Hall D Facility at JLab

E.Chudakov[1]

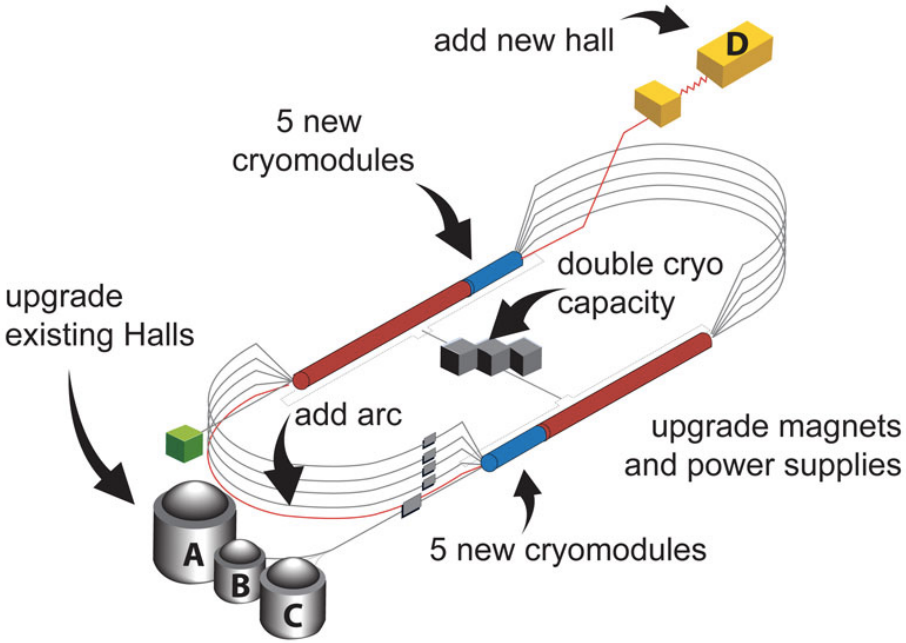
[1]Hall D Group Leader

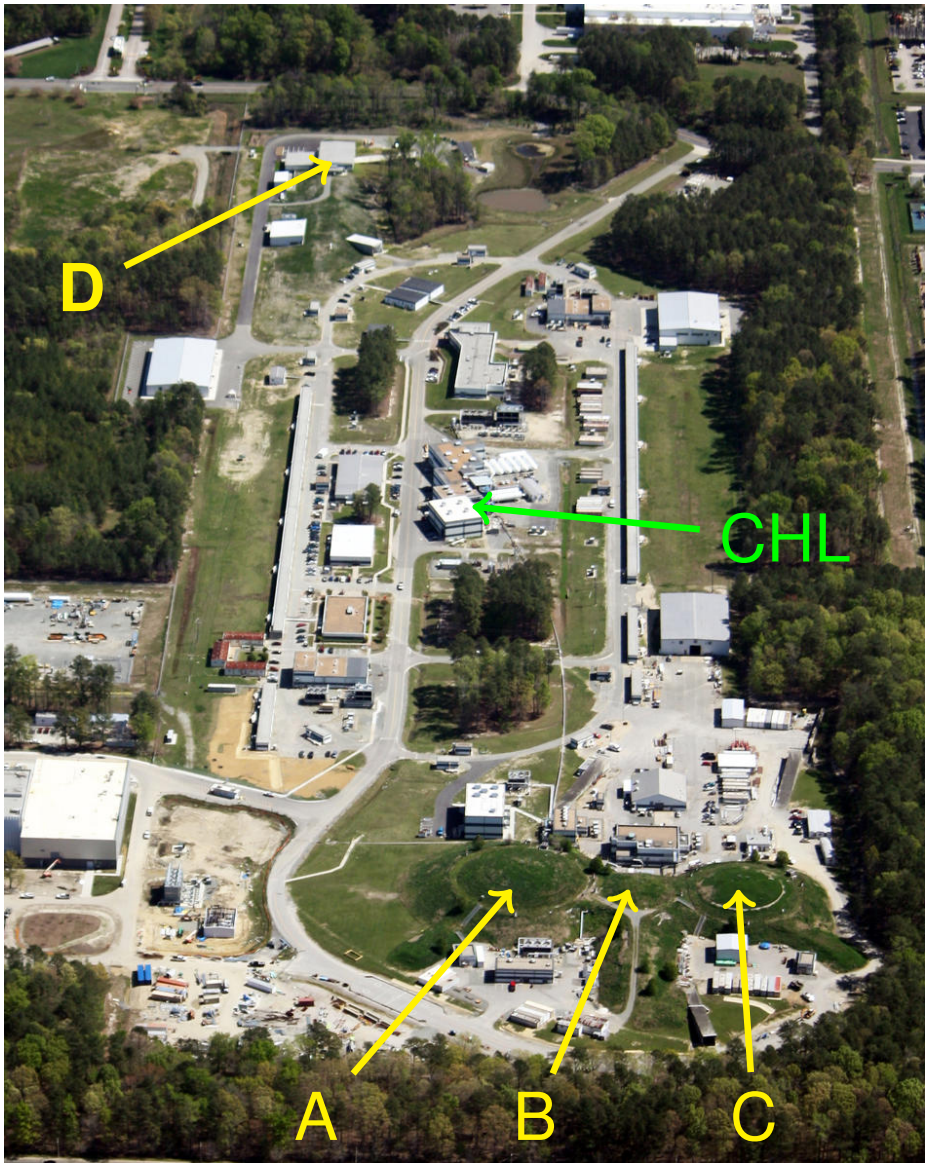
Presented at Workshop
Excited Hyperons in QCD Thermodynamics at Freeze-Out
JLab, 16-17 Nov 2016

Outline

1. JLab at 12 GeV
2. Physics motivation for Hall D: meson spectroscopy
3. Experiment GlueX in Hall D
   - Apparatus
   - First results
4. Experimental program and future plans

CEBAF Upgrade to 12 GeV





Upgrade Goals

- Accelerator: 6 GeV $\Rightarrow$ 12 GeV
- Halls A,B,C: e^- <11 GeV, < 100 μA
- Hall D: e^- 12 GeV $\Rightarrow$ γ-beam

Upgrade Status

- Reached 12 GeV in Dec 2015
- Halls A,D: finished
- Halls B,C: about a year to go

Meson spectroscopy

Naive quark model:

- Mesons are $\overline{q}q$, constituent quarks are $S = 1/2$ fermions
- No gluonic degrees of freedom
- Restrictions on the quantum numbers: J^{PC}:
  $P = (-1)^{L+1}$, $C = (-1)^{L+S}$

J	$--$	$++$	$-+$	$+-$
0		0^{++}	0^{-+}	
1	1^{--}	1^{++}		1^{+-}
2	2^{--}	2^{++}	2^{-+}	
3	3^{--}	3^{++}		3^{+-}

$q\overline{q}$ QN "exotic" QN

Glue and spectroscopy

Gluonic excitations $\Rightarrow$ hybrid mesons

- Predicted by models, Lattice QCD
- "Constituent gluon":
  LQCD: 1^{+-}, mass of 1-1.5 GeV
- Exotic QN: an excellent signature of a new degree of freedom
  no mixing with the regular $\overline{q}q$ states

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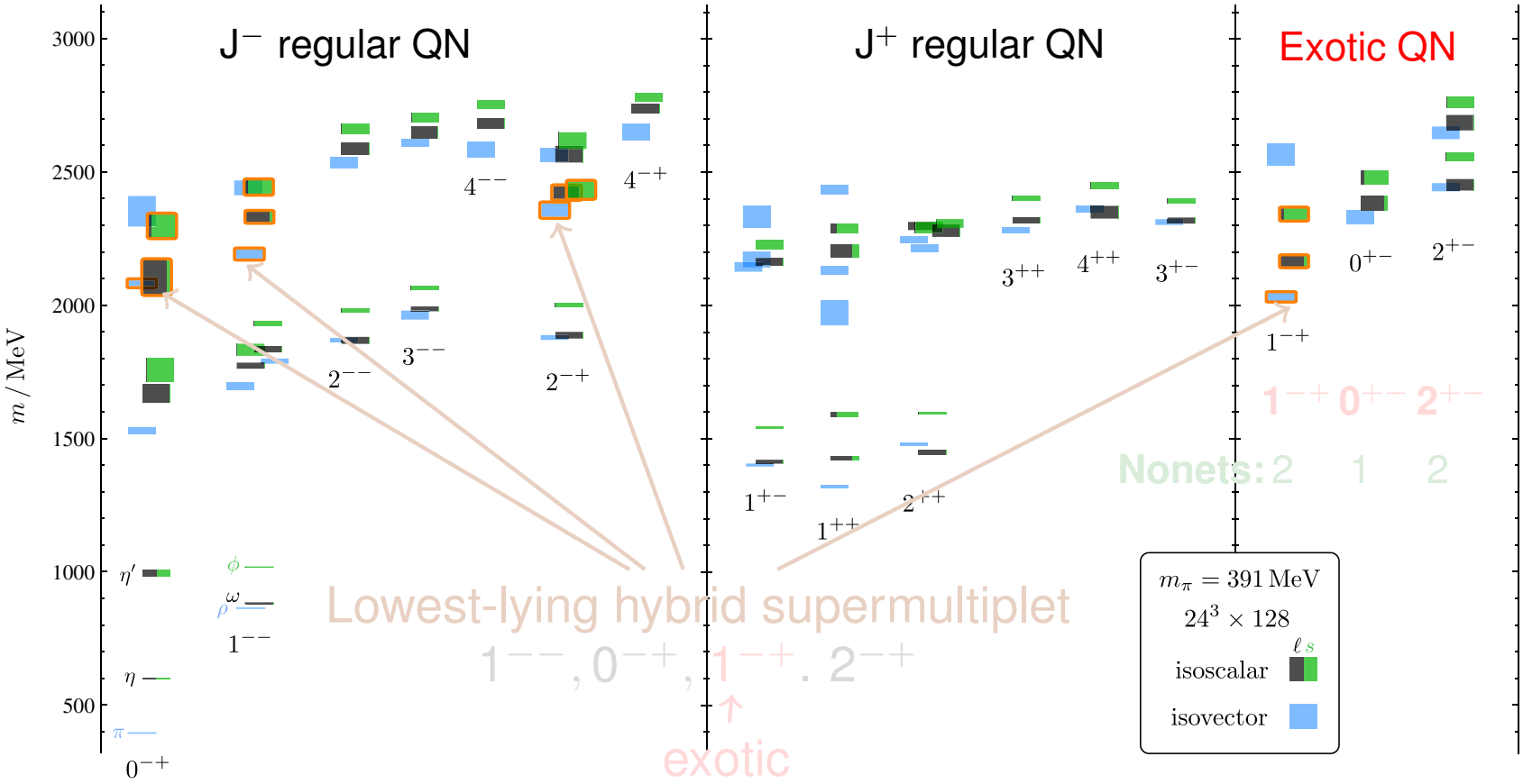
Lattice QCD - the Meson Spectra

