Double K_s^0 Photoproduction off the proton at CLAS

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CLAS Collaboration Meeting

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Which scalar mesons are we interested in?

$N^{2S+1}L_J$	J^{PC}	$I=1$ $u\bar{d}, d\bar{u}, (d\bar{d}-u\bar{u})/\sqrt{2}$	$I=1/2$ $u\bar{s}, s\bar{u}, d\bar{s}, s\bar{d}$	$I=0$ f'	$I=0$ f
1^1S_0	0^{-+}	π	K	η	η'
1^3S_1	1^{--}	$\rho(770)$	$K^*(892)$	$\phi(1020)$	$\omega(782)$
1^1P_1	1^{+-}	$b_1(1235)$	K_{1B}	$h_1(1380)$	$h_1(1170)$
1^3P_0	0^{++}	$a_0(1450)$	$K_0^*(1430)$	$f_0(1710)$	$f_0(1370)$
...					

- There are **4 isoscalar states** identified by experiment: $f_0(980)$, $f_0(1370)$, $f_0(1500)$ and $f_0(1710)$
- There are **only 2** slots for the f_0 states in the quark model
- The assignments of the f_0 states is still uncertain.

What theory predicts

LQCD calculations

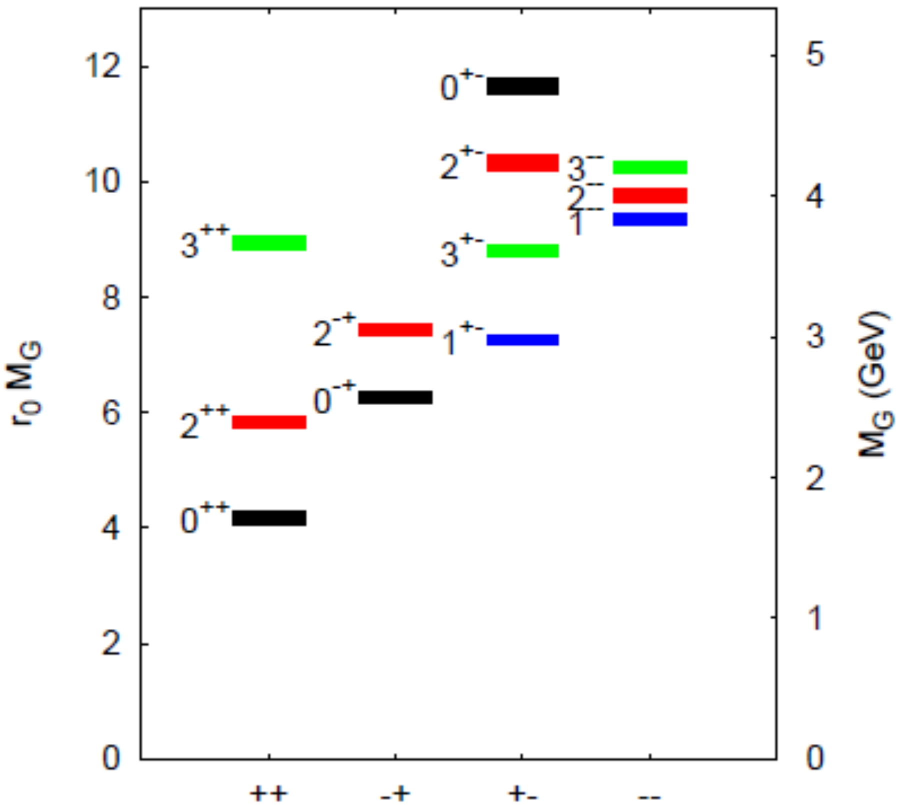


Figure: *Y Chen et al., PRD 73:014516 (2006)*

Mixing scenario

Physical states $f_0(1370)$, $f_0(1500)$, $f_0(1710)$

$$\begin{pmatrix} |f_1\rangle \\ |f_2\rangle \\ |f_3\rangle \end{pmatrix} = \begin{pmatrix} M_{1n} & M_{1s} & M_{1g} \\ M_{2n} & M_{2s} & M_{2g} \\ M_{3n} & M_{3s} & M_{3g} \end{pmatrix} \cdot \begin{pmatrix} |n\bar{n}\rangle \\ |s\bar{s}\rangle \\ |G\rangle \end{pmatrix}$$

are a mixture of bare states

Dependence on model

- Case 1: $M(Glueball) > M(s\bar{s})$
- $f_0(1370)$ strong SU(3) singlet component
- $f_0(1500)$ strong SU(3) octet component
- $f_0(1710)$ strong glueball component

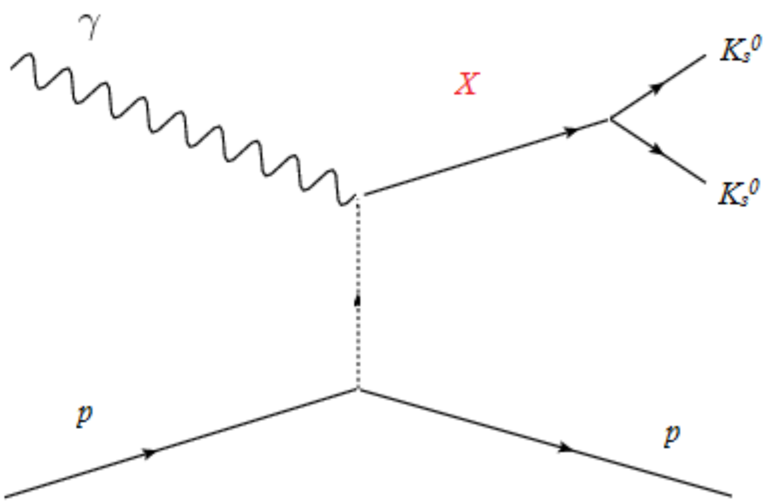
Case 2: $M(Glueball) < M(s\bar{s})$

- $f_0(1370)$ strong SU(3) singlet component
- $f_0(1500)$ strong glueball component
- $f_0(1710)$ strong SU(3) octet component

V. Crede, C.Meyer arXiv:0812.0600v3

PWA formalism

Isobar Model



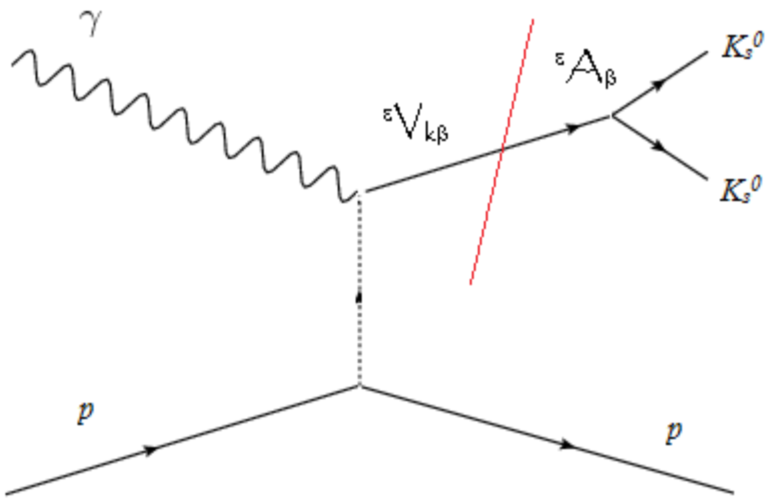
J.P. Cummings , D.P. Weygand, arXiv: physics/0309052v1

- The intensity I(τ)is expanded into a set of amplitudes :

$$\mathrm{I}(\tau) = \sum_{\epsilon,k} \left\{ \left| \sum_{\beta} \left({}^{\epsilon}V_{k\beta} \;\; {}^{\epsilon}A_{\beta}(\tau) \right) \right|^2 \right\}$$

