IAC Q&A and Discussion: Meeting with detector group

João Guimarães da Costa

(for the Physics and Detector Working Group)

中国科学院高能物理研究所

Institute of High Energy Physics
Chinese Academy of Sciences

International Advisory Meeting Committee

Beijing, October 29, 2020


Zoom 会议
Young-Kee Kim
IHEP A415
Peter Jenni
Katsunobu Oide
Brian Foster
Michel Davier
Yifang Wang
David Gross
Barry Barish
levichev
Marcel Demarteau
steinar.stapnes@cern.ch
nakada
maiani
Ian Shipsey
Qingjin XU
lucie.linssen@cern.ch
rohini
chenhs
Haijun Yang
WANG Meng
manqi
Geoffrey Taylor
Xinchou Lou
Gang.Chen@ihep.ac.cn
CH
22:10
2020/10/29


Zoom 会议
manqi
Geoffrey Taylor
Xinchou Lou
Gang.Chen@ihep.ac.cn
Yuanning Gao
Jie Gao
Liantao Wang
Chenghui Yu
Yong Liu
Jianbei Liu
Yaru Wu
Jianchun Wang
George Hou
Weidong Li
Hong-Jian He
HE XIAOGANG
纪全
Weiren
Bin Wang
Yunlong Chi
Zhaoru Zhang
Zhijun Liang (IH...
joao.guimaraes...
Yuan Zhang
Gang LI
22:10
2020/10/29

Questions from the IAC

Thank you for your extensive presentation to the IAC. It provides a good overview of ongoing activities and collaborative efforts on CEPC physics and detectors.

In preparation for the IAC Q&A sessions of Friday, we have been collecting a few questions. Could you please forward them to your physics and detector colleagues and try to address them at our breakout session?

For some of the questions some simple oral explanations from your side will be sufficient. Other questions are more targeted towards gaining overview; in such cases a few slides may be useful.

Due to time difference, some of us have not yet been able to provide input. So, we do not exclude sending a few more questions later.

Which are the biggest challenges your are facing in the current stage of the project or for the coming years (for example technical challenges, timeline, achieving collaboration, manpower, structure) ?

- Schedule can limit the extent of R&D. Need to find a balance between being ready for construction and targeting the most performing detectors
- International relations stability
- Availability of common software for detector concepts comparisons (working on it)
- Technical challenges:
  - Engineering design and scalability of calorimeters
  - Cooling systems of PFA calorimeter, vertex detector and beam pipe
  - Access to the most advanced sensor foundries and limited access to some electronics
  - Adding PID capabilities with minimal cost to Higgs physics

Which are the biggest challenges your are facing in the current stage of the project or for the coming years (for example technical challenges, timeline, achieving collaboration, manpower, structure) ?

- **Vertex detector R&D**:
  - Chinese HEP community has no direct access to 65nm CMOS technology; the requirement of 3 μm resolution is not easy to achieve.
  - Power consumption is still high, especially at the Z pole at a high rate. It is challenging to design cooling for the vertex detector.
  - Design of support structure is a big challenge, it needs to light with a low material budget, and it has to be robust enough and not vibrate in air cooling.

- Timeline:
  - Design a Full-size vertex detector prototype in 3 years (by 2023)
  - We will look for domestic foundry and also collaborate with international community to explore new technology for smaller feature size and lower power consumption. (Longer term plan)

Which are the biggest challenges your are facing in the current stage of the project or for the coming years (for example technical challenges, timeline, achieving collaboration, manpower, structure) ?

- The Preshower and the Muon detection system of IDEA would both be realised using the microRwell technology. Both detectors will be highly modular using a large number of basic microRwell “tiles”.
- The challenges for both detectors are then of course almost identical
- The biggest challenge will be to achieve the proper technological transfer to industry such that the basic microRWell tiles could in large part, if not completely, be built by industry.
- We have started an R&D program that should lead to the definition of the basic microRwell tiles within 2023-2024. The technology transfer has also started since 2-3 years and will proceed in parallel to the definition of the main characteristics of the microRwell tiles.
- This R&D program is, for the time being, being carried out by 3-4 INFN units and we therefore see room and scope for a more ample international collaboration. This would also ensure a better manpower coverage for the realisation of both detectors. The structure of the collaboration is at the moment rather simple and it could evolve as the collaboration increases.

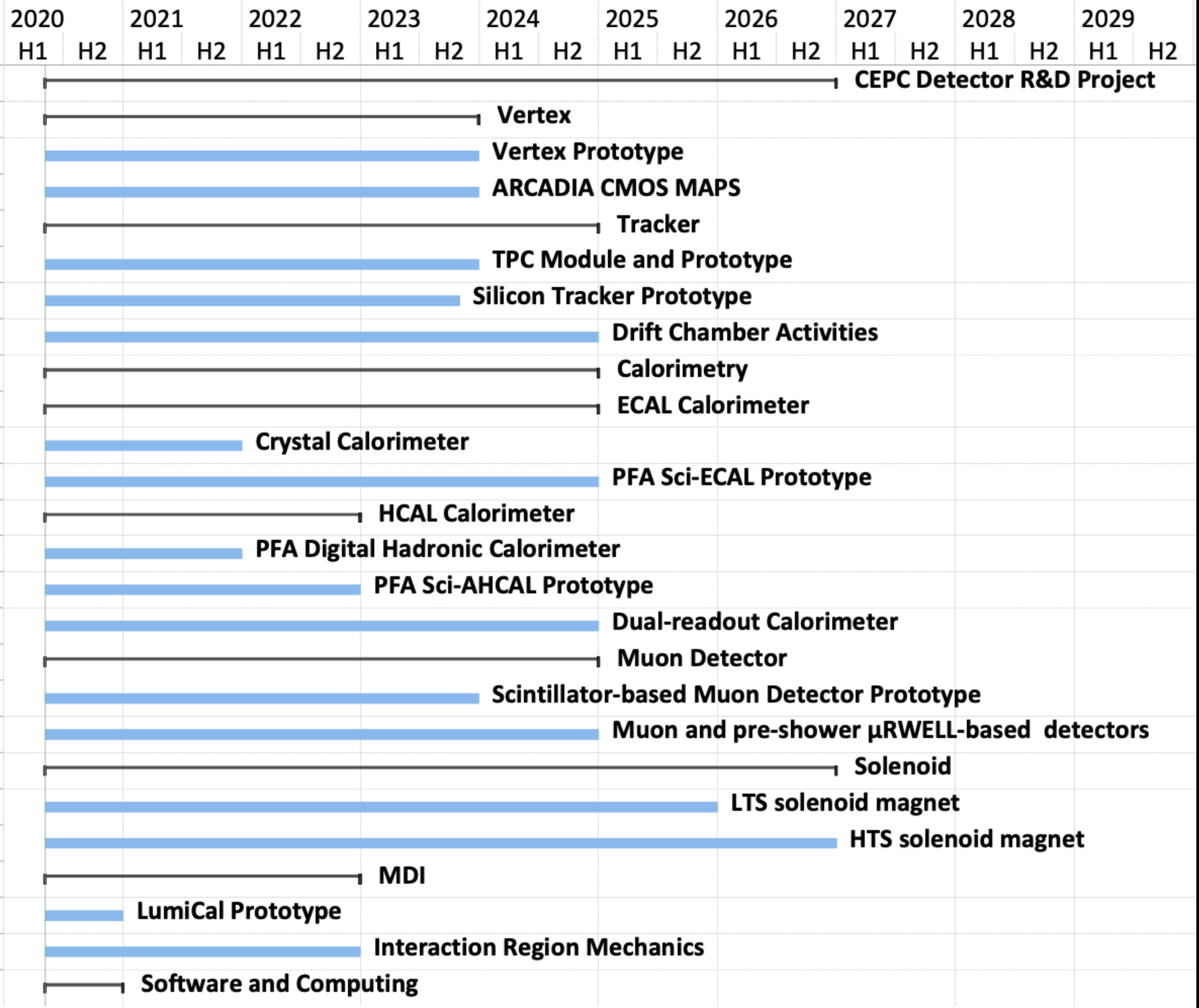
The current time line was driven by the wish to obtain a place for CEPC in the 14th 5-year plan. Now that this constraint may no longer be valid, can you estimate what it would take for the different subsystems to perform the detector R&D in depth in preparation for the TDR (time, expertise, international involvement) ?

