Der Wissenschaftsfonds.

An overview of meson phenomenology from the DSBSE approach

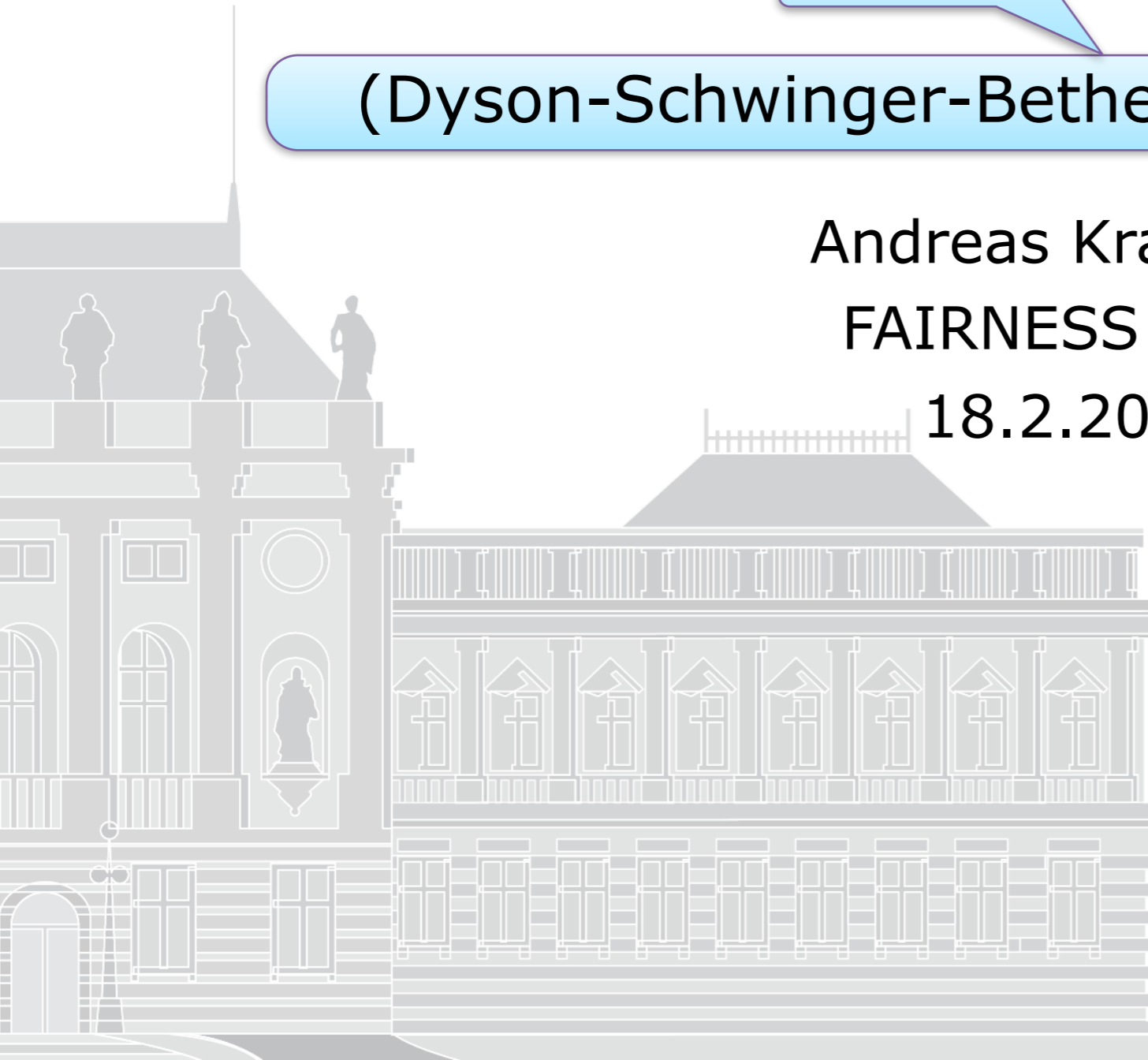(Dyson-Schwinger-Bethe-Salpeter-Equation)

Andreas Krassnigg

FAIRNESS 2016

18.2.2016
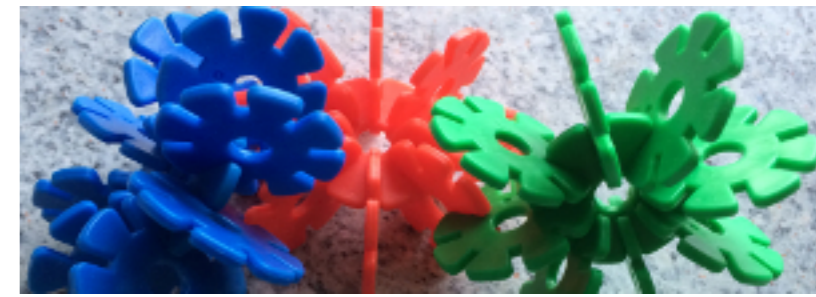
@akrassnigg

Metadata

Work done at:

University of Graz, Inst. f. Physik, NAWI Graz

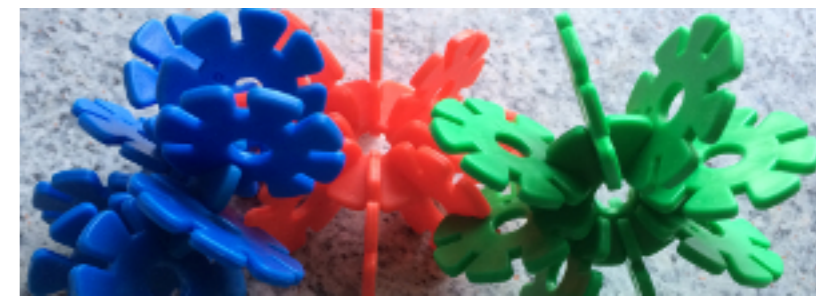Research group "Covariant Models of Hadrons"

http://Covariant.ModelsofHadrons.com

Collaborators:

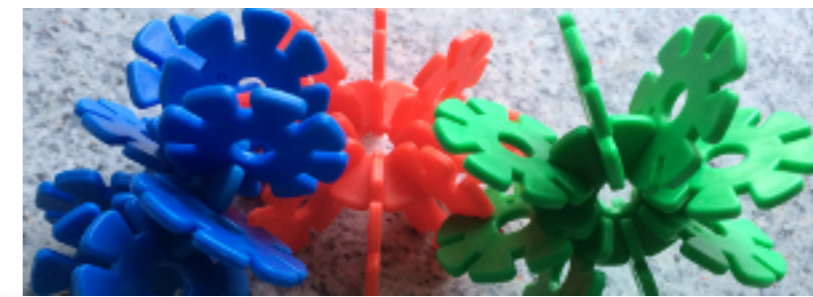M. Blank, M. Gomez-Rocha, T. Hilger, C. Popovici,

G. Eichmann, V. Mader

Outline

- Hadron Theory
- The Tool: DSBSE Formalism
- Spectroscopy - Just a Glimpse
- Hadron Decays
- Form Factors
- Outlook

Hadron Theory

- Study hadrons as composites of quarks and gluons...
- ... including:
  - Chiral symmetry and $D\chi SB$
  - correct perturbative limit (via $\alpha_{\rm p}(Q^2)$)
  - quark and gluon confinement
  - Poincare covariance
- Calculate Observables
- Provide comprehensive results for phenomenology


http://www.particlezoo.net/

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The Tool: DSBSE Formalism

- Dyson-Schwinger equations can be used to solve QCD
- Bethe-Salpeter and Faddeev-type equations allow covariant and symmetry-preserving study of bound-state problems
- Infinite set of coupled (and nonlinear) integral equations
- Numerical studies: Truncation $\leftrightarrow$ numerical effort
- Make the truncation respect symmetries
- Construct sophisticated models
- Perform reliable calculations of hadron properties
- Reviews:
  - C.D. Roberts and S.M. Schmidt, Prog. Part. Nucl. Phys. 45 (2000) S1
  - R. Alkofer and L. von Smekal, Phys. Rept. 353 (2001) 281
  - C. S. Fischer, J. Phys. G 32 (2006) R253
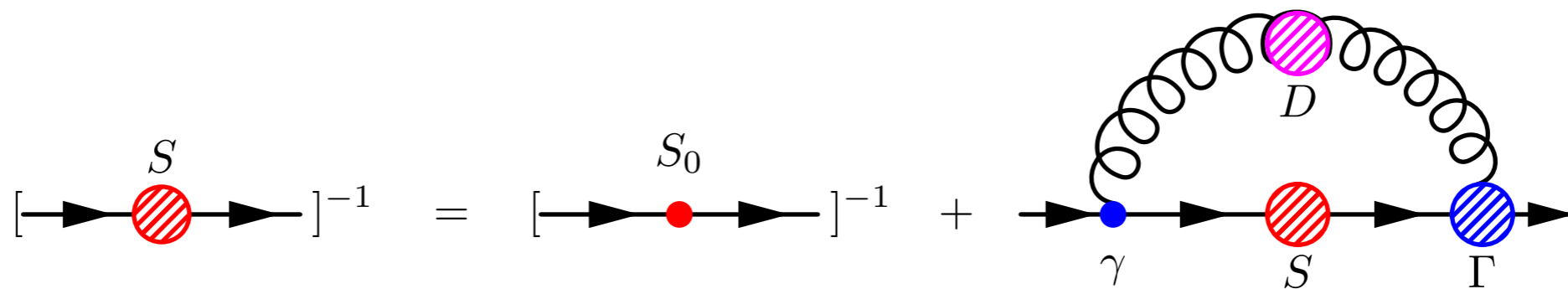 - C.D. Roberts, M. S. Bhagwat, A. Holl, S. V. Wright, Eur. Phys. J. Special Topics 140 (2007) 53
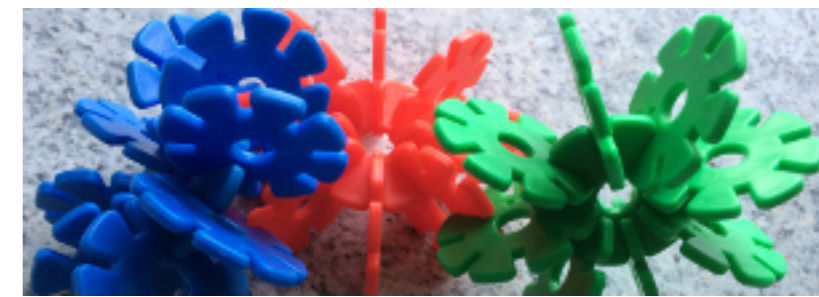
The DSBSE system
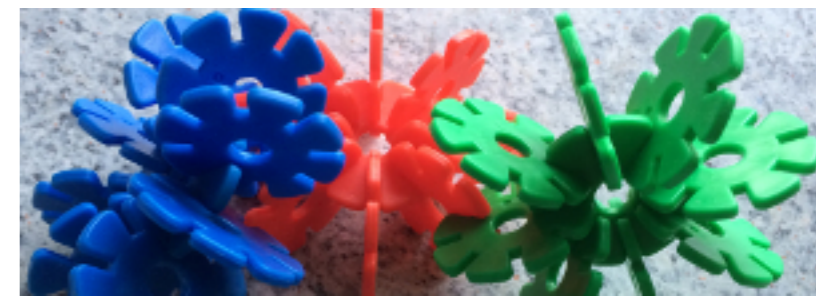
meson BSE

