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BUGEY III Neutrino Oscillation Experiment

Some Preliminary Results

E. KAJFASZ

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BUGEY III neutrino oscillation experiment
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Abstract

A preliminary analysis of data taken with one of our detectors at 15 and 95 m of a 2800 MW nuclear reactor core is discussed. The corresponding exclusion contour is presented. Schedule and limits we intend to reach for a 40 m measurement are also presented.

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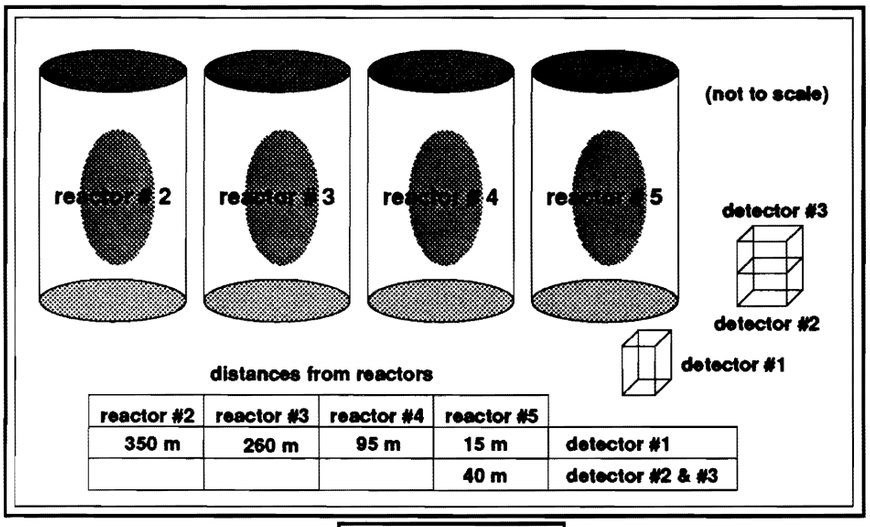
1. INTRODUCTION.

The Bugey neutrino oscillation experiment is performed near the four reactors of the Bugey Nuclear Power Plant, 30 km east from Lyon (France). Each reactor has a thermal power of 2800 MW and yields a flux of about 5.4 10^{20} antineutrinos/s. The reactor cores are 4 meter high and 3 meters in diameter. Three detectors are used as sketched in figure 1. Each one is a stainless steel tank filled with 600 liters of liquid scintillator. This pseudocumene based scintillator (NE 320) has a H/C ratio of 1.4 and is loaded with ^{6}Li (0.15%) [ref 1]. Optical tunnels define 98 cells of 8.2x8.2x85 cm^3 read by a photomultiplier (PM) at each end (figure 2). The detector(s) is (are) surrounded by a shield which, from outside inwards, is made of a 18 cm layer of lead (to reduce ambiant γ background), a 25 cm layer of water followed by a layer of B_4C (to reduce neutron background) and vessels filled with liquid scintillator read by a PM (to keep track of cosmic charged particles) used as veto counters [ref 2].



reactor #2	reactor #3	reactor #4	reactor #5	
350 m	260 m	95 m	15 m	detector #1
			40 m	detector #2 & #3

