$e^-e^+ \to ZH$ and $e^-e^+ \to HH$ in noncommutative space-time

20th IPM physics spring conference

School of particle and accelatores

Institude for research in fundemental science

May 22-23,2013 (1-2 Khordad 1392)

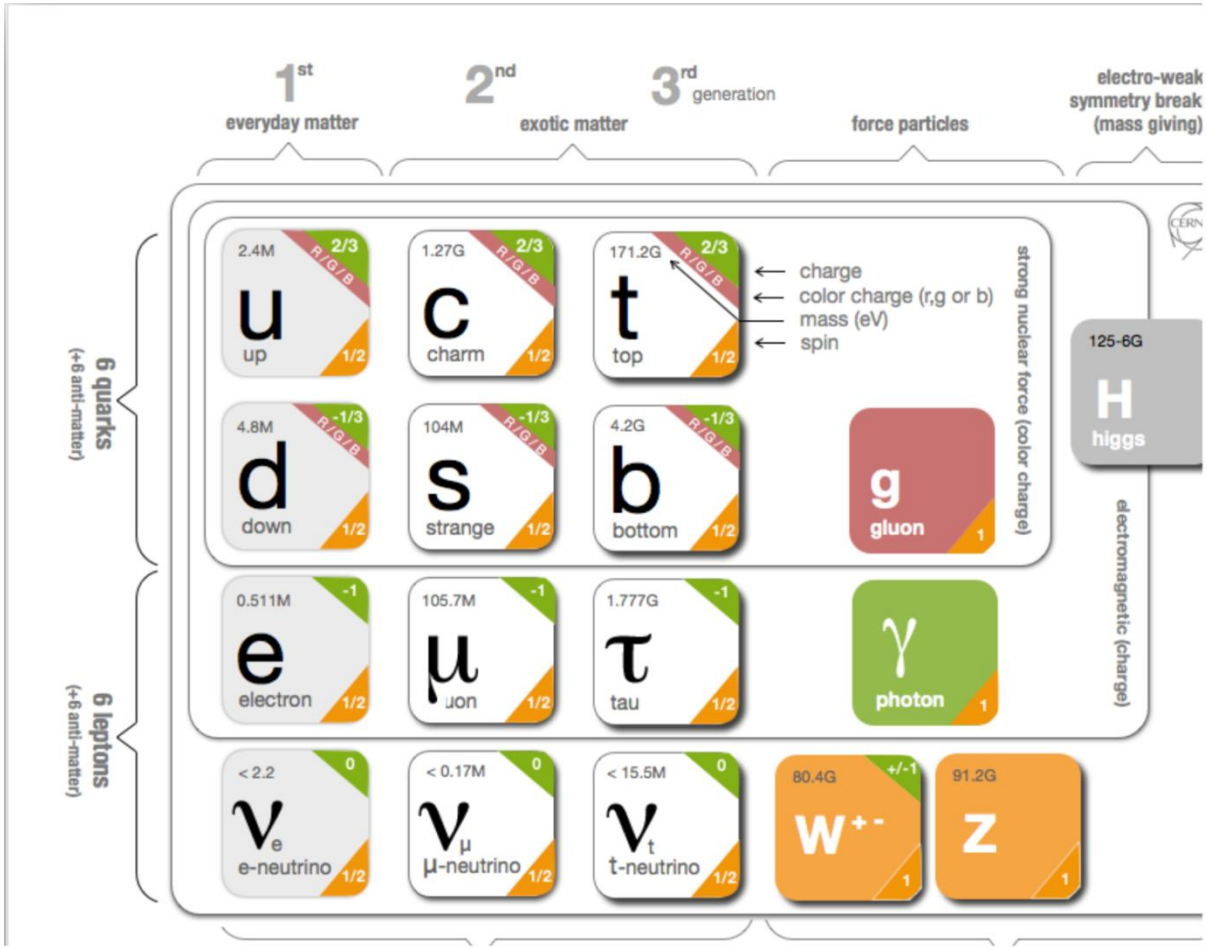
Saghar Batebi

Isfahan university of technology

OUTLINES

- The Higgs boson
- Higgs production at the LHC , ILC
- Standard model problems
- Noncomutative space time
- The action of the NCSM
- $e^{-}e^{+} \to ZH$
- $e^{-}e^{+} \to HH$

THE STANDARD MODEL OF PARTICLE PHYSICS



THE HIGGS BOSON

Higgs Field	El.magn. field	Weak fields
Complex scalar doublet		
(4 degrees of freedom)	$U(1)$ symm.	$SU(2)_L$ symm.
		W^+
Φ^+	B	W^0
Φ^0		W^-

Higgs mechanism : 3 degrees of freedom from Higgs fields

$\Rightarrow$ Longitudinal polarization of W^+, W^-, Z^0

$\Downarrow$

Massless γ, massive $W^\pm$ and Z^0 bosons

Remaining degree of freedom ...

