Status of Hall-D tagged photon beam facility and the GlueX detector.

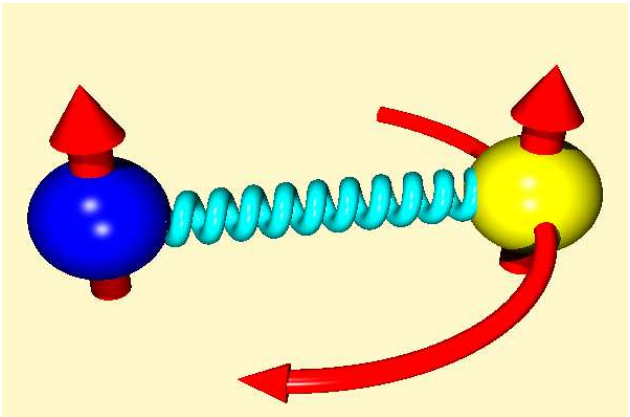
Benedikt Zihlmann
On behalf of the GlueX collaboration

Jefferson Lab

GLUEX Excitations Experiment

Light Meson Spectroscopy

2-fermion system $q\bar{q}$ with $^{(2S+1)}L_J$



Quantum Numbers

- $S = 0, 1$ and $L = 0, 1, 2, ...$
- J^{PC} with $J = L - 1, L, L + 1$ and $P = (-1)^{(L+1)}$ and $C = (-1)^{(L+S)}$
- $0^{++} \hat{=} {}^3P_0$ (Vacuum)

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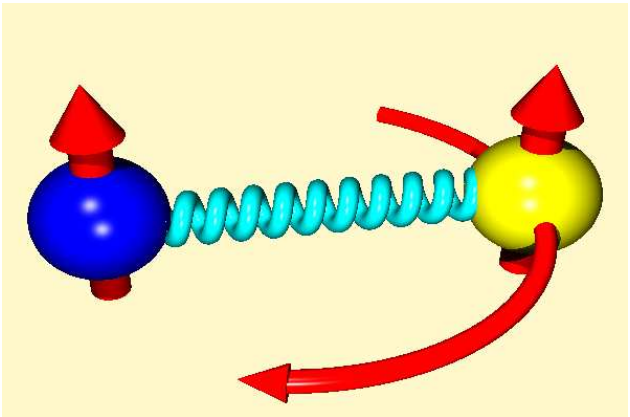

J^{--} and J^{++} $C = P$
$=> S = 1$

Quantum Numbers

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Quark Degrees of Freedom **ONLY**

	$\mathbf{0^{++}}$	$\mathbf{0^{-+}}$	
$\mathbf{1^{--}}$	$\mathbf{1^{++}}$		$\mathbf{1^{+-}}$
$\mathbf{2^{--}}$	$\mathbf{2^{++}}$	$\mathbf{2^{-+}}$	
$\mathbf{3^{--}}$	$\mathbf{3^{++}}$		$\mathbf{3^{+-}}$
$\mathbf{4^{--}}$	$\mathbf{4^{++}}$	$\mathbf{4^{-+}}$	
$\mathbf{5^{--}}$	$\mathbf{5^{++}}$		$\mathbf{5^{+-}}$

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GlueX Excitations Experiment

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2-fermion system
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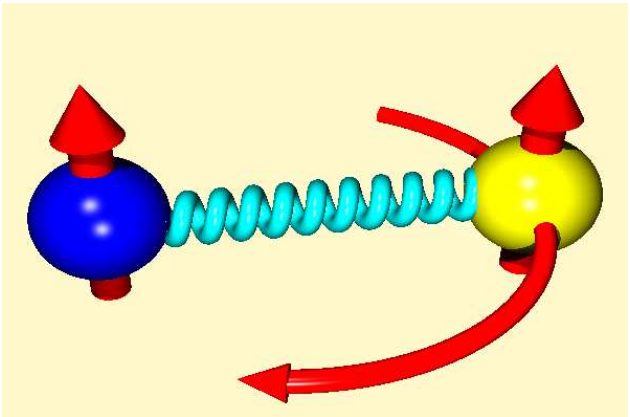

J^{--} and J^{++} $C = P$
$\Rightarrow$ $S = 1$ States
$\mathbf{0^{+-}}$, $\mathbf{1^{-+}}$, $\mathbf{2^{+-}}$, ...
need additional
degree of freedom!

Quantum Numbers

- $S = 0, 1$ and $L = 0, 1, 2, ...$
- J^{PC} with $J = L - 1, L, L + 1$ and $P = (-1)^{(L+1)}$ and $C = (-1)^{(L+S)}$
- $0^{++} \triangleq {}^3P_0$ (Vacuum)

Quark Degrees of Freedom **ONLY**

J^{PC} Exotic quantum numbers

$\mathbf{0^{--}}$	$\mathbf{0^{++}}$	$\mathbf{0^{-+}}$	$\mathbf{0^{+-}}$
$\mathbf{1^{--}}$	$\mathbf{1^{++}}$	$\mathbf{1^{-+}}$	$\mathbf{1^{+-}}$
$\mathbf{2^{--}}$	$\mathbf{2^{++}}$	$\mathbf{2^{-+}}$	$\mathbf{2^{+-}}$
$\mathbf{3^{--}}$	$\mathbf{3^{++}}$	$\mathbf{3^{-+}}$	$\mathbf{3^{+-}}$
$\mathbf{4^{--}}$	$\mathbf{4^{++}}$	$\mathbf{4^{-+}}$	$\mathbf{4^{+-}}$
$\mathbf{5^{--}}$	$\mathbf{5^{++}}$	$\mathbf{5^{-+}}$	$\mathbf{5^{+-}}$

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GLUEX Excitations Experiment

Additional Degrees of Freedom

EXOTIC Mesons:

- $q\bar{q} - q\bar{q}$ More quarks:Molecule
- $q\bar{q}g$ Additional Gluon: Hybrid-Meson
- ggg Only Gluons: Glueballs

Additional Degrees of Freedom

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HYBRID-Meson:

S = 0, L = 0, m = 1

$J^{PC} = \mathbf{1}^{++}, \mathbf{1}^{--}$

not exotic states

Additional Degrees of Freedom

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not exotic states

exotic states require $S \neq 0$

S = 1, L = 0, m = 1

$J^{PC} =$ $\mathbf{0^{-+}}$ $\mathbf{0^{+-}}$ $\mathbf{1^{-+}}$ $\mathbf{1^{+-}}$ $\mathbf{2^{-+}}$ $\mathbf{2^{+-}}$

Additional Degrees of Freedom

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J^{PC} Exotic quantum numbers

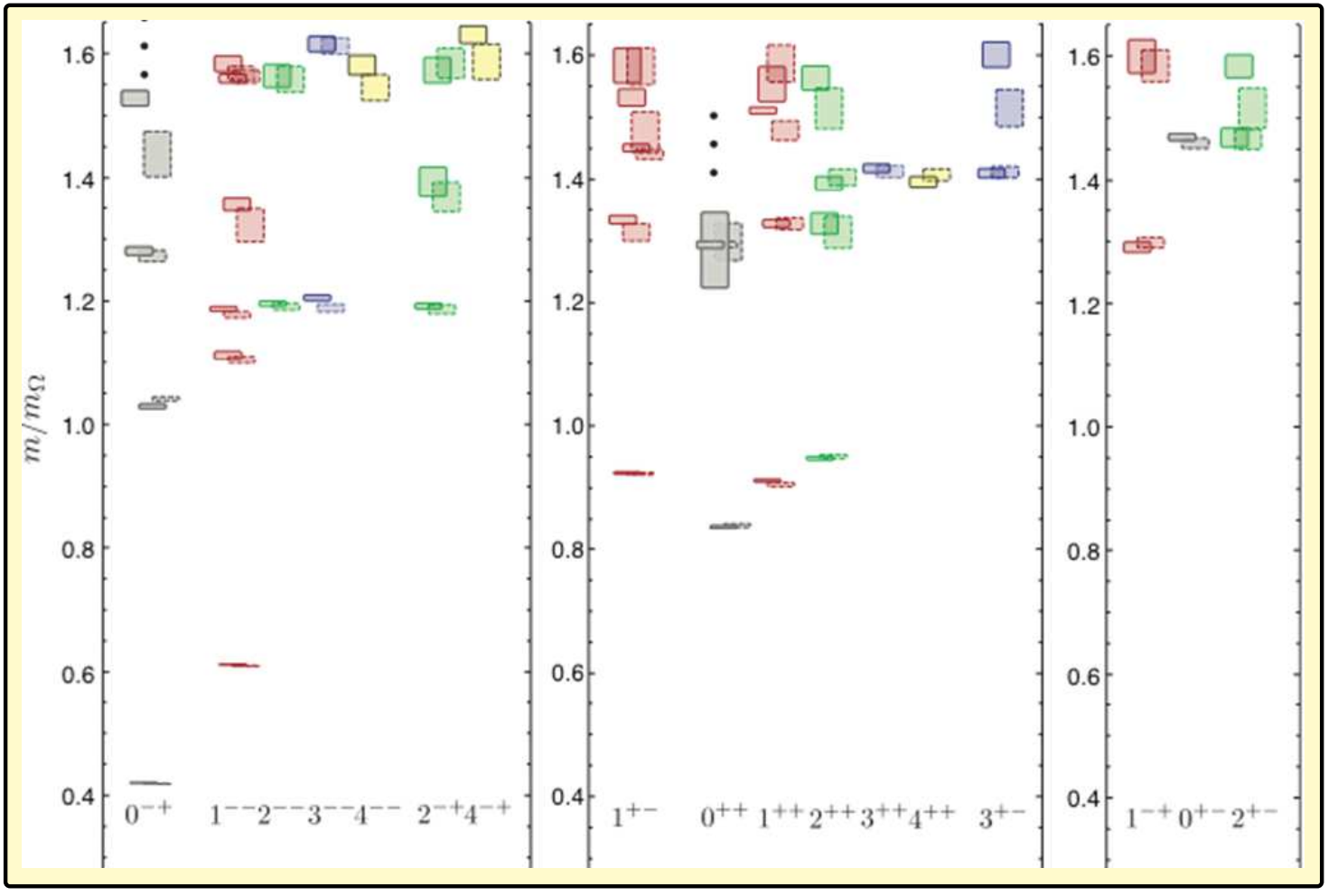
$\rightarrow$ A signature for exotic mesons like Glueball, $q\bar{q}$-$q\bar{q}$ Molecule or Hybrid Mesons

GlueX: Look for hybrid mesons with exotic quantum numbers

Hybrid Meson Mass Estimates

Latest lattice calculation predict full meson spectrum

J. Dudek et al. Phys. Rev. D82 (2010) 034508



$m_u = m_d = m_s$ quarks,
$m_\pi \sim$700MeV
2 lattice volumes

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Latest lattice calculation predict full meson spectrum

