GSI Helmholtzzentrum für Schwerionenforschung GmbH

GSI - May 9 2018
EMMI Hadron Physics Seminar

Hadron spectroscopy at Jefferson Lab

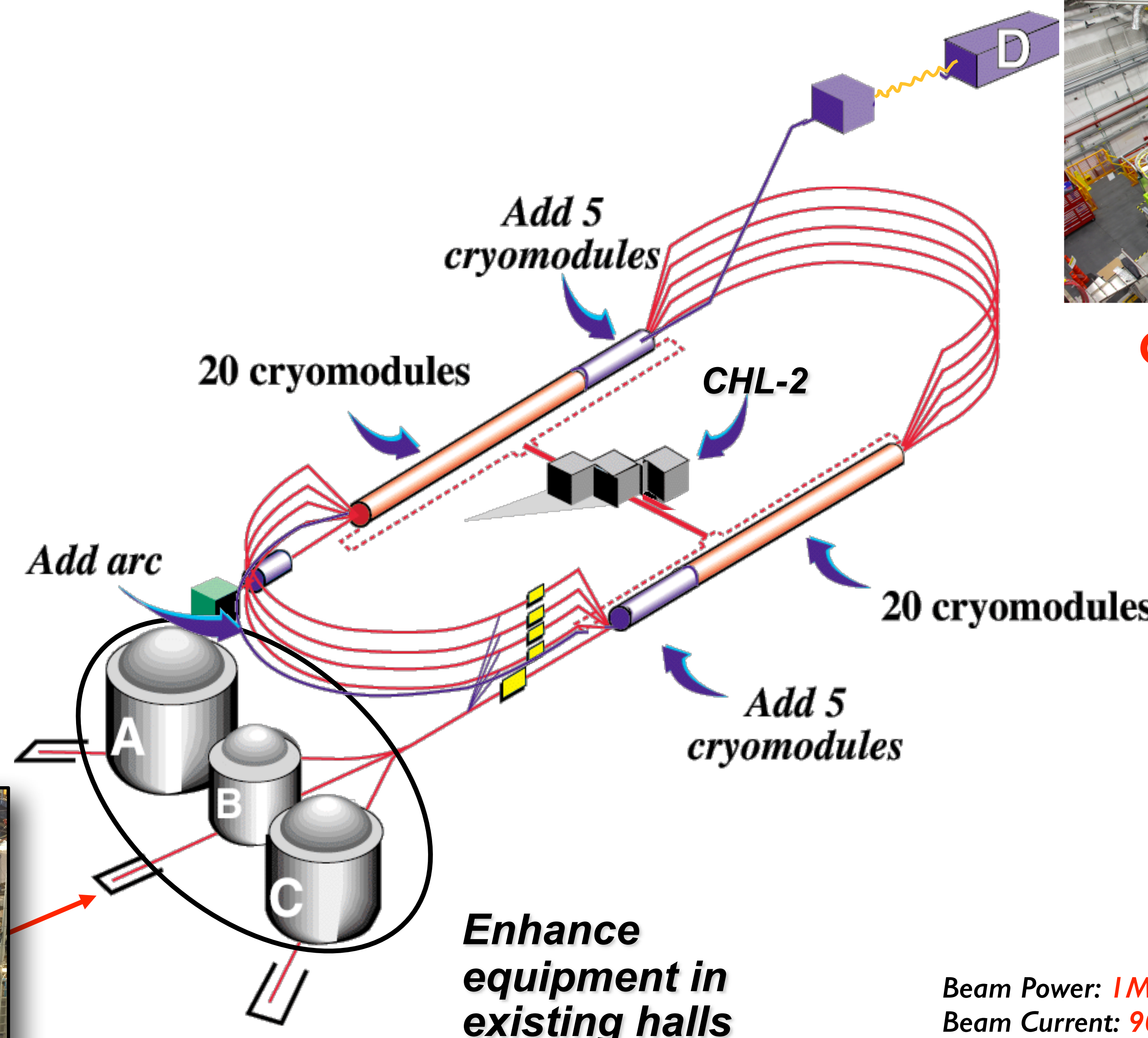
M.Battaglieri
INFN -GE
Italy

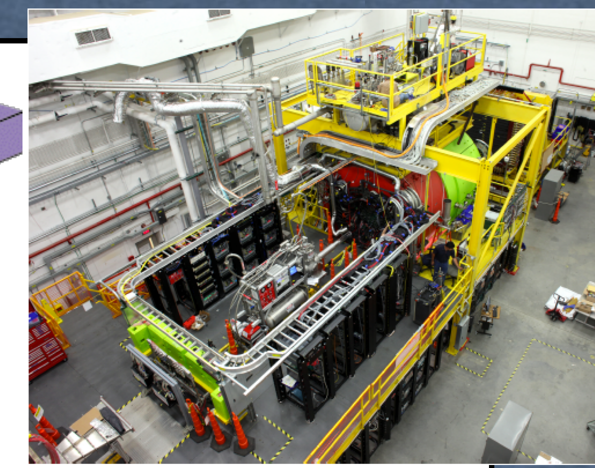
Jefferson Lab

- ✳ Primary Beam: Electrons
- ✳ Beam Energy: 12 GeV
    - $10 > \lambda > 0.1$ fm
      nucleon → quark transition
      baryon and meson excited states
- ✳ 100% Duty Factor (cw) Beam
    - coincidence experiments
    - Four simultaneous Beams with Independently Variable Energy and Intensity
        - complementary, long experiments
- ✳ Polarization (beam and reaction products)
    - spin degrees of freedom
    - weak neutral currents

L > 10^7 x SLAC at the time of the original DIS experiments!

Jefferson Lab at 12 GeV





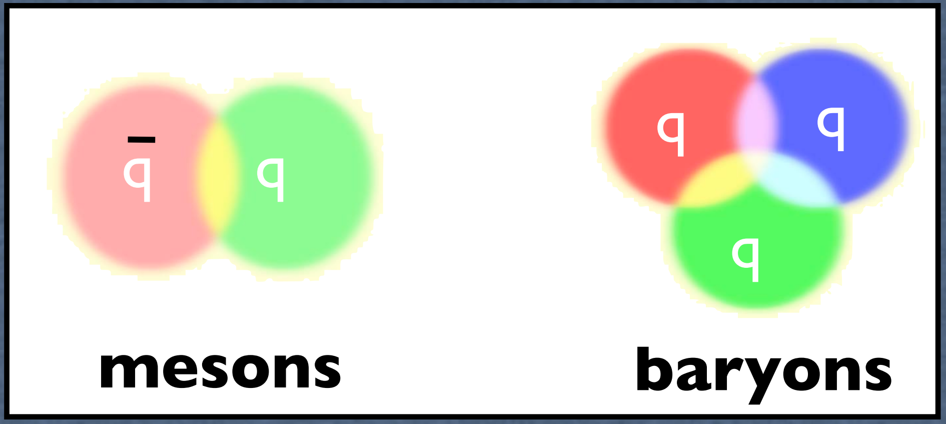
GLUEX

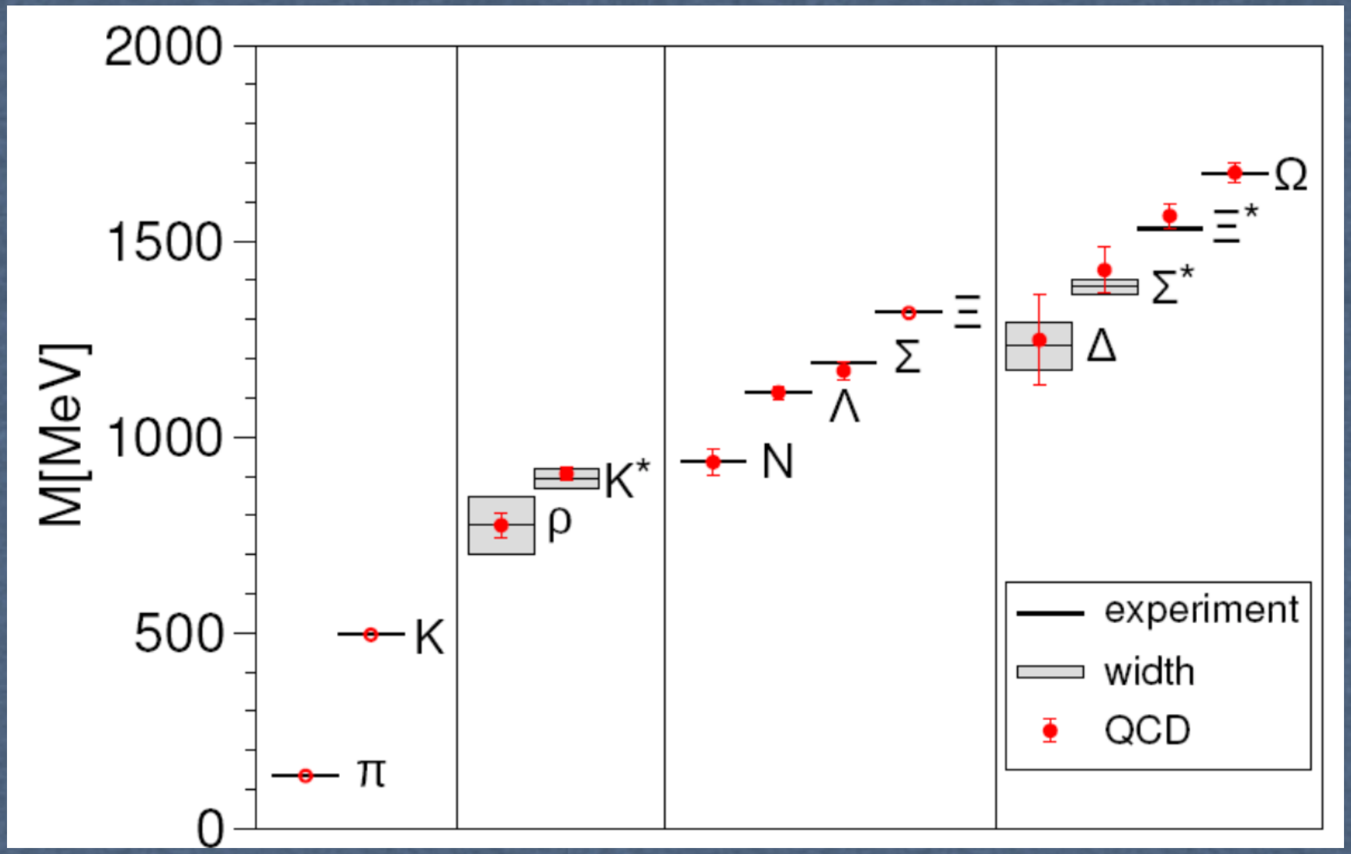
CLAS12

Beam Power: 1MW
Beam Current: 90 μA
Max Pass energy: 2.2 GeV
Max Enery Hall A-C: 10.9 GeV
Max Energy Hall D: 12 GeV

Beyond the quark model: hybrids and exotics

Quarks are confined inside colorless hadrons
they combine to 'neutralize' color force





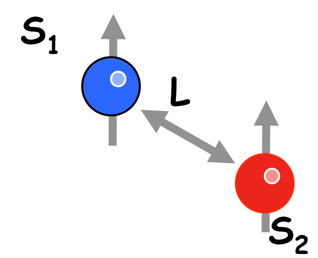
Observed mesons and baryons well described by 1st principles QCD

Science (2008)

The light quark meson spectrum

Constituent Quark Model

- Quark-antiquark pairs with total spin S=0,1 and orbital angular momentum L



$S=S_1+S_2$ $\quad J= L+S$

$P = (-1)^{L+1}$ $\quad C= (-1)^{L+S}$

Not all the J^{PC} combinations are allowed:

0^{++} 0^{+-} 0^{-+} 0^{--} 1^{++} 1^{+-} 1^{-+} 1^{--} 2^{++} 2^{+-} 2^{-+} 2^{--} 3^{++} 3^{+-} 3^{-+} 3^{--} …

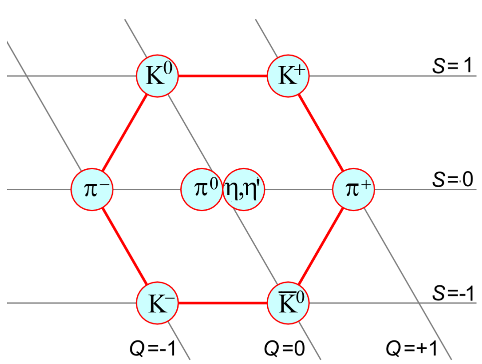
- SU(3) flavor symmetry
  → nonet ($8\oplus1$) of degenerate states

$J^{PC}= 0^{-+}$ ⇒ (π,K,η,η')

1^{--} ⇒ (ρ,K*,ω,Φ)

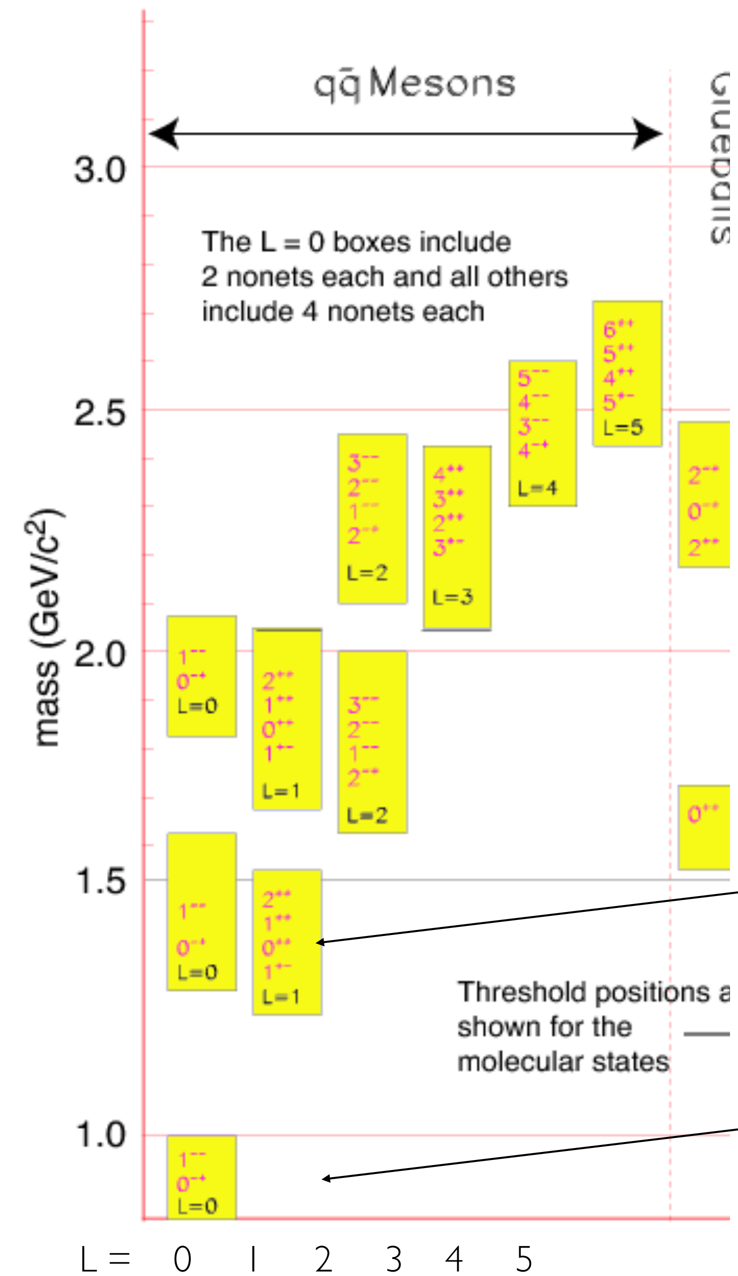
1^{+-} ⇒ (b_1,K_1,h_1,h_1')

…



- Great success in describing the lower mass states

Consider light quarks: u,d,s



a,K,f,f'
b,K,h,h'

ρ,K*,ω,ϕ
π,K,η,η'

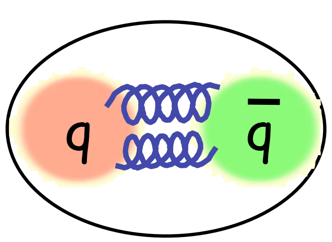
($q\bar{q}$ angular momentum)

- A number of predicted states is not experimentally observed and assignments are uncertain

The gluons and the meson spectrum

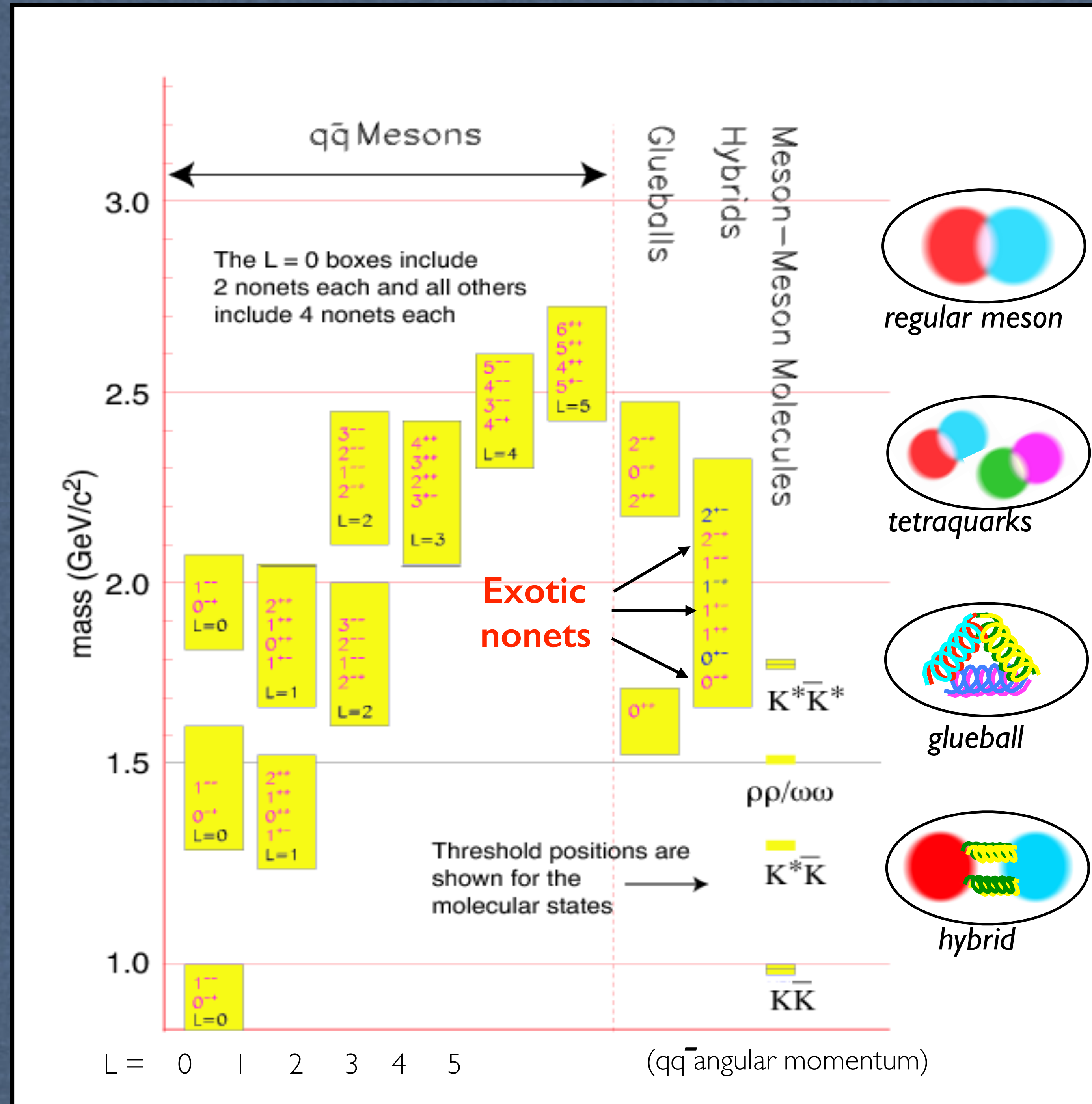
- Understanding gluonic excitations of mesons and the origin of confinement
- At high energy experimental evidence is found in jet production
- At lower energies the hadron spectrum carries information about the gluons that bind quarks
- Can we find hints of the glue in the meson spectrum?

