Measurement of θ_{13} with reactor neutrinos: systematics and background

The Double-Chooz project

H de Kerret – PCC College de France and APC

Reactor neutrinos detection

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

  n + Gd ->8 MeV+γs

  + H_2 -> 2.2 MeV
- Liquid scintillator (But Gd)
- Uncertainties on reactor 2% in norm

  2.7% in shape

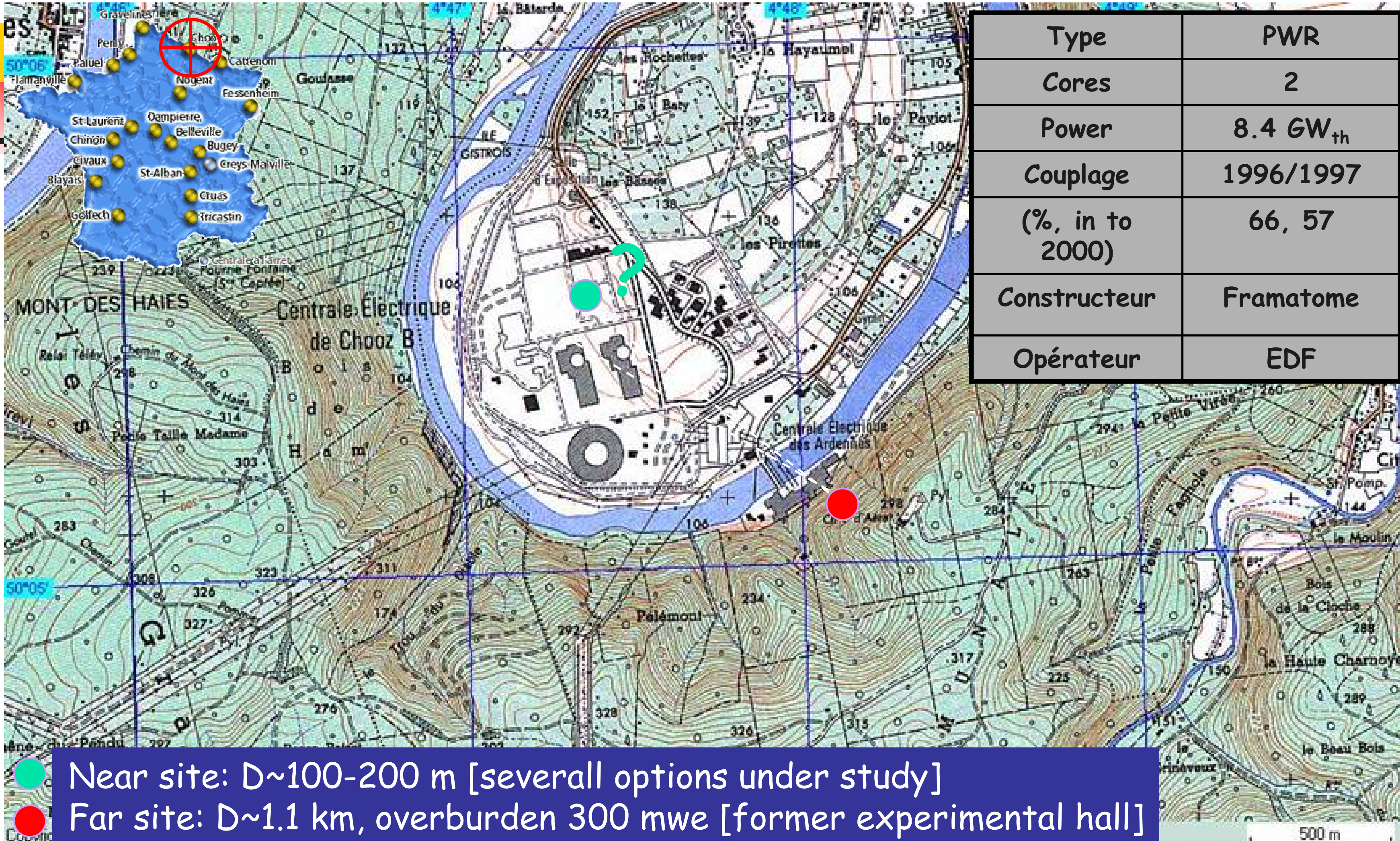
World wide community

- Workshops: Alabama, Munich (09/03)
- White book : first draft written (M.Goodman)
- Studied experimental site: Kashiwasaki (japan), Diablo canyon,.. (USA), Brazil, Taiwan .. And in europe: Penly, Cruas and Chooz

