STRONG 2020

STRONG2020 (Second Strong2020 online Workshop)

HaSP, light- and heavy-quark hadron spectroscopy

14-16 September 2021
University of York
Europe/Rome timezone

T2.1 Progress

Precision calculations in nonperturbative QCD (II): Effective Field Theories and Lattice QCD (LQCD).

T2.1 Task Progress.
Hadron resonances, form factors, LECs, fundamental parameters of QCD and light nuclei spectroscopy

Coordinators: Alessandro Lovato (ANL) and Assumpta Parreño (UB)

- EFTs complement LQCD, extrapolations to physical kinematics and covering regions not yet reachable in the lattice
- Combining perturbation theory and LQCD → extraction of fundamental constants (α_S)
- Development of methods to deal with the extraction of the properties of hadrons from the numerical calculations
- Study of nuclear systems with lattice and GFMC methods, combining chiral NN and 3N forces

Assumpta Parreño (UB)

STRONG2020 (Second Strong2020 online Workshop)

HaSP, light- and heavy-quark hadron spectroscopy

14-16 September 2021
University of York
Europe/Rome timezone

T2.1 Progress

From the mid-term report: "We aim at studying Lattice-QCD (LQCD) simulations in finite volumes. Methods will be developed to deal with the extraction of the properties of hadrons from the simulations. Lattice and Green's function MC simulations, combining chiral NN and 3N forces, will be also performed to study light and medium-heavy nuclei."

Outline:

1. Determination of the strong coupling constant α_S
2. Dispersive methods
3. LQCD calculations of baryon-baryon interactions in the SU(3) sector. Low Energy Coefficients. Ligt nuclear systems
4. Nuclear structure with chiral forces
5. New physics: test of lepton flavor universality

Determination of α_S

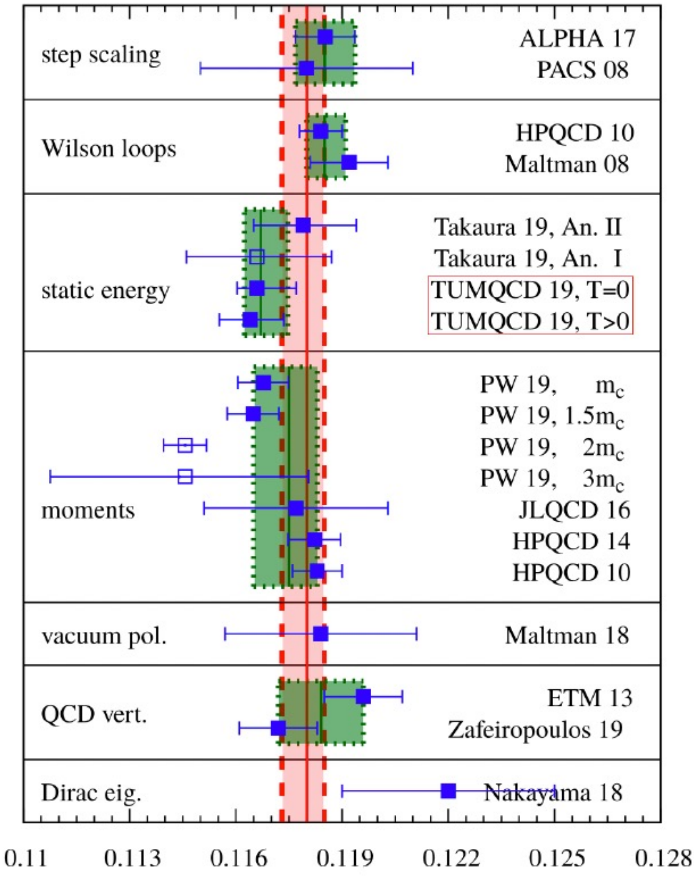
$$[M_{\mathrm{HAD}}(\Lambda_{\mathrm{QCD}}, m_q)]^{\mathrm{TH}} = [M_{\mathrm{HAD}}]^{\mathrm{EXP}}$$

world average values (PDG)

$$\alpha_s(M_Z) = 0.1185 \pm 0.0006 \quad (2013)$$
$$\alpha_s(M_Z) = 0.1181 \pm 0.0011 \quad (2018)$$

The exact value of the strong coupling α_s is subject to tension

QCD COLL



© Sebastian Steinbeisser

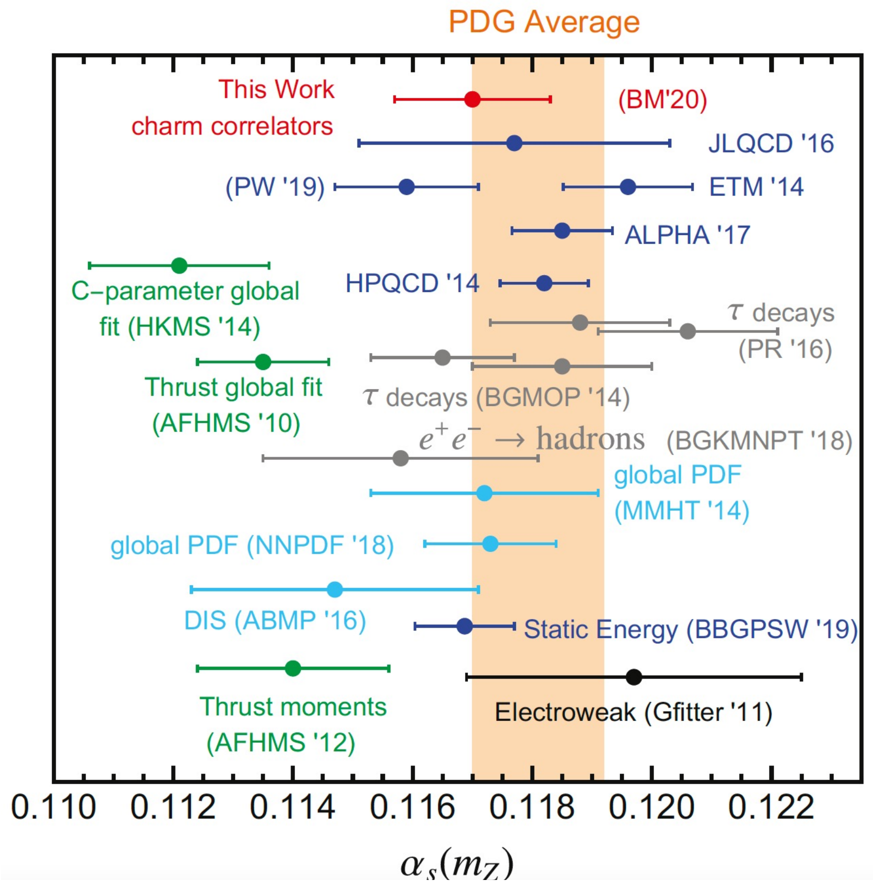
$$[M_{\rm HAD}(\Lambda_{\rm QCD}, m_q)]^{\rm TH} = [M_{\rm HAD}]^{\rm EXP}$$

world average values (PDG)

$$\alpha_s(M_Z) = 0.1185 \pm 0.0006 \quad (2013)$$
$$\alpha_s(M_Z) = 0.1181 \pm 0.0011 \quad (2018)$$

The exact value of the strong coupling α_s is subject to tension

D. Boito and V. Mateu, JHEP 03 (2020) 094



Determination of α_S

$$[M_{\rm HAD}(\Lambda_{\rm QCD}, m_q)]^{\rm TH} = [M_{\rm HAD}]^{\rm EXP}$$

world average values (PDG)

$\alpha_s(M_Z) = 0.1185 \pm 0.0006$ (2013)

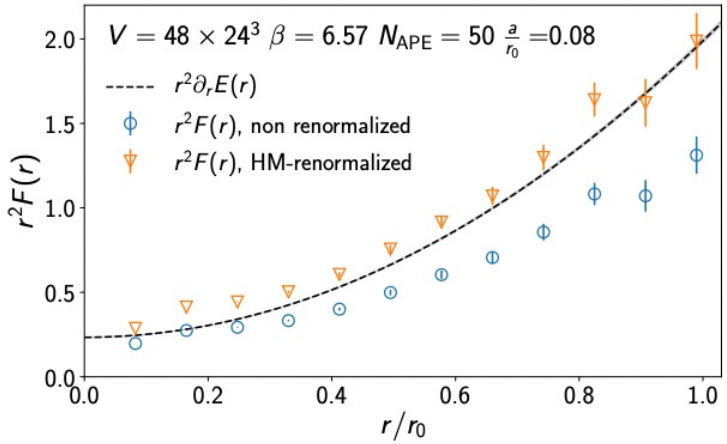
$\alpha_s(M_Z) = 0.1181 \pm 0.0011$ (2018)

TUM QCD COLL

Using LQCD, EFTs and data $\Rightarrow$strong coupling constant α_s.

input	$\alpha_s(M_Z)$
static energy [1]	$0.11660^{+0.00110}_{-0.00056}$

Viljami Leino @ Lattice 2019



$$F(r) = -\lim_{T\to\infty} \frac{i}{\langle {\rm Tr}(W_{r\times T})\rangle} \left\langle {\rm Tr}\left(P\left\{\exp\left(i\oint_{r\times T} {\rm d}z_\mu g A_\mu\right)\hat{\mathbf{r}}\cdot g\mathbf{E}(\mathbf{r},t^*)\right)\right\}\right\rangle$$

LQCD calc. N_f =2+1 light flavors

[1] TUMQCD Coll. A. Bazavov, N. Brambilla, X. Garcia i Tormo, P. Petreczky, J. Soto, A. Vairo, J. Heinrich Weber, PRD 100 (2019) 11, 114511

Determination of α_S

$$[M_{\mathrm{HAD}}(\Lambda_{\mathrm{QCD}}, m_q)]^{\mathrm{TH}} = [M_{\mathrm{HAD}}]^{\mathrm{EXP}}$$

