

Current and Future Research Projects on  
Particle Astrophysics in IHEP

**Shuang-Nan Zhang**

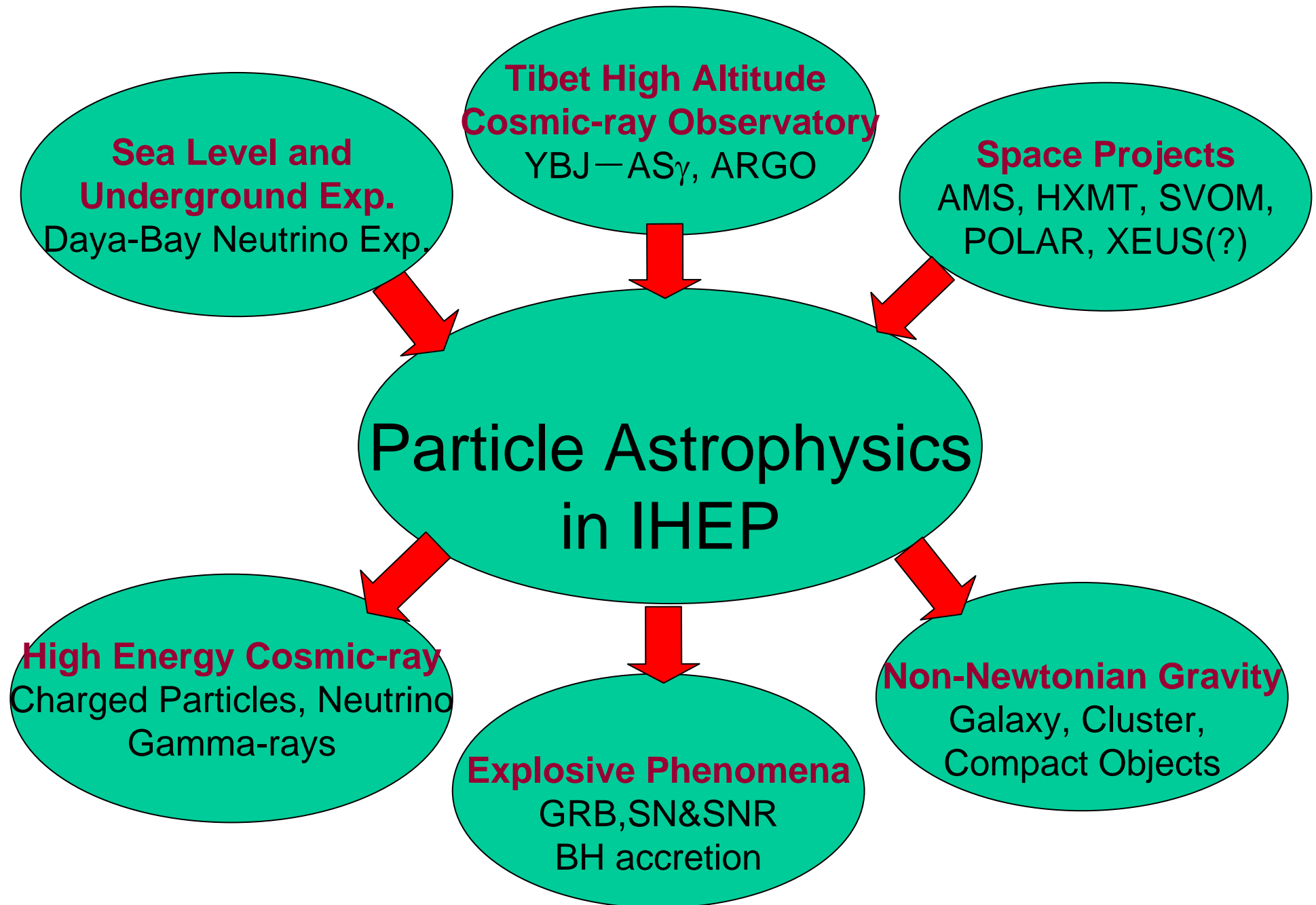
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# Sea Level and Underground Experiments

# Neutrino mixing parameters

$$\begin{pmatrix} \nu_e \\ \nu_\mu \\ \nu_\tau \end{pmatrix} = \begin{pmatrix} U_{e1} & U_{e2} & U_{e3} \\ U_{\mu1} & U_{\mu2} & U_{\mu3} \\ U_{\tau1} & U_{\tau2} & U_{\tau3} \end{pmatrix} \begin{pmatrix} \nu_1 \\ \nu_2 \\ \nu_3 \end{pmatrix}$$

## Parameterization of neutrino mixing

$$U = \begin{pmatrix} 1 & 0 & 0 \\ 0 & \cos \theta_{23} & \sin \theta_{23} \\ 0 & -\sin \theta_{23} & \cos \theta_{23} \end{pmatrix} \begin{pmatrix} \cos \theta_{13} & 0 & e^{-i\delta} \sin \theta_{13} \\ 0 & 1 & 0 \\ -e^{i\delta} \sin \theta_{13} & 0 & \cos \theta_{13} \end{pmatrix} \begin{pmatrix} \cos \theta_{12} & \sin \theta_{12} & 0 \\ -\sin \theta_{12} & \cos \theta_{12} & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

## 6 fundamental parameters in neutrino physics:

Known:  $|\Delta m^2_{32}|$ ,  $\sin^2 2\theta_{32}$ ,  $\Delta m^2_{21}$ ,  $\sin^2 2\theta_{21}$

Unknown:  **$\sin^2 2\theta_{13}$** ,  **$\delta$ , sign of  $\Delta m^2_{32}$**

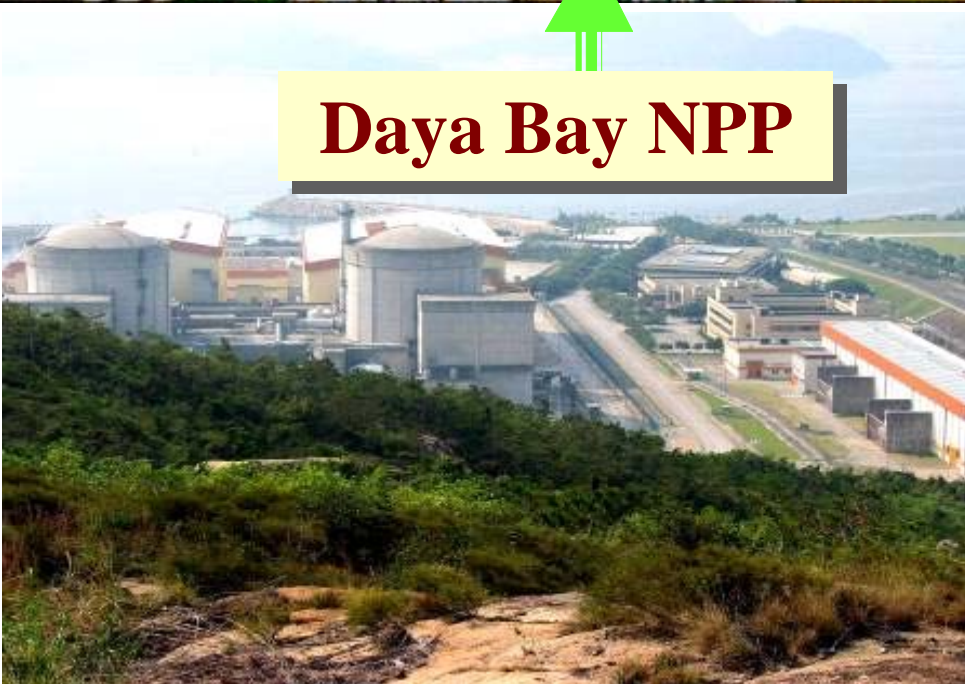
Exp. : reactor  $\nu$  **VLBL  $\nu$  oscillation**

Daya Bay Reactor **J-Parc  $\rightarrow$  Beijing**

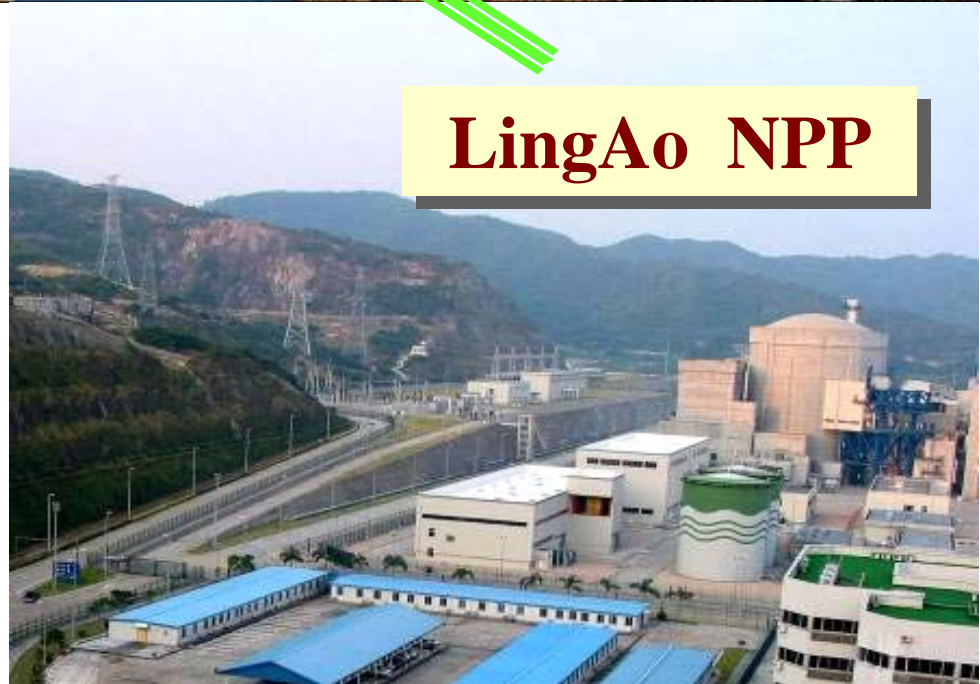
# Daya bay reactor neutrino experiment with sensitivity of 0.01 to $\sin^2 2\theta_{13}$



**Daya Bay NPP**



**LingAo NPP**



Far site:  
Overburden: ~1000 m.w.e.