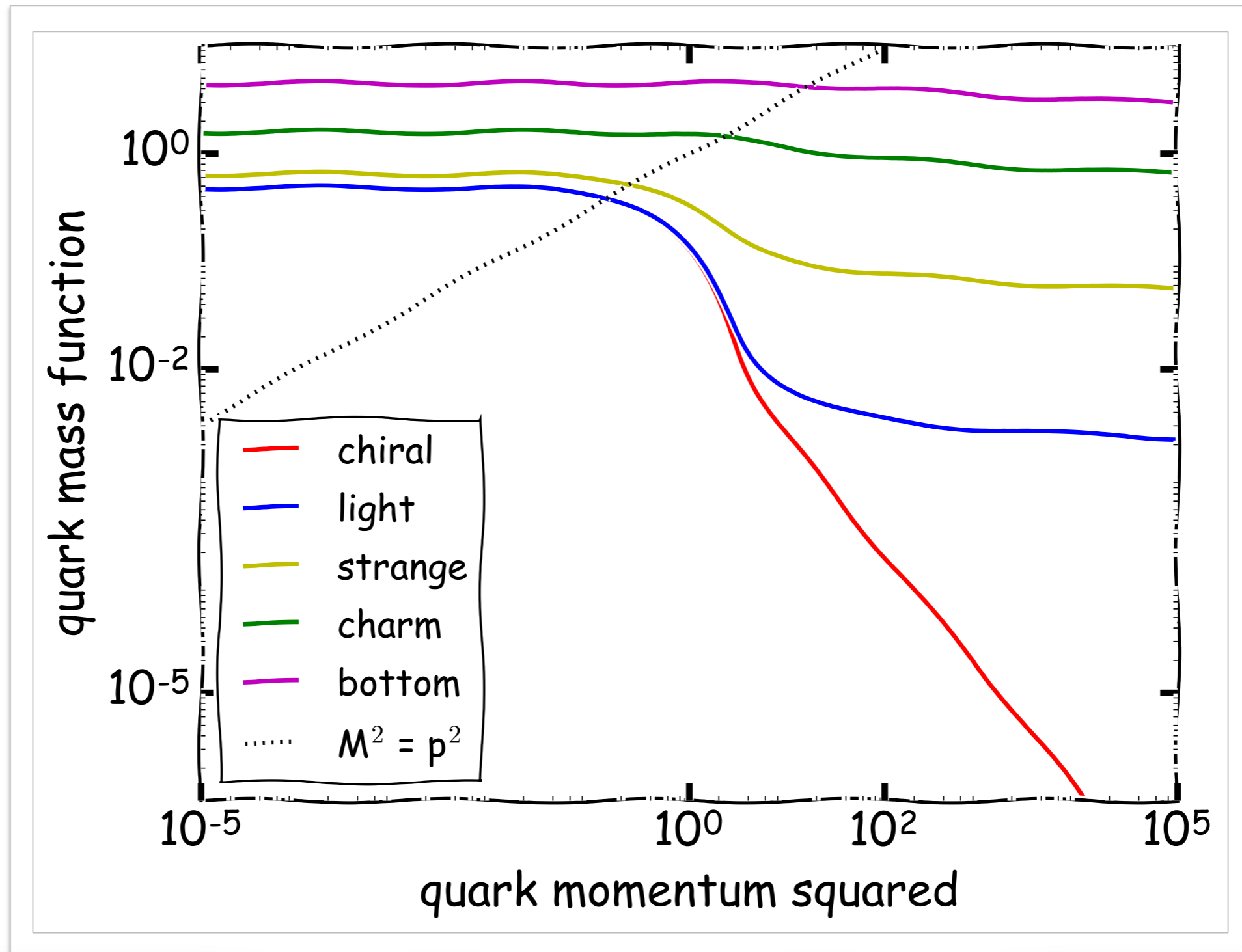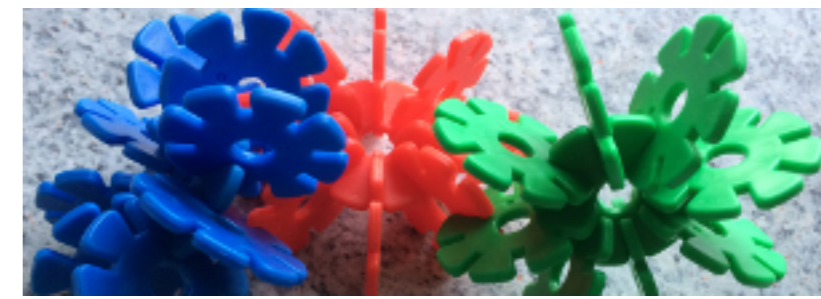

quark DSE

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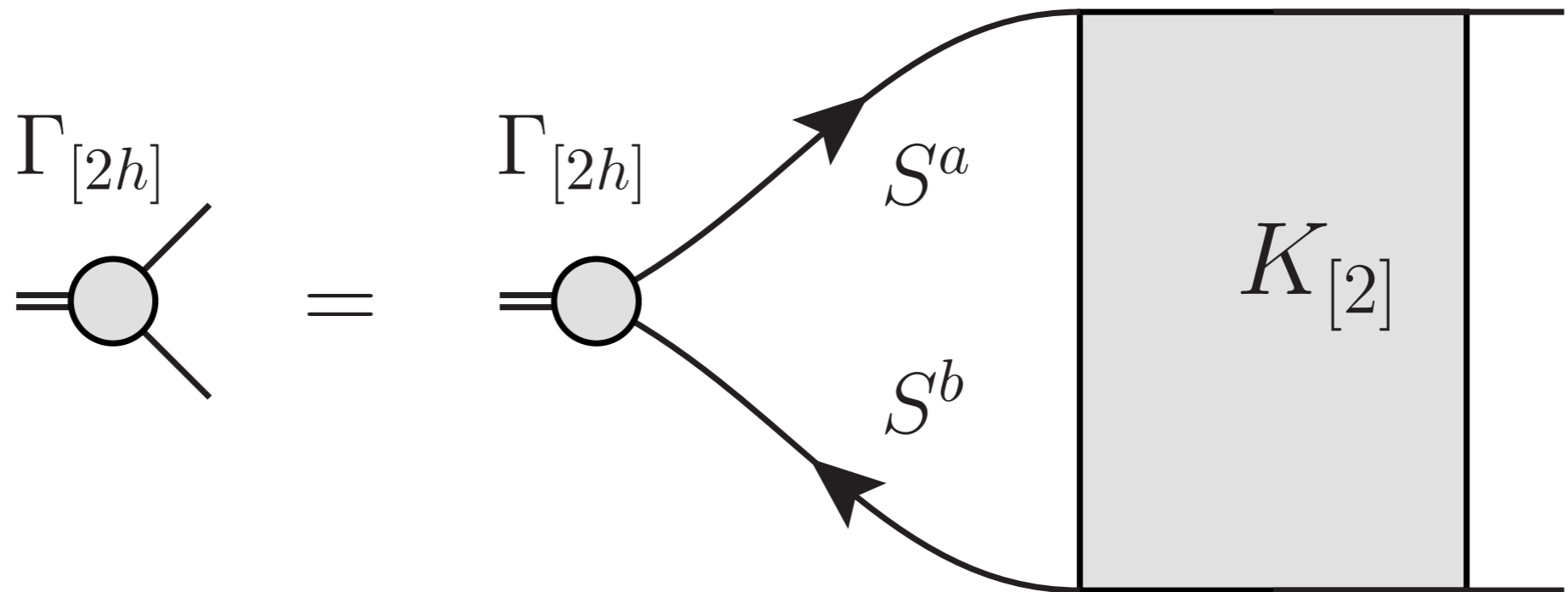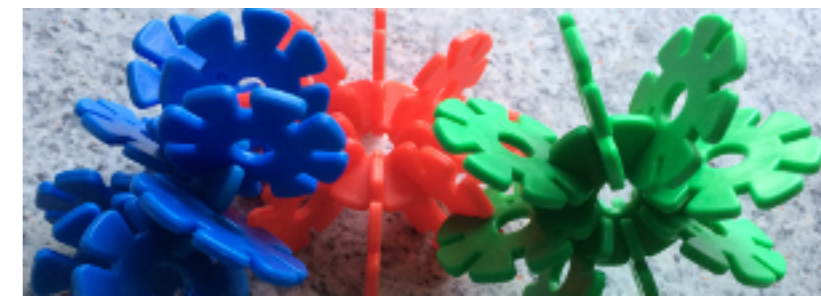
The DSBSE system
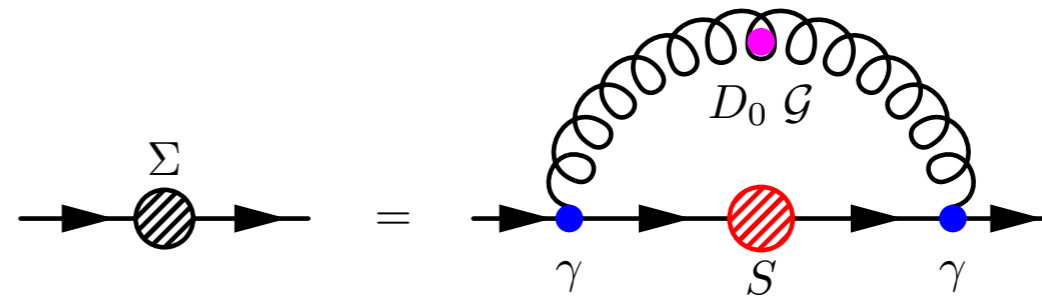
The quark DSE is often also called the QCD-