As an example: the double-Chooz project

- 2 identical detectors (12.6 m^3)
  - at 150 m. (artificial overburden)
  - at 1050 m. (use the pit of the Chooz experiment)
- Reach .03 in $\sin(2\theta_{13})^2$ (.05 in 1 year)
- 25 physicists of 4 European countries

The Chooz site



Type	PWR
Cores	2
Power	8.4 GW_{th}
Couplage	1996/1997
(%, in to 2000)	66, 57
Constructeur	Framatome
Opérateur	EDF

Near site: D~100-200 m [severall options under study]

Far site: D~1.1 km, overburden 300 mwe [former experimental hall]

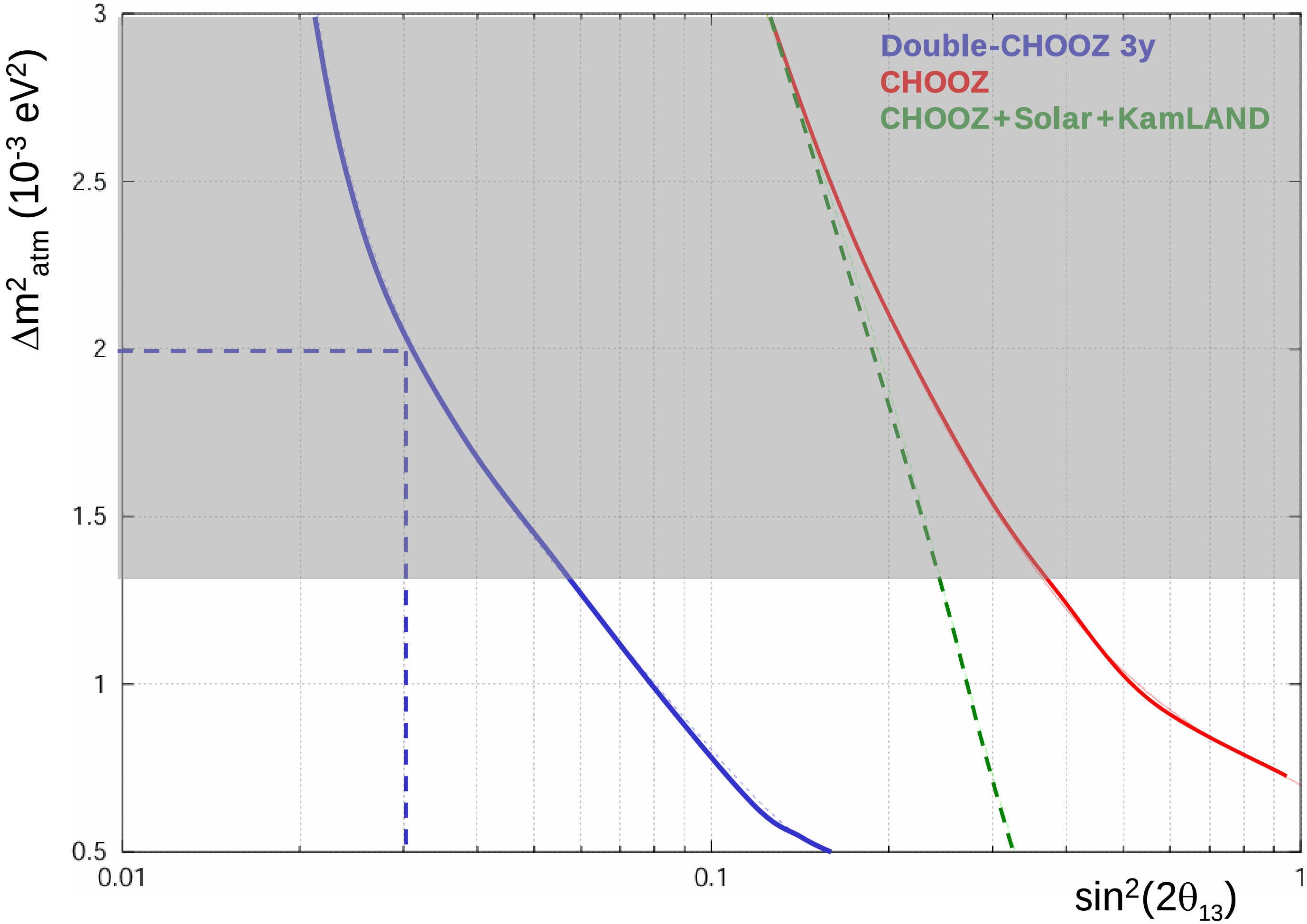
•Positive signs from EDF for reusing the former CHOOZ site. Near site → civil engineering

