Exotic Mesons

hybrid mesons & the GlueX experiment

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lattice results from the Hadron Spectrum Collaboration

where's the glue ?

strongly coupled gluonic field of QCD is not visible in spectroscopy

well established meson states have J^{PC} quantum numbers in the set allowed to $q\bar{q}$ with orbital angular momentum

$$n^{2S+1}L_J \quad \rightarrow \{0^{-+},\, 0^{++},\, 1^{--},\, 1^{+-},\, 1^{++},\, 2^{-+},\, 2^{--},\, 2^{++},\, \ldots\}$$

call the other possibilities ***exotic quantum numbers*** $\{0^{--},\, 0^{+-},\, 1^{-+},\, 2^{+-},\, \ldots\}$

construct from $q\bar{q}$ plus excited glue ? ***hybrid mesons***

construct from more quarks ? ***multiquarks*** less likely - also expect exotic flavor combinations

experiment

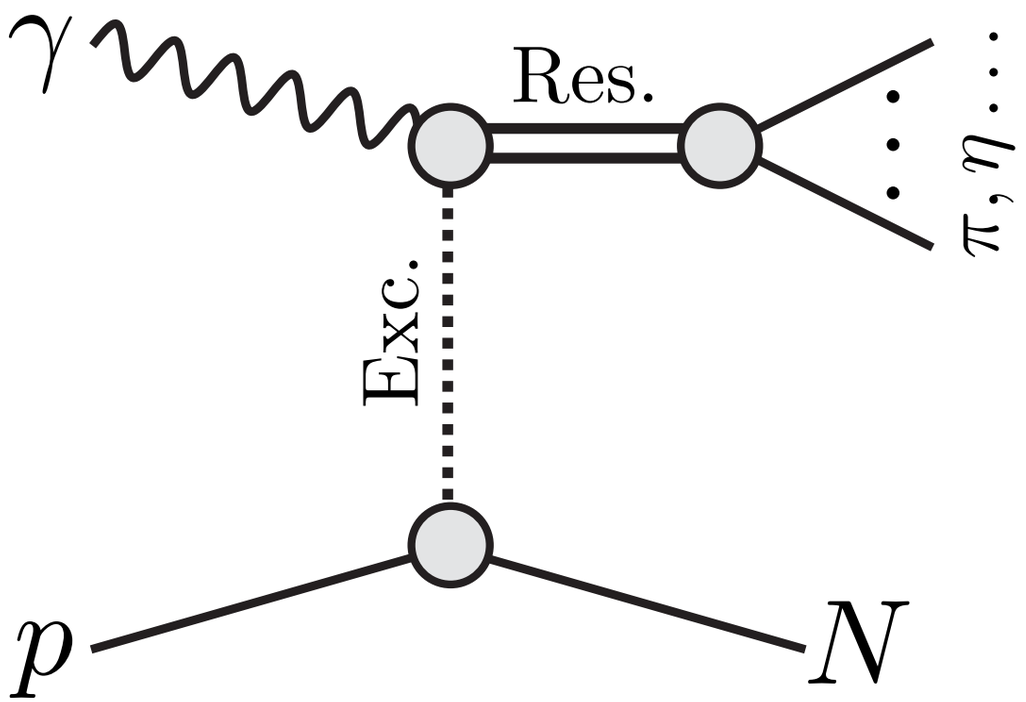
searches for exotics in pion beam experiments have been inconclusive

a future direction is to use a photon beam

GlueX @ 12 GeV JLab is on the horizon

Sacha's talk next

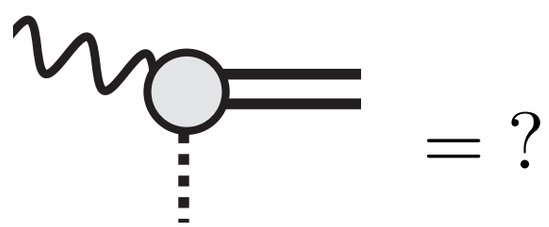
peripheral meson photoproduction



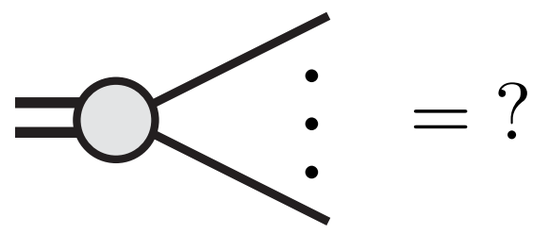
☆ where are the hybrids in mass ?

$$m(\text{Res.}) = ?$$

☆ do they couple strongly to photons ?



