Réunion annuelle du “Groupement de recherche” (GDR) - QCD 2016

Hadron Spectroscopy in Lattice QCD

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Outline

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- Hadron Spectroscopy
  - Masses
  - Decay Constants

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Introduction

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Hadron spectroscopy: charmonium mesons

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Lattice QCD - only way to use full QCD and do non-perturbative calculation

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Hadron spectroscopy: charmonium mesons

Lattice QCD - only way to use full QCD and do non-perturbative calculation

Ground state: pseudoscalar and vectorial cases

Spectroscopy

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Why? Study the masses and decay constants of mesons

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How? Using two-point correlation functions

Spectroscopy

Why? Study the masses and decay constants of mesons

How? Using two-point correlation functions

$$C(t) = \langle\Omega|\mathcal{O}_1(t)\mathcal{O}_2^\dagger(0)|\Omega\rangle \xrightarrow{t\to\infty} \mathcal{Z}_{\mathcal{O}_1\mathcal{O}_2}[e^{-mt}]$$

$$\mathcal{Z}_{\mathcal{O}_1\mathcal{O}_2} = \frac{1}{2m}\langle\Omega|\mathcal{O}_1(0)|M\rangle\,\langle M|\mathcal{O}_2^\dagger(0)|\Omega\rangle$$

$\mathcal{O}_1 - \mathcal{O}_2$: interpolating fields

m : meson mass

$|M\rangle$: ground state meson mass

$|\Omega\rangle$: vacuum state

Masses

Masses

Pseudoscalar Mass

Masses

Pseudoscalar Mass

$$C(t) = \langle \Omega | \mathscr{O}(t) \mathscr{O}^\dagger(0) | \Omega \rangle \xrightarrow{t \to \infty} \mathscr{Z}_{\mathscr{O}\mathscr{O}} [e^{-m_P t}]$$

$$\mathscr{Z}_{\mathscr{O}\mathscr{O}} = \frac{1}{2m_P} | \langle \Omega | \mathscr{O}(0) | M_P \rangle |^2$$

By a fit we extract:

$\mathscr{Z}_{\mathscr{O}\mathscr{O}}$

m_P

$\mathscr{O}^\dagger$: creation operator

$|M_P\rangle$: ground state pseudoscalar mass

m_p : pseudoscalar mass

Decay Constants

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Pseudoscalar Meson

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Pseudoscalar Meson

Decay constant definition

$$< \Omega|A|M_P >= f_P m_P$$

Decay Constants

Pseudoscalar Meson

Decay constant definition	$< \Omega \| A \| M_P > = f_P m_P$

So $\mathcal{O}_1 = A$
$\mathcal{O}_2 = P$

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$$\underbrace{< \Omega | A(0) | M_P >}_{f_P m_P} \underbrace{< M_P | P^\dagger | \Omega >}_{\sqrt{2 m_P} \sqrt{\mathcal{Z}_{PP}}} e^{-m_P t}$$

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$2 m_P \mathscr{Z}_{AP}$

Decay Constants

Pseudoscalar Meson

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Decay constant: $f_P m_P = Z_A \sqrt{2 m_P} \frac{\mathcal{Z}_{AP}}{\mathcal{Z}_{PP}}$

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Vector Meson

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So $\mathcal{O} = V$ $\quad C(t) =< \Omega | V_0(t) V_0^\dagger(0) | \Omega > \xrightarrow{t \to \infty}$

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$$C(t) = < \Omega | V_0(t) V_0^\dagger(0) | \Omega > \xrightarrow{t \to \infty} \underbrace{| < \Omega | V_0(0) | M_V > |^2}_{\mathscr{Z}_V} e^{-m_V t}$$

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Decay constant: $f_V m_V = Z_V \sqrt{\mathscr{Z}_V}$

Results (masses)

