The KMI φ project

Yasumichi Aoki [Kobayashi-Maskawa Institute(KMI), Nagoya University]

- at KMI2013 International Symposium -

Dec. 11, 2013

NAGOYA UNIVERSITY

KMI high performance computer φ

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- purpose
    - strong gauge dynamics, especially for BSM physics
    - solve the non-perturbative dynamics quantitatively
        - allows to test the theory against experiments: EW measurements, **LHC**

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  - strong gauge dynamics, especially for BSM physics
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- uniqueness
  - setting main target as BSM physics ↔ QCD dedicated computers
- operation policy
  - promote a few projects to grant large resource to maximize the outcome
  - while allowing small projects for test phase use / non-demanding tasks
  - anybody can use under collaboration with PI in KMI or Nagoya Univ.

KMI computer

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- non GPU nodes
  - 148 nodes
  - 2x Xenon 3.3 GHz
  - 24 TFlops (peak)

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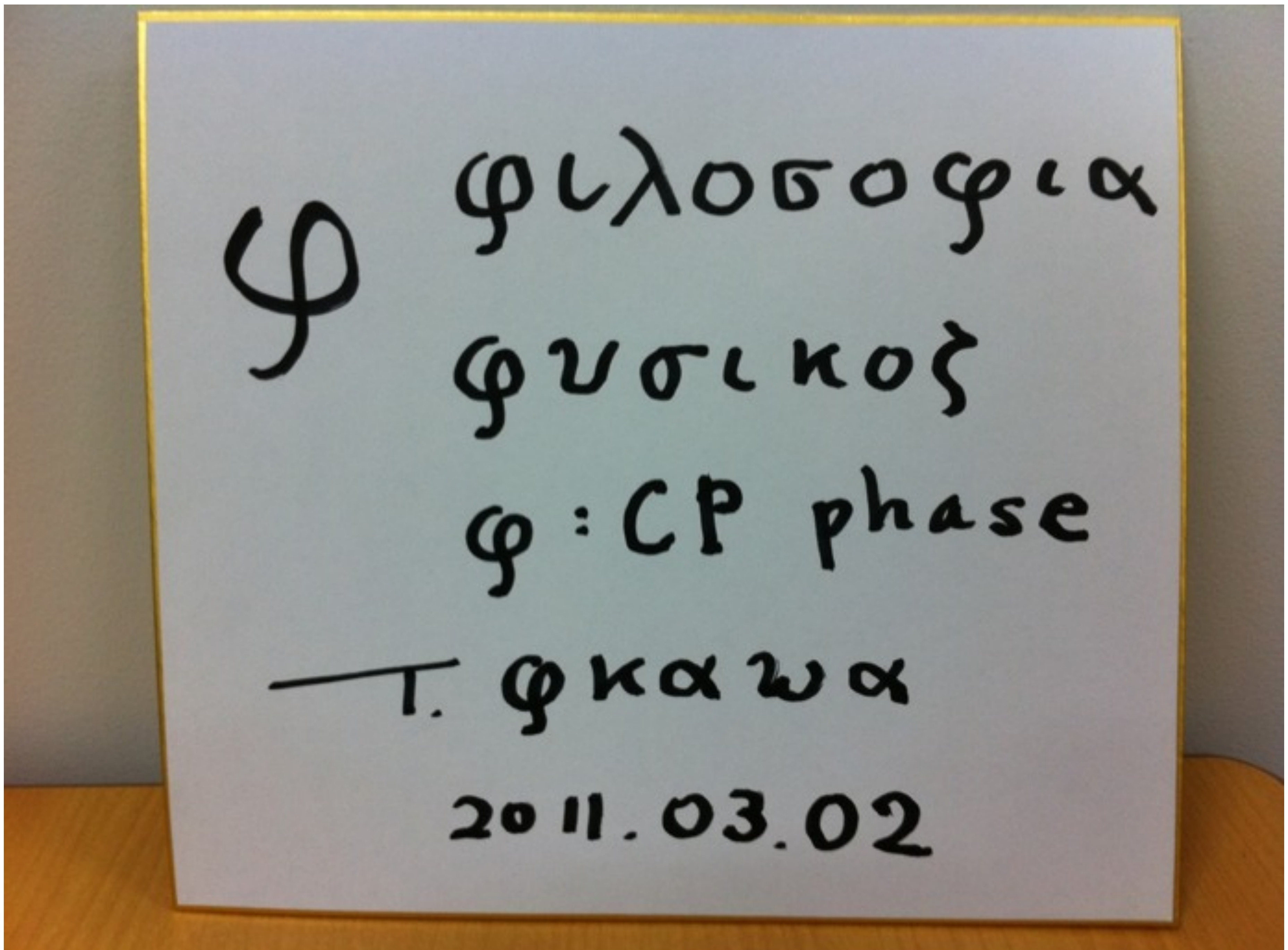
- 62 TFlops (peak; comparable to Japanese top 20 of top500 list @ 2012.10)

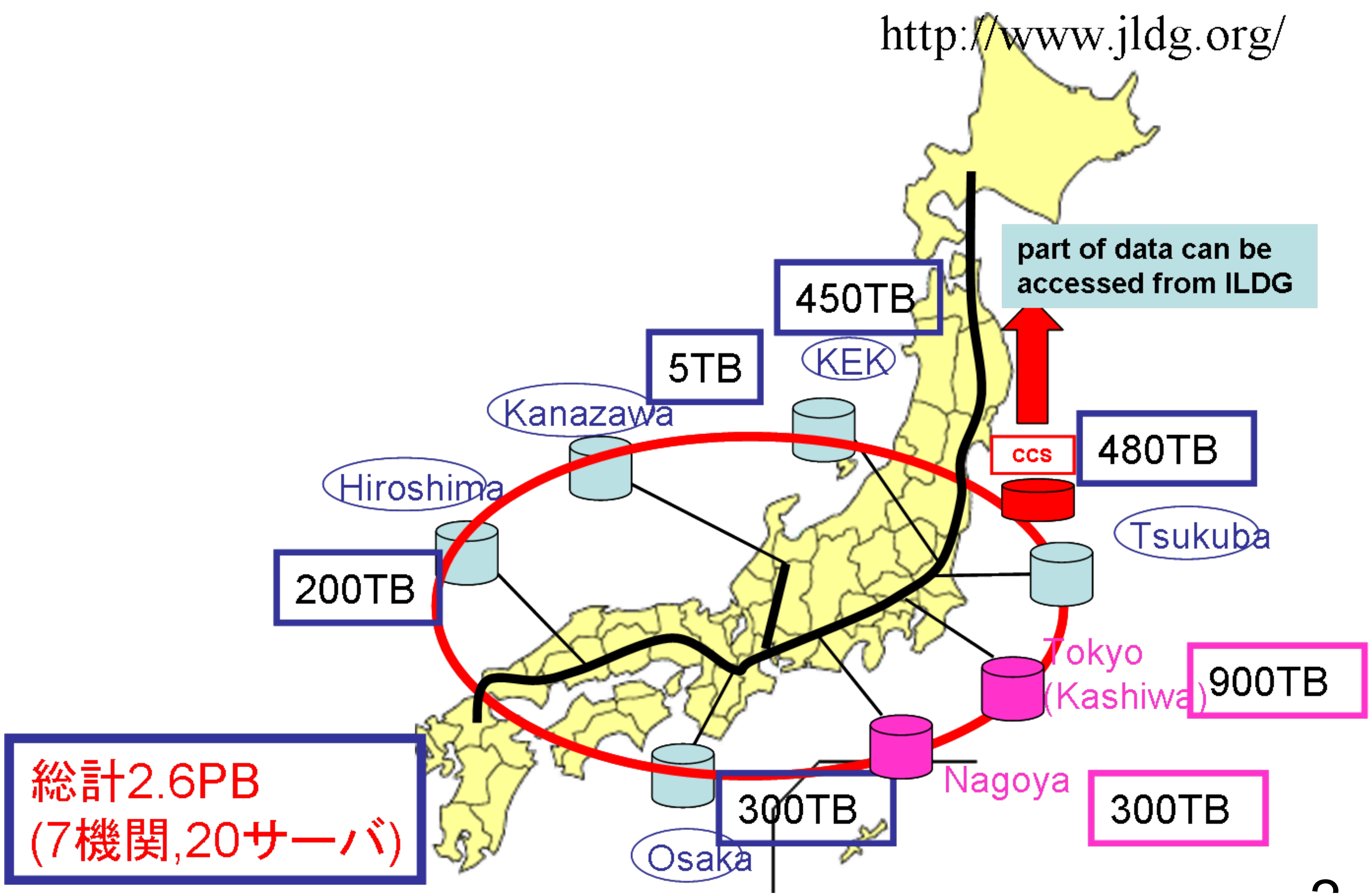
φ inauguration March 2, 2011

Inauguration Ceremony of φ
March 2nd, 2011



Infrastructure for global data sharing: JLDG

- Japan Lattice Data Grid server @ KMI connected to other site with SINET vpn



priority projects

Group	Project title	PI	Members
sc-su2phase	Lattice study of quantum-mechanical dynamics of two-color QCD with six flavors of quarks	M. Hayakawa	K. Ishikawa, Y. Osaki, S. Takeda, M. Tomii, N. Yamada
scgt8	Exploring for walking technicolor model with 8-flavor SU(3) gauge theory	T. Aoyama, T. Yamazaki	Y. Aoki, K. Hasebe, M. Kurachi, T. Maskawa, K. Miura, K.-i. Nagai, H. Ohki, E. Rinaldi, A. Shibata, K. Yamawaki
scgt12	Phase structure near the chiral phase boundary in many flavor QCD	Y. Aoki, H. Ohki	T. Aoyama, K. Hasebe, M. Kurachi, T. Maskawa, K. Miura, K.-i. Nagai, E. Rinaldi, A. Shibata, K. Yamawaki, T. Yamazaki
scgtmeas	Nonperturbative computation of the spectroscopy in SU(3) gauge theory	M. Kurachi, K.-i. Nagai	Y. Aoki, T. Aoyama, K. Hasebe, T. Maskawa, K. Miura, H. Ohki, E. Rinaldi, A. Shibata, K. Yamawaki, T. Yamazaki

- 2/3 of whole resource is granted to these 4 projects
- rest ~10 small projects

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LatKMI collaboration:
KMI's flagship project

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e/μ anomalous magnetic moment
→ talk by Aoyama (Today)

φ sub system and COSMOS @ KMI

- ctpl1 & ctpl2

COSMOS

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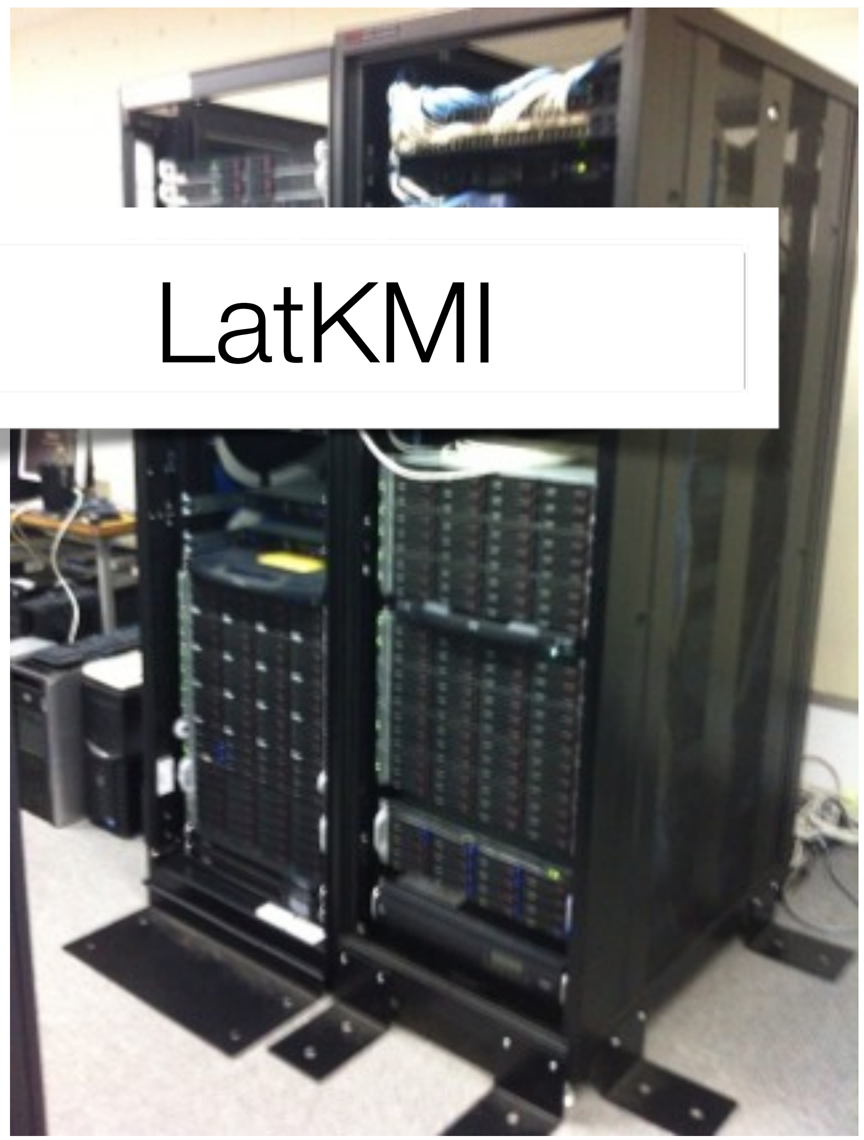
LatKMI



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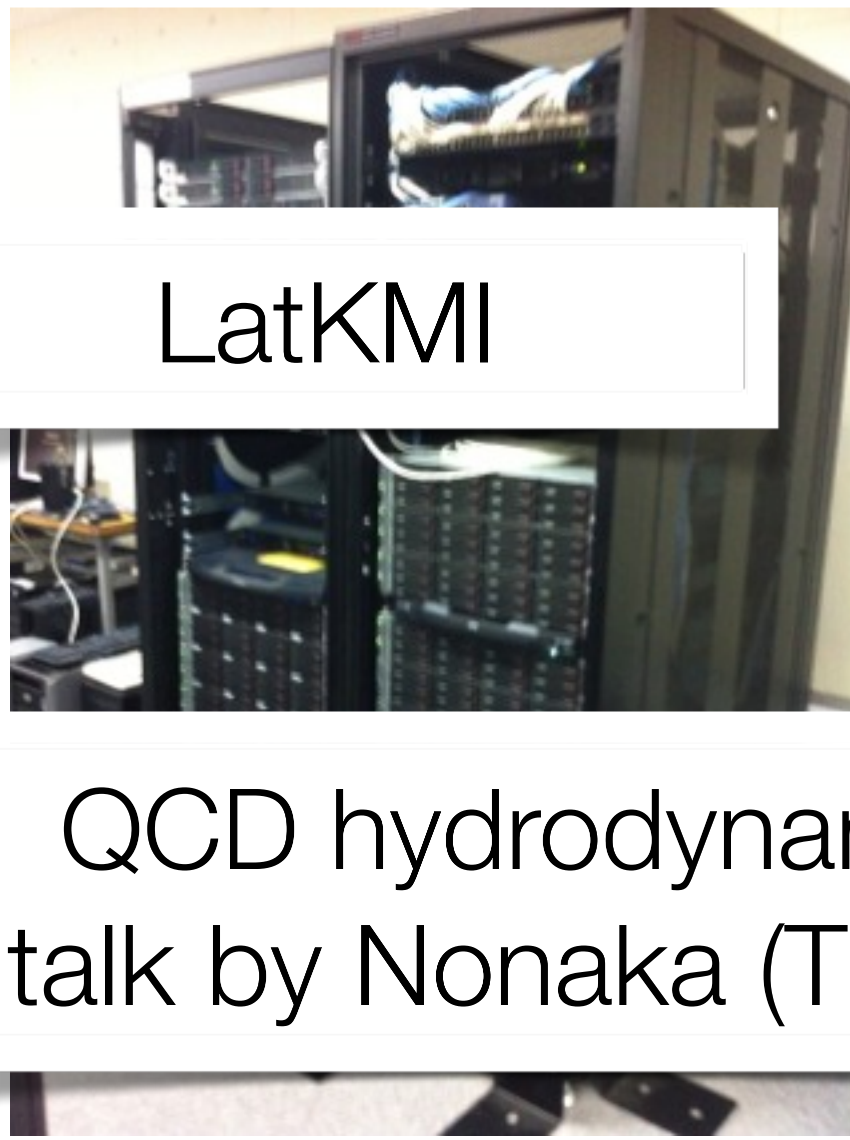
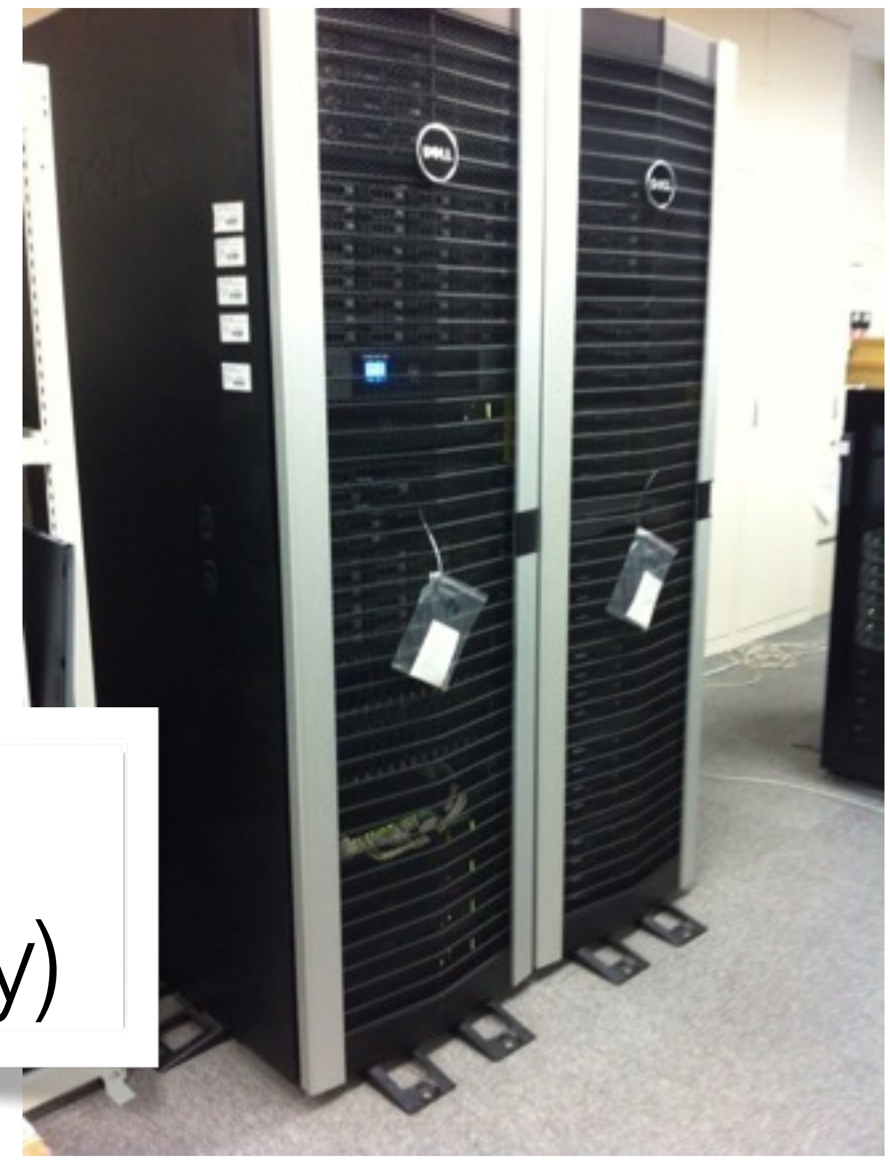


LatKMI

QCD hydrodynamics
→ talk by Nonaka (Thursday)

COSMOS



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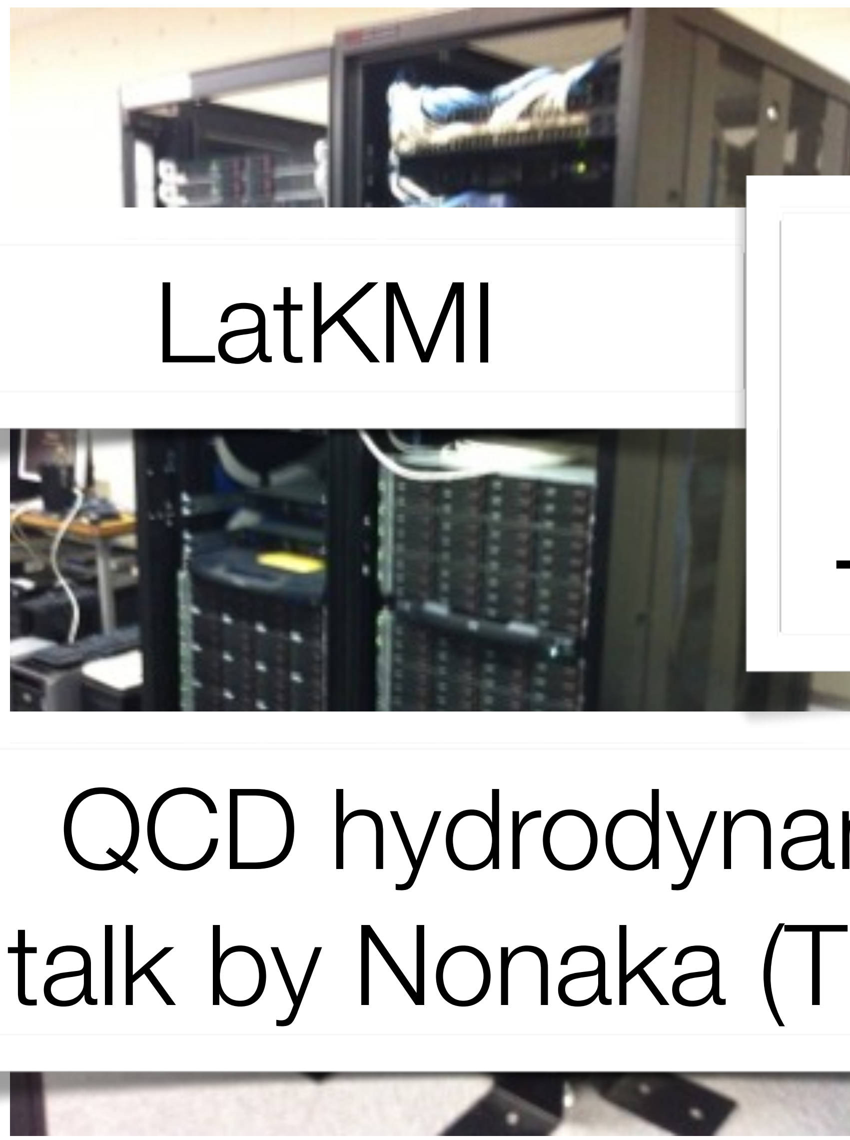

