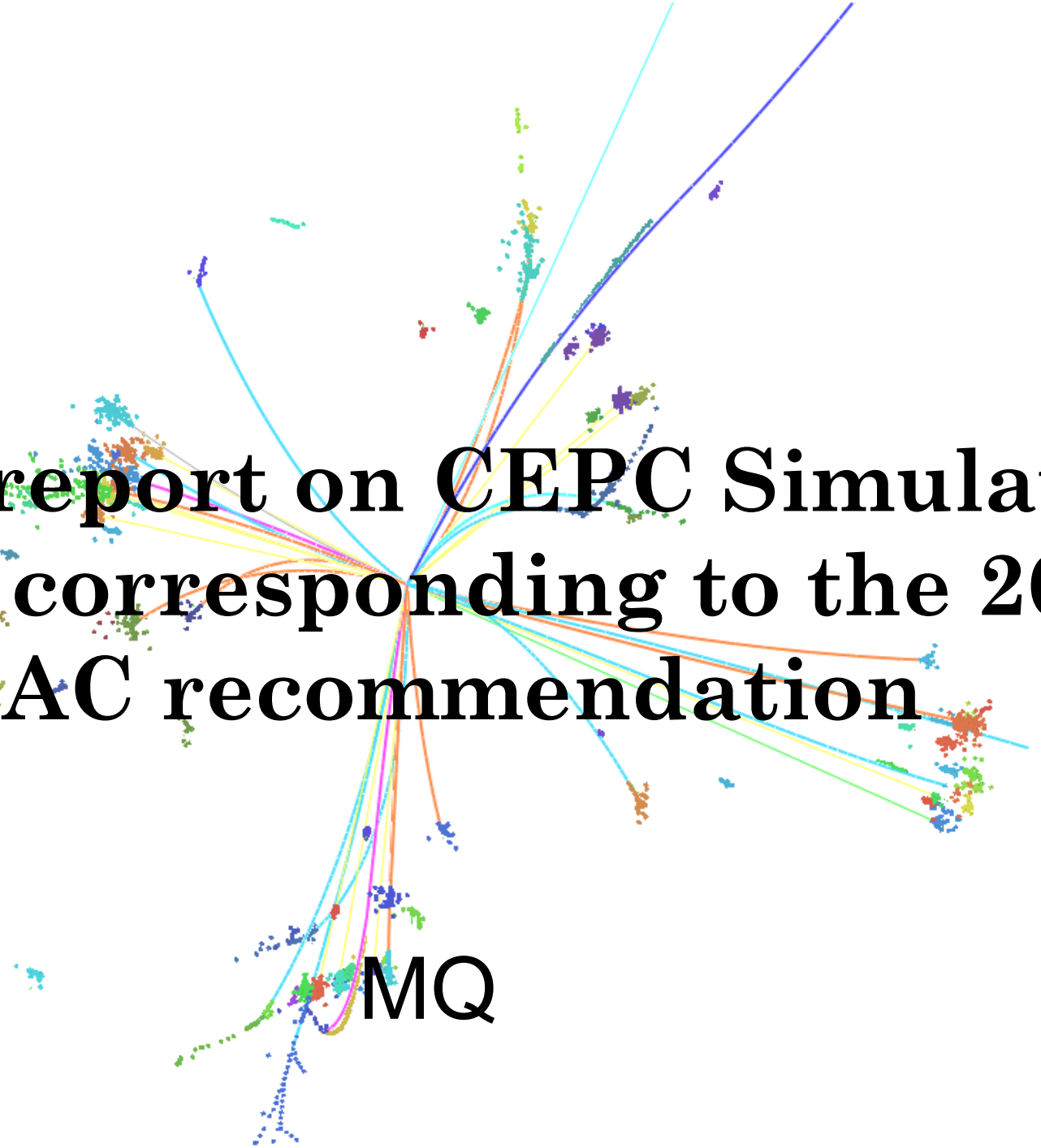

Status report on CEPC Simulation study: corresponding to the 2019 IAC recommendation

MQ

From IAC report 2019

Other recommended detector and physics studies:

Recommendation 16:

