SCGT 2012 KMI

Can the Higgs impostor hide near the conformal window ?

Julius Kuti
University of California, San Diego

Workshop on Strong Coupling Gauge Theories in the LHC Perspective

KMI Nagoya University, December 4-7, 2012

Many thanks to the KMI organizers for putting this timely meeting together!

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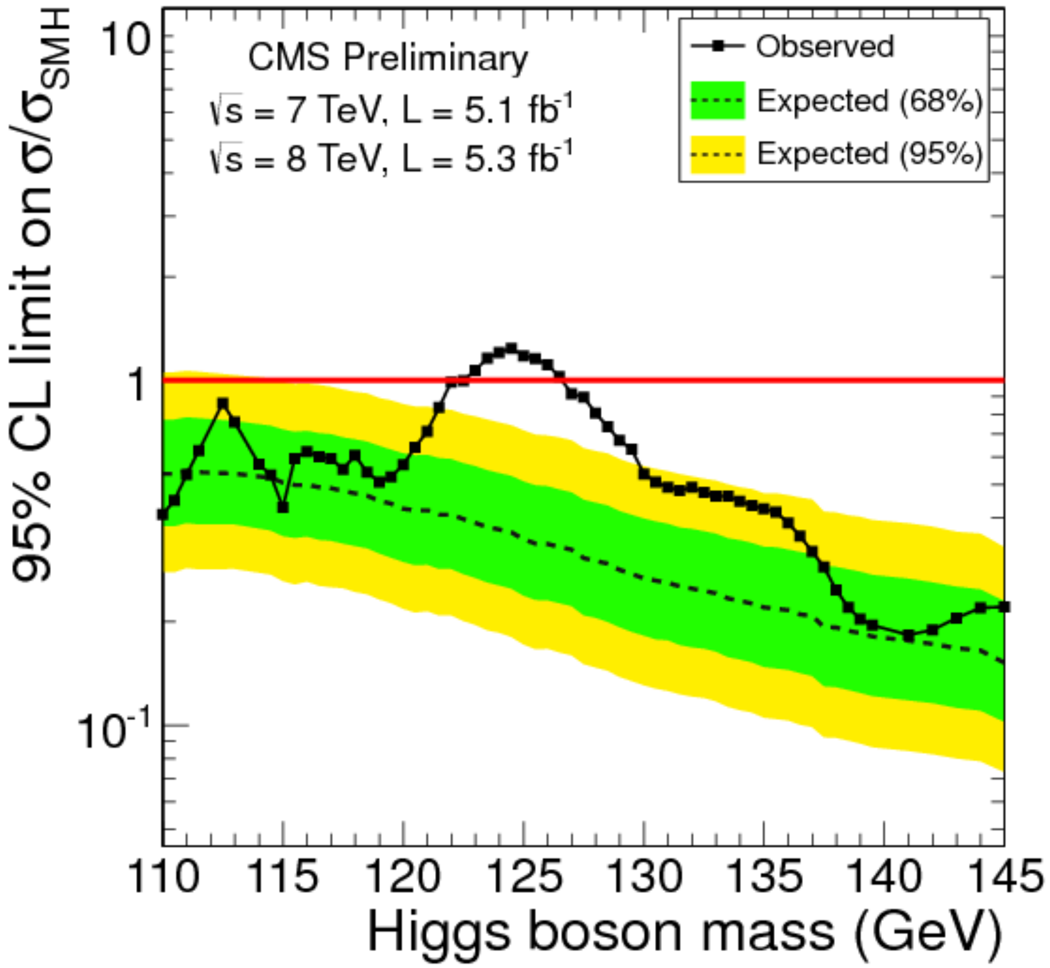
Thanks to my collaborators for some of the work discussed here (Lattice Higgs Collaboration):

Zoltan Fodor, Kieran Holland, Daniel Nogradi, Chris Schroeder, Chik Him Wong

similar to talk at Boulder USQCD BSM meeting:
lattice overview mixed with applications

revised for SCGT 2012 workshop

apologies for incomplete references in a huge field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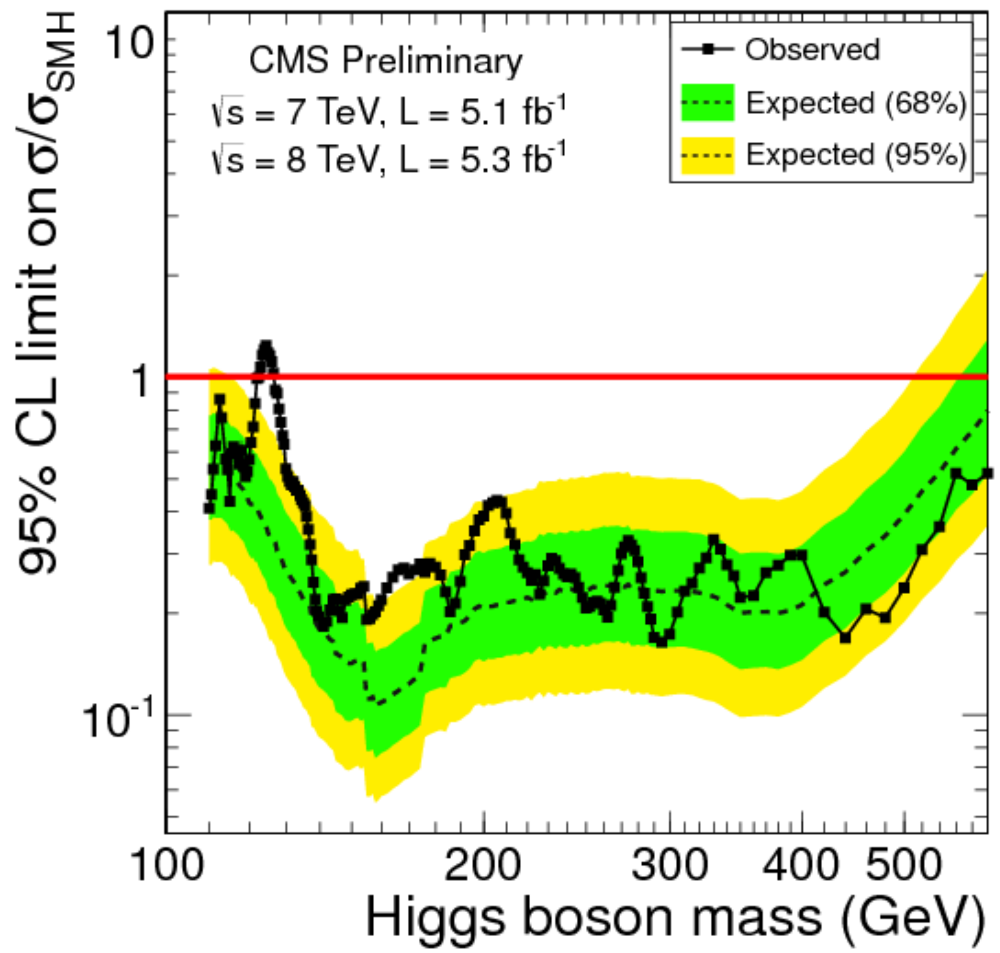
√s = 7 TeV, L = 5.1 fb-1
√s = 8 TeV, L = 5.3 fb-1
Observed
Expected (68%)
Expected (95%)
95% CL limit on σ/σSMH
Higgs boson mass (GeV)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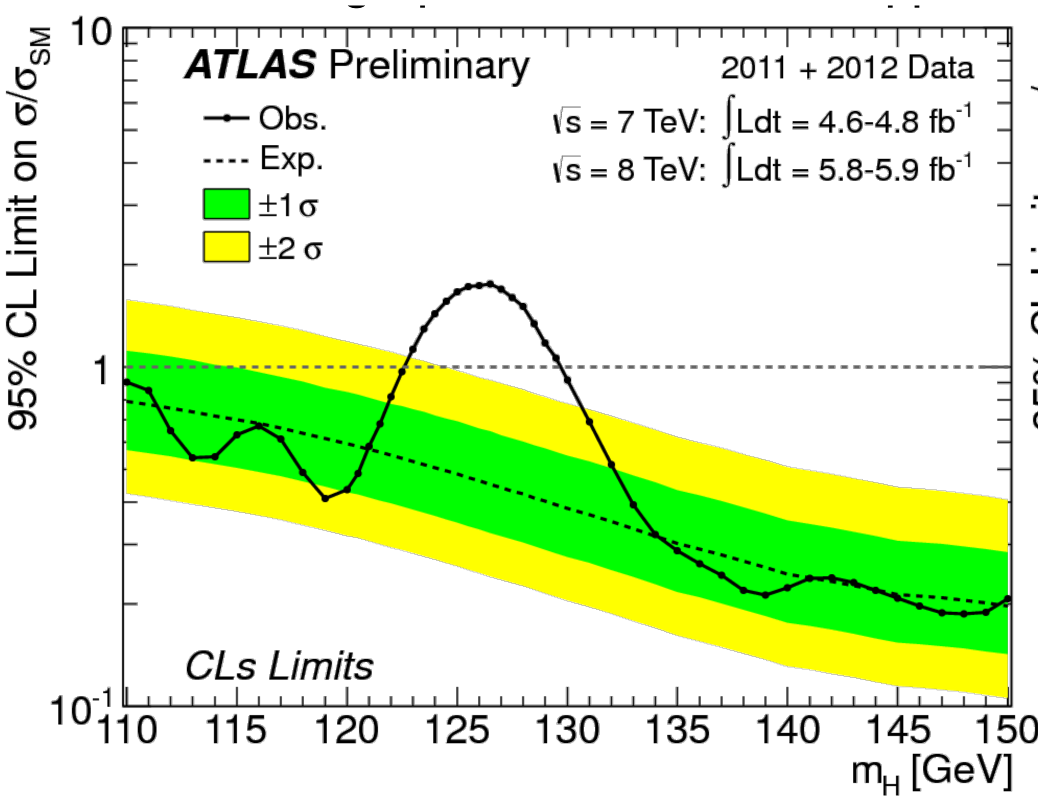
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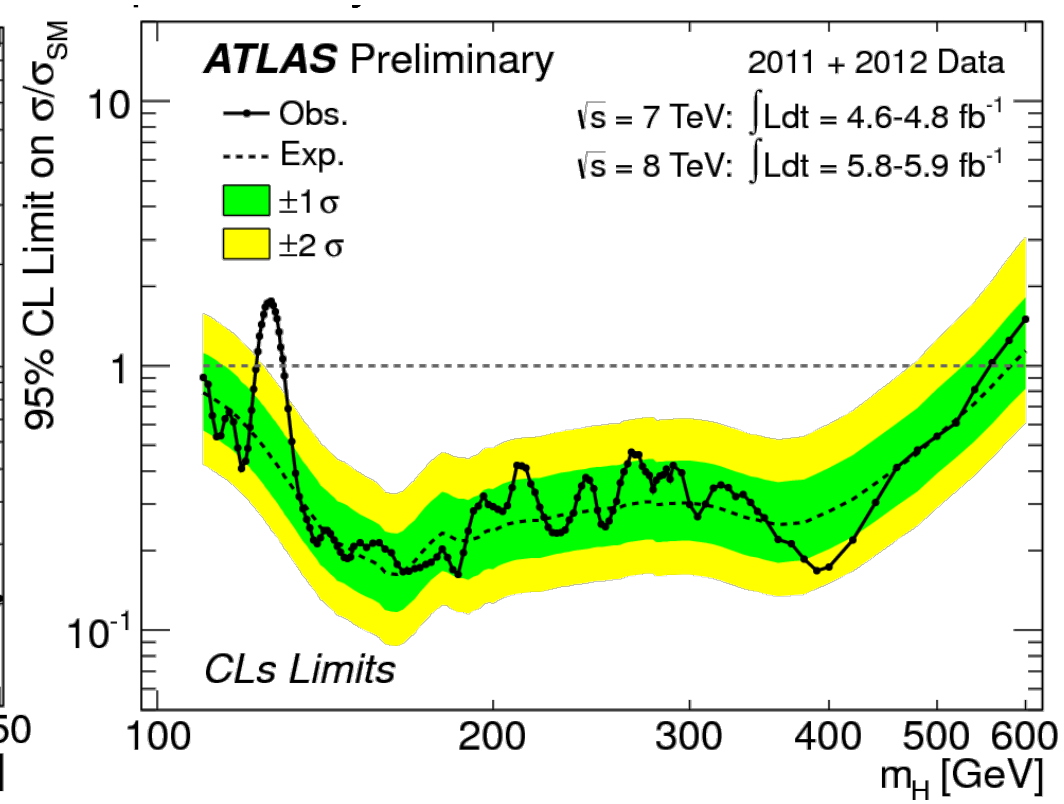
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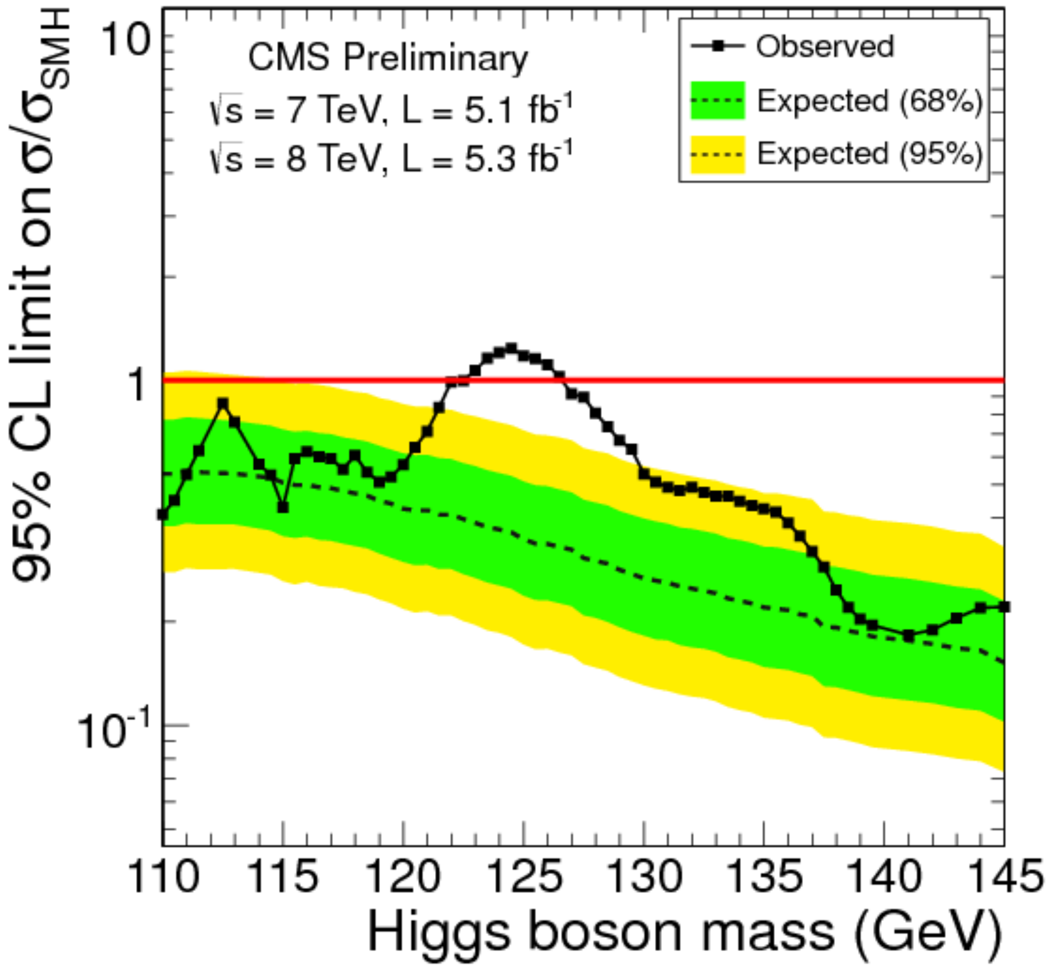
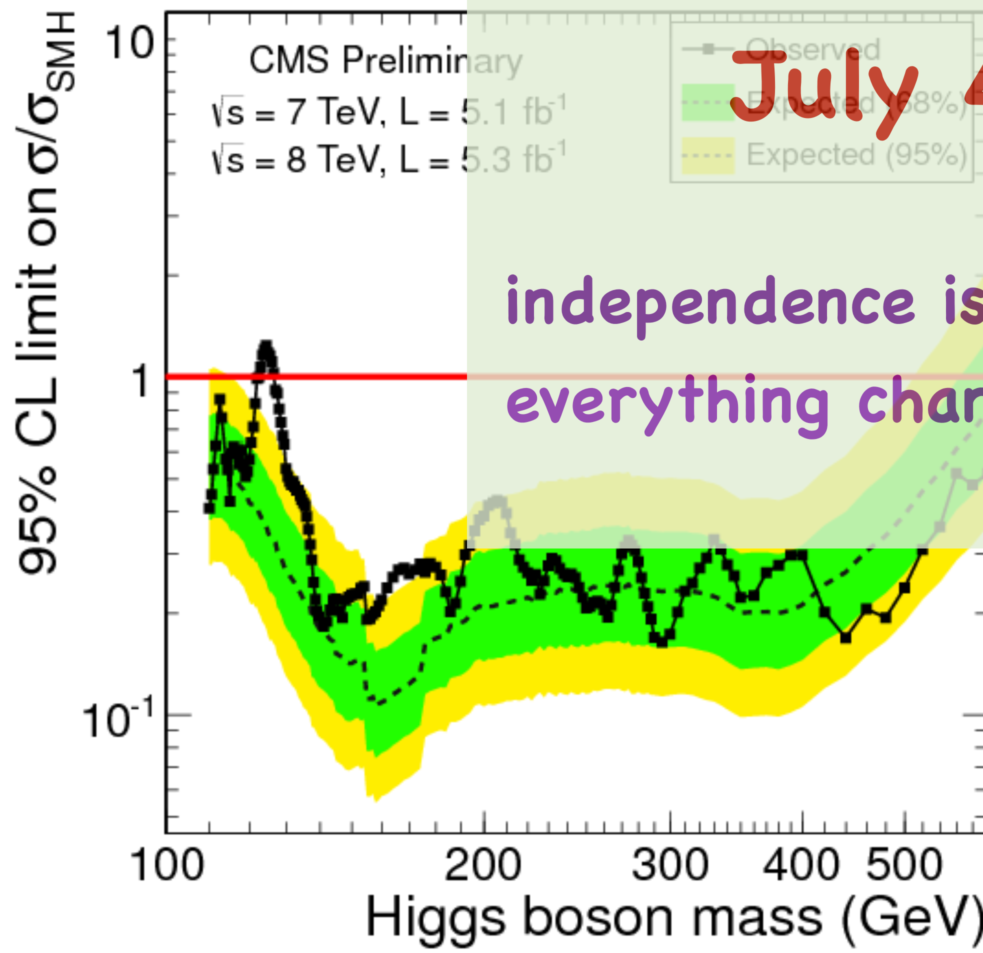
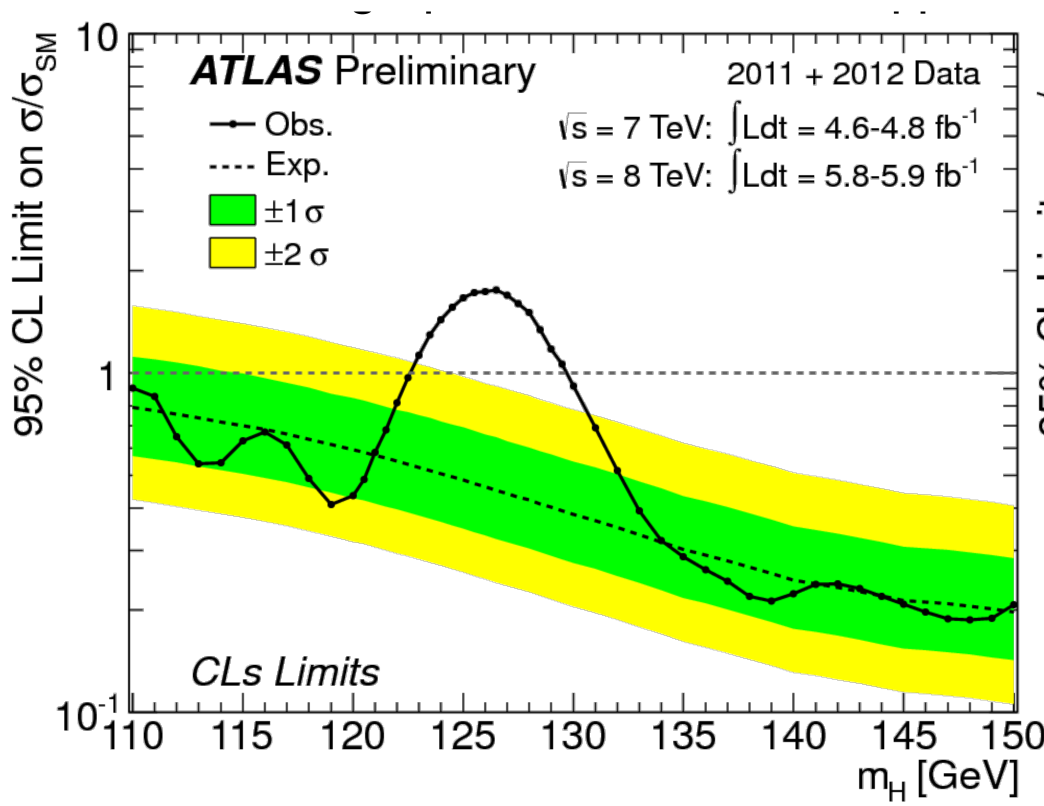
July 4th, 2012:

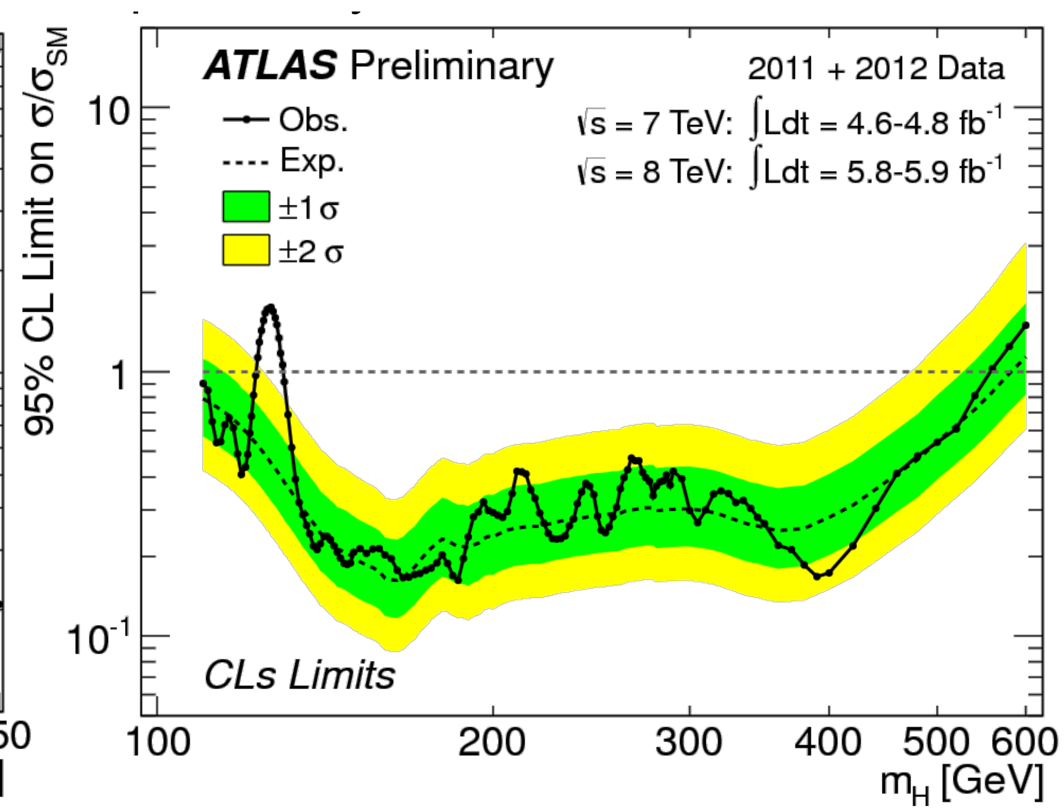
independence is lost

everything changed









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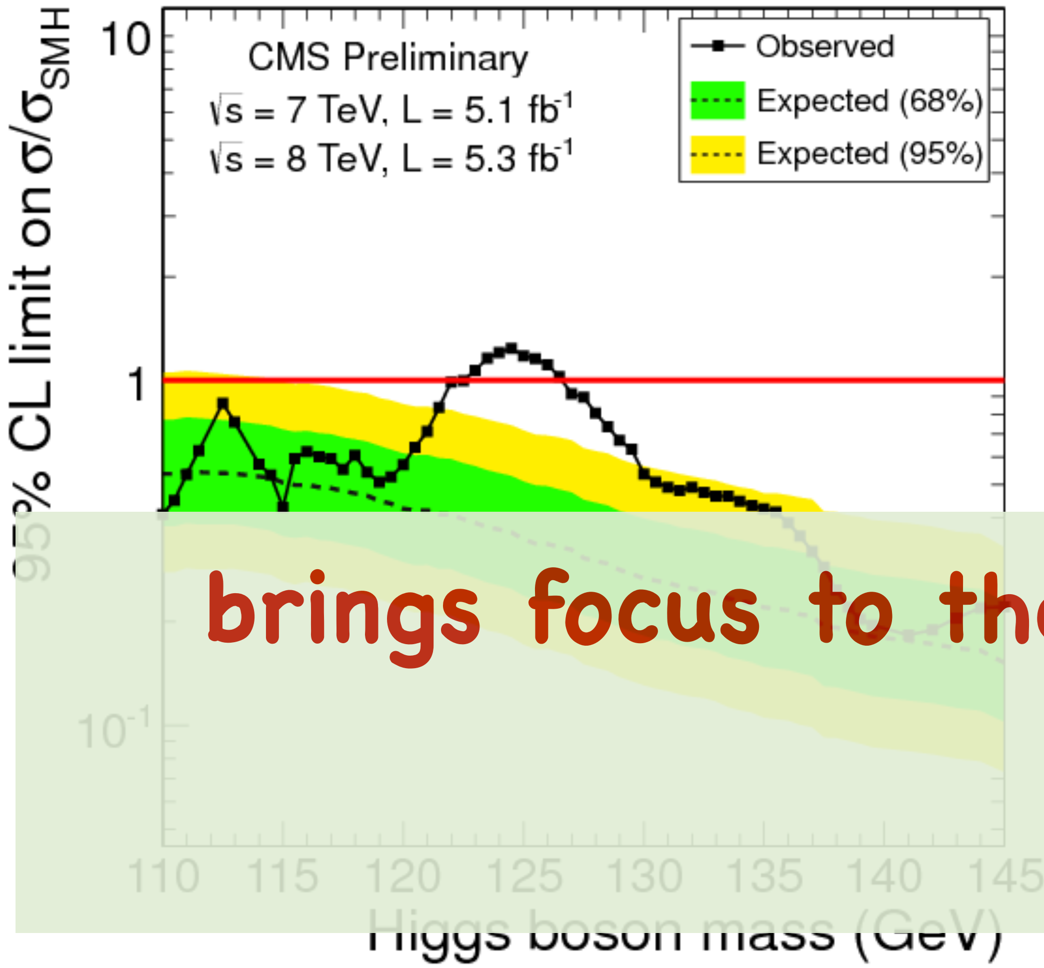

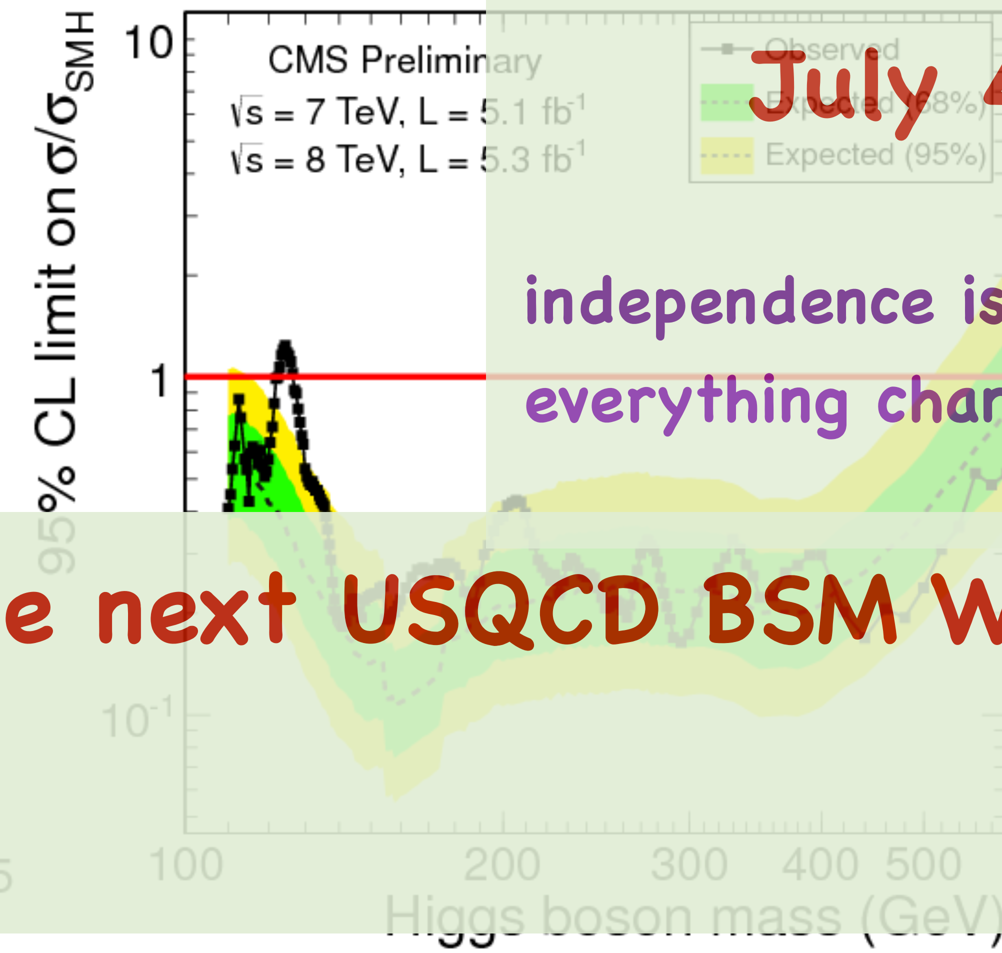

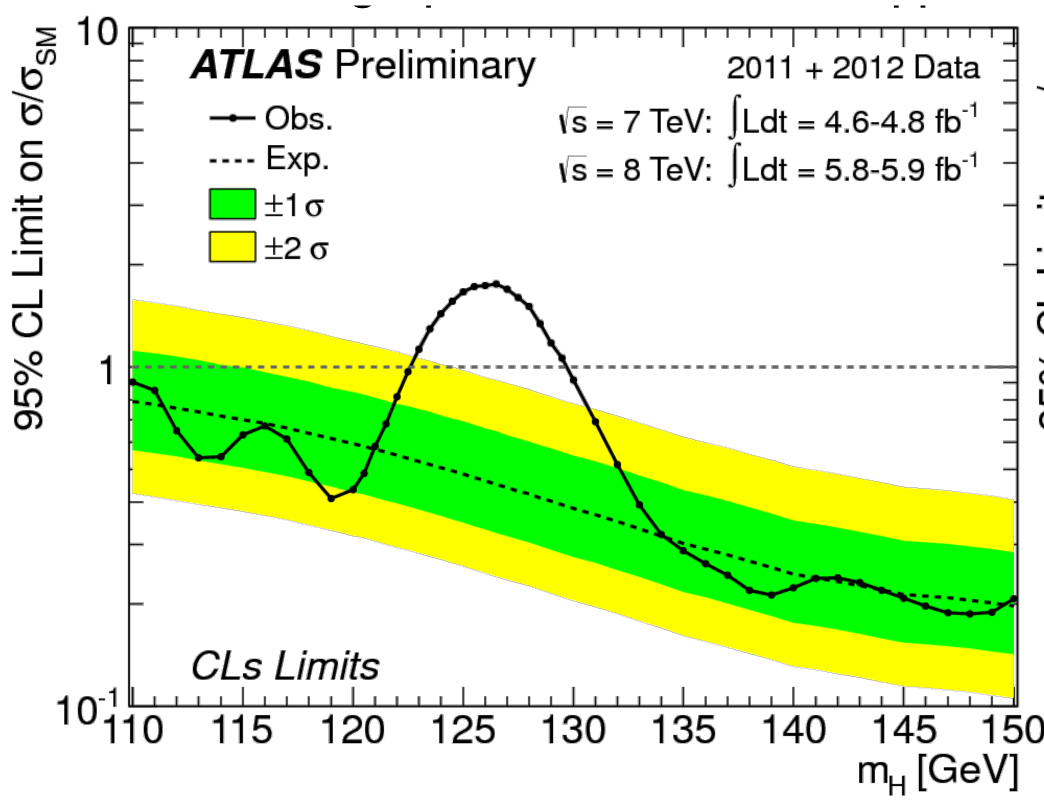

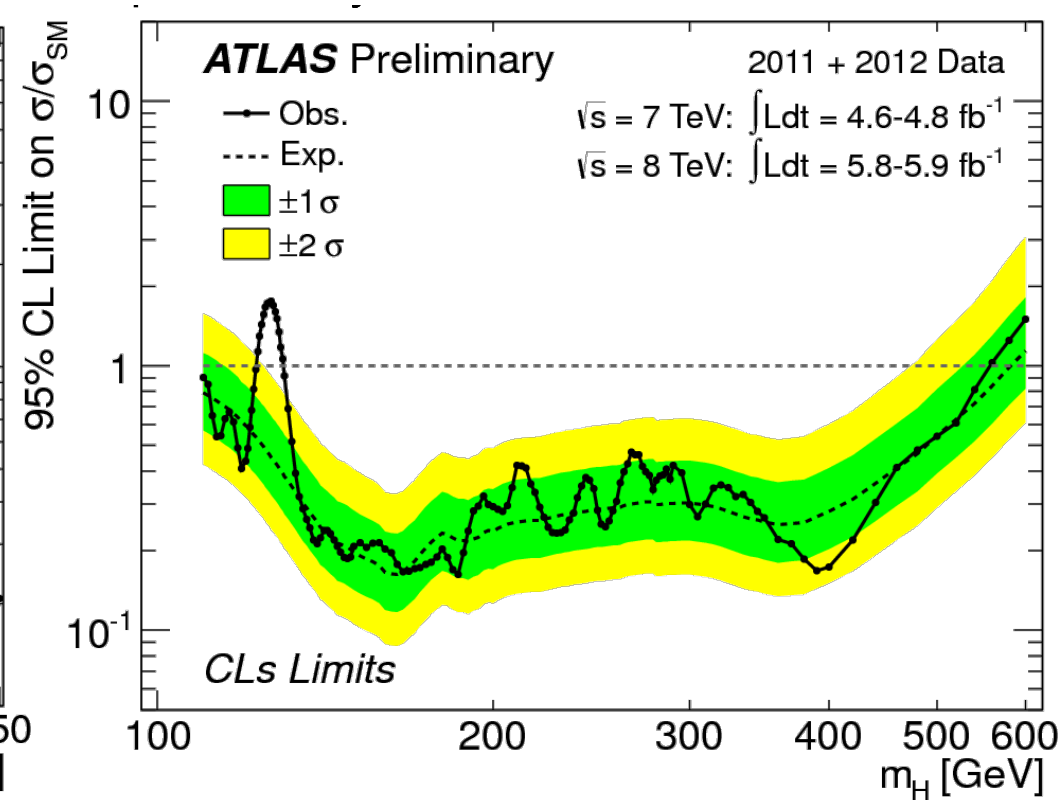

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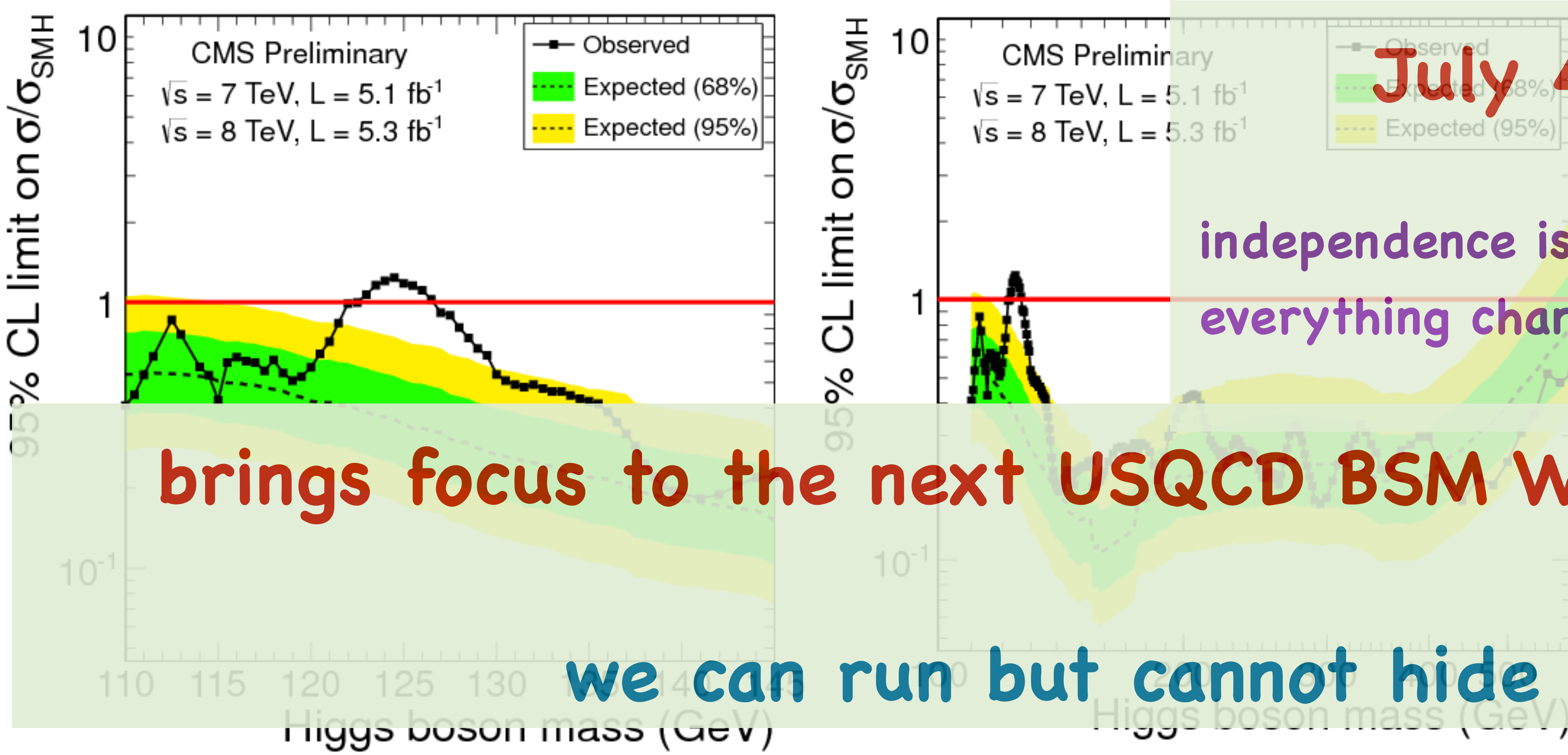
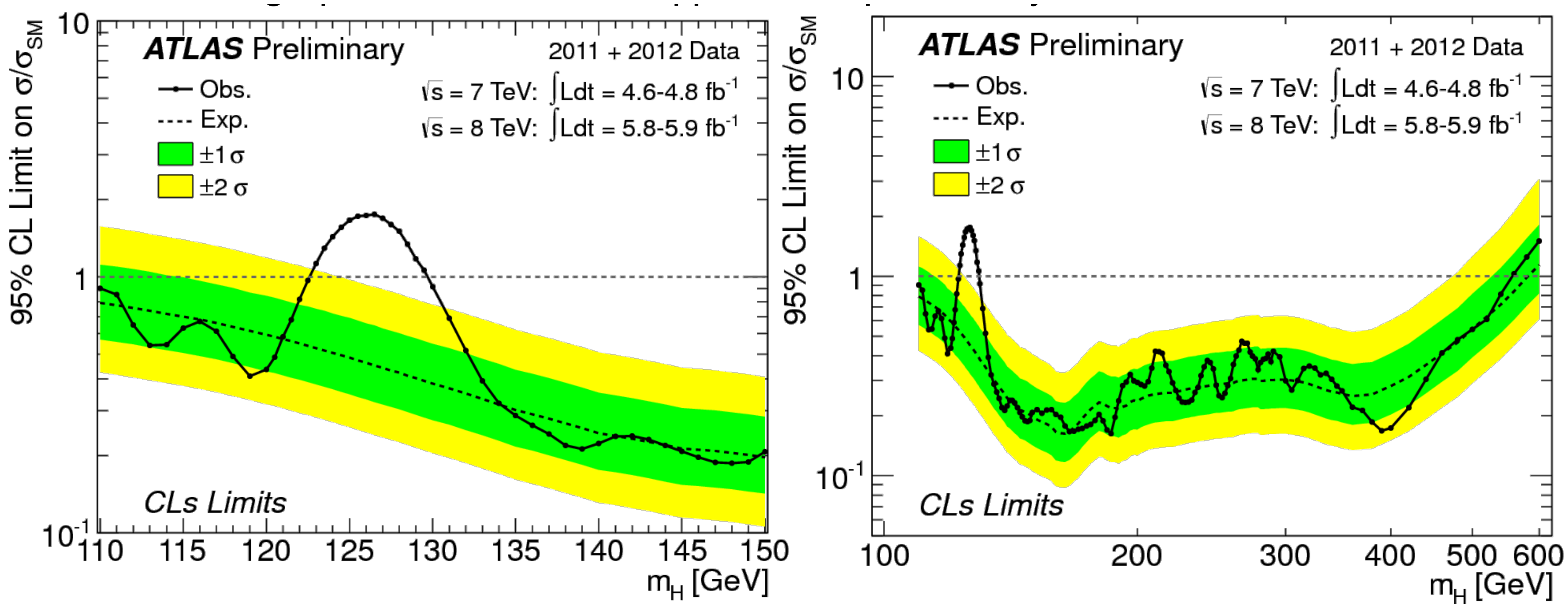
we can run but cannot hide





Conventional thinking before LHC was turned on:

- **New physics from strongly interacting particles will be found first**
  gluinos, s-quarks, technicolor, ...
- **Higgs is more difficult to find, particularly a light Higgs**
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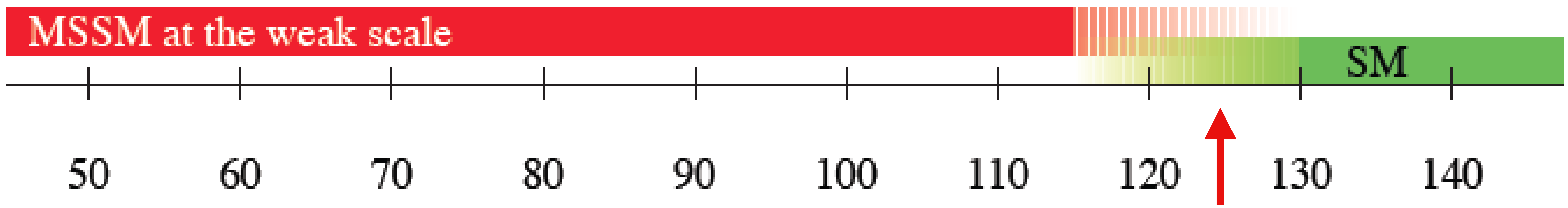
Wicked choice from Mother Nature: borderline for SUSY and SM (vacuum instability)



Is this the Higgs boson?

spin 0? parity? (begins to look like 0^{++})

$H \to \gamma\gamma$ (s=0 or 2 in s-wave)

$H \to bb$ and $H \to \tau\tau$ (favors s=0 in s-wave)

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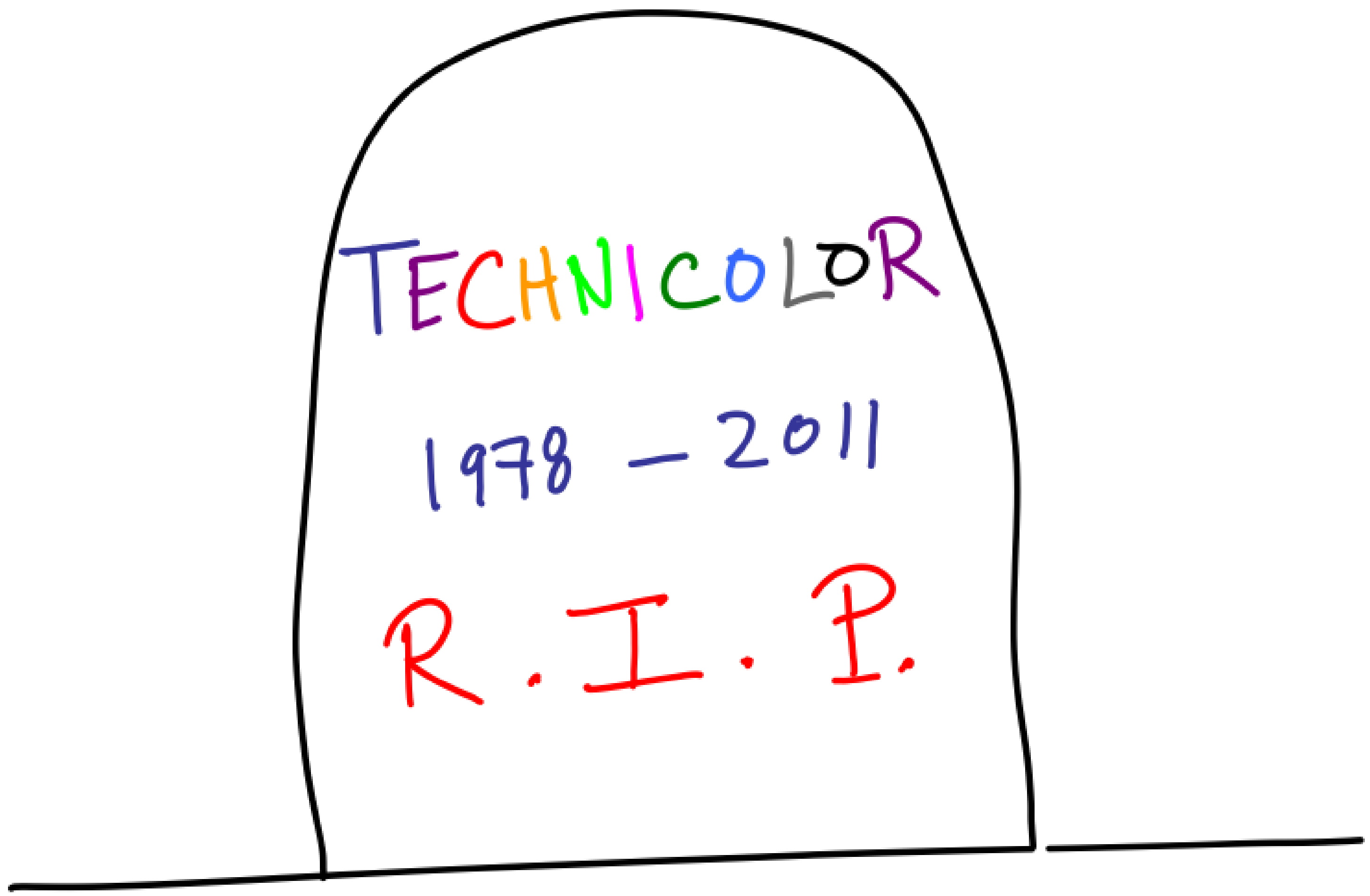
How do we plan lattice BSM with new Higgs-like particle?

