Status and Future of Hall D/GlueX

E.Chudakov[1]

[1] JLab

Presented at Workshop

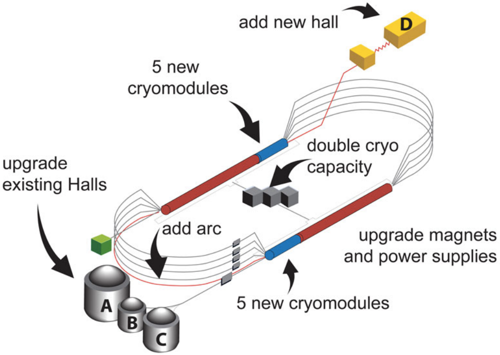
Nuclear Photoproduction with GlueX

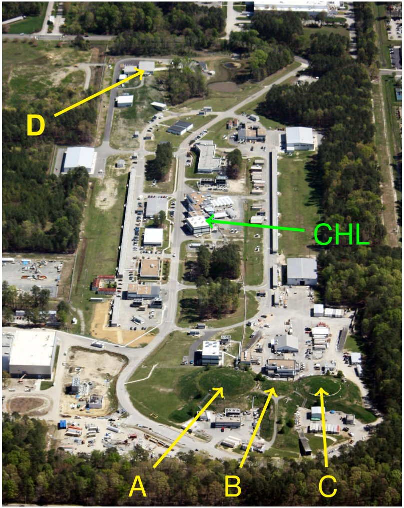
JLab, 28-29 Apr 2016

Outline

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

CEBAF Upgrade to 12 GeV





- Accelerator: 2.2 GeV/pass
- Halls A,B,C: e^- 1-5 passes $\leq$11 GeV
- Hall D: e^- 5.5 passes 12 GeV $\Rightarrow$ γ-beam
- Beam separation to 4 Halls at 250 MHz

Upgrade Status

- 12 GeV started in Feb 2016
- Halls A,D: running; B,C: start in 2017

Hall D at Jefferson Lab

- Hall D - a new hall at Jefferson Lab
  - Commissioning is complete
- Physics with high intensity polarized photon beams
  - *Experiment GlueX: search for exotic hybrid mesons*
  - Radiative widths of pseudoscalars, pion polarizability
  - Other topics in preparation: rare decays, nuclear effects
- A new beamline and a new large acceptance detector
  - Coherent Bremsstrahlung $\Rightarrow$ linearly polarized photons
  - Large solenoidal spectrometer $\Rightarrow$ a uniform acceptance
  - Fully pipelined electronics $\Rightarrow$ very high trigger/DAQ rate

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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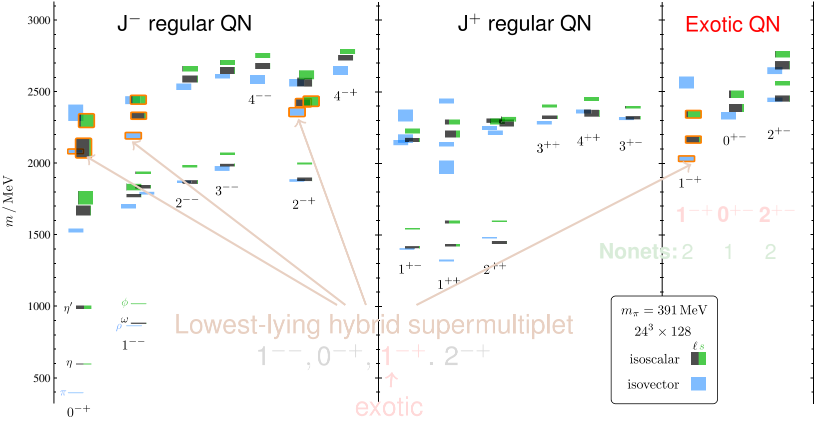
Lattice QCD - the Meson Spectra