1175 m

570 m

Ling Ao Near:  
Overburden: ~320 m.w.e.

672 m  
(12% slope)

590 m  
295 m  
(8% slope)

Daya Bay Near:  
Overburden: ~330 m.w.e.

Ling Dong NPP  
(under const.)

Ling Ao NPP

Daya Bay NPP

Total length of tunnel = 3372.5 m



# Schedule of the project

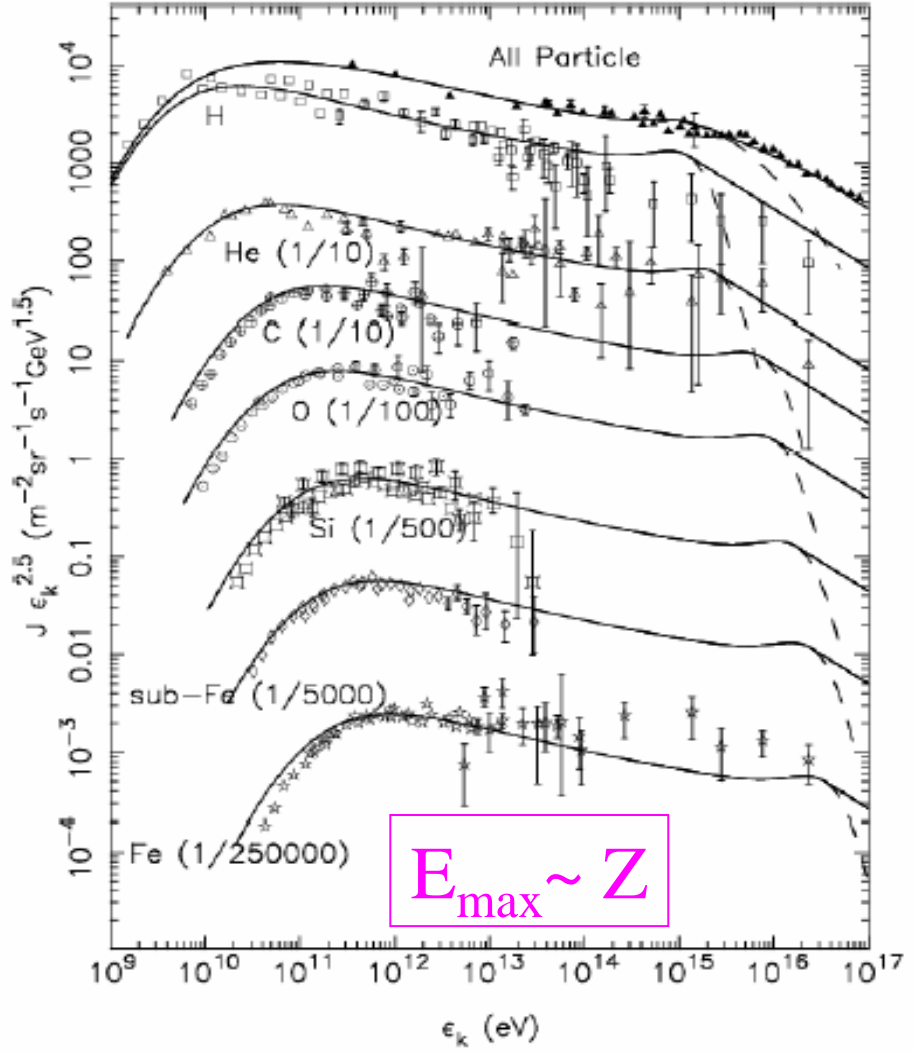
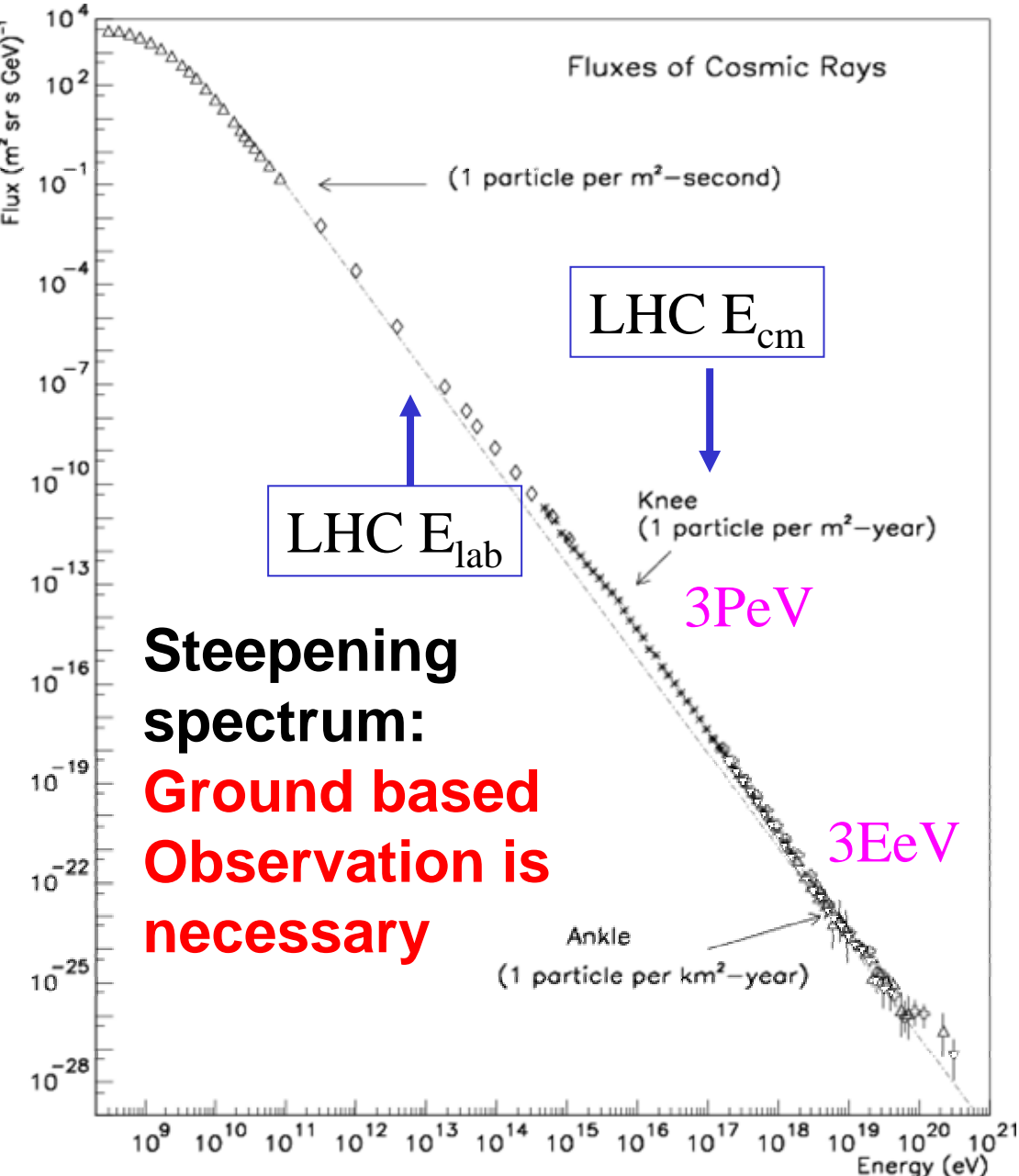
- **Schedule**

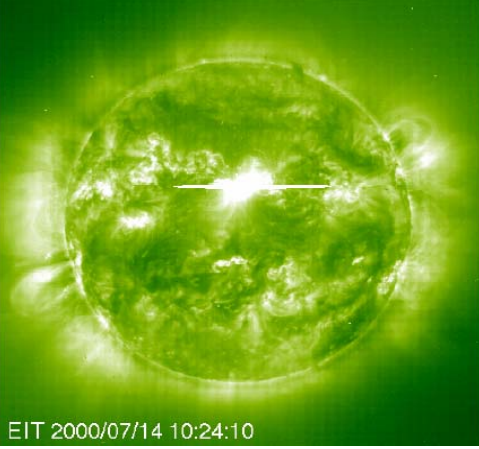
- **2004-2006**    **R&D, engineering design,  
secure funding**
- **2007-2008**    **construction**
- **2009**            **installation**
- **2010**            **running**

