GlueX: Search for Gluonic Excitations at JLab

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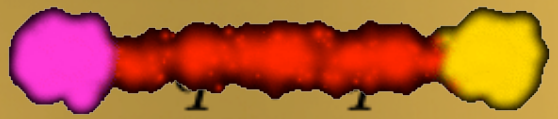
Motivation

Simple Meson Wave Function

Meson Wave Function



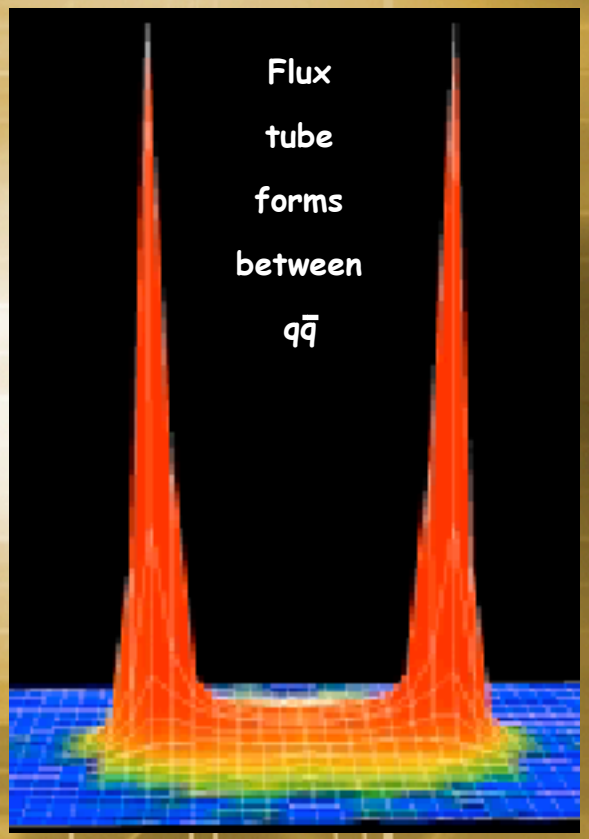
$$|\psi\rangle = |q\bar{q}\rangle + |q\bar{q}g\rangle + |gg\rangle + |q^2\bar{q}^2\rangle + \cdots$$

Confinement: Quarks cannot exist alone

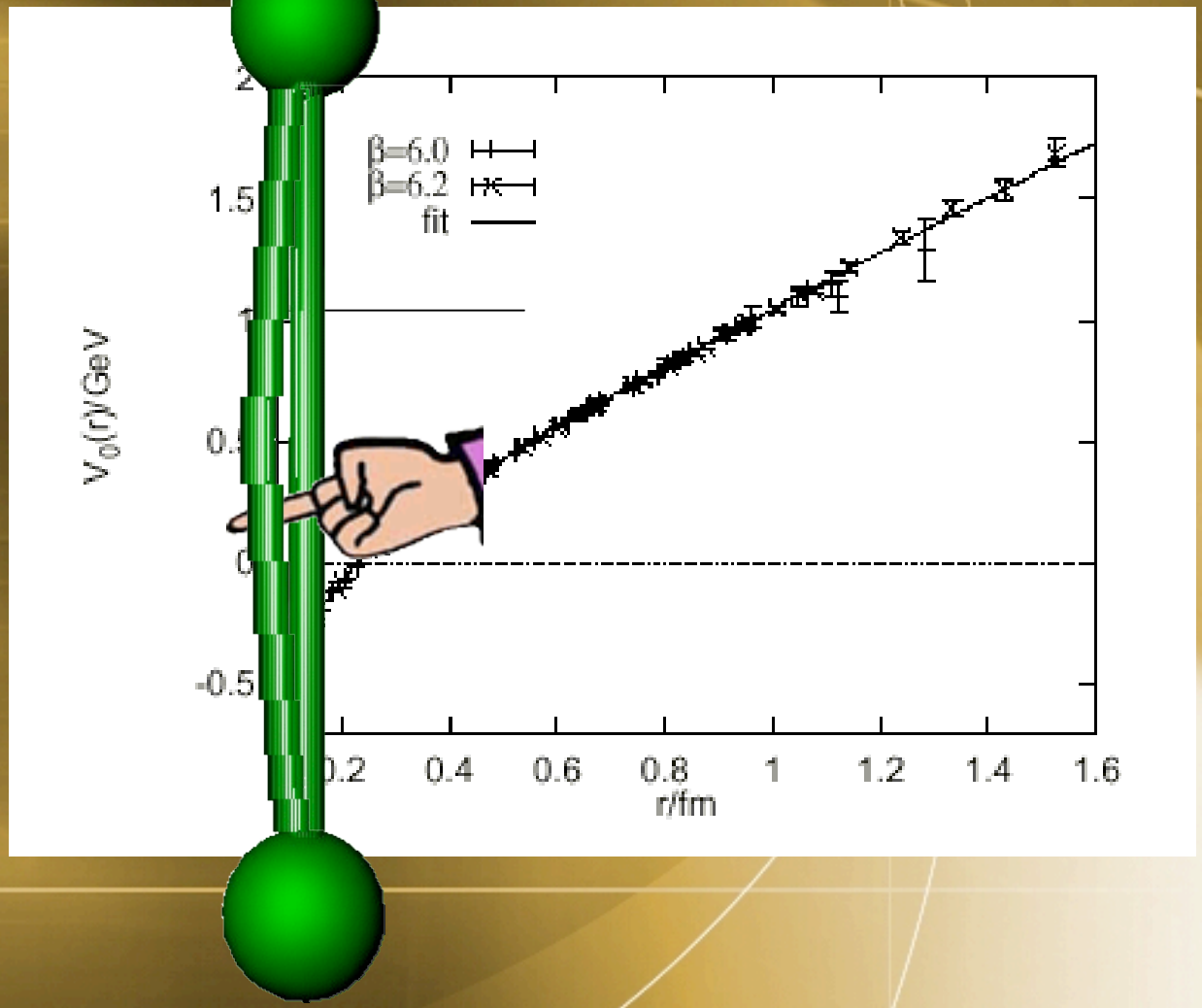
Hybrid Models

- **Bag Model**
- **Flux Tube Model**
- **Constituent Gluon Model**
- **QCD Sum Rules +**
  Lattice Gauge Theory (model indep.)

The Flux Tube Model



G. Bali



Hybrid Mesons

$q\bar{q}g$

~1GeV mass difference

$q\bar{q}$

Hybrid Mesons

$S = 0$
$L = 0$
$J^{PC} = 0^{-+}$

(π, K)

$L = 1$

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

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

Hybrid Meson
or ρ, ω, ϕ, … ?

