ATTIVITÀ DI QCDLAT NEL CALCOLO AD ALTE PRESTAZIONI

Tema1: QCD e fisica del sapore

Mauro Papinutto
(Universita` La Sapienza and INFN Sezione di Roma)

QCD simulation with N_f=2+1 flavors of non-perturbatively improved Wilson fermions

- Coordinated Lattice Simulations (CLS) is a joint effort involving the INFN iniziativa specifica QCDLAT (Sezioni di Milano-Bicocca, La Sapienza, Tor Vergata), CERN, DESY-Zeuthen, Dublin, HU Berlin, Mainz, Münster, Odense, Regensburg, Wuppertal, UAM Madrid.

- First round of simulations:

  2 PRACE projects have just finished: 70 Mch on BG/Q @CINECA (100.3% used) and 50 Mch on SuperMUC @LRZ.

  3 national projects: Gauss-Center and NIC in Jülich (Germany) and CSCS in Lugano (Switzerland).

- Goal: generation of several ensembles of gauge configurations with N_f=2+1 flavors of non-perturbatively improved Wilson fermions which allow reliable extrapolation to the continuum limit and to physical quark masses while keeping finite volume effects and other systematics under control.

- Careful tuning of physics parameters (quark masses m_u, m_s) needed

- Charm sea quark effects in low energy observables (≤ 1 GeV) expected of the order of few per mille [Knechtli et al., Lattice 2014].

- But cut-off effects introduced by the charm can be large => not worth simulating the charm sea quark if one can not reach per mille accuracy in the systematic uncertainties (finite volume, continuum and chiral limit extrapolations).

Problems

Lattice simulations close to the physical point are difficult because

- autocorrelations grow, $\tau_{\exp} \propto 1/a^2 +$ topology freezing
- accidental zero-modes of the Dirac operator are encountered
- the condition number of the Dirac operator grows as $m_{u,d} \to 0$

Proposed solutions

To circumvent the above issues a number of improvements has been proposed, namely