Arkani-Hamed '12

TRIUMPH OF WEAK COUPLING



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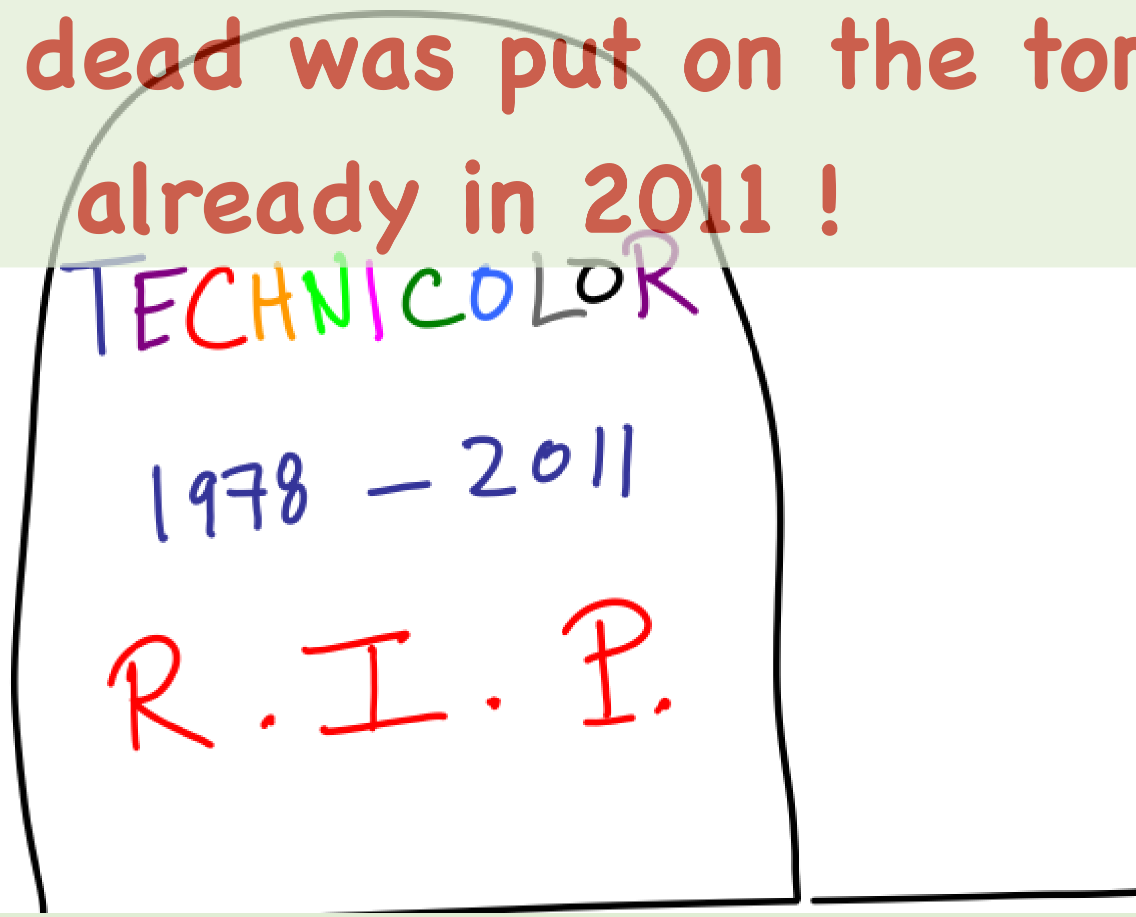

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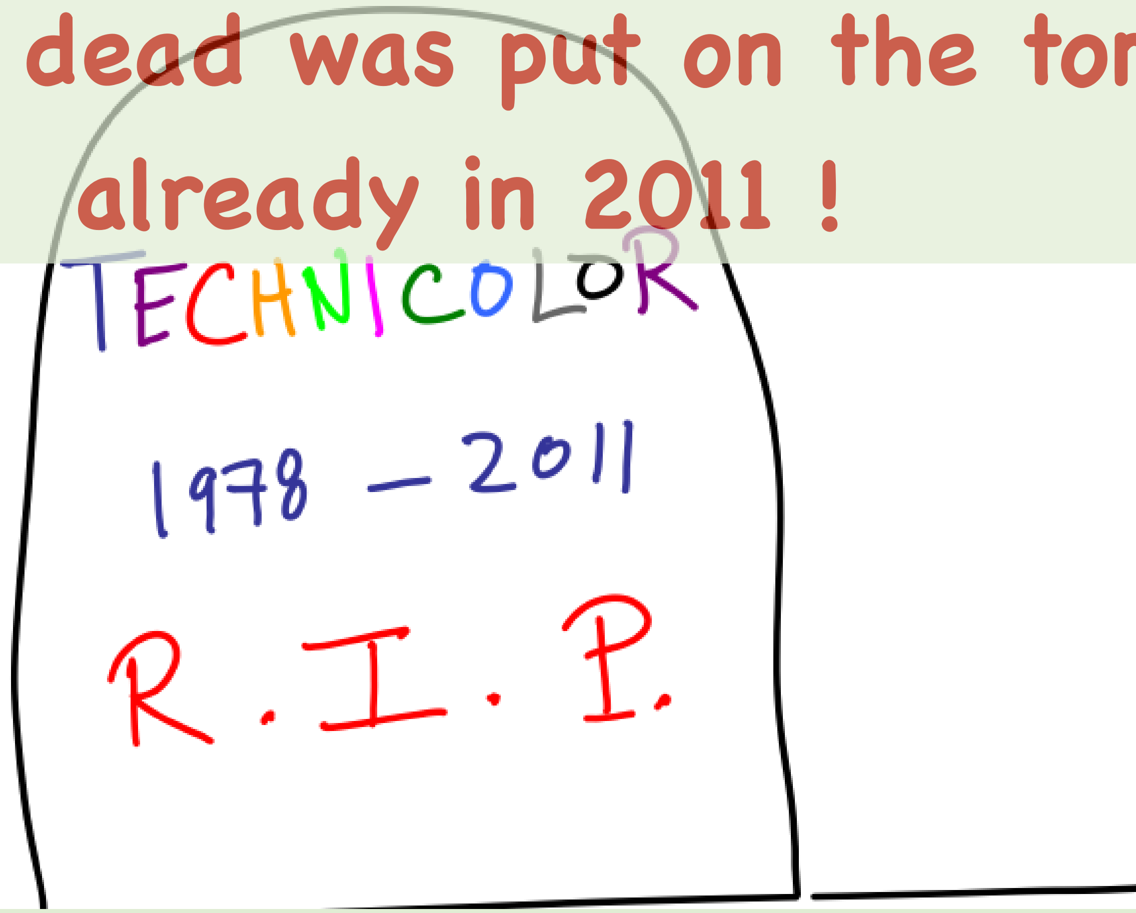

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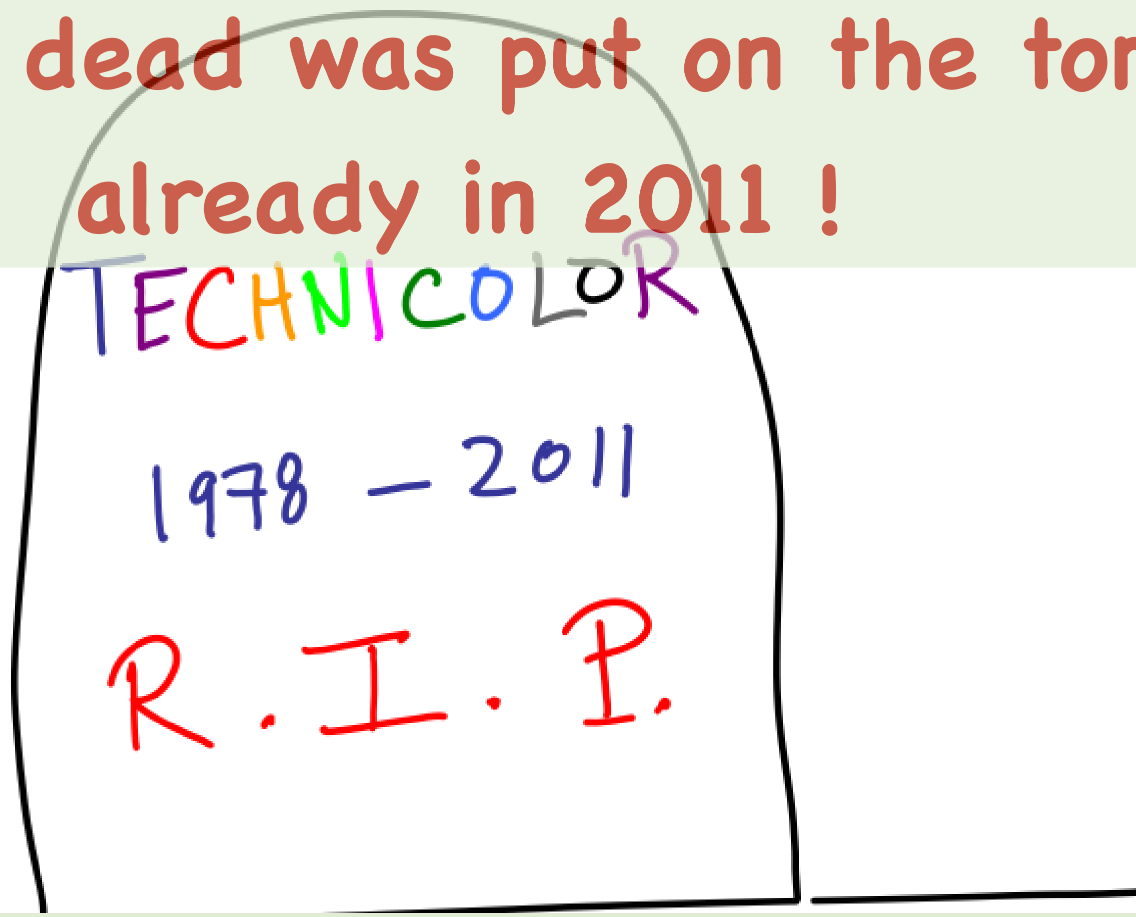

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why is SUSY not on the Tombstone?

What this talk is not:

- not a general review of work from lattice BSM groups
- will be broad range of talks from lattice groups in the workshop today
- not a promotion for the sextet model (spoiler alert: sexte model will often discussed)
- no SUSY (there is significant lattice N=4 SUSY progress)

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What this talk is:

mainly for off-lattice theorists whose help is needed to put together new plans, like the USQCD BSM White Paper for the next five years

- introduction to challenges of lattice methods commonly faced in lattice BSM work
- lattice specific: cut-off, finite volume, fermion mass
- navigating in a very large theory space of SCGT: fermion reps and the conformal window tuning, running coupling, dilaton, χSB, spectrum, etc.
- is this theory space large enough?
- caveat: very large field with large set of difficult problems, inevitably sampled with bias and limited in scope

Outline

how large Theory Space is needed?

the sextet model as a simple example

light scalar and dilaton mechanism close to CW

chiral condensates and spectroscopy

running (walking) coupling

light scalar spectroscopy of 0^{++} states

Summary and outlook

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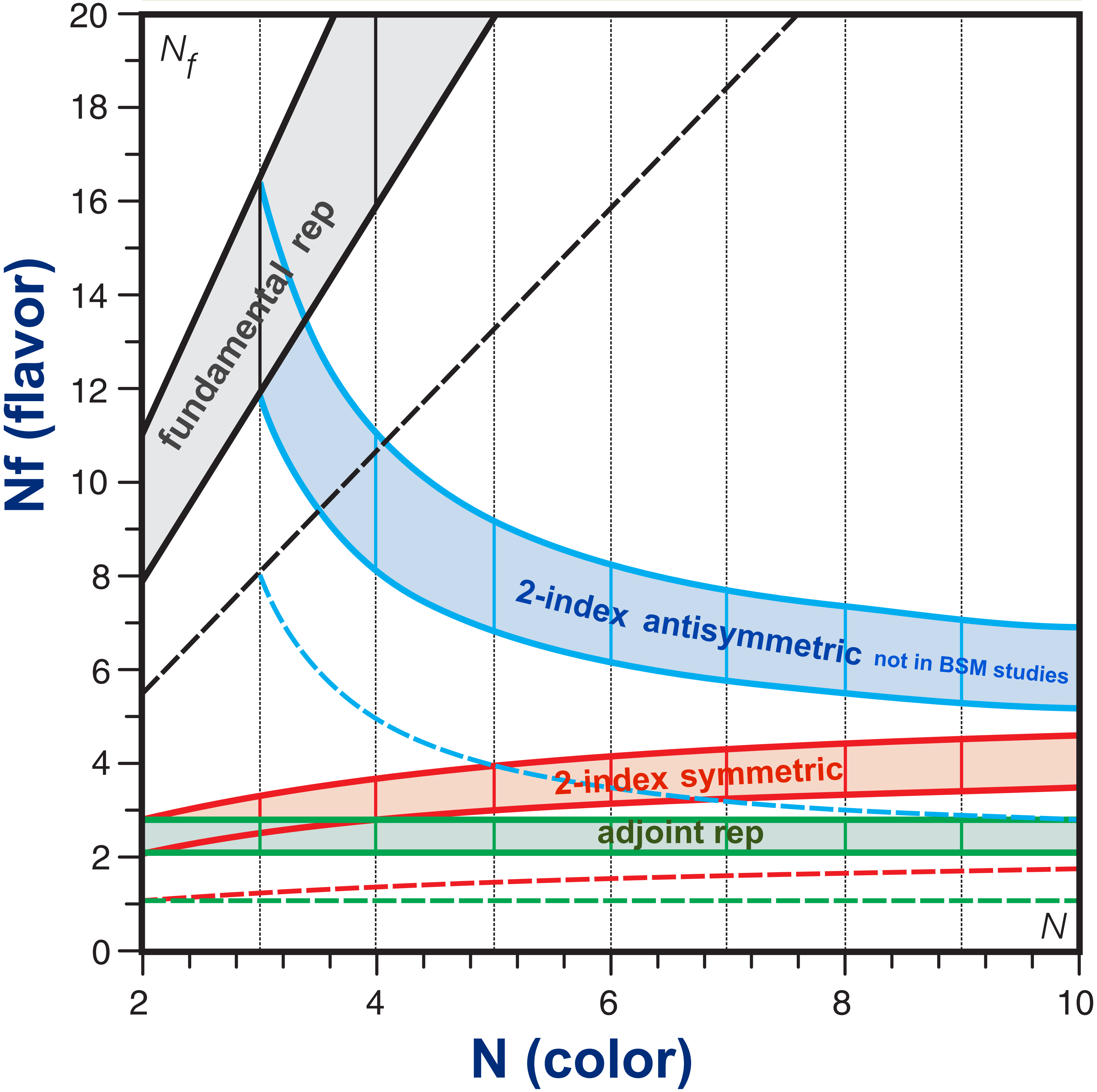
Summary and outlook

SCGT theory space and conformal window

color group, flavor, and fermion representation

(is the Higgs impostor hiding close to CW?)



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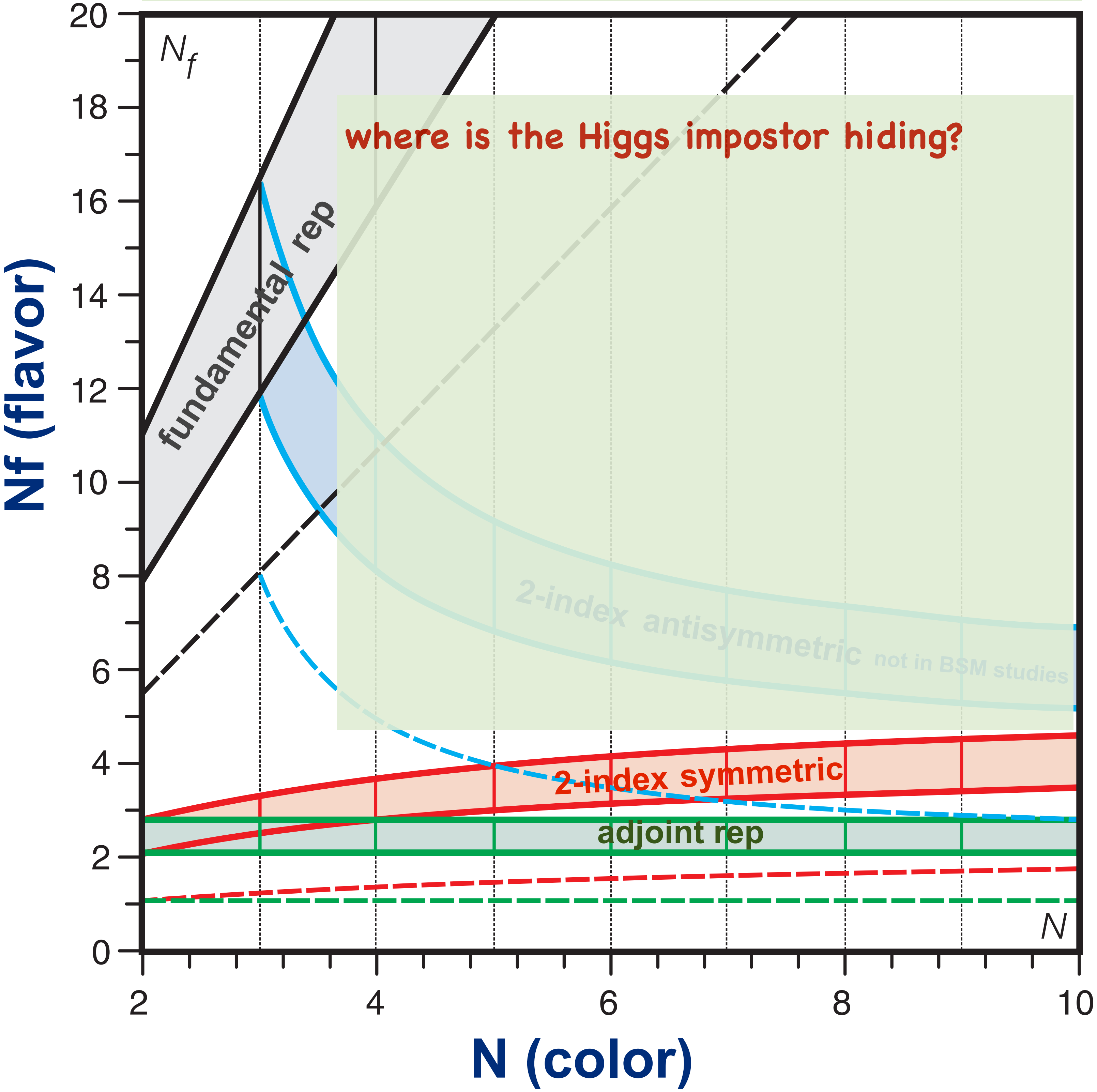

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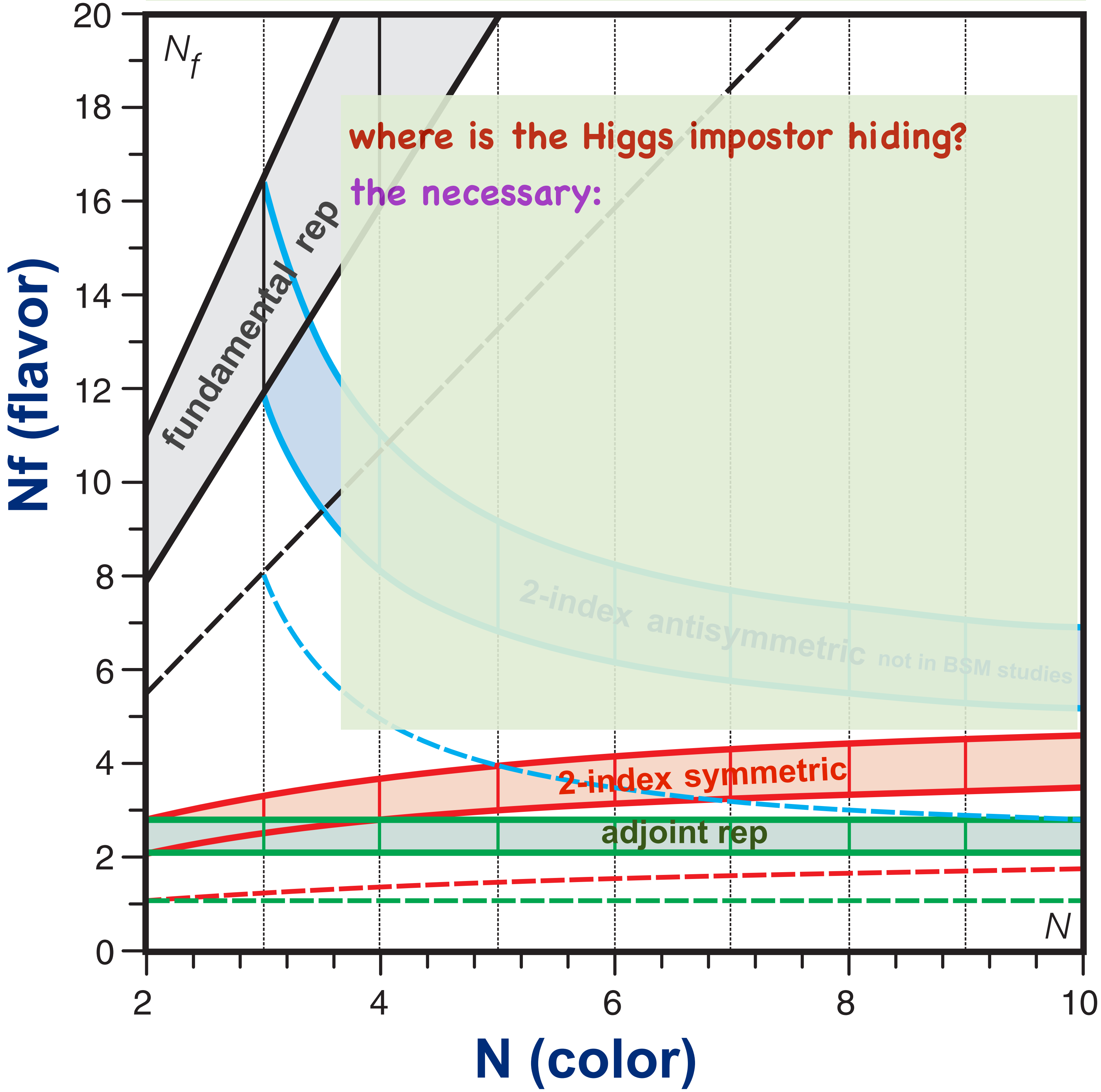

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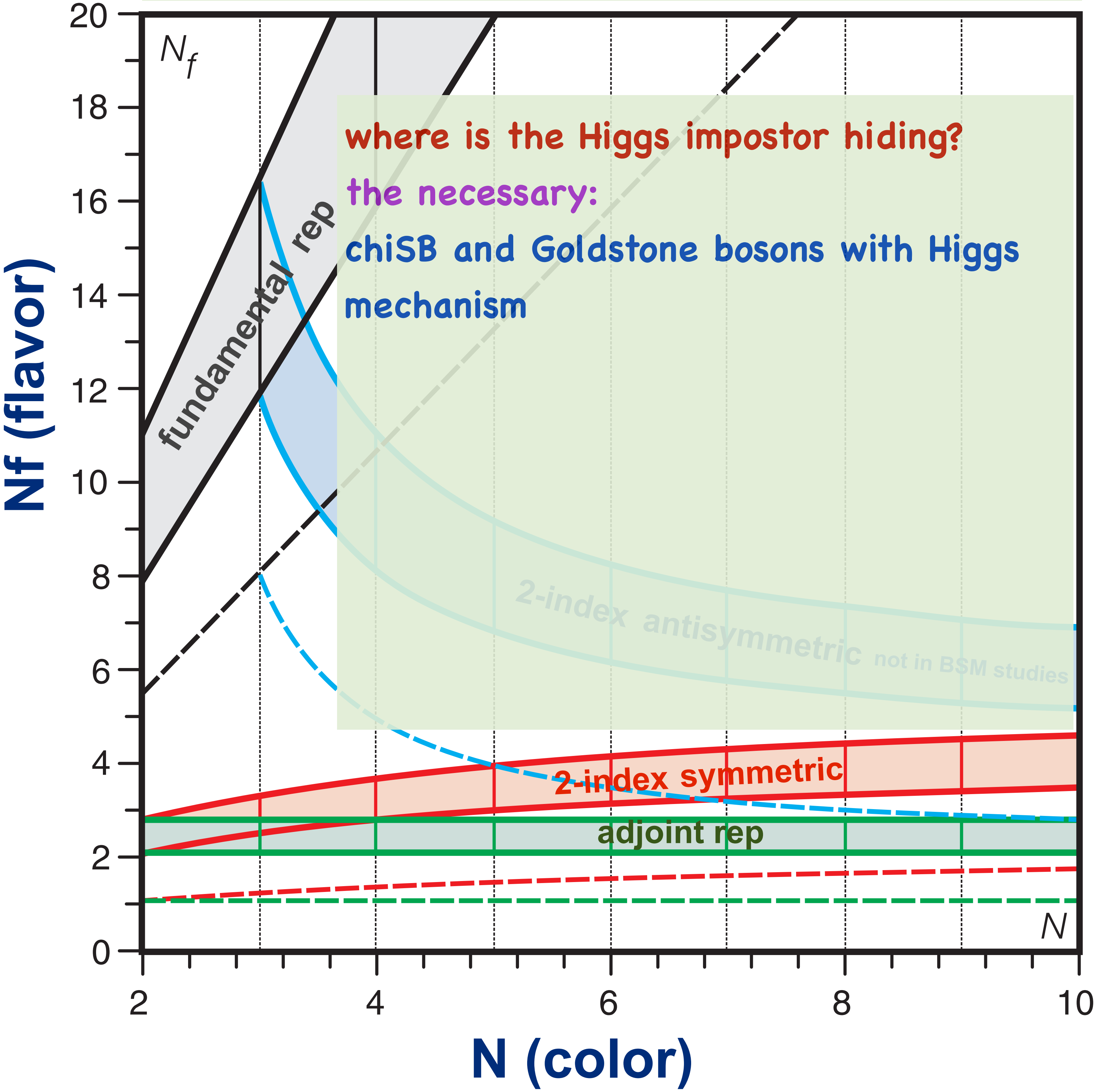

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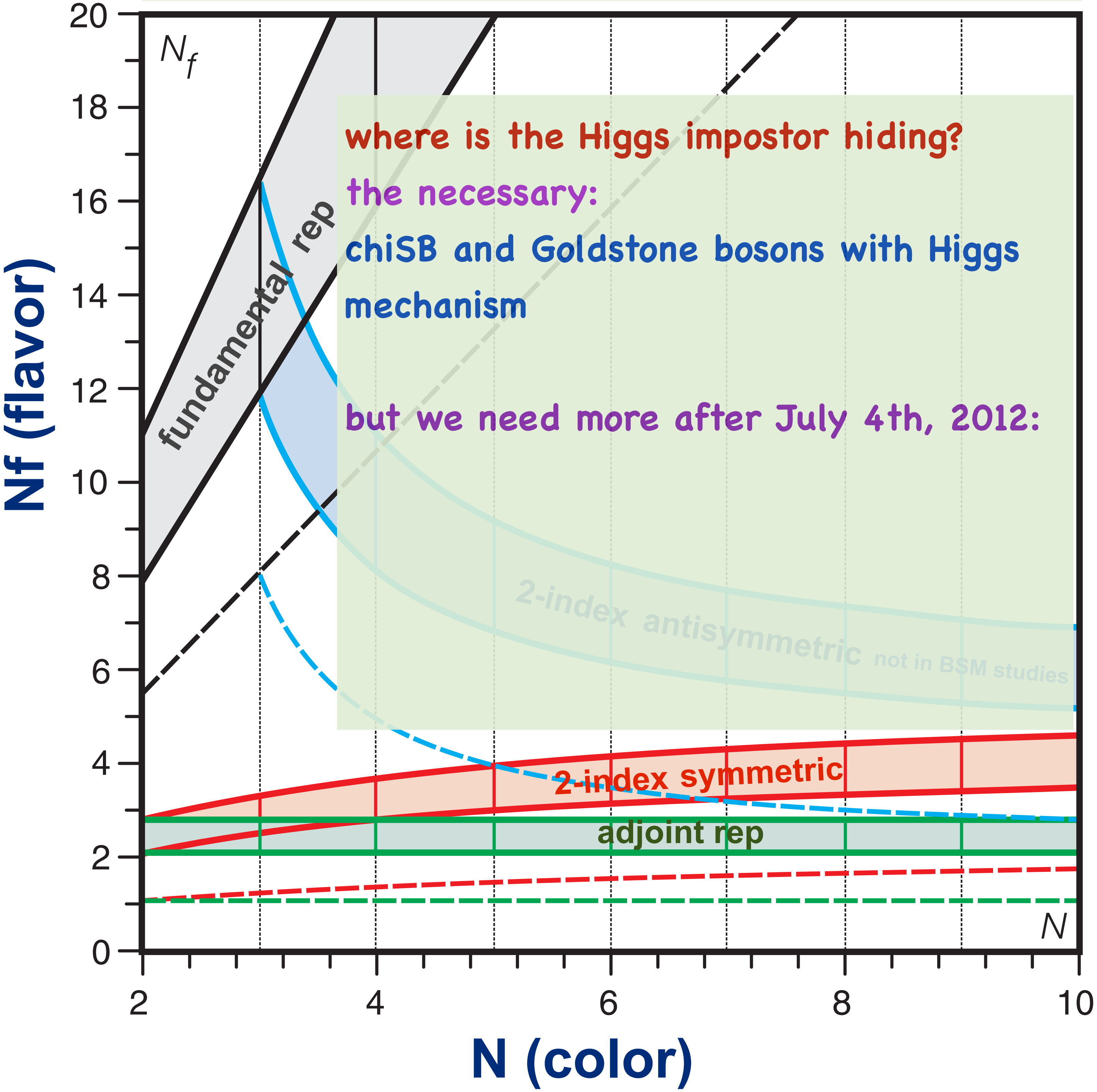

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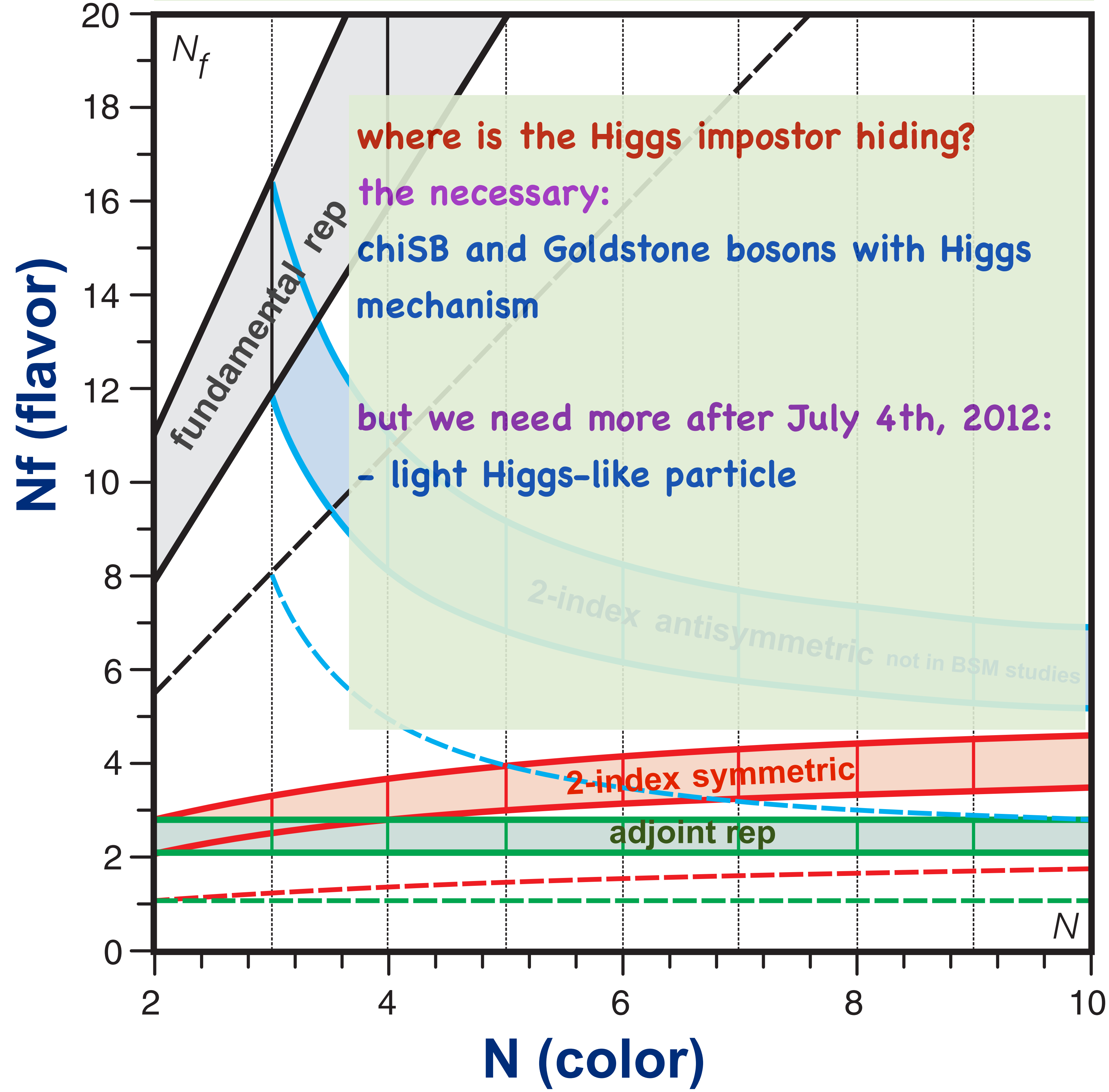

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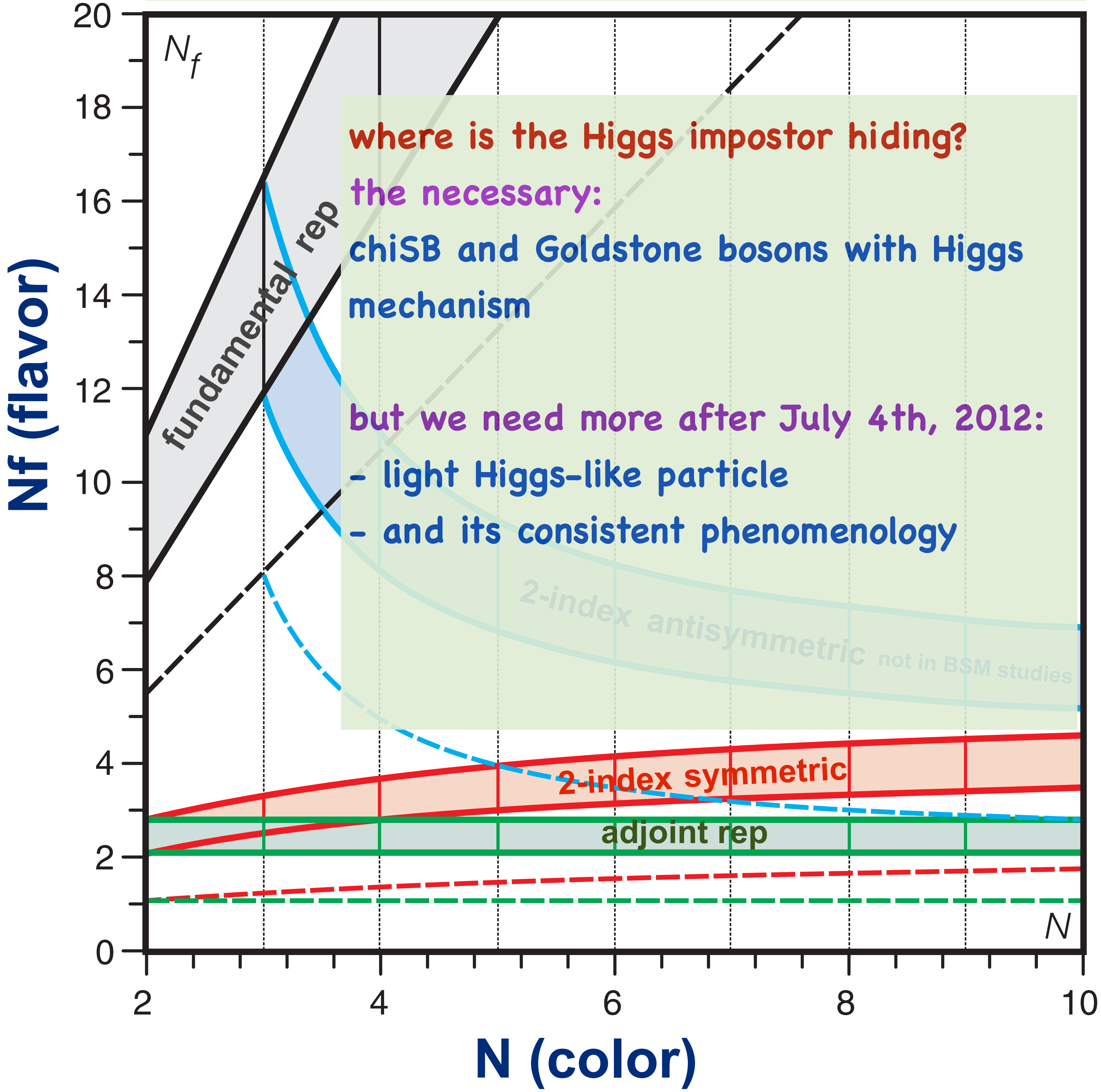

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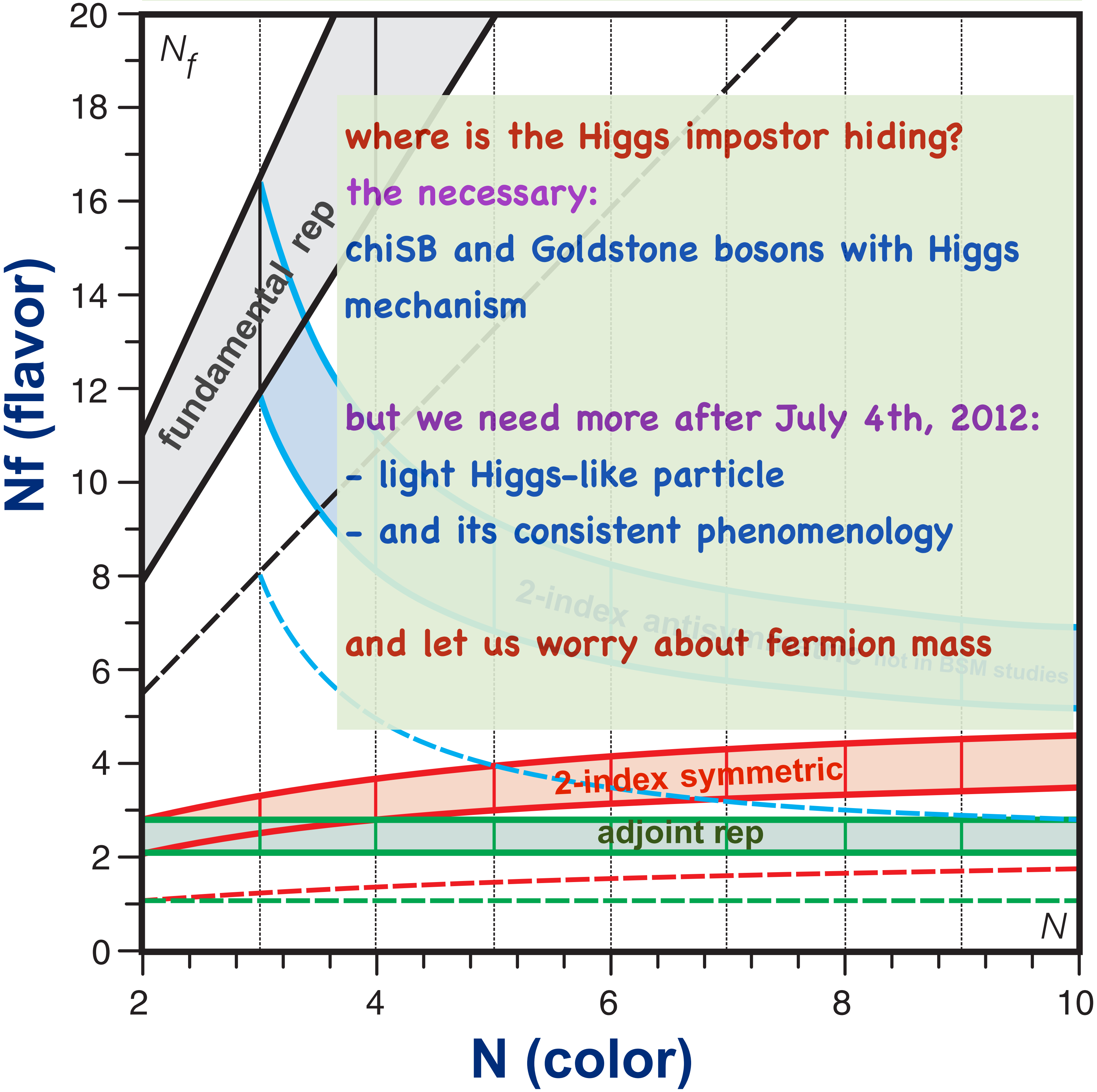

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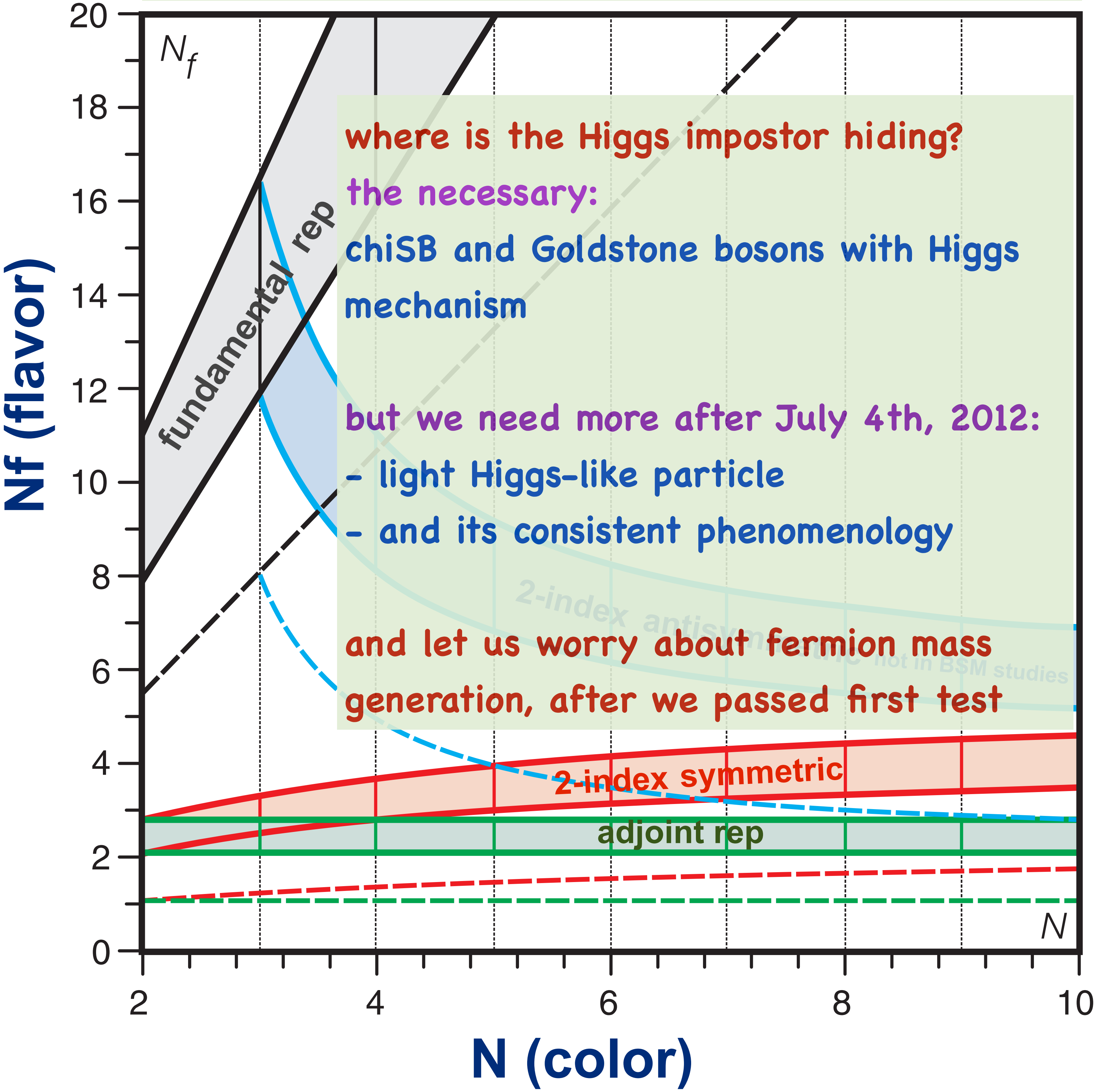

where is the Higgs impostor hiding?

the necessary:

chiSB and Goldstone bosons with Higgs mechanism

but we need more after July 4th, 2012:

- light Higgs-like particle
- and its consistent phenomenology

and let us worry about fermion mass generation, after we passed first test

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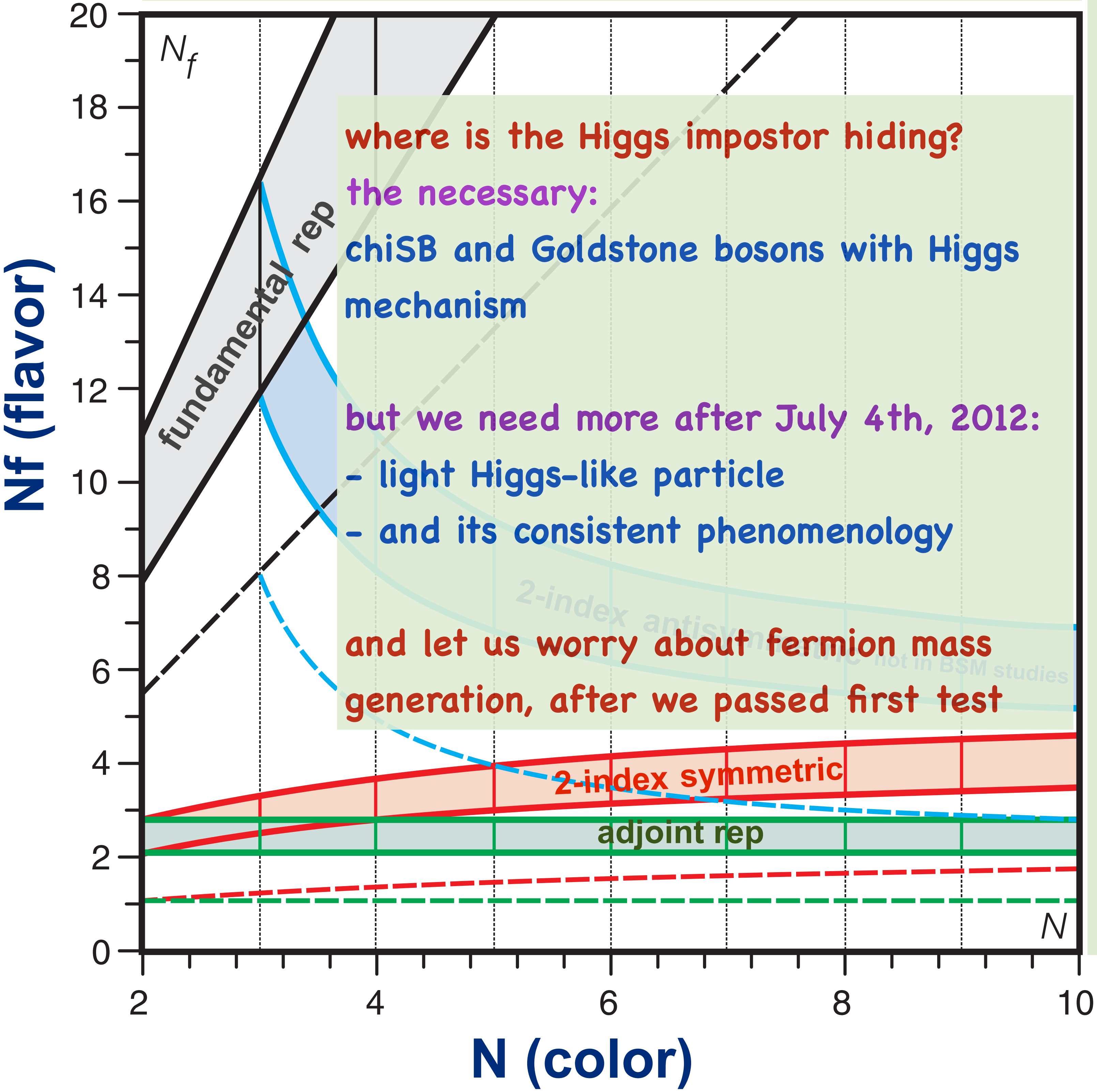

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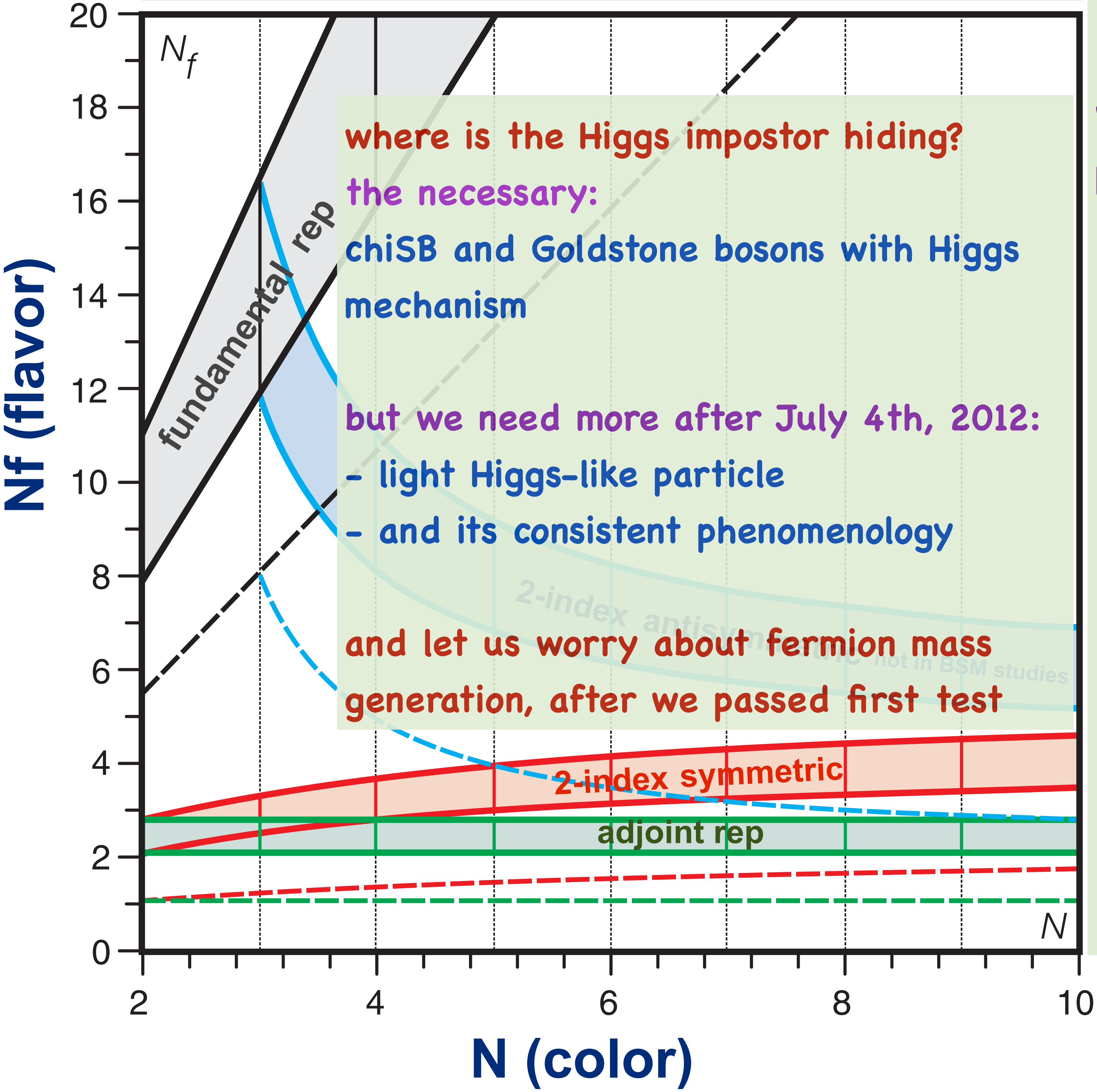

