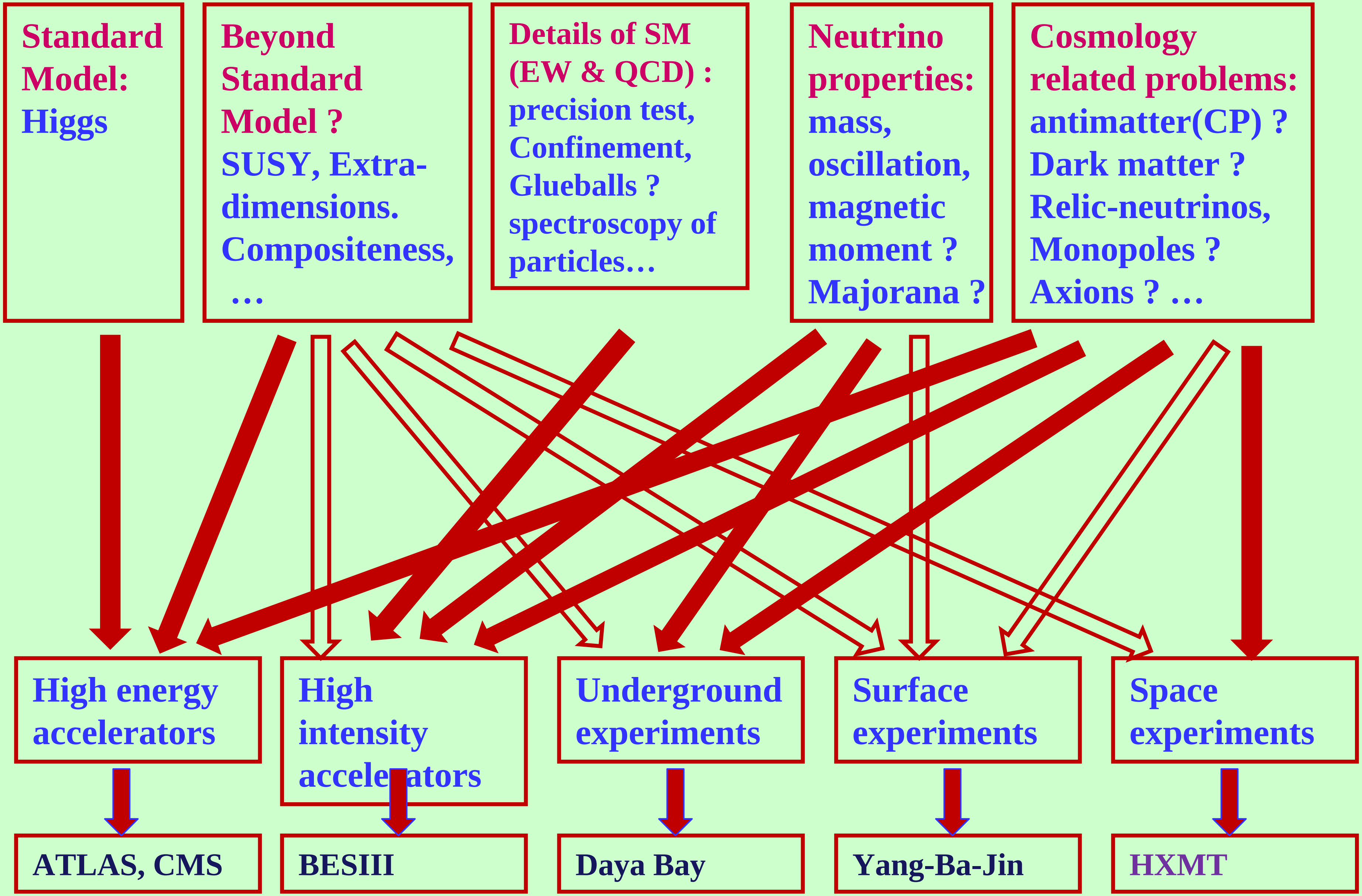
Experimental Particle Physics in China

Yifang Wang □□□

Institute of High Energy Physics

March 25, 2011, Tsinghua Univ.

Particle physics: problems and methods

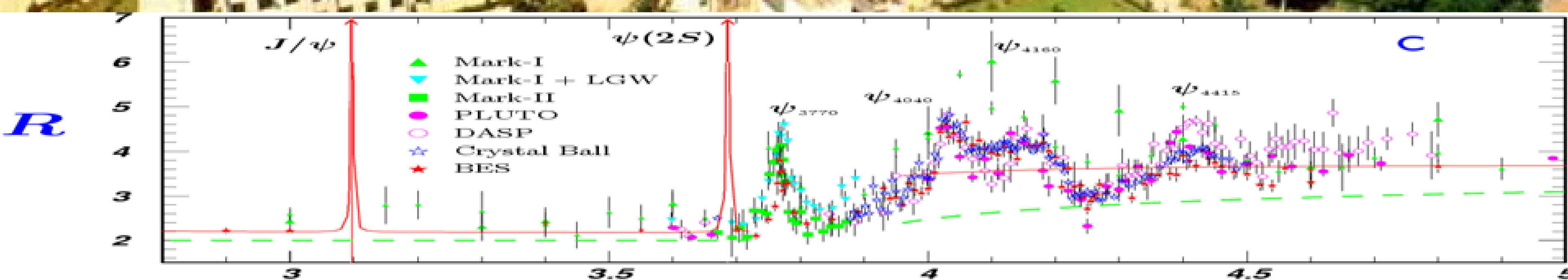


Current particle physics projects in China

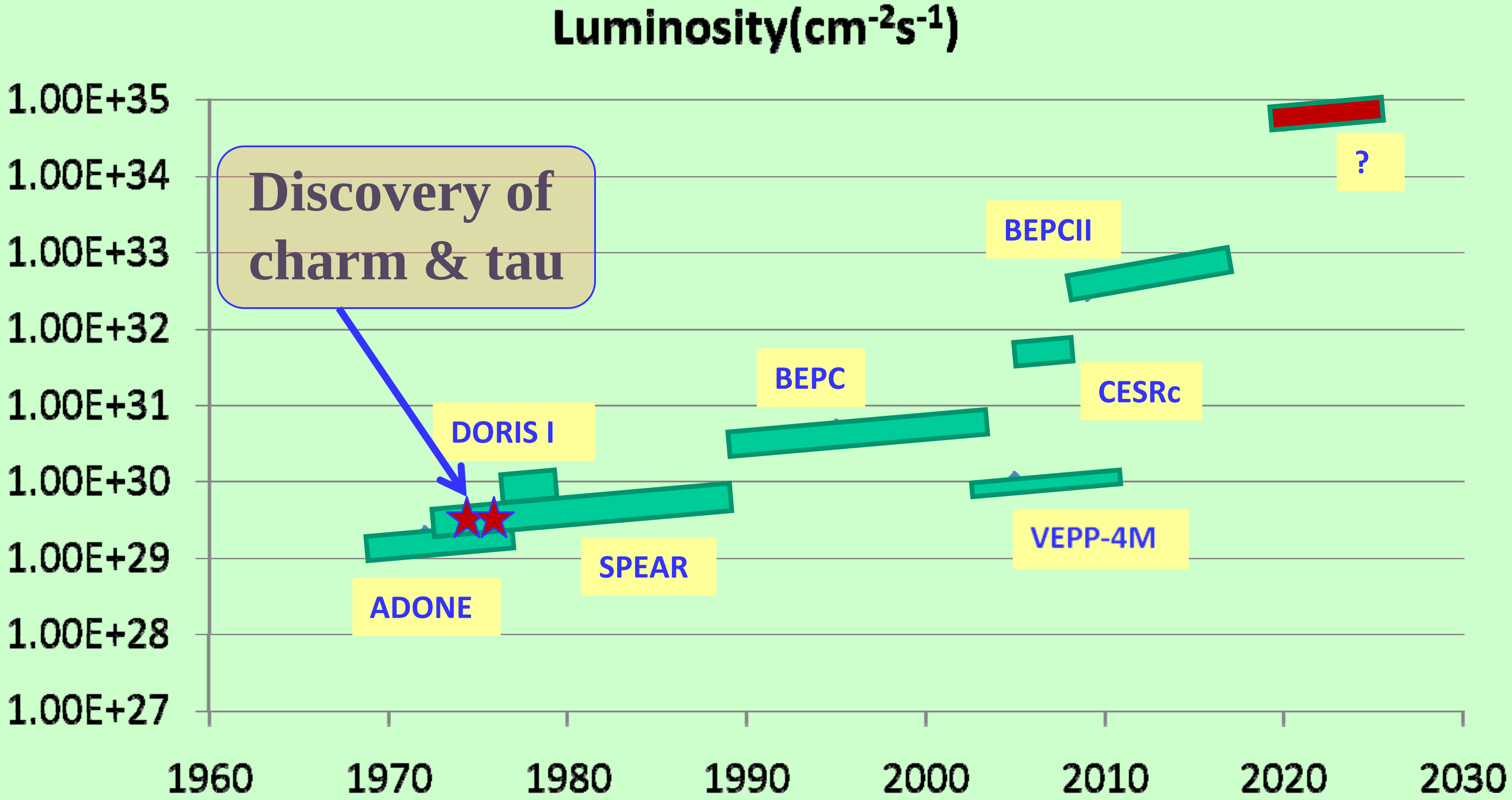
- **Large international collaboration:**
  - **LHC□ATLAS, CMS, LHCb**
  - **KEKB: BELLE**
  - **KamLAND, SuperK, AMS,…**
  - **RHIC: Star, Phenix□□□**
- **Domestically based high energy physics experiments**
  - **BEPC & BEPCII: BESII/BESIII** — **H.I. accelerator exp.**
  - **Daya Bay reactor neutrino experiment** — **Underground exp.**
  - **Yang-Ba-Jing cosmic-ray observatory** — **Surface exp.**

A balance of physics opportunities, financial resources, technological capabilities and needs, man power, experience, …

Beijing electron-positron collider(BEPC) & Beijing spectrometer(BES) at 2-5 GeV



A long history of Tau-charm colliders



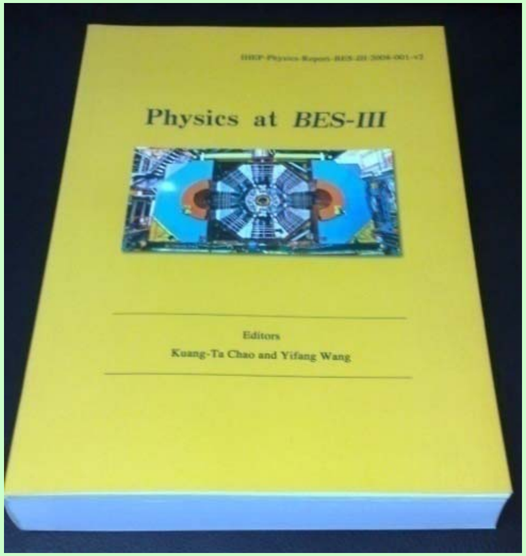
Luminosity $\propto$ No. of collision events