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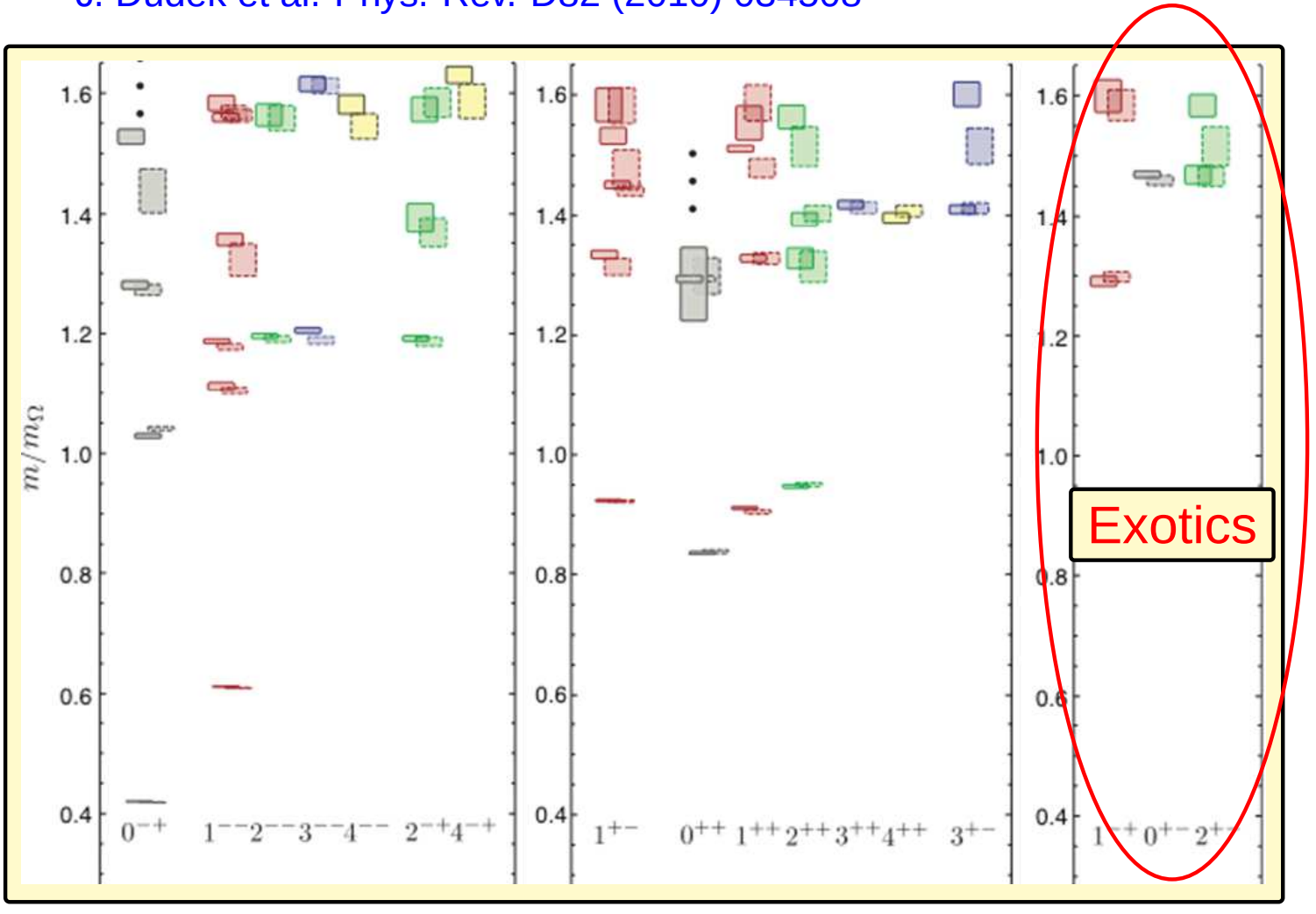

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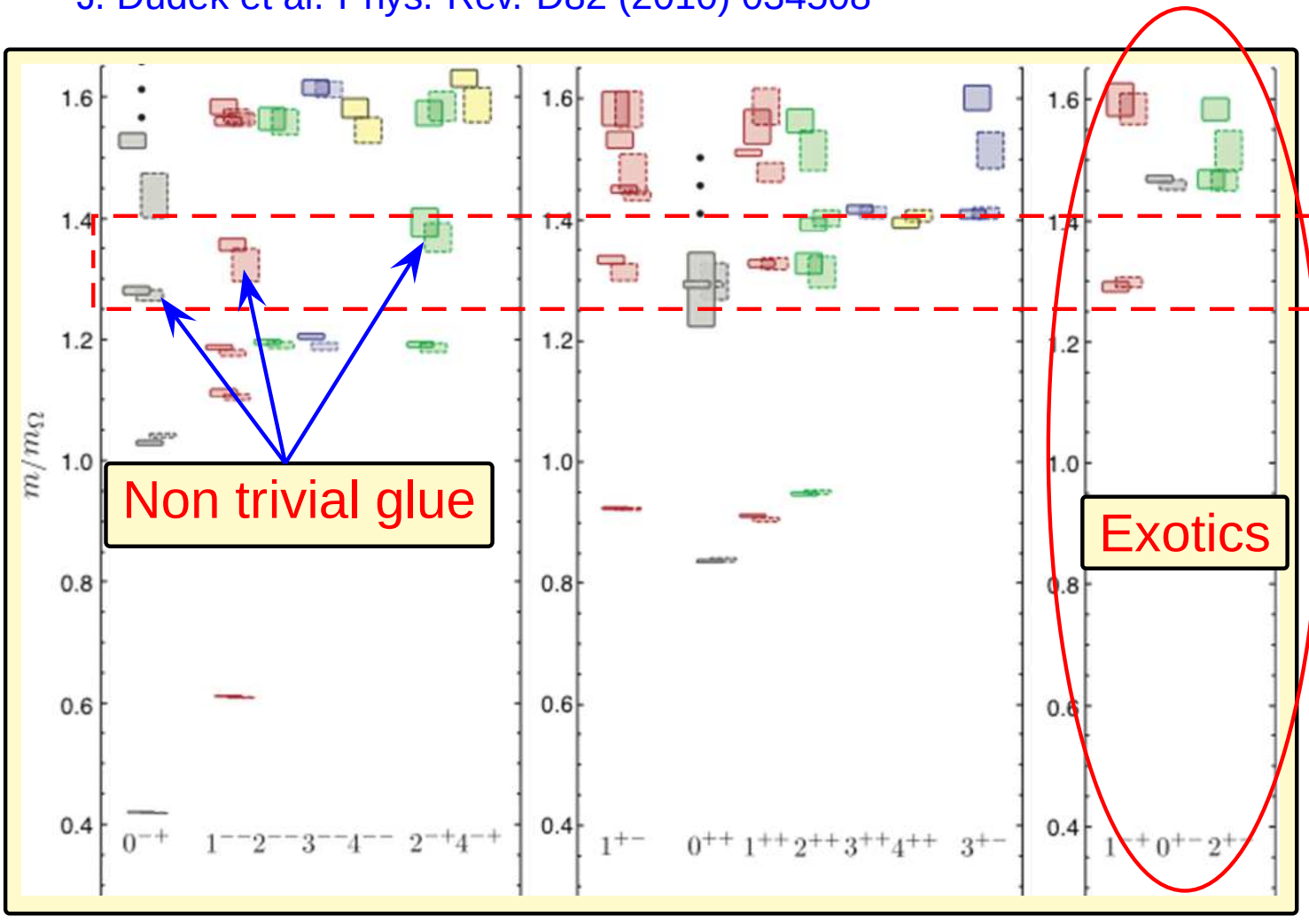

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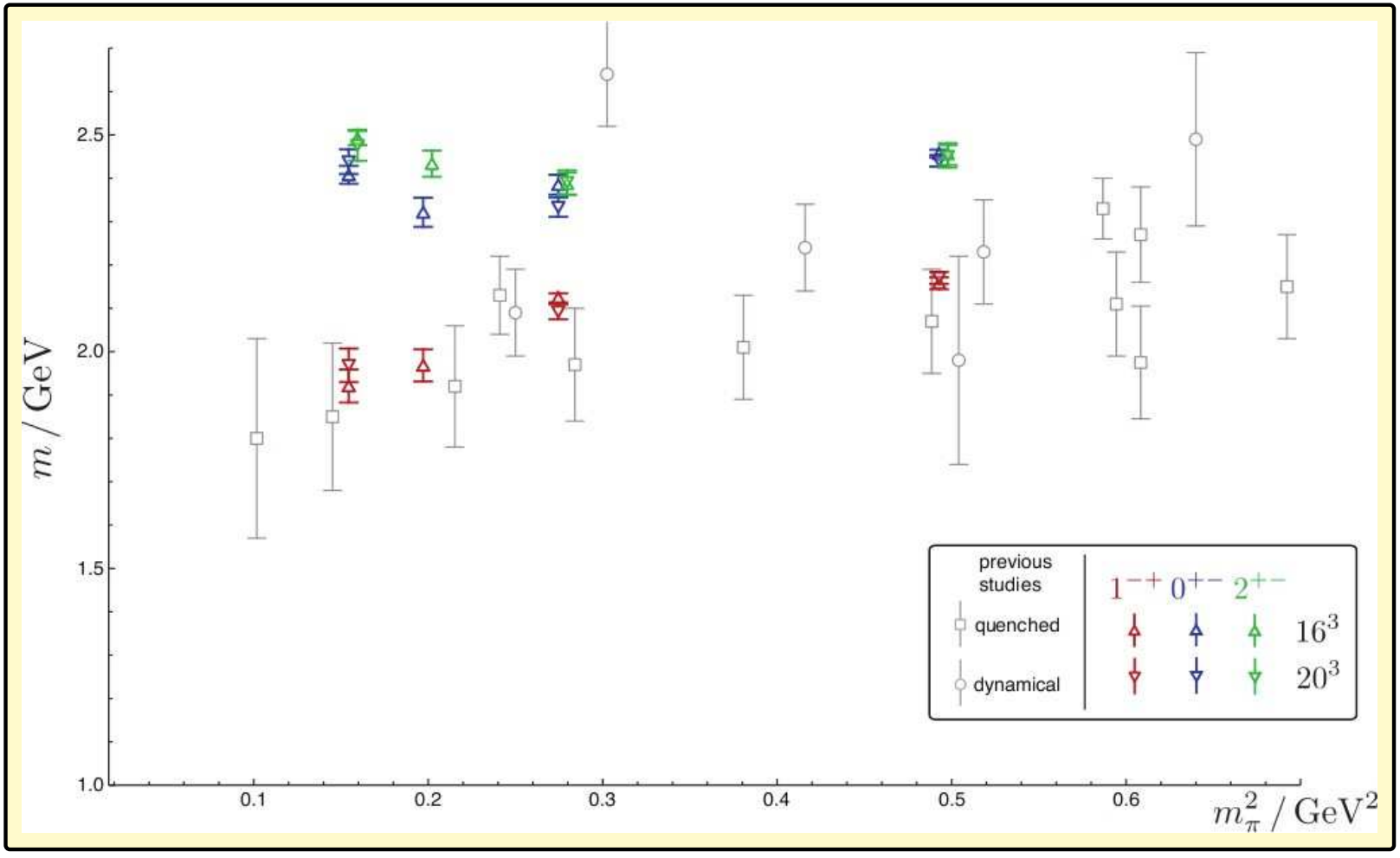
Hybrid Meson Mass Estimates

