

Amplitude analyses

in

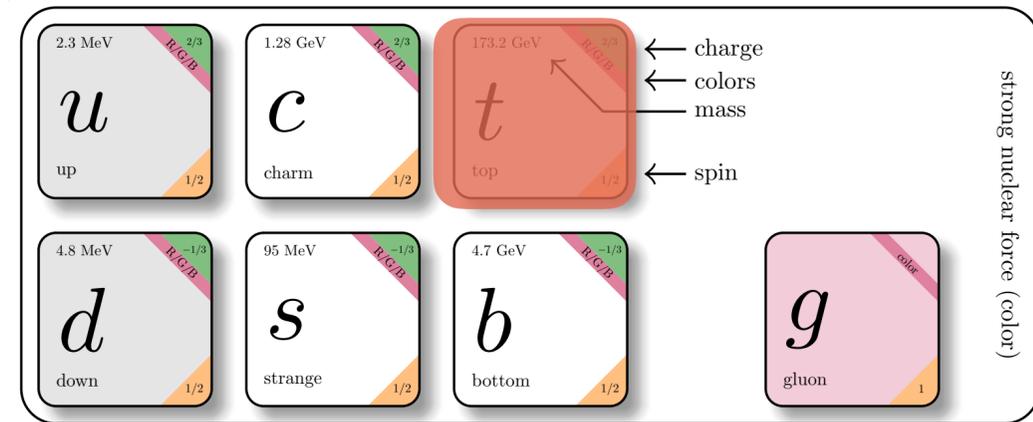
Hadron Spectroscopy

Snowmass CSS - July 20, 2022

Arkaitz Rodas

“... hadron spectroscopy illuminates the QCD interaction that binds quarks.”

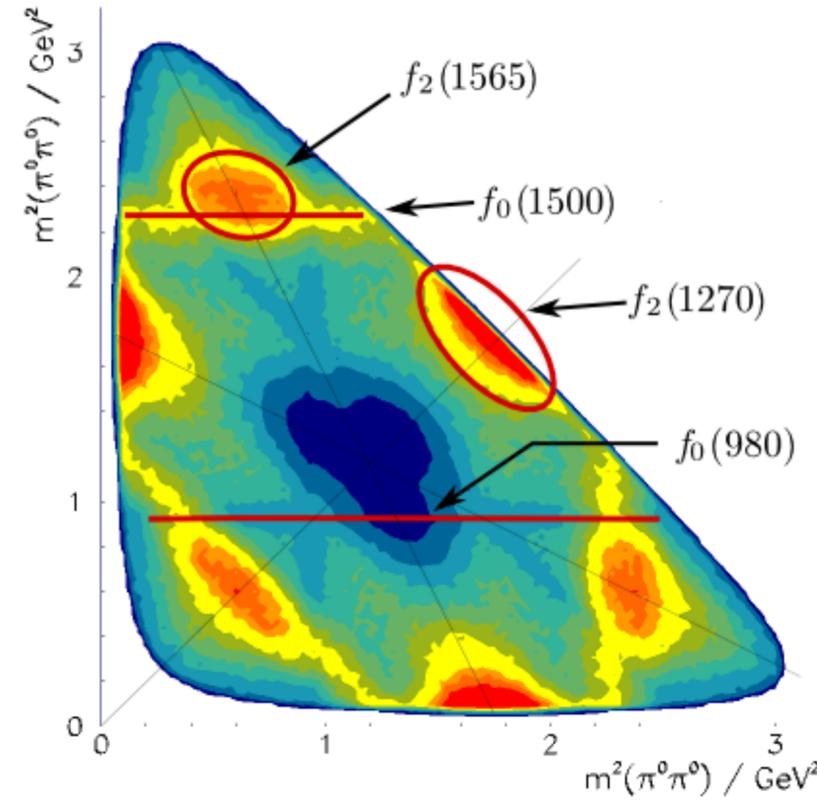
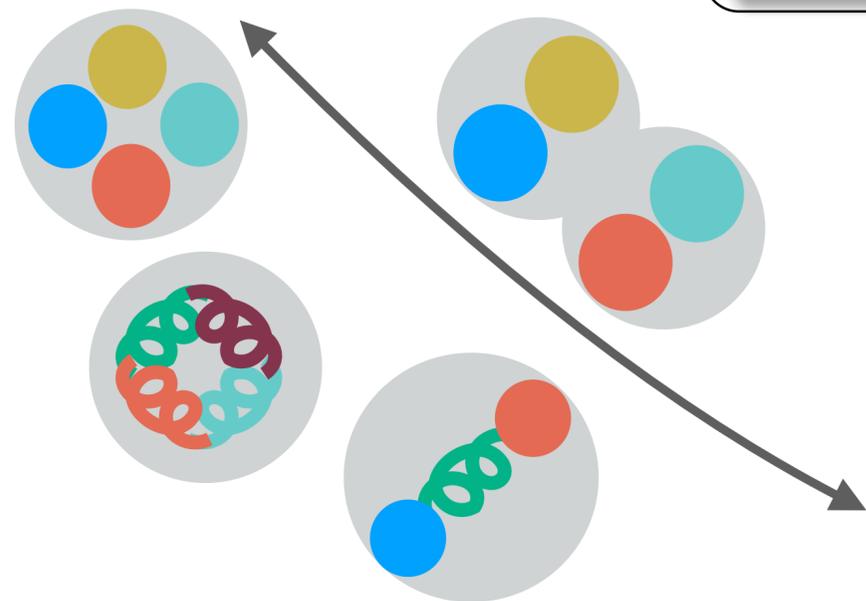
QCD



