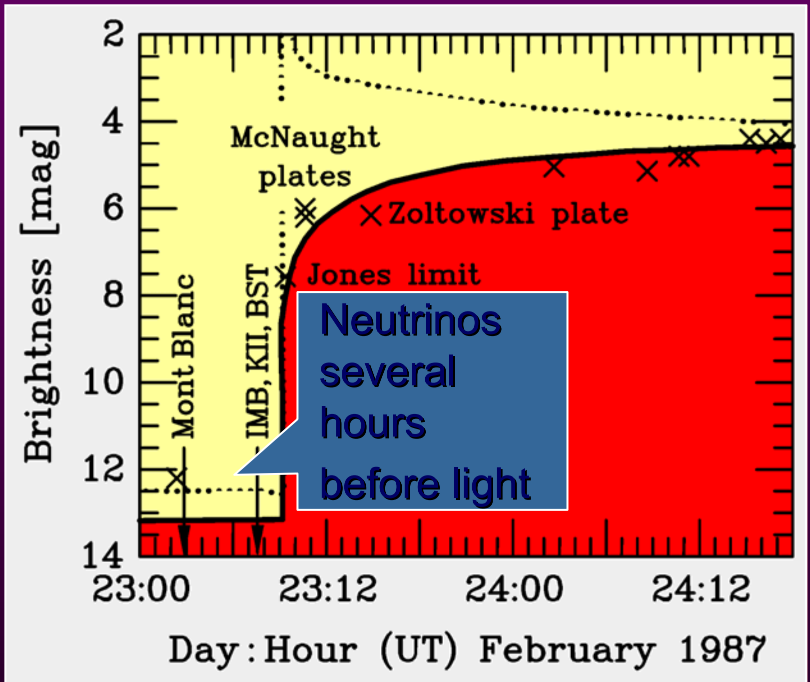






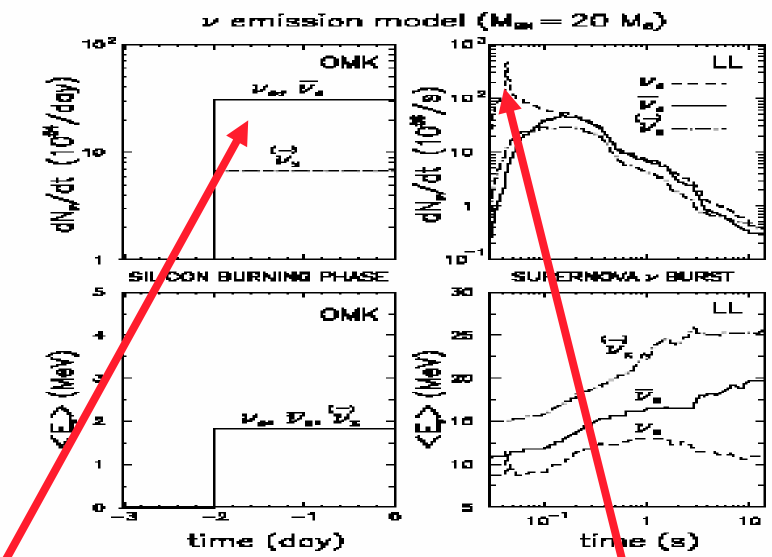
SN II Explosion

Early lightcurve of SN1987A



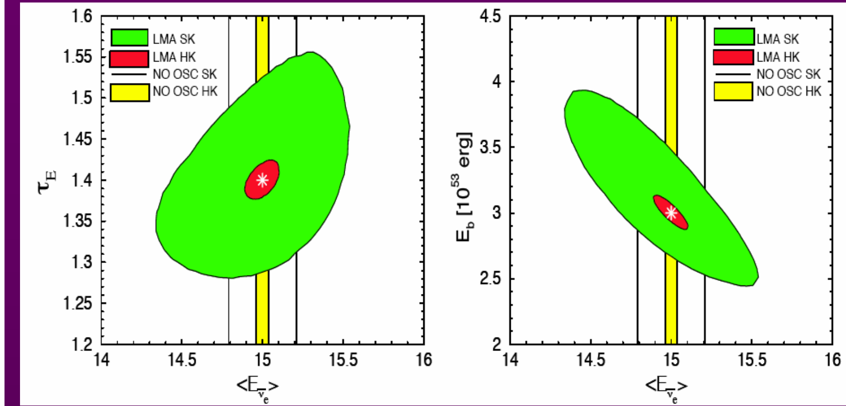
1. Si Burning
2. Neutronisation burst
3. Forward and reverse shocks, influences of turbulence?
4. SN pointing and SN early trigger (to 2-3 Mpc)
5. Visualize onset of black hole formation, access to the EOS of neutron star
6. R-process nucleosynthesis
7. Deduce value of θ_{13}

Be prepared to see the next SN explosion



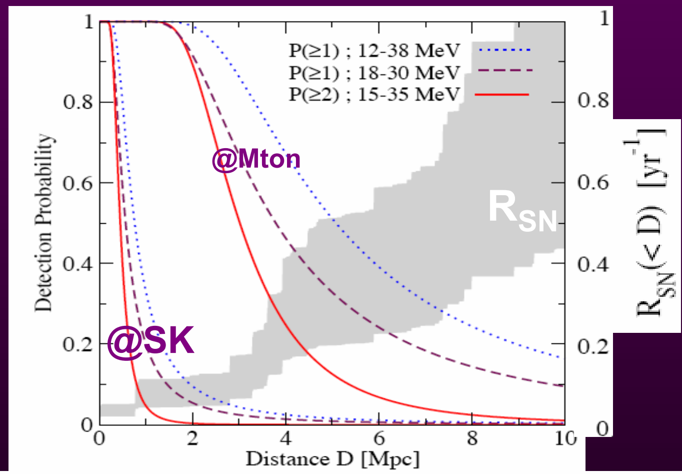
Si Burning (LENA and MEMPHYS/Gd)

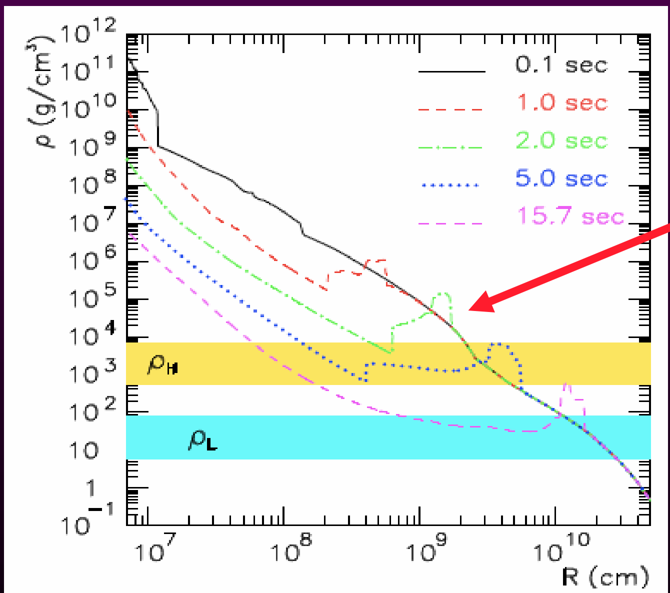
Neutronisation burst (GLACIER)



Luminosities and energies

Astroparticle trigger (GW antennas)





Shock Wave

Turbulance?