Hybrid Mesons

S = 1
L = 0
$J^{PC} = 1^{--}$

(ρ, ω)

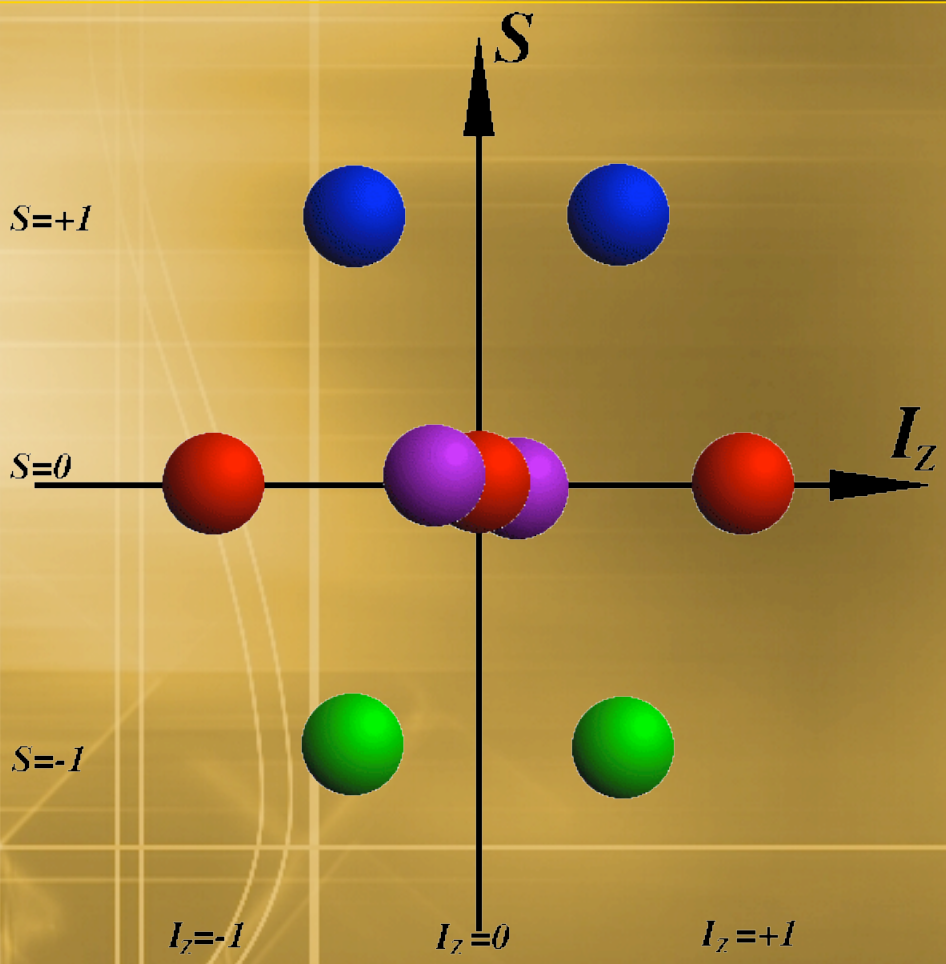
L = 1

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

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

Exotic!

Hybrids Should Appear as a Nonet



9 hybrid particles Should exist for each J^{PC} combination

1^{-+} Hybrid Mass spectrum

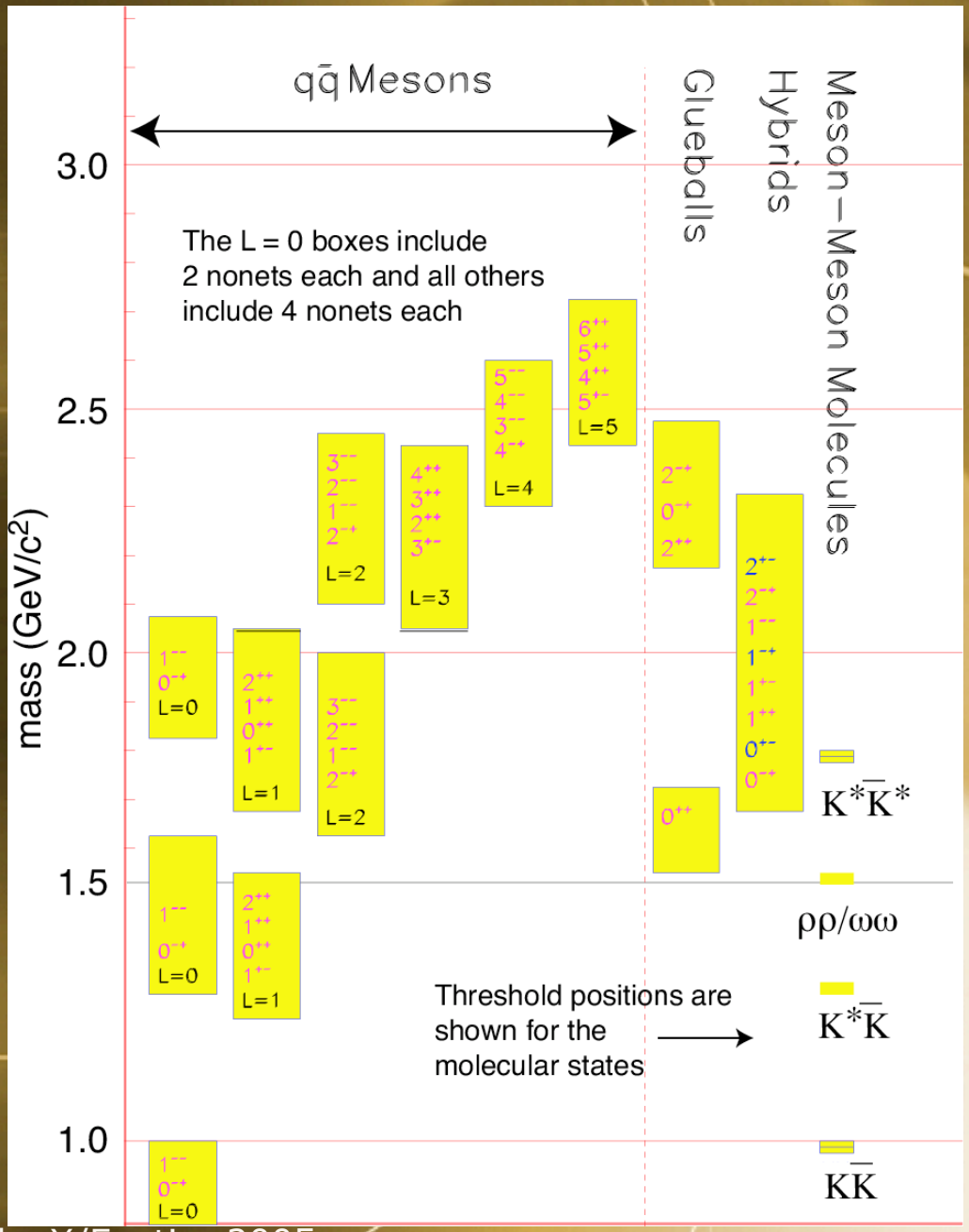
From LQCD calculations. All masses in GeV/c^2

Collaboration	$u\bar{u}/d\bar{d}$	$s\bar{s}$
UKQCD(97)	1.87 ± 0.2	2.0 ± 0.2
MILC(97)	1.97 ± 0.09 ± 0.30	2.170±0.080±0.30
MILC(99)	2.11 ± 0.10 ± (sys)	
SESAM(98)	1.9 ± 0.20	
Mei & Luo(03)	2.013 ± 0.026 ± 0.071	
Bernard et al.(04)	1.792 ± 0.139	2.100 ± 0.120

Light Meson Spectrum

Exotic quantum numbers imply deeper structure than simple $q\bar{q}$

(No mixing with those states!)



