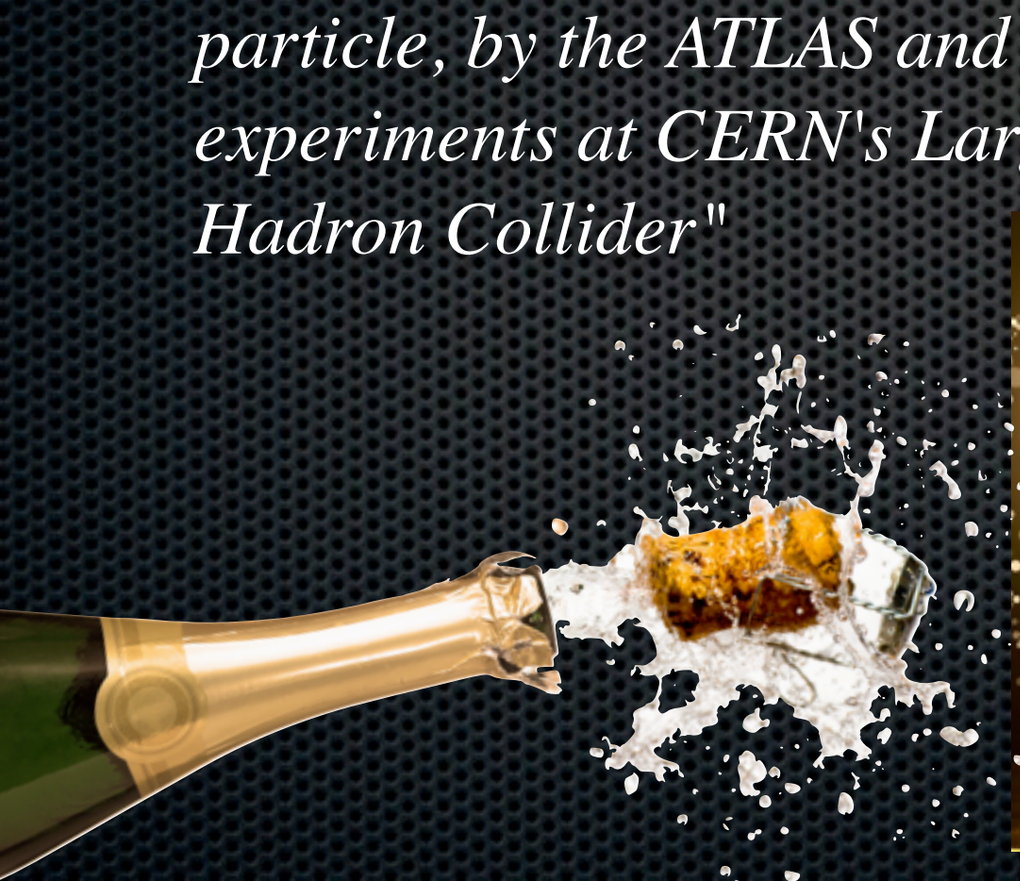
2013 NOBEL PRIZE IN PHYSICS

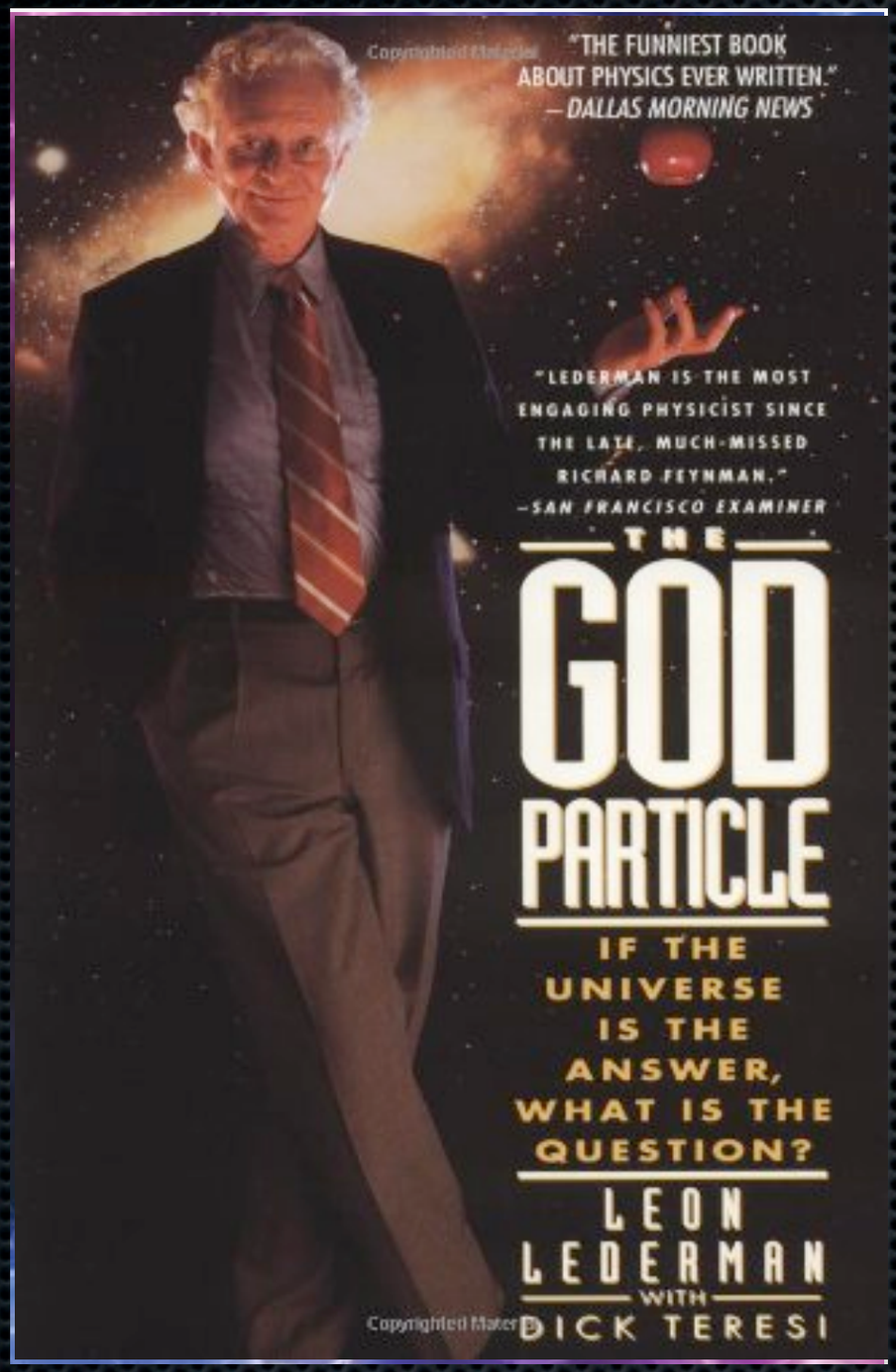
Francois Englert

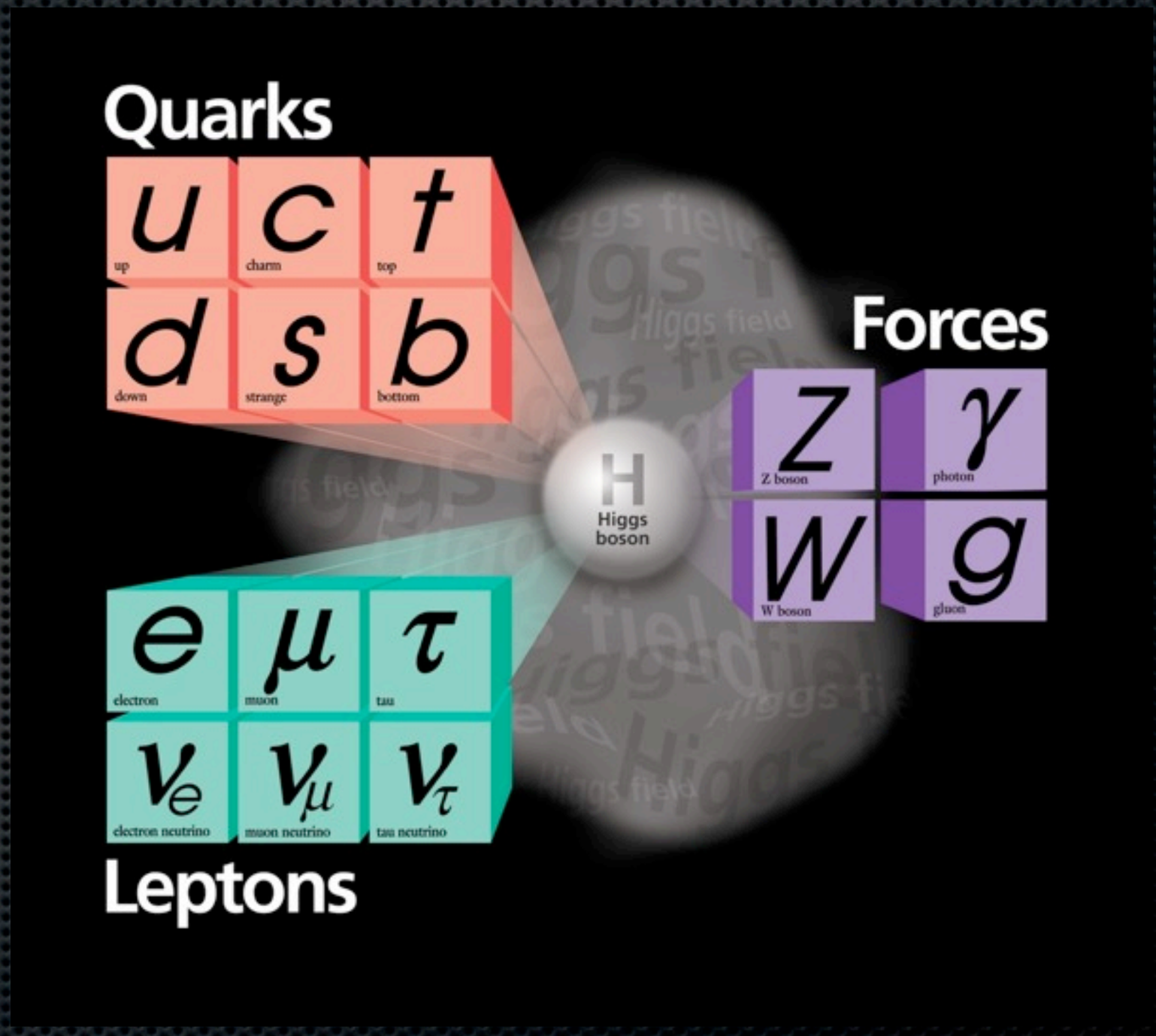
Peter W. Higgs

"for the theoretical discovery of a mechanism that contributes to our understanding of the origin of mass of subatomic particles, and which recently was confirmed through the discovery of the predicted fundamental particle, by the ATLAS and CMS experiments at CERN's Large Hadron Collider"



