Introduction to the GlueX Experiment at JLab

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Experimental Physics Division Seminar, Jan 18, 2018

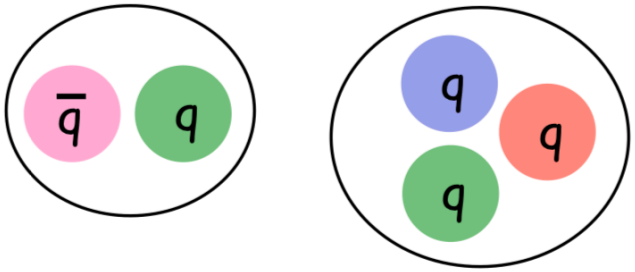
Jefferson Lab
Thomas Jefferson National Accelerator Facility

Outline

1. Spectrum of Mesons
2. The GlueX experiment
3. Early Results
4. Future Prospects

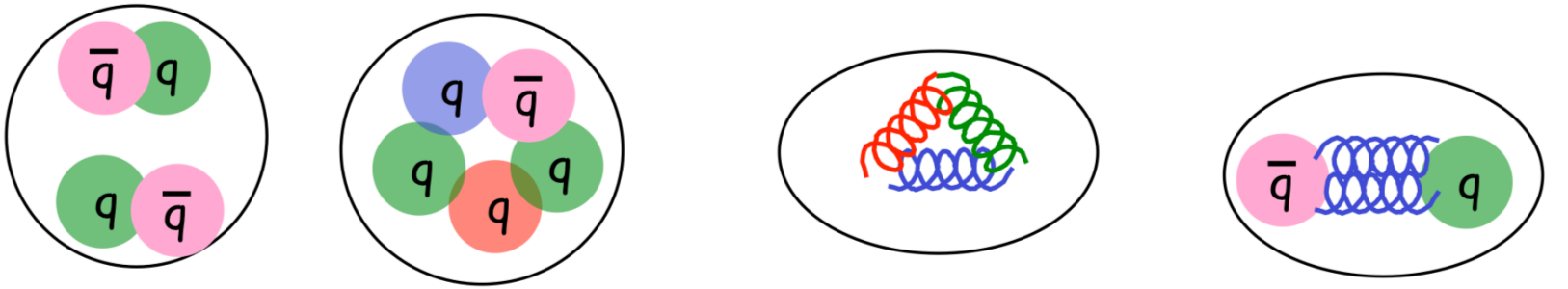
Quarks are confined inside colorless hadrons

Quark configurations observed in nature



mesons nucleons

Many other configurations are allowed by QCD, but do they exist?

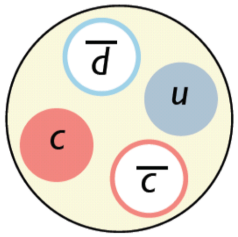


molecule pentaquark glueball meson hybrid meson

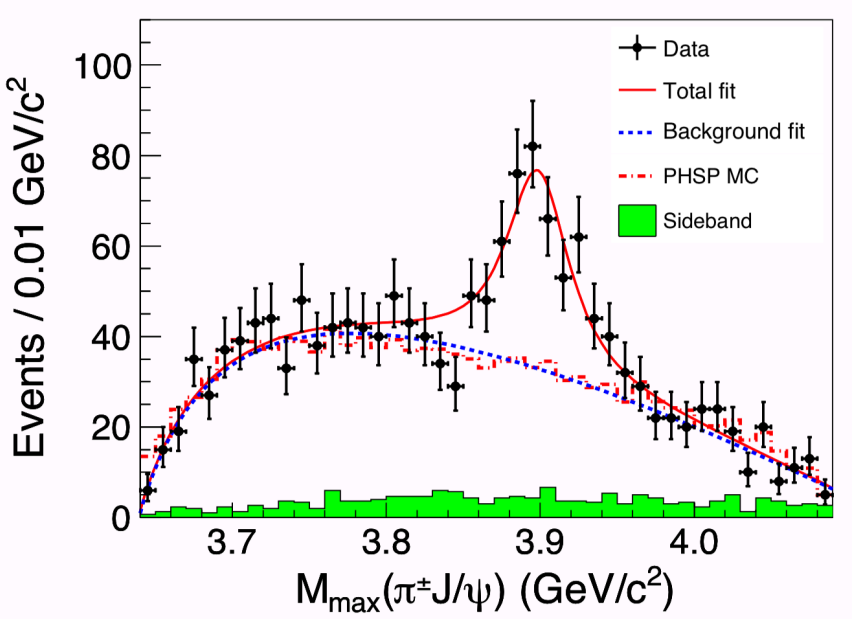
Tetraquark and Pentaquark Candidates

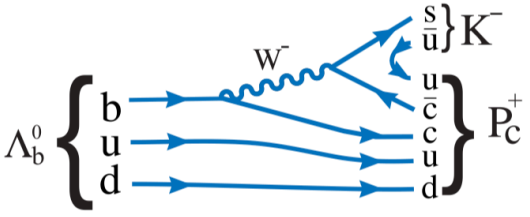
$$e^+e^- \to \pi^+\pi^- J/\psi$$

$$\Lambda_b^0 \to J/\psi\, p\, K^-$$

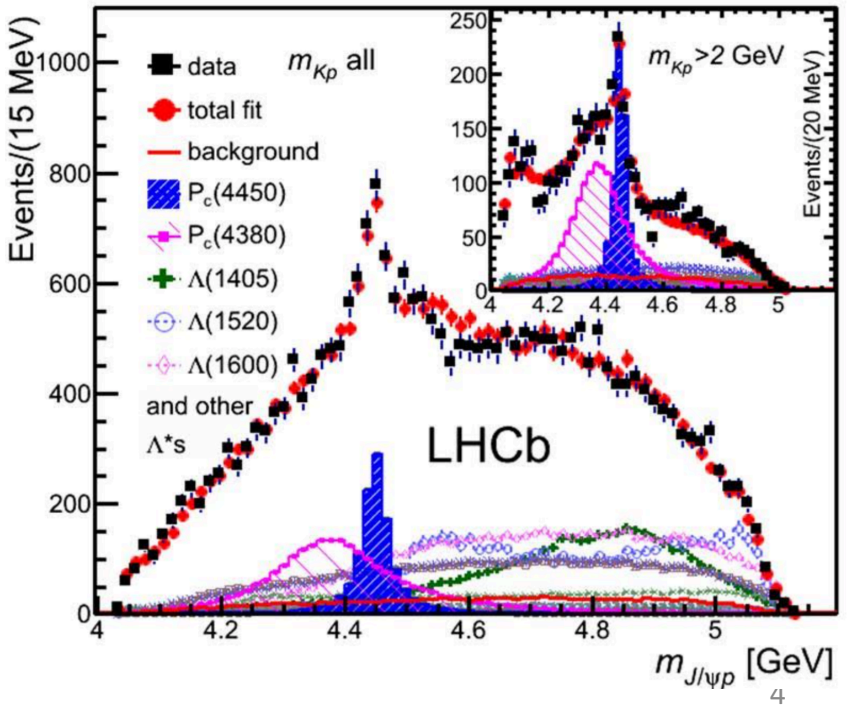


BESIII PRL 110 (2013) 252001
BELLE PRL 110 (2013) 252002





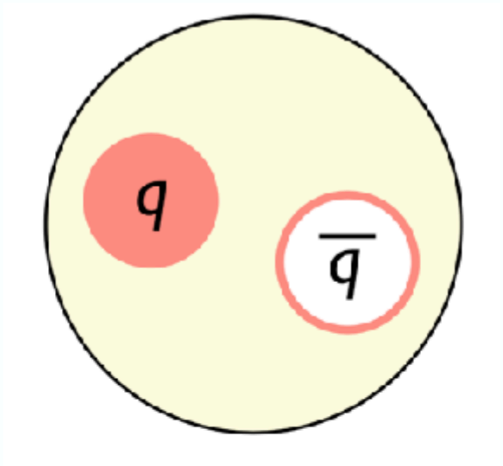
LHCb PRL 115 (2015) 072001

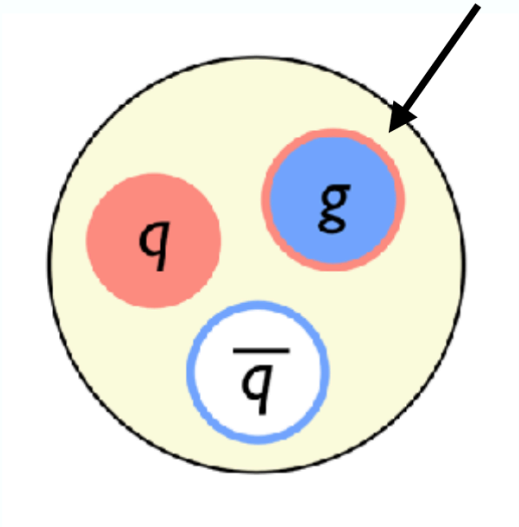


Meson Quantum Numbers

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

"constituent gluon"
$(J^{PC}) = 1^{+-}$
M ~ 1.0–1.5 GeV





"Normal" Meson

"Hybrid" Meson

Allowed J^{PC} : 0^{-+}, 0^{++}, 1^{--}, 1^{+-}, 2^{++}, …
Forbidden J^{PC}: 0^{--}, 0^{+-}, **1^{-+}**, 2^{+-}, …

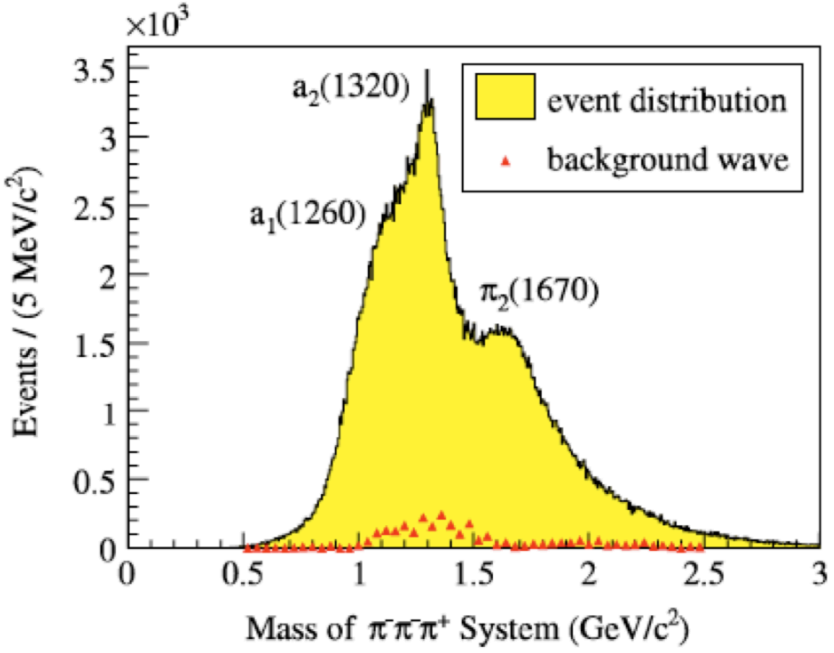
Allowed J^{PC} : 0^{-+}, **1^{-+}**, 2^{+-}, …

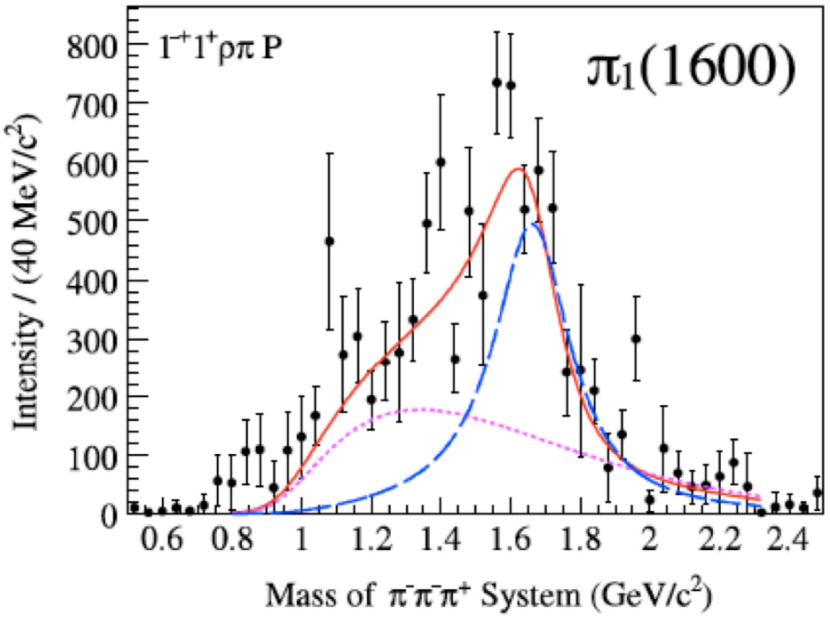
Lightest Hybrids: M ~ 2.0 – 2.6 GeV

COMPASS: Exotic 1^{-+} $\pi_1(1600)$->$\pi^+\pi^-\pi^-$

Analysis of π^-Pb $\rightarrow$ $\pi^+\pi^-\pi^-$Pb at COMPASS

PRL 104, 241803 (2010)





~0.4 M events

Intensity =1.7% of total

COMPASS: Phase Motion of Exotic

COMPASS PRL 104 (2010) 241803

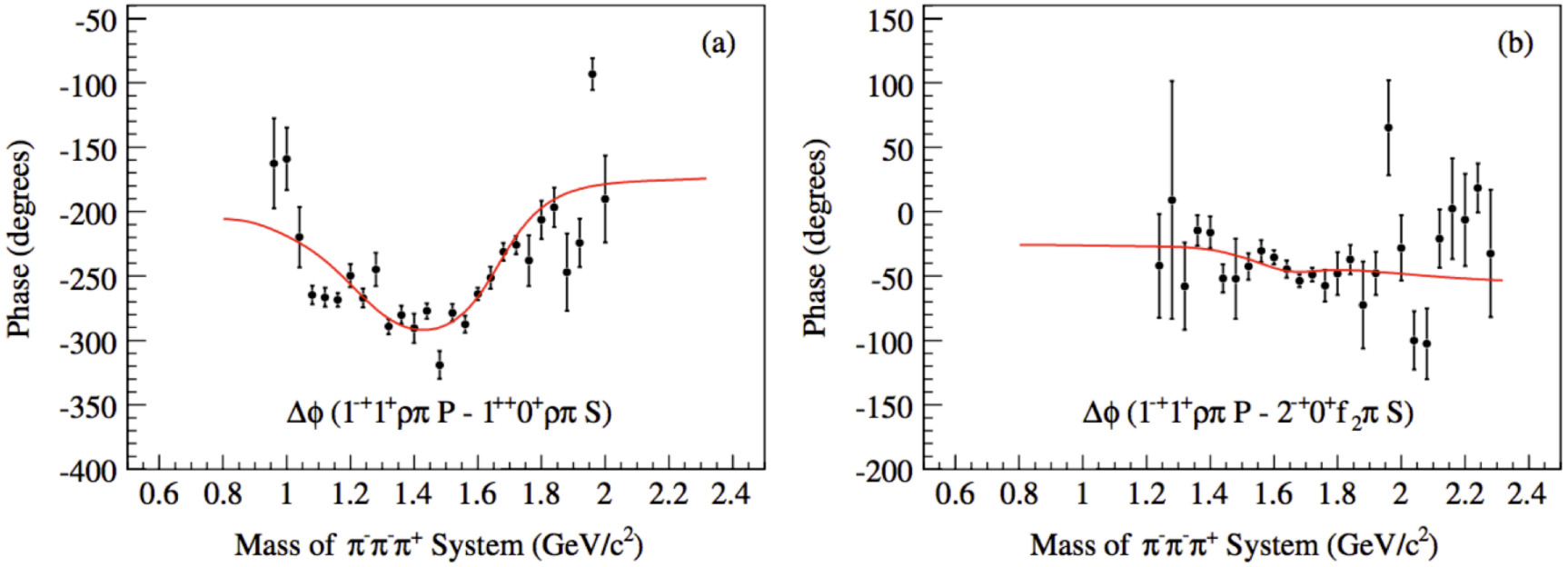
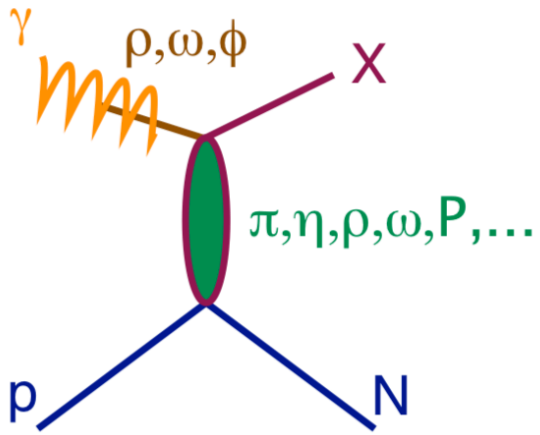


FIG. 3 (color online). Phase differences of the exotic $1^{-+}1^{+}\rho\pi P$ wave to the $1^{++}0^{+}\rho\pi S$ (a) and the $2^{-+}0^{+}f_2\pi S$ (b) waves. The data points represent the result of the fit in mass bins; the lines are the result of the mass-dependent fit.

