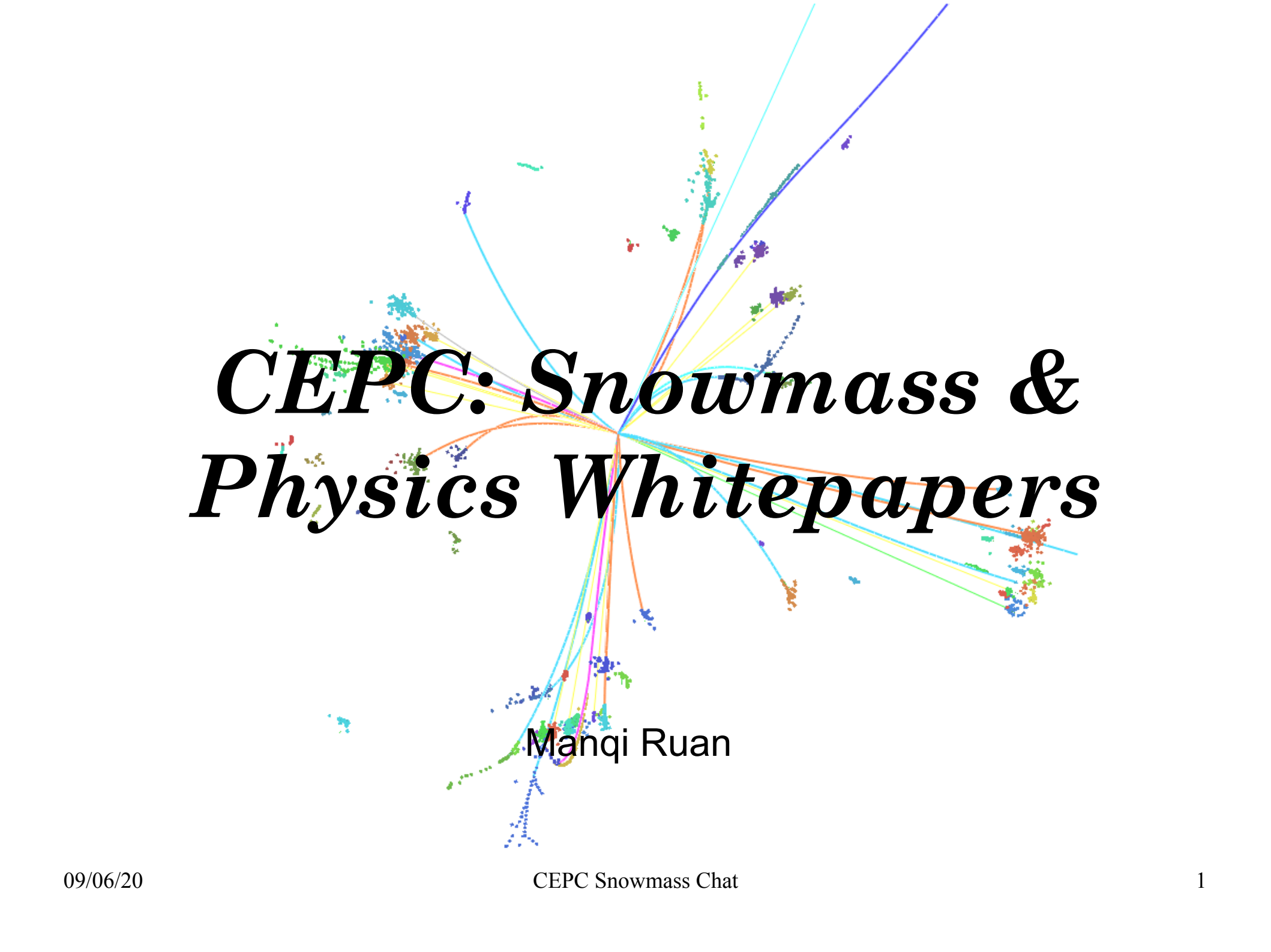


CEPC: Snowmass & Physics Whitepapers

Manqi Ruan

Snowmass 2021 (USA)

https://snowmass21.org/

Plan

decide what projects and areas at IHEP to focus on

designate persons to take up the responsibilities to prepare the documents

submit contributions, update archieve, organize activities, …

attend workshops, request and make presentations, participate in discussion

(opportunities for our young staff, postdocs, and students to learn and to engage)

……

Schedule

LOI: present - August 31, 2020

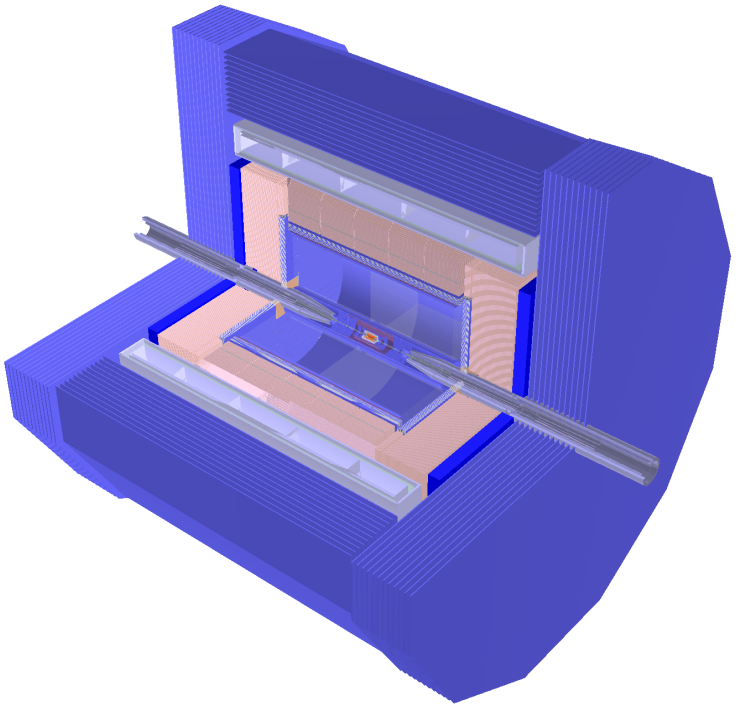
Contributed papers: present - July 31, 2020

