Hall D Report

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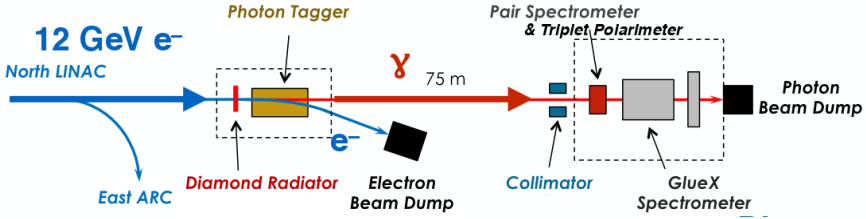
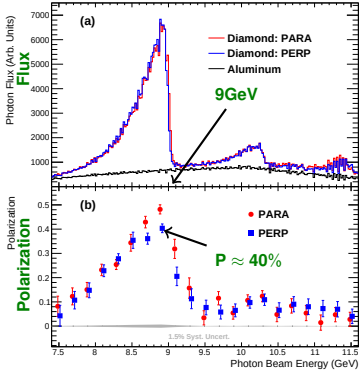
Hall D Group Leader

JLab PAC50, Jul 2022

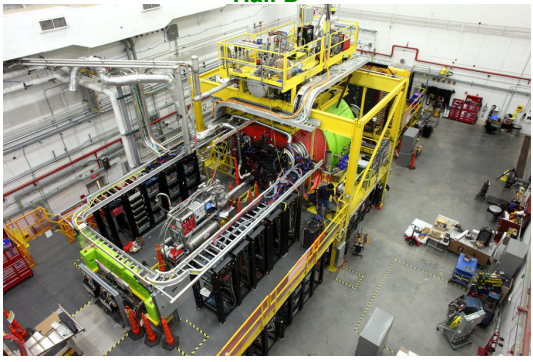
Hall D Apparatus



Photon Beam Spectrum



Hall D



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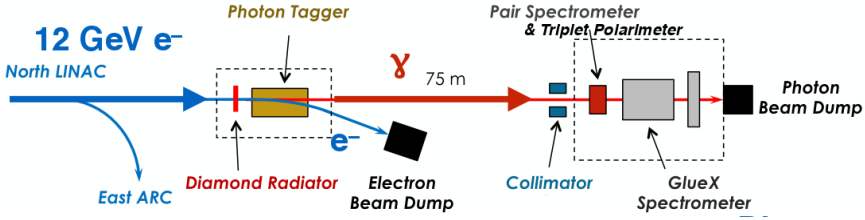

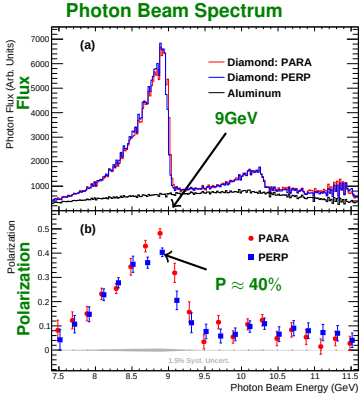

Photon beam

- Linear polarization
- Tagging $\sigma E/E \sim 0.1\%$
- Pair Spectrometer & Triple Polarimeter

Spectrometer

- Acceptance: $1^\circ < \theta < 120^\circ$
- Resolutions: $h^\pm$: $\sigma_p/p \sim 1 - 3\%$
  γ: $\sigma_E/E \sim 6\%/\sqrt{E} + 2\%$
- Trigger: all photoproduction at $E_{BEAM} > 7$ GeV
  DAQ in 2021: 85 kHz (photoproduction + EM background)

Physics Program in Hall D

Experiment	Title	PAC rating	PAC days	PAC #	data taken
E12-06-102	Mapping the Spectrum of Light Quark Mesons and Gluonic Excitations with Linearly Polarized Photons	A	120	30	100%
E12-12-002	A study of meson and baryon decays to strange final states with GlueX in Hall D	A	220	42	33%
E12-13-003	An initial study of hadron decays to strange final states with GlueX in Hall D	Grp	200	40	
A	Eta Decays with Emphasis on Rare Neutral Modes: The JLab Eta Factory(JEF) Experiment	Grp	100	45	0%
E12-10-011	A Precision Measurement of the eta Radiative Decay Width via the Primakoff Effect	A-	79	35	47%
E12-13-008	Measuring the Charged Pion Polarizability in the $\gamma\gamma \to \pi^+\pi^-$ Reaction	A-	25	40	≈40%
A	Measuring the neutral pion polarizability	Grp		48	
E12-19-003	Studying Short-Range Correlations with Real Photon Beams at GlueX	B+	15	47	100%
E12-19-001	Strange Hadron Spectroscopy with Secondary KL Beam in Hall D	A-	200	48	
E12-20-011	Measurement of the high-energy contribution to the Gerasimov-Drell-Hearn sum rule	A-	33	48	

