FROST Experiment

Helicity Amplitude and EM coupling constants in Exclusive Pion Photo-production

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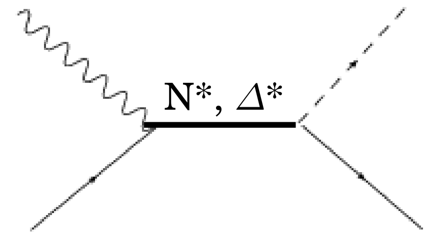


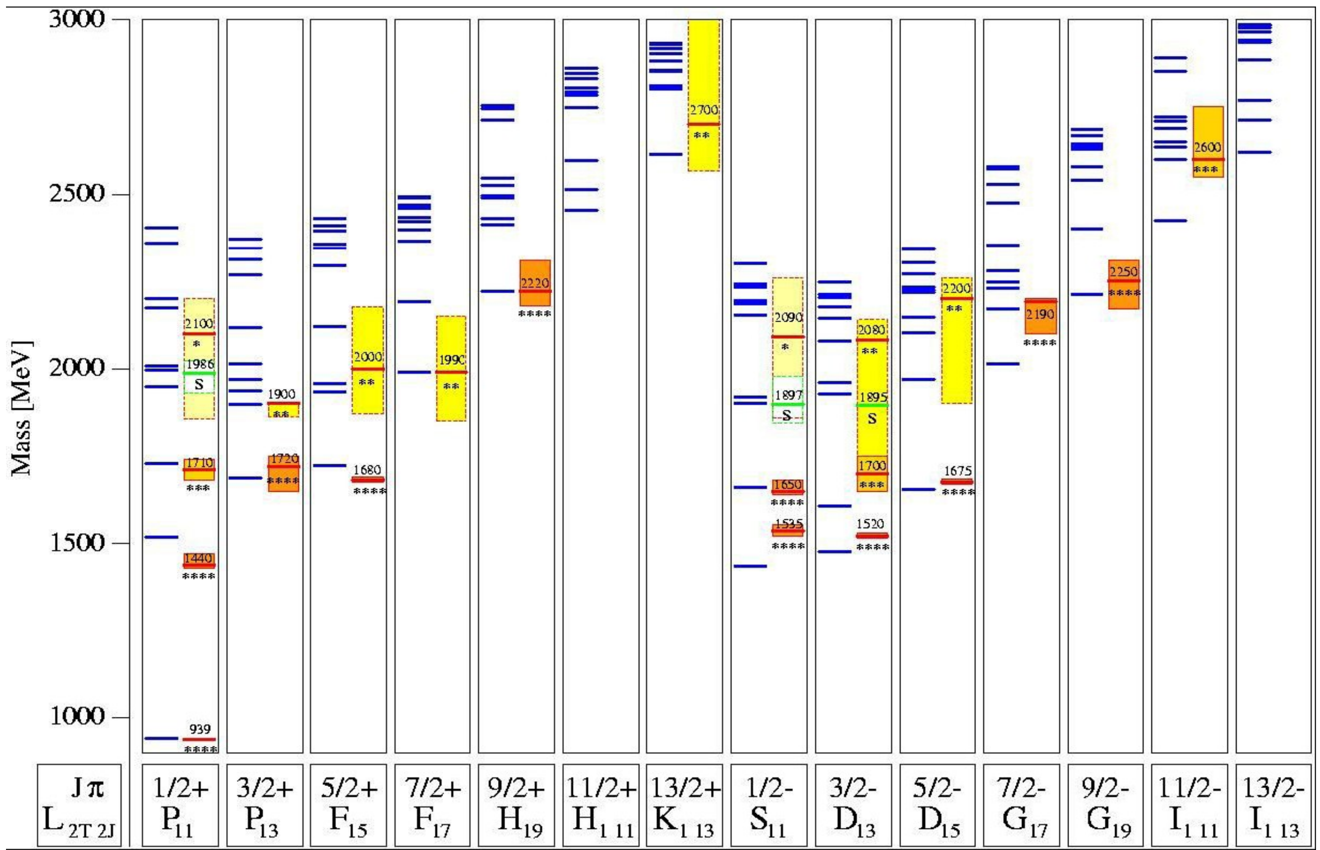
Baryon Resonances

Missing resonances

Parameters (mass, width, and couplings to various decay modes) are poorly known

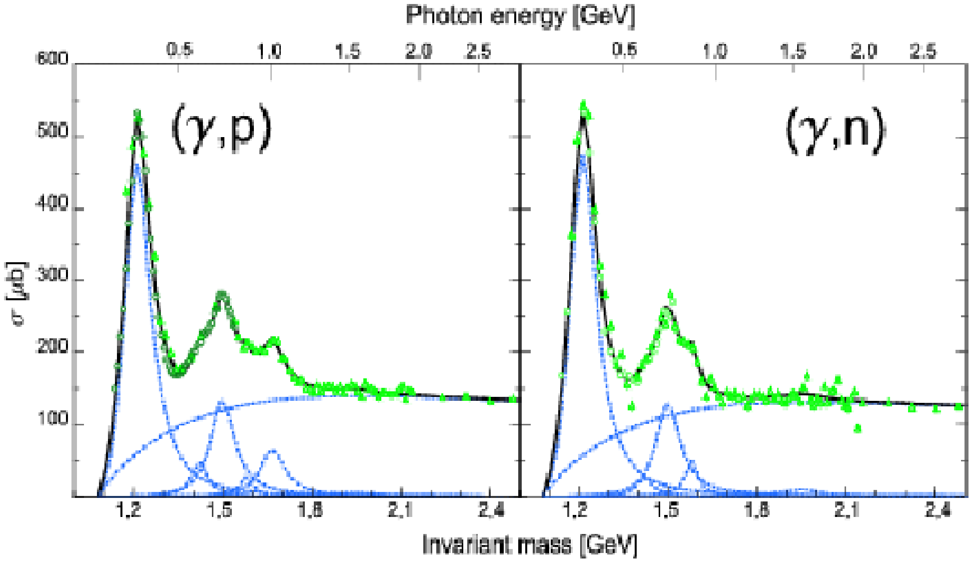
Many broad overlapping resonances

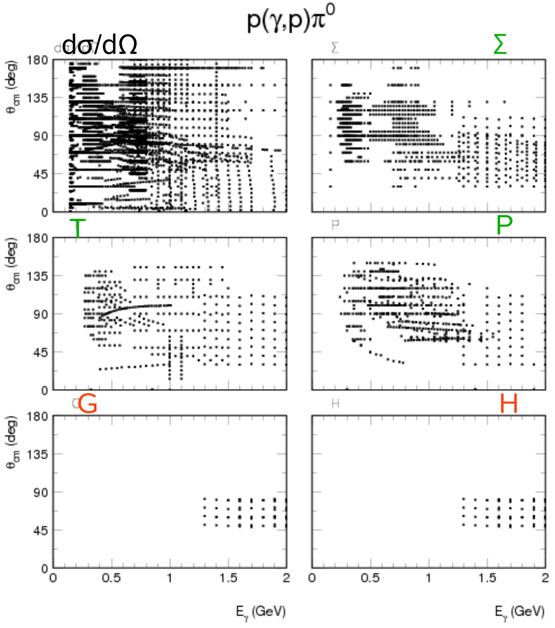
I = ½



Overlap of Partial Waves

To determine each amplitude
of partial wave at resonance regions
--> need to determine the strength
of contribution of each partial wave





dσ/dΩ :
unpolarized observable
Σ,T, P :
single polarized observables
G, H:
double polarized observables

Observables

Complete set of observables for helicity amplitudes -->8 experiments

Photon beam		Target			Recoil			Target + Recoil			
					x'	y'	z'	x'	x'	z'	z'
		x	y	z				x	z	x	z
unpolarized	σ_0		T			P		Tx'	-Lx'	Tz'	Lz'
linearly	$-\Sigma$	H	(-P)	-G	$O_{x'}$	(-T)	$O_{z'}$	(-Lz')	(Tz')	(-Lx')	(-Tx')
circularly		F		-E	-Cx'		-Cz'				

For Beam and Target double polarization (fixed energy and fixed angle)

