Fundamental composite Higgs dynamics on the lattice

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Introduction

- Before CERN:
    - 2007-2010 : PhD, Grenoble, France
    - 2010-2013 : Postdoc, DESY-Zeuthen, Germany
    - 2013-2015 : Postdoc, CP3-Origins, Denmark

- Research Interests :
    - Lattice QCD :
        - ★Nucleon structure calculation
        - ★σ-terms, strangeness of the nucleon
        - ★Disconnected diagrams

$\Rightarrow$ Poor signal-over-noise ratio, renormalisation issues

- Lattice BSM :
    - ★Extensions of the SM with strong dynamics ?
    - ★ What are the key (lattice) observables ?
    - ★Use the lattice approach into a predictive machine for theories that are not observed in Nature.

$\Rightarrow$ Requires new ideas/techniques depending on the underlying theory

Unified Composite Higgs

- SU(2) gauge theory with $N_f = 2$ Dirac fermions in the fundamental representation.

$$\mathcal{L} = -\tfrac{1}{4}F^a_{\mu\nu}F^{a\mu\nu} + i\overline{U}\gamma^\mu D_\mu U + i\overline{D}\gamma^\mu D_\mu D + \tfrac{m}{2}Q^T(-i\sigma^2)C\,EQ + \tfrac{m}{2}\left(Q^T(-i\sigma^2)C\,EQ\right)^\dagger$$

- Pseudo-real irrep of SU(2): **global flavour symmetry is upgraded to SU(4)** :

$$Q \equiv \begin{pmatrix} U_L \\ D_L \\ \widetilde{U}_L \\ \widetilde{D}_L \end{pmatrix} \equiv \begin{pmatrix} U_L \\ D_L \\ -i\sigma_2 C\bar{u}_R^T \\ -i\sigma_2 C\bar{d}_R^T \end{pmatrix}, \quad E = \begin{pmatrix} 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \\ -1 & 0 & 0 & 0 \\ 0 & -1 & 0 & 0 \end{pmatrix}$$

- Infinitesimal SU(4) transformation $Q \longrightarrow \left(1 + i\sum_{n=1}^{15}\alpha^n T^n\right)$
- Generators that leaves the Lagrangian invariant satisfy : $ET^n + T^{nT}E = 0$
- Chiral symmetry breaking pattern : **SU(4) breaks to SP(4)** $\Longrightarrow$ 5 Goldstone Bosons

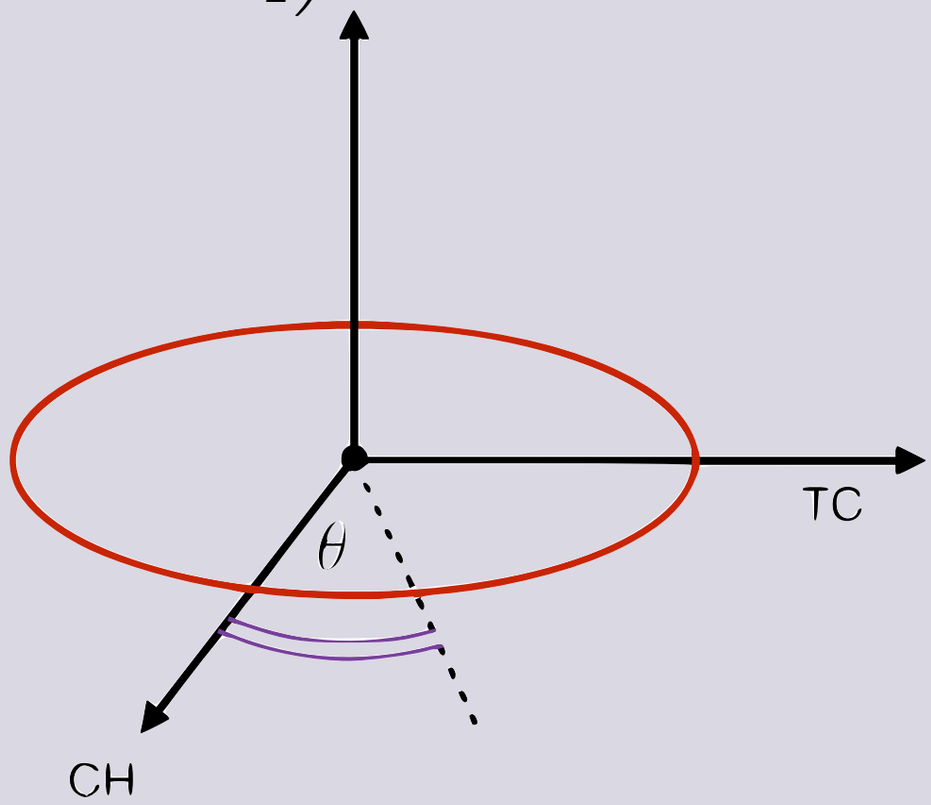
EW embedding

[G. Cacciapaglia & F. Sannino, JHEP04(2014)III]