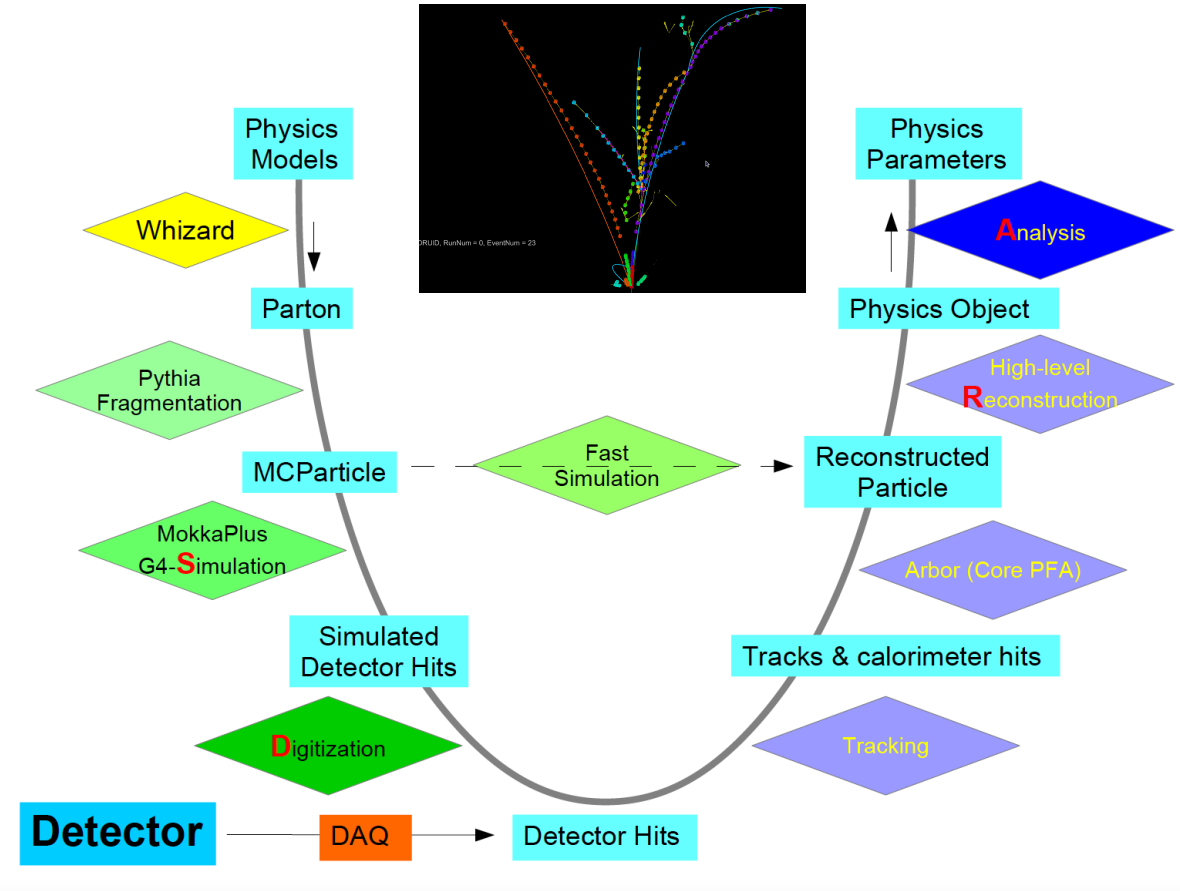
various workshops up to July 2021, when the 2021 Snowmass Summer Study (July 11 - 20, 2021 at UW Seattle) will take place

……

May 14, 2020 7

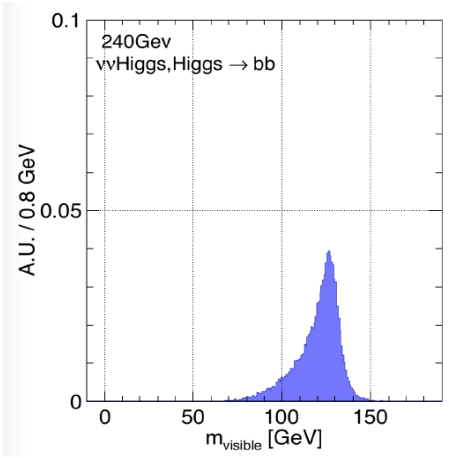
Full Simulation & Reconstruction

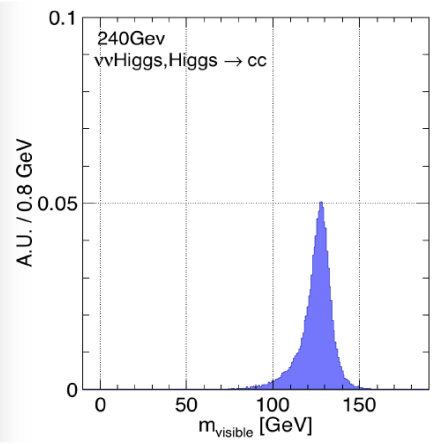


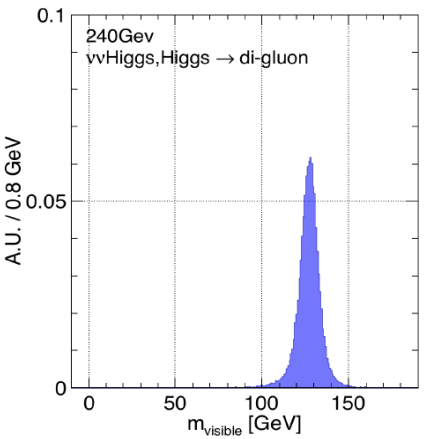


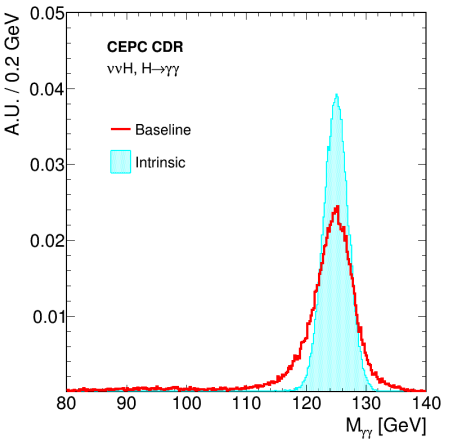
Starting from the ilcsoft & rewriting all the PFA/high-level reconstruction algorithms.

