



116 members from  
26 institutions

# Latest results from GlueX

Mark Dalton, for the GlueX Collaboration  
[www.gluex.org](http://www.gluex.org)



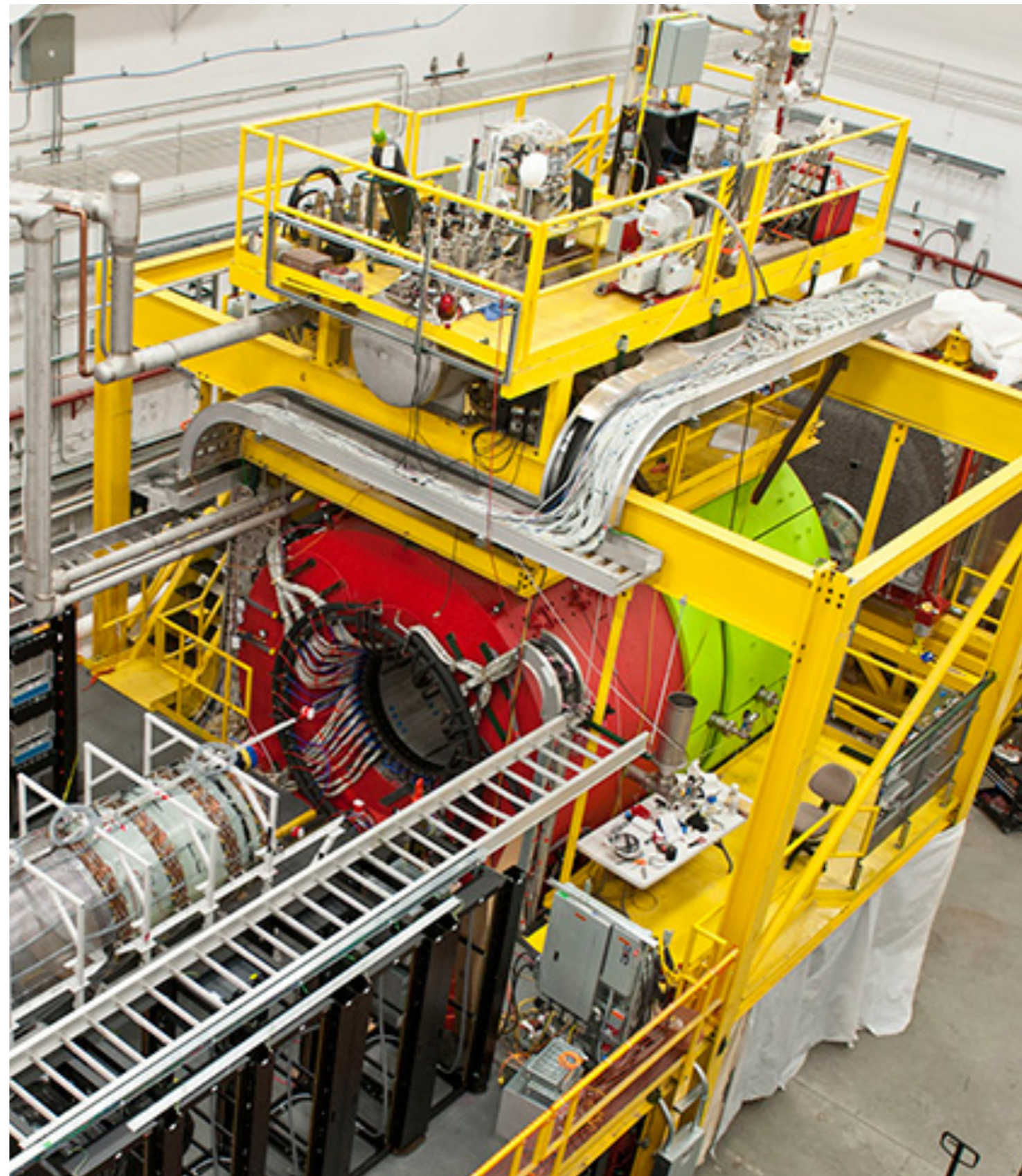


# Outline

What is GlueX trying to accomplish?  
understanding QCD through  
hadron spectroscopy

How are we different?  
High Intensity  
Production mechanism  
Photon beam  
Polarization  
Neutral detection

What have we done so far?  
Built the detector  
Commissioning and calibration  
Extracted some physics



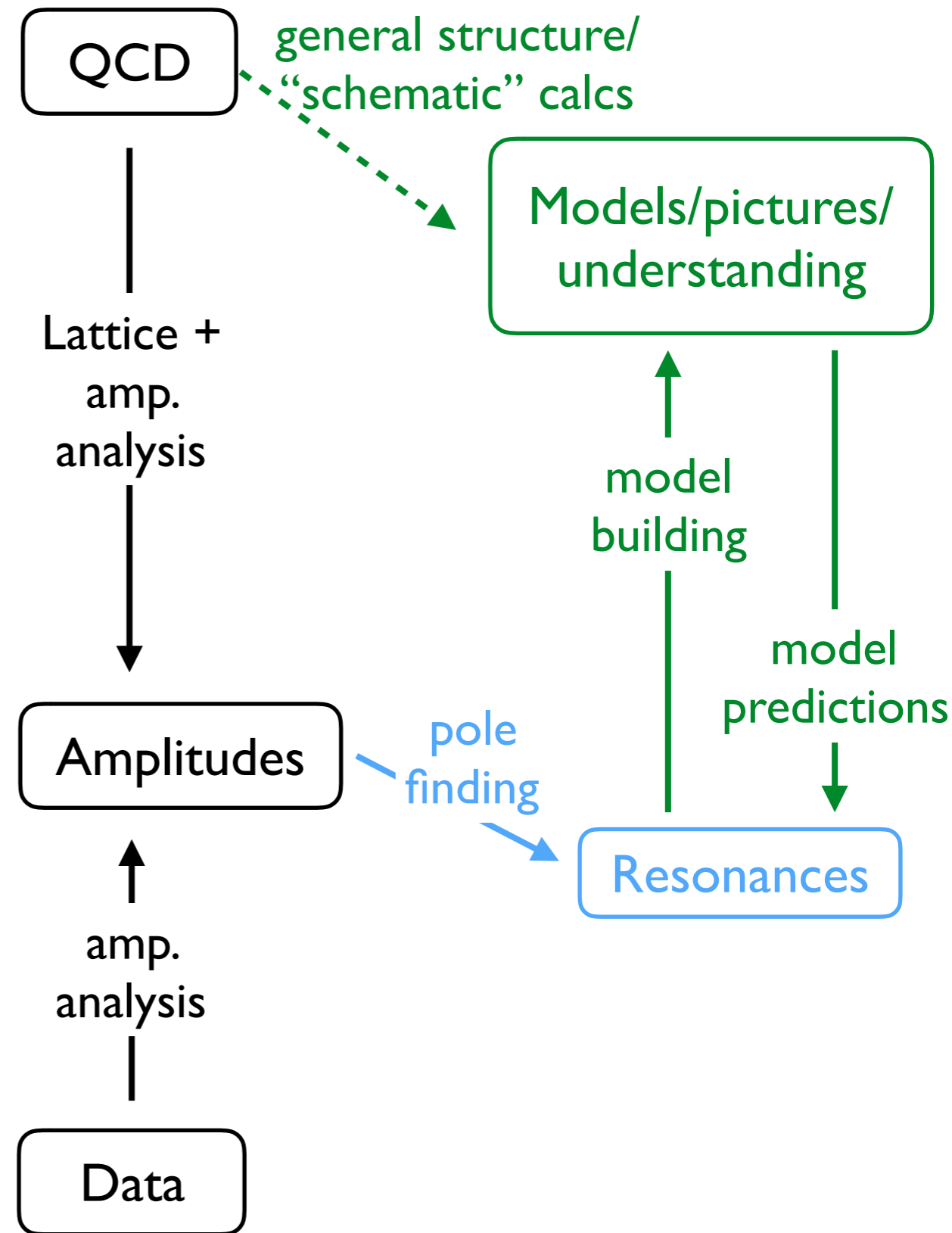
# QCD and Spectroscopy

## QCD

- six flavors of quarks with various masses
- strongly interacting quarks **and gluons**
- asymptotic freedom
- confinement

## Hadrons

- spectrum dominated by colorless “quark model” states (quark—anti-quark and 3 quark states)
- gluonic degrees of freedom suppressed or difficult to observe





# Meson Quantum Numbers

Mesons have well defined quantum numbers:  
total spin  $J$ , parity  $P$ , and C-parity  $C$   
represented as  $J^{PC}$

$$P(q\bar{q}) = (-1)^{L+1}$$

$$C(q\bar{q}) = (-1)^{L+S}$$

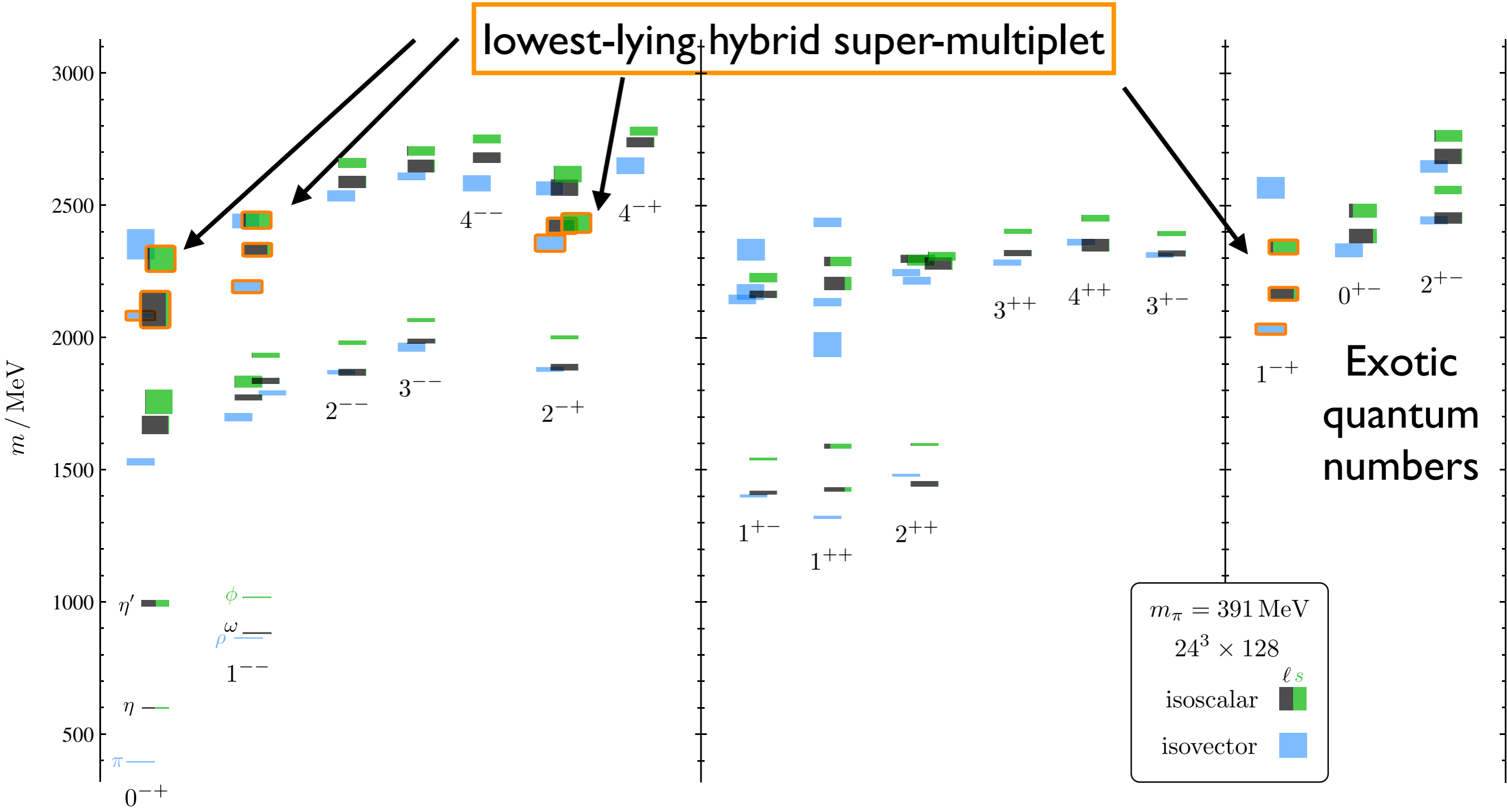
S	L	J	P	C	$J^{PC}$	Mesons				Type
0	0	0	-	+	$0^{-+}$	$\pi$	$\eta$	$\eta'$	$K$	pseudoscalar
1	0	1	-	-	$1^{--}$	$\rho$	$\omega$	$\phi$	$K^*$	vector
0	1	1	+	-	$1^{+-}$	$b_1$	$h_1$	$h'_1$	$K_1$	axial vector
1	1	0	+	+	$0^{++}$	$a_0$	$f_0$	$f'_0$	$K_0^*$	scalar
1	1	1	+	+	$1^{++}$	$a_1$	$f_1$	$f'_1$	$K_1^*$	axial vector
1	1	2	+	+	$2^{++}$	$a_2$	$f_2$	$f'_2$	$K_2^*$	tensor