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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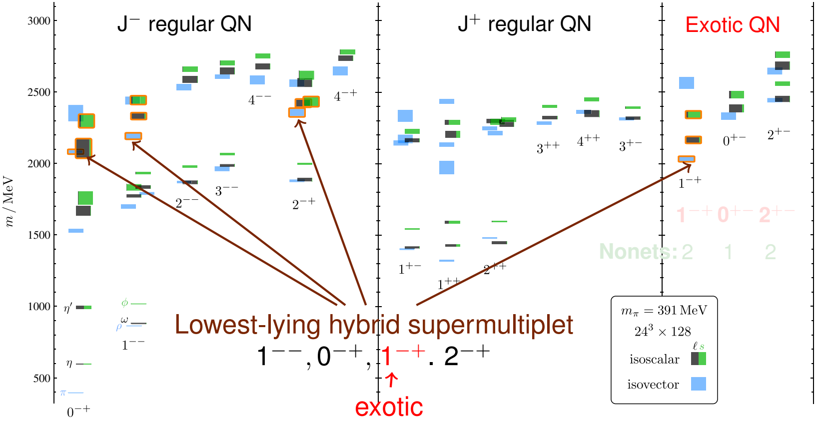

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Jefferson Lab

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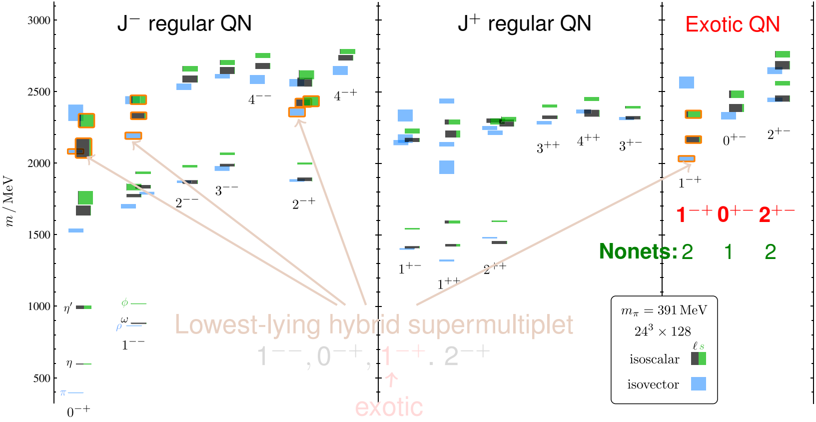

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Hybrids: expected features and ways to detect

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

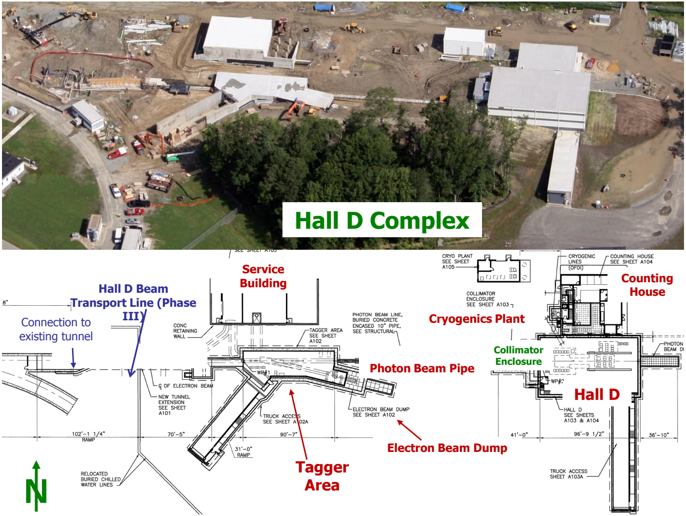
- General requirements:
  - Hermeticity and uniform acceptance for charged particles and photons
  - Good enough resolution to identify exclusive reactions
  - High statistics
- Specific feature: tagged photon beam
  - *Linear polarization helps the QN identification*
  - Beam γ and π^- have different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

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, and Yerevan Physics Institute.

Over 100 collaborators from 23 institutions. Others are planning to join and more are welcome.

