Technical status of GP-65 and Plan for GP-X

International Scientific Event “GRAND” Collaboration Meeting, 2025, Warsaw Poland

Pengfei Zhang(XDU)； Yi zhang(PMO)； Yan huang (NAOC). 2025.06.2

（Xidian University，zhangpf@mail.xidian.edu.cn)

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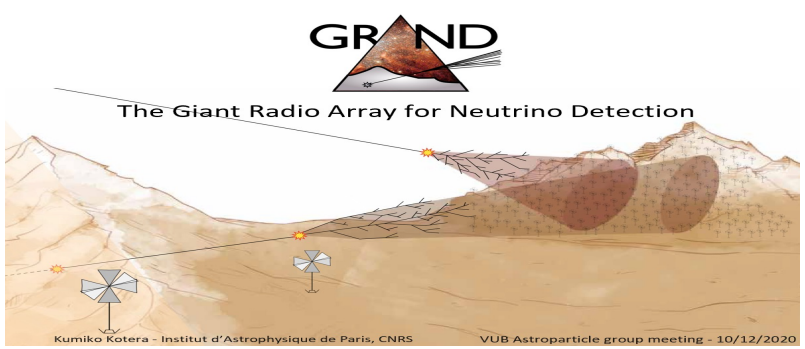
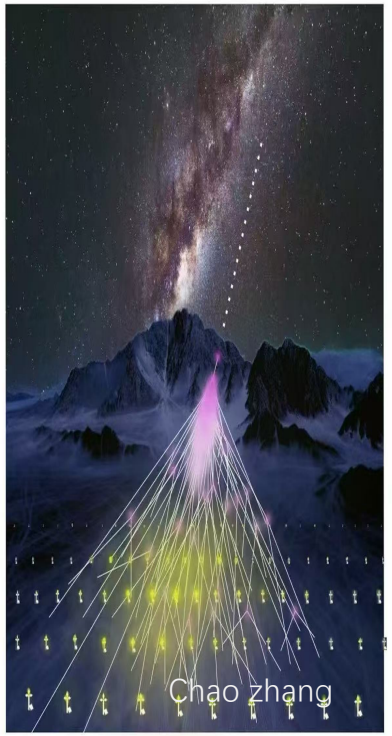
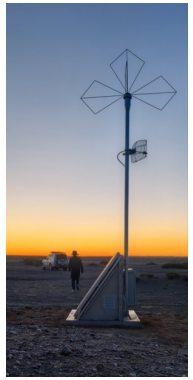
(2) Key technique achievements from GP13 and GP65 .

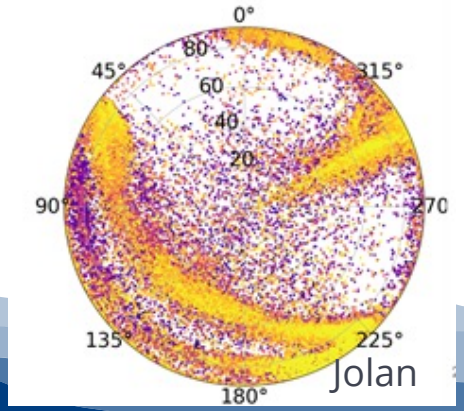
(3) Remain tasks for GP65.

(4) The plan for GPX/GRAND-BEACON









Time line of Xiaodushan site

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Old center station installation

* Road
* Room
* Power supply
* Network（Microwave
* DAQ computer
* Rocket

GP13 Installation and running

* Antenna
* LNA
* WIFI
* GPS
* Solar panel, Battery
* Sensor

Hardware firm ware software update for GP13 and test

* Thermal problem
* LNA (Electrostatic, thermal)
* WIFI-rocket
* EMC
* GPS time
* Battery

** MD/ UD/ CD
** Beacon etc.

Installation of New center station and GP65

* Room
* Power supply
* Network（Microwave)
* DAQ computer
* Rocket
* Antenna
* LNA
* WIFI
* GPS
* Battery

GP 65 debug → Calibration and data process

* Communication improvement
* Noise suppress
* Gain calibration
* GPS time calibration
* Interference suppression
* Trigger optimization

* Data process
* CR candidates searching

Next generation preparation

March.2023 Sep.2023 April.2024 Oct.2024 Apri.2025 Now

The GP65 system : Three-Level Architecture of GP65

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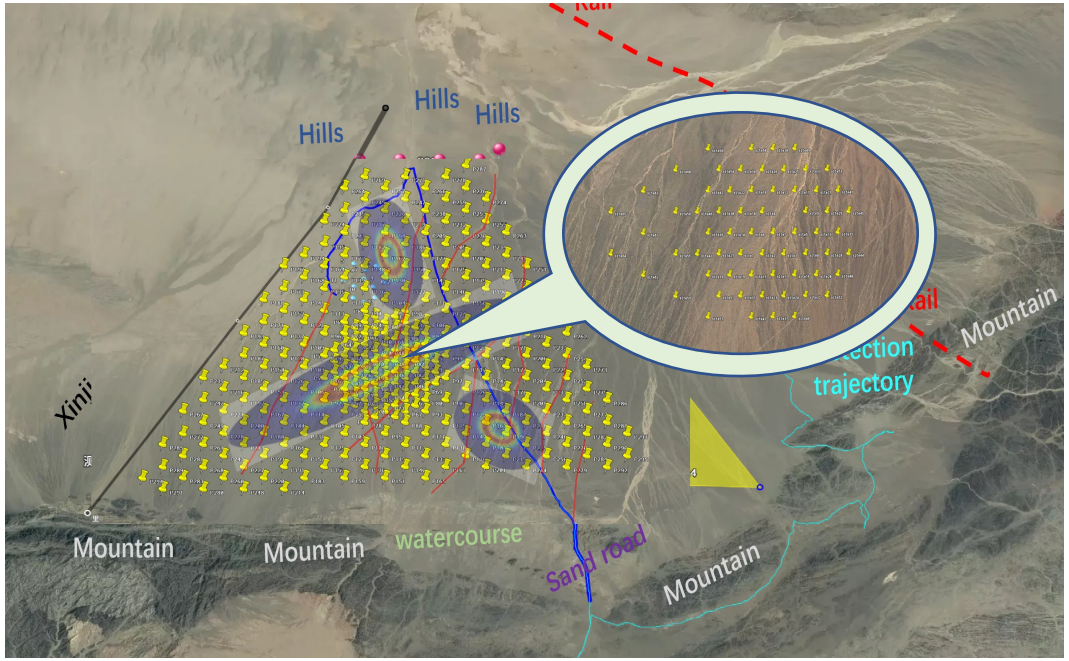
- 3 Level structure of GP65



Units

- Antenna and RF Chain
- FEB board
- Solar and power supply
- Mechanical and thermal protection
- GPS Time
- Wifi communication system

Center station

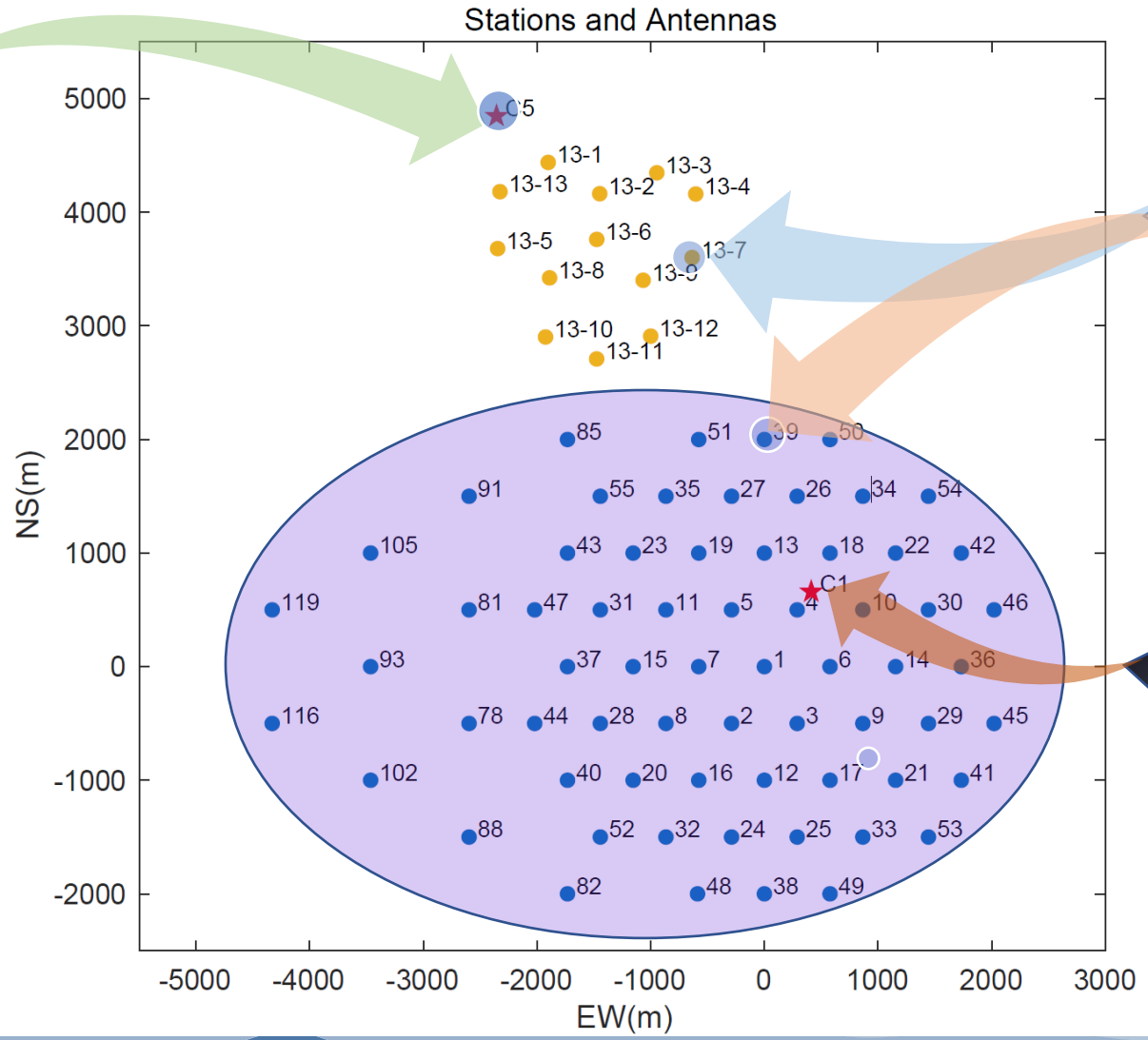
- Wifi Rocket
- DAQ system
- Solar and power supply
- Monitoring system and Living security
- Microwave communication system

PMO data server

- Internet access
- Data data storage and management
- Data access authorization and distribution

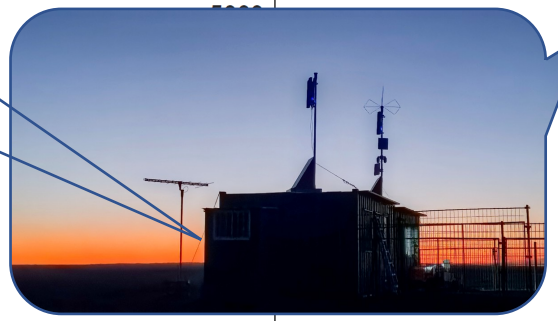
- (Hardware Firmware. software)

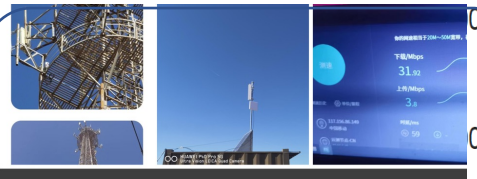
Part I： Statues of Xiaodushan（Dunhuang China） site

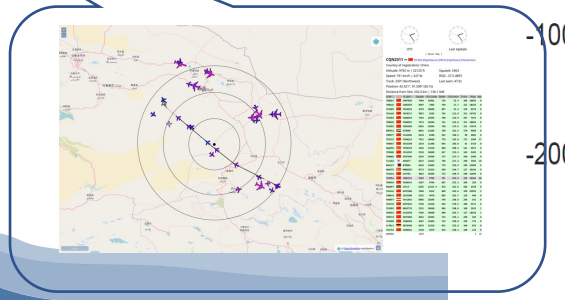


Part I：1、Old center station（Devices and function of C5）

- The old center station
- Include: 3 rooms; 8 Beds;
- DAQ room: **DAQ and analyze computers**;
- 30MBps **Microwave relay network transmission system**;
- **ADS-B system** (Airplane broadcast information collection)
- **3 Rocket system**
- 1800W Solar power supply capability;







Part I： 2、History and contribution of GP13

- GP13: **Running time：2023.3.1-2025.4.23**

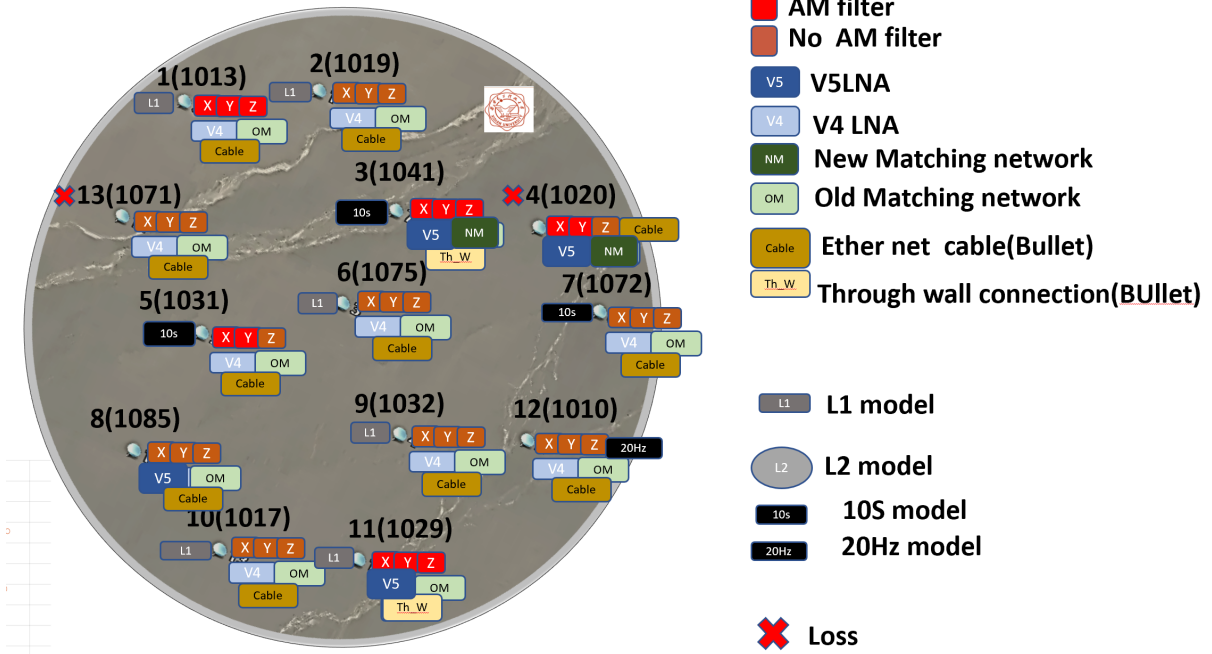
- Two version of solar panel fixed methods;
  (Foam based thermal isolation + window blind)

- Two version of FEB box fixed methods;
  (Independent shading distribution box)

- 4 Version of LNA
  (Single-ended to differential conversion, electrostatic protection, temperature stability, improved matching)

- 2 Version of Feb Firm ware (or 3-4)
  (Auger - PMO)

- 3 Version of Bullet installation methods
  (Inside outside EMC shading, Wireless adapter)



Part I： 2、History and contribution of GP13

- GP13： Running time： 2023.3.1-2025.4.23

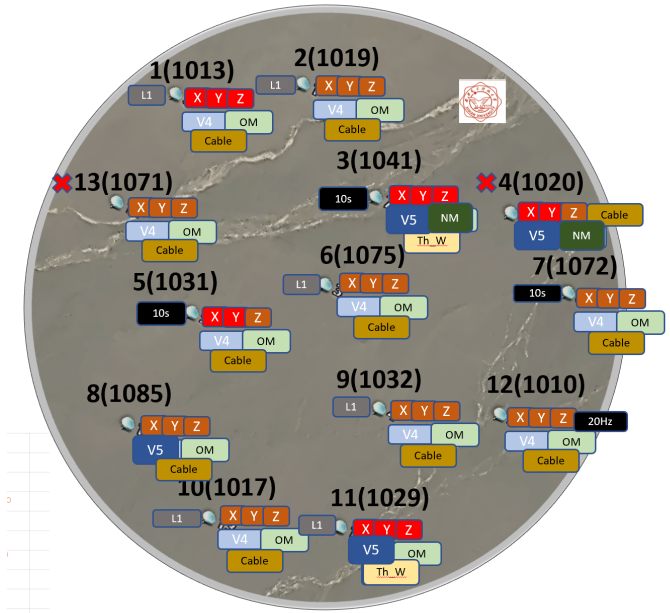
- 2 version of FEB EMC improvement;
  (Power supply ,twist cable, shield)

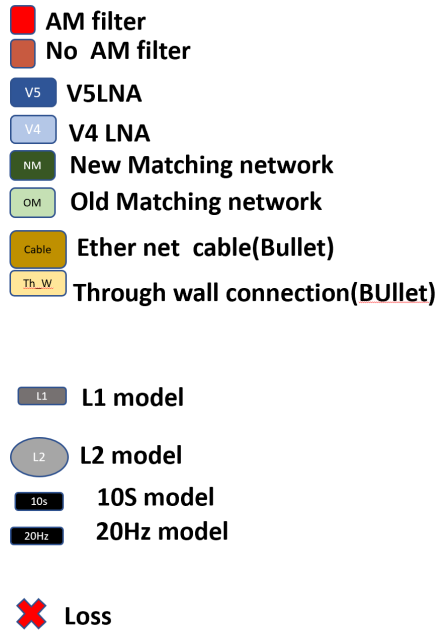
- 3 version of filters;
  (Inside, out side, embedded)

- Rocket based(communication) test;
  (Speed, distance, direction optimization, parameters choices)

- Beacon based test
  (Continue wave; pulse for trigger and so on)

- 2 version Power supply
  (Replace the high-power power management module)

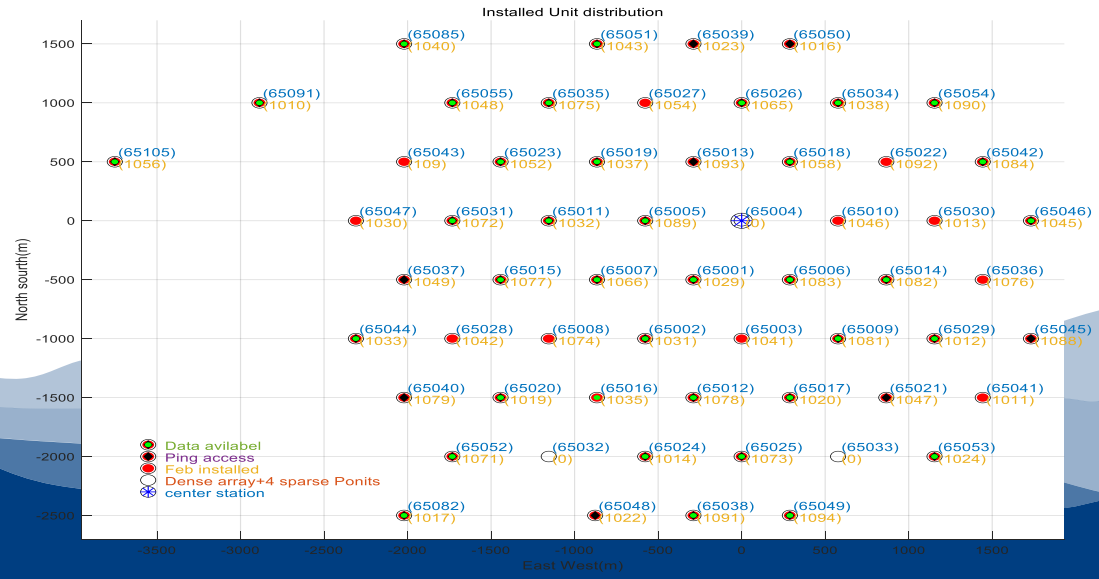




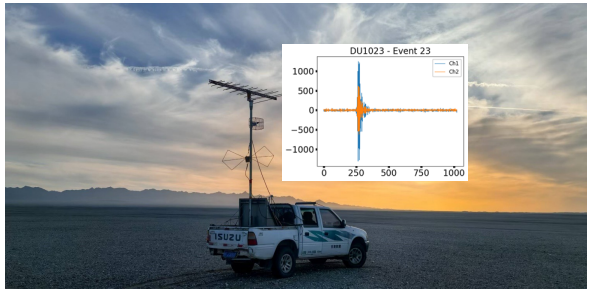
Part I： 3、New center station and GP65

- New center station
  - 3 bed rooms(10 seats)
  - One meeting room
  - 30MBps internet network
  - 1200W solar power
  - Beacon antenna
  - Base station for GP65
- GP 65
  - 64 base station is prepared;
  - 55 Unit installed and worked;

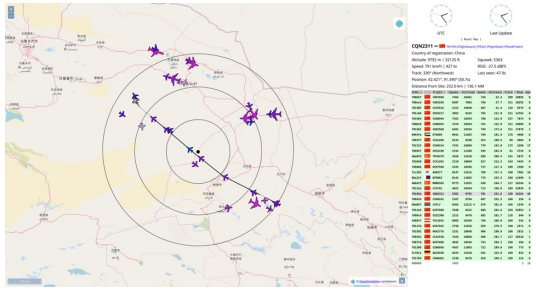
    Materials for 64 units are ready;