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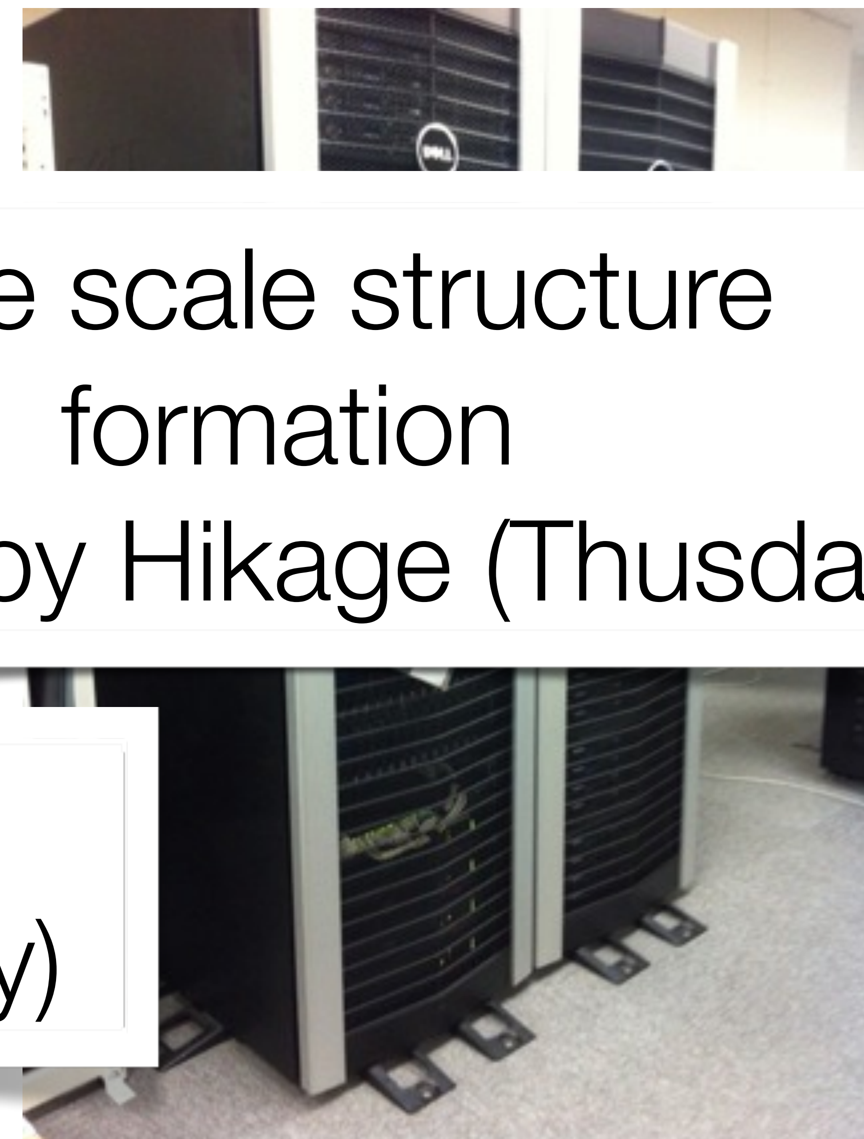


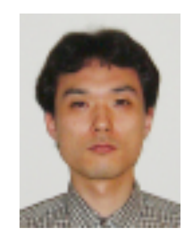
large scale structure formation
→ talk by Hikage (Thusday)

LatKMI collaboration

- YA, T.Aoyama, M.Kurachi, T.Maskawa, K.Miura, K.Nagai,

H.Ohki, K.Yamawaki, T.Yamazaki

名古屋大学    KMI

- E. Rinaldi

Lawrence Livermore National Laboratory

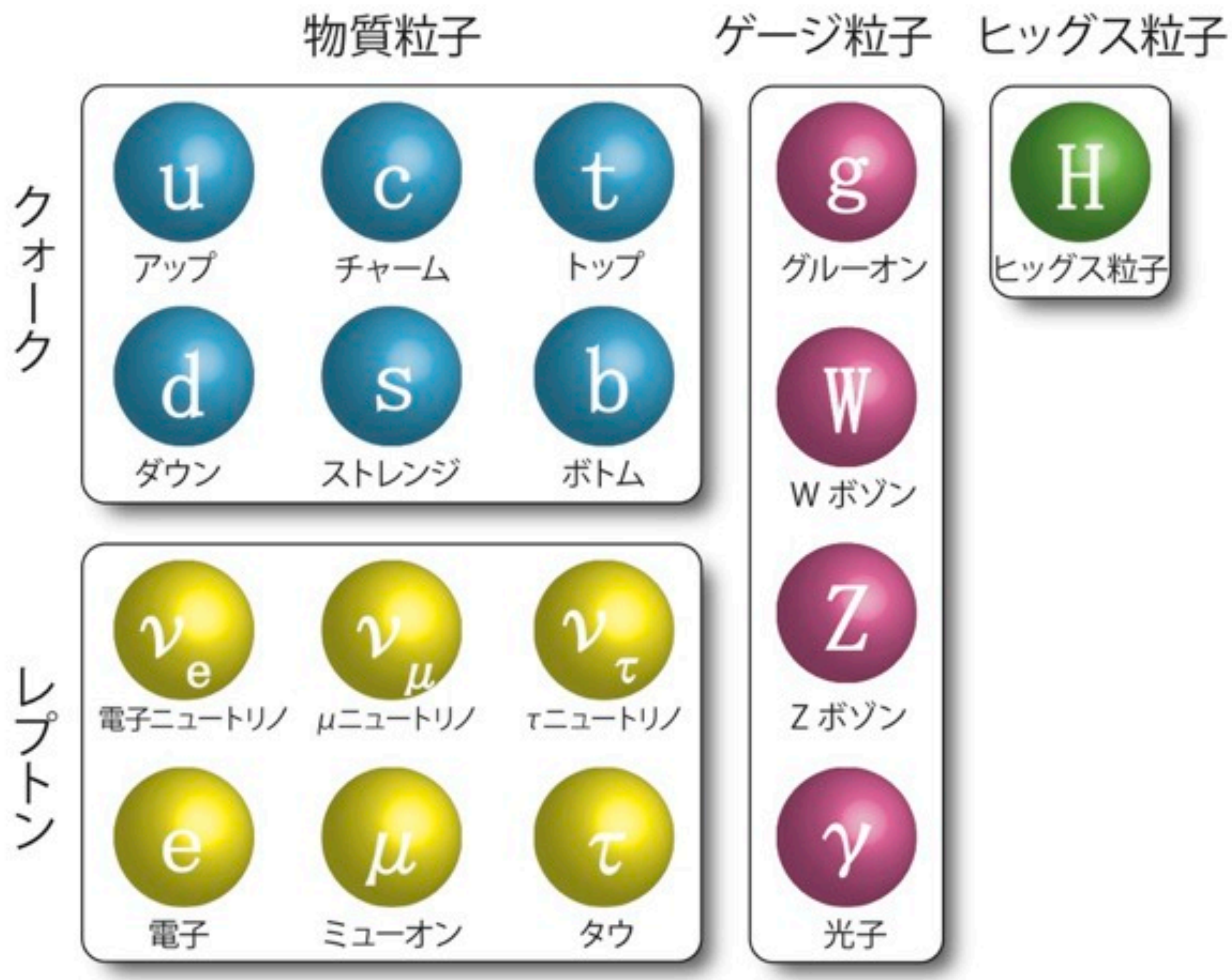
A.Shibata

KEK

LatKMI mission

- (kick off meeting at 28 Sep. 2010; computer installment 2 Mar. 2011)
- mission focused as time goes by...
- find / understand (near) **conformal dynamics** in gauge theory (late 2010)
    - /w state-of-the-art lattice discretization (HISQ) and large scale computation
- find **conformal window** in **SU(3)** gauge theory w. $\mathbf{N_f}$ m=0 fundamental fermions
- find a **walking technicolor theory** in SU(3) gauge theory
- investigate $\mathbf{N_f=8}$ in some detail
- investigate **flavor singlet scalar** in SU(3) gauge theory ⇔ Higgs
- test N_f=8 against experiment

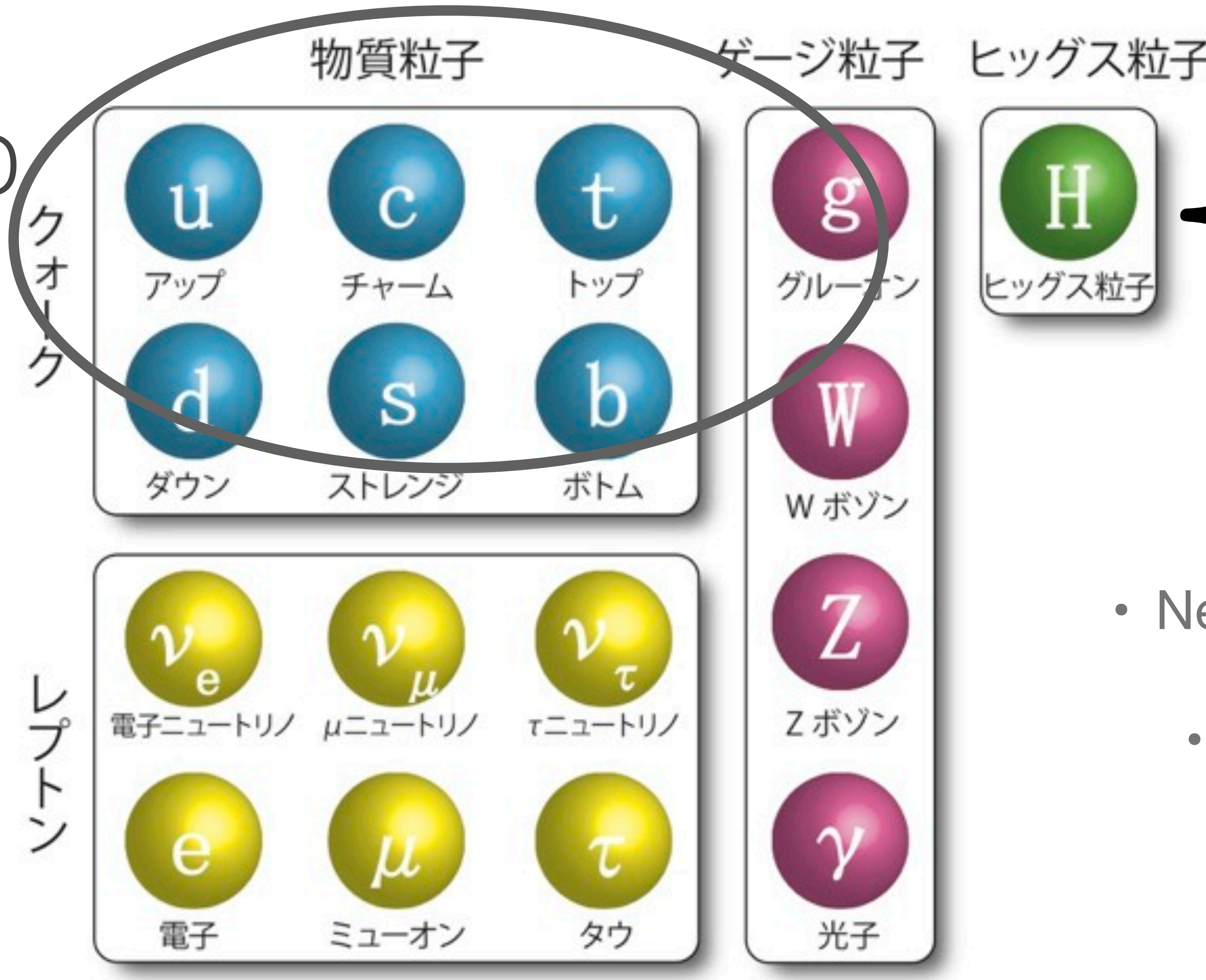
Physics motivation: new physics



Standard Model

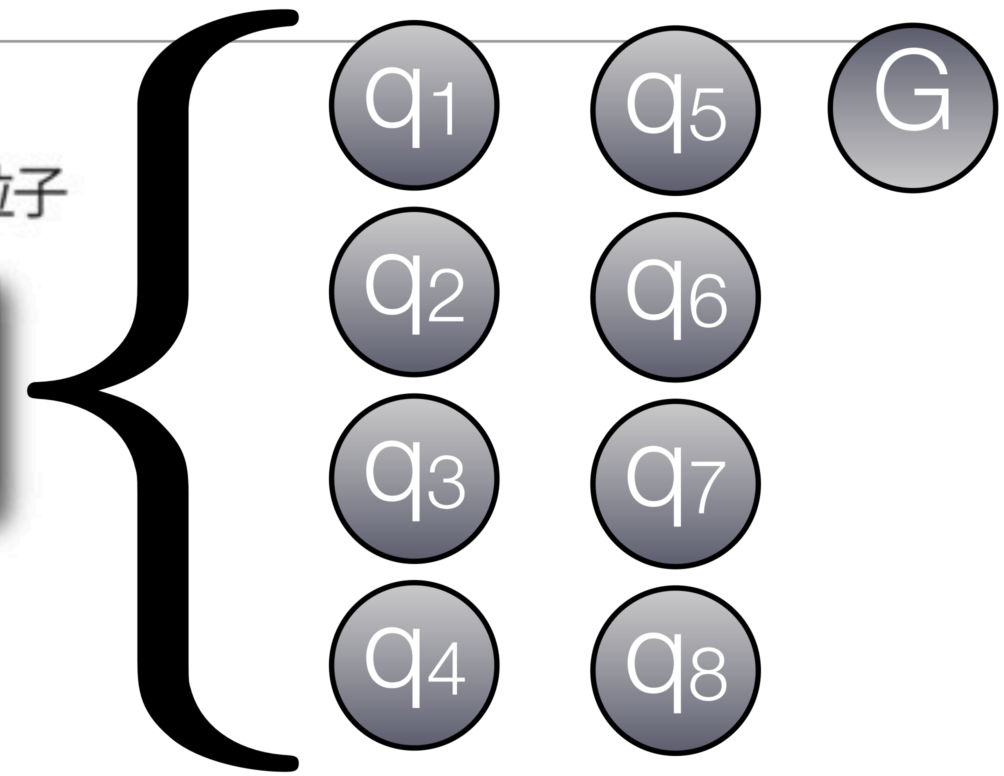
Physics motivation: new physics

QCD



Standard Model

techni-quarks **techni-glueon**



- New techni sector
  - QCD like interaction

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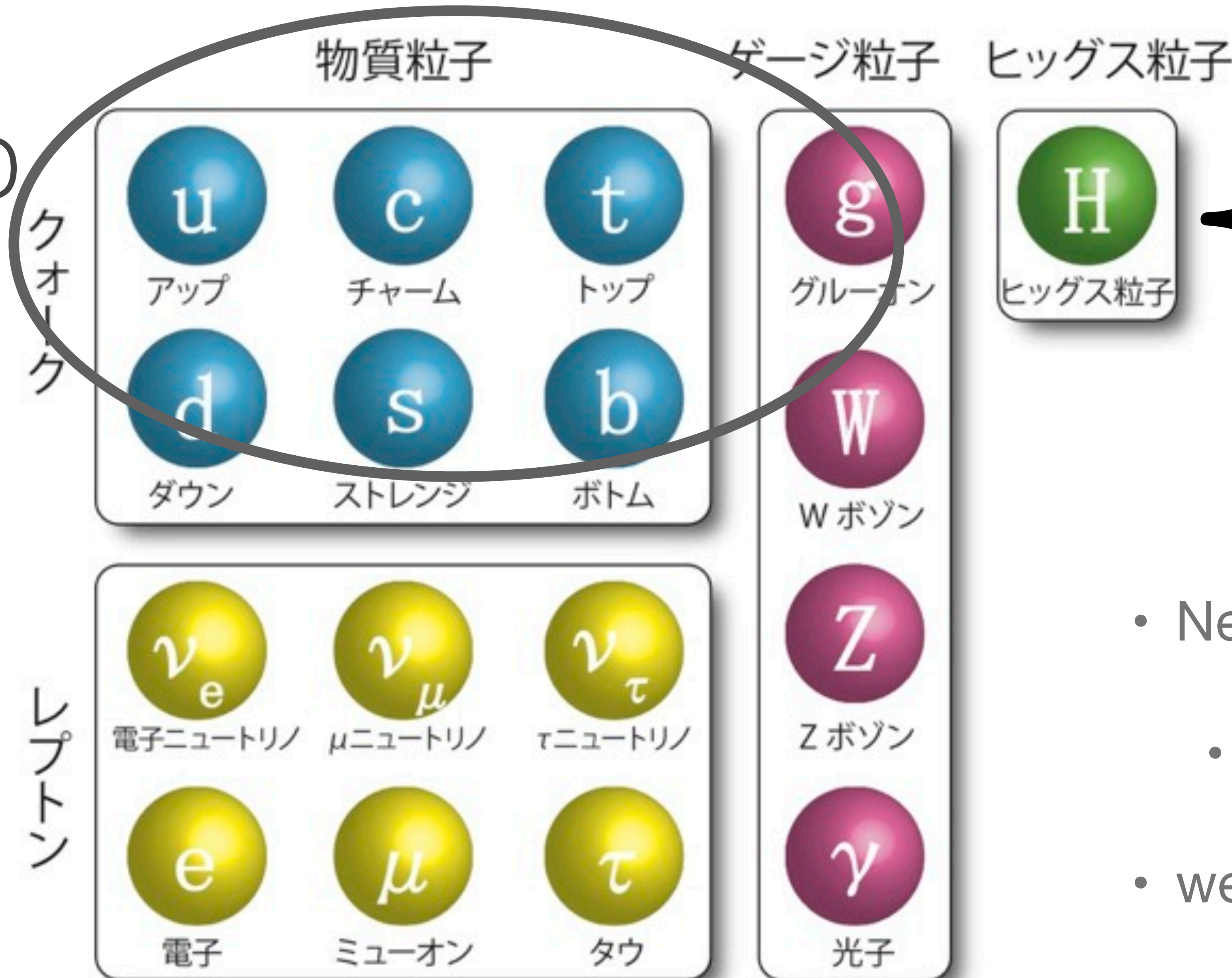

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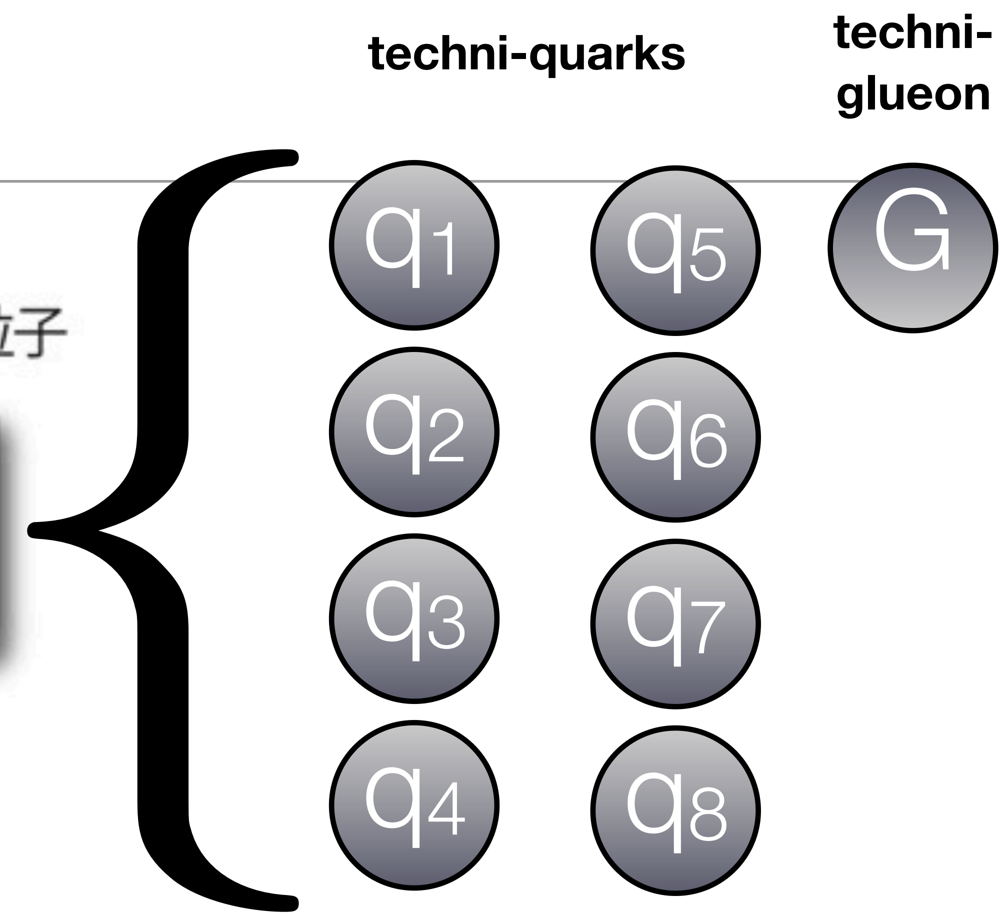