Why Are Hybrids Hard To See?

- Most searches involve looking at two body final states. Coupling of hybrids to two body final states is almost nonexistent
- "Large" masses (~2GeV/c^2)
- About 1/3 of the (exotic) states have broad widths

Hybrid Decays

Hybrids preferentially couple to states with Both an S-wave and P-wave meson

$X \rightarrow \pi\, b_1 \rightarrow \pi\, \omega\, \pi \rightarrow \pi\, \pi\, \pi\, \pi\, \pi$

$X \rightarrow \pi\, f_1 \rightarrow \pi\, \eta\, \pi\, \pi \rightarrow \pi\, \pi\, \pi\, \pi\, \pi\, \pi$

$X \rightarrow \eta\, a_2 \rightarrow \pi a_2 \rightarrow \pi K \overline{K}$

$X \rightarrow \pi\, a_1 \rightarrow \pi\, \rho\, \pi \rightarrow \pi\, \pi\, \pi\, \pi$

Hybrid Candidates(?)

$\pi_1(1400)$	1^{-+}	E852,Crys. Barrel,VES
$\pi_1(1600)$	1^{-+}	E852,Crys. Barrel,VES
$\pi_1(2000)$	1^{-+}	E852
$\pi_2(1880)$	2^{-+}	E852
$a_1(2096)$	1^{++}	E852

$\pi_1(1400)$ $J^{PC} = 1^{-+}$

$\pi_1(1400)$ [o]

$I^G(J^{PC}) = 1^-(1^{-+})$

Mass $m = 1376 \pm 17$ MeV
Full width $\Gamma = 300 \pm 40$ MeV

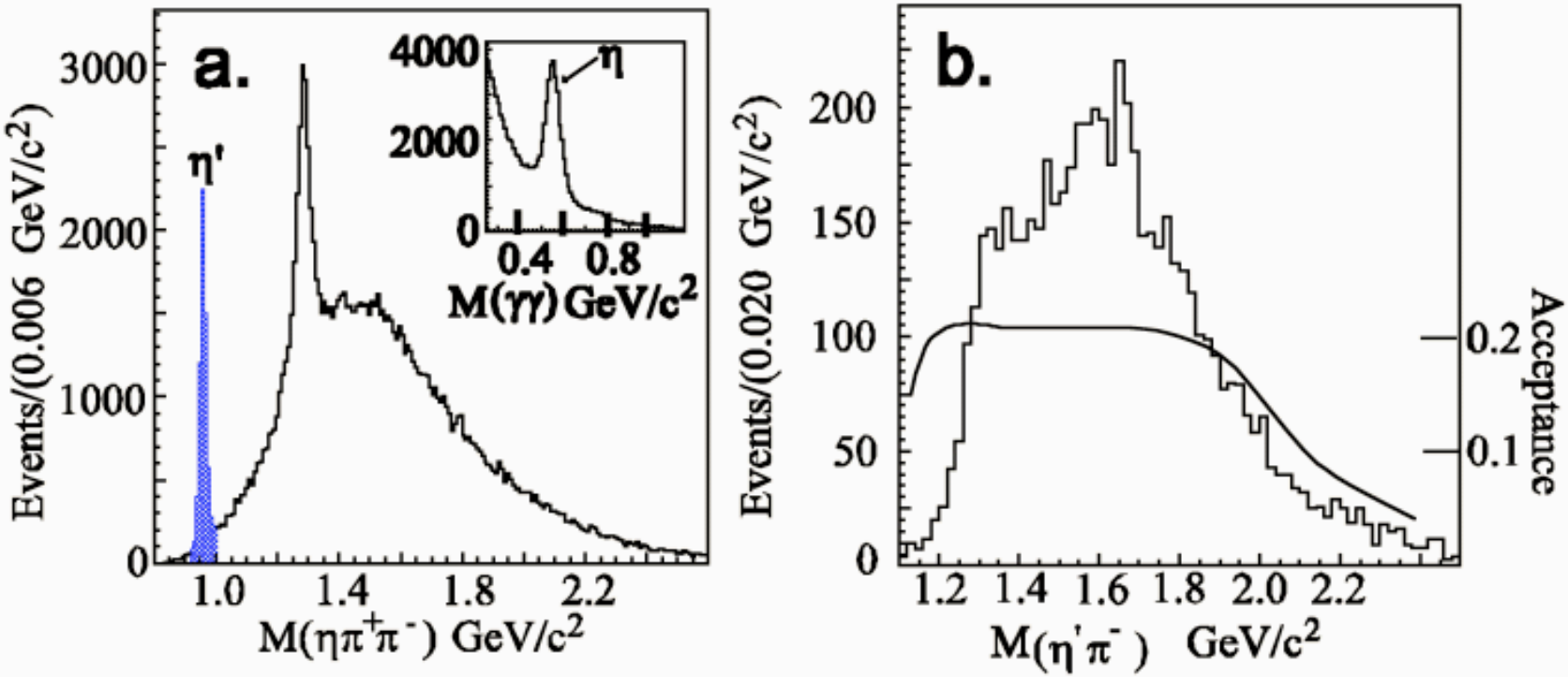
$\pi_1(1400)$ DECAY MODES	Fraction (Γ_i/Γ)
$\eta\pi^0$	seen
$\eta\pi^-$	seen

Decay modes not "hybrid-like"

(Looks like a meson-meson molecule!)

