Qing Qin (IHEP), Nu Xu (CCNU), XinChou Lou (IHEP)
For the CEPC-SppC Study Group
Outline

Progress & development since the CEPC meeting in Sept. 2015

- Organization and updates
- On the detector front
- On the accelerator front – CEPC and SppC
- Global effort
- R&D funding

high quality, real overall progress

At this meeting

- CEPC design towards CDR
- R&D progress and future activities
- Organization, plan and actions
The CEPC management was reorganized in May 2015, after the preCDR, moved forward with the CEPC CDR process; deadline ~ “year end of 2016”

Institutional Board
Chair: Y. N. GAO (Tsinghua U)
Deputy: J. GAO (IHEP)

Steering Committee
Chair: Yifang WANG (IHEP)
J. Gao, Y.N. GAO(Tsinghua U), Nu XU (CCNU), J. SHAN (IHEP), H.J. YANG (SJTU), Q. QIN(IHEP), H.J. HE(Tsinghua), Y.J. MAO(PKU), J. B. LIU(USTC), W.R.CHOU(FNAL/IHEP),X.C.LOU(IHEP),...

Project Directors
X.C. LOU(IHEP)
N. XU(CCNU), Q. QIN(IHEP)

Theory
H.J. HE(Tsinghua )
J.P.MA(ITP)
X.G.HE(SJTU)

Accelerator
Q. QIN( IHEP)
J. GAO (IHEP)
J.Y. TANG(IHEP)

Detector
Y.N.GAO(Tsinghua)
S. SHAN(IHEP)
N. XU(CCNU)
CEPC-SPPC Timeline (preliminary/ideal)

**CEPC**

1. **Pre-studies (2013-2015)**
3. **Construction (2021-2027)**
4. **Data taking (2028-2035)**

**1st Milestone**: Pre-CDR (Spring of 2015) → R&D funding request to Chinese government in 2016 (China’s 13th Five-Year Plan 2016-2020)

**2nd Milestone**: 13th 5yr-plan R&D (12M IHEP, ~100M MOST)

**SPPC**

2. **Engineering Design (2030-2035)**
3. **Construction (2035-2042)**
4. **Data taking (2042-2055)**

This is a good schedule to follow

April 8, 2016
• CEPC Detector supported by IHEP + other funds

Regular Meeting on March 31, 2016

Thursday, 31 March 2016 from 09:00 to 11:00 (Asia/Shanghai) at IHEP (A415)

CEPC Pre-research Project

March 2016

- 31 Mar Regular Meeting on March 31, 2016

February 2016

- 26 Feb Regular Meeting on Feb 25, 2016 (protected)

January 2016

- 28 Jan Regular Meeting on Jan 28, 2016 (protected)
- 07 Jan Regular Meeting on Jan 7, 2016 (protected)

December 2015

- 02 Dec Regular Meeting on Dec 3, 2015 (protected)

November 2015

- 12 Nov Regular Meeting on Nov 12, 2015 (protected)

October 2015

- 29 Oct Regular Meeting on Oct 29, 2015 (protected)
- 15 Oct Regular Meeting on Oct 15, 2015 (protected)

→ official meeting minutes and publications
CEPC accelerator design activities towards CDR

Weekly CEPC Accelerator design beam dynamics meeting after Pre-CDR towards CDR:

http://indico.ihep.ac.cn/category/350/

Website contents:
1) Talks ppt
2) Minutes

The main working fields:
1) Double ring schemes
2) Crab-waist collider parameters
3) Beam-beam effect simulations
4) Pretzel scheme
5) Dynamic aperture optimization (with FFS)
6) Boosters (conventional and wiggling dipole field schemes)
7) Magnet error effects on DA
8) MDI
9) SppC lattice design
10) CEPC bunch lengthening effects (other collective effects)
Progress & development

The detector front

Just a few examples; please attend detector sessions for details
CEPC Detector (preCDR) a reminder

ILD-like detector with additional considerations (*incomplete list*):

- Shorter $L^*$ ($1.5/2.5$m) → constraints on space for the Si/TPC tracker
- No power-pulsing → lower granularity of vertex detector and calorimeter
- Limited CM (up to 250 GeV) → calorimeters of reduced size
- Lower radiation background → vertex detector closer to IP
- …

- **Similar performance requirements to ILC detectors**
  - Momentum: $\sigma_{1/p} < 5 \times 10^{-5}$ GeV$^{-1}$ ← recoiled Higgs mass
  - Impact parameter: $\sigma_{r\phi} = 5 \theta/(p \cdot \sin^2\theta) \mu$m ← flavor tagging, BR
  - Jet energy: $\frac{\sigma_E}{E} \approx 3-4\%$ ← W/Z di-jet mass separation