•2x11.5 tons, D1=100-200m, D2=1050m. Sensitivity: 3 years ➔ $\sin^2(2\theta_{13})$ < ~0.03

CHOOZ-Far

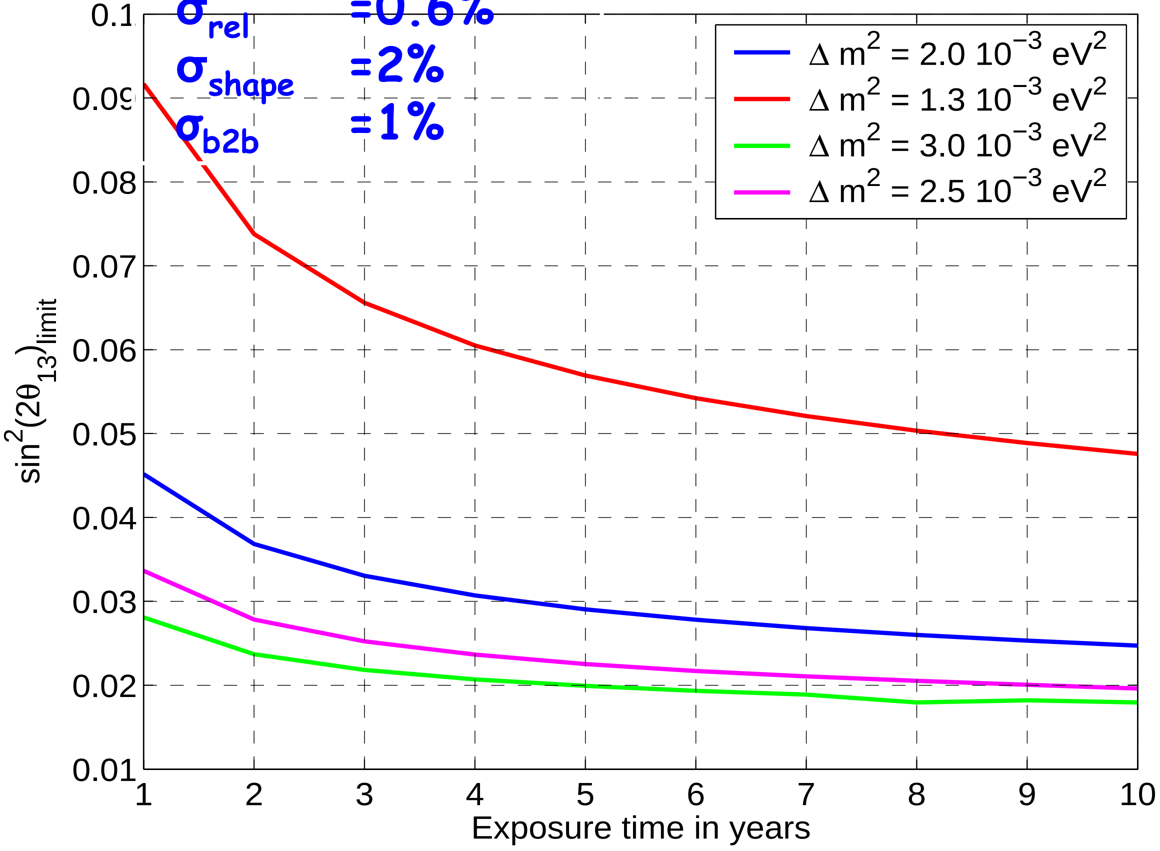
Picture taken in september 2003

Contours


Double-CHOOZ 3y
CHOOZ
CHOOZ+Solar+KamLAND
Δm^2_{atm} (10^{-3} eV^2)
3
2.5
2
1.5
1
0.5
0.01
0.1
1
$\sin^2(2\theta_{13})$