- open boundary conditions
- twisted mass infrared regulator
- deflated solver

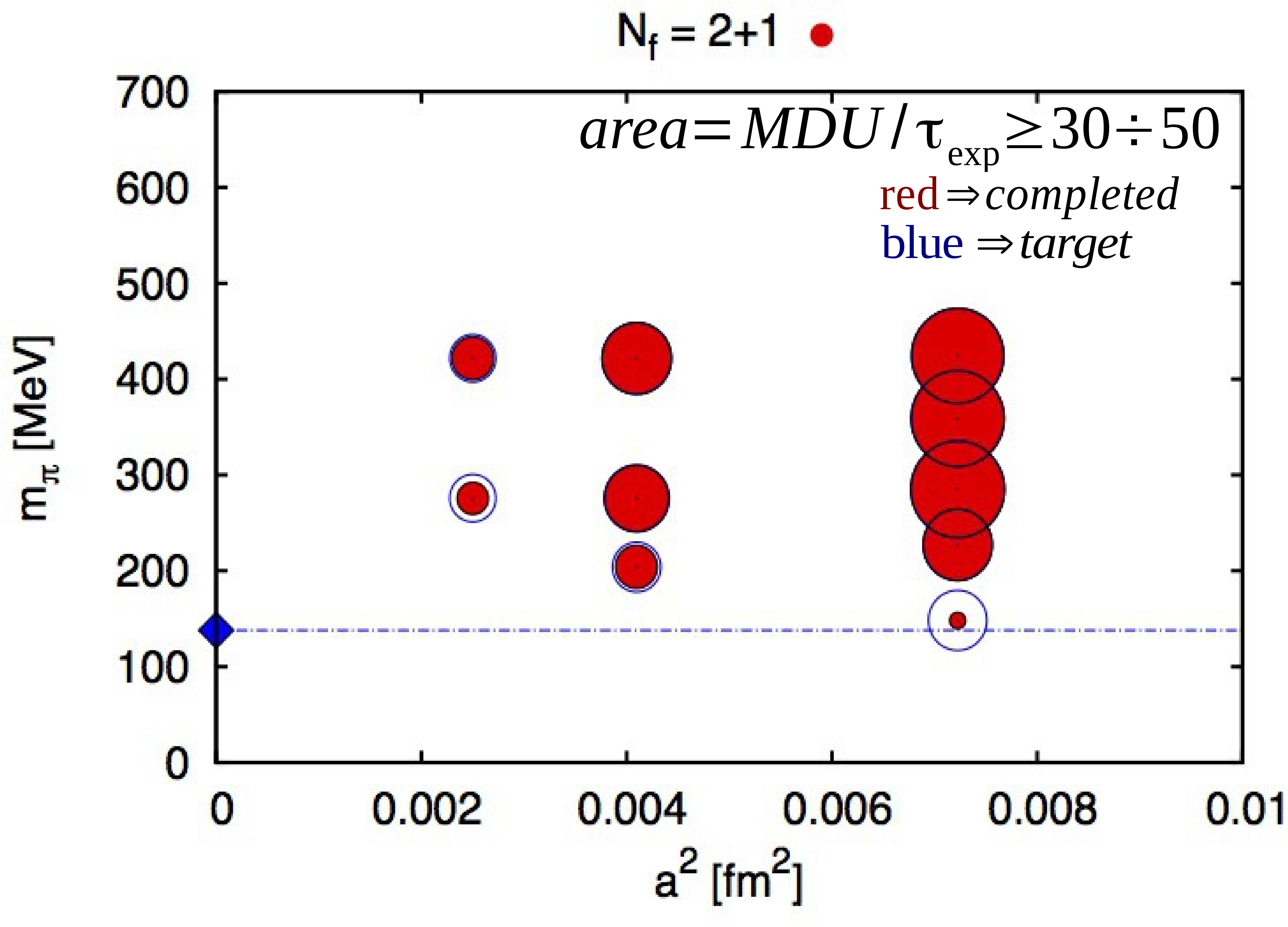
- Simulation performed with the publicly available openQCD code: http://luscher.web.cern.ch/luscher/openQCD/index.html

Quark mass trajectory

- In order to achieve O(a) improvement we choose to generate a set of ensembles with $m_u+m_d+m_s$ = const, starting from the SU(3) symmetric limit and decreasing $m_u = m_d$ toward the physical point.
- Great simplification of the tuning procedure.
- However many algorithmic parameters to be tuned to reach efficient simulations!

Overview: lattice spacings and pion masses

		0.085 fm	0.064 fm	0.05 fm	a [fm]
m_K	m_π	3.4	3.55	3.7	β
415 MeV	415 MeV	$32^3\times96$	$32^3\times96$	$48^3\times128$	
440 MeV	350 MeV	$32^3\times96$			
470 MeV	280 MeV	$32^3\times96$	$48^3\times128$	$64^3\times192$	$m_\pi L \geqslant 4$
480 MeV	220 MeV	$48^3\times96$	$64^3\times128$		
490 MeV	150 MeV	$64^3\times128$			
		60	105	170	$\tau_{exp}\,[MDU]$



N_f = 2+1
area = MDU / τ_exp ≥ 30÷50
red ⇒ completed
blue ⇒ target
700
600
500
400
300
200
100
0
m_π [MeV]
0
0.002
0.004
0.006
0.008
0.01
a^2 [fm^2]

