Exclusive Meson Production Workshop
22-24 Jan 2015, Jefferson Lab

Deeply Virtual Scalar Production

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← Mirror Image →
Symmetry Breaking

Global GPD program

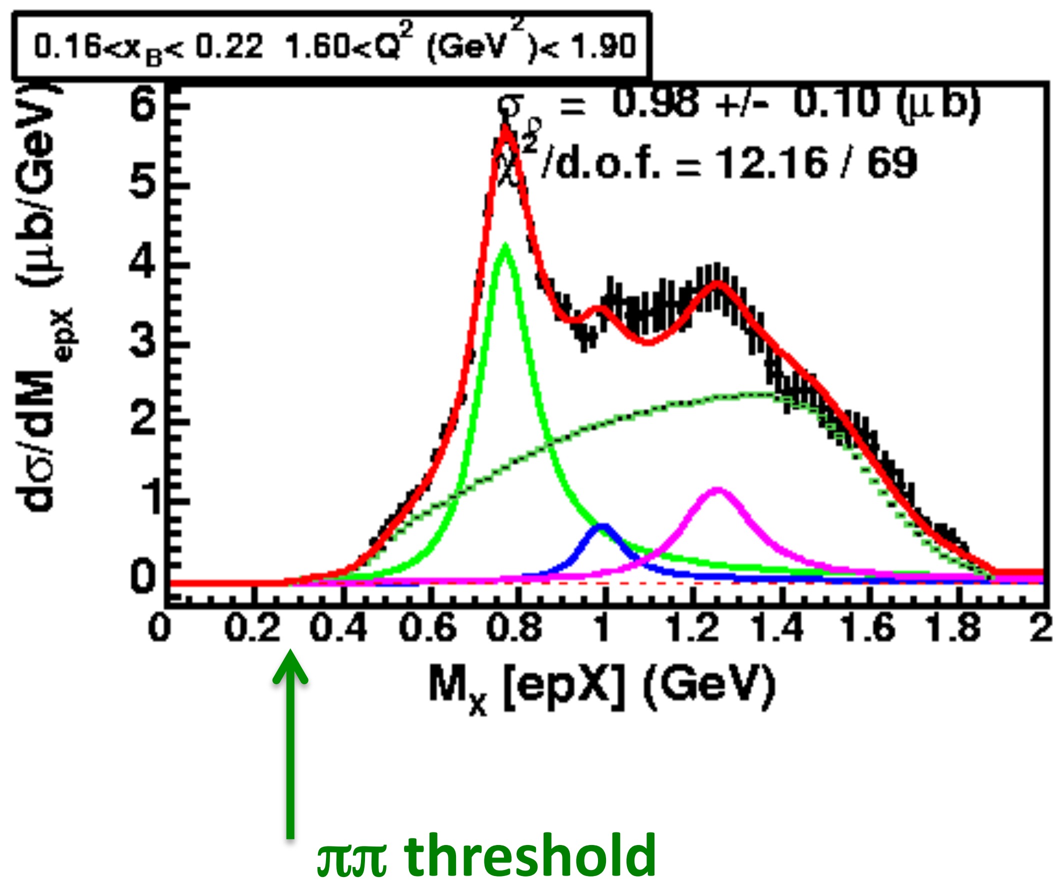
- GPD program
  - DVCS
  - Deep Virtual Vector Mesons: ρ, ϕ, ω, K*, J/Psi
  - Deep Virtual Pseudo Scalars: *pions, kaons, eta*
  - What about Scalars?
    - Orphan particle
    - σ, f_0, *etc*

Deep Virtual Hadron Production (DVHP)