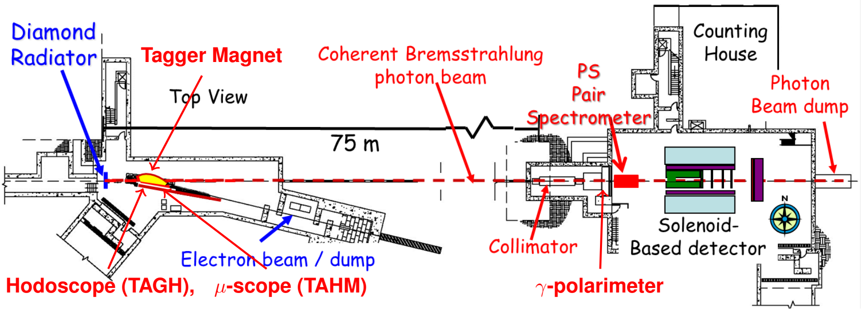
Hall D Complex



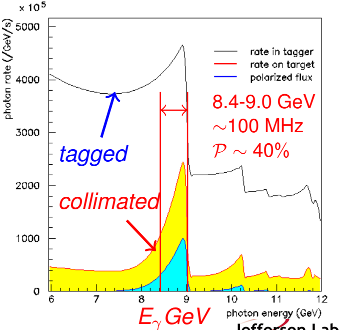
Civil
Photo July 2011
Ready Dec 2011

Beam/detector
Ready Oct 2014

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 $\mathcal{P} \sim 40\%$
  2.2 μA $\Rightarrow$ 100 MHz γ
- Energy/polarization measured:
  - Tagger spectrometer σ_E/E ~0.1%
  - Pair spectrometer: spectrum $\Rightarrow \sigma_{\mathcal{P}}/\mathcal{P}$ ~5%



