# CEPC

# Overview and Objectives

**Qing QIN (IHEP), Nu XU (CCNU), XinChou Lou (IHEP)**

**For the CEPC-SppC Study Group**

September 2, 2016

# Outline

## Overview

- Progress and updates
- Funding for designs and R&D
- International collaboration

## Objectives

- This meeting
- 13th 5-year period

## Summary

# A reminder about the CEPC-SppC

**Phase 1:** **$e^+e^-$ Higgs (Z) factory** **two detectors, 1M ZH events in ~10yrs**

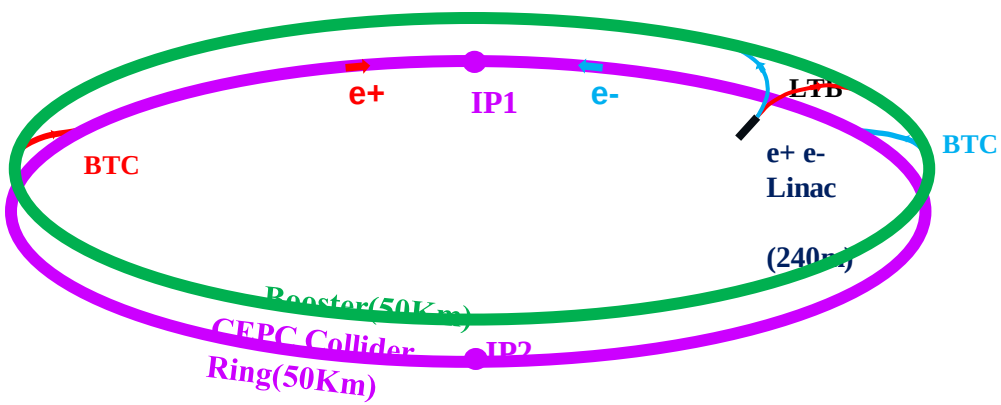
**Circular Electron Positron Collider (CEPC)**

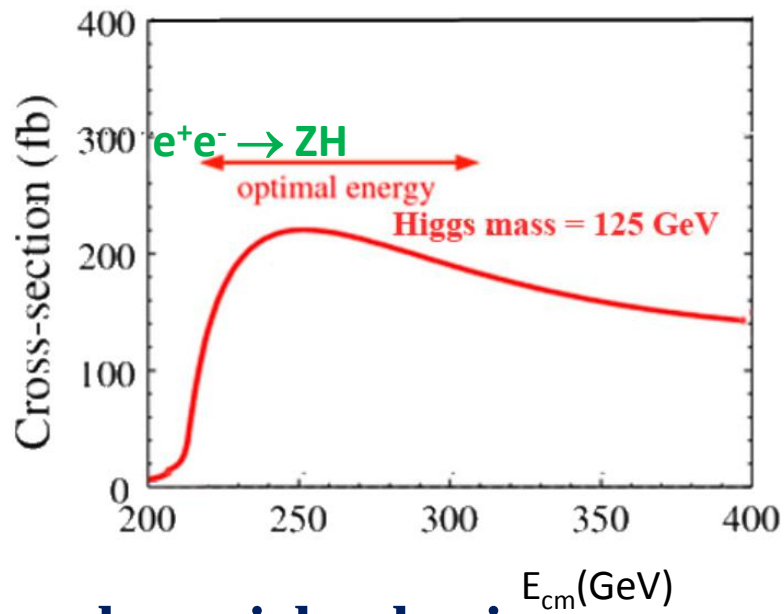
$E_{cm}$≈240GeV, luminosity ~$2\times10^{34}$ $cm^{-2}s^{-1}$, can also run at the Z-pole

**Precision measurement of the Higgs boson (and the Z boson)**

**Phase 2:** **a discovery machine**; pp collision with $E_{cm}$ ≈ 50-100 TeV; ep, HI options

**Super proton-proton Collider (SppC)**

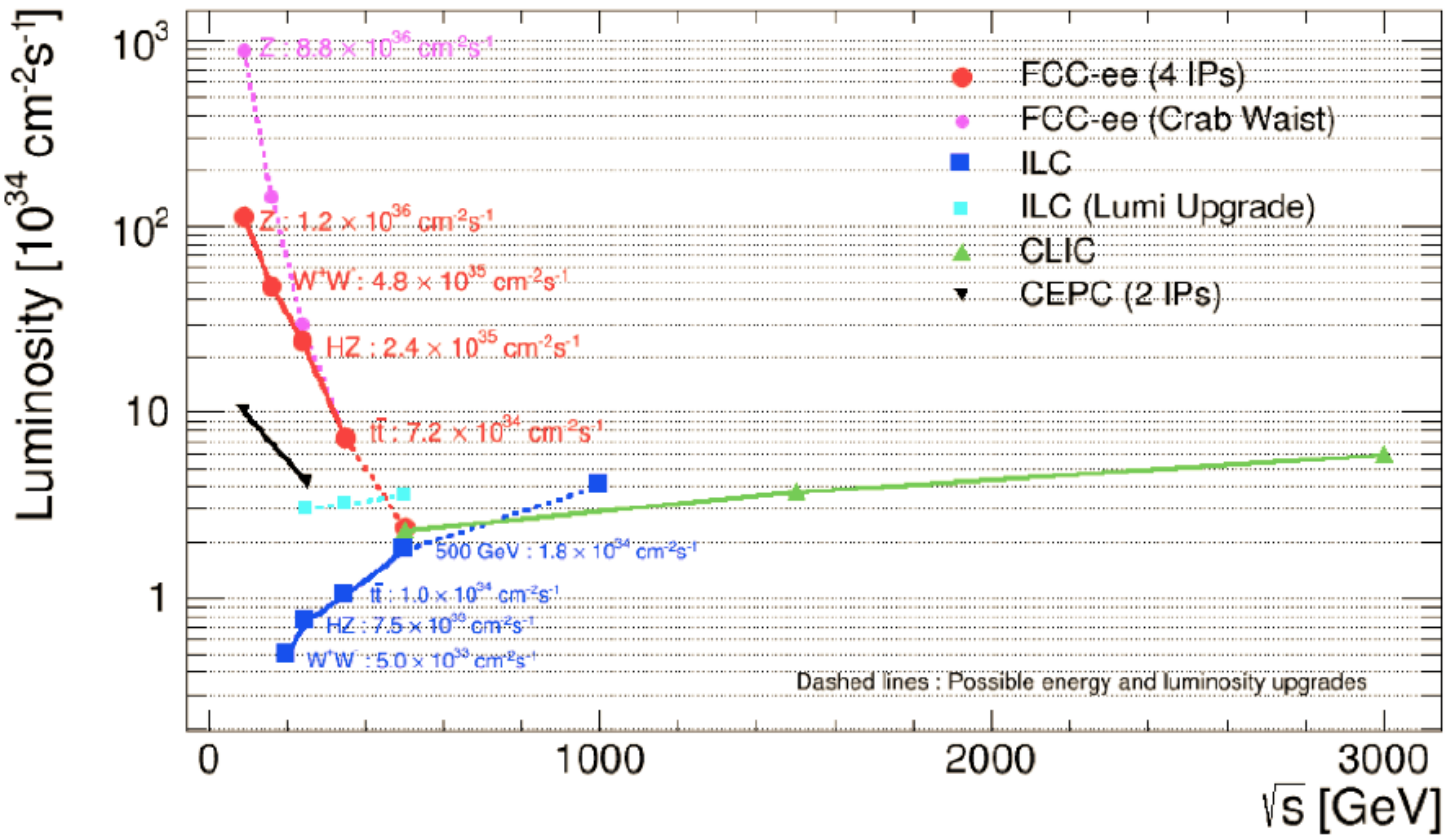



**favored post BEPCII accelerator based particle physics program in China**

# CEPC design goal

- Limit SR power to 50 MW per beam
- CEPC: single ring, head-on collision, up to 250 GeV (preCDR)
- FCC-ee: double ring, large crossing angle, up to 350 GeV




