Physics Motivation



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Understanding & Exploring

Particle physics is about addressing fundamental questions:



- Where did we come from?
- Where are we going?
- What are we made of?
- How does it all work?

We seek to **understand** what we see and **explore** where we cannot yet see.

The Path to Discovery



The Path to Discovery





as a tool of understanding





The Higgs Boson

July 2012: historic discovery @ LHC





Since then, considerable progress studying it @ LHC

Its properties match Standard Model predictions to ~20%

Higgs Precision



To Understand the Higgs

For all the excitement of discovery, we still know *very little* about the Higgs



It appears to be a particle without *intrinsic spin*. We have seen spinless **composite particles** before. We have never seen an **elementary** spinless particle!



Is it elementary, or composite?

The Standard Model predicts that it interacts with itself, unlike any other particle in nature.

Does it interact with itself?

A Spinless Particle?

Have seen spinless particles in nature already, e.g. η (quite composite!) and π ("mostly composite") mesons



Composite in the sense that they have finite size and are made of more fundamental constituents

 $\sim 1.4\,\mathrm{fm}$



CEPC will probe size of the Higgs well beyond this, providing strong evidence that the Higgs is elementary. *If not, an abundance of new physics awaits.*

A Self-interacting Particle?

The Standard Model Higgs is predicted to interact with itself

If so, it would be unlike anything yet seen in nature (all other interactions change particle identity)



Higgs self-interactions will remain unresolved by LHC. The CEPC can provide compelling evidence for this self-interaction. *Any deviations would point to a wealth of unforeseen new physics.*

A Quantum Probe

Classically test Higgs self-coupling via Higgs pair production.

Quantum mechanically test Higgs self-coupling via virtual corrections.



Powerful measurement of selfcoupling even allowing *many* modifications of Higgs properties in, conjunction w/ LHC data



Deep Implications



How is electroweak symmetry broken?

What is the fate of the universe?



The Value of Understanding

By studying the Higgs boson at the CEPC,

 Either we will discover something *never seen before* in nature (a spinless, self-interacting elementary particle)...



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 ...or we will discover evidence for an *abundance of new and unexpected* particles.



Even more: precision electroweak; flavor; precision QCD

as a tool of exploration





Known Unknowns







We know there is more beyond the Standard Model: **Dark Matter**

85% of the matter in the universe! Only infer its existence via gravity.

We only know about dark matter because it is *stable*; could be just one among a plethora of new particles in nature

Dark matter need not be a single, simple particle



Could well be an entire *dark sector* as diverse as the Standard Model

...and much more

??????

Hierarchy problem

Neutrino mass

Dark matter

Discovering the Unknown

How to discover new particles? As we always have: through their interaction with *fundamental forces*





Strong force

> Weak force

A New Force

The Higgs boson mediates a new fundamental force

A subtle force: significantly weaker than the others



 $\frac{V_{\rm Higgs}(r)}{V_{\rm Weak}(r)} \sim \frac{y^2}{g^2} e^{-(m_h - m_Z)r}$

An entirely new tool for discovery

Precision of the CEPC makes it an ideal collider

Dark Matter & Higgs

An example: dark matter interacting via the Higgs





95% C.L. upper limit on selected Higgs Exotic Decay BR



A Quantum Probe

CEPC can also probe new particles interacting via the "Higgs force" purely through their quantum effects





Implications for:

- Baryogenesis
- Hierarchy problem
- Dark Matter



Physics of the CEPC

- CEPC is a **machine for understanding**: an unprecedented tool for studying the Higgs and observing phenomena never before seen in nature.
- CEPC is a **machine for exploring**: a collider suited to discovering new particles interacting too weakly to be seen otherwise.
- CEPC is a **machine for today**: a technologically complete proposal; a chance to answer the fundamental questions of our era.

Thank you.