Also onset of black hole, measure EOS

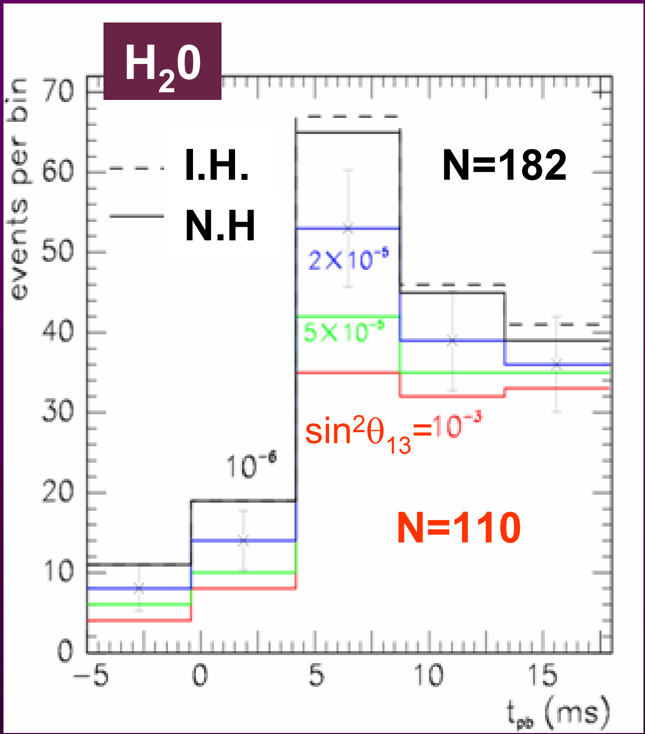
MEMPHYS Interaction	MEMPHYS Rates	LENA Interaction	LENA Rates	GLACIER Interaction	GLACIER Rates
$\bar{\nu}_e$ IβD	2×10^5	$\bar{\nu}_e$ IβD	9×10^3	$\nu_e^{CC}(^{40}Ar, ^{40}K^*)$	2.5×10^4
$\overset{(-)}{\nu}_e^{CC}(^{16}O, X)$	10^4	ν_x pES	7×10^3	$\nu_x^{NC}(^{40}Ar^*)$	3.0×10^4
ν_x eES	10^3	$\nu_x^{NC}(^{12}C^*)$	3×10^3	ν_x eES	10^3
		ν_x eES	600	$\bar{\nu}_e^{CC}(^{40}Ar, ^{40}Cl^*)$	540
		$\bar{\nu}_e^{CC}(^{12}C, ^{12}B^{\beta^+})$	500		
		$\nu_e^{CC}(^{12}C, ^{12}N^{\beta^-})$	85		

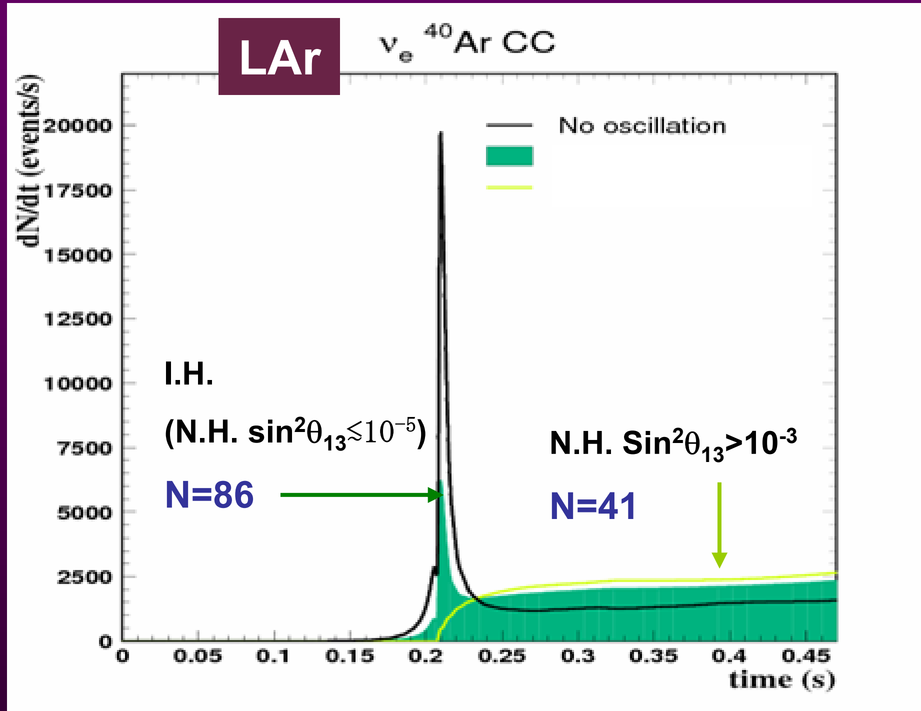
Neutronization Burst Rates

MEMPHYS	60	ν_e eES
LENA	~ 10	$\nu_e^{CC}(^{12}C, ^{12}N^{\beta^-})$
GLACIER	380	$\nu_x^{NC}(^{40}Ar^*)$

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_2O)**

Time evolution of the energy spectrum: Burst + Shock Wave +Earth

θ_{13} parameter + mass Hierarchy

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

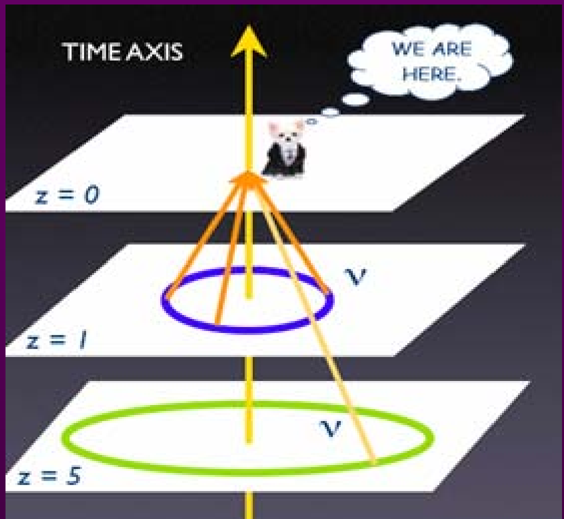
Hierarchy	$\sin^2\theta_{13}$	ν_e neutronization peak	Shock wave	Earth effect
Normal	$\gtrsim 10^{-3}$	Absent	ν_e	$\bar{\nu}_e$ ν_e (delayed)
Inverted	$\gtrsim 10^{-3}$	Present	$\bar{\nu}_e$	ν_e $\bar{\nu}_e$ (delayed)
Any	$\lesssim 10^{-5}$	Present	—	ν_e $\bar{\nu}_e$

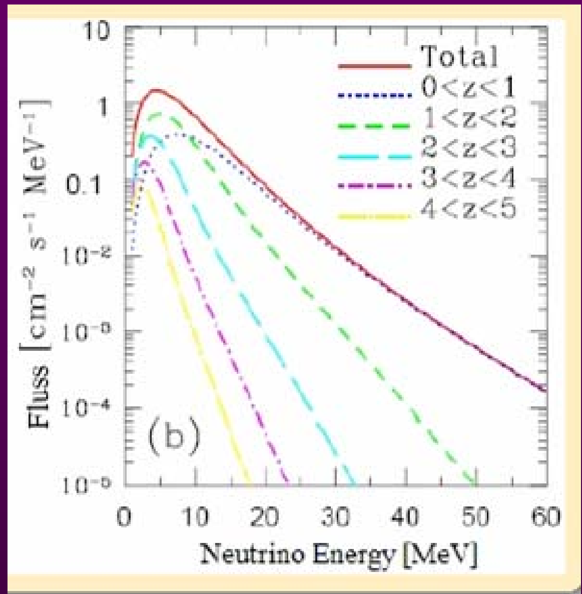
A. Mirizzi

1) **$\sin^2\theta_{13} \gtrsim 10^{-3}$** earth effects or shock wave $\nu_e / \bar{\nu}_e$ =>mass hierarchy (use icecube?)

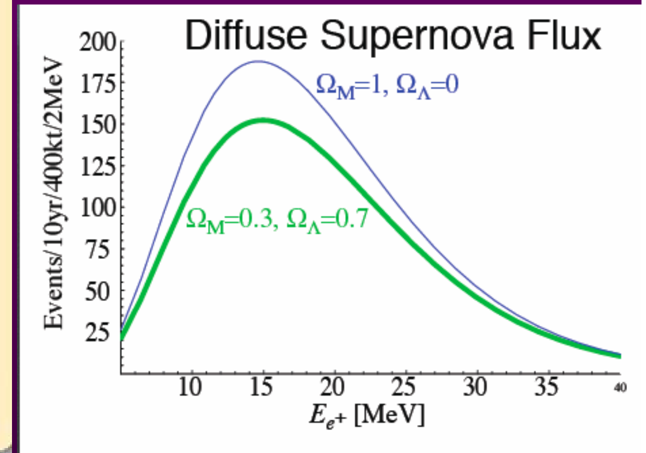
2) If Double beta decay has excluded inverted hierarchy and the neutronisation peak is present => **$\sin^2\theta_{13} \lesssim 10^{-5}$**

Diffuse SNν





Hall, Murayama et al.