- R&D research will continue to be mostly led by funding availability
- At this stage, the current R&D timescale is not much affected (see next page)
- TDR will be done by International Collaborations (see next question) and ultimately driven by them
- We should be ready by construction date, even if the construction starting time would not be changed (2030).
  - Longer time will allow us to produce better performing detectors at lower cost

- IDEA's R&D will be completed by next European Strategy, ready for a decision soon afterwards (2026). If more R&D funding was available times could be anticipated.
- DR Calorimeter R&D likely to be finished by 2026; Drift Chamber could be ready a little earlier 2023-2024.

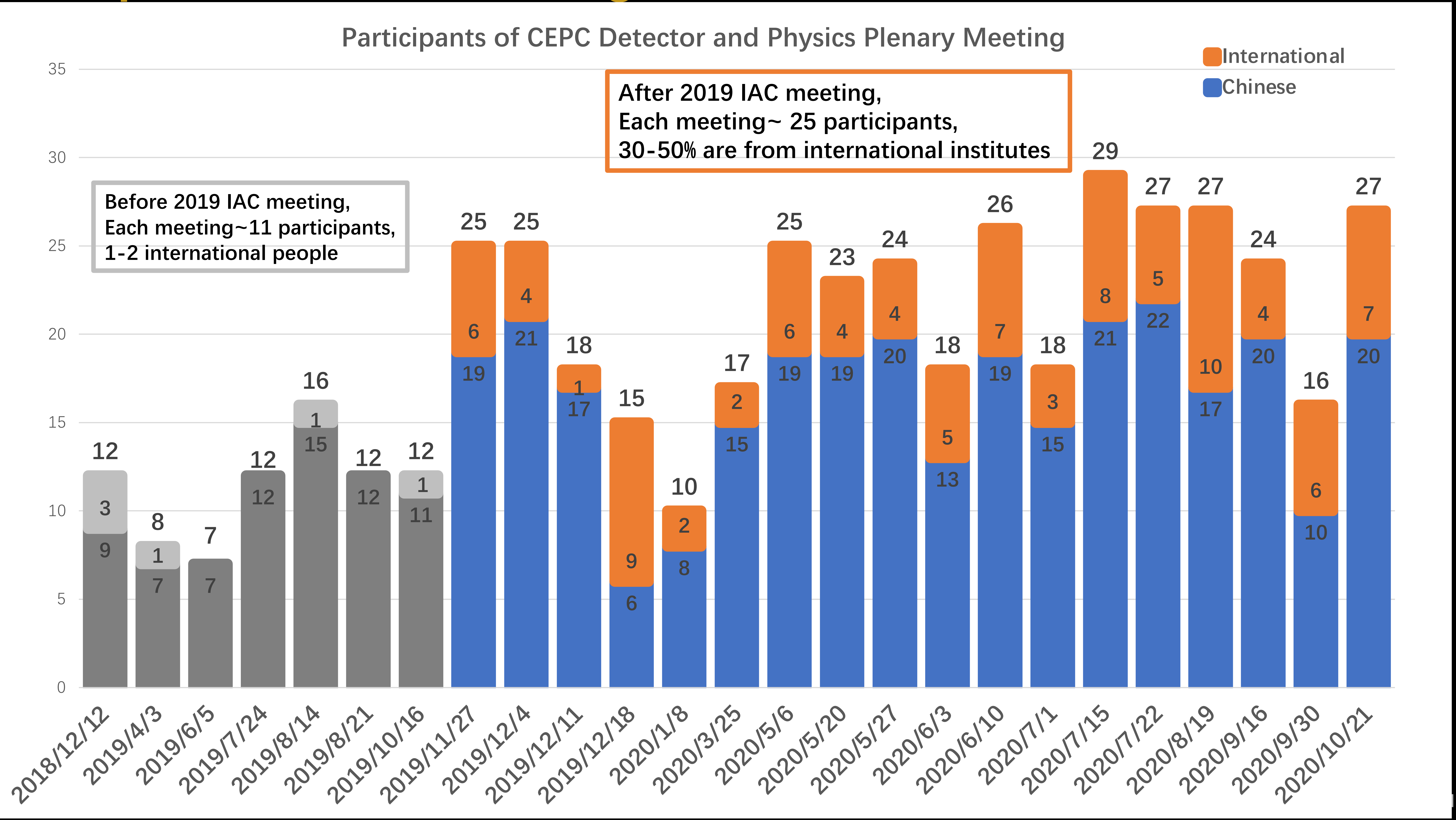
Projects overview: R&D schedule

PBS	Task Name	Finish
	CEPC Detector R&D Project	**26/12/31**
1	**Vertex**	**23/12/29**
1.1	Vertex Prototype	23/12/29
1.2	ARCADIA CMOS MAPS	23/12/29
2	**Tracker**	**24/12/31**
2.1	TPC Module and Prototype	23/12/29
2.2	Silicon Tracker Prototype	23/10/31
2.3	Drift Chamber Activities	24/12/31
3	**Calorimetry**	**24/12/31**
3.1	**ECAL Calorimeter**	**24/12/31**
3.1.1	Crystal Calorimeter	21/12/31
3.1.2	PFA Sci-ECAL Prototype	24/12/31
3.2	**HCAL Calorimeter**	**22/12/30**
3.2.1	PFA Digital Hadronic Calorimeter	21/12/31
3.2.2	PFA Sci-AHCAL Prototype	22/12/30
3.3	**Dual-readout Calorimeter**	**24/12/31**
4	**Muon Detector**	**24/12/31**
4.1	Scintillator-based Muon Detector Prototype	23/12/29
4.2	Muon and pre-shower µRWELL-based detectors	24/12/31
5	**Solenoid**	**26/12/31**
5.1	LTS solenoid magnet	25/12/31
5.2	HTS solenoid magnet	26/12/31
6	**MDI**	**22/12/30**
6.1	LumiCal Prototype	20/12/31
6.2	Interaction Region Mechanics	22/12/30
8	**Software and Computing**	**20/12/31**



The screen shots in Joao's presentation showing many meetings of various groups working on various aspects of the detector are very encouraging. What is the balance of international to Chinese participants in these meetings and how many people overall participate typically in each type of working group meeting on a regular basis. What is the trajectory compared to 12 months ago?

Plenary Physics and Detector Meeting



The screen shots in Joao's presentation showing many meetings of various groups working on various aspects of the detector are very encouraging. What is the balance of international to Chinese participants in these meetings and how many people overall participate typically in each type of working group meeting on a regular basis. What is the trajectory compared to 12 months ago?

- Calorimeter
  - Plenary PFA CALO meeting, biweekly, Thu 9 am, 10-15 people, mostly domestic
  - ECAL, monthly, China/Japan meeting, 10 participants, 50% from Japan
  - DR meetings exist between Italy, UK, Croatia, US, and Korean
- Tracker — biweekly, Thu 4 pm — 20-30 participants
  - 50% international participation (UK, Italy, Germany)
  - Participation already established last year, but grew this year with inclusion of more groups
- Offline Software — two bi-weekly international meetings + CEPC specific
  - EDM4HEP, and Key4HEP (hosted by CERN) both biweekly
  - Two L2 bi-weekly CEPC specific meetings (ACTS, CEPC software), Monday, 2:30 pm
    - ACTS, participation grew in last year, 6 —>12 people, 1 international (DESY)
    - IHEP, China Universities, and a few participates from UK to join soon
  - Several L3
    - Calorimeter, monthly, IHEP-Japan meeting, 10 participants, 50% from Japan
    - Drift chamber software, weekly, Friday morning, 10 participants from China

The screen shots in Joao's presentation showing many meetings of various groups working on various aspects of the detector are very encouraging. What is the balance of international to Chinese participants in these meetings and how many people overall participate typically in each type of working group meeting on a regular basis. What is the trajectory compared to 12 months ago?

- MDI
  - Biweekly meetings, Wednesday 9 am, ~20 people, mostly from IHEP+IPAS
- Vertex
  - ASIC design, weekly, Monday 3:30 pm, ~10 people, 2 from Barcelona
  - Mechanics, weekly, Friday 9:30 am, no international participation but UK people interested
- Physics and Simulation
  - Topical meetings:
    - Top physics
    - Snowmass preparation
    - Flavor meetings

Please comment also on Chinese/non-Chinese participation in the detector technology R&D projects that were shown.