# High Altitude Mountain Experiments

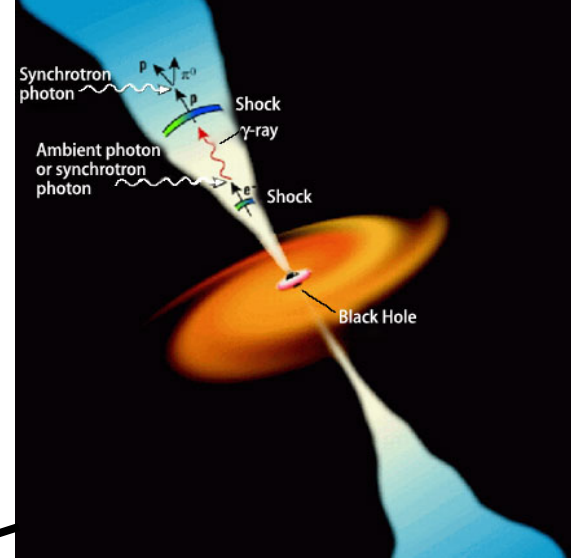


# CR spectrum





$$E_{\max} = \beta ZBL$$

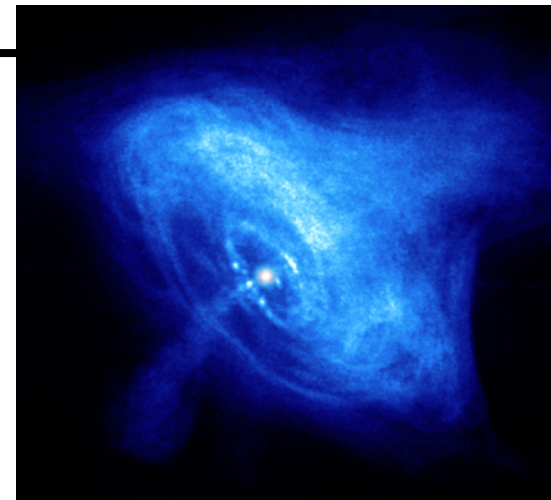
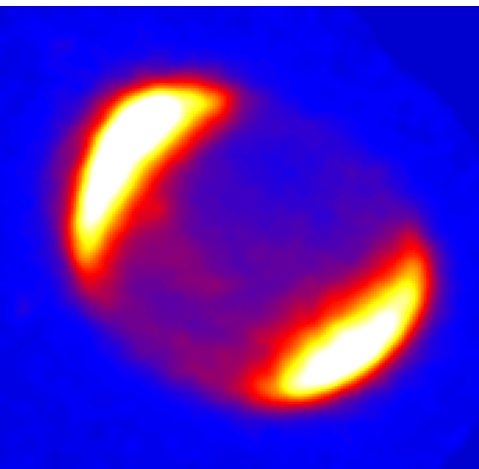
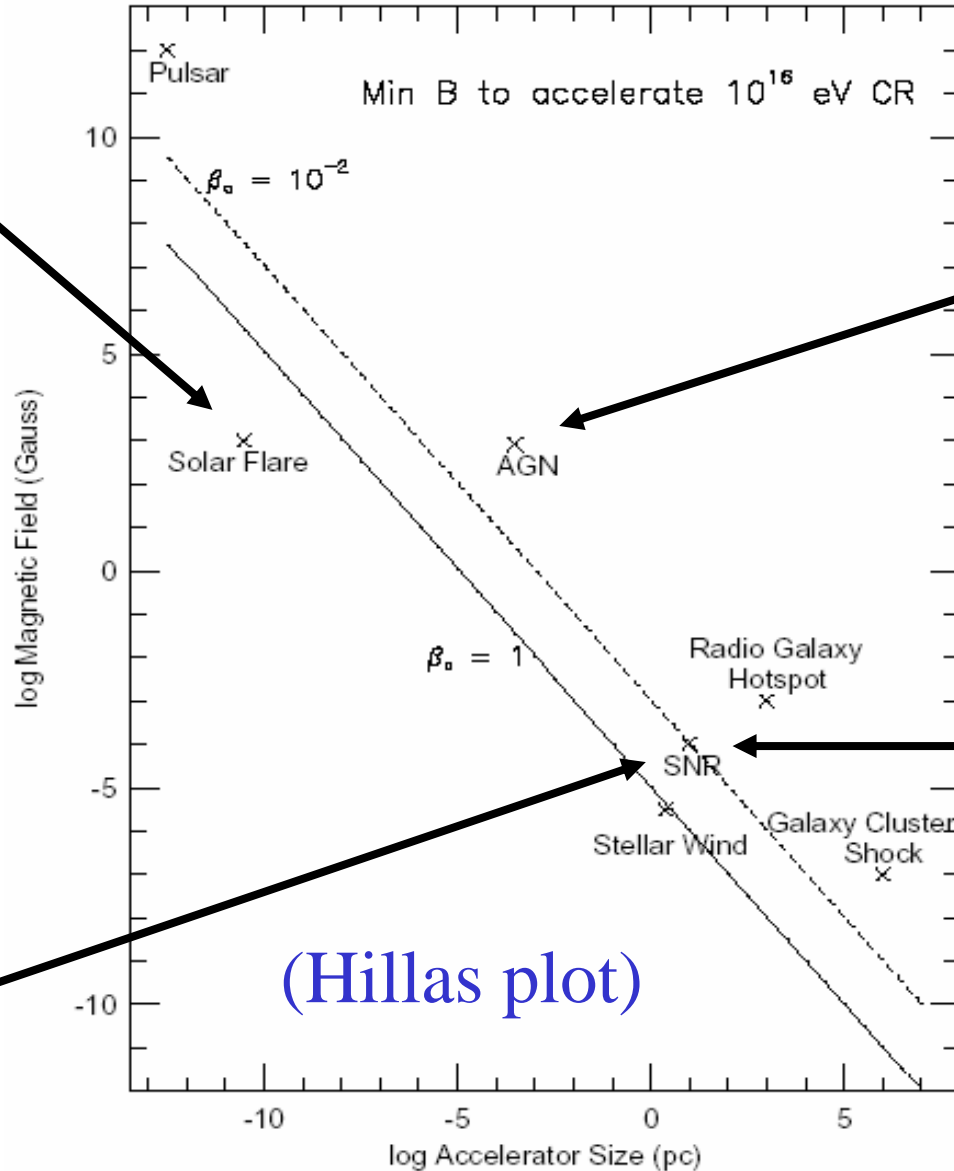


