Lattice QCD tells us that the gluonic field between quarks is confined in flux tubes and their excitations can result in mesons with exotic quantum numbers. GlueX will use linearly polarized photons to map out the spectrum of exotic mesons.

Flux tubes lead to confinement.
GlueX will be located in a new experimental Hall D and is the flagship physics for the JLab 12 GeV upgrade.

12 GeV electrons will be used to produce 9 GeV polarized photons.
Mass (GeV/c^2) Exotic Hybrid Masses (flux tube, LQCD) mass reach of GlueX extends from m_\pi to 2.8 GeV

- Linearly polarized photons of sufficient energy - 9 GeV
- Amplitude analysis to identify quantum numbers of produced states
  - adequate detector (acceptance & resolution)
  - statistics
  - analysis tools

The Amplitude Analysis of Very Large Data Sets is the Unique Challenge for GlueX
Example: Amplitude Analysis of the $3\pi$ System

The analysis is based on the **isobar model** that assumes an intermediate $2\pi\pi$ resonance.

$$I(m_{3\pi}, t, \tau) = \eta(\tau) \sum_\varepsilon \left| \sum_b a_b^\varepsilon(m_{3\pi}, t) A_b^\varepsilon(\tau) \right|^2$$

- **Observed intensity**
- **Spin variables:** $J, M, S$
- **Kinematic variables**: $\tau = \{\theta_{GJ}, \phi_{GJ}, \theta_H, \phi_H, m_{\pi\pi}\}$

**Acceptance**

**Production**

**Decay**

(a) **resonance:** $X$ decay

$X(2^+) \rightarrow f_2(1275)\pi$

(b) **isobar:** $R_{\pi\pi}$ decay

$f_2(1275) \rightarrow \pi\pi$
The Fitting Challenge

\[ I(m_{3\pi}, t, \tau) = \eta(\tau) \sum_\varepsilon \left| \sum_b a_b^\varepsilon(m_{3\pi}, t) A_b^\varepsilon(\tau) \right|^2 \]

the fit parameters

Do unbinned maximum likelihood fit for \( n \) events:

\[
L = \frac{e^{-\mu} \mu^n}{n!} \prod_{i=1}^{n} \int \eta(\tau_i) I(\tau_i) d\tau
\]

normalization determined using \( N \) Monte Carlo events

Minimize \(-\ln(L)\)

\[
-\ln L \propto -\sum_{i=1}^{n} \ln \left( \sum_{bb'} a_b a_{b'}^* A_b A_{b'}^* \right) + \sum_{bb'} a_b a_{b'}^* \left( \frac{1}{N} \sum_{i=1}^{N} A_b A_{b'}^* \right)
\]

for a given fit these are fixed: so compute & cache - a simplification arising from the isobar model assumption and its inherent factorization.
Doing the fits on Parallel Processors

exercise using CLEO data using 110 processor cluster using small (1K) event samp

$\chi_{c0} \rightarrow KK\pi\pi$ (13 Amplitudes, 1K Events)

- **Fit Time [min]**
  - 0
  - 5
  - 10
  - 15
  - 20
  - 25
  - 30
  - 35
  - 40

- **Number of Processors**
  - 0
  - 5
  - 10
  - 15
  - 20
  - 25
  - 30
  - 35
  - 40
  - 45
  - 50

- **25 fit parameters**
- **time minimum**
- **shifts with increase data set size and increasing amplitude complexity**
- **parallel overhead becoming important**

$1/N$
Example: Going Beyond the Isobar Model

This involved exploring physics that break factorization:

Isobar Model: Data from Brookhaven E852 have been analyzed using this model.

Other Mechanisms: The so-called ‘Deck Model’ is one of several that will be studied.
GlueX Data Rates

\[ \sigma_{\gamma p}^{total}(E_\gamma @ 9 \text{ GeV}) = 120 \ \mu\text{b} \]

\[ 10^7 \ \gamma/\text{s on } 30 \text{ cm } LH_2 \Rightarrow 15 \text{ kHz} \]

event size = 5 kB

This implies recording data at 100 MByte/s and collecting 1 PByte of data per year

\[ 10^8 \ \gamma/\text{s on } 30 \text{ cm } LH_2 \Rightarrow 150 \text{ kHz} \]

Level-3 trigger will reduce the recording rate to 15 kHz or 100 MByte/s
Prepare for GlueX Challenge - Use Existing Data

Collaborative Research:
Open Access Amplitude Analysis on a Grid

A. R. Dzierba, G. C. Fox, M. R. Shepherd and A. P. Szczepaniak
Indiana University, Bloomington, IN
C. A. Meyer
Carnegie Mellon University, Pittsburgh, PA
R. T. Jones
University of Connecticut, Storrs, CT
J. J. Dudek
Old Dominion University, Norfolk, VA
submitted - September 2006

Data from existing experiments
E852 at BNL and CLAS at JLab
will be used in developing the
Amplitude Analysis Toolkit

Sample sizes:
E852 - tens of GB (10 TB raw)
CLAS - factor 10 larger

Start using OSG in Summer 2007 for a
3-year period.

The proposal requests funding for
four postdoctoral fellows to work on:
(1) phenomenology; (2) GRID; and
(3) tools for fitting.

Grid Implementation

Our Grid strategy will build on Open Science Grid (OSG) software and hardware. JLab has committed to use and support this approach and Indiana University is an active existing partner. OSG provides core middle ware and leaves application specific software to the individual experiments.
Jefferson Lab Contribution: The Jefferson Lab Computing Center supports the lab’s physics requirements to store and analyze data for the scientific program, and fully intends to support the computing model in this proposal. Specifically we plan to establish an infrastructure for sharing compute and storage resources within the GlueX collaboration based on the OSG consortium’s Virtual Data Toolkit. Jefferson Lab will serve as the collaboration’s Virtual Organization Registration Authority for DoE Science Grid certificates, to provide authentication and authorization for access to these resources. The laboratory will work with the collaborating institutions in this proposal to support this computing model using OSG, as well as investigate enhancements to Jefferson Lab’s resources to interface OSG middle-ware with the Grid services of Jefferson Lab and GlueX.

OSG and GlueX: The amplitude analysis toolkit design was developed in consultation with the OSG management. We plan to make its distributed resources accessible as sites on the OSG infrastructure, depend on the OSG supported reference software stack, and plans to work with the OSG on the common and experiment specific services needed by amplitude analysis applications.
## Data Production for Hall-D and the 12 GeV upgrade

Based on a discussion between:
Roy Whitney, Graham Heyes, Andy Kowalski and Elton Smith

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### Notes:

- All data numbers are in PB except when otherwise stated.
- All CPU numbers assume 2008 hardware, i.e. already scaled from present and are a count of CPU's not boxes, quad-CPU boxes count as 4 not 1.
- In 2005 we have approx. 200 CPUs but the 2008 hardware scaling factor brings this down to 100.

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### Table:

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<th>Raw /yr</th>
<th>Prod /yr</th>
<th>Sim Raw</th>
<th>Sim Prod</th>
<th>work/Cache</th>
<th>Sim CPU</th>
<th>Raw Prod CPU</th>
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Prepared in 2005
Add two year delay
GlueX
Computing Environment

Main storage - at JLab