Hadron Spectroscopy from Lattice QCD

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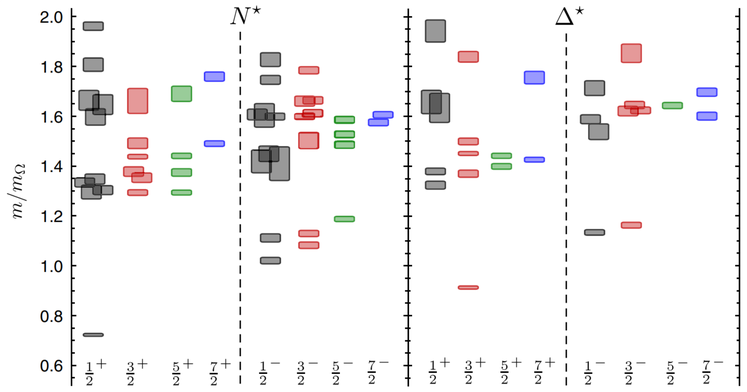
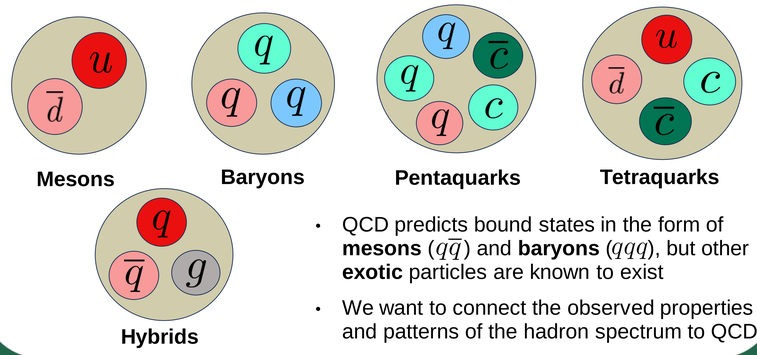
Hadron Spectroscopy



R. Edwards, J. Dudek et. al. Phys. Rev. D 84, 074508

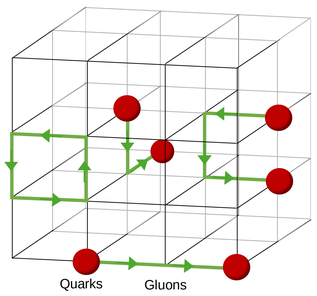
- Studies **mass** and **lifetime** of QCD bound states and resonances



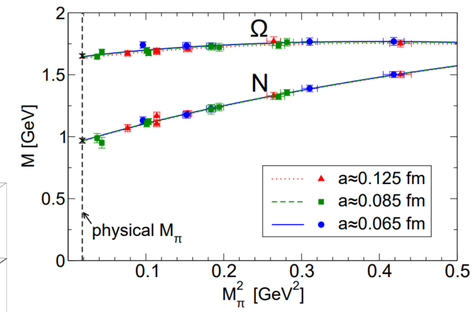
- QCD predicts bound states in the form of **mesons** ($q\bar{q}$) and **baryons** (qqq), but other **exotic** particles are known to exist
- We want to connect the observed properties and patterns of the hadron spectrum to QCD

Lattice QCD

- Finite **Volume, Spacing**
- $m_\pi > m_{\pi,\text{phys.}}$
- Ensemble of field configurations generated by **Monte Carlo**

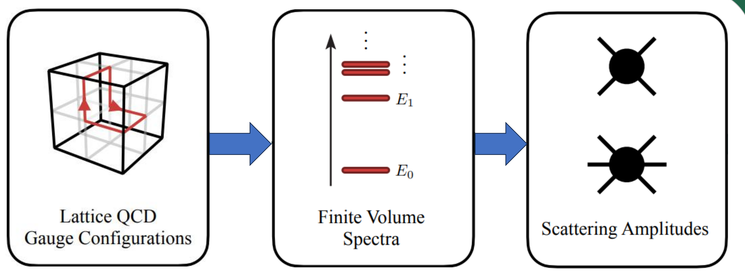


S. Dürr et al, Science 322,1224-1227(2008).



$$C(\tau) \equiv \langle O(\tau) O^\dagger(0) \rangle$$
$$= \int \mathcal{D}\psi \mathcal{D}\bar{\psi} \mathcal{D}U e^{-S_{\text{QCD}}} O(\tau) O^\dagger(0)$$
$$= \sum_{\mathfrak{n}} \langle 0|O(\tau)|\mathfrak{n}\rangle \langle \mathfrak{n}|O^\dagger(0)|0\rangle e^{-E_{\mathfrak{n}}\tau}$$