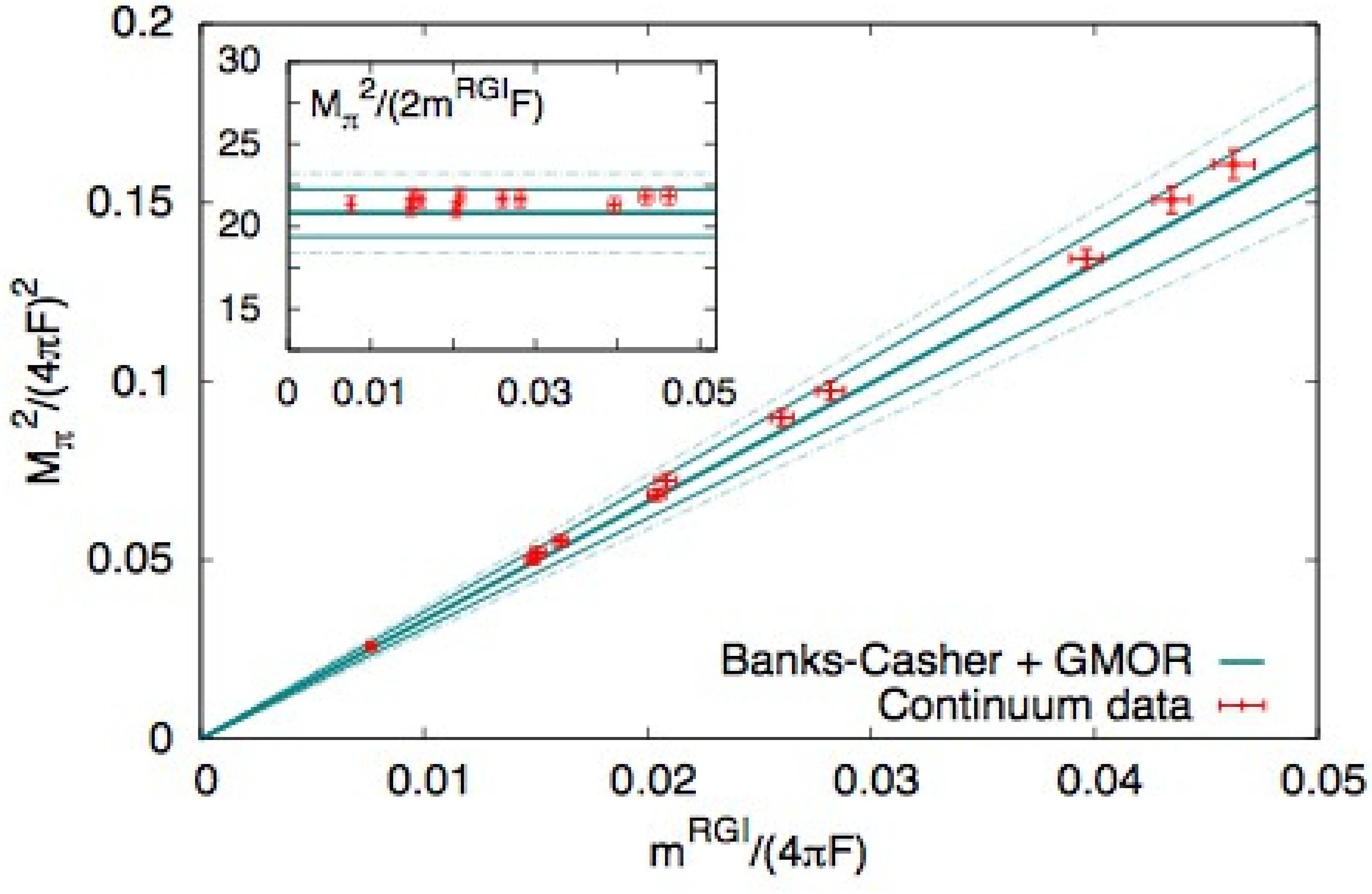
- More statistics needed on the lightest points (the most expensive ones) especially at the coarsest lattice spacing (the only one at the physical pion mass) and to possibly add another ensemble with physical pion mass at the intermediate lattice spacing => A lot of computer time on large parallel architectures still needed.

- Thanks to these ensembles it will be possible to carry out many interesting physics projects to unprecedented accuracy:

  1) Coupling constant and lambda parameter;
  2) Light, strange and charm quark masses;
  3) Pion and Kaon decay constants;
  4) Chiral condensate;
  5) Low energy constants of SU(2) and SU(3) chiral pert. theory;
  6) Decay constants of charmed mesons;
  7) Baryon spectrum;
  8) Axial charge of the nucleon;
  9) Kaon B-parameter and $K \to \pi$ semi-leptonic form factors;
  10) Nucleon form factors and moments of parton distributions.