- *Perform detailed simulation studies to better understand the physics needs from the detector at the various CEPC energy stages; draw consequences about the corresponding detector performance requirements (e.g. photon resolution, jet resolution, added value of PID) and study how this influences the detector design.*
- *Study the physics case for performing flavor physics including the tau lepton at the Z-peak. Draw conclusions on a possible impact on the detector design.*
- *Given that time-of-flight detectors with a time resolution in the 30-50 ps are becoming available, study their potential added value for a CEPC detector by assessing a few key physics benchmarks.*
- *Assess the added value of dE/dx capabilities in the tracker.*
- *Assess the added value of the muon detector system. As a result, define the number of muon detection layers to include, together with their required performance.*

From IAC report 2019

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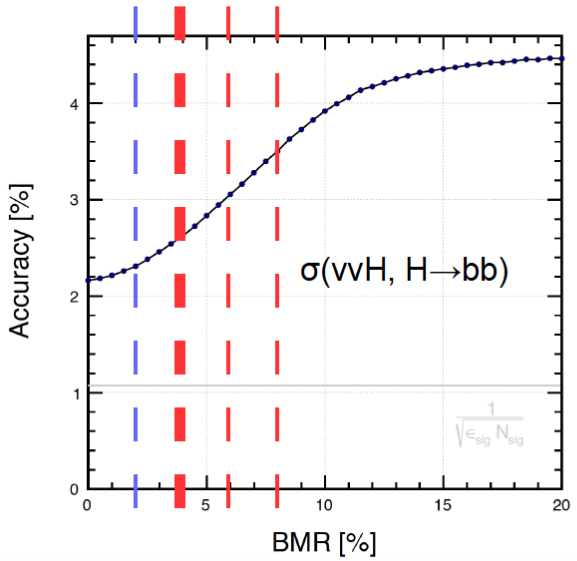
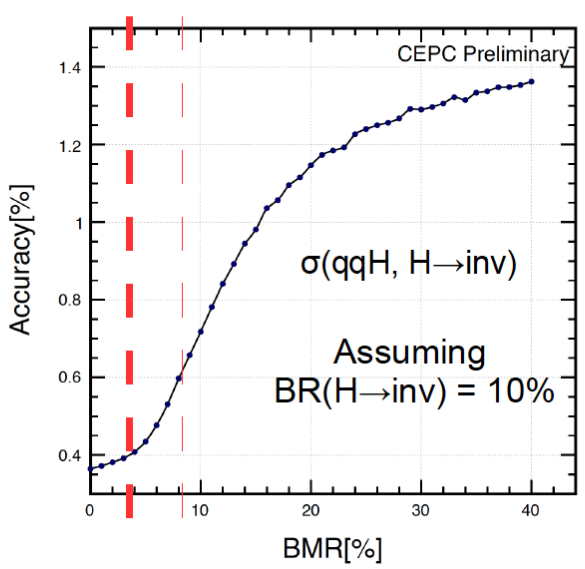
- Key words: Requirement, and Flavor

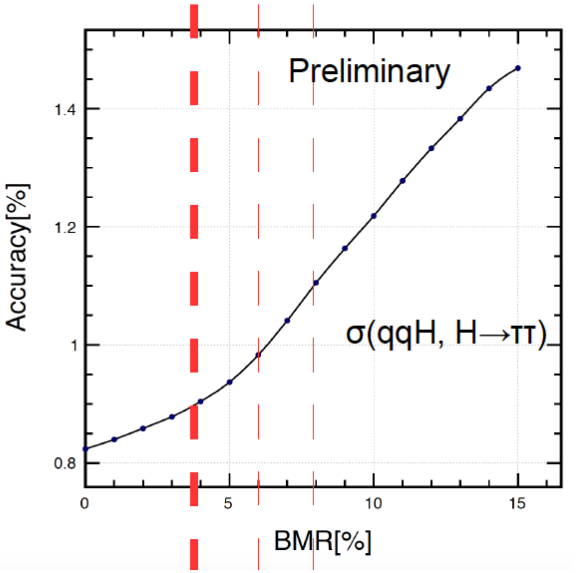
CEPC Physics requirements

- Higgs & Top
  - Jet
  - VTX
  - Leptons, mostly isolated
- WW: beam energy
- Z pole
  - EW: beam energy & luminosity
  - Flavor:
    - Object identification & finding, especially inside jets
    - Reconstruction of VTX and jet charge
    - Momentum/Energy resolution