REACHING FOR THE HORIZON



The Site of the Wright Brothers' First Airplane Flight



The 2015
LONG RANGE PLAN
for NUCLEAR SCIENCE



Understanding the QCD spectrum

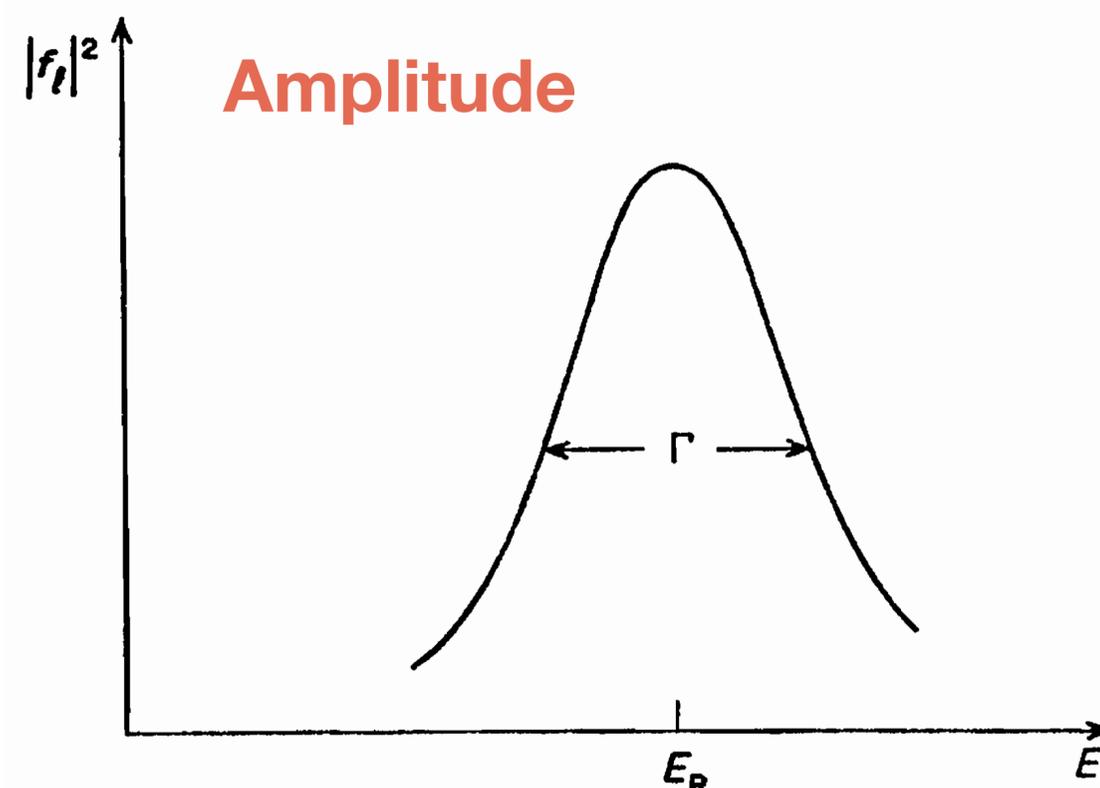
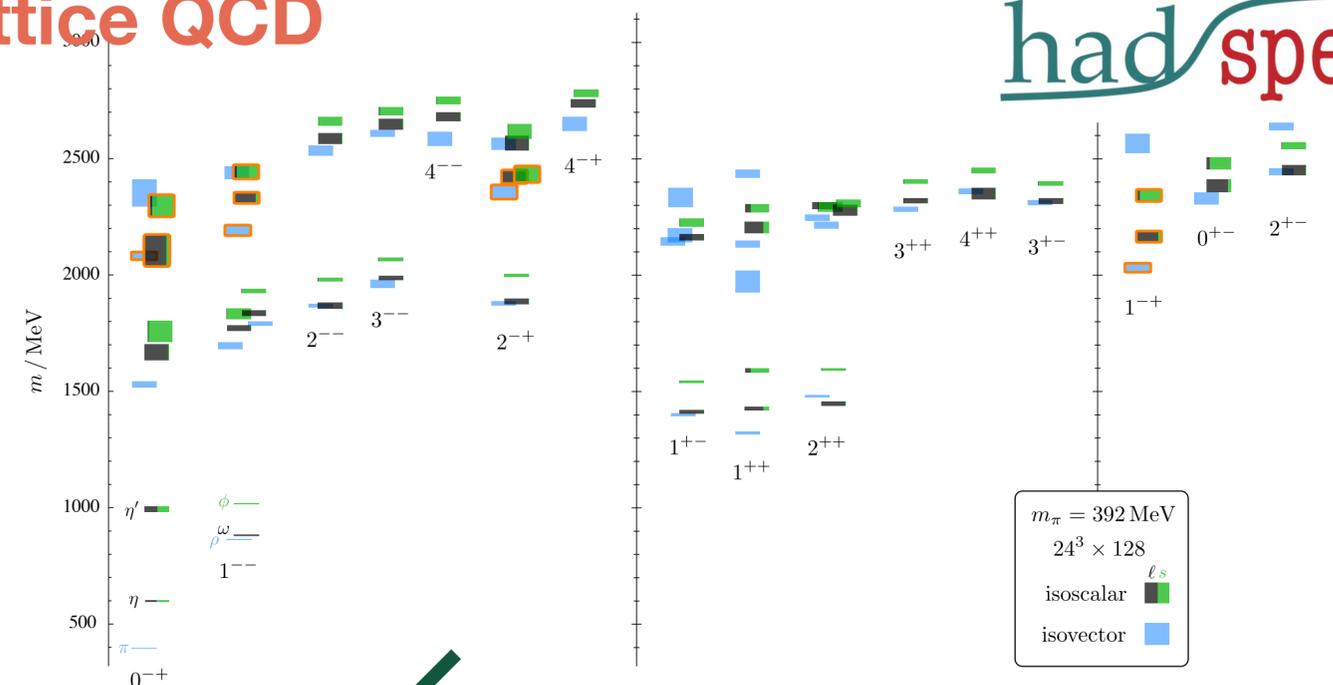
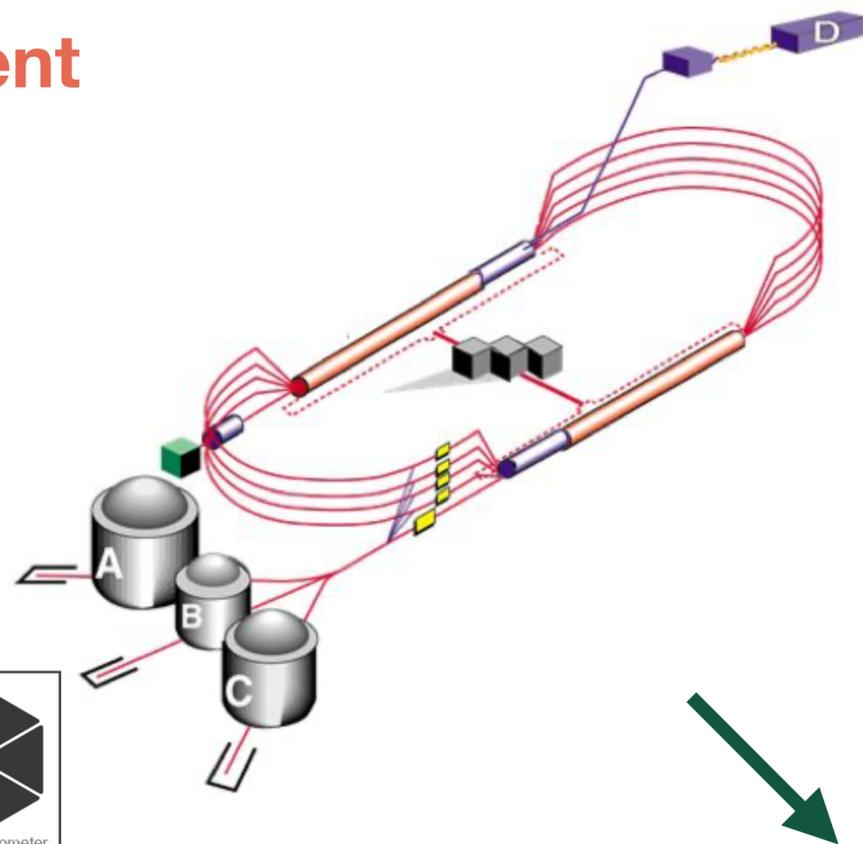
Determine the spectrum

