lattice QCD @ JLab

Raúl Briceño - http://bit.ly/rbricenoPhD

Norfolk, VA [Home to ODU]

OLD DOMINION UNIVERSITY

Jefferson Lab

had spec

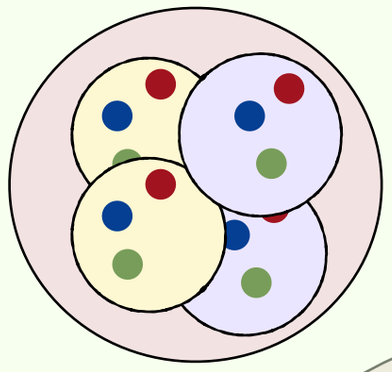
Paris, 2019

JLab, VA

lattice QCD @ JLab

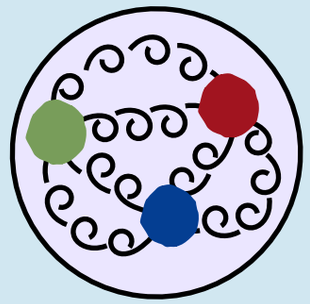
nuclear structure

how do nucleons come together to form low-lying nuclei?



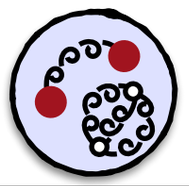
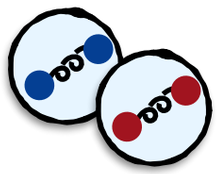
hadron structure

how do quarks come together to form hadrons?



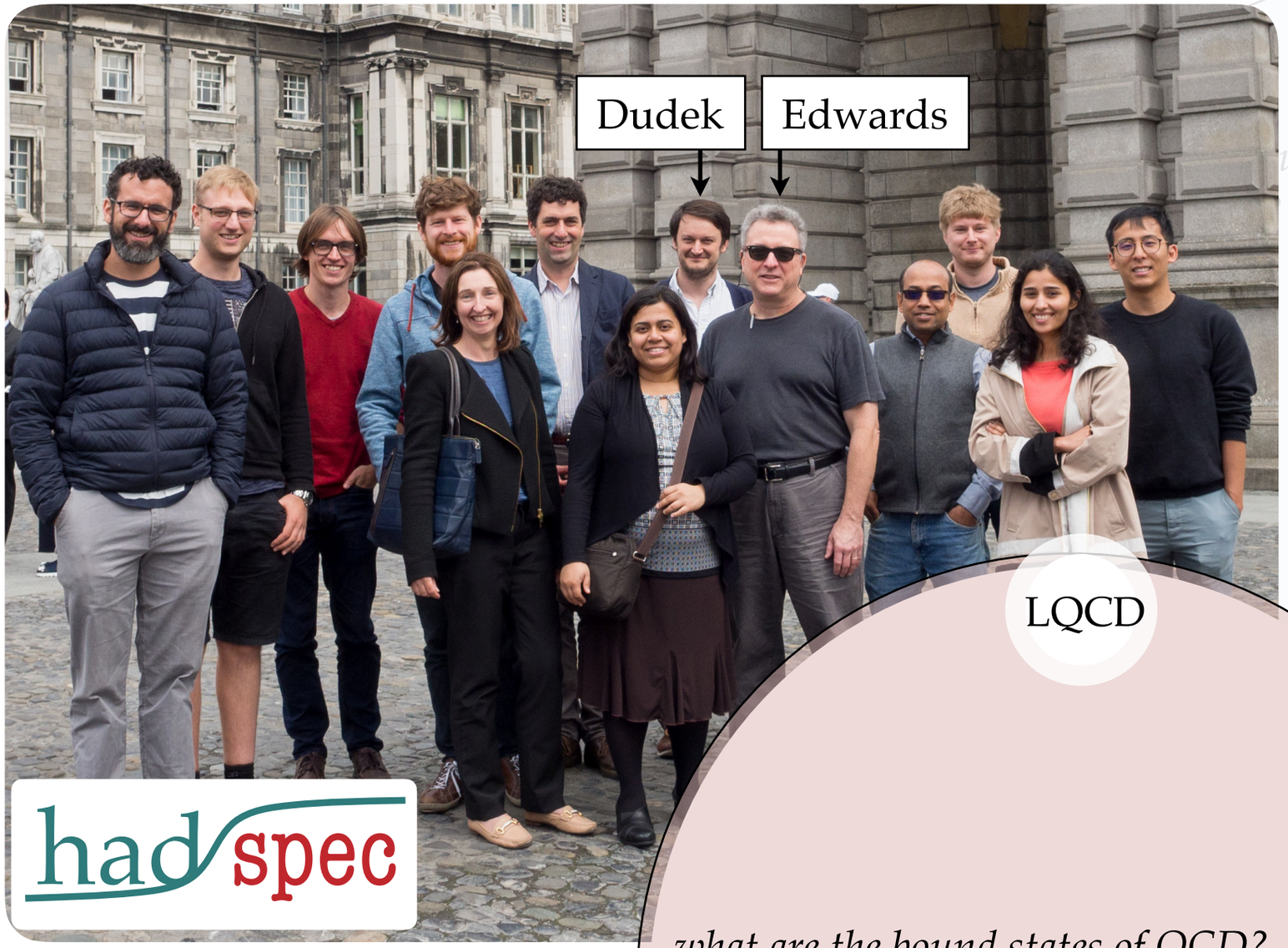
LQCD

what are the bound states of QCD

$$|n\rangle_{\mathrm{QCD}} = c_0$$  $$+ c_1$$  $$+ c_2$$  $$+ c_3$$  $$+ \cdots$$

spectroscopy

lattice QCD @ JLab



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LQCD

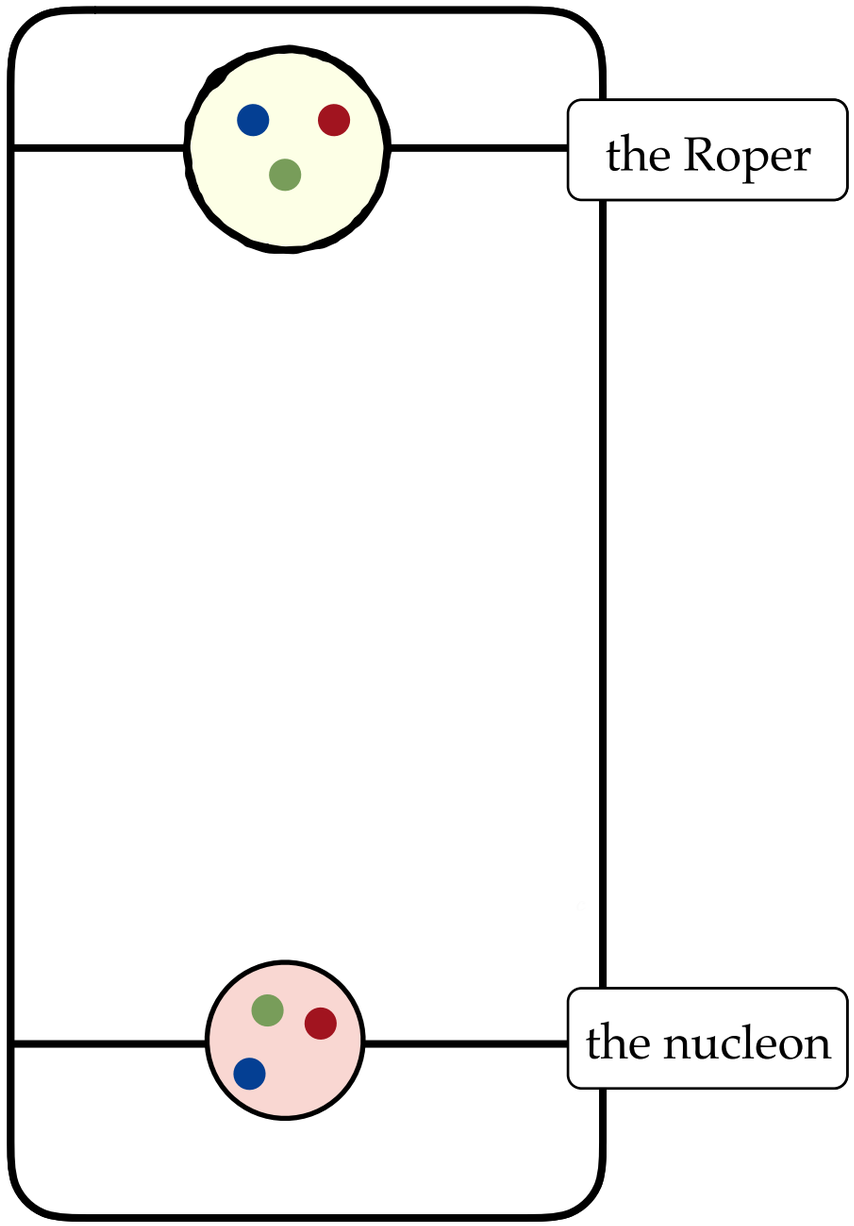
what are the bound states of QCD?

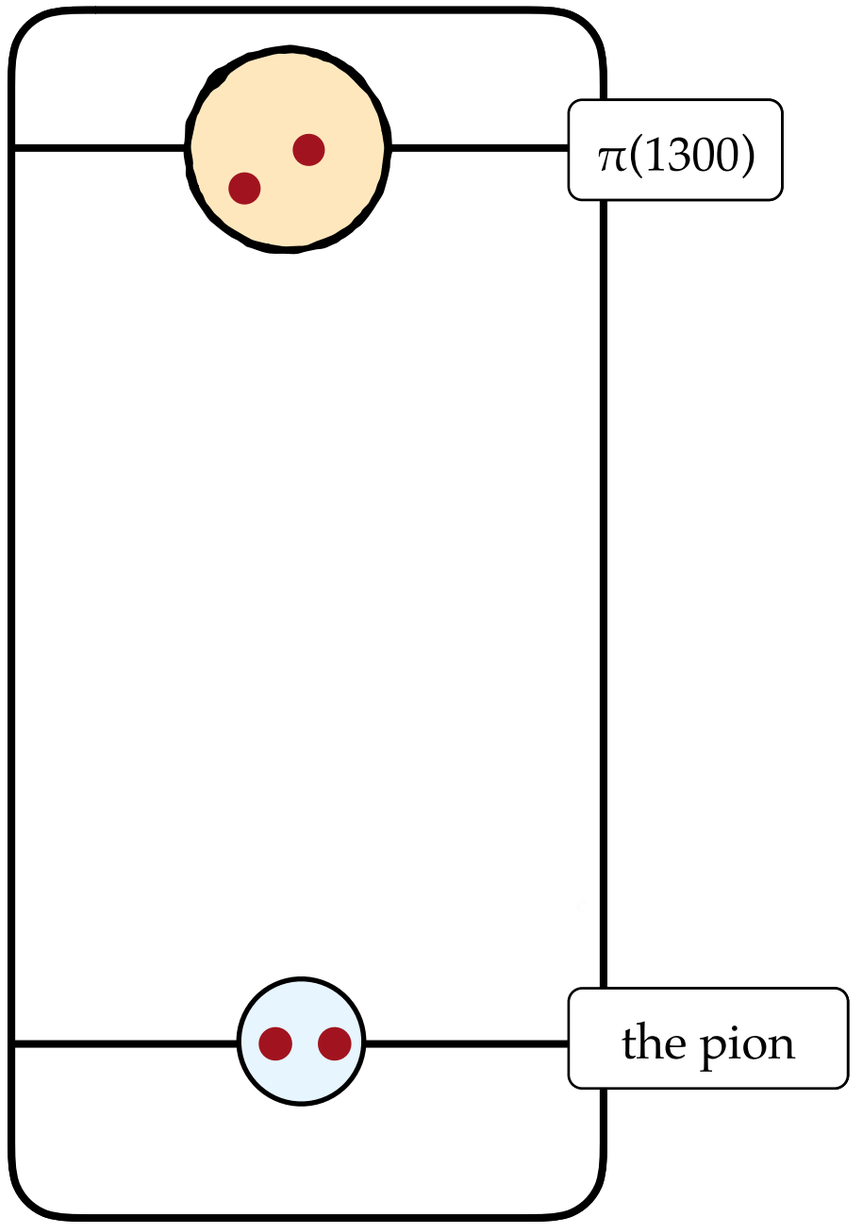
$$|n\rangle_{\mathrm{QCD}} = c_0 + c_1 + c_2 + c_3 + \cdots$$