Requirement from benchmark analysis: BMR < 4%







- Boson Mass Resolution: relative mass resolution of vvH, H→gg events
  - Free of Jet Clustering
  - Be applied directly to the Higgs analyses
- The CEPC baseline reaches 3.8%

	BMR = 2%	4%	6%	8%
σ(vvH, H→bb)	2.3%	2.6%	3.0%	3.4%
σ(vvH, H→inv)	0.38%	0.4%	0.5%	0.6%
σ(qqH, H→ττ)	0.85%	0.9%	1.0%	1.1%

BMR: an example from Higgs measurements
Goal: Provide similar plots for Flavor Benchmarks

CEPC Flavor Physics

- Haibo, etc:
  - Excellent overview of the CEPC flavor physics at the PreCDR/CDR.
  - Could be significantly enhanced - quantified by Benchmark analyses
- Strong interests from collaboration
  - July 2019 CEPC Physics WS at PKU, 70 participants, more than 1/3 are flavor physics oriented. Call for CEPC Flavor Physics Report, many ppl participated
  - Topical discussion/group works continues
  - Further discussion occurs at Jan 2020 Hongkong IAS workshop
- Since 2017, Resource & Manpower are steadily allocated on the flavor performance & analyses studies – but need reinforcement
  - Flavor Physics is very rich, and sometime complicated/subtle
  - Need to carefully compare to LHCb/Belle-II, dedicated, very competitive flavor factories

Working Group and Conveners

Chapter One: Introduction
Conveners: Hai-Bo Li, Jonathan Rosner

Chapter Two: Leptonic and semileptonic b-hadron decays ← Sebastien Descotes-Genon
Conveners: Sebastien Descotes-Genon , Jeorme Charles, Abner Soffer,Florian Bernlochner, Bob Kowalewski

Chapter Three: b-hadronic decays and CP violation ← Abi Soffer
Conveners: I.I. Bigi, Chao-Qiang Geng, Abner Soffer, Yue-Hong Xie
Yu-Kuo Hsiao

Chapter Four: Rare and forbidden b-hadron decays
Conveners: Wolfgang Altmannshofer, Soeren A. Prell, Emmanuel Stamou

Chapter Five: Charm physics ← Marek Karliner & Jon Rosner
Conveners: Chun-Hui Chen, Hai-Yang Cheng, Jonathan Rosner
Hai-Yang Cheng

Chapter Six: Exotic hadron and Spectroscopy with heavy flavors ← Marek Karliner & Jon Rosner
Conveners: Marek Karliner, Jonathan Rosner, Wei Wang

Chapter Seven: τ Physics ← Lorenzo Calibbi
Conveners: Emilie Passemar, Emmanuel Stamou, Lorenzo Calibbi

Chapter Eight: Flavor physics in Z decays ← Lorenzo Calibbi
Conveners: Wolfgang Altmannshofer, Lorenzo Calibbi

Chapter Nine: Two photon and ISR physics with heavy flavors ← Vladimir Bytev
Conveners: S. I. Eidelman, Alexey Zhemchugov, D. Dedovich, Lian-Tao Wang ??

Chapter Ten: Summary and Conclusion
Conveners: Hai-Bo Li, Manqi Ruan
Dan Yu & Taifan Zheng