explicitly exotic quantum numbers

$0^{--}, 0^{+-}, 1^{-+}, 2^{+-}, 3^{-+}, \dots$



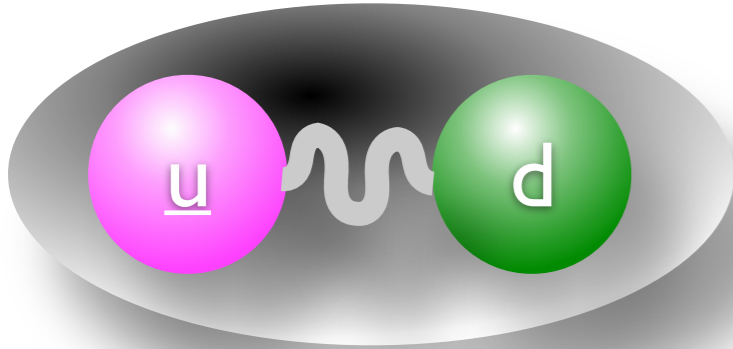
# Light Quark Mesons from Lattice



Dudek et al. PRD 88 (2013) 094505

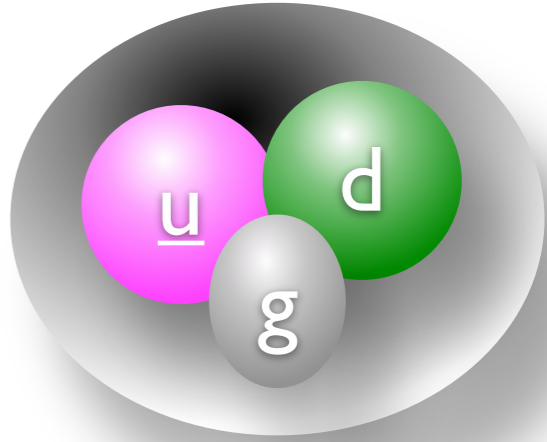
# Models for gluonic excitations

Transverse oscillation of flux tube

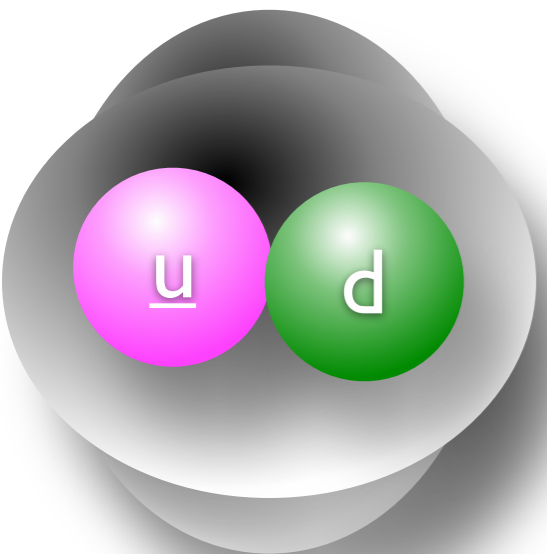


High symmetry leads to too many states

Constituent gluon quasiparticle



Bag model  
gluonic boundary mode



Correct quantum numbers, model disfavored for other reasons

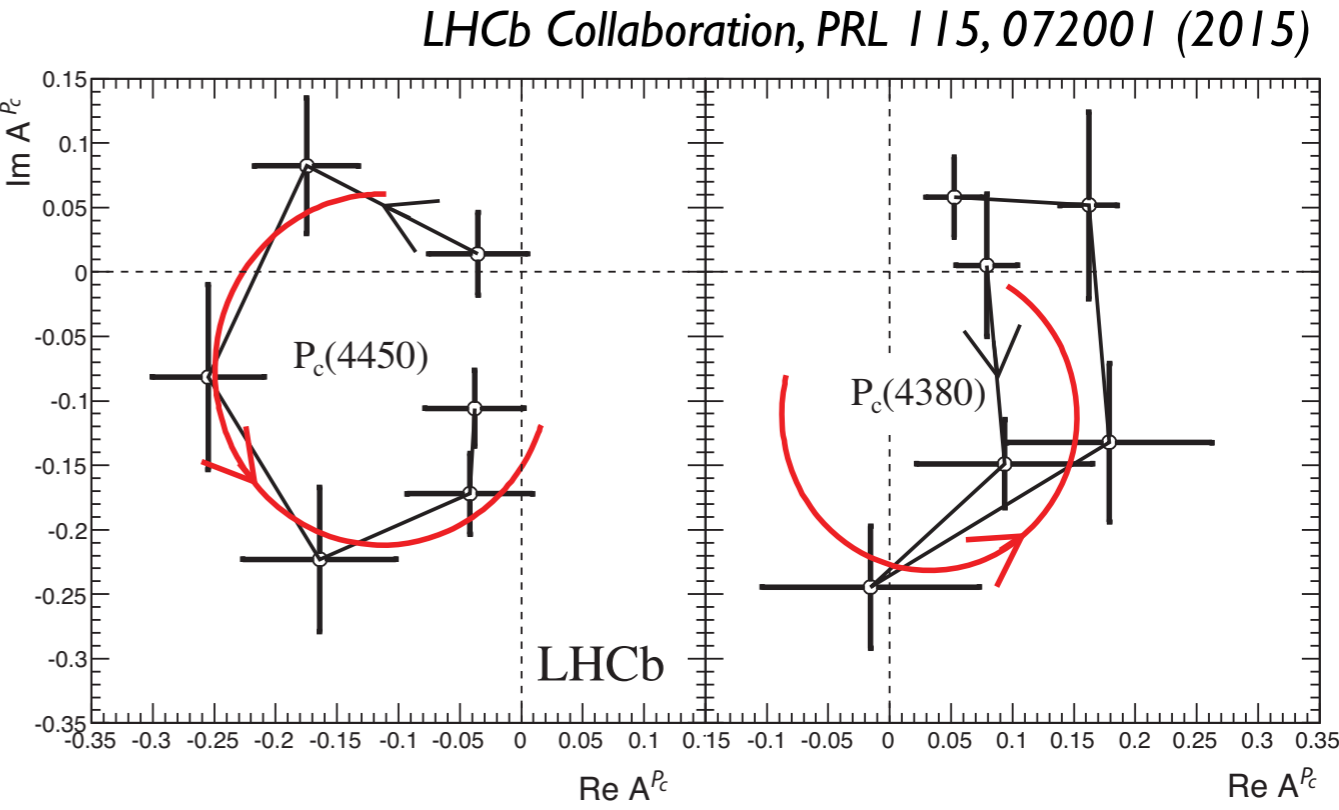
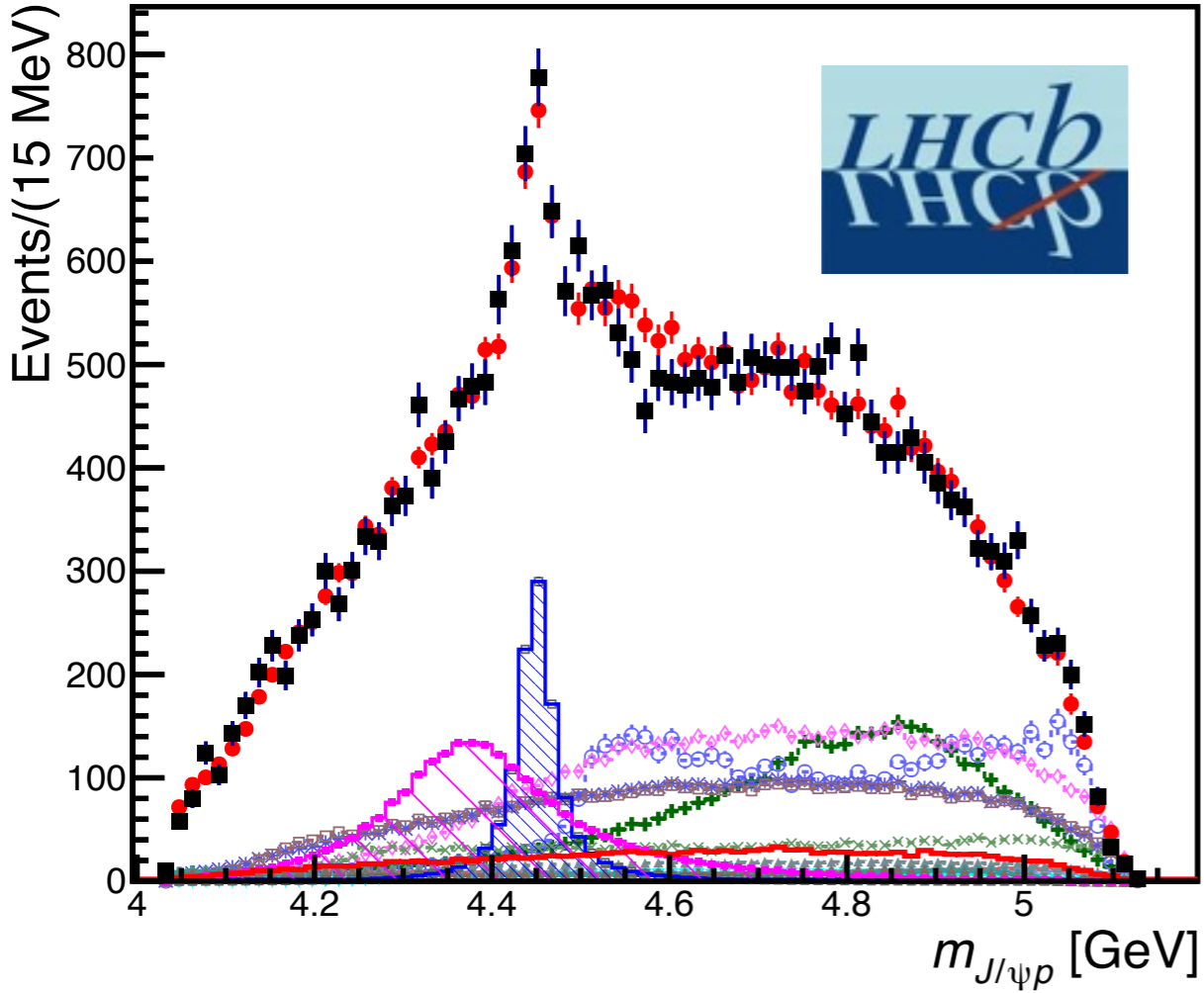
- $I^-$  gluon and S-wave qq not exoitc
- $I^-$  gluon and P-wave qq too many states
- $I^+$  gluon and P-wave qq works,  $M \sim 1-1.5$  GeV

Phys. Rev. D 84 (2011) 074023



# Exotic Charmed Baryons

$$B \rightarrow pK J/\psi$$



*Pentaquark Candidates*

# Exotic Charmed Mesons

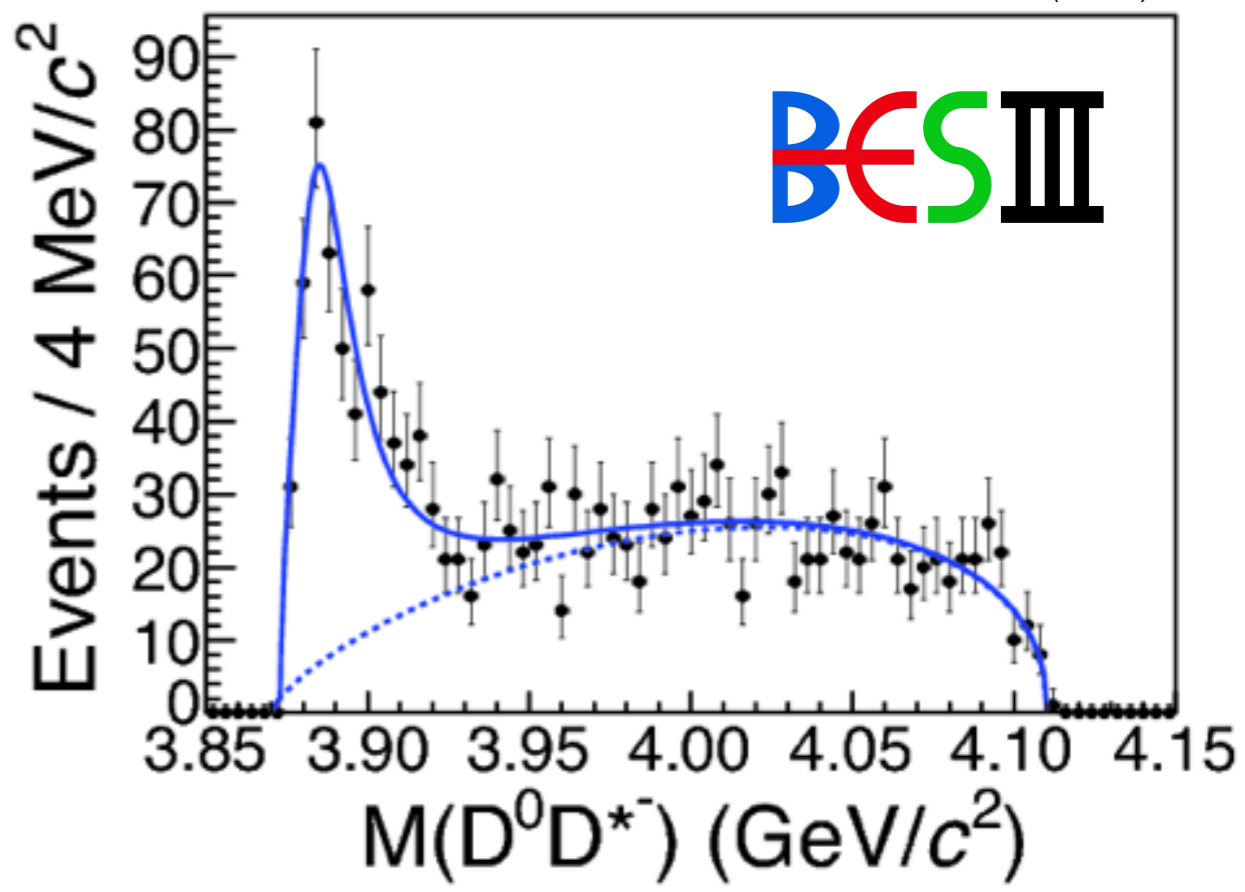
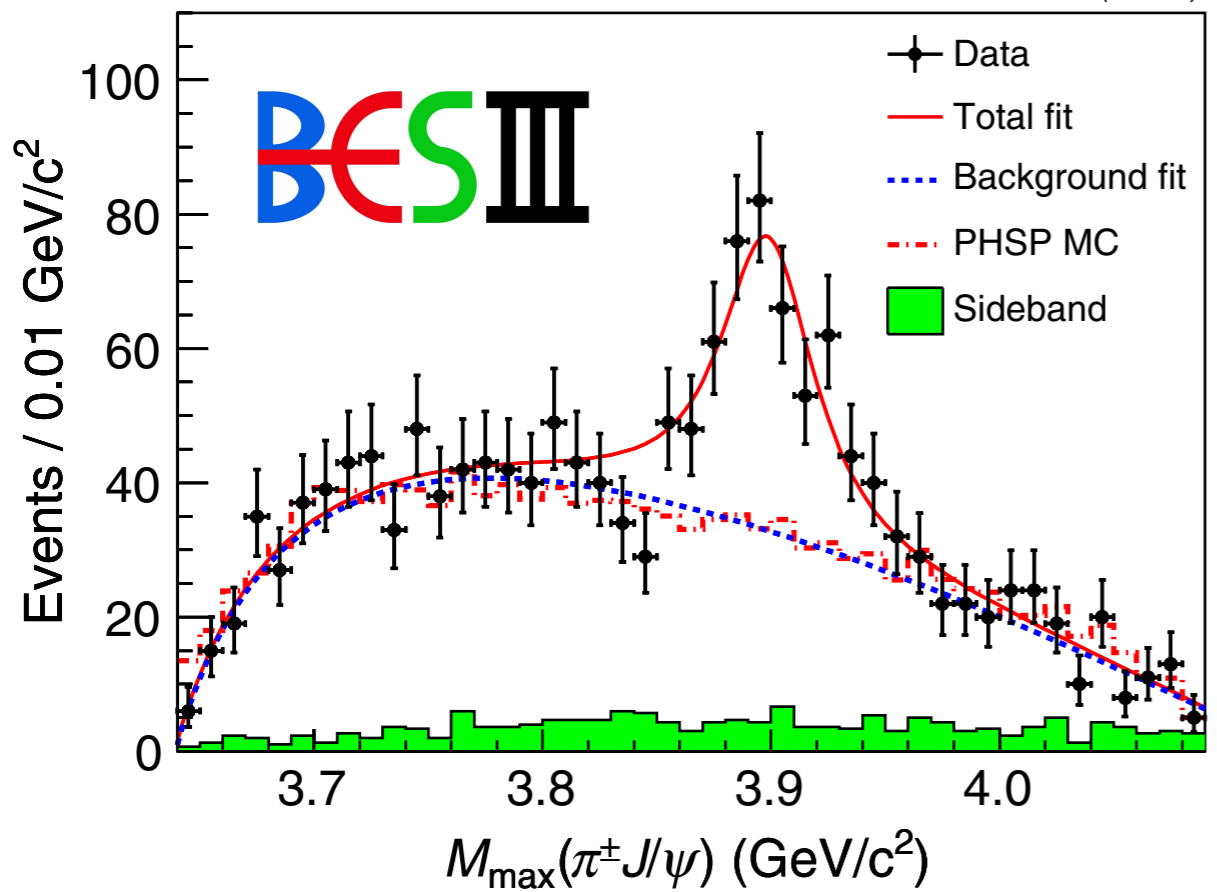
$$e^+e^- \rightarrow \pi^\mp Z_c^\pm$$

$$Z_c^\pm \rightarrow \pi^\pm J/\psi$$

BESIII Collaboration, PRL 110, 252001 (2013)

$$Z_c^\pm \rightarrow (\overline{D^0} D^{*\mp})^\pm$$

BESIII Collaboration, PRL 112, 022001 (2013)



