Outline

- Last News on Baryon FF near threshold
- The Neutral Baryon Puzzle
- Spacelike - Timelike Relationship
- Interference Pattern in $J/\psi \rightarrow p\bar{p}$
- Conclusions and Perspectives

January 7th, 2013
Cross sections and analyticity

Space-like region
\( e\bar{B} \rightarrow e\bar{B} \)
FF’s are real

Time-like region
Unphysical region
No data
Data region
\( e^+ e^- \leftrightarrow \bar{B} \bar{B} \)
FF’s are complex

Time-like: had. helicity = \( \begin{cases} 1 & \Rightarrow |G_E| \\ 0 & \Rightarrow |G_M| \end{cases} \)

\( G_E(4M_B^2) = G_M(4M_B^2) \)

Elastic scattering
\[
\frac{d\sigma}{d\Omega} = \frac{\alpha^2 E'_e \cos^2 \frac{\theta}{2}}{4E^3_e \sin^4 \frac{\theta}{2}} \left[ G_E^2 - \tau \left( 1 + 2(1 - \tau) \tan^2 \frac{\theta}{2} \right) G_M^2 \right] \frac{1}{1 - \tau}
\]

\( \tau = \frac{q^2}{4M_B^2} \)

Annihilation
\[
\frac{d\sigma}{d\Omega} = \frac{\alpha^2 \beta C}{4q^2} \left[ (1 + \cos^2 \theta)|G_M|^2 + \frac{1}{\tau} \sin^2 \theta |G_E|^2 \right]
\]

Coulomb correction
\[
\beta = \sqrt{1 - \frac{1}{\tau}}
\]
The Coulomb Factor

$\gamma^* B \rightarrow B \overline{B}$

$p\overline{p}$ Coulomb interaction as FSI
[Sommerfeld, Sakharov, Schwinger, Fadin, Khoze]

**Distorted wave approximation**

$$C = |\psi_{\text{Coul}}(0)|^2$$

- **S-wave:**
  $$C = \frac{\pi \alpha}{\beta} \left(1 - \exp\left(-\frac{\pi \alpha}{\beta}\right)\right) \xrightarrow{\beta \rightarrow 0} \frac{\pi \alpha}{\beta}$$

- **D-wave:**
  $$C = 1$$

No Coulomb factor for boson pairs (P-wave)
Sommerfeld Enhancement and Resummation Factors

Coulomb Factor $C$ for S-wave only:

- Partial wave FF:
  \[ G_S = \frac{2G_M\sqrt{q^2/4M^2} + G_E}{3} \quad G_D = \frac{G_M\sqrt{q^2/4M^2} - G_E}{3} \]

- Cross section:
  \[ \sigma(q^2) = 2\pi\alpha^2\beta \frac{4M^2}{(q^2)^2} \left[ C |G_S(q^2)|^2 + 2|G_D(q^2)|^2 \right] \]

\[ C = \mathcal{E} \times \mathcal{R} \]

- Enhancement factor: \[ \mathcal{E} = \pi\alpha/\beta \]

- Step at threshold:
  \[ \sigma(4M^2) = \frac{\pi^2\alpha^3}{2M^2} \beta \left| G_S(4M^2) \right|^2 = 0.85 \left| G_S(4M^2) \right|^2 \text{ nb} \]

- Resummation factor:
  \[ \mathcal{R} = 1/[1 - \exp(-\pi\alpha/\beta)] \]

- Few MeV above threshold:
  \[ C \simeq 1 \Rightarrow \sigma(q^2) \propto \beta \left| G_S(q^2) \right|^2 \]
The $e^+e^- \rightarrow \tau^+\tau^-$ case

\[ e^+ e^- \rightarrow \tau^+ \tau^- \]

$W_{\tau\tau}$ (GeV) vs $\sigma_{\tau\tau}$ (nb)

- **KEDR**
- **BES**

- **With Coulomb corr.**
- **Without Coulomb corr.**
- **With only enhancement factor**

January 7th, 2013

Baryon Form Factors at threshold
Baryon Form Factors at threshold

January 7th, 2013
Pointlike Baryons?