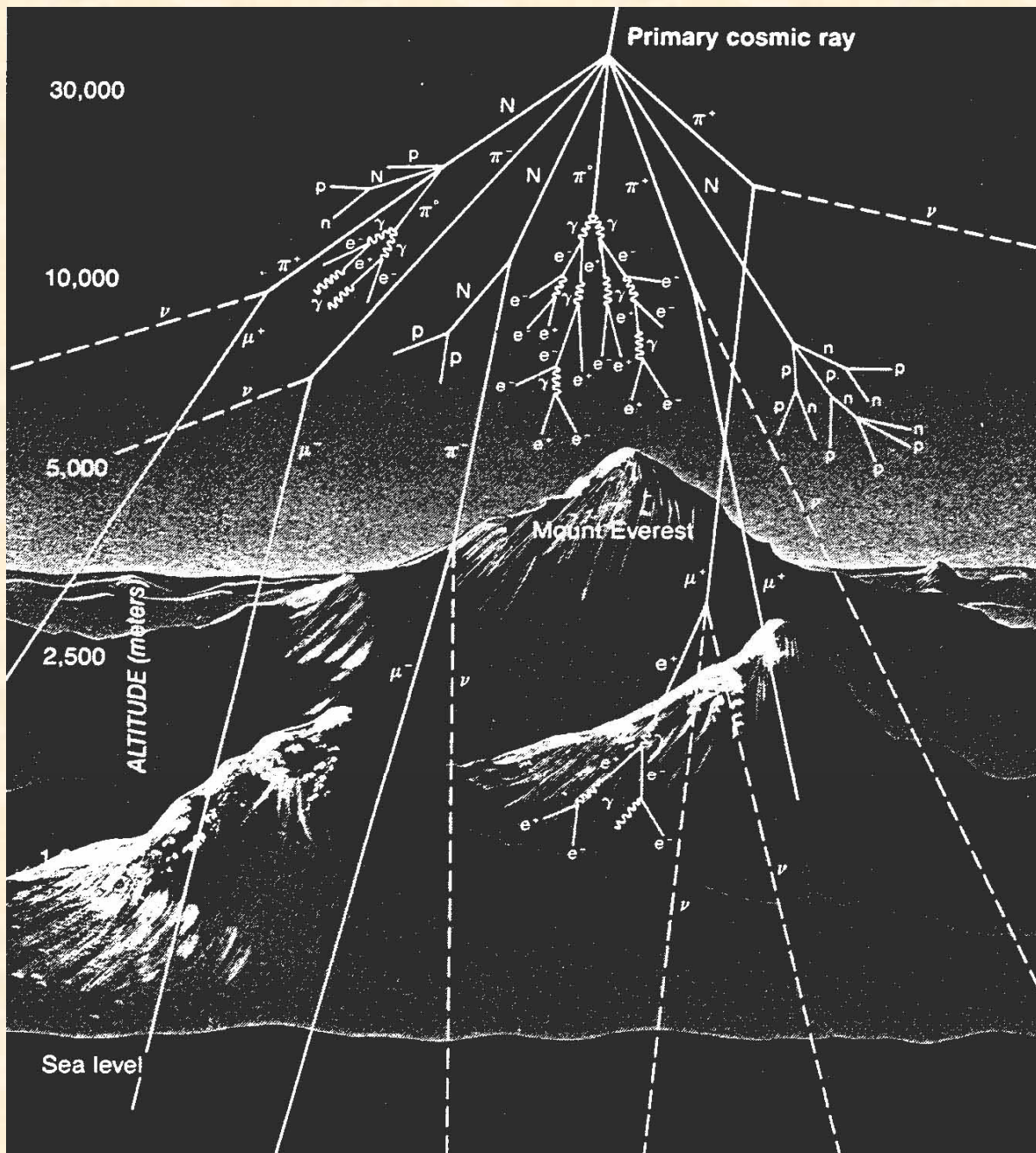
Solar flares:  $10^{11}\text{eV}$

AGN:  $10^{18-20}\text{eV}$

SN1006:  $10^{16}\text{eV}$

Crab:  $10^{16}\text{eV}$





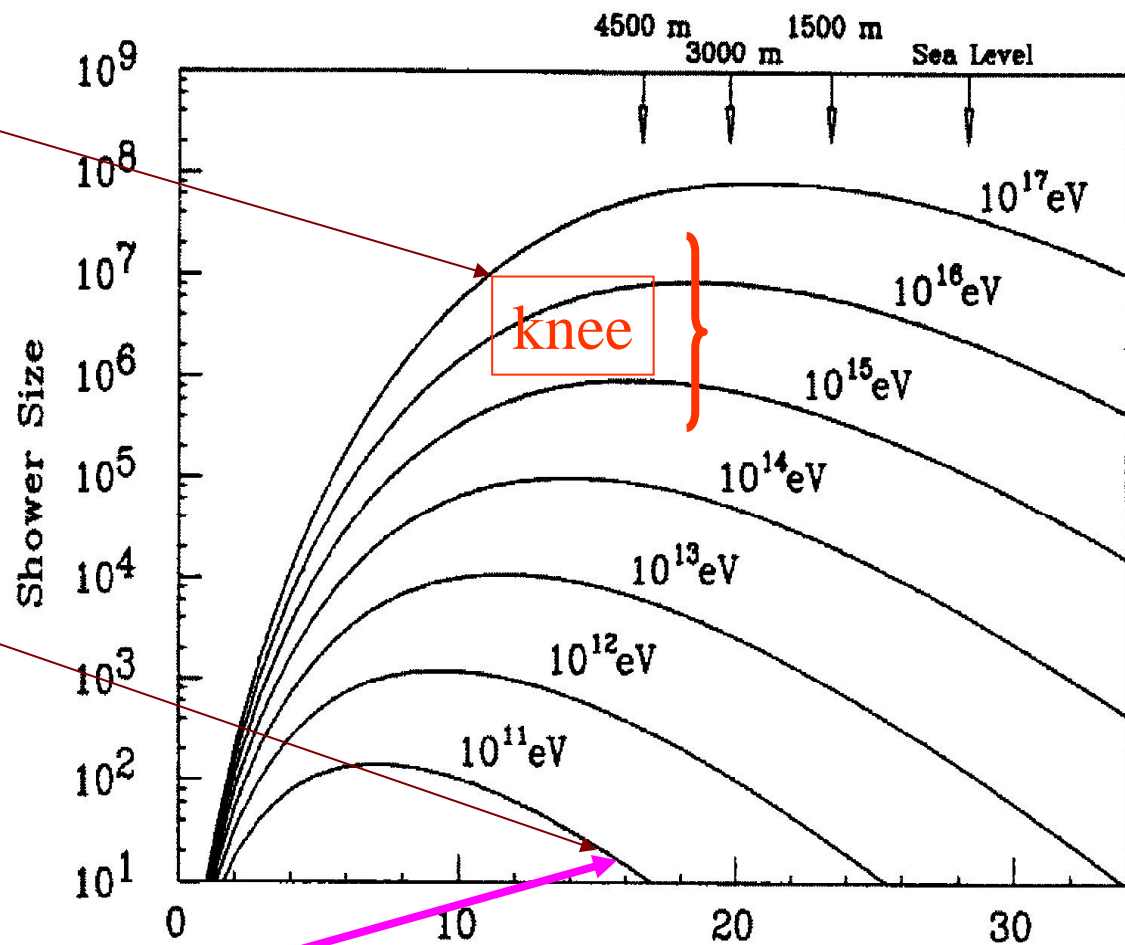
**(Extensive Air Shower)**

# Advantage of YangBaJing altitude (4300M)

–Number of secondary reach maximum, **in favor of knee physics**, including composition and spectrum measurement.

–Low energy threshold, in favor of  $\gamma$  ray astronomy

–Better angular, energy resolution



$\gamma$  ray astronomy

Atmospheric Depth (r.l.)

(Ong)

12

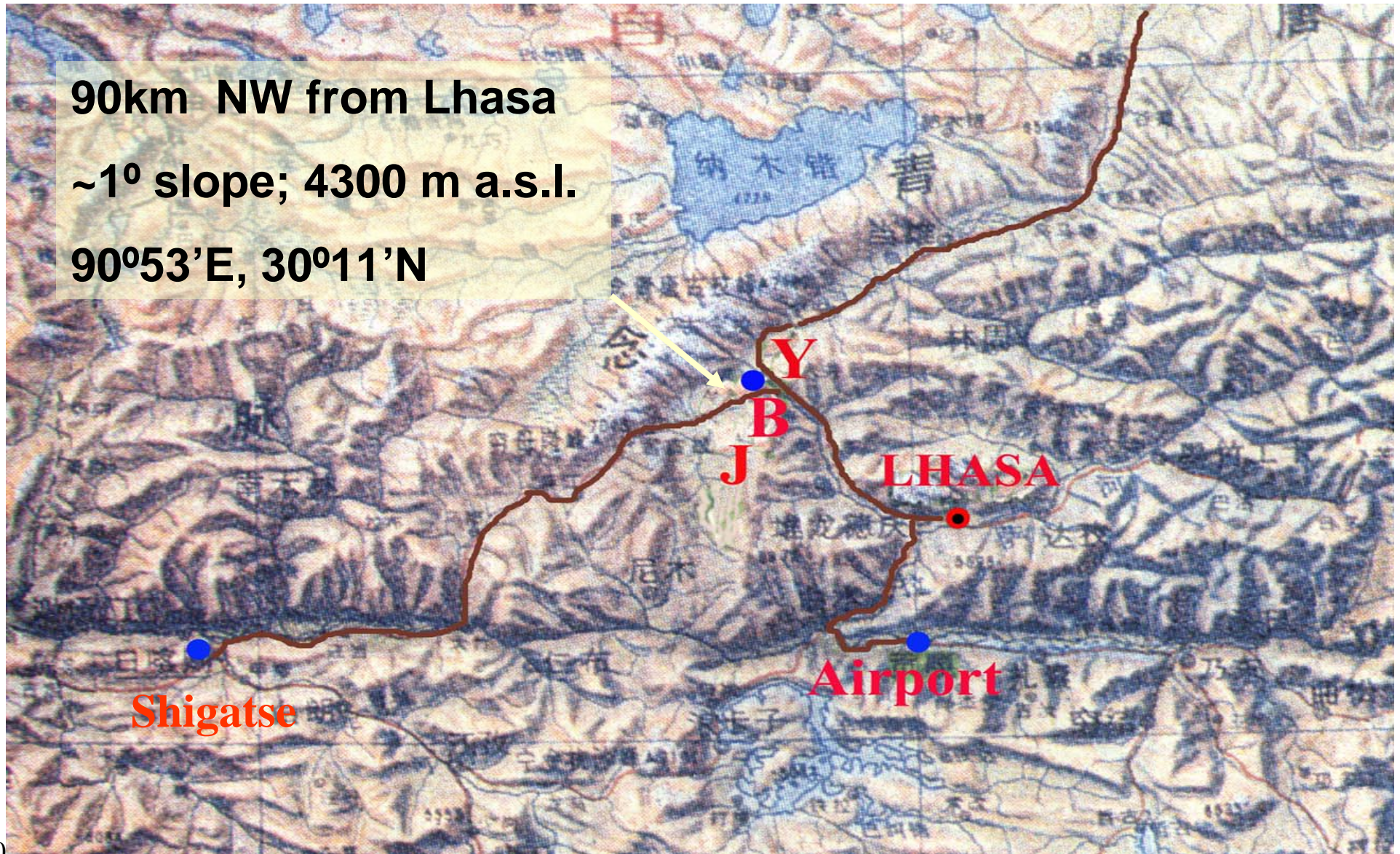
# Requirements on Observation Site

high quality operation, low cost and long life-span:

- Altitude 4300m a.s.l.
- Topography flat and wide, plenty of space.
- Climate easy for construction, operation & living.
- Traffic accessible to highway, airport or railway station.
- Power existed electric power line network.
- Logistics not far from local town/modern city.
- Neighborhood 1000s of residents: clinic, post office, school ...
- Communication Telephone, mobile phone, high speed optical fiber network (155Mbps today).