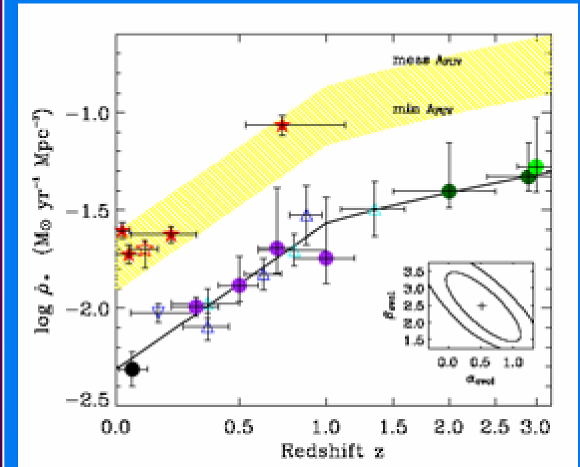


Detection of SNν with z ≲ 1

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

Flux(E) may be a complementary probe of the Dark Energy as the Large Supernova Survey (eg. LSST)

Current limit close to a detection?



Formation Etoile

GALEX

$(1+z)^{2.5}$ z<1

$(1+Z)^{0.5}$ z>1

Astrophys.J. 619 (2005) L47

Supernova

$$\frac{dN_\nu}{dE_\nu} \propto \frac{E_\nu^2}{\exp(E_\nu/T_\nu - \eta) + 1},$$

$$T_{\nu_e} = 3 \text{ MeV},$$

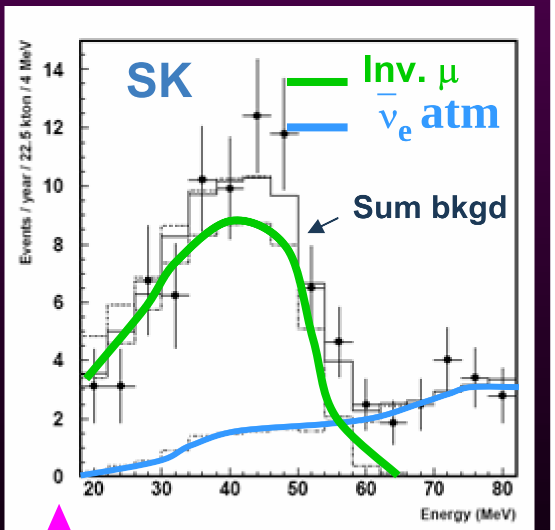
$$T_{\bar{\nu}_e} = 5 \text{ MeV},$$

$$T_{\nu_x} = 8 \text{ MeV}$$

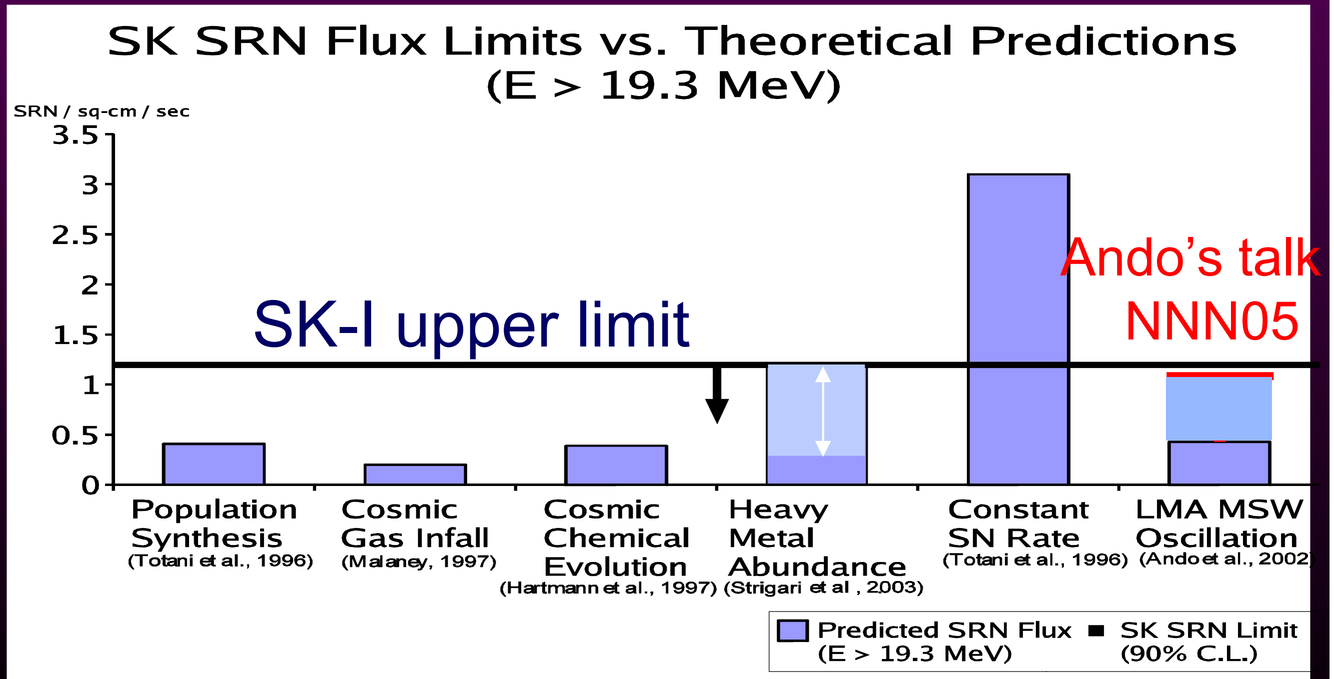
E_ν > 11.3 MeV	E_ν > 19.3MeV
5.1 $cm^{-2}s^{-1}$	1.2 $cm^{-2}s^{-1}$

Les oscillations (LMA) augmente quelque peu le flux E>30MeV

Phys. Rev. Lett 90, 061101 (2003)