spectroscopy

QCD Spectroscopy

Resonances are the 99% of QCD





- confirmation
- production mechanism
- identification of prominent decay channels
  - couplings to decay channels
- structure

QCD Spectroscopy

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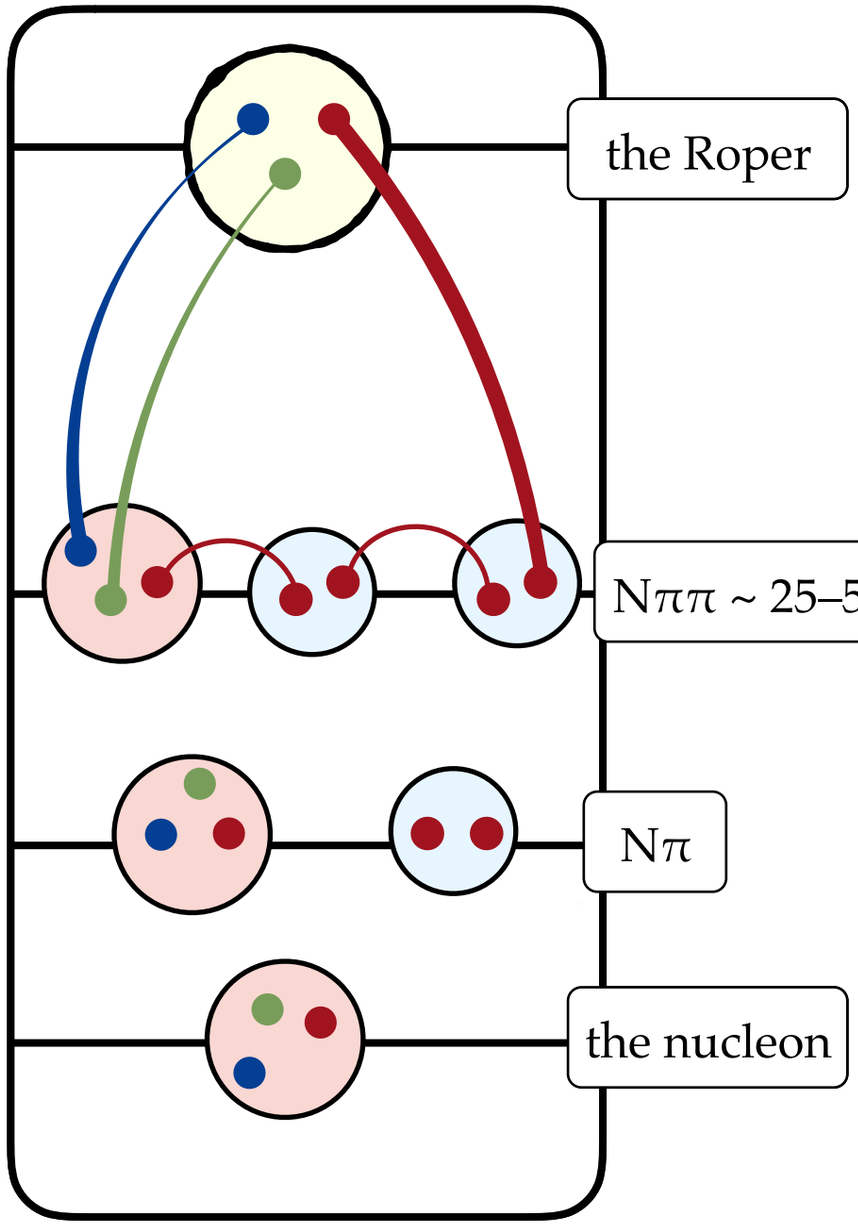
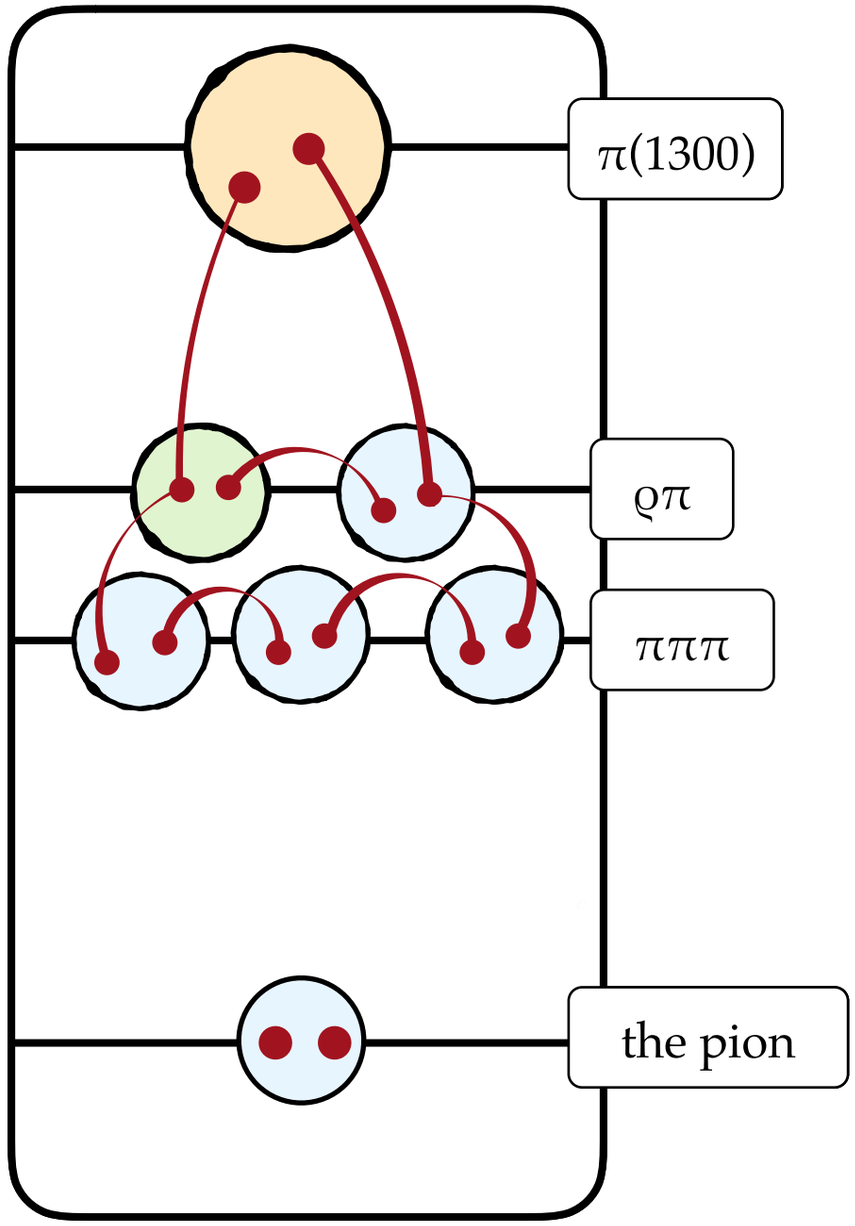
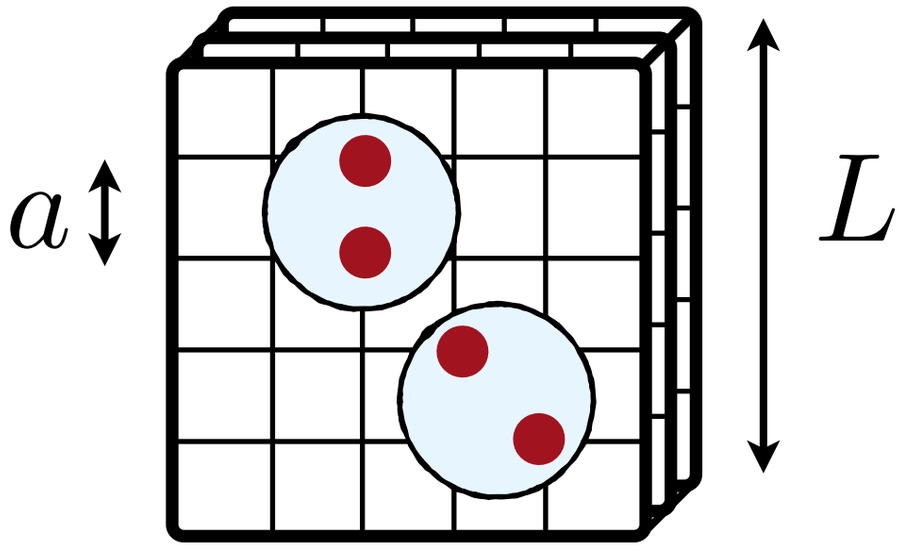




multichannel, multiparticle system!
hard, but not obviously impossible…

QCD Spectroscopy on the lattice

- Wick rotation [Euclidean spacetime]: $t_M \to -it_E$
- Monte Carlo sampling
- quark masses: $m_q \to m_q^{\text{phys.}}$
- lattice spacing
- finite volume