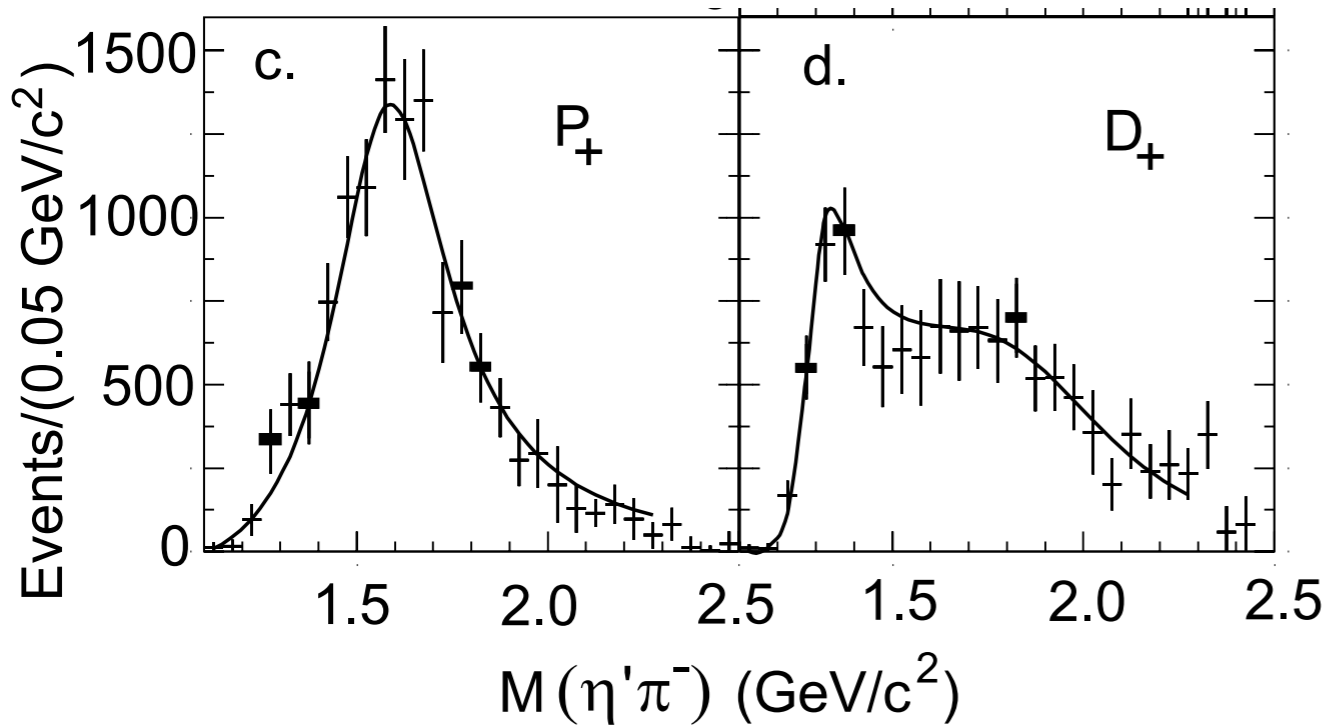
*Tetraquark Candidates*



# Exotic Light Mesons

$$\pi_1 \rightarrow \eta' \pi$$

E852: 18 GeV  $\pi$  on p

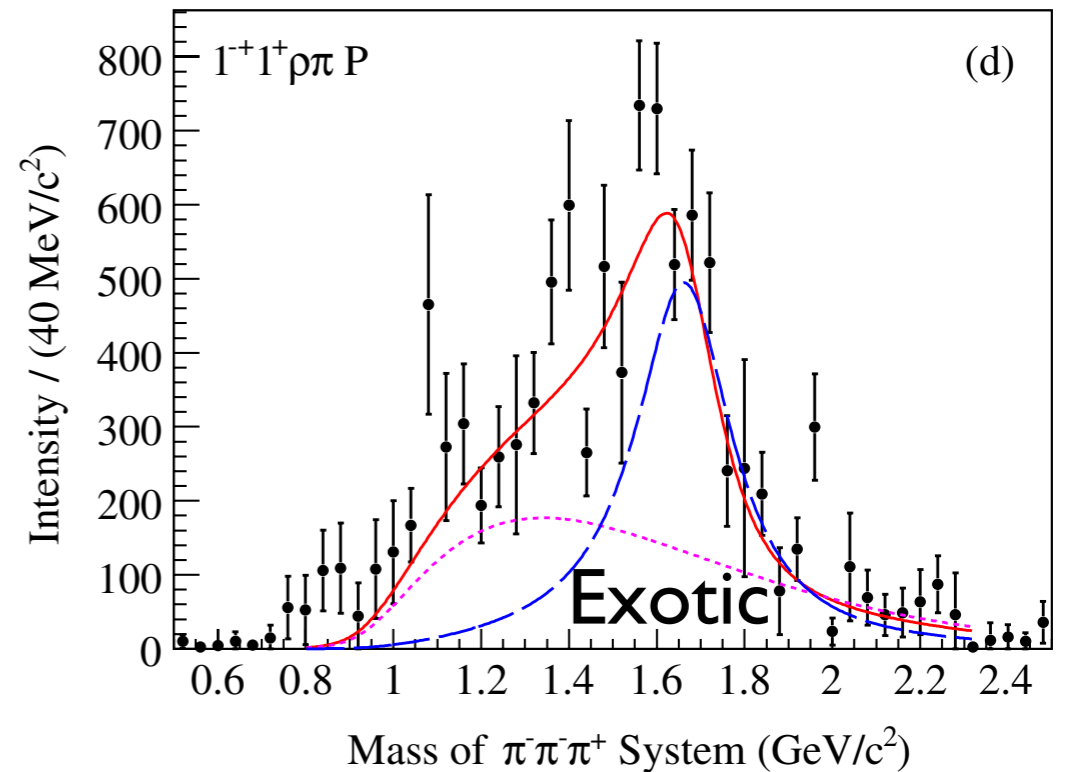
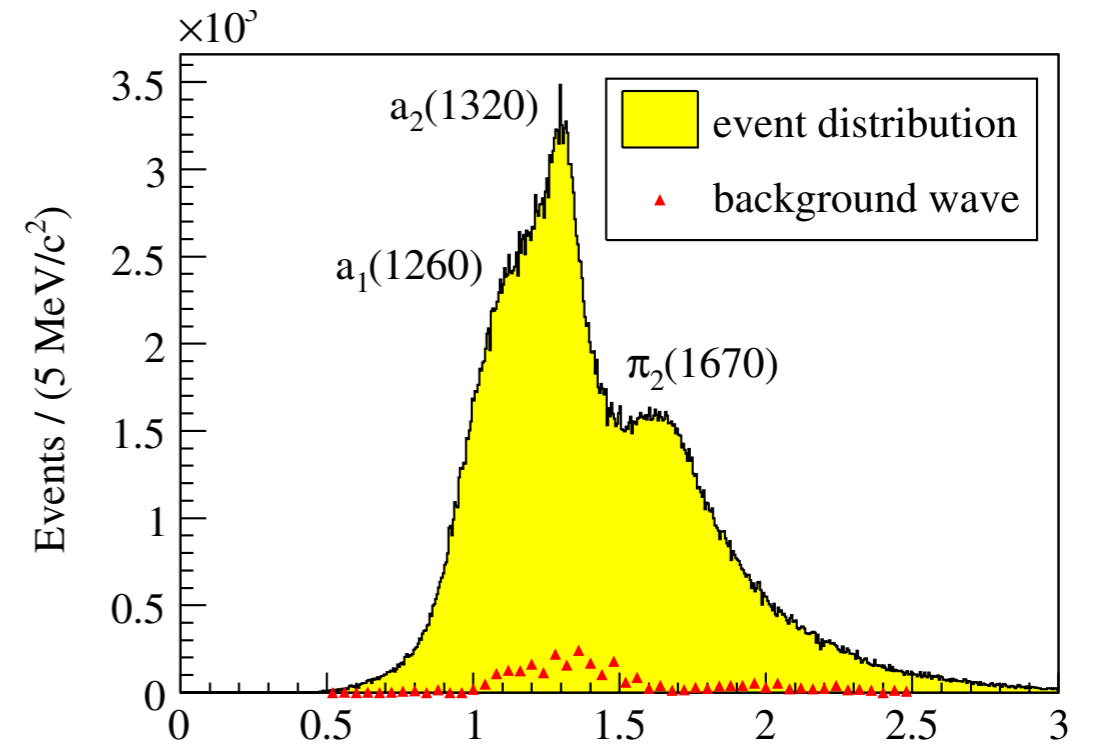


PRL 86, 3977 (2001)

“Understanding” requires a spectrum of hybrid states

$$\pi_1 \rightarrow \rho \pi$$

COMPASS: 190 GeV  $\pi$  on Pb



PRL 104, 241803 (2010)

# QCD systems

QCD permits color single states with arbitrary numbers of quarks  
we see only very few species, why?

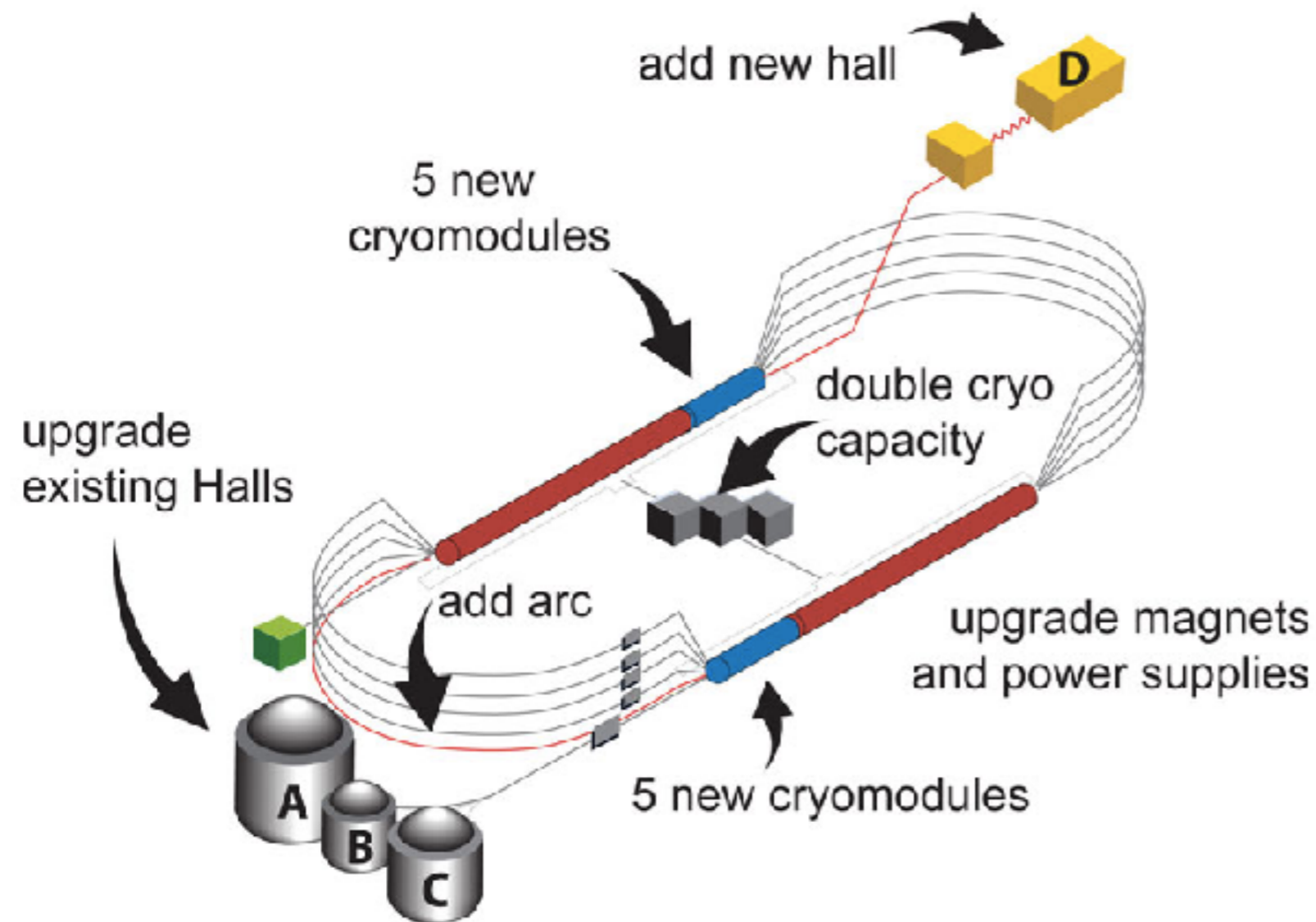
Interesting landscape of exotic QCD states  
Evidence for new types of mesons in heavy quark systems  
Reports of hybrids from VES, E852, Crystal barrel, COMPASS  
But, no clear spectrum of states

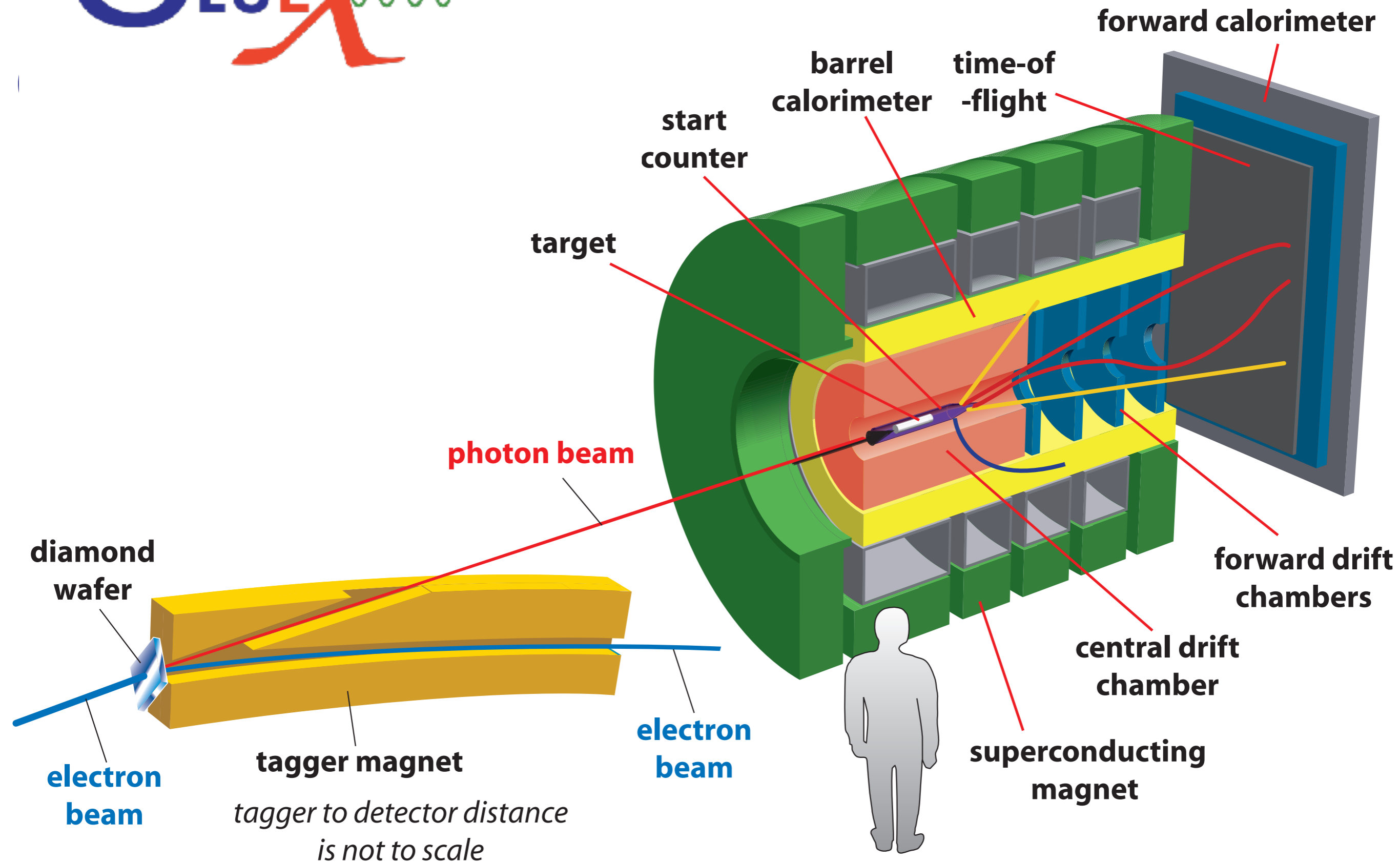
Great time for GlueX  
Complementary: light quark systems  
Unique: intensity and production mechanism