Why it is interesting

in the past
in the era of LHC
in the future

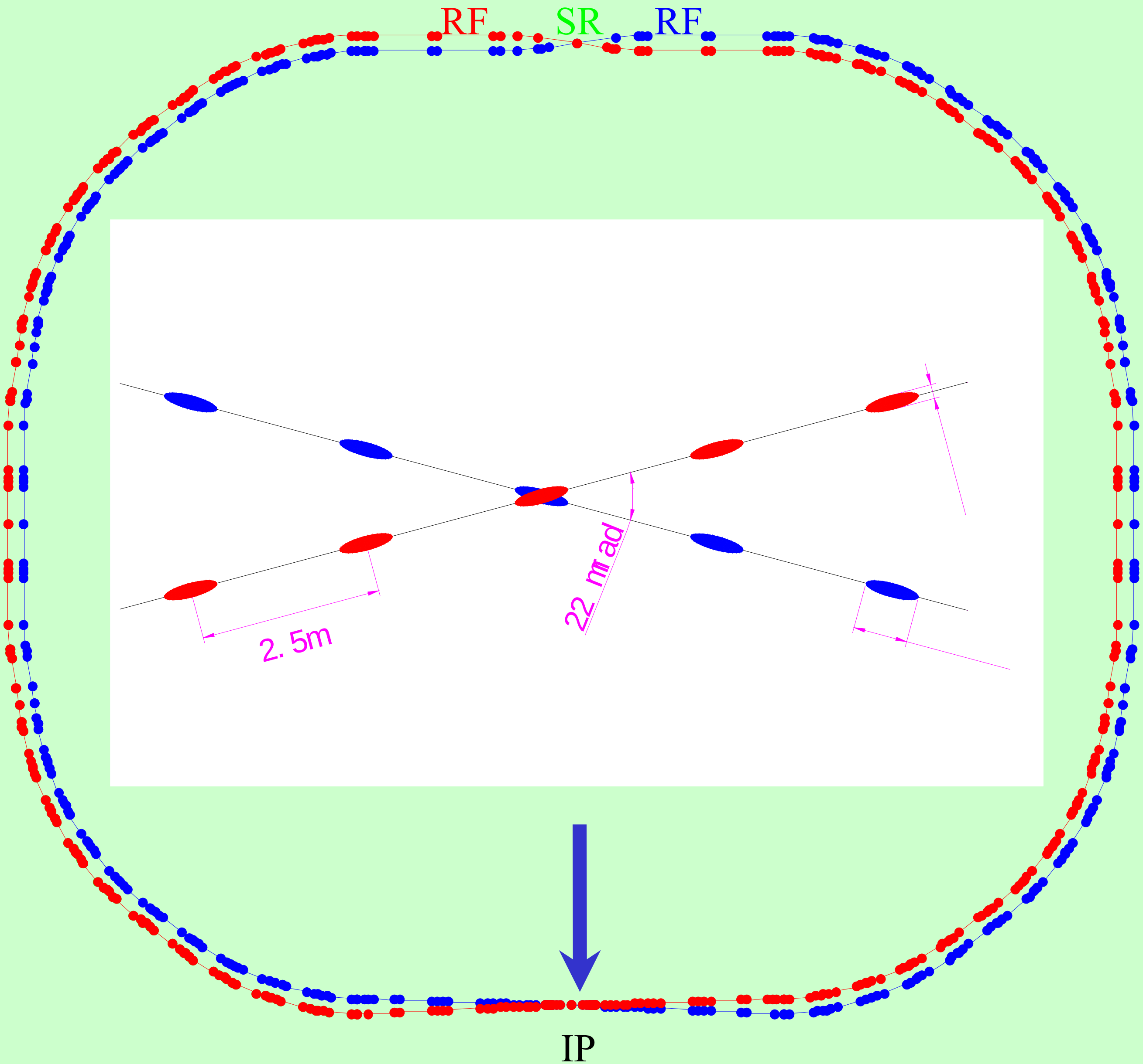
- Flavor physics ➔Complementary to LHC: virtual vs real
- Abundant resonances(J/ψ family, huge Xsections)
- Tau-charm threshold production(in pairs➔ tagging ➔ background free, no fragmentation, kinematic constraints, quantum coherence,…)
- Charm quark: A bridge between pQCD and non-pQCD
- A ruler for LQCD
- J/ψ decay ➔ Gluon rich environment
- A broad spectrum & efficient machine:

$$\begin{pmatrix} e & \mu & \tau \\ \nu_e & \nu_\mu & \nu_\tau \end{pmatrix} \qquad \begin{pmatrix} u & c & t \\ d & s & b \end{pmatrix}$$



hep-ex/0809.1869
IJMP A V24,No 1(2009) supp

BEPC II upgrade: a new double ring machine



Beam energy:
1.0-2.3 GeV
Luminosity:
1×10^{33} $cm^{-2}s^{-1}$
No. of bunches:
93
Total current:
0.91 A
SR mode:
0.25A @ 2.5 GeV

Construction: 2003-2008

LINAC□240m long□to accelerate e+/e- to 2.3 & 2.5GeV

Linear accelerator

Modulator: microwave power source

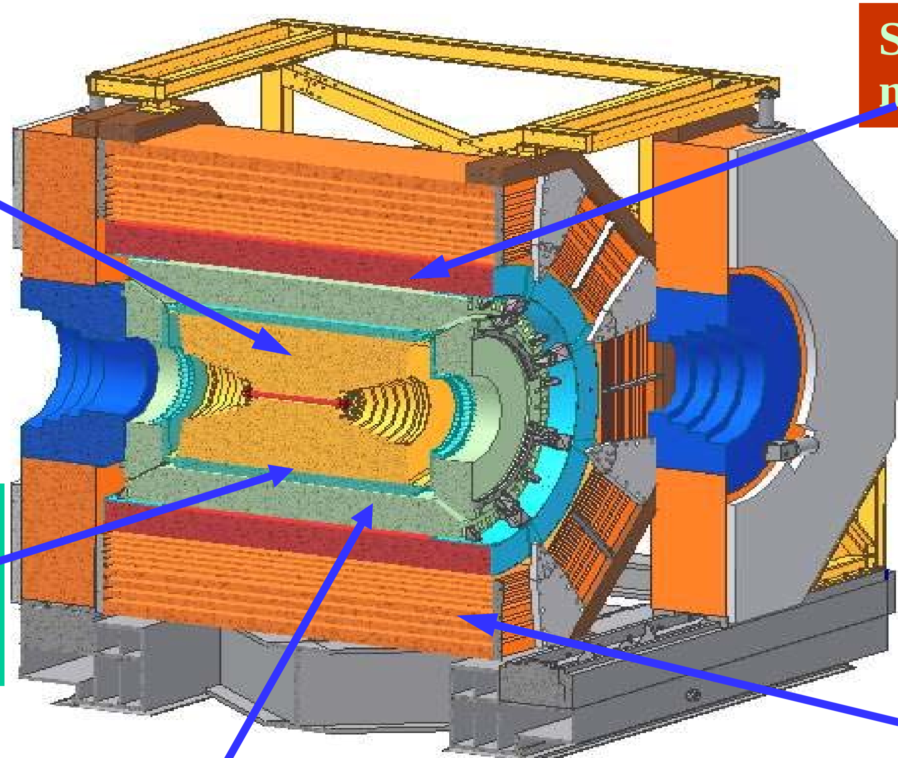
Double-ring collider:

~ 240m, e+/e- are accumulated to 0.9 A and controlled to have a head-on collision

BESIII Detector: cover the collision point to obtain particle type, energy, momentum, …

Main Drift Chamber (MDC)
△P/P @1GeV= 0.5-0.7 %
$\sigma_{dE/dx}$ ($^{0}/_{0}$) = 6-8%

Super-conducting magnet: 1.0 tesla



Time Of Flight (TOF)
σ_T =80-90 ps Barrel
100-110 ps endcap

Muon counter:
8-9 layers of RPC
$\delta_{R\Phi}$=1.4 cm~1.7 cm

EMC□ △E/√E($^{0}/_{0}$) = 2.5 -3 % (1 GeV)
(CsI) $\sigma_{z,\phi}$(cm) = 0.5 - 0.7 cm/√E

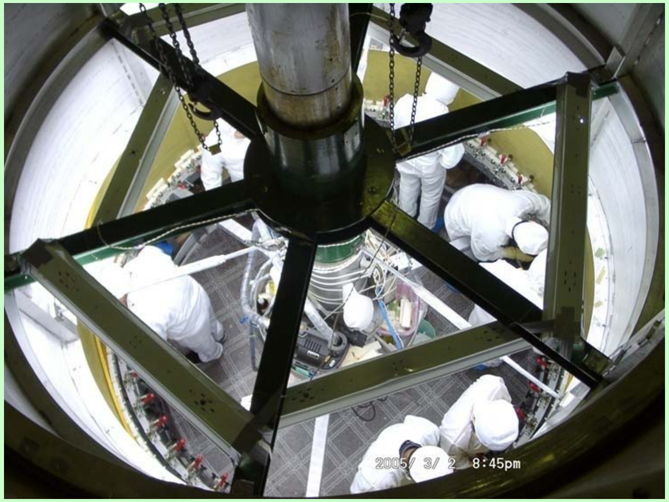
Total weight: 730t□readout ch.: 40000, data rate: 50MB/s, man power: ~1000 man*yr, Cost: 30M$

BESIII Detector Construction

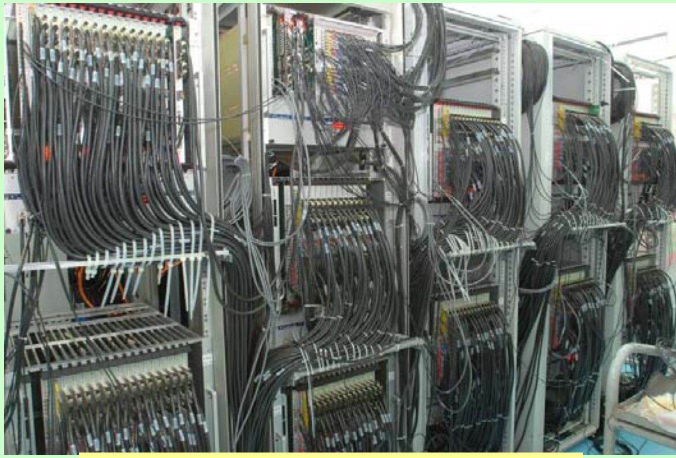
Drift chamber to measure momentum

Calorimeter to measure energy

Muon chamber



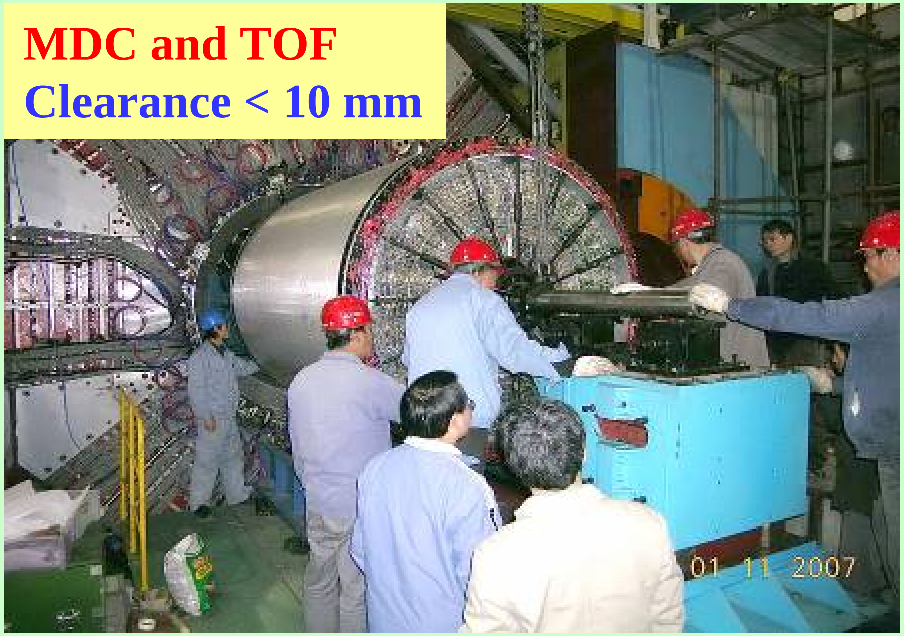
Superconducting magnet



Readout electronics

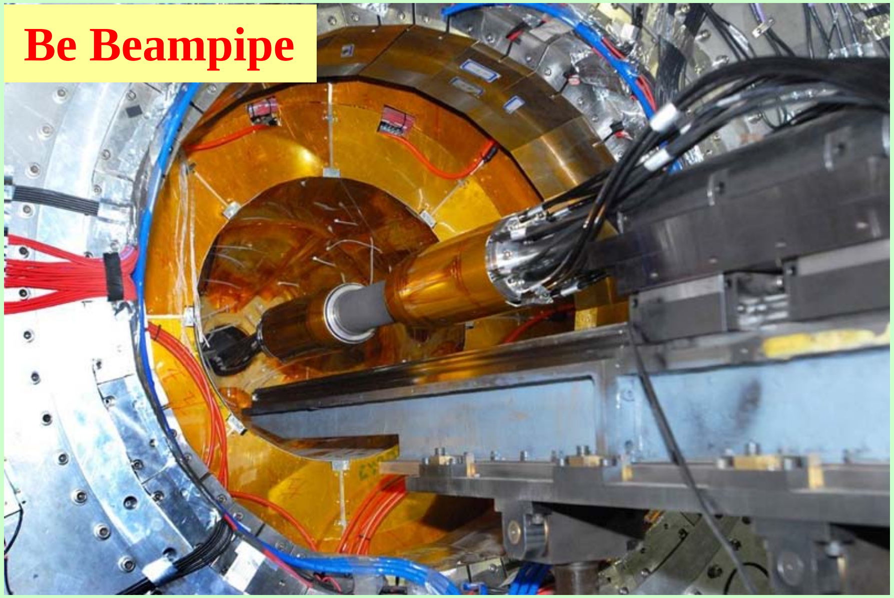
NIM A614 (2010)

