

# Light Quark Mesons Physics Working Group

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# The Light Quark Mesons PWG

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- New structure since early 2014, three PWGs:
  - Charmonium PWG
  - Charmonium Exotics PWG
  - Light Quark Mesons [LQM] PWG (no charm, no baryons)
- Large overlap of interests and activities of the three groups
  - regular, joint meetings (Wed., 10:30 am)
- Manpower situation
  - Participation in the joint meetings is ranging between 5 and 10 people
  - Direct and better measure for LQM
    - 3 analysts involved during the scrutiny process in 2014
    - 1 commitment to pursue one study using full simulation in future

# Involved People and Institutes




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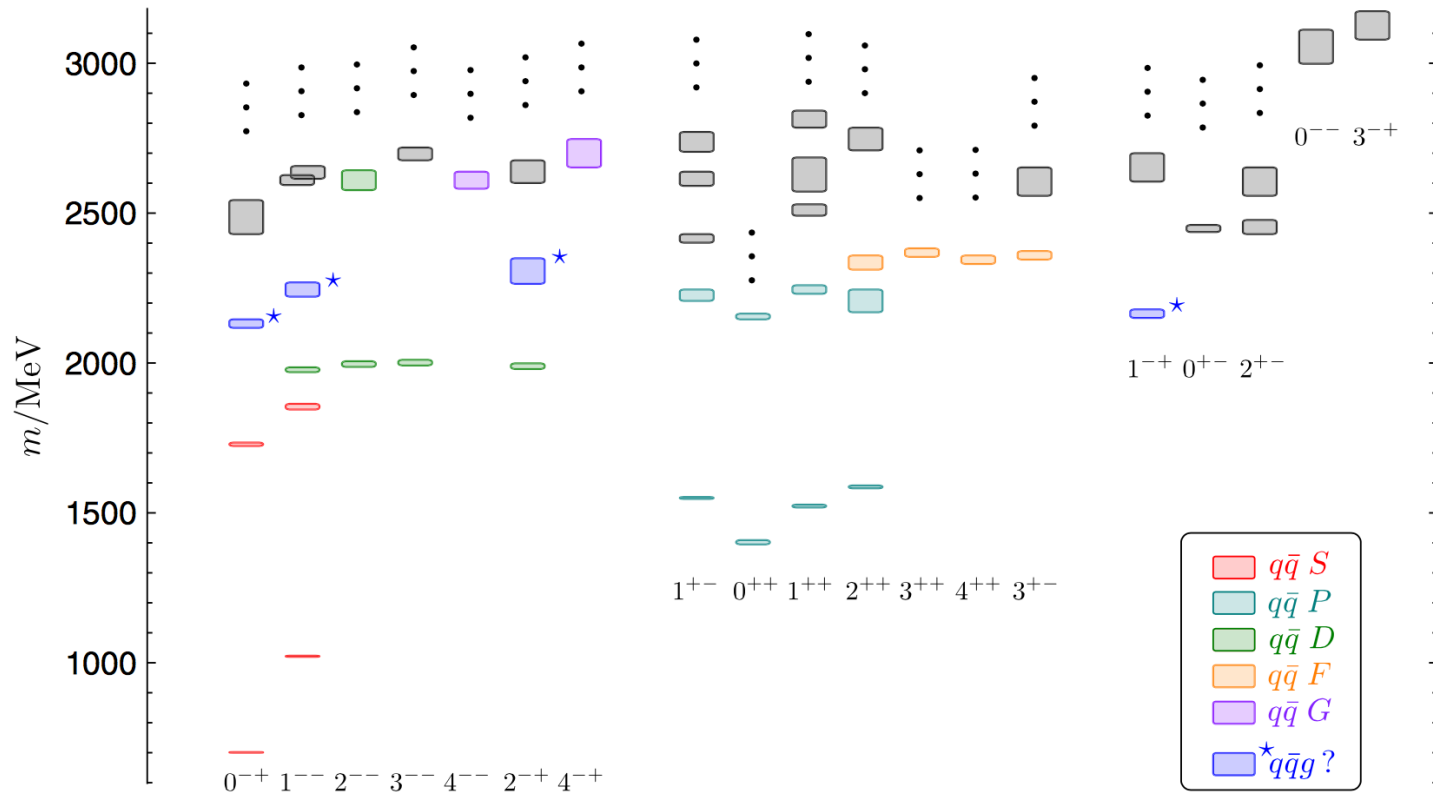
- Univ. Bochum
  - M. Albrecht, M. Pelizäus, T. Schröder
  