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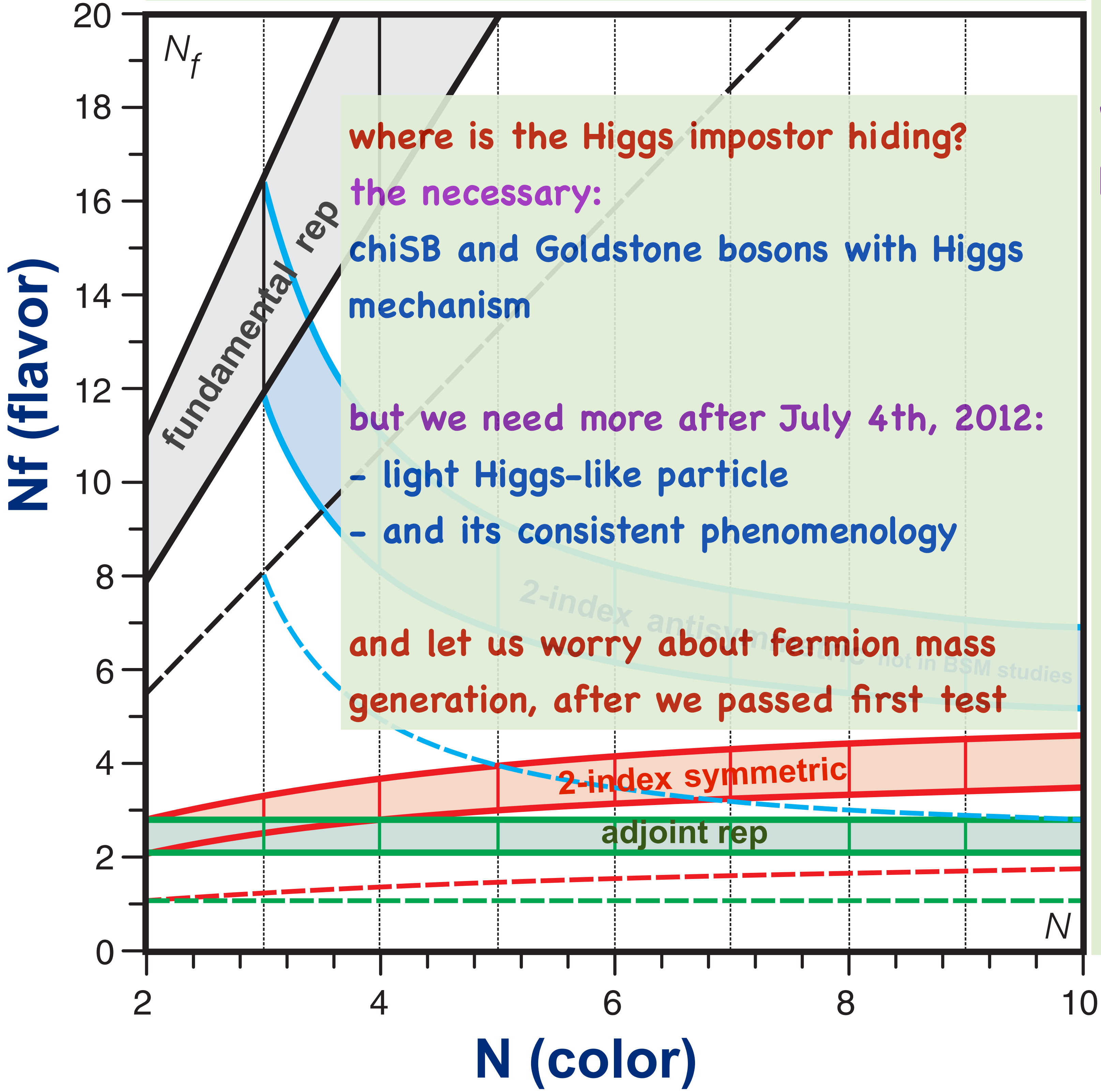

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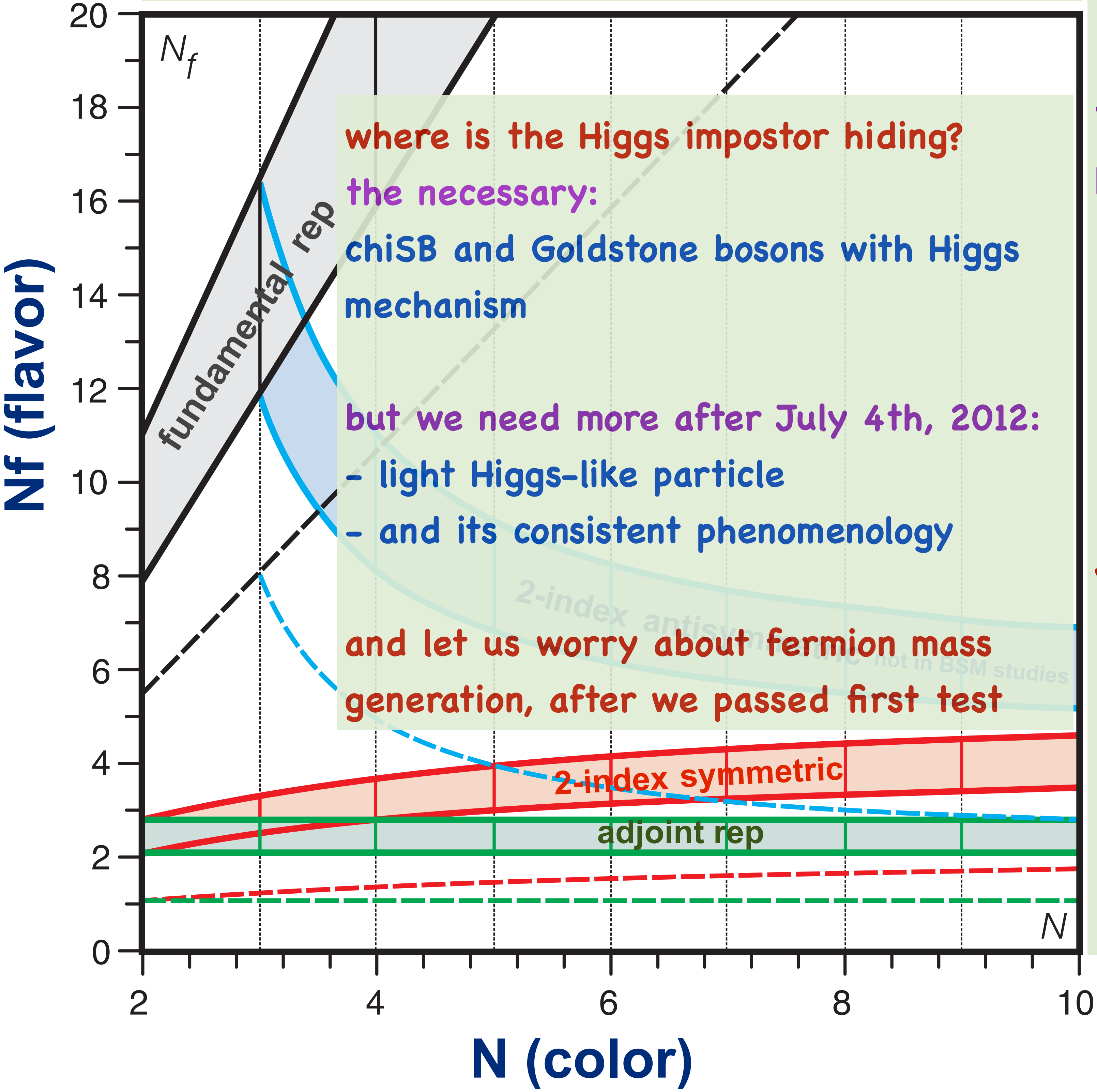

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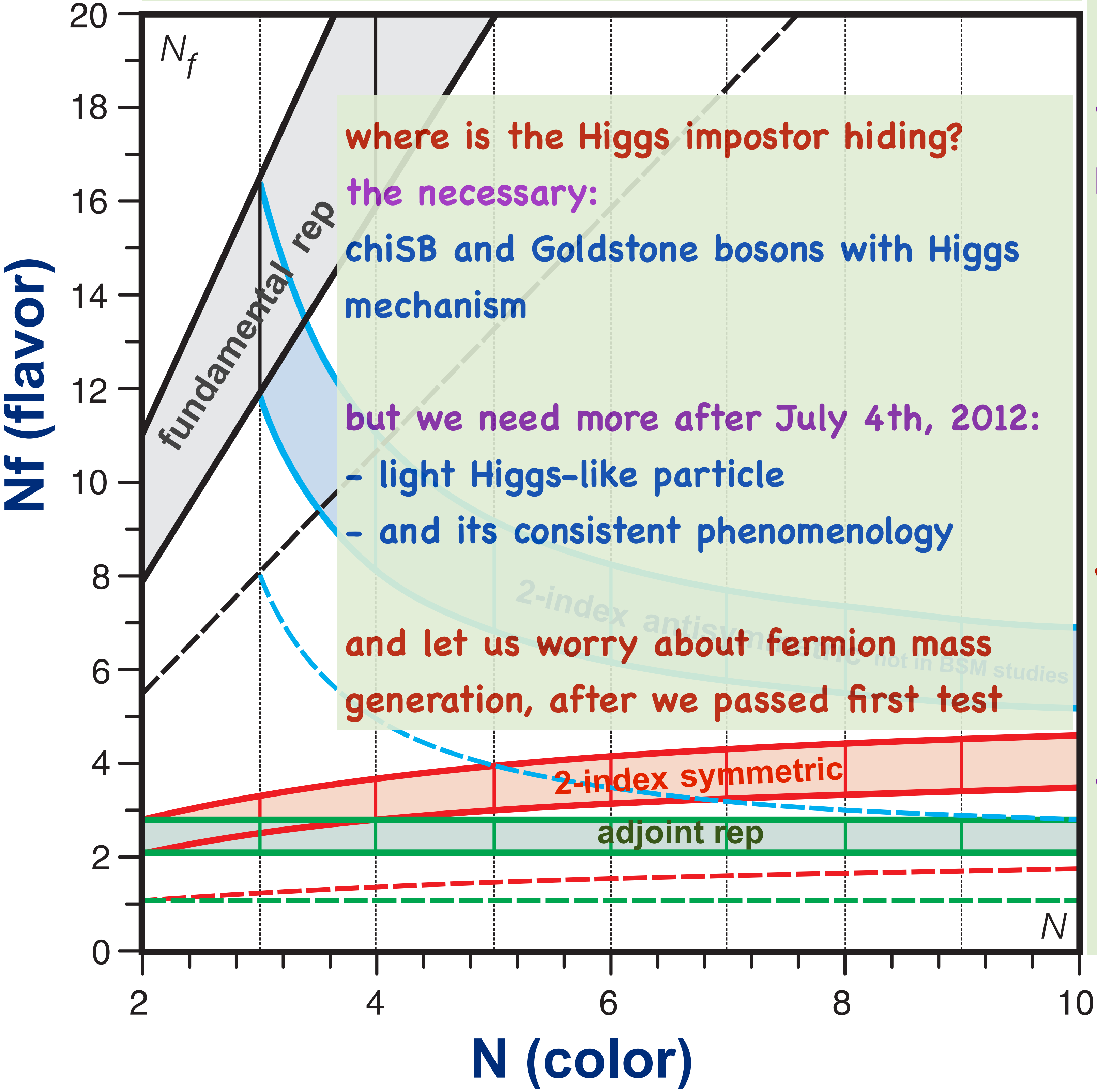

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We will say:

if interesting models are hiding, with light scalars, there will be new clues for change of perspective

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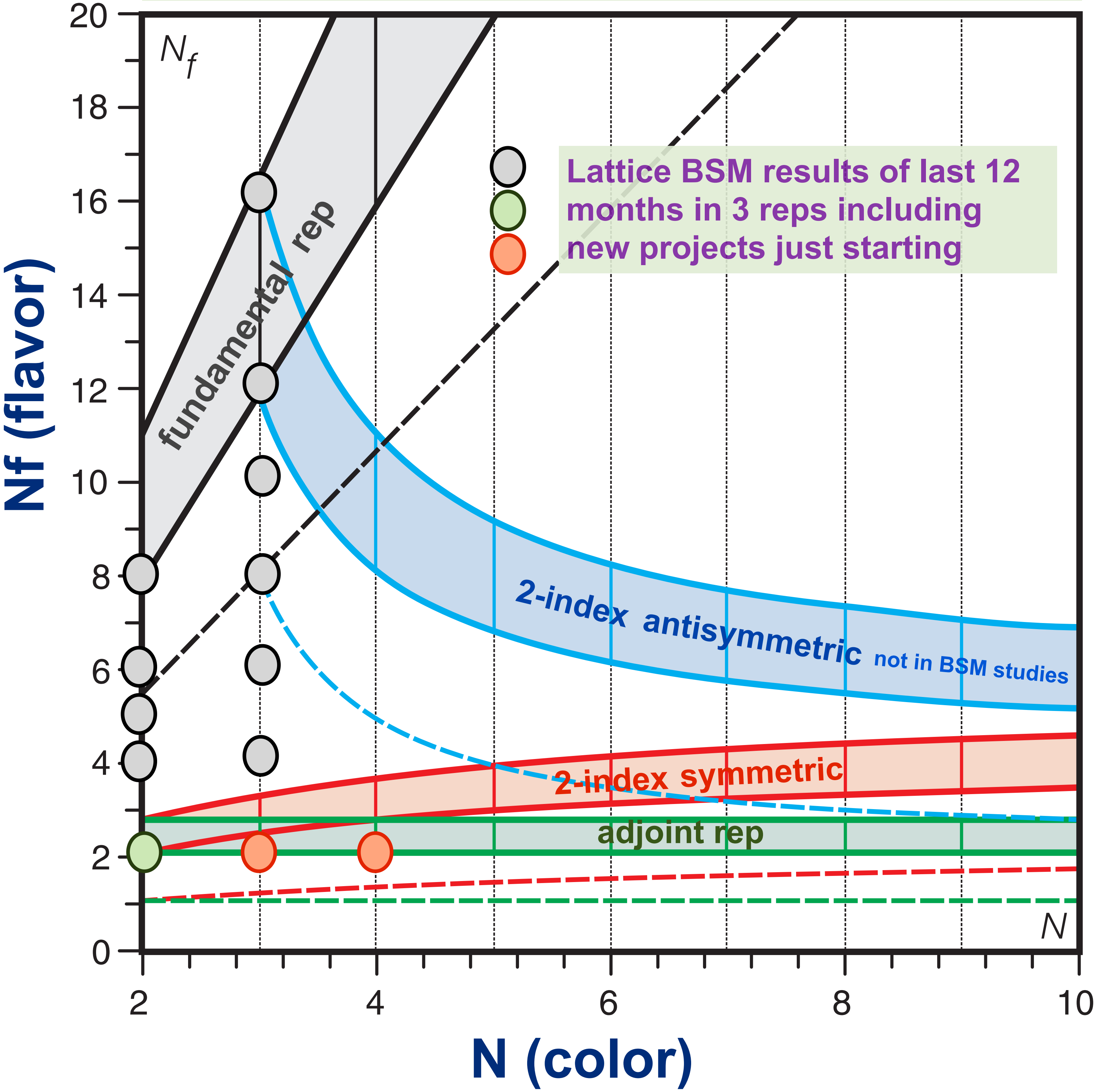
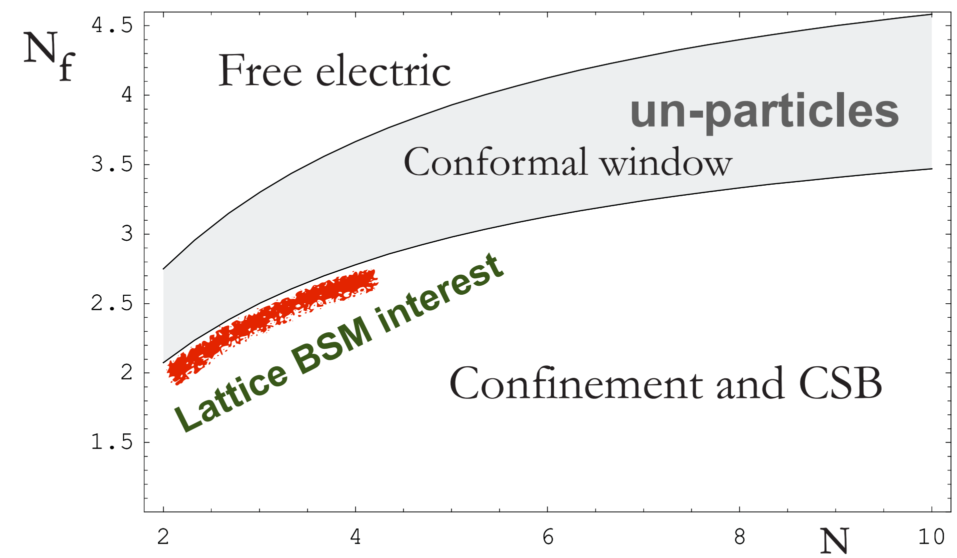


for each rep BSM interest is below conformal window but close to it:



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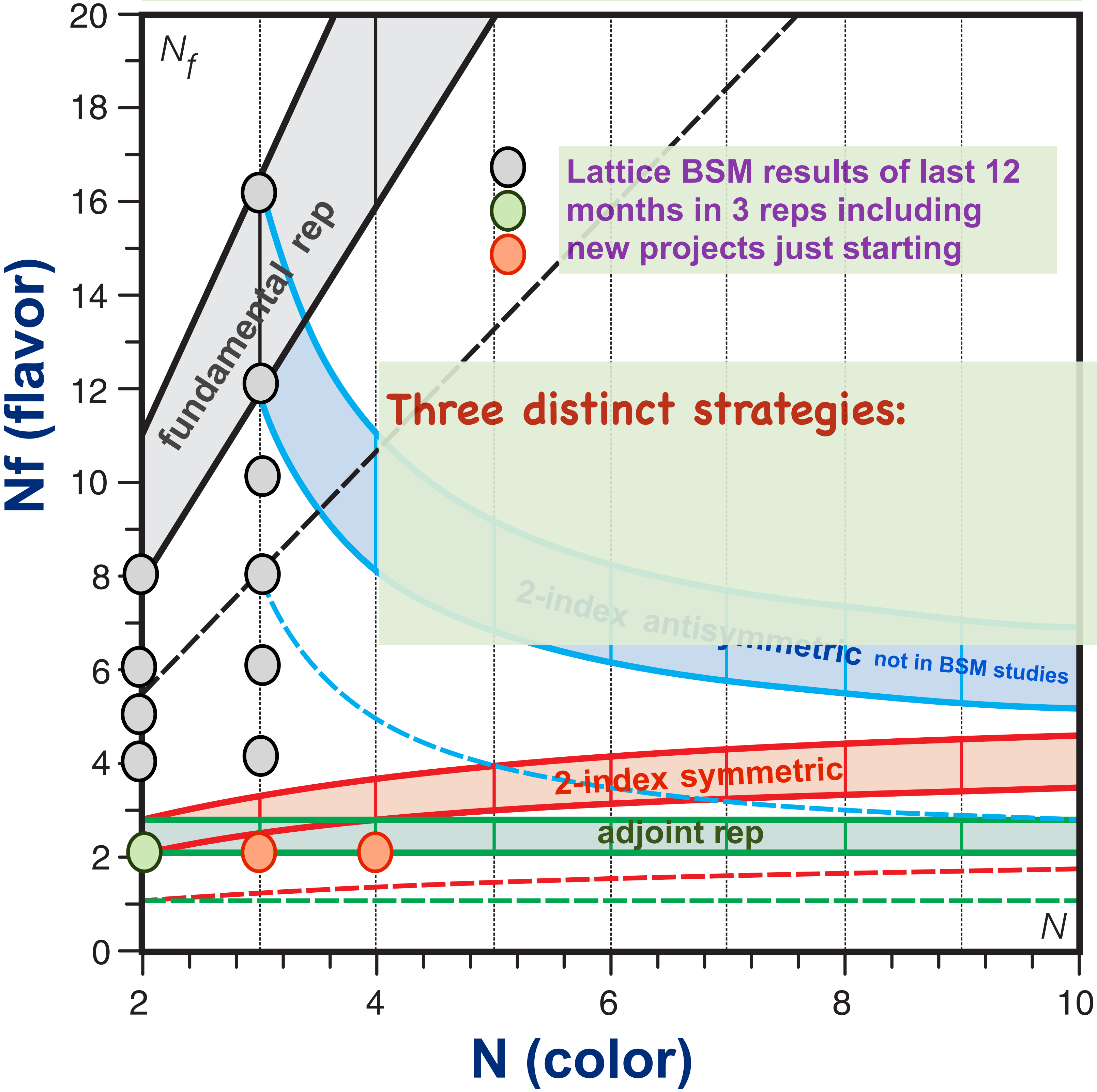

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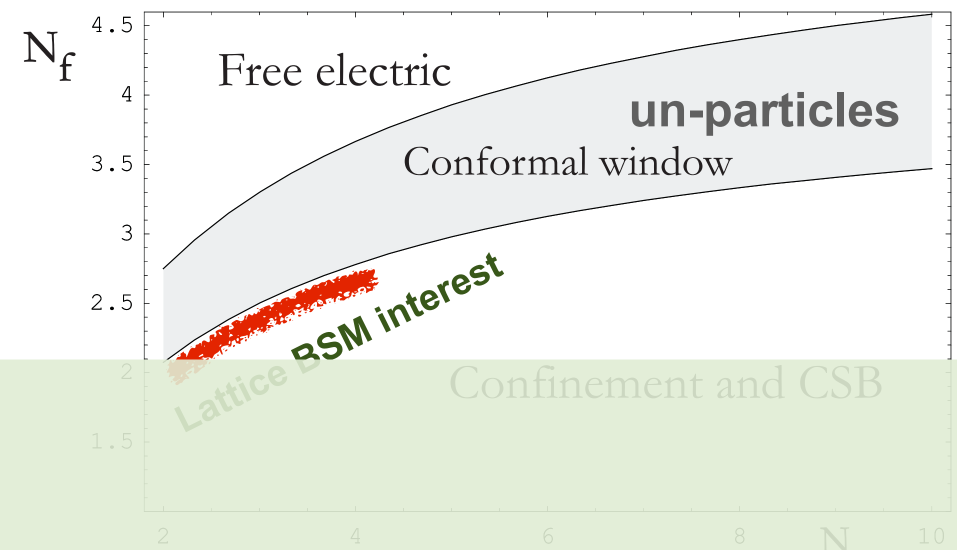

Three distinct strategies:

SCGT theory space and conformal window

color group, flavor, and fermion representation

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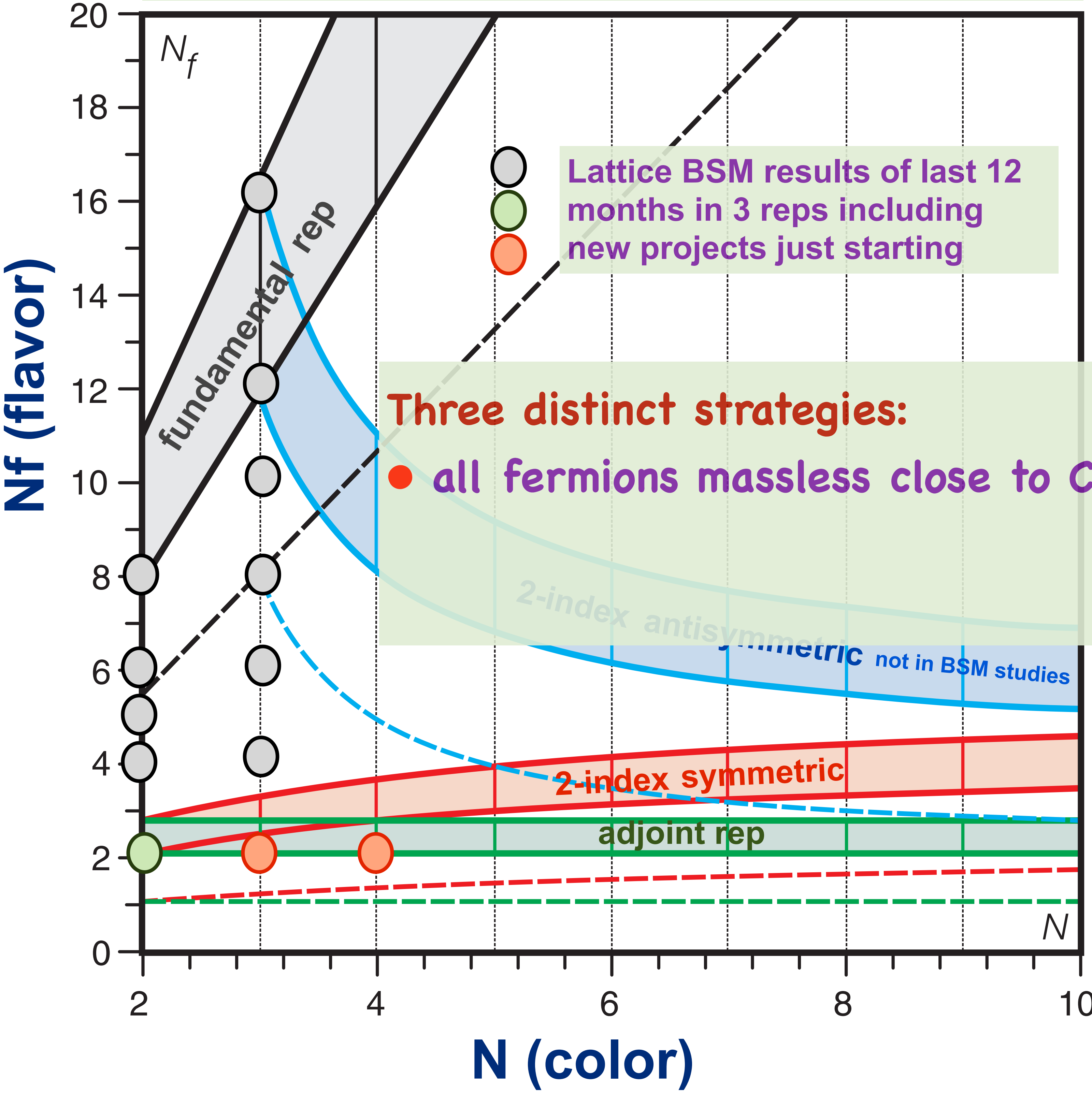

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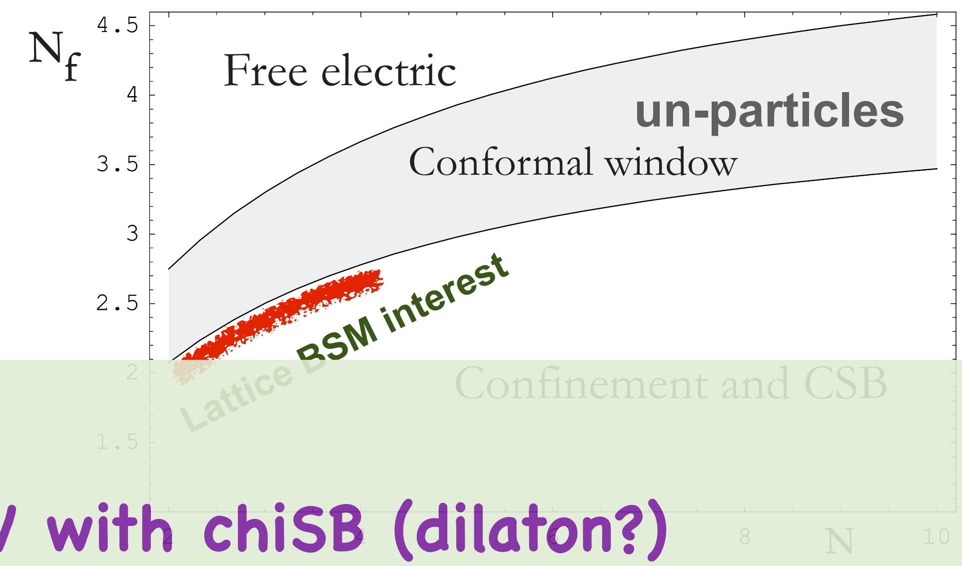

Three distinct strategies:

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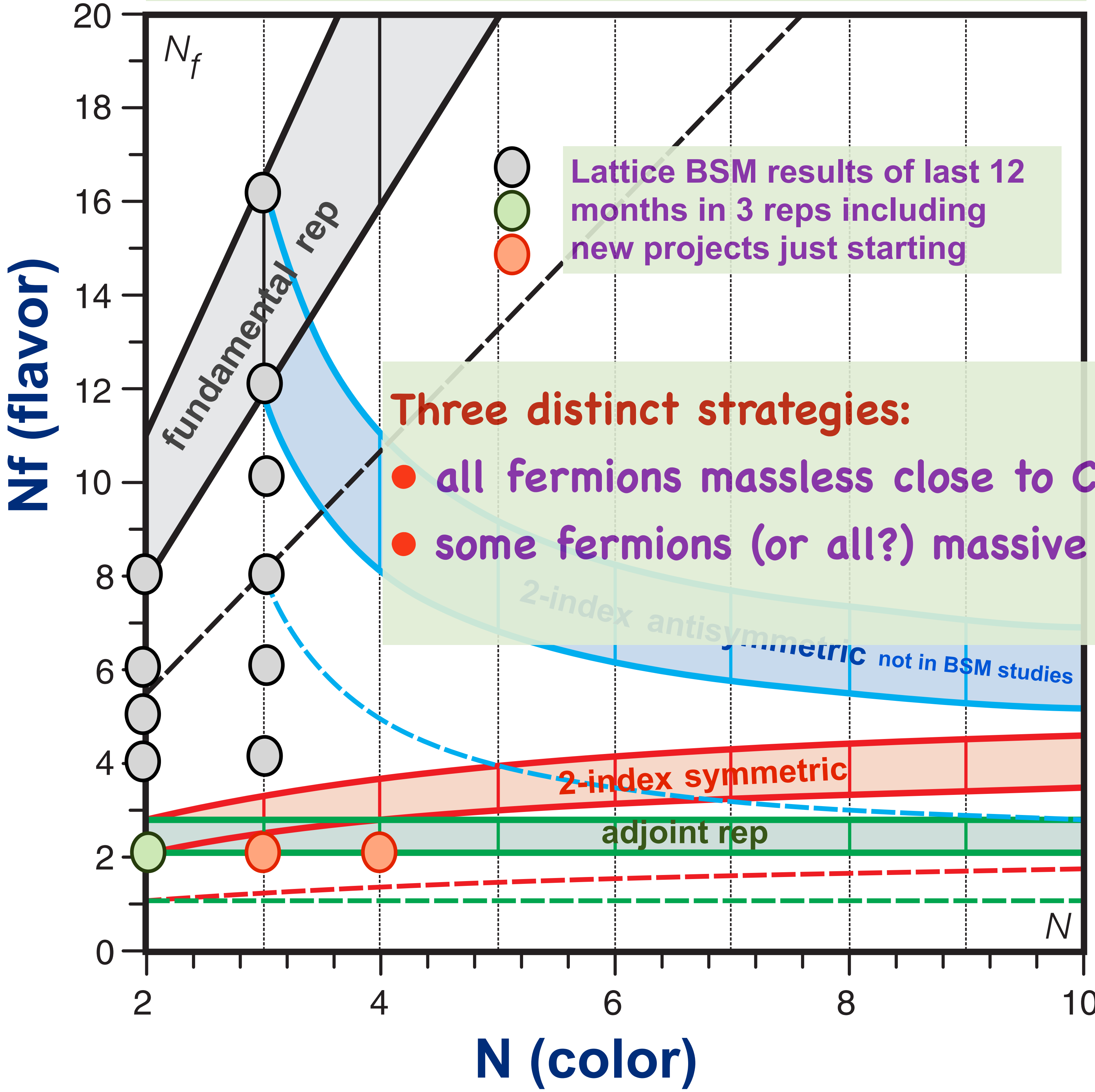

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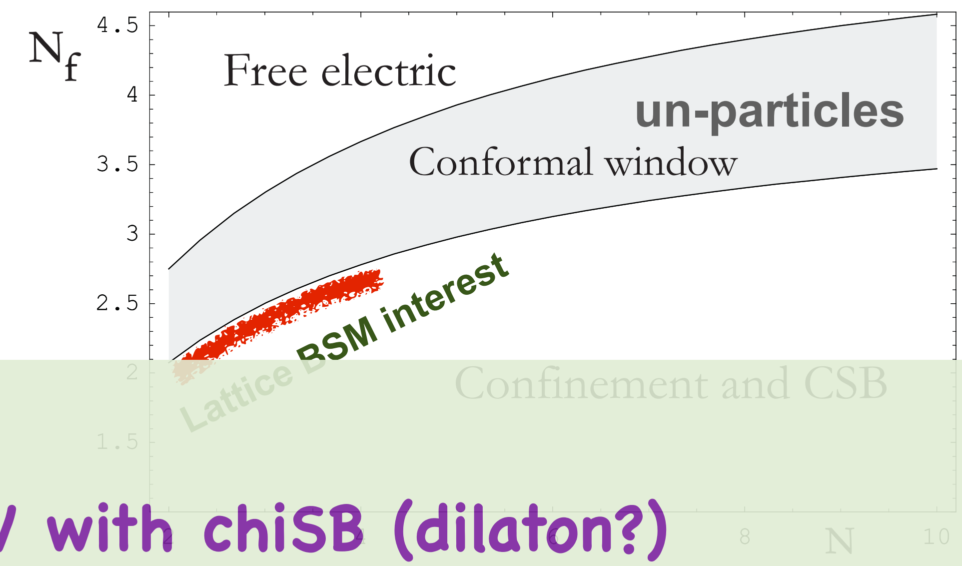

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- all fermions massless close to CW with chiSB (dilaton?)
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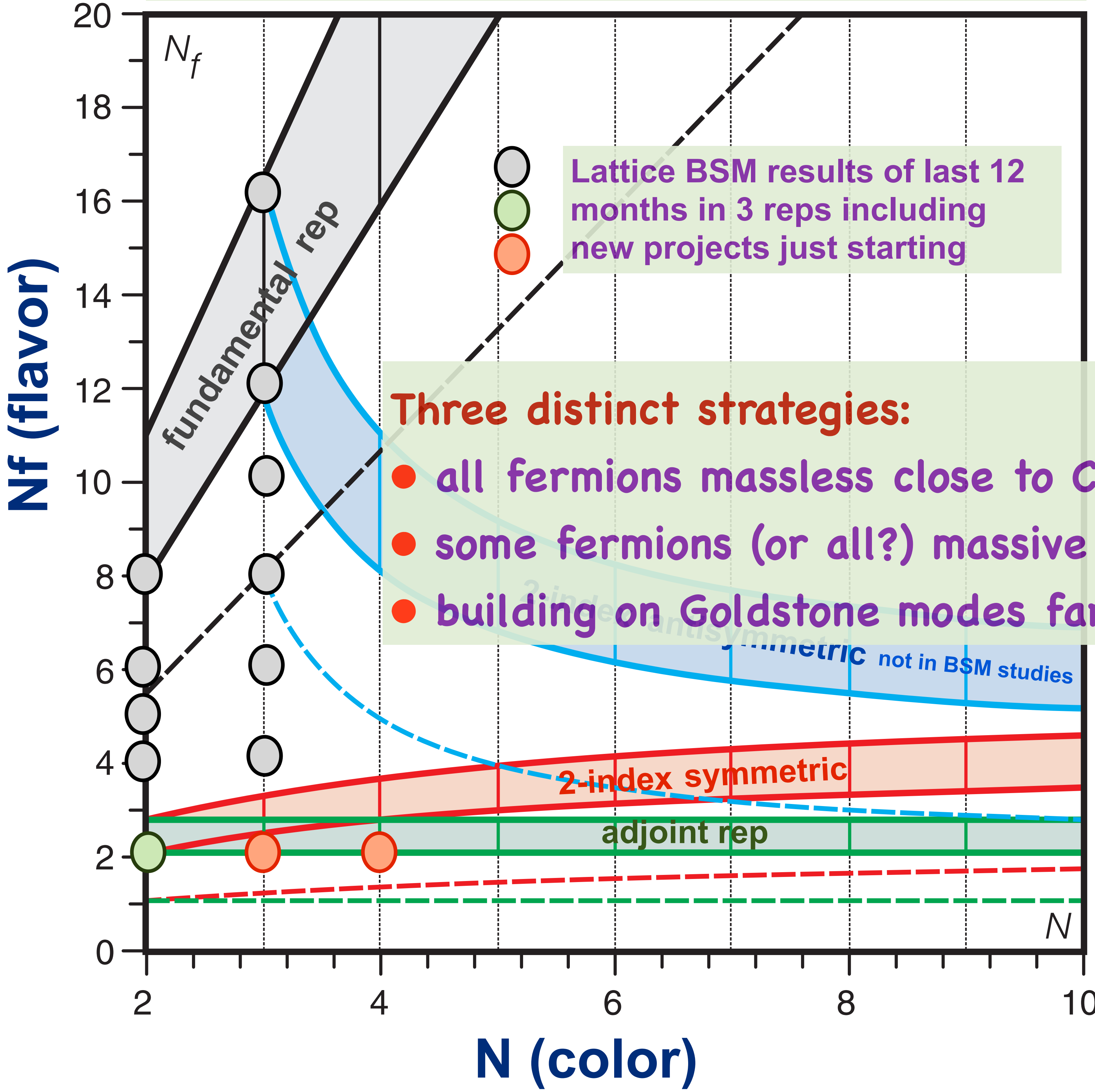

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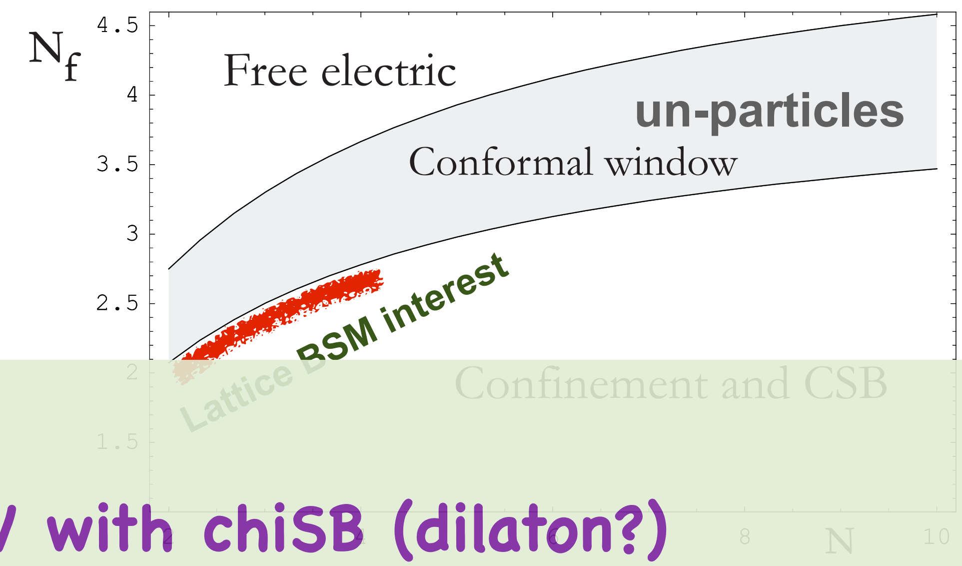

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- all fermions massless close to CW with chiSB (dilaton?)
- some fermions (or all?) massive (conformal Technicolor close to CW)
- building on Goldstone modes far from CW (like little Higgs?)

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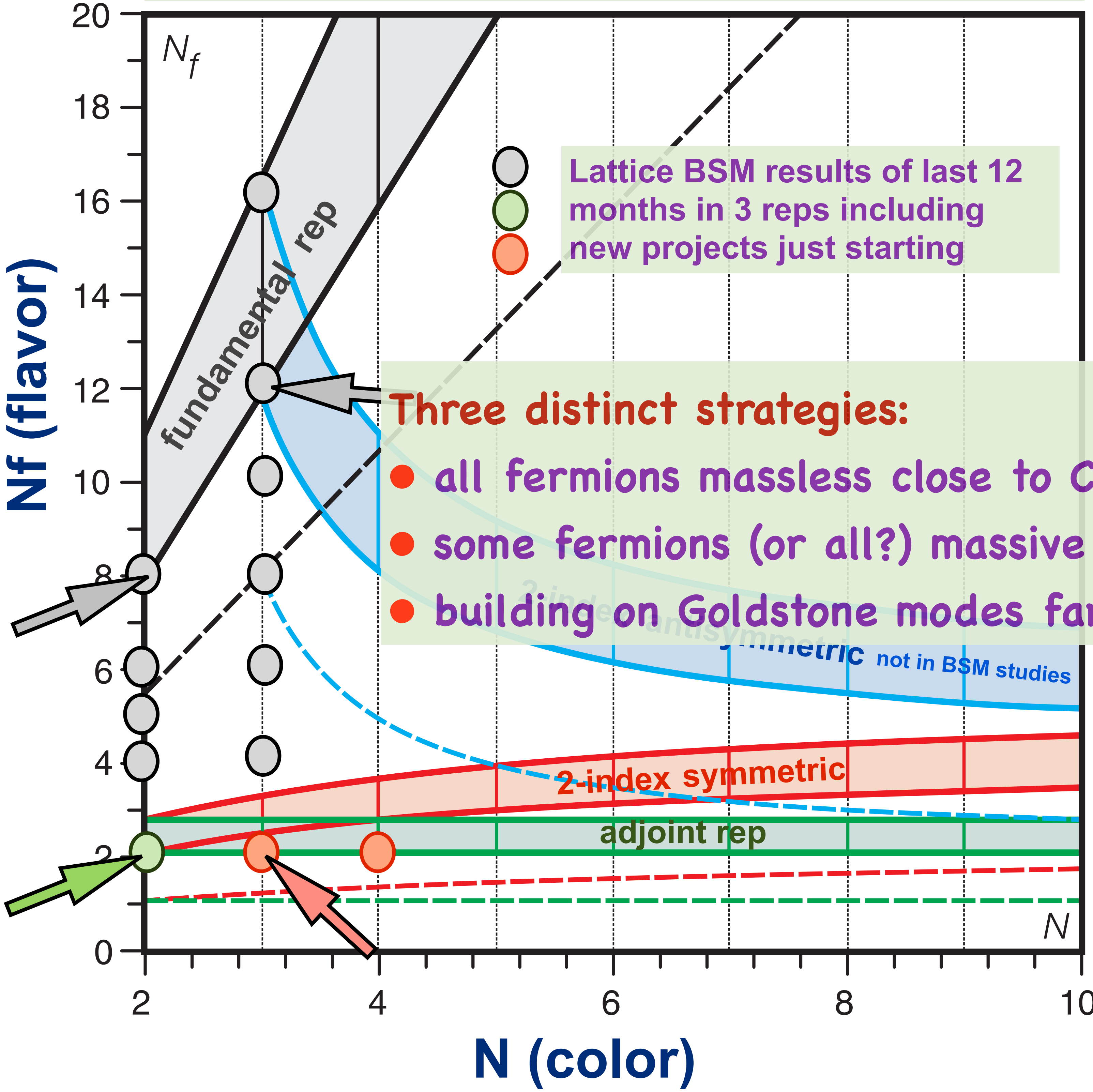

Lattice BSM results of last 12 months in 3 reps including new projects just starting

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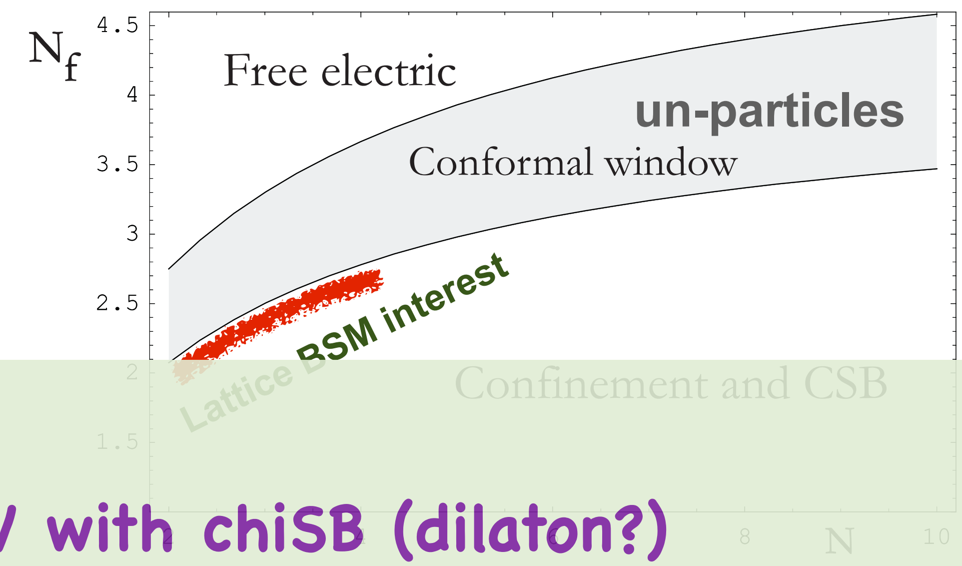

Three distinct strategies:

- all fermions massless close to CW with chiSB (dilaton?)
- some fermions (or all?) massive (conformal Technicolor close to CW)
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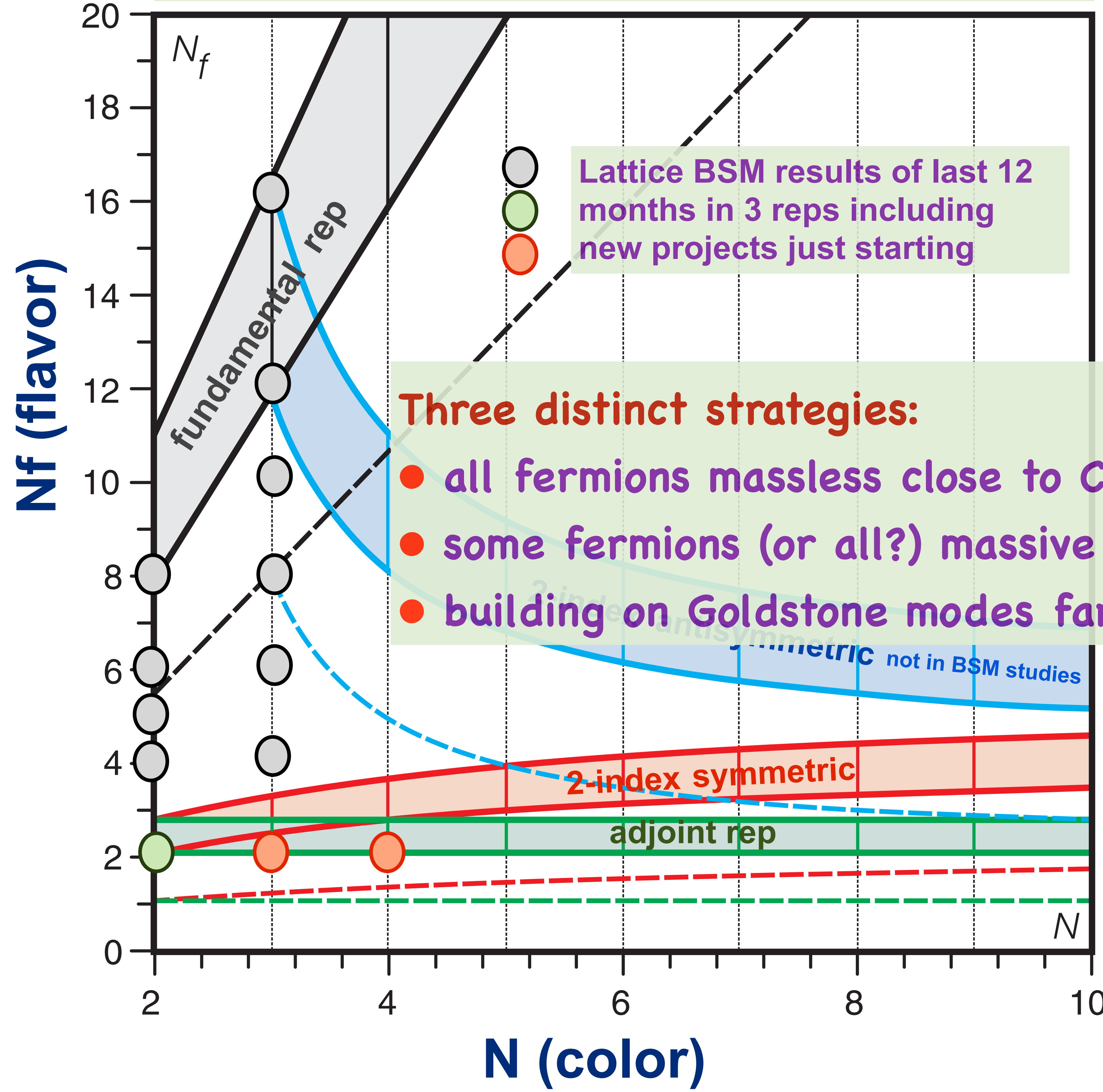
SCGT theory space and conformal window

color group, flavor, and fermion representation

(is the Higgs impostor hiding close to CW?)