☆ pattern of hadronic decays ?



using lattice QCD to explore all these unknowns

lattice QCD

dynamical QCD studies on anisotropic lattices

- 2+1 flavours of quark - clover quark action
- $a_s \sim 0.12$ fm, $a_t^{-1} \sim 5.6$ GeV
- $V \sim (2.0)^3$ fm^3 , $(2.4)^3$ fm^3 , $(2.9)^3$ fm^3 , $(3.8)^3$ fm^3
- $m_\pi \sim 700, 520, 450, 400, (230)$ MeV

Phys.Rev.D79:034502,2009

distillation technology with many operators

large scale spectrum

how its done: ***Christopher Thomas*** - later in the session

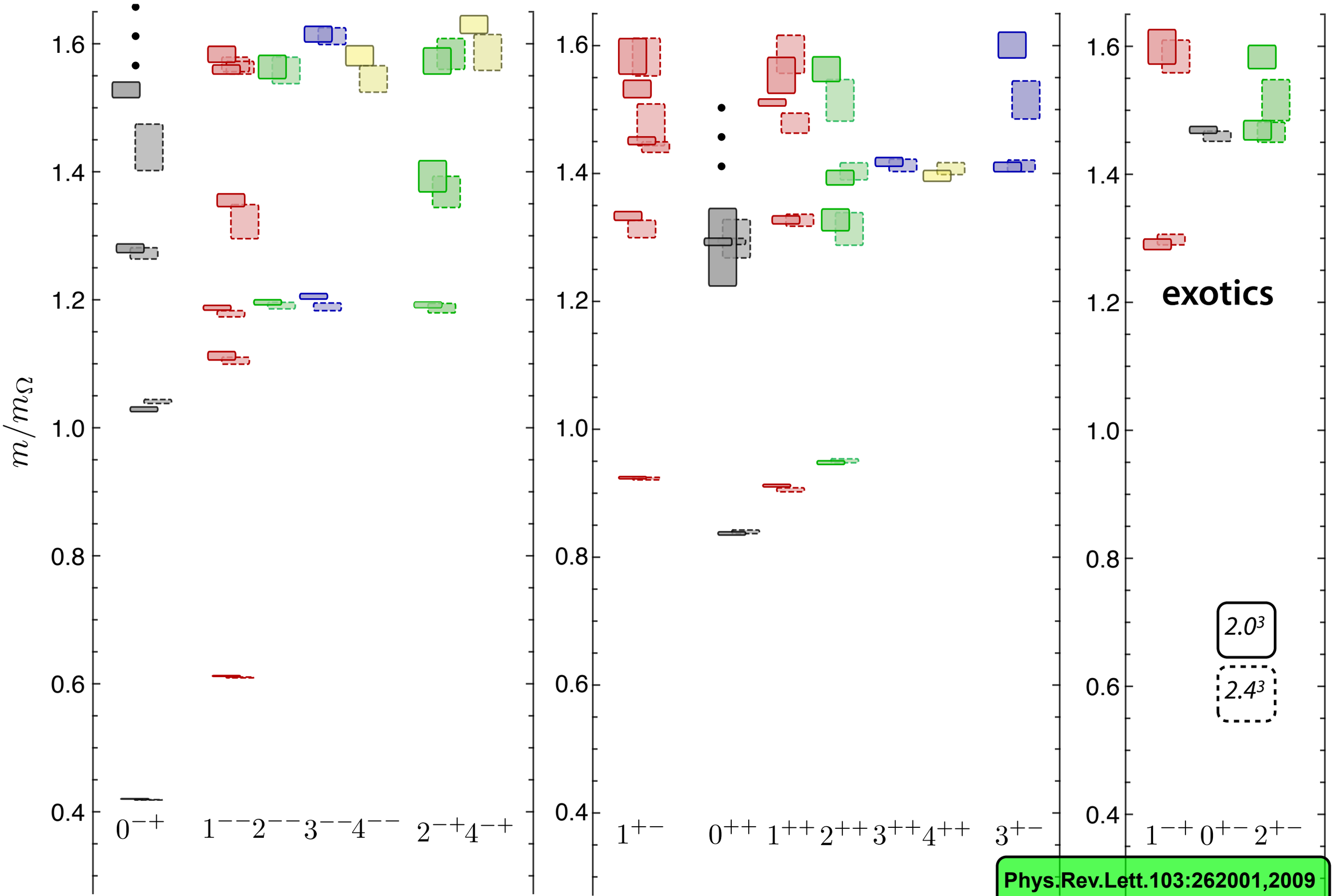
Phys.Rev.D80:054506,2009

$$(\mathrm{CGC's})_{ij\ldots}\ \bar{\psi}\overleftrightarrow{D}_i\overleftrightarrow{D}_j\ldots\psi$$

use orthogonality of state vectors in the operator space to extract many states - ***variational solution***

