

Measurement of the distance from nuclear reactors to detectors in Dayabay neutrino experiment

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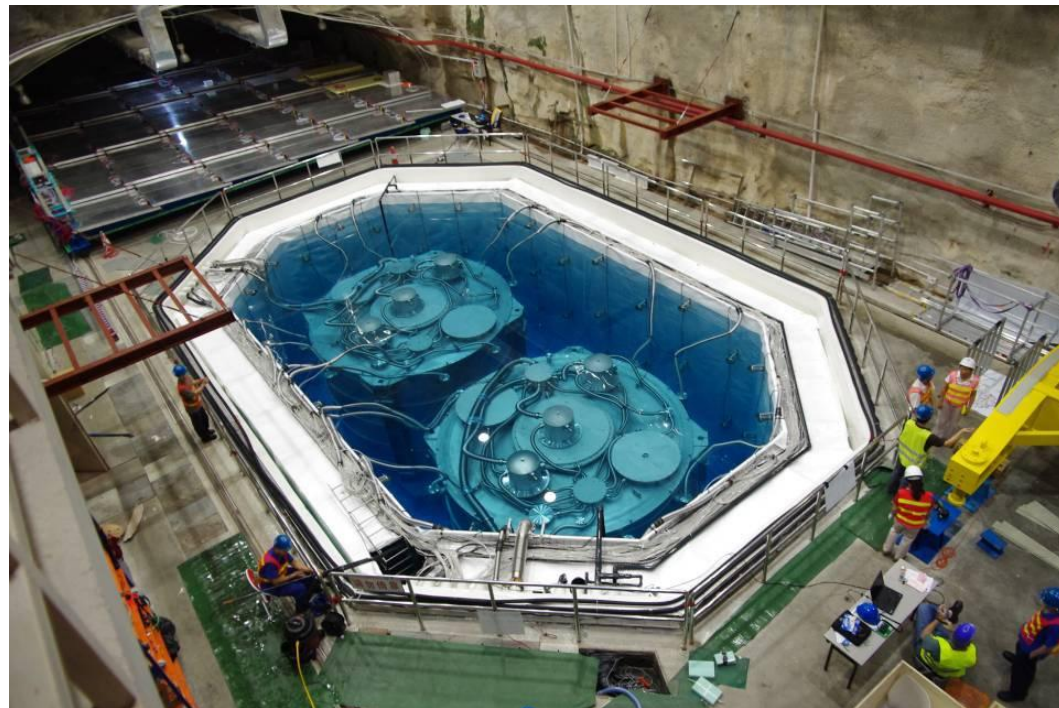
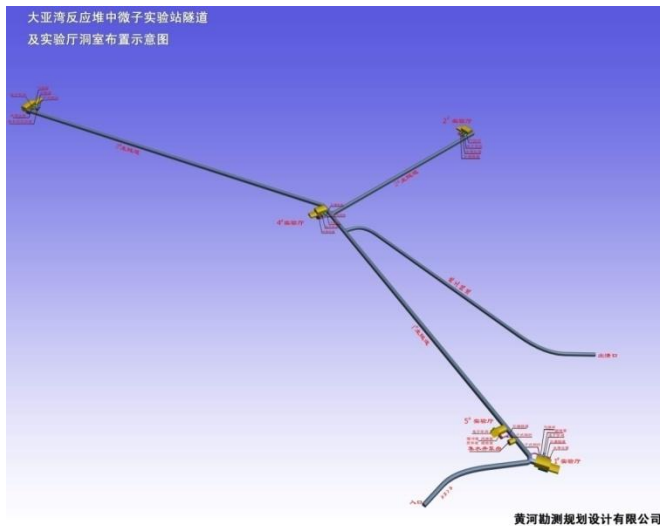
1. Introduction

---- Dayabay neutrino experiment

- The Daya Bay Neutrino experiment is a physical experiment, which is carrying out in GuangDong, China, is also the largest international cooperation project in basic science field at present in China.
- Dayabay neutrino experiment is a neutrino oscillation experiment by detecting neutrinos produced in nuclear reactors of dayabay nuclear station. There are 8 neutrino detectors in the tunnel.