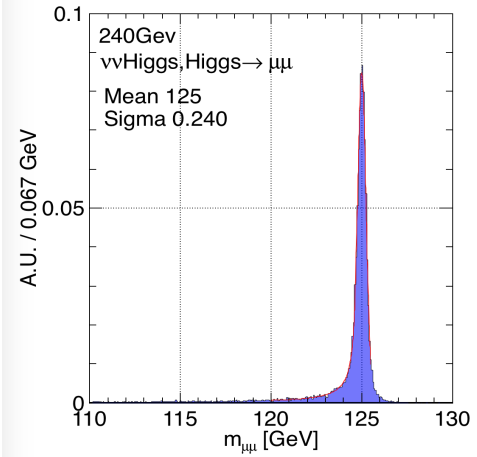
Reconstructed Higgs Signatures

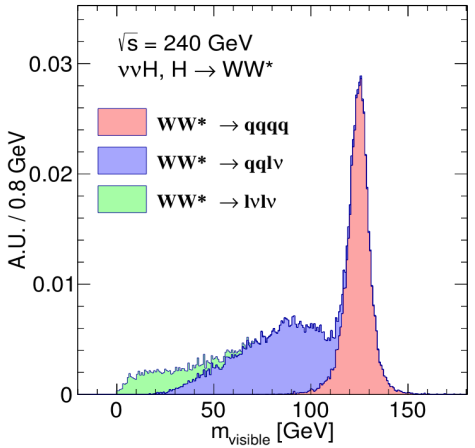


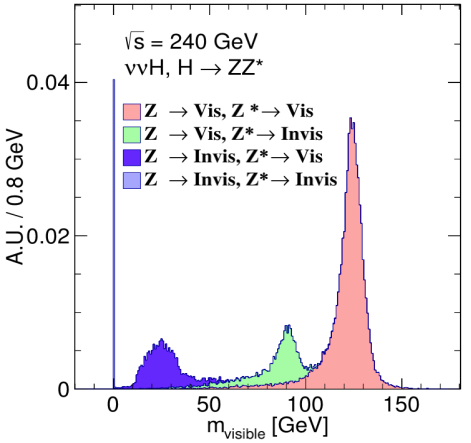


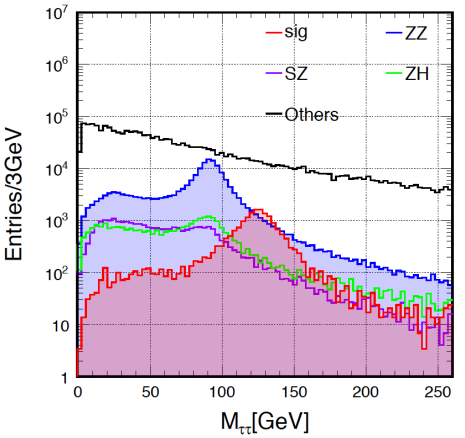












Clear Higgs Signature in all SM decay modes

Massive production of the SM background (2 fermion and 4 fermions) at the full Simulation level

Right corner: di-tau mass distribution at qqH events using collinear approximation

Delphes Card Validated by Full Sim is also available

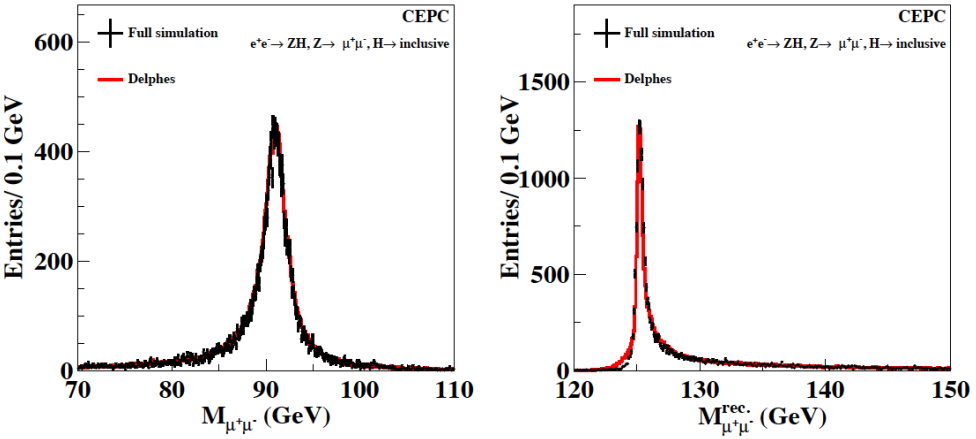


Fig. 1. The di-muon invariant mass (left) and recoil mass (right) distribution in $e^+e^- \to \mu^+\mu^- H$ events. The dot with error bar and red histogram represent respectively full and fast simulation (same in the following plots).

https://arxiv.org/pdf/1712.09517.pdf

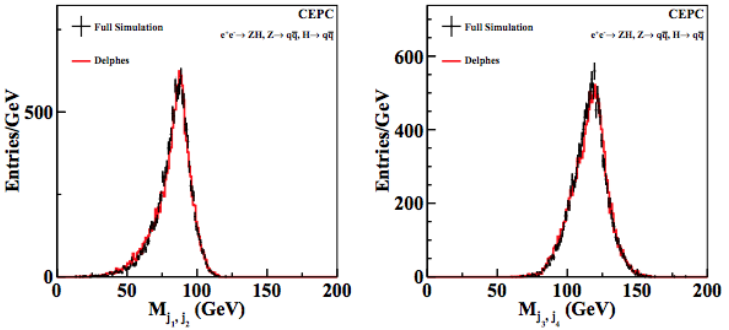


Fig. 4. The invariant mass of the jet pair corresponding to the reconstructed Z (left) and Higgs (right) systems.

