

# The Experimental Program at IHEP CAS

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IHEP, CAS

INSTR20  
Novosibirsk, Feb 24-28, 2020



# Introduction



- ❖ IHEP CAS was officially established in 1973, but can trace its history back to 1950. It is the leading institute in China for study of particle physics and accelerator technology.
- ❖ It currently has ~1500 employees, ~400 students, ~400 visiting researchers, and an annual budget of ~ 1.3 Billion CNY.
- ❖ The main campus at Beijing is the site of BEPC/BES. It has Dongguan branch in southern China. It also runs experiments at various other locations including Daya Bay, Jiangmen, Yangbajing, Daocheng.
- ❖ The institute has a very rich experimental program in fields from collider physics, astroparticle, neutrino, accelerator, to technology application.
- ❖ This presentation gives a brief introduction on selected projects that IHEP manages or as PI.

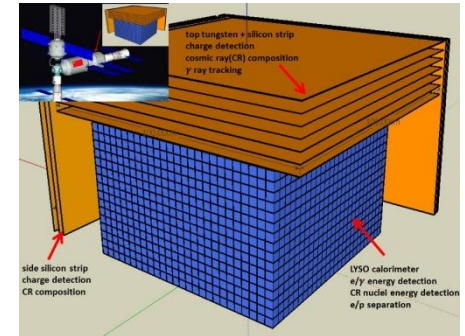
*Many thanks to my colleagues for providing materials: Jun Cao, Zhen Cao, Xinchou Lou, Changzheng Yuan, Shuangnan Zhang.*



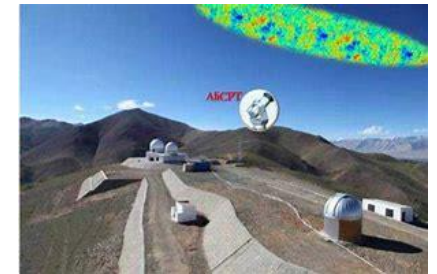
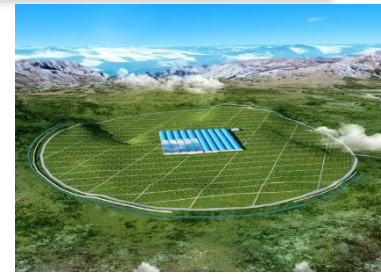
# The IHEP Experimental Program



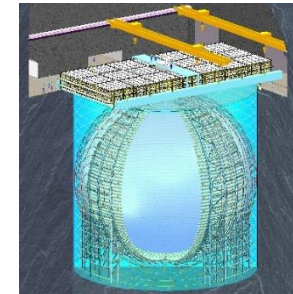
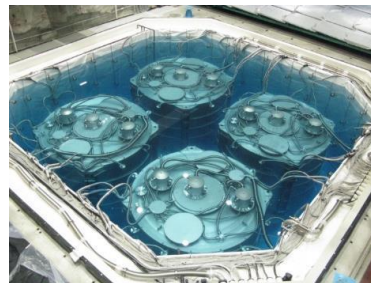
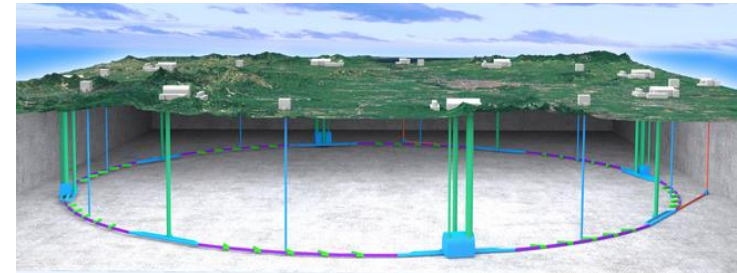
Space



High Mountains



Ground /  
underground



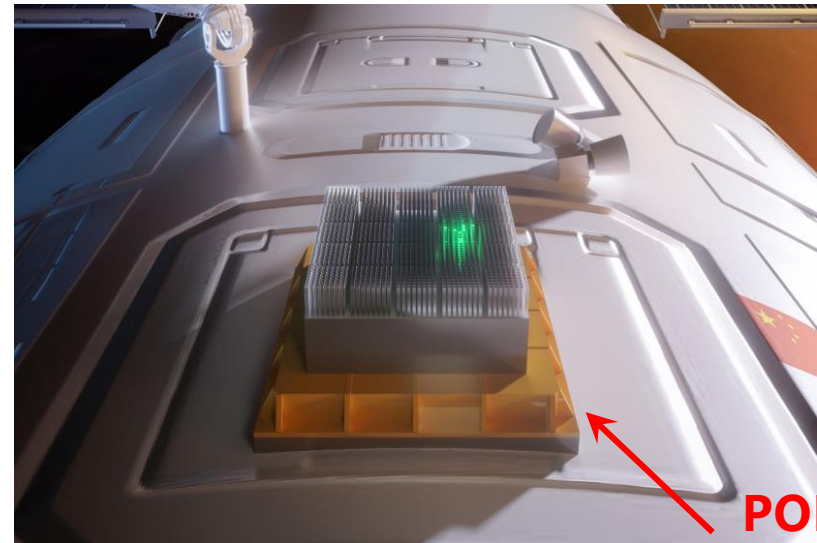
# Space High Energy Program



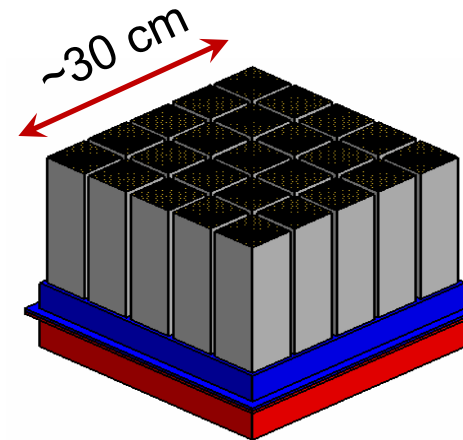
# POLAR



- ❖ POLAR aims for Gamma Ray Burst (GRB) polarization measurements.
- ❖ An international collaboration: China, Switzerland, France, and Poland.
- ❖ It was launched on Sept 15, 2016, onboard China's space lab TG-2.
- ❖ Had discovered 55 GRBs and obtained the largest sample of GRB polarization measurements with high precision.



**POLAR**  
**On TG-2**



40x40 pixels,  
Scint + MAPM

PIs: Shuang-Nan Zhang (IHEP), Martin Pohl & Xin Wu (UniGe)



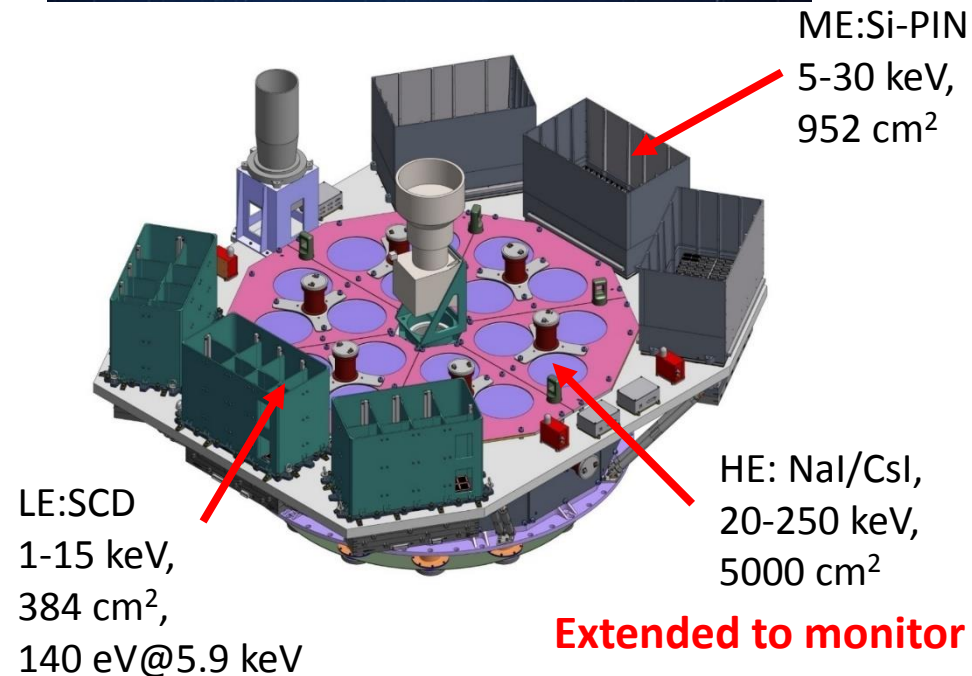
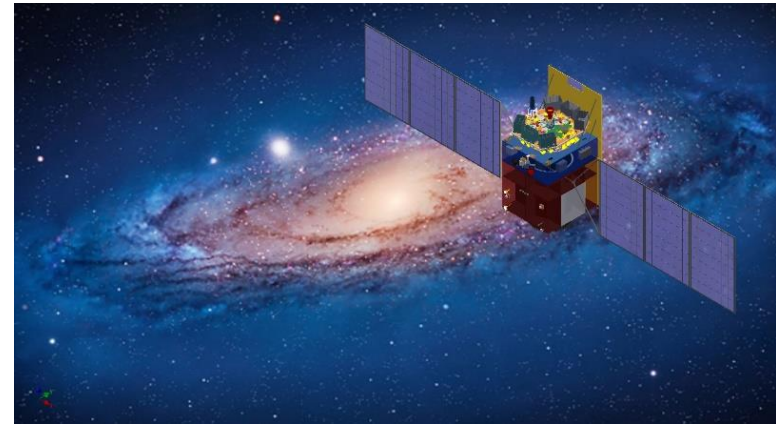