Jefferson Lab

Hall D/GlueX Spectrometer and DAQ

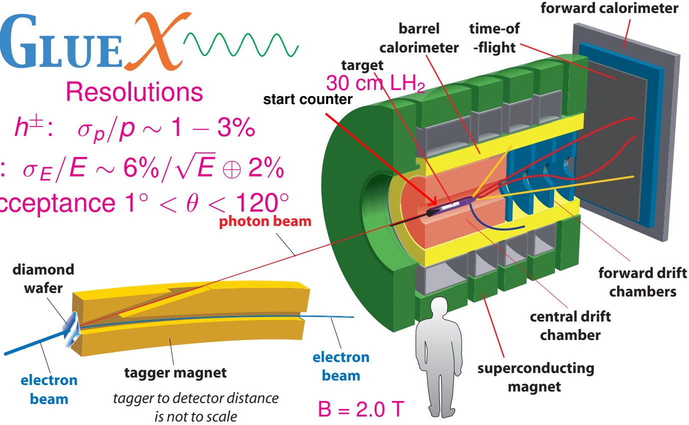
GlueX

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

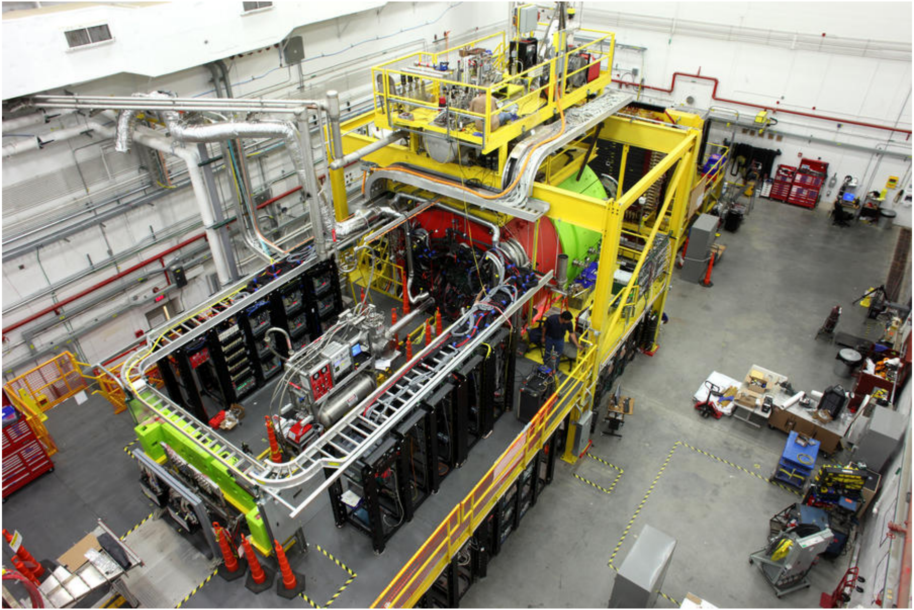
- 2017 L3
- 2018 Cherenkov

Photoproduction γp 15 kHz for a 100 MHz beam

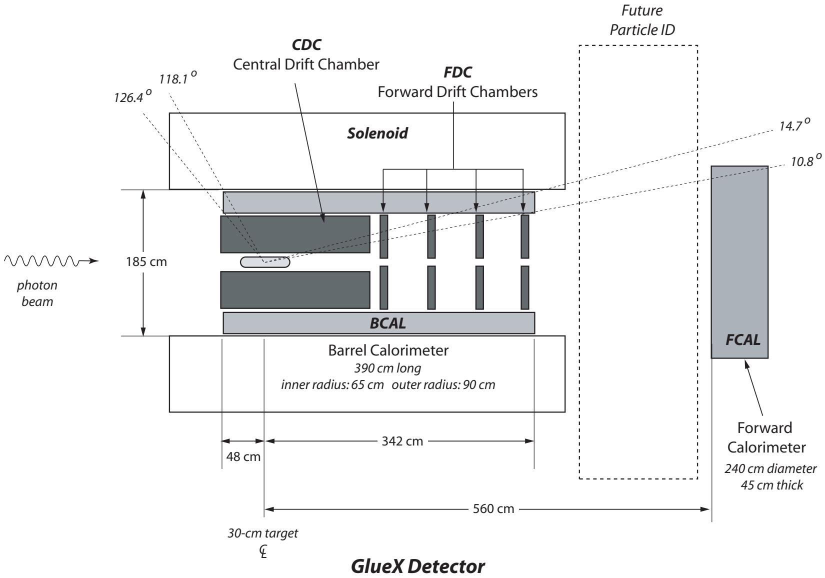
Beam 10 MHz/GeV: inclusive trigger 20 kHz $\Rightarrow$ DAQ $\Rightarrow$ tape

Beam 100 MHz/GeV: inclusive trigger 200 kHz $\Rightarrow$ DAQ $\Rightarrow$ L3 farm $\Rightarrow$ tape