R. Baldini Ferroli, S. Pacetti, A. Zallo and A. Zichichi
Advantages

- All \( q \) at the same time \( \rightarrow \) Better control on systematics
- c.m. boost \( \rightarrow \) at threshold efficiency \( \neq 0 + \sigma_W \sim 1 \text{ MeV} \)
- Detected ISR \( \gamma \) \( \rightarrow \) full \( pp \) angular coverage

Drawbacks

- \( \mathcal{L} \propto \) invariant mass bin \( \Delta w \)
- More background
Incredibly good at threshold ($\sim 1$ MeV/c$^2$), as $e^+e^-$ c.m.
$\Delta p_T/p_T \sim 0.5\%$ at 1 GeV
BABAR: $e^+ e^- \rightarrow p\bar{p}$

January 7th, 2013
Baryon Form Factors at threshold
Proton form factor at $q^2 = 4M_p^2$

\[ \sigma(e^+ e^- \rightarrow p\bar{p})(4M_p^2) = 0.83 \pm 0.05 \text{ nb} \]

\[ \sigma(e^+ e^- \rightarrow p\bar{p})(4M_p^2) = \frac{\pi^2 \alpha^3}{2M_p^2} |G^p(4M_p^2)|^2 = 0.85 |G^p(4M_p^2)|^2 \text{ nb} \]

\[ |G^p(4M_p^2)| = 1 \]

\[ |G^p(4M_p^2)| = 0.99 \pm 0.04(\text{stat}) \pm 0.03(\text{syst}) \]
Proton form factor at $q^2 = 4M_p^2$

At $q^2 = 4M_p^2$ protons behave as pointlike fermions!
Sommerfeld Resummation Factor Needed?
At threshold: \( \frac{G_E}{G_M} = 1 \Rightarrow \begin{cases} \ G_S \in \mathbb{R} \\ \ G_D = 0 \in \mathbb{R} \end{cases} \)

\( \sigma(q^2), |\frac{G_E}{G_M}| \rightarrow G_S, G_D \)

\( G_S = \sqrt{1 - \exp(-\frac{\pi\alpha}{\beta})} \)

No need of Resummation Factor

For a wide energy range (\( \sim 200 \text{ MeV} \)):

- Proton behaves as a pointlike particle
- e.m. dominance, no strong interaction?
- Mild sensitivity to \( \overline{B}B \) invariant mass resolution
BaBar: $|G_E^p/G_M^p|$ and $\sigma(e^+e^- \rightarrow p\bar{p})$

### Plot 1

- **Y-axis:** $|G_E^p/G_M^p|$
- **X-axis:** $W_{pp}$ (GeV)

### Plot 2

- **Y-axis:** $\sigma_{pp}$ (nb)
- **X-axis:** $W_{pp}$ (GeV)

**January 7th, 2013**

**Baryon Form Factors at threshold**
B\(\text{ABAR}: \left| G_E^p / G_M^p \right| \) and \( \sigma(e^+ e^- \rightarrow p\bar{p}) \)

\[ \sqrt{1 - \exp(-\pi\alpha/\beta)} \]

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Baryon Form Factors at threshold
Baryon Form Factors at threshold
Integrated Sommerfeld factor

\[ \frac{1}{\Delta W} \int_0^{\Delta W} \left[ 1 - \exp\left(-\frac{\pi \alpha}{\beta}\right) \right] dw \]

\[ \Delta W \text{ (MeV)} \]
Other charged baryon FF’s at threshold
$e^+ e^- \rightarrow \Lambda_c^+ \bar{\Lambda}_c$ and $e^+ e^- \rightarrow p \bar{N}(1440) + \text{c.c.}$

[Belle PRL 101, 172001]

[BaBar PRD 73, 012005]

