Dalitz analysis of the decay
\[ B^+ \rightarrow \pi^+ \pi^- \pi^+ \]
* charged conjugate states implied throughout talk

Outline of Talk
* Introduction
* Analysis technique
* Results
* Summary & Conclusions
B^+ → π^+ π^- π^+ is a charmless 3-body B decay

Why study charmless 3-body B decays?

Interference from both penguin & tree amplitudes can give direct CP violation.

Time-dependent measurements & interferences between intermediate states can allow measurement of all three CKM angles.

Can search for signs of new physics such as enhanced branching fractions or CP asymmetries - new physics particles can enter in the loop diagrams.

Can improve understanding of the nature of some intermediate resonances, i.e. hadronic physics.
Dalitz plot is a representation of e.g. the $\mathcal{B} \to PPP$ phase space.

In our case $P$=pseudoscalar=charged pion.

The invariant masses are constrained by $m_B^2+m_i^2+m_j^2+m_k^2=m_{ij}^2+m_{ik}^2+m_{jk}^2$

Make a 2D scatter plot in $m_{ij}^2$ and $m_{jk}^2$

Our case: $m_{ij}$=low mass $\pi^+\pi^-$ combo, $m_{jk}$=high mass $\pi^+\pi^-$ combo

Structure in the DP gives information on resonance masses, widths and spins, relative phases, interference etc.

Model each contribution to the DP as a separate amplitude with a complex coefficient (isobar model).

Red points show a spin 0 resonance

Green points show spin 1 resonance

Purple points show spin 2 resonance

Each of these has a different mass, width & composition.
Dalitz-plot analysis of $B^+ \rightarrow \pi^+\pi^-\pi^+$

In principle can extract the CKM angle $\gamma$ from the interference between $B^+ \rightarrow \chi_{c0}\pi^+$ & other modes such as $B^+ \rightarrow \rho^0\pi^+$

This mode also provides important information to improve the DP model in $B^0 \rightarrow \pi^+\pi^-\pi^0$, which is used to measure the CKM angle $\alpha$

BF & $A_{CP}$ measurements used to test factorisation and other effective theories

Light meson spectroscopy aided by information from as many different final states as possible
Previous BaBar Results

PRD 72, 052002 (2005) used 232×10^6 \( \overline{B}B \) events (~half of this analysis)
Prominent \( \rho(770) \) and 3\( \sigma \) evidence for \( f_2(1270) \)

**TABLE II.** Summary of average branching fraction (\( \mathcal{B} \)) and charge asymmetry (\( \mathcal{A} \)) results. The first uncertainty is statistical, the second is systematic, while the third is model-dependent.

<table>
<thead>
<tr>
<th>Mode</th>
<th>( \mathcal{B}(B^\pm \rightarrow \text{Mode}) \times 10^{-6} )</th>
<th>90% CL UL ( \mathcal{B} \times 10^{-6} )</th>
<th>( \mathcal{A} ) (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>( B^\pm \rightarrow \pi^\pm \pi^\pm \pi^\mp ) Total</td>
<td>16.2 ± 1.2 ± 0.9</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>( \rho^0(770) \pi^\pm, \rho^0(770) \rightarrow \pi^+ \pi^- )</td>
<td>8.8 ± 1.0 ± 0.6 ± 0.1</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>( \rho^0(1450) \pi^\pm, \rho^0(1450) \rightarrow \pi^+ \pi^- )</td>
<td>1.0 ± 0.6 ± 0.2 ± 0.2</td>
<td>&lt;2.3</td>
<td>+15.5 ± 62.1 ± 7.9 ± 0.4</td>
</tr>
<tr>
<td>( f_0(980) \pi^\pm, f_0(980) \rightarrow \pi^+ \pi^- )</td>
<td>1.2 ± 0.6 ± 0.1 ± 0.4</td>
<td>&lt;3.0</td>
<td>+49.5 ± 53.7 ± 4.9 ± 0.3</td>
</tr>
<tr>
<td>( f_2(1270) \pi^\pm, f_2(1270) \rightarrow \pi^+ \pi^- )</td>
<td>2.3 ± 0.6 ± 0.2 ± 0.3</td>
<td>&lt;3.5</td>
<td>—</td>
</tr>
<tr>
<td>( B^\pm \rightarrow \pi^\pm \pi^\mp \pi^\mp ) Nonresonant</td>
<td>2.3 ± 0.9 ± 0.3 ± 0.4</td>
<td>&lt;4.6</td>
<td>+8.0 ± 41.2 ± 6.5 ± 2.4</td>
</tr>
<tr>
<td>( \chi_{c0} \pi^\pm, \chi_{c0} \rightarrow \pi^+ \pi^- )</td>
<td>—</td>
<td>&lt;0.3</td>
<td>—</td>
</tr>
<tr>
<td>( f_0(1370) \pi^\pm, f_0(1370) \rightarrow \pi^+ \pi^- )</td>
<td>—</td>
<td>&lt;3.0</td>
<td>—</td>
</tr>
<tr>
<td>( \sigma \pi^\pm, \sigma \rightarrow \pi^+ \pi^- )</td>
<td>—</td>
<td>&lt;4.1</td>
<td>—</td>
</tr>
</tbody>
</table>
asymmetric $e^+e^-$ collider: 9 GeV (e-) / 3.1 GeV (e+)