τ = final state variables
V = production amplitudes
A = decay amplitudes

PWA formalism



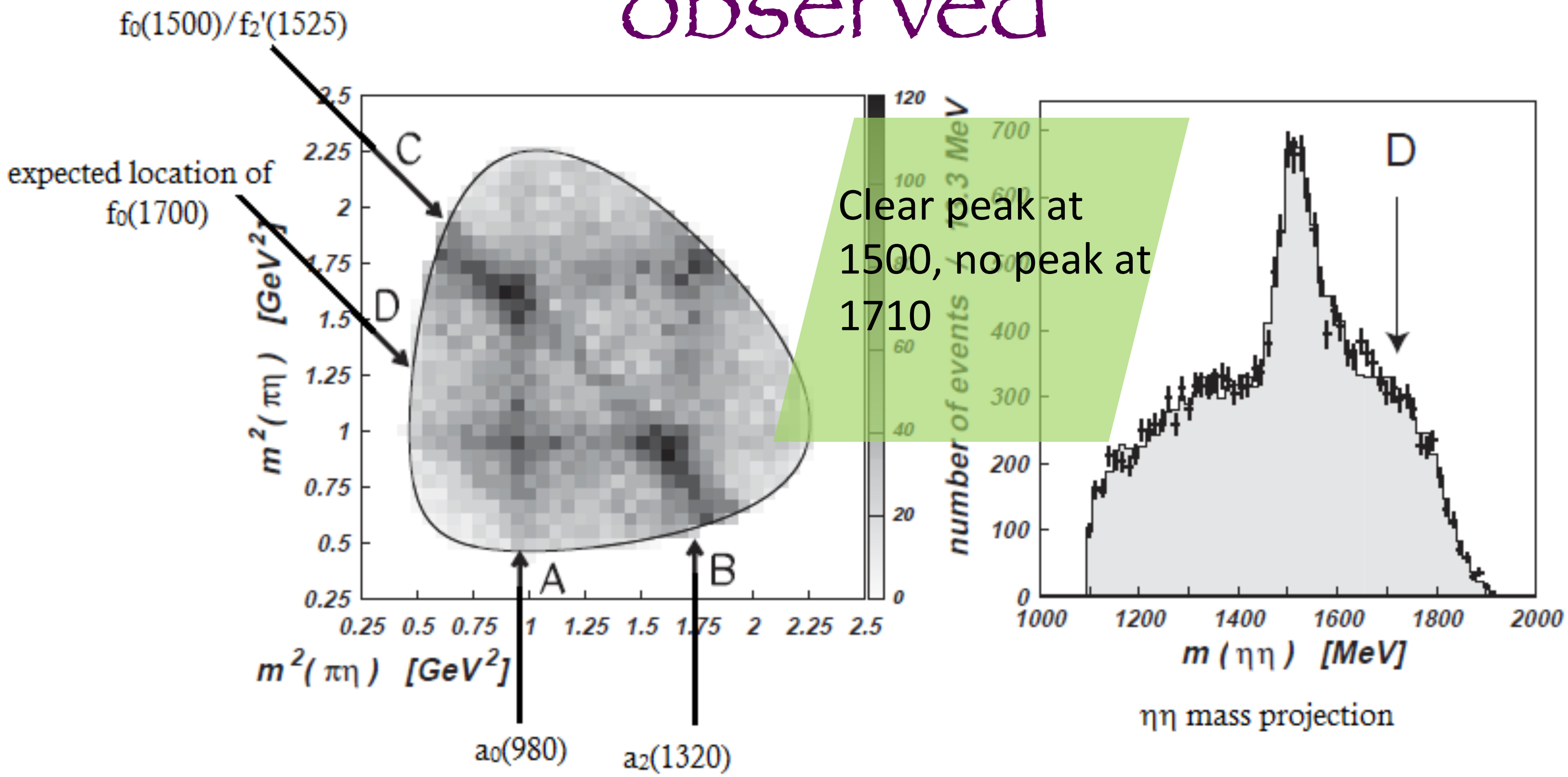
- Data is binned in mass and each mass bin is fit independently

- For each event, production amplitudes are calculated to maximize the likelihood of the event

$$\mathcal{L} = \left[\frac{\bar{n}^n}{n!}\, e^{-\bar{n}}\right] \prod_i^n \left[\frac{I(\tau_i)}{\int (\tau)\eta(\tau)d\tau}\right]$$

- Amplitudes are factored into production amplitudes, $^{\varepsilon}V_{\kappa\beta}$ (to be fitted), and decay amplitudes, $^{\varepsilon}A_{\beta}$ (calculated)

What previous experiments observed

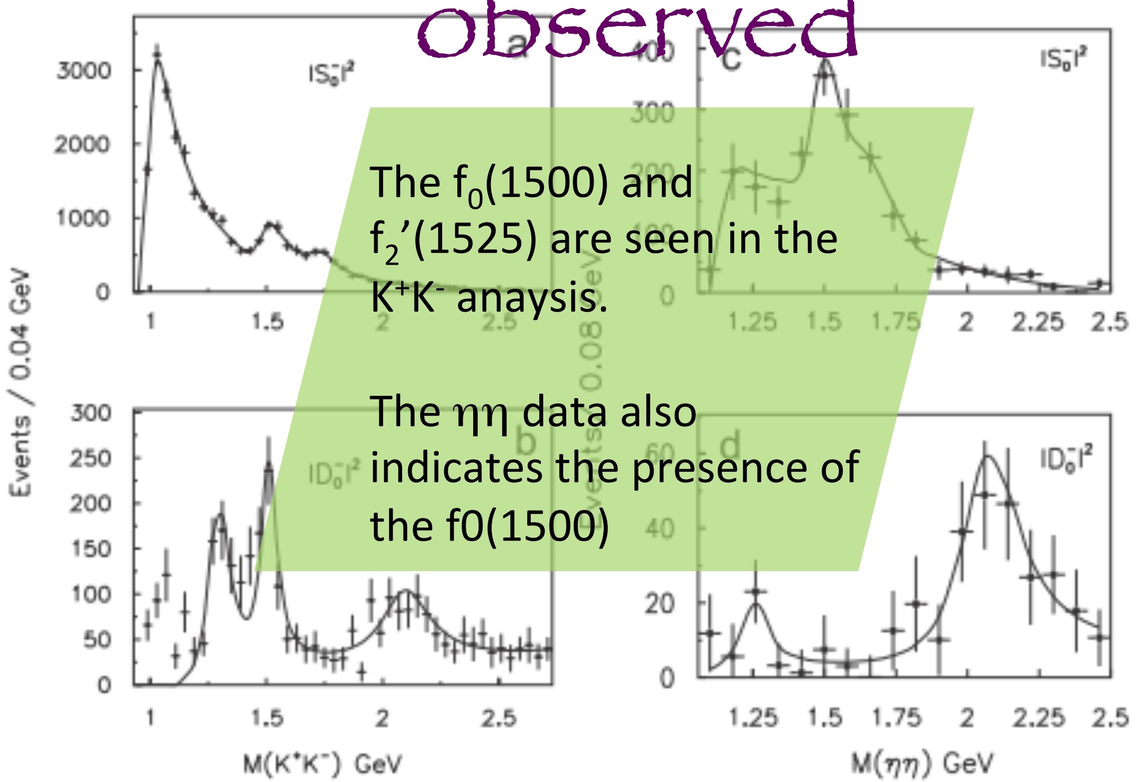


$$p\bar{p} \rightarrow \pi^0 \eta\eta$$

P pbar annihilation : Crystal Barrel

C. Amsler and N.A. Tornqvist, Phys. Rept. 389 (2004) 61.

What previous experiments observed



The $f_0(1500)$ and $f_2'(1525)$ are seen in the K^+K^- anaysis.

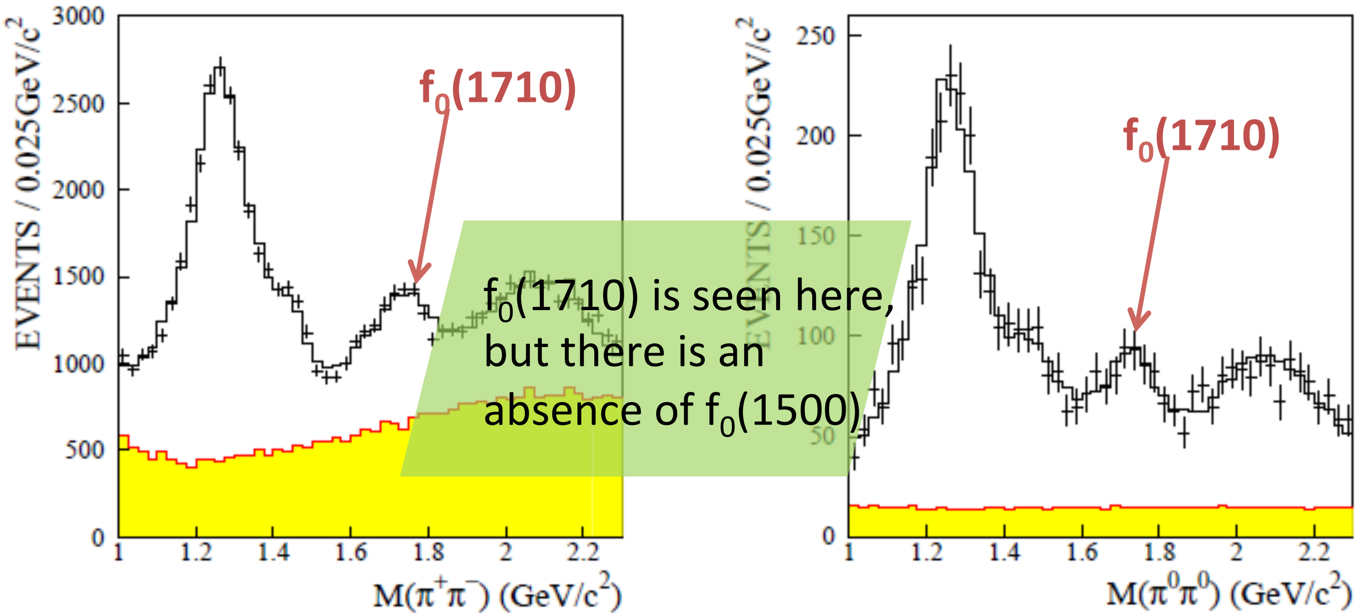
The ηη data also indicates the presence of the f0(1500)