J.Dudek et al PRD 83 (2011); PRD 84 (2011), PRD 88 (2013)

Hybrids identified: States with non-trivial gluonic fields



Calculations for $m_\pi \sim 400 MeV$

Orange frames - lightest hybrids

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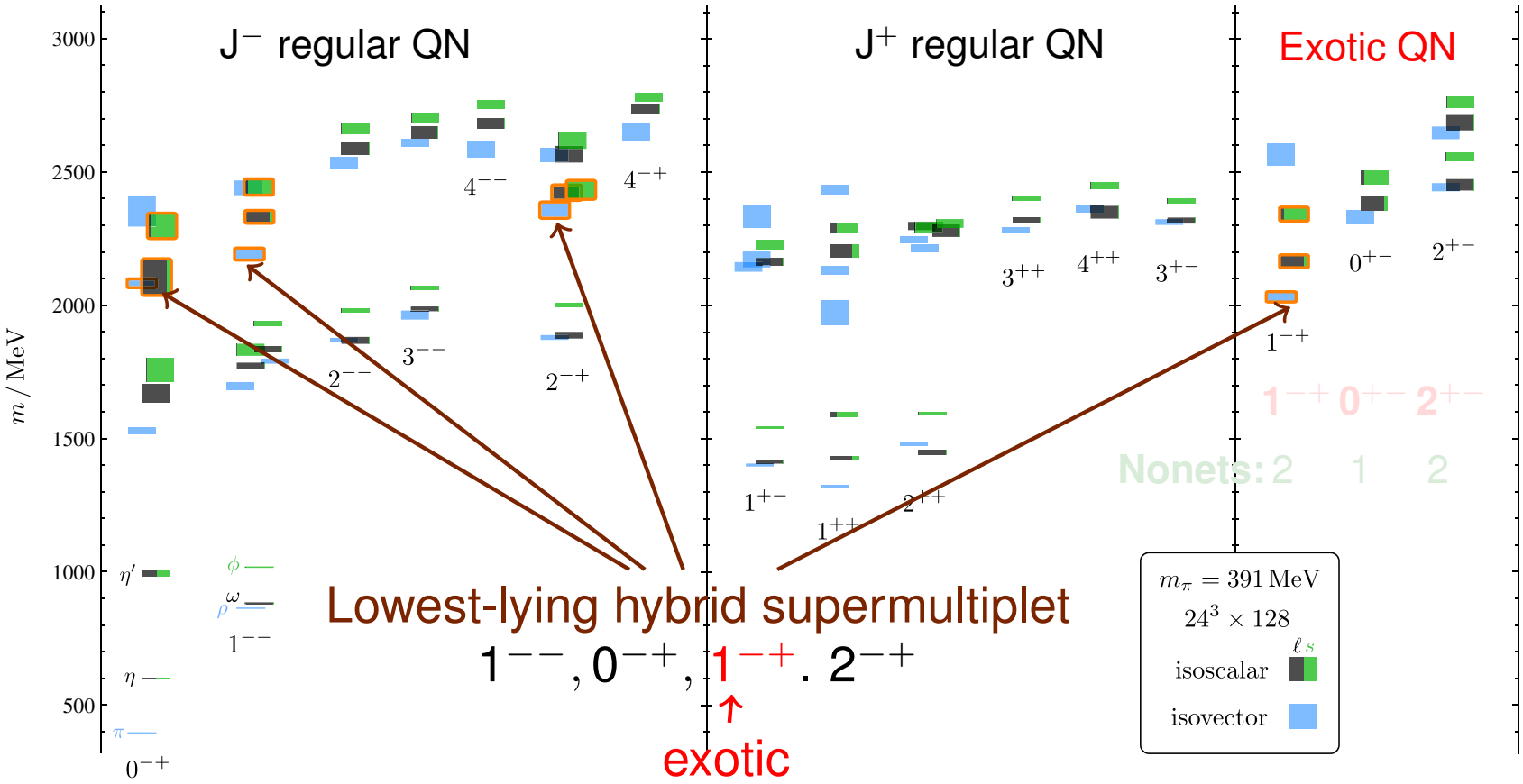

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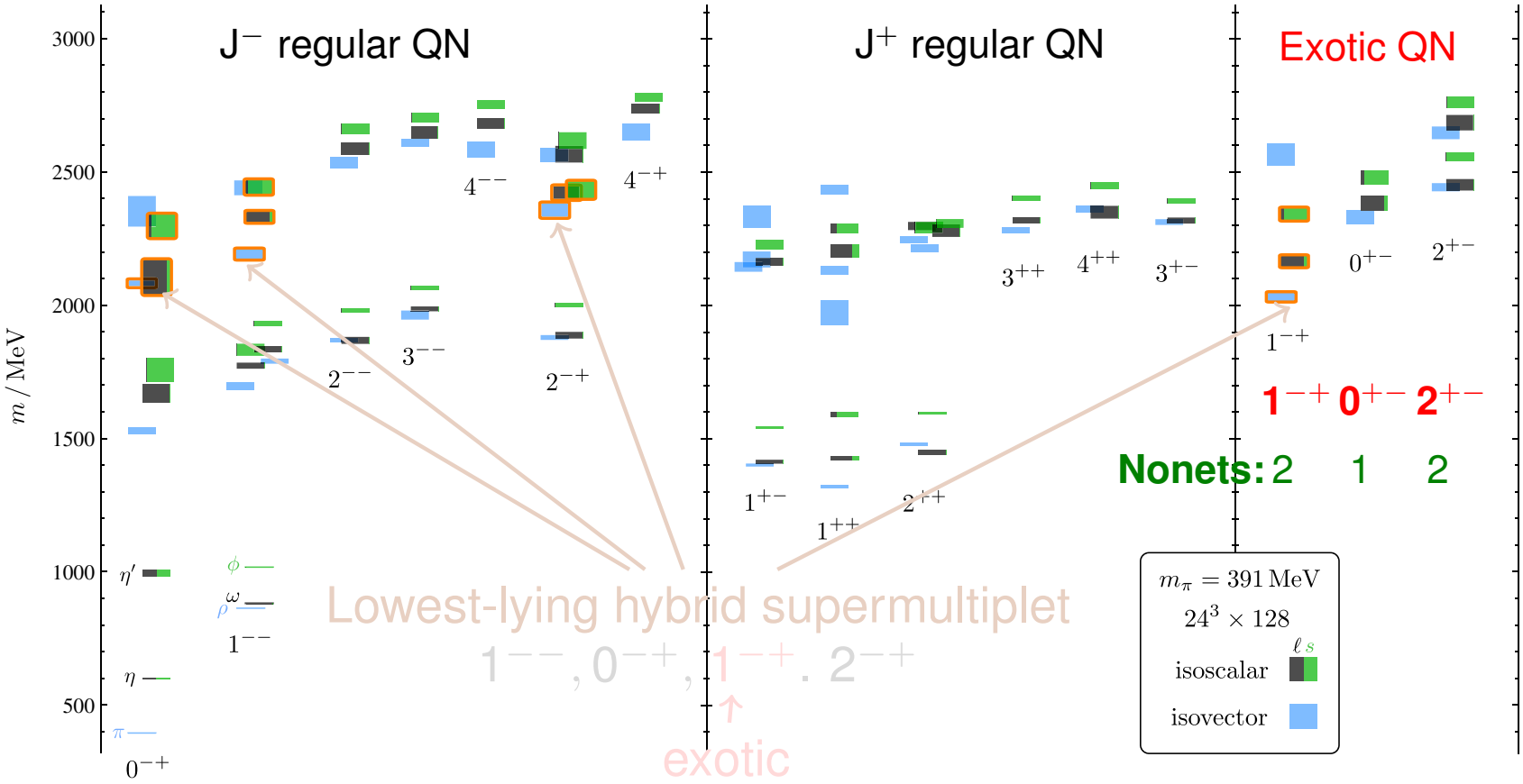

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Hybrids: expected features and ways to detect

Masses

- LQCD: 1^{-+} $\sim$2.0 – 2.4 GeV/c^2
  0^{+-} $\sim$2.3 – 2.5 GeV/c^2
  2^{+-} $\sim$2.4 – 2.6 GeV/c^2

Full Widths

- *Models*: 0.1 – 0.5 GeV/c^2

Decays

- Final states: multiple $\pi^{\pm}$ and γ

No calculations for the decay widths or cross sections so far.