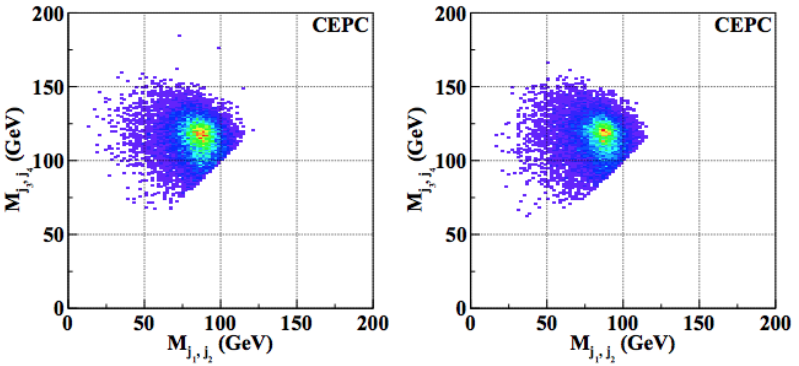


Fig. 5. The Scattering plots of M_{j_1,j_2} vs. M_{j_3,j_4} in full (the left) and fast (the right) simulation, respectively.

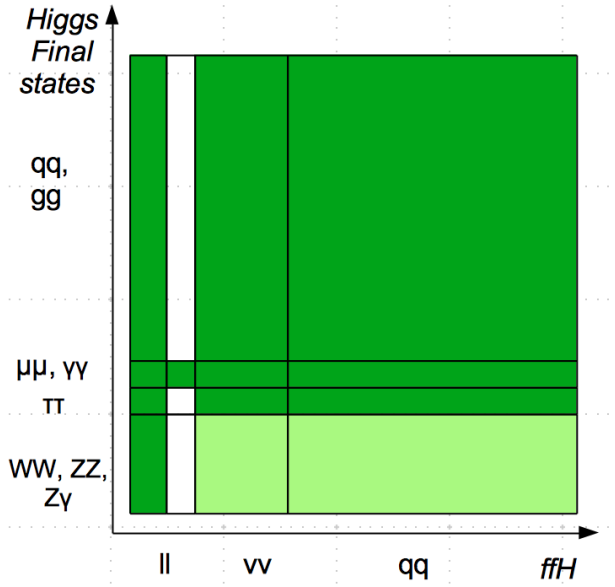
Performance validated on Lepton & Jets
Not quite on jet flavor, jet charge, photon conversion

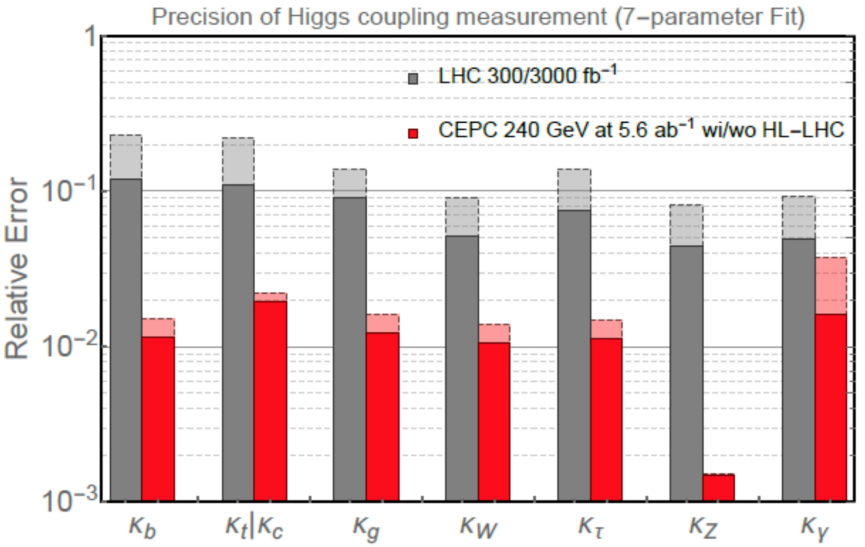
CDR Samples & consumed CPU time

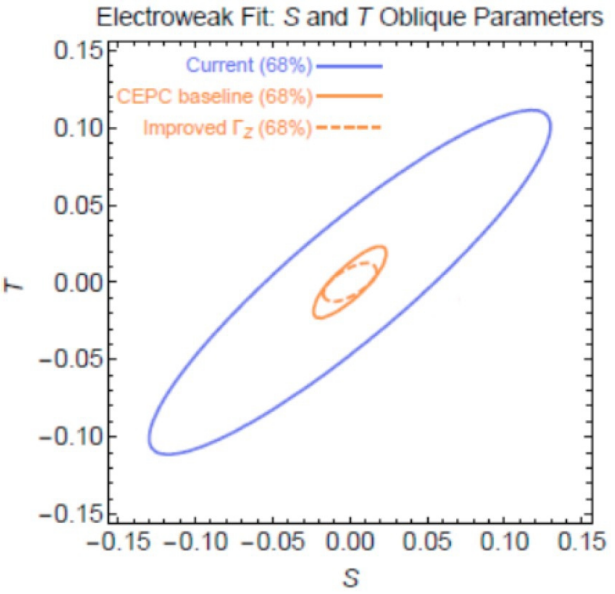
	ZH	ZZ	SM bkg (2f+4f)	Zpole
event number	1.14m	6.39m	801m+101m	10^12
generated number	1.32m+5m(with different final states)	5.9m	26m+91m	54.6m
time	2.5w	2.36w	5.2w+36.4w	10.9w
Simu	12T	6.9T	22T+104T	38T
	12T	6.9T	22T+104T	———————
Reco	No data (if need to be stored, ~130% simu size)			
Dst	1.1T	767G	4.3T+11.2T	4.4T
	854G	740G	2.9T+5.1T	———————

