Light Meson Spectroscopy at Phase-One

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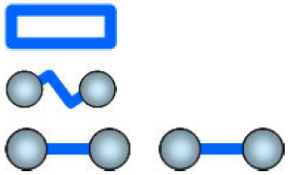
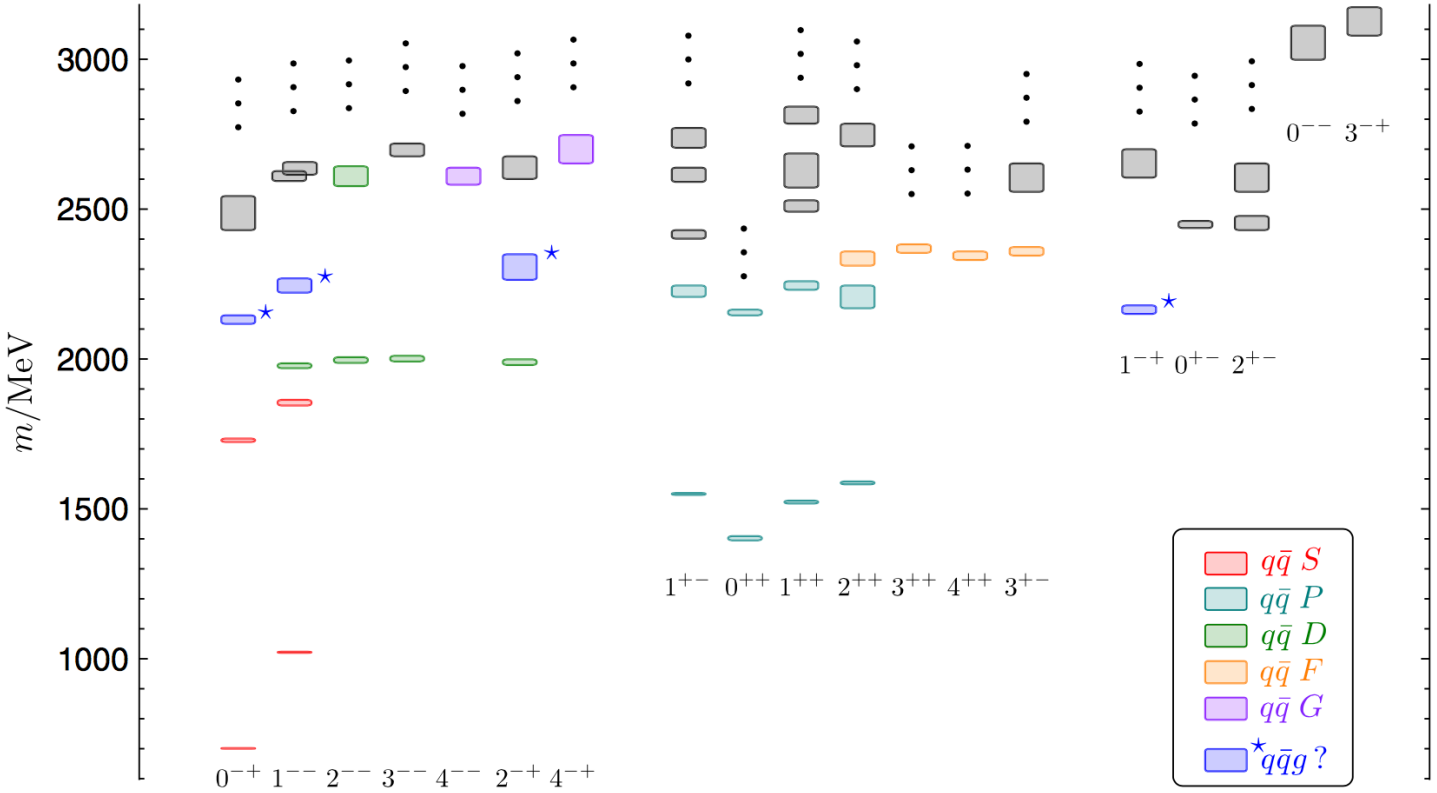
Light Meson Spectrum

Color-less $q\bar{q}$ states (q = u, d, s)
Multipletts of $q\bar{q}$ mesons with same J^{PC}

Additional color-less states:

- Glueballs: gg, ggg
- Hybrids: $q\bar{q}g$
- Tetraquarks: $(q\bar{q})(q\bar{q})$