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Baryon Form Factors at threshold
$e^+ e^- \rightarrow p\bar{N}(1440) + \text{c.c.}$

\[
\sigma_{\text{Coulomb}} = \frac{16\pi^2\alpha^3 M_p^{3/2} M_N^{3/2}}{(M_p + M_N(1440))^5} \left| G^{pN(1440)} \right|^2 = \left| G^{pN(1440)} \right|^2 \times 0.49 \text{ nb}
\]

\[
\left| G^{pN(1440)} \right| = 1.04 \pm 0.09
\]
The neutral baryons puzzle
Neutral Baryons puzzle ($B_{ABAR}$)

\[
\sigma(e^+e^- \to B^0\overline{B}^0) = \frac{4\pi\alpha^2/\beta C_0}{3q^2} \left[ |G_{B^0}^M|^2 + \frac{2M_{B^0}^2}{q^2} |G_{B^0}^E|^2 \right] \rightarrow \frac{\pi\alpha^2/\beta}{2M_{B^0}^2} |G_{B^0}^E|^2 \rightarrow 0
\]

No Coulomb correction at hadron level: \( C_0 = 1 \)

\[
\sigma(e^+e^- \to \Lambda\overline{\Lambda}) (\text{pb})
\]

\[
\sigma(e^+e^- \to \Sigma^0\overline{\Sigma}^0) (\text{pb})
\]

\[
\sigma(e^+e^- \to \Lambda\overline{\Sigma}^0) (\text{pb})
\]

Like a remnant of Coulomb interactions at quark level?

\( C_0 \propto \beta^{-1} \)

as \( \sqrt{q^2} \rightarrow 2M_{B^0} \)

For any neutral baryon

\[
\sqrt{\sigma_{B^0\overline{B}^0}} \propto \frac{|G_{B^0}|}{M_{B^0}}
\]

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Baryon Form Factors at threshold
Baryon octet and $U$-spin

$$(Y, I_3) \to (Y_U, U_3)$$

$$U_3 = -\frac{1}{2} I_3 + \frac{3}{4} Y$$

$$Y_U = -Q$$

U-spin relation: $G_{\Sigma^0} - G_{\Lambda} + \frac{2}{\sqrt{3}} G_{\Lambda\Sigma^0} = 0$

$$M_{\Sigma^0} \sqrt{\sigma_{\Sigma^0\Sigma^0}} - M_{\Lambda} \sqrt{\sigma_{\Lambda\Lambda}} + \frac{2}{\sqrt{3}} M_{\Lambda\Sigma^0} \sqrt{\sigma_{\Lambda\Sigma^0}} = (-0.06 \pm 6.0) \times 10^{-4}$$
Baryon octet and $U$-spin

\[ (Y, l_3) \rightarrow (Y_U, U_3) \]

\[ U_3 = -\frac{1}{2} l_3 + \frac{3}{4} Y \]

\[ Y_U = -Q \]

**U-spin relation:**

\[ G^{\Sigma^0} - G^\Lambda + \frac{2}{\sqrt{3}} G^{\Lambda \Sigma^0} = 0 \]

\[ M_{\Sigma^0} \sqrt{\sigma_{\Sigma^0 \Sigma^0}} - M_\Lambda \sqrt{\sigma_{\Lambda \Lambda}} + \frac{2}{\sqrt{3}} M_{\Lambda \Sigma^0} \sqrt{\sigma_{\Lambda \Sigma^0}} = (-0.06 \pm 6.0) \times 10^{-4} \]
BESIII (Yan Liang) vs BABAR

Baryon Form Factors at threshold

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Graph 1: Cross section (pb) vs $\sqrt{S}$ (GeV)

Graph 2: Cross section (pb) vs $\sqrt{S}$ (GeV)
Only SND, CMD2(?) and BESIII can measure this cross section

No other experiments at present and in near future will be able to perform such a measurement

Data  $\sim 1.5$

Naively  $\sim |Q_d/Q_u|$

pQCD  $< 1$

Soliton models  $\sim 1$

VMD (Dubnicka)  $\gg 1$
\( e^+ e^- \rightarrow n\bar{n} \): preliminary result from SND

