Determining the full meson photo-production amplitude from "*complete*" experiments

A.M. Sandorfi[1] and S. Hoblit[2]

[1] Thomas Jefferson National Accelerator Facility
[2] University of Virginia

- *spin-observables in $J^{\pi}=0^{-}$ production and "complete" experiments*

  Q: can such data provide total amplitudes ?

- *the mechanics of fitting out the amplitudes*
  - potentials and limitations
  - constraining the phase

- *tests with mock data – a work in progress*

Idealized path to search for N*, Δ* states via $J^{\pi}=0^{-}$ photo-production

(1) determine the production amplitude from experiment

- search for resonant structure:
  Analytic Continuation, Argand circles,
  phase motion, Speed plots, etc.

Never been done
even after 50 yr of exps

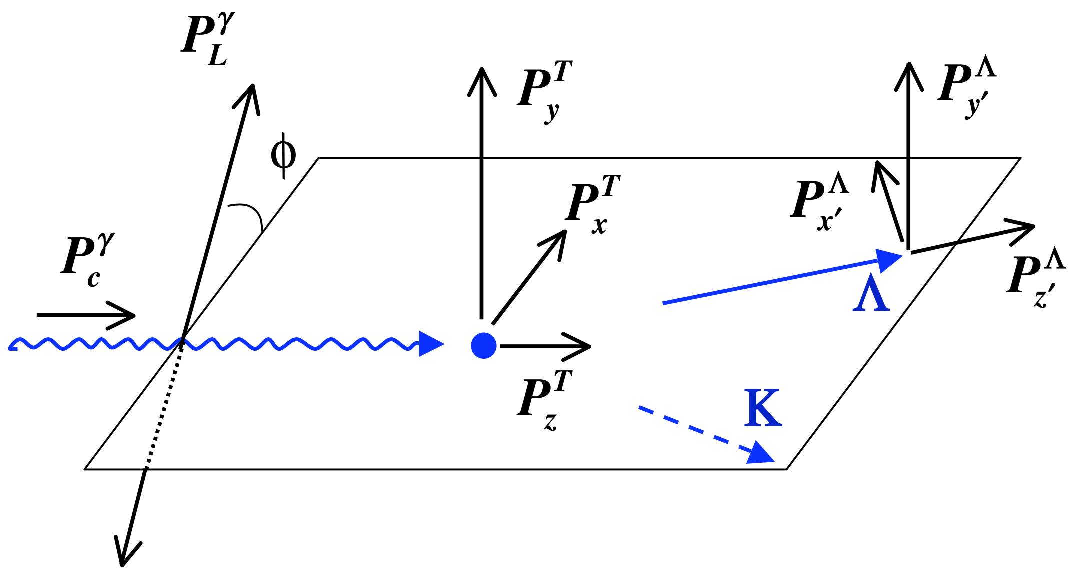
(2) separate resonance and background components

- determine resonant γN* and decay couplings;
  contact with LQCD, DSE, Hadron models

-without exp Amplitudes
models have conjectured resonances
and adjusted couplings to compare
with limited data

Polarized Pseudoscalar meson photo-production:

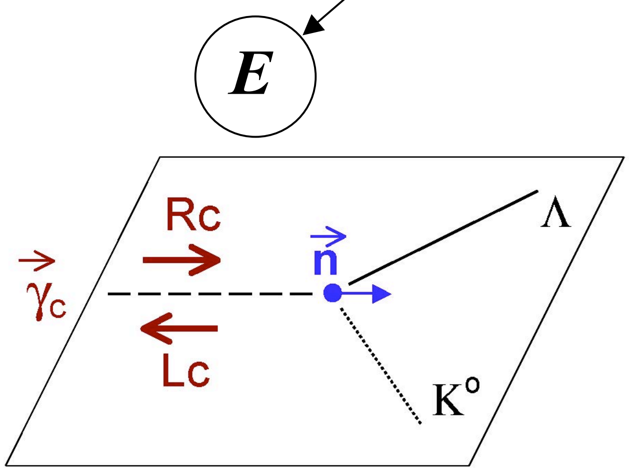
$$\vec{\gamma} + \vec{N} \rightarrow K + \vec{\Lambda}$$

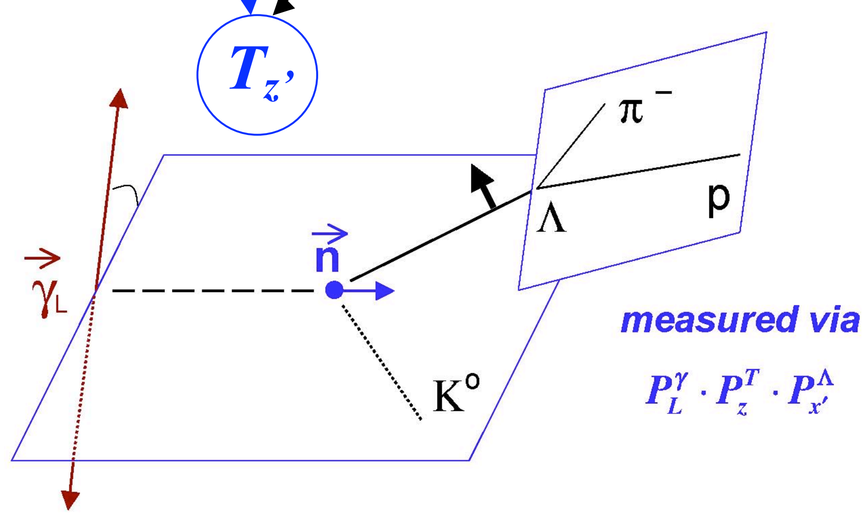


Polarization observables in $J^{\pi} = 0^{-}$ meson photo-production :

- *single-pol observables measured from double-pol asy*
- *double-pol observables measured from triple-pol asy*

Photon beam		***Target***			***Recoil***			***Target - Recoil***								
					x'	y'	z'	x'	x'	x'	y'	y'	y'	z'	z'	z'
		x	y	z				x	y	z	x	y	z	x	y	z
unpolarized	σ_0		T			P		$T_{x'}$		$L_{x'}$		Σ		$T_{z'}$		$L_{z'}$
linearly P_γ	Σ	H	P	G	$O_{x'}$	T	$O_{z'}$	$L_{z'}$	$C_{z'}$	$T_{z'}$	E		F	$L_{x'}$	$C_{x'}$	$T_{x'}$
circular P_γ		F		E	$C_{x'}$		$C_{z'}$		$O_{z'}$		G		H		$O_{x'}$	





Requirements for a complete determination of the amplitude, unique to within a phase and free of ambiguities:

⇔ ***8 carefully chosen observables*** *- Barker, Donnachie, Storrow, NP* ***B95****(75)*
*- Chiang & Tabakin, PR****C55****,2054(97)*

(I) cross section and the three single-polarization observables:

{σ, Σ, P, T}

(II) four double-polarization observables:

- 2 + 2 select cases from: ***Beam-Target***, ***Beam-Recoil***, ***Target-Recoil***
- 2 + 1 + 1 select cases from: ***Beam-Target***, ***Beam-Recoil***, ***Target-Recoil***

- in practice, one needs linear and circular beam polarization, at least one orientation of target polarization and recoil polarization

  ⇔ by the time you accumulate that in a 4π detector, you have all 16

⇒ ∃ huge redundancy, at least in principle!

Chaing&Tabakin _practice-principle

$\gamma + p \rightarrow K^{+}\Lambda$ *series of JLab experiments:*

Photon beam		***Target***			***Recoil***			***Target - Recoil***								
					x'	y'	z'	x'	x'	x'	y'	y'	y'	z'	z'	z'
		x	y	z				x	y	z	x	y	z	x	y	z
unpolarized	σ_0		T			P		$T_{x'}$		$L_{x'}$		Σ		$T_{z'}$		$L_{z'}$
linearly P_γ	Σ	H	P	G	$O_{x'}$	T	$O_{z'}$	$L_{z'}$	$C_{z'}$	$T_{z'}$	E		F	$L_{x'}$	$C_{x'}$	$T_{x'}$
circular P_γ		F		E	$C_{x'}$		$C_{z'}$		$O_{z'}$		G		H		$O_{x'}$	

status	***CLAS run period***	***beam***	***target***	***Full set of 16***
complete	***g1***	γ , $\vec{\gamma}_c$	LH_2	***Miskimen/Schumacher***
complete	***g8***	$\vec{\gamma}_L$	LH_2	***Cole***
complete	***g9a - P^T_z***	$\vec{\gamma}_L$, $\vec{\gamma}_c$	***FROST - $C_4\vec{H}_9O\vec{H}$***	***Klein, Pasyuk***
2010	***g9b - P^T_x***	$\vec{\gamma}_L$, $\vec{\gamma}_c$	***FROST - $C_4\vec{H}_9O\vec{H}$***	***Klein, Pasyuk***

$\gamma + n(p) \rightarrow K^0 \Lambda$ *experiments at JLab with HDice:*

- *single-pol observables measured from double-pol asy*
- *double-pol observables measured from triple-pol asy*

Photon beam		*Target*			*Recoil*			*Target - Recoil*								
					x'	y'	z'	x'	x'	x'	y'	y'	y'	z'	z'	z'
		x	y	z				x	y	z	x	y	z	x	y	z
unpolarized	σ_0		T			P		$T_{x'}$		$L_{x'}$		Σ		$T_{z'}$		$L_{z'}$
linearly P_γ	Σ	H	P	G	$O_{x'}$	T	$O_{z'}$	$L_{z'}$	$C_{z'}$	$T_{z'}$	E		F	$L_{x'}$	$C_{x'}$	$T_{x'}$
circular P_γ		F		E	$C_{x'}$		$C_{z'}$		$O_{z'}$		G		H		$O_{x'}$	

⇑

simultaneous B-R with HD ⇔ ***Full set of 16***

schedule	*CLAS run period*	*beam*	*target*	*spokesmen*
2006-2007	*g13*	$\vec{\gamma}_L$	LD_2	*Nadel-Turonski*
2010-2011	*g14*	$\vec{\gamma}_L , \vec{\gamma}_c$	$\vec{H} \cdot \vec{D}$ *ice*	*Sandorfi/Klein*

The mechanics of inferring amplitudes from data

(I) ***theory ⇒ experiment: eg. generating mock data***

$$\frac{d\sigma}{d\Omega} = \frac{|P^{CM}_{\pi,\eta,K}|}{E^{cm}_{\gamma}} \cdot \left| \langle N(\pi,\eta,K)| \sum F_i \; |\gamma N\rangle \right|^2 ,$$ ***CGLN, PR106(1957)***