BESIII installation

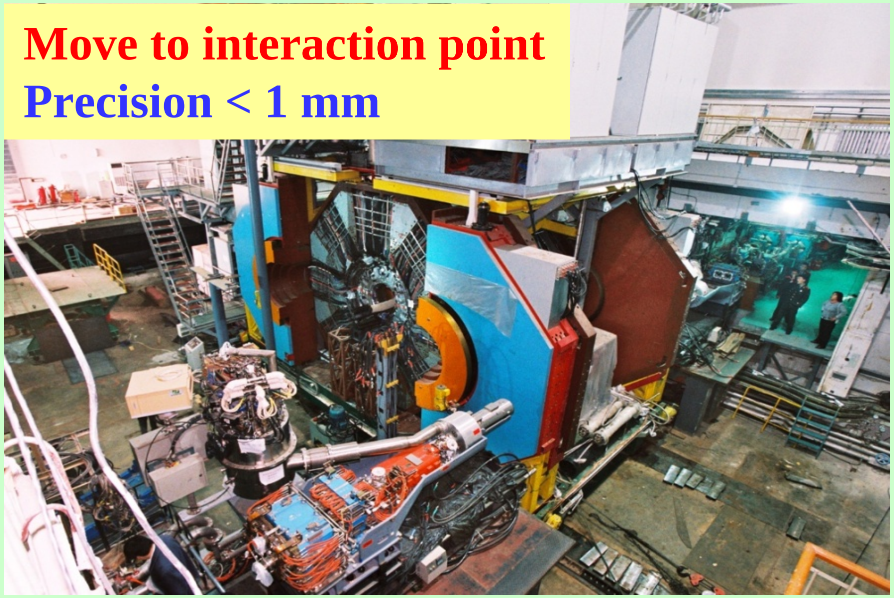


MDC and TOF
Clearance < 10 mm

EMC
Clearance < 15 mm

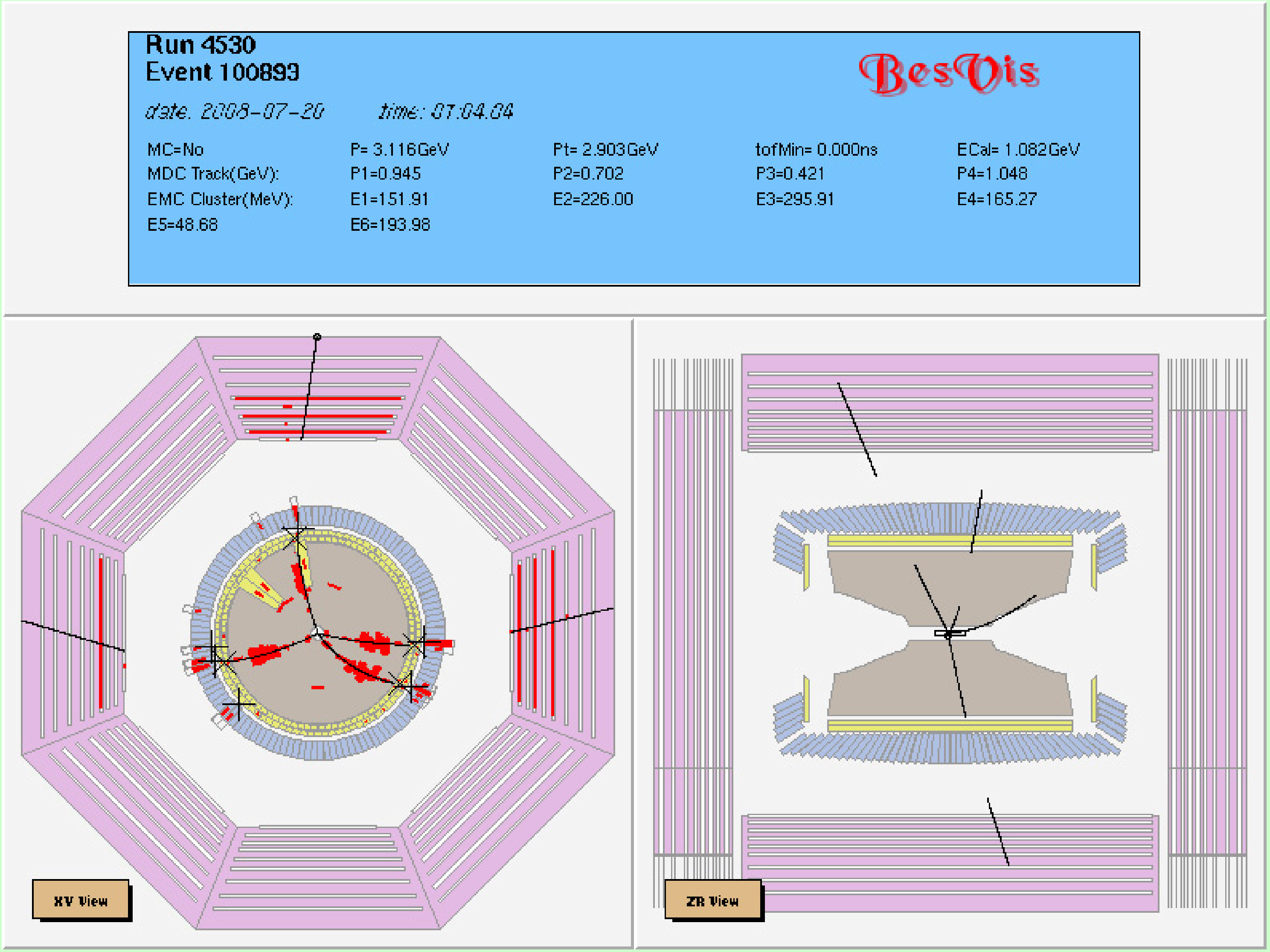


Be Beampipe



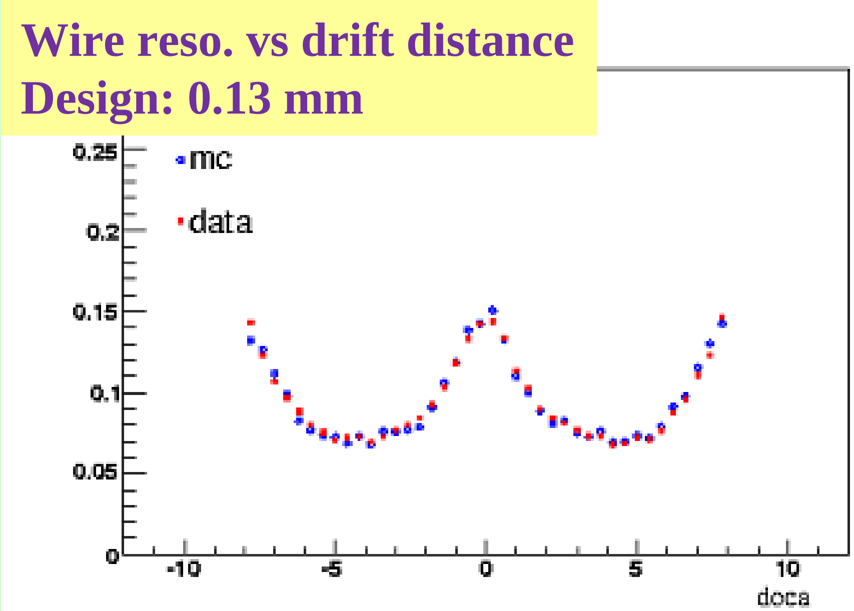
Move to interaction point
Precision < 1 mm

First collision event on July 19, 2008

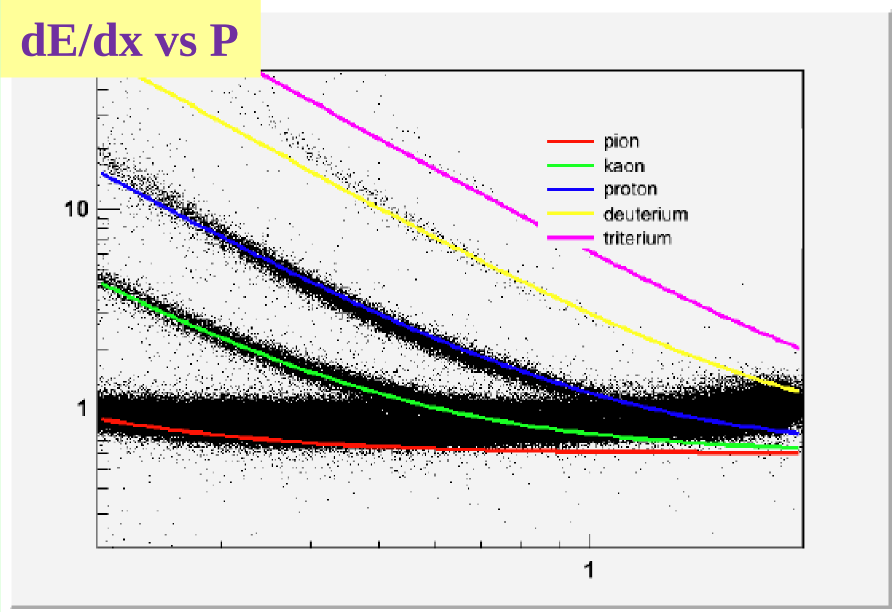


Excellent detector performance

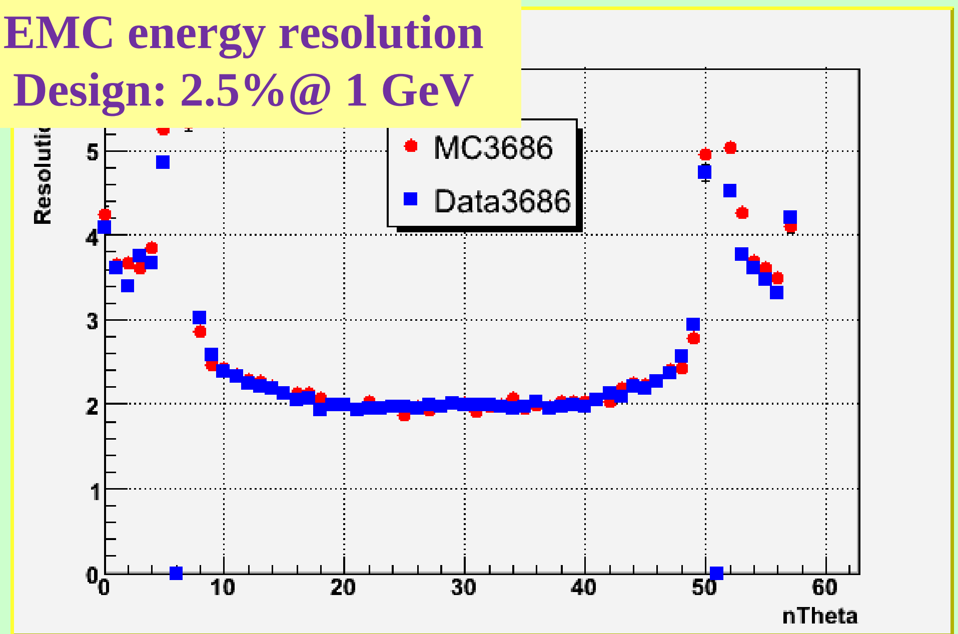
Wire reso. vs drift distance
Design: 0.13 mm



dE/dx vs P



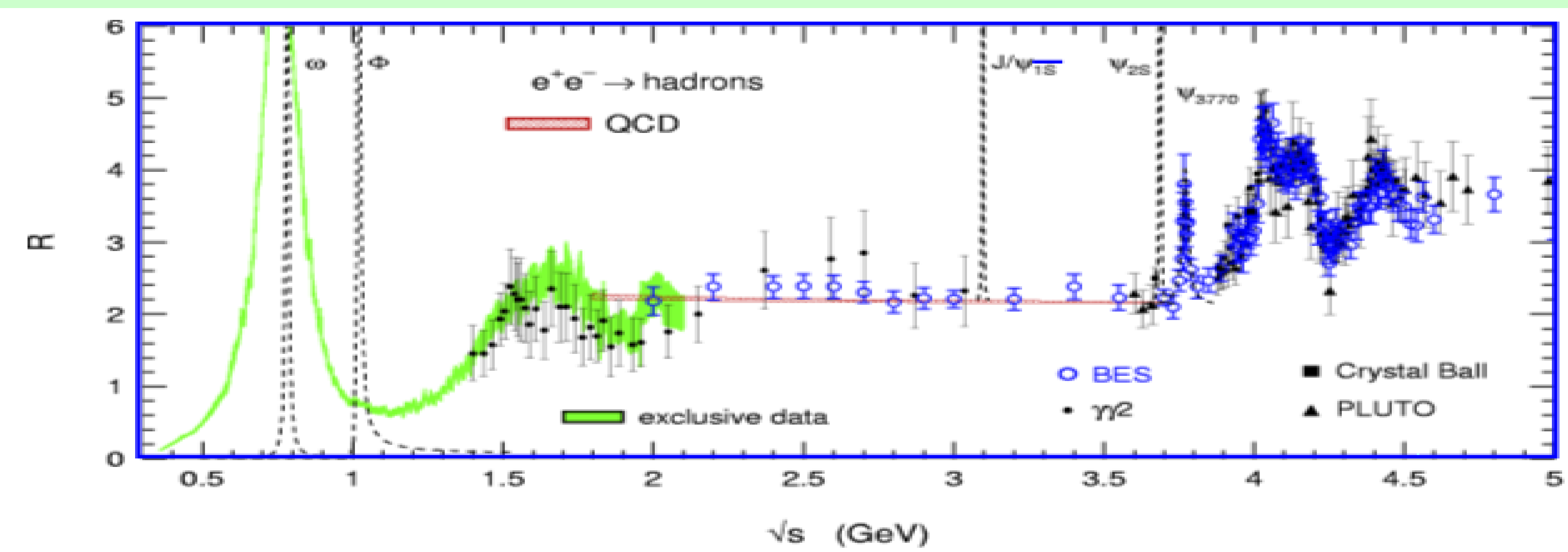
EMC energy resolution
Design: 2.5%@ 1 GeV



