HEP Program in China

Hesheng Chen

Institute of High Energy Physics

Beijing 100049, China

Institute of High Energy Physics

- **Institute of Modern Physics: established at 1950**
- **Institute of High Energy Physics: independent Institute for Particle physics at 1973**

  → Comprehensive and largest fundamental research center in China
  - **1050 employees, 2/3 of them are physicists and engineers,**
  - **400 PhD Students and postdoctors**
- **Goal of IHEP: multiple discipline research center**

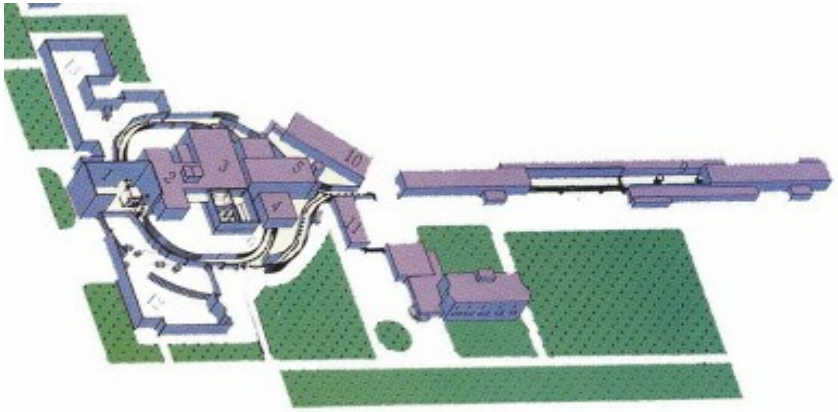
Major research fields at IHEP

- **Particle physics:**
  - **Charm physics @ BEPC**
  - **LHC exp.**
  - **Yangbajing cosmic ray observatory**
  - **particle astrophysics**
  - **ν physics: Daya Bay reactor ν exp.**
- **Accelerator technology and applications**
  - **High Lumi. e+e- collider: BEPCII**
  - **High power proton accelerator**
- **Radiation technologies and multidiscipline**
  - **Synchrotron radiation source and applications**
  - **Spallation neutron source and application**
  - **Multiple discipline research**

Beijing Electron Positron Collider (BEPC) at IHEP

E_{beam}~ 1-2.5 GeV

τ-charm energy region



BESI: run from 1989-1998
BESII: run from 1999-2004
BESIII: construction completed, running now

A unique e^+e^- machine in the τ-charm energy region from 1989 – till CLEOc (2003).

With BESI and BESII data:

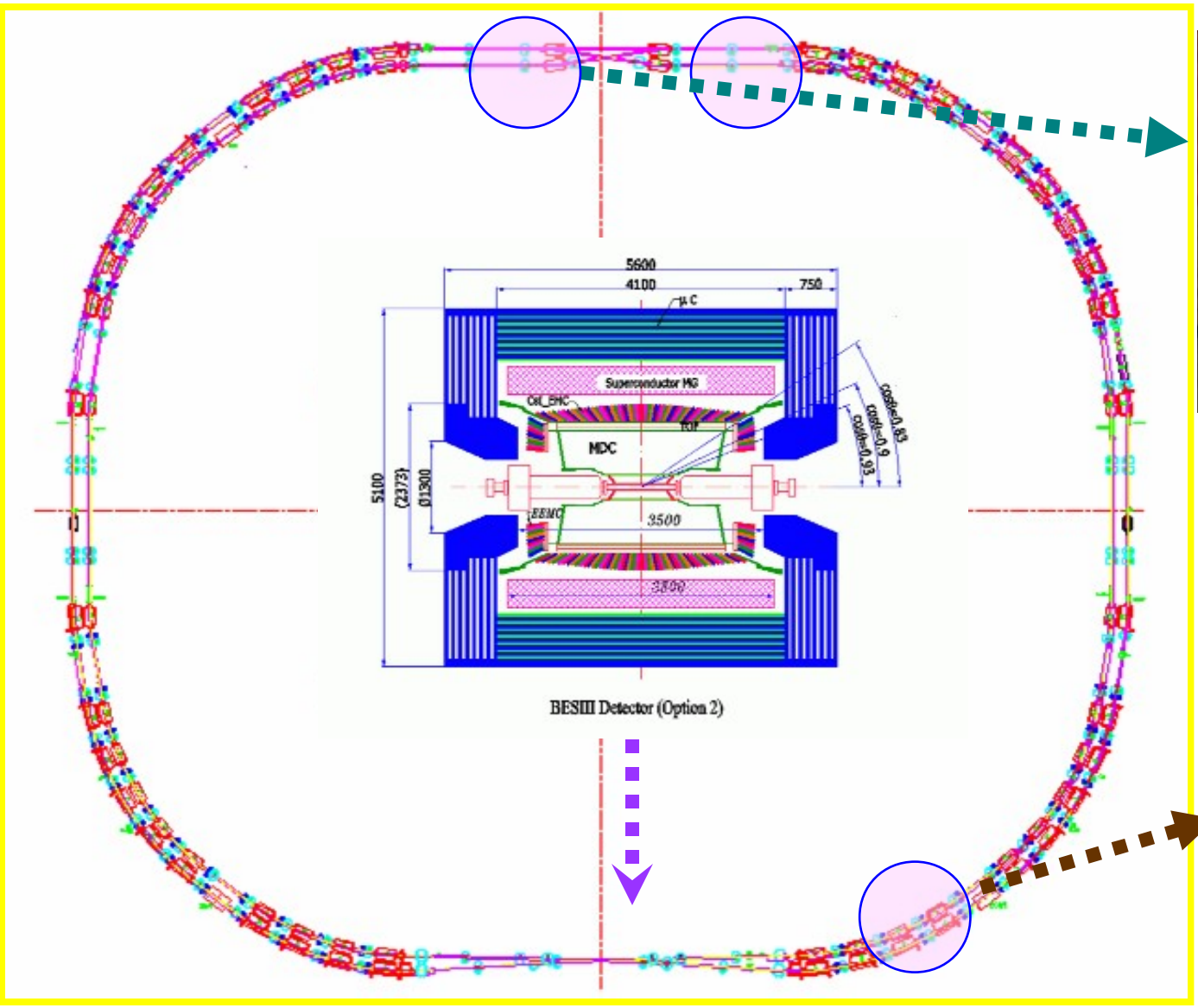
- precision measurement of τ mass: 10 times improved. Lepton universality!
- R measurements improve uncertainties by a factor of 2-3 ($\Delta R/R \sim 6\ \%$). Great impact to M_H and $\alpha(M_z)$, $g-2$

- Some new particles X(1835) observed. Hard to be interpreted as conventional hadrons.

Precision measurement requires high statistics and

5

BEPCII: a high luminosity double-ring collider



SC RF

Two rings

BEPCII design goal

Energy range	**1 – 2.1 GeV**
Optimum energy	**1.89 GeV**
Luminosity	**1×10^{33} $cm^{-2}s^{-1}$ @ 1.89 GeV**
Injection	**Full energy injection upto 1.89 GeV Positron injection rate > 50 mA/min**
# of bunches	**93**
Beam Current	**0.91 A**
Bunch length	**1.5 cm**
Synchrotron mode	**250 mA @ 2.5 GeV**

Beam energy can reach 2.3GeV.

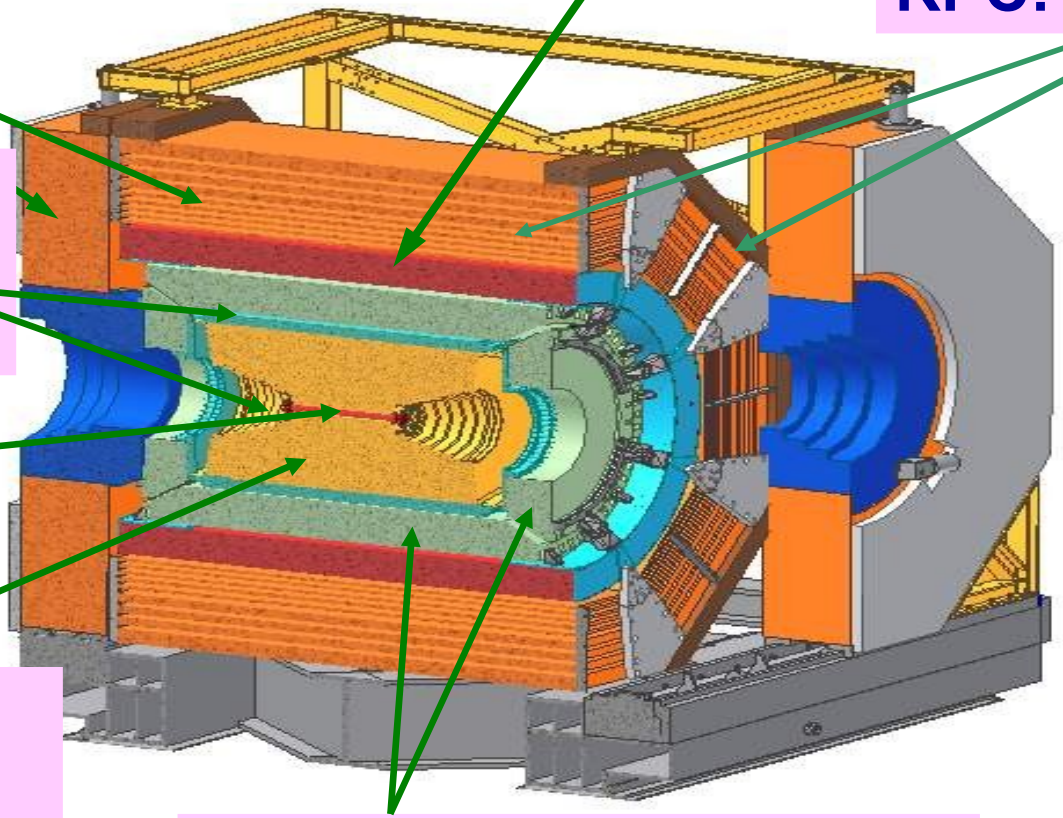
Storage Ring installation finished

The BESIII Detector

Magnet yoke

SC magnet, 1T

RPC: 9 layers



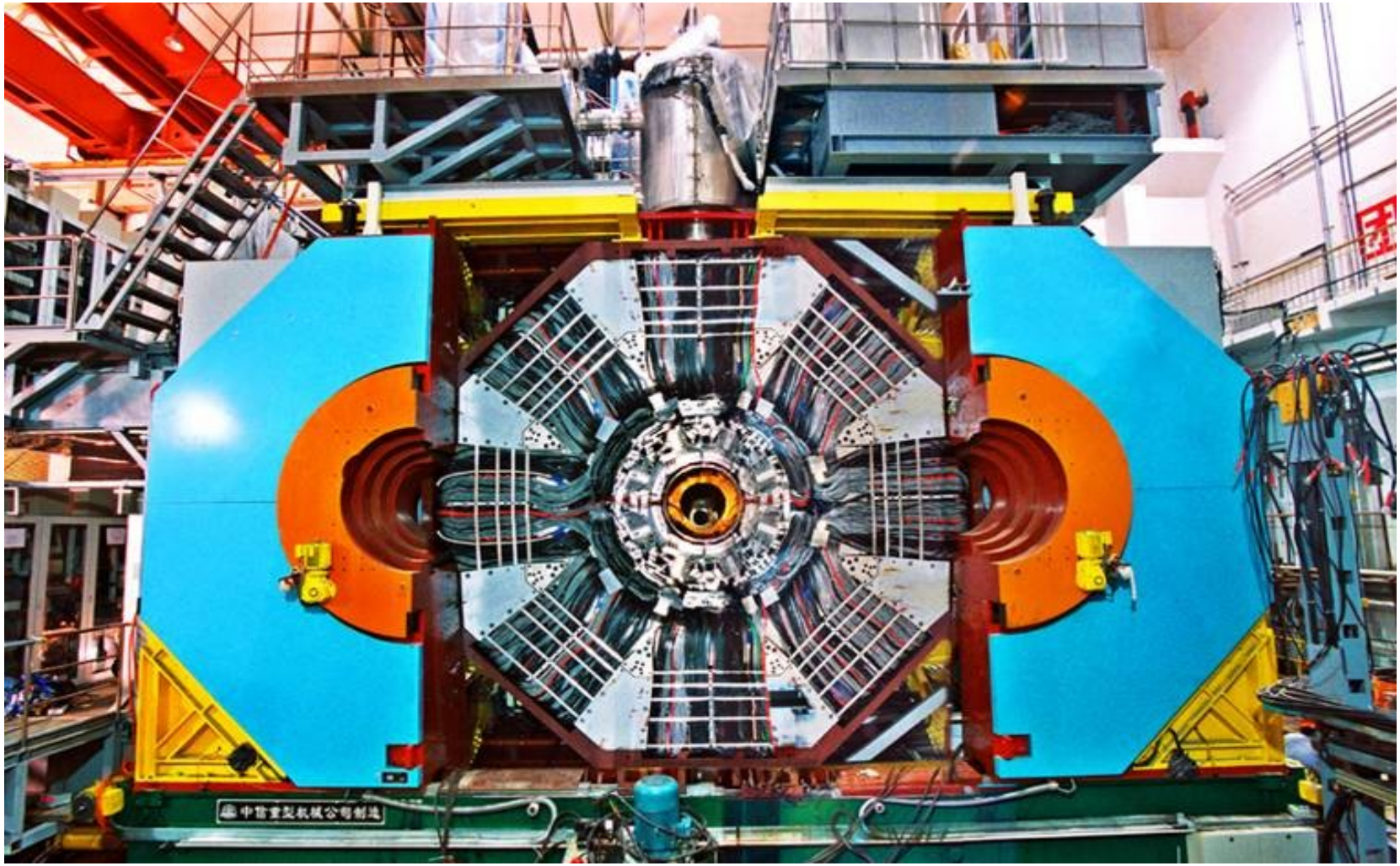
TOF,
σ_t (ps) = 100 ps Barrel
110 ps Endcap

Be beam pipe

MDC,
σ_{XY} (μm) = 130
△P/P = 0.5 % (1 GeV)
$\sigma_{dE/dx}$ = 6-7 %

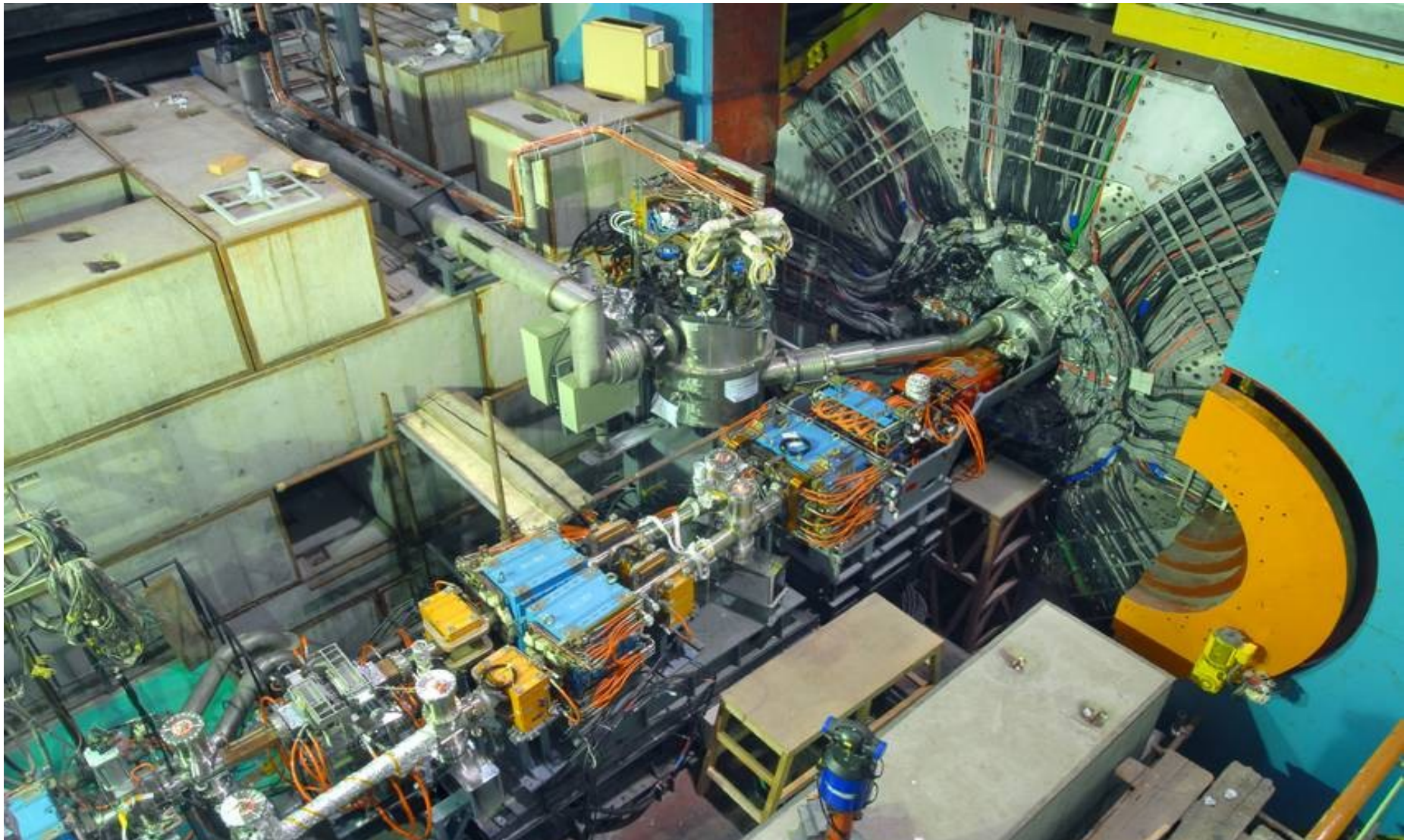
CsI(Tl) calorimeter,
△E/√E = 2.5 % (1 GeV)
σ_z,ϕ(cm) = 0.5cm/√E

Detector installation completed this April, and moved to IR in May, 2008.



