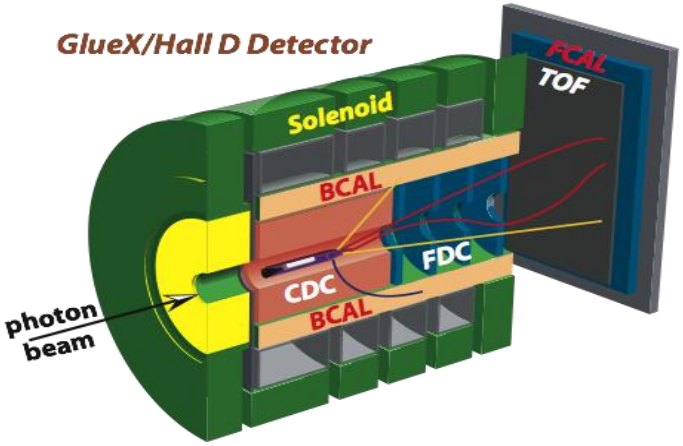


Jefferson Lab

Status of the GlueX Experiment: Early results and Future Plans

A. Somov, Jefferson Lab

for the GlueX collaboration

The 11th Workshop on Hadron Physics in China and Opportunities Worldwide, Tianjin, China, August 22 – 28, 2019

Outline

- GlueX detector in experimental Hall D and experiments

  - linearly polarized photon beam
  - main goal: search for exotic hybrid mesons

- GlueX early results

  - prospects for search for hybrid mesons

  - photoproduction of J/ψ close to threshold

  - beam asymmetries of meson production

- Status of the PrimEx η experiment

- Future detector upgrade

  - study rare decays of η mesons

Hall D Physics Program: Approved Experiments

Name	Days	Detector Upgrade	Target
Mapping the spectrum of light quark mesons and gluonic excitations with Linearly polarized photons	120		LH_2
A study of meson and baryon decays to strange final states with GlueX in Hall D	220 (200)	PID	LH_2
A precision measurement of the η radiative decay width via the Primakoff effect	79		LH_2, LHe_4
Measuring the charged pion polarizability	25		Pb
Studying short range correlations with real photon beams at GlueX	15		LHe, LD, C
Eta decays with emphasis on rare neutral modes: The JLab Eta Factory experiment (JEF)		Forward Calorimeter	LH_2

Hall D Timeline

- GlueX Phase I (low luminosity)

  - Spring 2016: Initial production run 15 pb^{-1}, $E\gamma > 8$ GeV
  - Spring 2017: 53 pb^{-1}
  - Spring / Fall 2018: 153 pb^{-1} (291 pb^{-1} in total)

- Spring 2019:

  - Primakoff η experiment (30 % of statistics)
  - Commissioning of DIRC particle ID detector

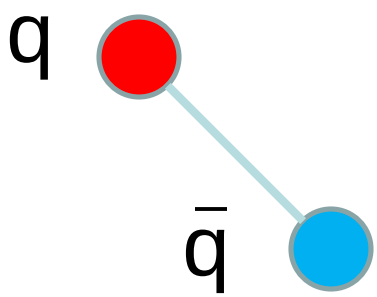
- GlueX Phase II (high luminosity)

  - Start in the Fall of 2019
  - Increase luminosity by a factor of two
    (at least 6 times large statistics than in GlueX Phase I)

- Upgrade forward calorimeter: 2023 (?)

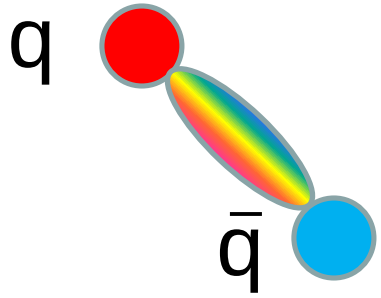
Exotic Mesons

Conventional Mesons



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

Hybrid Mesons



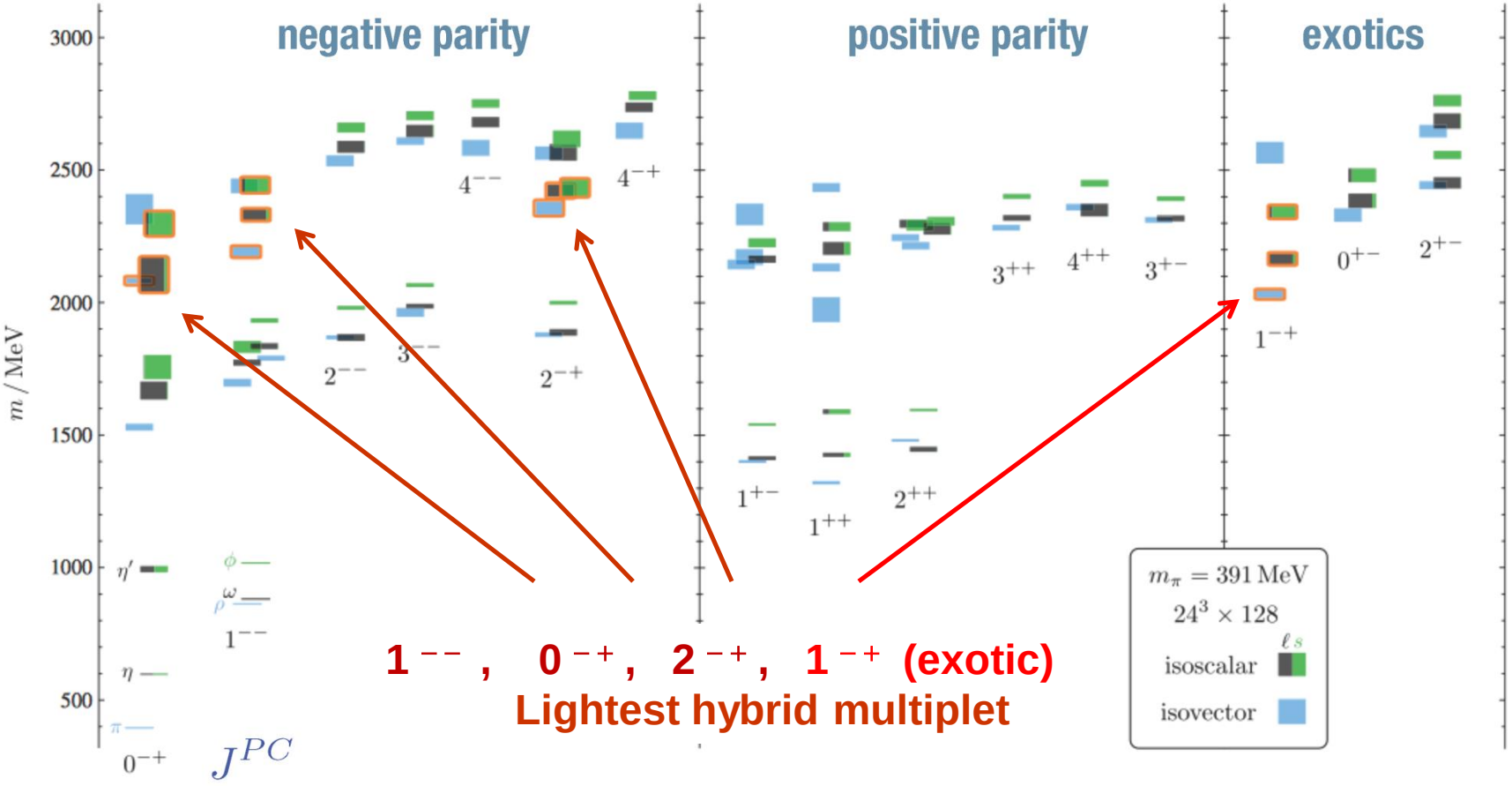
- Excited gluonic field coupled to a $q\bar{q}$ pair can result in hybrid mesons with **exotic J^{PC}**

- Predicted by several models. Recent calculations using lattice QCD - constituent gluon with $J^{PC} = 1^{+-}$ and mass 1 – 1.5 GeV

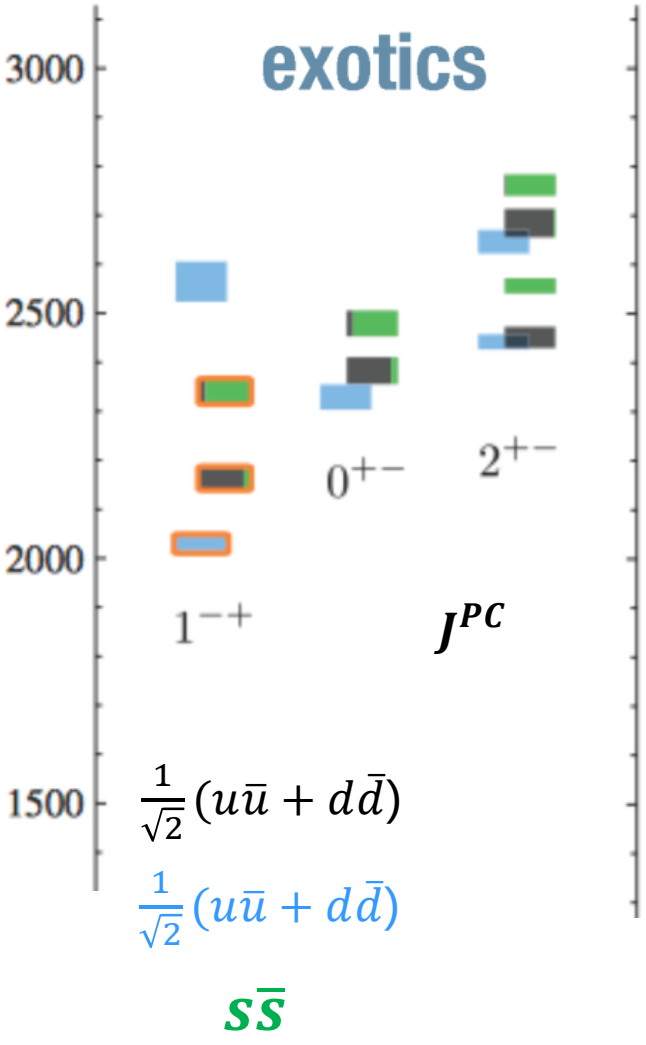
J^{PC}: 0^{--} 0^{-+} 0^{+-} 0^{++} 1^{--} 1^{-+} 1^{+-} 1^{++} 2^{--} 2^{-+} 2^{+-} 2^{++}

Lattice QCD Predictions

Dudek et al. PRD 88 (2013) 094505



Lattice QCD Predictions



Mass predictions:

	1^{-+}	2.0 – 2.4 GeV/c^2
J^{PC}	0^{+-}	2.3 – 2.5 GeV/c^2
	2^{+-}	2.4 – 2.8 GeV/c^2

- Lattice calculations predict light-quark hybrid mesons and mesons with strange quark content

Search Modes of Exotic Decays

J^{PC}	Exotic Meson	Possible Decays
1^{-+}	π_1 (1900) η_1 (2100) η_1' (2300)	$\rho\pi$, $b_1\pi$, $f_1\pi$, $\eta\pi$, $\eta'\pi$, ηa_1 $f_2\eta$, $a_2\pi$, ηf_1, $\eta\eta'$, $\pi(1300)\,\pi$ K^*K, $K_1(1270)\,K$, $K_1(1410)\,K$, $\eta\eta'$
2^{+-}	b_2 (2500) h_2 (2500) h_2' (2600)	$\omega\pi$, $a_2\pi$, $\rho\eta$, $f_1\rho$, $a_1\pi$, $h_1\pi$, $b_1\eta$ $\rho\pi$, $b_1\pi$, $\omega\eta$, $f_1\omega$ $K_1(1270)\,K$, $K_1(1410)\,K$, $K_2^*\,K$, $\phi\eta$
0^{+-}	b_0 (2400) h_0 (2400) h_0' (2500)	$\pi(1300)\,\pi$, $h_1\pi$, $f_1\rho$, $b_1\eta$ $b_1\pi$, $h_1\eta$ $K_1(1270)\,K$, $K_1(1460)\,K$, $h_1\eta$

Easy channels, statistics needed, hard

- Search for mesons in many final states

Experimental Status

- Exotic mesons have been searched in several experiments: GAMS, VES, CBAR, E852, COMPASS, CLAS
- Exotic Meson Candidate ($J^{PC} = 1^{-+}$)

$\pi_1(1400) \rightarrow \eta\pi$

Seen by several experiments. Interpretation unclear: dynamic origin, 4-quark state. Not a hybrid (?)

$\pi_1(1600) \rightarrow \eta'\pi$
$\pi_1(1600) \rightarrow \rho\pi$
$\pi_1(1600) \rightarrow b_1\pi$
$\pi_1(1600) \rightarrow f_1\pi$

- First seen by VES, E852, COMPASS
- 3π controversial:
  - 3π not seen in photoproduction (CLAS)
- May be a hybrid
- Need more analysis and data

$\pi_1(2000) \rightarrow f_1\pi$
$\pi_1(2000) \rightarrow b_1\pi$

- Seen by E852 (but not seen by VES)
- Statistics is limited
- May be a hybrid

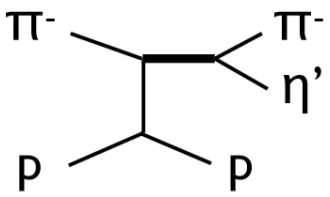
Evidence for Exotic Light-quark Mesons

- Many searches, strongest evidence for π_1 in $\eta'\pi$ and $\eta\pi$ P-waves
- COMPAS data is described by a coupled-channel analysis by Joint Physics Analysis Center (JPAC)

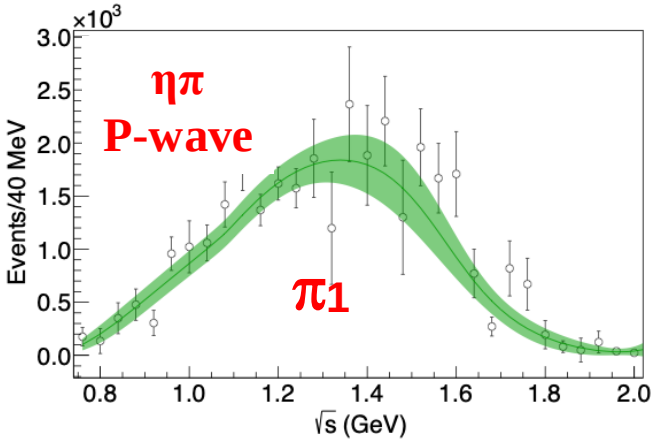
Rodas et al. PRL 122, 042002 (2019)

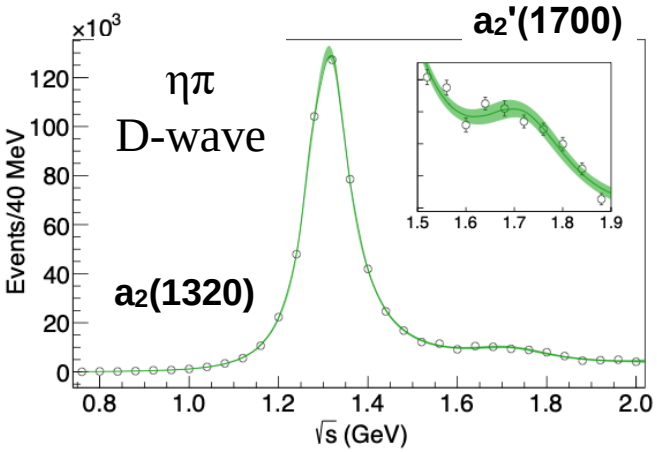
COMPAS

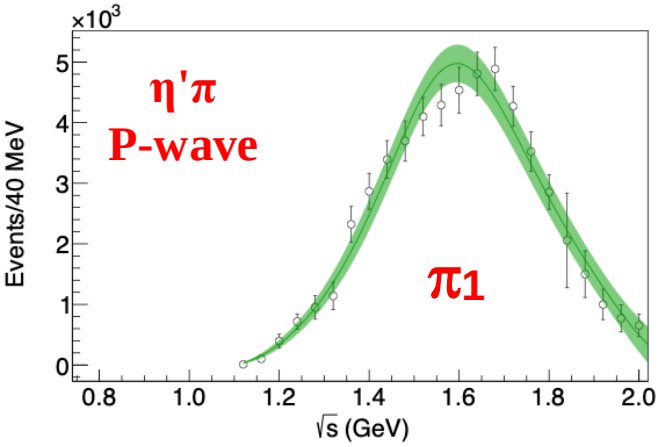
$\pi_1 \rightarrow \eta\pi$ / $\eta'\pi$

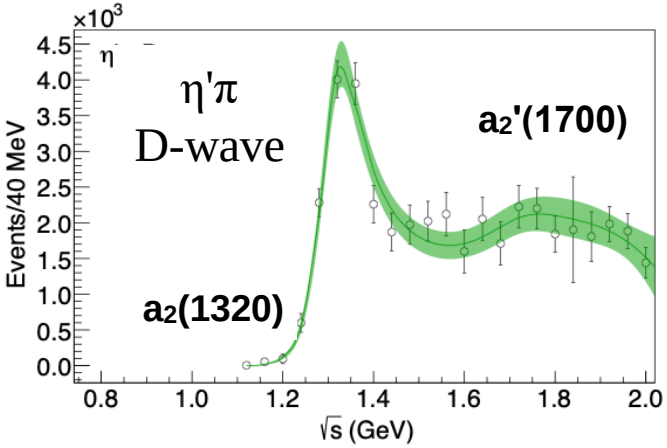


PLB 740, 303 (2015)





