Hadron Spectroscopy 1

Remote connection: https://bluejeans.com/468208461

Convener: Marco Battaglieri (INFN-GE)

Location: CEBAF Center (L102)

08:30 **Hadron Spectroscopy Working Group Business** *20'*
Speaker: Marco Battaglieri (INFN-GE)

08:50 **JPAC report** *25'*
Speaker: Vincent Mathieu (IU)

09:15 **Finite energy sum rules in pseudoscalar meson photoproduction** *25'*
Speaker: Jannes Nys (Ghent University)

09:40 **Preparing for CLAS12 data analysis** *25'*
Speaker: Derek Glazier (University of Glasgow)

10:05 **PyPWA** *25'*
Speaker: Carlos Salgado (NSU/JLab)

10:30 **Coffee Break** *30'*

11:00 **Full CLAS12 simulation and reconstruction: e p -> e' p pi0 (remote)** *25'*
Speaker: Stefan Diehl (University of Giessen)

11:25 **Analysis of eta->pi+pi-X, X = pi0/g within the CLAS g12 data set** *25'*
Speaker: Daniel Lersch (Forschungszentrum Juelich)

11:50 **Determination of Cx, Cz, and P for gamma d->K0 Lambda(p) from g13 Data** *25'*
Speaker: Colin Gleason (South Caroline University)

12:15 **Polarization observables for the Lambda hyperon for photon energies up to 5.45 GeV** *25'*
Speaker: Shankar Adhikari (Florida Internation University)

12:40 **Omega-meson Photoproduction off of Deuterium using CLAS g10 data** *25'*
Speaker: Taya Chetry (Ohio University)

13:05 **Lunch** *1h25'*

14:30 **Status of HSWG analysis reviews** *30'*

16:00 **Coffee break** *30'*

HSWG

CLAS Collaboration Meeting
JLab, March 30 2017

Agenda

- ✳ Status of ongoing analysis
- ✳ Status of analysis review
- ✳ ACE and HSWG in CLAS12 era: building a sweet and regulated framework for spectroscopy (K.Hicks)

Activities

- ✳ Regular report at HSWG on JPAC activity to strengthen exp/the connection
- ✳ Analysis review: check technical analysis and if the physics (technically) correctly extracted
- ✳ Analysis ready for a plenary presentation?

Talks

- ✳ Over all CLAS contributions, HSWG-related are 30-40%
- ✳ Strong interaction with the CSC
- ✳ List of possible topics/speakers on the latest CLAS results
- ✳ JSA-TFC funds $20k allocated for 2016
- ✳ JSA-TFC funds available for N* conference (August 20 - 23, 2017 at the University of South Carolina, Columbia, SC)

AgCE summary (K.Hicks)

Assumptions

- Software group provides the framework for reconstruction
  - Assume this is (or will be) fully functional
  - Assume simulations are handled in the same way as data
- Calcom group provides the calibrations
  - Assume the calibration procedures are standardized
  - We might need additional corrections that come later in the analysis chain
- Reconstruction -> HIPO file -> post-processing -> DST
  - During post-processing, apply momentum corrections, fiducial cuts, etc.
  - This step (and after) is where the ACE is focusing.

✳ Role of the WG: natural place where to discuss analysis procedures and check analysis quality

✳ We need to define procedures to:

- ✳ define standard analysis procedures
- ✳ QA of standards implementation
- ✳ revise standards

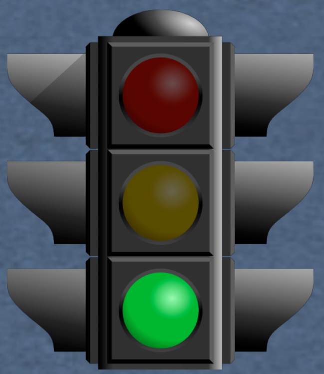
✳ Start to work now since the time is limited (not wait till the next coll meeting!)

✳ Extensive discussion at the next Coll meeting

Categories of Recommendations

- Data cooking:
  - Calibration procedures are being discussed by CalCom
  - Data skimming: what variable should be kept for the DST?
    - How loose should the cuts be for, say, electron ID?
- Data corrections:
  - Which ones should be done as post-reconstruction?
    - Energy loss corrections, momentum corrections, loose fiducial cuts?
- Simulations:
  - What should be done post-gemc and before reconstruction?
- Radiative corrections:
  - how to calculate/correct these?

WG Reviews status since last Collaboration meeting



E asymmetry for g n -> pi^- p from g14 (HDice) data
PI: F.Klein
RC: B.Briscoe, P.Cole, M.Dugger

Gamma p to K0K0 from the g12 Data Set
PI: Kenneth Hicks and Shloka Chandavar
RC: Carlos Salgado (Chair), Derek Glazier , Lorenzo Zana

Analysis report on the ep \to e'p pi+ pi- reaction in the CLAS detector with a 2.039 GeV beam
PI: Gleb Fedotov
RC: Nikolay Markov (Chair), Evgeny Golovach , Daniel Carman

Measurement of the g d o p pi- (p) Quasi-free xsec
PI: Paul Mattione
RC: Eugene Pasyuk (Chair), Nicholas Compton , Nicholas Zachariou

DONE!

Less than 6 months!

WG Reviews status

New since last meeting

Coherent omega-meson photoproduction off the deuteron
PI: T.Chetry
RC: B.McKinnon, P.Cole, N.Zachariou
Status: 1st round

Radiative decay of eta' to pi+ pi- gamma from g11 data set
PI: G. Mbianda Njencheu
RC: R. Schumacher, S.Schadmand, A.Celentano
Status: 1st round

In progress

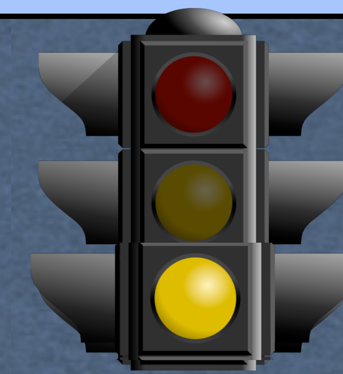
Measurement of Cross-Sections of exclusive pi^{0} Photo-production on Hydrogen from 1.1 GeV - 5.45 GeV using e+e-gamma
PI: Michael Kunkel
RC: Carlos Salgado (Chair), Lei Guo , Yordanka Ilieva
Status: 2nd round, healthy

Polarization Observables T and F in the $\vec{p}(\vec{\gamma},\pi 0)p$ Reaction
PI: H.Jiang
RC: Barry Ritchie (Chair), Volker Crede , Bryan McKinnon
Status: Ist round done

Cascade polarization in photoproduction
PI: J.Bono et al.
RC: A. D'Angelo (Chair), M.Kunkel, E Pasyuk
Status: 2nd round, healthy

Polarized structure function sigmaLT from the single pi0 electroproducion on the proton in the resonance region
PI: Nick Markov
RC: V.Crede, Ralf Goethe, Yelena Prok
Started Sept 2014
Status: is moving forward

WG Reviews status



Measurement of Sigma in pi- photoproduction on the neutron from the g13b dataseta
PI: D.Sokhan (GlasgowU) et al.
RC: Eugene Pasyuk (Chair), Nicholas Zachariou , Paul Mattione
Timeline: jun 2016
Status: lost contact with the author after !st round

KLambda and KSigma from FROST
PI: N.Walforf et al.
RC: S.Strauch, M.Holtrop, P.Mattione,
I round of comments in May 2015, waiting for a revised
Status: stalled for a long while, now it seems to be resurrected

Exclusive Photo-Production Measurement of K+Sigma*- off Quasi-Free Neutrons in Deuterium
PI: H.Lu (SCU) et al.
RC: N.Zachariou, M.Dugger, D.MacGregor
Status: resumed with reshuffled committee, still waiting …

Pentaquark search in g10 by using the MMSA method
PI: Kenneth Hicks et al.
RC: Stepan Stepanyan (Chair), Lei Guo , Bryan McKinnon
Status: stopped communication from 6 months

Spin observables in eta meson photoproduction on the proton from FROST data
PI: R.Tucker (ArizonaU) et al.
RC: K.Livingston, J.Price, Xiangdong Wei
Timeline: jun 2016
Status: on-hold

Proposal: release the analysis; set up a restricted committee + someone from the SC/run-group to go trough the analysis and see if the latest issues have an easy fix

Progress on JPAC projects with CLAS

Vincent MATHIEU

- **providing model for MC simulations**

  $\gamma p \to \pi p \qquad \gamma p \to \eta p \qquad \gamma^{(*)} p \to K\Lambda$

  $\gamma^* p \to \pi\pi p$

- **Joint analysis of data**

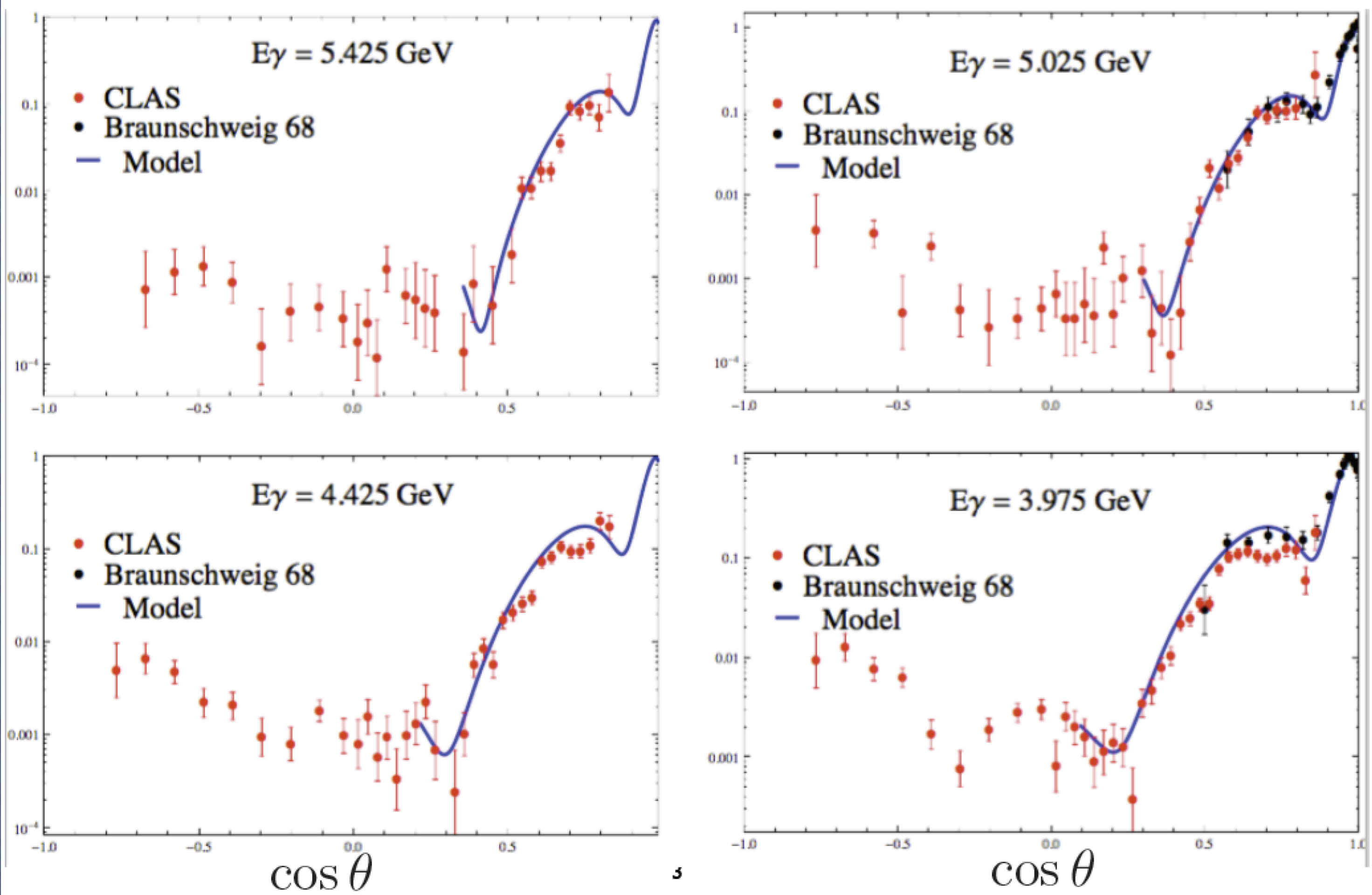
  $\gamma p \to K\bar{K}p$

  $\pi p \to \eta\pi p \qquad \pi p \to \pi\pi\pi p$ **with COMPASS**

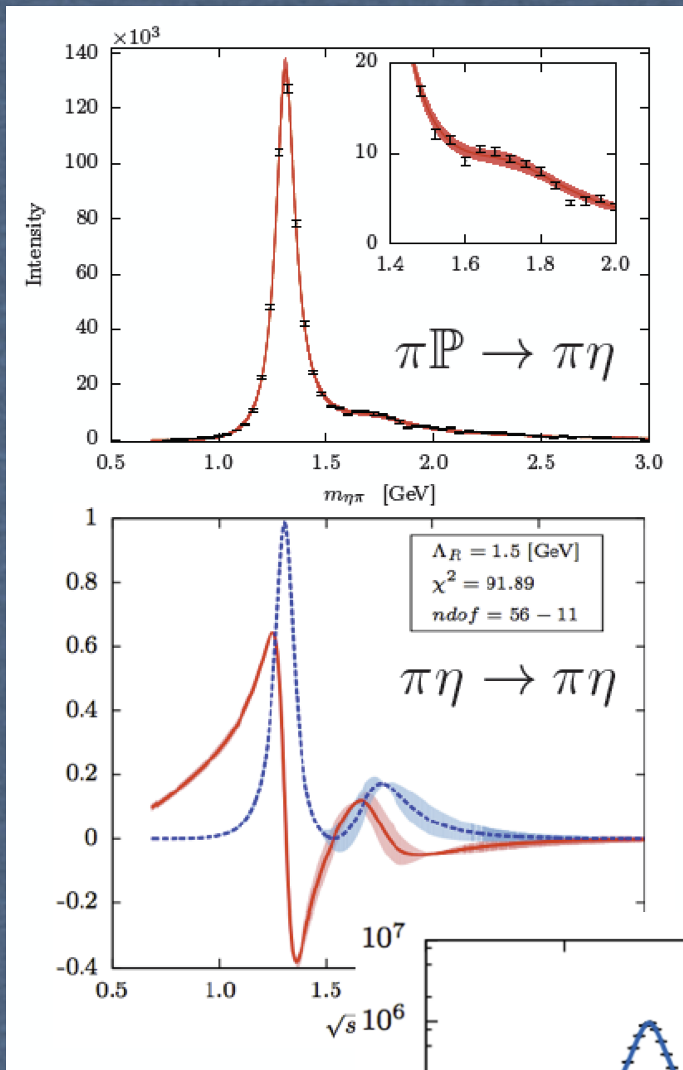
$$\gamma p \to \pi^0 p$$

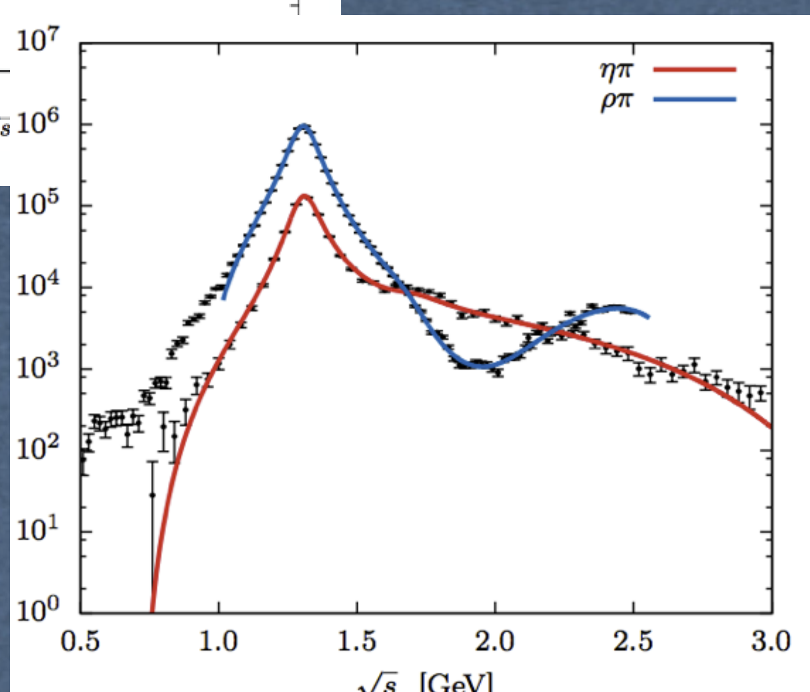
Blue line: Predictions from VM et al Phys. Rev. D92 074013