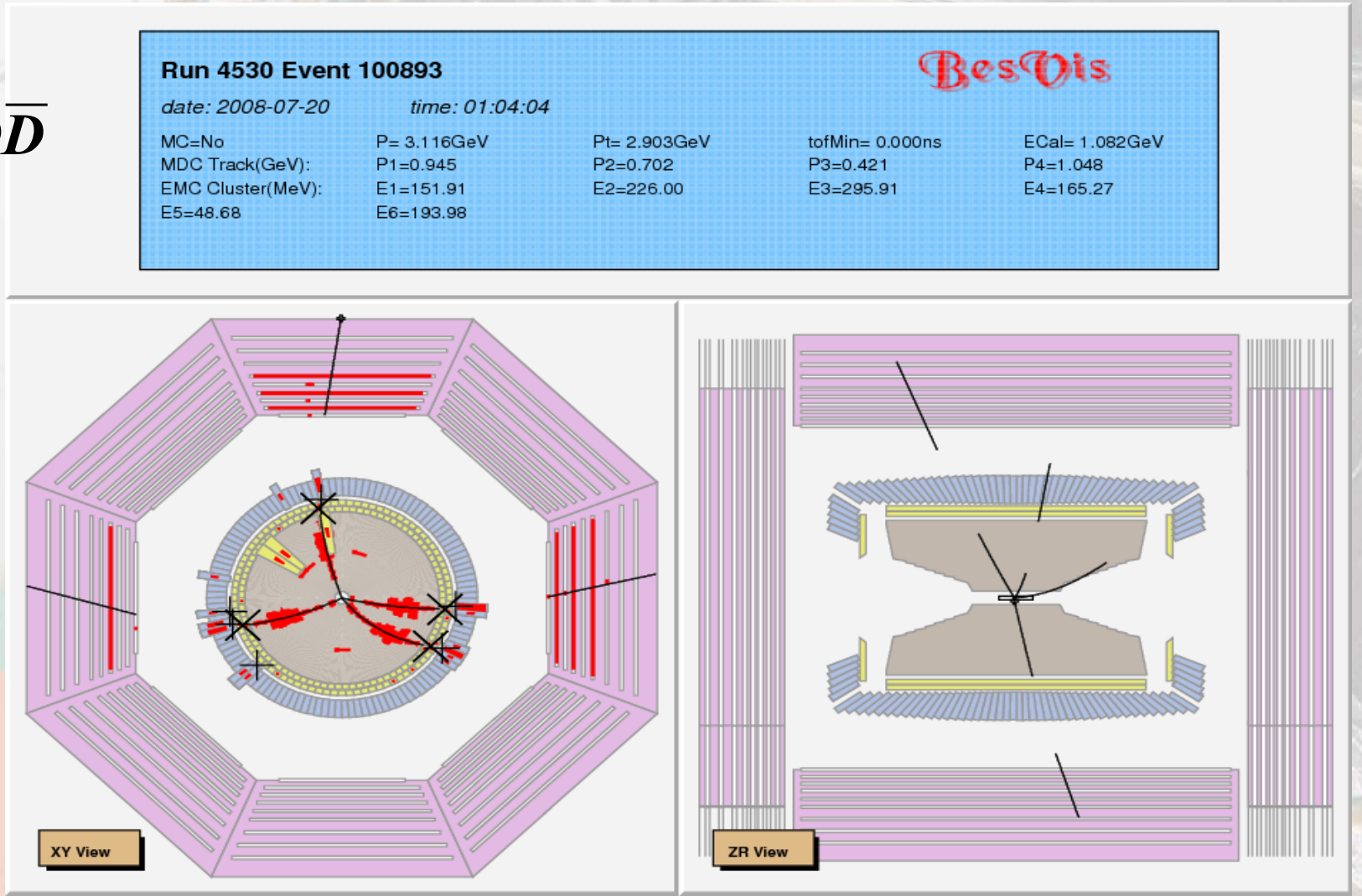
Joint Commissioning

- BESIII detector moved into the IR in May
- Joint commissioning started 22 June.



- First physics event was detected at BESIII in July 19, 2008.
- MDC noise problem was solved.
- 10M ψ ‘ events collected for calibration

$\psi(3770) \rightarrow D\overline{D}$



Main parameters achieved in collision mode

parameters	design	Achieved	
		BER	BPR
Energy (GeV)	1.89	1.89	1.89
Beam curr. (mA)	910	630	700
Bunch curr. (mA)	9.8	>10	>10
Bunch number	93	93	93
RF voltage	1.5	1.5	1.5
ν_s @1.5MV	0.033	0.032	0.032
β_x^*/β_y^* (m)	1.0/0.015	~1.0/0.016	~1.0/0.016
Inj. Rate (mA/min)	200 e^- 50 e^+	>200	>50
Lum. (× 10 cm s)	1	0.11	

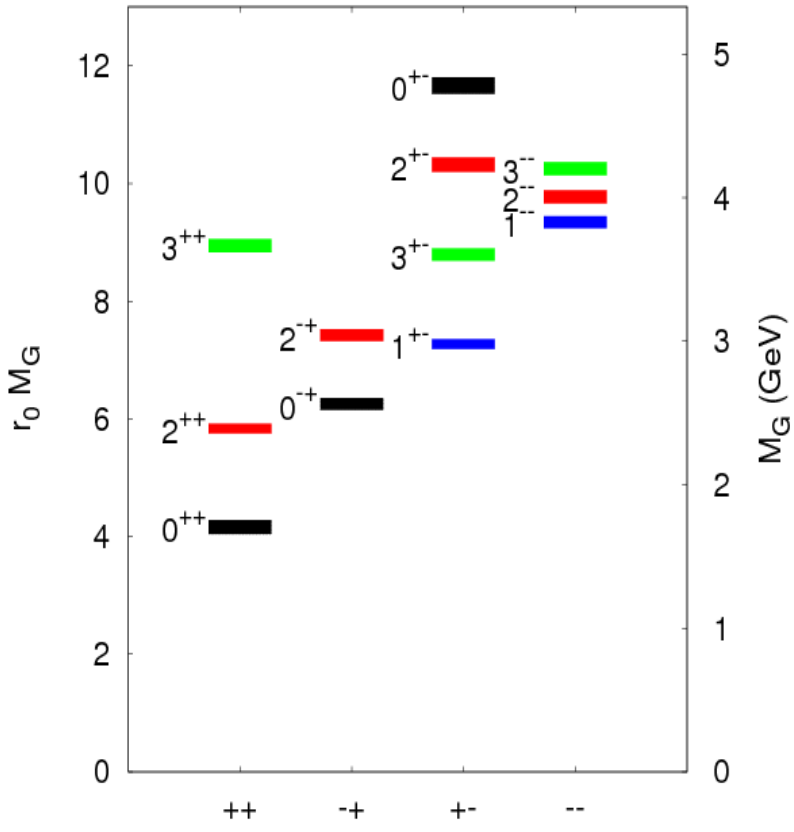
Physics at BEPCII/BESIII

- Precision measurement of CKM matrix elements
- Precision test of Standard Model
- QCD and hadron production
- Light hadron spectroscopy
- Charmonium production/decays
- Search for new physics/new particles

Physics	Energy (GeV)	Peak Luminosity (10 cm s)	Events/year	Existing data
J/ψ	3.097	0.6	10×10	60×10 (BESII)
τ	3.67(?)	1.0	12×10	--
ψ ’	3.686	1.0	3×10	27 ×10 (CLEOc) 14 ×10 (BESII)
D	3.77	1.0		

Search for glueballs

- LQCD predicts the lowest glueball state is 0 . The mass is around 1.5 GeV – 1.7 GeV.
- LQCD predicts the next lightest glueball is 2 . The mass is around 2.4 GeV.
- LQCD predicts the 0-+ glueball mass in the range of 2.3-2.6 GeV.
- The mix of glueball with ordinary $q\bar{q}$ meson makes the situation more difficult.



Y. Chen et al., PRD 73 (2006) 014516

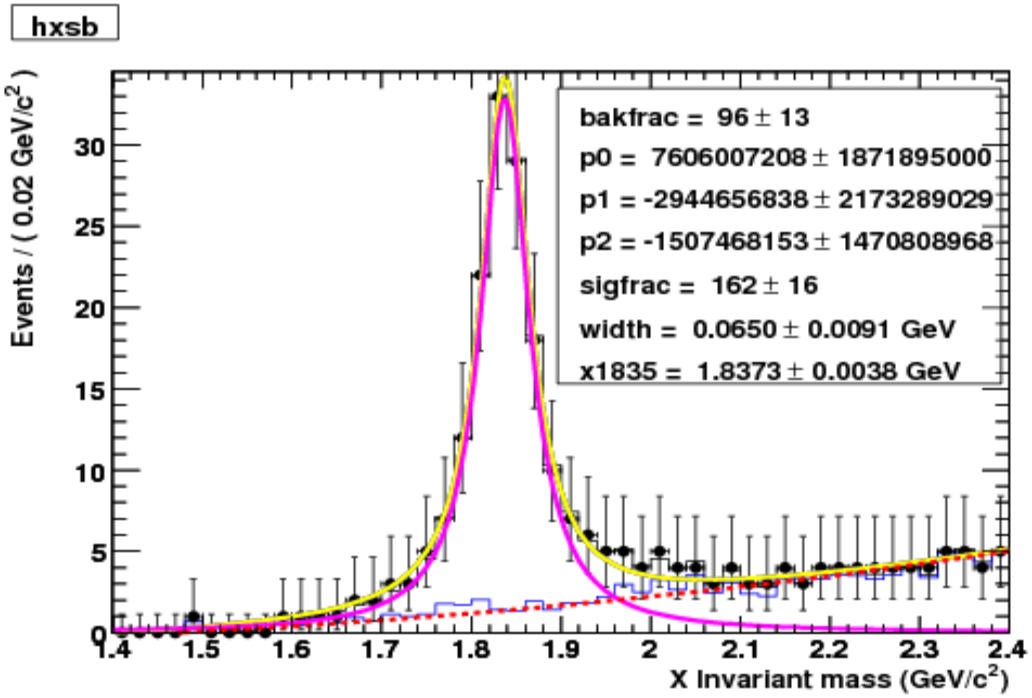
0 0 J

Glueball candidates: f (1500), f (1700), f (2220)

Example: X(1835) at BESIII (58M J/ψ)

