

Quantum Field Theory and the Higgs Mechanism

Dr. Chung Kao, Chenyu Fang, and Ishan Varma

What's the Plan?

- Study different decay modes of the Higgs boson
- Simulate decay processes using MadGraph
- Understand the foundations of Quantum Field Theory (QFT)

```
*****
*
*                               W E L C O M E to
*                               M A D G R A P H 5 _ a M C @ N L O
*
*
*                               *
*                               * *
*                               * * * 5 * *
*                               * *
*                               *
*
*                               V E R S I O N  2 . 9 . 1 5
*                               2 0 2 3 - 0 5 - 1 2
*
*                               T h e  M a d G r a p h 5 _ a M C @ N L O  D e v e l o p m e n t  T e a m  -  F i n d  u s  a t
*                               https://server06.fynu.ucl.ac.be/projects/madgraph
*                               a n d
*                               http://amcatnlo.web.cern.ch/amcatnlo/
*
*                               T y p e  ' h e l p '  f o r  i n - l i n e  h e l p .
*                               T y p e  ' t u t o r i a l '  t o  l e a r n  h o w  M G 5  w o r k s
*                               T y p e  ' t u t o r i a l  a M C a t N L O '  t o  l e a r n  h o w  a M C @ N L O  w o r k s
*                               T y p e  ' t u t o r i a l  M a d L o o p '  t o  l e a r n  h o w  M a d L o o p  w o r k s
*
*
* *****
```

What's the Plan?

- Study different decay modes of the Higgs boson
- Simulate decay processes using MadGraph
- Understand the foundations of Quantum Field Theory (QFT)

```
*****
*
*                               W E L C O M E to
*                               M A D G R A P H 5 _ a M C @ N L O
*
*
*                               *
*                               * *
*                               * * * 5 * * *
*                               * *
*                               *
*
*                               V E R S I O N 2 . 9 . 1 5
*                               2 0 2 3 - 0 5 - 1 2
*
*                               T h e M a d G r a p h 5 _ a M C @ N L O D e v e l o p m e n t T e a m - F i n d u s a t
*                               https://server06.fynu.ucl.ac.be/projects/madgraph
*                               a n d
*                               http://amcatnlo.web.cern.ch/amcatnlo/
*
*                               T y p e ' h e l p ' f o r i n - l i n e h e l p .
*                               T y p e ' t u t o r i a l ' t o l e a r n h o w M G 5 w o r k s
*                               T y p e ' t u t o r i a l a M C a t N L O ' t o l e a r n h o w a M C @ N L O w o r k s
*                               T y p e ' t u t o r i a l M a d L o o p ' t o l e a r n h o w M a d L o o p w o r k s
*
*
*
*****
```

What's the Plan?

- Study different decay modes of the Higgs boson
- Simulate decay processes using MadGraph
- Understand the foundations of Quantum Field Theory (QFT)

```
*****
*
*                               W E L C O M E to
*                               M A D G R A P H 5 _ a M C @ N L O
*
*
*                               *
*                               * *
*                               * * * 5 * * *
*                               * *
*                               *
*
*                               V E R S I O N  2 . 9 . 1 5
*                               2 0 2 3 - 0 5 - 1 2
*
*                               T h e  M a d G r a p h 5 _ a M C @ N L O  D e v e l o p m e n t  T e a m  -  F i n d  u s  a t
*                               https://server06.fynu.ucl.ac.be/projects/madgraph
*                               a n d
*                               http://amcatnlo.web.cern.ch/amcatnlo/
*
*                               T y p e  ' h e l p '  f o r  i n - l i n e  h e l p .
*                               T y p e  ' t u t o r i a l '  t o  l e a r n  h o w  M G 5  w o r k s
*                               T y p e  ' t u t o r i a l  a M C a t N L O '  t o  l e a r n  h o w  a M C @ N L O  w o r k s
*                               T y p e  ' t u t o r i a l  M a d L o o p '  t o  l e a r n  h o w  M a d L o o p  w o r k s
*
*
*
*****
```