# Jefferson Lab

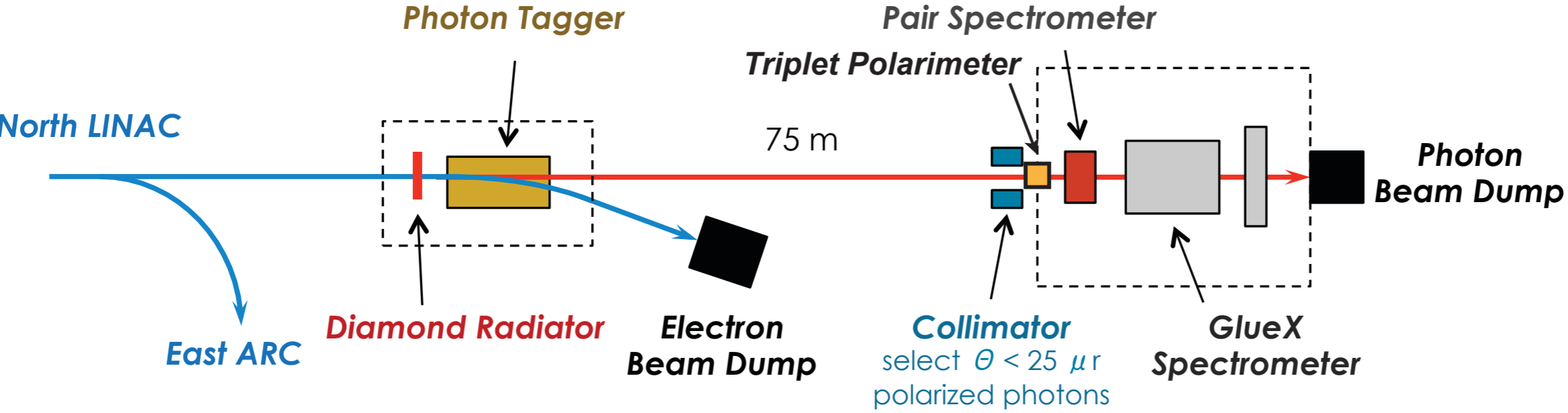
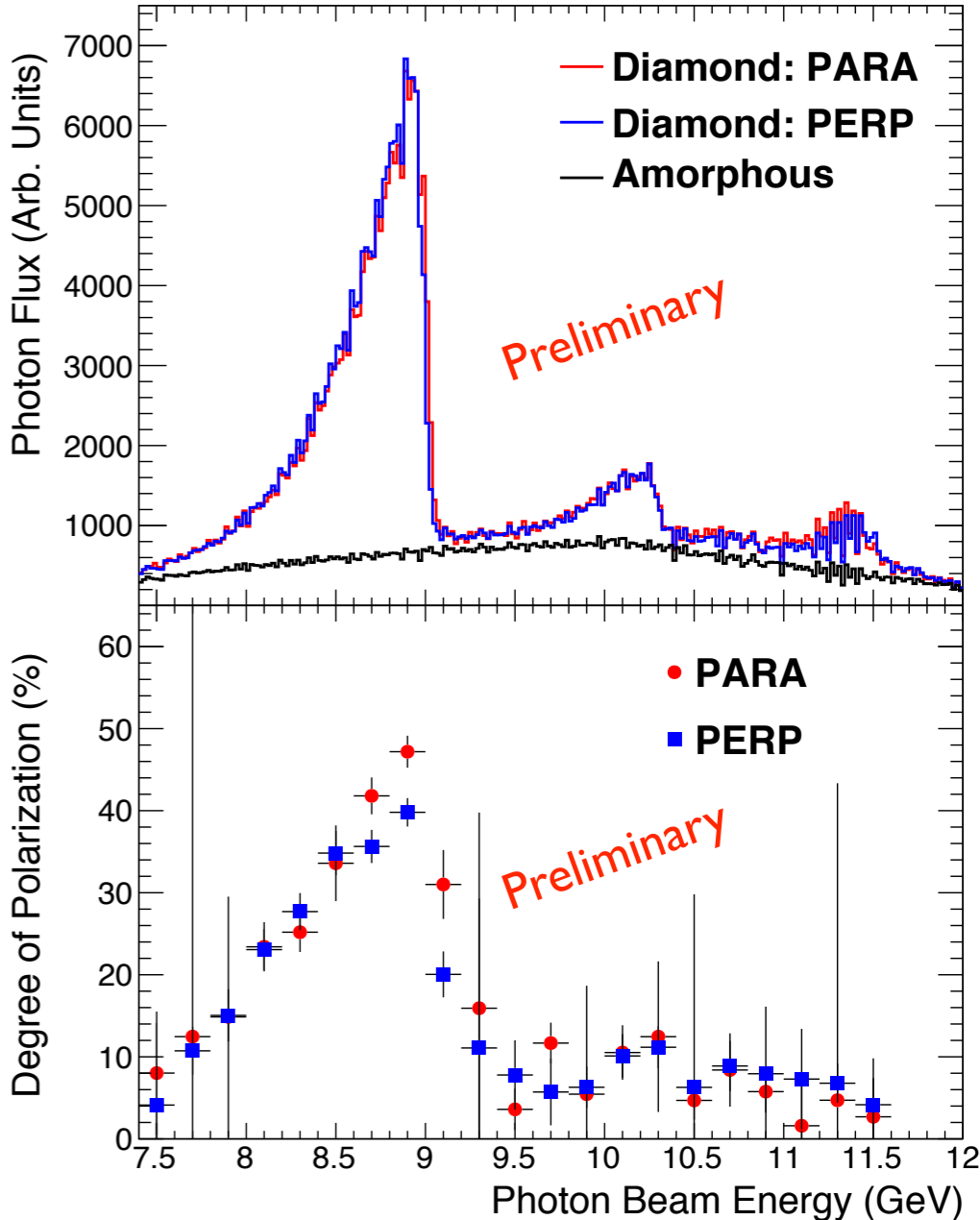
CEBAF Accelerator, 12 GeV electron beam  
4 experimental end stations  
Newport News, Virginia







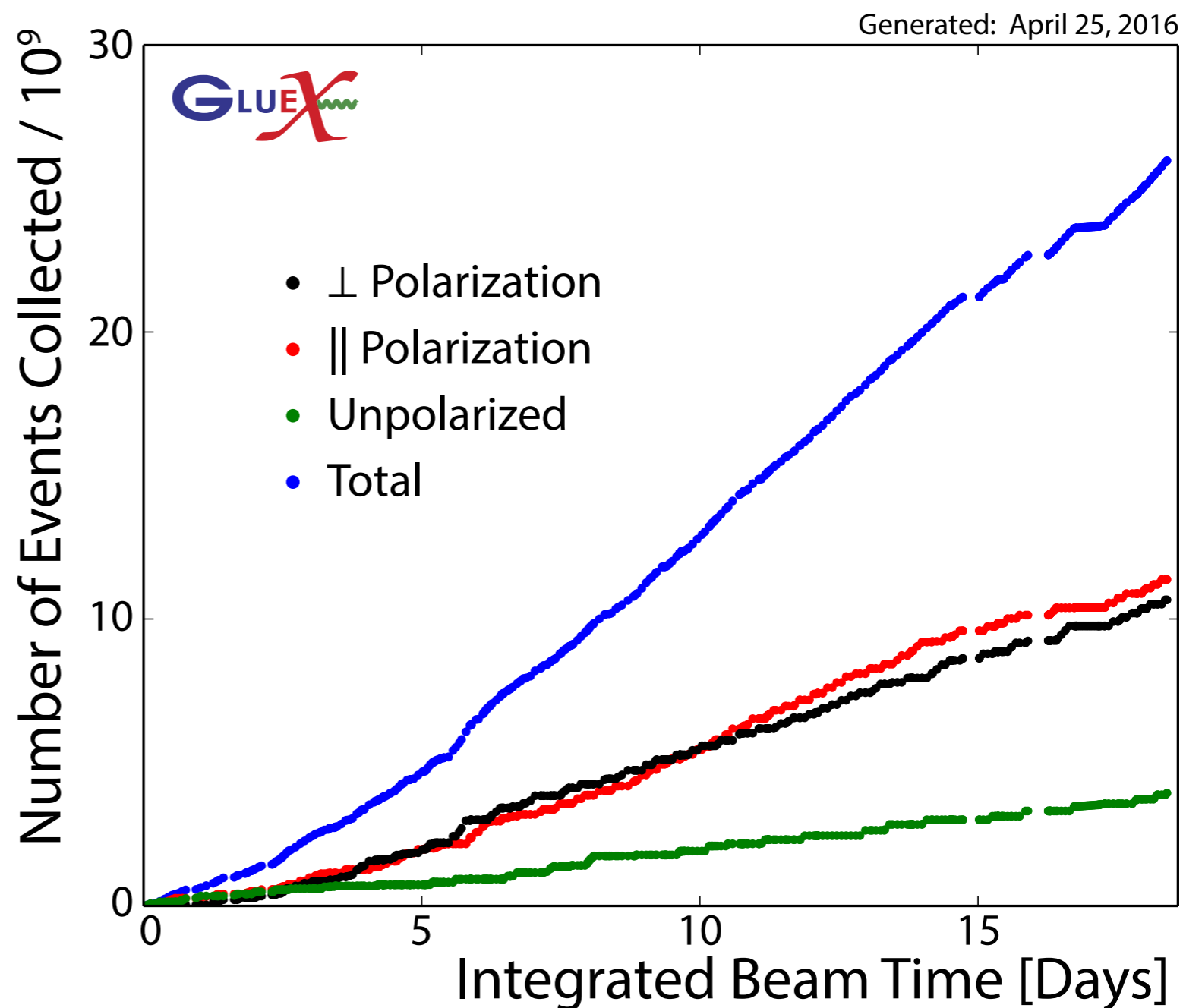
# Photon Beam



# Spring 2016 running

Final commissioning period

- detector calibration
- data acquisition and analysis infrastructure
- opportunistic physics results



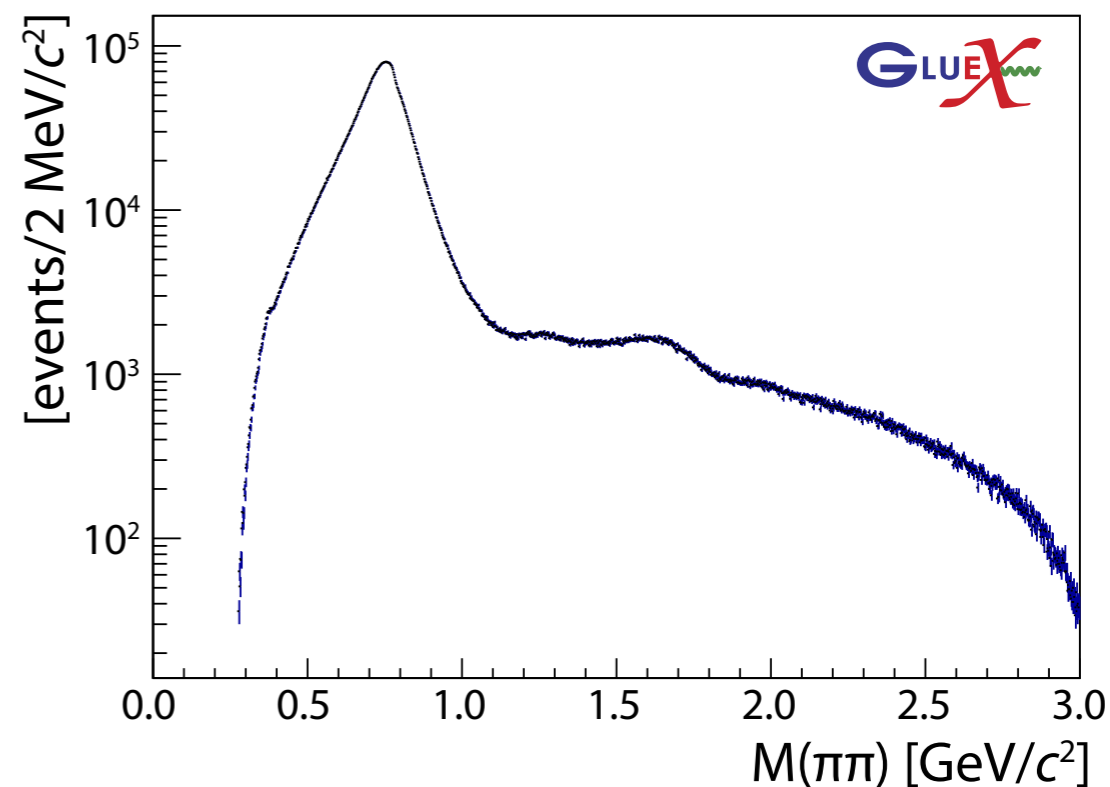
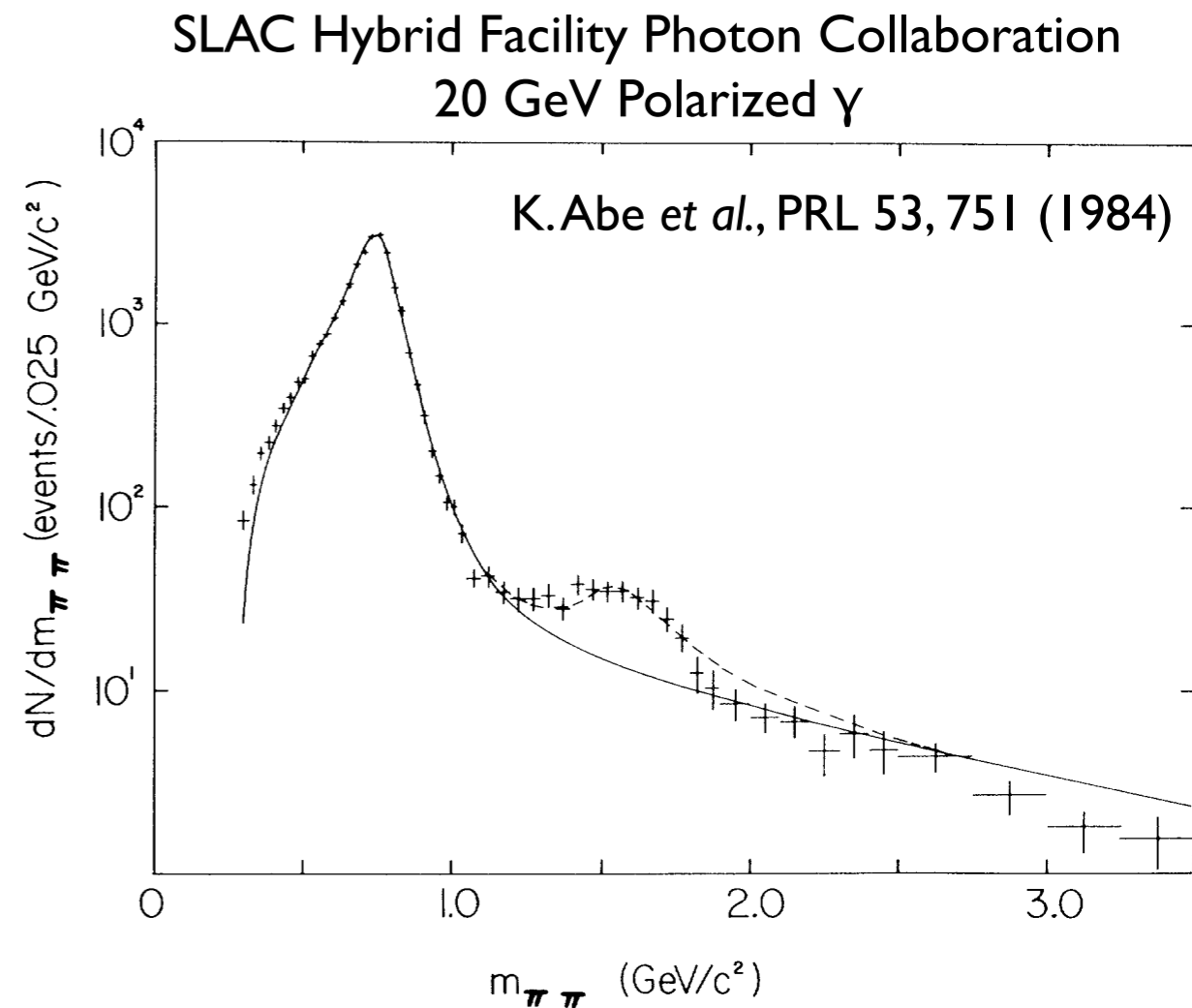


# Intensity

Showing a subset of spring 2016 data:  
achieve  $\sim 10^7$   $\gamma/s$  in coherent peak  
7 days at 50% ( $\sim 1$   $\text{pb}^{-1}$ )

Planned initial GlueX running  
100 days at  $10^7$   $\gamma/s$   
(10x stats)

High intensity running  
200 days at  $5 \times 10^7$   $\gamma/s$   
(100x stats)