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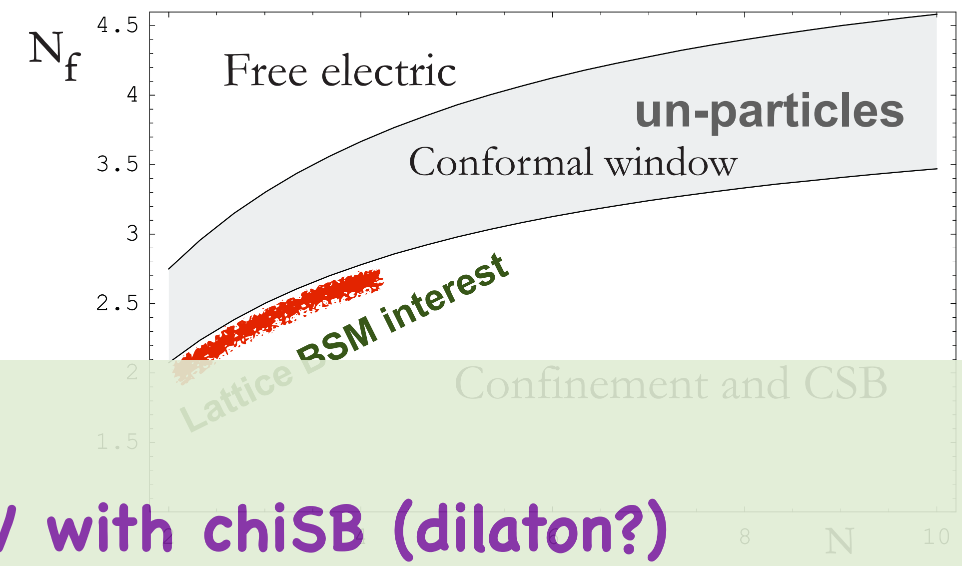

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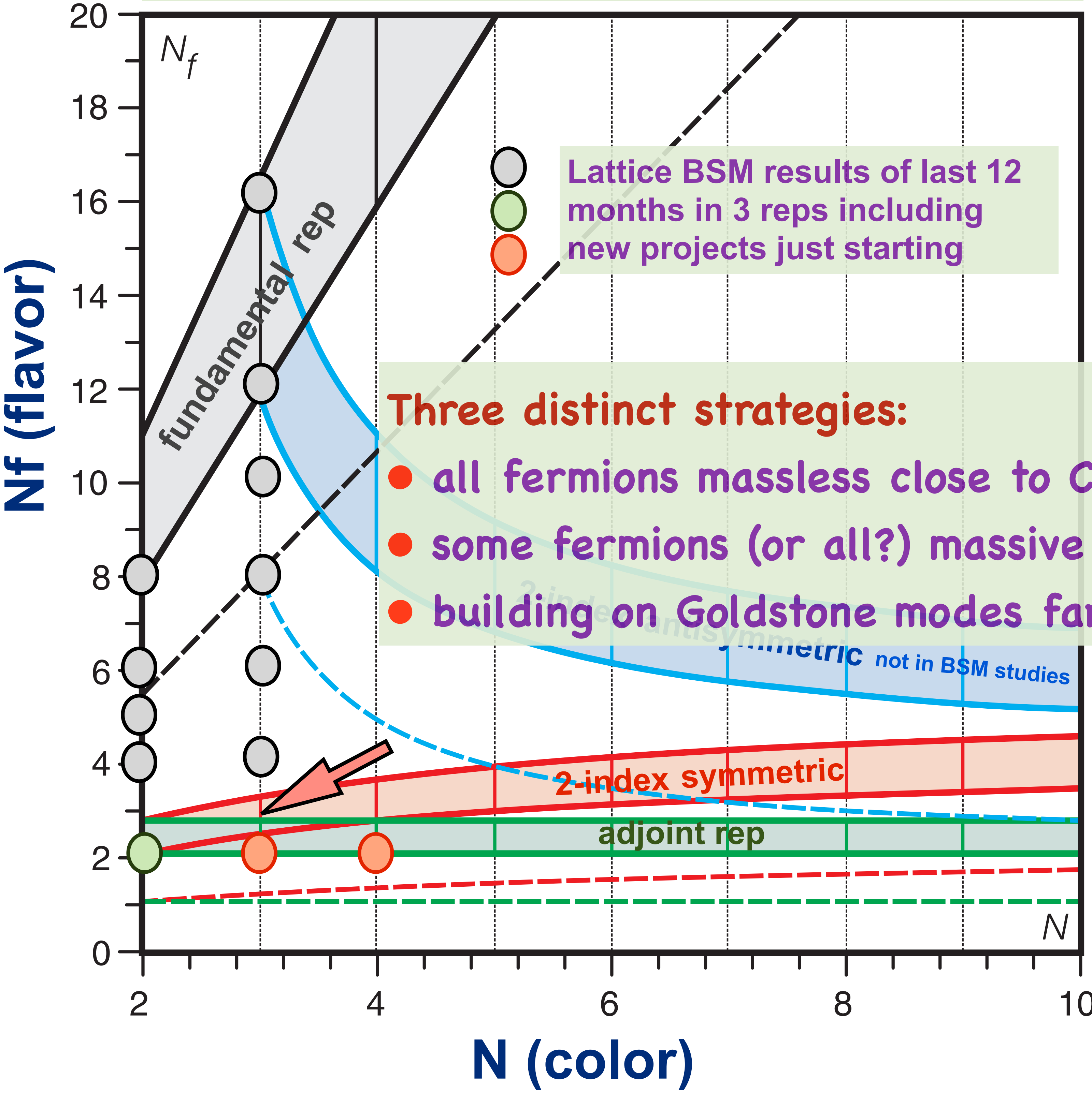

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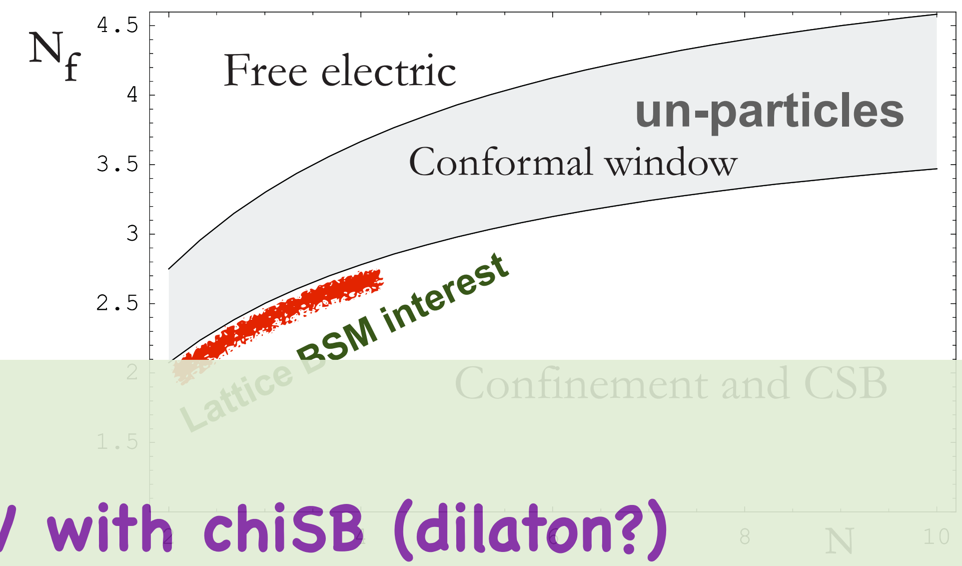

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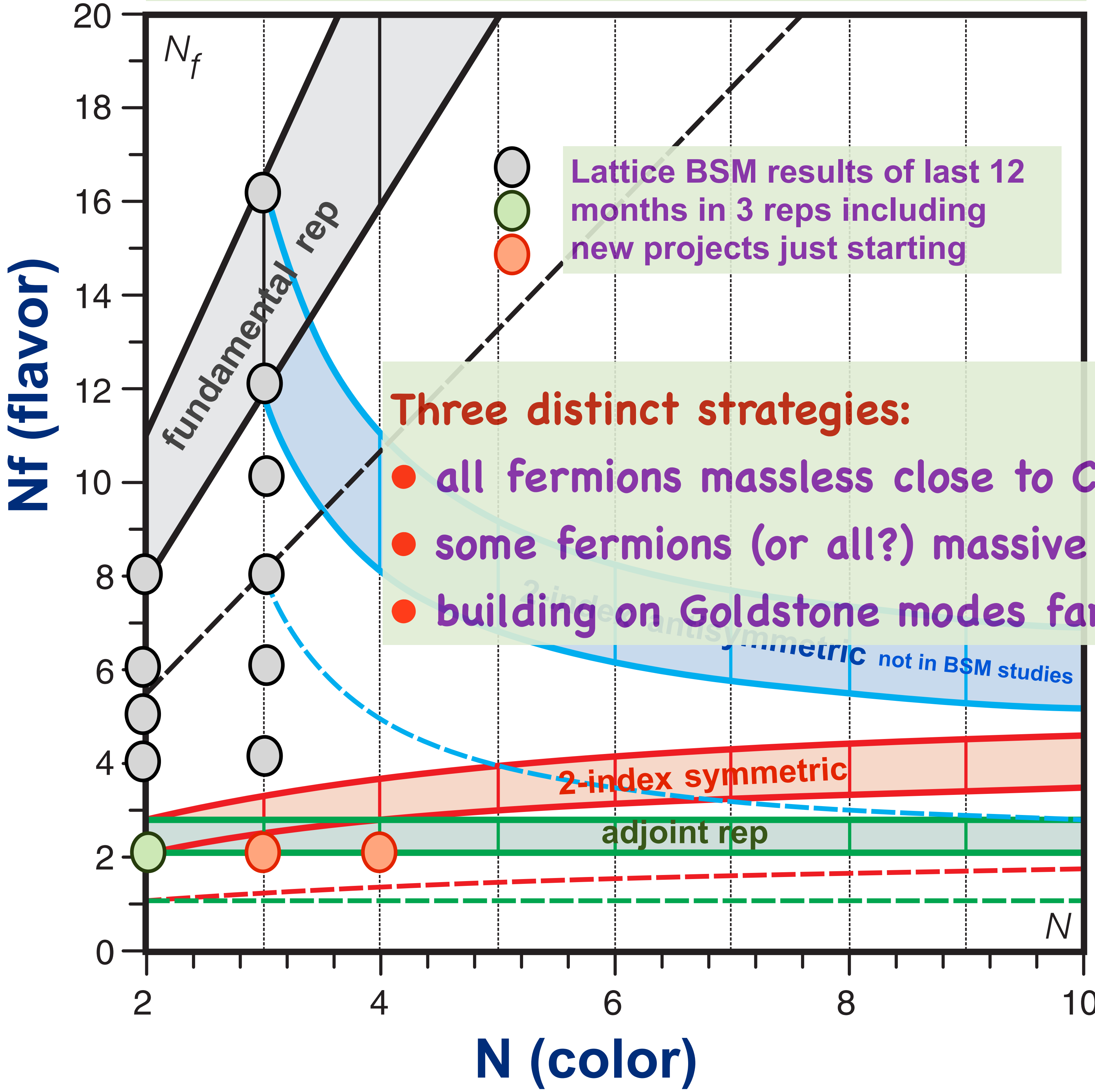

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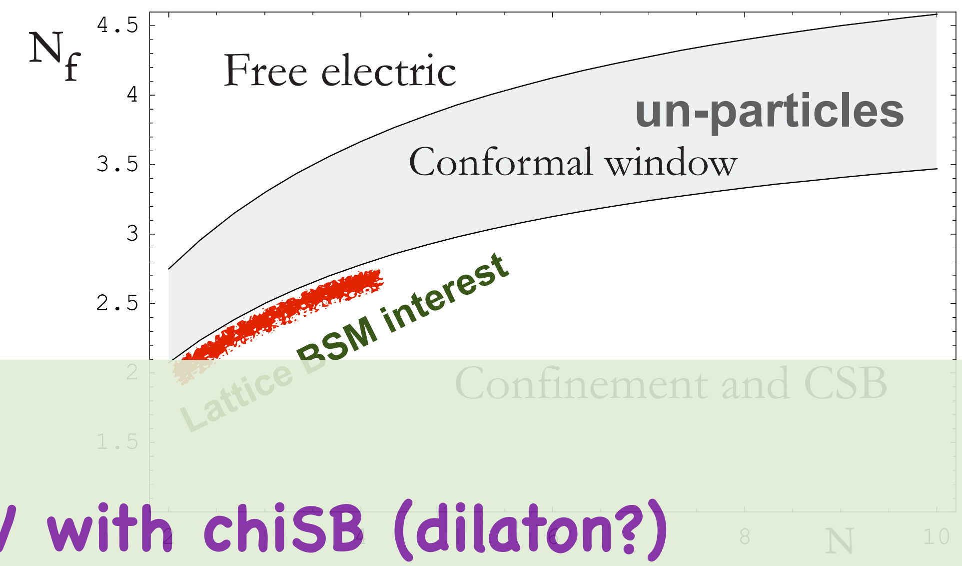

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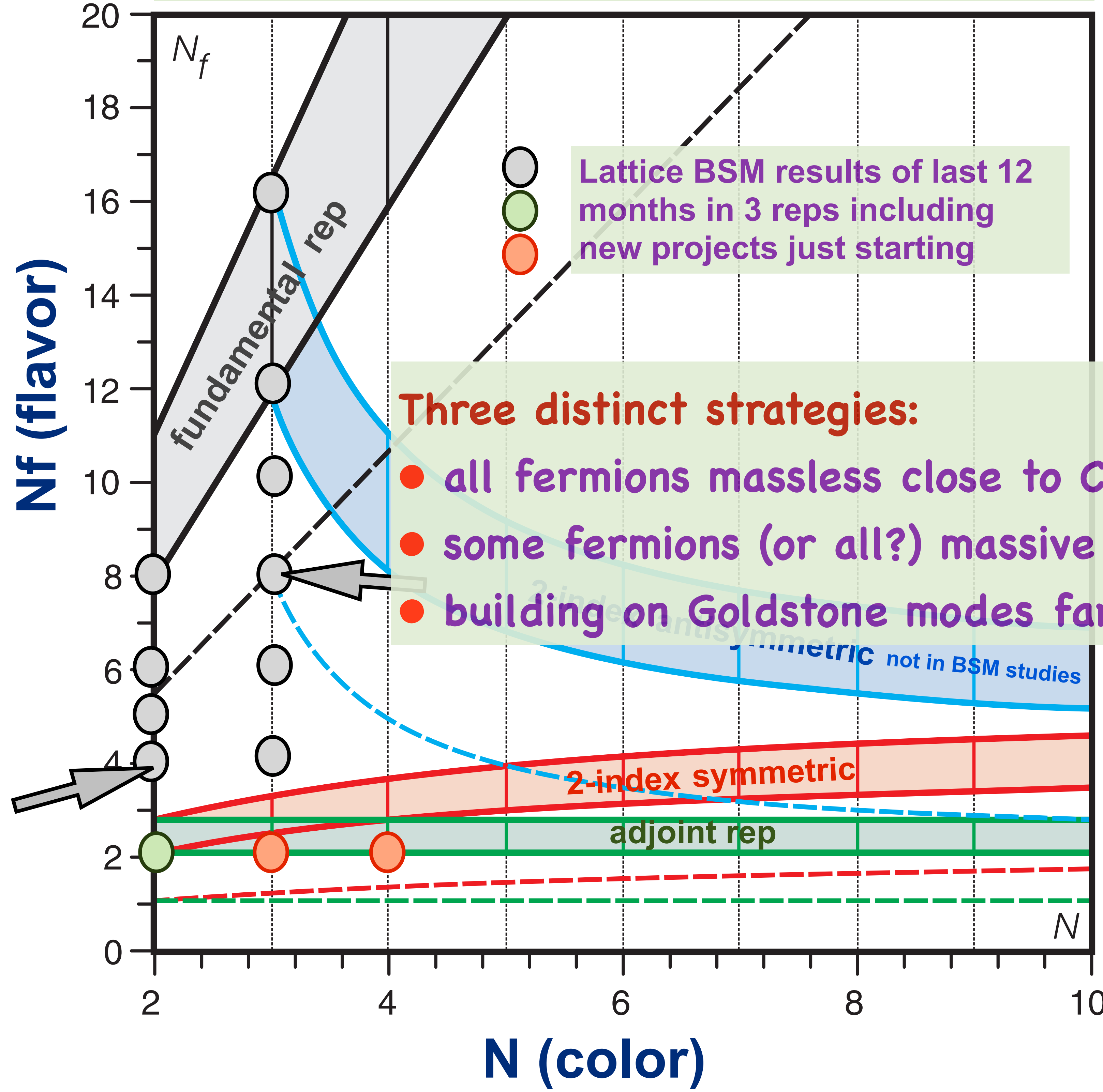

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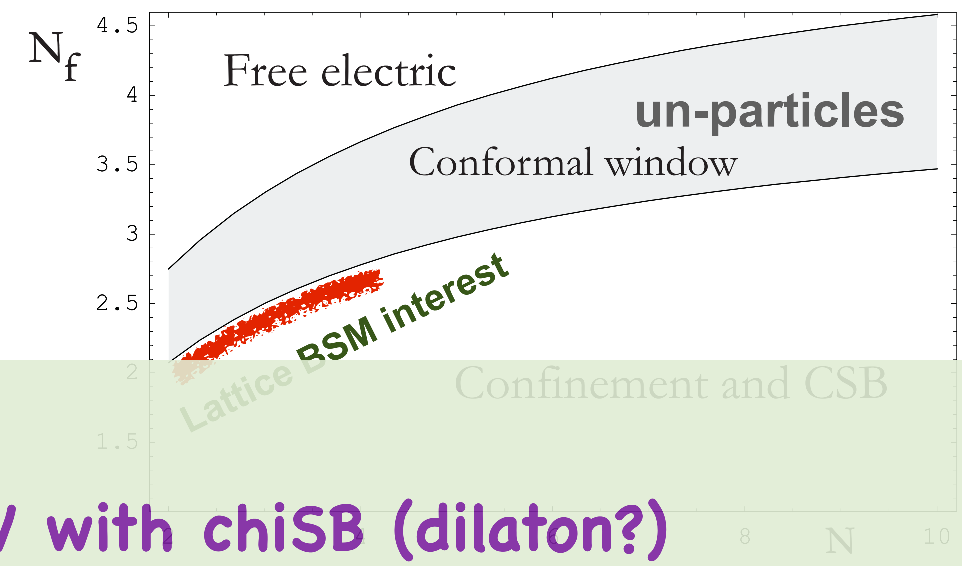

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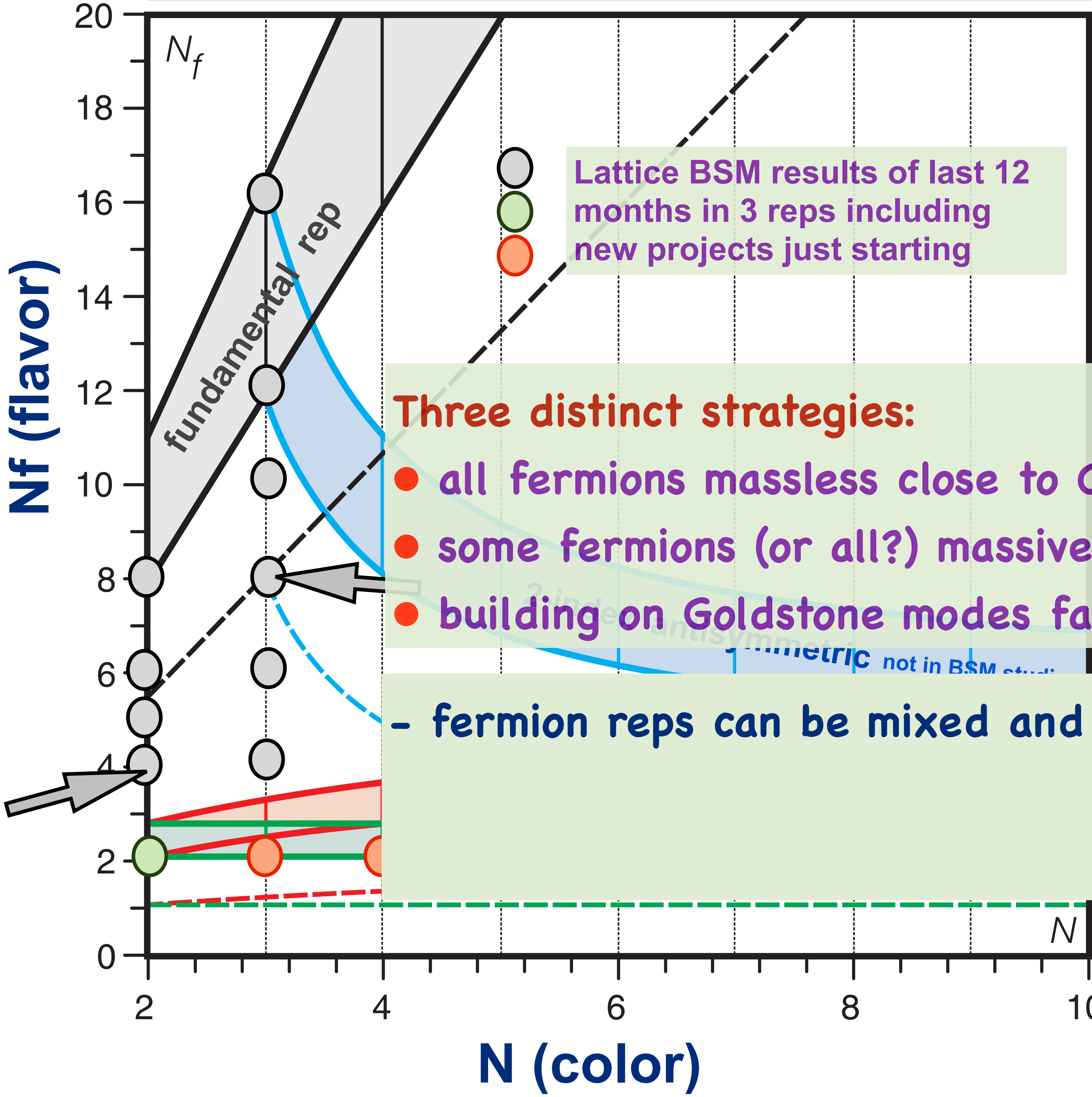

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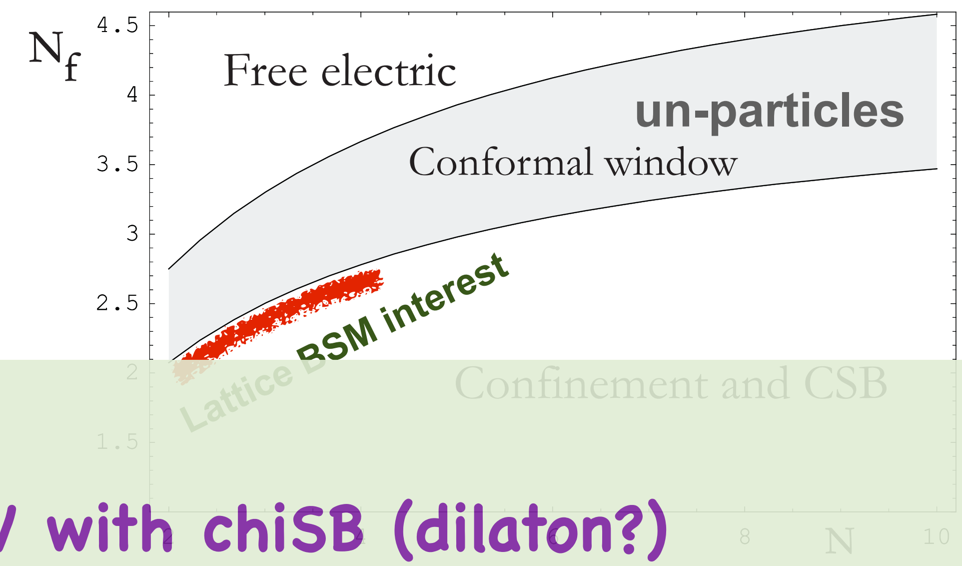

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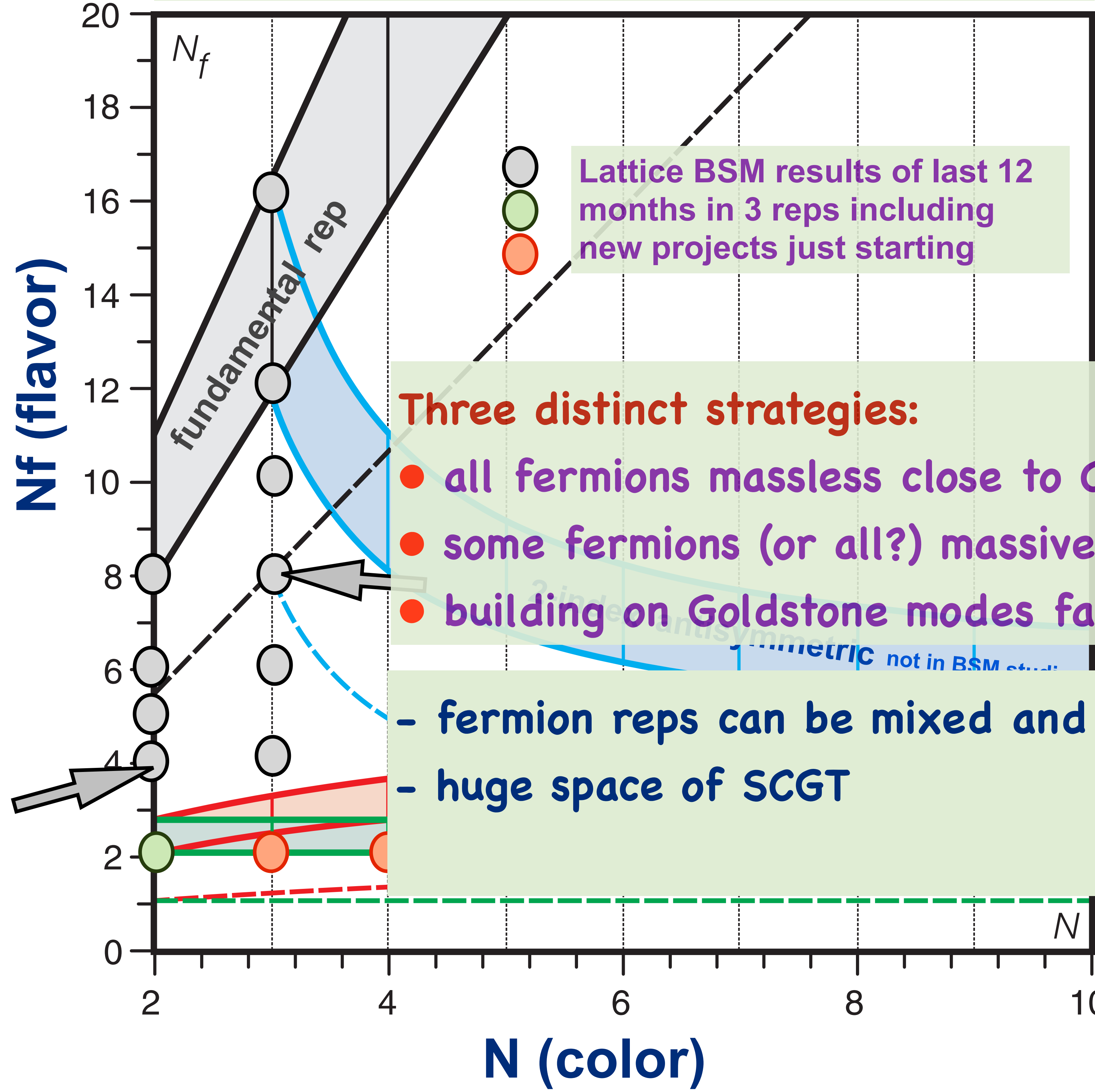

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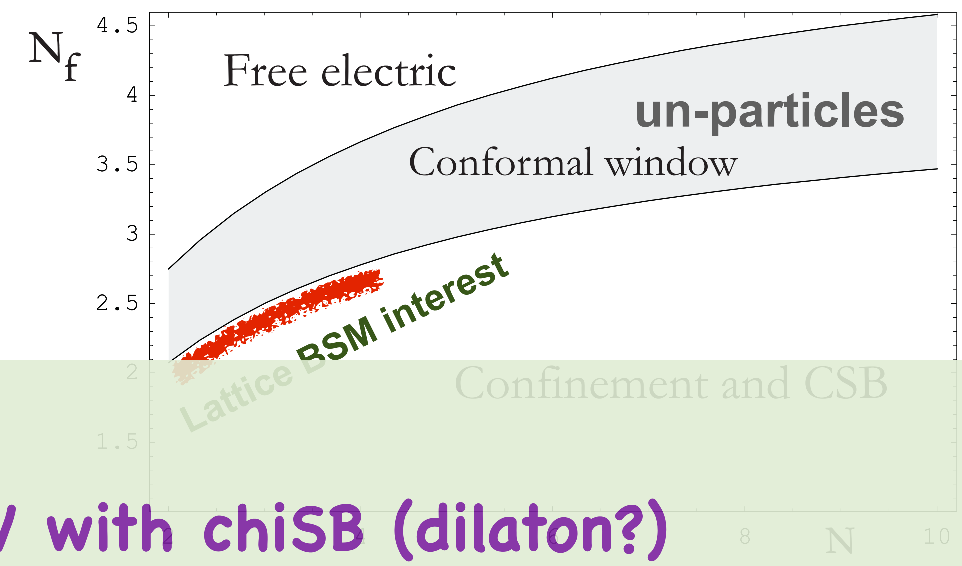

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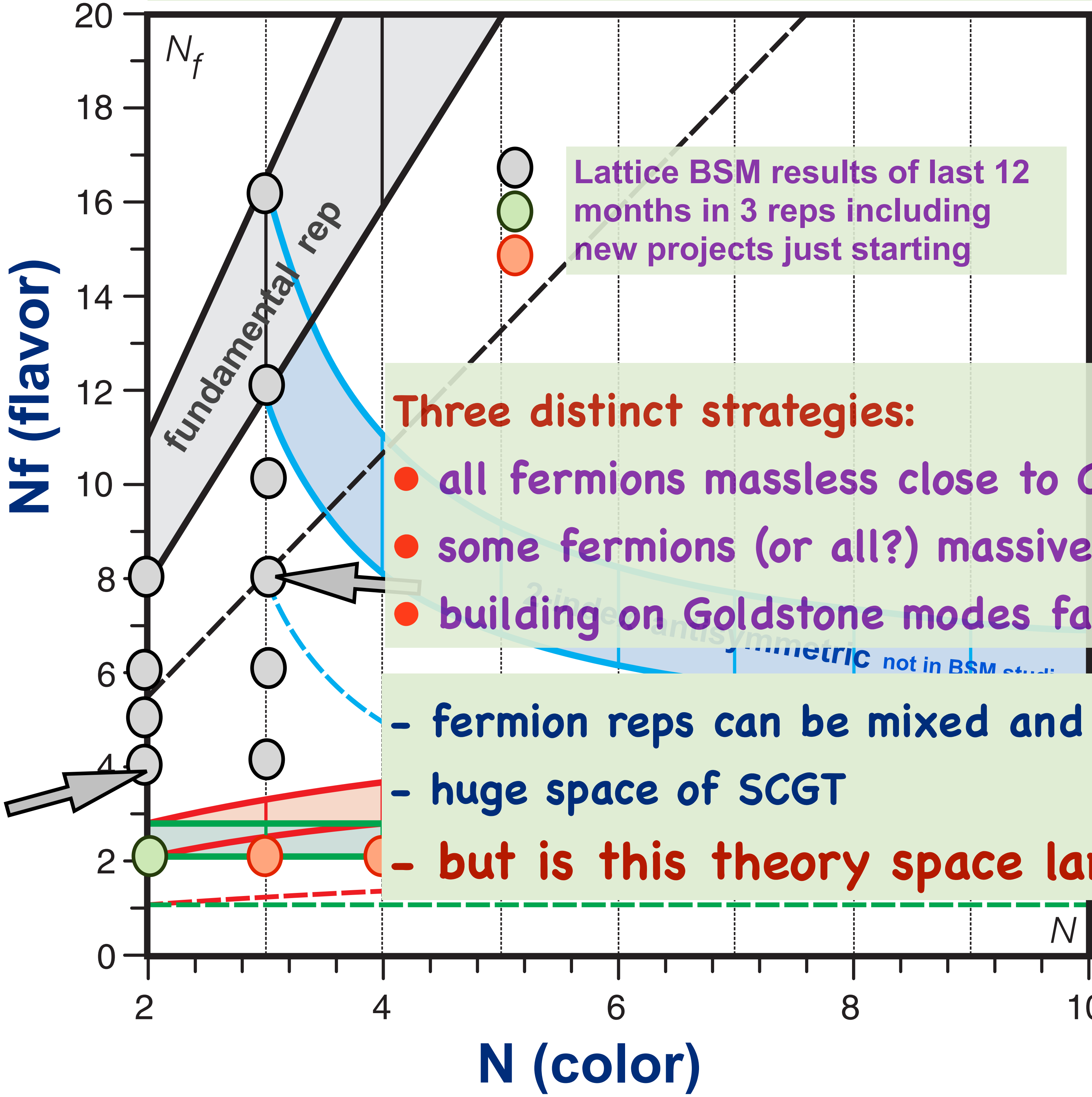

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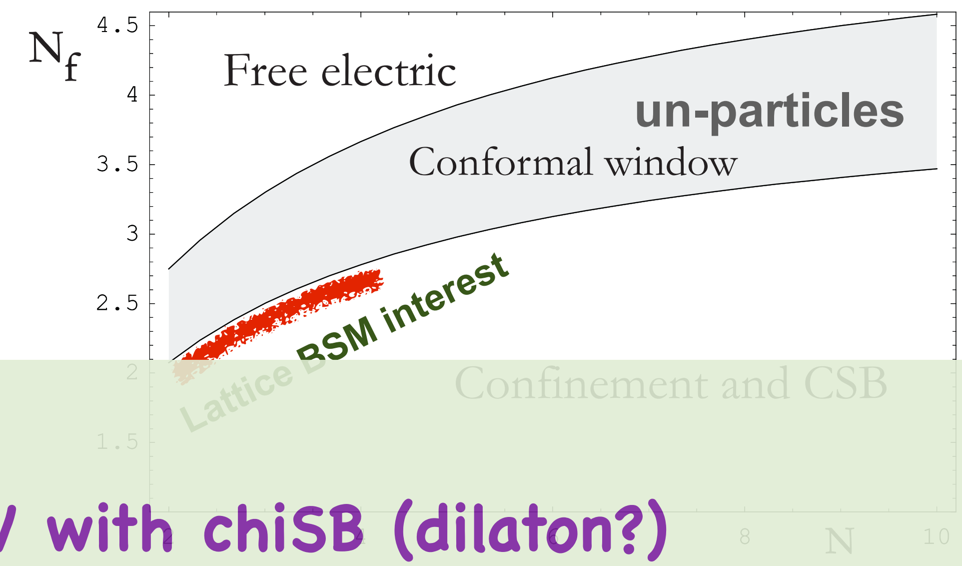

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- fermion reps can be mixed and some masses can be turned on
- huge space of SCGT
- but is this theory space large enough?

For some: extensions of SCGT theory space (incomplete):

- Gauge-Higgs unification (Hosotani and new Japanese lattice collaboration with Hetrick from USCQD)
  5-dimensional gauge theory with compactification
  3 european groups are doing it: Knechtli et al., Del Debbio et al, de Forcrand et al.

- little Higgs (builds on Goldstone modes) fine-tuned?
  What is the UV completion? - lattice work, like symmetry breaking pattern in SU(5)?
  Does it fit into original theory space? - it could, depending on choice of UV completion

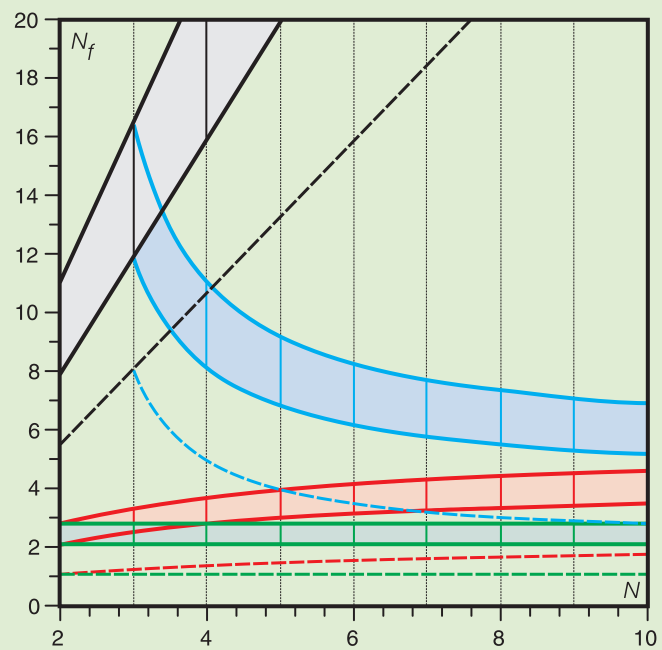
- Randall-Sundrum, radion? holographic Higgs? (talks at workshop)
  no lattice work?

- Top color (talks at workshop) - no lattice work yet

- Composite gauge theories - abandoned?
  early work Harari, Fritzsch, others ...

- This talk remains focused on SCGT theory space
  close to the conformal window
  keeps our hands full

  BSM white paper strategies?



some key issues in SCGT theory space:

- most projects try to stay close to conformal window - some parametric tuning?
- when is close “close enough”?
- role of walking coupling?
- separation of two scales to facilitate dilaton mechanism?
- light scalar with or without dilaton?
- there are candidate models with limited results
- very difficult issues on-lattice and off-lattice
- let us try first the simplest model: Nf=2 sextet fermion rep

Outline

how large Theory Space is needed?

the sextet model as a simple example

light scalar and dilaton mechanism close to CW

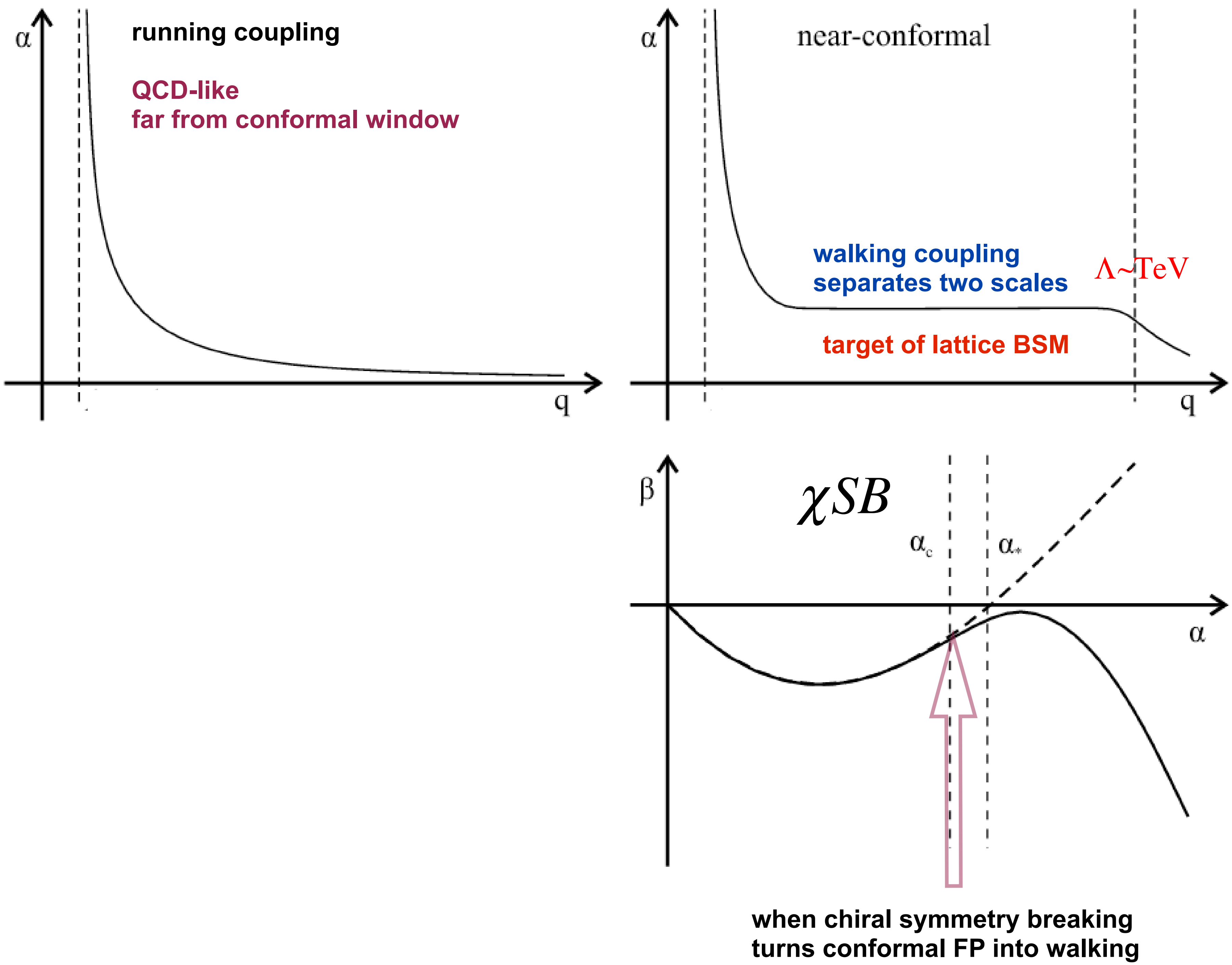
chiral condensates and spectroscopy

running (walking) coupling

light scalar spectroscopy of 0^{++} states

Summary and outlook

simple realization of composite Higgs: Nf=2 SU(3) sextet representation



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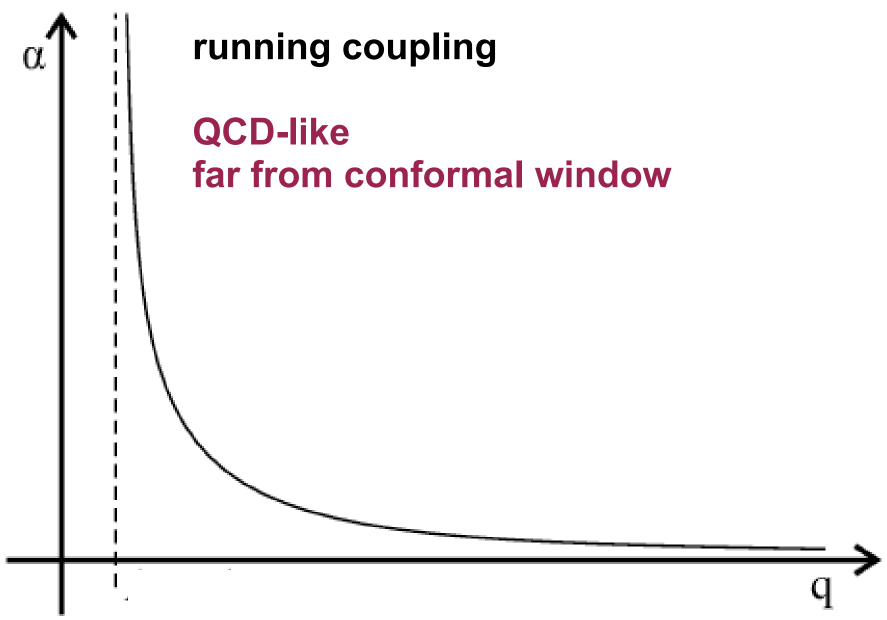
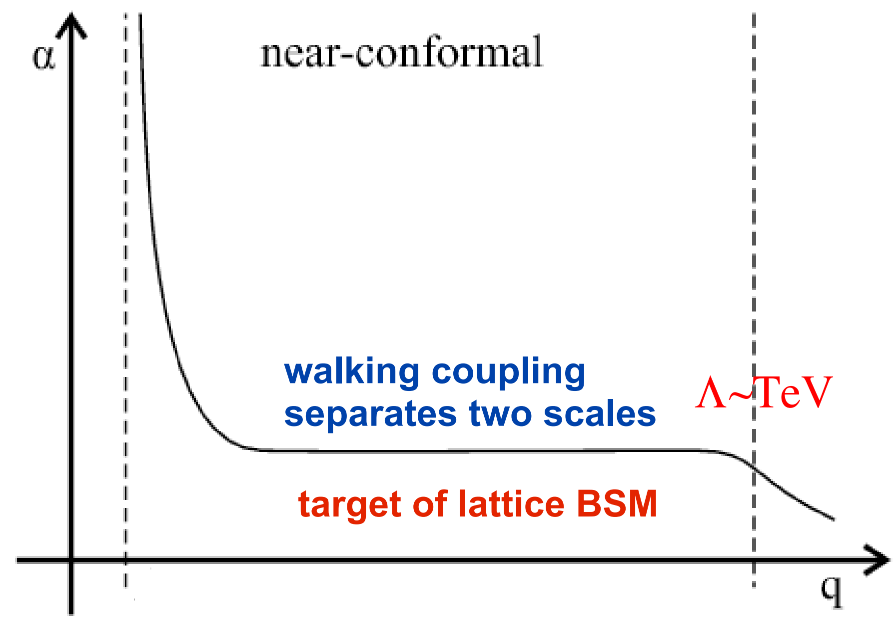




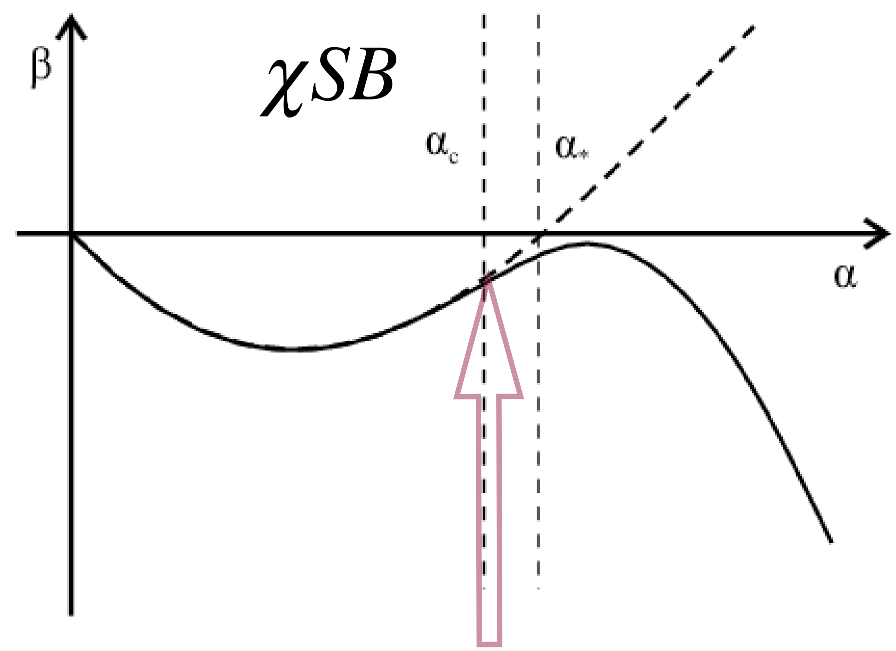
original Technicolor paradigm replaced with
sextet SU(3) color rep:

one massless fermion doublet $\begin{bmatrix} u \\ d \end{bmatrix}$
χSB on Λ~TeV scale

three Goldstone pions
become longitudinal
components of weak bosons

composite Higgs mechanism
scale of Higgs condensate ~ F=250 GeV

conflicts with EW precision constraints?



