Vision of Future Colliders

Yifang Wang

Institute of High Energy Physics, CAS

KAIST-KAIX, July 8, 2019

- The following is only my personal view
- I am not representing my organization, nor my country

Why Future Colliders ?

- Science
  - Fundamental questions:
    - Space, time, Universe, Big bang, elementary particles, unification,…
  - Immediate questions:
    - Higgs properties, EW, QCD, flavors, searches for SUSY, extra-D, compositeness, dark matter, sterile/seasaw neutrinos, …
  - Evaluation: directly or indirectly related to fundamental problems ? single or multiple purpose ? (concrete) searches or measurements ? new search territory ? sensitivity ?
  - Don’t forget about the gut feeling and luck
- Other benefits:
  - Technology, education and personal Training, etc.

What colliders to choose from?

- e^+e^-
  - Linear Collider：
    - ILC: 250 GeV, 1×10^{34} $cm^{-2}s^{-1}$, ~7B$, ~2025/2035
    - CLIC: 380 GeV, 1×10^{34} $cm^{-2}s^{-1}$, ~7B$, ~2030/2040
  - Circular Collider
    - FCC-ee: 90-350 GeV, 8×10^{34} $cm^{-2}s^{-1}$, ~10B$, ~2030/2040
    - CEPC: 90-250 GeV, 5×10^{34} $cm^{-2}s^{-1}$, ~5B$, ~2022/2030
- PP
    - FCC-hh: 100 TeV, ~1×10^{35} $cm^{-2}s^{-1}$, ~20B$, ~2050/2060
    - FCC-hh(Low), 40 TeV, ~1×10^{35} $cm^{-2}s^{-1}$, ~10+5B$, ~2030/2040
    - SPPC: 100 TeV, ~1×10^{35} $cm^{-2}s^{-1}$, ~10B$, ~2040/2050
- ep
- $\mu^+\mu^-$
    - Proton driver: muon cooling ?
    - e^+: enough intensity ?
- wake-field acceleration
    - Beam quality, power efficiency, …
    - may be used by CEPC(ILC & CLIC ?) as injectors

Sciences

- No guaranteed discoveries
- At the turning point
- Best approach?
  - "small cost" to look for hints. If yes, go for direct searches
  - My favorite:

$$\mathcal{L} = \mathcal{L}_{SM} + \sum_i \frac{c_i}{M^2}\mathcal{O}_{6,i} \qquad \delta \sim c_i \frac{v^2}{M^2}$$

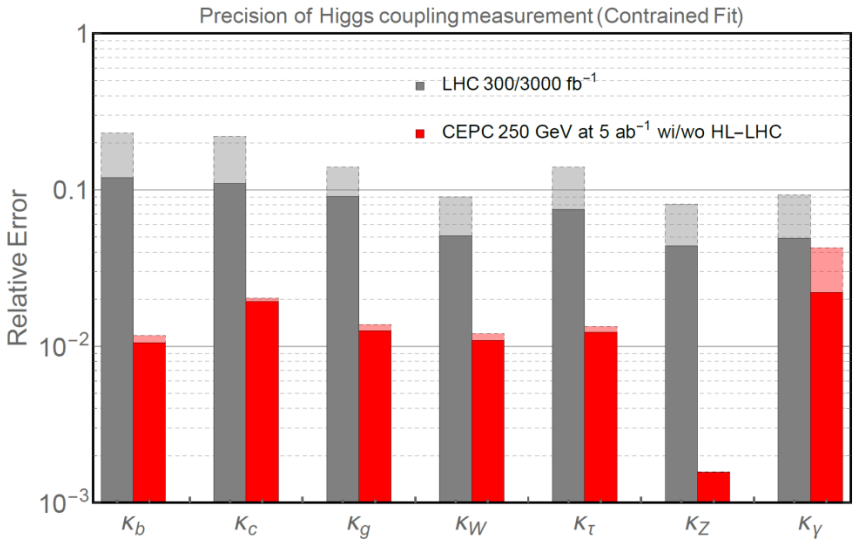
No signal at LHC:

Direct searches: M ~ 1 TeV

10% precision: M ~ 1 TeV

Look for signals at CEPC/FCC-ee:

1% precision ➔ M ~10 TeV



m_H^2 = 36,127,890,984,789,307,394,520,932,878,928,933,023
−36,127,890,984,789,307,394,520,932,878,928,917,398
= (125 GeV)^2 ! ?