At a Cluster of ~1k CPU

Backbone of the CEPC physics potential study at CDR







Precision Higgs Physics at CEPC

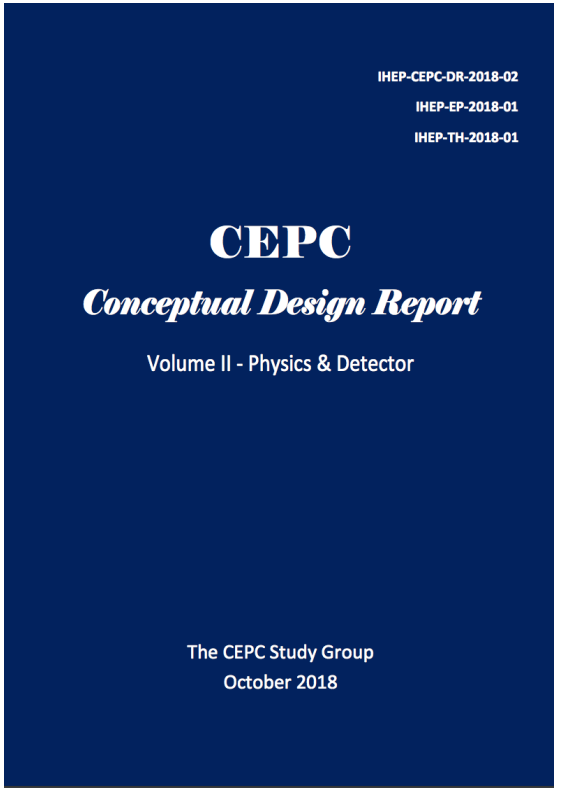
Initial assessments of Higgs physics potential at the CEPC based on the white paper (to be submitted)

Chinese Physics C Vol. XX, No. X (201X) 010201

Precision Higgs Physics at the CEPC*

Fenfen An[4,21] Yu Bai[9] Chunhui Chen[21] Xin Chen[5] Zhenxing Chen[3] Joao Guimaraes da Costa[4] Zhenwei Cui[3] Yaquan Fang[4,6] Chengdong Fu[4] Jun Gao[10] Yanyan Gao[20] Yuanning Gao[5] Shao-Feng Ge[15,27] Jiayin Gu[13] Fangyi Guo[1,4] Jun Guo[10,11] Tao Han[5,29] Shuang Han[4] Hong-Jian He[10,11] Xianke He[10] Xiao-Gang He[10,11] Jifeng Hu[10] Shih-Chieh Hsu[30] Shan Jin[8] Maoqiang Jing[4,7] Ryuta Kiuchi[4] Chia-Ming Kuo[19] Pei-Zhu Lai[19] Boyang Li[5] Congqiao Li[3] Gang Li[4] Haifeng Li[12] Liang Li[10] Shu Li[10,11] Tong Li[12] Qiang Li[3] Hao Liang[4,6] Zhijun Liang[4] Libo Liao[4] Bo Liu[4,21] Jianbei Liu[1] Tao Liu[14] Zhen Liu[24,28] Xinchou Lou[4,6,31] Lianliang Ma[12] Bruce Mellado[17] Xin Mo[4] Mila Pandurovic[16] Jianming Qian[22] Zhuoni Qian[18] Nikolaos Rompotis[20] Manqi Ruan[4] Alex Schuy[30] Lian-You Shan[4] Jingyuan Shi[9] Xin Shi[4] Shufang Su[23] Dayong Wang[3] Jing Wang[4] Lian-Tao Wang[25] Yifang Wang[4,6] Yuqian Wei[4] Yue Xu[5] Haijun Yang[10,11] Weiming Yao[26] Dan Yu[4] Kaili Zhang[4,6] Zhaoru Zhang[4] Mingrui Zhao[2] Xianghu Zhao[4] Ning Zhou[10]

https://arxiv.org/pdf/1810.09037.pdf



Focus w.r.t CDR studies

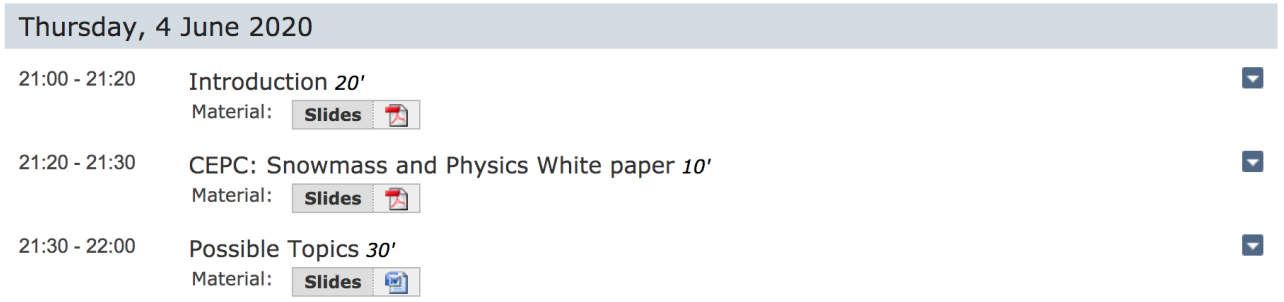
- Objective: Better quantification on
  - The CEPC **Physics Potential** On Flavor, EW, QCD, BSM, ... and Higgs
  - The Detector **Physics Requirements**
  - Feasibility & Optimization for the **Detector Design** (subdetector & integration) +
  - In addition: Software Frame, reconstruction algorithm, Computing development

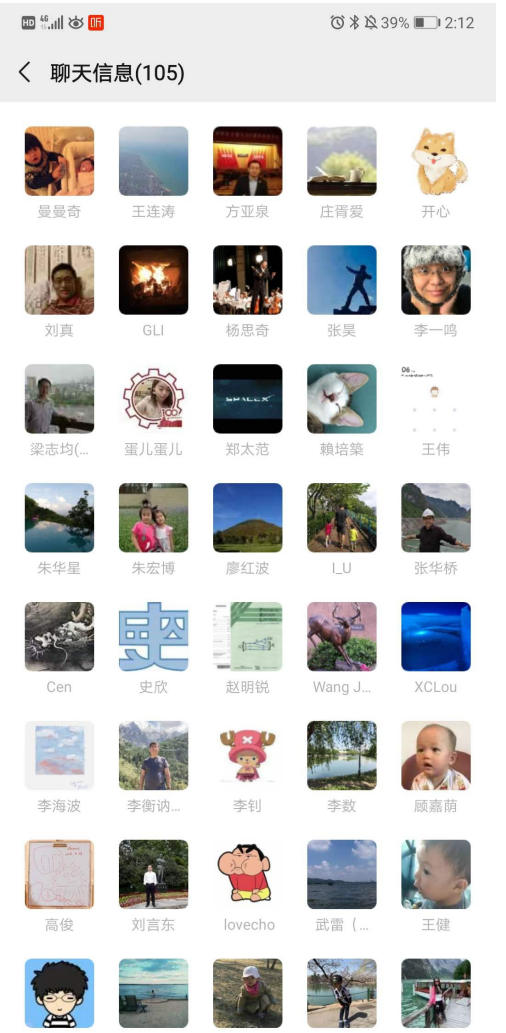
- Needs clear benchmarks + analyses with clear standards (interfaces) and sufficient communication