Photoproduction Mechanisms



ρπ,ρω	→	π_1
ωω,ρρ	→	η_1
ωω,ρρ,ϕω	→	η'_1
ρP	→	b_0
ωP	→	h_0
ωP, ϕP	→	h'_0
ωπ,ρη,ρP	→	b_2
ρπ,ωη,ωP	→	h_2
ρπ,ωη,ϕP	→	h'_2

Simple quantum number counting for production: $(I^G)J^{PC}$ up to L=2

P = Pomeron exchange

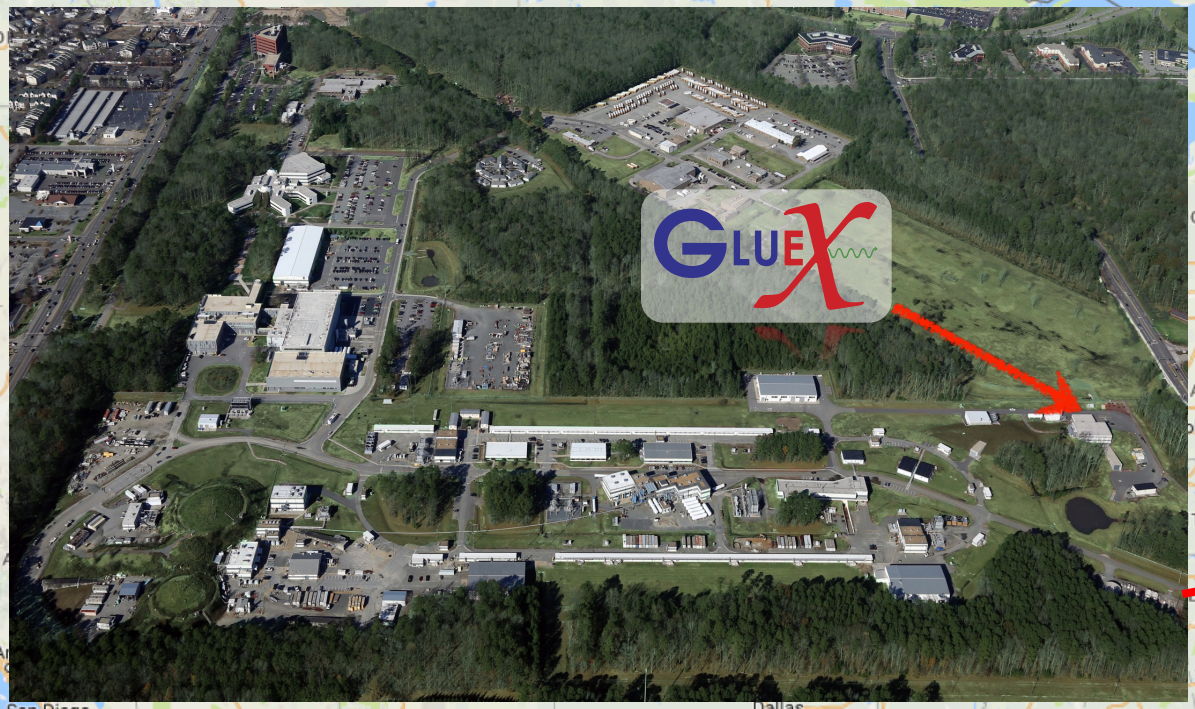
ρπ is charge-exchange only

Can couple to all the lightest exotic hybrid nonets through photoproduction and VMD.

Linear polarization is a filter on the naturality of the exchanged particle.

Cite from: C. A. Meyer GlueX Design Review

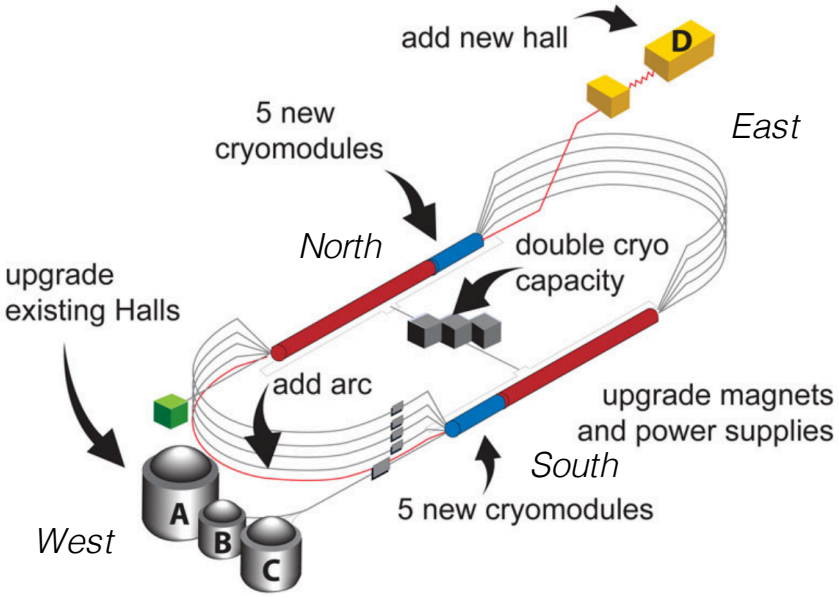
Introduction

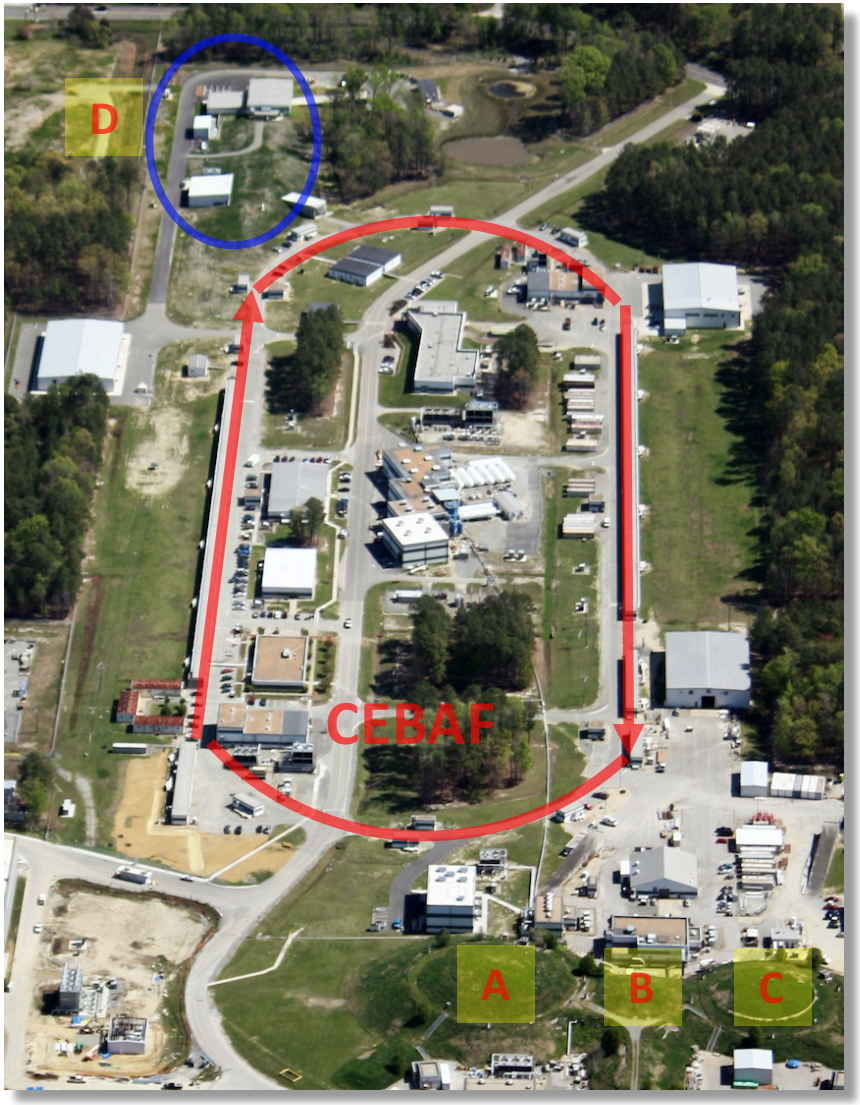


Thomas Jefferson
(1743–1826)

Thomas Jefferson National Accelerator Facility (Jefferson Lab)

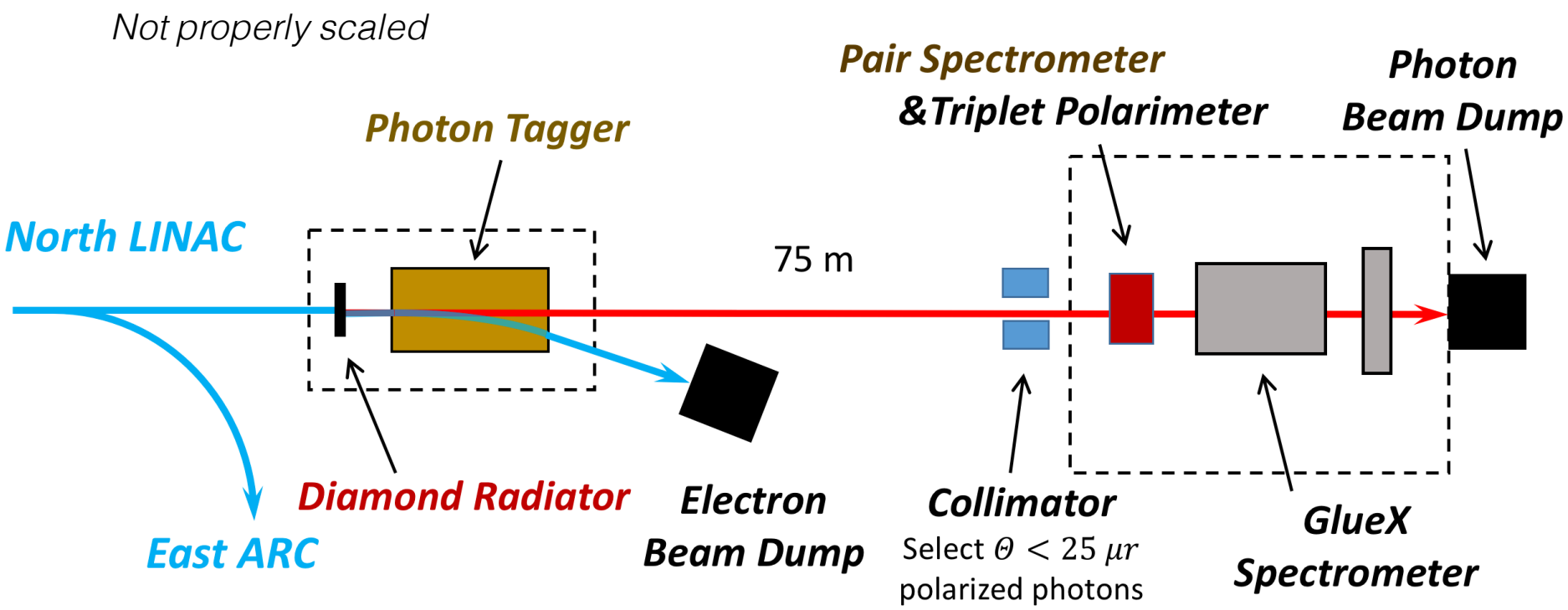
The Accelerator: CEBAF



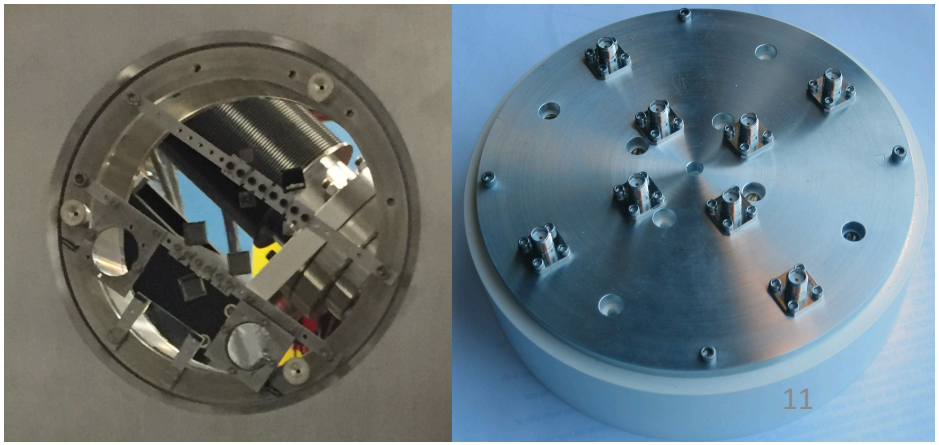


- The 12 GeV upgrade is coming to the accomplishment
- Accelerator: 2.2 GeV/pass
- Halls A, B, C: 1-5 passes <11 GeV
- Hall D: 5.5 passes →12 GeV
- Halls A&D started data taking in 2016 spring
- Halls B&C started data taking in 2017 spring

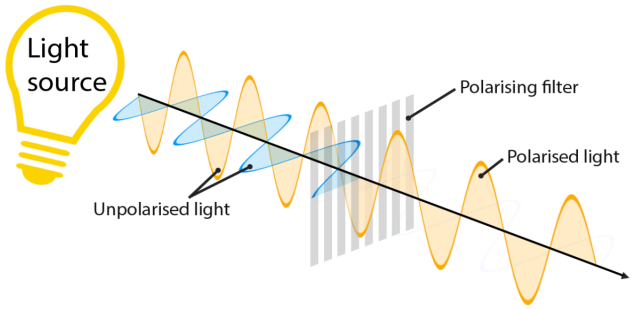
The GlueX Experiment: Photon Beamline



- Photon beam generated via coherent bremsstrahlung off thin diamond radiator (20μm x 3mm x 3mm)
  - Photon energies tagged by scattered electrons
- Photon linear polarization P$_\gamma$ ~ 40% in peak
- Design intensity of 10^8 γ/s in peak