Search for non-standard states with explicit gluonic degrees of freedom



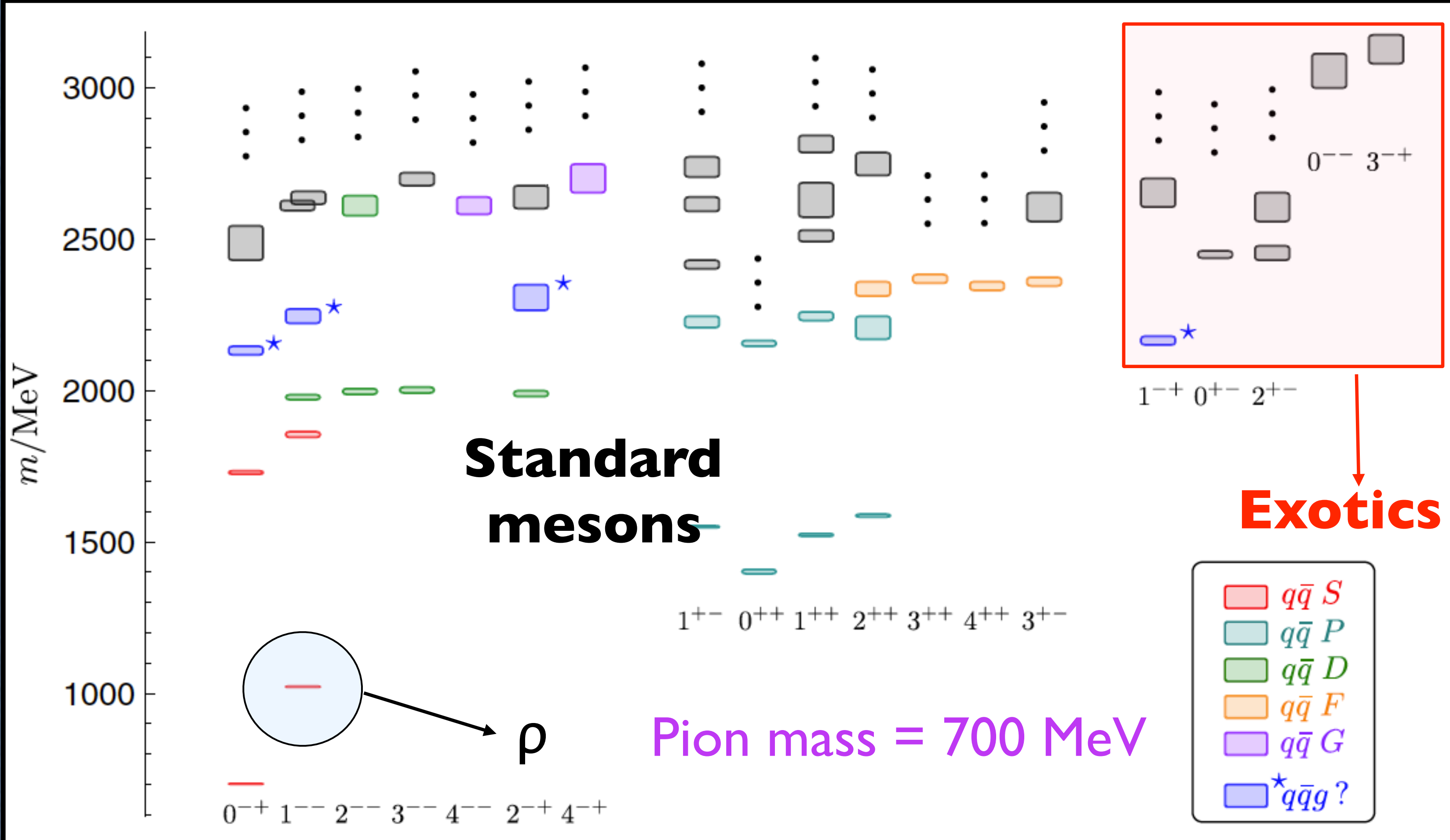
Not-allowed J^{PC} = $0^{--}, 0^{+-}, 1^{-+}, 2^{+-}$ ...

Unambiguous experimental signature for the presence of gluonic degrees of freedom in the spectrum of mesonic states

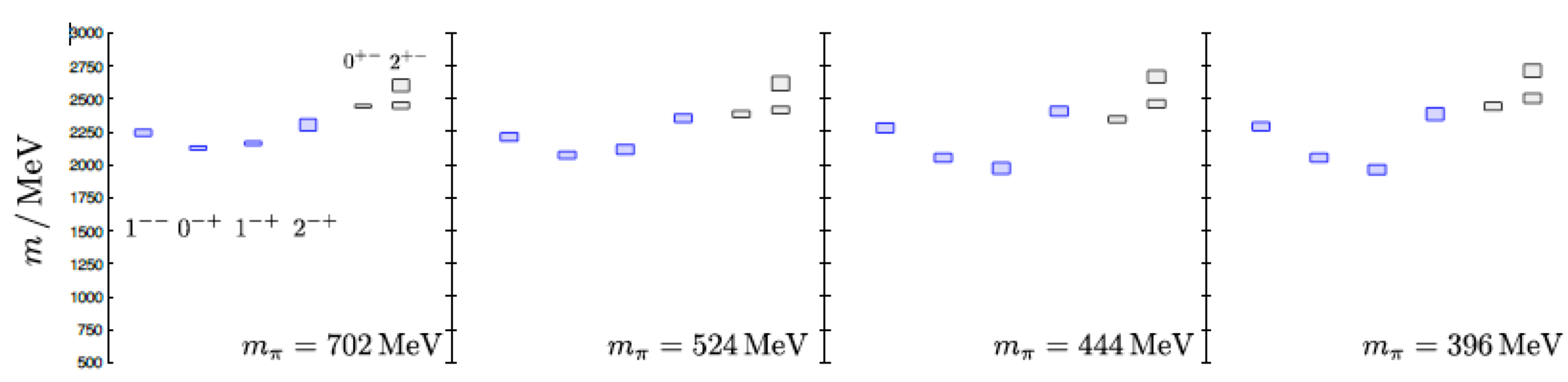


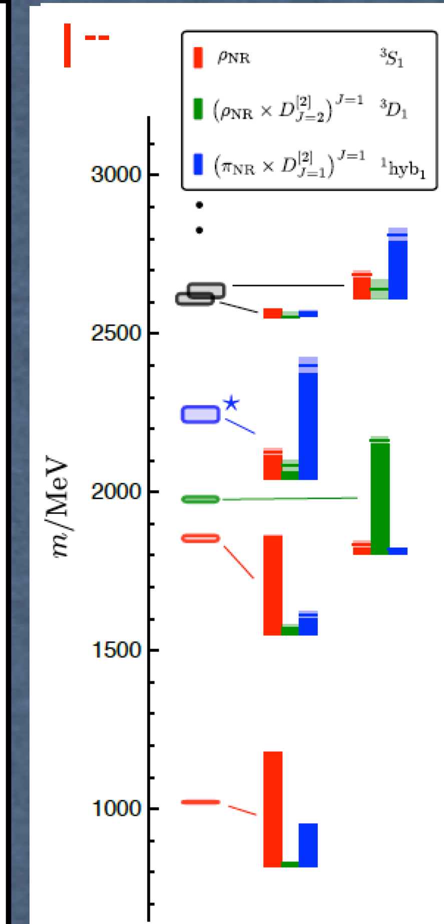
one of the most important issue in hadron physics and main motivation for the JLab 12 GeV upgrade

Lattice QCD calculations



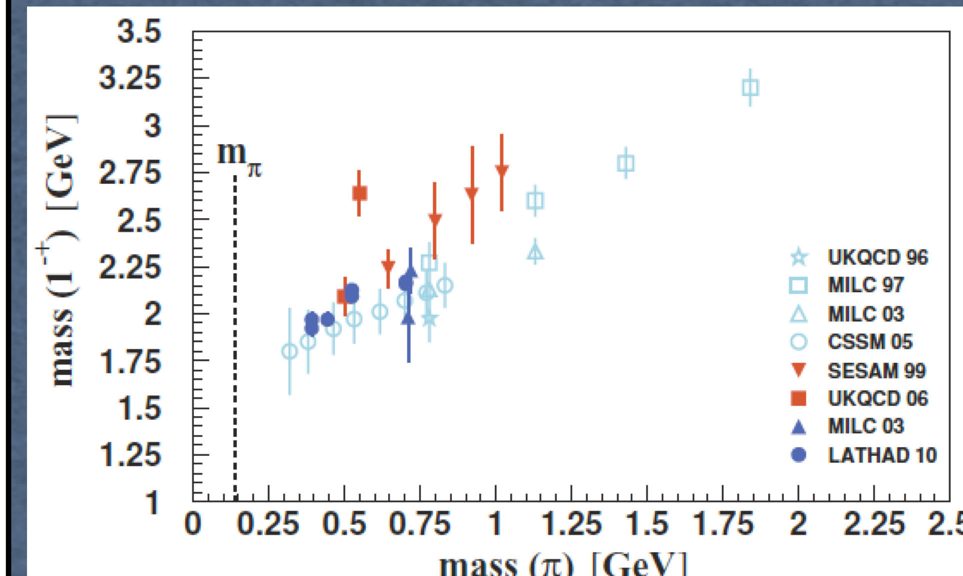
J.Dudek et al Phys.Rev.D82 (2010) 034508 J.Dudek et al., Phys. Rev. D84, 074023 (2011)





in blue: overlap with $J^{PC}=1^{-+}$ operator interpreted as qq in S-wave + $J_g^{P_gC_g}=1^{+-}$ in P-wave

- Interpretation in term of CQM + Gluon field
- Dependence on Lattice size
- Dependence on pion mass



The CLAS12 physics program

Photoproduction of hyperons with CLAS12

Exp-12-008 "Very Strange Experiment"

Search for missing excited hyperon states

✳ Excited cascades
- Hyperon spectrum less know wrt N*
- How quark masse change the effective degrees of freedom in hadron spectra
- $\Xi^-(1530)$, $\Xi^-(1820)$
- $K^+K^+\pi^-$, $K^+K^+K^-p$

✳ Ω^- photoproduction
- 3 s quarks systemPoorly know
- Quantum number poorly known
- $K^+K^+K^0$, $K^+K^+K^0K^-$

✳ Quantum numbers and production dynamics determination
- Parity and polarisation measurement of $\Xi^-(1820)$
- Ω^- cross section

- Excellent K identification
- Excellent resolution to use missing mass technique
- Decay and production of multi kaon systems
- Detached vertex capability polarization

Requirements

1) 4π detector
2) High intensity 6-10 GeV

Meson spectroscopy with photons in CLAS12

Exp-11-005 "MesonEx"

Study the meson spectrum in the 1-3 GeV mass range to identify gluonic excitation of mesons (hybrids) and other quark configuration beyond the CQM

✳ Hybrid mesons and Exotics
- Search for hybrids looking at many different final states
- Charged and neutral-rich decay modes
- γ p → p 3π, γ p → p η π, ...

✳ Hybrids with hidden strangeness and strangeonia
- Intermediate mass of s quarks links long to short distance QCD potential
- Good resolution and kaon Id required
- γ p → p ϕ π, γ p → p ϕ η, γ p → p 2K π, ...

✳ Scalar mesons
- Poorly know f_0 and a_0 mesons in the mass range 1-2 GeV
- Theoretical indications of unconventional configurations (qqqq or gg)
- γ p → p 2π, γ p → p 2K, ...

- Decay and production of exclusive reactions, different final states (charged/neutral)
- Detector requirements: good acceptance, energy resolution, particle Id
- ...ia PWA

Requirements

1) 4π detector
2) High intensity 6-10 GeV photon beam

Light Meson Decay

Exp-12-06-108b "LMD"

Transition Form Factor of the eta' Meson with CLAS12

✳ Transition form factor of the eta' meson
- hadronic light-by-light (HLBL) contribution to the muon anomalous magnetic moment a_μ
- Dalitz decays of η′ mesons, η′ → γ e+ e–
- η′ produced in e p → e p η′
- 0.5% statistical uncertainties (disregarding higher order effects)

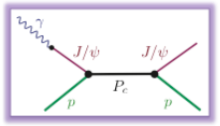
- Studied in g12 (CLAS6)
- Detector requirements: high luminosity, lepton trigger capability, large angle acceptance
- External photon pair production background suppressed by exploiting the 1 mm vertex resolution

LHCb Pentaquark with C...

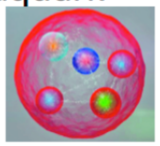
Exp-12-12-001a "Pentaquark"

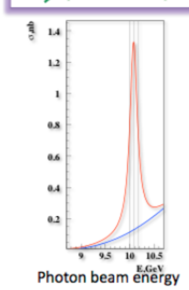
Near threshold J/psi photoproduction and s... pentaquarks with CLAS12

Search for LHCb Pentaquark



$$\gamma + p \to P_C \to J/\psi + p$$
$$J/\psi \to e^+e^-$$
$$J/\psi \to \mu^+\mu^-$$





$BR(P_c \to J/\psi p) = 1\%$ $L = 10^{35} cm^{-2} s^{-1}$

	$P_c(4380)$		$P_c(4450)$	
	Minimum	Maximum	Minimum	Maximum
Untagged mode	48	500	70	220
Tagged mode	20	600	28	880
Total	68	1100	98	1100

98 events/day for narrow $P_c(4450)$ pentaquark state at nominal CLAS12 luminosity

Nucleon resonances studies with CLAS12

Exp-12-009 "N" and Exp-12-06-108a "KY"*

Study the baryon spectrum to map the Q2 evolution of excited states in an unexplored domain

✳ Single and multi pions Xsec
- Extended kinematic coverage in the unexplored Q^2 region between 5-10 GeV
- Precise and abundant data for many final states

✳ Hyperon electroproduction
- Natural extension to single and multi K final states

✳ Photocoupling extraction
- Mapping the NN* transition form factors to pin down the underlying dynamics
- Phenomenological models to parametrize the data, and PWA for full interpretation
- Well established analysis procedure tested with CLAS data

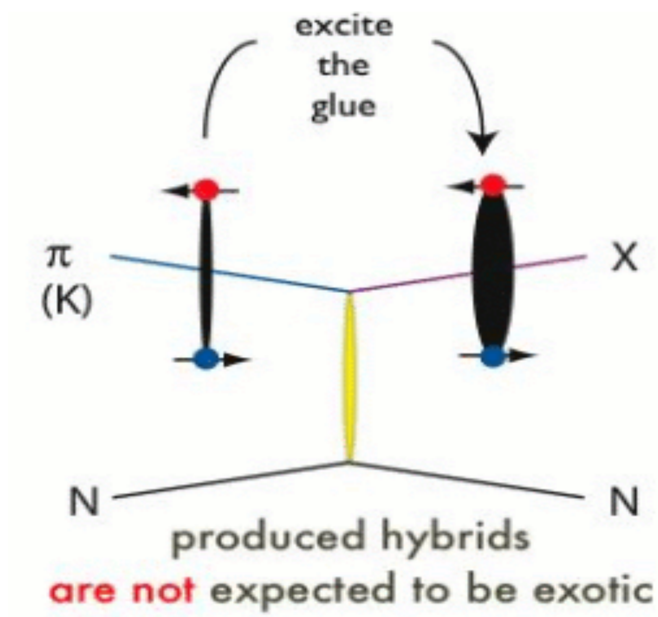
- Isobar model and beyond
- Detector requirements: good acceptance, energy resolution, particle Id
- Identification of exotic configuration via PWA

Requirements

1) 4π detector
2) High intensity 10 GeV electron beam

Why photoproduction

★ Photoproduction: exotic J^{PC} are more likely produced by S=1 probe



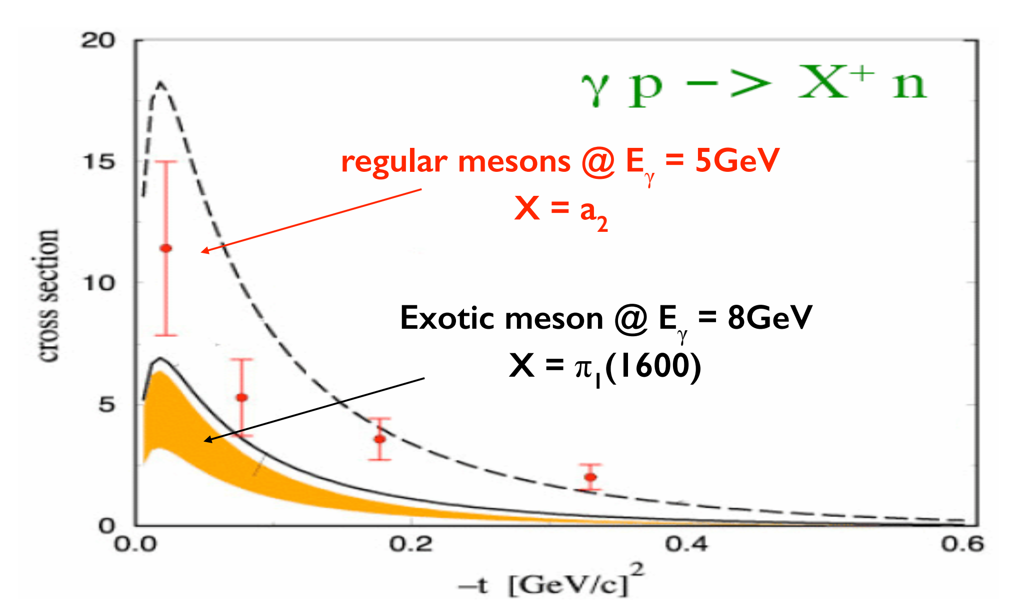
Need spin-flip for exotic quantum number

No spin-flip for exotic quantum number

★ Linear polarization acts like a filter to disentangle the production mechanisms and suppress bg

★ Production rate for exotics is expected comparable as for regular mesons

A. Afanasev and P. Page et al. PR A57 1998 6771
A. Szczepaniak and M. Swat PLB 516 2001 72

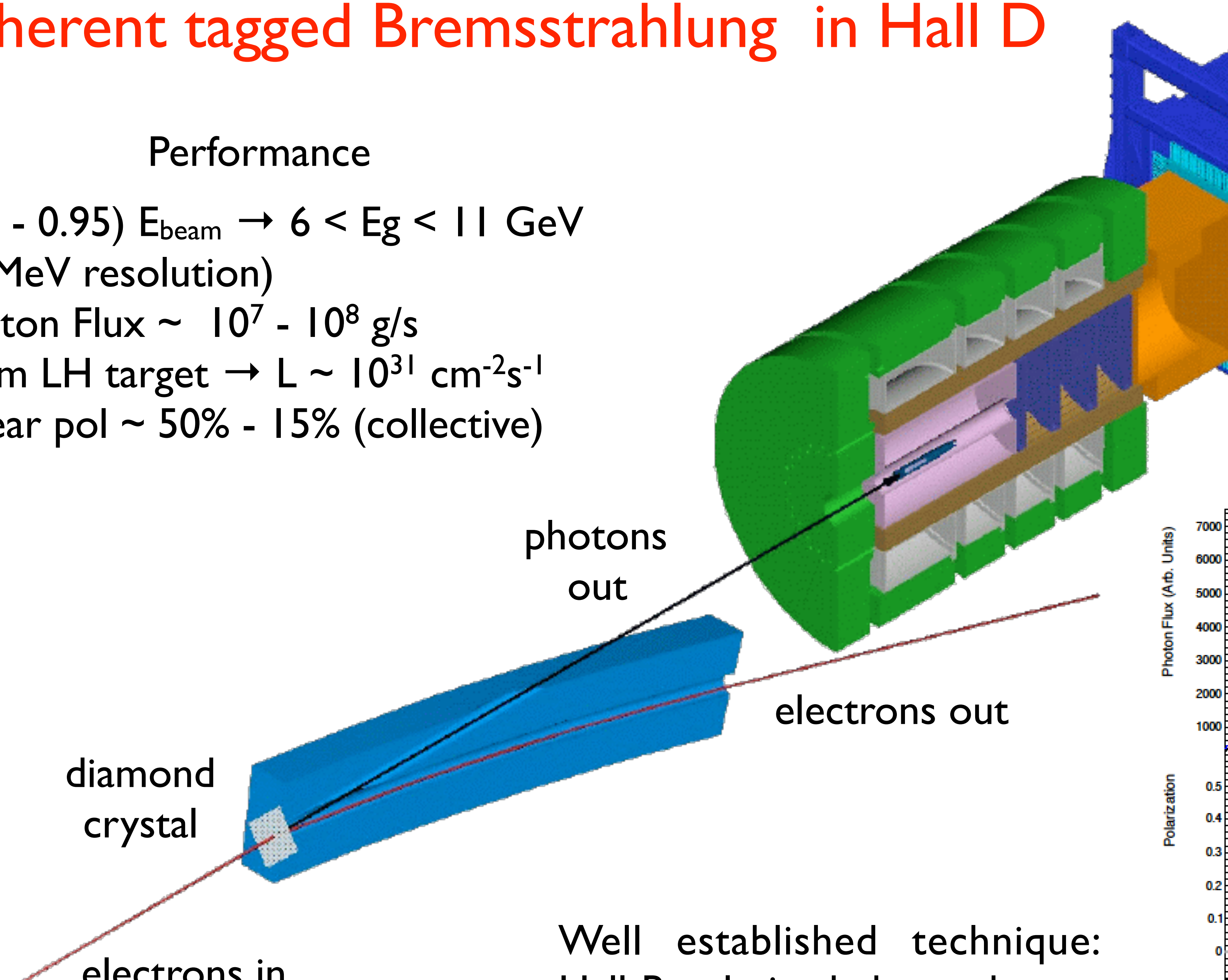


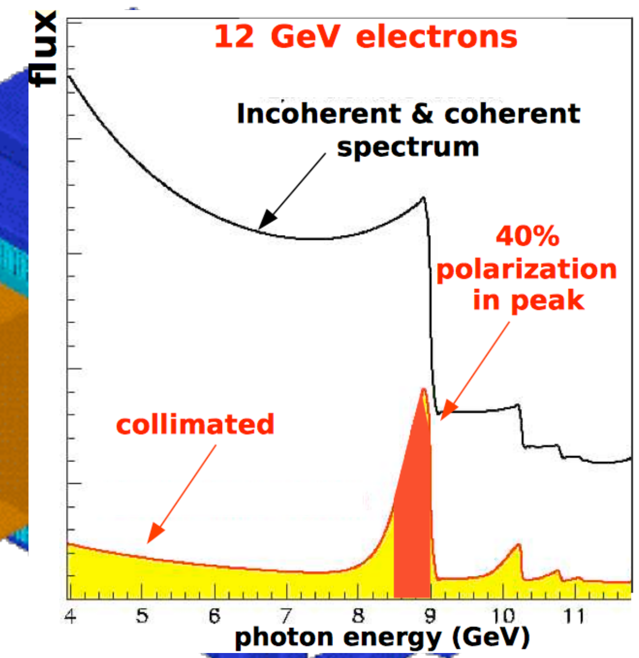
Meson spectroscopy with photons at JLab-12GeV

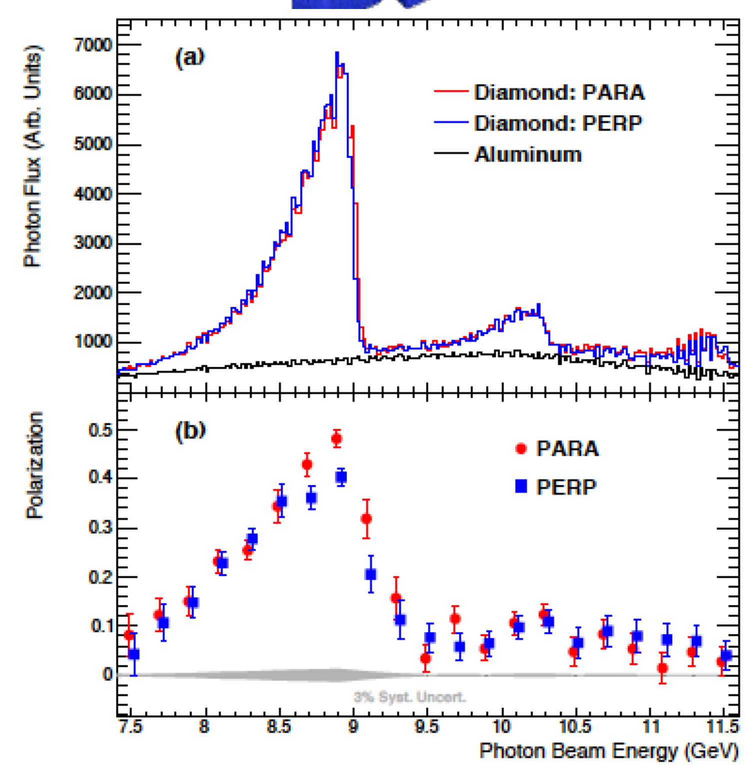
Coherent tagged Bremsstrahlung in Hall D