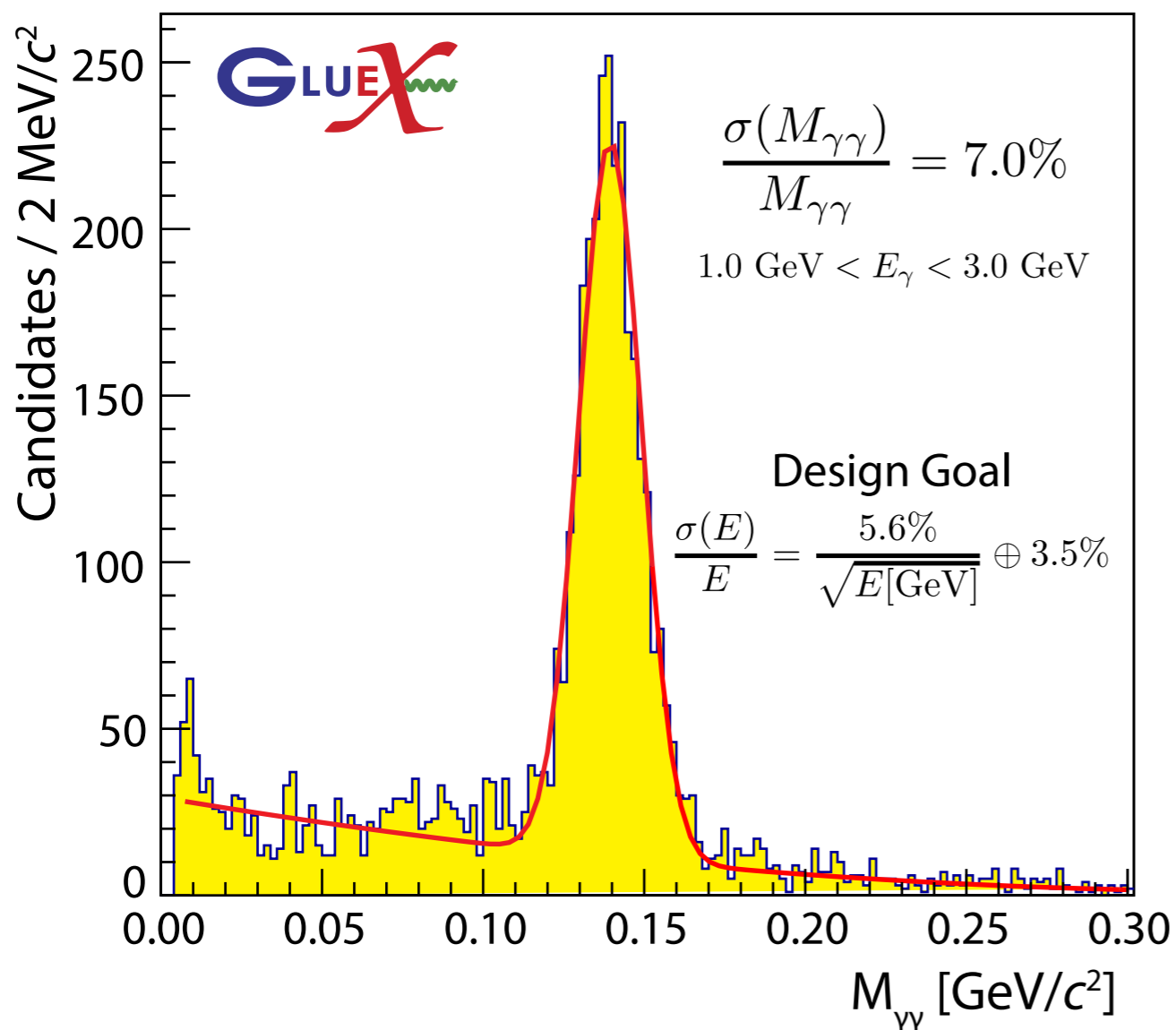


M. R.

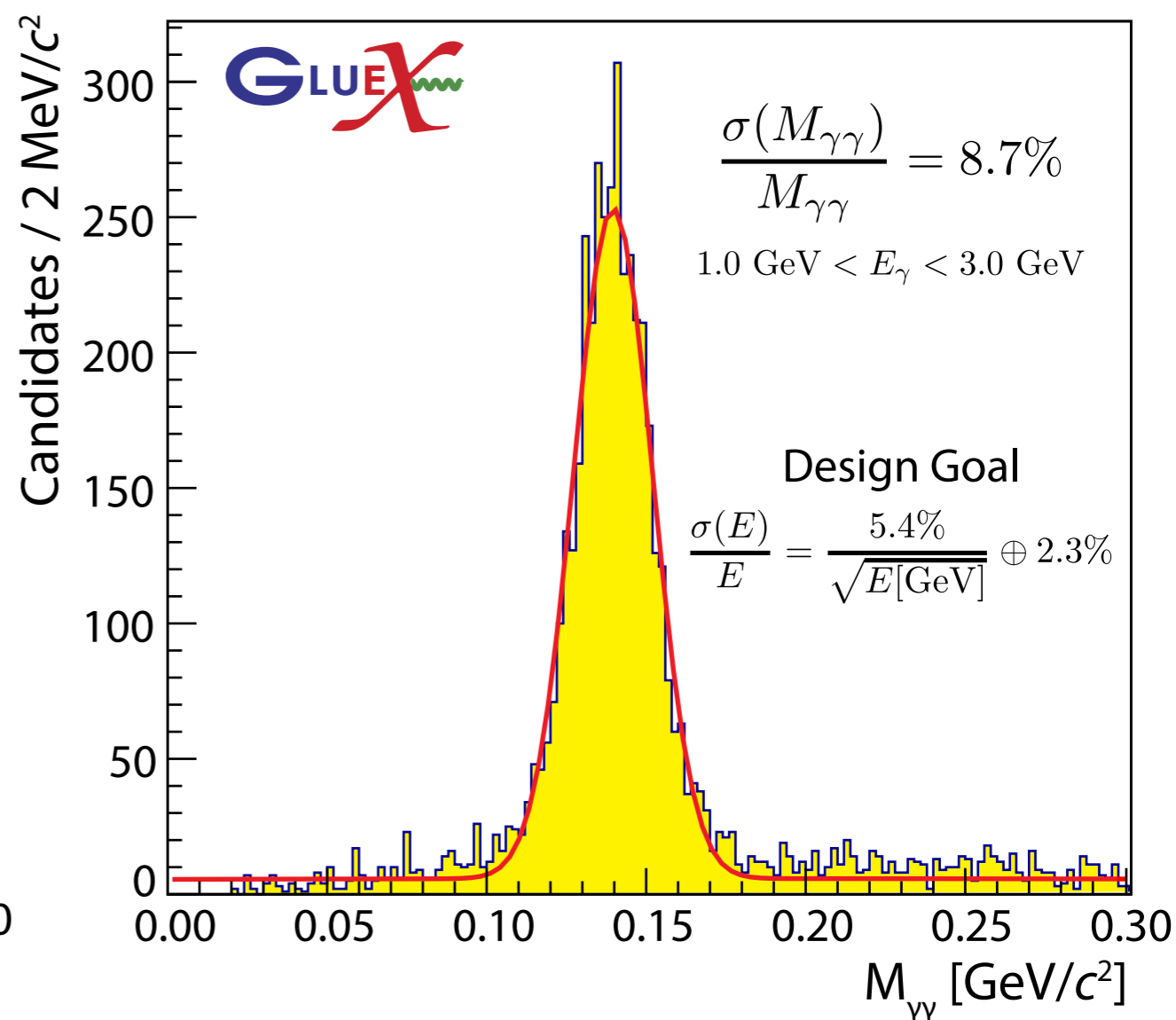
# Detector Performance

Calorimeters approaching design energy resolution

Forward Lead Glass Calorimeter

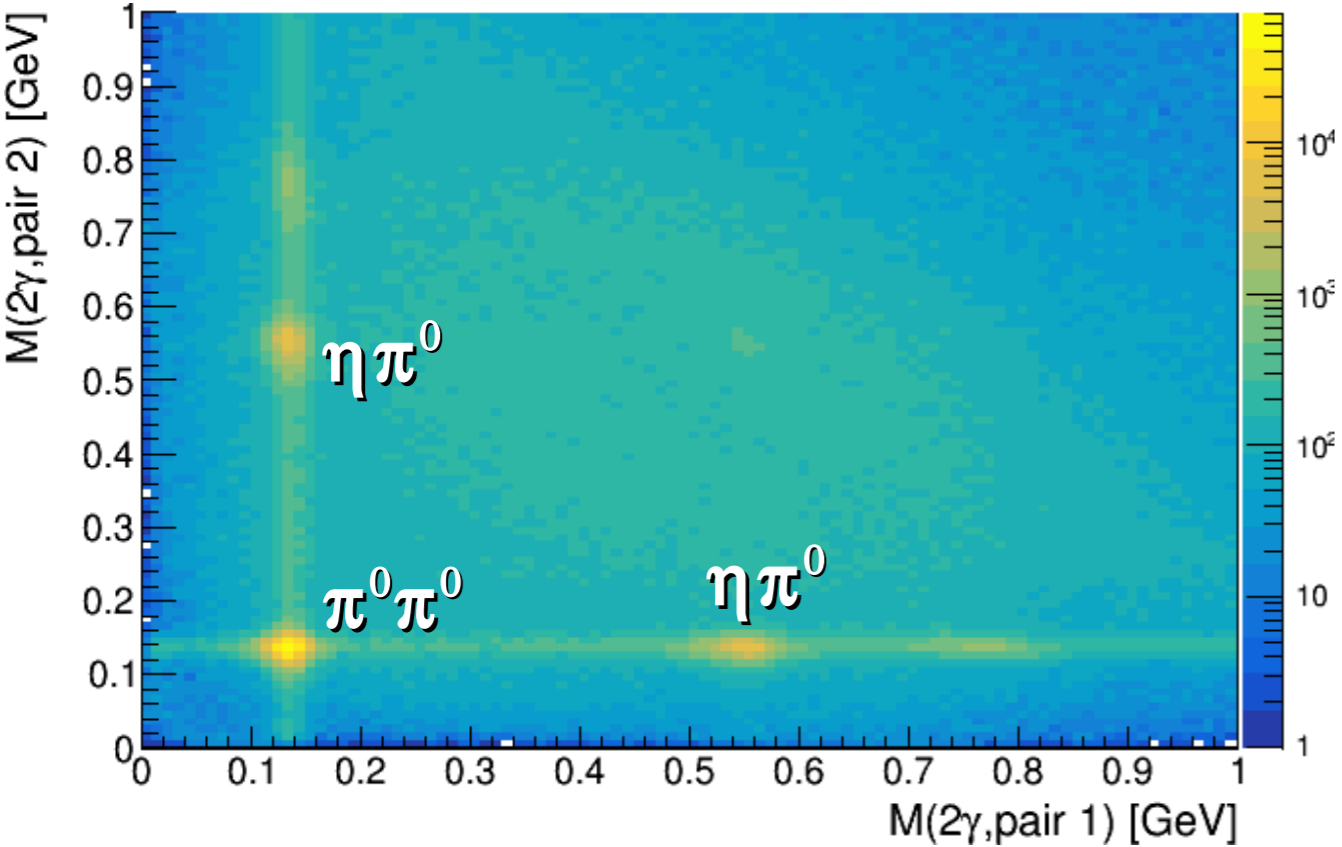


Barrel Lead-Scintillating Fiber Calorimeter

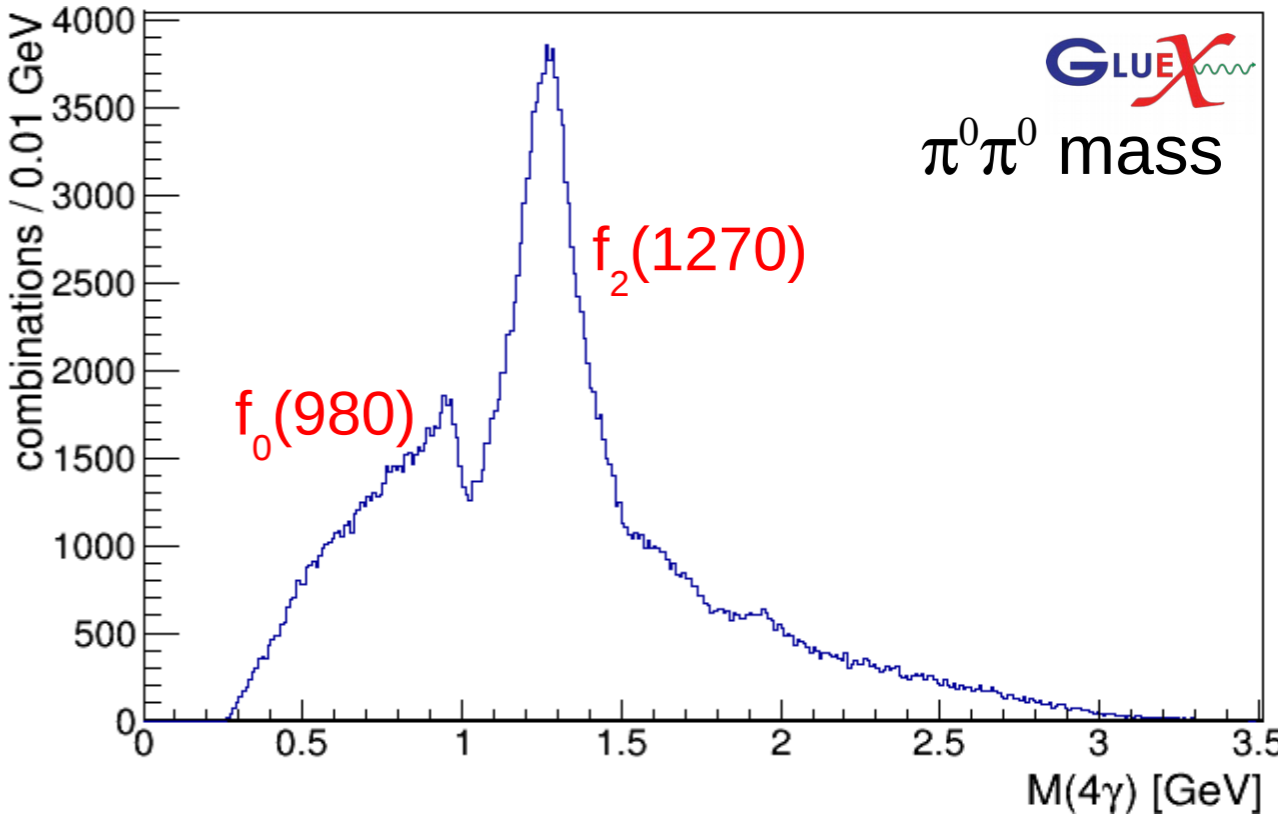
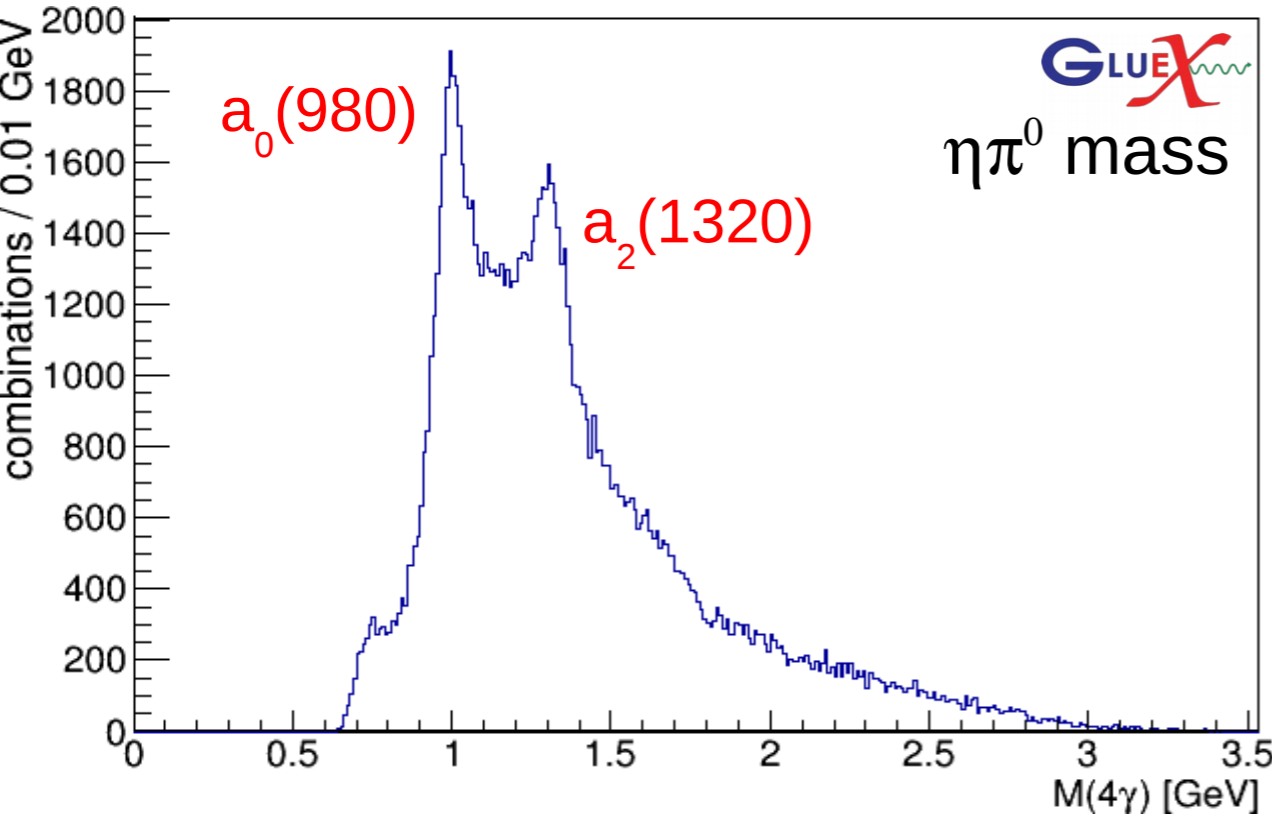