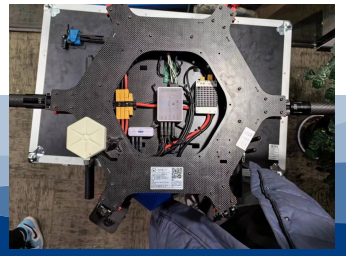
- Beacon system



- ADS-B system



- UAV based calibration system



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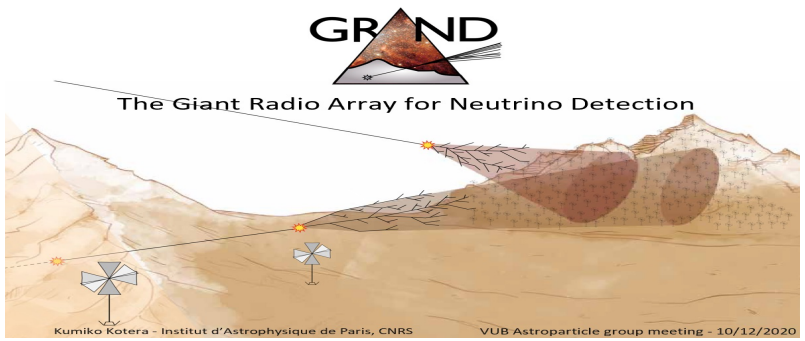
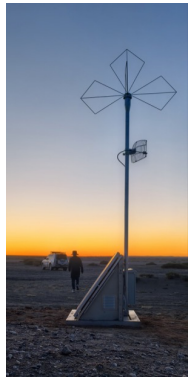
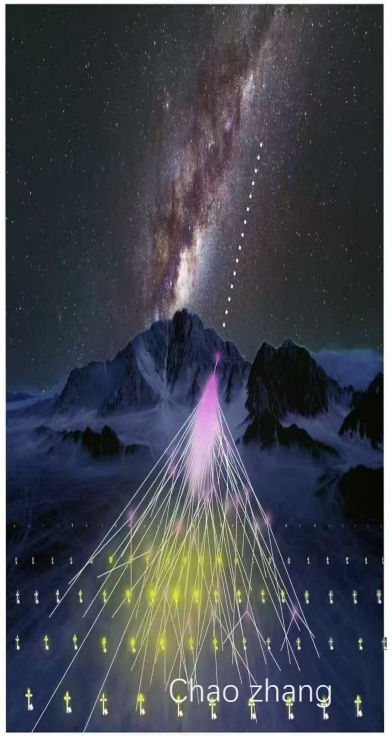
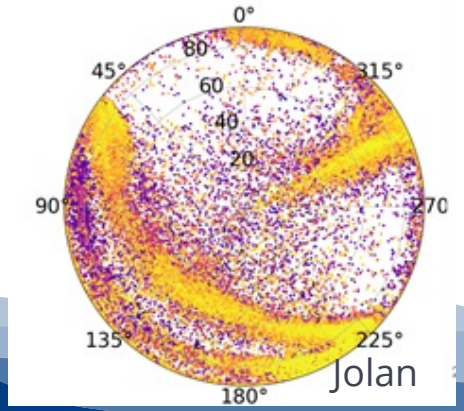


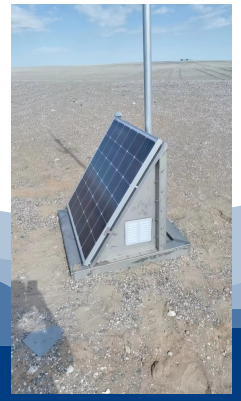


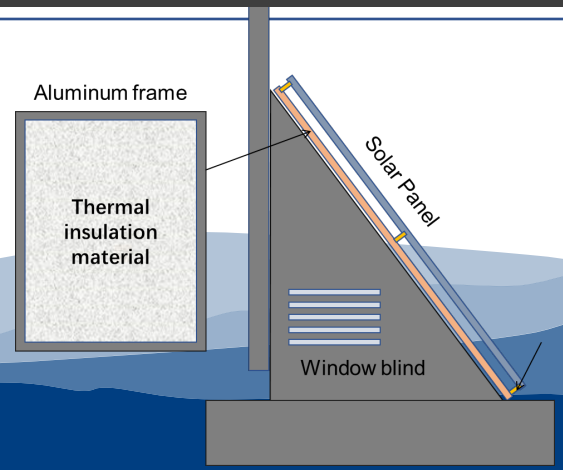


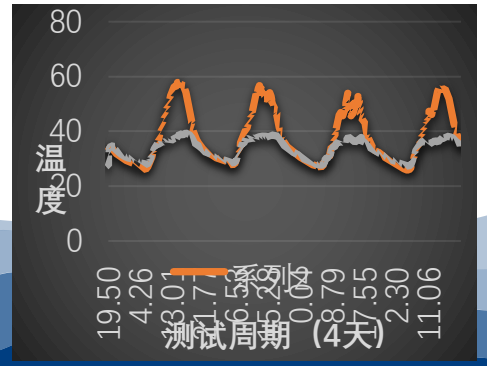


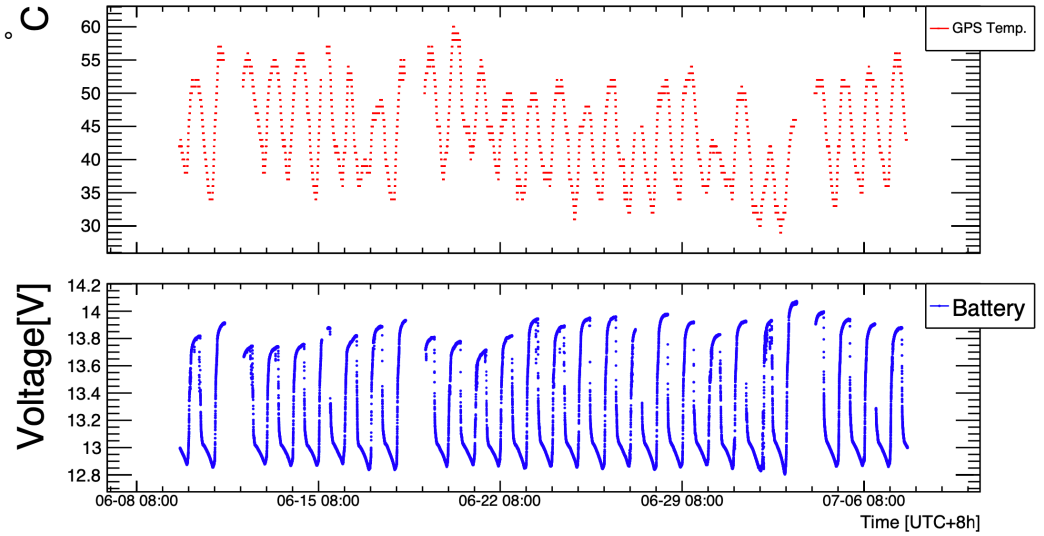
Part II：1、 Stable power supply and communication system

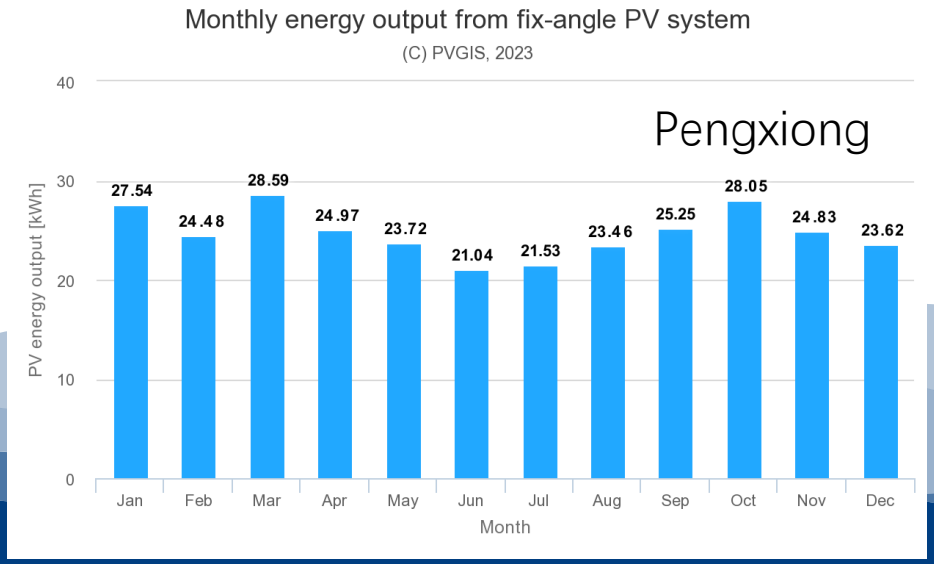
Network 15 Km 30MHz







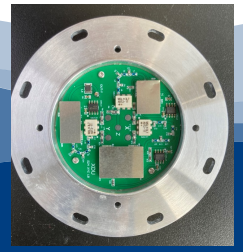


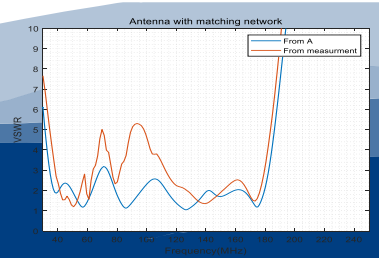


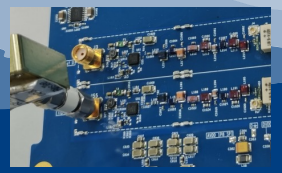
Part II：2、Great improvements to the Antenna-FEB –GPS-Wifi-DAQ system

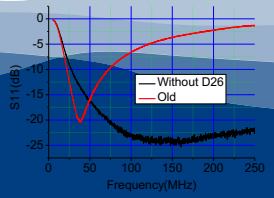
Xu xin(Antenna), Xu xing; Charles(FEB), Fengwei(LNA),Bohao(DAQ), Hanrui (Matching), Hongwei Pan(filters), Fred(Wifi) , Gaofei (Thermal). Liwang (Mechnical), Pengxiong （Test， data anlyze etc ） , Yutang(Support); Pengfei, Yizhang, Oliver， Kumiko ， Yanhuang (organization)； etc

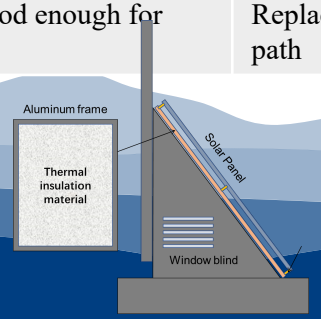
No.	Issue	Description	Analysis	Solution	Status
1	Nano time error	Nano time obtained in dudaq is abnormal	CTP counter is reset before read event in each run	Add 2s delay between initialization and event reading	Okay
2	Pulse position error	Pulse position in trace is not consistent with settings	Post time is calculated under 250M clock, so it is doubled	The parameter is divided by 2 before calculation	Okay
3	Notch filter	Four filters cannot be used at the same time	Data width is not wide enough in the implementation of notch filters	Increase data width in the structures of mult and add	Okay
		Filter response abnormal	False bits is used in floating-point to fixed-point number conversion	Use 12 bits for filter parameters calculation in software	Okay
4	Chopped data	Data channel by channel is shifted	Reason not clear	Disappear in V1B now	Okay
5	Data throughput	1kHz of 1024 samples per channel is not achieved	Possible data transfer error when trigger rate is too high	Double the capacity of the event FIFO, it works in current V1B	Okay
6	Trace length error	Unexpected trace length in L1 data package	Auto reboot function leads to some errors about readout trace length parameters	Turn off the auto reboot function in daq software	Okay
7	Trigger pattern	Trigger pattern cannot reflect the real trigger mode of hits	Bug in HDL logic	Fixed	Okay
8	Lose connection	FEB cannot be ssh after long time running	Power supply for MPSOC is not good enough for stable running	Replace the ferrites on the VCCINT supply path	Okay

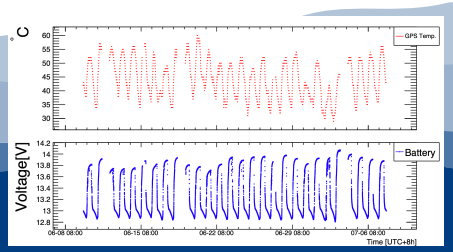






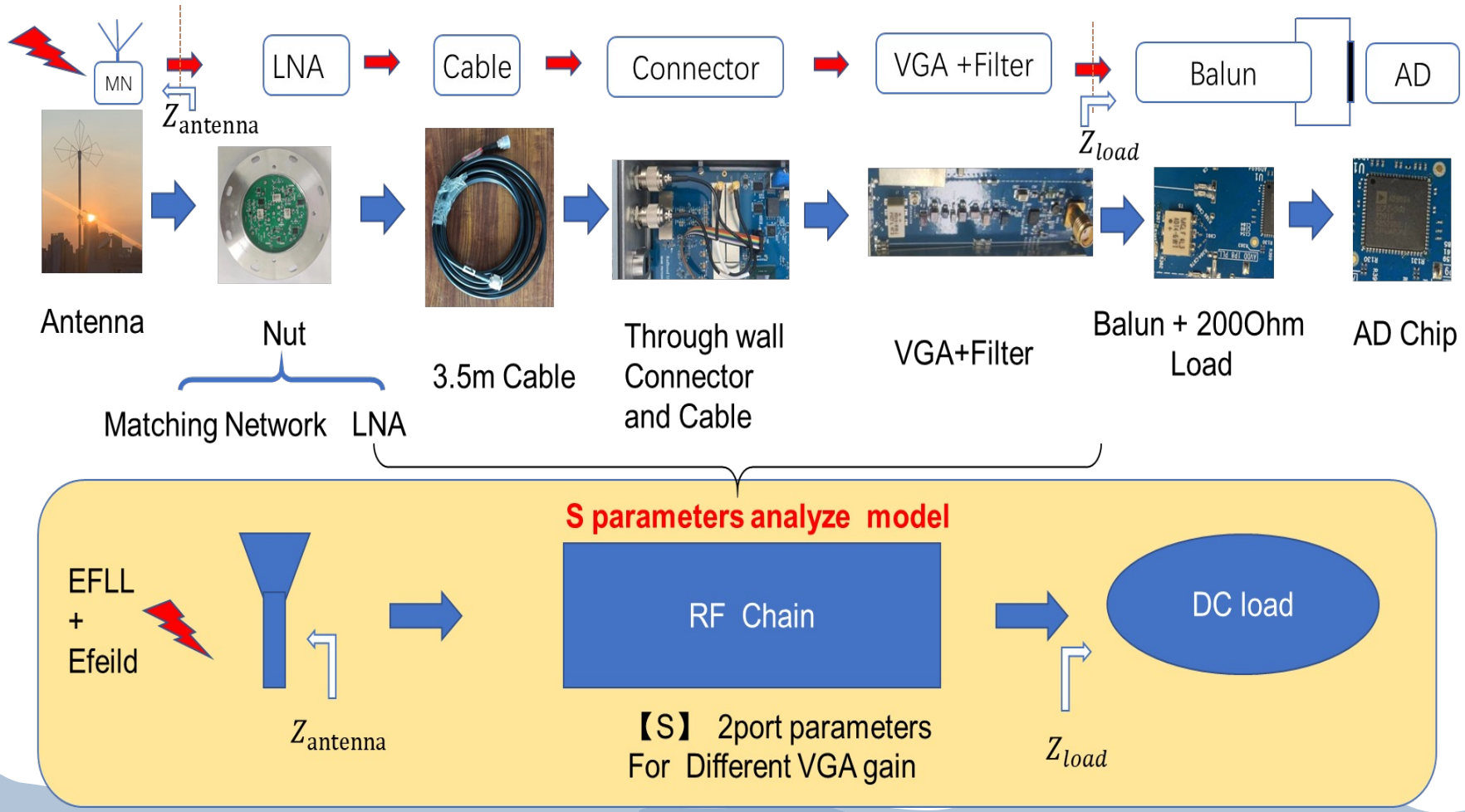


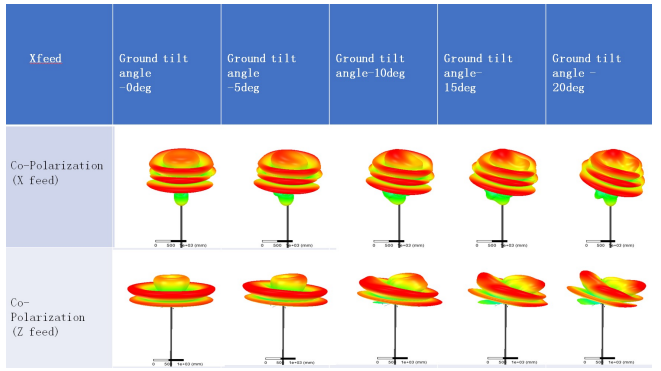


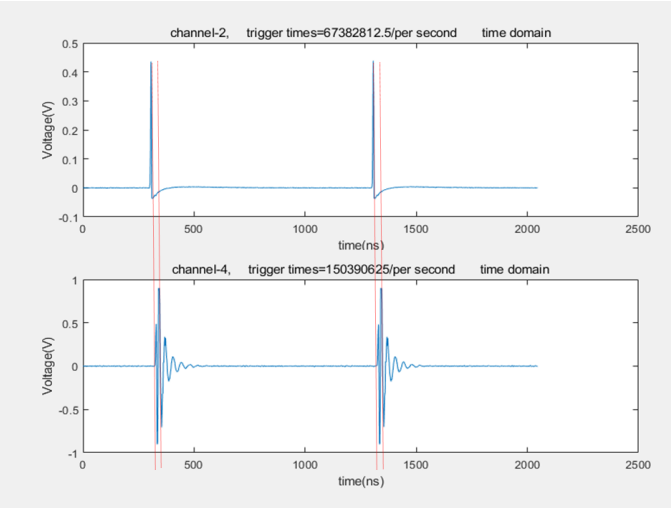


Part II： 3、A clear understanding of the radio frequency link

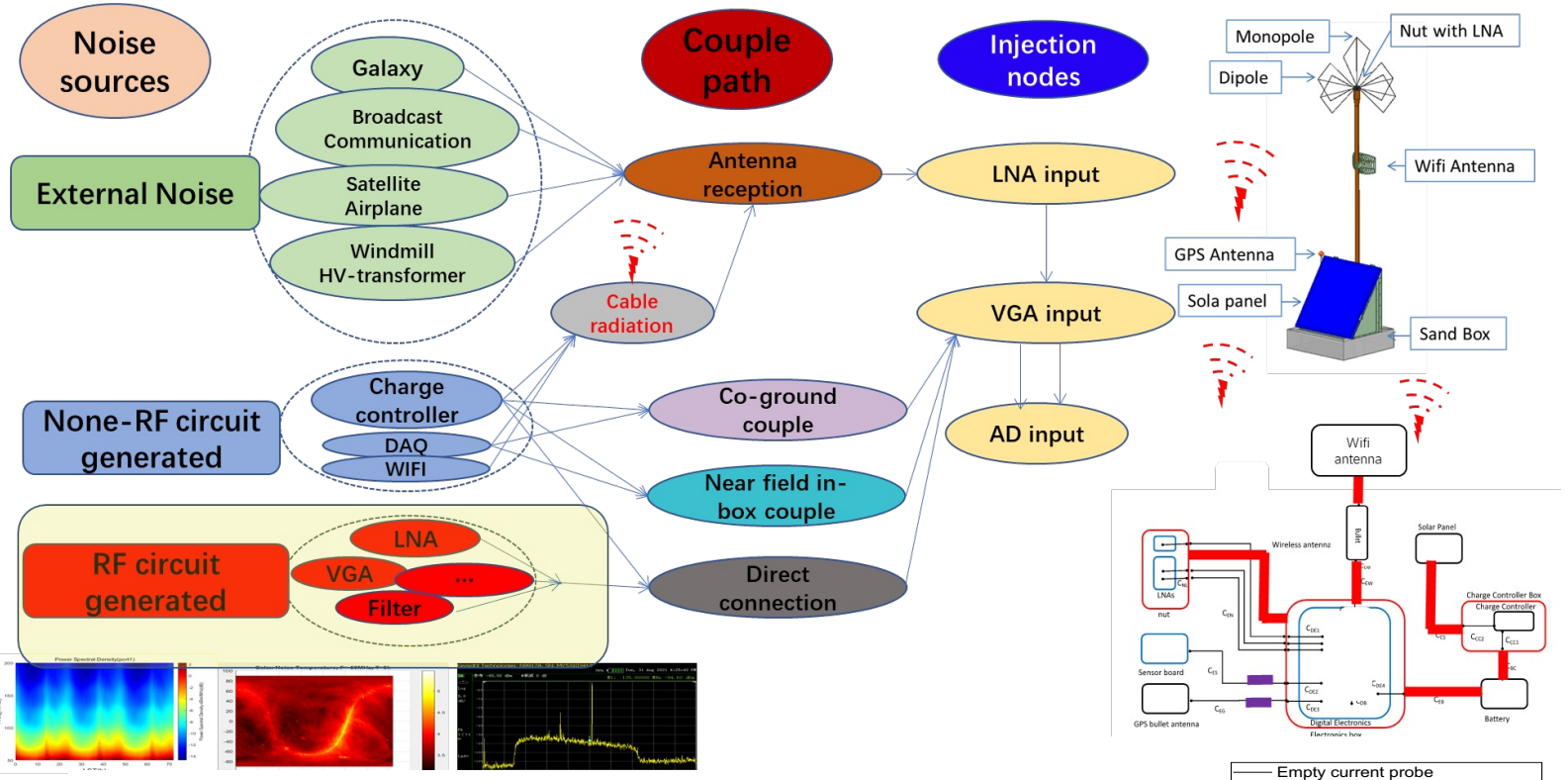
Xu xin， Stavros， Oliver， Ramesh， Lech, etc.