Time behavior of $\sin^2(2\theta_{13})$ sensitivity for different Δm^2

σ_{abs} =2%
σ_{rel} =0.6%
σ_{shape} =2%
σ_{b2b} =1%



systematics

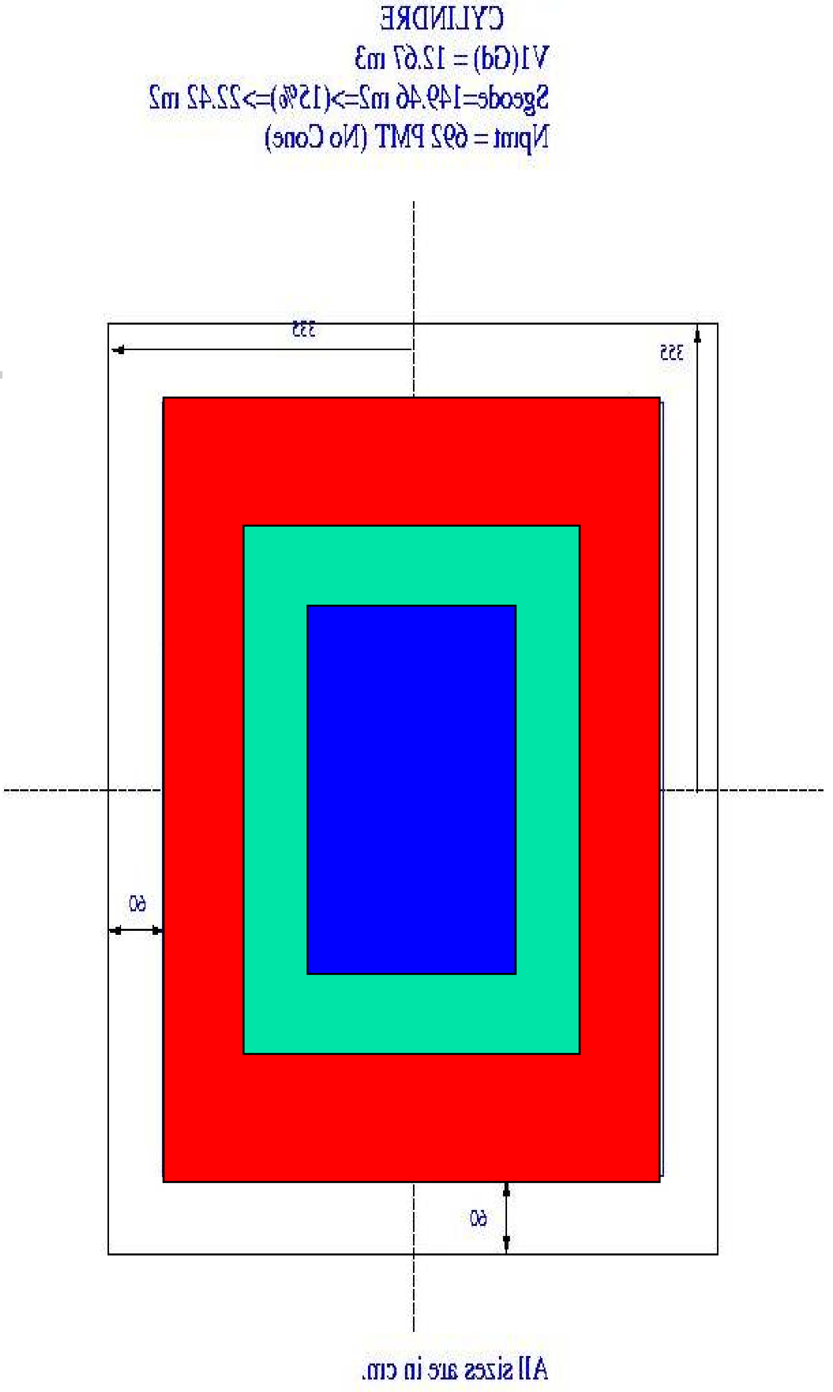
- 2 detectors (suppress the physical uncertainties)
- detector design to control the effect of some calibration uncertainties