Higgs: the ~~Goddamn~~ Particle





对称性和自发破缺

$$\underbrace{SU(3)_{\text{Color}}}_{\text{QCD}} \otimes \underbrace{SU(2)_{\text{Left}} \otimes U(1)_{\text{Hyper charge}}}_{\text{WEAK} \oplus \text{QED}}$$

(Strong Interaction)

(Unification of Weak and Electromagnetic)

对称性自发破缺

(希格斯机制)

$U(1)_{\text{E.M.}}$

量子电动力学

(电磁相互作用)

对称性意味着“力”

电磁相互作用（Abelian gauge symmetry）

规范变换

$$\psi(x) \to e^{iq\alpha(x)}\psi(x)$$
$$A_\mu(x) \to A_\mu(x) - \partial_\mu\alpha(x)$$

$$D_\mu \equiv \partial_\mu + iqA_\mu(x)$$

QED

$$\begin{aligned}\mathcal{L} &= \bar{\psi}\left(i\gamma^\mu D_\mu - m\right)\psi \\ &= \bar{\psi}\left(i\gamma^\mu \partial_\mu - m\right)\psi - qA_\mu\bar{\psi}\gamma^\mu\psi \\ &= \mathcal{L}_{\text{free}} - J^\mu A_\mu\end{aligned}$$

规范对称性要求光子的质量为零 $\cancel{\frac{1}{2}m_\gamma^2 A^\mu A_\mu}$

对称性意味着“力”