Figure 1. Set up

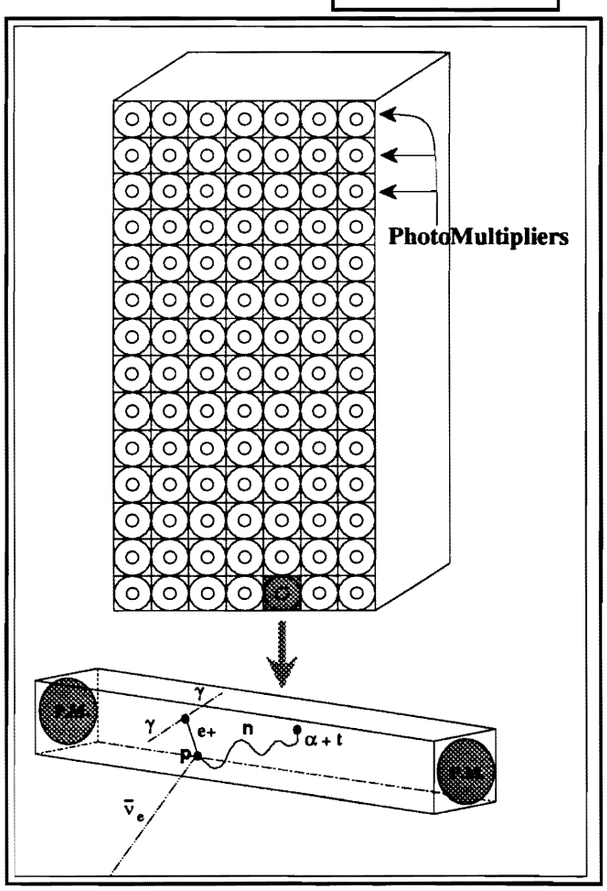


Figure 2. A detector

2. DETECTOR PROPERTIES.

The scintillator is used as a target for the antineutrinos; it detects the positron, thermalizes the neutron and detects the neutron via $^6Li + n_{th} \rightarrow \alpha + t$ giving rise to a sharp line of 530 keV electron equivalent energy. The mean life time of the neutrons coming from antineutrinos is about 30 μs in our detectors and the mean distance between the positron and the neutron detection points is roughly 5 cm. The localization of the antineutrino events combined to the short correlation time between

the positron and the neutron allows us to reduce our accidental background. Discrimination between different particle types is made using pulse shape discrimination (PSD) (figures 3 and 4) [ref 1 and 2].

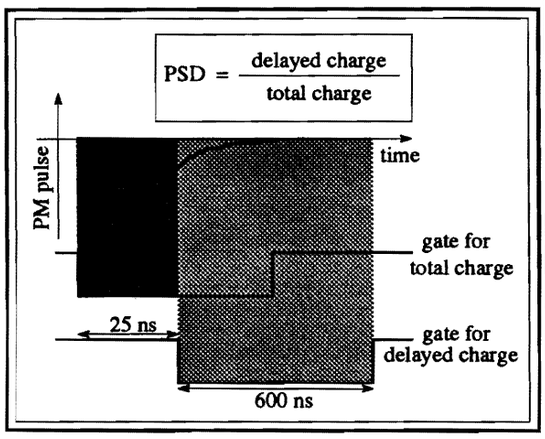


Figure 3. PSD definition

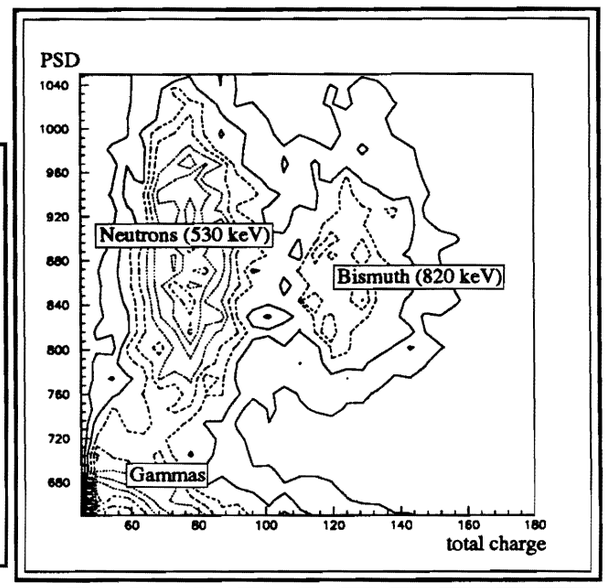


Figure 4. Heavy particle PSD vs total charge of a Bismuth enriched sample of events

3. ON-LINE ANTINEUTRINO SIGNATURE.

We require a 100 μs delayed coincidence between a "neutron" pulse and a "positron" pulse in neighboring cells; a "neutron" pulse following the "positron" pulse defines the on-line "neutrino" trigger,whereas a "neutron" pulse followed by a "positron" pulse defines the on-line "accidental" trigger.