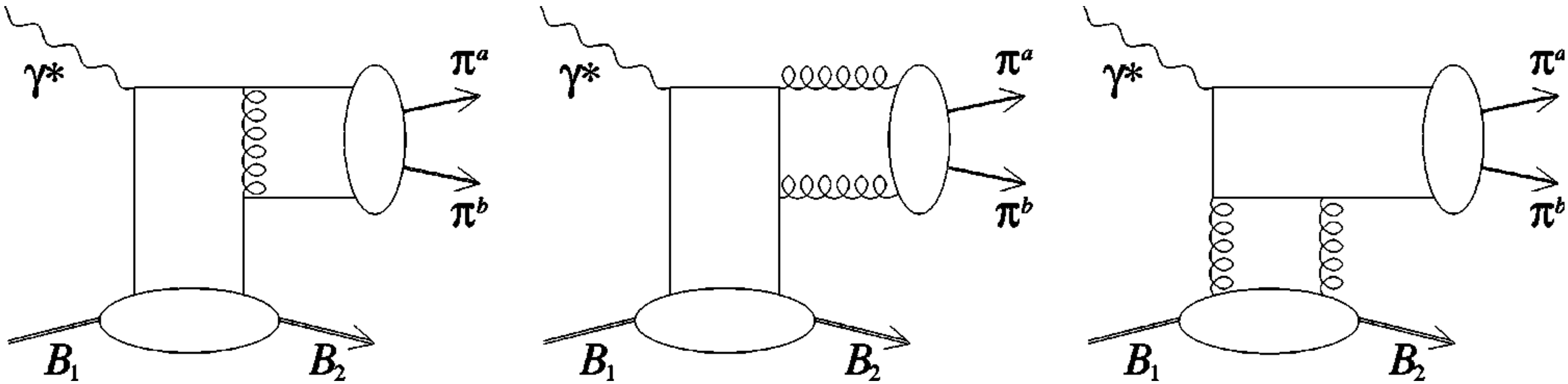
- Factorization of DVHP does not require isolation of a resonant final state (Deep Virtual Meson Production): DVMP $\subset$ DVMP
- Consider Deep Virtual $\pi\pi$ production at $\pi\pi$ mass threshold
  - Dominated by scalar channel
  - 'sigma'-meson, Higgs particle of nuclear physics
  - Connection to $\pi\pi$ scattering amplitude

Example of CLAS data (cf. M.Guidal)

- rho(770)
- $f_0(980)$
- $f_2(1270)$
- Phase space
  $\pi\pi \oplus \Delta\pi$
- $\pi\pi$ **at threshold**
  - **High Luminosity needed**
  - **High resolution mass & angular distributions for → $J^p = 0^+, 1^-,...$**
  - **$\pi^+ \pi^-$ and $\pi^0 \pi^0$ → Isospin= 0, 1,...**



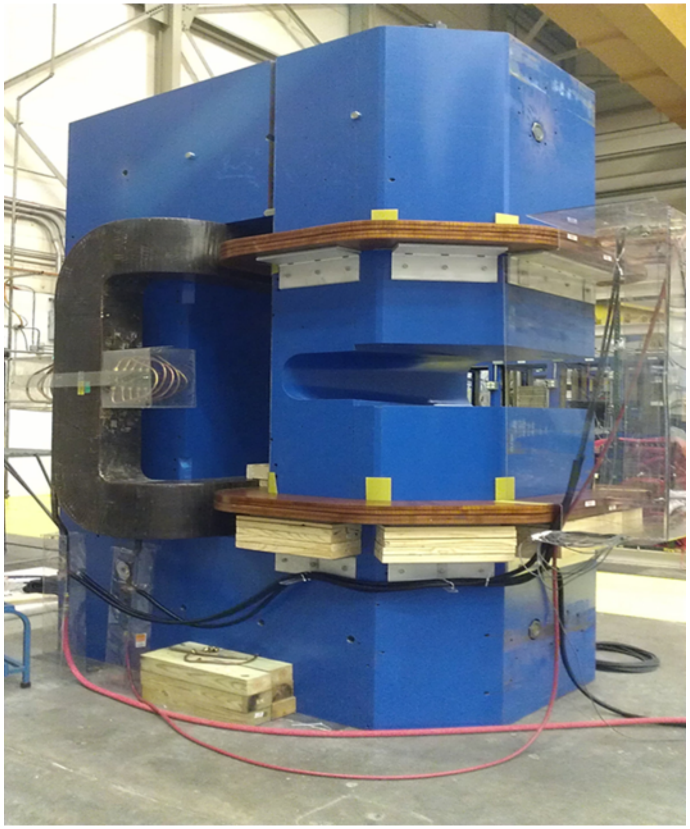
Why Scalars?