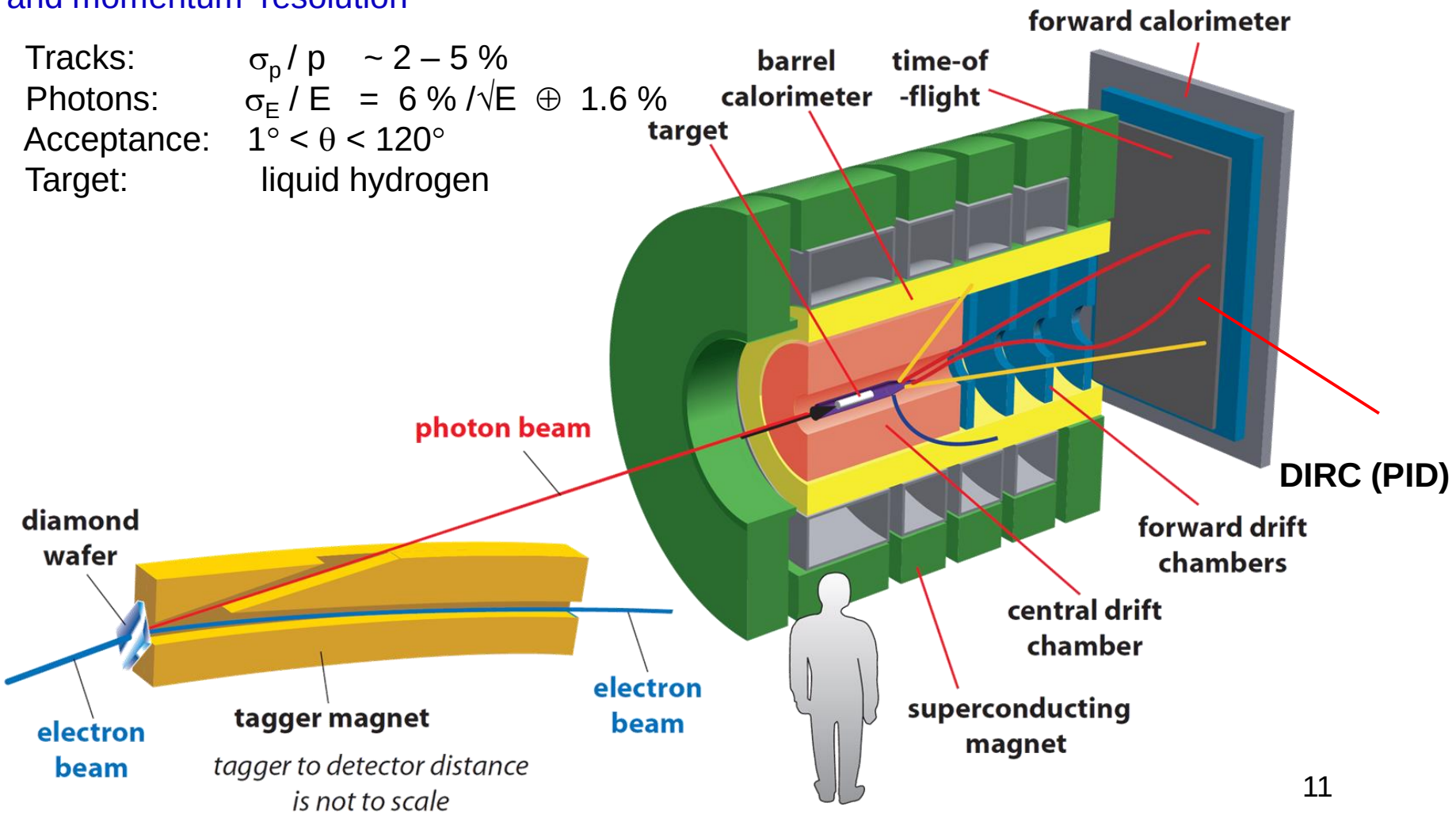




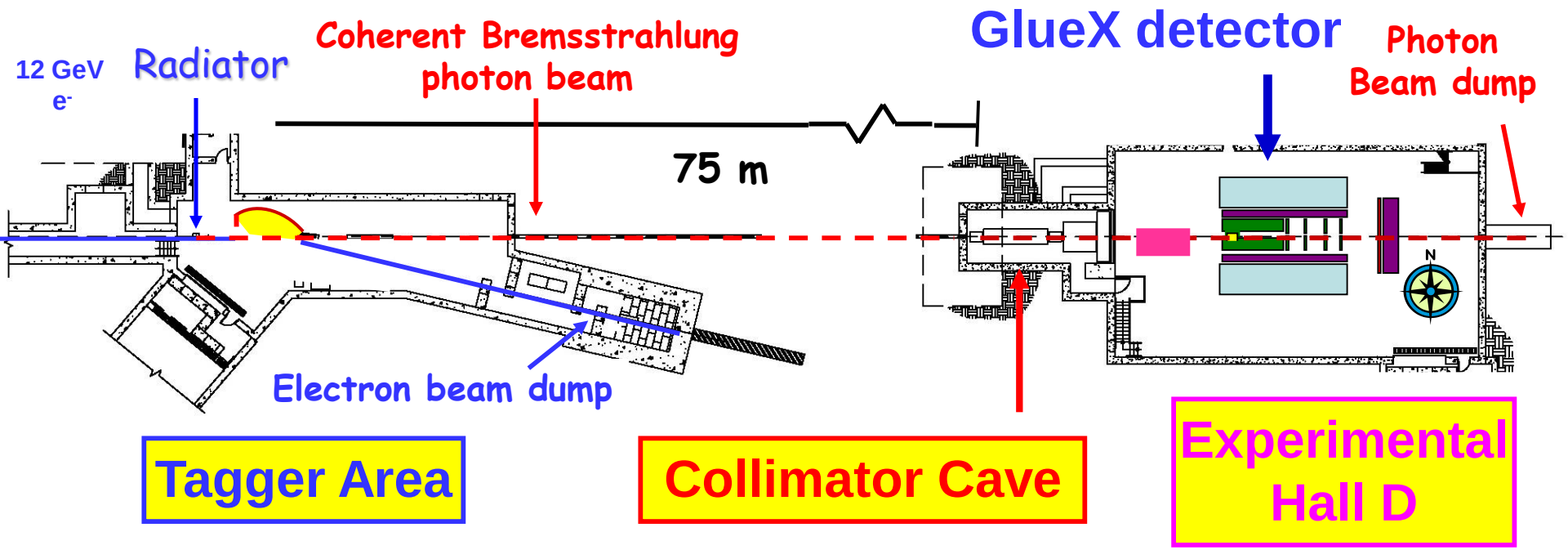
GlueX Detector

- Optimized to detect multi-particle final states
- Hermetic, large/uniform acceptance for charged and neutral particles, good energy and momentum resolution

Tracks: σ_p / p ~ 2 – 5 %
Photons: $\sigma_E / E = 6\,\% / \sqrt{E} \oplus 1.6\,\%$
Acceptance: $1° < \theta < 120°$
Target: liquid hydrogen



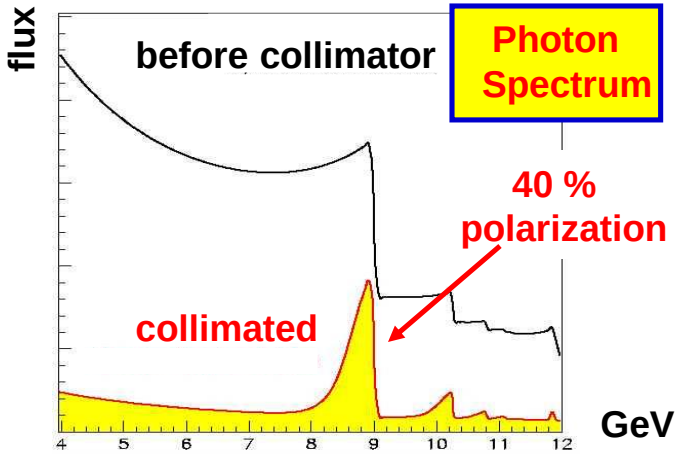
Polarized Photon Beam



- **Beam photons are produced by 12 GeV electrons (I < 1.1 μA) on a thin diamond crystal (20 – 50 μm)**
- **Photon energy: detect bremsstrahlung electrons**

$$\Delta E / E \sim 10^{-3}$$

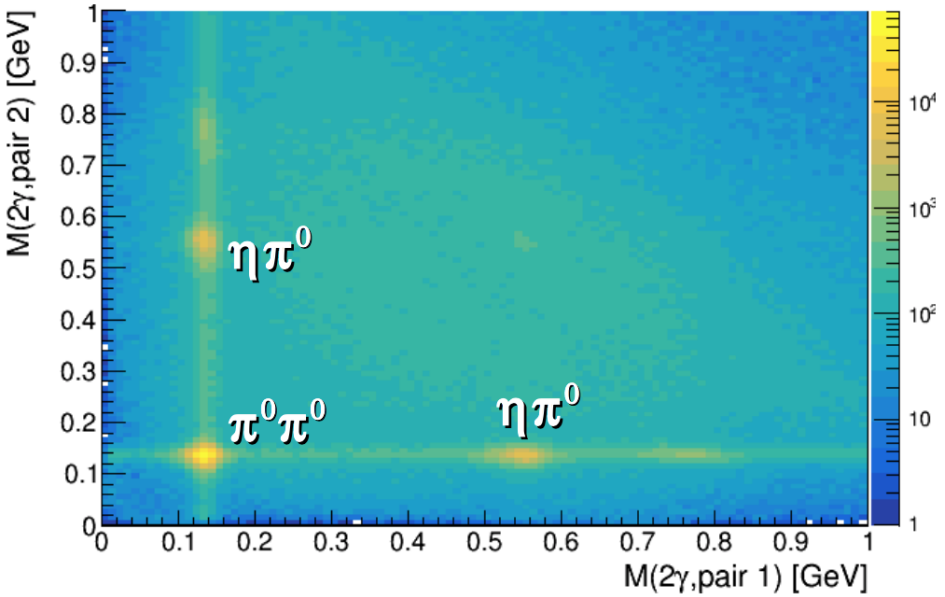
- **Pass beam photons through the collimator**
  - **increase the fraction of linearly polarized photons**
  - **beam intensity: $5 \cdot 10^7$ γ/sec for 8.4 < E_γ < 9.1 GeV**



Status of the Search for Exotic Mesons

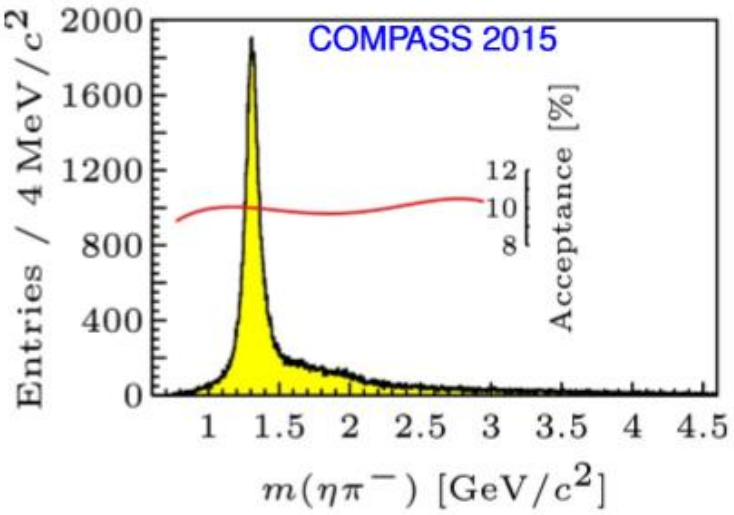
- 20 % of the recorded GlueX (Phase I) data
- Able to reconstruct well known channels
- Understanding of efficiencies and acceptances Is in progress
- PWA analysis:

  - Started looking on the lowest predicted exotic states: π_1 (1^{-+}) meson reconstructed in $\eta'\pi$ and $\eta\pi$ modes

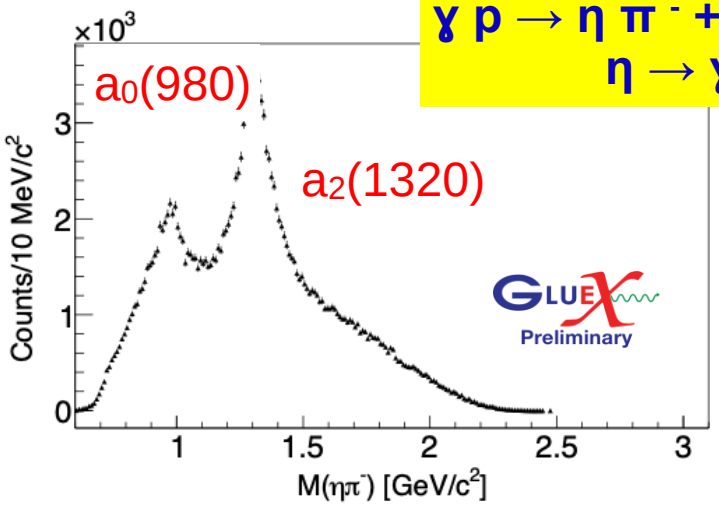


Expect more than two times larger statistics than in COMPASS (for GlueX Phase I)

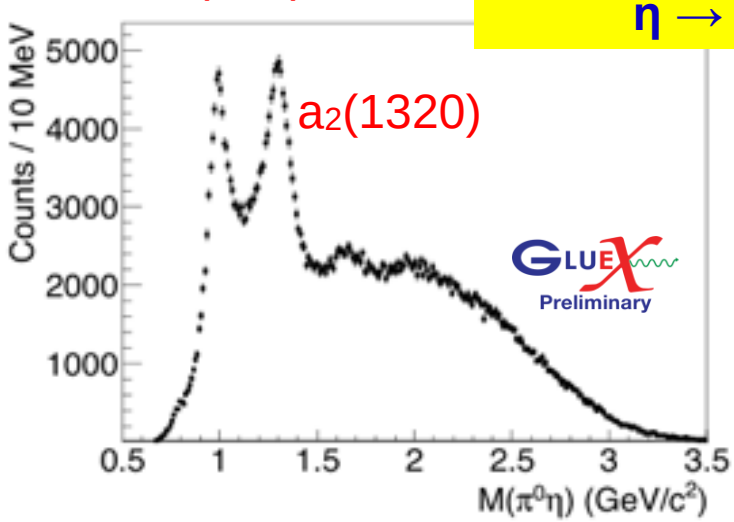
Prospect for Spectroscopy: γ p → p + π η



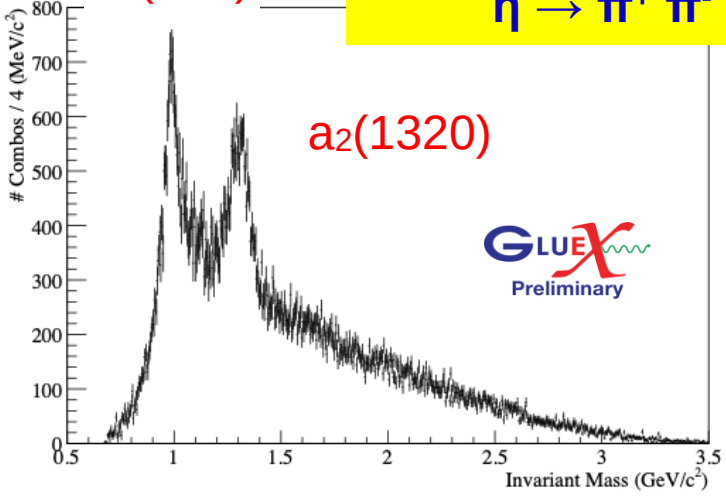
γ p → η π⁻ + Δ⁺⁺
η → γγ



γ p → η π⁰ + p
η → γγ



γ p → η π⁰ + p
η → π⁺ π⁻ π⁰



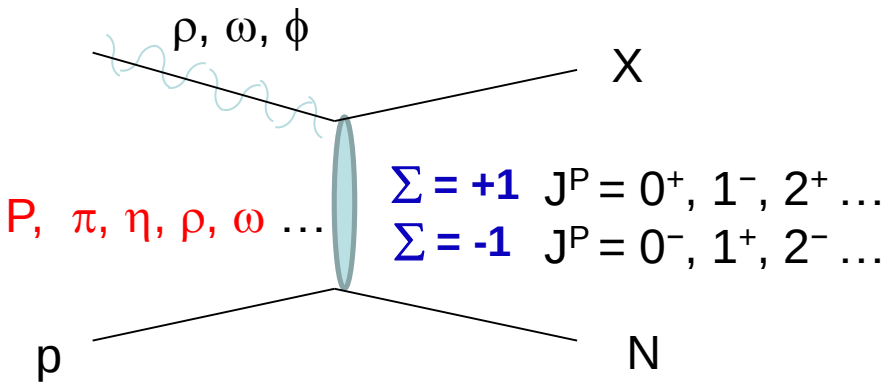
Beam Asymmetries

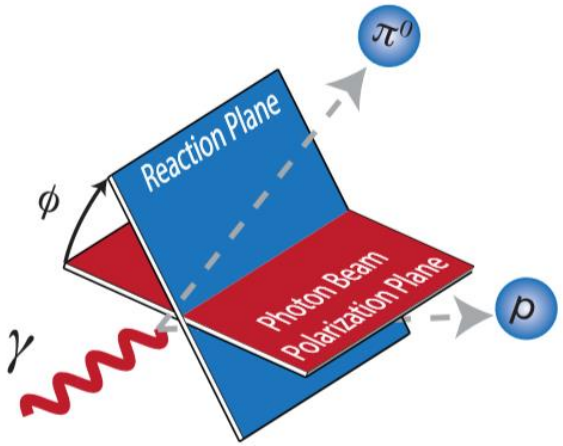
- Measure angular distributions

$$\sigma = \sigma_0 \cdot [\, 1 - P_\gamma \cdot \Sigma \cdot \cos(2\varphi) \,]$$

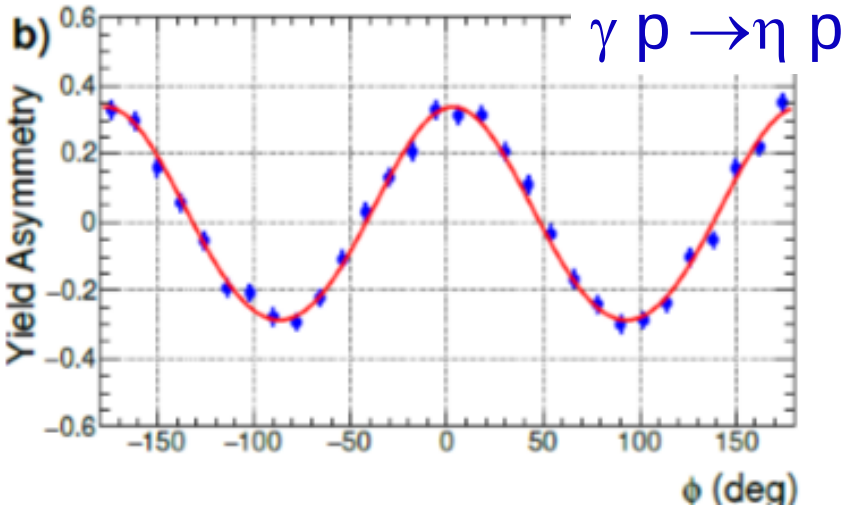
for two orientations of the beam polarization

- Asymmetry Σ depends on the production mechanism (naturality)

