The International Workshop "Higgs Modes in Condensed Matter and Quantum Gases"

June 23-25, 2014
@ Yukawa Institute for Theoretical Physics, Kyoto Univ.

Opening

Ippei Danshita, YITP

On the behalf of the organizing committee

Kinkakuji

ドリームチーム
金閣

Welcome to YITP, Kyoto

Ginkakuji

Philosopher's path

Please acknowledge the workshop !!

Examples:

The authors thank the Yukawa Institute for Theoretical Physics at Kyoto University, where this work was initiated [completed] during the **YITP-W-14-02** on "Higgs Modes in Condensed Matter and Quantum Gases".

The authors thank the Yukawa Institute for Theoretical Physics at Kyoto University. Discussion during the YITP workshop **YITP-W-14-02** on "Higgs Modes in Condensed Matter and Quantum gases".

Please provide your presentation file (if possible) !!

After your talk, you will be asked to provide your presentation file.

We are going to upload the files on the workshop website.

You may set your poster today

The rooms for the poster session are

Y206 (P1-P14)
Y306 (P15-P30)

Group photo before the lunch break today !

The "birth" of the Higgs boson

BROKEN SYMMETRIES AND THE MASSES OF GAUGE BOSONS

Peter W. Higgs
Tait Institute of Mathematical Physics, University of Edinburgh, Edinburgh, Scotland
(Received 31 August 1964)

$$L = -\tfrac{1}{2}(\nabla\varphi_1)^2 - \tfrac{1}{2}(\nabla\varphi_2)^2 - V(\varphi_1^2 + \varphi_2^2) - \tfrac{1}{4}F_{\mu\nu}F^{\mu\nu},$$

where

$$\nabla_\mu\varphi_1 = \partial_\mu\varphi_1 - eA_\mu\varphi_2,$$

$$\nabla_\mu\varphi_2 = \partial_\mu\varphi_2 + eA_\mu\varphi_1,$$

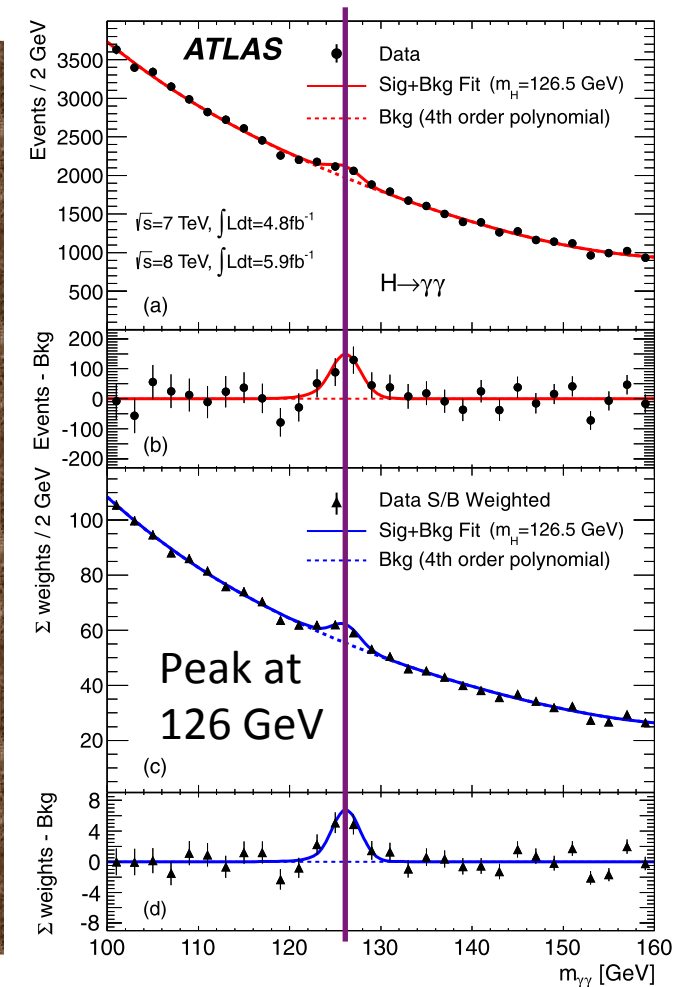$$F_{\mu\nu} = \partial_\mu A_\nu - \partial_\nu A_\mu,$$