$$D_\mu = \Big(\qquad \Big) \Big\updownarrow (L/a)^3 \times (T/a)$$

QCD Spectroscopy on the lattice

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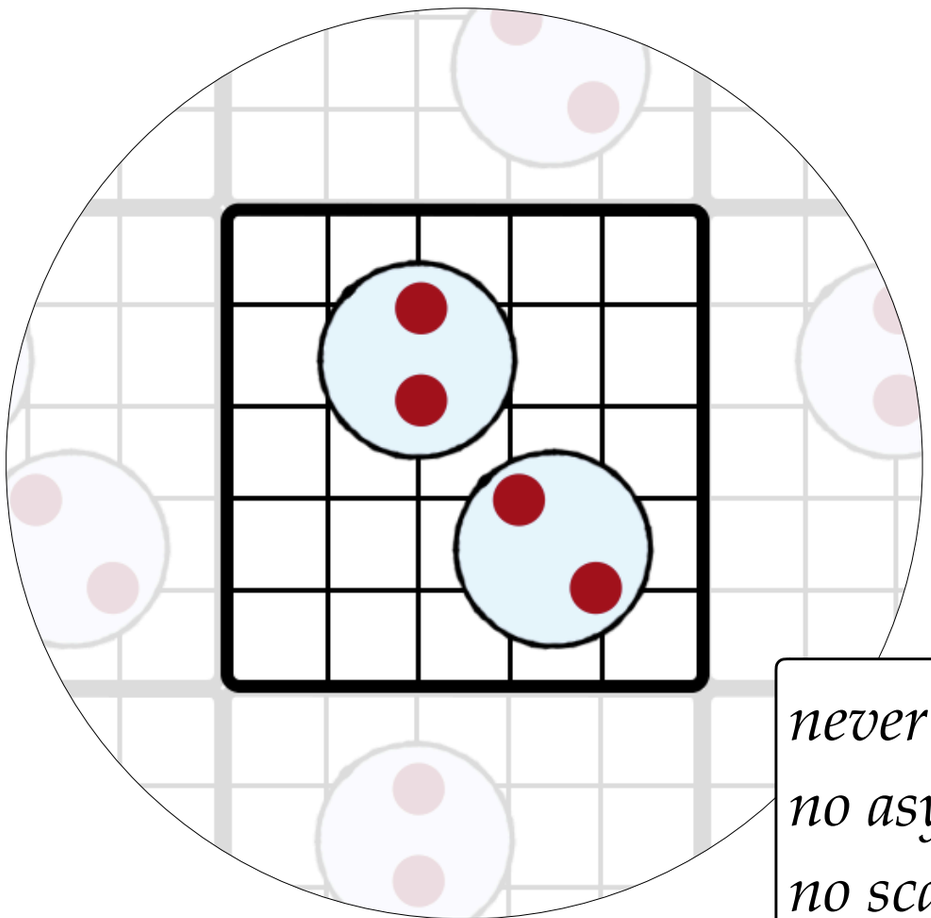
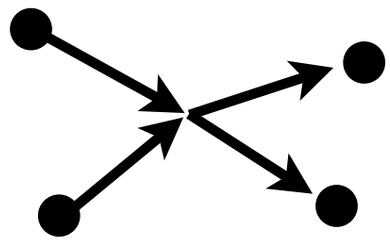


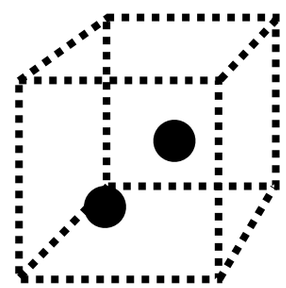
never free
no asymptotic staes
no scattering

partial wave amplitudes

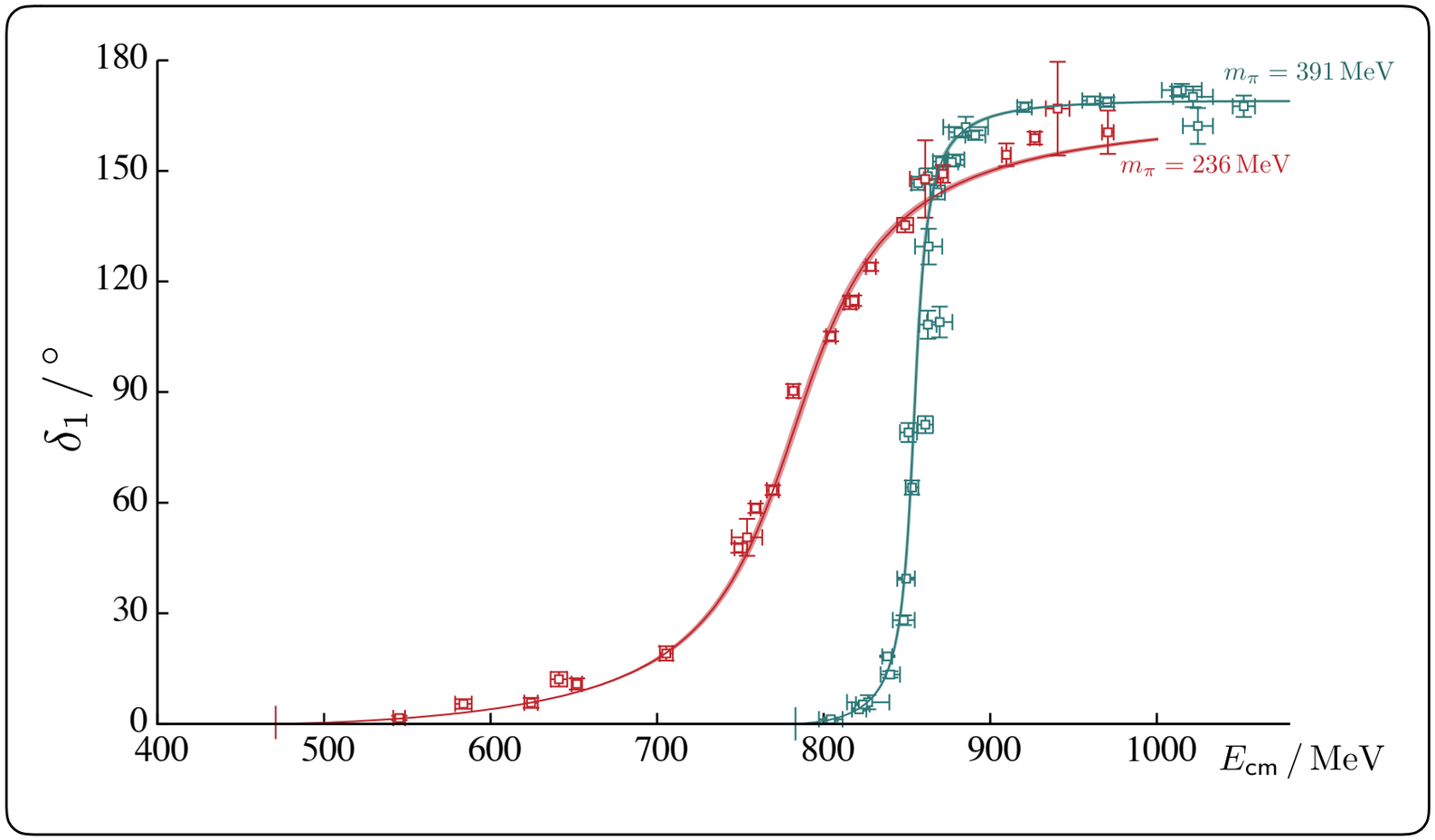


all-orders mapping

spectrum

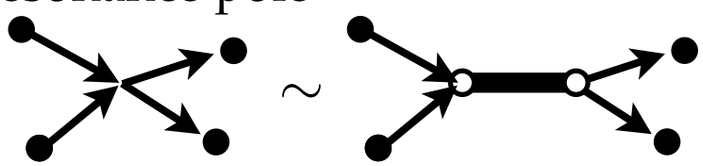


$\pi\pi$ scattering - (I=1 channel)



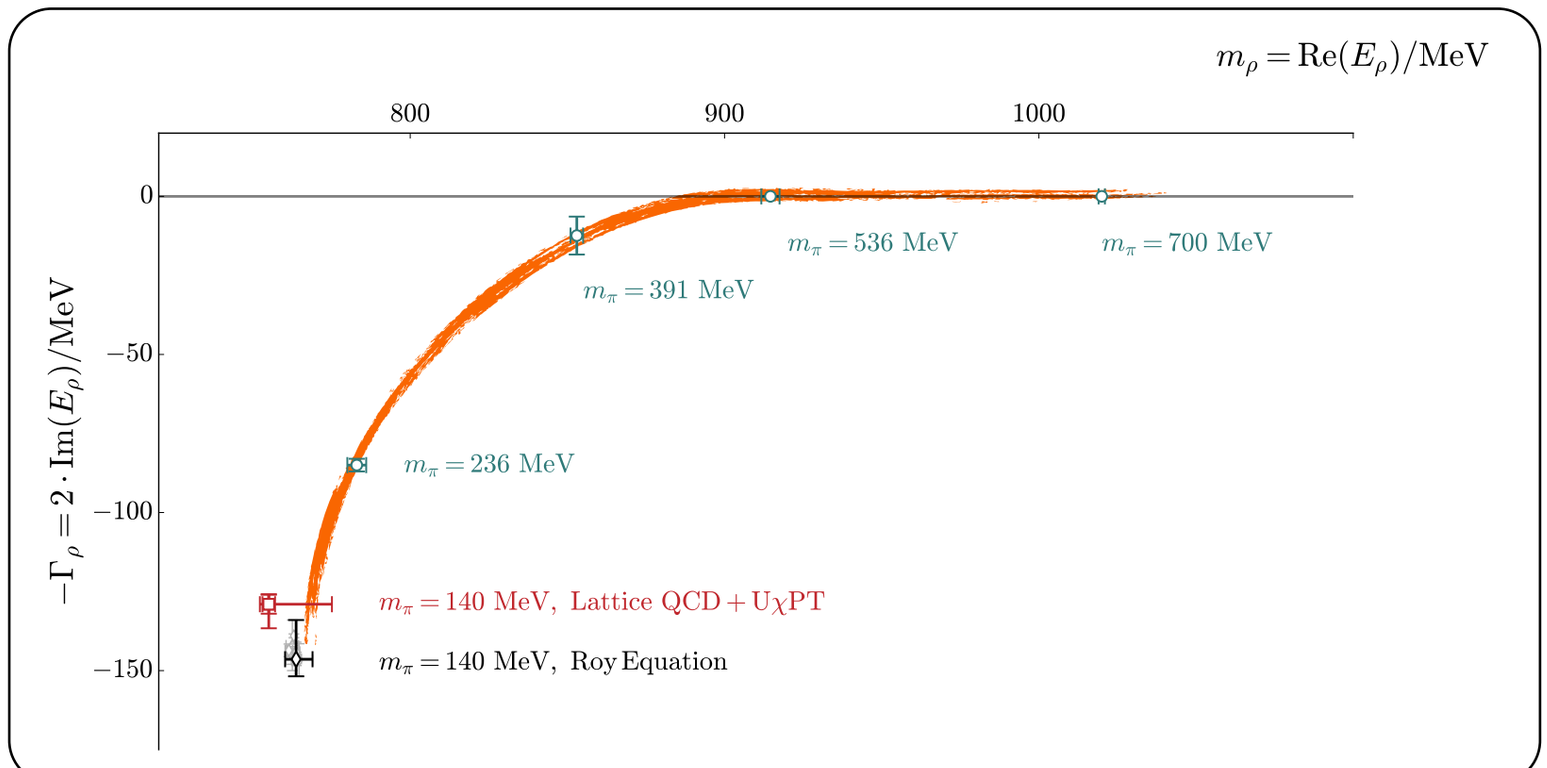
$$\mathcal{M} \sim \frac{1}{p\cot\delta - ip}$$