Extrapolate to the physical pion mass:



Hybrid Meson Mass Estimates

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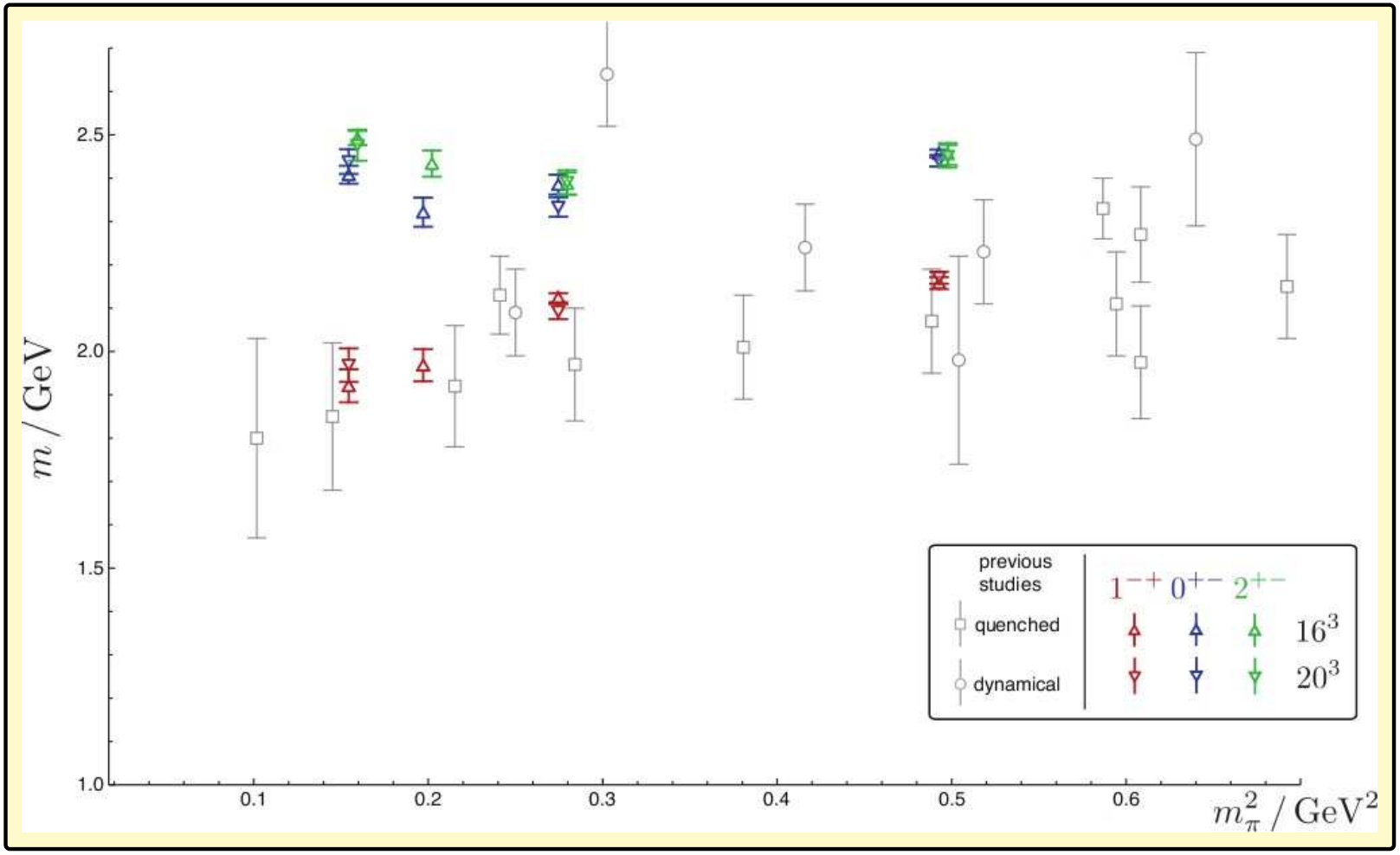
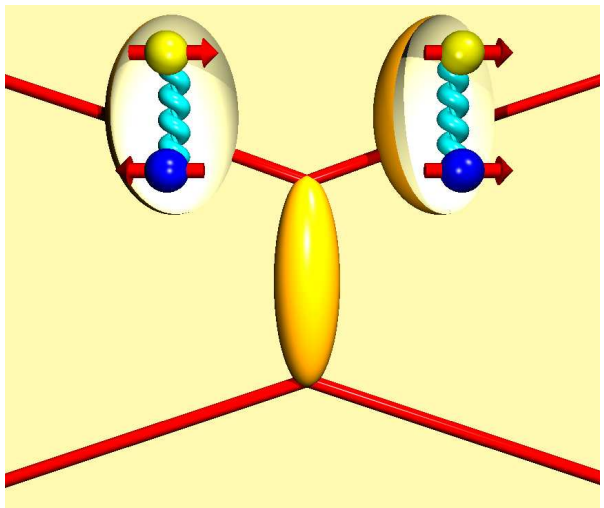


Lightest hybrid mesons around 2 GeV/c^2

Hybrid Meson Production

Pion Beam

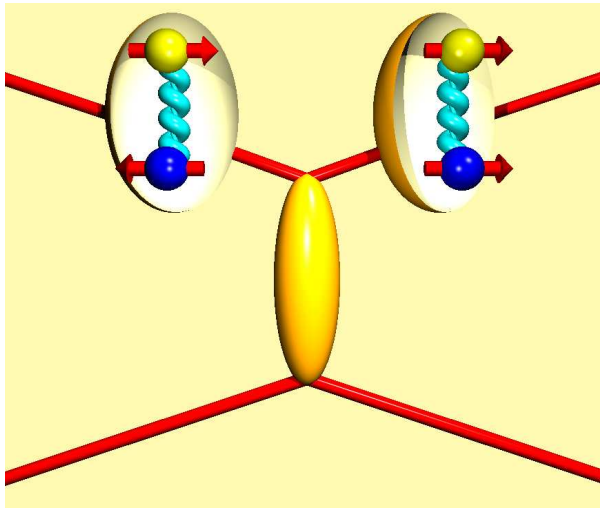


- π with **S=0, L=0** and Δm=1
  $1^{++}, 1^{--}$
- Require spin flip

- E852, GAMS, KEK, VES, COMPASS

Hybrid Meson Production

Pion Beam



- π with **S=0, L=0** and Δm=1
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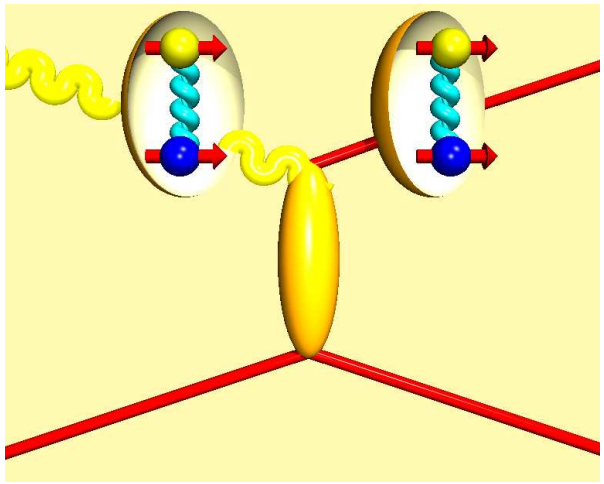
Photon Beam



- γ with **S=1, L=0** and Δm=1
  $0^{-+}, 0^{+-}, 1^{-+}, 1^{+-}, 2^{-+}, 2^{+-}$
- No spin flip required
- photon linerarly polarized
- CLAS

Reports on Hybrid Mesons

Best Candidate: $\pi_1(1600)$

VES	$\pi^- N$	$\rightarrow$	$p b_1 \pi^-$
	$\pi^- N$	$\rightarrow$	$p f_1 \pi^-$
	$\pi^- N$	$\rightarrow$	$p \eta' \pi^-$
E852	$\pi^- p$	$\rightarrow$	$p b_1 \pi^-$
	$\pi^- p$	$\rightarrow$	$p f_1 \pi^-$
	$\pi^- p$	$\rightarrow$	$p \eta' \pi^-$
	$\pi^- p$	$\rightarrow$	$p \rho \pi^-$
Crystal Barrel	$\bar{p} n$	$\rightarrow$	$b_1 \pi^-$
COMPASS	$\pi^- p$	$\rightarrow$	$\rho \pi$

Partial Wave Analysis:

- Strong evidence for 1^{-+} wave in $b_1\pi$, $f_1\pi$, $\eta'\pi$
- Dispute in $\rho\pi$
- Missing PWs in analysis?
- Feed through $a_2(1670)$?
- CLAS no signal in $\gamma p \rightarrow (n)\pi^+\pi^+\pi^-$

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$\pi_1(1600)$ good candidate for a 1^{-+} resonance!

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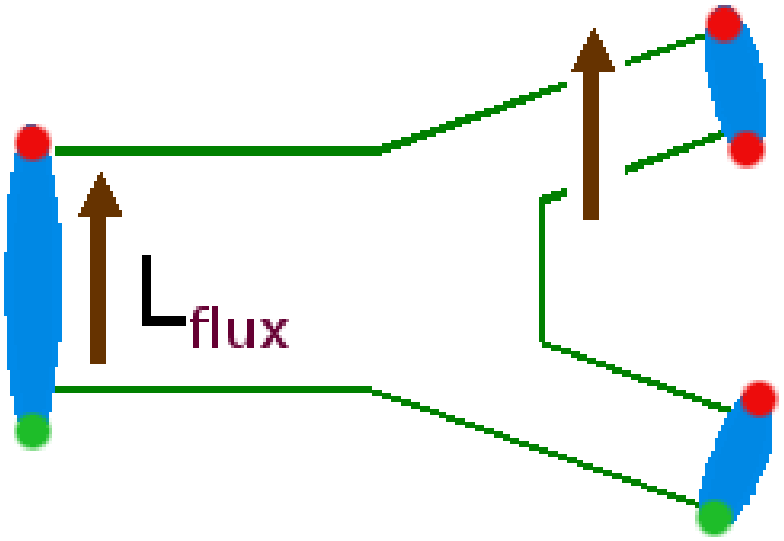
GLUEX citations periment

Hybrid Meson Decay

Model dependent estimates of decay products.

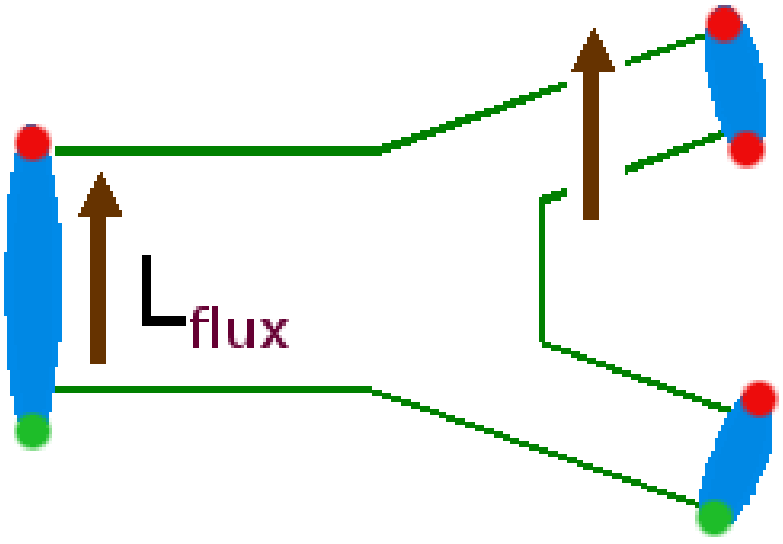


Model assumption:

Decay into L=1,L=0 mesons

Hybrid Meson Decay

Model dependent estimates of decay products.