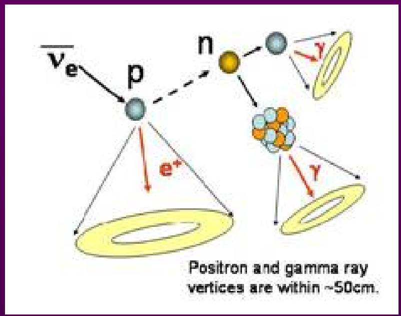
Réacteur + Sun



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

$H_2$0 + n-capture

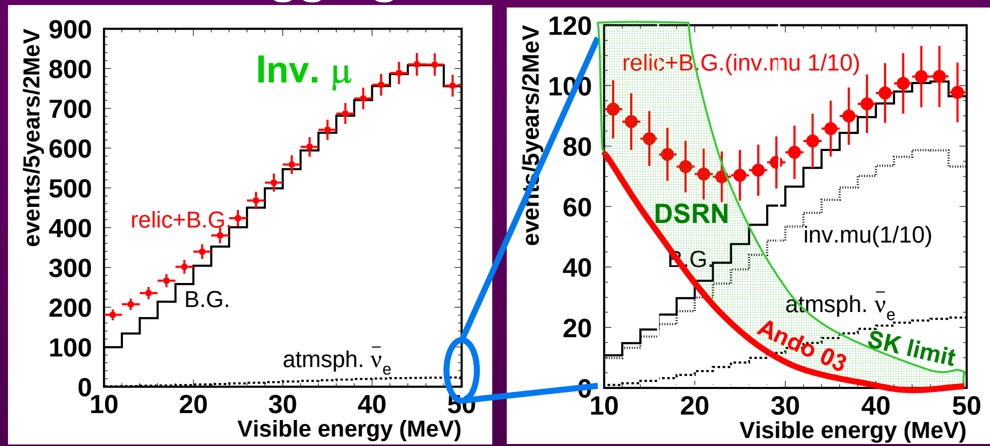
30% PMT coverage



ΔT(p: 2MeV γ) = ~ 200 μs

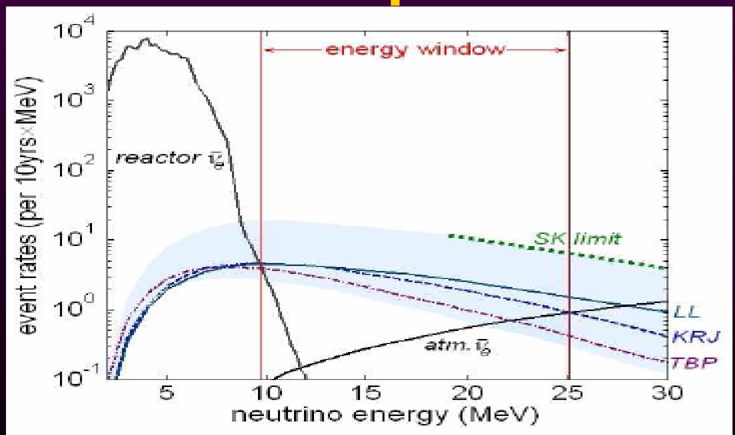
ΔT(**Gd**: 8MeV γ) = few 10^{th} μs

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

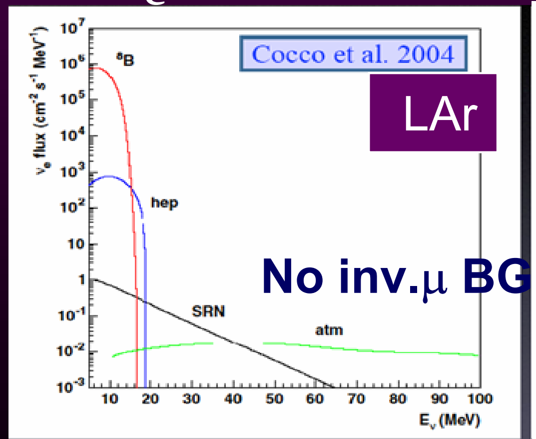


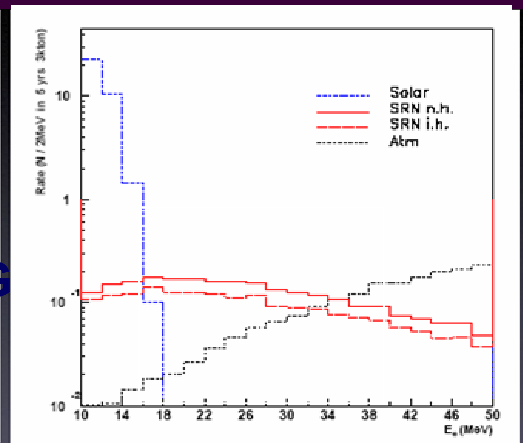
Nakahata+Vagins @ NNN05

LENA + n-capture



$\nu_e + {}^{40}Ar \rightarrow {}^{40}K^* + e^-$

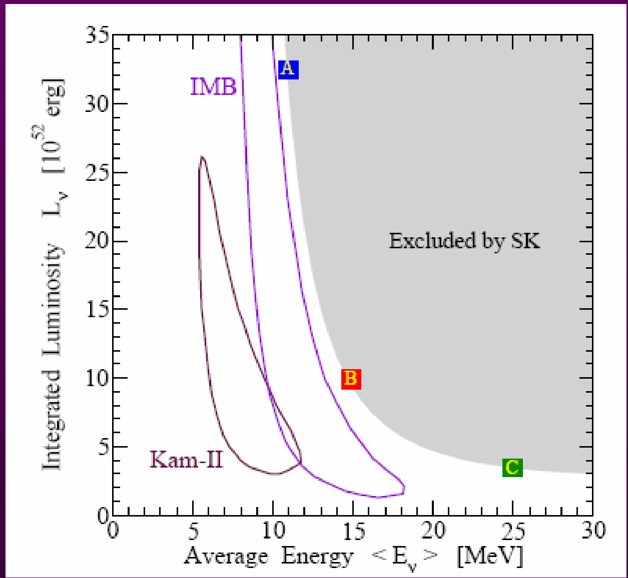




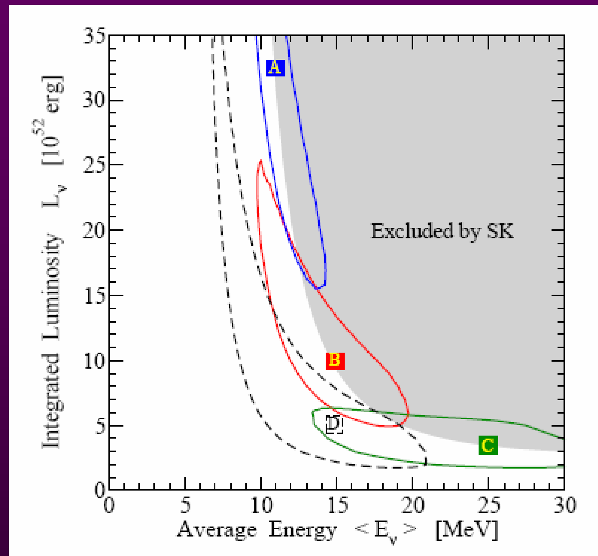
***: at SK limit**

SN parameter measurements: « explosion vs DSN »

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



DSN
5yrs SK-Gd
⇔1yr MEMPHYS-1shaft-Gd

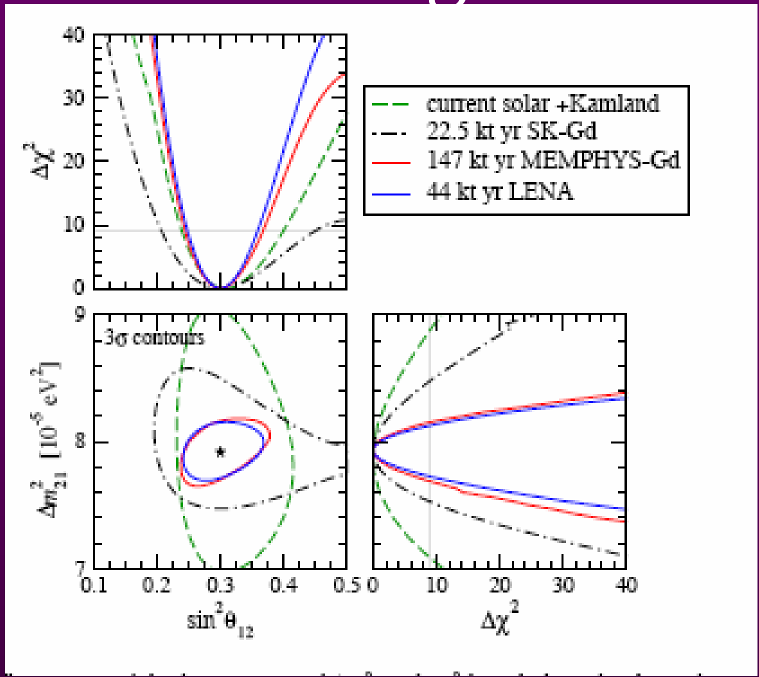


Yukse, Ando Beacom astro-ph/0509297

Interaction	Exposure	Energy Window	Signal/Bkgd
1 shaft MEMPHYS + 0.2% Gd (with bkgd Kamioka)			
$\bar{\nu}_e + p \rightarrow n + e^+$ $n + Gd \rightarrow \gamma$ (8 MeV, 20 μs)	0.7 Mt.y 5 yrs	$[15 - 30]$ MeV	(43-109)/47
LENA at Pyhäsalmi			
$\bar{\nu}_e + p \rightarrow n + e^+$ $n + p \rightarrow d + \gamma$ (2 MeV, 200 μs)	0.4 Mt.y 10 yrs	$[9.5 - 30]$ MeV	(20-230)/8
GLACIER			
$\nu_e + {}^{40}Ar \rightarrow e^- + {}^{40}K^*$	0.5 Mt.y 5 yrs	$[16 - 40]$ MeV	(40-60)/30