Domestic community: activating

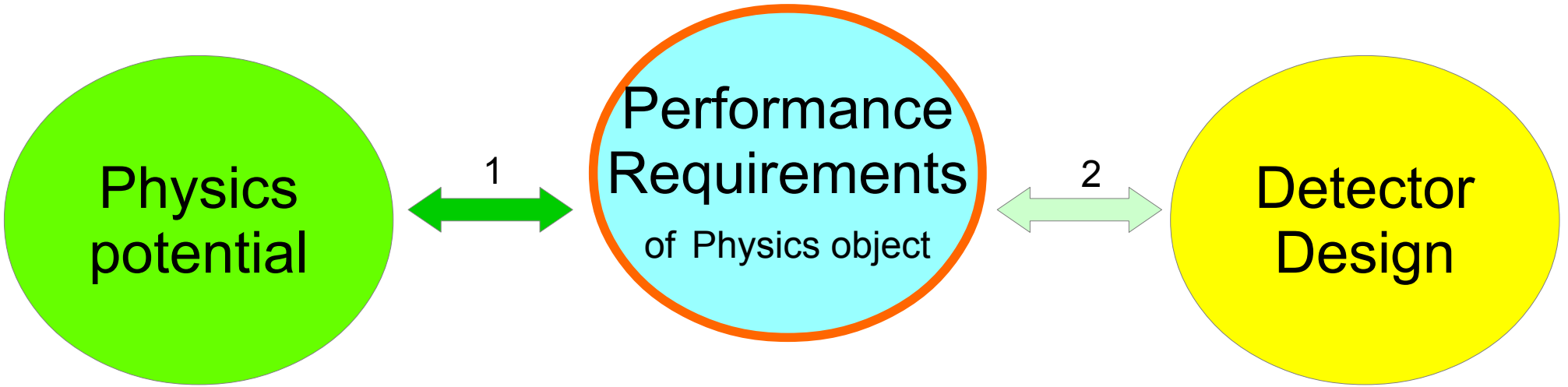
Topical Group Pages

- EF01: EW Physics: Higgs Boson properties and couplings
- EF02: EW Physics: Higgs Boson as a portal to new physics
- EF03: EW Physics: Heavy flavor and top quark physics
- EF04: EW Precision Physics and constraining new physics
- EF05: QCD and strong interactions: Precision QCD
- EF06: QCD and strong interactions: Hadronic structure and forward QCD
- EF07: QCD and strong interactions: Heavy Ions
- EF08 - BSM: Model specific explorations
- EF09 - BSM: More general explorations
- EF10: BSM: Dark Matter at colliders





Bridging: essential for the CEPC MC study



- 1st bridge: To illustrate the accuracy dependence on the performance, mostly Via dedicated Fast Simulation, Validated by Full Simulation
- 2nd bridge: To model the dependence of performance on detector design (technology & geometry), via Full Simulation + Validated by Test beam/cosmic
- CDR Baseline provides a fixed point for all those scans...

Self-organization with external potential

Names

	EF01	02	03	04	05	06	07	08	09	10
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LoI for Snowmass 2021. Deadline: end of August

1. LoI two pages. It should be an indication of a topic one would like to work on (should be **deliverable**) . Snowmass conveners will use these as a way of assessing the landscape of ideas.

2. After submitting the LoI, subsequent work should lead to a set of results. These can be publishable papers. It will also be contribution to the Snowmass. Such contribution due end of July 2021.

Topics

Possible topics

1. Higgs properties

Interference effect in higgs coupling measurement

Refined predictions.

Differential observables.

Higgs Self Couplings

Key requirement on Tracker & VTX (Flavor Tagging)

2. Electroweak precision

Systematics study: focusing on one or two

WW process

TGC (remark: Jet can be measured to energy resolution of 4%, direction resolution of 1%)

Afb(b) – sin^2(theta_W) (remark: Jet Charge Measurement)

3. Flavor

Rare B decay channel study, e.g. b->sll, b->c l nu and so on

Z and Higgs flavor violating decay

Physics Object at Jet and corresponding Benchmarks:

- Tau in the Jet: Bc->Tauv
- Lepton in the Jet: B/C meson Leptonic decay
- Pi-0: Z->tautau, Br(tau->X)
- MET at Jet: leptonic decay of Heavy Flavor Mesons, Bs->Phi+vv

…

4. Precision calculation

Corrections to Zh and other EW observables, ttbar. Not full calculation. Is there a doable (on a year scale) project here?

5. QCD

Alpha_s projection (c.f. FCC-ee)

Gluon/quark differentiation

Other event shape

Quarkonium physics?

http://ihepbox.ihep.ac.cn/ihepbox/index.php/s/x9L1ITEJaBoZac6

Tasks & Actions

- Maintain a regular software release/validation with clear manual/release note
- Increase the accessibility of sample (depends on the actual demands from the analysts)
- Maintain the existing software, especially the Delphes based Fast Simulation
- Process future production is necessary (360 GeV?)