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- weakly coupled with SM sector

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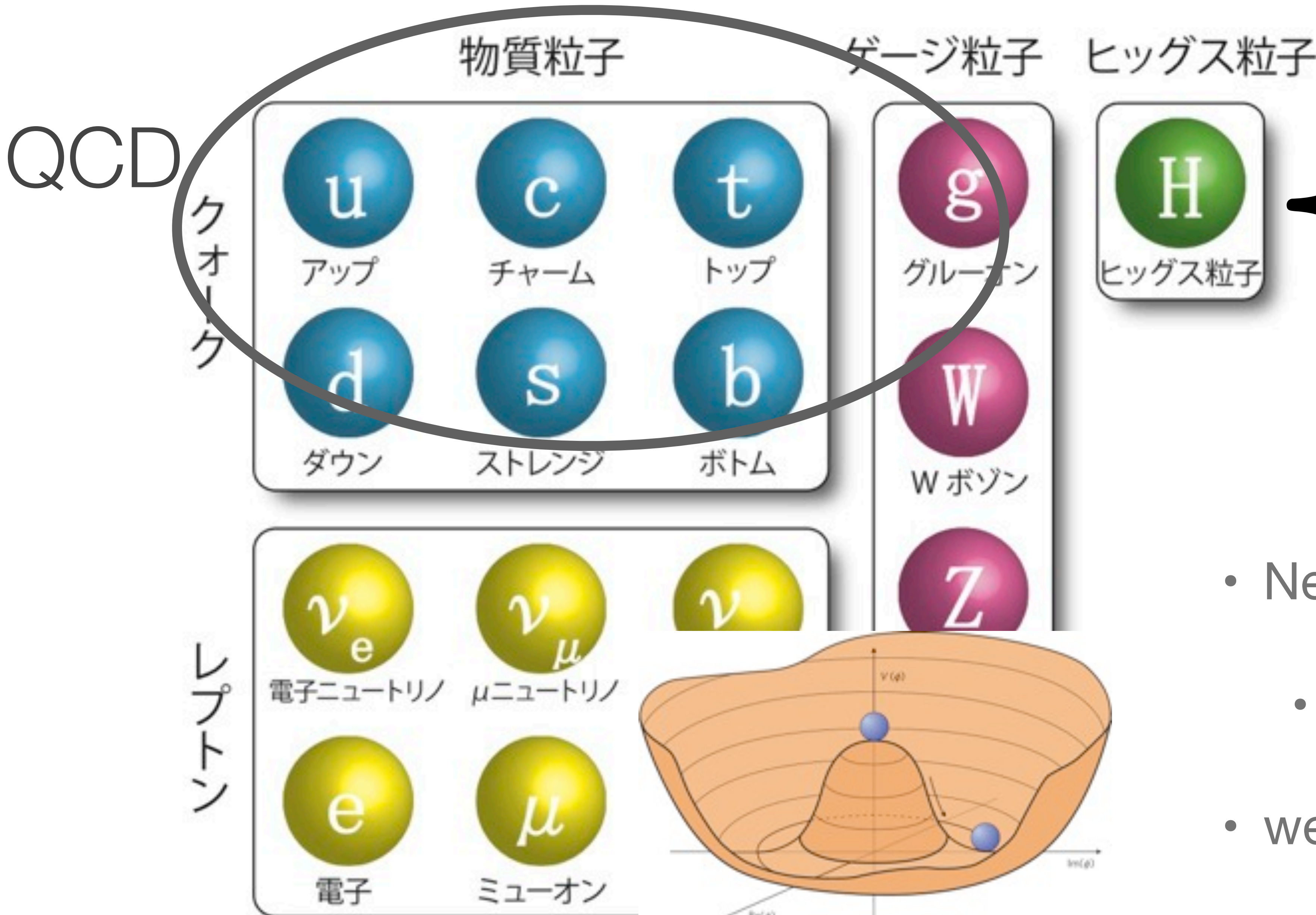

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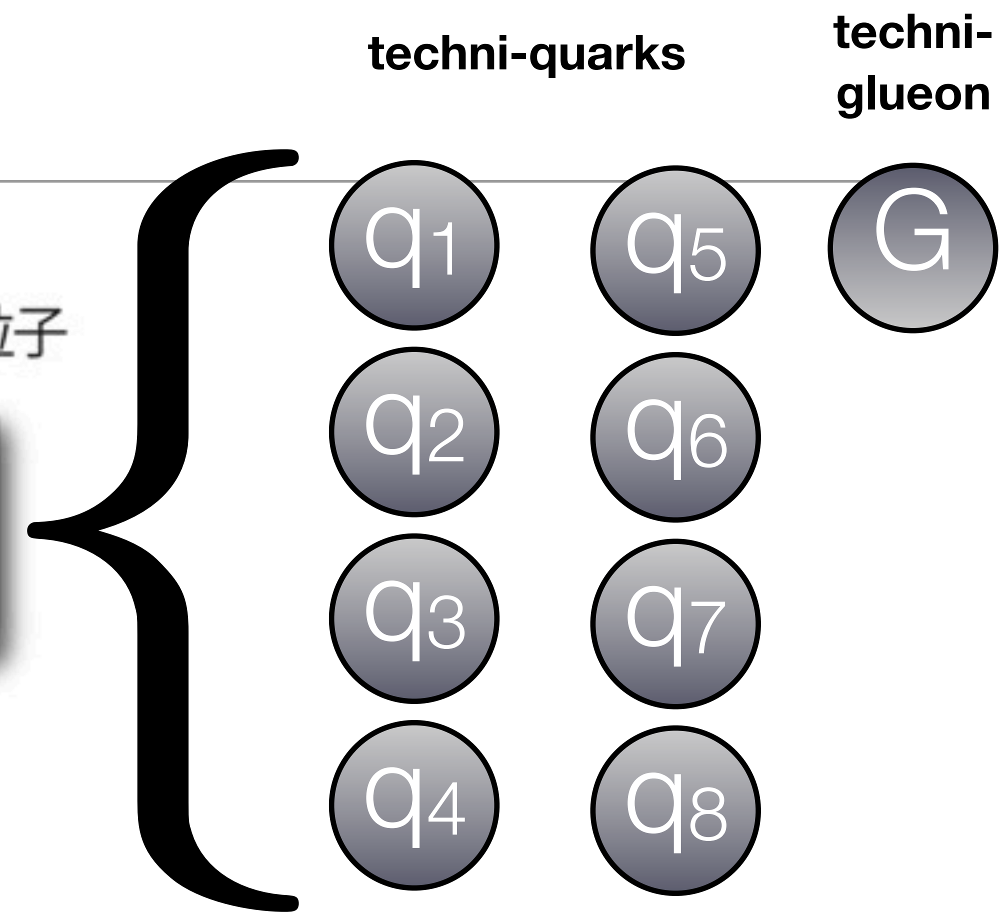

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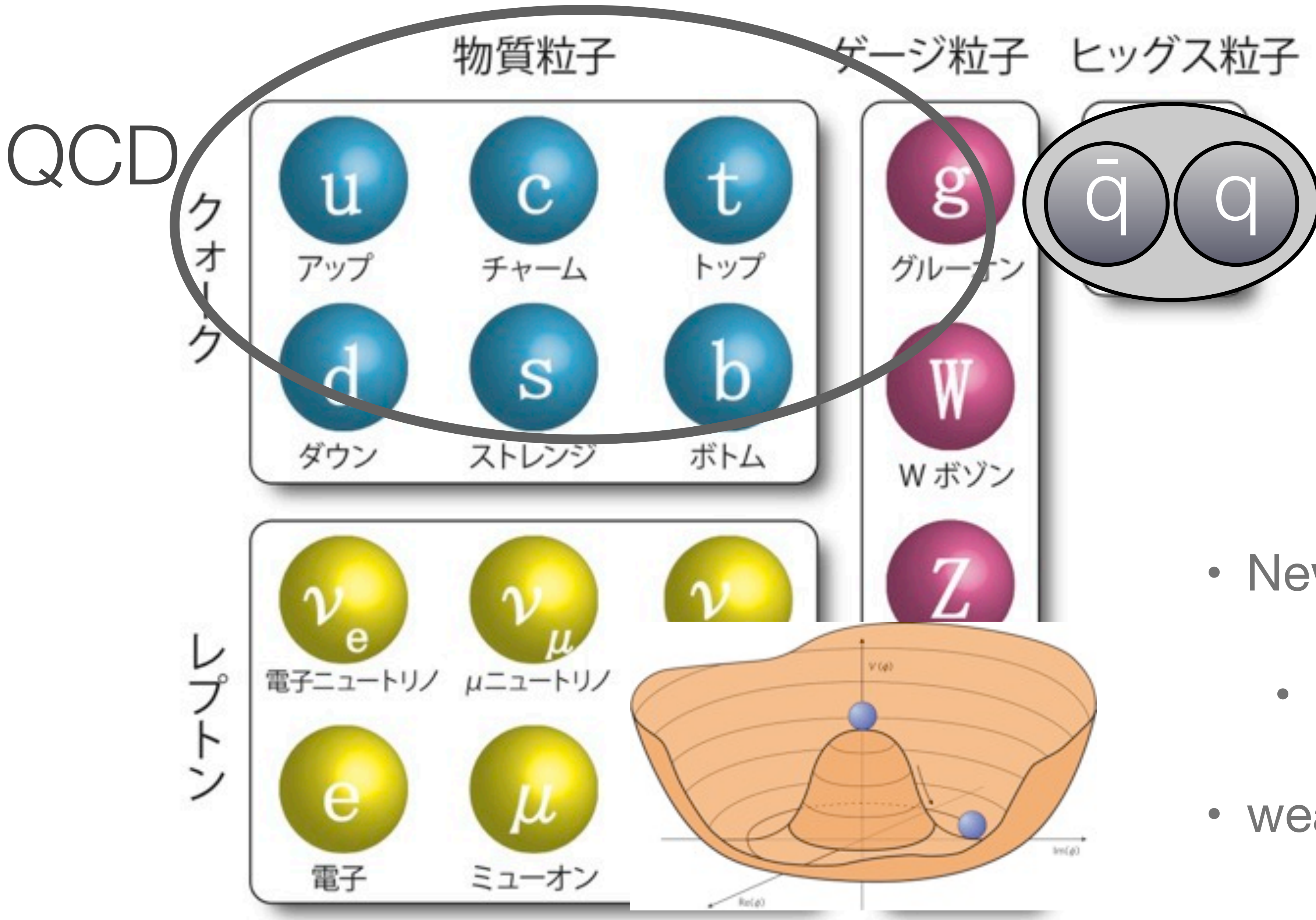

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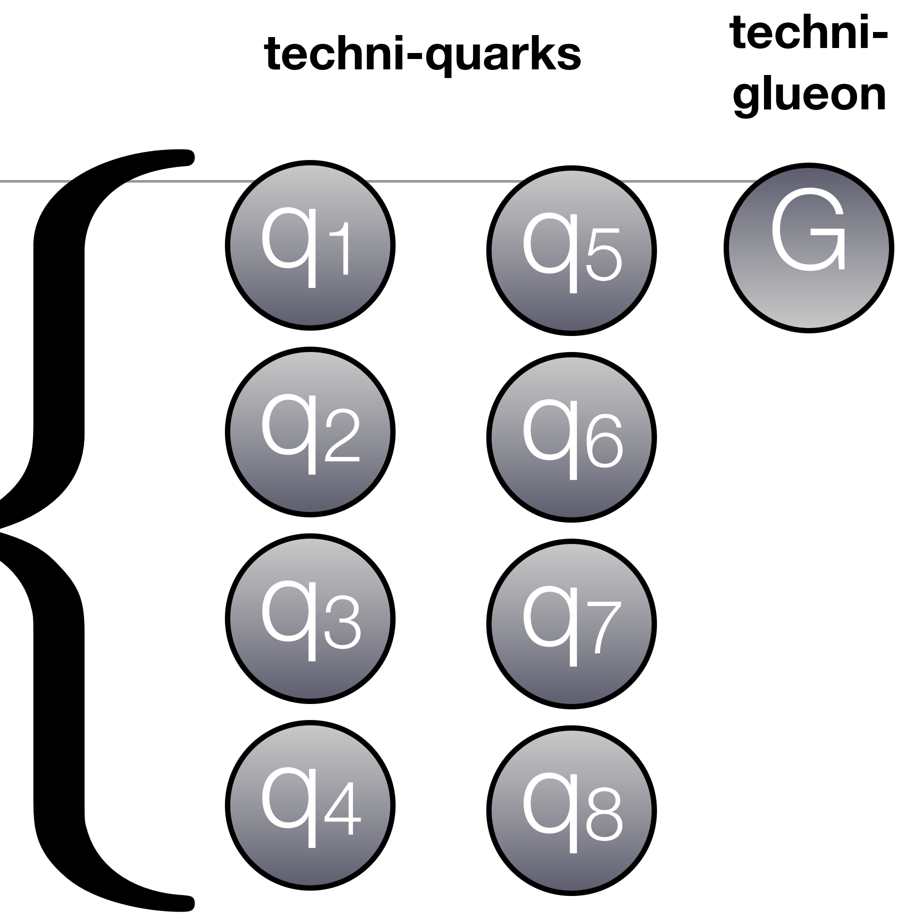

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- weakly coupled with SM sector
- resemble Higgs mechanism
- produce Higgs like particle

Walking Technicolor (WTC)

- a candidate of the new physics beyond the Standard Model of particles
- could replace Higgs sector of the Standard Model
  - Higgs sector is a low energy effective theory of WTC
- free from the gauge hierarchy problem (naturalness)
- gives explanation of the electro-weak gauge symmetry breaking,
  - thus origin of mass of the elementary particles
- "Higgs" = pseudo Nambu-Goldstone boson
  - due to breaking of the approximate scale invariance

  ➡Techni Dilaton (Yamawaki, Bando, Matsumoto)

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➡ developing field

➡ still controversies

LatKMI publications

- LatKMI, PRD 85 (2012), "Study of the conformal hyperscaling relation through the Schwinger-Dyson equation" [non-lattice]
- LatKMI, PRD 86 (2012), "Lattice study of conformality in twelve-flavor QCD"
- LatKMI, PRD 87 (2013), "Walking signals in Nf=8 QCD on the lattice"
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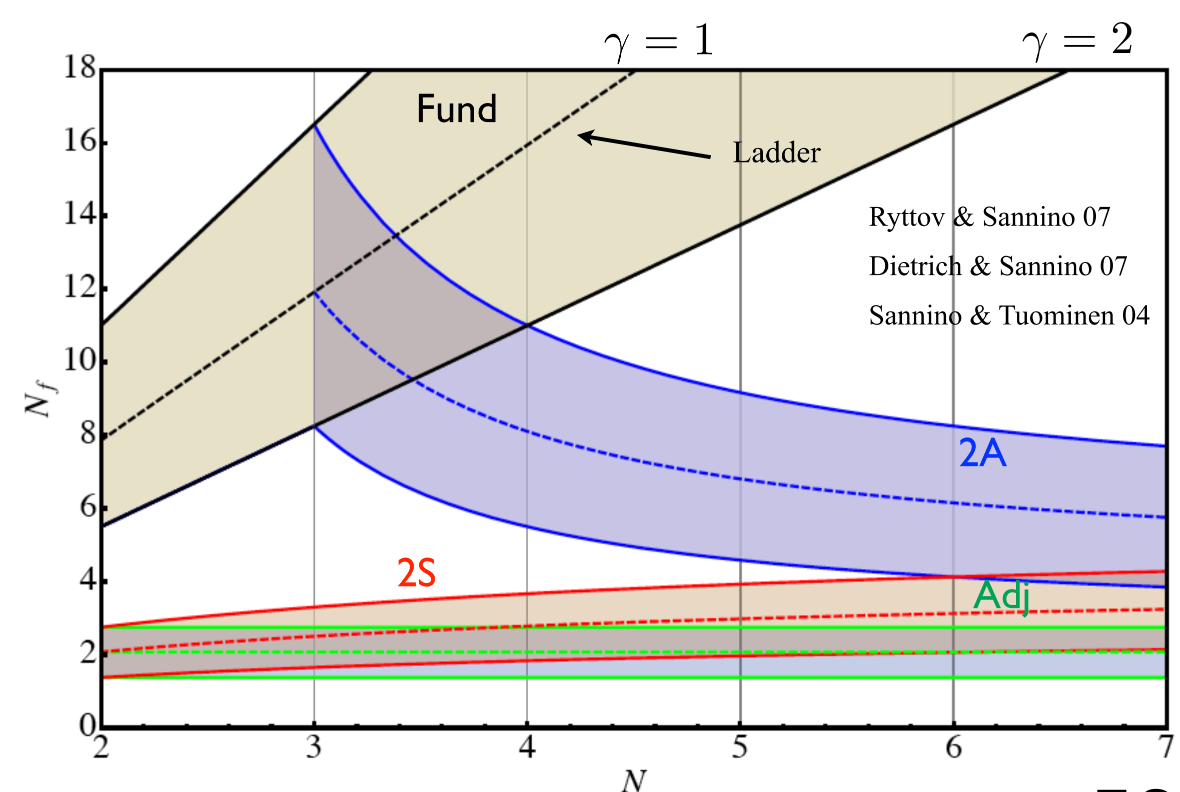
models being studied:

- SU(3)
  - fundamental: Nf=6, 8, 10, 12, 16
  - sextet: Nf=2
- SU(2)
  - adjoint: Nf=2
  - fundamental: Nf=8
- SU(4)
  - decuplet: Nf=2

SU(N) Phase Diagram



F.Sannino

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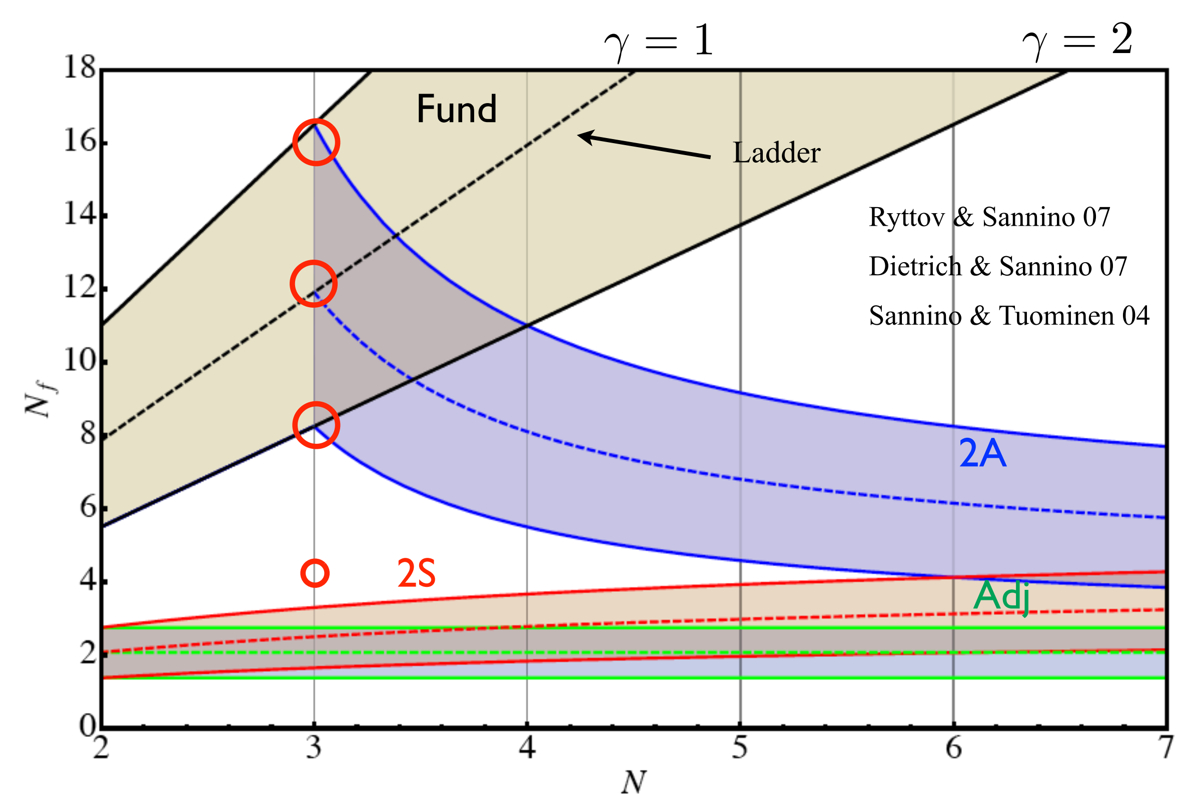

