A (quasi-real) photon tagging facility for CLAS12

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CLAS at Jefferson Lab.

- CEBAF Large Acceptance Spectrometer
- Part of Jefferson Lab, 6GeV e- beamline

**Torus Magnet**
6 Superconducting Coils

**Target** + γ start counter

**Drift Chamber**
35,000 cells

**Time of Flight**
Plastic Scintillator,

**Electromagnetic Calorimeter**
lead/plastic scintillator, 1296 PMTs

**Cherenkov Counter**
e/π separation, 256 PMTs

- Excellent charged particle ID and reconstruction
- Used for reactions with up to 6 GeV e- beam
- Or secondary bremsstrahlung photon beams...
Real Photon Tagger

- Real photons produced via bremsstrahlung in radiator
- Momentum of degraded $e^-$ analysed in dipole spectrometer
- Characteristic $1/E_\gamma$ distribution
- Tagged range: $0.2 < E_\gamma < 0.95$
- Linear polarised photons using coherent brem. on diamond radiator
- High polarisation, up to 90%, at low $E_\gamma$
- Maximum $W = 3.4$ GeV
- Intensity of $10^7 \gamma$ s$^{-1}$ integrated over full energy range

Within 3 years – JLAB upgrade to 11 GeV
But cannot use present tagger with 11 GeV $e^-$ beam!!
CLAS12

- Large angle acceptance for charged and neutral particles
- Excellent momentum resolution for charged particles

**Forward Detector**
- TORUS Magnet
- Forward silicon vertex tracker
- HThresh Cerenkov Counter
- LThresh Cerenkov Counter
- Forward TOF System
- Preshower calorimeter
- E.M. Calorimeter

**Central Detector**
- SOLENOID magnet
- Barrel silicon tracker
- Central TOF

**Proposed updates**
- Micromegas (CD)
- Neutron detector (CD)
- **Forward Tagger**  ➔  Enable e- detection below 5°
Photoproduction with CLAS12

- CLAS12 has evolved to study internal nucleon dynamics through GPDs, using high intensity 11 GeV $e^-$ beam
- Detector also meets requirements of measuring photoproduction reactions with multiparticle final states
  - Many interesting physics possibilities:
    - **Meson spectroscopy on H searching for exotic states**
    - **Spectroscopy on He4 and other nuclear targets**
    - **Heavy mass baryon resonances (Cascades and $\Omega$)**
    - **Baryon spectroscopy (hyperon production)**
    - **Glueball search in $k^0k^0$ channel**
    - **Baryon/meson radiative decays**
    - **J/Psi photoproduction near threshold (on H and nuclei)**
Quasi-Real Photon Tagging

(...will enable these interesting physics measurements)

- Small angle $e^{-}$ scattering
  
  $\Rightarrow Q^2 < 0.1 \text{(GeV/c)}^2$ virtual photon $\Leftrightarrow$ (almost)real photon
  
  -high virtual photon flux $\Rightarrow$ high production rates

- Tagged by measuring forward angle $e^{-}$ ($< 5^\circ$)

- $0.5 < E_{e'} < 4 \text{ GeV} \Leftrightarrow 7 < E_y < 10.5 \text{ GeV}$ with 11 GeV beam

- Quasi-real photons are linearly polarised wrt scattering plane
  
  - Simplifies PWA

- High $e^{-}$ luminosity $10^{35} \text{ cm}^{-2}\text{s}^{-1}$ or $10^{7} \gamma\text{s}^{-1}$

- Only $e^{-}$ contributing to hadronic interactions are detected in coincidence

  with CLAS12

Cross section for inclusive hadronic reactions

Hadronic rate $2-5^\circ = 8.6\text{kHz}$

$5-20^\circ = 3.8\text{kHz}$
The Tagger
-Still under development!!

- **calorimeter** to determine the electron energy with few % accuracy

- **tracker** to determine precisely the electron scattering plane and the photon polarization
  - GEM or micromegas

- **veto** to distinguish photons from electrons
  - plastic scintillator tiles
The Calorimeter

- Requirements:
  - Operate in high em background
    - Moeller (10MHz), Elastic Radiative (0.1MHz)
    - Small Moliére radius
    - Radiation hardness
  - Fast timing
    - Avoid pile-up
    - Coincidence with CLAS12
  - Energy resolution
    - ID final states with missing mass
  - Light read-out in magnetic field
    - APD readout

PbWO4

- $\tau_{\text{Decay}} \sim 6.5 \text{ ns}$
- $R_M \sim 2.1 \text{ cm}$
- $\rho \sim 8.3 \text{ g/cm}^3$
- $X_0 \sim 0.9 \text{ cm}$
- Light yield 0.3% (LY NaI(Tl))