杨振宁和米尔斯（1954）

定域同位旋对称性意味着有3个无质量的规范波色子和同位旋耦合

$$\begin{pmatrix} p \\ n \end{pmatrix}$$

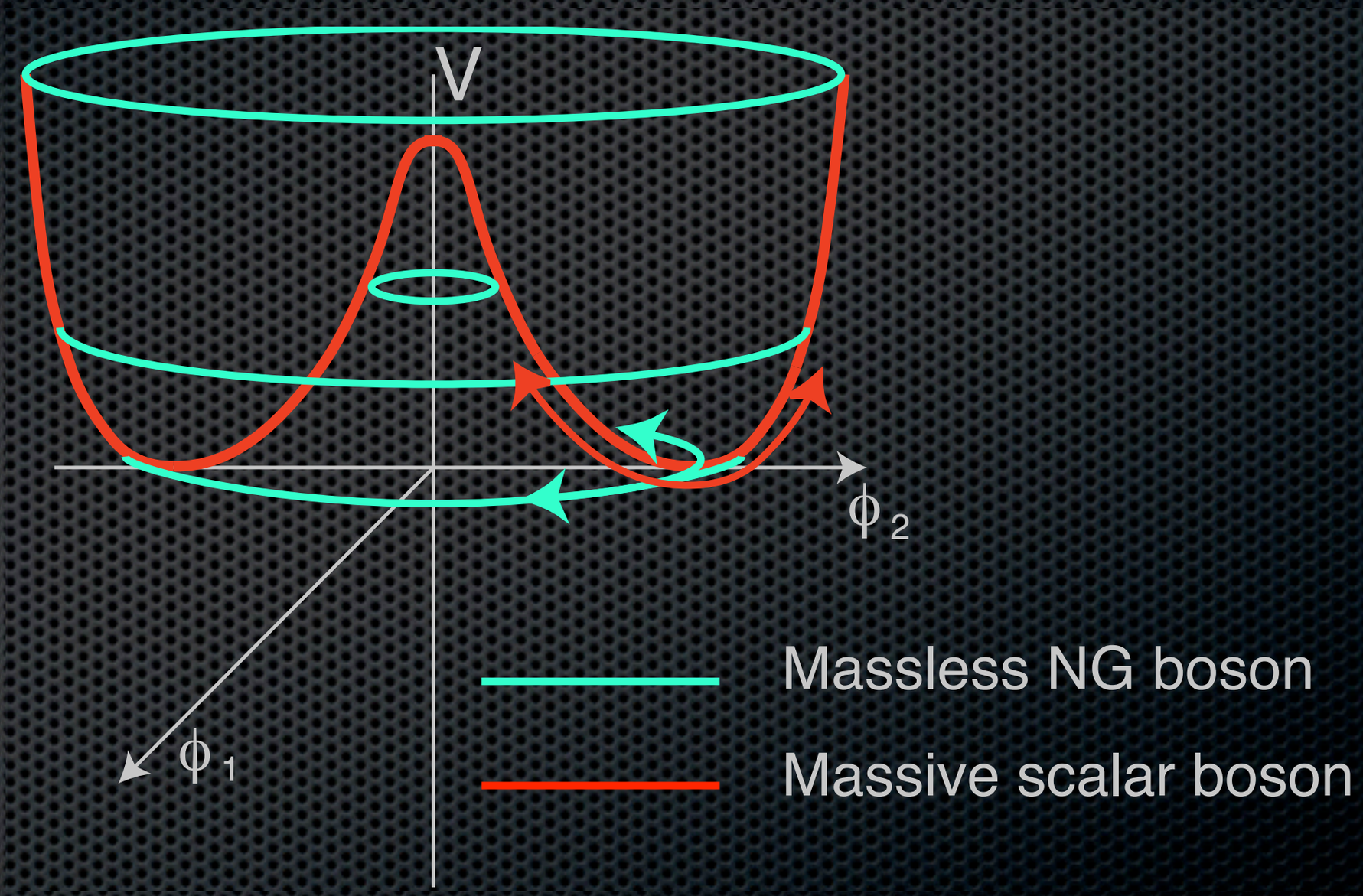
Nambu-Goldstone boson

(1960)

2008 nobel prize

Yoichiro Nambu

Jeffrey Goldstone (1961)