$\pi_1(1600)$ $J^{PC} = 1^{-+}$

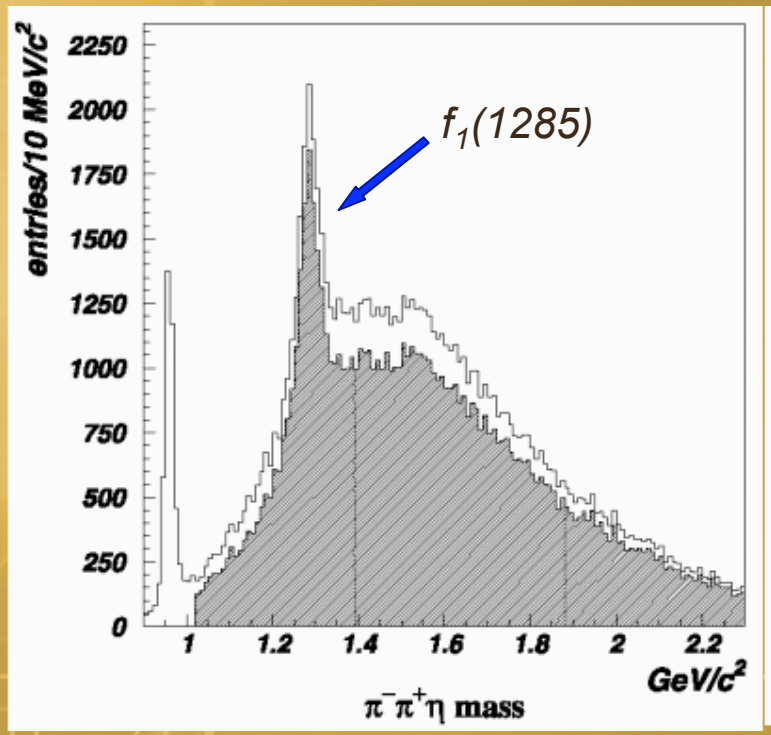
$\pi^- p \to p\pi^-\pi^-\pi^+\eta$ $\pi^- p \to p\pi^-\pi^-\pi^+\pi^o\pi^o$

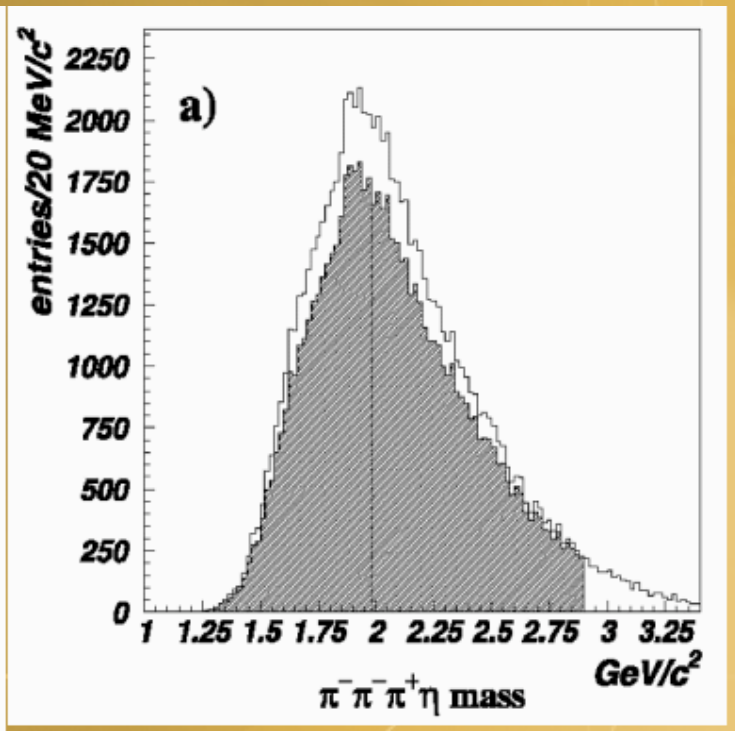


E852 PRL **86**, 3977 (2001)

$\pi_1(2000)$ $J^{PC} = 1^{-+}$

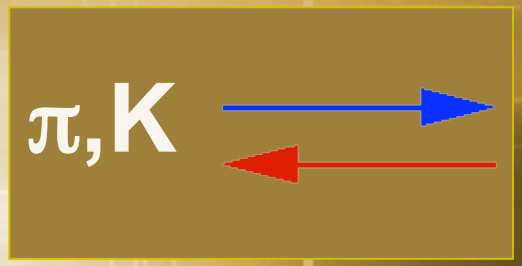
$$\pi_1(2000) \rightarrow b_1\pi \rightarrow \omega\pi\pi \rightarrow \pi^+\pi^-\pi^-\pi^o\pi^o$$
$$\pi_1(2000) \rightarrow f_1\pi \rightarrow \pi^+\pi^-\eta\pi^- \rightarrow \pi^+\pi^-\gamma\gamma\pi^-$$