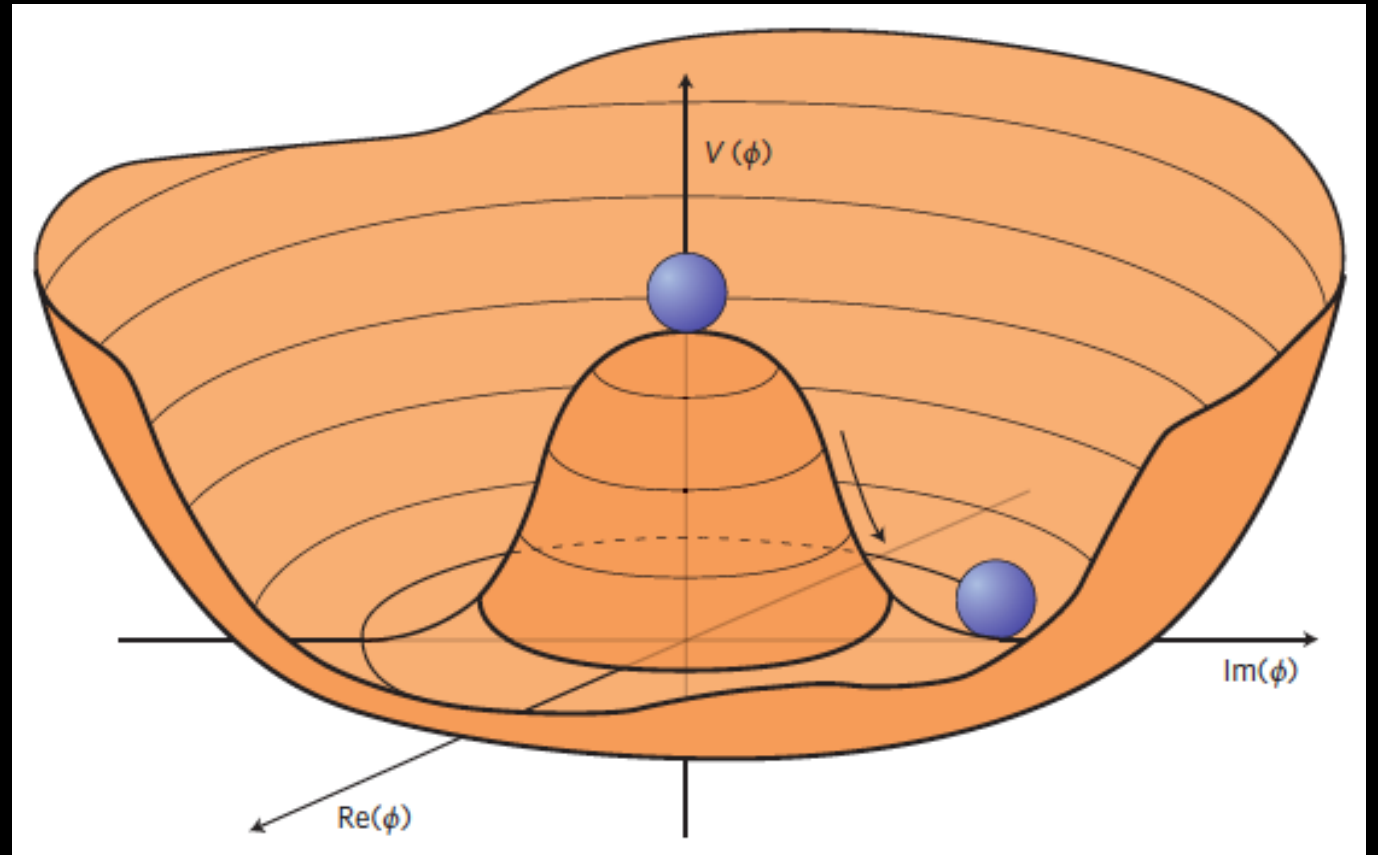
What's the Plan?

- Study different decay modes of the Higgs boson
- Simulate decay processes using MadGraph
- Understand the foundations of Quantum Field Theory (QFT)

```
*****
*
*                               W E L C O M E  t o
*                               M A D G R A P H  5  _ a M C @ N L O
*
*
*                               *
*                               * *
*                               * * * 5 * * *
*                               * *
*                               *
*
*                               V E R S I O N  2 . 9 . 1 5
*                               2 0 2 3 - 0 5 - 1 2
*
*                               T h e  M a d G r a p h  5  _ a M C @ N L O  D e v e l o p m e n t  T e a m  -  F i n d  u s  a t
*                               https://server06.fynu.ucl.ac.be/projects/madgraph
*                               a n d
*                               http://amcatnlo.web.cern.ch/amcatnlo/
*
*                               T y p e  ' h e l p '  f o r  i n - l i n e  h e l p .
*                               T y p e  ' t u t o r i a l '  t o  l e a r n  h o w  M G 5  w o r k s
*                               T y p e  ' t u t o r i a l  a M C a t N L O '  t o  l e a r n  h o w  a M C @ N L O  w o r k s
*                               T y p e  ' t u t o r i a l  M a d L o o p '  t o  l e a r n  h o w  M a d L o o p  w o r k s
*
*
* *****
```

