Partial Wave Amplitudes of K^+K^-

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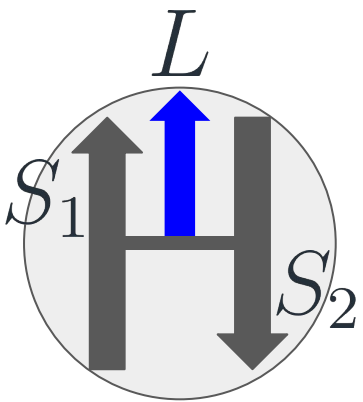
Science and Technology Facilities Council

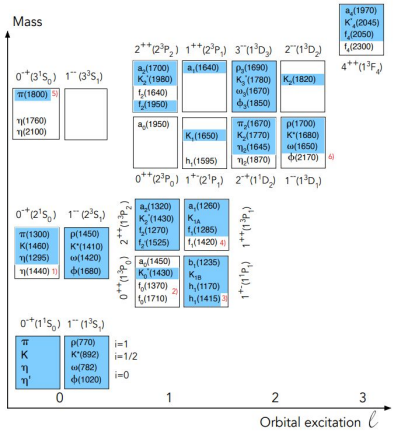
Meson Spectroscopy

The objective is to understand the properties of the mesons which includes mass, width, quantum numbers and decay mechanisms.

Constituent quark model



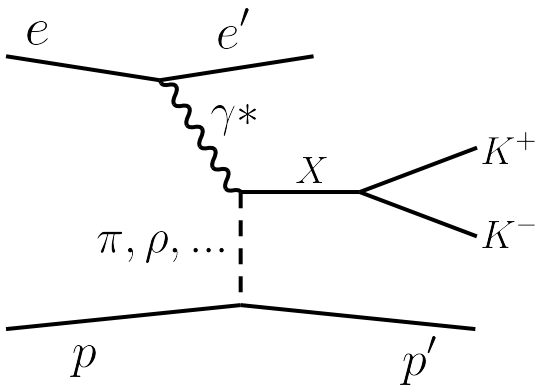
$$J = |L + S|$$
$$P = (-1)^L$$
$$C = (-1)^{L+S}$$



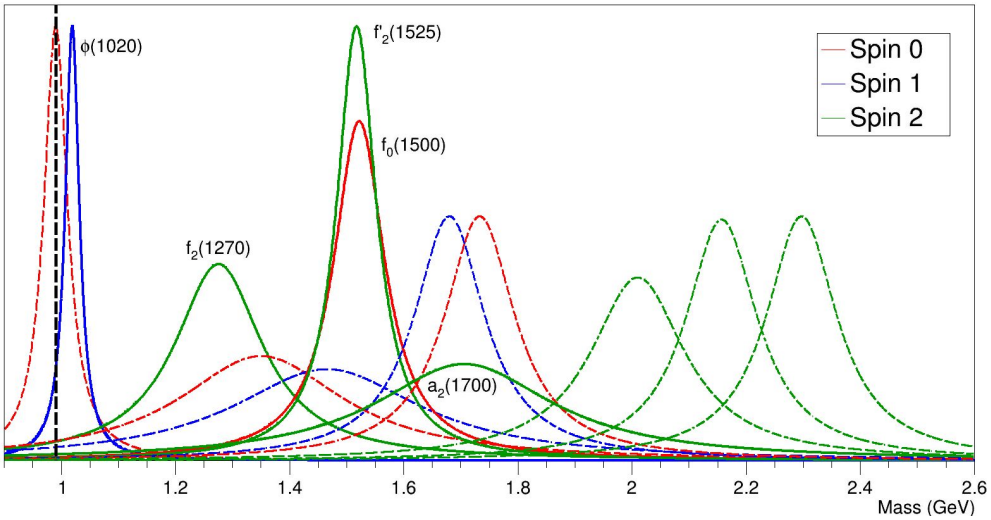
https://pdg.lbl.gov/2021/reviews/rpp2021-rev-light-mesons-spectroscopy.pdf