↑ ***(Cartesian) ⇔ (Spherical) H_i helicity amplitudes***

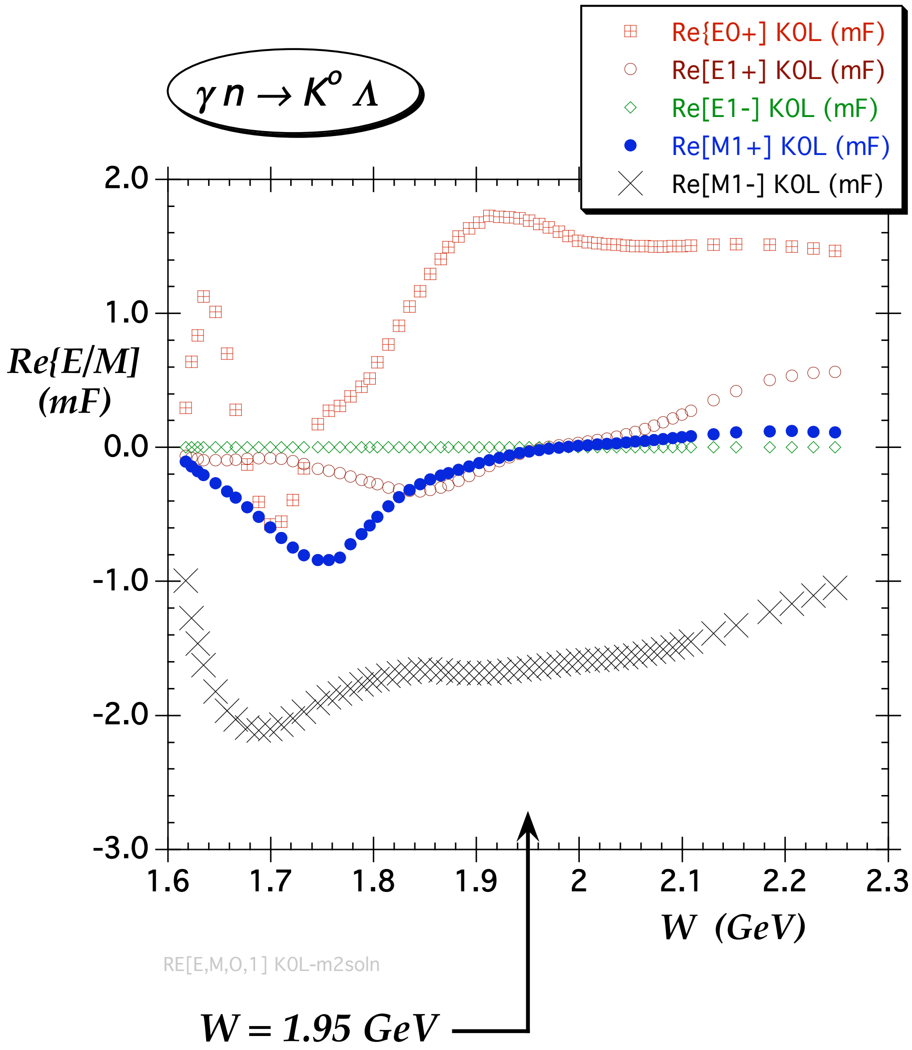
multipoles ⇒ observables

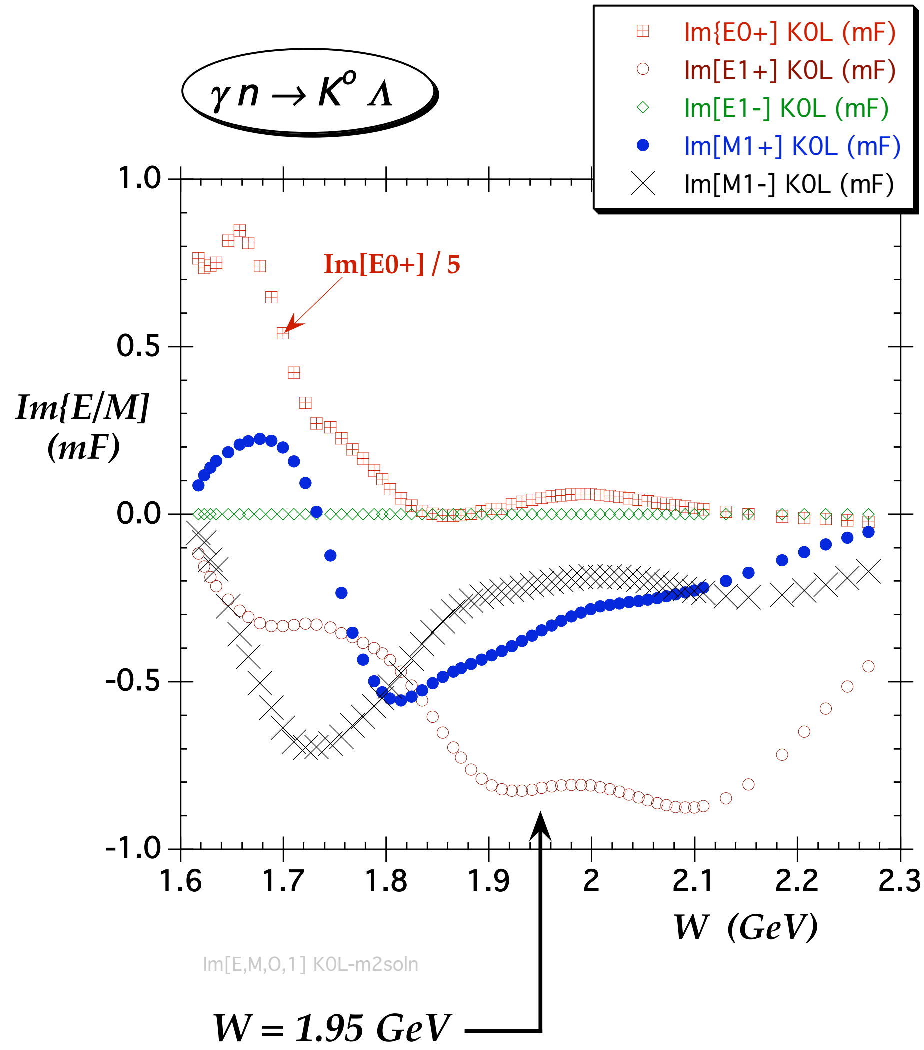
- $\{E_{\ell\pm}\ , M_{\ell\pm}\} \otimes \{P_\ell\ , P'_\ell\ , P''_\ell\} \Leftrightarrow \{\textit{functions of } W/E_\gamma\} \otimes \{\textit{functions of } \theta_{CM}\}$

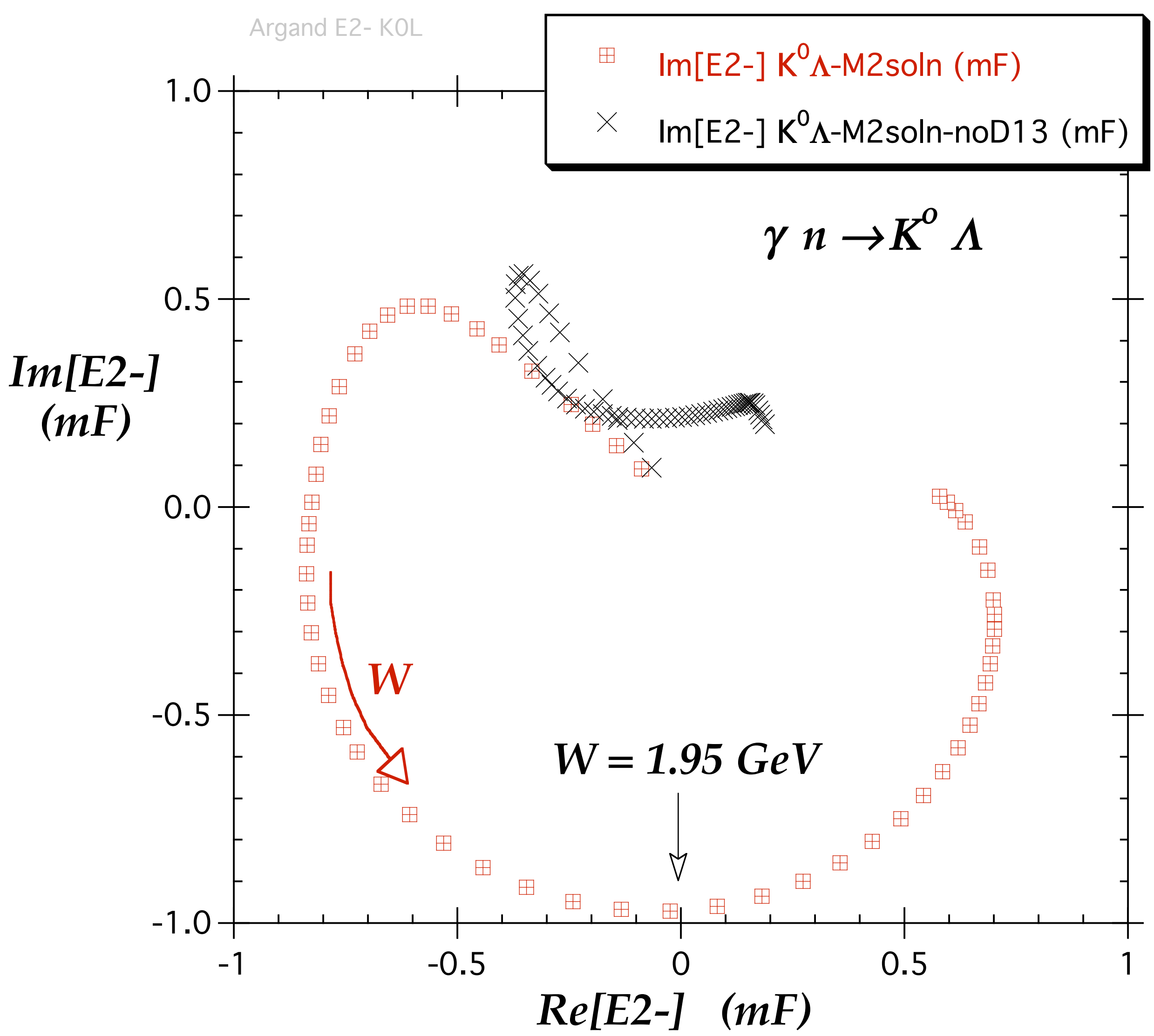
$\Rightarrow \{F_1\ , F_2\ , F_3\ , F_4\}_{CGLN} \Leftrightarrow \{\textit{functions of } (W/E_\gamma\ , \theta_{CM})\}$

$\Rightarrow \{\sigma_0\ , \Sigma\ , T\ , P\ , E\ , \ldots L_{z'}\} \Leftrightarrow \{\textit{functions of } (W/E_\gamma\ , \theta_{CM}\ , \phi)\}$

eg. ***multipoles from: B. Julia-Diaz, T-S. H. Lee***
- M2 (full) solution -







Argand E2- K0L
Im[E2-] K^{0}Λ-M2soln (mF)
Im[E2-] K^{0}Λ-M2soln-noD13 (mF)
$\gamma\ n \rightarrow K^o\ \Lambda$
Im[E2-]
(mF)
W
W = 1.95 GeV
1.0
0.5
0.0
-0.5
-1.0
-1
-0.5
0
0.5
1
Re[E2-] (mF)

Constructing the CGLN F_i amplitudes:

$$F_1(x) = E_{0+} + \left(M_{1+} + E_{1+} \right) \cdot P_2'(x) + \left(2M_{2+} + E_{2+}\right) \cdot P_3'(x) + \left(3M_{2-} + E_{2-}\right) + \left(3M_{3+} + E_{3+}\right) \cdot P_4'(x) + \left(4M_{3-} + E_{3-}\right) \cdot P_2'(x) + \left(4M_{4+} + E_{4+}\right) \cdot P_5'(x) + \left(5M_{4-} + E_{4-}\right) \cdot P_3'(x)$$

$$F_3(x) = + \left(E_{1+} - M_{1+} \right) \cdot P_2''(x) + \left(E_{2+} - M_{2+}\right) \cdot P_3''(x) + \left(E_{3+} - M_{3+}\right) \cdot P_4''(x) + \left(E_{3-} + M_{3-}\right) \cdot P_2''(x) + \left(E_{4+} - M_{4+}\right) \cdot P_5''(x) + \left(E_{4-} + M_{4-}\right) \cdot P_3''(x)$$