Reactors and geoneutrinos

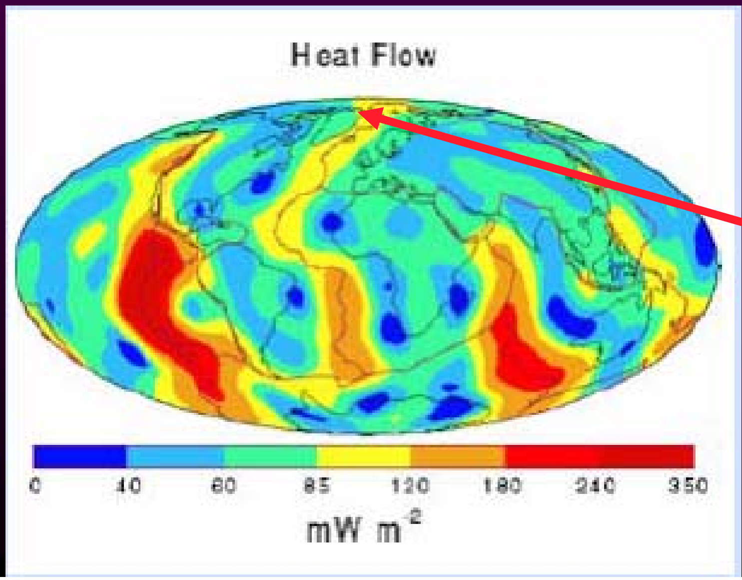
S.Petkov, T. Schwetz



time	spread(Δm^2_{21}) 1 yr	spread(Δm^2_{21}) 7 yr	spread($\sin^2\theta_{12}$) 1 yr	spread($\sin^2\theta_{12}$) 7 yr
SK-Gd	6.0%	2.8%	36.6%	18.6%
MEMPHYS-Gd	2.9%	1.4%	20.0%	13.2%
LENA	2.5%	1.2%	18.0%	9.8%
solar + KamLAND	11.3%		24.9%	

Measuring θ_{12} at Fréjus with nearby reactors <D>=300 km, Flux 3.4 MW/KM2/4π

MEMPHYS: challenging to set a threshold at 3MeV
A dedicated reactor exp. may be more sensitive (ex. SPMIN)



LENA (50kT) @ Pyhäsalmi:

Reactor bck 2000 ev/year,

1 TW georeactor 200 ev/y , 4σ after 1 year,

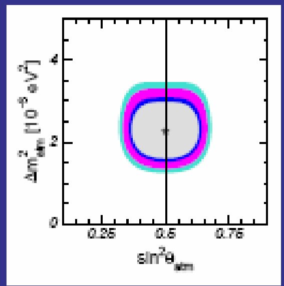
a sensitivity of 0.3 TW after 10 years

Summary of the non-accelerator program

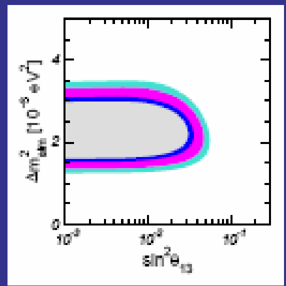
Topics	GLACIER (100 kt)	LENA (50 kt)	MEMPHYS (440 kt)
Proton decay			
$e^+\pi^0$	0.5×10^{35}	-	1.0×10^{35}
$\bar{\nu}K^+$	1.1×10^{35}	0.4×10^{35}	0.2×10^{35}
SN ν (10 kpc)			
CC	$2.5\ 10^4 (\nu_e)$	$9.0\ 10^3 (\bar{\nu}_e)$	$2.0\ 10^5 (\bar{\nu}_e)$
NC	$3.0\ 10^4$	$3.0\ 10^3$	-
ES	$1.0\ 10^3 (e)$	$7.0\ 10^3 (p)$	$1.0\ 10^3 (e)$
DSN ν (5 yrs Sig./Bkgd)	40-60/30	9-110/7	43-109/47 (*)
Solar ν (1 yr Sig.)	$4.5\ 10^4/1.6\ 10^5$ (^{8}B ES/Abs)	$2.0\ 10^6/7.7\ 10^4/1.6\ 10^4/360$ (^{7}Be/pep/^{8}B ES/^{8}B CC)	$1.1\ 10^5$ (^{8}B ES)
Atmospheric ν (1 yr Sig.)	$1.1\ 10^4$	TBD	$4.0\ 10^4$ (1-ring only)
Geo ν (1 yr Sig.)	below threshold	≈ 1000	need 2 MeV threshold
Reactor ν (1 yr Sig.)	-	$1.7\ 10^4$	$6.0\ 10^4$ (*)
Dark Matter 10 yrs Sig.	3 events ($\sigma_{ES} = 10^{-4}$,$M > 20$ GeV)	TBD	TBD

Oscillations...

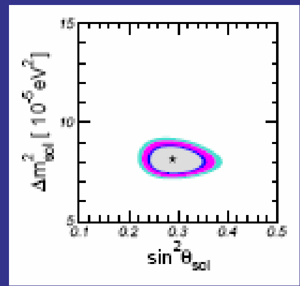
$$U = \begin{pmatrix} 1 & 0 & 0 \\ 0 & c_{23} & s_{23} \\ 0 & -s_{23} & c_{23} \end{pmatrix} \begin{pmatrix} c_{13} & 0 & e^{-i\delta} s_{13} \\ 0 & 1 & 0 \\ -e^{i\delta} s_{13} & 0 & c_{13} \end{pmatrix} \begin{pmatrix} c_{12} & s_{12} & 0 \\ -s_{12} & c_{12} & 0 \\ 0 & 0 & 1 \end{pmatrix}$$