Red points: Data from CLAS (in preparation) Courtesy of M. Kunkel

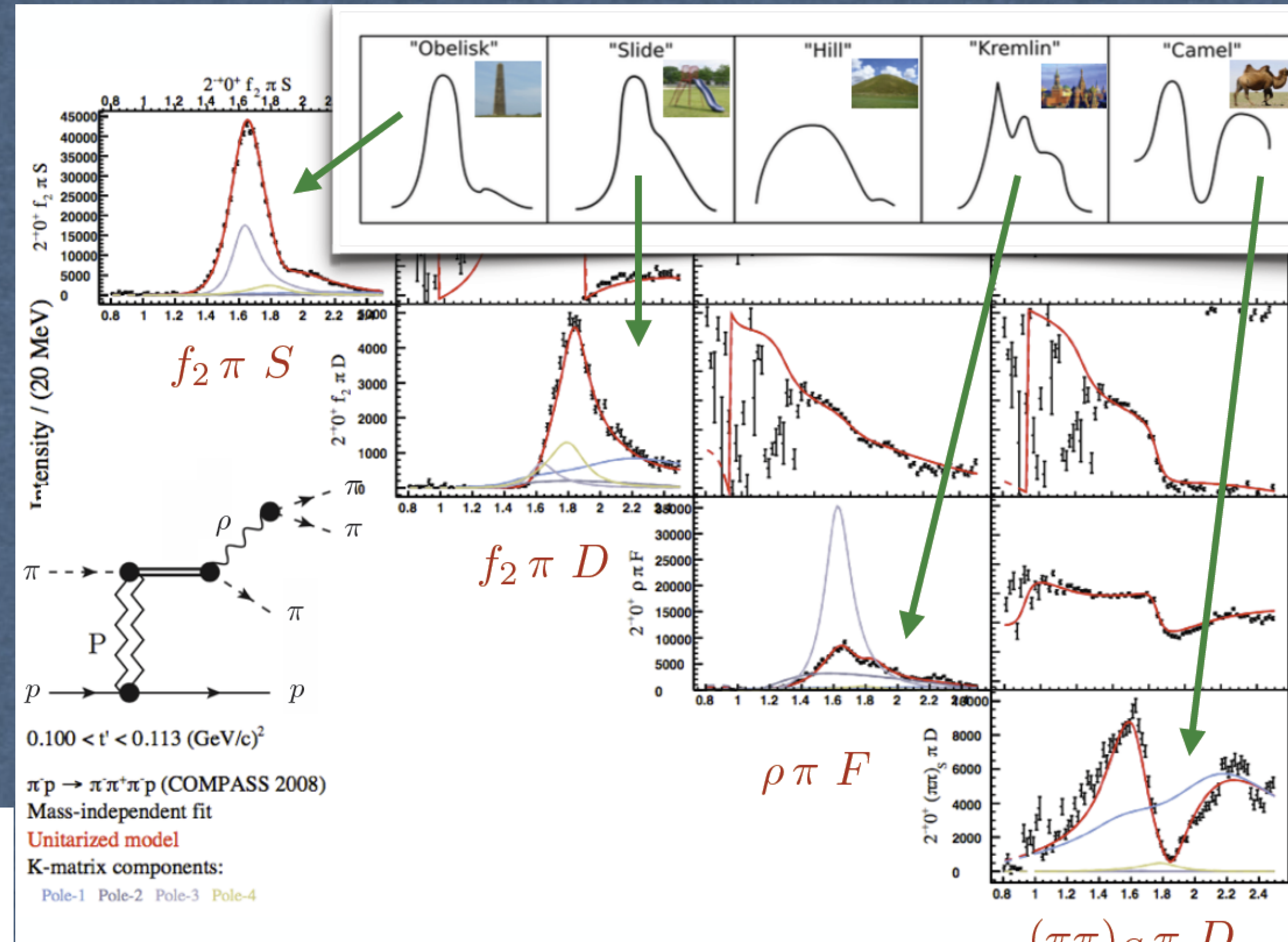


Eta-Pi@COMPASS





3Pi @COMPASS: 2^{-+}



courtesy of M. Mikhasenko

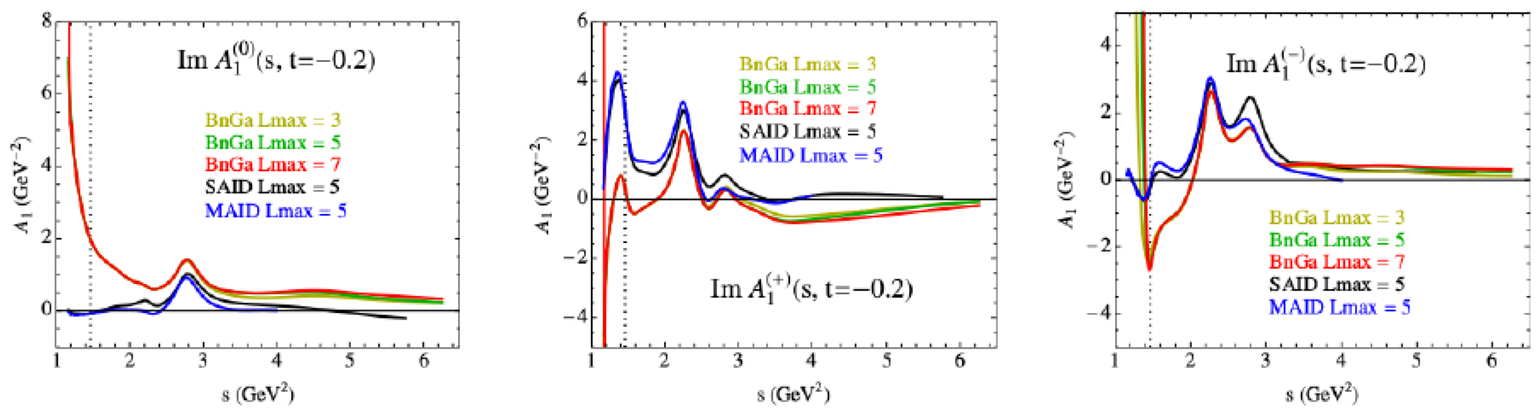
2017 International Summer Workshop on Reaction Theory
June 12-22, 2017, Bloomington, Indiana, USA

Finite-Energy Sum Rules

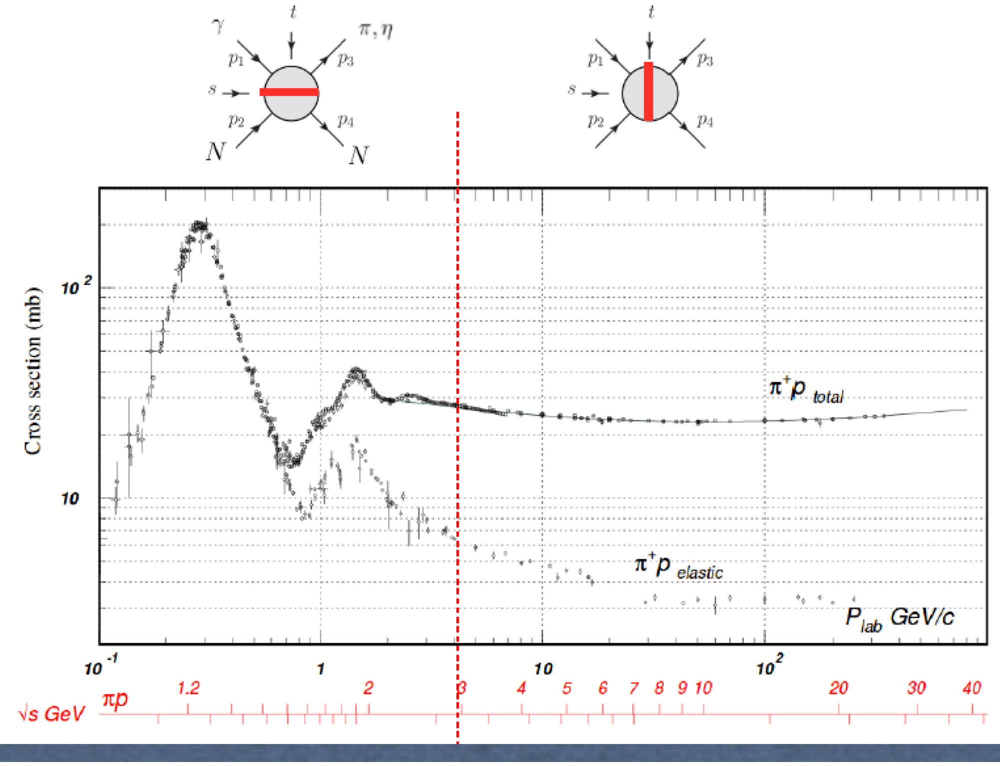
Jannes Nys
Ghent University
Joint Physics Analysis Center

Given the s-dependence at high energies, one can **predict the** **t-dependence** **at** ***high energies***, using only ***low-energy*** **models**

