Current design of Veto PMT placement

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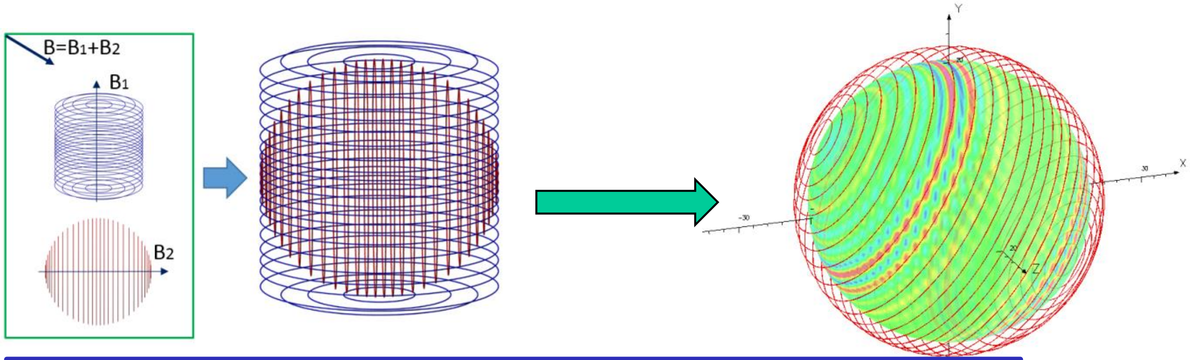
2018-04-06

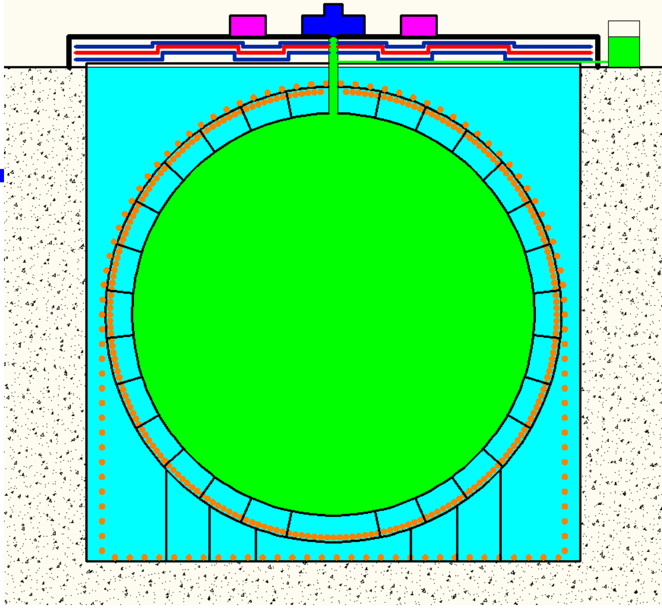
The 2nd EMF workshop, Bangkok, Thailand

Outline

- Compensation coils
- PMT position optimization
- Summary

Earth magnetic field shielding coils

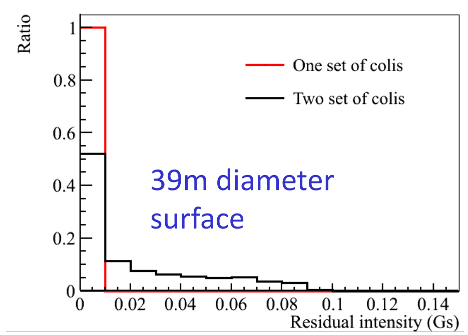


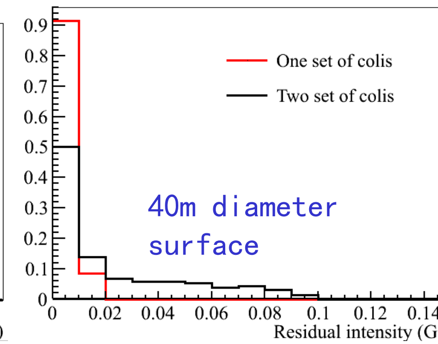


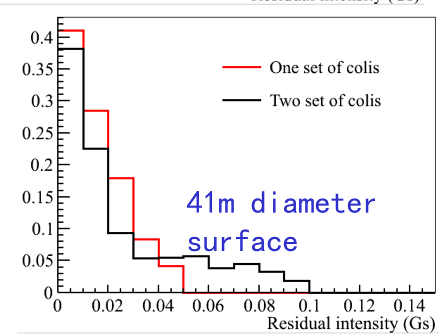
- **Consideration of compensation coils：**
  - At early time, we use one sets of coils.It's too hard to installation for that time(The coils are not allowed support by stainless steel(SS) frame). We change one sets of coils to two sets of coils.
  - Now, our suggestion is to return back to one sets of coils.
- One sets of coils vs. two sets of coils：
  - Installation： there are no big difference between one sets or two sets coils(we can have support structure on SS frame)
  - Coils and installation work quantity reduce ~50%;save cost；
  - One sets of coils performance are better than two sets's as right figure shown.
  - The coils direction should be accurate in installation.

Resident intensity on different diameter surface）

39m-40m diameter



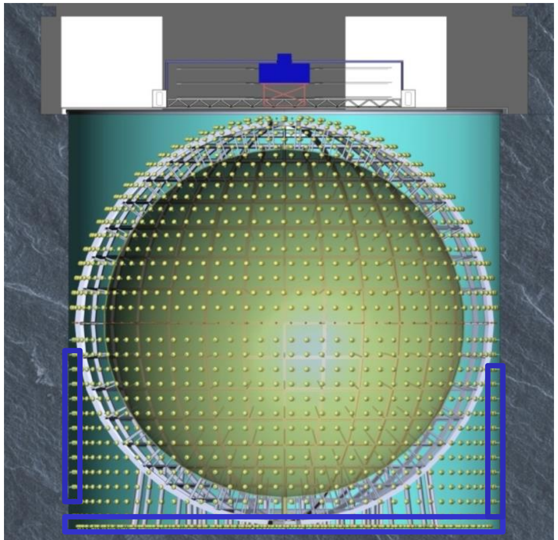




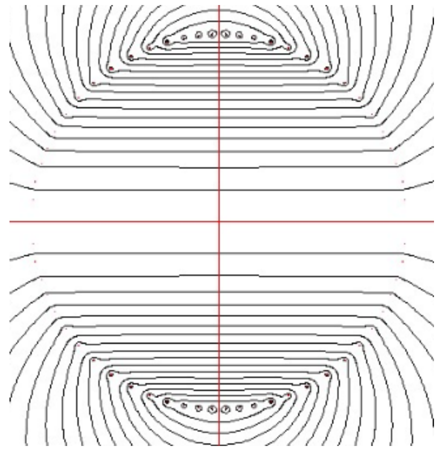
41m diameter surface is the veto PMT region

Two sets of coils

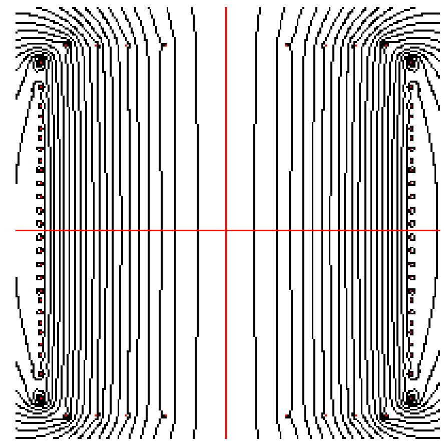
- The coils can have good shielding in central detector region.
- The bottom veto PMT region is too close to the coils with large residual intensity.