Coupled channel PWA analysis of K^+K^- and $\pi^+\pi^-$ data

Central Production : WA102

D. Barberis et al., [WA102 Collaboration], Phys. Lett. B462 (1999) 462, hep-ex/9907055

What previous experiments observed

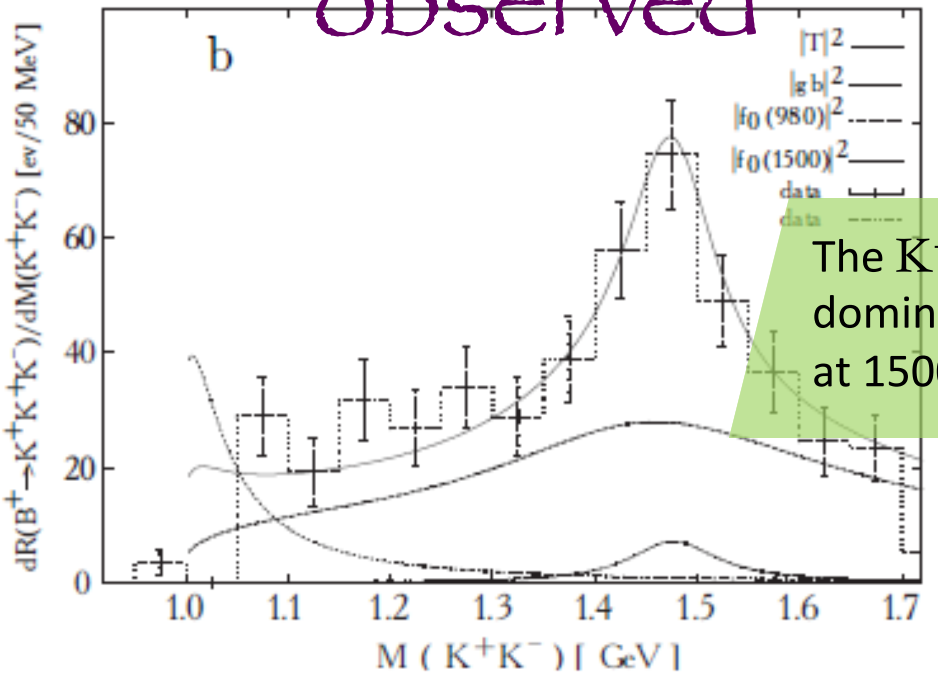


Partial wave analysis of $J/\Psi \longrightarrow \gamma\pi^+\pi^-$ and $\gamma\pi^0\pi^0$

J/ψ radiative decay : BES II

M. Ablikim et al., [BES Collaboration] Phys. Lett. B 642 (2006) 441

What previous experiments observed



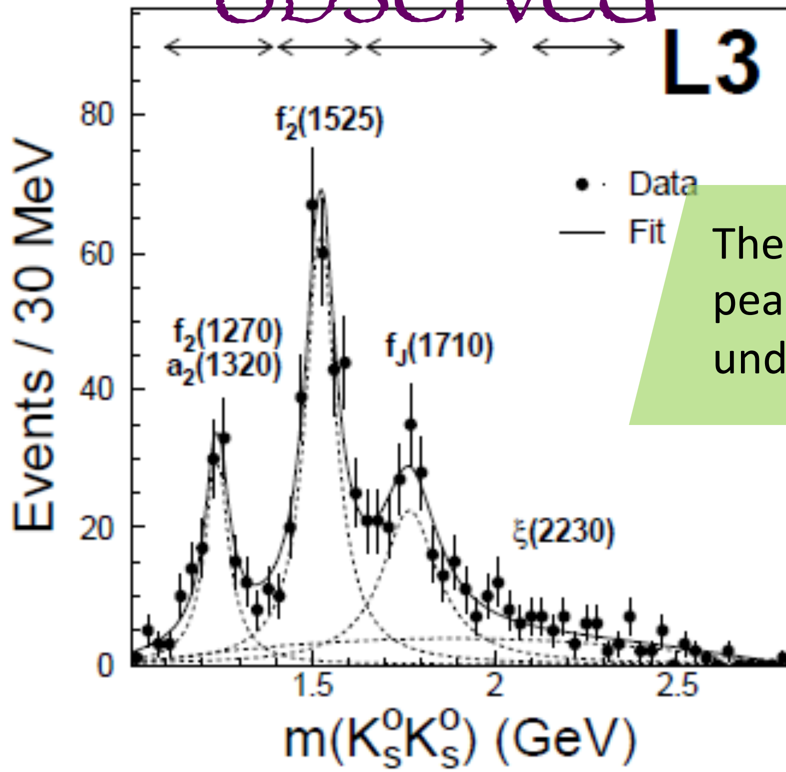
The K^+K^- spectrum is dominated by a peak at 1500 MeV

$B^+ \rightarrow K^+K^+K^-$

B meson decays : Belle

P. Minkowski and W. Ochs, Eur. Phys. J. C39 (2005) 71, hep-ph/0404194

What previous experiments observed

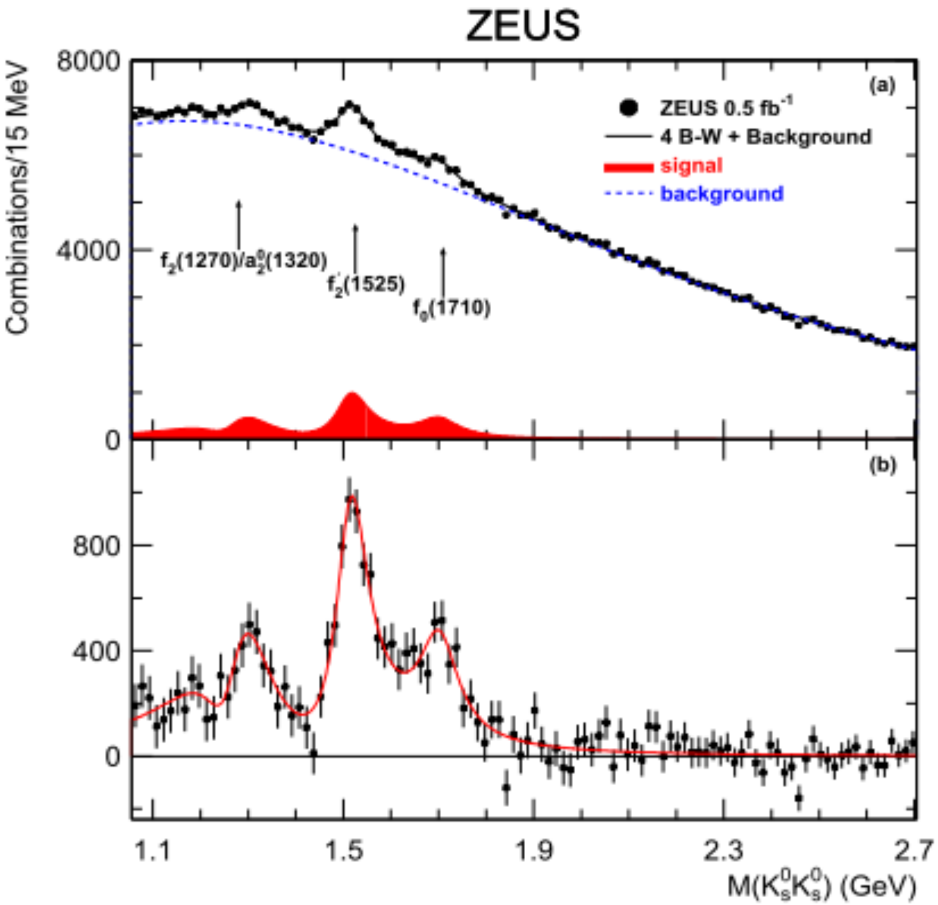


The LEP data shows a peak at 1710 MeV with undetermined spin

$\gamma\gamma$ Collisions : LEP $\quad \gamma\gamma \rightarrow K_s^0 K_s^0$

M. Acciarri et al., [L3 Collaboration] Phys. Lett. B501 (2001) 173, hep-ex/0011037

The paper that got us interested..