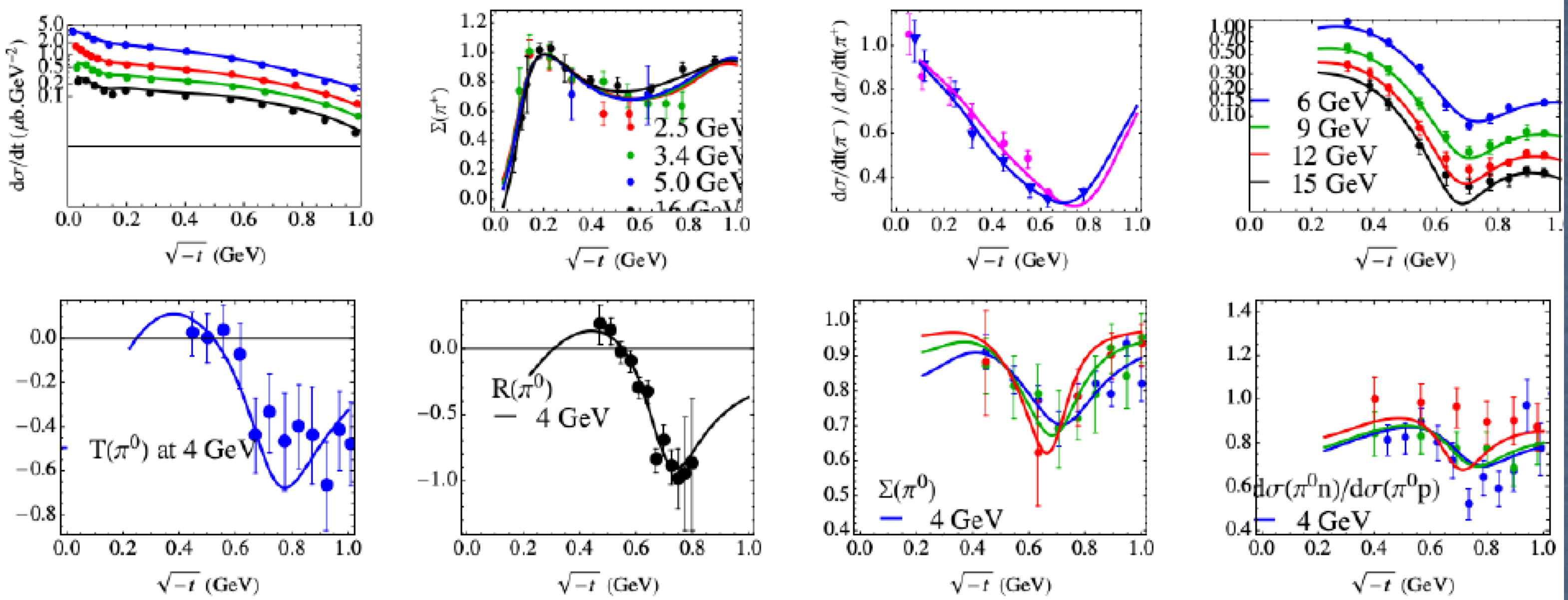
Pion photoproduction



Finite-Energy Sum Rules

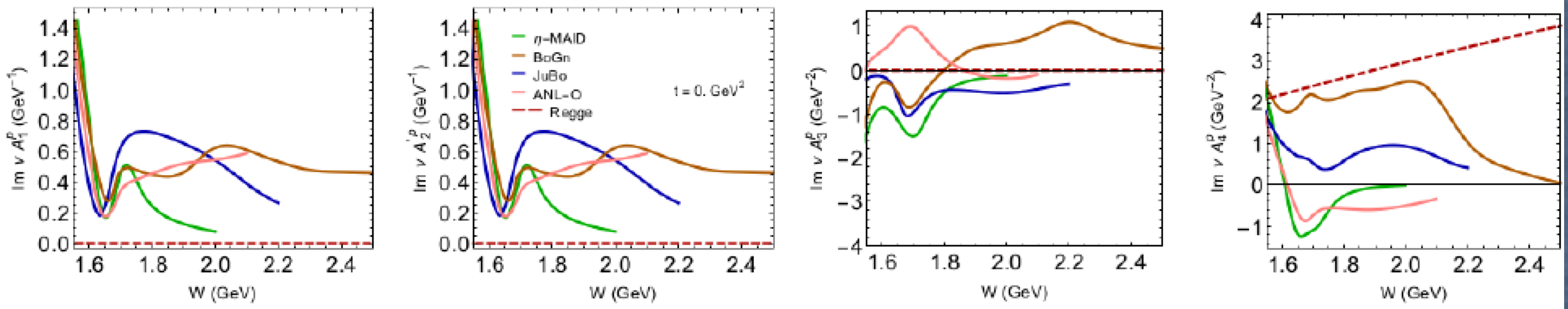


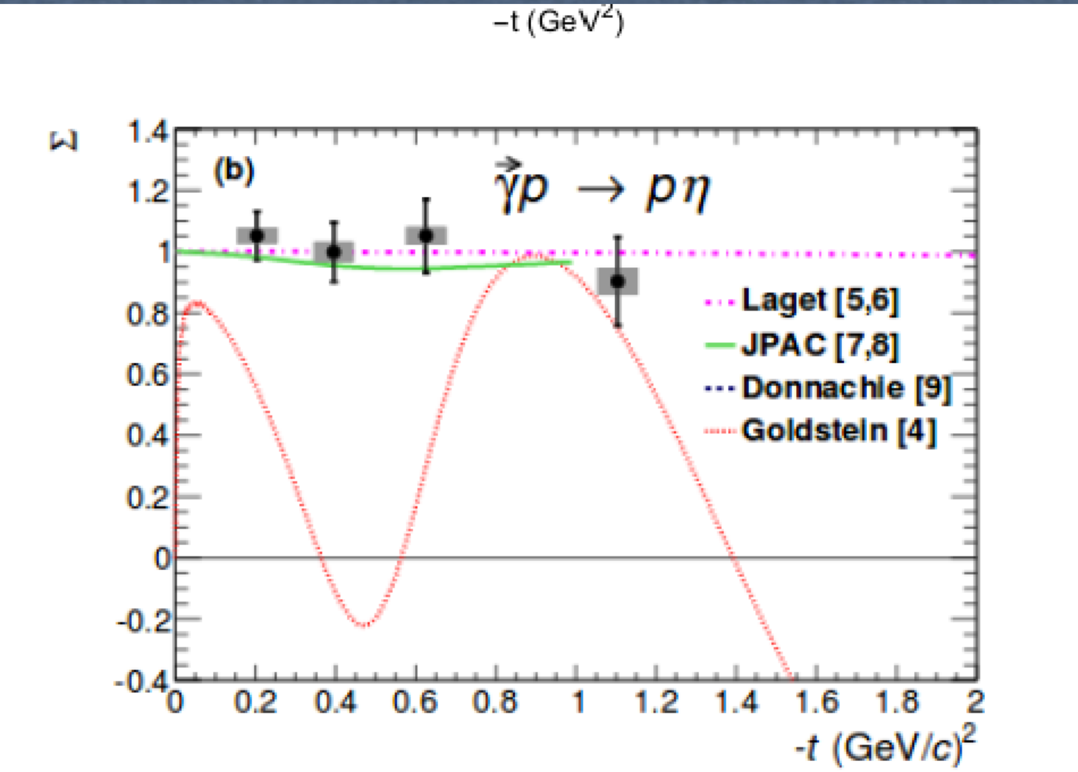
Pion photoproduction



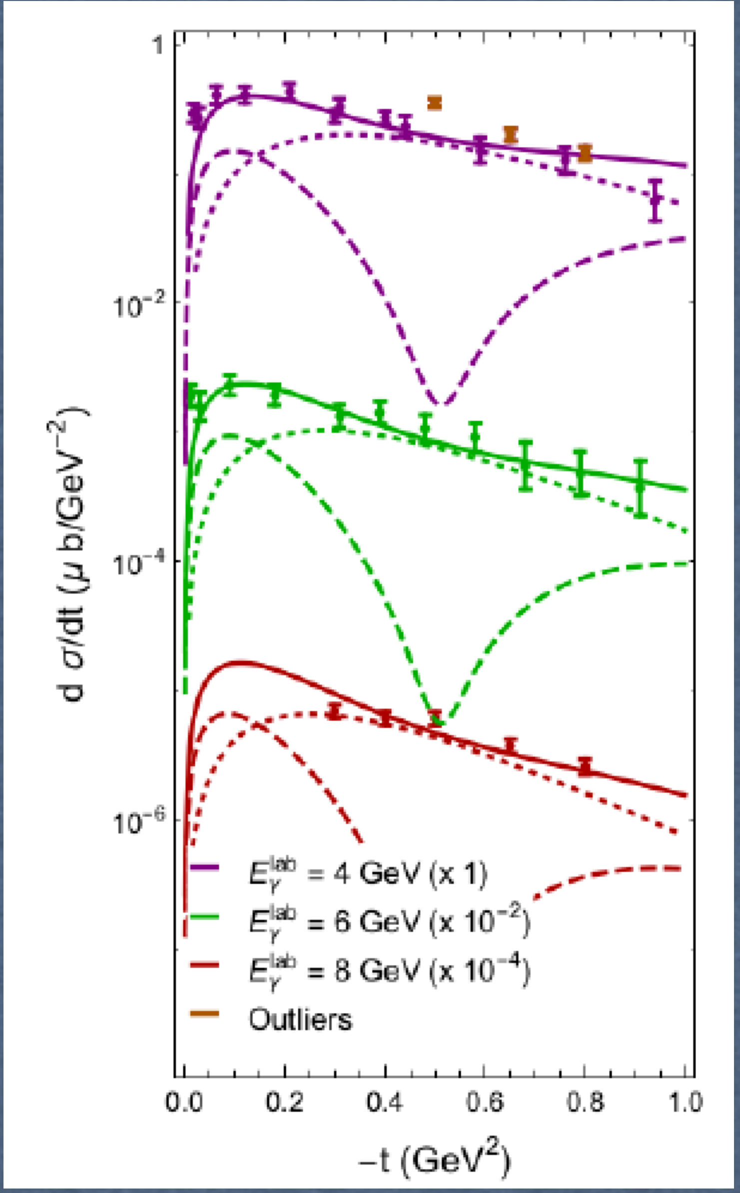
- Finite-energy sum rules connect low and high energy regime
- Successful predictions at high energies based on low-energy models
- Provides information at the amplitude level

Eta photoproduction



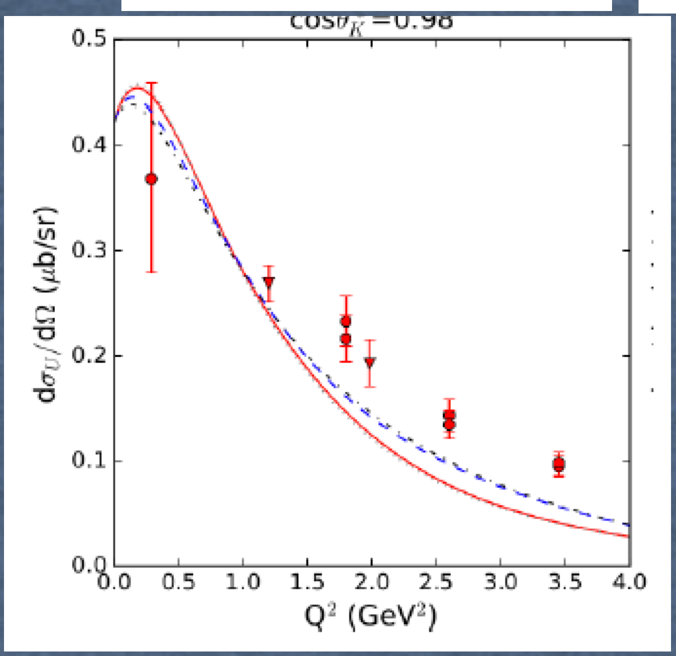


Al Ghoul *et al.* (GlueX) 1701.08123

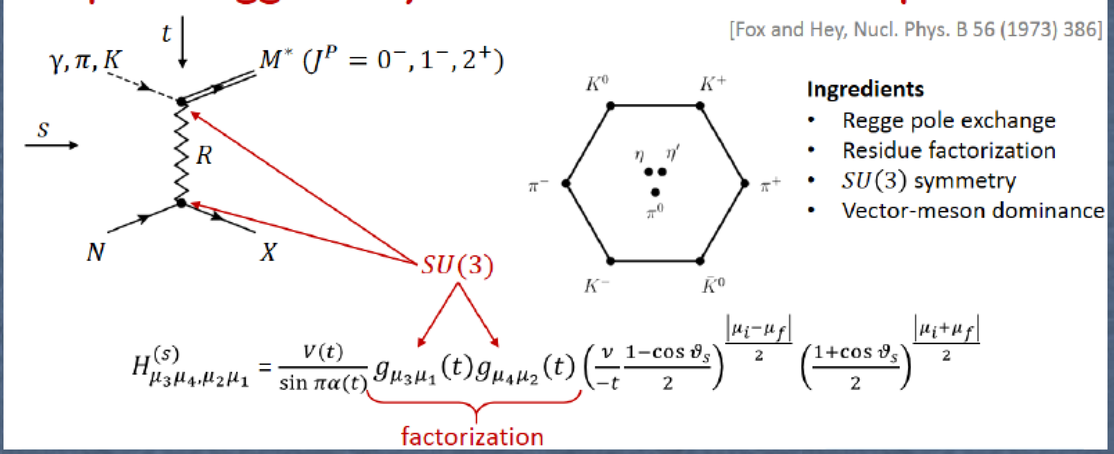


$\gamma^{(*)}p \rightarrow K^+\Lambda$

Extending RPR (Ghent) from photoproduction to electroproduction



Coupled Regge analysis of meson resonance production

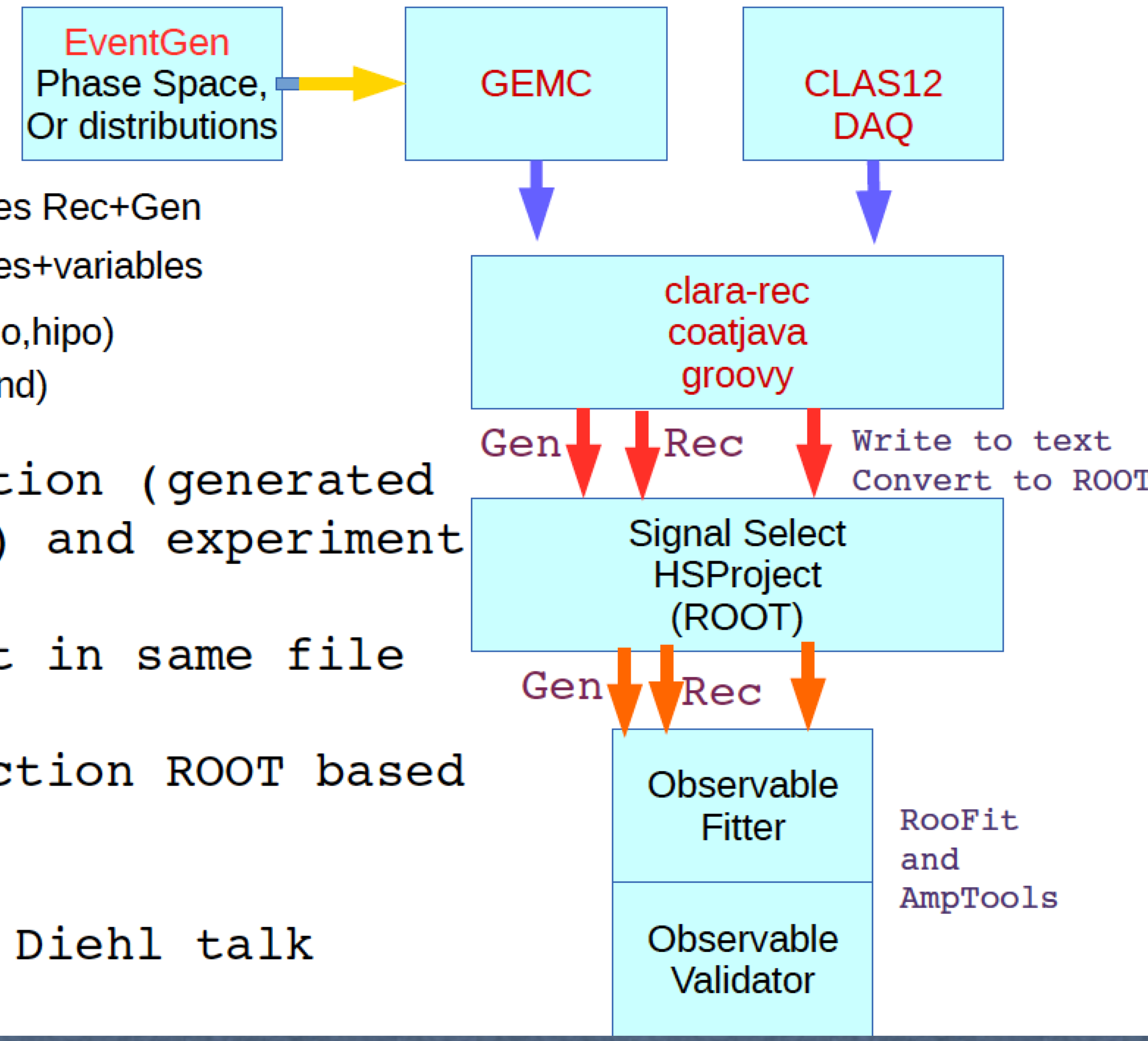


Preparing for CLAS12 Data Analysis

Derek Glazier
University of Glasgow
Hadron Spectroscopy Working Group

HASPECT Data Analysis

- HSParticles Rec+Gen
- HSParticles+variables
- Other (evio,hipo)
- Other (Lund)



