Spectroscopy with Antiprotons

Bernhard Ketzer
Rheinische Friedrich-Wilhelms-Universität Bonn

Johannes Bernhard
CERN EN-EA

COMPASS LoI Mini-Workshop
CERN
20 June 2018
Charmonium Spectrum

Many new (narrow) states discovered in recent years

Assignment not clear

Some definitively not charmonium-like

Quark model:

- $SU(3)_{\text{flavor}}$:
  \[ q \otimes \bar{q}' = 3 \otimes \bar{3} = 8 \oplus 1 \]

- color singlets
  - Many new (narrow) states discovered in recent years
  - Assignment not clear
  - Some definitively not charmonium-like

[S. Olsen et al., Rev. Mod. Phys. 90, 015003 (2018)]
• Unphysical pion mass: 400 MeV
• No decays
• May still be used as guidance, e.g. pattern for Hybrids

[Hadron Spectrum Coll., L. Liu et al., JHEP 07, 126 (2012)]
**Production Mechanisms**

**Diffraction**
- E852, VES, COMPASS
  - light mesons
  - exotic states: multi-quark, hybrids

**Antiproton annihilation**
- E760, E835, Crystal Barrel (PANDA)
  - charmed mesons, high-spin states
  - exotic states: multi-quark, hybrids, glueballs
  - production cross sections
Monte Carlo Simulations

1. $p\bar{p} \rightarrow \pi^- Z_c^+(4430)$, with $Z_c^+ \rightarrow \pi^+ J/\psi$,

2. $p\bar{p} \rightarrow \pi^0 Z_c^0(4430)$, with $Z_c^0 \rightarrow \pi^0 J/\psi$,

3. $p\bar{p} \rightarrow \eta h(4300)$, with $h \rightarrow \pi^0 \pi^0 J/\psi$ (fictitious $c\bar{c}$ hybrid at 4.3 GeV) and $\eta \rightarrow \gamma\gamma$,

- beam momentum: 12 GeV/c
- $J/\psi \rightarrow \mu^+\mu^-$
Monte Carlo Simulations

1. $p\bar{p} \rightarrow \pi^- Z_c^+(4430)$, with $Z_c^+ \rightarrow \pi^+ J/\psi$,

2. $p\bar{p} \rightarrow \pi^0 Z_c^0(4430)$, with $Z_c^0 \rightarrow \pi^0 J/\psi$,

3. $p\bar{p} \rightarrow \eta h(4300)$, with $h \rightarrow \pi^0 \pi^0 J/\psi$ (fictitious $c\bar{c}$ hybrid at 4.3 GeV) and $\eta \rightarrow \gamma \gamma$
Setup

- Target spectrometer a la E835, WASA
  - charged-particle tracking
  - identification of particles
  - electromagnetic calorimeter
- Forward spectrometer a la COMPASS
  - ECAL0
- Trigger:
  - dimuons
  - dielectrons
Antiproton Beams

• Production of Antiprotons not an issue
  – Atherton parameterisation for 20 GeV/c:
    \[ \frac{0.41 \text{ pbar}}{\text{int.proton}} \div \frac{\text{GeV}}{\text{steradian}} \]
  – Solid angle \( \pi \cdot 10^{-5} \)
  – Assume target efficiency of 40% and \( 10^{13} \) ppp on target
  – Assume 2 GeV/c momentum bite
  – Particle flux: \( 0.4 \cdot 10^{13} \cdot 0.41 \cdot \pi \cdot 10^{-5} \cdot 2 \) pbar = \( 10^8 \) pbar per pulse
    (half for 12 GeV/c beam)

• Note: \( e^- \) needs to be well filtered by including a lead degrader
• For RP limit of \( 10^8 \) on total flux, maximum antiproton flux limited mainly by purity, hence upper limit of
  – \( 1.8 \cdot 10^7 \) pbar per pulse for 12 GeV/c
  – \( 1.1 \cdot 10^7 \) pbar per pulse for 20 GeV/c
Antiproton Beams

- M2 mainly optimised for muon beams (e.g. rather flat tunnel, scrapers)
- Expected transmission losses: Vacuum not complete, 80 m missing
- Initial cost estimate for vacuum pipes: 90-110 kCHF
- Replace Collimator 5 by XCHV (vacuum)
- Remove absorbers in Bend 4, install vacuum pipe
- Time for installation: Order of a few weeks

**pbar fraction at Compass (after 1.1 km transport)**

- $e^-$ unsuppressed
- $e^-$ 90% suppressed
- $e^-$ 99% suppressed
Antiproton Beams

- Further optimisation of beam PID: Either dedicated CEDAR with new optical system and radiator gas for low momenta (cost to be studied) or new threshold Cherenkov with large area photo detector (e.g. ThickGEM or LAPPD-like), study to be launched end of this year
- New optics, try improve parallelism at CEDARs and try to enlarge acceptance by changing frontend optics (e.g. DDFF-D to FDDFFD)
Thank you!
Monte Carlo for e\(^-\) production:

- Process \(\pi^0 = (\pi^+ + \pi^-)/2\), \(\pi^0 \rightarrow \gamma\gamma\)
- \(x = E_e/E_\gamma\) with \(f(x) = x^2 + (1-x)^2 + 2x(1-x)/3\)

Extrapolation from CERN West Area experience:

- e\(^-\) about 8% of beam at -120 GeV/c (\(\theta = 0\) mrad)

Possible reduction:

- Thin Pb sheet in strong focus (degrader)
- Drawback: might affect parallelism at CEDARs (Beam PID)