J. J. Dudek, Phys. Rev. D84 (2011) 074023

Light Mesons in $\bar{p}p$ Annihilation at PANDA

- Antiproton-proton annihilation
  - huge cross sections for light meson production: 100 nb … 10 µb
  - gluon rich processes → production of glueballs and hybrids

- Access in formation to
  - neutral resonances with m > 2.25 GeV/c^2 and
  - non-exotic quantum numbers

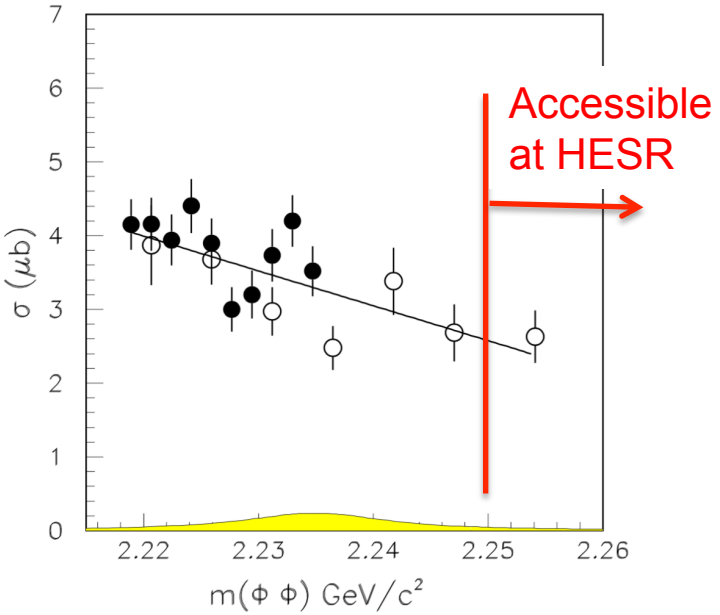
- Access in production to all resonances with
  - at least one recoil meson and
  - variable center-of-mass energy (→ tunable phasespace)

- Many broad and overlapping states
  - requires (often) partial wave analysis techniques to identify resonances

Search for glueballs in ΦΦ

- One channel related to light meson spectroscopy $\bar{p}p \rightarrow \Phi\Phi$ [K. Goetzen]
- Study of narrow $f_J(2230)$ previously reported by MARK III and BES II
  - outdated, since this state is excluded by Babar and BES III with superior statistics
  - not accessible in formation at HESR
- Still to do: Scan above 2.25 GeV
  - Jetset (1998): cross section >100x larger than expected from OZI rule → gluonic component?
  - broad $f_2(2300)$ and $f_2(2330)$ glueball candidates
- Need an update on this topic

$\bar{p}p \rightarrow \Phi\Phi$ Cross Section



Jetset, Phys. Rev. D 57, 5370 (1998)

Glueball Studies

- Studies performed for the scrutiny report
  - focus on feasibility and performance for 6 different detector options
  - carried out in fast simulation

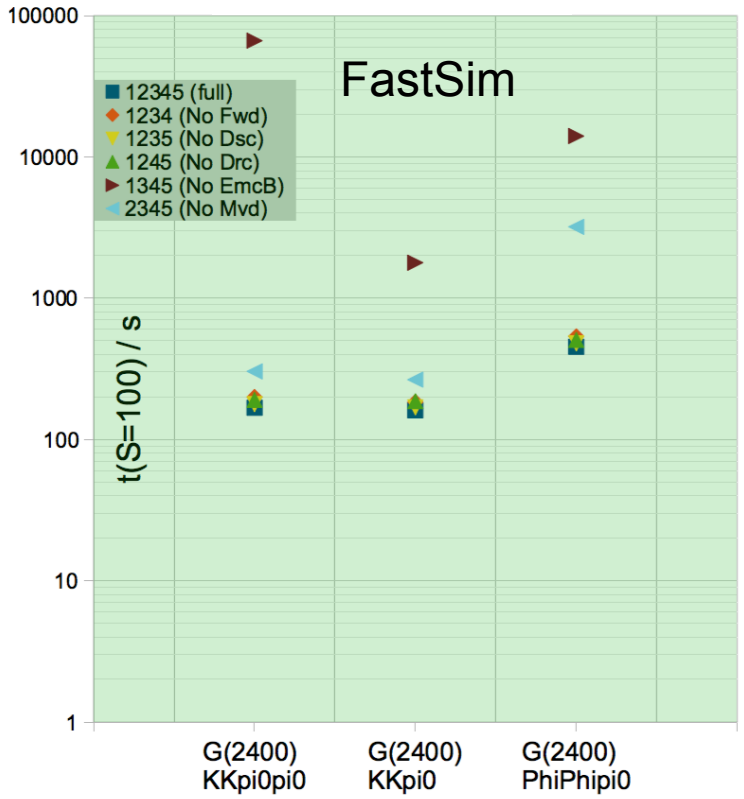
- Study of glueball production in $\bar{p}p \rightarrow K^+K^-\pi^0$, $K^+K^-\pi^0\pi^0$ and $\Phi\Phi\pi^0$
  - assuming cross section of 10 nb (including decays to final state)
  - background cross sections 50 to 80 mb