Parallel simulation (generated and reconstruct) and experiment

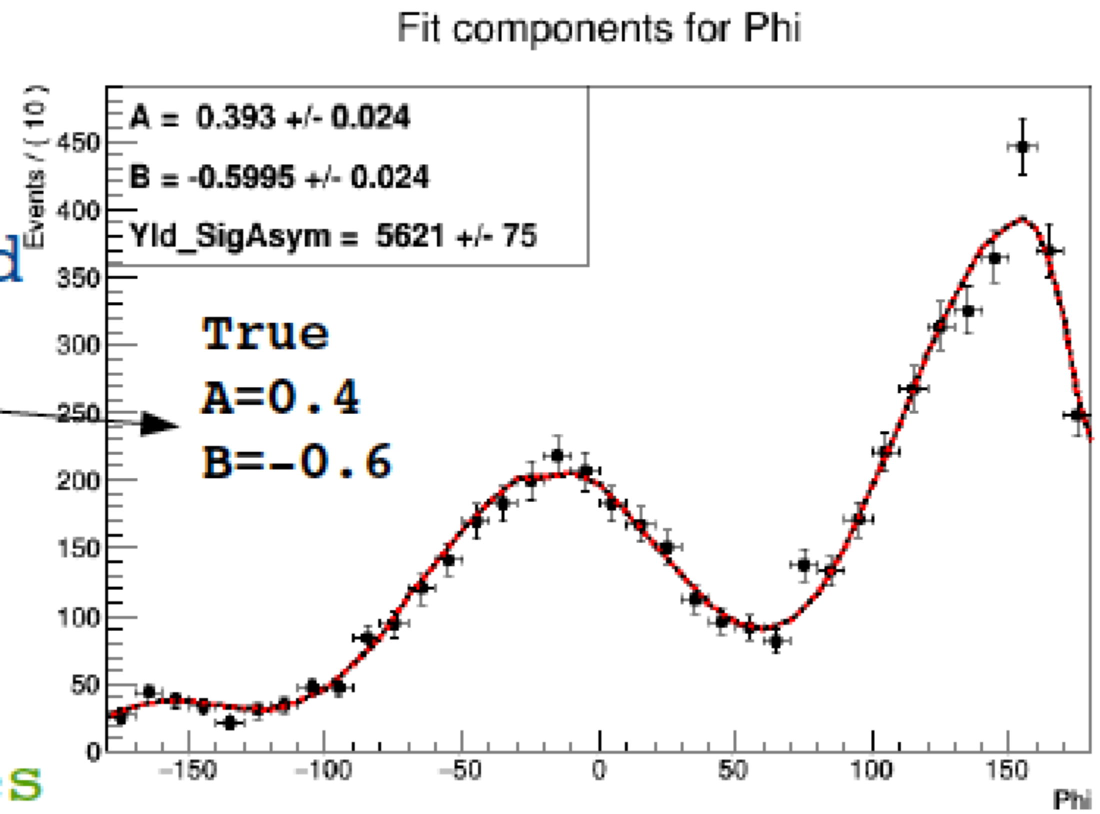
Gen and Rec kept in same file

After reconstruction ROOT based analysis tools

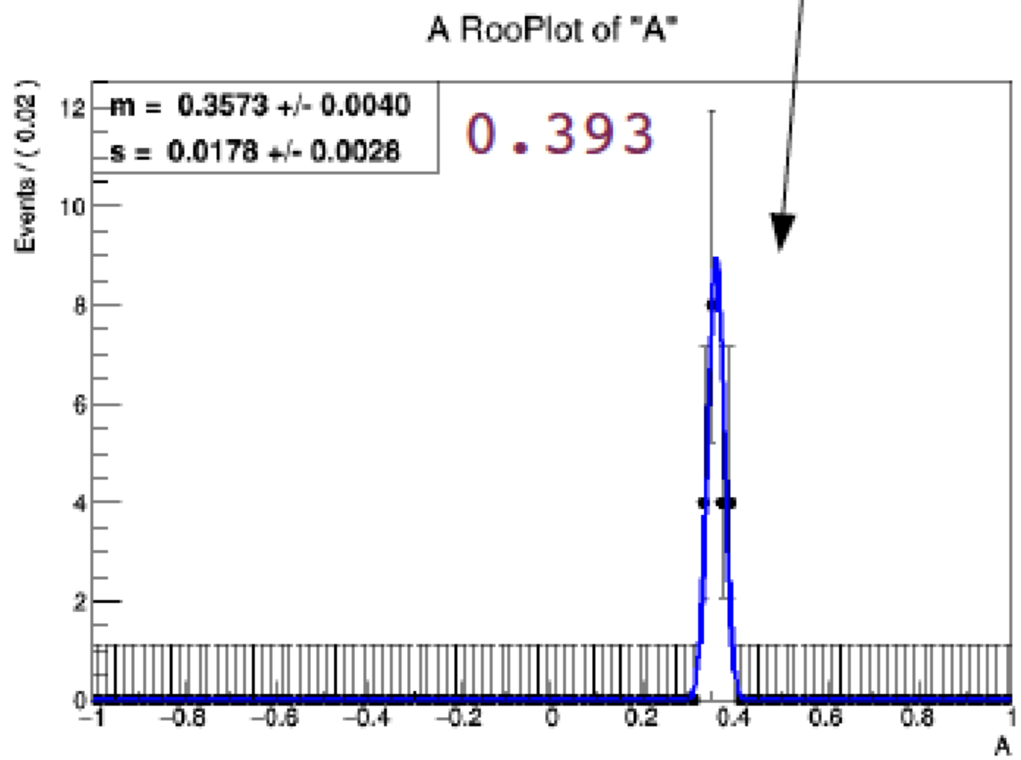
See also Stefan Diehl talk

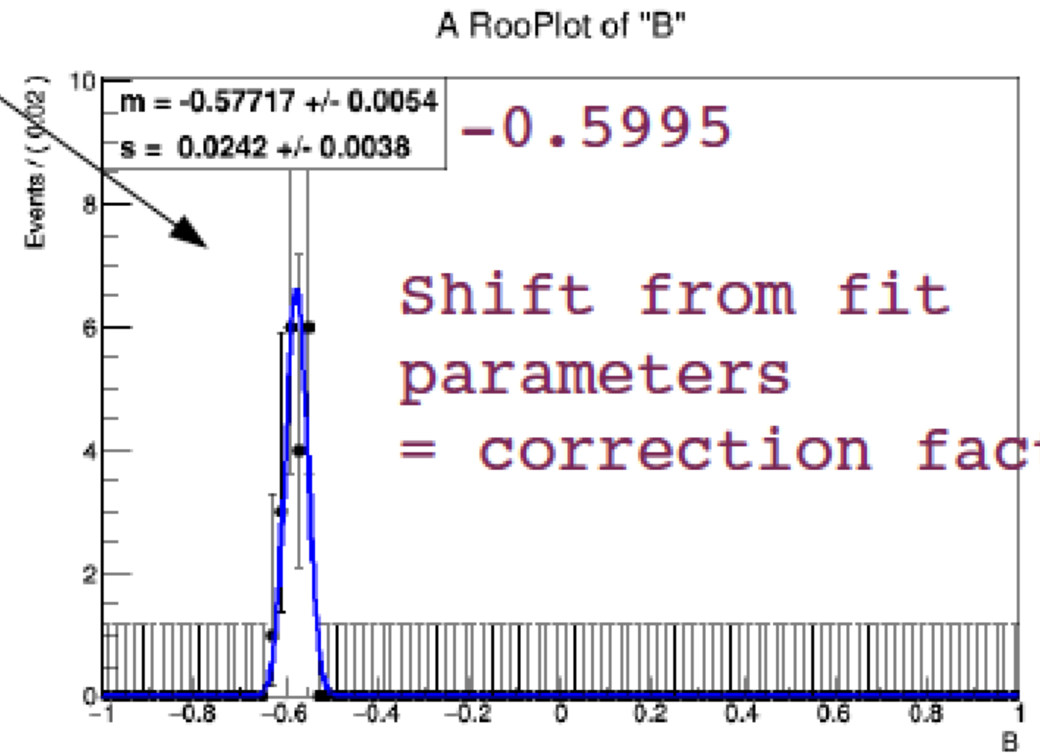
Toy Example

Observable Extraction:
Extended Maximum Likelihood
with acceptance correction



Extraction Validation :
Toy MC Method
Generate and fit from
simulated events many times





Shift from fit
parameters
= correction factor

Simulation of e p → e p π^0 with the CLAS12 simulation and reconstruction / analysis framework

JUSTUS-LIEBIG-UNIVERSITÄT GIESSEN

Stefan Diehl

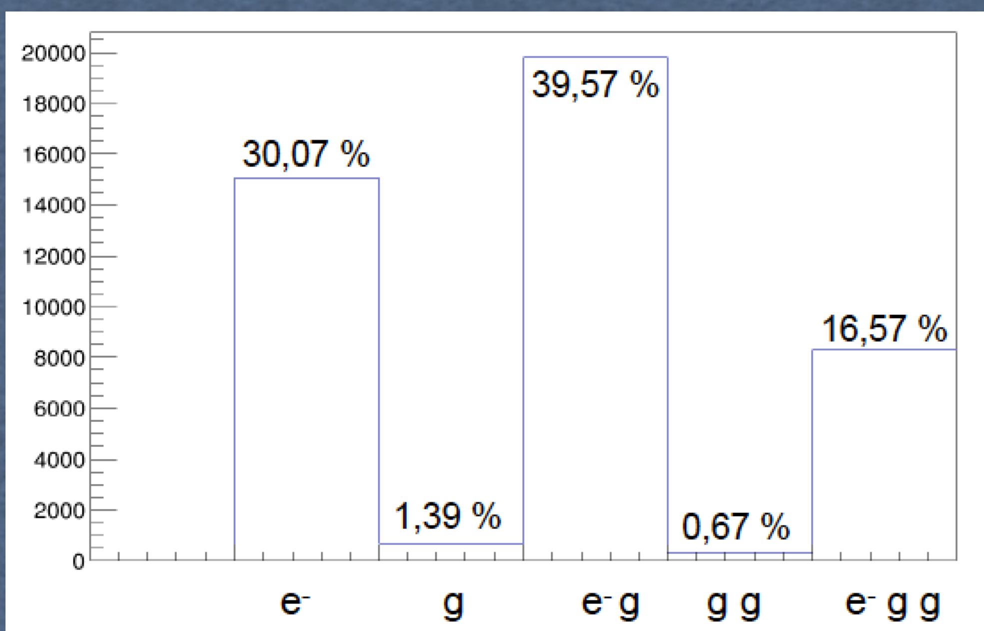
2nd Physics Institute, Justus-Liebig-University Giessen

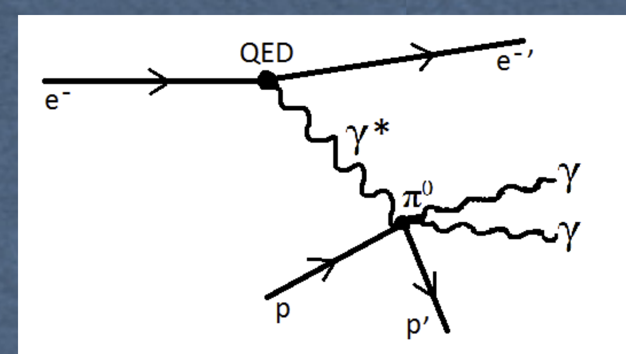
Aim: Simulation of the channel e p → e p π^0

Secondary aim: Get the complete simulation and analysis chain working

Steps of the simulation/analysis chain:

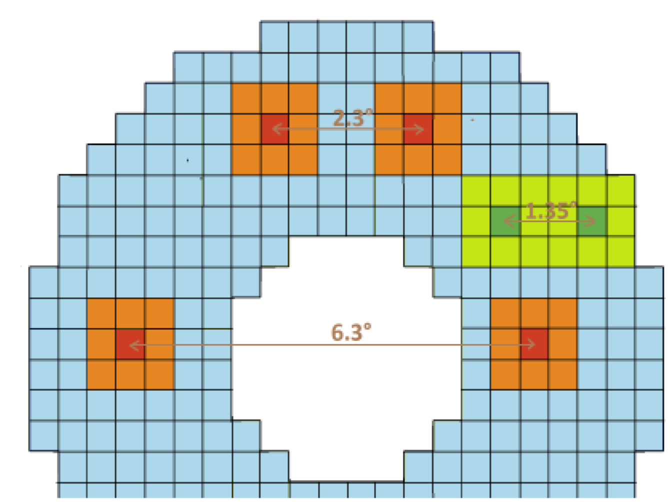
- Generate physics data with AmpTools
- Simulate the response of the CLAS detector and the forward tagger with gemc
- Reconstruct the data with CLARA
- Convert the output to the HASPECT format (root)
- Do physics analysis with the HASPECT framework





→ ~ 20 cm at FT position

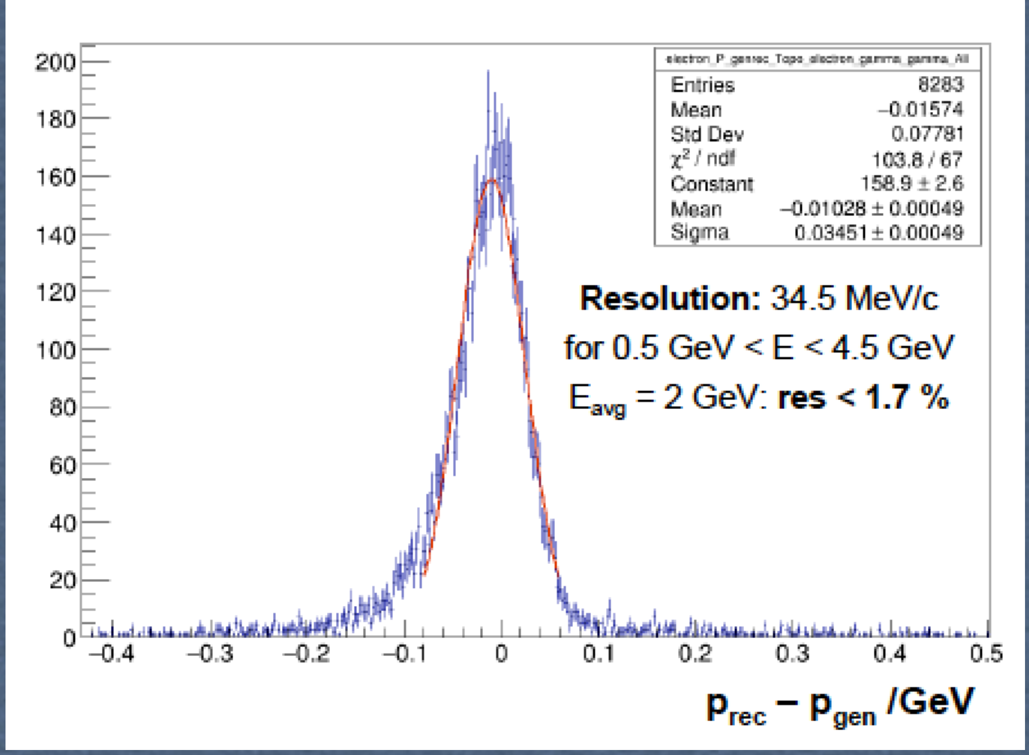
- for most events > 4 °

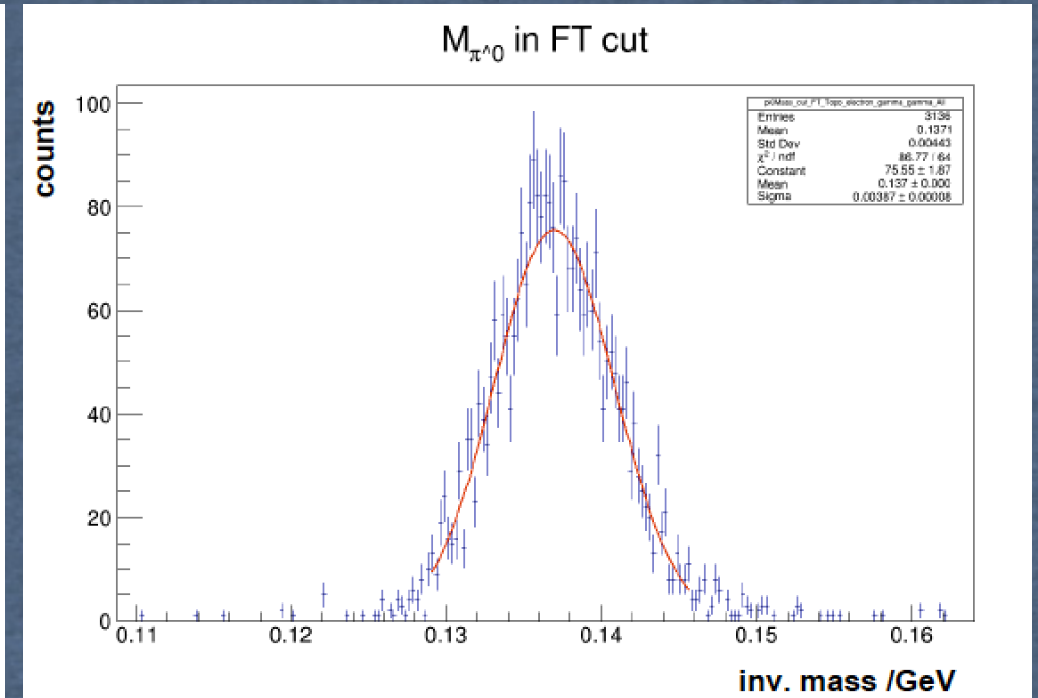


- average angle = 2.4°
  → ~ 8 cm at FT position (5 crystals)
- for most events > 1.5°

Distribution of the gammas on the detectors:

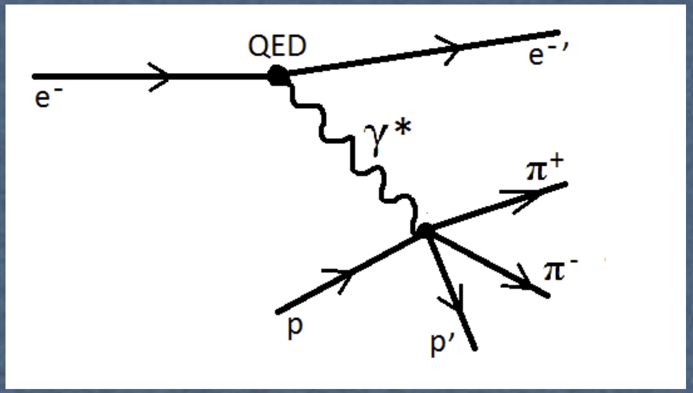
a) Both gammas detected in the FT: 55.7 %
b) One gamma detected in the FT: 30.6 %
c) Both gammas detected in the forward calorimeter (FD): 6.7 %
d) One gamma detected in the forward calorimeter (FD): 14.2 %