- HIM / GSI
  - K. Götzen, F. Nerling
  
- Univ. Mainz / HIM
  - Ch. Motzko

# Light Meson Spectrum

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

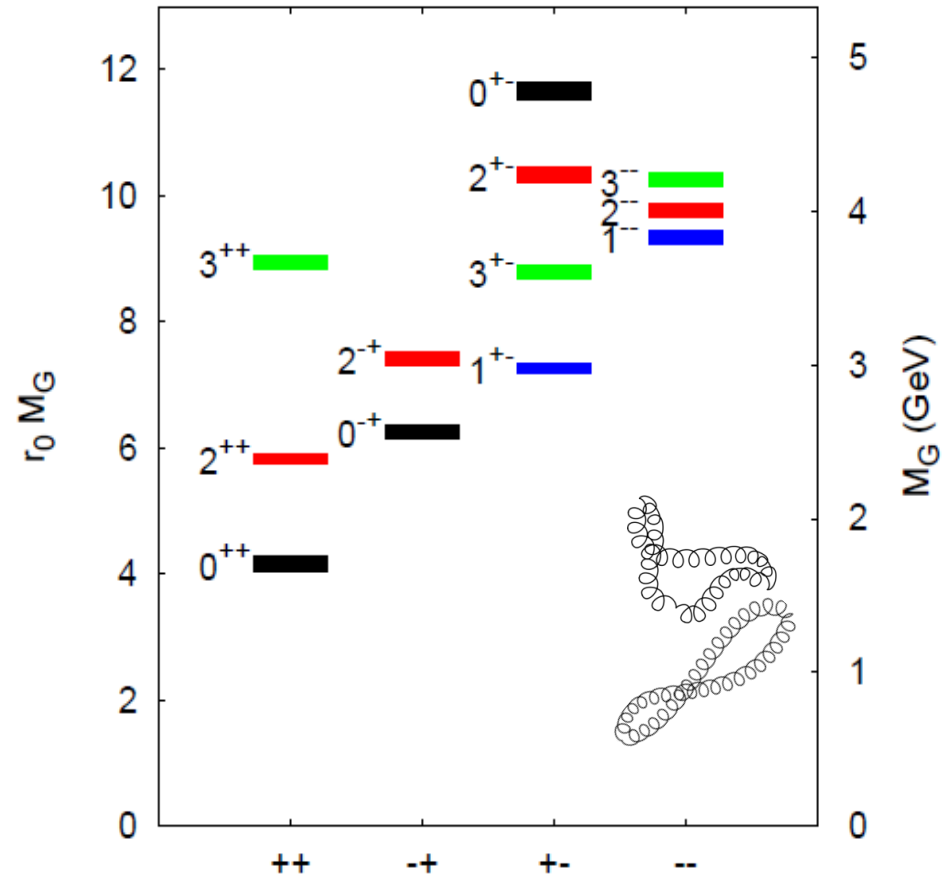
Additional color-less states:

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



# Glueballs

## Glueball Spectrum (Lattice QCD)



C. Morningstar, M. Peardon, Phys. Rev. D60, 34509 (1999)

C. Morningstar, M. Peardon, Phys. Rev. D56, 4043 (1997)

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

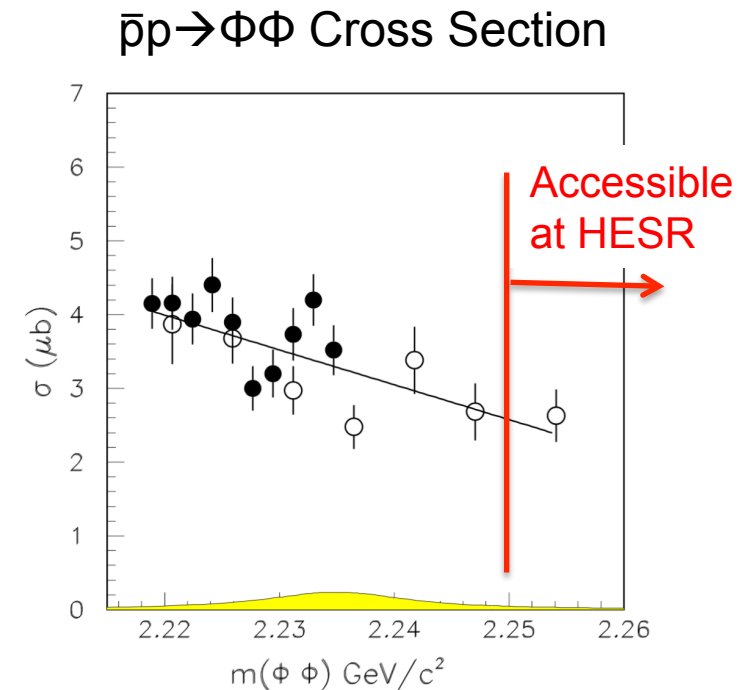
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- Antiproton-proton annihilation
  - huge cross sections for light meson production: 100 nb ... 10  $\mu$ b
  - gluon rich processes  $\rightarrow$  production of glueballs and hybrids
- Access in formation to
  - neutral resonances with  $m > 2.25 \text{ GeV}/c^2$  and
  - non-exotic quantum numbers
- Access in production to all resonances with
  - at least one recoil meson and
  - variable center-of-mass energy ( $\rightarrow$  tunable phasespace)
- Many broad and overlapping states
  - requires (often) partial wave analysis techniques to identify resonances

# Recent Achievements

# Physics Performance Report (2009)

- 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  $\rightarrow$  gluonic component?
  - broad  $f_2(2300)$  and  $f_2(2330)$  glueball candidates
- Need an update on this topic