- Two interesting alignments of the condensate :

$\Sigma_H \equiv E = \begin{pmatrix} 0 & 1 \\ -1 & 0 \end{pmatrix}$: break EW symmetry $\qquad \Sigma_B \equiv \begin{pmatrix} i\sigma_2 & 0 \\ 0 & -i\sigma_2 \end{pmatrix}$: does not break EW

- General superposition : $\Sigma_0 = \cos\theta\ \Sigma_B + \sin\theta\ \Sigma_H$



- $Q_L = (U_L, D_L)$: $SU(2)_L$ doublet with hypercharge 0
- $\tilde{U}_L, \tilde{D}_L$: $SU(2)_L$ singlet with hypercharge $\pm 1/2$
- Electric charge matrix :

$$Q = \mathrm{diag}\left(\frac{1}{2}, -\frac{1}{2}, -\frac{1}{2}, \frac{1}{2}\right)$$

- Two limit cases :
  - θ = 0 : EW does not break : composite Higgs limit
  - θ = π/2 : EW breaks + DM candidate : technicolor limit

- Mixed case is natural : 0 < θ < π/2

$\Longrightarrow$ the model interpolate between TC and CH

GB scattering

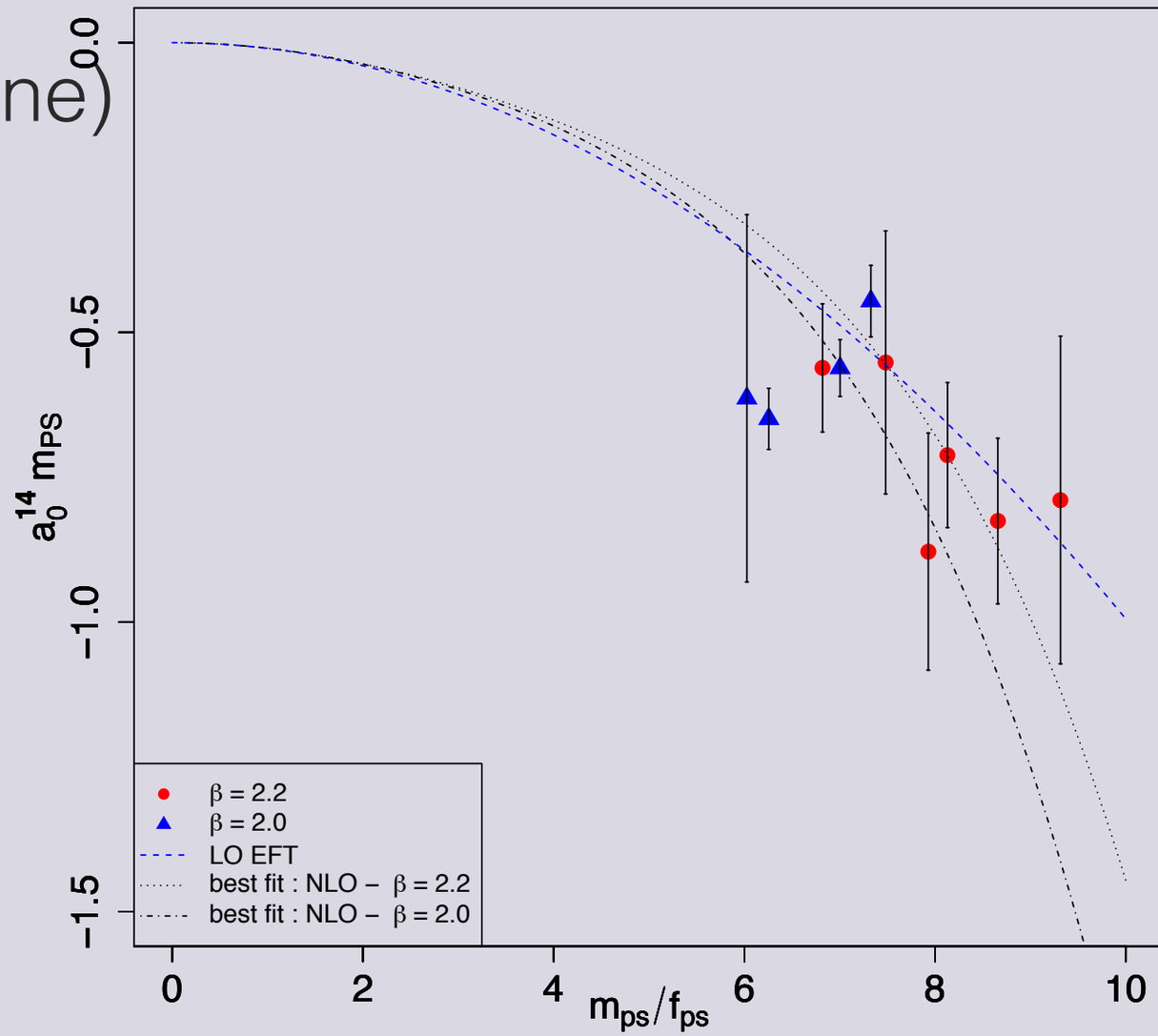
- Scattering properties of the W are related to the scattering of the underlying GB. (Equivalence Theorem)