atmospheric + K2K



CHOOZ

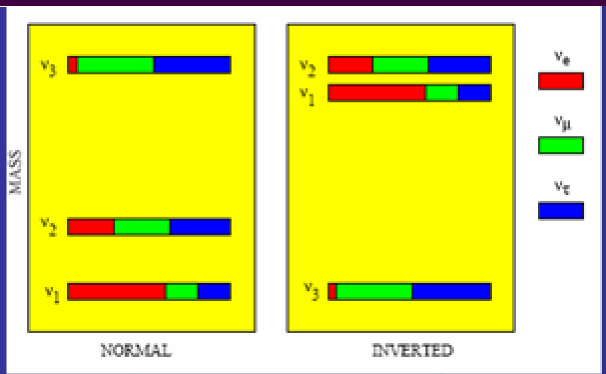


solar + KamLAND

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

Échelle de masse



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

Octant de θ_{23}

θ_{13}

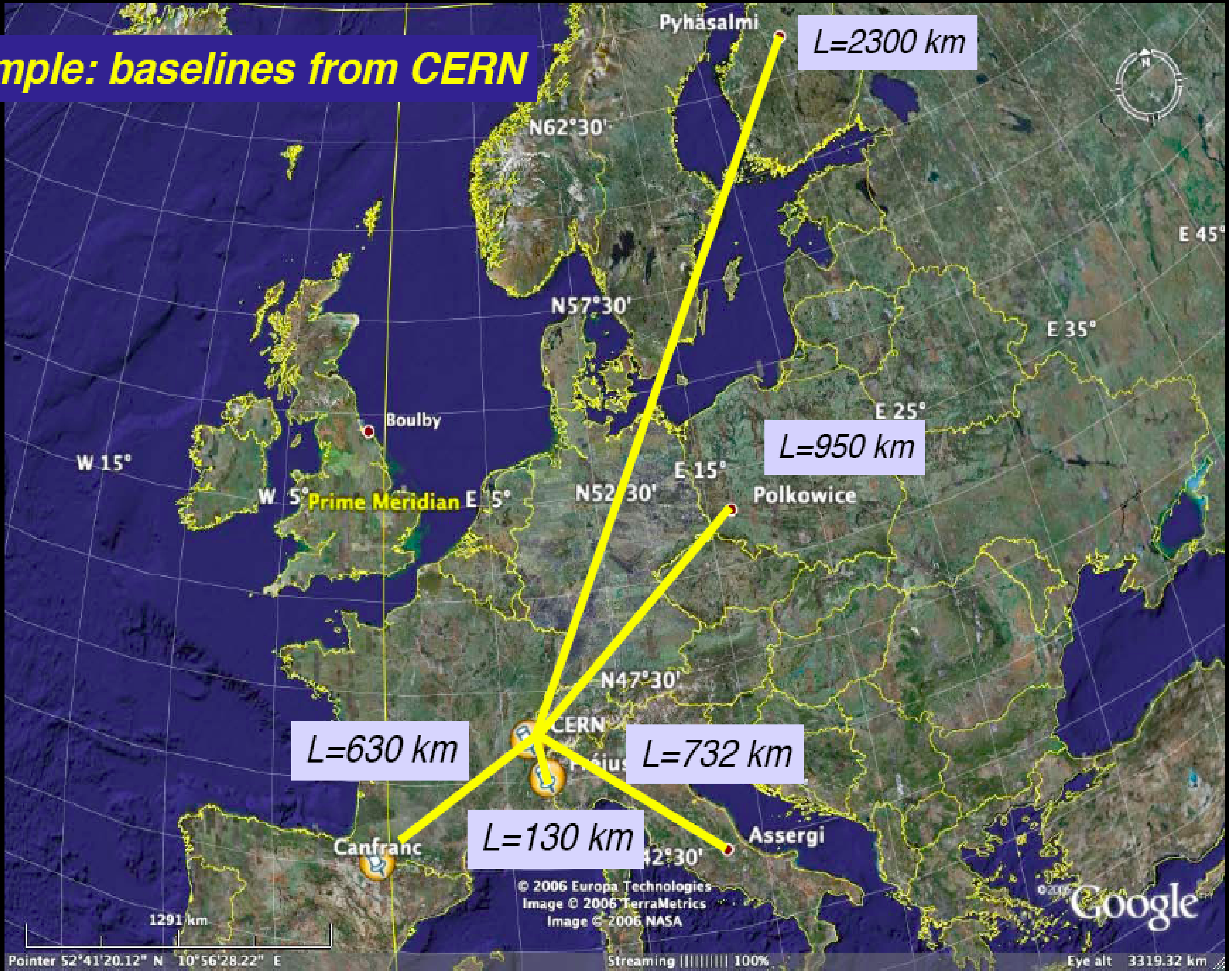
δ_{CP}

Hierarchy

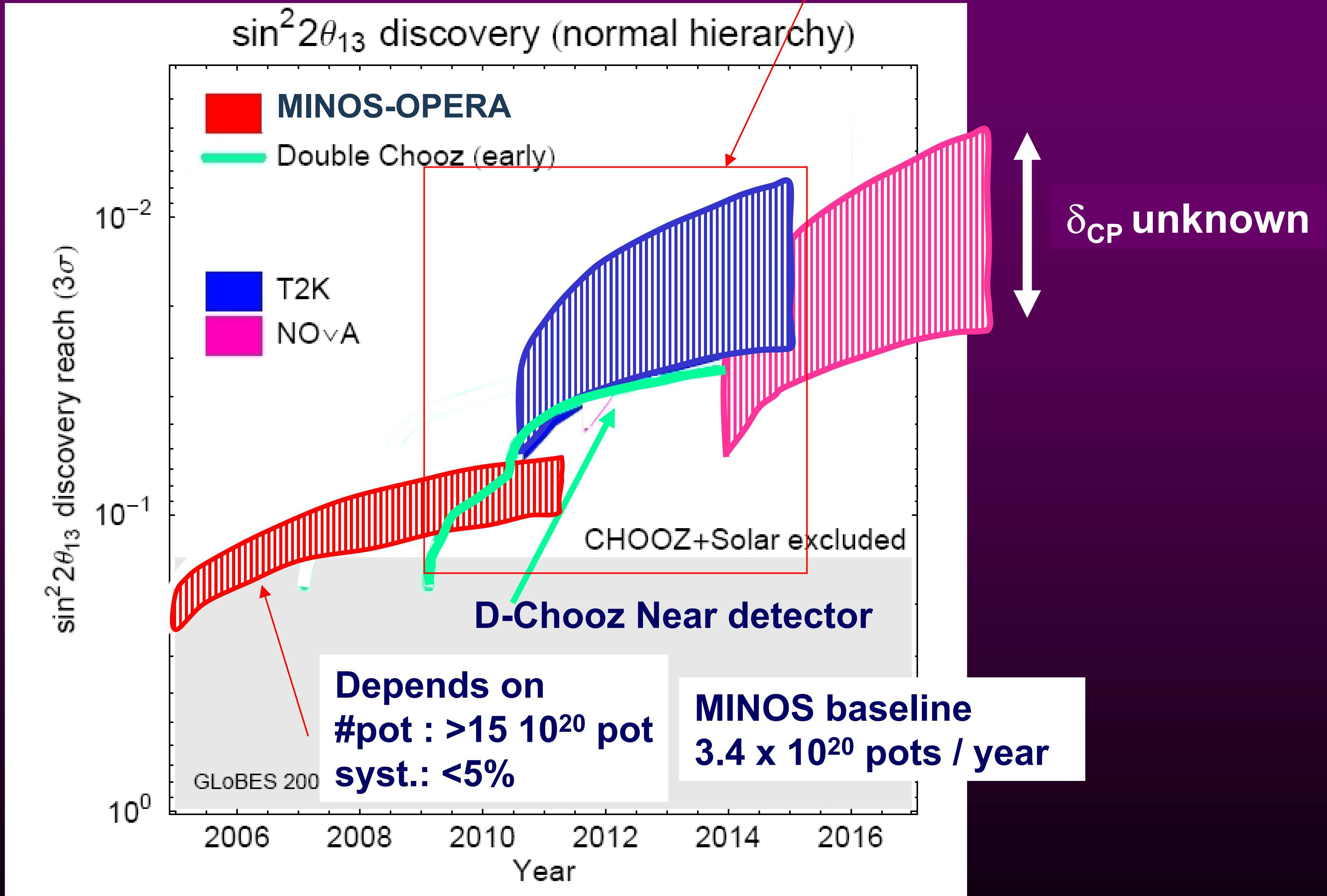
?