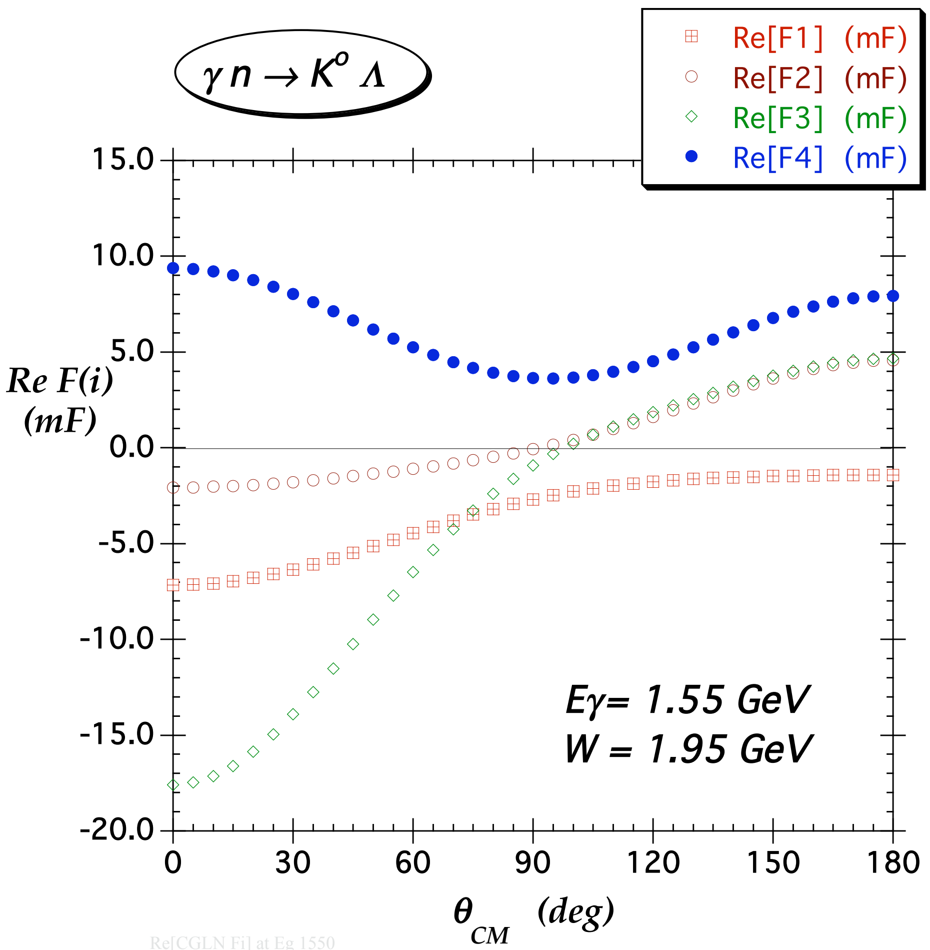
$$F_2(x) = \left(2M_{1+} + M_{1-}\right) + \left(3M_{2+} + 2M_{2-}\right) \cdot P_2'(x) + \left(4M_{3+} + 3M_{3-}\right) \cdot P_3'(x) + \left(5M_{4+} + 4M_{4-}\right) \cdot P_4'(x)$$

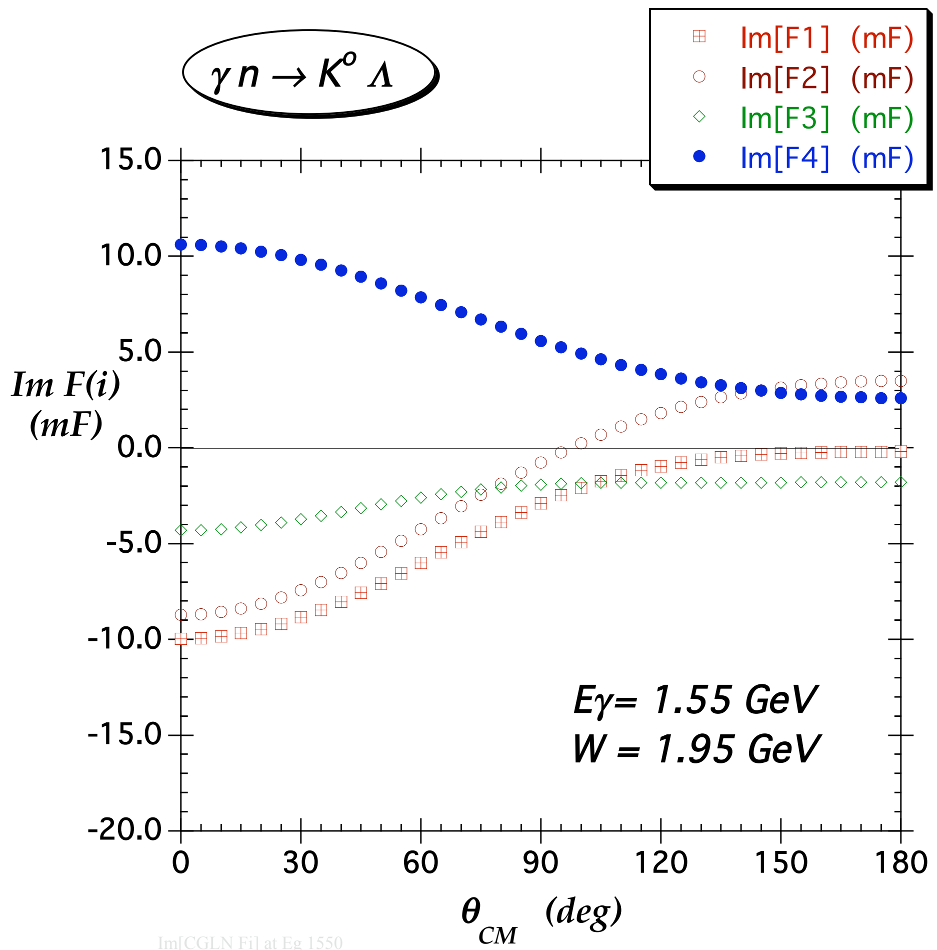
$$F_4(x) = \left(M_{2+} - E_{2+} - E_{2-} - M_{2-} \right) \cdot P_2''(x) + \left(M_{3+} - E_{3+} - E_{3-} - M_{3-} \right) \cdot P_3''(x) + \left(M_{4+} - E_{4+} - E_{4-} - M_{4-} \right) \cdot P_4''(x)$$

$P_\ell \,, P_\ell' \,, P_\ell'' \equiv$ *Legendre functions*

$$x = cos(\theta_{CM})$$

eg. ***CGLN amplitudes at W = 1.95 GeV***
- calculated from the multipoles of B. Julia-Diaz, T-S. H. Lee





notation:

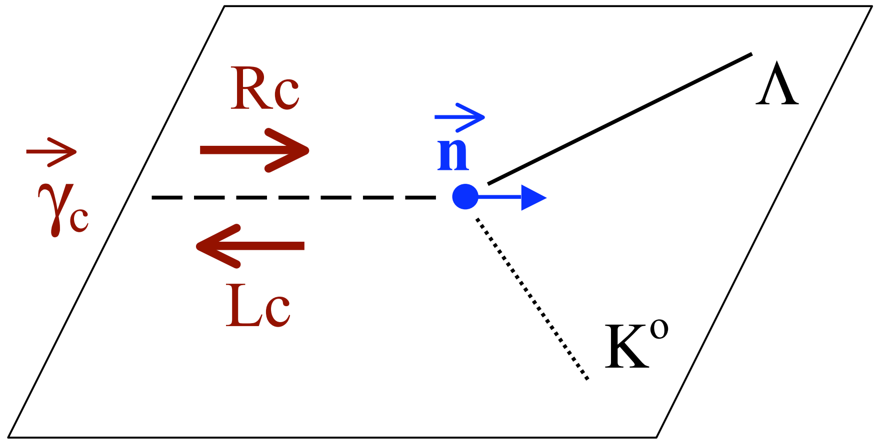
$$\hat{A}_{asy} = \sigma_o \cdot A_{asy}$$

eg:

$$E = \frac{\sigma_{Anti} - \sigma_{Par}}{\sigma_{Anti} + \sigma_{Par}}$$

$$\sigma_o = \tfrac{1}{2}\left(\sigma_{Anti} + \sigma_{Par}\right)$$

$$\Rightarrow \hat{E} = \tfrac{1}{2}\left(\sigma_{Anti} - \sigma_{Par}\right)$$



$$\{F_1\ ,\ F_2\ ,\ F_3\ ,\ F_4\}_{CGLN} \Leftrightarrow \{\textit{functions of } (W / E_\gamma\ ,\ \theta_{CM})\}$$

$$\Rightarrow \{\sigma_0\ ,\ \hat{\Sigma}\ ,\ \hat{T}\ ,\ \hat{P}\ ,\ \hat{E}\ ,\ \ldots \hat{L}_{z'}\} \Leftrightarrow \{\textit{functions of } (W / E_\gamma\ ,\ \theta_{CM}\ ,\ \phi)\}$$

hat notation

Observables in terms of the CGLN F_i amplitudes, i = 1-4 : $\rho = \left|P^{CM}_{\pi,\eta,K}\right| / E^{cm}_{\gamma}$

- Andy & Harry's signs – confirmed Aug 22'09.

$$\sigma_0 = \left\{ \begin{array}{l} |F_1|^2 + |F_2|^2 + \tfrac{1}{2}\sin^2\theta \cdot \left(|F_3|^2 + |F_4|^2\right) \\ + \Re e\left[\sin^2\theta \cdot \left(F_2^* F_3 + F_1^* F_4 + \cos\theta \cdot F_3^* F_4\right) - 2\cos\theta \cdot F_1^* F_2\right] \end{array} \right\} \cdot \rho$$

$$\hat{\Sigma} = -\left[\tfrac{1}{2}\sin^2\theta \cdot \left\{|F_3|^2 + |F_4|^2\right\} + \sin^2\theta \cdot \Re e\left\{F_2^* F_3 + F_1^* F_4 + \cos\theta \cdot \left(F_3^* F_4\right)\right\}\right] \cdot \rho$$

$$\hat{T} = \Im \mathrm{m}\left\{\sin\theta\left[F_1^* F_3 - F_2^* F_4 + \cos\theta \cdot \left(F_1^* F_4 - F_2^* F_3\right) - \sin^2\theta \cdot F_3^* F_4\right]\right\} \cdot \rho$$

$$\hat{P} = \Im \mathrm{m}\left\{\sin\theta\left[-2F_1^* F_2 - F_1^* F_3 + F_2^* F_4 + \cos\theta \cdot \left(F_2^* F_3 - F_1^* F_4\right) + \sin^2\theta \cdot F_3^* F_4\right]\right\} \cdot \rho$$

$$\hat{T}_{x'} = \Re e\left\{\sin^2\theta\left[-F_1^* F_3 - F_2^* F_4 - F_3^* F_4 - \tfrac{1}{2}\cos\theta \cdot \left(|F_3|^2 + |F_4|^2\right)\right]\right\} \cdot \rho$$

$$\hat{L}_{x'} = +\Re e\left\{\sin\theta\left[|F_1|^2 - |F_2|^2 + \tfrac{1}{2}\sin^2\theta \cdot \left(|F_4|^2 - |F_3|^2\right) - F_2^* F_3 + F_1^* F_4 + \cos\theta\left(F_1^* F_3 - F_2^* F_4\right)\right]\right\} \cdot \rho$$

$$\hat{T}_{z'} = \Re e\left\{\sin\theta\left[-F_2^* F_3 + F_1^* F_4 + \cos\theta\left(F_1^* F_3 - F_2^* F_4\right) + \tfrac{1}{2}\sin^2\theta \cdot \left(|F_4|^2 - |F_3|^2\right)\right]\right\} \cdot \rho$$

$$\hat{L}_{z'} = \Re e\left\{ \begin{array}{l} 2F_1^* F_2 - \cos\theta\left(|F_1|^2 + |F_2|^2\right) + \sin^2\theta \cdot \left(F_1^* F_3 + F_2^* F_4 + F_3^* F_4\right) \\ + \tfrac{1}{2}\cos\theta\sin^2\theta \cdot \left(|F_3|^2 + |F_4|^2\right) \end{array} \right\} \cdot \rho$$

$$\hat{E} = -\left[-|F_1|^2 - |F_2|^2 + \Re e\left\{2\cos\theta \cdot \left(F_1^* F_2\right) - \sin^2\theta \cdot \left(F_2^* F_3 + F_1^* F_4\right)\right\}\right] \cdot \rho$$

$$\hat{G} = +\sin^2\theta \cdot \Im m\left\{F_2^* F_3 + F_1^* F_4\right\} \cdot \rho$$

$$\hat{F} = \sin\theta \cdot \Re e\left[F_1^* F_3 - F_2^* F_4 - \cos\theta \cdot \left(F_2^* F_3 - F_1^* F_4\right)\right] \cdot \rho$$

$$\hat{H} = -\sin\theta \cdot \Im \mathrm{m}\left[2F_1^* F_2 + F_1^* F_3 - F_2^* F_4 + \cos\theta \cdot \left(F_1^* F_4 - F_2^* F_3\right)\right] \cdot \rho$$