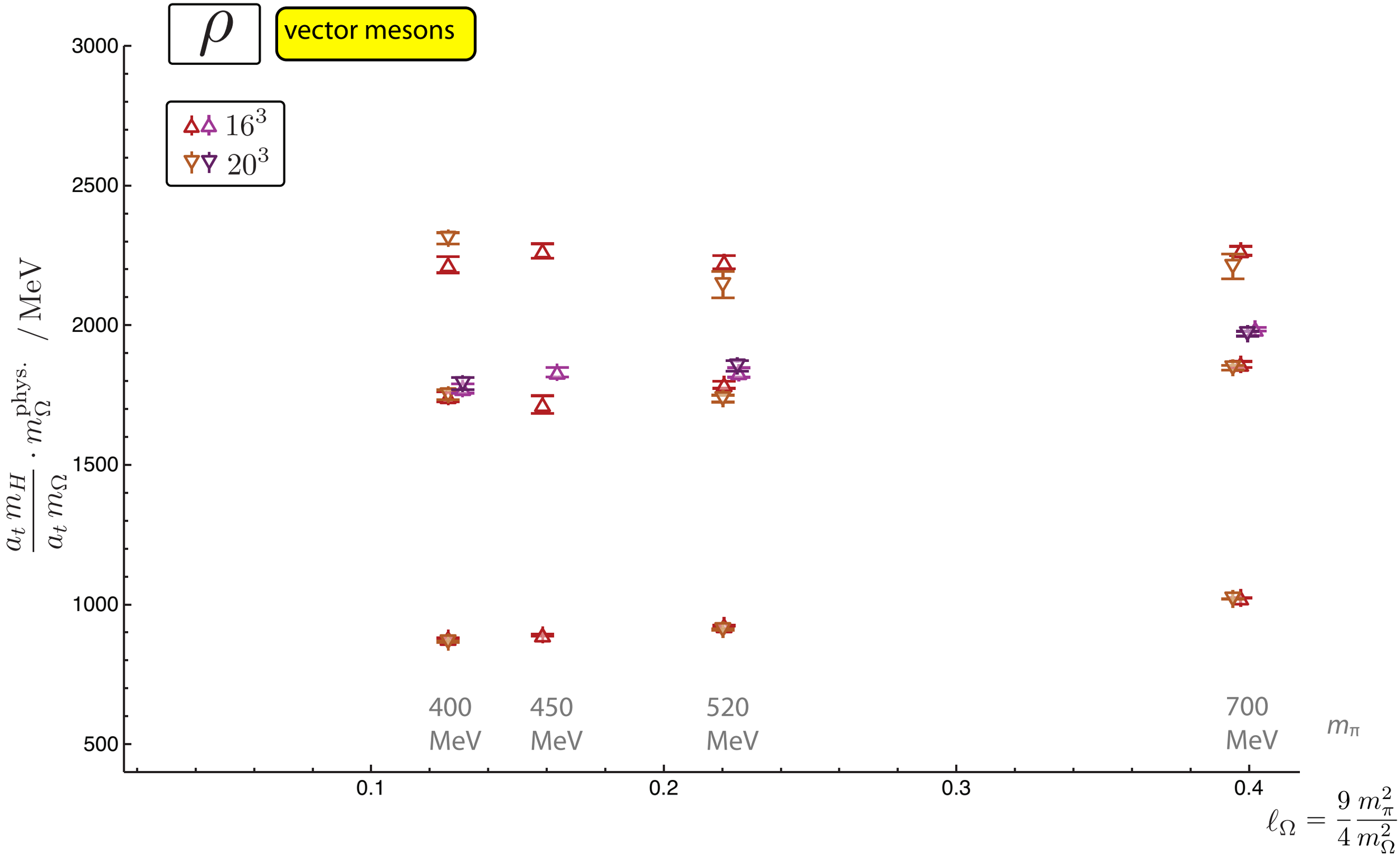
isovector meson spectrum

three flavours of quark all at the strange mass, m_π~700 MeV



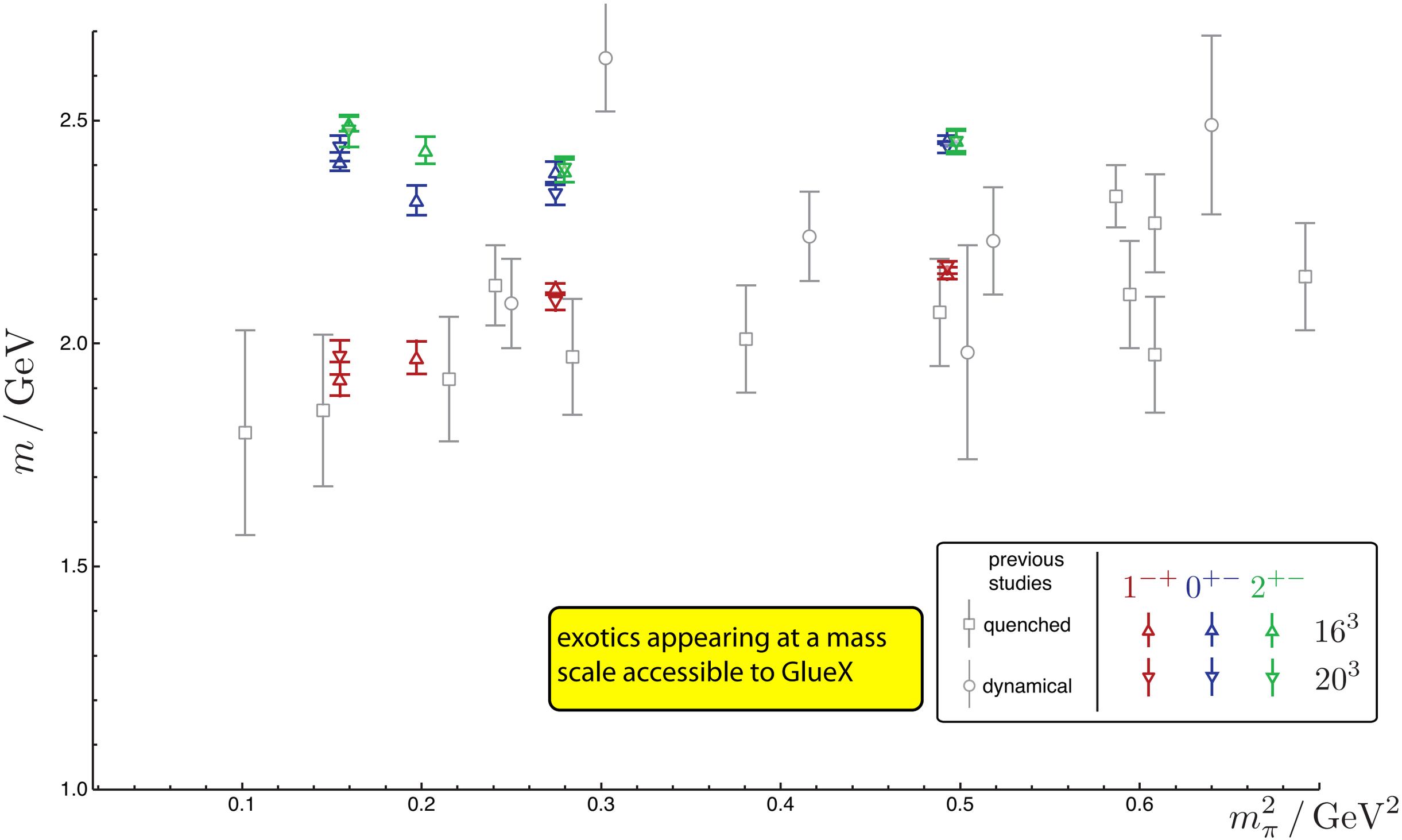
Phys.Rev.Lett.103:262001,2009

quark mass dependence



arXiv:1004.4930 [hep-ph]

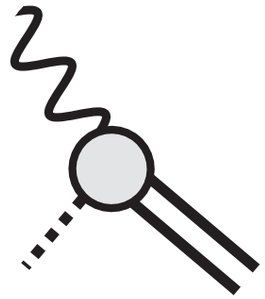
quark mass dependence



exotics appearing at a mass scale accessible to GlueX

arXiv:1004.4930 [hep-ph]