It is worth noting that an essential feature of the type of theory which has been described in this note is the prediction of incomplete multiplets of scalar and vector bosons.[8] It is to be expected that this feature will appear also in theories in which the symmetry-breaking scalar fields are not elementary dynamic variables but bilinear combinations of Fermi fields.[9]

The remarked scalar boson
is now called Higgs boson !!!
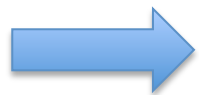
The discovery of the Higgs boson at the LHC

Large Hadron Collider

CMS

LHCb

ATLAS

ALICE

p p

Photo is from http://people.physics.tamu.edu

ATLAS

Data

Sig+Bkg Fit (m_H=126.5 GeV)

Bkg (4th order polynomial)

$\sqrt{s}$=7 TeV, $\int$Ldt=4.8fb^{-1}

$\sqrt{s}$=8 TeV, $\int$Ldt=5.9fb^{-1}

H$\rightarrow\gamma\gamma$

Data S/B Weighted

Sig+Bkg Fit (m_H=126.5 GeV)

Bkg (4th order polynomial)

Peak at 126 GeV

$m_{\gamma\gamma}$ [GeV]

ATLAS collaboration
Phys. Lett. B (2012)

Detection of the standard model Higgs boson !!!

- Search for particle theories beyond the standard model
- **Studies of Higgs modes in cond-mat and quant-gas**

Interactions between cond-mat and particle physics

Cond-mat (Superconductor)

Particle phys

BCS ('57)
& Bogoliubov ('58)
& Anderson ('58)

Nambu ('60, '61)
Goldstone ('61, '62)

Especially, the massless
Anderson-Bogoliubov (AB) mode

Symmetry breaking and
the Nambu-Goldstone mode

Anderson ('63)

Higgs ('64)

AB mode becomes massive due to
the coupling to the gauge field,
which is called plasmon

The Higgs mechanism and
the associated Higgs mode

Littlewood & Varma ('81)

Amplitude mode, which is indeed a Higgs mode

Communication between the two fields seems very productive !!

Diversity of Higgs modes in cond-mat and quant-gas

Experimental observations were made in

- S-wave superconductors ($NbSe_2$, $Nb_{1-x}Ti_xN$)

- P-wave superfluids (liquid ^3He)

- Quantum magnets ($TlCuCl_3$, $KCuCl_3$)

- CDW phases ($TbTe_3$, $La_{2-x}Sr_xCuO_4$)

- Ultracold bosons in optical lattices

Theoretical predictions were made for

- Exciton-polariton BEC

- Ultracold fermions with/without optical lattices

- Atoms in optical cavities

and more !!!

Diversity of Higgs modes in cond-mat and quant-gas

Experimental observations were made in

- S-wave superconductors ($NbSe_2$, $Nb_{1-x}Ti_xN$)

- P-wave superfluids (liquid ^3He)

- Quantum magnets ($TlCuCl_3$, $KCuCl_3$)

- CDW phases ($TbTe_3$, $La_{2-x}Sr_xCuO_4$)

- Ultracold bosons in optical lattices

Interesting questions arise:

- What are the conditions for Higgs modes to emerge?

- What kinds of properties are universal ?

- Are there different types of Higgs mode?
  If yes, how can one categorize them?

- Does spatial dimension matter?   and more !!!