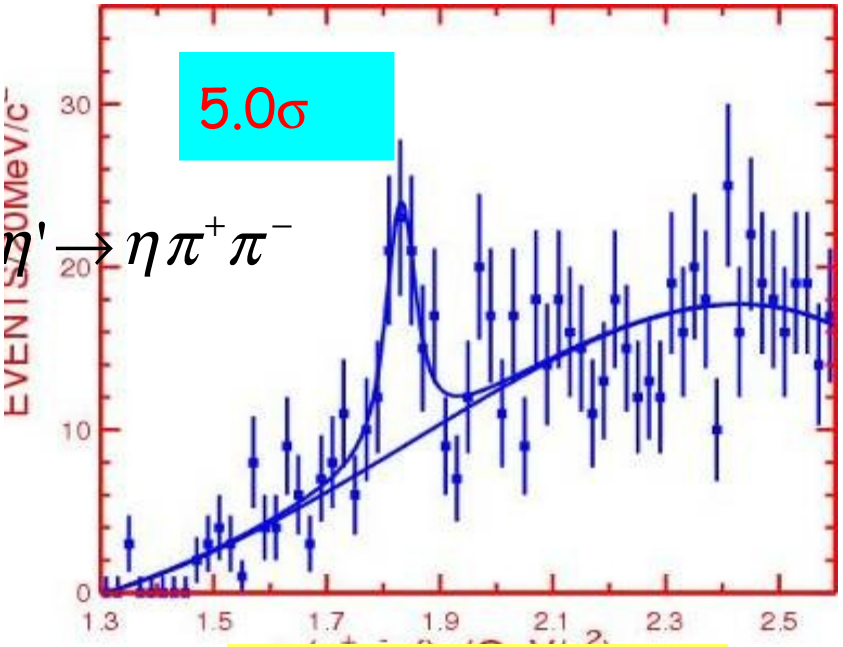
2 years' data taking

at BESIII



M(η'ππ) GeV/c²

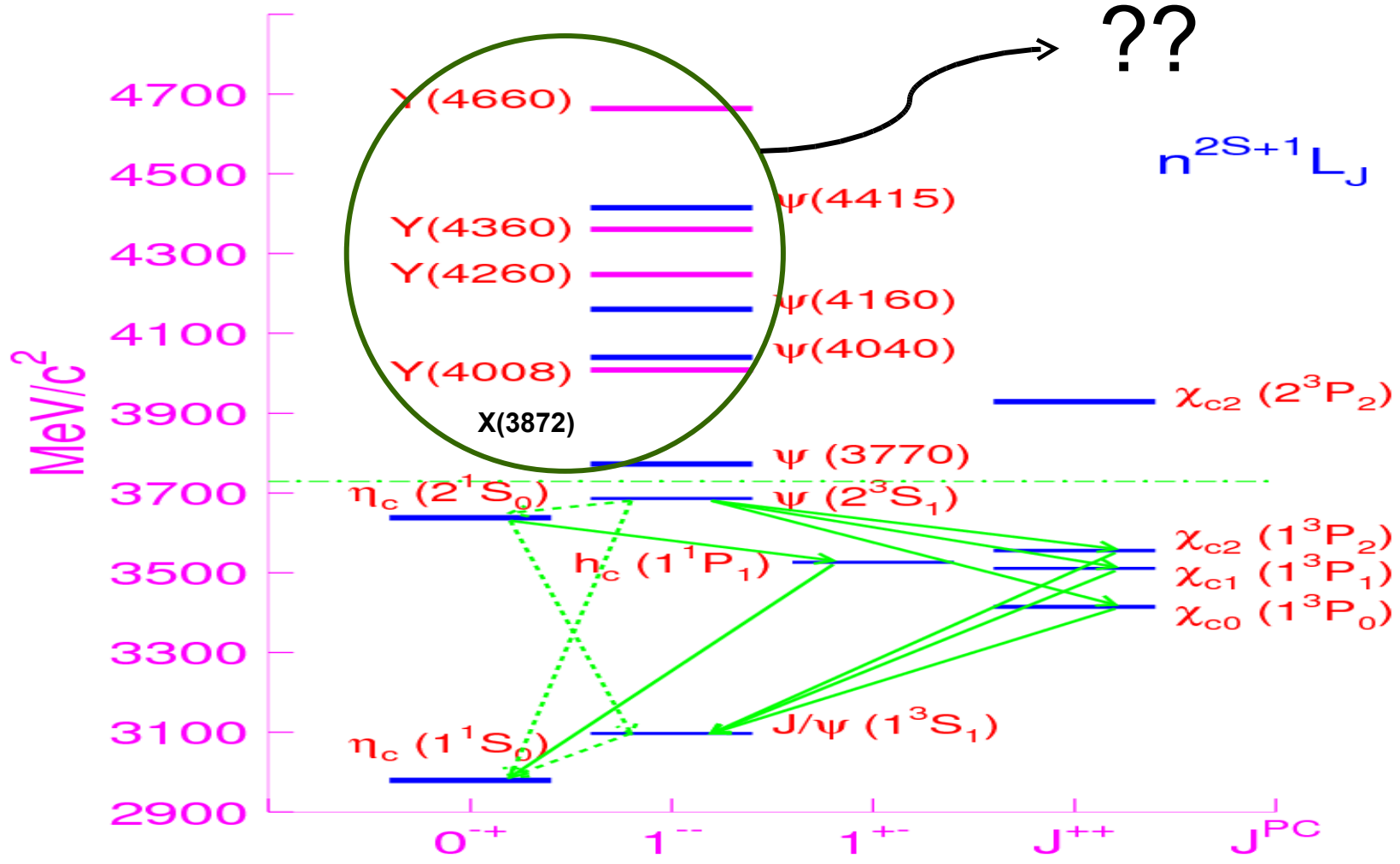
at BESII



M(η'ππ) GeV/c²

Charmonium production and decay

Charmonium spectroscopy



Impact of Charm Physics

- **Precision CKM**

~ 5%

~ 10%

PDG06

|Vus|	|Vus|	|Vub|	|Vcd|	|Vcs|	|Vcb|	|Vtd|	|Vts|	|Vtb|
0.97377 ± 0.00027	0.2257 ± 0.0021	0.00431 ± 0.00030	0.230 ± 0.011	0.957 ± 0.017 ± 0.093	0.0416 ± 0.0006	0.0074 ± 0.0008		>0.78

BES accuracy

- For leptonic D decays

$$\sigma(|V_{cd}|)/(|V_{cd}|) = 2.3\%$$
$$\sigma(|V_{cs}|)/|V_{cs}| = 1.7\%$$
$$\frac{\sigma(|V_{cd}|/|V_{cs}|)}{|V_{cd}|/|V_{cs}|} = 1.3\%$$

- For semileptonic D decays ($D_s \to K$ and $D_s \to \phi$):

$$\sigma(|V_{cd}|)/(|V_{cd}|) = 2.4\%$$
$$\sigma(|V_{cs}|)/|V_{cs}| = 1.3\%$$

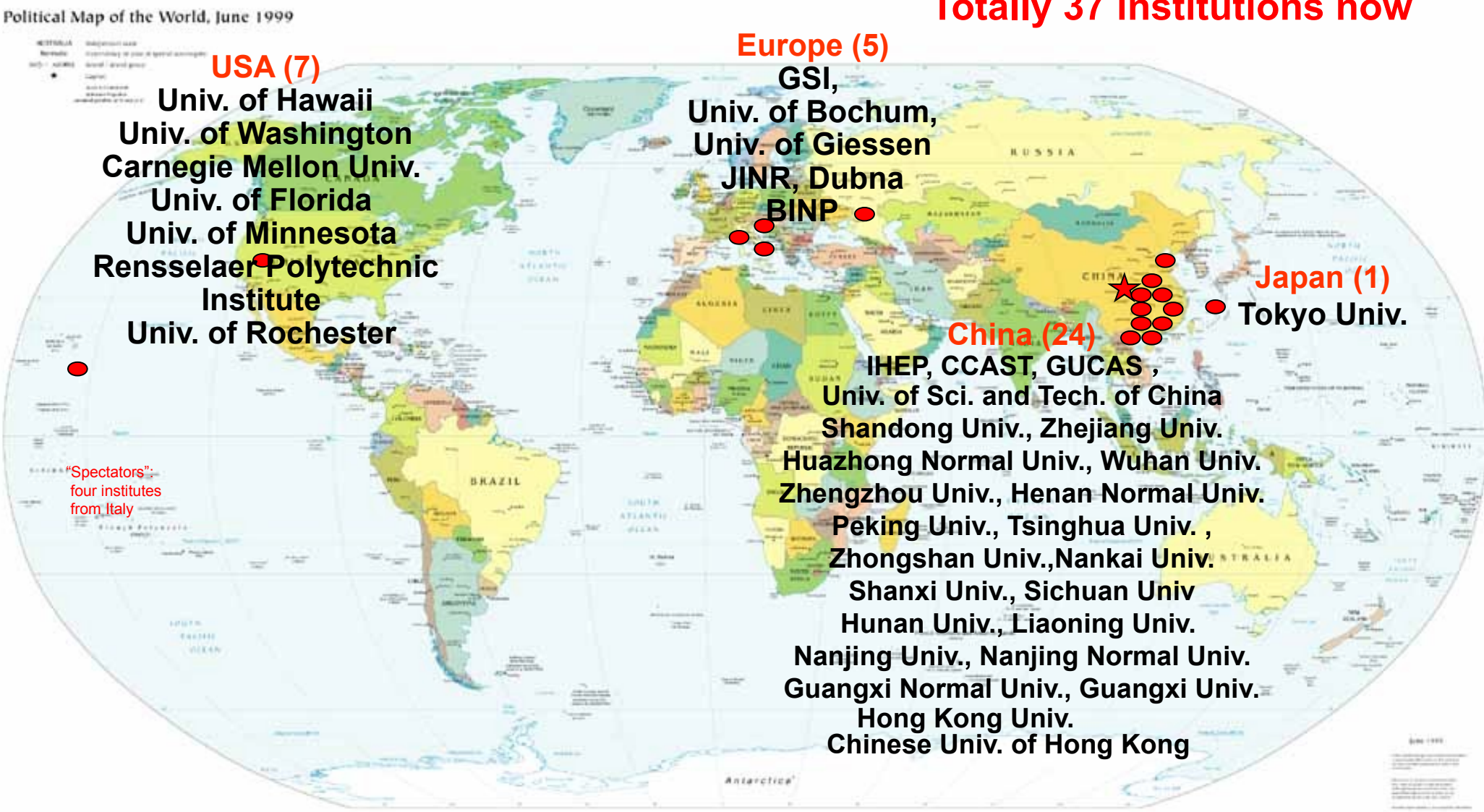
BESIII: < 2%

$|V_{td}/V_{ts}|$=0.208+-0.007

BESIII improves precision indirectly

BESIII collaboration

Totally 37 institutions now



USA (7)
Univ. of Hawaii
Univ. of Washington
Carnegie Mellon Univ.
Univ. of Florida
Univ. of Minnesota
Rensselaer Polytechnic Institute
Univ. of Rochester

"Spectators": four institutes from Italy

Europe (5)
GSI,
Univ. of Bochum,
Univ. of Giessen
JINR, Dubna
BINP

Japan (1)
Tokyo Univ.

China (24)
IHEP, CCAST, GUCAS ,
Univ. of Sci. and Tech. of China
Shandong Univ., Zhejiang Univ.
Huazhong Normal Univ., Wuhan Univ.
Zhengzhou Univ., Henan Normal Univ.
Peking Univ., Tsinghua Univ. ,
Zhongshan Univ.,Nankai Univ.
Shanxi Univ., Sichuan Univ
Hunan Univ., Liaoning Univ.
Nanjing Univ., Nanjing Normal Univ.
Guangxi Normal Univ., Guangxi Univ.
Hong Kong Univ.
Chinese Univ. of Hong Kong

Precision measurement of ν mixing θ_{13}: Daya Bay reactor ν experiment

- Daya Bay nuclear power plant: 4 reactor cores, 11.6 GW
  2 more in 2011 for a total of 17.4 GW
- Mountains near by, easy to construct a lab with enough overburden to shield cosmic-ray backgrounds
- Begin data taking with the Near-Far configuration Dec. 2010
- Expect to reach sensitivity of 0.01 with 3 years of running.

Design considerations: sensitivity of 0.01

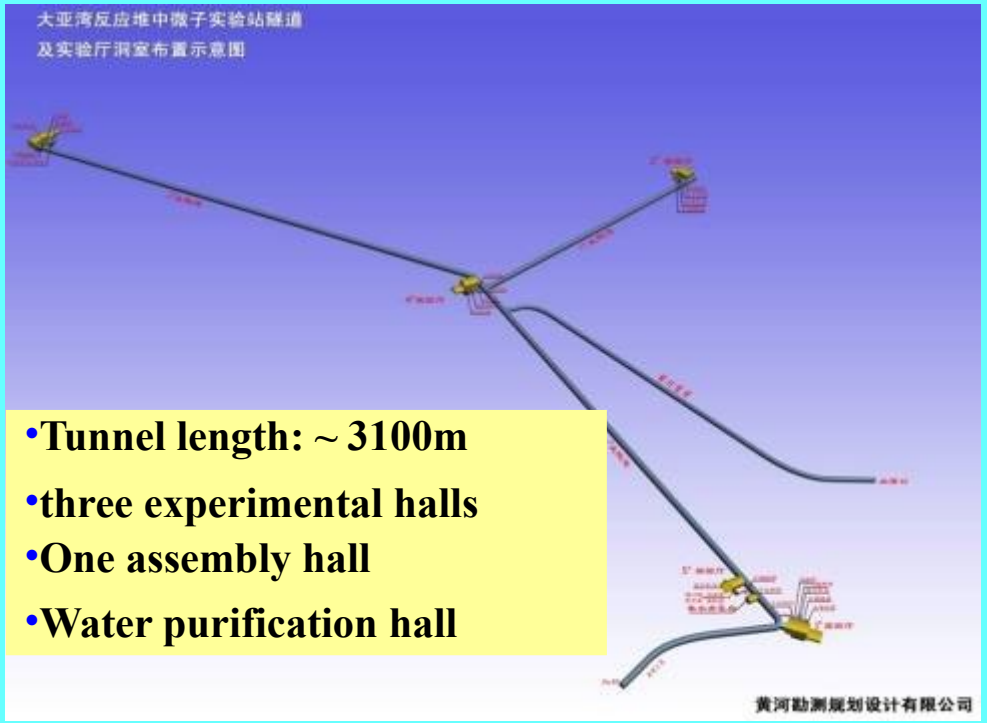
- ***Identical near and far detectors*** **to cancel reactor-related errors**
- ***Multiple modules*** **for reducing detector-related errors and cross checks**
- ***Three-zone detector modules*** **to reduce detector-related errors**
- ***Overburden and shielding*** **to reduce backgrounds**
- ***Multiple muon detectors*** **for reducing backgrounds and cross checks**
- ***Movable detectors*** **for swapping**

Experimental layout

- Identical detector at near and far site to perform relative measurement in order to cancel reactor related systematic error
- Experimental halls are connected by 3000m tunnel

- Signal rate ：
  ~1200/day Near
  ~350/day Far
- Backgrounds ：
  B/S ~0.4% Near
  B/S ~0.2% Far

Civil construction



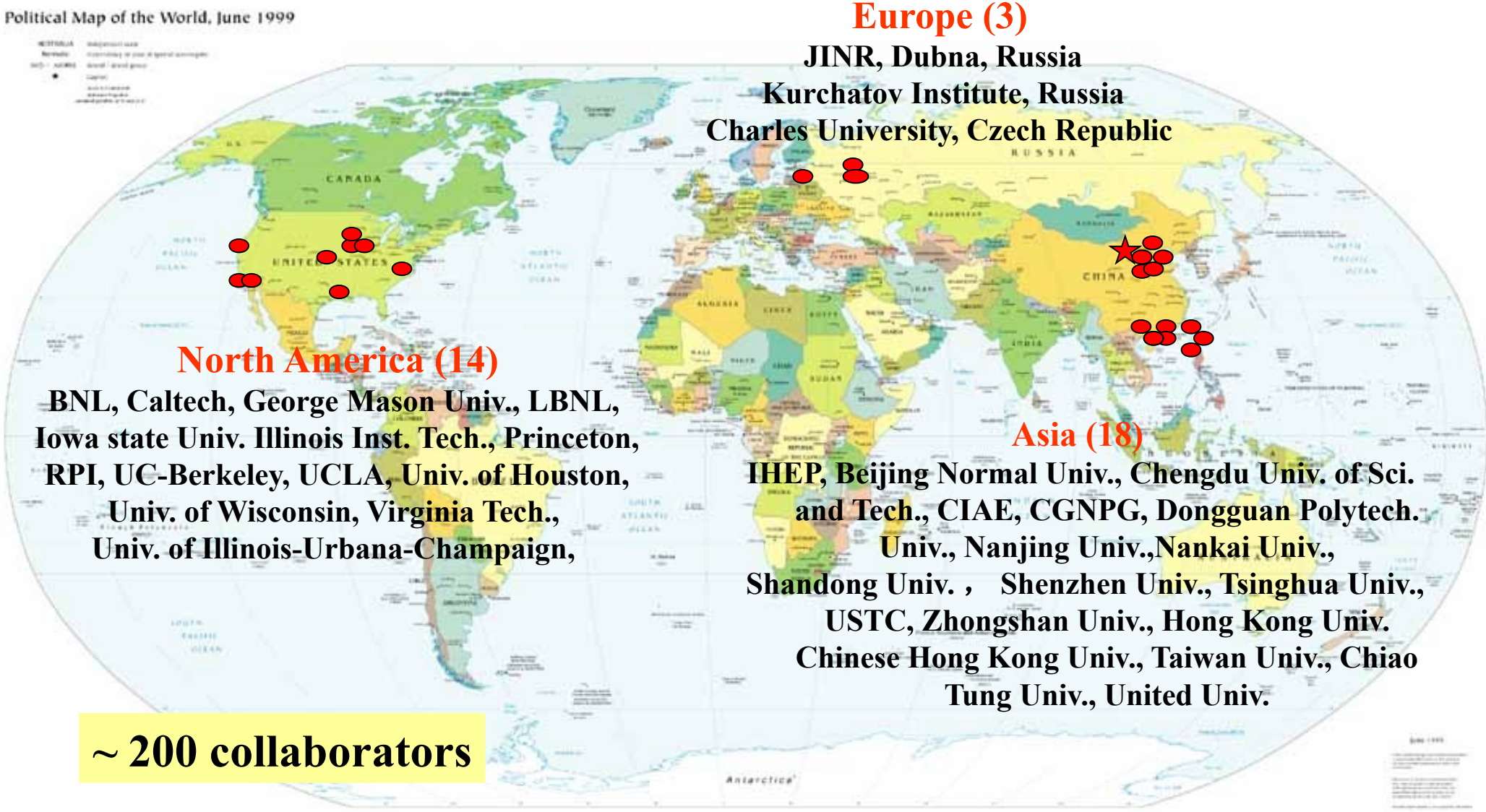
- Tunnel length: ~ 3100m
- three experimental halls
- One assembly hall
- Water purification hall

Construction tunnel

Entrance tunnel

Surface assembly building

Daya Bay collaboration



Europe (3)

JINR, Dubna, Russia
Kurchatov Institute, Russia
Charles University, Czech Republic

North America (14)

BNL, Caltech, George Mason Univ., LBNL, Iowa state Univ. Illinois Inst. Tech., Princeton, RPI, UC-Berkeley, UCLA, Univ. of Houston, Univ. of Wisconsin, Virginia Tech., Univ. of Illinois-Urbana-Champaign,

Asia (18)

IHEP, Beijing Normal Univ., Chengdu Univ. of Sci. and Tech., CIAE, CGNPG, Dongguan Polytech. Univ., Nanjing Univ.,Nankai Univ., Shandong Univ. , Shenzhen Univ., Tsinghua Univ., USTC, Zhongshan Univ., Hong Kong Univ. Chinese Hong Kong Univ., Taiwan Univ., Chiao Tung Univ., United Univ.