- considerable installation / new equipment required

https://www.jlab.org/Hall-D/runs.html

Hall D physics runs

Year	Dates	Calendar days	Beam, GeV	ABU[1] + BANU	ABU	Experiment	PDL	Comment	PAC days[3]	PAC days total
2016	Feb, 3 - Mar, 23	49	12.0	?	?	E12-06-102	B.Zihlmann	Engineering run, solenoid at 1200A	3+25	25
2017	Jan, 30 - Mar, 9	40	11.7	58%	51%	E12-06-102	B.Zihlmann	Production	20	45
2018	Jan, 12 - Mar, 5	52	11.7	52%	46%	E12-06-102	B.Zihlmann	Production	26	71
2018	Mar, 29 - May, 6	38	11.7	58%	52%	E12-06-102	B.Zihlmann	Production	19	90
2018	Sep, 21 - Nov, 26	66	11.7	53%	47%	E12-06-102	B.Zihlmann	Production	33	**123**
2018	Nov, 28 - Dec, 9	12	10.3	?	N/A	E12-10-011	L.Pentchev	Commissioning, low energy	N/A	
2018	Dec, 12 - Dec, 18	7	9.0	?	N/A	E12-10-011	L.Pentchev	Commissioning, low energy	N/A	
2019	Feb, 8 - Feb, 21	13	11.6	45%	N/A	E12-12-002	B.Zihlmann	1/2 DIRC Commissioning	6	6
2019	Feb, 21 - Mar, 5	15	11.6	52%	37%	E12-10-011	L.Pentchev	Installation, Production on Be, LHe, FOM=0.97[4]	7.3	7.3
2019	Mar, 8 - Apr, 15	38	11.2	73%	68%	E12-10-011	L.Pentchev	Production on LHe, FOM=0.85[4]	16.1	23.4
2019	Nov, 25 - Dec, 20	25	11.4	34%	32%	E12-12-002	B.Zihlmann	DIRC commissioning, actual start Dec, 3. PAC days = 0.32*25	8	14
2020	Jan, 10 - Mar, 24	75	11.4	62%	56%	E12-12-002	B.Zihlmann	Production with DIRC at high rate. First 2 weeks - lower rate	38	52
2020	Jul, 27 - Sep, 21	56	11.4	46%	38%	E12-12-002	B.Zihlmann	Production with DIRC at high rate	21.5	73.5
2021	Sep, 16 - Nov, 4	50	10.1	51%	45%	E12-10-011	L.Pentchev	Production on LHe, FOM=0.56[4]	14	37.4
2021	Nov, 8 - Dec, 21	43	10.9	70%	60%	E12-19-003	L.Pentchev	Production on LHe, LD, C FOM=0.73[5] PAC=43*0.6*0.73=19	19	**19**
2022	Jun, 8 - Jul, 27	50	11.6			E12-13-008	S.Taylor	*Running...*	25 ?	**25**
2022	Aug, 4 - Nov, 6	95	11.4			E12-10-011	L.Pentchev	Production on LHe, FOM=0.91[4]	43.2 ?	**80.6**
2022	Nov, 11 - Dec, 18	38	11.4			E12-12-002	B.Zihlmann		19 ?	92.5
2023	Jan, 16 - Mar, 19	63	11.4			E12-12-002	B.Zihlmann		31.5 ?	124
2023	Jul, 17 - Mar, 17	216						**FCAL2 installation**		

E12-12-002 GlueX-II
E12-10-011 PrimeX-η
E12-19-003 SRC
E12-13-008 CPP/NPP

1. ABU - Available Beam in Use (fraction of the calendar time), BANU - Beam Available Not in Use
3. PAC days - Assumed to be 50% of the calendar days
4. The figure-of-merit FOM for PRIMEX-η depends on the beam energy because of the Primakoff cross section and the background levels depends on the energy. The proposal assumed a 12 GeV beam. Our calculations were normalized to 11.7 GeV: FOM(11.7)=1.
5. SRC/CT: Assuming that the coherent edge is selected at the same energy (8.7 GeV) and that the beam current is selected keeping the same low energy flux (0.1-3 GeV), and ignoring the polarization, a conservative estimate for the improvement in the beam flux at 10.9 GeV is (10.9)/FOM(11.7)=73%

https://www.jlab.org/Hall-D/runs.html

Hall D physics runs

Year	Dates	Calendar days	Beam, GeV	ABU[1] + BANU	ABU	Experiment	PDL	Comment	PAC days[3]	PAC days total
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2018	Mar, 29 - Ma								19	90
2018	Sep, 21 - No								33	**123**
2018	Nov, 28 - Dec								N/A	
2018	Dec, 12 - Dec								N/A	
2019	Feb, 8 - Feb,								6	6
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Ongoing run: 2022/06/08 → 2023/03/19