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



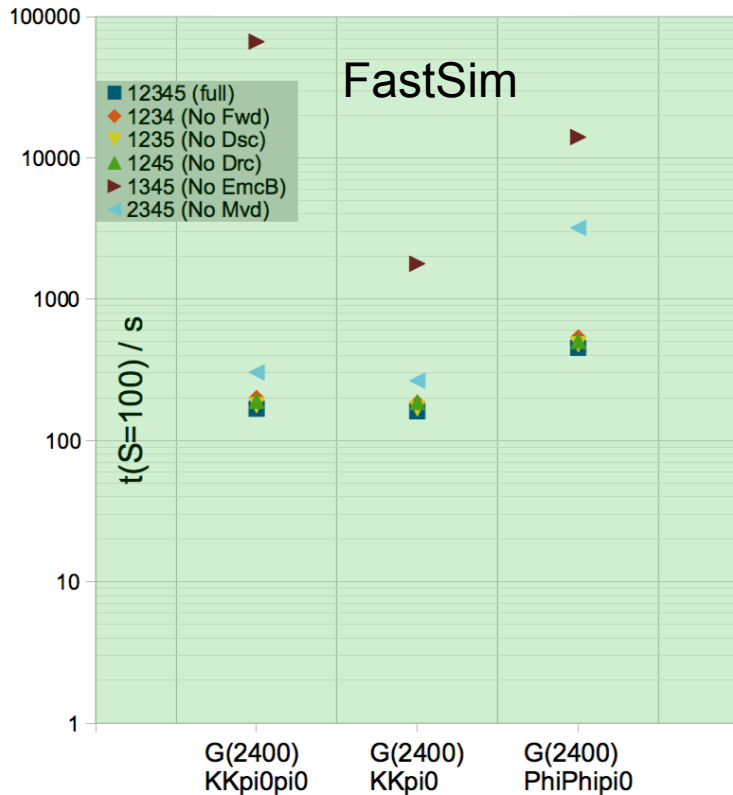
# Glueball Studies

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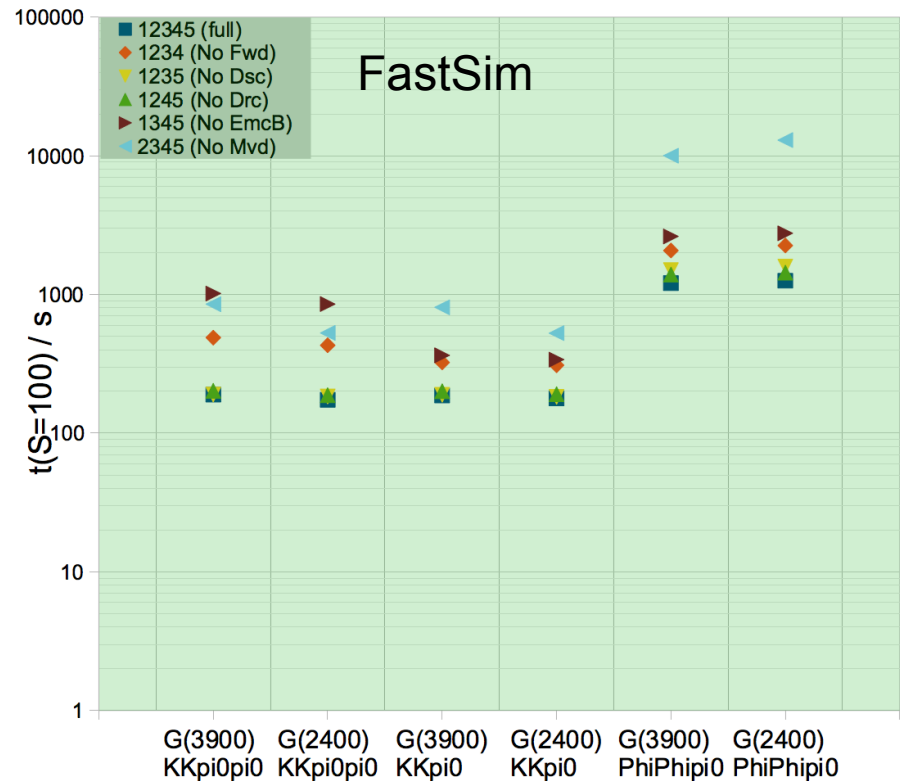
- Studies performed for the scrutiny report
  - focus on feasibility and performance for 6 different detector options
  - carried out in fast simulation
- Study of glueball production in  $\bar{p}p \rightarrow K^+K^-\pi^0$ ,  $K^+K^-\pi^0\pi^0$  and  $\Phi\Phi\pi^0$ 
  - assuming cross section of 10 nb (including decays to final state)
  - background cross sections 50 to 80 mb
- “Light” glueball  $m = 2400 \text{ MeV}/c^2$  (could be  $2^{++}$  or  $0^{-+}$ )
  - $E_{\text{CMS}} = 2.57 \text{ GeV}$  and  $5.47 \text{ GeV}$
  - could be broad, study final states w/o intermediate resonances
- “Heavy” glueball  $m = 3900 \text{ MeV}/c^2$ 
  - $E_{\text{CMS}} = 5.47 \text{ GeV}$
  - could be narrow, assume  $\Gamma = 10 \text{ MeV}$
  - search for narrow signal in production