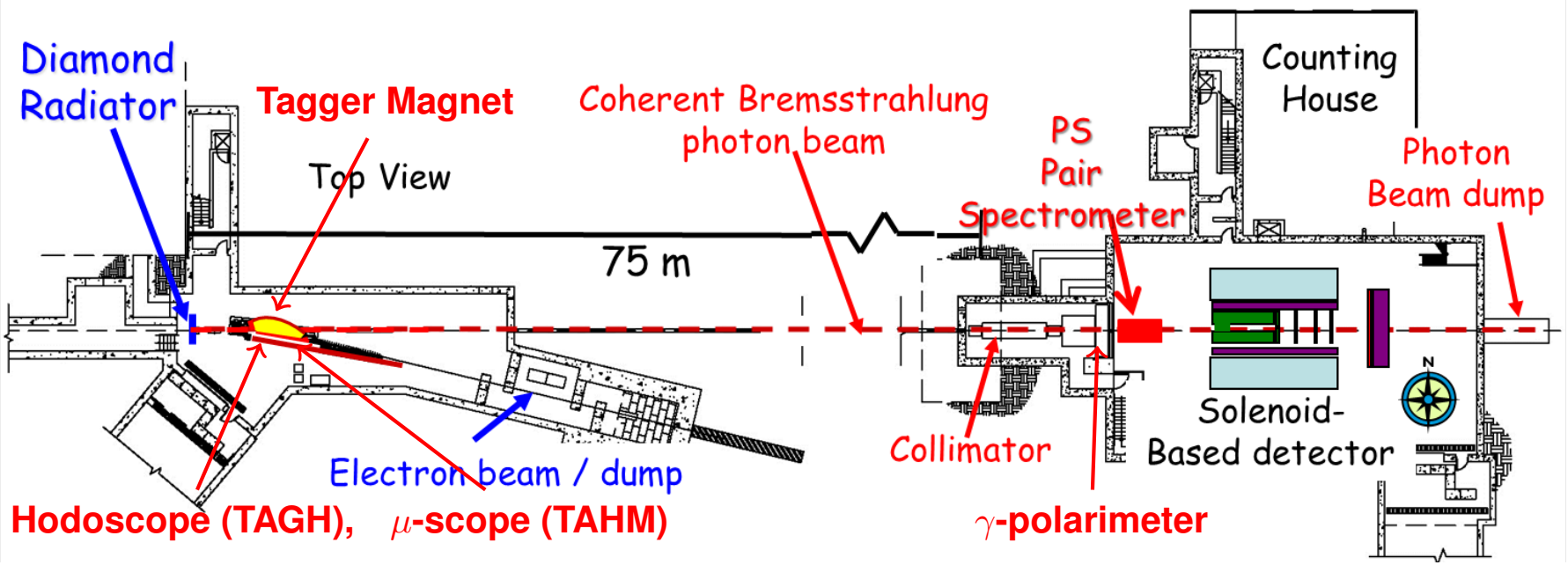
How to detect the hybrids?

- Detect the final states
- Identify the QN using the Partial Wave Analysis (PWA)

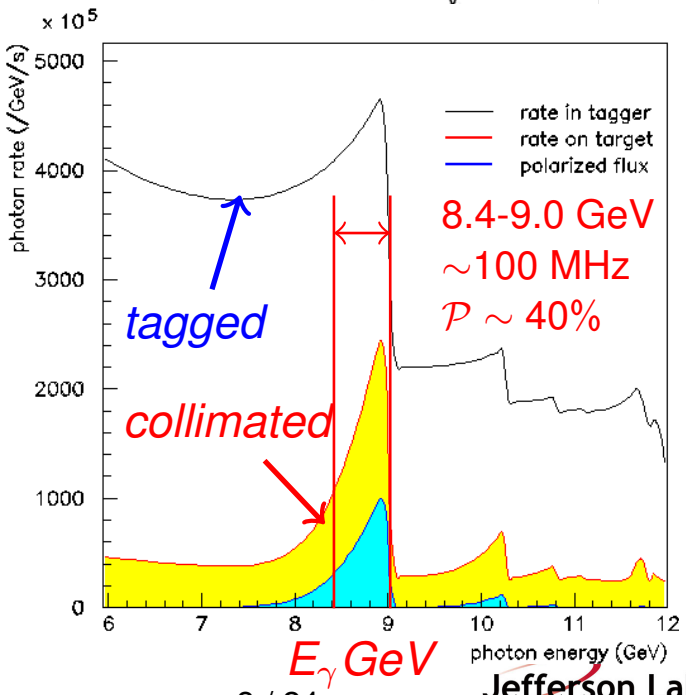
GlueX Experiment: Design Goals and Features

- General requirements:
  - Hermeticity and uniform acceptance for charged particles and photons
  - Good enough resolution to identify exclusive reactions
  - High statistics
- Specific feature: tagged photon beam
  - *Linear polarization helps the QN identification*
  - Beam γ and π^- have different couplings to the hybrid states $\Rightarrow$ complementary to the π^--beam experiments
  - Few photoproduction data exist so far
- Considerable theoretical support for the PWA

Hall D/GlueX Beamline



- 12 GeV e^- beam $0.05 - 2.2\ \mu$A
- 20 μm diamond: coherent $<$25 μrad
- Collimation $r <$1.8 mm at $\sim$ 80 m
- Coherent peak $8.4 - 9.0$ GeV $\quad \mathcal{P} \sim 40\%$
  $2.2\ \mu$A $\Rightarrow$ 100 MHz γ GlueX-I: 10 MHz
- Energy/polarization measured:
  - Tagger spectrometer $\sigma_E/E \sim$0.1%
  - Pair spectrometer: spectrum $\Rightarrow \sigma_{\mathcal{P}}/\mathcal{P} \sim$5%