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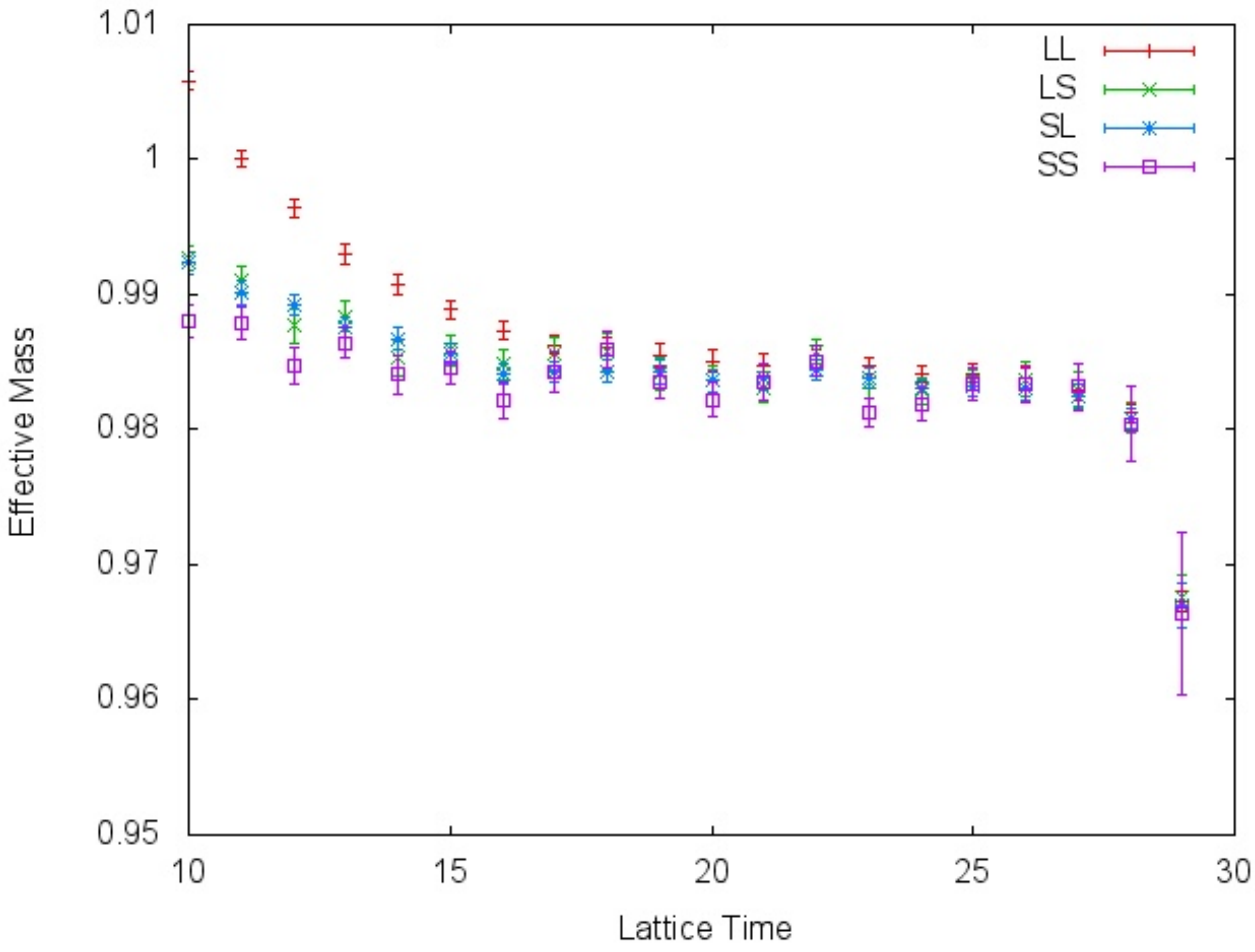
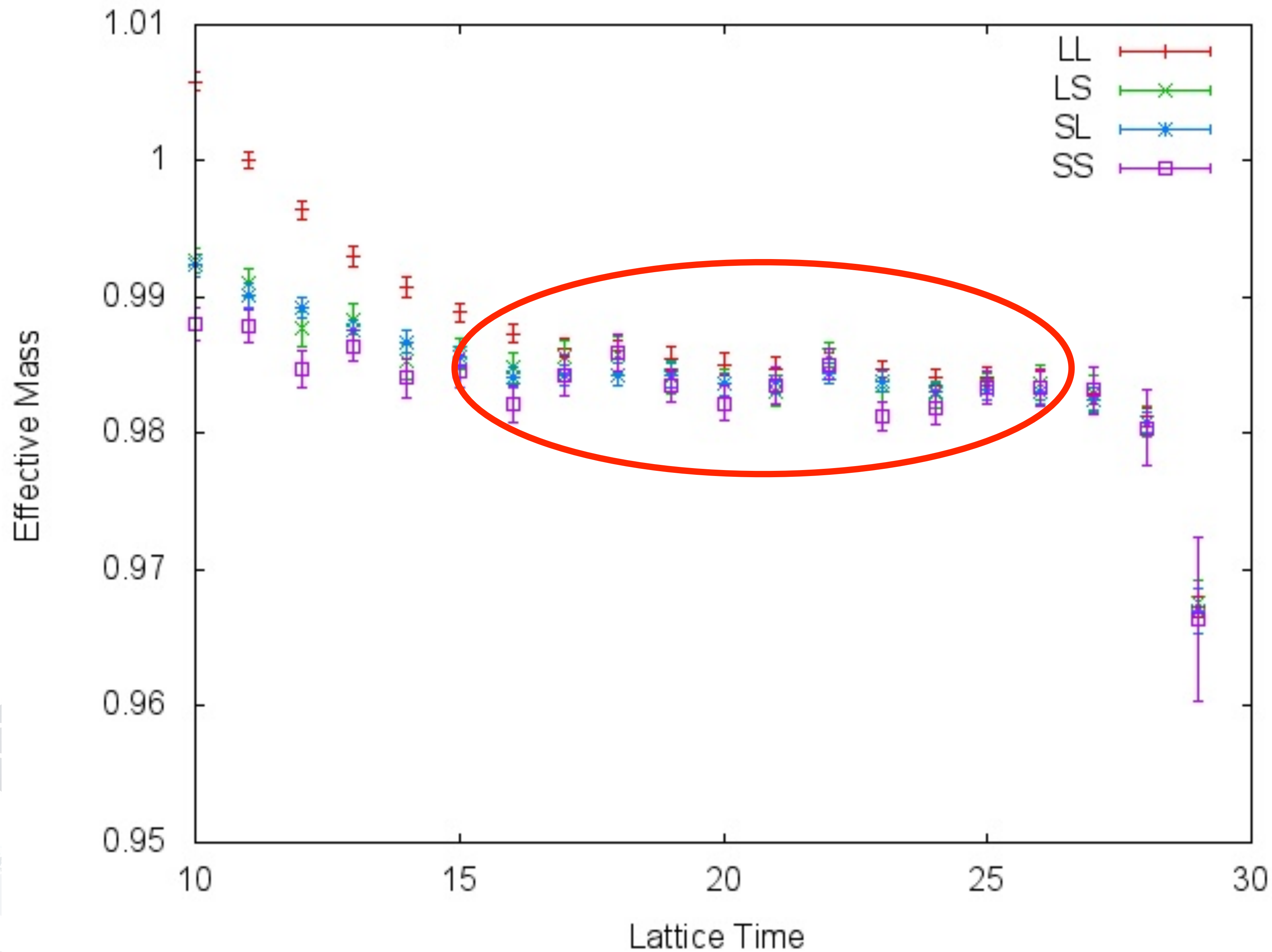
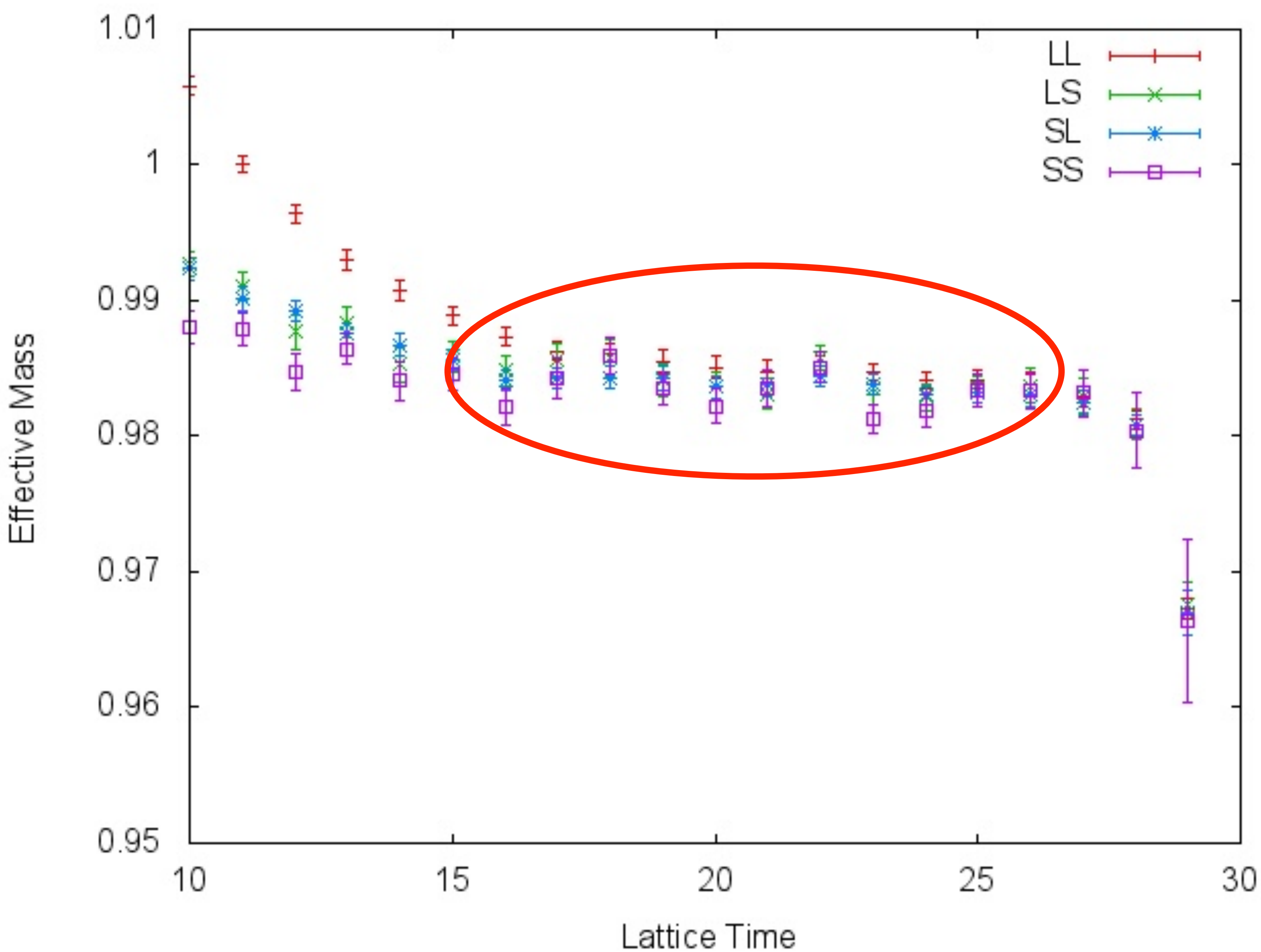


Results (masses)



Effective Mass Plateau

Results (masses)



Effective Mass Plateau

LL 0.9857 +/- 0.0004
LS 0.9850 +/- 0.0004
SL 0.9851 +/- 0.0004
SS 0.9858 +/- 0.0005

Results (decay constants)

	Pseudoscalar	Vectorial
LL	0.1209 +/- 0.0005 GeV	0.1983 +/- 0.0004 GeV
LS	0.0003 +/- 0.0005 GeV	0.0582 +/- 0.0004 GeV
SL	0.0004 +/- 0.0005 GeV	0.0308 +/- 0.0004 GeV

Conclusion and Perspectives

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Next step: Consider excited states