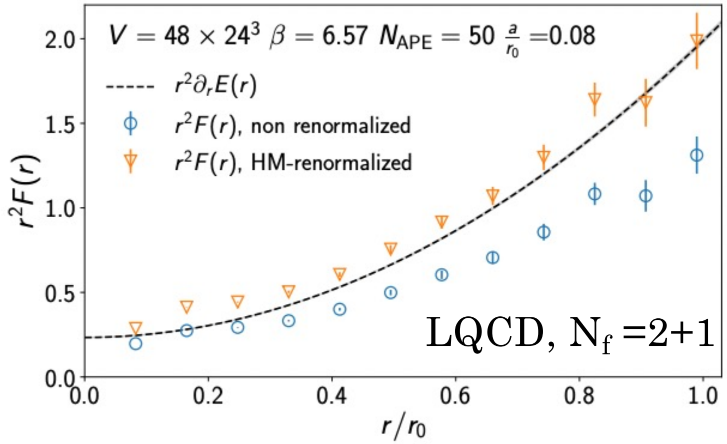
TUM QCD COLL

world average values (PDG)

$\alpha_s(M_Z) = 0.1185 \pm 0.0006$ (2013)

$\alpha_s(M_Z) = 0.1181 \pm 0.0011$ (2018)

Viljami Leino @ Lattice 2019



Using LQCD, EFTs and data ⇒strong coupling constant α_s.

input	$\alpha_s(M_Z)$
static energy [1]	$0.11660^{+0.00110}_{-0.00056}$

LQCD combined with perturbative result $F(r) = dE/dr$

$$F(r,\nu=1/r) = \frac{C_F}{r^2}\alpha_s(1/r)\left[1 + \frac{\alpha_s(1/r)}{4\pi}(\tilde{a}_1 - 2\beta_0) + \frac{\alpha_s^2(1/r)}{(4\pi)^2}(\tilde{a}_2 - 4\tilde{a}_1\beta_0 - 2\beta_1) - \frac{\alpha_s^2(1/r)}{(4\pi)^2}\frac{a_3^L}{2\beta_0}\ln\frac{\alpha_s(\mu_{us})}{\alpha_s(1/r)} + \frac{\alpha_s^2(1/r)\alpha_s(\mu_{us})}{(4\pi)^3}a_3^L\ln\frac{C_A\alpha_s(1/r)}{2r\mu_{us}} + \frac{\alpha_s^3(1/r)}{(4\pi)^3}(\tilde{a}_3 - 6\tilde{a}_2\beta_0 - 4\tilde{a}_1\beta_1 - 2\beta_2) + \mathcal{O}(\alpha_s^4)\right].$$

[1] TUMQCD Coll. A. Bazavov, N. Brambilla, X. Garcia i Tormo, P. Petreczky, J. Soto, A. Vairo, J. Heinrich Weber, PRD 100 (2019) 11, 114511

Determination of α_S

$$[M_{HAD}(\Lambda_{QCD}, m_q)]^{TH} = [M_{HAD}]^{EXP}$$

TUM QCD COLL

world average values (PDG)

$\alpha_s(M_Z) = 0.1185 \pm 0.0006$ (2013)

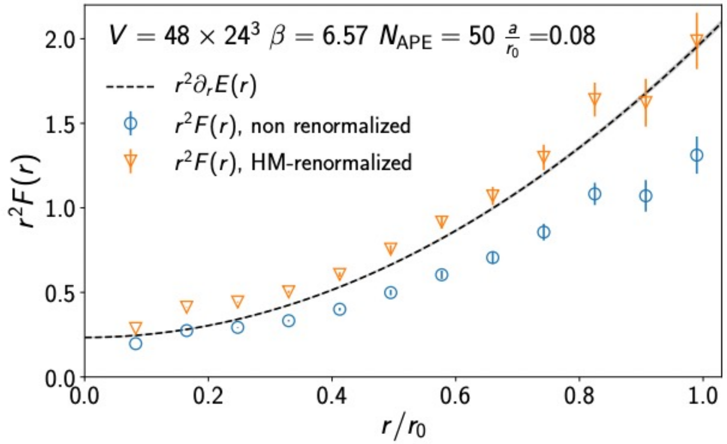
$\alpha_s(M_Z) = 0.1181 \pm 0.0011$ (2018)

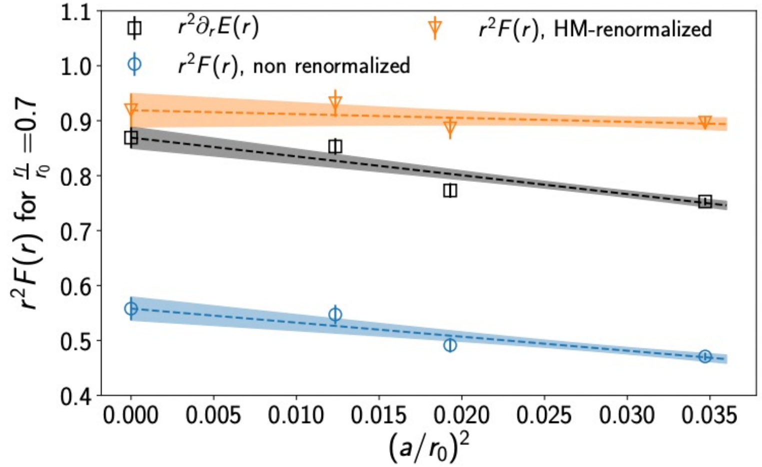
Using LQCD, EFTs and data ⇒strong coupling constant α_s.

input	$\alpha_s(M_Z)$
static energy [1]	$0.11660^{+0.00110}_{-0.00056}$

$$F(r) = -\lim_{T\to\infty} \frac{i}{\langle \mathrm{Tr}(W_{r\times T})\rangle} \left\langle \mathrm{Tr}\left(P\left\{ \exp\left(i \oint_{r\times T} \mathrm{d}z_\mu g A_\mu \right) \hat{\mathbf{r}} \cdot g\mathbf{E}(\mathbf{r}, t^*) \right) \right\rangle$$

Viljami Leino @ Lattice 2019

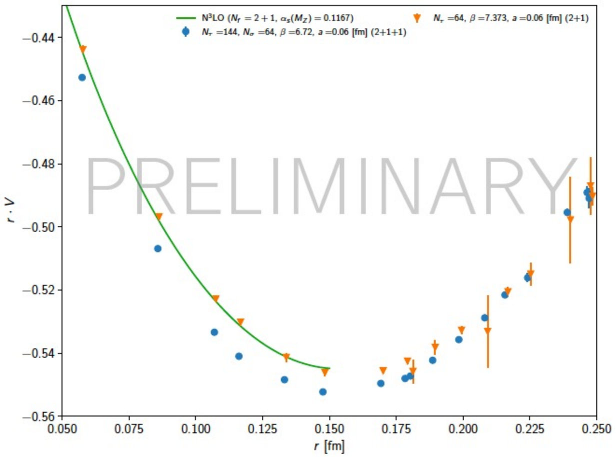




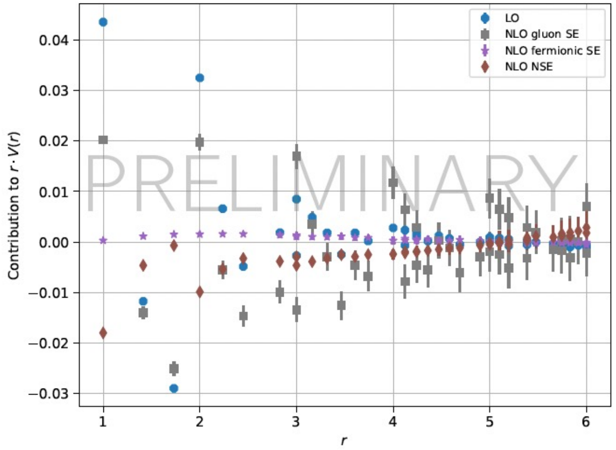
update by Viljami Leino talk today 16/9 @ 18h

[1] TUMQCD Coll. A. Bazavov, N. Brambilla, X. Garcia i Tormo, P. Petreczky, J. Soto, A. Vairo, J. Heinrich Weber, PRD 100 (2019) 11, 114511

$$[M_{HAD}(\Lambda_{QCD}, m_q)]^{TH} = [M_{HAD}]^{EXP}$$



2+1 vs 2+1+1 potential



different LPT contributions

Improvements/ongoing work

QCD COLL

- Improve the **2+1 flavor** determination**:** We have measured the static potential from **2+1+1 flavor MILC configurations**. We see effects of the finite **dynamic charm quark** in the lattice data and can qualitatively describe the effects using **perturbation theory**. We're also looking into the lattice scale determination, r_{0,1,2}/a, which hasn't been done for 2+1+1-flavor simulations

- We're working on a one-loop lattice perturbation theory calculation in order to improve the tree-level correction that's necessary in order to counteract the discretization artifacts due to the finite lattice spacing at short distances

update by Viljami Leino talk today 16/9 @ 18h

Determination of α_S

$$[M_{\mathrm{HAD}}(\Lambda_{\mathrm{QCD}}, m_q)]^{\mathrm{TH}} = [M_{\mathrm{HAD}}]^{\mathrm{EXP}}$$

world average values (PDG)

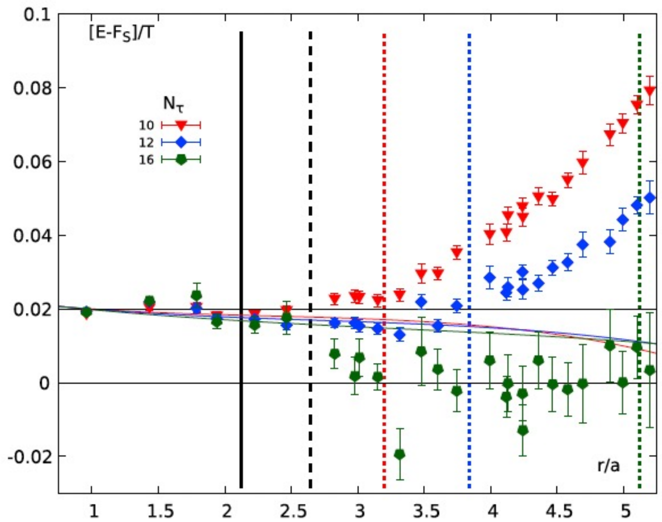
$$\alpha_s(M_Z) = 0.1185 \pm 0.0006 \quad (2013)$$
$$\alpha_s(M_Z) = 0.1181 \pm 0.0011 \quad (2018)$$

TUM QCD COLL

New method

Using LQCD, EFTs and data ⇒strong coupling constant α_s.

input	$\alpha_s(M_Z)$
static energy [1]	$0.11660^{+0.00110}_{-0.00056}$
singlet free energy at finite temperature [1]	$0.11638^{+0.00095}_{-0.00087}$



$$F_S(r,T) = -T \ln \left(\frac{1}{N_c} \langle \mathrm{Tr}[W(r) W^\dagger(0)] \rangle \right)$$

[1] TUMQCD Coll. A. Bazavov, N. Brambilla, X. Garcia i Tormo, P. Petreczky, J. Soto, A. Vairo, J. Heinrich Weber, PRD 100 (2019) 11, 114511

TUM QCD COLL

- New simulations with Gradient flow algorithm (heavy quark diffusion coefficient)

  → Viljami Leino on Tuesday 14/9 @ 15h

- Measurement of the static force directly from the lattice simulations without relying to numerical derivatives of static potential.