Simulating the extraction of multipoles (a work in progress):

- create *mock data*:

  - using multipoles from EBAC-Juliá-Días/Lee/Sato "M2"amplitude, generate observables with appropriate energy and angular coverage
  - Gaussian smear the predictions with the expected statistical widths

- fitting *mock data*, varying multipoles:

  (1) **limiting case:**
  - generate observables in 10 deg steps from 10^0 to 170^0 CM; assign each an error of 0.1% and Gaussian smear the predictions (Note: no data set will ever be that good !)

  a) search from a starting point within ~25% of the generating soln
  ⇒ converges rapidly to EBAC "M2" multipoles ✔

  b) as a starting point for the search, use Born values;
  Monte Carlo sampling of parameter space, then Gradient search

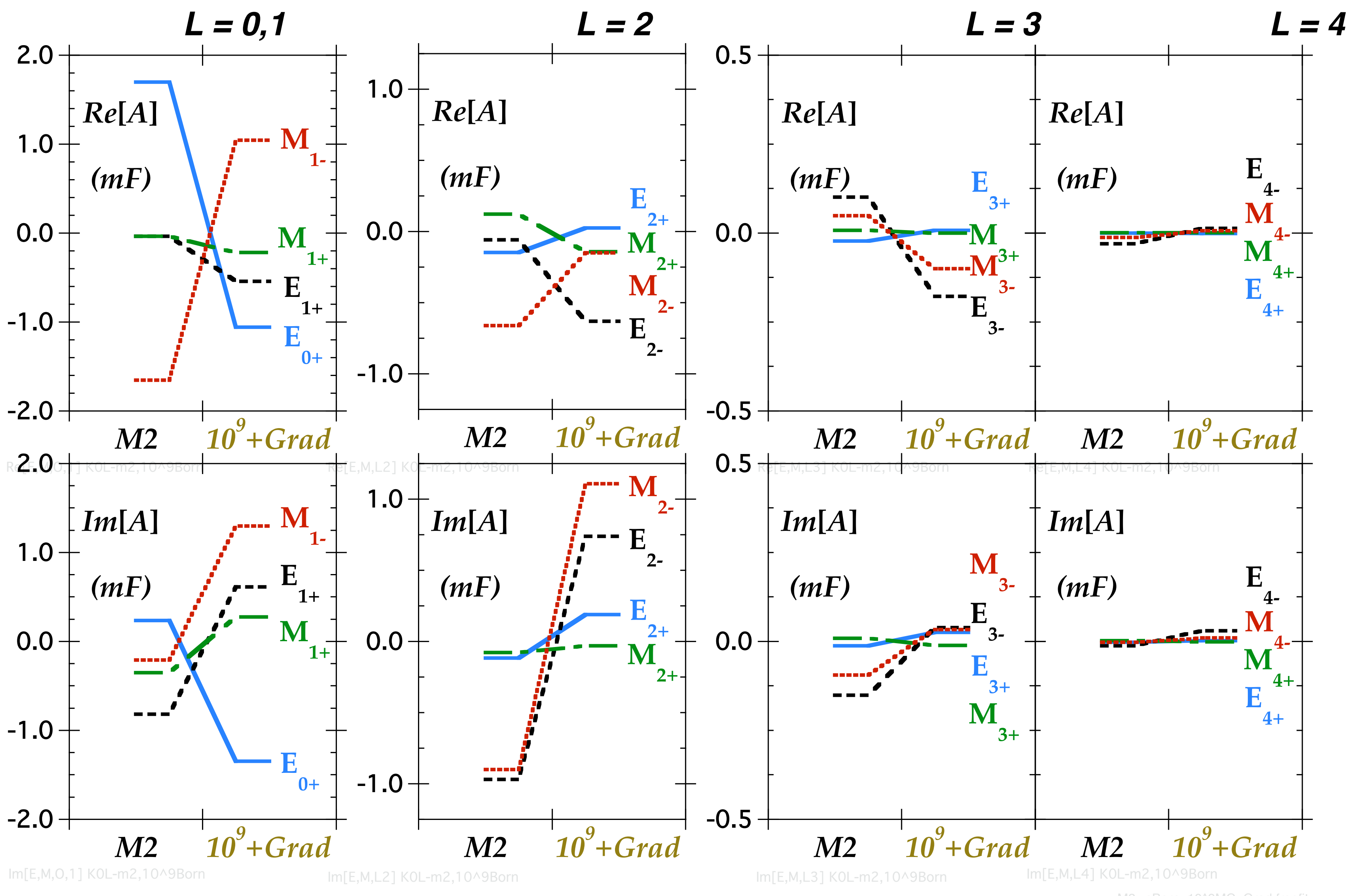
$\vec{n}(\vec{\gamma},K^o\vec{\Lambda})$

EBAC M2 vs Born + 10^9 MC + gradient search

$\chi^2/df = 0.996$ - better than M2 to mock data

W = 1.95 GeV

new soln = M2 x $e^{i(136.04\ deg)}$



- χ^2 surface has a large number of local minima !

- in general, fitted soln will be rotated from generating amplitude by some angle dependent on the statistical fluctuations in data

c) fixing the common phase with high L Born :

- $S_{\beta\alpha} = 1 + 2i\, T_{\beta\alpha}$, for reactions $\alpha \rightarrow \beta$

- $$T_{\beta\alpha} = \sum_L T^L_{\beta\alpha} P_L \;\rightarrow\; T'_{\beta\alpha} = \sum_L e^{i\phi_{\beta\alpha}(w)} T^L_{\beta\alpha} P_L$$

- $$O_{exp} = \left|\sum c T_{\beta\alpha}\right|^2 \;\Leftrightarrow\; \left|\sum c e^{i\phi_{\beta\alpha}} T_{\beta\alpha}\right|^2$$

- vary multipoles for all L that are expected to differ from Born (eg. L=0-3); include higher L multipoles fixed to their Born values

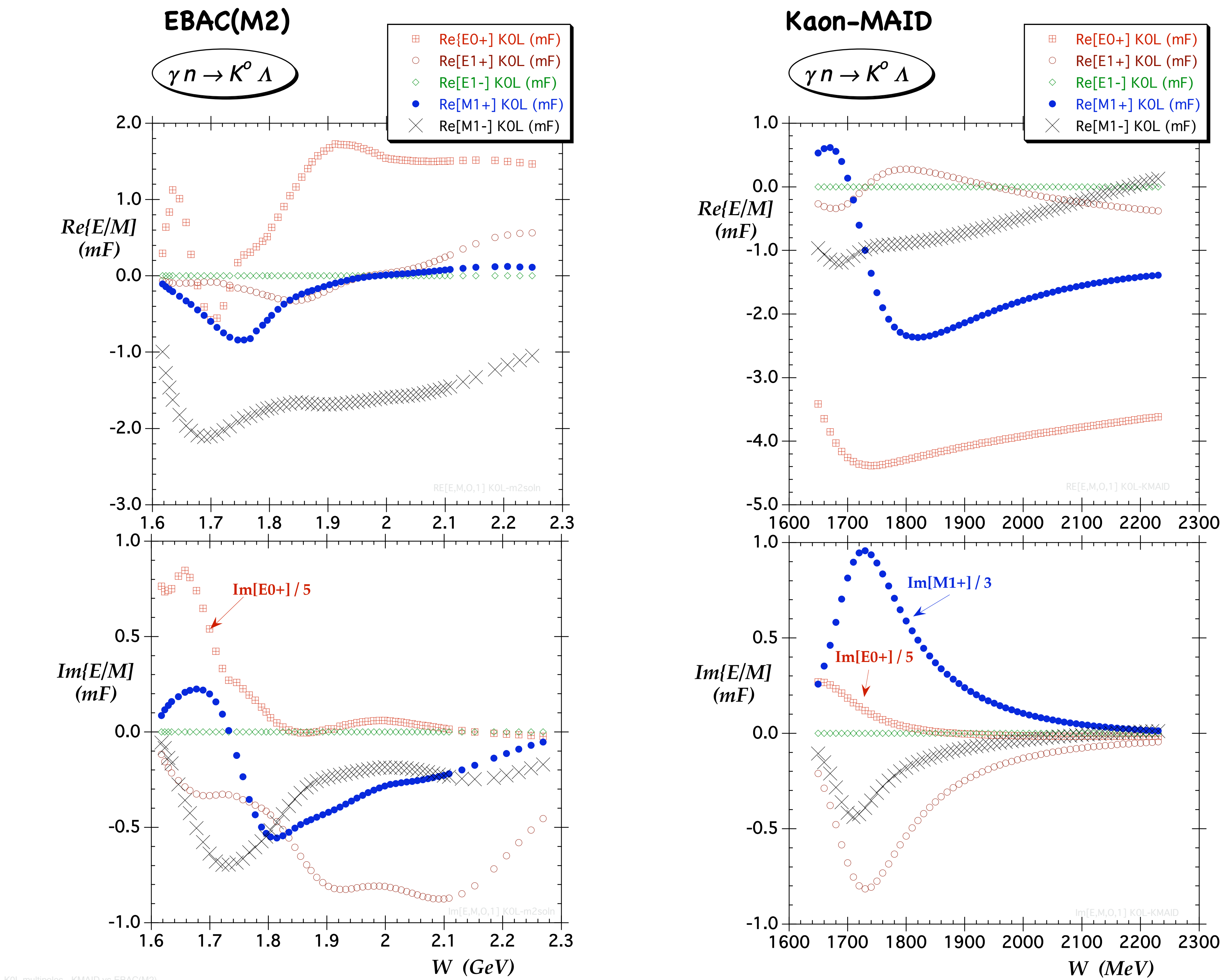
⇒ uniquely finds the generating amplitude !