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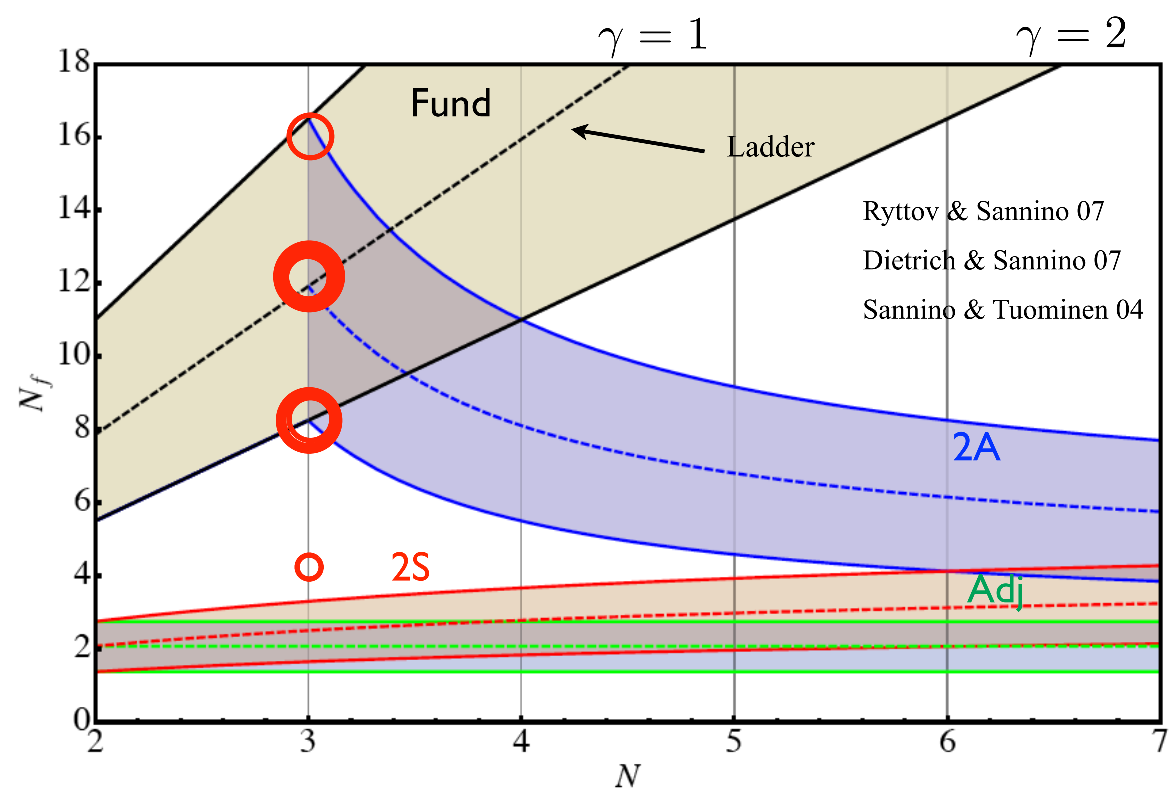
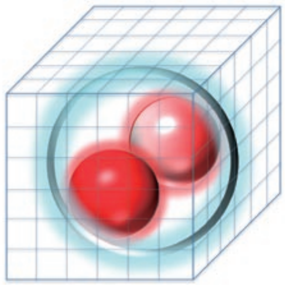
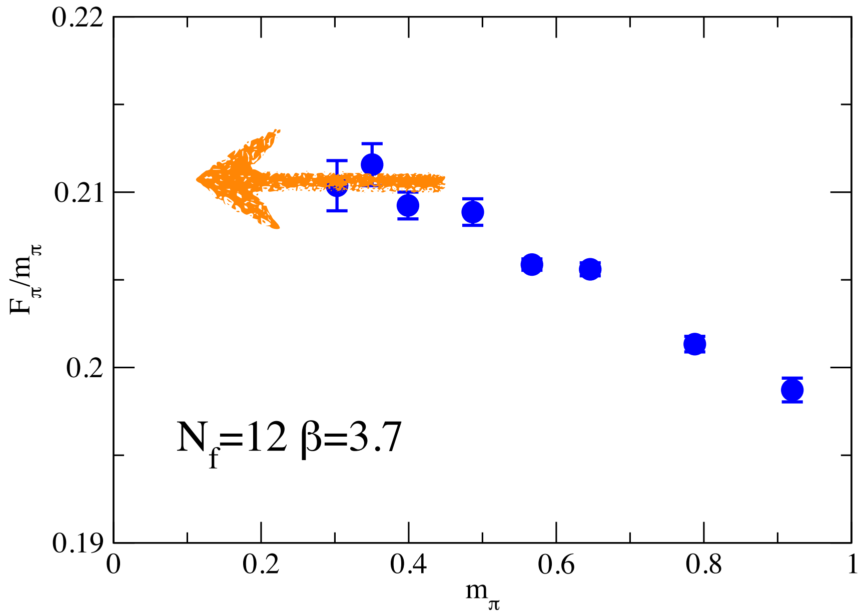


a crude analysis: F_π/M_π vs M_π leads to a likely scenario

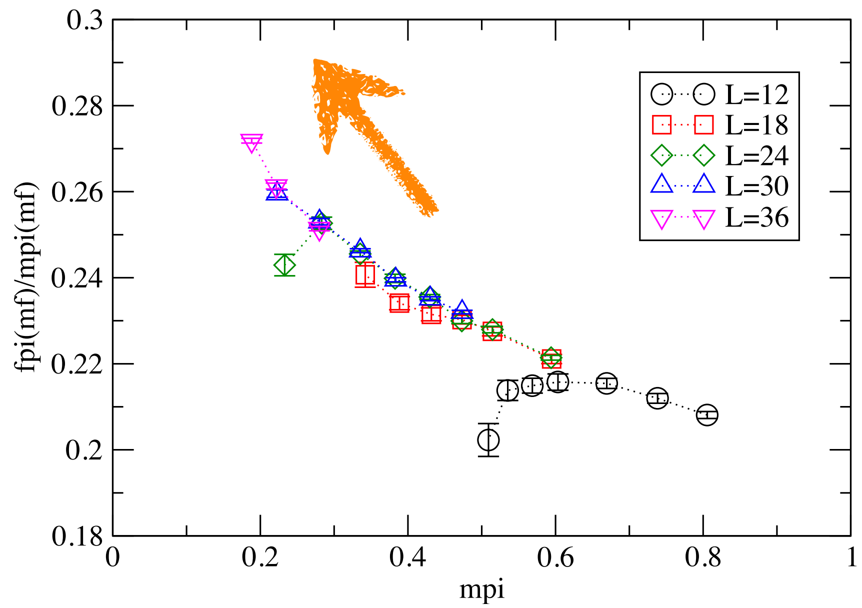


N_f=12



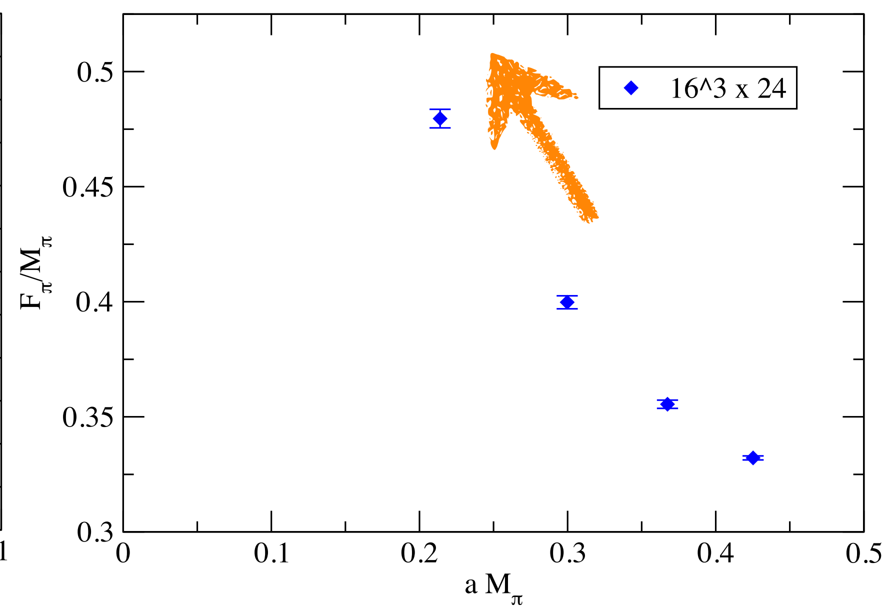
- conformality

N_f=8



- ~~chiral symmetry~~

N_f=4



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Hadron spectrum: response to mass (m_f) deformation

- IR conformal phase:
  - coupling runs for $\mu<m_f$: like $n_f=0$ QCD with $\Lambda_{QCD}\sim m_f$
  - multi particle state : $M_H \propto m_f^{1/(1+\gamma_m^*)}$; $F_\pi \propto m_f^{1/(1+\gamma_m^*)}$ (criticality @ IRFP)

- SχSB phase:
  - ChPT
  - at leading: $M_\pi^2 \propto m_f$, ; $F_\pi = F + c\, m_f$

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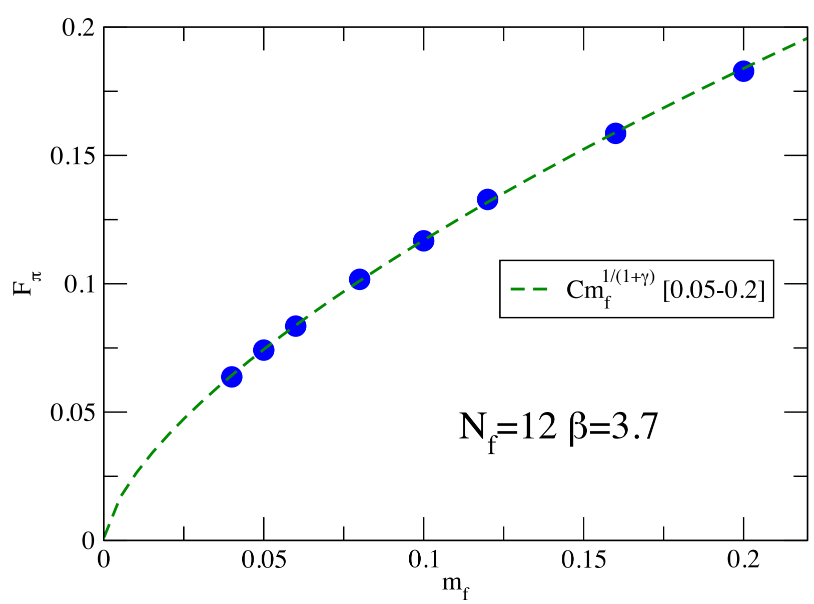
Detailed analysis of F_π vs m_f

N_f=12



- conformality
- $F_\pi \to Cm_f^{1/(1+\gamma)}$
- γ~0.5

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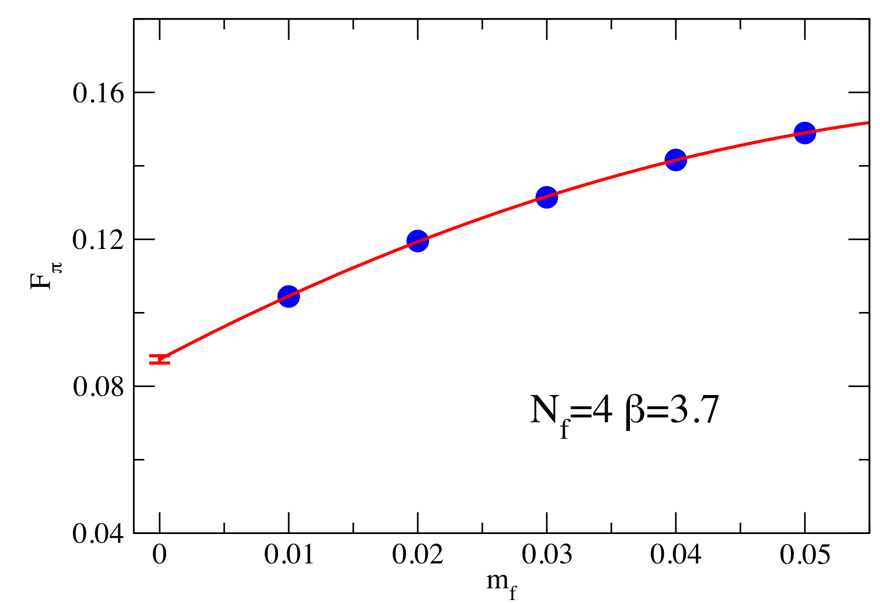

- ~~chiral symmetry~~
- $F_\pi \to F \neq 0$

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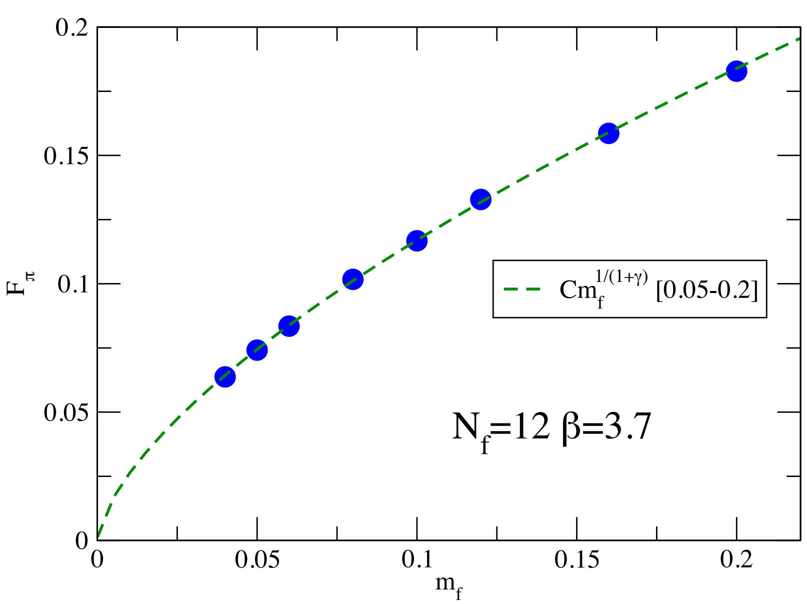

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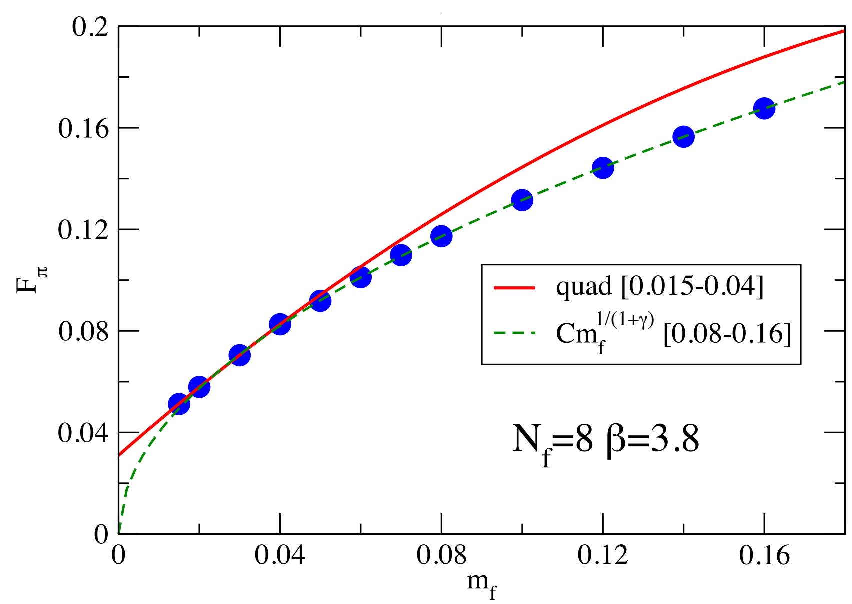


- ~~chiral symmetry~~
- $F_\pi \to F \neq 0$

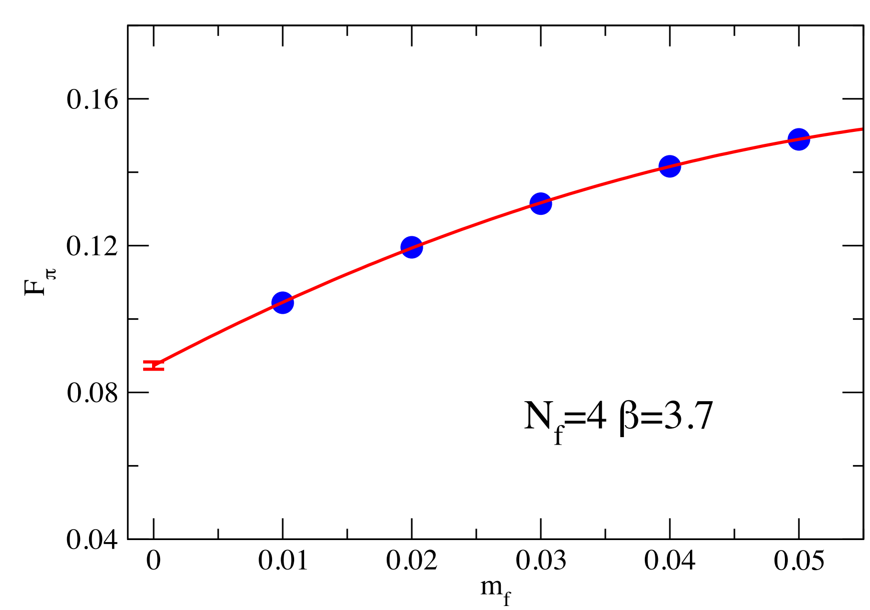
$m_f \to 0$

- $F_\pi \to Cm_f^{1/(1+\gamma)}$

intermediate m_f

- γ~0.9

N_f=4



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Detailed analysis of F_π vs m_f

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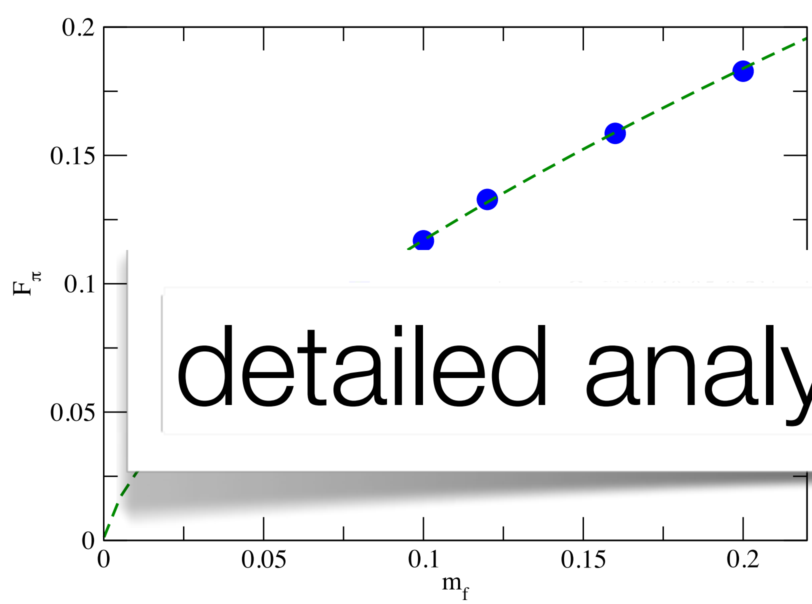

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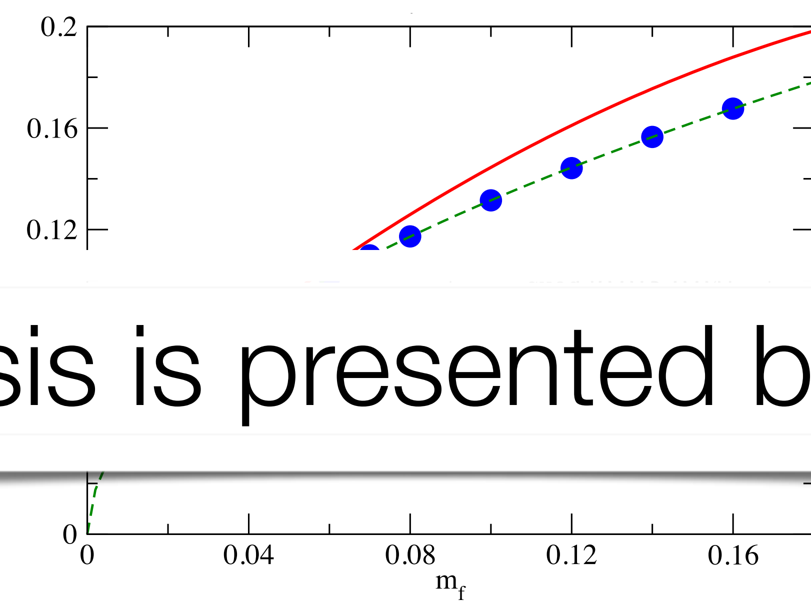

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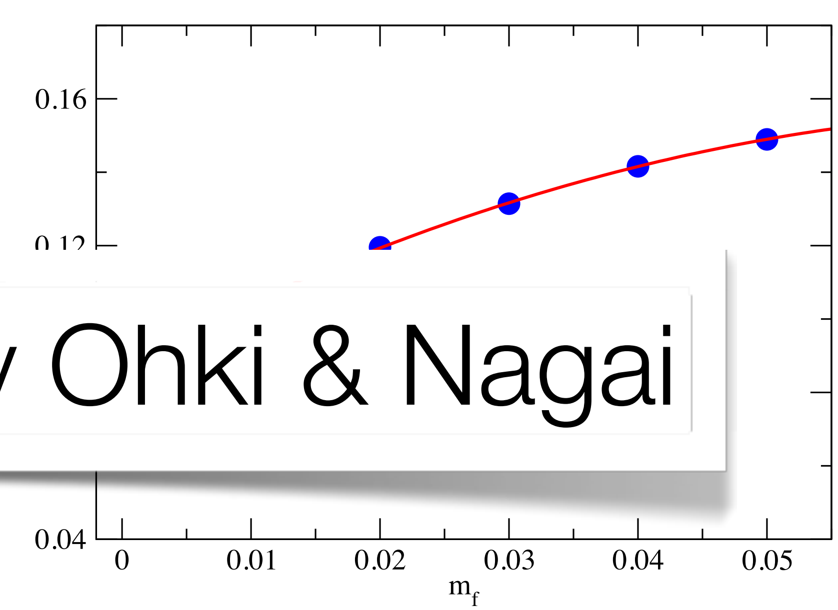

detailed analysis is presented by Ohki & Nagai

- conformality
- $F_\pi \to C m_f^{1/(1+\gamma)}$
- γ~0.5

- ~~chiral symmetry~~
- $F_\pi \to F \neq 0$

m_f→0

- $F_\pi \to C m_f^{1/(1+\gamma)}$

intermediate m_f

- γ~0.9

- ~~chiral symmetry~~
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crucial difference between N_f=8 and 12

- conformal ↔ broken chiral symmetry picture:
  - property should emerge in the $m_f \to 0$, $V \to \infty$ limit
- N_f=12
  - conformal hypothesis:
    - getting better in $m_f \to 0$, $V \to \infty$
  - broken chiral symm. analysis: $f_\pi(m_f \to 0) \neq 0$; but very long extrapolation
- N_f=8
  - conformal hypothesis
    - good for intermediate m_f ↔ getting worse in $m_f \to 0$
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N_f=8: an interpretation