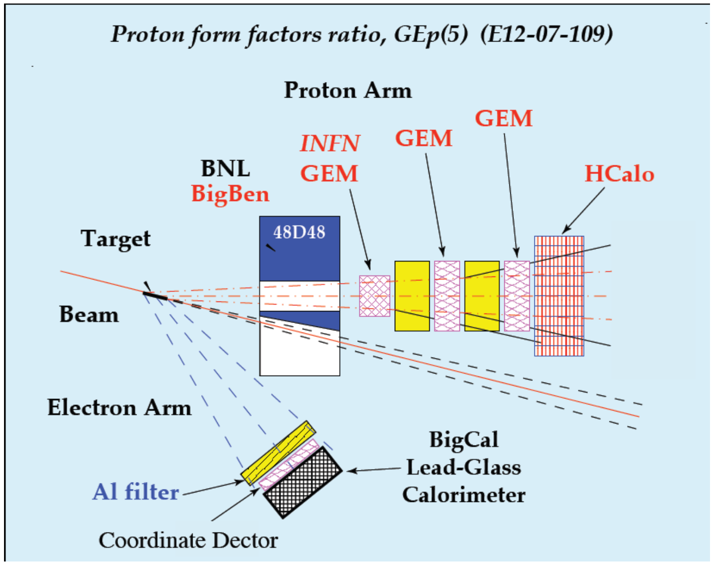
- 0^+0 channel has a gluon Distribution amplitude
  - What is the gluon content of the σ-meson?
- Near ππ threshold:
  " …the dependence of the intensity on $m_{\pi\pi}$ is related to the effective chiral Lagrangian (EChL) describing **the interaction of soft pions with gravity**. Therefore one can use data on hard exclusive pion pair production to probe this yet **unknown part of the EChL**."
  (Lehmann-Dronke, Schaefer, Polyakov, Goeke, PRD, **63**, 114001)

Experimental Opportunities/Options

- Deep Virtual **$\pi\ \pi$** production at large Q^2, W^2:
  Near $\pi\pi$ threshold and
  at small t_{Min}–t.
- Approximate 2-body kinematics:
  - Both pions ~parallel to **q**-vector, correlated with (e,e')
  - Performance:
    - Hall A: Super Bigbite Spectrometer (SBS) for $\pi^+\ \pi^-$ pair,
      HRS or BigBite for e^-.
    - New ECal in SBS for $\pi^0\ \pi^0$ pair?
      Or thin Shower max in front of HCal?
  - SBS: Luminosity ≥ 4•10^{38}/(cm^2sec)

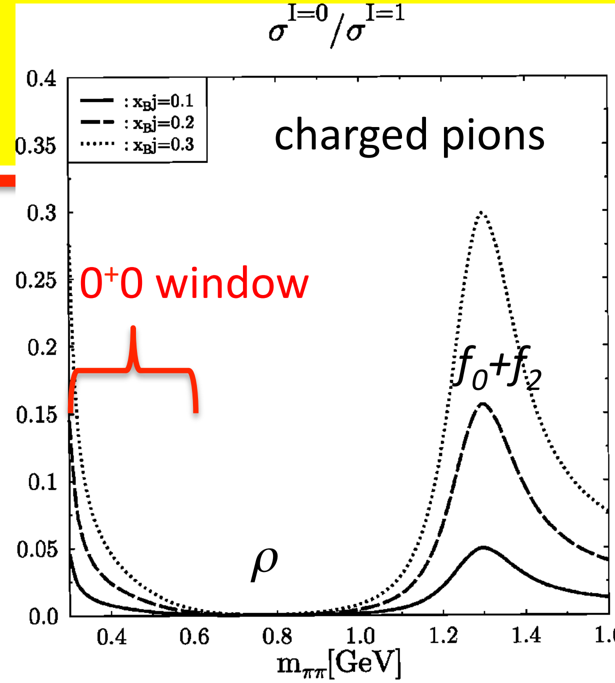


Super Bigbite (SBS), Sample parameters



- Acceptance (θ_{SBS} = 15°)
  - 70 msr ~ (±5° H) x (±12° V)
  - ≥(±50%) Δp/p
- Charged particle resolution
  - $\delta p/p = 0.3\% + 0.03\% GeV/p$
  - $\sigma_\theta = [0.14 + 1.3 GeV/p]$ mrad
- PbGlass Calorimeter for electron arm
  - Operate at 50°C for continuous annealing of Rad damage
- Need to add large (6.5 m^2) ECal or PreShower detector in front (or instead) of HCalo in SBS.
  - Assume $15\%/\sqrt{E_\gamma}$ and ±2mr (1cm @ 5m) resolution.