April 8, 2016
CEPC Detector – Pixel Vertex Detector

high precision, low power consumption, fast readout pixel sensors

- CMOS technology: in collaboration with IPHC Strasbourg, France (Key Lab, IHEP)
- SOI technology: in collaboration with KEK, Japan (NSFC)

<table>
<thead>
<tr>
<th>Strategies</th>
<th>Target 1: fine pitch, low power</th>
<th>Target 2: ~1 µs time resolution</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fine pitch to achieve &lt;3µm single point resolution for the inner most layer</td>
<td>Relaxed requirement on single point resolution</td>
</tr>
<tr>
<td></td>
<td>Low power compatible with air cooling</td>
<td>Low power compatible with air cooling</td>
</tr>
<tr>
<td></td>
<td>Relaxed requirement on readout speed (flexible)</td>
<td>Enhanced readout speed by a factor of 10</td>
</tr>
<tr>
<td>Specifications</td>
<td>16 µm pitch</td>
<td>~1µs readout intervals</td>
</tr>
<tr>
<td></td>
<td>50 mW/cm²</td>
<td>20-30 µm pitch to achieve σ~5µm</td>
</tr>
<tr>
<td></td>
<td>10-100 µs readout speed</td>
<td>50 mW/cm²</td>
</tr>
</tbody>
</table>

April 8, 2016
CEPC Detector – Pixel Vertex Detector

- **Compact Pixel for Vertex (CPV1) – SOI sensors**
  - 16*16 μm with in-pixel-discrimination
  - Based on the measurement of full depletion
  - Double-SOI process for shielding and radiation enhancement
  - Submitted in June, 2015

- Preliminary test results
  - Gain of amplifier measured compatible with the design value
  - A decent ENC noise ~ 17e⁻
  - Radiative source test in preparation

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**Funding from NSFC**


**CPV1 digital pixel layout**

![Diagram of CPV1 digital pixel layout](image)

April 8, 2016
CEPC Detector – Pixel Vertex Detector

CMOS Sensor design and production

- Initialized CEPC pixel sensor design based **CMOS** technology
- **1st joint MPW submission** with IPHC last November to understand charge collection with different diode geometries, epitaxial-layer properties and possible radiation hardness

CMOS sensor working principle

- On-going design effort on **in-pixel electronics and readout architecture**; second MPW submission later this year

Funding from Key Lab, IHEP
Sensor Characterization (Preparation)

- Prepare test system to characterize charge collection
  - NI crate based or customized DAQ system
- Signal response with the TCT scan system
  - Commissioned to achieve resolution ~ 30μm (target: 10μm)

- Irradiation facilities @ NINT allowing TID up to 5 MRad (Co-60) and NIEL up to $10^{14}$ 1MeV $n_{eq}$/cm$^2$ (pulsed neutron reactor)
TCAD Simulation

- Important to understand/predict device performance and assist sensor design
- 3D device simulation with improved boundary treatment and reliable physics models to estimate charge collection

- Simulation results to be verified with real measurements
Simulation of occupancy

- Occupancy@250GeV
  - Very important parameter for TPC
  - Detector structure of the ILD-TPC like
  - ADC sampling 40MHz readout
  - Time structure of beam: 4us/Branch
  - Beam Induced Backgrounds at CEPC@250GeV (Beam halo muon/e+e-pairs)+γγ→hadrons with safe factors (×15)

New ideas for the ions

- GEM+Micromegas hybrid module
  - GEM as the preamplifier device
  - GEM as the device to reduce the ion back flow continuously
  - Stable operation in long time
  - Reach to the higher gain than standard Micromegas with the pre-amplification GEM detector
  - Increase the operating voltage of GEM detector to enlarge the whole gain

Supported by 高能所创新基金

CLIC_ILD ~30%@3TeV
1×6mm² Pads
CLIC_ILD ~12%@3TeV
1×1mm² Pads
NO TPC Options!

April 8, 2016

YL Li, Huirong Qi et. al.
Common efforts R&D

Collaboration for the IBF R&D:
CEA Scalay (France)
IHEP, Tsinghua Univ. (China)

Collaboration for the Laser calibration R&D:
Tsinghua University, Beijing
IHEP, Beijing

Targets:
- R&D of IBF used UV light
  - Goal: ~0.1% IBF, Resistive Micromegas modules, Hybrid modules
- Laser optical design
- TPC Prototype design with Laser calibration
  - Readout active area: ~200mm², Drift length: ~500mm
- ASIC electronic readout
  - Goal: ~32Chs/CHIP, Channels: ~1K
- Toward CEPC CDR

April 8, 2016
Tests of SiPM at IHEP

SiPM pe spectrum

The dark noise of the new SiPMs is 1/3 to the old

pulse height spectrum.