Hall D

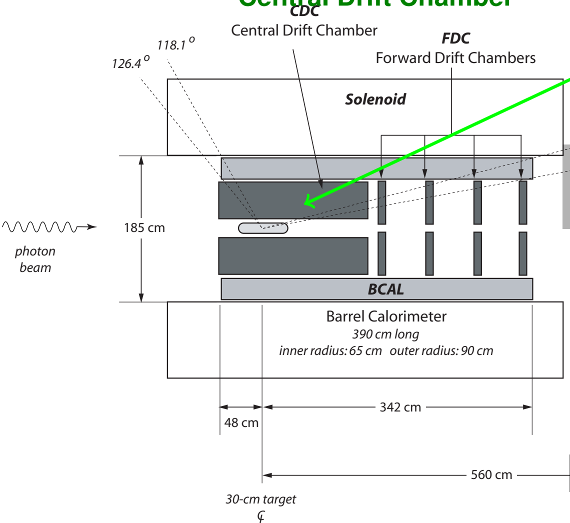


Spectrometer, Detectors and Dimensions



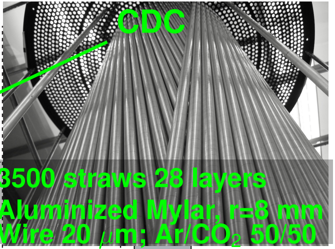
Spectrometer, Detectors and Dimensions

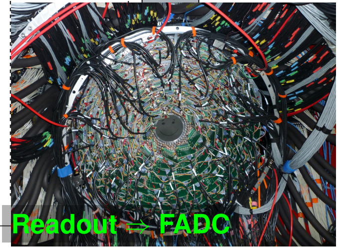
Central Drift Chamber



GlueX Detector

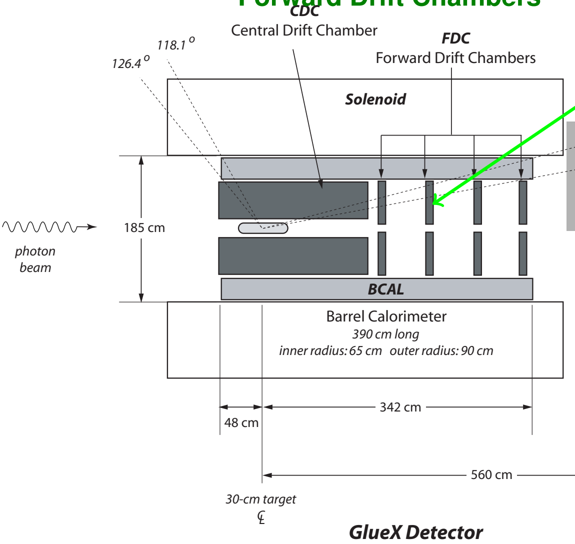
Future





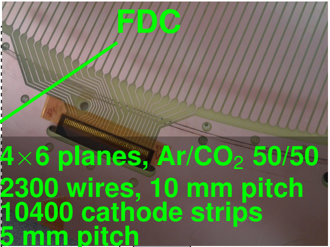
Spectrometer, Detectors and Dimensions

Forward Drift Chambers

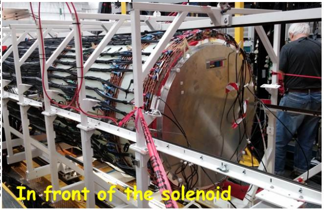


Future

FDC



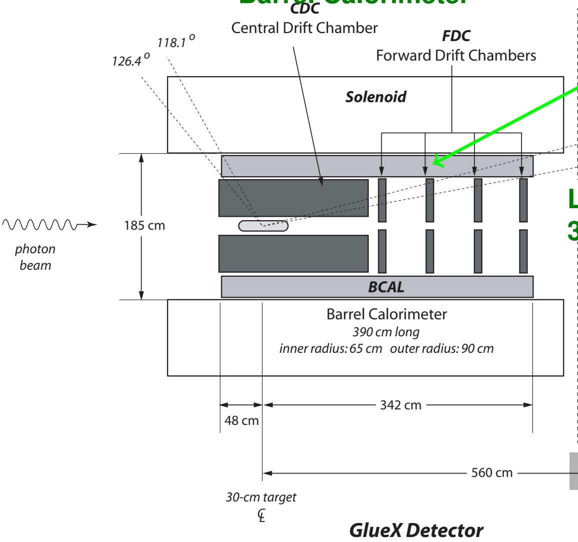
4×6 planes, Ar/CO_2 50/50
2300 wires, 10 mm pitch
10400 cathode strips
5 mm pitch



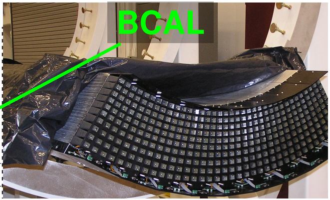
Readout: strips $\Rightarrow$ FADC
Readout: wires $\Rightarrow$ TDC