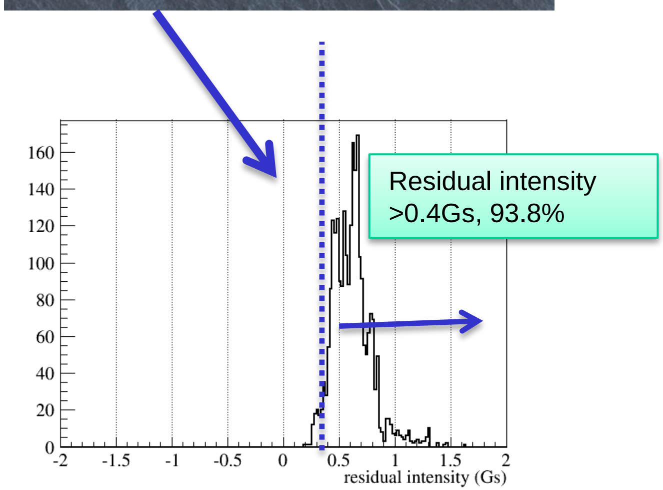


Horizontal magnetic field B_2



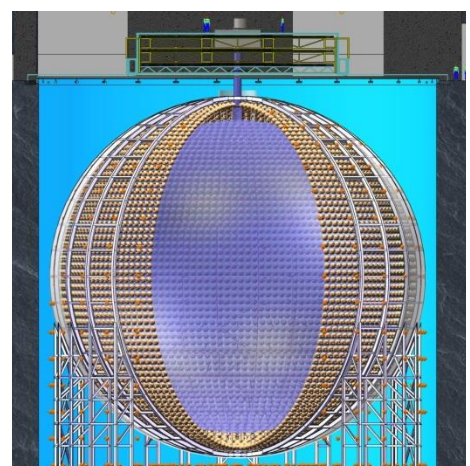
Vertical magnetic field B_1



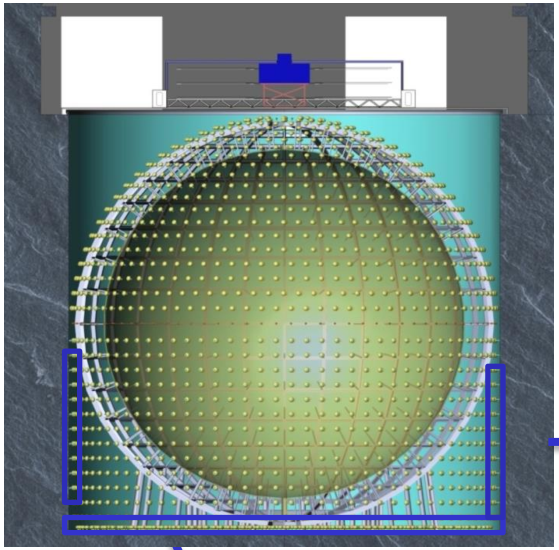


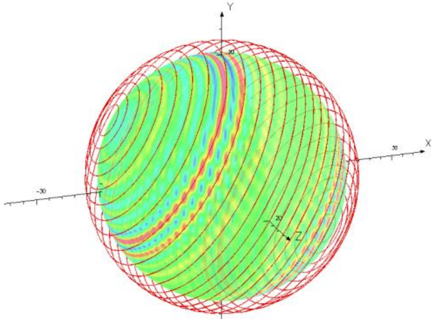
- We need to move some veto PMTs far from coils .

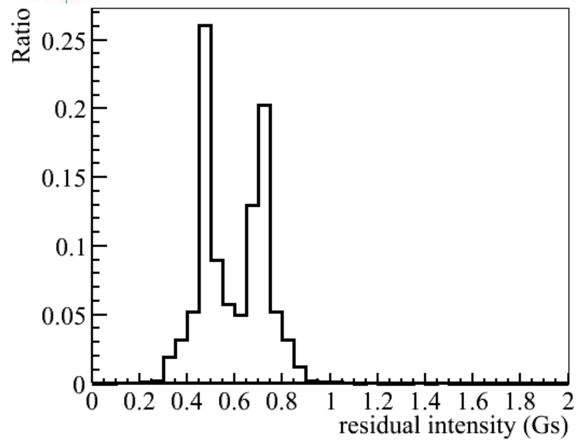
DocDB1468−v12



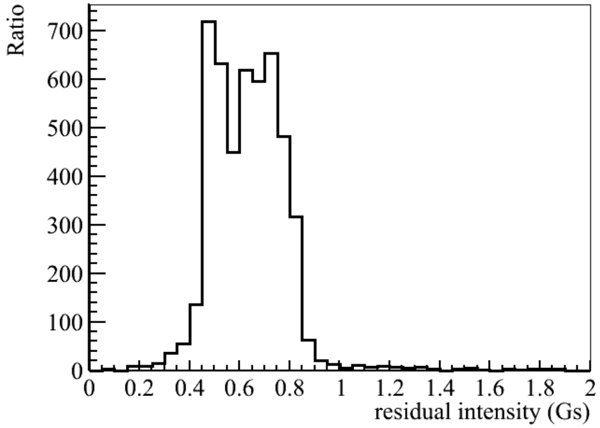
One sets of coils







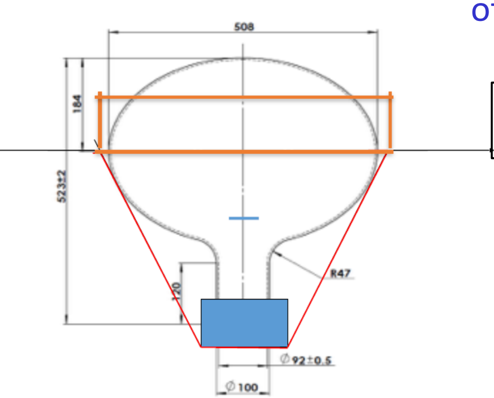
Residual intensity of region(PMT close to the pool wall)



Residual intensity of bottom veto PMT region

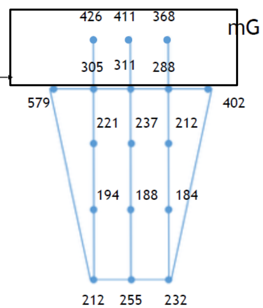
Shielding material performance

DocDB2178

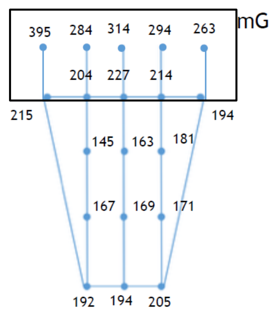


big size

Residual intensity in different position of the shielding material.



big size
3layers

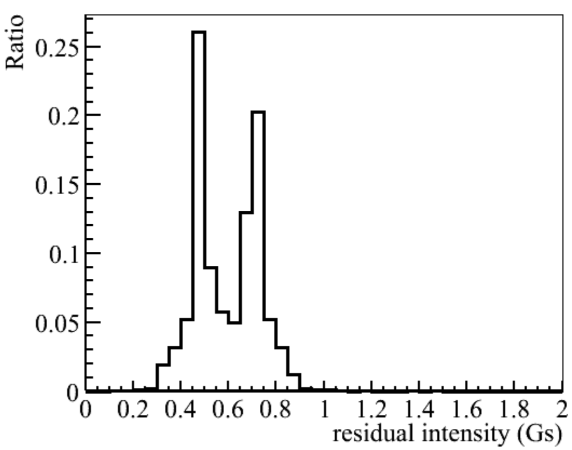


big size
3layers +bent

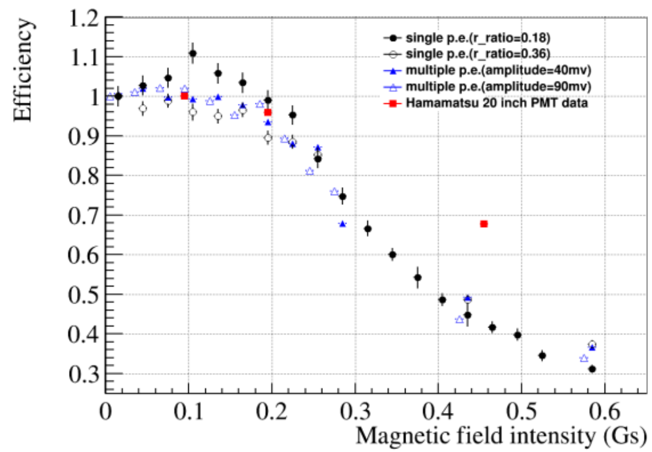
geomagnetic field intensity = 500mG
PMT is at 90° with the geomagnetic field

- Based on measurement, the magnetic shielding decrease 20-50% after using shielding material.
- If the intensity is 0.5-0.8Gs and assumed 20-50% decrease after shielding , the residual intensity is 0.3-0.6Gs.
- The veto PMT efficiency loss can reach 30-70%。