- CPP/NPP run 50 calendar days
- 7 days for CPP deinstallation and preparation for PrimeX
  - Removal of the muon detector
  - Reinstalling the μ-scope in the regular position
  - Reinstalling the Compton Calorimeter (CCAL)
  - Reinstalling the cryo target
  - Move the crate with FADC125 back to CDC
- PRIMEX-η run 95 calendar days
- 4 days for changeover to GlueX
  - DIRC installation
- GlueX-II run 101 calendar days, in 2 parts

E12-12-002	GlueX-II
E12-10-011	PrimeX-η
E12-19-003	SRC
E12-13-008	CPP/NPP

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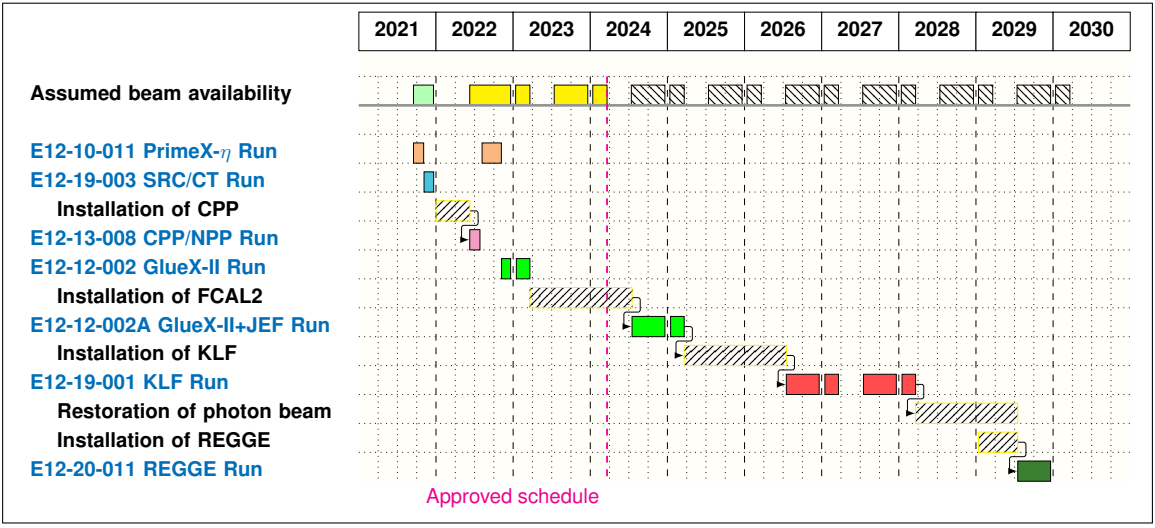
Hall D running schedule: outlook



- Assuming 30 weeks/year for Hall D running
- Assuming timing budgeting for KLF and REGGE
- Assuming timely construction of JEF,KLF,REGGE

Hall D Community

GlueX Collaboration

- 140 participants from 32 institutions from 12 countries
- Currently 19 graduate students
- 19 PhDs since 2016

KLF Collaboration

- 200 participants from 68 institutions from 19 countries
- Partly overlapping with GlueX

SRC/CT group

- 30 post-bachelor researchers + a part of the GlueX collaboration
- 3 graduate students + 1 postdoc (dedicated to Hall D SRC)

Hall D staff

- 12 staff scientists + 2 hiring
- 2 postdocs
- 8 engineering and technical group

Hall D Highlights

Data taking

- GlueX-I (E12-06-102) 100% complete
- PrimeX-η (E12-10-011) 47% of total
- GlueX-II (E12-12-002) 33% of total
- SRC/CT (E12-19-003) 100% of total

Data processing

- E12-06-102 100%
- E12-10-011 2019 data 100%
- E12-12-002 2020 spring data 100%

Data analysis and results

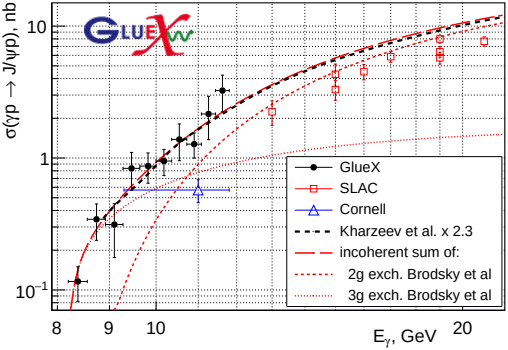
- Physics analysis of E12-06-102 data:
  - J/ψ: 1 PRL paper (2019, 25% of data): *124 citations - Plenty of interest*
  - Beam asymmetries: 5 PRC papers
  - Search for axion-type particles: 1 PRD paper
  - Talks since PAC49: 21 at APS DNP meetings, 14 at other conferences and workshops
  - Step by step analysis strategy: asymmetries, SDME, cross sections, PWA
- Technical papers: 24 NIMA publications in total