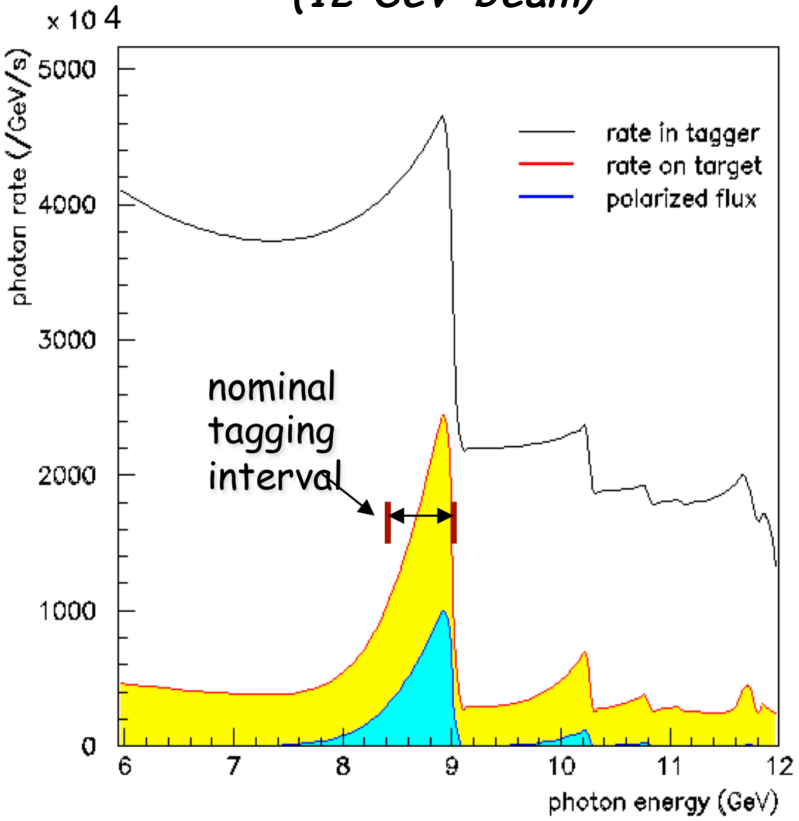


Linearly polarized photon beam

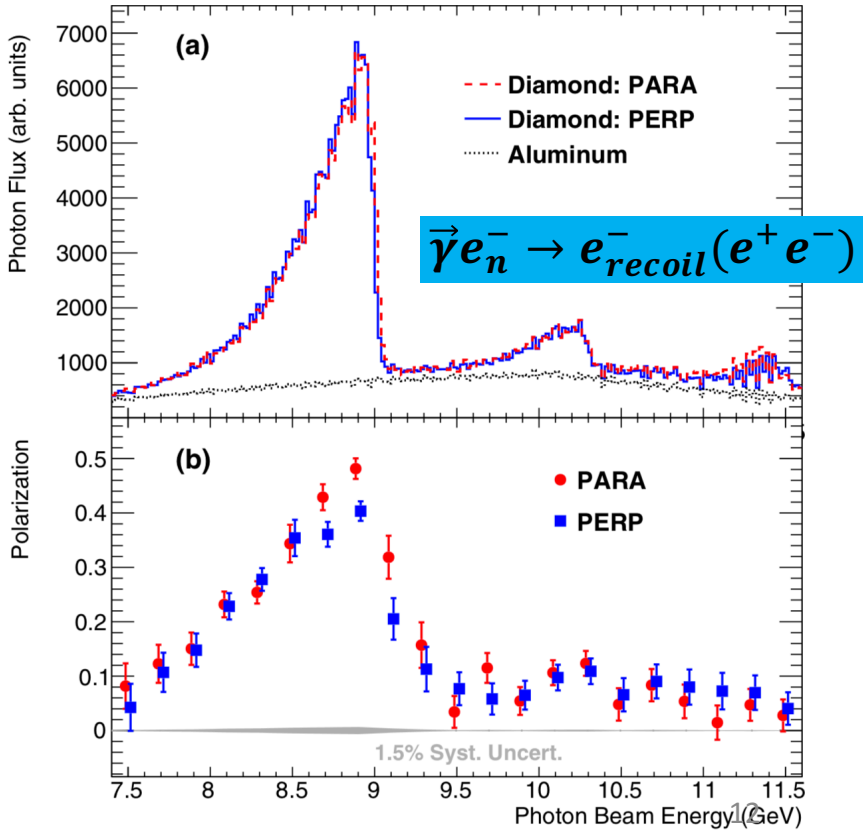


1. The beam photons are predominantly produced along the direction of the incident electron beam
2. Angular distribution for coherent bremsstrahlung is narrower than incoherent process.

Calculated Spectrum (12 GeV beam)



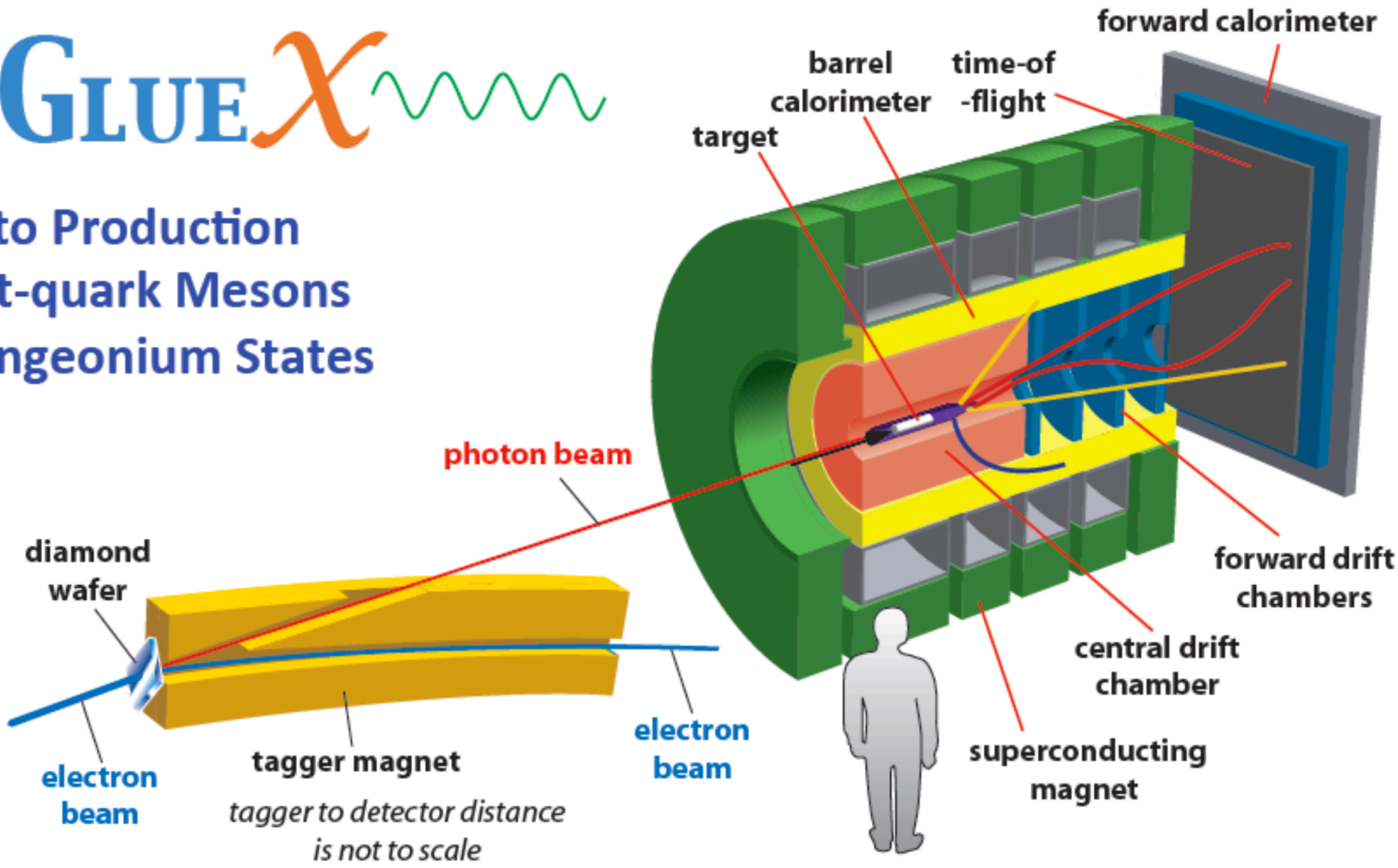
Measured Spectrum



The GlueX Detector

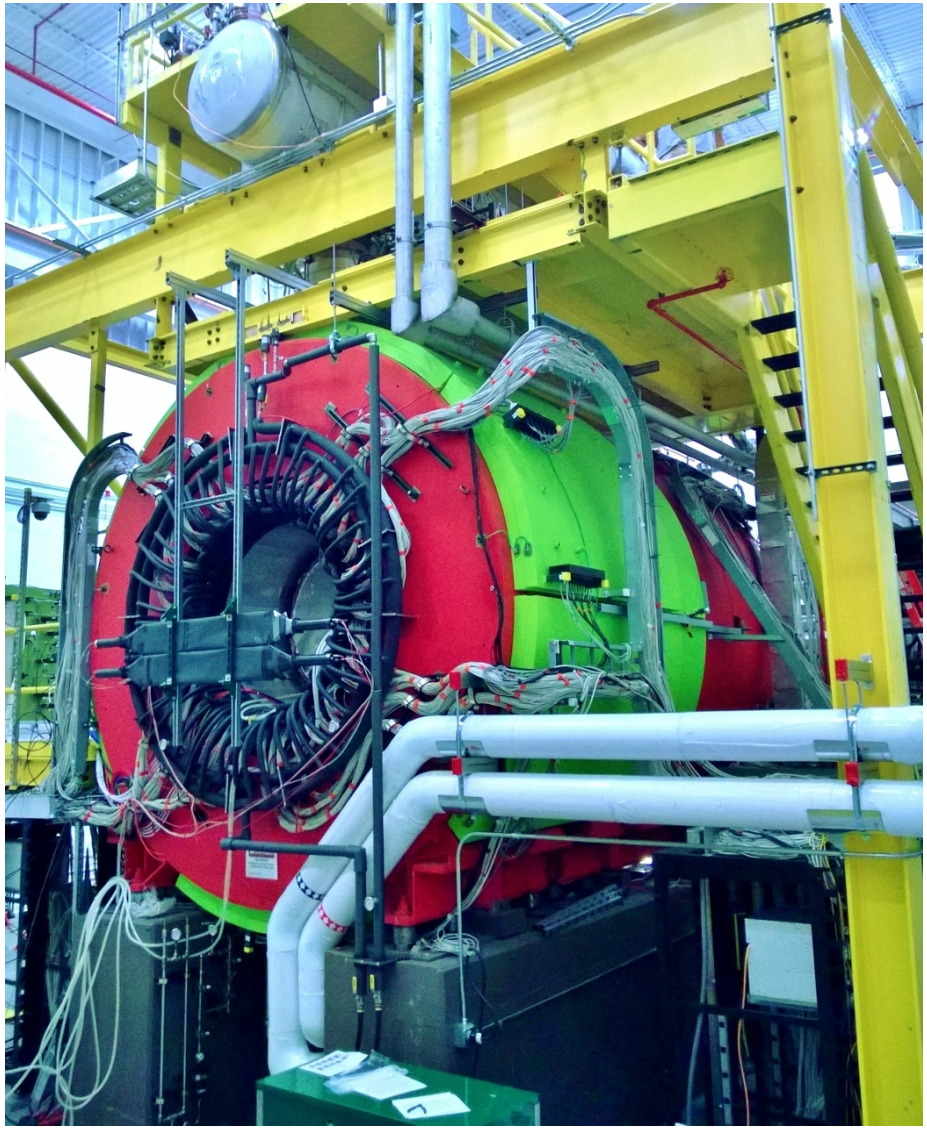
GLUEX

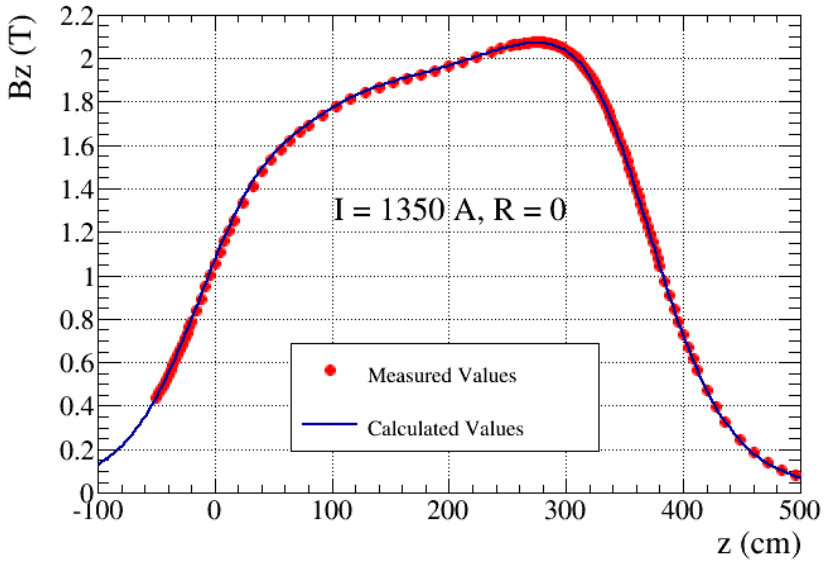
Photo Production
Light-quark Mesons
Strangeonium States