ZEUS Collaboration: S. Chekanov, et al, *Inclusive K0SK0S resonance production in ep collisions at HERA, Phys.Rev.Lett.101:112003,2008, arXiv:0806.0807v2*

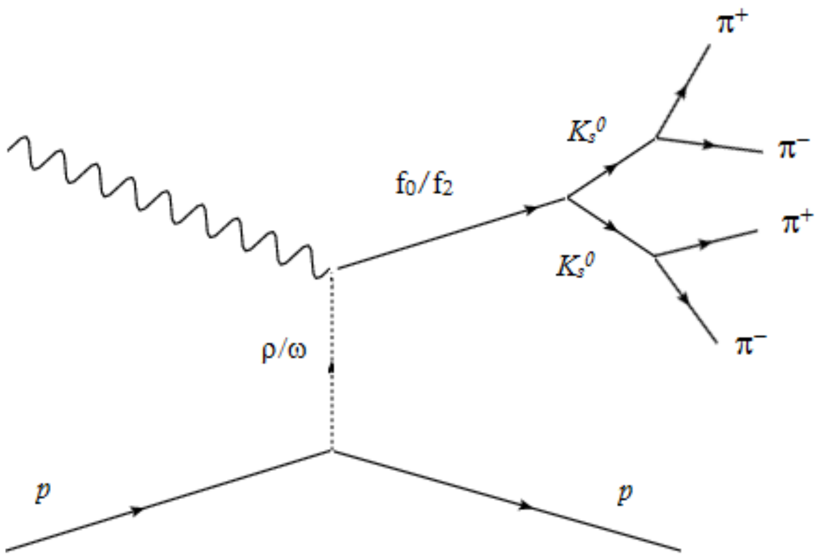
Why choose strange decay?

M.Chanowitz suggests in PRL 95, 172001 (2005) that glueballs are more likely to decay to strange channels

Why choose $K_s^0K_s^0$?

Ensure that the final state has the same PC =++ as the lightest glueball

Photoproduction of scalar mesons

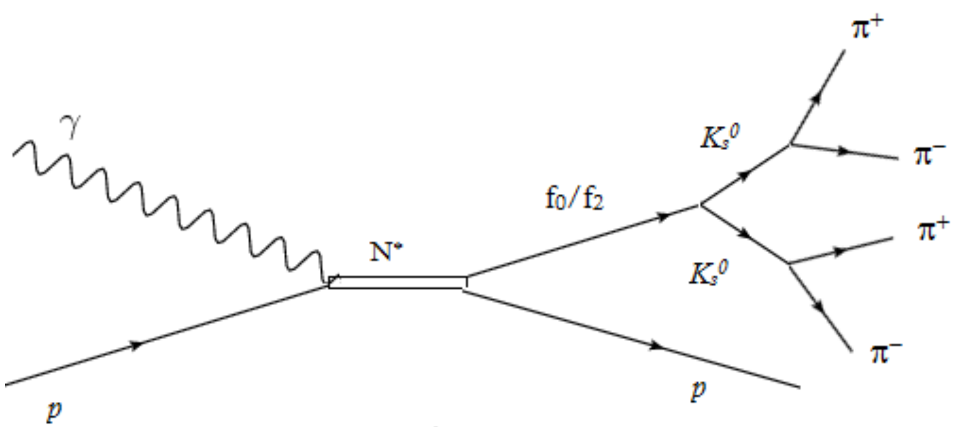


Photoproduction might be effective in producing scalar mesons via Pomeron Exchange or via the hadronic component of the photon.

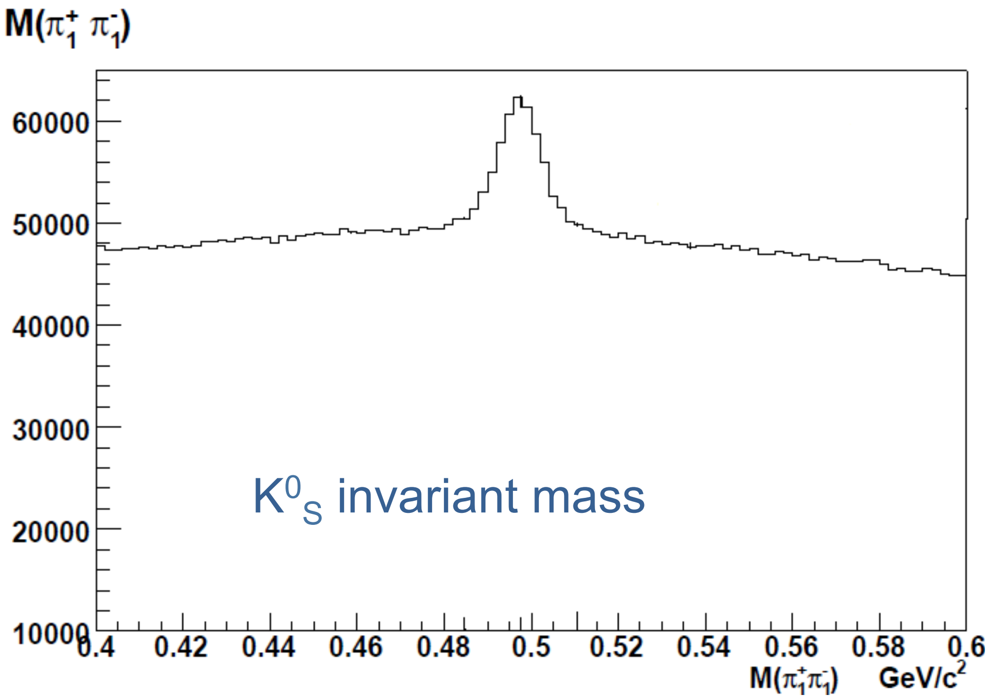
Vincent Mathieu, Nikolai Kochelev, Vicente Vento arXiv:0810.4453

Photoproduction is a good way to study scalar mesons. Dominant mechanism : ρ, ω exchange

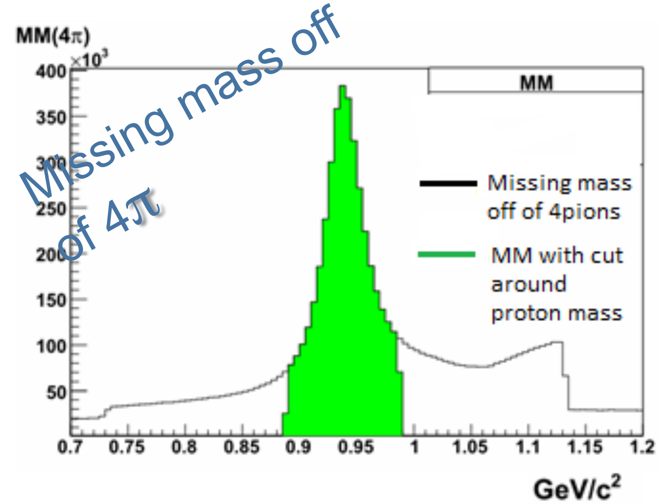
A. Donnachie, Y.S Kalashnikova arXiv:0806.3698v1