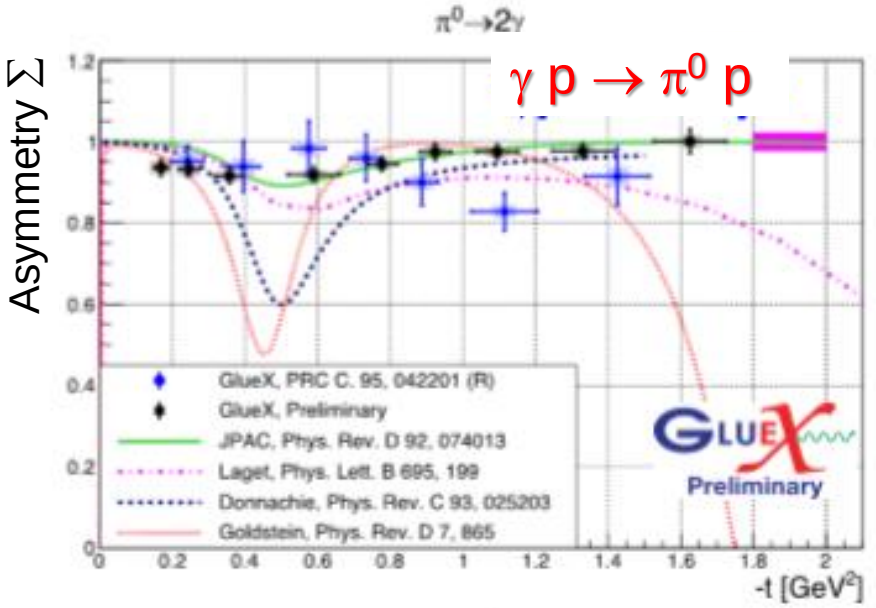


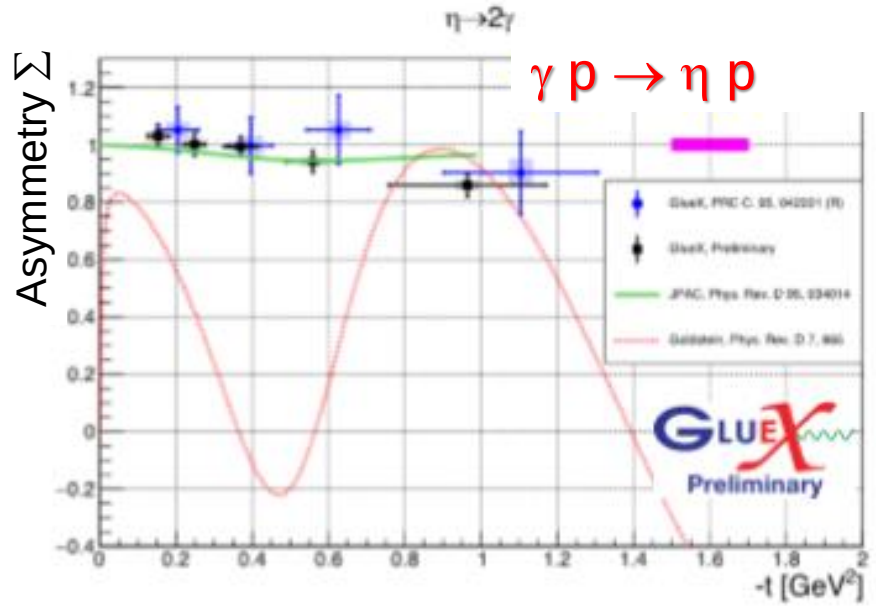


$$\frac{N_\perp - N_\parallel}{N_\perp + N_\parallel} \sim P_\gamma \Sigma \cos 2\phi$$



Beam Asymmetries: $\gamma + p \rightarrow p + \pi^0 / \eta$



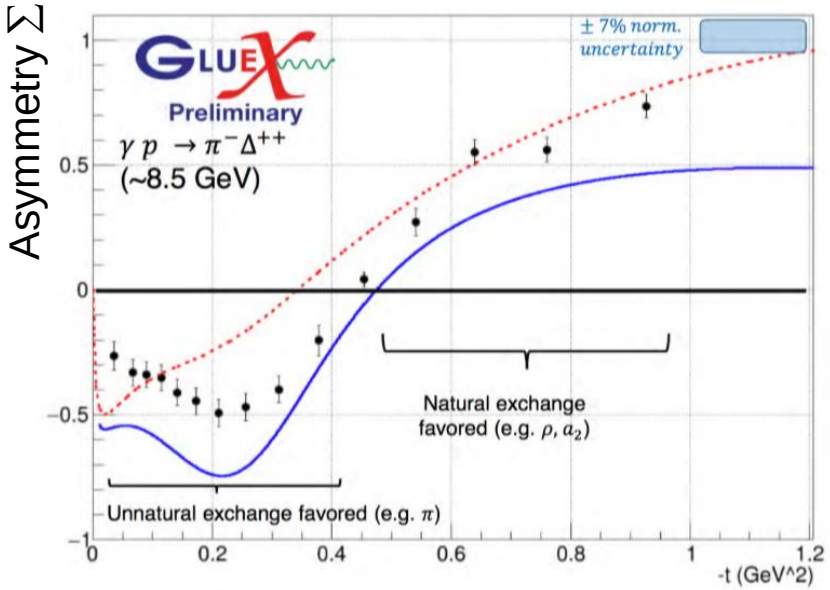


First GlueX physics publication

PRC 95, 042201 (2017)

- Natural exchange dominates $\Sigma \sim 1$
- Improved measurements
  - increase statistics by a factor of 8
- More papers on asymmetries expected in 2019

Beam Asymmetries: New Measurements

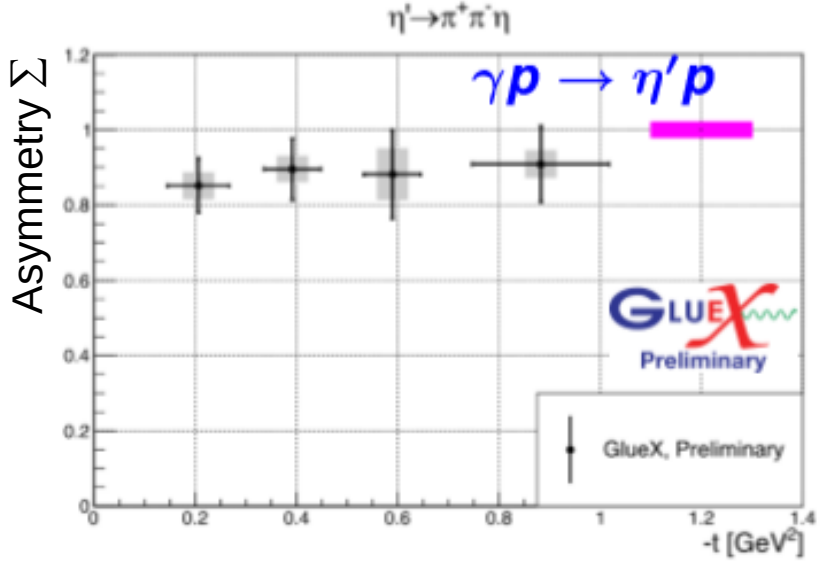


$\gamma\, p \rightarrow \pi^-\, \Delta^{++}$

Dominated by pion exchange at small *t*

B.-G. Yu and K.-J. Kong, PLB 769, 262 (2017)

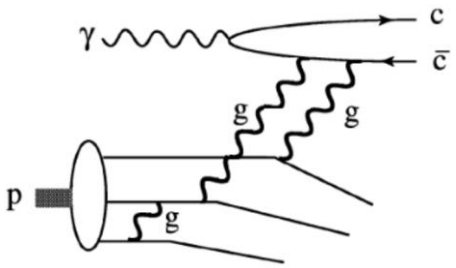
B.-G. Yu and K.-J. Kong, PLB 769, 262 (2017)



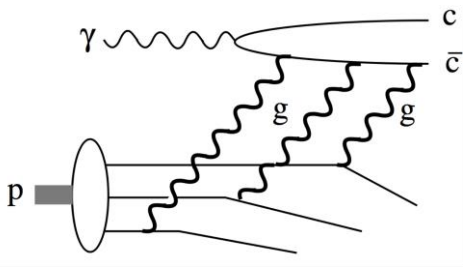
$\gamma\, p \rightarrow \eta'\, p$

J/ψ Production Near Threshold

- Production cross section is sensitive to high-x gluon distribution



leading-twist

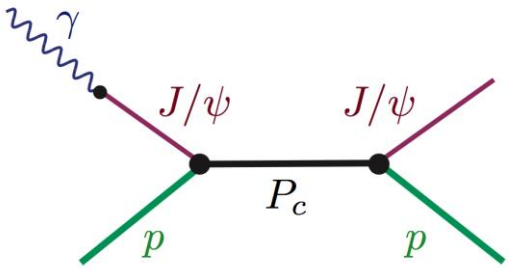


higher-twist

Brodsky et al., PLB 498 (2002)

- Search for the LHCb pentaquark

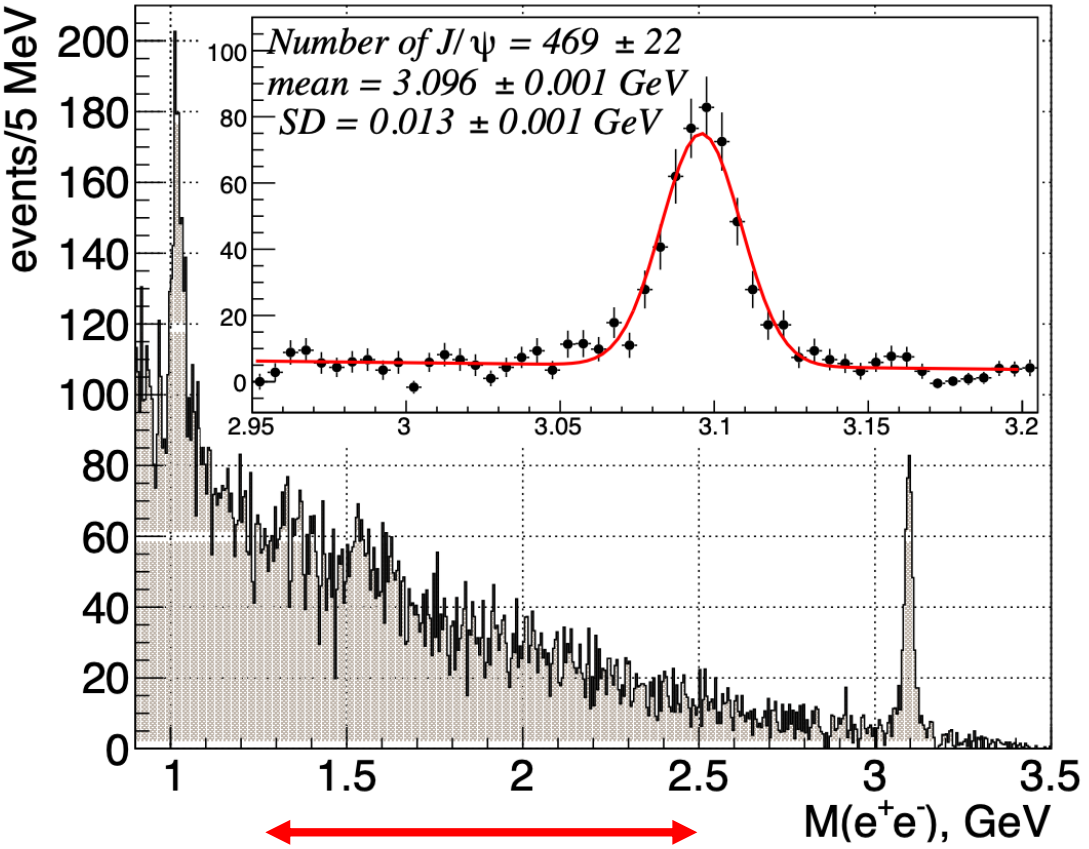
s-channel production $\gamma + p \rightarrow P_c(4450) \rightarrow J/\psi + p$ at 10.1 GeV



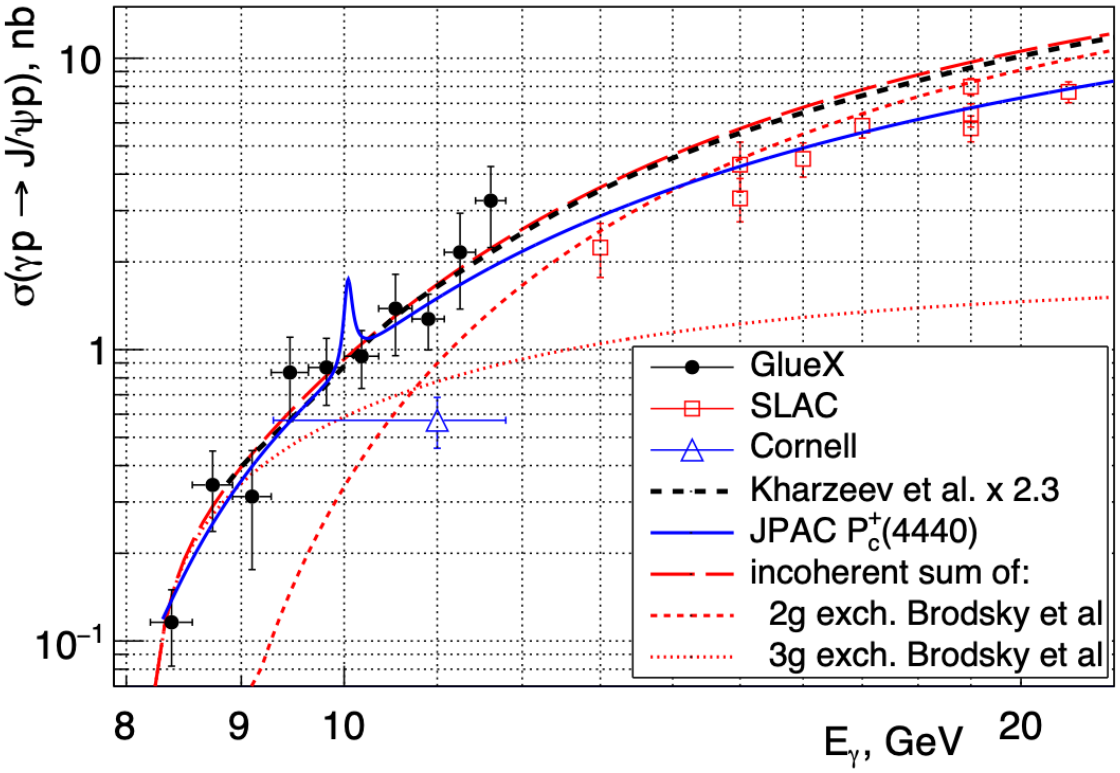
Primary uncertainty in
Br (P (4450) → J/ψ + p)
assuming VMD

Reconstruction of $J/\psi \rightarrow e^+ e^-$

- Kinematically fit exclusive reaction
- Normalize cross section to the Bethe – Heitler reaction
  $\gamma p \rightarrow (e^+e^-)p$
- Analysis is based on about 25 % of the collected data



J/ψ Cross Section Measurement



- Cross section measured by SLAC and Cornel in 1975 (E > 11 GeV, inclusive production)
- Three-gluon exchange dominates (shape of the distribution)
- Large gluonic contribution to the proton mass
  Y.Hatta et al, 1906.00894 (2019)

(see talk by Y. Hatta tomorrow)

LHCb Pentaquark

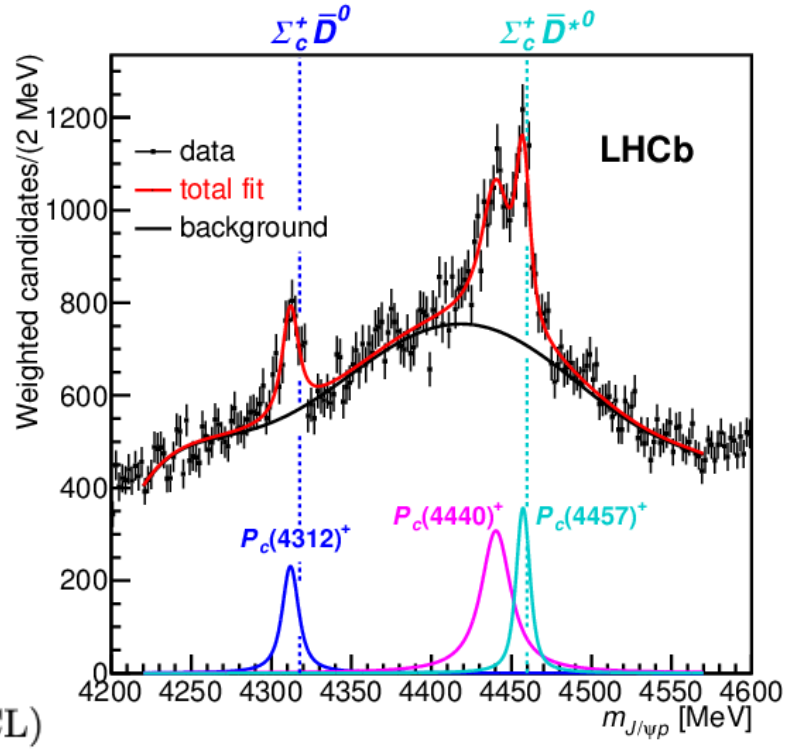
$\Lambda_b \rightarrow J/\psi\, p\, K^-$

- 3 narrow peaks in the J/ψ p mass spectrum

  - No spin parity identification

  - Several possible descriptions

    (see talk by L. Zhang)

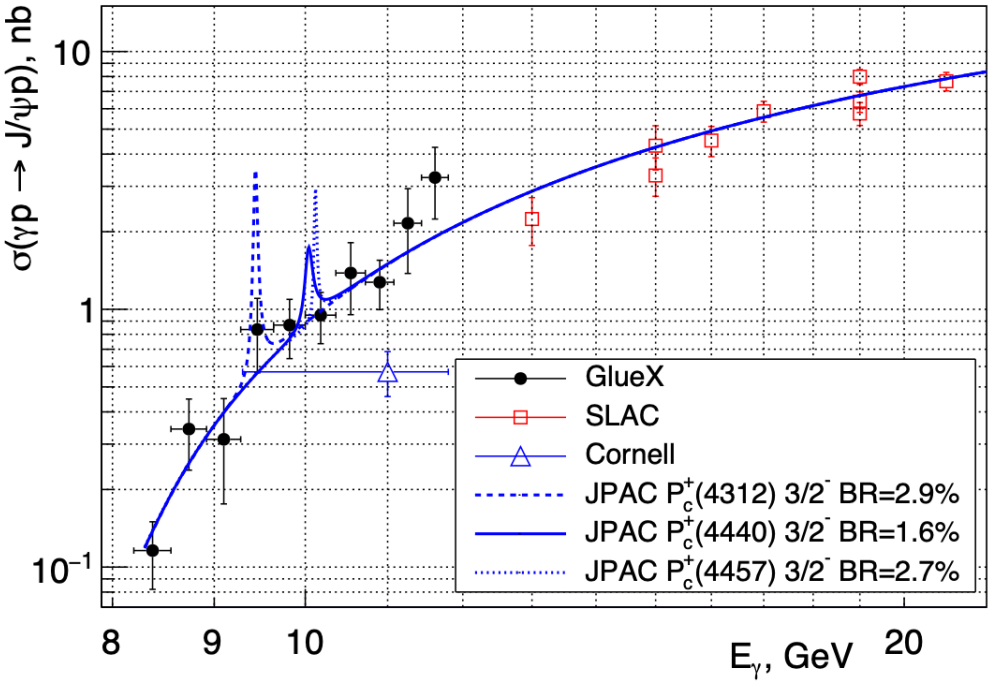


State	M [MeV]	Γ [MeV]	(95% CL)
$P_c(4312)^+$	$4311.9 \pm 0.7^{+6.8}_{-0.6}$	$9.8 \pm 2.7^{+\ 3.7}_{-\ 4.5}$	(< 27)
$P_c(4440)^+$	$4440.3 \pm 1.3^{+4.1}_{-4.7}$	$20.6 \pm 4.9^{+\ 8.7}_{-10.1}$	(< 49)
$P_c(4457)^+$	$4457.3 \pm 0.6^{+4.1}_{-1.7}$	$6.4 \pm 2.0^{+\ 5.7}_{-\ 1.9}$	(< 20)

LHCb, PRL 122, 222001 (2019)

GlueX: Search for Pentaquark States

GlueX Collaboration, PRL 123, 072001 (2019)