resonance pole

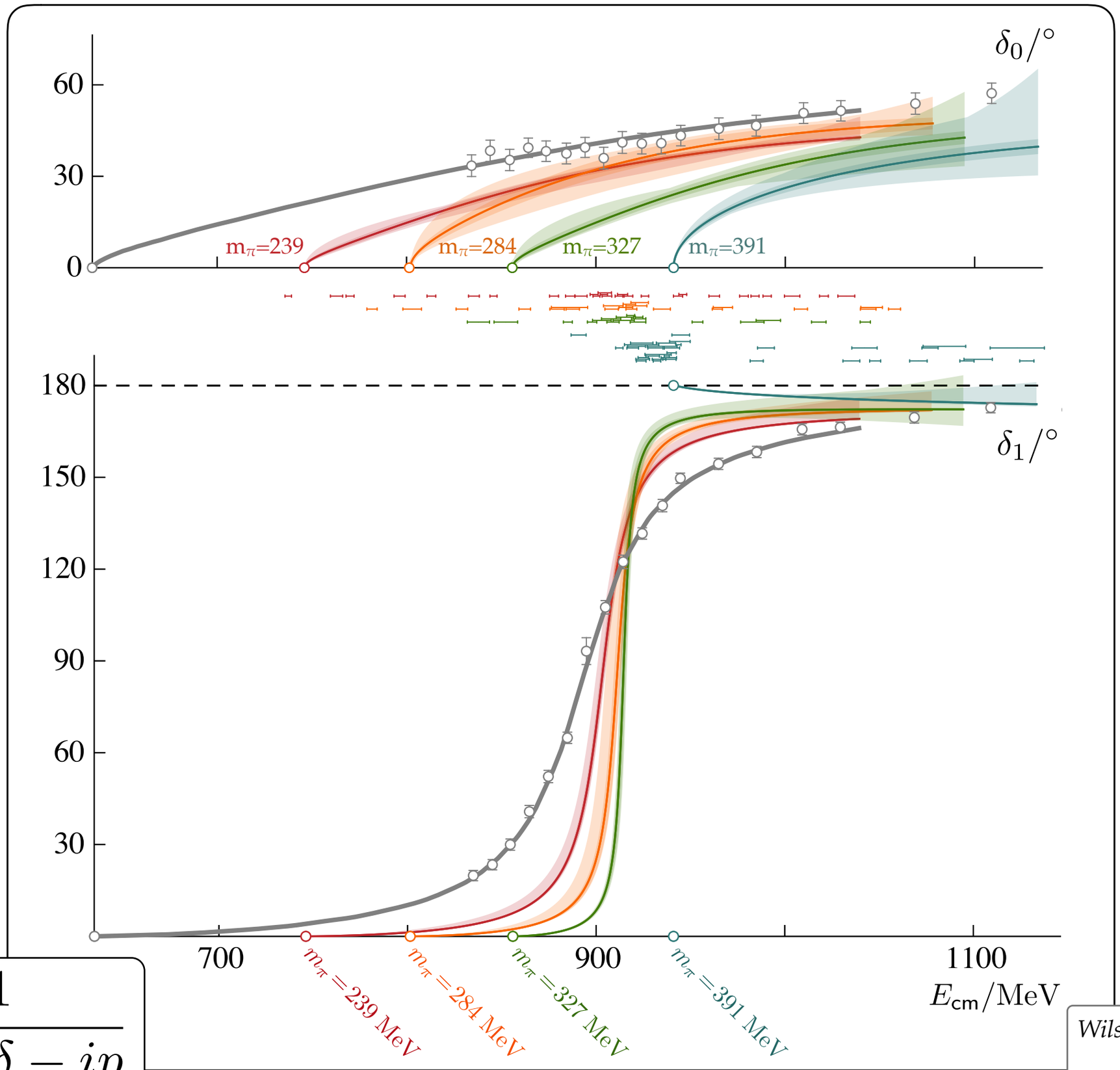


$$\sim \frac{1}{s - s_0}$$

$$s_0 = (m_R - i\Gamma_R/2)^2$$



πK scattering - (I=1/2 channel)



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Wilson, RB, Dudek, Edwards, & Thomas (2019)

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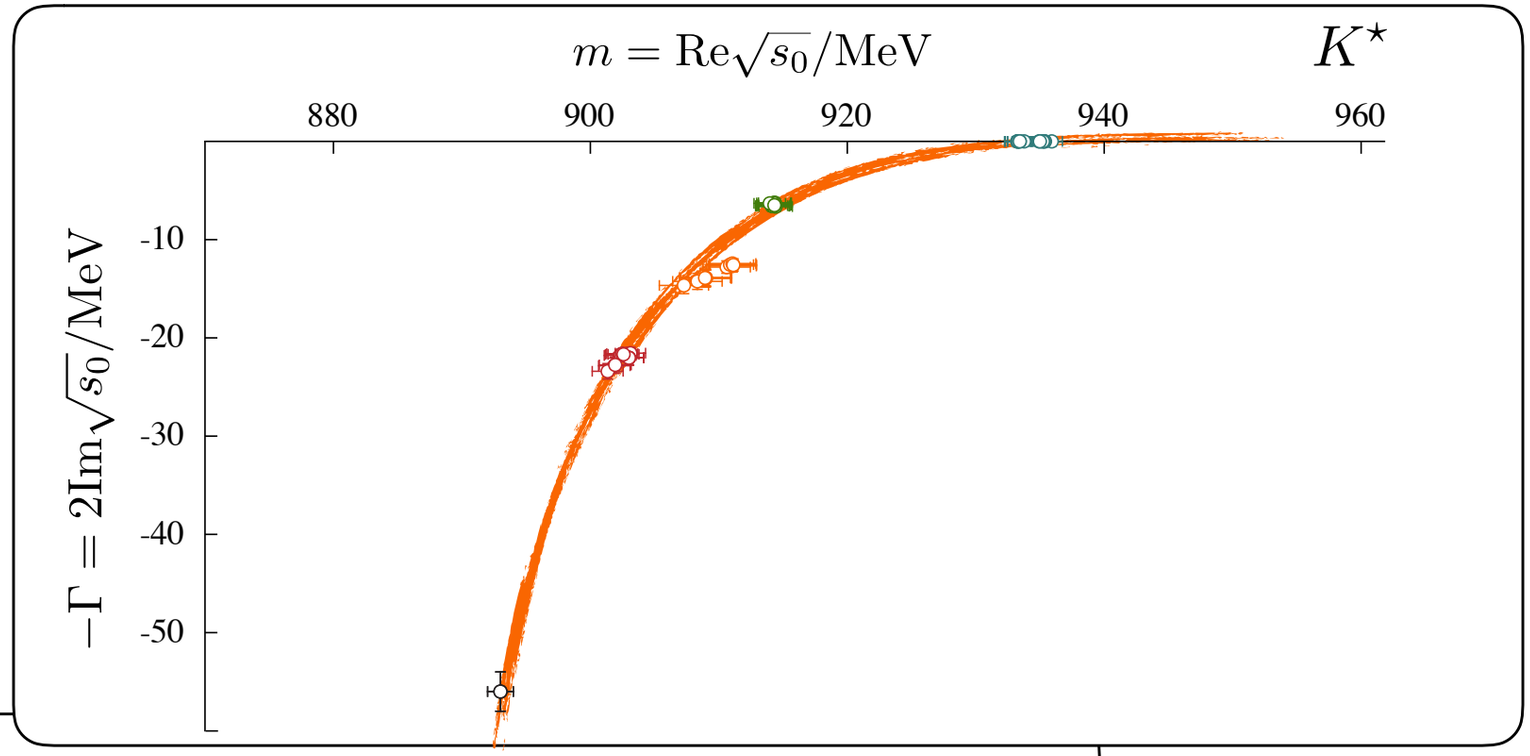