1. Introduction

---- Dayabay neutrino experiment



neutrino detectors



1. Introduction

----Alignment Measurement

- Distance from neutrino detectors to Daya bay reactors is essential in physics analysis in this experiment.
- Our purpose is to measure the 3D distance from 8 neutrino detectors and to 6 Daya bay reactor cores. As the picture shown, 6 Nuclear reactors are located in nuclear power station, and 8 neutrino detectors are located underground in the northwest of Dayabay nuclear power station.



Geographical location of nuclear reactors and neutrino detectors

2. Measurement scheme

---- Measurement instruments

4 kinds of instruments are investigated in this measurement:

GPS

total station

level equipment

laser tracker



laser tracker



total station



GPS

2. Measurement scheme

-- layout of control points

In order to make connection of the reactor cores and detector centers, two types of control points are laid out.

- One is the new buried monuments in this measurement process, as shown in fig (a), which are mainly distributed in the tunnel region and the two entrances area of the tunnel .
- The other is the forced observation pillars already existed in nuclear power station construction, which are mainly distributed in nuclear power station region, as shown in fig (b).



fig (a)

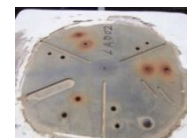
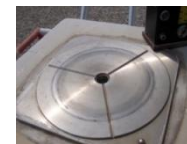


fig (b)

2. Measurement scheme

--how measurement area divides

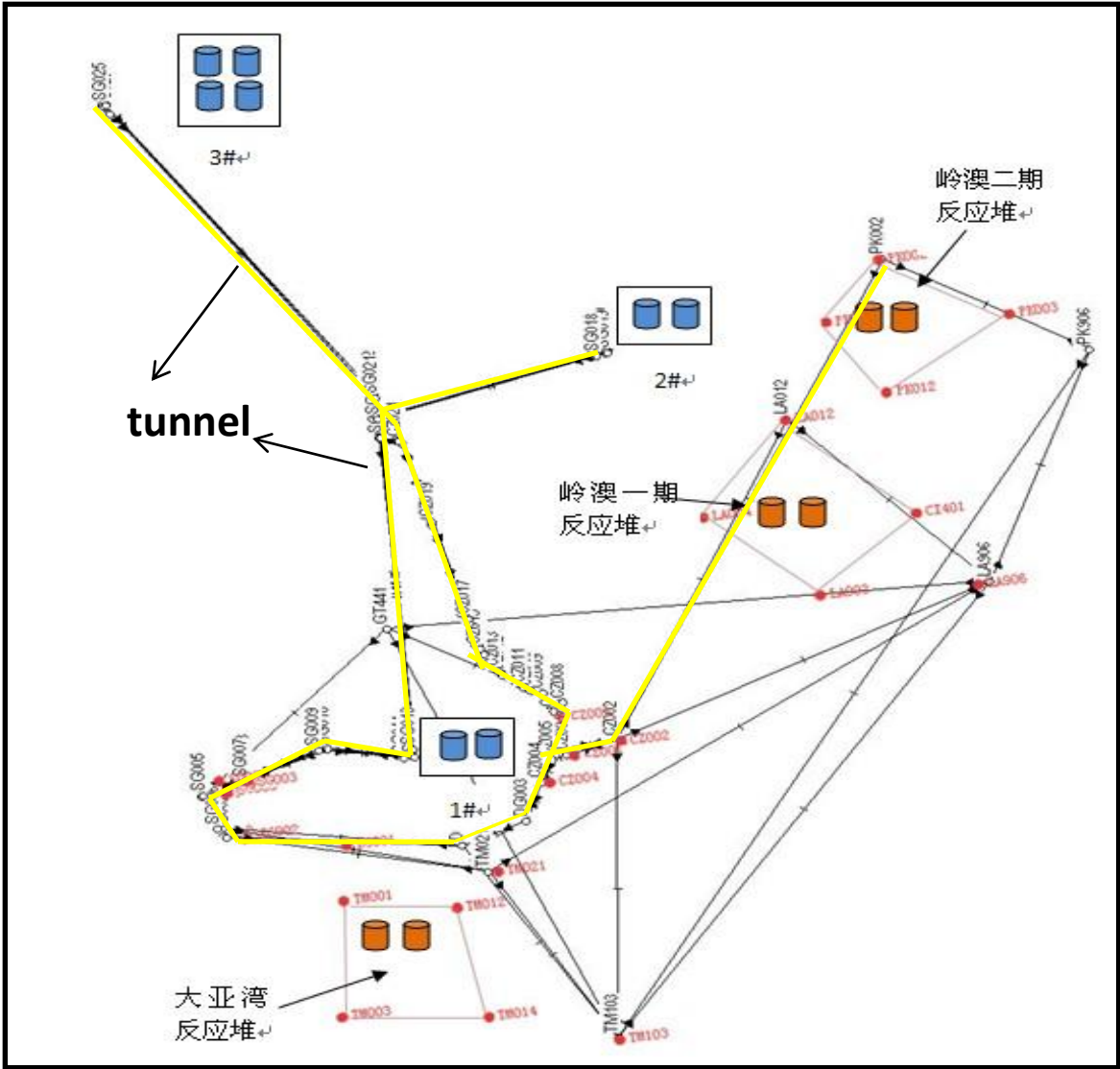
The whole measurement area divides into three parts :