Performance

(0.5 - 0.95) E_{beam} → 6 < Eg < 11 GeV
(10MeV resolution)
Photon Flux ~ 10^7 - 10^8 g/s
30cm LH target → L ~ 10^{31} $cm^{-2}s^{-1}$
Linear pol ~ 50% - 15% (collective)







Well established technique:
Hall-B polarized photon beam

Meson spectroscopy with photons at JLab-12GeV

Coherent tagged Bremsstrahlung in Hall D

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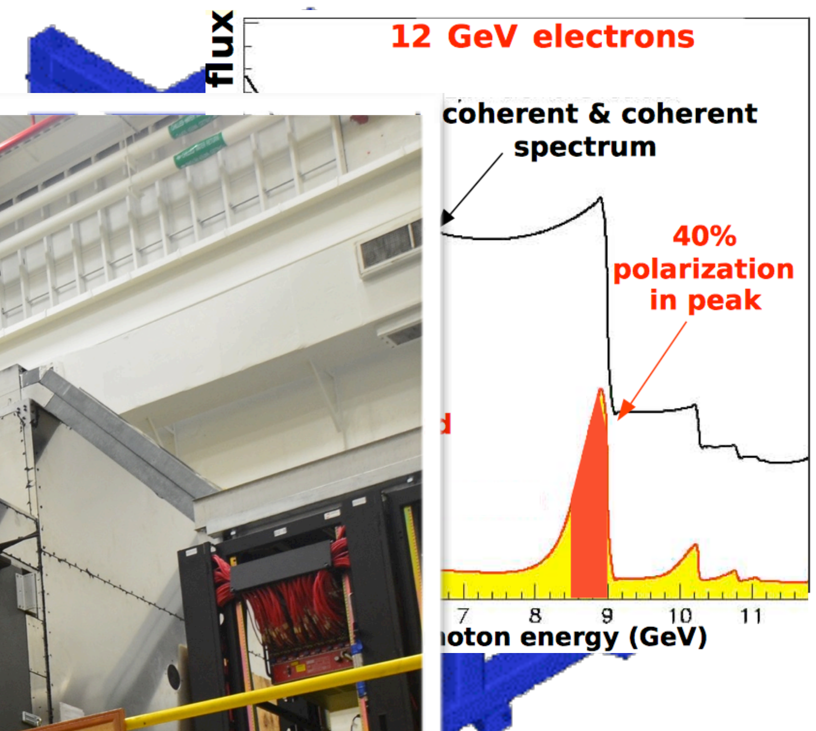

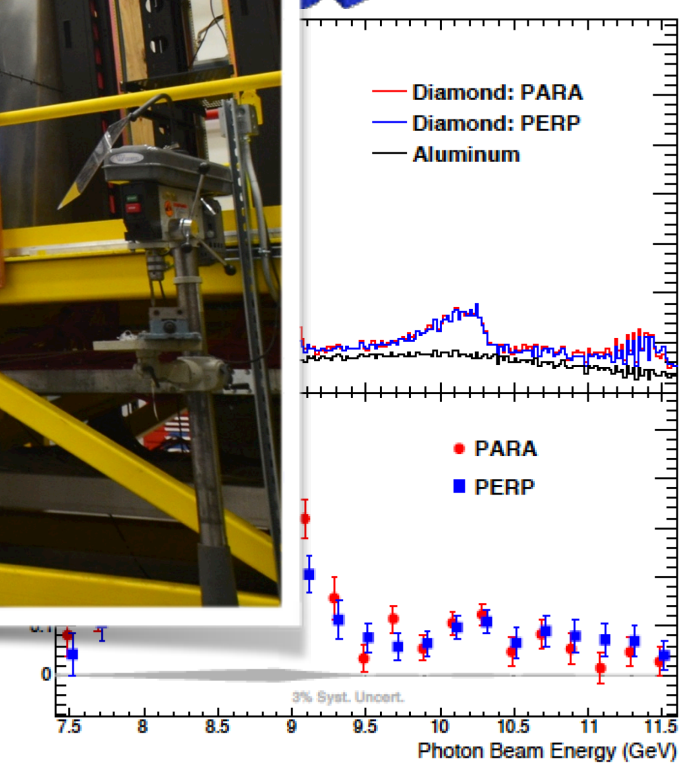

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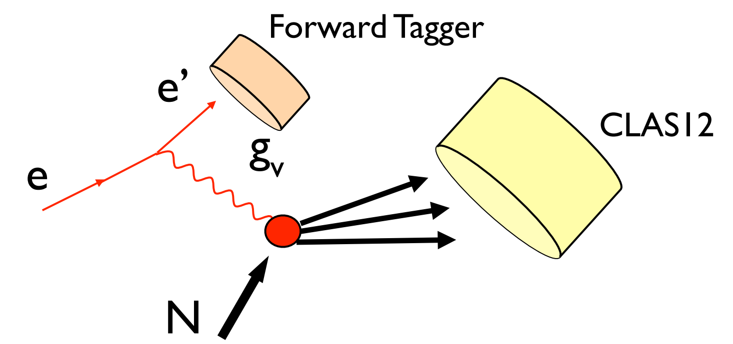
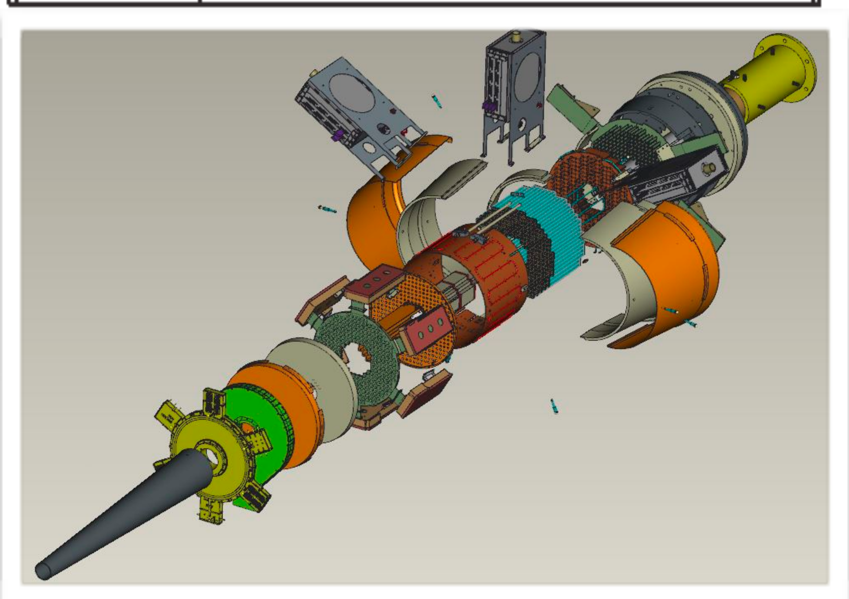
electrons in

Well established technique:
Hall-B polarized photon beam

Quasi-real photoproduction with CLAS12 (Low Q^2 electron scattering)



$E_{scattered}$	0.5 - 4.5 GeV
θ	2.5^o - 4.5^o
ϕ	0^o - 360^o
ν	6.5 - 10.5 GeV
Q^2	0.01 - 0.3 GeV^2 ($< Q^2 >$ 0.1 GeV^2)
W	3.6 - 4.5 GeV

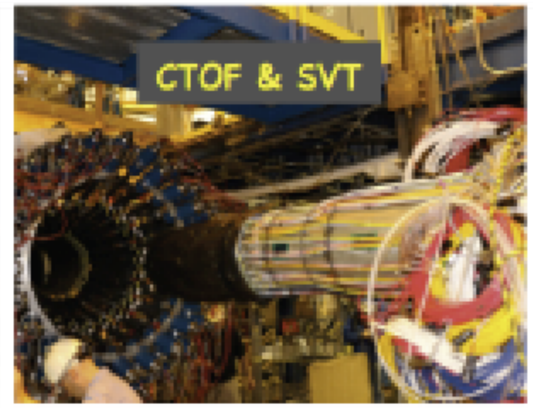


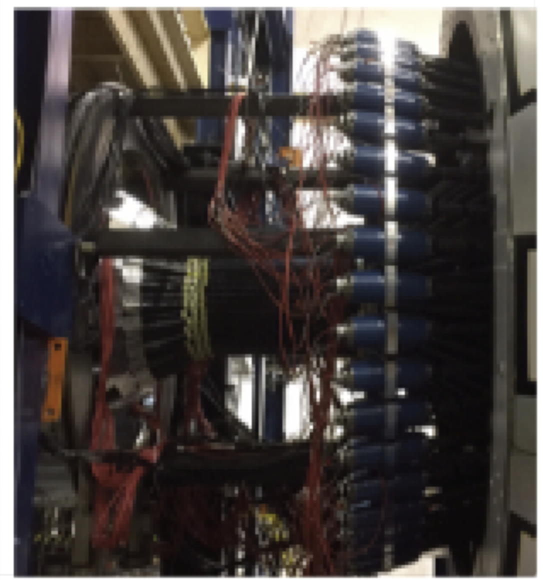
- ★ Electron scattering at "0" degrees (2.5^{O} - 4.5^{O})
  - ➤ low Q^2 virtual photon ⇔ real photon
- ★ Photon tagged by detecting the scattered electron at low angles
  - ➤ High energy photons $6.5 < E_g < 10.5$ GeV
- ★ Quasi-real photons are linearly polarized
  - ➤ Polarization ~ 70% - 10% (measured event-by-event)
- ★ High Luminosity (unique opportunity to run thin gas target!)
  - ➤ Equivalent photon flux $N_\gamma \sim 5\ 10^8$ on 5cm H_2 ($L=10^{35}$ $cm^{-2}s^{-1}$)
- ★ Multiparticle hadronic states detected in CLAS12
  - ➤ High resolution and excellent PID (kaon identification)

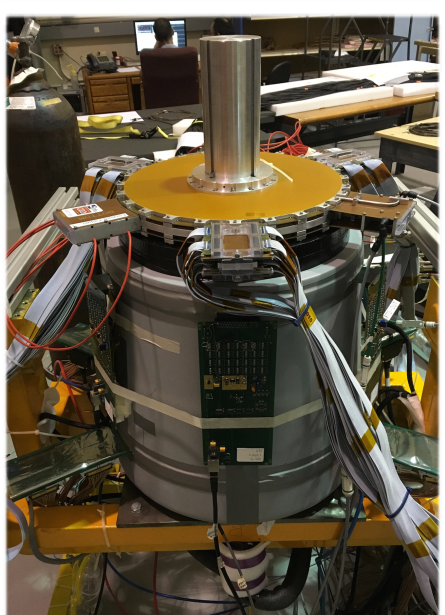
Complementary to Hall-D (GLUEX)

The Forward Tagger and CLAS12

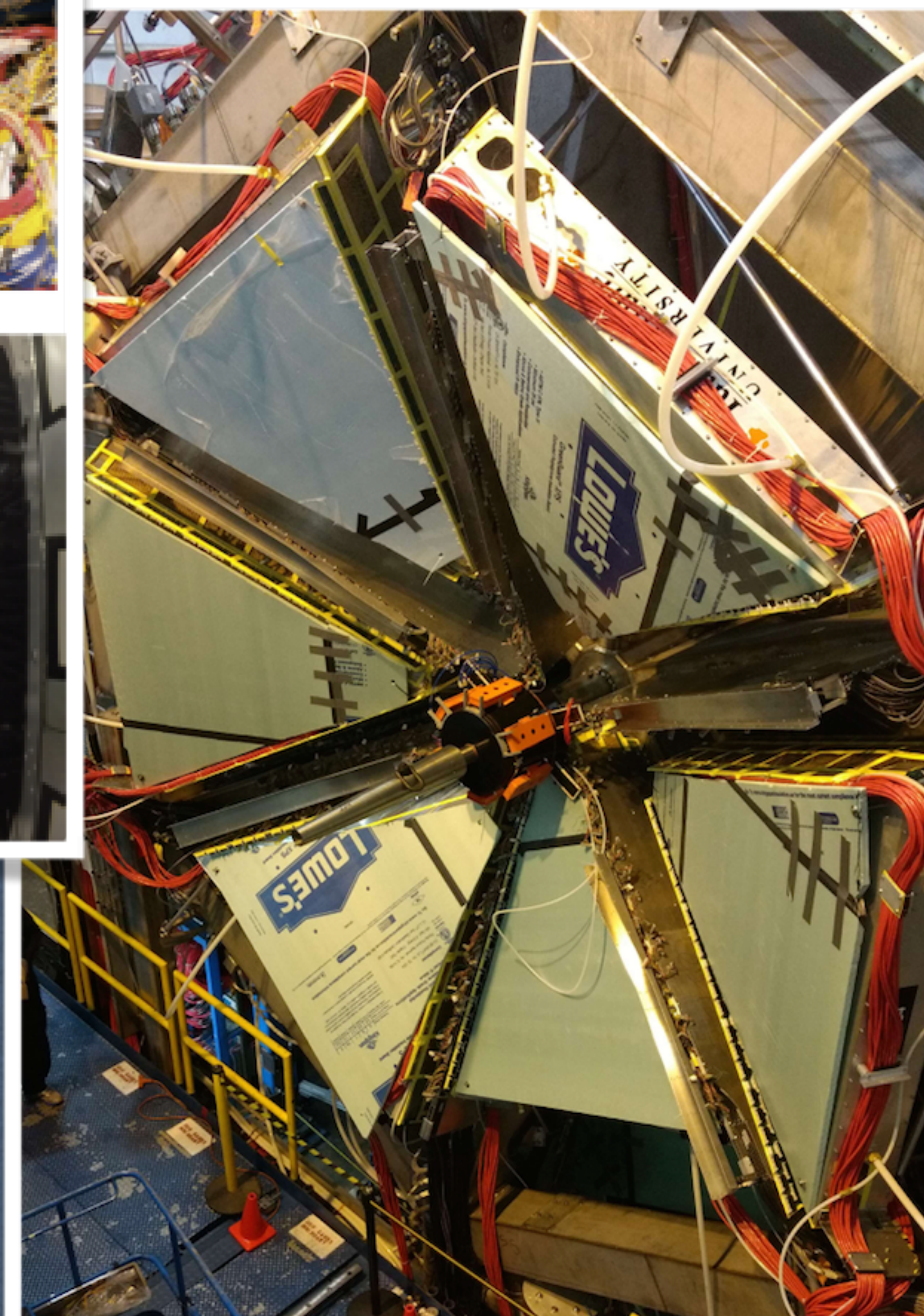
The CLAS12 detector







The FT installed in CLAS12



FT-Cal: $PbWO_4$ calorimeter

electron energy/momentum

Photon energy (ν=E-E')

Polarization $\varepsilon^{-1} \approx 1 + \nu^2/2EE'$

INFN-GE, INFN-RM2, INFN-TO, JLab

FT-Hodo: Scintillator tiles

veto for photons

EdinburghU+JMU+NSU+Jlab

FT-Trck: MicroMegas

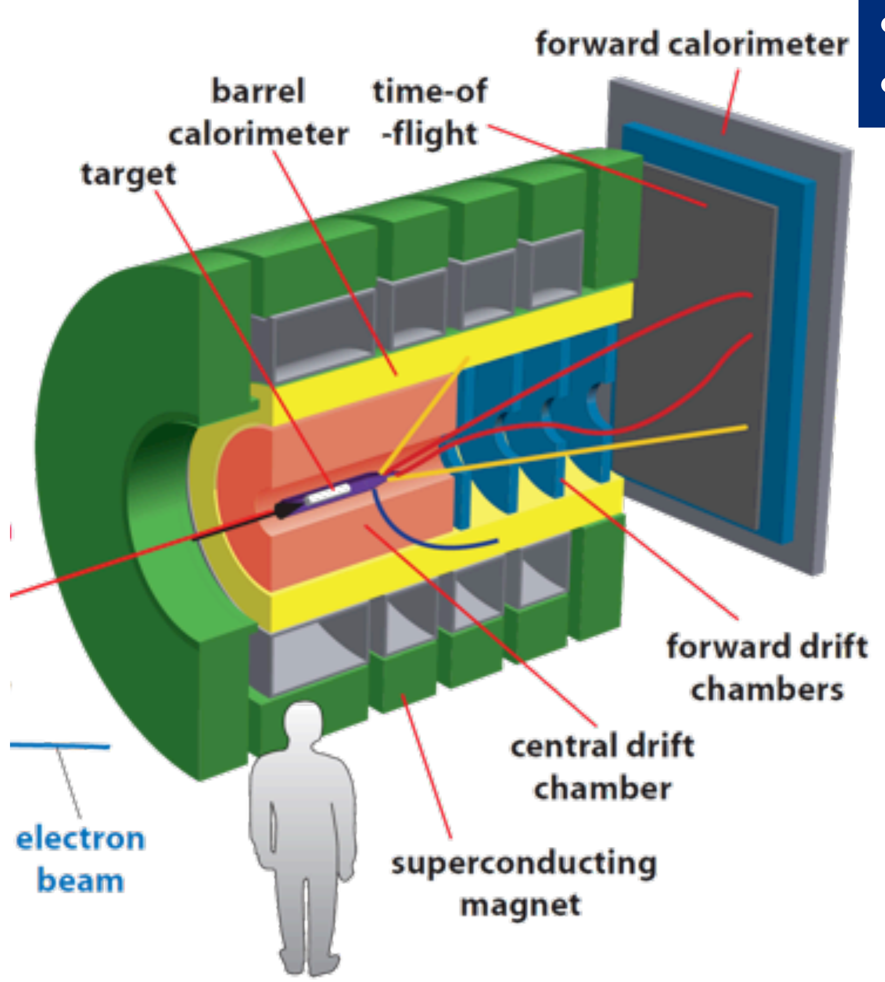
electron angles and polarization plane

Saclay + OhioU+Jlab

Meson spectroscopy with photons at JLab-12 GeV

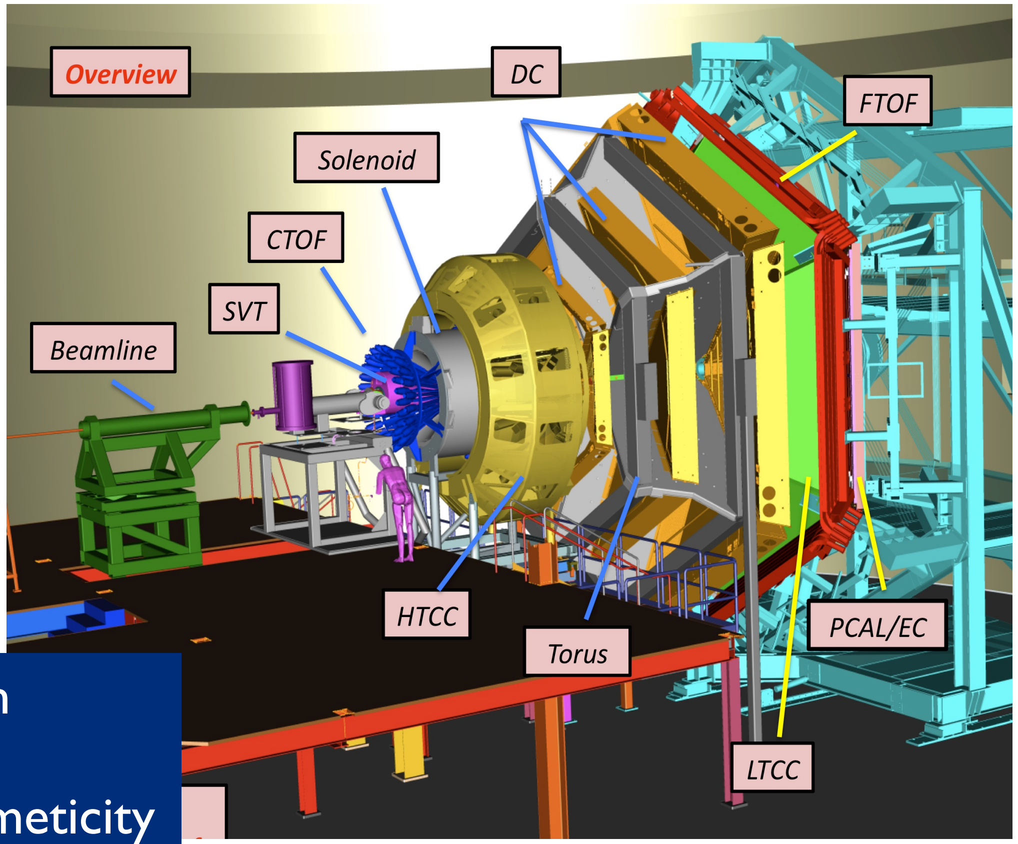
- Determination of JPC of meson states requires PWA
- Decay and production of exclusive reactions
- Good acceptance, energy resolution, particle identification