Experiment



Lattice QCD

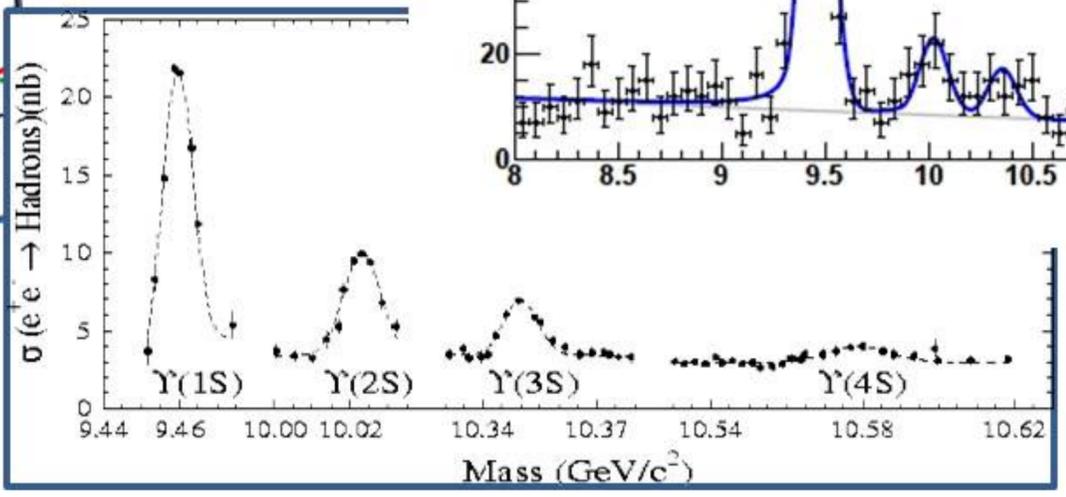
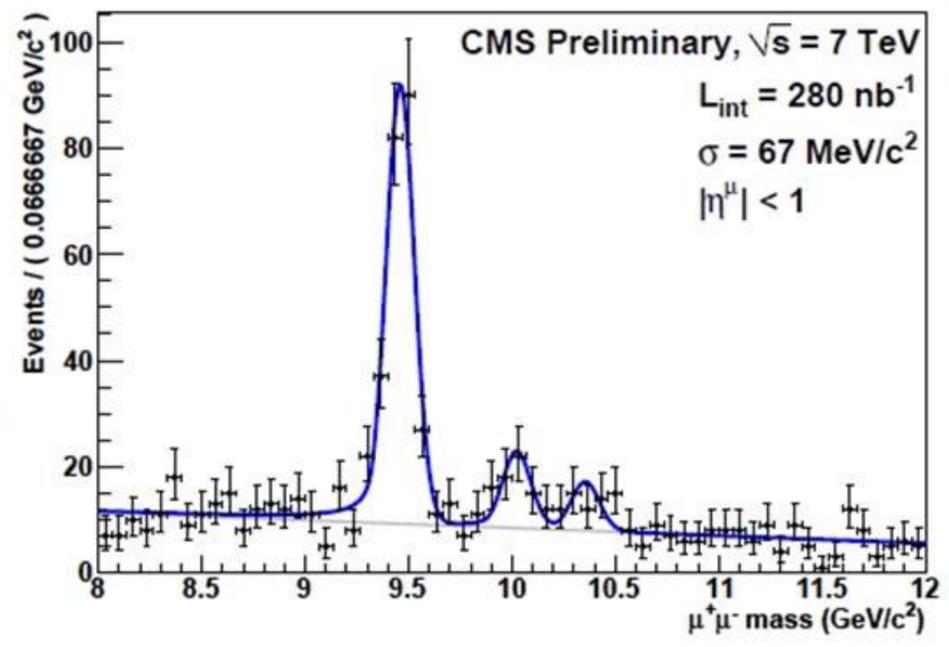
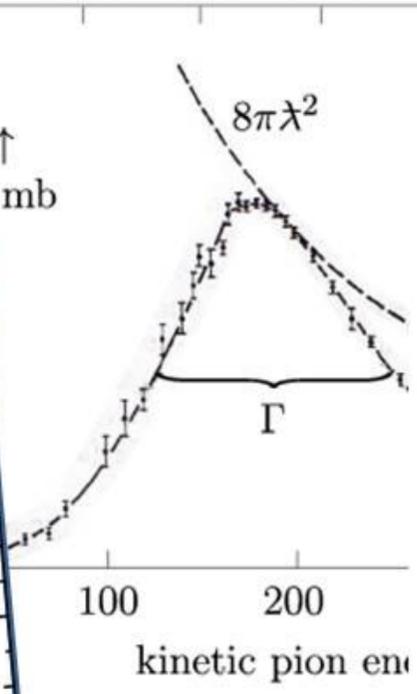
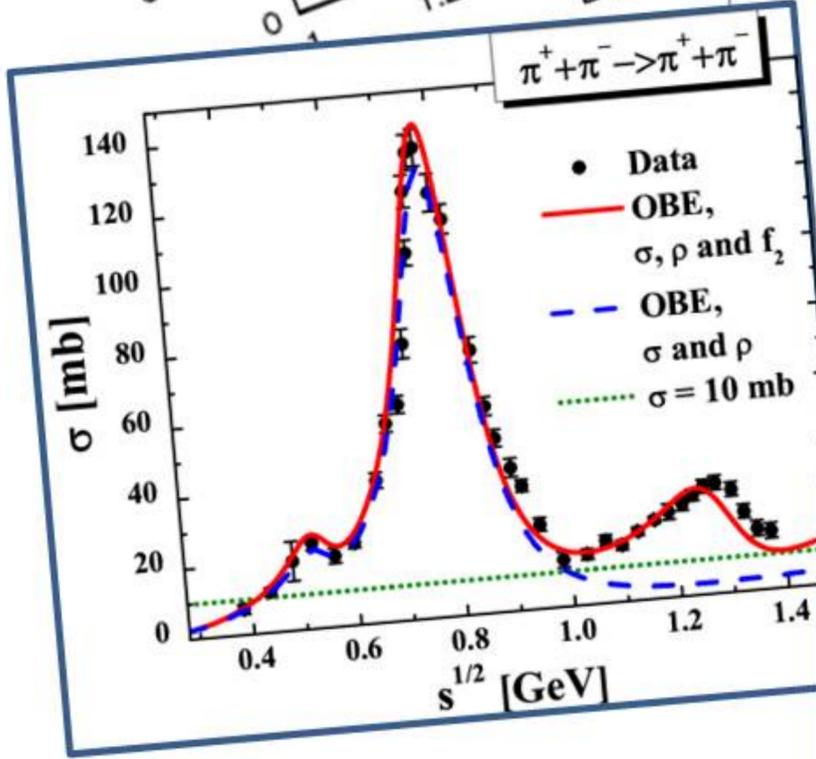
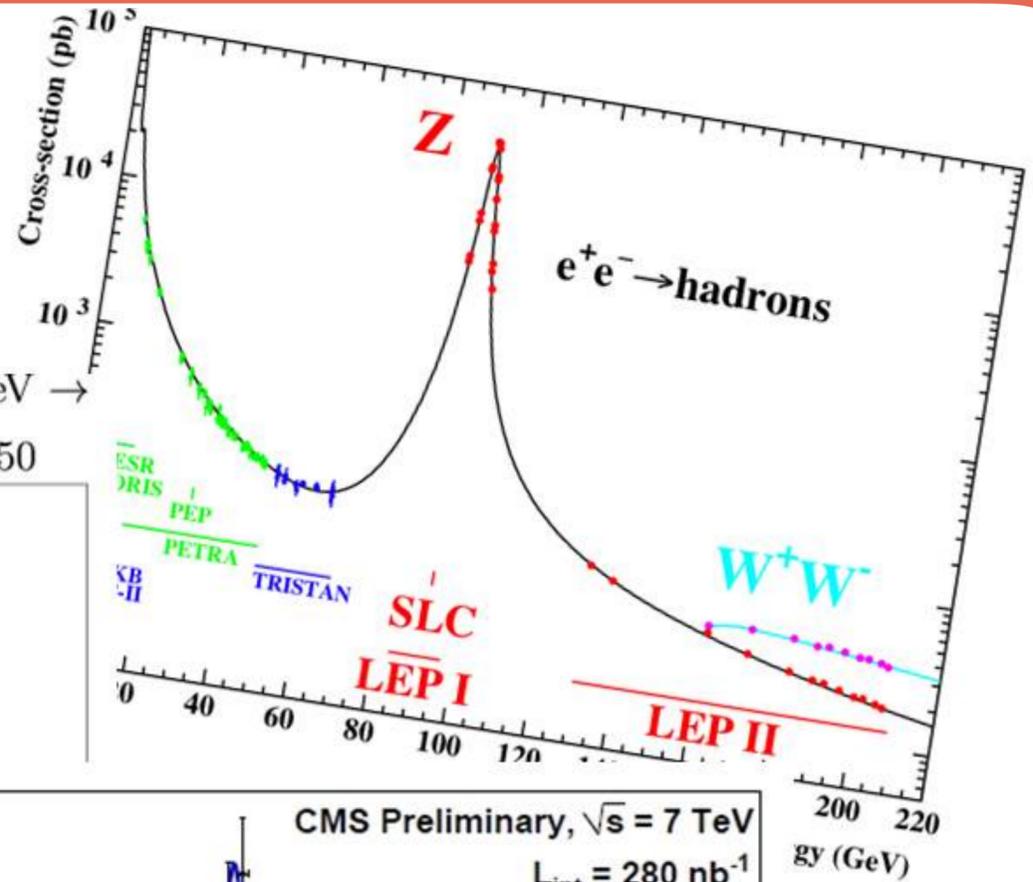
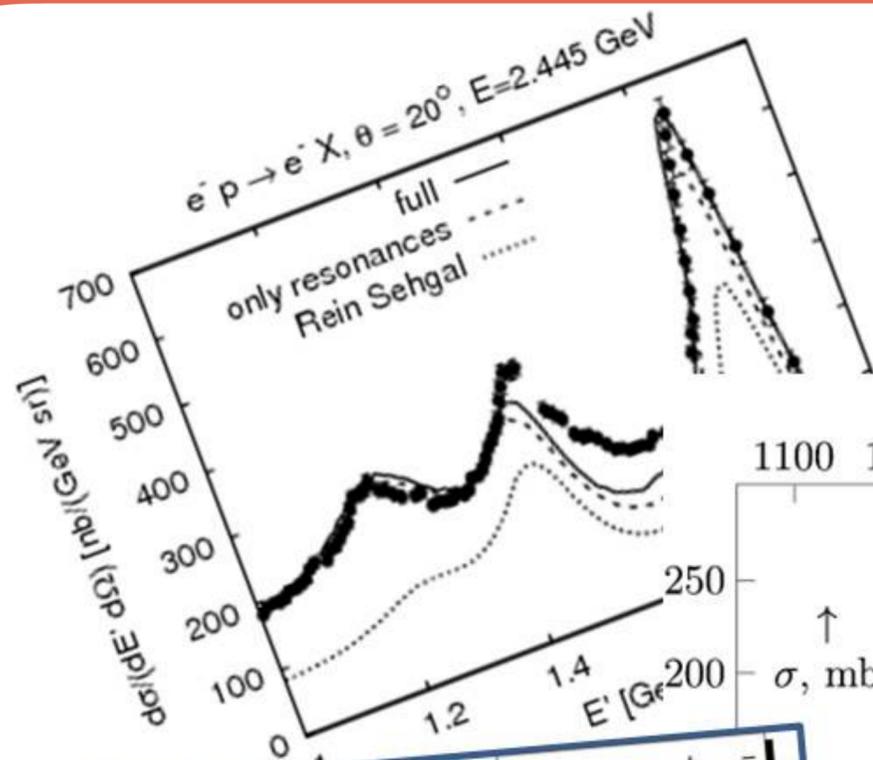
had spec