  This can offer an alternative way to measure running coupling and scale setting on the lattice.

  → Viljami Leino talk today 16/9 @ 18h

Fitting the strong coupling with sum-rules

Total hadronic cross section

$$R(s)=\frac{\sigma(e^+e^-\to \text{hadrons})}{\sigma(e^+e^-\to\mu^+\mu^-)}$$

Moments of the cross section

$$M_n=\int_{4m^2}^{\infty}\frac{\mathrm{d}s}{s^{n+1}}R(s)\overset{z=\frac{s}{4m^2}}{=}\frac{1}{(4m^2)^n}\int_1^{\infty}\frac{\mathrm{d}z}{z^{n+1}}R(z)$$

Ideal to compute heavy quark masses: high sensitivity

[known to 4-loop]

perturbative expansion

$$M_q^{(n)}=\frac{1}{[2\,\overline{m}_q(\mu_m)]^{2n}}\sum_{i,a,b}\left[\frac{\alpha_s(\mu_\alpha)}{\pi}\right]^i c_{i,a,b}^{(n)}(n_f)\,\ln^a\!\left(\frac{\mu_m}{\overline{m}_b(\mu_m)}\right)\ln^b\!\left(\frac{\mu_\alpha}{\overline{m}_q(\mu_m)}\right)$$

Ratios of moments

$$R_q^{X,n}\equiv\frac{\left(M_q^{X,n}\right)^{\frac{1}{n}}}{\left(M_q^{X,n+1}\right)^{\frac{1}{n+1}}}$$

loose their mass-dimension, along with mass sensitivity !!!

perturbative expansion

$$\hat{R}_q^{X,n}=\sum_{i=0}\left[\frac{\alpha_s(\mu_\alpha)}{\pi}\right]^i\sum_{j=0}^{i-1}\log^j\!\left(\frac{\mu_m}{\overline{m}_q(\mu_m)}\right)\sum_{k=0}^{\max(i-1,0)} r_{i,j,k}^{X,n}\log^k\!\left(\frac{\mu_\alpha}{\mu_m}\right)$$

logarithmic mass dependence starting at $\mathcal{O}(\alpha_s^2)$

The trick can be used for the vector correlator (charm and bottom), but also for the pseudo-scalar case, with moments computed on the Lattice

UNIVERSITY OF SÃO PAULO
São Carlos Institute of Physics
VNiVERSiDAD Đ SALAMANCA
CAMPUS DE EXCELENCIA INTERNACIONAL

D. Boito and V. Mateu
JHEP 03 (2020) 094

$$[M_{\mathrm{HAD}}(\Lambda_{\mathrm{QCD}}, m_q)]^{\mathrm{TH}} = [M_{\mathrm{HAD}}]^{\mathrm{EXP}}$$

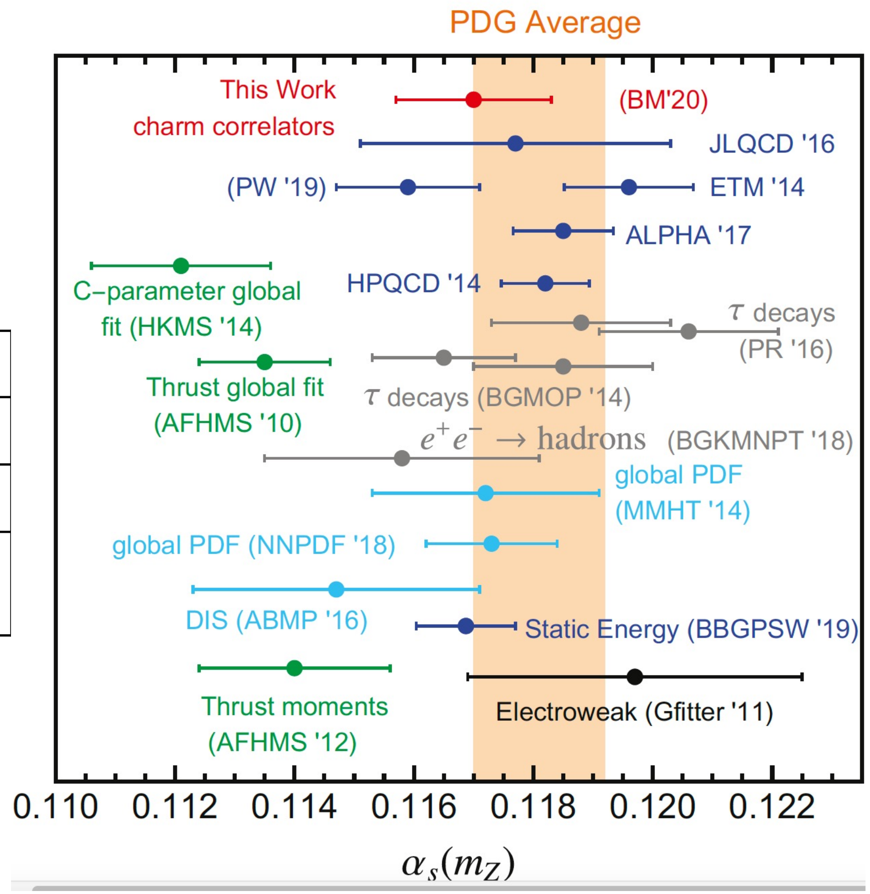
world average values (PDG)

$$\alpha_s(M_Z) = 0.1185 \pm 0.0006 \quad (2013)$$
$$\alpha_s(M_Z) = 0.1181 \pm 0.0011 \quad (2018)$$

Using LQCD, EFTs and data ⇒strong coupling constant α_s.

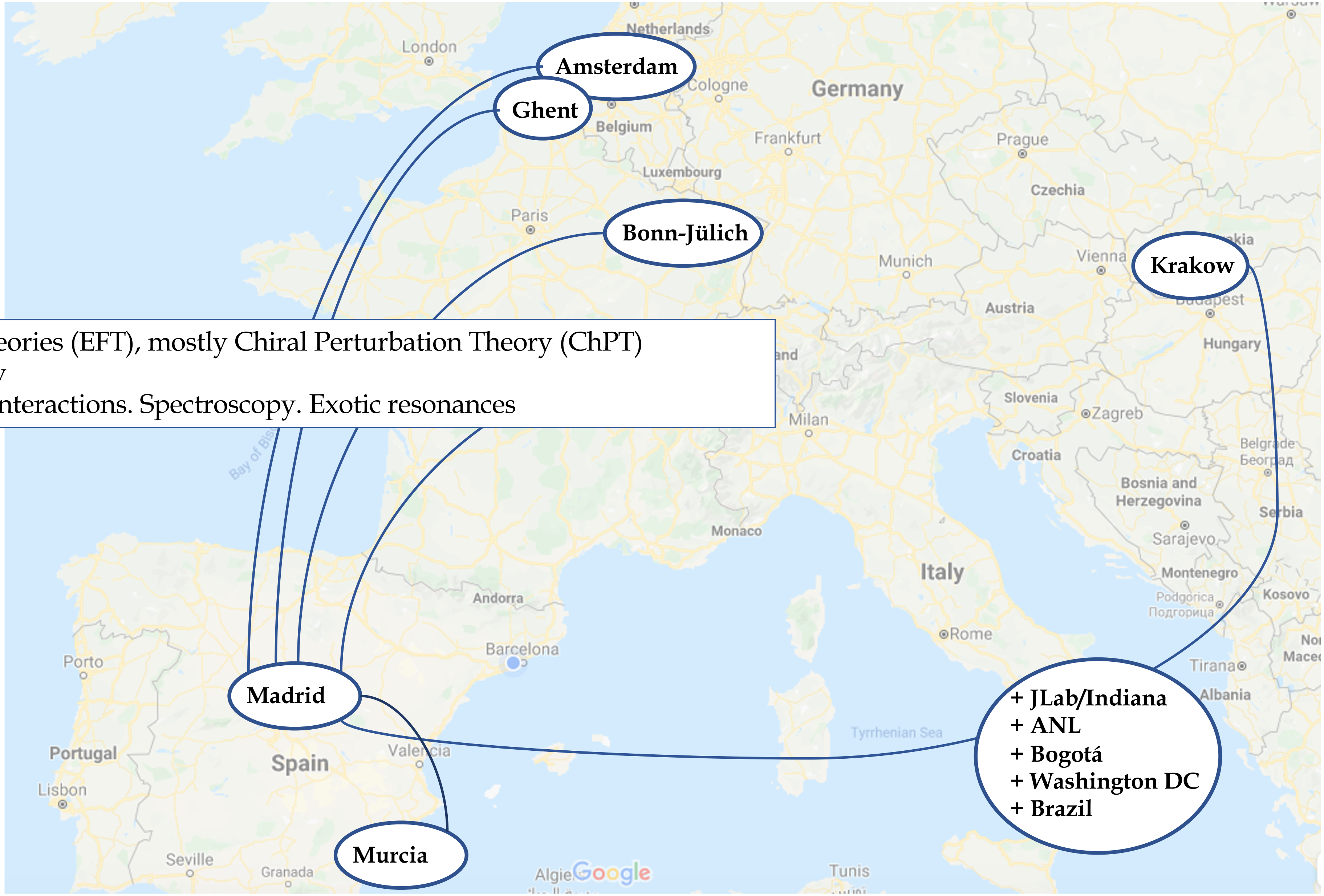
input	$\alpha_s(M_Z)$
static energy [1]	$0.11660^{+0.00110}_{-0.00056}$
singlet free energy at finite temperature [1]	$0.11638^{+0.00095}_{-0.00087}$
dimensionless ratios of roots of the moments charm- and bottom-quark correlators [2]	0.1170 ± 0.0014