-Equation

Solutions to the quark DSE

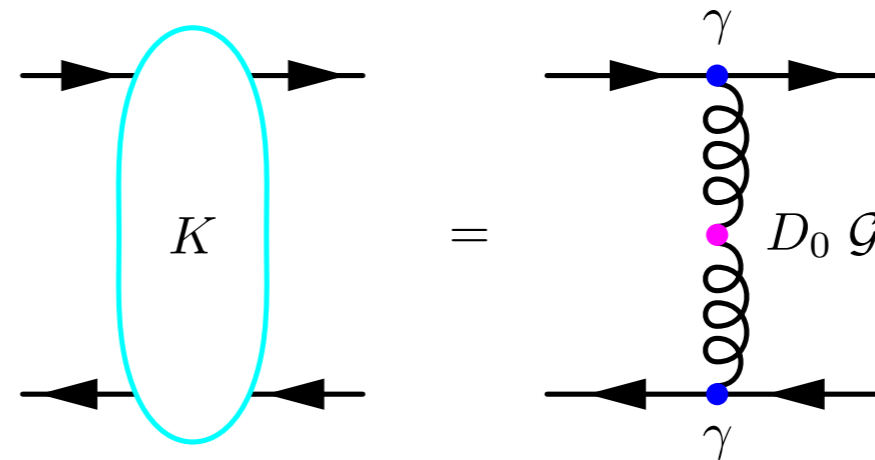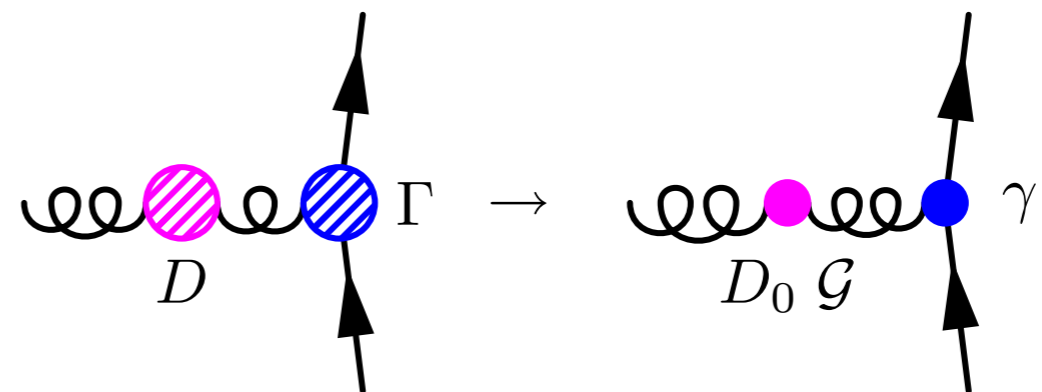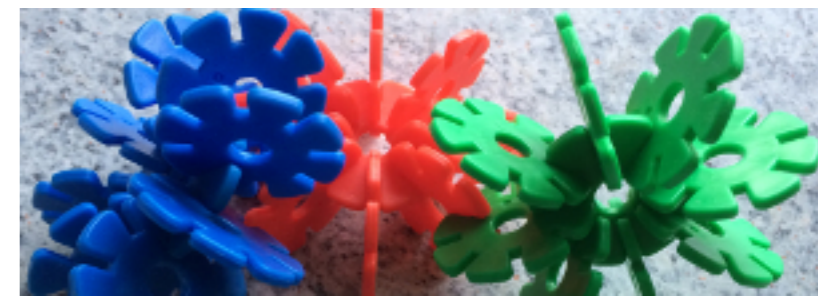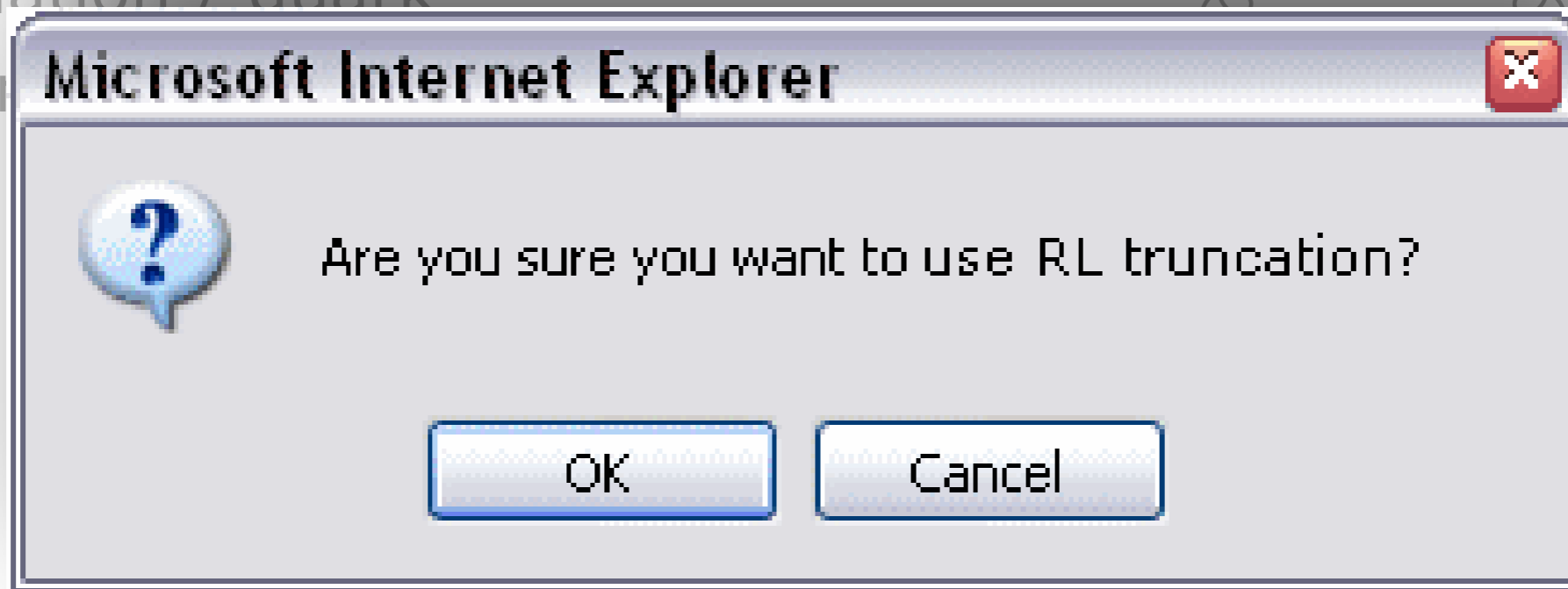# Rainbow-Ladder Truncation

Gap equation / quark self-energy:

BSE:

Interaction:

Rainbow-Ladder Truncation

Gap equation / quark
self-energy:

$D_0\,\mathcal{G}$

BSE:

Microsoft Internet Explorer

? Are you sure you want to use RL truncation?

[OK]   [Cancel]

Interaction:

D Γ $\to$ $D_0\,\mathcal{G}$ γ
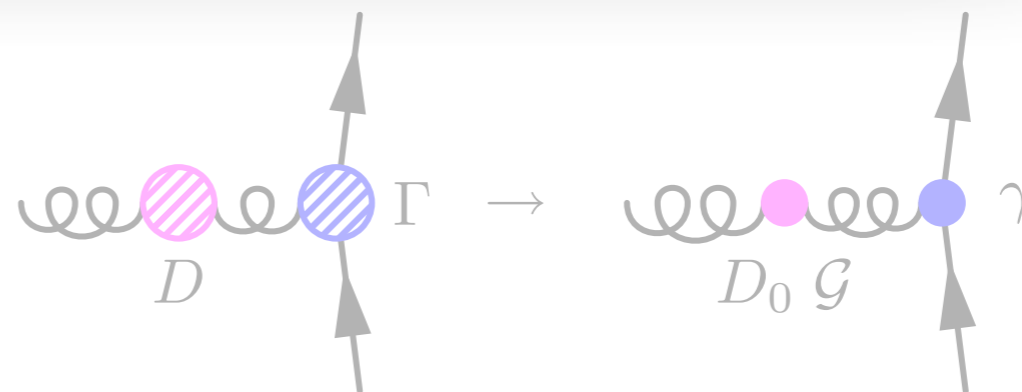
Beyond Spectroscopy

Leptonic decay:

Γ_π S $\gamma_5\gamma_\mu$ S
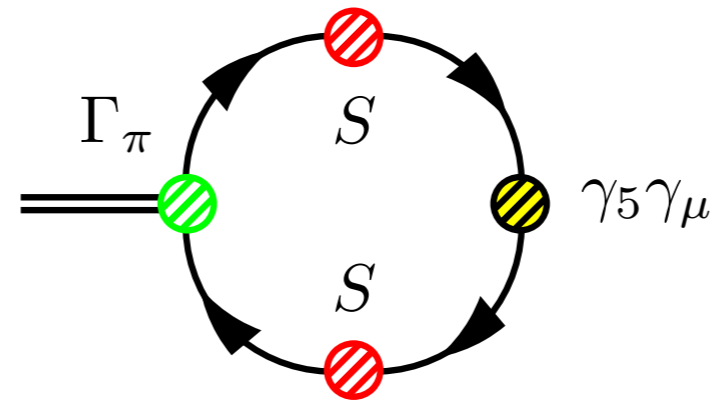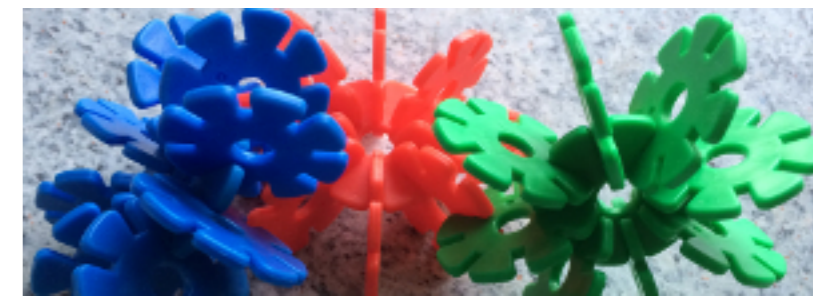
Hadronic decay
& Form factor:

$\Gamma_{\rho/\gamma}$ S S Γ_π Γ_π S
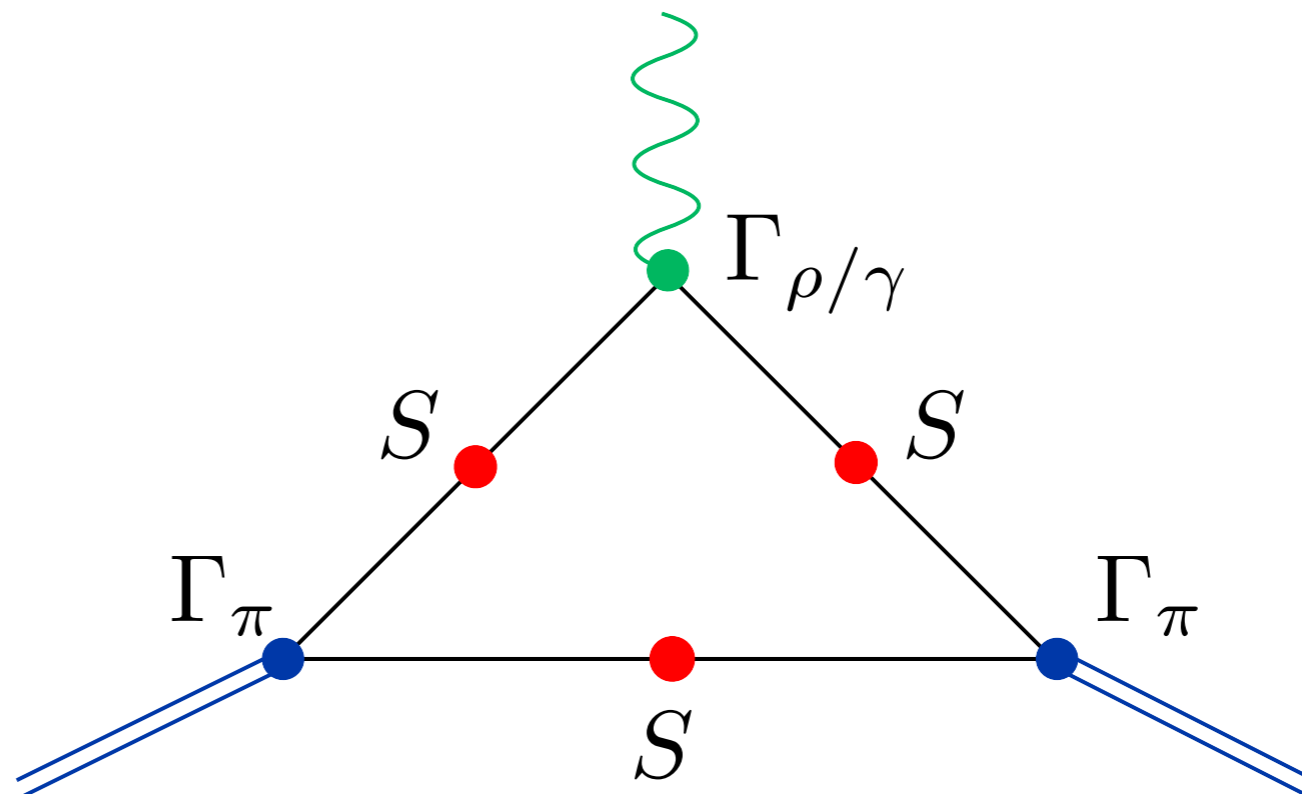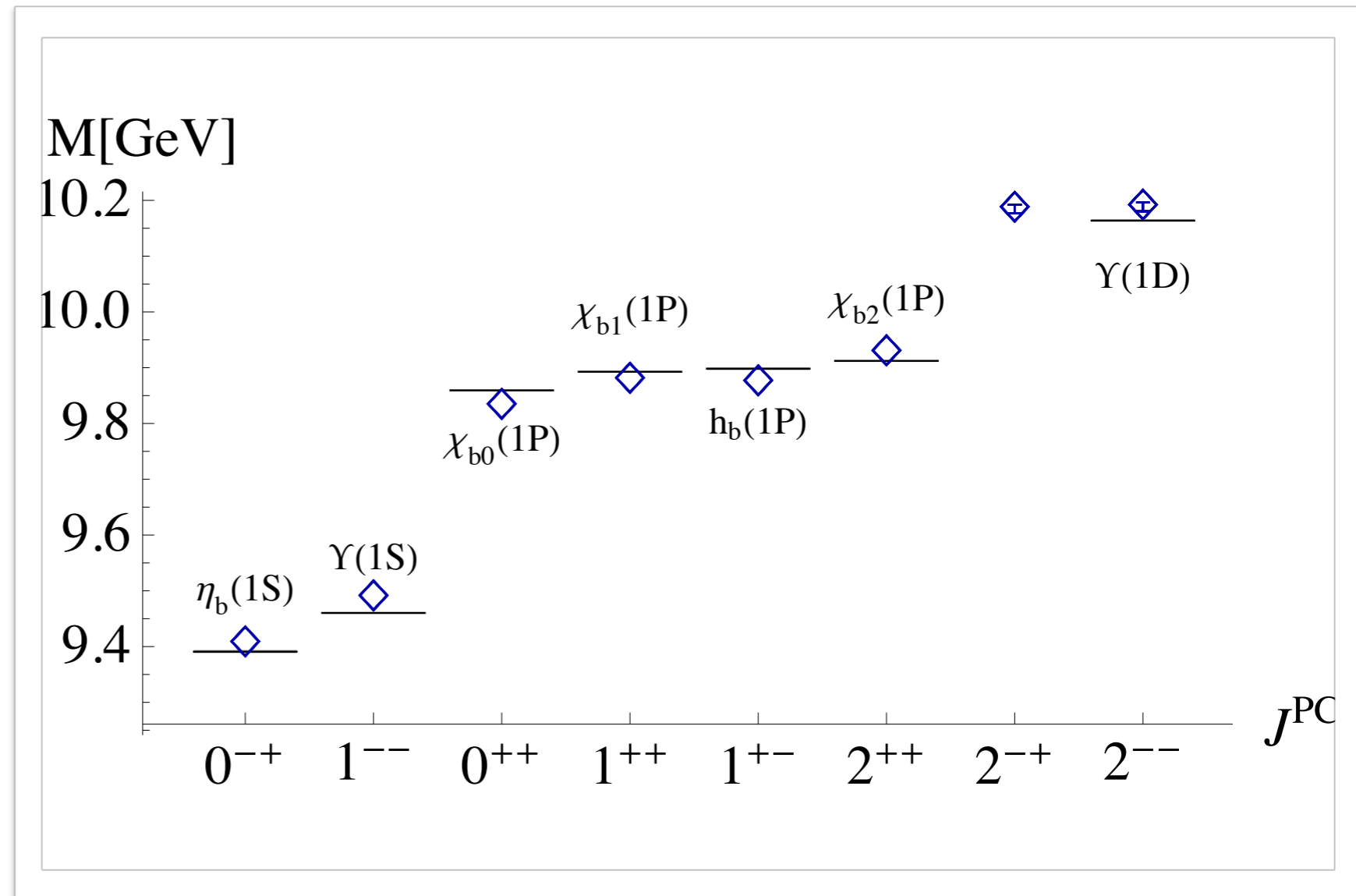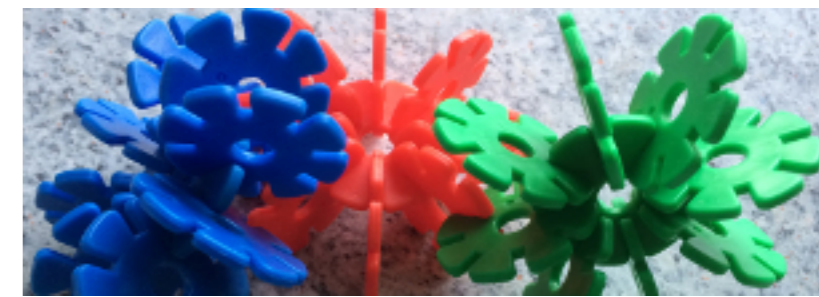
Spectroscopy

- Use RL truncation for simplicity on comprehensive scale

- apply it to systems where corrections beyond RL are expected least important
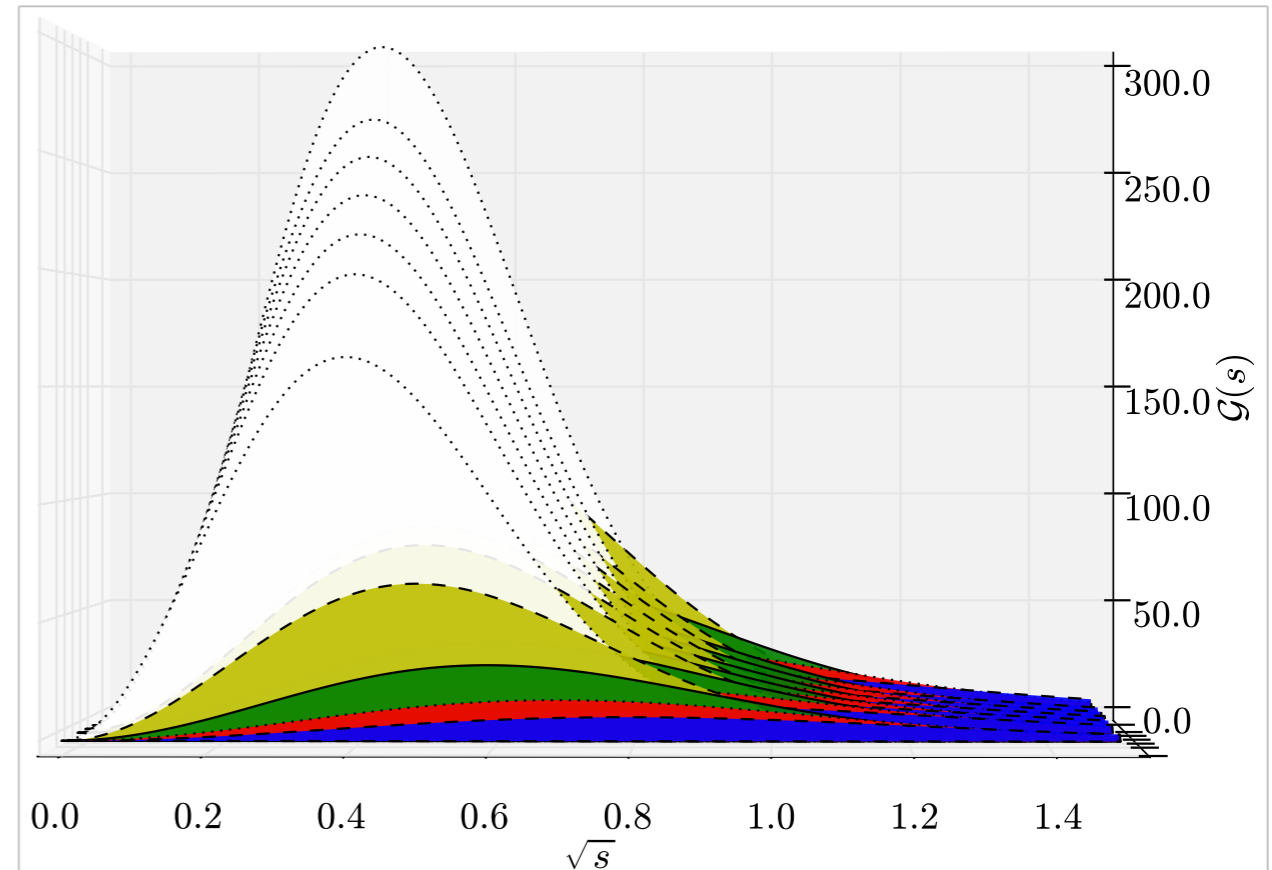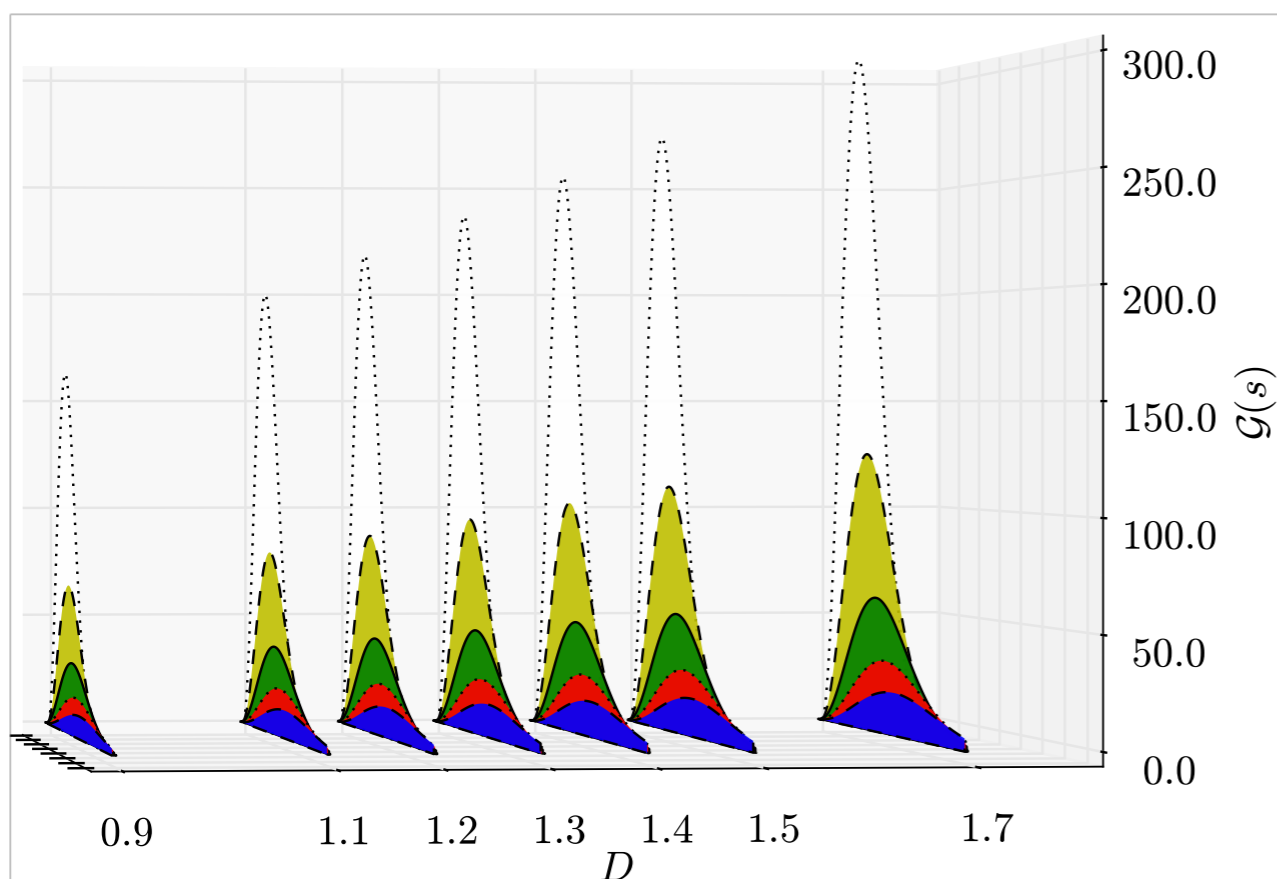
- First attempt: Bottomonium ground states:
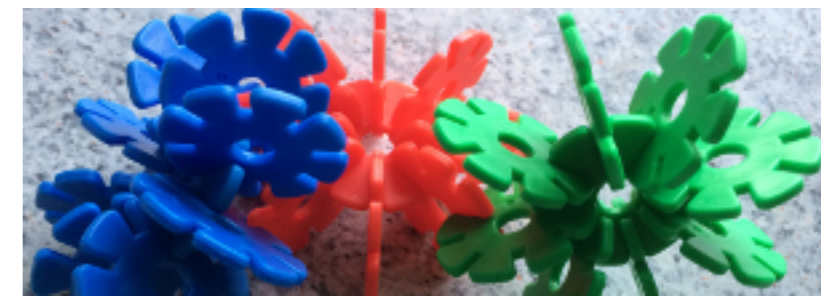