Channel

Channel: $ep \rightarrow e'pK^+K^-$



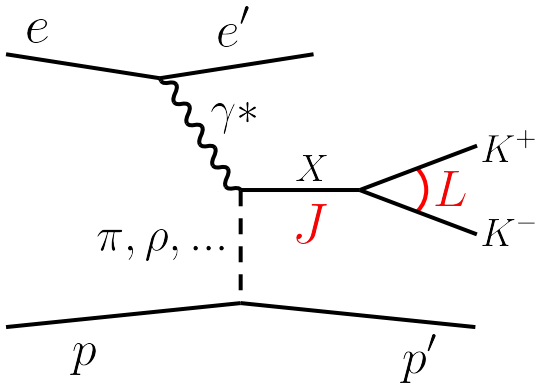
Resonances



(branching fractions not considered)

Partial Wave Formalism

Channel: ep⟶e'pK$^+$K$^-$



$$\frac{d\sigma}{dt dm_{K^+K^-} d\Omega d\Phi} = I(\Omega, \Phi)$$

$$I(\Omega, \Phi) = I^0(\Omega) - P_\gamma I^1(\Omega)\cos 2\Phi - P_\gamma I^2(\Omega)\sin 2\Phi$$

$$I(\Omega) \propto \sum A(\Omega) A^*(\Omega)$$

$$A(\Omega) = \sum_{l,m} l_m Y_l^m(\Omega)$$

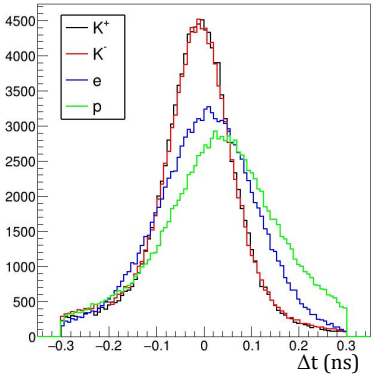
K$^+$K$^-$ partial waves provide information on J of X.

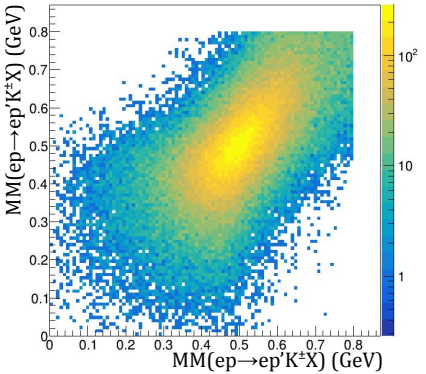
Event Selection

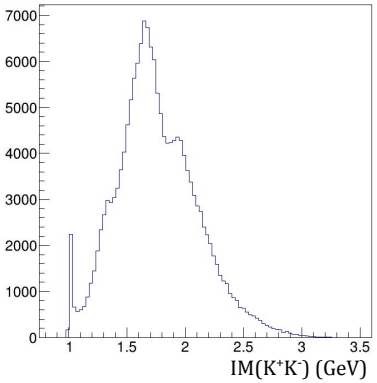
Conditions:

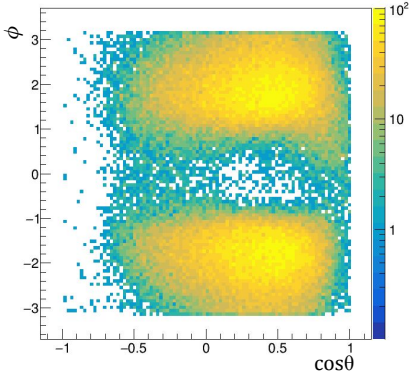
- Exclusive e'pK$^+$K$^-$
- $|\Delta t| < 0.3$ ns
- $|MM^2(e'pK^+K^-)| < 0.01$ GeV^2
- $0.4 < E_{e'} < 5$ GeV
- e' in FT
- Kaons in FD
- MM(ep→ep'K$^\pm$X) < 0.8 GeV