Time resolution
Design: 80ps

BESIII data taking status & plan

	Previous Data set	BESIII Near future
J/psi	BESII 58M	2009□200M□2012□1 B
Psi’	CLEO□28 M	2009□100M
Psi”	CLEO□0.8 /fb	2010□0.9/fb□2011-12□3.5/fb
ψ(4040)/ψ(4160) & scan	CLEO□0.6/fb @ ψ(4160)	2011□0.4/fb @ ψ(4040) 2013□4/fb
R scan & Tau	BESII	2014



Initial Physics results of BESIII

- **Light hadron physics**
  - Confirmation of BESII results
    - threshold enhancement γppbar, X(1835), …
  - New resonances
  - New observations: e.g. a_0-f_0 mixing
- **Charmonium physics**
  - Improved measurements
    - h_c, η_c, χ_{cJ}, , …
  - New observations
    - χ_{cJ} decays
    - h_c decays

8 papers published
~20 analysis under review
~40 analysis on the way

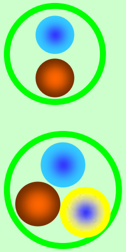
Light hadron spectroscopy

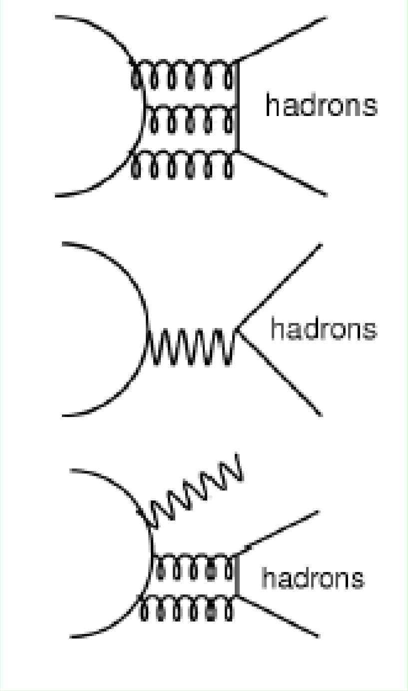
- Baryon spectroscopy
- Charmonium spectroscopy
- Glueball searches
- Search for non-qqbar states

J/ψ decays Ideal for new hadrons searches: gluon rich, energetically favorable, huge cross section

meson□$q\bar{q}$□

Baryon□qqq□

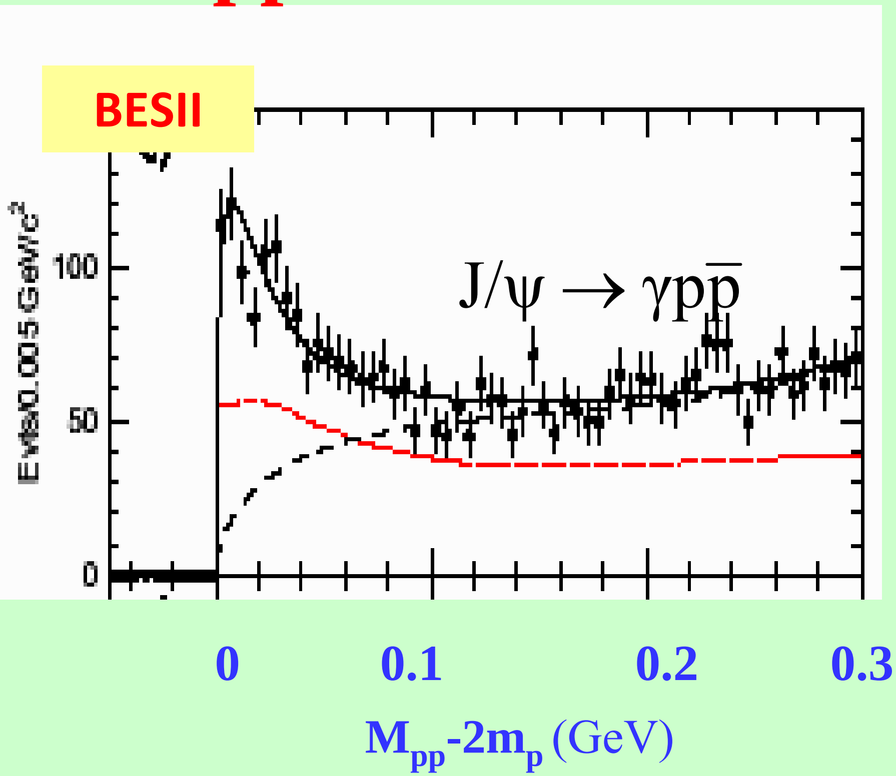




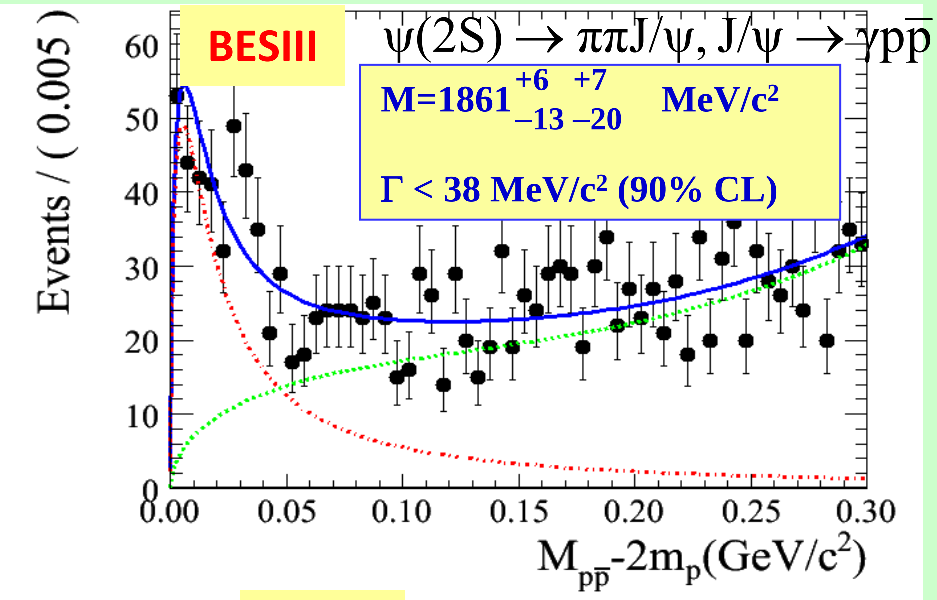
New hadrons: predicted by QCD

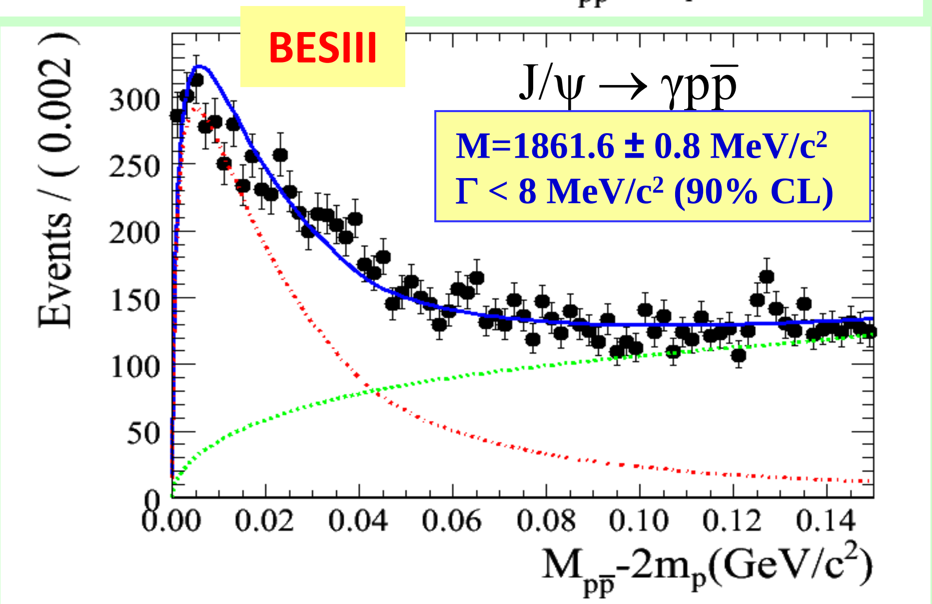
- Multi-quarks□□$q\bar{q}q\bar{q}$□
- Hybrids□(qqg□qqqg…)
- Glueballs□gg□ ggg …□

Confirmation of the BESII observation: $p\bar{p}$ threshold enhancement in J/ψ decays



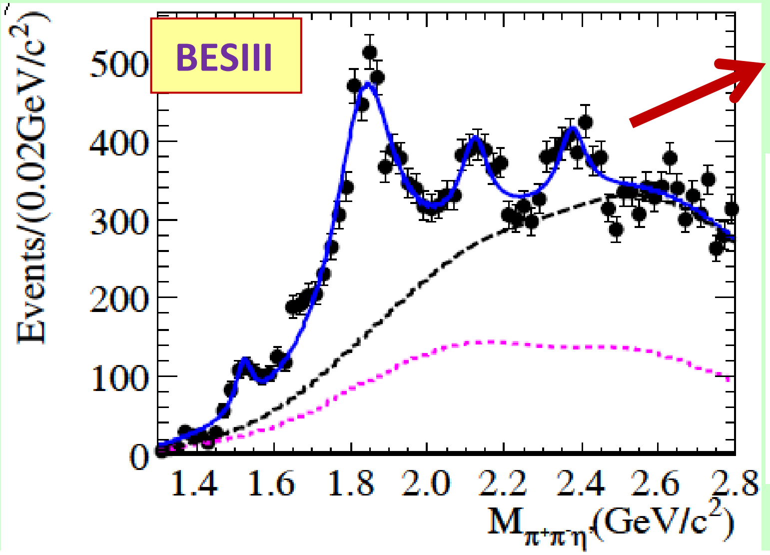
$M = 1859^{+3\ +5}_{-10\ -25}$ MeV/c²
Γ < 30 MeV/c² (90% CL)





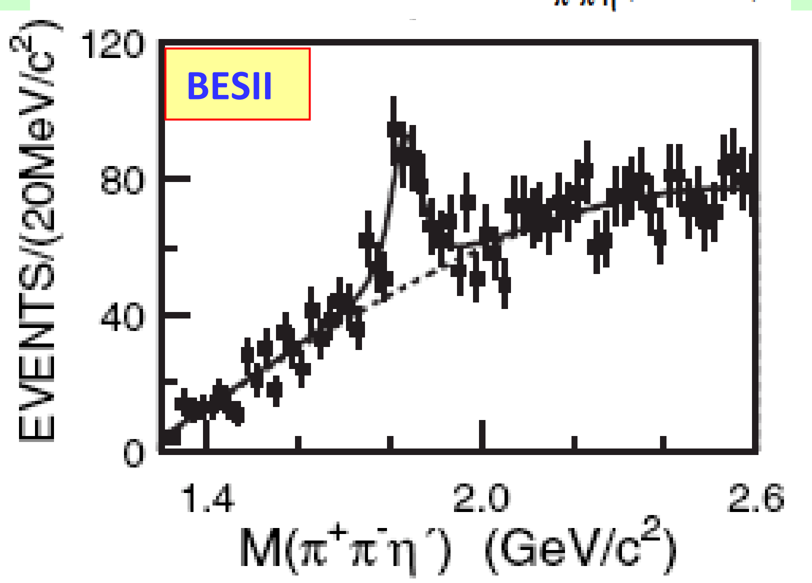
arXiv:1001.5328,
Chinese Phys. C 34□2010□421