Cannot access to the Absolute mass scale, Majorana phases…

Example: baselines from CERN

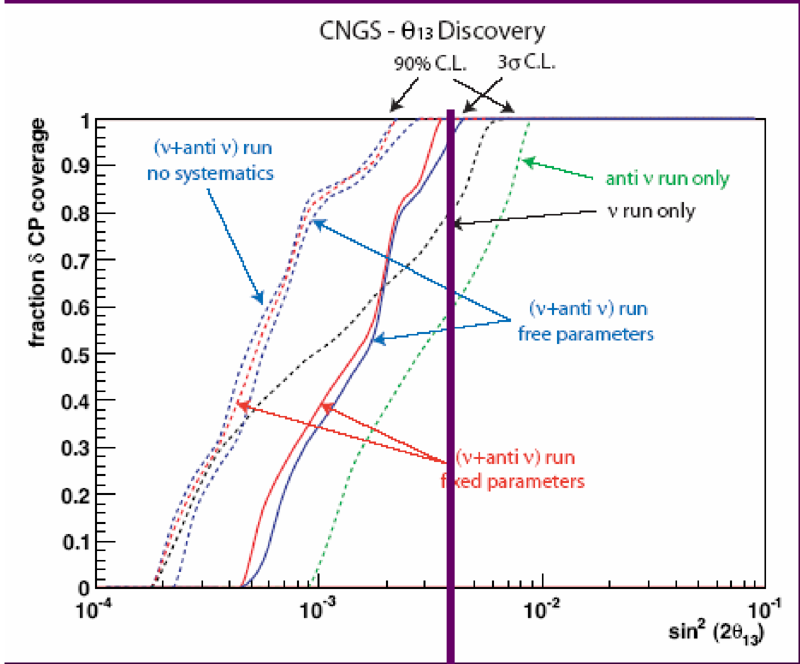


θ_{13} : sensibility evolution **Present French road map**

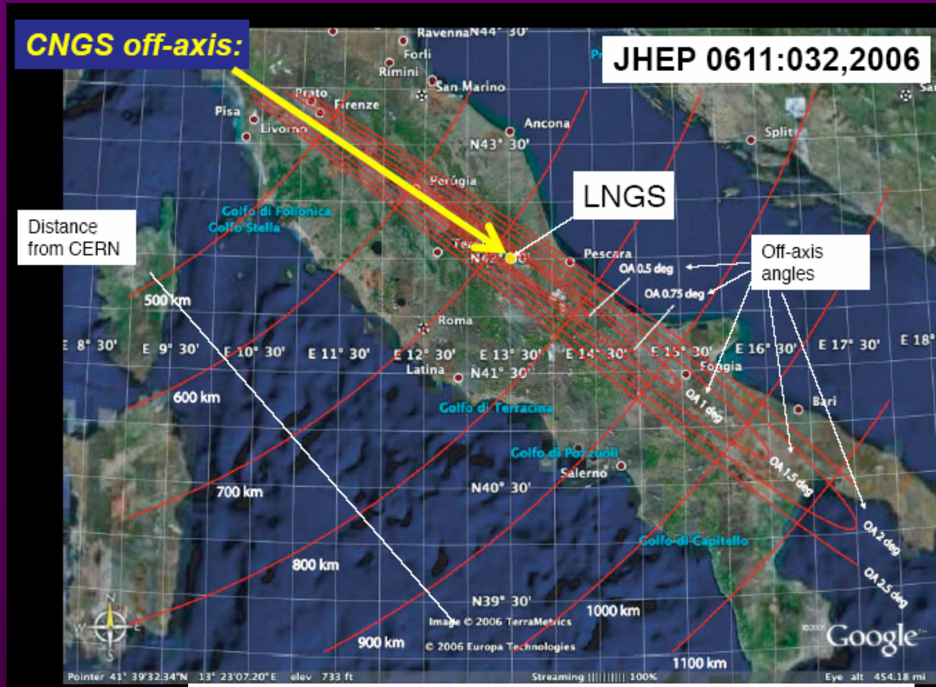


Adapted from P. Huber et al. hep-ph/0601266 & G. Mention GDR ν oct06 & MINOS Prog P & N Phys 06

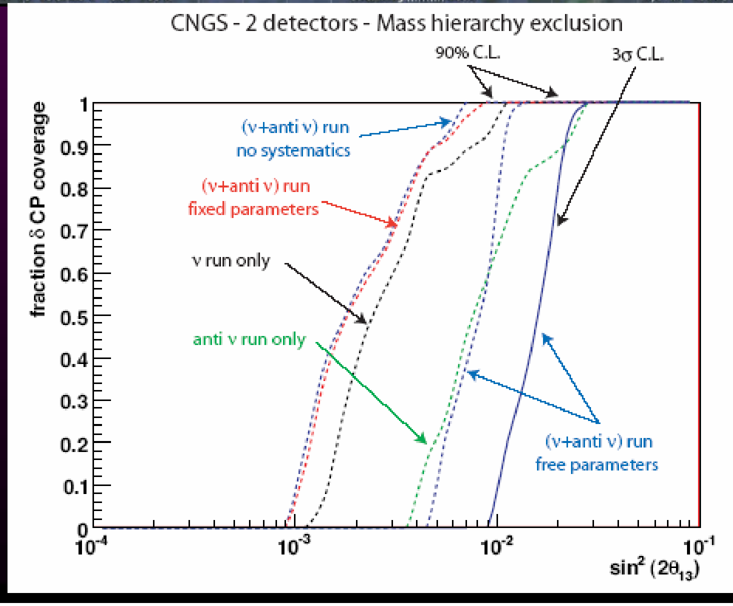
Using an upgrade of CNGS-off Axis + GLACIER



$\sin^2 2\theta_{13} > 0.004$ at 3σ



Can also use 2 baselines
850km + 1050km
for Hierarchy



Meregaglia, A., and A. Rubbia, 2006, eprint hep-ph/0609106.

Future Super Beam and/or β Beam (for instance at CERN)