Hall-D - GlueX Detector



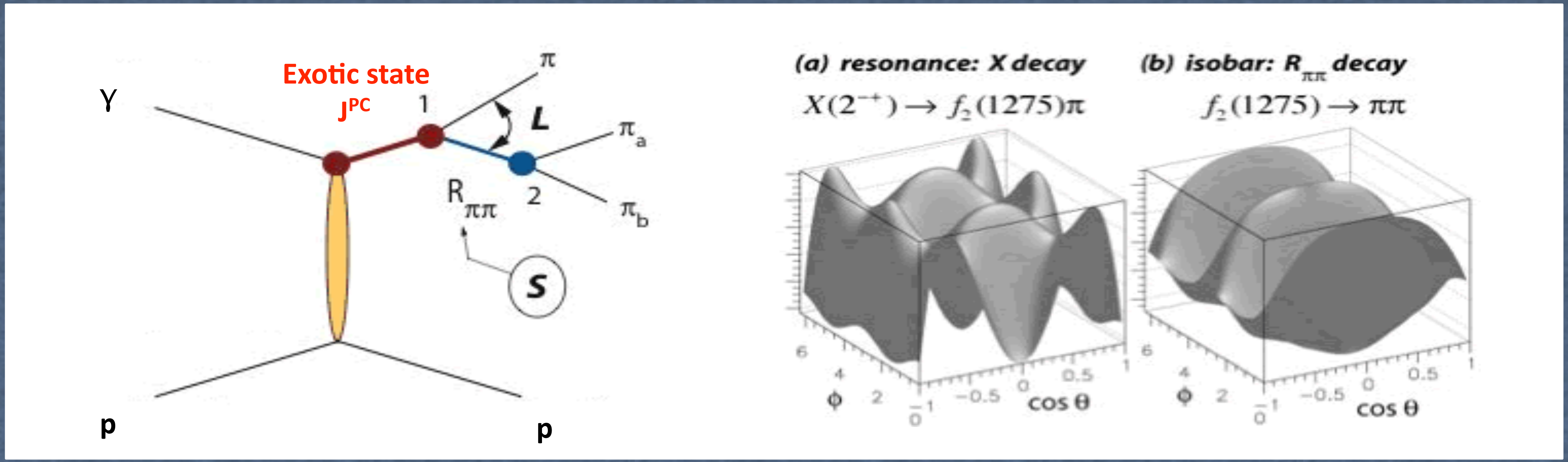
- Good hermeticity
- Uniform acceptance
- Limited resolution
- Limited pID

Hall-B - CLAS12 Detector

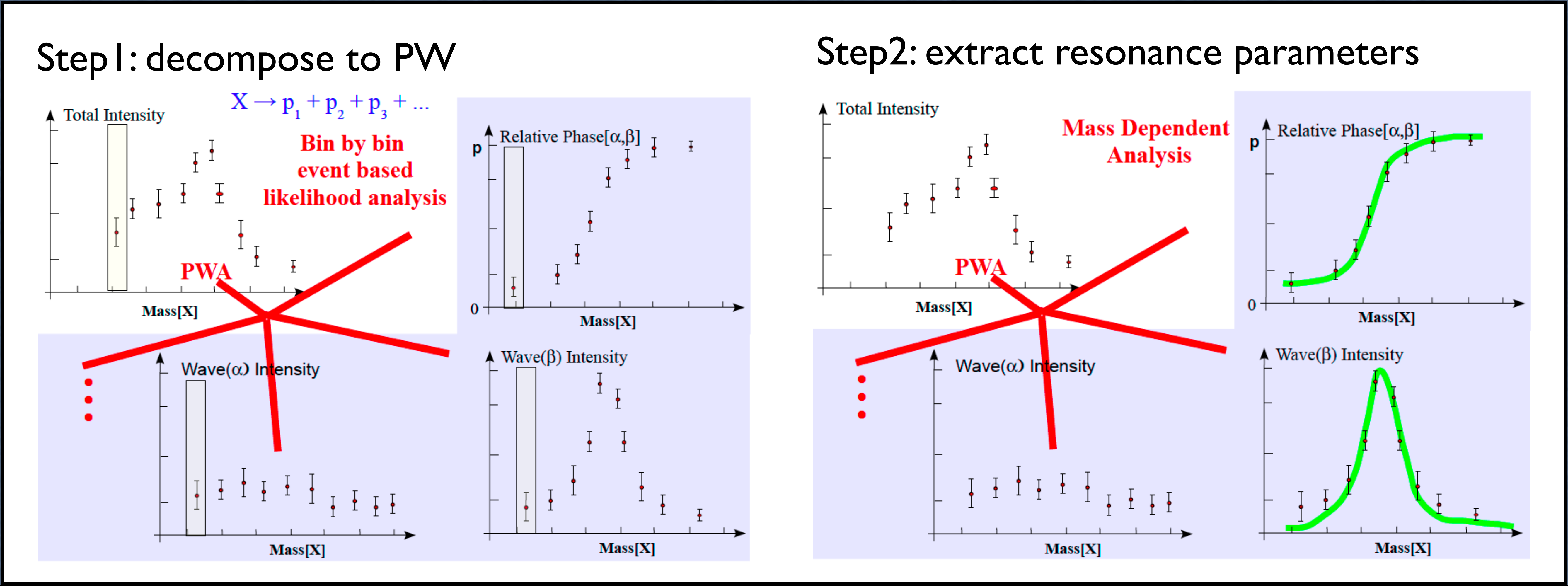


- Good resolution
- Good pID
- Reasonable hermeticity
- Un-uniform acceptance

From the data to the spectrum: Partial Wave Analysis

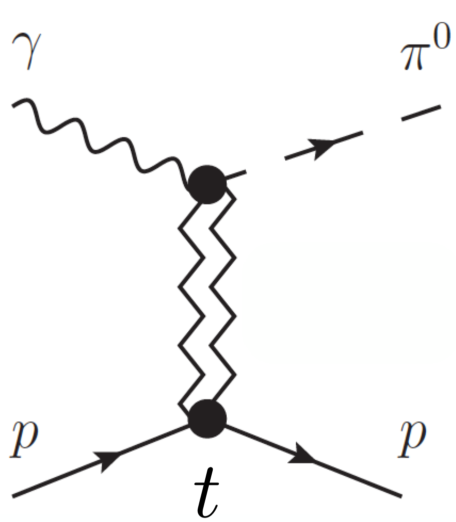


- Parametrize the cross section in term of partial waves
- Fit to data to extract amplitudes
- A model is needed to parametrize amplitudes: Isobar Model, Dispersion Relations, ...



Early GlueX Physics

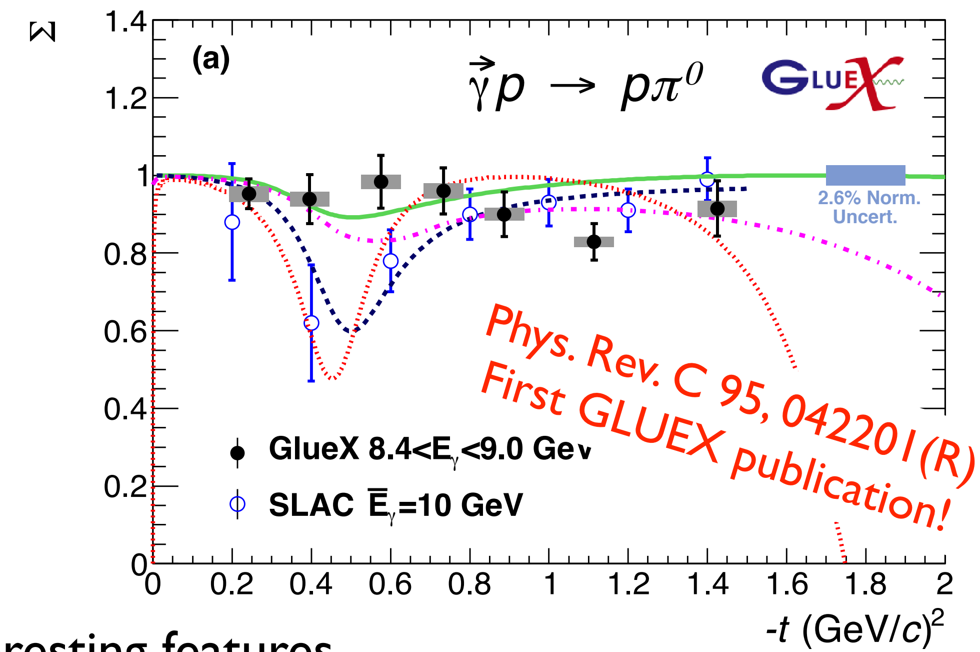
$\gamma p \to \pi^0 p$



- Beam asymmetry Σ provides insight into dominant production mechanism

$$\Sigma = \frac{|\omega+\rho|^2 - |h+b|^2}{|\omega+\rho|^2 + |h+b|^2}$$

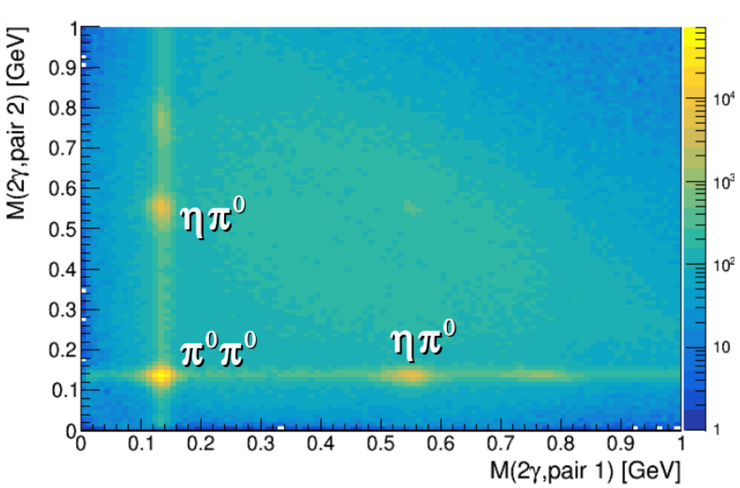
- Understanding production mechanism critical to disentangling J^{PC} of observed states in exotic hybrid search

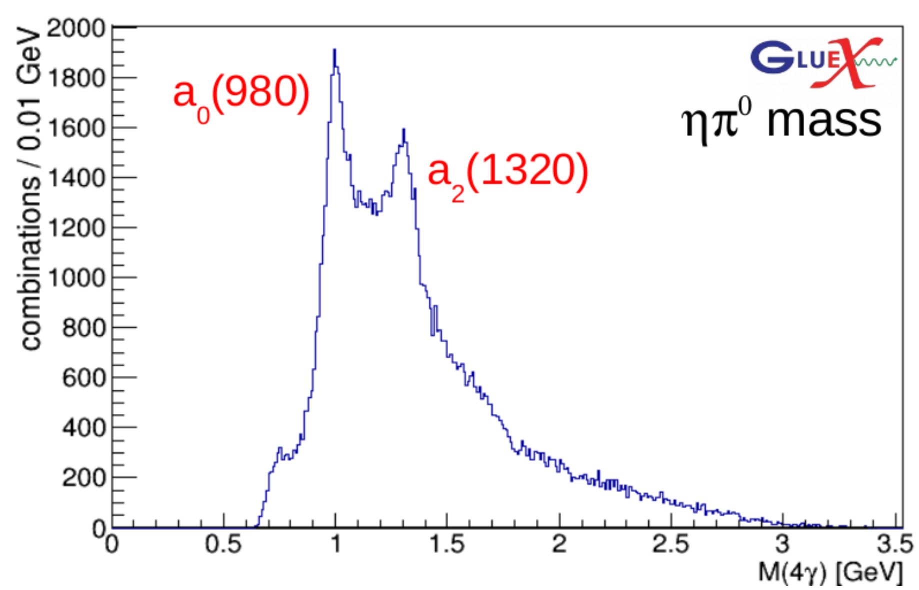


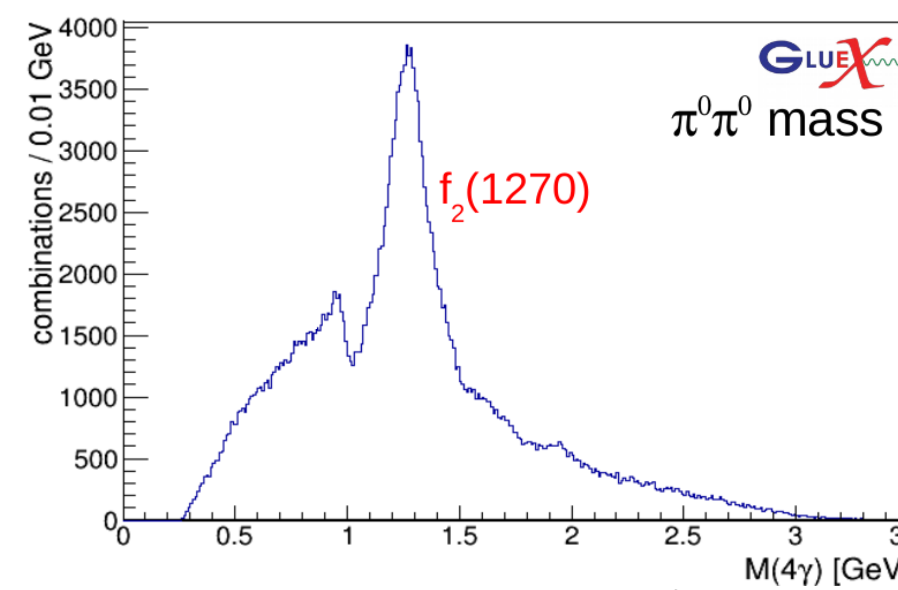
Phys. Rev. C 95, 042201(R)
First GLUEX publication!

- Preliminary studies are already showing interesting features

$\gamma p \to 4\gamma p$







- Previous photoproduction data very sparse for channels with multiple neutrals particles
- Preliminary studies are already showing interesting features

Some selected results form CLAS6

MB, R.DeVita A. Szczpaniak et al Phys.Rev.Lett. 102:102001,2009
MB, R.DeVita A. Szczpaniak et al Phys.Rev. D80:072005,2009

$$\langle Y_{\lambda\mu}\rangle(E_\gamma, t, M) = \frac{1}{\sqrt{4\pi}}\int d\Omega_\pi \frac{d\sigma}{dt\,dM\,d\Omega_\pi} Y_{\lambda\mu}(\Omega_\pi)$$

Amplitude parametrization (Dispersion relation)

Related to $\pi\pi$ scattering matrix: phase-shift, inelasticity, S-P-D-F amplitude in 0.4 GeV < $M_{\pi\pi}$ < 1.4 GeV

$$a_{lm,I}(s) = \frac{1}{2}[I + S_{lm,I}(s)]\boxed{\tilde{a}_{lm,I}(s)} - \frac{1}{\pi} D^{-1}_{lm,I}(s) PV \int_{s_{th}} ds' \frac{N_{lm,I}(s')\rho(s')\boxed{\tilde{a}_{lm,I}(s')}}{s'-s}$$

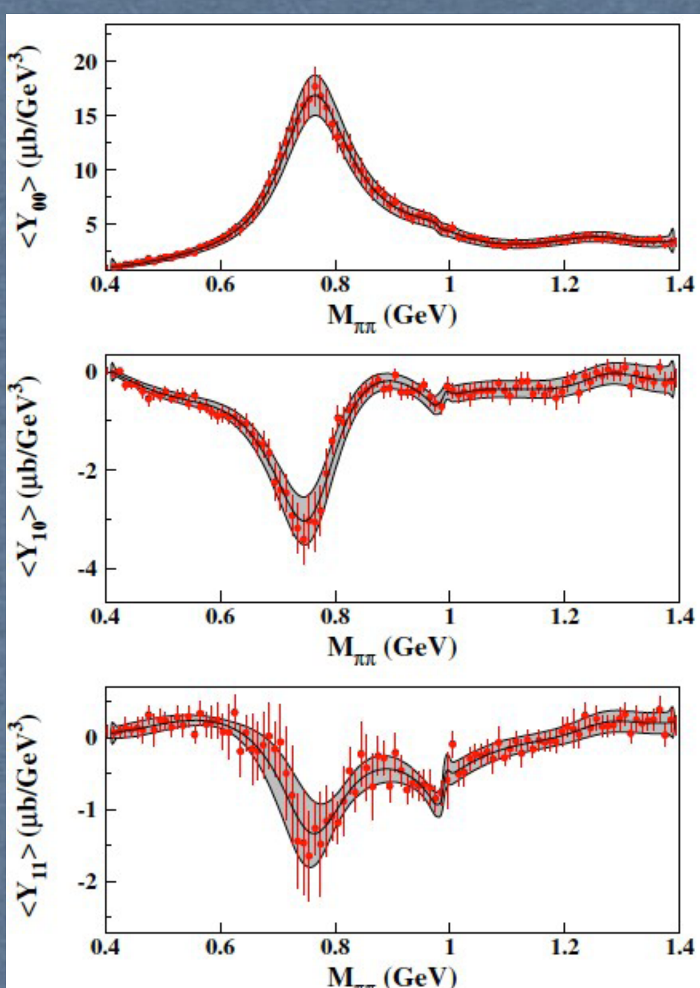
$$\tilde{a}_{lm,I} = [\mathcal{A} + \mathcal{B}s + \mathcal{C}s^2 + \cdots][k]$$

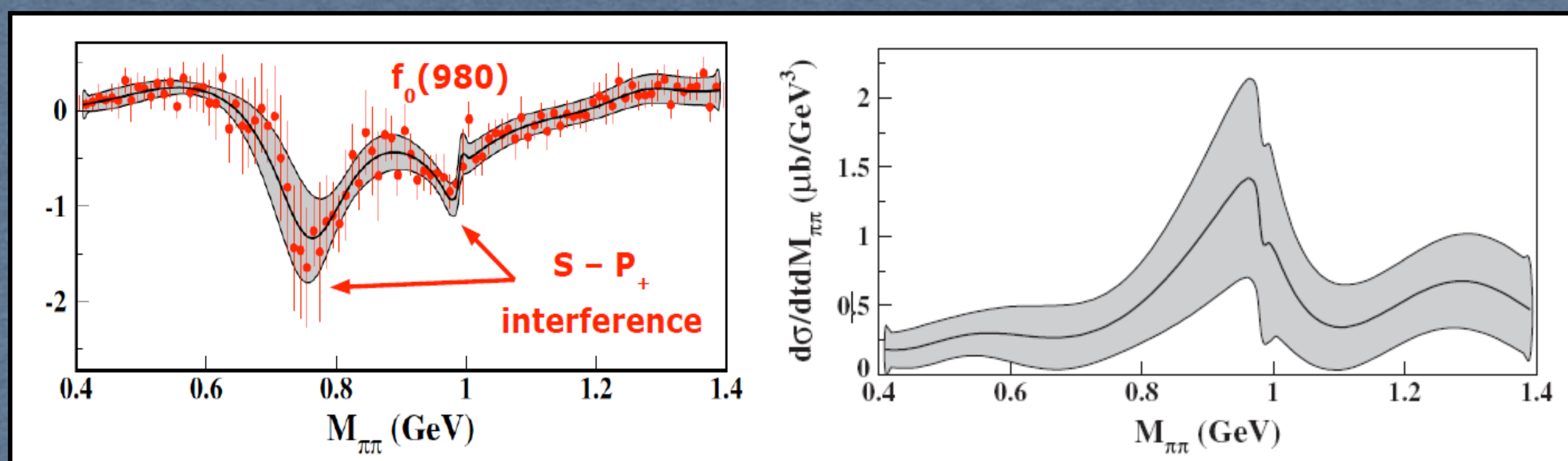
Expanded in a Taylor series: coefficient fit to the experimental moment

$\gamma\, p \rightarrow p\, \pi\, \pi$

$M(\pi^+\pi^-)$ spectrum below 1.5 GeV:

- P-wave: ρ meson
- D-wave: $f_2(1270)$
- S-wave: σ, $f_0(980)$ and $f_0(1320)$





First observation of the $f_0(980)$ in a photoproduction experiment

the follow-up ...