(1) nuclear power station region : GPS survey is carried out in this region, where direct intervisibility is severely cut off by barbed wires.

(2) in the tunnel : GPS signal can't reach this area, so we use total station and level in this area ,in some part laser tracker is also used.

(3) in the tunnel entrance area : Both GPS and total station survey are carried out.

2. Measurement scheme





- **GPS survey**
 - **total station survey**
 - **leveling**
-
-  **neutrino detectors**
 -  **reactors**

Fig. Sketch map of measurement scheme

2. Measurement scheme

--GPS survey experiment

- Many measuring control points are under high voltage wire .So GPS survey experiment under the high voltage wire is carried out to research the influence of high voltage wire to GPS survey.



GPS survey experiment under the high voltage wire

2. Measurement scheme

--GPS survey experiment

- There are some compared baselines measured by both GPS receivers and total-stations under the high voltage wire as well as others (launch tower, near building) ,as table 2 shown.
- Small difference has been discovered after comparison between both method.
- The GPS survey experiment under the high voltage wire (220 KV) has shown that it could be feasible .We can ignore the influence to GPS from high voltage wire.

Table.2 The difference results of this experiments (unit: m)

the slant computed by total-station observation	The slant computed by GPS observation	The difference	The observation environment
118.48645	118.49089	-0.004440	5-m away from 20-m-high Building, almost 15 sec
111.31130	111.30852	0.002780	
190.21070	190.21168	0.000978	Under the high voltage wire (220kv)
489.40263	489.40396	0.001335	
1126.21963	1126.21668	-0.002954	The longest baseline in the GPS control network
1216.59313	1216.58782	-0.005310	

2. Measurement scheme

--GPS Survey outside the tunnel

- 4 GPS receivers are applied in this survey, Topcon and Sokkia.
- Every tunnel entrance and reactor core has 4 GPS control points, and other extra control points are only used to coordinate conversion .
- The 4-hour observations have been done at tunnel entrance, as well as reactor cores. Then the others is totally 4-hours.

GPS network technology index

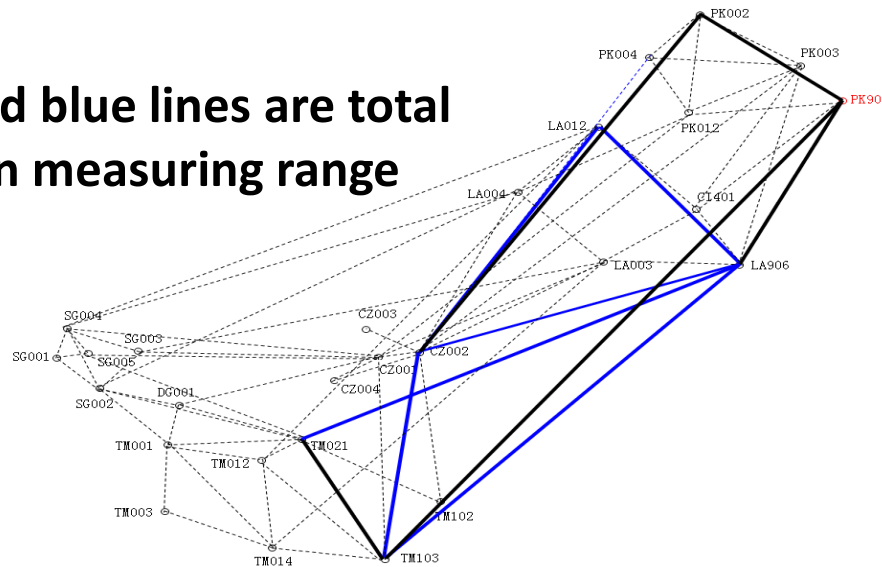
	technology index
Satellite cutoff elevation angle	15°
Effective satellite number in Synchronous observations	≥4
Numbers of_observation time	≥2
Sampling interval	10"
Observation time	3 hours