Veto PMT region magnetic intensity



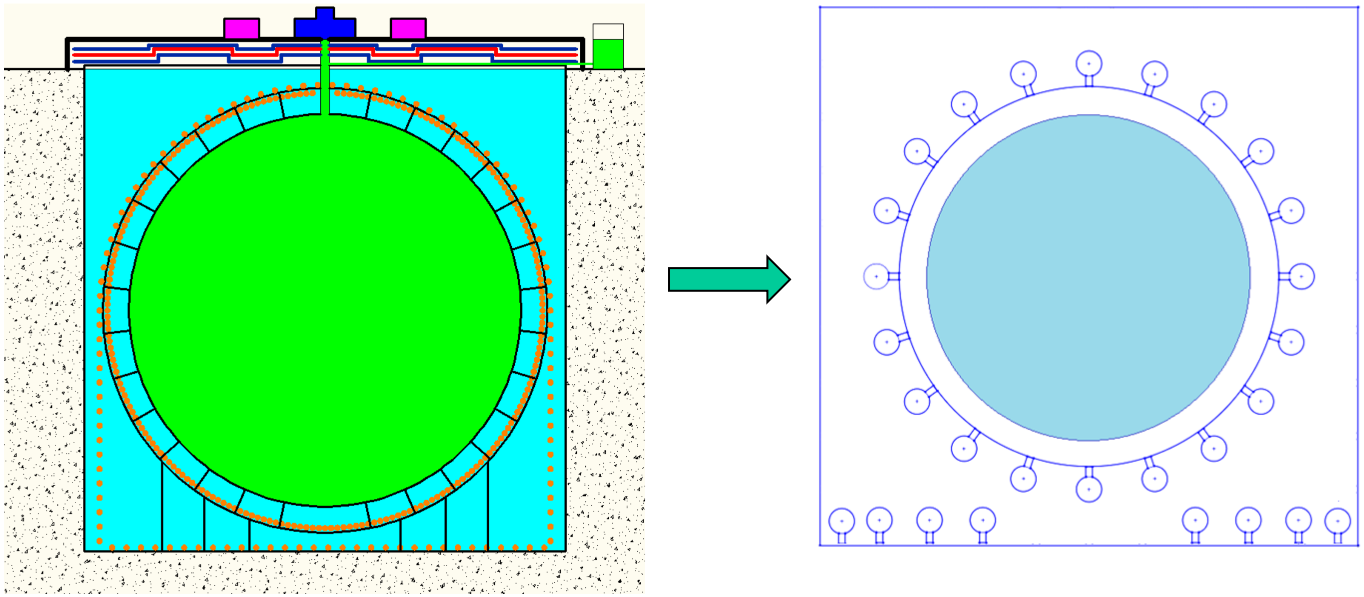
PMT efficiency vs magnetic intensity



Veto PMT optimization

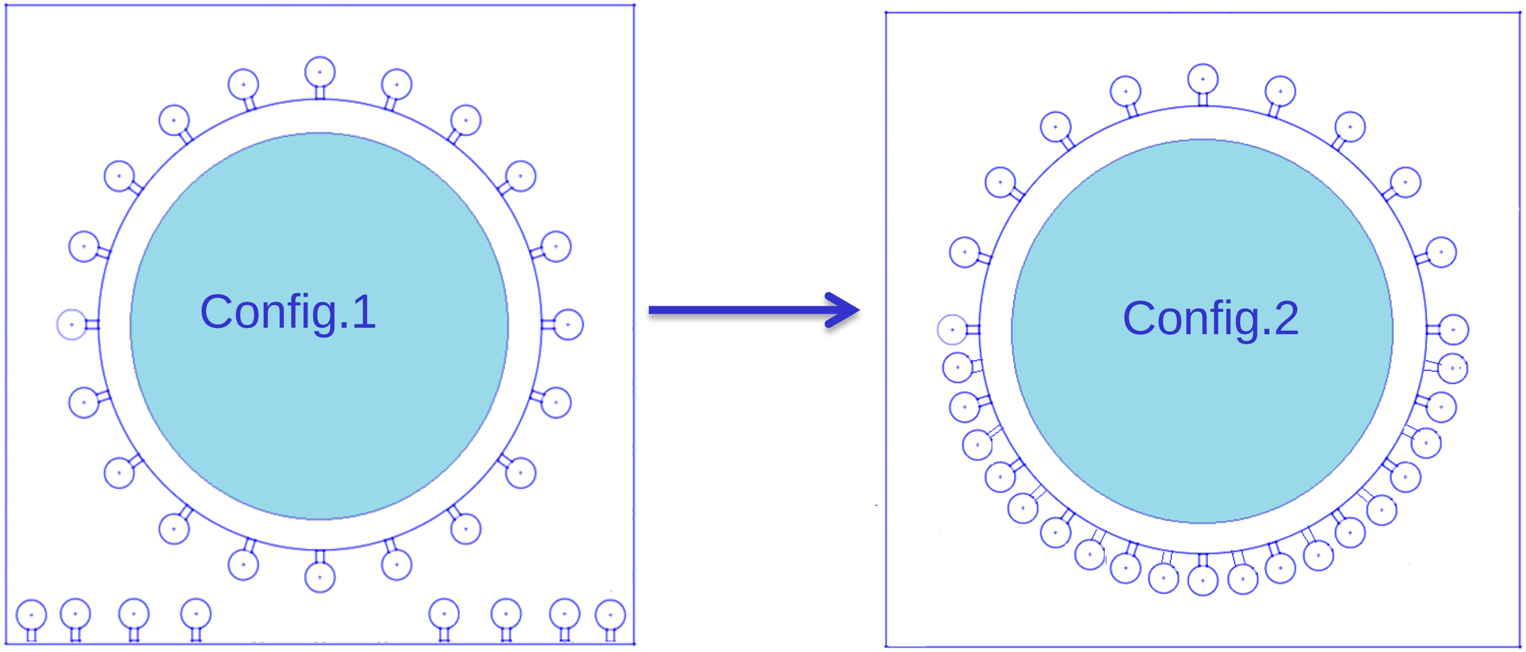
DocDB2878

- Earth magnetic field shielding coils
  - 2 Sets of coils->1 Sets of colis
    - Installation： No big difference between 1 and 2 sets(There are support structure on the stainless steel frame)
    - Cost reduced ~50%; installation work reduced ~50%.
    - One sets of Coils shielding is better.
  - Baseline design:
    - move some veto PMTs to the SS frame.
    - There are no PMT at bottom center(high intensity field region)。

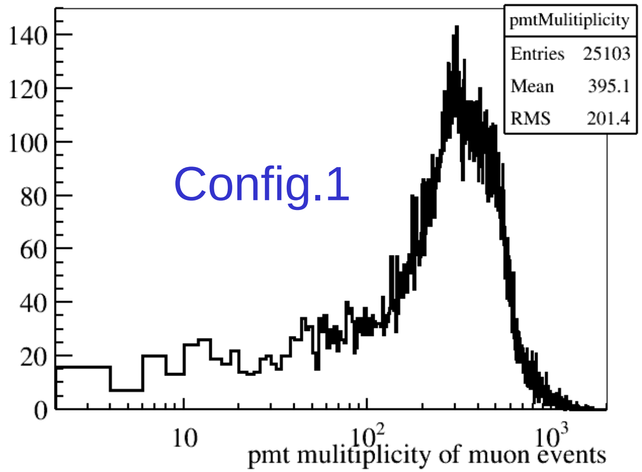


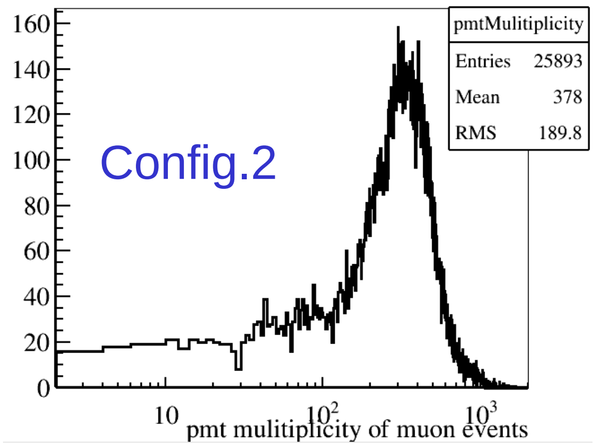
Veto PMT optimization

- **DocDB2953:**
  - **After consideration the shielding material and resident magnetic intensity(PMT magnetic shielding(Doc2084)), we intend to move all the bottom to the SS frame to reduce the magnetic field influence.**