Combining experimental and lattice information
on charm correlators into a single fit



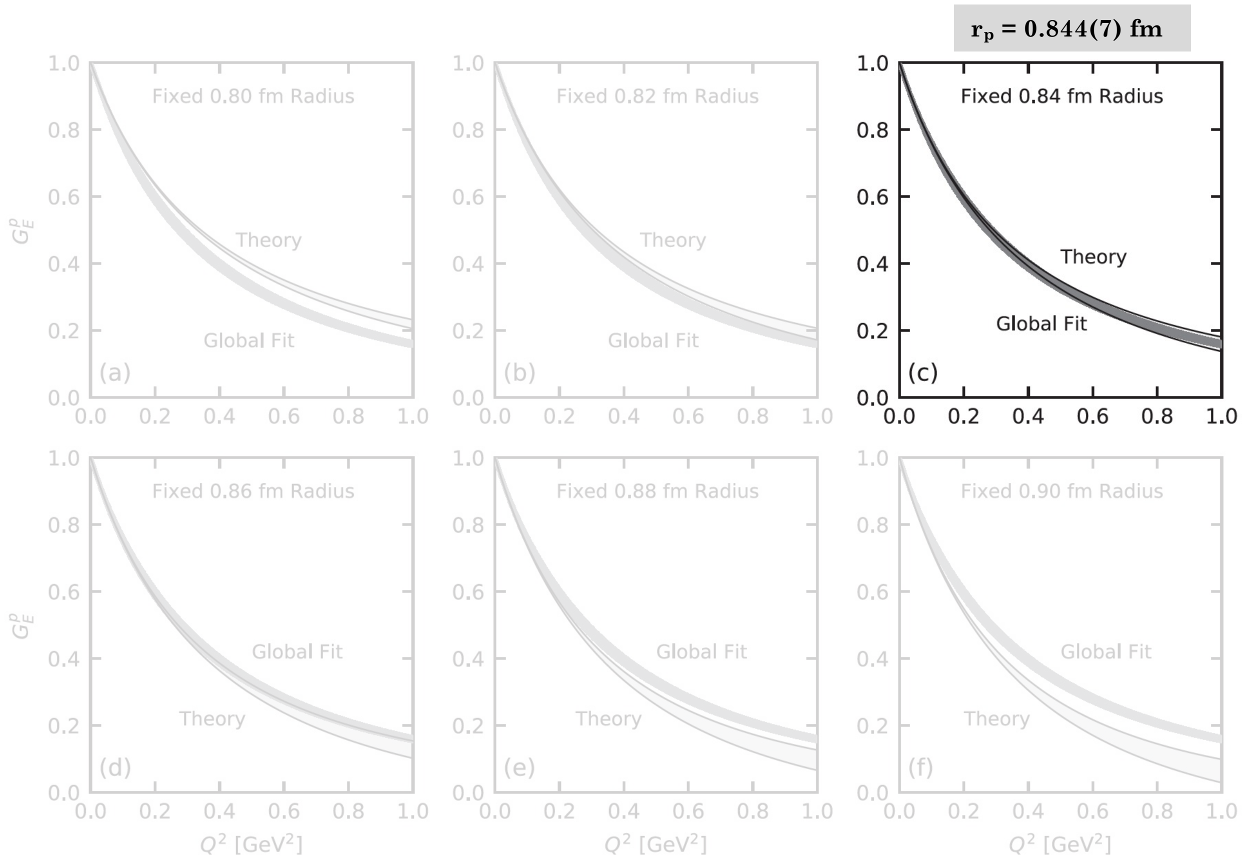
[1] TUMQCD Coll. A. Bazavov, N. Brambilla, X. Garcia i Tormo, P. Petreczky, J. Soto, A. Vairo, J. Heinrich Weber, PRD 100 (2019) 11, 114511
[2] D. Boito and V. Mateu, JHEP 03 (2020) 094

- Effective Field Theories (EFT), mostly Chiral Perturbation Theory (ChPT)
- Dispersion Theory
- Hadron-Hadron Interactions. Spectroscopy. Exotic resonances



Proton charge radius

Proton radius with EFT improved dispersively

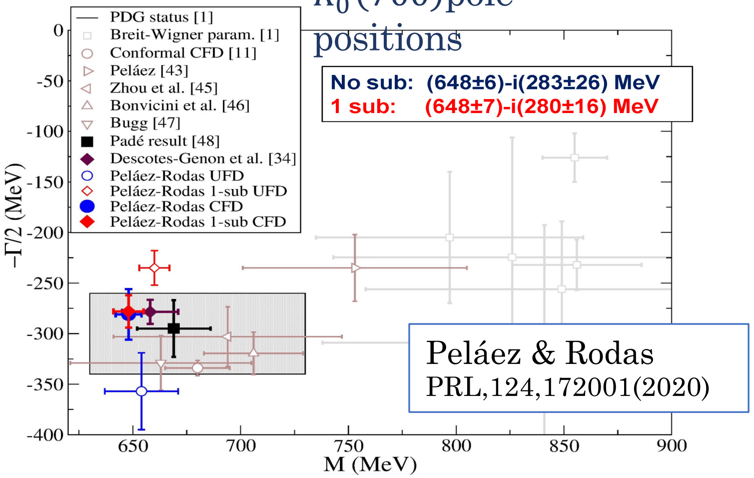


Alarcón et al. PRC 99 (2019)

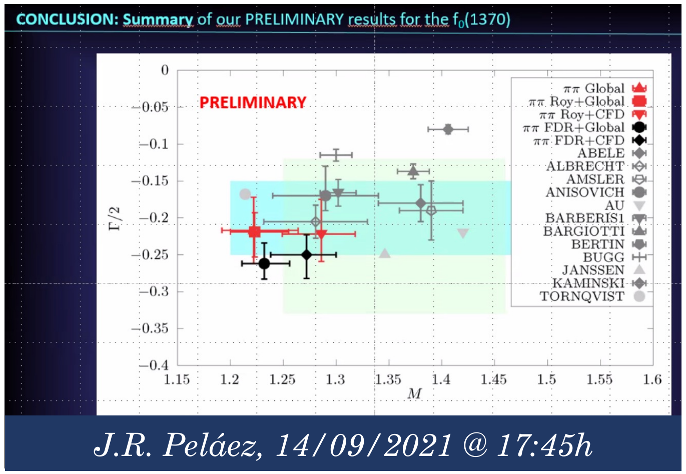
Dispersive and analytic methods

model-independent analyses to describe final state interactions

$K_0^*(700)$pole positions



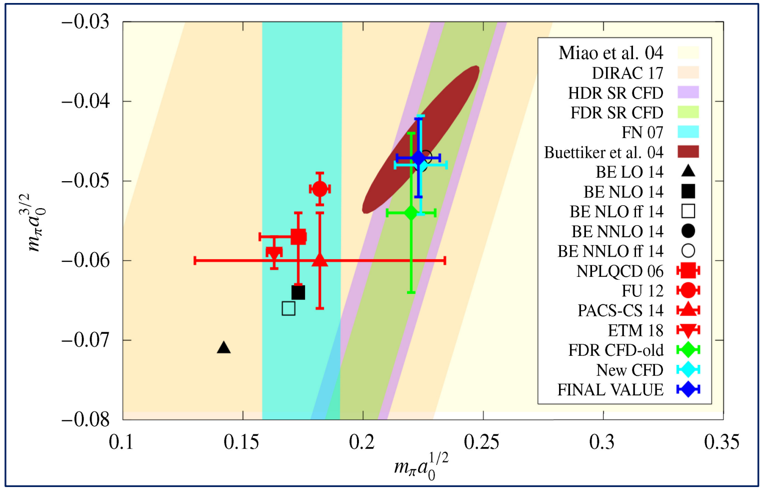
f0(1300) from meson scattering data



Talk by JR Peláez in the december workshop:
"Dispersive study of π K and π π → K $\bar{\mathrm{K}}$ scattering:
threshold parameters and κ/K*(700) resonance determination"

Dispersive $K\pi$ scattering

Peláez & Rodas arXiv: 2010.11222 (to appear in Phys. Rept.)