- Model-dependent estimations of Br(Pc →J/ψ p) assuming $J^P=3/2^-$, and widths taken from LHCb

  $P_c(4312)$ < 4.6%

  $P_c(4440)$ < 2.3%

  $P_c(4457)$ < 3.8%

  upper limits at 90 % CL

(JPAC model PRD 94, 034002)

Disfavor hadrocharmonium and some molecular models

Primakoff η Experiment

- PrimEx η experiment with the GlueX detector to measure the width $\Gamma(\eta \rightarrow \gamma\gamma)$ using Primakoff process

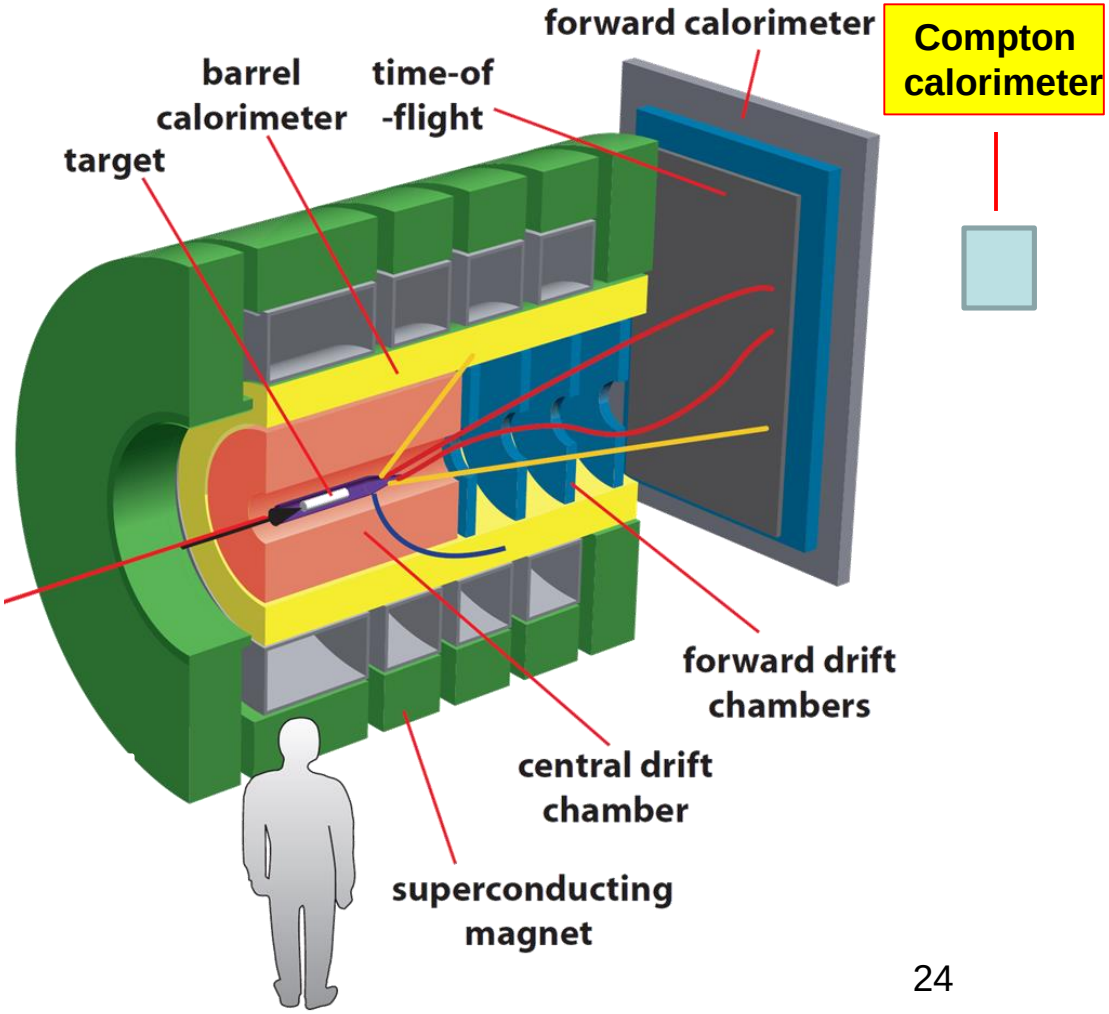
  - collected about 30 % of data in Spring 2019

  - two targets: LH_4 and LH_2

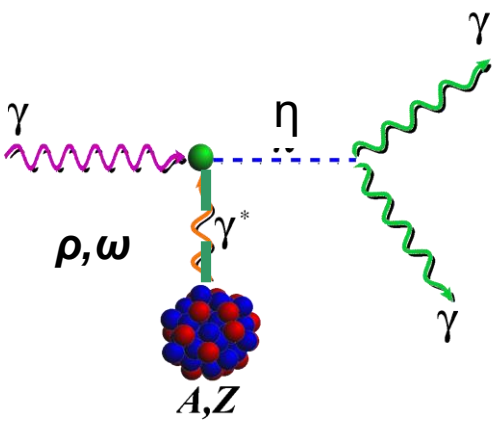
  - the experiment complements the Primakoff program at Jefferson Lab (measurement of $\Gamma(\pi^0 \rightarrow \gamma\gamma)$ in Hall B)

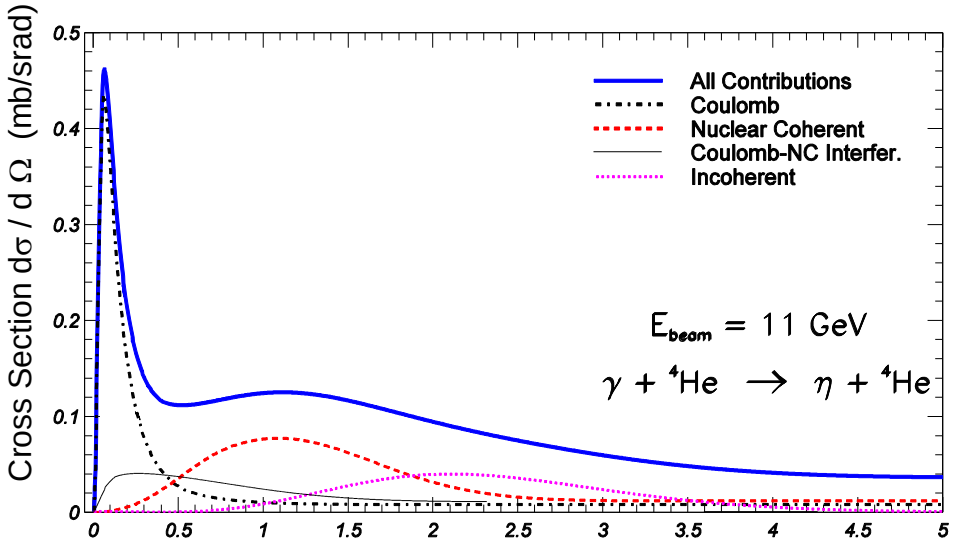
Primakoff η Experiment

- New liquid He and Be targets
- New Compton Calorimeter
- Use Compton events for:
  - absolute luminosity normalization (Be target)
  - stability monitoring (He target)
- Solenoid field switched off
- Beam energy range if interest
  9 GeV – 11.2 GeV
- Collected 30 % of the total statistics
  - use LHe target in Spring 2019



The Primakoff Method





$$\frac{d\sigma_{\mathrm{Pr}}}{d\Omega} = \Gamma_{\gamma\gamma} \frac{8\alpha Z^2}{m_\pi^3} \frac{\beta^3 E^4}{Q^4} \left|F_{e.m.}(Q)\right|^2 \sin^2\theta_\pi$$

- Extract decay width $\Gamma(\eta\rightarrow\gamma\gamma)$ from the measured cross section $d\sigma/d\Omega$

- Use low A targets LH_2 and LHe_4 to control:
  - coherency
  - contributions from nuclear processes

Measurements of $\Gamma(\eta \to \gamma\gamma)$

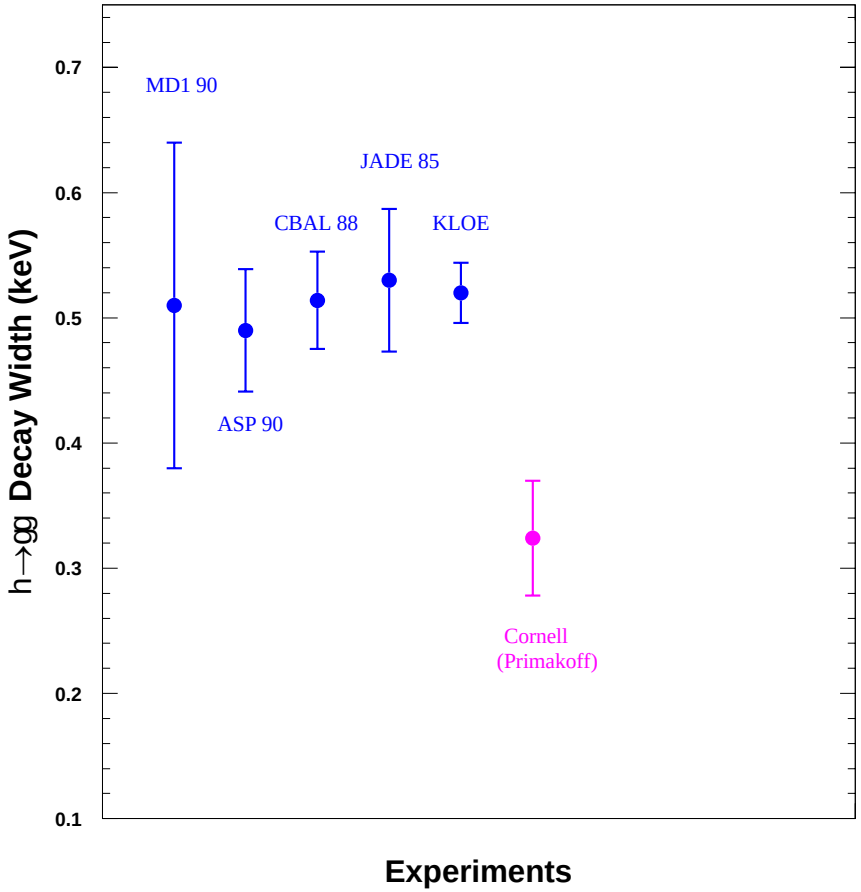
- The partial width $\Gamma(\eta \to \gamma\gamma)$ was derived from measurements

  - collider experiments in the reaction

    $e^+ e^- \to e^+ e^- \eta$

  - Primakoff production of η mesons

- Some disagreemnts between collider and Primakoff results



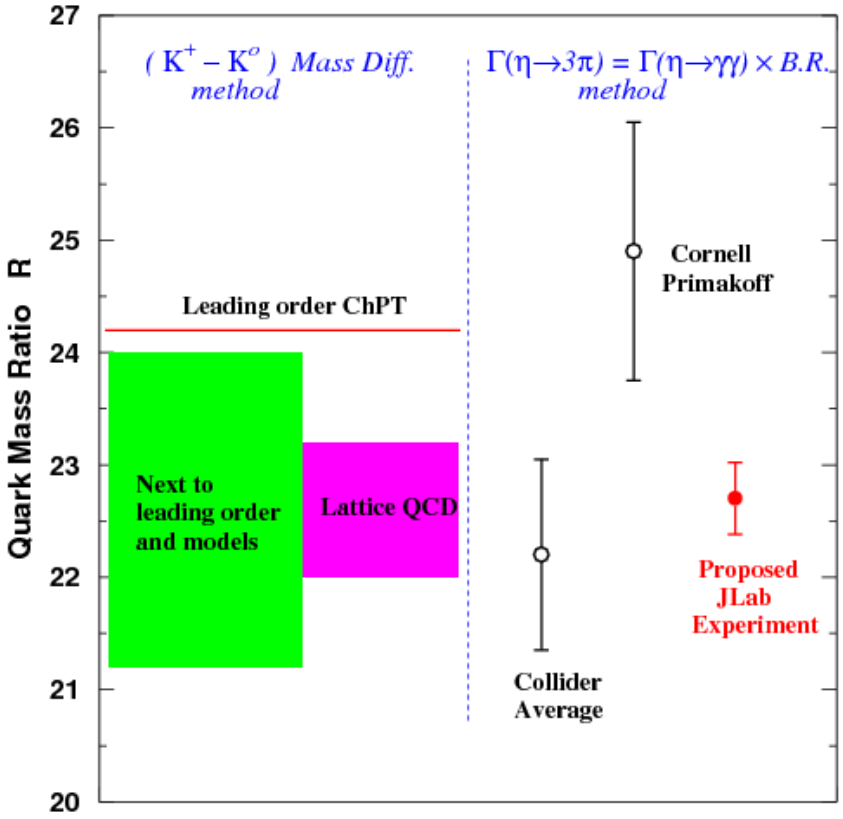
New PrimEx experiment in Hall D at Jefferson Lab

Measure $\Gamma(\eta \to \gamma\gamma)$ using Primakoff process with the precision of 3.2%

Physics Motivation

- **Light quark mass ratio:**

H. Leutwyler PLB, 378,1996



- $\Gamma(\eta\to\gamma\gamma)$ obtained in PrimEx can be used to compute $\Gamma(\eta\to3\pi)$

$$\Gamma(\eta\to3\pi)=\Gamma(\eta\to\gamma\gamma)\cdot BR(3\pi)\,/\,BR(\gamma\gamma)$$

Branching fractions are measured with good precision

- $\eta\to3\pi$ is forbidden by isospin symmetry. The quark mass ratio R can be extracted from the width $\Gamma(\eta\to3\pi)$

$$R^2 = \frac{m_s^2 - \hat{m}^2}{m_d^2 - m_u^2}, \qquad \text{where } \hat{m} = \frac{1}{2}(m_u + m_d)$$

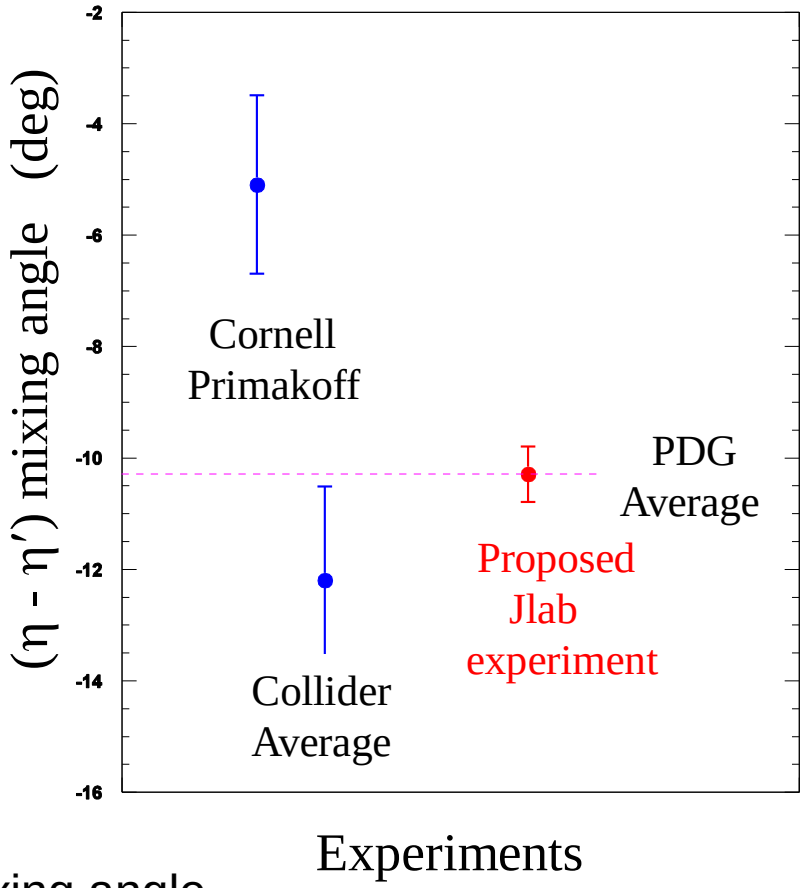
Physics Motivation

- **Significantly improve all η decay widths in PDG**

$$\Gamma(\eta \to X) = \Gamma(\eta \to \gamma\gamma) \cdot BR(X) / BR(\gamma\gamma)$$

- **(η - η′) mixing angle**

$$\begin{pmatrix} \eta \\ \eta' \end{pmatrix} = \begin{pmatrix} \cos\theta & -\sin\theta \\ \sin\theta & \cos\theta \end{pmatrix} \cdot \begin{pmatrix} \eta_8 \\ \eta_0 \end{pmatrix}$$

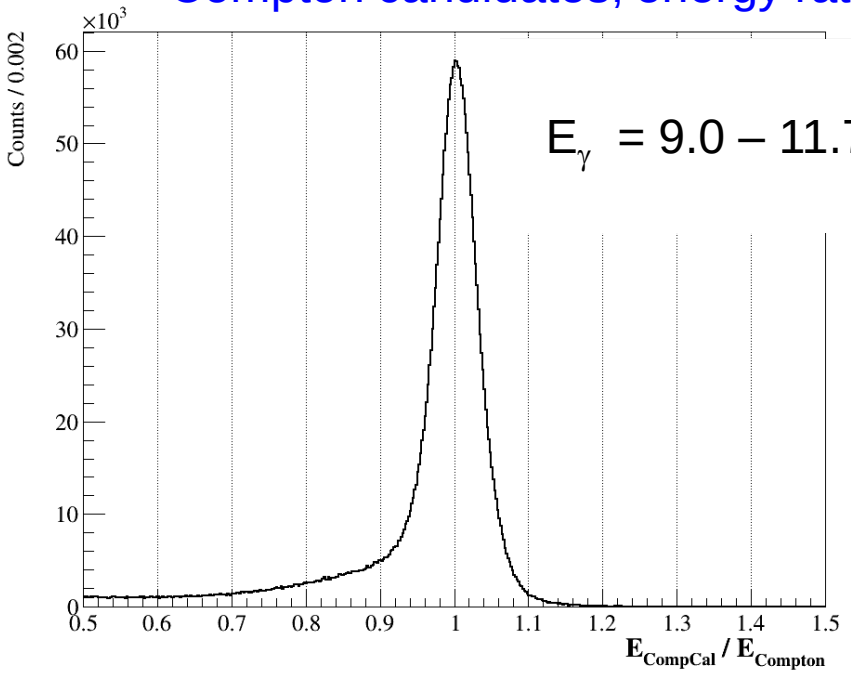


- Model dependent extraction of the mixing angle
- Uncertainty in the Γ(η'→γγ) has less impact on the angle extraction

Reconstruction of Compton Events

- Measure Compton $\gamma + e \rightarrow \gamma + e$ cross section in the forward direction during physics production runs
- Monitor target thickness and beam flux during production runs (rate of reconstructed events ~ 30 Hz)
- Use Compton for the cross section normalization