**CEPC:**
**$10^6$ Higgs**
**$10^{10}$ Z**

**FCC-ee:**
**$10^7$ Higgs**
**$10^{12\text{-}13}$ Z**

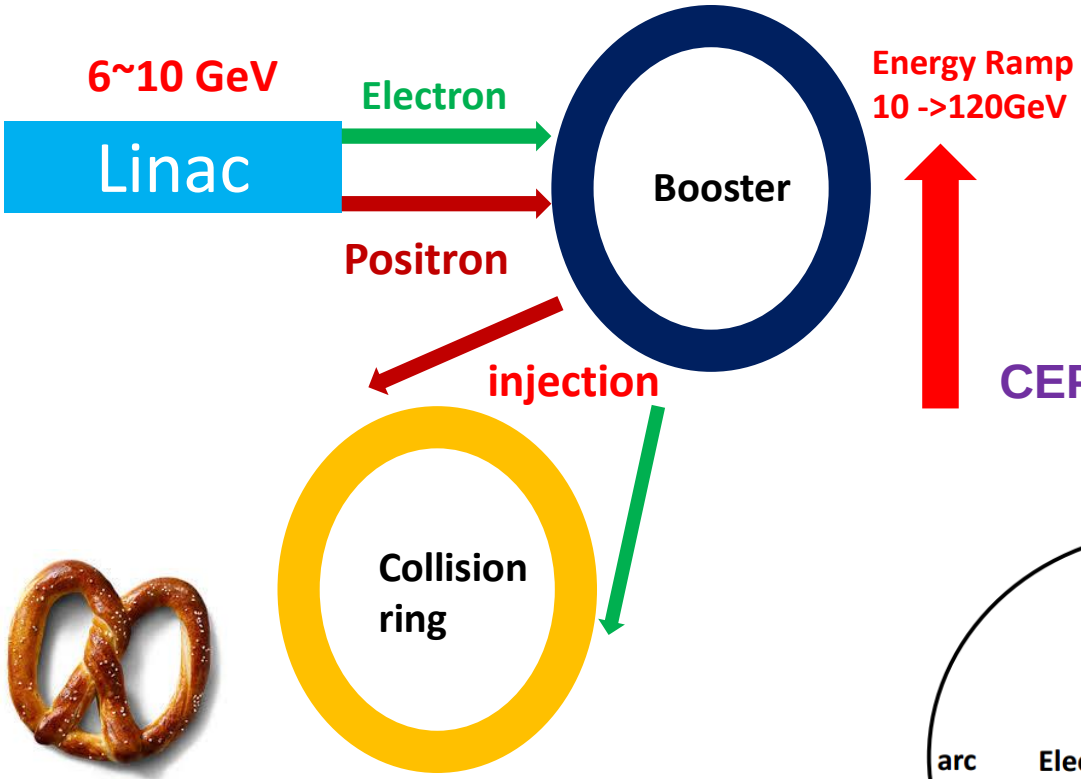
# CEPC and SppC

# Accelerators progress and status

**Gao Jie's presentation this morning; parallel sessions**

# The CEPC Accelerator preCDR + beyond

## CEPC Accelerator Baseline Design




**Single ring**: cheap, low lumi.

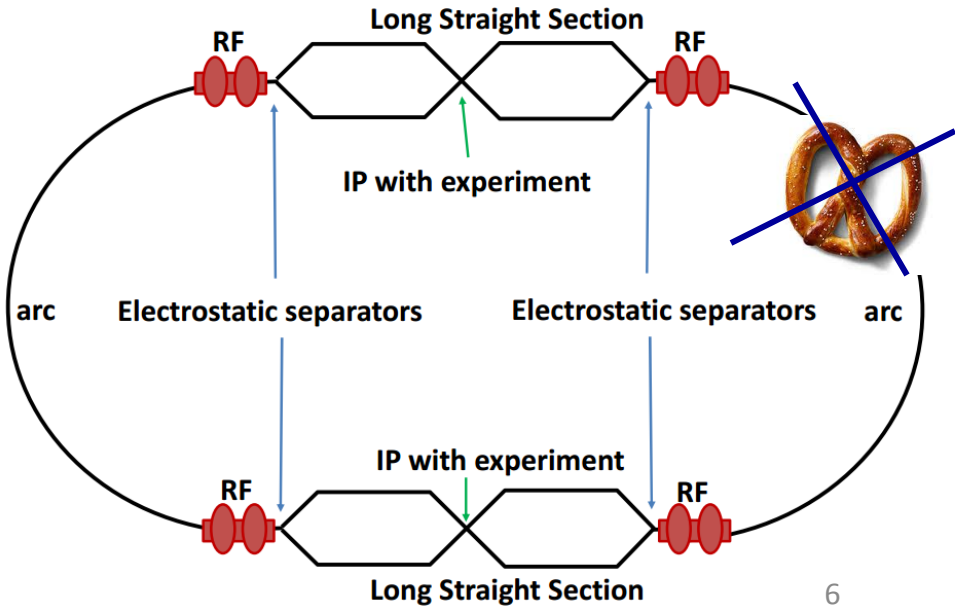
**Double ring:** expensive, high lumi

**Local Double ring:** a balance?



Pretzel scheme to separate opposing beams at crossings

## CEPC Accelerator local double rings



J Gao *et. al.*

# CEPC-SppC Accelerator: considerations & progress

- **CEPC-SppC parameter space (map) scan (Done)**
  - Ring circumference from 54km-100km (CEPC and SppC)
  - Energy (Higgs, Z, W), luminosity, beam ridiation power, crossing angle

- **CEPC design with four option proposals (Done)**
  Main ring options: Pretzel (head-on), Partial Double Ring (PDR), Advanced Partial Double Ring (APDR), Double Ring (DR)

DA optimizations is underway

- **CEPC main ring collective effects for Higgs and Z energies (Done)**

- **CEPC MDI designs with head-on collision and with crossing angle (Done)**

- **CEPC boosters with too option proposals (Done)**
  - Low Field Scheme (LFS) and Alternating Field Scheme (AFS)
    (Done with good DA satisify CDR)