# Insight HXMT



- ❖ **Insight** Hard X-ray Modulation Tele. was launched in June 2017.
- ❖ It is sensitive in 3 different energy ranges.
- ❖ Directly measured the strongest magnetic field in the universe  $\sim 10^{13} \text{G}$
- ❖ Observed Quasi-Periodical Oscillation (QPO) phenomena of Black Hole X-ray Binaries at energies  $> 150 \text{ keV}$ , RMS saturates above  $20 \text{ keV}$ .
- ❖ Participated in the “multi-messenger” discovery of the 1<sup>st</sup> binary neutron star (BNS) GW event.
- ❖ Accumulate  $\sim 100 \text{ GRBs/yr}$  @  $\sim \text{MeV}$

PI: Shuang-Nan Zhang (IHEP)



**Extended to monitor  
GRB in MeV range**



# GECAM



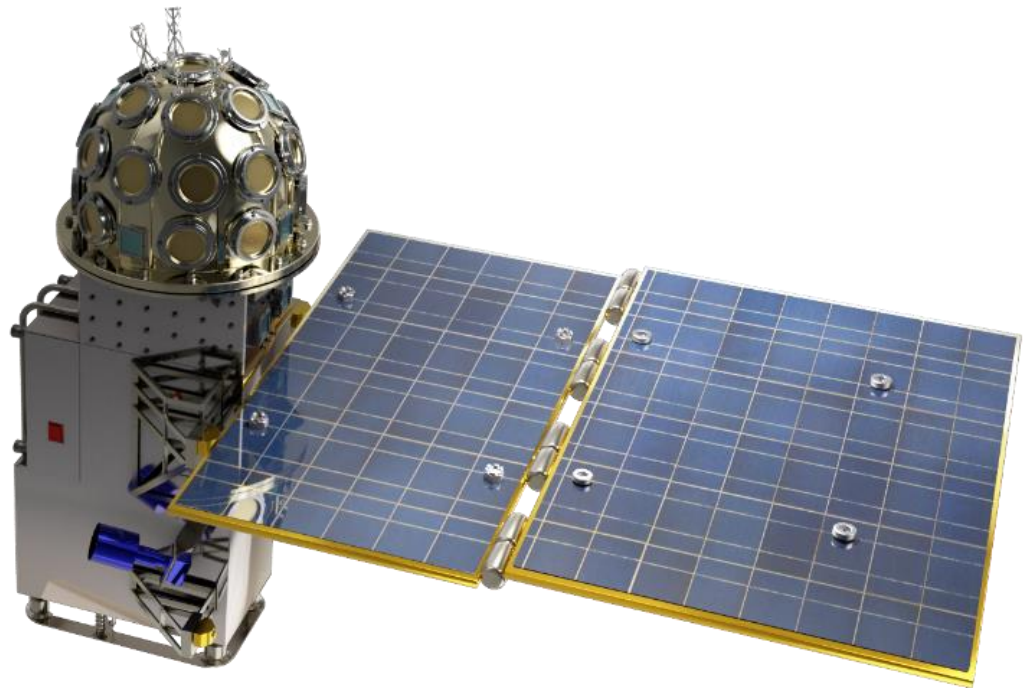
- ❖ Gravitational wave burst high-energy Electromagnetic Counterpart All-sky Monitor (GECAM)
- ❖ Sciences: GW GRB (GW EM from keV to MeV). Fast Radio Bursts (FRB), High Energy Neutrinos (HEN), GRB, Magnetar
- ❖ Performance 100% all-sky FOV, high sensitivity, wide energy band, good localization ( $\sim 1$  deg)

Plan to launch in 2020

Life time > 3 yrs

2 x

PI: Shaolin Xiong (IHEP)

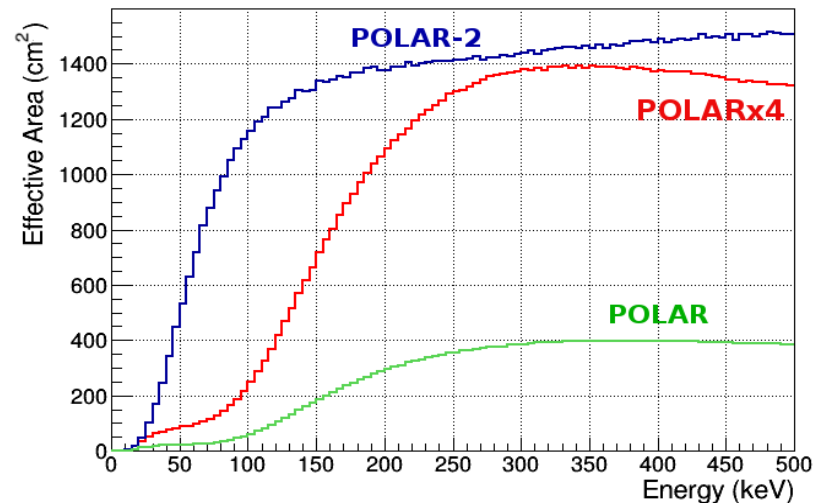
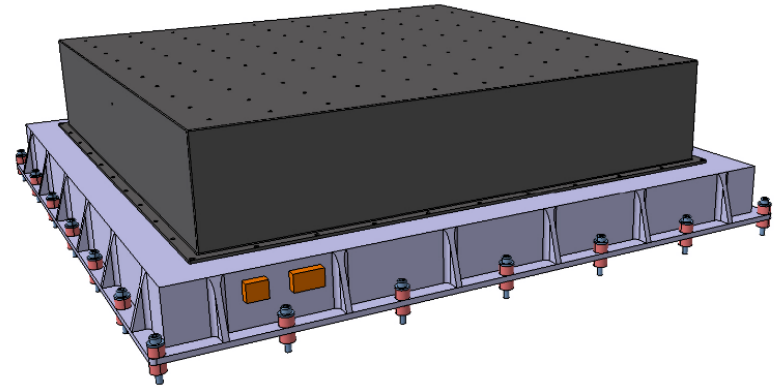




# POLAR-2



- ❖  $4 \times \text{POLAR} + \text{SiPM}$ : much higher sensitivity
- ❖ More sensitive than Fermi-GBM: gravitational wave counter part searchers
- ❖ Detailed polarization measurements of 30 GRBs per year
- ❖ Time resolved polarization measurements for 10 GRBs per year
- ❖ **Launch ~2024 on CSS**, operation for 2 years



PIs: Xin WU (UniGE), Shuang-Nan Zhang (IHEP)