~ 200 collaborators

LHC Experiments

1. CMS
   - 1/3 of CSC at muon end caps (IHEP)
   - RPC of barrel muon (Beijing Univ.)
   - Physics and MC
2. Atlas
   - Drift Monitor chambers (IHEP)
   - TGC (Shandong Univ.)
   - Physics and MC
3. LCG: Tier 2
4. LHCb: Tsinghua Univ.
5. Alice: CIAE…

ILC R&D

- **Activities:**
  - **SC cavities**
  - **Dumping ring design**
  - **Positron source**
  - **detector R&D (IHEP and Tsinghua Univ.…)**
  - **works for EXFEL also very useful for ILC R&D**
- **Funding:**
  - **IHEP fund: 8.5M RMB for SC cavities**
  - **some funds from CAS and NSF in various ways.**
  - **……**

Yangbajing Cosmic Ray Observatory （Tibet a.s.l. 4300m）

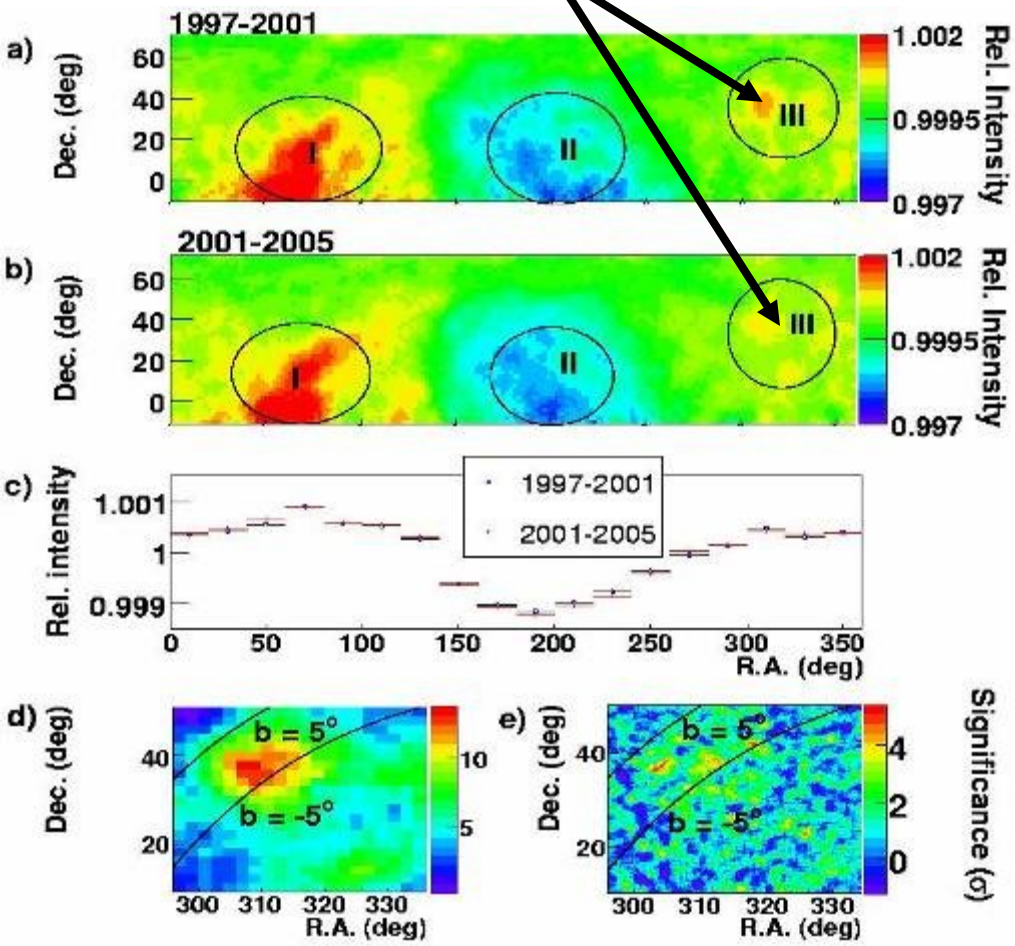
IHEP-INFN Argo RPC　　China-Japan Air Shower Array

New anisotropy component and corotation of GCR

(Science 314(2006) 439-443)

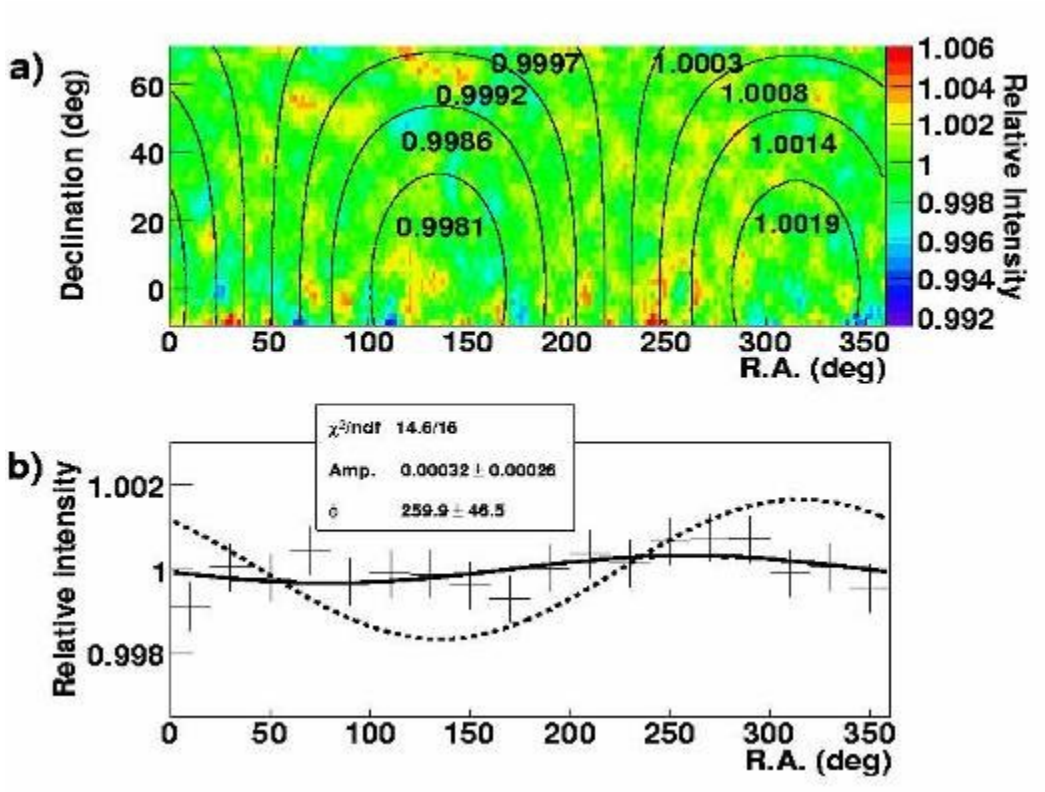
Celestial Intensity map (E~3TeV)

New anisotropy component



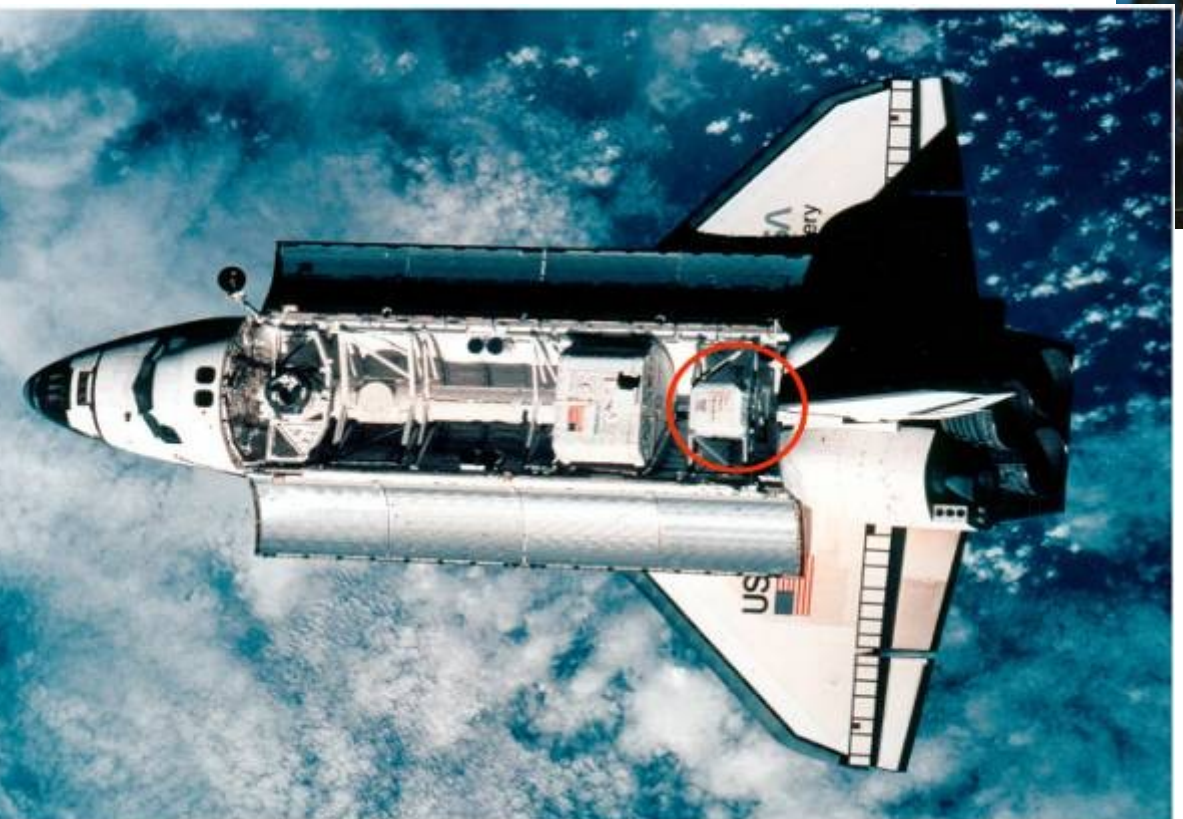
Intensity @ E~300TeV

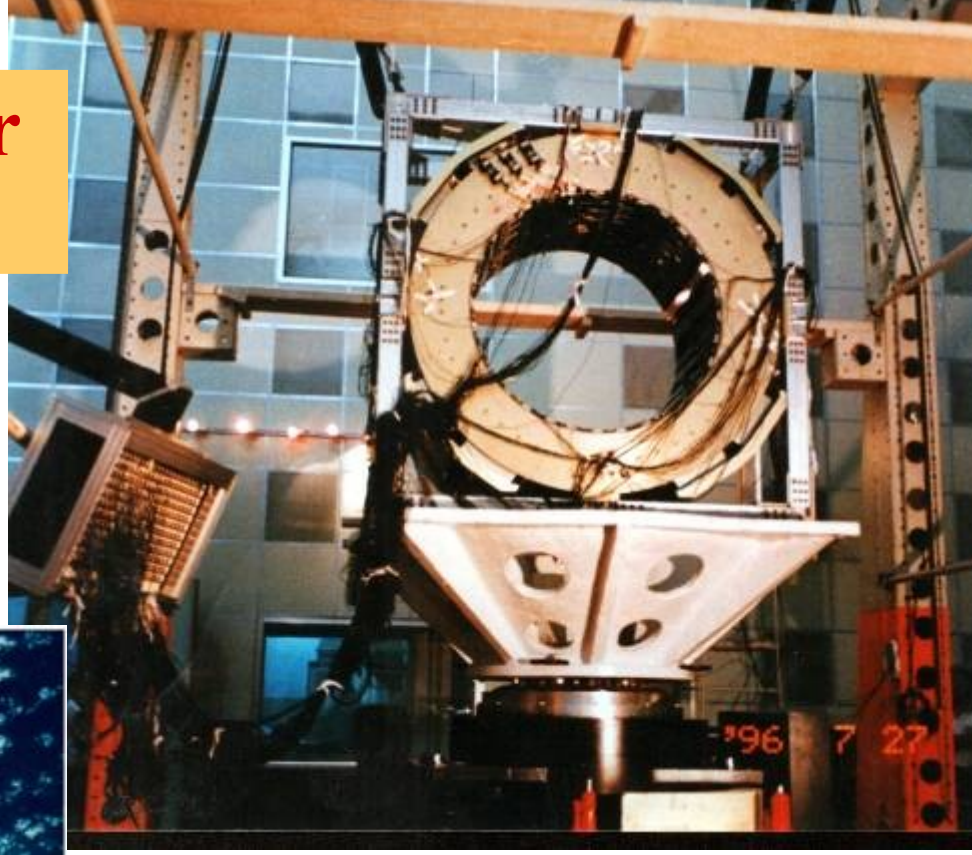
Amp=0.16% w/o corotation;
Observation: 0.03%±0.03%.



Alpha Magnetic Spectrometer

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



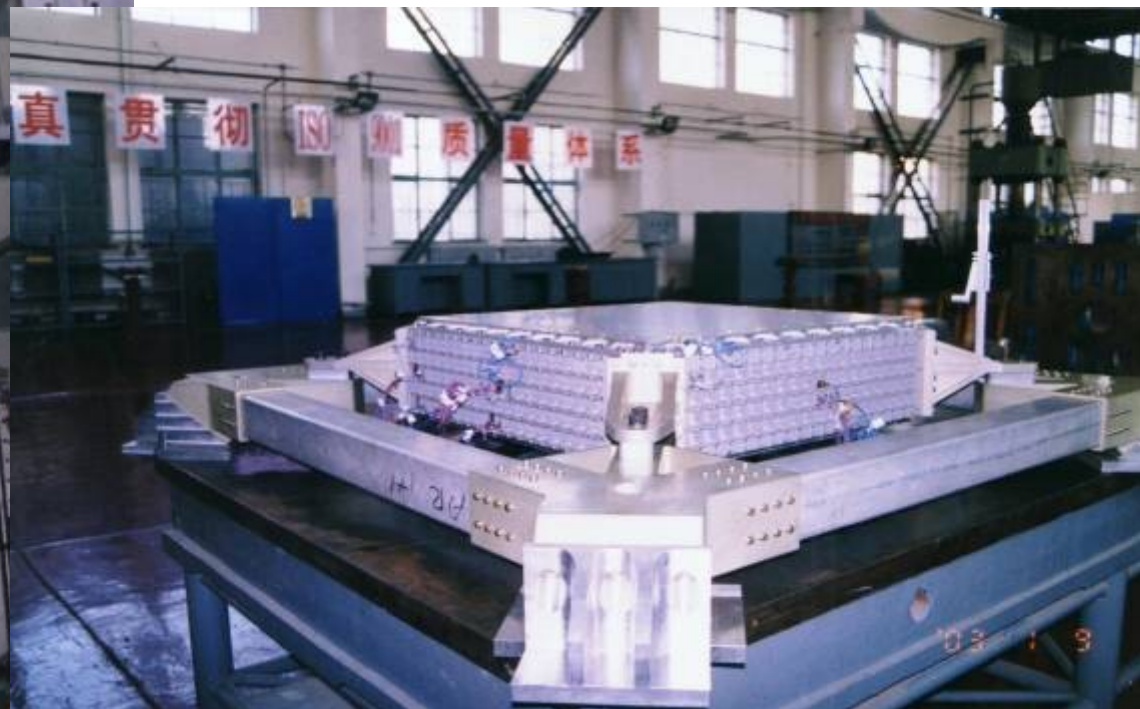


AMS01 permanent magnet and structure were built at Beijing, and became the first big magnet in space as payload of Discovery June 1998.