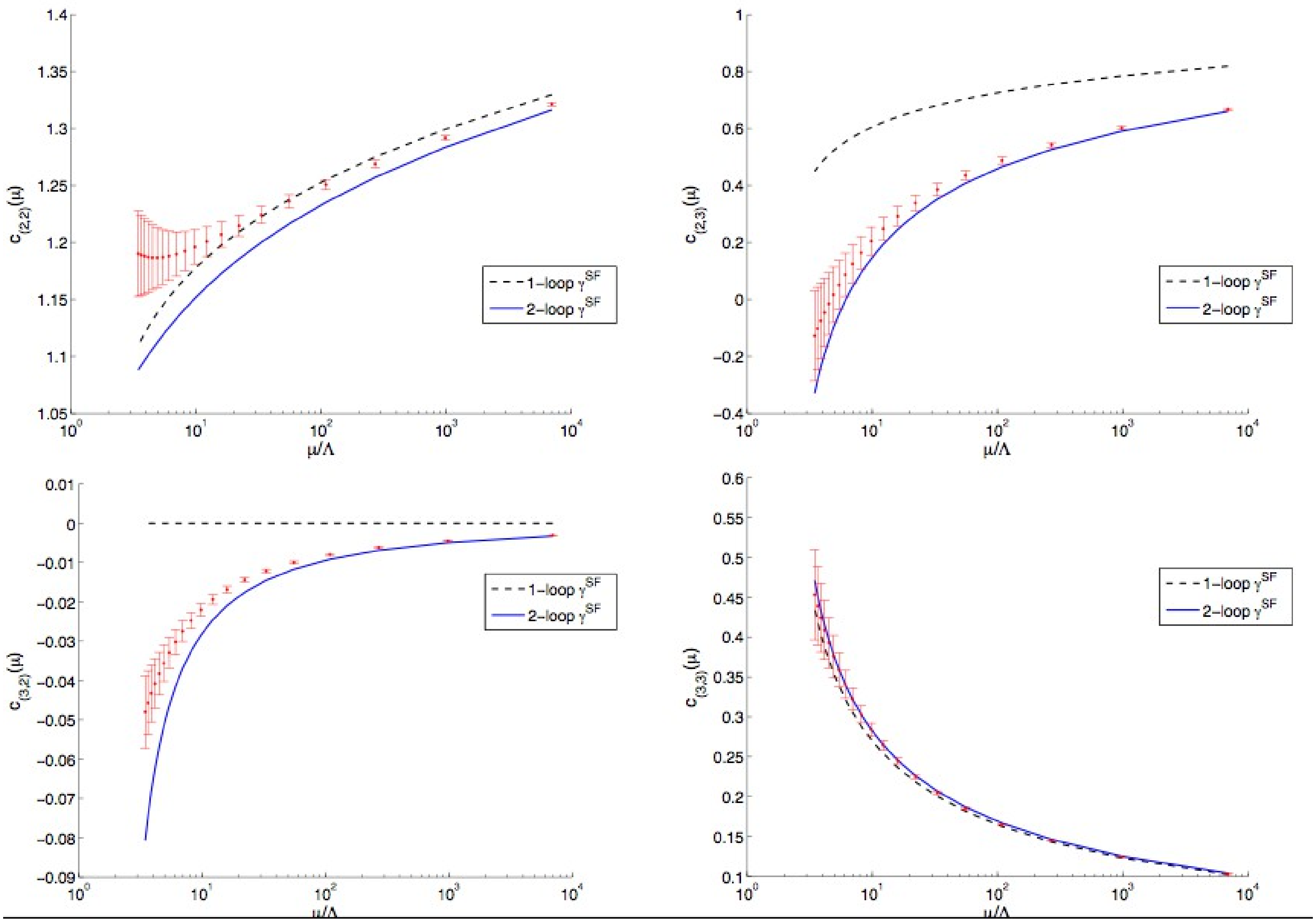
N_f=2 on-going projects

Banks-Casher relation: chiral condensate in QCD ↔ spectral density of the Dirac operator for λ=0 [Giusti, Engel et al, arXiv:1406.4987]