Equipment in Hall D

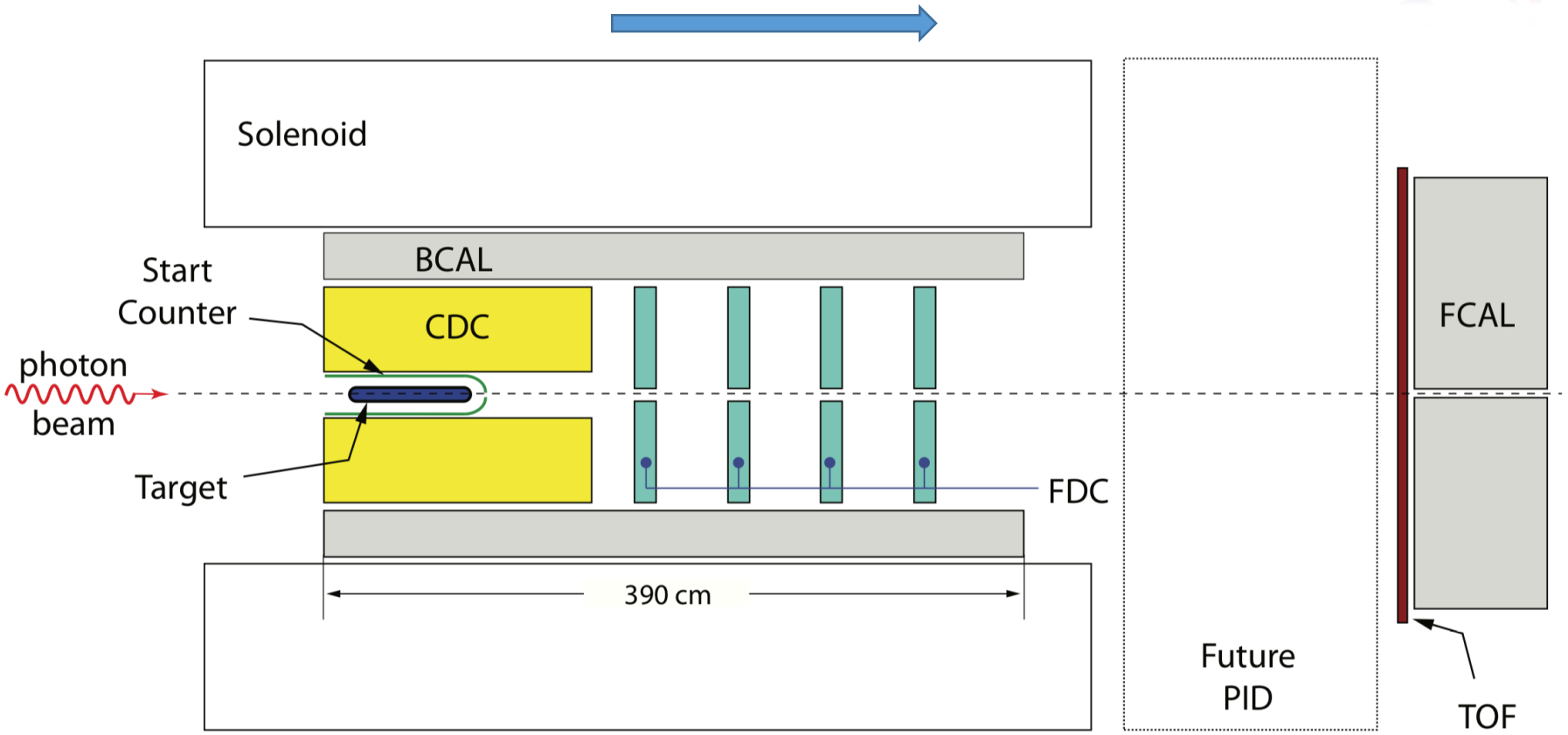
The Superconducting Solenoid

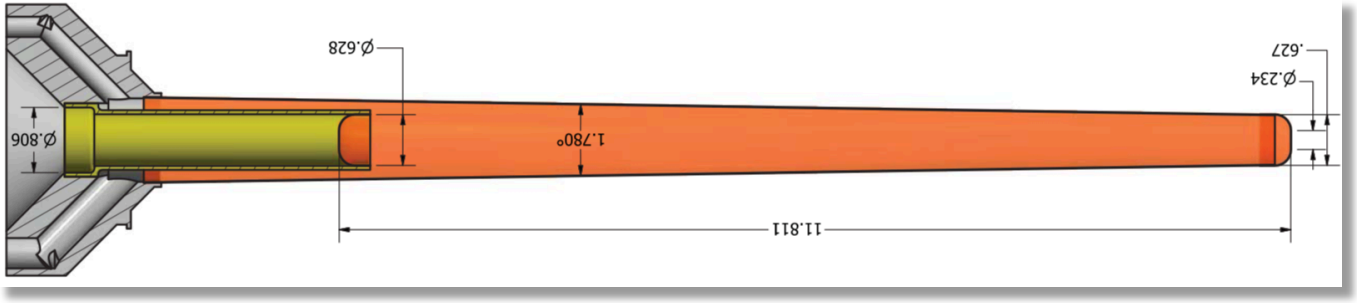




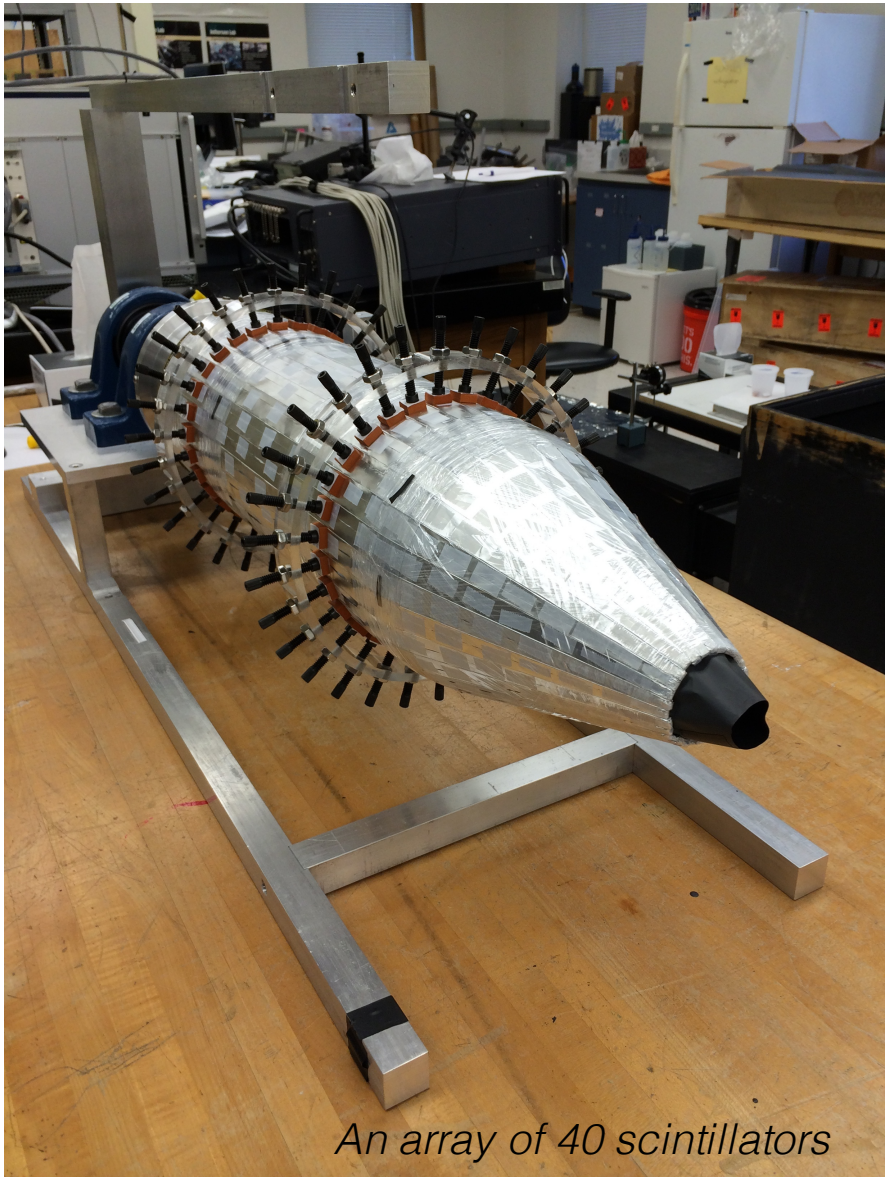
1. The solenoid first built and used in the Large Aperture Solenoid Spectrometer (LASS) at SLAC in 1971;
2. Three coils were later used a second time for the $\mu \rightarrow e\gamma$ experiment at Los Alamos National Lab from 1993 to1995.
3. All four LASS coils have been extensively repaired, refurbished, tested and assembled at Jefferson Lab. The final GlueX solenoid has a bore of 1.85 m and measures 4 m long.

The GlueX Detector and Target

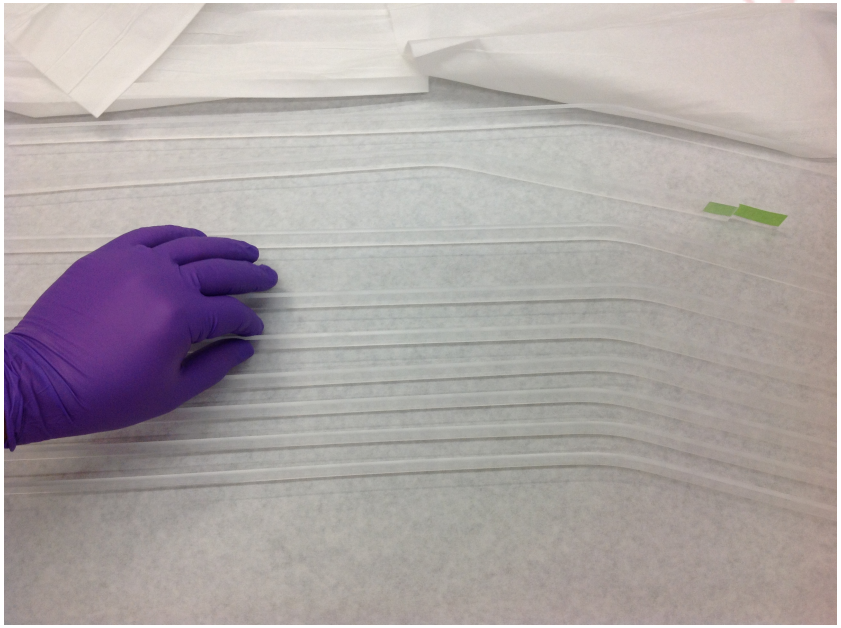




The Start Counter

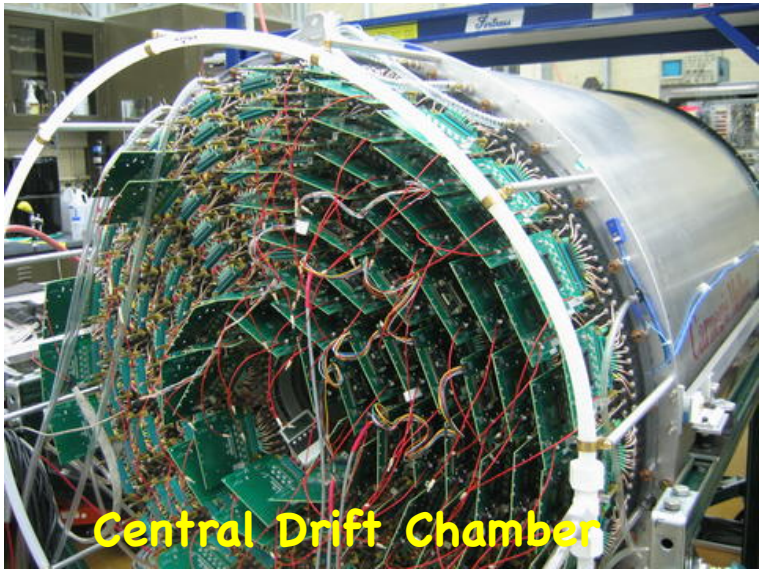


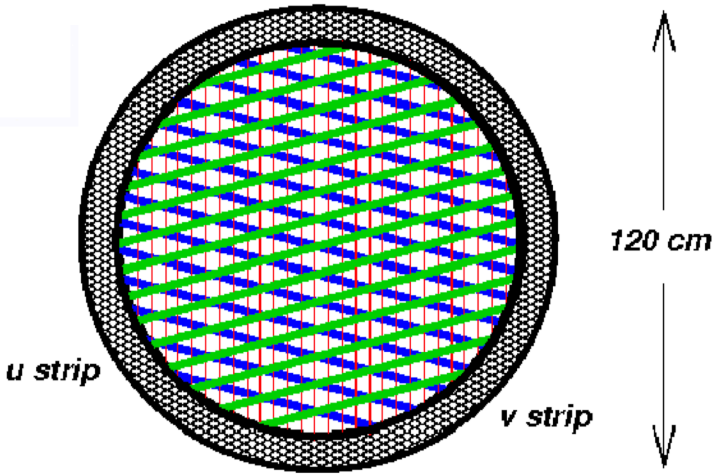
An array of 40 scintillators



1. To identify the electron beam bucket associated with the detected particles;
2. The start counter with a resolution of about 270 ps will provide the necessary information to identify the correct beam bunch from which the event originated.
3. This arrangement makes is possible to trigger on charged particles at angles between 3.0° and 134° over the full length of the target.