Extracting $J^{\pi}I = 0^{+}0$ Channel



- $m_{\pi\pi}$ dependence:
- Angular Moments $\langle P_0 \rangle$, $\langle P_1 \rangle$, ...
- Isospin separation *via*
  $\pi^+\pi^-$ / $\pi^0\pi^0$
  - $J^{\pi}I = 1^{-}1$ channel vanishes *for* $\pi^0\pi^0$

← $\pi^+\pi^-$ →

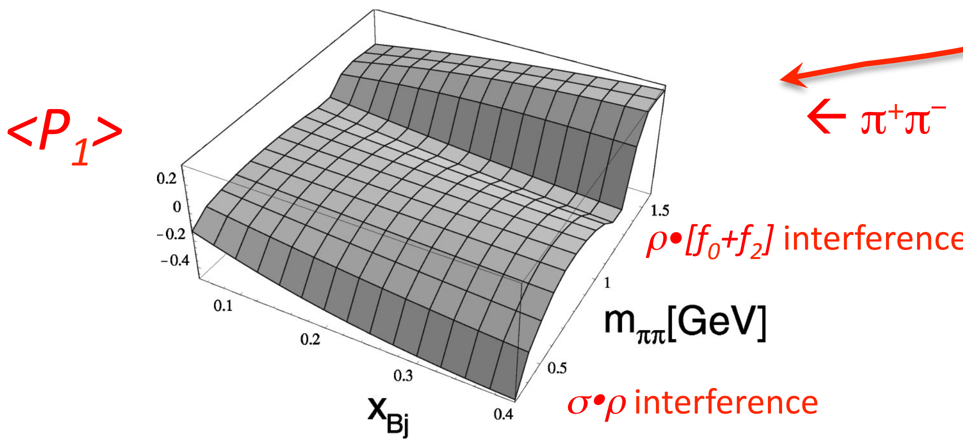


FIG. 4. $\langle P_1(\cos\theta)\rangle^{\pi^+\pi^-}$ as a function of x_{Bj} and $m_{\pi\pi}$.

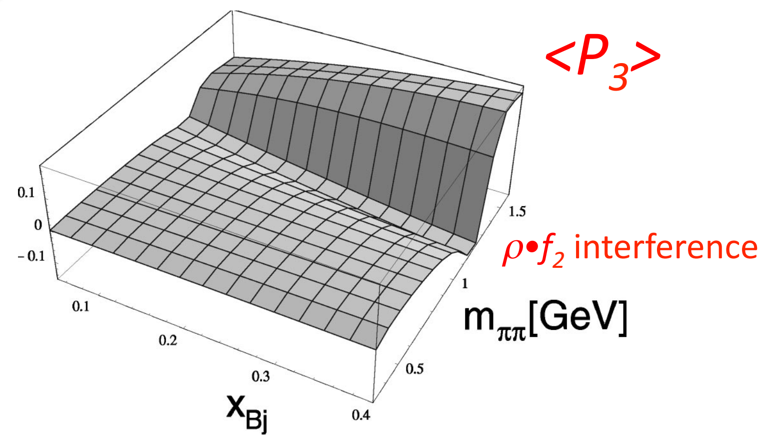
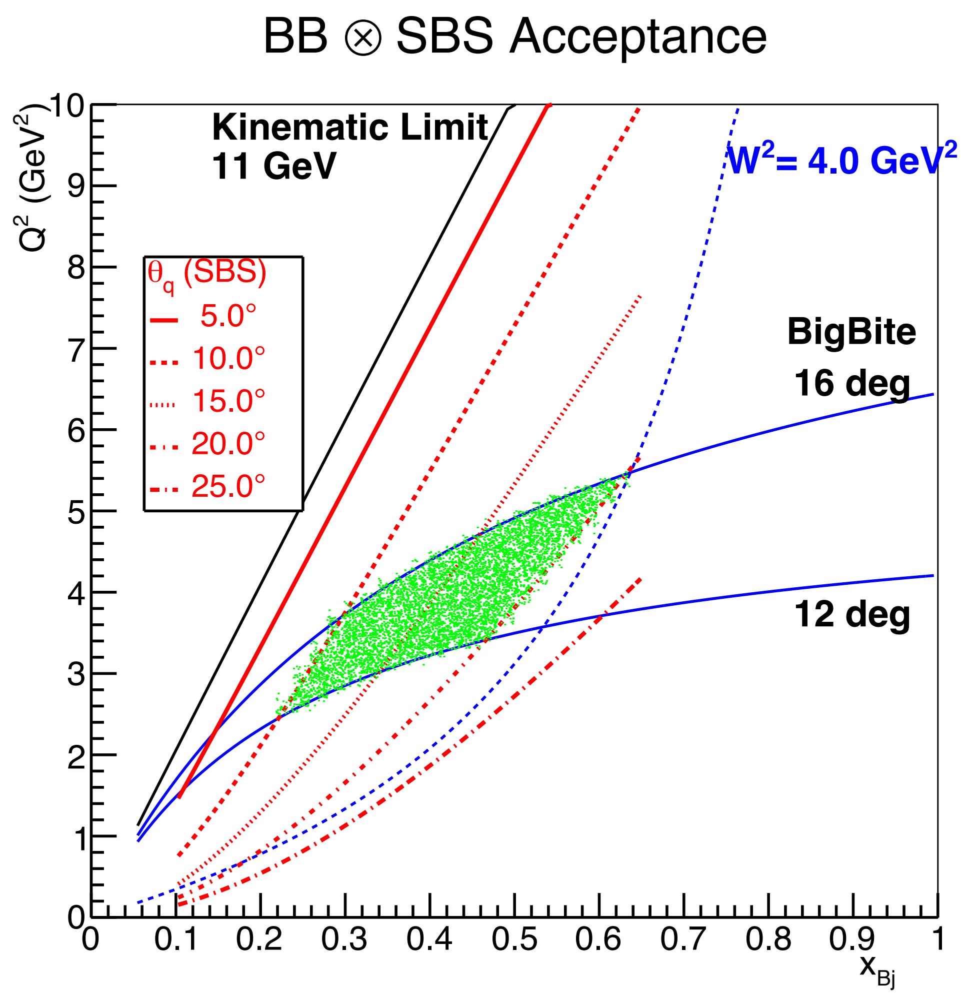