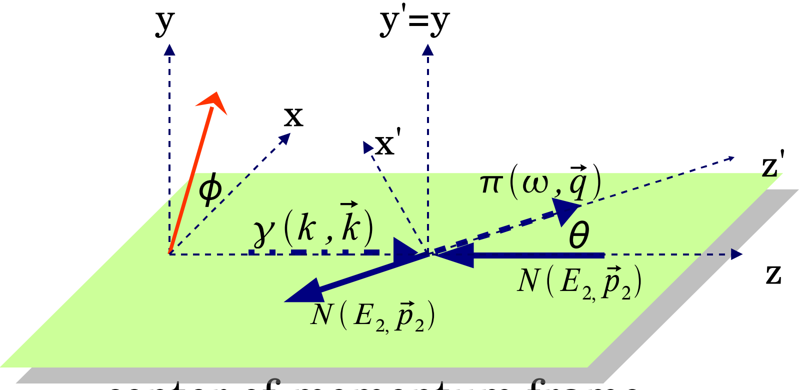
$$\frac{d\sigma}{d\Omega} = \left(\frac{d\sigma}{d\Omega}\right)_{un}\Big(1 - P_L \Sigma \cos(2\phi) + P_x\{P_c F - P_L H \sin(2\phi)\} - P_y\{-T + P_L P \cos(2\phi)\} - P_Z\{P_c E - P_L G \sin(2\phi)\}\Big)$$

$P_{x,y}$:transversely polarized target

P_z :longitudinally polarized target

$P_L(\phi)$:linearly polarized beam at an angle Φ to the reaction plane

P_c :right circularly polarized beam



center-of-momentum frame

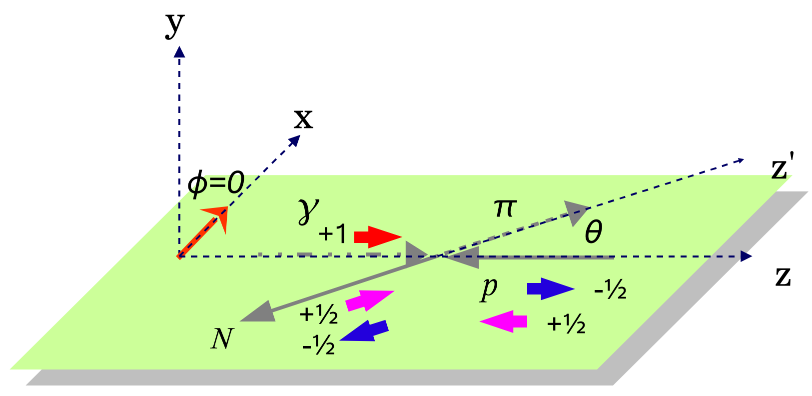
Helicity Amplitudes and Observables for γ p -> π N

$$\frac{d\sigma(\theta)}{d\Omega} = \frac{q}{k}\sum_{spins}|A_{fi}|^2 = \frac{q}{k}\sum_{i=1}^{4}|H_i|^2$$

	λ_i	λ_f
H_1	+3/2	+1/2
H_2	+1/2	+1/2
H_3	+3/2	-1/2
H_4	+1/2	-1/2

λi: total initial helicity
+1±½ = +1/2, +3/2
λf: total final helicity
+1/2, -1/2

Observables	*Helicity representation*
$(d\sigma/d\Omega)_{un}$	$1/2(\|H_1\|^2+\|H_2\|^2+\|H_3\|^2+\|H_4\|^2)$
Σ	$\mathrm{Re}(-H_1H_4^*+H_2H_3^*)$
T	$\mathrm{Im}(H_1H_2^*+H_3H_4^*)$
P	$\mathrm{Im}(-H_1H_3^*-H_2H_4^*)$
G	$\mathrm{Im}(H_1H_4^*-H_3H_2^*)$
H	$\mathrm{Im}(-H_2H_4^*+H_1H_3^*)$
E	**$1/2(\|H_1\|^2-\|H_2\|^2+\|H_3\|^2-\|H_4\|^2)$**
F	$\mathrm{Re}(-H_2H_1^*-H_4H_3^*)$



center-of-momentum frame

G9a Experiment at JLab

Experiments at Jlab

Photon beam		Proton Target		
		x	y	z
unpolarized	σ_0		T	
linearly	$-\Sigma$	H	(-P)	-G
circularly		F		-E