Model decay modes:

0^{+-}:	$\rightarrow b_1\pi$	$\rightarrow$	$\pi^+\pi^-\pi^0\pi^0\pi^0$
1^{-+}:	$\rightarrow a_1\pi$	$\rightarrow$	$\pi^+\pi^-\pi^+\pi^-$
1^{-+}:	$\rightarrow b_1\pi$	$\rightarrow$	$\omega\pi\pi$
	$\rightarrow f_1\pi$	$\rightarrow$	$\eta\pi\pi\pi$
	$\rightarrow \rho\pi$	$\rightarrow$	$\pi\pi\pi$

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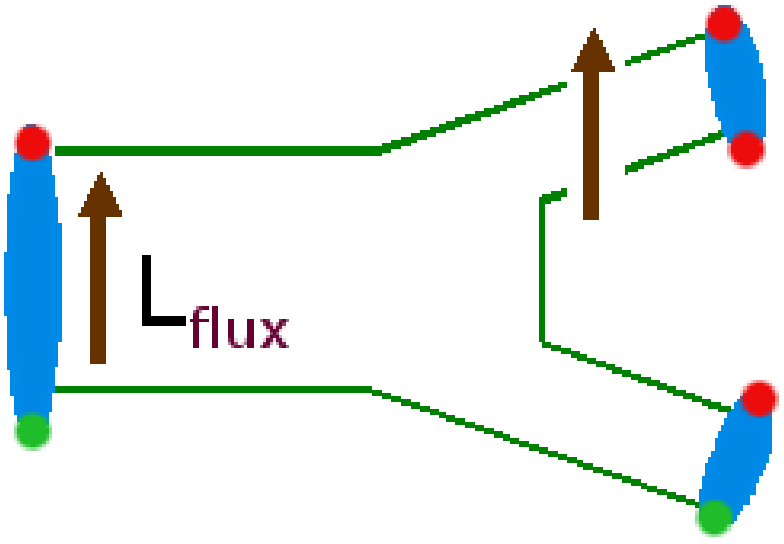
Hybrid Meson Decay

Model dependent estimates of decay products.



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$\rightarrow f_1\pi \rightarrow \eta\pi\pi\pi$

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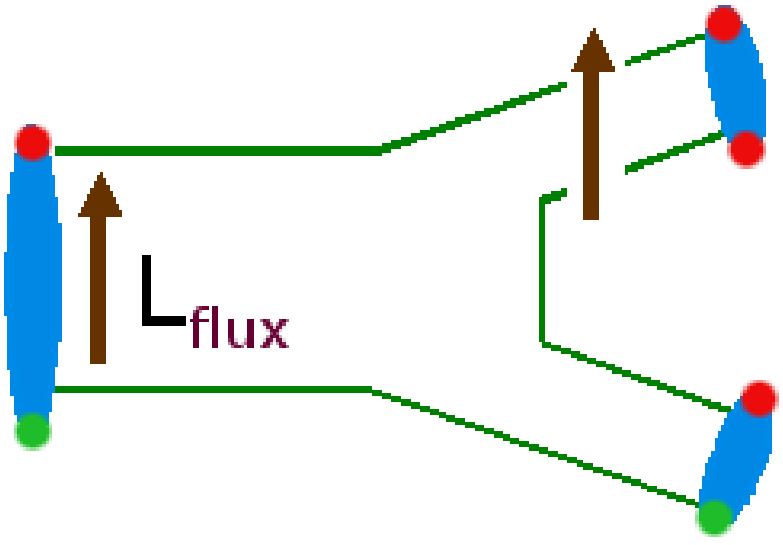
Multi particle final states with neutral and charged particles!

Hybrid Meson Decay

Model dependent estimates of decay products.



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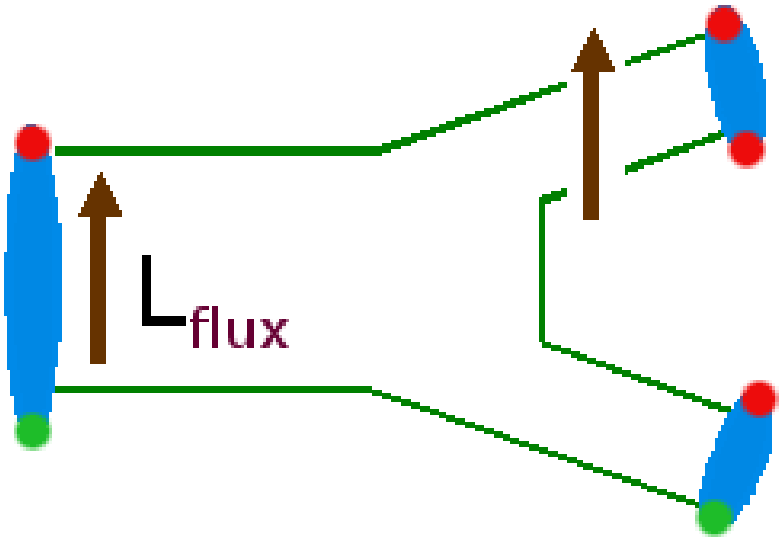
Multi particle final states with neutral and charged particles!

- 70% involve at least one π^0
- 50% more than one π^0

Hybrid Meson Decay

Model dependent estimates of decay products.



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$\rightarrow \rho\pi \rightarrow \pi\pi\pi$

Multi particle final states with neutral and charged particles!

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- 50% more than one π^0

Need hermetic detector with good calorimetry!

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GlueX Excitations Experiment