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- What's observed:
  - chiral symmetry spontaneously broken for $m_f \to 0$
  - hyperscaling for intermediate m_f
  - largish $\gamma \sim 0.6\text{-}1$ for various observables

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  - largish $\gamma \sim 0.6$-1 for various observables
- can be interpreted as "**walking**":

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  - largish $\gamma \sim$ 0.6-1 for various observables
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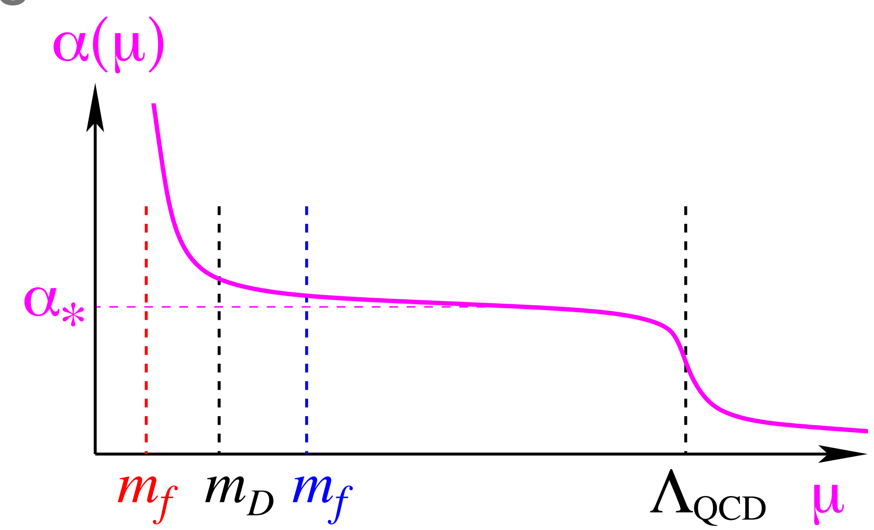
  - probing energy scale with $\mu \sim m_f$ → schematic picture



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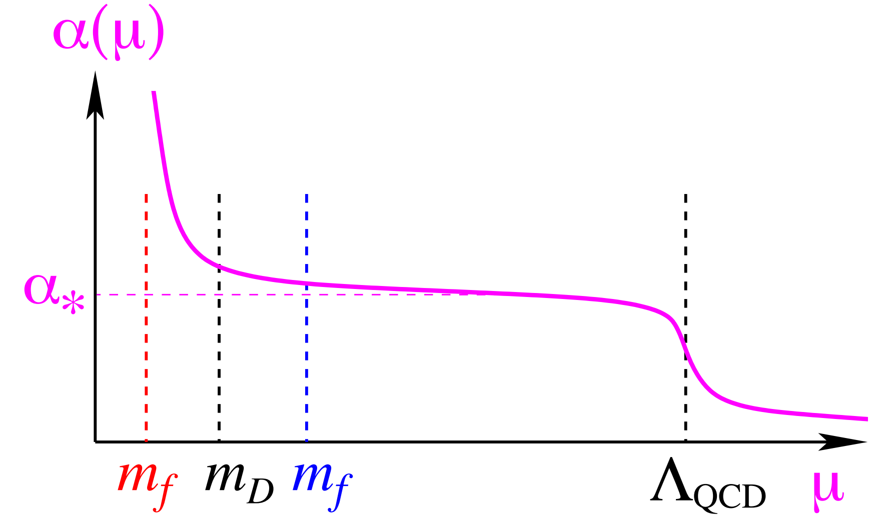

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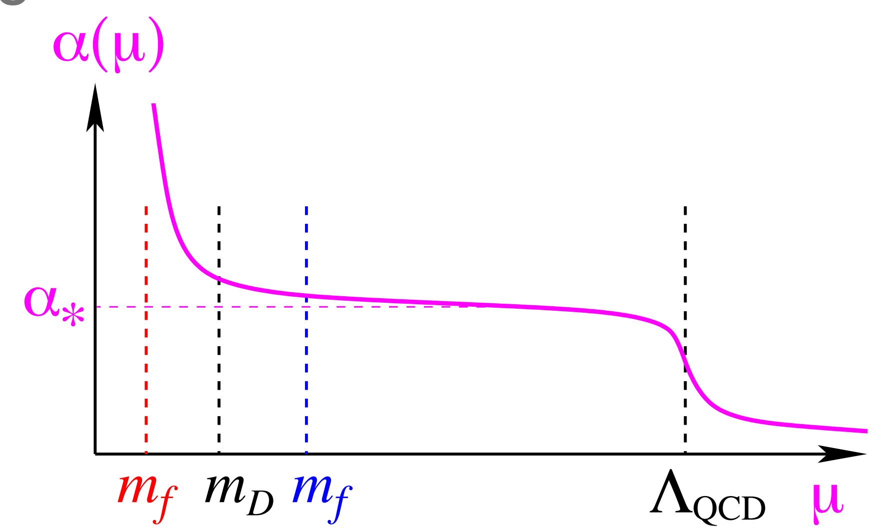

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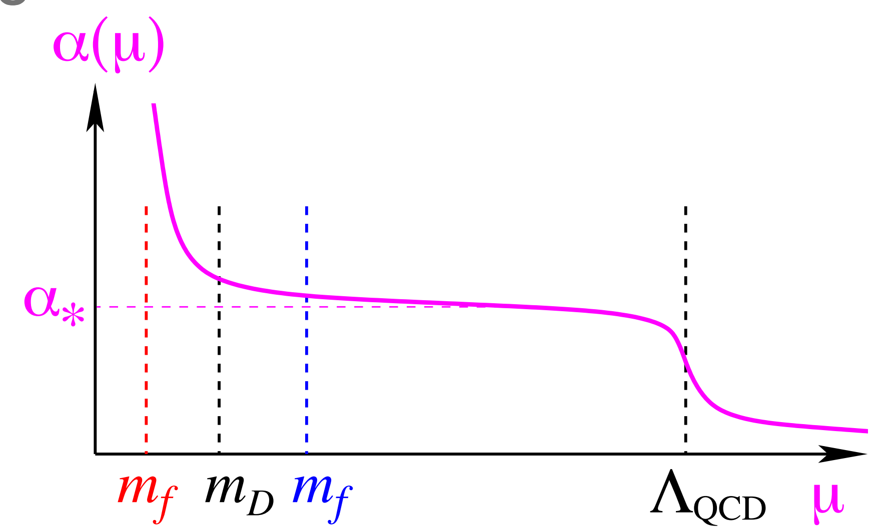

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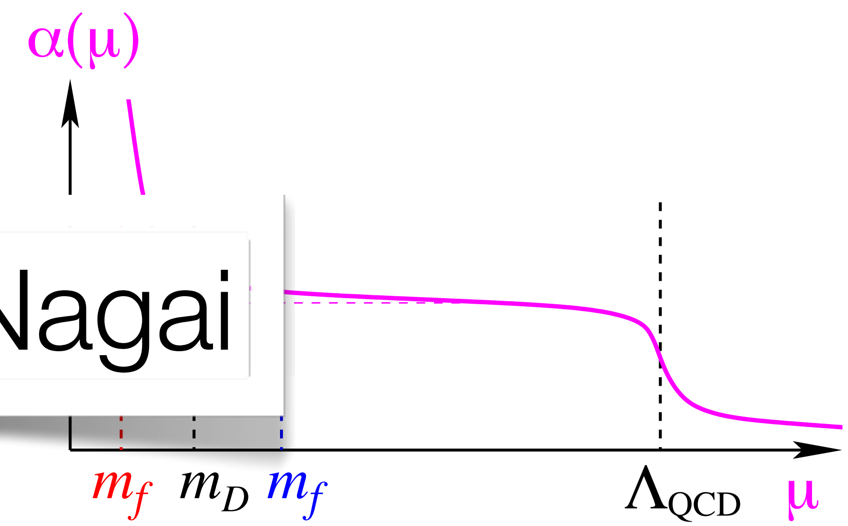
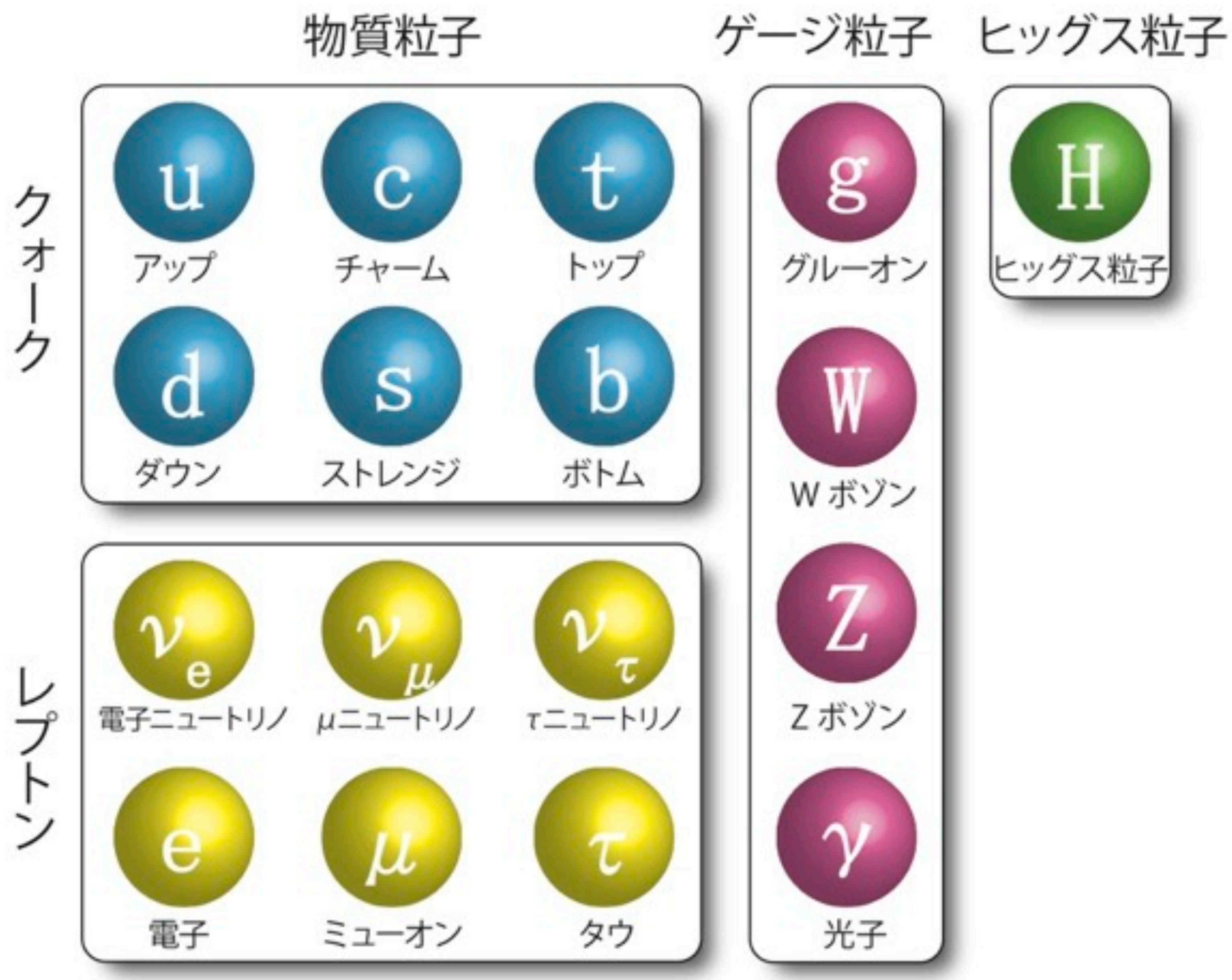
details presented by Nagai



Physics motivation: new physics



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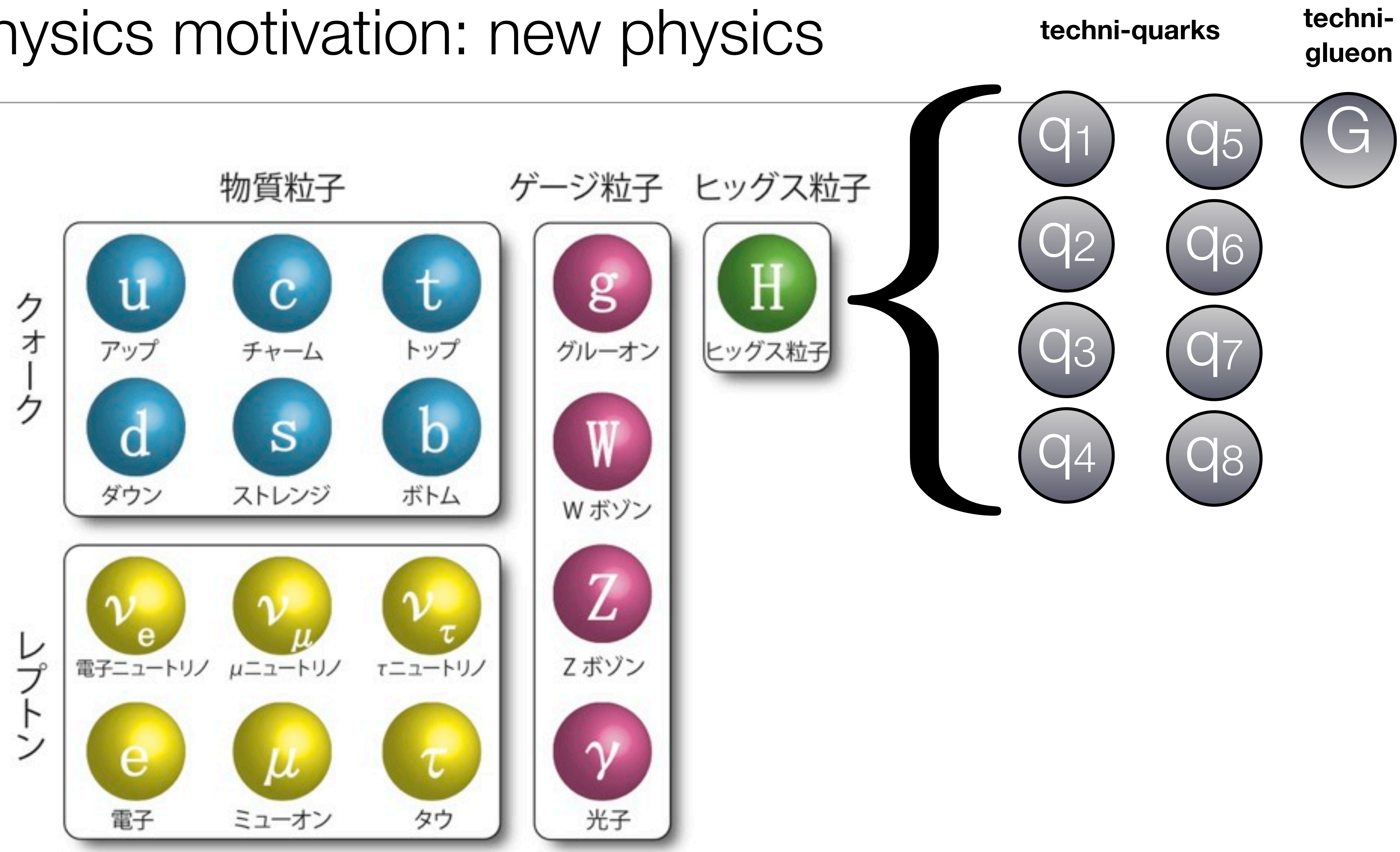

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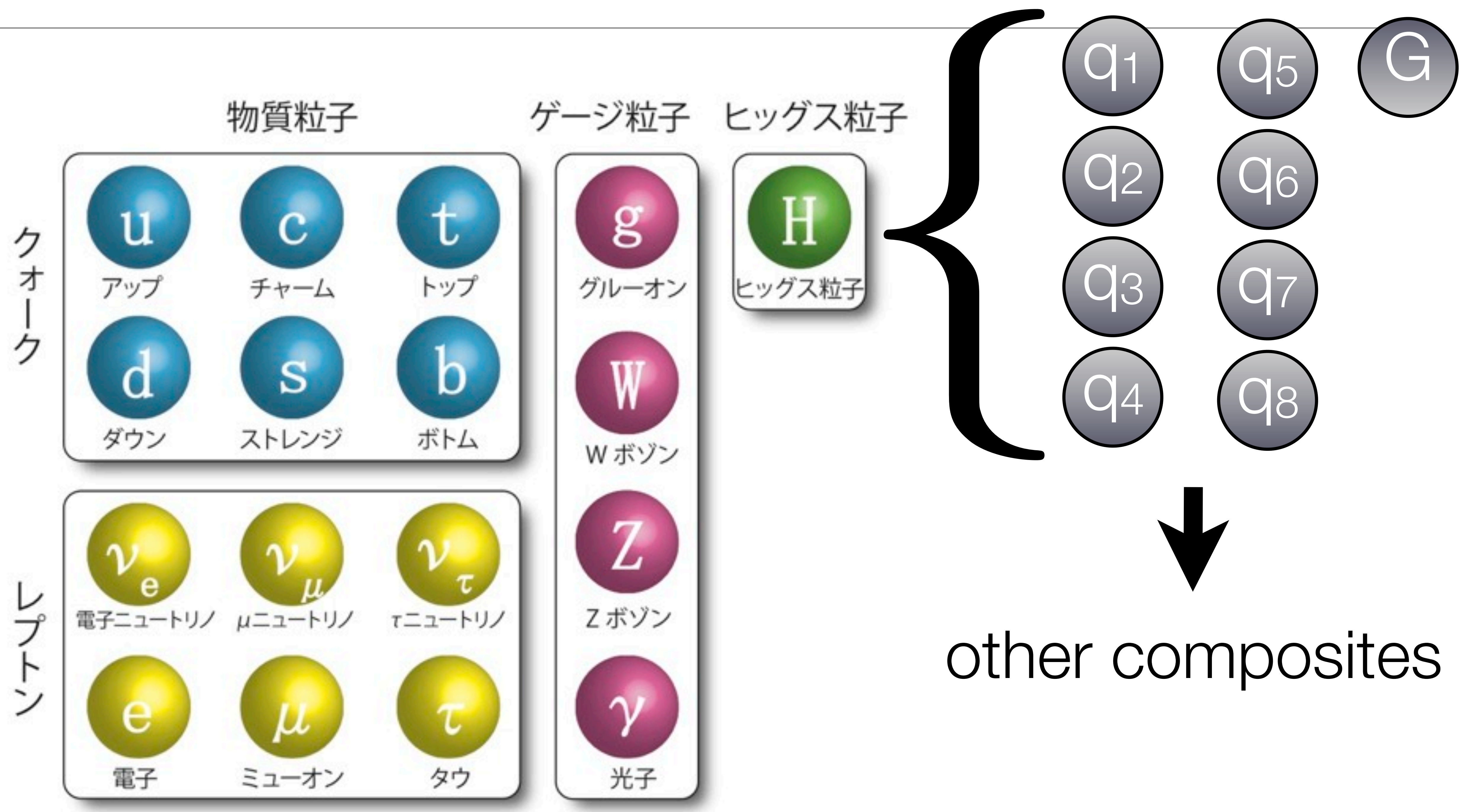