Flavor: Performance and Analysis

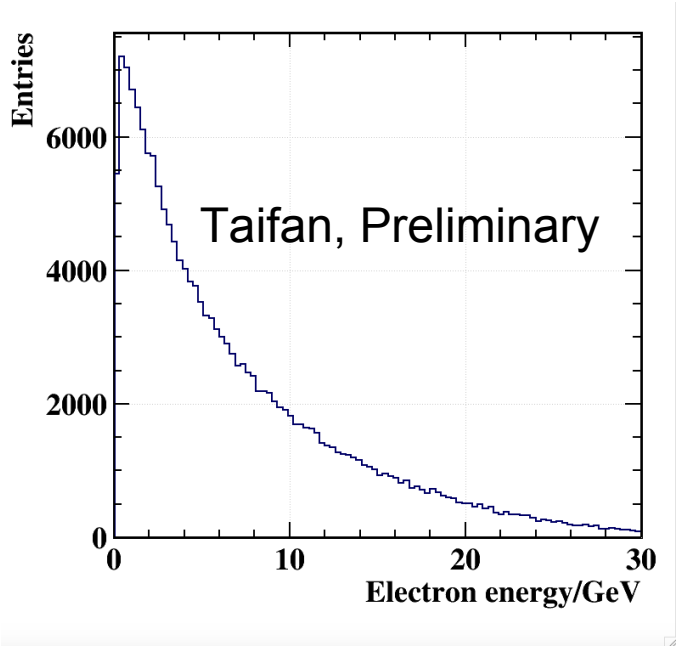
- Flavor: Tera Z data cannot all be processed with Full simulation
- Method
  - Performance via Full Simulation:
    - Understand the dependence on detector, provide different working curve/working points
  - Physics analysis relies strongly on Fast Simulation.
    - MCTruth level analysis – ideal detector – analysis the irreducible background;
    - Smearing: irreducible background with different detector resolution;
    - Identification: contamination by mis-id (using different working point provided by the full sim studies)
  - Theory interpretation (i.e. Wei Wang from SJTU)

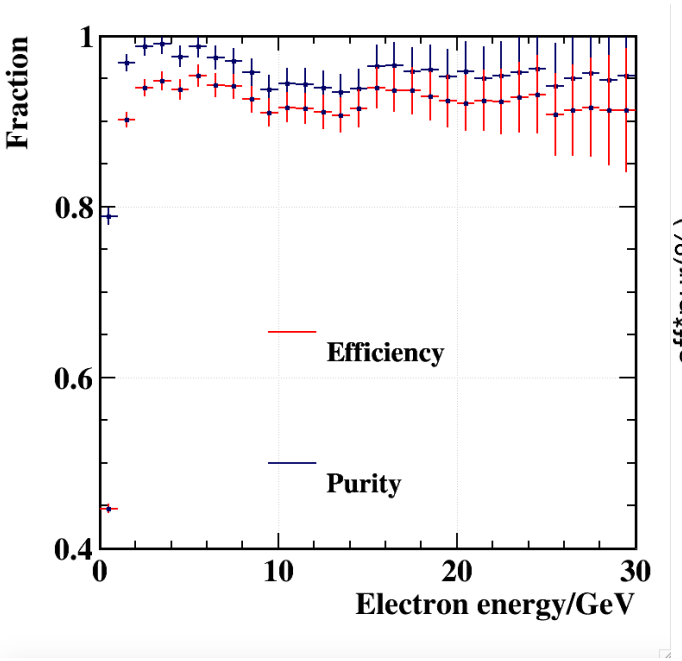
Performance

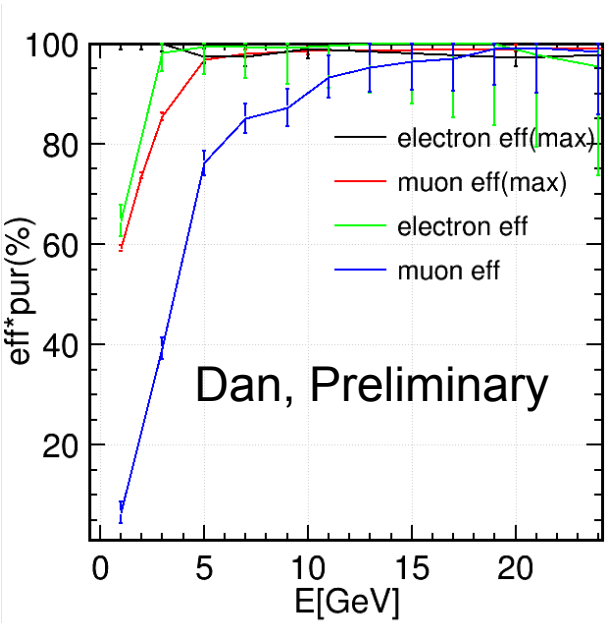
- Isolated Leptons (EPJC 2017):
  - *Baseline provides excellent identification for isolated Lepton with energy > 2 GeV, without muon chamber.*
- VTX Optimization on Flavor tagging (JINST 2018)
  - *Closer > Lighter > Smaller Pixel*
- Pid (EPJC 2018)
  - *eff & purity of 95% at Z->qq samples, for tracks with E > 2 GeV*
- K_long, Lambda performance (EPJP accepted, 2020)
  - *Inclusive eff of 40%/30% achieved with purity > 90%*
- Photon/pi-0 reconstruction performance (EPJP submitted)
  - *pi-0 with E < 30 GeV can be successfully reconstructed*
- Jet lepton identification (On going)
  - *Degrading induced by the separation/calorimeter - clustering performance*
- Jet Charge measurement using Kaon, Lepton, and VTX charge (initiated)
  - Subtle, Critical for CP and EW (AFB) measurements!