- "Light" glueball m = 2400 MeV/c^2 (could be 2^{++} or 0^{-+})
  - E_{CMS} = 2.57 GeV and 5.47 GeV
  - could be broad, study final states w/o intermediate resonances

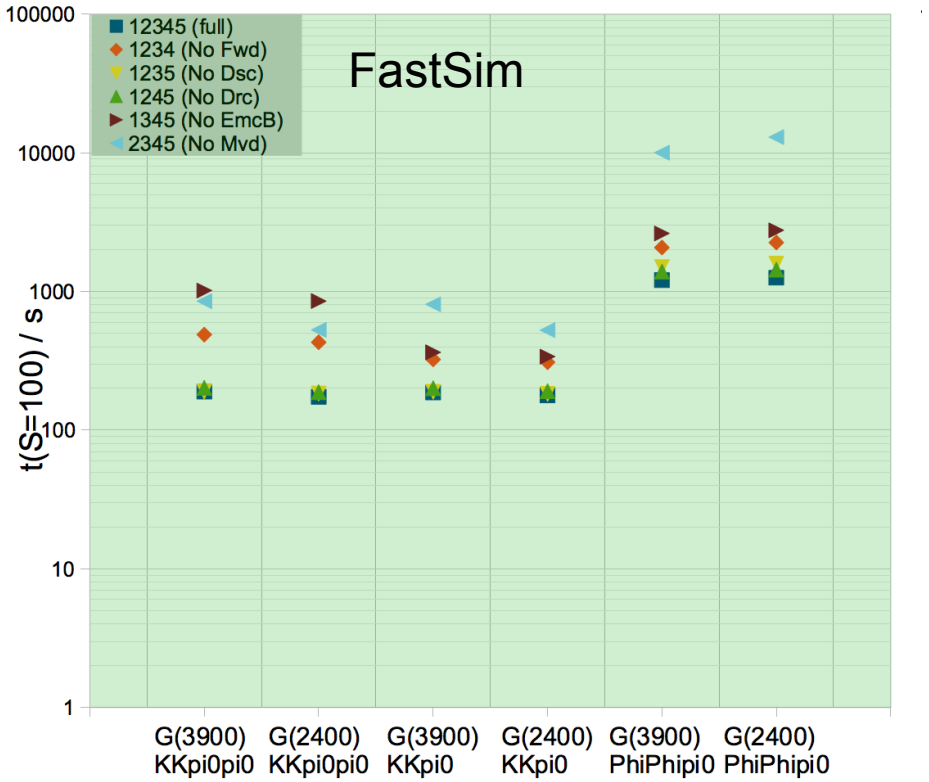
- "Heavy" glueball m = 3900 MeV/c^2
  - E_{CMS} = 5.47 GeV
  - could be narrow, assume Γ = 10 MeV
  - search for narrow signal in production