PBS	Task Name	Page	Subtasks	Context	Team	Document Responsible
	CEPC Detector R&D Project					
1	**Vertex**					
1.1	**Vertex Prototype**	5	9	CEPC	China+ international collaborators	Zhijun, Ouyang
1.2	**ARCADIA CMOS MAPS**	6	6	Generic	INFN, Italy	Manuel Rolo
2	**Tracker**					
2.1	**TPC Module and Prototype**	6	12	CEPC	IHEP, Tsinghua	Huirong
2.2	**Silicon Tracker Prototype**	6	8	Generic	China, UK, Italy	Harald Fox, Meng Wang
2.3	**Drift Chamber Activities**	4	3	FCC-ee/CEPC	INFN, Novosibirsk	Franco Grancagnolo
3	**Calorimetry**					
3.1	**ECAL Calorimeter**					
3.1.1	Crystal Calorimeter	5	6	CEPC	IHEP, Princeton + others	Yong Liu
3.1.2	PFA Sci-ECAL Prototype	3	3	CEPC	USTC, IHEP	Jianbei Liu
3.2	**HCAL Calorimeter**					
3.2.1	PFA Digital Hadronic Calorimeter	4	5	CEPC	SJTU, IPNL, Weizmann, IIT, USTC	Haijun Yang, Imad Laktineh, Shikma Bressler
3.2.2	PFA Sci-AHCAL Prototype	4	4	CEPC	USTC, IHEP, SJTU	Jianbei Liu
3.3	**Dual-readout Calorimeter**	5	5	FCC-ee/CEPC	INFN, Sussex, Zagreb, South Korea	Roberto Ferrari
4	**Muon Detector**					
4.1	Scintillator-based Muon Detector	4	5	CEPC	Fudan, SJTU	Xiaolong Wang, Liang Li
4.2	Muon and pre-shower µRWELL-	5	4	FCC-ee/CEPC	INFN, LNF	Paolo Giacomelli
5	**Solenoid**					
5.1	LTS solenoid magnet	4	4	CEPC	IHEP+Industry	Zhu Zian
5.2	HTS solenoid magnet	4	4	CEPC	IHEP+Industry	Zhu Zian
6	**MDI**					
6.1	LumiCal Prototype	4	2	ILC/CEPC	AC, IHEP	Suen Hou
6.2	Interaction Region Mechanics	3	4	CEPC	IHEP	Hongbo Zhu
8	**Software and Computing**	7	11	CEPC	IHEP, SDU	Li Weidong, Ruan Manqi, Sun Shengseng, Li Gang

In the light of the recent evolution in governmental approval process, to which extent do you believe to have guaranteed resources to carry out key progress, waiting for more clear and substantial commitments from their government. What is their prioritization process, in view of the available and guaranteed resources? What is the plan to piggy back on existing detector design and R&D efforts worldwide, and to seek synergies and collaboration?

- The availability of the R&D research funds in China so far have been independent of this decision
- Expect funds for FCC-ee research to grow, which will allow for common R&D
- Already working on LHC detector upgrades that can provide know-how for CEPC later: ATLAS silicon tracker, ATLAS timing detector, LHCb silicon tracker, CMS Silicon calorimeter

The ESPPU gives high priority to a future Higgs factory. Assuming that this will generate an upgoing trend in engagement in e+e- studies, in particular for the circular options, do you see emerging opportunities for collaboration with FCC-ee in order to achieve design and performance improvements overall for both? Has there been a trend in this direction recently?

- Yes, there is now a clear push in Europe for studies and R&D towards a circular e+e-
- Interest in working on FCC-ee projects grew, but several participants emphasize that these are also of interest for CEPC
  - Track demonstrator
  - The IDEA collaboration is targeting both
  - EDM4HEP and Key4HEP of common FCC-ee and CEPC
- Continued interest in exchange programs with Italian colleagues

The International Detector Advisory Committee (IDAC) did not meet since its 1st meeting in 2019. The IDAC is composed of talented scientists, eager to help CEPC. How do you see the role of IDAC and how do you plan to work with (and profit from) IDAC in going forward?

- The name of this committee is "International Detector R&D Review Committee"
- The charge follows the 2018 recommendation from IAC (see next slide)
- Initial function was to review international R&D proposals for detector work on CEPC
  - Advise on detector designs and suggested technologies is welcome
- Aiming for two meetings per year:
  - Meeting around March 2021, independently of the workshop, would be desirable

CEPC International Detector R&D Committee (IDC)

Committee proposed by CEPC IAC

Charge

Evaluate International proposals for detector R&D relevant to the CEPC

Independent organ to evaluate the importance and suitability of worldwide detector R&D proposals for CEPC and produce short report with findings.

Evaluate the quality of the research proposed independently of the CEPC project, and therefore unbiased regarding internal institutional or personal interests

Later, this committee is expected to evolve to evaluate the Letters of Intent for the CEPC Detectors submitted by the proponents of the International Detector Collaborations

One of the main challenges in the detector design will be to set performance requirements followed by detector optimisaton for the different CEPC energy stages. This may lead to conflicting requirements and compromises to be made. Moreover, various detector technologies may be competing for a place in the same concept. What is your approach to tackling this, and what will be a good timing for setting up means for systematic comparisons, e.g. through a defined set of physics benchmarks, and other gauging factors.

- Physics and performance requirements are being updated now (as reported yesterday)
  - (work done together FCC-ee)
- Need the software baseline
  - More directly comparisons of concepts could be done in one year (with common software platform)
- Higgs run should have priority in what regards performance, but it is conceivable that the two detectors are optimized differently.
  - Need to evaluate the added value of PID for Higgs study

- Cost and international contributions will be an issue

Over recent years the number of sub-detector options for CEPC has increased. At the same time, much work has been invested in the software stack for detector simulation and event reconstruction, including the move to the common Key4hep software framework. Can you comment on the progress in the detailed integration of the different sub-detectors in the full software framework. How is this dealt with in the case of physics benchmark studies, where a multitude of options can become heavy on manpower and can make it difficult to bring coherence in results and comparisons.

- See slides from Weidong

The common software development for future colliders, as illustrated by Joao's report on the common workshop on software for a e+e- collider earlier this year, is very positive and should be encouraged. Can you elaborate a bit more in detail on the planning and whether there is real cooperative work on the work floor by the Higgs factory communities? Do the software stack of CEPC and FCC-ee really get integrated?

- See answer by Weidong
- Add DELPHES cards for CEPC detectors?

Two interaction regions are foreseen. What is the present plan of the CEPC management to approve the corresponding detector projects? Will there be at some point a call for LOI's and proposals submitted by proto-collaborations with subsequent development into real projects that need to be approved? Of course the people involved in the present designs and studies will be in good position to be leading actors, but for a machine that will be the leading accelerator in the world at that time, some outsiders will certaily emerge with their own ideas and projects.

- The procedure for selecting the two detectors is unchanged
- Letters of Intent will be submitted
- The detector committee is expected to evolve to evaluate the Letters of Intent for the CEPC Detectors submitted by the proponents of the International Detector Collaborations

Flavour at the Z: this part of the program, together with EWPT, being specific to CEPC and not shared by ILC, deserves a high-profile dedicated effort, reflected also in the detector design.
Related to this: On Joao's slide 12 for flavor physics, what are the assumptions (integrated lumi: peak lumi, running time) for CEPC? Would be good to complete the table with tau-tau statistics, very useful for comparison to Belle II.

Particle	@ Tera-Z	@ Belle II		@ LHCb
b hadrons				50 fb^{-1}
B^+	6×10^{10}	3×10^{10}	($50\,ab^{-1}$ on $\Upsilon(4S)$)	3×10^{13}
B^0	6×10^{10}	3×10^{10}	($50\,ab^{-1}$ on $\Upsilon(4S)$)	3×10^{13}
B_s	2×10^{10}	3×10^{8}	($5\,ab^{-1}$ on $\Upsilon(5S)$)	8×10^{12}
b baryons	1×10^{10}			1×10^{13}
Λ_b	1×10^{10}			1×10^{13}
c hadrons				
D^0	2×10^{11}			
D^+	6×10^{10}			
D_s^+	3×10^{10}			
Λ_c^+	2×10^{10}			
τ^+	3×10^{10}	5×10^{10}	($50\,ab^{-1}$ on $\Upsilon(4S)$)	

Huge amount of charmed hadrons more than trillions

arXiv: 1808.10567 arXiv: 1808.08865

Tera-Z of CEPC ← 2 years running with the luminosity $1x10^{36}/cm^2.s^{-1}$

Info

- CEPC: $3x10^{10}$ Z → tau tau, with $1.0x10^{36}$ luminosity ; efficiency for tau pair reconstruction : 90%
- FCC-ee: $1x10^{11}$ Z → tau tau, with 4.6 x 10^{36} luminosity; efficiency for tau pair reconstruction : 90%
- BelleII: $5x10^{10}$ tau pairs at Y(4S) with integrated luminosity 50 ab^{-1}; efficiency for tau pair reconstruction : 15%
- STCF: 2.1x 10^{10} with 10 ab^{-1}; efficiency: less than 10%.