Jefferson Lab

Hall D/GlueX Spectrometer and DAQ

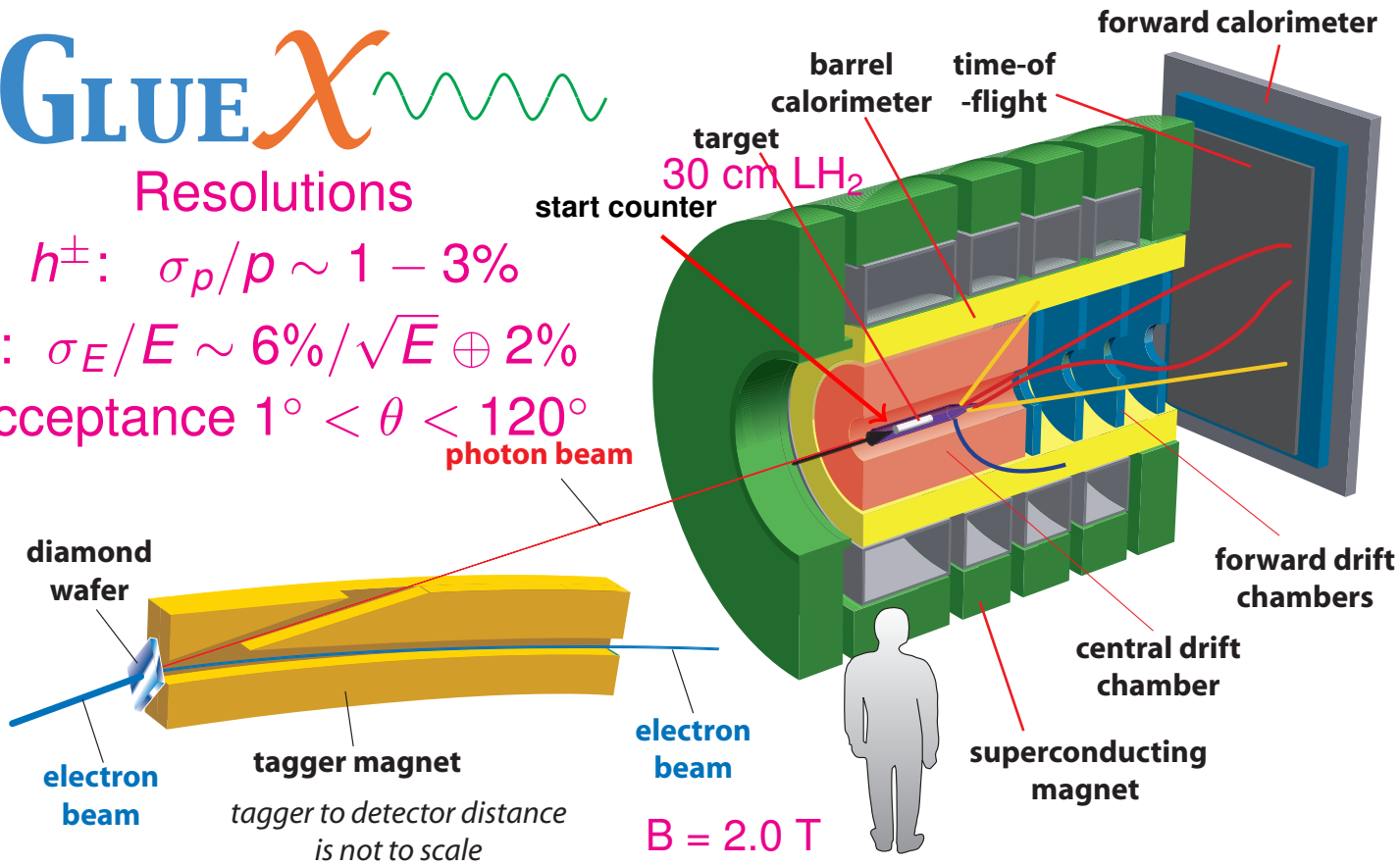
GlueX

Resolutions

$h^{\pm}$: $\sigma_p/p \sim 1-3\%$

γ: $\sigma_E/E \sim 6\%/\sqrt{E} \oplus 2\%$

Acceptance $1^\circ < \theta < 120^\circ$



Detectors

- CDC, FDC
- BCAL, FCAL
- TOF, ST

Plans to add

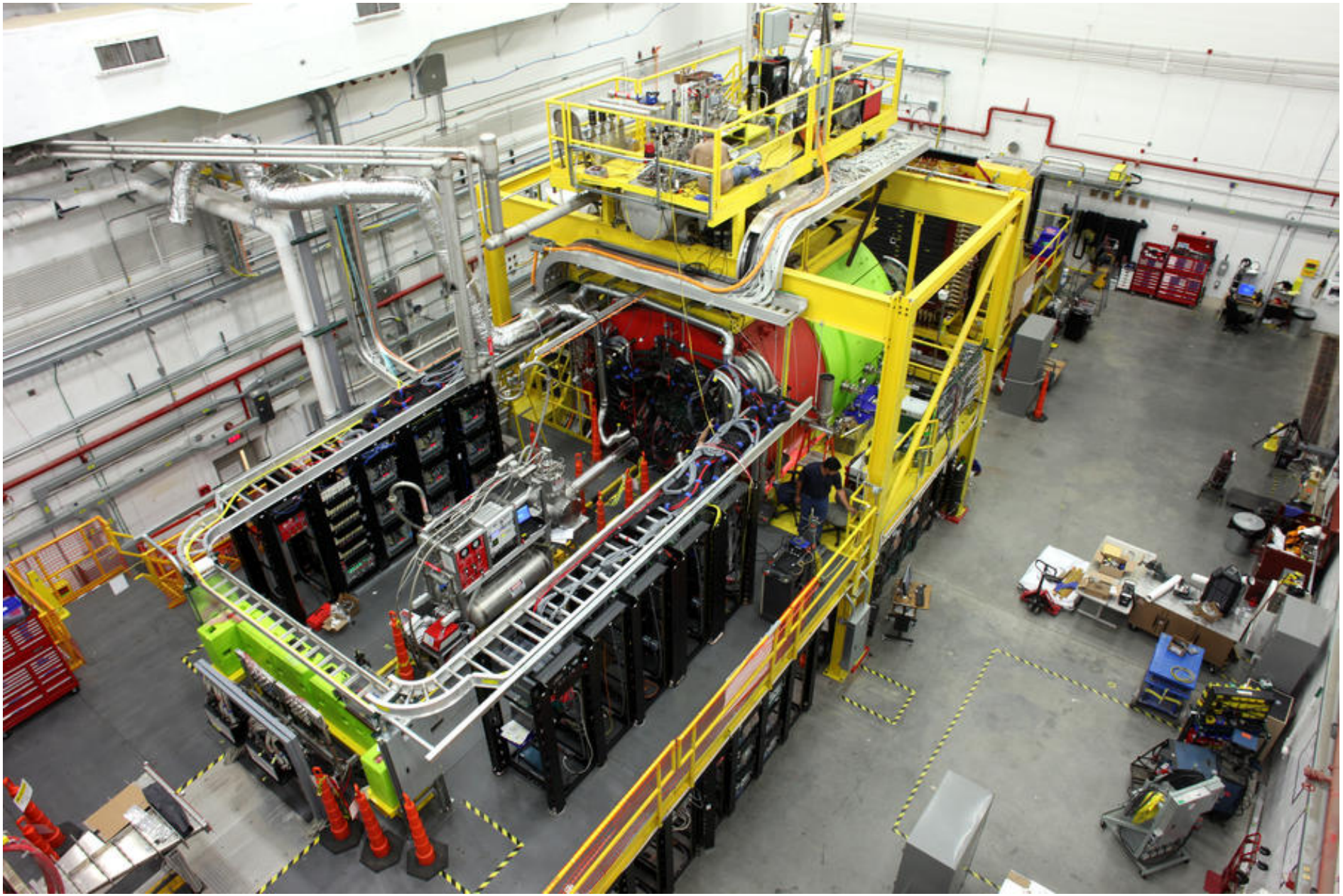
- 2017 L3
- 2018 DIRC

Photoproduction γp 1.5 kHz for a 10 MHz beam; Trigger $\sum E_{CAL} > X$

GlueX-I 10 MHz/peak: trigger 20 kHz $\Rightarrow$ DAQ $\Rightarrow$ tape 30 kHz spring 2016

GlueX-II 50 MHz/peak: trigger 100 kHz $\Rightarrow$ DAQ $\Rightarrow$ L3 farm $\sim$ 20 kHz $\Rightarrow$ tape

Hall D



Physics Program

Proposal/ experiment	Status	Title	Beam days	PAC #
E12-06-102	A	Mapping the Spectrum of Light Quark Mesons and Gluonic Excitations with Linearly Polarized Photons	120	30
E12-10-011	A-	A Precision Measurement of the eta Radiative Decay Width via the Primakoff Effect	79	35
E12-13-003	A	An initial study of hadron decays to strange final states with GlueX in Hall D	200	40
E12-13-008	A-	Measuring the Charged Pion Polarizability in the $\gamma\gamma \rightarrow \pi^+\pi^-$ Reaction	25	40
C12-12-002	A	A study of meson and baryon decays to strange final states with GlueX in Hall D	220	42
C12-14-004	C2	Eta Decays with Emphasis on Rare Neutral Modes: The JLab Eta Factory(JEF) Experiment		42

Physics Program

Established schedule

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2016 Fall – 2018 Spring

Physics Program

Established schedule

Intention

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2016 Fall – 2018 Spring

2018 Fall –

2019 Spring –

Physics Program

Proposal/ experiment	Status	Title	Beam days	PAC #
LOI12-15-001		Physics with secondary K_L° beam		43
LOI12-15-006		ω-production on nuclei		43
LOI12-16-001		Lepton Universality in Bethe-Heitler production of lepton pairs		44
LOI12-16-002		Probing short-range nuclear structure and dynamics		44
LOI12-16-005		Target helicity correlations in GlueX		44

Workshops on Physics Program

- 2016 Feb 1-3: K_L Workshop - about 60 participants
- 2016 Apr 28-29: Nuclear Photoproduction with GlueX - about 30 participants

The GlueX Collaboration

Arizona State, Athens, Carnegie Mellon, Catholic University, Univ. of Connecticut, Florida International, Florida State, George Washington, Glasgow, GSI, Indiana University, ITEP, Jefferson Lab, U. Mass. Amherst, MIT, MEPhi, Norfolk State, North Carolina A&T, Univ. North Carolina Wilmington, Northwestern, Santa Maria, University of Regina, W&M, Wuhan, and Yerevan Physics Institute.

Over 100 collaborators from 23 institutions.

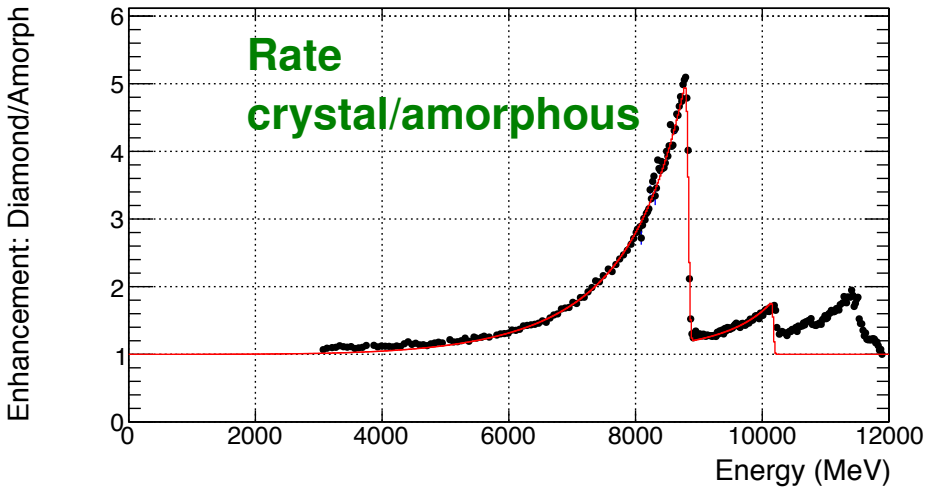
Commissioning an running

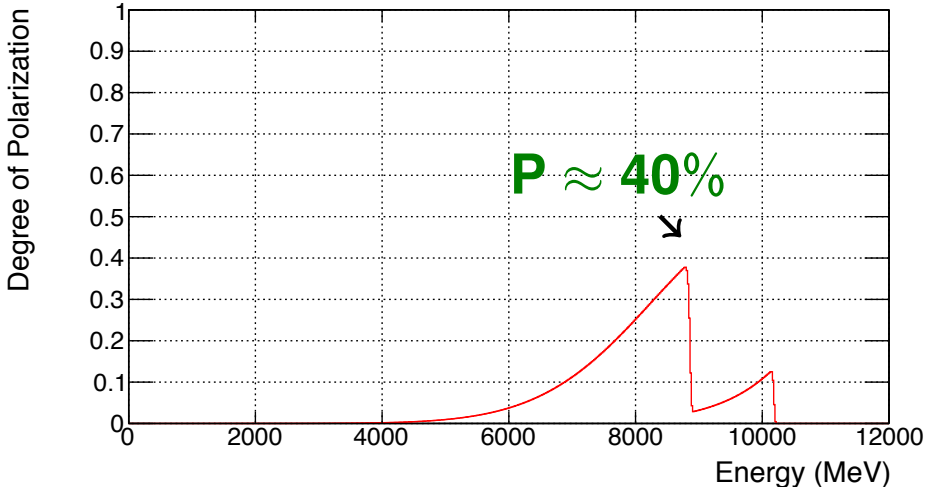
Runs with beam:

- Fall 2014 10.0 GeV beam: beam commissioning and detector checkout
- Spring 2015 5.5 GeV beam: 1 week of beam - commissioning
- Fall 2015 12 GeV beam (accelerator priority) $\sim$ 2 days of beam
- Spring 2016: 12 GeV beam - 60 days GlueX engineering run
  - Data for early physics results

Hall D/GlueX Beam: Coherent Bremsstrahlung

Run 10492: 50 µm diamond





Polarization measurements

- Derived from the spectrum
- Triple polarimeter
  $\gamma e^- \rightarrow e^+ e^- e^-$
- Processes like $\gamma p \rightarrow \rho^\circ p$

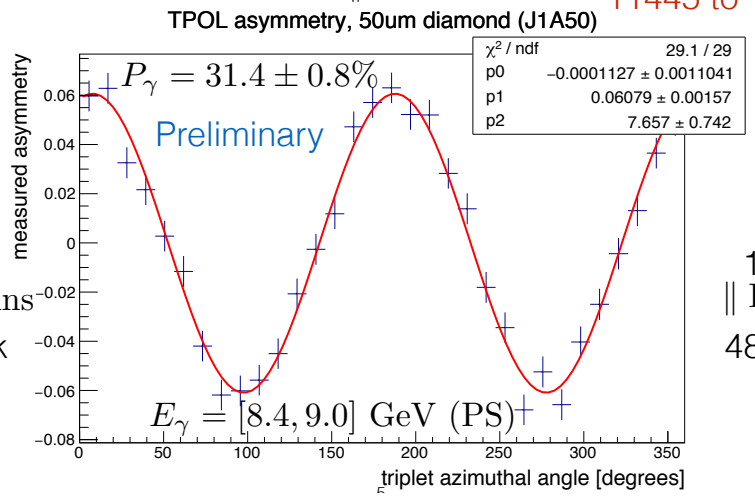
J1A50 (50um), 3 mm hole

75 um converter

$$\frac{N(\phi)_\perp - N(\phi)_\parallel}{N(\phi)_\perp + N(\phi)_\parallel} = P_\gamma \Sigma \cos(2\phi)$$