Excellent photon counting

The cross-talk of the new SiPMs is 10% to the old
CEPC Detector – Calorimeters

### Tests of Scintillator strip at IHEP

- **Scintillator strip irradiated with β collimated (1mm) from Sr-90**
- **SIPM**
  - Strip: 5mm × 45mm × 2mm
- **SIPM**
  - Strip: 10mm × 90mm × 2mm

- Peaky Npe near MPPC
- Larger Npe than ILD probably due to different scintillator material and reflector.
- Significant reduction of Npe with long strip.

### HCAL: GRPC Study

- **Mylar layer (50μ)**
- **PCB (1.2mm)+ASIC(1.7 mm)**
- **PCB support (polycarbonate)**
- **Readout ASIC (Hardroc2, 1.6mm)**
- **Readout pads (40mm × 40mm)**
- **Cathode glass (1.1mm) + resistive coating**
- **Anode glass (0.7mm) + resistive coating**

- Negligible dead zone (tiny ceramic spacers)
- Large size: 1 × 1 m²
- Cost effective
- Efficient gas distribution system
- Homogenous resistive coating

### WELL-THGEM Beam Test at IHEP in Oct., 2015

- 7 THGEMs were installed, and 5 of them were used, and flushed with Ar/iso-butane = 97:3.
- 1 threshold, binary readout
- 900 MeV proton beam was used
- 5cm × 5cm sensitive region

### Large-area GEM @ USTC

- **GEM assembly using a novel self-stretching technique**
- **APV25 GEM readout**
- **INFN APV25 chip**

- Large-area GEM (0.5x1m²) is one of main detector R&D focuses at USTC recently.
- Technology has been developed and matured to produce high-quality GEM detectors as large as ~1m² that are also applicable to CEPC DHCAL.

- Resolution uniformity ~11%
- Gain uniformity ~16%
- Can reach gain of 10⁴ at 4000V
Key technology:
- Optimization of Magnetic filed
- Superconductor
- Inner winding and impregnating
- Coil cryogenic system
- Power lines with HTS
- Manufacturing and assembling of huge scale yoke

Test results:
1. RRR value declined by about 1/3 after the stranding process.
2. The decrease of the critical current is less than 5%.
CEPC Detector – Software & Tools

A dedicated analysis framework
Novices can start from root ...

Feed all types of particle object to the combination engine for further processing

ee+X, μμ+X, jj+ee, jj+μμ ... Data → ntupes → plots

PFA/PID/JER
Arbor v1 → v3(KD)

- Total invariant mass
  - Total inv. Mass for h+bb events
  - Total inv. Mass for h+cc events
  - Total inv. Mass for h+gg events

Dedicated Isolate lepton and tau finder being optimized

- 统计工具:
  - 变量的shape information 可用在fit中.
  - 可以同时测量分值比和散射截面.
  - 可以将各个道的 migration 和相关性引入统计工具之中.

- 多变量分析:
  - 多个道引入多变量分析的方法: h→bb,cc,gg,ll

- 数据驱动(data-driven)的方法:
  - 产生较完整数据(背景),用来进行data-driven method’s 练习.
  - 三月份workshop给学生们一次tutorial,介绍ATLAS中各种用到的data-driven methods.
CEPC Detector – Software & Tools

New geometry: CEPC_o_V2

- New calo, TPC, and MDI
- Smaller TPC & Calo sizes
- More details in MDI
- Detailed B field map

Shrink the ILD detector

An important step towards sizing, design & optimization of the CEPC detector

<table>
<thead>
<tr>
<th>Parameter</th>
<th>CEPC_o_v2</th>
<th>CEPC_v1</th>
</tr>
</thead>
<tbody>
<tr>
<td>LStar_zbegin</td>
<td>1150</td>
<td>1146.9</td>
</tr>
<tr>
<td>VXD_inner_radius</td>
<td>12</td>
<td>15</td>
</tr>
<tr>
<td>VXD_radius_r1</td>
<td>12</td>
<td>15</td>
</tr>
<tr>
<td>VXD_radius_r3</td>
<td>35</td>
<td>37</td>
</tr>
<tr>
<td>TPC_outer_radius</td>
<td>1500</td>
<td>1800</td>
</tr>
<tr>
<td>Hcal_layers</td>
<td>40</td>
<td>48</td>
</tr>
<tr>
<td>Ecal_cells_size</td>
<td>10</td>
<td>4.9</td>
</tr>
<tr>
<td>Field_nominal_value</td>
<td>3</td>
<td>3.5</td>
</tr>
<tr>
<td>Yoke_Layers</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>

Plus:
- full simulation of all analyses
- two papers: one published and other answering the referee’s questions

Need more validation
To be released soon ...