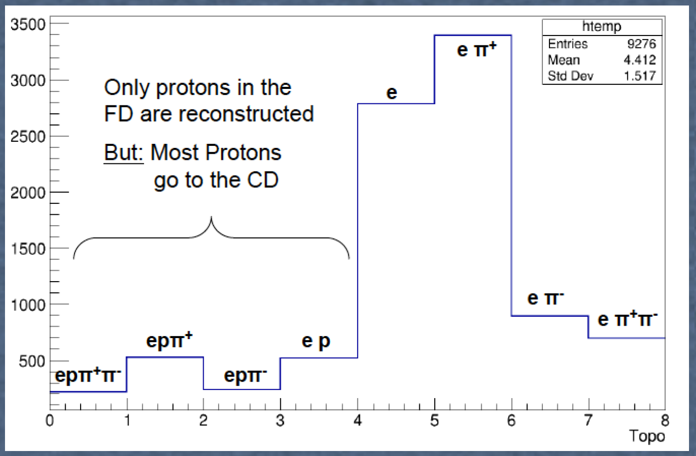


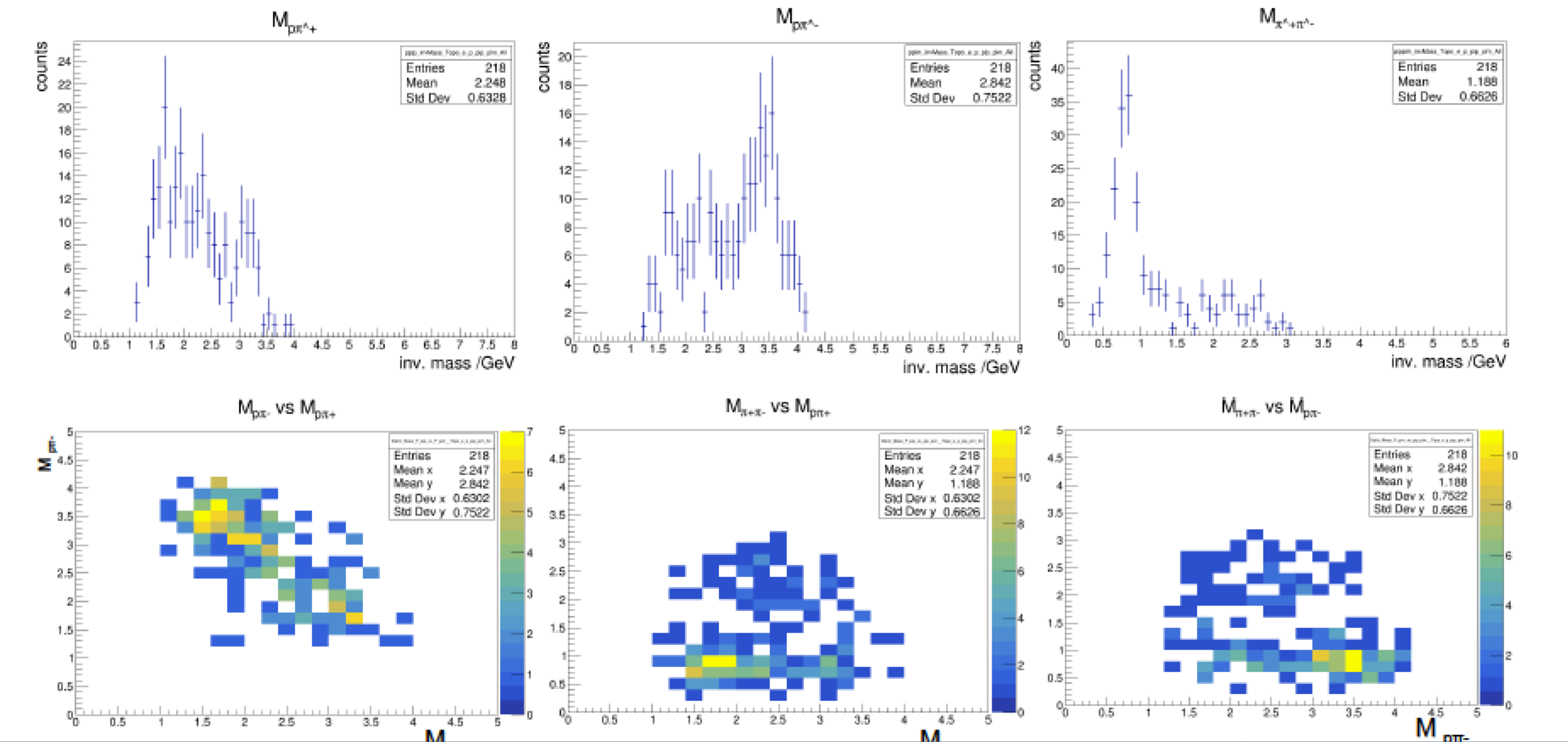


137 MeV/c² reconstructed (*lit.:* 134,98 MeV/c²)

Resolution: 3.9 MeV/c²







PyPWA

A Partial-Wave/Amplitude Analysis Software Framework

Carlos W. Salgado
other team members

B. DeMello, M. Jones
W. Phelps and J. Pond

PyPWA

Our philosophy

Liberate the user from software/hardware worries about amplitude analysis calculations. Provide the user with an "underneath" software/hardware framework (that is also accessible if the user needs to adjust). <> AUTOMATION

- Types of analysis
  - Parameter Estimation - Fitting
  - Model Selection - Bayesian
  - SIMULATION (Monte Carlo)
- Basic TOOLS/MODULAR to be use in the analysis
- Well Documented (Tutorials-in-code documentation-Sphinx)
- Interact with multiple programing languages
- Interact with other amplitude analysis packages
- Integrated use of the JLab Scientific Computing Resources
- Parallelization & Vectorization
- Own graphical package and interface with PyROOT (CERN)

The PyPWA framework and toolkit is divided in

GENERAL-SHELL (PyFit,PySim)

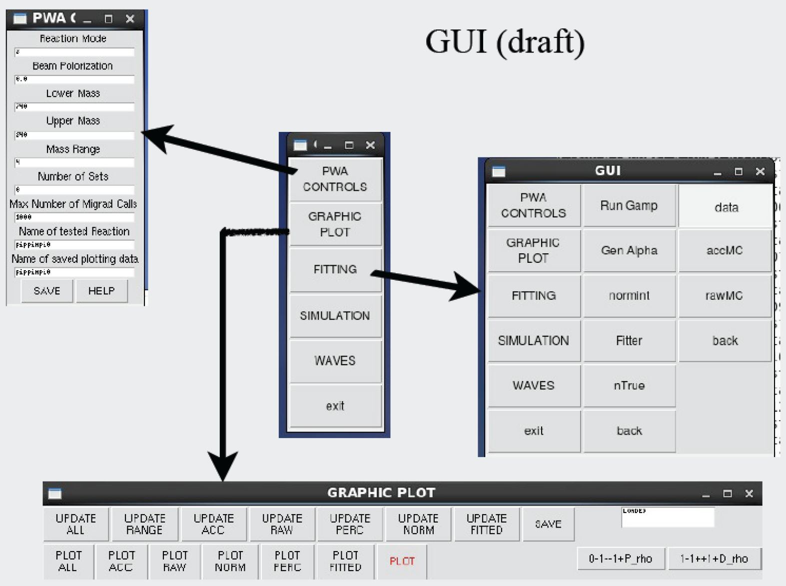
- Fitting and Simulation.
- User can input any model.
- Interface is through user defined Python scripts using templates.
- Integrated batch farm interface.
- Multithreaded.
- Simulation produces "masks" to be used on user formatted MC.

ISOBAR

- Fitting and Simulation.
- Exclusively uses the isobar amplitude model and photo-production (linear pol)
- Easy install and mass binning.
- Takes advantage of the GAMP[1] event format (4-momenta) and the GAMP amplitude generator utilizing "keyfiles" for physics descriptions.
- Optional use of "Q factor" - quality
- Interface is with GUIs
- Interacts directly and exclusively with the JLab batch farm
- Integrated plotting through Python

[1] Cummings and Weygand (PWA2000)

GUI (draft)



Scientific Computing Resources at Jefferson Lab

Summary of resources at JLab:

- High Performance Computing (HPC) for LQCD, ~8,440 cores, ~380 GPUs, and 48 Xeon Phi cards
- **Batch Computing for Experimental Physics (the "farm"), ~3,800 cores**
- Multiple Disk Systems (online storage), ~1.4 Petabytes
- The Tape Library for offline storage, 10 Petabytes
- Interactive nodes, a wide area gateway node, and several system administration support nodes

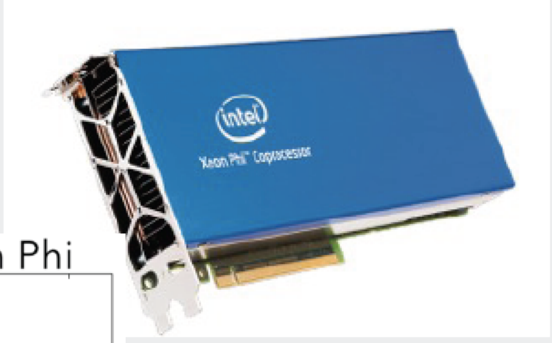
All farm nodes are connected to both an Ethernet fabric and an Infiniband fabric, where the IB fabric is used f
speed access to the file servers.

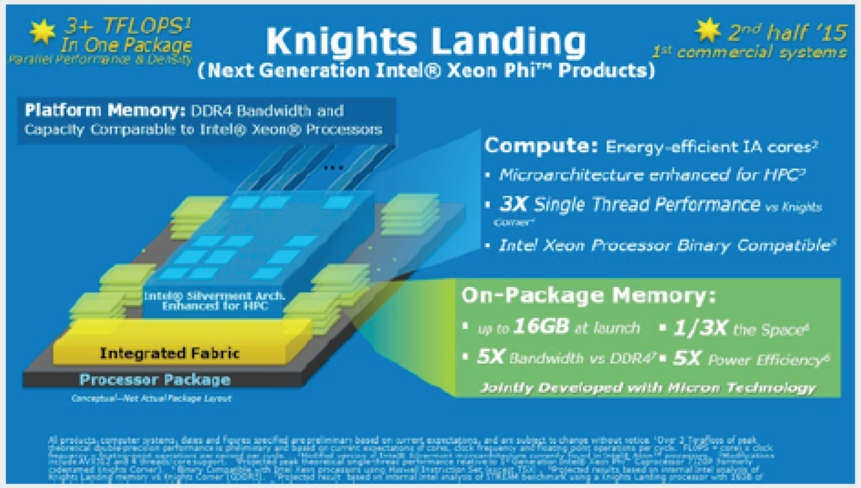
Xeon Phi (Knights Landing) + OmniPath Cluster (LQCD)

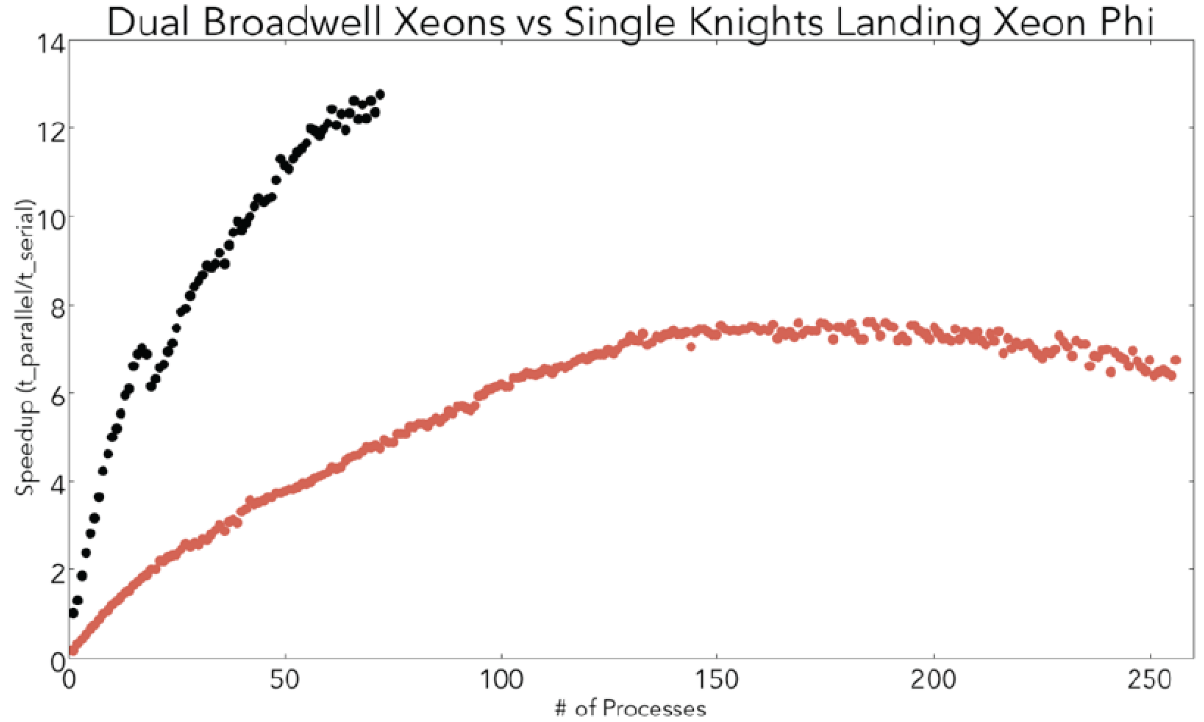
- **16p** (2016 Phi, formally known as **SciPhi-XVI**) -- 264 nodes, 64 core bandwidth memory, 192 GB main memory, Omni-Path fabric (100 Gb/s), 1TB disk

Each Knights Landing (KNL) node has 64 cores, hyper-threaded 4 ways (256 virtual cores) running at 1.3 GH
bandwidth memory has a bandwidth above 450 GB/s, and the main memory has a bandwidth of about 90 GE

Knight's Landing:
- 64 Silvermont cores
- Socketed and PCI-Express versions available
- Back to homogeneous computing?



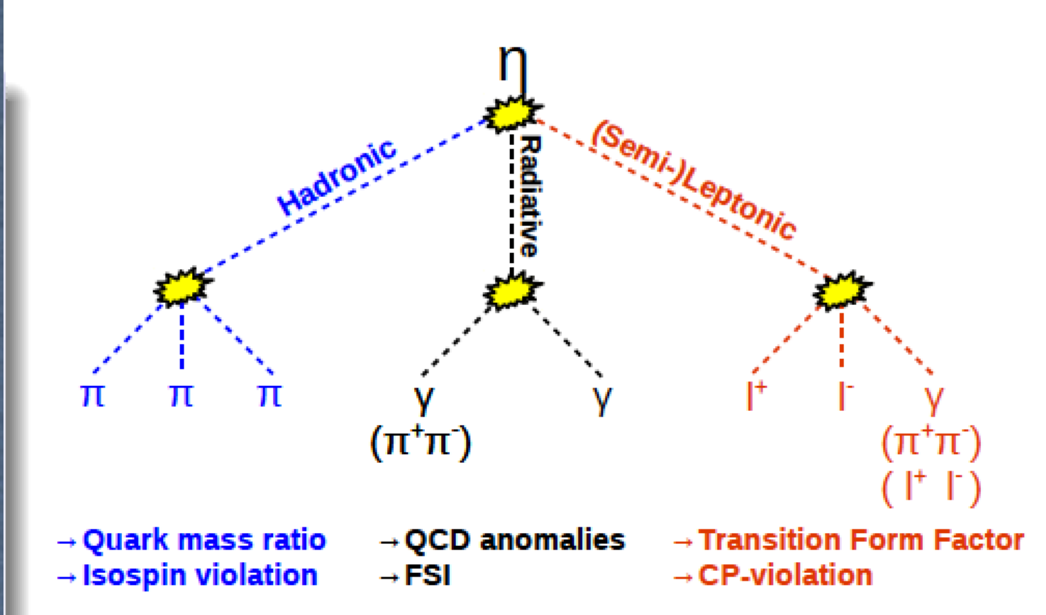




Main point -> -Python multiprocessing affords users the ability to utilize all of the cores on their local machine without having to fight with any specialized tools for parallelizing their code

Analysis of $\eta \to \pi^+\pi^-(X)$, $X = \pi 0/\gamma$ within the CLAS G12 Data Set

Daniel Lersch

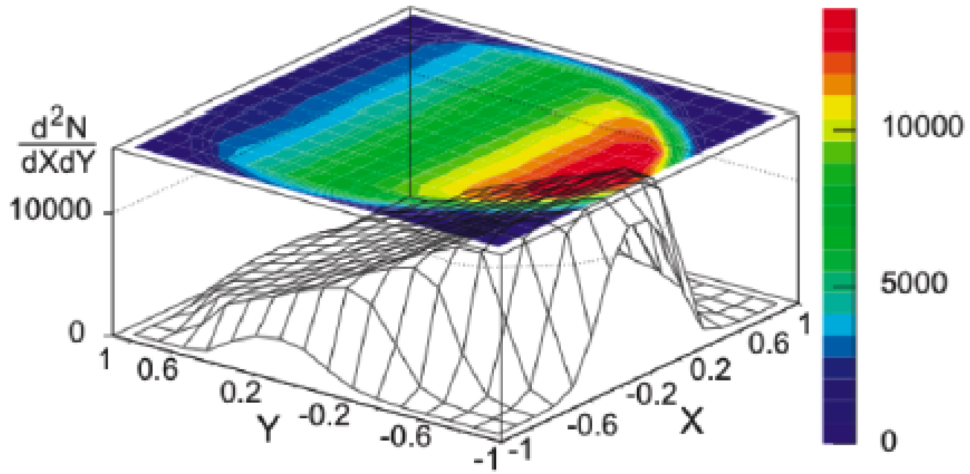


Analysis Status of $\eta \to \pi^+\pi^-\pi^0$

Set up Analysis for $\eta^{(\prime)} \to \pi^+\pi^-\gamma$

- Decay $\eta \to \pi^+\pi^-\pi^0$ is G-violating $\Rightarrow$ Forbidden to first order
- Decay is driven by isospin breaking part of strong interaction
  $\Rightarrow$ C is conserved