PEP-II Peak Luminosity  $1.2 \times 10^{34}$ cm$^{-2}$s$^{-1}$

BaBar recorded 424 fb$^{-1}$ at Y(4S)

$4.65 \times 10^8$ Y(4S)$\rightarrow B\bar{B}$ events
SVT, DCH: charged particle tracking: vertex & mom. resolution, $K^0_s/\Lambda$
EMC: electromagnetic calorimeter: $\gamma/e/\pi^0/\eta$
DIRC, IFR, DCH: charged particle ID: $\pi/\mu/K/p$
Highly efficient trigger for B mesons
Threshold kinematics: we know the initial energy \((E^*_{beam})\) of the \(Y(4S)\) system. Therefore we know the energy & magnitude of momentum of each \(B\) meson.

\[
m_{ES} = \sqrt{E^*_{beam} - P_B^*} \]

\[
\Delta E = E^*_B - E^*_{beam} \]

Event topology

Also, use neural networks + unbinned maximum likelihood fits.
**Backgrounds**

**B Mesons**
Explicitly veto 2-body states that can mimic $B^+ \rightarrow \pi^+\pi^\mp\pi^+$
- $B^+ \rightarrow D^0\pi^+$ with $D^0 \rightarrow \pi^+\pi^-$ and/or mis-ID's $D^0 \rightarrow \pi^+K^-/K^+K^-$
- $B^+ \rightarrow K_s\pi^+$ with $K_s \rightarrow \pi^+\pi^-$
- $B^+ \rightarrow [J/\Psi, \Psi(2S)]\pi^+$ with $\Psi \rightarrow l^+l^-$ with mis-ID's l's as $\pi$'s

Estimate background due to other B meson decays
Number of events estimated from MC and used in ML fit
I) 2-body with extra track: $B^0 \rightarrow \pi^+\pi^-$ plus $\pi^+$ (11 events)
II) 3-body with mis-ID track(s): $B^+ \rightarrow K^+\pi^-\pi^+$ (199 events)
III) $B^0 \rightarrow \pi^+\pi^-\pi^0$ with $\pi^-$ substituted for $\pi^0$ (120 events)
IV) B combinatorial backgrounds (495 events)

**Continuum**: $e^+e^- \rightarrow u\bar{u}, d\bar{d}, s\bar{s}, c\bar{c}$
modeled using MC and below-$Y(4S)$ data
The total signal amplitudes for $B^+$ and $B^-$ decays are:

\[
A \equiv A(m_{\text{max}}^2, m_{\text{min}}^2) = \sum_j c_j F_j(m_{\text{max}}^2, m_{\text{min}}^2)
\]
\[
\bar{A} \equiv \bar{A}(m_{\text{max}}^2, m_{\text{min}}^2) = \sum_j \bar{c}_j \bar{F}_j(m_{\text{max}}^2, m_{\text{min}}^2)
\]