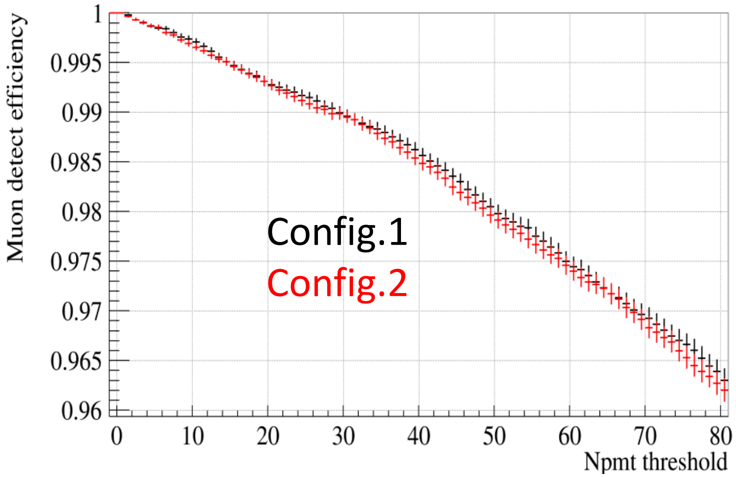
Muon detection efficiency





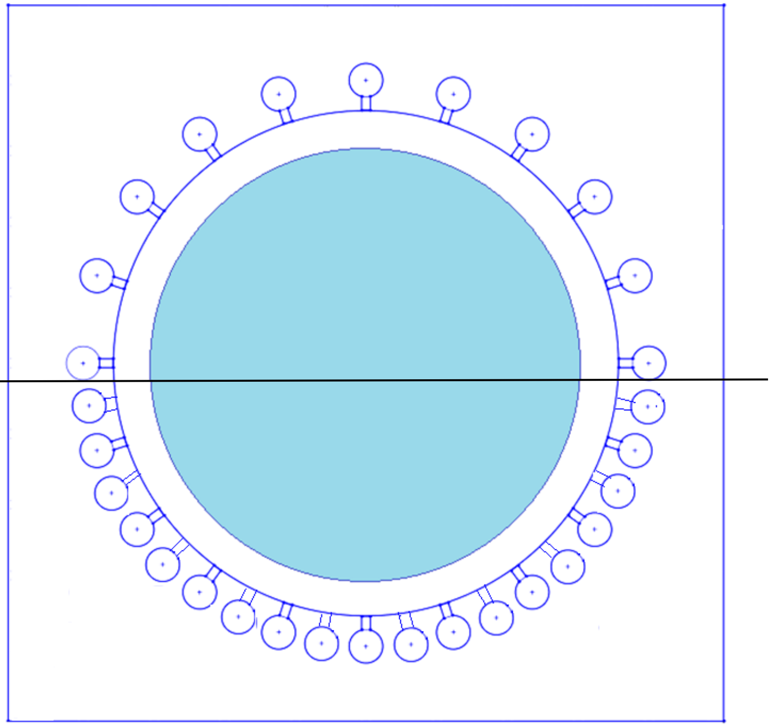
- Assumed PMT noise coincidence in 200ns,PMT dark noise 50kHz ,veto window 1ms for future analysis and we can afford the 1% dead time from noise coincidence. The coincidence rate should <10Hz. nPMT =54.

	Cut nPMT=54
Config.1	(97.81+/-0.09)%
Config.2	(97.72+/-0.09)%



- The efficiency difference is very small~0.1%.
- We prefer config.2, mover all the bottom PMT to ball surface.

Upper half sphere and lower half sphere comparison

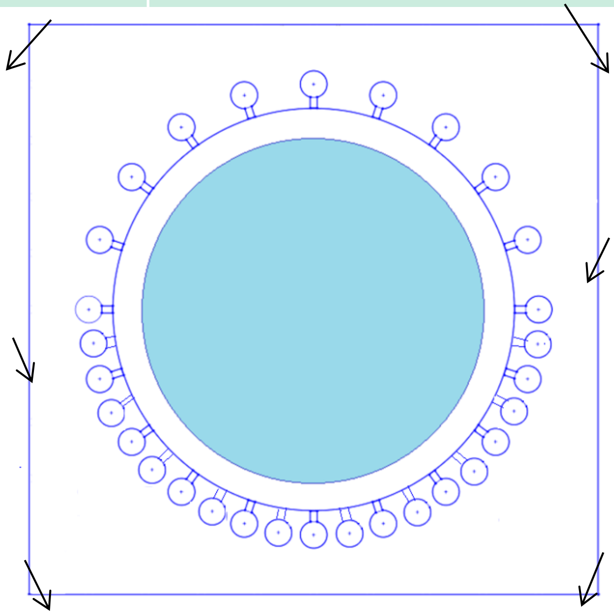


- **Muon detection ability**
- The lower half shpere PMTs fired PMT ability is better than upper's.

	p.e./PMT/muon	Fired N/PMT/muon	p.e. difference （p.e./PMT/muon） （Top-Bottom)/Bottom	Fired number difference （firedN/PMT/muon） （Top-Bottom)/Bottom
Upper half sphere PMT	0.816	0.147	40%	-8.7%
Lower half sphere PMT	0.582	0.161		

Untagged corner clipping muons

	Upper half sphere PMT	Lower half sphere PMT
Untagged Muon	1.16%	0.59%

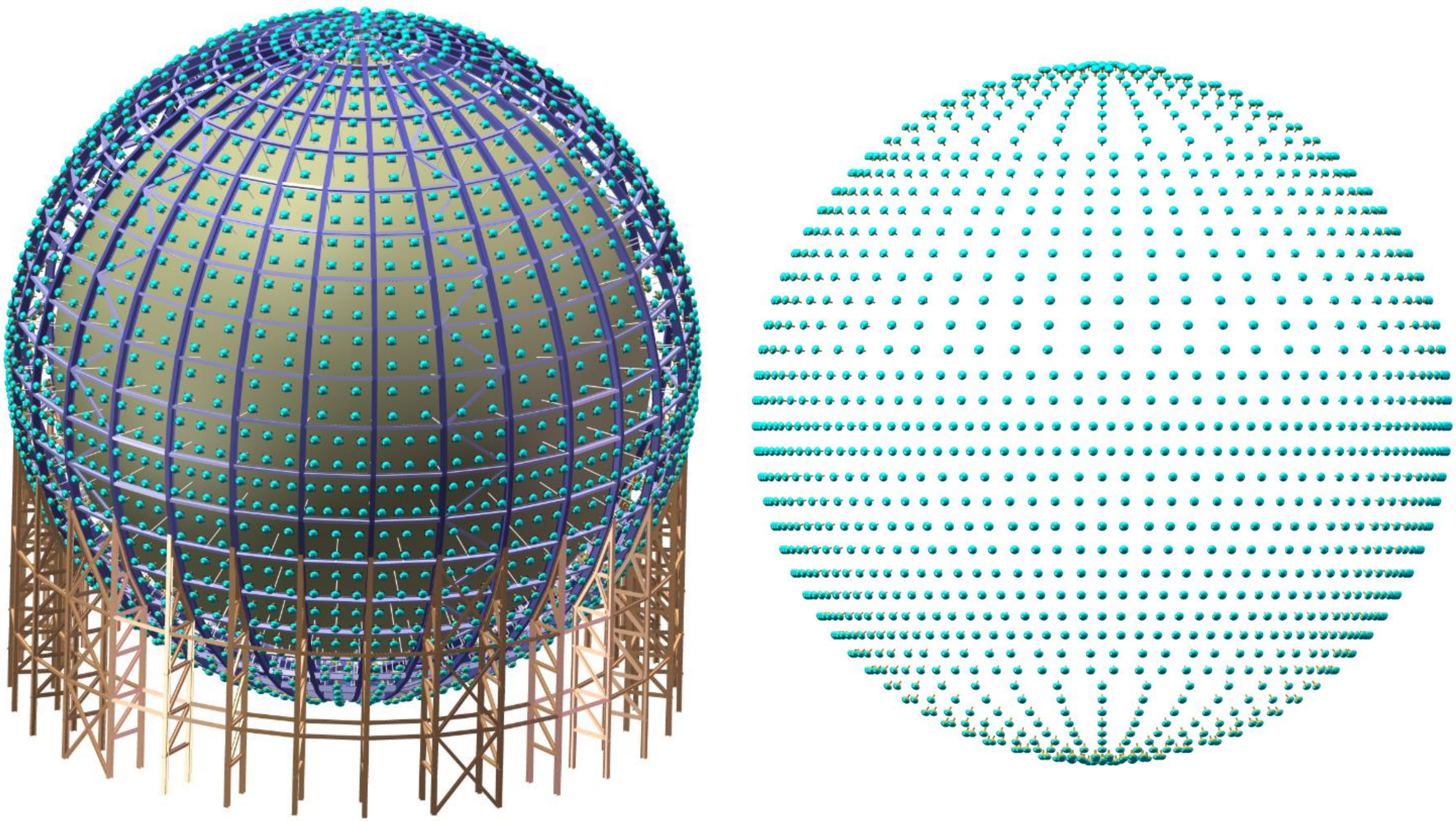


When WC untagged muon going through central detector, it could be tagged by central detector.
The corner clipping muon is far from central detector.
Fast neutron contribution can be neglect.

Include the TT muon detection ability

	Upper half sphere PMT	Lower half sphere PMT
Untagged Muon	0.6%	0.59%

Veto PMT placement(new)



Summary

- Based on current installation strategy, we intend to use the one set of coils system.
  - One sets of coils performance is better than two sets of coils.
  - Reduce the cost and quantity installation work .
- Veto PMT optimization
  - Based on current consideration(coils and shielding material measurement), we intend to move the bottom veto PMT to the stainless steel frame.
- Untagged muon
  - Mainly corner clipping events and far from the central detector, the fast neutron background contribution is small.
  - Combine with TT, the top and bottom untagged muon event ratio is roughly same.