4. CALIBRATIONS.

An Am/Be source emits fast neutrons and 4.4 MeV gammas, with which we carry out:

- a neutron calibration of each cell every month,
- a gamma calibration of each cell every other week.

A spark gap connected to a bunch of 2x98 optical fibers (one optical fiber for each PM) is used to:

- daily monitor the changes in the PM gains and the liquid properties, allowing us to daily interpolate the source calibrations.

In this way we manage to daily monitor for each cell:

- the neutron energy peak position,
- the neutron PSD,
- the positron PSD,
- the energy calibration (to better than 1%).

5. STATUS OF THE LIQUID SCINTILLATORS.

In detector # 2 & 3, the liquids are stable but contaminated with Uranium to a level of 1 ppb [ref 3]. For detector # 1,the liquid has no Uranium contamination problem but is slowly degrading (2 to 4 % per month on the number of photoelectrons/MeV); however due to our daily monitoring it is possible to correct for this degradation.

6. AVAILABLE DATA FOR DETECTOR # 1.

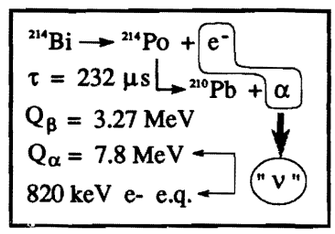
- ON data 15 m (reactor #5) > 100 000 antineutrinos
  95 m (reactor #4) 1800 antineutrinos
- OFF data

run	reactor #5 (15m)	reactor #4 (95m)	reactor #3 (260m)	# days
POF1	OFF	ON	ON	47
POF2	OFF	OFF	ON	6
POF3	OFF	OFF	OFF	40

7. BACKGROUND.

The background is measured and substracted using reactor OFF data. There are mainly two types of identified background:

- accidentals: they are measured on-line using a special trigger "neutron" before "positron",
- correlated, coming from:
  - fast neutrons from cosmic ray μ stops (rejected by veto counters and positron PSD)
  - Bismuth correlated events (rejected by software cuts)



8. PRELIMINARY ANALYSIS OF DETECTOR #1 DATA.

8.a. Analysis cuts.

The analysis cuts used were the following:

- positron energy: E(e+) > 1 MeV,
- positron PSD: PSD(e+) within +- 3 σ of the mean,
- 2.2 σ elliptical cut on (neutron PSD: PSD(n), neutron energy: E(n))
- time difference between neutron and positron: $\Delta t(n,e+) < 60\ \mu s$,
- longitudinal distance between neutron and positron: $\Delta z(n,e+) < 35$ cm,
- multi-dimensional cut [ref 6].