The F’s contain the strong force dynamics: $F_j = \bar{F}_j$

\[
F_j(m_{\text{max}}^2, m_{\text{min}}^2) \equiv R_j(m)X_j(p^*)X_j(q)T_j(m)
\]

\[j = \text{spin of resonance, } m = \text{mass of resonance}\]
\[q = \text{momentum of daughter in rest frame of resonance}\]
\[p^* = \text{momentum of bachelor pion in B rest frame}\]

$X_j = \text{Blatt-Weisskopf barrier form factors}$

$R_j(m) = \text{resonance line shapes}$

$\rho$’s use Gounaris-Sakurai parameterization, others relativistic BWs

$T_j(m) = \text{angular distribution (use Zemach tensor formulism)}$

The c’s contain the weak force dynamics:

\[c_j = (x_j + \Delta x_j) + i(y_j + \Delta y_j) \quad \bar{c}_j = (x_j - \Delta x_j) + i(y_j - \Delta y_j)\]

$\Delta x_j$ and $\Delta y_j$ are CP violating components
The fit fraction for an individual amplitude is:

\[
FF_j = \frac{\int\int (|c_j F_j|^2 + |\bar{c}_j \bar{F}_j|^2) dm^2_{\text{max}} dm^2_{\text{min}}}{\int\int (|A|^2 + |\bar{A}|^2) dm^2_{\text{max}} dm^2_{\text{min}}}
\]

Note: sum of fit fractions can be <1 or >1 due to interference.

The CP asymmetry for a contributing resonance is:

\[
A_{CP,j} = \frac{|\bar{c}_j|^2 - |c_j|^2}{|c_j|^2 + |\bar{c}_j|^2}
\]

The nominal model includes \(\rho(770), \rho(1450), f_2(1270), f_0(1370)\) + non-resonant but additional resonance added too, e.g. \(f_0(980)\).
Event yields are extracted using an unbinned extended maximum likelihood fit.

\[ L = e^{-N} \prod_j N_j \prod_k P_k (m_{\text{max}}^2, m_{\text{min}}^2, m_{ES}, \Delta E, q_B) \]

\[ N = \sum N_k \text{ with } N_k = \text{ event yield for category } k. \]

\( N_e = \text{ total number of events in data sample} \)
\( q_B = \text{ charge of the } B \text{ meson} \)
\( P_k = \text{PDF for category } k: P = P(m_{ES}) \times P(\Delta E) \times P(\text{Dalitz}) \)

The signal reconstruction efficiencies are determined as a function of location in Dalitz plot \((m_{\text{max}}^2, m_{\text{min}}^2)\) for \(B^+\) and \(B^-\) separately using MC.

Procedure is extensively tested with Monte Carlo toy MCs and embedded MCs.
We calculate a chisq between a model & data:
Number of events in a bin vs predicted number
The best model is the one with the lowest chisq/dof

4335 $B^\pm$ candidates yields $1219\pm50$ signal events

Fit to Data

PRD 79, 072006 (2009)

“sPlots”
NIM A 555 (2005) 356
Many sources of systematic errors considered
allow $B\bar{B}$ backgrounds to float
vary the PDF parameters
compare with data/MC control samples: $B^- \rightarrow D^0\pi^-$, $D^0 \rightarrow K^-\pi^+$
tracking efficiency & particle ID
modeling of Neural Network
Dalitz plot model (composition of model & values of masses, widths, etc)