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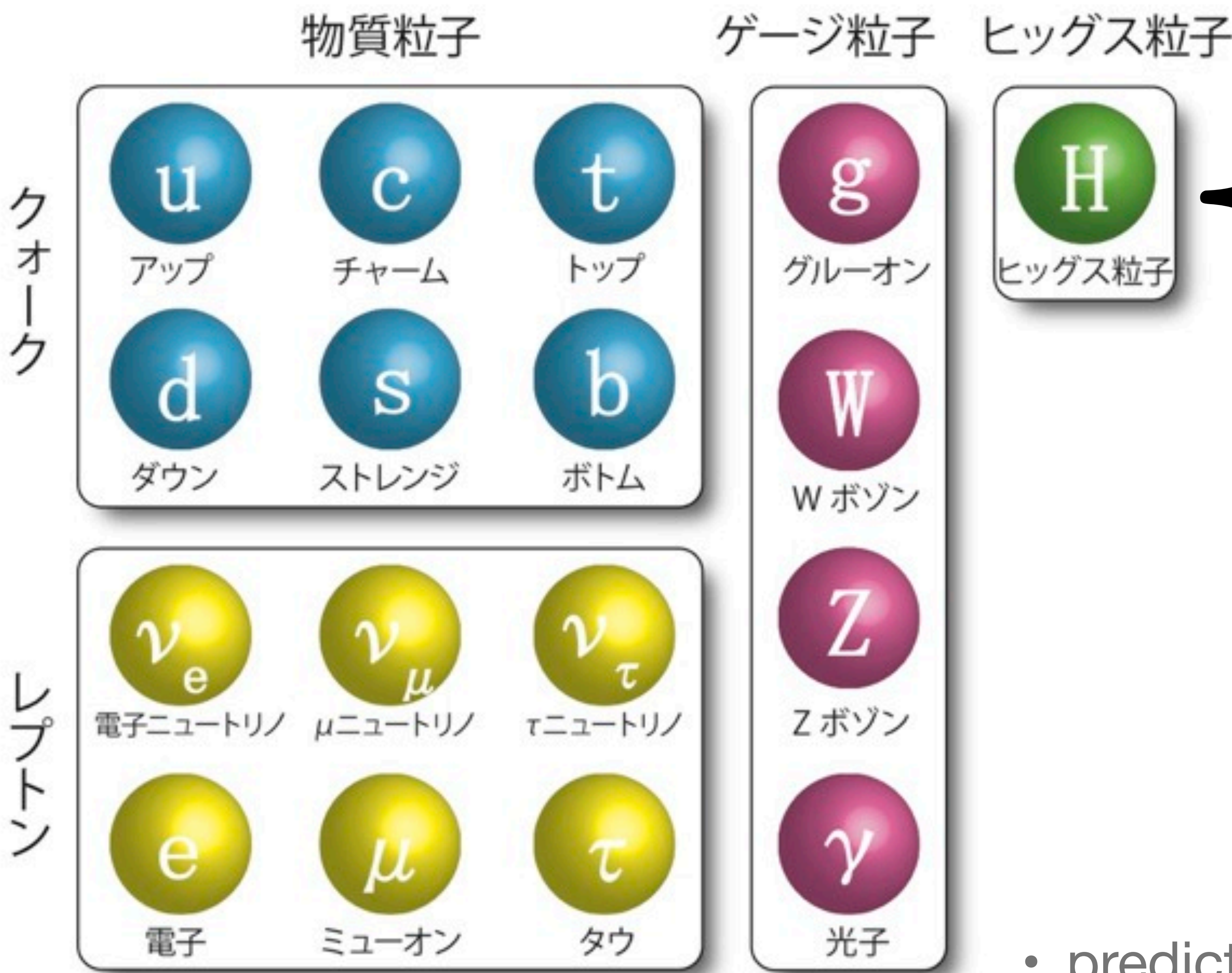
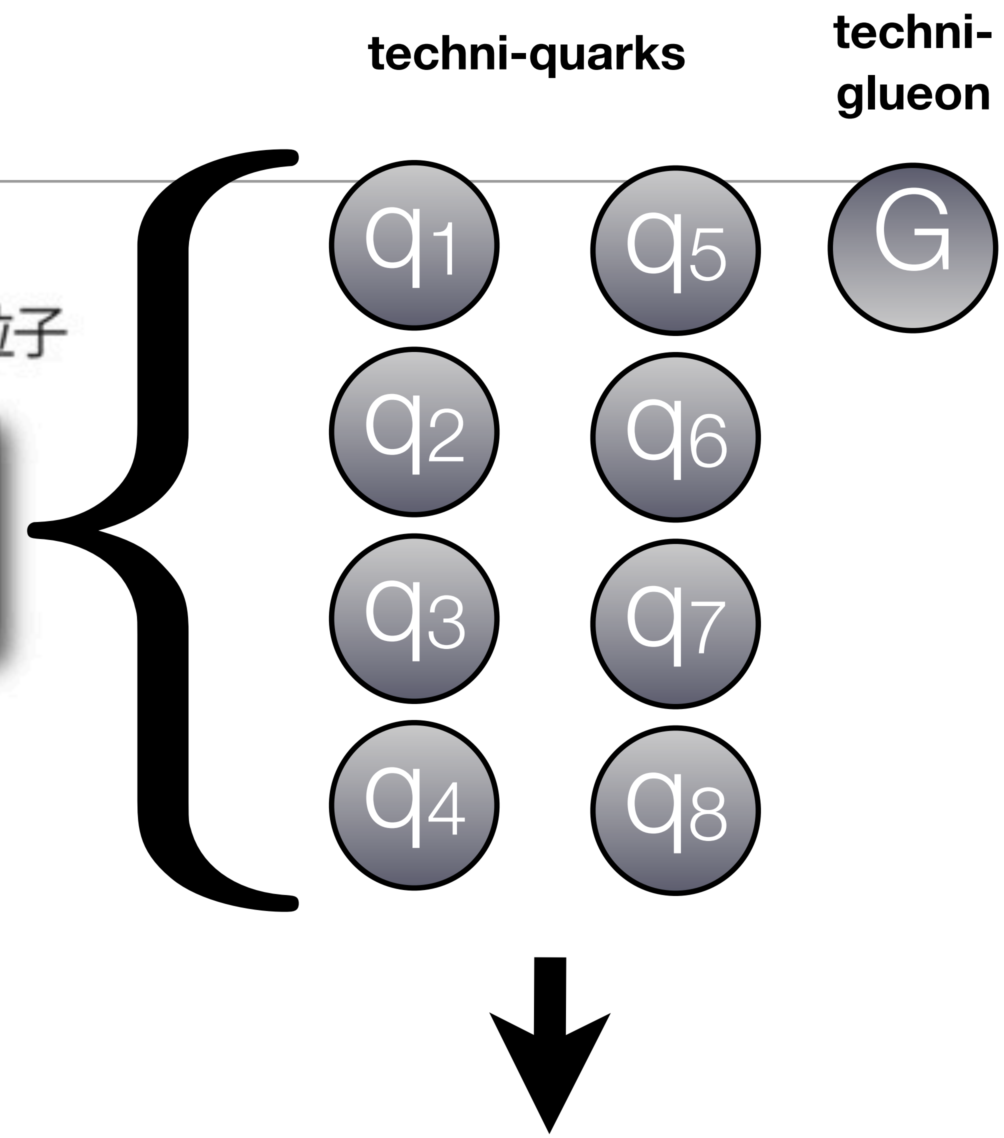




other composites

- prediction of other composites

➡compare with experiments → LHC

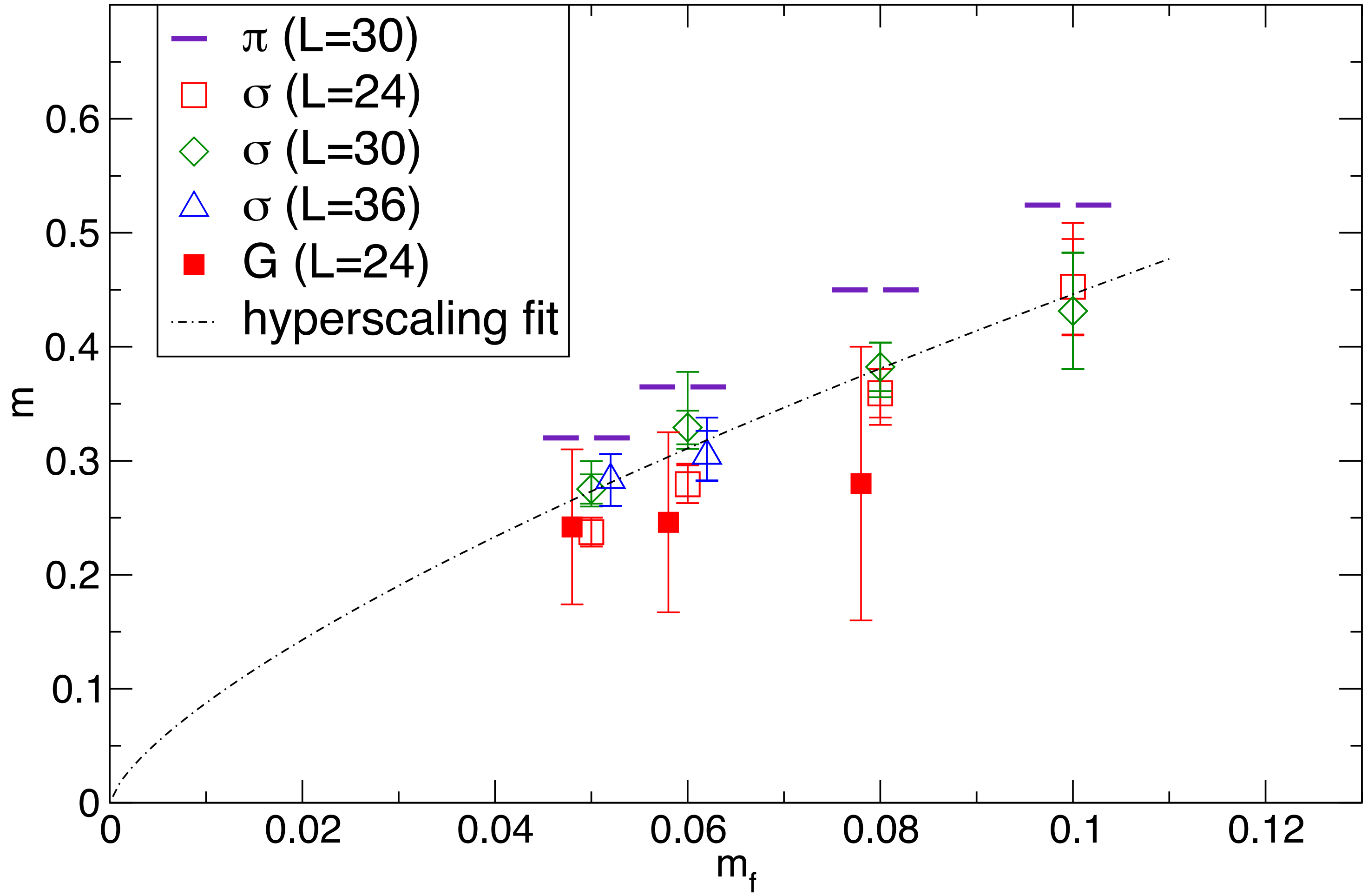
N_f=8 spectrum

- with input F_π = 246 /√N GeV (N: # weak doublet in techni-sector)
- prediction: $M_\rho/F_\pi = 7.7(1.5)(^{+3.8}_{-0.4})$ (with only technicolor dynamics)
  - for example: $M_\rho = 970(^{+515}_{-195})$ GeV for one family model: N=4
- Higgs mass ?
  - 125 GeV (LHC) seems very light for technicolor
  - 0++: one of the difficult quantities on the lattice
  - multi-faceted nature of N_f=8 adds another difficulty: delicate chiral extrapl.

➡ first analyze simpler N_f=12, which shares “conformality” → techni dilaton

➡Is 0++ state light in (mass deformed) N_f=12 theory ?

flavor singlet scalar spectrum in N_f=12 theory



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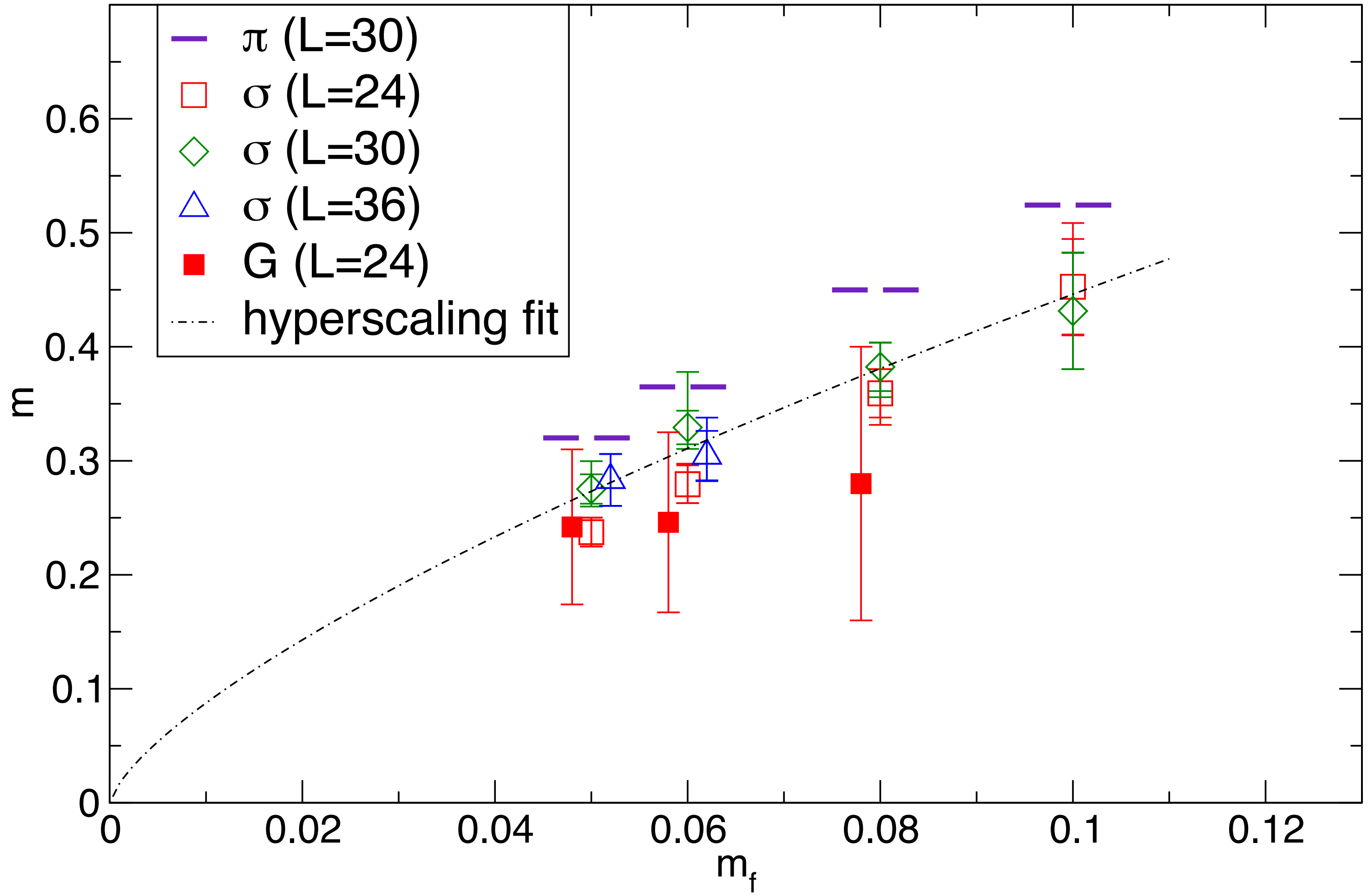

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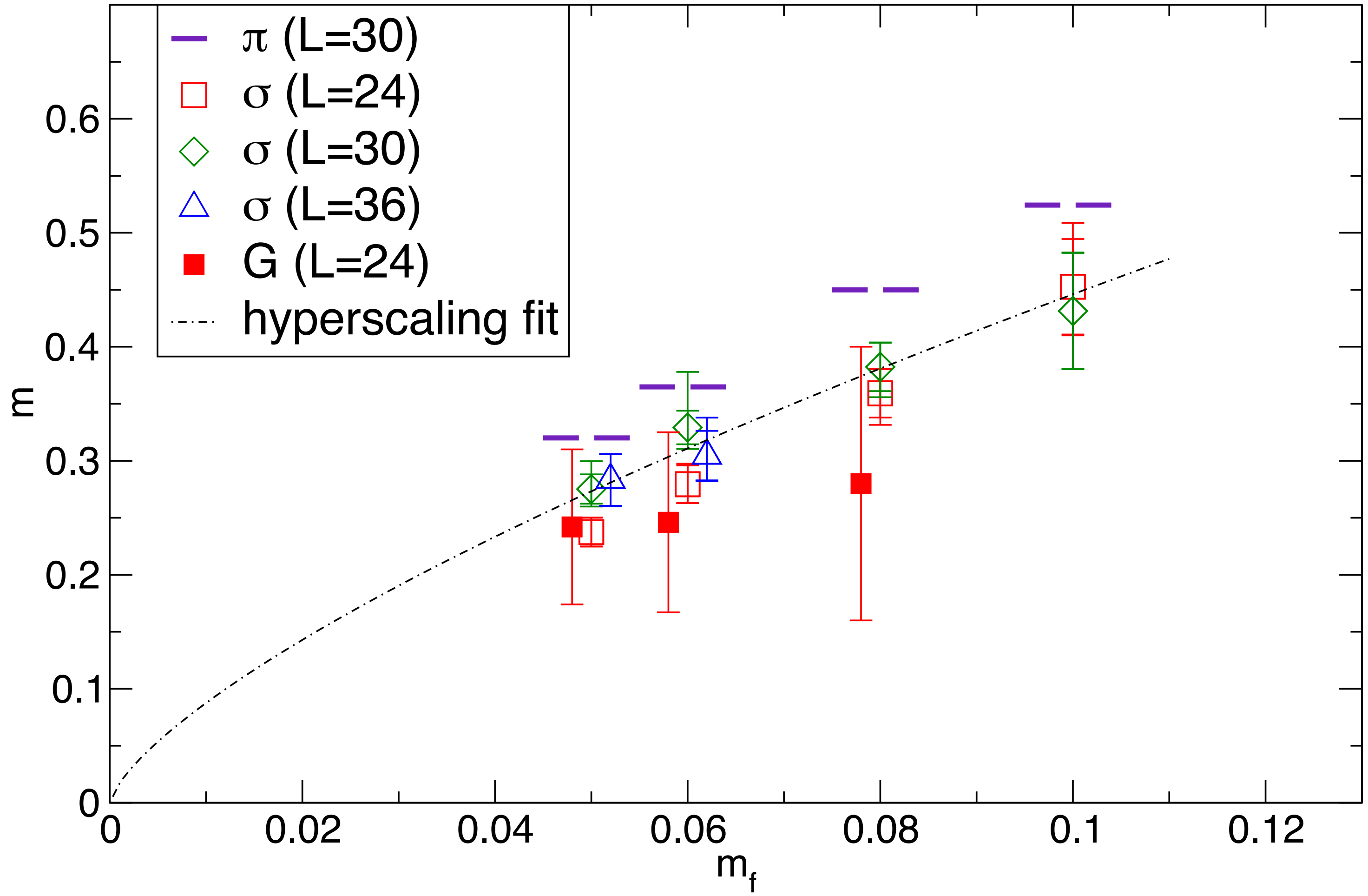

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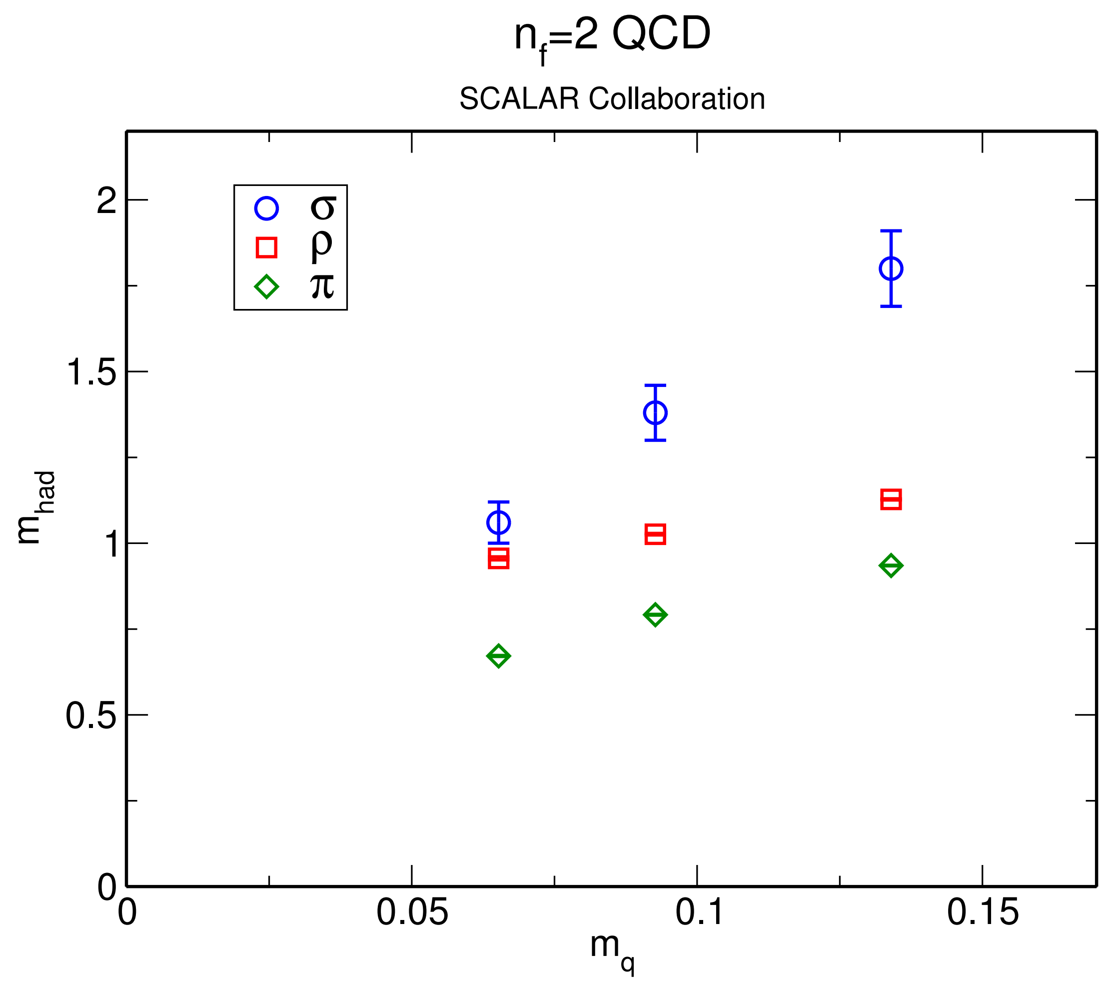