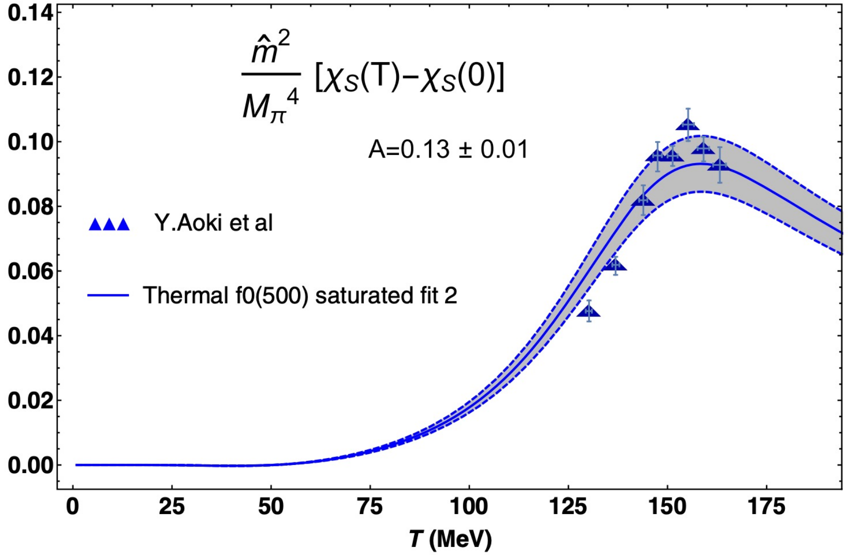
Precision dispersive approaches versus unitarized chiral perturbation theory for the lightest scalar resonances $\sigma/f_0(500)$ and $\kappa/K_0^*(700)$

Eur. Phys. J. Spec. Top. (2021) 230:1539–1574
https://doi.org/10.1140/epjs/s11734-021-00142-9

José R. Peláez[1,a], Arkaitz Rodas[2,3,b], and Jacobo Ruiz de Elvira[4,c]

1 Departamento de Física Teórica, Universidad Complutense and IPARCOS, 28040 Madrid, Spain
2 Department of Physics, College of William and Mary, Williamsburg, VA 23187, USA
3 Thomas Jefferson National Accelerator Facility, 12000 Jefferson Avenue, Newport News, VA 23606, USA
4 Albert Einstein Center for Fundamental Physics, Institute for Theoretical Physics, University of Bern, Sidlerstrasse 5, 3012 Bern, Switzerland

role of σ/f0(500) state on scalar susceptibility χ_S

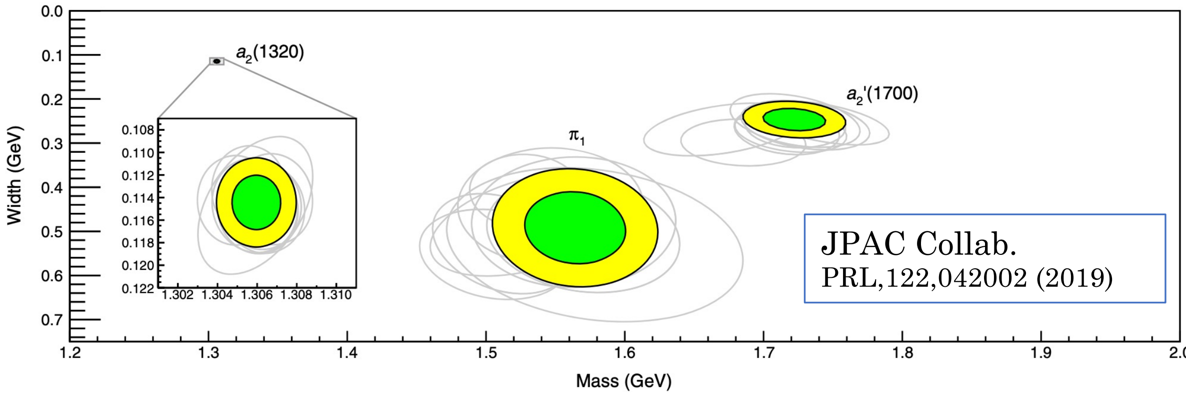


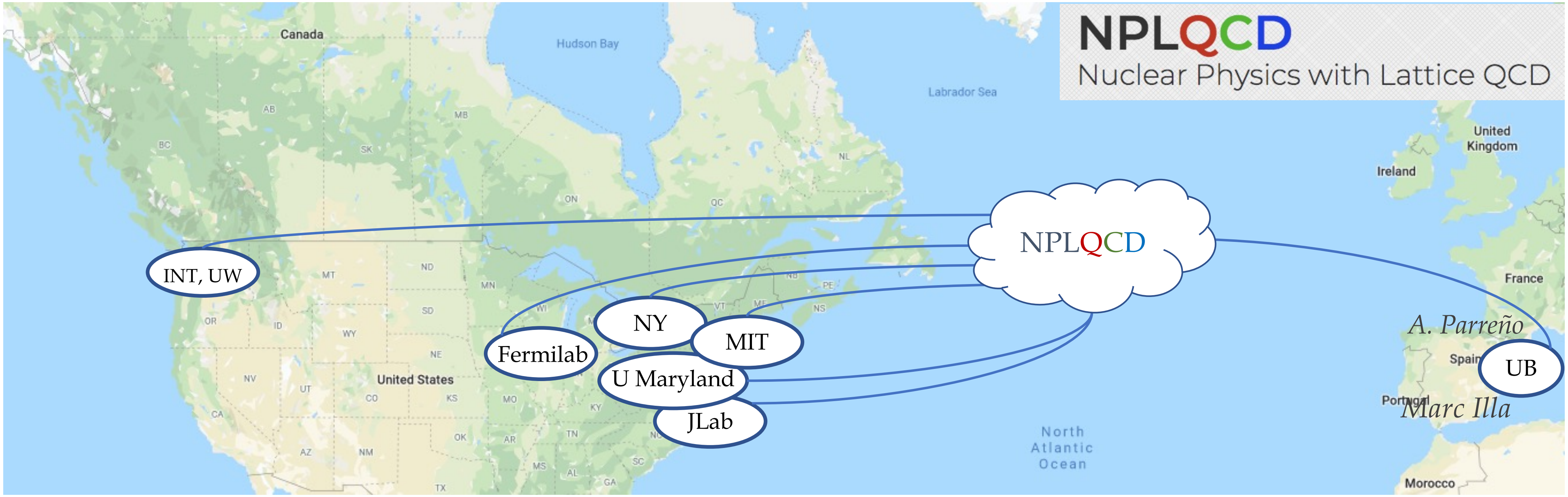
Ferreres-Solé, Gómez-Nicola, Vioque-Rodríguez
PRD99(2019)036018

Final State Interactions in

$$\pi p \to \eta^{(\prime)} \pi p$$

Lightest hybrid
Candidate pole





M. Illa, Today Sep. 16 @ 17:30

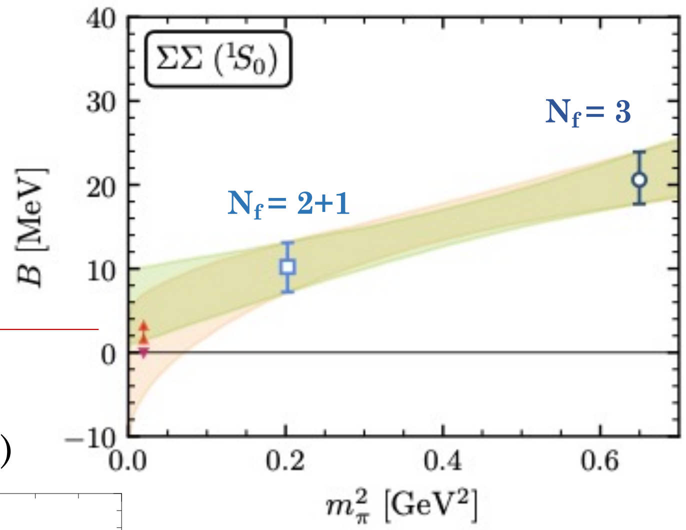
Matching lattice QCD to EFT in the baryon sector

one lattice spacing
unphysical light quark masses
different volumes

Recent work

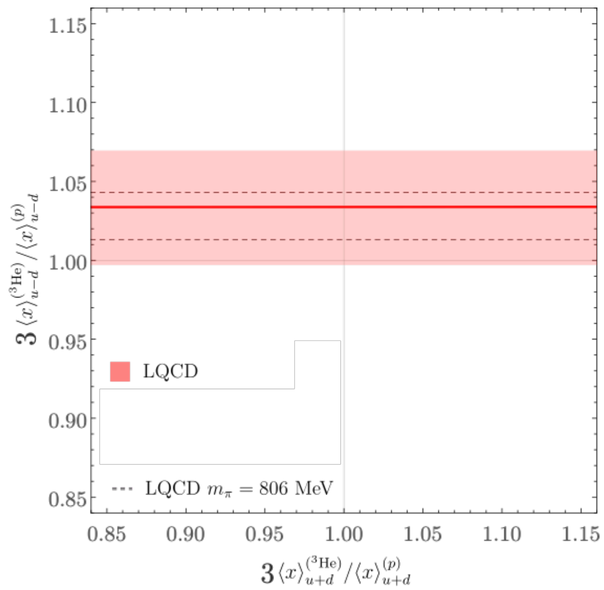
Talk by M. Illa, Thu 16 @ 17:30h

Baryon-Baryon interactions, strangeness from 0 to -4
Phys. Rev. D 103, 054508 (2021) @ m_π ~450 MeV

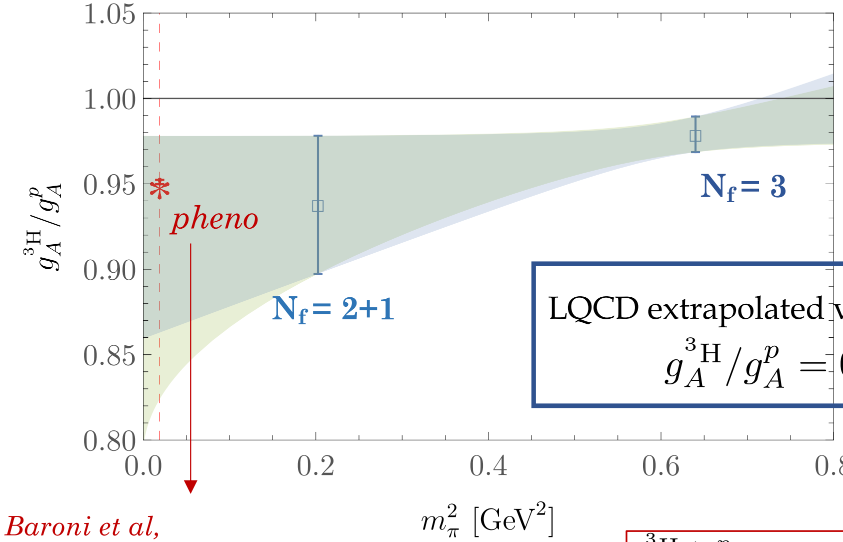


NSC97, χEFT @ NLO

Momentum fraction of ^{3}He
Phys. Rev. Lett. 126, 202001 (2021)