<table>
<thead>
<tr>
<th>Source</th>
<th>$x$</th>
<th>$y$</th>
<th>$\Delta x$</th>
<th>$\Delta y$</th>
<th>Fit fraction</th>
<th>$A_{CP}$</th>
<th>Signal yield</th>
<th>Signal asymmetry</th>
</tr>
</thead>
<tbody>
<tr>
<td>$B\bar{B}$ yields</td>
<td>0.02</td>
<td>0.04</td>
<td>0.02</td>
<td>...</td>
<td>0.02</td>
<td>1.4</td>
<td>0.01</td>
<td></td>
</tr>
<tr>
<td>$B\bar{B}$ PDF</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>3.3</td>
<td>...</td>
<td></td>
</tr>
<tr>
<td>Signal PDF</td>
<td>0.02</td>
<td>0.02</td>
<td>0.01</td>
<td>0.02</td>
<td>0.01</td>
<td>0.08</td>
<td>48.3</td>
<td>0.01</td>
</tr>
<tr>
<td>$q\bar{q}$ Dalitz plot</td>
<td>0.06</td>
<td>0.03</td>
<td>0.05</td>
<td>0.05</td>
<td>0.03</td>
<td>0.14</td>
<td>47.7</td>
<td>...</td>
</tr>
<tr>
<td>$B\bar{B}$ Dalitz plot</td>
<td>0.03</td>
<td>0.03</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
<td>0.10</td>
<td>31.6</td>
<td>0.02</td>
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<tr>
<td>Efficiency Dalitz plot</td>
<td>...</td>
<td>0.01</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>0.03</td>
<td>0.6</td>
<td>...</td>
</tr>
<tr>
<td>Fit bias</td>
<td>0.01</td>
<td>0.02</td>
<td>0.02</td>
<td>0.01</td>
<td>...</td>
<td>0.05</td>
<td>2.8</td>
<td>...</td>
</tr>
</tbody>
</table>
The decay is dominated by $B^+ \rightarrow \rho(770)^0\pi^+$ and $3\pi$ non-resonant.
The $\chi_{c0}, \chi_{c2},$ & $f_0(980)$ components not statistically significant.

**Branching Fraction Results**

<table>
<thead>
<tr>
<th>Mode</th>
<th>Fit fraction (%)</th>
<th>$B(B^+ \rightarrow \text{Mode})(10^{-6})$</th>
<th>stat</th>
<th>syst</th>
<th>model</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\pi^+\pi^-\pi^+$ Total</td>
<td></td>
<td>15.2 $\pm$ 0.6 $\pm$ 1.2$^{+0.4}_{-0.3}$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\rho^0(770)\pi^+; \rho^0(770) \rightarrow \pi^+\pi^-$</td>
<td>53.2 $\pm$ 3.7 $\pm$ 2.5$^{+1.5}_{-7.4}$</td>
<td>8.1 $\pm$ 0.7 $\pm$ 1.2$^{+0.4}_{-1.1}$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\rho^0(1450)\pi^+; \rho^0(1450) \rightarrow \pi^+\pi^-$</td>
<td>9.1 $\pm$ 2.3 $\pm$ 2.4$^{+1.9}_{-4.5}$</td>
<td>1.4 $\pm$ 0.4 $\pm$ 0.4$^{+0.3}_{-0.7}$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$f_2(1270)\pi^+; f_2(1270) \rightarrow \pi^+\pi^-$</td>
<td>5.9 $\pm$ 1.6 $\pm$ 0.4$^{+2.0}_{-0.7}$</td>
<td>0.9 $\pm$ 0.2 $\pm$ 0.1$^{+0.3}_{-0.1}$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$f_0(1370)\pi^+; f_0(1370) \rightarrow \pi^+\pi^-$</td>
<td>18.9 $\pm$ 3.3 $\pm$ 2.6$^{+4.3}_{-3.5}$</td>
<td>2.9 $\pm$ 0.5 $\pm$ 0.5$^{+0.7}_{-0.5}$ ($&lt; 4.0$)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\pi^+\pi^-\pi^+$ nonresonant</td>
<td>34.9 $\pm$ 4.2 $\pm$ 2.9$^{+7.5}_{-3.4}$</td>
<td>5.3 $\pm$ 0.7 $\pm$ 0.6$^{+1.1}_{-0.5}$</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

$\chi_{c0} \pi^+; \chi_{c0} \rightarrow \pi^+\pi^-$ - $< 1.5$

$\chi_{c2} \pi^+; \chi_{c2} \rightarrow \pi^+\pi^-$ - $< 0.1$

$\chi_{c0}, \chi_{c2}$ & $f_0(980)$ components not statistically significant.