$$t_l(s) \simeq \frac{-M\Gamma}{M^2 - s - iM\Gamma}$$

Breit-Wigner

Very simple





Simple ordinary hadrons

Complicated:

What do we do?



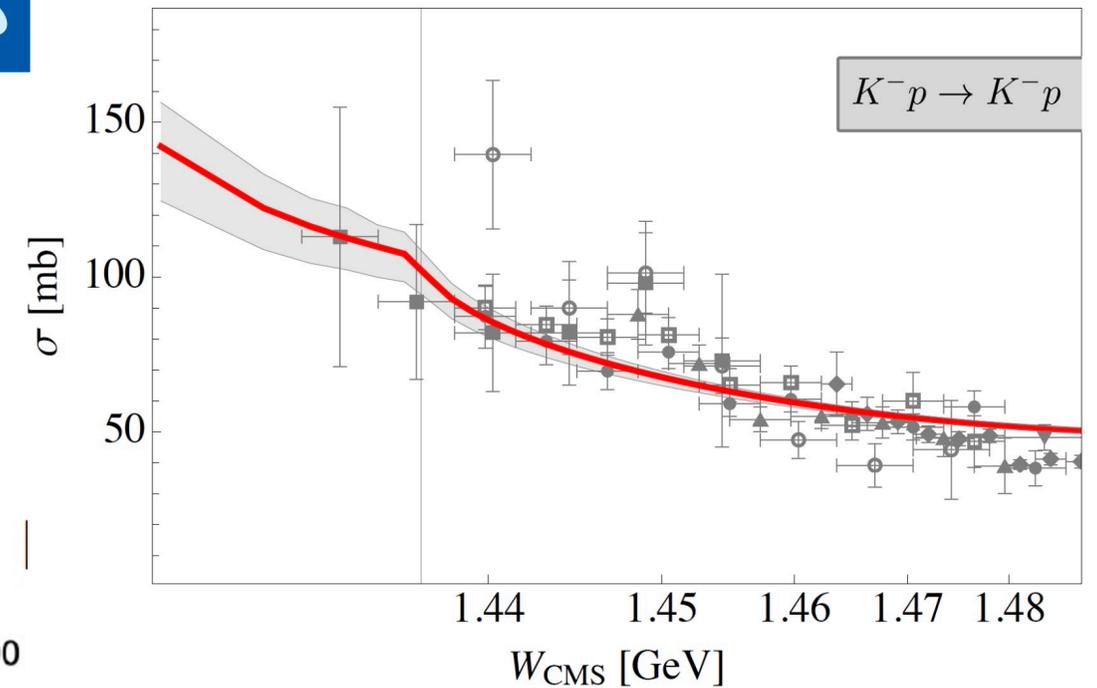
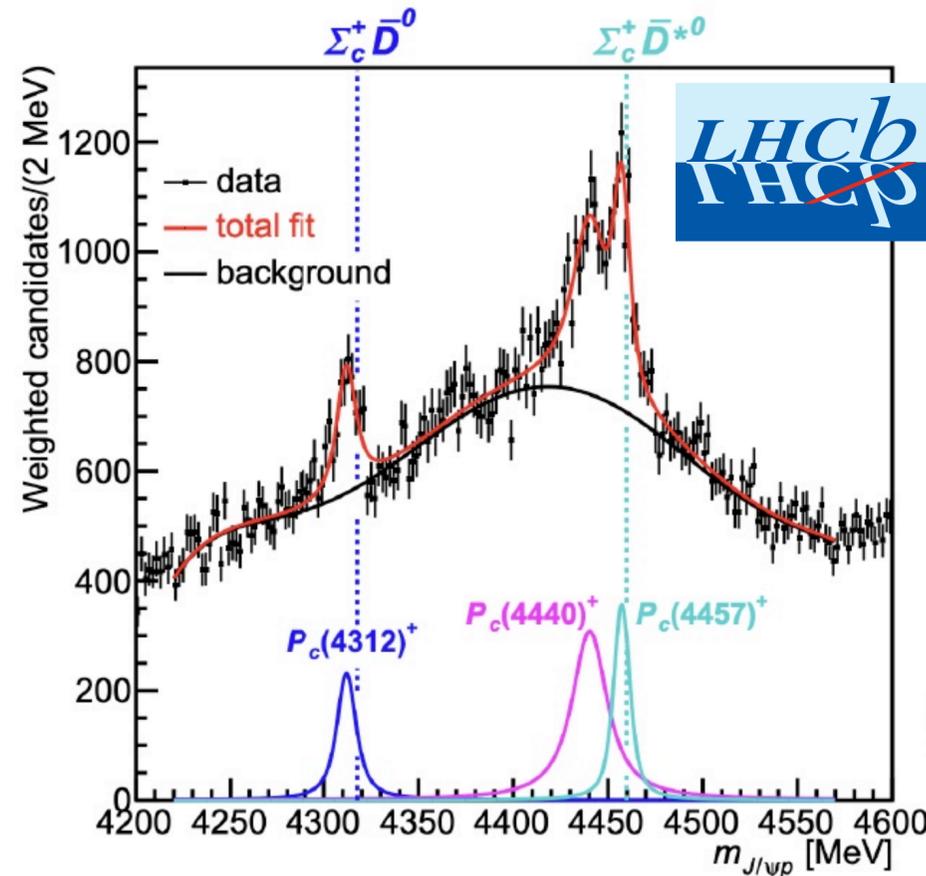
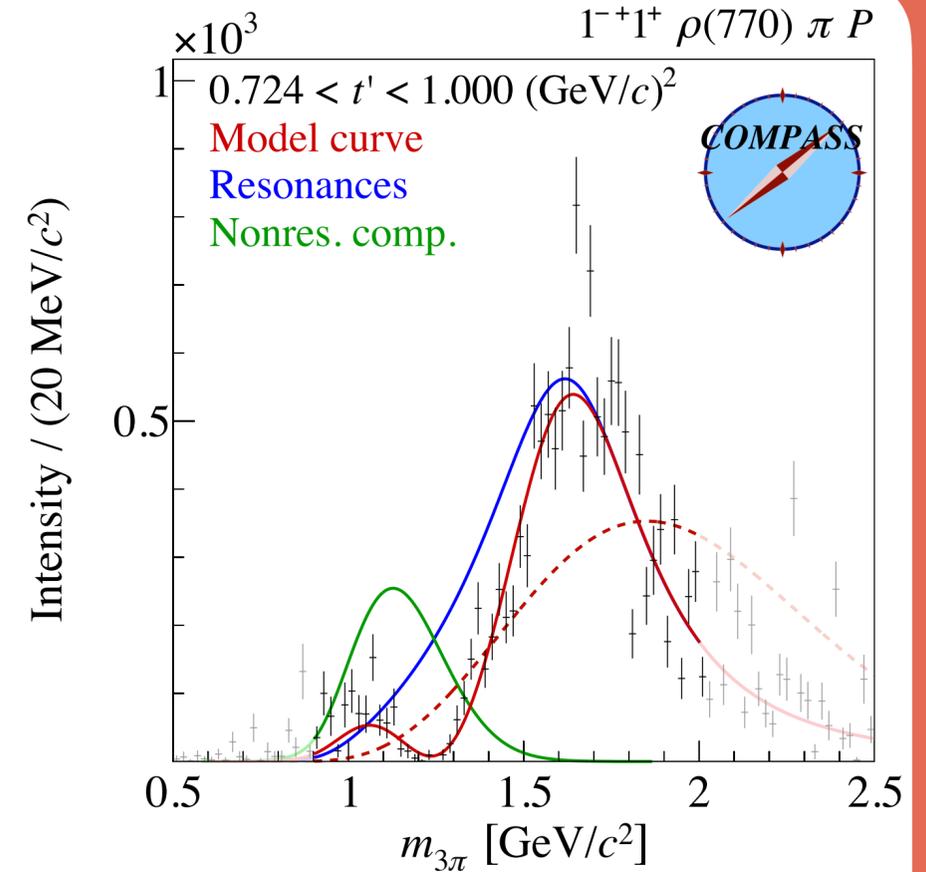
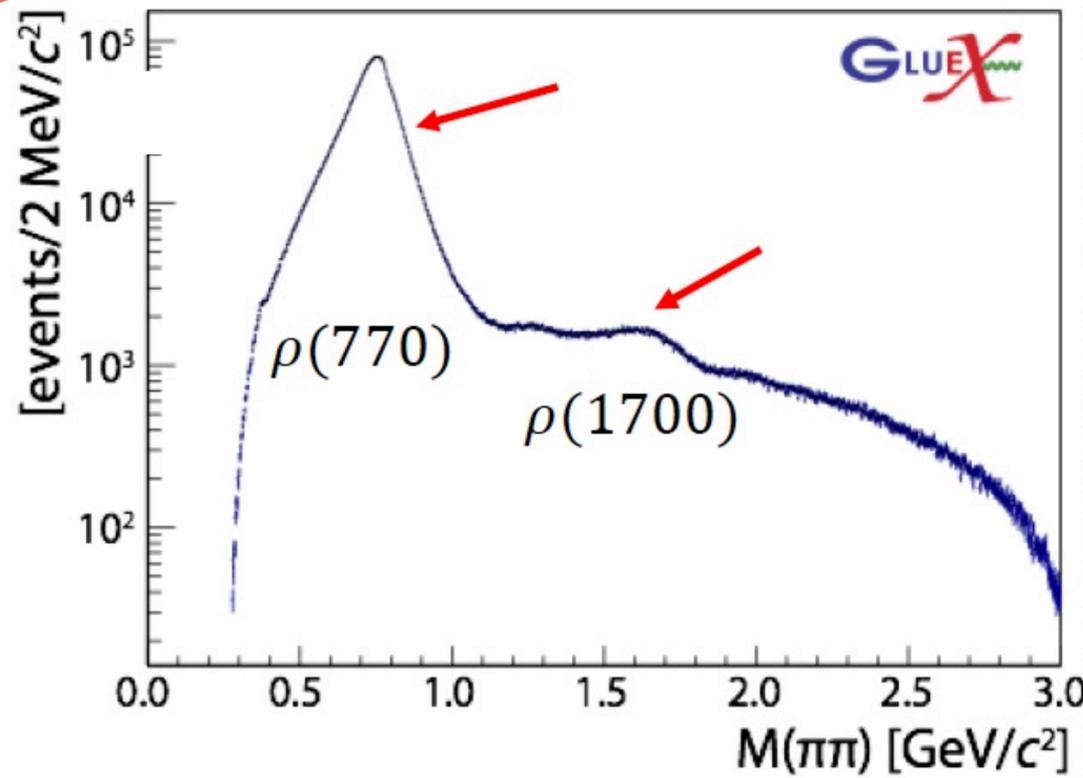
Glueballs