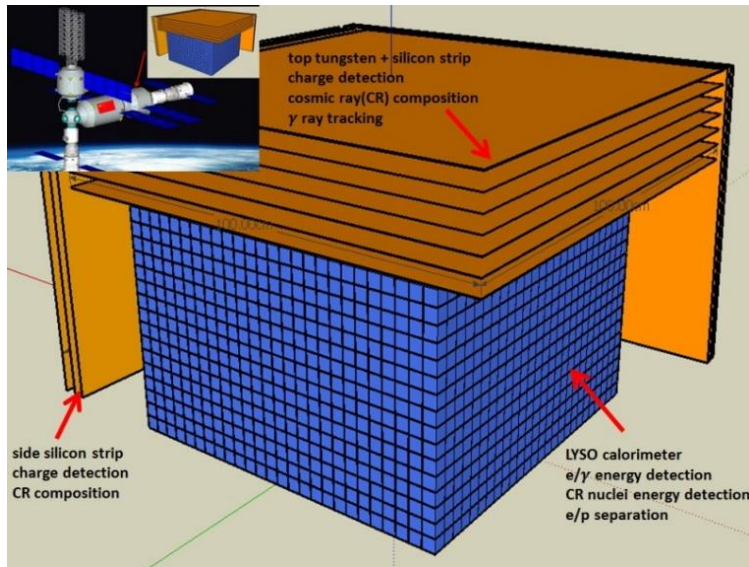




# HERD and eXTP

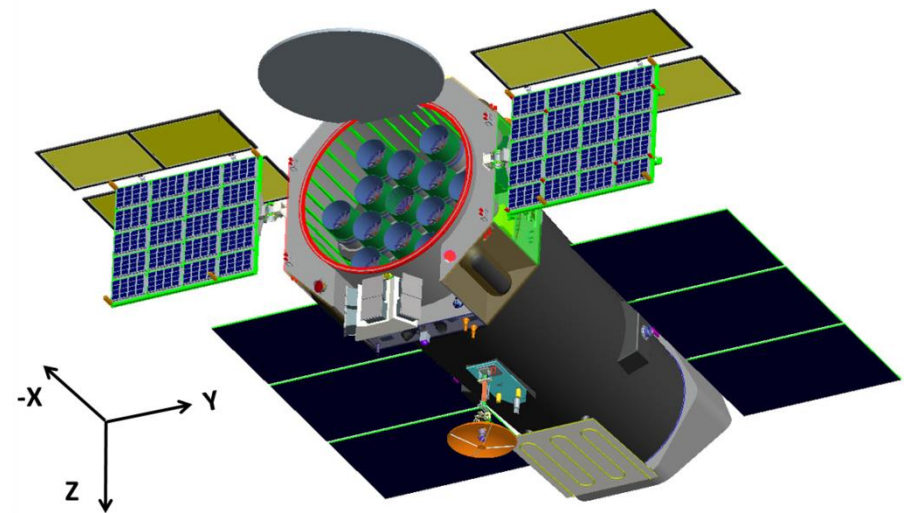


- ❖ High Energy cosmic-Ray Detection (HERD) on CSS.
- ❖ enhanced X-ray Timing and Polarimetry (eXTP)



Aim: 2025?

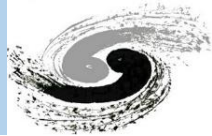
PI: Shuang-Nan Zhang (IHEP)  
Europe: Giovanni Ambrosi (INFN/Perugia)



Aim: 2027?

PI: Shuang-Nan Zhang (IHEP)  
Europe: Marco Feroci (INAF, Rome)

# High Mountain Cosmic Ray Program



# Yangbajing International Cosmic Ray Observatory

- ❖ ASy experiment since 1990 (China, Japanese), size  $\sim 50,000 \text{ m}^2$ .
- ❖ ASy observed the highest energy gamma rays ( $>100 \text{ TeV}$ ) from Crab Nebula in 1997.
- ❖ ARGO-YBJ experiment since 2007 (China, Italy), size  $\sim 6,500 \text{ m}^2$ .



Yangbajing, Tibet  
4300 m a.s.l.

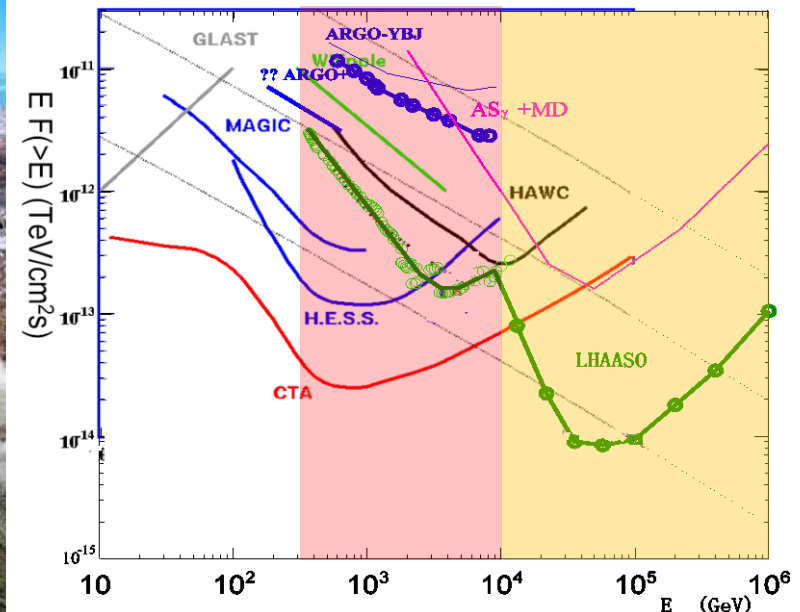
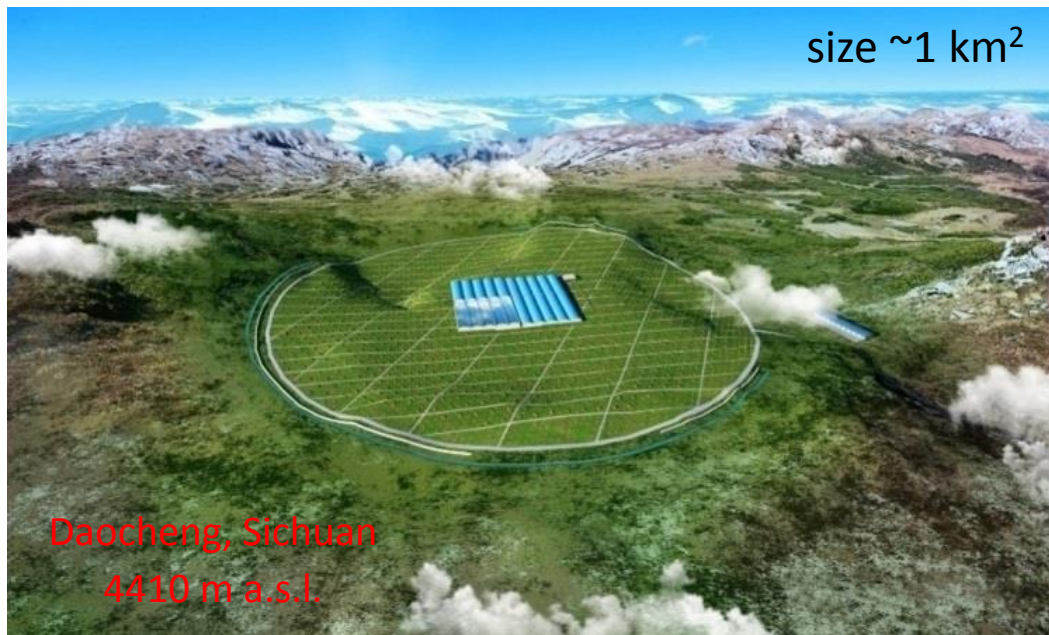




# LHAASO



- ❖ The Large High Altitude Air Shower Observatory (LHAASO) will continuously survey the gamma-ray sky for steady and transient sources from about 100 GeV to PeV energies
- ❖ International collaboration: China, France, Italy, Russia, Switzerland, Thailand.
- ❖ To finish full installation in 2021. Part of LHAASO is already in operation.