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

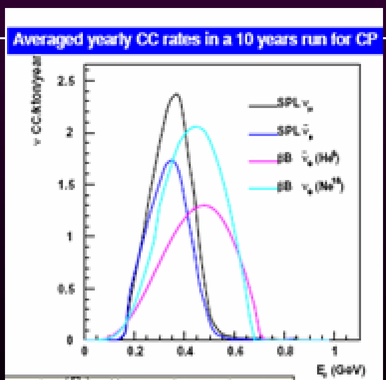
pure

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

^{18}Nd

^{6}He

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

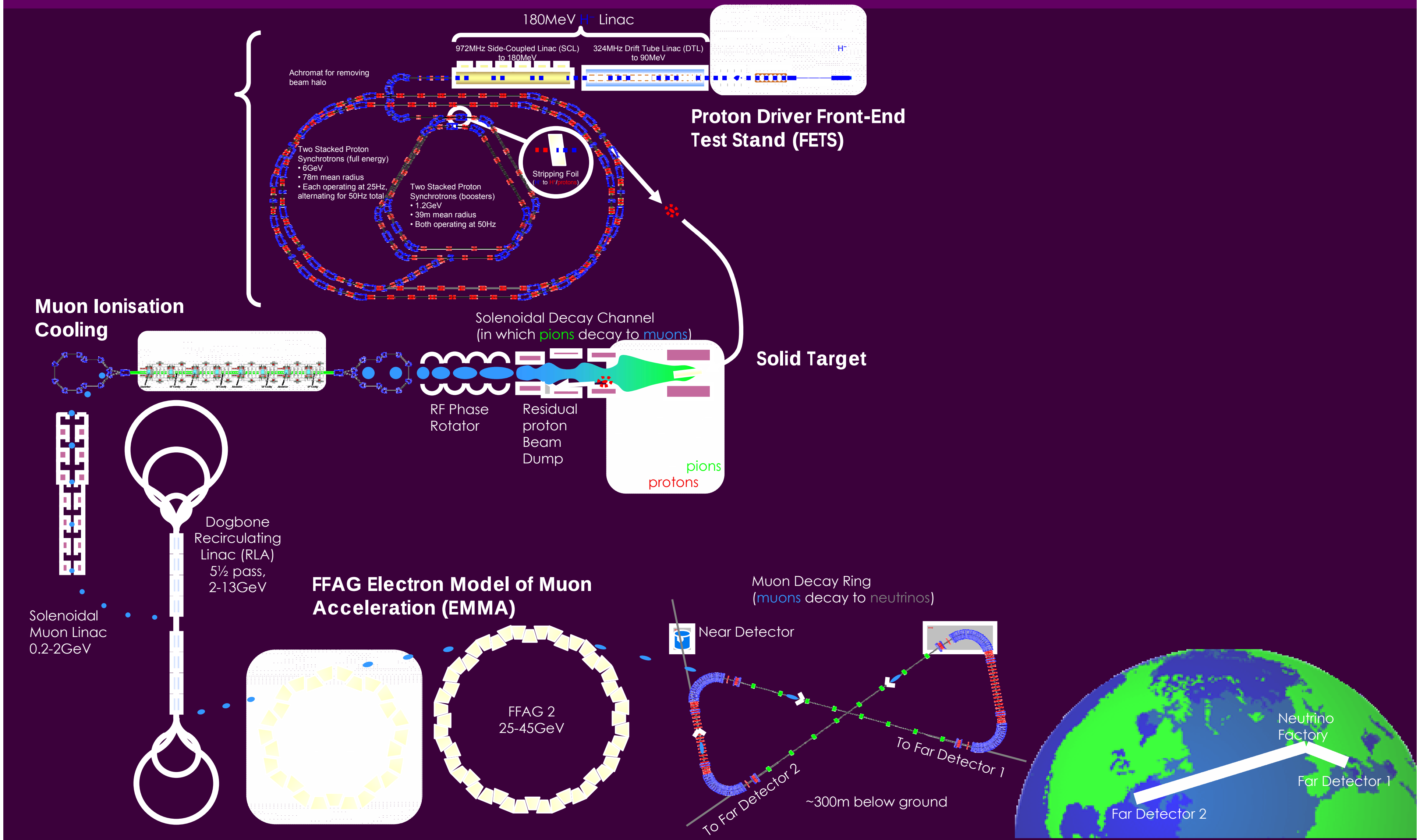


2 ways of testing CP, T and CPT : redundancy and check of systematics

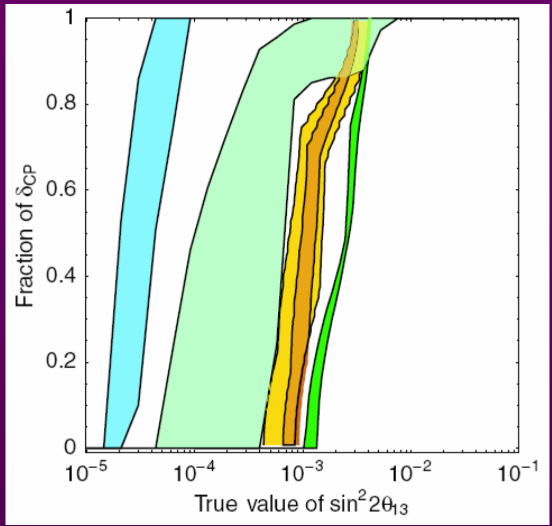
$\bar{\nu}_\mu$	107k	$\bar{\nu}_e$ (γ =100)	101k
ν_μ	81k	ν_e(γ =100)	144k

4Mt.y

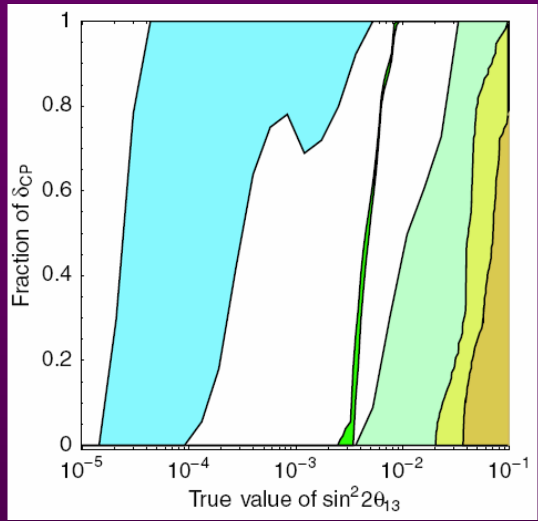
Neutrino Factory (possible design)



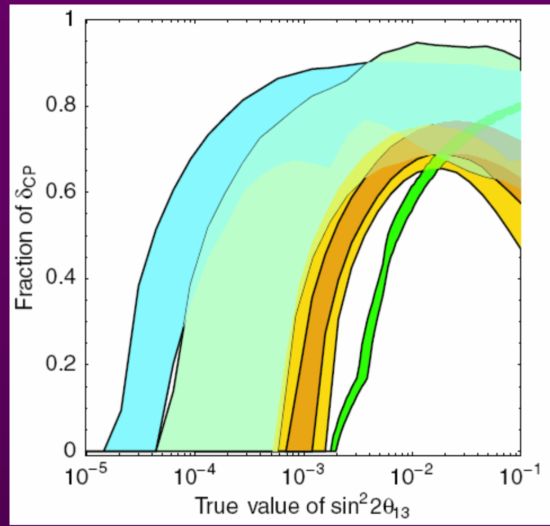
$\sin^2 2\theta_{13} \neq 0$ (3σ)



sign Δm^2_{31}



$\delta \neq 0$ AND $\delta \neq \pi$



SPL — 500kT H20 @ Frejus + SPL CERN (130km)

T2HK — 500kT H20 @ Kamioka + Tokay-II (300km)

WBB — 500kT H20 @ Homestake + BNL (2500km)

(SPL, T2HK, WBB: **Super Beams**)

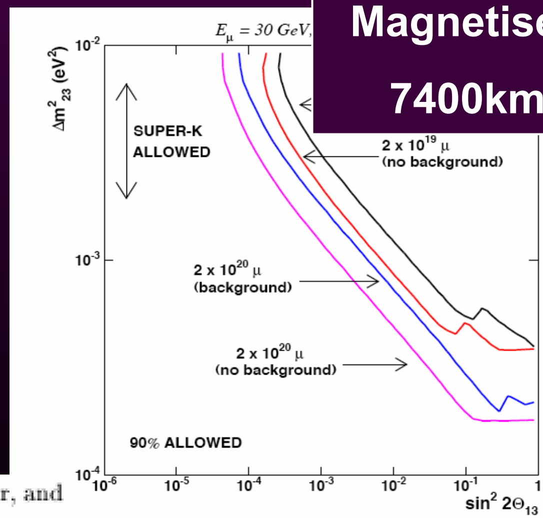
BB — 500kT H20 @ Frejus + βB-baseline CERN (130km)
500kT H20 @ Gran Sasso + βB-High Energy CERN (730km)

NF — 50kT-MINOS magnetized + 50GeV 4000km
20GeV 4000km + 7500km with improved threshold

GLACIER

Magnetised

7400km



Badertscher, A., M. Laffranchi, A. Meregaglia, A. Muller, and A. Rubbia, 2005, Nucl. Instrum. Meth. **A555**, 294.

ISS report Draft 12-feb-07

A possible strategy:

- **In case T2K-I has hints of oscillation Fréjus-CERN with superbeam and betabeam is the fastest way to explore CP violation in Europe,**
- **Otherwise one has to gauge the possibility:**
  - **to gain 1 order of magnitude on $\sin^2 2\theta_{13}$ and δ with the extra proton decay and supernova physics potential**
  - **to go directly to a gain of 2 orders of magnitude gain (Nufact) + technical feasibilities**

A Design Study on NuFAct+SPL+βB will be submitted to EU FP7

Outlook I

- In 5-6 years (2011-2012) there will be a new landcape in our science
  - LHC answers for supersymmetry (dark matter) and grand unification
  - DOUBLE-CHOOZ, T2K, DayaBay, Nova will have probed θ_{13} to 2.5-3°
  - Next generation astroparticle experiments about to start running or construction (advLIGO/VIRGO, KM3/ICECUBE, CTA, 1 ton DM and DBD)
  - Cosmological probes (PLANCK and beyond), Supernova surveys (LSST) will start providing information on the sum of neutrino masses and supernova statistics
- The large underground detectors probe
  - both the Lagrangian at the highest scales (proton decay and neutrino properties)
  - have a rich astroparticle and cosmology program.
- A large underground detector will be necessary somewhere in the world.

Outlook II

- In 5-6 years (2011-2012) will also be the times of world distribution of new very large infrastructures.
- Water Cherenkov, Liquid Scintillator and Liquid Argon present important physics complementarities (e.g flavours of proton decay, type of neutrinos in supernova searches) and also a lot of common R&D needs (cavities, photodetection). They work in synergy.
- In Europe a common design study for FP7 will help reach the required critical mass needed to study the three options with the required level of details.
- ApPEC/Aspera roadmap could permit its coordinated funding (also true for the other 5 large astroparticule infrastructures).
  - Coordination with HEPAP/P5/NSF, Canada, Asia sought . (EPP2010)
- Worldwide coordination (e.g. NNN workshops,05 Aussois, 06 Seattle, 07 Hamamatsu, 08 Europe) will benefit from a better coordinated EU effort.