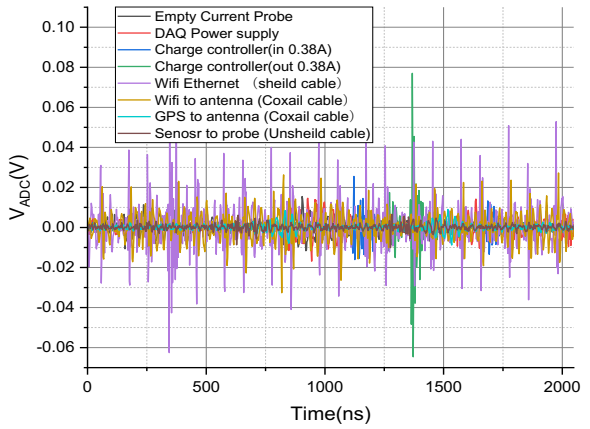


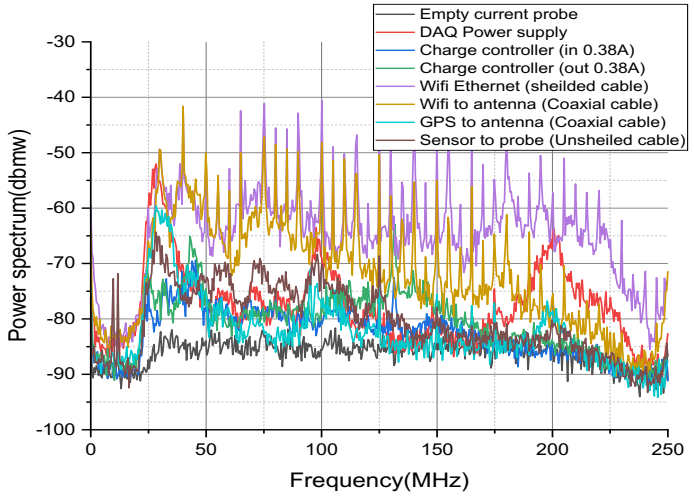


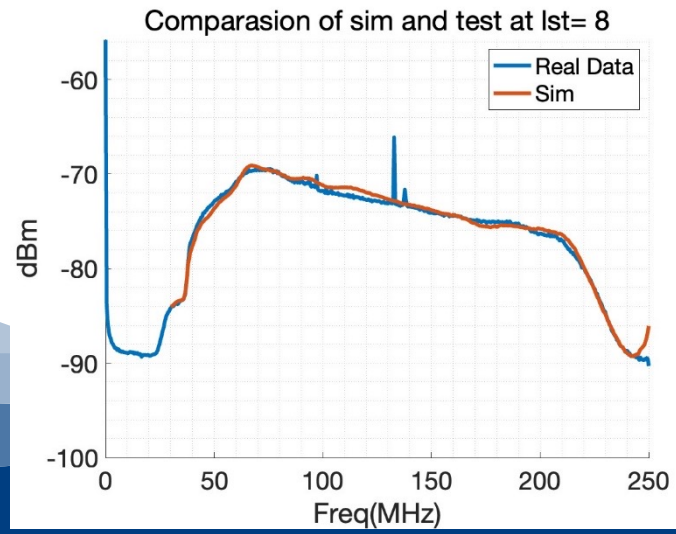
Part II：4、A clear understanding of noise and the suppress method



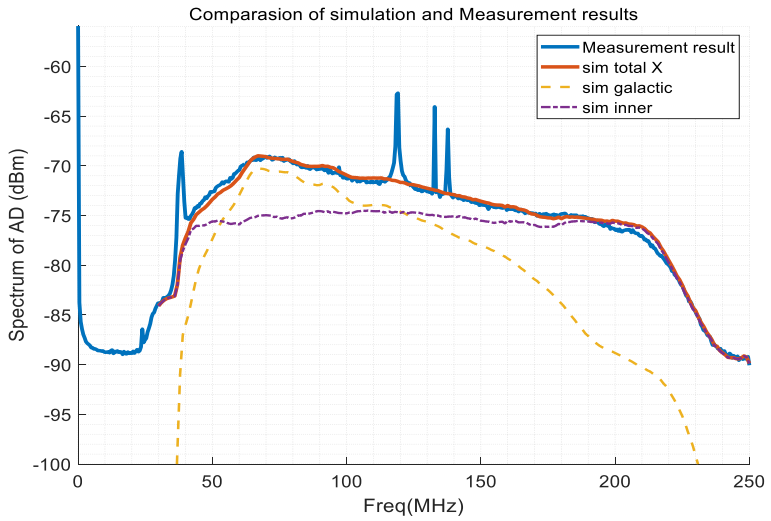
Source	Magnitude (RMS/ADCUnit) (0~250MHz) /(50~200)	Time domain		Frequency domain		Process
RF-Chain AD sample	12	Random noise		Random noise Within 50~200MHz		/
Power supply cable (Probe test)	30 (12)	Modulation noise		Bump：35MHz,110MHz ,190MHz		Filter(DC pass) 10MHz~500MHz, 60dB suppression
Charge controller (Probe test)	38(34)	Pulse（pair, 600ns）：width: 150ns		Wide band spectrum		Filter(DC pass) 10MHz~500MHz, 60dB suppression
Wifi Unsheilded Ethernet cable (Probe test)	400(320)	Strong Random noise		Wide band spectrum 20~120MHz 125~135MHz		replace
Wifi sheilded Ethernet cable (Probe test)	100(90)	Periodic noise		Wide band spectrum Peaks		Shield
Wifi Coaxil cable (Probe test)	65(43)	Periodic noise		Wide band spectrum Peaks		Filter (HF pass) 0~500MHz: 60dB suppression 5~5.5GHz 0.5dB insetloss
Laptop Couple To powersupply	150	Modulation noise		Bump: 35MHz,95MHz ,190MHz		/
GPS cable	15(10)	Pulse（pair）600ns（period）, 150nswidth (test without charging systerm)		Big bump 30MHz(?) Small bump 90/200MHz		/
Sensor	13(5)	Small Pulse		small bump 30~130MHz		/

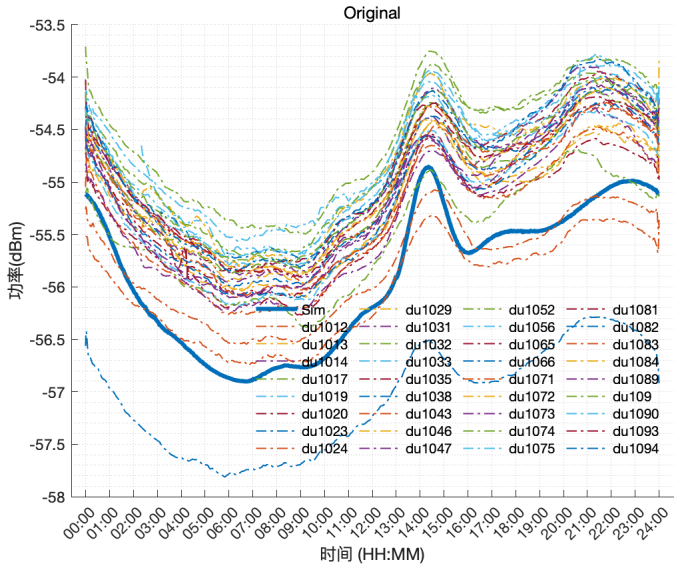


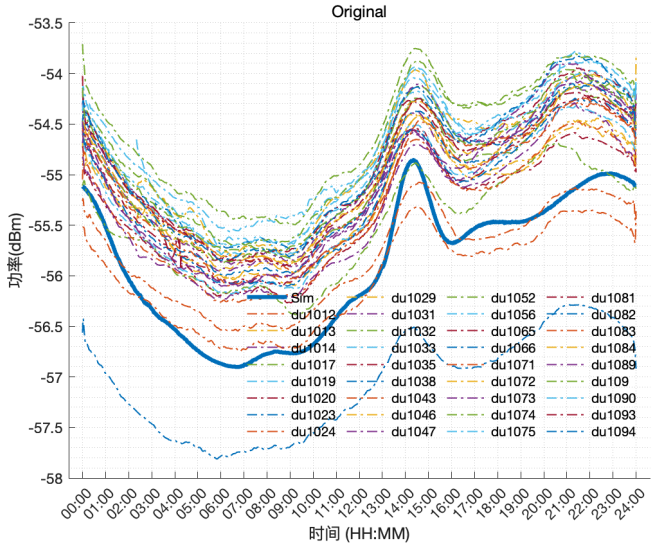


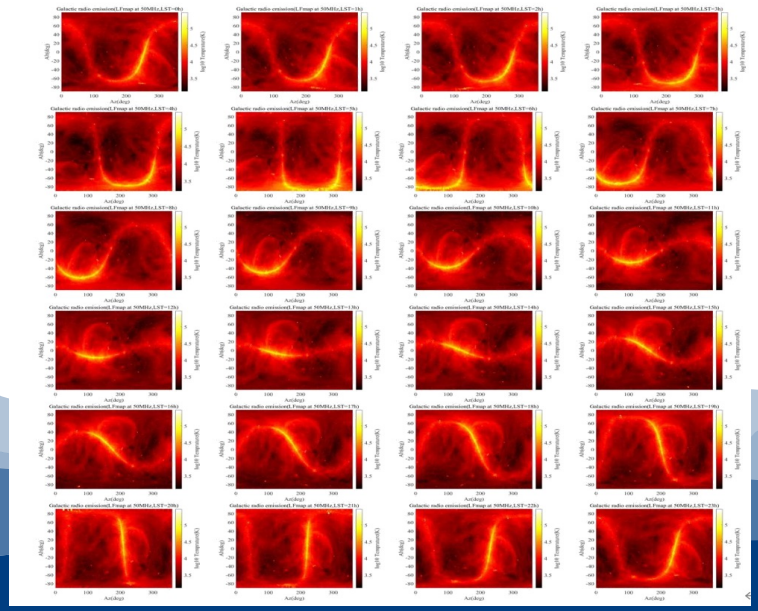


Part II： 4、A clear understanding of noise and the suppress method









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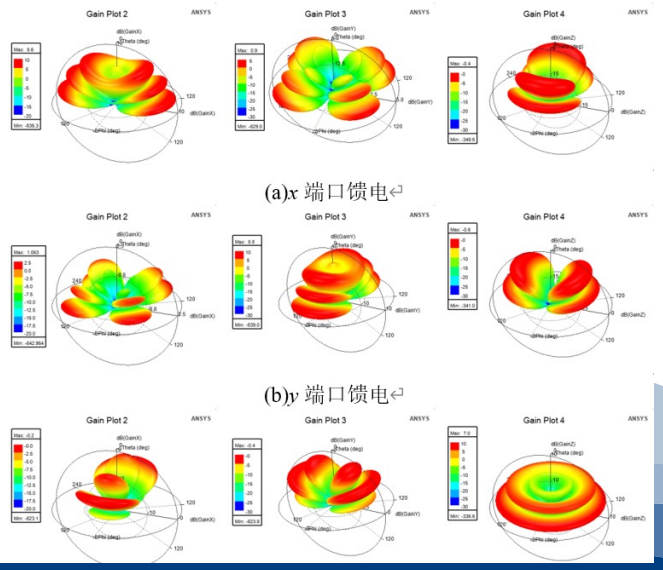

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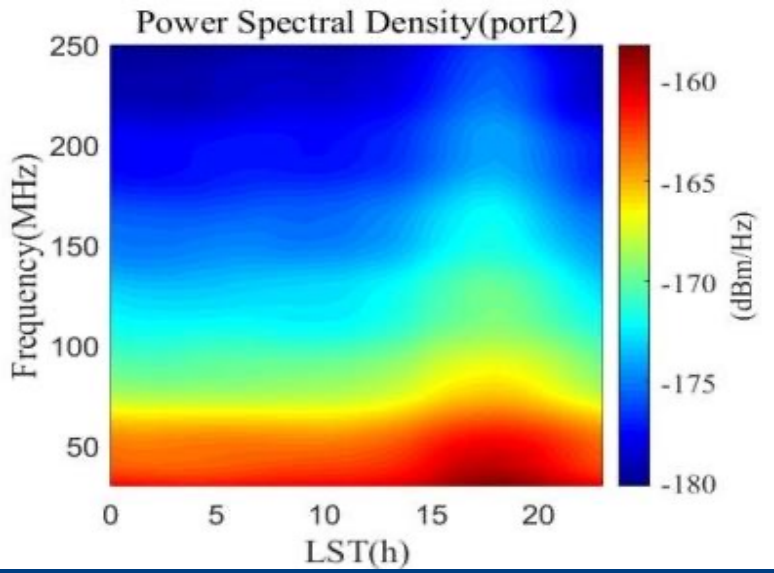
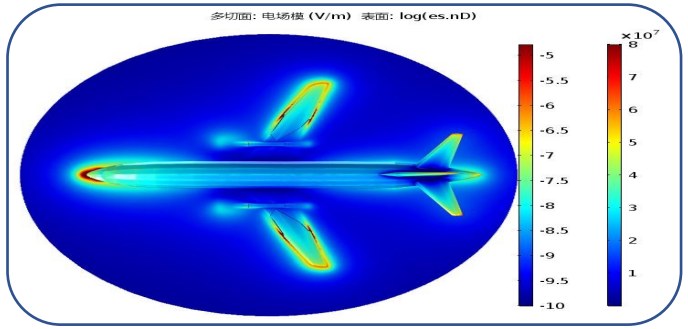
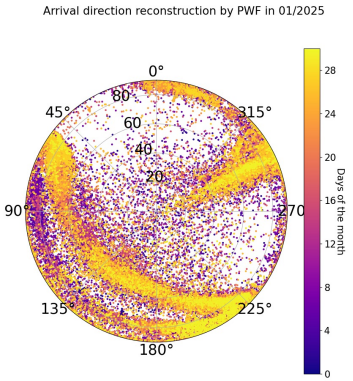
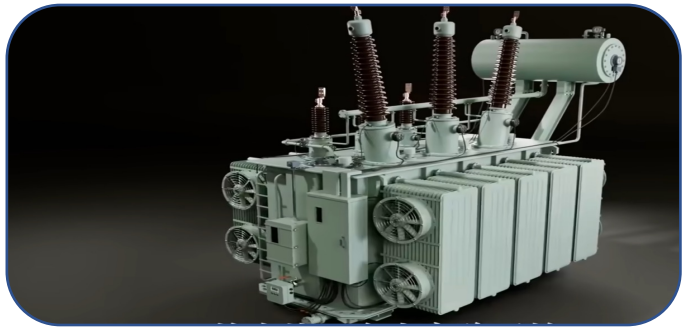
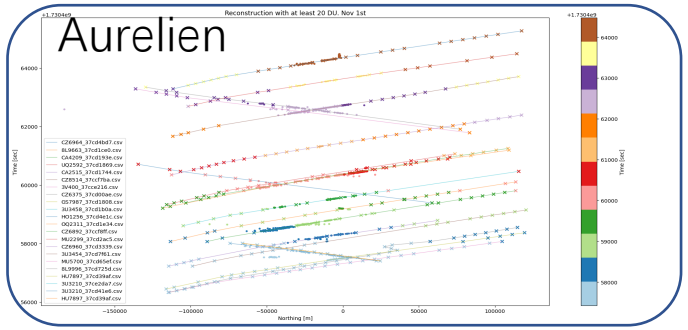


Part II： 5、A relative clear understand of the interfere sources









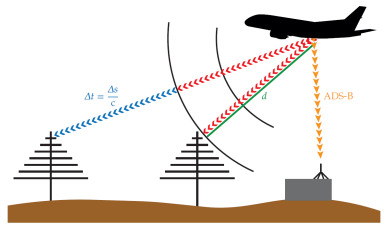
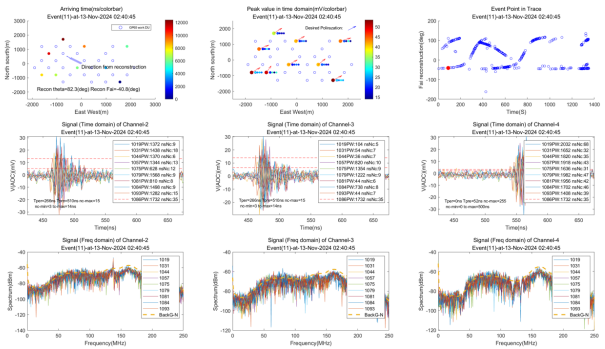


Figure 4. Concept of the time calibration using commercial airplanes. The airplane broadcasts its position via digital ADS-B packets at 1090 MHz. These signals are received and interpreted by a dedicated setup in the AERA field in real time. In addition, (some) commercial airplanes emit pulsed signals in the frequency range of 30–80 MHz recorded by the AERA detector stations.



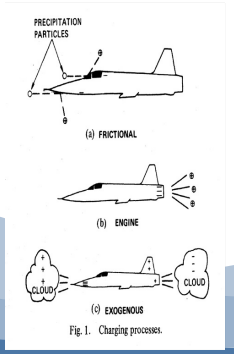


Fig. 1. Charging processes.

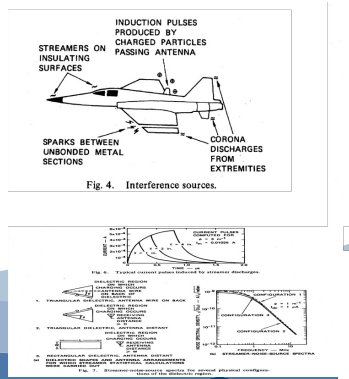


Fig. 4. Interference sources.

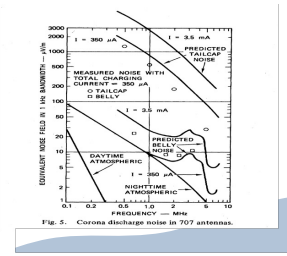


Fig. 5. Corona discharge noise in 707 antennas.

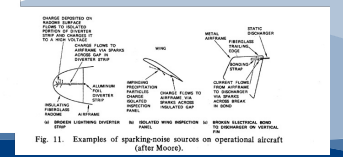
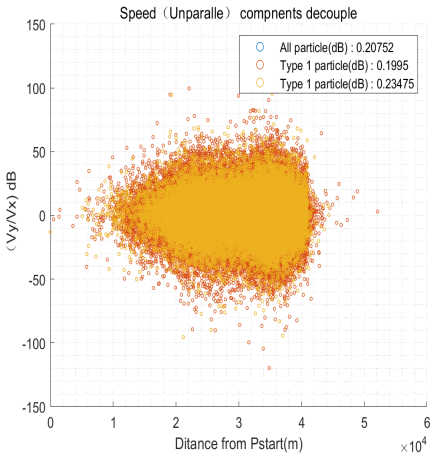
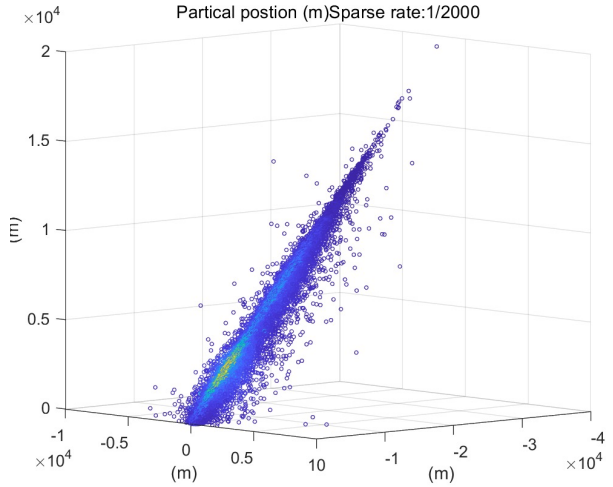
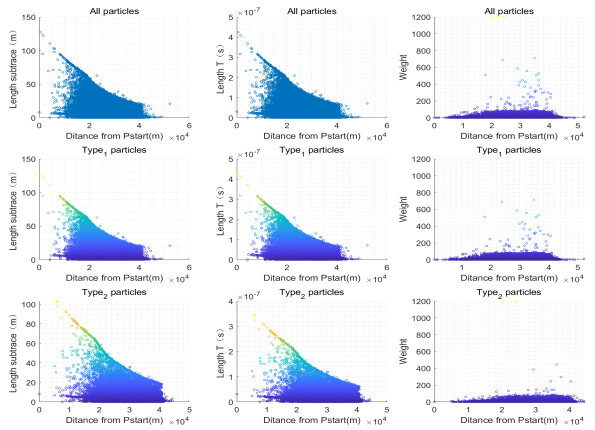


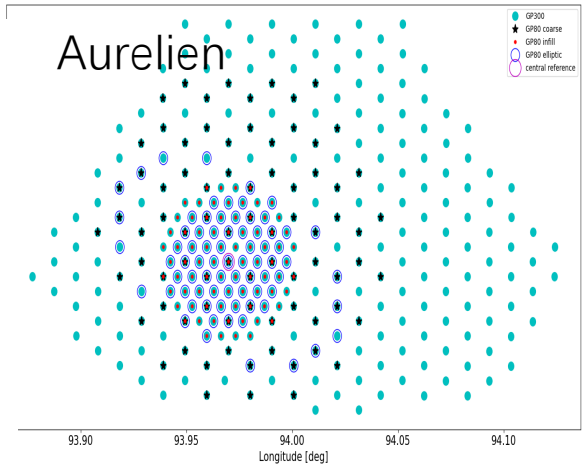
Fig. 11. Examples of sparking-noise sources on operational aircraft (after Moore).