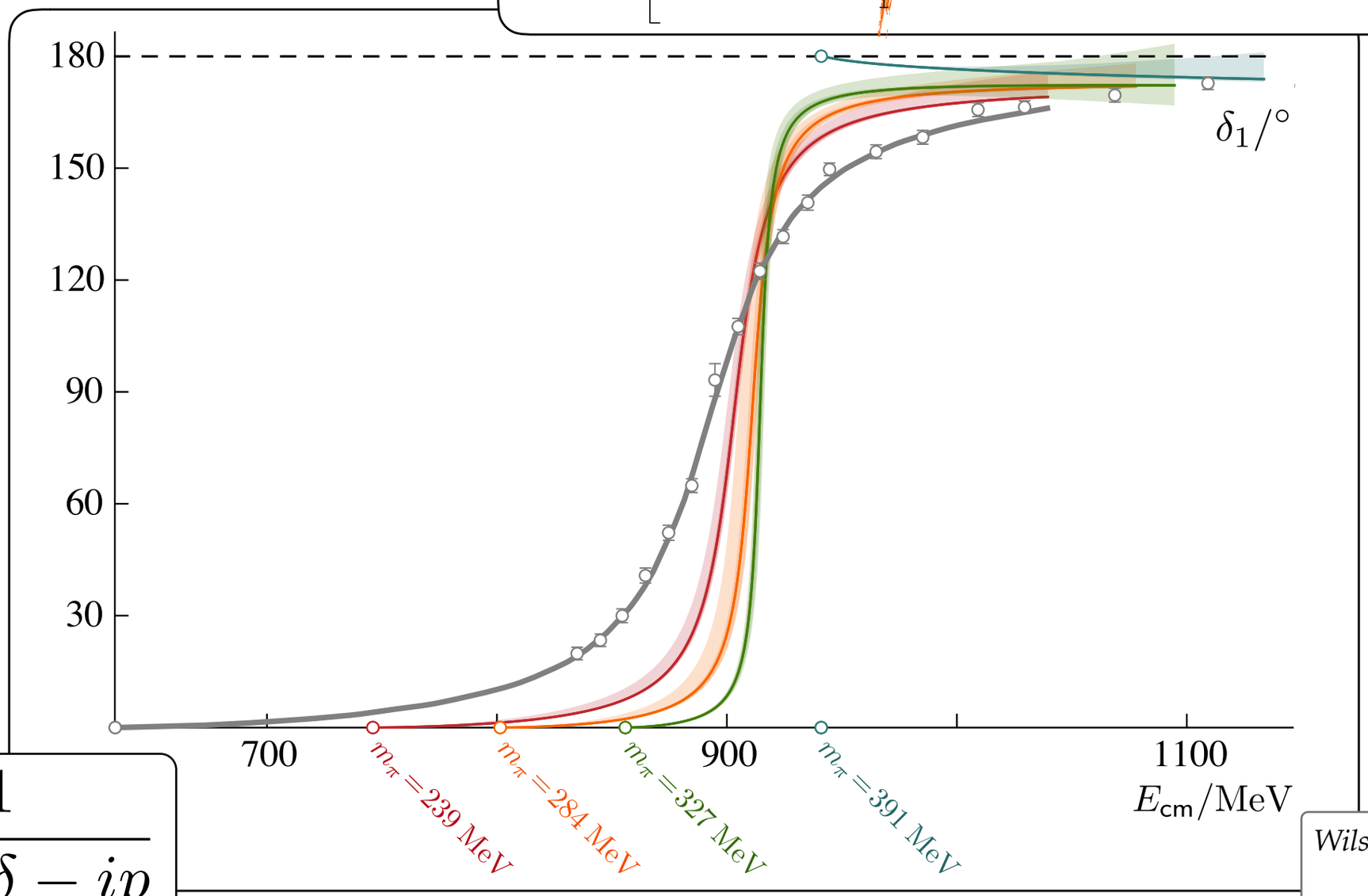

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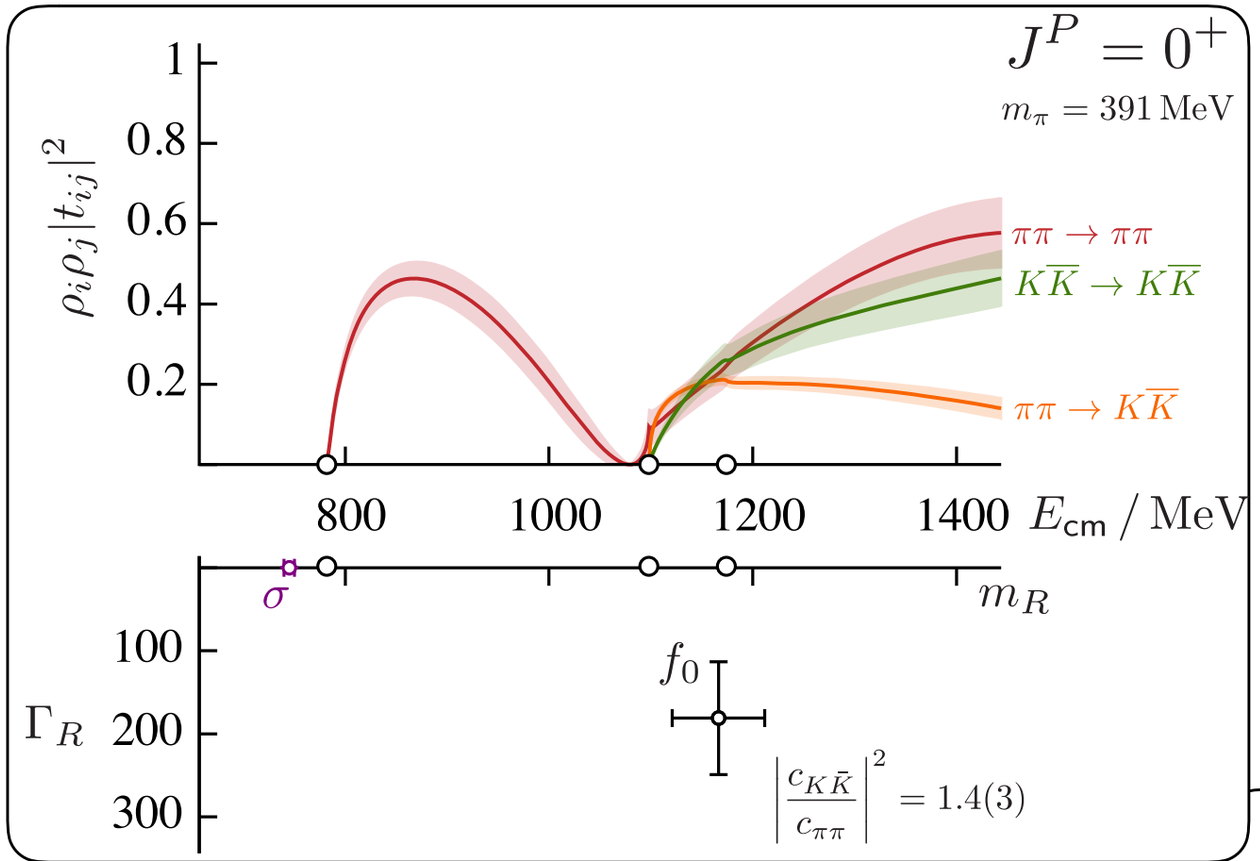
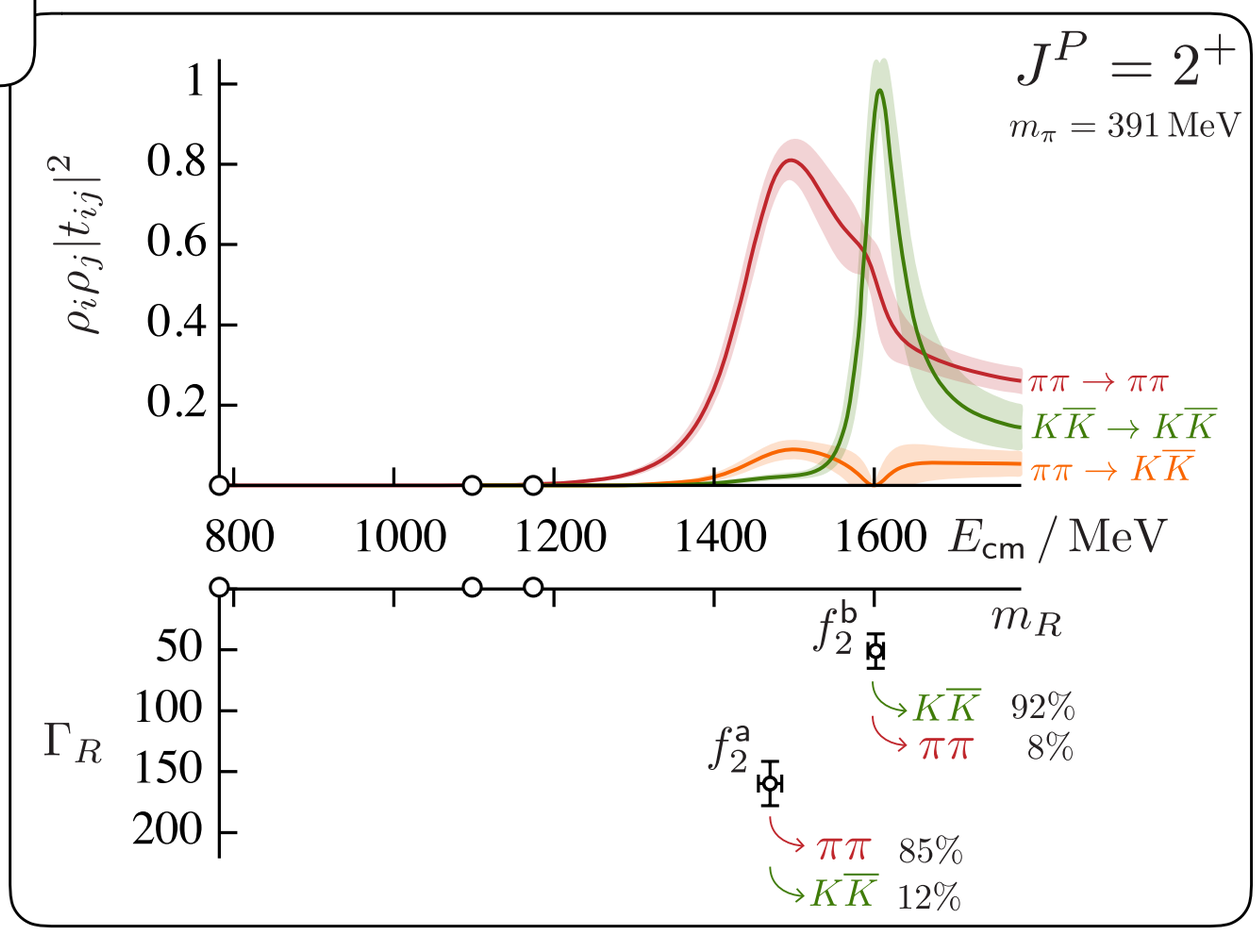
Wilson, RB, Dudek, Edwards, & Thomas (2019)

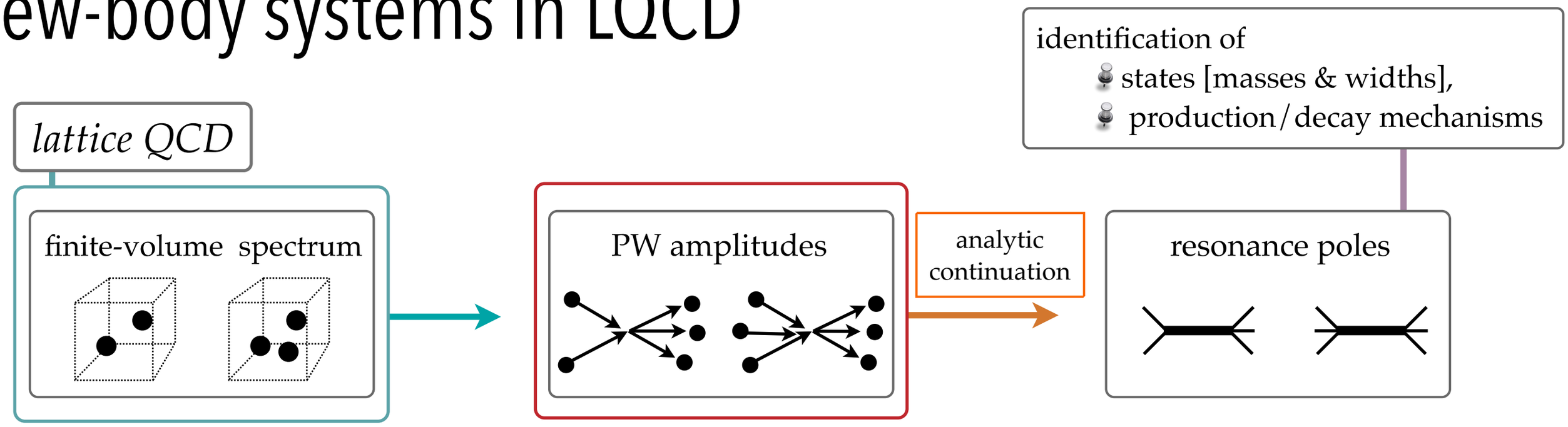
Scalar $\pi\pi$-KK





RB, Dudek, Edwards, & Wilson (2019)