All RG-A Spring 2019 runs

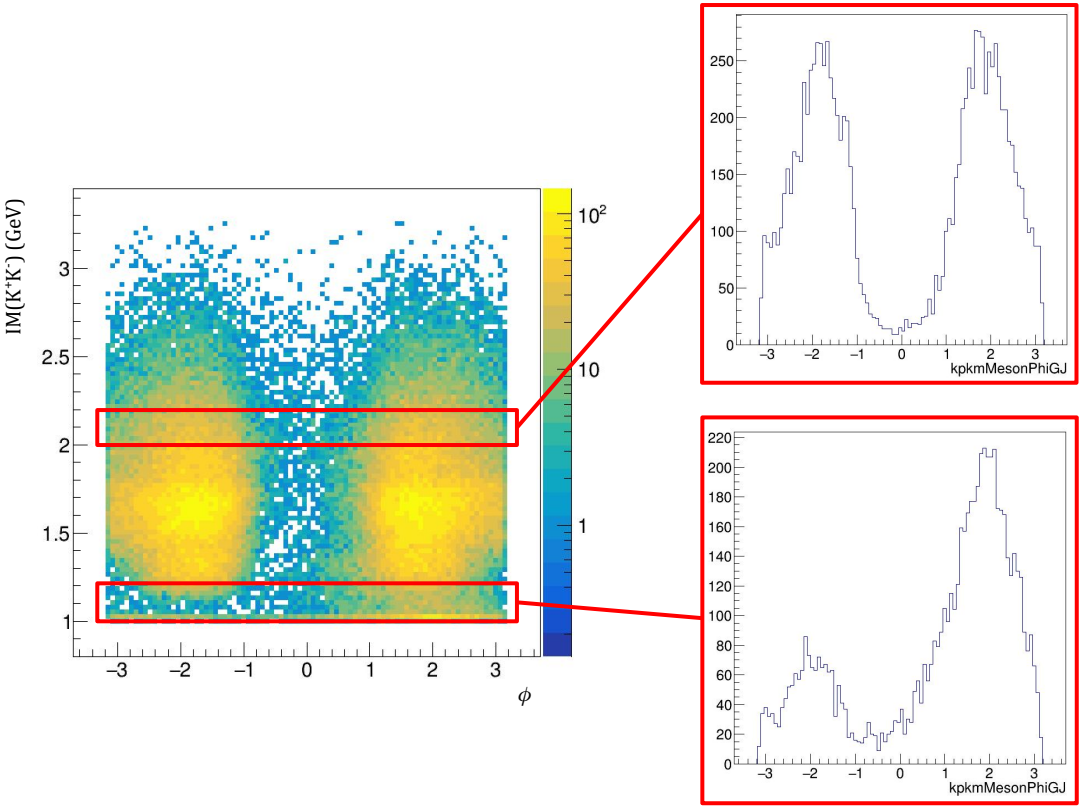








Angular Distributions



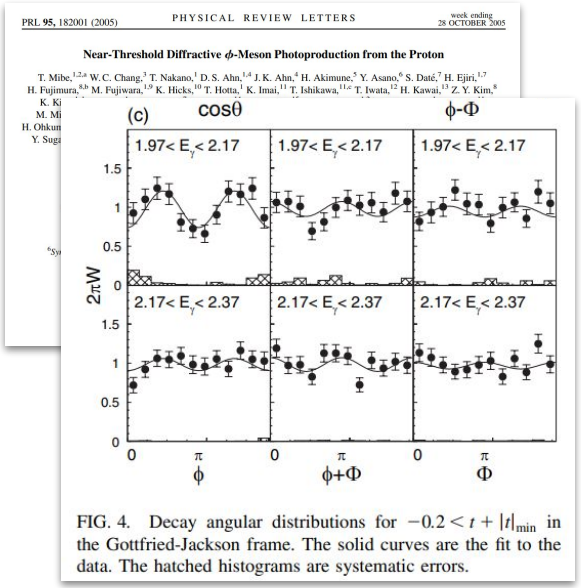
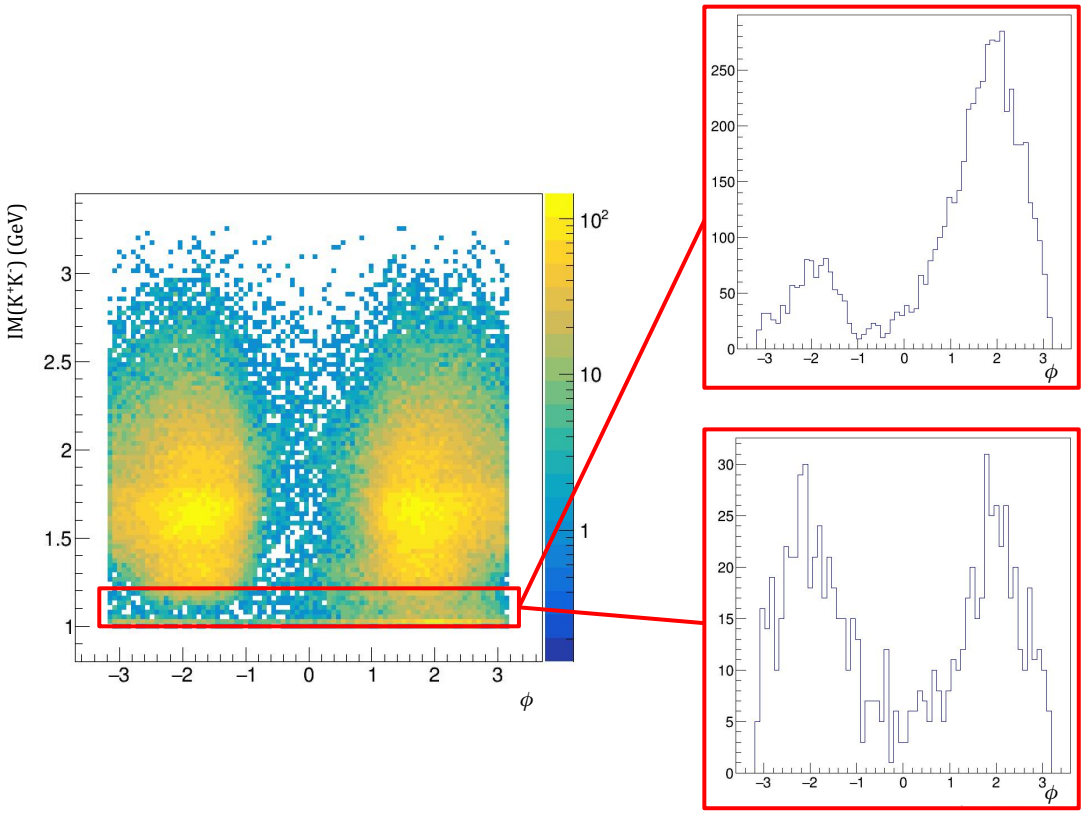


FIG. 4. Decay angular distributions for $-0.2 < t + |t|_{min}$ in the Gottfried-Jackson frame. The solid curves are the fit to the data. The hatched histograms are systematic errors.

Photoproduction of a ϕ meson on protons was studied by means of linearly polarized photons at forward angles in the low-energy region from threshold to $E_\gamma = 2.37$ GeV. The