Scan 2011
- Maximum energy: 2 GeV
- Efficiency \( \sim 30\% \)
- Above \( n\bar{n} \) threshold:
  \[ \sigma_{n\bar{n}} = 0.8 \pm 0.2 \text{ nb} \]
\( e^+ e^- \rightarrow n\bar{n} \)
$e^+ e^- \rightarrow n\bar{n}$ (FENICE)
Angle between $n$ and recoil direction of $\bar{n}$ in data

- The dots with error bars represent collider data
- The red histogram represents MC
- The red histogram represents the data from separated beam
Dispersive analysis of the ratio \( R = \frac{G_E^p}{G_M^p} \)

R. Baldini, S. Pacetti and A. Zallo
Space-like $G_E^p / G_M^p$ measurements

$$G_E^p = F_1^p + \frac{q^2}{4M_p^2} F_2^p$$

$$G_M^p = F_1^p + F_2^p$$

Space-like

$$\frac{G_E^p(q^2)}{G_M^p(q^2)} < 1$$

Time-like

$$\left| \frac{G_E^p(q^2)}{G_M^p(q^2)} \right| > 1$$

Radiative corrections of polarization technique

Radiative corrections in Rosenbluth method

January 7th, 2013

Baryon Form Factors at threshold
Space-like $G_E^p / G_M^p$ measurements

$G_E^p = F_1^p + \frac{q^2}{4M_p^2} F_2^p$

$G_M^p = F_1^p + F_2^p$

$$\mu_p G_E(q^2) / G_M(q^2)$$

Radiative corrections of polarization technique

Radiative corrections in Rosenbluth method

$F_1 / \frac{q^2}{4M_p^2} F_2$ cancellation

$G_E^p(q^2) / G_M^p(q^2) < 1$

$F_1 / \frac{q^2}{4M_p^2} F_2$ enhancement

$\left| \frac{G_E^p(q^2)}{G_M^p(q^2)} \right| > 1$
\[
\frac{d\sigma}{d \cos \theta} = \frac{\pi \alpha^2 \beta C}{2q^2} |G^p_M|^2 \left[ (1 + \cos^2 \theta) + \frac{4M^2_p}{q^2 \mu^2_p} \sin^2 \theta |R|^2 \right]
\]

\[R(q^2) = \mu_p \frac{G^p_E(q^2)}{G^p_M(q^2)}\]

\[|R(q^2)|/\mu_p\]

\[\sqrt{q^2} \text{ (GeV/c)}\]

- BABAR (ISR)
  PRD73, 012005
- LEAR (p\bar{p} \rightarrow e^+ e^-)
  NPB411, 3
- FENICE+DM2
- E835
  EPJC46, 421

\[\gamma\gamma \text{ exchange}\]
\[\gamma\gamma \text{ exchange interferes with the Born term}\]

Asymmetry in angular distributions
[PLB659, 197]

**January 7th, 2013**

Baryon Form Factors at threshold
$\gamma\gamma$ exchange from
$e^+ e^- \to p\bar{p}\gamma$ BABAR data

$$A(\cos \theta, q^2) = \frac{d\sigma}{d\Omega}(\cos \theta, q^2) - \frac{d\sigma}{d\Omega}(-\cos \theta, q^2)$$

$$+ \frac{d\sigma}{d\Omega}(\cos \theta, q^2) + \frac{d\sigma}{d\Omega}(-\cos \theta, q^2)$$

$$\langle A \rangle_{\cos \theta, q^2} = 0.01 \pm 0.02$$
$G_E$, $G_M$ and also $R$, if $G_M$ has no zeros, are analytic on the $q^2$ plane with a cut ($s_{th} = 4M^2_\pi$, $\infty$) [see e.g.: Eur. Phys. J. C 11, 709 (1999)]
$R(q^2)$ in the complex plane