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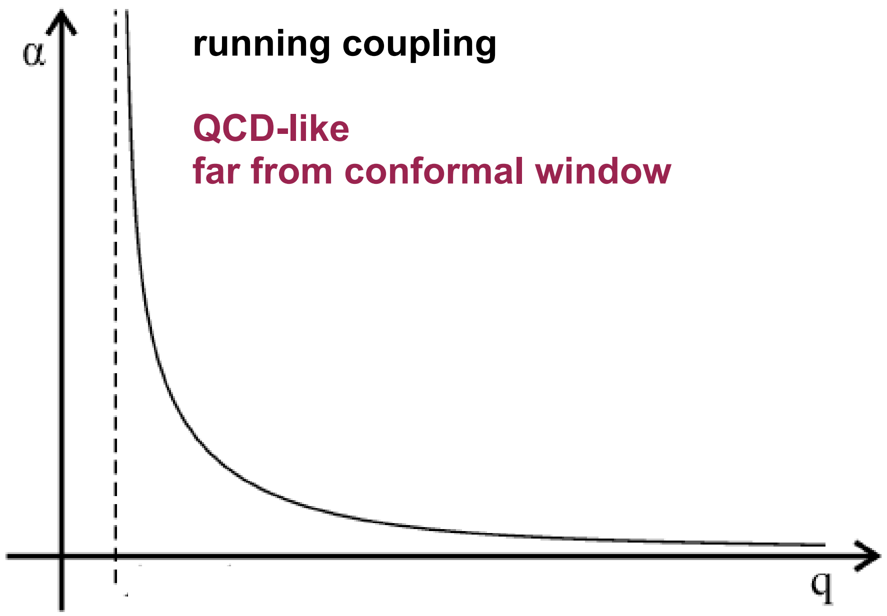

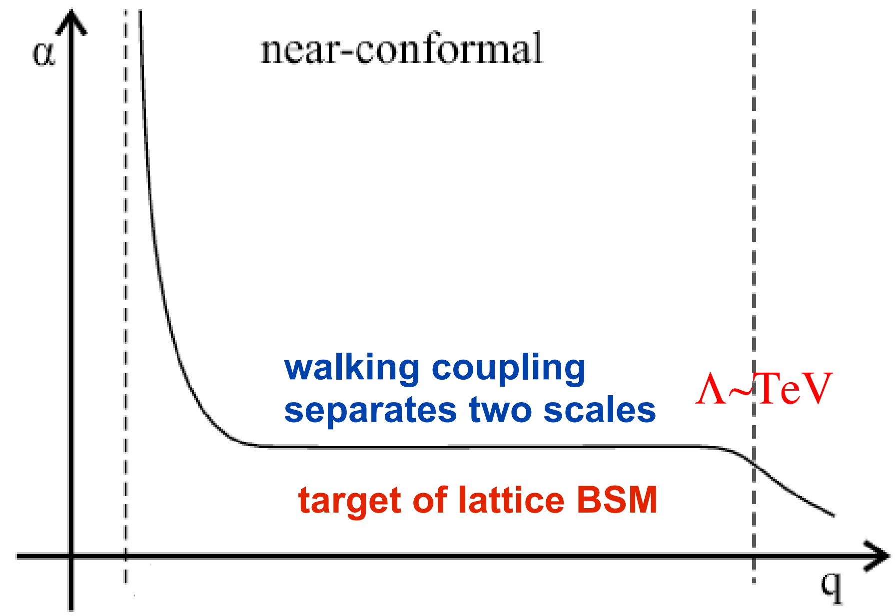

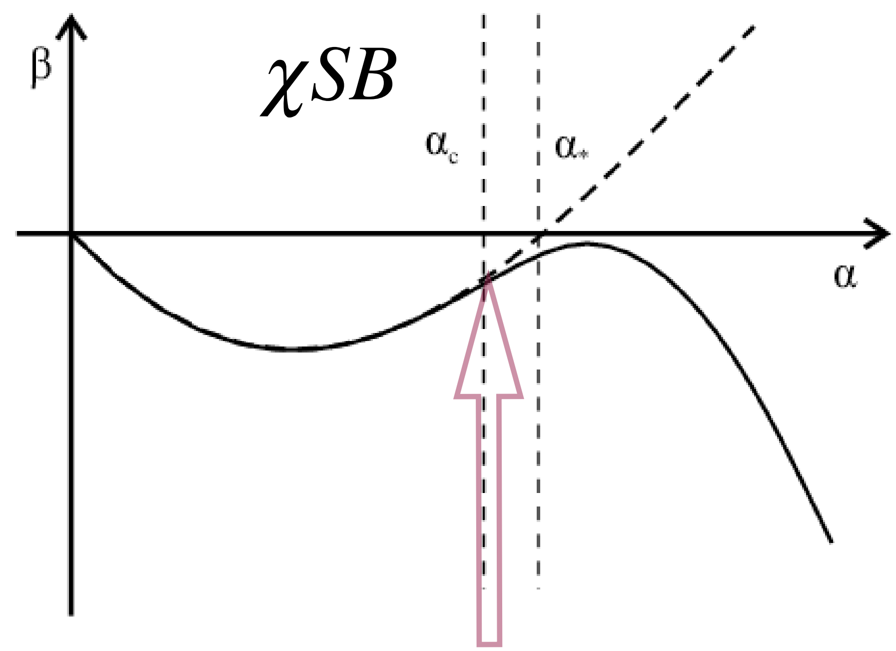

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walking gauge coupling

fermion mass generation not addressed

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broken scale invariance (dilaton)
and/or light non-SM composite Higgs
particle?

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Kogut,Shigemitsu,Sinclair
(quenched, 1984)

recent work:

DeGrand,Shamir,Svetitsky
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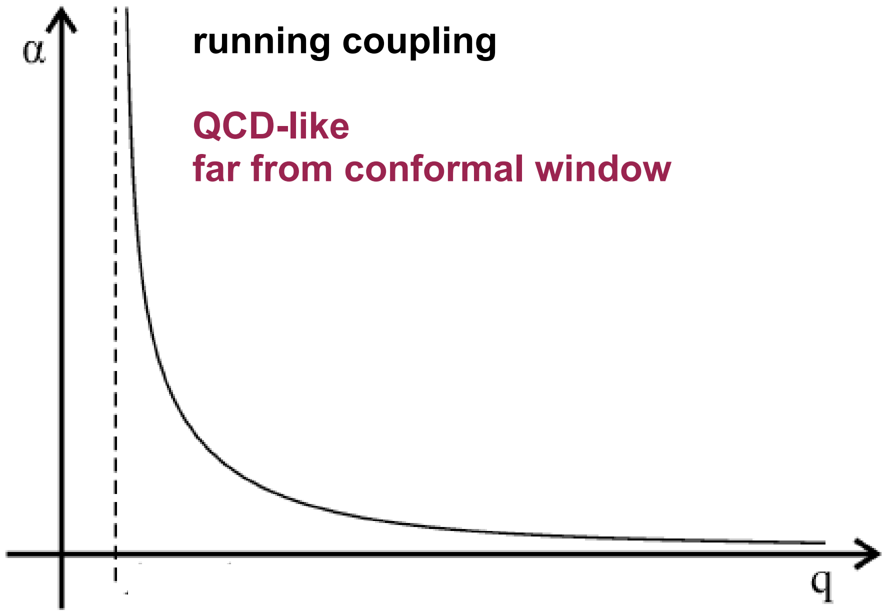

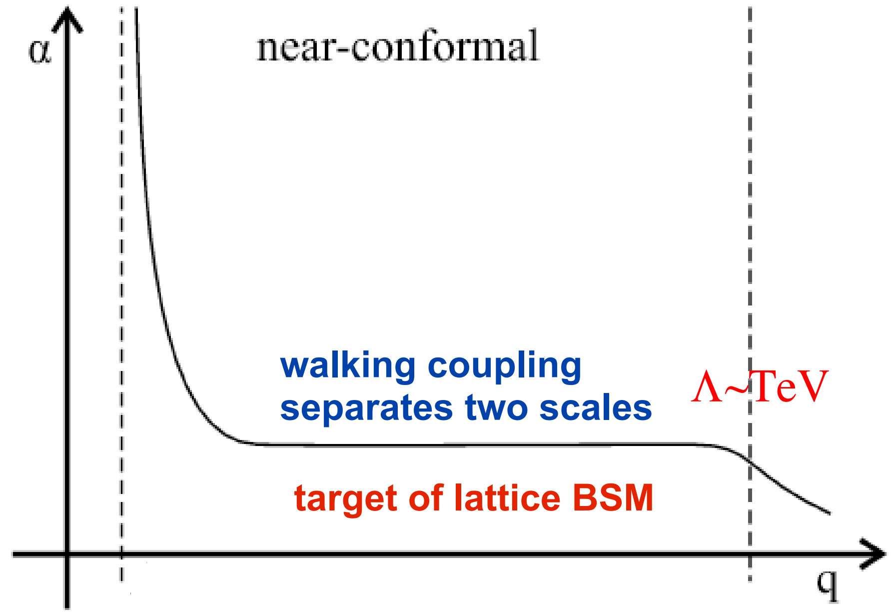

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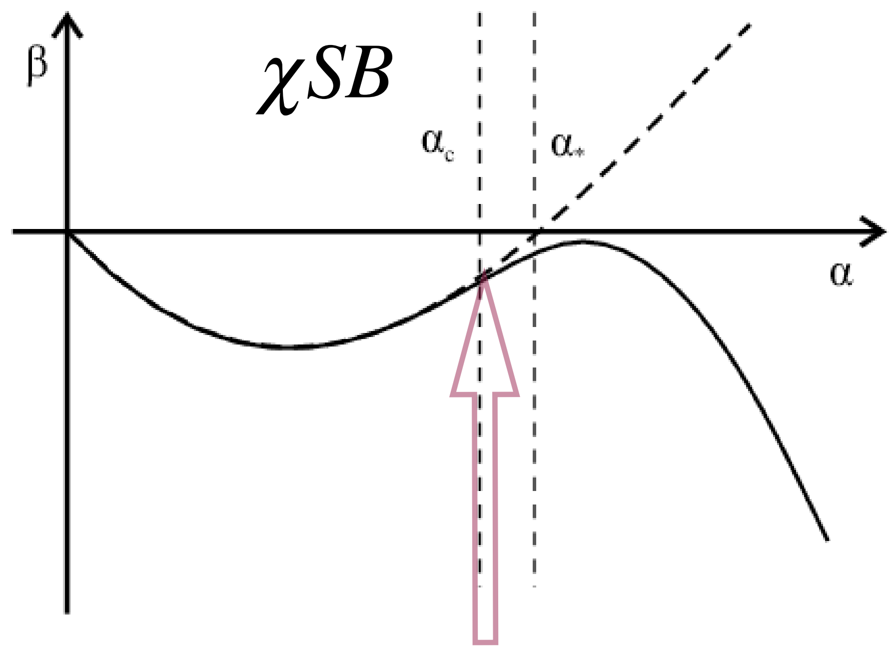

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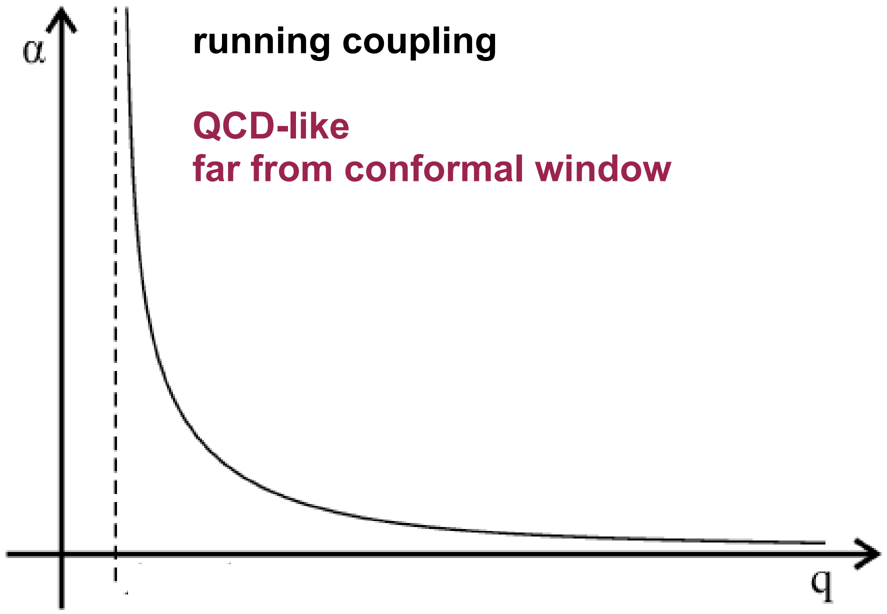

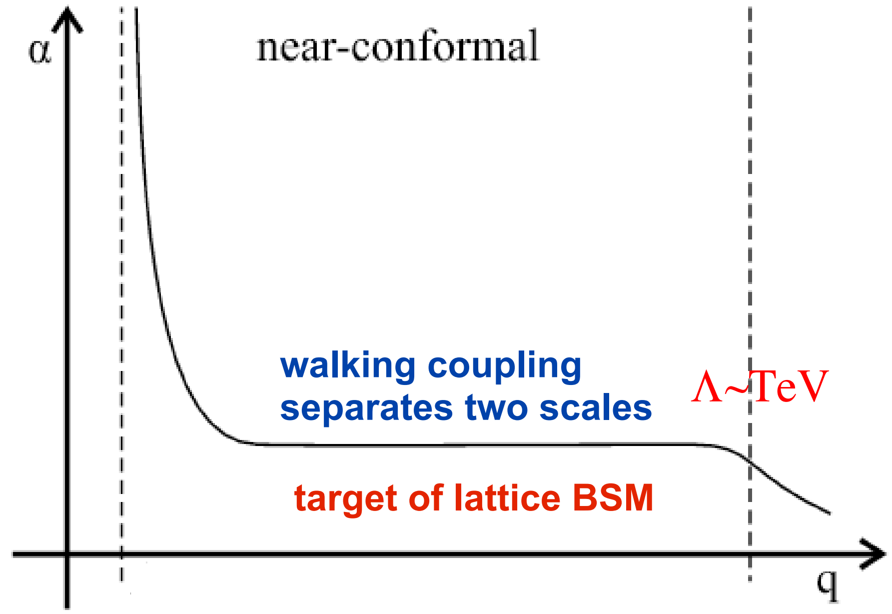

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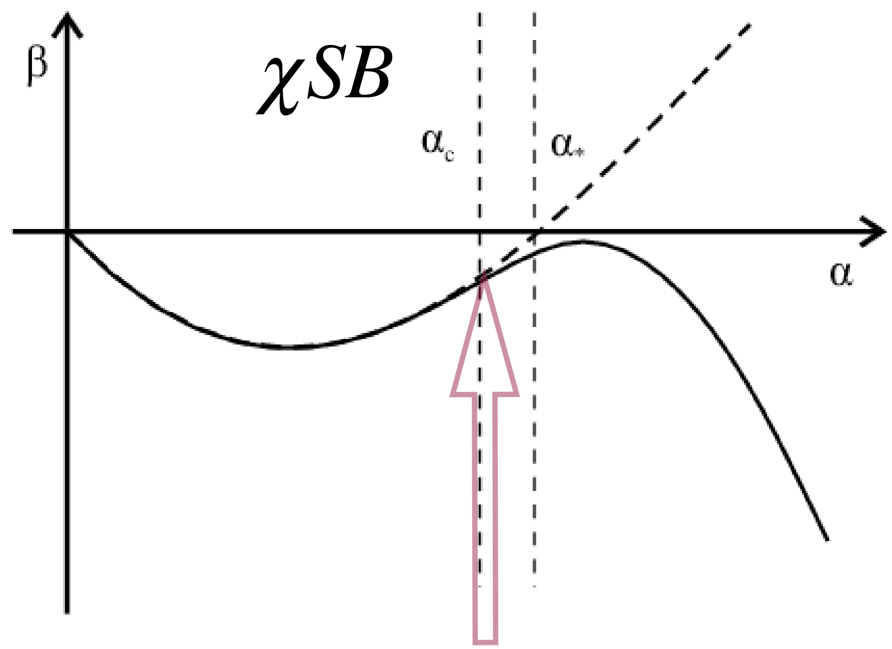

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role of third massive fermion flavor? EW singlet dark matter?

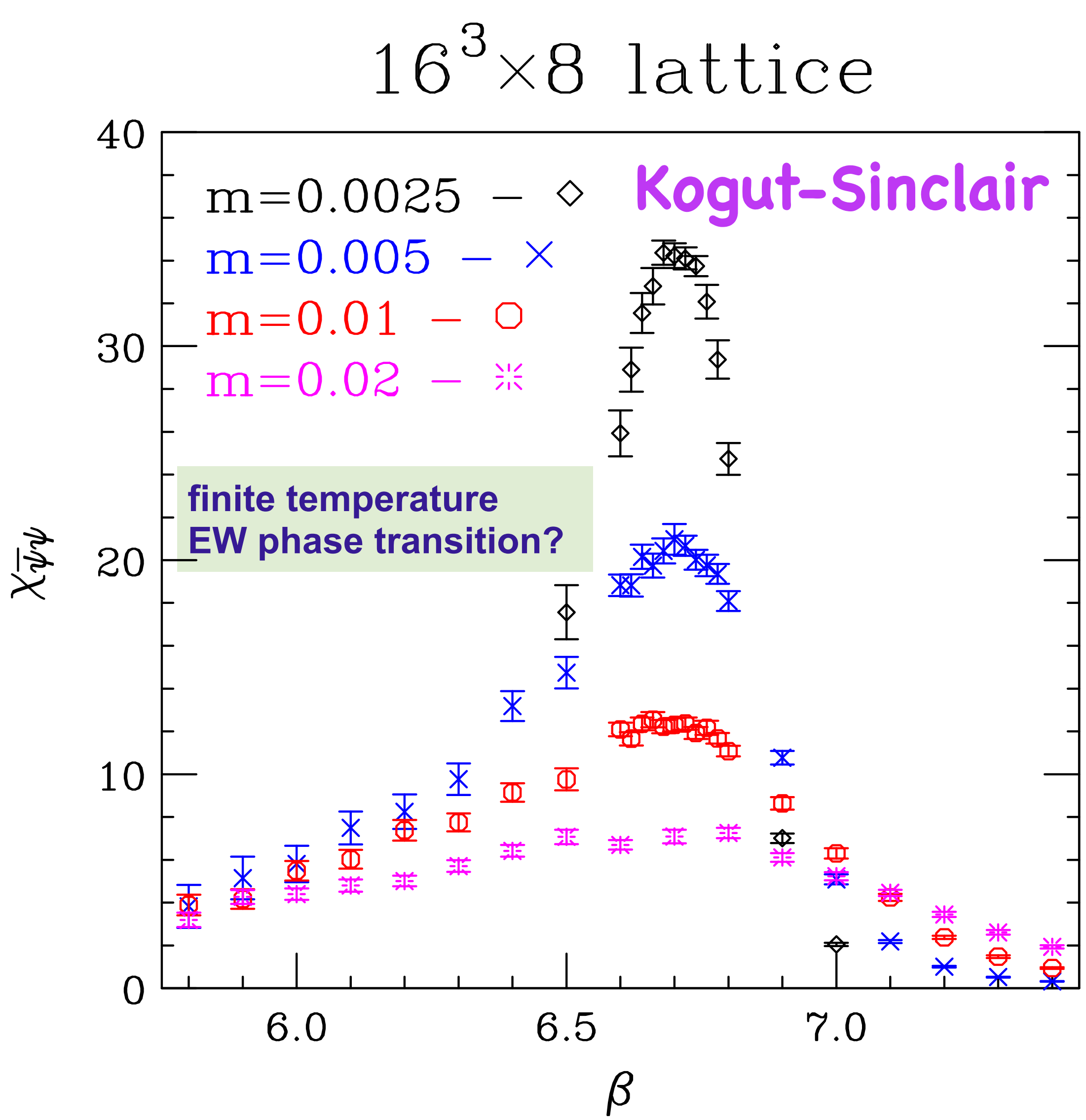
EW phase transition in sextet model - early universe

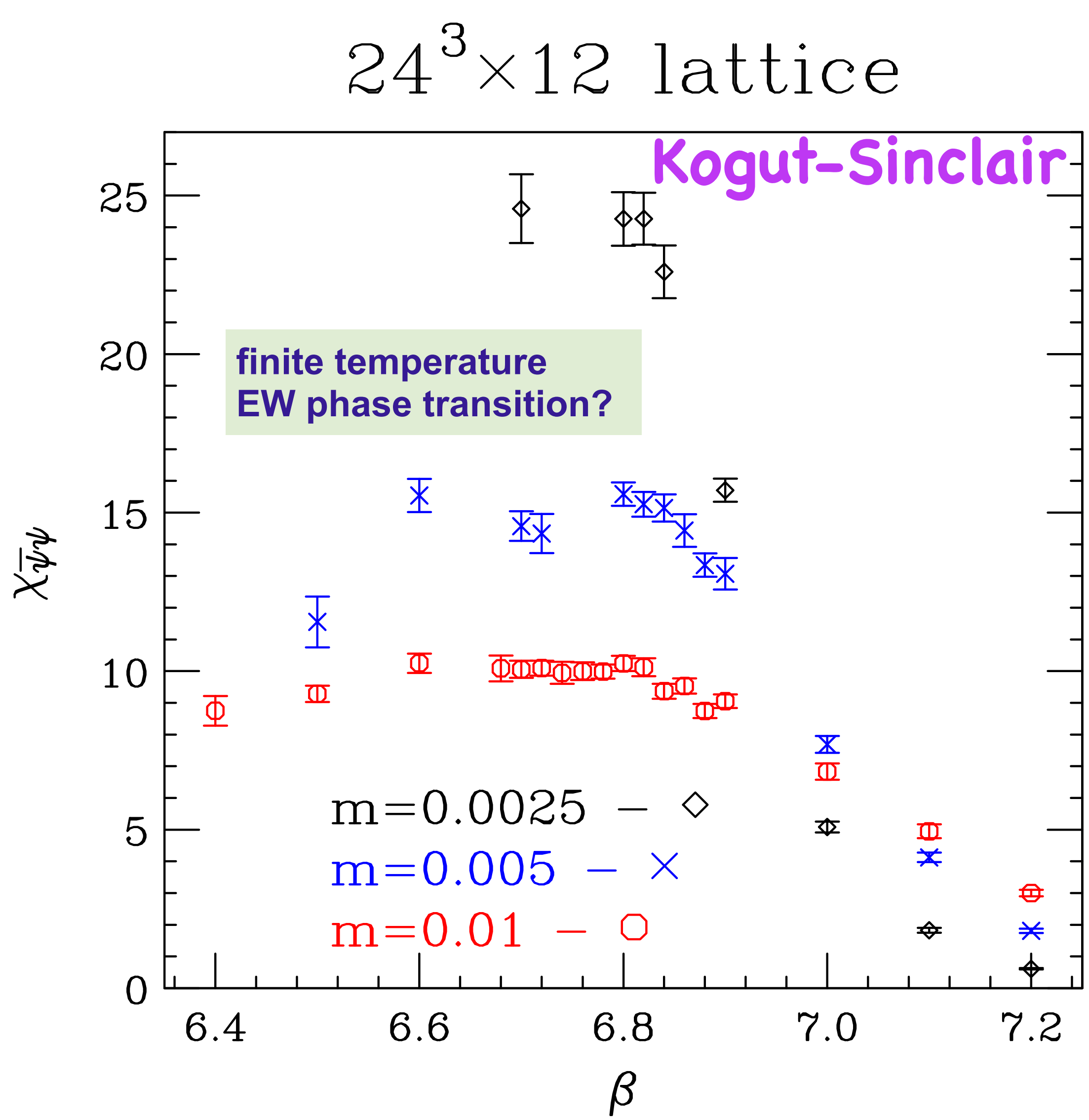
Kogut-Sinclair consistent with χSB phase at T=0

relevance in early cosmology

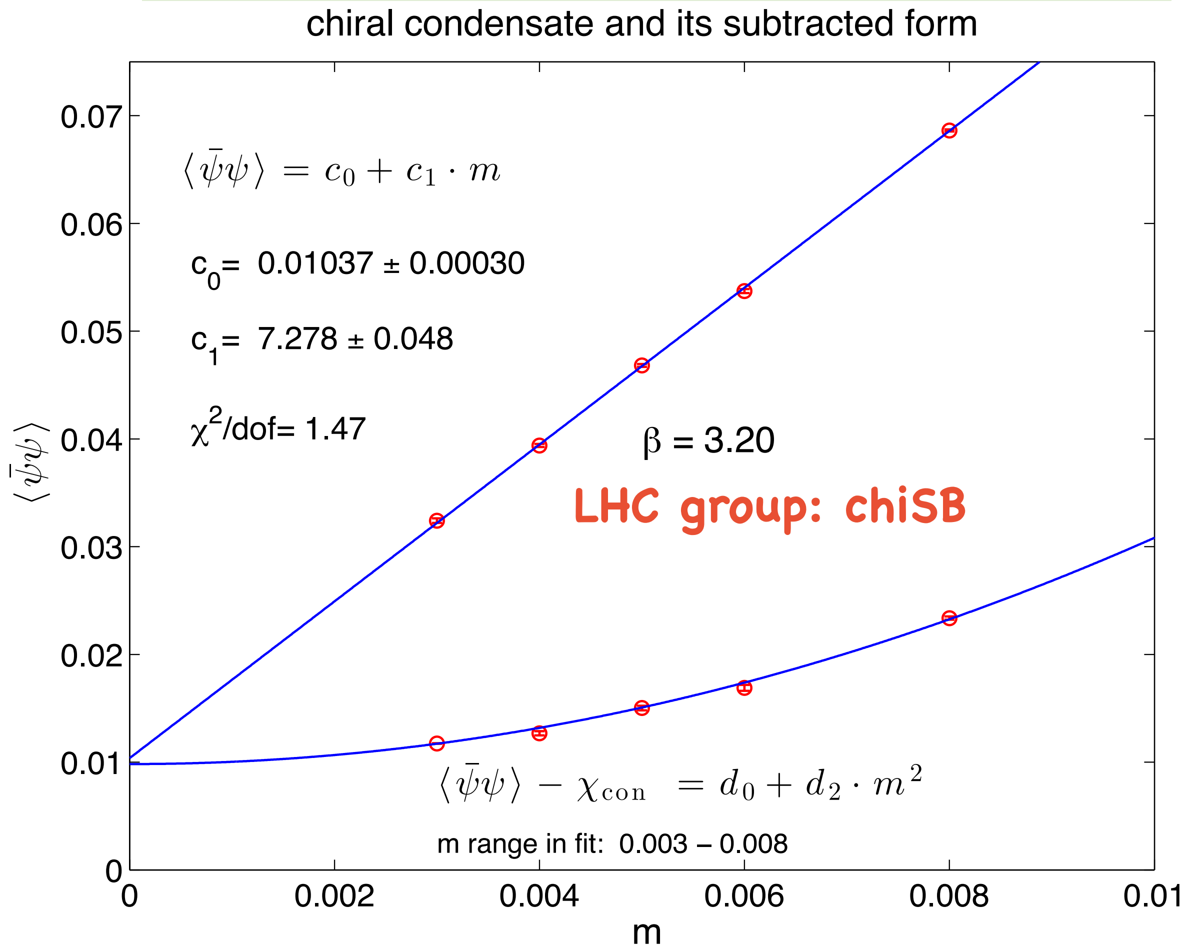
We are planning to run sextet thermodynamics

Third massive fermion flavor (electroweak singlet) dark matter?





LHC group: Phys. Lett. B 718, 657 (2012)



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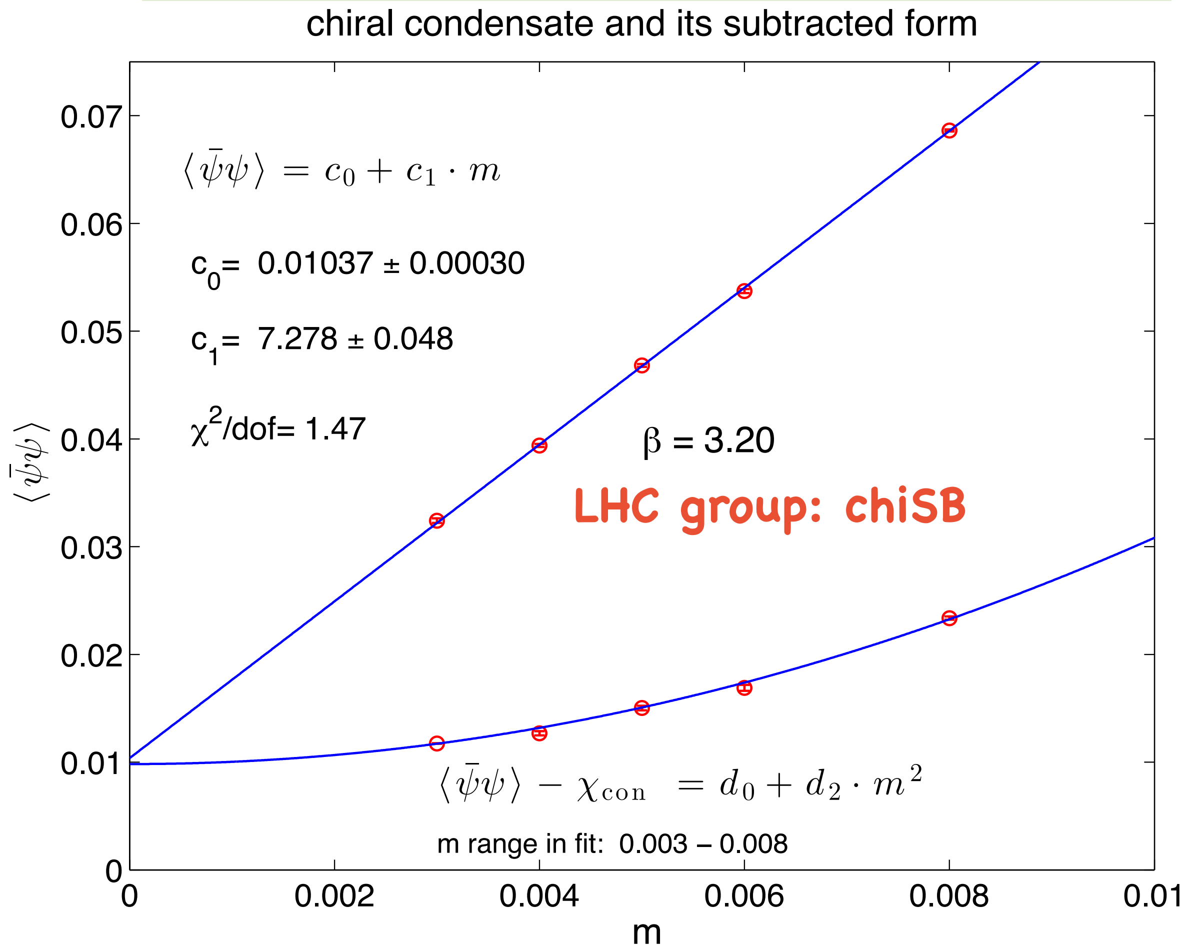

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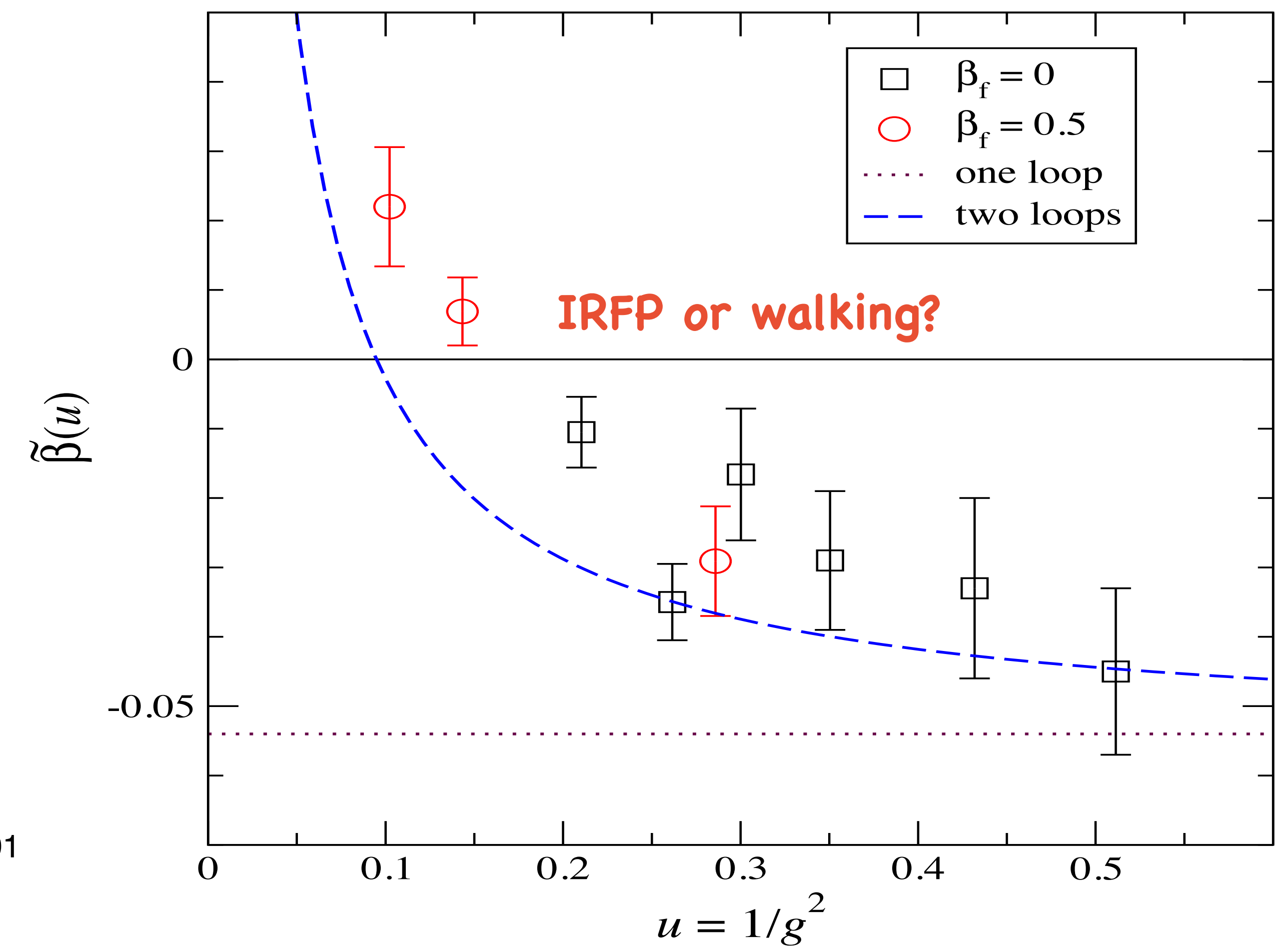

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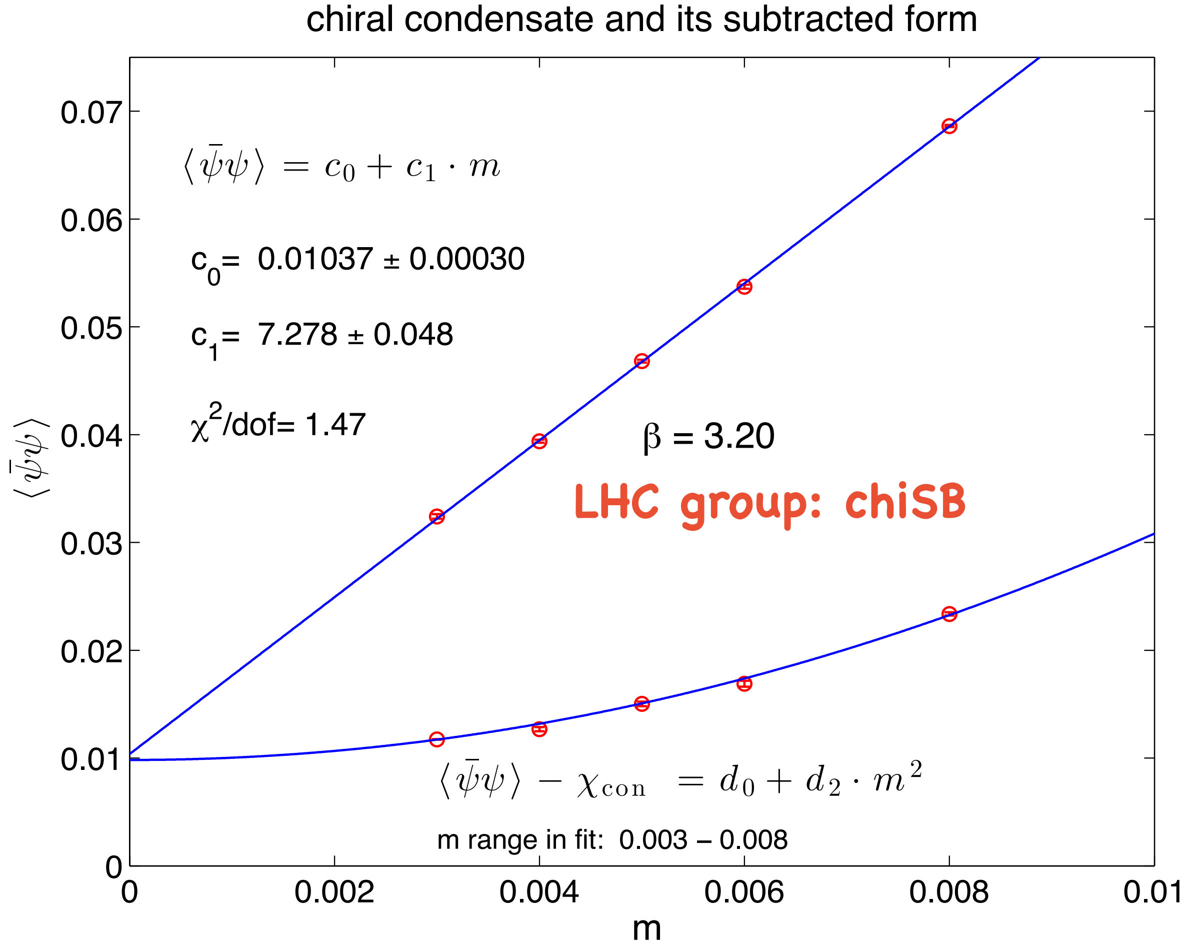

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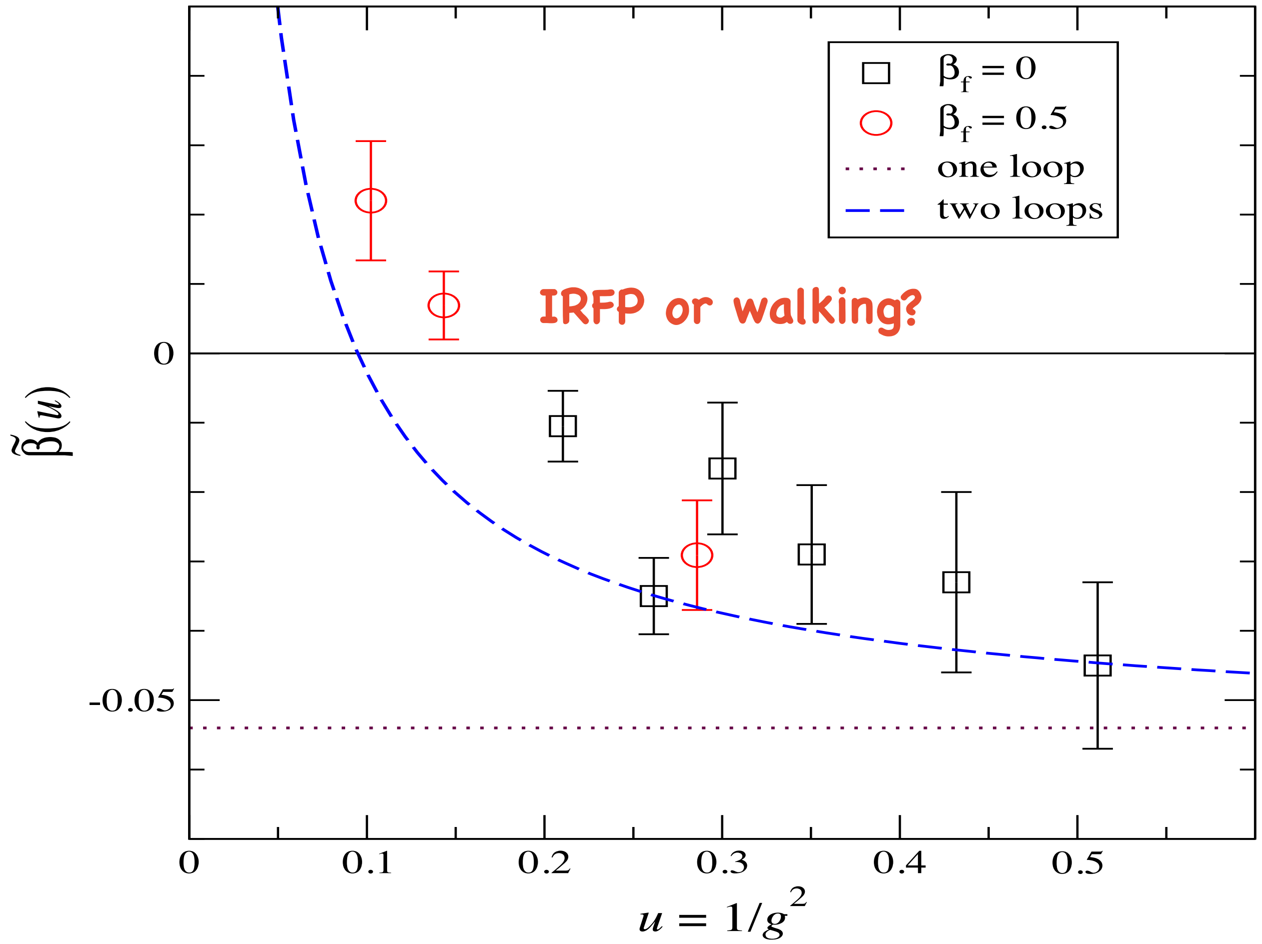

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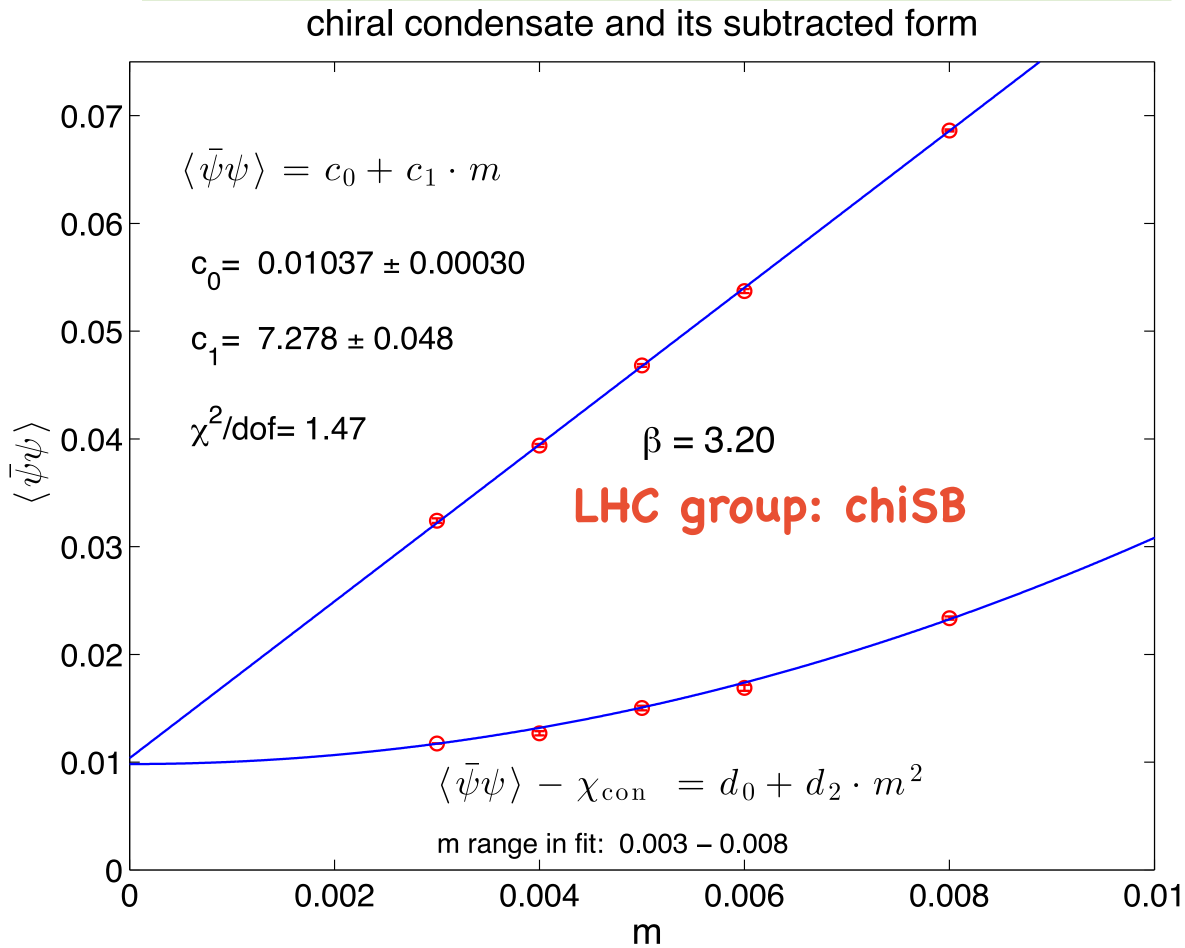

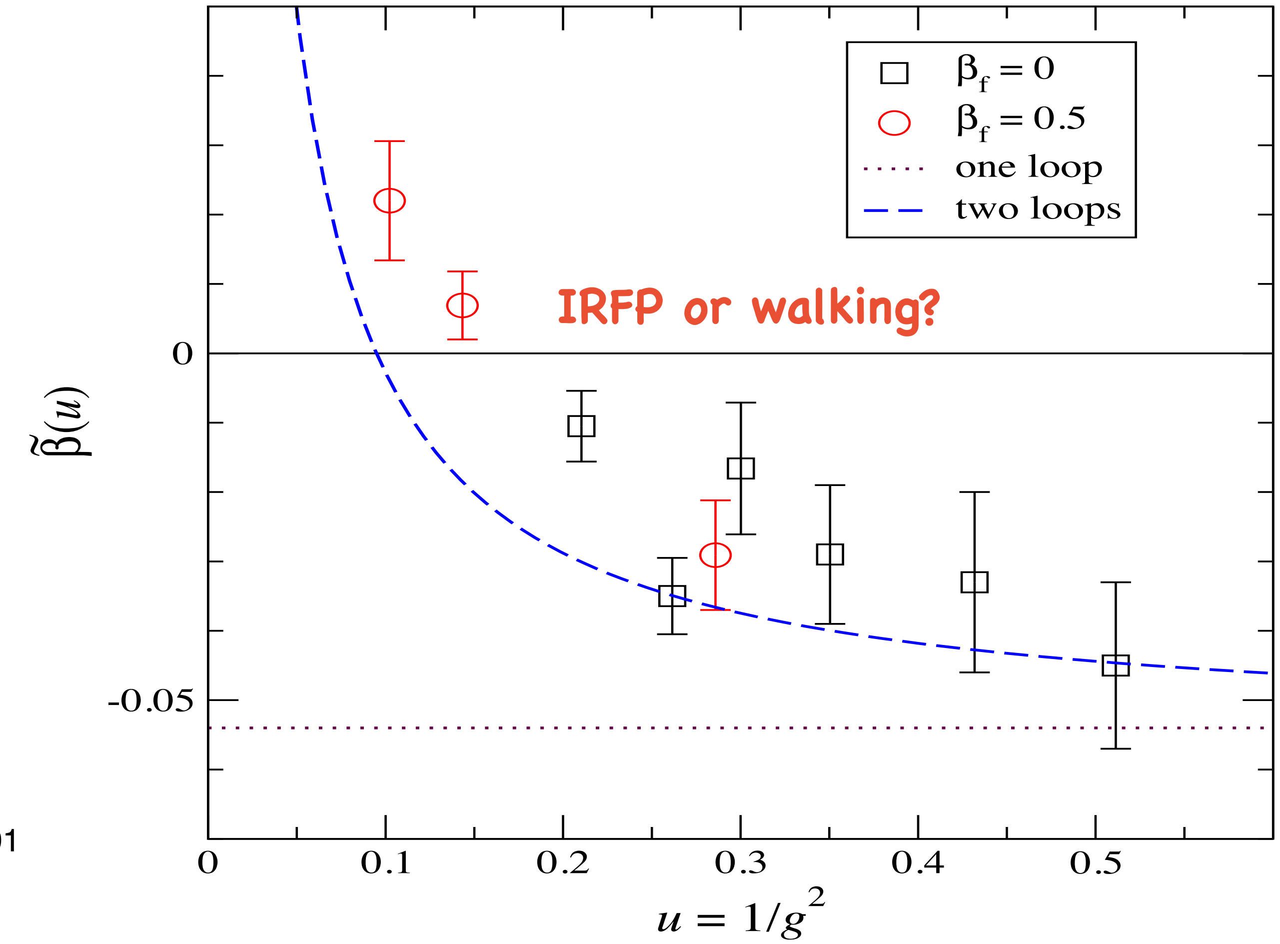

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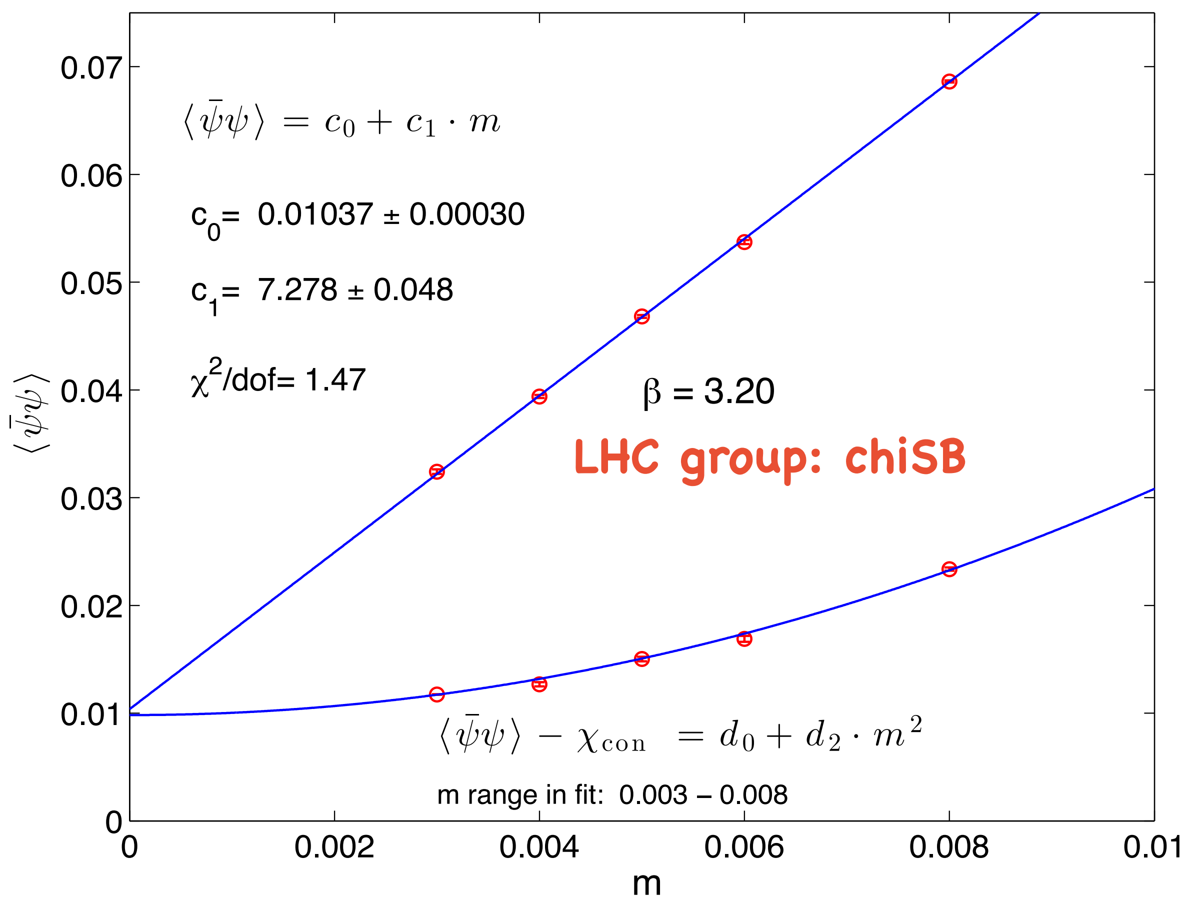

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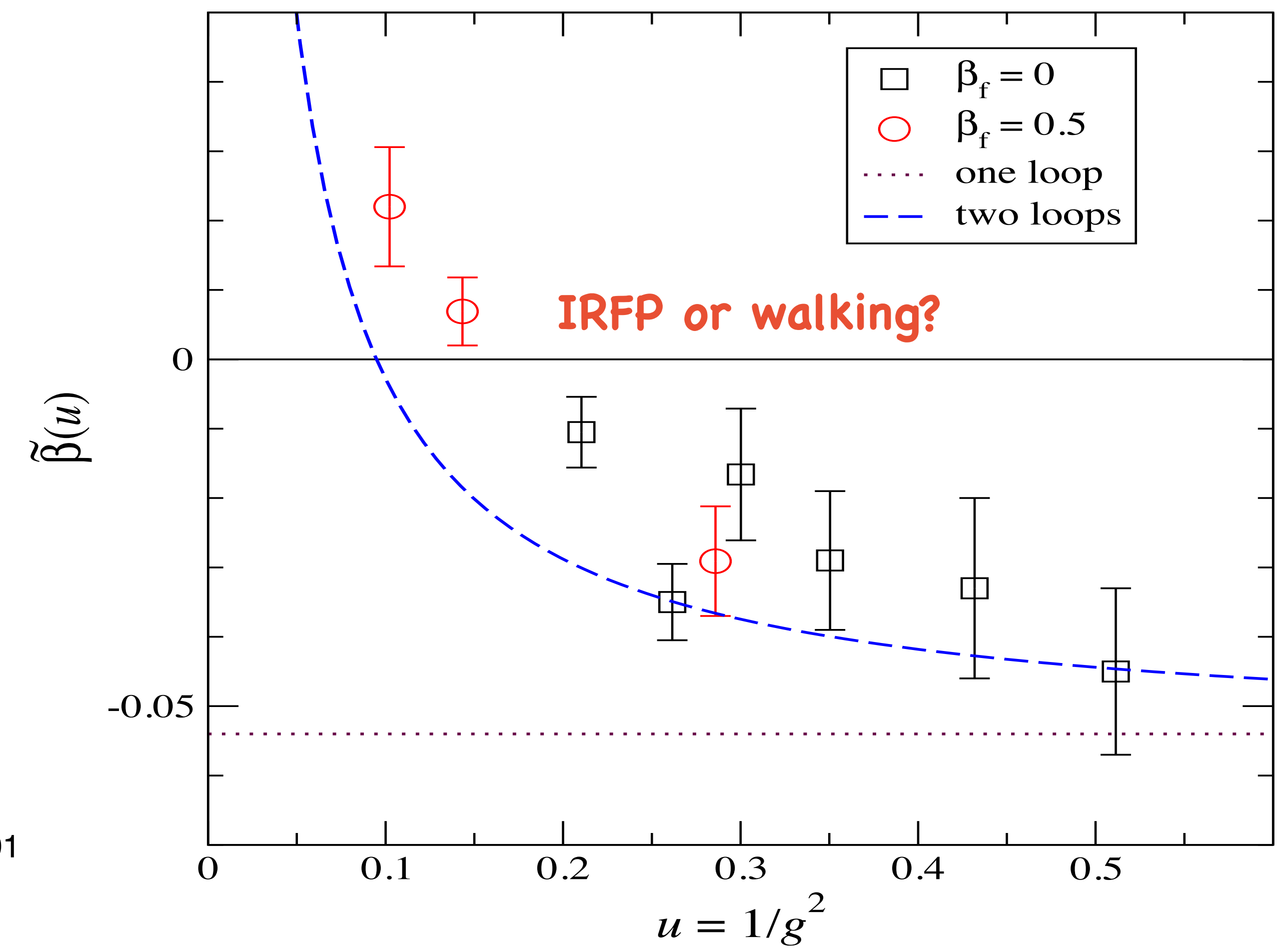

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consistency of results requires ➜ walking   light Higgs impostor as dilaton?

dilaton, or light scalar, as Higgs impostors?