Coming Reviews

- 2022 July 19-21: DOE Science and technology review
- 2022 Fall: 2-nd Review of GlueX progress in search for hybrids

GlueX E12-06-102: J/ψ production

PRL 123 (2019) 7, 072001 25% of GlueX-I data, 124 citations



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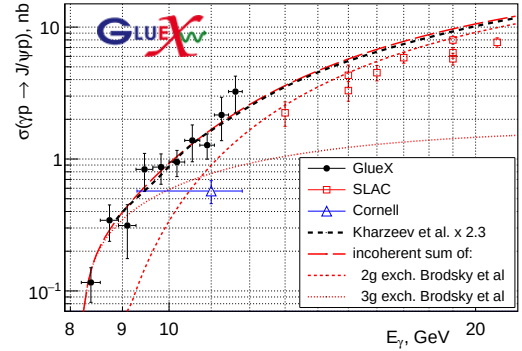
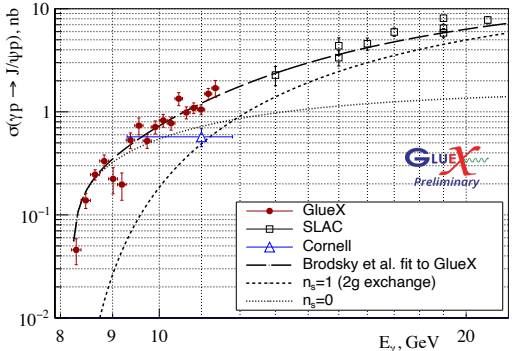
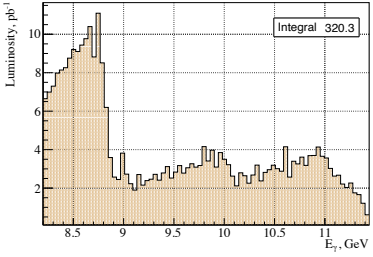


Full GlueX-I data, preliminary

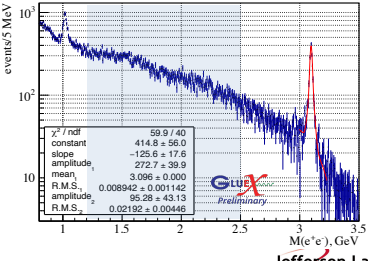


- $\gamma p \to J/\psi p, J/\psi \to e^+e^-$
- Kin. fit: mass resolution $\approx$ 13 MeV, no radiative tail 2140 ± 60 J/ψ
- BH 1.2-2.5 GeV used for normalization

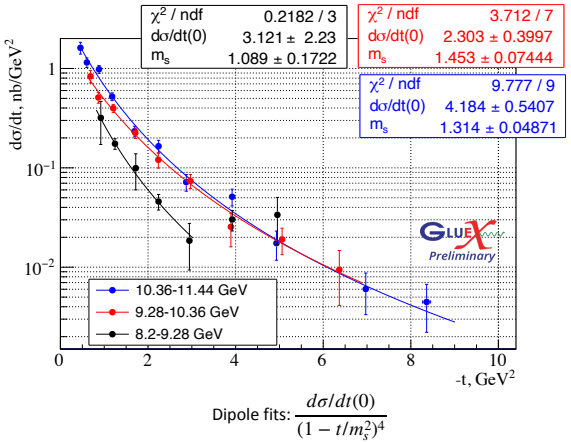
Luminosity (E_{BEAM})



e^+e^- invariant mass spectrum



GlueX E12-06-102: J/ψ production (continued)



Dipole fits: $\frac{d\sigma/dt(0)}{(1 - t/m_s^2)^4}$

$\frac{d\sigma}{dt}(0)$ extrapolation to threshold
Model-dependent applications

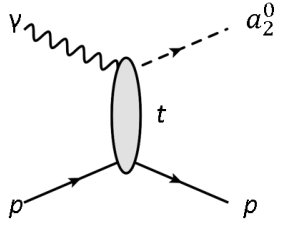
- $J/\psi - p$ scattering length $\approx$ 18 mfm
  EPJ A57(2021)2,56
  $\Rightarrow$ very weak $J/\psi - p$ interaction
- Proton mass radius $\approx$ 0.5 fm
  Kharzeev PRD104(2021)
- Relation to GFF-QCD
  Guo PRD103(2021); Mamo PRD104; Hatta PRD100