Dispersion relation for the imaginary part ($q^2 \leq s_{\text{th}}$)

$$G(q^2) = \lim_{\mathcal{R} \to \infty} \frac{1}{2\pi i} \oint_C \frac{G(z)dz}{z-q^2} = \frac{1}{\pi} \int_{s_{\text{th}}}^{\infty} \frac{\text{Im}G(s)ds}{s-q^2}$$
$R(q^2)$ in the complex plane

Dispersion relation for $R$ with subtraction at $q^2 = 0$

$$R(q^2) = R(0) + \frac{q^2}{\pi} \int_{s_{th}}^{\infty} \frac{\text{Im} R(s) ds}{s(s - q^2)}$$

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Baryon Form Factors at threshold
\[ R(q^2) = R(0) + \frac{q^2}{\pi} \int_{4M_{\pi}^2}^{\infty} \frac{\text{Im}R(s)}{s(s - q^2)} \, ds \]

- **\(R(q^2)\) space-like**
- **\(|R(q^2)|\) time-like**

**Graphs:**
- **JLab+MIT-Bates**
- **BABAR+DM2/FENICE+E835**

**Axes:**
- **\(q^2\) (GeV\(^2/c^2\))**
- **\(q^2\) (GeV\(^2/c^2\))**

**Title:** Baryon Form Factors at threshold

**Date:** January 7\(^{th}\), 2013
\[ R(q^2) = R(0) + \frac{q^2}{\pi} \int_{4M^2_\pi}^{\infty} \frac{\text{Im} R(s)}{s(s - q^2)} ds \]

\[ |R(q^2)| \text{ time-like} \]

\[ R(q^2) \text{ space-like} \]
\[ R(q^2) = R(0) + \frac{q^2}{\pi} \int_{4M^2_{\pi}}^{\infty} \frac{\text{Im} R(s)}{s(s - q^2)} \, ds \]

- \( R(q^2) \) space-like
- \( |R(q^2)| \) time-like

JLab + MIT-Bates

\( q^2 \) (GeV\(^2\)/c\(^2\))

BA Bar + DM2/ FENICE + E835

DR Approach
1/Q
\( \log^2 Q^2/Q^2 \)
Impr. \( \log^2 Q^2/Q^2 \)
IJL

\( q^2 \) (GeV\(^2\)/c\(^2\))

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Baryon Form Factors at threshold
\[ R(q^2) = R(0) + \frac{q^2}{\pi} \int_{4M^2}^{\infty} \frac{\text{Im}R(s)}{s(s - q^2)} ds \]

\( R(q^2) \) space-like

\( |R(q^2)| \) time-like

JLab+MIT-Bates

JLab preliminary

V. Punjabi DSPIN-09

Dubna, Russia

BABAR+DM2/FENICE+E835

DR Approach

1/Q

log^2 Q^2 / Q^2

Impr. log^2 Q^2/Q^2

IJJL

January 7th, 2013
Asymptotic $G_E^P(q^2)/G_M^P(q^2)$ and phase

**pQCD prediction**

$$\frac{G_E^P(q^2)}{G_M^P(q^2)} \xrightarrow{|q^2| \to \infty} -1$$

**Phase from DR**

$$\phi(q^2) = -\frac{\sqrt{q^2 - s_0}}{\pi} \text{Pr} \int_{s_0}^{\infty} \frac{\ln |R(s)| ds}{\sqrt{s - s_0}(s - q^2)}$$

**Phragmèn Lindelöf phase limit ↔ zeros**
Time-like magnetic proton form factor

Data obtained assuming $|G_M^p| = |G_E^p| \equiv |G_{eff}^p|$ (true only at threshold)

$$|G_{eff}^p|^2 = \frac{\sigma_{pp}(q^2)}{16\pi\alpha^2 C_e} \frac{\sqrt{1-1/\tau}}{4q^2} \left(1 + \frac{1}{2\tau}\right)$$
The integral equation for $G_M$