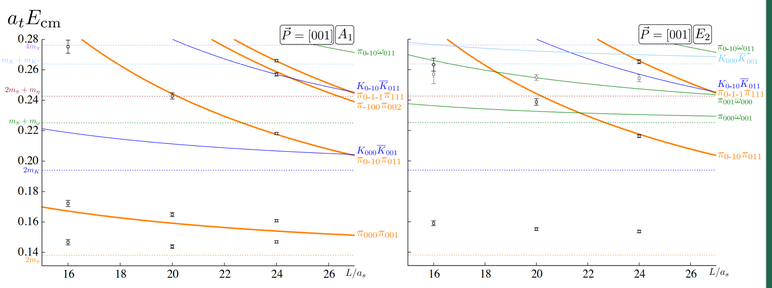
Finite Volume Spectrum



$$C_{ij}(\tau) = \langle O_i(\tau) O_j^\dagger(0) \rangle$$

$$E_{\mathfrak{n}} = \log \frac{\lambda_{\mathfrak{n}}(\tau)}{\lambda_{\mathfrak{n}}(\tau+1)}$$

- **Correlators** give finite volume **energy levels**
- **Luscher** connects F.V. spectrum to scattering amplitude



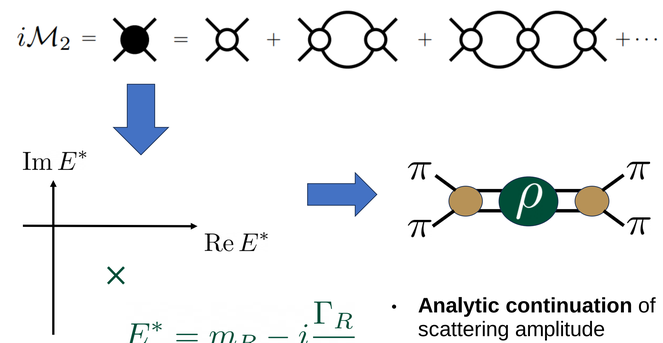
J. Dudek, R. Edwards, et. al. [HadSpec Collaboration], Phys. Rev. D 87, 034505

$$\det\left[F^{-1}(E,\mathbf{P}) + \mathcal{M}(E)\right] = 0$$

Finite Volume Energies — Partial Wave Amplitudes

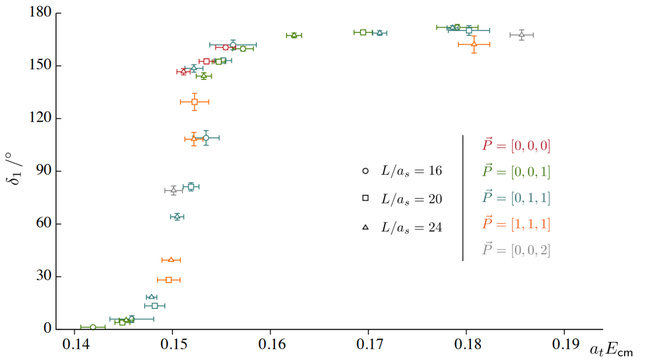
Lüscher Method

Amplitude Analysis



$$E^* = m_R - i\frac{\Gamma_R}{2}$$

- **Analytic continuation** of scattering amplitude
- **Resonances** appear as **poles** in complex E
- Extract **mass** and **decay width** from pole data



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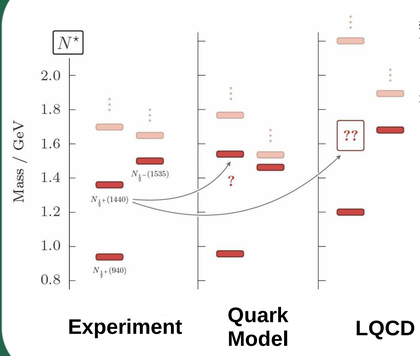
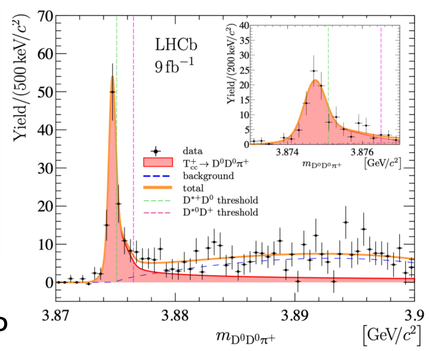
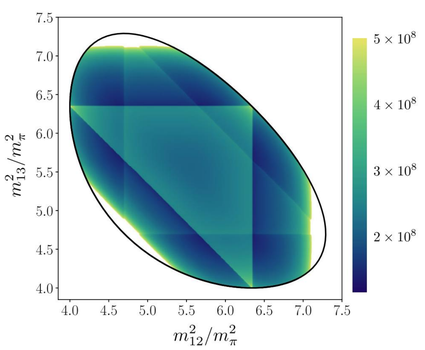
The Frontier





R. Aaij et al., Nature Physics 18, 751–754 (2022)



M. Hansen et al., Phys. Rev. Lett. 126, (2021) 012001

- Plenty of curiosities in light **baryon spectrum**. Even simplest baryon-meson systems **unexplored**
- Lattice provides a rigorous mechanism to **search** for **exotics** like the T_{cc} tetraquark candidate
- **3-body spectroscopy** requires further theoretical development and calculations.