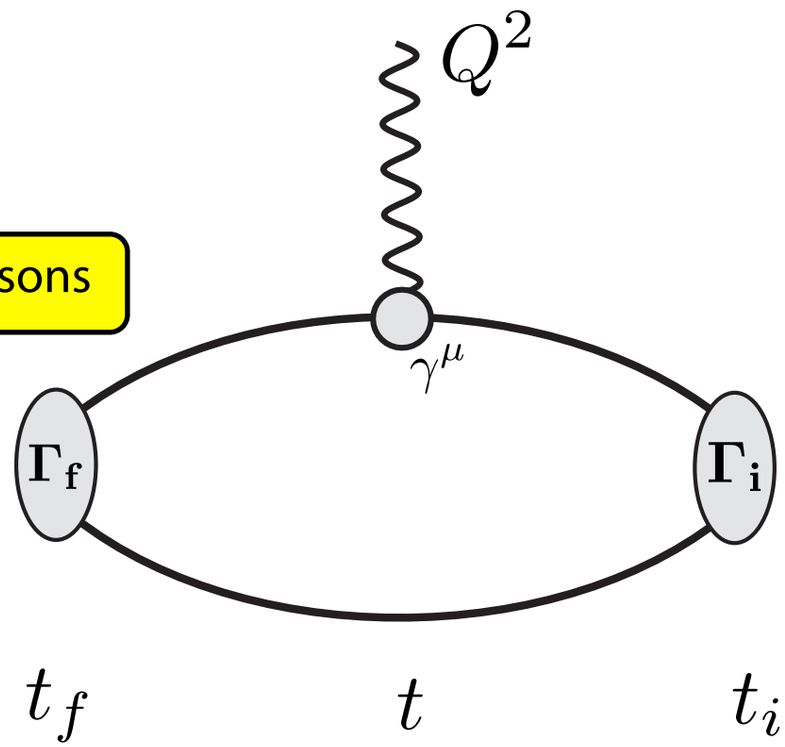
photocouplings



first results in charmonium - similar technology can be applied to light mesons

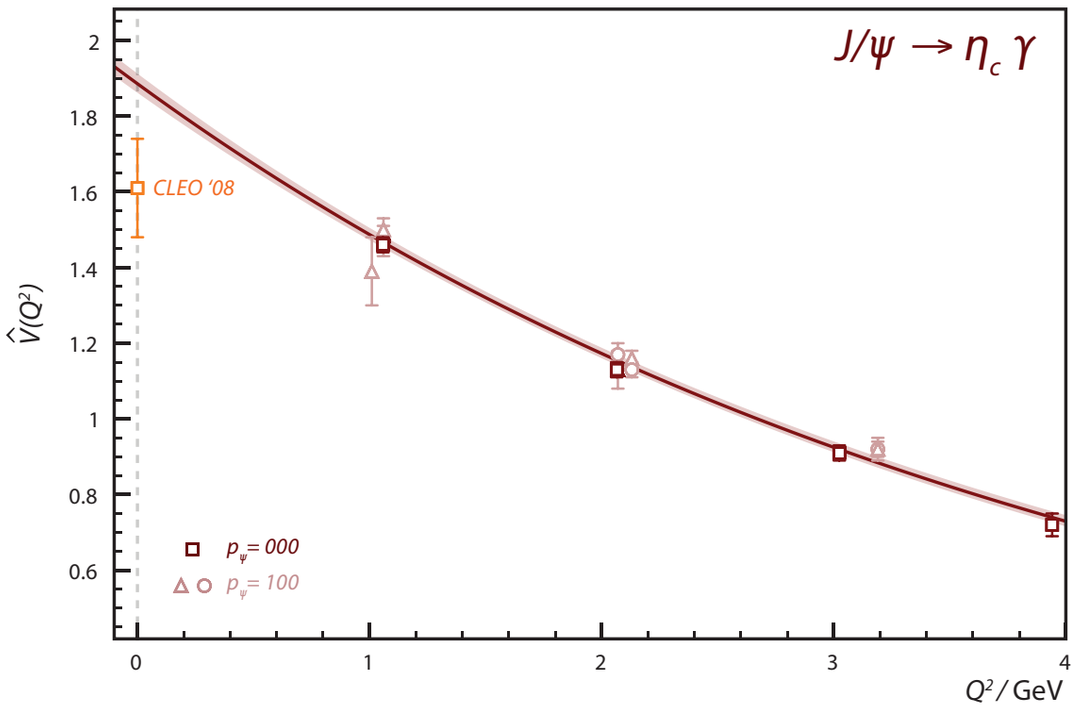
compute three-point functions

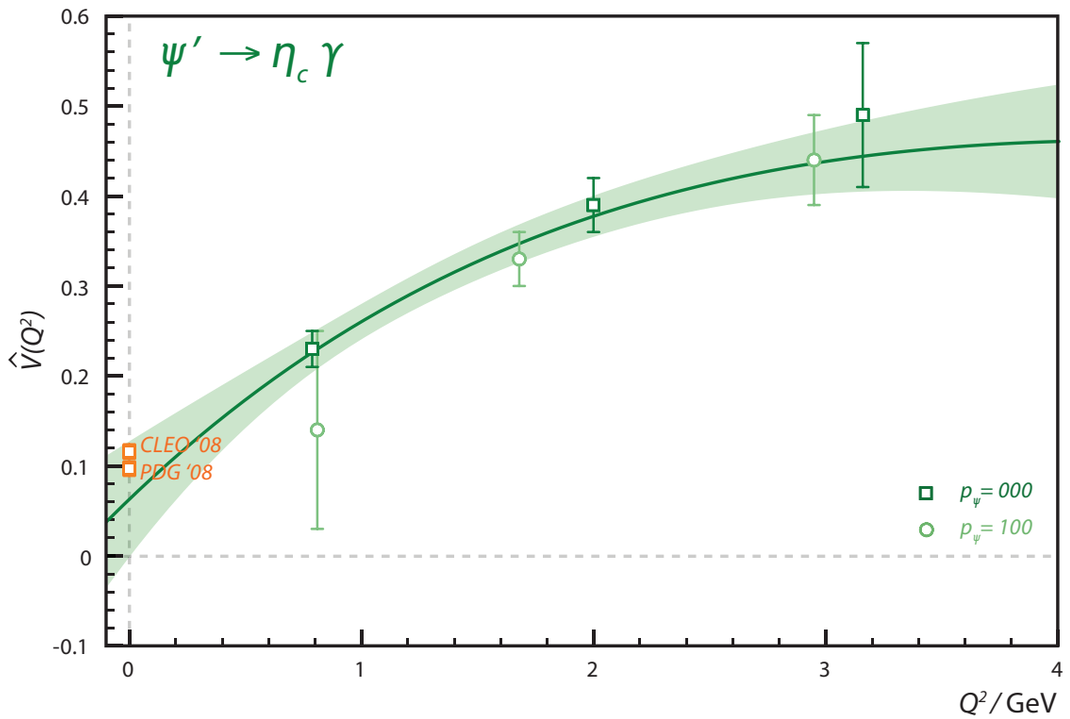
this first study is quenched



conventional - conventional transitions

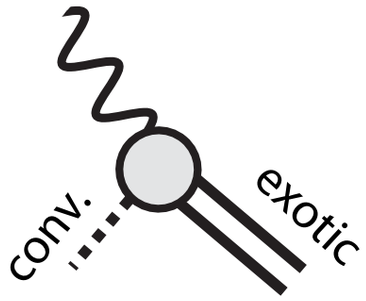
$$\left\langle 0 \left| \left(\bar{\psi}\Gamma_f\psi\right)_{t_f} \cdot \left(\bar{\psi}\gamma^\mu\psi\right)_t \cdot \left(\bar{\psi}\Gamma_i\psi\right)_{t_i} \right| 0 \right\rangle$$