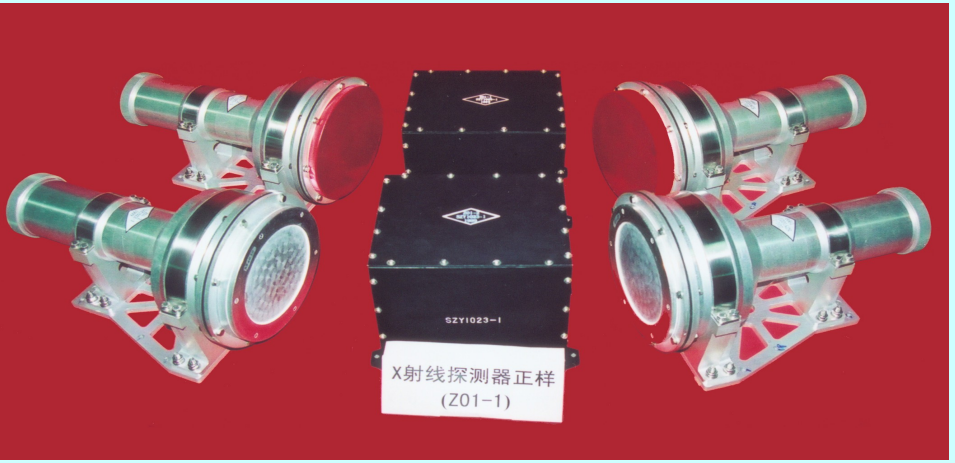
AMS02 ECAL: 700Kg
IHEP LAPP and PISA

Space qualification at Beijing

ECAL assembling at IHEP



γ Burst Detector

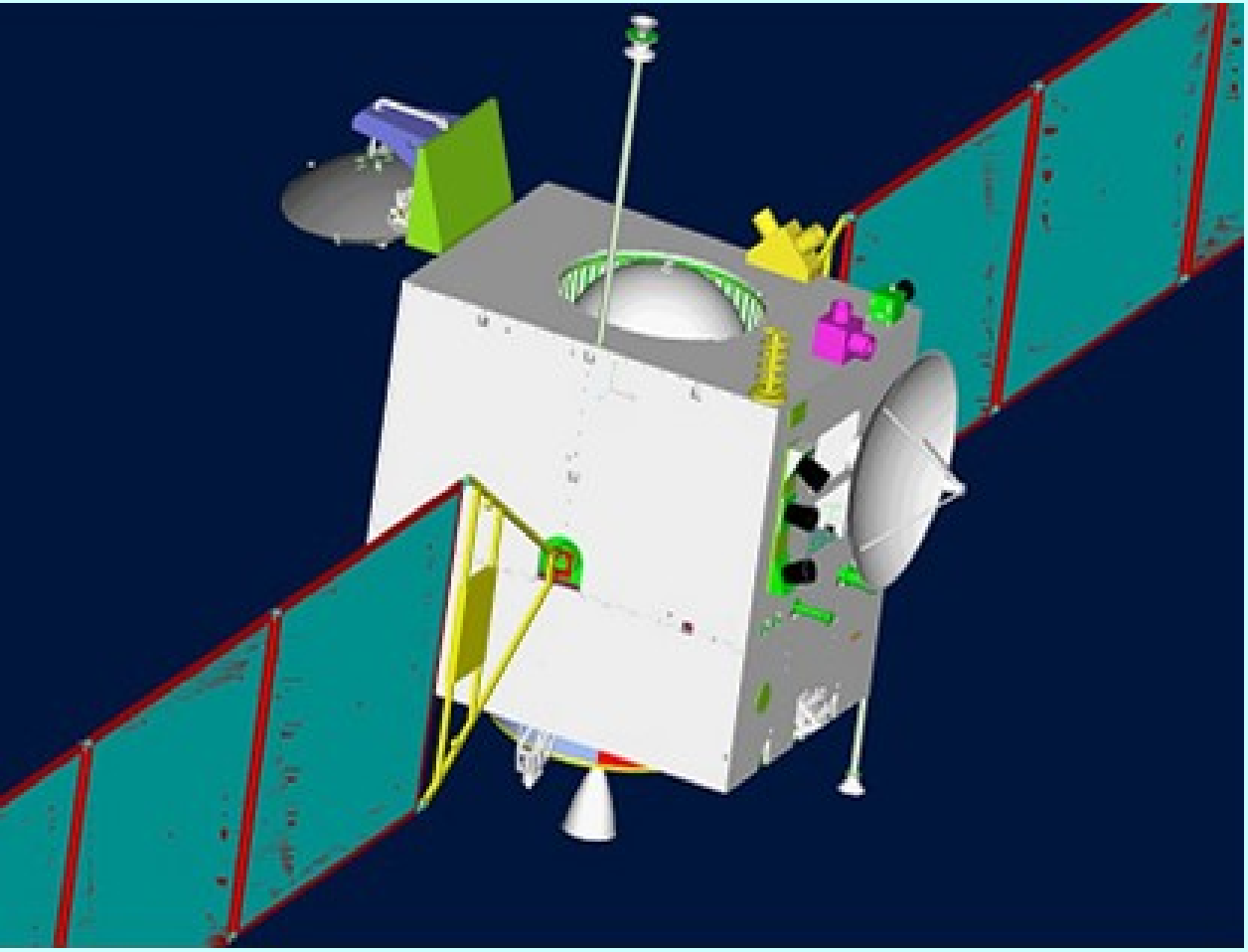


Shenzhou-2 Spacecraft

Flown 2001, First Astronomy detector of

ChangEr-1 (Chinese Moon Project)

Launched 24 Oct. 2007, Switch on 28 Nov.



Payload:

Optical System

X ray spectrometer

γ ray Spectrometer

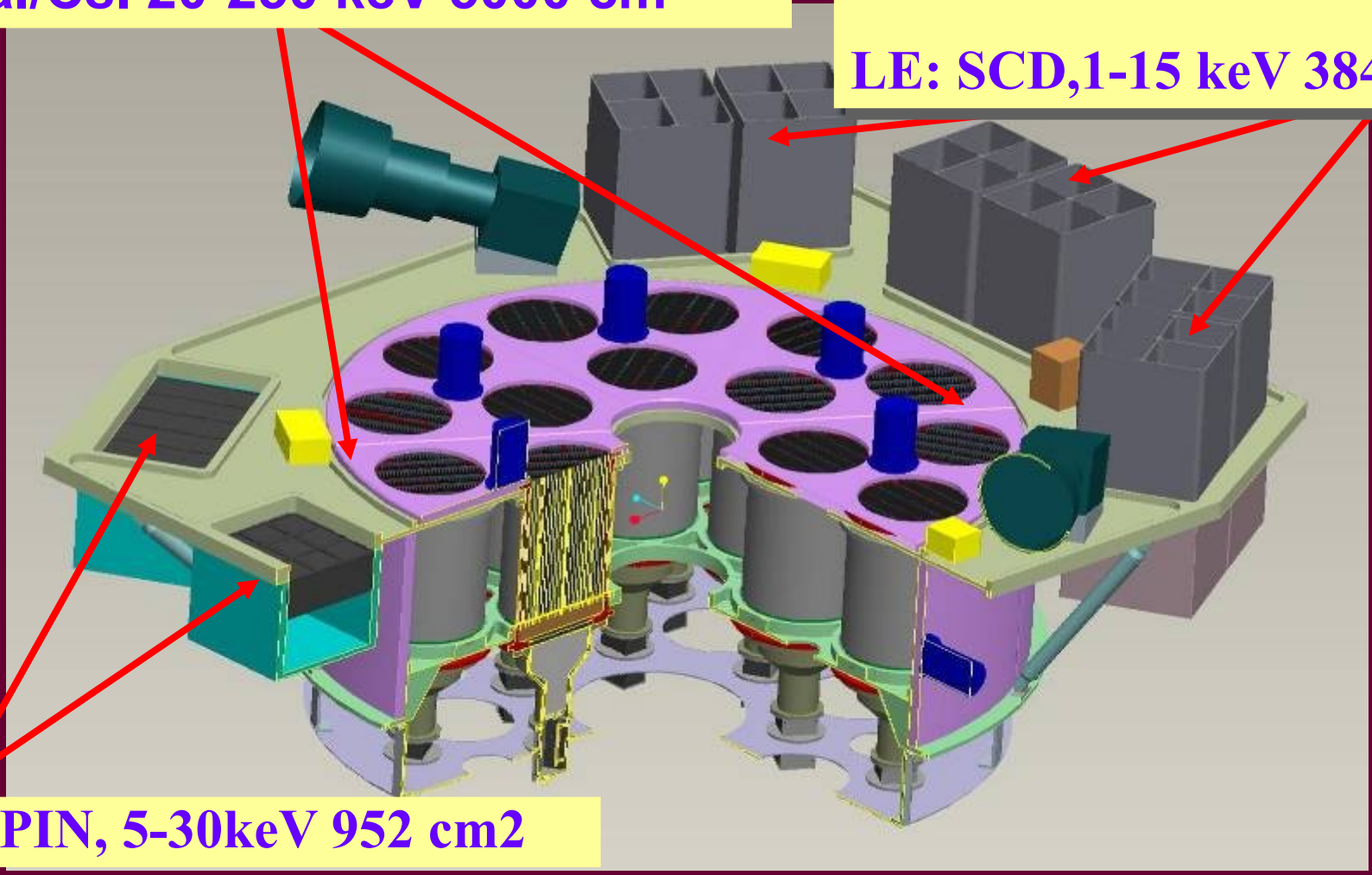
Laser altimeter

Solar wind detector

Made by Chinese Academy of Sciences

HE: NaI/CsI 20-250 keV 5000 cm^2

LE: SCD,1-15 keV 384 cm^2

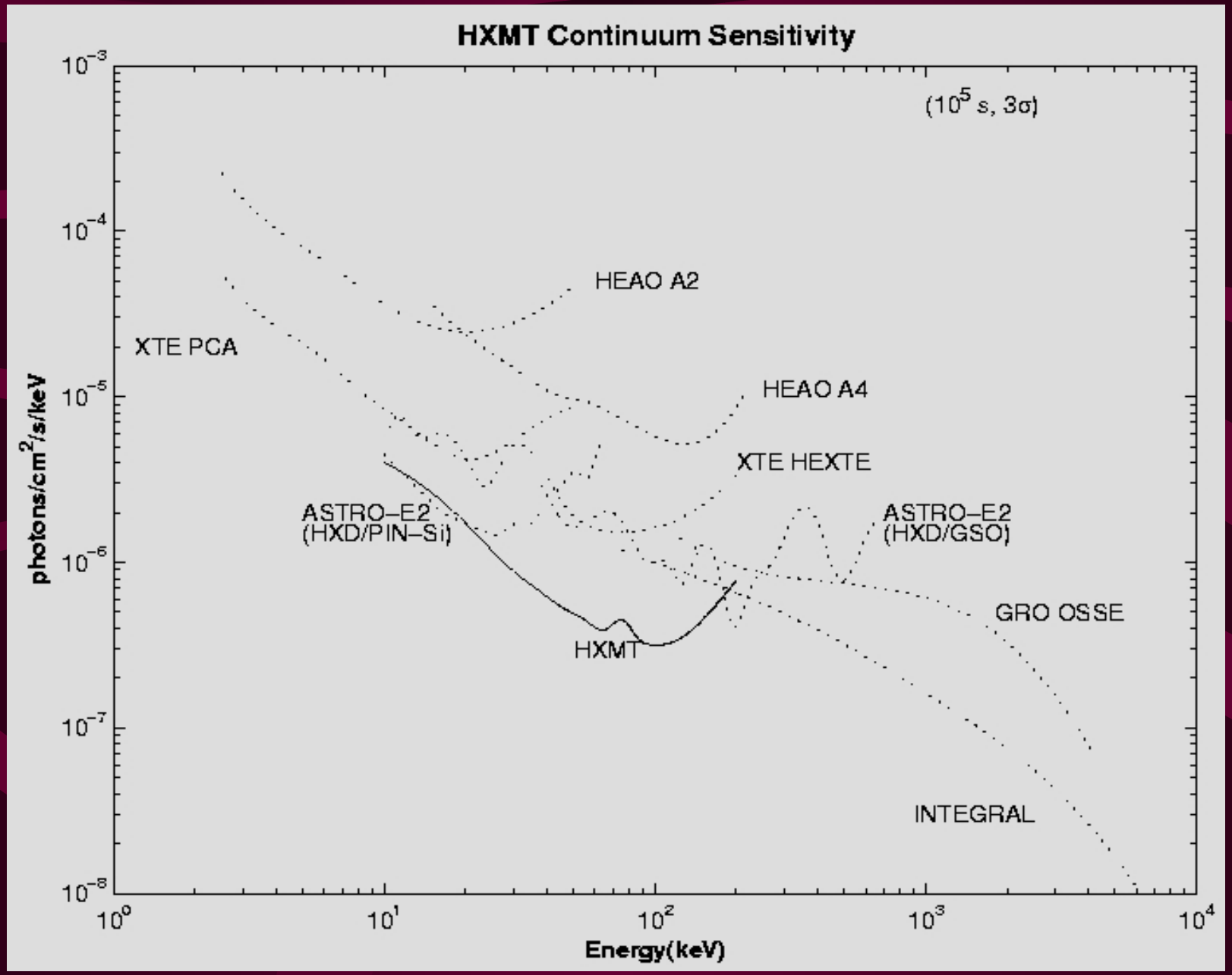


ME: Si-PIN, 5-30keV 952 cm2

Hard X-ray Modulation Telescope (HXMT)

Size： 1900×1600×1000 mm 1100 kg Satellite 2700 kg

Sensitivity



Key Physics Topics of HXMT

Hard X-ray sky survey with highest sensitivity

- High precision hard X-ray full sky map:
- Discover highly obscured supermassive BHs:
- Discover new types of high energy objects:

High precision pointed observations of HE objects

- Space-time in strong gravitational field: dynamics and radiation near stellar mass and supermassive BHs
- Equation of state in strong magnetic field: neutron star and its surface properties
- High energy particle acceleration: AGN, SNR, shock and relativistic jets
- Large scale structure: through hard X-ray detection of galaxy clusters

Chinese Particle Physics in 21st Century

- Chinese economy grows quickly and steadily
- Chinese government increases the supports to sciences and technology significantly and constantly .
- With construction of BEPCII/BESIII, Shanghai light source and CSNS, the new generation of Chinese accelerator and detector teams are shaping: young and growing fast.
- Strong demands on
  - the large scientific facilities based on accelerators.
  - the application of accelerator and detector technology

Chinese Particle Physics projects in medium and long term plan

- Charm physics @ BEPCII: next 8 years or more
- Intl. collaborations: LHC exp., ILC…
- Particle Astrophysics exp. at Space
  - Modulated hard X-ray telescope satellite
  - SVOM
  - Polar @ Chinese Spacelab.: polarization of γ burst
- Cosmic ray measurement
  - Yangbajing Cosmic ray Observatory: extension
- Neutrino experiments:
  - Daya Bay Reactor neutrino to measure $\sin^2 2\theta_{13}$
  - Very LBL oscillation: J-Prac→ Beijing (under discussion)
- South pole Dome A: 4m telescope (under discussion)

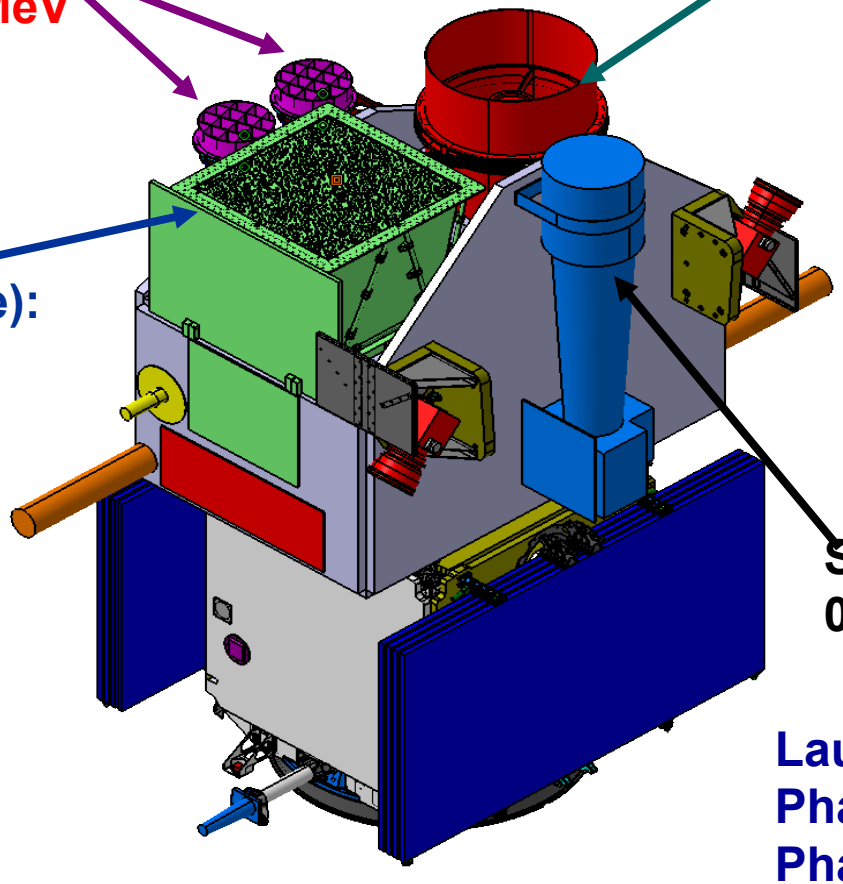
Chinese Particle Physics
Medium and Long Term Plan (cont.)