April 8, 2016
Progress & development

CEPC and SppC accelerators

Jie Gao’s talk will provide a full picture
same layout and hardware at the $Z(91)$ and $ZH(240)$

### CEPC Design Goal – Higgs Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Design Goal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Particles</td>
<td>$e^+, e^-$</td>
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<tr>
<td>Center of mass energy</td>
<td>240 GeV</td>
</tr>
<tr>
<td>Luminosity (peak)</td>
<td>$2 \times 10^{34}/\text{cm}^2\text{s}$</td>
</tr>
<tr>
<td>No. of IPs</td>
<td>2</td>
</tr>
</tbody>
</table>

### CEPC Design Goal – Z-pole Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Design Goal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Particles</td>
<td>$e^+, e^-$</td>
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<tr>
<td>Center of mass energy</td>
<td>45.5 GeV</td>
</tr>
<tr>
<td>Integrated luminosity (peak)</td>
<td>$&gt;1 \times 10^{34}/\text{cm}^2\text{s}$</td>
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<tr>
<td>No. of IPs</td>
<td>2</td>
</tr>
<tr>
<td>Polarization</td>
<td>Consider in the second round</td>
</tr>
</tbody>
</table>
CEPC Accelerator

CEPC Accelerator Baseline Design

Linac

- Electron
- Positron

6~10 GeV

Booster

Energy Ramp 10 -> 120 GeV

Collision ring

Single ring: cheap, low lumi.
Double ring: expensive, high lumi
Local Double ring: a balance?

Pretzel scheme to separate opposing beams at crossings
CEPC accelerator layout

For CEPC 120GeV beam:
- Max. deflection per separator is 66μrad.
- Using Septum Dipole after separator to acquire 15 mrad
### Preliminary Parameters for CEPC partial double ring (wangdou20160325)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Pre-CDR</th>
<th>H-high lumi.</th>
<th>H-low power</th>
<th>W</th>
<th>Z</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of IPs</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Energy (GeV)</td>
<td>120</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Circumference (km)</td>
<td>54</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SR loss/turn (GeV)</td>
<td>3.1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Half crossing angle (mrad)</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Piwinski angle</td>
<td>0</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>$N_e$/bunch ($10^{11}$)</td>
<td>3.79</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Bunch number</td>
<td>50</td>
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<tr>
<td>Beam current (mA)</td>
<td>16.6</td>
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<tr>
<td>SR power/beam (MW)</td>
<td>51.7</td>
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<td></td>
<td></td>
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<tr>
<td>Bending radius (km)</td>
<td>6.1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Momentum compaction ($10^5$)</td>
<td>3.4</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>$\beta_T x/v$ (m)</td>
<td>0.8/0.0012</td>
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<td></td>
<td></td>
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<tr>
<td>Emittance $x/v$ (mm)</td>
<td>6.12/0.018</td>
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<td></td>
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<tr>
<td>Transverse $\sigma_T$ (nm)</td>
<td>69.97/0.15</td>
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<td></td>
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<tr>
<td>$\xi$/IP</td>
<td>0.118</td>
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</tr>
<tr>
<td>$\xi^*$/IP</td>
<td>0.083</td>
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<tr>
<td>$E_C$ (GeV)</td>
<td>6.87</td>
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</tr>
<tr>
<td>$f_{RE}$ (MHz)</td>
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<tr>
<td>Nature $\sigma$ (mm)</td>
<td>2.14</td>
<td></td>
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</tr>
<tr>
<td>Total $\sigma$ (mm)</td>
<td>2.65</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>HOM power/cavity (kw)</td>
<td>3.6</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Energy spread (%)</td>
<td>0.13</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Energy acceptance (%)</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Energy acceptance by RF (%)</td>
<td>6</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>$n_T$</td>
<td>0.23</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Life time due to beamstrahlung cal (minute)</td>
<td>47</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$F$ (hour glass)</td>
<td>0.68</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$L_{max}$/IP ($10^{14}$cm^2s^-1)</td>
<td>2.04</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## Preliminary Parameters for CEPC PDR-100km