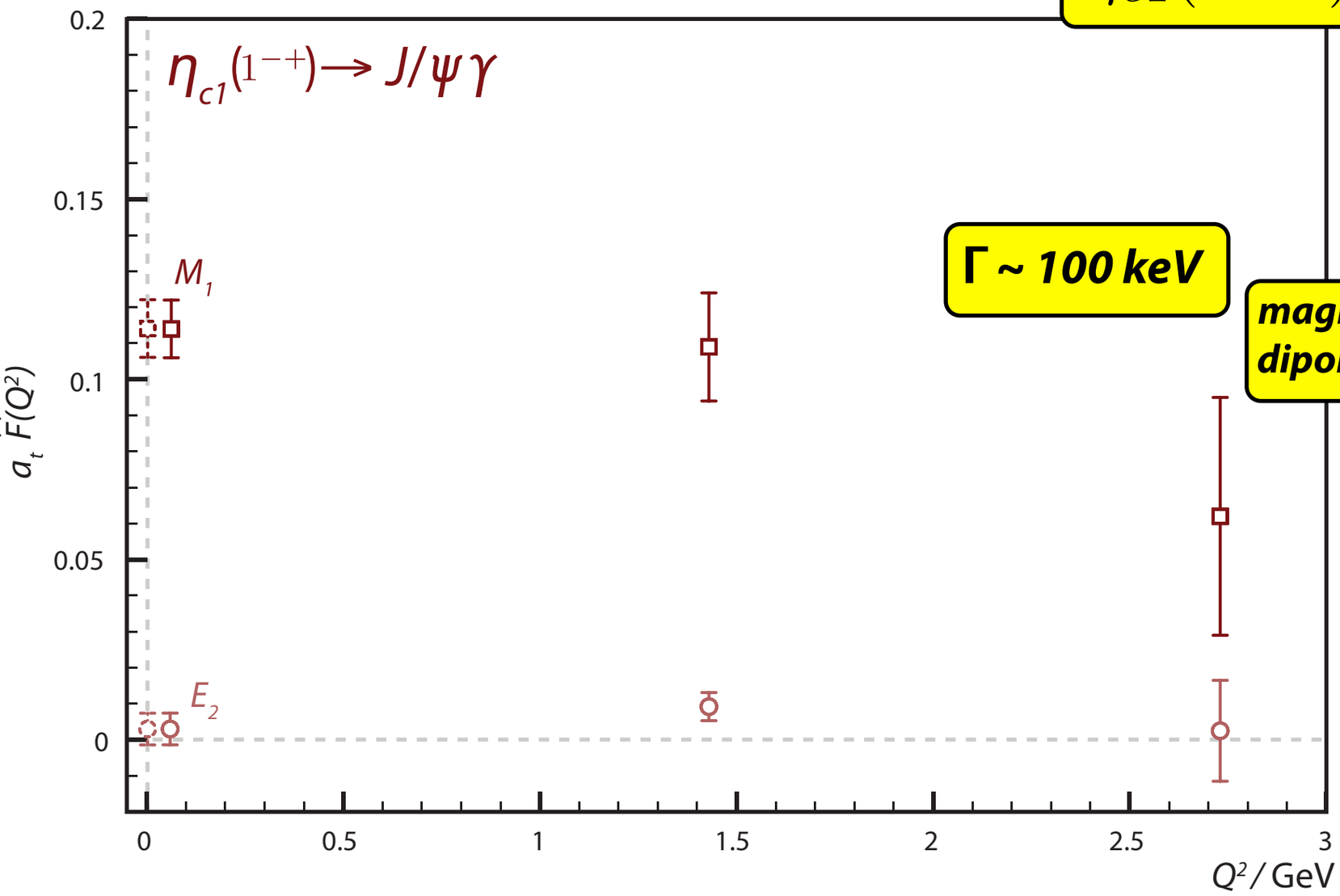


Phys.Rev.D79:094504,2009

exotic photocouplings



$\eta_{c1}(4300) \rightarrow J/\psi(3100)\ \gamma$



Γ ~ 100 keV

magnetic dipole

compare with $J/\psi \rightarrow \eta_c\gamma$ ~ 1 keV

quark spin flip ~ $\dfrac{\sigma}{m_c}$

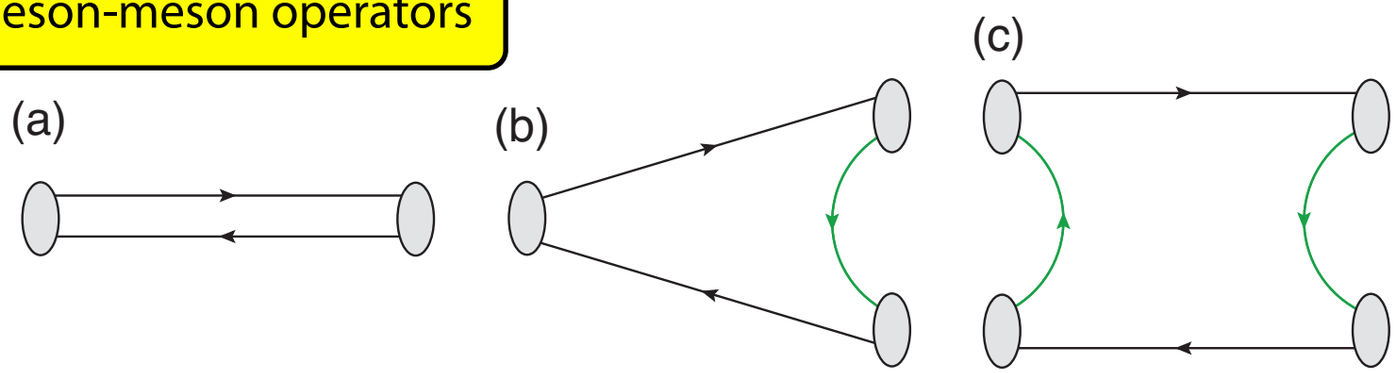
suggests there can be large exotic photocouplings in QCD

Phys.Rev.D79:094504,2009

hadronic decays