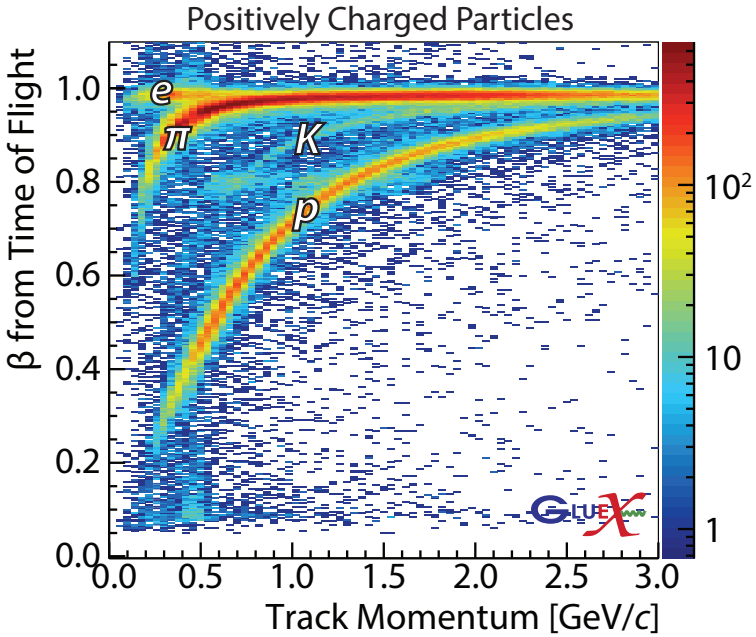
PERP/PARA
11445 to 11554

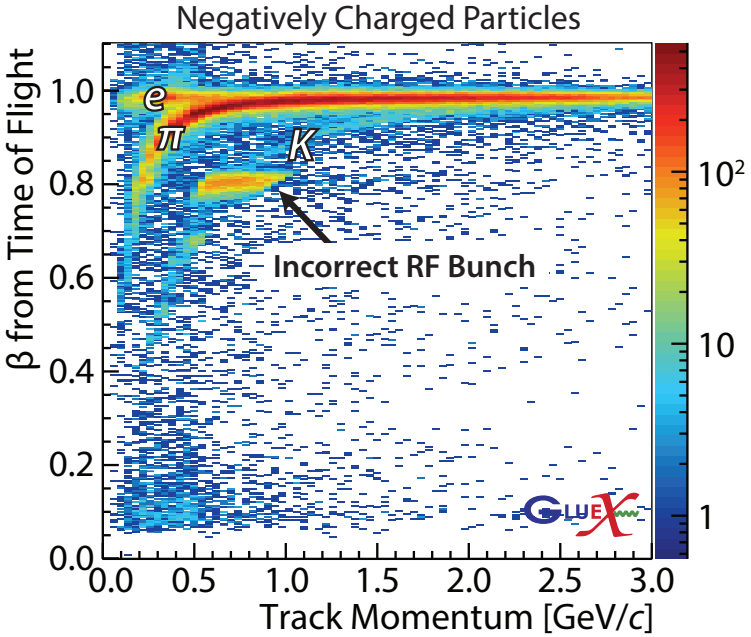
15
$\perp$ Runs
448k

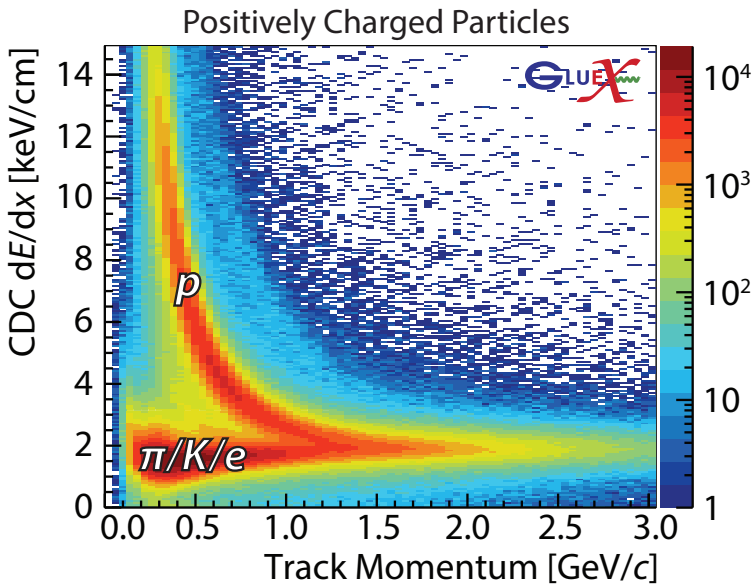


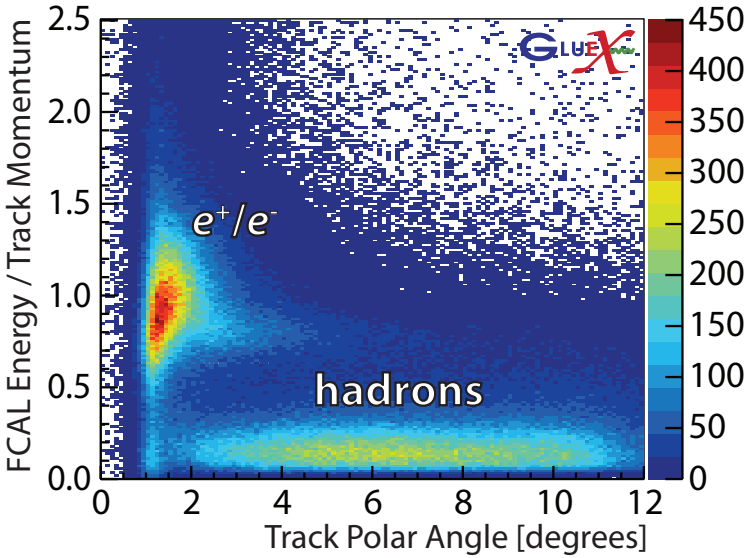
15
$\parallel$ Runs
482k

PID





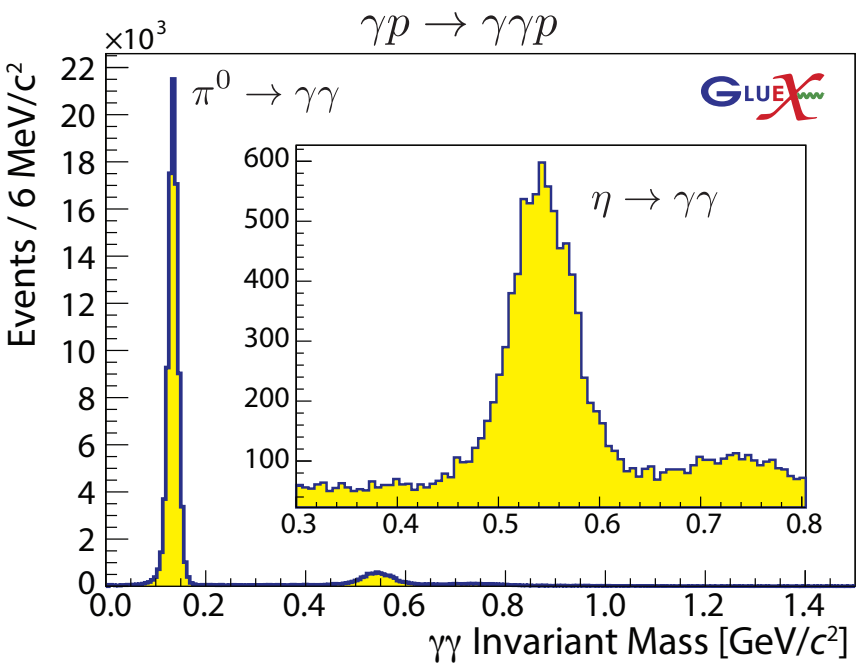




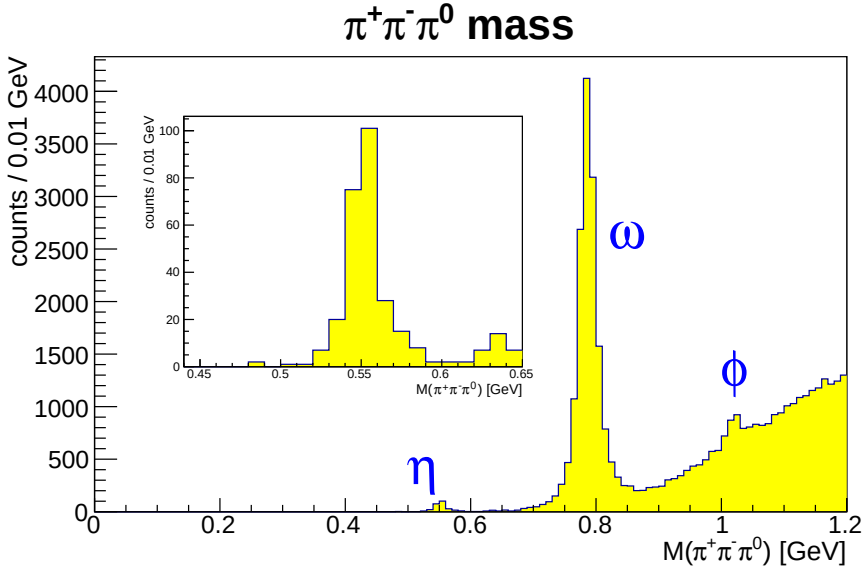
Jefferson Lab

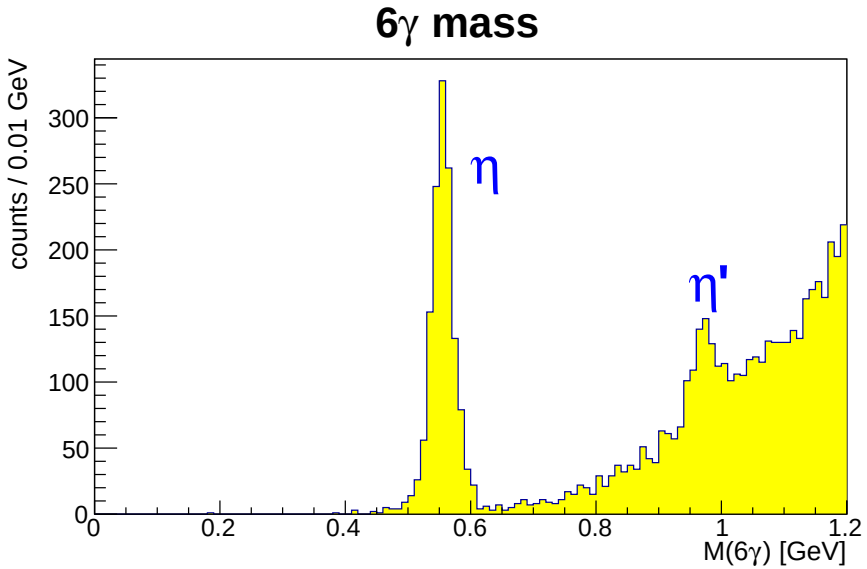
Event Reconstruction and Signals Observed

from 2015 data



from 2016 data



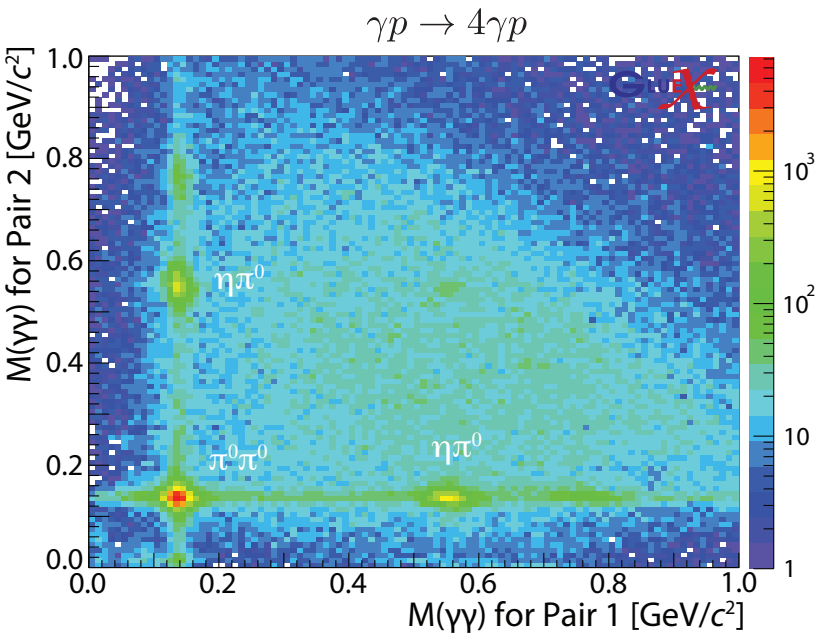


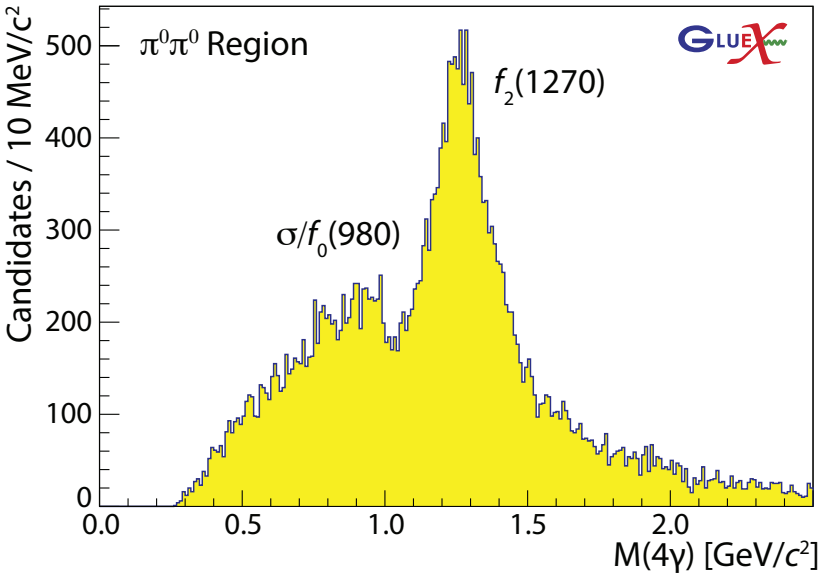
Exclusive reactions for X:

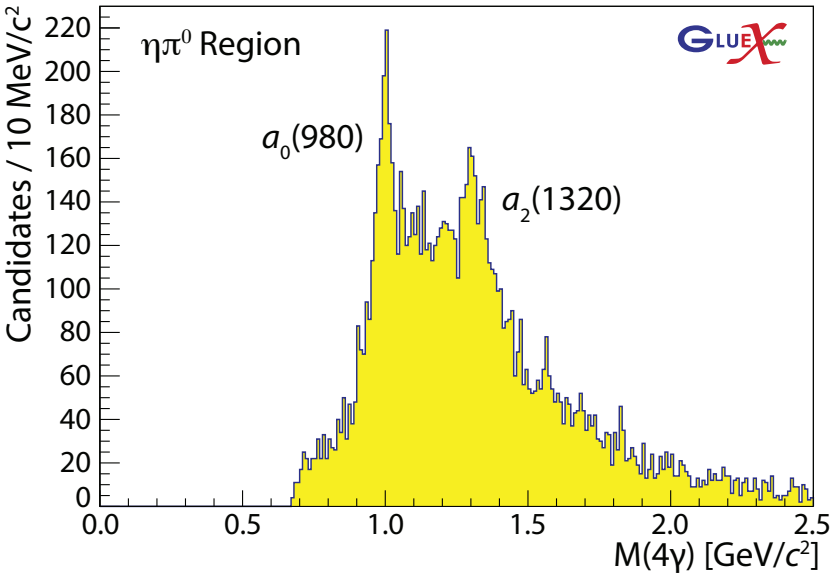
$$\gamma + p \to X + p$$

Event Reconstruction and Signals Observed

- Reaction $\gamma + p \rightarrow p + 4\gamma$
- Combinations $\pi^\circ\pi^\circ$ and $\eta\pi^\circ$