Central and Froward Drift Chamber

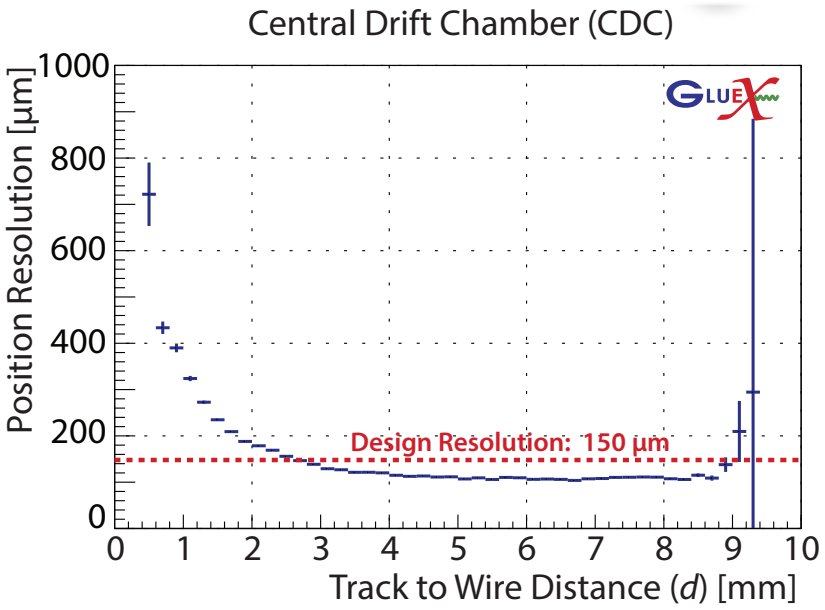


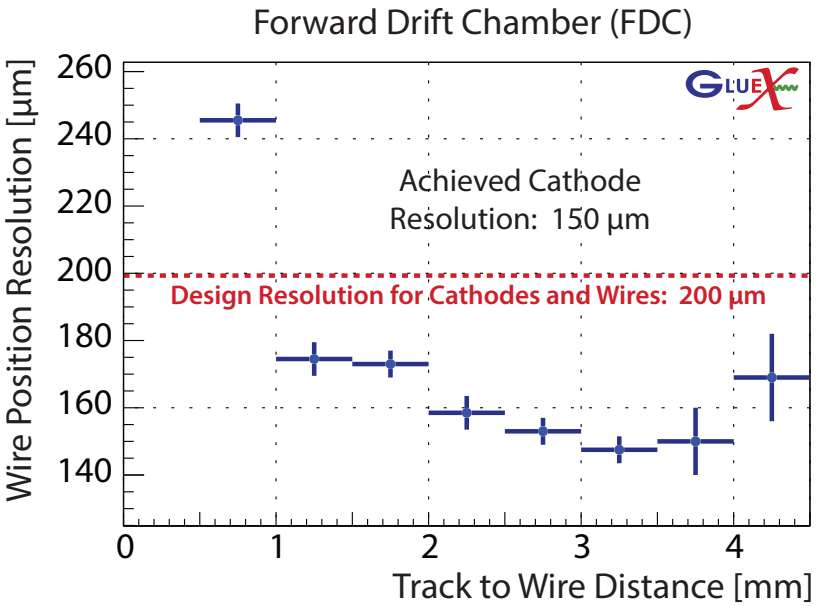


4 packages x 6 planes

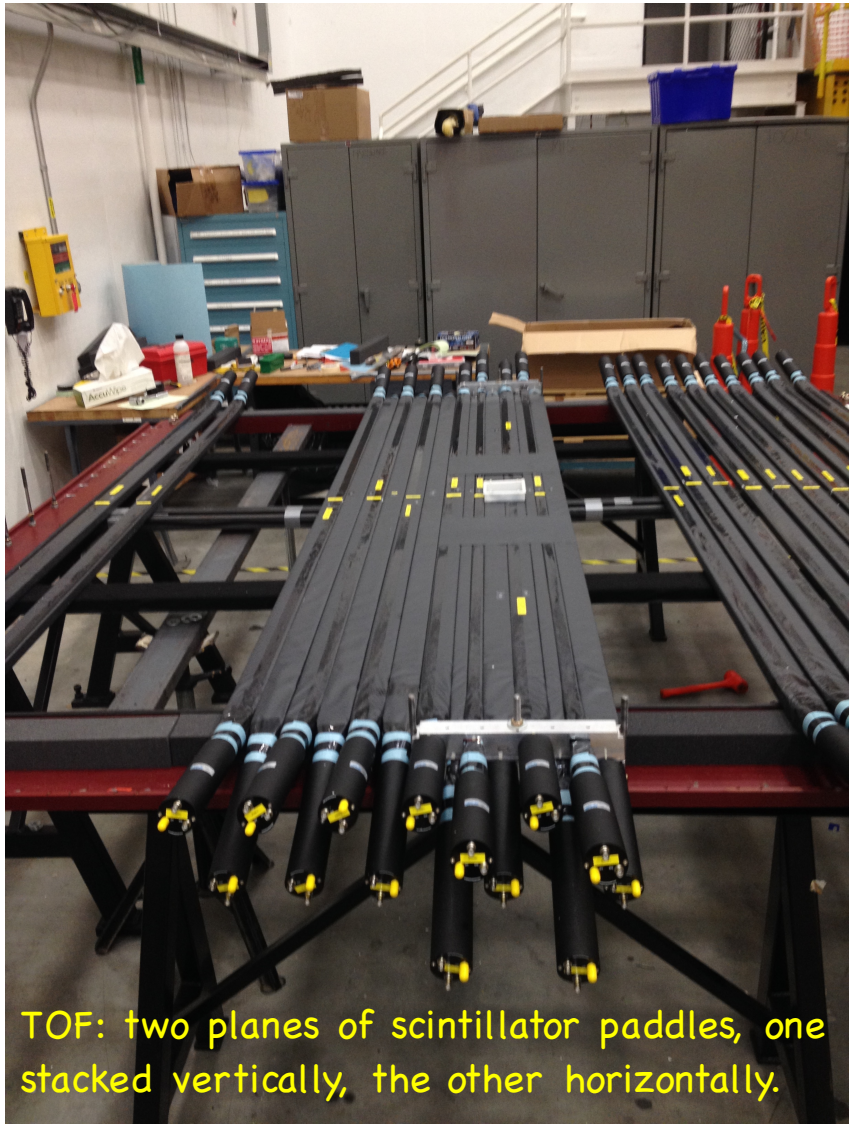
Drift Chamber Performance

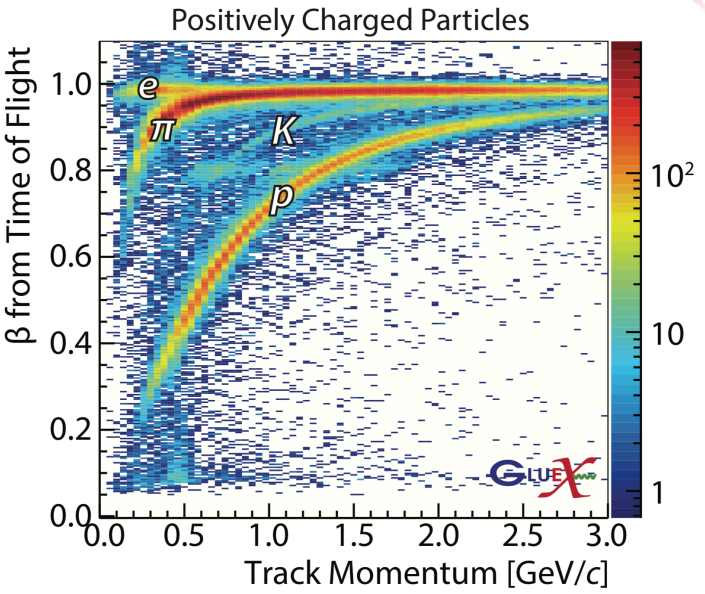
Drift Chamber exceed designed position resolution

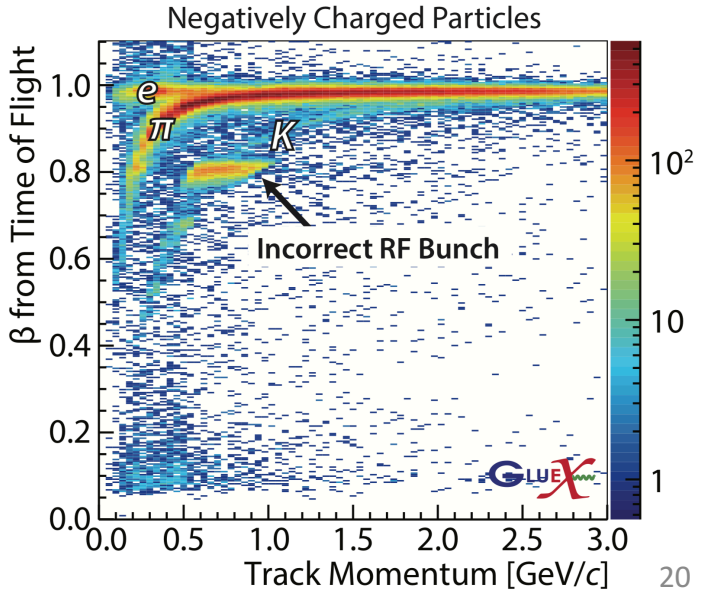




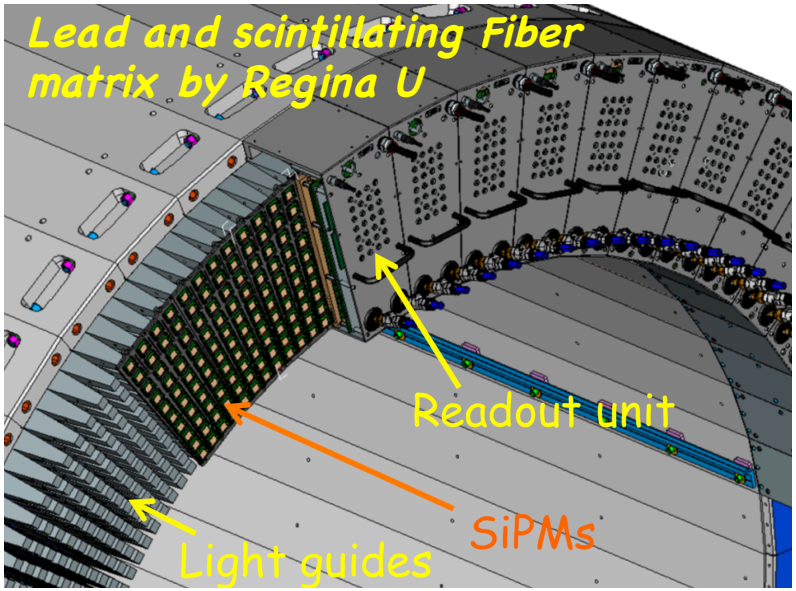
Time of Flight and PID

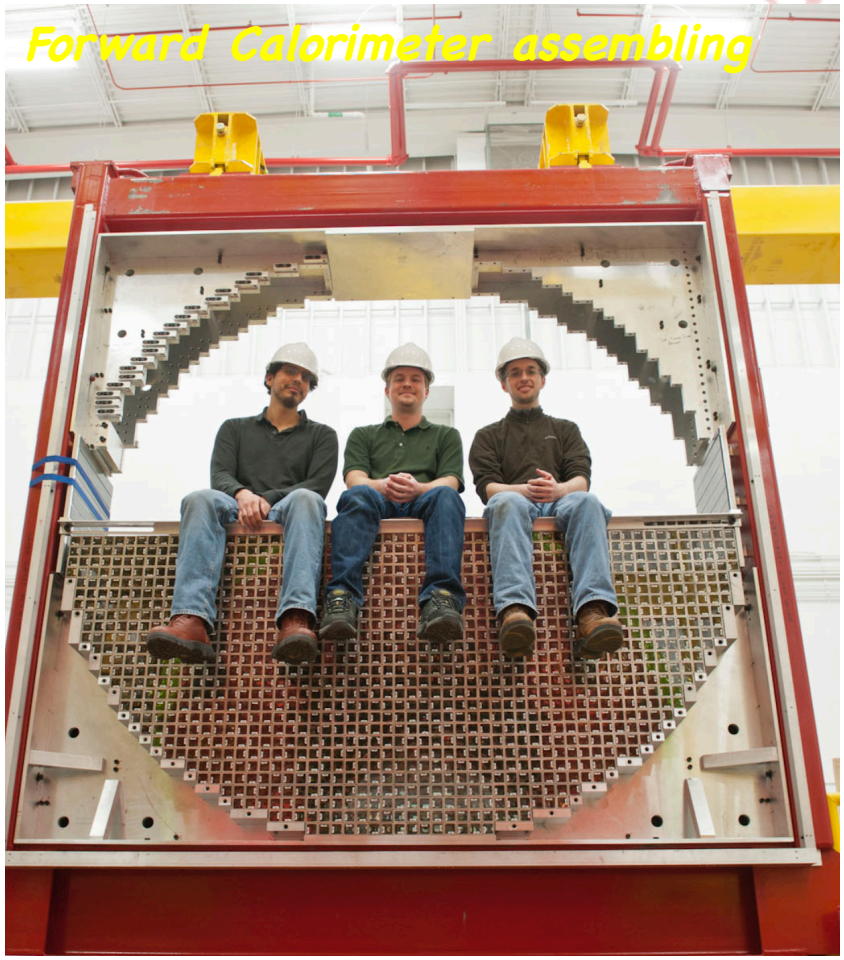






Barrel and Froward Calorimeter



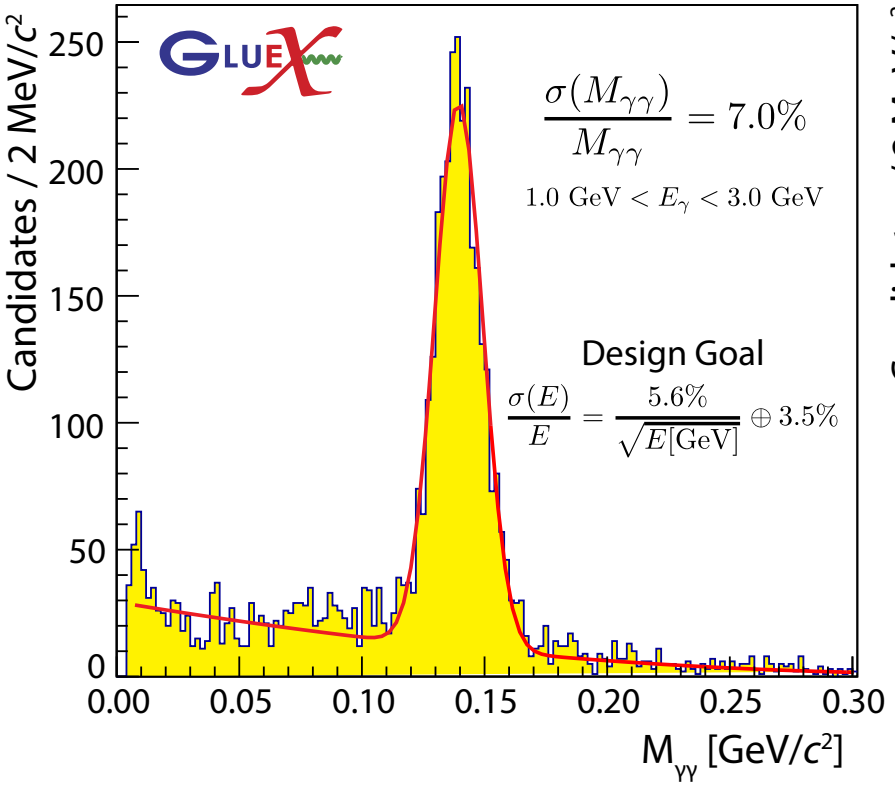


FCAL: consisting of 2800 element 4 x 4 x 45 cm lead glass bars, light produced is measured by PMTs

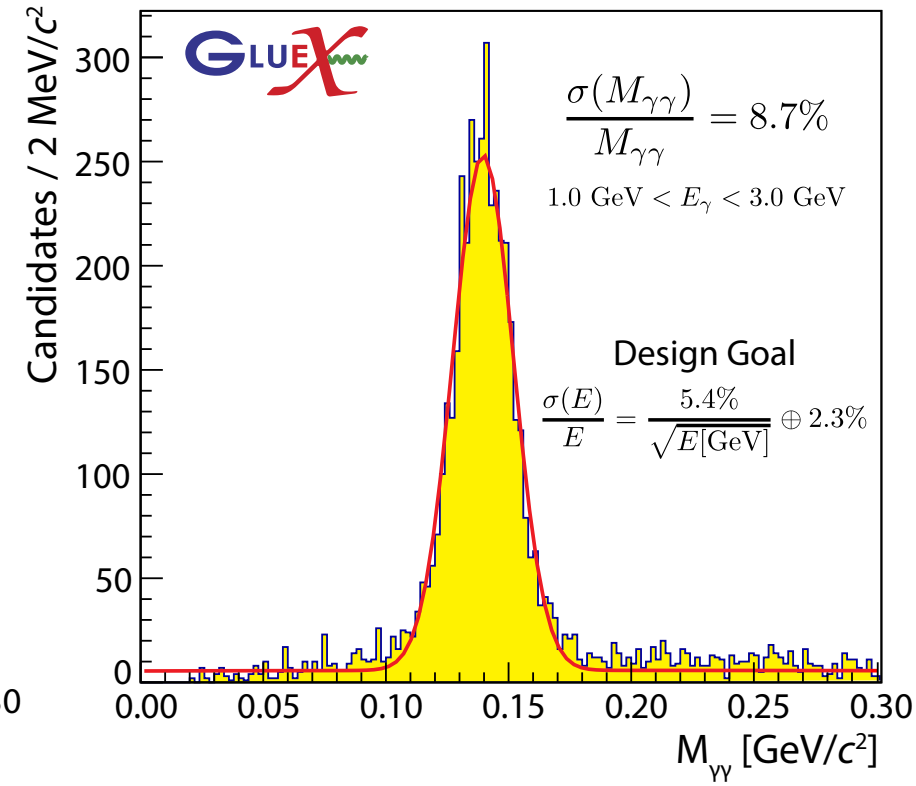
Performance of Calorimeter

Calorimeter approaching designed energy resolution

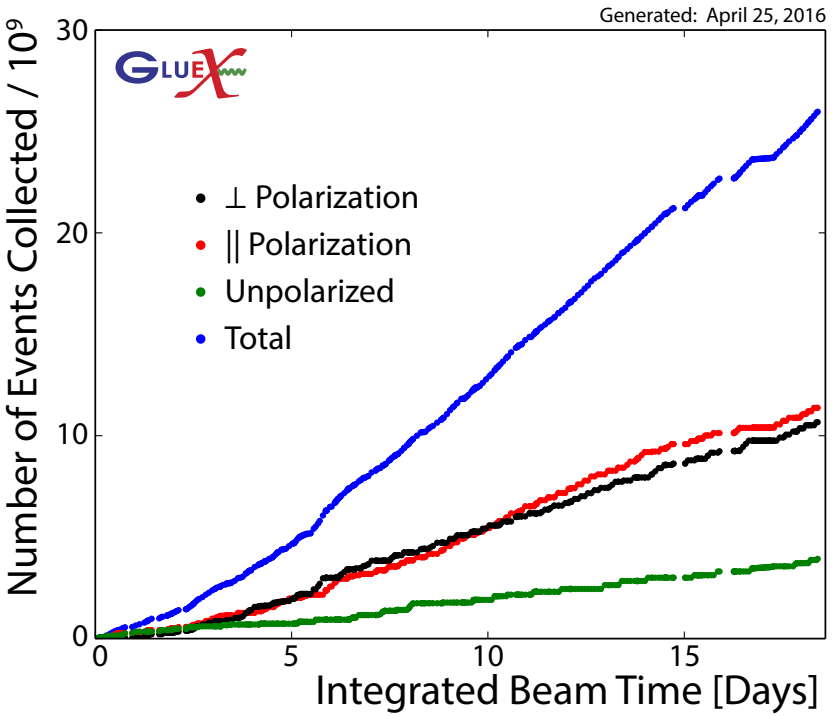
Forward Lead Glass Calorimeter



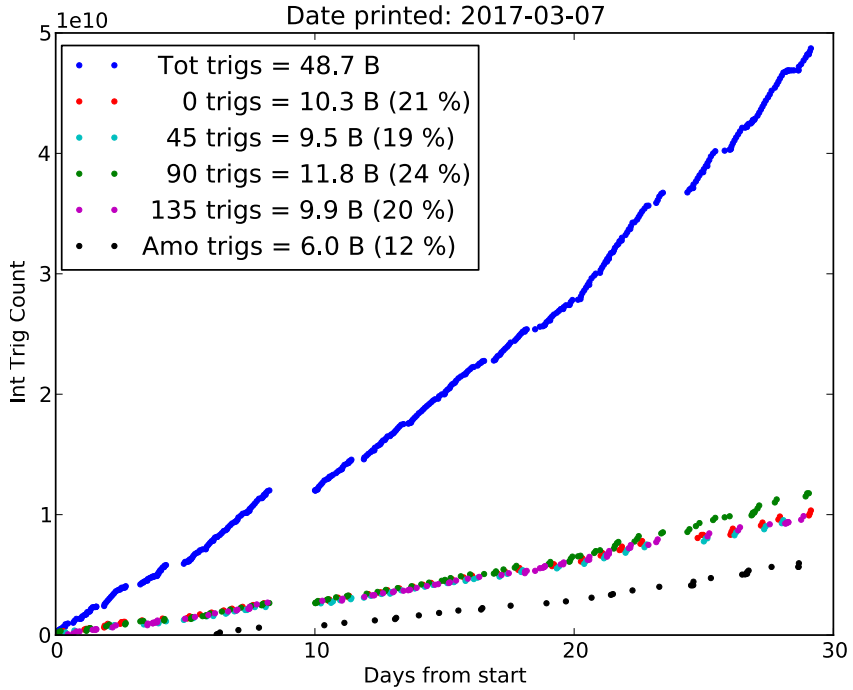
Barrel Lead-Scintillating Fiber Calorimeter