# *YBJ Satisfy all the requirements*

90km NW from Lhasa  
~1° slope; 4300 m a.s.l.  
90°53'E, 30°11'N

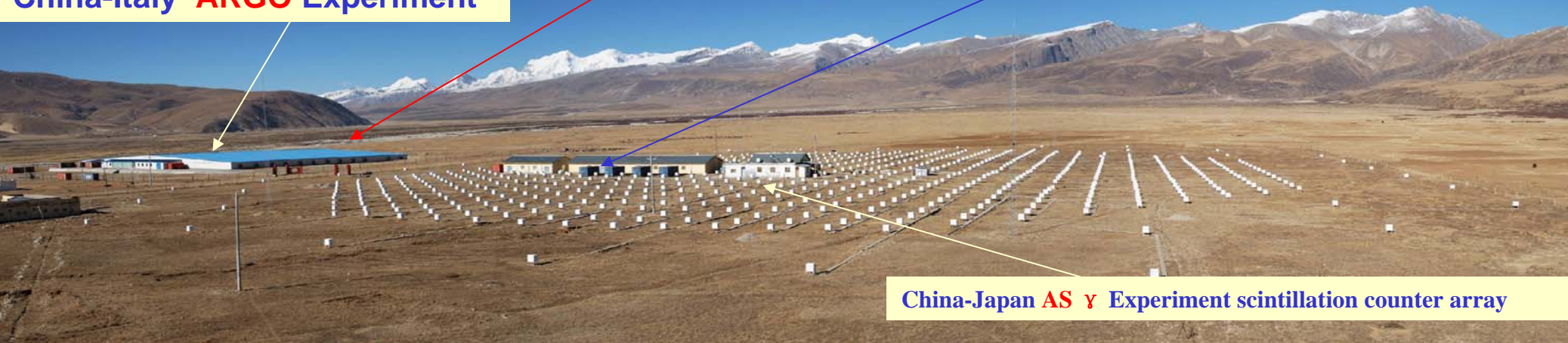


# As $\gamma$ , ARGO (High Duty cycle, Large F.O.V)

~100 GeV

~TeV

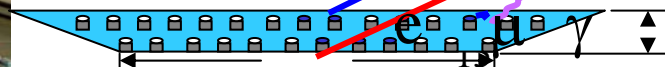
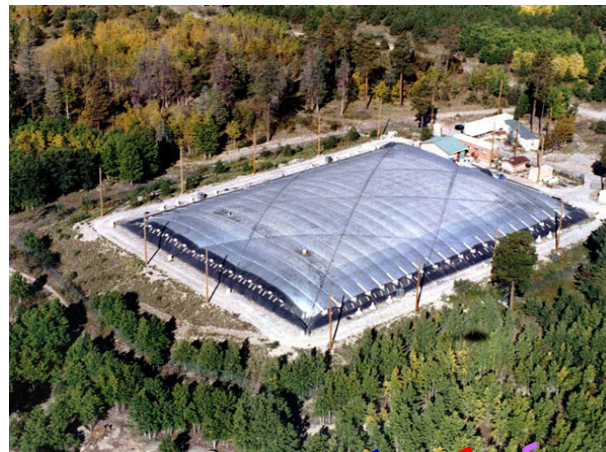
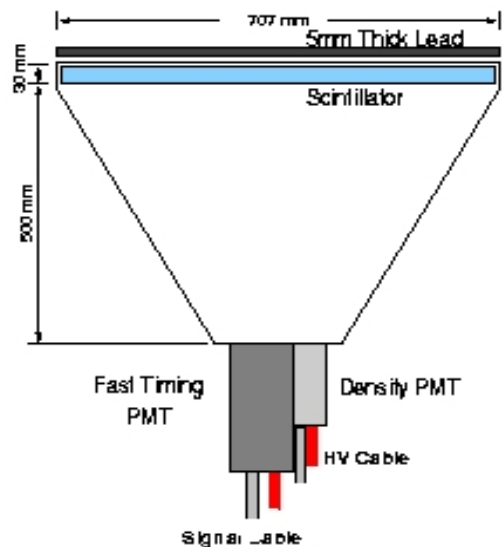
China-Italy ARGO Experiment



AS  $\gamma$  scintillation counter

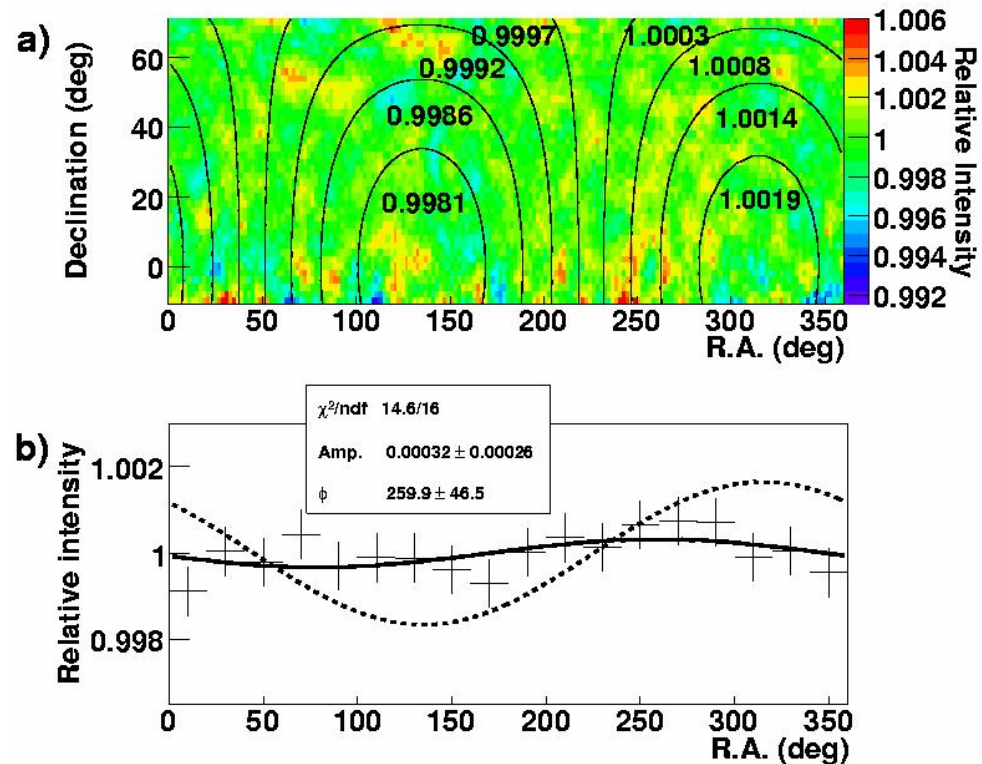
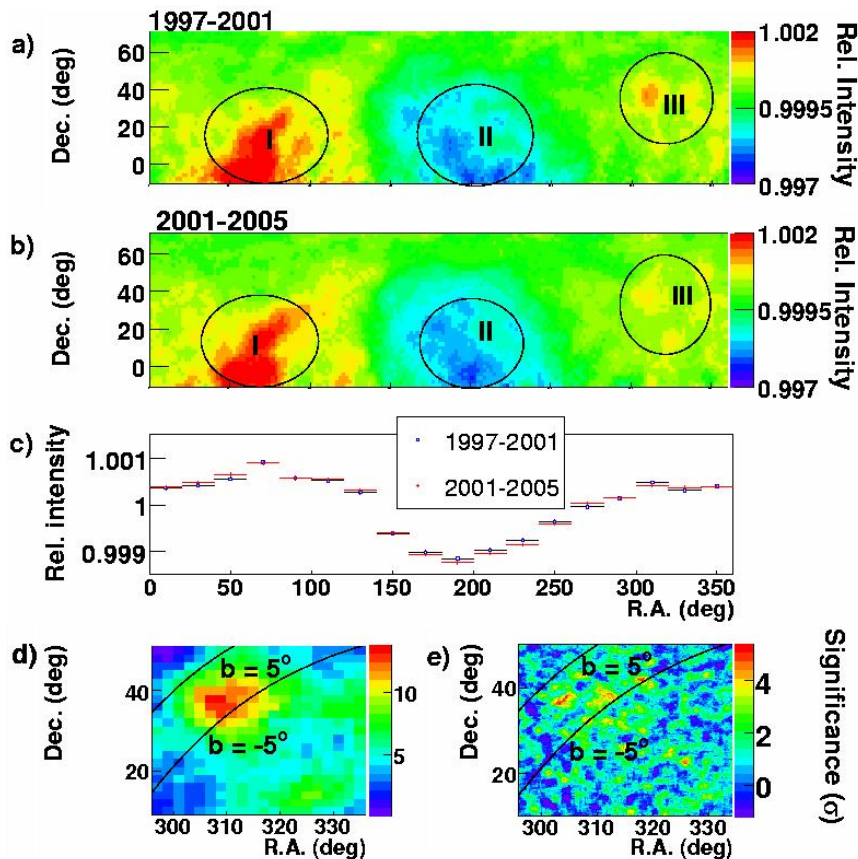
ARGO hall, floored by RPC.  
Fully installed in July 2006.