few-body systems in LQCD



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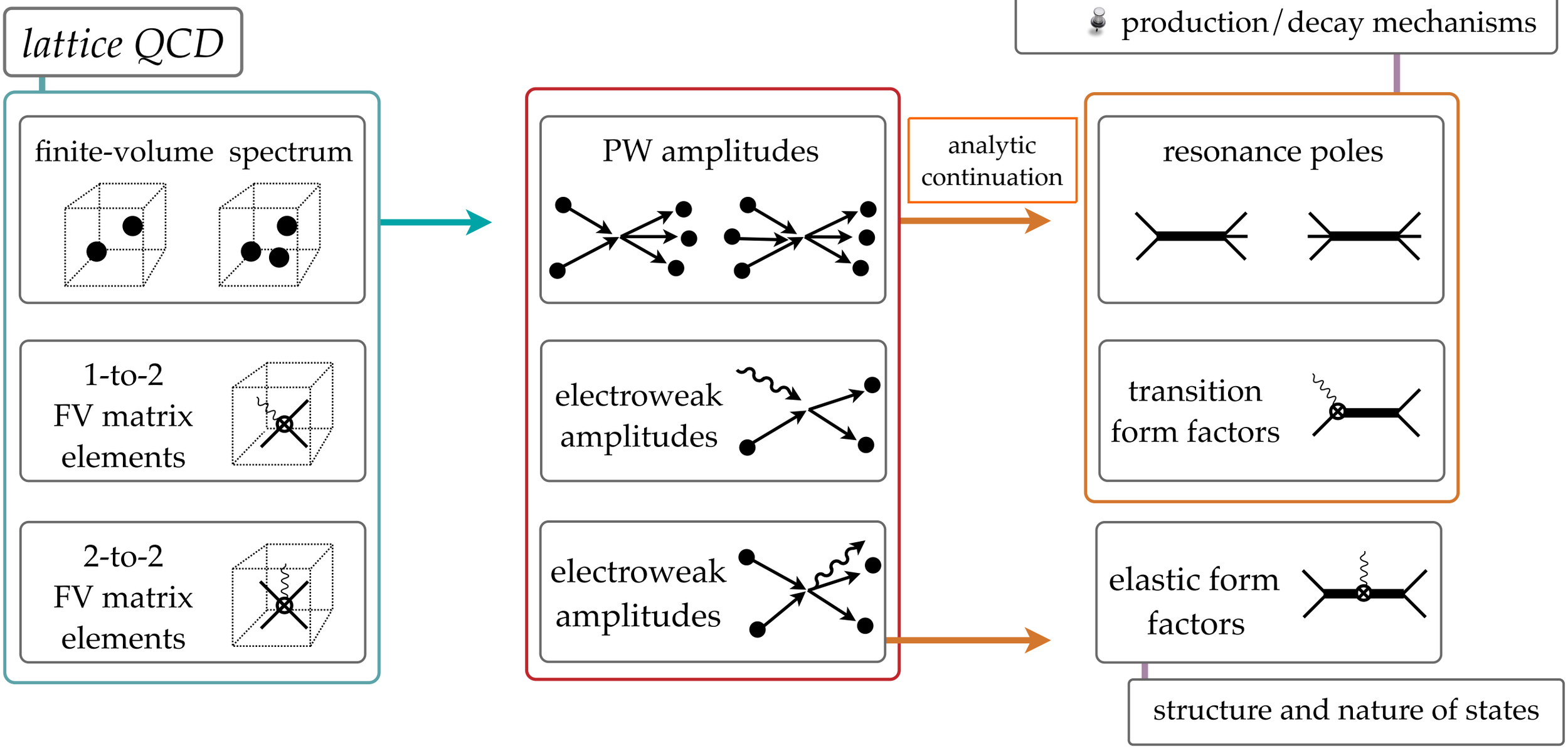
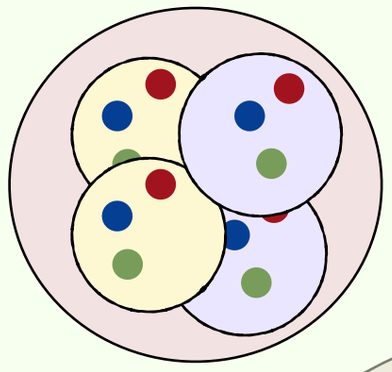


These techniques are being tested and implemented for *A=0* systems first, but they are necessary and will be applied for light nuclear systems…

lattice QCD @ JLab

nuclear structure

how do nucleons come together to form low-lying nuclei?



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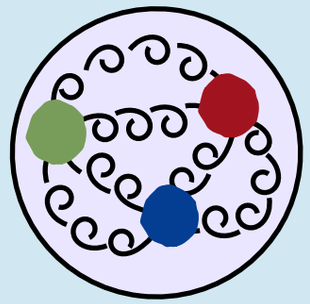

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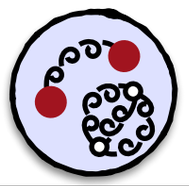
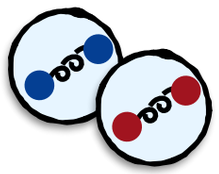
$$|n\rangle_{\mathrm{QCD}} = c_0$$  $$+ c_1$$  $$+ c_2$$  $$+ c_3$$  $$+ \cdots$$

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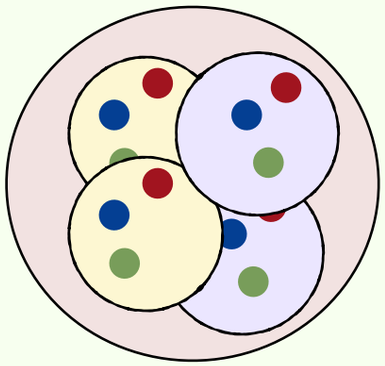
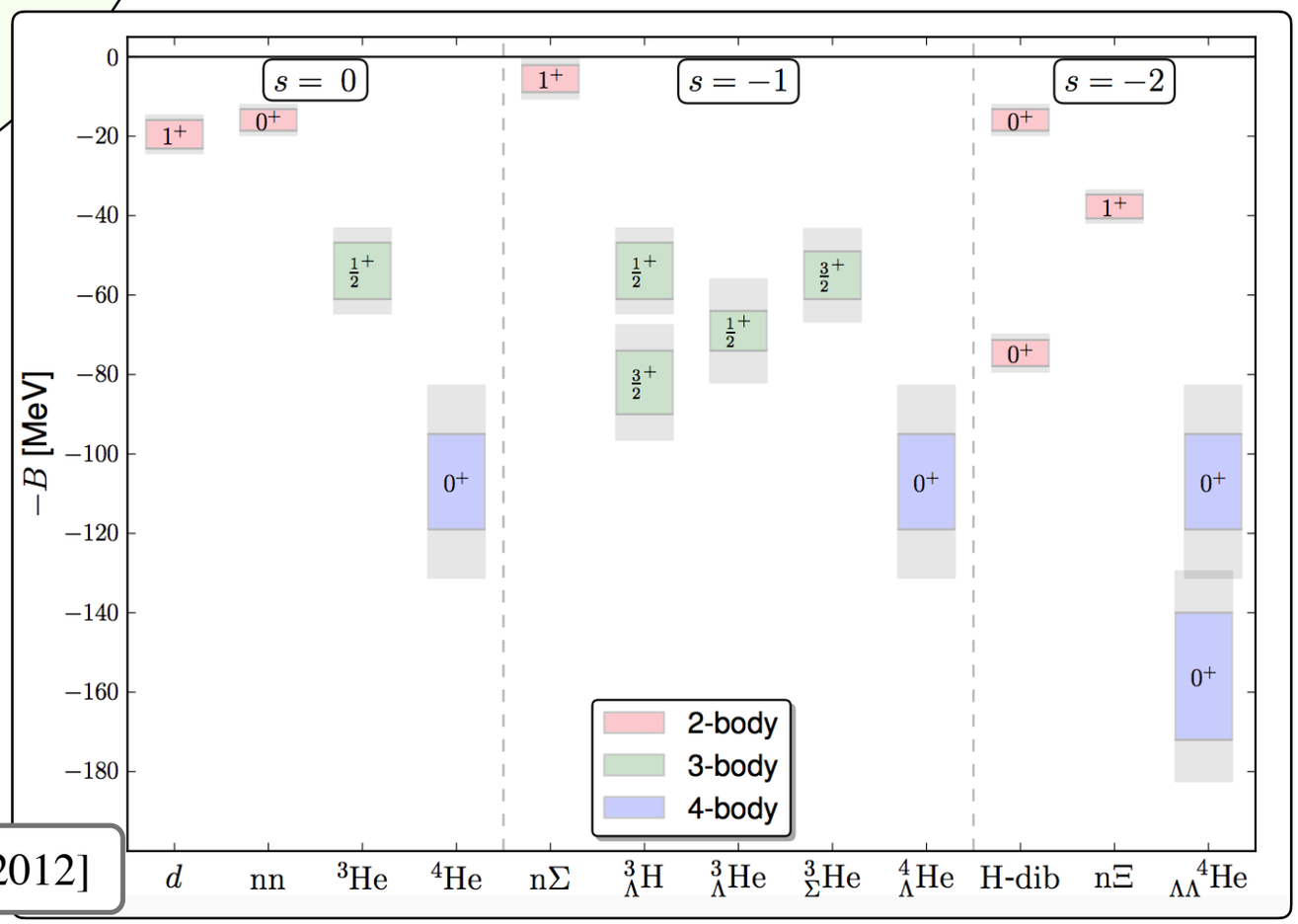


Orginos



Nuclei @ $m_\pi = 400$MeV [**Orginos et al. 2012.** 2012]

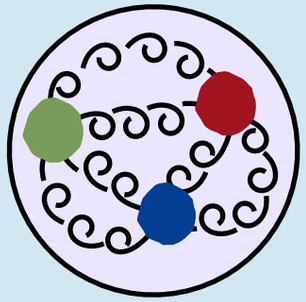
lattice QCD @ JLab

Orginos

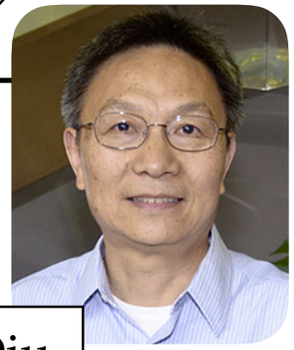
Radyushkin

Richards

how do quarks come together to form hadrons?