Dalitz Plot Analysis of $\eta \to \pi^+\pi^-\pi^0$



(a) KLOE coll., *JHEP*, 05, (2008)

Dime

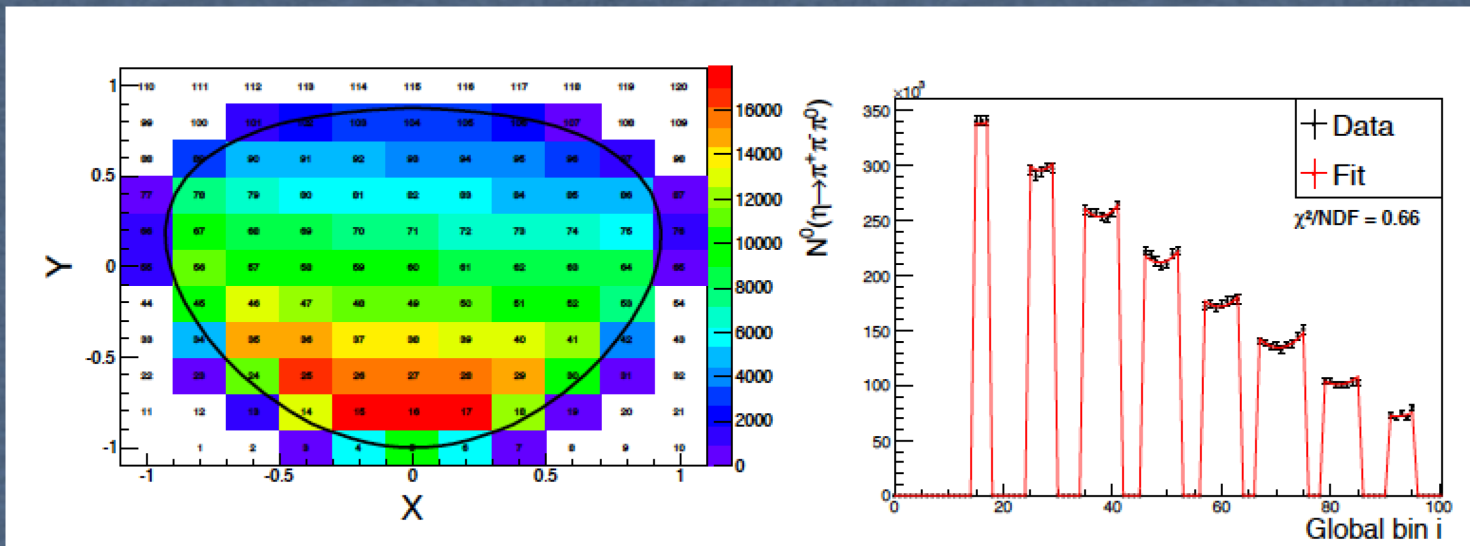
Parameterise decay width Γ:

$$\frac{d^2\Gamma}{dXdY} \propto (1 + aY + bY^2 + cX + dX^2 + eXY + fY^3 + gX^2Y + \ldots)$$

$c \neq 0$ and $e \neq 0$:

i) Imply C-violation
ii) Cause asymmetries within the Dalitz Plot

Compare Dalitz Plot parameters a,b,d,f from experiment and theory

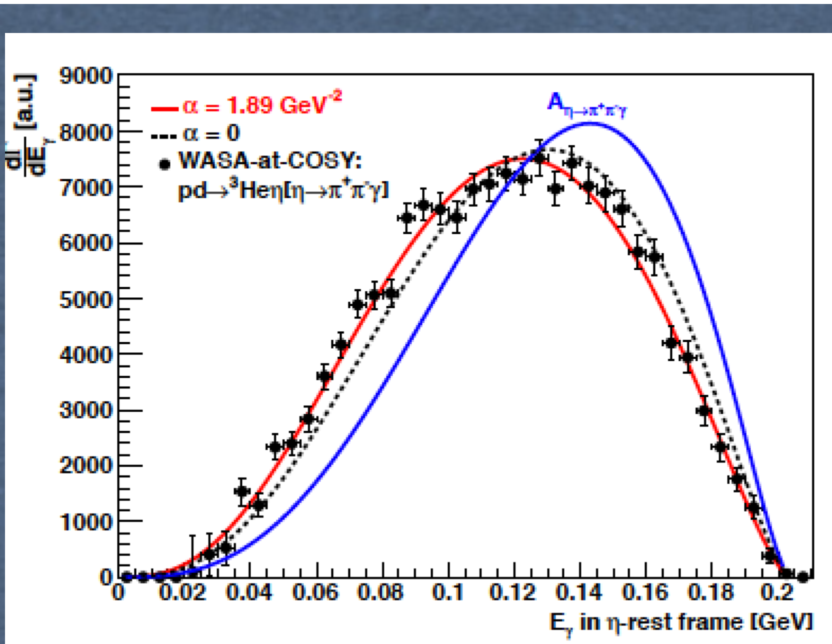


Summary of the Systematic Errors/Effects

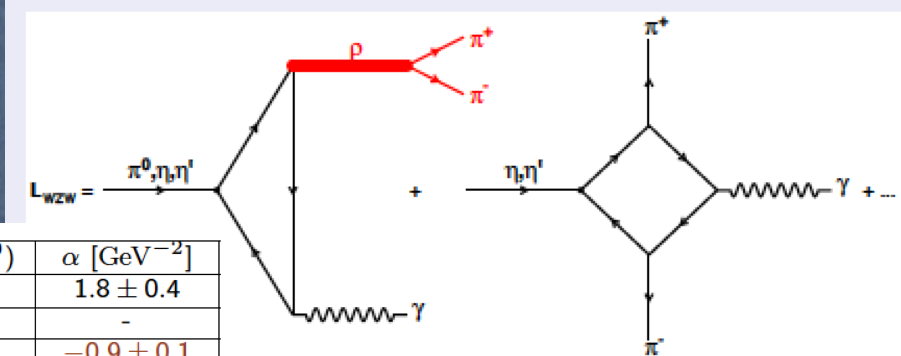
Parameter	σ_{stat}	σ_{beam}	σ_{fit}	σ_{im}	σ_{π^0}	σ_{tot}
$a = -1.135$	± 0.021	$^{+0.042}_{-0.039}$	$^{+0.274}_{-0.159}$	$^{+0.046}_{-0.042}$	$^{0.016}_{0.060}$	$^{+0.281}_{-0.179}$
$b = 0.149$	± 0.020	$^{+0.3}_{-0.281}$	$^{+0.289}_{-0.322}$	$^{+0.118}_{-0.136}$	$^{0.045}_{-0.012}$	$^{+0.435}_{-0.449}$
$c = 0.013$	± 0.008	$^{+0.103}_{-0.115}$	$^{+0.008}_{0.007}$	$^{+0.004}_{-0.001}$	$^{+0.003}_{-0.018}$	$^{+0.103}_{-0.117}$
$d = 0.120$	± 0.020	$^{+0.004}_{-0.037}$	$^{+0.007}_{-0.032}$	$^{+0.008}_{-0.019}$	$^{+0.002}_{-0.003}$	$^{+0.011}_{-0.053}$
$e = 0.014$	± 0.021	$^{+0.004}_{-0.038}$	$^{+0.006}_{-0.040}$	$^{+0.019}_{-0.026}$	$^{+0.003}_{-0.002}$	$^{+0.021}_{-0.061}$
$f = 0.269$	± 0.048	$^{+0.057}_{-0.337}$	$^{+0.074}_{-0.030}$	$^{+0.095}_{-0.228}$	$^{+0.087}_{-0.052}$	$^{+0.159}_{-0.411}$
$g = -0.055$	± 0.068	$^{+0.038}_{-0.099}$	$^{+0.021}_{-0.118}$	$^{0.066}_{-0.004}$	$^{0.014}_{-0.006}$	$^{+0.038}_{-0.154}$

Exp.	$-a$	b	c	d	e	f
WASA	1.144(18)	0.219(66)	−0.007(9)	0.086(33)	−0.020(52)	0.115(37)
KLOE(16)	1.095(6)	0.145(8)	0.0	0.081(9)	0.0	0.141(15)
G12 (5.0)	$1.135^{+0.302}_{-0.02}$	$0.149^{+0.455}_{-0.469}$	$0.013^{+0.111}_{-0.125}$	$0.120^{+0.032}_{-0.073}$	$0.014^{+0.042}_{-0.082}$	$0.269^{+0.207}_{-0.459}$

$\eta\to\pi^+\pi^-\gamma$: The Box Anomaly and $\pi^+\pi^-$ FSI



Beyond chiral limit:



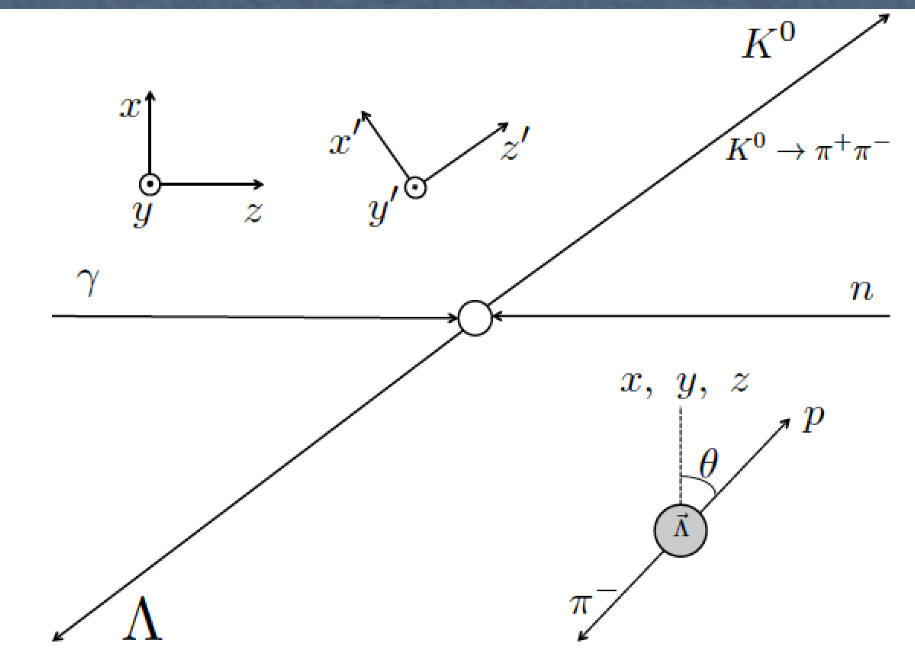
		$\Gamma(\eta\to\pi^+\pi^-\gamma)/\Gamma(\eta\to\pi^+\pi^-\pi^0)$	α [GeV^{-2}]
Experiment	Phys. Rev.,D2:501-505, 1970	0.202 ± 0.006	1.8 ± 0.4
	Phys. Rev.,D7:2569-2571, 1973	0.209 ± 0.004	-
	Phys. Rev.,D7:2565-2568, 1973	-	-0.9 ± 0.1
	Phys.,C50:451-454, 1991 *	-	2.7 ± 0.1
	Phys. Lett.,B402:195, 1997*	-	1.8 ± 0.53
	Phys. Rev. Lett.,99(122001), 2007	0.175 ± 0.013	-
	Phys. Rev. Lett.,B707:243-249, 2013	-	1.89 ± 0.86
	Phys. Lett.,B718:910-914, 2013	0.1856 ± 0.003	1.32 ± 0.2
	-	-	-
	-	-	-
Theory	Phys. Scripta, T99:55-67, 2002	0.2188 ± 0.0088	0.64 ± 0.02
	Europ. Phys. Journal, C31:525-547, 2003	0.1875 ± 0.0094	0.23 ± 0.01
	Phys. Lett., B237:488-494, 1990	0.1565 ± 0.0063	-0.7 ± 0.1
	Phys. Scripta, T99:55-67, 2002	0.119 ± 0.0048	-1.7 ± 0.02

Determination of the Polarization Observables C_x, C_z, and P for $\vec{\gamma}d \to K^0\vec{\Lambda}(p)$ From g13a Data

CLAS Meeting March 2017

Colin Gleason

- Identification of the reaction of $\vec{\gamma}d \to K^0\vec{\Lambda}(p) \to p\pi^+\pi^-\pi^-(p)$
- Background subtraction and observable calculation.
- Preliminary results
  - Comparison with current Bonn–Gatchina projections
  - Comparison with $K^+\Lambda$
  - Dependence on neutron virtuality

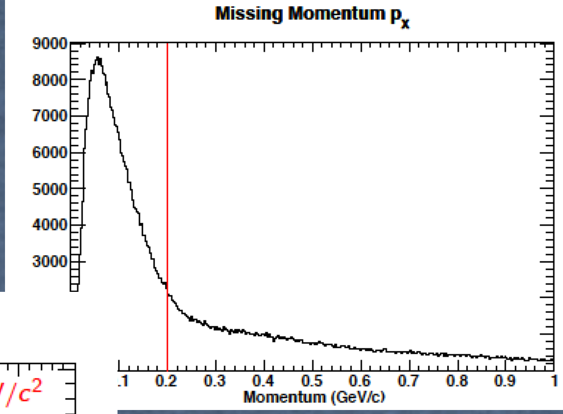


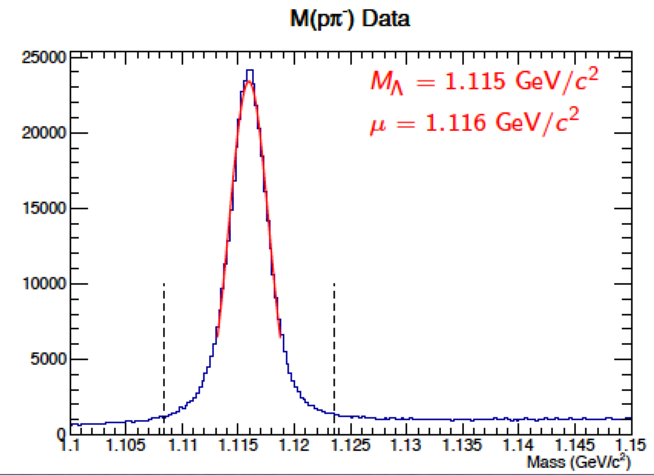
$$\frac{d\sigma}{d\Omega} = \sigma_0[1 - \alpha\cos\theta_x P_{circ} C_x - \alpha\cos\theta_z P_{circ} C_z + \alpha\cos\theta_y P]$$

$C_{x,z}$ measure polarization transfer from γ to Λ w.r.t. x/z axis, P is the Λ recoil polarization

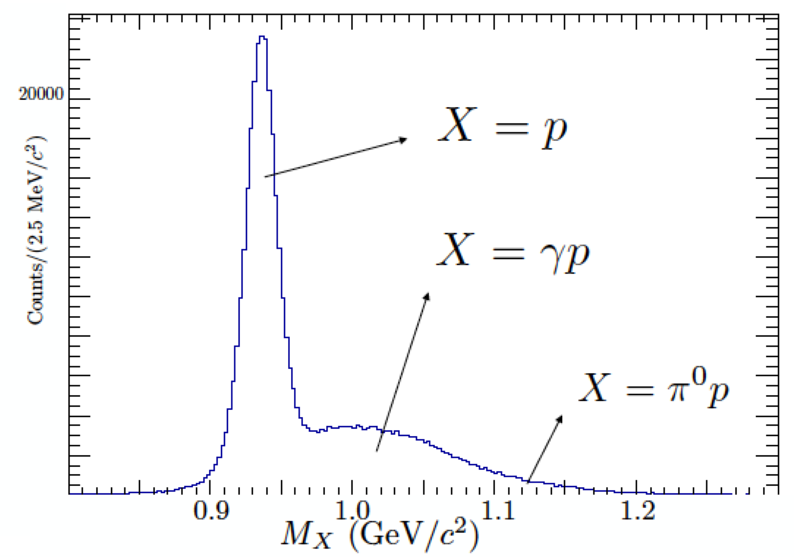
$\gamma d \to K^0\Lambda(p) \to \pi^+\pi^- p\pi^-(p)$