- **CEPC injector (e+e-) with two option proposals (Done)**
  - S-band injector and C-band injector (S-band satisfying CDR)
  - Injector damping (Done)

- **CEPC key technologies + R&D (localted and partil start)**
  - 650MHz klystron, 650MHz 5 cell and 2 cell cavity, Nitrogen dopping, instrumentation...
  - 1.3Ghz 9cell cavity (done)

- **SppC lattice and minimum ring circumferce question (Done)**

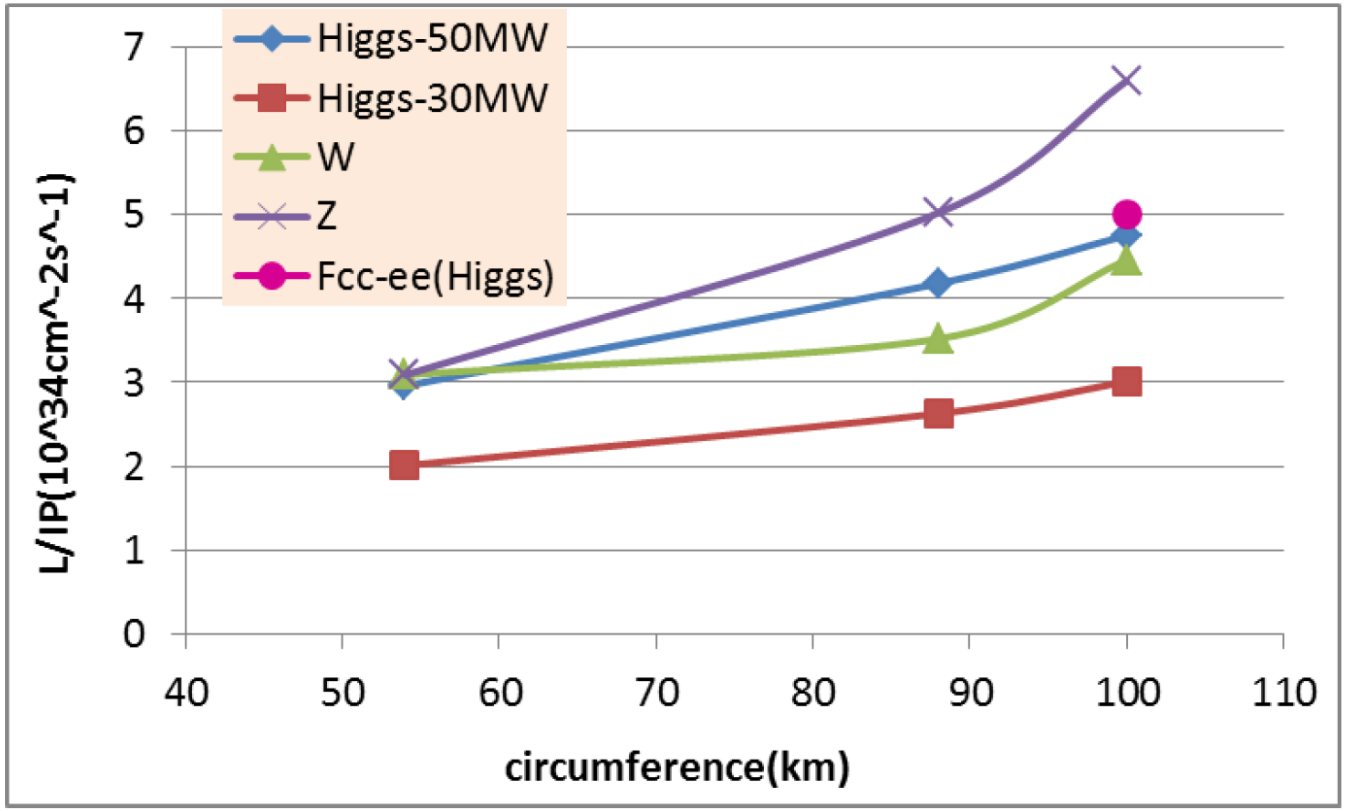
DA optimizations is underway

# CEPC Accelerator

## Luminosity vs Circumference

J. Gao *et. al.*

**Preliminary**



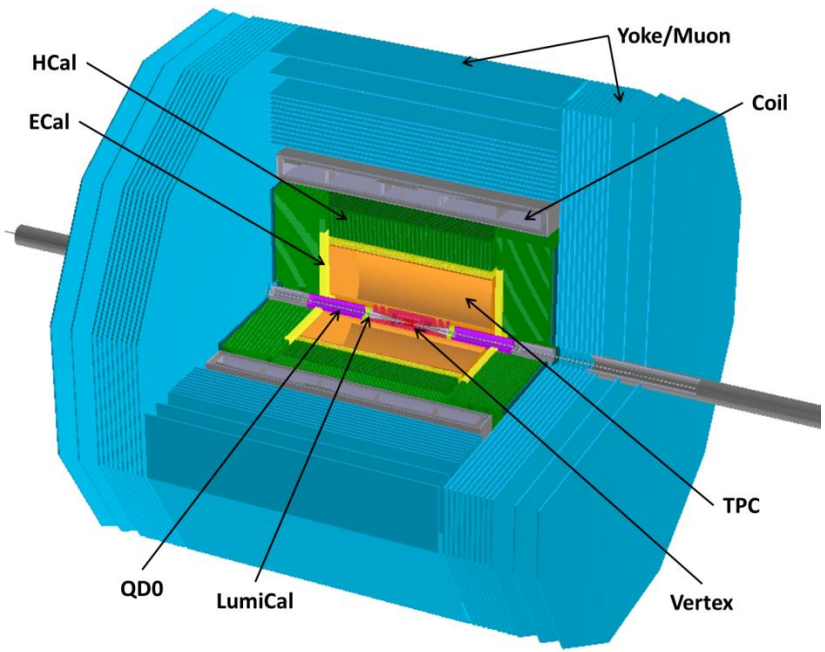

CEPC Accelerator Group: obtained parameters for partial double ring, various length (54km, 88km, and 100km). **See J. Gao's talk.**

# CEPC and SppC

## The detector & the simulation

**Much progress – talks at parallel sessions**

# CEPC Detector (preCDR)




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

- Shorter L* (**1.5**/2.5m) → 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: $\sigma_{1/p} < 5\times10^{-5}\ \mathrm{GeV}^{-1}$ ← recoiled Higgs mass
  - Impact parameter: $\sigma_{r\phi} = 5 \oplus 10/(p\cdot\sin^{\frac{3}{2}}\theta)\ \mu\mathrm{m}$ ← flavor tagging, BR
  - Jet energy: $\frac{\sigma_E}{E} \approx 3-4\%$ ← W/Z di-jet mass separation