Flavor Physics

Some progress since CDR — 2 sessions at workshop — 9 talks

Particle	**@ Tera-Z**	**@ Belle II**		**@ LHCb**
$\boldsymbol{b}$ **hadrons**				
B^+	2×10^{10}	3×10^{10}	$(50\,\mathrm{ab}^{-1}$ on $\Upsilon(4S))$	3×10^{13}
B^0	2×10^{10}	3×10^{10}	$(50\,\mathrm{ab}^{-1}$ on $\Upsilon(4S))$	3×10^{13}
B_s	7×10^9	3×10^8	$(5\,\mathrm{ab}^{-1}$ on $\Upsilon(5S))$	8×10^{12}
b baryons	3×10^9			1×10^{13}
Λ_b	3×10^9			1×10^{13}

vs Belle II: b baryons, Λ_b, 100x B_s
vs LHCb: low bkg→neutrals (γ, π_0,…)

Unique sensitivity to processes unavailable at LHCb or Belle II: flavor-violating Z decays*, lepton universality in Z decays*, rare $b \to s\tau\tau$ decays, rare $b \to s\nu\nu$ decays, B_c decays*, semi-tauonic $b \to c\tau\nu$ decays, τ decays, FCNC single top.

similarly, physics at the top threshold and slightly above should be revamped. For long time CEPC focused on the Higgs energy-stage, keeping the other runs in the sidelines. We recommend that the management, and the physics coordination, show more firm commitment to make this an integral part of the program. The relevant physics studies should be promoted. This goes together with achieving compelling evidence that the accelerator design is not only compatible with the higher energy stage, but also optimized for it.

- Running at the top threshold is an upgrade to the CEPC project.
- It is important that we focus on the core goals of the project, although we understand the need to ensure the accelerator will be upgradable to higher energies at a modest cost
-

Re-evaluation of physics requirements

Physics process	Measurands	Detector subsystem	Performance requirement
$ZH, Z \to e^+e^-, \mu^+\mu^-$ $H \to \mu^+\mu^-$	$m_H, \sigma(ZH)$ $\mathrm{BR}(H \to \mu^+\mu^-)$	Tracker	$\Delta(1/p_T) =$ $2 \times 10^{-5} \oplus \frac{0.001}{p(\mathrm{GeV}) \sin^{3/2}\theta}$
$H \to b\bar{b}/c\bar{c}/gg$	$\mathrm{BR}(H \to b\bar{b}/c\bar{c}/gg)$	Vertex	$\sigma_{r\phi} =$ $5 \oplus \frac{10}{p(\mathrm{GeV}) \times \sin^{3/2}\theta} (\mu\mathrm{m})$
$H \to q\bar{q}, WW^*, ZZ^*$	$\mathrm{BR}(H \to q\bar{q}, WW^*, ZZ^*)$	ECAL HCAL	$\sigma_E^{\mathrm{jet}}/E =$ $3 \sim 4\%$ at 100 GeV
$H \to \gamma\gamma$	$\mathrm{BR}(H \to \gamma\gamma)$	ECAL	$\Delta E/E =$ $\frac{0.20}{\sqrt{E(\mathrm{GeV})}} \oplus 0.01$

under discussion → started at the workshop last year

Physics at near the top threshold

Led by Yaquan Fang

- The target accuracy of e^+e^- for top mass measurement is O(10) MeV and in a model independent way with luminosity around 200-400 fb^{-1}
  - with optimized setup: ~ 1 year of running (~480 fb^{-1}/year)

- Considering the run for top coupling measurement at CEPC, 360 GeV should be enough
  - Need to investigate the feasibility of running with a lower energy
  - The expected precision for the coupling is much better than LHC
  - 2 ab^{-1} luminosity corresponds to 4-5 years with optimized setup

- 360 GeV run is helpful for the Higgs width measurement
  - The results are not much different from the running at 365 GeV

- Some thoughts on new physics with 360 GeV have been addressed
  - 2HDM, Georgi-Machacek (GM) models, H—>sh (2HDM+S)

Flavor Physics

Some progress since CDR — 2 sessions at workshop — 9 talks

Particle	@ Tera-Z	@ Belle II		@ LHCb
b hadrons				
B^+	2×10^{10}	3×10^{10}	$(50\,\mathrm{ab}^{-1}$ on $\Upsilon(4S))$	3×10^{13}
B^0	2×10^{10}	3×10^{10}	$(50\,\mathrm{ab}^{-1}$ on $\Upsilon(4S))$	3×10^{13}
B_s	7×10^{9}	3×10^{8}	$(5\,\mathrm{ab}^{-1}$ on $\Upsilon(5S))$	8×10^{12}
b baryons	3×10^{9}			1×10^{13}
Λ_b	3×10^{9}			1×10^{13}

vs Belle II: b baryons, Λ_b, 100x B_s
vs LHCb: low bkg→neutrals (γ, π_0,…)

Unique sensitivity to processes unavailable at LHCb or Belle II: flavor-violating Z decays*, lepton universality in Z decays*, rare $b \to s\tau\tau$ decays, rare $b \to s\nu\nu$ decays, B_c decays*, semi-tauonic $b \to c\tau\nu$ decays, τ decays, FCNC single top.

TDAQ

Working on expanding the Trigger and DAQ requirements for the CEPC from the CDR into a better understanding of the overall situation

Triggerless running has impact on detector design, power consumption and cooling

TDAQ and Online
Conveners: Prof. Zhen An LIU (IHEP), David Newbold (UKRI), Chris Bee (CERN)
Location: Grand Ballroom C (Online Meeting Room:https://weidijia.zoom.com.cn/j/66965146553)

10:30 **Introduction of the TDAQ requirements** *10'*
Speaker: Prof. Zhen An LIU (IHEP)
Material: Slides

10:40 **Requirements from the LumiCal, Suen Hou** *10'*
Speaker: Suen Hou (IPAS)
Material: Slides

10:50 **Requirements from the Vertex Dedector** *10'*
Speaker: Mr. Wei WEI (IHEP)
Material: Slides

11:00 **Requirements from the TPC** *10'*
Speaker: Dr. Huirong Qi (IHEP)
Material: Slides

11:10 **Requirements from the ECAL & HCAL** *10'*
Speaker: Dr. Yong Liu (IHEP)
Material: Slides

11:20 **Pixel readout technologies and the challenges for the future** *20'*
Speaker: Garcia-Sciveres Maurice (LBNL)
Material: Slides

TDAQ and Online
Conveners: Prof. Zhen An LIU (IHEP), David Newbold (UKRI), Chris Bee (CERN)
Location: Grand Ballroom C (Online Meeting Room:https://weidijia.zoom.com.cn/j/66965146553)

14:00 **Requirements from the Drift Chamber** *10'*
Speaker: Francesco Grancagnolo (INFN-Lecce)
Material: Slides

14:10 **Requirements from DR Calorimeter** *10'*
Speaker: Roberto Ferrari (INFN)
Material: Slides

14:20 **Requirements from the Muon Detector** *10'*
Speaker: Paolo Giacomelli (INFN-Bo)
Material: Slides

14:30 **Requirements from the Silicon Tracker** *10'*
Speaker: Jens Dopke (STFC Rutherford Appleton Laboratory)
Material: Slides

14:40 **LHCb software-only trigger** *15'*
Speaker: Dorothea vom Bruch (LPNHE)

14:55 **ATLAS HLT tracking optimisation** *15'*
Speaker: Mark Sutton (Sussex)
Material: Slides

15:10 **High-Precision Timing Distribution Systems for LHC experiments** *15'*
Speaker: Eduardo Mendes (CERN)
Material: Slides

Series of discussions culminated in the workshop, to continue to followup, led by Zhen An Liu

Software and Reconstruction algorithms

Last year reported that we had started developing a new CEPC software platform (moving away from iLCSoft)

Workshop in Bologna (June 12-13) (FCC, CEPC, ILC, CLIC) kicked-off collaboration: https://agenda.infn.it/event/19047/

Consensus:

- Develop a Common Turnkey Software Stack (Key4hep) for future collider experiments
- Maximize the sharing of software components between experiments

CEPCSW is now fully integrated with Key4hep, and supports application development