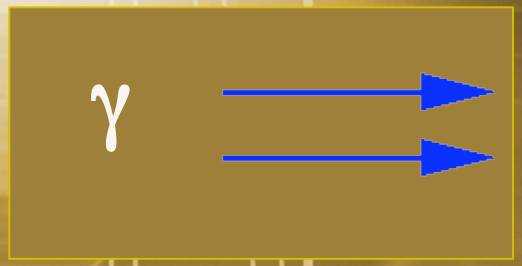


E852 hep-ex/0405044 v1 (2004) ; E852 Phys. Lett. B595(2004) 109-117

Hadroproduction vs. Photoproduction



Non-Exotic



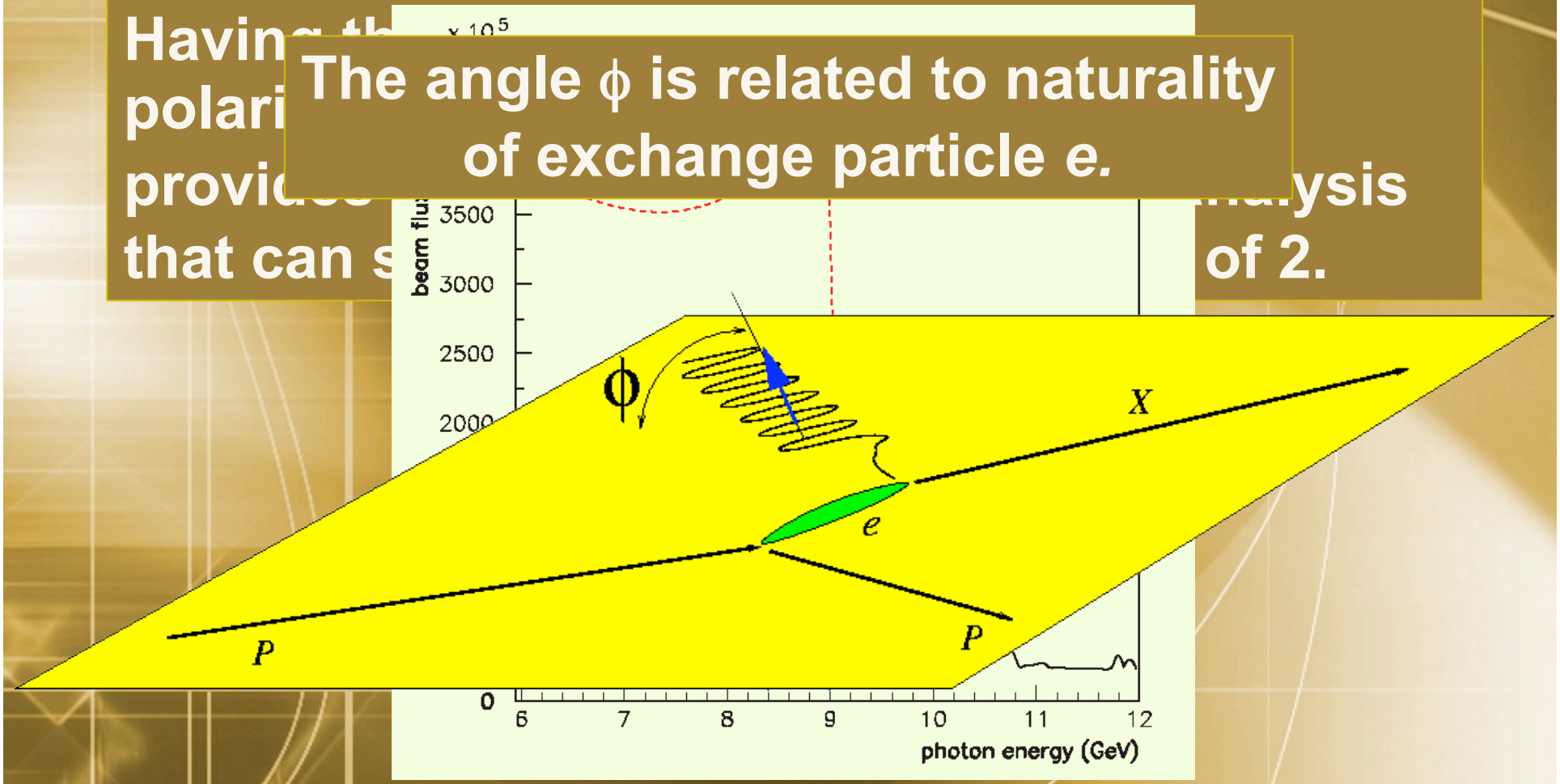
Exotic*

Linearly Polarized γs

(produced by coherent bremsstrahlung)

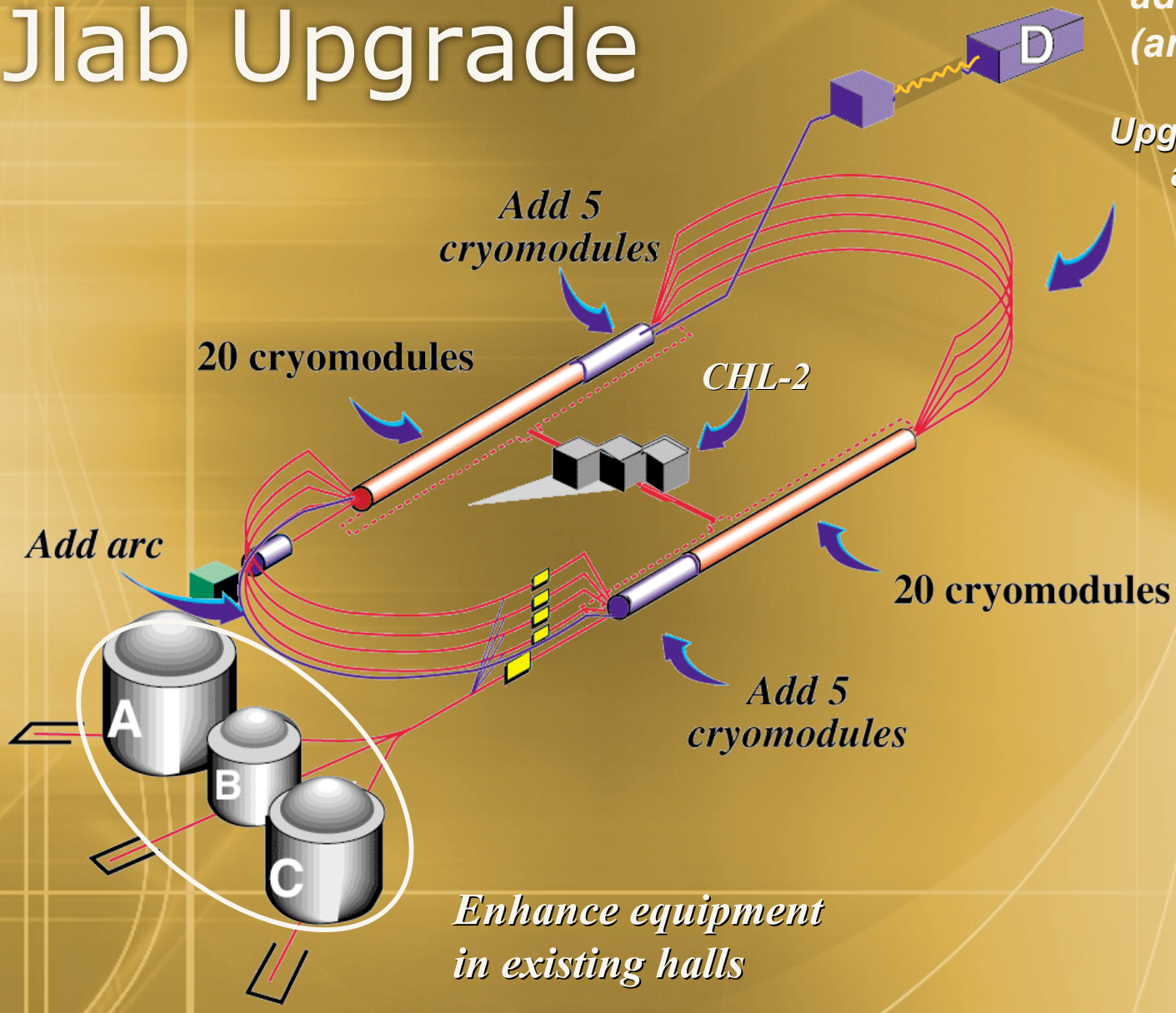
Having th… polari… provid… that can s… …ysis of 2.