**Sub-detector groups consider design options, identify challenges, plan R&D**

Ouyang Qun, HB Zhu *et. al.*

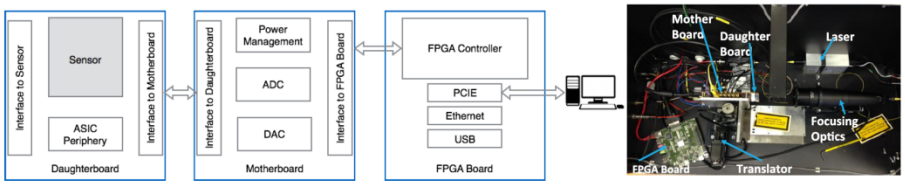
# CEPC Detector – Pixel Vertex Detector

- ✓1st submission - Joint submission with IPHC last November;
- ✓received 12 (+20) diced sensors (more on the way);
- ✓Aimed to evaluate the **charge collection performance** with different diode geometries, substrate properties and potential radiation tolerance;

Funding from Key Lab, IHEP

## Pixel Sensor Characterization

- DAQ system being developed to characterize the pixel sensors; design also compatible with the commercial NI platform



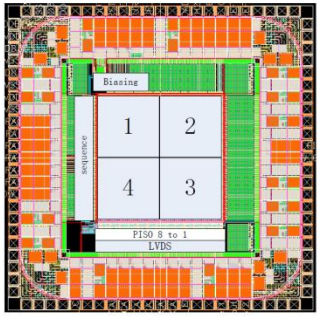

DAQ System TCT System

- Design simulated and verified; daughterboard/motherboard schematics completed; on-going effort on PCB design/DAQ software
- Auxiliary instruments: TCT system (ready), beat source platform (being set up), irradiation facility (contacted), SmartScope (being ordered), beam telescope (to be constructed) and more … *to improve the general infrastructure for silicon detector development*

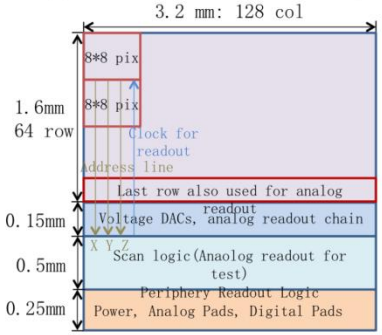
## 2nd Submission

***Details in Qun's Talk***

- Digital output with prototype designs of in-pixel electronics (e.g. high gain and low noise CSA, or differential amplifier/two-stage amplifier + latch) and readout architecture (zero suppression, XYZ readout …)




In-pixel electronics designs (sub-matrix 1-4)




XYZ readout

- Design in progress, **target submission**: early 2017

# CEPC Detector – TPC

H. R. Qi *et. al.*

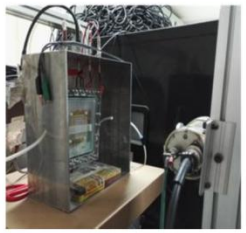
**Minimize the effect of ion backflow;**

**Properties of a CEPC TPC subdetector**

## Test of the GEM-MMG module

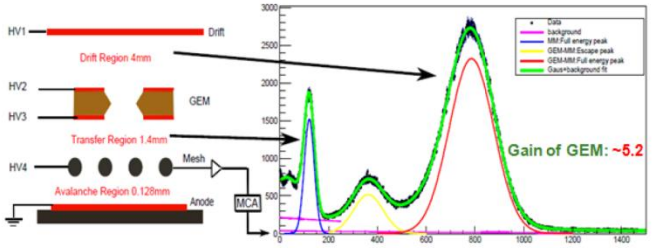
Supported by 高能所创新基金

- Test of GEM+Micromegas module
  - GEM and Bulk-Micromegas
  - Assembled and test
  - Active area: 50mm×50mm
  - X-tube ray and X-ray radiation source
  - Simulation using the Garfield
  - Separated GEM gain: 1~10
  - Stable operation time: more than 48 hours



GEM+Micromegas Module with X-ray

Source: $^{55}$Fe, Gas mix: Ar(97) + $iC_4H_{10}$(3)




An example of the 55Fe spectra showing the correspondence between the location of an X-ray absorption and each peak.

| | GEM+MMG 420LPI ( IHEP ) | 2GEMs + MMG 450 LPI ( Yale University ) | Micromegas only 450 LPI ( Yale University ) |
|---|---|---|---|
| Ion Back Flow | ~0.5% Edrift = 0.25 kV/cm | (0.3 –0.4)% Edrift = 0.4 kV/cm | (0.4 –1.5)% Edrift= (0.1-0.4) kV/cm |
| <GA> | 3000~4000 | 2000 | 2000 |
| ϵ-parameter(=IBF*GA) | 15~20 | 6~8 | 8~30 |
| E –resolution | ~16% | <12% | <= 8% |
| Gas Mixture ( 2-3 components) | Ar + iC4H10 | Ne+CO2+N2, Ne+CO2,Ne+CF4, Ne+CO2+CH4 | X + iC4H10 (Ar+CF4+iC4H10) |
| Sparking ( $^{241}$Am) | $<10^{-8}$ | $< 3.*10^{-7}$(Ne+CO2) (N.Smirnov report) | $\sim 10^{-7}$ (S. Procureur report) |
| Possible main problem | Thin frame | More FEE channel | # |
| Goals | CEPC TPC | ALICE upgrade | # |

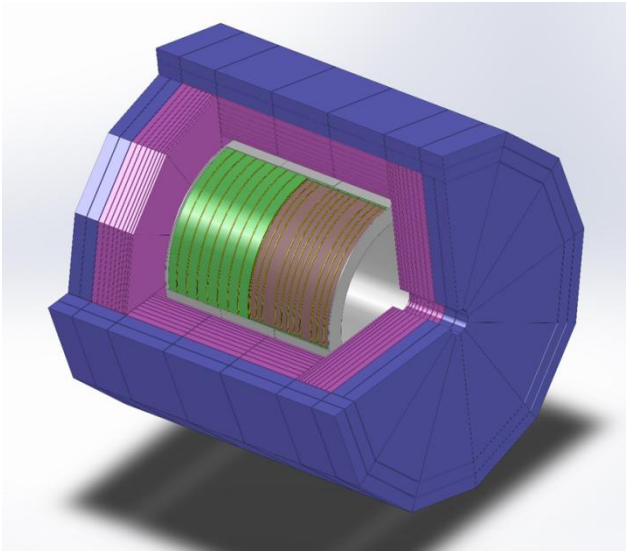
- 5 -

**Participating international collaboration (ILC, RD, …)**

# CEPC Detector – Detctor Magnet

L. Zhao *et. al.*

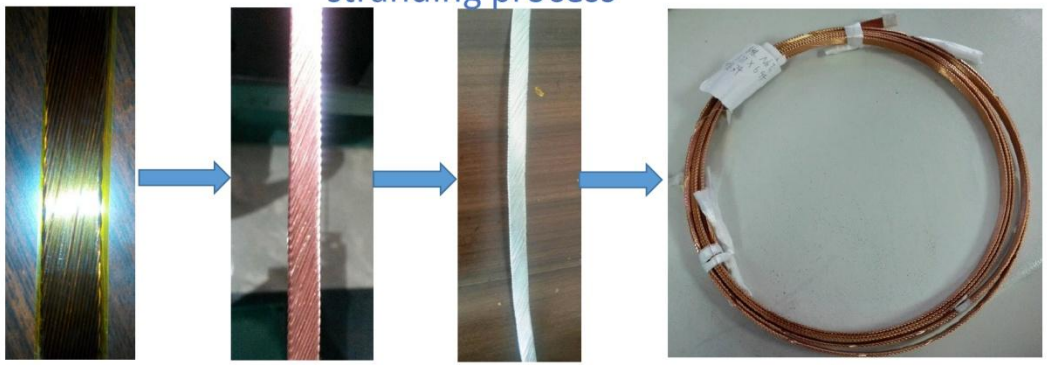
Funding：IHEP IF



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

stranding process



Number of strands：20
Strand diameter：1.0mm
Materiel: Copper
Complete time:2015.5

Number of strands：17
Strand diameter：0.727mm
Materiel :Nb/Ti
Complete time:2015.7