Event selection

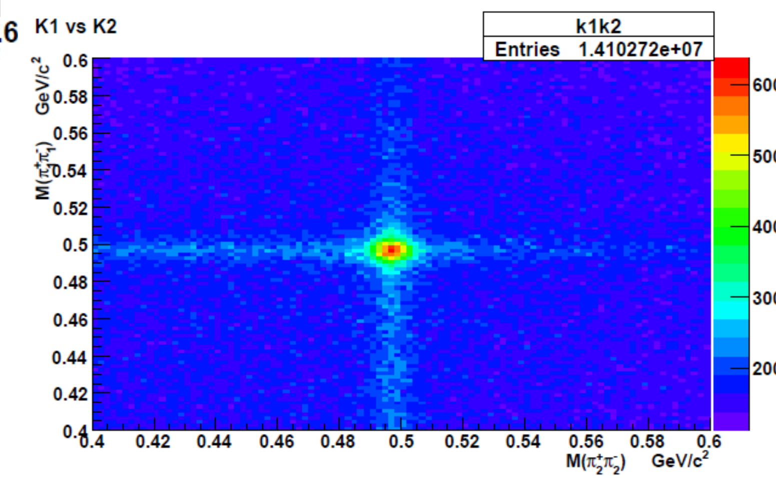


$K^0{}_S$ invariant mass

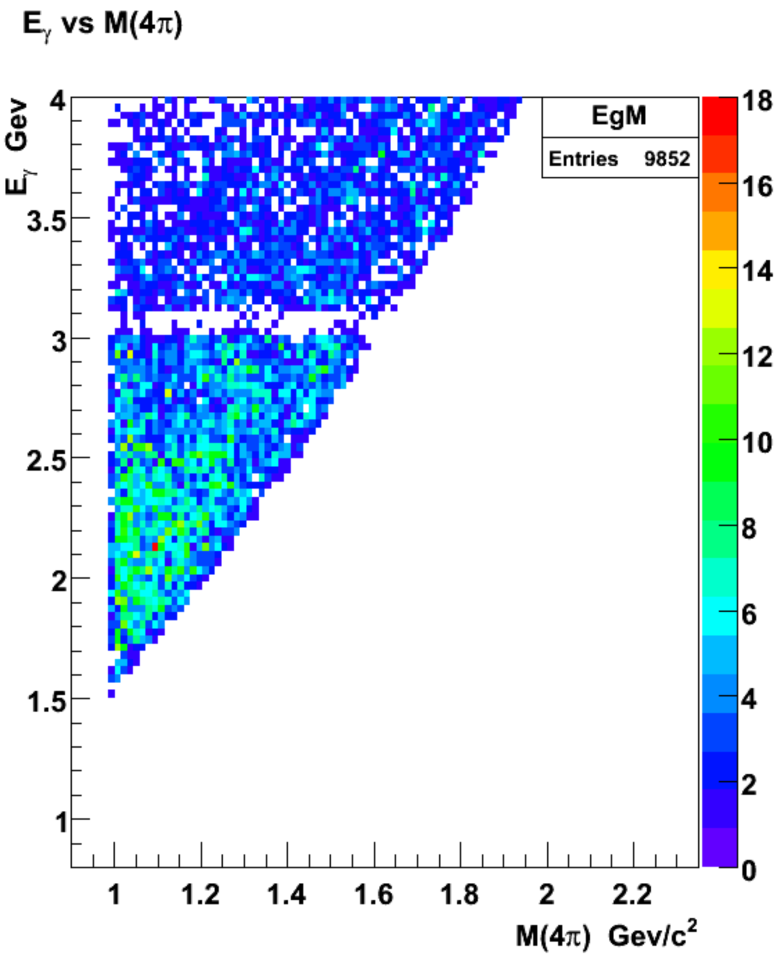


Missing mass off of 4π

The adjoining plot shows the high correlation between the two $K^0{}_s$



Event selection



The threshold photon energy to produce an $f_0(1500)$ is 2.7 GeV.

In our analysis, we make a cut $E_\gamma > 2.7$ GeV

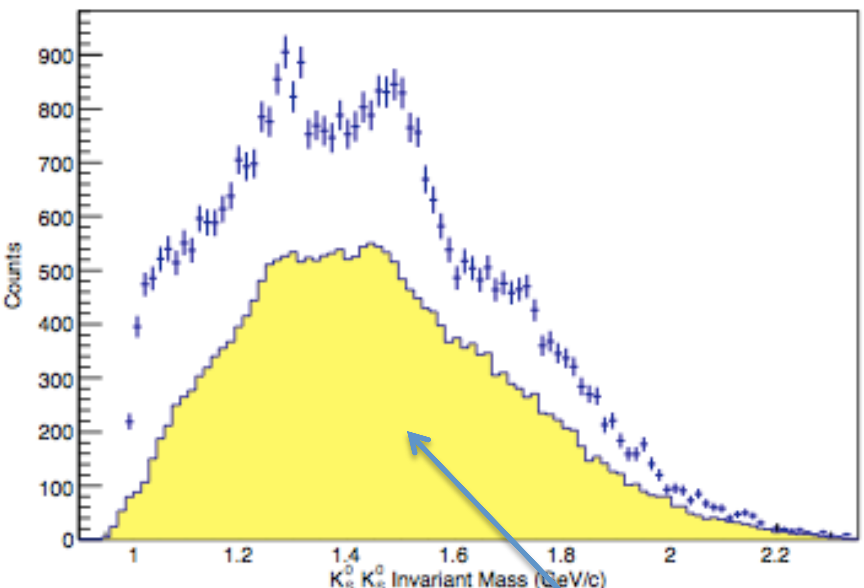
Cuts used in this analysis

Cut Level	Type of Cut	Size of Cut
1	Timing Cut for identification of pions	± 1 ns
2	Fiducial Cut	Fit to CLAS acceptance
3	Missing mass (proton)	± 0.0497 GeV (3σ)
4	Photon beam energy	2.7-3.0 and 3.1-5.1 GeV
5	K_S^0 peak and sideband subtraction	0.01614 GeV (3σ)

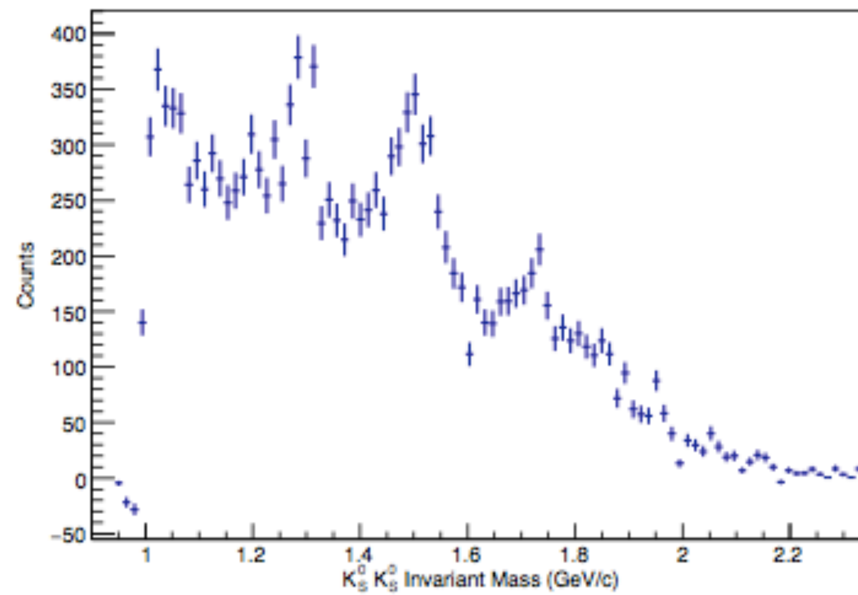
Table I. The event selection criteria (cuts) used in this analysis.

$M(K_sK_s)$ Spectra

Signal + Background (S+B)



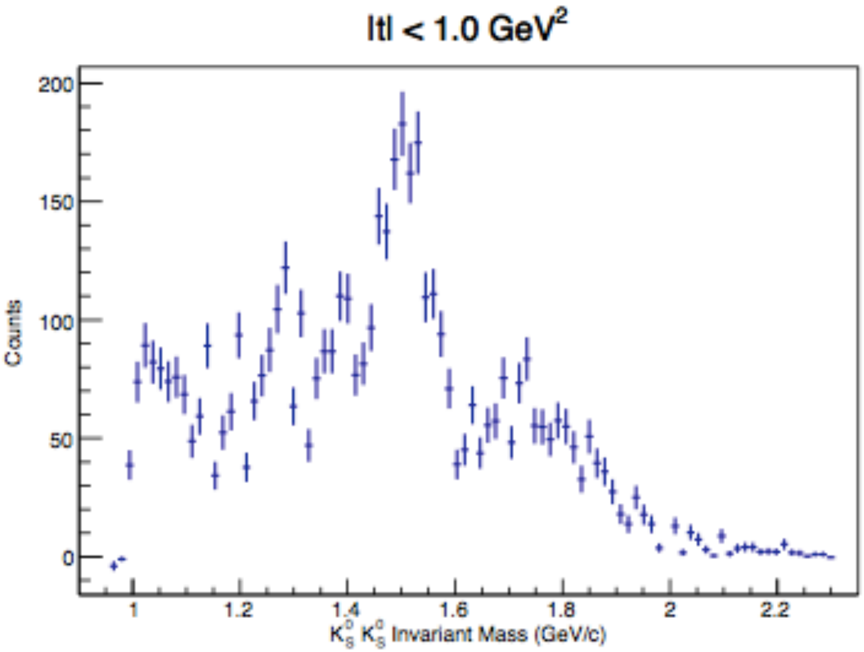
Signal - Background (S-B)