(but requires sufficient statistics for all non-Born multipoles)

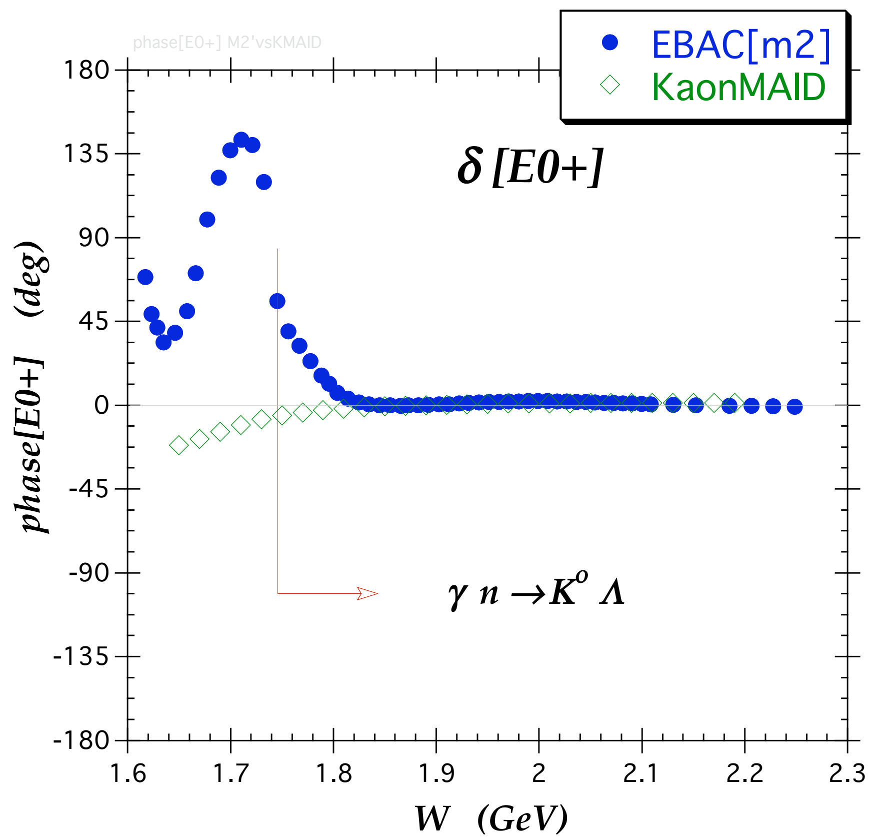
- realistic case: the data will run out of statistical accuracy before the multipoles run out of non-Born components;

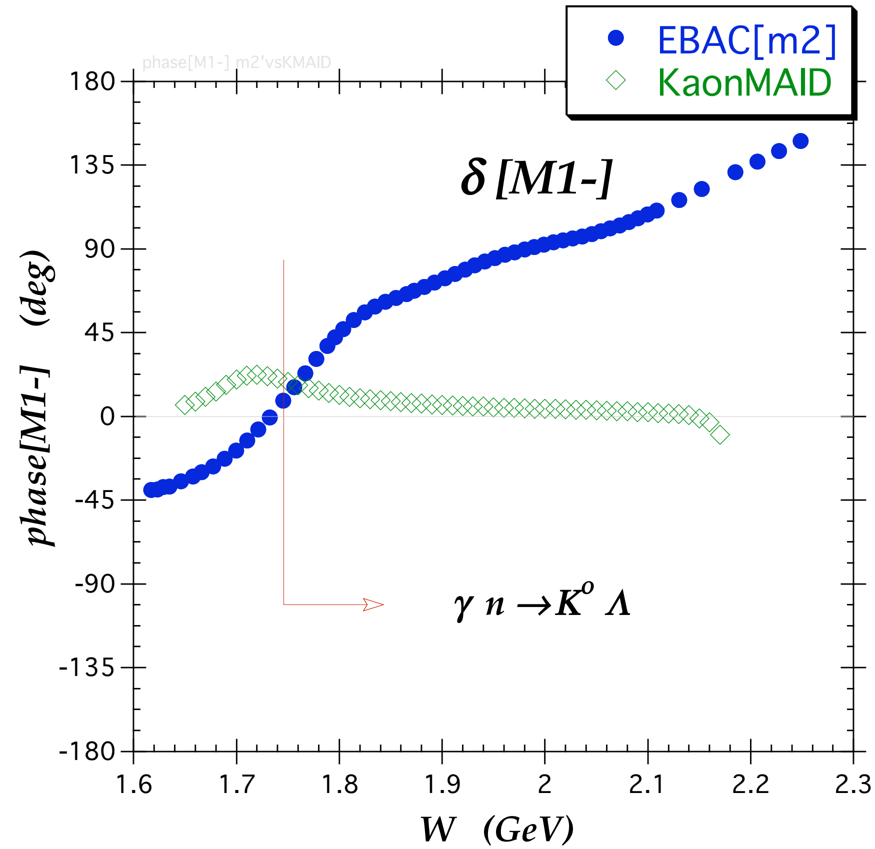
  (eg. stat sufficient to fit L=0-2, but L=3-4 may be non-Born;
  fixing L=5-8 to Born <u>DOES NOT</u> determine the phase !)

- alternatively, lock phase of one multipole to something regarded as "known" $\Leftrightarrow$ not a trivial choice for $\gamma N \rightarrow K\Lambda$



EBAC(M2)
Kaon-MAID
γ n → K° Λ
Re{E0+] K0L (mF)
Re[E1+] K0L (mF)
Re[E1-] K0L (mF)
Re[M1+] K0L (mF)
Re[M1-] K0L (mF)
Re{E/M] (mF)
Im{E/M] (mF)
Im[E0+] / 5
Im[M1+] / 3
W (GeV)
W (MeV)
K0L multipoles - KMAID vs EBAC(M2)





K0L phases - KMAIDvsEBAC(m2)

- realistic case: the data will run out of statistical accuracy before the multipoles run out of non-Born components;

  (eg. stat sufficient to fit L=0-2, but L=3-4 may be non-Born; fixing L=5-8 to Born DOES NOT determine the phase !)

- alternatively, lock phase of one multipole to something regarded as "known" $\Leftrightarrow$ not a trivial choice for $\gamma N \to K\Lambda$

(2) Realistic case:

- using EBAC(M2) multipoles L=0-4, generate observables for energies of JLab experiments with expected angular coverage; Gaussian smear predictions with the expected statistical widths.

- start multipole search at non-resonant Born values;

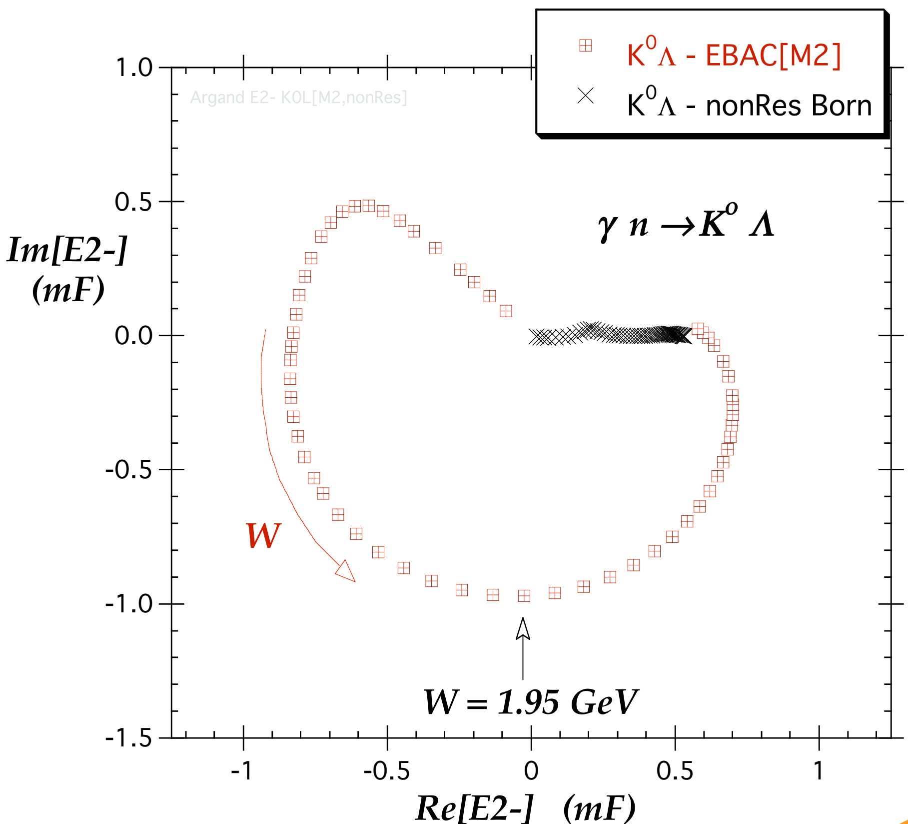
- lock phase of M(1-), or E(0+), to EBAC(M2) values;

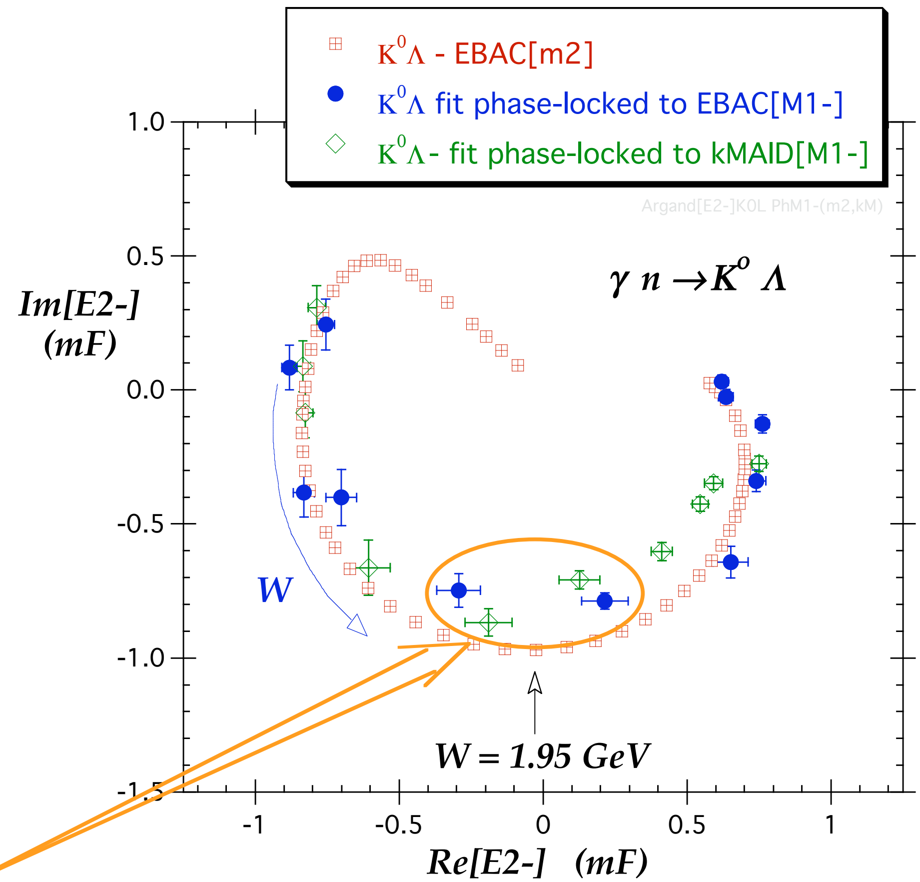
- 10^7 Monte Carlo sample of parameter space for L=0-3; Gradient search whenever χ^2 is within 10^4 of best value;

E2- multipole of EBAC(M2) with D_{13}(1950) resonance

fit to expected JLab data, with phase locked to M1- of EBAC(m2)

fit to expected JLab data, with phase locked to M1- of KaonMAID





χ^2_{df} {fits to mock data} ~ 1.2

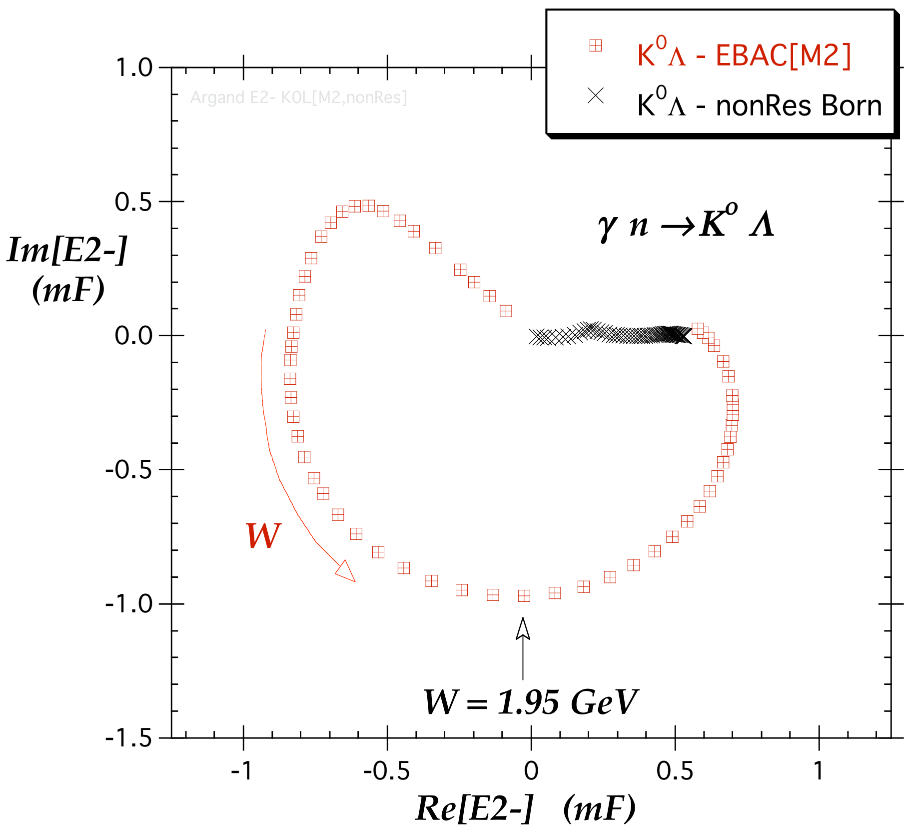
~15% less than χ^2_{df} {mock data to generating Amp}