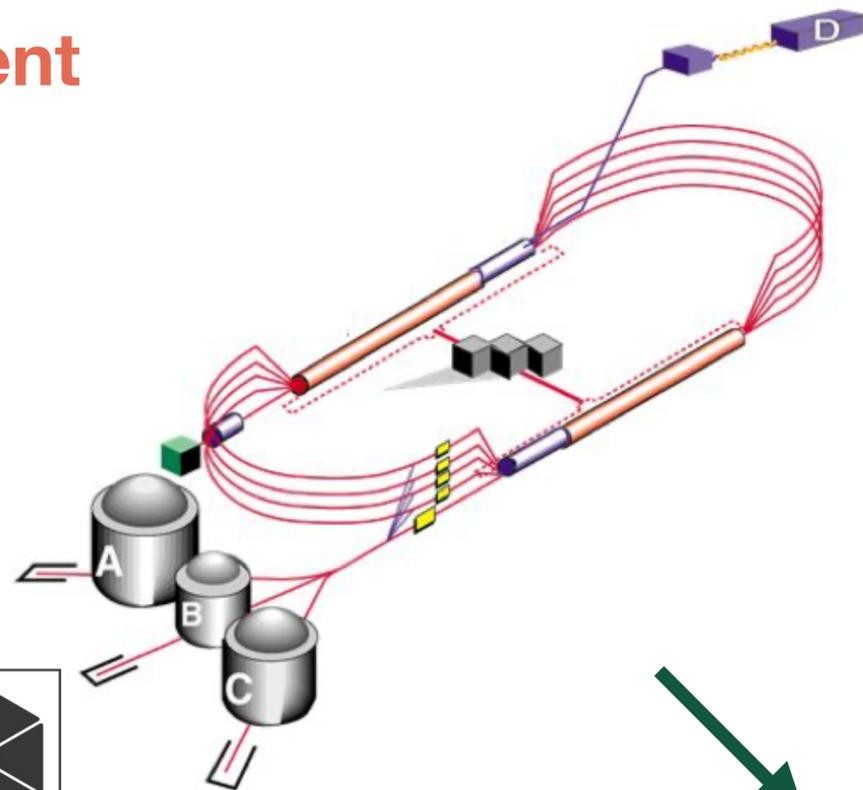
Tetra-quarks/
Penta-quarks/
Molecules



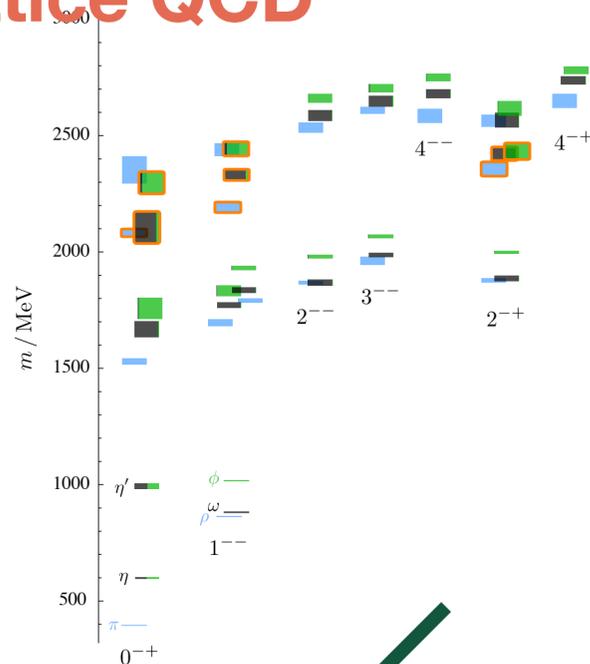
Light scalars



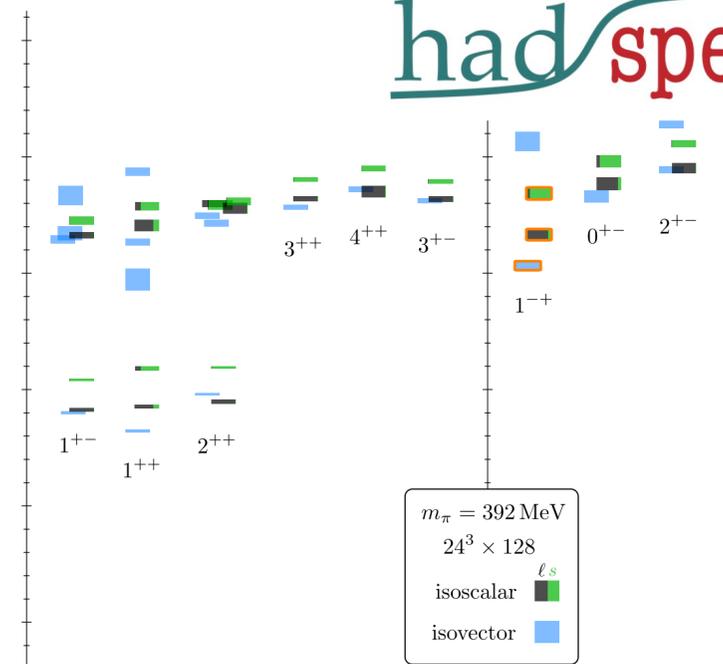
Experiment



Lattice QCD



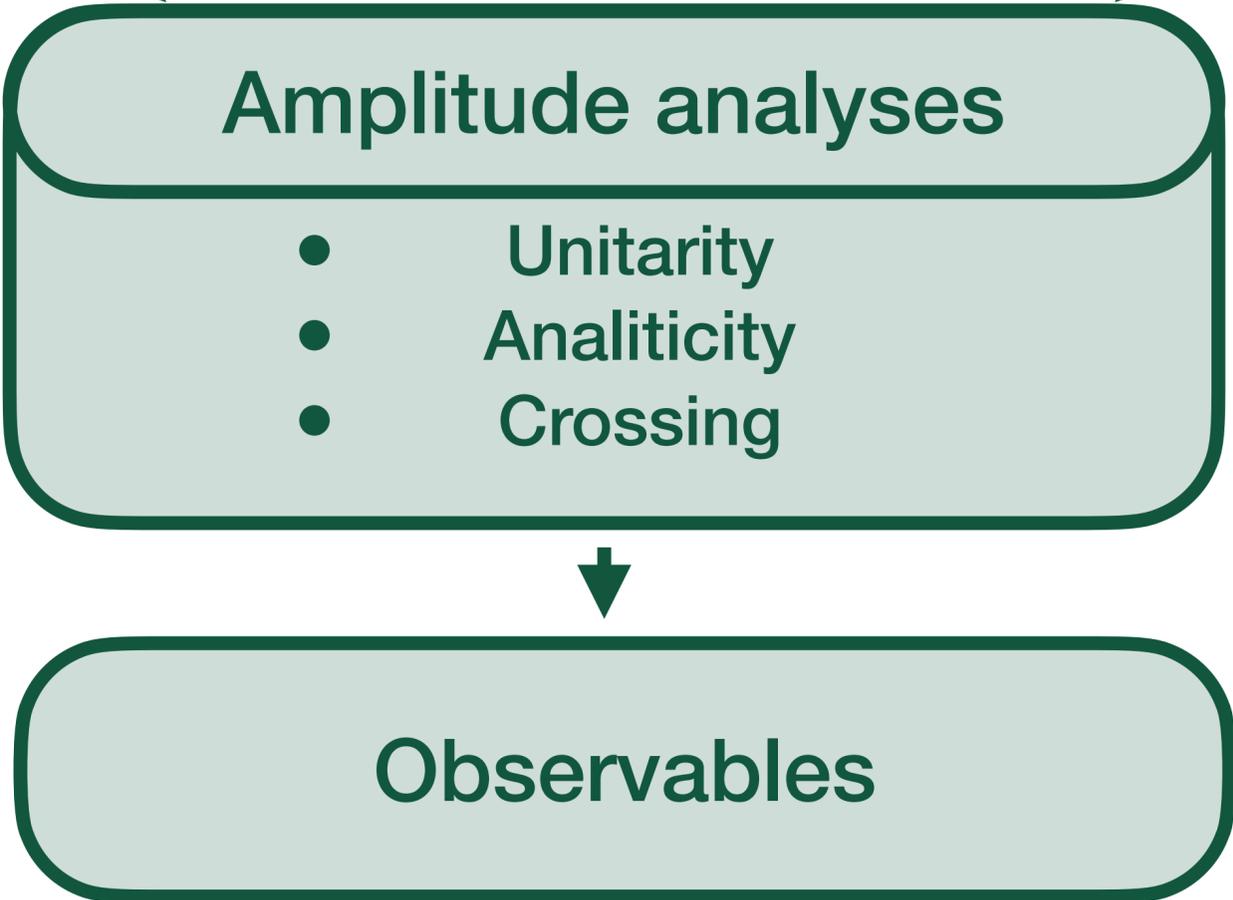
had spec



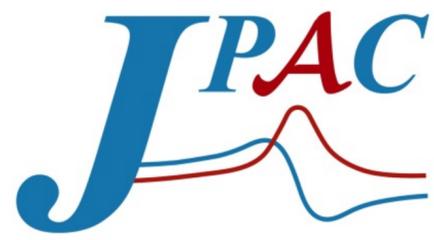
$m_\pi = 392$ MeV
 $24^3 \times 128$
isoscalar l_s
isovector

S-matrix principles

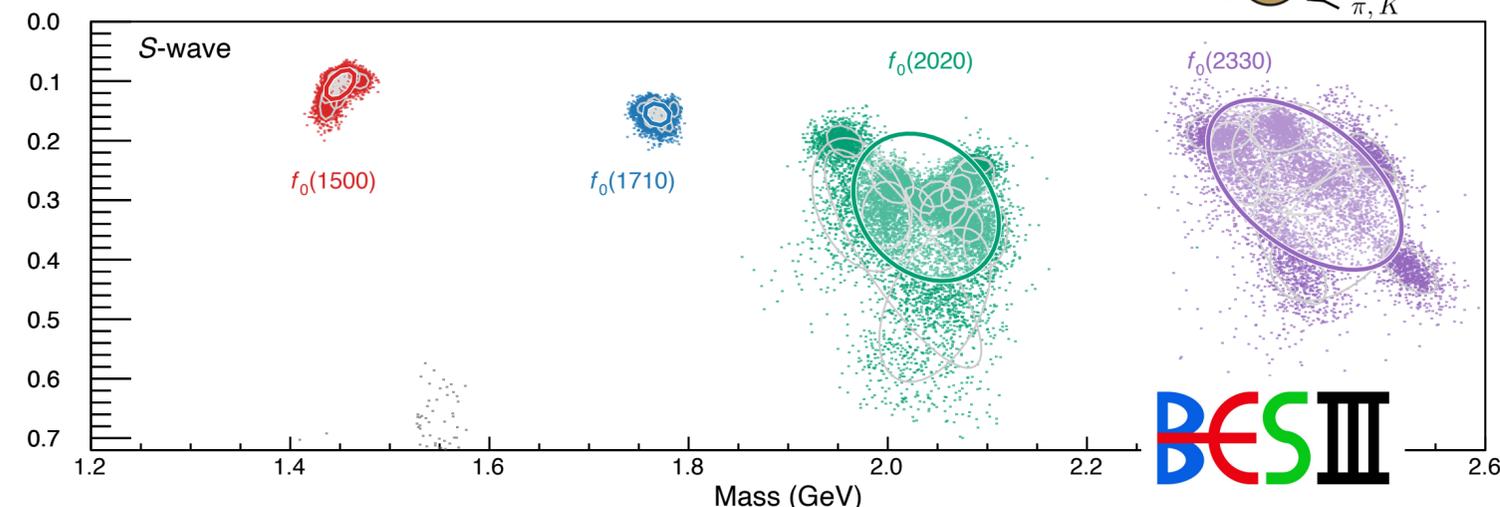
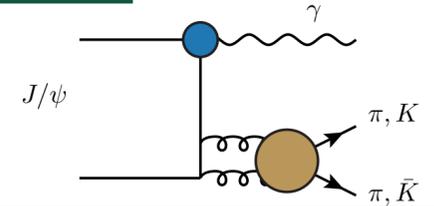
General QFT,
not only QCD