The dilaton: pseudo-Goldstone particle of broken scale invariance

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scale anomaly (RG invariant)

$$\partial_\mu \mathcal{D}^\mu = \Theta^\mu_\mu = \frac{\beta(\alpha)}{4\alpha} G^a_{\mu\nu} G^{a\mu\nu}$$

$$\mathcal{D}^\mu = \Theta^{\mu\nu} x_\nu$$

Dilatation current
symmetric energy-momentum tensor

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Looking for PCDC relation among three unknowns:

1. dilaton mass m_σ
2. dilaton decay constant f_σ
3. non-perturbative gluon condensate

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symmetric energy-momentum tensor

$$\langle 0|\Theta^{\mu\nu}(x)|\sigma(p)\rangle = \frac{f_\sigma}{3}(p^\mu p^\nu - g^{\mu\nu} p^2) e^{-ipx}$$

Looking for PCDC relation among three unknowns:

1. dilaton mass m_σ
2. dilaton decay constant f_σ
3. non-perturbative gluon condensate

$$\langle 0|\partial_\mu \mathcal{D}^\mu(x)|\sigma(p)\rangle = f_\sigma m_\sigma^2 e^{-ipx}$$

$$\left[\Theta^\mu_\mu\right]_{NP} = \frac{\beta(\alpha)}{4\alpha}\left[G^a_{\mu\nu} G^{a\mu\nu}\right]_{NP}$$

long history of PCDC relation
only non-perturbative part kept in derivation

$$\left[\Theta^\mu_\mu\right]_{NP} = \frac{\beta(\alpha)}{4\alpha} G^a_{\mu\nu} G^{a\mu\nu} - \langle 0|\frac{\beta(\alpha)}{4\alpha} G^a_{\mu\nu} G^{a\mu\nu}|0\rangle_{PT}$$

recently:
Bai and Appelquist Phys.Rev. D82 (2010) 071701
Matsuzaki and Yamawaki arXiv:1206.6703[hep-ph]

earlier:
Dietrich, Sannino, Phys.Rev. D 72 (2005) 055001
and others ...

$$m_\sigma^2 \simeq -\frac{4}{f_\sigma^2}\langle 0|\Big[\Theta_\mu^\mu(0)\Big]_{NP}|0\rangle$$

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there are two different expectations on limit of right-hand side ratio when conformal window is approached:

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$g(\mu=\Lambda)=g_c$ **where ChiSB is triggered** $\frac{m_\sigma}{f_\sigma}\to 0$

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mass-dependent beta-function of sextet model

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- position of IRFP inside CW not tunable with m
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$$b_0(x) = 1 - 6x + \frac{12x^2}{\sqrt{1+4x}} \ln \frac{\sqrt{1+4x}+1}{\sqrt{1+4x}-1}$$

$$\beta_1(x) = \frac{17}{12}C_A^2 - (\frac{5}{6}C_A + \frac{1}{2}C_F)\cdot T_F \sum_f b_1(x)$$

$$b_1(x) = \frac{-0.45577x + 0.26995}{x^2 + 2.1742x + 0.26995}$$

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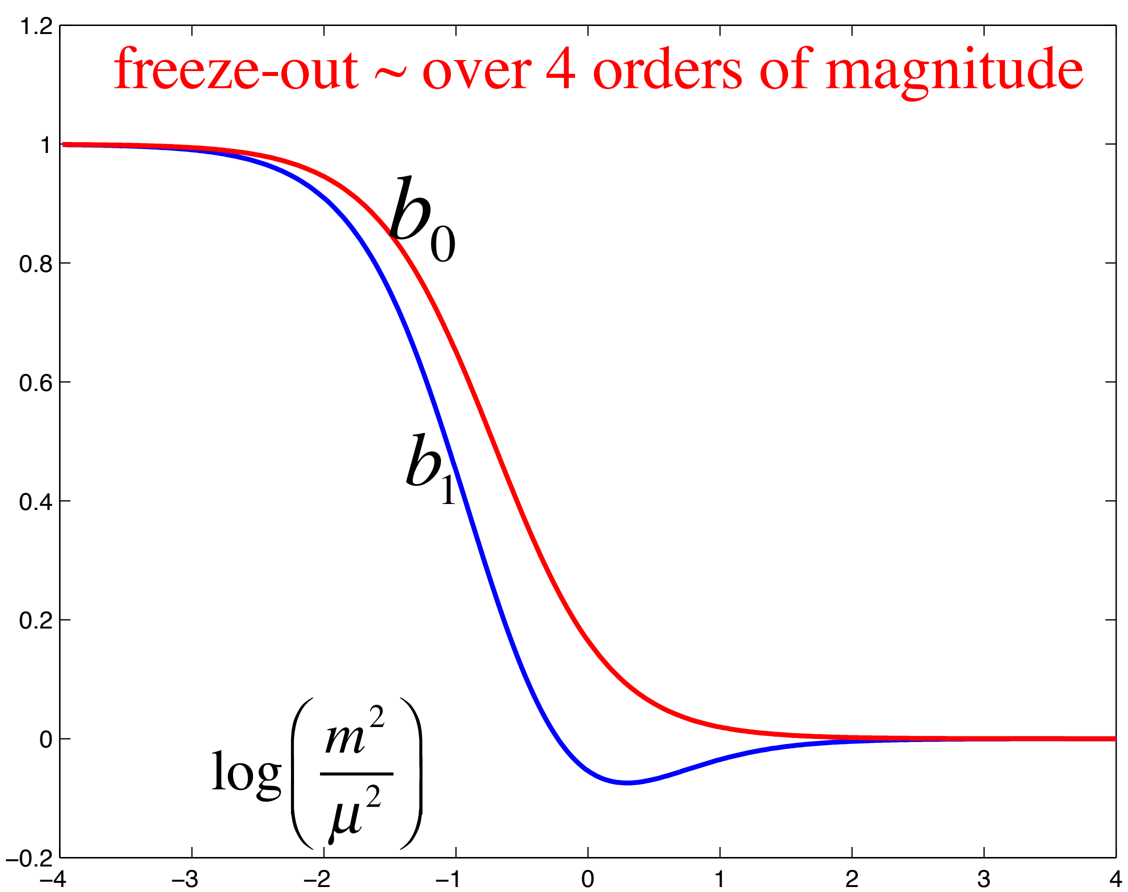

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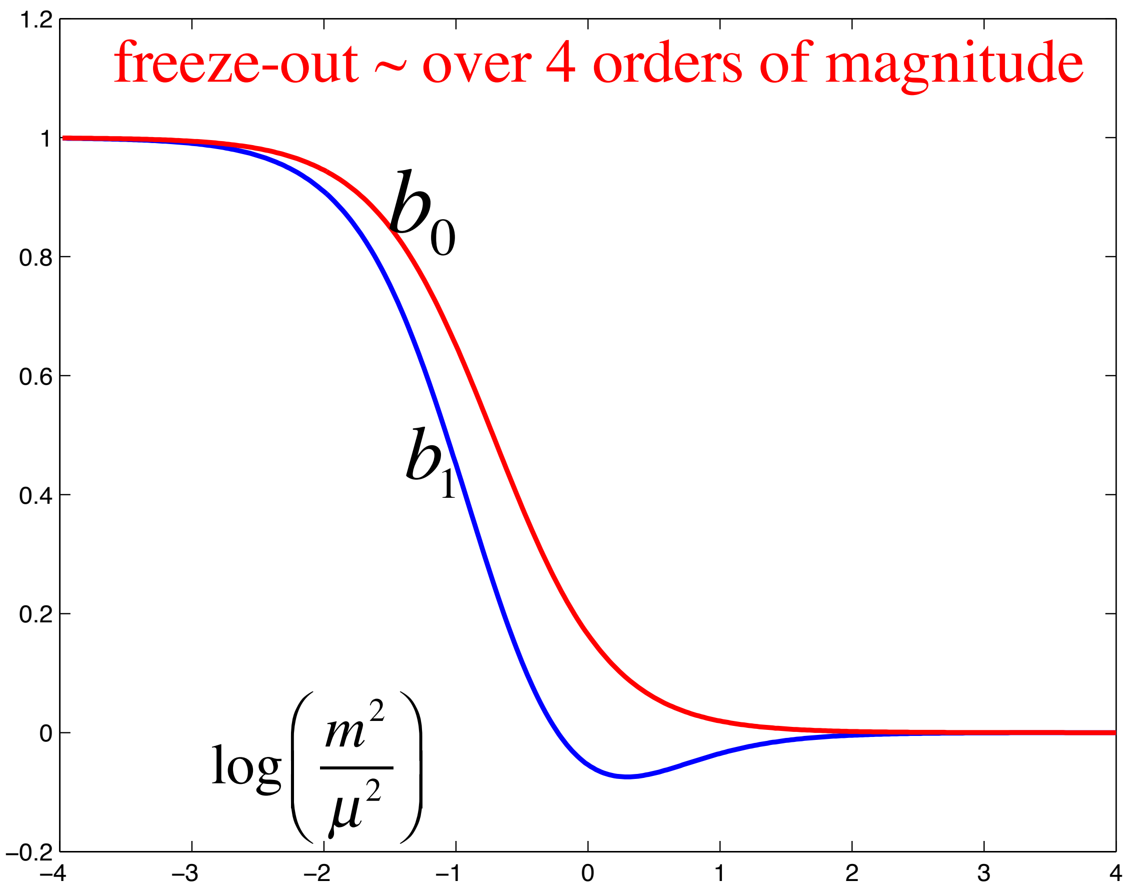

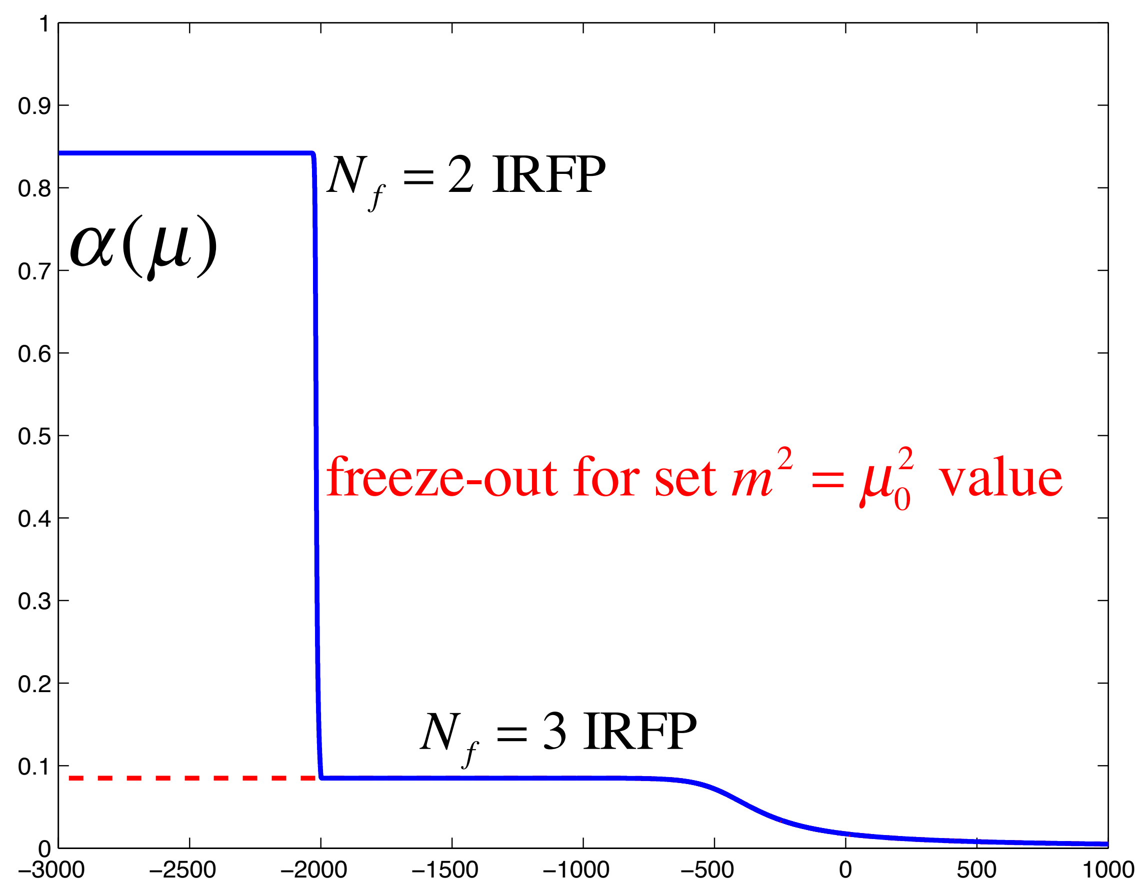

four-fermion operator

tunable deformation of IRFP?

large-N double trace limit

Witten, Rastelli, Vecchi ...

which scenario is realized will depend on the scaling dimension and on other intrinsic properties of IRFP

for any model choice things are set

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f flows to fixed points

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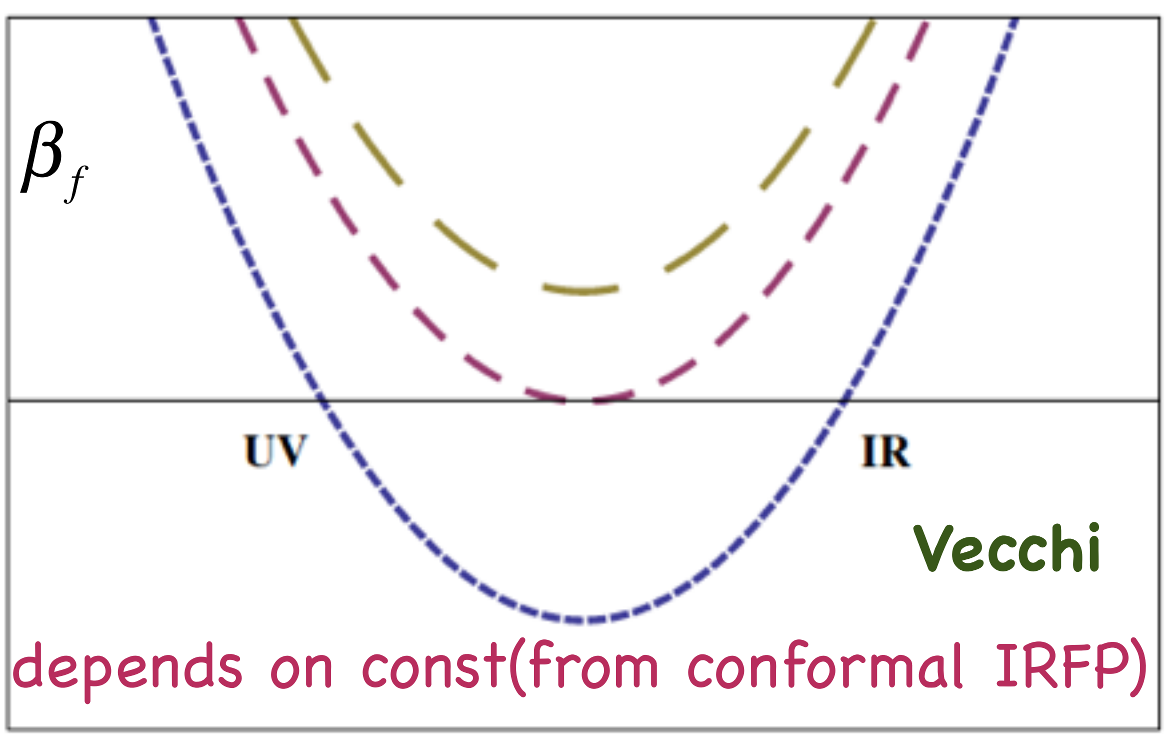

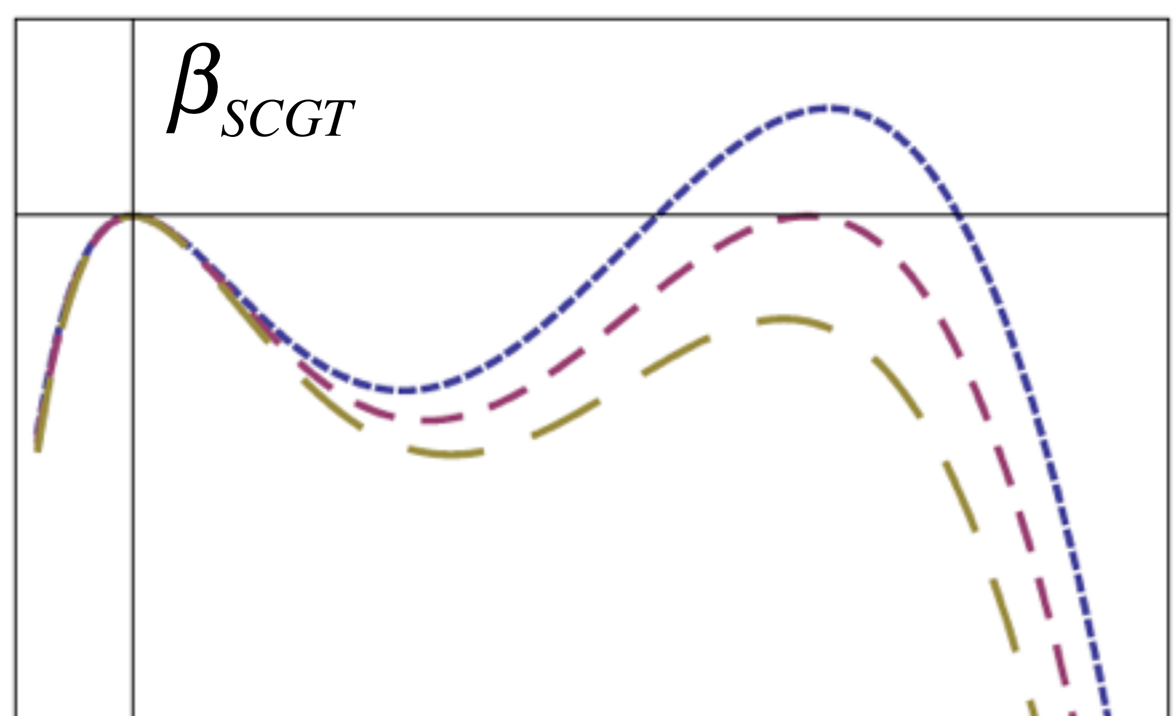

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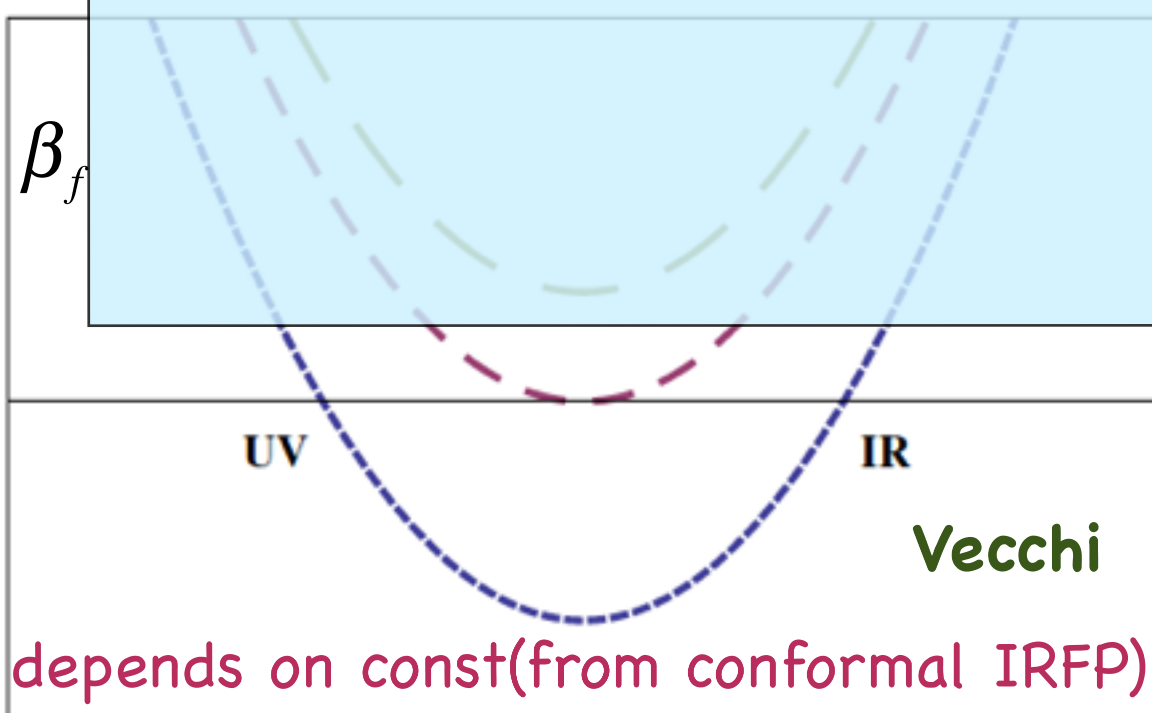
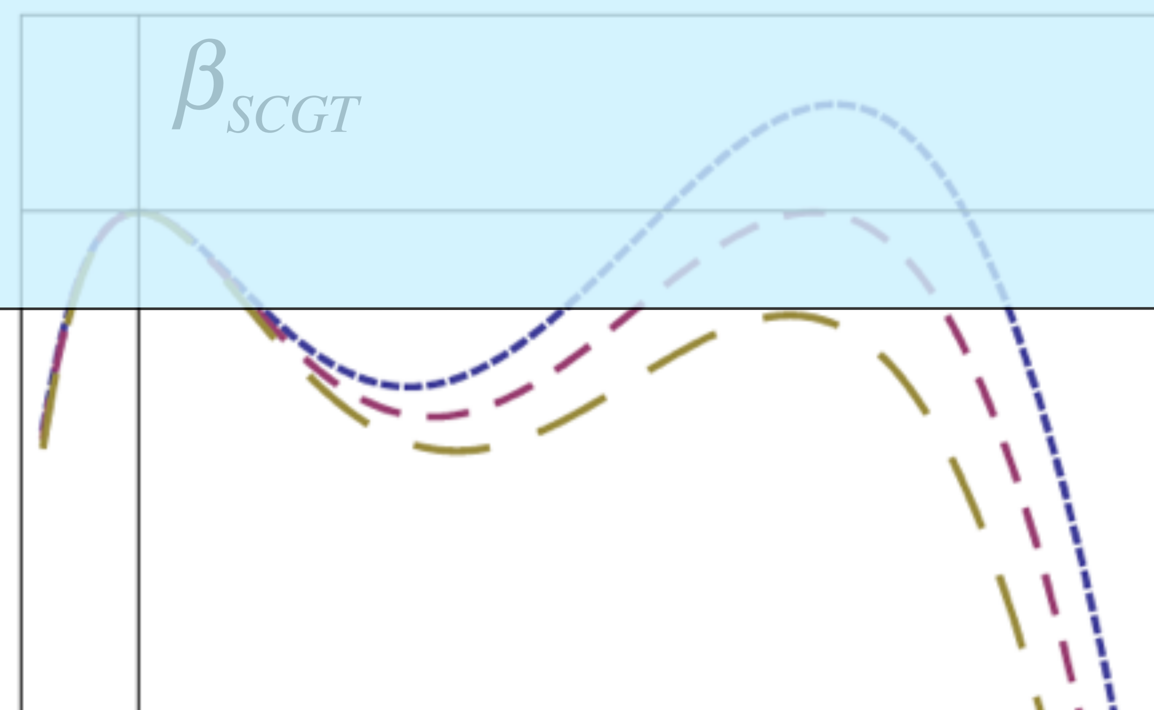
for any model choice things are set

f flows to fixed points SCGT not continuously tunable





four-fermion operator

tunable deformation of IRFP?

large-N double trace limit

Witten, Rastelli, Vecchi ...

$$\mathcal{L}_{\mathrm{CFT}} + \frac{f}{2}\mathcal{O}^\dagger_{ij}\mathcal{O}^{ij}$$

$$\mathcal{L}_{\mathrm{def}} = f(q_R^\dagger q_L)(q_L^\dagger q_R) \qquad \langle e^{i\int \mathcal{L}_{\mathrm{def}}}\rangle_{\mathrm{CFT}}$$

$$f(\Lambda) - \frac{v}{2\Delta - d} f^2(\Lambda)(\Lambda^{2\Delta-d} - \Lambda'^{2\Delta-d}) = f(\Lambda')$$

which scenario is realized will depend on the scaling dimension and on other intrinsic properties of IRFP

$$\langle \mathcal{O}(x)\mathcal{O}(y)\rangle \equiv \frac{v}{|x-y|^{2\Delta}}\frac{\Gamma(d/2)}{2\pi^{d/2}}$$

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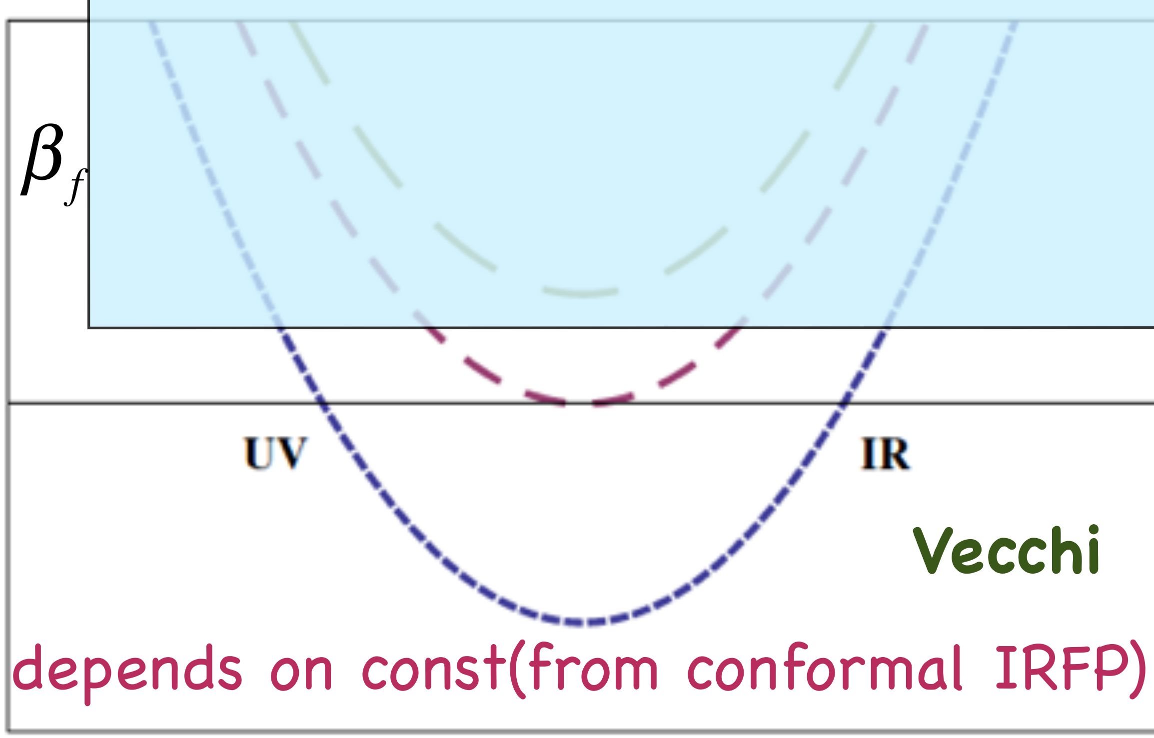

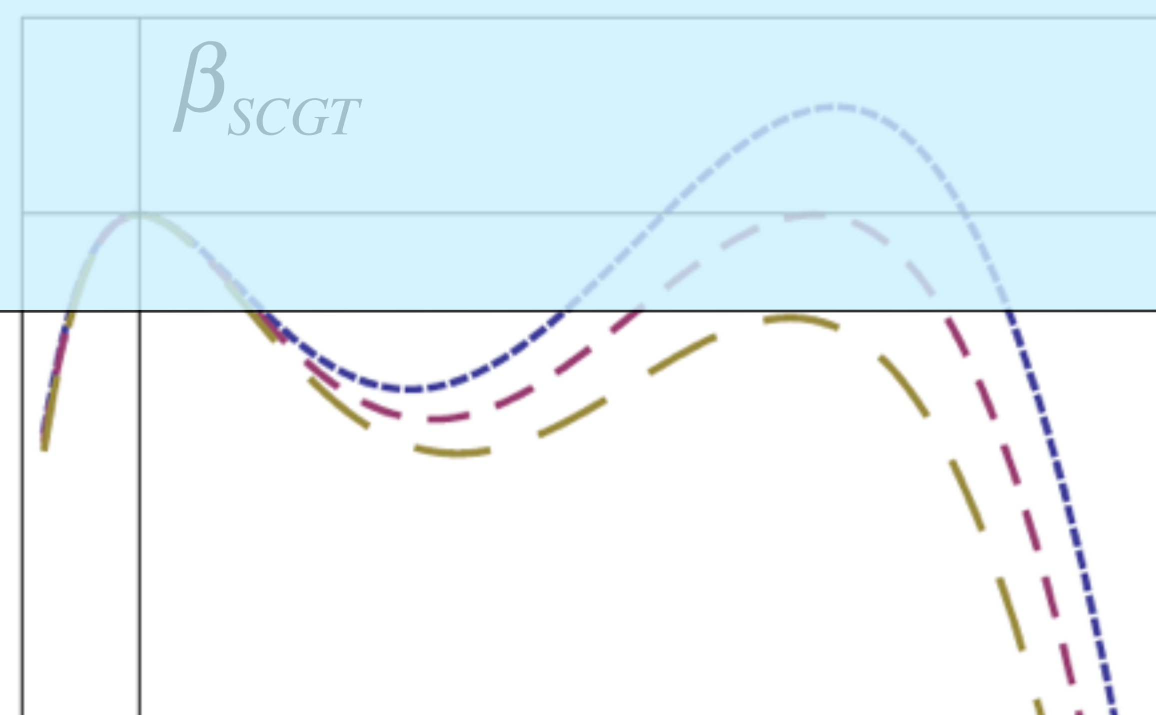

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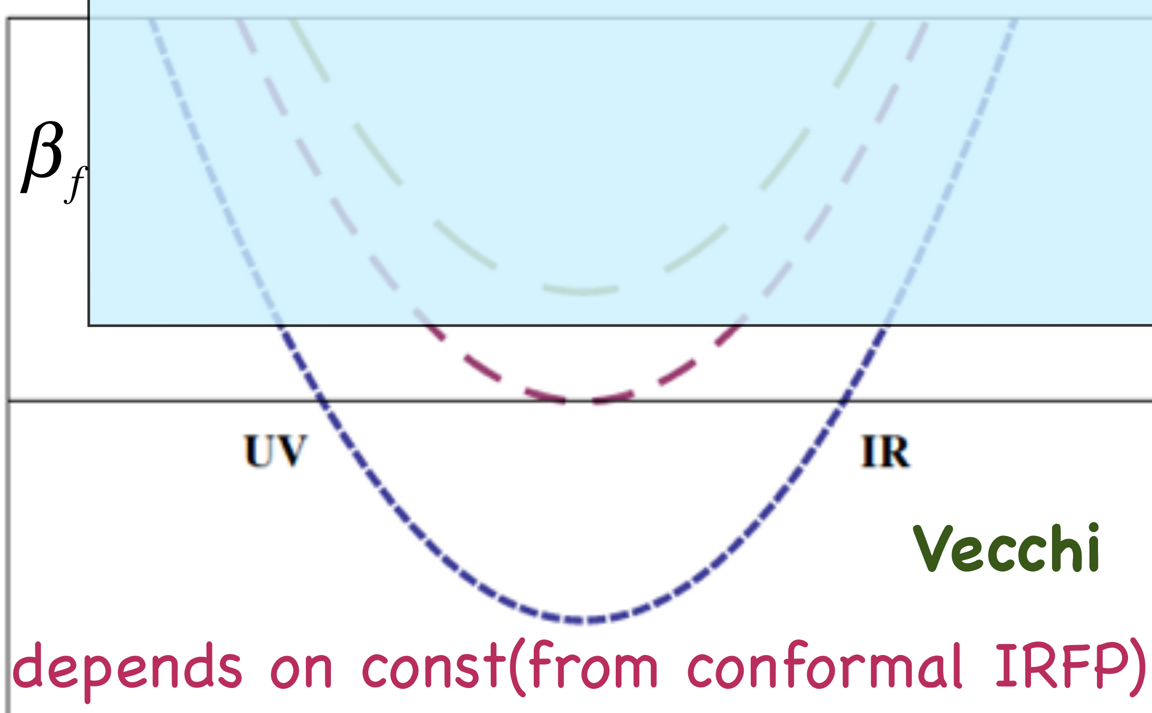

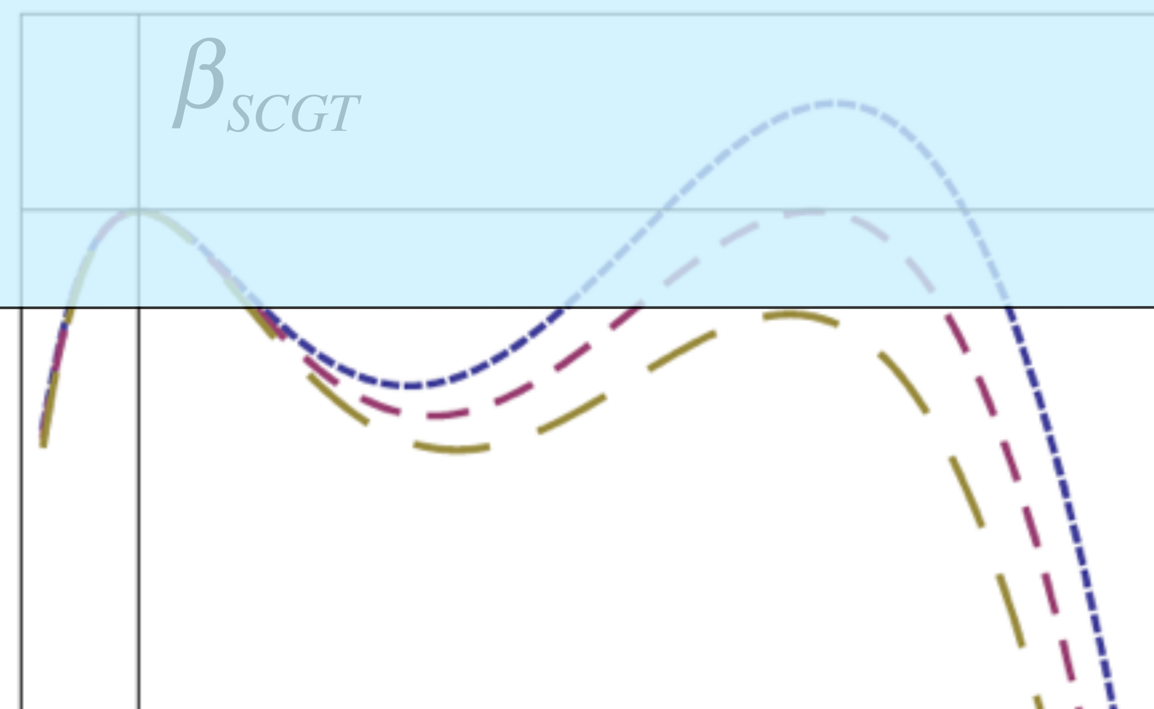

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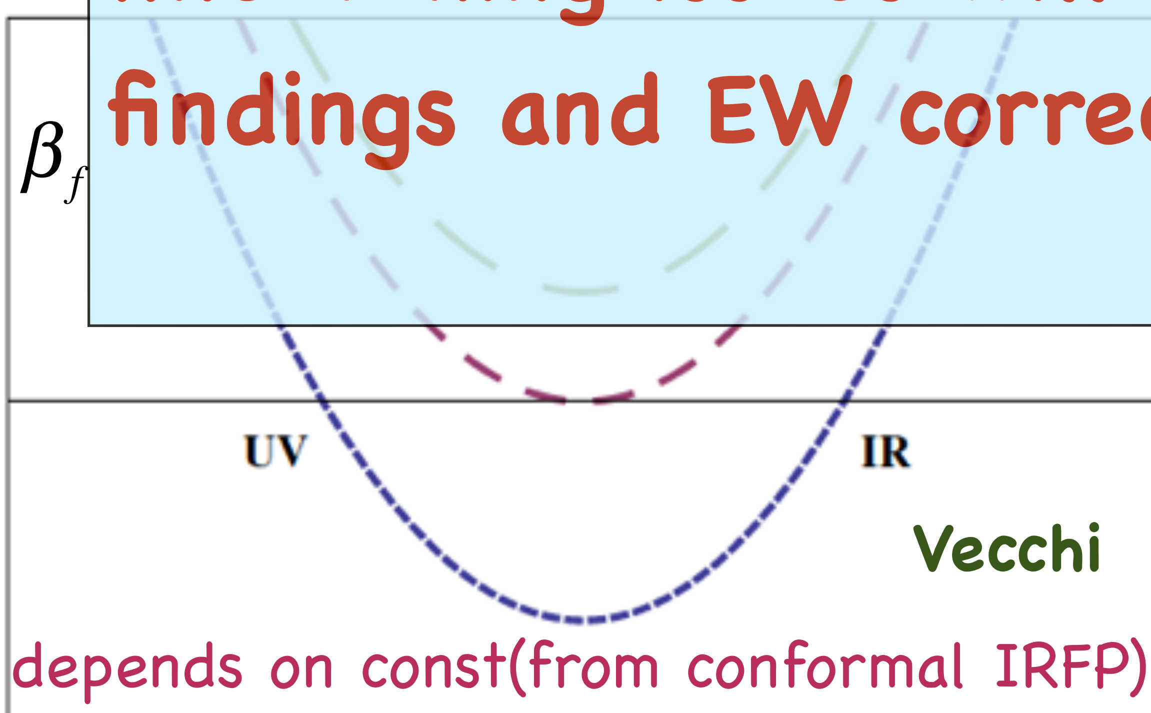
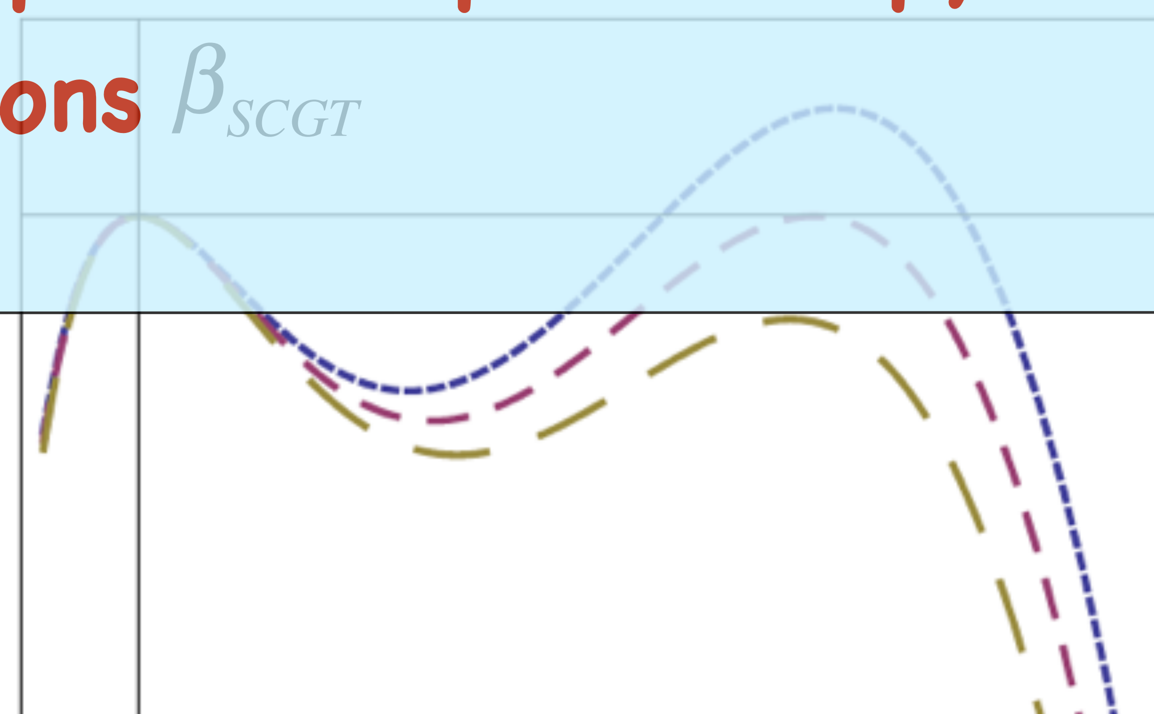
There are SCGT models close to CW: hunt for light 0++ scalar state ?

fine-tuning issues will depend on spectroscopy findings and EW corrections





BSM lattice tools to hunt for light 0^{++} scalar:

- establish chiSB or phase with chiral symmetry
- spectroscopy, confining force, with control of $m \rightarrow 0$ limit
- running coupling (walking?)
- light scalar? disconnected diagrams?
- control of cutoff, finite volume, and fermion mass limits
  - hard problems, studies remain limited
  - hard even in lattice QCD where we know the answers!
  - and we only have a fraction of lattice QCD resources

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the sextet model as a simple example

light scalar and dilaton mechanism close to CW

chiral condensates and spectroscopy

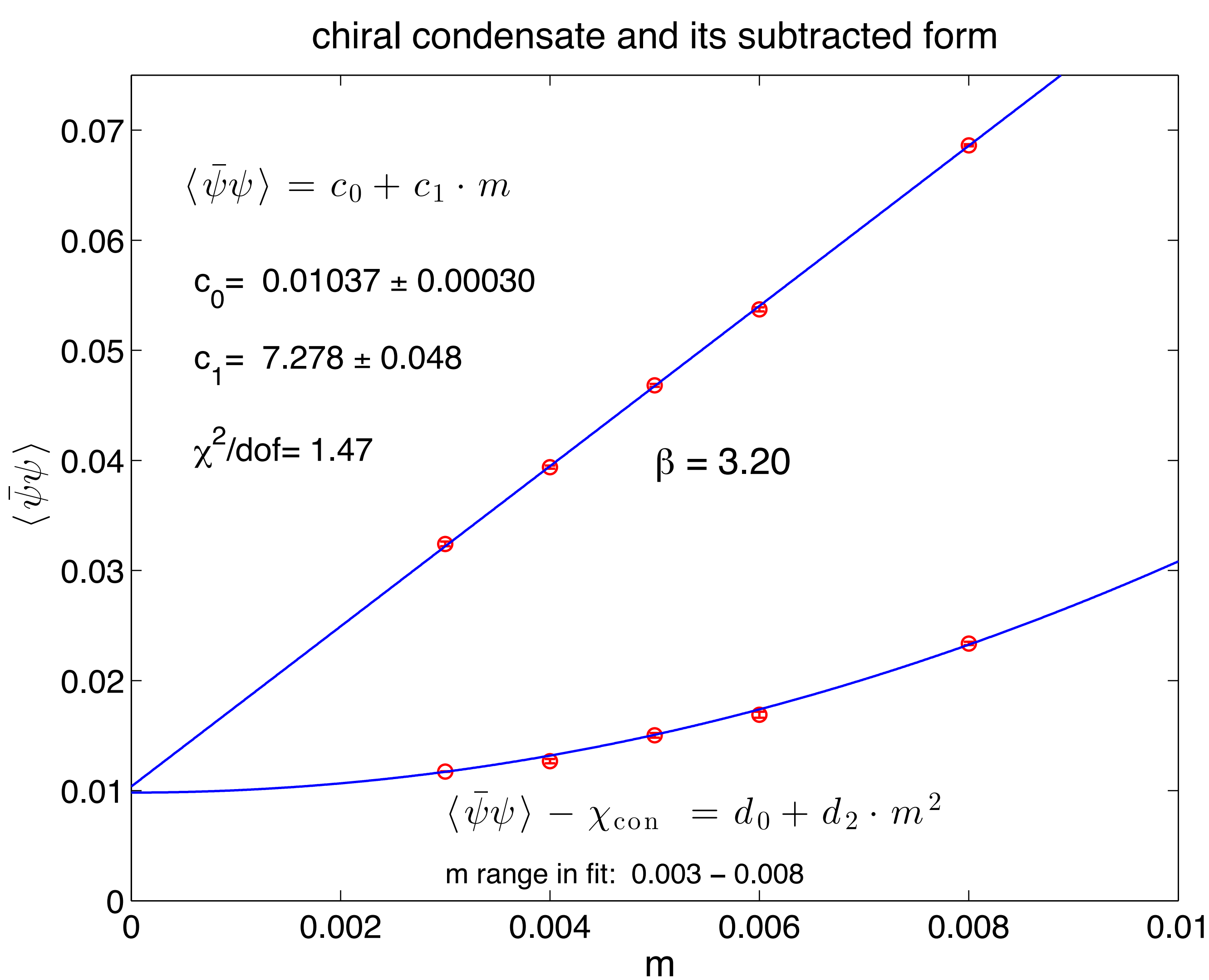
running (walking) coupling

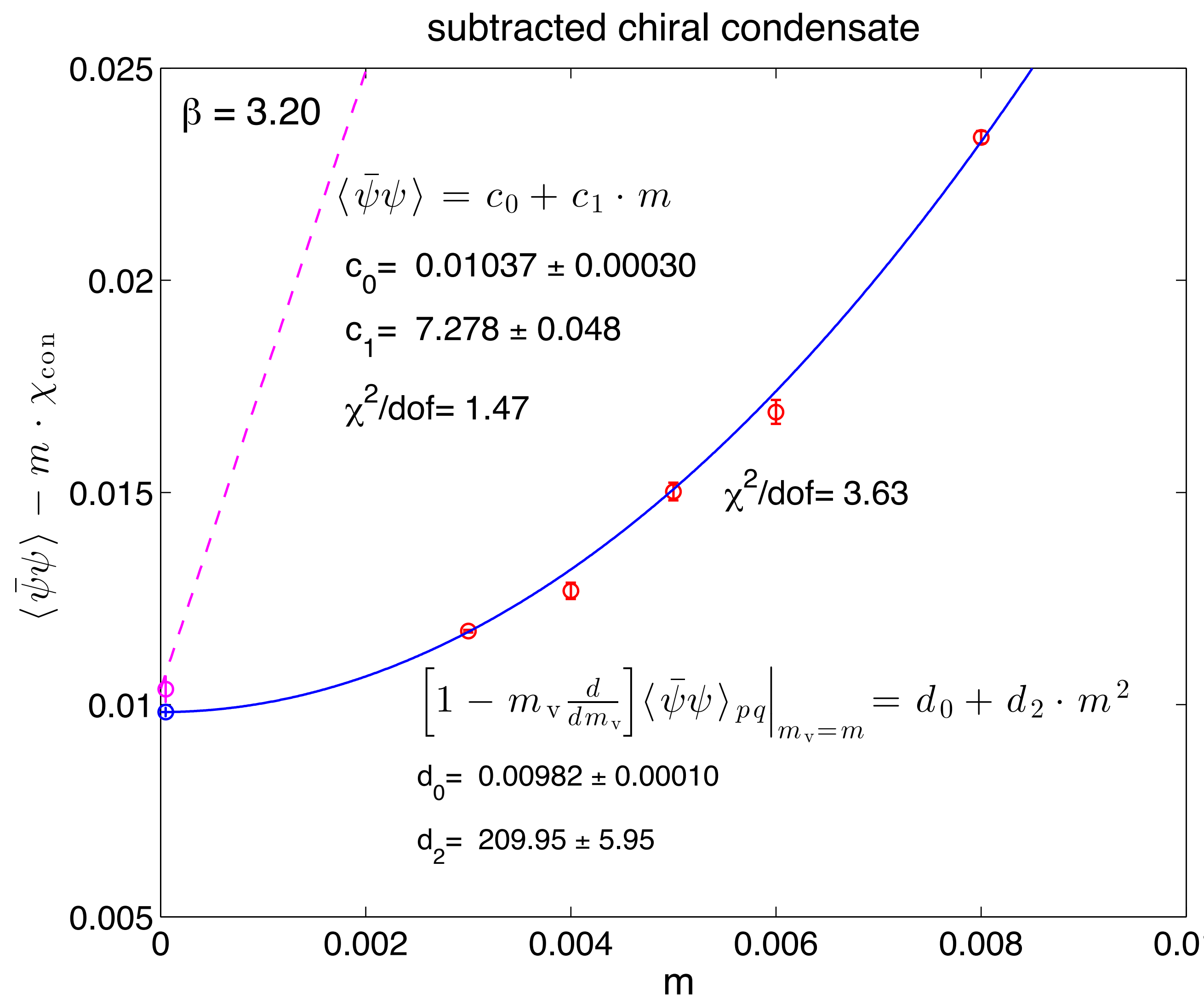
light scalar spectroscopy of 0^{++} states