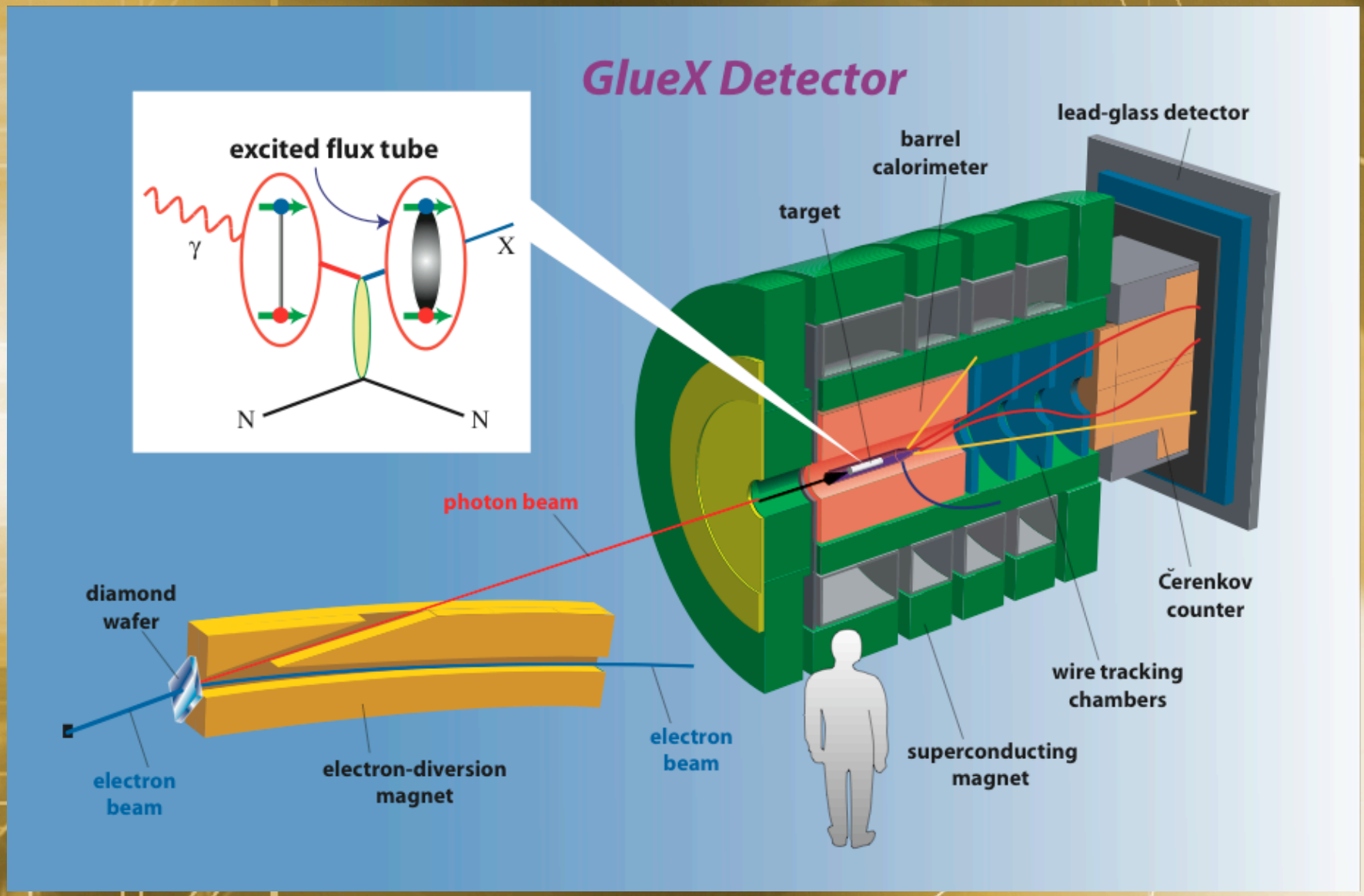
The angle ϕ is related to naturality of exchange particle *e*.



Location of Jefferson Lab

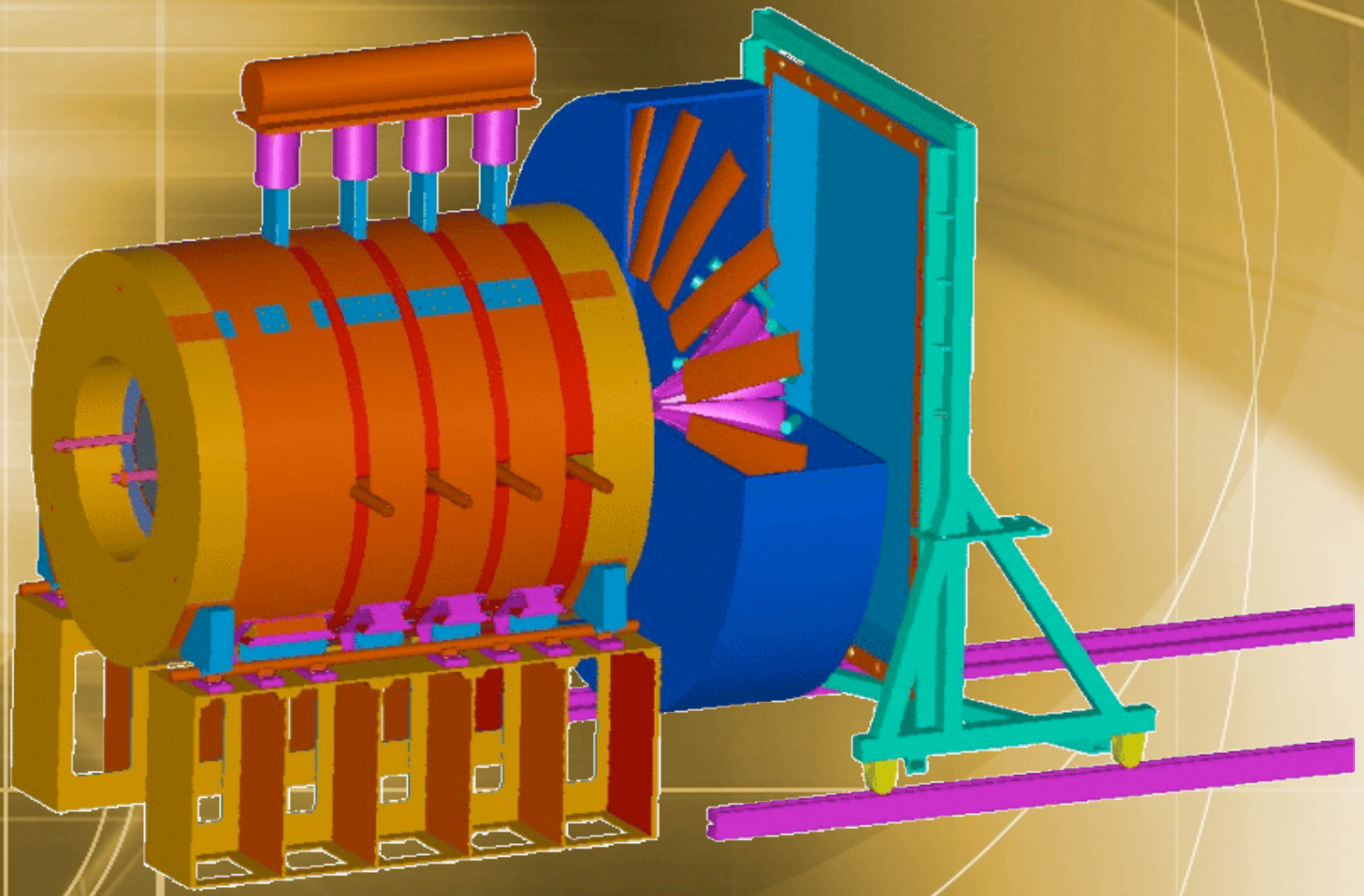
Jlab Upgrade




GlueX Detector
excited flux tube
γ
X
N
N
lead-glass detector
barrel calorimeter
target
photon beam
diamond wafer
Čerenkov counter
wire tracking chambers
electron beam
electron-diversion magnet
electron beam
superconducting magnet