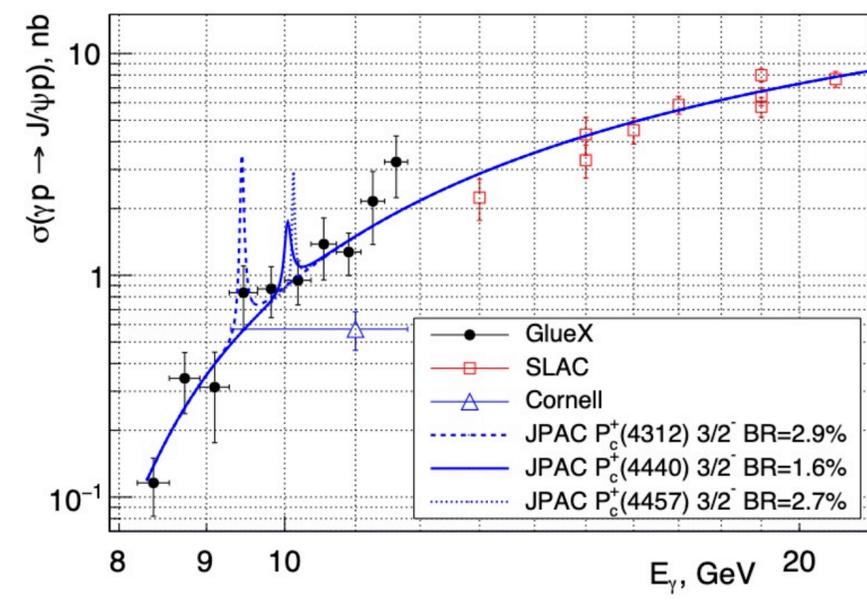
Accomplishments: Exp+ Theory



Glueball searches



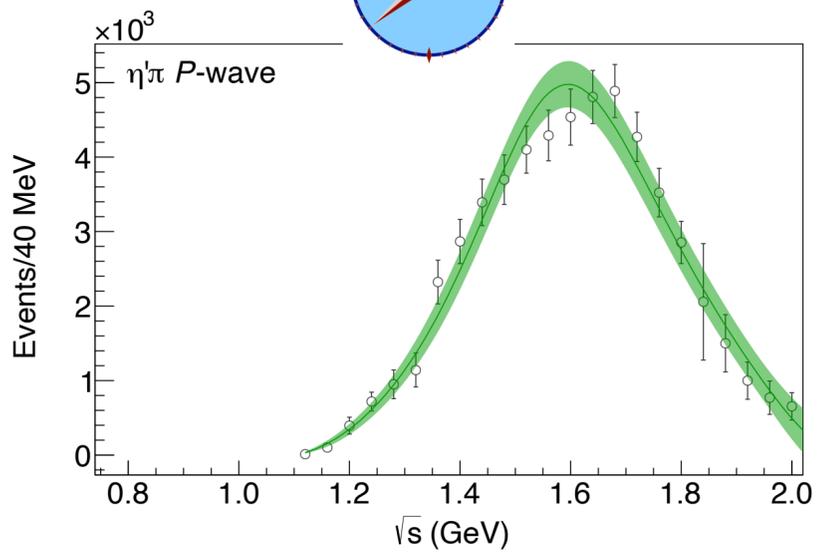
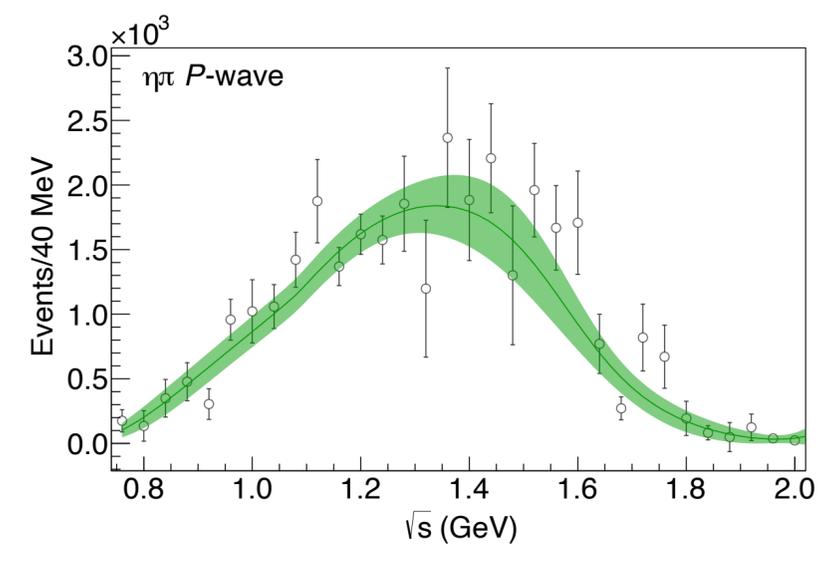
Finding the highest glueball component



Pentaquarks at JLab?

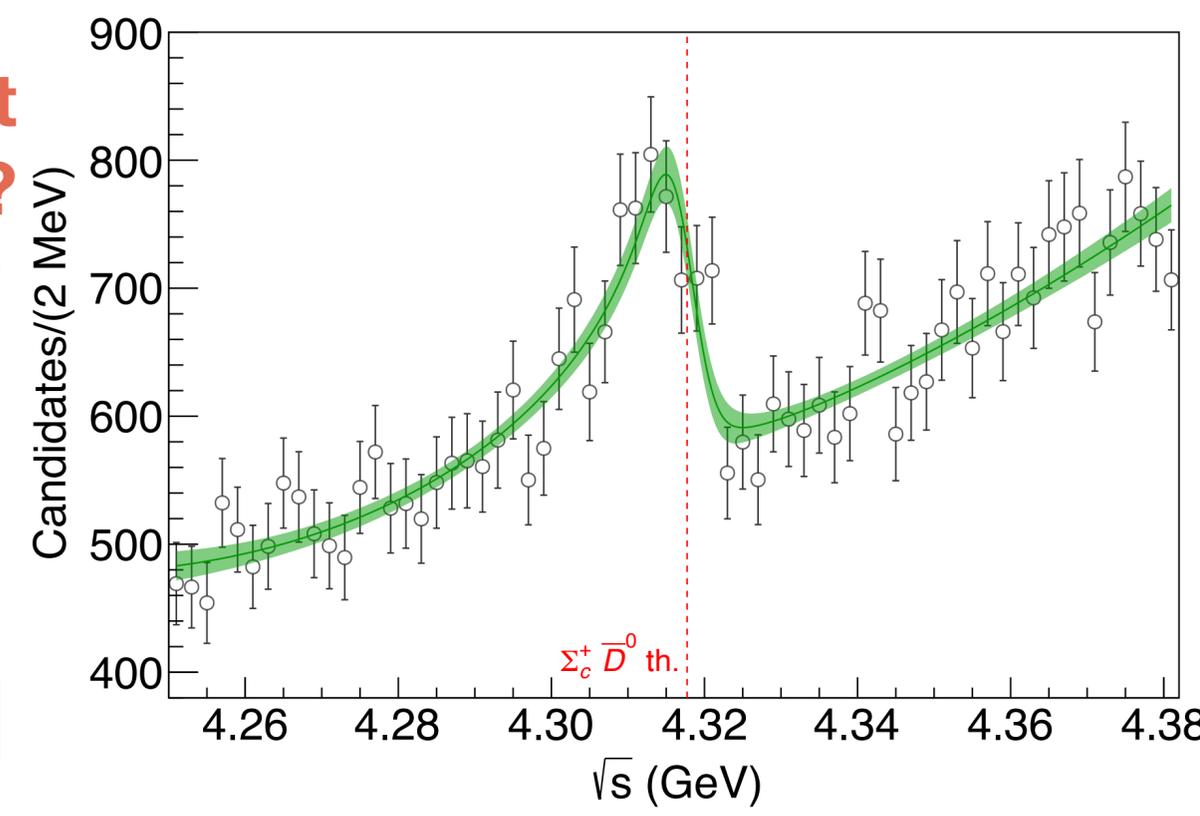


Hybrid meson(s)

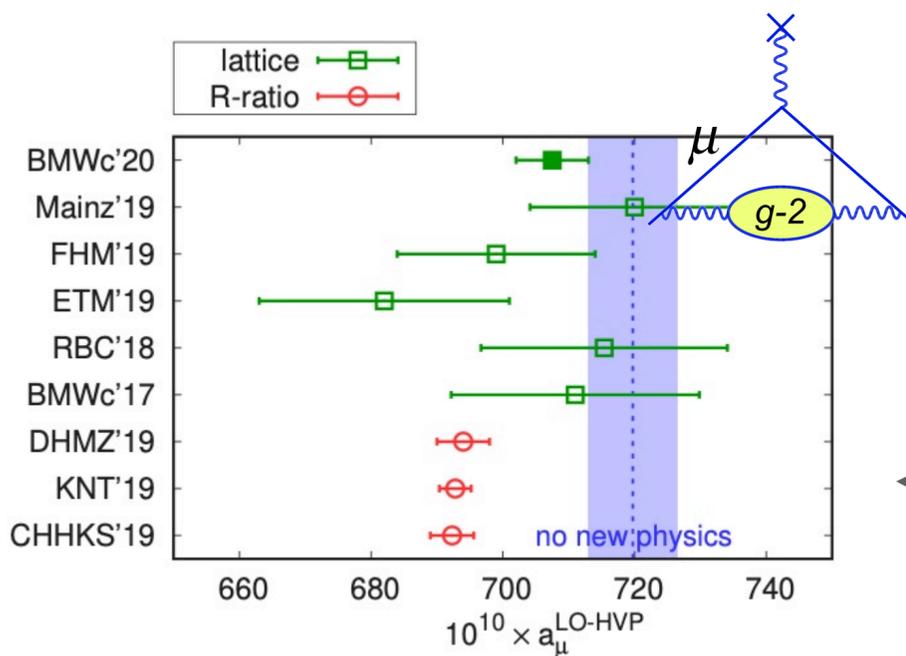
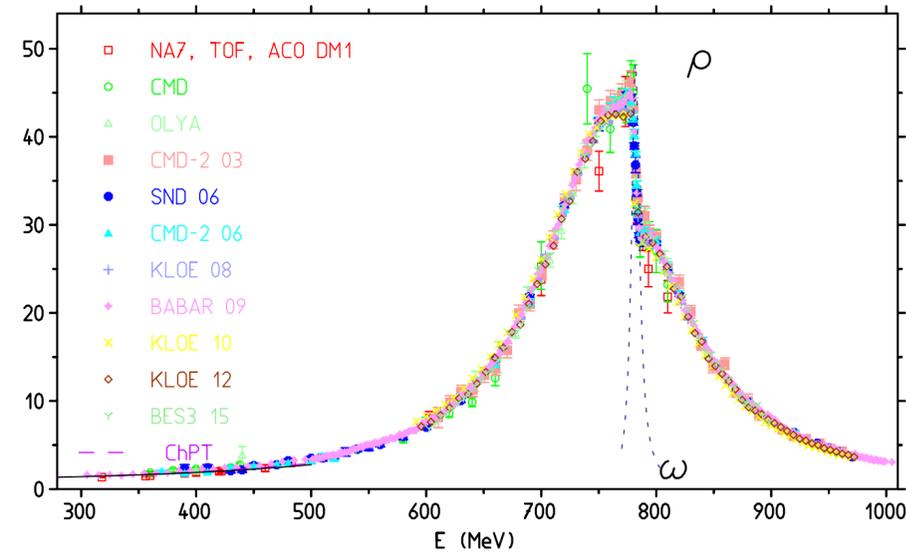
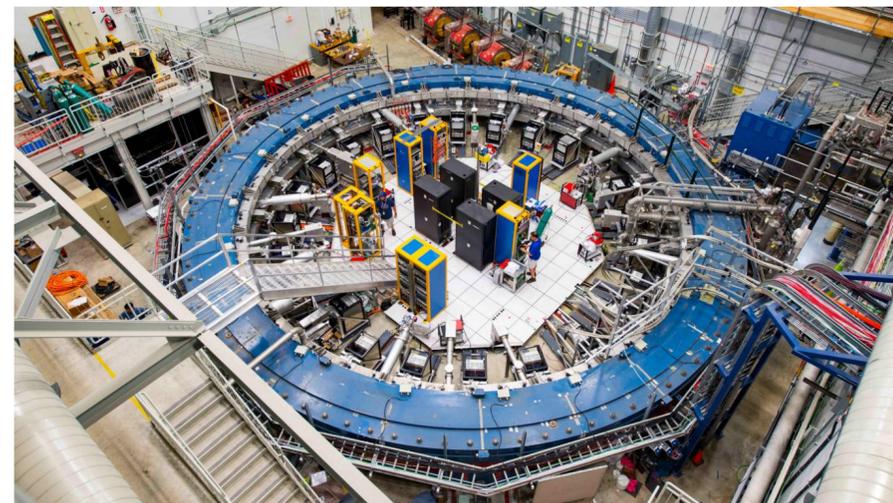


2 vs 1 hybrid; discussed for 20+ years

Pentaquarks at LHCb? Compositeness



Physics beyond what's known?