meson-meson scattering phase shifts from finite volume spectrum

require meson-meson operators

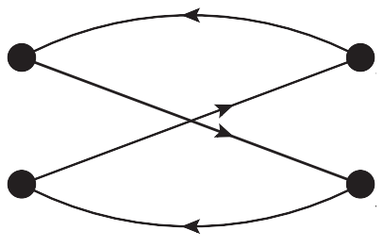


easier first test isospin=2, e.g. ππ

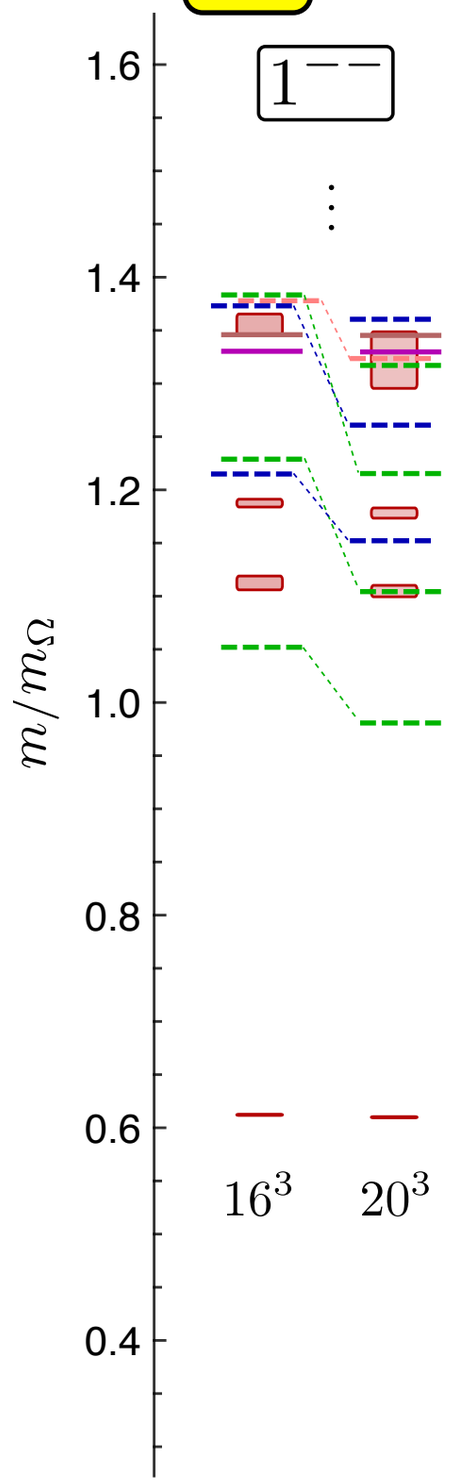
$$\sum_{\vec{p}} Y_L^M(\vec{p}) \sum_{\vec{x}} e^{i\vec{p}\cdot\vec{x}}\, \bar{u}_{\vec{x}}\gamma^5 d_{\vec{x}} \cdot \sum_{\vec{y}} e^{-i\vec{p}\cdot\vec{y}}\, \bar{u}_{\vec{y}}\gamma^5 d_{\vec{y}}$$