hadron structure



Qiu

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Orginos

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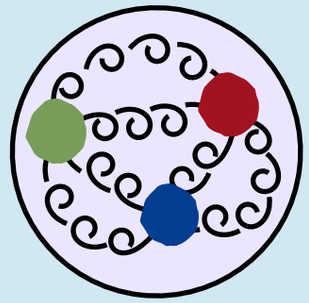


nature
International journal of science

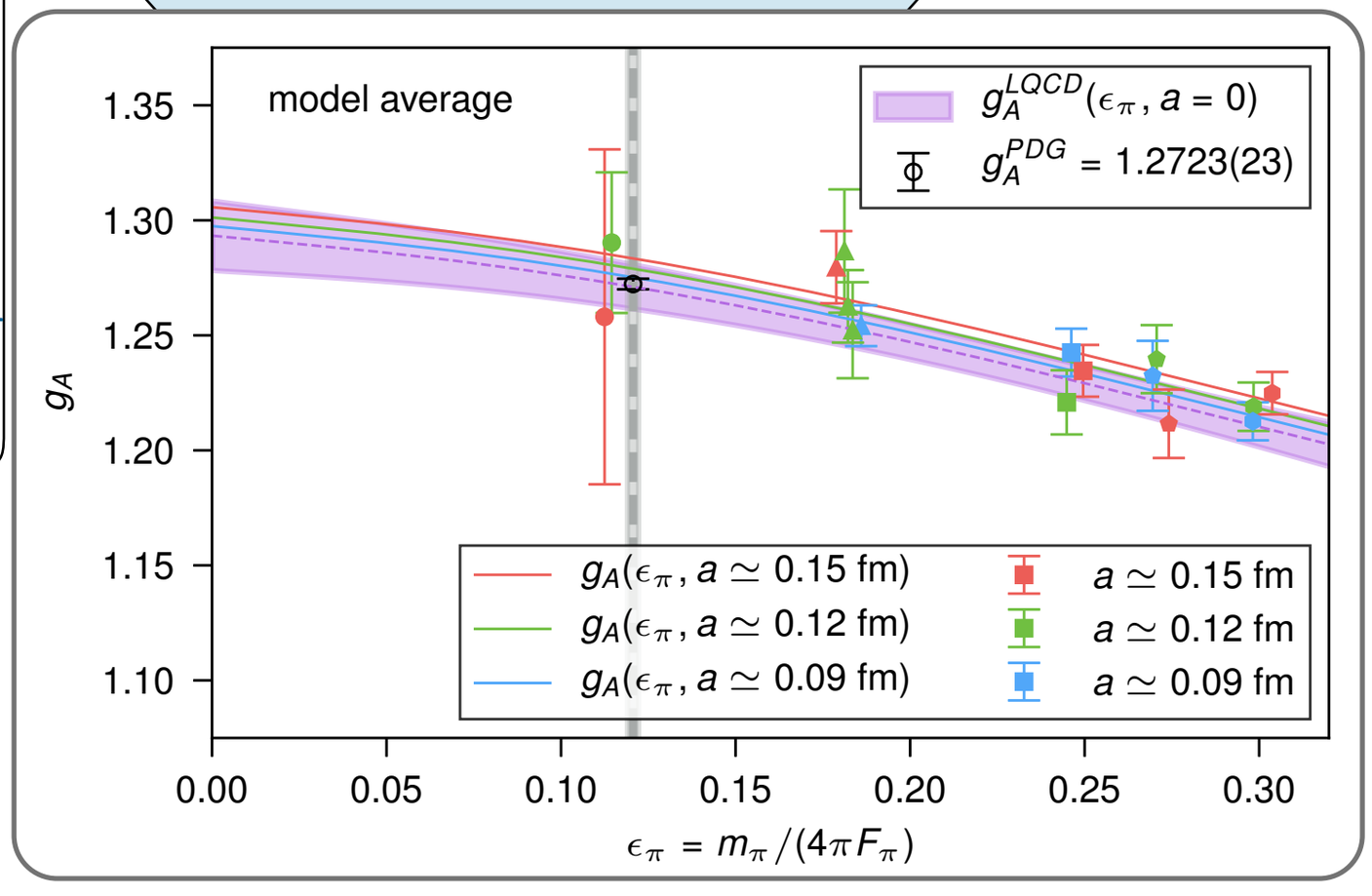
Altmetric: 114 More detail »

Letter | Published: 30 May 2018

A per-cent-level determination of the nucleon axial coupling from quantum chromodynamics

C. C. Chang, A. N. Nicholson, E. Rinaldi, E. Berkowitz, N. Garron, D. A. Brantley, H. Monge-Camacho, C. J. Monahan, C. Bouchard, M. A. Clark, B. Joó, T. Kurth, K. Orginos, P. Vranas & A. Walker-Loud

Nature **558**, 91–94 (2018) | Download Citation



PDFs in the lattice

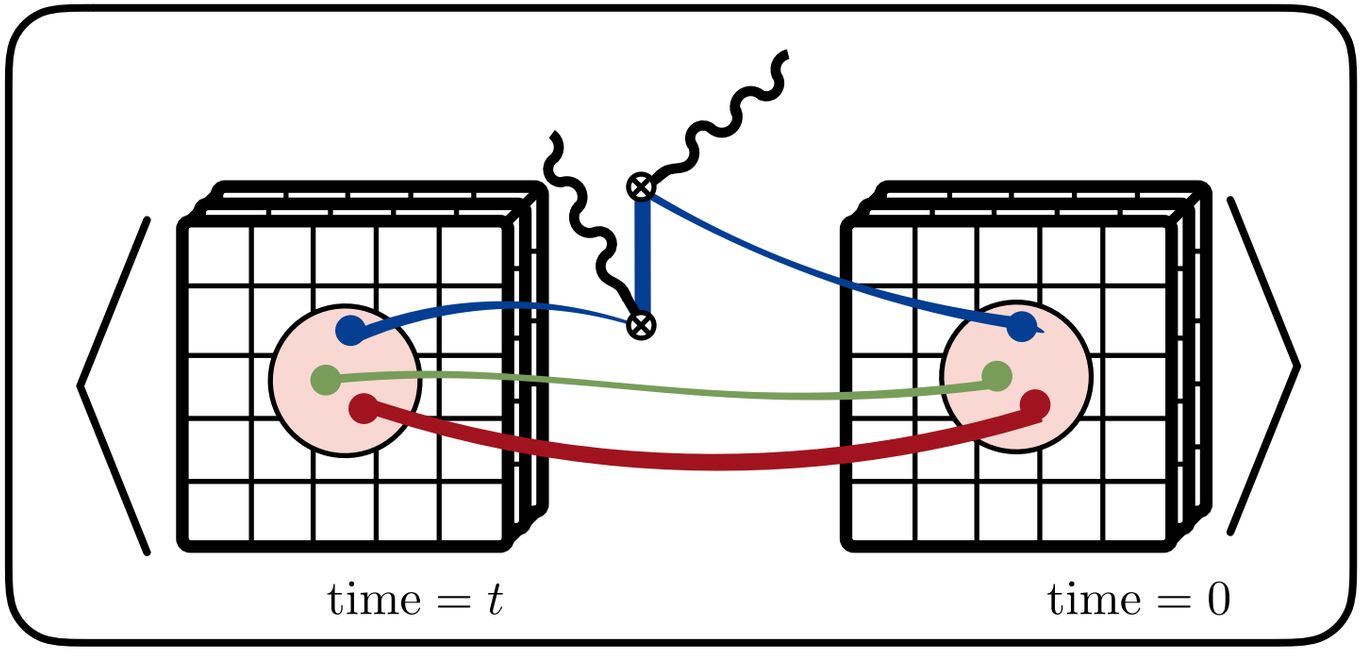
$\langle N|\mathcal{O}|N\rangle_{\text{latt.}}$ → $\langle N|\mathcal{O}|N\rangle_{\text{Min.}}$ —factorization→ PDFs

How can parton distribution functions (PDFs) be determined from Euclidean correlators?

- ☑ Using quasi-PDFs [Ji 2013]
- ☑ Using pseudo-PDFs [**Radyushkin** 2017]
- ☑ Using bi-local operators [Braun & Müller 2008, Ma & **Qiu** 20014]
- ☑ …

Are these matrix elements obtained from Euclidean correlators, the same as those from Minkowski correlators?

☑ Yes [**RB, Hansen**, & Monahan [2012]