# Neutral particle detection

$$\gamma p \rightarrow p + 4\gamma$$

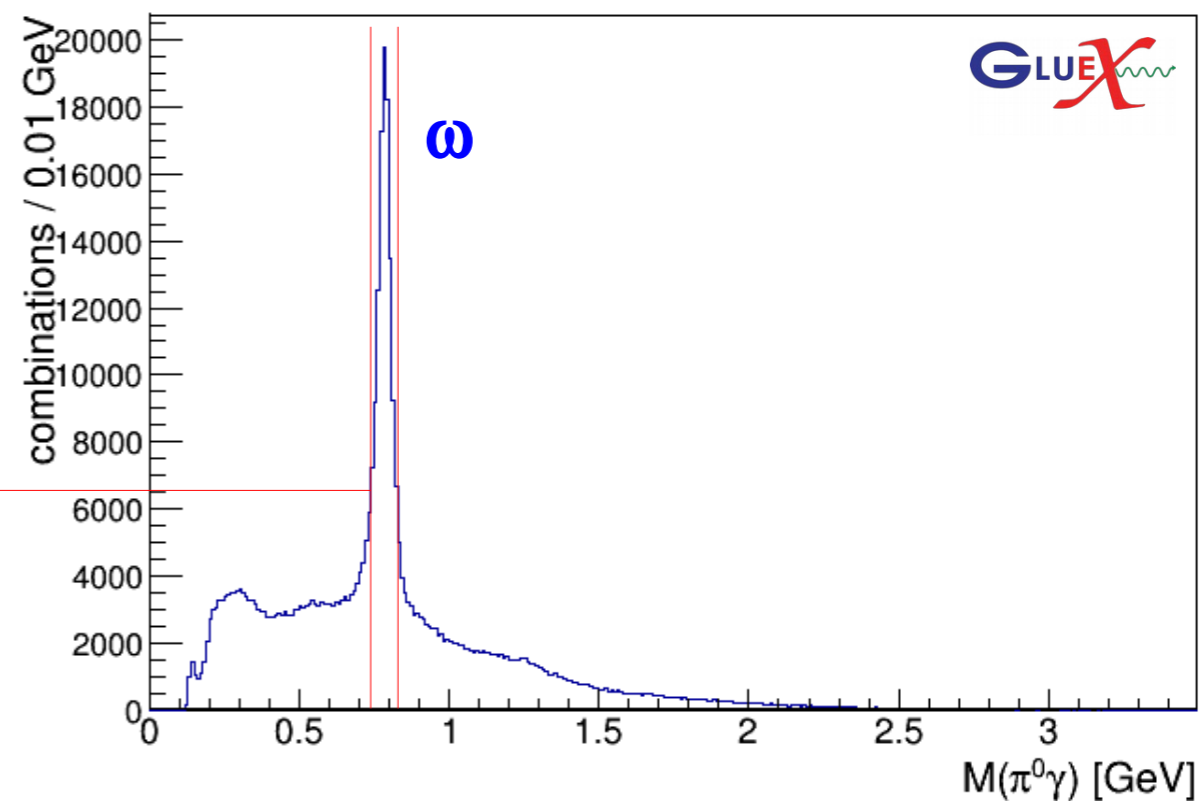
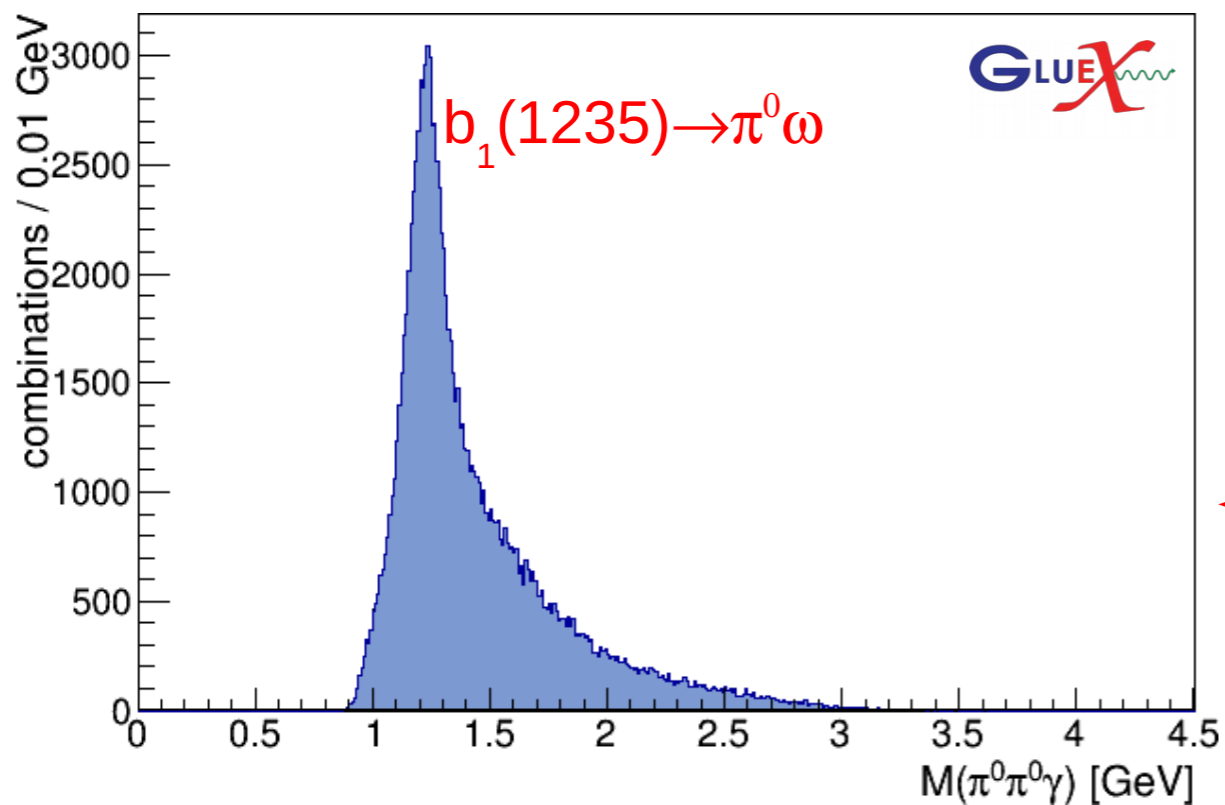
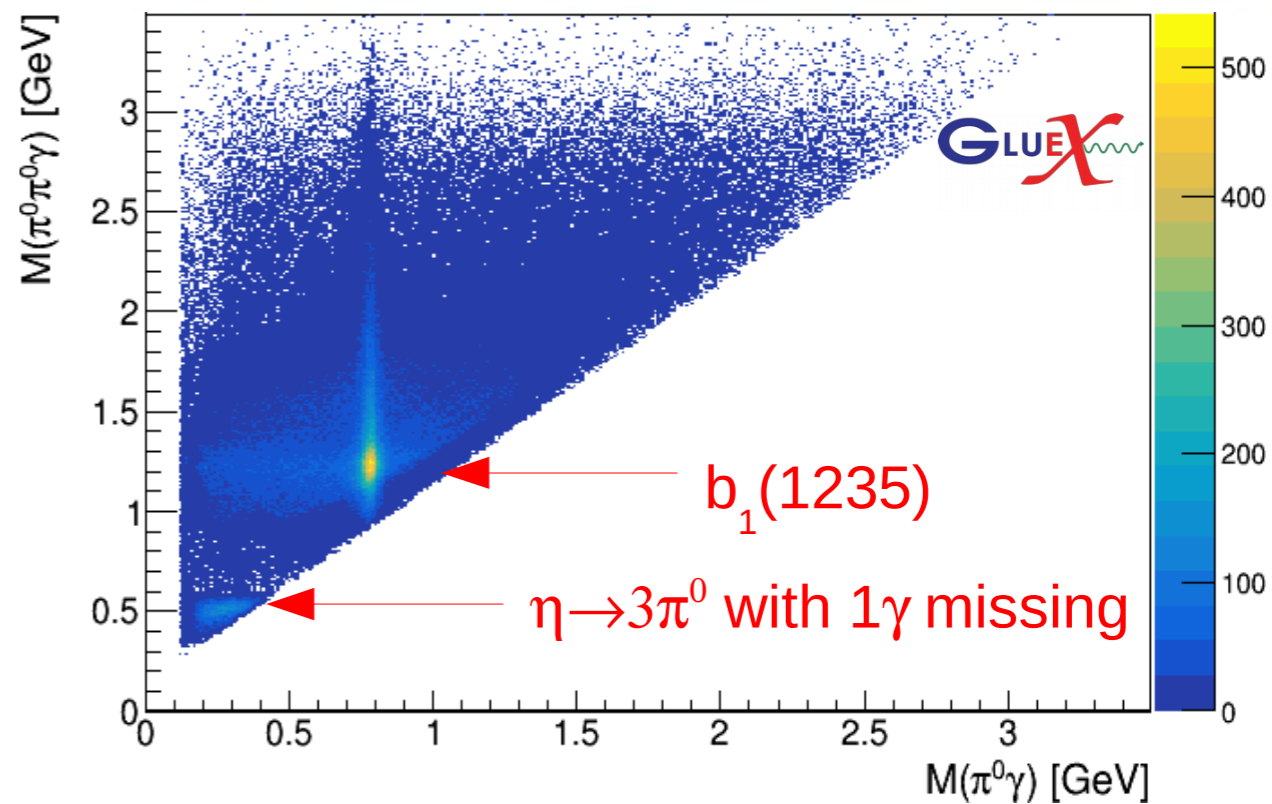
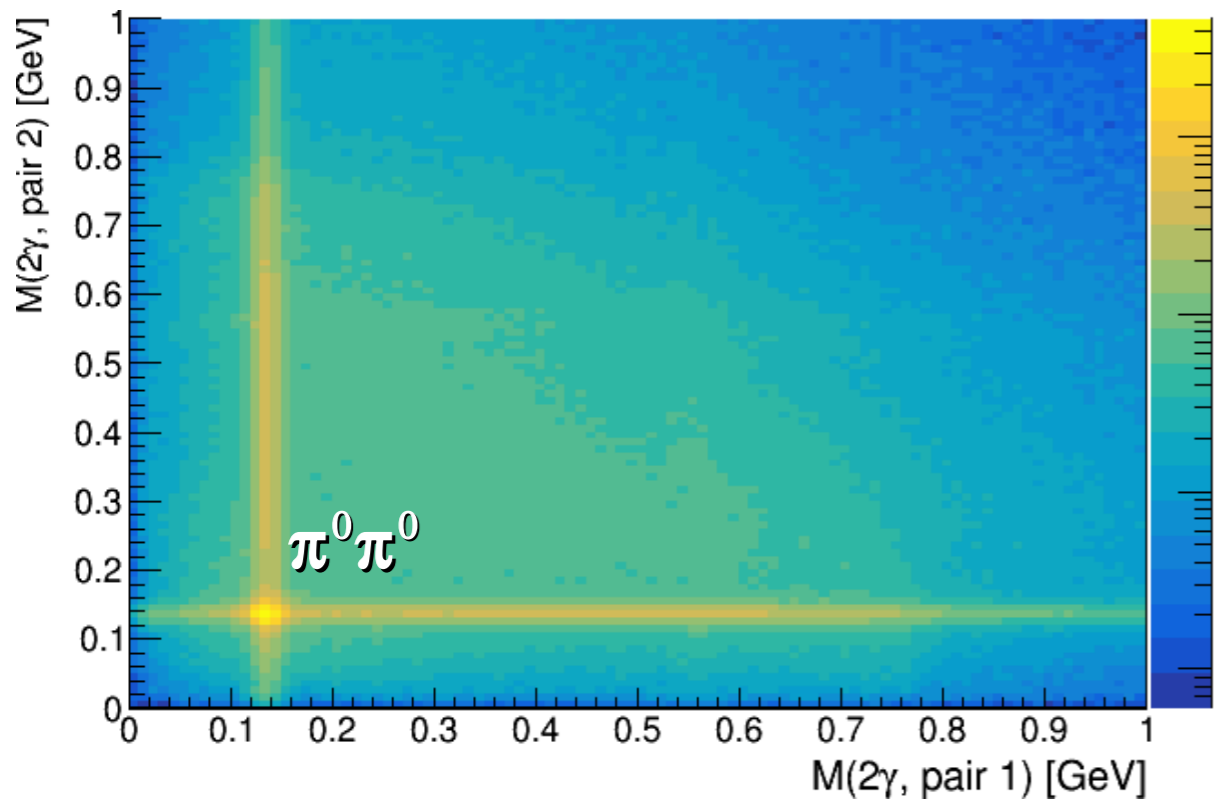


- Robust neutral performance critical for mapping spectrum
- High-multiplicity photon final states resolved
- Interesting features
  - missing photon
  - scalar and tensor mesons