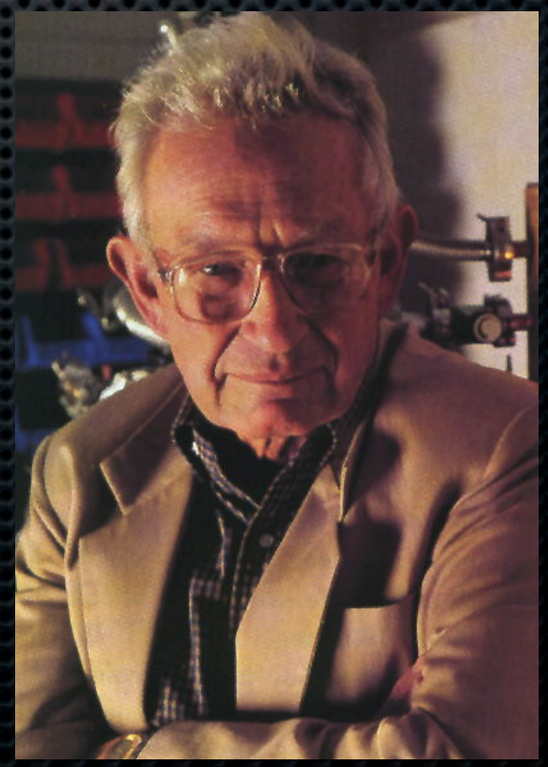


Goldstone, Salam, Weinberg (1962)

Anderson (1963)

指出超导中的Goldstone模式会因其电磁耦合获得质量，并且产生一个纵向极化模式。

- “the Goldstone zero-mass difficulty is not a serious one, because we can probably cancel it off against an equal Yang-Mills zero-mass problem”



没有指出Goldstone定理的瑕疵，
也没有探讨相对论性的理论模型

Phys. Rev. 130 (1963) 439

对称性自发破缺

Higgs Kibble Guralnik Hagen Englert Brout

1964年：Goldstone定理并不适用于规范理论

每个无质量的Goldstone玻色子和一个无质量的规范玻色子组成一个有质量的玻色子，同时还产生有质量的标量粒子

1964年3组人不约而同地...

VOLUME 13, NUMBER 9 PHYSICAL REVIEW LETTERS 31 AUGUST 1964

BROKEN SYMMETRY AND THE MASS OF GAUGE VECTOR MESONS*

F. Englert and R. Brout
Faculté des Sciences, Université Libre de Bruxelles, Bruxelles, Belgium
(Received 26 June 1964)

Volume 12, number 2 PHYSICS LETTERS 15 September 1964

BROKEN SYMMETRIES, MASSLESS PARTICLES AND GAUGE FIELDS

P. W. HIGGS
Tait Institute of Mathematical Physics, University of Edinburgh, Scotland

Received 27 July 1964

VOLUME 13, NUMBER 16 PHYSICAL REVIEW LETTERS 19 OCTOBER 1964

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)

VOLUME 13, NUMBER 20 PHYSICAL REVIEW LETTERS 16 NOVEMBER 1964

GLOBAL CONSERVATION LAWS AND MASSLESS PARTICLES*

G. S. Guralnik,† C. R. Hagen,‡ and T. W. B. Kibble
Department of Physics, Imperial College, London, England
(Received 12 October 1964)

电弱理论（1967）

Steven Weinberg

Abdus Salam

1979 nobel prize

将希格斯机制引入到Glashow的轻子电弱理论，
S. L. Glashow, Nucl. Phys. 22 (1961) 579

使用真空隐藏电弱对称性

3个有质量的规范波色子 W^+ W^- Z^0

1个无质量的规范波色子 γ

1个有质量的希格斯粒子

为何叫“希格斯机制”?

[11] In obtaining the expression (11) the mass difference between the charged and neutral has been ignored.

[12]M. Ademollo and R. Gatto, Nuovo Cimento 44A, 282 (1966); see also J. Pasupathy and R. E. Marshak, Phys. Rev. Letters 17, 888 (1966).

[13]The predicted ratio [eq. (12)] from the current algebra is slightly larger than that (0.23%) obtained from the ρ-dominance model of Ref. 2. This seems to be true also in the other case of the ratio $\Gamma(\eta \to \pi^+\pi^-\gamma)/\Gamma(\gamma\gamma)$ calculated in Refs. 12 and 14.

[14]L. M. Brown and P. Singer, Phys. Rev. Letters 8, 460 (1962).

A MODEL OF LEPTONS*

Steven Weinberg†
Laboratory for Nuclear Science and Physics Department,
Massachusetts Institute of Technology, Cambridge, Massachusetts

(Received 17 October 1967)

[3]P. W. Higgs, Phys. Letters 12, 132 (1964), Phys. Rev. Letters 13, 508 (1964), and Phys. Rev. 145, 1156 (1966); F. Englert and R. Brout, Phys. Rev. Letters 13, 321 (1964); G. S. Guralnik, C. R. Hagen, and T. W. B. Kibble, Phys. Rev. Letters 13, 585 (1964).