M. Blank, A.K., PRD 84 (2011) 096014

Parameters

- Next step: more freedom in effective interaction:
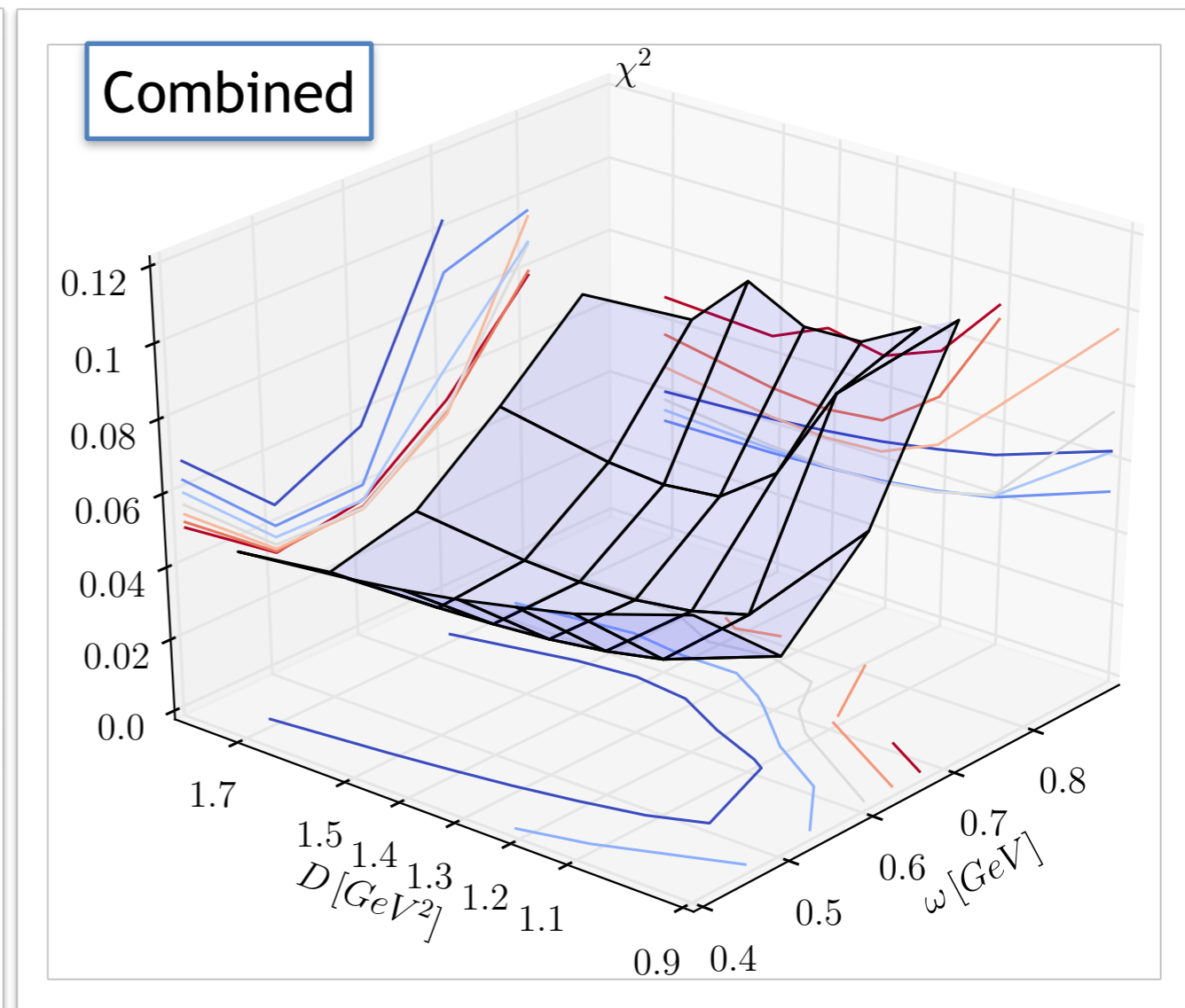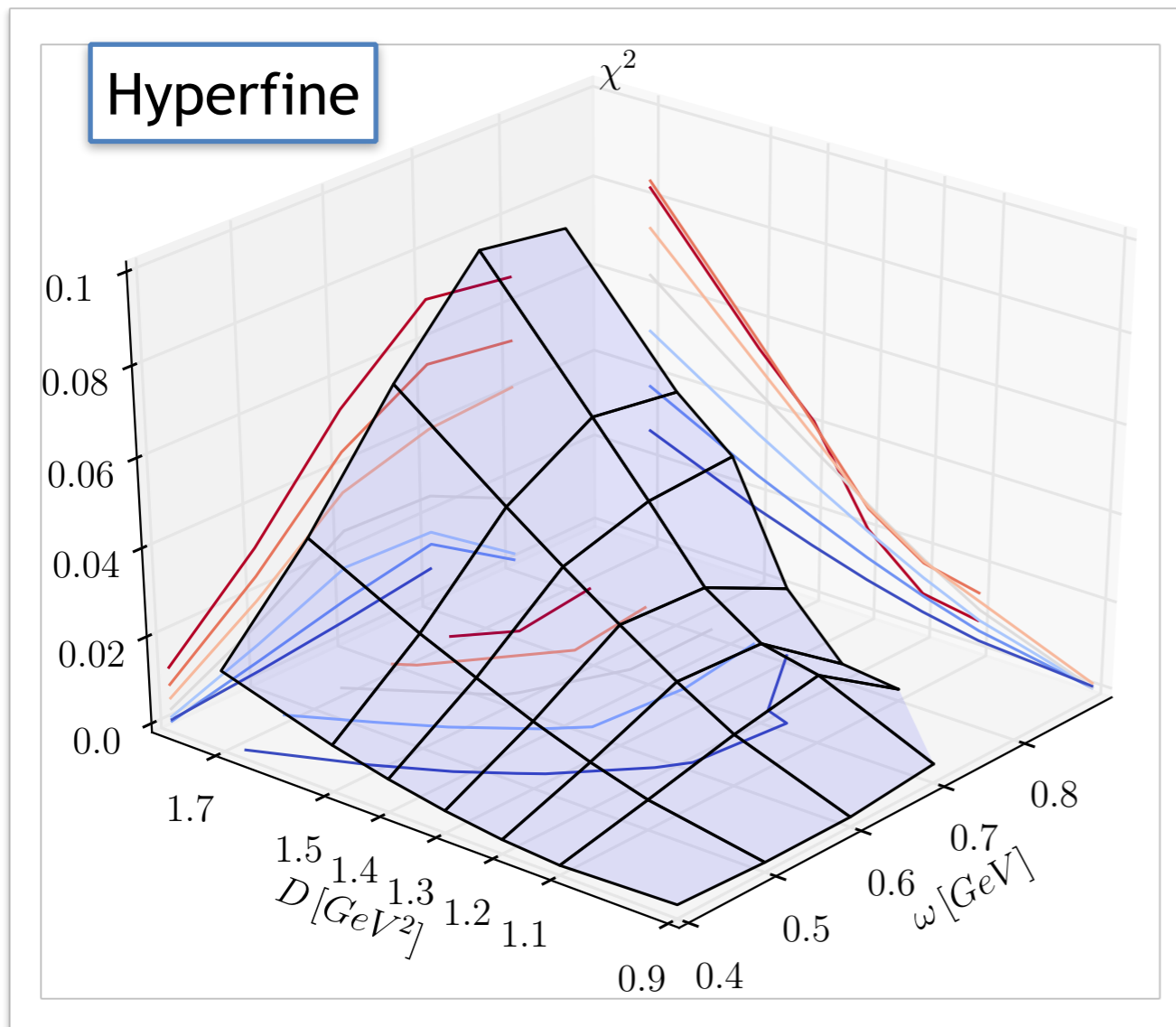 Unchain MT: P. Maris, P.C. Tandy, PRC 60 (1999) 055214