  ➔Less accidentals → less cuts
- Address the few remaining source of uncertainties

  → .5% on the relative normalisation of the 2 detectors

Detector design

- A scintillating buffer around the target (to see the gammas from positron capture and Gd decays) ~60 cm
- A non scintillating buffer in front of pmts (reduce the single rates) ~ 1m
- Increase as much as possible the active buffer for the fast neutrons coming from outside



Data analysis: few cuts

- Identify the positron: threshold? No
  the neutron: threshold? 6 MeV cut

- Link them
  - time cut ? Yes
  - space cut? No

→Measure the neutrino energy (from e^+)

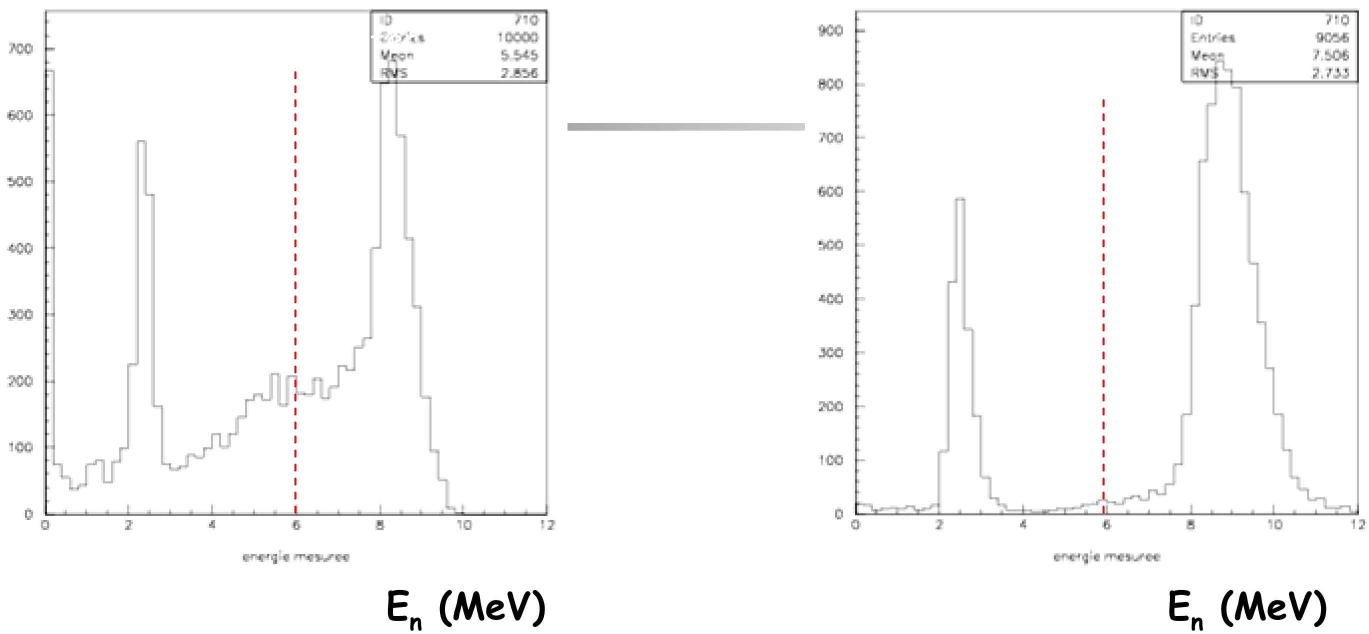
2 detectors: the solution

- Reactor uncertainties
- Distances (distance between detectors rather than to the core)
- Physics of the target (% of free protons, spectrum of Gd capture, neutronics at the detector frontier) if we use the same liquid in both detectors
- Physical cuts (time positron-neutron, gammas from GD not well known)

2 detector: the problem

- Relative target size (volume and density)
- Neutron identification → 6MeV cut on the products of Gd capture
- Live time → 0.1%
- Energy scale → shape of the nu spectrum
  - linearity
  - work in measured energy (no correction)
  - MC: allowed range of differences (light yield, attenuation length , etc..)

Delayed n & Scintillating buffer



- ✓ **Gadolinium loaded scintillator (~0.1%)**
  - Gd ➔ 8 MeV γ's (capture on Gd : 86.6%±1.0% in CHOOZ, Eur.Phys.J. C27 (2003) 331-374)
  - H ➔ 2.2 MeV γ's
  - n capture prob. ±1.0% (CHOOZ) → 0% with 2 detectors (MC uncertainty)
  - **Δt (e+-n)** → ±0.4% (CHOOZ) → 0% with 2 detectors (MC uncertainty)

- ✓ **n energy**→ ±0.4% (CHOOZ) → Scintillating buffer mandatory (as in CHOOZ)