Data Sets



Initial physics data (≈ 80 h)



2018 low-intensity data

2014-2015: Detector Commissioning
Spring 2016: GlueX Engineering Run
Spring 2017: First Physics runs
April 2017: First Physics Result published

The GlueX Collaboration

Wuhan University joined the GlueX Collaboration in 2016; GlueX/BESIII: A Workshop on Common Topics was held in August 2017 in Beijing; In December 2017 IHEP (CAS) was approved to be a member of the GlueX Collaboration.

The GlueX Collaboration

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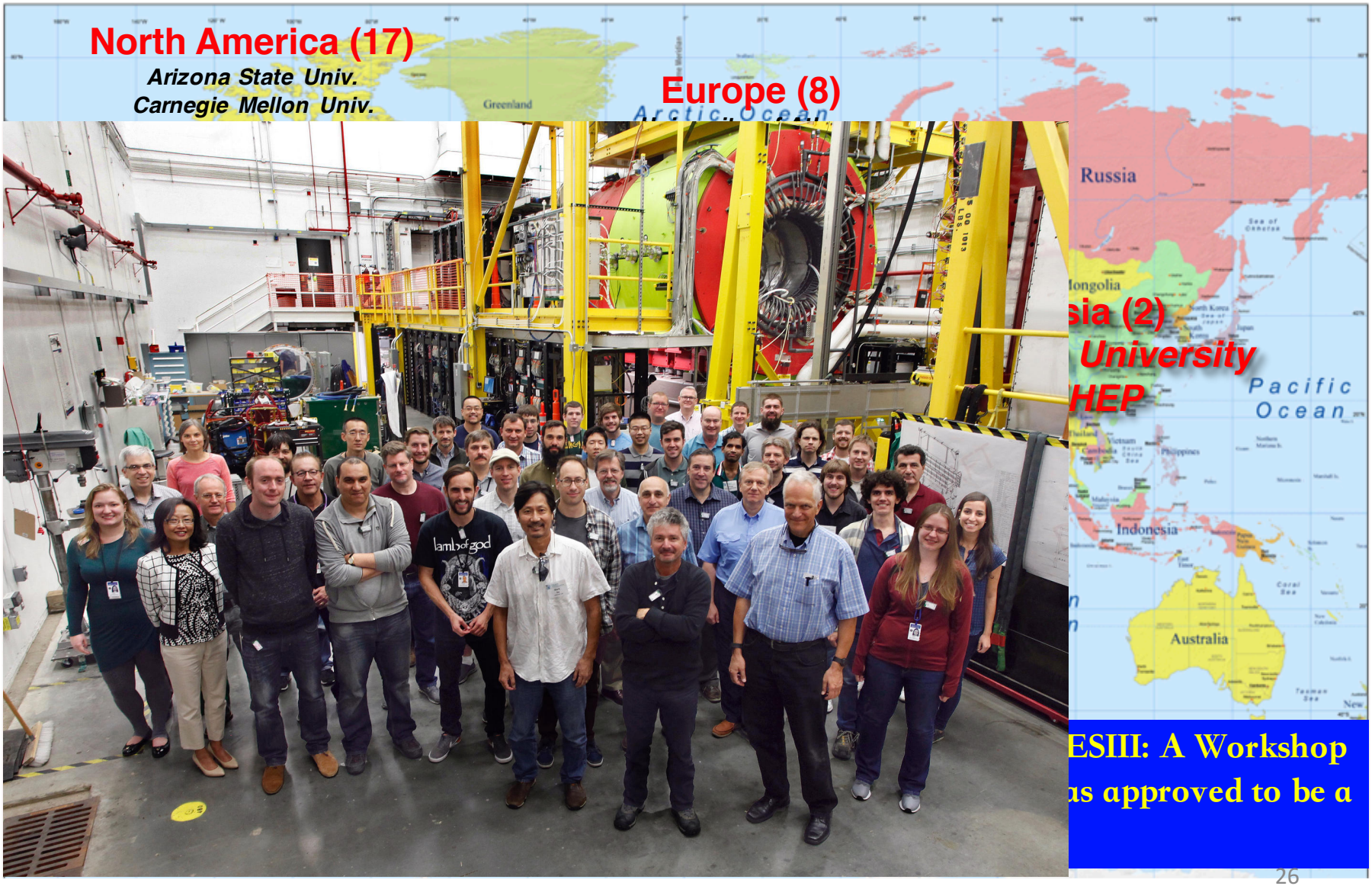
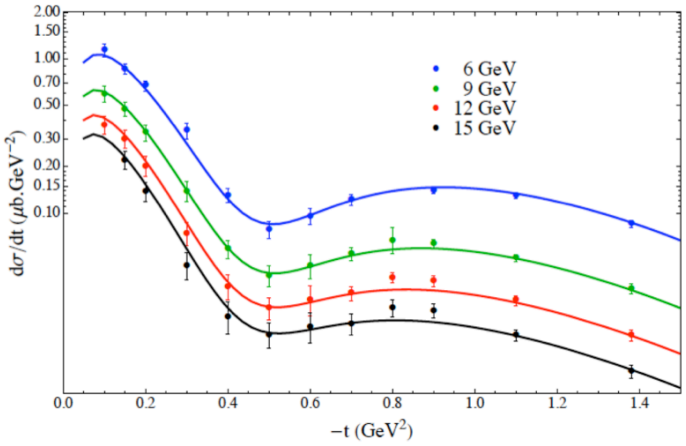
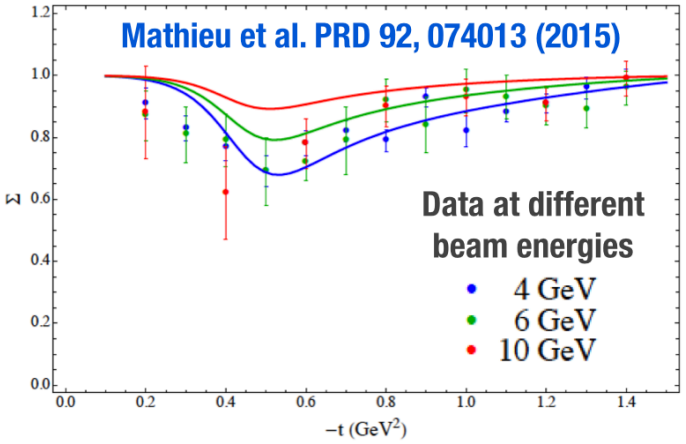


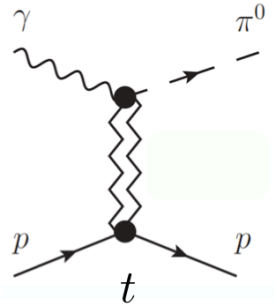
Psuedoscalar mesons π^0/η Photoproduction

JPAC Regge Model





SLAC: PRD 4, 1937 (1971)



Exchange J^{PC}

$1^{--} : \omega, \rho$

$1^{+-} : b, h$

$$\frac{d\sigma}{dt} = \sigma_{\perp} + \sigma_{\parallel} = |\rho + \omega|^2 + |b + h|^2$$

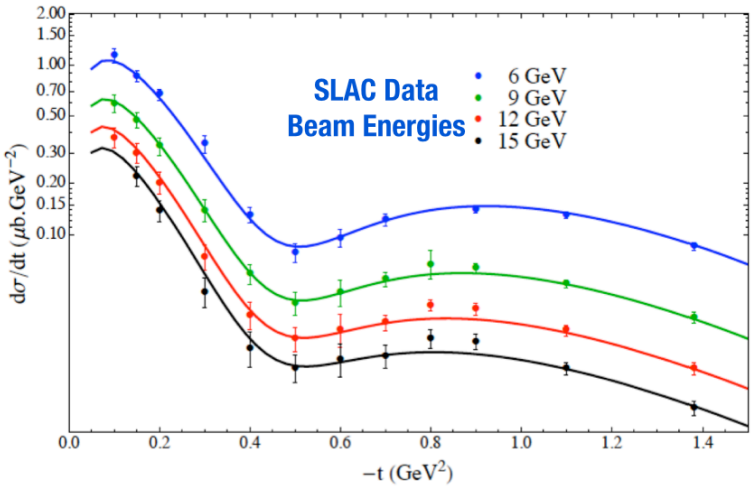
$$\Sigma = \frac{|\omega + \rho|^2 - |h + b|^2}{|\omega + \rho|^2 + |h + b|^2}$$

The high intensity, linearly polarized photon beam of GlueX/Hall D will provide important new constraints on Regge models

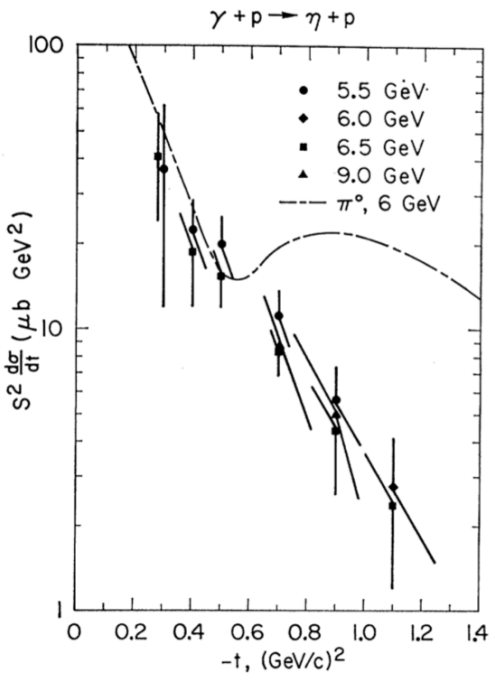
There are no previous measurements of the Σ asymmetry for $\gamma p \to \eta p$ with $E_\gamma > 3$ GeV

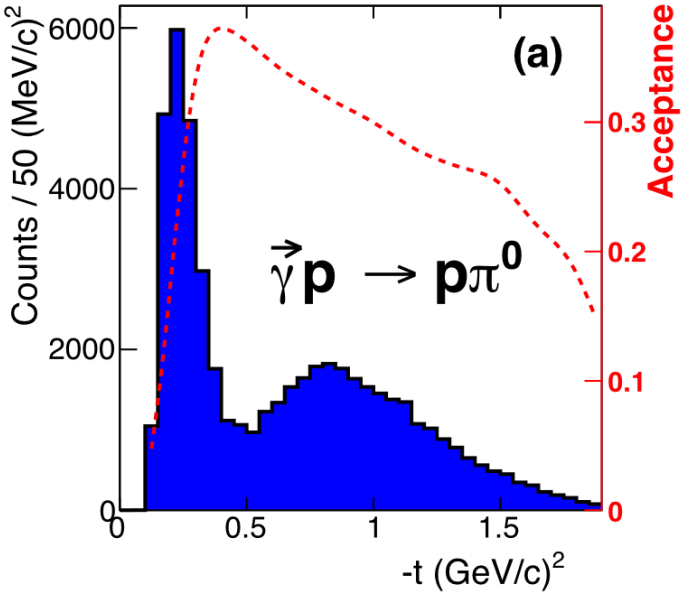
Final -t distributions

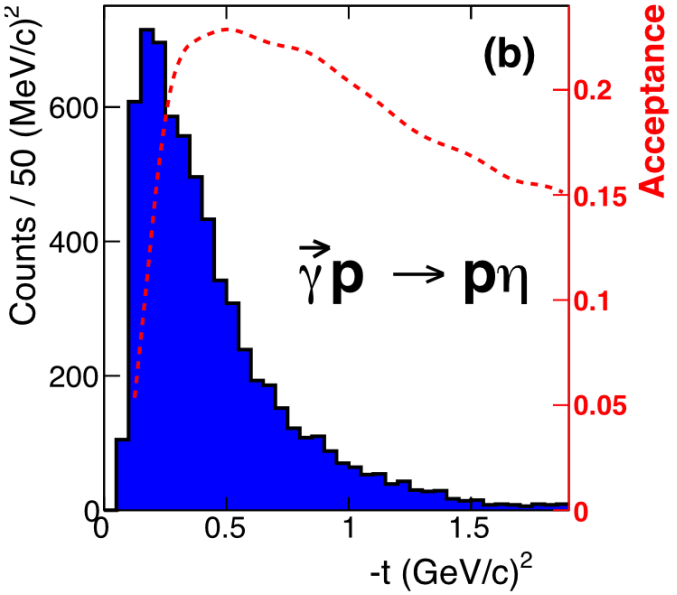
V. Mathieu (JPAC): PRD 92, 074013



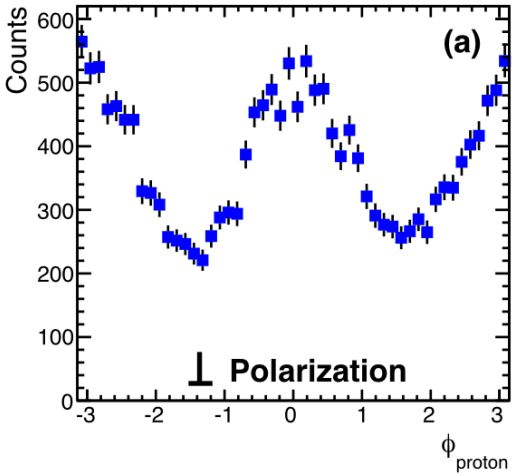
SLAC: PRD 1, 27 (1970)