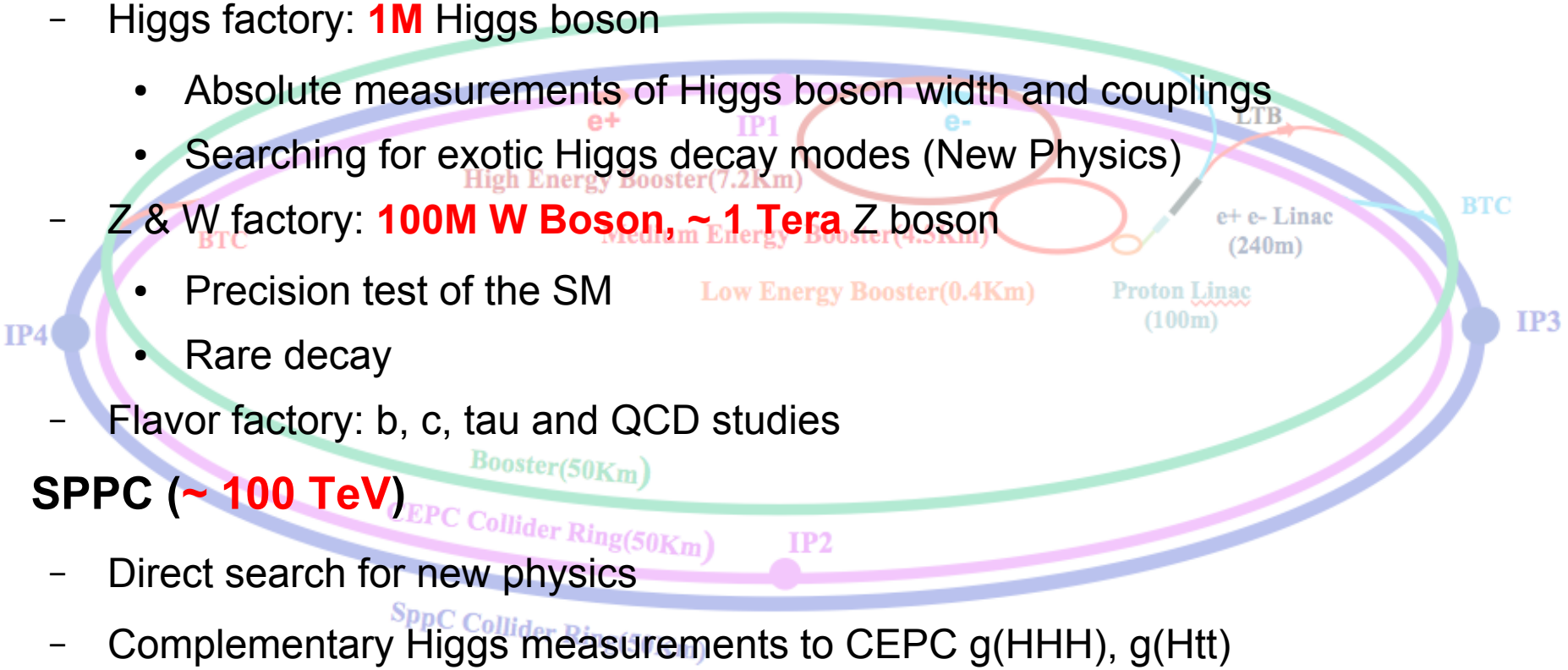
Back up

MC Task

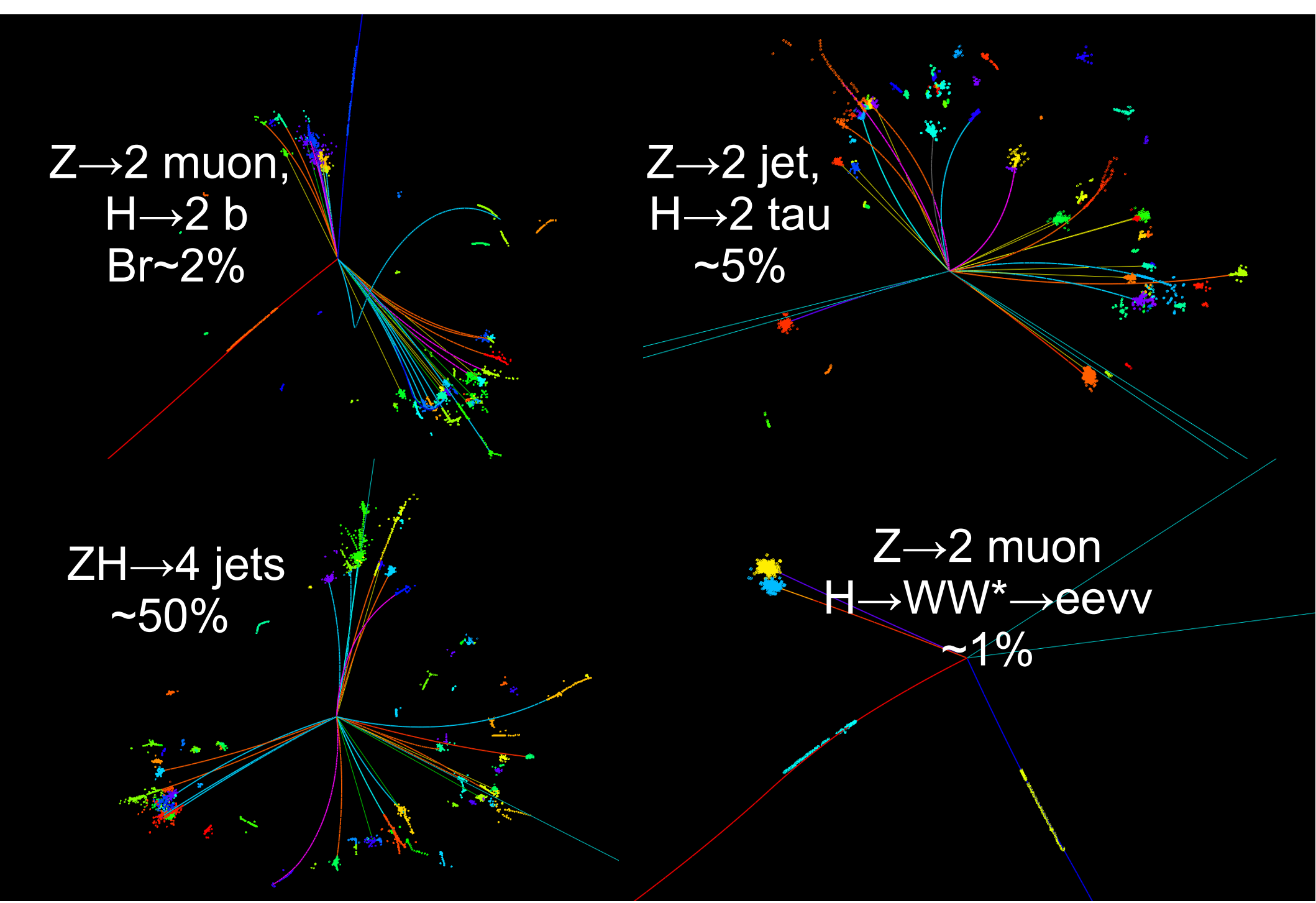
- The CEPC MC Studies is supported by the Computing Center of IHEP
- The access of sample & software support is not ideal
  - Most works are operated with IHEP Cluster
  - Software releases at: http://cepcsoft.ihep.ac.cn/
- The Communication between the analyzer + pheno/theory, the MC Force, the CEPC sim team is essential:
  - What scientific problem the analyzer focus, what synergies can be made with existing/on going studies, what support she/he actually needs
- Depends on the actual demands/needs, the CEPC simulation group are happy to collaborate, to overcome the technical difficulties
  - Accessibility of Samples
  - Production of New Samples
  - Allocation on computing resource
- EF Conveners will play an important role...