Number of strands：24
Strand diameter：0.727mm
Materiel :Nb/Ti
Complete time:2015.8

Number of strands：18
Strand diameter：1.2mm
Materiel :Nb/Ti
Complete time:2016.2

insert process

Copper cable +Aluminum alloy

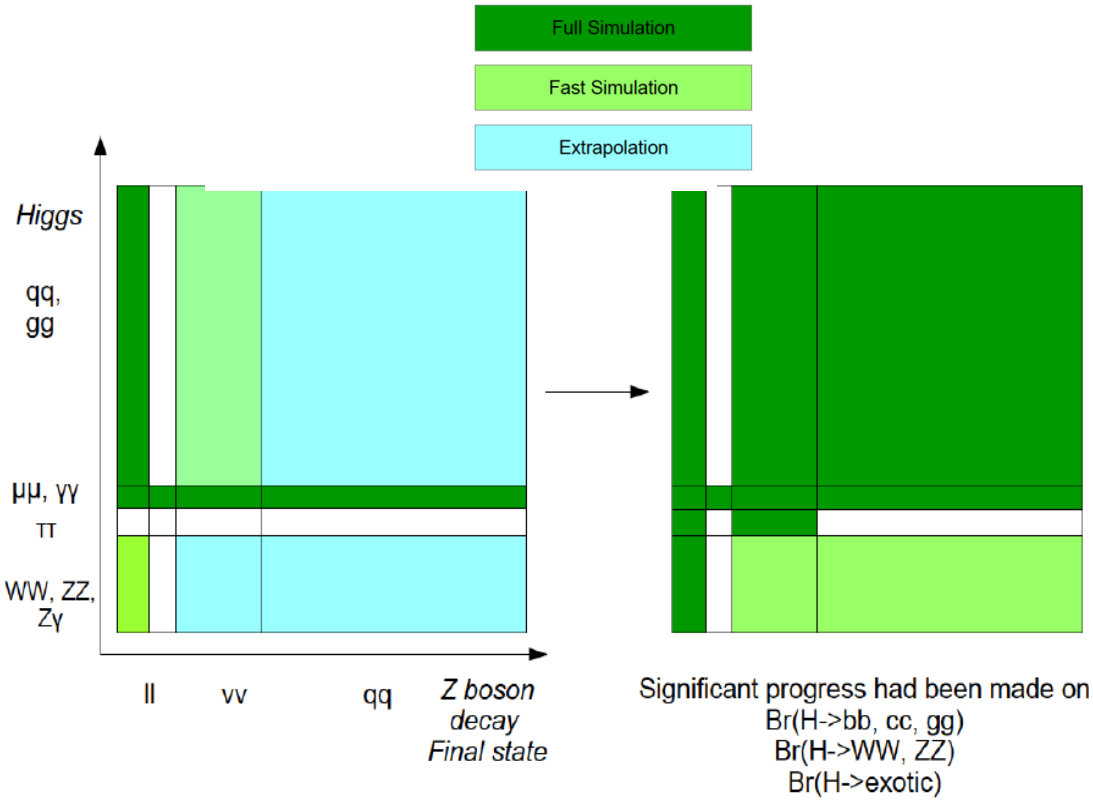
Test results:

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

## Physics analysis, PreCDR->now




| | PreCDR | Now |
|---|---|---|
| σ(ZH) | 0.51% | 0.50% |
| σ(ZH)*Br(H→bb) | 0.28% | 0.21% |
| σ(ZH)*Br(H→cc) | 2.1% | 2.5% |
| σ(ZH)*Br(H→gg) | 1.6% | 1.7% |
| σ(ZH)*Br(H→WW) | 1.5% | 1.2% |
| σ(ZH)*Br(H→ZZ) | 4.3% | 4% |
| σ(ZH)*Br(H→ττ) | 1.2% | 1.0% |
| σ(ZH)*Br(H→γγ) | 9.0% | 9.0% |
| σ(ZH)*Br(H→μμ) | 17% | 17% |
| σ(ννH)*Br(H→Zγ) | - | - |
| σ(ννH)*Br(H→bb) | 2.8% | 2.8% |
| Higgs Mass/MeV | 5.9 | 5.0 |
| | | |
| σ(ZH)*Br(H→inv) | | |
| Br(H→ee) | | |
| Br(H→bbχχ, 4b) | $<10^{-3}$ | 95%. CL = 3e-4 |

**See Manqi's Talk**

M.Q. Ruan

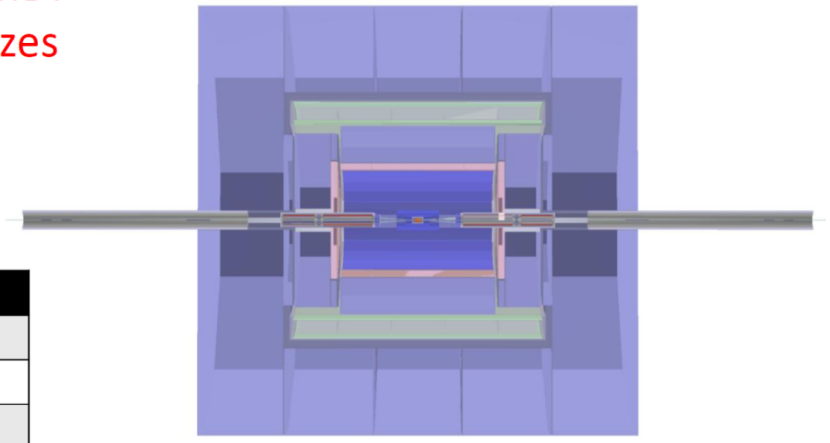
G. Li, MQ Ruan, YQ Fang *et. al.*

# CEPC Detector – Software & Tools

## New geometry: CEPC_o_V2

**shrink the ILD detector**

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



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

| Parameter | CEPC_o_v2 | CEPC_v1 |
|---|---|---|
| LStar_zbegin | 1150 | 1146.9 |
| VXD_inner_radius | 12 | 15 |
| VXD_radius_r1 | 12 | 15 |
| VXD_radius_r3 | 35 | 37 |
| TPC_outer_radius | 1500 | 1808 |
| Hcal_nlayers | 40 | 48 |
| Ecal_cells_size | 10 | 4.9 |
| Field_nominal_value | 3 | 3.5 |
| Yoke Layers | 2 | 3 |