Confirmation of BESII observation□ X(1835) in J/ψ →γη'ππ



Two new resonance

resonance	M(MeV/c^2)	Γ(MeV/c^2)	Stat. sig.
X(1835)	1838.1 ± 2.8	179.5 ± 9.1	$> 25\sigma$
X(2120)	2124.8 ± 5.6	101 ± 14	$> 7.2\sigma$
X(2370)	2371.0 ± 6.4	108 ± 15	$> 6.7\sigma$



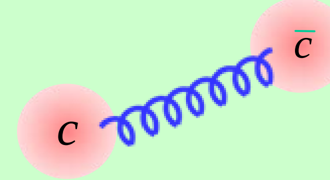
significance£º7.7 σ

$$M = 1833.7 \pm 6.1(\text{stat}) \pm 2.7(\text{syst})\ \text{MeV}$$

$$\Gamma = 67.7 \pm 20.3\,(\text{stat}) \pm 7.7(\text{syst})\ \text{MeV}$$

PRL

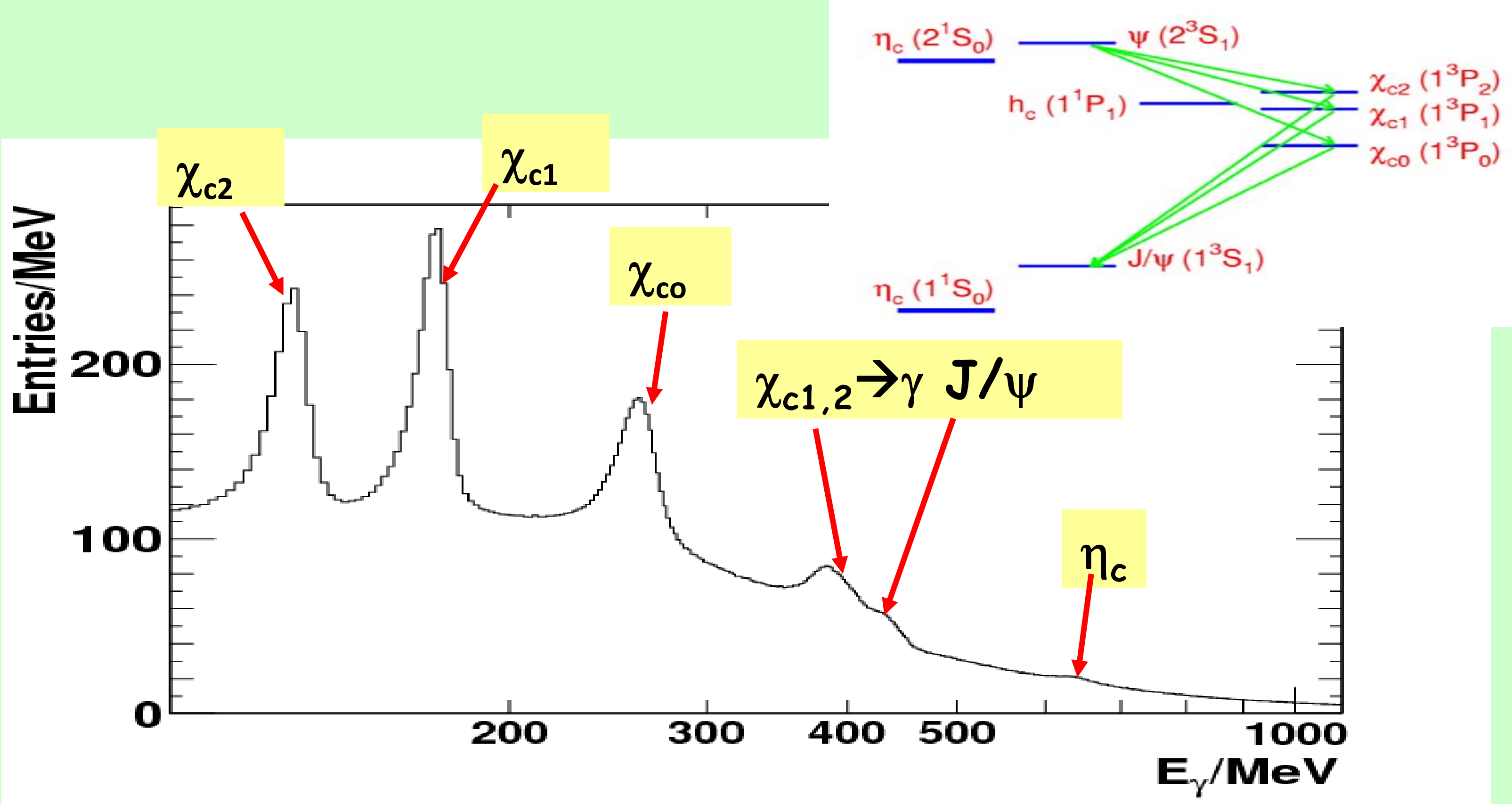
Charmonia physics



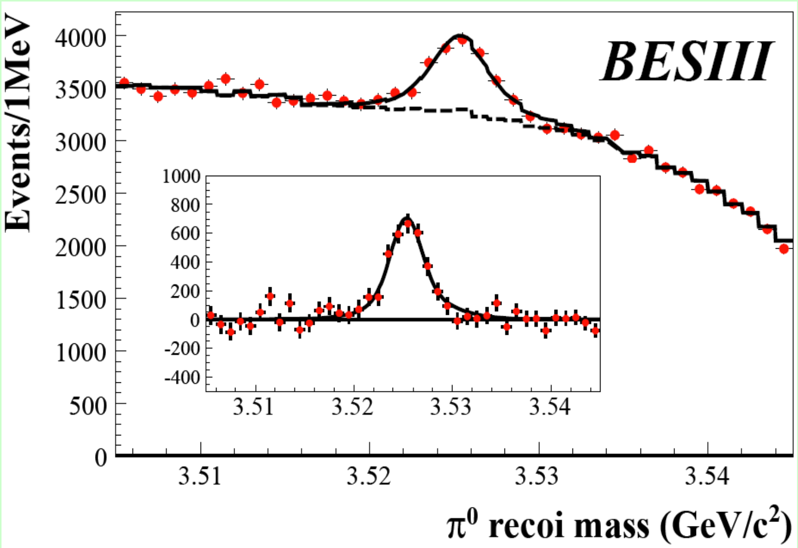
- **Understand how quarks form a hadron?**
  - Production, decays, transition, spectrum

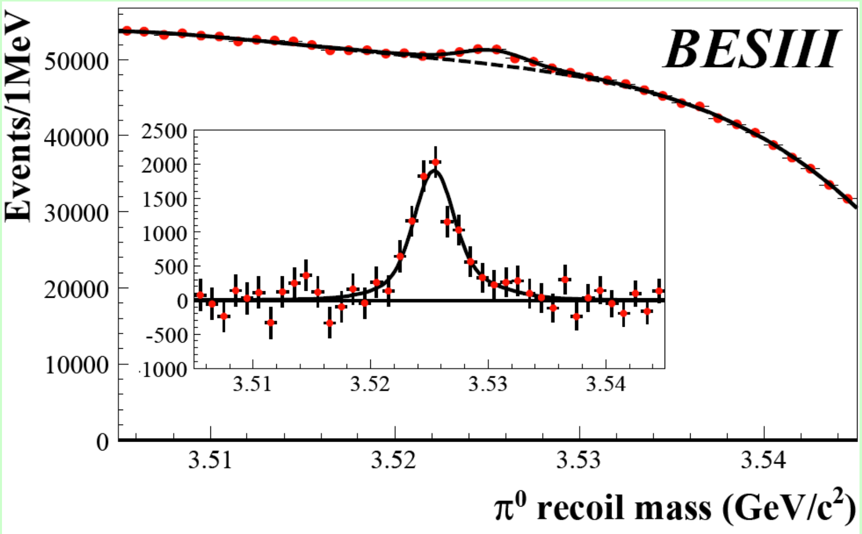
Examples of interesting/long standing issues:

- ρπ puzzle
- Missing states ?
- Mixing states ?
- New states above open charm thre.(X,Y,Z,…)



Observation of h_c in $\psi(2S)\rightarrow\pi^0 h_c, h_c\rightarrow\gamma\eta_c$





$M(h_c)^{Inc}$ = 3525.40±0.13±0.18 MeV

$\Gamma(h_c)^{Inc}$ = 0.73±0.45±0.28 MeV

$Br(\psi'\rightarrow\pi^0 h_c)\times Br(h_c\rightarrow\gamma\eta_c)^{Inc}$

=(4.58±0.40±0.50) ×10^{-4}

$Br(\psi'\rightarrow\pi^0 h_c)$ = (8.4±1.3±1.0) ×10^{-4}

$Br(h_c\rightarrow\gamma\eta_c)$ = (54.3±6.7±5.2) %

arXiv:1002.0501

Phys.Rev.Lett.

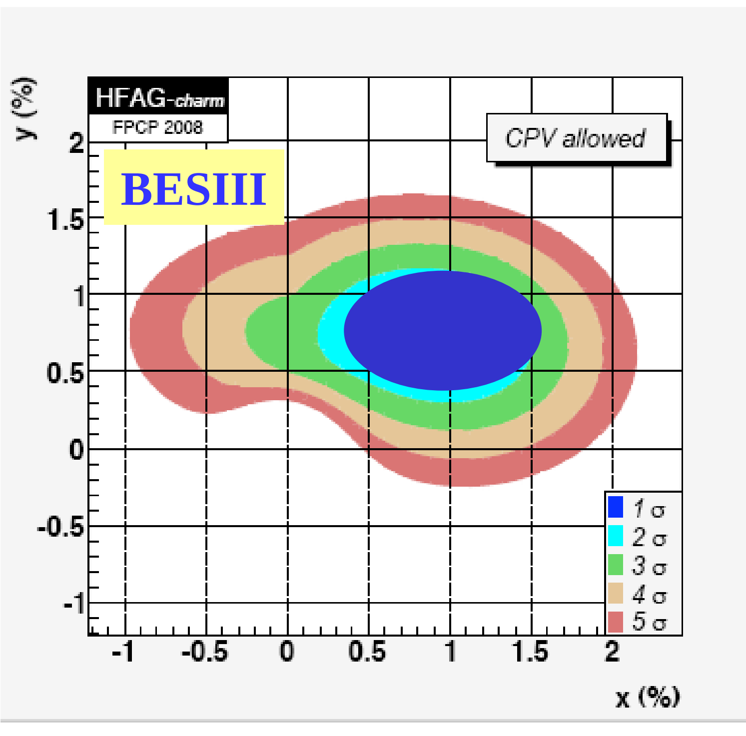
104(2010) 132002

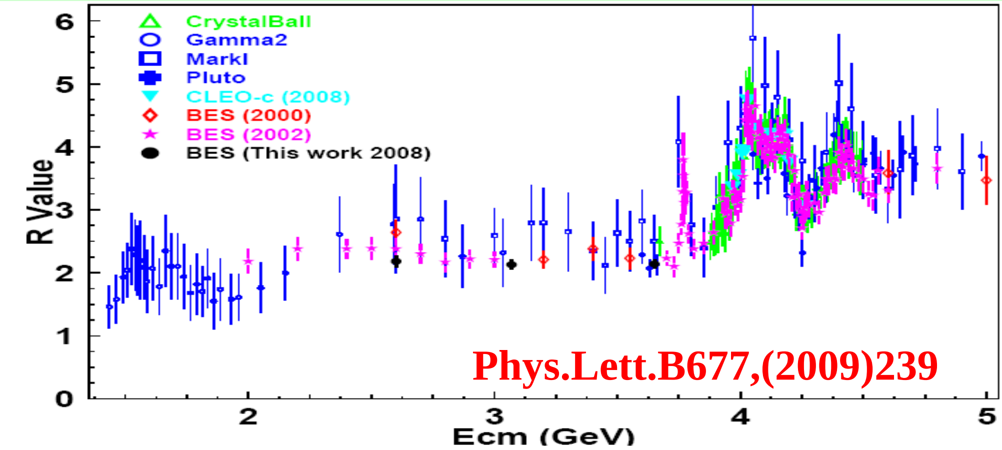
BESIII measured for the first time

$\Gamma(h_c)^{Inc}$, $Br(\psi'\rightarrow\pi^0 h_c)$ & $Br(h_c\rightarrow\gamma\eta_c)$

Other physics programs at BESIII

- Charm physics
  - DD mixing and CPV
  - CKM matrix elements
    - V_{cs}: 11% ➔ 1.2%
    - V_{cd}: 4% ➔ 1.4%
- QCD
  - pQCD ⟺ non-pQCD
  - Form factor of hadrons
  - measurement of R & α_s
- Tau physics
  - Tau mass
  - Tau decays:





Phys.Lett.B677,(2009)239

BESIII: a large collaboration

48 institutions
~ 300 collaborators

Prospects: reach charm programs

- **BESIII (2008 – 2020 ?)**
- **Future charm programs**
  - **LHCb at CERN□now @3.5TeV□**
  - **BELLE II at SuperB factory□~ 2014 □**
  - **PANDA at GSI□~ 2017□**
- **New machines under discussion:**
  - **Frascati(super flavor factory)** **2020 ?**
  - **Novosibirsk(super tau-charm factory)**

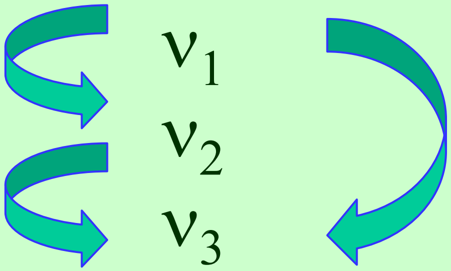
L ~ 10^{35} $cm^{-2}s^{-1}$
Expand the life time of tau-charm colliders to > 50 years !