- Quasi–free events selected with $p_n < 0.2$ GeV/c

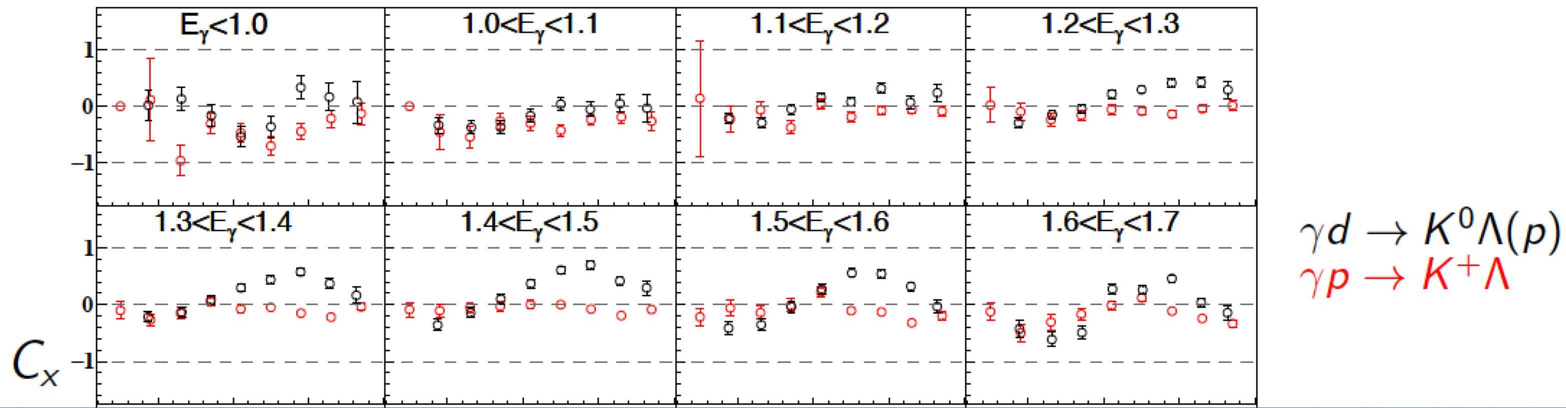




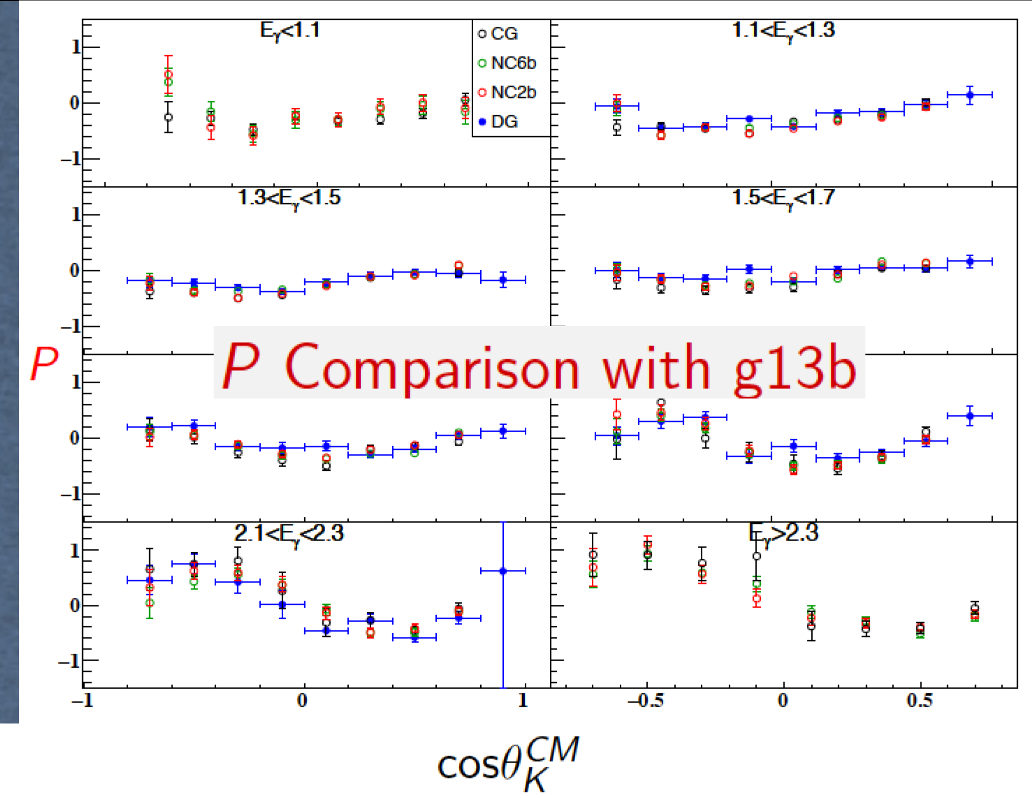
Background Channels: $\gamma d \to K^0\Lambda(X)$



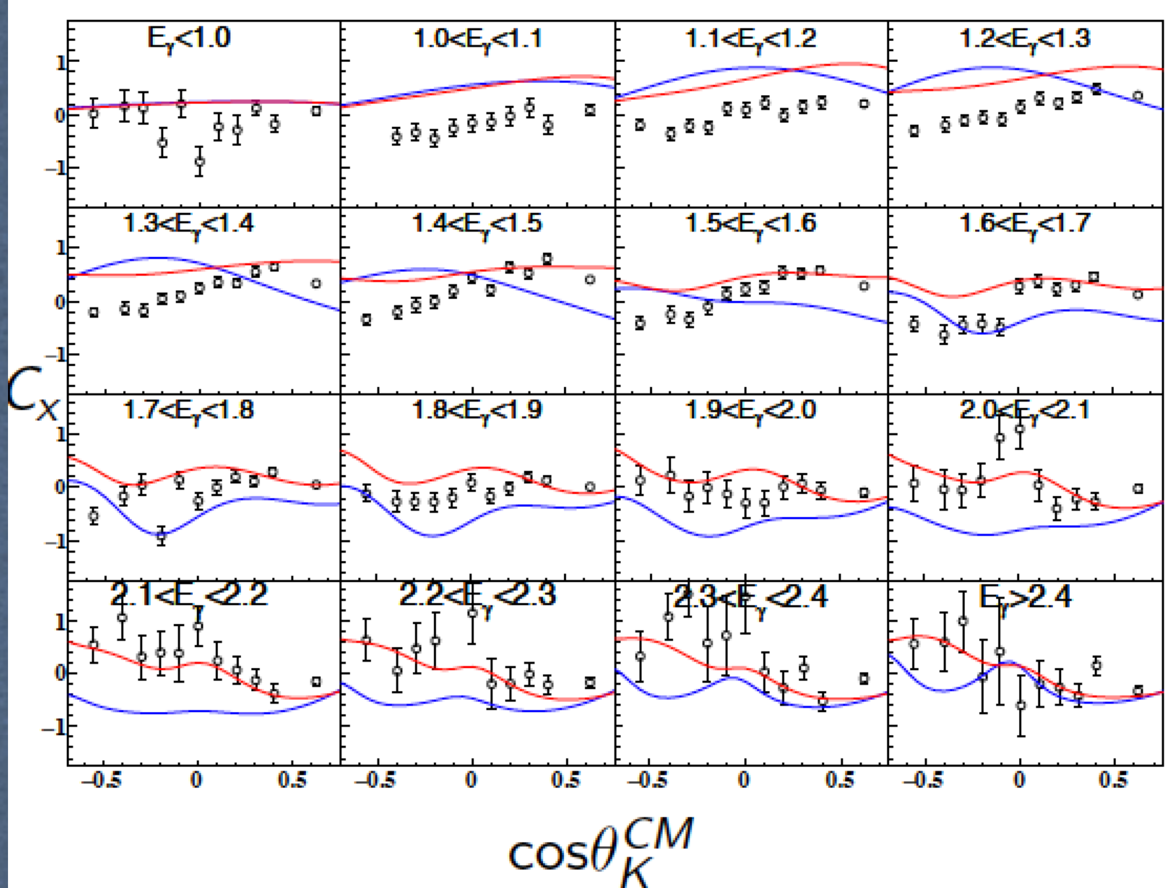
C_x: Comparison of $\vec{\gamma} d \to K^0 \vec{\Lambda}(p)$ to $\vec{\gamma} p \to K^+ \vec{\Lambda}$



P Comparison with g13b



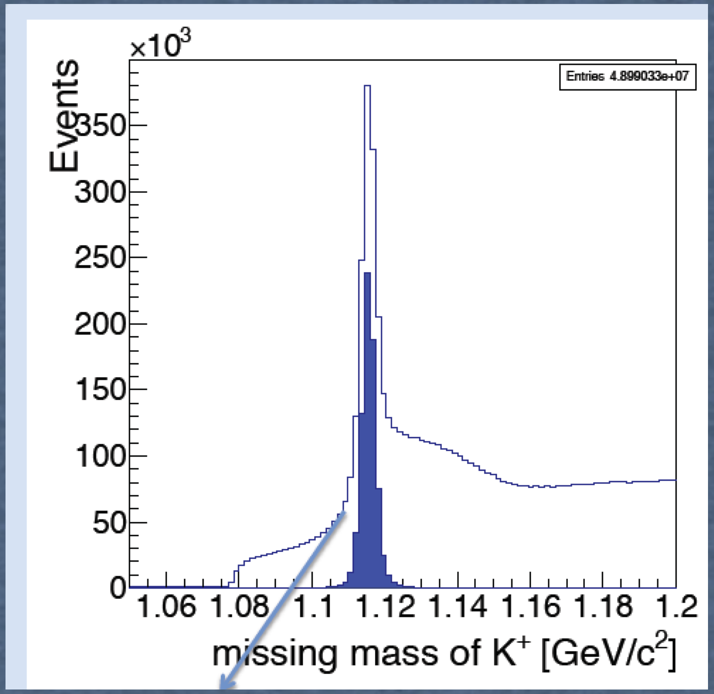
C_x for $\gamma d \to K^0 \Lambda(p)$

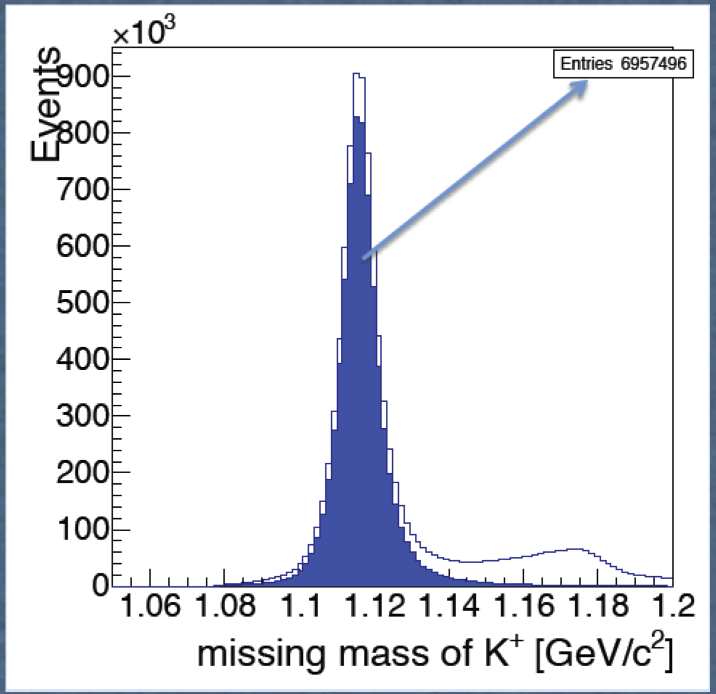


- $K^0\Lambda$ cross–sections resulted in two reasonable solutions from BonnGa PWA.
- BonnGa provided me with the two solutions projected onto C_x, C_z, P
- Same resonances included, two sets of parameters give reasonable fit to $\gamma d \to K^+\Sigma^-(p)$ and $K^0\Lambda(p)$
- **No $K^0\Lambda$ polarization observables included in fits**
- Potential impact: resolution of current ambiguity, or lead to new results

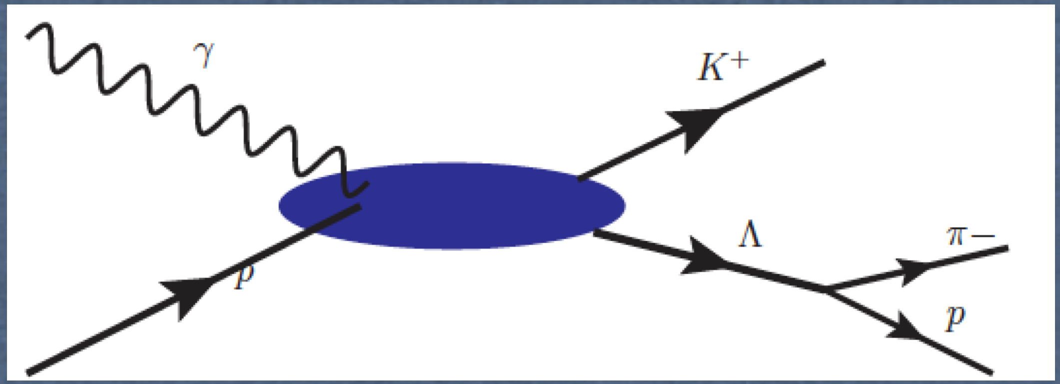
Measurement of polarization observables for the Λ hyperon for photon energies up to 5.45 GeV.