Earth magnetic field measurement on JUNO site

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2018-04-06

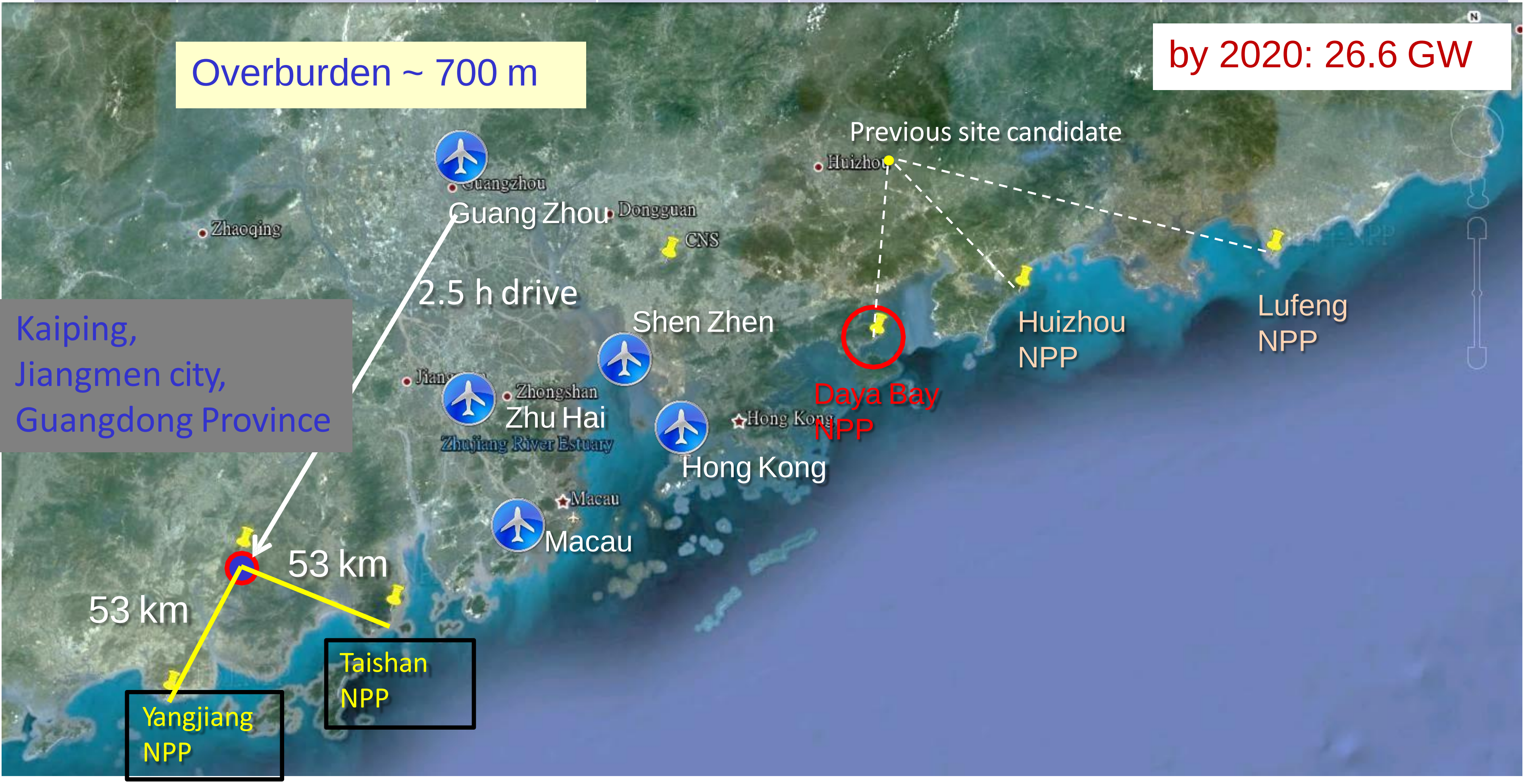
The 2nd EMF workshop, Bangkok, Thailand

Motivation

- **Earth magnetic field(EMF) measurement on JUNO site**
  - Determine the earth magnetic field(EMF) direction
    - It can help us to determine the compensation coils direction and provide the accurate information for detector installation.
  - Now, we can go underground which is not far from the experiment hall to do measurement.

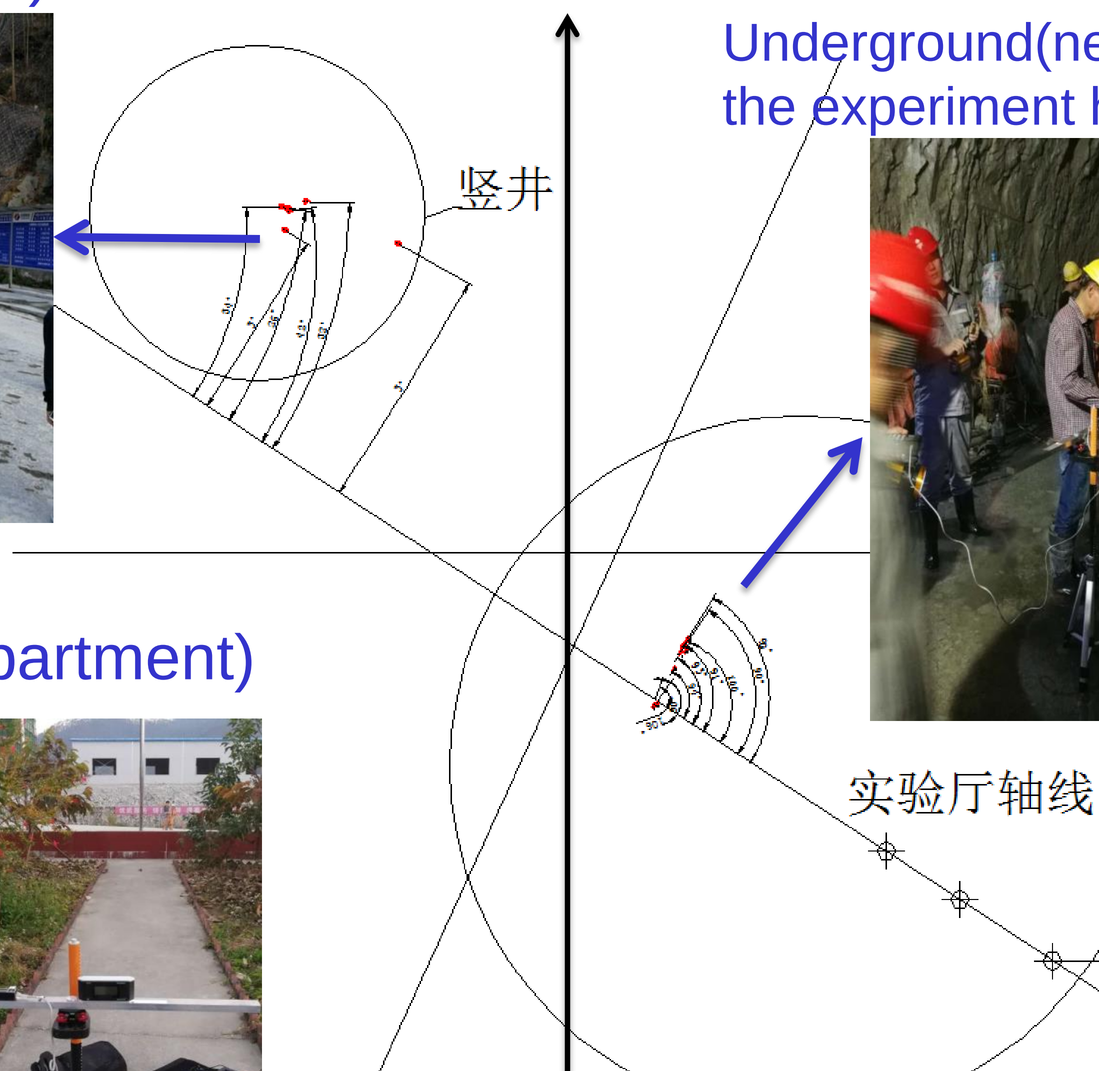
Location of JUNO

NPP	Daya Bay	Huizhou	Lufeng	Yangjiang	Taishan
Status	Operational	Planned	Planned	Under construction	Under construction



JUNO site

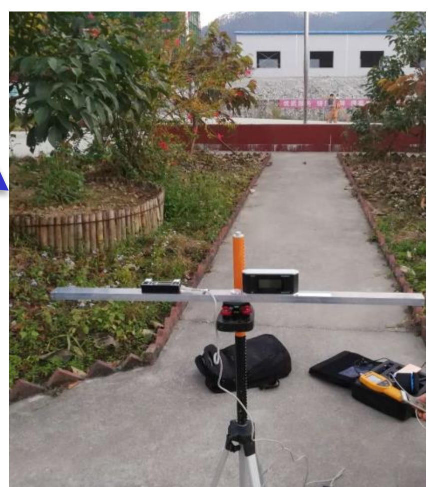
Ground(drilled shaft)



Underground(nearest place the experiment hall~70m)

Ground(project department)