PDG: $(16.2\pm1.5)\times10^{-6}$

$f_0(1370)$ mass=$1400\pm50$ MeV/c$^2$
$f_0(1370)$ width=$300\pm80$ MeV

determined from ML fit
All CP asymmetries are consistent with zero.

**“Best Fit Solution”**

<table>
<thead>
<tr>
<th>Mode</th>
<th>$A_{CP}$ (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\pi^+\pi^-\pi^+$ Total</td>
<td>$+3.2 \pm 4.4 \pm 3.1^{+2.5}_{-2.0}$</td>
</tr>
<tr>
<td>$\rho^0(770)\pi^\pm$; $\rho^0(770) \rightarrow \pi^+\pi^-$</td>
<td>$+18 \pm 7 \pm 5^{+2}_{-14}$</td>
</tr>
<tr>
<td>$\rho^0(1450)\pi^\pm$; $\rho^0(1450) \rightarrow \pi^+\pi^-$</td>
<td>$-6 \pm 28 \pm 20^{+12}_{-35}$</td>
</tr>
<tr>
<td>$f_2(1270)\pi^\pm$; $f_2(1270) \rightarrow \pi^+\pi^-$</td>
<td>$+41 \pm 25 \pm 13^{+12}_{-8}$</td>
</tr>
<tr>
<td>$f_0(1370)\pi^\pm$; $f_0(1370) \rightarrow \pi^+\pi^-$</td>
<td>$+72 \pm 15 \pm 14^{+7}_{-8}$</td>
</tr>
<tr>
<td>$\pi^+\pi^-\pi^+$ nonresonant</td>
<td>$-14 \pm 14 \pm 7^{+17}_{-3}$</td>
</tr>
</tbody>
</table>

Large variation in the $A_{CP}$'s between best & 2nd best fit:

**Resonance**  | $A_{CP}$ (best) | $A_{CP}$ (2nd best) |
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>$\rho^0(770)\pi^\pm$</td>
<td>$+0.18 \pm 0.07$</td>
<td>$+0.03 \pm 0.08$</td>
</tr>
<tr>
<td>$\rho^0(1450)\pi^\pm$</td>
<td>$-0.06 \pm 0.28$</td>
<td>$-0.54 \pm 0.24$</td>
</tr>
<tr>
<td>$f_2(1270)\pi^\pm$</td>
<td>$+0.41 \pm 0.25$</td>
<td>$+0.55 \pm 0.20$</td>
</tr>
<tr>
<td>$f_0(1370)\pi^\pm$</td>
<td>$+0.72 \pm 0.15$</td>
<td>$-1.00 \pm 0.58$</td>
</tr>
<tr>
<td>Nonresonant</td>
<td>$-0.14 \pm 0.14$</td>
<td>$-0.11 \pm 0.14$</td>
</tr>
</tbody>
</table>

$x^2_{best}/dof = 82/84$

$x^2_{2nd}/dof = 86/84$
B$^{+}\rightarrow\pi^{+}\pi^{-}\pi^{+}$ Conclusions

- This analysis uses the full BaBar data set
  Published: PRD 79, 072006 (2009)
- Decay is dominated by $\rho(770)\pi$ & $3\pi$ non-resonant
  No evidence for $x_{c0}$, $x_{c2}$, & $f_0(980)$
  BFs in good agreement with PDG & theories
- All CP asymmetries consistent with zero
  Lack of $x_{c0}$ & $x_{c2}$ implies this mode is not useful for
  CKM angle $\gamma$ measurement with present data samples.
- These results will help other analyses
  Reduce model related errors in determination of CKM
  angle $\alpha$ from time dependent Dalitz analysis of
  $B^0 \rightarrow \pi^{+}\pi^{-}\pi^0$
Extra slides
BaBar K/π ID

BaBar DIRC

θc (rad)

K

π

BaBar

p(GeV/c)

D^{*+} \rightarrow D^0 \pi^+

D^0 \rightarrow K^+ \pi^-

K Efficiency

π Fake Rate

p [GeV/c]
Background subtracted Dalitz plot
exclude charm and charmonia regions
## Best & 2\textsuperscript{nd} Best Fit Results