2. Measurement scheme

--Survey with Total Station outside the tunnel

- We can obtain measuring point coordinates on WGS84 by GPS measurement. WGS84 is World Coordinate System, while the total station coordinate system on level surface for used in the tunnel is independent Coordinate System from WGS84.
- Total station measurement is carried out on some of the control points outside the tunnel for coordinate conversion.

Black and blue lines are total station measuring range



Measuring range outside the tunnel

2. Measurement scheme

--Measurement in the tunnel

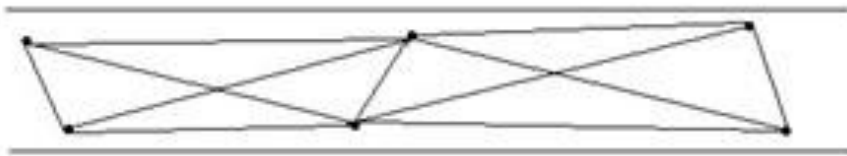
In the tunnel, where GPS signal can not reach, we use total station to carry out horizontal and vertical survey .

- horizontal: double traverse survey method**
- vertical: trigonometric leveling method, and Leveling is also carried out in the tunnel to verify the accuracy of trigonometric leveling .**

2. Measurement scheme

--Traverse survey with Total Station

- Double traverse survey with total station is carried out in the tunnel.
- 2 Leica TDA5005 total station were used. Four survey times for each station were performed in face left and right.
- In addition, the traverse is closed in two different ways from one entrance to the other, one is through the mountain top, another is through the road outside of tunnel.



Double traverse network



Traverse closure of the two entrances

2. Measurement scheme

--Trigonometric leveling with Total Station

- 2 Leica TDA5005 total station were used. Four survey times for each station were performed in face left and right.
- Reciprocal observation method is used in trigonometric leveling. When one direction observation finished, the other direction observation starts quickly. The time of reciprocal observations is short, and atmospheric environment change is insignificant, so it could offset much of the effect of earth curvature and refraction in an average of the reciprocal observations.



2. Measurement scheme

--Design of Standard bar

- In trigonometric leveling, Instrument height is usually measured by measuring tape, accuracy of which is better than 1 mm.
- To improve the accuracy, a standard bar is designed, of which the reading error is 0.02mm, repeatability better than 0.1mm and accuracy better than 0.3mm, as shown in fig .



Standard bar

2. Measurement scheme

--Leveling

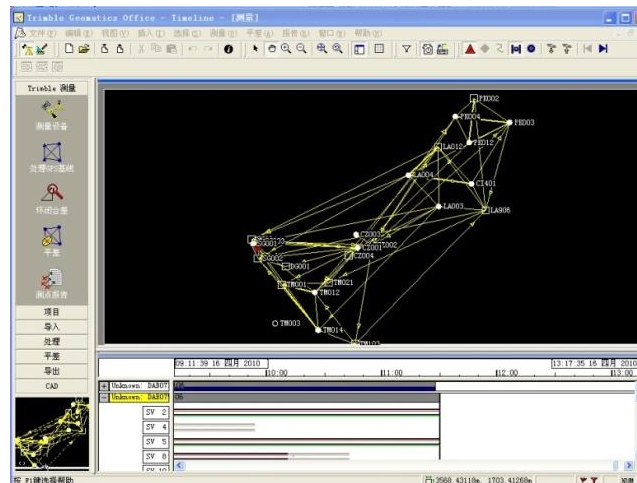
- Leveling is also carried out in the tunnel to verify accuracy of trigonometric leveling . It turns out that precise trigonometric leveling survey can replace the second order leveling .
- Leica NA2 leveling was used.



3. Data processing and precision analysis

----GPS baseline calculation

- The collected observations were processed using the software Trimble Geomatics Office.
- According to observation environment and satellite status, changing satellite altitude angles, cutting satellite tracking and selecting solution error model are carried out in Baseline Calculation.
- GPS survey base line outside the tunnel as fig shown.