differential cross sections at $t = -|t|_{min}$ do not increase smoothly as E_γ increases but show a local maximum at around 2.0 GeV. The angular distributions demonstrate that ϕ mesons are photoproduced predominantly by helicity-conserving processes, and the local maximum is not likely due to unnatural-parity processes.

Phys. Rev. Lett. 95, 182001

Angular Distributions



Trigger 21 only:

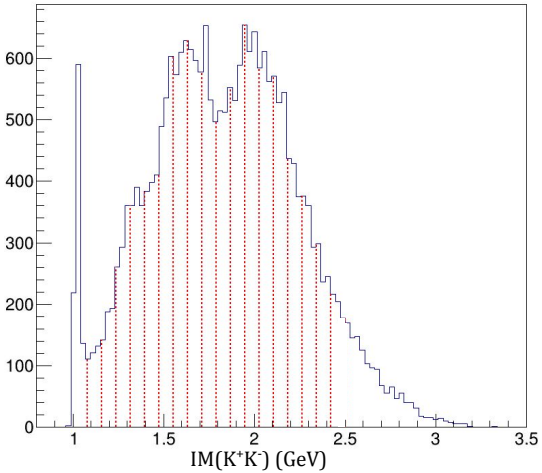
- Hit in FT, 2 hits in any 2 FD sectors
- Prescaler = 1

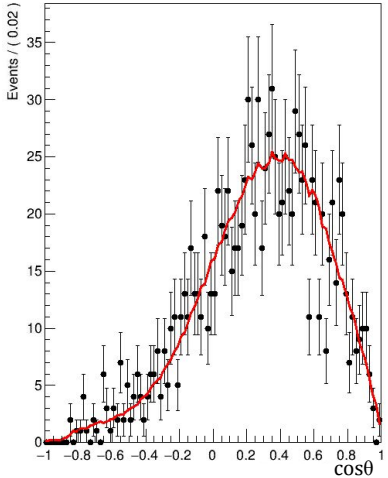
Trigger 20 only:

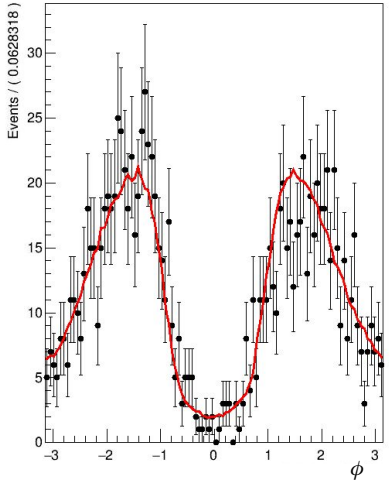
- Hit in FT, hit in FD, hit in CD
- Prescalar = 20

Extracting Amplitudes

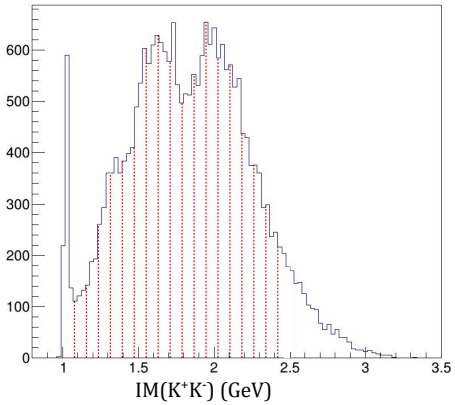
Partial wave amplitudes for S, P and D waves are extracted using brufit by fitting the intensity function to distributions in 20 IM(K^+K^-) bins.

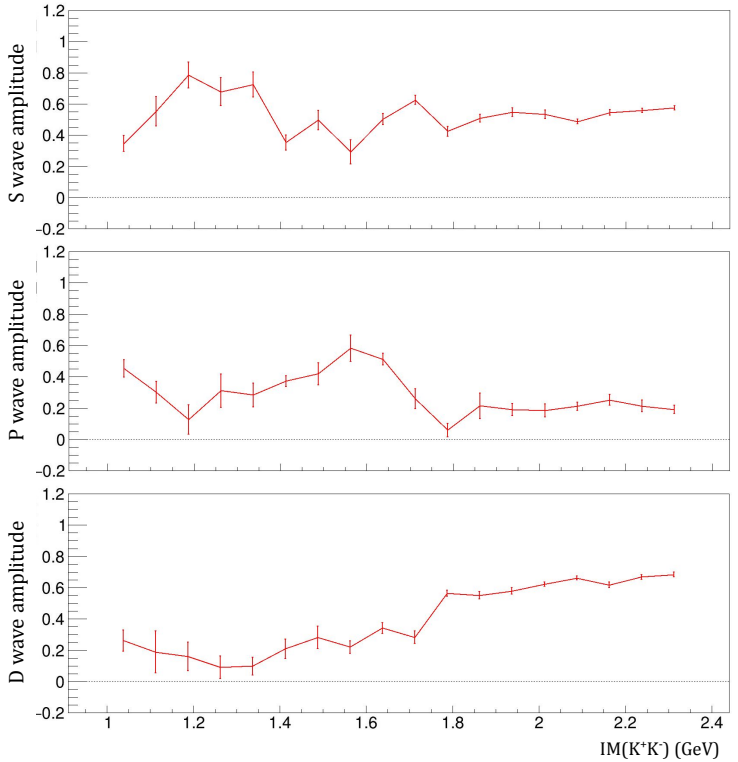






Extracting Amplitudes





Outlook

- Understand effect of triggers on kinematic variables, specifically the Gottfried-Jackson angles
- Improve fitting procedure by introducing clustering algorithm
- Understand baryon background by making use of Van Hove method or equivalent
- Conduct systematic study on all cuts
- Consider semi-inclusive final state $ep \rightarrow e'(p)K^{+}K^{-}$

Thank you for listening

Resonances

Meson	mass (MeV)	Width (MeV)	JPC	KK BR (%)
phi(1020)	1019.5	4.3	1--	49.1
f_2(1270)	1275.4	186.6	2++	4.6
a_2(1320)	1318.2	107.8	2++	4.9
f_0(1500)	1522	108	0++	8.5
f'_2(1525)	1517.3	84.4	2++	88.8
a_2(1700)	1706	380	2++	1.3