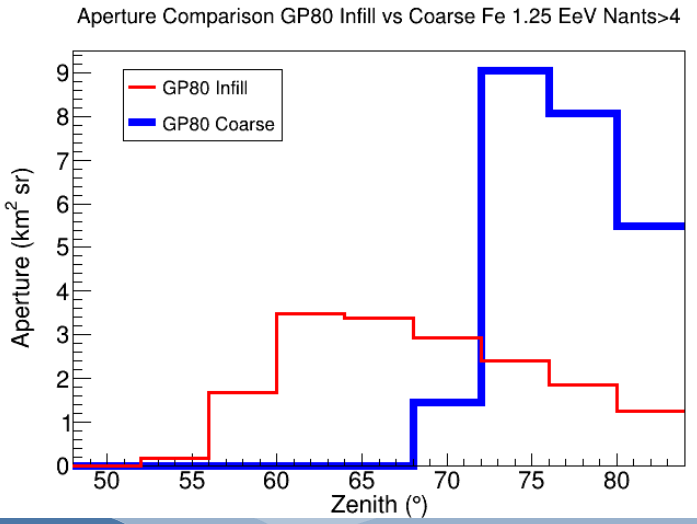
Part II： 6、EAS simulation improvement and system simulation tool development

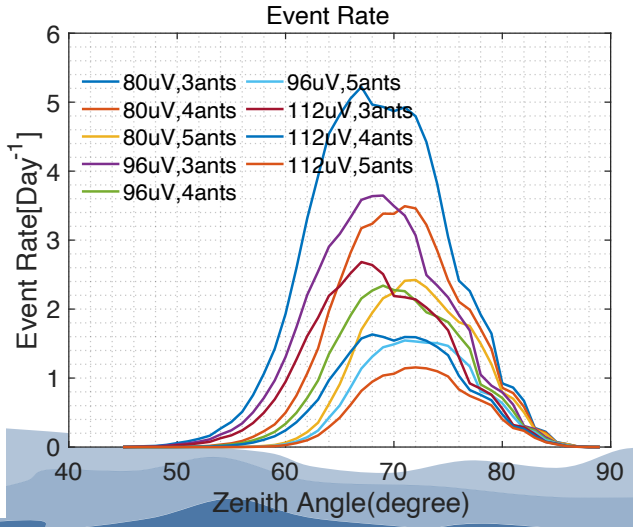


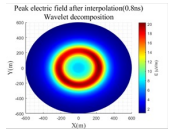


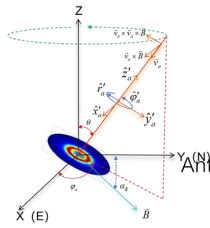


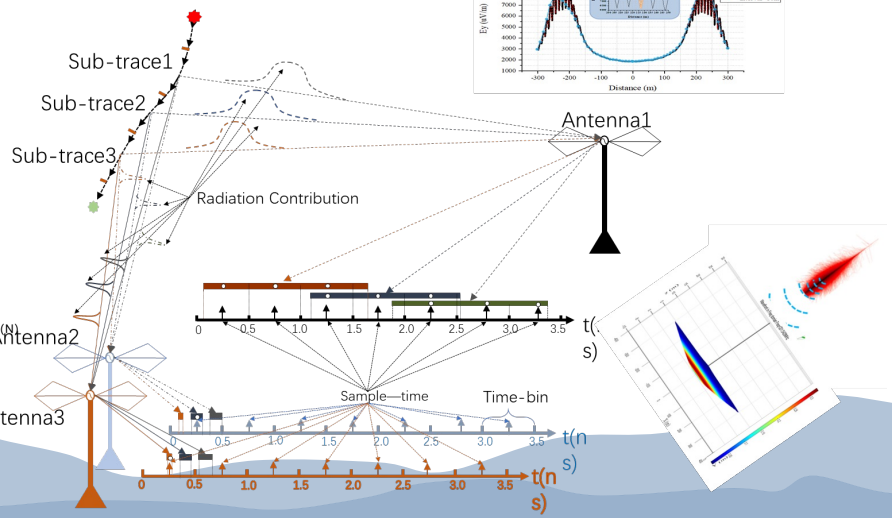




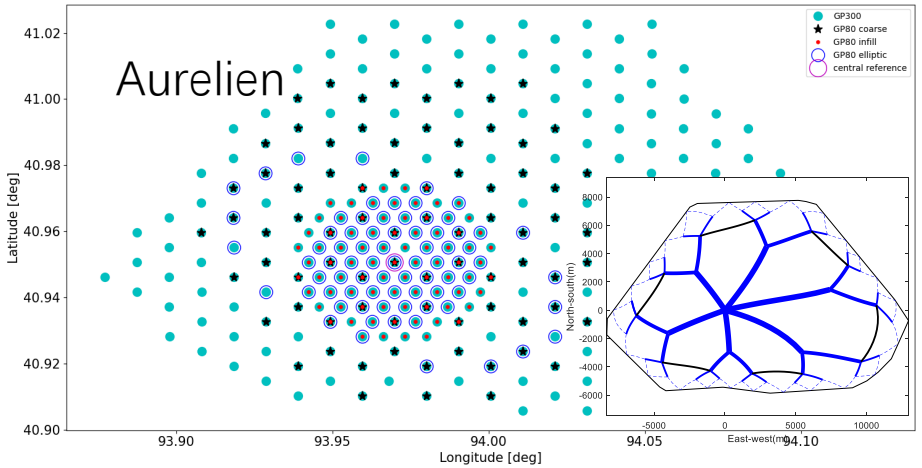


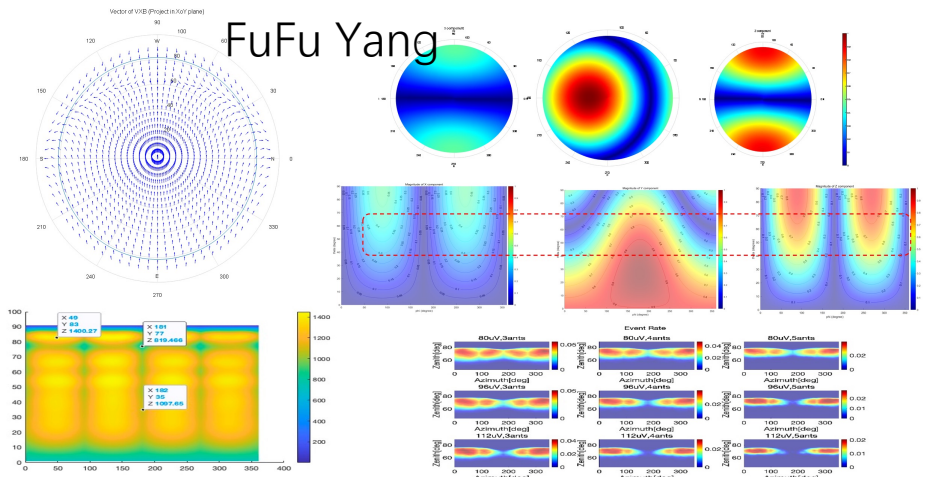


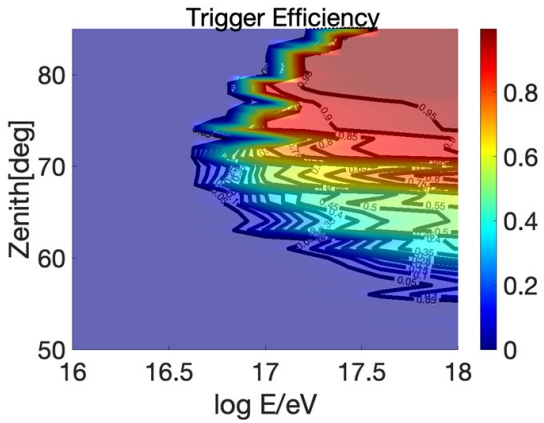




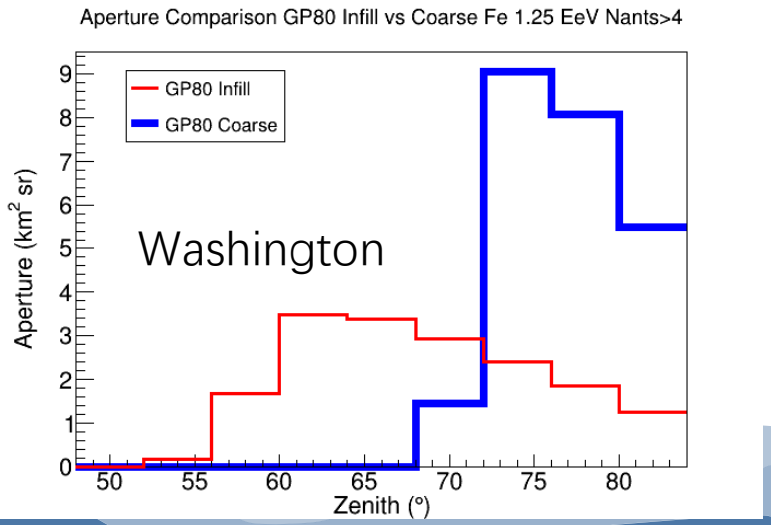
Part II： 7、A better understand of trigger, layout ,expected event number or even roading optimization

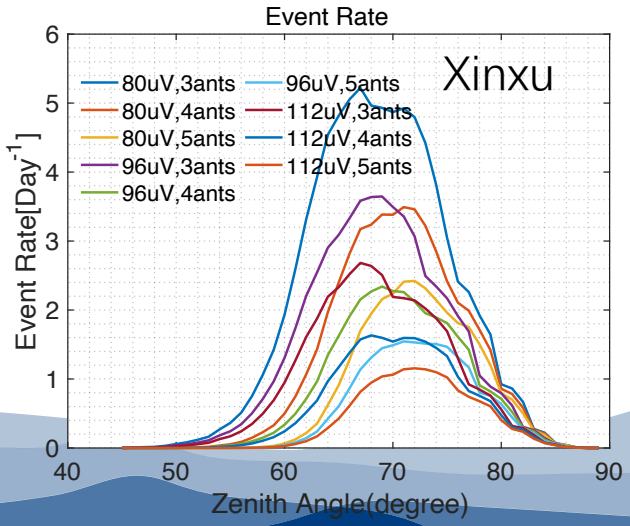


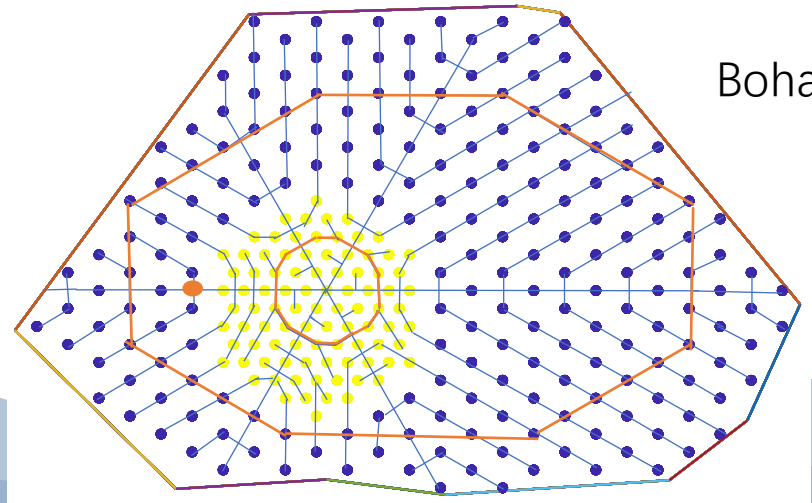




Pengfei



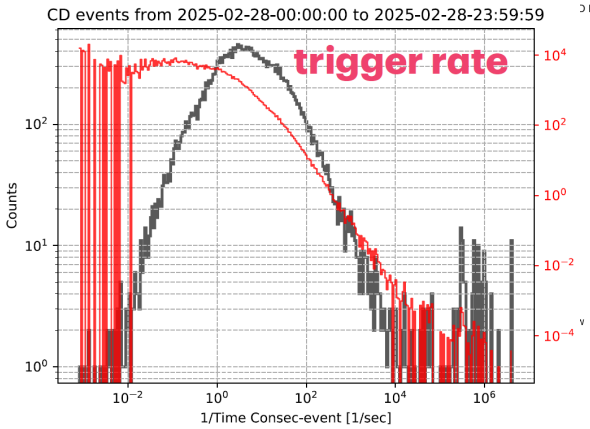


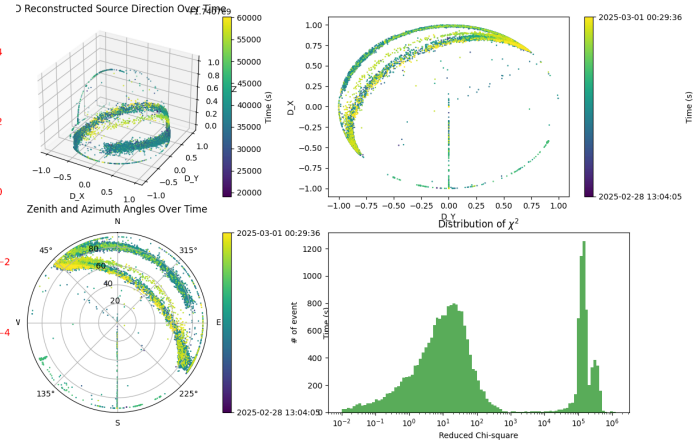


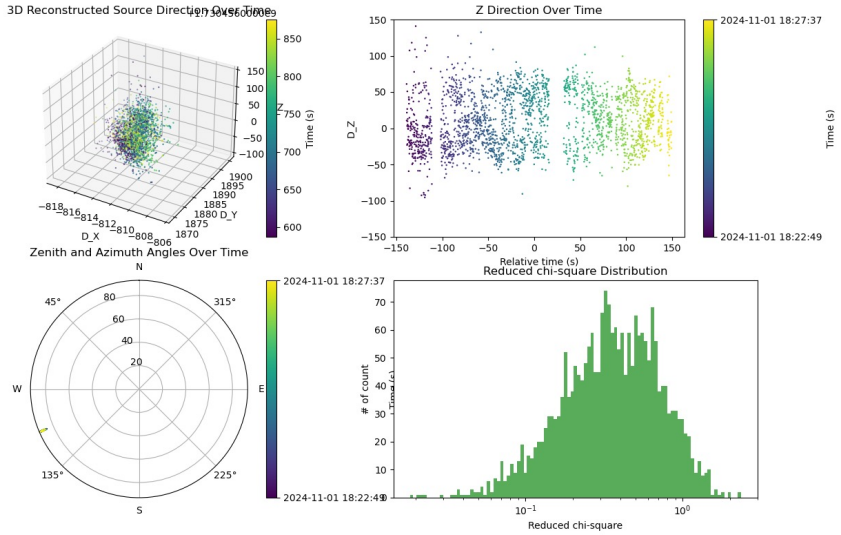
Part II： 8、A ‘stable ‘ MD, T1, T3 Trigger operation and events record

Xidian University

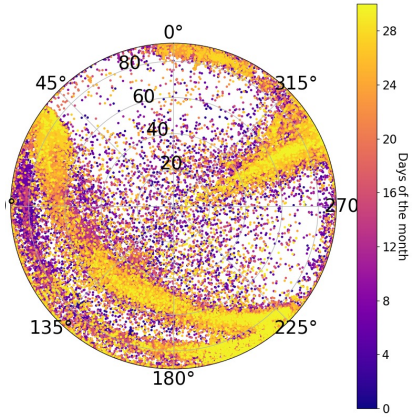
Hardware 、Operation 、CR searching groups etc

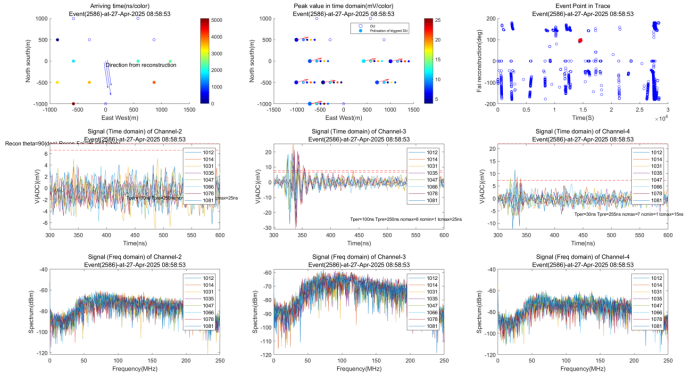


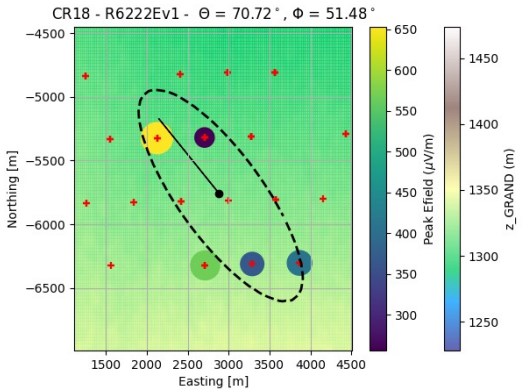


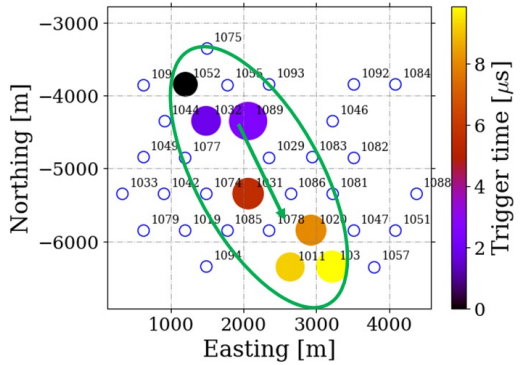


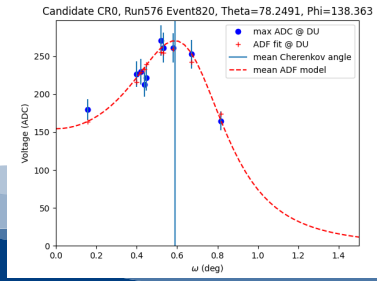
Arrival direction reconstruction by PWF in 01/2025

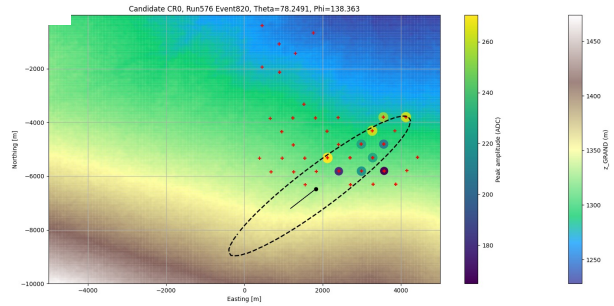








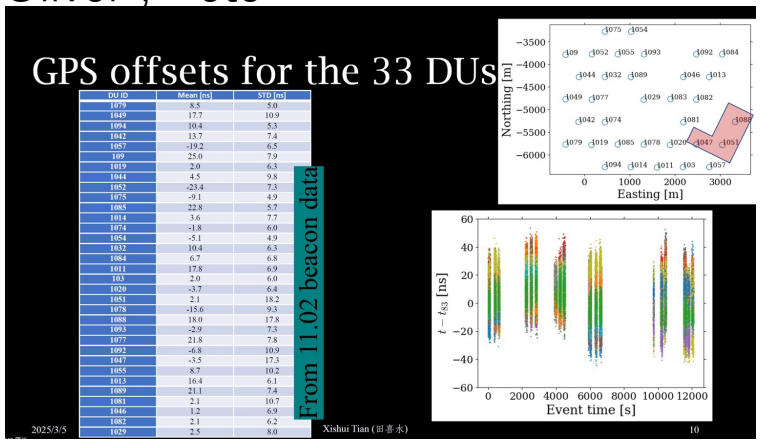




Pengxiong, Jolan Xishui, Lukas, Hanrui,etc

Part II： 9、Preliminary Study on Calibration： time, Gain, Pattern

Xidian、Xishui、 Xuxing、Pengxiong
Oliver， etc



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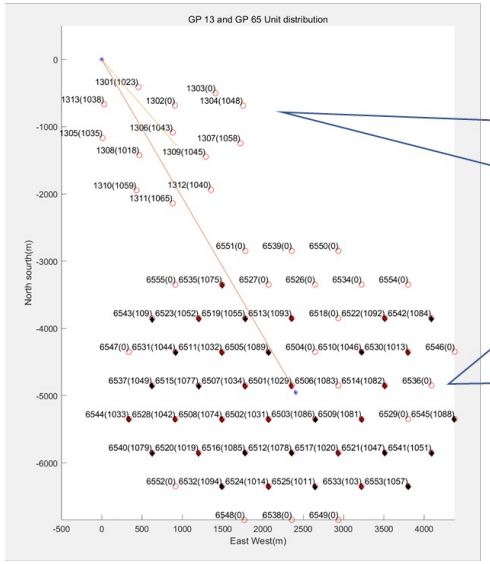

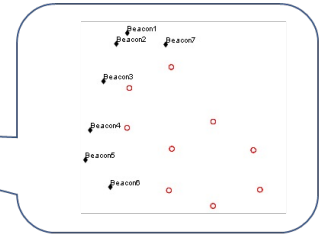

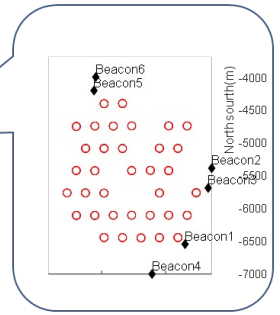

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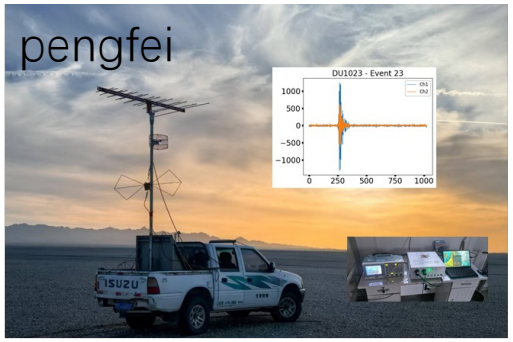
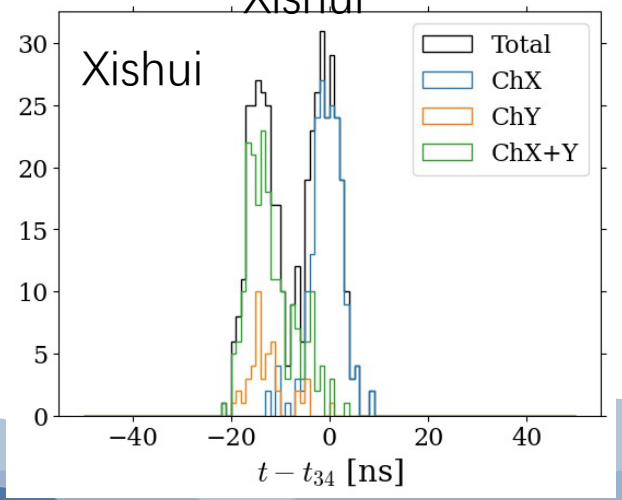


- Beacon (115MHz)
  - 3pulse
  - 100ms
  - 5V
  - 3minites
- DU
  - 1034+GP13/GP65
  - No LNA
  - L1 trigger
  - X or Y trigger

Xishui



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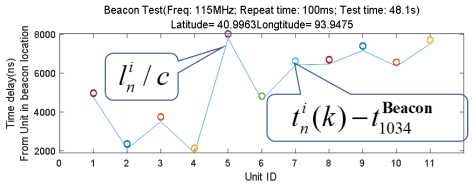