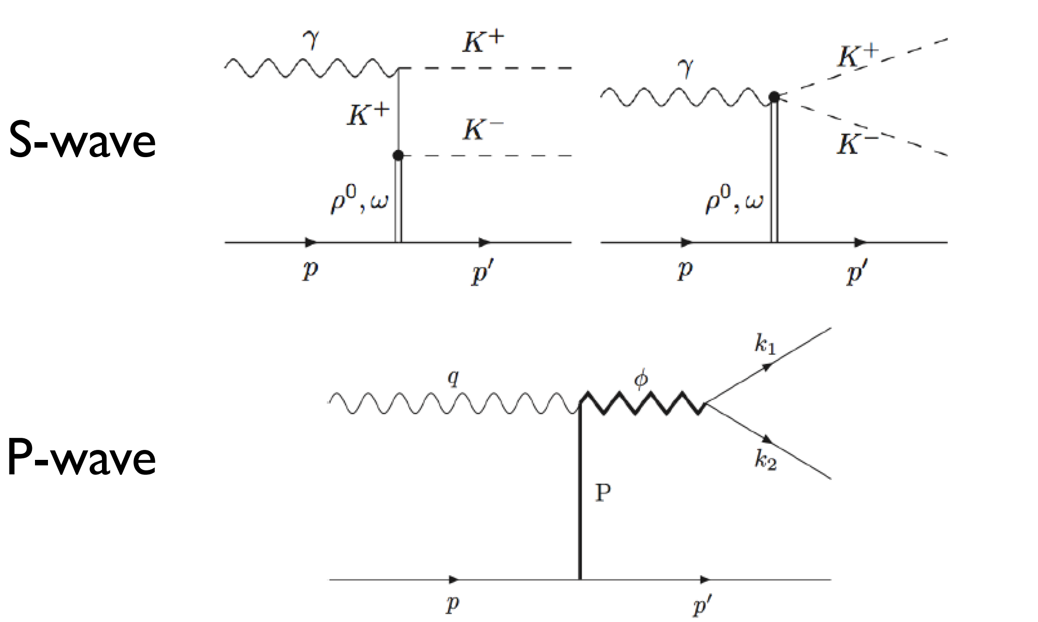
γ p → p k k

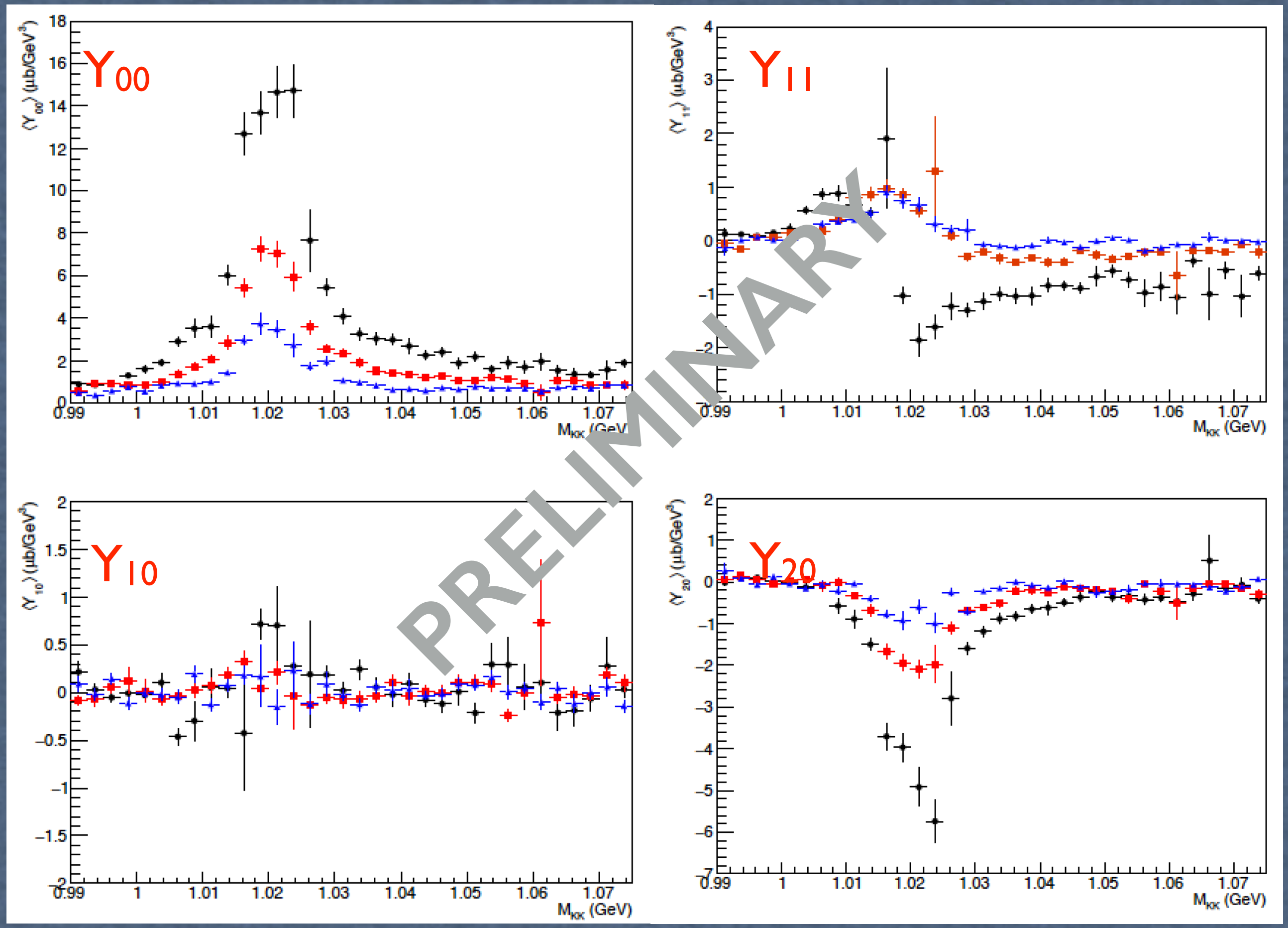
- S.Lombardo (IU/Cornell)
- Full analysis from g11 CLAS6 data set
- S-P interference in 2k system

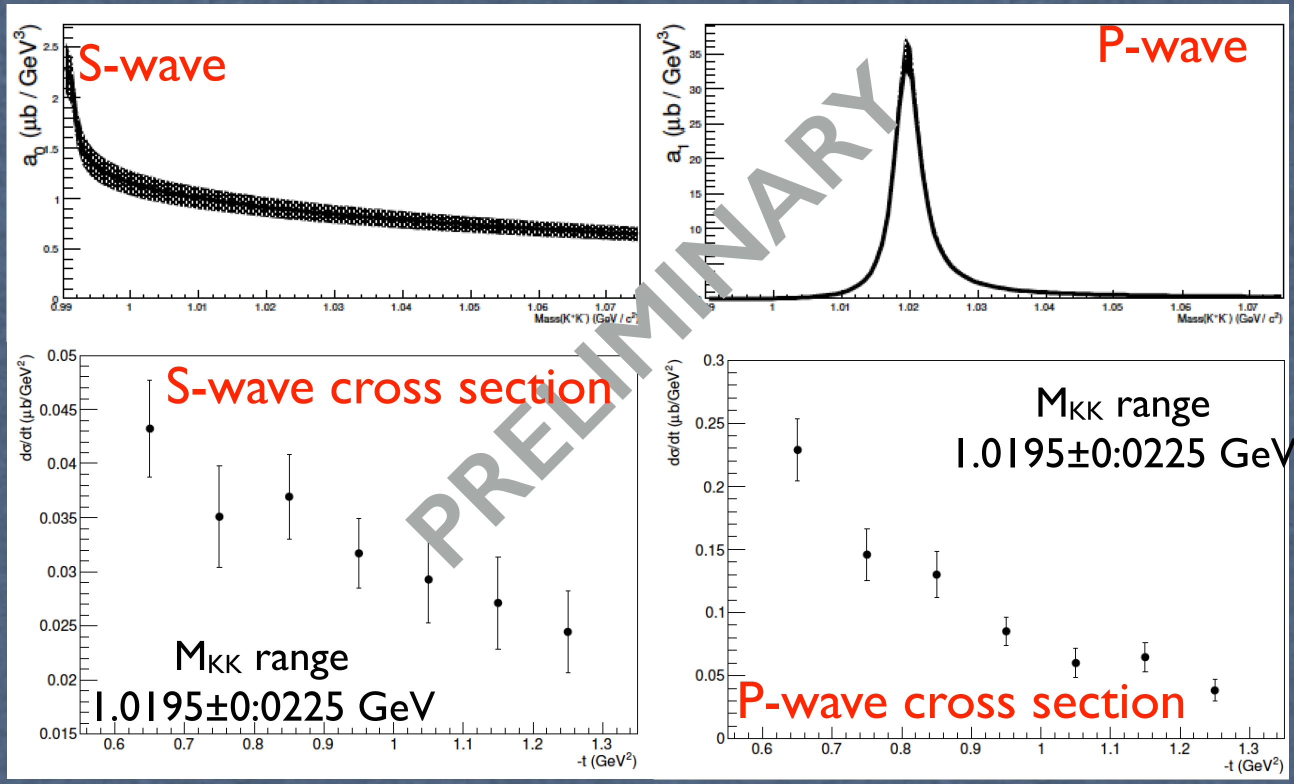
Method:

- Extract moments from data
- Parametrise amplitudes with a model: P-wave: pomeron, s-wave: rho, omg t-exch
- Fit moments to obtain PW cross sections

L. Bibrzycki, L. Lesniak, A. P. Szczepaniak Acta Phys.Polon. B36 (2005) 3889-3896







2k amplitudes provided by JPAC

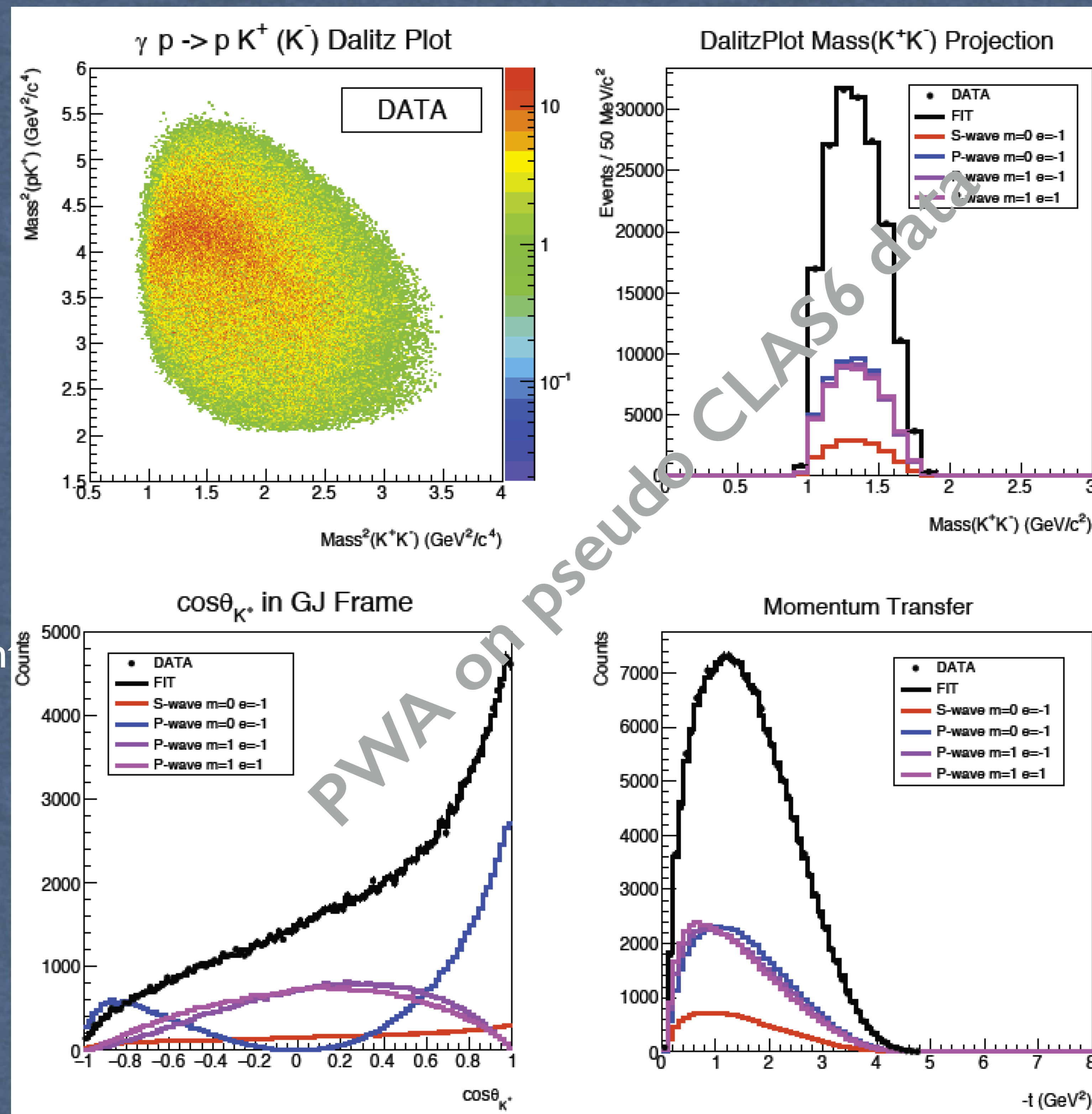
towards a full PWA

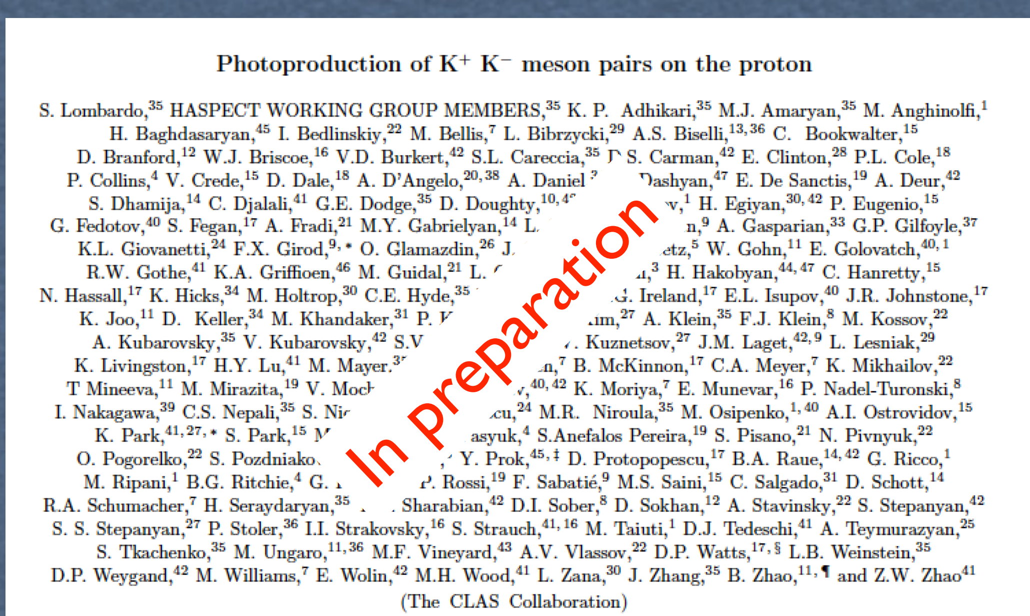
γ p → p k k

- I.Stankovic (U Edinburgh)
- Full PWA using the same CLAS6 - g11 data set

Procedure:

- Extract moments from data in a model independent way and compare to the previous CLAS6 analysis
- Test the fit procedure on pseudo data
- Run the full PWA to extract the dominant and sub-leading waves





Photoproduction of K+ K− meson pairs on the proton

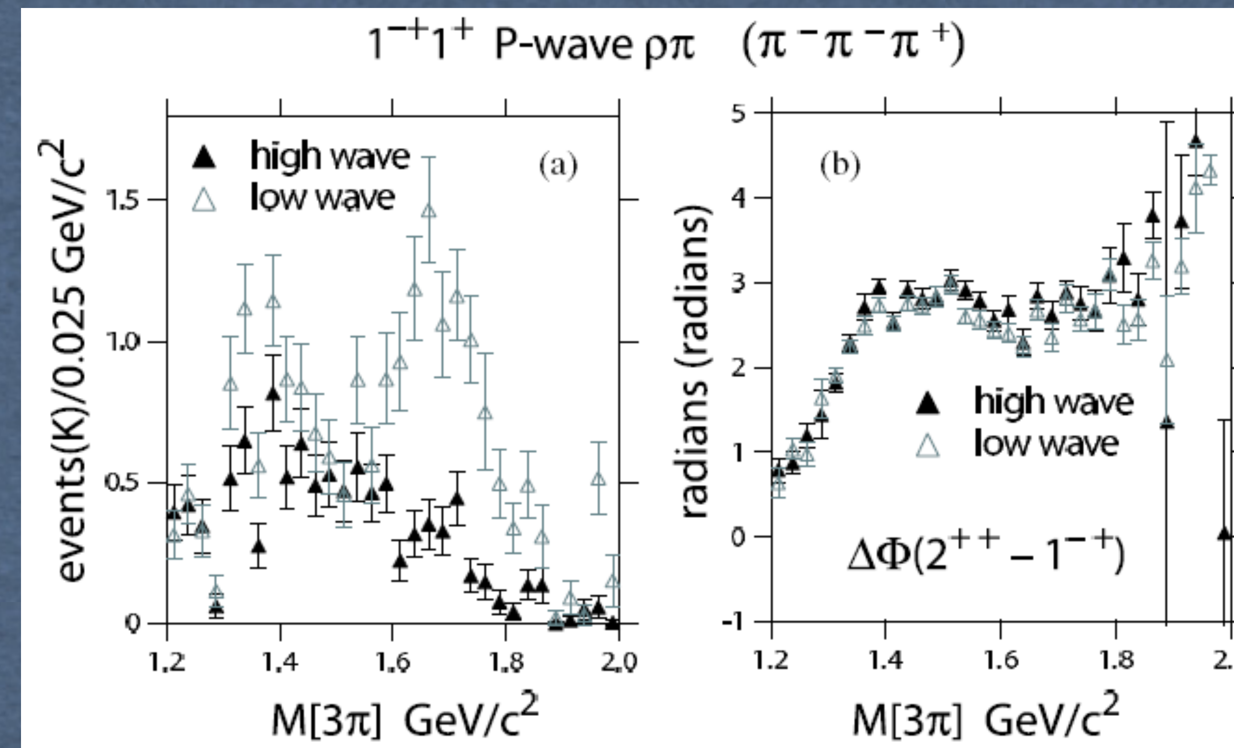
S. Lombardo,[35] HASPECT WORKING GROUP MEMBERS,[35] K. P. Adhikari,[35] M.J. Amaryan,[35] M. Anghinolfi,[1] H. Baghdasaryan,[45] I. Bedlinskiy,[22] M. Bellis,[7] L. Bibrzycki,[29] A.S. Biselli,[13,36] C. Bookwalter,[15] D. Branford,[12] W.J. Briscoe,[16] V.D. Burkert,[42] S.L. Careccia,[35] S. Carman,[42] E. Clinton,[28] P.L. Cole,[18] P. Collins,[4] V. Crede,[15] D. Dale,[18] A. D'Angelo,[20,38] A. Daniel ashyan,[47] E. De Sanctis,[19] A. Deur,[42] S. Dhamija,[14] C. Djalali,[41] G.E. Dodge,[35] D. Doughty, H. Egiyan,[30,42] P. Eugenio,[15] G. Fedotov,[40] S. Fegan,[17] A. Fradi,[21] M.Y. Gabrielyan,[14] A. Gasparian,[33] G.P. Gilfoyle,[37] K.L. Giovanetti,[24] F.X. Girod,[9,*] O. Glamazdin,[26] W. Gohn,[11] E. Golovatch,[40,1] R.W. Gothe,[41] K.A. Griffioen,[46] M. Guidal,[21] H. Hakobyan,[44,47] C. Hanretty,[15] N. Hassall,[17] K. Hicks,[34] M. Holtrop,[30] C.E. Hyde,[35] Ireland,[17] E.L. Isupov,[40] J.R. Johnstone,[17] K. Joo,[11] D. Keller,[34] M. Khandaker,[31] A. Klein,[35] F.J. Klein,[8] M. Kossov,[22] A. Kubarovsky,[35] V. Kubarovsky,[42] Kuznetsov,[27] J.M. Laget,[42,9] L. Lesniak,[29] K. Livingston,[17] H.Y. Lu,[41] M. Mayer, B. McKinnon,[17] C.A. Meyer,[7] K. Mikhailov,[22] T Mineeva,[11] M. Mirazita,[19] K. Moriya,[7] E. Munevar,[16] P. Nadel-Turonski,[8] I. Nakagawa,[39] C.S. Nepali,[35] M.R. Niroula,[35] M. Osipenko,[1,40] A.I. Ostrovidov,[15] K. Park,[41,27,*] S. Park,[15] S.Anefalos Pereira,[19] S. Pisano,[21] N. Pivnyuk,[22] O. Pogorelko,[22] Y. Prok,[45,‡] D. Protopopescu,[17] B.A. Raue,[14,42] G. Ricco,[1] M. Ripani,[1] B.G. Ritchie,[4] Rossi,[19] F. Sabatié,[9] M.S. Saini,[15] C. Salgado,[31] D. Schott,[14] R.A. Schumacher,[7] H. Seraydaryan,[35] Sharabian,[42] D.I. Sober,[8] D. Sokhan,[12] A. Stavinsky,[22] S. Stepanyan,[42] S. S. Stepanyan,[27] P. Stoler,[36] I.I. Strakovsky,[16] S. Strauch,[41,16] M. Taiuti,[1] D.J. Tedeschi,[41] A. Teymurazyan,[25] S. Tkachenko,[35] M. Ungaro,[11,36] M.F. Vineyard,[43] A.V. Vlassov,[22] D.P. Watts,[17,§] L.B. Weinstein,[35] D.P. Weygand,[42] M. Williams,[7] E. Wolin,[42] M.H. Wood,[41] L. Zana,[30] J. Zhang,[35] B. Zhao,[11,¶] and Z.W. Zhao[41]
(The CLAS Collaboration)

In preparation

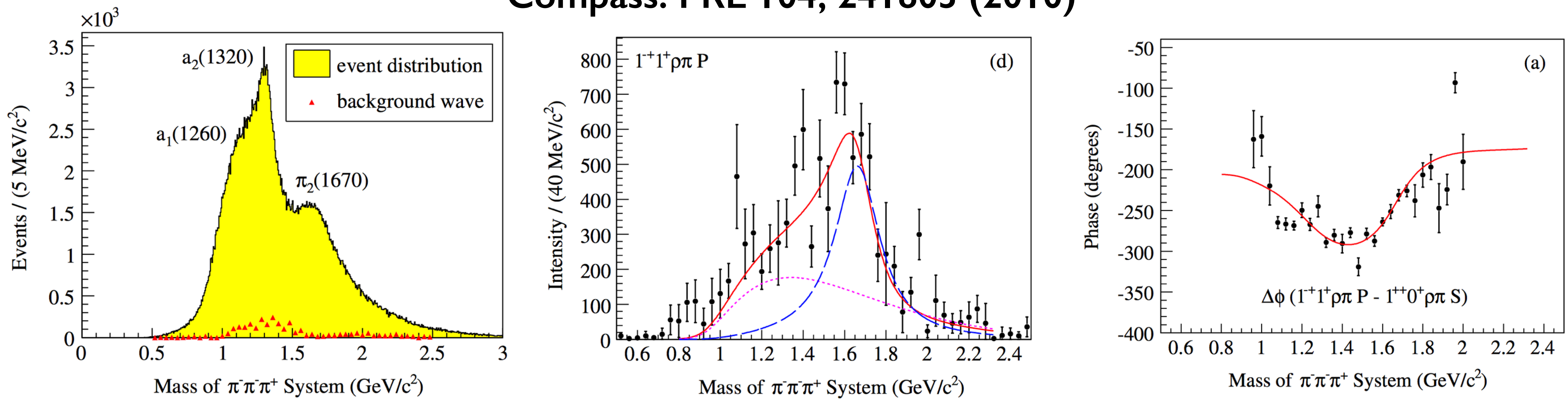
The 3π system from CLAS6-g12 data set

Reference reaction
$\gamma\, p \rightarrow (n)\, \pi^+ \pi^+ \pi^-$

- ✳ Possible evidence of exotic meson $\pi_1(1600)$ in $\pi^- p \rightarrow p\, \pi^- \pi^- \pi^+$ (E852-Brookhaven)
- ✳ Not confirmed in a re-analysis of a higher statistic sample
- ✳ Now confirmed by Compass
- ✳ Simple final state with low bg



Compass: PRL 104, 241803 (2010)