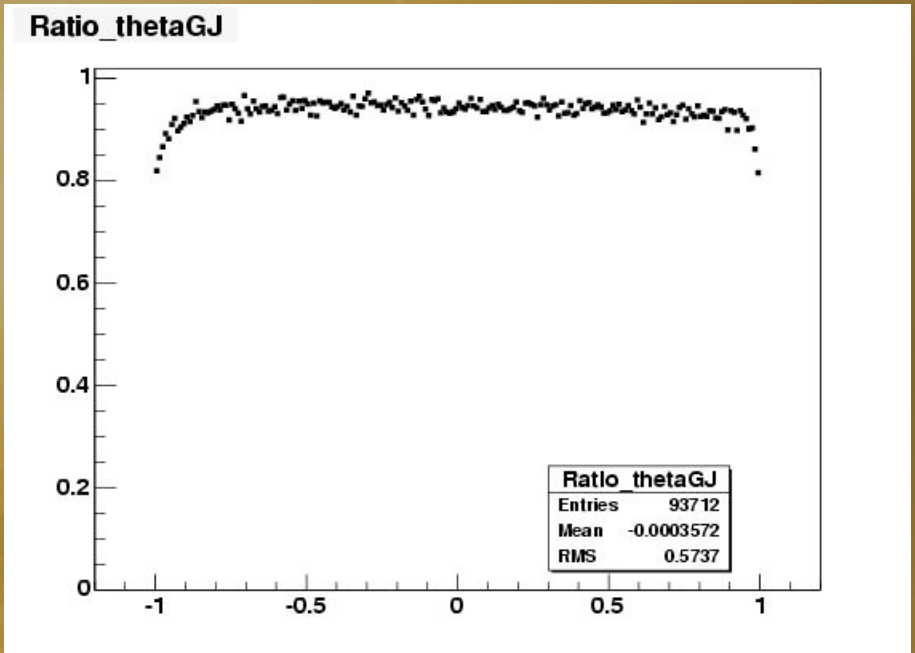
The GlueX Detector

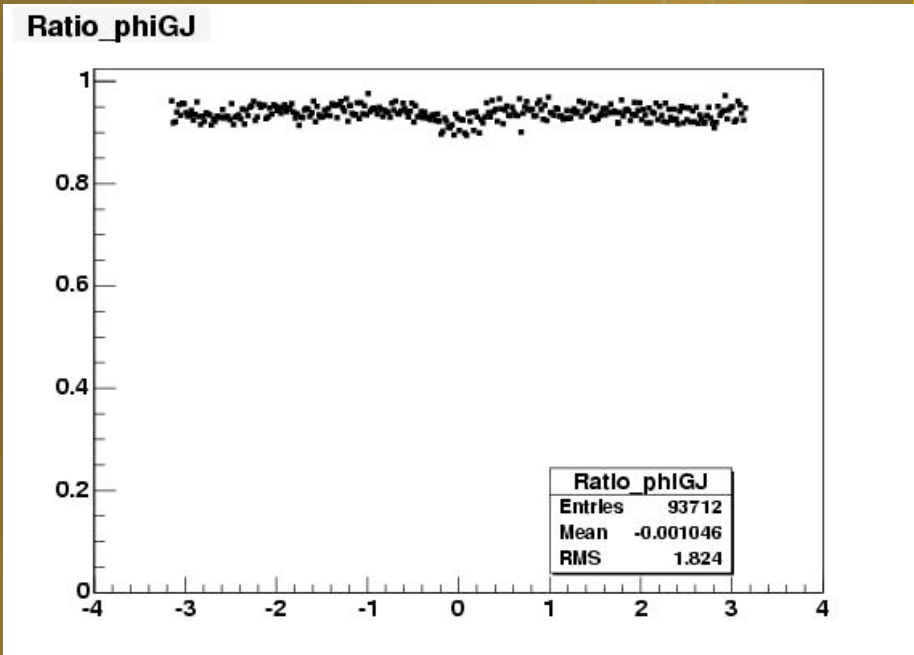
(all aboard!)



Acceptance of GlueX detector

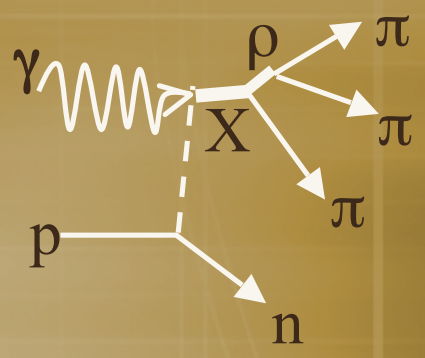
$\gamma\, p \rightarrow \eta_1\, p \rightarrow \pi^+\pi^-4\gamma\, p$