Jet leptons

- At Benchmark of Bc->Tauv->evvv
  - Baseline performance (eff*purity ~ 90%) much better than ALEPH Afb measurement with leptonic decay B (eff*purity ~ 70%) *ALEPH Collaboration / Physics Letters B 384 (1996) 414–426*







- Strong Correlation with the clustering performance identified
  - Jet lepton id performance converge to the isolated lepton case, with good clustering
  - Clustering Performance quantifies the separation/PFA performance

Flavor Physics benchmarks

- Benchmark selection
  - CEPC comparative advantage oriented
  - Physics significant
  - Simple & Representative,
  - Sud-detector performance sensitive
- Many Benchmarks proposed at PKU meeting (July 2019)
  - Sebastian Descotes-Genon: B->tau physics
  - Marek Karliner: Pc, 4/5 quark states, ISR return
  - Lorenzo Calibbi & Haibo: Tau exotic decays
  - Abi Soffer: semileptonic b-decay and CP violation
  - Wenbing: CP measurement via J/psiphi
  - Yu-Kuo: Baryonic B-decay...
- Half of these topics are covered by current flavor physics analysis

Benchmark analyses: status

- Bc -> tau+v -> e + 3v (In finalization, by Taifan Zhen, Fenfen An, Lu. Cao)
  - *Rely on the flavor tagging (Z->bb), jet lepton identification*
  - *Percentage level accuracy could be achieved at the CEPC*
  - *Current identification of jet lepton is good enough for this channel*
- B0 -> J/psi + Phi -> mumu KK (by Mingrui Zhao of 401)
  - *Rely on the Jet Charge measurement,*
  - *MCTruth level study, to mount/Xcheck corresponding performance study*
- Tau -> muon + photon (by Yudong Wang, etc)
  - *Photon energy resolution, lepton id*
  - *MCTruth + Smearing level.*
- b -> stautau (by Linfeng Li of HKUST)
  - *Reducible background might strongly limit the final accuracy*

Flavor Physics benchmarks + Key performances

	B->tau	B semileptonic	B Baryonic	Tau	CP	Pc
Flavor Tagging	Y	Y	Y		Y	
Jet lepton	Y	Y		Y		
Pid			Y		Y	Y
Jet Charge					**Y**	
ECAL	Y	Y	Y	Y	Y	Y
Tracker			Y	Y	Y	Y
Current Benchmark	Bc→tauv→ evvv; B→stautau			Tau exotic decays	B0 → J/psi + Phi → mumu KK	