Dispersion relation subtracted at $t = 0$

$$\ln G(t) = \frac{t \sqrt{s_{th} - t}}{\pi} \int_{s_{th}}^{\infty} \ln |G(s)| \frac{ds}{s \sqrt{s - s_{th}}(s - t)}$$

- Less dependent on the asymptotic behavior of the FF
- $\ln G(0) = 0 \Rightarrow$ no further terms have to be considered

Splitting the integral $\int_{s_{th}}^{\infty}$ into $\int_{s_{th}}^{s_{phy}'}$ + $\int_{s_{phy}'}^{\infty}$ we obtain the integral equation

Data and Theory

$$\ln G(t) - I_{\text{phy}}^{\infty}(t) = \frac{t \sqrt{s_{th} - t}}{\pi} \int_{s_{th}}^{s_{phy}'} \ln |G(s)| \frac{ds}{s \sqrt{s - s_{th}}(s - t)}$$

Unknown

To avoid instabilities around $s_{phy} = 4M_N^2$, the upper boundary has been shifted to $s_{phy}' = s_{phy} + \Delta$, with $\Delta \simeq 0.5$ GeV$^2$

We impose continuity of the FF at $s_{phy}'$ and $s_{th}$, in addition, at the upper boundary $s_{phy}'$, continuity of the first derivative is also required

A regularization, depending on a free parameter $\tau$, is introduced by requiring the FF total curvature in the unphysical region to be limited
Solving procedure

Minimize: \( \chi^2 = \chi^2_{\text{data}} + \chi^2_{\text{theory}} + \tau^6 \cdot \chi^2_{\text{regu}} \)

\[ \chi^2_{\text{regu}} = \int_{s_{\text{th}}}^{s'_{\text{phy}}} \left[ \frac{d^2 \ln |G(s)|}{ds^2} \right]^2 ds \propto \text{total curvature in } [s_{\text{th}}, s'_{\text{phy}}] \]

Pion FF to fix the regularization parameter \( \tau \)

Space-like (DR) and time-like data (yellow bands) have been used as input in the integral equation to retrieve the time-like FF in the nucleon unphysical region.
Solving procedure

Minimize: \( \chi^2 = \chi^2_{\text{data}} + \chi^2_{\text{theory}} + \tau^6 \cdot \chi^2_{\text{regu}} \)

\[
\chi^2_{\text{regu}} = \int_{s_{th}}^{s'_{\text{phy}}} \left( \frac{d^2 \ln |G(s)|}{ds^2} \right)^2 ds \propto \text{total curvature in } [s_{th}, s'_{\text{phy}}]
\]

Pion FF to fix the regularization parameter \( \tau \)

Space-like (DR) and time-like data (yellow bands) have been used as input in the integral equation to retrieve the time-like FF in the nucleon unphysical region (gray band).
Nucleon magnetic form factors

\[ |\tilde{G}_p^{M}(q^2) / \mu_p| \]

\[ |\tilde{G}_n^{M}(q^2) / \mu_n| \]

Steep behavior near by the threshold

\[ M_1 \sim 770 \text{ MeV} \quad \Gamma_1 \sim 350 \text{ MeV} \]

\[ M_2 \sim 1600 \text{ MeV} \quad \Gamma_2 \sim 350 \text{ MeV} \]

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Baryon Form Factors at threshold
$J/\psi$ strong and electromagnetic phase
Resonant contributions

\[ \Gamma_{J/\psi} \sim 93 \text{KeV} \rightarrow \text{pQCD} \]
\[ \text{pQCD: all amplitudes almost real}^{[1,2]} \]
\[ \text{QCD} \rightarrow \Phi_p \sim 10^\circ \ [1] \]

Non-resonant continuum

\[ \text{pQCD regime} \]
\[ A_{EM} \in R \]

\[ \text{Strong} \rightarrow A_{3g} \]
\[ \text{Electromagnetic} \rightarrow A_v \]
\[ \text{Non-resonant Continuum} \rightarrow A_{EM} \]