Photon Polarization

Consider l+N⟶l'+N', where l is a lepton, which is mediated by a virtual photon. The virtual photon polarization matrix is,

$$\rho_{ij} = \begin{pmatrix} \frac{1}{2}(1+\epsilon) & -\frac{1}{2}i(1+\epsilon^2)^{1/2} & -[\frac{1}{2}\epsilon_L(1+\epsilon)]^{1/2} \\ \frac{1}{2}i(1+\epsilon^2)^{1/2} & \frac{1}{2}(1-\epsilon) & -i[\frac{1}{2}\epsilon_L(1-\epsilon)]^{1/2} \\ -[\frac{1}{2}\epsilon_L(1+\epsilon)]^{1/2} & i[\frac{1}{2}\epsilon_L(1-\epsilon)]^{1/2} & \epsilon_L \end{pmatrix}$$

$\epsilon_L \approx 0$

$$\rho_{ij} = \begin{pmatrix} \frac{1}{2}(1+\epsilon) & -\frac{1}{2}i(1+\epsilon^2)^{1/2} & 0 \\ \frac{1}{2}i(1+\epsilon^2)^{1/2} & \frac{1}{2}(1-\epsilon) & 0 \\ 0 & 0 & 0 \end{pmatrix}$$

Real photon: Transversely, circularly polarised

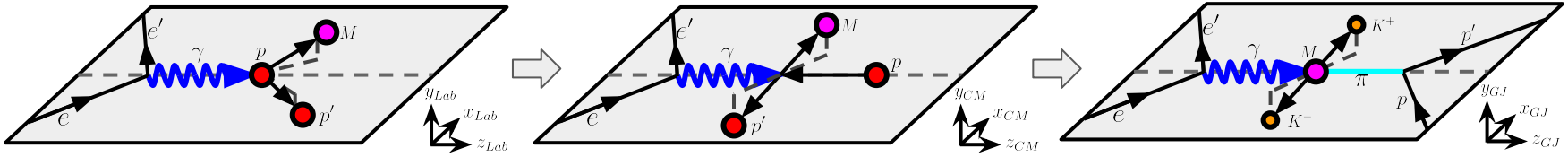
$$\nu = E_e - E_{e'}$$

$$\epsilon_L = (Q^2/\nu^2)\epsilon$$

$$Q^2 = 4E_e E_{e'} sin^2(\theta_{e'}/2)$$

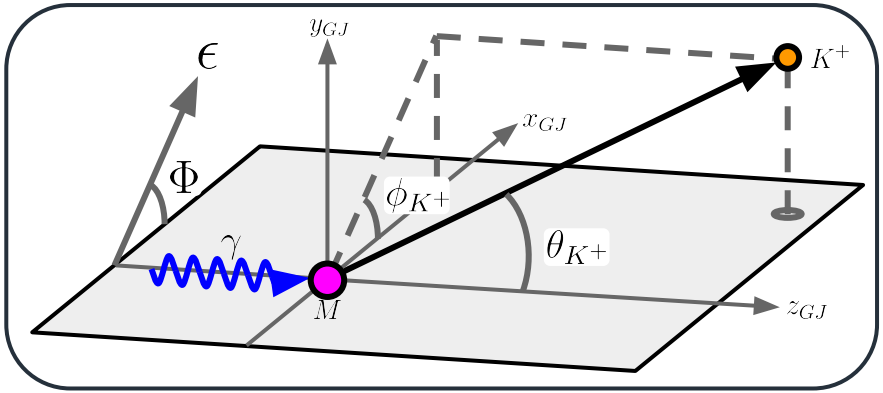
$$\epsilon = [1 + 2\frac{Q^2+\nu^2}{Q^2}\tan^2\theta_{e'}/2]^{-1}$$