$$\vec{p} = \frac{2\pi}{L_s}(n_x, n_y, n_z)$$

extract $\delta_L(E)$ at discrete E

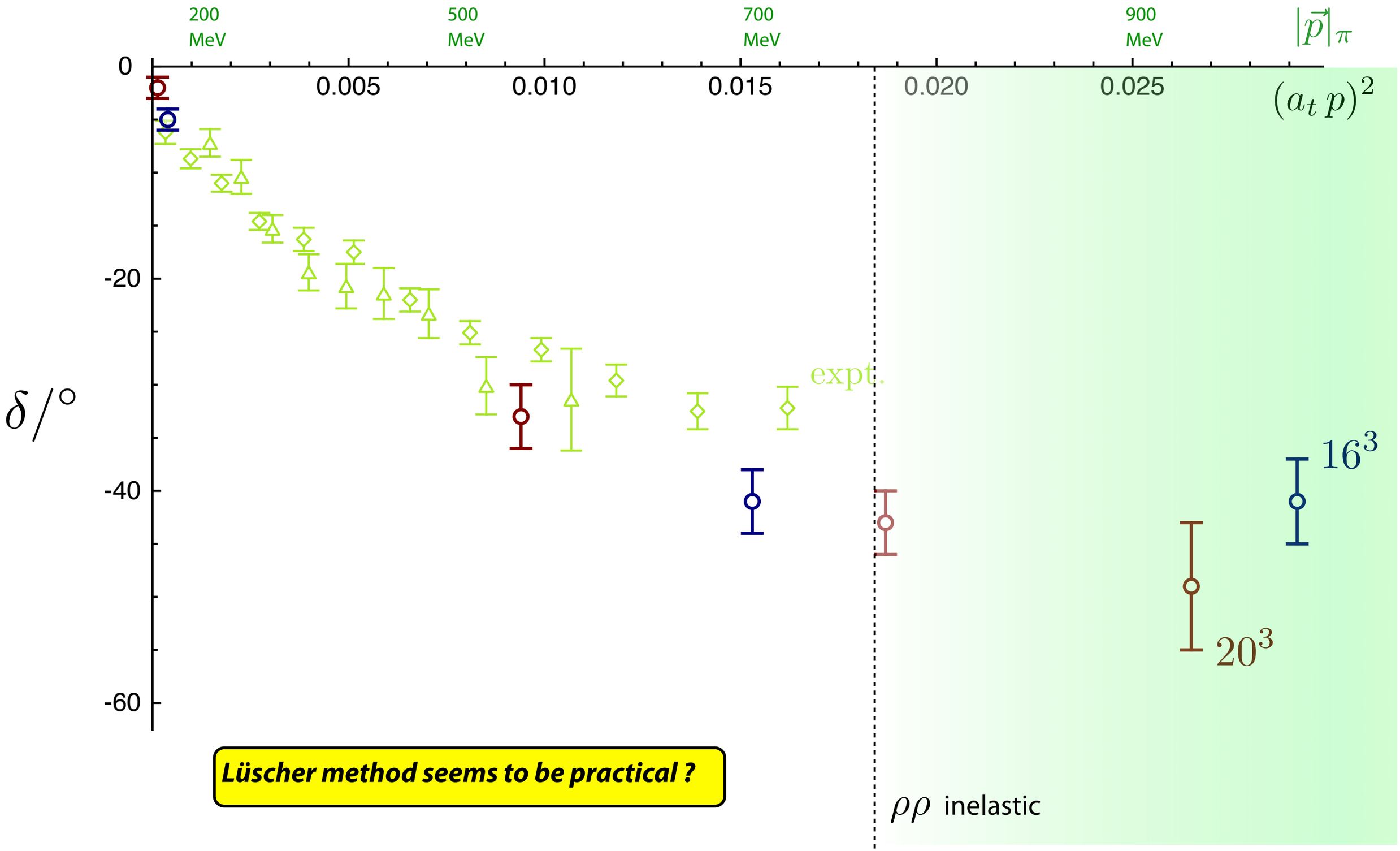


e.g.



ππ isospin=2

N_F = 2+1 (u,d,s) $m_\pi \sim 400$ MeV



Lüscher method seems to be practical ?

summary

ongoing program to compute quantities of relevance to GlueX

lattice QCD efforts with Hadron Spectrum Collaboration

these works:
Dudek, Edwards, Richards, Thomas @ JLab
Peardon @ Trinity College, Dublin

technology to extract a large number of finite volume energy states is ready

radiative coupling physics is a relatively simple extension

reliable ***resonance*** physics requires inclusion of operators resembling two-mesons with momentum

constructions underway - non-resonant examples OK?