项目部



Measurement design and error estimation

Support bars

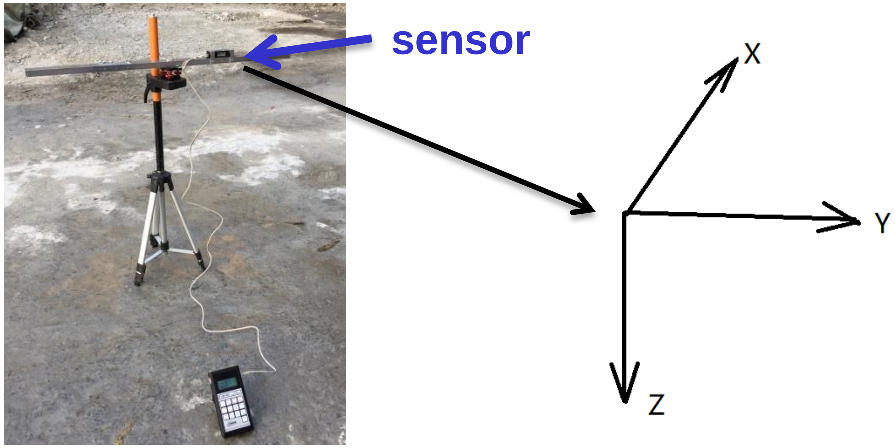
- Level measurement

FVM-400手持式矢量磁通门计
FVM-400 Handheld Vector Fluxgate Magnetometer

Probe Size:
25.4 mm W x 25.4 mm H x 100.6 mm L (1"W x 1"H x 4"L).
Electronics Case:
100 mm W x 44 mm H x 193mm L (3.94"W x 1.73"H x 7.60"L).
Probe To Electronics Cable Length:
Seven feet standard. Other lengths are possible up to a maximum length of one hundred feet.

Electronic Total Station

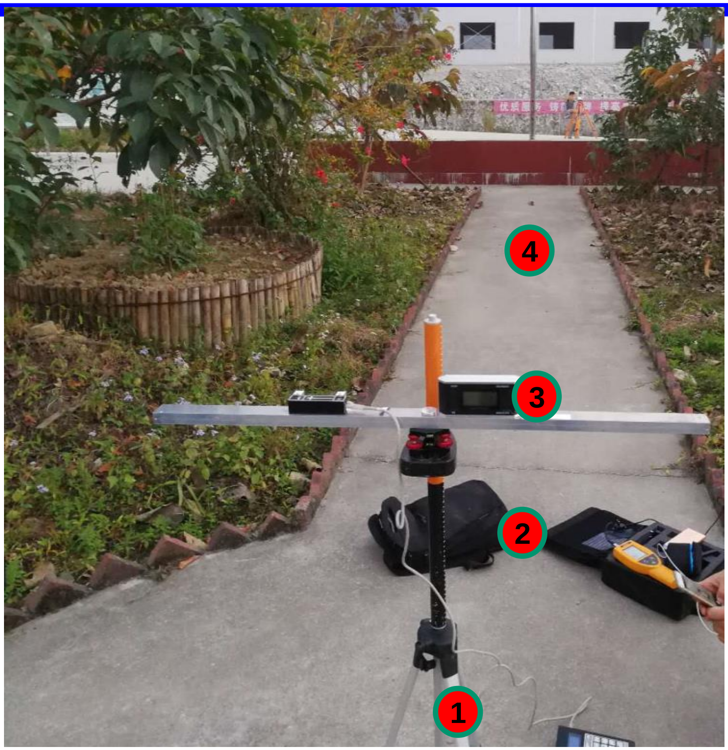
Systematic error estimation

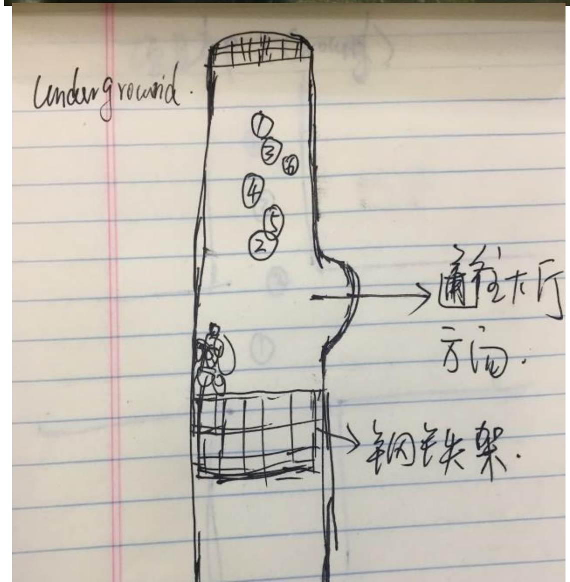


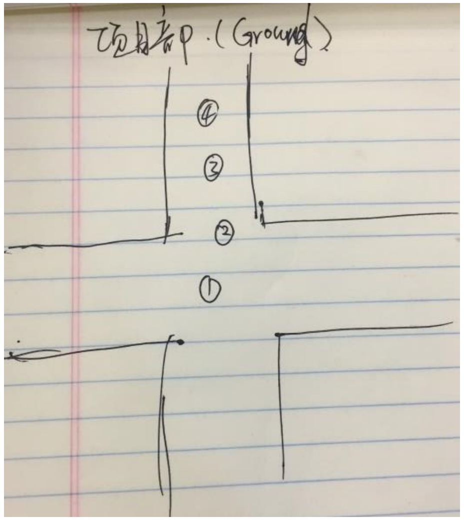
X-Y plane(Declination) error		
error	Deg	
magnetometer	0.1	From data sheet
Support bar direction (by Electronic Total Station)	0.4	The direction error is determined by the laser spot dimension. ~6mm@1meter support bar measurement.
Total	0.5	

Inclination error		
error	Deg	
magnetometer	0.1	From data sheet
Level measurement	0.2	
Support bar deformation	<0.2	<2mm at 1 meter length
total	0.3	

Measurement







Measurement data

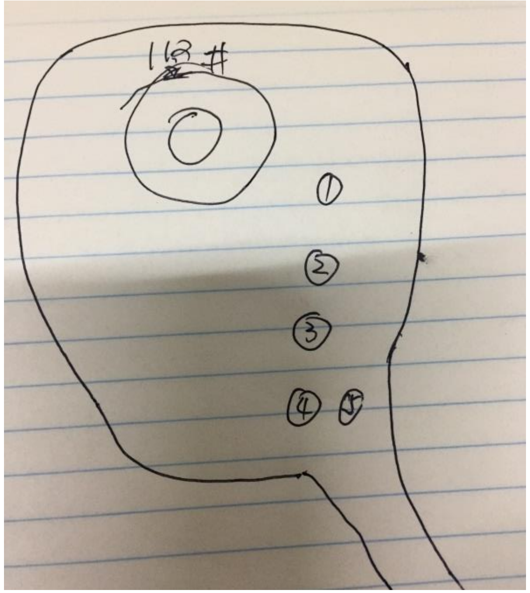
Underground(nearest place to the experiment hall~70m)

	斜井底部，1月18号上午		斜井底部，1月18号下午			
uT	1	2	3	4	5	6
Bx	31.679	30.626	31.529	32.256	32.378	34.382
By	-20.869	-22.172	-21.032	-20.018	-19.423	-16.06
Bz	24.587	24.606	24.63	24.509	24.741	24.687
Bxy	37.935	37.809	37.900	37.963	37.757	37.948
Bsum	45.206	45.111	45.200	45.187	45.141	45.271
平x偏角°	0	0	0	0.3	0	0
平y偏角°	0.35	0.35	0	0	0	0
x与东西方向夹角	58.672	56.47	58.163	60.19	60.63	66.919
B东(uT)	-1.355	-1.566	-1.236	-1.334	-1.047	-1.296
B北(uT)	37.911	37.777	37.880	37.939	37.742	37.926
B下(uT)	24.587	24.606	24.63	24.509	24.741	24.687
北偏西(deg)	2.047	2.373	1.869	2.014	1.589	1.957

Ground(project department)

	项目部，1月18号下午			
位置	中心	向路口1	向路口2	向路口3
uT	1	2	3	4
Bx	3.808	1.472	8.437	4.432
By	-37.557	-37.761	-36.555	-37.475
Bz	24.927	24.831	24.89	24.769
Bxy	37.750	37.790	37.516	37.736
Bsum	45.237	45.218	45.022	45.139
水平x偏角°	0	0	0	0
水平y偏角°	0	0	0	0
Bx与东西方向夹角	8.772	5.311	15.737	9.674
B东(uT)	-1.964	-2.029	-1.794	-1.928
B北(uT)	37.698	37.735	37.473	37.687
B下(uT)	24.927	24.831	24.89	24.769
北偏西 (deg)	2.982	3.079	2.741	2.929

Ground(drilled shaft)



There is a huge wire netting around the mountain.

	地面竖井处，1月18日下午				
位置	地面靠近竖井	远离竖井1	远离竖井2	远离竖井3	远离竖井4
uT	1	2	3	4	5
Bx	-5.241	12.819	9.05	14.431	19.838
By	-31.046	-38.569	-37.863	-38.416	-38.118
Bz	23.784	24.204	23.915	23.828	24.109
Bxy	31.485	40.644	38.930	41.037	42.971
Bsum	39.459	47.305	45.688	47.453	49.272
水平x偏角°	0	0	0	0	0
水平y偏角°	0	0	0	0	0

Different positions intensity have large fluctuation. This is may effect by the huge wire netting. We'll not use this serial data to do analysis.