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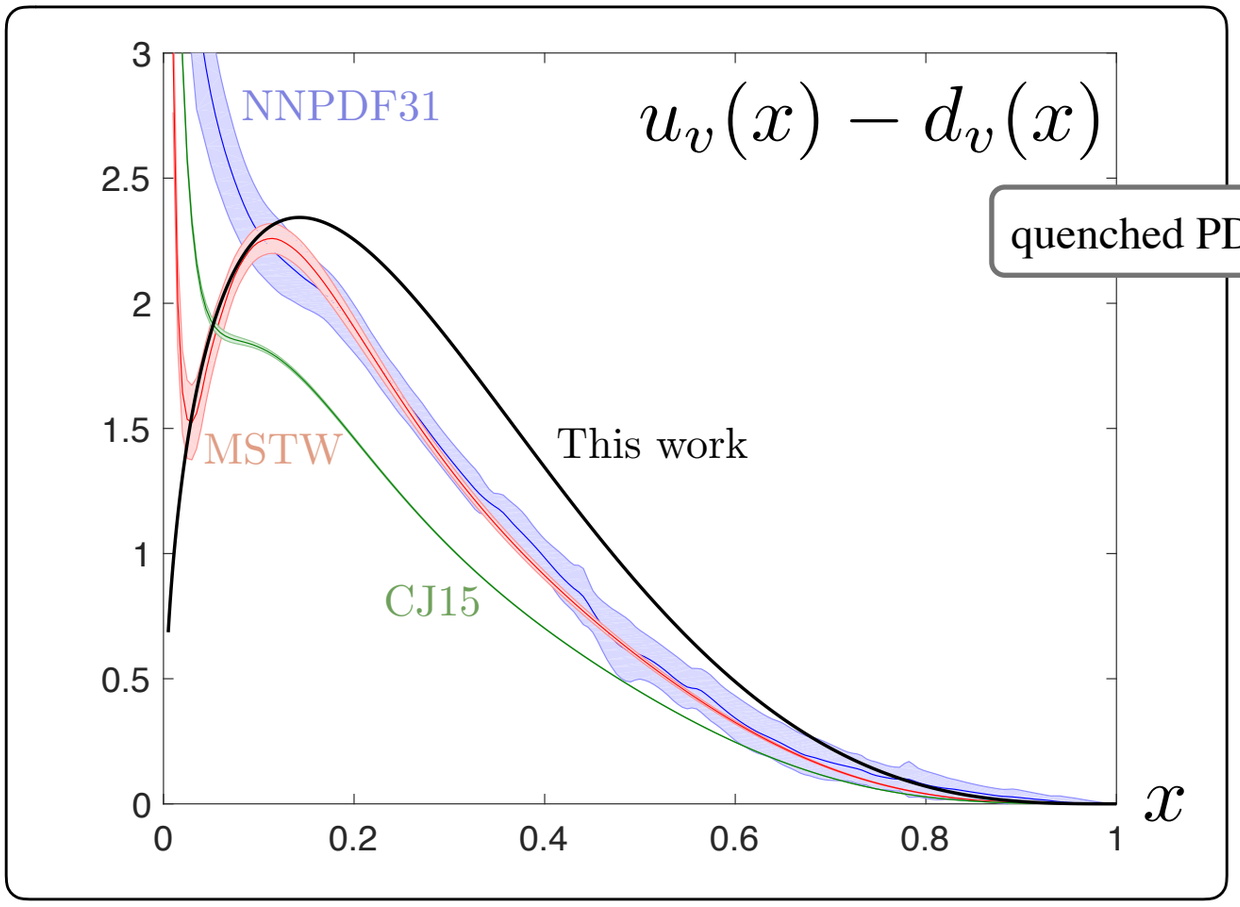
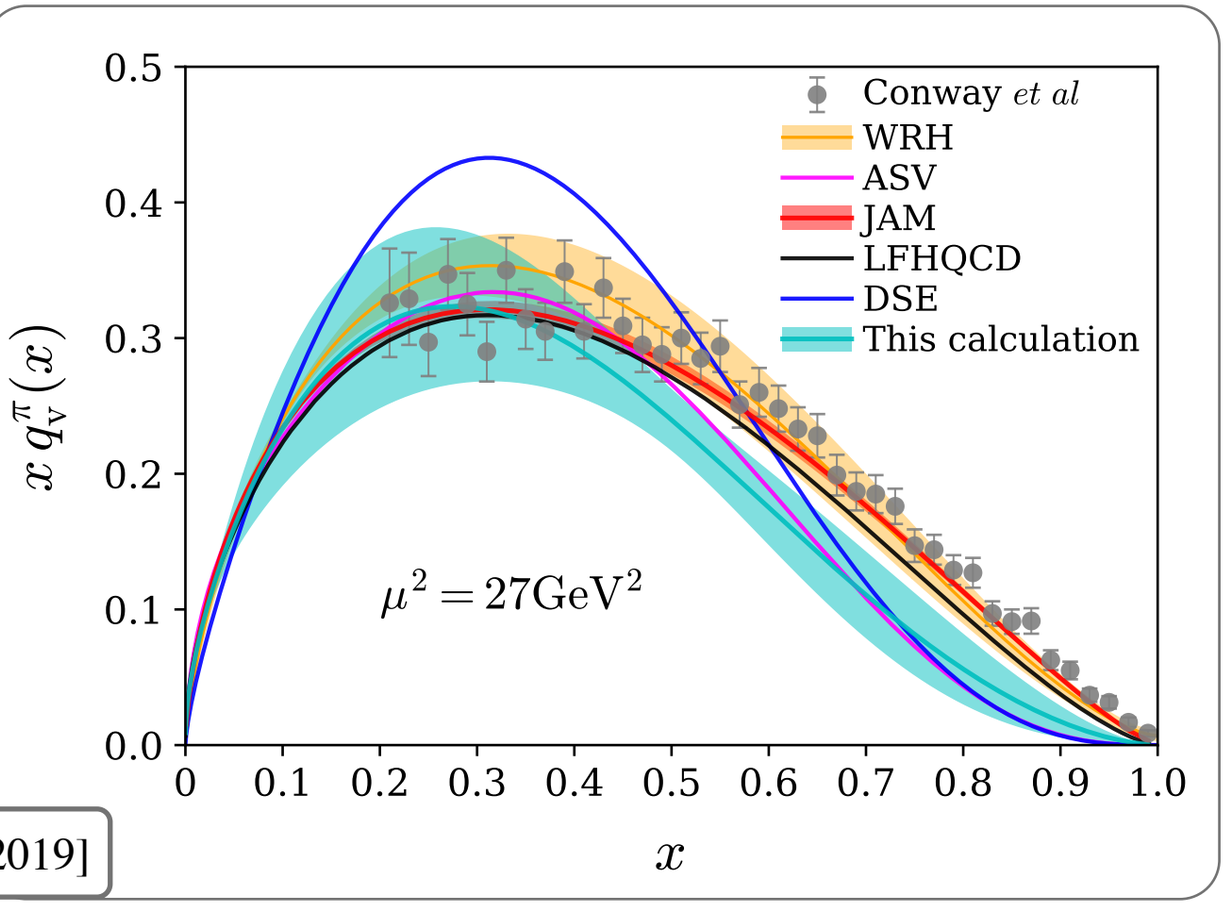


quenched PDFs [**Orginos, et al.** 2017]



Pion Valence Quark Distribution @ $m_\pi = 400\text{MeV}$ [**Sufian, et al.** 2019]

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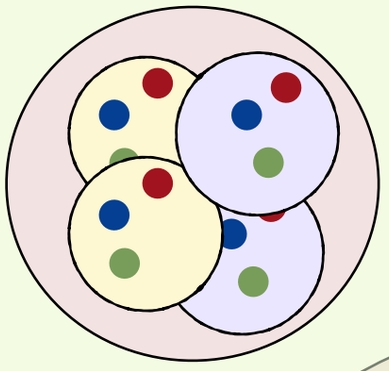

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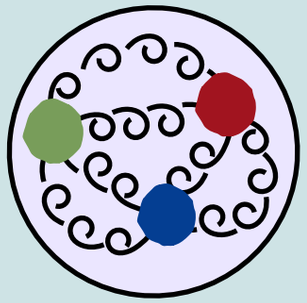

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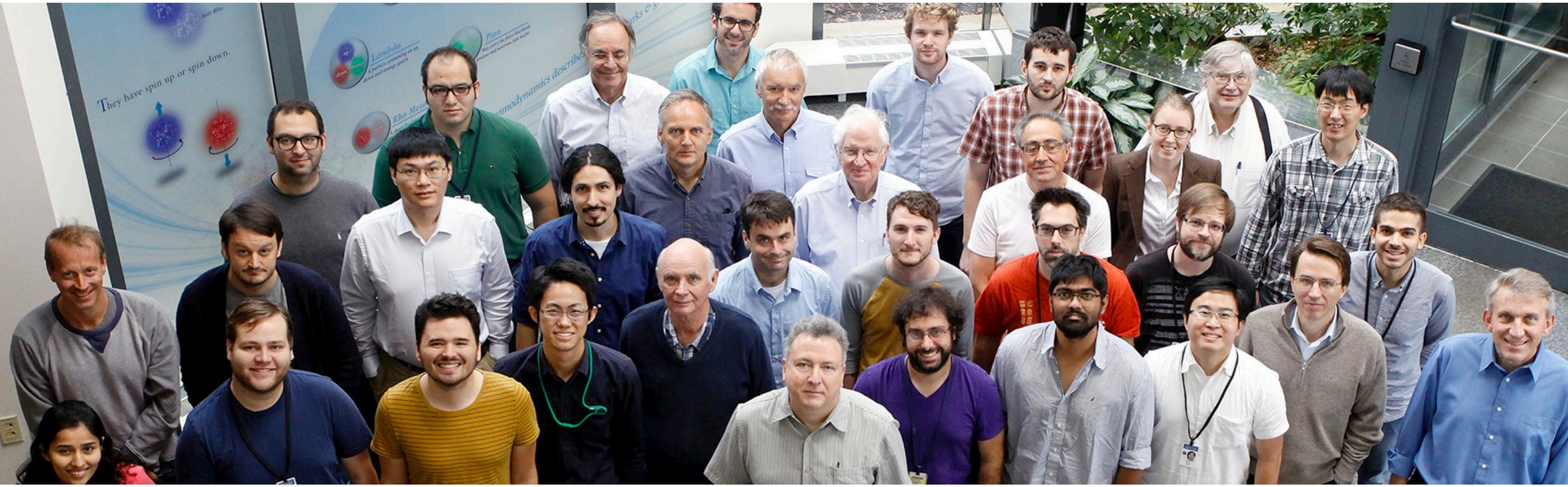
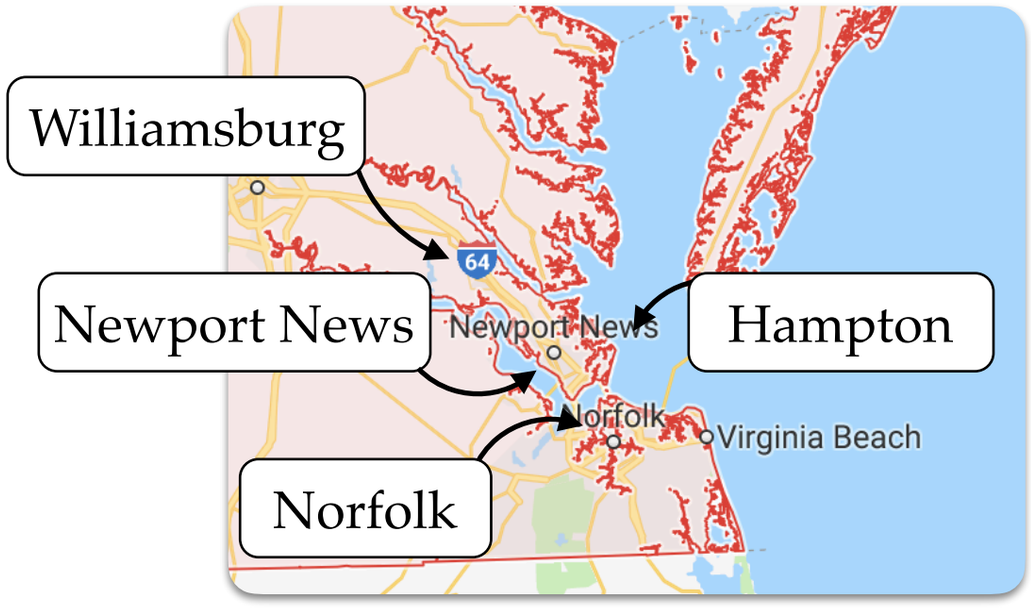
EIC: Ultimately, in order to understand the structure of nucleons and nuclei at increasingly high energies, it will require bringing these formalism and technologies together.

spectroscopy

JLab theory group





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