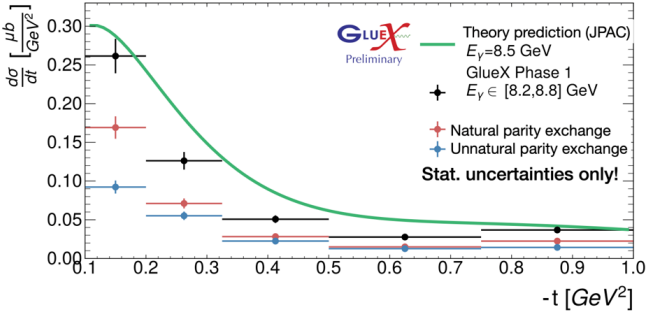
$\sigma(E)$ dependence
Various calculations

- QCD LO,NLO *Ivanov et al EPJ C34 (2004)*
- GPD+LQCD GFF *Guo et al PRD 103 (2021)*
- Open charm exchange *Du et at EPJ C80 (2020)*

- The results will be presented by L.Pentchev at a Workshop on Hard Exclusive Reactions on July 20: https://indico.phys.vt.edu/event/51/
- GlueX outlook on J/ψ: GlueX-II - $\times$4 statistics; better $e^{\pm}$ identification with FCAL2 and possible TRD - reduction of systematic errors

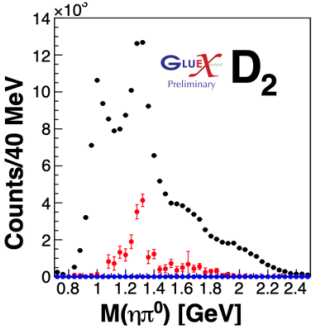
GlueX E12-06-102: Path towards exotic searches: $\gamma p \to a_2(1320)p, a_2 \to \eta\pi$





- Relevant for $\pi_1(1600) \to \eta\pi, \eta'\pi$ search
- Validates theoretical amplitudes and analysis techniques
- Forms a benchmark needed to analyze $\eta'\pi$ states

- The a_2 production cross section was obtained using the intensity of D waves obtained using PWA

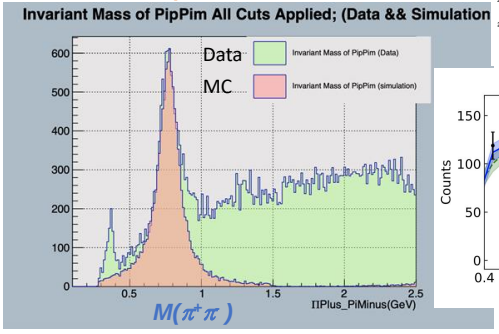


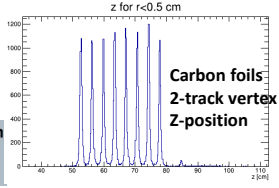
Hall D

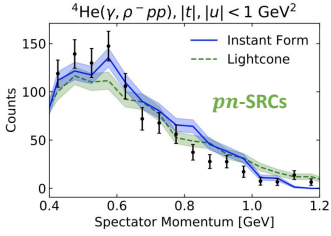
SRC/CT E12-19-003 ran in FY22

- Reconstruct recoil nucleons in reactions A(γ, p π^- p) , A(γ, ρ^0 p p) . . .
- Determine fraction of np, pp SRC pairs
- Nuclear targets: LD, LHe, C
- Analysis underway (graduate students from Duke, GW, Miss. St., MIT):
  - Short-range correlations
  - Color transparency
  - Several other exotic topics.