- **High power proton Accelerator:**
  - **Chinese Spallation Neutron Source**
  - **Accelerator Driven Subcritical system**
- **Advance Light Source: ERL + XFEL**

IHEP extents research fields, to protein structure, nano-science, material science…

→ Multiple discipline research center

SVOM: multi-wavelenth GRB project



Scientific instruments :

- GRMs (gamma-ray monitors)
- CXG (hard X-ray camera)
- SXT(Soft X-ray Telescope)
- VT (visible telescope)

Launch 2011-2012
Phase A: 2007
Phase A review:Mar. 2008

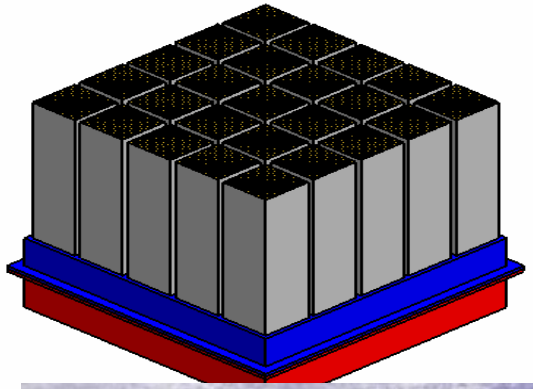
China-France collaboration

POLAR mission status

- **Instrument conception proposed by N. Produit, et al., NIM (2005)**
- **On board China's spacelab TG-2: launch time 2011-12**

  (Phase 2 of China manned spacecraft program.)
- **FOV of POLAR: ~½ sky**
- **MDP is 10%: >10 GRBs per year down to 10% polarization;**

POLAR



Tian-Gong

天宫

Palace in Heaven

Future Plan of Yangbajing: Largest high mountain CR measurement complex

Expand the size of the detector by order of magnitude, improve γ/P indetifiction

- γ astronomy: precision measurement of γ spectrum of Galaxy, CMB cut-off
- precision measurement of spectrum of CR components of knee.
- monitor time-changing γ source in north
- CR spectrum of 0.1PeV- 1EeV, second knee

Tentative design of the complex detector array

Two major components

- **1km² complex array forγrays & CRs >30TeV**
  - **1 km² scintillation detector array**
  - **40k m² μ detector array**
  - **28 C-telescopes**
  - **1k m² burst detector (or hadronic calorimeter)**
- **90k m² water Cerenkov detector for γ> 100GeV**

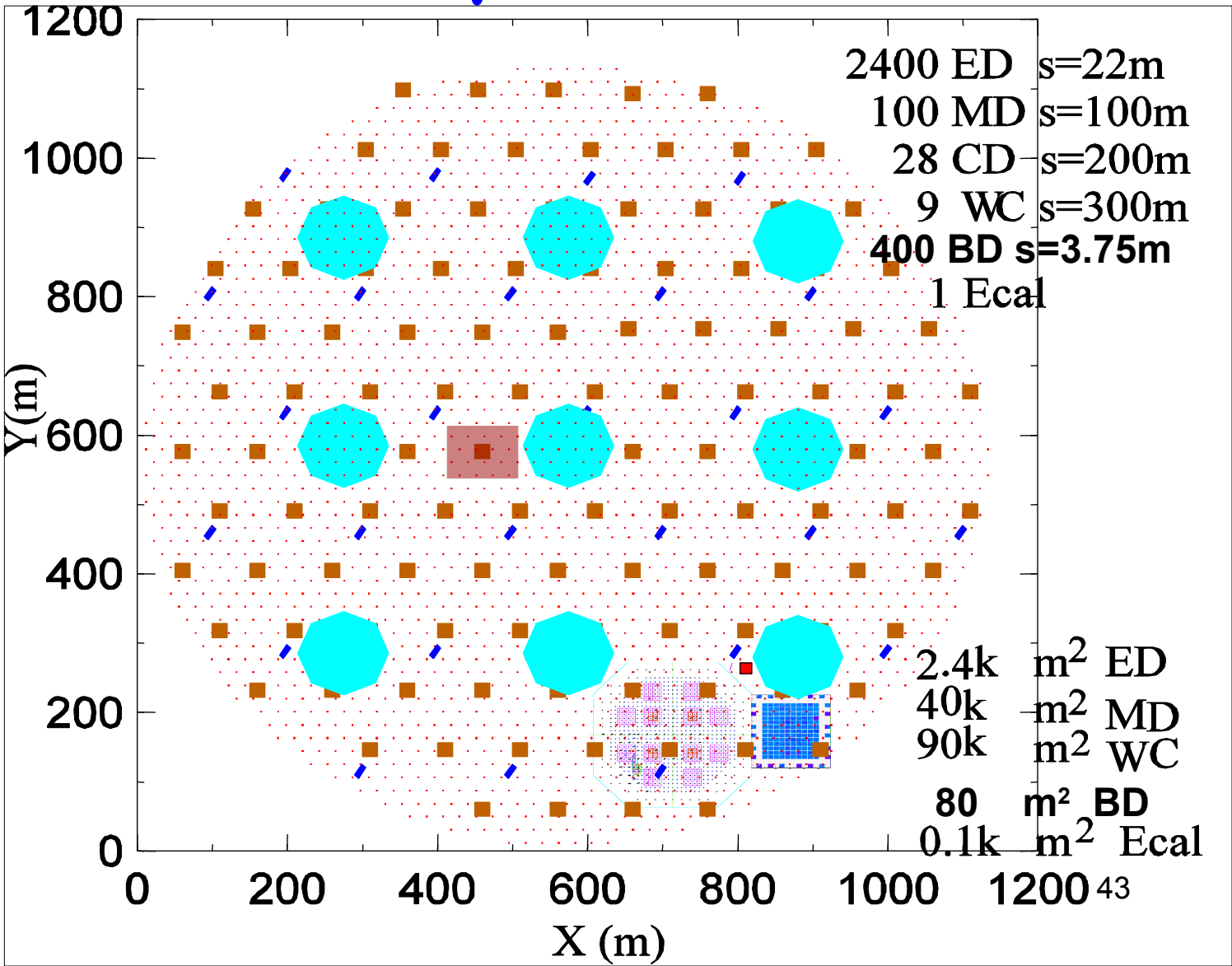
Future plan of Yangbajing : complex of CR+γdetectors

WC: 9x10 m

μ : 100x400m

e : 2400x1m

CT: 28

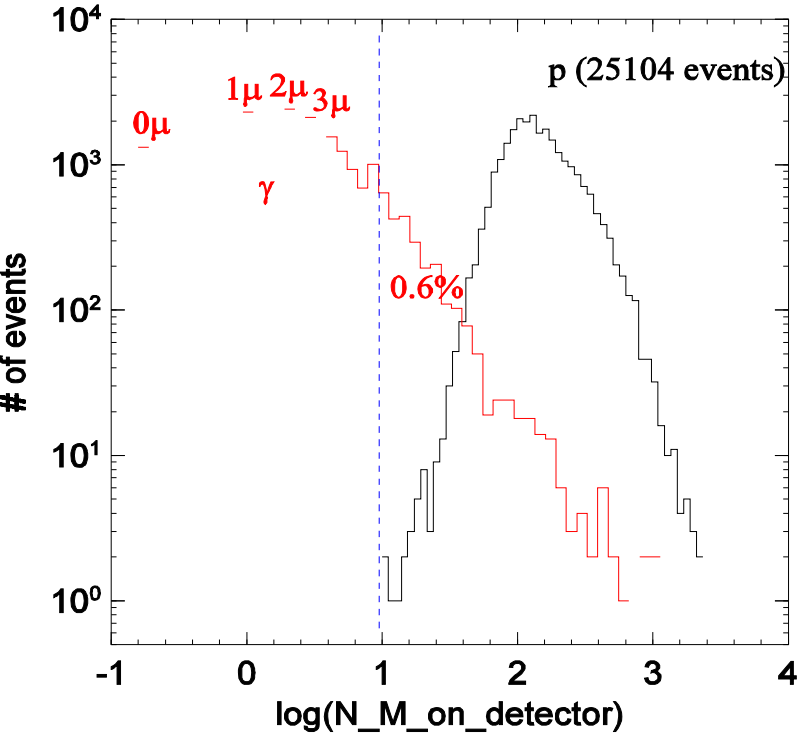


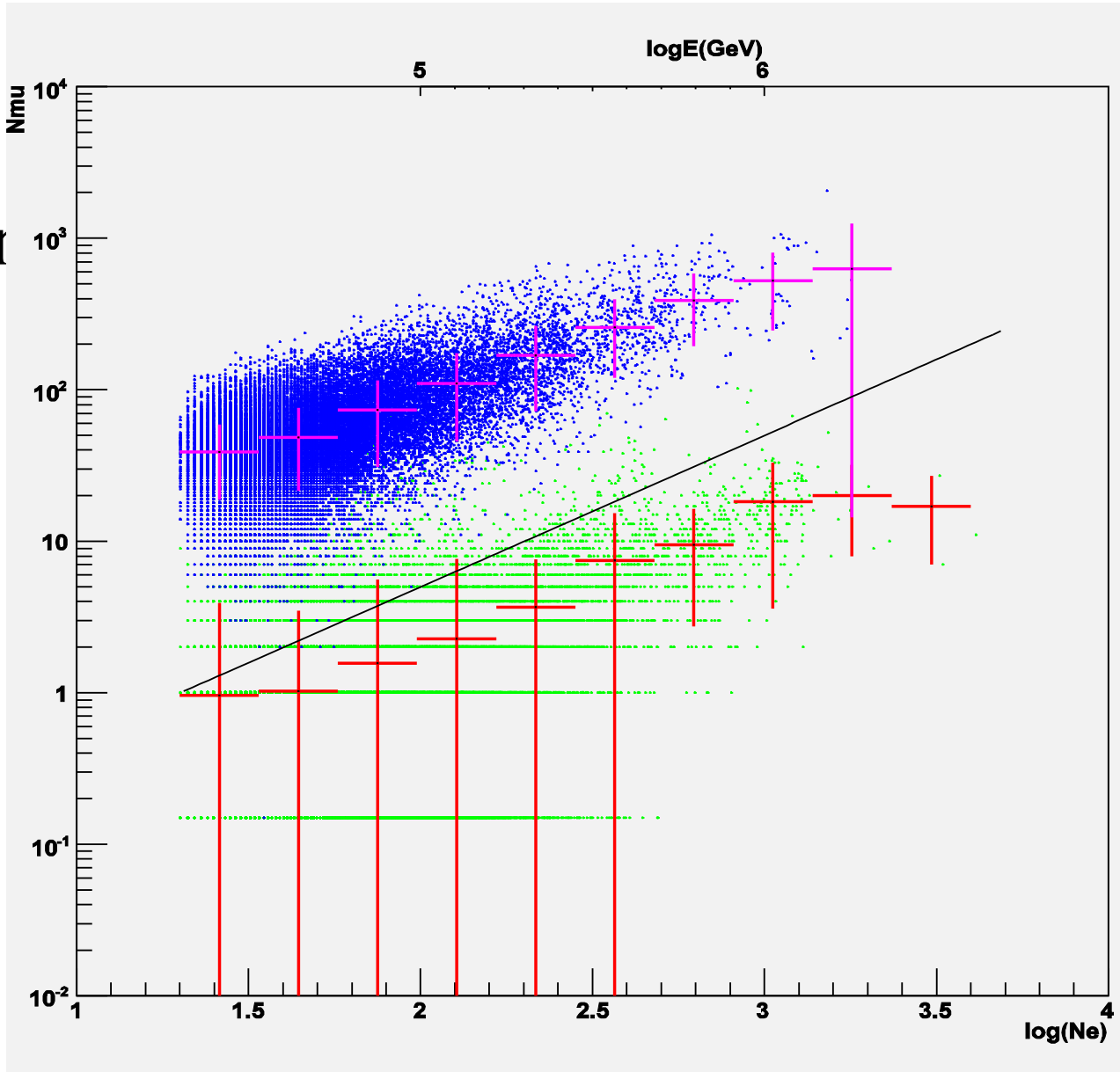
γ/p discrimination

- Above 60TeV

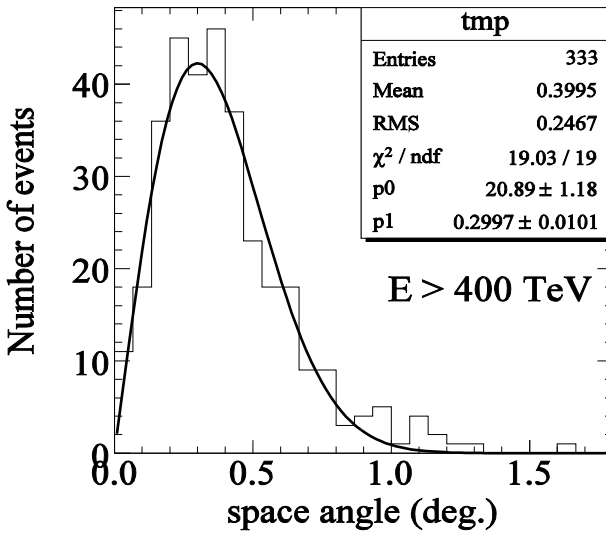
CR BG-free(10^{-5})

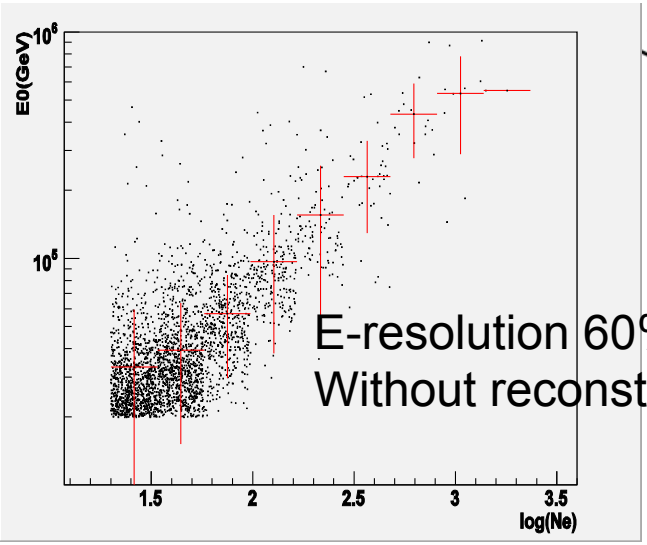
- γsurvival rate ~99%
- Angular resolution 0.5°