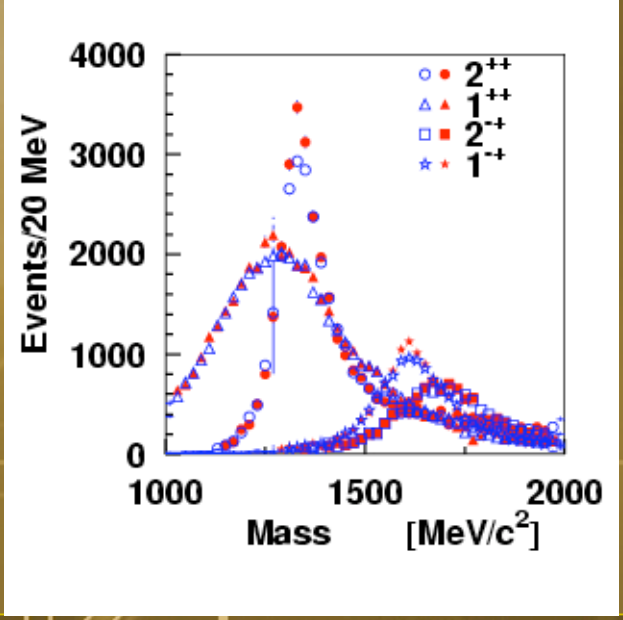
$\cos\theta_{GJ}$ ϕ_{GJ}

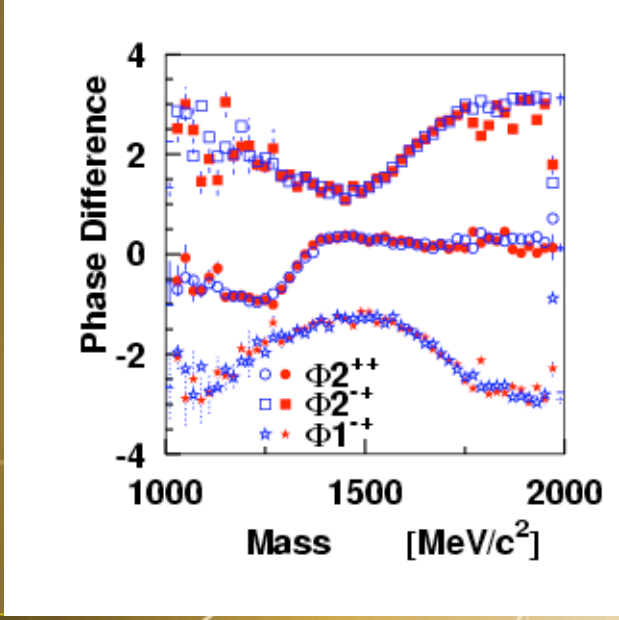
PWA Double Blind Monte Carlo Study of 3π Final states



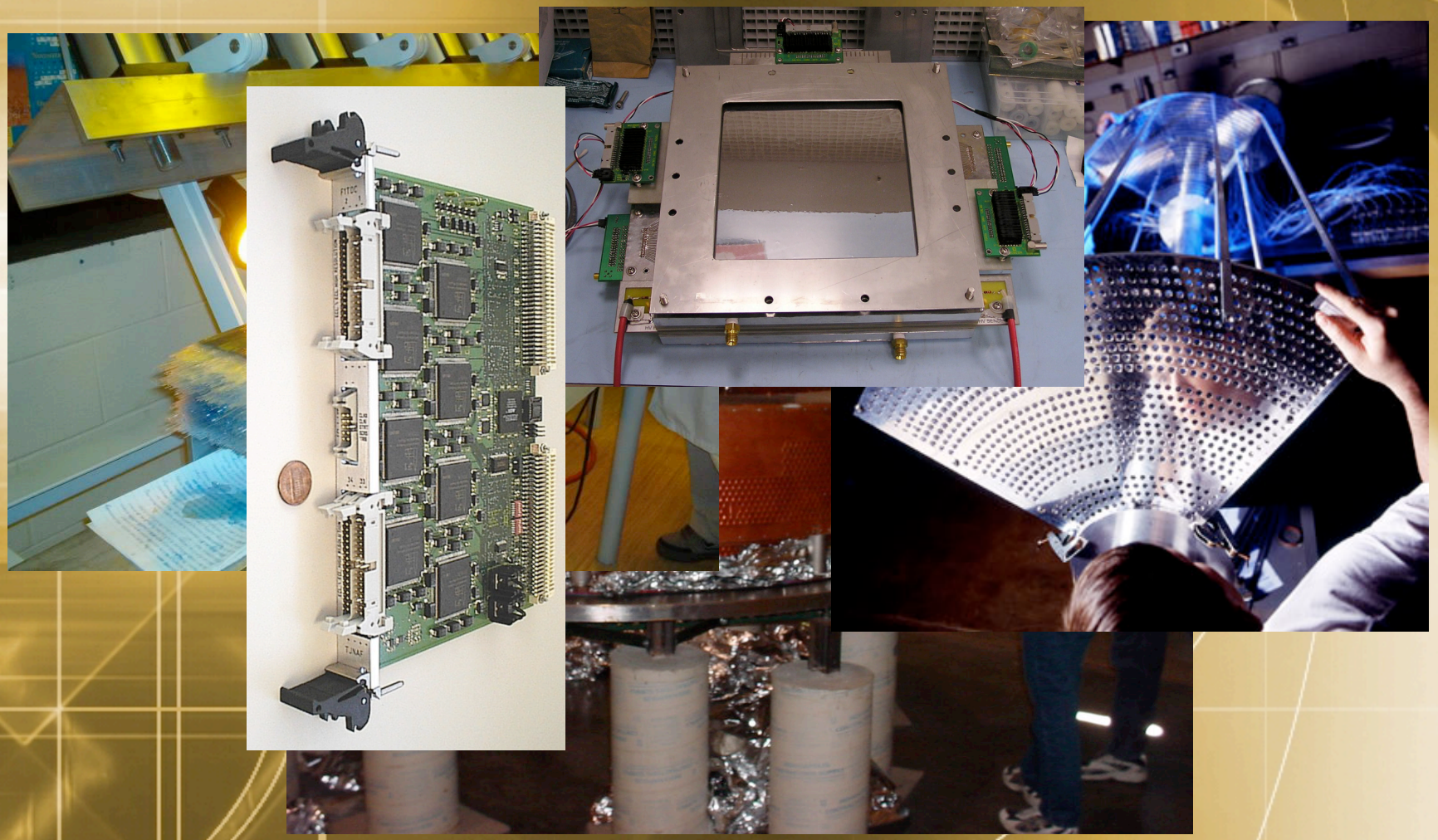
$$\gamma\, p \rightarrow \pi_1^{+} n \rightarrow \pi^{+}\pi^{+}\pi^{-} n$$
$$\rightarrow \pi^{+}\pi^{0}\pi^{0} n$$

Background waves included
$a_1(1260)$, $a_2(1320)$ and p_2 (1670)





Protoyping and Testing



Beam Flux and Event Rate

E_{el} ... eV

R		
Hadr Rate		)
Trigger Rate	20kHz	200kHz
Data rate	100 MB/s	1GB/s

In the first year, GlueX will exceed existing photoproduction data by a couple of orders of magnitude. It will also exceed existing hadroproduction data.

Status of Upgrade

April 2004	**CD-0 Signed**
July 2005	**Lehman review (CD-1)**
2011	**Start of GlueX data taking**

Summary

- **Understanding confinement means understanding the glue which binds quarks. Hybrid mesons are perhaps the most promising subject for studying the nature of the glue**

- **A rich spectrum of hybrid mesons is predicted. Models agree the masses of hybrid states should be around 2GeV, some with exotic J^{PC}.**

Summary

- **GlueX is being constructed to map out the *spectrum* of Exotic Hybrid Mesons with *unprecedented statistics*.**

- **GlueX will begin taking data in 2011**