Shankar Adhikari
Florida International University



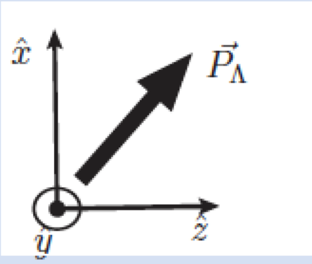


- $K^+ p \pi^-$ (3track)
- $K^+ p (\pi^-)$ (2track)

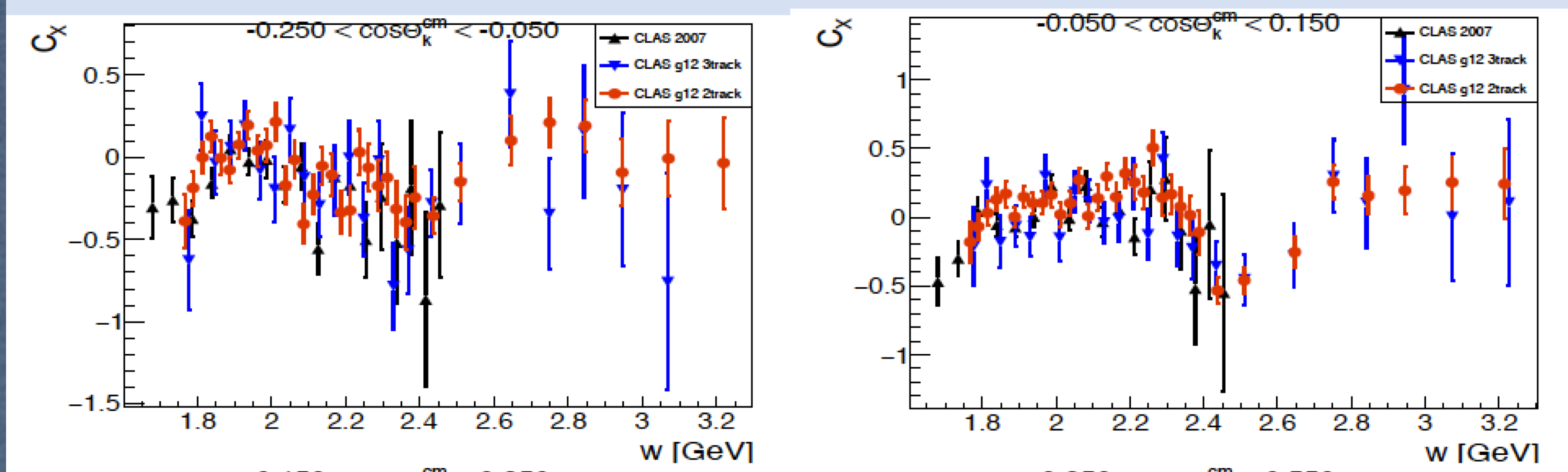


$$\rho_\Lambda \frac{d\sigma}{d\Omega_{K+}} = \frac{d\sigma}{d\Omega_{K+}}\Big|_{unpol} \{1 + \sigma_y P + P_{beam}(C_x \sigma_x + C_x \sigma_x)\}$$

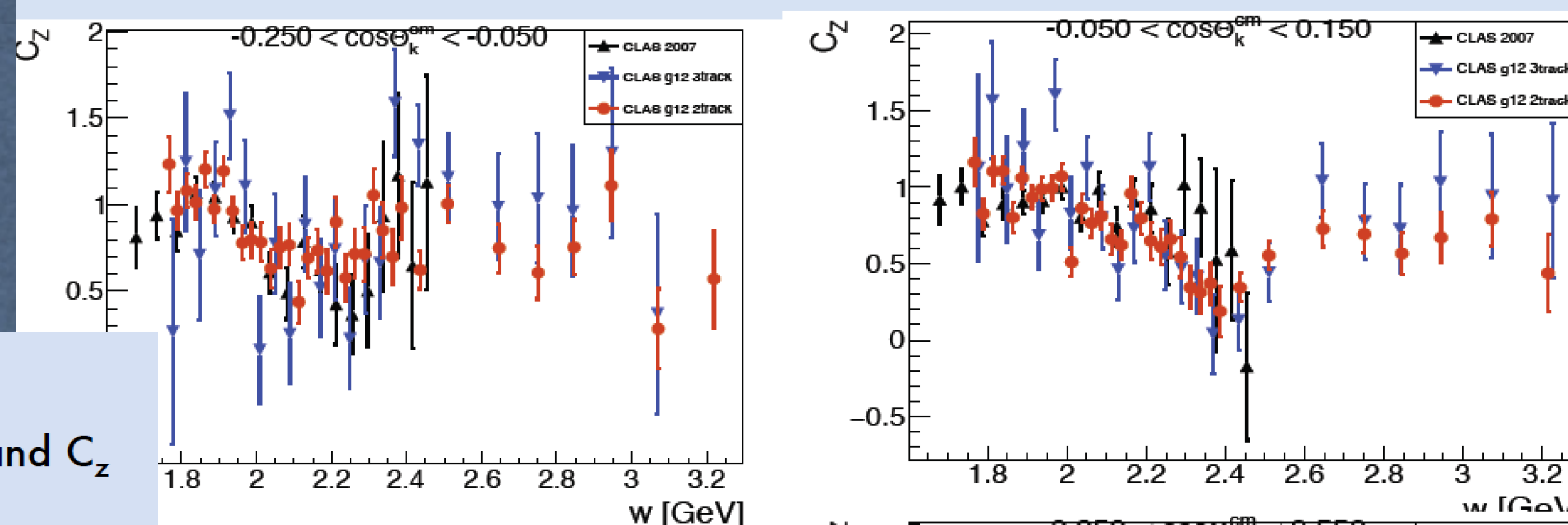
$$\rho_\Lambda = \left(1 + \vec{\sigma}.\vec{P_\Lambda}\right)$$ Density matrix.



Comparision with g1c: C_x



Comparision with g1c: C_z



Conclusion and Outlook

- Measured Lamba polarization observables C_x and C_z using g12 dataset for 1.75 < w < 3.3 GeV.
  - 3 method: 1d/2d/ML methods, all showing consistent results.
  - 2 topologies analyzed: results are mostly self-consistent.
- Preliminary C_x/C_z results:
  - Statistical uncertainty are much smaller than previous g1c results for w < 2.6 GeV.
  - In the good agreement with earlier CLAS results.
  - First time measurement for w > 2.6 GeV.
  - Can be used to constrain non-resonant(t-channel) contribution.

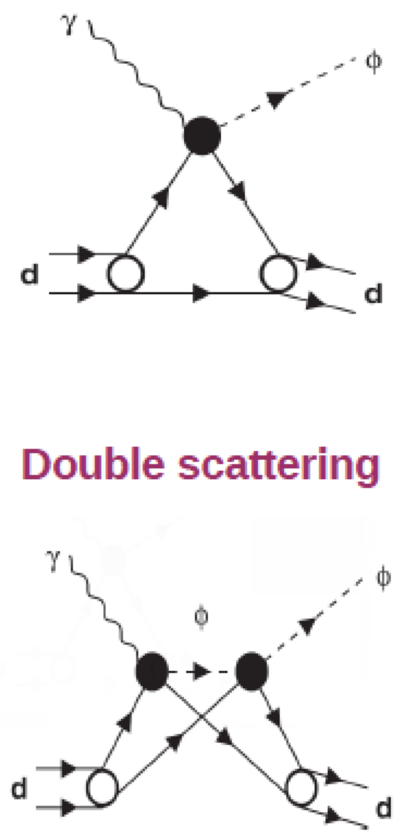
Coherent ω-Meson Photoproduction off Deuterium from CLAS

Taya Chetry
Ken Hicks

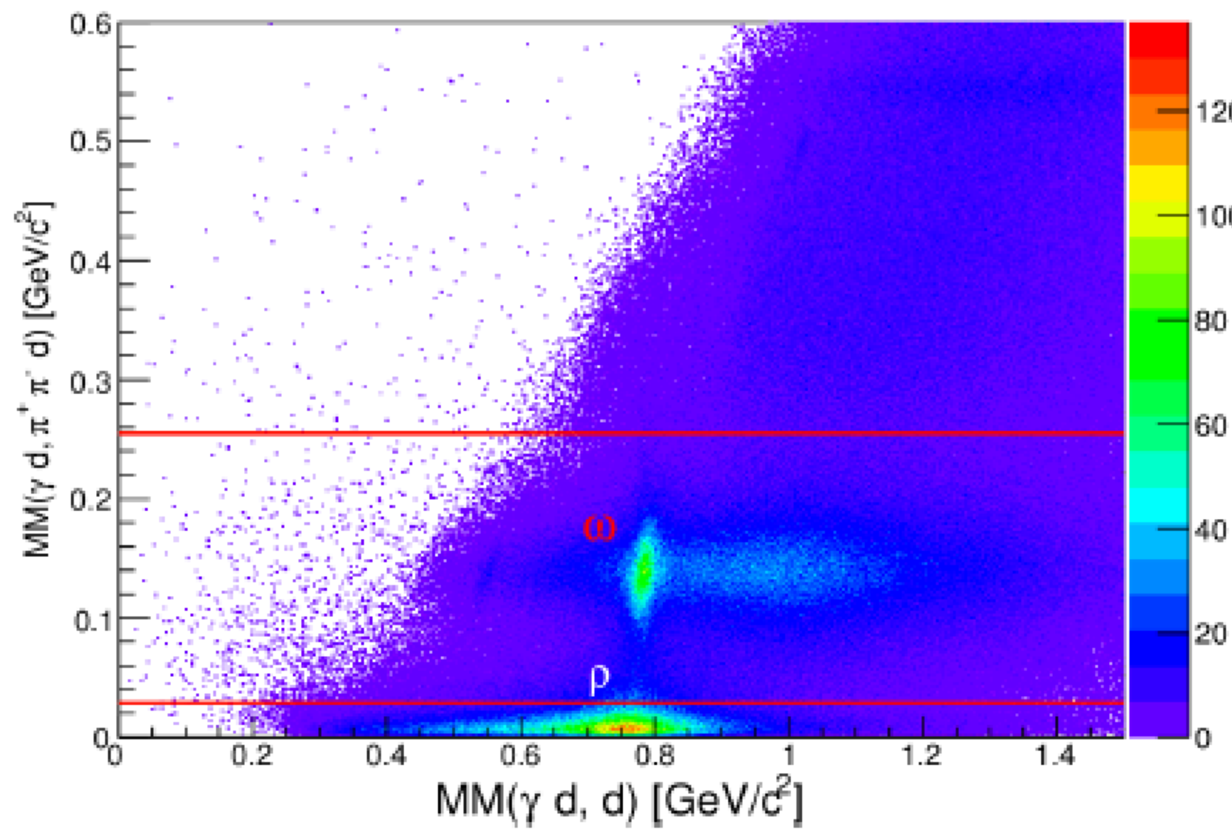
$\gamma d \to \varphi d$

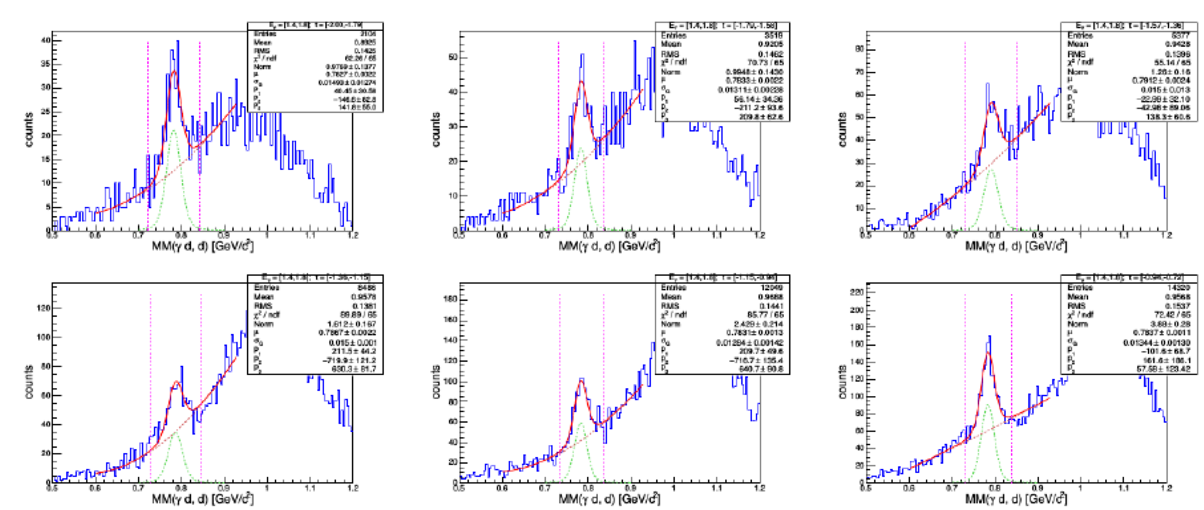
Single scattering

Double scattering

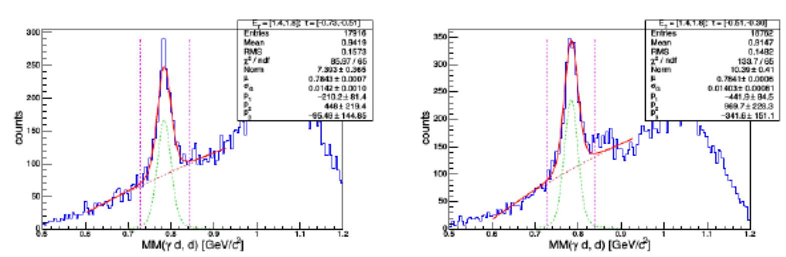


$$\gamma d \to \omega d \to \pi^+ \pi^- d \; (\pi^0)$$





Yield is extracted by taking integral of the Voigt function

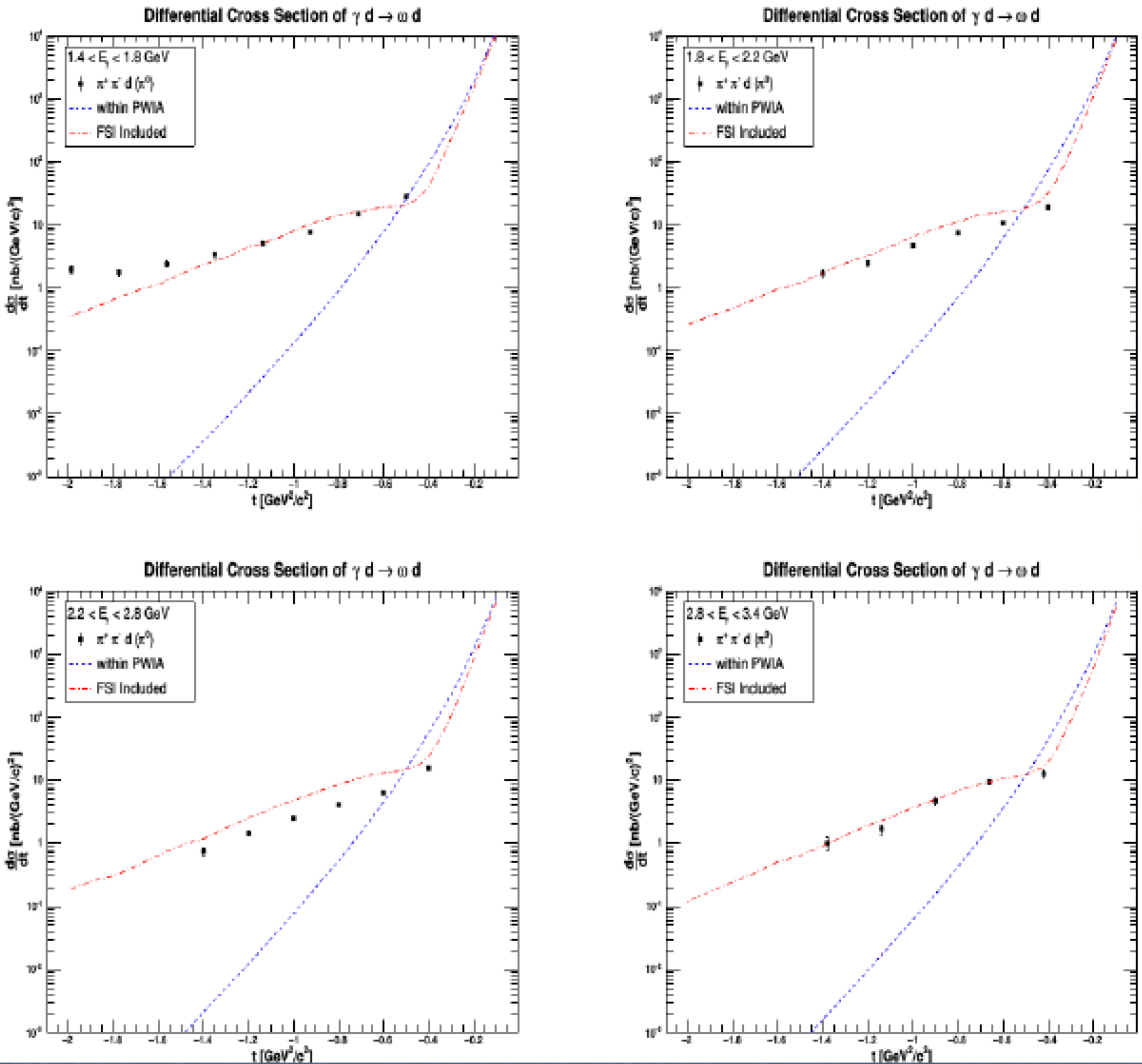


Fit Functions
Voigt
Pol2

Differential Cross-section

Preliminary

- Calculations are provided by Dr. Sargsian (FSU).
- Production of ω is within the Vector Dominance Model.
- Does not include:
  - Pion exchange contribution at low energy.
  - At large | t |, contibution of ρ–ω mixing.



PRELIMINARY