ρ^0 Transparency

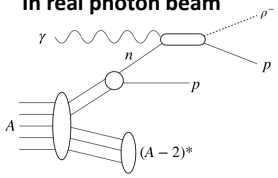




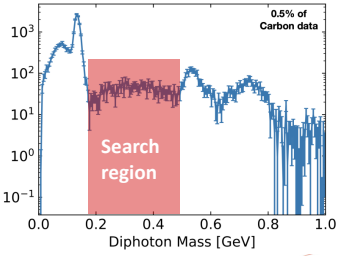


- Short range correlations
- Color transparency

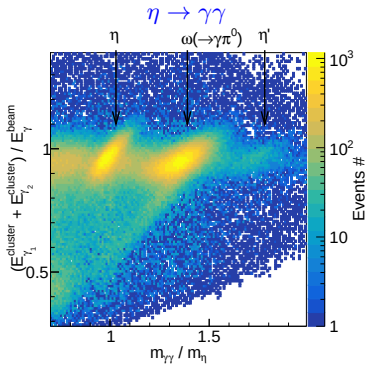
In real photon beam

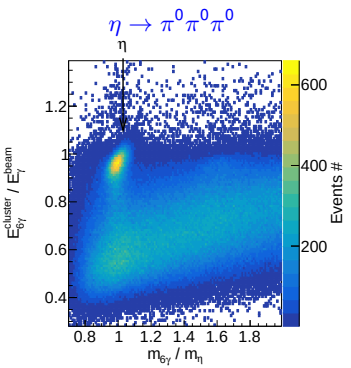


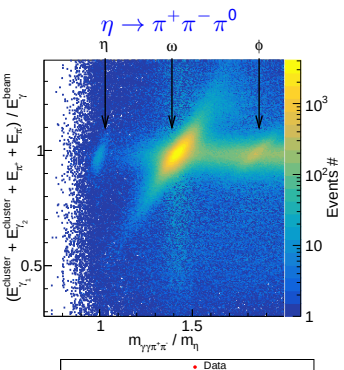
Axion-Like Particle (ALP) Search

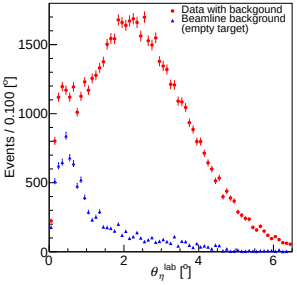


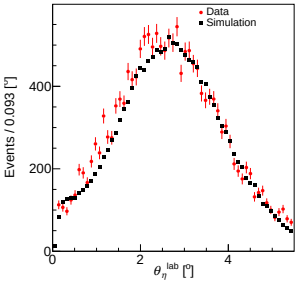
PrimeX-η (Primakoff reaction $\gamma Z \to \eta Z$) new run: 3 decay modes

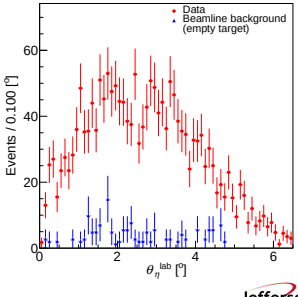






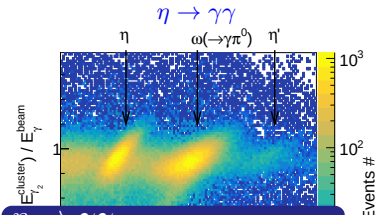






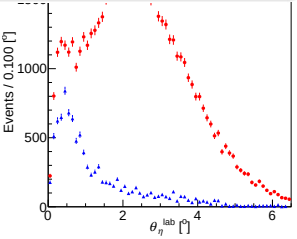
Jefferson Lab

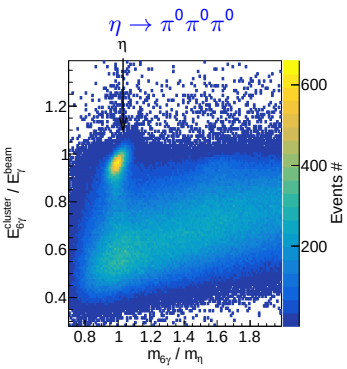
PrimeX-η (Primakoff reaction $\gamma Z \to \eta Z$) new run: 3 decay modes

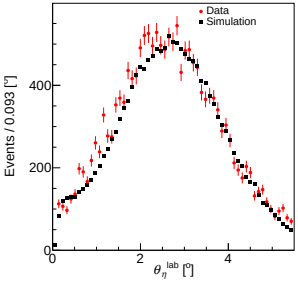


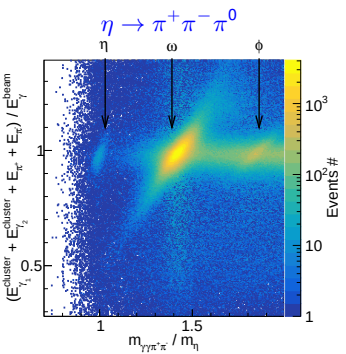
$\eta \to \gamma\gamma$

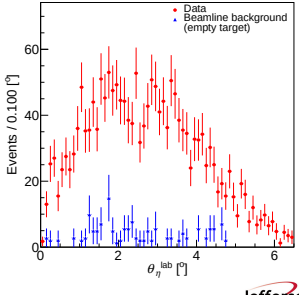
Large “Empty target” BG
at small θ
Reduced by TOF veto $\Rightarrow$ charged
Likely EM: Pairs, Compton
$\gamma \to$ 2 particles produced
downstream imitate small θ



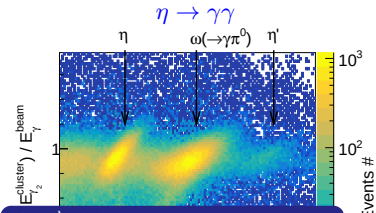






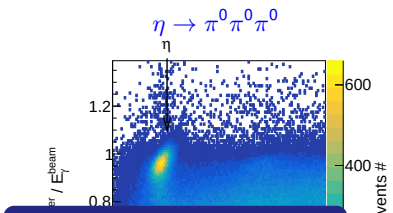


PrimeX-η (Primakoff reaction $\gamma Z \to \eta Z$) new run: 3 decay modes



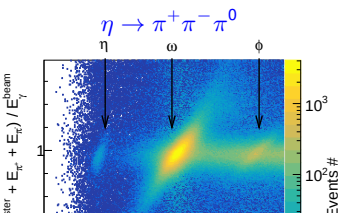
$\eta \to \gamma\gamma$

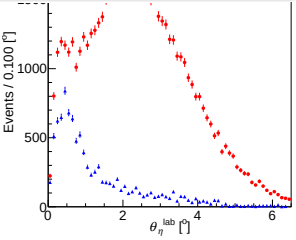
Large "Empty target" BG
at small θ
Reduced by TOF veto ⇒ charged
Likely EM: Pairs, Compton
$\gamma \to$ 2 particles produced
downstream imitate small θ