Summary and outlook

chiral symmetry breaking at $m \neq 0$

Nf=2 SU(3) sextet chiral condensate





two independent determinations of the chiral condensate

(partially cancelled UV divergences in subtracted form)

consistently non-vanishing in chiral limit

all sextet results are treated as inf volume (only m=0.003 is truly extrapolated)

relying on L·Mπ > 5 (less than one percent L correction)

spectral mode number density analysis more powerful

(Giusti and Luscher, Boulder group, Patella ...)

complete control on UV divergences: **node number density of chiral condensate**

$$\rho(\lambda, m) = \frac{1}{V}\sum_{k=1}^{\infty}\langle\delta(\lambda-\lambda_k)\rangle \qquad \lim_{\lambda\to 0}\lim_{m\to 0}\lim_{V\to\infty}\rho(\lambda,m)=\frac{\Sigma}{\pi}$$

spectral density

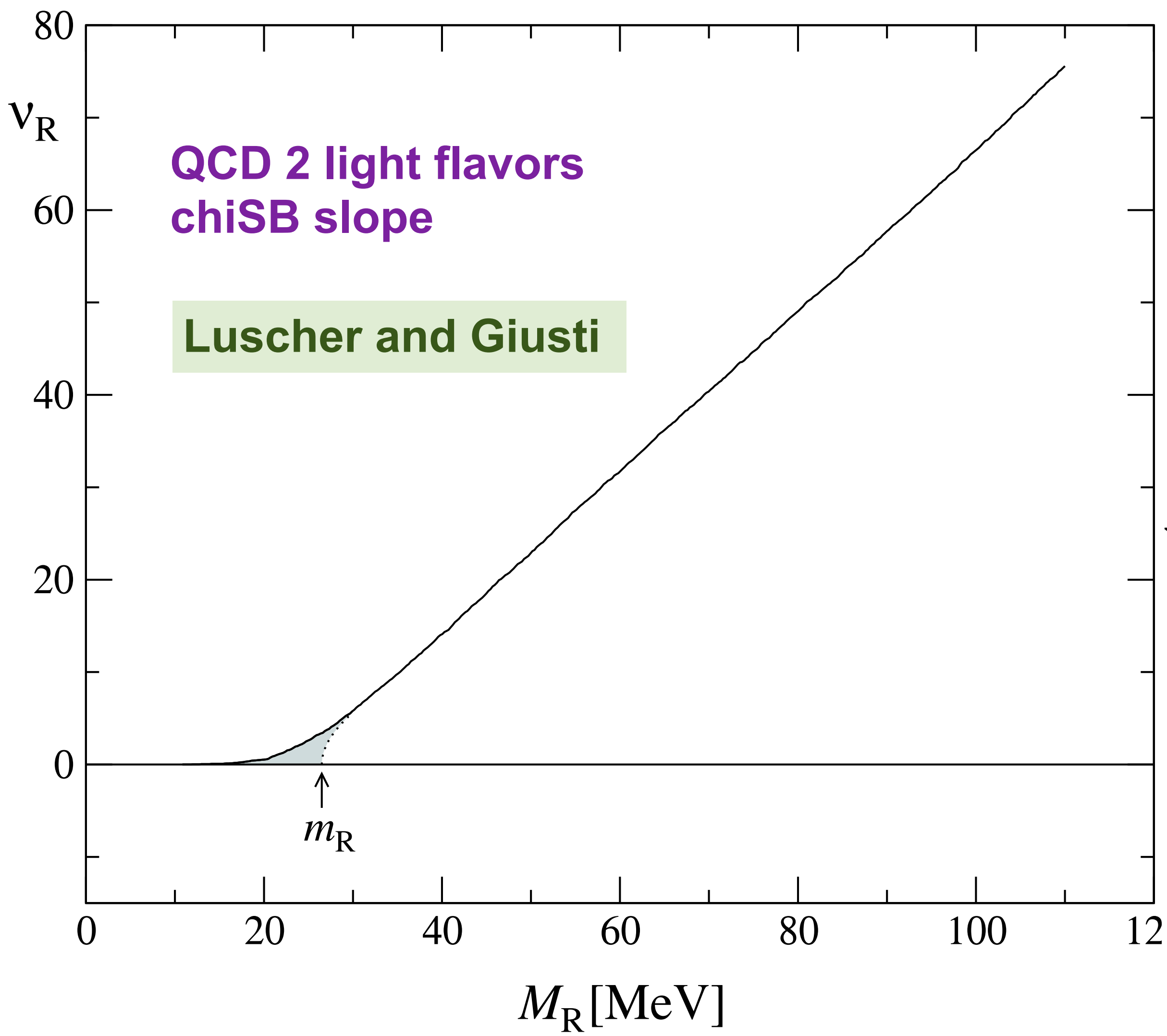
$$\nu(M,m) = V\int_{-\Lambda}^{\Lambda}\mathrm{d}\lambda\,\rho(\lambda,m), \qquad \Lambda=\sqrt{M^2-m^2}$$

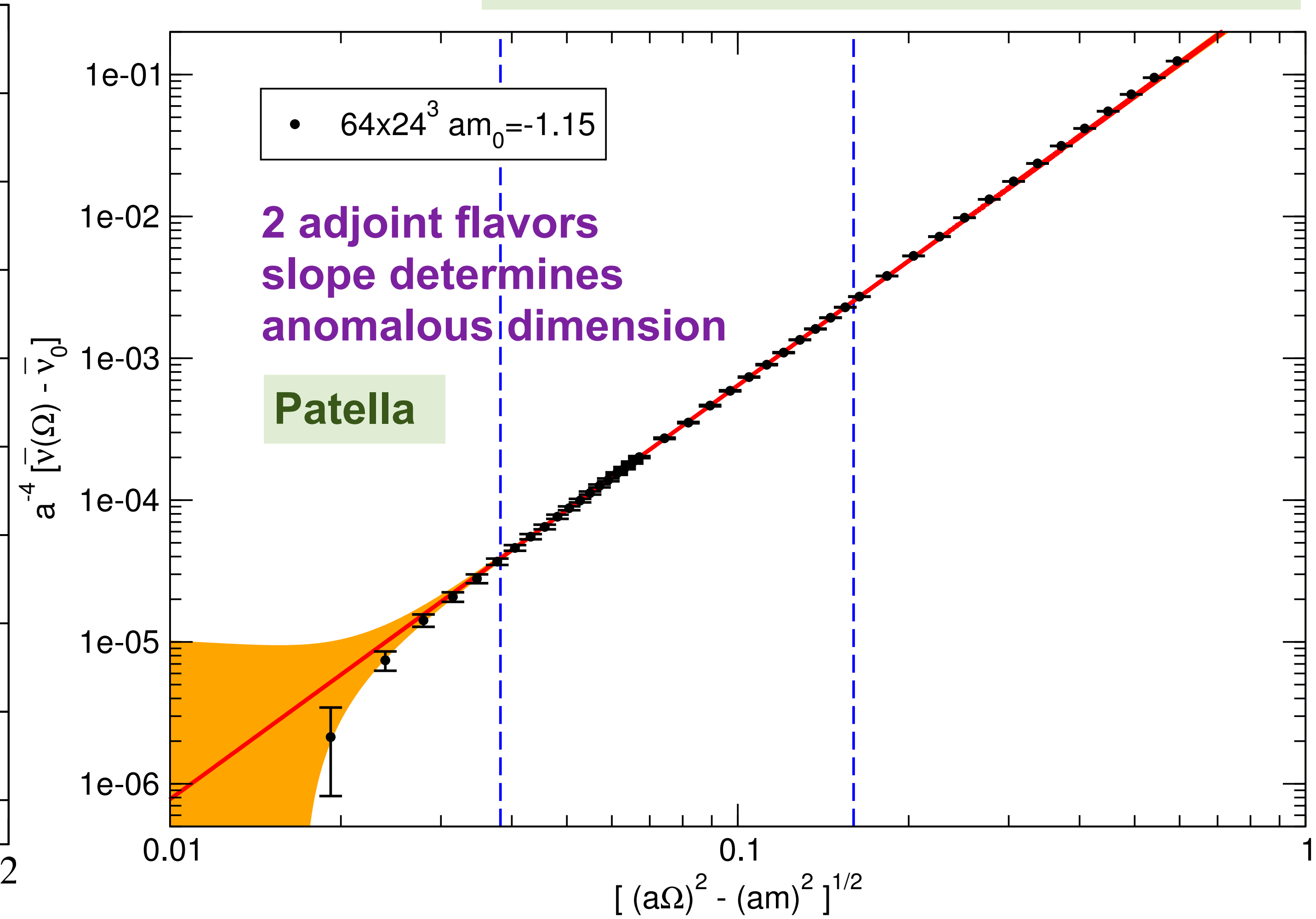
mode number density

$$\nu_{\mathrm{R}}(M_{\mathrm{R}},m_{\mathrm{R}})=\nu(M,m_{\mathrm{q}})$$

renormalized and RG invariant

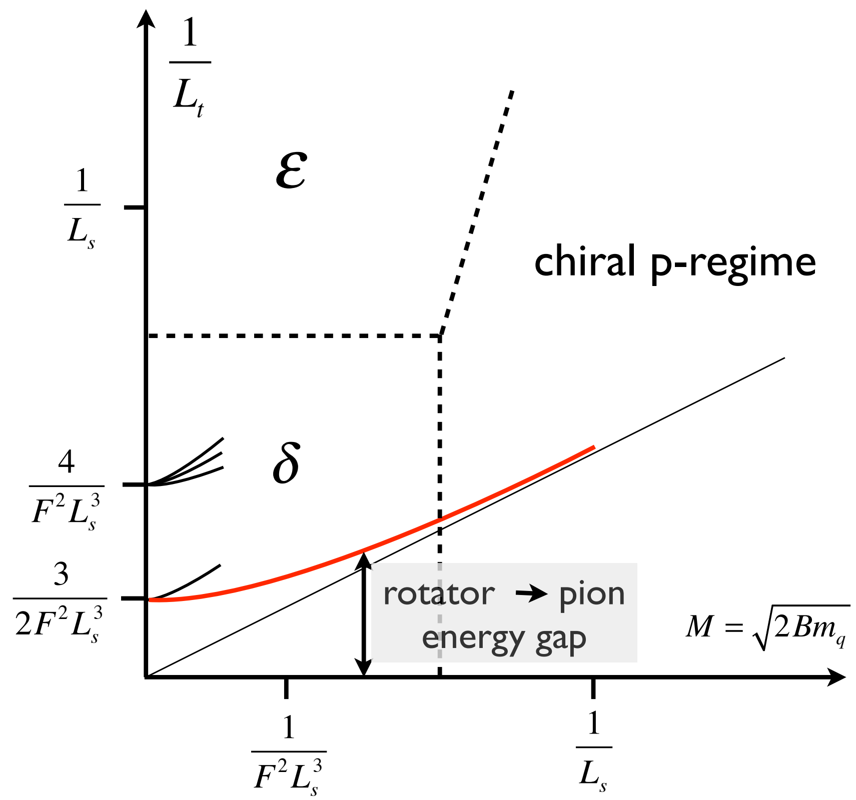
Del Debbio, Luscher, and Giusti
Boulder group (A. Hasenfratz talk)
Patella
earlier DeGrand

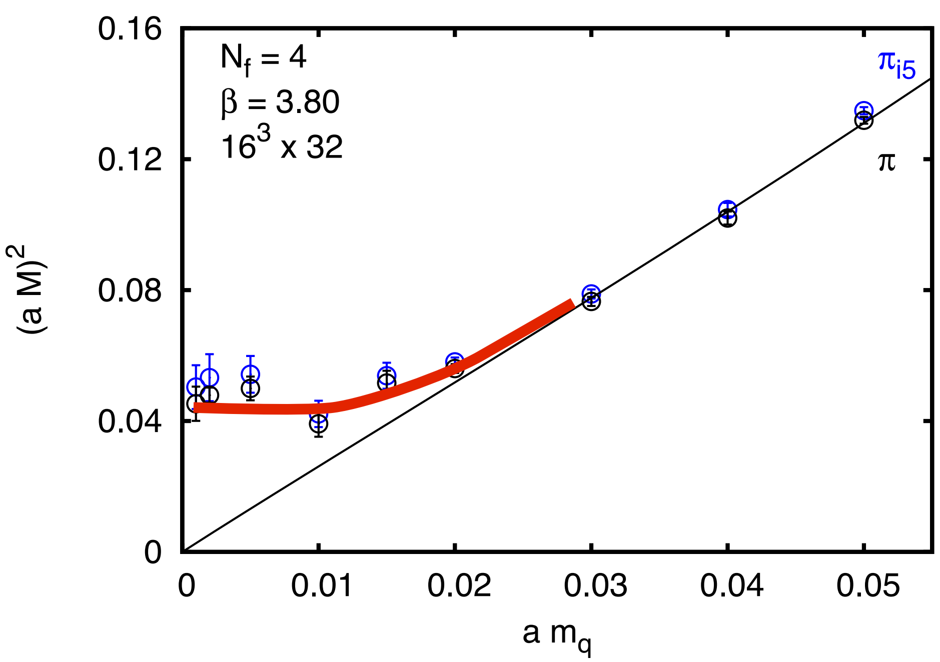




spectroscopy and force $m \neq 0$

mass deformed chiral SB in finite volume below conformal window:





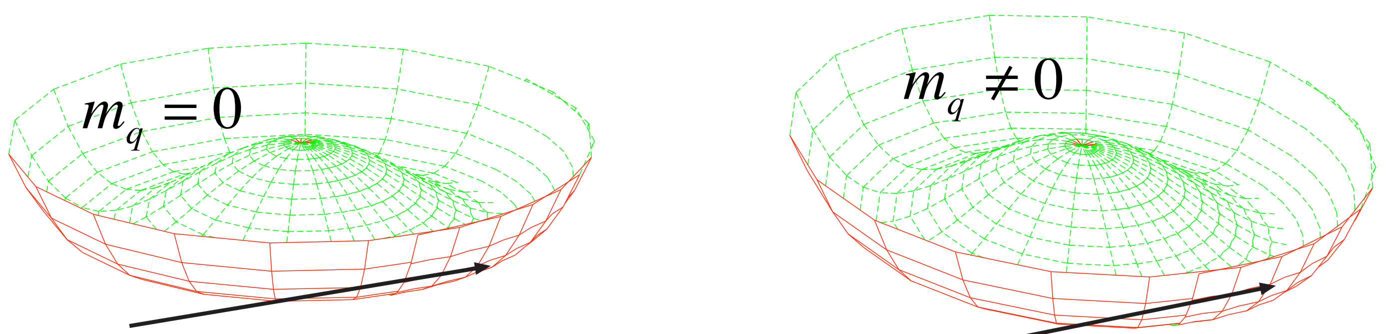
Goldstone dynamics is different in each regime

study of δ and ε-regimes (RMT)

and p-regime (probing chiral loops)

complement each other

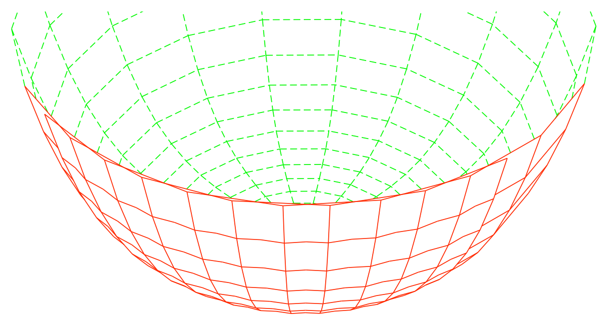
interpretation of rotator levels in $m_q \to 0$ limit:



Veff: chiral condensate in flavor space

arbitrary orientation of condensate

tilted condensate



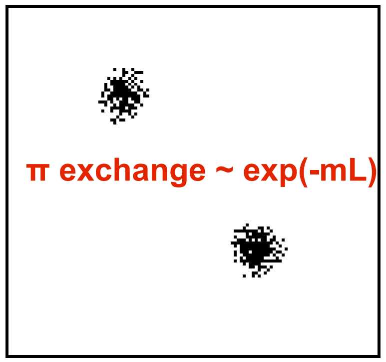
Not to misidentify rotator gaps as evidence of chirally symmetric phase !

sextet simulations are in the p-regime β=3.2 and β=3.25

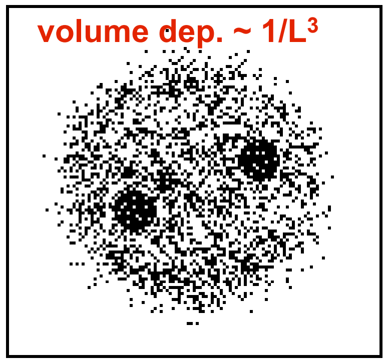
crossover to asymptotic finite volume behavior :

$$\hat{V}(\vec{k}) = \frac{F(\vec{k})^2}{\vec{k}^2 + m^2}$$ extended hadron with form factor $F(\vec{k})$

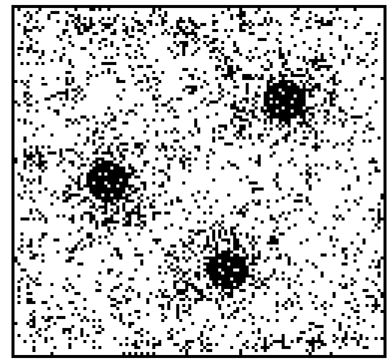
large volume hadrons point-like



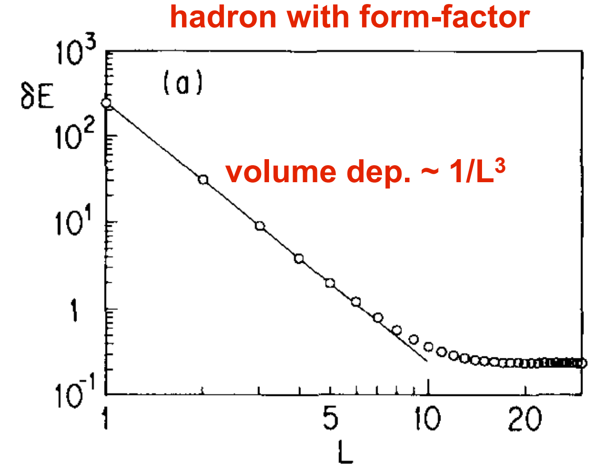
squeezed wave-function



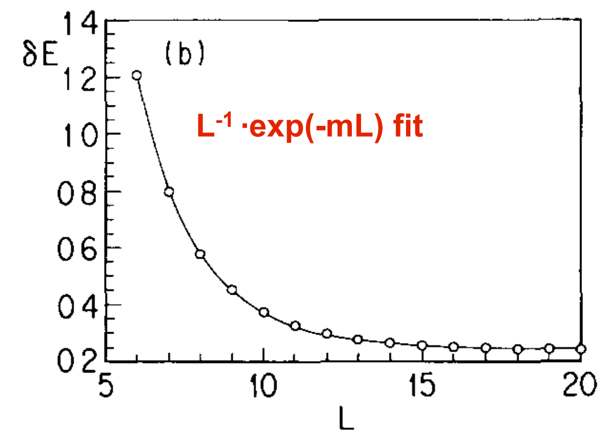
crossover to femto world



hadron with form-factor



$$F(k) = \frac{1}{1 + c \cdot \vec{k}^2}$$



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$\delta E = \sum_{\vec{n}} V(\vec{n}L)$ hadrom self energy from interaction with images

$\delta E = \frac{1}{L^3} \sum_{\vec{n}} \hat{V}(\vec{n}\frac{2\pi}{L})$ Poisson resummation, $\hat{V}(\vec{k})$ is the Fourier transform

$\hat{V}(\vec{k}) = \frac{1}{\vec{k}^2 + m^2} \Rightarrow \mathrm{V(r)} = \frac{e^{-mr}}{r}$ for large r in point-like approximation

$\delta E \approx V(0) + 6V(L)$ $\quad \delta E \approx \frac{e^{-mL}}{L}$ point-like interaction for large L (non-relativistic)

Lüscher made it relativistic using field theory

Leutwyler put in the chiral vertices, hence the $\tilde{g}(mL)$ form in chiral PT

the size where the $1/L^3$ correction to the masses disappears and the exponential behavior sets in depends on the behavior of the hadron form factor

the characteristic inverse power vs. exponential behavior can frustrate at limited lattice sizes the analysis of chiral vs. conformal hypotheses

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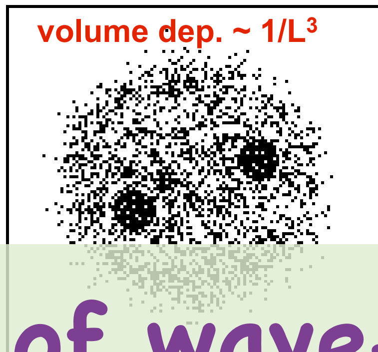

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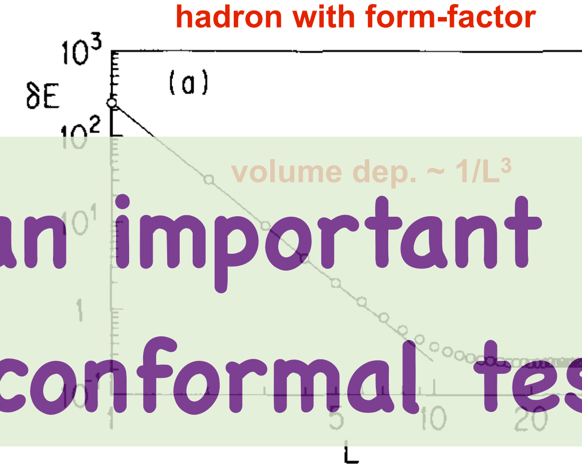

$$F(k)=\frac{1}{1+c\cdot\vec k^2}$$

Squeezing of wave-functions is an important effect potentially confusing chiral and conformal tests

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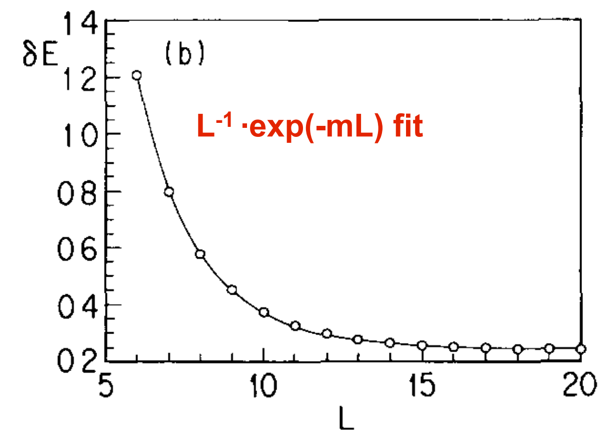

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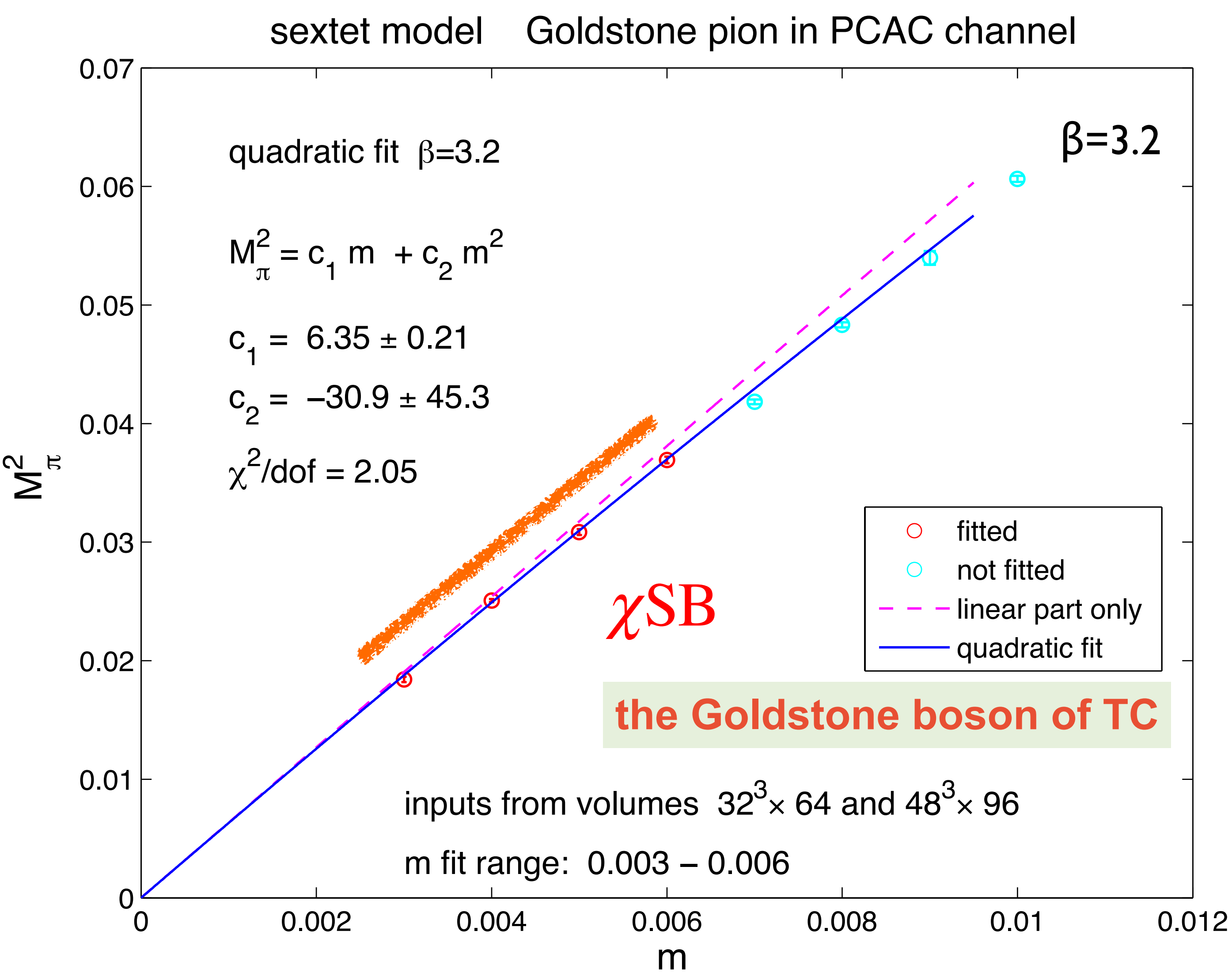
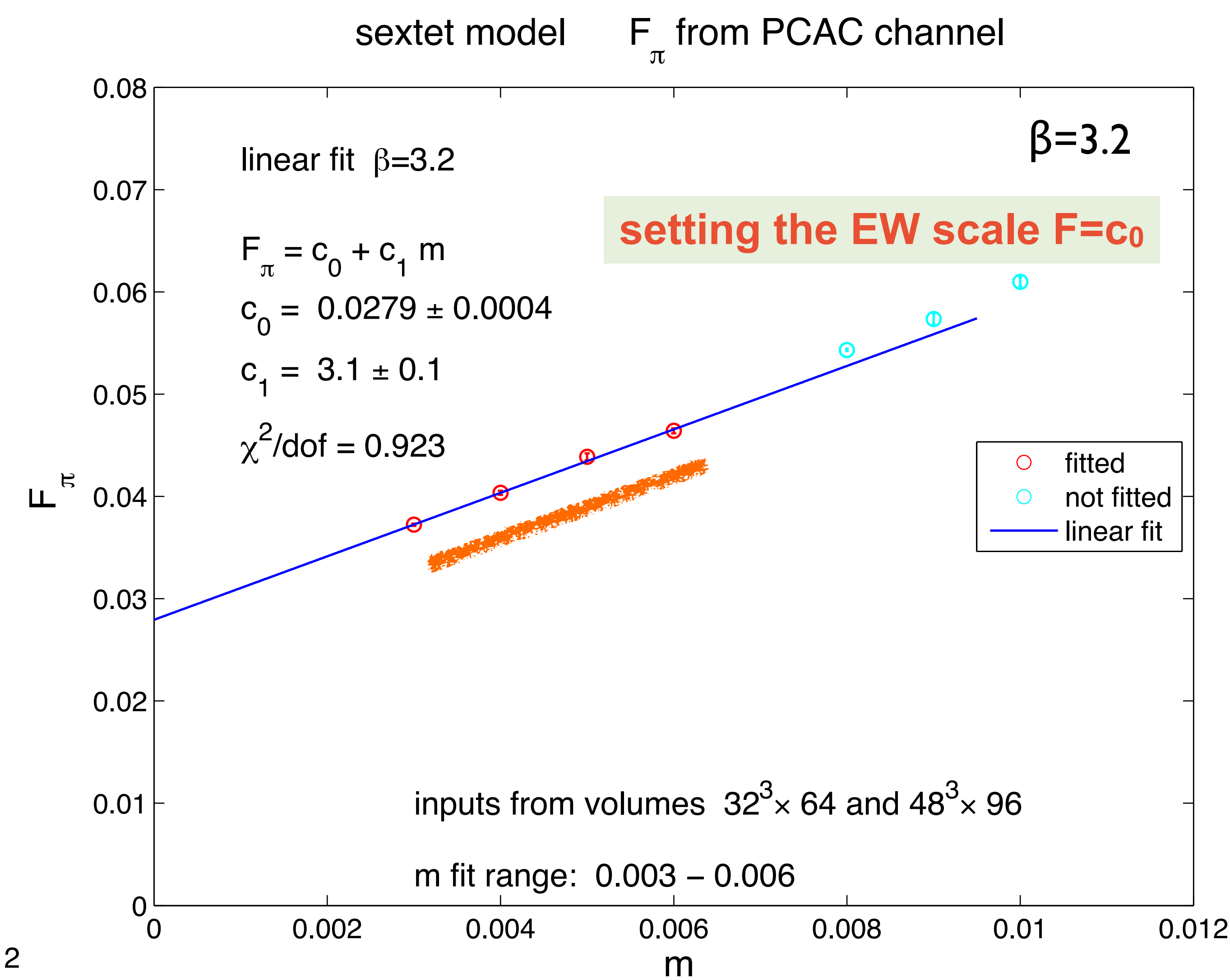
Nf=2 SU(3) sextet chiral fits of M_π and F_π



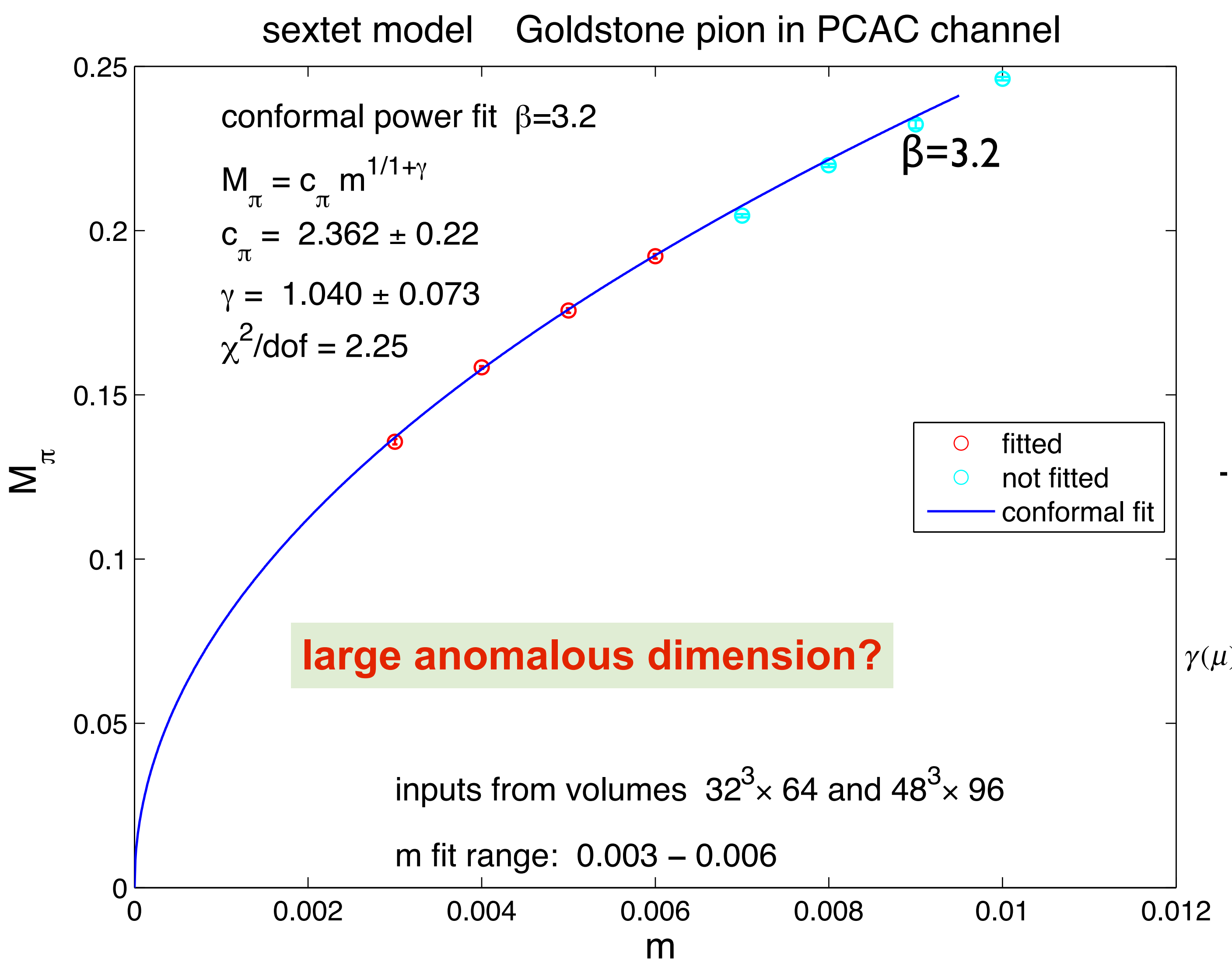


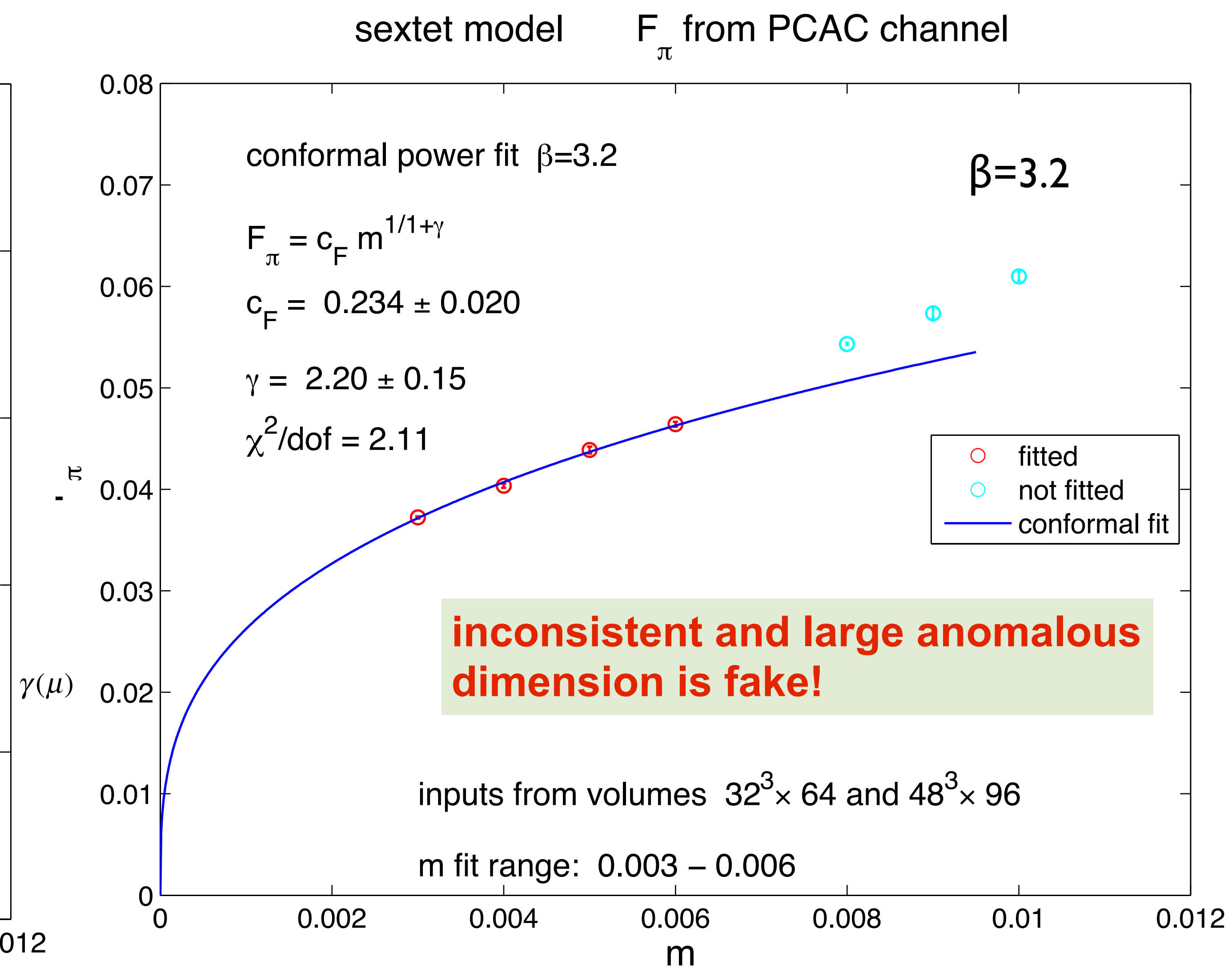
m=0.003-0.006 range close to chiral log regime? Nf=2 helps, more QCD-like

log detection will require more precise data

consistency with partially quenched staggered chiral perturbation theory?

conformal hypothesis breaks down in global fits:

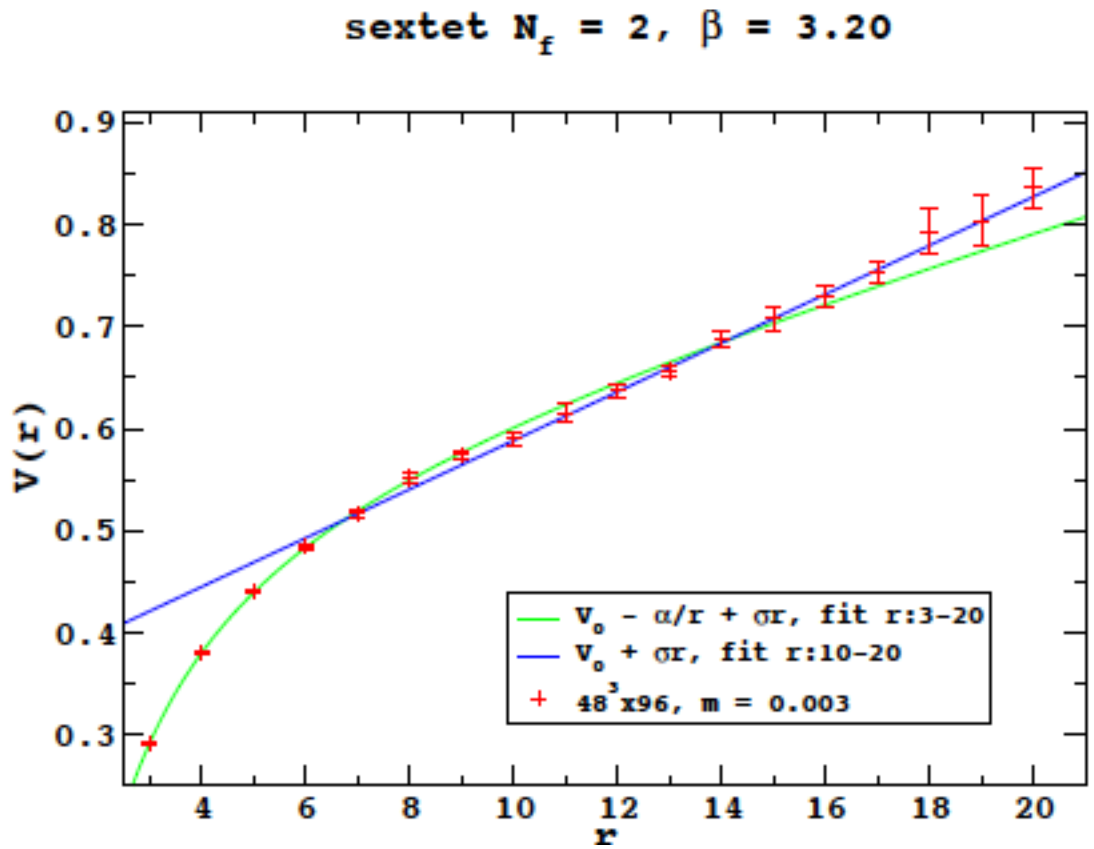


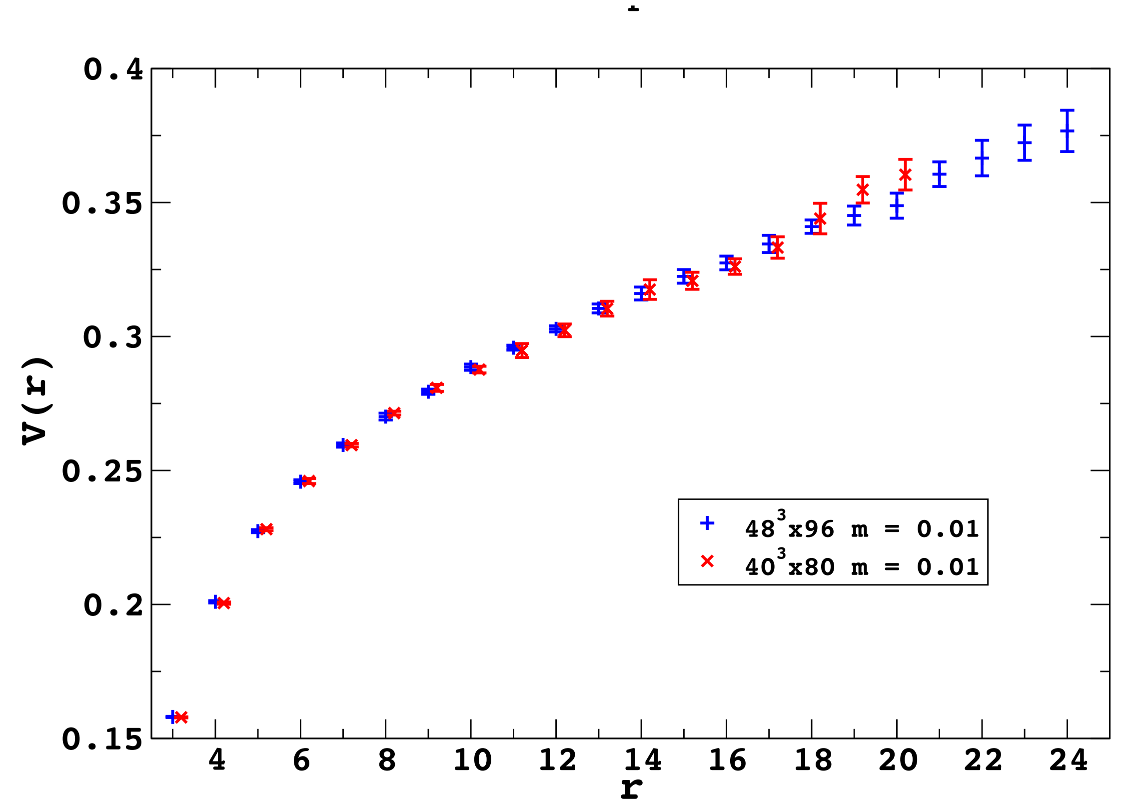


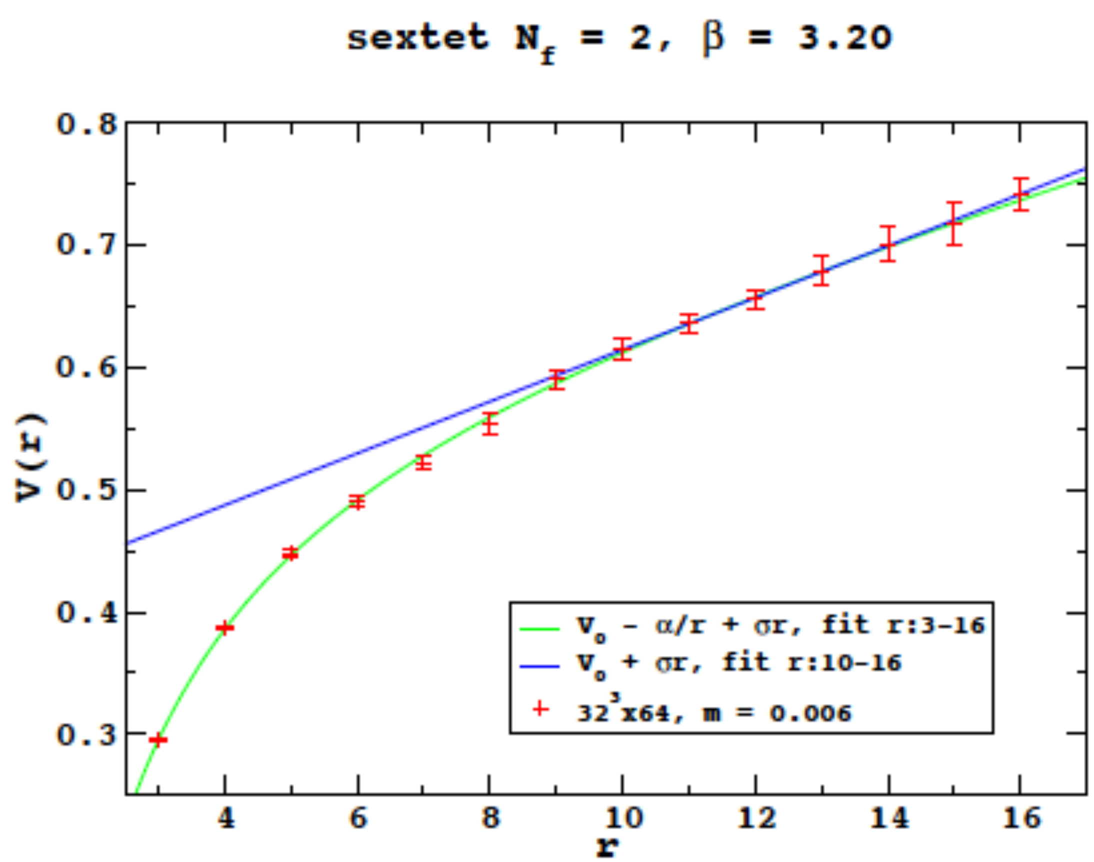
large effective "critical exponents" (γ) are forced by chiral behavior in far infrared