H^0 neutral scalar boson

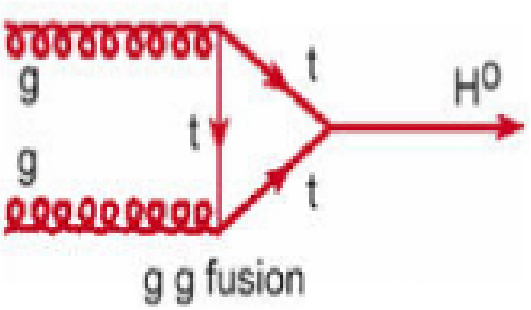
Higgs boson mass m_H ... free parameter ... if known

Higgs phenomenology (production/decay) fully determined

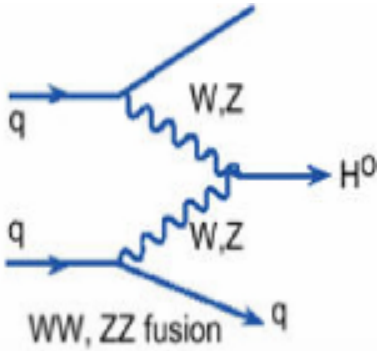
THE HIGGS BOSON

- Charge = 0
- Spin = 0
- Mass = ??
- Coupling proportional to the mass

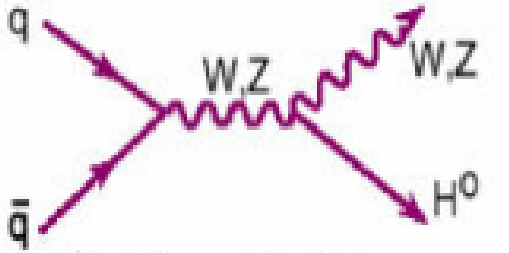
HIGGS PRODUCTION AT THE LHC



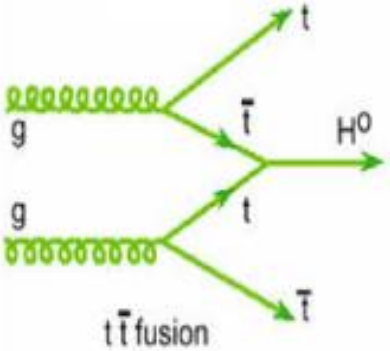
g g fusion



WW, ZZ fusion

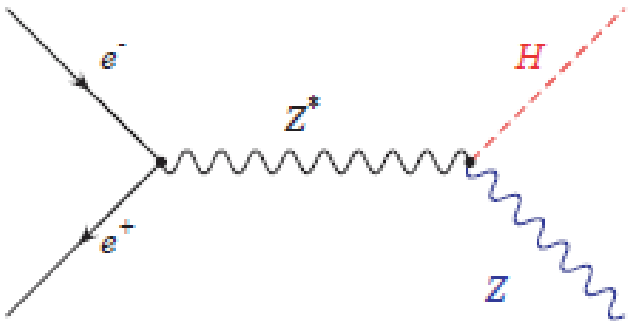


W, Z bremsstrahlung

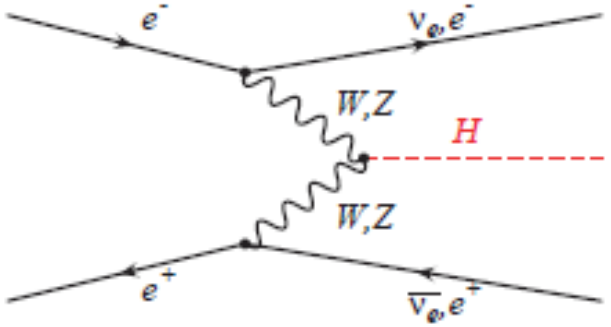


t t̄ fusion

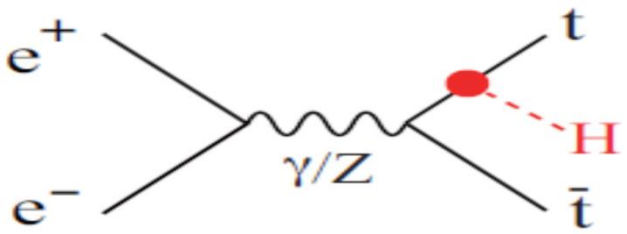
HIGGS PRODUCTION AT ILC



Higgs-Strahlung



Weak Boson Fusion



STANDARD MODEL PROBLEMS

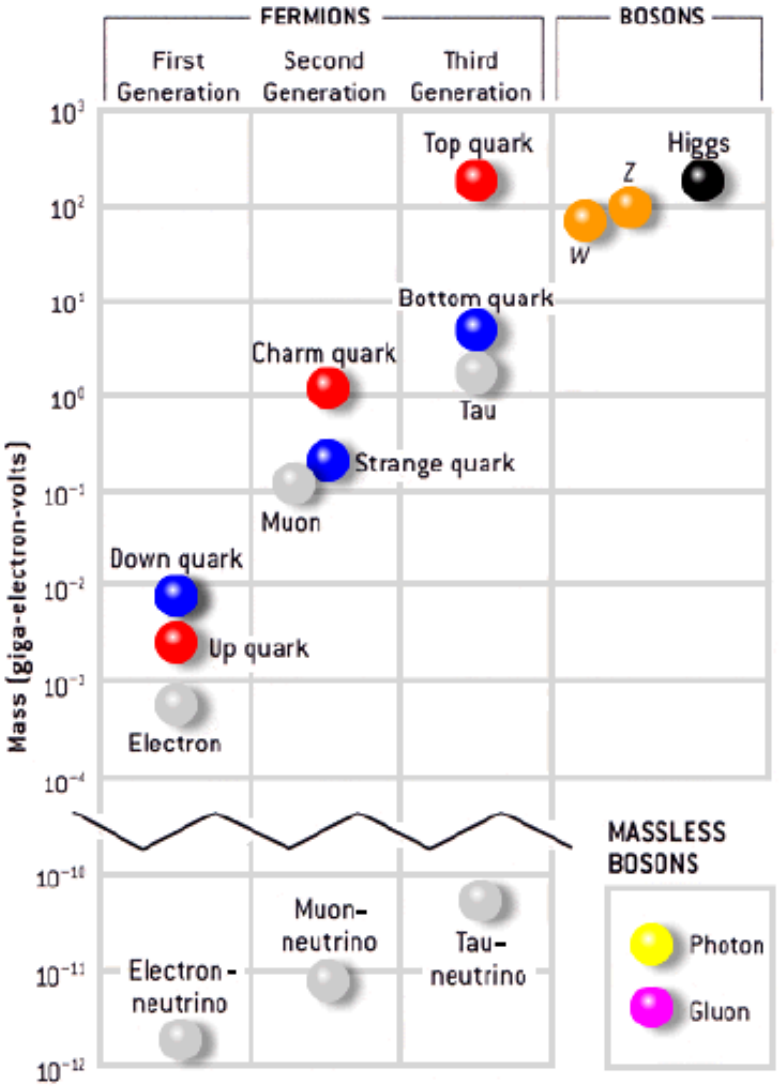
- **Experimental problems**

- Gravity. The standard model does not explain gravity
- Neutrino oscillations
- Matter–antimatter asymmetry
- The nature of dark matter and dark energy
- The origin of mass

- **Theoretical problems**

- Hierarchy problem
- Number of parameters

Standard model parameters: are there relations? why these values?



NONCOMMUTATIVE SPACE-TIME

space-time becomes non-commutative at very short distances, planck scale $M_{Pl} = 10^{19} GeV$ when quantum gravitation becomes relevant.

$$[x^{\mu}, x^{\nu}]_{*} = i\theta^{\mu\nu} = \frac{1}{\Lambda^2} C^{\mu\nu}$$

Dimension of energy

Constant antisymmetric matrix

$$f \star g(x,\theta) = f(x,\theta) \exp\left(\frac{i}{2} \overleftarrow{\partial}_{\mu} \theta^{\mu\nu} \vec{\partial}_{\nu}\right) g(x,\theta).$$

$$[\hat{\Lambda} \star \hat{\Lambda}'] = \frac{1}{2}\{\Lambda_a(x) \star \Lambda'_b(x)\}[T^a, T^b] + \frac{1}{2}[\Lambda_a(x) \star \Lambda'_b(x)]\{T^a, T^b\}$$

NONCOMMUTATIVE SPACE-TIME

there are two approaches to construct the standard model in the noncommutative space.