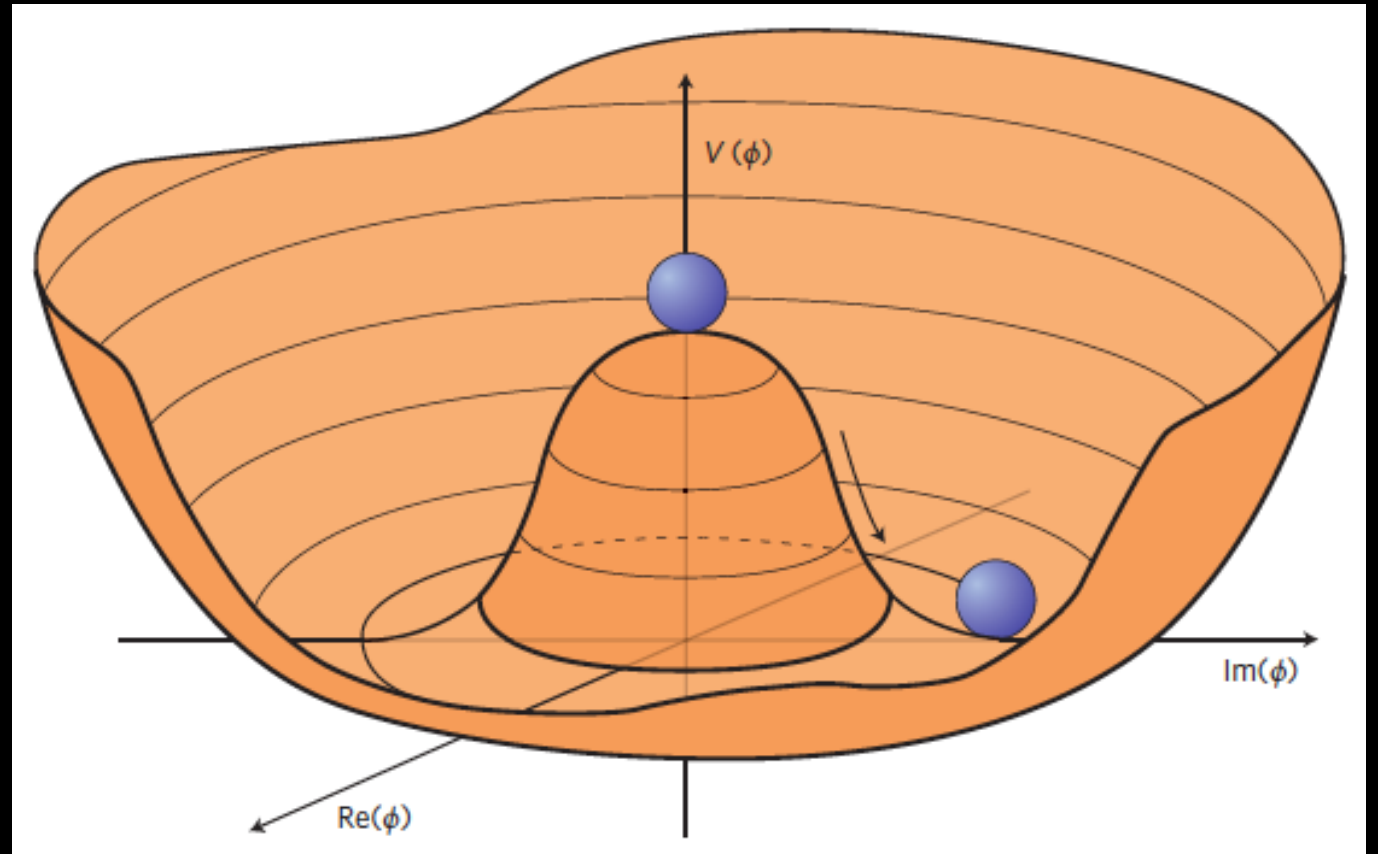
The Higgs Mechanism

- The $-m^2\phi^*\phi$ and $-m(\bar{\psi}_L\psi_R + \bar{\psi}_R\psi_L)$ terms
- Plotting $V(\phi)$ and the sombrero potential
- The vacuum expectation value
- Local symmetries and gauge bosons
- The Goldstone boson disappears
- The fields are coupled
- New mass terms appear