Theoretical+data driven predictions



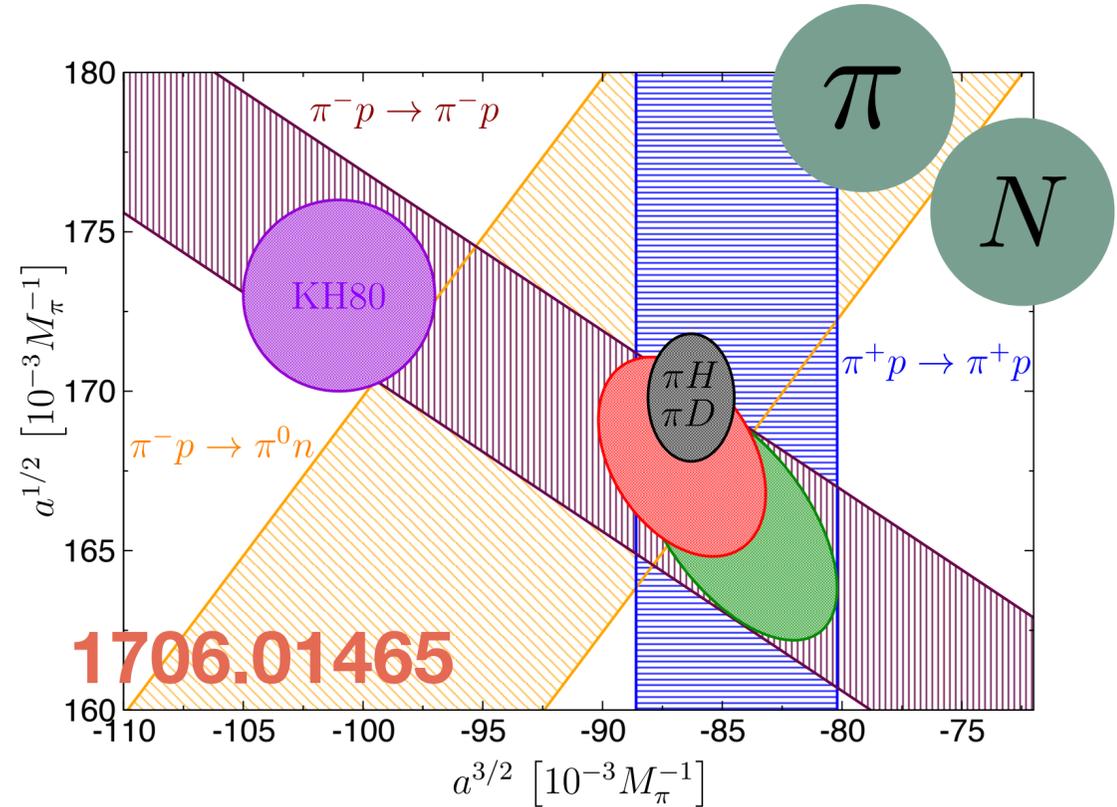
$$(g - 2)_\mu$$



Dark matter search?

Dispersive analyses

Elaborated Amplitude analyses produce (very) successful results

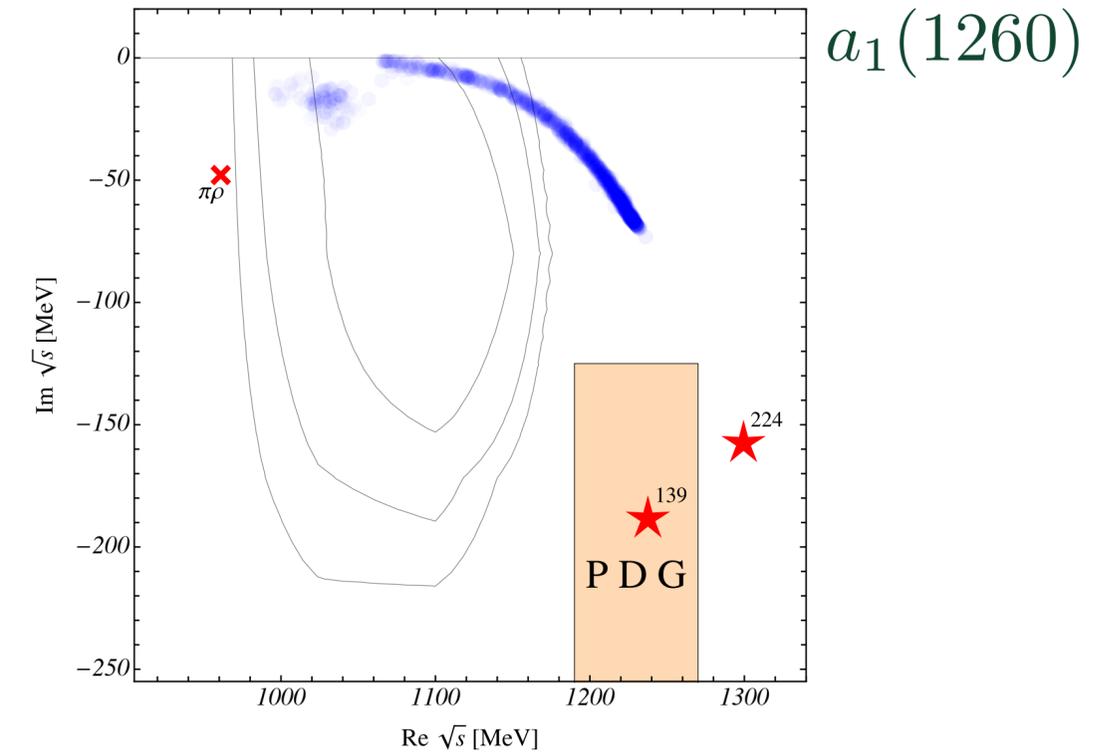
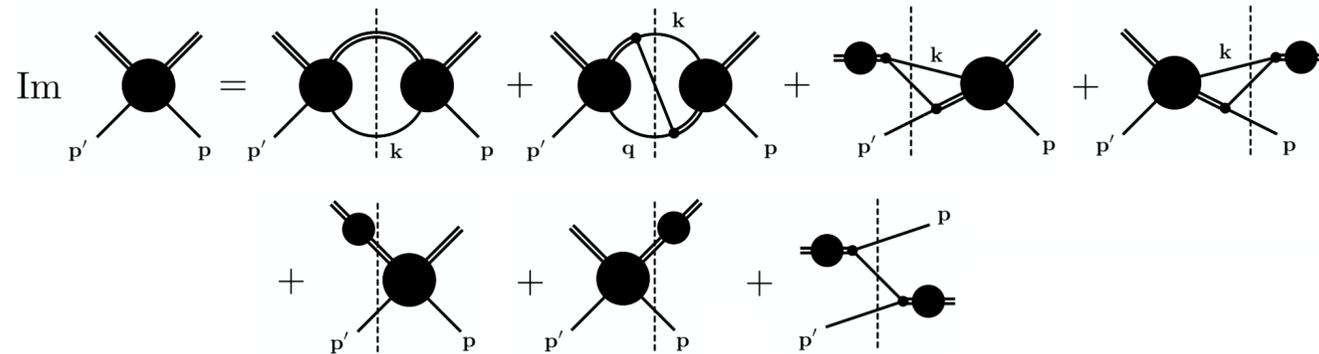


Support Experiments



And others...