		E_γ
	g1	0.5 ~ 2.9 GeV
	g8	0.9 ~ 2.1 GeV
	g9a	0.5 ~ 2.4 GeV
	g9b	

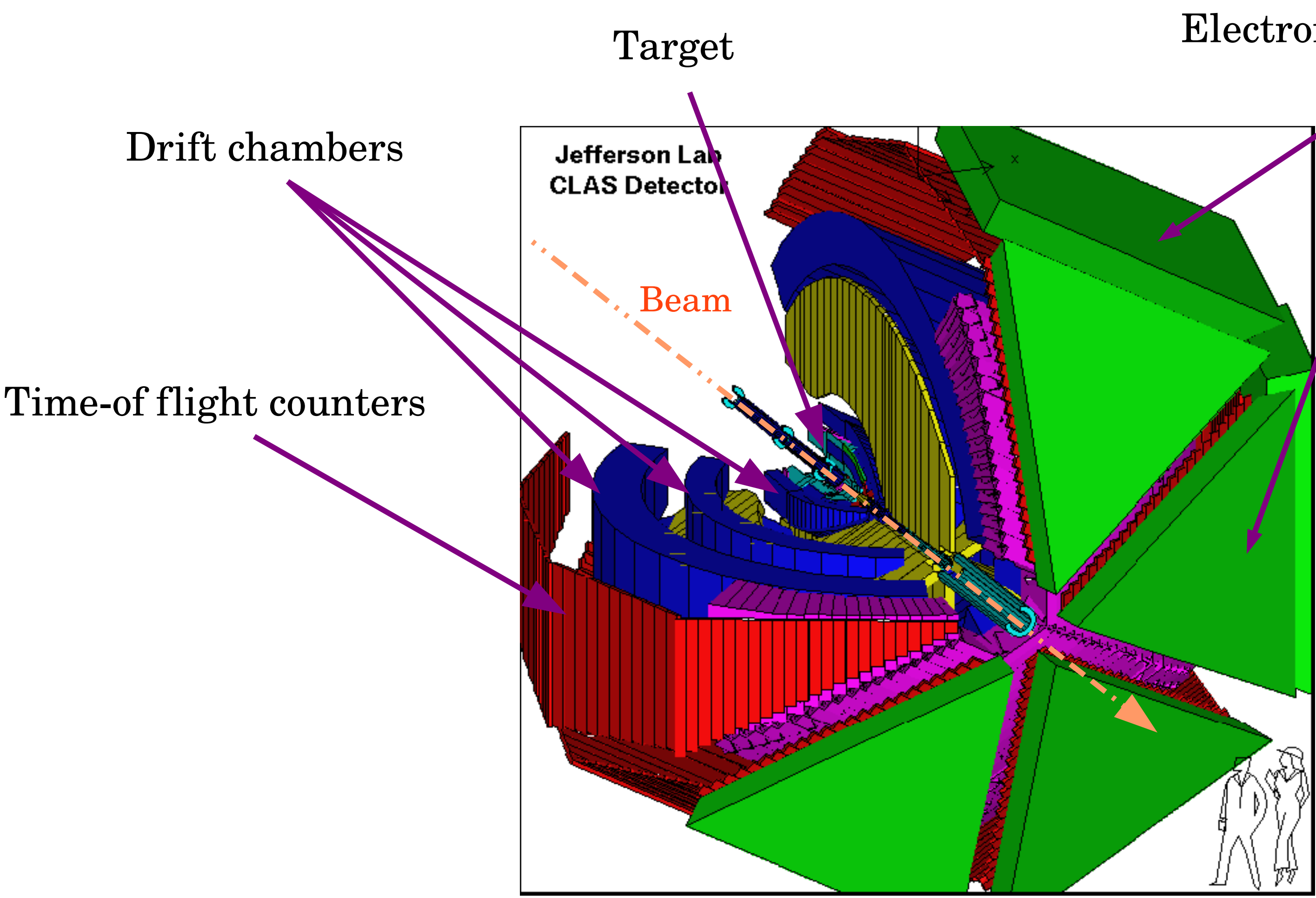
g1 : unpolarized beam and target --> σ_0

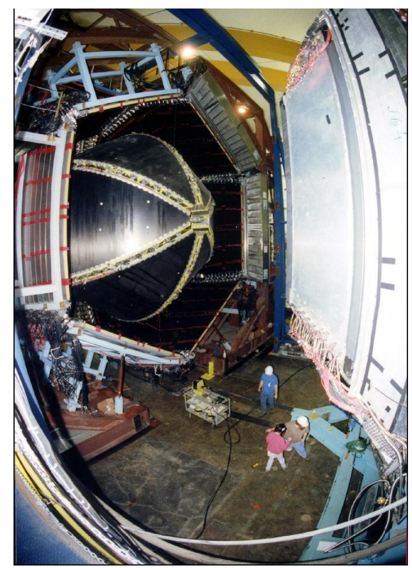
g8 : linearly polarized beam --> Σ

g9a : linearly polarized beam and longitudinally polarized target
circularly polarized beam and longitudinally polarized target

g9b : linearly polarized beam and transversely polarized target
(2010) circularly polarized beam and transversely polarized target