# Neutral particle detection

$$\gamma p \rightarrow p + 5\gamma$$

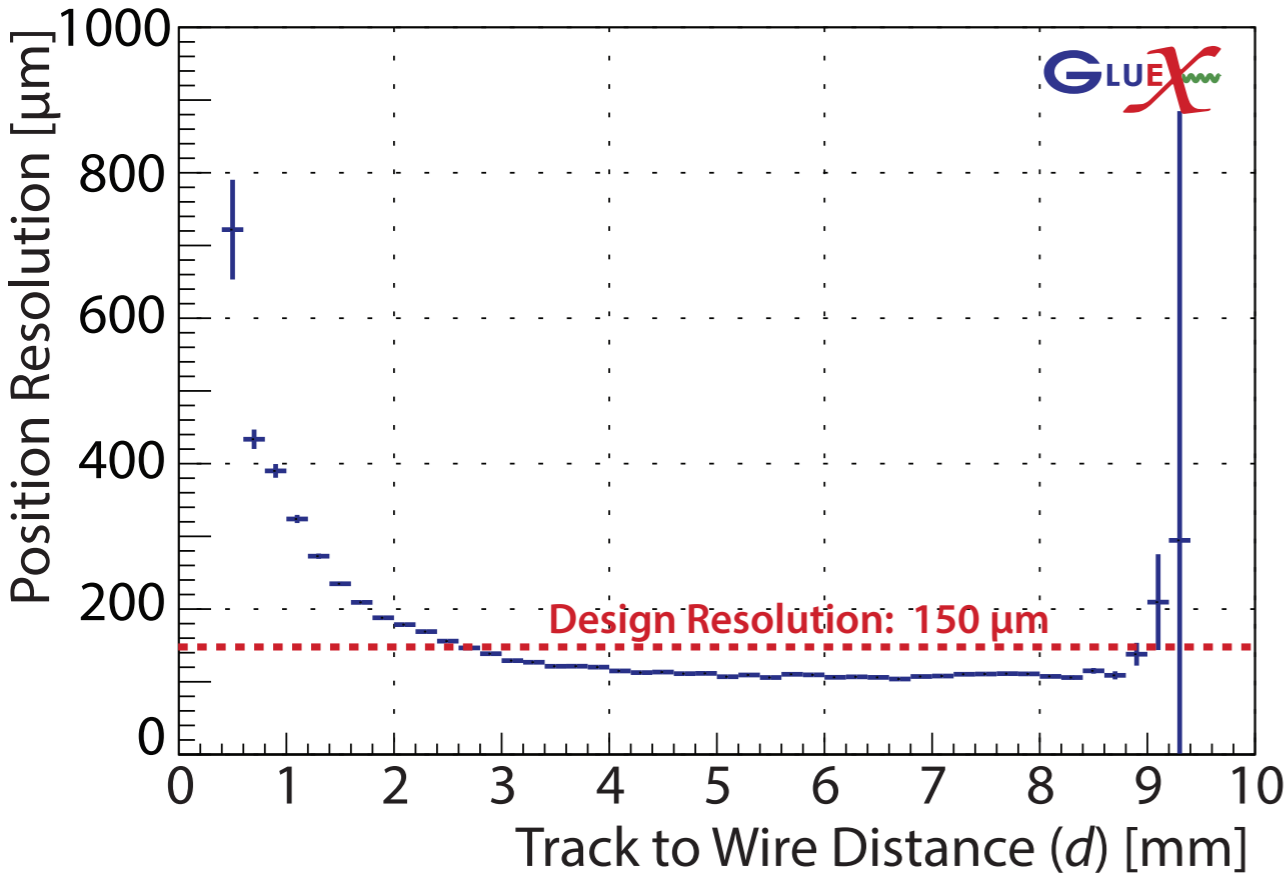




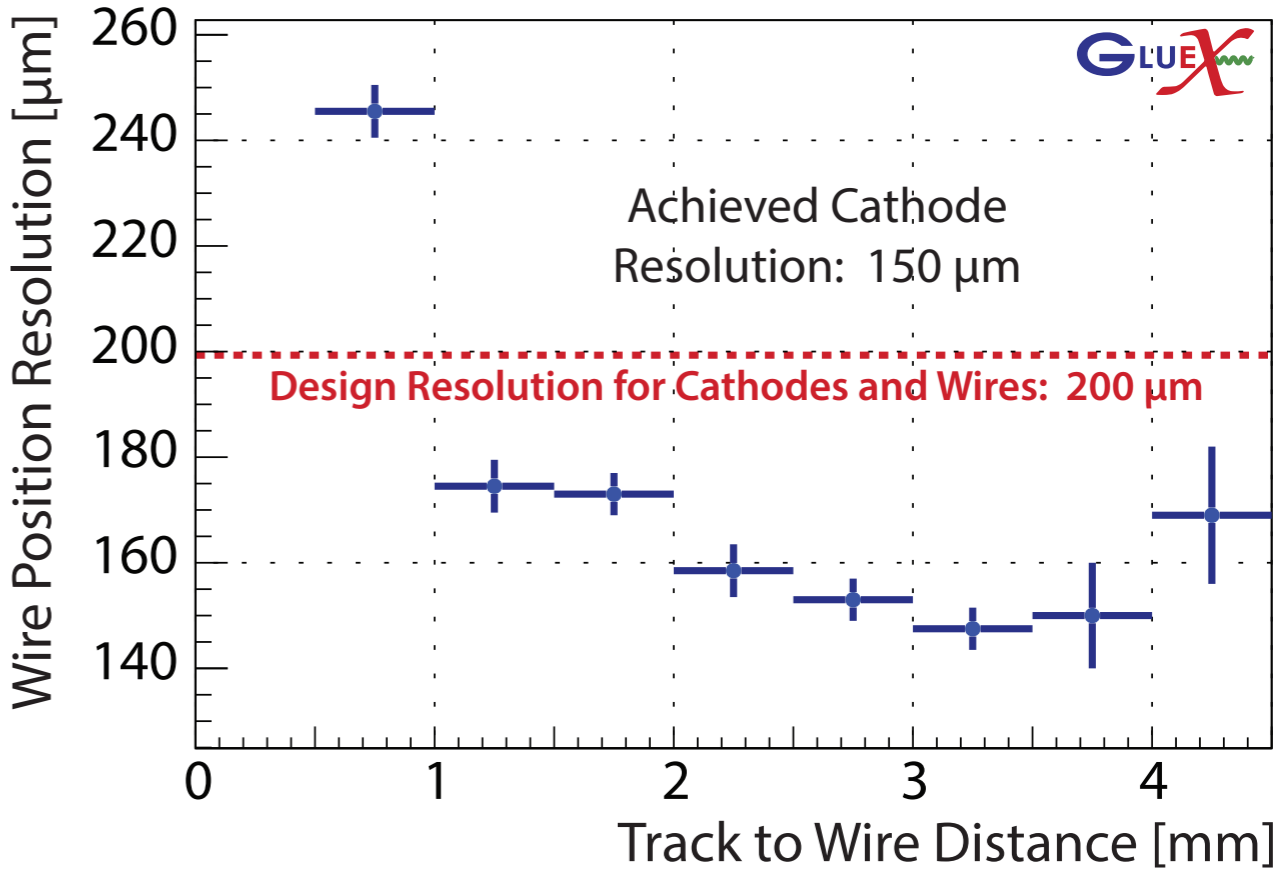
# Detector Performance

Drift chambers exceed design position resolution

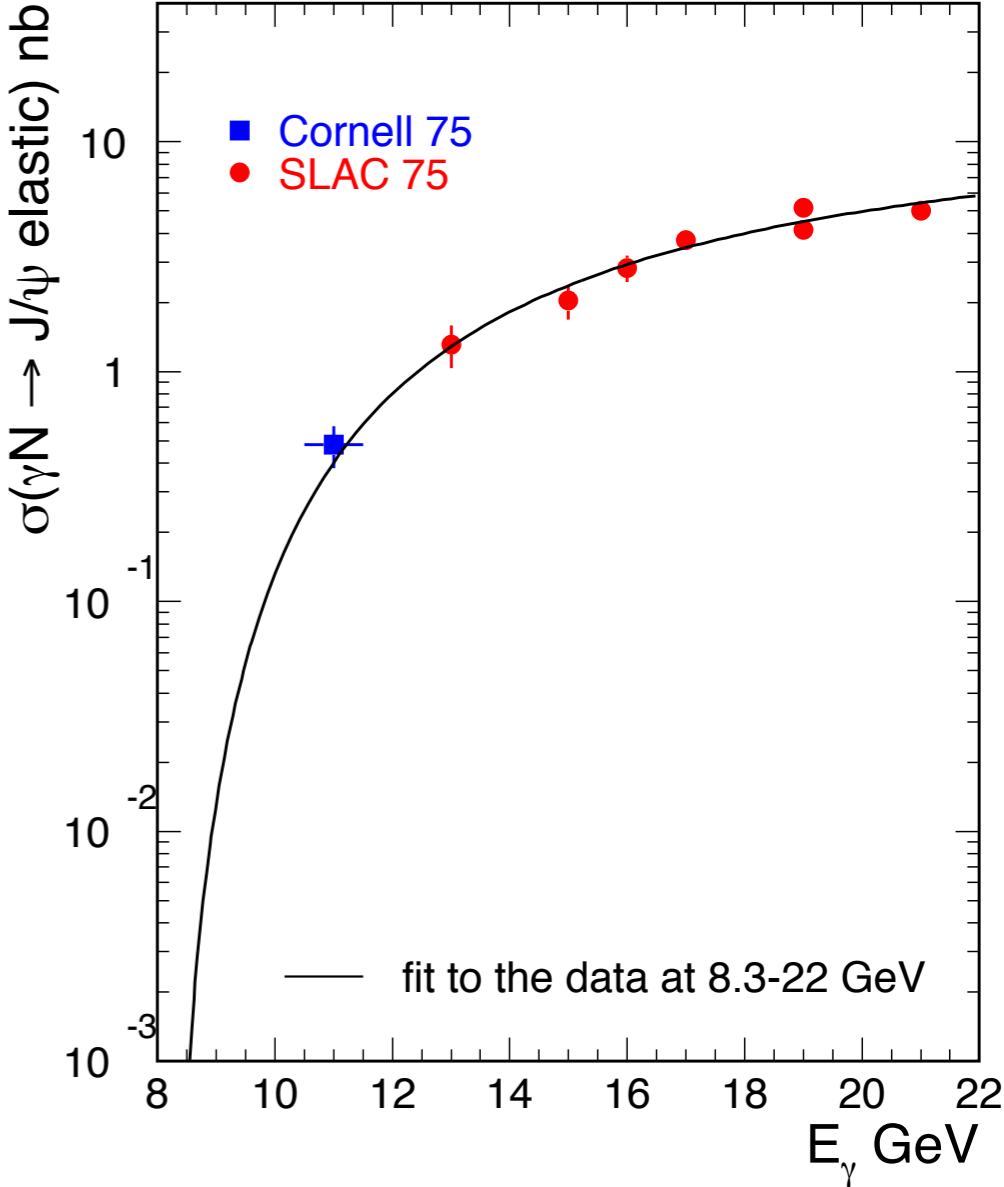
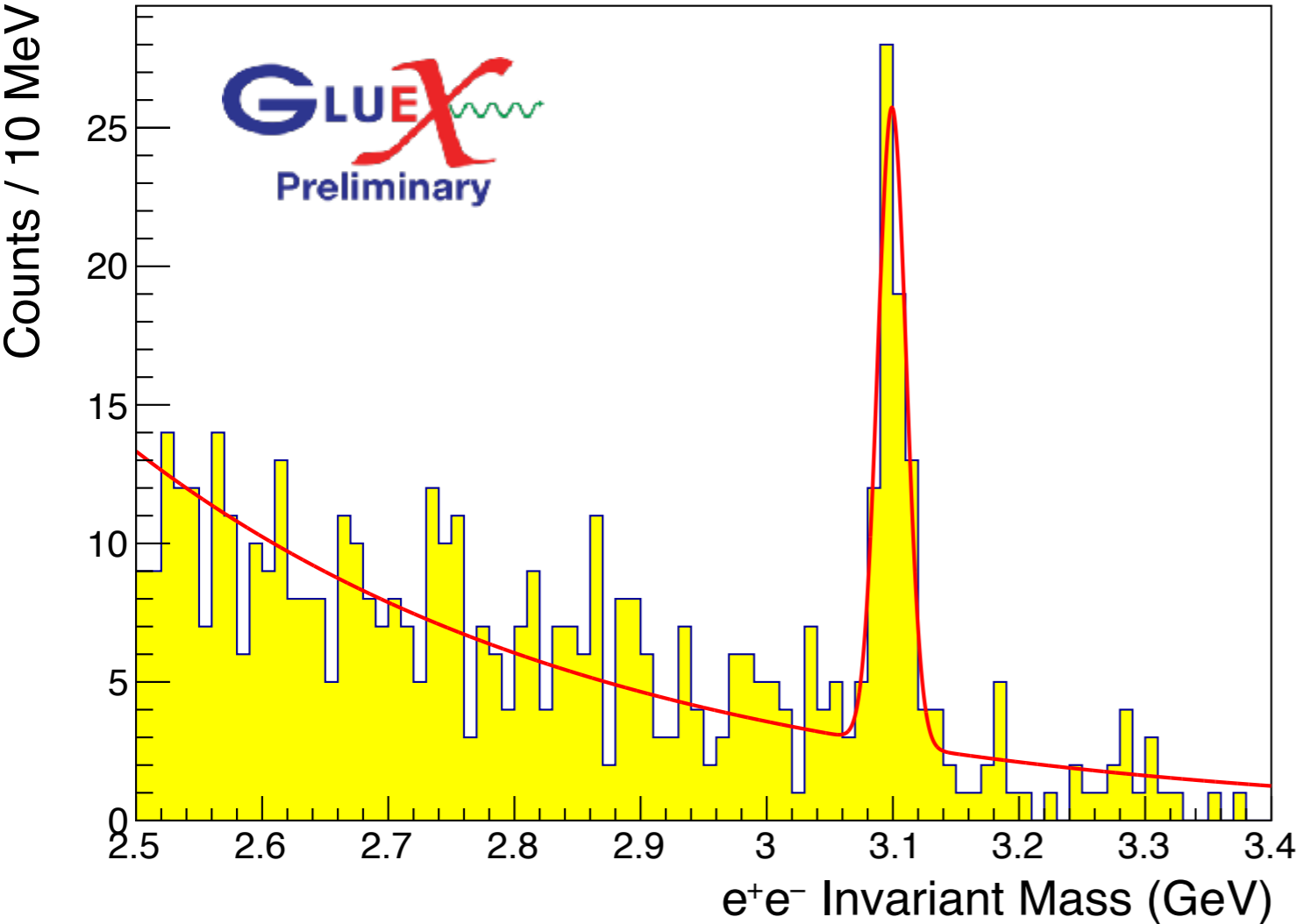
Central Drift Chamber (CDC)



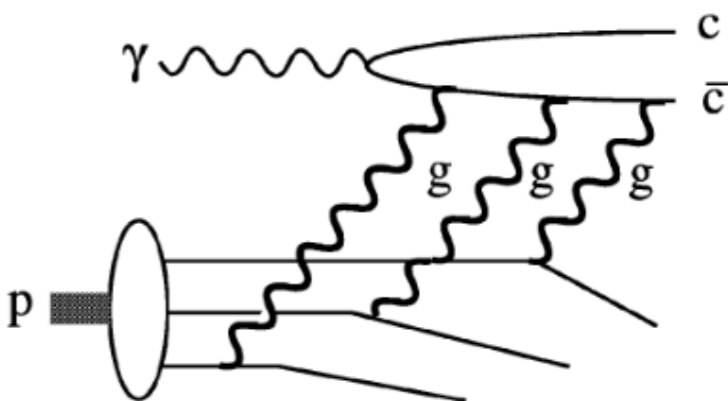
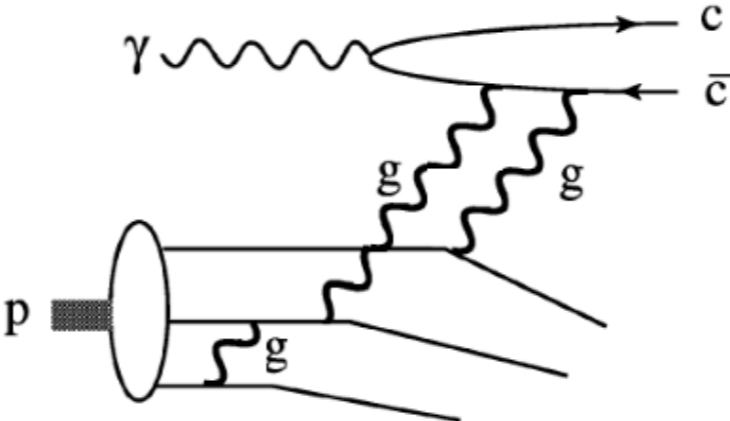
Forward Drift Chamber (FDC)



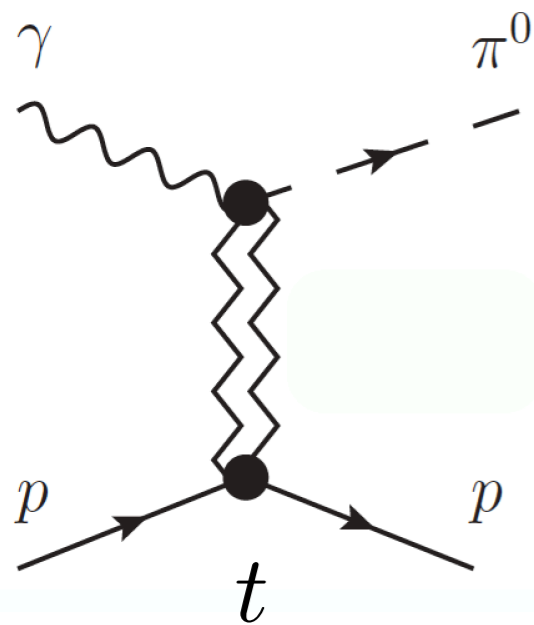
# Near threshold $J/\psi$ production



$N(J/\psi) = 66 \pm 9$   
 $M(J/\psi) = 3099.3 \pm 1.8 \text{ MeV}$   
 $\sigma = 11.2 \pm 1.6 \text{ MeV}$



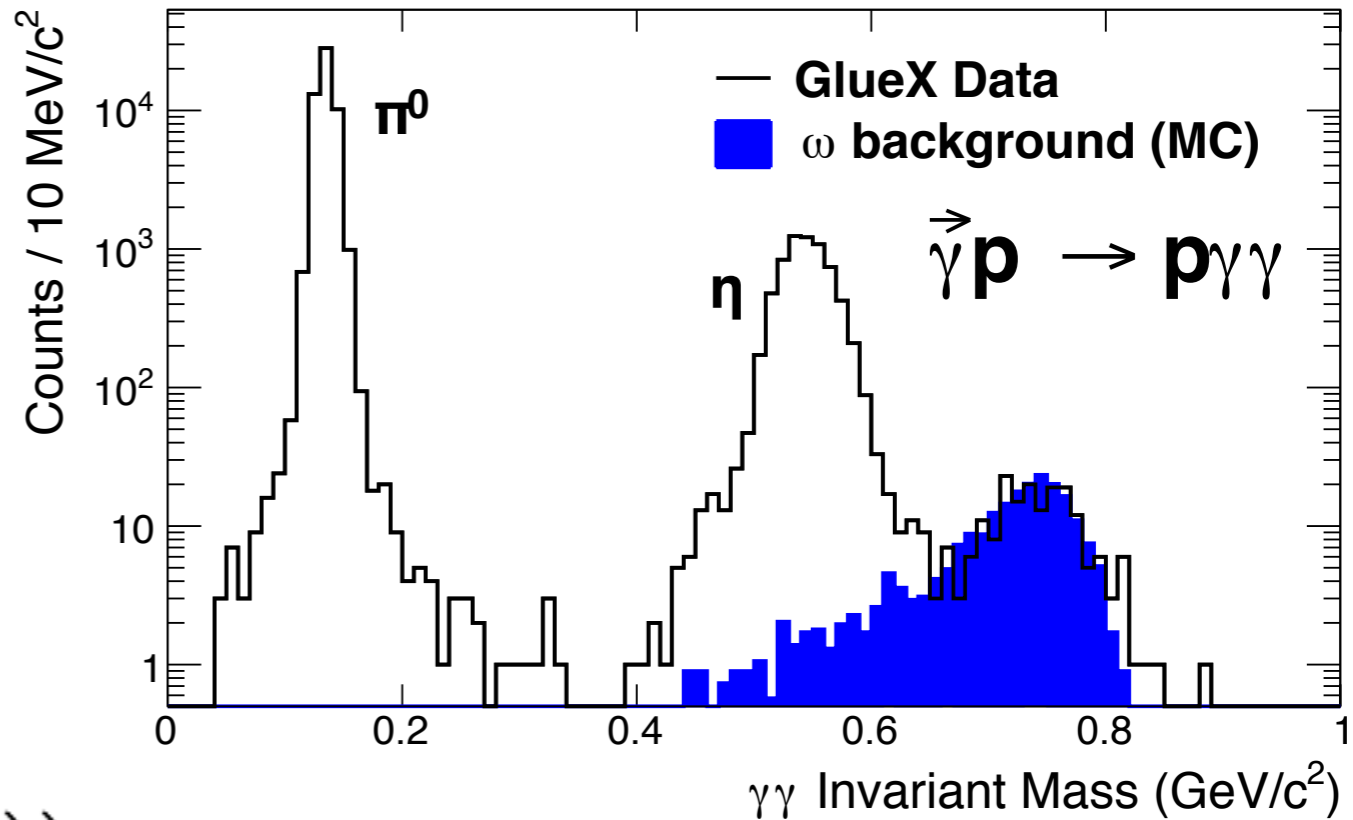
# $\Sigma$ asymmetry for exclusive $\pi^0$ and $\eta$