Compton candidates, energy ratio



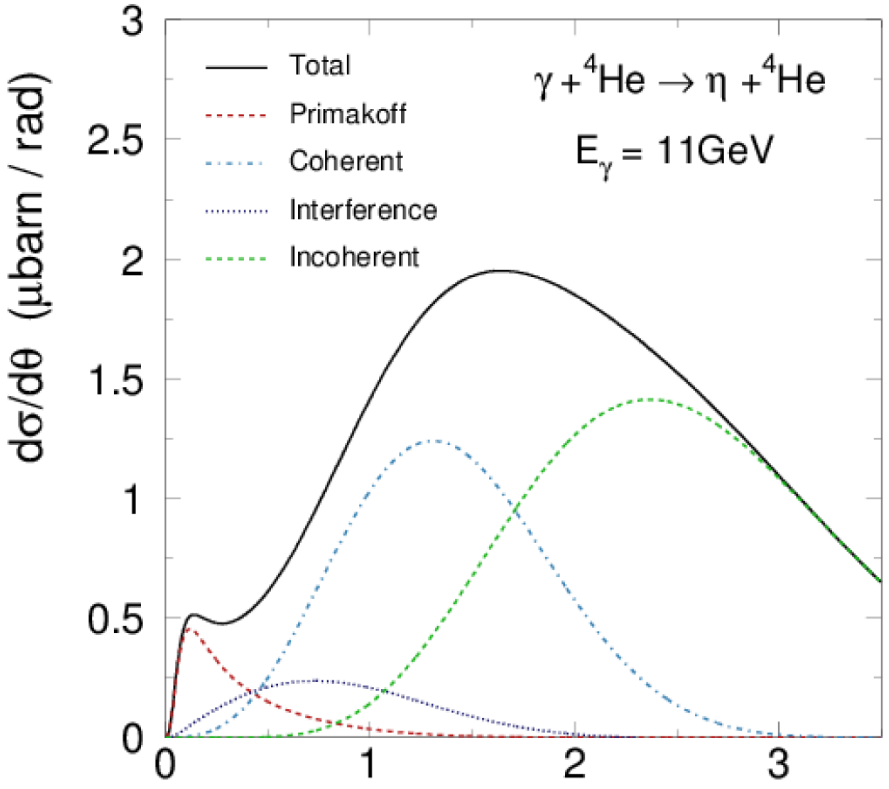
E_γ = 9.0 – 11.7 GeV

- Install Compton calorimeter behind forward calorimeter

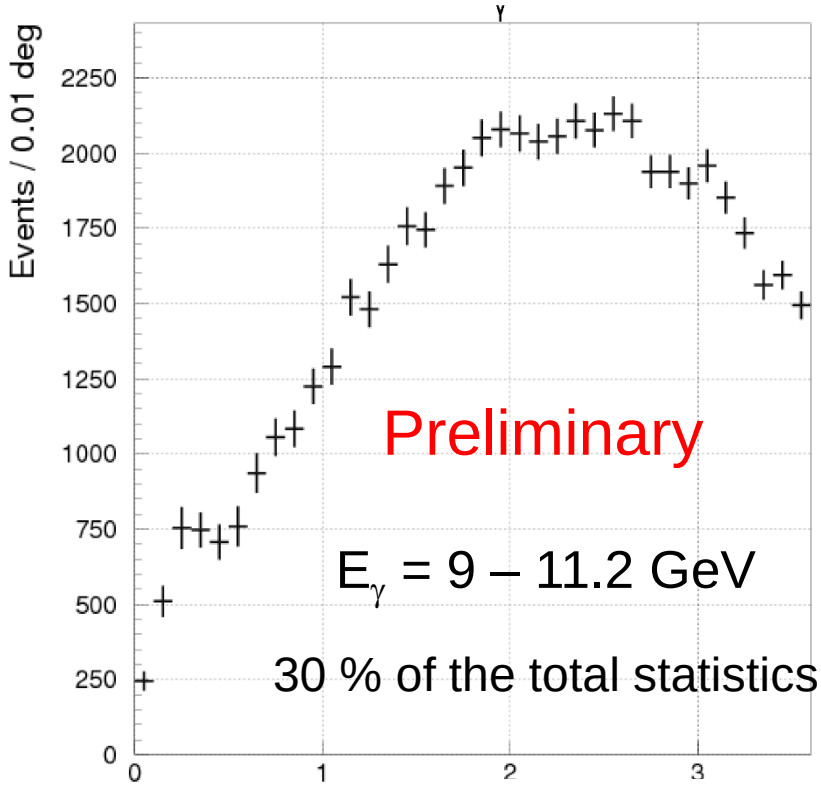
- 12x12 (24 x 24 cm^2) $PbWO_4$ crystals

$\eta \rightarrow \gamma\gamma$ Angular Distribution

MC predictions

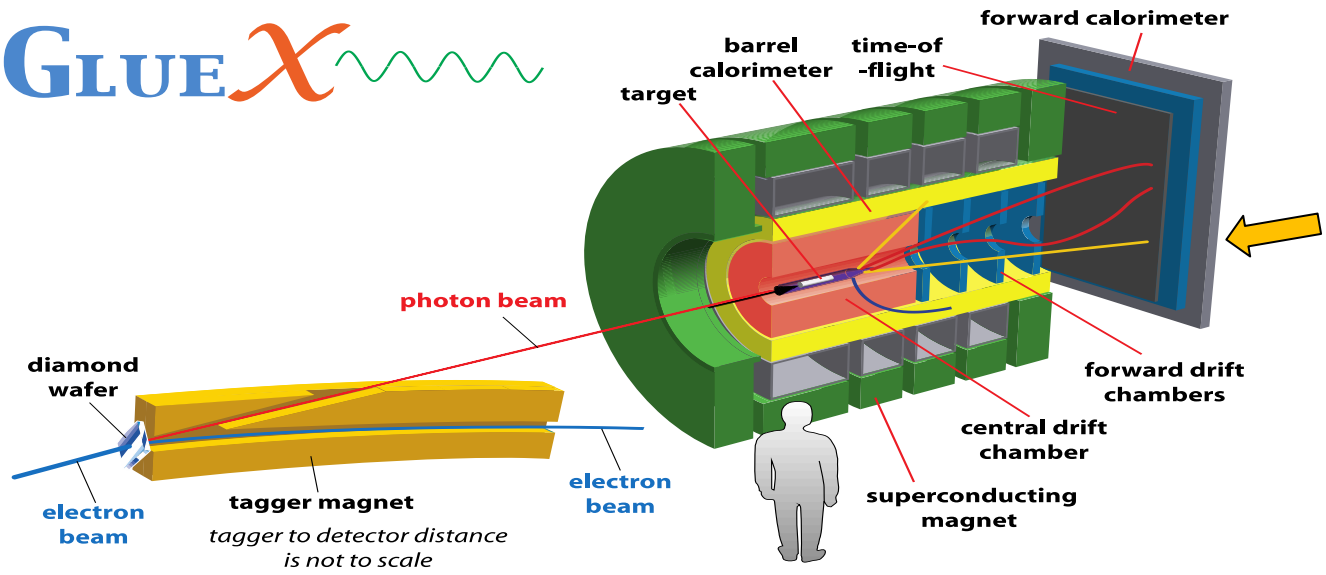


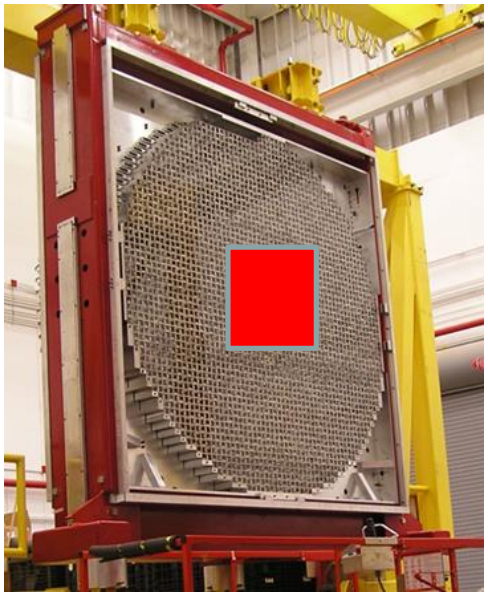
He target, Spring 2019



GlueX Upgrade

FCAL





- Upgrade the inner part of the lead glass Forward Calorimeter with the $PbWO_4$ crystals (**FCAL-II**)

- significantly improve detection of multi-photons from η decays
- allow to study rare decays such as $\eta \rightarrow \pi^0\gamma\gamma$ in the $\gamma + p \rightarrow \eta + p$ reaction using a beam of tagged photons with the energy between 9 – 11.7 GeV

Jefferson Lab Eta Factory (JEF)

JEF Project Overview

Mode	Branching Ratio	Physics Highlight	Photons
priority:			
$\pi^0 2\gamma$			4
$\gamma + B$	beyond SM	leptophobic dark boson	4
$3\pi^0$	$(32.6 \pm 0.2)\%$	$m_u - m_d$	6
$\pi^+\pi^-\pi^0$	$(22.7 \pm 0.3)\%$	$m_u - m_d$, CV	2
3γ	$< 1.6 \times 10^{-5}$	CV, CPV	3
ancillary:			
4γ	$< 2.8 \times 10^{-4}$	$< 10^{-11}$[112]	4
$2\pi^0$	$< 3.5 \times 10^{-4}$	CPV, PV	4
$2\pi^0\gamma$	$< 5 \times 10^{-4}$	CV, CPV	5
$3\pi^0\gamma$	$< 6 \times 10^{-5}$	CV, CPV	6
$4\pi^0$	$< 6.9 \times 10^{-7}$	CPV, PV	8
$\pi^0\gamma$	$< 9 \times 10^{-5}$	CV, Ang. Mom. viol.	3
normalization:			
2γ	$(39.3 \pm 0.2)\%$		2

Upgrade the Forward Calorimeter

Main physics goal:

1. Probe interplay of VMD & scalar resonances in ChPT to calculate $O(p^6)$ LEC's in the chiral Lagrangian
2. Search for a dark boson (B)
3. Directly constrain CVPC new physics
4. Constrain the light quark mass ratio

Impact of $\eta \to \pi^0\gamma\gamma$ measurements on ChPT

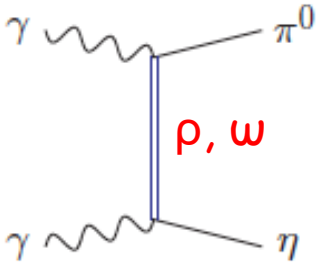
- Unique probe for the high order ChPT: the major contributions to $\eta \to \pi^0\gamma\gamma$ are two $O(p^6)$ counter-terms in the chiral Lagrangian

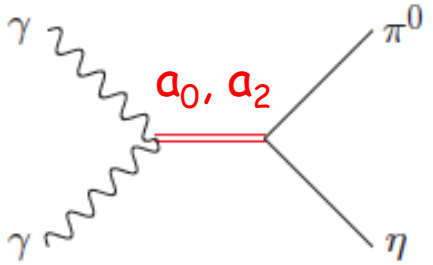
  L. Ametller, J, Bijnens, and F. Cornet, Phys. Lett., B276, 185 (1992)

- Study contribution of scalar resonances in calculation of $O(p^6)$ low-energy constants (LEC) in the chiral Lagrangian

- Shape of Dalitz distribution is sensitive to the role of scalar resonances

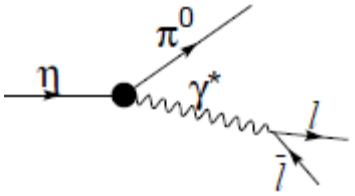
Higher order LEC's are dominated by resonances
Gasser, Leutwyler 84; Ecler, Gasser, Pich, de Rafael1989; Donoghue, Ramirez, Valencia 1989



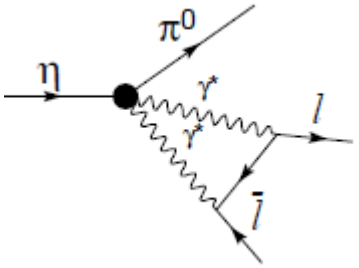


- A cross-check of LEC's with different processes

C and CP violating



C and CP conserving background

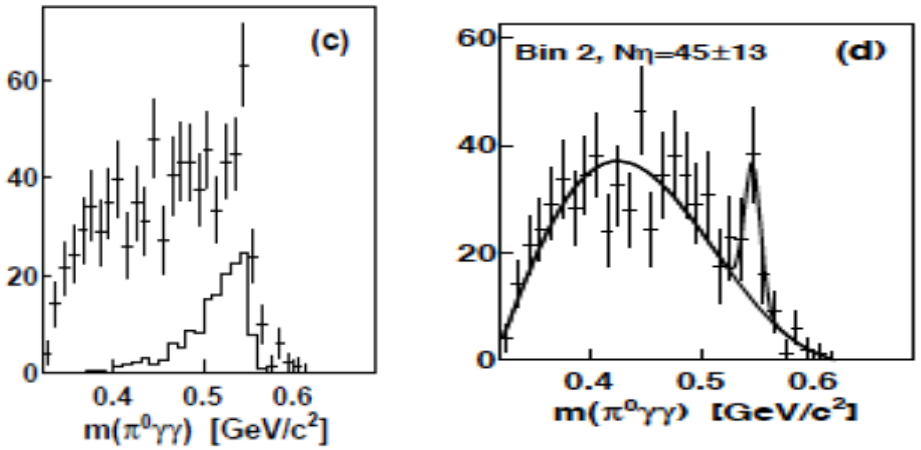


J.N. Ng, et al., Phys. Rev., D46, 5034 (1992)

Measurements of $\eta \rightarrow \pi^0\gamma\gamma$

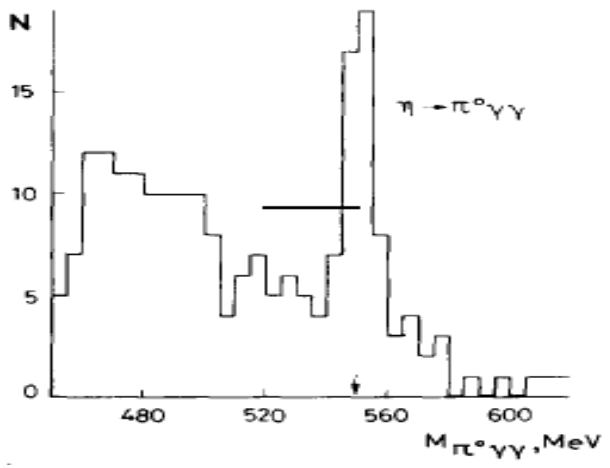
A2 at MAMI (Phys.Rev. C90, 025206,2014)

$\gamma p \rightarrow \eta p$ (E_γ=1.5 GeV)



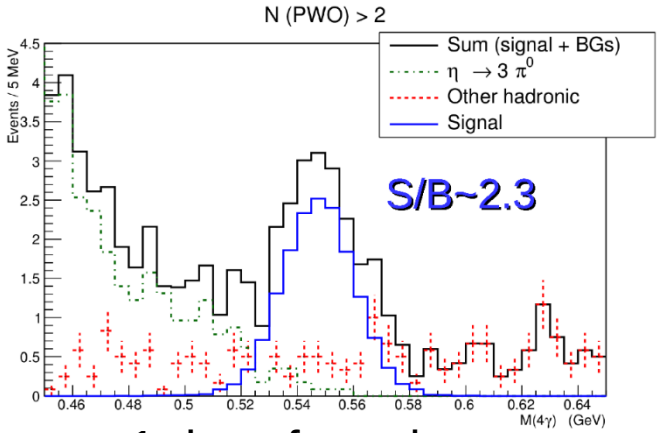
GAMS (Z. Phys. C25,225, 1985)

$\pi p \rightarrow \eta p$ (E_π= 30 GeV)



JEF (proposed)

$\gamma p \rightarrow \eta p$ (E_γ = 9-11.7 GeV)

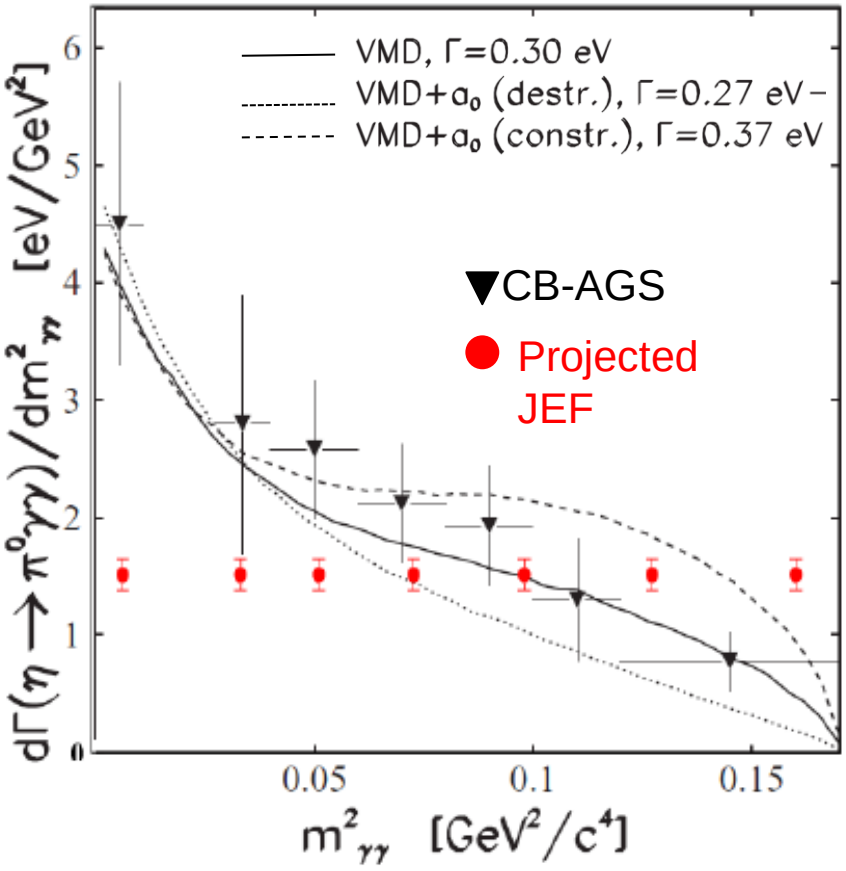


1 day of running

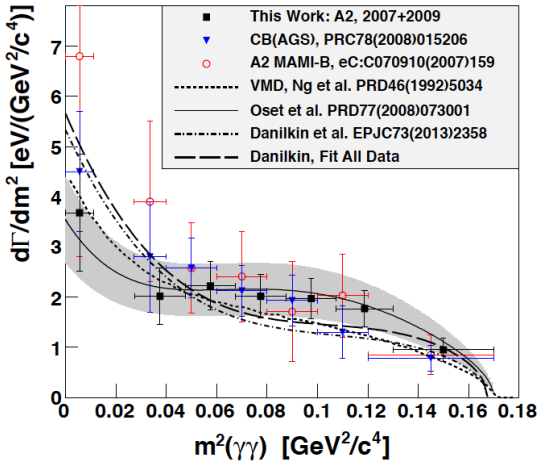
- Smaller background with η energy boost
- Large statistics

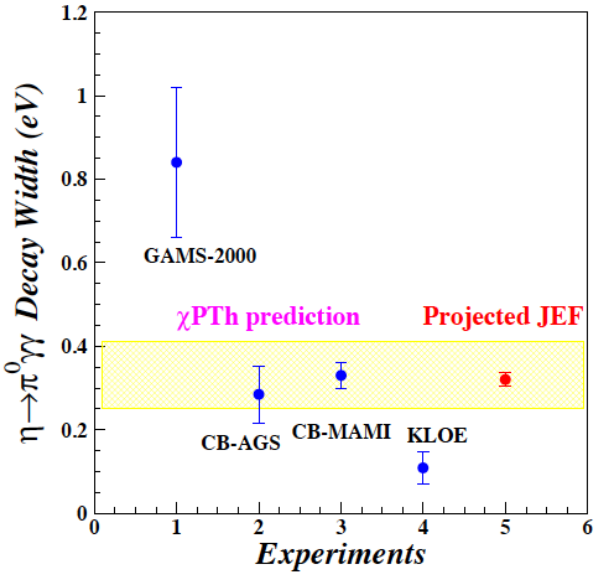
Projections for $\eta \to \pi^0\gamma\gamma$ Decay

Prakhov et al., Phys. Rev. C78, 015206 (2008)



A2 at MAMI arXiv:1405.4904, 2014





Constrain contribution of scalar resonances in the calculation of $O(p^6)$ low-energy constants

Search for B boson

- Dark leptophobic B-boson

$$L = \frac{1}{3} g_B \bar{q} \gamma^\mu q B_\mu + \ldots$$

- Arises from a new gauge baryon symmetry $U(1)_B$

Early studies by Lee and Yang, Phys.Rev.,98 (1955) 1501; Okun, Yad.Fiz., 10 (1969) 358,

- Unified genesis of baryonic and dark matter

- the $m_B < m_p$ region is strongly constrained by long-range forces search exp. ; the $m_B > 50 GeV$ has been investigated by the collider experiments

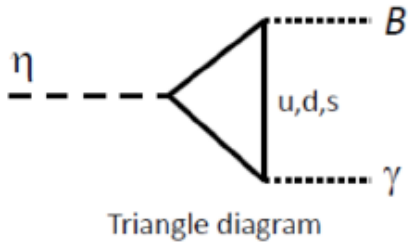
- GeV-scale domain is poorly constrained

discovery opportunity!