- $U(3)\times U(2)\times U(1)$ which is reduced to $SU(3)_C \times SU(2)_L \times U(1)_Y$ by an appropriate symmetry [2].

- $SU(3)_C \times SU(2)_L \times U(1)_Y$ based on star products and Seiberg-Witten (SW) maps, the number of gauge fields, couplings and particles are the same as the ordinary one [1]

[1] N. Seiberg and E. Witten, *JHEP* **9909, 032** (1999).
[2] M. Chaichian, P. Preˇsnajder, M. M. Sheikh-Jabbari and A. Tureanu, *Eur.Phys.J.*C**29**:413-432,(2003) [hep-th/0107055];

NONCOMMUTATIVE SPACE-TIME

Appropriate Symmetry breaking

$U(3)\times U(2)\times U(1) \longrightarrow SU(3)_C \times SU(2)_L \times U(1)_Y$

two new scalars, the so called Higgsac's.

Seyberg-Witten map

$SU(3)_C \times SU(2)_L \times U(1)_Y$

$$\hat{\psi} = \psi + e\,\theta^{\nu\rho}\,A_\rho \partial_\nu \psi$$

$$\hat{A}_\mu = A_\mu + e\,\theta^{\nu\rho}\,A_\rho\,[\partial_\nu A_\mu - \frac{1}{2}\partial_\mu A_\nu]\ .$$

THE ACTION OF THE NCSM

$$S_{NCSM} = S_{fermions} + S_{gauge} + S_{Higgs} + S_{Yukawa}\,.$$

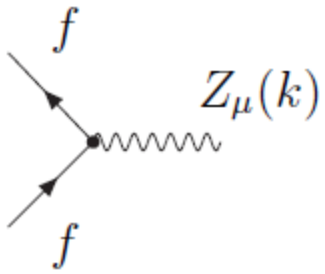
$$S_{fermions} = \int d^4x \sum_{i=1}^{3} \Big(\bar{\hat{L}}_L^{(i)} * (i\gamma^\mu \hat{D}_\mu \hat{L}_L^{(i)}) + \bar{\hat{Q}}_L^{(i)} * (i\gamma^\mu \hat{D}_\mu \hat{Q}_L^{(i)}) + \bar{\hat{e}}_R^{(i)} * (i\gamma^\mu \hat{D}_\mu \hat{e}_R^{(i)}) + \bar{\hat{u}}_R^{(i)} * (i\gamma^\mu \hat{D}_\mu \hat{u}_R^{(i)}) + \bar{\hat{d}}_R^{(i)} * (i\gamma^\mu \hat{D}_\mu \hat{d}_R^{(i)}) \Big),$$

$$S_{Higgs} = \int d^4x \left(h_0^\dagger (\hat{D}_\mu \hat{\Phi}) * h_0 (\hat{D}^\mu \hat{\Phi}) - \mu^2 h_0^\dagger (\hat{\Phi}) * h_0 (\hat{\Phi}) - \lambda h_0^\dagger (\hat{\Phi}) * h_0 (\hat{\Phi}) * h_0^\dagger (\hat{\Phi}) * h_0 (\hat{\Phi}) \right)$$

B. Melic, K. Passek-Kumericki, J. Trampetic, P. Schupp, and M. Wohlgenannt, *Eur. Phys. J.* **C42** (2005) 483–499, [hep-ph/0502249].