^{3}H axial charge
Phys. Rev. D 103, 074511 (2021)



LQCD extrapolated value to m_π^{phys}

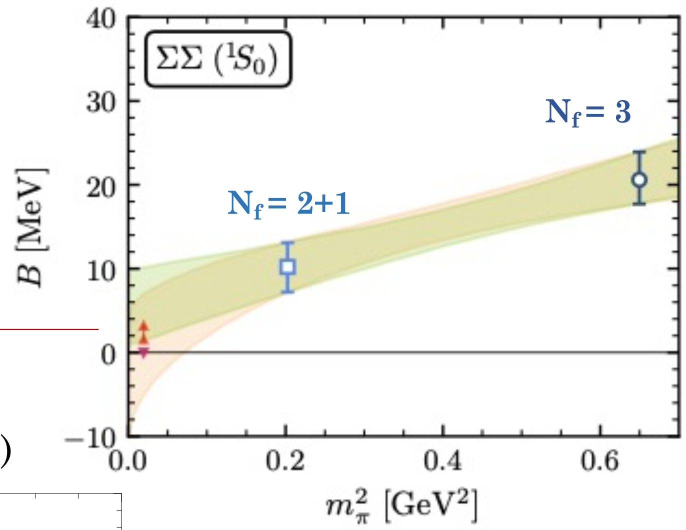
$$g_A^{^3\mathrm{H}}/g_A^p = 0.91^{+0.07}_{-0.09}$$

Baroni et al,
PRC 94, 024003 (2016); PRC95 059902 (2017)

$$\boxed{g_A^{^3\mathrm{H}}/g_A^p = 0.9511(13)}$$

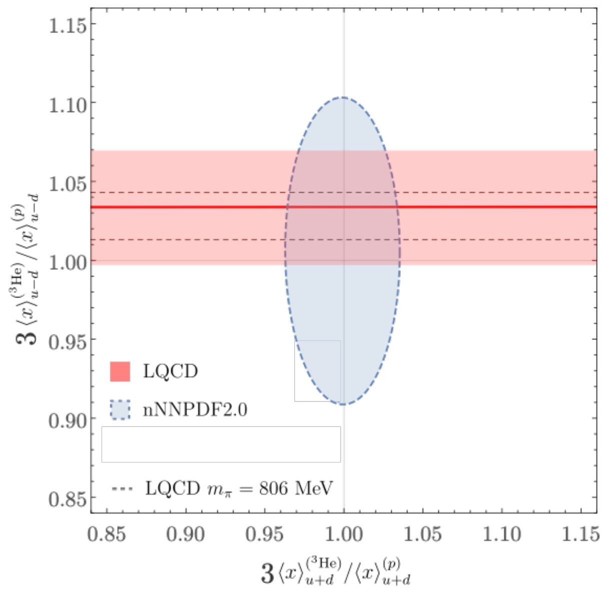
Recent work

Baryon-Baryon interactions, strangeness from 0 to -4
Phys. Rev. D 103, 054508 (2021) @ m_π ~450 MeV

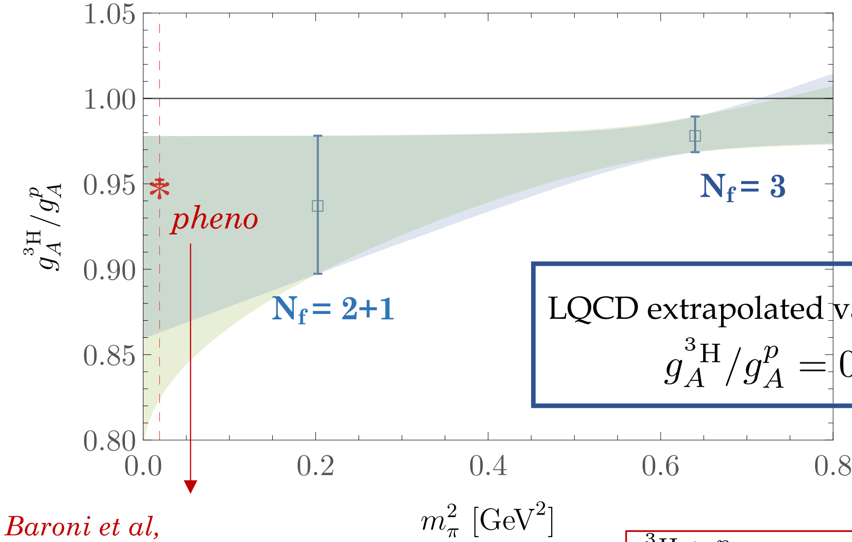


NSC97, χEFT @ NLO

Momentum fraction of ^{3}He
Phys. Rev. Lett. 126, 202001 (2021)



^{3}H axial charge
Phys. Rev. D 103, 074511 (2021)



LQCD extrapolated value to m_π^{phys}

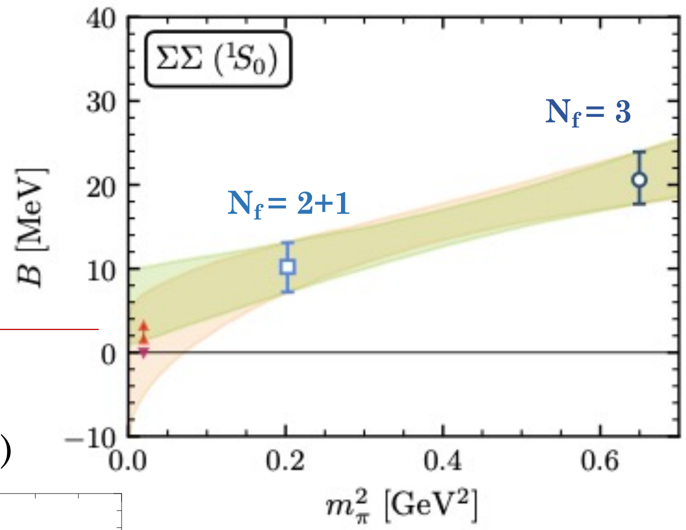
$$g_A^{^3\mathrm{H}}/g_A^p = 0.91^{+0.07}_{-0.09}$$

Baroni et al,
PRC 94, 024003 (2016); PRC95 059902 (2017)

$$g_A^{^3\mathrm{H}}/g_A^p = 0.9511(13)$$

Recent work

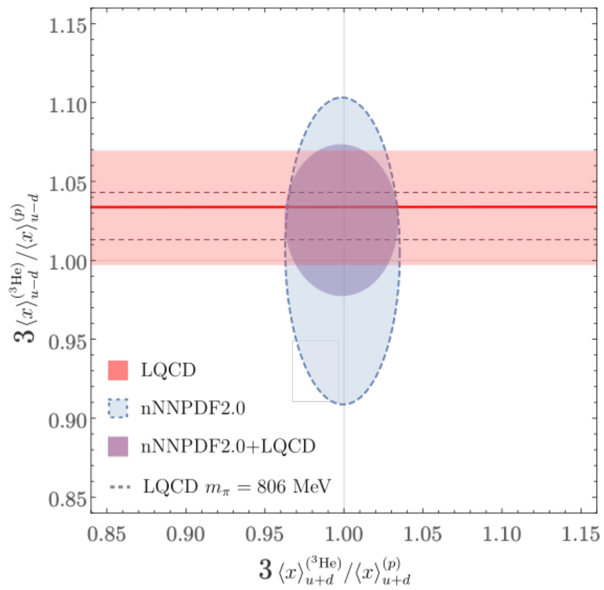
Baryon-Baryon interactions, strangeness from 0 to -4
Phys. Rev. D 103, 054508 (2021) @ m_π ~450 MeV



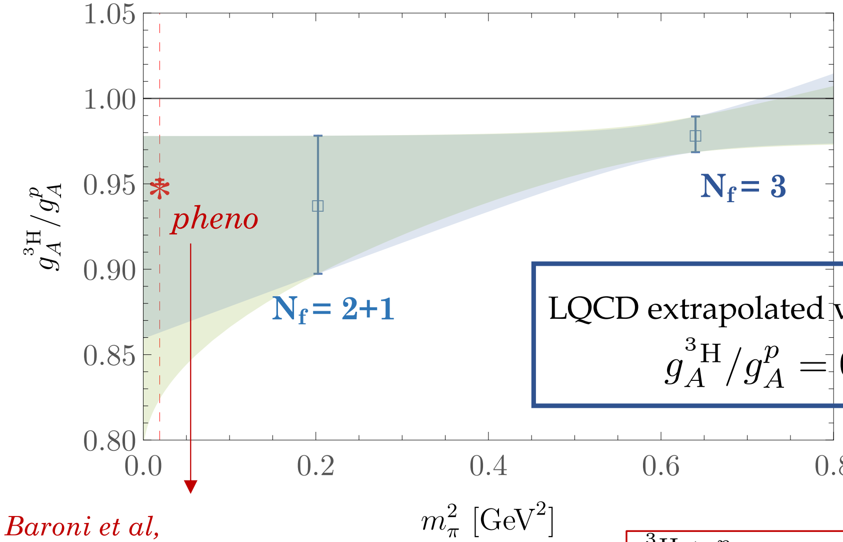
NSC97, χEFT @ NLO

Nuclear matrix elements from LQCD
Phys. Rept. **900**, 1 (2020)

Momentum fraction of ^{3}He
Phys. Rev. Lett. 126, 202001 (2021)



^{3}H axial charge
Phys. Rev. D 103, 074511 (2021)