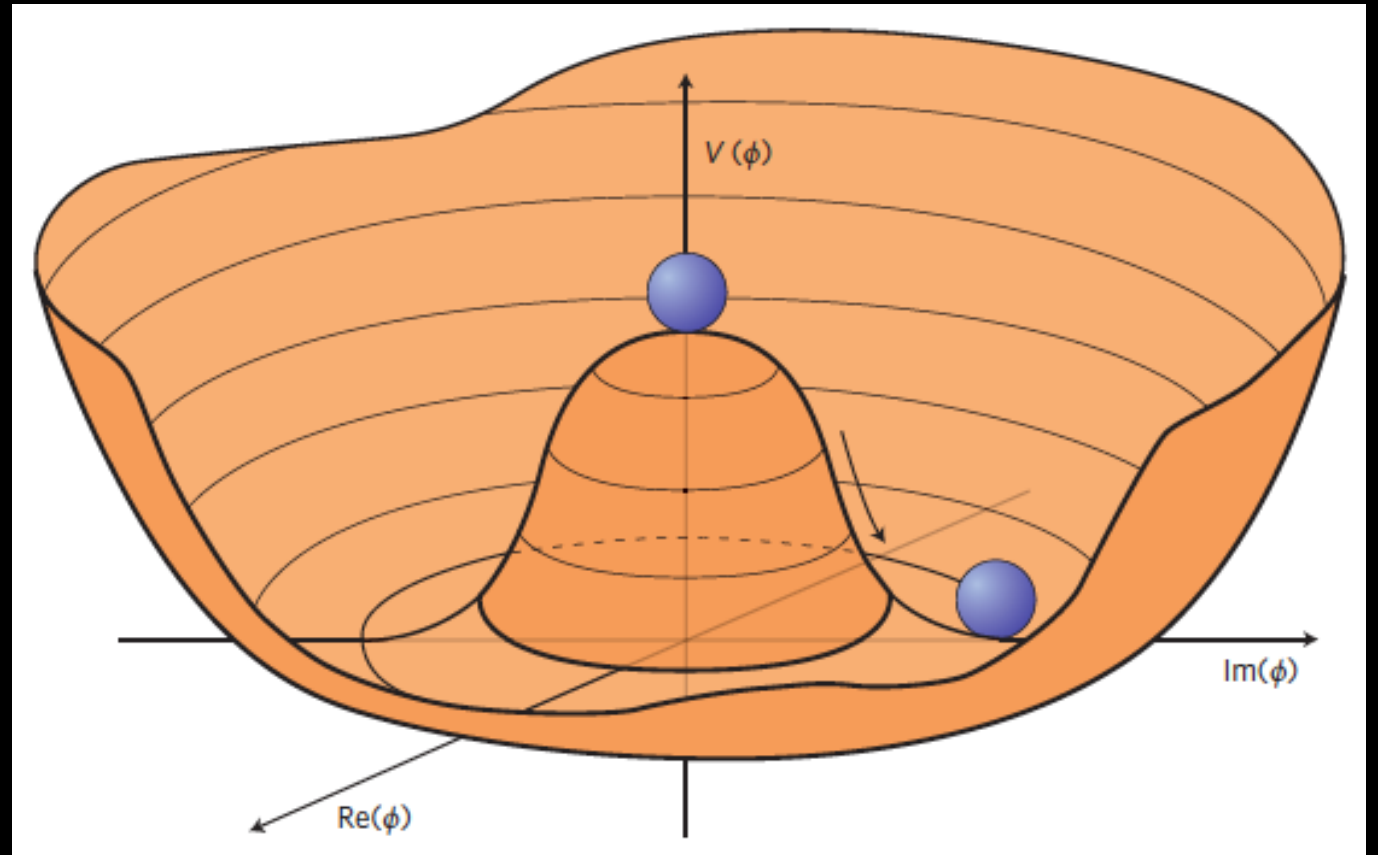
The Higgs Mechanism

- The $-m^2\phi^*\phi$ and $-m(\bar{\psi}_L\psi_R + \bar{\psi}_R\psi_L)$ terms
- Plotting $V(\phi)$ and the sombrero potential
- The vacuum expectation value
- Local symmetries and gauge bosons
- The Goldstone boson disappears
- The fields are coupled
- New mass terms appear