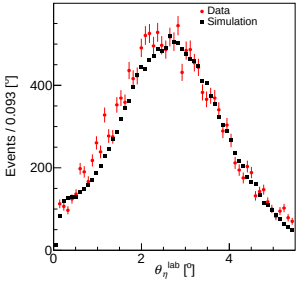


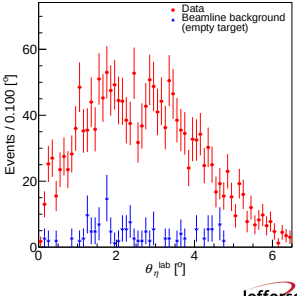
$\eta \to \pi^0\pi^0\pi^0$

No "Empty target" BG
at small θ









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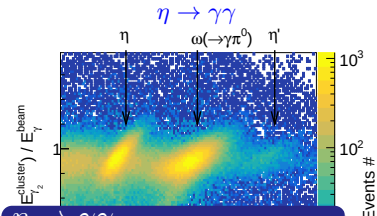
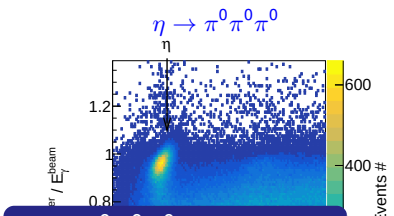
PrimeX-η (Primakoff reaction $\gamma Z \to \eta Z$) new run: 3 decay modes



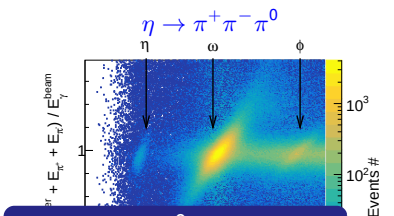
$\eta \to \gamma\gamma$

Large "Empty target" BG
at small θ
Reduced by TOF veto $\Rightarrow$ charged
Likely EM: Pairs, Compton
$\gamma \to$ 2 particles produced
downstream imitate small θ



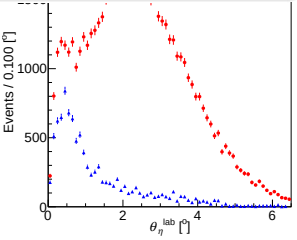
$\eta \to \pi^0\pi^0\pi^0$

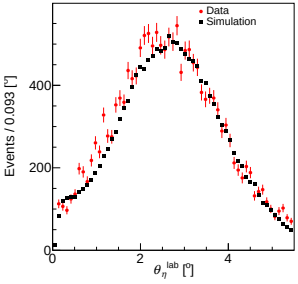
No "Empty target" BG
at small θ

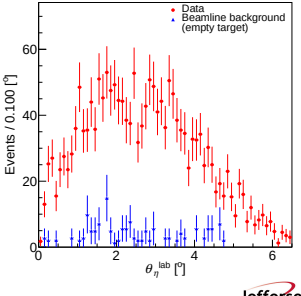


$\eta \to \pi^+\pi^-\pi^0$

No "Empty target" BG
at small θ







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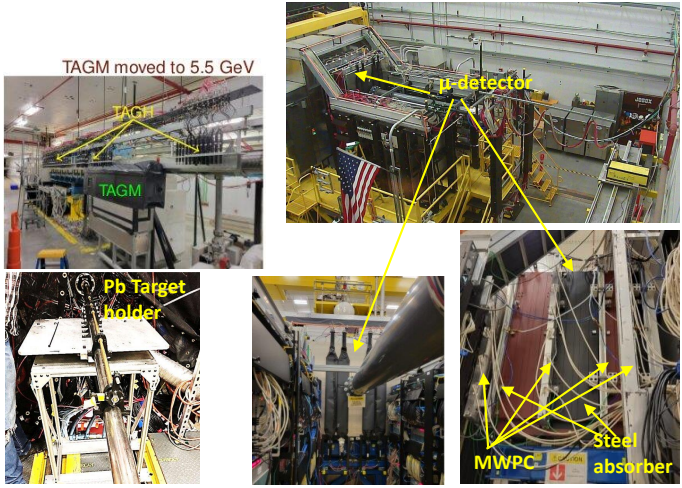
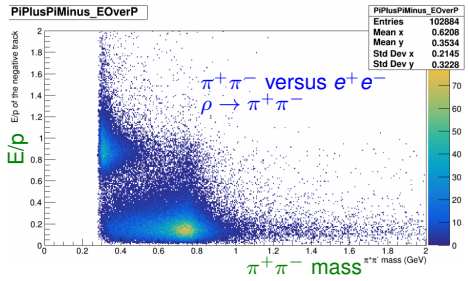
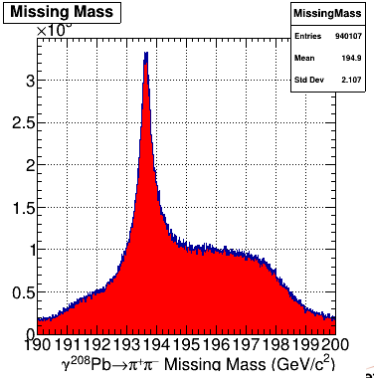
E12-12-008: CPP/NPP Running