Search for B-boson in η decay

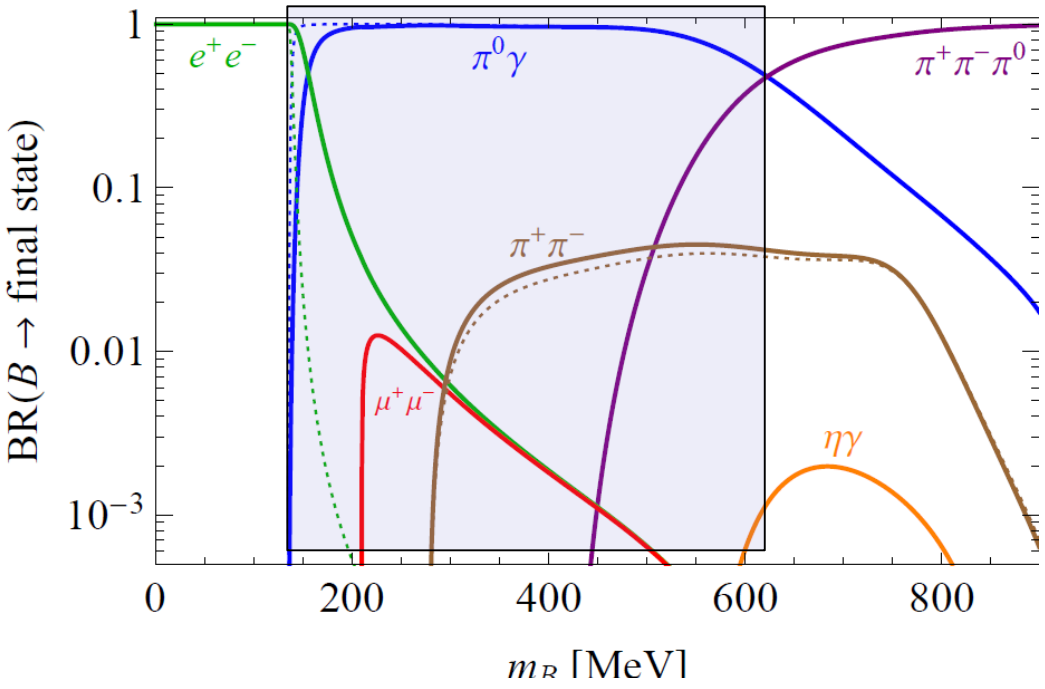
B production: A.E. Nelson, N. Tetradis, Phys. Lett., B221, 80 (1989)

$\eta \rightarrow B\gamma$ decay ($m_B < m_\eta$)



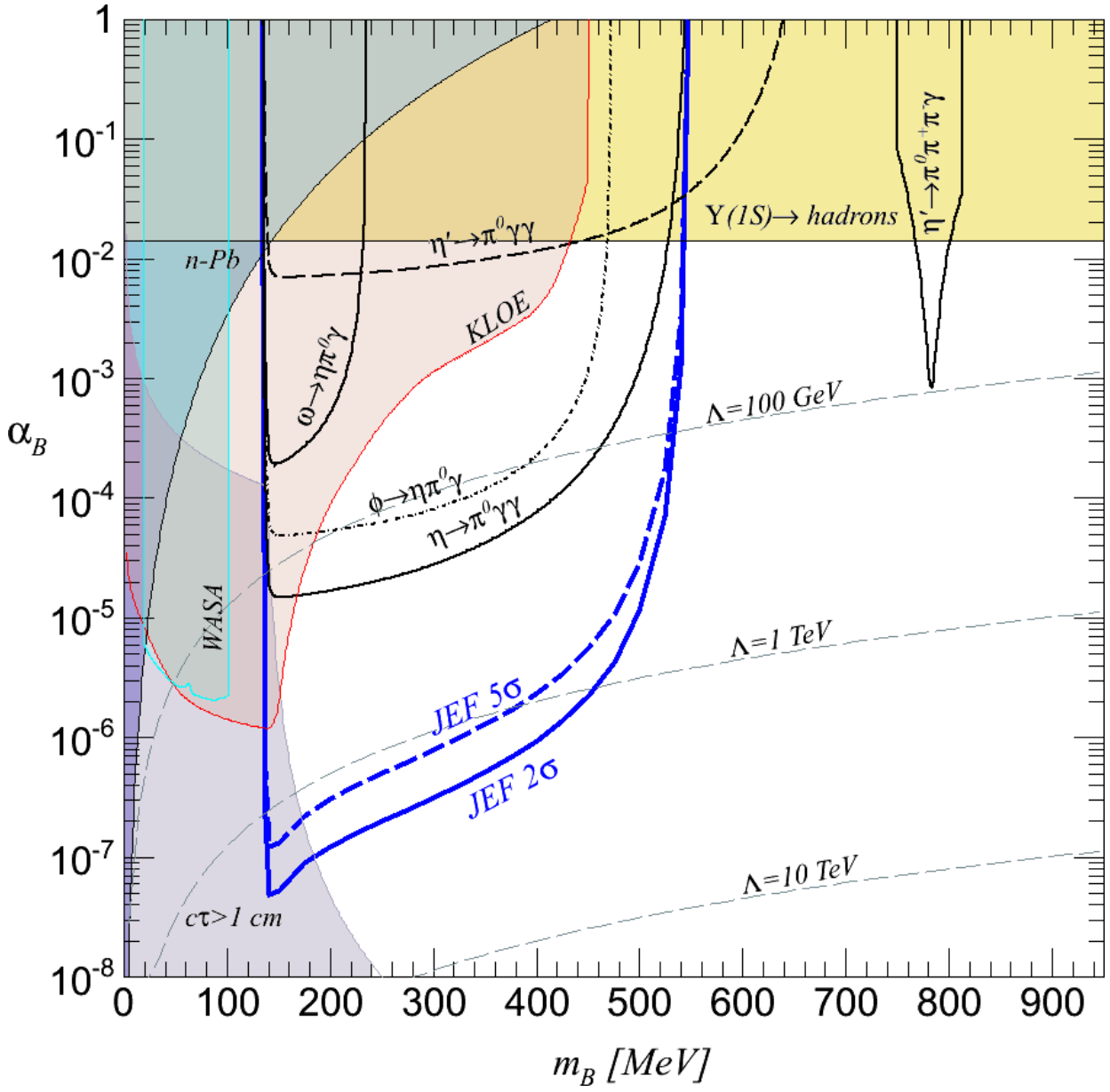
Triangle diagram

B decay: $B \rightarrow \pi^0\gamma$ in 140-600 MeV mass range



S. Tulin, Phys.Rev.,D89, 14008 (2014)

JEF Experimental Reach ($\eta \to B\gamma \to \pi^0\gamma\gamma$)



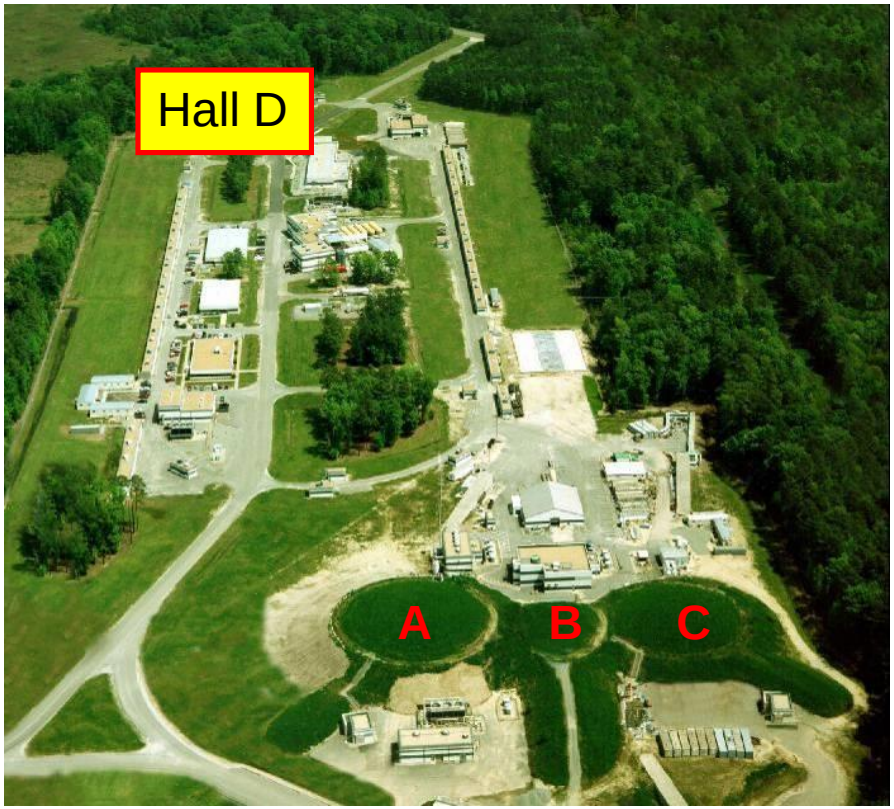
A stringent constraint on the leptophobic B-boson in 140-550 MeV range

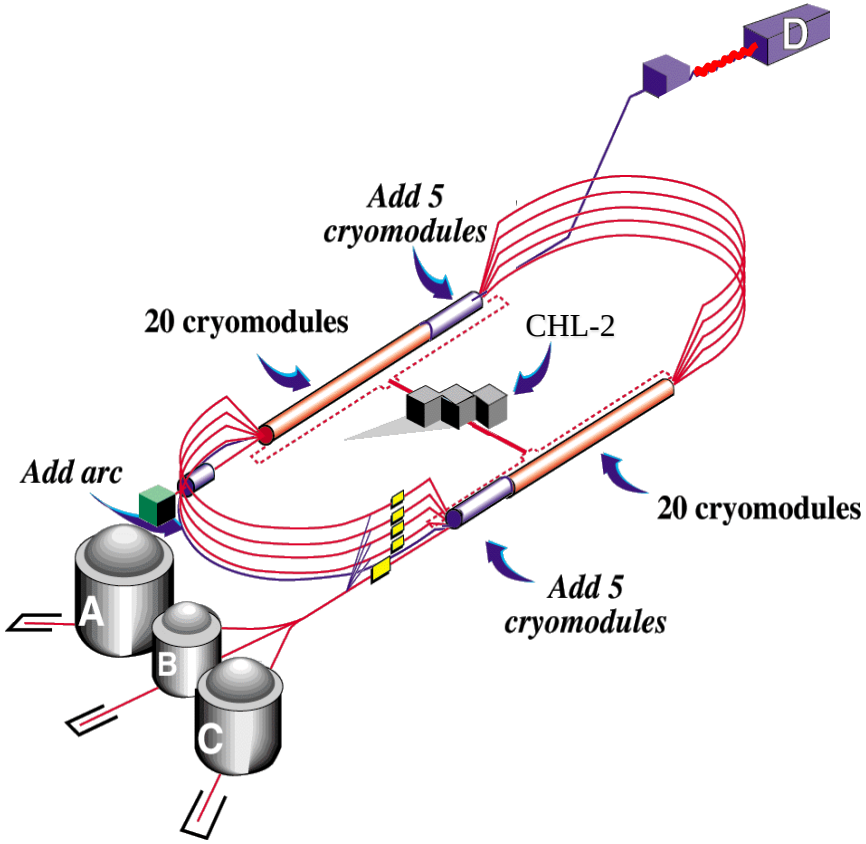
Summary

- GlueX has collected a large sample of photoproduction data
- First physics results based on 20% of the collected data:
  - measurement of the J/ψ production near threshold
  - measurements of beam asymmetries
- The GlueX detector provides a unique capability to perform a precision measurement of the η radiative decay width using Primakoff reaction
- The PrimEx η experiment collected about 30 % of required data in Spring 2019
- Future upgrade of the GlueX calorimeter will extend the physics potential of GlueX and provide an opportunity to study rare decays of η mesons

Backup Slides

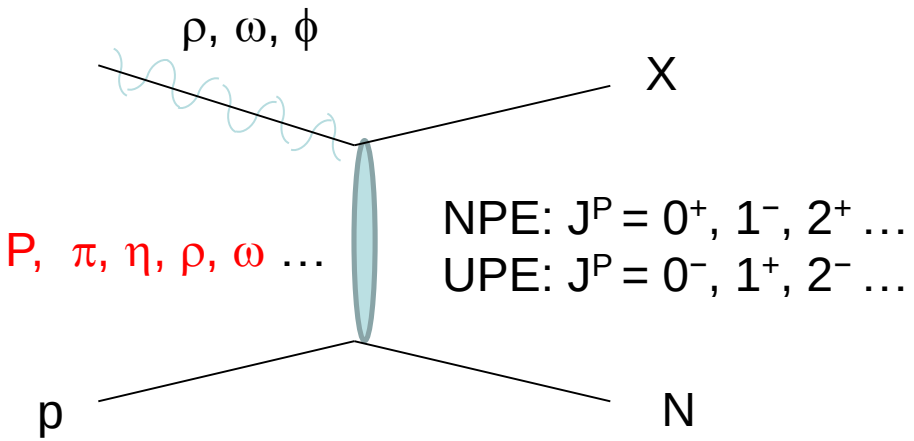
CEBAF Upgrade to 12 GeV





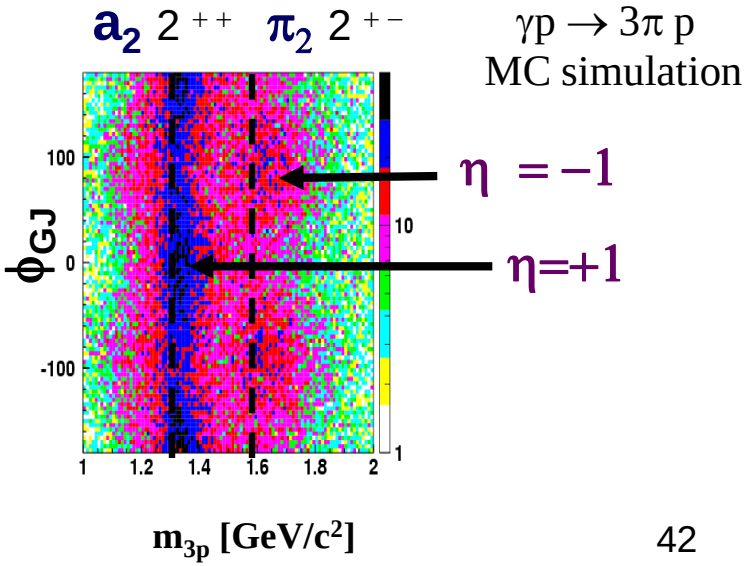
- Upgrade CEBAF energy from 6 GeV to 12 GeV.
- New experimental Hall D with GlueX detector
  - photon beam (linear polarization)

Photoproduction of Exotic Mesons



Exchange particle		Final States	
P	0^+	$0^{+-}, 2^{+-}$	b^0, h, h′
π^0	0^-	2^{+-}	b_2^0, h_2, h_2'
$\pi^\pm$	0^-	1^{-+}	$\pi_1^\pm$
ω	1^-	1^{-+}	π_1, η_1, η_1'

- t-channel exchange
- couple to photoproduction (via Vector Meson Dominance)
- Polarized photon beam helps to determine production mechanism (naturality)

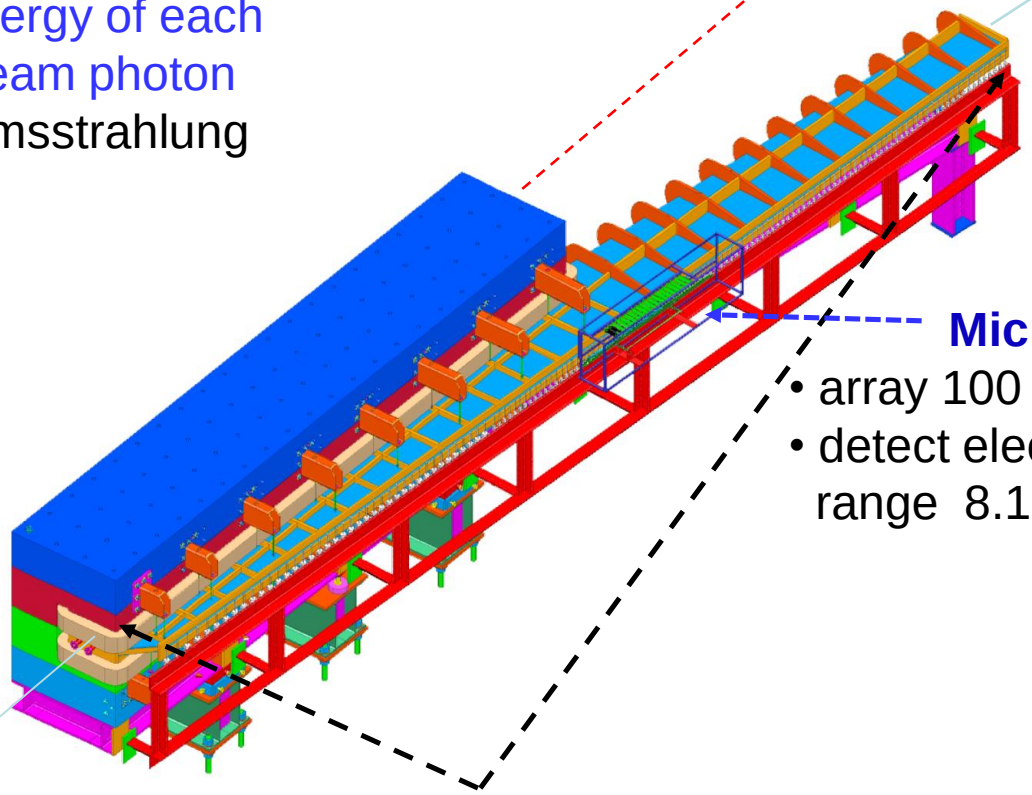


Tagged Photon Beam

Electrons to the beam dump

Photons to Hall D

- Measure energy of each individual beam photon
  - detect bremsstrahlung electron