Daya Bay reactor neutrino experiment

- **Motivation: search for new type of oscillation**

θ_{12} **solar ν oscillation**

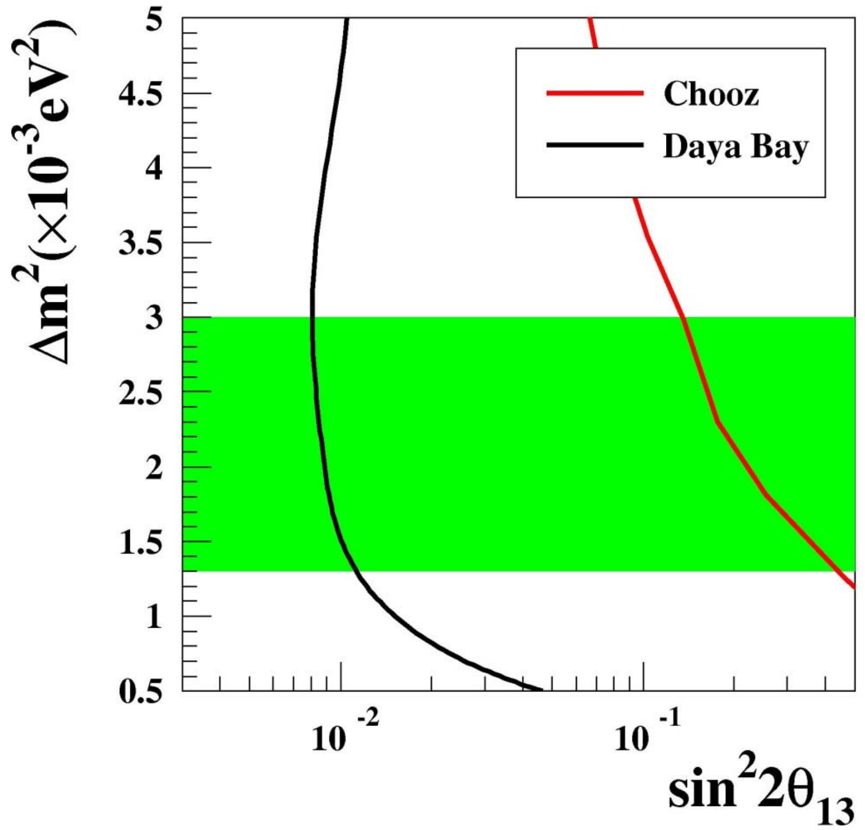
θ_{23} **atmospheric ν oscillation**



θ_{13} **?**

- **Advantages at Daya Bay**
  - **High power□second to the world□**
  - **Mountains near by, easy to to shield cosmic-rays**

Sensitivity to $Sin^2 2\theta_{13}$



sources	Uncertainty
Reactors	0.087% (4 cores) 0.13% (6 cores)
Detector (per module)	0.38% (baseline) 0.18% (goal)
Backgrounds	0.32% (Daya Bay near) 0.22% (Ling Ao near) 0.22% (far)
Signal statistics	0.2%

Other physics capabilities:

Supernova watch, Sterile neutrinos, …

Daya Bay collaboration

Europe (3)

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

North America (14)

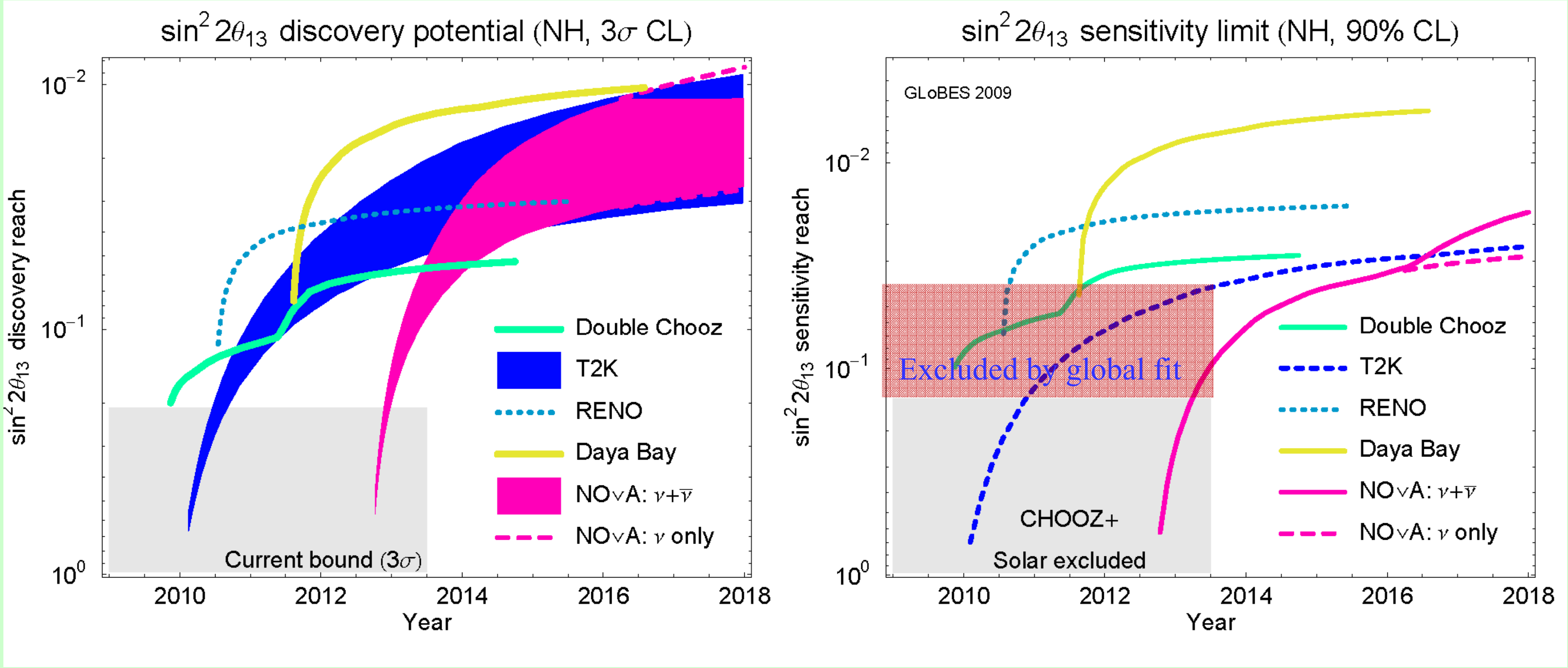
BNL, Caltech, George Mason Univ., LBNL, Iowa state Univ. Illinois Inst. Tech., Princeton, RPI, UC-Berkeley, UCLA, Univ. of Houston, Univ. of Wisconsin, Virginia Tech., Univ. of Illinois-Urbana-Champaign,

Asia (15)