MILAGRO, Jemez (2630M)



# Two dimensional observation on large scale anisotropy of TeV Cosmic-ray using the Tibet Air Shower Array

(*Science*, Oct. 20, 2006)

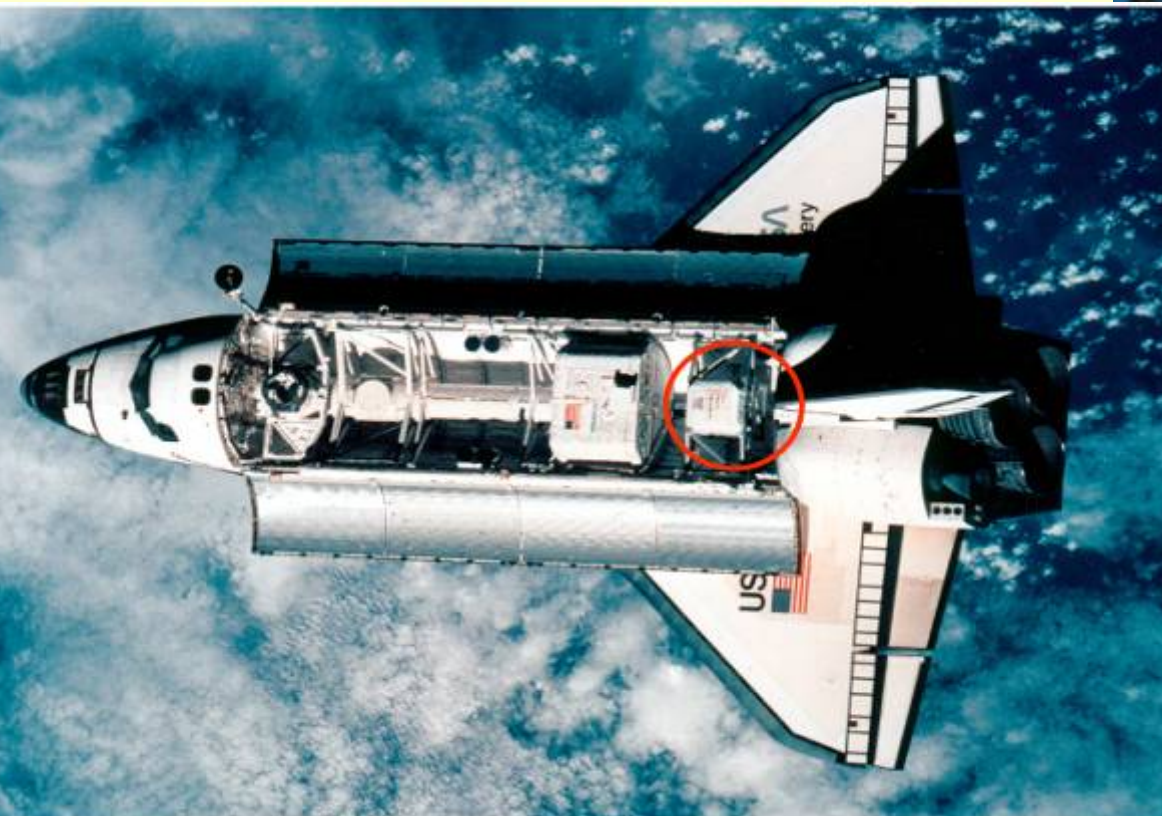
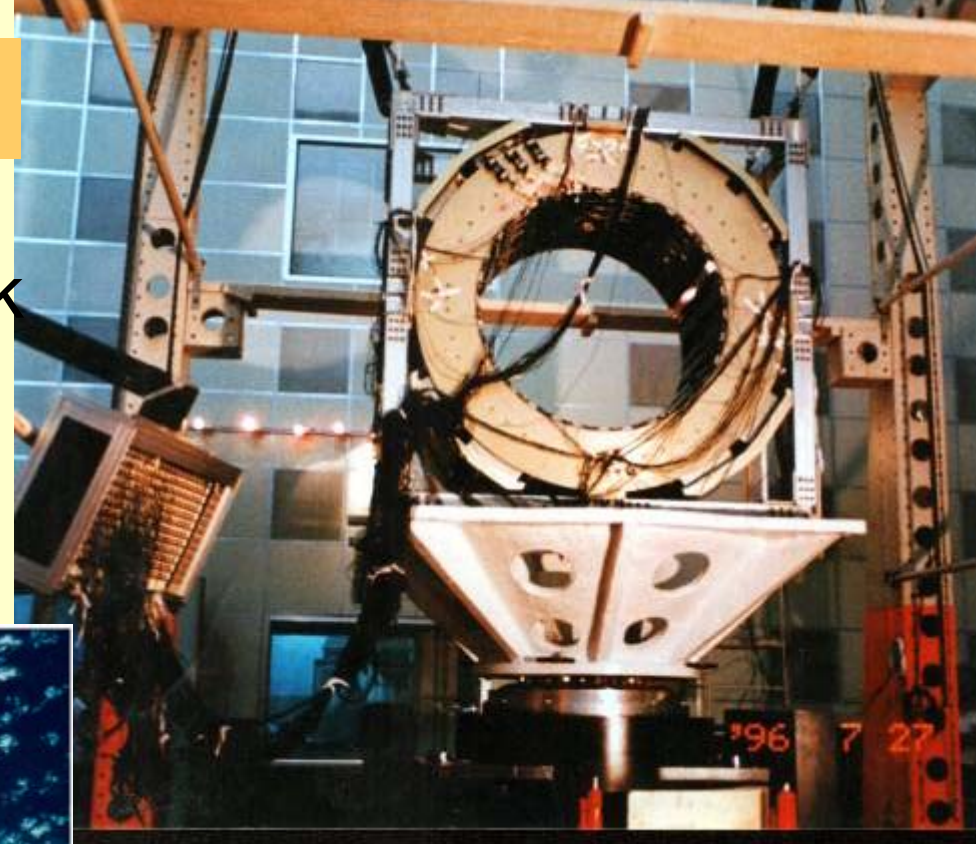




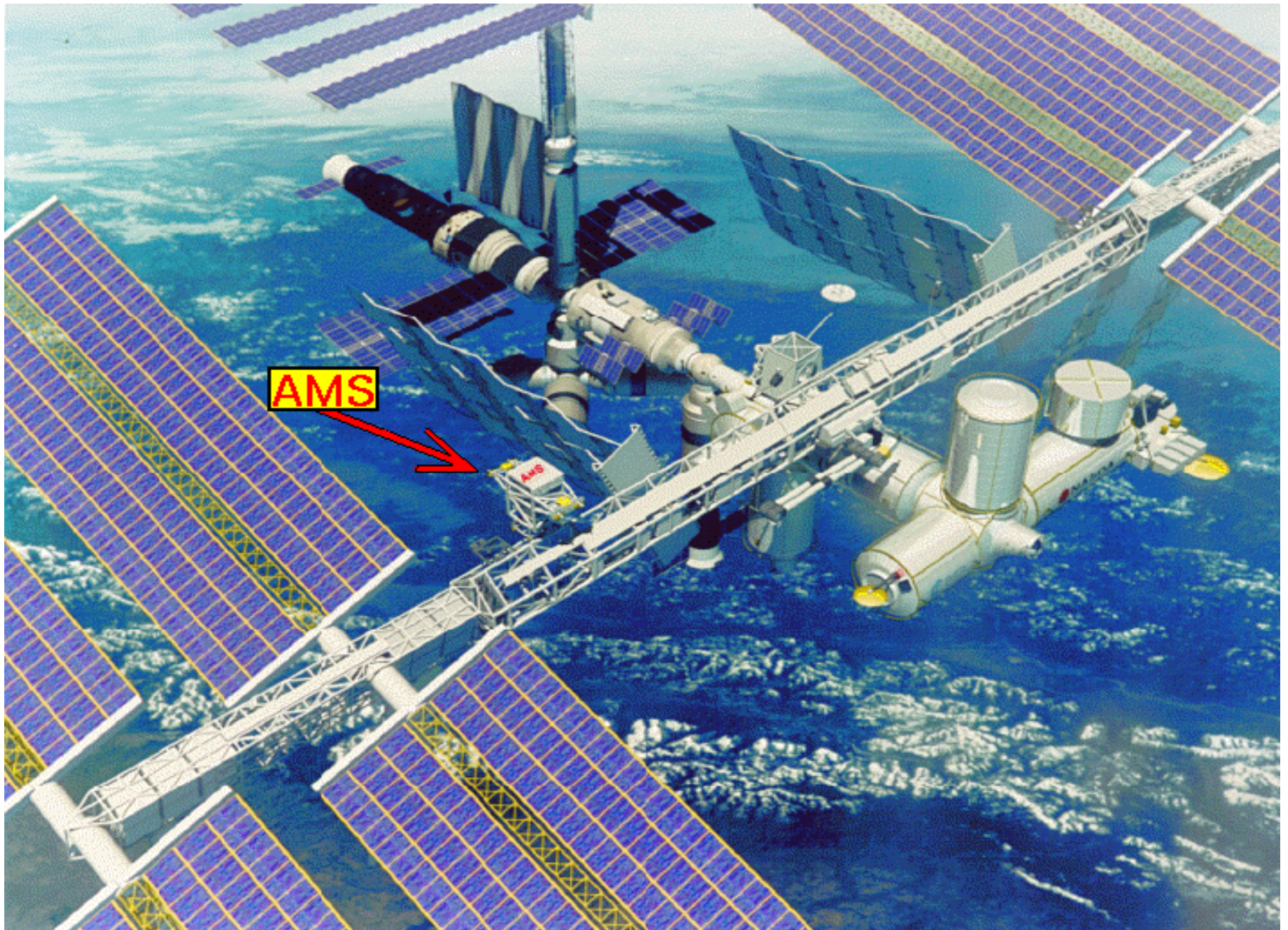
# Space Experiments

# Alpha Magnetic Spectrometer

- Search for antimatter and dark matter
- precision measurement of gamma-ray and isotopes



AMS01 permanent magnet and structure were built at Beijing, & became the first big magnet in space as payload of Discovery June 1998.



