Remarks on the Antiproton Source and Possible Experiments

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The FNAL Antiproton Source is a unique and valuable resource

- The number of antiprotons accumulated per unit time is unmatched by any other existing or planned facility.
- Stochastic cooling (and the absence of synchrotron radiation) provides a very small beam energy spread.
- The beam energy can be precisely calculated using the measured revolution frequency and the orbit length calculated using beam position monitor measurements and the Accumulator lattice model.
- These features were exploited (most recently in 2000) by the charmonium experiments E760 and E835.

The E760/E835 Technique

- Charmonium states can be formed by complete antiproton-proton annihilation.
  - E760/E835 used a hydrogen “gas-jet” target in the Antiproton Accumulator at AP50.
- E760/E835 concentrated on final states including J/ψ —> e^+e^-
  - Electrons identified by Pb-glass and gas Cherenkov detectors
  - Photons measured by Pb-glass
  - Charged tracks measured (but no magnetic field)
  - Beam energy scanned in small steps; yield in specific final state measured as a function of beam energy.
    - World’s most precise measurements of charmonium masses and widths.

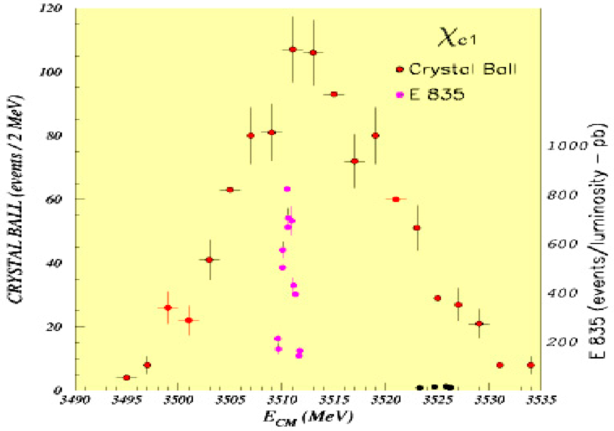
Taken from Bettoni PANDA talk

comparison e^+e^- versus $p\bar{p}$

e^+e^- interactions:
only 1^{--} states formed
other states populated in secondary decays
(moderate mass resolution)

production of $\chi_{1,2}$

$$e^+e^- \to \psi'$$
$$\hookrightarrow \gamma\chi_{1,2}$$
$$\hookrightarrow \gamma\gamma\, J/\psi$$
$$\hookrightarrow \gamma\gamma e^+e^-$$

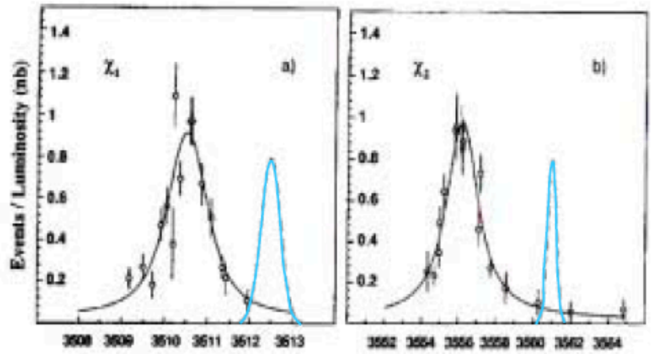


$p\bar{p}$ reactions:
all states directly formed
(very good mass resolution)

formation of $\chi_{1,2}$

$$p\bar{p} \to \chi_{1,2}$$
$$\hookrightarrow \gamma\, J/\psi$$
$$\hookrightarrow \gamma e^+e^-$$

E 760 (Fermilab)



σ_m (beam) = 0.5 MeV

Physics drivers for the design of a new charmonium experiment

- Most obvious goal = mass and width of the singlet charmonium states.
  - Not directly accessible in e^+e^-.
  - E760/E835 attempted measurements using decays to η_c --> $\gamma\gamma$ (small branching fraction/problematic backgrounds).
  - New experiment should use $\eta_c \longrightarrow \Phi\Phi \longrightarrow 2K^+2K^-$ (Magnetic spectrometer required).
- "New" states such as X(3872) are probably best measured (as in previous experiments) using decays to $J/\psi \longrightarrow e^+e^-$
  - Experiment must retain very good electron & photon measurement capability.

CPT test using relativistic antihydrogen

- Antihydrogen is produced in the gas-jet target - exits the Accumulator in the ground state.
  - 99 antihydrogen atoms were observed by E862 with 0 background.
- The atoms enter a 7kG magnet and a large fraction are excited to N=2 long-lived Stark state by laser light.
- Atoms exit magnet & pass through a field-free region, then enter a second magnet with field 6-8 kG. The mixture of N=2 Stark states in the second magnet depends on the time spent in the field-free region, the fine structure, and the Lamb shift.
- Distribution of field ionization in the second magnet reflects probability of being in each of the three N=2 Stark states.
- Monte Carlo —> an experiment in which 100 atoms exit the first magnet in N=2,L will yield a 1% measurement of the fine structure and a 5% measurement of the Lamb shift. Assuming that only the 2S level is shifted by a CPT violating force, the 1σ sensitivity is 50 parts per billion of the 2S binding energy.