See Xingtao Huang's talk during workshop for details

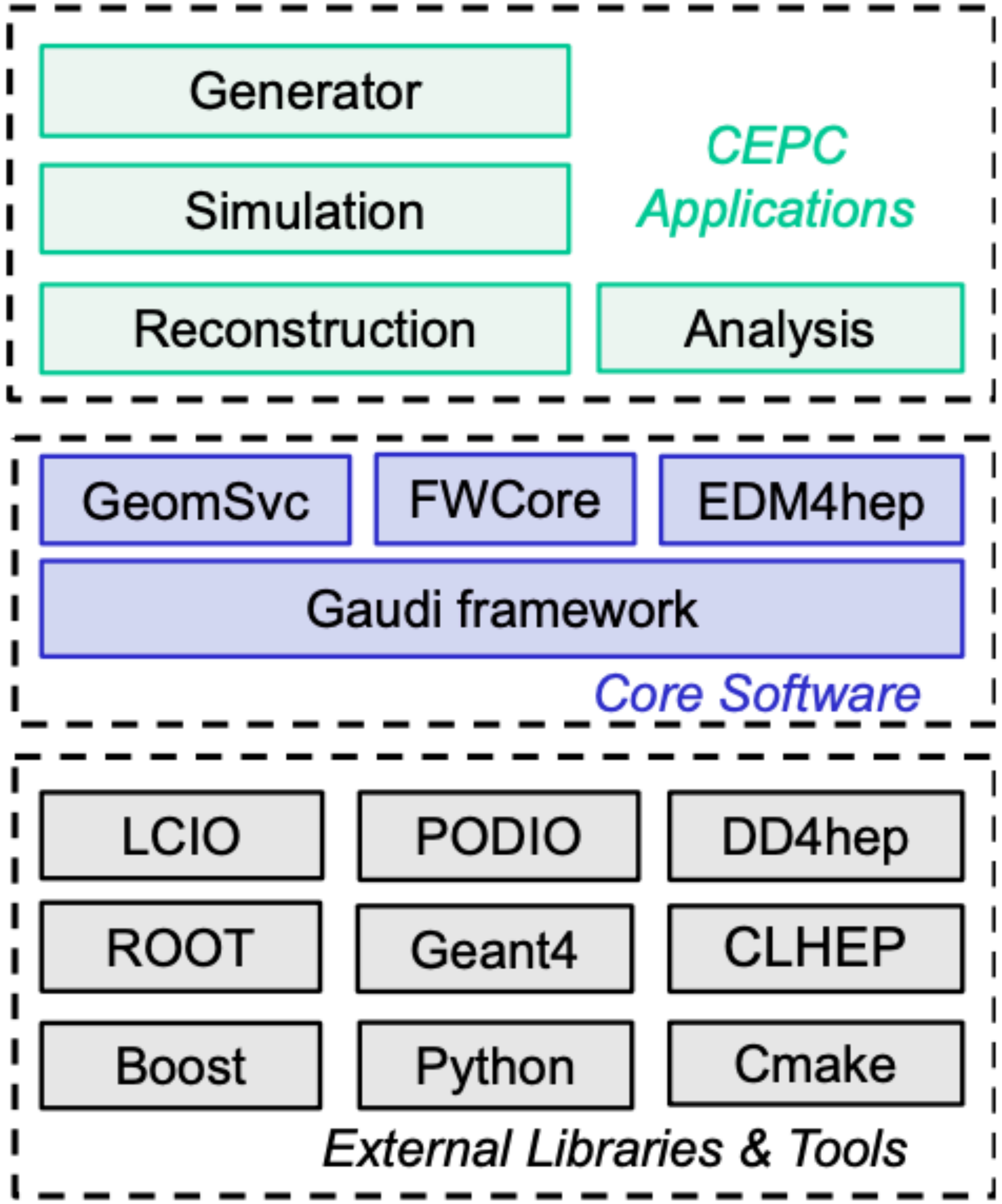
CEPCSW and Core Software

Architecture of CEPCSW

- External libraries
- Core software
- CEPC applications for simulation, reconstruction and analysis

Core software

- Gaudi framework: defines interfaces to all software components and controls their execution.
- EDM4hep: generic event data model for HEP collider experiments
- FWCore :manage event objects defined by EDM4hep.
- GeomSvc :a DD4hep-based geometry service to provide a unified way to access detector geometry data.
- Both FWCore and EDM4hep are Key4hep packages.



CEPCSW Progress and Plans

- Further progress made since last CEPC workshop
  - Detector simulation framework was developed and used for the study of CEPC_v4 detector and reference detector
  - ECAL fast simulation with the frozen shower method was developed to speed up the simulation of electromagnetic shower
  - Finished porting of digitization and reconstruction algorithms for trackers and ECAL from Marlin to CEPCSW
  - k4Pandora package was developed to integrate Pandora with CEPCSW and became part of Key4hep software stack
- CEPCSW is managed with Github, deployed with CVMFS, and available for all CEPC Sites

- Plan
  - Adding more components from Key4hep when they are available
  - Non-uniform magnetic field and pile-up of beam backgrounds
  - Development of simulation and reconstruction algorithms for the reference detector (SiTrk+DC, Crystal bar ECal)
  - Add algorithms for building reconstructed particles