World Magnetic Model(WMM) calculation

Underground

Model Used:	WMM2015						
Latitude:	22.125° N						
Longitude:	112.508° E						
Elevation:	-410.0 m Mean Sea Level						
Date	Declination (+ E | - W)	Inclination (+ D | - U)	Horizontal Intensity	North Comp (+ N | - S)	East Comp (+ E | - W)	Vertical Comp (+ D | - U)	Total Field
2018-01-24	-2.5764°	33.1994°	37,936.9 nT	37,898.5 nT	-1,705.3 nT	24,824.7 nT	45,337.3 nT
Change/year	-0.0585° /yr	0.1474° /yr	-21.2 nT/yr	-22.9 nT/yr	-37.7 nT/yr	125.5 nT/yr	51.0 nT/yr
Uncertainty	0.28°	0.22°	133 nT	138 nT	89 nT	165 nT	152 nT

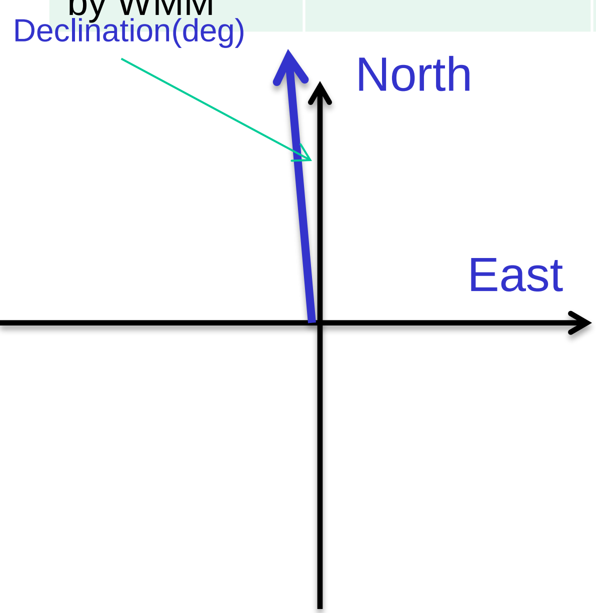
Ground

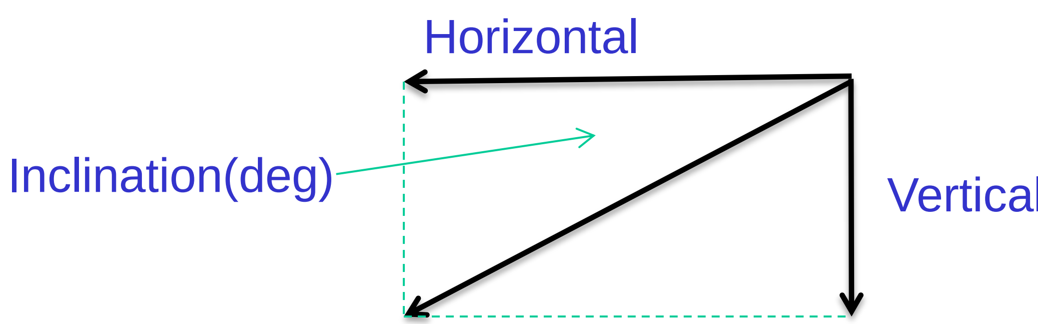
Model Used:	WMM2015						
Latitude:	22.125° N						
Longitude:	112.508° E						
Elevation:	70.0 m Mean Sea Level						
Date	Declination (+ E | - W)	Inclination (+ D | - U)	Horizontal Intensity	North Comp (+ N | - S)	East Comp (+ E | - W)	Vertical Comp (+ D | - U)	Total Field
2018-01-24	-2.5761°	33.1985°	37,927.4 nT	37,889.1 nT	-1,704.7 nT	24,817.6 nT	45,325.5 nT
Change/year	-0.0584° /yr	0.1473° /yr	-21.2 nT/yr	-22.9 nT/yr	-37.7 nT/yr	125.4 nT/yr	51.0 nT/yr
Uncertainty	0.28°	0.22°	133 nT	138 nT	89 nT	165 nT	152 nT

There are no big difference between underground and ground.

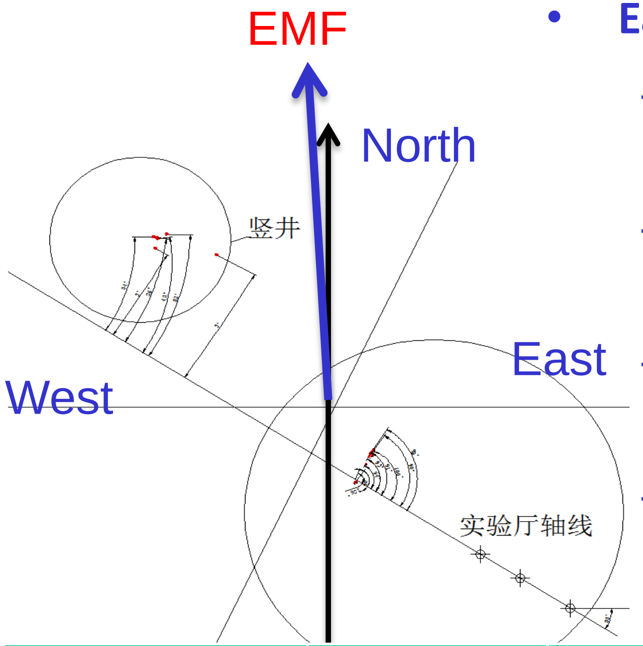
Results(I)

	Declination(deg) (+East|-West)	Inclination(deg) (+Down|+Up)	Horizontal intensity(uT)	Vertical intensity(uT)	Total intensity(uT)
Underground	-1.97±0.56	33.07±0.32	37.89±0.08	24.67±0.07	45.21±0.11
Ground	-2.93±0.52	33.40±0.38	37.70±0.19	24.85±0.18	45.21±0.26
DocDB2599 first Measure.	-4.9±1.4	32.4±1.0	36.6±0.9	23.3±0.7	43.39±1.14
Calculation by WMM	-2.58±0.28	33.20±0.22	37.93±0.14	24.82±0.16	45.34±0.16