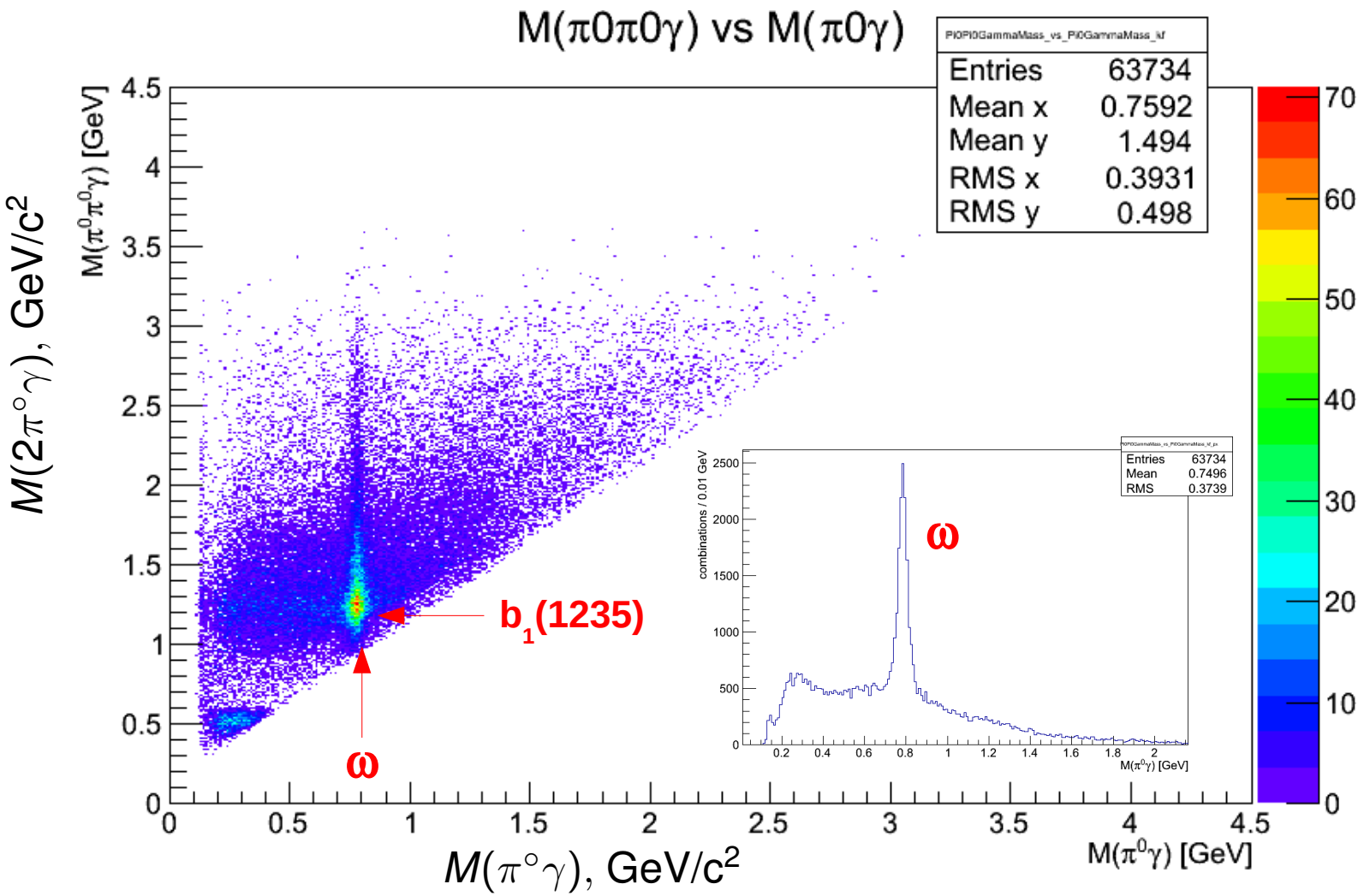




Event Reconstruction and Signals Observed

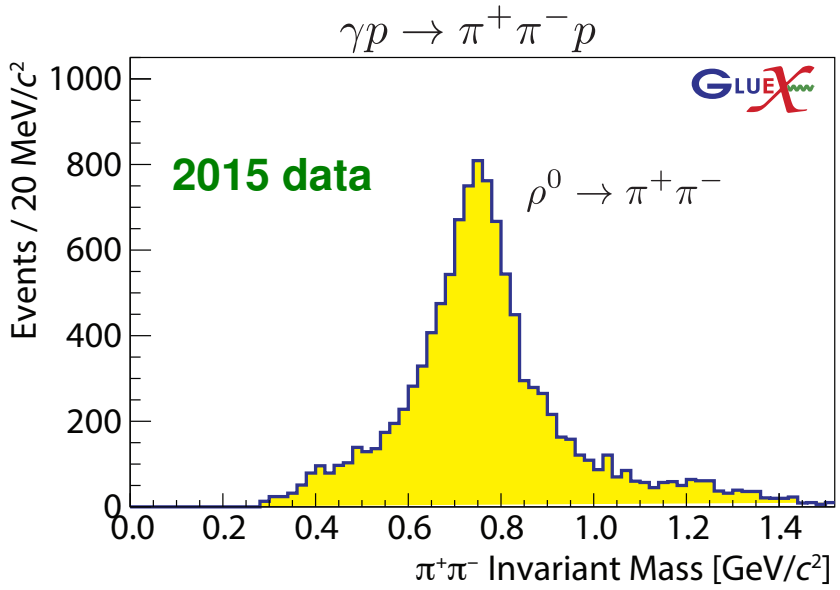
from 2016 data

$\gamma p \rightarrow 2\pi^{\circ}\,\gamma\,p \rightarrow 5\gamma\,p$

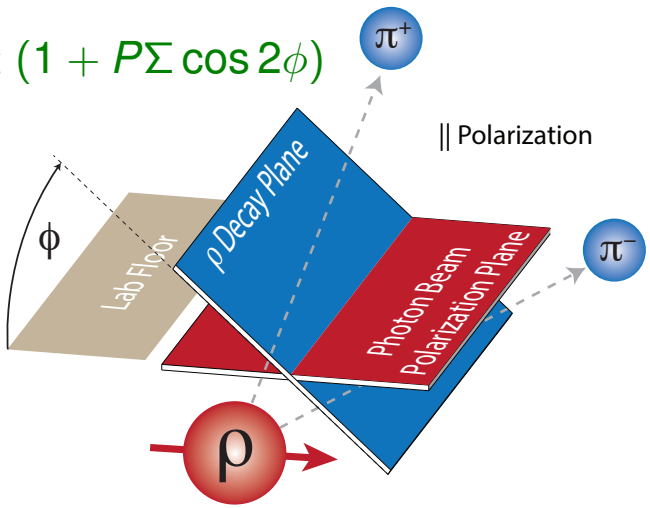


Jefferson Lab

Physics With Linearly Polarized Beam

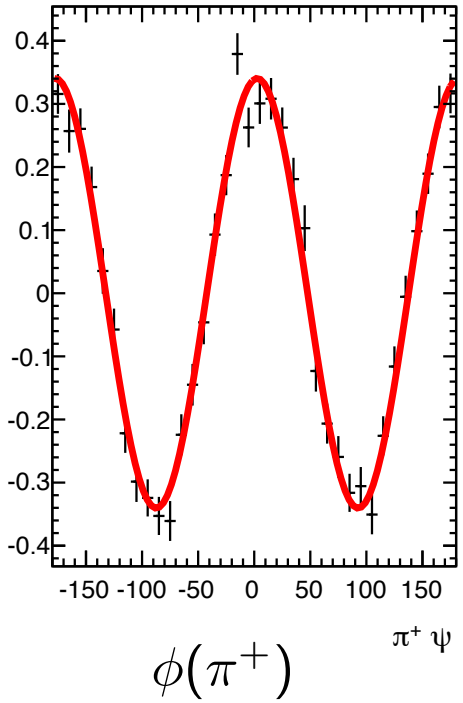


$$\frac{d\sigma}{d\phi} \propto (1 + P\Sigma \cos 2\phi)$$



from 2016 data

- 38k (1% of total) $\gamma p \to \rho^\circ p$ in $8.4 < E_\gamma < 9.0$ GeV
- 2 crystal orientations at 90°
- $\frac{N_0 - N_{90}}{N_0 + N_{90}} = P\Sigma \cos 2\phi$



$P\Sigma = \mathbf{0.341 \pm 0.007\%}$

Summary

- Hall D/GlueX - a complex for spectroscopy studies in linearly polarized photon beam
- Fall 2016 starts regular GlueX data taking
  main program - search for exotic mesons
- Planned upgrade: Cherenkov detector for kaon identification to be installed in 2018
- A scientific program beyond the search for exotic hybrid is in place and growing