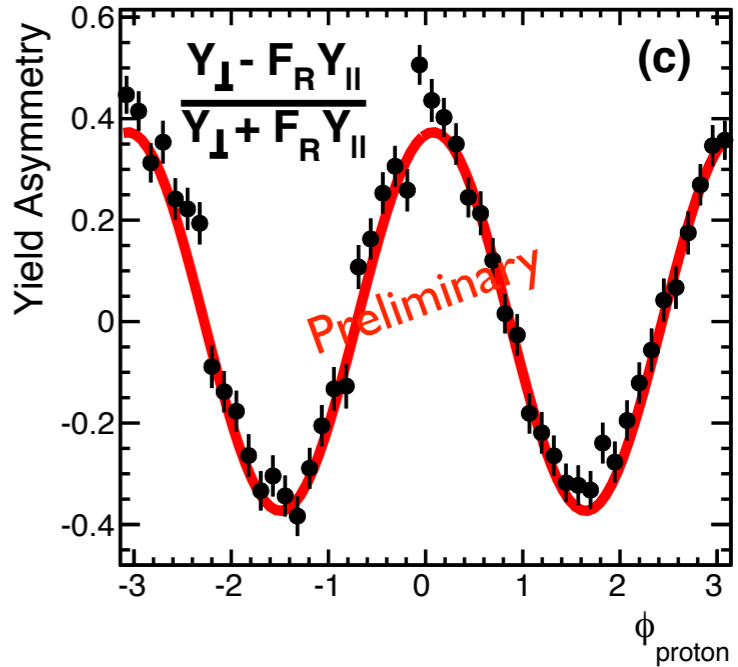
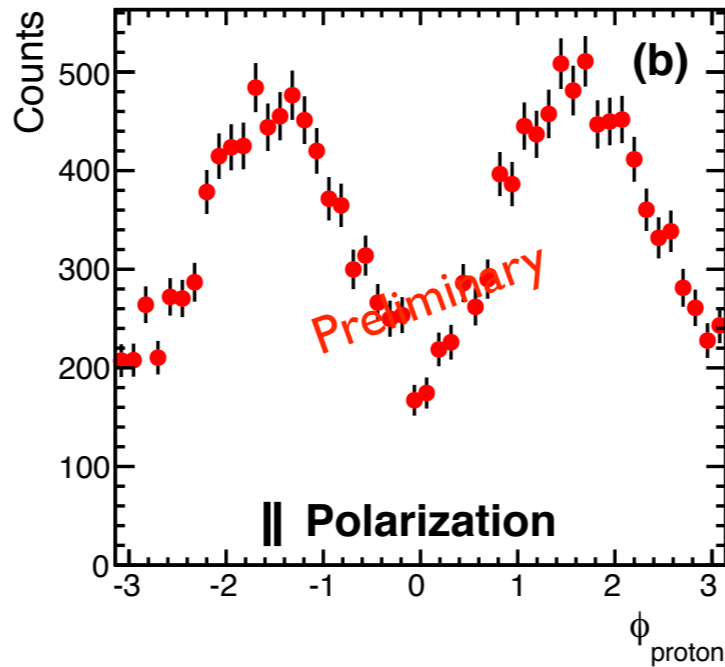
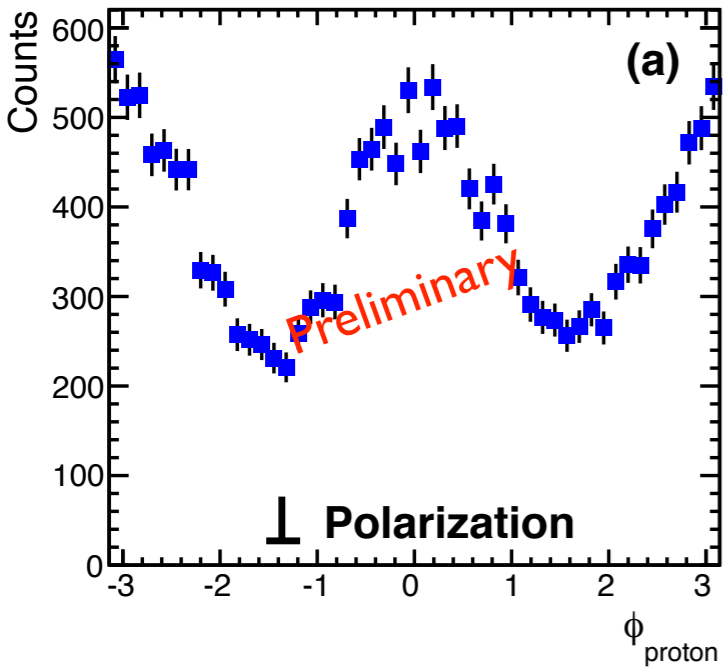
**Exchange  $J^{PC}$**

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

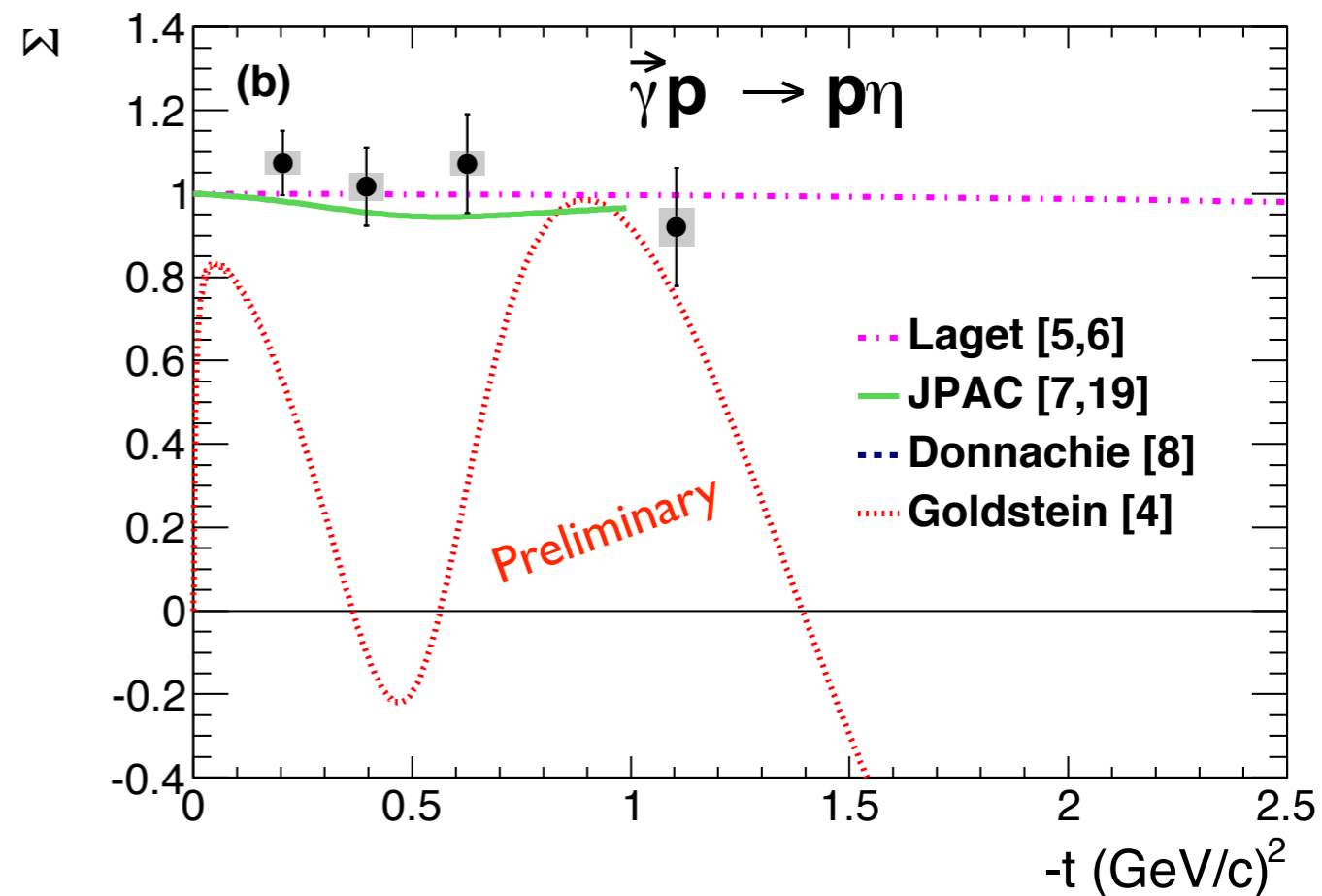
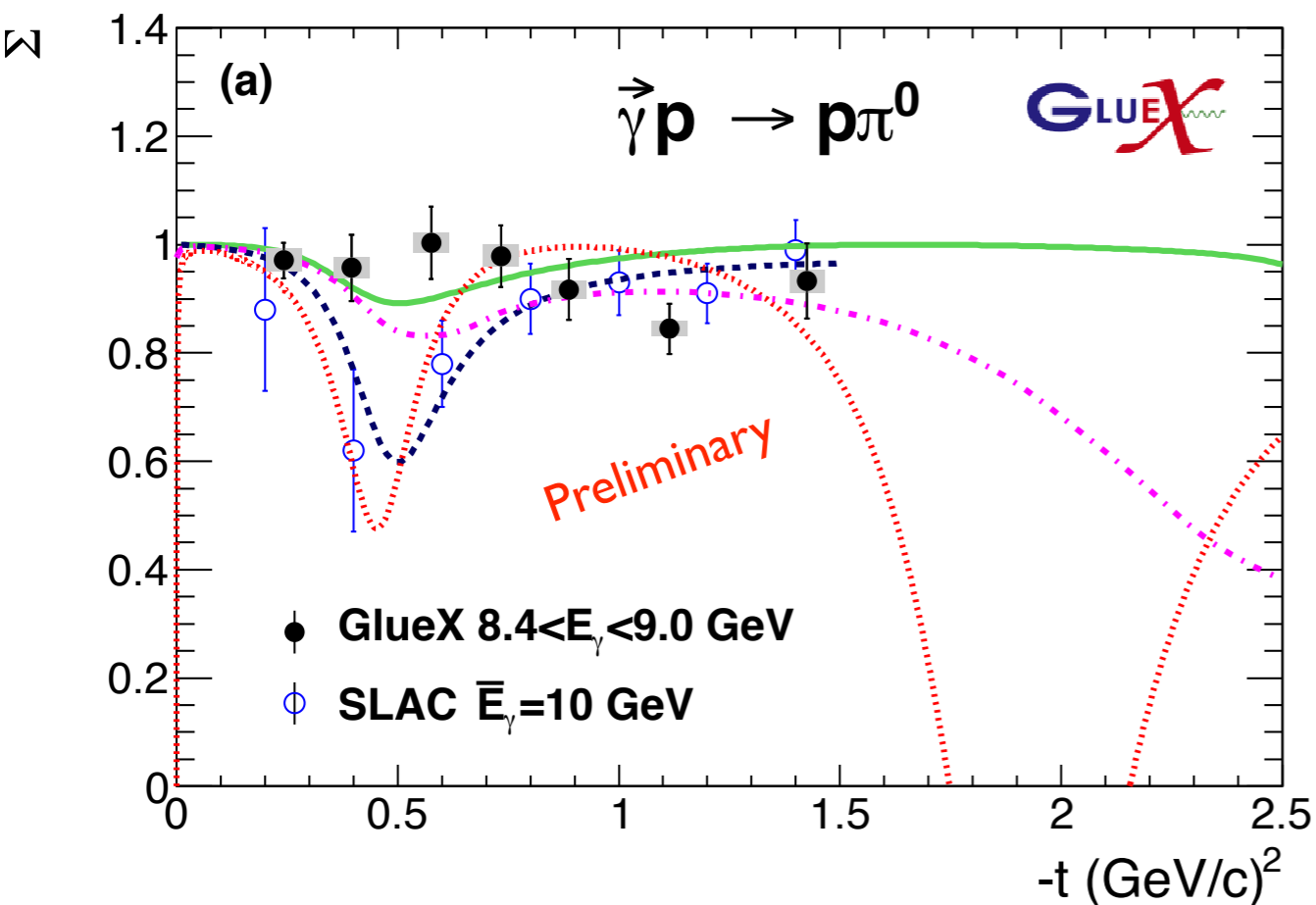
$1^{+-} : b, h$



$$\sigma = \sigma_0 (1 - P_\gamma \Sigma \cos 2(\phi_p - \phi_\gamma^{\text{lin}}))$$



# $\Sigma$ asymmetry for exclusive $\pi^0$ and $\eta$



- Consistent with previous measurements
- Consistent with unity, no  $t$  dependence
- Don't observe diffraction dip at  $-t \sim 0.5$  GeV (vector Reggeon dominance)
- First GlueX paper: under collaboration review



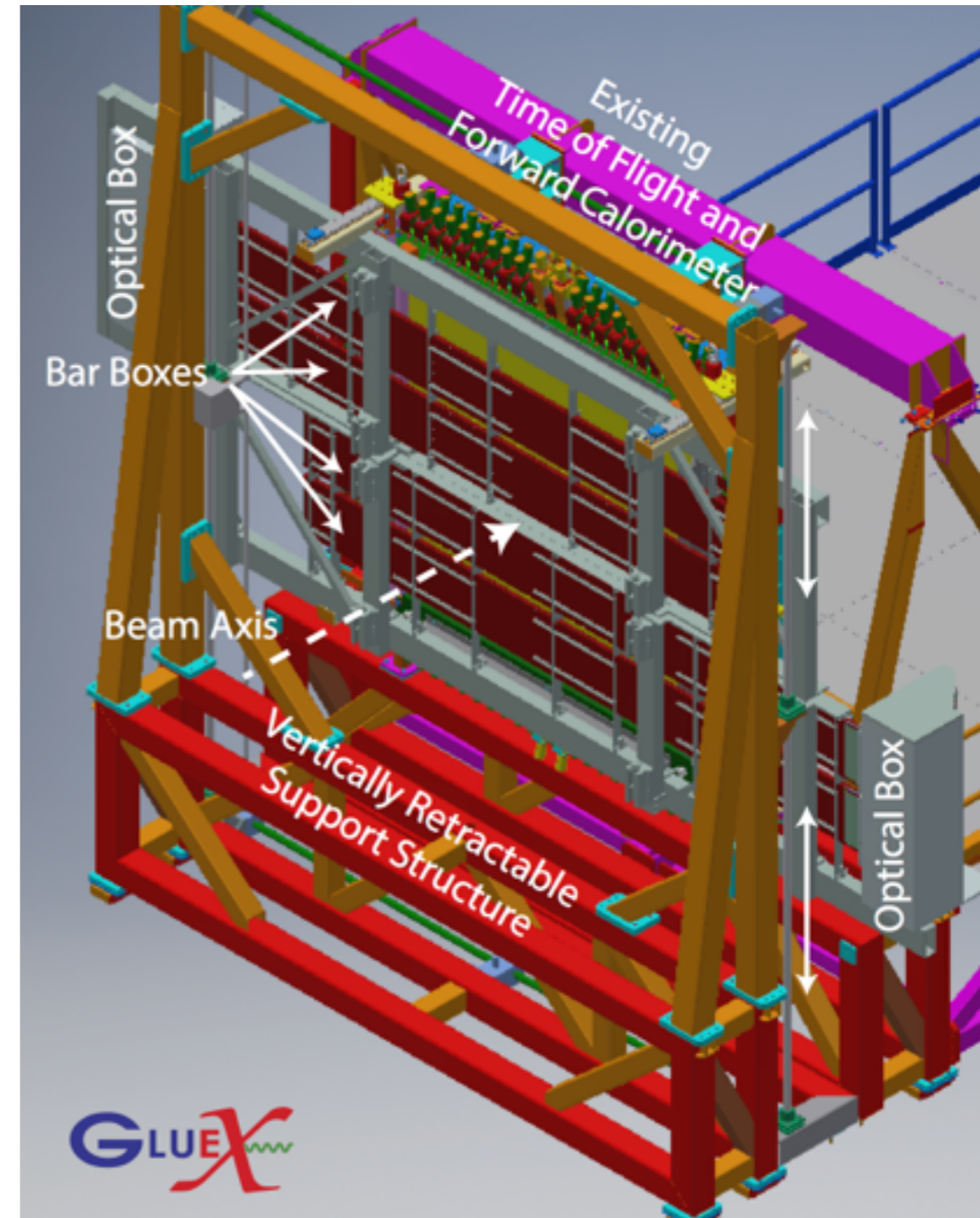
# Future Plans

Next 6-12 months:

- production run at  $10^7$   $\gamma$ /s in coherent peak
- 10x larger data sample than presented today

Next 2-4 years:

- enhanced particle identification
- ( $\pi$ /K separation)
- 100x more statistics
- Additional dedicated running:
- $\Gamma\gamma\gamma(\eta)$  via Primakoff
- charged pion polarizability



Future PID detector constructed from BaBar DIRC components

# Summary

GlueX positions to make timely contribution to hadron spectroscopy  
highly capable detector

Detector successfully commissioned

Spring 2016 run

significantly exceed previous photoproduction samples at this energy

coordinated analysis strategy

increase analysis complexity as understanding of detector improves  
end goal of searching for hybrid mesons.

first preliminary results are becoming available

expect to submit first paper for publication “soon”

# Backups

# Final -t distributions

SLAC: PRD 1, 27 (1970)

V. Mathieu (JPAC): PRD 92, 074013