<table>
<thead>
<tr>
<th></th>
<th>Favored solution</th>
<th>Second solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inclusive signal yield</td>
<td>1219 ± 50</td>
<td>1195 ± 45</td>
</tr>
<tr>
<td>Inclusive signal $A_{CP}$</td>
<td>+0.032 ± 0.044</td>
<td>+0.015 ± 0.043</td>
</tr>
<tr>
<td>$q\bar{q}$ background yield</td>
<td>2337 ± 62</td>
<td>2358 ± 64</td>
</tr>
<tr>
<td>$q\bar{q}$ background $A_{CP}$</td>
<td>+0.002 ± 0.027</td>
<td>+0.011 ± 0.027</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Resonance</th>
<th>Fit fraction</th>
<th>$A_{CP}$</th>
<th>Fit fraction</th>
<th>$A_{CP}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\rho^0(770)\pi^\pm$</td>
<td>0.532±0.037</td>
<td>+0.18±0.07</td>
<td>0.458±0.033</td>
<td>+0.03±0.08</td>
</tr>
<tr>
<td>$\rho^0(1450)\pi^\pm$</td>
<td>0.091±0.023</td>
<td>−0.06±0.28</td>
<td>0.064±0.016</td>
<td>−0.54±0.24</td>
</tr>
<tr>
<td>$f_2(1270)\pi^\pm$</td>
<td>0.059±0.016</td>
<td>+0.41±0.25</td>
<td>0.079±0.016</td>
<td>+0.55±0.20</td>
</tr>
<tr>
<td>$f_0(1370)\pi^\pm$</td>
<td>0.189±0.033</td>
<td>+0.72±0.15</td>
<td>0.030±0.019</td>
<td>−1.00±0.58</td>
</tr>
<tr>
<td>Nonresonant</td>
<td>0.349±0.042</td>
<td>−0.14±0.14</td>
<td>0.365±0.042</td>
<td>−0.11±0.14</td>
</tr>
</tbody>
</table>
Model Parameterization

Blatt-Weisskopf Barrier Form Factors:
\[ r_{BW} = 4.0 \pm 1.0 \text{ (GeV/c)}^{-1} \]

Breit-Wigner line shape:
\[ q_0 = q(m_0) \]

Zemach Tensors:
\[ T_j^{J=0} = 1, \]
\[ T_j^{J=1} = -2 \vec{p} \cdot \vec{q}, \]
\[ T_j^{J=2} = \frac{4}{3} [3(\vec{p} \cdot \vec{q})^2 - (|\vec{p}| |\vec{q}|)^2] \]

Gounaris-Sakurai parameterization
\[ \left. \frac{dh}{dm} \right|_{m_0} = h(m_0) \left[ \left( \frac{q_0^2}{m_0^2} \right)^{-1} - \left( \frac{m_0^2}{2m_0^2} \right)^{-1} \right] + \left( 2m_0^2 \right)^{-1} \]
\[ h(m) = \frac{2}{\pi} \frac{q}{m} \ln \left( \frac{m + 2q}{2m_\pi} \right) \]
\[ f(m) = \frac{m_0^3}{q_0^2} \times \left[ q^2 [h(m) - h(m_0)] + \left( \frac{m_0^2}{2 - m_0^2} \right) q_0^2 \left. \frac{dh}{dm} \right|_{m_0} \right] \]
\[ R_j(m) = \frac{1}{(m_0^2 - m^2) - im_0 \Gamma(m)} \]
\[ \Gamma(m) = \Gamma_0 \left( \frac{q}{q_0} \right)^{2J+1} \frac{m_0^2}{m} \frac{X_j^2(q)}{X_j^2(q_0)} \]

Non-resonant:
\[ \alpha_{nr} = 0.28 \pm 0.06 \text{ (GeV/c}^2\text{)}^{-2} \]
Predictions

Li and Yang, PRD 73, 114027 (2006).


Scheme A2

Scheme B2