温伯格的再次乌龙

VOLUME 27, NUMBER 24 PHYSICAL REVIEW LETTERS 13 DECEMBER 1971

Physical Processes in a Convergent Theory of the Weak and Electromagnetic Interactions*

Steven Weinberg

Laboratory for Nuclear Science and Department of Physics, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139

(Received 20 October 1971)

[2]P. W. Higgs, Phys. Rev. Lett. 12, 132 (1964), and 13, 508 (1964), and Phys. Rev. 145, 1156 (1966); F. Englert and R. Brout, Phys. Rev. Lett. 13, 321 (1964); G. S. Guralnik, C. R. Hagen, and T. W. B. Kibble, Phys. Rev. Lett. 13, 585 (1965); T. W. B. Kibble, Phys. Rev. 155, 1554 (1967). Also see A. Salam, in *Elementary Particle Physics*, edited by N. Svartholm (Almqvist and Wiksells, Stockholm, 1968), p. 367.

匪夷所思的巧合

Phys. Rev. Lett. 12, 132–133 (1964)

Large Angle *p-p* Elastic Scattering at 30 bev

W. F. Baker, E. W. Jenkins, and A. L. Read
Brookhaven National Laboratory, Upton, New York

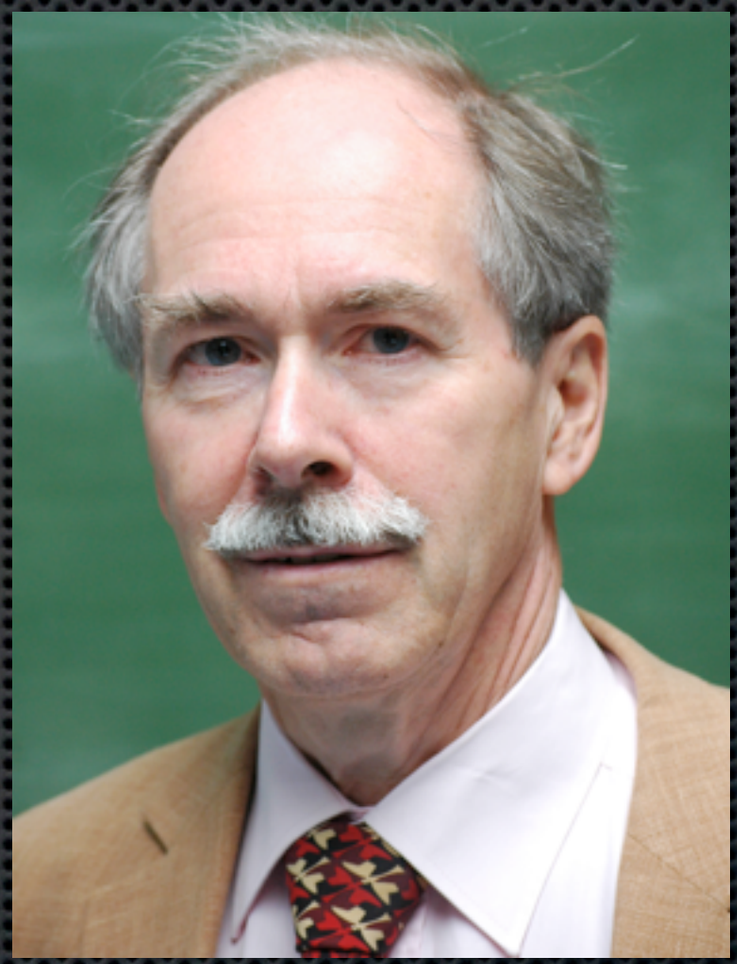
G. Cocconi*, V. T. Cocconi*, A. D. Krisch, J. Orear, R. Rubinstein, D. B. Scarl, and B. T. Ulrich
Laboratory of Nuclear Studies, Cornell University, Ithaca, New York

Received 13 January 1964; published in the issue dated 3 February 1964

时间提前到1964年1月份!!!

1971-72年

- t’Hooft 和 Veltman证明电弱理论的可重整化性



1999 Nobel Prize

- 1972年在费米实验室举办的高能物理会议上，电弱理论部分的报告人B. W. Lee，首次提出“Higgs meson”。

寻找希格斯粒子

“We should perhaps finish with an apology and a caution. We apologize to experimentalists for having no idea what is the mass of the Higgs boson, unlike the case with charm, and for not being sure of its couplings to other particles, except that they are probably all very small.