CLAS Detector

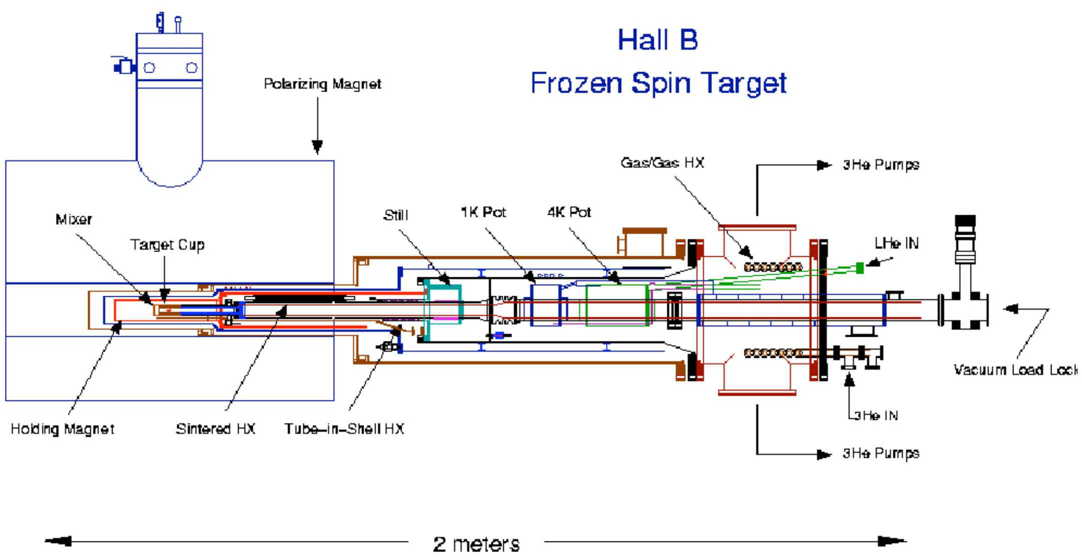




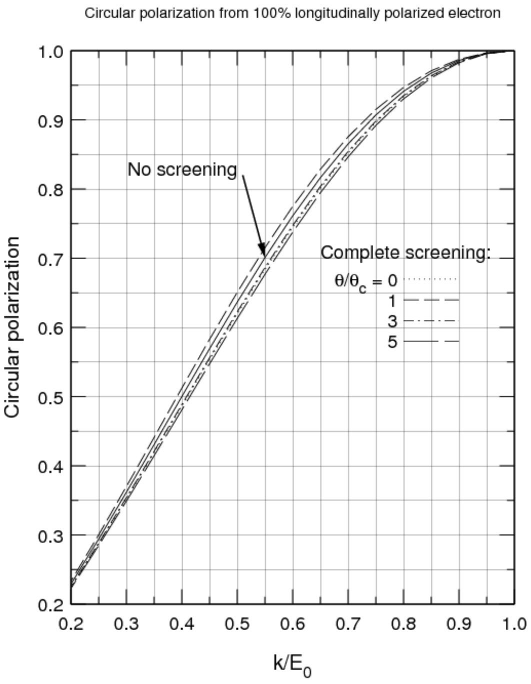
Polarized Target

Butanol (C_4H_9OH)

	Design goal	Result
High polarizations (longitudinal)	80%	82 ~85%
Long spin-relaxation times	500hours	1600~2800 hours
Short re-polarization time	few hours	few hours
Holding mode (0.5T)	< 50mK	28 ~ 30mK