APPENDIX

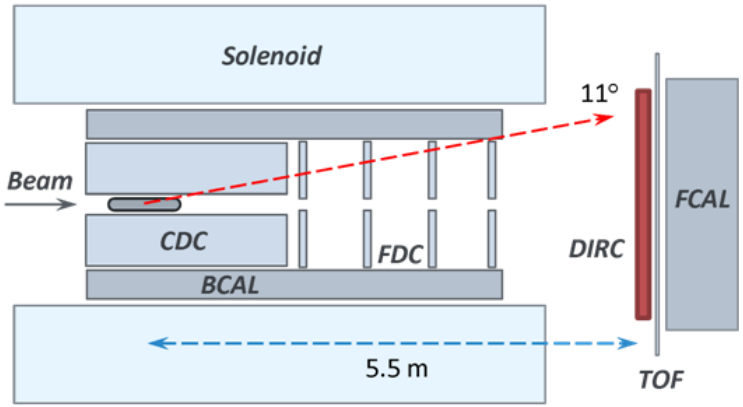
Future Forward Kaon Identification

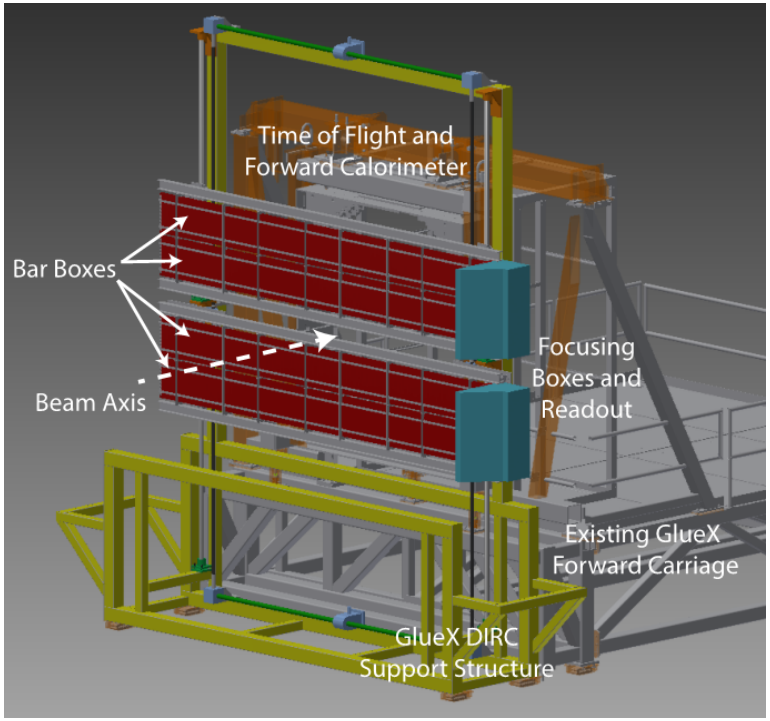
Present PID: TOF, dE/dx, Kinematics

Upgrade

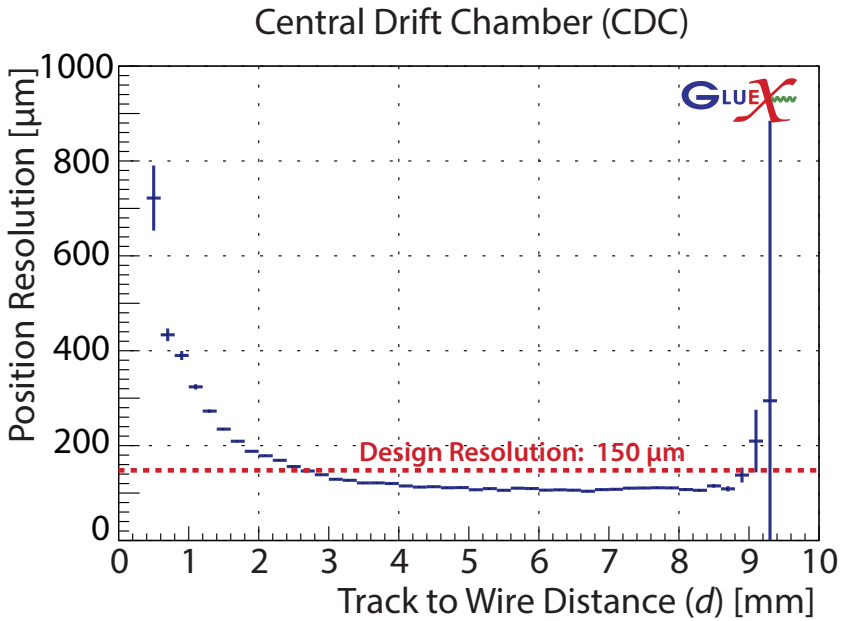
DIRC project, ENP capital budget

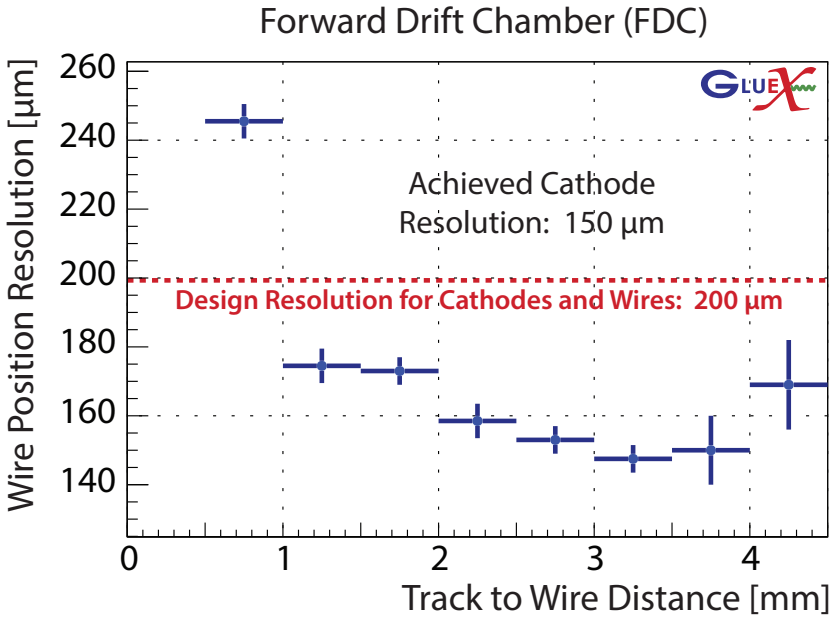
- 4 of the BaBar DIRC bar boxes
- New readout system
- Allows to study:
  - Strangeonium and hybrids
  - Hyperons
- Installation planned for 2018

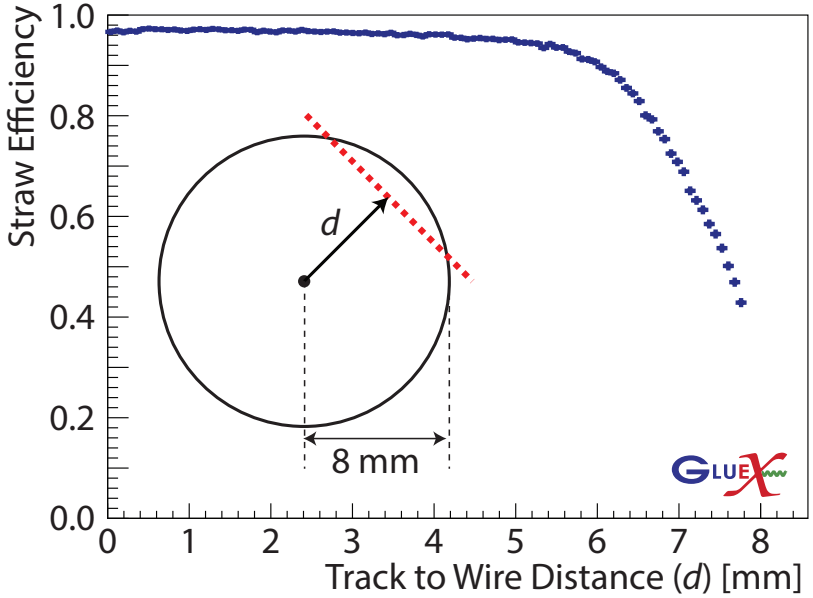


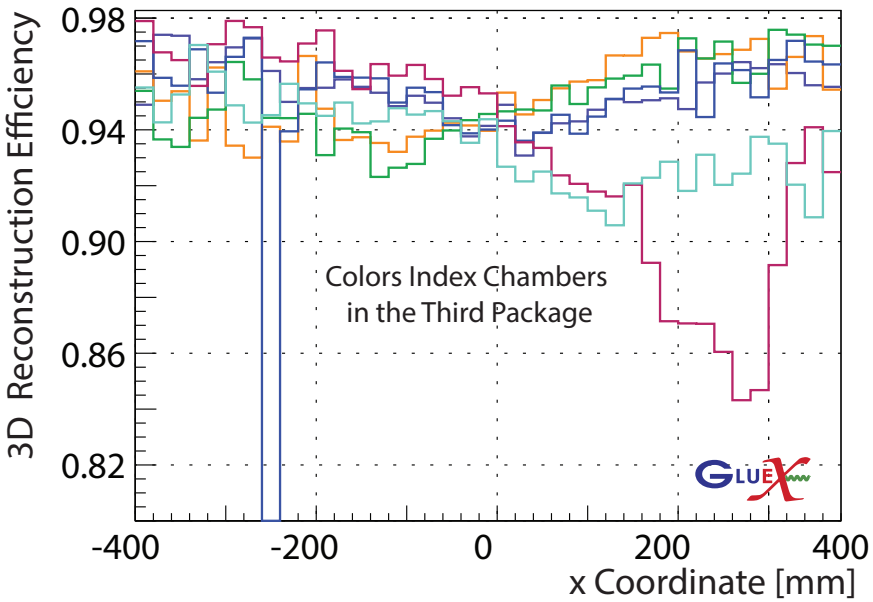


Tracking


Central Drift Chamber (CDC)
Position Resolution [μm]
Design Resolution: 150 μm
Track to Wire Distance (d) [mm]


Forward Drift Chamber (FDC)
Wire Position Resolution [μm]
Achieved Cathode
Resolution: 150 μm
Design Resolution for Cathodes and Wires: 200 μm
Track to Wire Distance [mm]


Straw Efficiency
d
8 mm
Track to Wire Distance (d) [mm]


3D Reconstruction Efficiency
Colors Index Chambers
in the Third Package
x Coordinate [mm]

Photon Detection