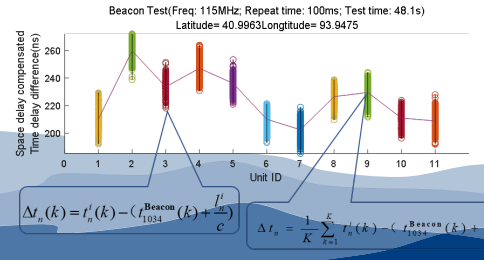

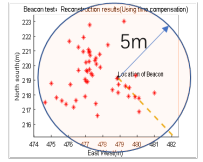

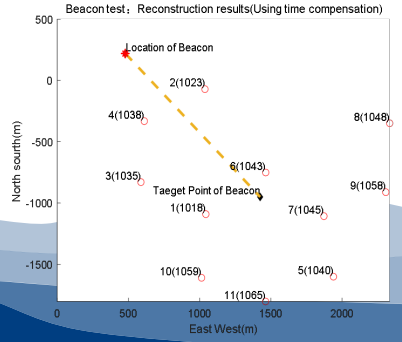

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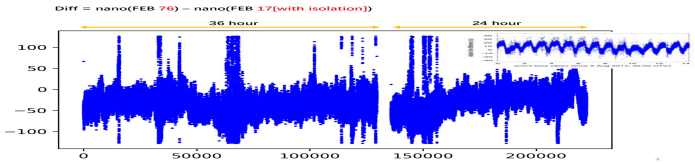
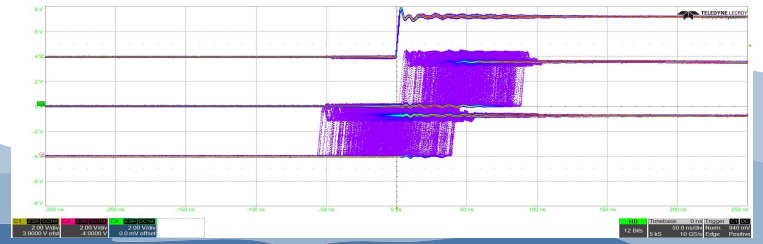
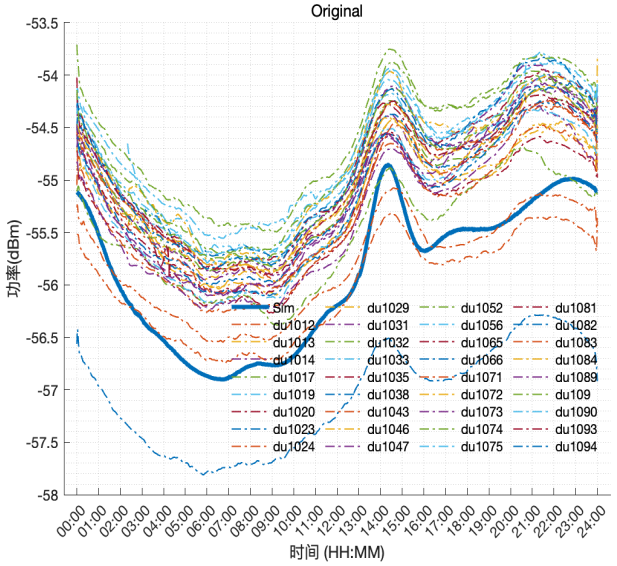
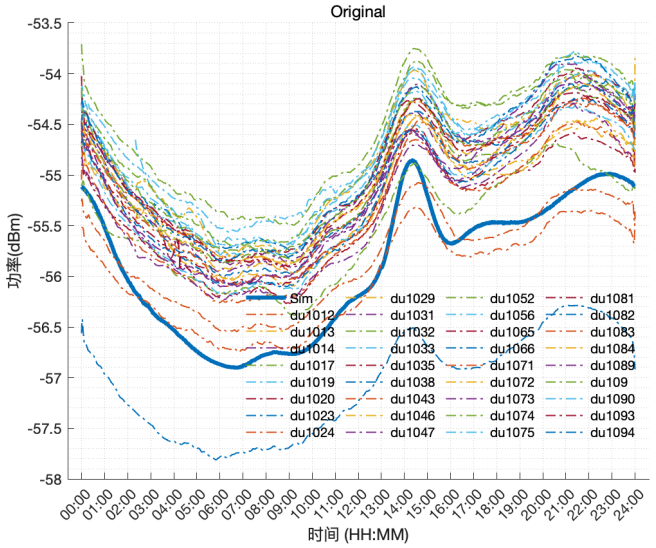
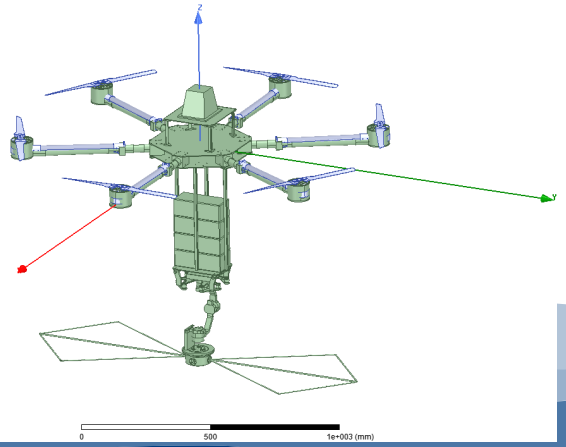


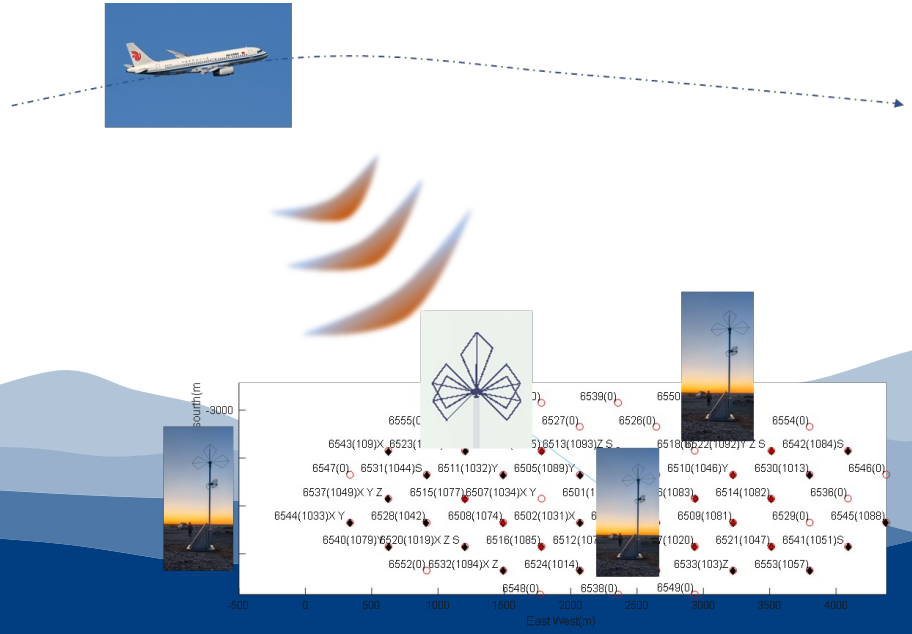


Part II： 9、Preliminary Study on Calibration： time, Gain, Pattern









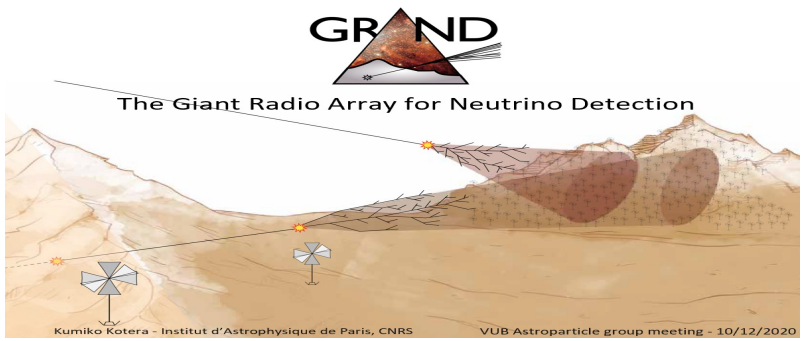
Contents

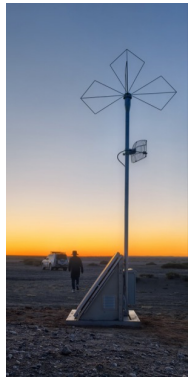
(1) Statues of Xiaodushan site.

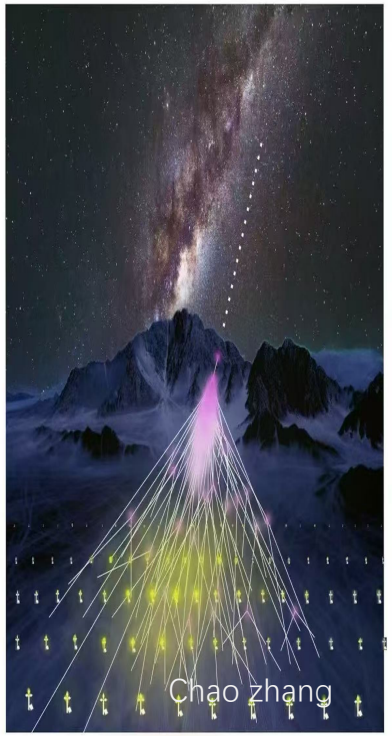
(2) Key technique achievements in GP13 and GP65 .

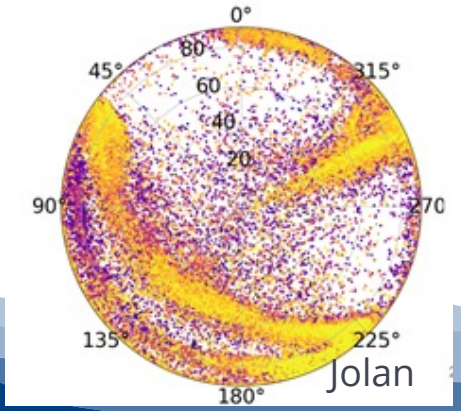
(3) Remain tasks for GP65.

(4) The plan for GP300/GP100/Heron



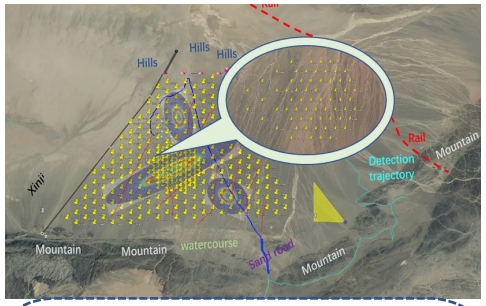


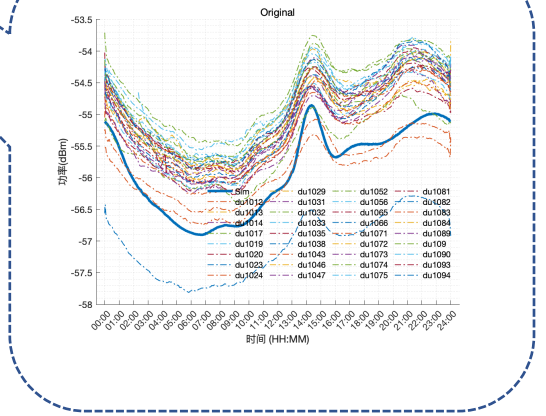


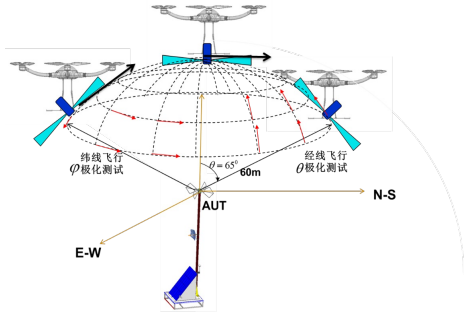


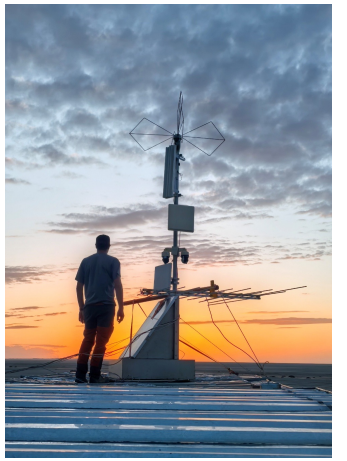
- **FEB update for stable running**

  - Location test based on RTK;
  - Gain calibration based on galactic noise
  - Pattern calibration and test based on UAV;
  - GPS time calibration based on Beacon and airplane;
  - Arm direction modification and calibration
  - Communication unbalance improvement
  - Data process (Trigger, filter, classify, reconstruction)



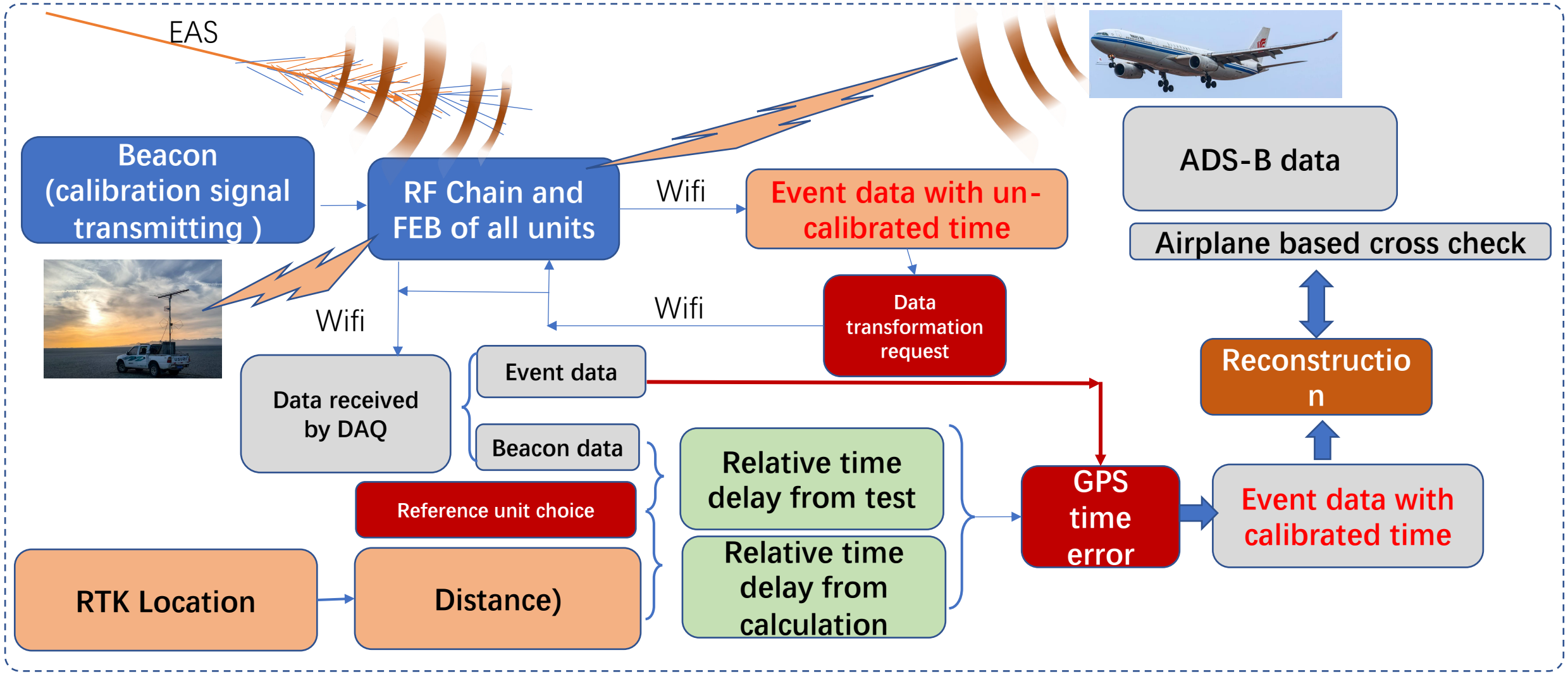






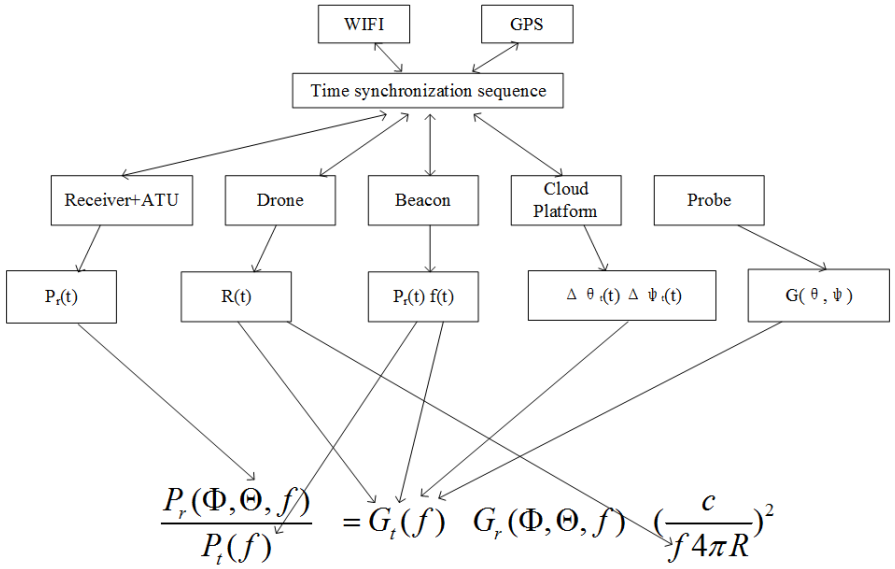
RTK based Location	Gain calibration	Pattern calibration UAV	GPS time calibration	Arm direction	Communication improvement
Center station	RF Chain model	UAV	Beacon antenna	Magnetic orientation tool	Rocket antenna design
Differential antenna	MD data	Antenna	Signal generation	Mechanical adjustment	Wifi antenna direction modify
portable power source	Galactic data	Driver	Soft ware update		
		Signal generation	Auxiliary verification		

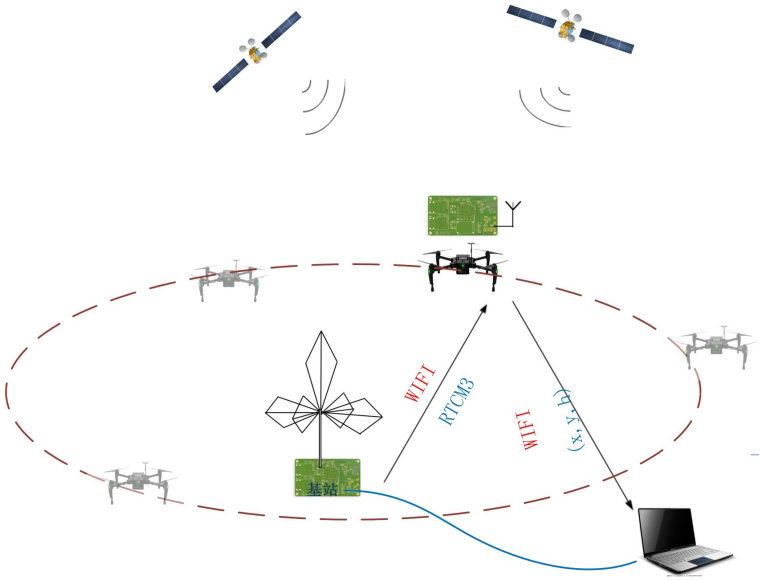
Typical task： GPS time calibration



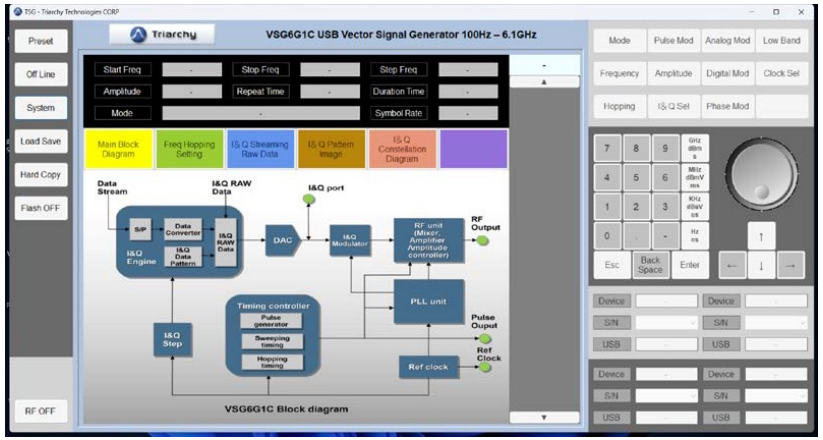
25

Typical task： UAV based Radiation pattern calibration





- AUT +DAQ +PC
- RTK + miniPC +Data transmission
- UAV+Flight controller Unit
- RF signal generator +PA+antenna



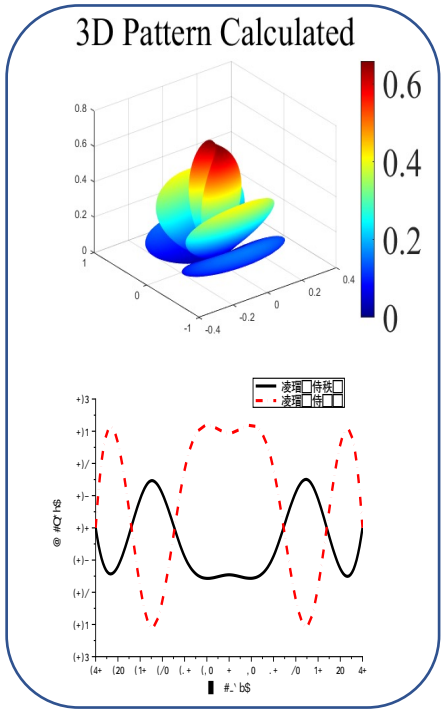
26

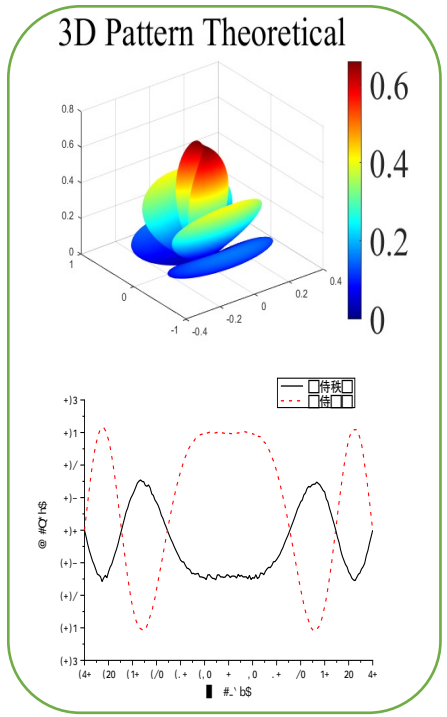
Typical task： Air plane-base pattern calibration: not a good candidate for the Initialization correction but for Run-time correction?