Particles decaying to 3-body

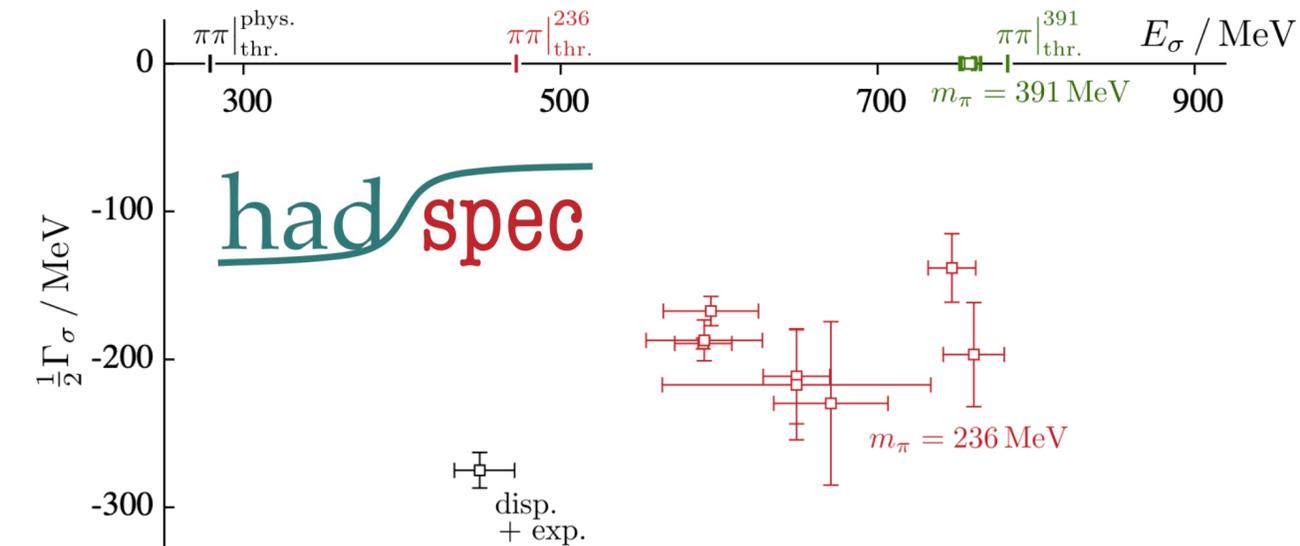


Extending dispersive formalisms

To challenging sectors

Amplitude analyses on lattice QCD

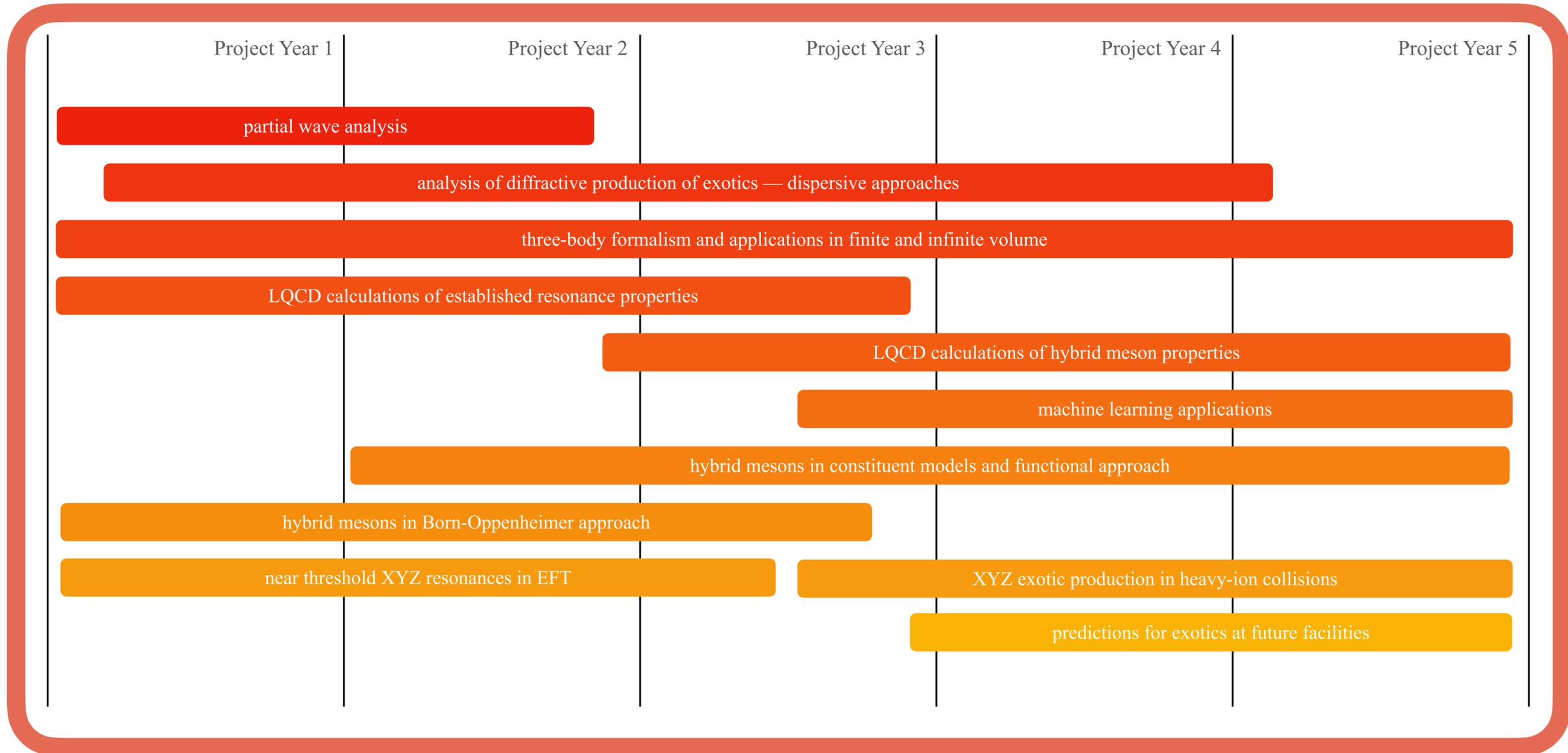
Calculation of the levels on the lattice is “superb”, amplitudes not so much



The ExoHad Topical Collaboration



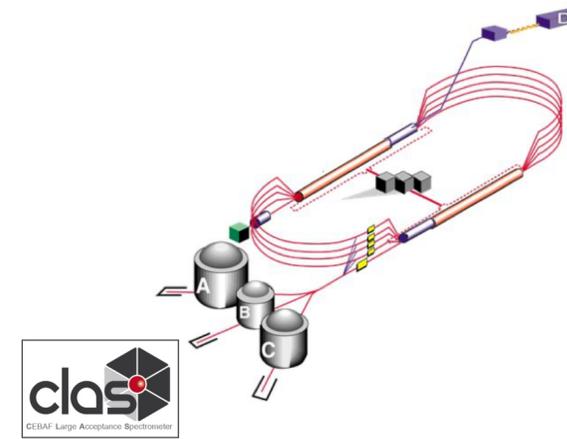
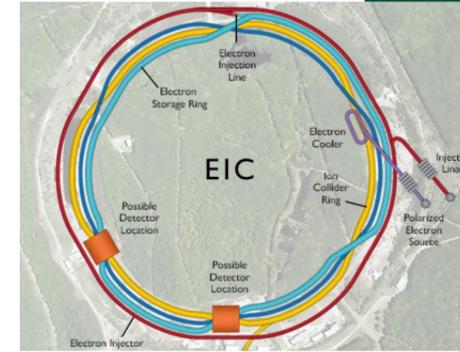
Understanding exotics



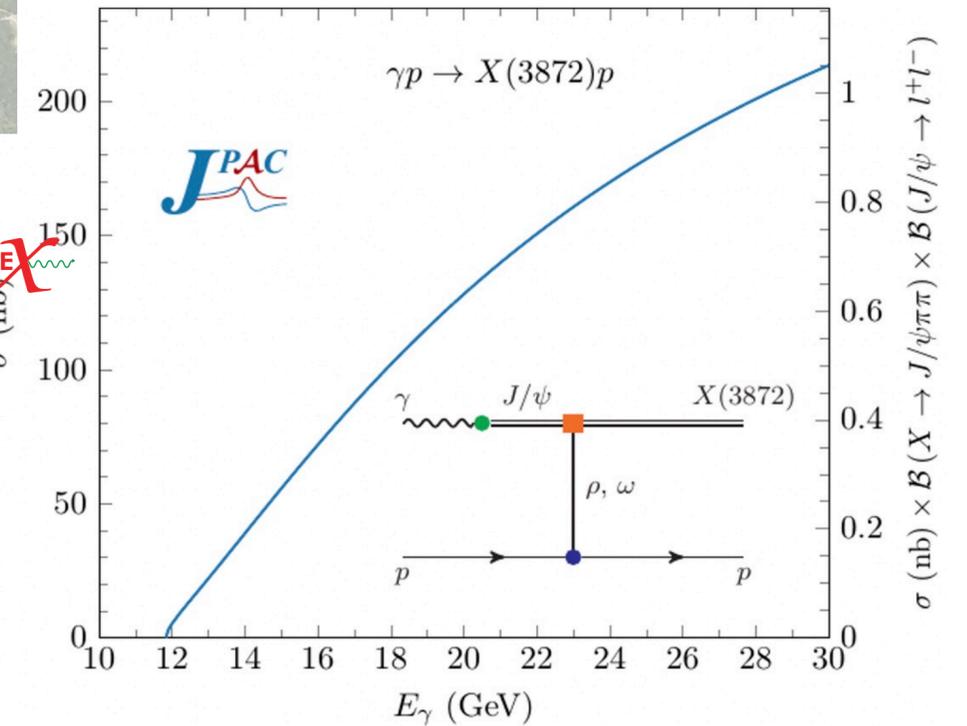
Supporting new Experimental Programs

XYZ at JLab/EIC And others...

Enough phase space/luminosity



GLUEX

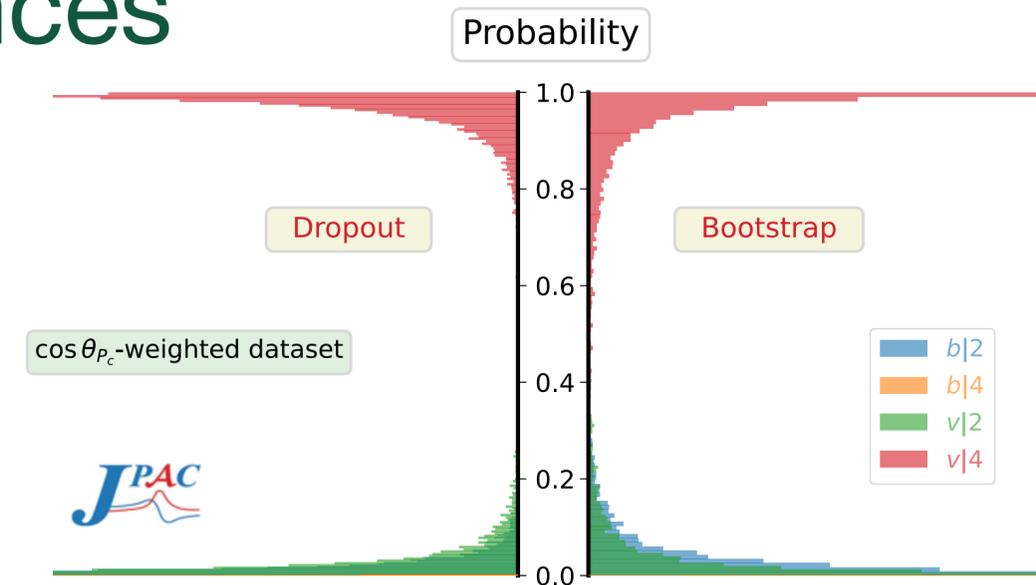


New tools for extracting resonances

Making “pole hunting” robust+easy

ML for exotics

Automating unbiased tools



Summary / Outlook

Exciting time for spectroscopy!!

Experiment

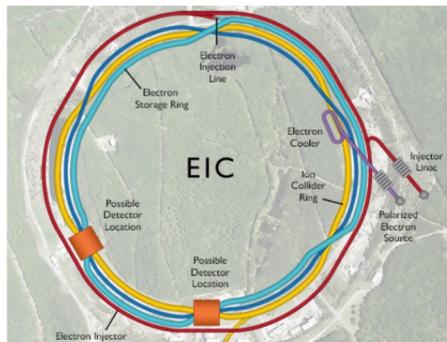


Exotics



Multi-body

Various productions



Lattice QCD



And others...

Photo-production

Current insertions for form factors

Multi-body

Amplitude analyses