• If both real, they must interfere ($\Phi_p \sim 0^\circ/180^\circ$)

• On the contrary $\Phi_p \sim 90^\circ \rightarrow$ No interference

  $\frac{J/\psi}{\psi} \rightarrow N\bar{N} (\frac{1}{2}^{+}\frac{1}{2}^{-}) \; \Phi_p = 89^\circ \pm 15^\circ$ \footnote{1}; 89$^\circ$ \pm 9$^\circ$\footnote{2}
  $\frac{J/\psi}{\psi} \rightarrow V\bar{P} (1-0^{-}) \; \Phi_p = 106^\circ \pm 10^\circ$ \footnote{3}
  $\frac{J/\psi}{\psi} \rightarrow P\bar{P} (0-0^{-}) \; \Phi_p = 89.6^\circ \pm 9.9^\circ$ \footnote{4}
  $\frac{J/\psi}{\psi} \rightarrow V\bar{V} (1-1^{-}) \; \Phi_p = 138^\circ \pm 37^\circ$ \footnote{4}

• Results are model dependent

• Model independent test:

  interference with the non resonant continuum

\footnote{2} J.M. Bian, $\psi$ \rightarrow ppbar and $\psi \rightarrow n\bar{n}$bar measurement by BESIII, approved draft
J/ψ → N\bar{N}

Favoured channel 3g match 3qq̅ pairs

Without EM contribution p = n, due to isospin

EM contribution amplitudes have opposite sign, like magnetic moments

\[ BR_{n\bar{n}} \text{ expected} \sim \frac{1}{2} BR_{p\bar{p}} \]

\[ R = \frac{Br(J/ψ \rightarrow n\bar{n})}{Br(J/ψ \rightarrow p\bar{p})} = \left| \frac{A_3^g + A^n_γ}{A_3^g + A^p_γ} \right|^2 \]

\[ A_3^g, A_γ \in \mathcal{R} \quad R \ll 1 \]

\[ A_3^g \perp A_γ \quad R \approx 1 \]

But the BR are almost equal according to BESII[1]:

\[ BR(J/ψ \rightarrow p\bar{p}) = (2.112 \pm 0.004 \pm 0.027) \cdot 10^{-3}\% \]

\[ BR(J/ψ \rightarrow n\bar{n}) = (2.07 \pm 0.01 \pm 0.14) \cdot 10^{-3}\% \]

➢ Suggests 90° phase

[1] J.M. Bian, J/ψ → pp\bar{p} and J/ψ → nn\bar{n} measurement by BESIII, accepted for publication PRD
Was an Interference Already Seen?

BES in $e^+e^- \rightarrow \mu^+\mu^-$
(no strong amplitude)

$\phi - \omega$ interference in $e^+ e^- \rightarrow \pi^+ \pi^- \pi^0$ 
($\phi = 90^\circ$ not universal: $\phi = 180^\circ$ fit)
Full interference as seen by PANDA or BESIII

\begin{align*}
\sigma_{pp} \text{ (nb)} & \quad W_{pp} \text{ (MeV)} \\
\text{PANDA} \quad (\Delta \rho_{\bar{p}}/\rho_{\bar{p}} = 10^{-4}) & \quad \text{BESIII}
\end{align*}

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Baryon Form Factors at threshold
$e^+e^- \rightarrow \mu^+\mu^-$

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Baryon Form Factors at threshold
$e^+e^- \rightarrow 2(\pi^+\pi^-)$
Conclusions

- Pointlike Behavior at and well above threshold
- No Sommerfeld Resummation Factor
- Neutral baryon non zero cross section at threshold?
- $G_E^p$ space-like → $-1$ asymptotically?
- Imaginary $J/\psi$ strong decay amplitude?

Perspectives

- BESIII: ISR and scan
- Data from SND and CMD2
- PANDA could explore FFs below threshold through $p\bar{p} \rightarrow \pi^0 l^+ l^-$
- SuperTauCharm?