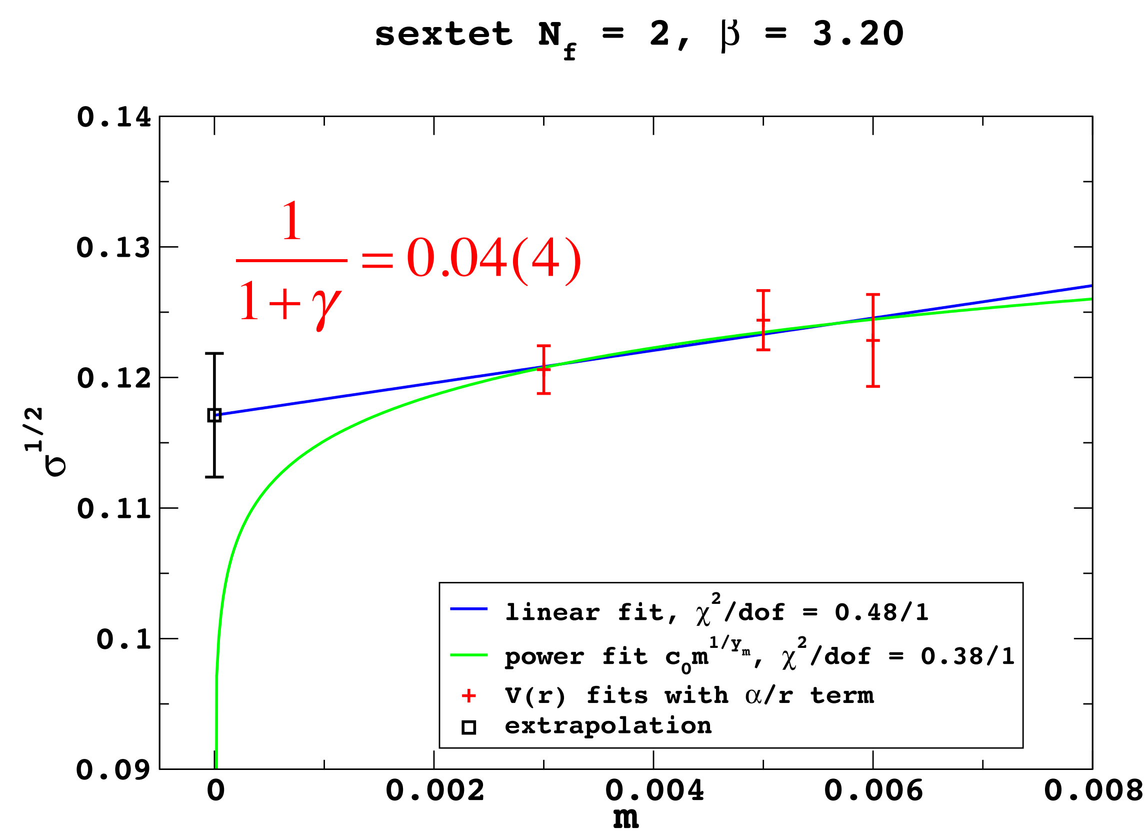
it is not the running $\gamma(\mu)$ at scale μ!

sextet simulations confining force at finite m? (LHC group)









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running coupling at m=0

running coupling at m=0

Schrodinger functional

running coupling at m=0

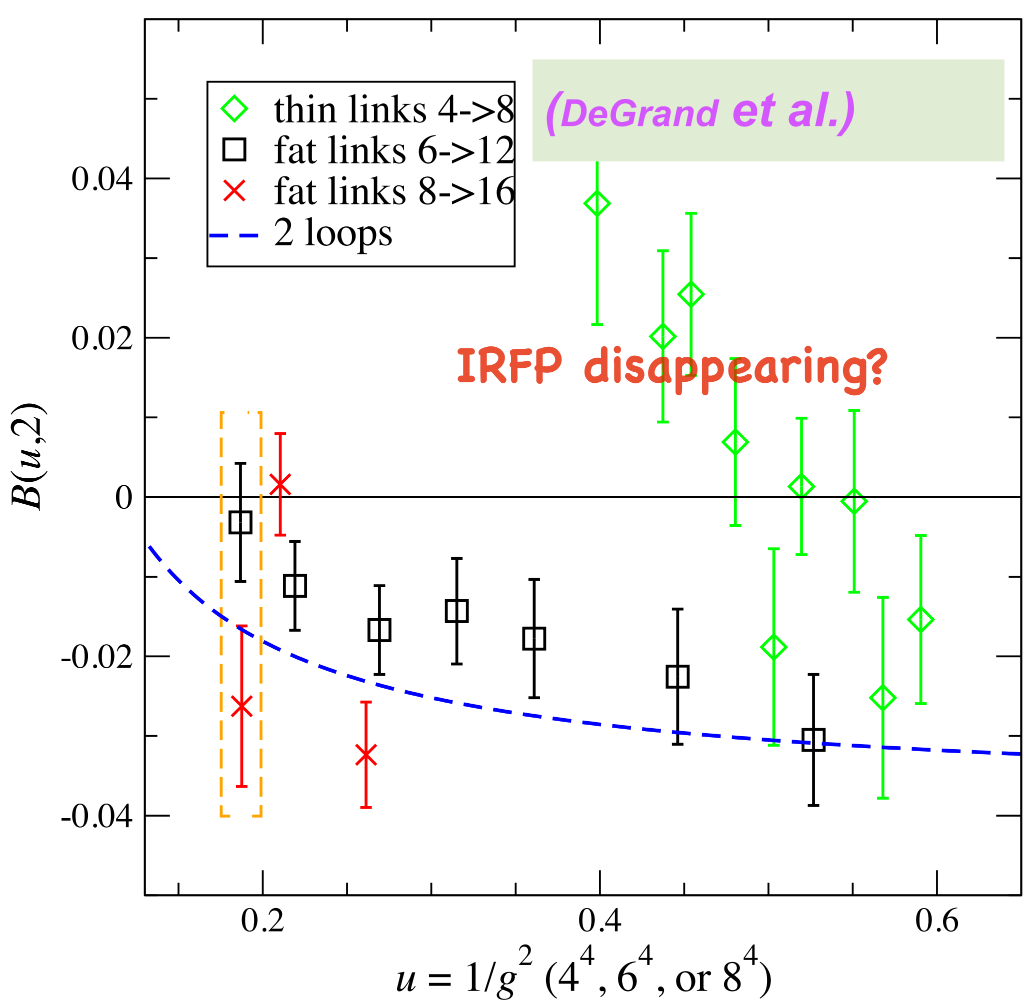
Schrodinger functional

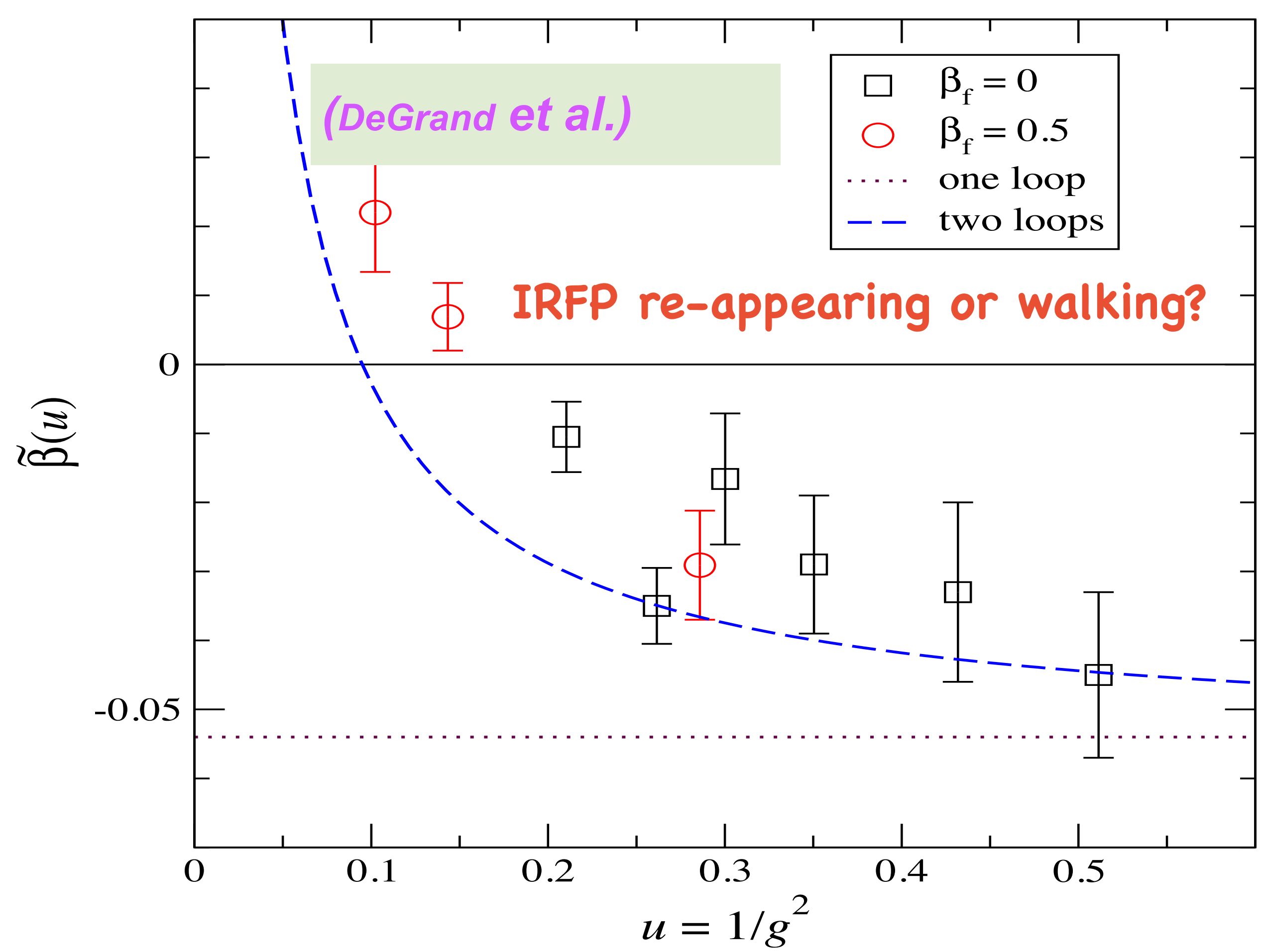
New gradient flow coupling

DeGrand et al. find: Nf=2 sextet beta function may have an IRFP zero, or walks?

good work and difficult model

chiral symmetry breaking is not inconsistent with the results ➜ walking?





Some independent method using a different running coupling scheme?

LHC group

Running coupling definition from gauge field gradient flow

$$\langle E(t) \rangle = \frac{3}{4\pi t^2}\alpha(q)\left\{1 + k_1\alpha(q) + O(\alpha^2)\right\}, \quad q = \frac{1}{\sqrt{8t}}, \quad k_1 = 1.0978 + 0.0075 \times N_f$$

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t is the gradient flow time

Running coupling definition (range is $(8t)^{1/2}$) :

while holding $c = (8t)^{1/2}/L$ fixed: $\alpha_c(L) = \frac{4\pi}{3}\frac{\langle t^2 E(t)\rangle}{1+\delta(c)}$

$$\delta(c) = \vartheta_3^4(e^{-1/c^2}) - 1 - \frac{c^4\pi^2}{3}$$

3rd Jacobi function

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massless fermions; antiperiodic all directions s=1.5 step

N_f=4 staggered fermions; 4-stout; L=12-18; 16-24; 24-36

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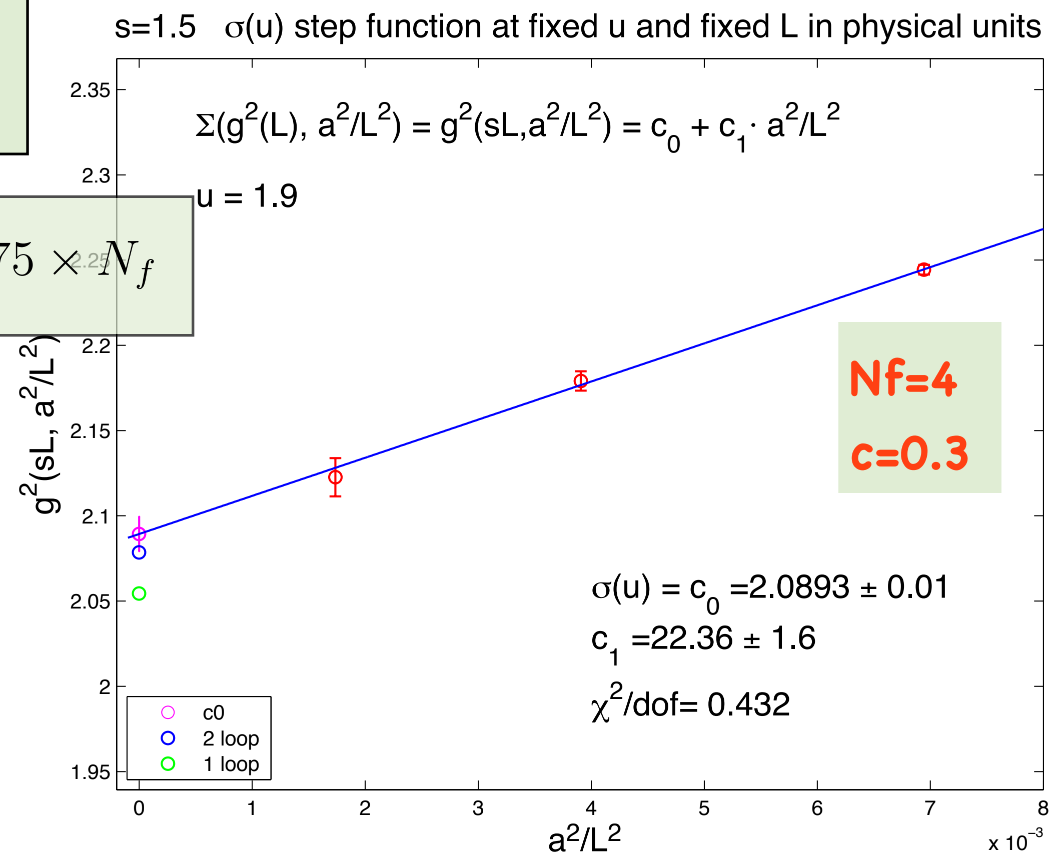

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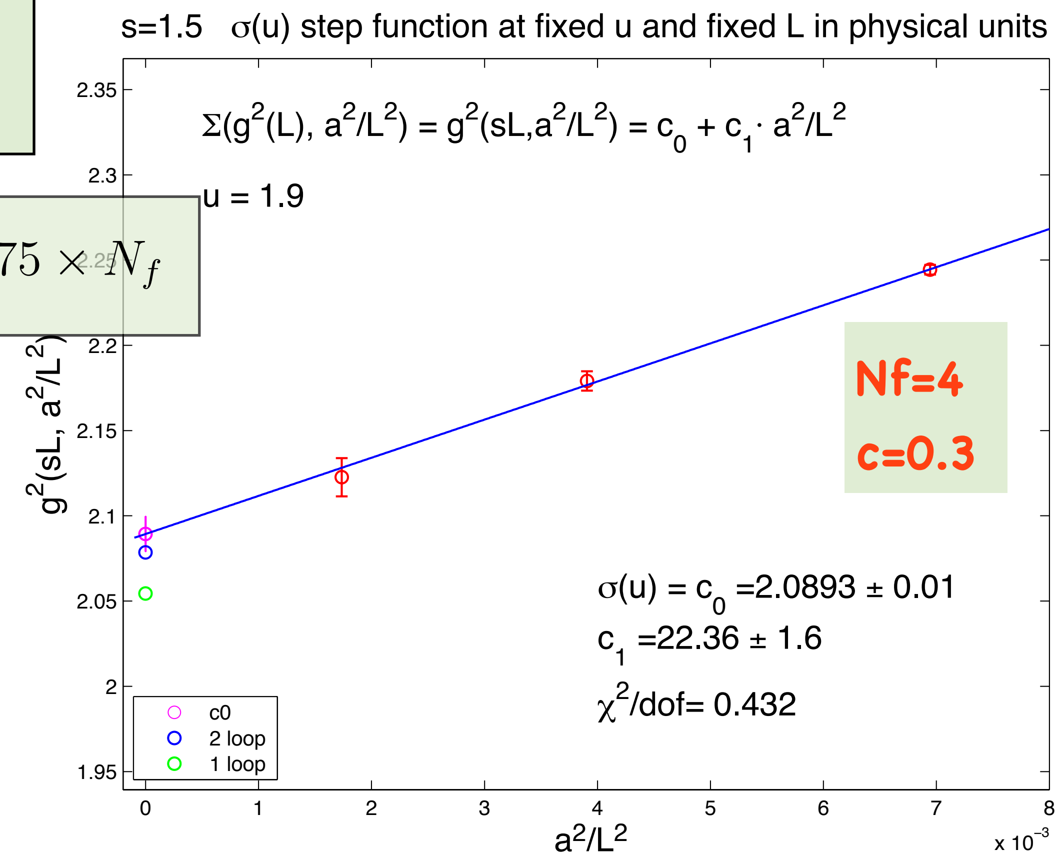

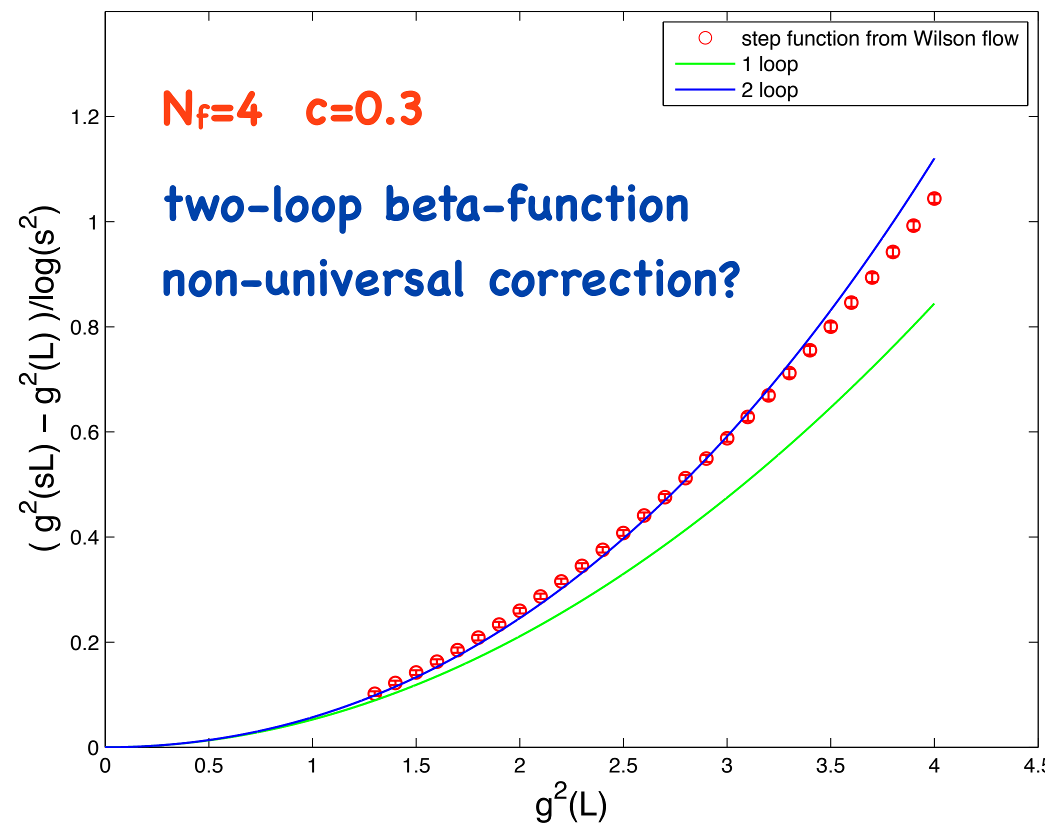

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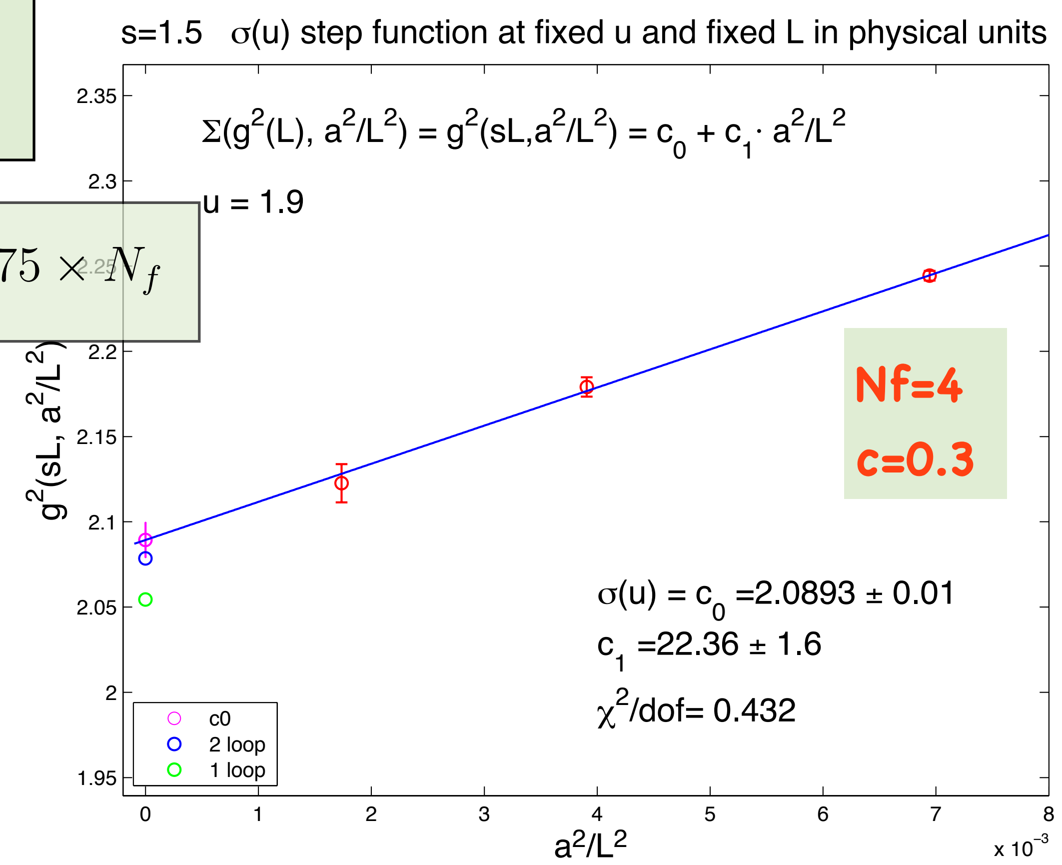
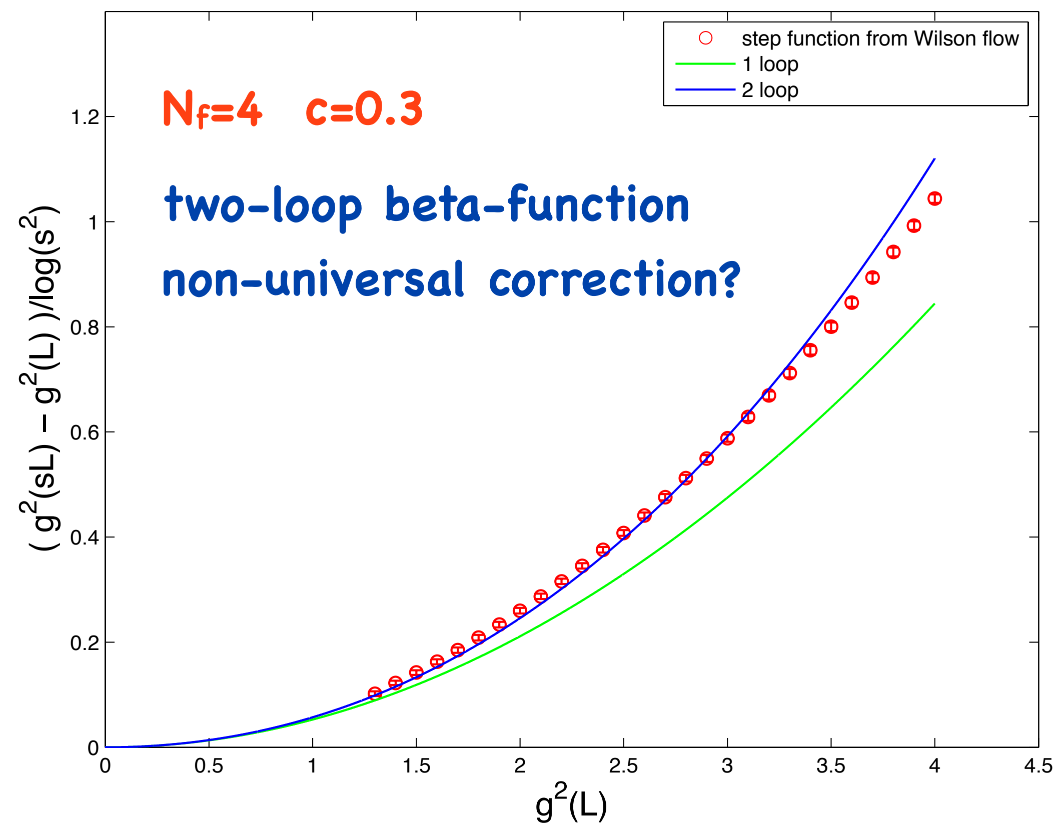
$$\delta(c) = \vartheta_3^4(e^{-1/c^2}) - 1 - \frac{c^4\pi^2}{3}$$

3rd Jacobi function





massless fermions; antiperiodic all directions s=1.5 step

Nf=4 staggered fermions; 4-stout; L=12-18; 16-24; 24-36

run production now in sextet model

Outline

how large Theory Space is needed?

the sextet model as a simple example

light scalar and dilaton mechanism close to CW

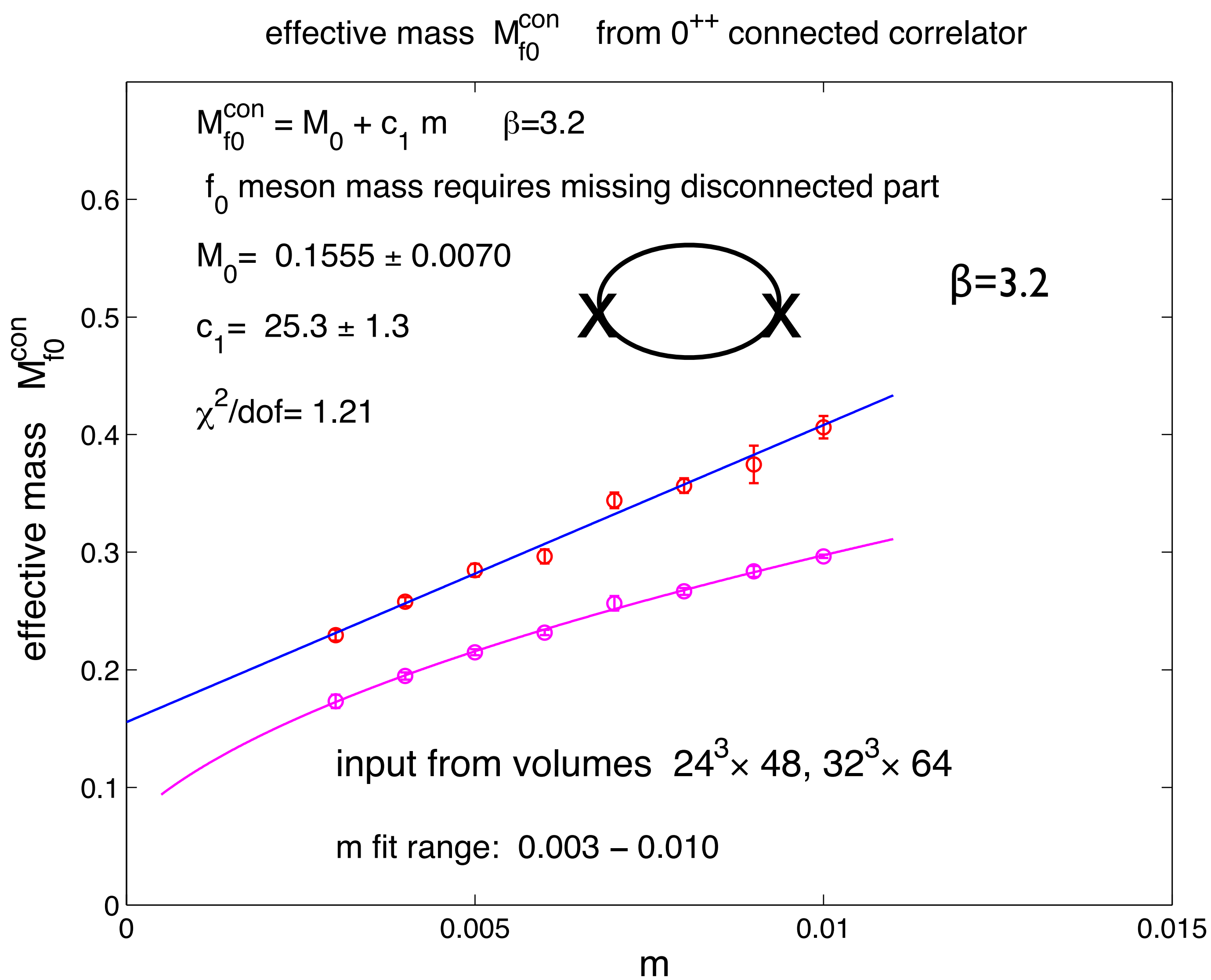
chiral condensates and spectroscopy

running (walking) coupling

light scalar spectroscopy of 0^{++} states

Summary and outlook

Nf=2 SU(3) sextet chiral fits: f_0 state with 0^{++} quantum numbers:



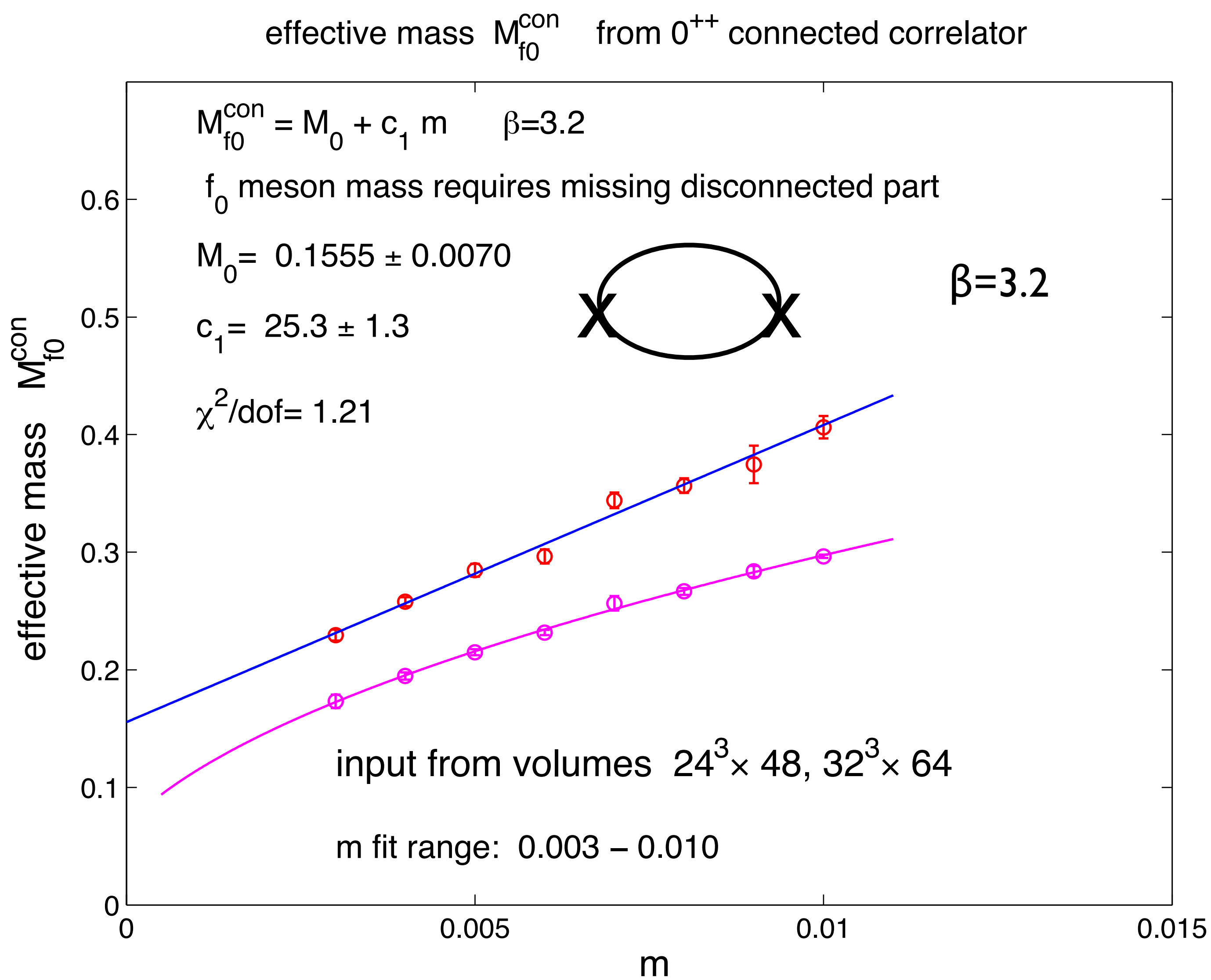
M(f_0)/F ~ 6
without disconnected diagram:

Higgs impostor in coupled channels?

ππ, 0^{++} glueball, f_0 scalar coupled!

0^{++} glueball can have low mass!

Nf=2 SU(3) sextet chiral fits: f_0 state with 0^{++} quantum numbers:



$M(f_0)/F \sim 6$
without disconnected diagram:

Higgs impostor in coupled channels?

ππ, 0^{++} glueball, f_0 scalar coupled!

0^{++} glueball can have low mass!

annihilation diagram with good signal/noise: demanding project

CMU group demonstrated that it can be done!

CMU ➜ UCSD: Ricky Wong is lead in the sextet application of the method

staggered fermions with rooting presents added complications (Bernard et al.)

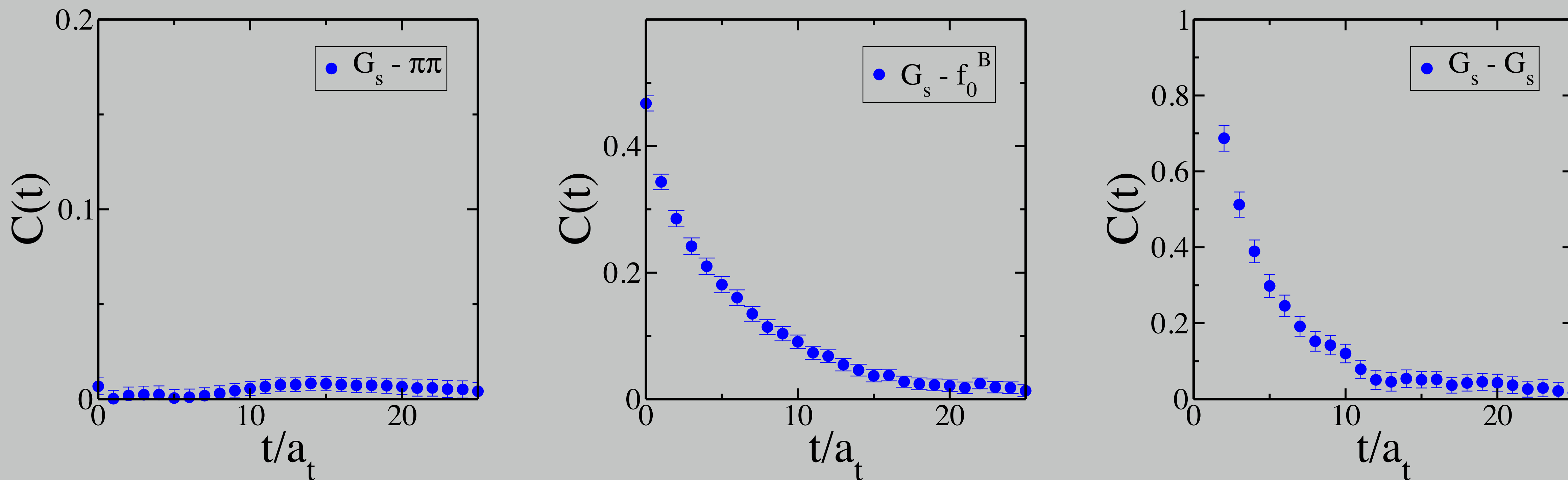
light scalar? (Higgs impostor?)

first step is to solve the mixing of the 0^{++} scalar state with 0^{++} glueball state and with two-pion state

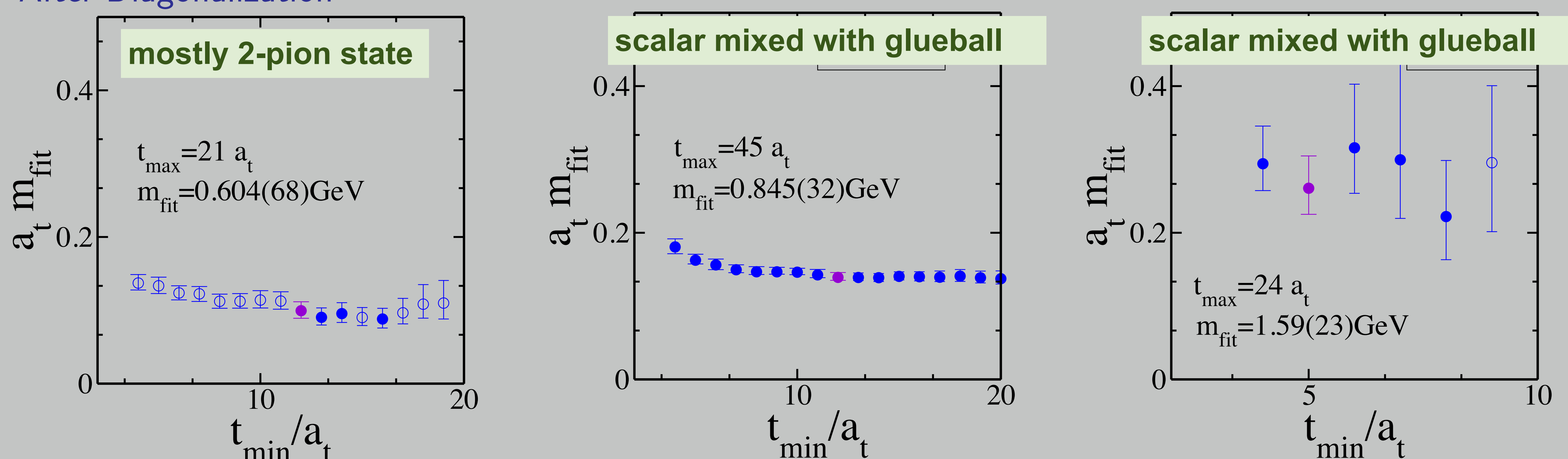
first finding of Nf=12 low mass glueball from KMI group is promising

Preliminary Results–Particle(s) Mixing in $J^{PG} = 0^{++}$ Channel

- Lowest Energy Levels: Mixture of f_0(or σ), G_S and $I = 0$ S-Wave of $\pi\pi$ at rest
- Examined on $16^3 \times 128$ $N_f = 2 + 1$ $m_\pi = 0.3911(14)$GeV Anisotropic Clover Ensemble (99 configs; Time Dilution: Full, LapH Dilution: Full, Spin Dilution: Full; Two f_0 Operators f_0^A and f_0^B)



- After Diagonalization



Level 0: $\pi\pi$ Dominates

Level 1: f_0 Dominates

Level 2: G_S and f_0 Dominate

Preliminary Results–Particle(s) Mixing in $J^{PG} = 0^{++}$ Channel

Chik Him Wong[1*], John Bulava[2], Justin Foley[3], You-Cyuan Jhang[1], Keisuke Juge[4], David Lenkner[1], Colin Morningstar[1]
[1]Carnegie Mellon University, Pittsburgh, US [2]NIC, DESY Zeuthen, Germany
[3]University of Utah, Salt Lake City, US [4]University of the Pacific, Stockton, US

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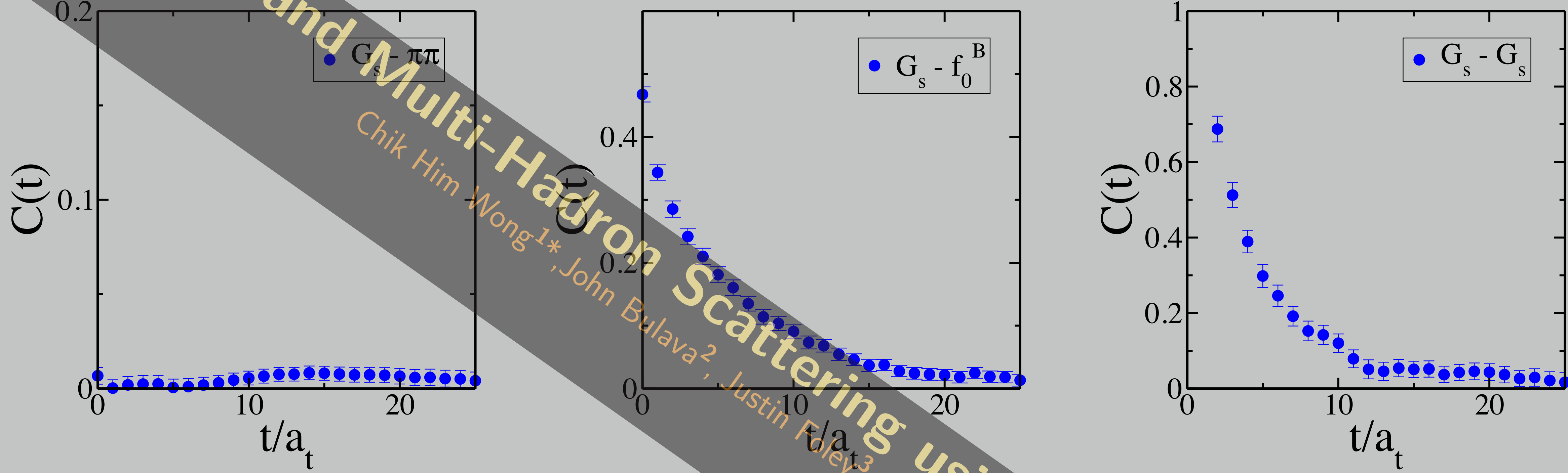

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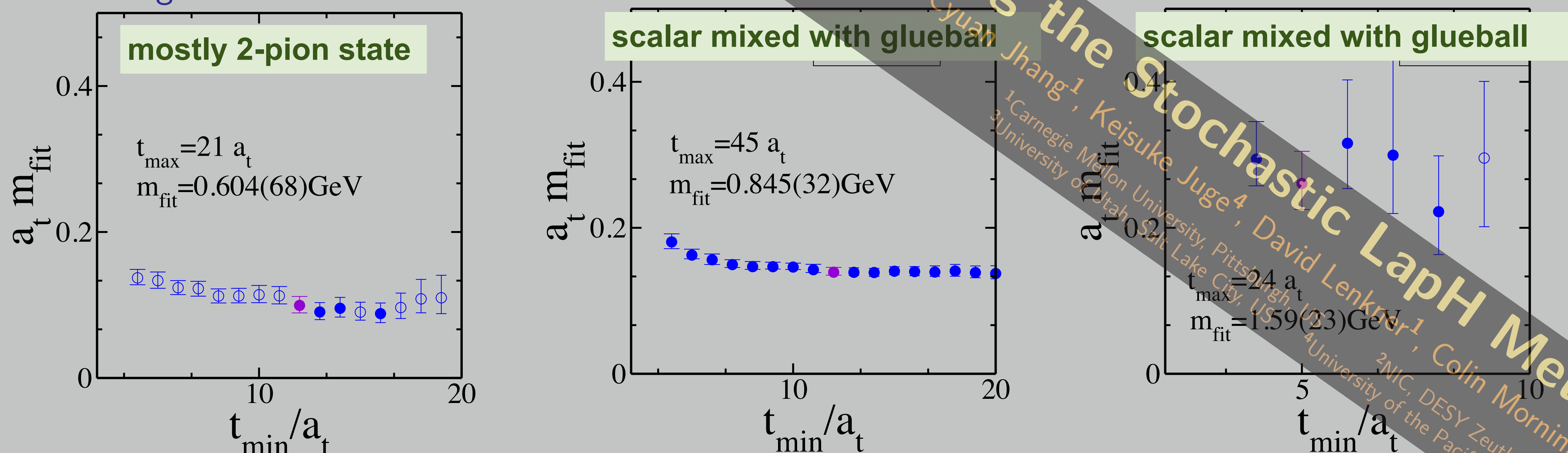

Level 0: $\pi\pi$ Dominates — Level 1: f_0 Dominates — Level 2: G_S and f_0 Dominate

Preliminary Results–Particle(s) Mixing in $J^{PG} = 0^{++}$ Channel

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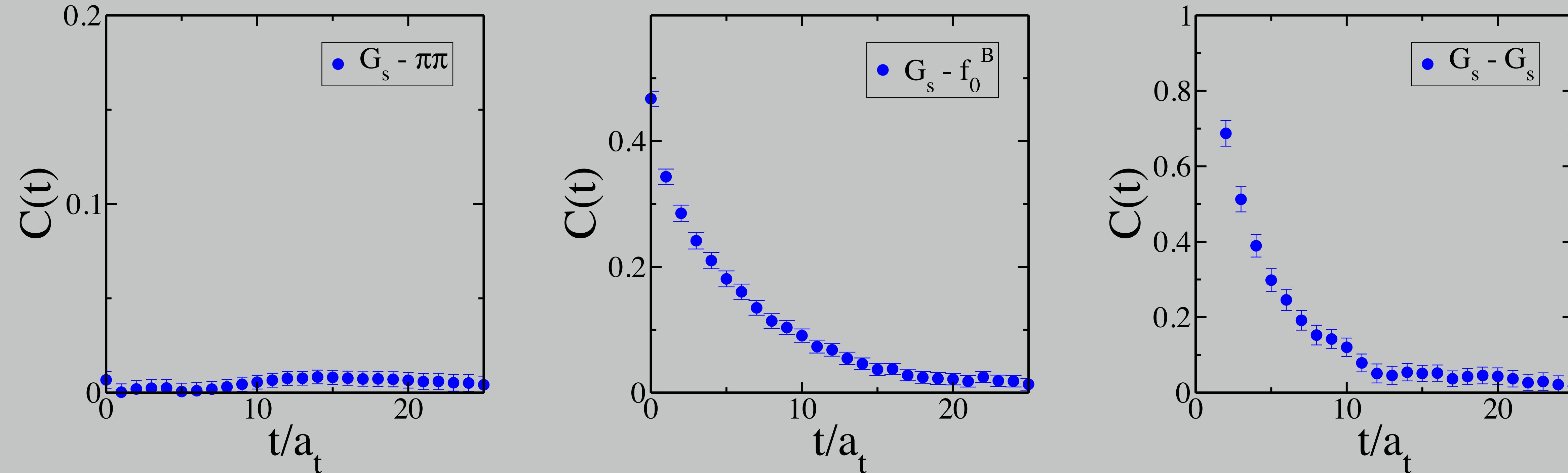

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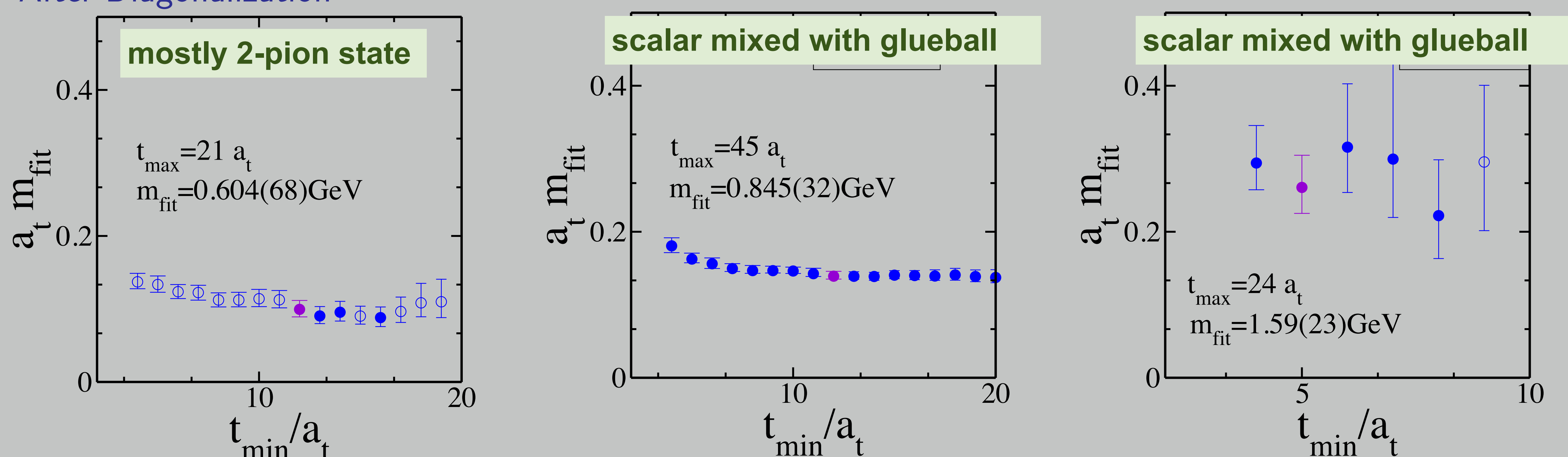

Level 0: $\pi\pi$ Dominates

Level 1: f_0 Dominates

Level 2: G_S and f_0 Dominate

Summary and Outlook

- Lattice community has developed powerful tools to study BSM theories

- The most interesting models are the hardest to calculate

- Sextet model close to CW? remains Higgs impostor candidate - unresolved issues

- Close to conformal window large fluctuations in finite volume make the the identification of conformal and chiSB phases difficult

- new algorithmic developments have major impact:
  fermion matrix inversion, improved disconnected correlators, ...

- Scalar spectrum from disconnected correlators is high lattice BSM priority

- Lattice BSM community is "theory aware" but more off-lattice input can help

backup slides

conformal scaling test with FSS - physical model fit (spline fit similar)