- Need more validation
- To be released soon …

**Plus:**

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

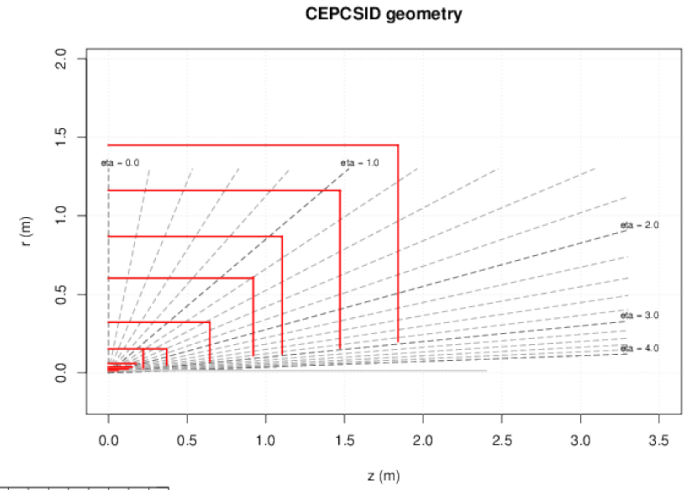
# CEPC Detector – Software & Tools

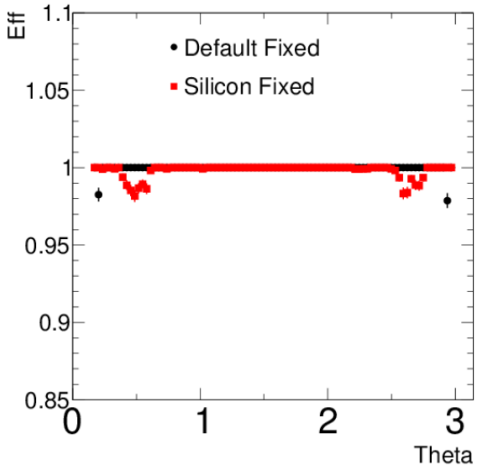
Weimin Yao *et. al.*
See his talk

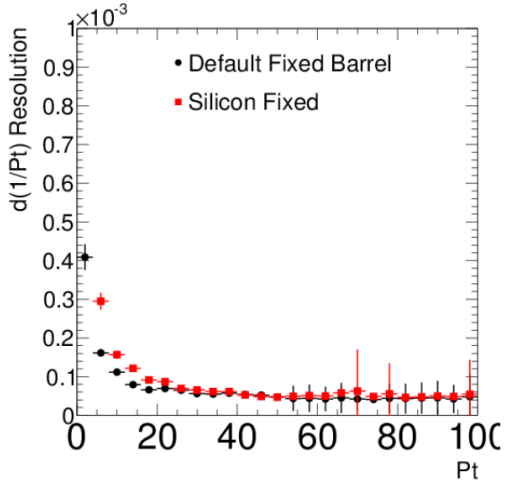
## Full Silicon Tracker for CEPC*

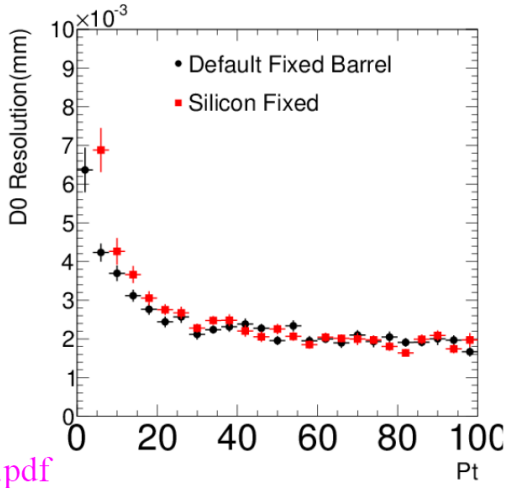
*cepc.ihep.ac.cn/~cepc/cepc_twiki/index.php/Pure_Silicon_Detector

- Implemented a full silicon detector option in Mokka and tested in simulation and reconstruction.
- The single muon tracking performance is comparable to CEPC V1, meeting the physics requirements.

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Weimin Yao *et. al.*

# CEPC Detector – Software & Tools

## Impact of Detector Coverage on B(H → invisible) measurement and Search for H → z γ decay at CEPC

- One of golas at CEPC is to measure zH → qq invisible decay.
- Due to small L*, detector coverage is likely to be reduced, θ>10 to 20 deg.

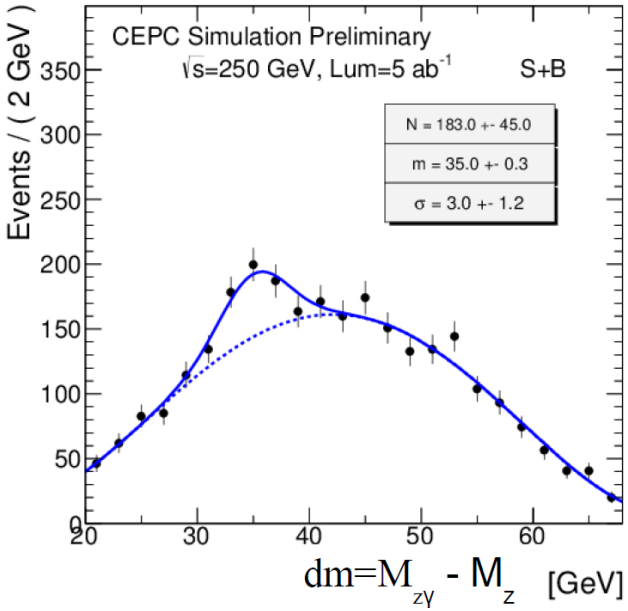
Sensitivity on $B(H \rightarrow invisible)$

| $\lvert cos\theta \rvert <$ | 0.985 | 0.966 | 0.940 |
|---|---|---|---|
| Signal with Br=0.1% | 294.331 | 286.853 | 273.194 |
| Eff of Signal | 40.78% | 39.75% | 37.86% |
| $\sqrt{B}$ | 231.6 | 245.9 | 264.6 |
| Sensitivity | 0.0787% | 0.0857% | 0.0969% |

- With 5 $ab^{-1}$, CEPC will have sensitivity on $B(H \rightarrow invisible) = 0.079\%$ for $\lvert cos\theta \rvert < 0.985$ and 0.097% for $\lvert cos\theta \rvert < 0.940$
- The sensitivity is worse by 23% by reducing detector coverage from $\theta > 10$ to 20 degrees.

//indico.ihep.ac.cn/event/6162/contributions/8/material/slides/0.pdf

- Measurement of B(H → zγ) is sensitive to BSM at loop level.
- Initial study of zH → zzγ → qqννγ is promising to be 4 σ with 5 $ab^{-1}$.