FIG. 5. $\langle P_3(\cos\theta)\rangle^{\pi^+\pi^-}$ as a function of x_{Bj} and $m_{\pi\pi}$.

BigBite(e') ⊗ SuperBigbite(ππ)

- A single setting
- Mass resolution:
  - Charged Channel: $\delta(M_{\pi\pi}) \sim 0.002$ GeV
  - Neutral Channel: $\delta(M_{\pi\pi}) \sim 0.09$ GeV



ππ Threshold Behavior

- ππ Distribution Amplitude
  $\propto C = 1 + b\, m_\pi^2 + \ldots$
- Chiral Lagrangian
  $C \sim 1 - [4L_{11} + L_{12} - 2L_{13}]\, 8 m_\pi^2 / f_\pi^2$
  - Gravitational coupling of pion field.

$$\mathcal{L}^{(4)} = -\mathrm{i}L_9\, \mathrm{Tr}[F^{\mu\nu}\partial_\mu U \partial_\nu U^\dagger] + L_{11} R\, \mathrm{Tr}[\partial_\mu U \partial^\mu U^\dagger] + L_{12} R_{\mu\nu}\, \mathrm{Tr}[\partial^\mu U \partial^\nu U^\dagger] + L_{13} R\, \mathrm{Tr}[mU + U^\dagger m] + \cdots. \tag{79}$$

Here $F^{\mu\nu}$ is the field strength of the photon field, $R_{\mu\nu}$ and R are the Ricci tensor and the curvature scalar of an external gravitational field, and $U = \exp(i\pi^a \lambda^a / f_\pi)$ is the non-linear pseudo-Goldstone field. The ellipsis stands for the terms of the EChL that are not relevant for us here. Now we can use the results of the calculations in Refs. [36,37] to express the constant C and the near threshold behavior of the functions F_π, f_0, and f_2 in terms of the constants L_i in the EChL (79).

Conclusions

- The scalar $\pi\pi$ channel of DVHP offers novel physics
  - Gluon DA
  - Gravitational terms in Chiral Lagrangian
- An exploratory program seems feasible with equipment currently under construction in Halls A & B.
- Assistance in developing a cross section code for Monte Carlo simulations would be greatly appreciated.

$\pi\pi$ Mass resolution

- $\theta/2$ = 0.05 rad = ½ opening angle of pion pair.
- ν = 5 GeV: p_π = 2.5 GeV
  - $M^2 = 4m_\pi{}^2 + (2p_\pi \sin(\theta/2)^2 \sim 4m_\pi{}^2 + (p_\pi\, \theta)^2$
  - M^2 = 0.08 GeV^2 + 0.06 GeV^2 = 0.14 GeV^2
  - M = 0.38 GeV
- Charged Particle
  - $\delta(M) \sim M \;\; \delta p/p \oplus p\, \delta\theta$
  - $\delta(M)$ = 0.001 GeV $\oplus$ 0.002 GeV
- Neutral
  - $\delta p/p$ = 15%/sqrt(p)
  - $\delta\theta$ = 1cm/5m = 2e-3
  - $\delta(M)$= (0.4)(0.1) + (2.5)(0.002) = 0.09 GeV