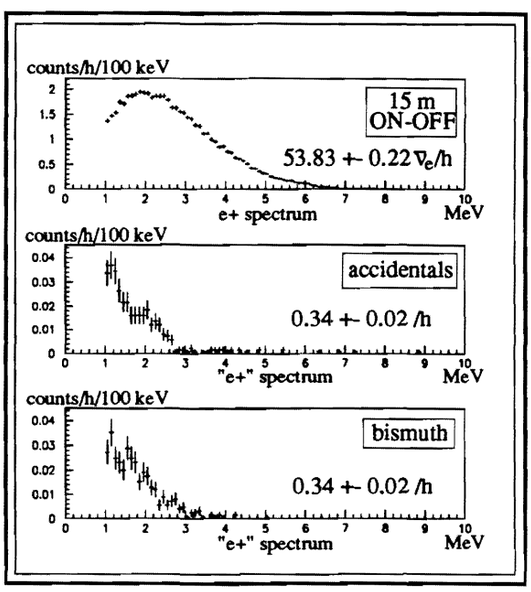


Figure 5. Positron spectra for 15 m data

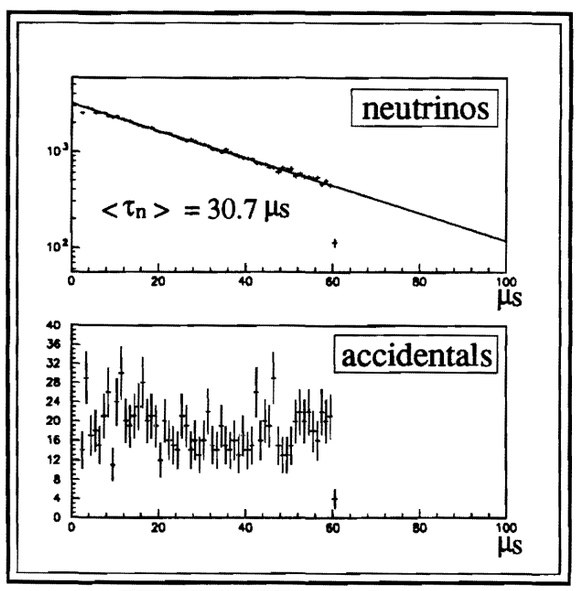


Figure 6. Time distributions

8.b. 15 m data.

These data were taken while reactor #5 was ON. Figure 5 shows the energy spectra of neutrino, accidental and Bismuth events. The number of detected antineutrinos is found to be 53.83 +- 0.22 /h after cuts (§ 8.a). Figure 6 shows the $\Delta t(n,e+)$ distribution for neutrino and accidental events. Figure 7 shows the very good agreement between the distribution of the number of neutrinos detected along the 14 lines of the detector and the same distribution generated with our Monte-Carlo. The first and last lines are underpopulated due to neutron leaks; the decrease between top and bottom is due to a solid angle effect.

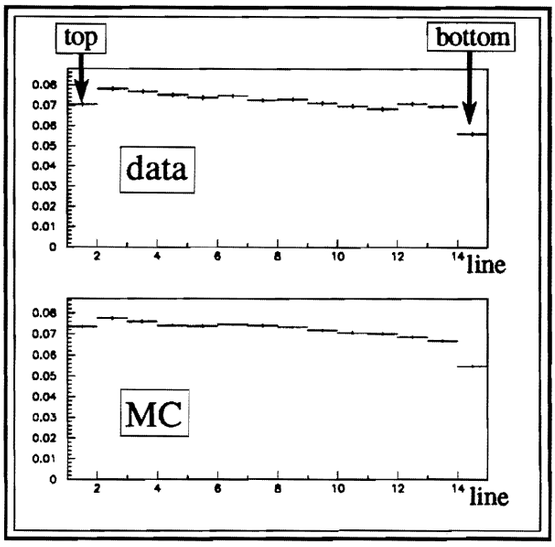


Figure 7. Neutrino events along lines

8.c. 95 m data.

These data were taken while reactor #5 was OFF and reactor #4 was ON. The number of detected antineutrinos is found to be 1.23 +- 0.13 /h after cuts (§ 8.a). Figure 8 shows the energy spectrum of neutrino events and the ratio between the energy spectra of neutrinos coming from 15m and those coming from 95m. This ratio is in good agreement with the difference $\Delta\Omega$ in solid angle between these two distances. Figure 9 shows the 90 % C.L. contour extracted from the comparison of the 95 m and the 15 m data, taking into account a conservative 10 % systematic error.