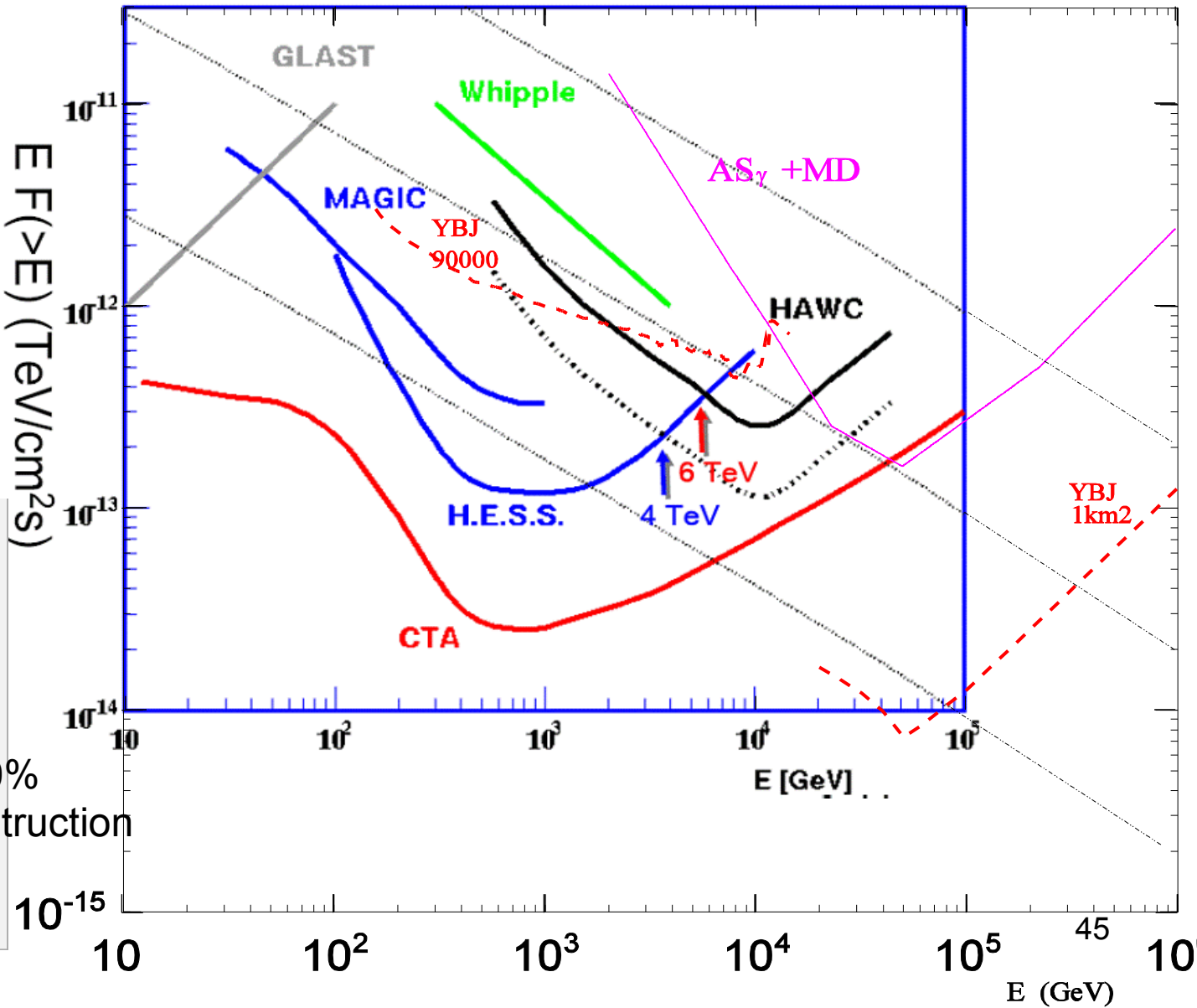




Sensitivities for 100TeV γsky

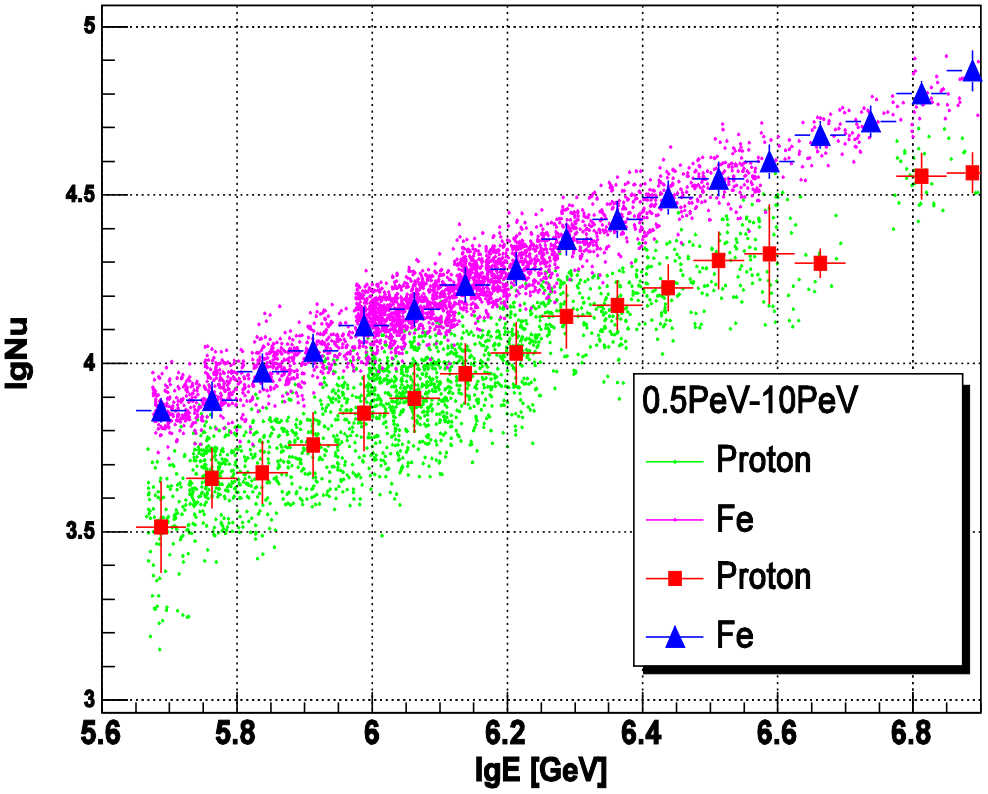


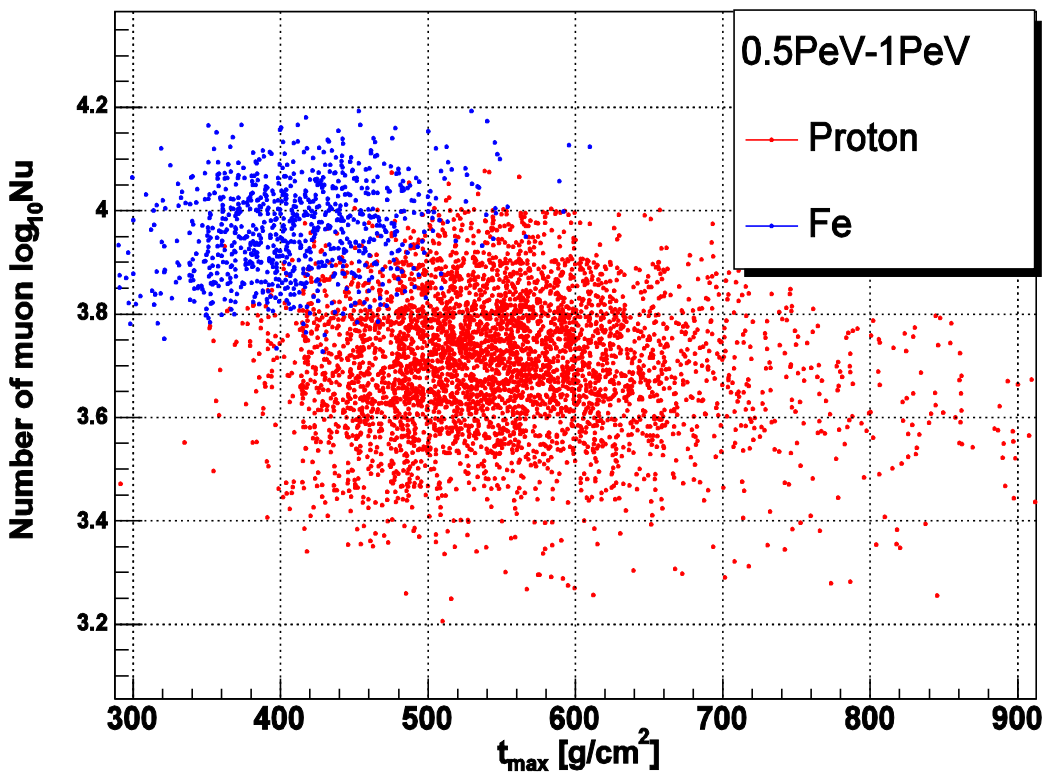




Resolution for light and heavy composition

μ -content, Xmax and HE (>30TeV) shower particles





Dome A for Astronomy

National Natural Science Foundation of China

Chinese Academy of Sciences

State Oceanic Administration

Site Survey

Seeing/Atmospheric Turbulence

Cloud Coverage

Atmospheric Transparency

Ice Cap Stability

Precipitable Water Vapor

Sky background

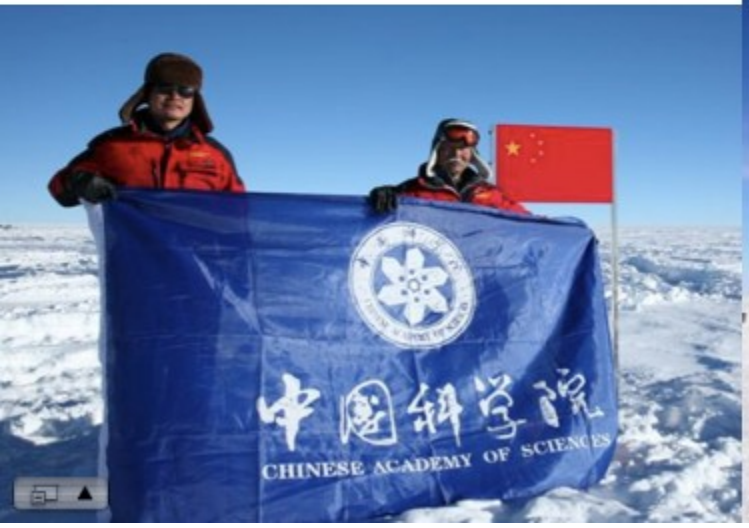
Weather

Why Antarctica?

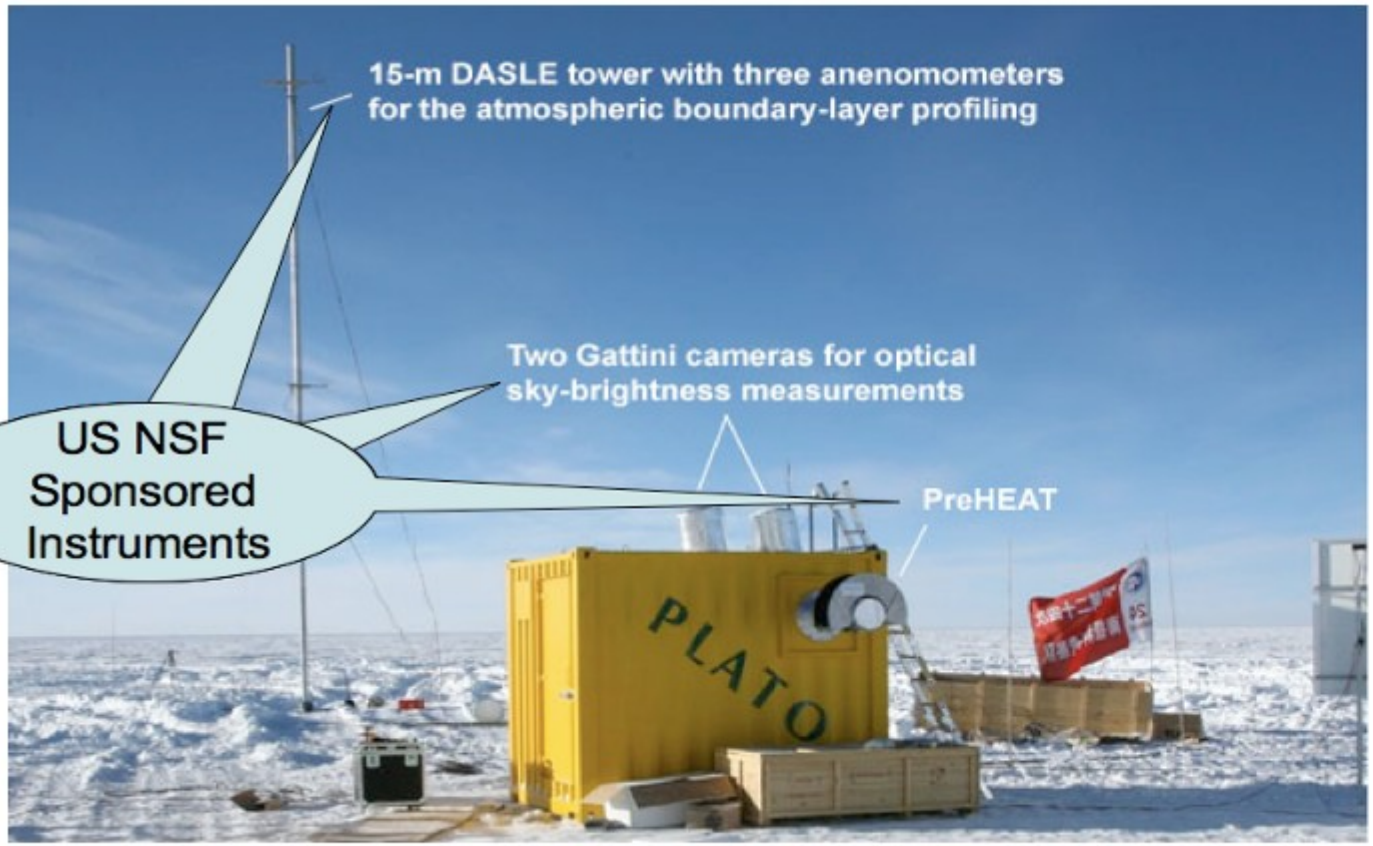
Astronomical observations are best done at sites with clear and stable atmosphere. The Antarctic plateau is such an ideal place that high quality images of around 0.3 arc seconds may be obtained. The Antarctic plateau is cold and dry, and has a continuous observable night of over 3 months.