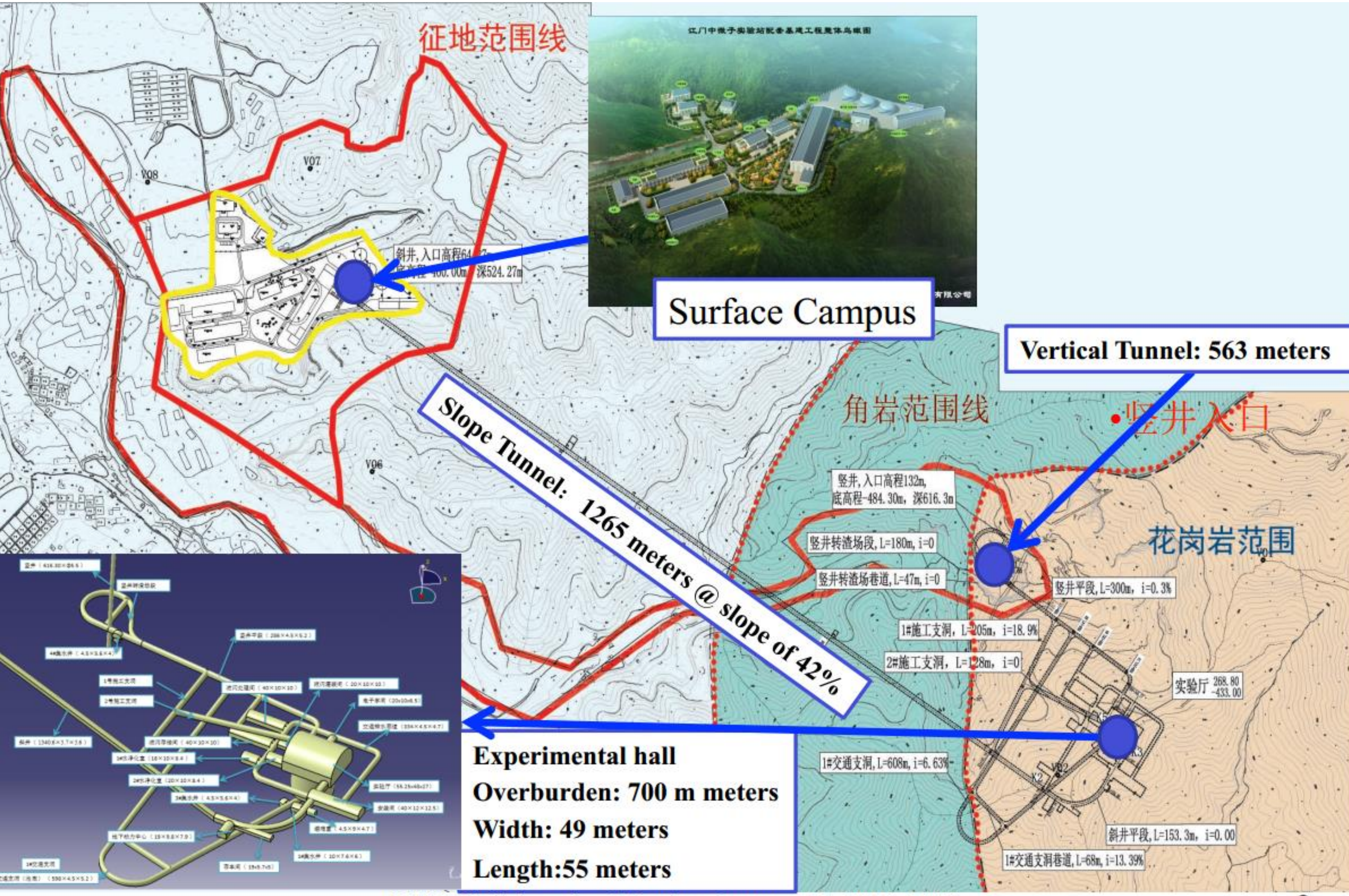


Summary

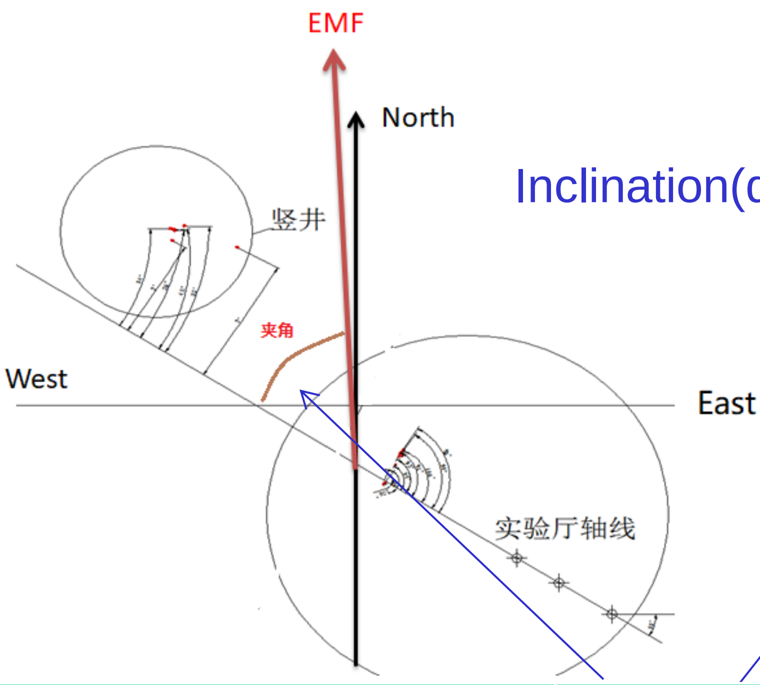


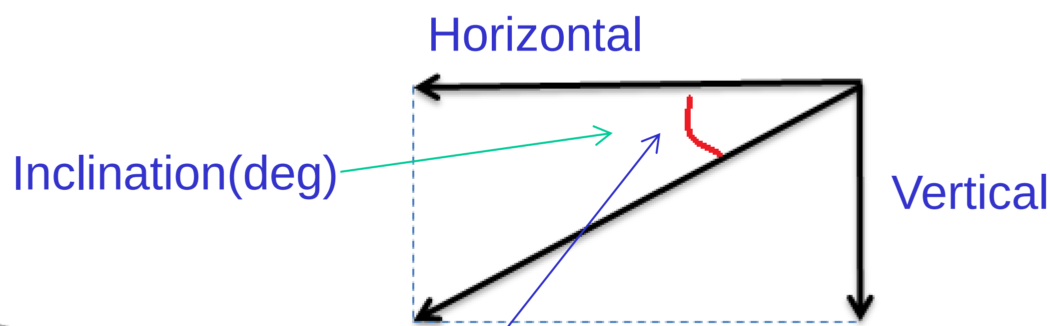
- **Earth magnetic field(EMF) measurement on JUNO site**
  - The measurement results are consist with the Model calculation.
  - There are no big difference between ground and under ground.
  - The measurement error is well controlled within 1 degree, which can satisfy our requirement.
  - The direction change(inclination) in time can’t be neglected. We may need a pre-setting value to compensation this effect.

	Angle between EMF and hall axis	Declination(deg) (+East|-West)	Inclination(deg) (+Down|+Up)	Horizontal intensity(uT)	Vertical intensity(uT)	Total intensity(uT)
Underground	54.75±0.56	-1.97±0.56	33.07±0.32	37.89±0.08	24.67±0.07	45.21±0.11
Ground	53.79±0.52	-2.93±0.52	33.40±0.38	37.70±0.19	24.85±0.18	45.21±0.26
Calculation by WMM	54.14±0.28	-2.58±0.28	33.20±0.22	37.93±0.14	24.82±0.16	45.34±0.16
Change/year(deg)	-0.0583	-0.058	0.147			


征地范围线
Surface Campus
Vertical Tunnel: 563 meters
角岩范围线
竖井入口
花岗岩范围
Slope Tunnel: 1265 meters @ slope of 42%
竖井,入口高程132m,
底高程-484.30m,深616.3m
竖井转渣场段,L=180m,i=0
竖井转渣场巷道,L=47m,i=0
竖井平段,L=300m,i=0.3%
2#施工支洞,L=128m,i=0
1#交通支洞,L=608m,i=6.63%
斜井平段,L=153.3m,i=0.00
1#交通支洞巷道,L=68m,i=13.39%
Experimental hall
Overburden: 700 m meters
Width: 49 meters
Length:55 meters

Angle between EMF and hall axis



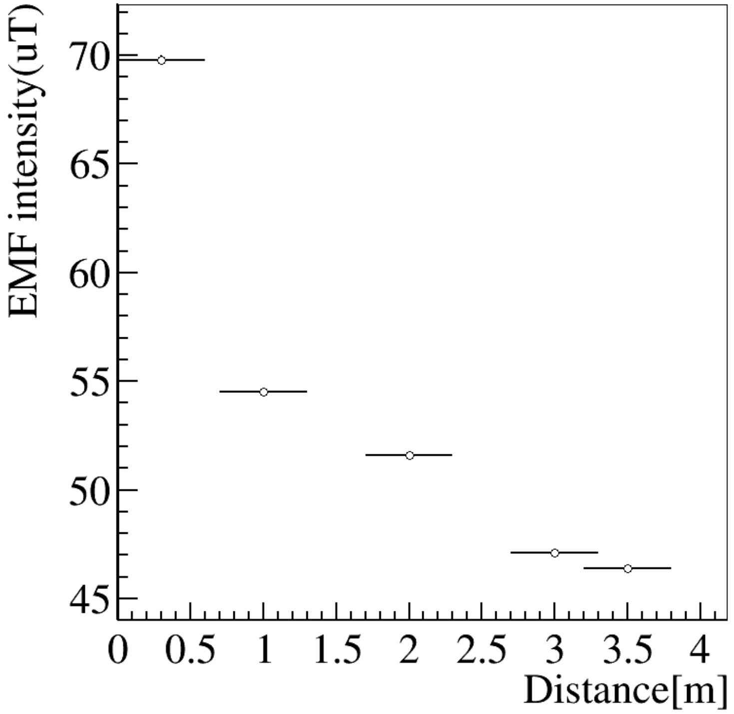


If we consider the rotation of the EMF per year, we pre-set 5years (2year for installation+3years running).

	与实验厅轴线夹角	Inclination(deg)（朝下角度）(+Down|+Up)
Underground	54.75±0.56	33.03±0.32
Ground	53.79±0.52	33.40±0.38
Average value	54.27	33.22
Change/year(deg)	-0.0584	0.147
Consider the EMF rotation and compensation	54.0	34.0

Steel influence on the magnetic intensity

- If sensor is too close to the big steel structure , it will have obvious influence on the EMF intensity.
- We do a simple measurement of the intensity verse distance from the steel structure.




Thanks!

Result for Secular Change in EMF

$$B_{res}^{max} = \left(\frac{B - EMF}{EMF} \right)_{max} \times 100\%$$

Φ (m)	Perfect	1	-1	2	-2	3	-3	5	-5
39.5	5.22	5.70	5.65	6.77	6.69	8.10	8.05	11.27	11.18
41.5	21.62	21.95	21.98	22.98	22.95	24.27	24.16	27.35	27.28

Secular change in EMF gives small change in residual-B within 20 years (<10%)