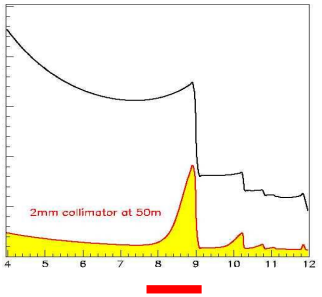


Microscope

- array 100 x 5 of thin scintillators
- detect electrons in the energy range 8.1 GeV < E_γ < 9.2 GeV

12 GeV e beam

Radiator

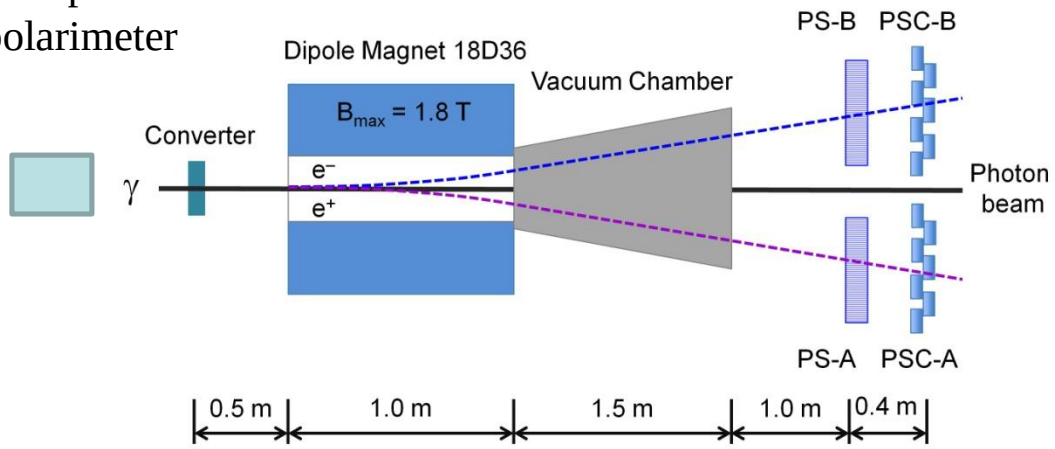


Fixed Array Hodoscope

- cover large energy range 3 GeV < E_γ < 11.78 GeV
- 233 counters installed
- detect tagged electrons with E_γ > 9.2 GeV during data runs

Photon Flux and Beam Polarization: Pair Spectrometer

Triplet polarimeter



Two layers of scintillator detectors:

High-granularity hodoscope (measure photon energy in the range 6 – 12 GeV)

Low-granularity counters (use in the trigger)

- Reconstruct the energy of a beam photon by detecting the $e^{\pm}$ pair produced by the photon in a thin converter
  - measure the spectrum of the collimated photon beam
  - monitor the photon beam flux
  - calibrate energy of tagger detectors

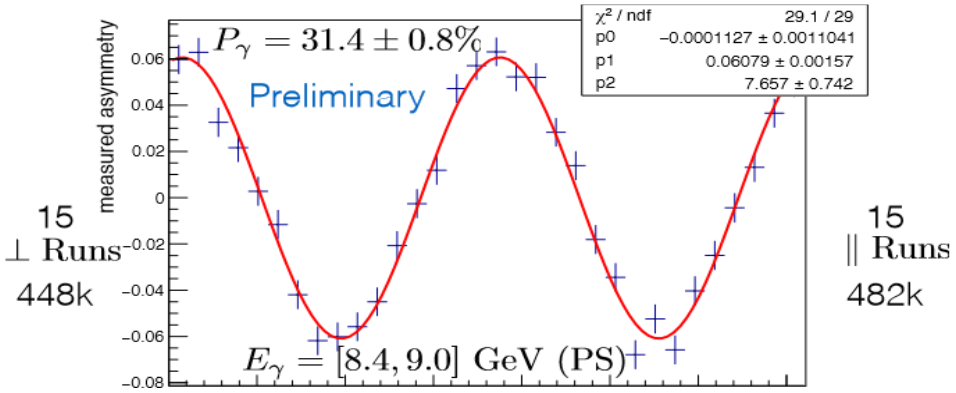
Beam Polarization

- Polarization measurements:
  - triplet production process e $\gamma \rightarrow$ e$^-$ e$^+$ e$^-$ (Triplet Polarimeter)
  - photon beam spectrum (Pair Spectrometer, Tagger Microscope)
  - physics channel like $\gamma p \rightarrow \rho p$
- Two orthogonal orientations of the polarization plane (radiator orientation)
  - horizontal and perpendicular

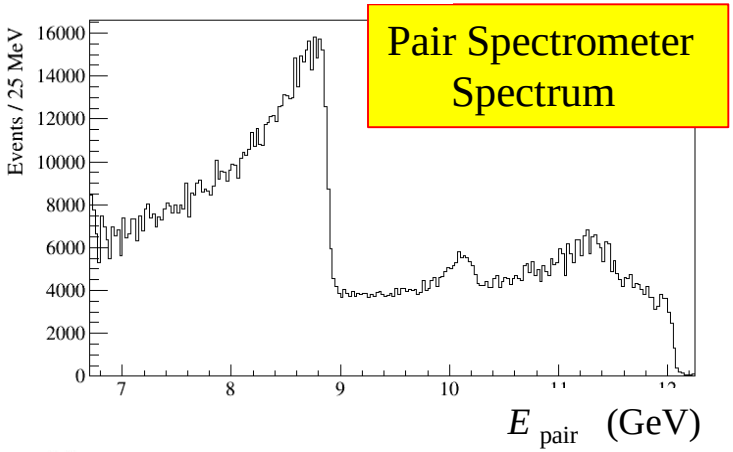
Polarimeter

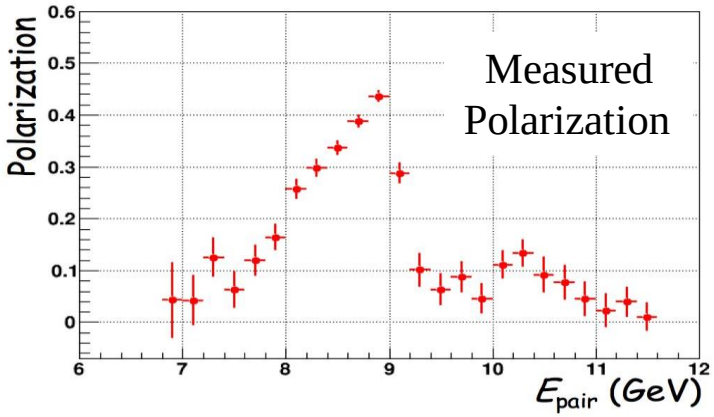
$$d\sigma_{\parallel,\perp} \propto 1 \pm P_{\parallel,\perp} \Sigma \cos 2\phi$$

$$\frac{N_\perp - N_\parallel}{N_\perp + N_\parallel} \sim P_\gamma \Sigma \cos 2\phi$$



Pair Spectrometer Spectrum





GlueX Detector

Tracking:

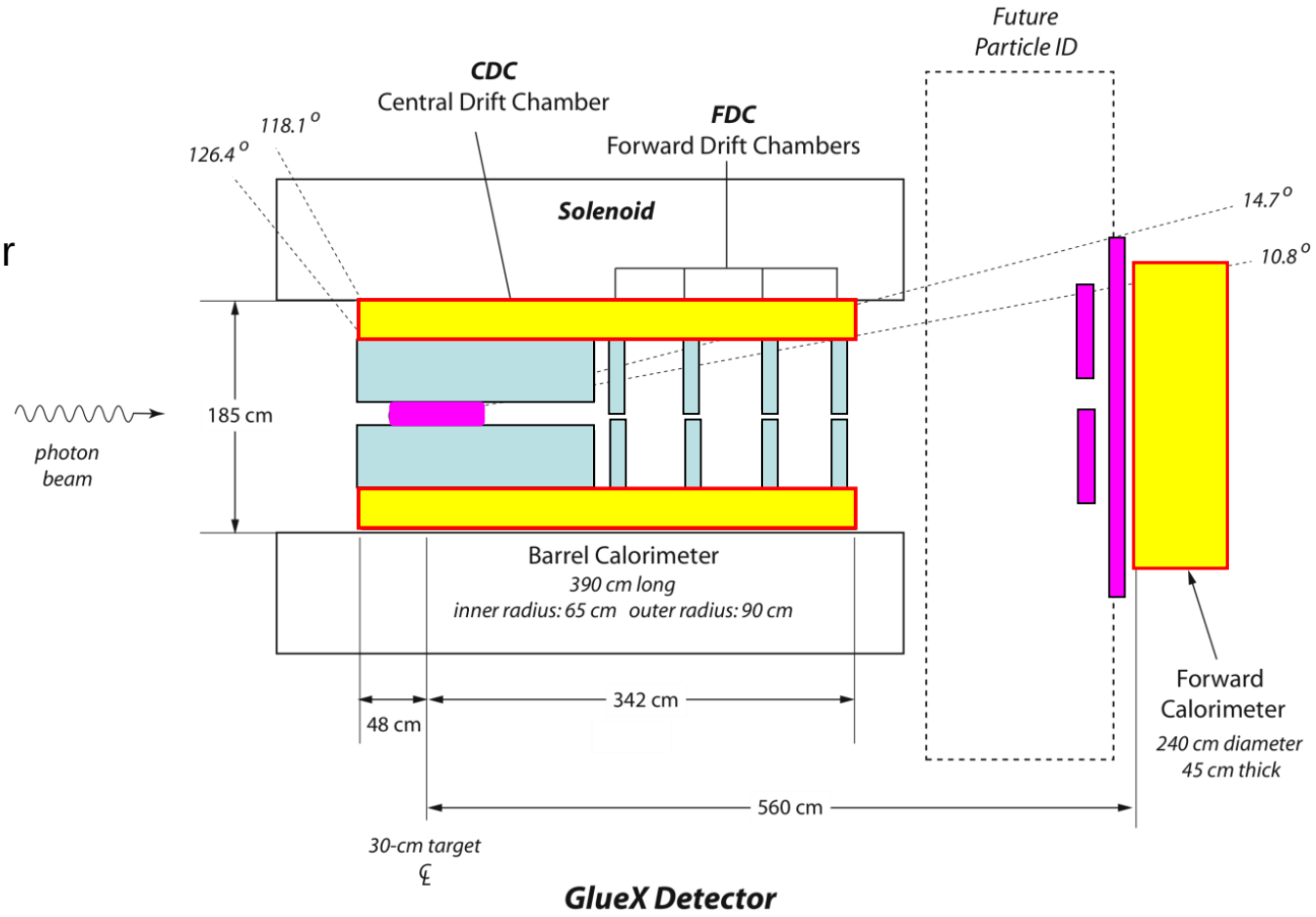
- Central Drift Chamber
- Forward Drift Chamber

Calorimetry:

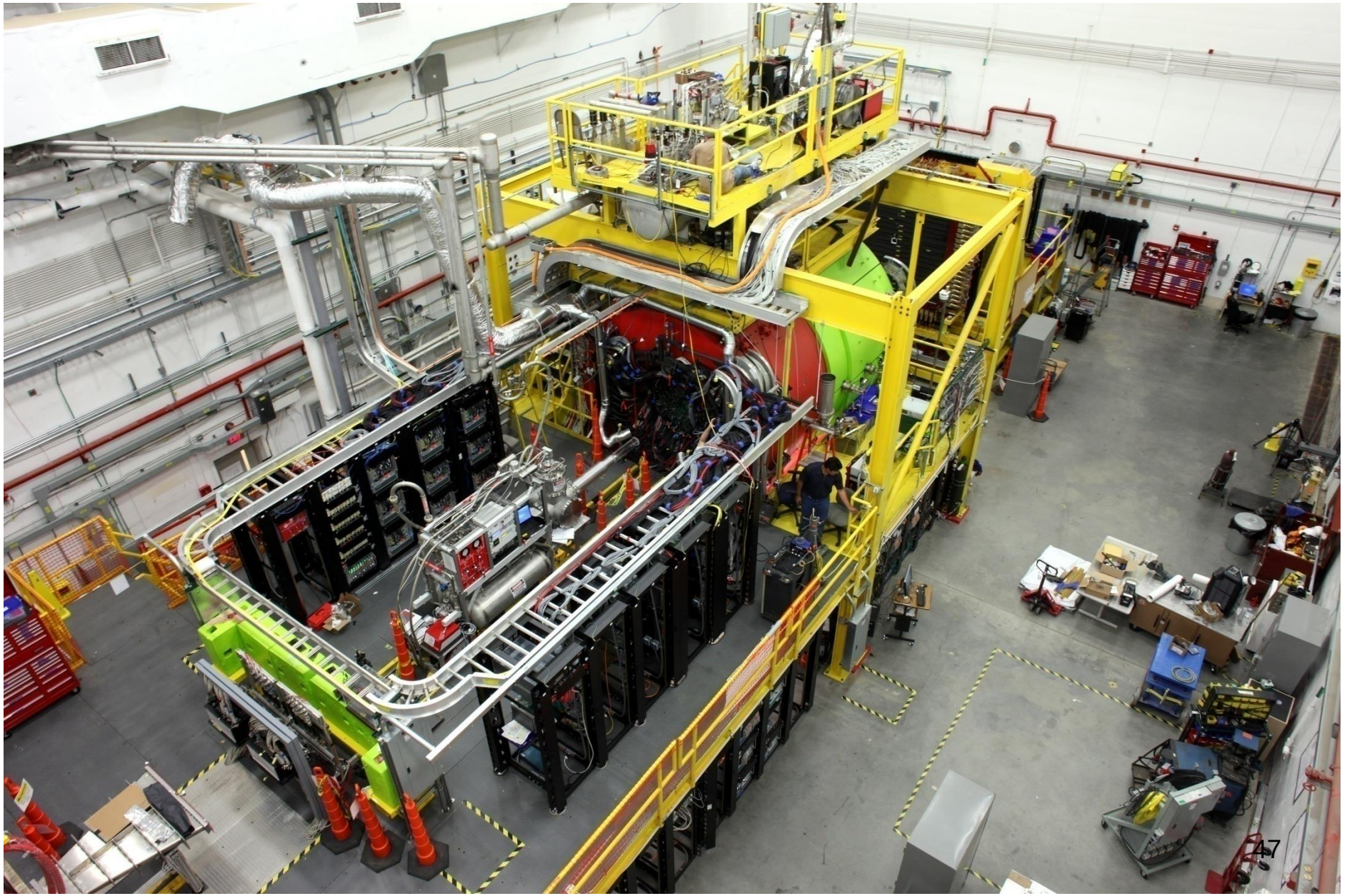
- Barrel Calorimeter
- Forward Calorimeter

PID:

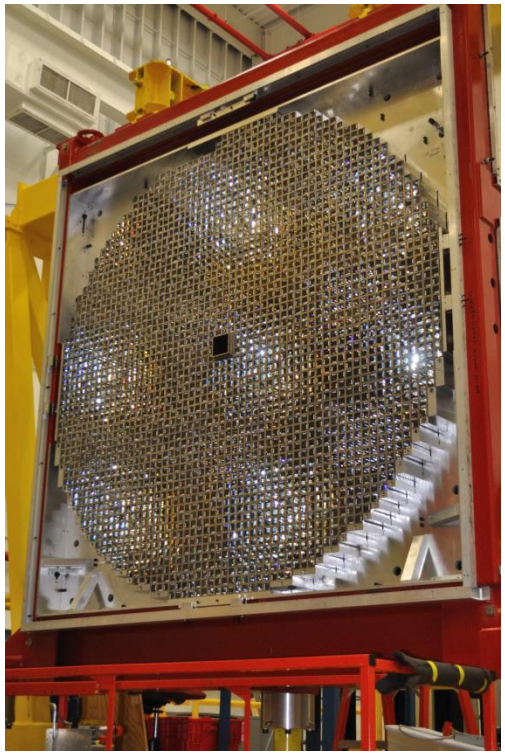
- Time of Flight wall
- Start Counter
- Barrel Calorimeter
- DIRC detector



GlueX Detector



Calorimetry

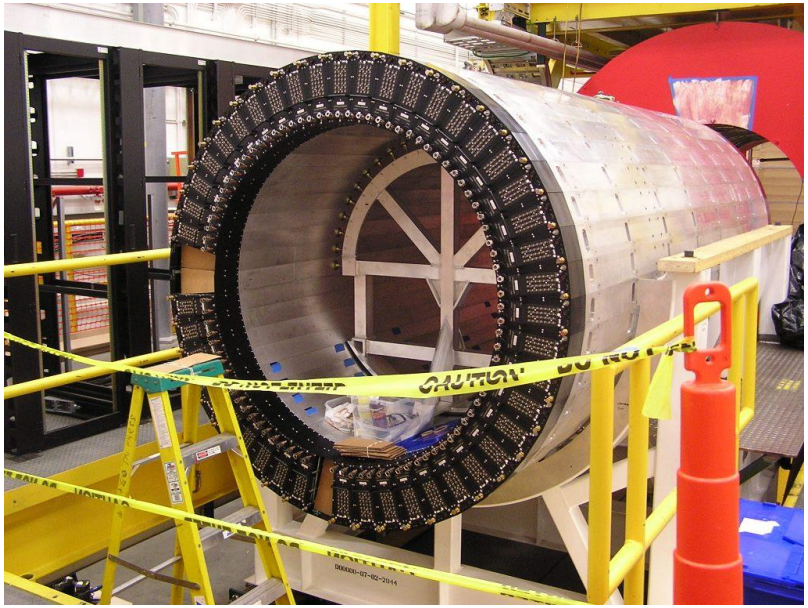


Forward Calorimeter:

- Angular coverage $2° < \theta < 11°$
- 2800 Pb-glass blocks: 4cm x 4 cm x 45 cm
- **$\sigma_E / E = 6\% / \sqrt{E} \oplus 2.0\%$**
- **$\sigma_{xy} = 6.4\ mm / \sqrt{E}$**

Barrel Calorimeter:

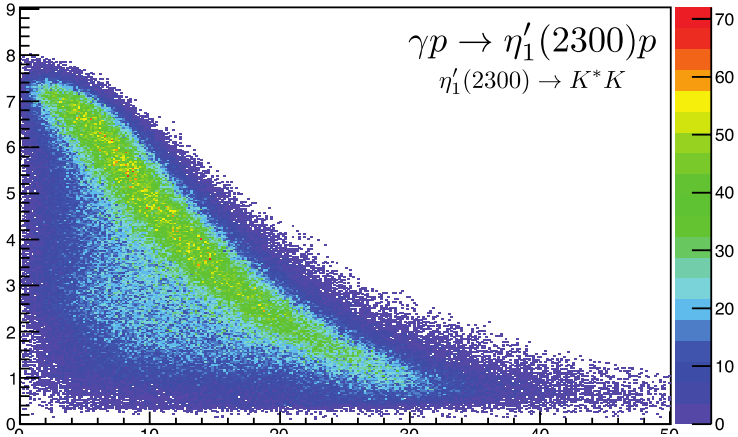
- Angular coverage $11° < \theta < 120°$
- 191 layers Pb:ScFib:Glue (37:49:14%)
- Double side readout (SiPM)
- **$\sigma_E / E = 6\% / \sqrt{E} \oplus 1.6\%$**
- **$\sigma_Z = 5\ mm / \sqrt{E}$**
- **$\sigma_t = 74\ ps / \sqrt{E} \oplus 33\ ps$**



Kaon Identification

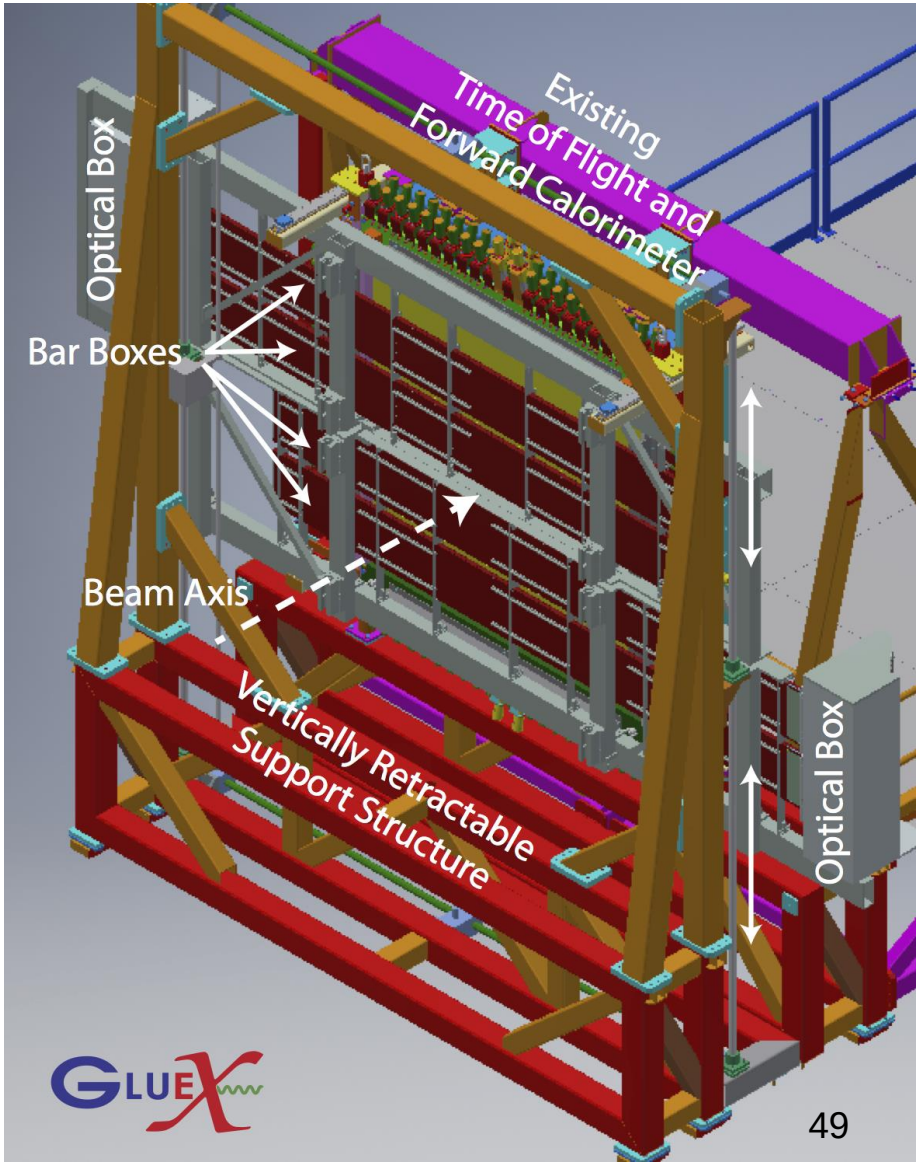
- Install quartz bars
  (used in BaBar DIRC)

  - improve K/π separation up to 4.0 GeV/c

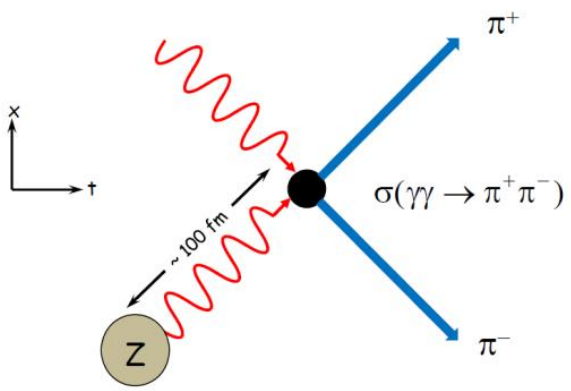


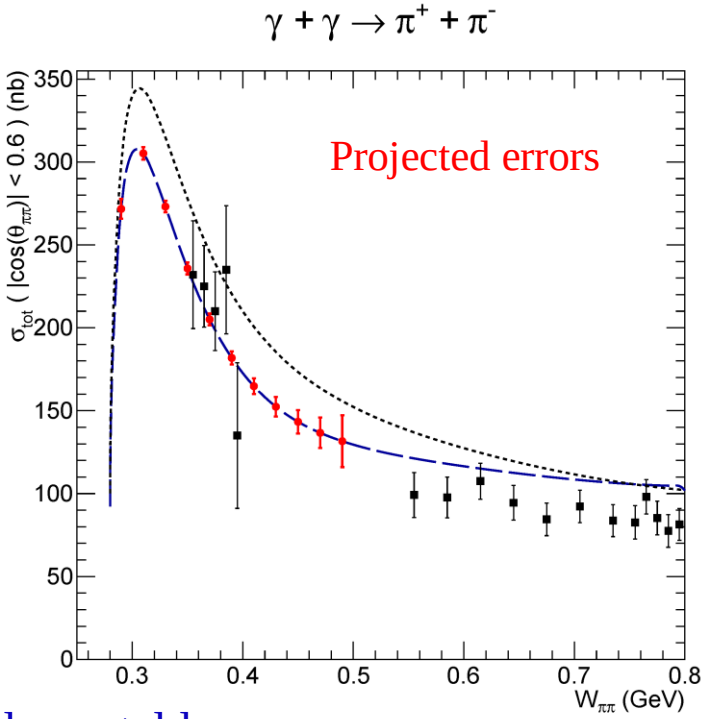
Eff = 15 % (no DIRC)
Eff = 33 % (with DIRC) purity 95 %

- installation scheduled for spring 2018



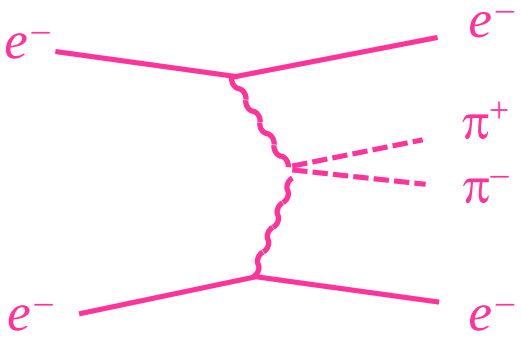
Charged Pion Polarizability

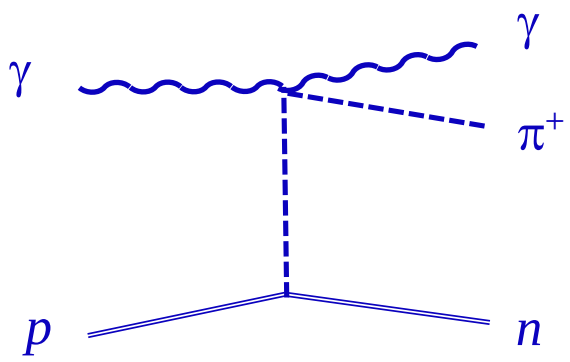


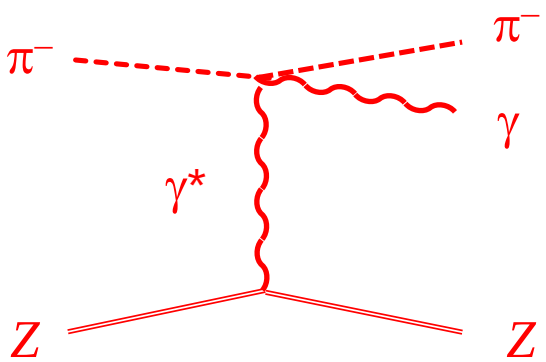


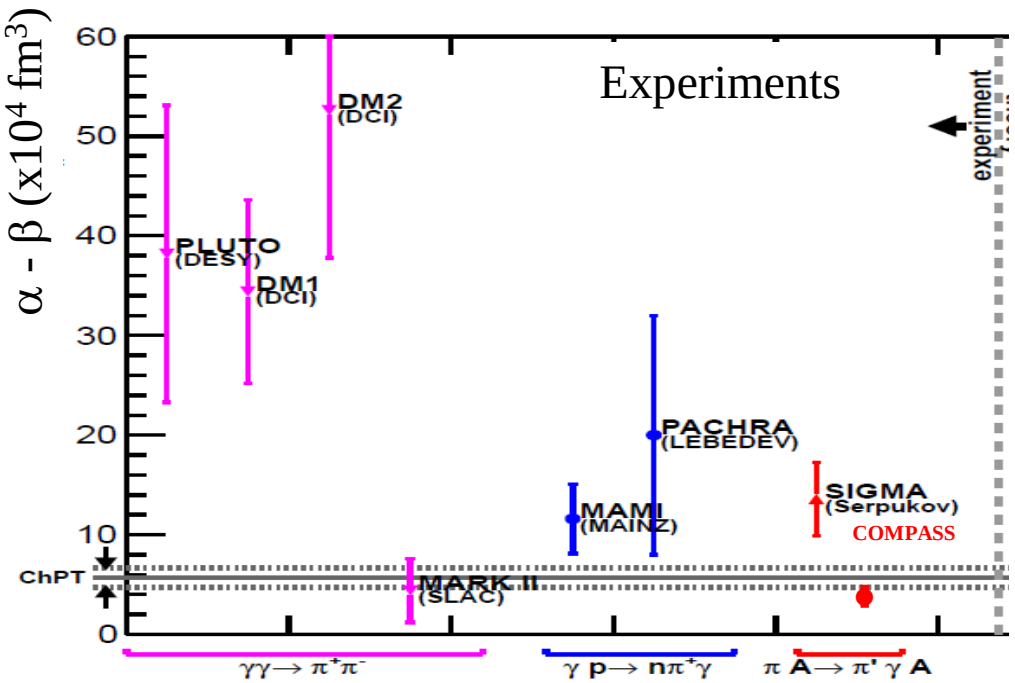
- Electric and magnetic dipole polarizabilities are fundamental low-energy properties of strong interactions
- Use Primakoff production γ A $\rightarrow$ π^+ π^- A to extract pion polarizability
  - *test χ_{PT} predictions*
- Use polarized photon beam to reduce background from ρ decays and $\mu^+\mu^-$
- Require new muon detector

Charged Pion Polarizability









- ChPT prediction: *Nucl. Phys. B 745 (2006)*

  $\alpha_\pi - \beta_\pi = (5.7 \pm 1.0) \cdot 10^{-4}$ fm^3

  $\alpha_\pi \approx - \beta_\pi$

- Latest measurement of COMPASS

  ($\pi^- \gamma \to \pi^- \gamma$) *PRL 114, 062002 (2015)*

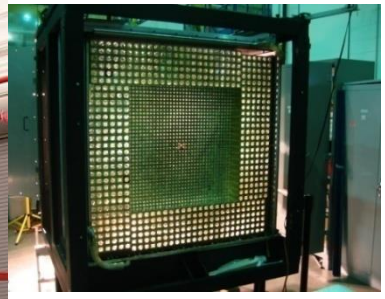
  $\alpha_\pi = (2.0 \pm 0.6 \pm 0.7) \cdot 10^{-4}$ fm^3

  assuming $\alpha_\pi = - \beta_\pi$

- GlueX expectation

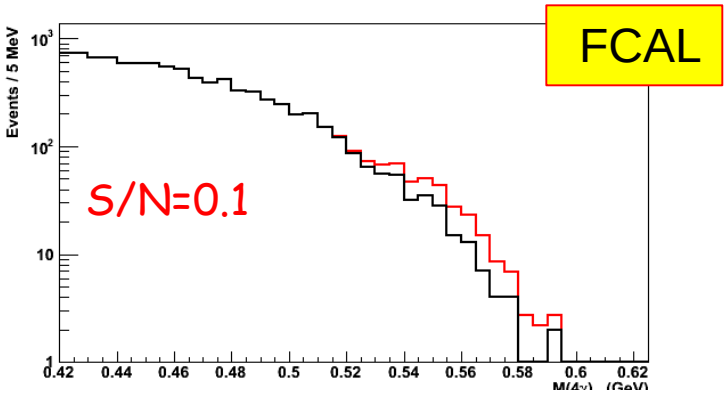
  $\sigma (\alpha_\pi - \beta_\pi) \sim 0.6 \cdot 10^{-4}$ fm^3

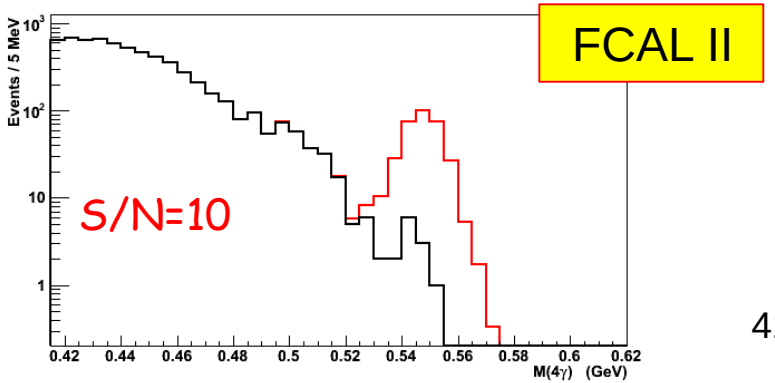
New Calorimeter for GlueX: FCAL-II



- **Replace the inner part of FCAL with the PWO insertion:**
  - 100x100 cm^2 in Size (2496 $PbWO_4$)
  - 2cm x 2cm x 18cm per module

signal: $\eta \to \pi^0\gamma\gamma$ background: $\eta \to 3\pi^0$





FCAL-II ($PbWO_4$) vs. FCAL (Pb glass)

Property	Improvement factor
Energy σ	2
Position σ	2
Granularity	4
Radiation-resistance	10

C Invariance

- Maximally violated in the weak force and is well tested
- SM prediction:
  BR(η→3γ) $<10^{-19}$ via P-violating weak interaction.
- Study constraints on CVPC from EDM
  - no constraints in the presence of a conspiracy or new symmetry; only the direct searches are unambiguous

M. Ramsey-Musolf, phys. Rev., D63 (2001);
talk at the AFCI workshop,
studies are in progress

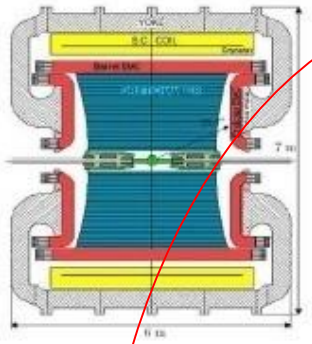
C Violating η neutral decays

Final State	Branching Ratio (upper limit)	Gammas in Final State
3γ	$< 1.6 \cdot 10^{-5}$	3
$\pi^0\gamma$	$< 9 \cdot 10^{-5}$	
$2\pi^0\gamma$	$< 5 \cdot 10^{-4}$	5
$3\gamma\pi^0$	Nothing published	
$3\pi^0\gamma$	$< 6 \cdot 10^{-5}$	7
$3\gamma 2\pi^0$	Nothing published	

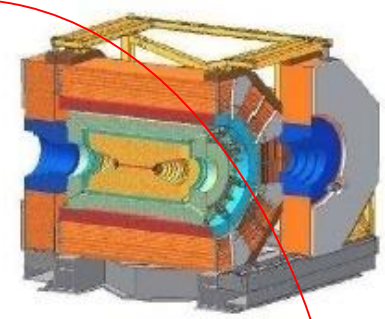
World competition in η decays

e^+e^- Collider

KLOE-2 at DAϕNE



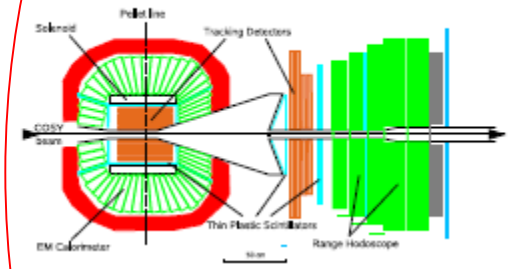
BESIII at BEPCII



Low energy η-facilities

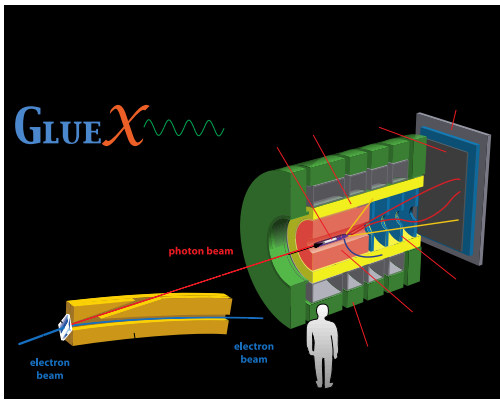
Fixed-target

WASA at COSY

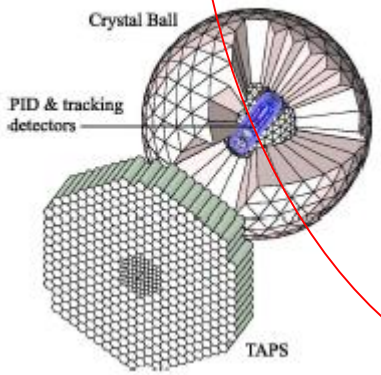


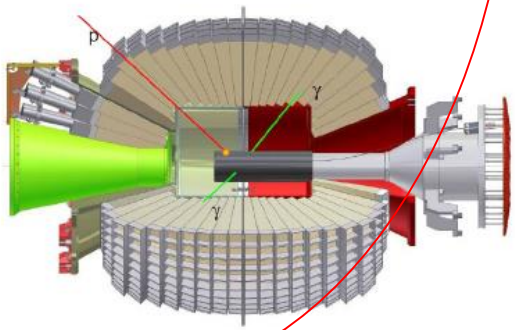
hadroproduction

High energy η-facility



Crystall Ball at MAMI





photoproduction