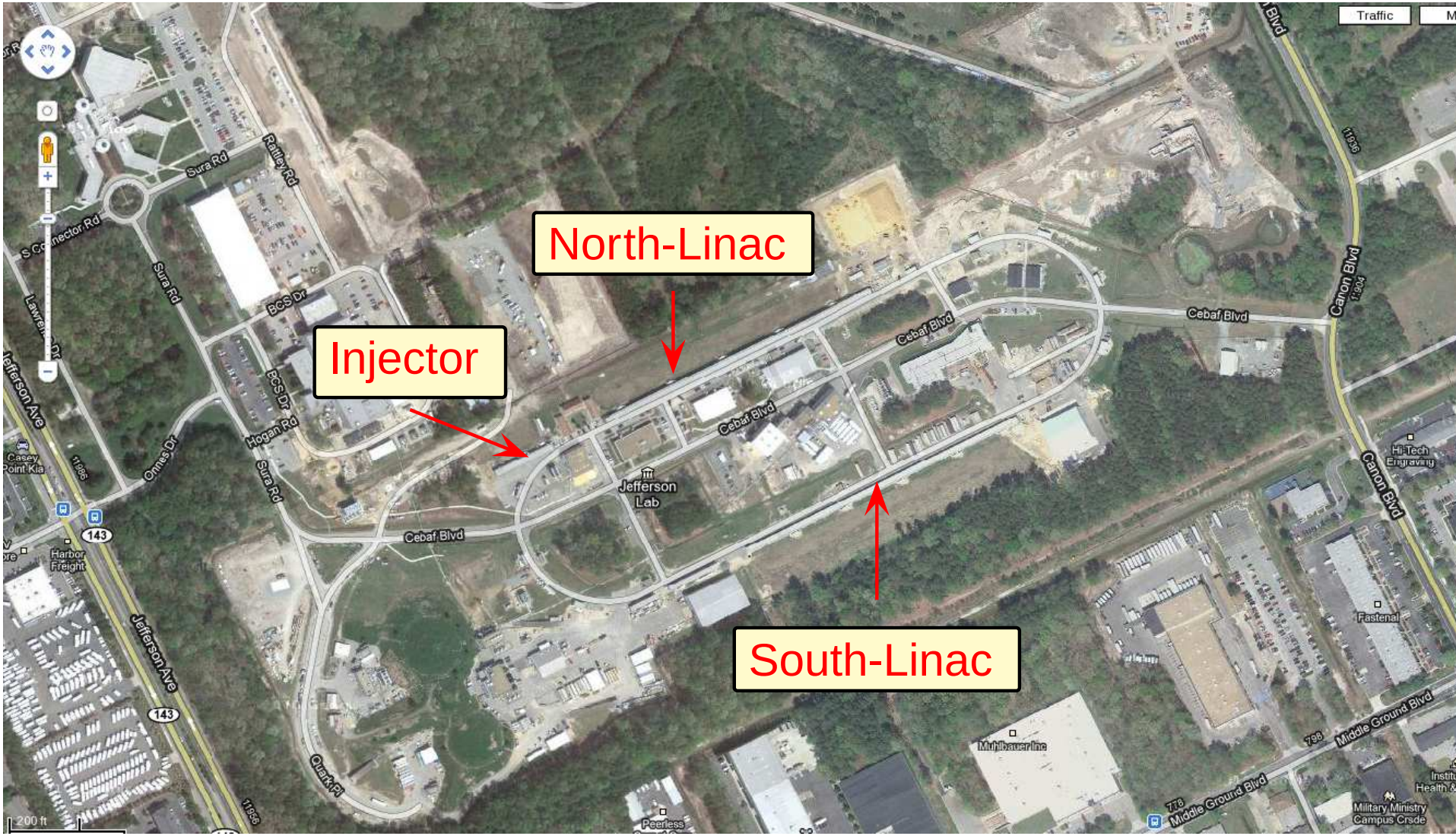
CEBAF Accelerator Site

Jefferson Lab

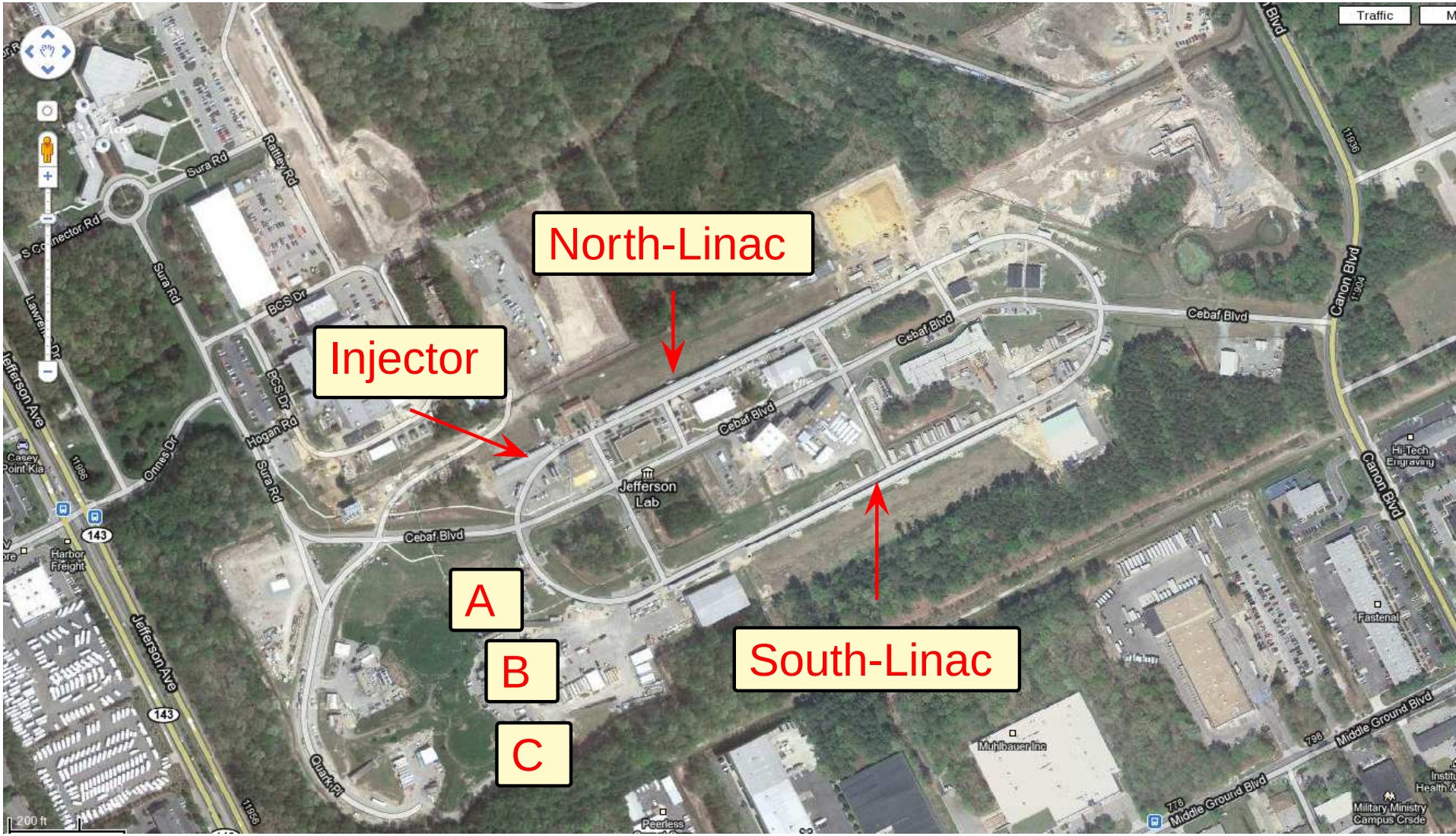
GlueX Excitations Experiment

CEBAF Accelerator Site

CEBAF Accelerator Site



CEBAF Accelerator Site



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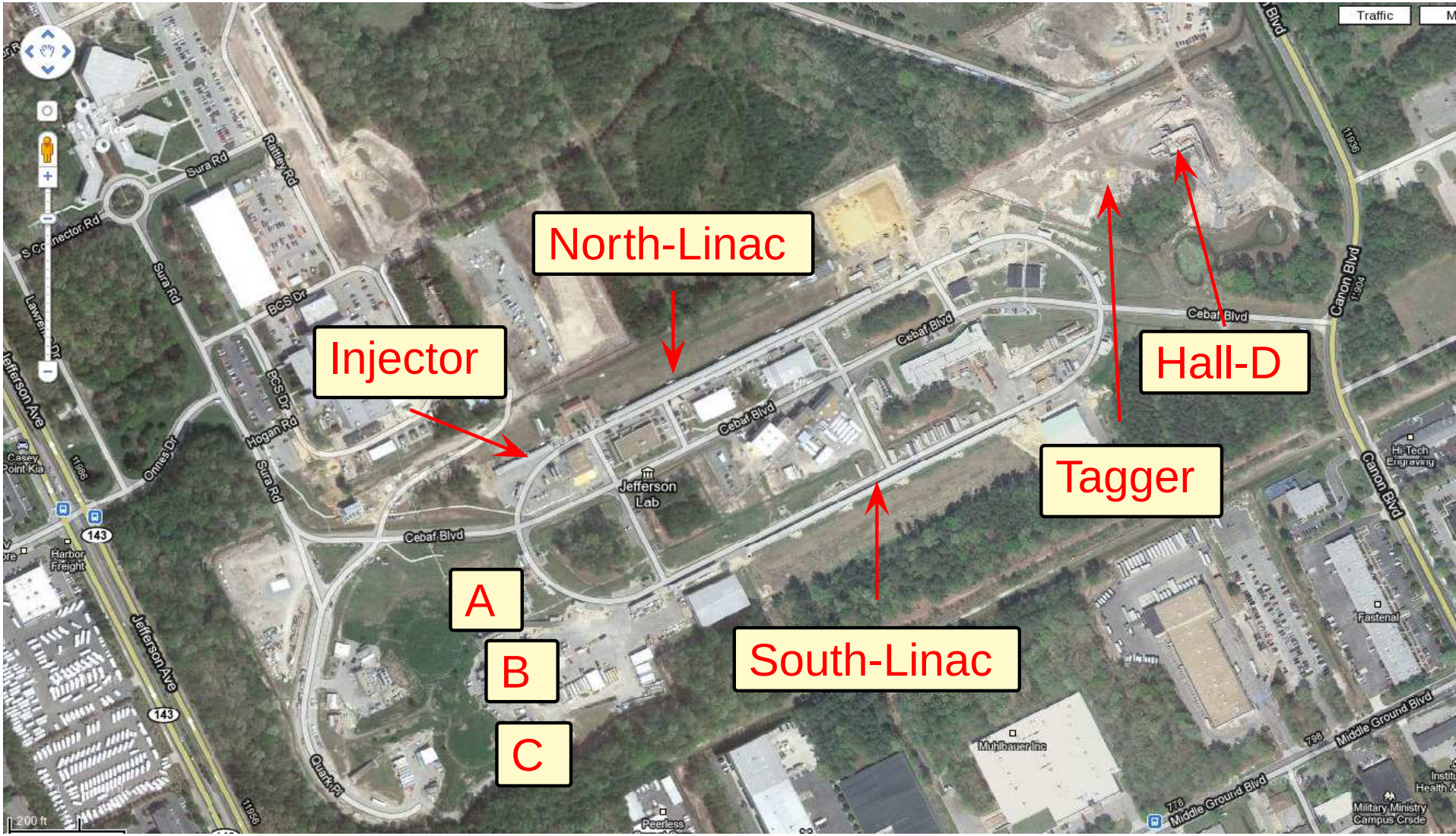
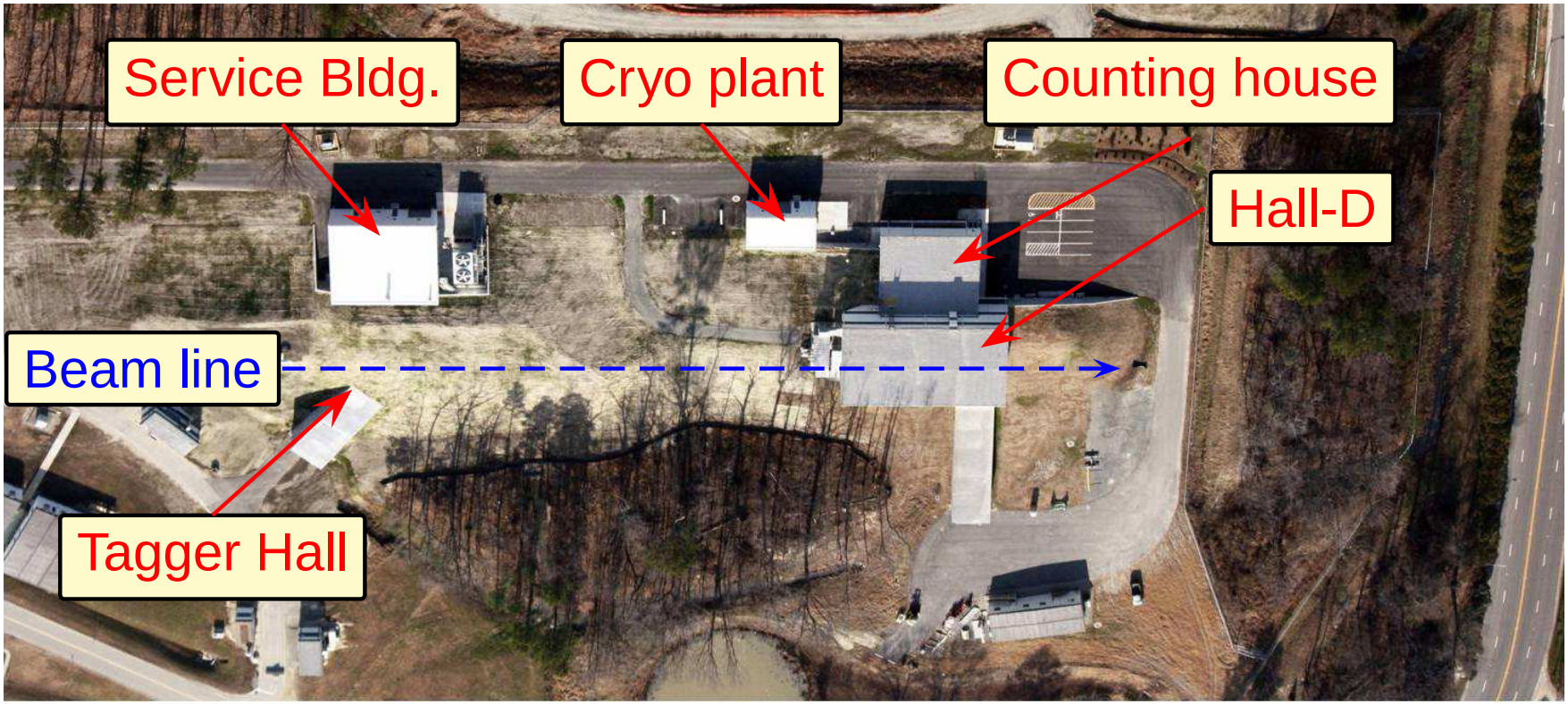
GlueX Excitations Experiment

CEBAF Accelerator Site



Hall-D Complex

Hall-D complex: Civil construction complete!



- Halls ready for equipment.
- Solenoid detector magnet installed.