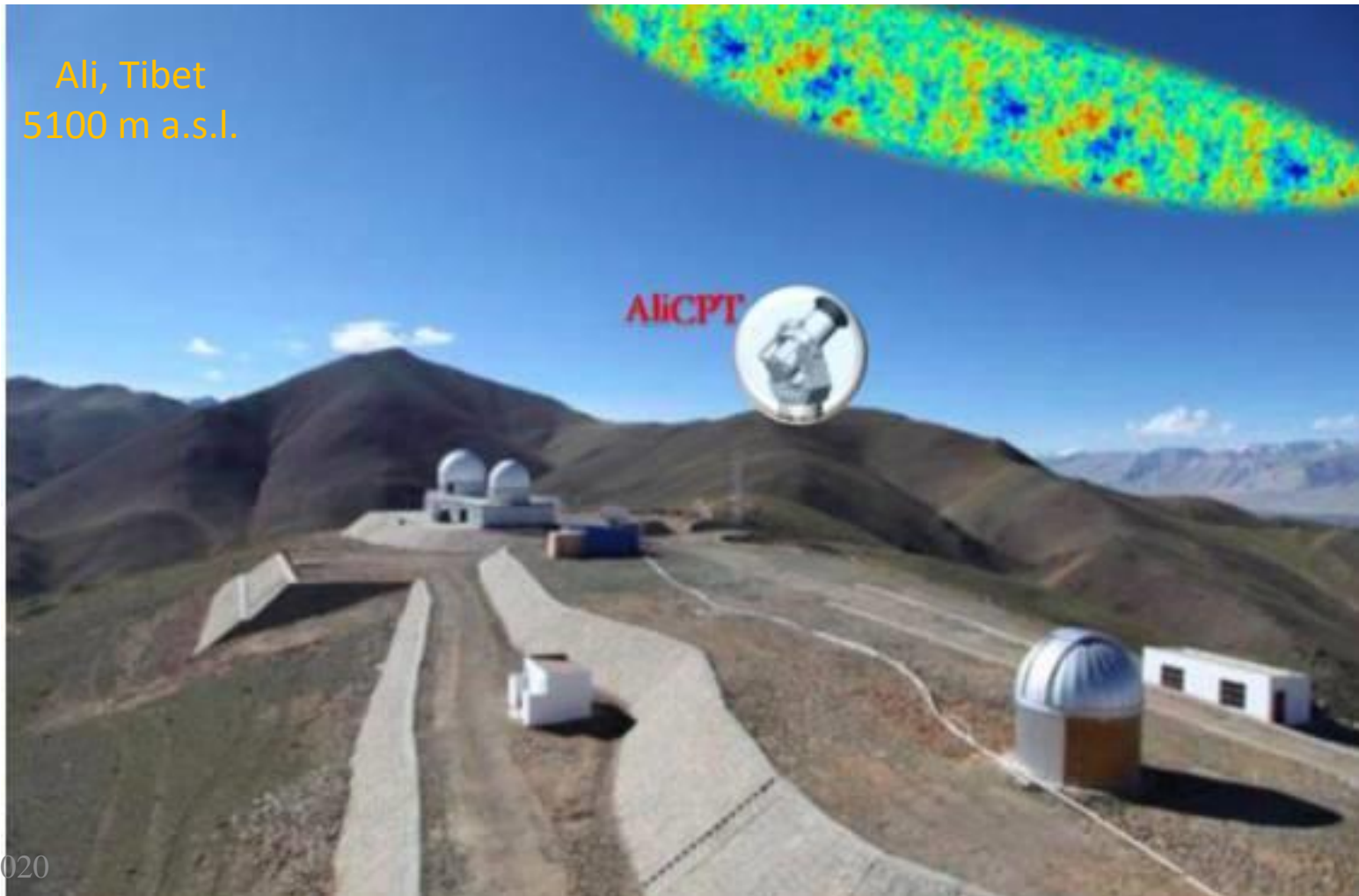


# AliCPT



- ❖ Ali CMB Polarization Telescope is to probe primordial GW.
- ❖ With CMB missions in the south hemisphere to provide a full sky coverage.
- ❖ Will start operation in year 2020.

Ali, Tibet  
5100 m a.s.l.





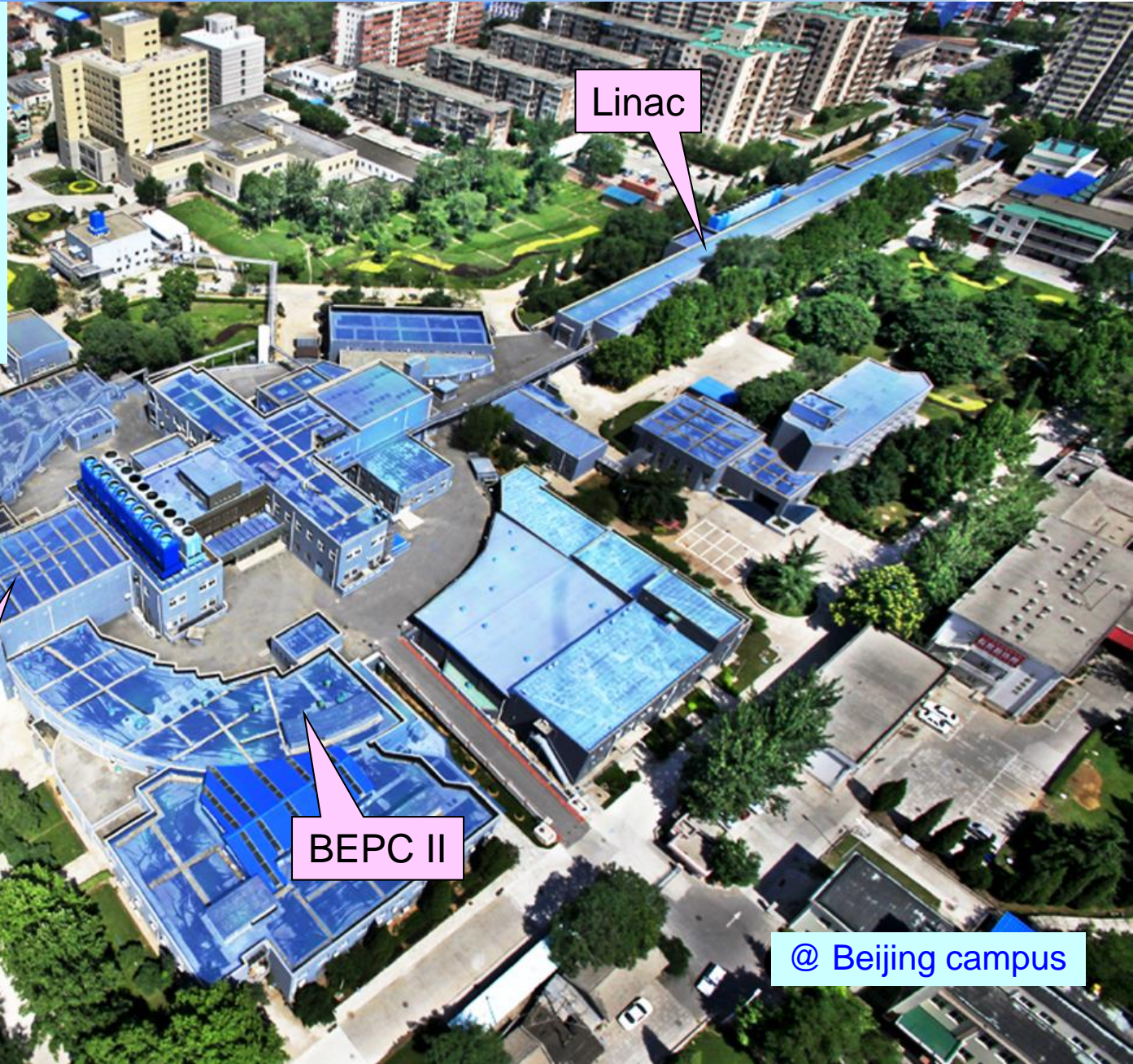
# Collider Experiments



# Beijing Electron Positron Collider (BEPC)



- ❖  $E_{cm} = 2.0\text{--}4.6\text{ GeV}$   
(2.0-4.9 GeV from 2019)
- ❖ 1989-2004 (BEPC):  
 $L_{peak} = 1.0 \times 10^{31} / \text{cm}^2 \text{s}$
- ❖ 2008-now (BEPC II):  
 $L_{peak} = 1.0 \times 10^{33} / \text{cm}^2 \text{s}$



Linac

BES III  
detector

BEPC II

@ Beijing campus





# BES III Experiment



72 institutes from China, Germany, India, Italy, Japan, Mongolia, Netherlands, Pakistan, Russia, South Korea, Sweden, Thailand, Turkey, UK, USA