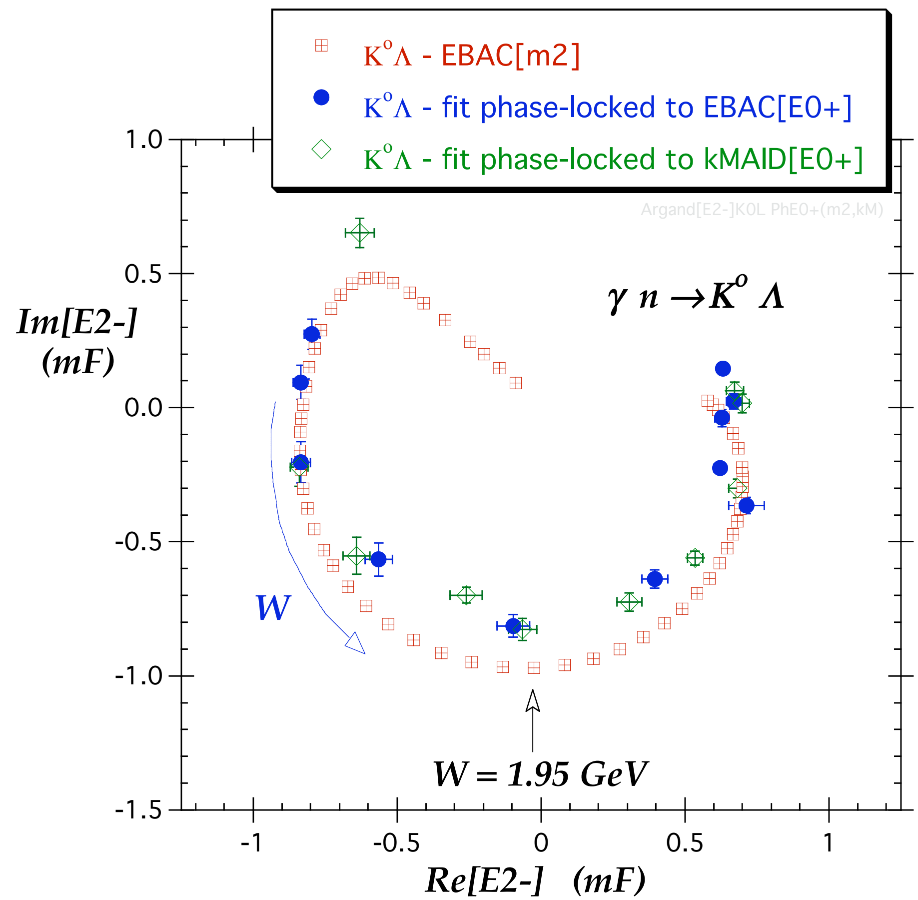
Argand[E2-] EBAC,kMAID vs fit w M1- phLk

E2- multipole of EBAC(M2) with D_{13}(1950) resonance

fit to expected JLab data, with phase locked to E0+ of EBAC(m2)

fit to expected JLab data, with phase locked to E0+ of KaonMAID



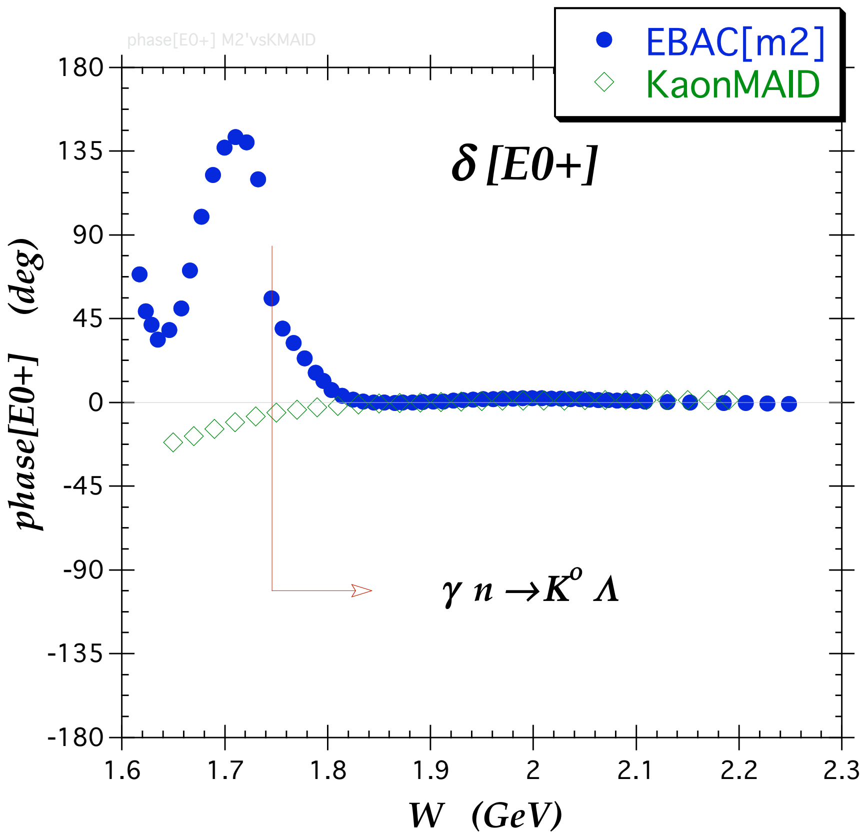


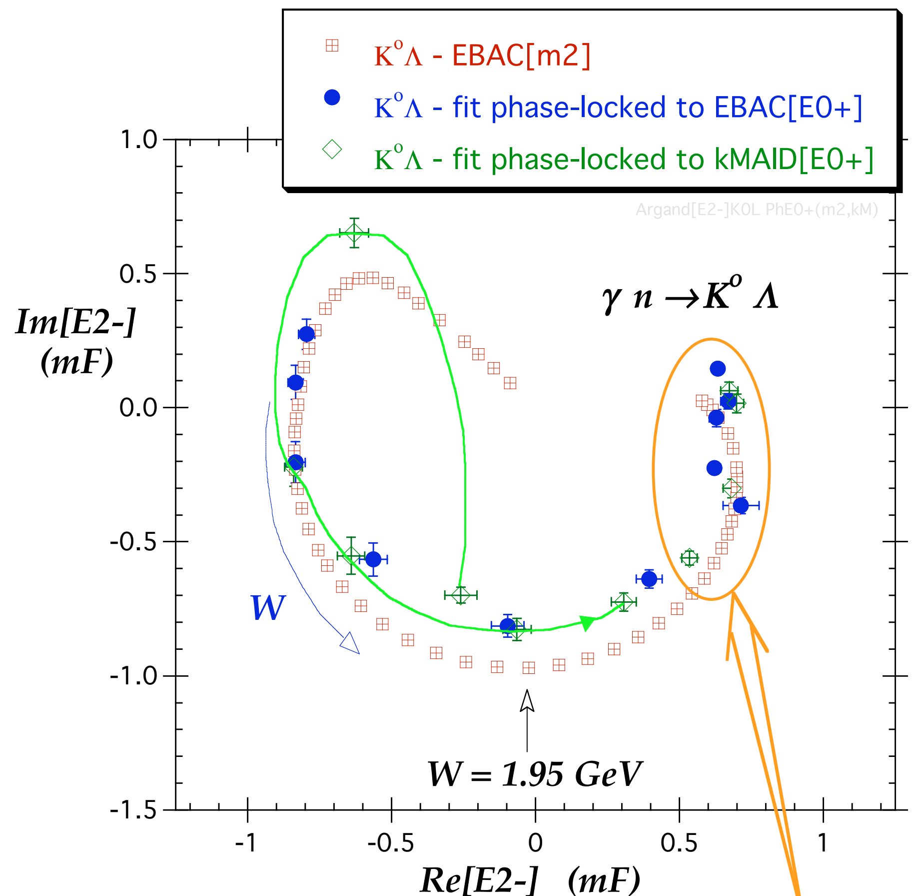
Argand[E2-] EBAC,kMAIDvsFIT w E0+phLk

E2- multipole of EBAC(M2) with D_{13}(1950) resonance

fit to expected JLab data, with phase locked to E0+ of EBAC(m2)