T. Hilger, M. Gomez-Rocha, A.K., arXiv:1508.07183
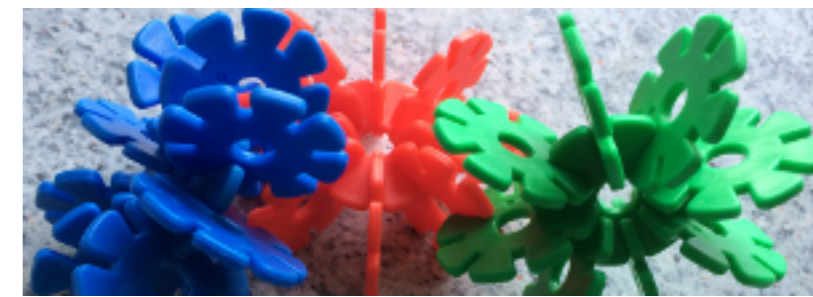
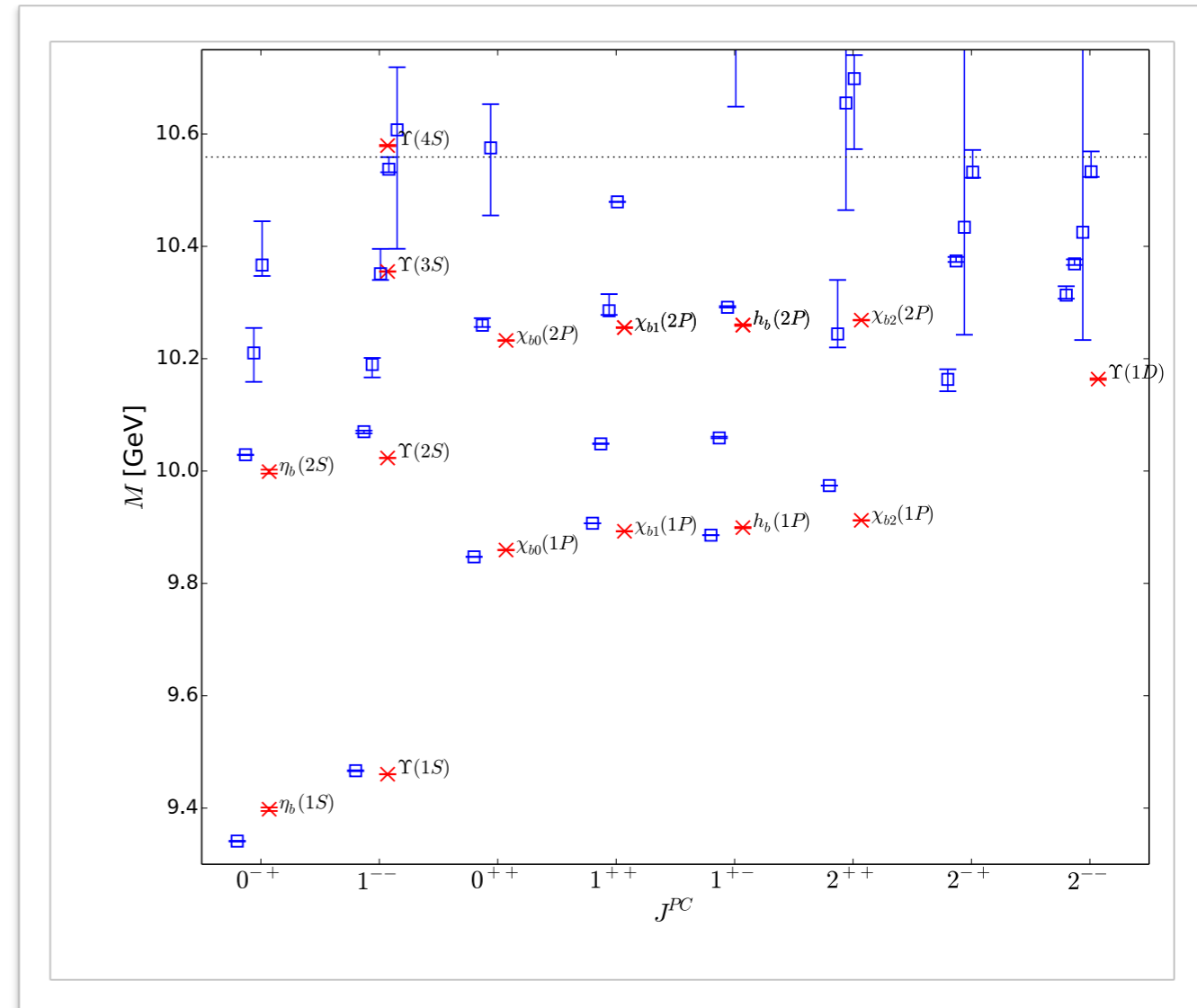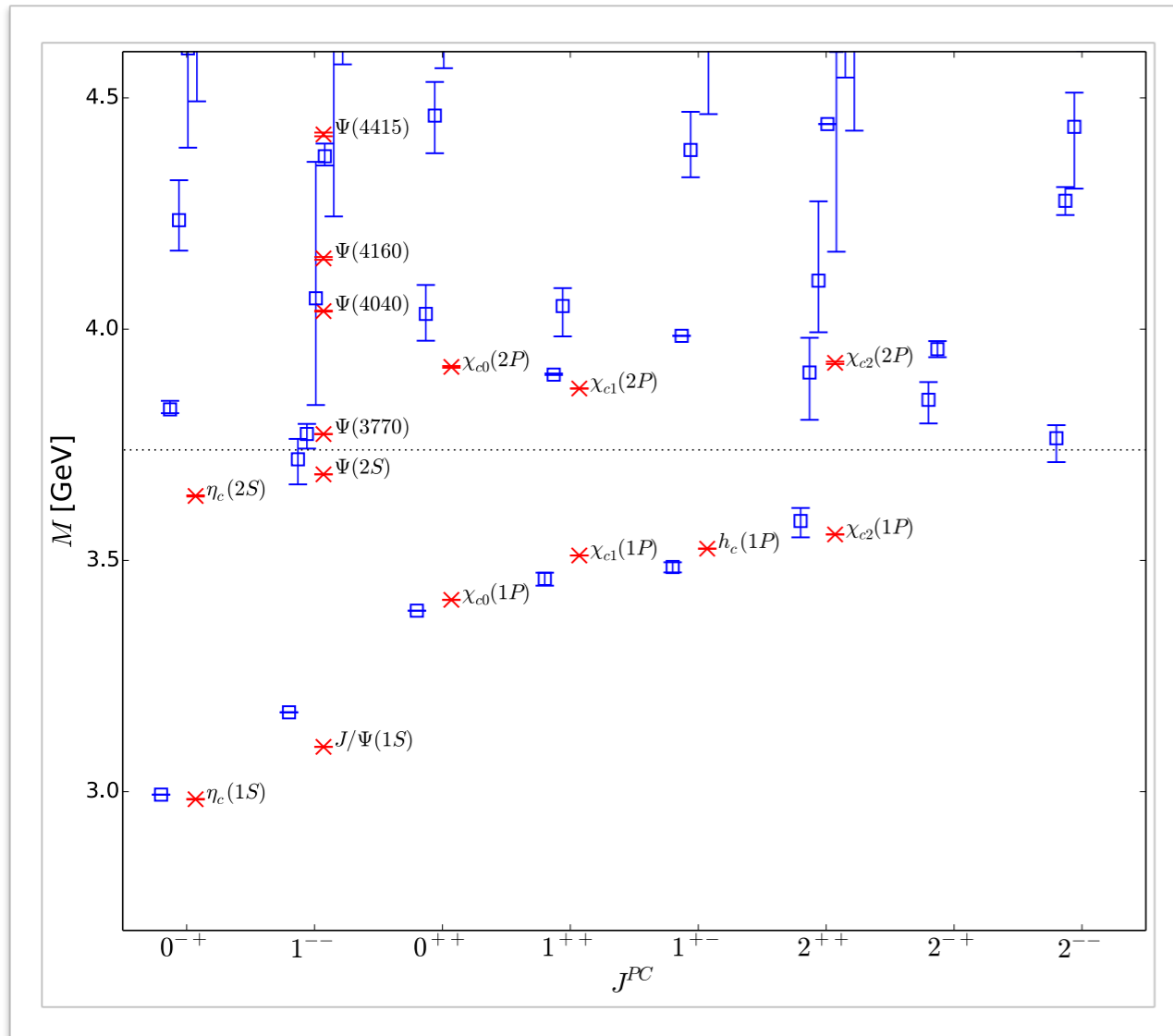UNIVERSITY OF GRAZ

Fitting

- Next step: more freedom in effective interaction:
  Unchain overall strength D and inverse effective range ω

Spectroscopy

- Next step: more freedom in effective interaction: $b\bar{b}$ and $c\bar{c}$

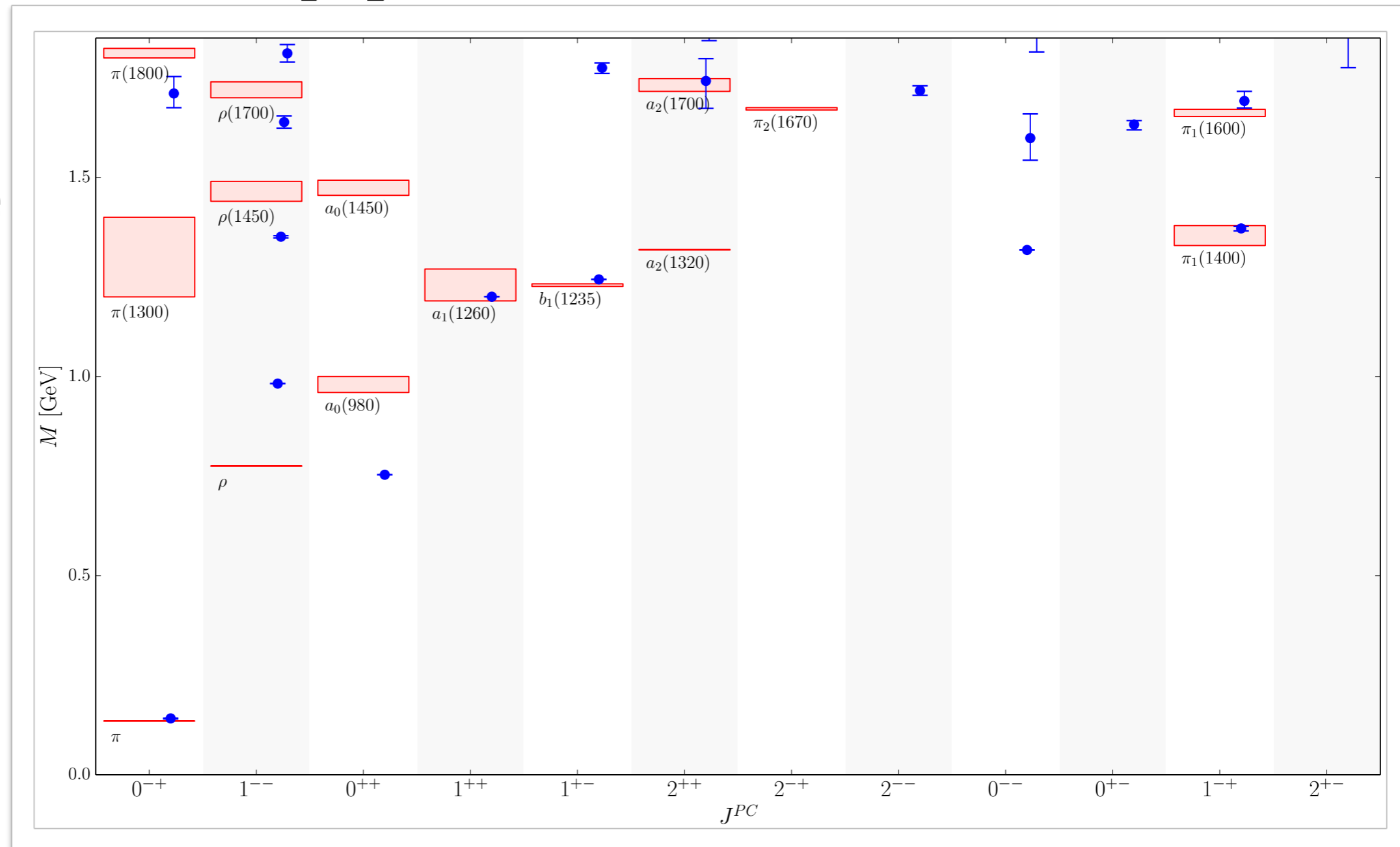# Spectroscopy

- Next step: investigate exotic quantum numbers:

- quarkonia: light, heavy

FWF Der Wissenschaftsfonds.