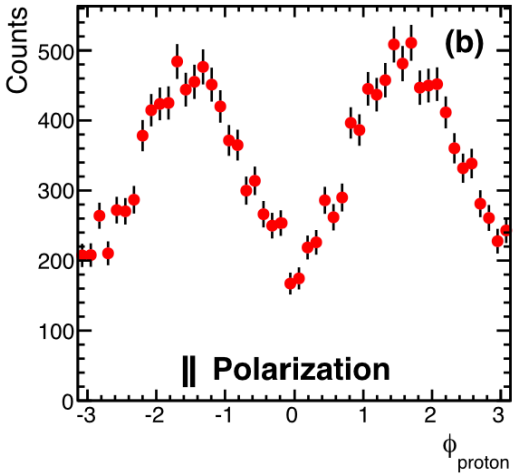


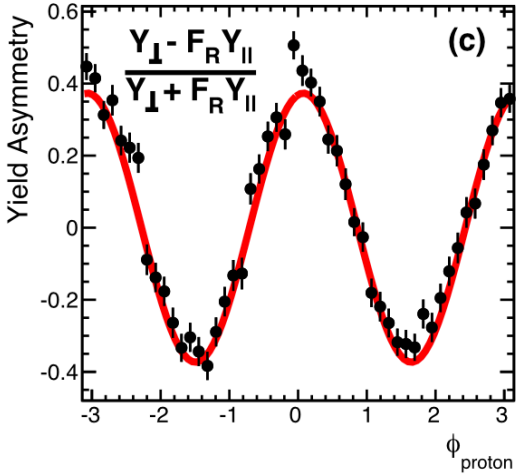




Beam Asymmetry: Method







$$Y_\perp \propto N_\perp(1 + P_\perp \Sigma \cos 2\phi_{\text{proton}})\ \phi_\gamma = 90^\circ$$
$$Y_\parallel \propto N_\parallel(1 - P_\parallel \Sigma \cos 2\phi_{\text{proton}})\quad \phi_\gamma = 0^\circ$$

$$\frac{Y_\perp - F_R Y_\parallel}{Y_\perp + F_R Y_\parallel} = \frac{(P_\perp + P_\parallel)\Sigma \cos 2\phi_{\text{proton}}}{2 - (P_\perp - P_\parallel)\Sigma \cos 2\phi_{\text{proton}}}$$

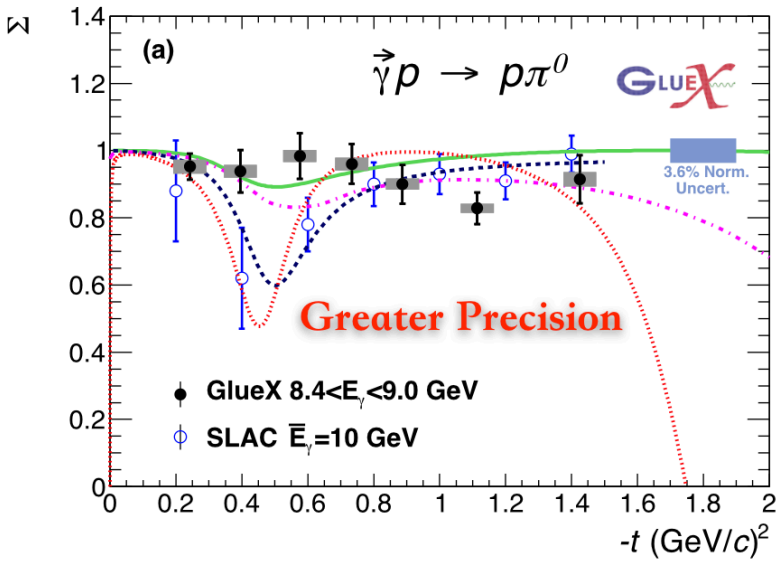
Repeat in bins of -t for both π^0 and η

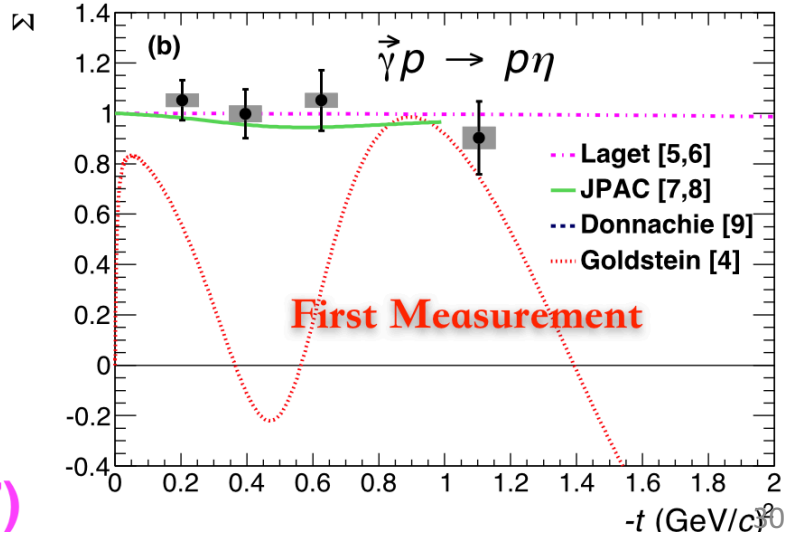
$$F_R = \frac{N_\perp}{N_\parallel}$$

Cite from: Zhenyu Zhang EPD Seminar 6/20/2017

Beam Asymmetry: Results

- Measured asymmetries consistent with previous SLAC data
- Our measured Σ asymmetries are close to 1, with little evidence of -t dependence
- Don't observe prominent dip in beam asymmetry at -t = 0.5 $(GeV/c)^2$ as seen in the cross section
- Our data are somewhat consistent with the JPAC and Laget calculations





PHYS REV C 95, 042201(R) (2017)

J/ψ Photoproduction Near Threshold

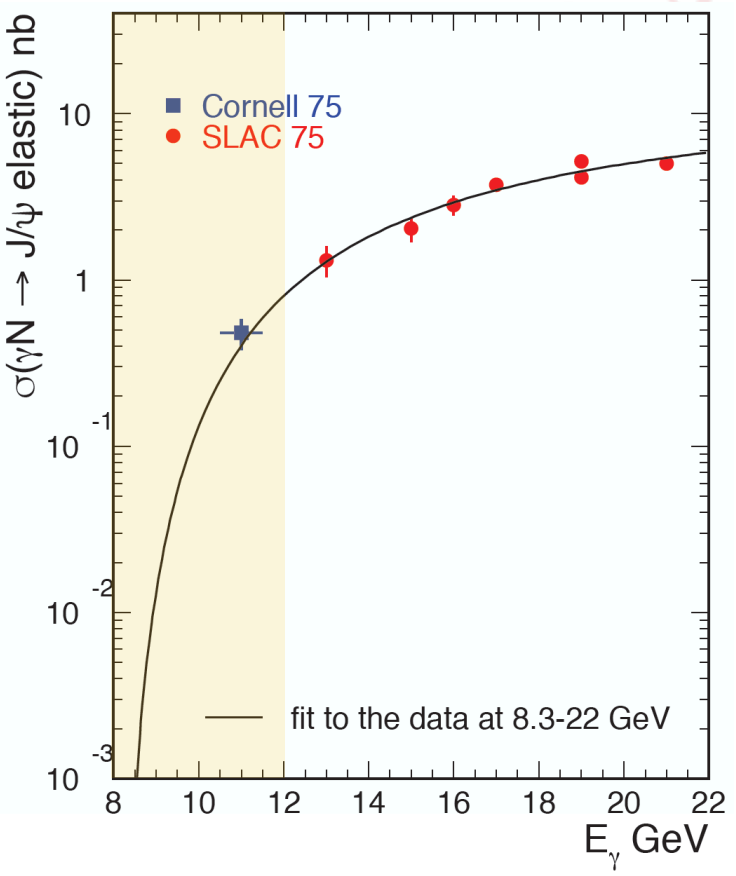
- Threshold production is experimentally clean, ideal for studying J/ψ+N interaction
- Can also study coupling of resonant J/ψ+p states to photon through s-channel production.
  - Pc(4450) produced at E(ɣ) ~ 10.3 GeV
  - Several existing studies:

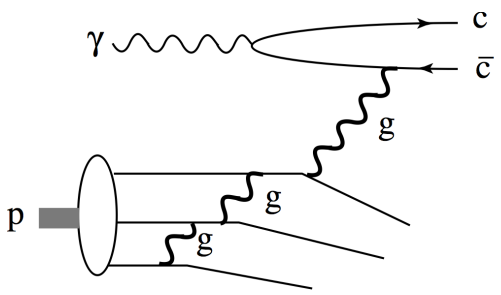
    Wang, Liu, and Zhao, PRD 92, 034022 (2015).

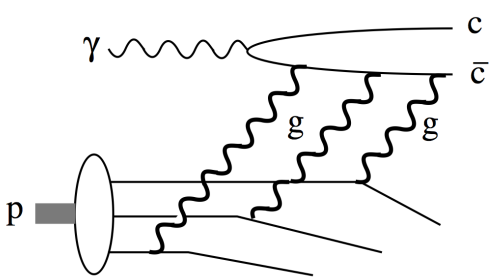
    Kubarovsky and Voloshin, PRD 92, 031502 (2015).

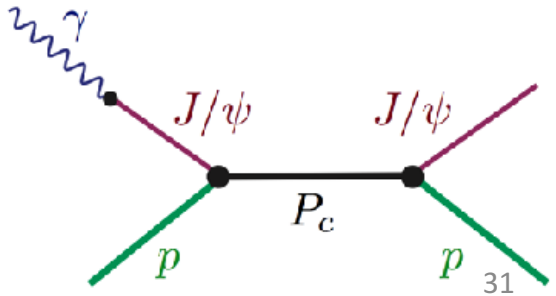
    Karliner and Rosner, PLB 752, 329 (2016).

    Hiller Blin et al., PRD 94, 034002 (2016).
  - Example: KR finds σ_{peak} ~ 12 nb assuming Br(Pc → p J/ψ)=10% Large theoretical uncertainties exist.



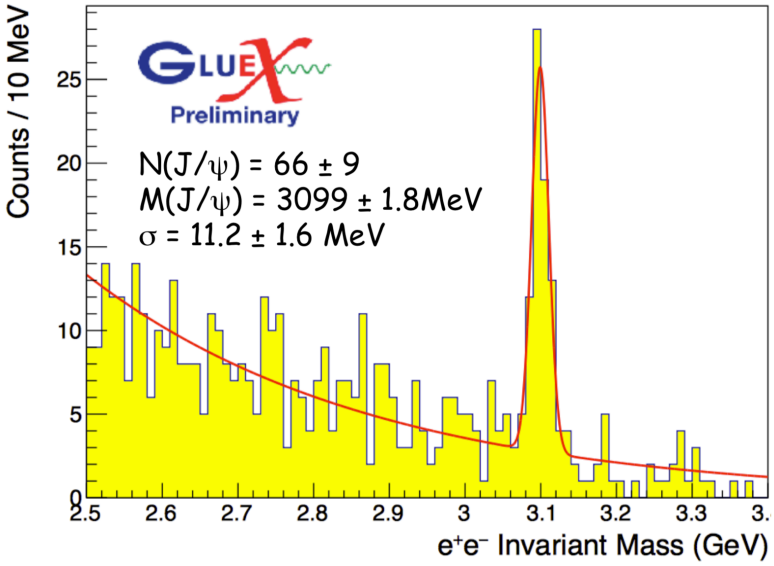


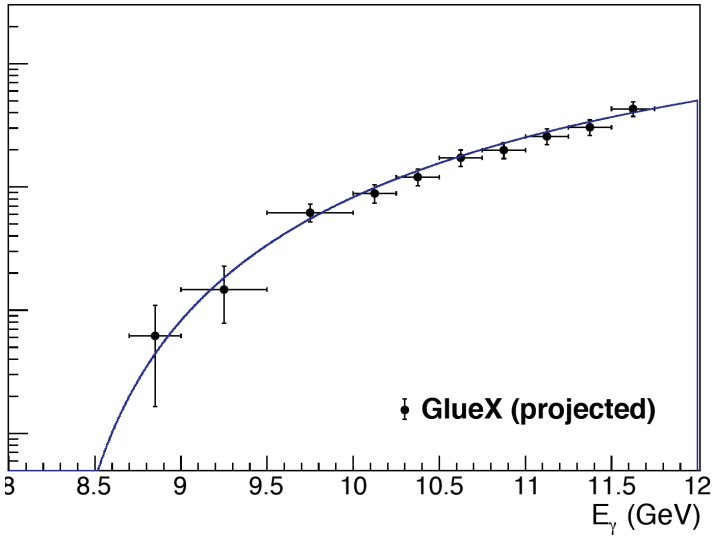




J/ψ Photoproduction Near Threshold

- For initial GlueX running, expect 10 x current data, ~700 J/ψ. Allows first detailed look at cross sections near threshold, first searches for resonant states in this region.
- In ~2019, high-luminosity GlueX running will begin, with updated particle identification and 10x more data. This will enable:
  - Study of angular distributions in detail
  - Study of polarization effects

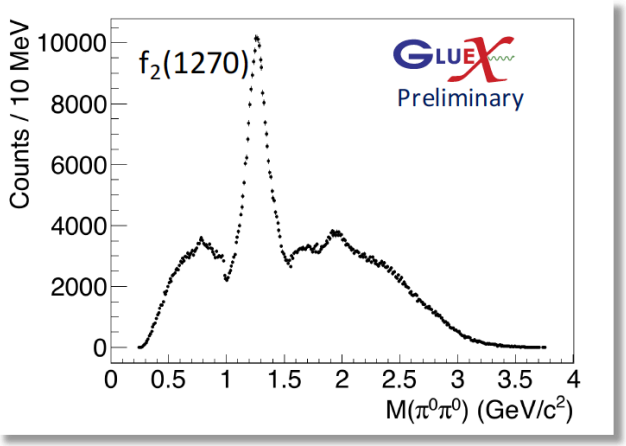




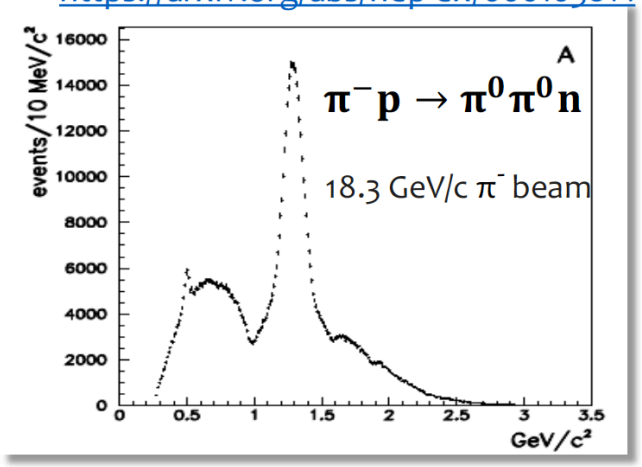
Four photon final states

- **The γ+p→p+4γ channel is rich in physics potential, contains a lot of channels**
- **The $\pi^0\pi^0/\pi^0\eta$ are dominant processes, can be used to study the properties of $f_0(980)$ and $a_0(980)$ mesons, hunt for exotic states, discriminate among models for scalars.**