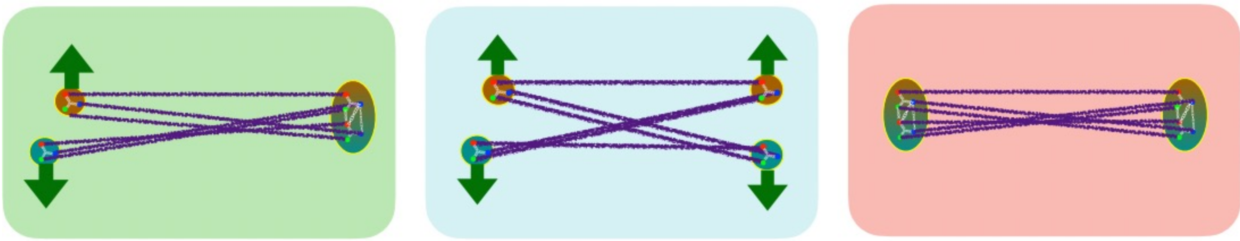
LQCD extrapolated value to m_π^{phys}
$$g_A^{^3\mathrm{H}}/g_A^p = 0.91^{+0.07}_{-0.09}$$

Baroni et al,
PRC 94, 024003 (2016); PRC95 059902 (2017)

$$\boxed{g_A^{^3\mathrm{H}}/g_A^p = 0.9511(13)}$$

Variational method to extract the energy spectrum

S. Amarasinghe, et al. [NPLQCD], arXiv:2108.10835 [hep-lat]

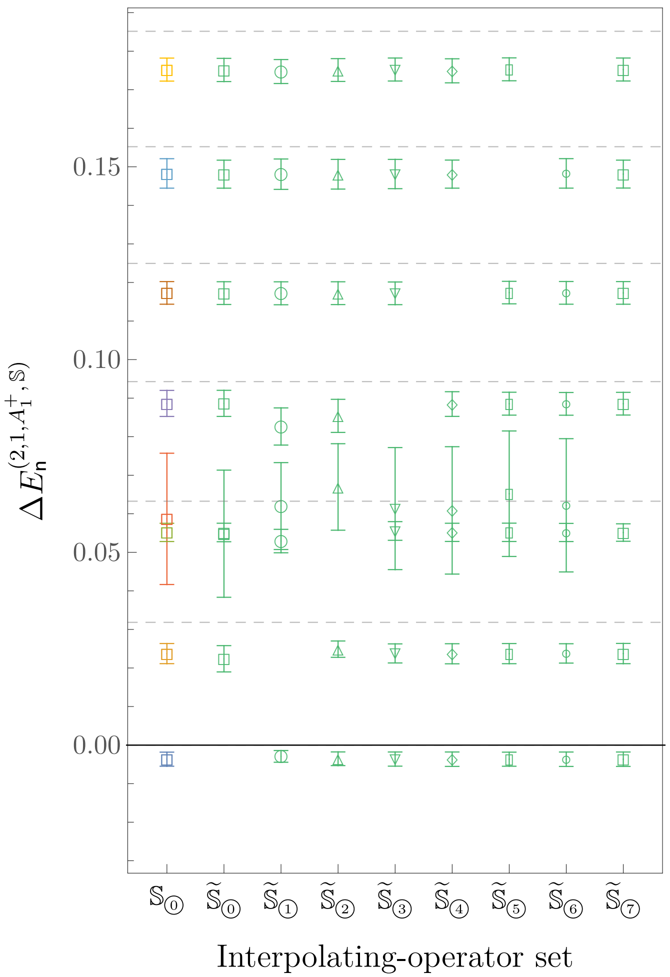


50 ways to build a deuteron:
a variational calculation of two-nucleon systems

M. Wagman @ 38th International Symposium
for Lattice Gauge Theory, MIT (online), July 2021

Our results demonstrate the importance of using an interpolating-operator set with significant overlap onto all energy levels of interest and further demonstrate that having a large interpolating-operator set is not sufficient to guarantee that a set will have good overlap onto the ground state or a particular excited state.

NN (I=1) with $N_f = 3$

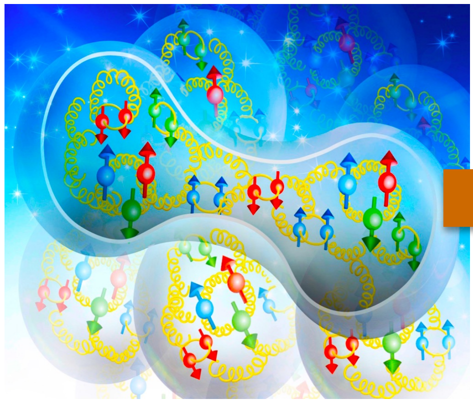


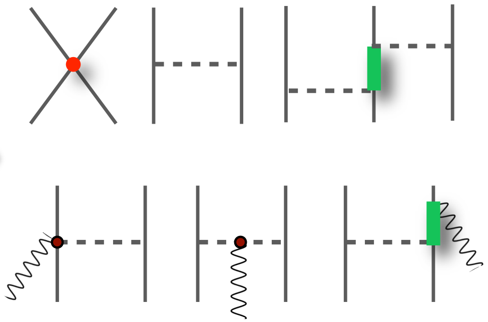
Nuclear structure with chiral forces

- Francesco Pederiva: University of Trento and INFN-TIFPA
- Alessandro Lovato: INFN-TIFPA & Argonne National Laboratory

Nuclear structure with Chiral forces,
A. Lovato @ Theoretical aspects of Hadron Spectroscopy and Phenomenology, 12/2020 (virtual)

Goal:
Describe nuclei and nucleonic matter as they emerge from individual interactions among protons and neutrons





Formalism:
nuclear quantum Monte Carlo methods → input realistic nuclear interactions

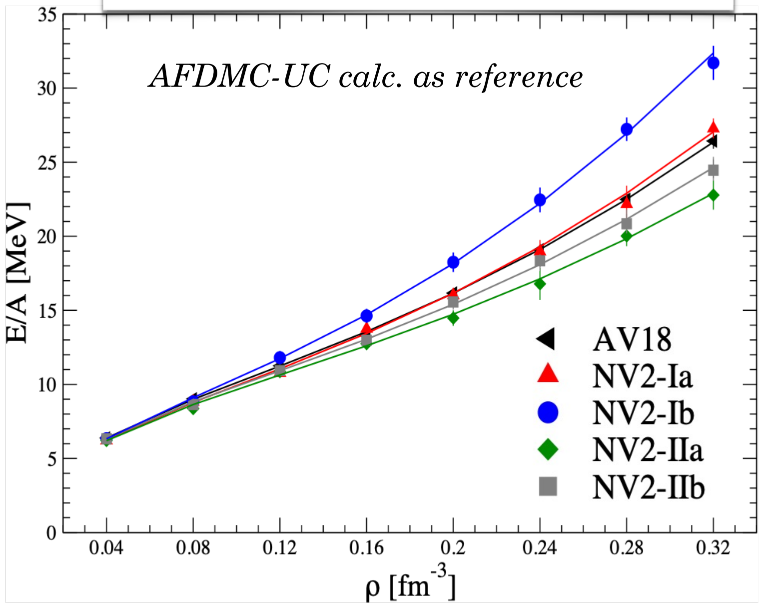
Neutron matter with chiral-EFT potentials

Impact:
- The equation of state is imprinted in gravitational-wave signal from coalescing neutron stars;
- Test microscopic nuclear Hamiltonians fit on light nuclear systems:

Approach
- We use as input the Norfolk, Delta-full, chiral effective field theory nucleon-nucleon potentials
- We compare Brueckner-Bethe-Goldstone, Fermi hypernetted chain, and quantum Monte Carlo

M. Piarulli, AL et al., PRC **101**, 045801(2020)

Results
- We observe good agreement among BBG, FHNC and QMC, once unconstrained propagation is performed in quantum Monte Carlo to control the fermion-sign problem;
- With the exception of the NV2-Ib case, the maximum spread among the NN nuclear potentials EoS is within 5 MeV per particle up to $\rho = 2\rho_0$
- Work in progress to include consistent three-body interactions;



Emerging areas, including quantum computing and machine-learning techniques.

Recent Publications:

- Nuclear energy density functionals grounded in ab initio calculations,
  F. Marino, et. al., Phys. Rev. C 104 (2021) 2, 024315

- Nuclei with up to A = 6 nucleons with artificial neural network wave functions,
  A. Gnech, et. al., arXiv:2108.06836 [nucl-th]

Alessandro Lovato,
"Light nuclei with artificial neural networks",
Today, Wed. 15 @ 14:30

Ab initio calculations of heavy nuclei $A \sim 100$

UNIVERSITAT DE BARCELONA

TECHNISCHE UNIVERSITÄT DARMSTADT

UNIVERSITY of WASHINGTON

TRIUMF

Goal

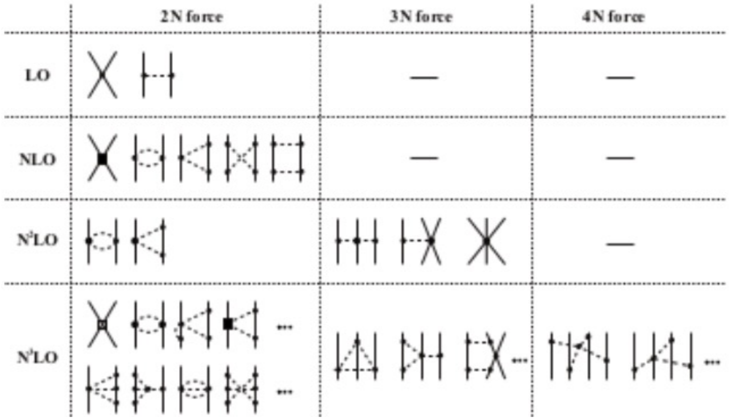
Ab initio calculations of medium-mass and heavy nuclei
based on chiral EFT NN+3N forces

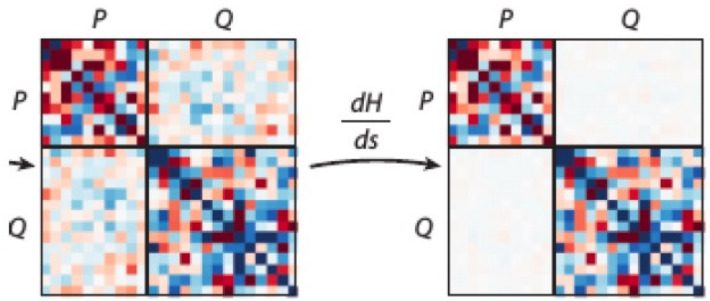
Many-body method

Valence-space in-medium similarity renormalization group (VS-IMSRG):
builds nuclear shell model interaction H_{eff}
in small model space (P) from full space (P+Q)