10 TeV: 10^{-4} New Physics < 10 TeV ?

Technology & Innovation

- New machine should have new technologies
  - New technologies for our own advancement
    - SC technologies, SRF cavities, …
    - We need to ask for enough advancement
  - bring something new to the society, to gain public support
    - WWW, SC magnet for MRI, accelerator applications,…
    - It is hard to plan, but we should try
- New to balance feasibility, cost and aggressiveness
- Realistic possibilities ?
  - High Tc super-conducing technologies: cables, magnet, …
    - SPPC's choice: Iron-based HTC, 3-5$/(KA·m)
  - Table-top accelerators: laser/plasma accelerators
    - CEPC injector
  - SRF cavities: quantum computing ?
  - …

Money?

- Too expensive, we can only afford 1 machine in the world ?
  - The US spending(as a fraction of GDP) is less than that of 60's

BEPC: Cost/4yrs/GDP of China 1984 ≈ 0.0001
SSC: Cost/10yrs/GDP of US 1992 ≈ 0.0001
LEP: Cost/8yrs/GDP of EU 1984 ≈ 0.0002
LHC: Cost/10yrs/GDP of EU 2004≈ 0.0003
ILC: Cost/8yrs/GDP of JP 2018 ≈ 0.0002
CEPC: Cost/8yrs/GDP of China 2020 ≈ 0.00005
SppC: Cost/8yrs/GDP of China 2036 ≈ 0.0001

- Now, Asia stands for ~40% of the world economy, can we double(%GDP of 60's in the US+EU) the world HEP spending ?
- Asia countries should
  - Propose new machines, support each other, and build regional centers
  - Enhance investment in HEP from all Asia countries
  - coordinate national plans

Find new money, spend it wisely

How to get a project？

- Science & Cost: performance-cost ratio
- Feasibility: Technology, Schedule, man power, etc.
- International issues
  - Cooperation
    - A must
  - Competition
    - Also a must
    - Lessons from SSC & ILC
  - Non-science perturbation:
    - Relations between countries
    - deals between counties/regions,…
    - Personality of leaders
- We need to have some luck

Strategy: My Personal View

- Highest priority: Higgs coupling to 1%
  - FCC-ee and CEPC should proceed in parallel until one is approved:
    - Competition can enhance the chance for both
    - Higgs factory is too important to miss
  - Try to get one of the ILC and CLIC
    - Linear technology can not be ignored
    - High energy lepton collider(~10 TeV) will be needed, if new physics is discovered
    - Continue to lobby for ILC, and continue the CLIC effort
    - Only ILC/CLIC is not enough, multi-detectors needed anyway: we should forget about the push-pull option
- Major R&D effort for pp collider:
  - Aiming for (iron-based) HTC magnet(~ 10-15 yrs): FCC-hh/SPPC
  - Low energy FCC-hh(40 TeV) option lacks the technology impact
- Maintain R&D effort for $\mu^+\mu^-$ and wake-field acceleration

Welcome criticism

My view on all choices

	Science	Upgradability	Technology maturity	Low cost ?	Available now ?
ILC	****	*	****	****	*****
CLIC	****	**	***	***	****
CEPC	*****	****	****	*****	*****
SppC	****	*	*	**	*
FCC-ee	*****	****	****	****	*****
FCC-pp	****	*	**	*	**
VLHC(40 TeV)	***	**	****	***	*****
Muon collider	*****	**	?	?	?
Plasma	*****	**	? ?	***	?