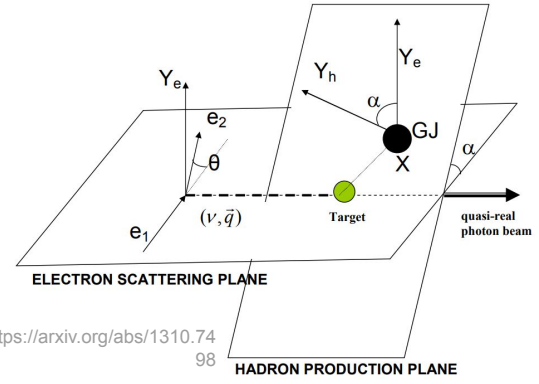
Gottfried-Jackson Frame



$$x_{GJ} = y_{GJ} \times z_{GJ}, \qquad y_{GJ} = \frac{p_\gamma \times p_{p'}}{|p_\gamma \times p_{p'}|}, \qquad z_{GJ} = \frac{p_\gamma}{|p_\gamma|},$$

$$\theta_{K^+} = \cos^{-1}\left(\frac{p_{K^+} \cdot z_{GJ}}{|p_{K^+}|}\right), \qquad \phi_{K^+} = \cos^{-1}\left(\frac{y_{GJ} \cdot (p_{K^+} \times z_{GJ})}{|p_{K^+} \times z_{GJ}|}\right)$$





https://arxiv.org/abs/1310.7498

Event selection and RG-A Triggers

TrigMeson (21) - Event triggered by a detection in the FT with energy 200-4000MeV and hit in both planes of the FT hodoscope, and detections in any two FD sectors using the DC, FTOF and PCAL where DC and FTOT have their own conditions for each detection but PCAL>10MeV for both detections (useful for ep → e’ hF+/−hF+/−X)

TrigFTFDCD (20) - Event triggered by a detection in the FT with energy 200-4000MeV and hit in both planes of the FT hodoscope, a detection in any FD sector using the DC, FTOF and PCAL where PCAL>10MeV, and a detection in the CD using CTOF (useful for ep → e’ hF+/−hC+/−X)

$\Delta t = TOF_{FTOF} - TOF_{hyp}$

$TOF_{hyp} = P/\sqrt{(P^2 + m^2)}$

Fitting

Fitting uses a Monte-Carlo Markov Chain (MCMC) algorithm:

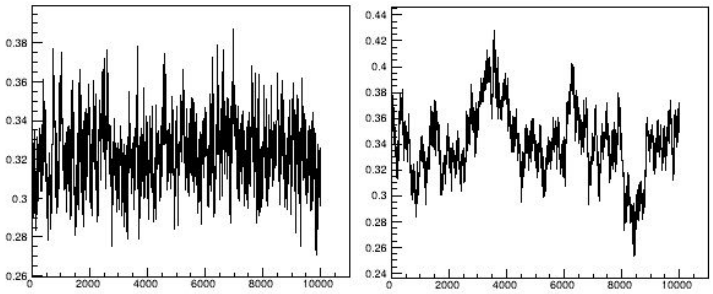
- Random steps (chain property) in parameter space generated only using information of previous step (Markov property) to find global minimum/maximum

$$-\ln L_{acc}^{ext}(p) \;\propto\; -\sum_{i}^{N} \ln f(\tau_i : p)\,\eta(\tau_i) + A(p)$$

$$A(p) \;\simeq\; \sum_{j}^{M} f(\tau_j : p)$$

https://indico.jlab.org/event/829/contributions/14273/attachments/10776/16321/PolarisedTwoPion.pdf

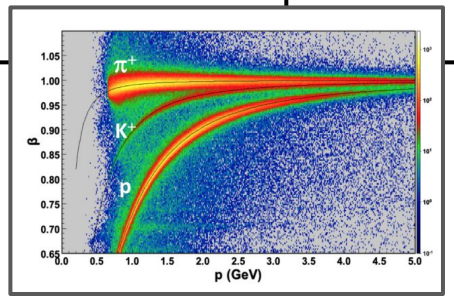
MCMC chain for same parameter, different data sets



good fit poor fit

MesonEx vs GlueX

	Low Q2 electroproduction CLAS12	Coherent Bremsstrahlung GlueX
γ energy	6.5 - 10.5 GeV	8.4-9.0 GeV
Polarization	10% - 80%	~40%
Polarization	event-by-event	average
Photon Flux (30cm LH2)	10^6 – 10^7 γ/s	10^6 – 10^7 γ/s
Hadron PID	$K^{\pm}/\pi$ separation for p<2.5GeV	no $K^{\pm}$ id



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