Close connection with Nambu-Goldstone modes
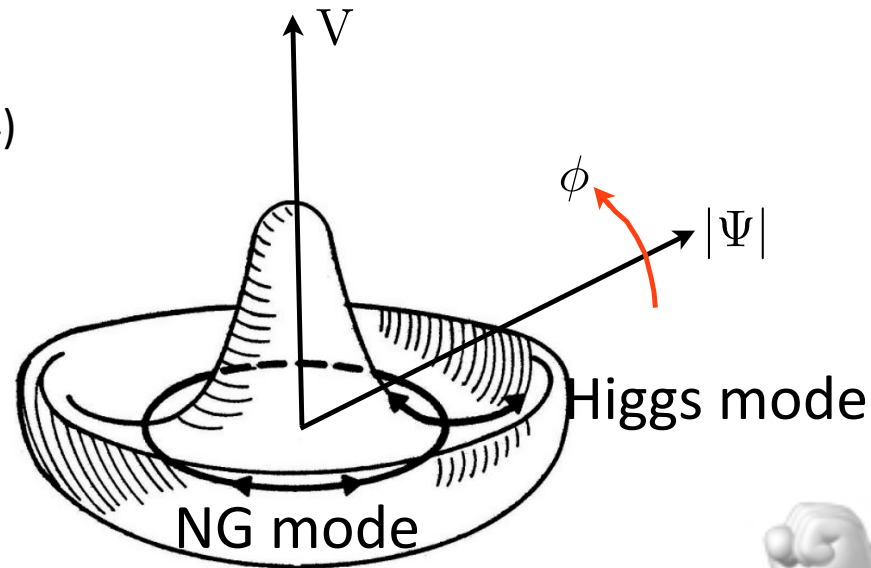
Figure is from
Pekker & Varma (2014)

NG and Higgs modes are brothers,
whose parent is the Mexican hat.
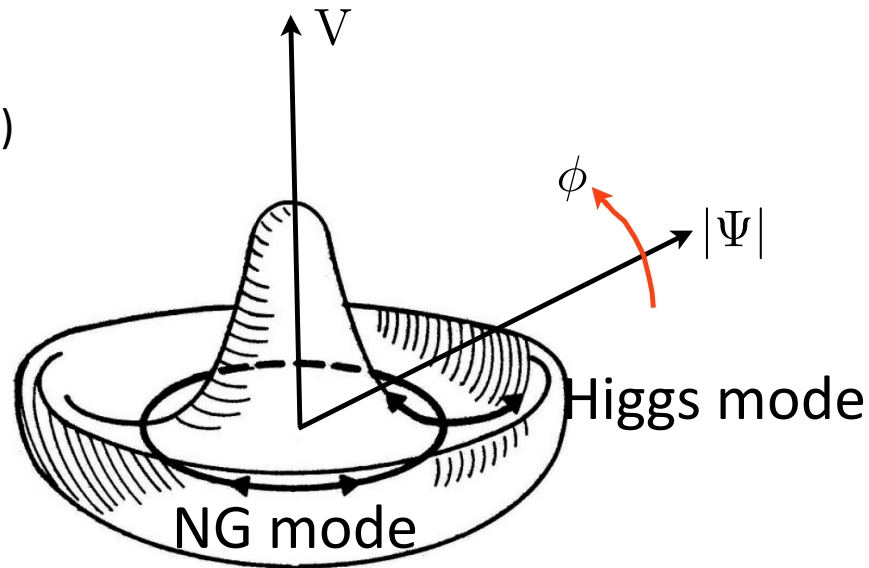
Recent developments regarding NG modes:

· Counting rules

· Transmission & scattering properties

· NG modes upon topological excitations

etc.

Close connection with Nambu-Goldstone modes

Figure is from
Pekker & Varma (2014)

NG and Higgs modes are brothers,
whose parent is the Mexican hat.

Recent developments regarding NG modes:

- Counting rules

- Transmission & scattering properties

- NG modes upon topological excitations

etc.

New properties &
deeper understanding
of Higgs modes

Let us start with bosons in optical lattices !!