People

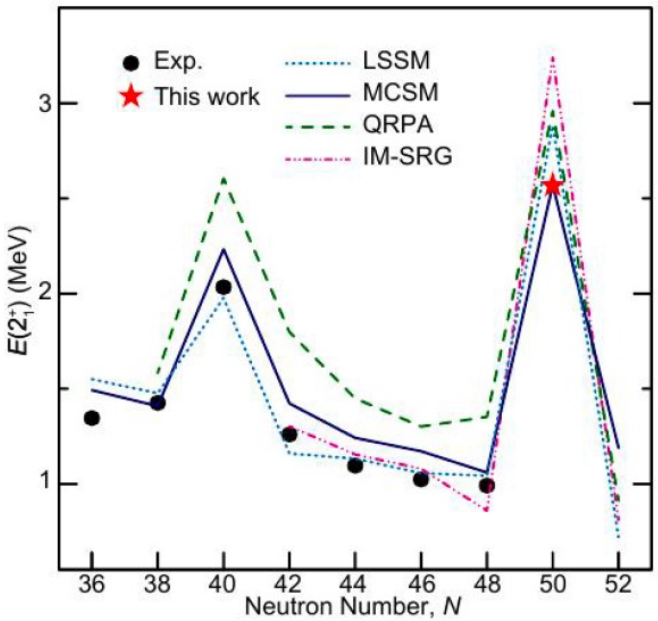
J. Menéndez (Barcelona), A.Schwenk (Darmstadt), R. Stroberg (Seattle), J. Holt (TRIUMF)

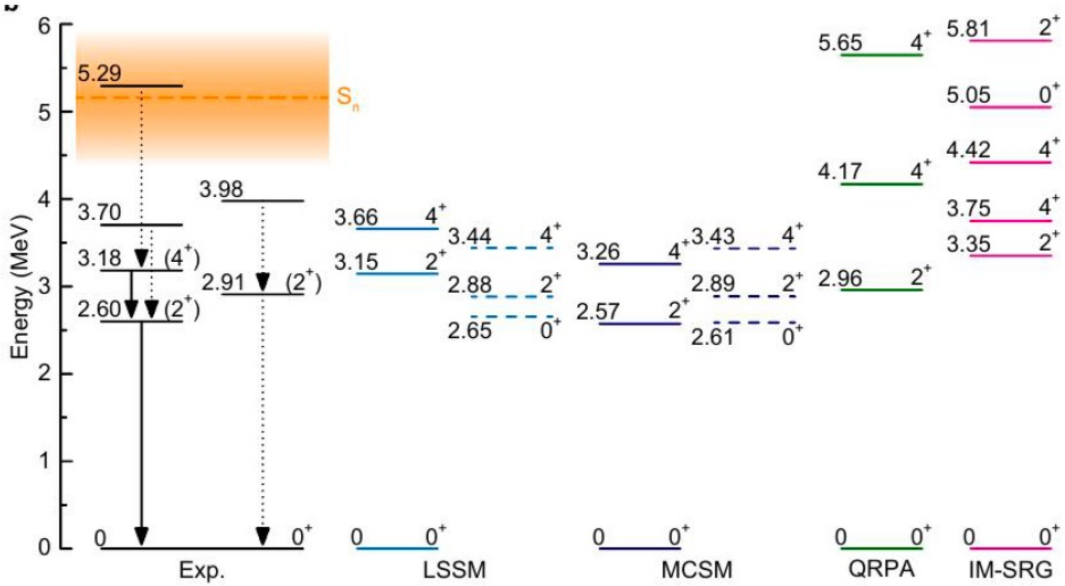




Doubly magic ^{78}Ni

Highlight: VS-IMSRG predicts doubly magic ^{78}Ni (2^+ energy $\sim$ 2.5MeV) good agreement with RIKEN RIBF measurement as well as $E(2^+)$ energies along Ni isotopic chain



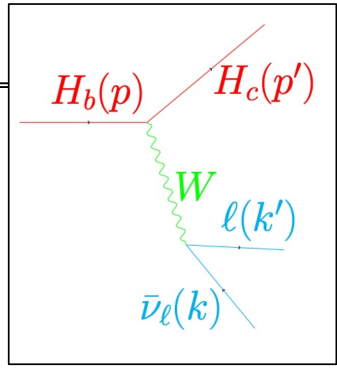


VS-IMSRG misses low-lying deformed band (low-lying 0^+ excited state)
Next step: avoid truncations in H_{eff} related to collectivity

New physics: test of lepton flavor universality (LFU)

semileptonic $b \longrightarrow c$ decays: $H_b \longrightarrow H_c \ell \, \bar{\nu}_\ell, \; \ell = \tau$ or μ, e

Tests of LFU in $\Lambda_b \longrightarrow \Lambda_c \ell \bar{\nu}_\ell$, $\ell = \tau, e/\mu$, and $b \longrightarrow s \ell^+ \ell^-$ decays using LQCD form-factors and searches for BSM signals



$$\frac{d^2\Gamma}{d\omega d\cos\theta_\ell} \sim a_0(\omega) + a_1(\omega)\cos\theta_\ell + a_2(\omega)(\cos\theta_\ell)^2$$

$$\frac{d^2\Gamma}{d\omega dE_\ell} \sim c_0(\omega) + c_1(\omega)\frac{E_\ell}{M} + c_2(\omega)\frac{E_\ell^2}{M^2}$$

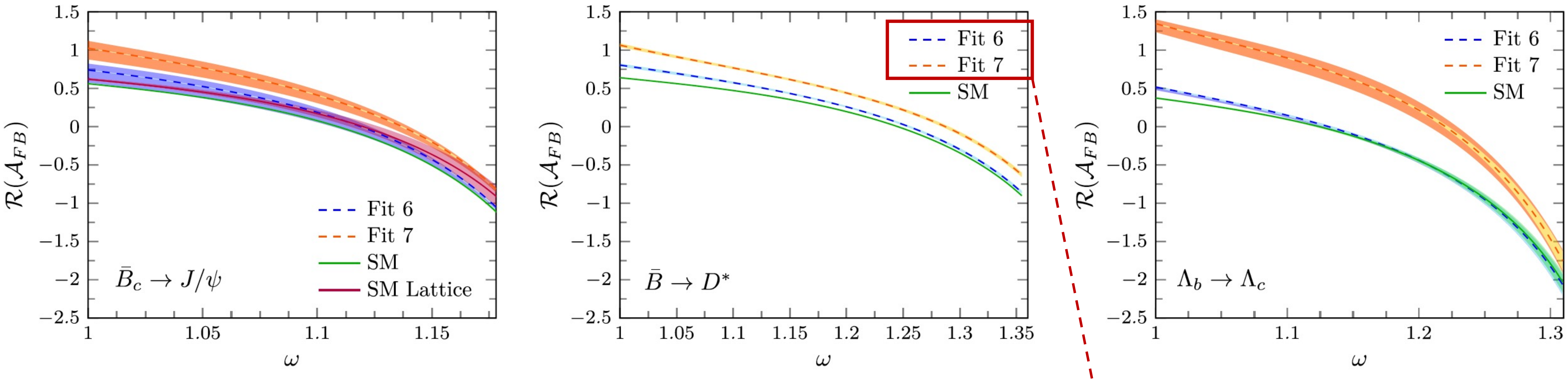
ω: product of the hadron four-velocities
θ_ℓ : angle made by the three-momenta of the charged lepton and the final hadron in the W^- CM frame

N. Penalva, E. Hernández, and J. Nieves, PRD 100 (2019); JHEP 06 (2021), PRD 101.11 (2020); PRD 102, 096016 (2020); arXiv: 2107.13406 [hep-ph]

Also, see poster presentation yesterday, Wed. 15, by Neus Penalva

ratio forward-backward asymmetry
might disentangle between different
BSM scenarios

$$\mathcal{R}(\mathcal{A}_{\rm FB}) = \frac{(\mathcal{A}_{\rm FB})_\tau}{(\mathcal{A}_{\rm FB})^{\rm SM}_{\ell=e,\mu}} = \frac{\left[\frac{a_1}{2a_0+2a_2/3}\right]_\tau}{\left[\frac{a_1}{2a_0+2a_2/3}\right]^{\rm SM}_{\ell=e,\mu}}$$



New Physics (BSM) adjusted to solve LFU anomalies in semileptonic $\bar{B}$- decays

N. Penalva, E. Hernández, and J. Nieves, PRD 100 (2019); JHEP 06 (2021), PRD 101.11 (2020); PRD 102, 096016 (2020); arXiv: 2107.13406 [hep-ph]

UNIVERSIDAD
DE GRANADA

Neutrino and electron scattering processes with nuclei and nucleons

- from the quasi-elastic regime to the inelastic ones,
- including also the deep inelastic scattering (DIS)

Our work is important for the analyses of the neutrino experiments with the aim of reducing the systematic errors in the determination of the neutrino mixing matrix elements, including the possible CP-violating phase in the lepton sector, of importance for the full understanding of the phenomenon of neutrino oscillations and possible explanations about the matter-antimatter asymmetry in the Universe.

Renormalization group:
analysis of the dependence on scale of nuclear and hadronic interactions according to the (isospectral) similarity renormalization group and its implications in nuclear and neutron matter

Partonic structure:
analysis of the pion single and double parton distributions, quasidistributions and pseudodistributions which are directly comparable to experimental analysis or incipient lattice calculations by a suitable choice of the renormalization scale.

Uncertainty quantification in NN interactions:
analysis of the impact of statistical and systematic errors in the chiral and non-chiral descriptions of NN scattering data according to the self-consistent 2013-Granada NN database (8000 measurements)

Review on the proton radius,
by Clara Peset , Antonio Pineda and Oleksandr Tomalak

"We review determinations of the electric proton charge radius from a diverse set of low-energy observables. We explore under which conditions it can be related to Wilson coefficients of appropriate effective field theories."