fit to expected JLab data, with phase locked to E0+ of KaonMAID





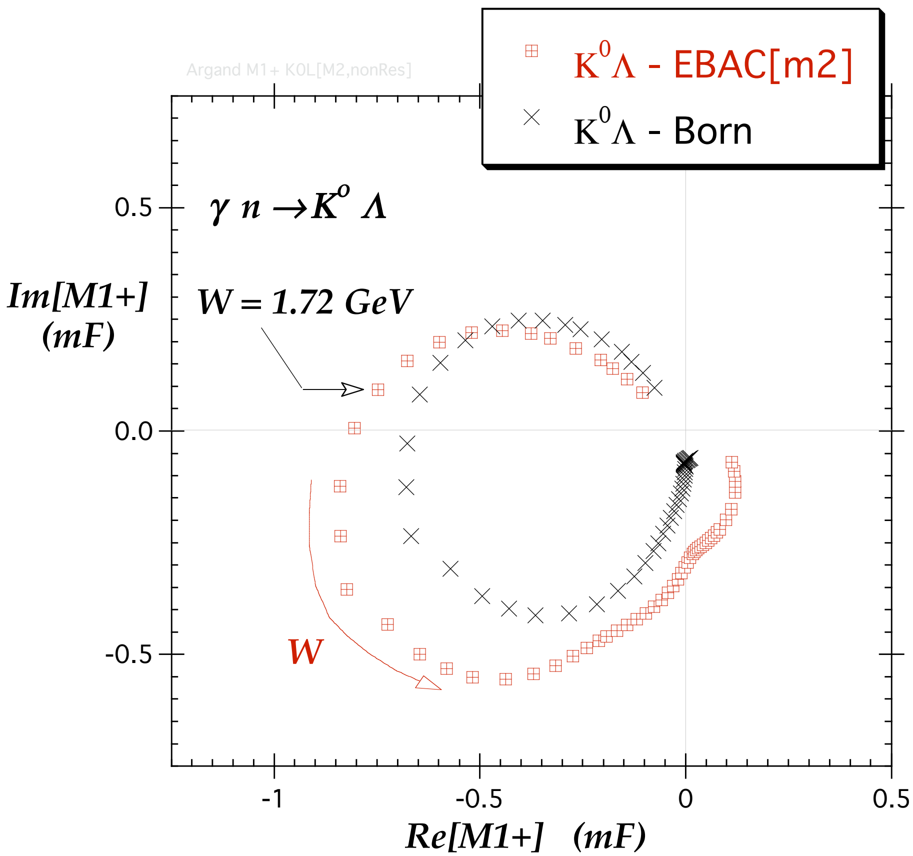
χ^2_{df} {fits to mock data} ~ 2-4

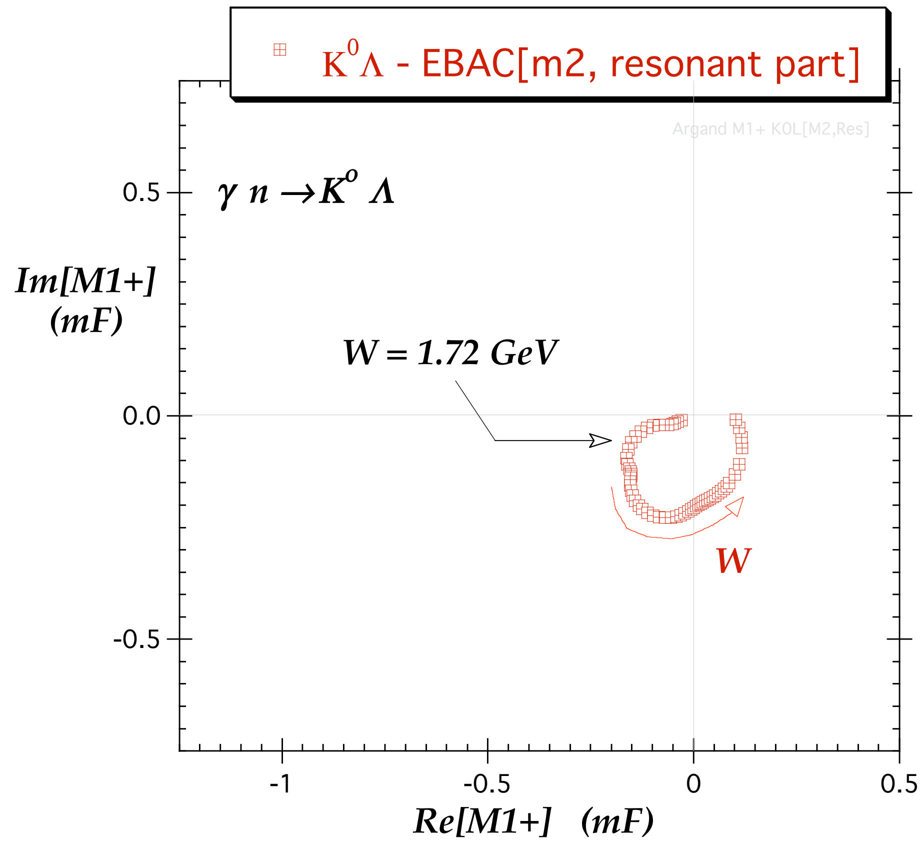
→ χ^2 valleys very narrow !

Argand[E2-] EBAC,kMAIDvsFIT w E0+phLk

M1+ multipole of EBAC(M2) with P_{13}(1720) resonance

- **** P_{13} with small resonant part and large background;
- EBAC PRC73 (06); not seen in latest EBAC analysis (09)



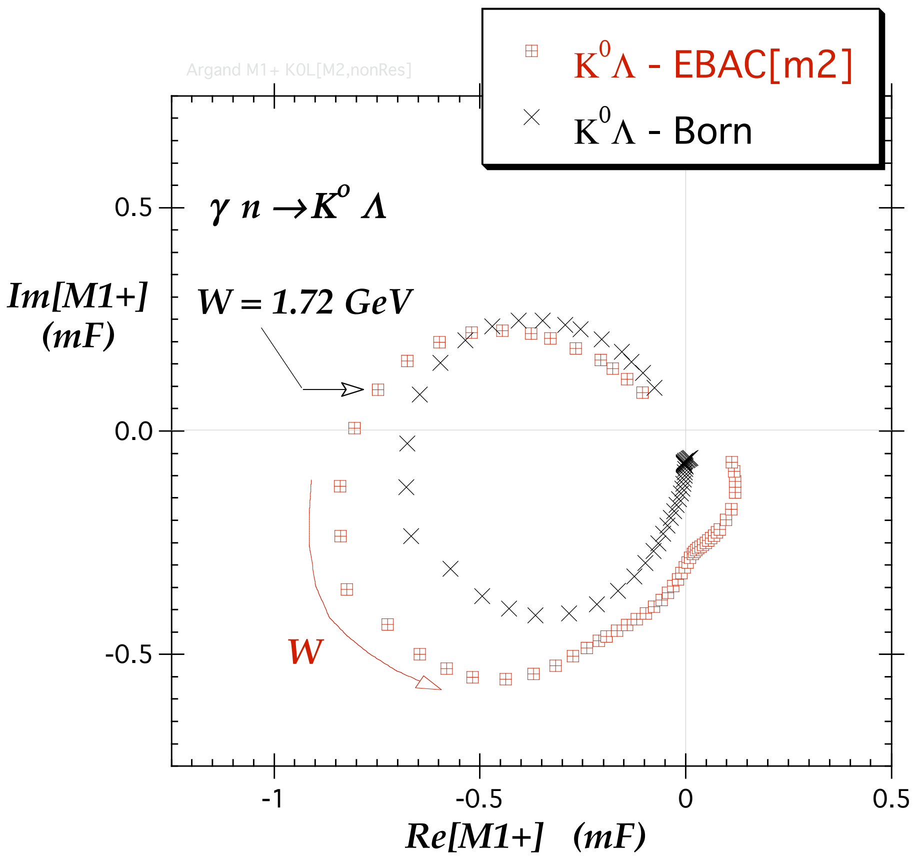


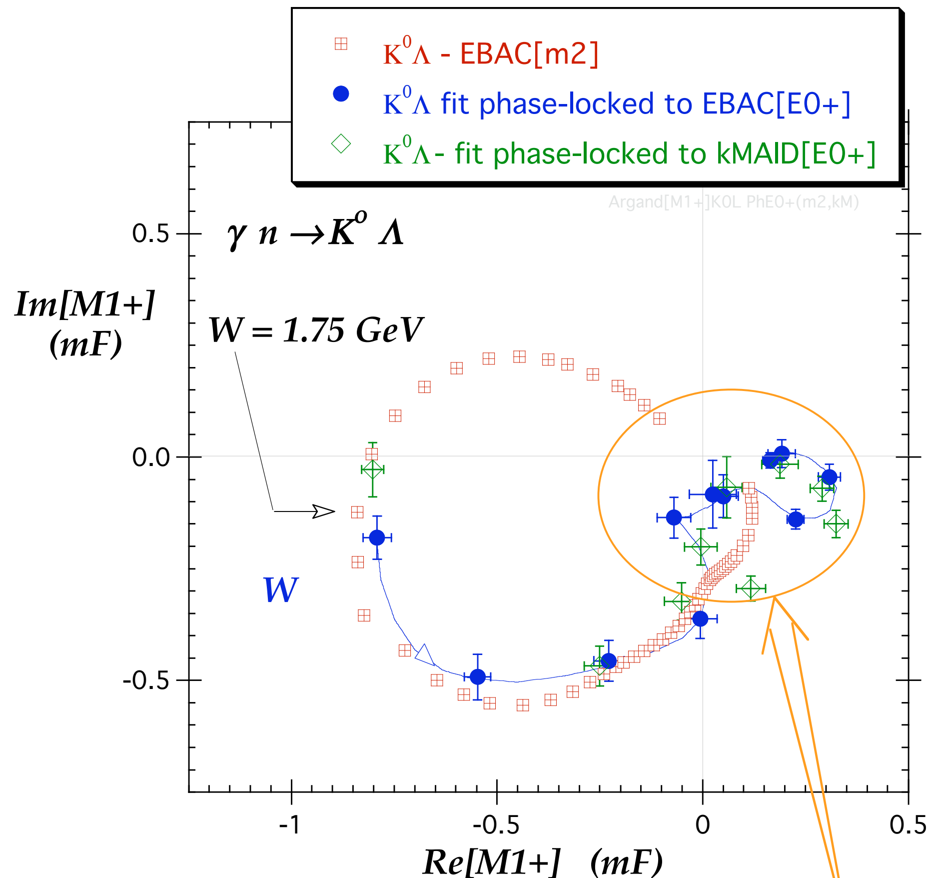
Argand[M1+] EBAC(m2)

M1+ multipole of EBAC(M2) with P_{13}(1720) resonance

fit to expected JLab data, with phase locked to E0+ of EBAC(m2)