Spectrometer, Detectors and Dimensions

Barrel Calorimeter

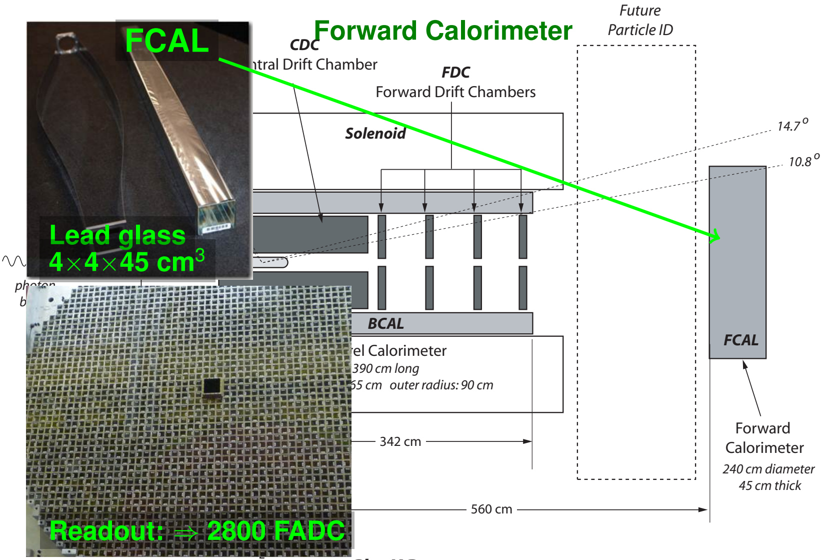


Future



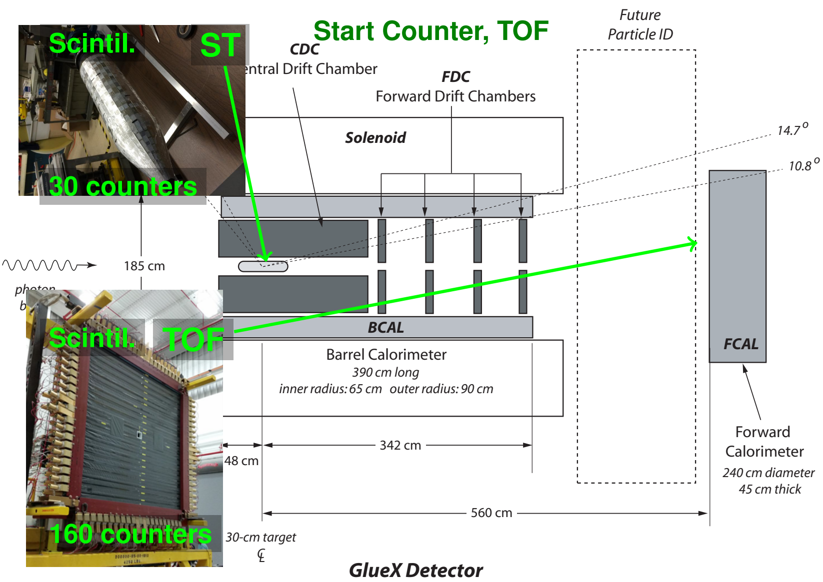
Lead-scintill.fibers
3840 light guides ⇒ SiPMs

Spectrometer, Detectors and Dimensions



GlueX Detector

Spectrometer, Detectors and Dimensions



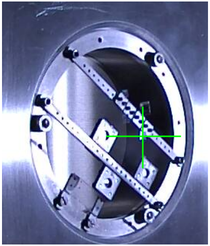
Hall D/GlueX Commissioning Status

Runs with beam:

- Fall 2014 10.0 GeV beam: beam commissioning and detector checkout
  - Unpolarized beam and nuclear target
- Spring 2015 5.5 GeV beam: 1 week of beam - commissioning
  - Commissioning of the linearly polarized beam
  - Commissioning of the Liquid Hydrogen target
- Spring 2016 12 GeV beam (Feb 10 - Apr 25)
  - Engineering run: commissioning is complete
  - Data for early physics results
  - $\sim$ 24 G events recorded

Hall D/GlueX Beam: Coherent Bremsstrahlung

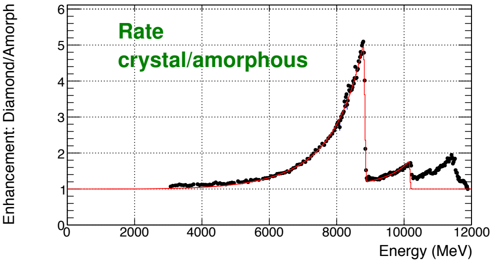
- 20-50 μm thick diamond radiators
- Precision alignment using a goniometer