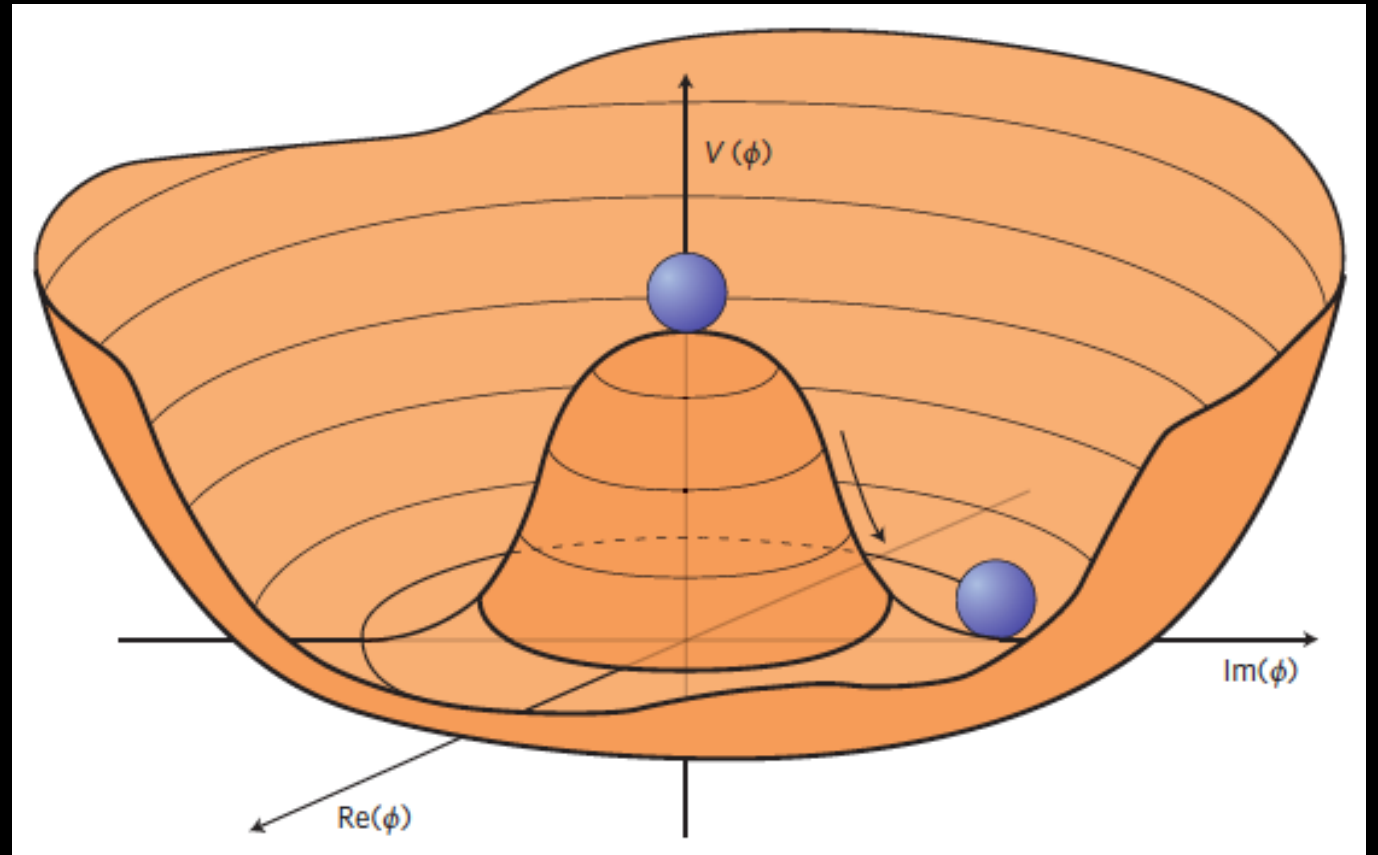
The Higgs Mechanism

- The $-m^2\phi^*\phi$ and $-m(\bar{\psi}_L\psi_R + \bar{\psi}_R\psi_L)$ terms
- Plotting $V(\phi)$ and the sombrero potential
- The vacuum expectation value
- Local symmetries and gauge bosons
- The Goldstone boson disappears
- The fields are coupled
- New mass terms appear