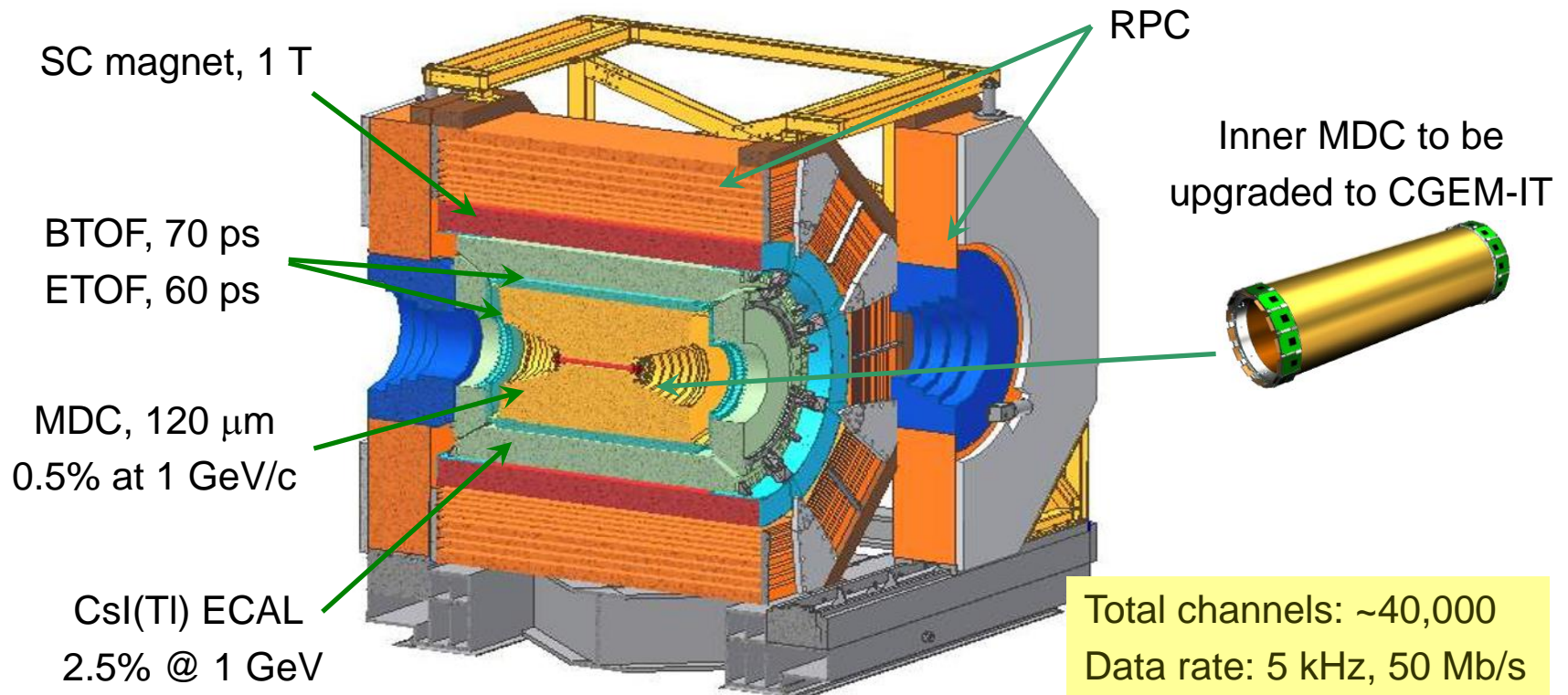
BES I : 1989 – 1995

BES II : 1998 – 2004

**BES III: 2008 – ?late 2020s**

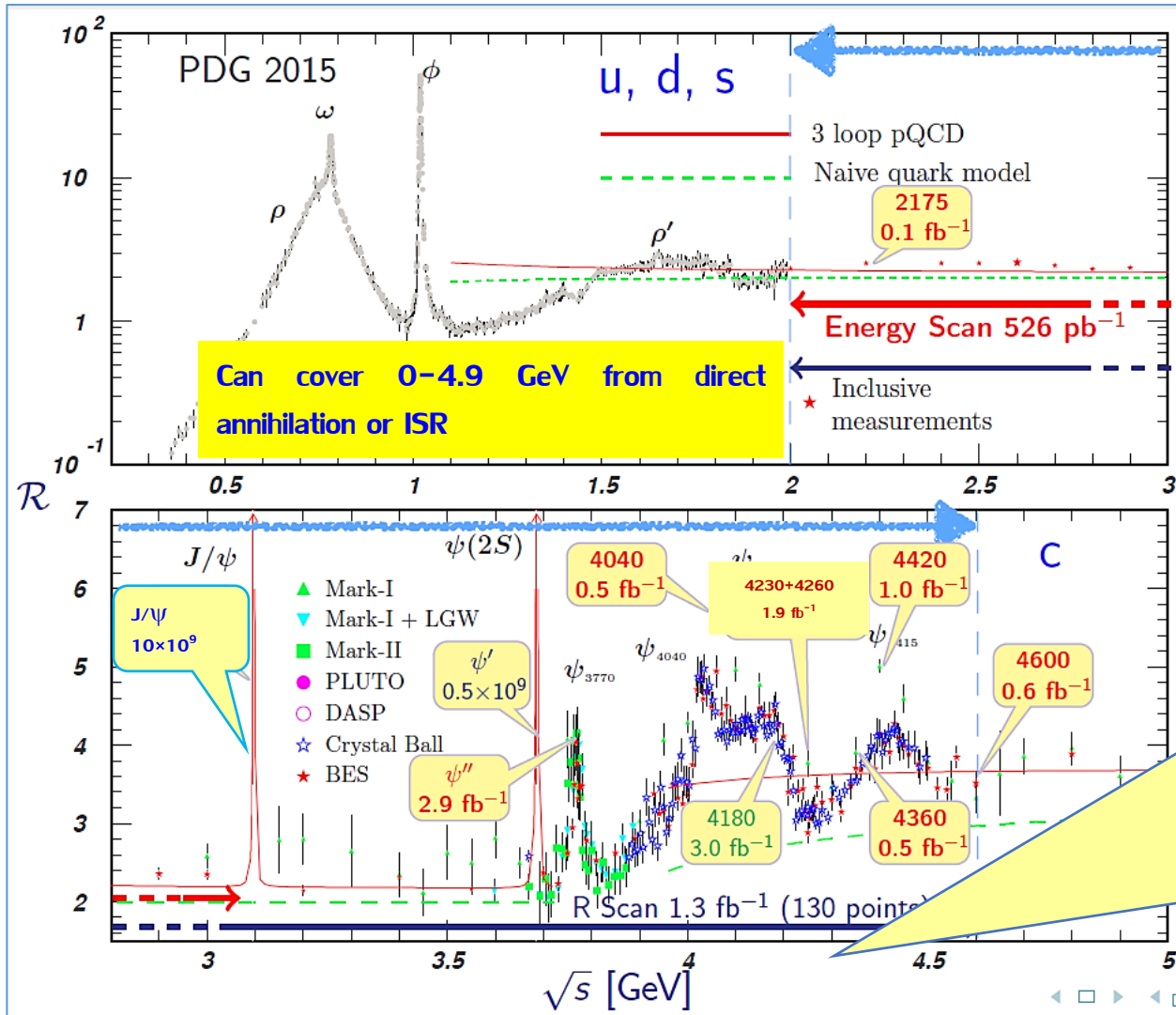
BES III white paper released in Dec 2019

<https://arxiv.org/abs/1912.05983>





# BES III Data Sets and R Scan



4130,  
4160,  
4190,  
4200,  
4210,  
4220,  
4236,  
4245,  
4270,  
4280,  
4290,  
4315,  
4340,  
4380,  
4400,  
4440,  
...  
 $7.7 \text{ fb}^{-1}$