fit to expected JLab data, with phase locked to E0+ of KaonMAID





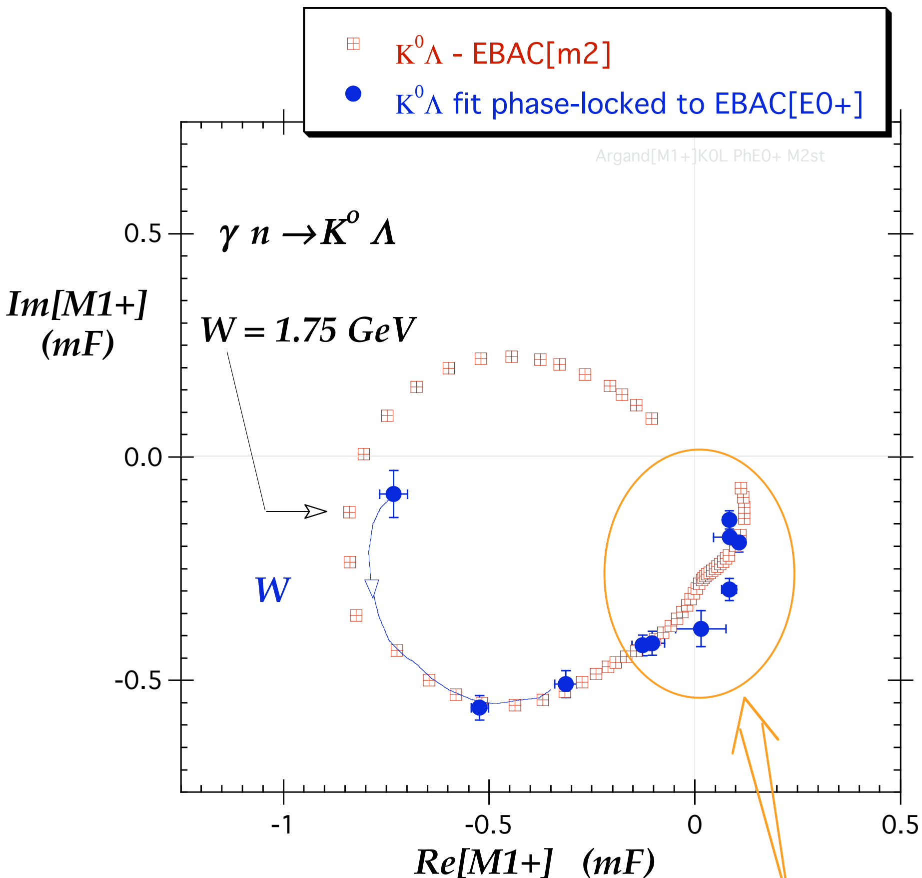
χ^2_{df} ~ 2-4 for W >2050

Argand[M1+] EBAC,kMAID vs fit w E0+ phLk

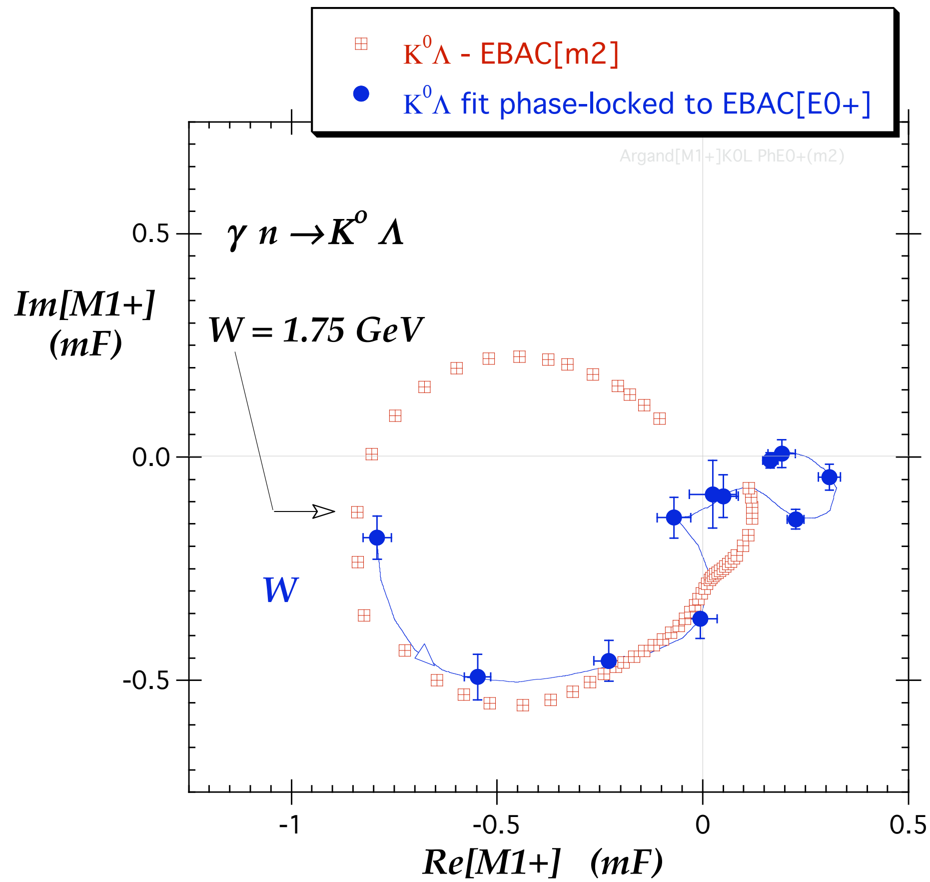
M1+ multipole of EBAC(M2) with P_{13}(1720) resonance

fit to expected JLab data, with phase locked to E0+ of EBAC(m2)

- start at EBAC(m2)
- Gradient search



- start at Born
- 10^7 Monte Carlo + Gradient



$\chi^2_{df} \sim 1$

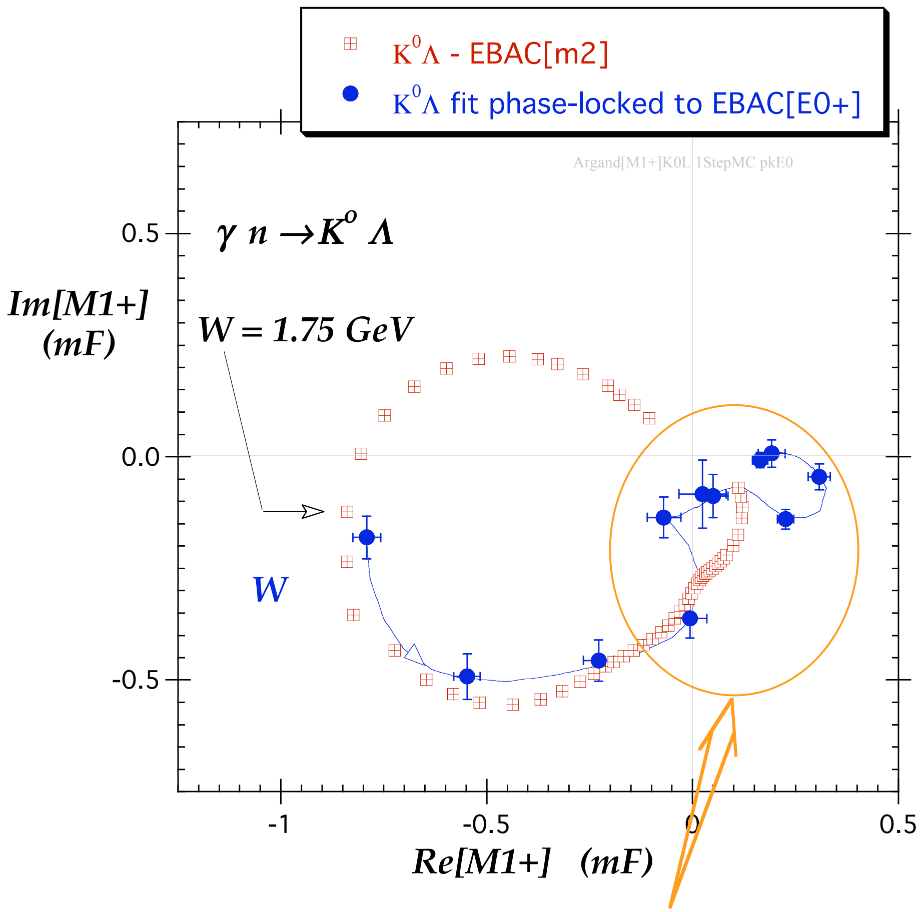
small errors → very narrow minima

Argand[M1+] fitVSstart w E0+phLk

M1+ multipole of EBAC(M2) with P_{13}(1720) resonance

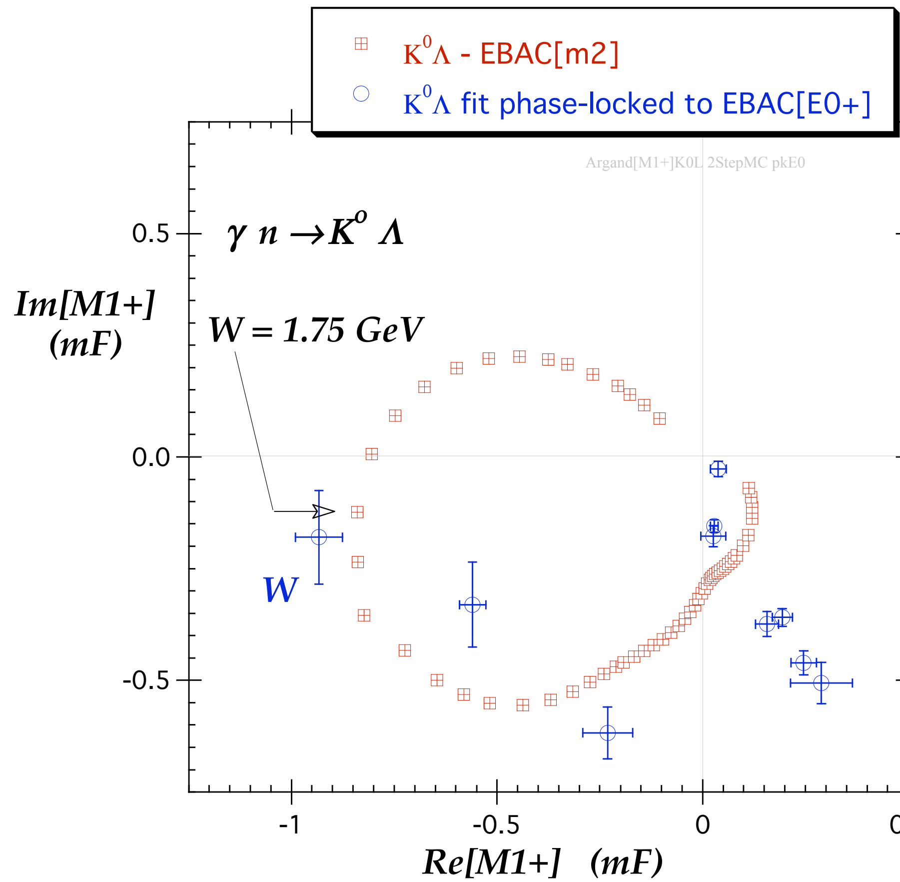
fit to expected JLab data, with phase locked to E0+ of EBAC(m2)

(1) start at Born(L=0-4); vary L=0-3;
- 10^7 Monte Carlo + wide Gradient



χ^2_{df} ~ 2-4 for W >2050

(2) start at soln(1); vary L=0-4 ;
- 10^7 Monte Carlo + narrow Gradient



χ^2_{df} ~ 1 everywhere

Argand[M1+] 2StepMC wE0+phLk

Coupled-channel constraints on the phase:

- $S_{\beta\alpha} = 1 + 2i\, T_{\beta\alpha}$, for reactions $\alpha \to \beta$
- $$O_{exp} = \left|\sum c T_{\beta\alpha}\right|^2 \Leftrightarrow \left|\sum c e^{i\phi_{\beta\alpha}} T_{\beta\alpha}\right|^2$$
- $S^+ S = 1 \quad \Rightarrow \quad i\left[T_{\beta\alpha} - T^+_{\beta\alpha}\right] = \sum_n T^+_{\beta n} T_{n\alpha}$
- phase rotation $\Rightarrow$ $i\left[T'_{\beta\alpha} - T'^+_{\beta\alpha}\right] = \sum_n T'^+_{\beta n} T'_{n\alpha}$

  but $\quad e^{i\phi_{\beta\alpha}} i\left[T_{\beta\alpha} - T^+_{\beta\alpha}\right] \neq \sum_n e^{-i(\phi_{\beta n} - \phi_{n\alpha})} T^+_{\beta n} T_{n\alpha}$

With coupled channels, arbitrary phase may leave O_{exp} invariant, but this does not generally satisfy Unitarity. (Mark Paris, Alfred Svarc)

$\Rightarrow$ *complete* experiments in two channels could constrain phases
- obvious choice is $\gamma N \to \pi N$; challenge is recoil polarization !

Partial Summary - of a work in progress

Complete sets of spin-observables will soon be available for γ+N $\rightarrow$ $K\Lambda$
(and possibly $\gamma n \rightarrow \pi^- p$) from g9 and g14

Prospects for directly fitting out the **full** (Res+Bgk+cc+…) multipoles:

- 16 observables X N angles fitted to 24 parameters (L=0-3) at each W; χ^2 space has a large number of valleys (even when the Chiang-Tabakin requirements are met)

- in principle, phase can be constrained by one of the following:
  - the high L Born limit
    (which requires sufficient statistics in ALL non-Born partial waves),
  - by CC-Unitarity (which requires *complete* data in at least 2 channels),
  - or by locking phase to that of one partial wave
    (if models can agree on one with minimal uncertainty - eg. E0+ ?)

- from a combination of Monte Carlo sampling and Gradient searches, with the phase of one multipole determined, it will be possible to deduce the **full** amplitude, which will reveal the resonant structure in the multipoles

Caviats:

- fits to the current round of experiments will probably be limited to L=0-3; fits to L=4 improve χ^2 but produce meaningless results
  $\Rightarrow$ such analyses should provide reliable L=0-2 multipoles.

- below W=2000, χ^2{to "smeared data"} < χ^2{"data" to unsmeared pts};
  $\Rightarrow$ "better" solutions than the generating amplitude,
  but still reasonably close;

  $\Rightarrow$ statistical errors, coupled with many local minima, lead to systematic uncertainties in multipoles; statistics could help and some observables may be more useful than others - still to come

- for W > 2050, present χ^2_{df} >2 and valleys are very narrow; which will certainly complicate searches for potentially *new* states

Next steps:

(a) expand MC search:

MC iterations	net samples/parameter
10^7	2
10^9	2.4
10^{11}	3
10^{24}	10

(b) test effects of systematic errors on data
$\Leftrightarrow$ will lead to systematic uncertainties in deduced multipoles

- asymmetry ratios can cancel many exp. systematics,
  BUT, observables no longer bi-linear combinations of multipoles
  $\Rightarrow$ greatly increased number of local minima

- potentially larger in $\gamma p \to K^+\Lambda$
  since BR cannot be measured simultaneously with BT and TR

- more to come