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

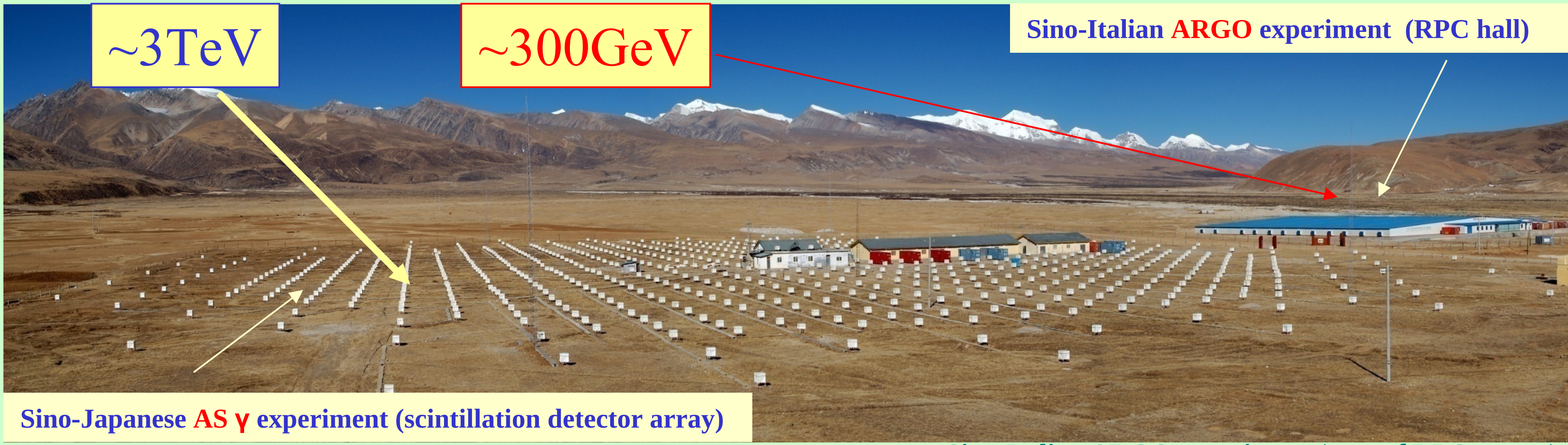
~ 200 collaborators

Race to measure θ_{13}

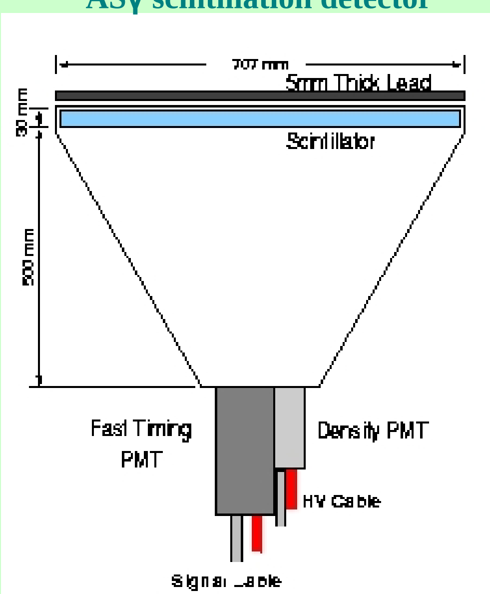


P. Huber, M. Lindner, T. Schwetz, W. Winter JHEP 0911:044,2009, arXiv:0907.1896,

Yangbajing Cosmic-ray Observatory: Asγ & ARGO experiment

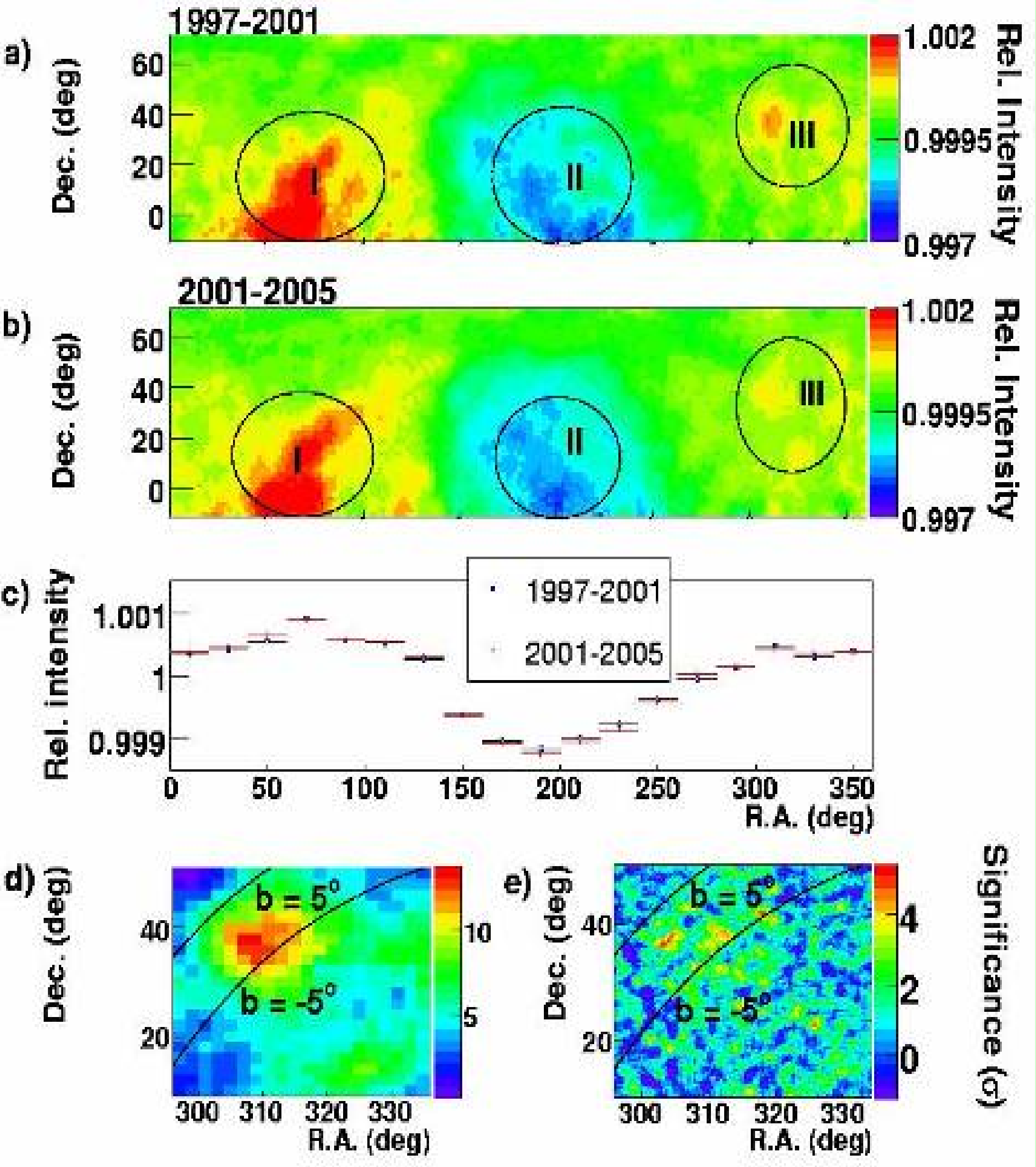


ASγ scintillation detector



Sino-Italian ARGO experiment (part of RPC carpet)

Cosmic-ray anisotropy in TeV energy



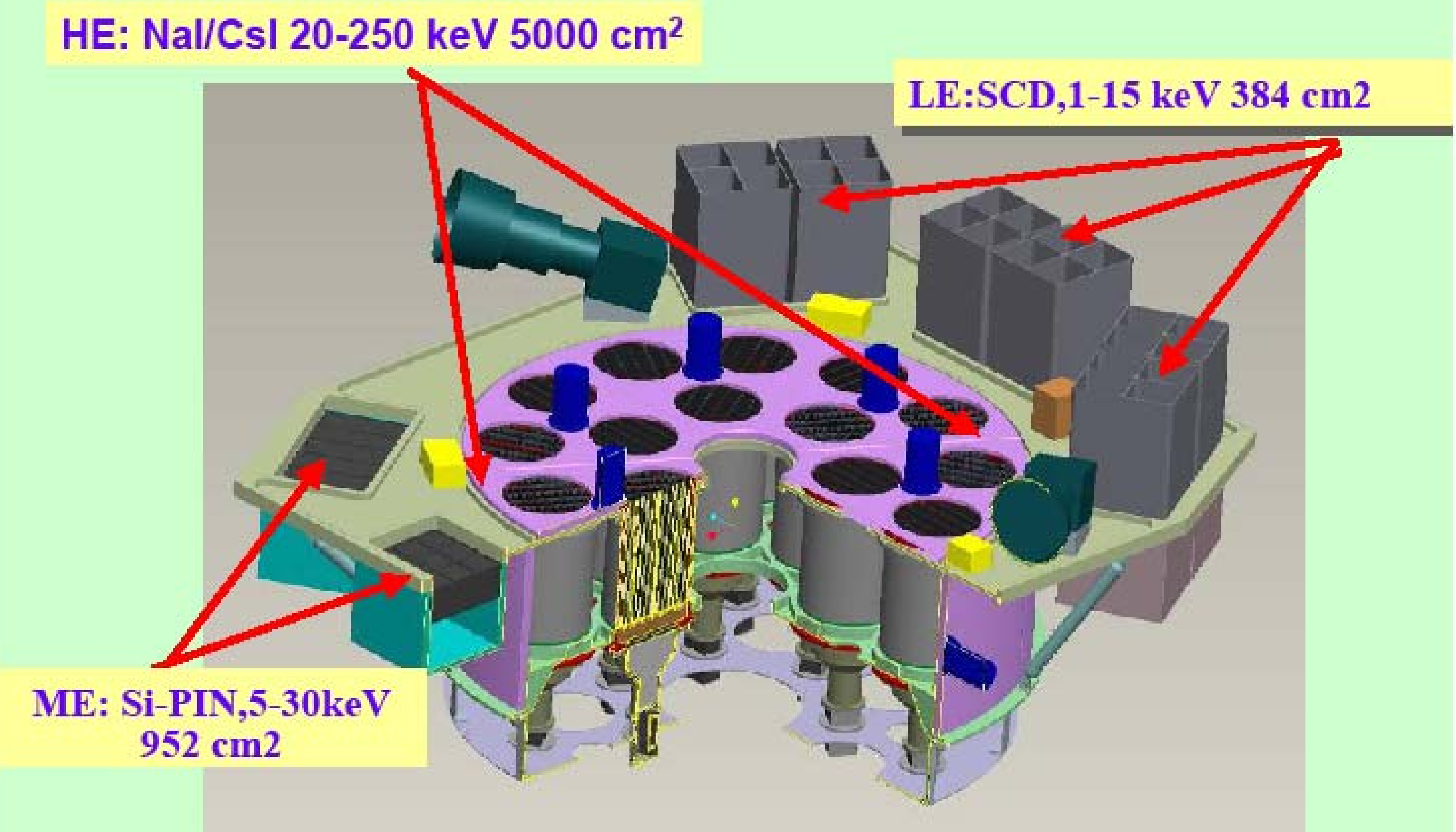
- Highest precision measurement in 2D
- A new anisotropy component from Cygnus direction;
- Established for AGN Mrk421□12 σ
- Correlated with X-rays
- Stable over time, insensitive to solar activity

Science, Oct.20, 2006
APJ 711(2010)119-124

Future of HEP in China

- **High energy accelerators**
  - **International collaboration: LHC,ILC,…**
- **High intensity accelerators**
  - **International collaboration: PANDA, BELLE II,…**
  - **a new machine at 2020 ?**
- **Underground experiments**
  - **Next generation neutrino exp. □ √**
  - **New exp. on Dark matter, ββ decay or proton decay ?**
- **Surface experiments**
  - **Construction of LHAASO exp. √**
- **Space experiments**
  - **Construction of HXMT exp. √**
  - **New exp. on cosmic rays, dark matter, astrophysics ?**

Hard X-ray Modulation Telescope (HXMT)

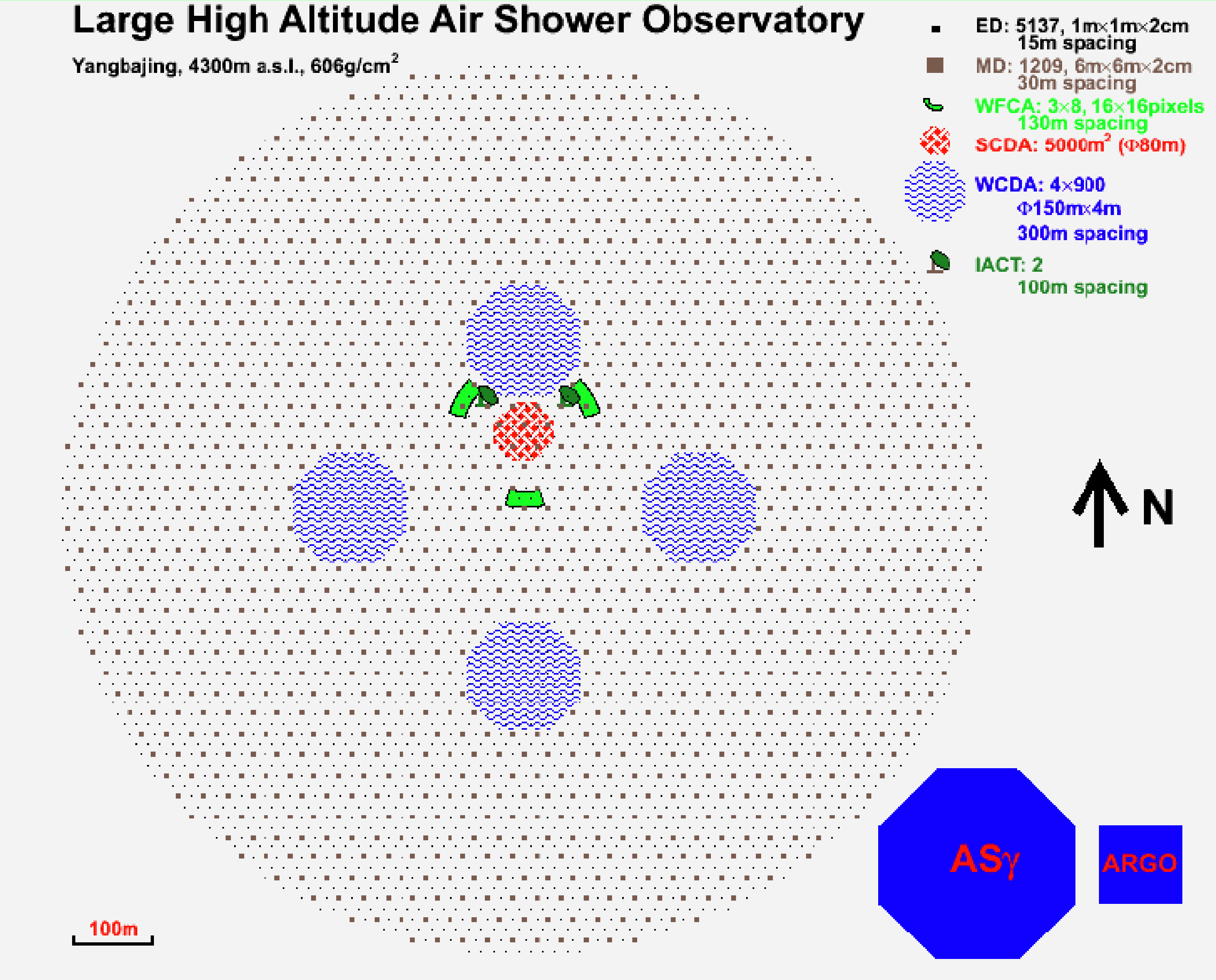


Size: 1900×1600×1000 mm 1100 kg Satellite 2700 kg

Comparison of HXMT and other two telescopes in the same energy band.