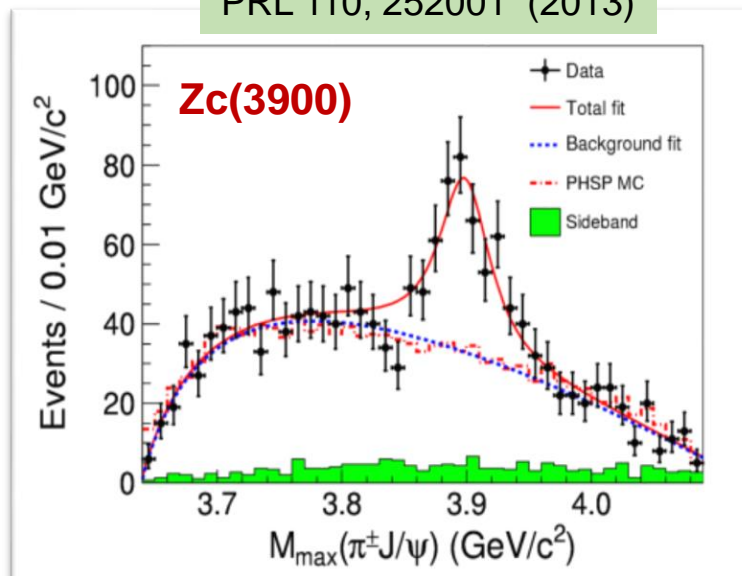


# BES III Recent Physics Focuses



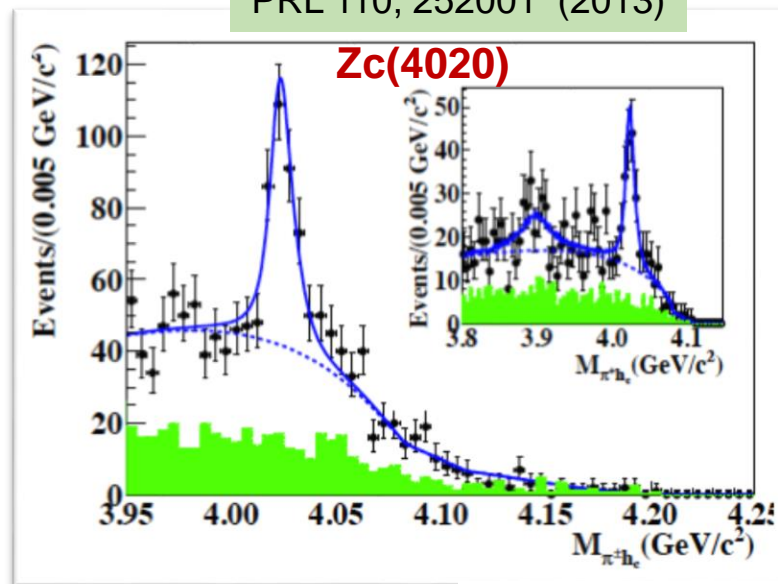
- ❖ XYZ particles: Discovery, PWA for particle properties, decay modes
- ❖ Light hadrons: glueballs, ...
- ❖ Charm decays: CKM, decay constants, form factors, LFU
- ❖ Baryons: form factors & polarization

PRL 110, 252001 (2013)



from  $e^+e^- \rightarrow \pi^+\pi^-J/\psi$

PRL 110, 252001 (2013)

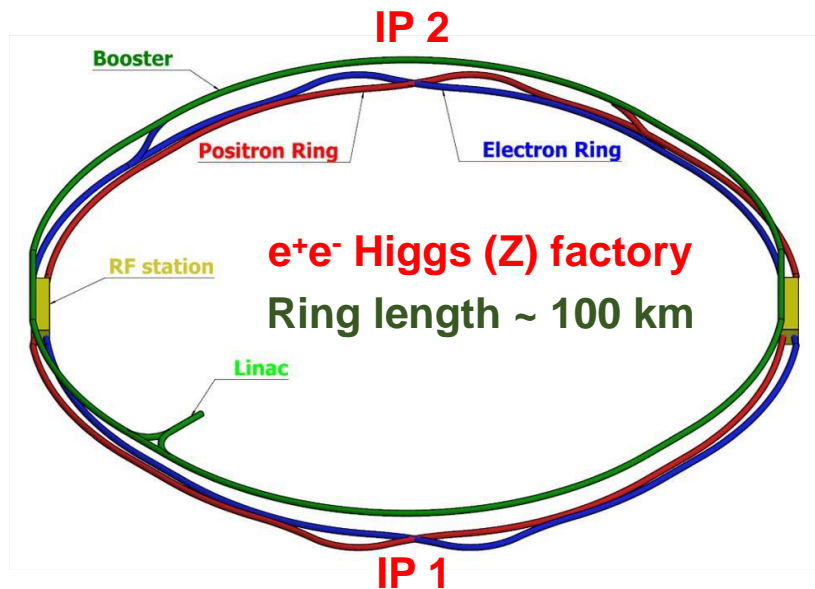


from  $e^+e^- \rightarrow \pi^+\pi^-h_c$





- ❖ Circular Electron Positron Collider is a possible accelerator based particle physics program in China after BEPC II.
- ❖ It runs at ZH (240 GeV), Z,  $W^+W^-$  (158-172 GeV), and possibly tt (365 GeV).
- ❖ In a 10-year program 1-2 M Higgs can be produced for  $\leq 1\%$  precision in key measurements of Higgs boson properties.
- ❖ It also provides study of EW, QCD, flavor ( $\sim 10^{12}$  Z) physics and search for BSM.
- ❖ Upgradable to a pp collider (SppC) with  $E_{cm} \sim 50$ -100 TeV.



Lumin / IP	Higgs	W	Z (2T)
$\times 10^{34}$	5.2	14.5	101.6

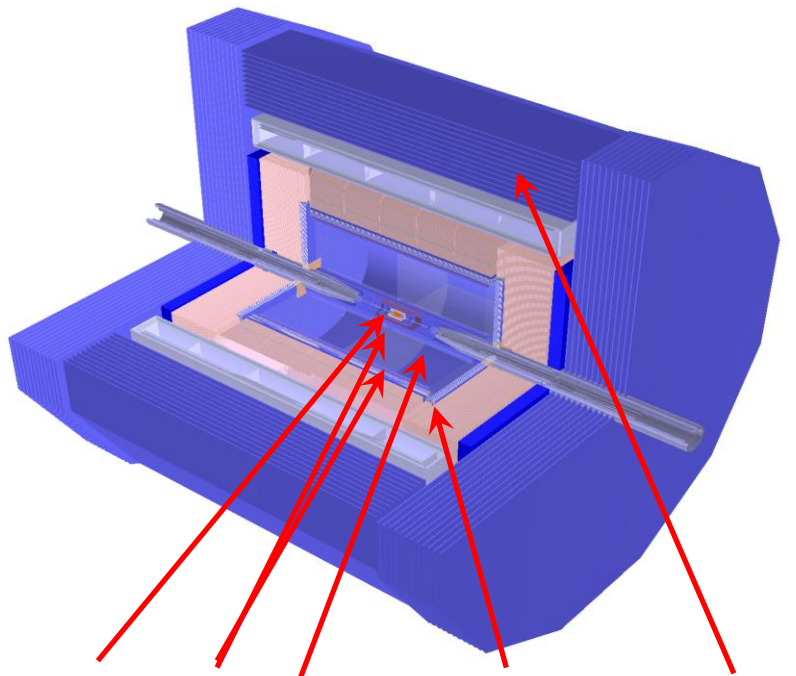
- ❖ Double ring baseline design
- ❖ Switchable between H and Z / W without hardware change.
- ❖ Use half SRF for Z and W.



# CEPC Detectors



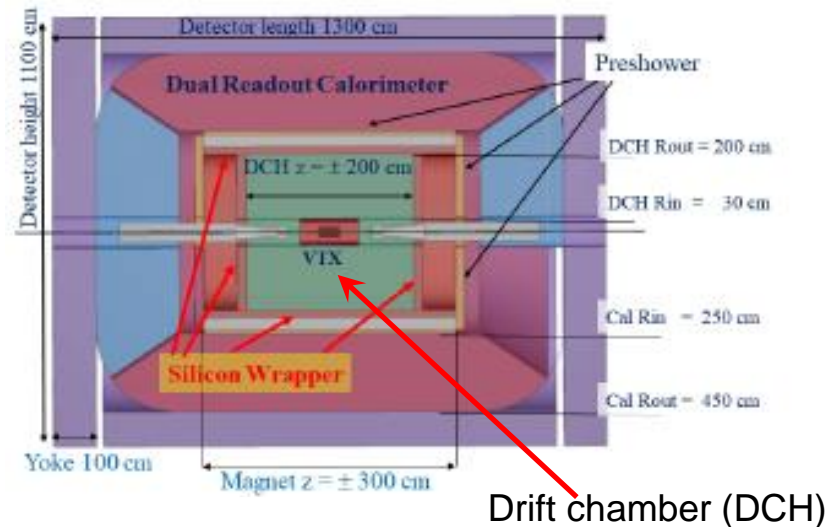
## Baseline concept (derived from ILD)



Si Vertex, Si + TPC, PFA ECAL & HCAL, Muon

The Si + TPC trackers may be replaced with a full silicon tracker

## IDEA concept



- ❑ Final two detectors may be a mixture of options.
- ❑ R&D of the sub-detectors are progressing (See Huirong Qi's presentation on TPC).