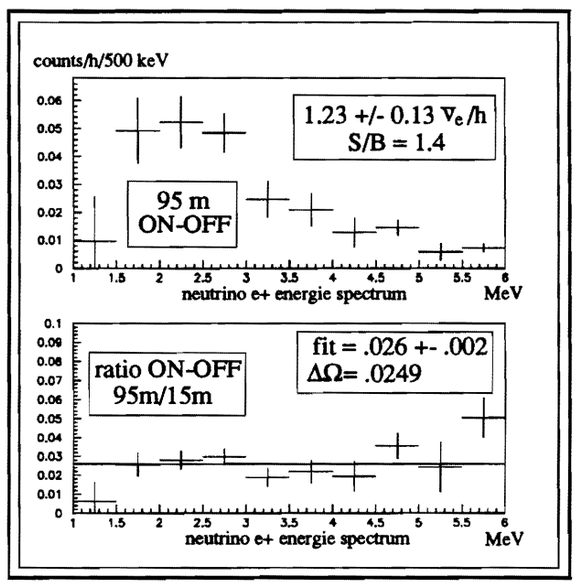


Figure 8. Data for 95 m

8.d. Background data.

The background components, using the 6 days of run POF2 OFF data are the following:

- correlated	Bismuth (estimated)	0.26 (+- 0.05) /h
	ν's from reactor #3	0.15 /h
	remaining background	0.42 (+- 0.12) /h
	total	0.83 +- 0.11 /h
- accidentals		0.25 +- 0.05 /h

9. CONCLUSIONS.

9.a. detector #1.

The data taking is now over. The analysis needs to be finalized including:

- cuts optimization,
- even better background rejection:
  - better estimate of Bismuth contamination,
  - use interpolated neutron calibrations,
  - use shape of "neutron" pulses as measured by 100 MHz Flash Adcs [ref 4],
- lower the systematics (normalization, cuts efficency ...).

For the 15m data, as we have a high statistics, it will be possible to discriminate between Schreckenbach and Tengblad measured spectra [ref 5]. For 95m data a slightly better contour should come out.

9.b. detector #2 and 3 (40m data).

Data have been taken from June 91 on. Data acquisition should continue till summer 92, including 3 months of "OFF data" from April to June. The expected 90 % C.L. contour for the comparison between these data and the 15m data is shown in Figure 9. A final analysis, combining the source spectrum (0m) and the 15, 40, 95 m data should be performed before the end of 92.

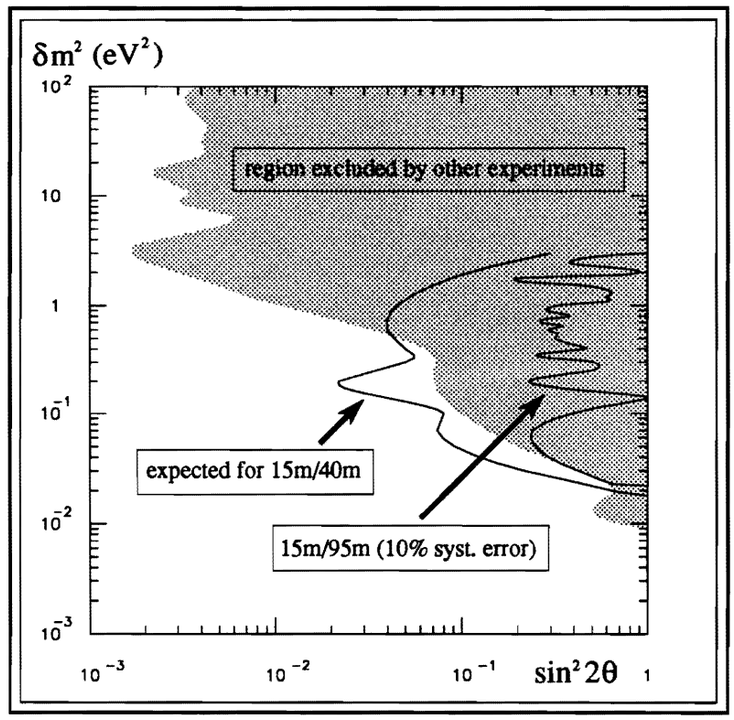


Figure 9. Contours (90 % C.L.)

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