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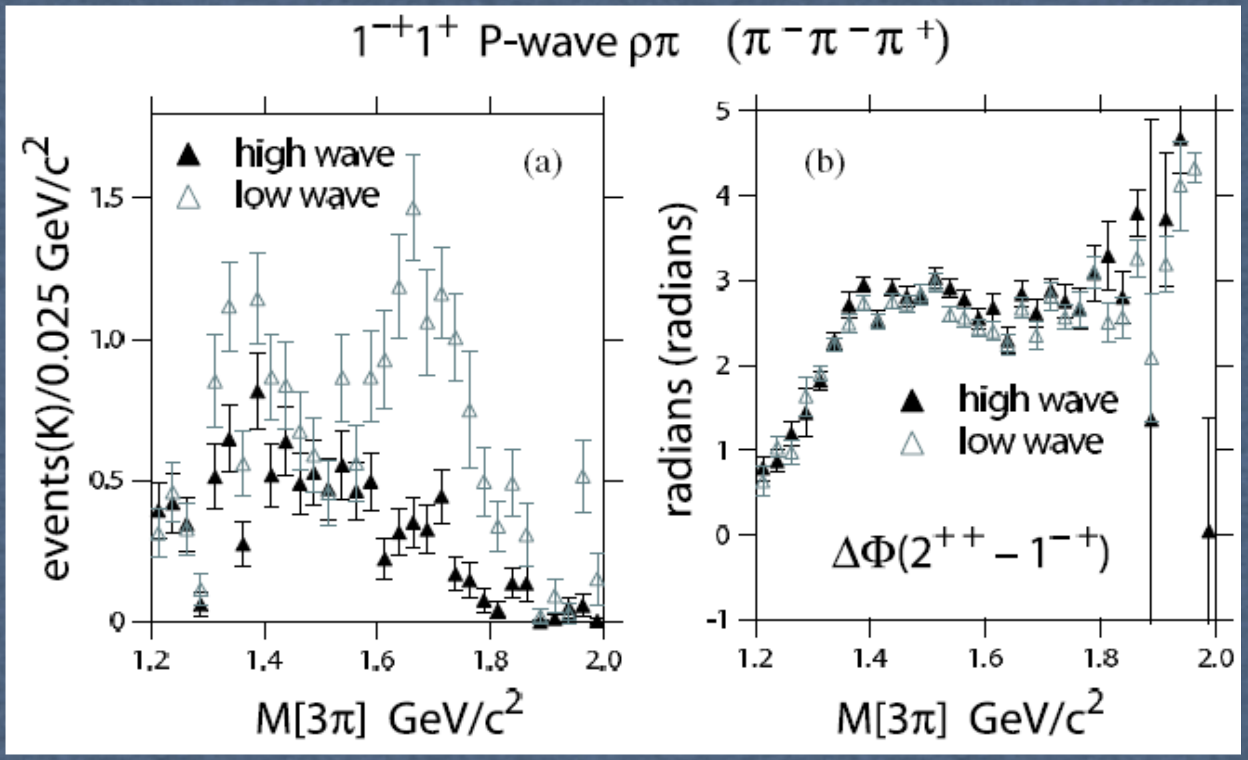
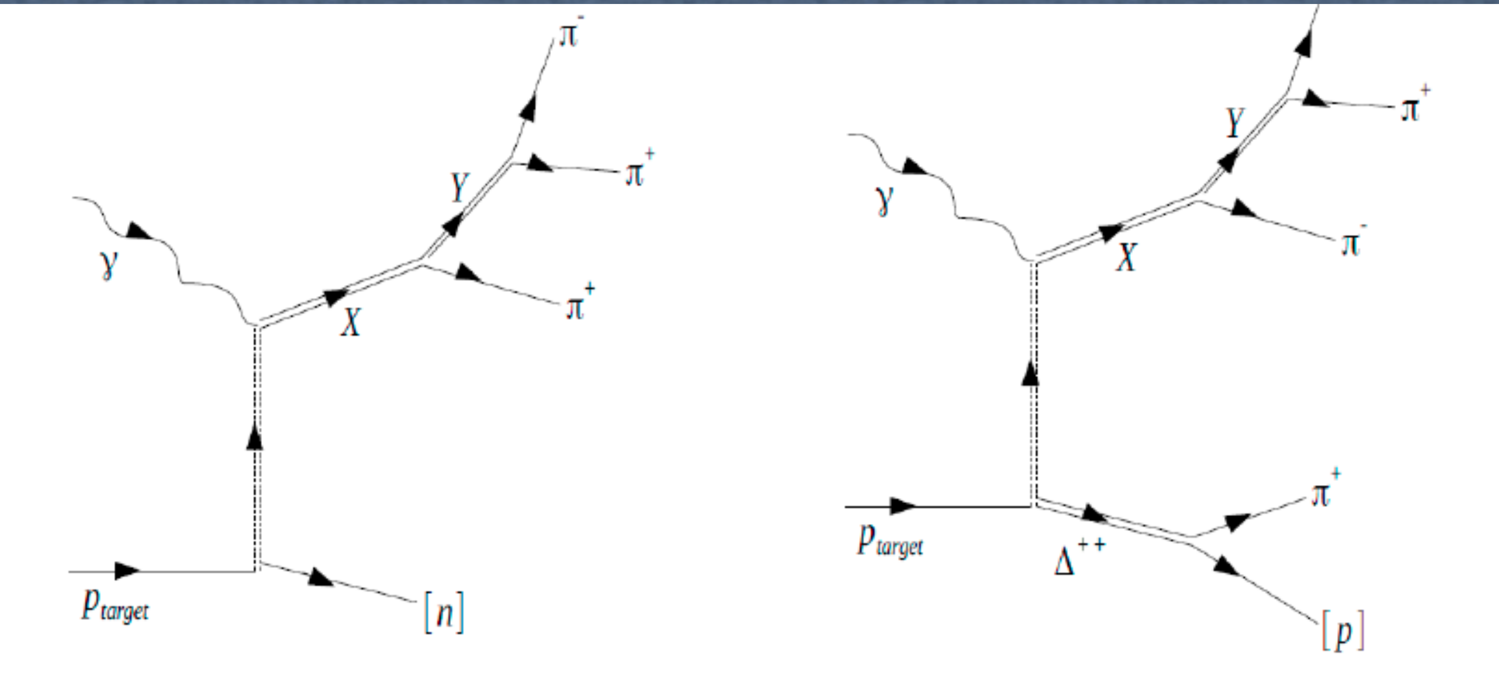




$\gamma\, p \rightarrow n\, \pi^+ \pi^+ \pi^-$

- Three charged pions selected
- Neutron identified by energy and momentum conservation

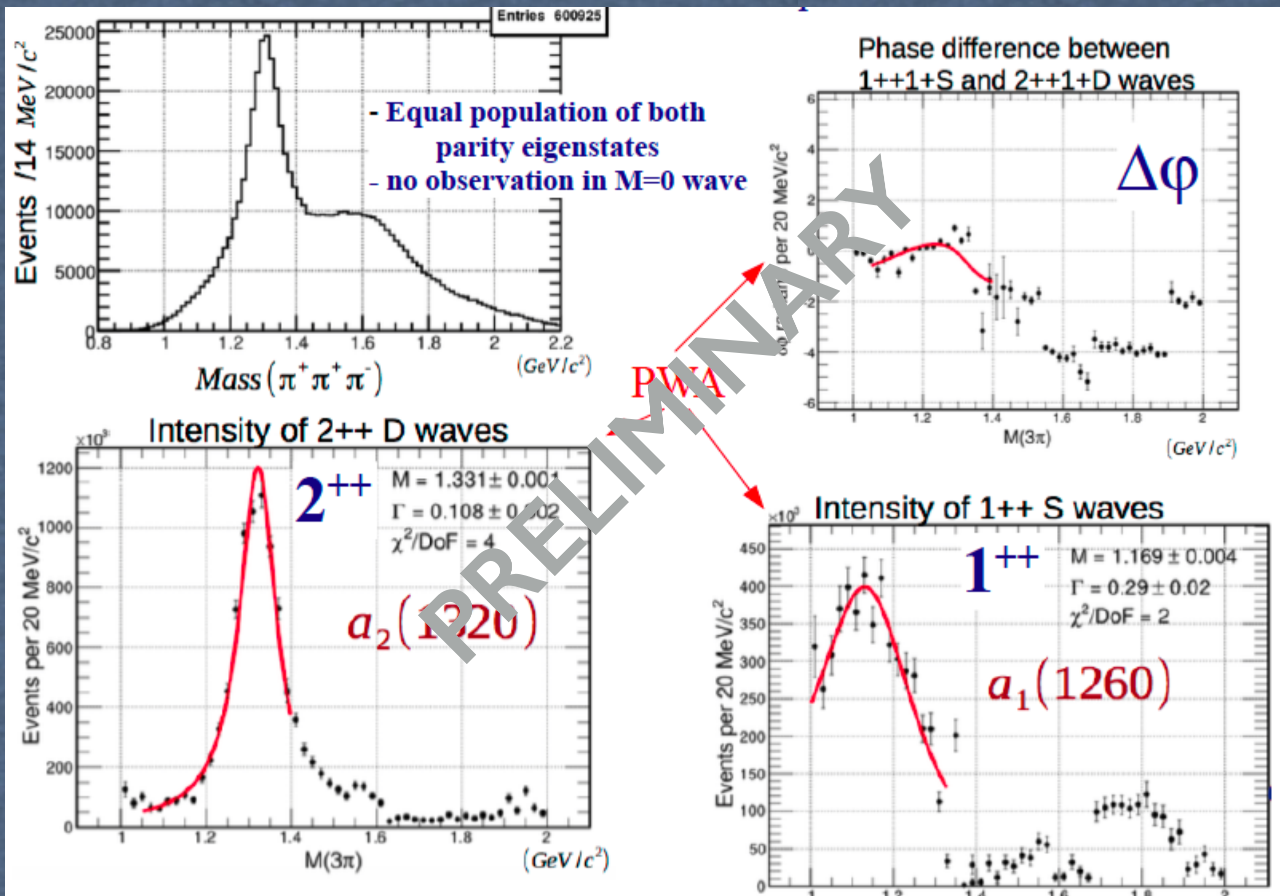
$\gamma\, p \rightarrow \Delta^{++}\, \pi^+ \pi^- \pi^-$

- Four charged pions selected
- Proton identified by energy and momentum conservation

A.Tsaris, P.Eugenio (FSU)

The 3π system from CLAS6-g12 data set

$\gamma\, p \rightarrow n\, \pi^+ \pi^+ \pi^-$

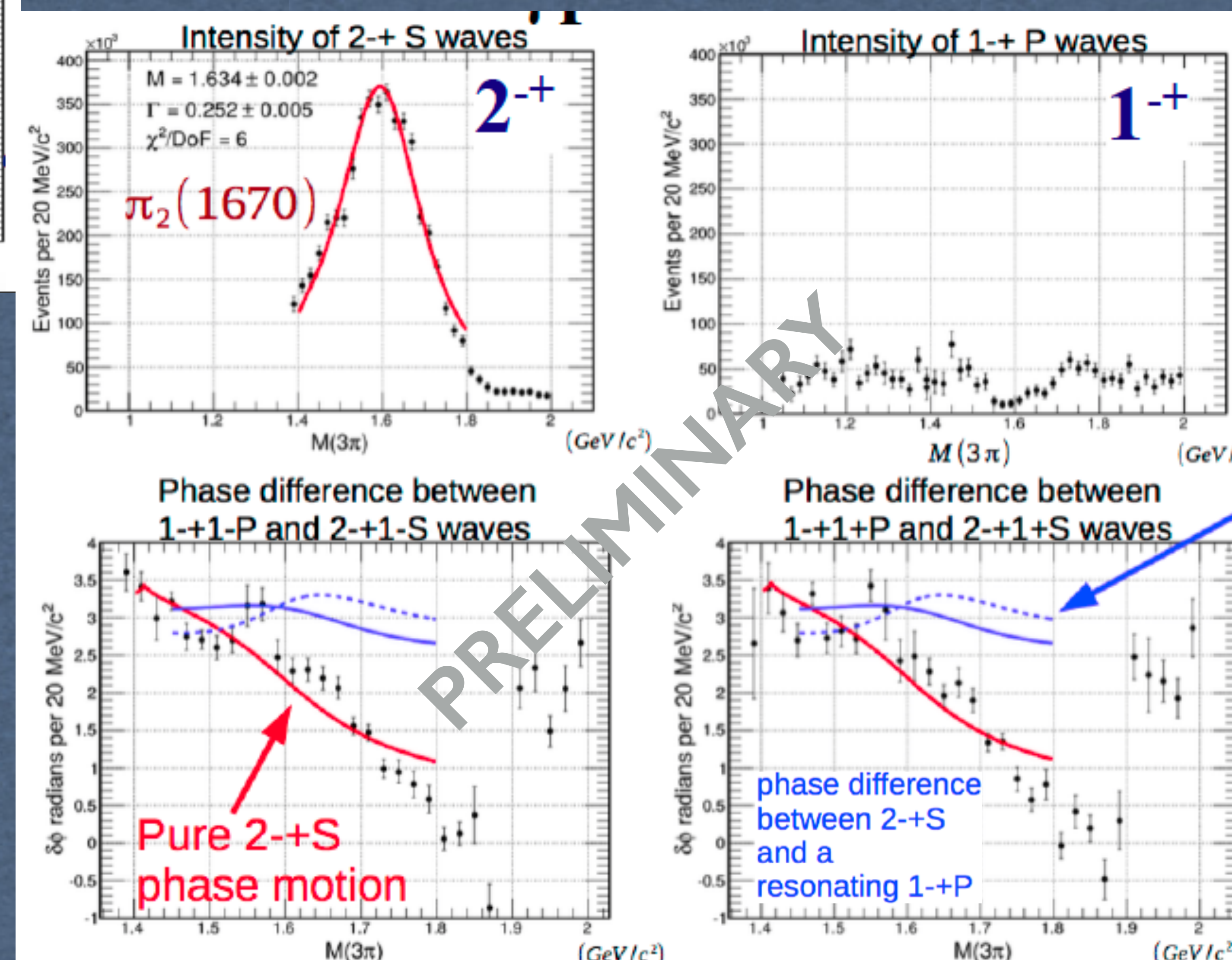


A. Tsaris (2016 FSU Dissertation)

PWA in CLAS is feasible!

Needs to have higher energy and statistics and test other final states ➜ CLAS12

- First observation of the $a_1(1260)$ in a photoproduction experiment
- The $a_2(1320)$ and $\pi_2(1670)$ observed
- The J^{PC}=1-+ does not show resonant behaviour and consistent with non-resonant non interfering wave relative to a resonant $\pi_2(1670)$
- Same results for $\gamma\, p \rightarrow \Delta^{++} \pi^+ \pi^- \pi^-$



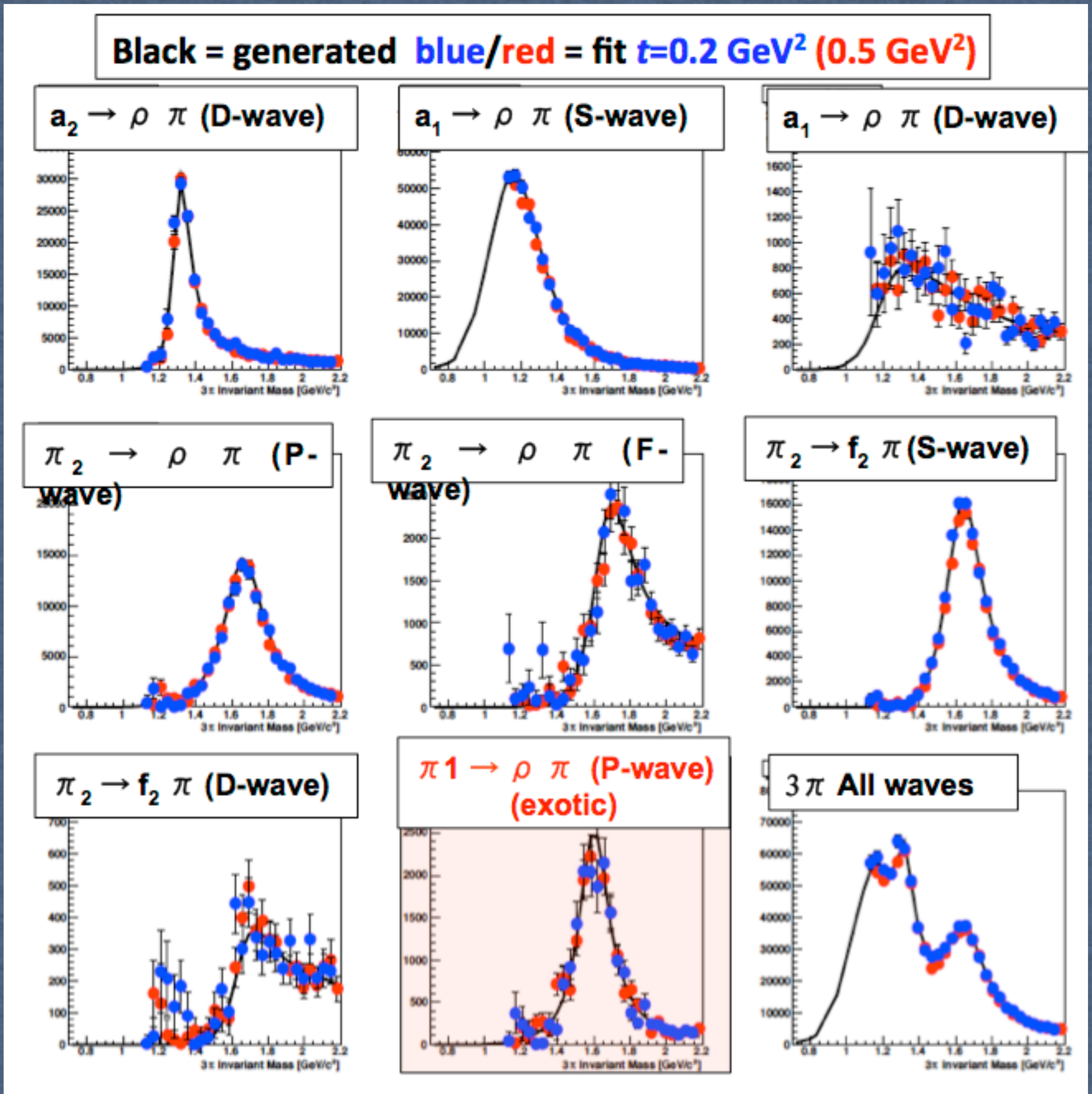
PWA with CLAS12

D.Glazier (U of Glasgow)

$\gamma p \to n \pi^+ \pi^+ \pi^-$

- The process is described as sum of 8 isobar channels:
  - $a_2 \to \rho \pi$ (D-wave)
  - $a_1 \to \rho \pi$ (S-wave)
  - $a_1 \to \rho \pi$ (D-wave)
  - $\pi_2 \to \rho \pi$ (P-wave)
  - $\pi_2 \to \rho \pi$ (F-wave)
  - $\pi_2 \to f_2 \pi$(S-wave)
  - $\pi_2 \to f_2 \pi$ (D-wave)
  - $\pi 1 \to \rho \pi$ (P-wave) (exotic)
- Amplitudes calculated by A.Szczepaniak and P.Guo
- CLAS12 acceptance projected and fitted
- PWA is stable against CLAS12 acceptance/ resolution distortion

PWA in CLAS12 is feasible!