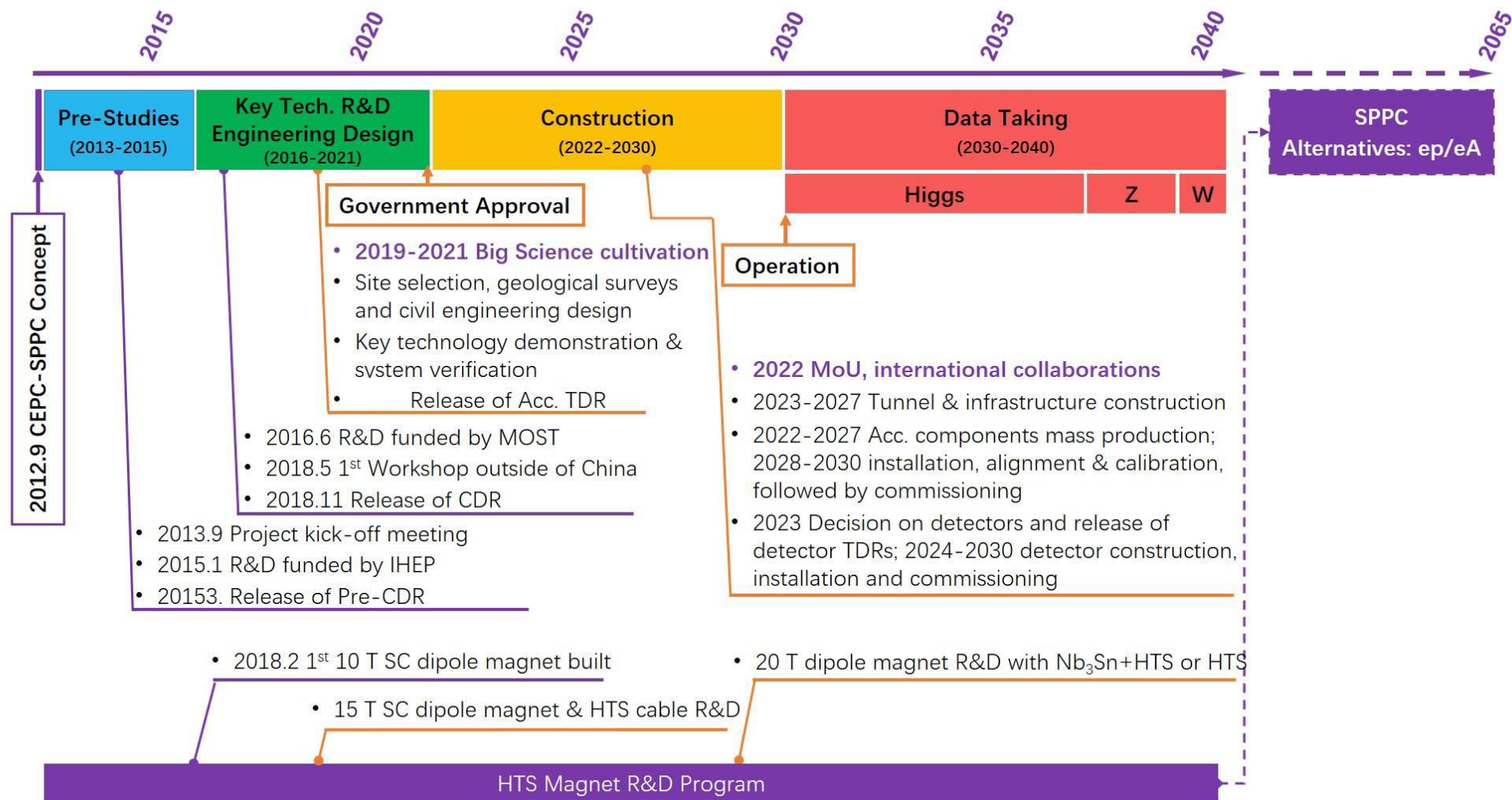
# CEPC Progressing



- ❖ Kick-off on Sep 13, 2013, inspired by the Higgs discovery @ LHC.
- ❖ PreCDR was released in March 2015
- ❖ CDR was released in Aug/Oct 2018 for Vol 1: accelerator, and Vol 2: physics & detector respectively.
- ❖ Towards TDR (2022 ?)
  
- ❖ Regular workshops were held in China, Europe, USA. The recent ones are
  - [CEPC Workshop 2019 China edition \(Nov 18-20, 2019\), Beijing.](#)
  - [Experiment/Detector](#), [Accelerator](#), [Physics](#) mini-workshops (Jan 16-18, 2020), Hongkong.
  - [The 2<sup>nd</sup> USA workshop\(April 22-23, 2020\), DC.](#)
  - [CEPC workshop 2020 EU edition \(May 4-6, 2020\), Marseille.](#)
  - [CEPC Workshop 2020 China edition \(Oct 26-28, 2020\), Shanghai.](#)
  
- ❖ Active international advisory committee (IAC), international accelerator R&D committee (IARC) and international detector R&D committee (IDRC).
  
- ❖ The international collaboration continuously grows. It is essential for the project, especially towards a successful TDR.



# CEPC Timeline (Ideal)



# Underground Neutrino Experiments

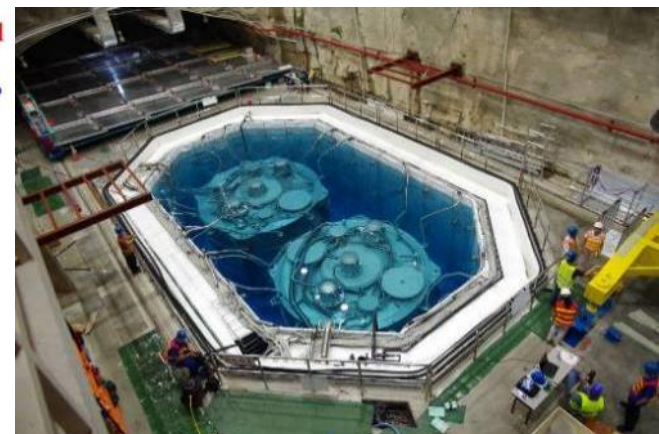
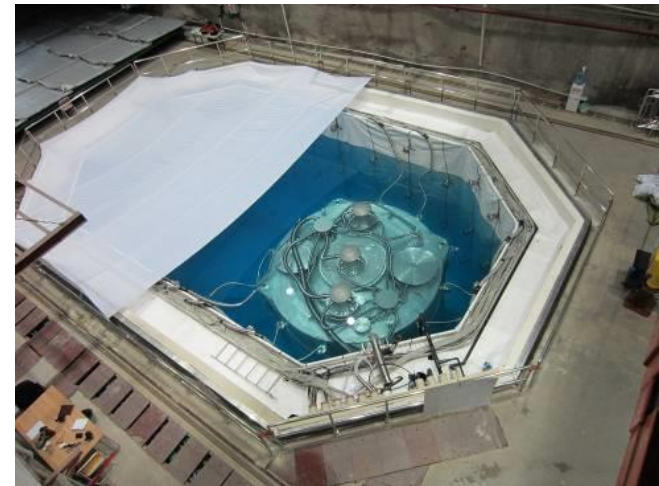
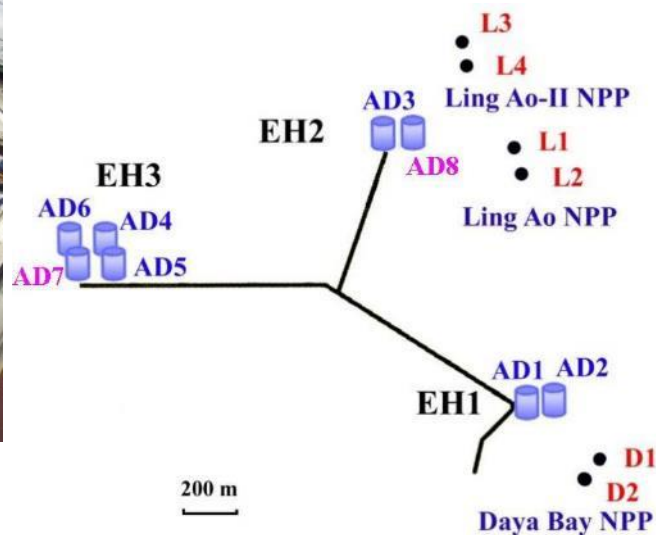
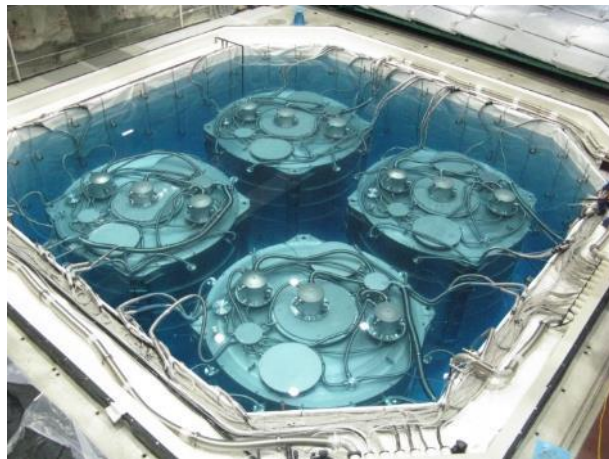




# Daya Bay Reactor Neutrino Experiment



- Daya Bay experiment was designed to measure  $\theta_{13}$  mixing angle
- Collaboration of 40 institutes from China, USA, Russia, Czech, Hongkong, Taiwan.