Neutrino experiments backgrounds

- Accidentals
  - "e^+" : gammas from pmts , etc..
  - "n" : 0.04 Hz from cosmics
- Correlated events

muons → spallation fast neutrons→ recoil protons + capture of n

- Cosmogenics: Li^9,etc..

Strategy: S/B > 100
target -> measurement of B better than 50%

MEASURE IT:

- below 1.1 MeV (in the 0.5 – 0.9 Range)
- above 8 MeV (only 0.1% of neutrinos)
- power fit (2 months/year with 1 reactor on 1 reactor off)

Chooz

- Correlated 1.01/d+-.04 (sys)+-.1(stat)
- Accidentals 0.42/d +-.05

- SIGNAL 26/d full power

FAR detector: improve the Chooz S/B

- Target volume * 2.2 (cylindrical target)
- Background /3

  - non-scintillating buffer for pmts's gammas

  - thicker active buffer for fast neutrons (coming from outside) + outer veto (over the detector)

→ S/B increased by 6

→ Cost of the detector by 2

NEAR detector

- Shallow overburden: 55 mwe at 150 meters → 500 Hz of muons, 25% dead time (with 500 microsec. Gate)
- Important signal : 3000 evts /day
- Expected correlated background :

  - 20 ^{9}Li (upper limit : gives 1/d at Chooz: not observed)

  - 15 fast neutrons

  .5/d at FAR * muon ratio (30), but better buffers

schedule

- Far detector : install end of 2006
- NEAR “ : 2007

→ FIRST RESULT 2008

→ Detectors cost <10 Meuros

conclusion

- Improve the current limit on θ_{13} (which is sin 2 θ_{13})^2=.2) for the more recent atmospheric mass) by an order of magnitude is possible with nuclear reactors
- The European project Double-Chooz is the most advanced→ a first result to be expected end of 2008

Neutrino energy

- Full mc simulation:neutrino energy

MC with differences between both detectors

measured energy for each detector

contours

→define the allowed differences between the detector