A new (old?) approach: Veneziano amplitudes

γ p → p ω → p πππ

- A. Celentano (INFN-GE)
- Decay decouples production from genuine meson-meson interaction
- ω decay $M(\pi^+\pi^-) < 0.45$ GeV
- 3-body effects

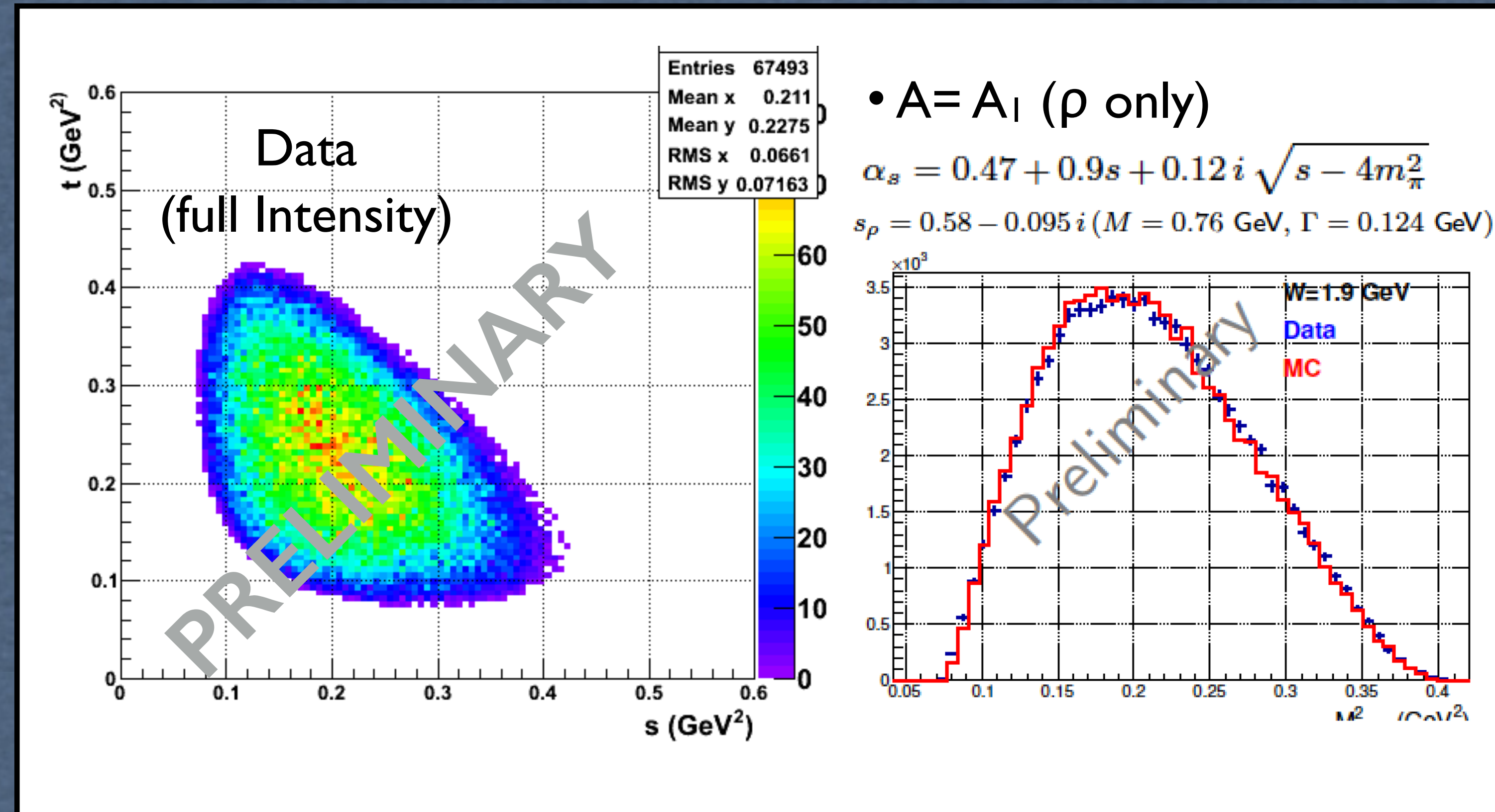
Analysis in collaboration with JPAC

$$A_\lambda = \varepsilon_{\mu\nu\alpha\beta}\, p_+^\nu p_-^\alpha p_0^\beta \varepsilon_\lambda^\mu\, A(s,t,u)$$

$$I = \sum_{\lambda,\lambda'} A_\lambda^* \rho_{\lambda'}^\lambda A_{\lambda'} = K^2 W_\rho(\theta,\phi)|A|^2$$

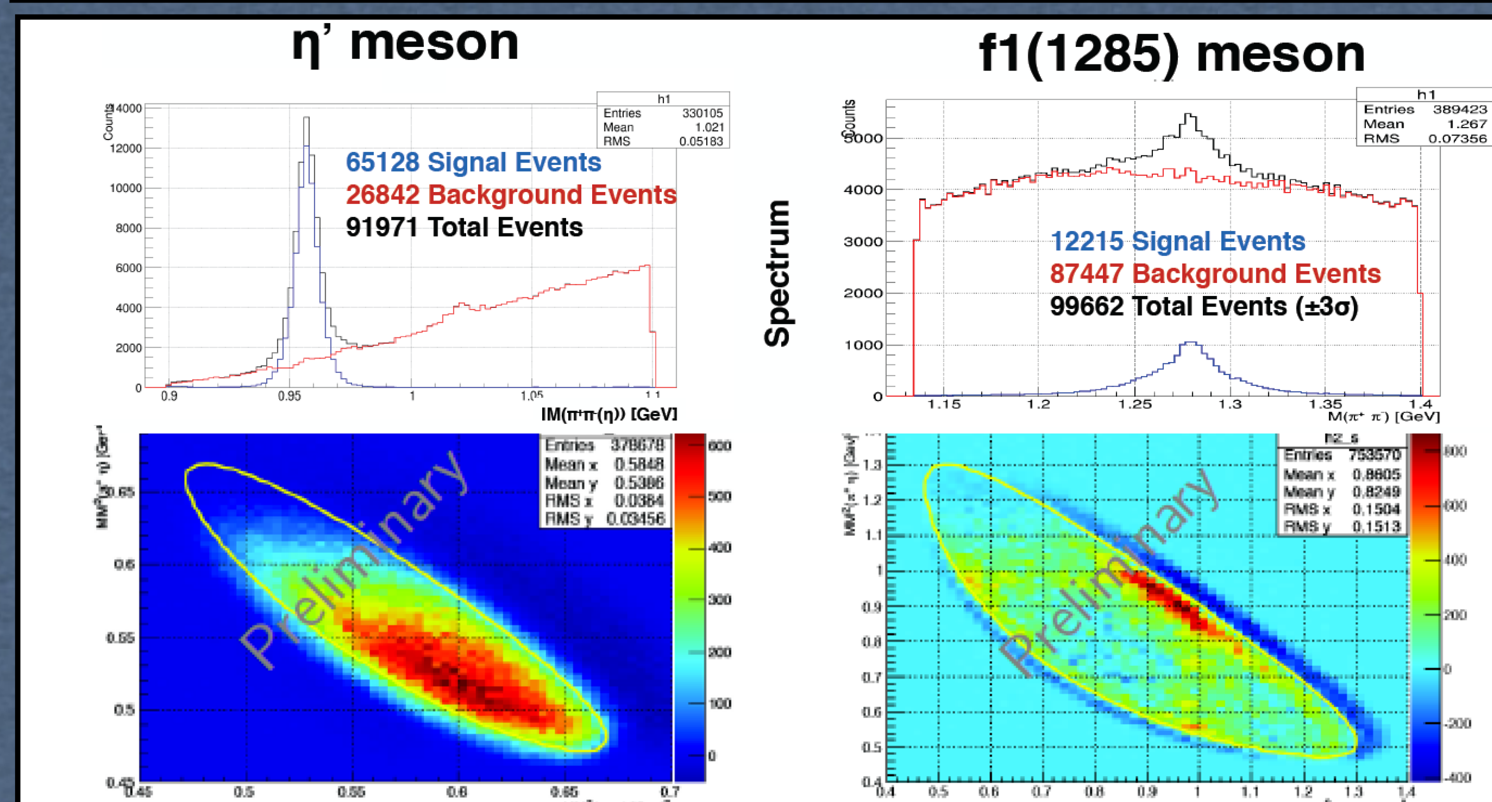
$$K^2 = s\,t\,u - m^2(M^2-m^2)^2 = |\vec{p_a}\times\vec{p_b}|^2$$

$W_\rho(\theta,\phi)$: Spin density matrix



γ p → p η’→ p π π η
→ p f$_1$(1285) η

- A. Rizzo (INFN-RM2)
- (πη) invariant mass spectrum
- η’ decay M(πη) <0.8 GeV

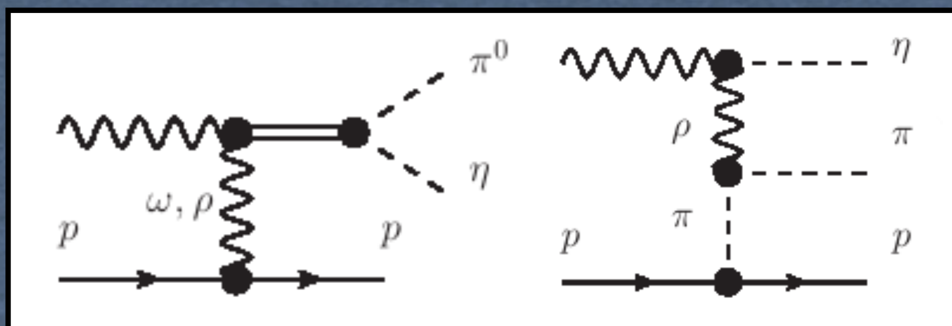


amplitudes provided by JPAC

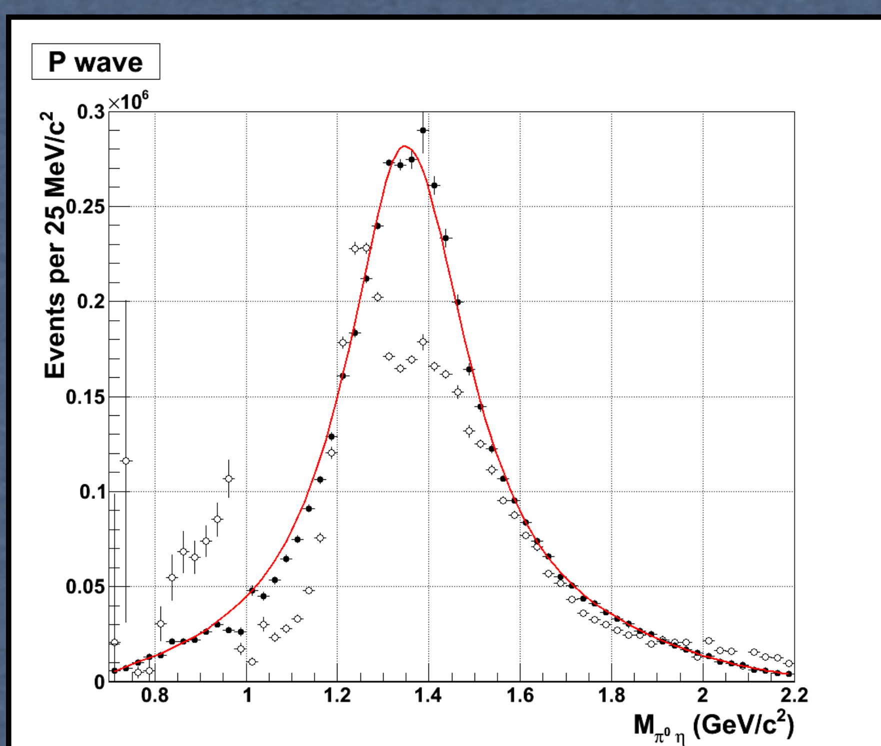
The ηπ in CLAS6-g12

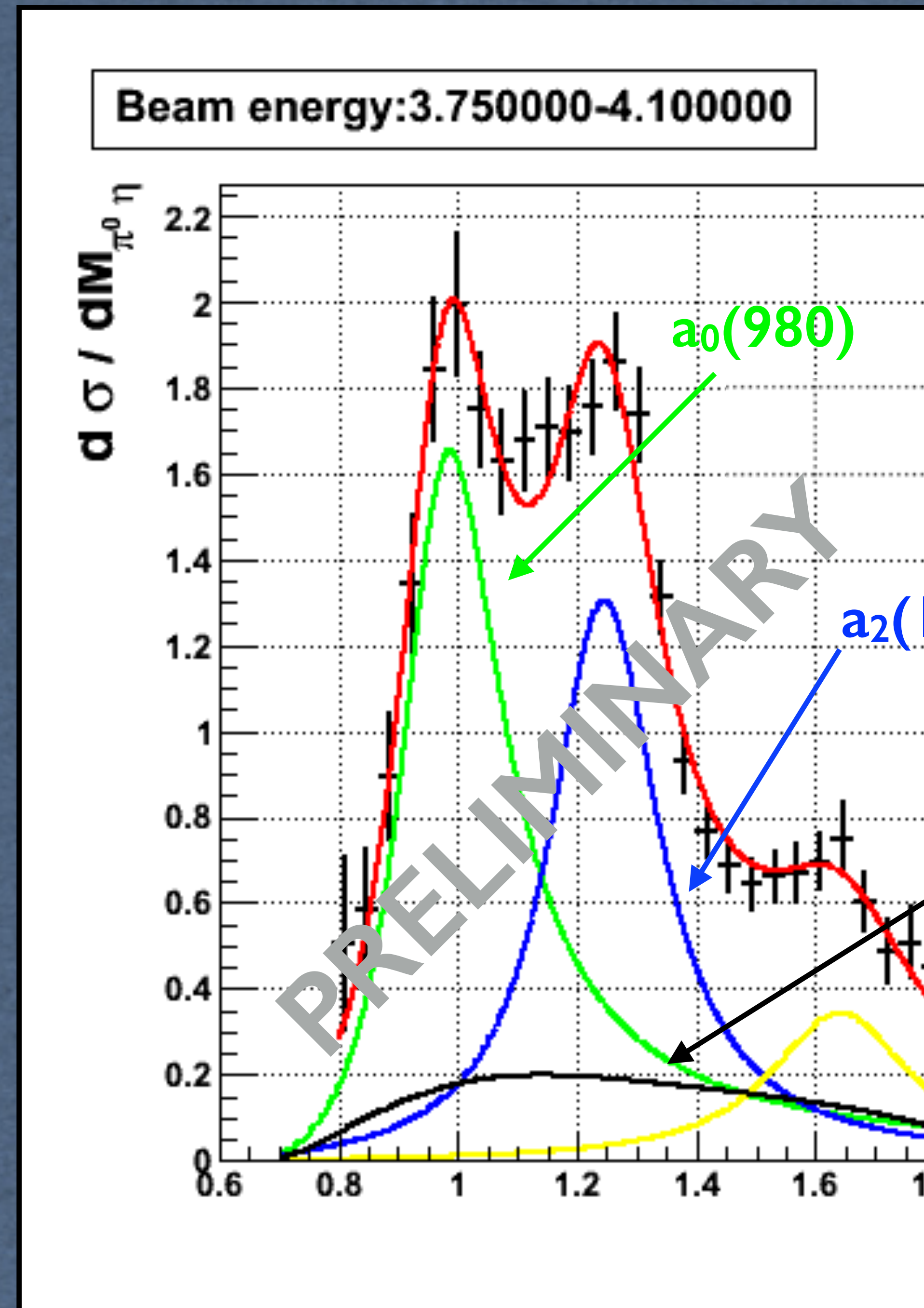
$\gamma p \rightarrow p \eta \pi$

- A.Celentano (INFN-GE) PhD Thesis



- Amplitudes provided by V.Mathieu (ECT*) and A.Szczepaniak (IU&JLab)
- Preliminary analysis on CLAS6 data to fix parameters





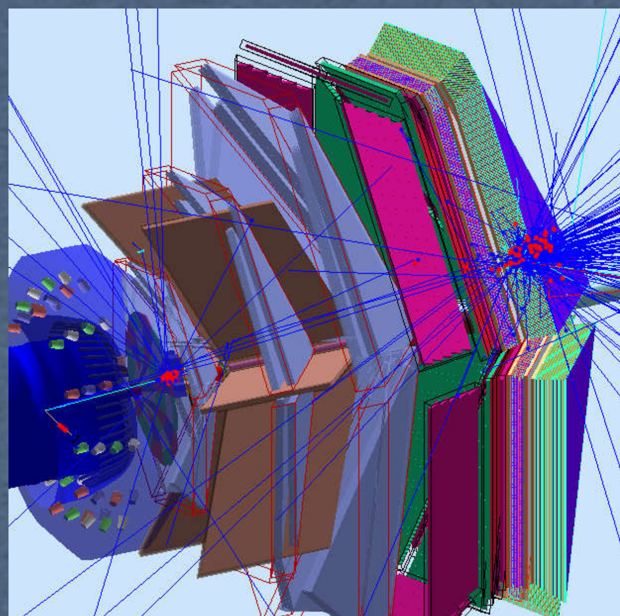
Resonance	J^{PC}
$a_0\,(980)$	0^{++}
$a_2\,(1320)$	2^{++}
$a_2\,(1700)$	2^{++}
$\pi_1\,(1400)$	1^{-+}

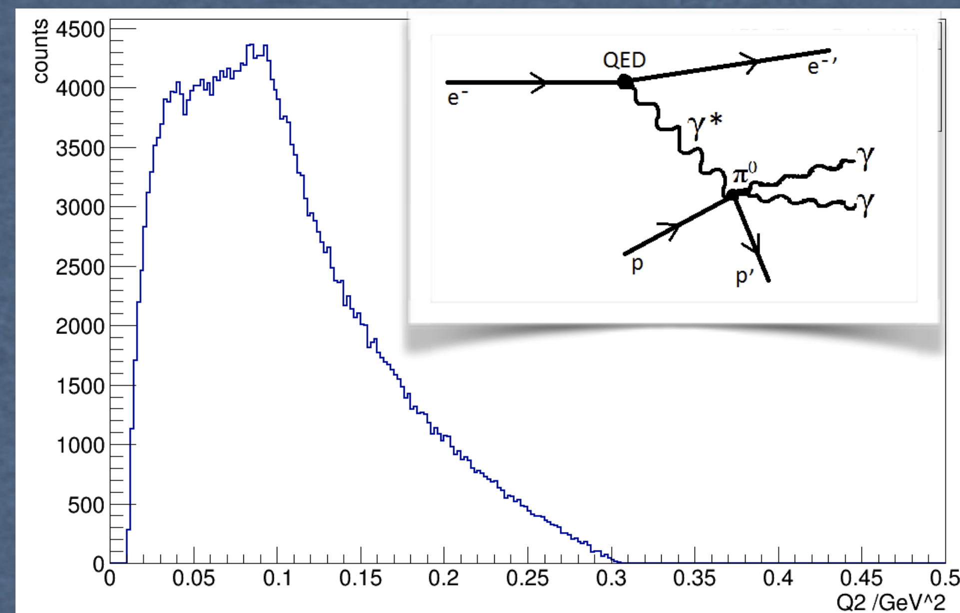
- Full projection on CLAS12 and PWA
- Sensitivity for P-wave > 5% $a_2(1320)$

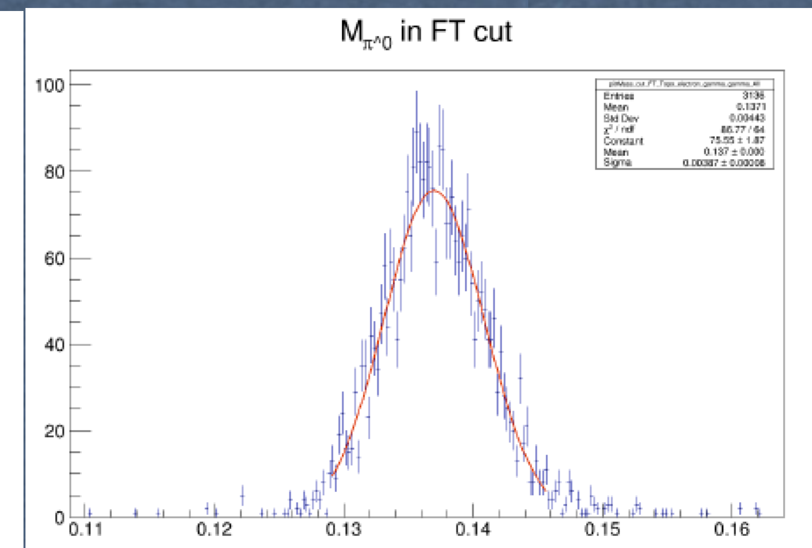
Needs higher energy, higher statistics ➜ CLAS12

PWA with CLAS12

High level physics analysis is starting soon!





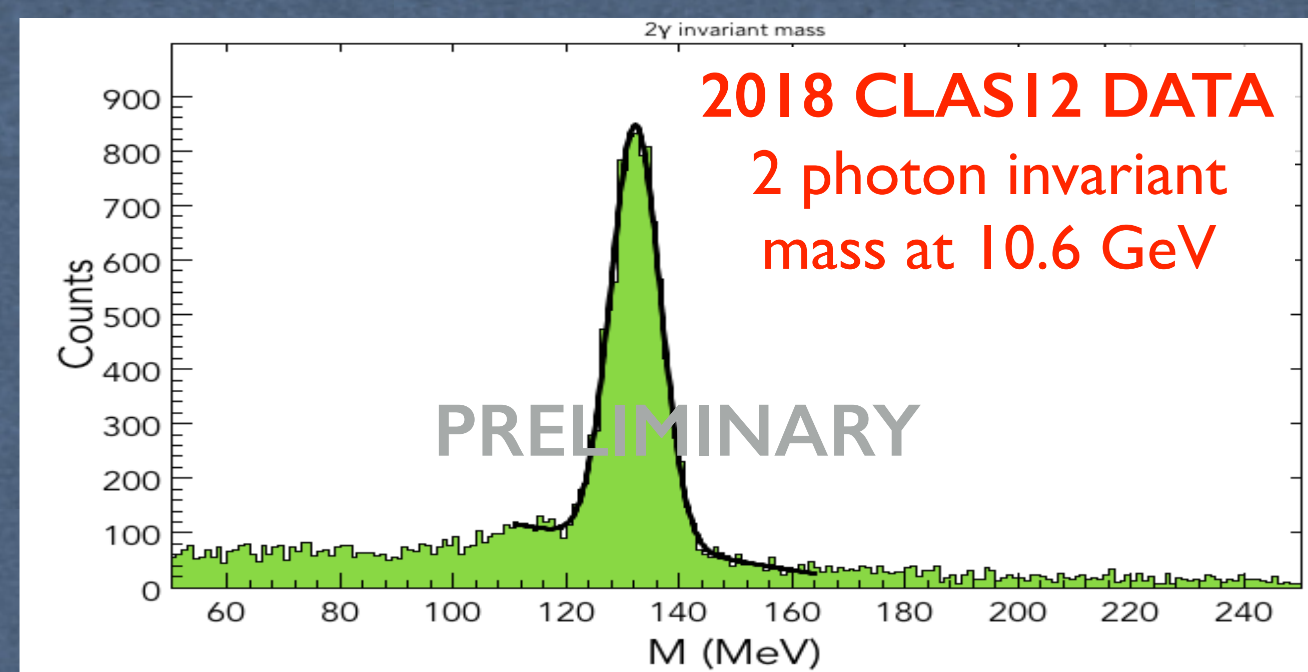


137 MeV/c² reconstrcuted (lit.: 134,98 MeV/c²)

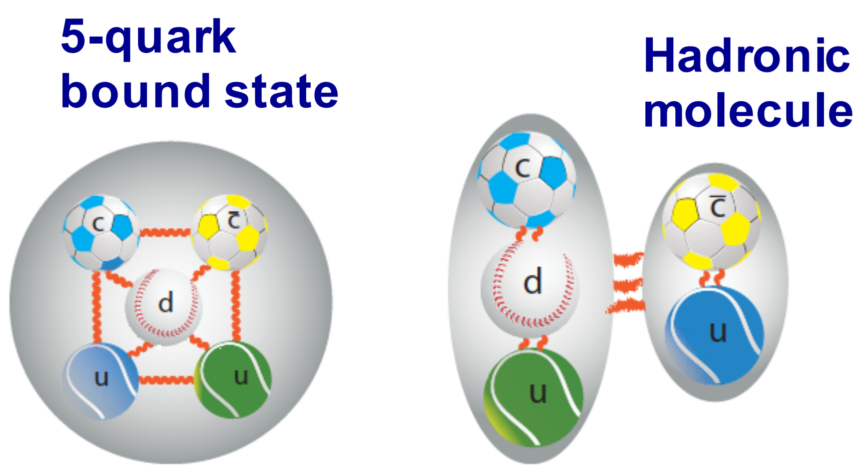
- γ_v Linear polarisation: σ'_{TT} (Σ)
- Xsection
- Large-t behaviour - $d\sigma/dt(90^{\circ})$
- e- polarisation: σ_{TL} (no available in photoproduction!)
- Full PWA