GPS survey base line

3 . Data processing and precision analysis

-----GPS adjustment

unrestrained adjustment: decides the geometry of GPS control network

constraint adjustment: The known data should be introduced

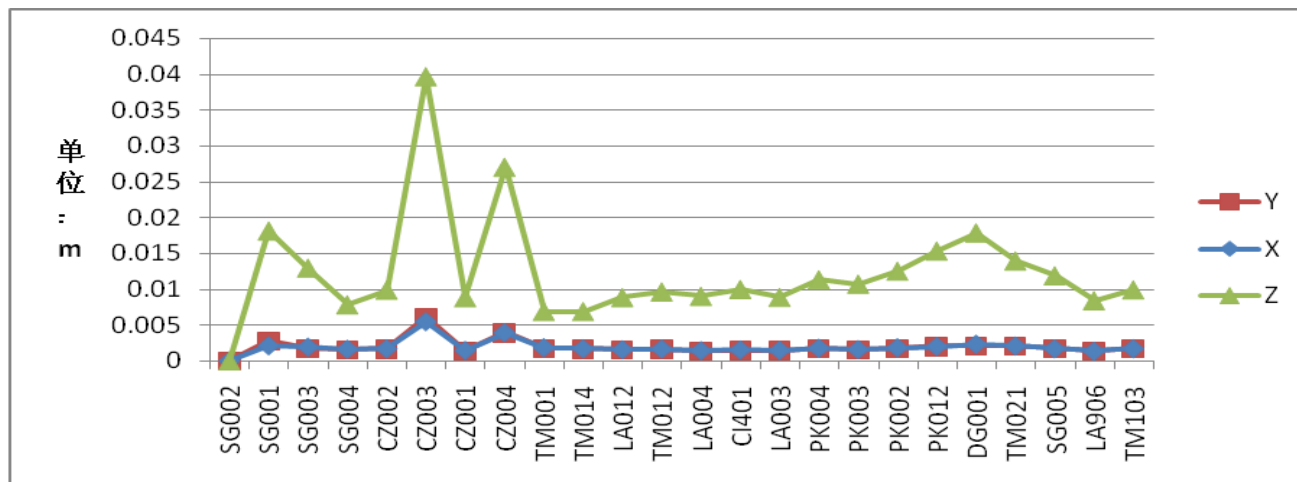
Unit: mm	B	L	H
The best	0.68	0.66	0.343
The poorest	2.03	2.3	18.23
average	0.99	0.99	6.93
Standard deviation	1.05	1.06	7.75

The statistical results for adjustment in the WGS 84

3. Data processing and precision analysis

---GPS precision analysis

This figure depicts all adjustment residuals on north(X), east(Y) and height(Z). Average positional precision of GPS network is 12.6mm.



GPS network adjustment residual

3. Data processing and precision analysis

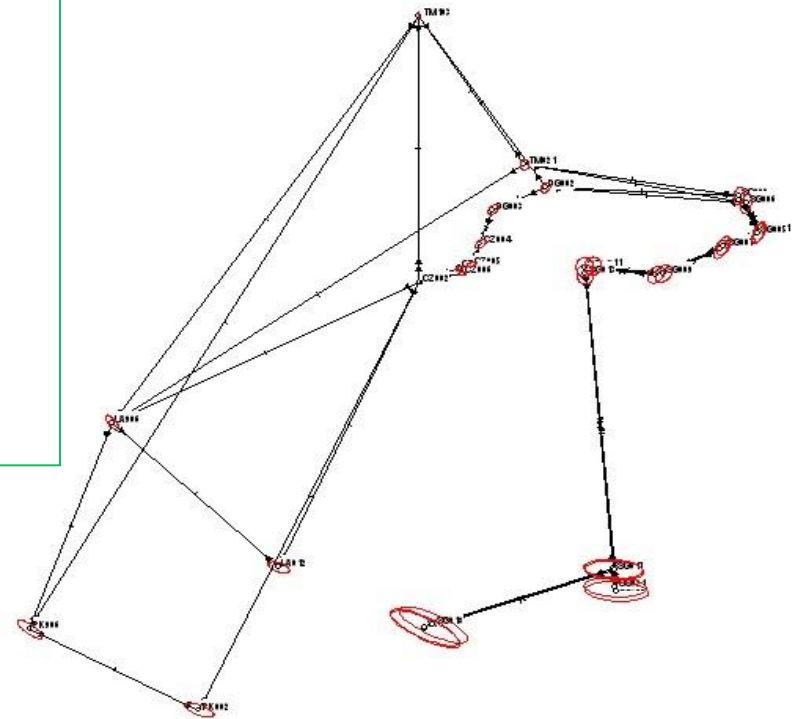
----horizontal survey data of total station