AMS



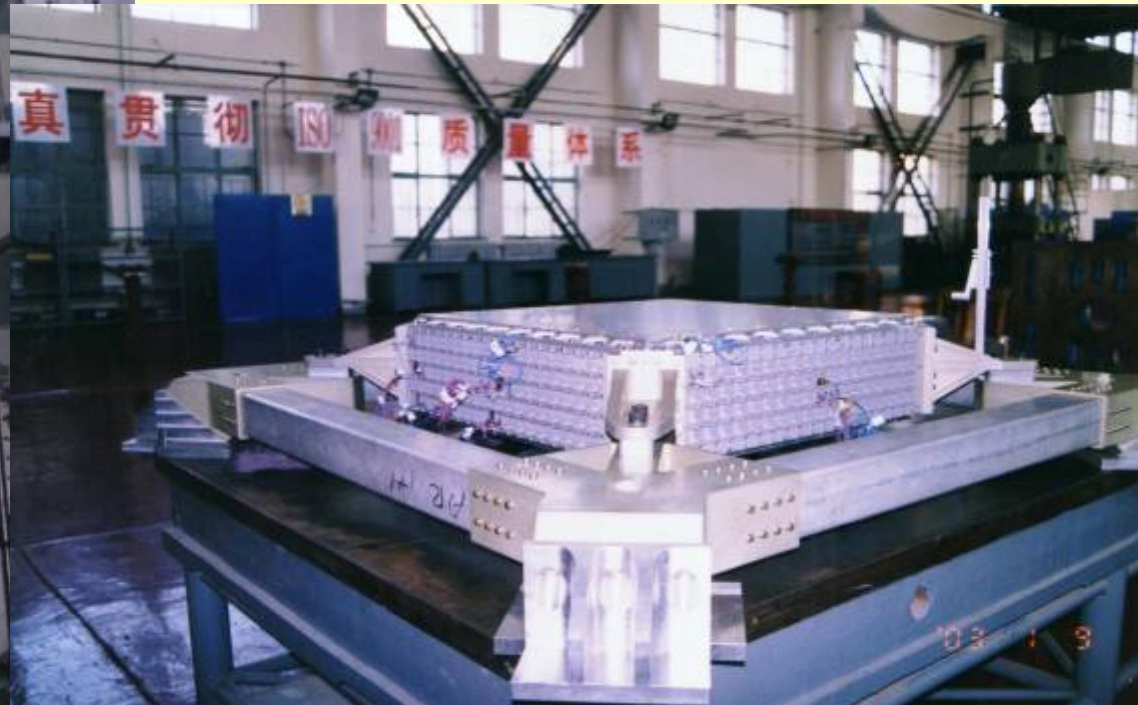
AMS



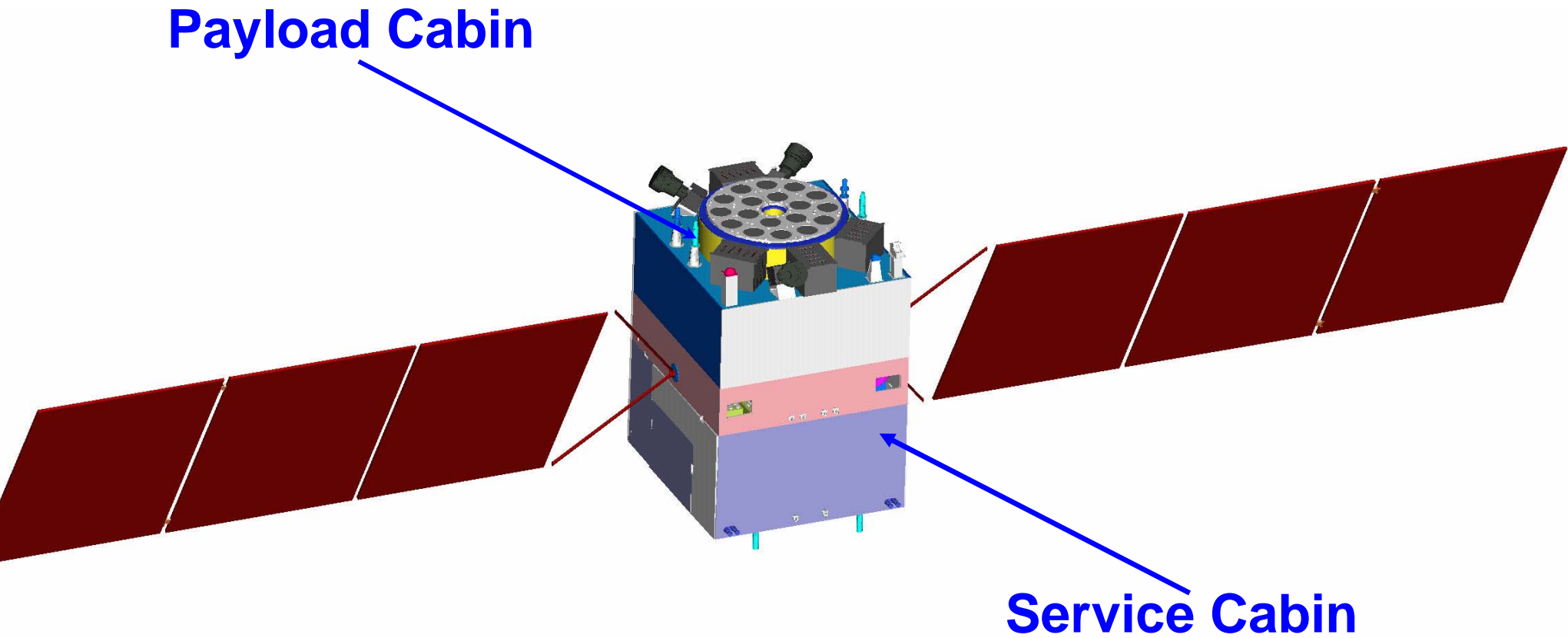
# AMS02 ECAL: IHEP, PISA and LAPP

Space qualification at Beijing

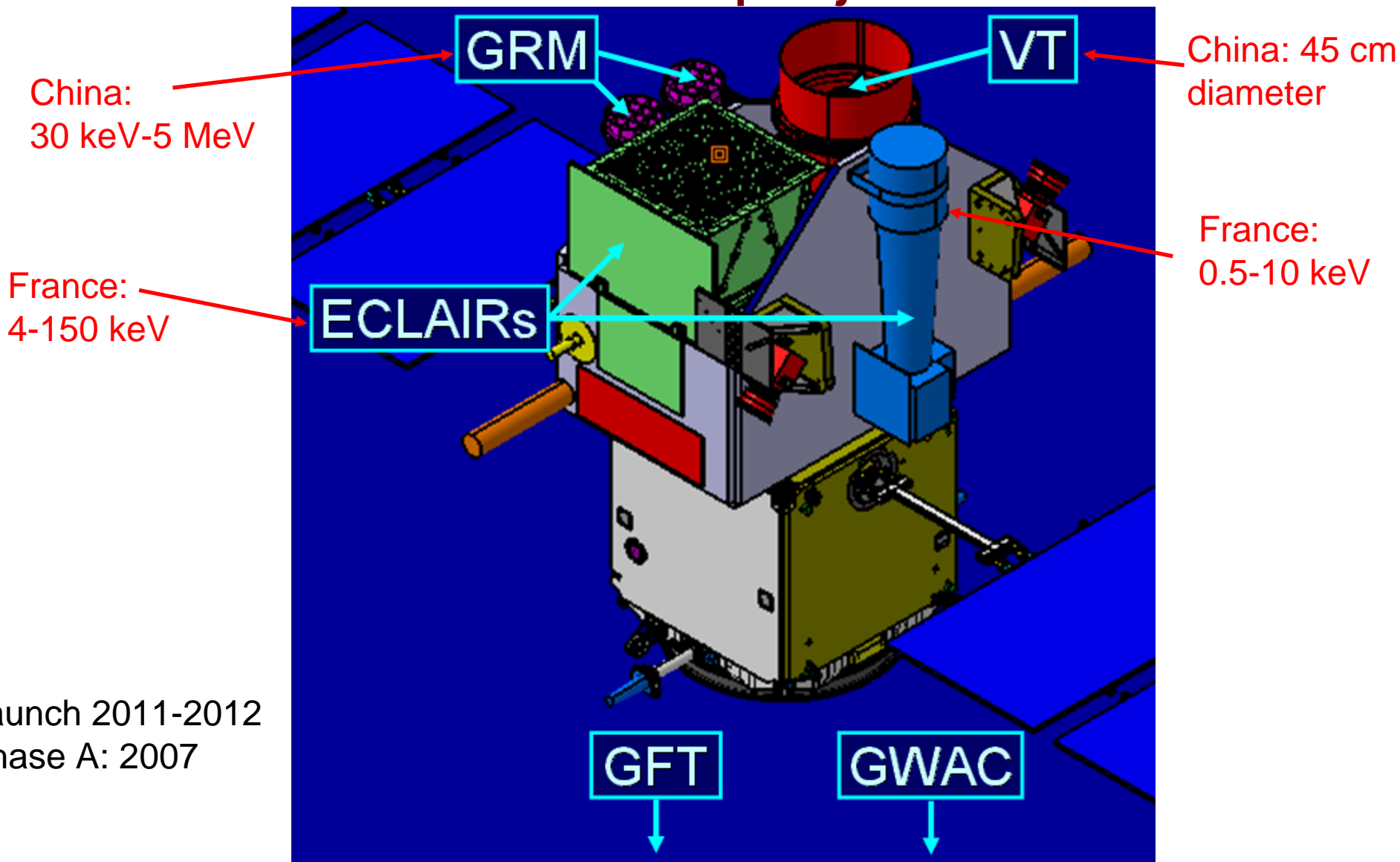
ECAL assembling at IHEP



# HXMT in space



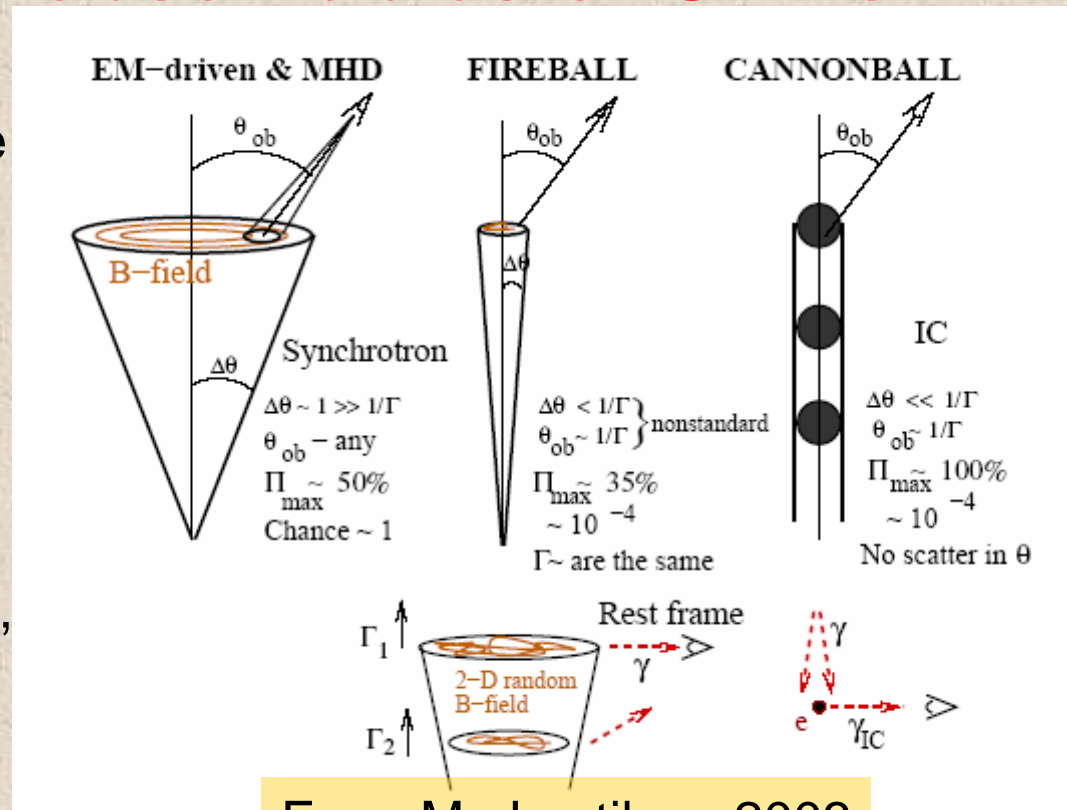
# A multi- $\lambda$ GRB project: SVOM



## China-France collaboration

# GRB prompt emission polarization: one of the last observables of GRBs

- Different GRB models
  - E-M Model: well defined, moderate  $P_{\text{lin}} \sim 50\%$
  - Fireball Model: high values excluded  $P_{\text{lin}} \sim 10\text{-}20\%$
  - Cannon ball Model: full range possible  $P_{\text{lin}} = 0 - 100\%$
- Probe quantum gravity (???):
  - Amelino-Camelia G., 2000, Nature, 408, 661
  - Amelino-Camelia G., et al., 1998, Nature, 393, 763
  - Piran T, 2005, Lect. Notes Phys, 669, 351
  - Fan, Y-Z; Wei, D-M; Xu, D. 2007, MNRAS, 376, 1857



From M. Lyutikov, 2003

See papers discussing various GRB models:  
T. Piran, A. Dar, M. Lyutikov, D. Eichler, G. Ghisellini, D. Lazzatti, M. Medvedev, E. Rossi etc.

# Current GRB polarization measurements

- *Polarization of the prompt  $\gamma$ -ray emission from the  $\gamma$ -ray burst of 6 December 2002 (RHESSI), Coburn, W; Boggs, S. E., *Nature*, 2003, 423, 415 (122 citations):*
- $P_{\text{lin}} = 80 \pm 20\%$  (highly significant detection!)
- *Re-analysis of polarization in the  $\gamma$ -ray flux of GRB 021206, Rutledge, R. E.; Fox, D. B., *MNRAS*, 2004, 350, 1288*
- *Statistical Uncertainty in the Re-Analysis of Polarization in GRB021206, Coburn, W; Boggs, S. E., 2003astro.ph.10515B*