$e\,p \rightarrow e'\,p\,\pi0$ ($\gamma\,p \rightarrow p\,\pi0$)

- S.Dihel (U Giessen)
- Full CLAS12 GEANT4 simulation
- Full reconstruction
- Electroproduction amplitudes provided by JPAC (V.Mathieu)
- AMPTOOLS
- Electron detected at small angles in the CLAS12-FT

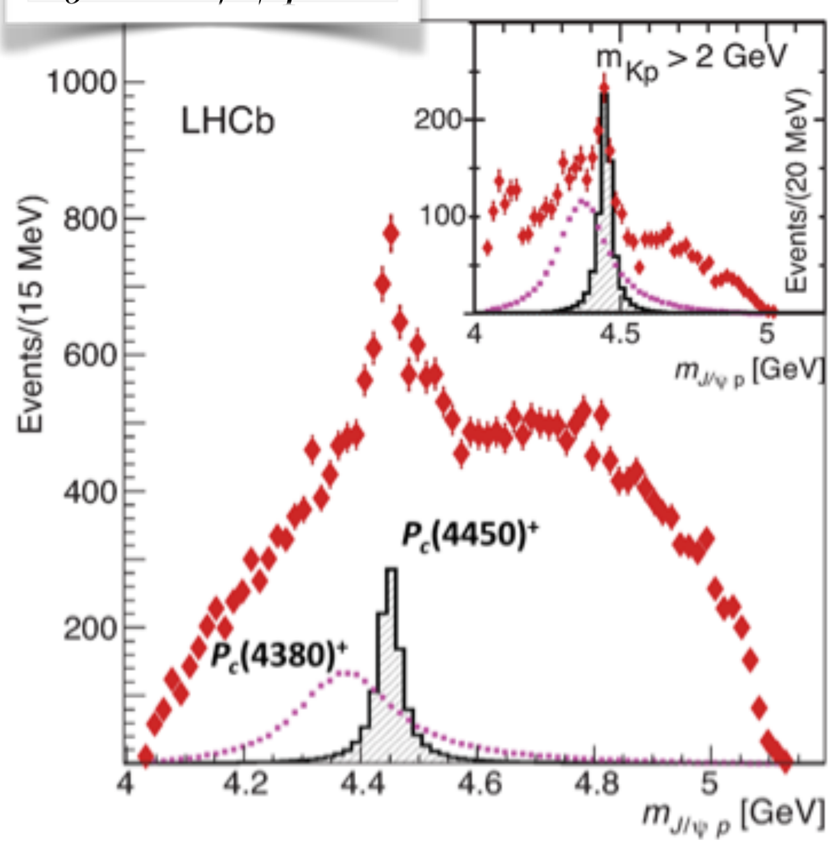


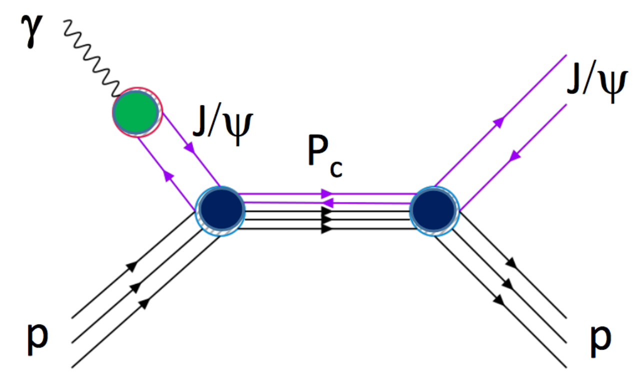
Pentaquark search at JLab

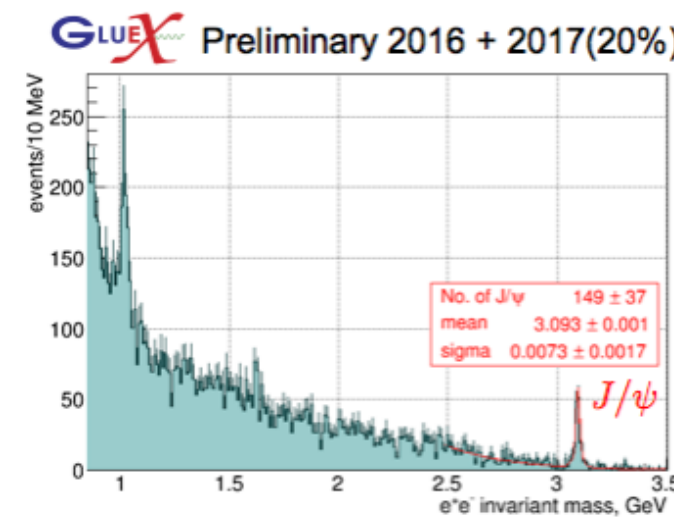


or cusp, triangle singularity, etc…

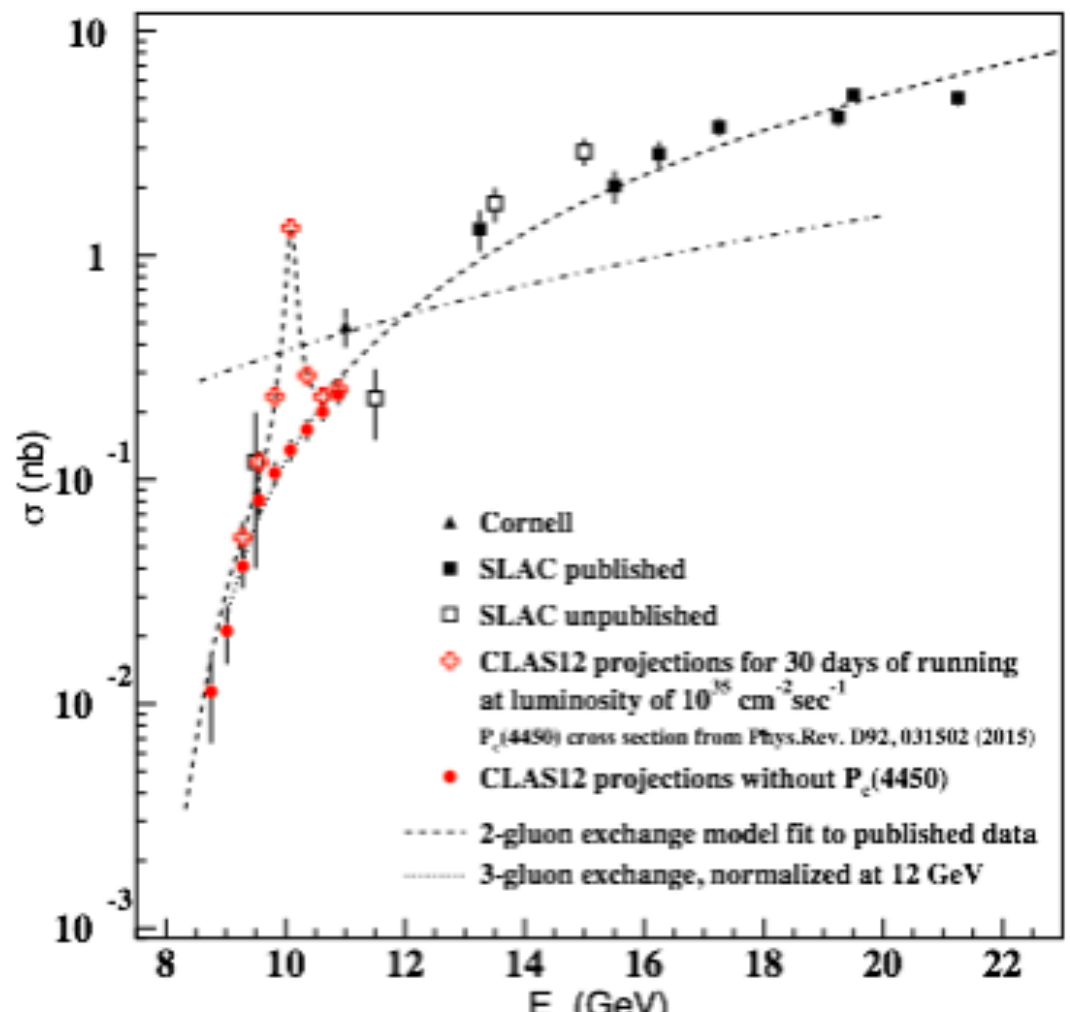
$\Lambda_b \to J/\psi p K^-$







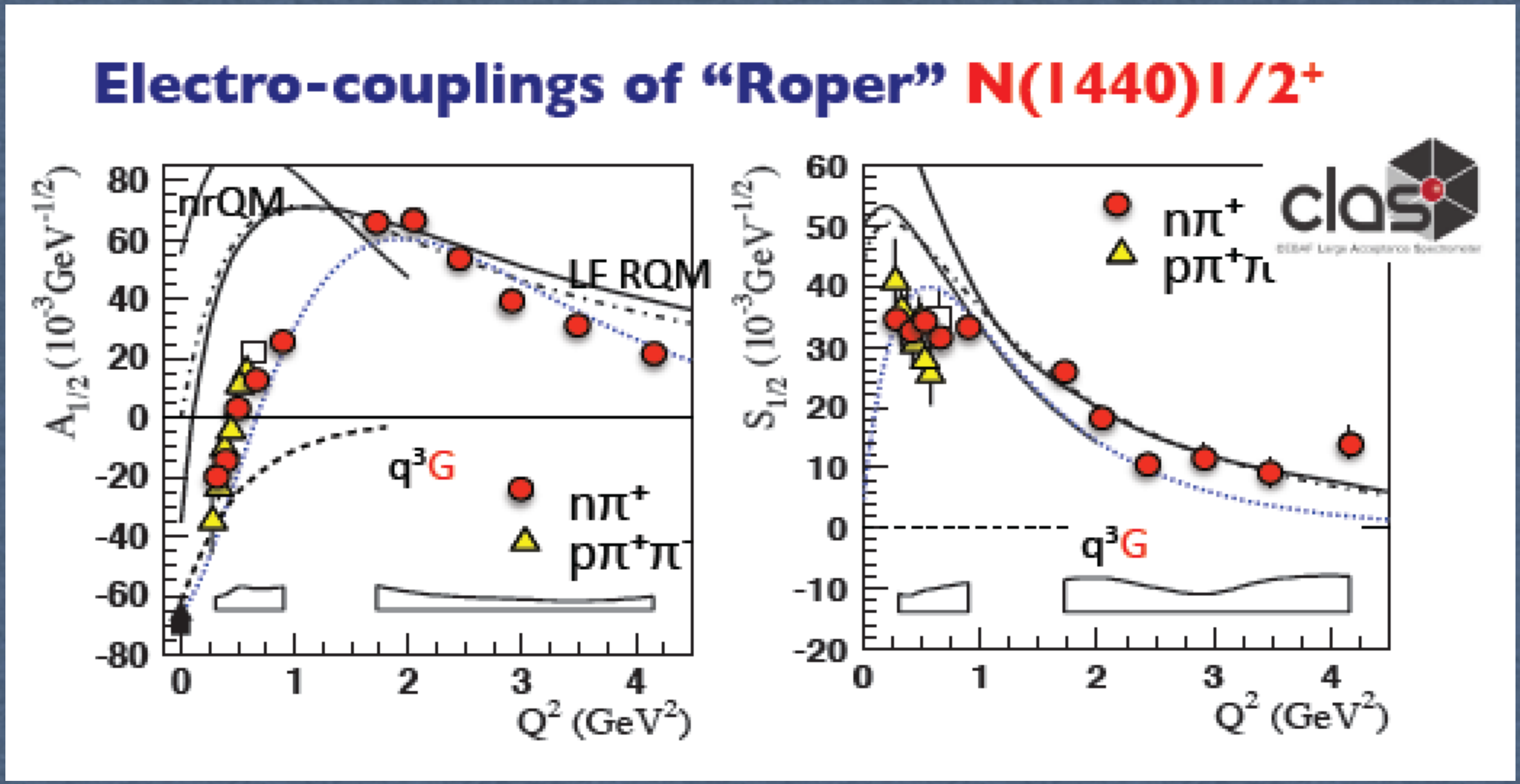
- J/ψ photoproduction at threshold
- Observation of charm at GLUEX
- Projections with CLAS12 shows a significant sensitivity



Transition form factor evolution in Q^2 as a filter?

Electro-production can be used to explore the hadron structure at different wavelengths (Q2)

A drop of the transverse helicity amplitudes $A_{1/2}(Q_2)$ faster than for ordinary three quark states, because of extra glue-component in valence structure



A suppressed longitudinal amplitude $S_{1/2}(Q_2)$ in comparison with transverse electro-excitation amplitude Q3G Q3G

- Nπ and Nππ give consistent results
- $A_{1/2}$ changes sign and has large magnitude at high Q^2
- QM fails to reproduce low Q^2 behavior, LFQM better at large Q^2
- Both $A_{1/2}(Q^2)$ and $S_{1/2}(Q^2)$ inconsistent with hybrid model prediction

CLAS12 will map out the full meson/baryon spectrum and its evolution in Q2

Hadron spectroscopy ingredients

✳ Experiment

✳ Theory

✳ **Analysis strategy**

- PWA: Isobar Model, ad-hoc solutions for limited kinematic domain
- PWA: how far can go a model-independent PWA in the real world?
- Multiple channels approach (Q2 as a filter?)
- Spot vs systematic studies
- Could meson decay's studies simplify the analysis?
- Data: CLAS6 (g11, g12, eXX), CLAS12

JLab Working Groups activity:
HASPECT, LMD, CLAS/PANDA, JPAC, …

✳ Analysis tools

JLab Working Groups activity

★ HASPECT (HAdron SPEctroscopy CenTer) WG

- Stable working group in Genova + satellites
- Weekly skype meetings and HASPECT weeks
- Analysis of CLAS data and projection on CLAS12

★ LMD (Light Mesons Decay) WG

- Stable working group at JLab
- Involvement of Julich Group
- Interest for a wide community (e+e- colliders)

★ CLAS/PANDA Joint Activity Board

- Mixed committee to explore overlaps and synergies
- light and heavy quark spectroscopy
- complementarity of production/annihilation

★ JPAC (Joint Physics Analysis Center)

- Develop the analysis framework
- Analysis of JLab and world-data
- Progress in amplitude analysis

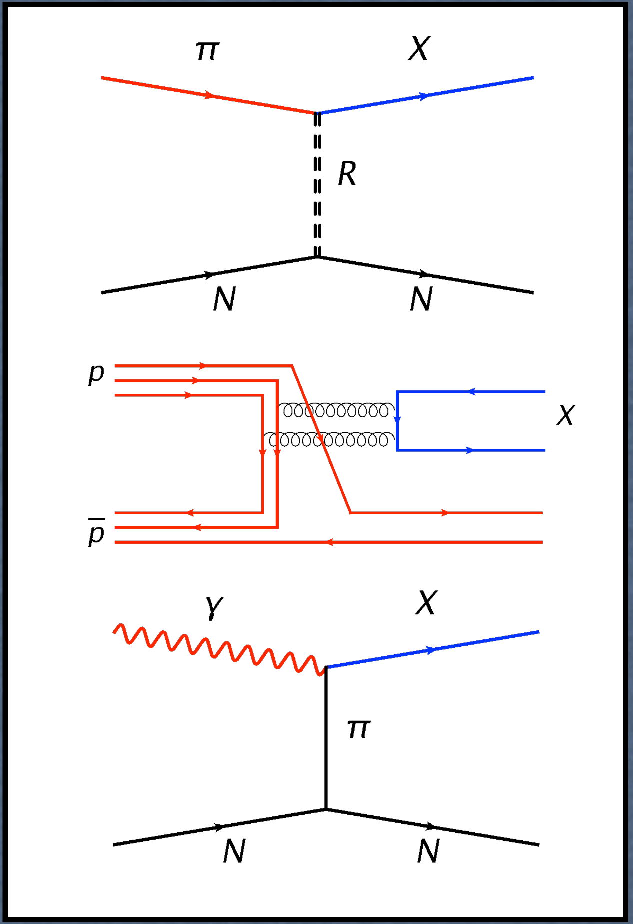
★ PyPWA project

Present:

- e+e-: BESIII and KLOE
- B decay: LHCb
- Belle, CLEO, BABAR

Future:

- Photoproduction at JLab:
- p p-bar at GSI: PANDA



Act locally but think globally!

INDIANA UNIVERSITY BLOOMINGTON | Jefferson Lab — Thomas Jefferson National Accelerator Facility | THE GEORGE WASHINGTON UNIVERSITY WASHINGTON, DC

Joint Physics Analysis Center

HOME PROJECTS PUBLICATIONS LINKS

U.S. DEPARTMENT OF ENERGY | National Science Foundation

JPAC acknowledges support from DOE and NSF

NEWS

November 2016:

- The $\gamma p \to \eta p$ page is online.

June 2016:

- The $\gamma p \to J/\psi p$ page is online.
- The πN page is online.

October 2015:

- The $\bar{K}N$ page is online.

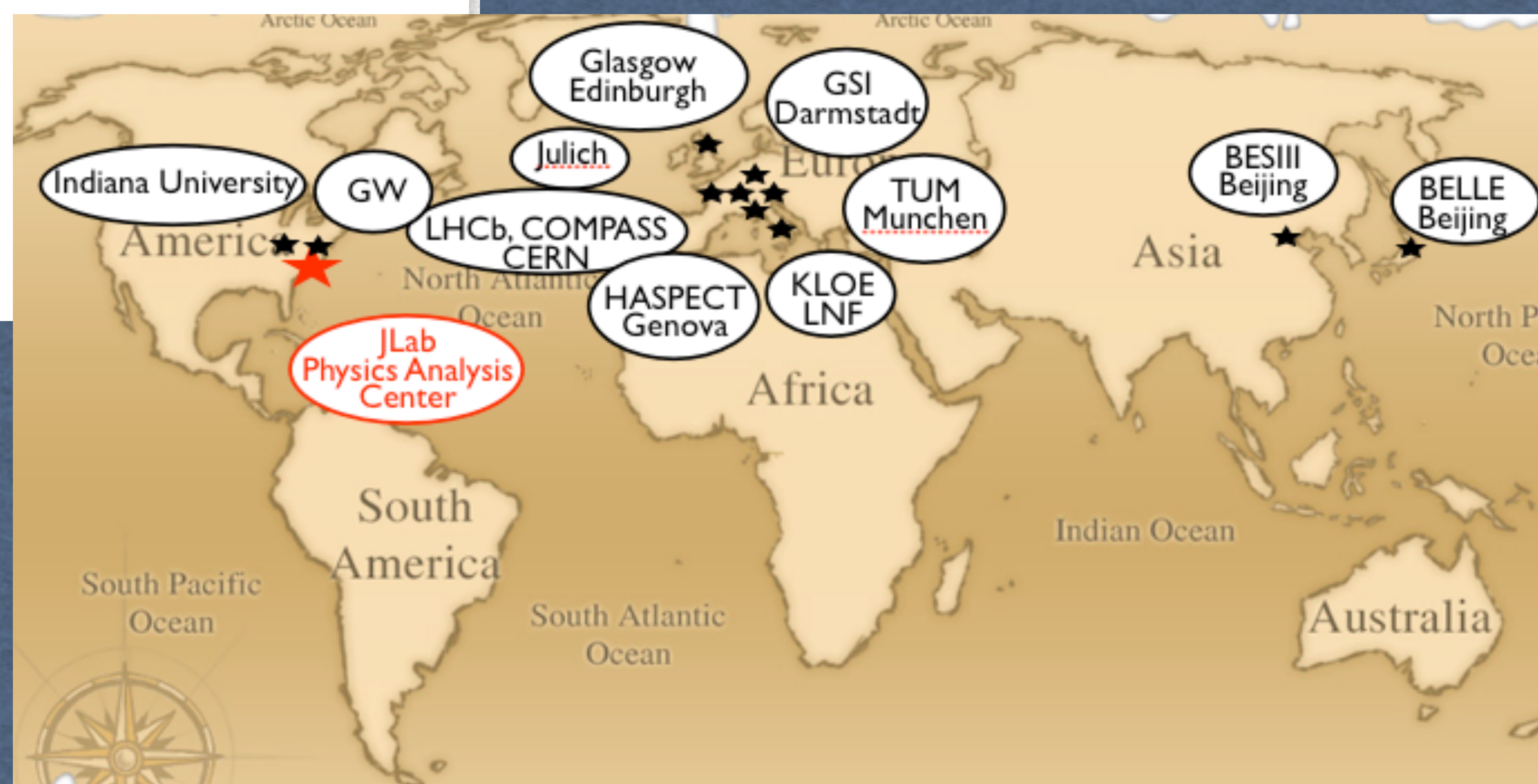
May 2015:

- The website is launched.
- The $\gamma p \to \pi^0 p$ page is online.
- The $\omega, \phi \to 3\pi$ page is online.
- The $\eta \to 3\pi$ page is online.

V.Mathieu

Global strategy:

✳Creation of twin and parallel centers for both analysis and theory development
✳Collaboration and exchanges: personnel, short visits, ...
✳Coordination via Joint Physics Analysis Center
✳Creation of a "Hadron spectrum" working group



Common funding plans:

- European-FP7 (EU calls and local): HaSP-STRONG2020
- DOE-Topical -collaboration proposals
- Canaletto/LiQuHas (Italy/Polland)

Conclusions

✳ Comprehensive meson spectroscopy program at JLab (Gluex & MesonEx)

✳ Exotics and strangeness-rich mesons search with CLAS12 detector exploiting excellent resolution and particle ID

✳ Bremsstrahlung and Low Q^2 electron scattering to produce a high intensity, linear polarized, real (Hall-D) and quasi-real (Hall-B) photon beam

✳ Experience in PWA gained with CLAS6 will be valuable for CLAS12 and GLUEX

✳ Expected abundant and precise data requires a solid PWA analysis framework

✳ Continuous interaction between JLab WGs (HASPECT, LMD, JPAC) and the other centers (CERN, BESIII, GSI, Julich) to meet the challenge

High-performance detectors, high intensity e/γ beams, strong analysis framework are the ingredients to make JLab a leading facility in modern hadron spectroscopy

Backup slides