Horizontal survey data adjustment

- detection of outliers
- adjustment
 - input :horizontal angle and horizontal distance
 - software: MAA
 - COSA
 - SURVEY

Unit: mm	error
The best	1.1
The poorest	9.9
average	3.9

error in point measurement



error ellipse distribution

3. Data processing and precision analysis

----Height survey data of total station

**Vertical survey data adjustment
input : altitude difference
software: ShanWei**

**Geometric leveling is also
carried out in the tunnel, the
difference between total station
trigonometric leveling and
geometric leveling is given as
shown. The difference is small.**

Unit: mm	error
The best	1.56
The poorest	4.16
average	3.4

error in point measurement

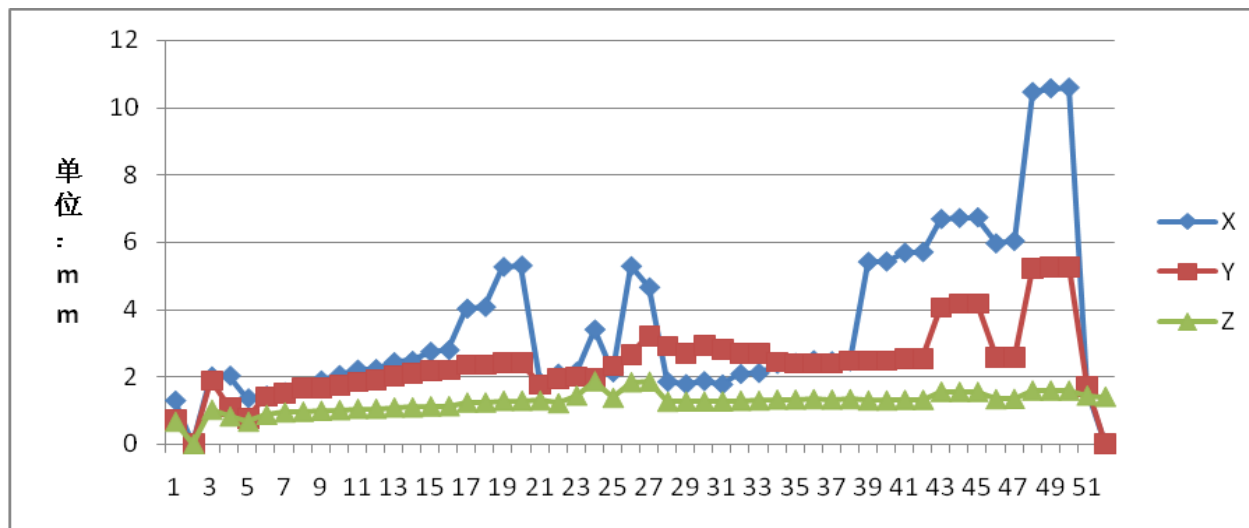
Unit: mm	difference
The best	0.03
The poorest	1.62
average	0.6

Difference between geometric
leveling and trigonometric leveling

3. Data processing and precision analysis

----Precision analysis of Total station survey

- This Figure depicts all adjustment residuals on horizontal(X, Y) and vertical (Z) of total station network. Average positional precision of total station network is 6.5mm.



Total station network adjustment residual

3. Data processing and precision analysis

----The overall precision of the distance

- Precision of GPS network(12.6mm) and total station network(6.5mm) in the distance measurement are introduced above. Besides, considering both the error of reactor cores to control points in nuclear power station and the measuring error of laser tracker , the overall precision of the distance is about 18 mm.

4. Conclusions

- 1. The overall precision of the distance from nuclear cores to neutrino detectors is about 18 mm in the range of 4 kilometers.**
- 2. The trigonometric leveling leveling survey can replace the second order leveling.**
- 3. The GPS coordinate in WGS84 could be transferred on to the Geoid trigonometric leveling.**

Thank you !