CPP/NNP - Pion Polarizability

- Installation of a muon detector, solid (Pb) target, moving TAGM to 5.5 GeV, new trigger logic
- Running at 30 nA with the coherent peak at about 5.5 GeV
- DAQ rate is about 70 kHz



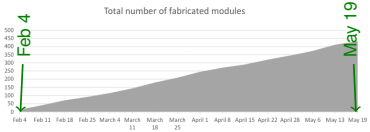


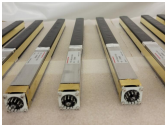


JEF E12-12-002A: status of $PbWO_4$ FCAL insert

item	#	ordered	delivered	expected
crystals SICCAS D		1004	292	292 (+ a few dozens)
crystals CRYTUR D		296(+50)	181	346
crystals SICCAS C			440	440
crystals CRYTUR Adm		550		550
crystals total	1600			1628 (732+896)
PMT	1600	1650	1290	1650 (140 are from CCAL)
FADC, crates	1200	1200	about all	
HV channels	1600	1600		
module components	1600	part	part	FY21-22
signal cables	1200	1200 part	part	building
HV cables	1200	1200 ?	0	building

750 modules made, ≈30/week





Manpower

- Hall D, Det.Sup.Grp., Universities
- 2022 summer 1.7 FTE*Y students

Construction

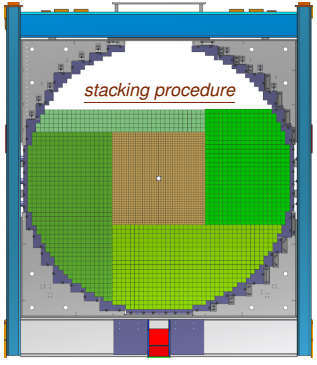
Sufficient budget in FY22

- Modules construction ongoing
- PMT bases, cables: starting
- Frame: first PRs sent

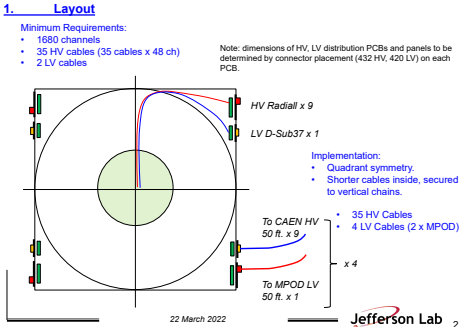
Installation

About 16 months Mar 23 - Jul 24

- FCAL - take apart
- FCAL modules refurb.
- Frame, restack with crystals
- Dark room and cooling
- Cabling, electronics



Design of the cables arrangement



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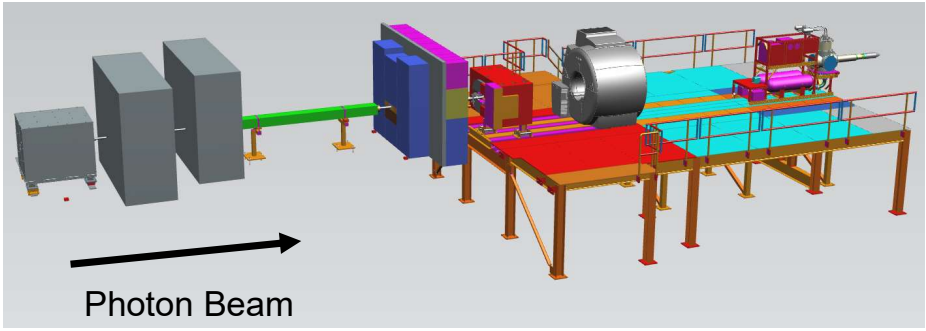
KLF E12-19-001: Spectroscopy with K_L beam



Ongoing Design

- Technical design: Be target and collimator cave - finished; upstream platform - in progress
- Conceptual design: Compact Photon Source - in progress, thermal and radiological analysis