(wangdou20160329)

| Number of IPs | Energy (GeV) | Circumference (km) | SR loss/turn (GeV) | Half crossing angle (mrad) | Piwinski angle | N_e/bunch (10^{11}) | Bunch number | Beam current (mA) | SR power/beam (MW) | Bending radius (km) | Momentum compaction (10^{-5}) | \( \beta_{\text{IP}} \) x'y' (m) | Emittance x/y (nm) | Transverse \( \sigma_{\text{IP}} \) (um) | \( \xi/\text{IP} \) | \( \epsilon/\text{IP} \) | \( V_{\text{RF}} \) (GV) | \( f_{\text{RF}} \) (MHz) | Nature \( \sigma_r \) (mm) | Total \( \sigma \) (mm) | HOM power/cavity (KW) | Energy spread (%) | Energy acceptance (%) | Energy acceptance by RF (%) | \( n_e \) | Life time due to beamstrahlung_cal (minute) | \( F \) (hour glass) | \( I_{\text{max}}/\text{IP} \) (10^{4} cm^{-2}s^{-1}) |
|---------------|--------------|-------------------|-------------------|---------------------------|----------------|---------------------|--------------|-------------------|---------------------------|-----------------------------|--------------------------|-----------------------------|-----------------------------|----------------|-----------------------------|----------------|-----------------------------|

See J Gao’s talk
CEPC PDR Luminosity vs circumference

April 8, 2016
SppC Accelerator

- Study team is still growing, regular meetings
- We are making progress on SPPC study steadily, on both the collider and injector accelerators.
  - Pre-conceptual designs (main parameters, accelerator frame, stage schemes, lattice and layout, etc)
  - Key accelerator problems (collimation, beam screen, etc.)
  - Key technology R&D (high-field superconducting magnets, cryogenic vacuum, etc.)
• Lattice design: three persons (1 postdoc, 2 students) working on the SPPC lattice
  – Race-track lattice to be compatible with CEPC
  – We do not need to by-pass the CEPC detectors
  – Different schemes (@70, 100 TeV)

• Collimation Study: two persons (1 postdoc, 1 student) working on collimation method and schemes
  – Transverse and longitudinal collimation in the same long straight section (overcoming beam loss at arc encountered by LHC)

• High-field SC magnets: seeking collaboration with industry, HT conductor research units, international partners
Global effort
**The First IHEP-BINP CEPC Accelerator Collaboration Workshop**

**Jan. 12-13, 2016, IHEP**

http://indico.ihep.ac.cn/event/5410/other-view?view=standard

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MoU between IHEP and BINP on Electron Positron Circular Colliders has been agreed by both Lab Directors, waiting for final signature.
IAS Conference Accelerator Program
(Jan. 18-21, 2016, Hongkang)

More than 30 accelerator physicists from CERN, SLAC, KEK, BINP, INFN, Cornell, BNL, LBNL, IHEP etc.

Very successfully international Conference (could be regarded as a Pre-meeting for the first CEPC International Collaboration Meeting, in Sept. 2016 (TBD)
CEPC Accelerator International Collaboration Status

- CEPC accelerator design group members sent out to the collaborating labs
  - **KEK**: Yiwei Wang, Yun Zhang (on Lattice collaboration) *(done)*
  - **SLAC**: Tianjian Bian (On booster design) *(now)*
  - **BNL**: Feng Su (On dynamic aperture optimizations) *(now)*
  - **LAL**: Sha Bai (On MDI) *(now)*
  - **CERN**: Na Wang *(done)* and Xiaohao Cui *(now)* (On collective effects and lattice)
R&D Funding
科技部国家重点研发计划 ~90M RMB

“大科学装置前沿研究”重点专项2016年度项目申报指南
新一代粒子加速器和探测器关键技术和方法的预先研究

- 高能环形正负电子对撞机预先研究 ~45M RMB

国家重点研发计划
项目预申报书
已于3月递交

期待2017年
- 高能环形正负电子对撞机关键技术验证 ~45M RMB
Future

- CDR
- R&D funding
- Make progress in critical design and R&D
- International collaboration
- Follow closely the schedule

“Highest Quality is required in the presence of Fcc, ILC, ....”
This Meeting

- CEPC design towards CDR
  Physics goals; detector-accelerator design; ...

- R&D progress and future activities

- Organization, plan and actions

“要创新，把目标定高些，要往上跳才能够得着的目标” - 王贻芳