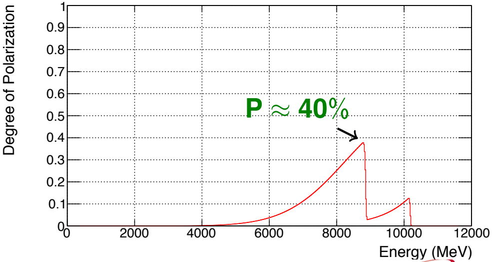


Polarization measurements

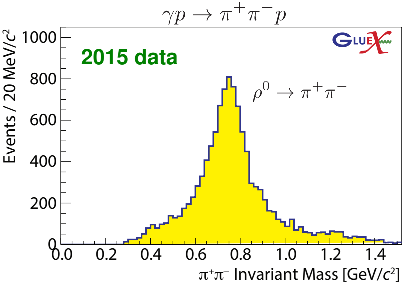
- Derived from the spectrum
- Triple polarimeter $\gamma e^- \rightarrow e^+ e^- e^-$
- Processes like $\gamma p \rightarrow \rho^\circ p$

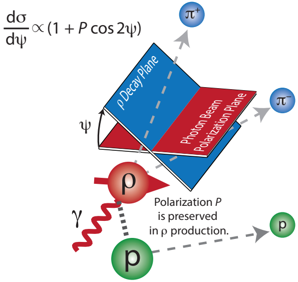
Run 10492: 50 µm diamond





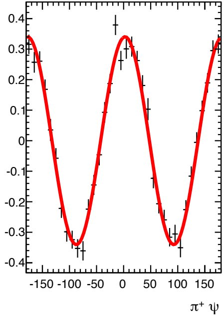
Physics With Linearly Polarized Beam





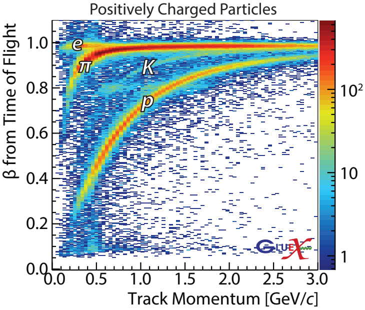
from 2016 data

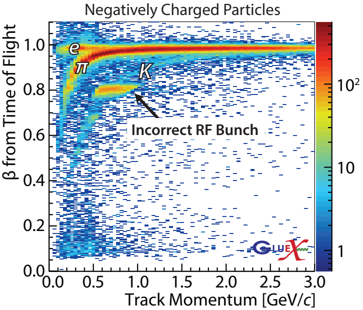
- 38k $\gamma p \to \rho^\circ p$ in $8.4 < E_\gamma < 9.0$ GeV
- 2 crystal orientations at 90°
- $\frac{N_0 - N_{90}}{N_0 + N_{90}} = P\Sigma\cos 2\psi$

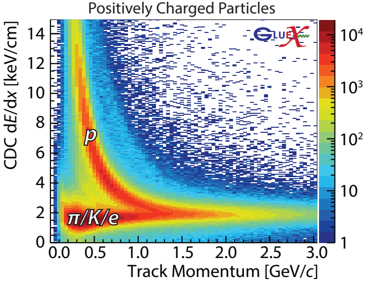


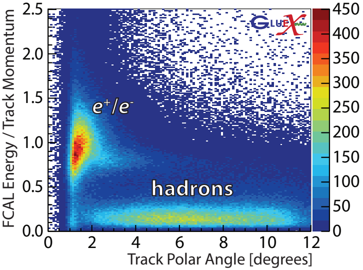
$P\Sigma = \mathbf{0.341 \pm 0.007\%}$

PID


Positively Charged Particles
β from Time of Flight
Track Momentum [GeV/c]
e
π
K
p

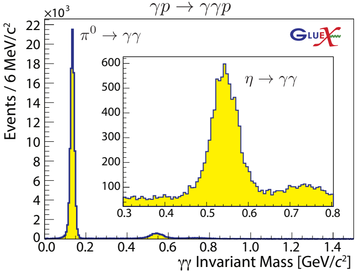

Negatively Charged Particles
β from Time of Flight
Track Momentum [GeV/c]
e
π
K
Incorrect RF Bunch