Glueball Studies

Light glueball
at E_{CMS} = 2.57 GeV



Light / heavy glueball
E_{CMS} = 5.47 GeV



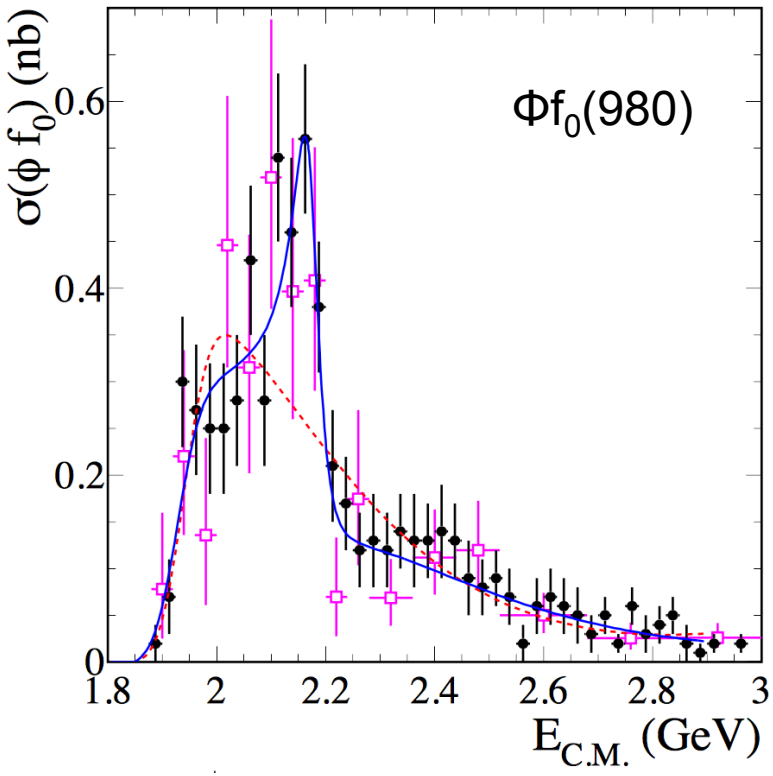
[Malte Albrecht]

MSV (10^{31} cm^{-2}s^{-1}): 800 … 8000 / d reconstructed signal events depending on channel

Y(2175)

- Y(2175)→$\Phi f_0(980)$ observed in ISR events $e^+e^- \rightarrow \gamma_{ISR}K^+K^-\pi^+\pi^-$
  - m ~ 2175 MeV/c^2; Γ~ 60 MeV
- Confirmed by BES III in J/ψ→Y(2175)η [2014]
- Similar: Y(4260) →J/ψ $f_0(980)$ also observed in ISR events
- Is Y(2175) a light analogue to the Y(4260)?

BaBar, Phys.Rev.D74, 091103 (2006)



If yes: Are there other analogies of the X, Y, Z states in the light meson sector?

Y(2175) Studies

- $\bar{p}p \to Y(2175)\pi\pi, Y(2175)\pi^0$ at E_{CMS}= 3 GeV
  - Y(2175) reconstructed in $\Phi\pi^+\pi^-$ and $\Phi\pi^0\pi^0$
  - assumed signal cross section: 100 nb
  - background cross section: 70 mb

Beam-time to record 1000 reconstructed events in the $\Phi\pi^+\pi^-\pi^0$ final state

	$f_{BR} = 5\,\%$	$f_{BR} = 10\,\%$	$f_{BR} = 30\,\%$
$L = 2{\cdot}10^{30}$	99.5 d	24.9 d	2.8 d
$L = 2{\cdot}10^{31}$	9.95 d	2.49 d	0.28 h
$L = 2{\cdot}10^{32}$	0.995 d	0.249 d	0.028 h

[Ch. Motzko]

