Overview of the GlueX Experiment and of the Beamline Development at UConn

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Quantum Numbers: Quark Pair

Mesons may be characterized by quantum numbers J^{PC}:

$$\vec{J} = \vec{L} + \vec{S}$$
$$P = (-1)^{l+1} \quad \Longleftarrow \hat{P} \mid l, m_l\rangle_{f\bar{f}} = (-1)^{L+1} \mid l, m_l\rangle_{f\bar{f}}$$
$$C = (-1)^{l+s} \quad \Longleftarrow \hat{C} \mid l, m_l\rangle_{f\bar{f}} = (-1)^{L+1}(-1)^{S+1} \mid l, m_l\rangle_{f\bar{f}}$$

$\vec{L}$	$\vec{S}$	J^{PC}		
0	0	0^{-+}	π, K, η, η'	pseudoscalar
0	1	1^{--}	ρ, K^*, ω, ϕ	vector
		0^{++}		scalar
1	1	1^{++}		axial vector
		2^{++}		tensor

Quantum Numbers: Flux Tube

For the gluon flux tube, given the inversion rules

$$\hat{C}|cw\rangle = -1|cw\rangle \qquad \hat{P}|cw\rangle = |ccw\rangle$$
$$\hat{C}|ccw\rangle = -1|ccw\rangle \qquad \hat{P}|ccw\rangle = |cw\rangle$$

the possible quantum numbers for lowest rotational state are:

state	P	C	J^{PC}
$\|cw\rangle + \|ccw\rangle$	$+$	$-$	1^{+-}
$\|cw\rangle - \|ccw\rangle$	$-$	$+$	1^{-+}

How to identify these?

Hybrid Meson Identification

Naive approach: collide a meson (e.g. π) and look for the excitations!

Looking at the Quantum Numbers:

$$0^{+-}_{q\bar{q}} \times [1^{+-}, 1^{-+}]_g \longrightarrow [1^{++}, 1^{--}]_{q\bar{q}g}$$

- not exotic quantum numbers: these states will mix with those without excited glue!

But, starting from $s = 1$ state:

$$1^{--}_{q\bar{q}} \times 1^{+-}_g \longrightarrow [\mathbf{0}, 1, \mathbf{2}]^{+-}_{q\bar{q}g} \quad \Longleftarrow \text{exotic states! (in bold)}$$
$$1^{--}_{q\bar{q}} \times 1^{-+}_g \longrightarrow [0, \mathbf{1}, 2]^{-+}_{q\bar{q}g}$$

Experimental Approach

The most obvious spin-1 particle? Photon

- Rely on pair production to create $s = 1$ mesons.
- Optimize mean polarization helps analysis to prepare a definite state of parity
- Optimize beam energy: calculations and possible sightings of excited states suggest that they lie around 1.5 - 2.5 GeV Cross-section of these decays scales steeply with energy (8 GeV minimum!)
- As usual, optimize the usable event rate

Polarized Photon Production

The optimal method for producing a polarized, high energy, high rate photon beam is through *Coherent Bremsstrahlung* (CB) - bremsstrahlung in an ordered crystal.

Qualitative Concept of CB:

1. inverse lattice space $\Longleftrightarrow$ momentum space of the virtual photons constituting the Coulomb field
2. occupation levels of this momentum space are discrete
3. photons of common occupation scatter coherently with electrons
4. occupation levels "selected" by kinematics defined in part by crystal orientation

CB Spectrum

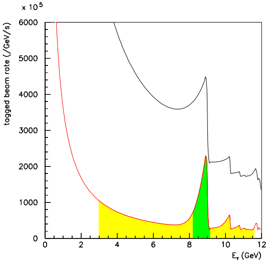

Figure: Spectrum calculated with expected parameters of the future beamline. Note the enhancement due to coherent scattering superimposed over conventional bremsstrahlung background. (Region of interest to GlueX shaded in green.)

Crystal Wafer Studies

We must learn how to characterize radiators that will serve in the beamline. Best fabrication method will be singled out in the process.

- *Interesting problem under investigation:* How to reconstruct the surface that generated an interference pattern. Difficult problem to invert: information is essentially lost when *intensity* is measured.
- X-ray crystalography studies conducted as an alternate method of probing the surface and to varify crystal domain uniformity over the area of the wafer.

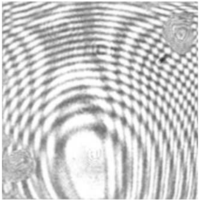

Figure: Michelson interferogram of a diamond wafer

Photon Energy Determination

Unlike charged particle beams with precisely tuned energy, the energy of the photon is broadly distributed. **How do we know the energy of the photon generating an event in the detector?**

Answer: Post-bremsstrahlung electrons are spectrally analyzed in a magnetic spectrometer. (Original beam energy very well known.) The photons are thus "tagged".

Challenges in Tagger design:

- usual care and expense of high-field dipole magnet
- high rates in the tagger channels
- demanding time resolution
- low noise and cross-talk between channels

Choice of Energy Range

Design choice compromises:

	Energy	
Performance Parameter	$\sim$ 6 GeV	$\sim$ 12 GeV
Cross-section of exotics	low	high
Polarization fraction	high	low
Event rate	high	low

Range chosen by GlueX: around the pronounced peak 8.4 - 9 GeV.

State of the CEBAF Accelerator

Currently, bunches up to 6 GeV are served to Halls A, B and C. The upgrade doubles the maximum energy and allows delivery to the new Hall D.

Hall D is designed entirely around the photon as a probe. An extended beamline is under design to provide beam of desired parameters.

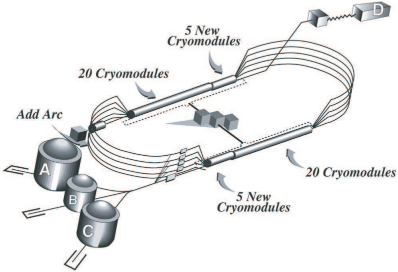

Figure: 12 GeV upgrade plan.

General Photon Beamline Scheme

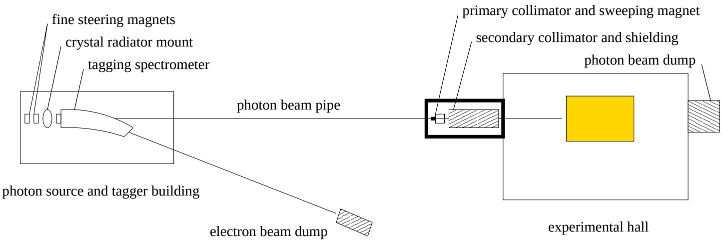

Figure: Basic outline of the photon beam line.

Additional tasks for the beamline:

- background cleanup
- polarimetry and energy calibration
- beam position feedback via “active collimator”

Collaboration List

Institution	Collaborators
University of Athens	Y. Chatziantonaki, D. Fassouliotis P. Ioannou, S. Katsaganis, C. Kourkoumeli, G. Voulgaris
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