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# Theory

## A rich program at this meeting

11:00 - 12:00 Parallel Session I: Theory
Convener: Prof. Junjie Cao (Henan Normal University)
Location: Conference Room 3

11:00 **Towards precision theoretical description on high e progress of FDC project** *25'*
Speaker: Prof. Jianxiong Wang (IHEP)

11:25 **Quarkonium production at CEPC** *25'*
Speaker: Prof. Yanqing Ma (PKU)

14:00 - 16:05 Parallel Session II: Theory
Convener: Prof. Yi Liao (Nankai University)
Location: Conference Room 3

14:00 **Double parton scatterings at the 100 TeV SppC** *25'*
Speaker: Prof. Qinghong Cao (PKU)

14:25 **Precision Higgs production** *25'*
Speaker: Prof. Lilin Yang (PKU)

14:50 **CEPC and degenerate electroweakino** *25'*
Speaker: Prof. Jing Shu (ITP)

15:15 **Searching exotic Higgs decay at CEPC** *25'*
Speaker: Dr. Hao Zhang (IHEP)

15:40 **Interference effects on Higgs mass measurement at CEPC** *25'*
Speaker: Guang-Zhi Xu (Liaoning University)

16:20 - 18:00 Parallel Session III: Theory
Convener: Prof. Qing Wang (Tsinghua University)
Location: Conference Room 3

16:25 **Searching for dark matter at future high energy colliders** *25'*
Speaker: Dr. Pengfei Yin (IHEP)

16:50 **New physics for neutrinoless double beta decay** *20'*
Speaker: Prof. Peihong Gu (SJTU)

17:10 **Discovery potential of Higgs boson pair production through 4 lepton modes at a 100 TeV collider** *25'*
Speaker: Prof. Qishu Yan (UCAS)

17:35 **Measure the Shape of Effective Higgs Theory at an Electron-Positron Collider** *25'*
Speaker: Prof. Tao Liu (HKUST)

Saturday, 3 September 2016

08:30 - 09:20 Parallel Session I: Theory
*Discussion within each working group on CDR and R&D plans*
Convener: Prof. Jianping Ma (ITP)
Location: Conference Room 3

# Theory

## Some of the very nice results have come out

### Probing dark particles indirectly at the CEPC

Qing-Hong Cao (CICQM, Beijing & Peking U. & Peking U., CHEP & Peking U., SKLNPT) , Yang Li, Bin Yan, Ya Zhang (Peking U. & Peking U., SKLNPT) , Zhen Zhang (Peking U., CHEP)

Apr 26, 2016 - 21 pages

**Nucl.Phys. B909 (2016) 197-217**
(2016-08)
DOI: 10.1016/j.nuclphysb.2016.05.010
e-Print: arXiv:1604.07536 [hep-ph] | PDF

### Left-right non-linear dynamical Higgs

Jing Shu, Juan Yepes (Beijing, Inst. Theor. Phys. & Beijing, KITPC)

Dec 31, 2015 - 41 pages

e-Print: arXiv:1512.09310 [hep-ph] | PDF

### Heavy Higgs Bosons at Low $\tan\beta$ : from the LHC to 100 TeV

Nathaniel Craig (UC, Santa Barbara) , Jan Hajer, Ying-Ying Li, Tao Liu (Hong Kong U. Sci. Tech.) , Hao Zhang (UC, Santa Barbara)

May 27, 2016 - 23 pages

e-Print: arXiv:1605.08744 [hep-ph] | PDF

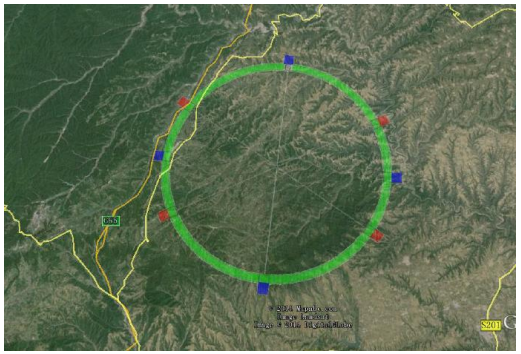
# CEPC and SppC

## Site and civil engineering

# Site selections (example locations)



1)



2)

3)

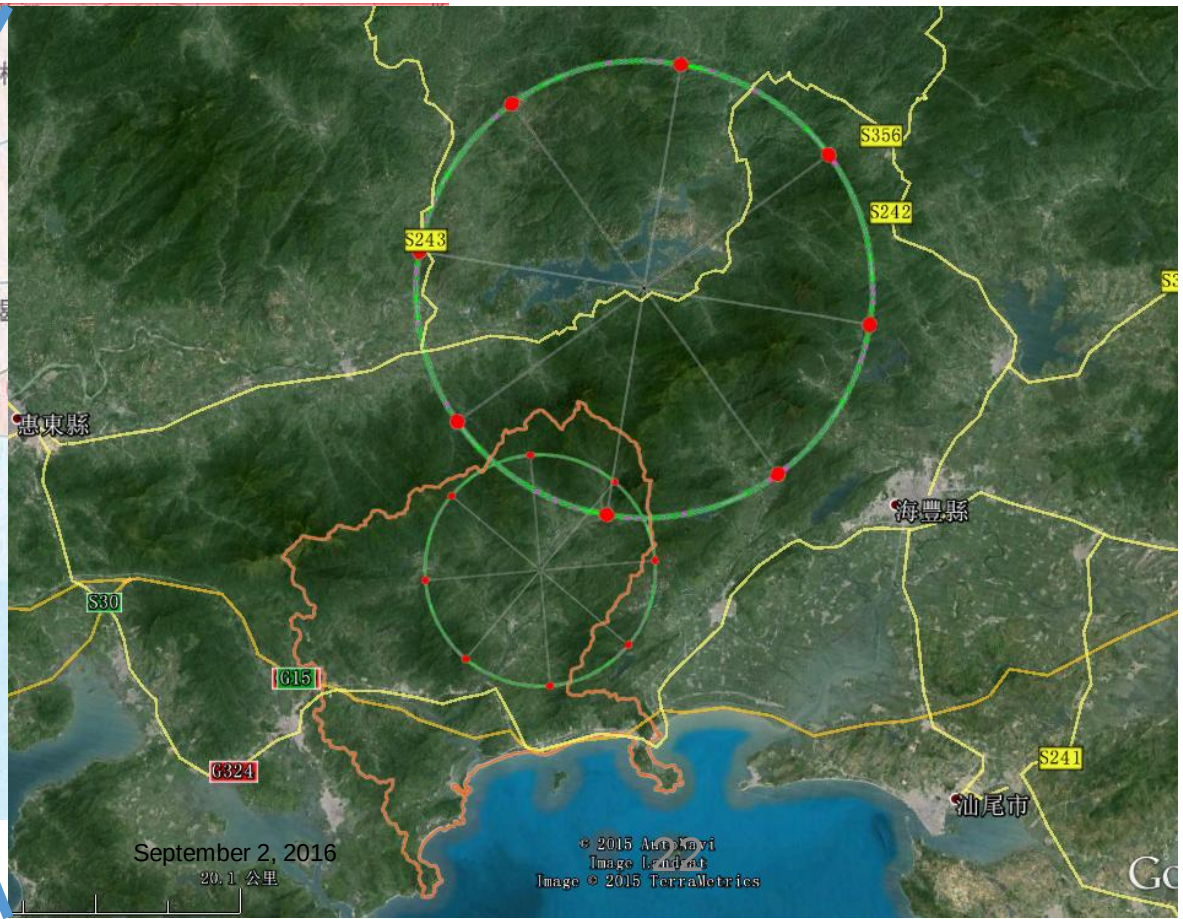
1) Qinhuangdao

2) Shanxi Province

3) Near Shenzhen and Hongkong

# Site Selection

- Continue to work on site selection
- Previously investigated: 300 km north-east of Beijing
- A new possibility close to Hong Kong, invited by the local government