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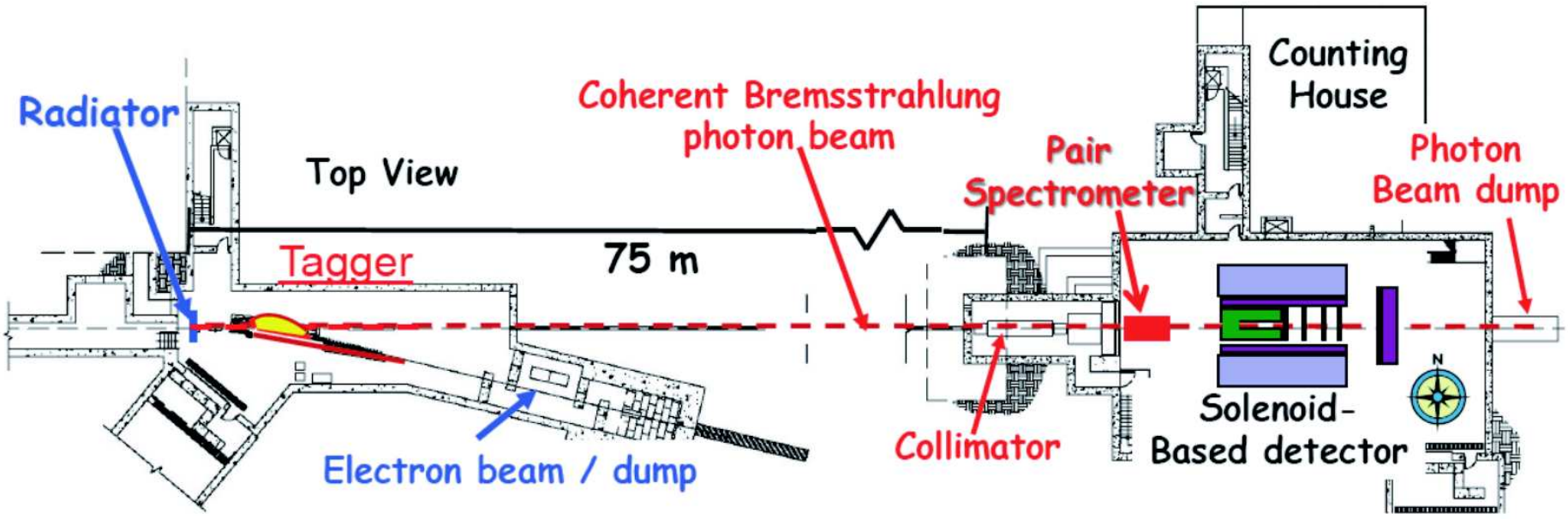
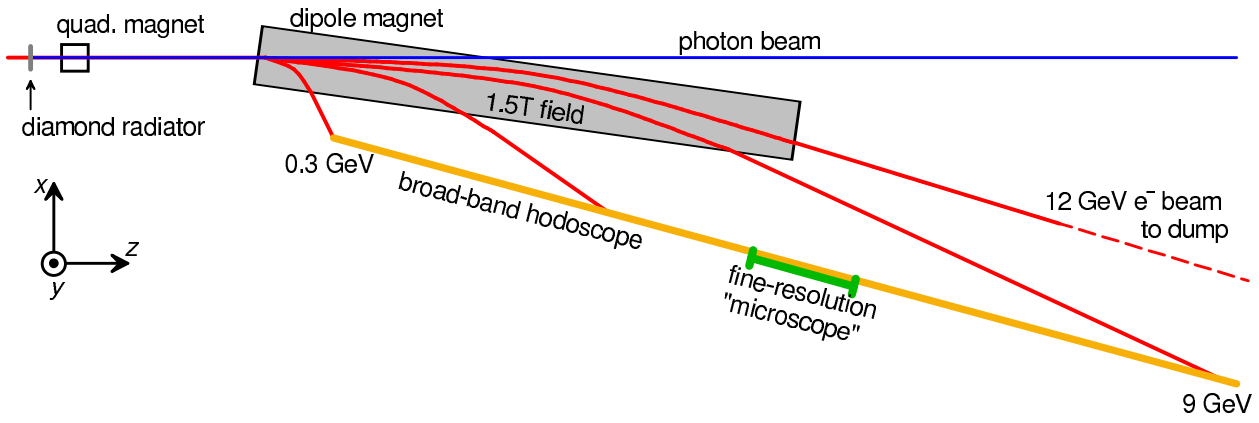
GlueX Experiment

The Hall-D Beam Line

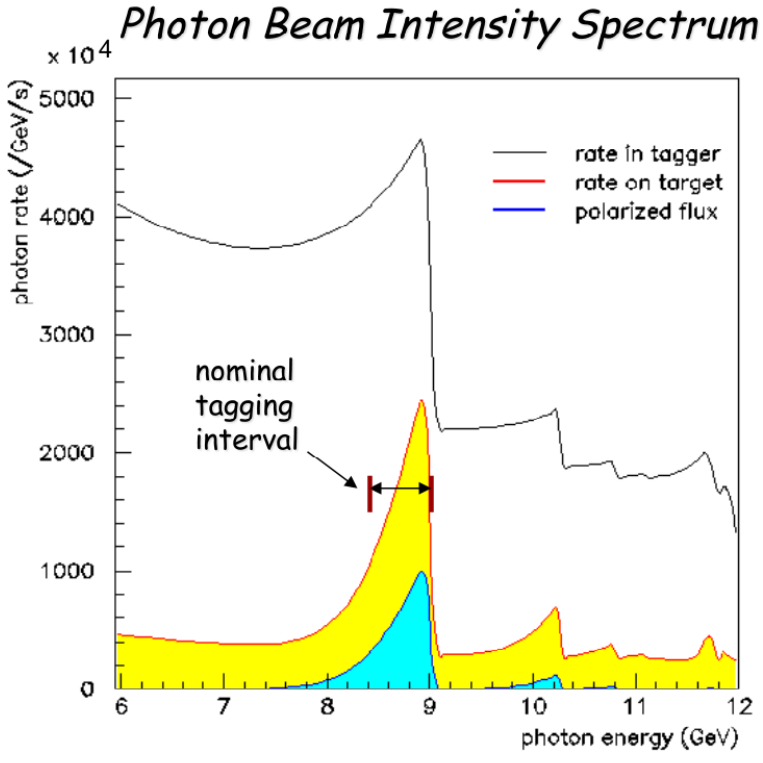


- e^-(12GeV/c) beam
- 20μm thick diamond radiator
- Coherent Bremsstrahlung
- 76m Photon beam line for collimation.
- 40% polarization at 9 GeV
- Hall-D beam dump for photons only!

Photon Beam Tagger



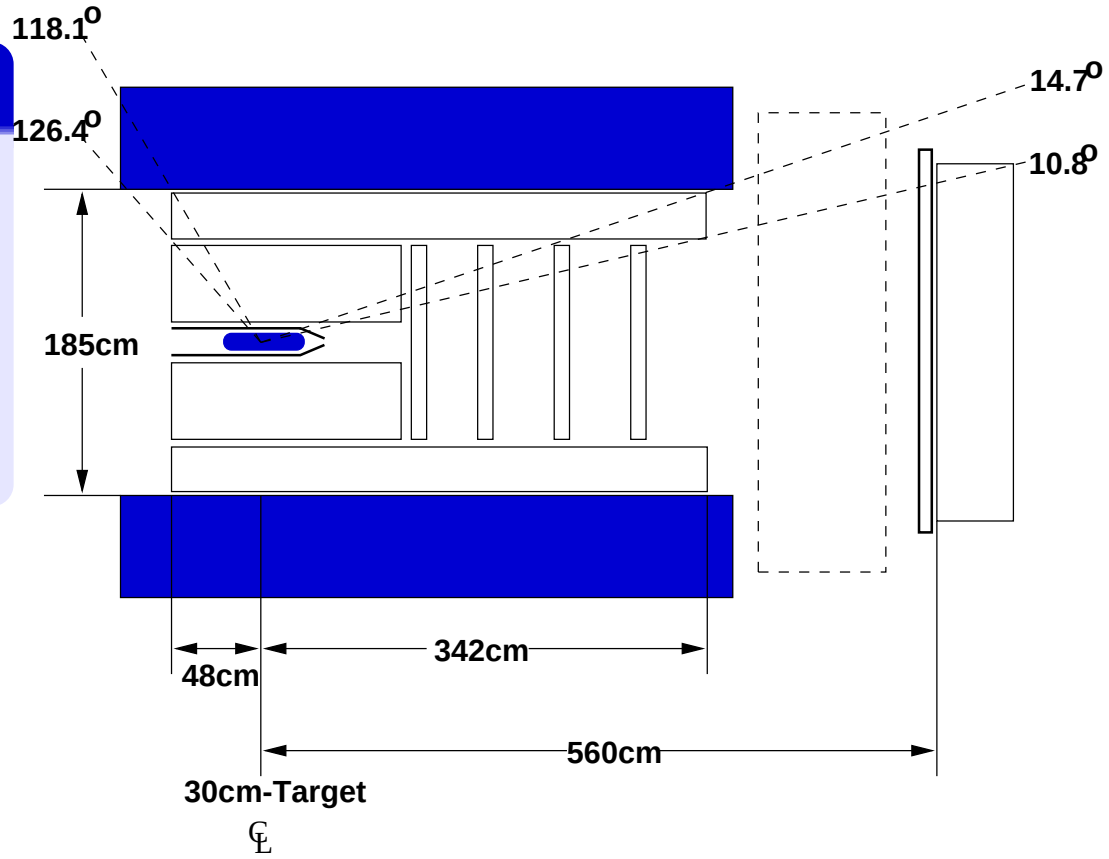
- 20μm thick diamond radiator
- 76 m flight path to collimator
- 40% polarization at peak (9GeV)
- $10^8 \gamma/s$ at 8.3-9.1 GeV
- Fixed Array Hodoscope
  3-11.7 GeV
- Microscope 800 MeV coverage