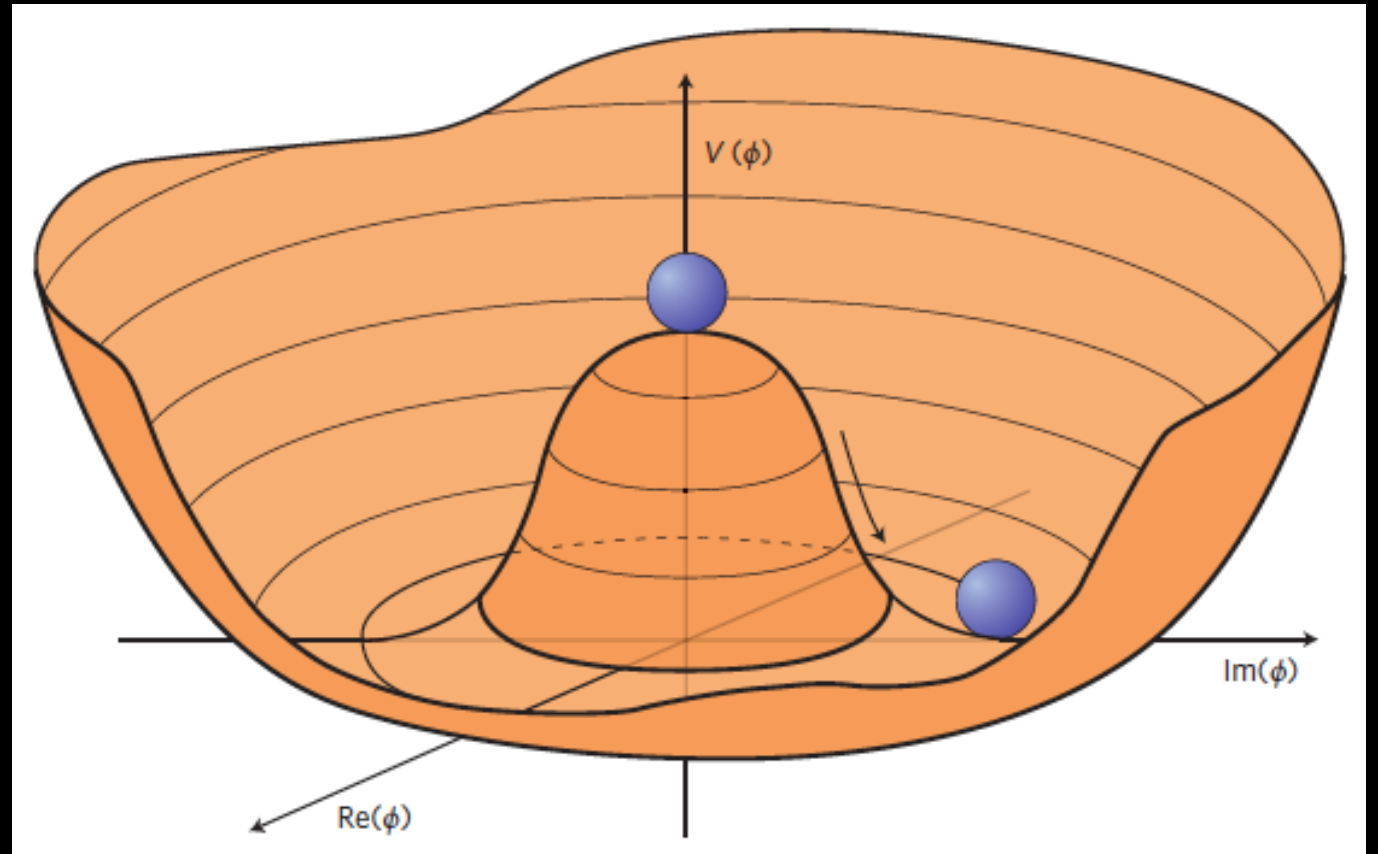
The Higgs Mechanism

- The $-m^2\phi^*\phi$ and $-m(\bar{\psi}_L\psi_R + \bar{\psi}_R\psi_L)$ terms
- Plotting $V(\phi)$ and the sombrero potential
- **The vacuum expectation value**
- Local symmetries and gauge bosons
- The Goldstone boson disappears
- The fields are coupled
- New mass terms appear



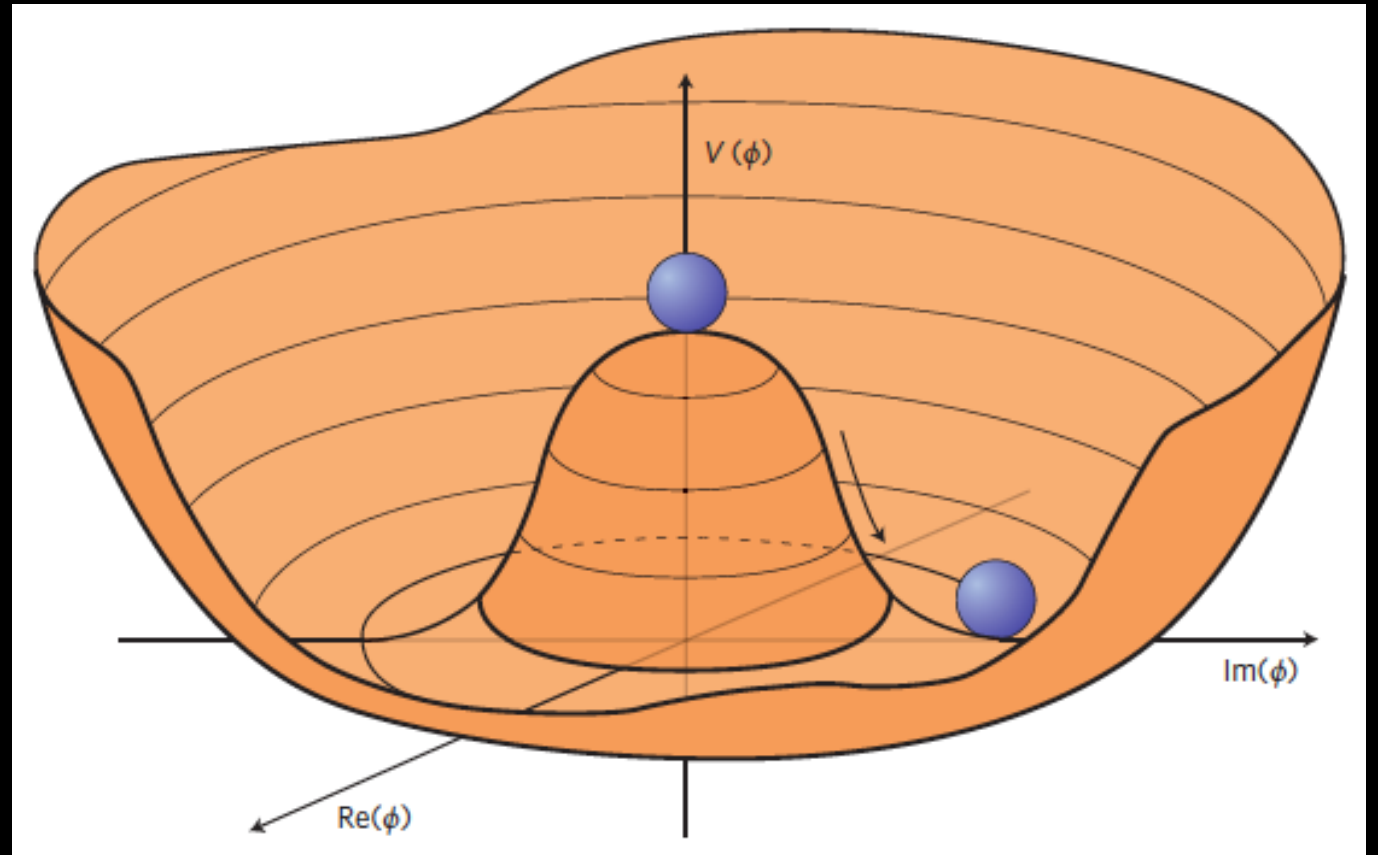
The Higgs Mechanism

- The $-m^2\phi^*\phi$ and $-m(\bar{\psi}_L\psi_R + \bar{\psi}_R\psi_L)$ terms
- Plotting $V(\phi)$ and the sombrero potential
- The vacuum expectation value
- **Local symmetries and gauge bosons**
- The Goldstone boson disappears
- The fields are coupled
- New mass terms appear