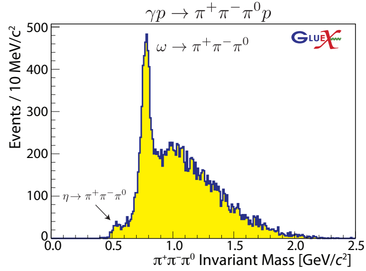

Positively Charged Particles
CDC dE/dx [keV/cm]
Track Momentum [GeV/c]
p
π/K/e


FCAL Energy / Track Momentum
Track Polar Angle [degrees]
e+/e-
hadrons

Event Reconstruction and Signals Observed

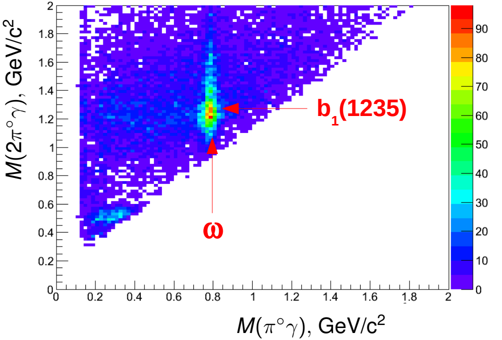
2015 data





from 2016 data

$\gamma p \to 2\pi^\circ \gamma p \to 5\gamma p$



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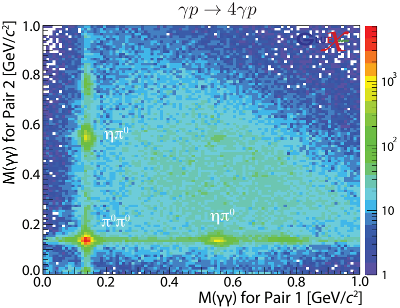
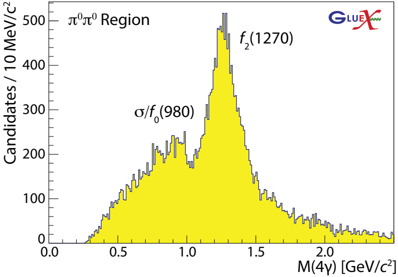
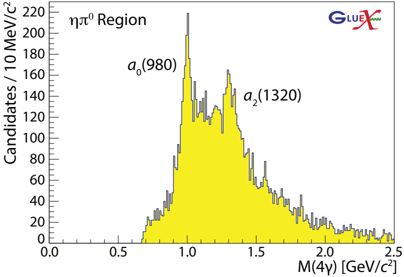
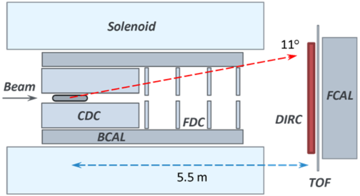






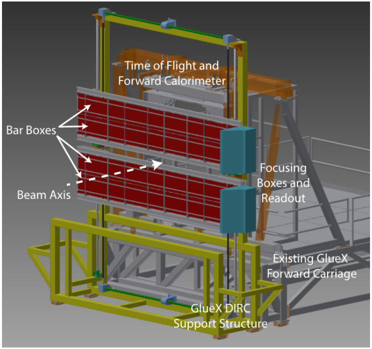
Forward Kaon Identification

Present PID: TOF, dE/dx, Kinematics



Upgrade

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



Hall D Preliminary Running Schedule

- 2016-2018 GlueX at “low” intensity of 10 MHz in the peak
- 2018 PRIMEX (Primakoff) experiment
- 2018 DIRC installation
- 2019-2022 GlueX at “high” intensity 5×10 MHz in the peak
  focus on hidden strangeness and hyperon resonances

APPENDIX

Hall D Physics Program

Proposal/ experiment	Sta- tus	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 η 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 $\gamma\gamma \to \pi^+\pi^-$ Reaction	25	40
E12-12-002	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 Experiment (JEF) *partly concurrent with GlueX* ($\eta \to 3\pi$)	(130)	42
LOI12-15-001		Physics with secondary K_L° beam		43
LOI12-15-006		ω-production on nuclei		43