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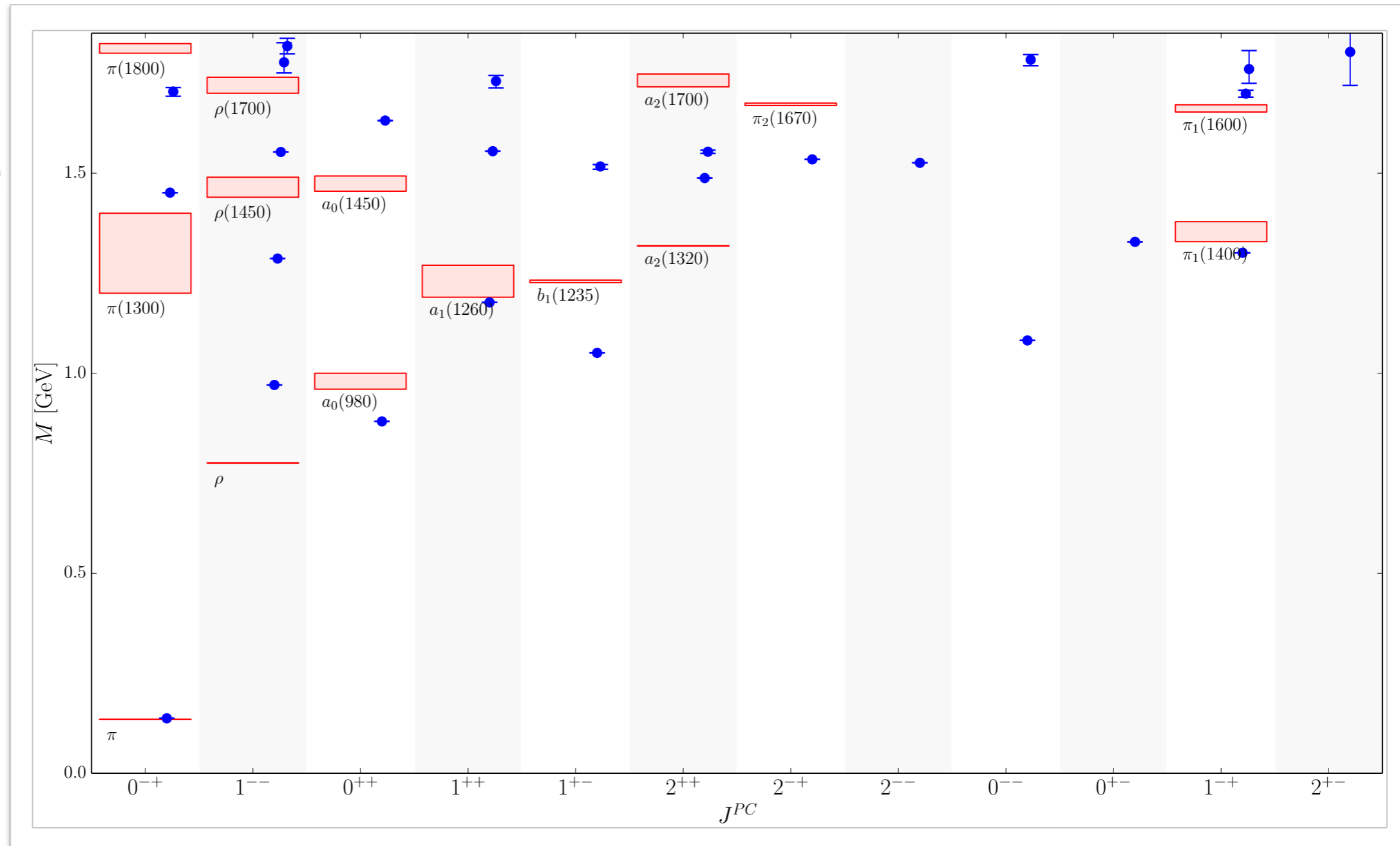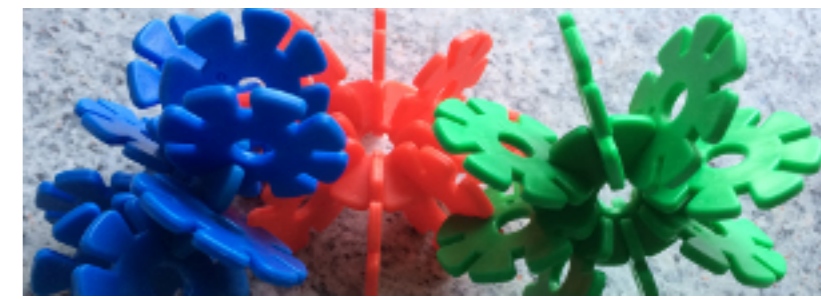# Spectroscopy

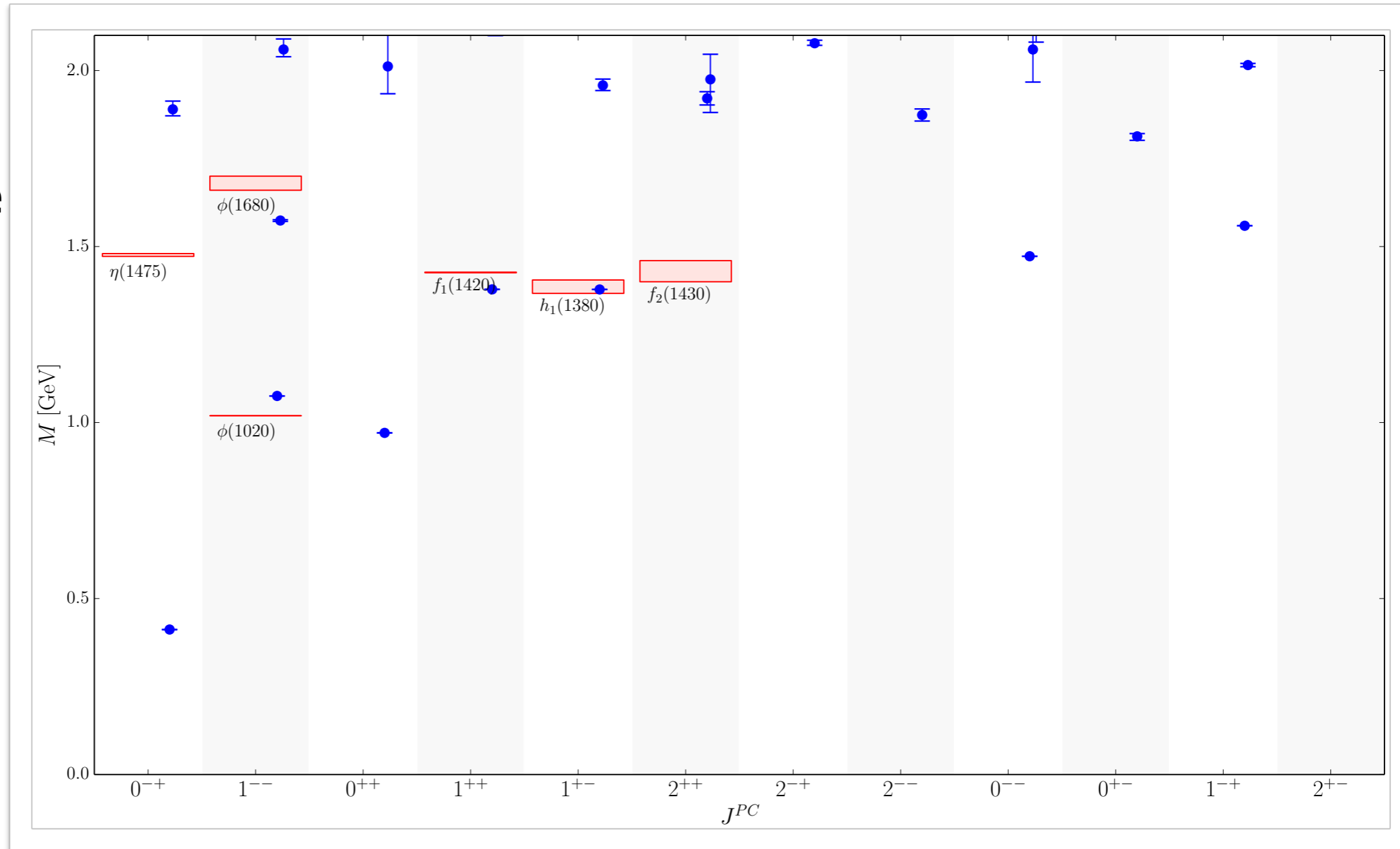- Next step: investigate light quarkonia

T. Hilger, M. Gomez-Rocha, A.K., arXiv:1508.07183

Spectroscopy

- Next step: investigate light quarkonia

T. Hilger, M. Gomez-Rocha, A.K., arXiv:1508.07183

Leptonic Decays

- Preliminary
- heavy quarkonia
- S vs. D wave in 1^{--} channel
- state ID
- missing states?

Ground states			
State	J^{PC}	f Calc.	f Exp.
η_c	0^{-+}	401	339(14)
J/Ψ	1^{--}	450	416(5)
η_b	0^{-+}	773	—
Υ	1^{--}	768	715(5)
First radial excitations			
$\eta_c(2S)$	0^{-+}	244(12)	189(50)
$\Psi(2S)$	1^{--}	30(3)	294(4)
$\eta_b(2S)$	0^{-+}	419(8)	—
$\Upsilon(2S)$	1^{--}	467(17)	497(4)
Second radial excitations			
$\eta_c(3S)$	0^{-+}	145(145)	—
$\Psi(3770)$	1^{--}	118(91)	99(3)
$\eta_b(3S)$	0^{-+}	534(57)	—
$\Upsilon(1D_1)$	1^{--}	41(7)	—

T. Hilger, A.K., in preparation

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Hadronic Decays

- Hadronic decay
- $\rho \to \pi\pi$
- Compare:
  - ∗ Experiment
  - ∗ Lattice QCD
- Analogously for baryon case
  $$\Delta \to N\pi$$

$g_{\rho\pi\pi}$
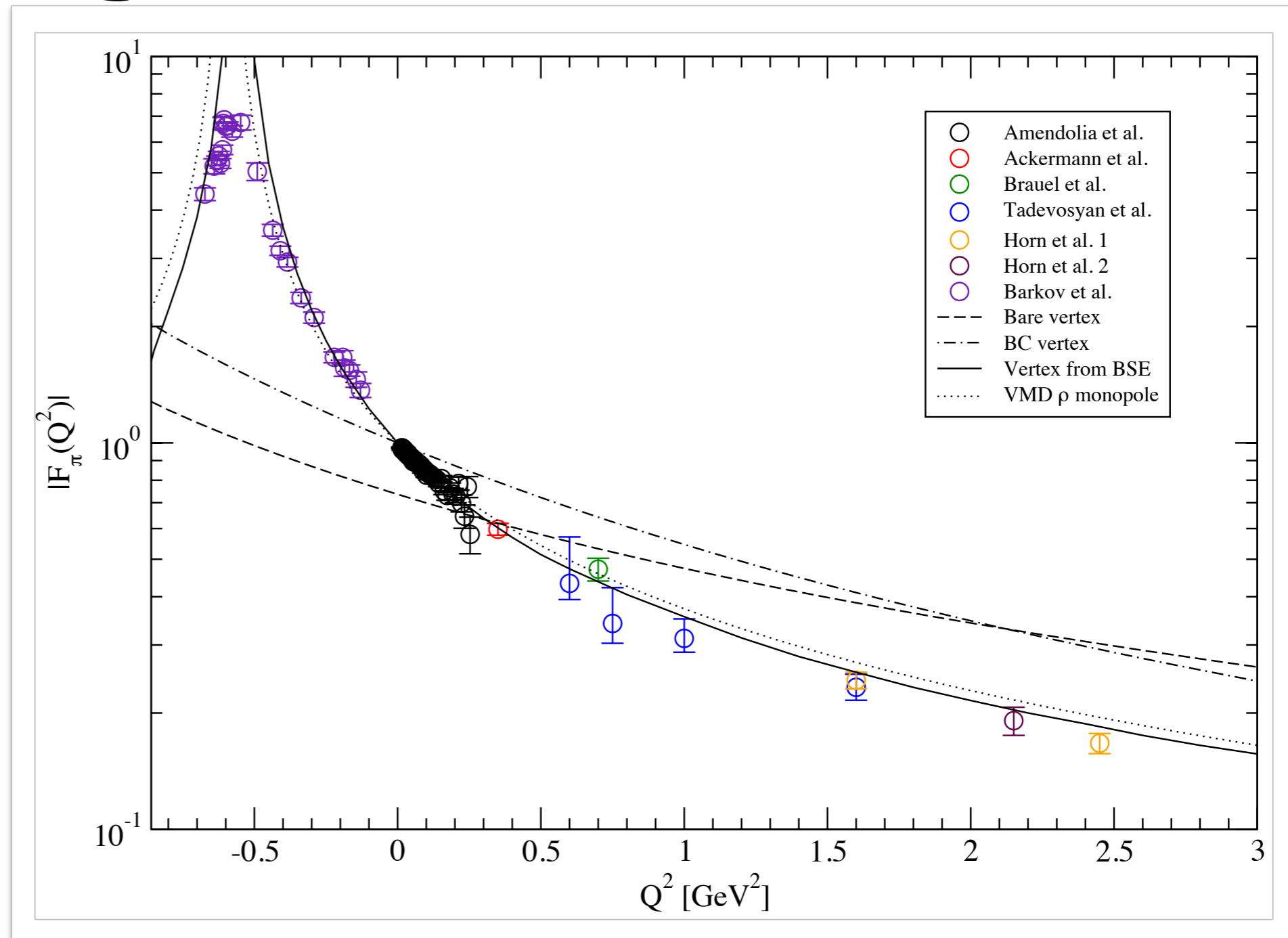
Legend:
- Goeckeler ´08
- Feng ´09
- Feng ´10
- Aoki ´10
- Frison ´10
- Lang ´11
- ∗ Physical Point