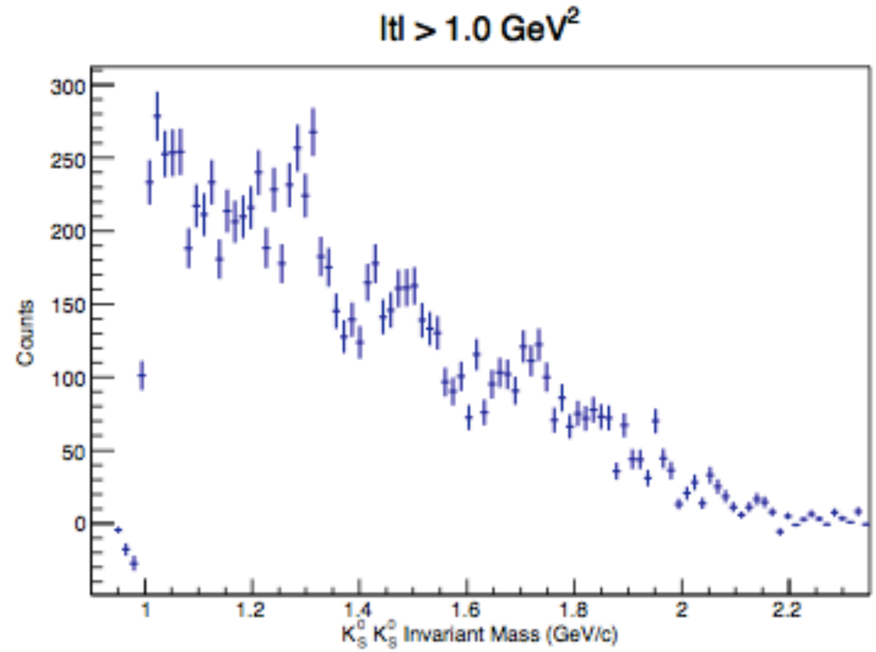
Background (2-D sidebands)

Cuts on Mandelstam t

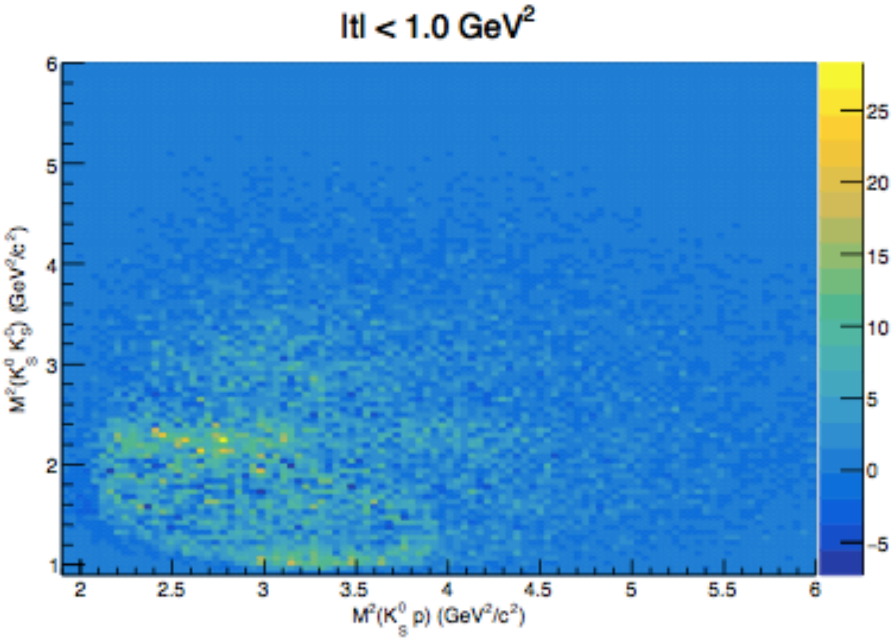
$t < 1.0$ GeV^2

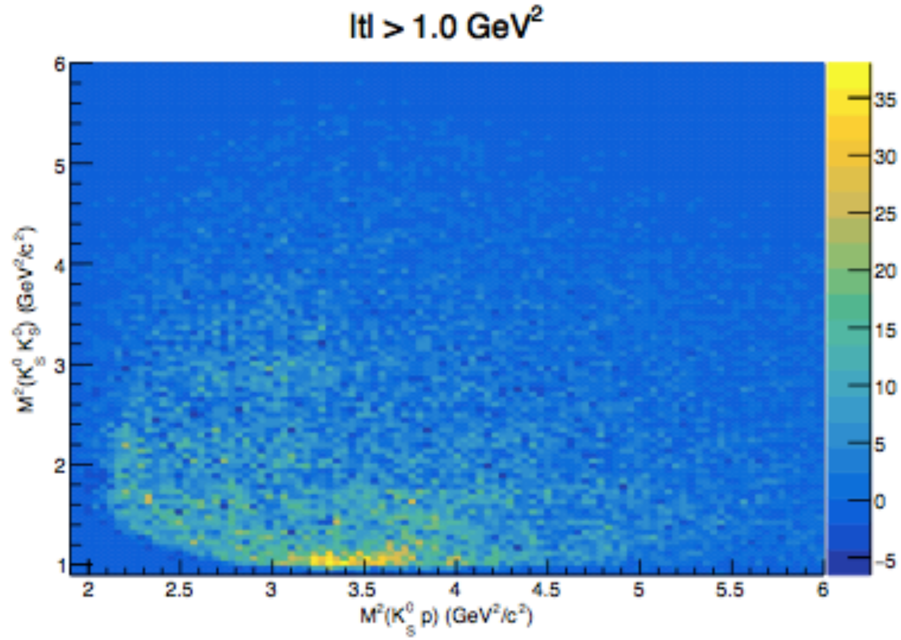


$t > 1.0$ GeV^2

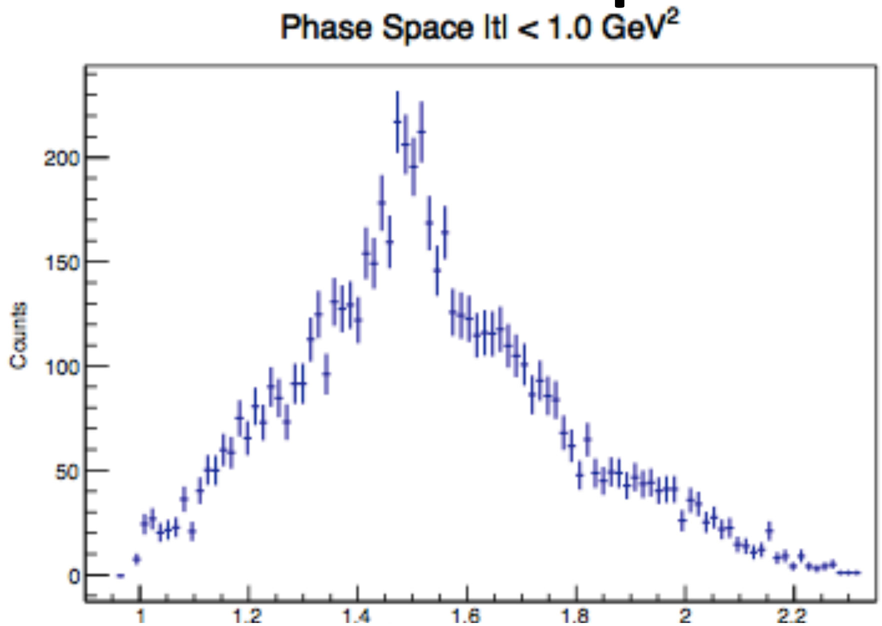


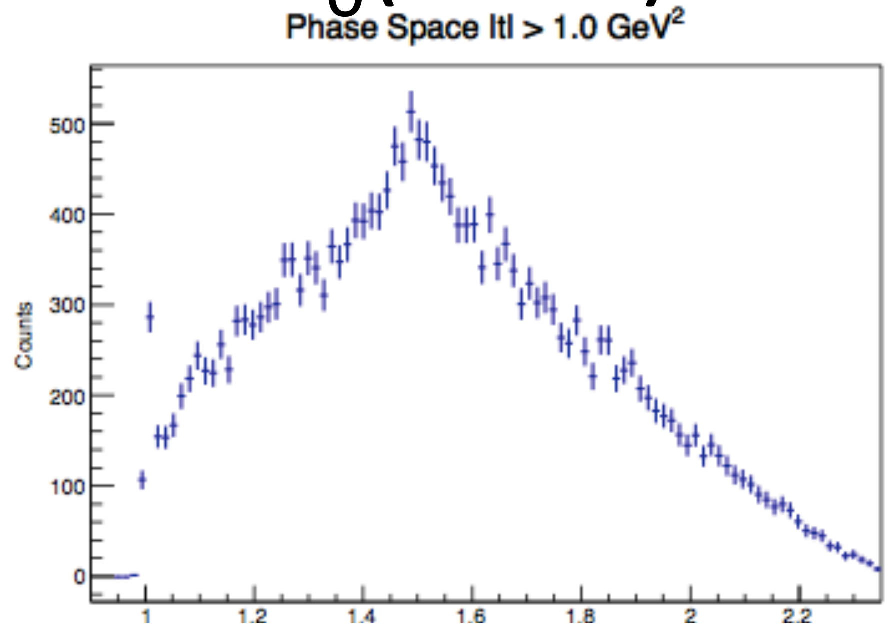
Dalitz Plots (cut on t)