# Glueball Studies

Light glueball  
at  $E_{\text{CMS}} = 2.57 \text{ GeV}$



Light / heavy glueball  
 $E_{\text{CMS}} = 5.47 \text{ GeV}$



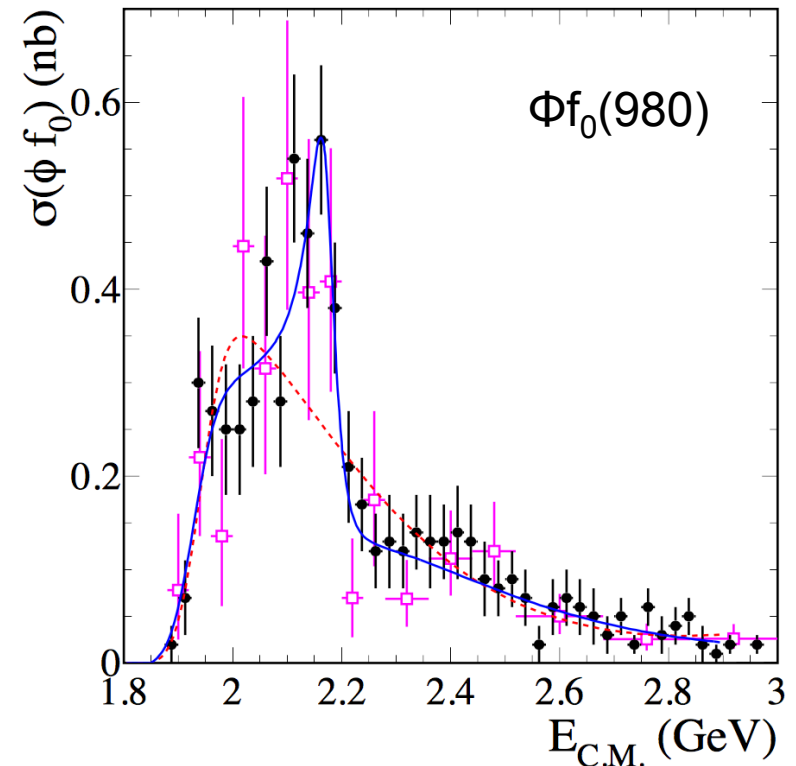
[Malte Albrecht]

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

# Y(2175)

- $Y(2175) \rightarrow \Phi f_0(980)$  observed in ISR events  $e^+e^- \rightarrow Y_{\text{ISR}} K^+ K^- \pi^+ \pi^-$ 
  - $m \sim 2175 \text{ MeV}/c^2$ ;  $\Gamma \sim 60 \text{ MeV}$
- Confirmed by BES III in  $J/\psi \rightarrow Y(2175) \eta$  [2014]
- Similar:  $Y(4260) \rightarrow J/\psi f_0(980)$  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

- $\bar{p}p \rightarrow Y(2175)\pi\pi, Y(2175)\pi^0$  at  $E_{\text{CMS}} = 3 \text{ GeV}$ 
  - 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]