Detector International Collaboration

Speakers at CEPC Workshop — Detector Parallel Sessions

** Sessions **	Talks **
Silicon	12
Gaseous	11
Calorimeter	10
MDI	10
TDAQ/online	13
Offline/Software	9
Performance	8
	73

Speakers

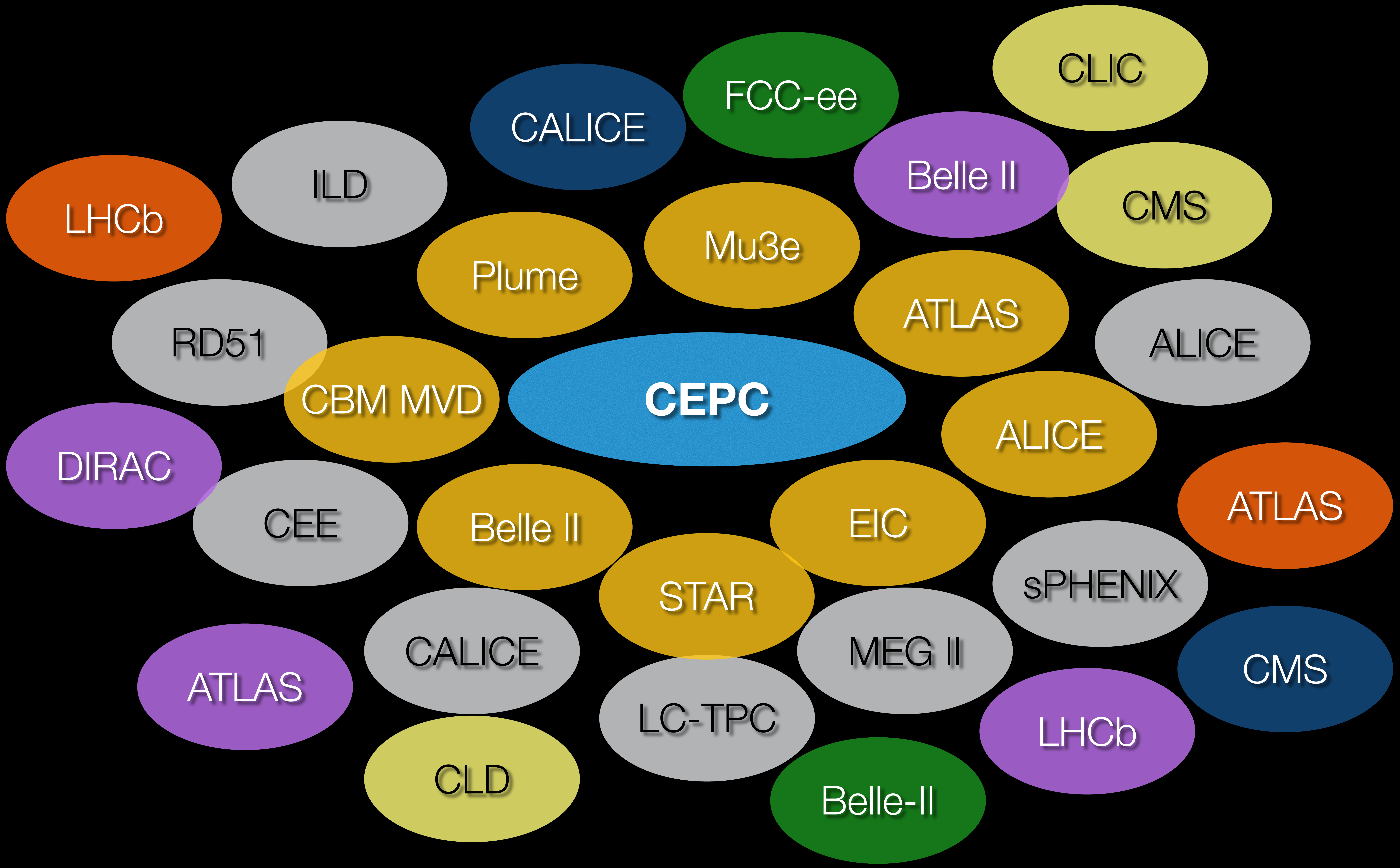
CEPC workshop

- Bologna
- CERN
- BNL
- Princeton
- Vinca
- IHEP ×3
- RAL
- IPNL, Lyon
- Shanghai
- Kiushu
- CERN
- LAL
- LPNHE
- MPI
- IHEP ×3
- Seoul
- Shanghai
- Strasbourg
- IPNL, Lyon
- USTC
- Sussex
- Karlsruher
- Birmingham
- Hamburg
- USTC
- Padova
- Stony Brook
- Hawaii
- Santa Cruz
- IHEP ×3
- Maryland
- Insubria
- Pavia
- Pisa
- CERN ×2
- Shandong
- Tsinghua ×2
- KEK
- Milano
- Pisa
- IHEP ×2
- IHEP ×2
- IHEP ×3
- CERN
- Lecce
- Sussex
- NIKHEF
- IHEP ×4
- CERN ×3
- Washington
- IPAS
- IPAS
- LBNL
- Lecce
- Bari
- MIT

Collaborations

** Sessions **

- Silicon
- Gaseous
- Calorimeter
- MDI
- TDAQ/online
- Offline/Software
- Performance



Main Detector and Physics Workshops in 2020

- Jan 18, 2020: Physics Potential Study for Future e+e- Higgs Factories
  - http://iasprogram.ust.hk/hep/2020/meeting_20200118.php
- Jan 16-17, 2020: Mini-workshop: Software and Physics Requirements for e+e- Colliders
  - http://iasprogram.ust.hk/hep/2020/workshop_experiment.php
- Jan 16-17, 2020: Mini-Workshop: Machine Detector Interface for Future Colliders:
  - http://iasprogram.ust.hk/hep/2020/workshop_accelerator.php
- May 28-29, 2020: CEPC MDI Workshop
  - https://indico.ihep.ac.cn/event/11801/
- July 22-23, 2020: Online mini-workshop on a detector concept with a crystal ECAL
  - https://indico.ihep.ac.cn/event/11938/other-view?view=standard
- Aug 28-29, 2020: Workshop on Detector & Accelerator Mechanics
  - https://indico.ihep.ac.cn/event/12324/

Snowmass — Letters of Intent

https://indico.ihep.ac.cn/event/12410/

Detector
14 LoI

Detector R&D
Conveners: Joao Guimaraes Costa, WANG Jianchun, Mr. Manqi Ruan (IHEP)

15:00 **CEPC Detectors Overview LoI** 1'
CEPC Detector Overview LOI
SNOWMASS21-EF1_EF4-IF9_IF0-260.pdf
Speakers: Joao Guimaraes Costa, Mr. Manqi Ruan (IHEP), WANG Jianchun
Material: Paper, Slides

15:02 **IDEA Concept** 1'
Speaker: Franco Bedeschi (INFN-Pisa)
Material: Paper

15:03 **Dual Readout Calorimeter** 1'
Speaker: Roberto Ferrari (INFN)
Material: Paper

15:04 **Drift Chamber** 1'
Speaker: Franco Grancagnolo
Material: Paper

15:06 **mu-RWELL (muons, preshower)** 1'
Speaker: Paolo Giacomelli (INFN-Bo)
Material: Paper

15:08 **Time Detector LoI** 1'
Speaker: Prof. Zhijun Liang (IHEP)
Material: Slides

15:09 **Key4hep** 1'
Speakers: Dr. Weidong Li (高能所), Dr. Tao LIN (高能所), Prof. Xingtao Huang (Shandong University), Wenxing Fang (Beihang University)
Material: Slides

15:10 **PFA Calorimeter** 1'
Speakers: Haijun Yang (Shanghai Jiao Tong University), Dr. Jianbei Liu (University of Science and Technology of China), Dr. Yong Liu (Institute of High Energy Physics)
Material: Slides

15:11 **High Granularity Crystal Calorimeter** 1'
Speaker: Dr. Yong Liu (Institute of High Energy Physics)
Material: Paper, Slides

15:12 **Muon Scintillator Detector** 1'
Speaker: Dr. Xiaolong Wang (Institute of Modern Physics, Fudan University)
Material: document

15:13 **Vertex LoI** 1'
Speaker: Prof. Zhijun Liang (IHEP)
Material: Slides

15:15 **MDI LoI** 1'
Speaker: Dr. Hongbo ZHU (IHEP)
Material: Slides

15:16 **TPC LoI** 1'
Speaker: Dr. Huirong Qi (Institute of High Energy Physics, CAS)
Material: Slides

15:17 **Solenoid R&D LoI** 1'
Speaker: Dr. Feipeng NING (IHEP)
Material: Slides

Physics
17 LoI

Open Physics Questions
Conveners: Mr. Manqi Ruan (IHEP)

16:00 **EF01-Higgs boson CP properties at CEPC** 3'
Speakers: Meng Xiao, Xin Shi
Material: Slides

16:03 **EF01-Measurement of branching fractions of Higgs hadronic decays** 3'
Speaker: Yanping Huang
Material: Slides

16:06 **EF02-Study of Electroweak Phase Transition in Exotic Higgs Decays with CEPC Detector Simulation** 3'
Speaker: Shu Li
Material: Slides

16:09 **EF03-Feasibility study of CP-violating Phase ϕs measurement via Bs → J/Ψϕ channel at CEPC** 3'
Speaker: Mingrui Zhao
Material: Slides

16:12 **EF03-Probing top quark FCNC couplings tqγ, tqZ at future e+e- collider** 3'
Speaker: Peiwen Wu
Material: Slides

16:15 **EF03-Searching for Bs → ϕνν and other b → sνν processes at CEPC** 3'
Speaker: Lingfeng Li
Material: Slides

16:18 **EF04-Measurement of the leptonic effective weak mixing angle at CEPC** 3'
Speaker: Siqi Yang
Material: Slides

16:21 **EF04-Probing new physics with the measurements of e+e- → W+W- at CEPC with optimal observables** 3'
Speaker: Jiayin Gu
Material: Slides

16:24 **EF05-Exlusive Z decays** 3'
Speaker: Qin Qin
Material: Slides

16:27 **EF05-NNLO electroweak correction to Higgs and Z associated production at future Higgs factory** 3'
Speaker: Zhao Li
Material: Slides

16:30 **EF08-SUSY global fits with future colliders using GAMBIT** 3'
Speaker: Peter Athron
Material: Slides

16:33 **EF08-Probing Supersymmetry and Dark Matter at the CEPC, FCCee, and ILC** 3'
Speaker: Tianjun Li
Material: Slides

16:36 **EF09-Search for Asymmetric Dark Matter model at CEPC by displaced lepton jets** 3'
Speaker: Mengchao Zhang
Material: Slides

16:39 **EF09-Search for t + j + MET signals from dark matter models at future e+e- collider** 3'
Speaker: Peiwen Wu
Material: Slides

16:42 **EF0910-Dark Matter via Higgs portal at CEPC** 3'
Speaker: Xin Shi
Material: Slides

16:45 **EF0910-Lepton portal dark matter, gravitational waves and collider phenomenology** 3'
Speaker: Ke-Pan Xie
Material: Slides

16:48 **RF1-Exploring new physics with Bc →τ v_τ** 3'
Speaker: Taifan Zheng
Material: Slides

CEPC Physics and Detector Meetings

https://indico.ihep.ac.cn/category/214/

Physics and Detector Meetings

Physics and Simulations	416 events
Vertex	12 events
Tracker	128 events
Calo&Muon	160 events
MDI	52 events
General	138 events
100 TeV Simulation	12 events
Pure Silicon Detector	8 events
Offline Software	1 event
Mechanics	3 events

Regular International Participation to the Plenary Meetings

CEPC Day meeting every month

October 2020

- 21 Oct CEPC Physics and Detector Plenary Meeting
- 14 Oct CEPC Physics and Detector Plenary Meeting

September 2020

- 30 Sep CEPC Physics and Detector Plenary Meeting
- 16 Sep CEPC Physics and Detector Plenary Meeting

August 2020

- 31 Aug CEPC Physics and Detector Snowmass Letters of Intent
- 19 Aug CEPC Physics and Detector Plenary Meeting