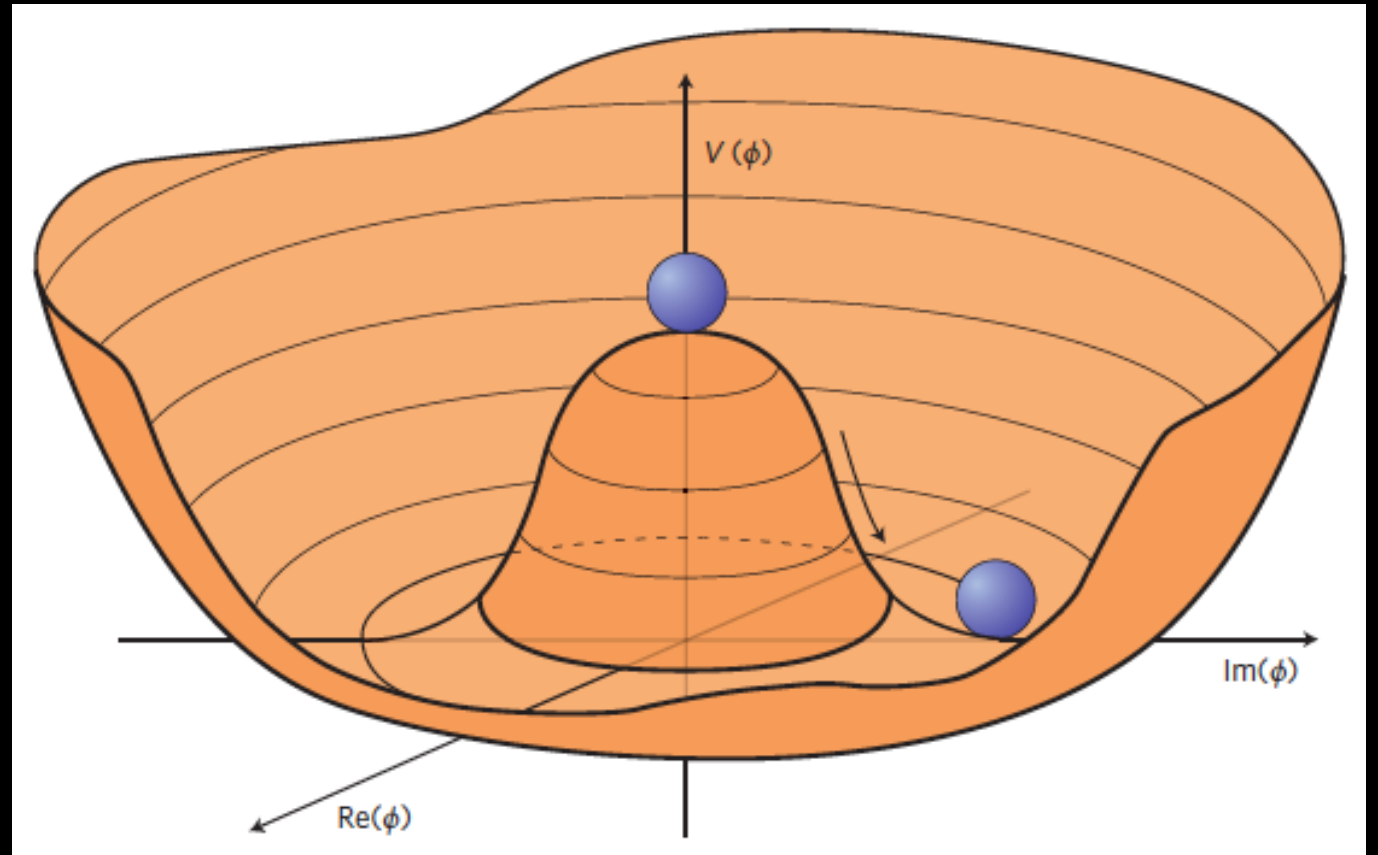
The Higgs Mechanism

- The $-m^2\phi^*\phi$ and $-m(\bar{\psi}_L\psi_R + \bar{\psi}_R\psi_L)$ terms
- Plotting $V(\phi)$ and the sombrero potential
- The vacuum expectation value
- Local symmetries and gauge bosons
- **The Goldstone boson disappears**
- The fields are coupled
- New mass terms appear