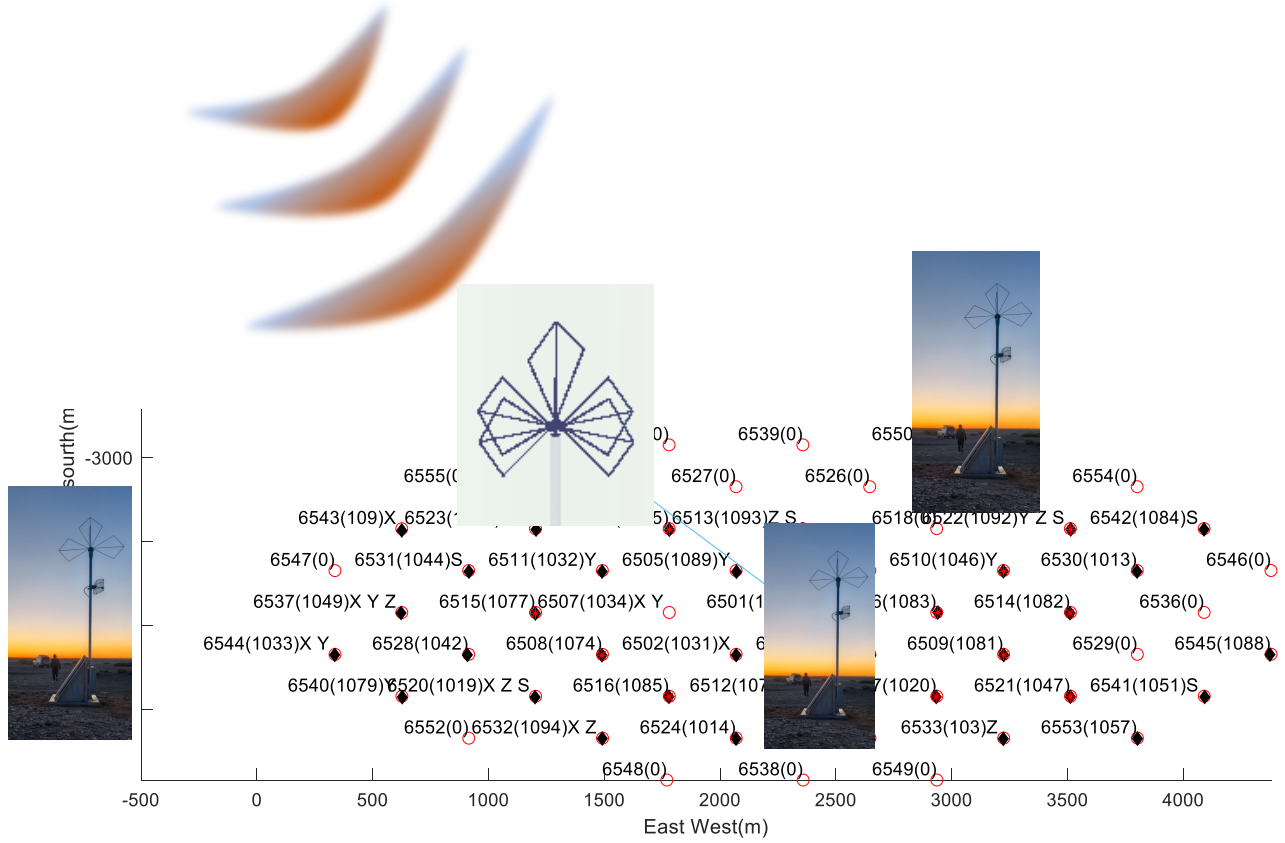
Polarization: Planner wave assumption

Character model:

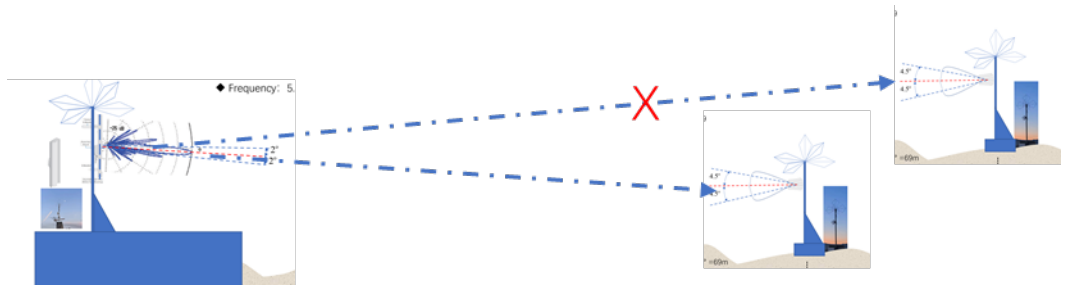
From several Points to 3D pattern

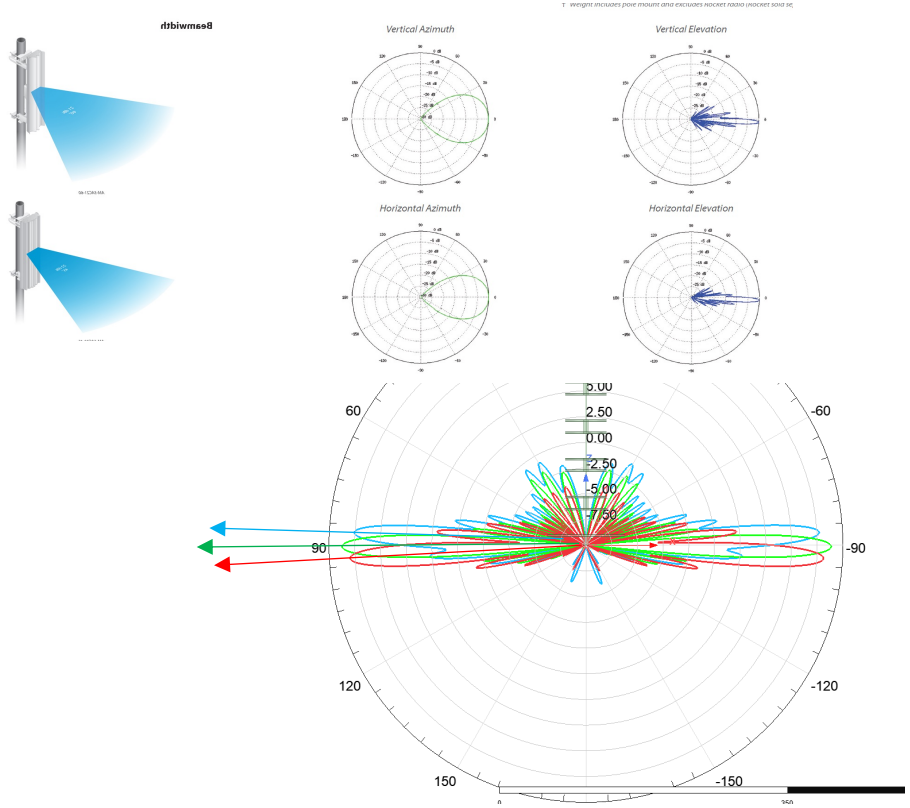




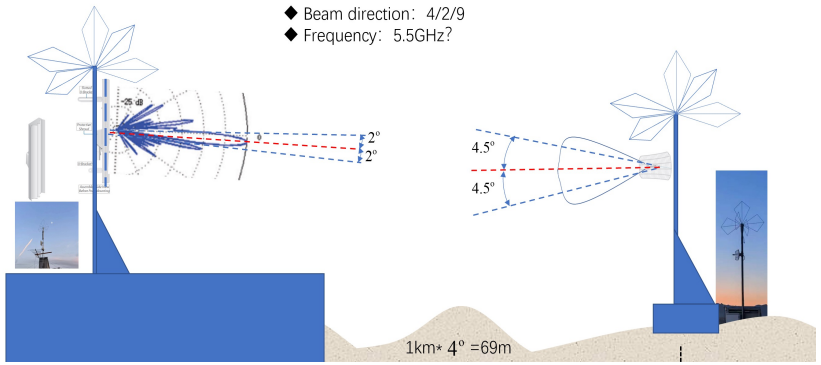


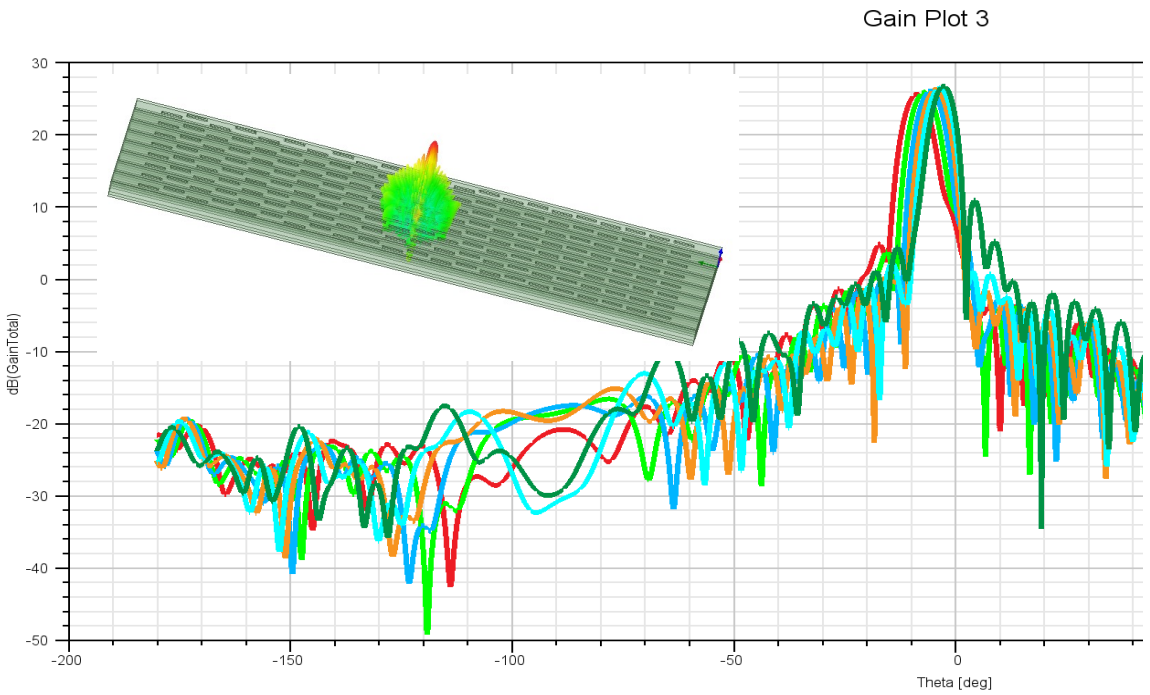
Typical task： communication improvement （Classify units based on beam direction）





◆ Power： 28dbm
◆ Beam direction： 4/2/9
◆ Frequency： 5.5GHz?





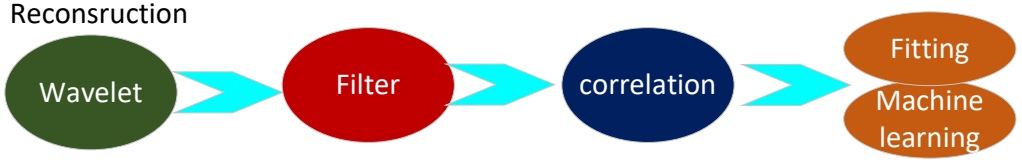
Combine 3 antenna together， generate high gain beam in different direction, classify units based on direction

Part III：Data process

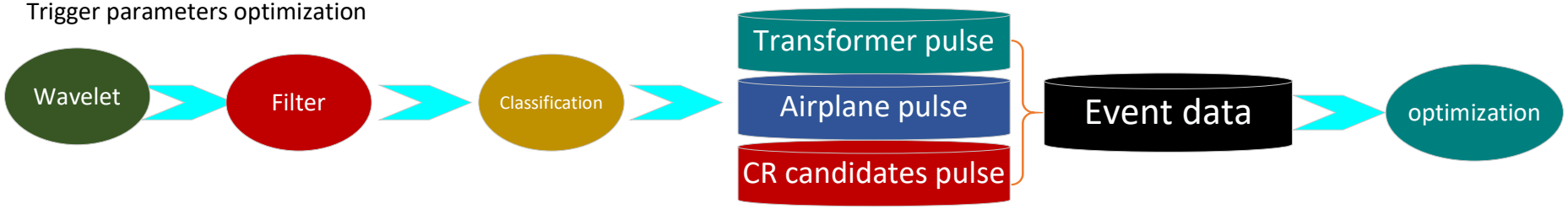
Xidian University

Denoise

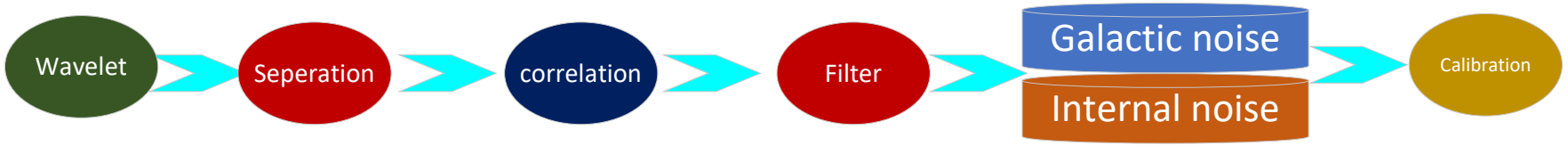
Reconsruction



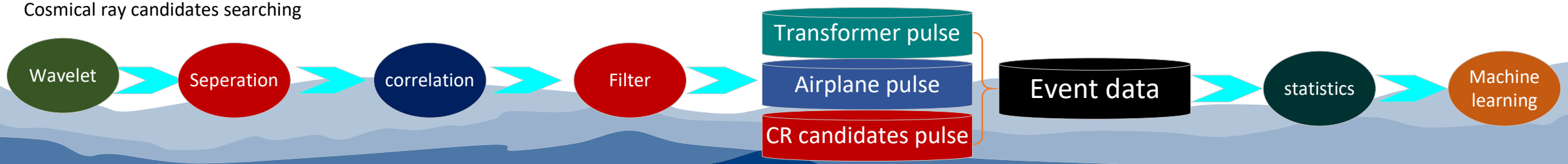
Trigger parameters optimization



Back ground noise Analyze



Cosmical ray candidates searching



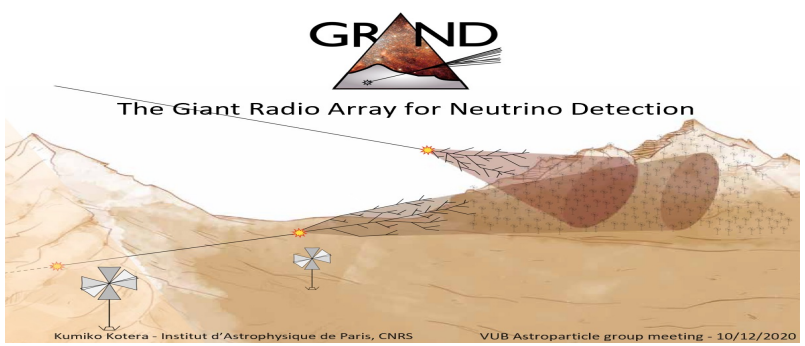
Contents

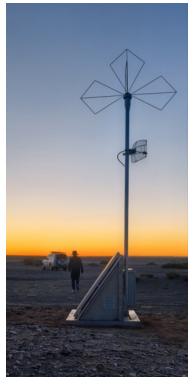
(1) Statues of Xiaodushan site.

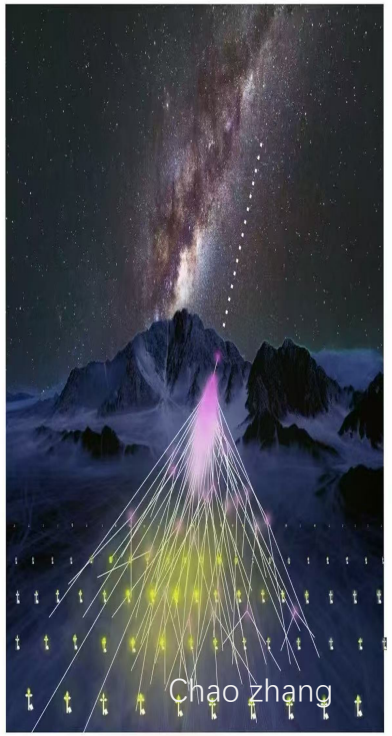
(2) Key technique achievements in GP13 and GP65 .

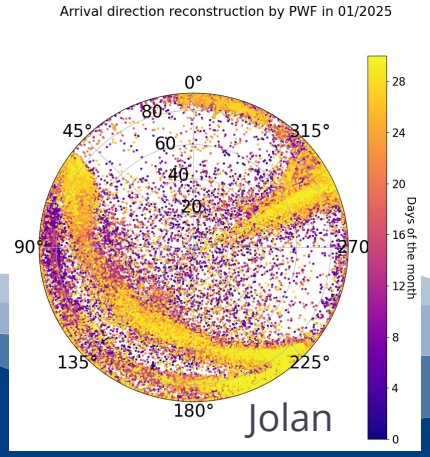
(3) Remain tasks for GP65.

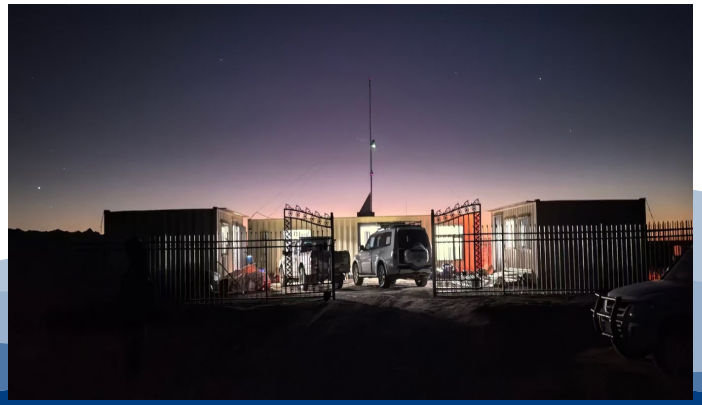
(4) The plan for GP300/GP100/Heron









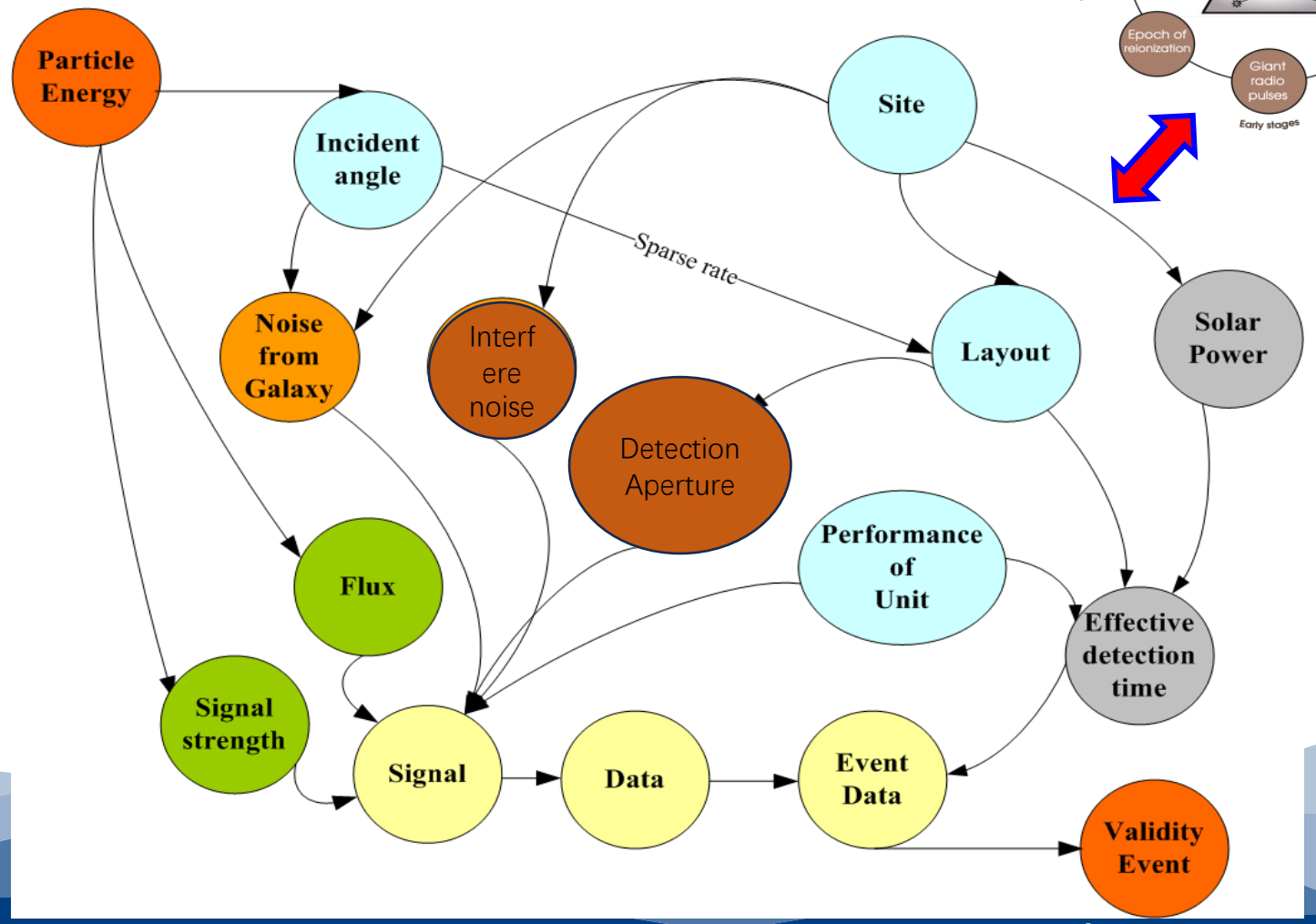


Detection capability

Success or failure?