VERTICES IN NCSM

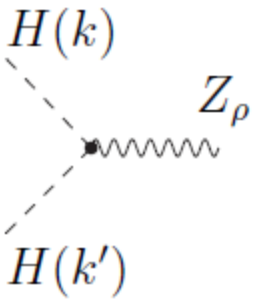
Correction to ffZ vertice



$$\frac{ie}{\sin 2\theta_W}\Big\{\Big(\gamma_\mu - \frac{i}{2}k^\nu \theta_{\mu\nu\rho}\, p_{in}^\rho\Big)\Big(c_{V,f} - c_{A,f}\,\gamma_5\Big)$$

$$-\frac{i}{2}\theta_{\mu\nu}\, m_f \Big[p_{in}^\nu \Big(c_{V,f} - c_{A,f}\,\gamma_5\Big) - p_{out}^\nu \Big(c_{V,f} + c_{A,f}\,\gamma_5\Big)\Big]\Big\},$$

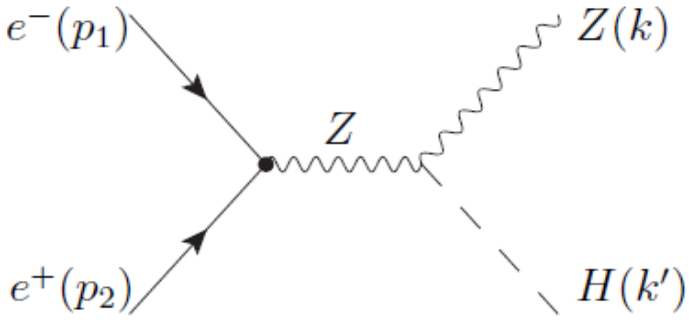
New vertice HHZ



$$-\frac{M_Z}{2v}[(k'^2 k_\beta + k^2 k'_\beta)\theta^{\beta\rho} + k'_\alpha k_\beta (k'-k)^\rho \theta^{\alpha\beta}$$

$$- m_H^2 (k'+k)_\alpha \theta^{\alpha\rho}]$$

$e^- e^+ \to ZH$



$$\left|\overline{M}\right|^2 = (2\frac{{M_Z}^3}{{\nu}^2}\frac{1}{{q}^2-{M_Z}^2})^2(1+\frac{1}{4}(q.\theta.p_1)^2)$$

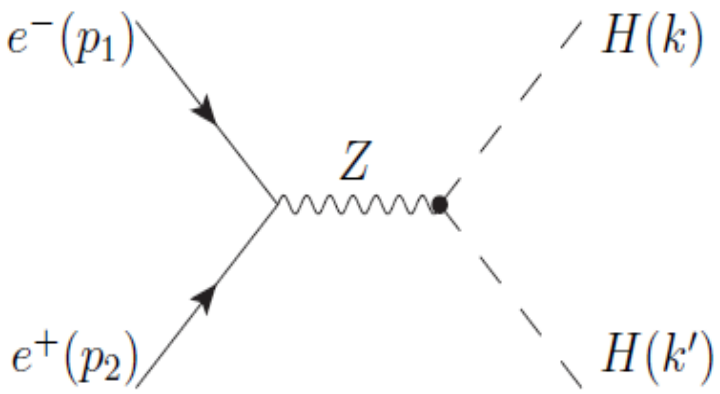
$$\times\{({C_V}^2+{C_A}^2)[p_1.p_2+\frac{2}{{M_Z}^2}(p_1.k)(p_2.k)]+3({C_V}^2-{C_A}^2){m_f}^2\}$$

$$\sigma(e^- e^+ \to ZH) = \frac{1}{96\pi}(\frac{M_Z}{\nu})^4({C_V}^2+{C_A}^2)\frac{|k|}{\sqrt{S}}[3{M_Z}^2+{k}^2]\left|\theta^{0i}\right|^2$$

$$k = [\frac{1}{4S}(S-{M_H}^2+{M_Z}^2)^2-{M_Z}^2]^{\frac{1}{2}}$$

$$E_{CM} = 1TeV \qquad \Lambda \geq 500GeV$$

$e^-e^+ \to HH$



$$|M|^2 = (\frac{M_Z}{v})^4 (\frac{1}{q^2 - M_z^2})^2 (C_V{}^2 + C_A{}^2)(k'.\theta.k)^2$$
$$[2((k'-k).p_1)((k'-k).p_2) - (k'-k)^2(p_1.p_2)]$$

$$\sigma(e^-e^+ \to HH) = \frac{1}{48\pi}(\frac{M_Z}{v})^4 (C_V{}^2 + C_A{}^2)\left|\theta^{0i}\right|^2 \times \frac{\sqrt{s}}{(S - M_Z{}^2)^2}(\frac{S}{4} - M_H{}^2)^{\frac{5}{2}}$$

$$E_{CM} = 1TeV \qquad \Lambda \geq 400GeV$$

Thanks for your attention