FastSim,
full detector setup

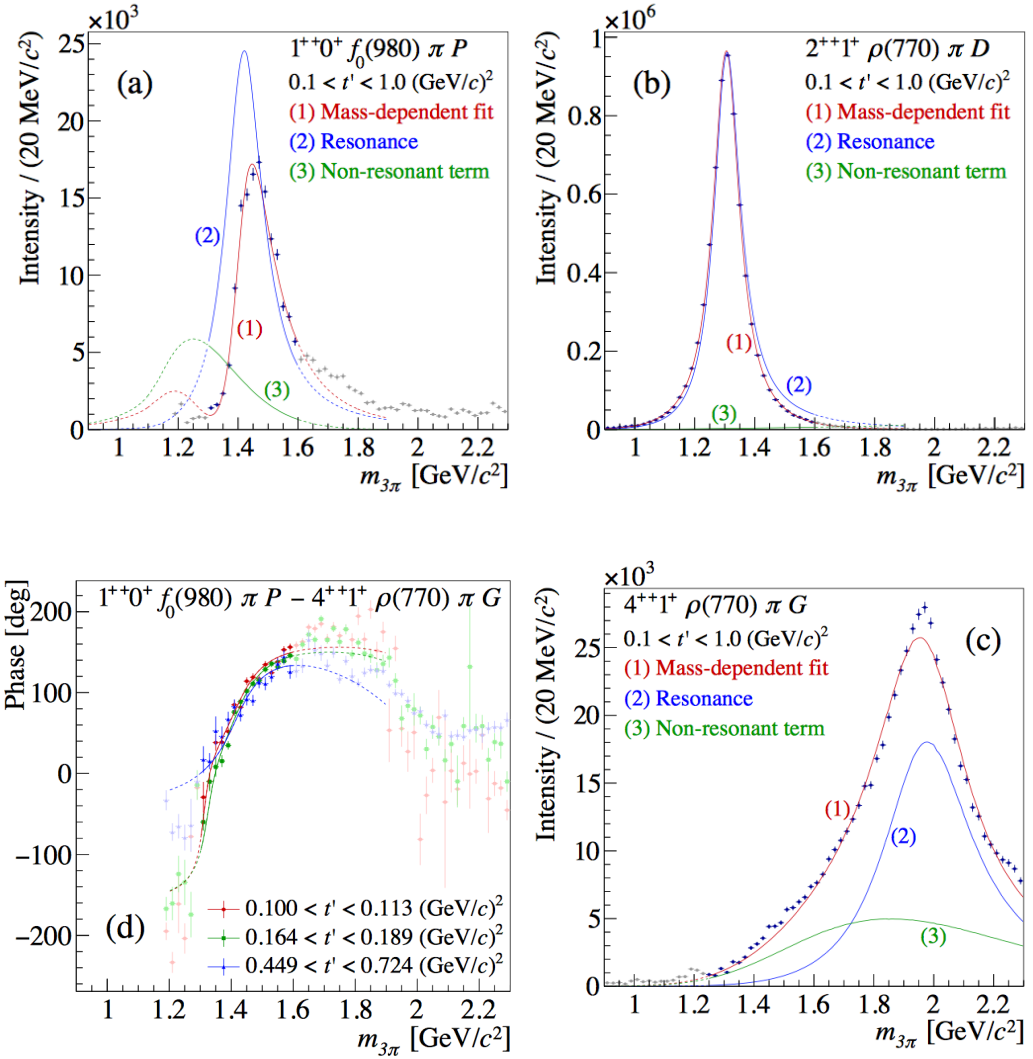
MSV (10^{31} cm^{-2}s^{-1}): 200 / d reconstructed signal events

Full simulation study: Efficiency too low after kinematic fit
(need to be redone w/ updated kinematic fitting package)

Recent Observation of $a_1(1420)$ at Compass

- Compass: Observation of a new axial-vector meson in diffractive 3π dissociation (m~1414 MeV and Γ~153 MeV)
  - 46 x 10^6 events analyzed
  - 88 waves fitted
- Iso-spin partner of $f_1(1420)$?
- $a_1(1420)$ and $f_1(1420)$ could be KK̄π molecules
- $f_1(1420)$ observed in $\bar{p}p \rightarrow K^0K^-\pi^+\pi^+\pi^-$

PANDA (MSV): 800 M / d produced 4π events



Compass, Phys. Rev. Lett. 115, 082001 (2015)

Two Years Early Physics Proposal

- Scrutiny Group merged proposals made by the various PWGs to a two year early physics proposal

Light meson spectroscopy:

- 30 days at 1.64 GeV/c
  - spectroscopy for states below 2.3 GeV/c^2
  - unprecedented data samples
  - can address $a_1(1420)$
- 7 days at 3.75 GeV/c
  - investigate Y(2175) and ΦΦ resonances

Plans

- Full simulation studies
  - Y(2175) → Φππ in $\bar{p}p$ → Y(2175)ππ, Y(2175)π^0
  - light glueball G→ΦΦ, K$\bar{K}$, K$\bar{K}$π in $\bar{p}p$ → Gπ^0, Gη, Gππ
  - energy scan $\bar{p}p$ → ΦΦ
  - a_1(1420) → 3π in $\bar{p}p$ → 4π, 5π

increasing complexity

https://panda-wiki.gsi.de/foswiki/bin/view/PhysicsCmt/PhysicsAnalysisActivities

- Include realistic backgrounds

- Address feasibility of partial wave analyses

Summary

- Light meson spectroscopy at PANDA
  - large production cross sections
  - gluon-rich processes (glueballs, hybrids)

- Feasibility studies
  - full simulation with realistic background estimations and
  - addressing partial wave analyses
  - prioritized list of channels

- Limited manpower
  - like in Charmonium / Charmonium-exotics PWGs
  - combine efforts as much as possible (e.g. data production, PWA)