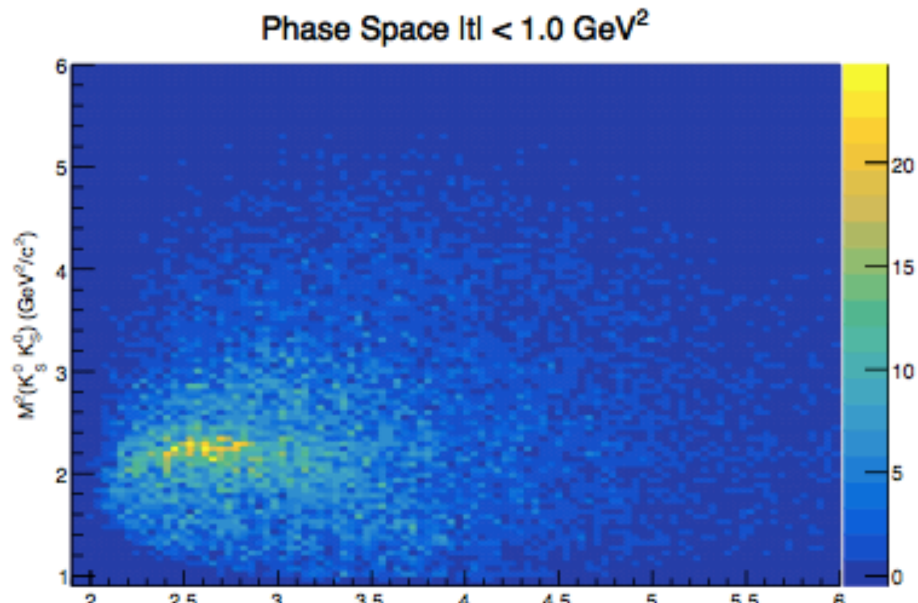


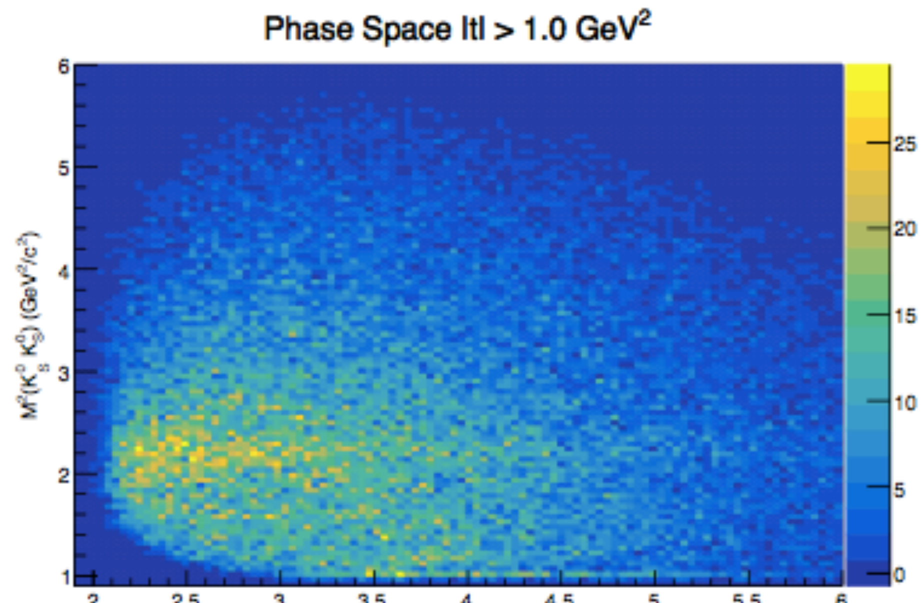


Phase space MC with $f_0(1500)$

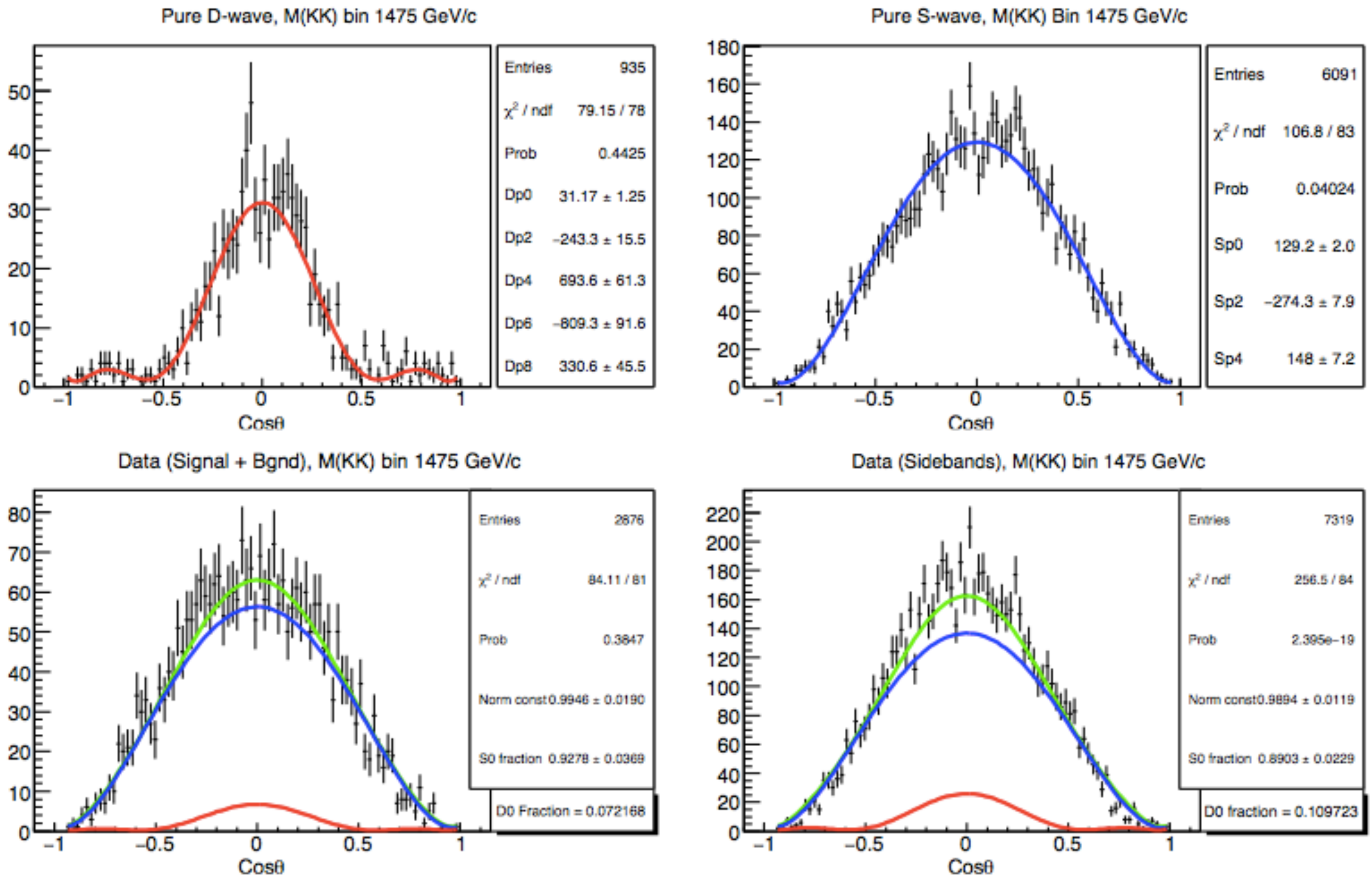




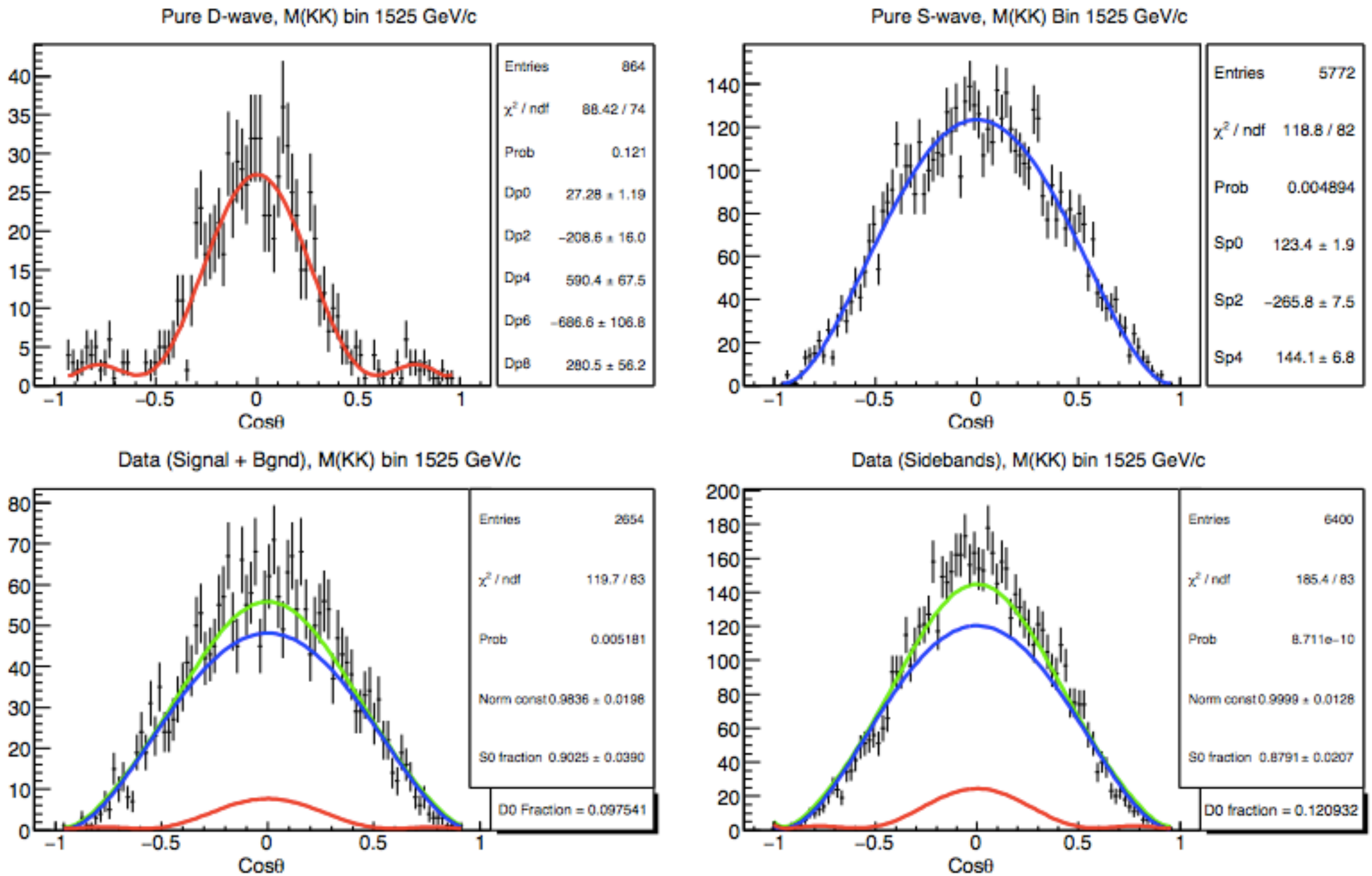




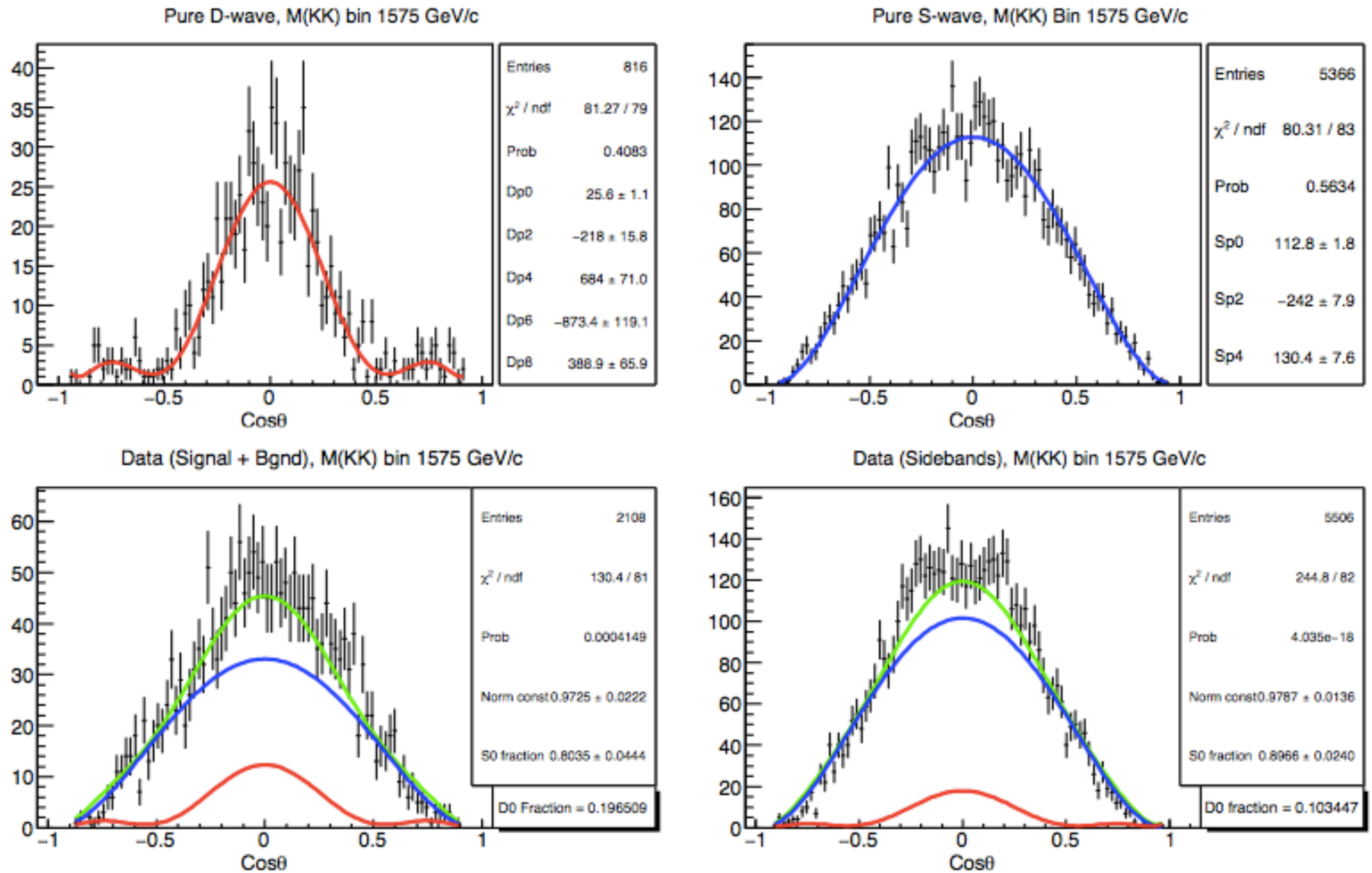
Angular Distributions (1475 MeV)



Angular Distributions (1525 MeV)



Angular Distributions (1575 MeV)



S-wave/D-wave fraction vs. M(KK)

Table II. Fraction of S-wave from fits to the S+B and sideband regions.

Mass Bin (MeV)	S-wave fraction (S+B region)	S-wave fraction (Sidebands)
1000-1050	1.000 ± 0.045	1.000 ± 0.031
1050-1100	1.000 ± 0.031	1.000 ± 0.029
1100-1150	0.973 ± 0.025	0.982 ± 0.018
1150-1200	1.000 ± 0.023	1.000 ± 0.015
1200-1250	1.000 ± 0.022	1.000 ± 0.011
1250-1300	1.000 ± 0.013	1.000 ± 0.063
1300-1350	1.000 ± 0.020	1.000 ± 0.011
1350-1400	1.000 ± 0.028	1.000 ± 0.026
1400-1450	1.000 ± 0.025	0.922 ± 0.019
1450-1500	0.928 ± 0.037	0.890 ± 0.023
1500-1550	0.903 ± 0.039	0.879 ± 0.021
1550-1600	0.803 ± 0.044	0.897 ± 0.024
1600-1650	0.791 ± 0.056	0.883 ± 0.032
1650-1700	0.762 ± 0.052	0.910 ± 0.031
1700-1750	0.660 ± 0.053	0.902 ± 0.033
1750-1800	0.690 ± 0.071	0.941 ± 0.041
1800-1850	0.845 ± 0.086	0.994 ± 0.096

Summary

- We see a significant peak above background at a mass of 1.50 GeV in $M(K_s K_s)$ in g12 data.
  – The calibrations for g12 are better than ~5 MeV.
- The peak at 1.50 GeV is enhanced at low $|t|$.
  – This is indicative of t-channel production.
- Angular distribution in the GJ frame suggest (but do not prove) that it is mostly S-wave.
  – This suggests we see the $f_0(1500)$ but cannot rule out some portion of the $f_2(1525)$ being present.
- Better data will be available at CLAS12 with FT.