- *Gamma-Ray Burst Polarization: Limits from RHESSI Measurements, Wiggler, C. et al, *ApJ*, 2004, 613, 1088*
- *Evidence of polarisation in the prompt  $\gamma$ -ray emission from GRB 930131 and GRB 960924 (BATSE/GRO), Willis, D. R. et al, 2005, *A&A*, 439, 245*
- *Polarisation studies of the prompt  $\gamma$ -ray emission from GRB 041219a using the spectrometer aboard INTEGRAL, McGlynn, S., 2007, *A&A*, 466, 895*

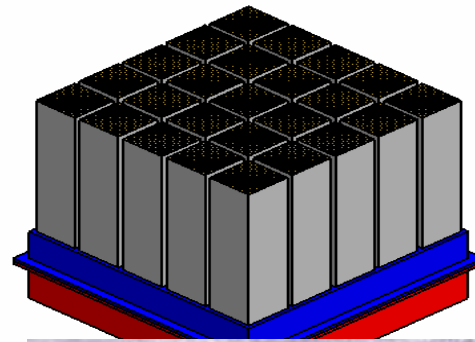
**Important, rare, large uncertainty & controversial!**



# POLAR mission status

- Instrument concept proposed by N. Produit, et al., NIM (2005)
- Onboard China's spacelab TG-2: launch time 2011-12
  - 2<sup>nd</sup> step of China's manned space flight program, to be confirmed by China's central government this year.
- FOV of POLAR:  $\sim 1/2$  sky
- MDP is 10%:  $>10$  GRBs per year down to 10% polarization;
- *Requires directionality known after the fact*

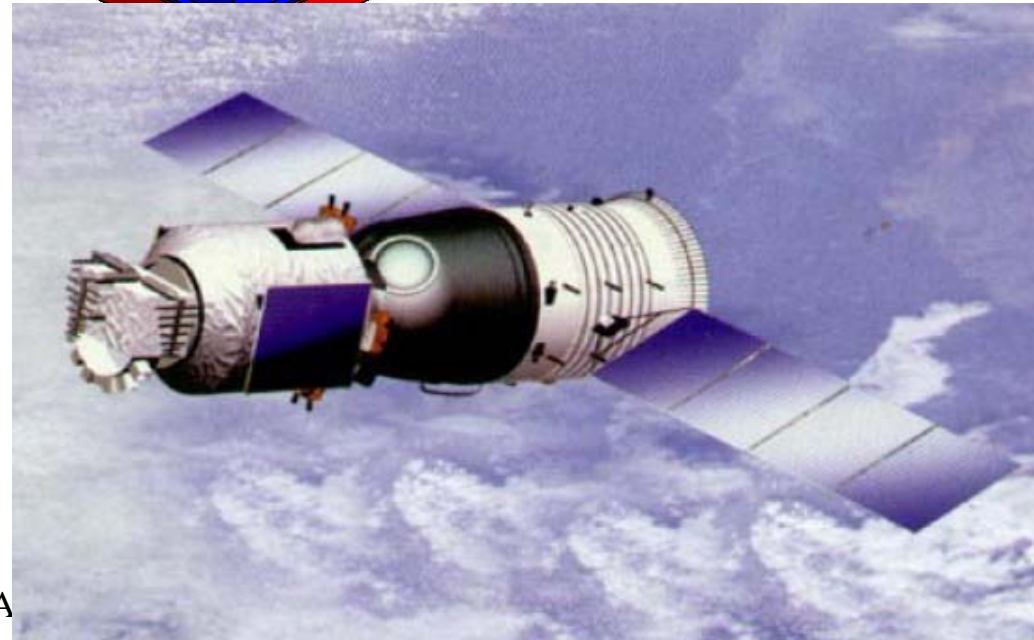
POLAR



Tian-Gong

天宫

Palace in  
Heaven



# The *joint* spacelab-TG POLAR team

- **China** Tsinghua/IHEP: Shuang Nan Zhang (**PI**)
- **China** IHEP: Bobing Wu, Shaolin Xiong, etc.
- **Switzerland** ISDC: Nicolas Produit (**Co-PI**), Daniel Haas
- **Switzerland** PSI: Wojtek Hajdas, Aliko Mchedlishvili
- **Switzerland** DPNC: Estela Suarez, Martin Pohl, Catherine Leluc, Divic Rapin
- **France** LAPP: Giovanni Lamanna, Jean-Pierre Vialle
- **Poland** IPJ: Radoslaw Marcinkowski, Michal Gierlik

**China >50% + others <50%**

# XEUS: X-ray Evolving Universe Spectrometer



Zhang is a Co-I in XEUS CV proposal;  
CAST proposed to do system level studies.