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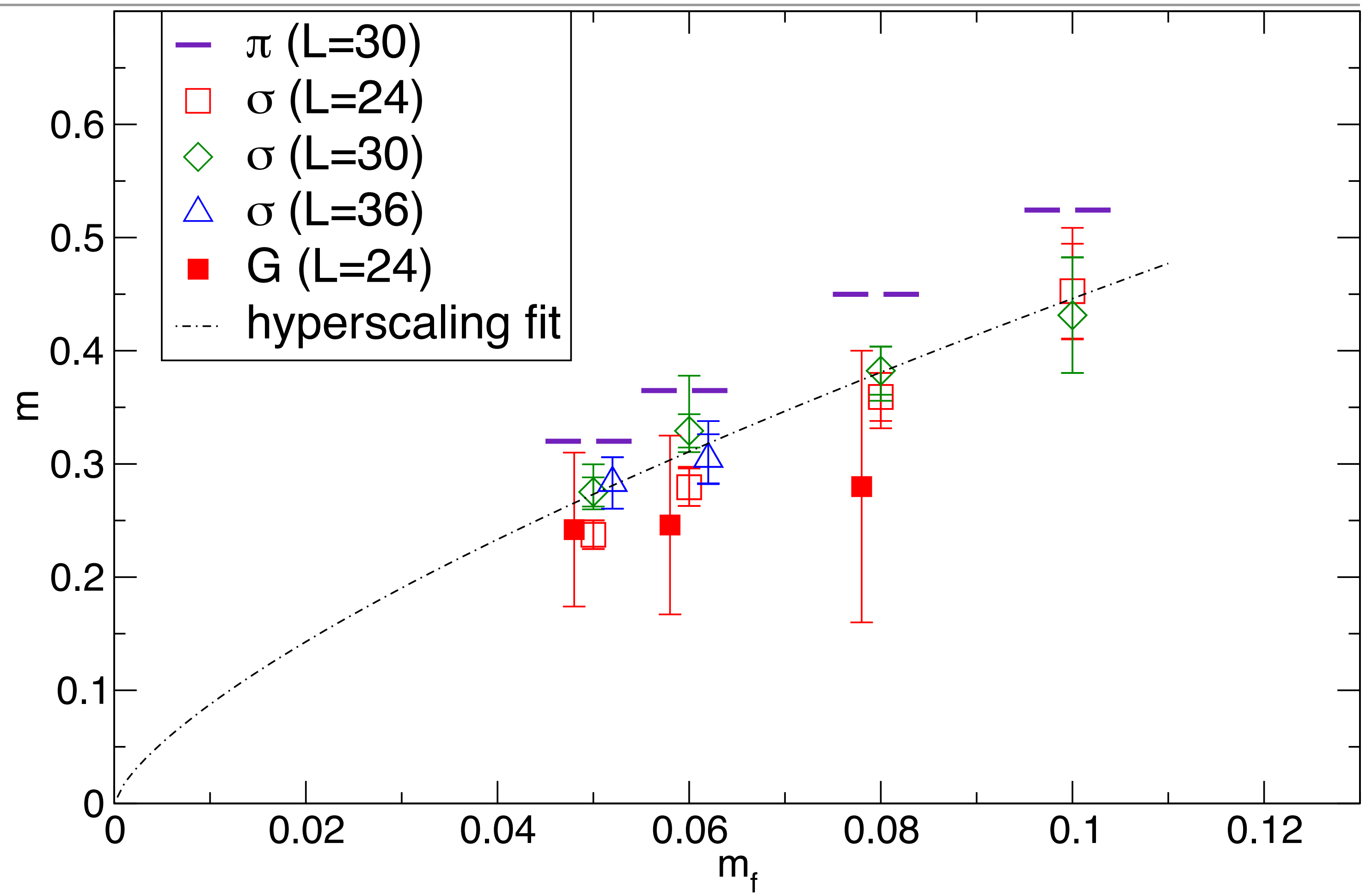

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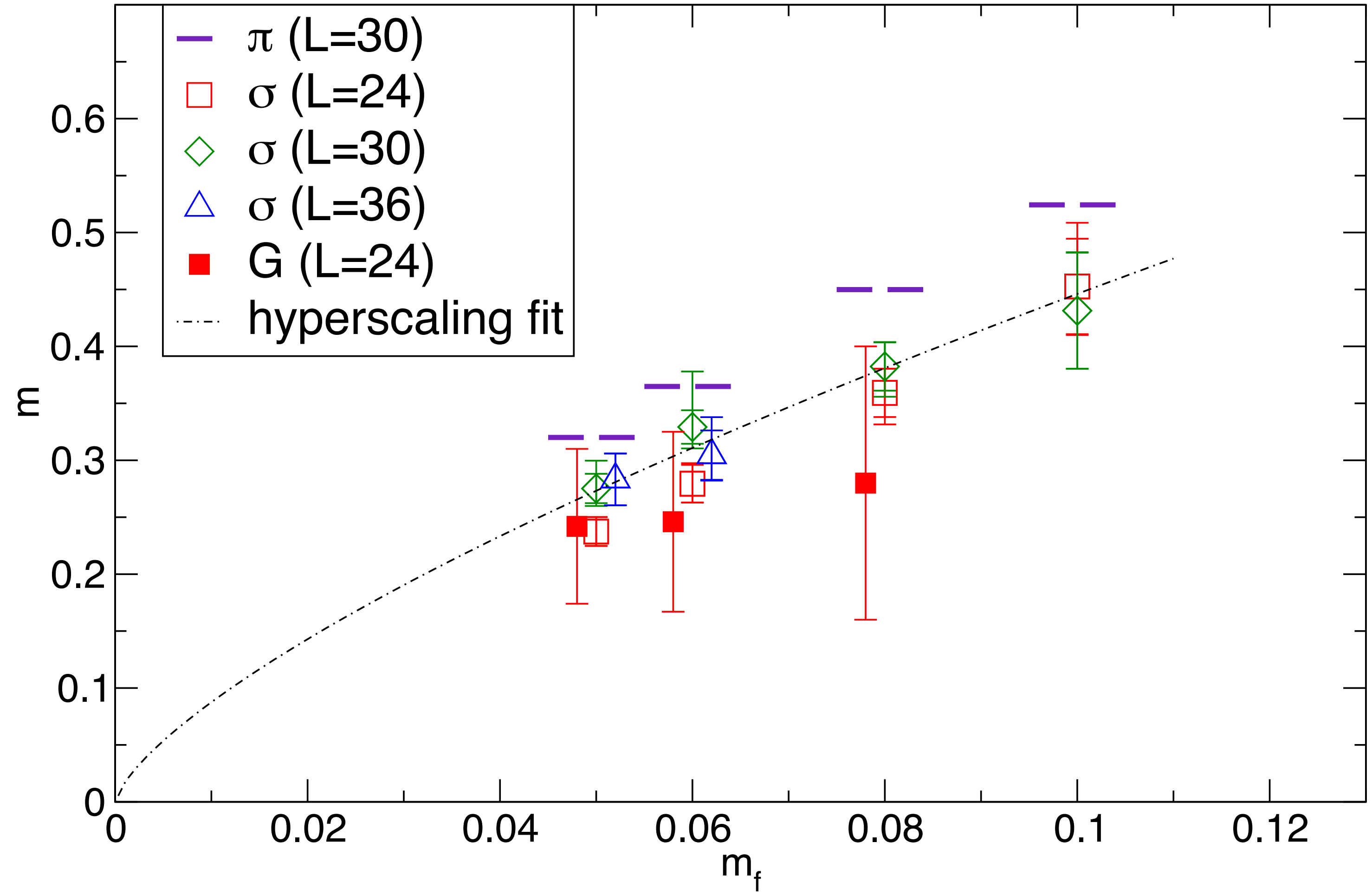

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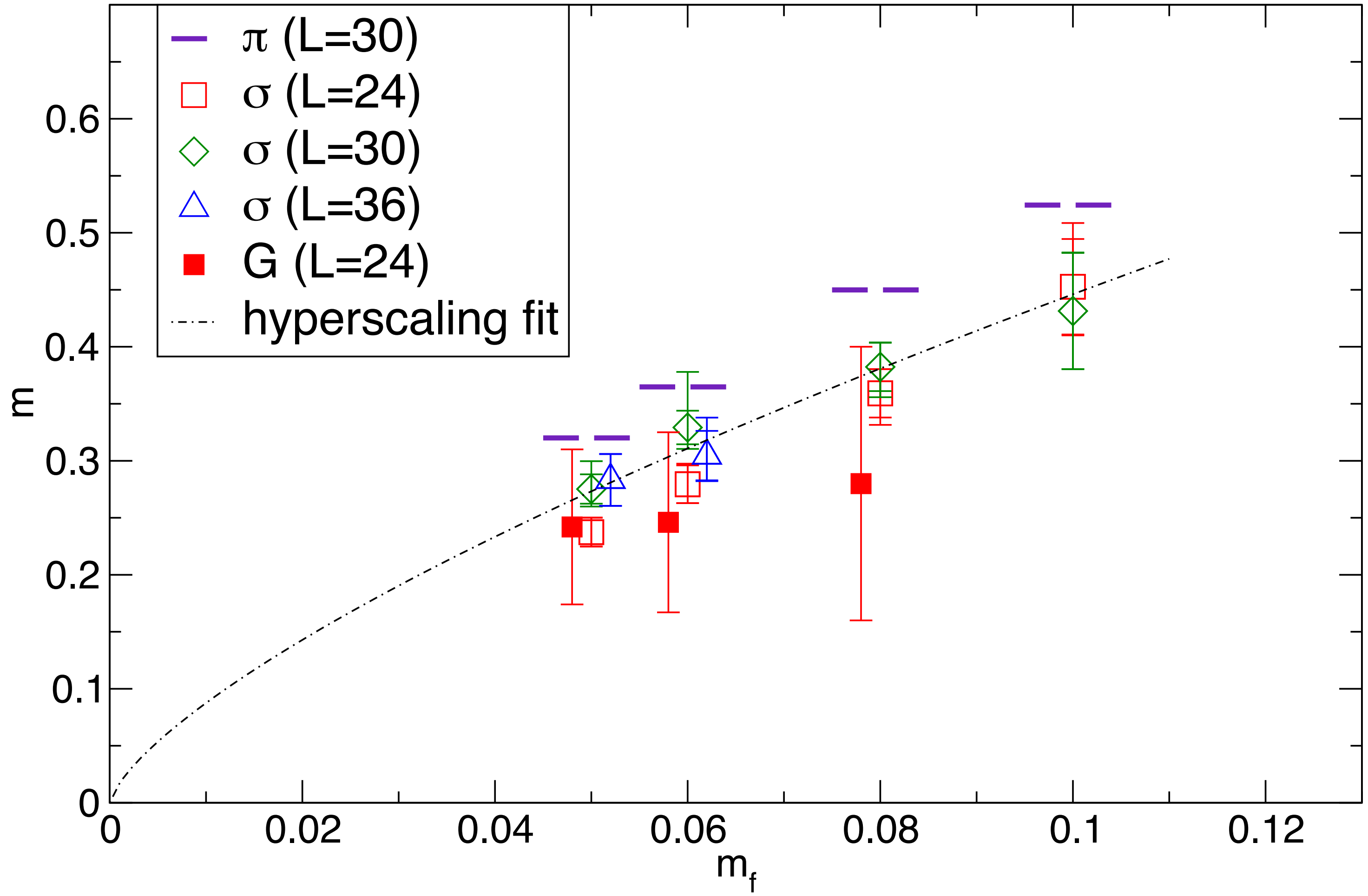

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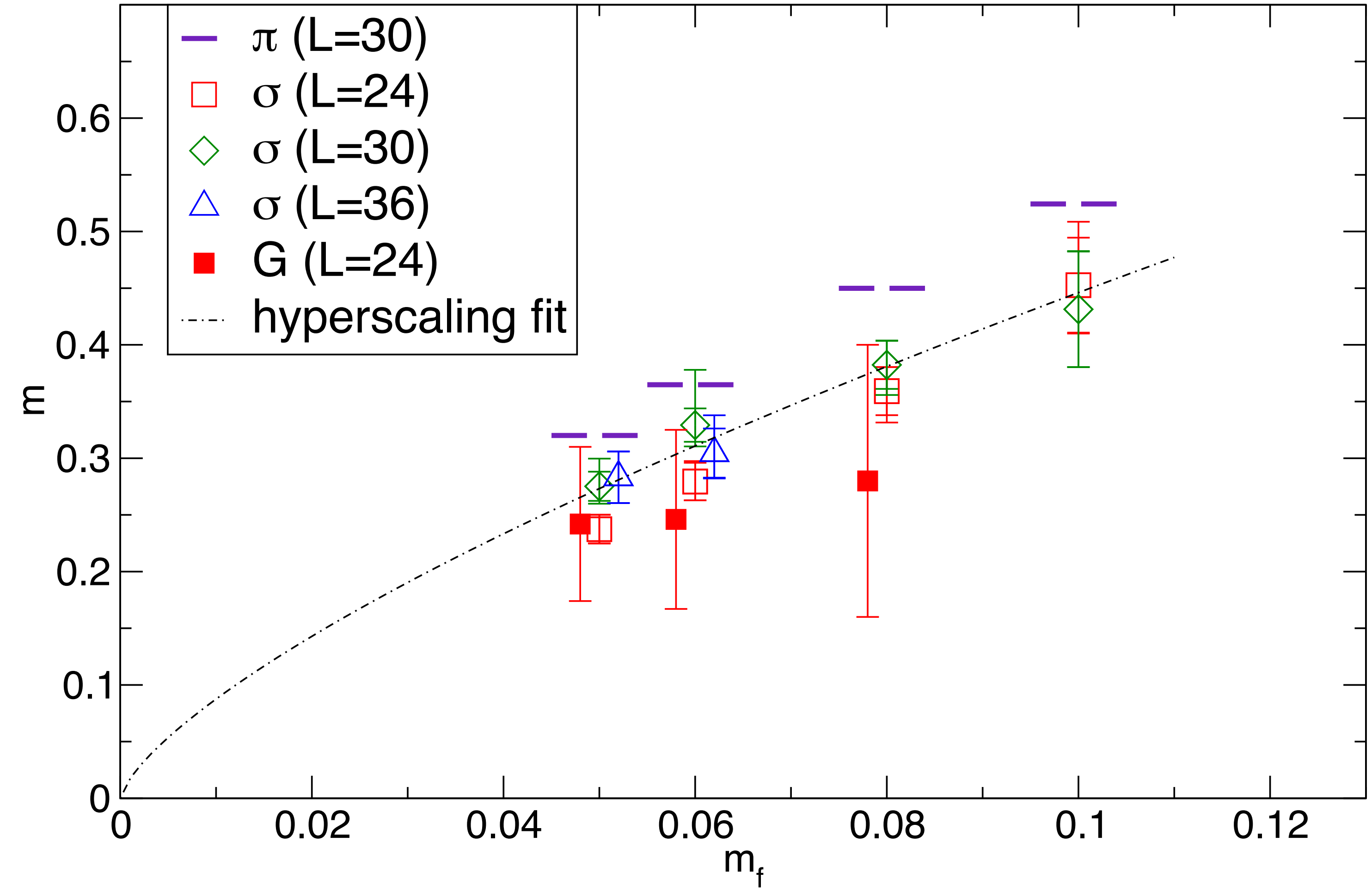

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- LatKMI, PRL 111 (2013), "Light composite scalar in twelve-flavor QCD on the lattice"

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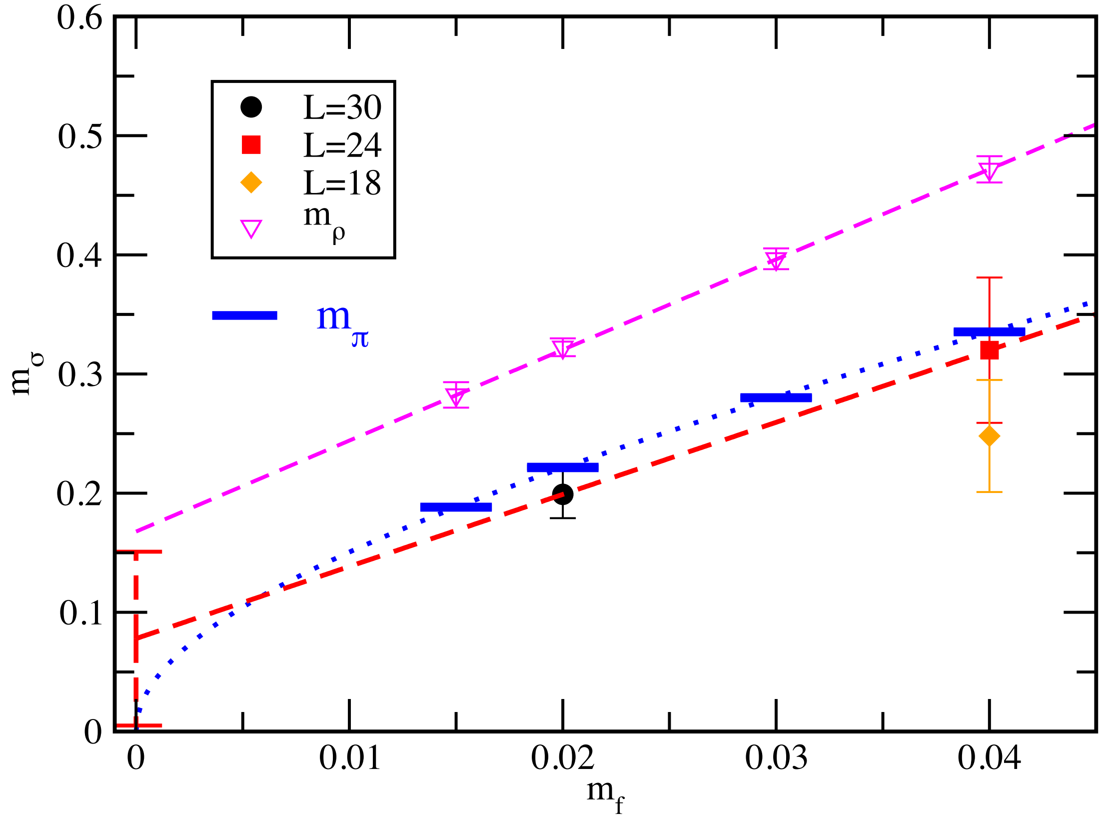

LatKMI PoS2013

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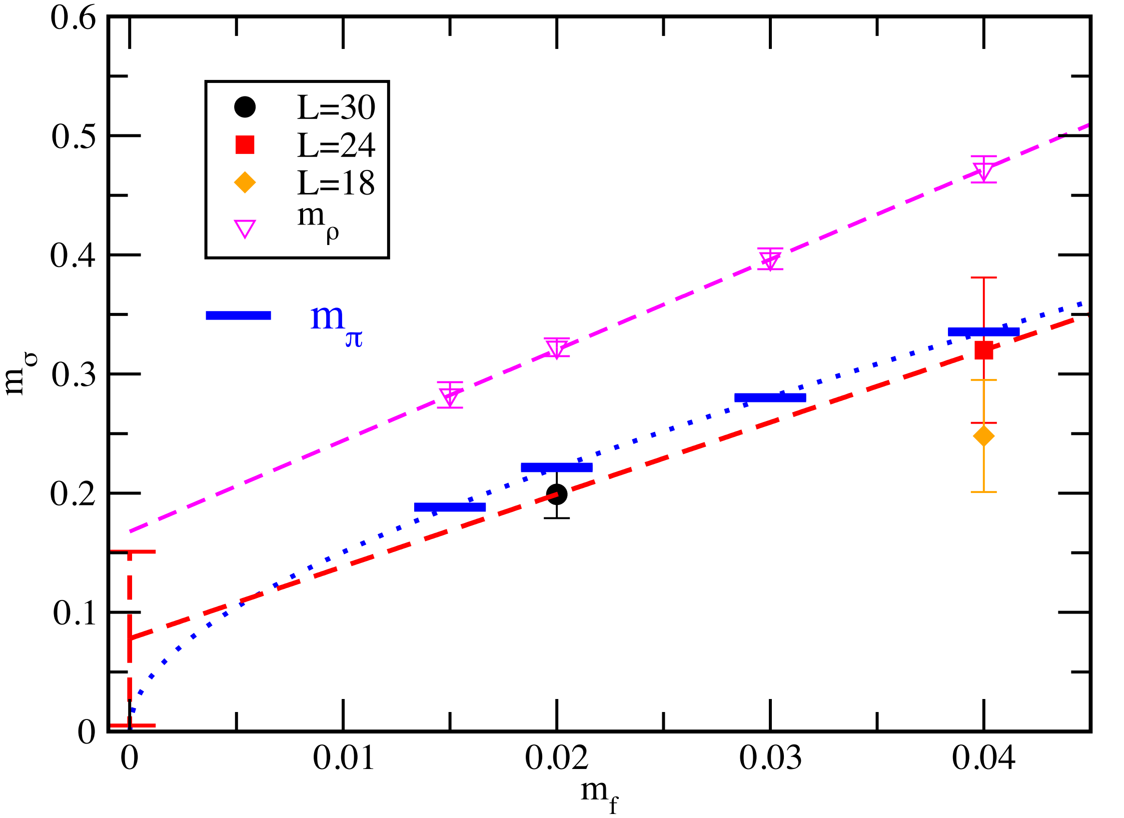

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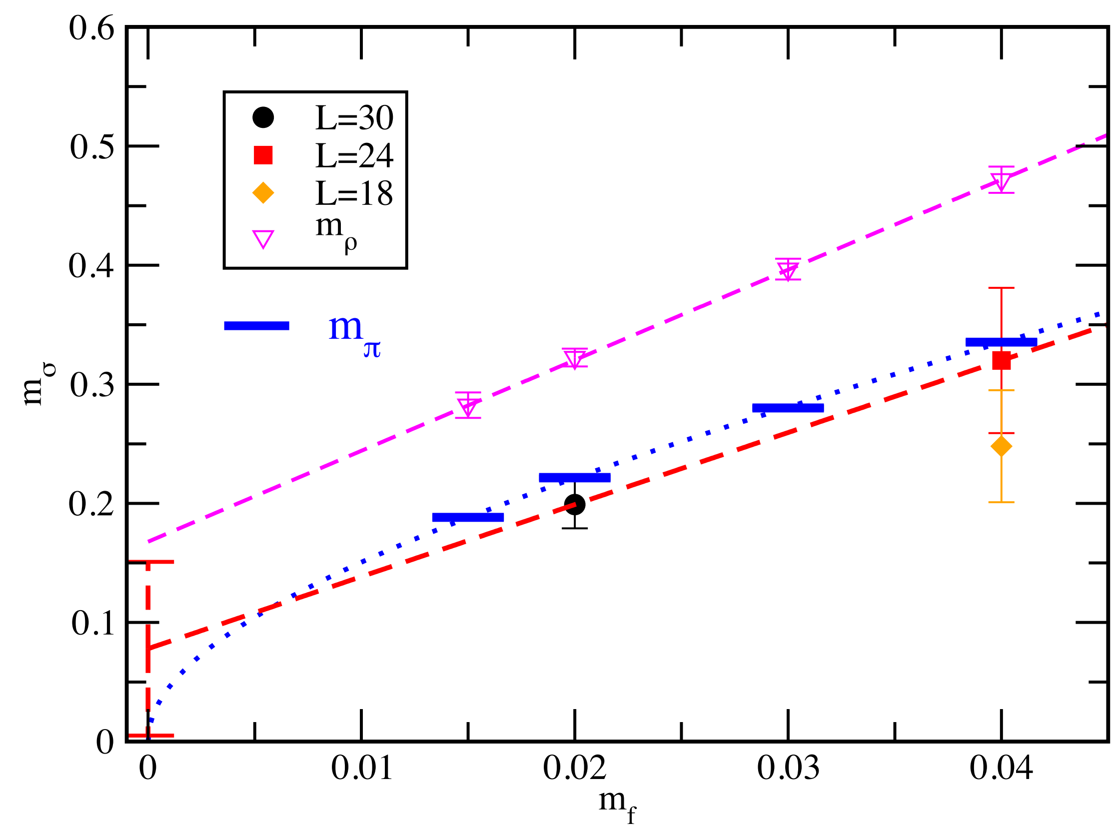