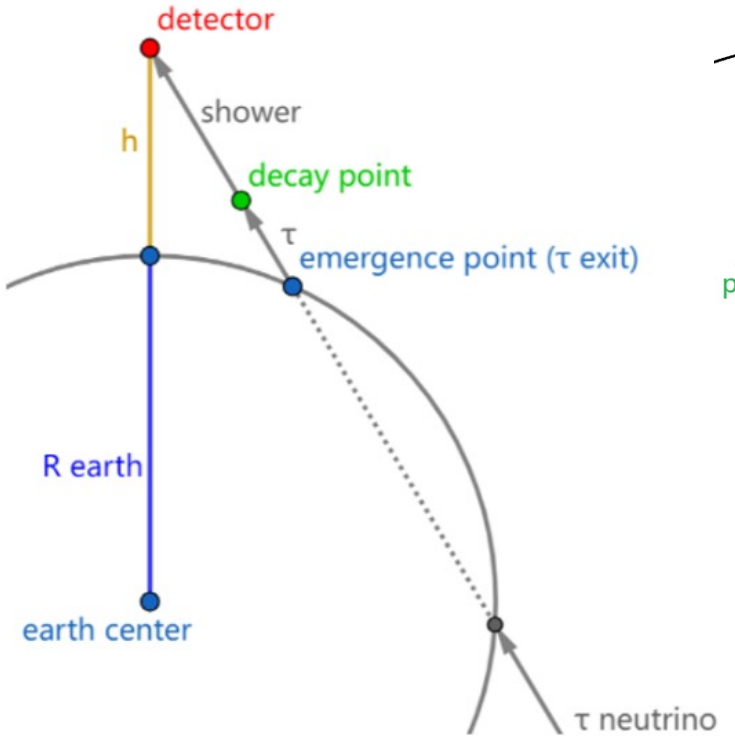
Detection precision

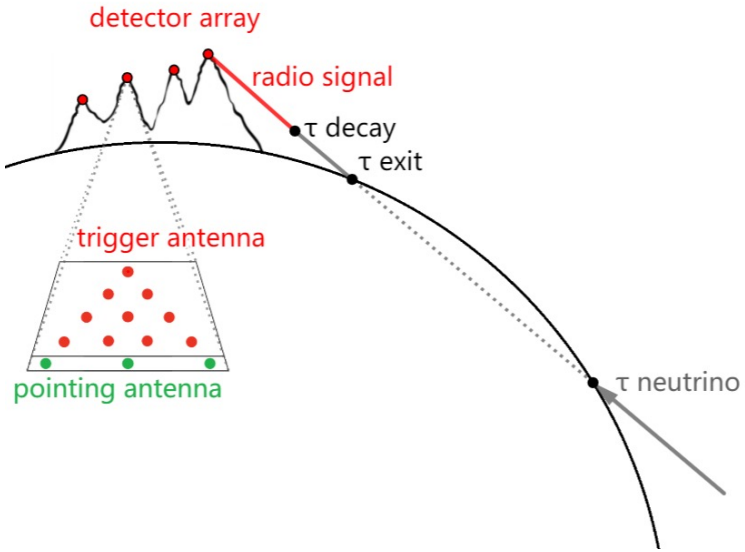
Good or bad?



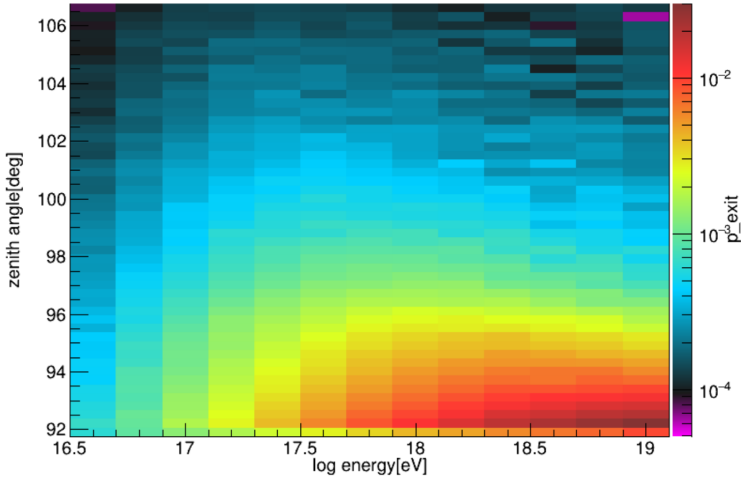
Part I： 1、Detection target , strategy and array scale

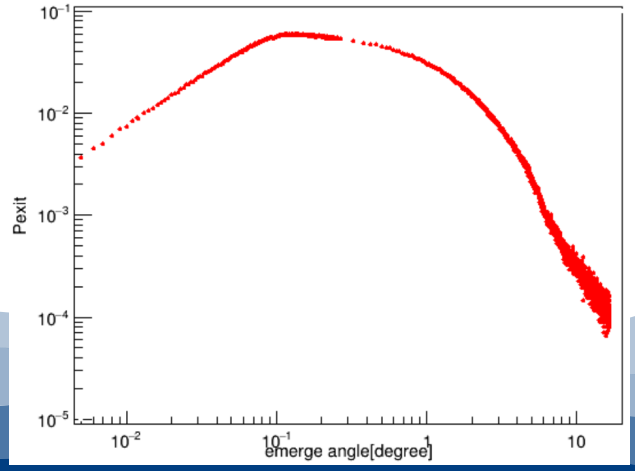
PMO:Xingyu



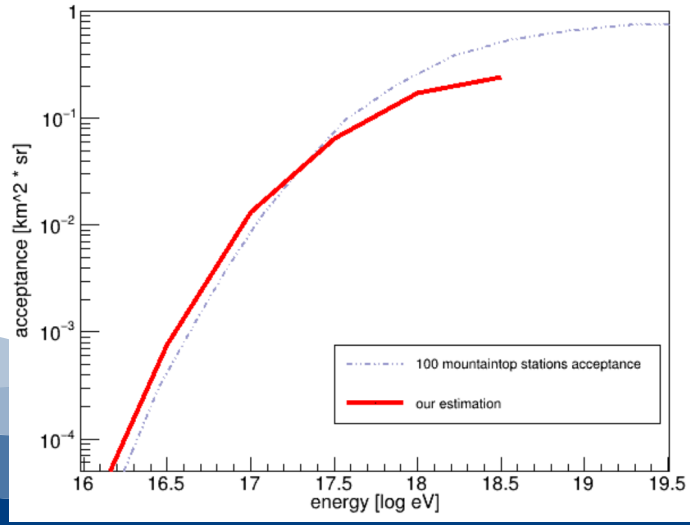


tau exit probability distribution

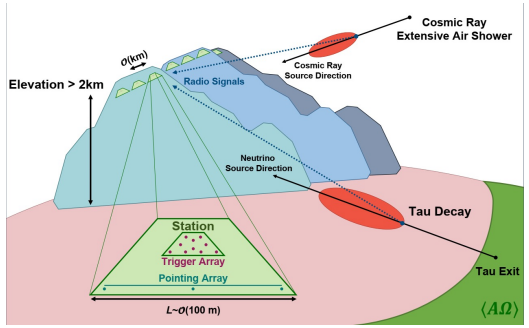


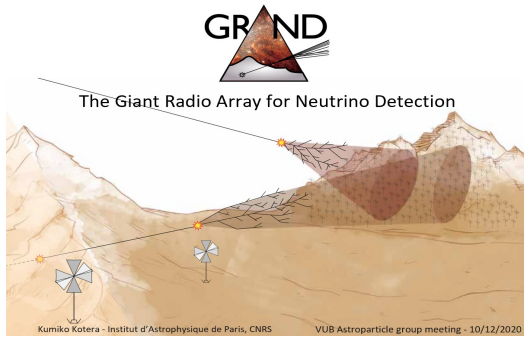


100 mountaintop stations acceptance



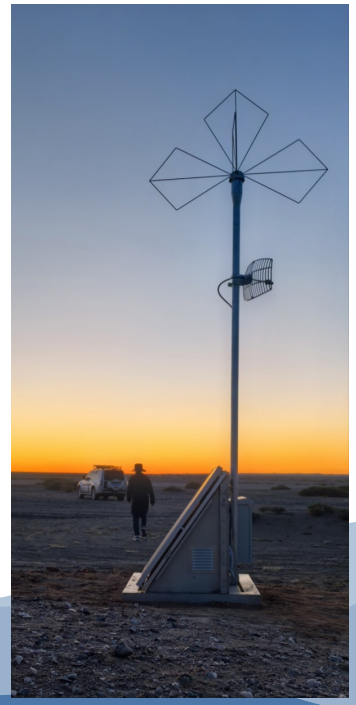
Part II： Beacon VS GRAND





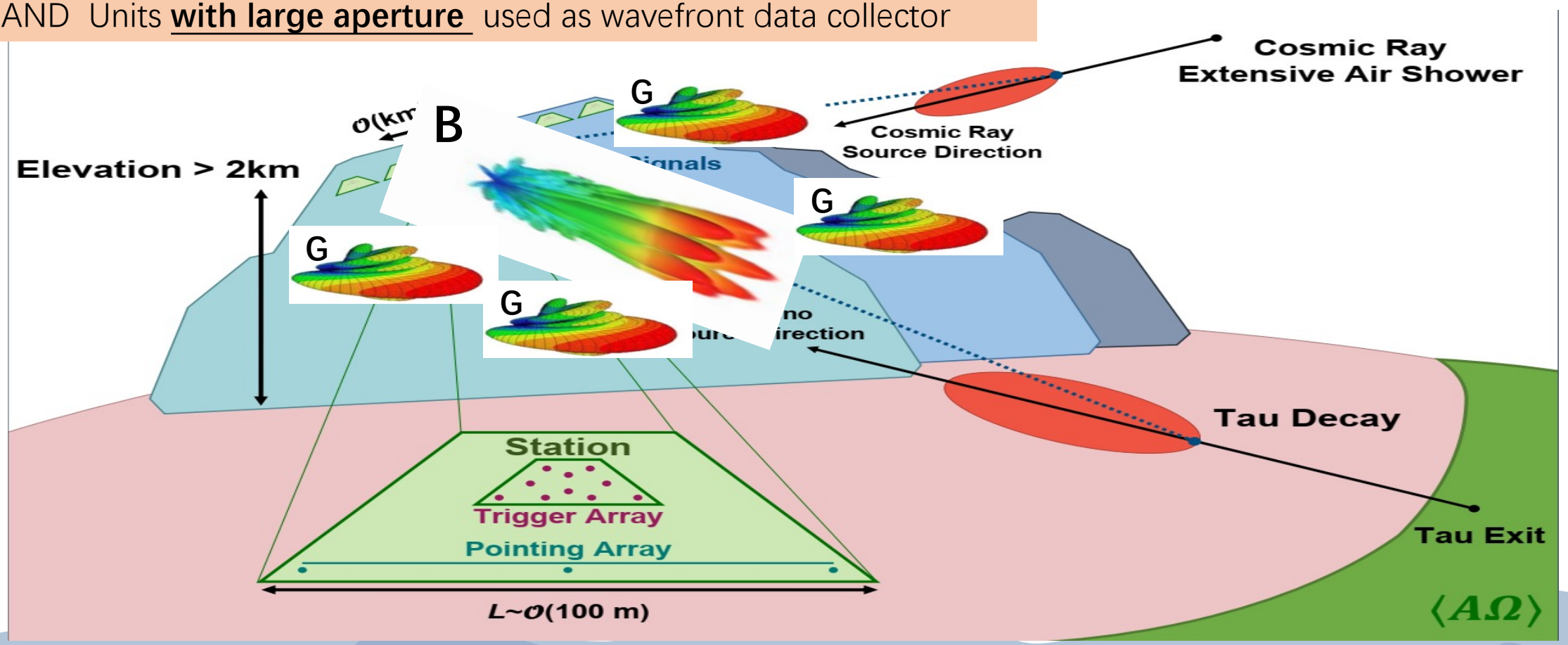
- High Gain Antenna
- LNA 36dB
- Array beam forming
- Fiber based Time synthesis?
- ADS cost: N
- High sensitivity
- 8bit/ 1024/30~80MHz

- Omi-direction Antenna
- LNA 40dB
- Coincident trigger
- GPS based time synthesis
- ADS cost: 1
- Large cover area
- 14bit/1024/50~200MHz

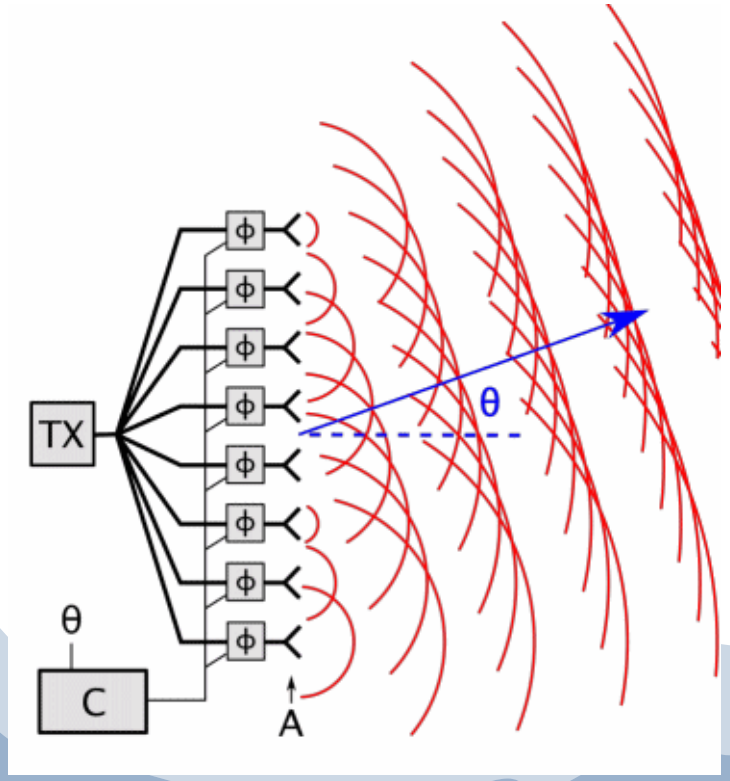


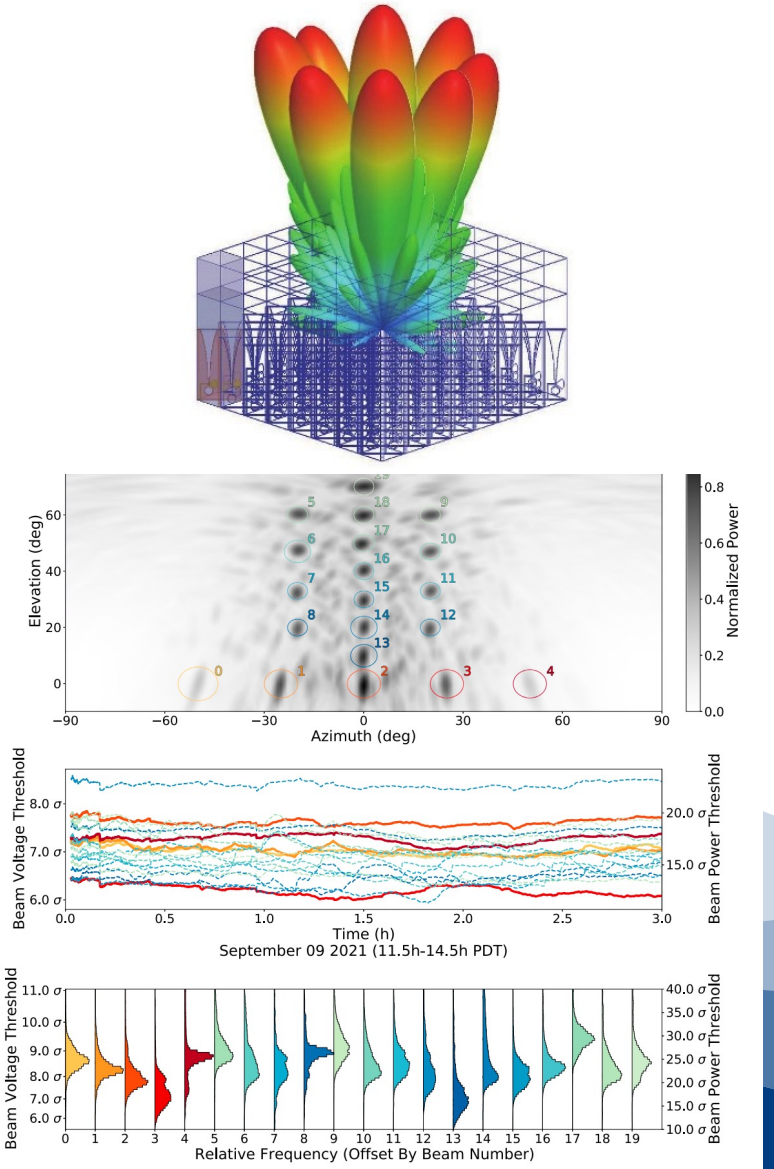
Part II： Beacon as trigger + GRAND large wavefront data collection

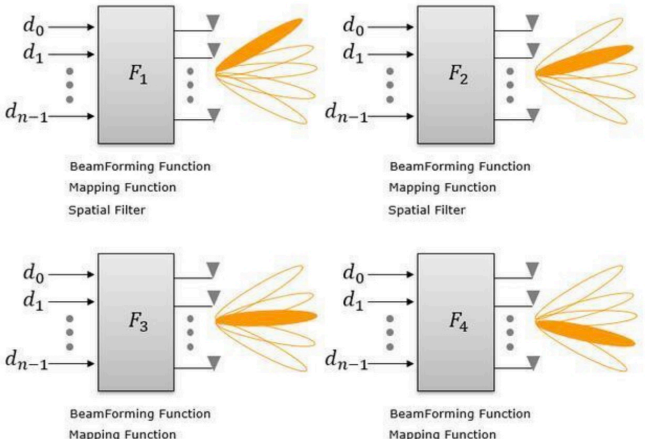
- Employ Beacon array **with high gain (sensitivity) multi-beam** as trigger
- The GRAND Units **with large aperture** used as wavefront data collector

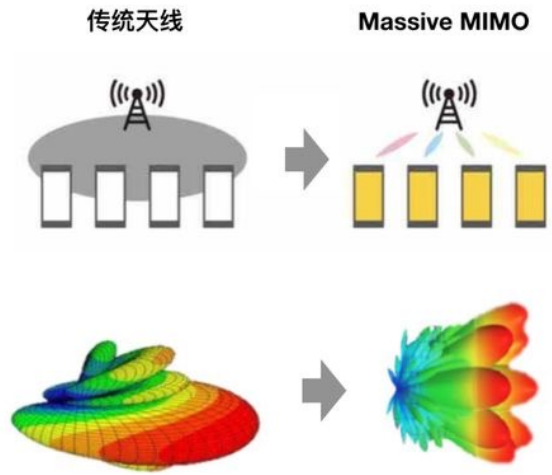


Part III Array choice： Phased array/ beam forming/ DBF

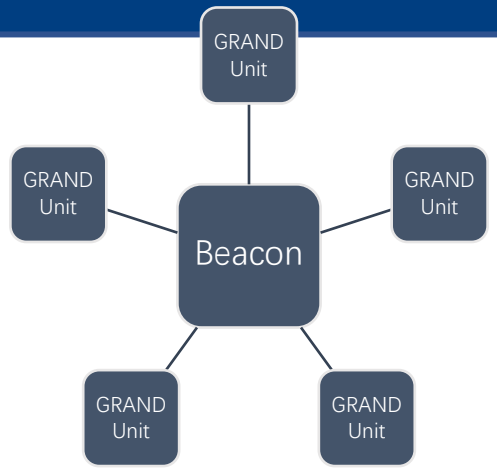








Part IV： System design



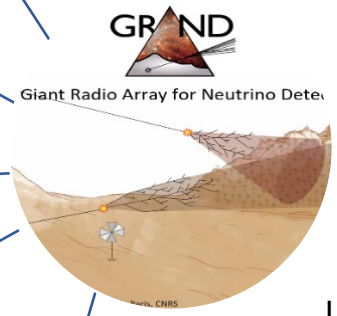
Antenna
- Radiator
- cable

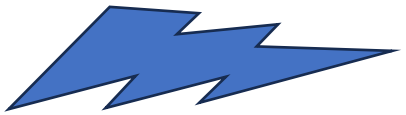
TF Chain
- LNA
- Filter

FEB
- Beam forming
- Trigger

Time & communication
- synchronization

Power supply





Trigger System
like calibration beacon now

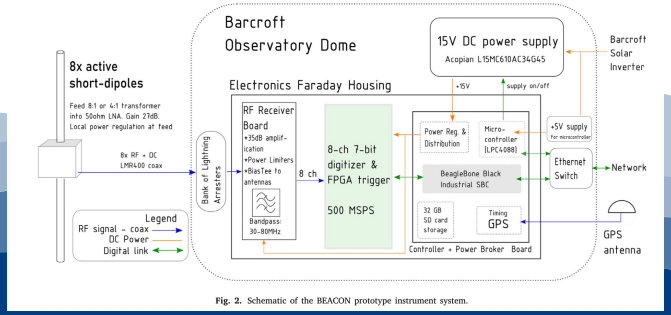
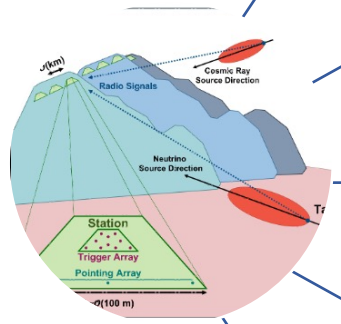


Fig. 2. Schematic of the BEACON prototype instrument system.