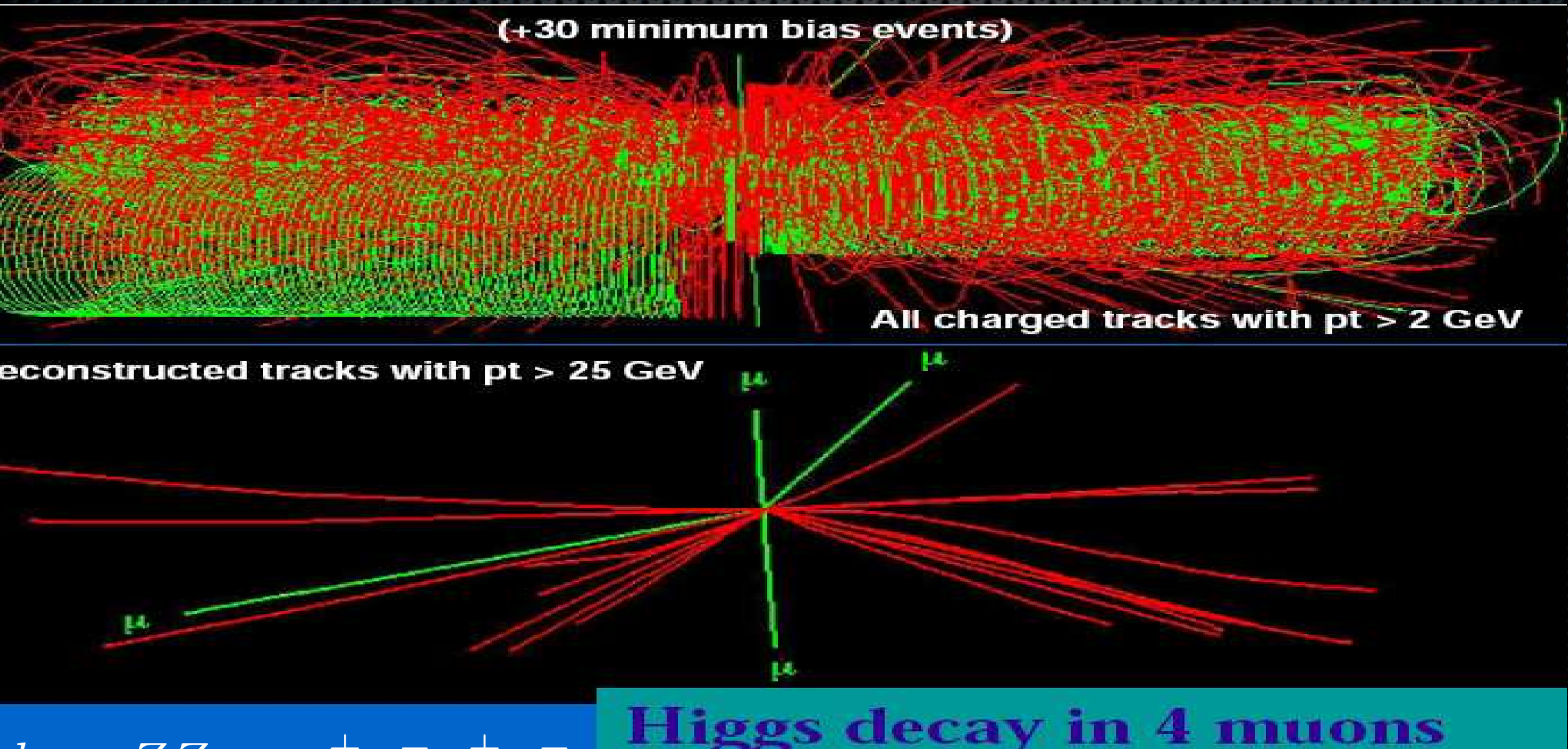
For these reason we do not want to encourage big experimental searches for the Higgs boson, but we do feel that people performing experiments vulnerable to the Higgs boson should know how it may turn up.”

J. Ellis, M.K. Gaillard, D.V. Nanopoulous,
Nucl. Phys. B 106 (1976) 292

见证奇迹的历史时刻

July 4th , 2012

希格斯粒子发现是理论+实验共同不懈的努力完成的



$h \to ZZ \to \mu^+\mu^-\,\mu^+\mu^-$

Higgs decay in 4 muons
1 in 10 ^{13} events