Science at CEPC-SPPC

- **Tunnel ~ 100 km**
- **CEPC (90 – 250 GeV)**
  - Higgs factory: **1M** Higgs boson
    - Absolute measurements of Higgs boson width and couplings
    - Searching for exotic Higgs decay modes (New Physics)
  - Z & W factory: **100M W Boson, ~ 1 Tera** Z boson
    - Precision test of the SM
    - Rare decay
  - Flavor factory: b, c, tau and QCD studies
- **SPPC (~ 100 TeV)**
  - Direct search for new physics
  - Complementary Higgs measurements to CEPC g(HHH), g(Htt)
  - ...
- **Heavy ion, e-p collision...**



Complementary


Z→2 muon,
H→2 b
Br~2%
Z→2 jet,
H→2 tau
~5%
ZH→4 jets
~50%
Z→2 muon
H→WW*→eevv
~1%

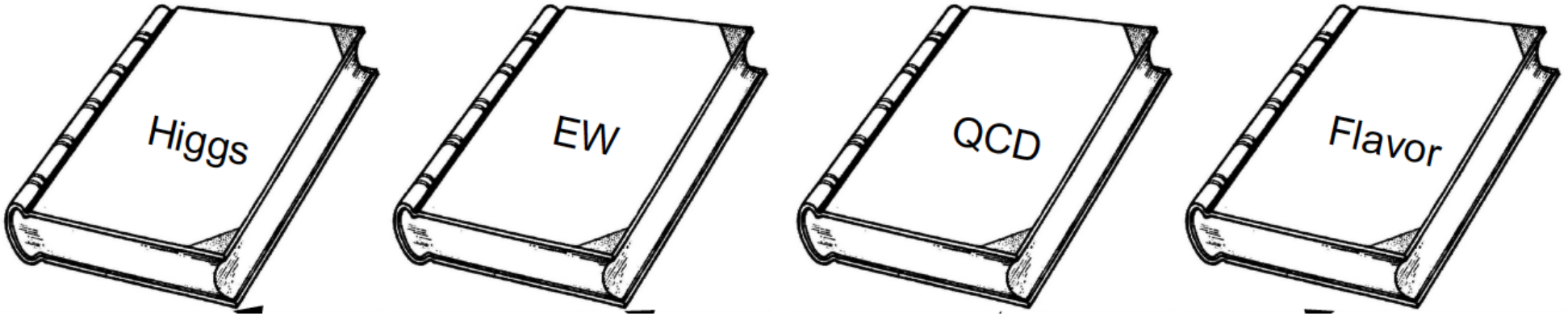
Supported Study & Publication

- A lot...

CDR released in Nov. 2018

- Higgs Physics Potential: Very well quantified in CDR
- More studies & Quantifications, is actually needed for other Physics searches:
  - EW, Flavor, QCD, BSM...

Objectives of this workshop



- To promote the physics study at TDR & to converge to the Physics White Papers
- Physics white papers:
  - Physics handbooks for new comers: PostDoc/Student
  - Official references for the physics potential
  - Guideline for future detector design/optimization

Snowmass

Topical Group Pages

- EF01: EW Physics: Higgs Boson properties and couplings
- EF02: EW Physics: Higgs Boson as a portal to new physics
- EF03: EW Physics: Heavy flavor and top quark physics
- EF04: EW Precision Physics and constraining new physics
- EF05: QCD and strong interactions: Precision QCD
- EF06: QCD and strong interactions: Hadronic structure and forward QCD
- EF07: QCD and strong interactions: Heavy Ions
- EF08 - BSM: Model specific explorations
- EF09 - BSM: More general explorations
- EF10: BSM: Dark Matter at colliders

Benchmark & Quantification

味物理本身是极为丰富的，而不同的味物理实验设施各有特色，具有明显的比较优势。因此，标志性测量的适当选取，是明确 Higgs/Z 工厂在味物理上的物理目标、量化其物理潜力、明确其比较优势，进而量化探测器需求的前提条件。这是 CEPC 实验设计的重要前提和不可或缺的研究，可以说没有这些量化分析探测器的要求，CEPC 上的味物理仅是一纸空谈。

From Haibo & MQ

Valid for all CEPC Physics Potential Studies...

Action

- Actively participate the Snowmass discussion
- Make proposals – (LoI), better benchmark based
  - Snowmass LoI before Aug. 31, 2020
  - Realistic modeling estimation with Pheno, Fast/Full Simulation at CEPC
- Accomplish the analyses at those proposal, converge to Snowmass Proceeding (July 31, 2021) & CEPC citables, which eventually become the backbone of CEPC White papers...

- The CEPC Simulation study group:
  - We are good at
    - Relative Reliable Estimation on the corresponding physics performance
    - Rough Estimation in the background, based on CDR samples – SM samples
  - Current bottleneck: man power (analysts), pheno studies (motivation & interpretation)
- Active iteration, till converge