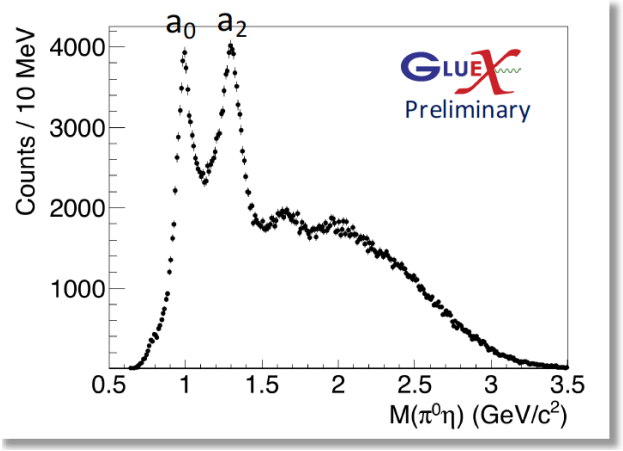
GlueX 2016 + 2017 low Intensity data:



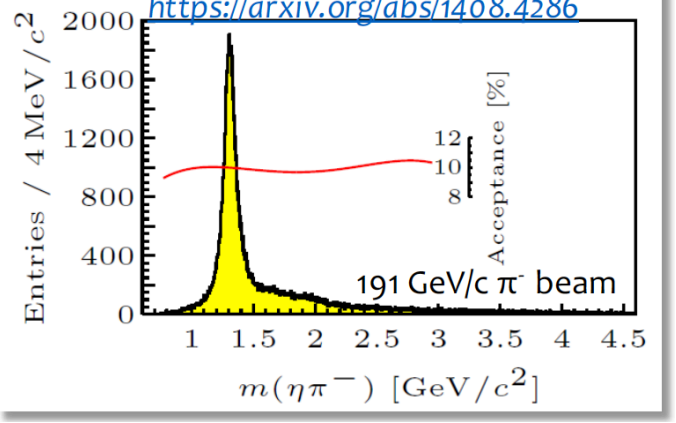
J. Gunter et al., E852 Collaboration,
https://arxiv.org/abs/hep-ex/0001038v1



GlueX 2016 + 2017 low Intensity data:



COMPASS π⁻+p→η+π⁻+p
https://arxiv.org/abs/1408.4286



Four photon final states

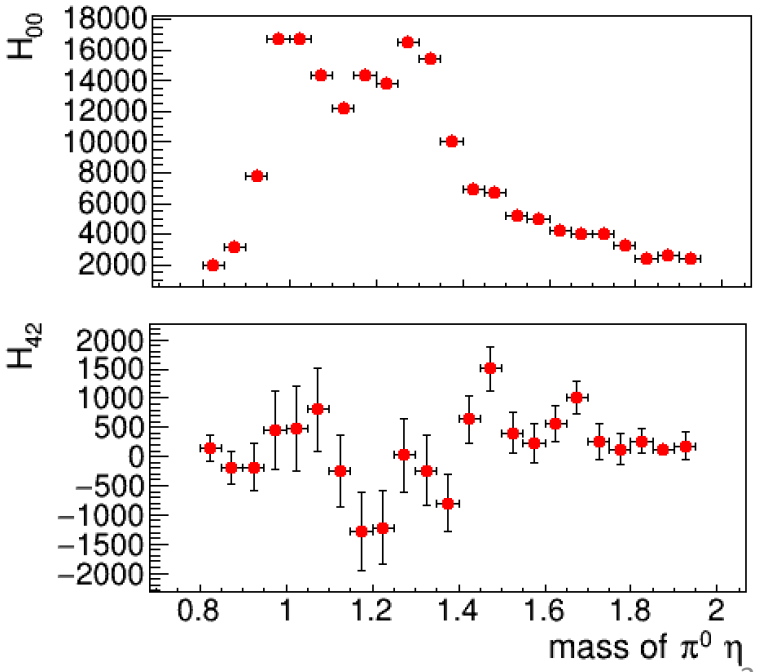
Advantages in analyzing moments:

- **Can be directly and unambiguously derived from the data,**
- **Can be expressed as bilinear in terms of the partial waves,**
- **Show specific sensitivity to a particular subset of partial waves,**
- **Quantitative comparisons to the same theoretical observables.**

$$H_{LM}(E_\gamma, t, M_{\pi\eta}) = \sqrt{4\pi}\int d\Omega_\pi \frac{d\sigma}{dt\, dM_{\pi\eta}\, d\Omega_\pi} \mathrm{Re}Y_{LM}(\Omega_\pi), \qquad (1)$$

$$H_{00} = |S_0|^2 + |P_0|^2 + |P_-|^2 + |D_0|^2 + |D_-|^2 + |P_+|^2 + |D_+|^2, \qquad (2)$$

$$H_{42} = \sqrt{\frac{10}{21}}|D_-|^2 - \sqrt{\frac{10}{21}}|D_+|^2, \qquad (3)$$



E852: PRD 67, 094015 (2003)

Outlook

- The GlueX experiment has been commissioned and finished the first physics run in both low and high intensity beam status.
  - An initial commissioning run in spring 2016 has yielded a data sample two order of magnitude in this energy region, and first physics results has been published early 2017.
  - Several analysis of beam asymmetry are ready once the 2017 data is included.
  - The upcoming run will open the door to the study of hybrid mesons.
- The data has opened up the study of dilepton physics at GlueX and allow us to begin to study the J/ψ production cross section near threshold.
- High luminosity GlueX running is planned to start in 2019 with upgraded detector, focusing on strange-quark states.
- Several other measurements are planned: GlueX supports a rich physics program.

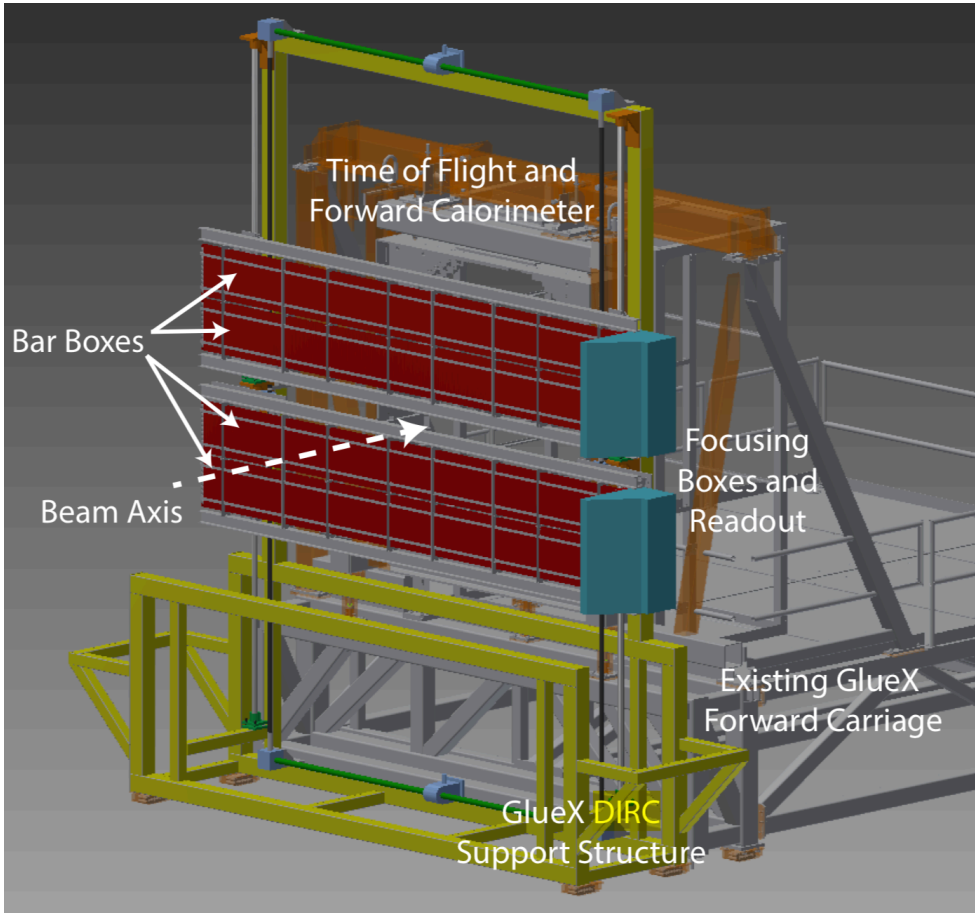
The Upgrade Proposal

Experiment	Description	Beam Time (days)
GlueX I	Study spectrum of light mesons and gluonic excitations (low intensity)	80
GlueX II	Study of hadron decays to strange final states (high intensity)	200+220
Primakoff eta	Eta radiative decay width	79
CPP	Charged pion polarizability measurement	25
Jlab Eta Factory	Rare eta decays	42 (conditional)

- DIRC detector for enhanced π/kaon identification will be installed starting 2018.
- Online computer farm will be added for high intensity running
- High resolution calorimeter is needed for parts of the JEF program

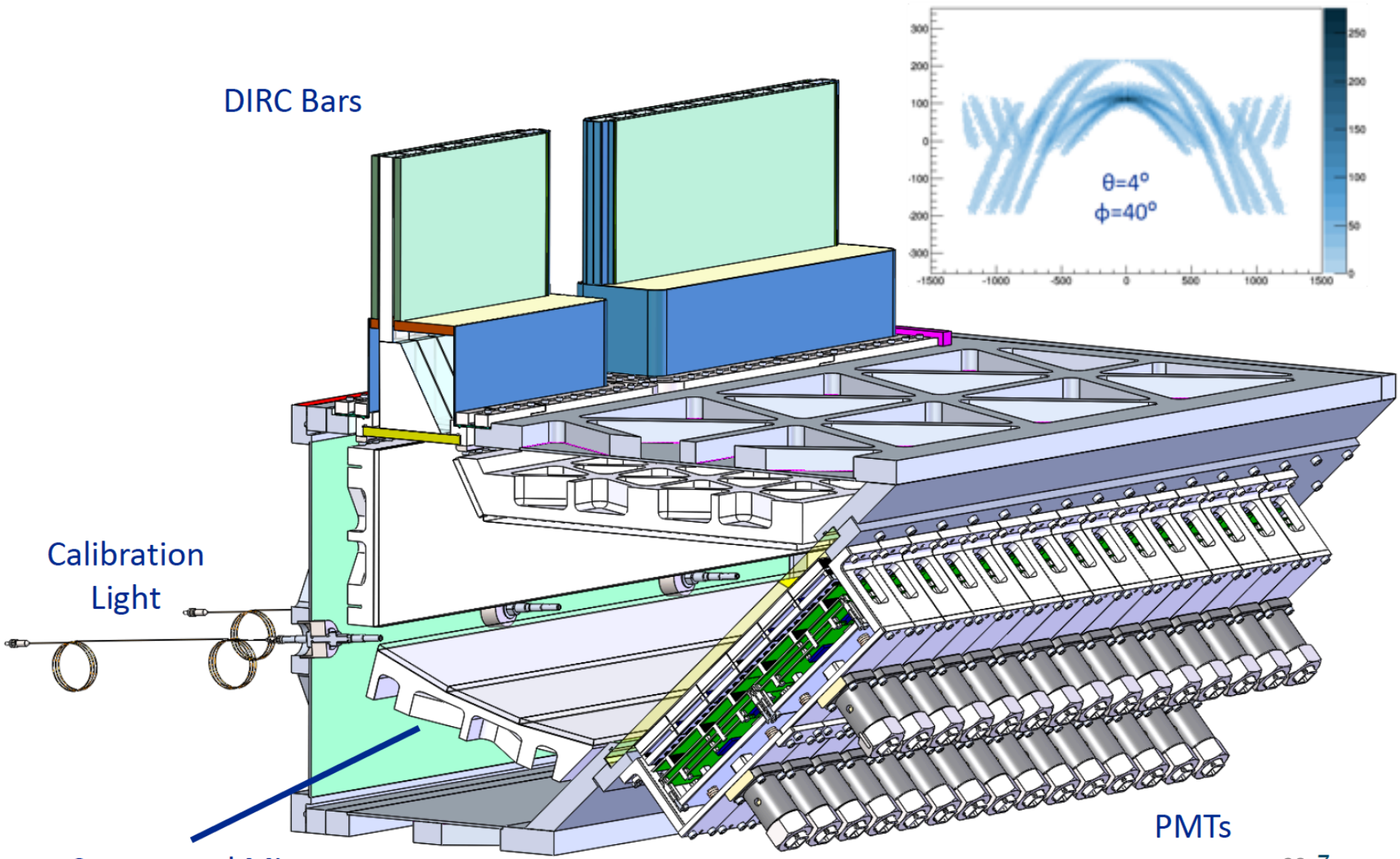
Forward Kaon Identification

- Four of the BaBar DIRC bar (quartz bar) boxes will be installed in front of the TOF wall.
- Baseline GlueX provided K/p separation up to about 2GeV/c. The addition of the DIRC pushes this up to 4.5 GeV/c.
- Strangeonium mesons and hybrids can be studied.
- Hyperon and cascade baryons can be studied.



Expected 2018

CURRENT DRAWING OF OPTICAL BOX



Cite from: John Hardin (MIT) 2017 DNP Meeting

Shipping of the DIRC

Cameras

Picture every ~10s

Laptop (Truck)

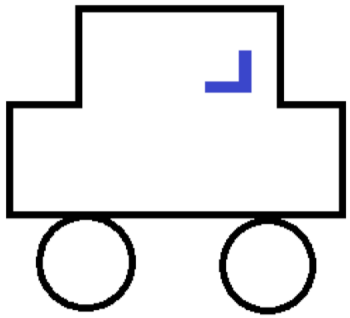
Processes pictures into time lapse video

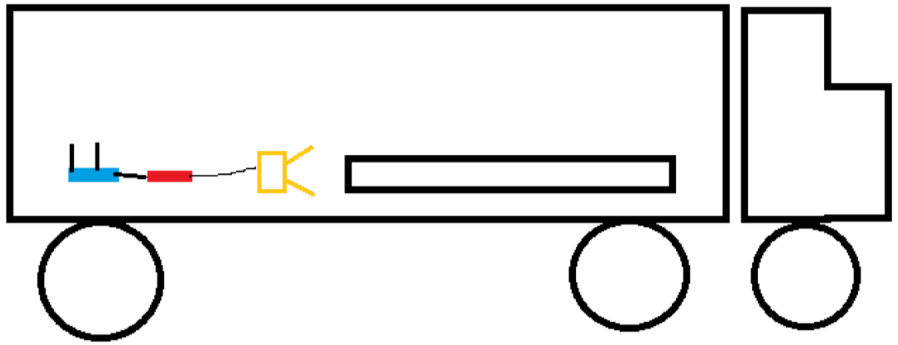
Router

-Maintains local wifi
-Tuned

Laptop (car)

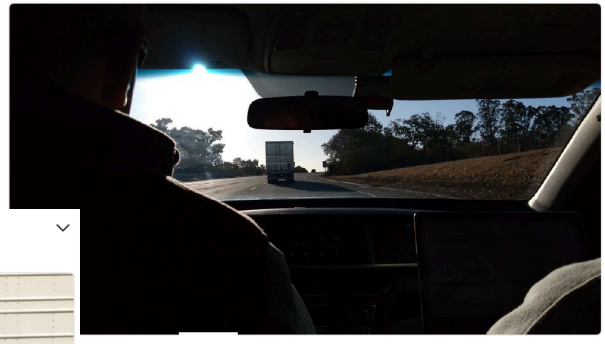
-Receives video
-Checked every ~15m





Shipping of the DIRC

GlueX DIRC @GlueX_DIRC · 5 Nov 2017
The bar box 0 chase is on!



GlueX DIRC @GlueX_DIRC · 10 Nov 2017
Bar box 0 has left the truck

GlueX DIRC @GlueX_DIRC · 4 Nov 2017
The last picture before I left @SLAClab. I'm in the truck in the back.

1 1

The End

But life is not only about physics !

Back up

Physics on GlueX