Circularly Polarized Photon Beam



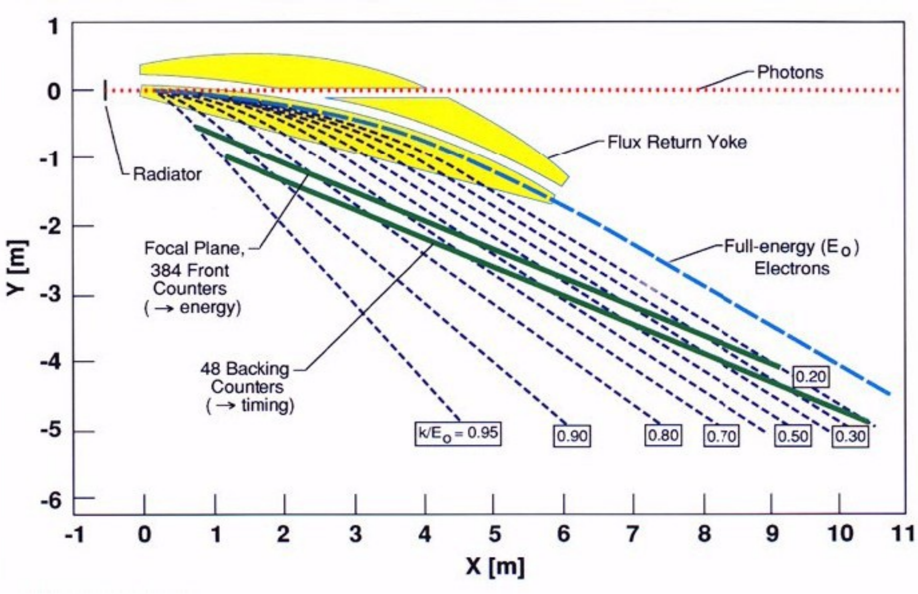
Bremsstrahlung

linearly polarized electron beam

use radiator of gold

depend on polarization of initial electron beam

and the ratio of photon energy to the initial electron energy



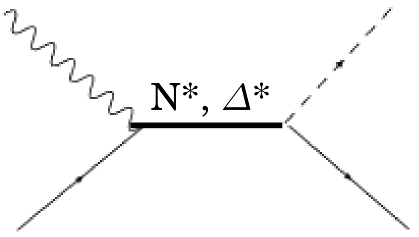
$$P(\gamma)=P(e)\frac{4x-x^2}{4-4x+3x^2}$$

$$x = \frac{k}{\epsilon_1}=\frac{(photon\,energy)}{(incident\,electron\,energy)}$$

H. Olson, L.C. Maximon
Phys. Rev. 114 p887 (1959)

Amplitudes from N^* and Δ^* for direct resonance term

Example S_{11} (Spin ½, Isospin ½)



Lagrangians

$$L_{piNN^*} = \frac{-H}{m} [\overline{N} \gamma_\alpha \tau_i N^* + \overline{N}^* \gamma_\alpha \tau_i N] \partial^\alpha \pi_i$$

$$L_{em} = \frac{-F^{\alpha\beta}}{4M} [\overline{N} \sigma_{\alpha\beta} \gamma_5 (G_S + \tau_3 G_V) N^* - \overline{N}^* \sigma_{\alpha\beta} \gamma_5 (G_S + \tau_3 G_V) N]$$

$G_S\ (G_p + G_n),\ G_V\ (G_p - G_n)$: *EM coupling constants* $(Q^2 = 0)$

Propagator (spin ½ resonances)

$$G(P^2, P) = \frac{\not{P} + M^*}{P^2 - M^{*2} + i M^* \Gamma(P^2)}$$

M: nucleon mass

$P^2 = M^{*2}$ (for $Q^2 = 0$)

Calculated amplitude (in the case of initial and final particles are proton)

$$A_f = \frac{G_p}{2M} \frac{H}{m} \overline{u}_2 \not{q} G(\not{\epsilon} \not{k} - \not{k} \not{\epsilon}) \gamma u_1$$

H : *Strong coupling constant* $(Q^2 = 0)$

Electromagnetic Coupling Constants

Partial Wave Analysis (PWA)

--> determine resonance couplings, $A_\lambda^I (I : isospin, \lambda : spin)$

$$A_\lambda^I \propto \frac{i B_\lambda^I \cdot \Gamma}{\sqrt{\Gamma_\pi}}$$

B_λ^I : *Imaginary Part of* H_i (*helicity amplitudes*)

Γ : *Full Width*

Γ_π : *Partial Width for the decay N* --> πN*

The case of S_{11} (in the case of initial and final particles are proton)

$$A_{1/2}^p(S_{11}) = \frac{-e}{\sqrt{2}} \frac{G_p}{M} \sqrt{\frac{k}{M(E_1+M)}} (M+M^*)$$

--> Determine the coupling constant Gp

Summery

1. Double polarized measurement is important
2. g9a experiment
   --> double polarization, beam and target
   --> part of a series of experiments to determine
   the invariant helicity amplitudes and
   electromagnetic coupling constants