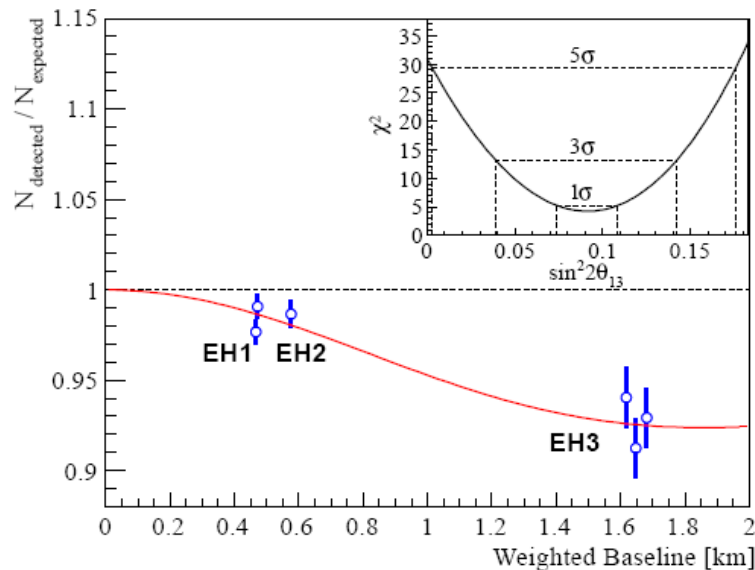
- 6 x 2.9 GW reactors in 3 NPPs.
- 3 x underground experimental halls
- 8 x 110-ton antineutrino detectors
- 3 x water Cherenkov detectors



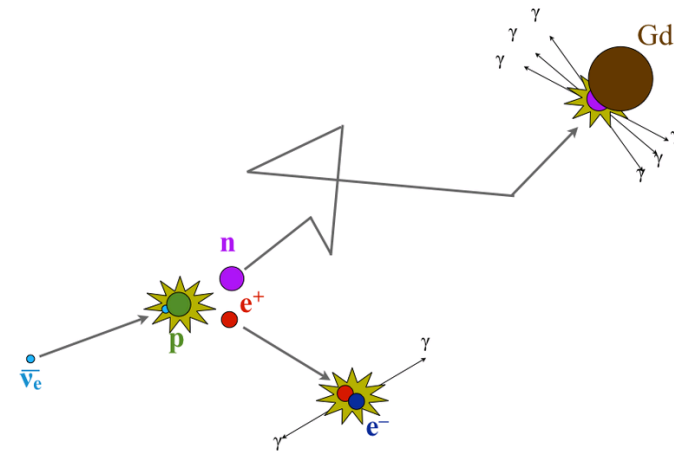
# DYB Neutrino Oscillation Measurements



Measurement from the first  
~2 months data taking



Antineutrinos are detected via the  
Inverse Beta Decay (IBD) reaction



**$\sin^2 2\theta_{13} = 0.092 \pm 0.016(\text{stat}) \pm 0.005(\text{syst})$**   
**Probability of non-zero  $\theta_{13}$   $5.2 \sigma$**

F.P. An et al., PRL 108, (2012) 171803

**$\sin^2 2\theta_{13} = 0.0856 \pm 0.0029$**   
**From 1958 days data taking**

D. Adey et al., PRL 121, (2018) 241805



# JUNO

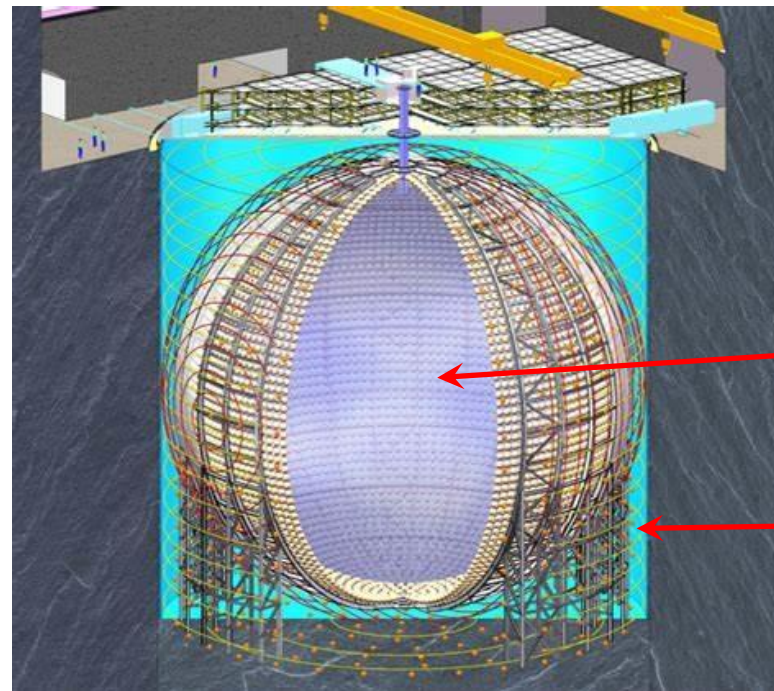


- ❖ Jiangmen Underground Neutrino Observatory is a multipurpose neutrino experiment.
- ❖ A collaboration of 72 institutions from 17 countries and regions.
- ❖ Installation progressing, expect to operate in 2021.

700 m underground



26.6 GW NPPs



20k 20" PMT  
25k 3" PMT

20 kton  
liquid scint.

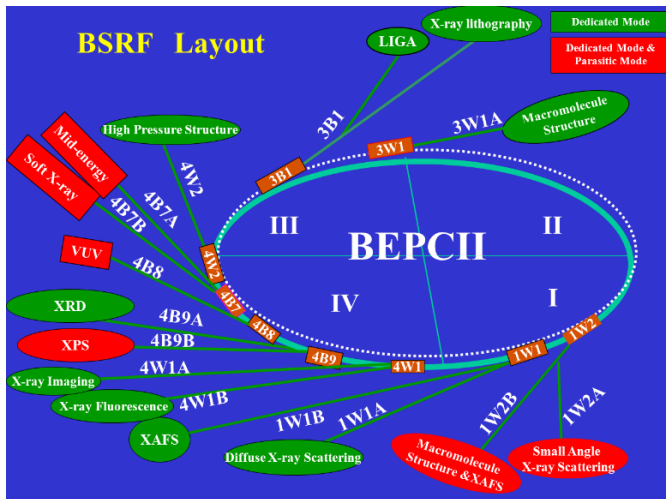
40 kton  
pure water

# General Experimental Platforms





# Beijing Synchrotron Radiation Facility



2.5GeV / 250mA in  
dedicated mode  
14 beamlines



BSRF @ the main campus  
operates since year 1991  
~2000 hrs/year, ~1800 users/year





# China Spallation Neutron Source



CSNS @ Dongguan campus, operates since end of 2017  
1.6 GeV proton beam on target, 62.5 mA (x5 in CSNS-II)







# High Energy Photon Source



Construction started at 2019

6 GeV SR facility

Brilliance:  $>10^{22}$  phs/s/mm<sup>2</sup>/mrad<sup>2</sup>/0.1%BW

Up to 300 keV photon energy





# Summary



- ❖ The IHEP CAS has a very rich experimental program in collider physics, astroparticle, neutrino, accelerator, and technology application fields.
- ❖ The current and future projects that are mainly supported by IHEP are introduced. IHEP welcomes international collaborations.
- ❖ IHEP is also very active in many other international collaborations that are not covered in this presentation.