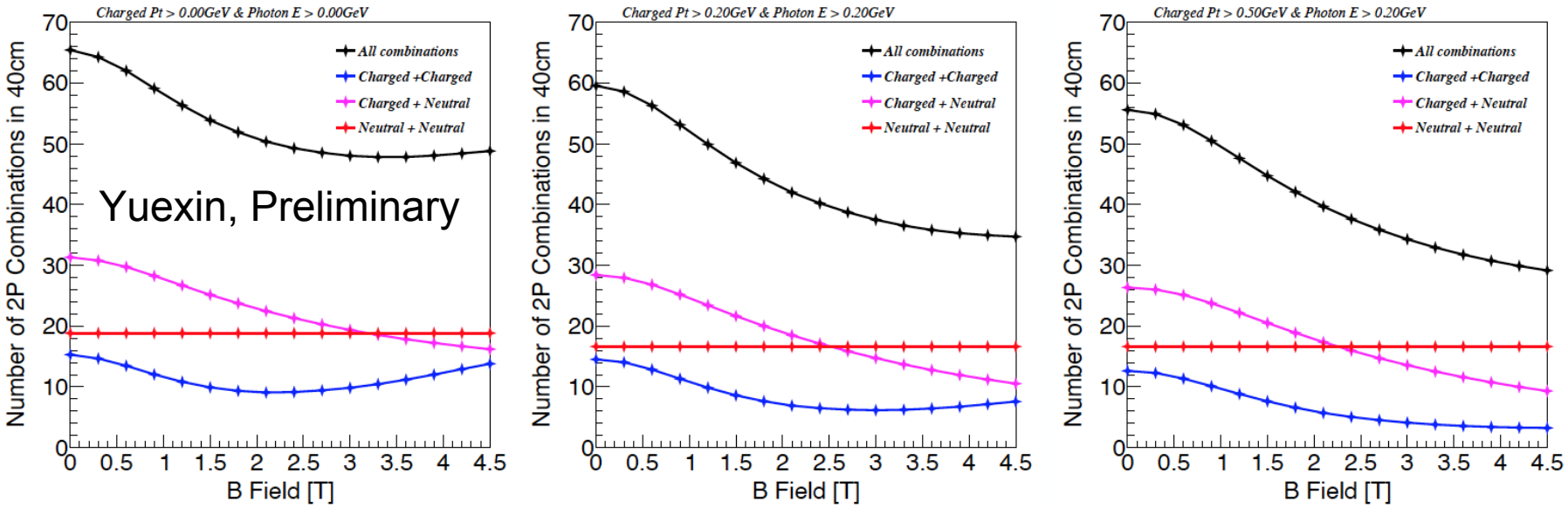
Jet charge measurement is a significant advantage V.S. LHCb. Need to quantify the performance

Goal: CEPC Flavor Physics white paper (report)

- The IAC recommendation shall be addressed by this report and corresponding supporting studies/citables
  - Landscape of CEPC flavor program + A series of Benchmark analysis
  - Performance – requirement analysis
  - Physics interpretation and comparison with other facilities
- Timeline: Many performance/benchmark studies will take lots of time. Status report can be made in 2020 IAC meeting.
- Difficulties: Lacking of manpower and communication
  - Many topics – important topics, such as the VTX reconstruction and jet charge measurement, are very subtle and need lots of experiences.
  - The current analysts – for example my students – are good at performance but lacking flavor physics experiences
  - Key physics benchmark analysis would be, ideally composed of actually analysts from other experiments, analysts, and theorists
  - Topical WS would be very helpful – not easy now

Other updates

- Higgs invisible concluded: By Yuhang & Xin, Submitted to CPC
- Br(H→bb, cc, gg) measurement via qqH: Progressing (Yongfeng)
- Separation requirement analysis: By Yuexin Wang
- Jet response at 2/4 jets: by Peizhu Lai, Finalization Phas
- Detector Optimization with respect to BMR: Yukun, Dan, etc
- Discussion with IDEA about common Generator sample



Conclusion

- The IAC recommendation is highly consistent with current CEPC simulation efforts: requirements, performance, analysis, and flavor physics
- Plan to address the IAC recommendation by the CEPC flavor physics white paper and corresponding documents. Performance – accuracy plots analogy to the BMR – Higgs accuracy plots shall be included.
- CEPC flavor simulation/analyses need to combine different methods:
  - Performance via Full Simulation and Analysis relies on Fast Simulation.
  - Proper modeling of the identification & reducible background contamination
- Significant progress on the flavor physics simulation
  - Good progress/coverage in Performance & object reconstruction
  - Multiple benchmark channels proposed, and half are covered by current analysis

Conclusion

- Strong interests
  - Involvement of HKUST, 401, SJTU, Shanxi Normal University, etc
  - Domestic experts can be further activated...
  - Many international leading experts
- Difficulties: manpower & communication
  - The flavor physics is very rich and sometime complicated, and facing strong competition from LHCb/Belle-II
  - Dedicated Workshops, to review the progress on physics studies, conclusions, and report writing are essential
  - The Corona Virus brings extra difficulties/uncertainties
  - Extra manpower, Postdoc - analysts, and supporting for the WS would be really helpful. Especially towards the Jet Charge measurement