Major Results of Dome A Site

1. Atmospheric boundary layer reaches as low as 9 meters
2. 99% of observable time
3. Likely the driest place on Earth
4. Coldest spot on Earth



The National Science Foundation of the US has played an important role in PLATO
- Iridium Modems - communication to Dome A Observatory
- GATTINI - two cameras for sky-brightness measurement
- PreHEAT - a sub-mm instrument for preciptible water vapor measurement
- Dasle - a 15 m tower for measuring atmospheric turbulence



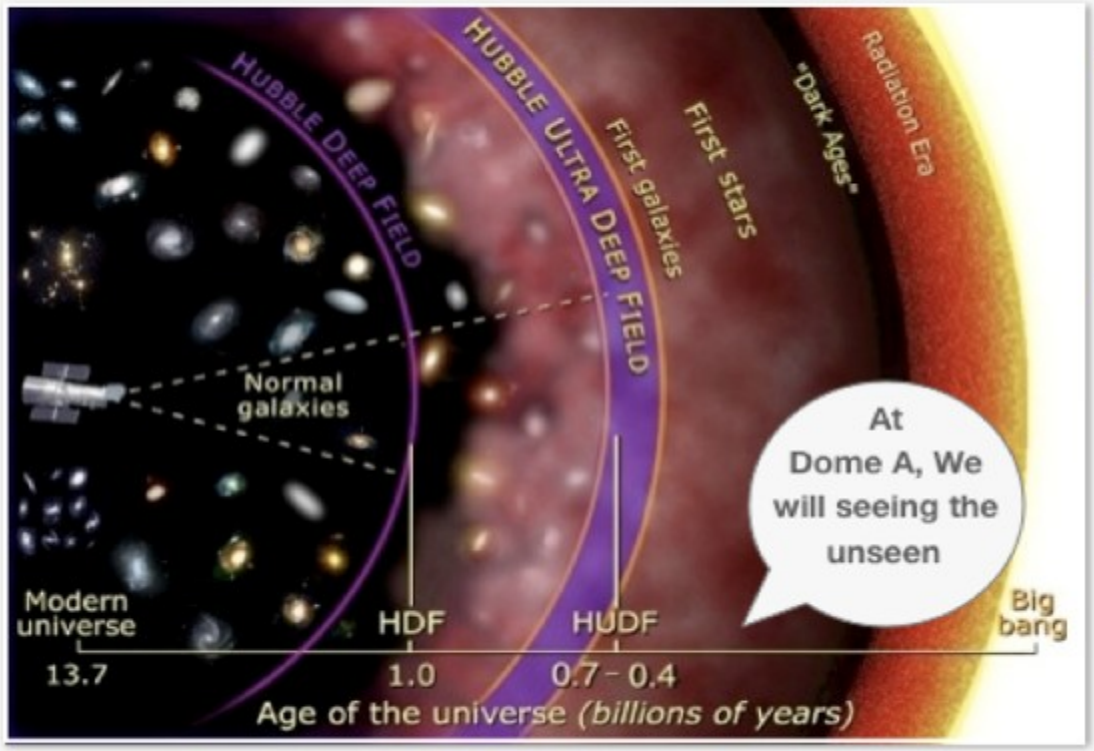
US Collaborators
- Texas A&M University
- University of Chicago
- University of California, Berkeley
- California Institute of Technology
- National Optical Astronomy Observatory

US Funding Agencies

National Science Foundation, USA

United States Antarctic Program

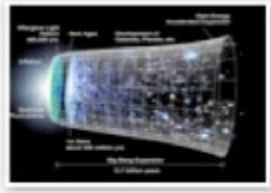
Science Programs



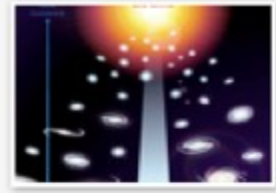
Many exciting sciences can benefit from the excellent observing conditions provided by Antarctic Plateau

HDF = Hubble Deep Field; HUDF = Hubble Ultra Deep Field

Dark Matter and Dark Energy



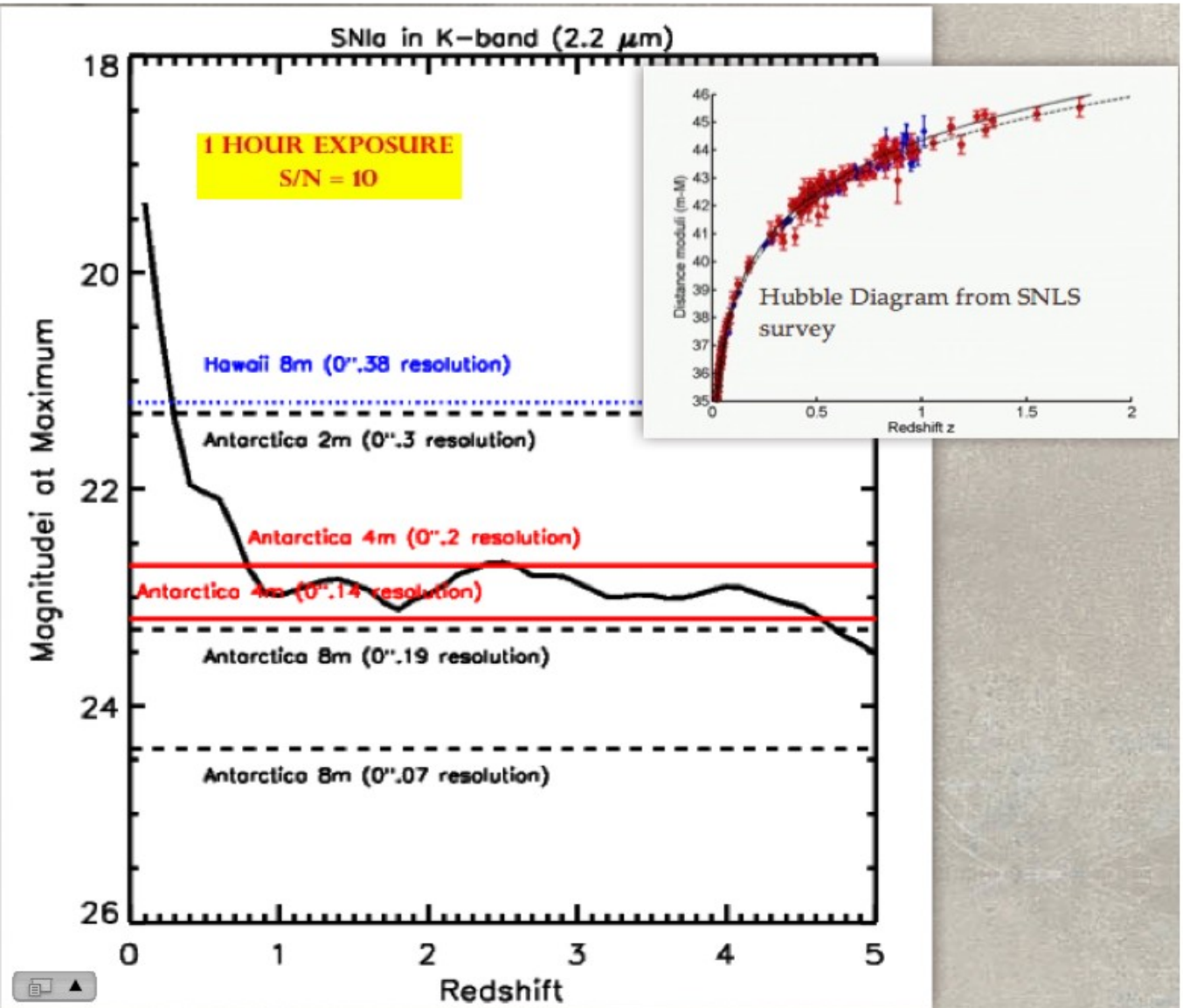
The First Light



Time Domain Astronomy

Extrasolar Planet

Science example: Supernova cosmology suffers from unknown dust extinction from the host galaxies, rest frame infrared observations can effectively eliminate this problem



Dome A will be the best site on Earth for K-band observations because of its low temperature and thermal background emission

A 2 meter telescope in Antarctica can outperform an 8 meter telescope in Mauna Kea, Hawaii.

A 4 meter telescope in Antarctica is able to observe SNIa out to redshift above 4!

Telescopes

- **CSTAR** - Four 14.5cm telescopes each with field of view of 5 degree, already in operation
- **AST3** - Three Schmidt Telescopes each with 75 cm diameter, and field of view of 3 degrees, will be installed in Nov. 2009.
- **Dome A 4 meter** - A wide field telescope under serious study, great for cosmological surveys, planned installation around 2015, about the same time as SNAP operation, highly complementary to SNAP.
- **Off-axis 8 meter telescope** - under study by Chinese Center for Antarctic Astronomy, University of Arizona, great for deep optical/IR surveys

VLBL ν Experiment of J-Parc to Beijing

- VLBL ν exp. with 2000 - 4000 km is very interesting for many important physics, if $\sin 2\theta_{13}$ is not too small:
  - Sign of the difference of ν mass square
  - CP phase of ν
  -

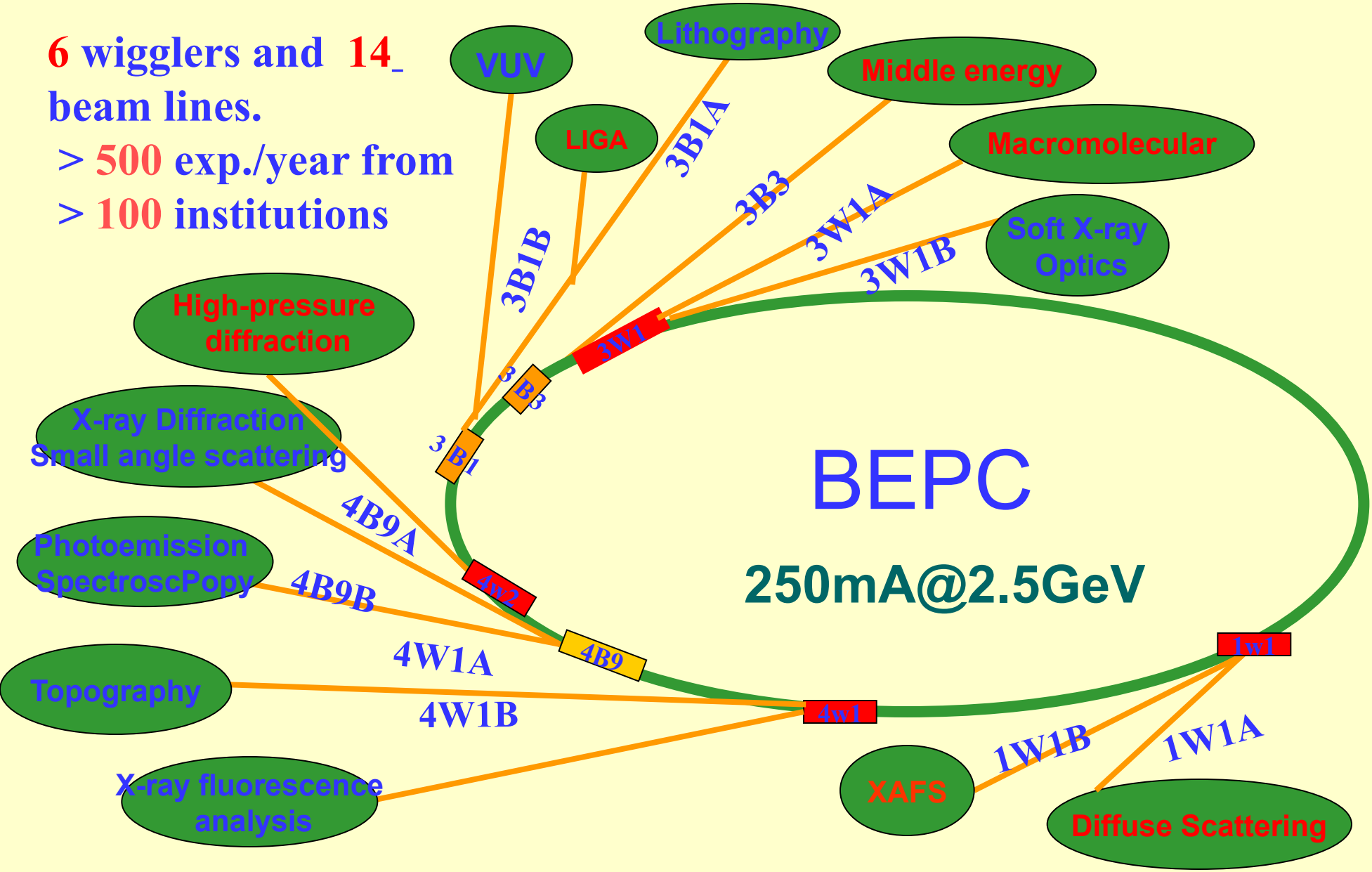
Multiple discipline research

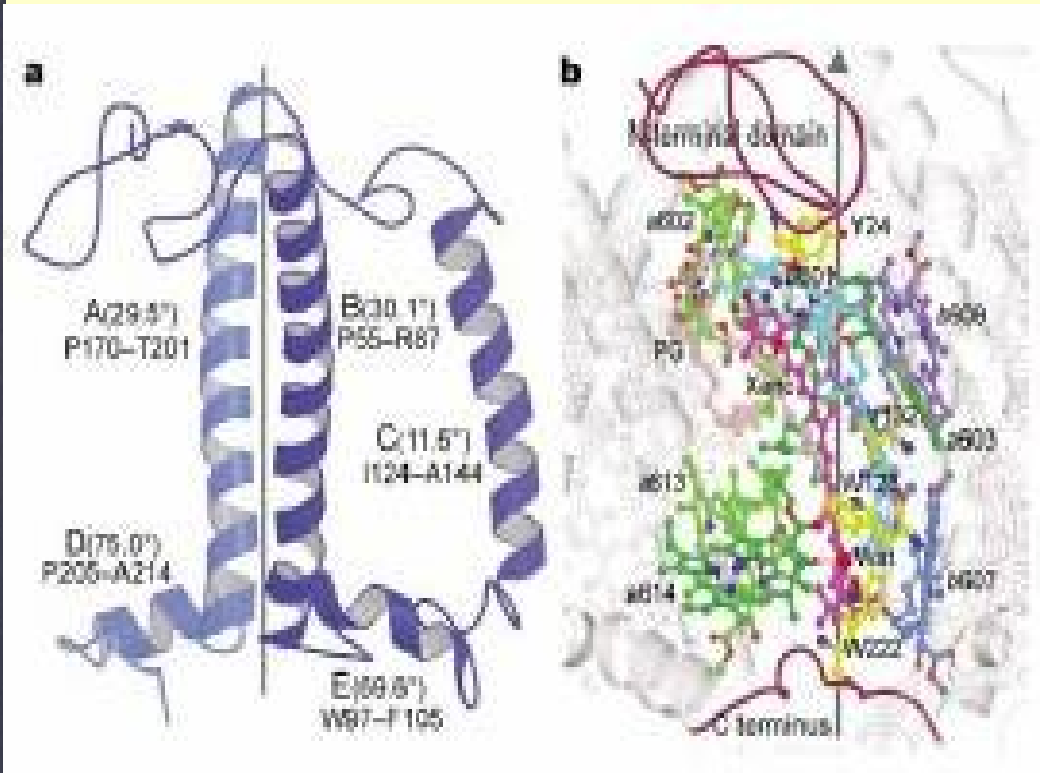
- **Large Facilities:**
  - **BSRF**
  - **CSNS**
  - **High current slow positron source**
  - **Beijing Advance Light Source (under discussion)**
- **Research fields:**
  - **Biology effects of nano-materials**
  - **Nuclear image and application**
  - **Protein structure and function**
  - **Environment studies with nuclear methods**
  - **Nano-material science**
  - **……**

6 wigglers and 14 beam lines.

> 500 exp./year from

> 100 institutions





Structure of third type of light–harvester protein. The structure diffraction data taken at BSRF.

More than 60 protein structure from BSRF were collected by PDB.

Chinese Spallation Neutron Source

- RCS H^- beam; RFQ,3.5MeV; 81MeV(DTL) to 230 MeV (+SCL), RCS: 1.6 GeV at 25 Hz
- 100KW (→ 250KW) @ target, 7 (→ 18) spectrometers
- Site: Dongguang, Guangdong.

Status of CSNS

- **Proposal approved officially at end of Sept.**
- **Feasibility study report is underway**
- **IHEP is in charge of the project with cooperation with Inst. of Physics.**
- **CSNS will be a branch of IHEP**
- **Budget: 1.4B RMB + the fund (0.5B) & the free land from the local governments**
- **Construction and commissioning: 7 year**
- **Major project for machine team and detector team after BEPCII/BESIII**
- **Design, R&D going smoothly. Many prototypes are under test.**

China – US cooperation

- Thank US labs for the strong supports to BEPCII
- Daya Bay experiment: Major collaborator. Open new page of China- US HEP cooperation .
- Construction of large facilities and multiple discipline researches
  - Synchrotron radiation facility
  - Spallation neutron source
  - Next generation light source
- LHC physics study and upgrade
- ILC R&D
- Particle Astrophysics & cosmic ray measurement: great potential !

Look Forward for more close cooperation

between China and US !