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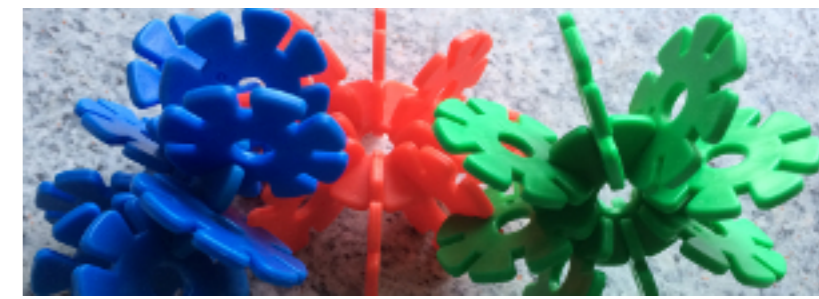
Electromagnetic FF

- Pion em ff
  - ✳ spacelike
  - ✳ timelike
- Consistent construction
- Charge conserv.
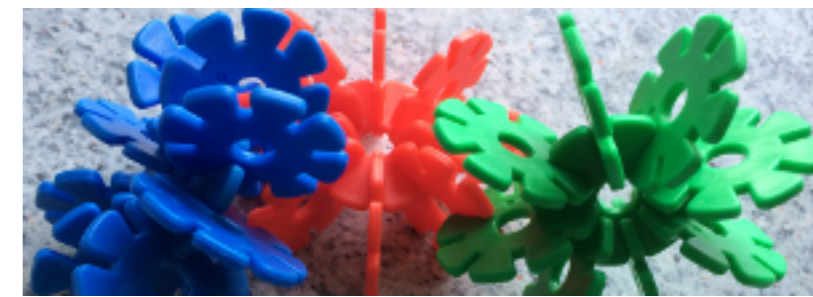- Charge radius
- Analogously for baryons

T. Hilger, G. Eichmann, A.K., in preparation

Where Can I Place My Order? - Outlook

- We have:
  - connection to QCD
  - covariance
  - correct chiral-limit behavior
  - symmetries & constraints
- We can compute:
  - meson spectra (comprehensively)
  - meson leptonic decay constants
  - meson e.m. properties
  - meson hadronic transitions/decays
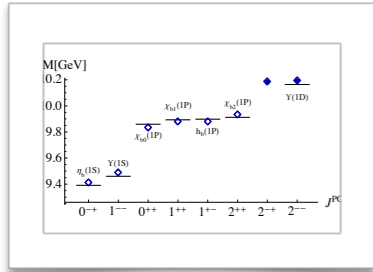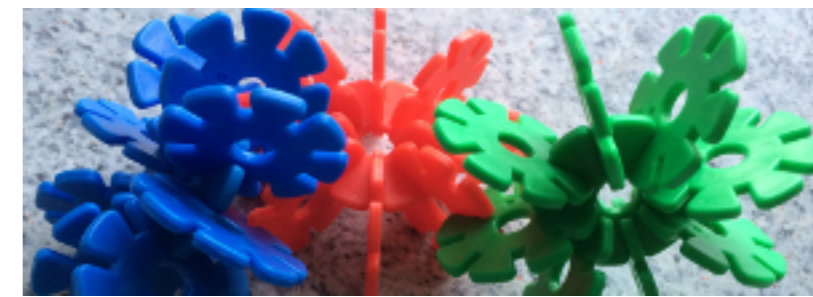 - baryon properties in consistent 3-quark setup
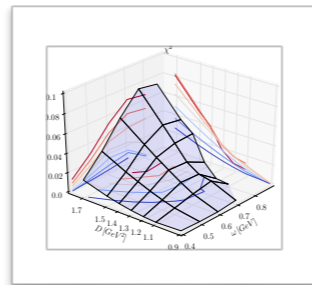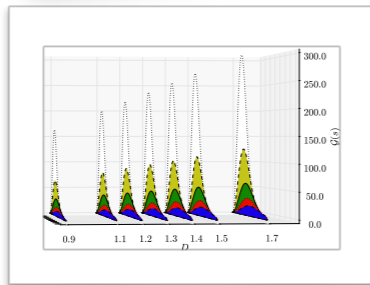 - your order goes here …

Hot off the press
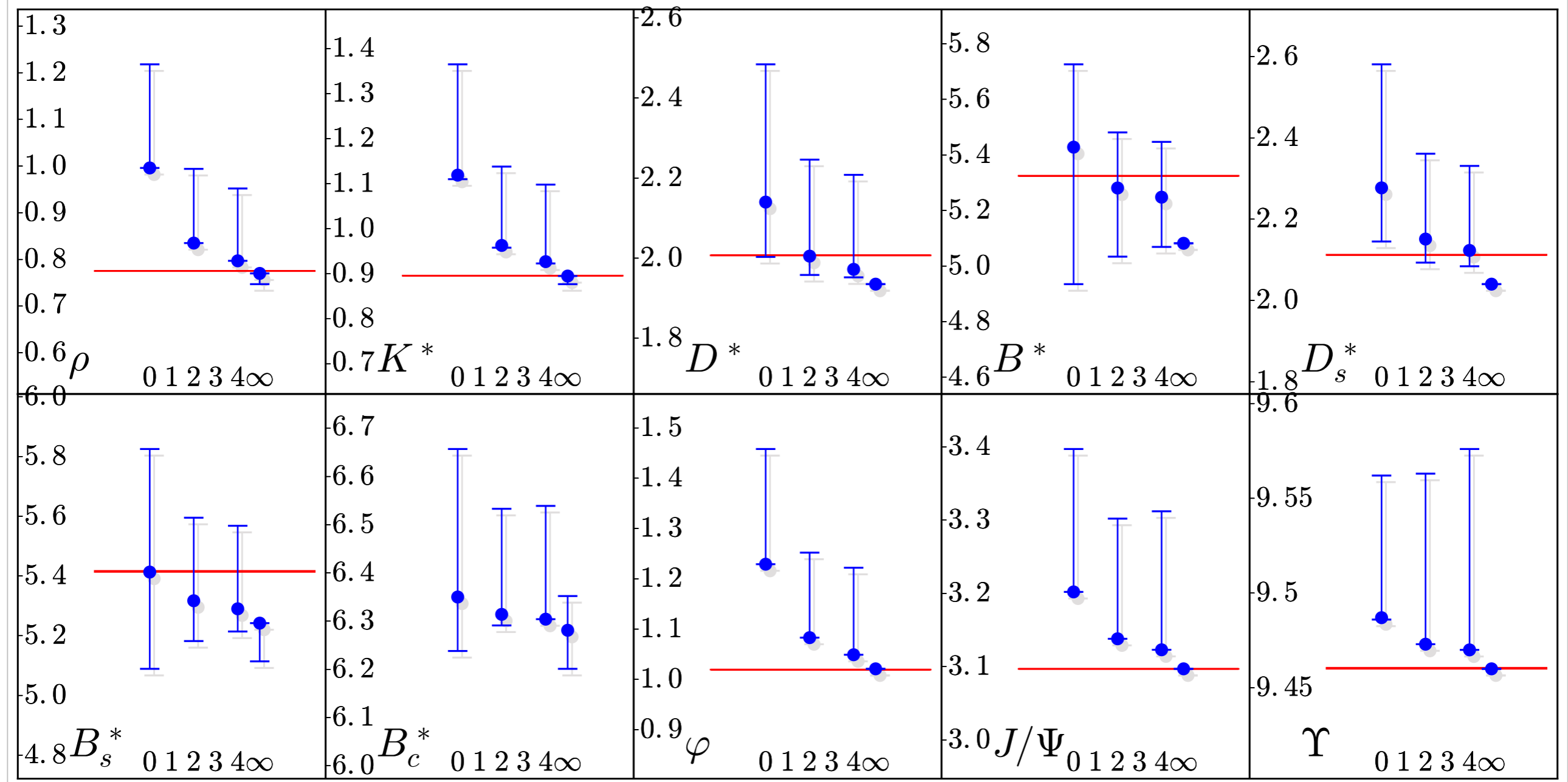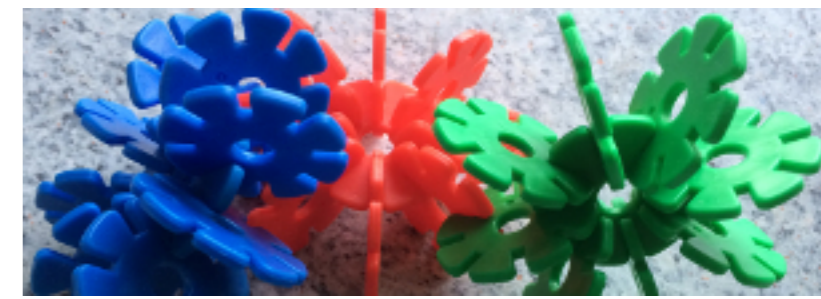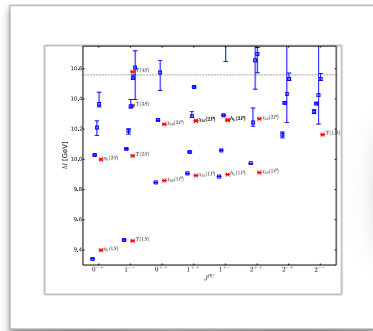
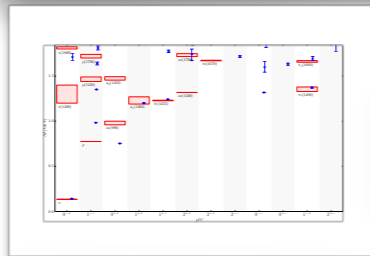Thank you very much for your attention!

Reminder

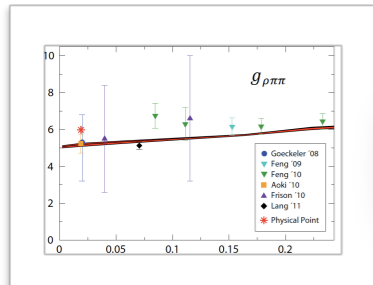M. Blank, A.K., PRD 84 (2011) 096014

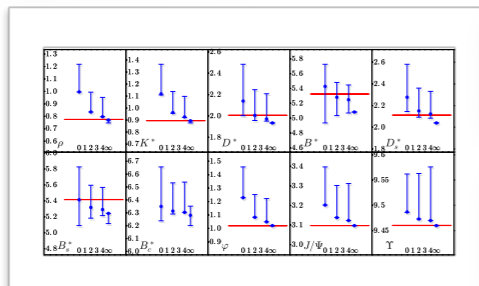T. Hilger, M. Gomez-Rocha, A.K., arXiv:1508.07183

T. Hilger, C. Popovici, M. Gomez-Rocha, A.K., PRD 91 (2015) 034013

T. Hilger, M. Gomez-Rocha, A.K., PRD 91 (2015) 114004

V. Mader, G. Eichmann, M. Blank, A.K., PRD 84 (2011) 034012

M. Gomez-Rocha, T. Hilger, A.K., PRD 92 (2015) 054030

M. Gomez-Rocha, T. Hilger, A.K., arXiv:1602.05002