[Quigg & Thacker PRD 1978]

- First step : scattering length (done)

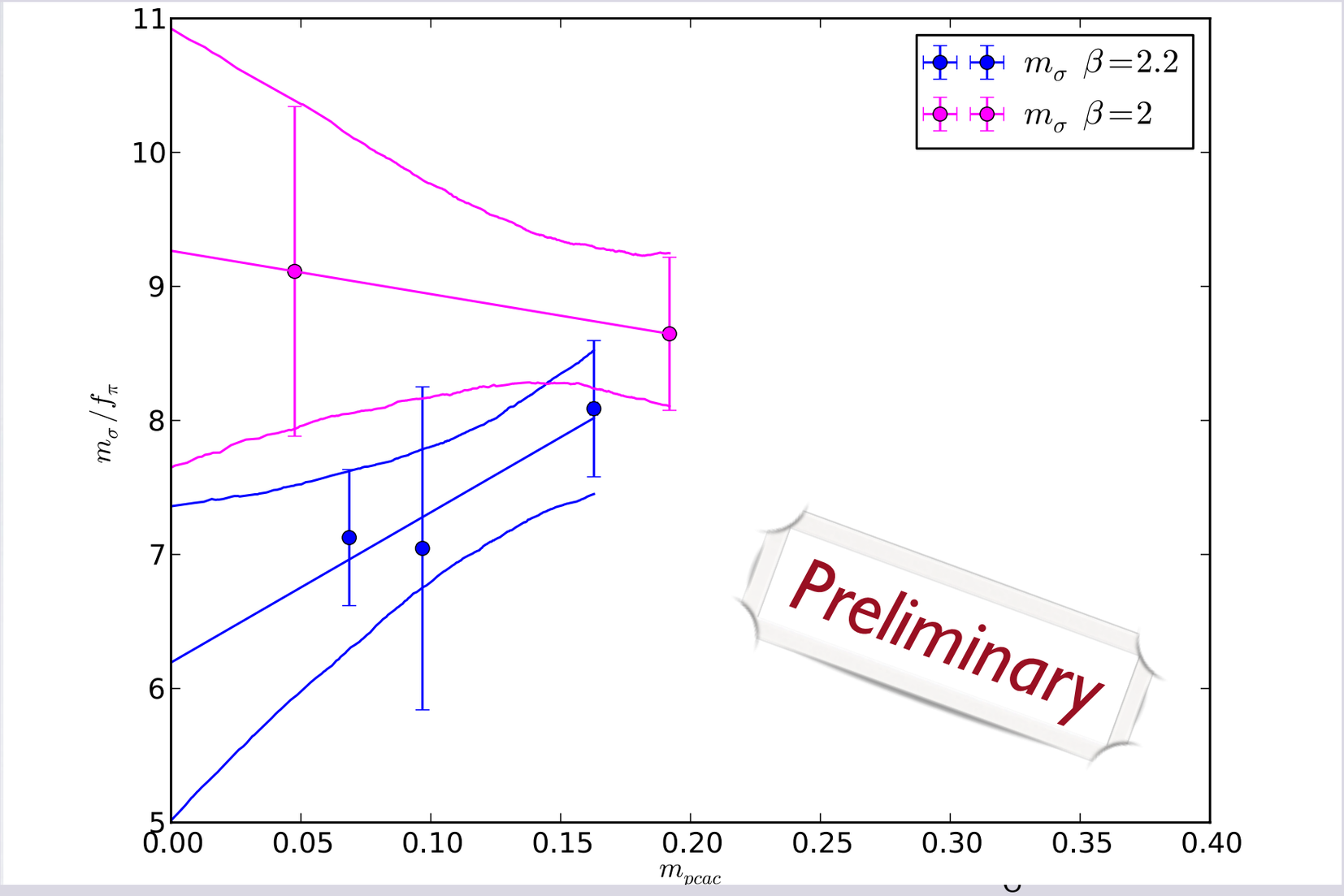
- Then : width of vector meson

$\Rightarrow$ Related to the decay rate into Ws of the new resonance



The σ

- Higgs field : linear combination of GB fields and of the σ field
- m_σ can in principle be determined numerically in isolation



⟹ Large contribution from disconnected diagrams

⟹ Unstable in the chiral limit

⟹ Large correction from the SM

Summary & Outlook

- One interesting framework :

  Unified Composite Higgs and Technicolor model

- Estimation of new observables (scattering properties, m_σ)
- Investigate properties of the DM candidate in the TC limit (my contribution to lattice 2015)

- Outlook :
  - Vector resonance decay rate into Ws
  - SM corrections ? (four-fermion interaction on the lattice ?)
  - Suggestions …