July 2020

- 22 Jul CEPC Physics and Detector Plenary Meeting
- 15 Jul CEPC Physics and Detector Plenary Meeting
- 01 Jul CEPC Physics and Detector Plenary Meeting

June 2020

- 10 Jun CEPC Physics and Detector Plenary Meeting
- 03 Jun CEPC Physics and Detector Plenary Meeting

May 2020

- 27 May CEPC Physics and Detector Plenary Meeting
- 20 May CEPC Physics and Detector Plenary Meeting
- 06 May CEPC Physics and Detector Plenary Meeting

April 2020

- 29 Apr CEPC Physics and Detector Plenary Meeting
- 15 Apr CEPC Physics and Detector Plenary Meeting

March 2020

- 25 Mar CEPC Physics and Detector Plenary Meeting

January 2020

- 08 Jan CEPC Physics and Detector Plenary Meeting

Particle Flow Calorimeter Collaborations

- CEPC HCAL:
  - Imad Laktineh, IPNL, University of Lyon, France (SDHCAL based on GRPC)
  - Shikma Bressler, Weizmann Institute of Science, Israel (SDHCAL based on RPWELL)
  - Enrique Kajomovitz, Israel Institute of Technology, Israel (SDHCAL based on RPWELL)
  - Hans-Christian Schultz-Coulon and Wei Shen, University of Heidelberg, Germany (Scintillator+Steel HCAL)

- CEPC ECAL:
  - Vincent Boudry, Jean-Claude Brient, LLR, France (Silicon+W ECAL)
  - Tohru Takeshita, Shinshu University, Japan (Scintillator+SiPM ECAL)
  - Wataru Ootani, University of Tokyo, Japan (Scintilator+W ECAL)
  - Christoph Tully, Princeton University, USA (Crystal ECAL)
  - Sarah Eno, University of Maryland, USA (Crystal ECAL)

  - Christophe de la taille, CNRS/IN2P3 Micro-Electronics Design Lab, Ecole Polytechnique Palaiseau, France (Readout electronics)

Silicon Vertex Detector

- CMOS pixel sensor development:
  - Marc Winter, Christine Hu-Guo, IPHC Strasburg, France
  - Sebastian Grinstein, Raimon Casanova, IFAE, Barcelona, Spain
  - ALICE, indirectly through CCNU
- SOI pixel sensor development
  - KEK, Japan
- Vertex Detector Prototype (MOST2):
  - CMOS Pixel Sensor development
    - Barcelona, IFAE
  - Mechanics and services
    - Liverpool, Oxford, RAL, QMU (UK)
    - Univ. Massachusetts (USA)

Trackers

- Time Projection Chamber
  - Paul Colas, Aleksan Roy, Stephan Anne., CEA-Saclay IRFU group, France (FCPPL)
  - Keisuke Fujii's group, KEK, Japan
  - Joined LC-TPC in Dec 2016
    - DESY test beam in 2018

- Silicon Tracker
  - Full Silicon Tracker Design
    - Weiming Yao, Berkeley (USA)
    - Sergei Chekanov, Argonne (USA)
  - Tracker Demonstrator
    - Harald Fox (Lancaster), Yanyan Gao (Edinburgh), Roy Lemmon (Daresbury), Tim Jones (Liverpool)
    - Ivan Peric (KIT)
    - Based on ALICE and ATLAS technology

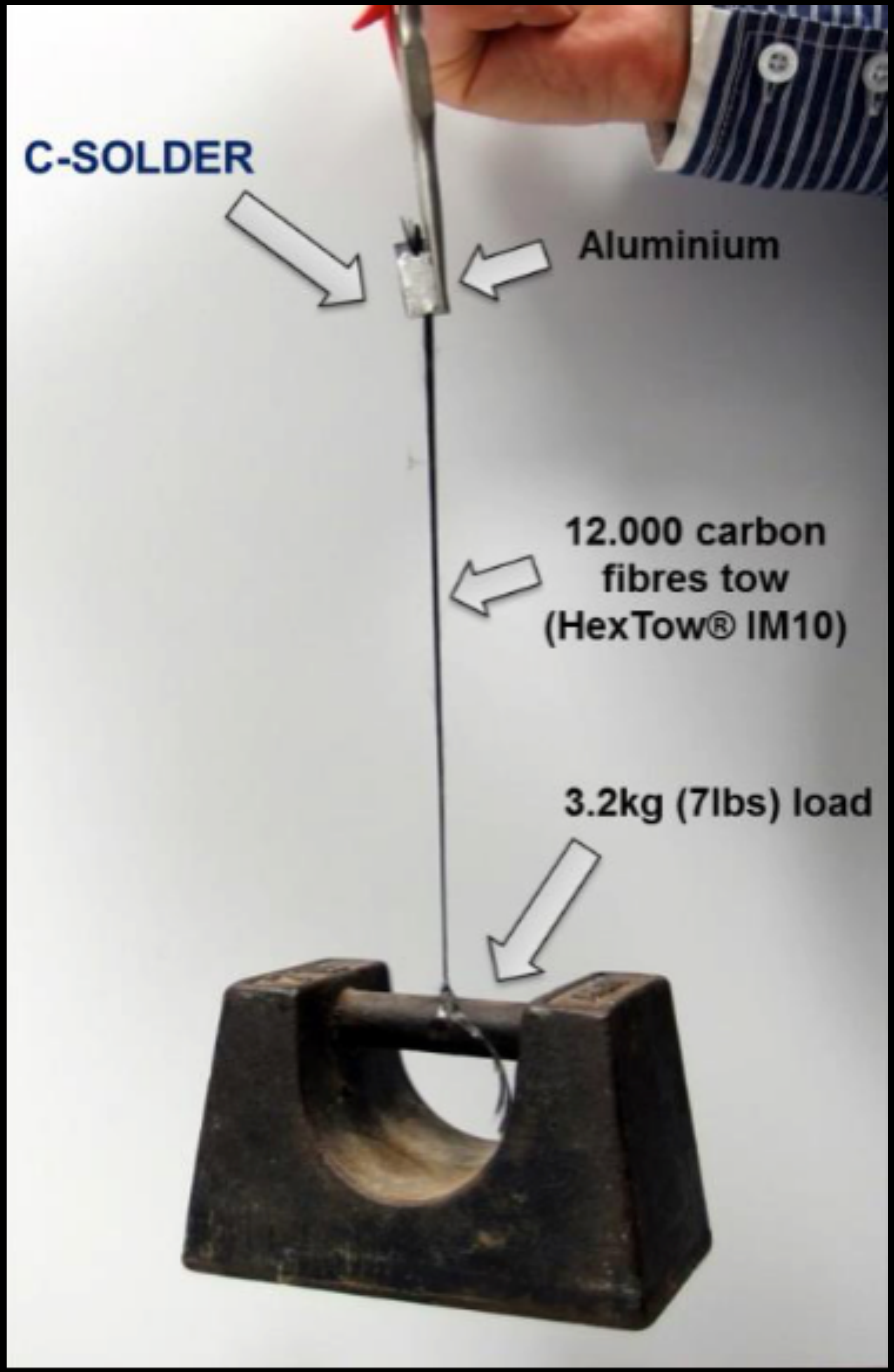
- China
  - Institute of High Energy Physics, CAS
  - Shangdong University
  - Tsinghua University
  - University of Science and Technology of China
  - Northwestern Polytechnical University
  - T.D. Lee Institute – Shanghai Jiao Tong University
  - Harbin Institute of Technology
  - University of South China
- Italy
  - INFN Sezione di Milano, Università di Milano e Università dell'Insubria
  - INFN Sezione di Pisa e Università di Pisa
  - INFN Sezione di Torino e Università di Torino
- Germany
  - Karlsruhe Institute of Technology
- UK
  - University of Bristol
  - STFC – Daresbury Laboratory
  - University of Edinburgh
  - Lancaster University
  - University of Liverpool
  - Queen Mary University of London
  - University of Oxford
  - University of Sheffield
  - University of Warwick

IDEA: Silicon

- Active pixel detectors (INFN: Milano, Torino)
  - SEED and ARCADIA (1 M€ INFN grant)
    - Low power, high resolution, stitching
    - First prototypes by late 2020 → test on beam
  - DAQ development for test beam
    - Potential collaboration with China (FEST grant supports travel to China)
- Active and passive CMOS for Si wrapper (INFN: Milano)
  - Continuation of ATLAS phase 2 upgrade work
- EU grants:
  - FEST (travel 4 yr), AIDA++ (applied)
- International collaboration:
  - UK-Oxford, ETH, Zurich university, (IHEP-China?)