- Existing CLAS inner calorimeter
- 424 16cm PbWO4 crystals
- $\sigma_E \sim 3\% E$

Also testing LYSO, considering sampling cal.
The geometry of the Forward Tagger Calorimeter based on the PbW04 crystals has been implemented in GEMC:

- 408 crystals
- 15x15x200 mm size
- Coverage from 1.8 to 5.2 deg.
- Tungsten beam pipe to shield from beam halo
Meson Spectroscopy

- Hybrid mesons contain excited gluons
- Study of excited gluons should enhance understanding of confinement
- Can have quantum numbers forbidden by quark model (exotic)
- Mesons with exotic quantum numbers likely to be hybrids

**Normal meson:**
- Flux tube in ground state
- Allowed 0-+, 1-+, ...

**Exotic meson:**
- Flux tube in excited state
- Combine quantum numbers of quark pair and flux tube
- Exotic 0+-, 1++, 2+-

- Lattice predicts $1^+$ exotic states masses around 2GeV, i.e. JLAB energies (1-3GeV)
- In photoproduction rates for exotics expected to be similar to normal mesons
- Linear polarisation has correlation with naturality of produced meson

- Half free parameters in PWA

Complimentary to JLAB GLUEX experiment
Partial Wave Analysis

- Required to factor out different isobar contributions
- e.g. photoproduction of $\pi_1(1600)$
  - $S=1, L_{QQ}=0, L_g=1 \Rightarrow J^{PC}=1^{-+}$
- Decays to $\rho\pi$ in P-wave

- Design of tagger being studied with simulation of CLAS12 and PWA
- INT/JLAB 12 GeV collaboration formed to provide numerical and phenomenological tools for amplitude analysis
Coherent production on nuclei

- Production of mesons on light nuclei can help simplify PWA
  - Significantly reduce s-channel resonance background
  - $S=I=0$ target acts as spin and parity filter for final state meson
  - Method requires detection of low energy recoil nucleus
    - Thin gas target (need high luminosity)
    - Time Projection Chamber e.g. GEMs (CLAS experiment EG6)

Incoherent production on nuclei

- Can filter additional spin-parities of final state meson
- Identify final state quantum numbers of recoil nucleus
  - Tag with nuclear decay $\gamma$
  - e.g. $^{12}\text{C}(0)\ 0^+ \rightarrow ^{12}\text{C}(4.4\text{ MeV})\ 2^+$
- No threshold on recoil energy or $t$
Cascade

Doubly strange members of SU(3)
Number of $\Xi^*$ should equal $N^*$ and $\Delta^*$
Currently 2, $4^*$ and 4, $3^*$ resonances measured
Properties not well known

**Advantages**

- Excited states narrow compared to $N^*$ (10MeV<100MeV)
- Extraction of excitation spectrum relatively straightforward
- 2 detached vertices from decays
- 2 kaons in final state

$\sigma_{\text{total}}(\gamma p \rightarrow 2K^+\Xi^-) \sim 10\text{nb}\sim1\text{Hz production rate}$

L. Guo et al. PRC 76, 025208 (2008)

- Will cover masses from 1.5 to 3.8 GeV
- Measure decay distributions
  $\Rightarrow$ Model independent extraction of properties

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Ω⁻ - the strangest baryon

Gell-Mann, Ne'eman predicted, as part of quark model, the Ω⁻ (1670) with S=-3, JP=3/2+
Observed in 1964 BNL confirming SU(3)$_F$

σ$_{\text{total}}$(γp → 3K$^+$Ω⁻) ~ 1nb~0.1Hz production rate

- Cross section measurement of γp → Ω⁻K$^+$K$^+$K$^0$
- Direct determination of quantum numbers with no assumptions
  - BABAR → J=3/2 , parity unknown experimentally
- Search for Ω⁻ excited states
  - Only 3 possible resonances measured
- Study of the photoproduction mechanism
  - First baryon where no constituents come from target proton
Summary

- JLAB $e^-$ beam will be upgraded to 11 GeV for 2013
  - 12 GeV for new Hall-D (GlueX experiment)
- The CLAS detector will undergo a complementary upgrade
  - CLAS12 – excellent charged and neutral particle detection
- A high luminosity ($10^{35} \text{cm}^{-2}\text{s}^{-1}$) $e^-$ will be used on a hydrogen target for several years to meet the requirements of DVCS experiments
- Addition of a quasi-real photon tagger will allow parasitic measurements in hadron spectroscopy
- **Exotic mesons, cascades, $\Omega^-$...**