# International Collaboration

- 2nd IAC meeting will take place in November 7-8, 2016.


- Establishing collaborative research with foreign institutes through MOU with IHEP

- **What's the mode for an international CEPC project?**

Key subject of discussions at this meeting

# R&D Funding

# Funding for Design and R&D

- **IHEP seed money**

  **12 M RMB/3 years (2015-2017)**

- **Chinese Ministry of Sci. & Technology**

  **~ 90 M / 6 years (2016-2021)**

  **1st grant of 36M RMB approved; 2nd grant in 2018**

- **China National Commission on Dev. & Reform**

  **No funding in 13th 5-year plan**

- **Other Sources (CAS, MOST, NSFC, …)**

  **seeking ~0.5 B RMB / 5 years for critical R&D**

# Funding for Design and R&D

国家重点研发计划
项目预申报书

**Ministry of Science and Technology**
**Requested 45M RMB; 36M RMB approved**

| | |
|---|---|
| 项目名称： | 高能环形正负电子对撞机相关的物理和关键技术预研究 |
| 所属专项： | 大科学装置前沿研究 |
| 指南方向： | 新一代粒子加速器和探测器关键技术和方法的预先研究 |
| 推荐单位： | 教育部 |
| 申报单位：（公章） | 清华大学 |
| 项目负责人： | 高原宁 |

# R&D Funding - NSFC

**Increasing support for CEPC D+RDby NSFC**
**5 projects (2015); 7 projects(2016)**

| CEPC相关基金名称（2015-2016） | 基金类型 | 负责人 | 承担单位 | |
|---|---|---|---|---|
| 高精度气体径迹探测器及激光校正的研究 (2015) | 重点基金 | 李玉兰/<br>陈元柏 | 清华大学/<br>高能物理研究所 | Tsinghua<br>IHEP |
| 成像型电磁量能器关键技术研究(2016) | 重点基金 | 刘树彬 | 中国科技大学 | USTC |
| CEPC局部双环对撞区挡板系统设计及螺线管场补偿(2016) | 面上基金 | 白莎 | 高能物理研究所 | IHEP |
| 用于顶点探测器的高分辨、低功耗SOI像素芯片的若干关键问题的研究(2015) | 面上基金 | 卢云鹏 | 高能物理研究所 | |
| 基于粒子流算法的电磁量能器性能研究 (2016) | 面上基金 | 王志刚 | 高能物理研究所 | |
| 基于THGEM探测器的数字量能器的研究(2015) | 面上基金 | 俞伯祥 | 高能物理研究所 | |
| 高粒度量能器上的通用粒子流算法开发(2016) | 面上基金 | 阮曼奇 | 高能物理研究所 | |
| 正离子反馈连续抑制型气体探测器的实验研究(2016) | 面上基金 | 祁辉荣 | 高能物理研究所 | |
| CEPC对撞区最终聚焦系统的设计研究(2015) | 青年基金 | 王逗 | 高能物理研究所 | |
| 利用耗尽型CPS提高顶点探测器空间分辨精度的研究 (2016) | 青年基金 | 周扬 | 高能物理研究所 | |
| 关于CEPC动力学孔径研究(2016) | 青年基金 | 王毅伟 | 高能物理研究所 | |

**I encourage university groups to apply for the CEPC funding at NSFC** **H. R. Qi**

# Note 1: NCDR review and approval

- 此次 发改委 发改委 项目 申请 的结果并不代表政府 结果并不代表政府 结果并不代表政府 结果并不代表政府 的态度，仅代表 仅代表 评审专家组 评审专家组 的个 人意见 .
- **11** 月份 **IAC**委员 几乎 全部 到场， 非常 重视 **CEPC .**
- 预期的经费能基本满足预研的需求.
- 同时CEPC要争取地方政府关于土建准备工作的支持.
- 经过5年的努力，CEPC在“十四五”初期很可能直接去发改委申请建设经费.

# 香山科学会议

## 高能环形正负电子对撞机-中国发起的大型国际科学实验

2016年10月18-19日

王乃彦、张焕乔、赵光达、张闯、王贻芳

**会议主题：**

**高能环形正负电子对撞机-中国发起的大型国际科学实验**

**中心议题：**

**CEPC科学意义、物理目标、发展潜力**

**CEPC预研究，和加速器、探测器、实验室建设**

**对社会发展的牵引作用和国际合作**

**CEPC方案，时间表和论证**

# 香山科学会议

## 高能环形正负电子对撞机-中国发起的大型国际科学实验

**申请召开本次会议的目的及预期成果**

- 向国内高能物理界通报并讨论LHC Run II实验结果和Higgs发现后高能粒子物理研究的最新进展，讨论CEPC与之相关的重要物理课题和研究方法，进一步明确我国未来高能环形正负电子对撞机项目发展目标和方向。
- 介绍CEPC 概念设计（CDR）进展和预研究项目实施状况，总结国际合作思路和进展，国内论证方案，分析CEPC项目的必要性、紧迫性、优先程度和可行性等，达成学术界内的共识。
- 研讨CEPC的设计、预研、造价估计及下一步工作计划，对CEPC项目进行风险分析，对可能出现的问题和难点做出合理、科学的对应方案。
- 给出我国建造、实施CEPC的路线图建议（如，我国开展CEPC预制研究的计划和前期专项经费投入建议、我国建造CEPC的国际合作模式和运行方式、以CEPC建造为目标的人才培养计划等），为政府的决策和部署提供必要的参考。

# CEPC and SppC

## Objectives

# Objective for this meeting

- **Orgagnization update**: members of the Steering Committee, the project management team
- **New funding request: plan and team**
- **Design of the CEPC accelerator and detector: plan and team**
- **CDR, R&D plan and execution**
- **International collaboration**

# Objective for 13th 5-year plan period

- **Complete CDR and critical R&D**
- **Be ready to construct the CEPC in 14th 5-year plan**

# Summary

- Much progress in design and R&D
- First MOST and NSFC grants for CEPC
- Seeking more R&D funding
- Continue design and R&D, move towards CDR
- Let’s work together to make it happen