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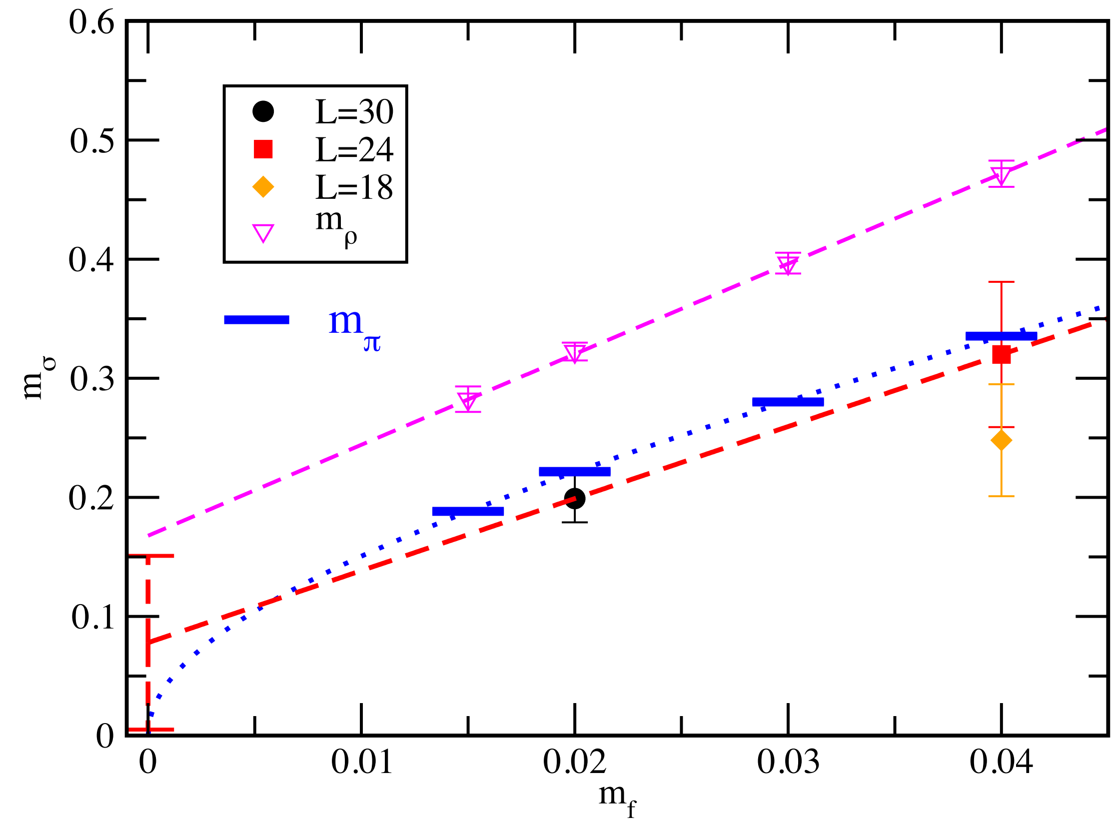

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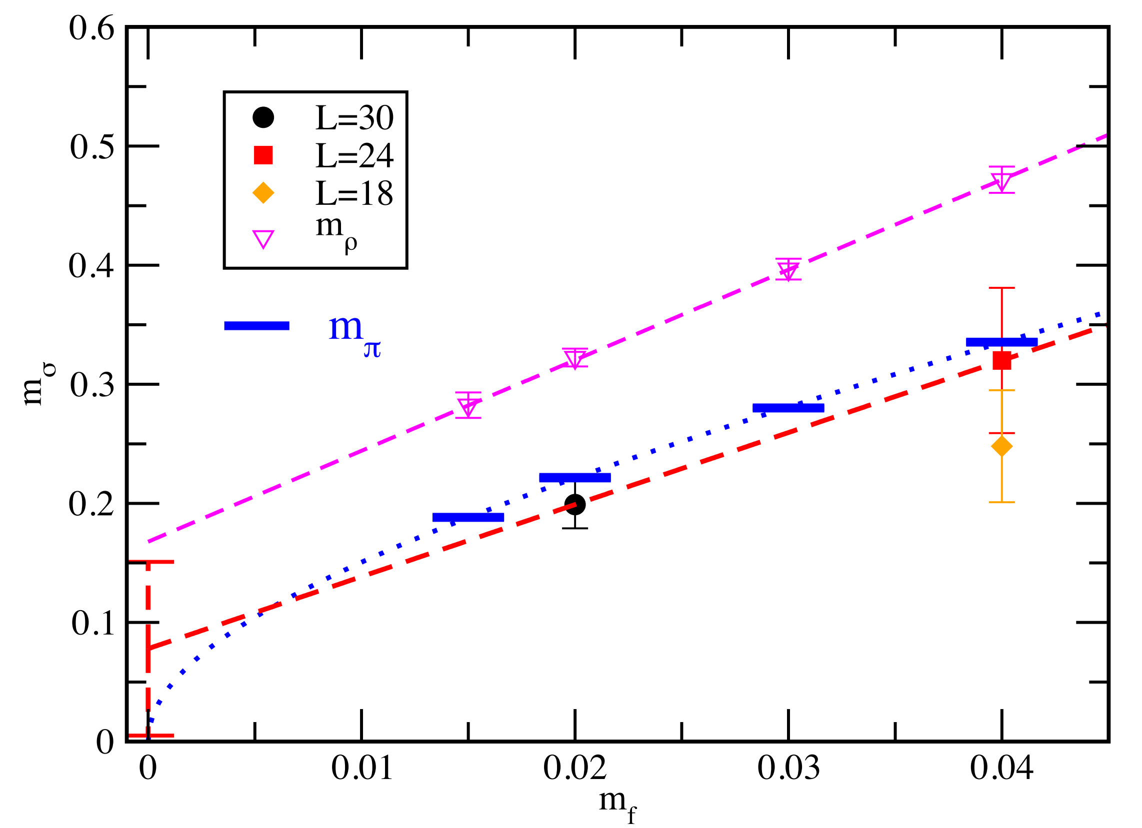

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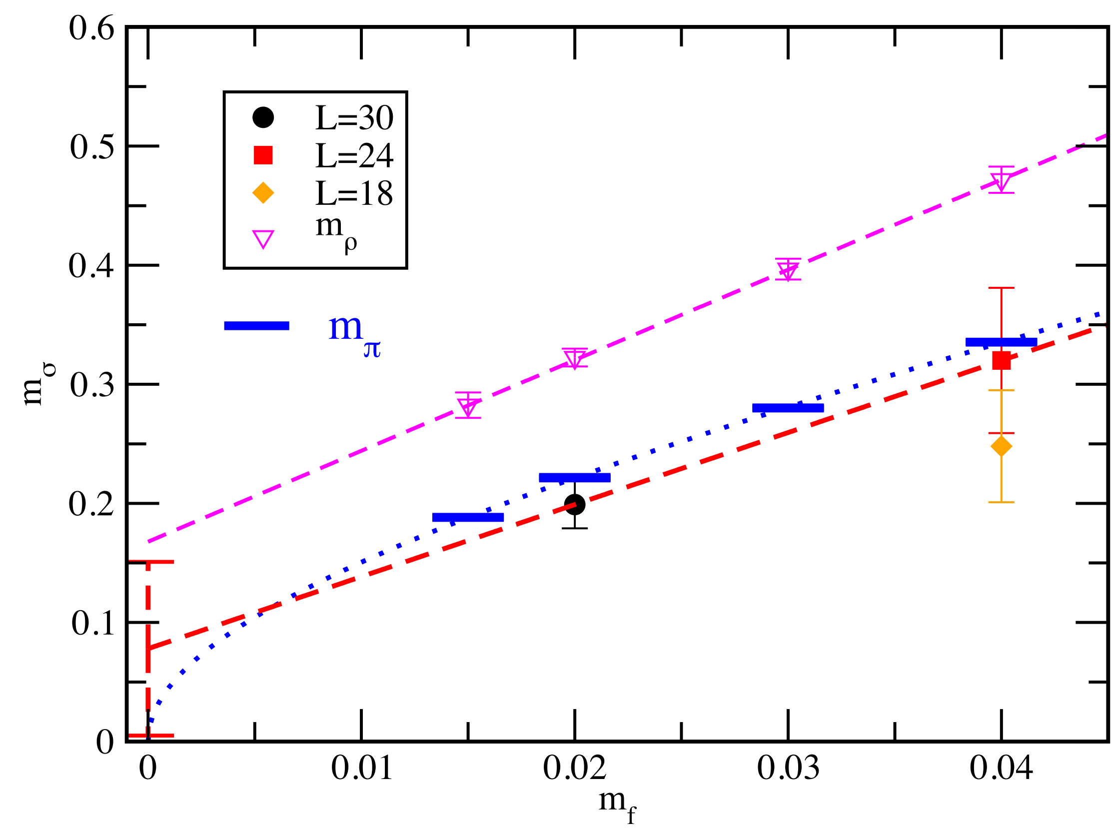

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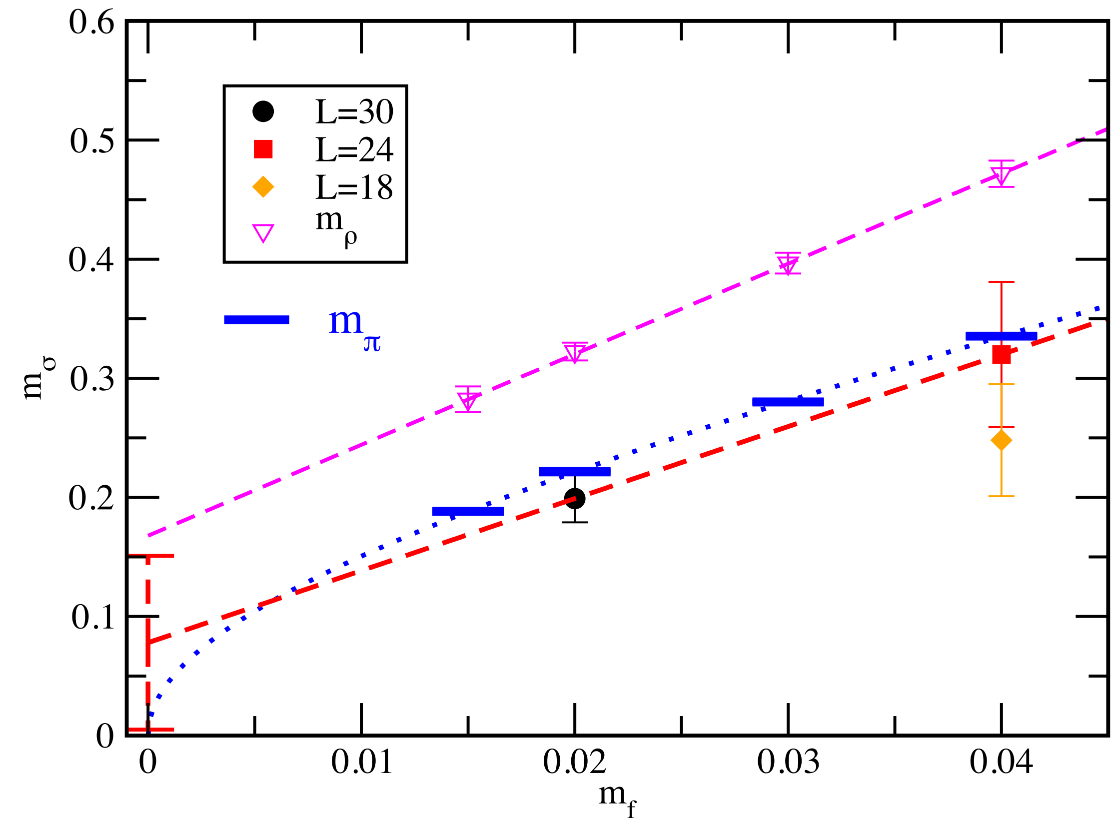

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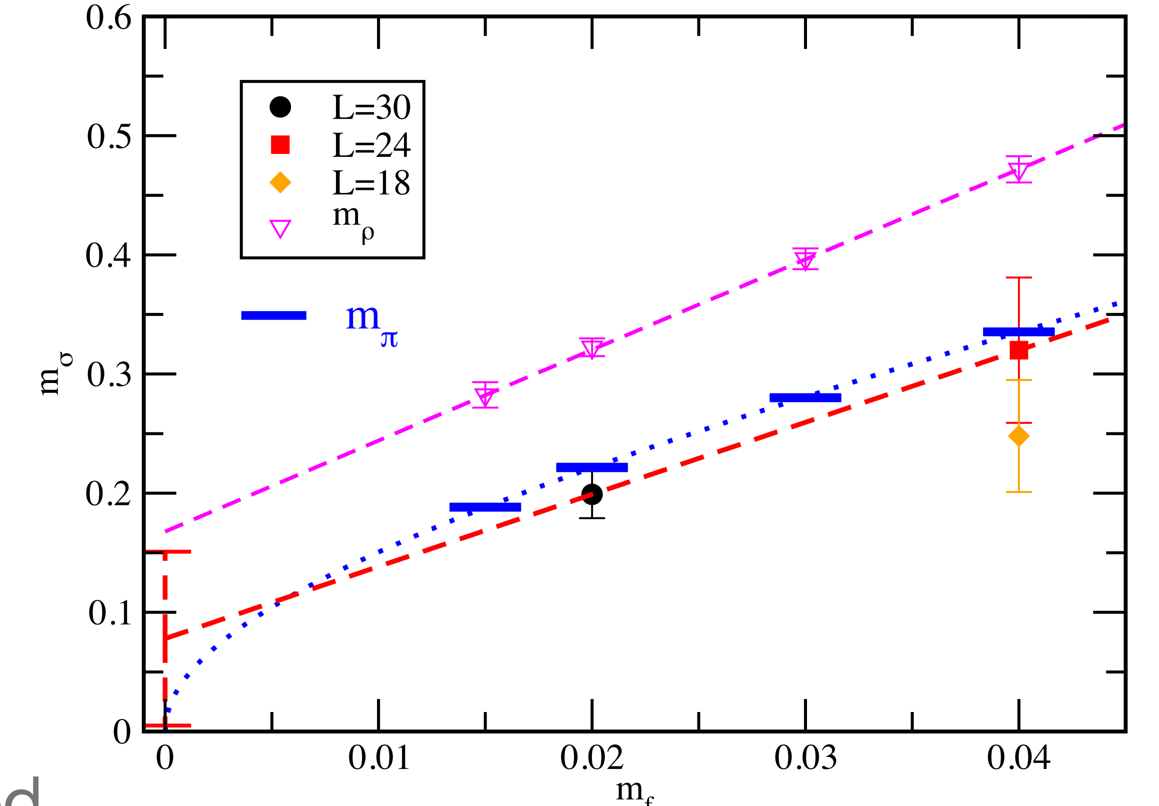

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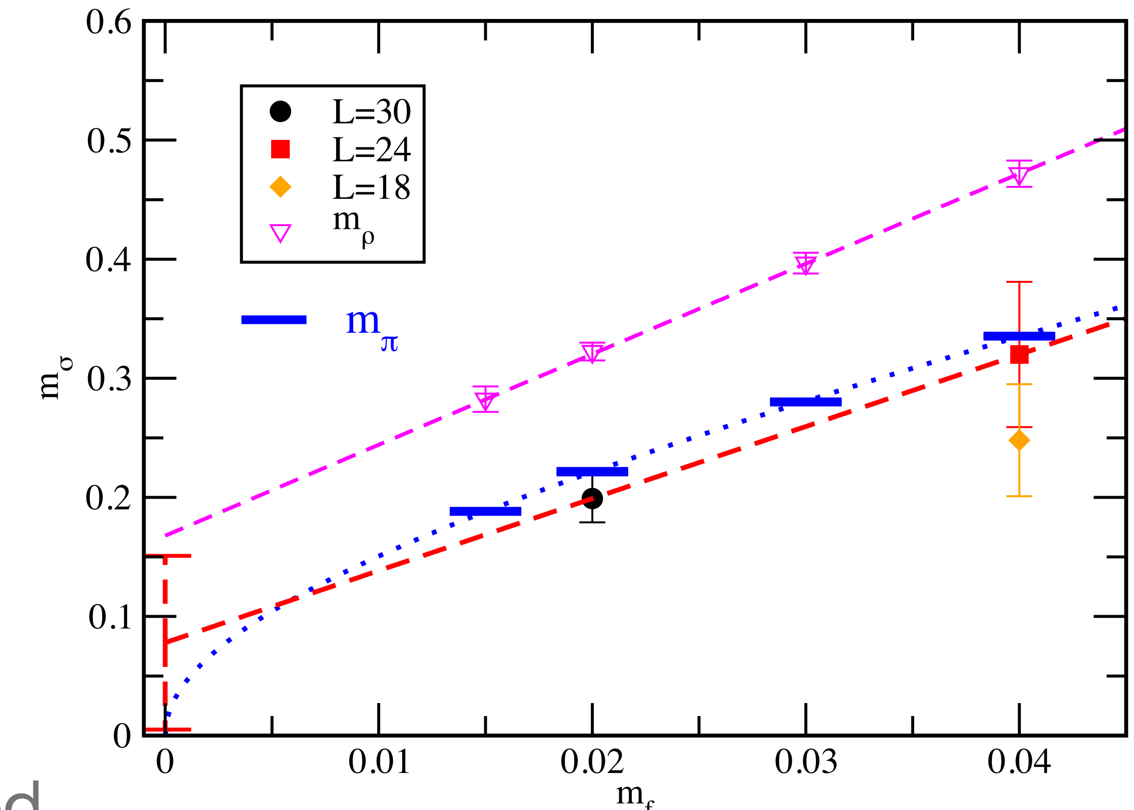

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details and updates to be presented by Yamazaki

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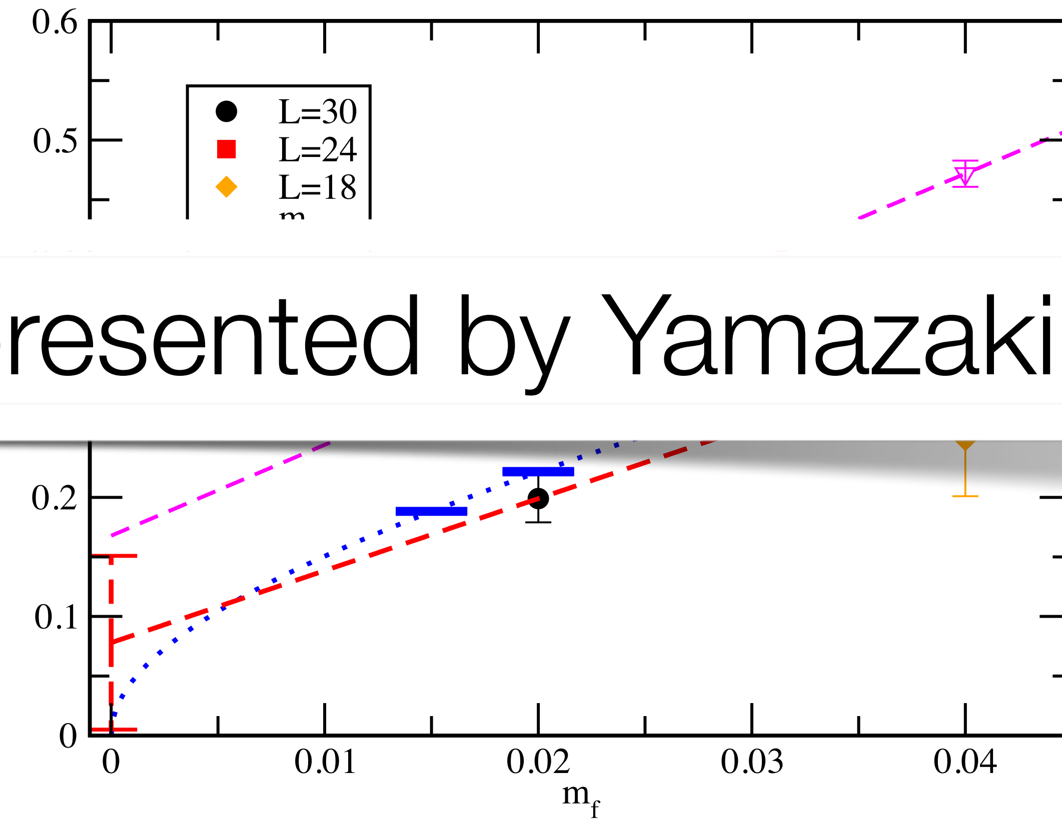

LatKMI PoS2013

Summary and Outlook

- KMI high performance computer φ has been used for 2.5 years, probing BSM possibilities for electro-weak symmetry breaking, through strong dynamics, producing interesting results.

- Results from LatKMI collaboration

  - 1st to show light composite scalar in N_f=12

  - N_f=8 is a candidate walking technicolor theory

  - 1st to find light scalar in N_f=8, which could realize 125 GeV Higgs

Summary and Outlook

- Solidness of the emerging picture will have to be investigated further:
  - precision needs to be improved
    - towards LHC run2 (2015-)
  - controversial pictures (conformal window) from different collaborations
- Calculation / technology development for other quantities are underway
  - S parameter: new method proposed for vacuum polarization function
  - low energy parameters in π and σ as effective light elements
  - Scaler (Higgs) decays need to be investigated
  - Finite Temperature ↔ Baryogenesis
  - Property of Dark Matter candidate: techni-baryon...

Thank you very much for your attention !