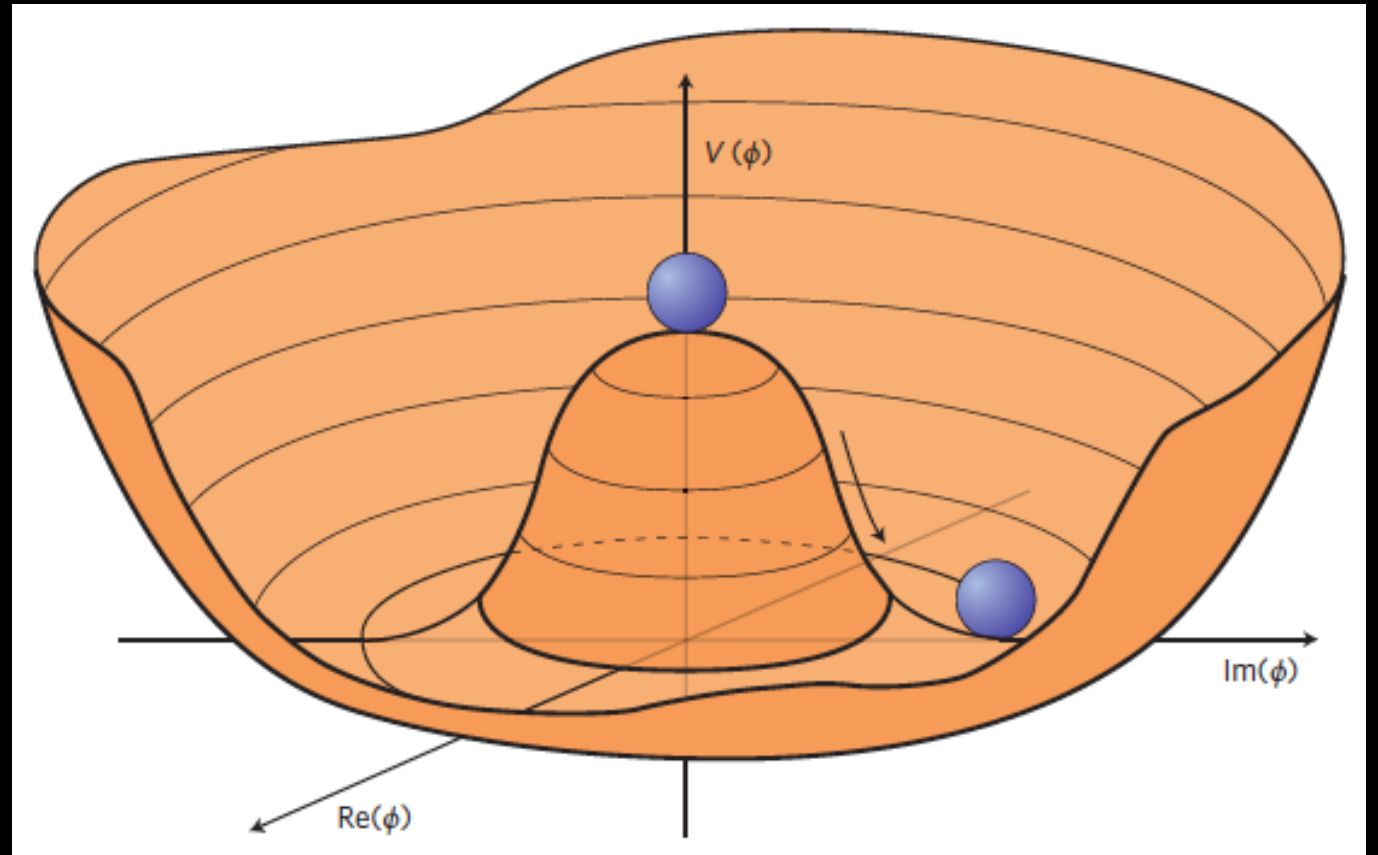
The Higgs Mechanism

- The $-m^2\phi^*\phi$ and $-m(\bar{\psi}_L\psi_R + \bar{\psi}_R\psi_L)$ terms
- Plotting $V(\phi)$ and the sombrero potential
- The vacuum expectation value
- Local symmetries and gauge bosons
- The Goldstone boson disappears
- **The fields are coupled**
- New mass terms appear



The Higgs Mechanism

- The $-m^2\phi^*\phi$ and $-m(\bar{\psi}_L\psi_R + \bar{\psi}_R\psi_L)$ terms
- Plotting $V(\phi)$ and the sombrero potential
- The vacuum expectation value
- Local symmetries and gauge bosons
- The Goldstone boson disappears
- The fields are coupled
- **New mass terms appear**



References

- Dr. Chung Kao lecture notes
- Dr. Thomas Moore unreleased textbook
- <https://th.bing.com/th/id/R.8f6b11a600a1a87ed427ad43133228f3?rik=zjmVhTcPOr8InQ&riu=http%3a%2f%2fcds.cern.ch%2frecord%2f1638469%2ffiles%2fhiggspotential.png&ehk=YqS1TW7tjKy4CKXHgNKBQDV%2foxApzVYjPOEtjo5UZEI%3d&risl=&pid=ImgRaw&r=0>
- <https://www.youtube.com/watch?v=G0Q4UAiKacw&t=1032s>