The GlueX Detector

Magnet, Target

- Solenoid (hermiticity)
- Super-conducting
- 2 Tesla
- LH target



The GlueX Detector

Tracking Chambers

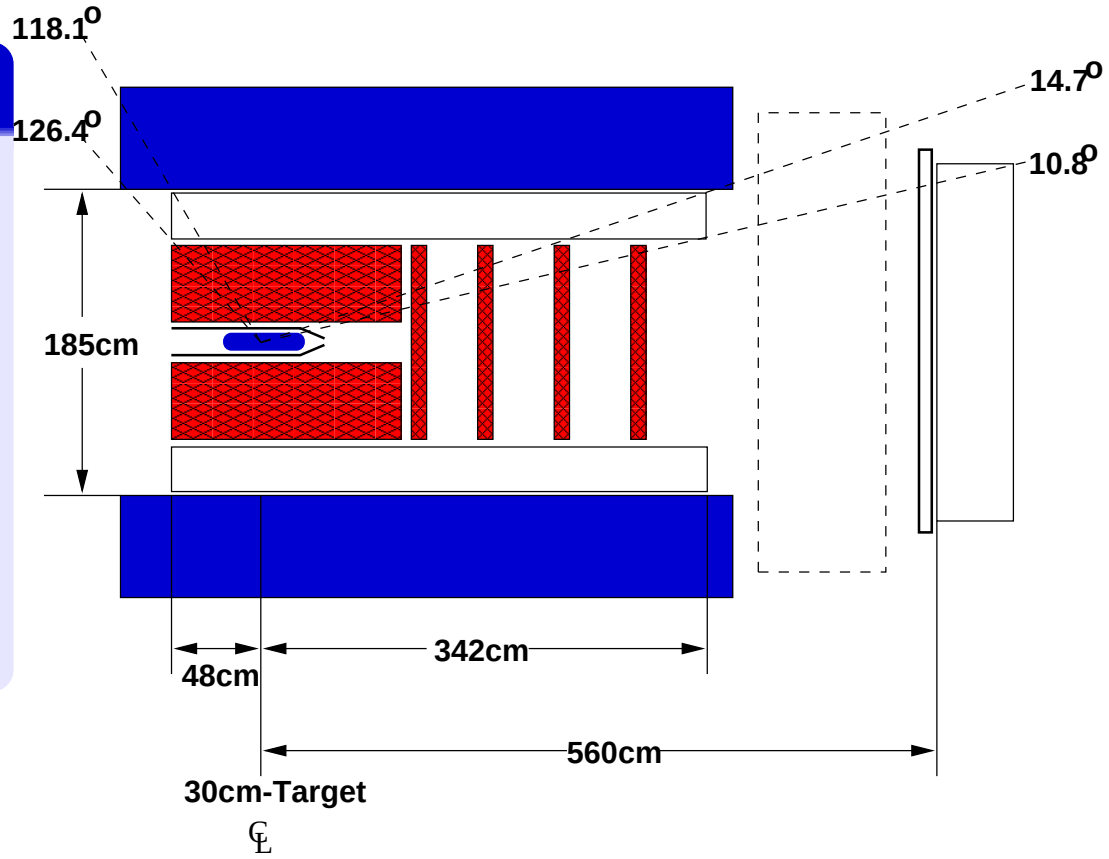
CDC

- Straw tube chamber
- dE/dx for PID

FDC

- Cathode strips

$\delta p/p \sim$1-2%



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GlueX Experiment

The GlueX Detector

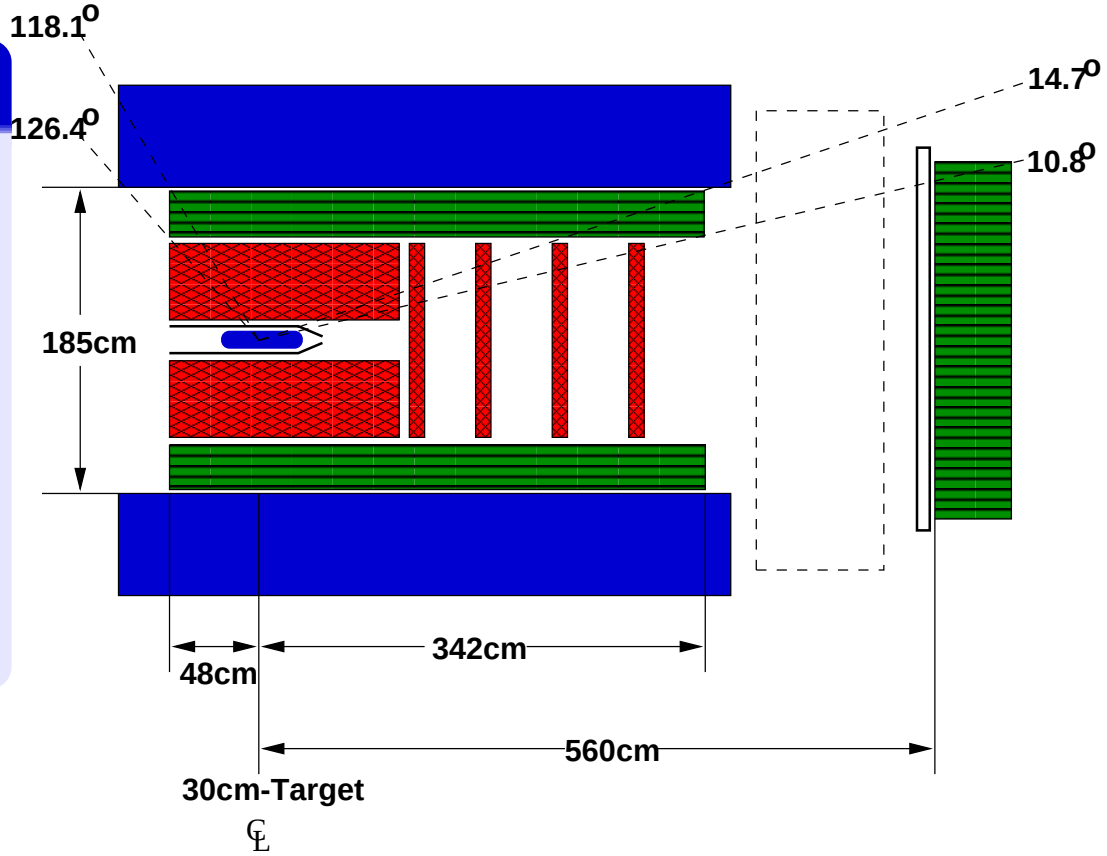
Calorimetry

Barrel Calo.

- Scin. fiber/lead
- $\delta E/E = 5.5/\sqrt{E} \oplus 1.6\%$

Forward Calo.

- Lead glass
- $\delta E/E = 5.7/\sqrt{E} \oplus 1.6\%$



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The GlueX Detector

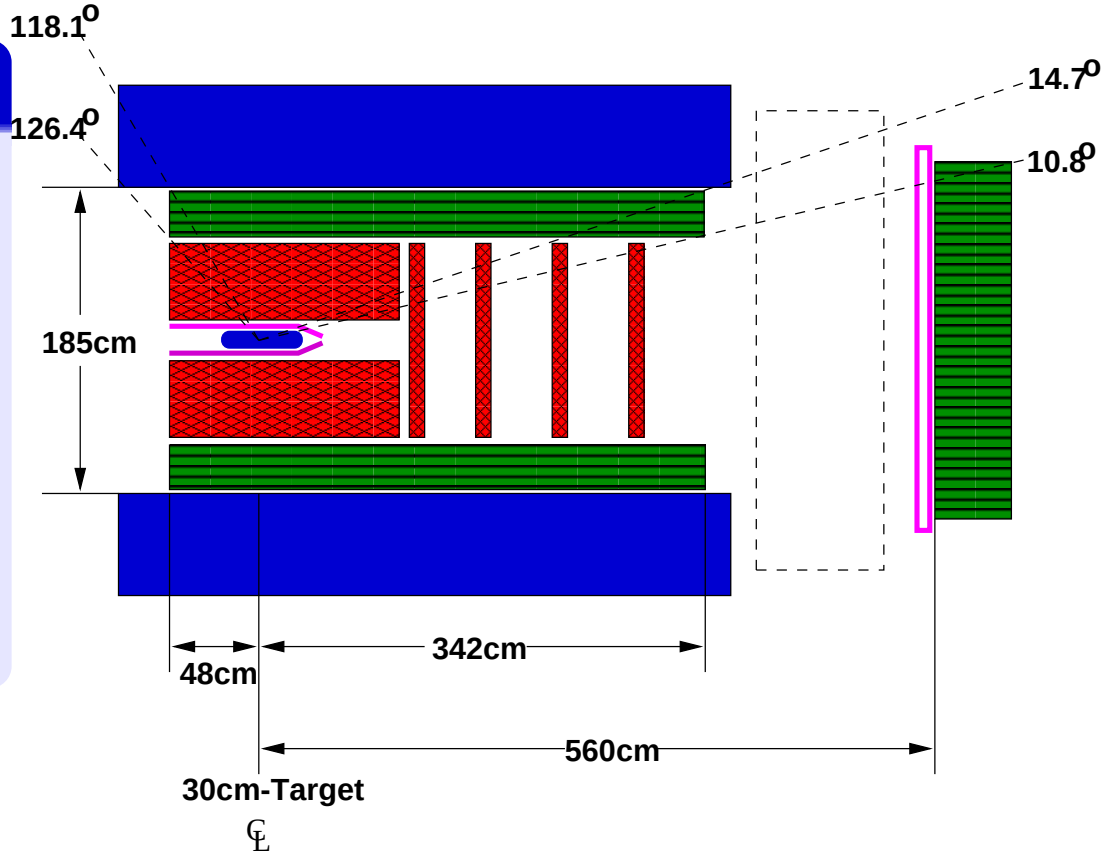
Timing

Start Counter

- Scintillators
- $\delta t/t = 300$ps

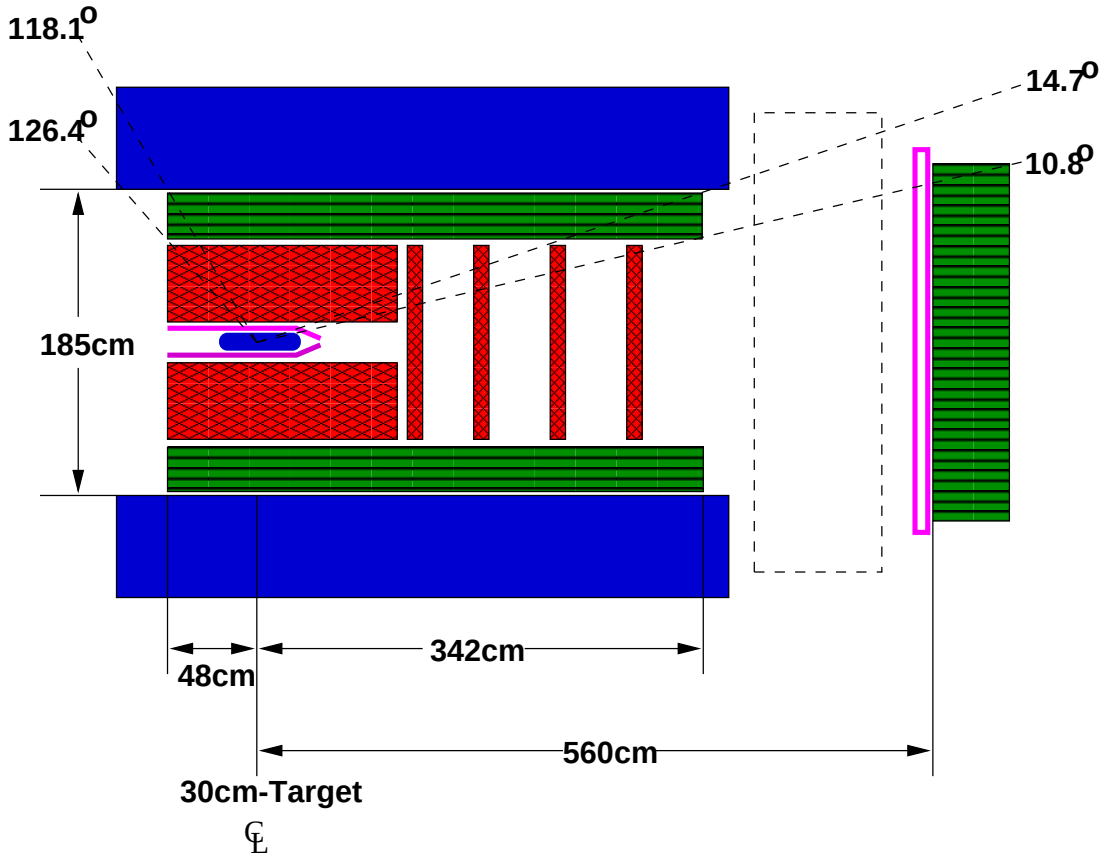
Time of Flight

- Scintillators
- $\delta t/t = 80$ps



The GlueX Detector

- Solenoid, Target
- Tracking
- Calorimetry
- Timing
- **Future PID**



Detectors under Construction

CDC:

Central Drift Chamber

- Straw tube chamber
- 3522 channels
- Flash ADC readout
- dE/dx for PID
- All straws installed
- All wires strung