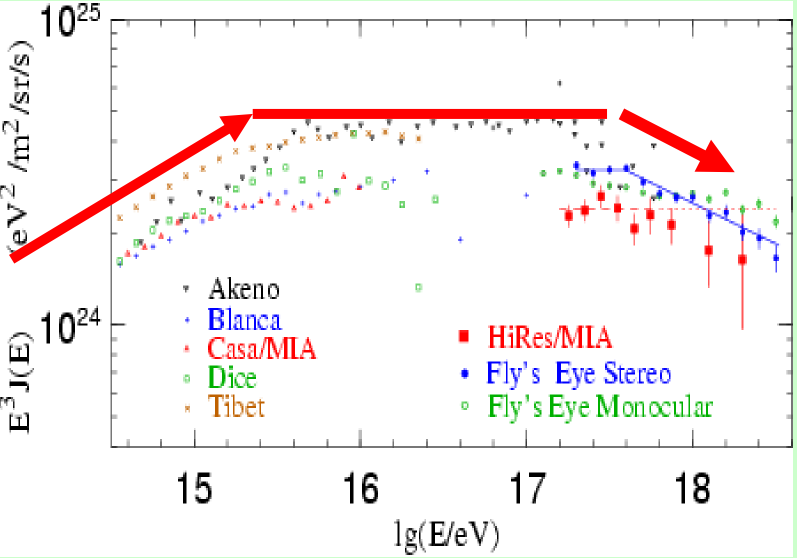
	Integral/IBIS	HXMT/HE	wift/BAT
			
Angular Resolution	12’	< 5’	14’
Source Location (20σ)	1’	< 1’	1’
Pointed Sensitivity (mCrab@100 keV)	3.8	0.5	9
Half Year Survey Sensitivity (mCrab)	2	0.5	1
Observation Capability			
All sky survey	ok	good	yes
Selected sky deep survey	good	good	bad
Narrow field pointing observation	bad	good	no

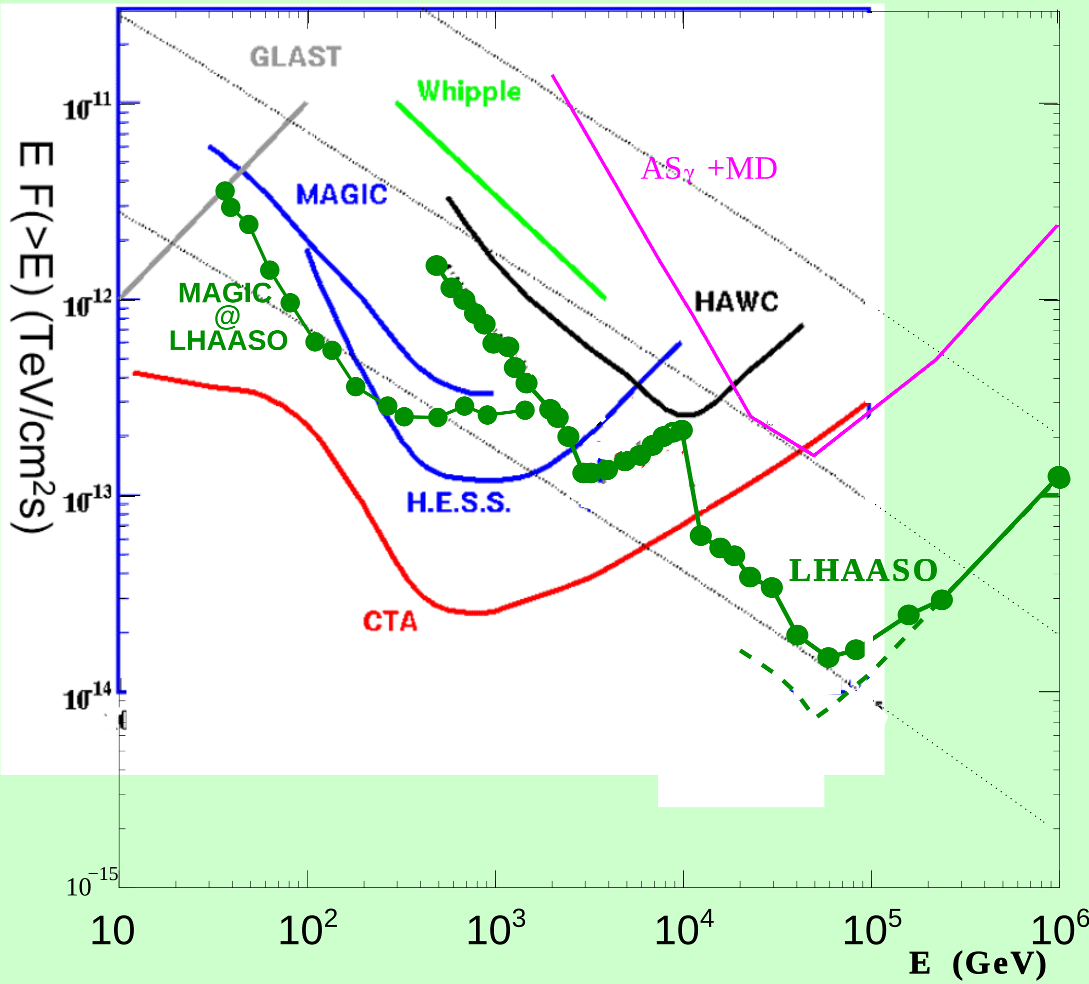
The future of Yangbajing Cosmic-ray observatory: LHAASO project



Scientific goal: origin of UHE cosmic-rays & γ-ray astronomy

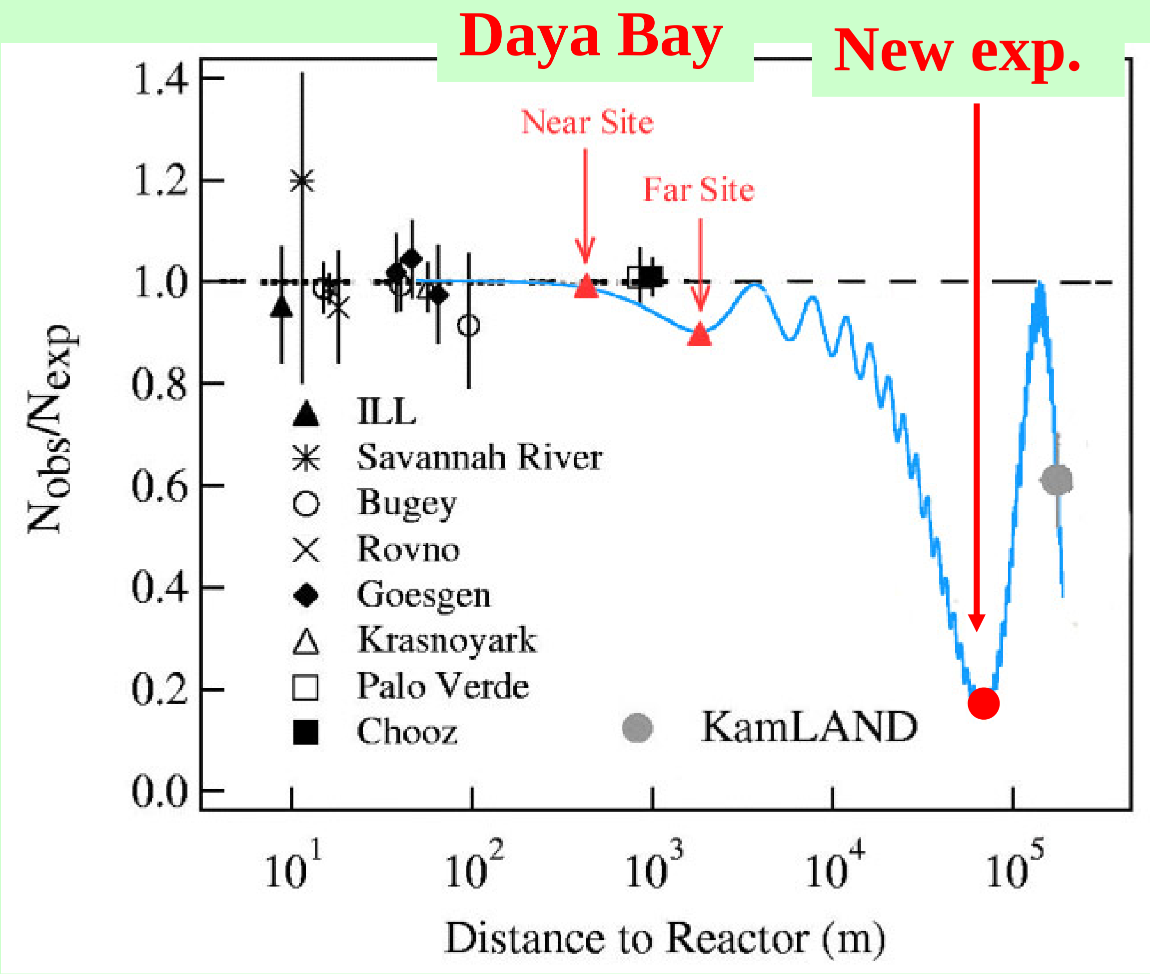
Cosmic-ray energy spectrum covering both "Knee" with absolute energy scale : understand acceleration mechanism





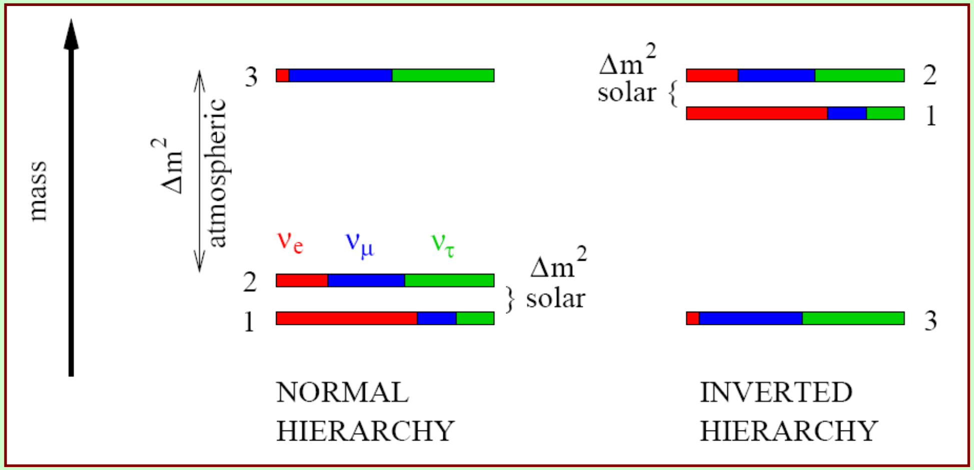
Sensitivity to γ-ray sources

A possible Future Neutrino Experiment for mass hierarchy

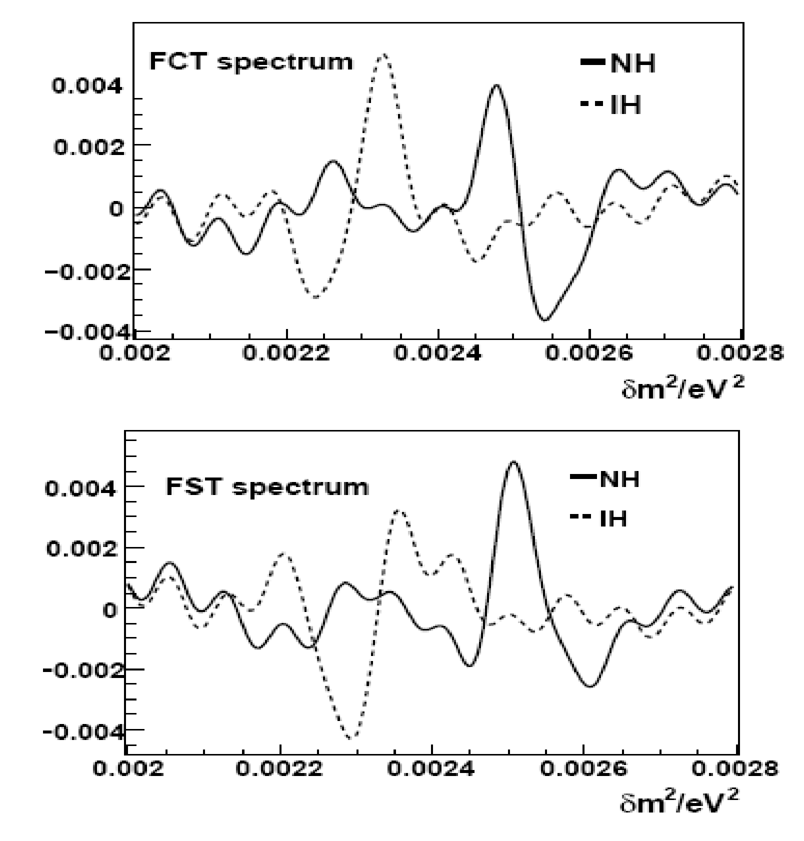


- Detector: 10-50kt liquid scintillator
- Energy reso.: 2-3%
- Scientific goal
  - ⇨ Mass hierarchy
  - ⇨ Precision meas. of mixing matrix elements
  - ⇨ Supernovae
  - ⇨ Geo-neutrino
  - ⇨ Atmospheric neutrinos
  - ⇨ Sterile neutrinos
  - ⇨ Exotic searches

Mass hierarchy at reactors



Crucial for all models beyond the SM, especially for the Dirac/Majorana nature of neutrinos



Effects of mass hierarchy can be seen from the distortion of neutrino energy spectrum at reactors after a Fourier transformation

L. Zhan,Y.F.Wang, J.Cao and L.J. Wen PRD78:111103,2008, PRD79:073007,2009

A Possible Location

Distance to reactor cores ~ 60 km
Total 14 cores, thermal power > 40 GW
overburden > 1000m.w.e

Summary

- Particle physics in China is in phase transition: experiments discussed above will bring us to a new stage
- Great progress has been seen on accelerator and detector technologies, as well as industrial supports
- Physics potential of these experiments are great, but remains to be demonstrated
- Future programs are more ambitious, welcome collaborators