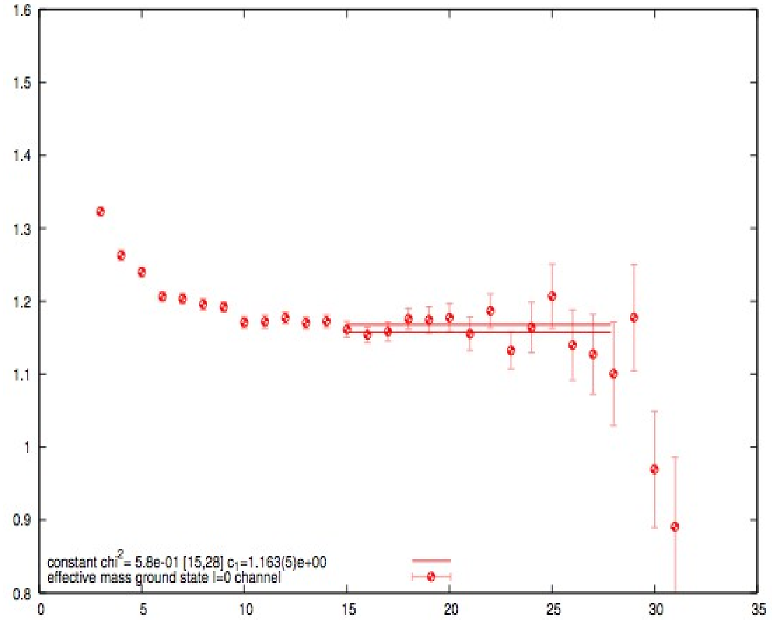


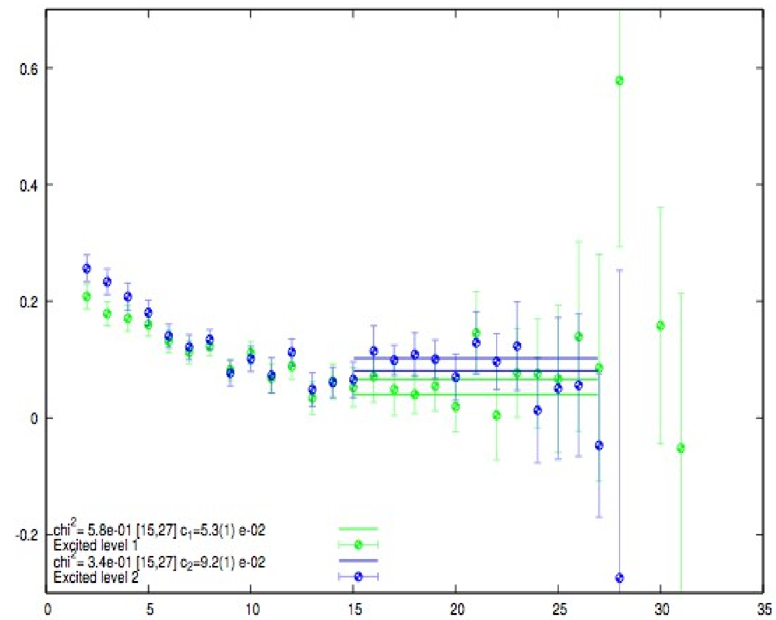
Renormalization of ΔF=2 four fermion operators in the Schrödinger Functional scheme and computation of the B-parameters relevant for BSM physics [Papinutto, Vladikas et al.].

Non perturbative RG evolution between 0.5 GeV and 60 GeV:



Exotic meson spectroscopy: is there a resonance or a bound state in the open channel with two charm quarks (doubly-charmed tetraquarks)? [Guerrieri, Papinutto, Tantalo]





Heavy-light meson physics by using HQET [Papinutto, Vladikas et al.]

Participation at the FLAG working group [Vladikas et al.]