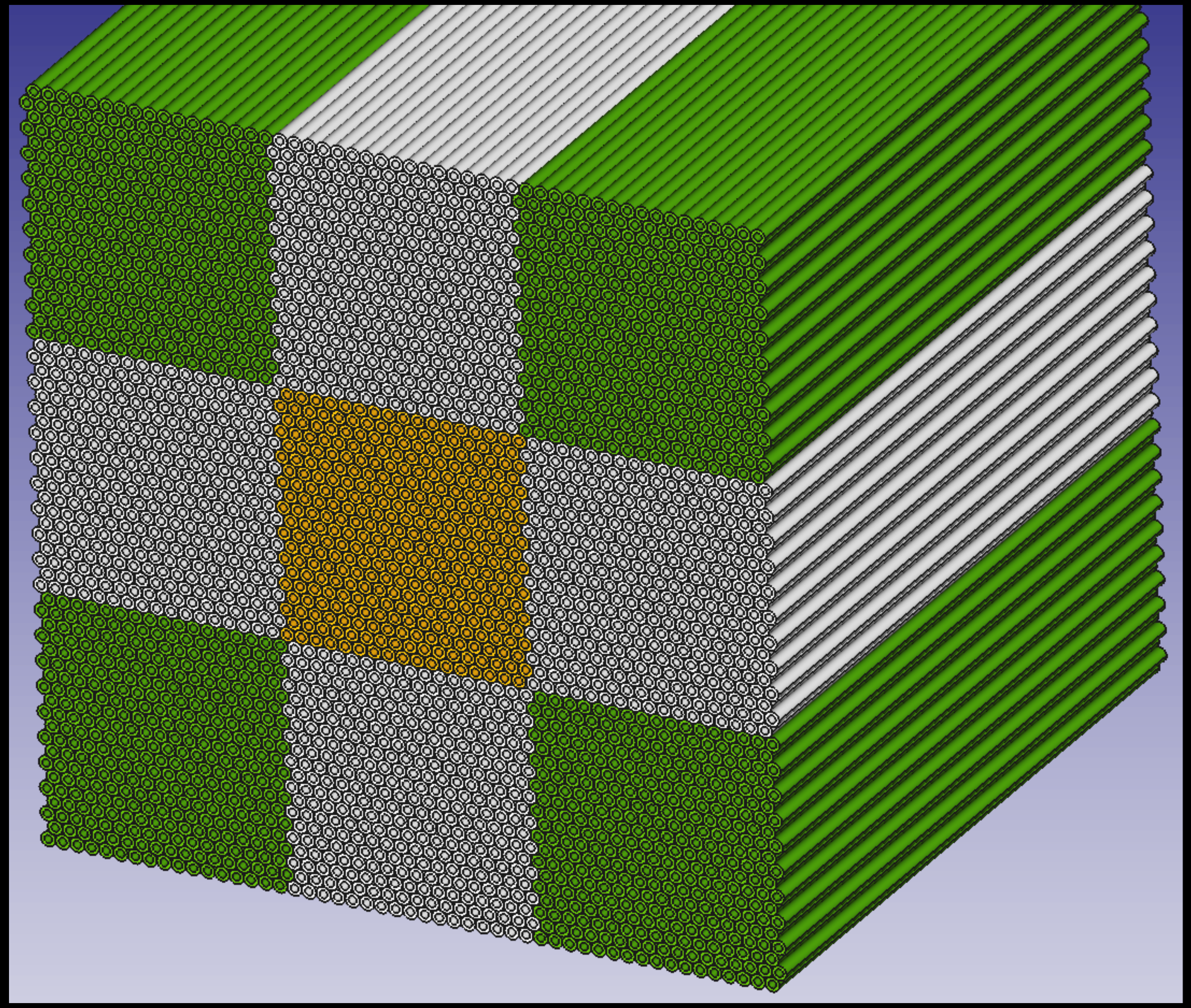
IDEA: Drift Chamber

- Drift chamber (INFN: Lecce, Bari)
  - Full length prototype
    - C-fiber wires
    - Cluster counting electronics
    - Non-flammable gases
- EU grants:
  - CREMLIN2, AIDA++ (Applied)
- International collaboration:
  - (BINP, Novosibirsk)



IDEA: DR calorimeter

- Full EM containment prototype (INFN: Pavia, Milano, Pisa)
  - 10 cm x 10 cm x 100 cm
    - Mechanics with metal capillaries 2 mm OD, 1.1 mm ID
    - 9 towers. Central tower read out with SiPM. Remaining with PMT.
    - Alpha-tester compact CAEN electronics (FERS system)



- EU grants:
  - AIDA++ (applied)
- Cofunded by INFN, UK, Croatia
- International collaboration:
  - UK: University of Sussex, RBI - Croatia, South Korea

IDEA: μRwell chambers

- Development of large area chambers with industrial partners ELTOS and TECHTRA (INFN: Bologna, Ferrara, Frascati)
  - μRwell technology
  - Test μRwell 2D readout
  - R&D on DLC+Cu sputtering with USTC (China)
- EU grants:
  - ATTRACT, CREMILN2, AIDA++(Applied)
- International collaboration:
  - USTC – China, BINP-Novosibirsk

Key R&D Issues Moving Forward

Updated Parameters of Collider Ring since CDR

	Higgs		Z (2T)	
	CDR	Updated	CDR	Updated
Beam energy (GeV)	120	-	45.5	-
Synchrotron radiation loss/turn (GeV)	1.73	1.8	0.036	-
Number of particles/bunch N_e (10^{10})	15.0	16.3	8.0	16.1
Bunch number (bunch spacing)	242 (0.68μs)	214 (0.7 μs)	12000	10870 (27ns)
Beam current (mA)	17.4	16.8	461.0	841.0
Synchrotron radiation power /beam (MW)	30	-	16.5	30
Cell number/cavity	2	-	2	1
β function at IP β_x^* / β_y^* (m)	0.36/0.0015	0.33/0.001	0.2/0.001	0.15/0.001
Emittance $\varepsilon_x/\varepsilon_y$ (nm)	[illegible]	0.68/0.0014	0.18/0.0016	0.52/0.0016
Beam size at IP σ_x/σ_y (μm)	20.9/0.068	15.0/0.037	6.0/0.04	8.8/0.04
Bunch length σ_z (mm)	[illegible]	[illegible]	[illegible]	[illegible]
Lifetime (hour)	0.67	0.35	2.1	[illegible]
Luminosity/IP L (10^{34} $cm^{-2}s^{-1}$)	2.93	5.0	32.1	101.1

These **luminosity** increases have not yet been absorbed into physics and detector studies

Luminosity increase factor: × 1.8 × 3.2

Some key R&D topics moving forward

- Machine Detector Interface
- Luminosity meter (LumiCal)
- Silicon Vertex (continue work on material budget versus resolution versus cooling)
    - Services design and integration

Some key R&D topics moving forward

- Machine Detector Interface
- Luminosity meter (LumiCal)
- Silicon Vertex (continue work on material budget versus resolution versus cooling)
  - Services design and integration
- Tracker

Trade off: Transparency <—> reliability/resolution

  - Time Projection Chamber
    - Finalize investigation of Ion back flow and field distortion at the Z pole and 2 Tesla
    - Follow up on the Pixel TPC possibility
  - Drift Chamber
    - Can it cope with the high rates at the Z pole? Enough resolution?
    - Can provide PID with dE/dx measurement
  - Full silicon tracker → need manpower increase to exploit this option
    - Are we adding too much material?
    - Need to add detector for particle identification

Some key R&D topics moving forward

- Calorimetry
  - ECAL, HCAL, DR
    - Finalize evaluation of the crystal calorimeter option
    - Cost versus physics performance
    - Cooling of PFA calorimeter? versus performance?

Some key R&D topics moving forward

- Calorimetry
  - ECAL, HCAL, DR
    - Finalize evaluation of the crystal calorimeter option
    - Cost versus physics performance
    - Cooling of PFA calorimeter? versus performance?

- Muon System optimization
  - Optimize number of layers

Optimization of detectors

Not an easy task without definite detectors/collaborations target

- Use a mixture of fast simulation and full simulation
- Need to consider engineering aspects
- Need to consider costing issues

Final remarks

CEPC CDR: http://cepc.ihep.ac.cn/

Now considering new ideas and developing new tools

Need more time to explore alternatives and test new ideas

Key accelerator and detector technologies R&D continues and are put to prototyping

Need to coordinate with engineers to study real detector feasibility

Need to expand international collaboration