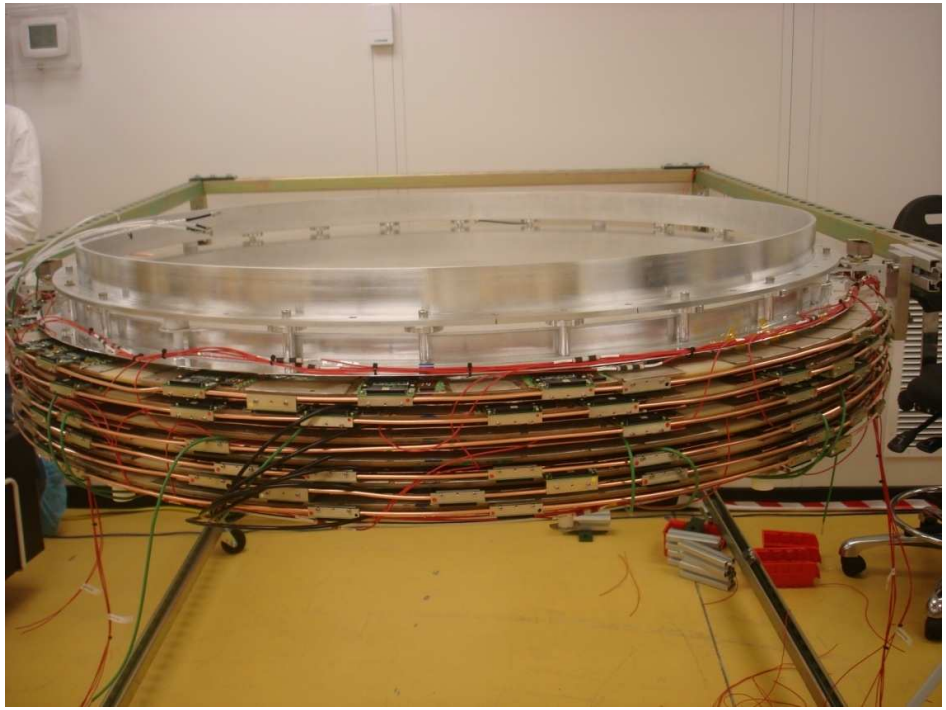
Built at Carnegie Mellon University

Detectors under Construction

FDC:

Forward Drift Chambers

- Cathode strip wire chambers
- 4 Packages with 6 planes
- TDC wire readout (2304)
- Flash ADC cathode strip (10368)
- Space point reconstruction
- 2 Packages built
- 3rd in production



Built at Jefferson Lab.

Detectors under Construction

BCAL:

Barrel Calorimeter

Modules built at University of Regina
Light guides at Univ. St. Maria, Chile

Jefferson Lab

GLUEX citations periment

Detectors under Construction

BCAL:

Barrel Calorimeter

- Scint. fiber lead matrix
- 48 Modules built
- Length: 380cm
- Thickness: 15.5 X_0
- SiPM array sensors (4000)
- Flash ADC and TDC readout

Modules built at University of Regina
Light guides at Univ. St. Maria, Chile

Jefferson Lab

GLUEX Excitations Experiment

Detectors under Construction

FCAL:

Forward Calorimeter

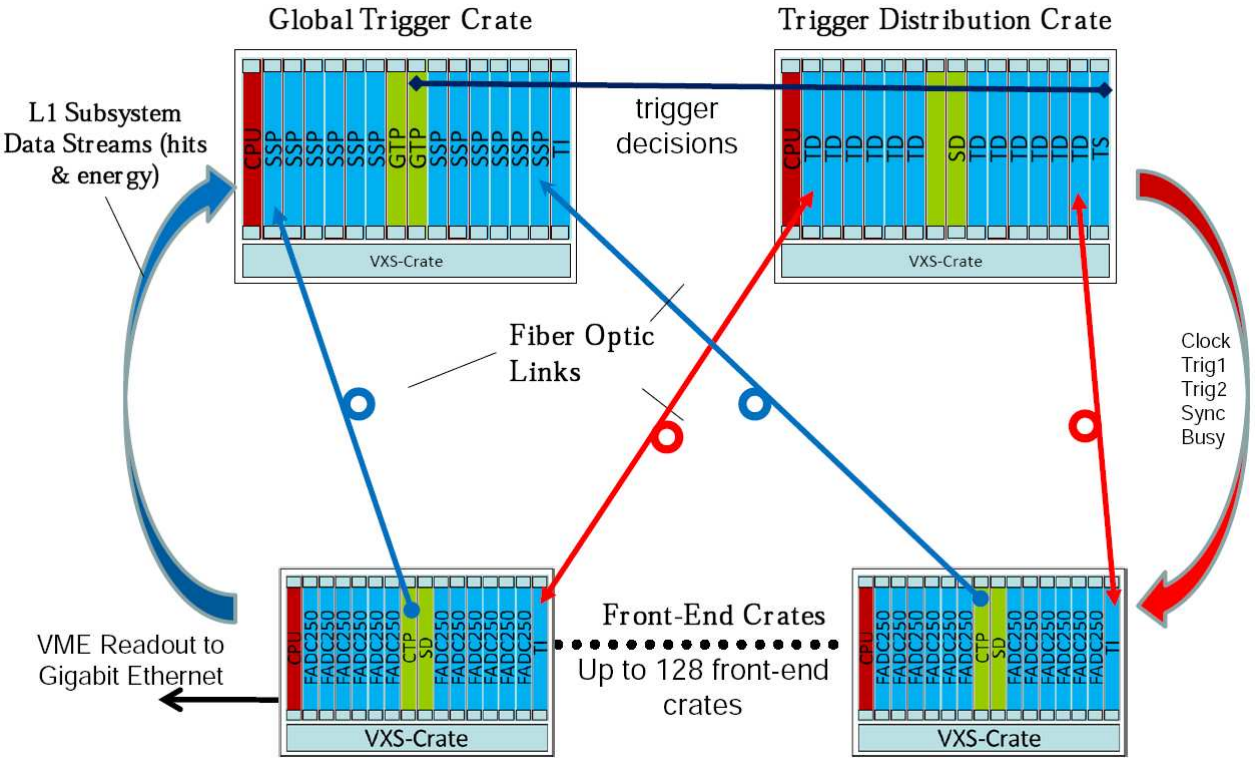
- Lead Glass 4 x 4 x 45 cm
- 2800 Modules
- Cockcroft-Walton bases
- Flash ADC readout
- Timing on Flash ADC

Modules built at Indiana University

Readout Electronics and Trigger

Fully pipelined front-end electronics with VXS backplane, developed at JLab

- 250 MHz fADC: 12bit, 16ch
- F1TDC: 60ps, 32ch or 120ps, 64ch
- 125 MHz fADC: 12bit, 72ch
- VMEx64/VXS back plane
- Trigger latency $\sim 3\mu s$
- 3GB/s DAQ rate
- 300MB/s to disk
- 3 PB/y to tape



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GlueX citations periment

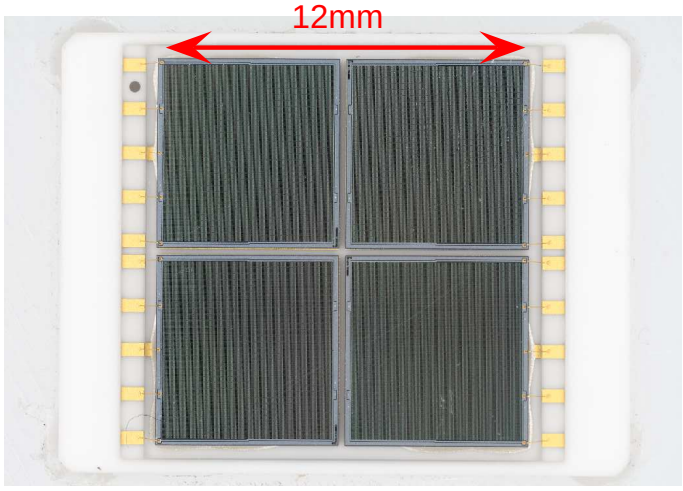
In the spot light

Two examples of new technologies in GlueX

- First Large scale use of SiPM arrays (Hamamatsu MPPC)
- 20 μm thick diamond radiator

In the spot light

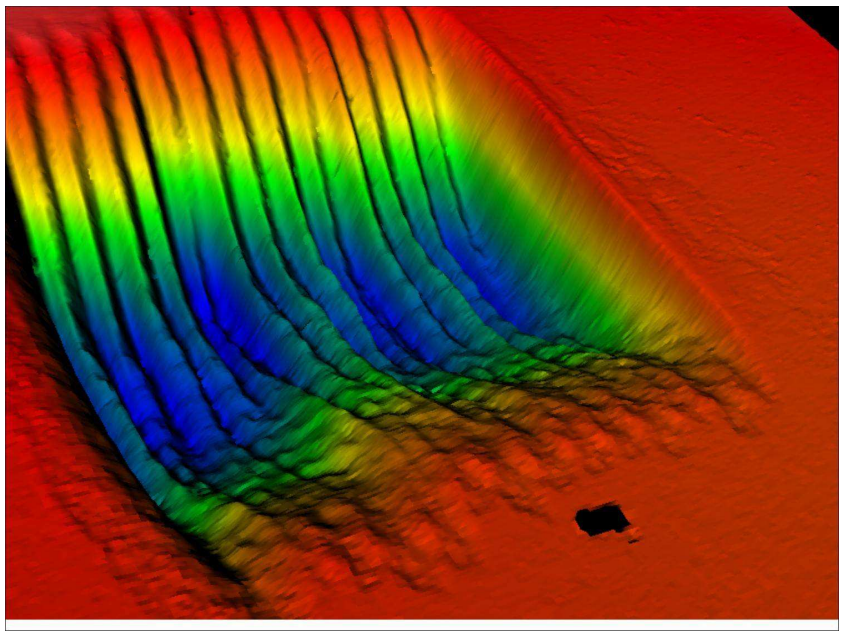
First large scale use of SiPM arrays(Hamamatsu MPPC):



- 3x3 mm^2 sensors
- 16 in one array
- Insensitive to magnetic field
- Photo detection efficiency $\sim$20%
- Gain $\sim 5 \cdot 10^5$
- Radiation sensitive

In the spot light

20 μm thick diamond radiator



Laser ablation of diamond

- Start with 300μm diamond 5x5 mm^2.
- Excimer laser to mill a window.
- 3x3 mm^2 area of 20μm.
- Developement at UConn based on work at BNL.

Timeline

Timeline depends on DOE funding schedule:

- Hall-D current status: 35% complete
- First Beam Test: April 2014, accelerator and beam lines
- First Beam on target: Fall 2015, Engineering run

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GlueX citations experiment

Physics Program in Hall-D

Approved Experiments:

- GlueX, Meson Spectroscopy, search for hybrid mesons
- Primakoff, $\Gamma_{\gamma\gamma^*}$ of η

Other physics topics:

- Pion Polarizability: $\gamma\gamma^* \rightarrow \pi^+\pi^-$
- Standard Model Tests: rare η decays
- Inverse DVCS: time like compton scattering
- .....