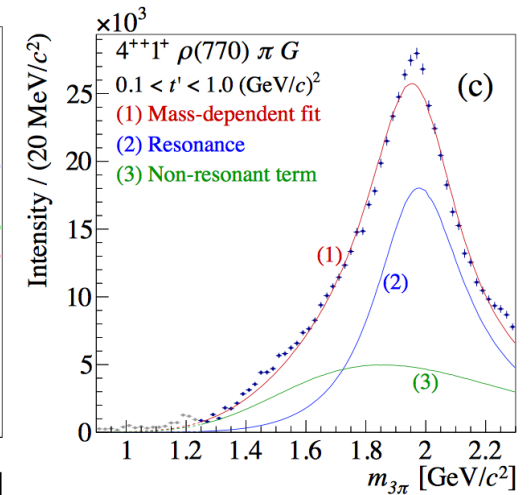
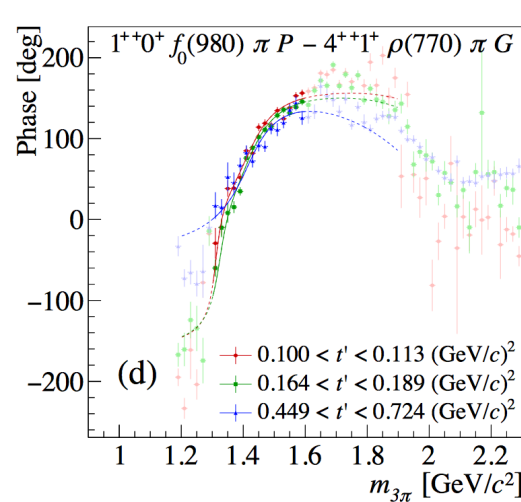
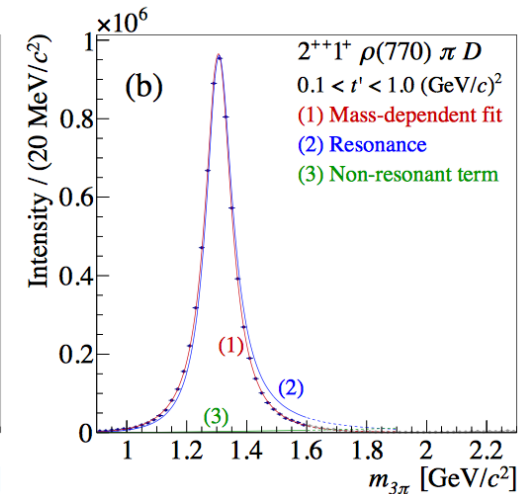
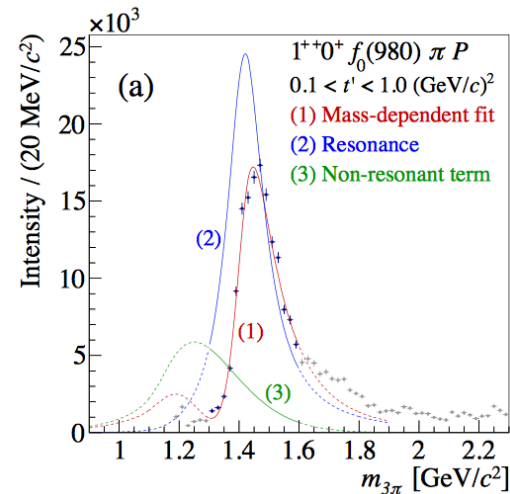
FastSim,  
full detector setup

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

# Future Plans

# Recent Observation of $a_1(1420)$ at Compass

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



PANDA (MSV): 800 M / d  
 produced  $4\pi$  events

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

# Two Years Early Physics Proposal

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- Scutiny 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<sup>2</sup>
  - unprecedented data samples
  - can address  $a_1(1420)$
- 7 days at 3.75 GeV/c
  - investigate  $Y(2175)$  and  $\Phi\Phi$  resonances

# Future Plans

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- Full simulation studies

- $Y(2175) \rightarrow \Phi\pi\pi$  in  $\bar{p}p \rightarrow Y(2175)\pi\pi, Y(2175)\pi^0$
- light glueball  $G \rightarrow \Phi\Phi, K\bar{K}, K\bar{K}\pi$  in  $\bar{p}p \rightarrow G\pi^0, G\eta, G\pi\pi$
- energy scan  $\bar{p}p \rightarrow \Phi\Phi$
- $a_1(1420) \rightarrow 3\pi$  in  $\bar{p}p \rightarrow 4\pi, 5\pi$



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

- Include realistic backgrounds
- Address feasibility of partial wave analyses



# Summary

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- Light meson spectroscopy at PANDA
  - large production cross sections
  - gluon-rich processes (glueballs, hybrids)
- Plans for feasibility studies
  - full simulation with realistic background estimations and
  - addressing partial wave analyses
  - prioritized list of channels available (more topics than people)
- Limited manpower
  - like in Charmonium / Charmonium-exotics PWGs
  - combine efforts as much as possible (e.g. data production, PWA)

→ New people are always welcome to participate!