Antenna
- Radiator
- cable

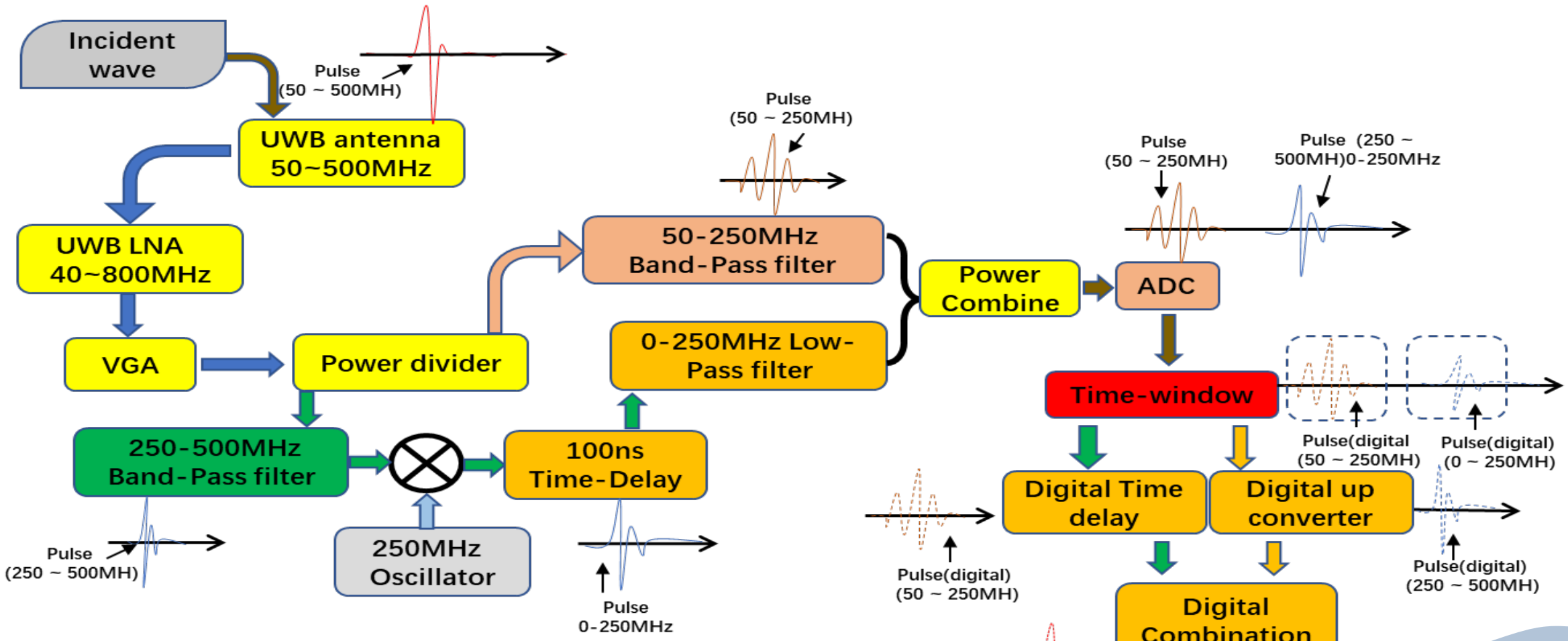
TF Chain
- LNA
- Filter

FEB
- Beam forming
- Trigger

Time & communication
- synchronization

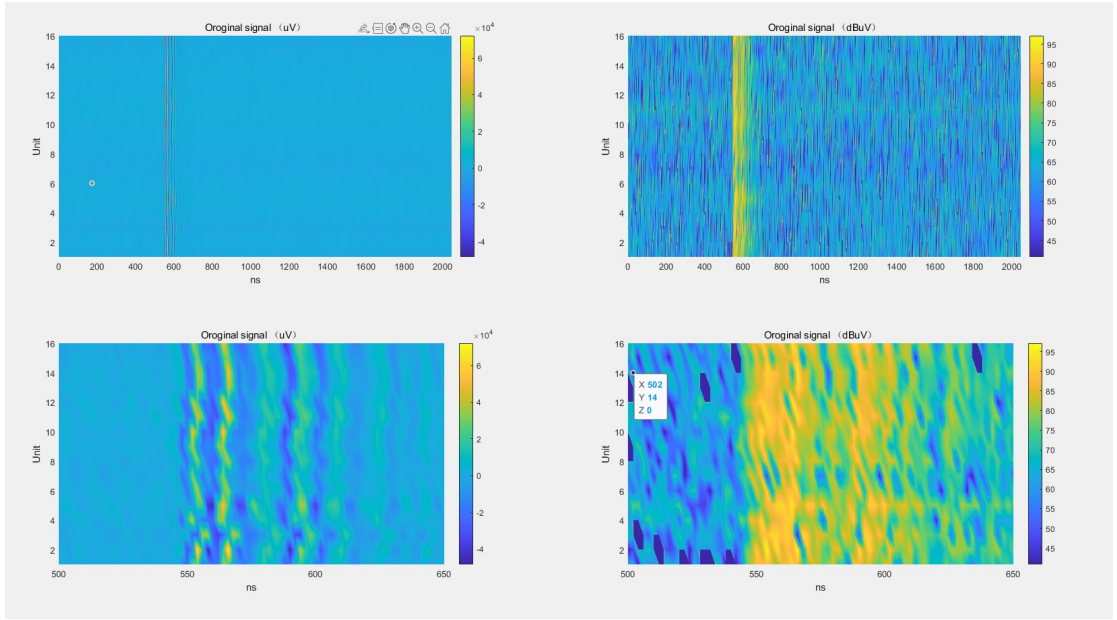
Power supply

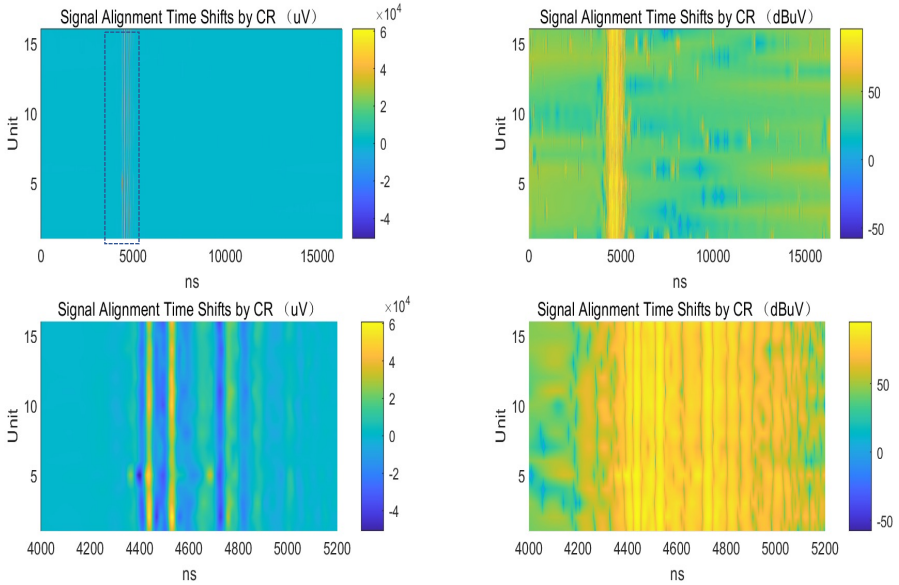
Part IV： Some other idea –Data enhancement

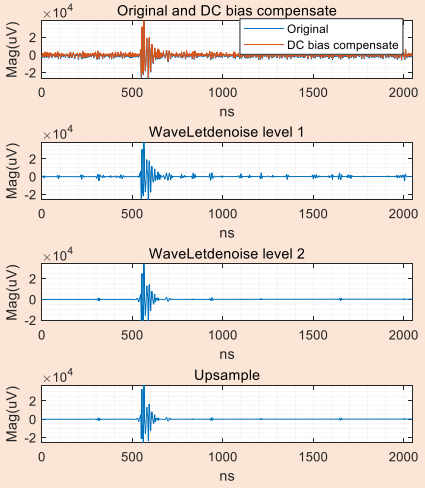


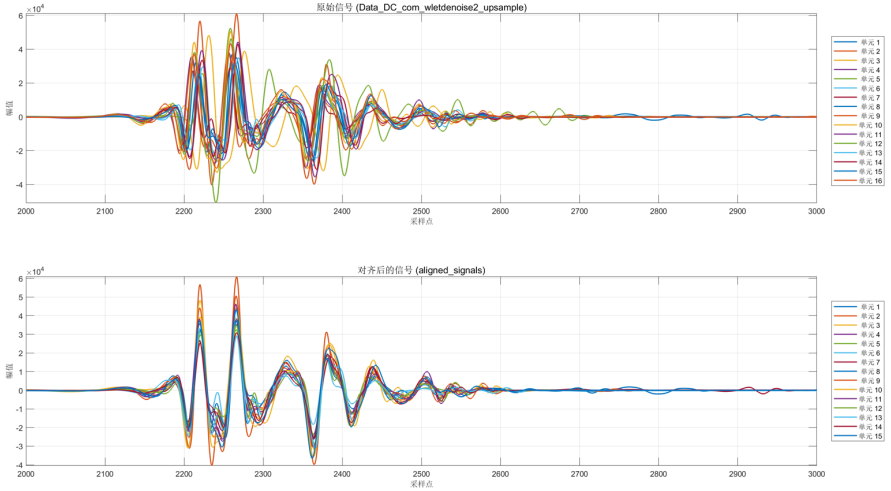
29dB of LNA provide compensation to the loss from power divider and filter

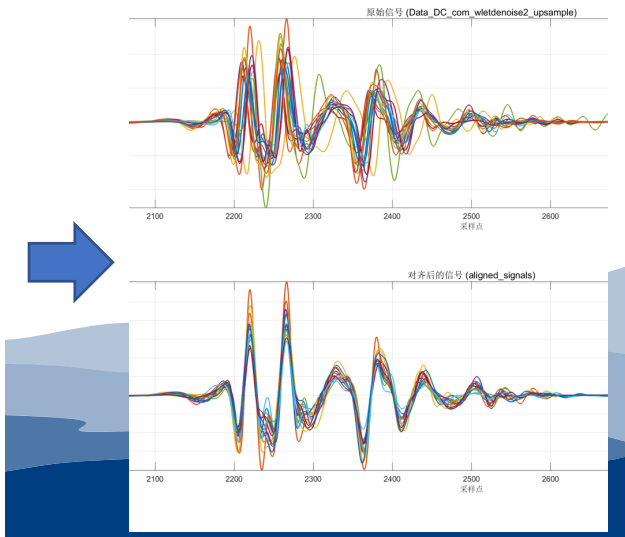
Part IV： Some other idea –data compression (More detail in report from Hanrui)



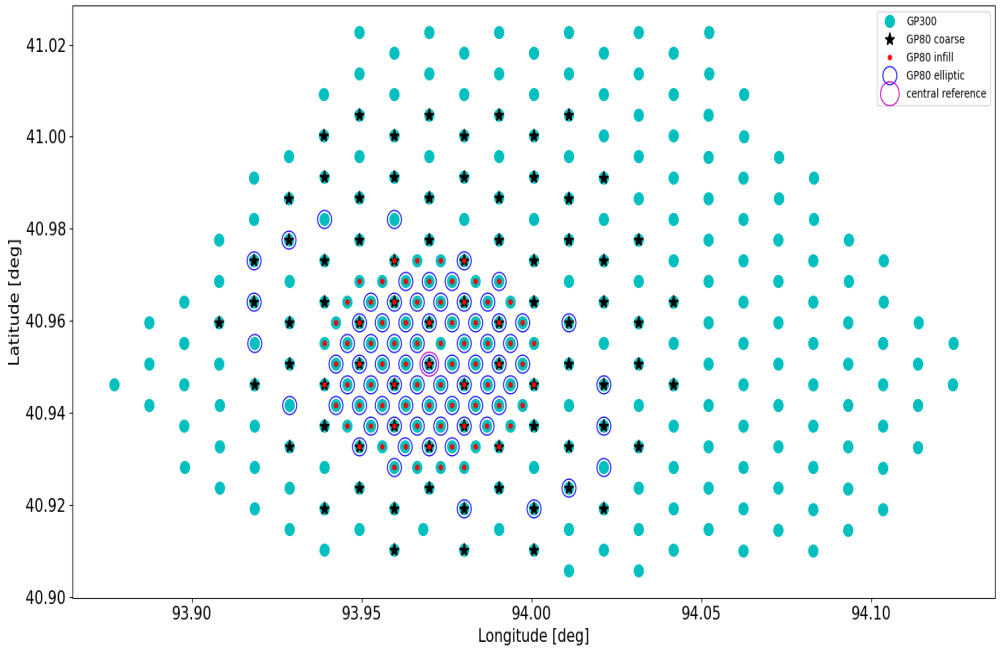


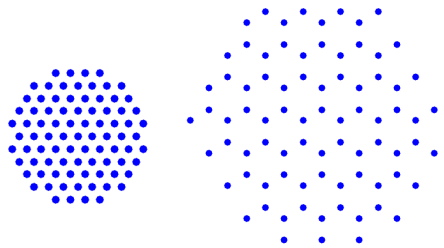


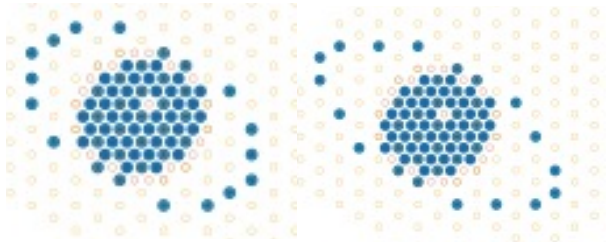


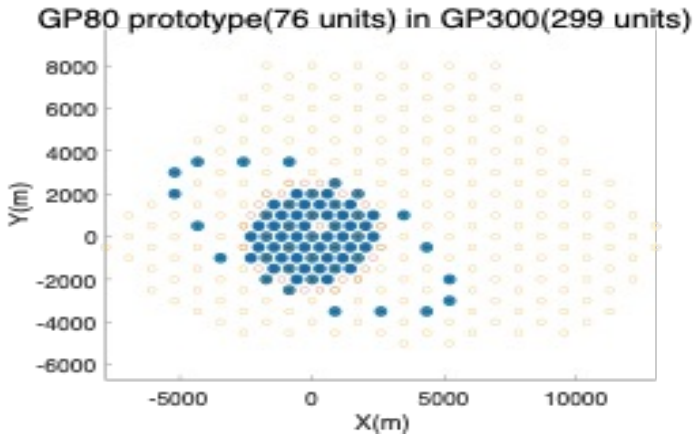


Part IV： 2、 The Choices of Layout



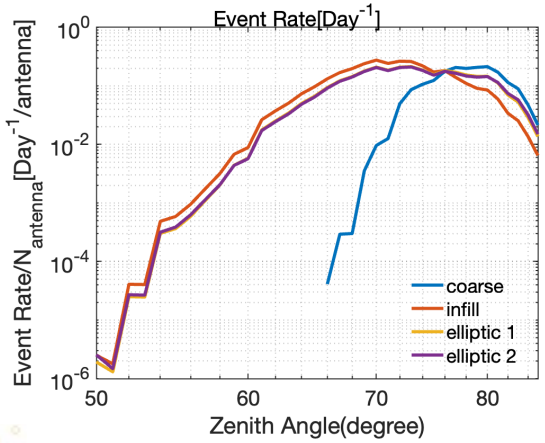


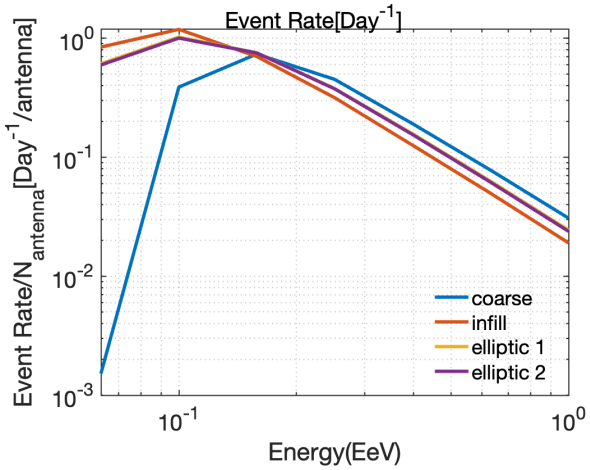


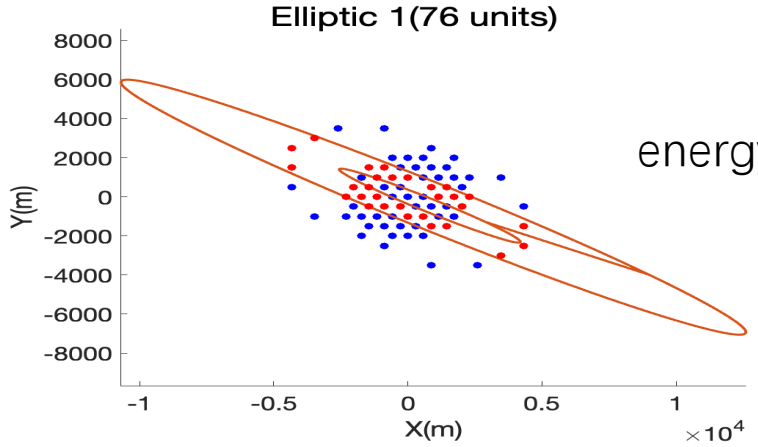


Performance evaluation:

- 200Events/day (75uv/m； 5antennas)
- 1 event/day for 85 degree zenith angle







Layout	Infill	Coarse	Elliptic 1	Elliptic 2
N_{ev}	275.51	150.11	228.65	225.38
$N_{ev}/N_{antenna}$	3.2413	1.8764	3.0086	2.9655

Typical case：

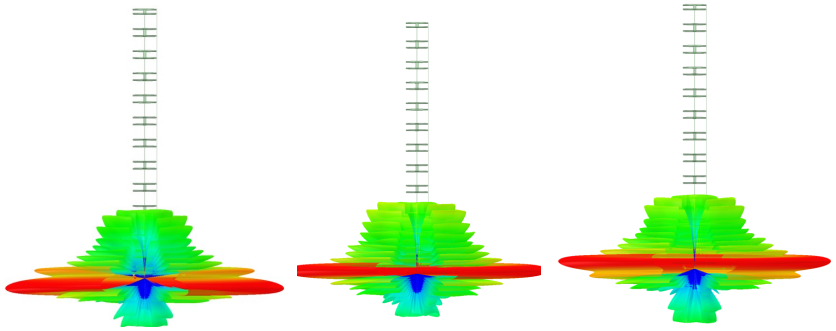
energy=0.4 EeV Zenith=85

Is it ok for reconstruction? : 28 units fired

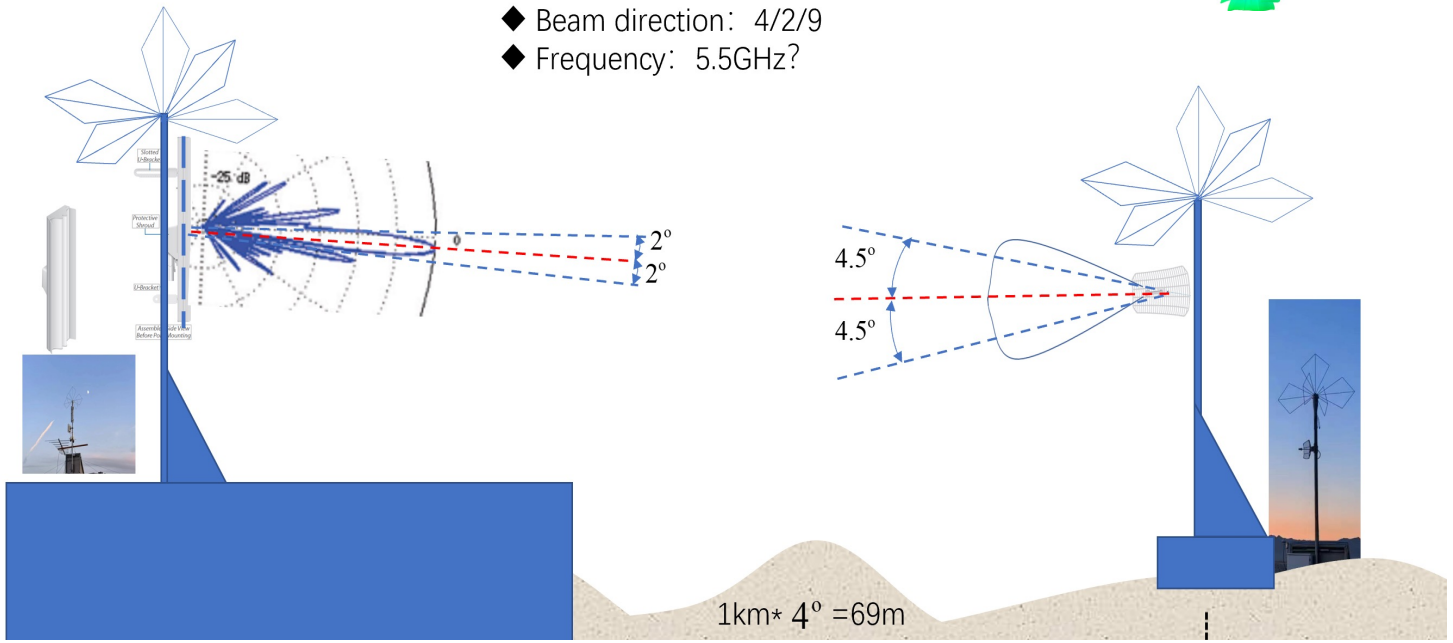
Part IV： 3、 The Choices of communication topology and Rocket antenna

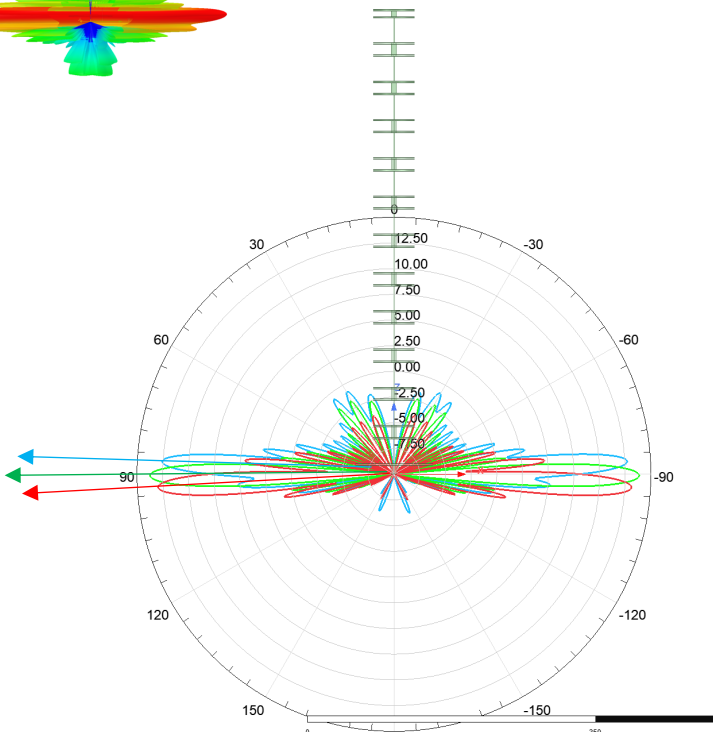
- PTP1： 180Mbps ； PTAP?
- Beam direction:

  Frequency depend “SCANNING CAPABILTY”



◆ Power： 28dbm
◆ Beam direction： 4/2/9
◆ Frequency： 5.5GHz?





Conclusion:

&. We are ready to move to a HECR detection time;

&. Calibration and data processing will be the key points For GP65;

&. Plan of GRAND-Beacon need more time and discuss！