A future $\pi^0$ detection facility in Hall C

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- **Scientific motivation**
  - L/T cross section separation
  - A $\pi^0$ detector for Hall C

- **Detector design**
  - PbWO4 crystals
  - Temperature controlled frame
  - Sweeping magnet
  - fADC
  - PMT base modification for high rate

- **Simulations**
  - GEMC/GEANT4 simulation
  - Cluster finding
Scientific motivation
Meson Reaction Dynamics

Small \(-t\) and large \(W\) → \(t\)-channel process
- Meson form factor describes the spatial distribution of the nucleon

High \(Q^2\) → “handbag” diagram
- The non-perturbative (soft) physics is represented by the GPDs
  - Shown to factorize from QCD perturbative processes for longitudinal photons [Collins, Frankfurt, Strikman, 1997]
Example: Ratio $R = \sigma_L/\sigma_T$ in the Exclusive limit

- Production of $\pi^+$ and $K^+$ feature a meson exchange contribution in the t-channel (pole term), whose impact on factorization has to be understood.

- In $\pi^-$ production the pole term is suppressed:
  - The t-dependence at small t can thus be associated with the structure of the nucleon rather than its pion cloud.
    - A large $R = \sigma_L/\sigma_T$ would imply the realization of the factorization theorem.
    - A large response in $\sigma_L$ may indicate non-pole contributions in $\pi^+$ production.

- Comparison of $R$ in $\pi^-$ and $\pi^+$ production important for understanding:
  - Pole and non-pole contributions in nucleon (spin) structure studies.
  - Non-pole contributions in $F_\pi$ extraction.
A new $\pi^0$ L/T facility in Hall C

- New PbWO$_4$ calorimeter provides $\pi^0$ detection facility in Hall C

- Provides opportunities to extend separations program for DVCS
  - initial DVCS separation
  - extensions to a broader kinematic range anticipated

MRI Consortium proposal submitted Jan 2012: CUA, ODU, FIU, JLab, Yerevan
Detector design
The detector system will consist of

PbWO4 blocks of the PRIMEX setup in a new temperature controlled frame

Essentially deadtime-less digitizing electronics

A sweeping magnet

HV bases with built-in amplifiers
PbWO$_4$ crystals

- Existing crystals from Primex Experiment

**$\pi^0$ detector features:**

- 31 x 36 matrix of PbWO$_4$ crystals
- 2.05 x 2.05 x 18 cm$^3$ each crystal

**Energy resolution**

$\sigma = 2.45\% @ 1. \text{ GeV}$

**Spatial resolution**

$\sigma = 5.6 \text{ mm @ 1. GeV}$
PbWO4 crystal has light yield of 2.5% / °C (at 25°C)

For measurement, temperature must be stable to ~0.1°C to achieve energy resolution of 0.5%

Construction of a frame to control the setup temperature:

- Temperature sensors
- Copper plates to refrigerate system
- Water cooling system
Resistive magnet based on the Horizontal Bend (HB) magnet design

☑ Normal-conducting copper coil magnet
☑ Aperture of 35x36 cm²
☑ Magnetic field strength of 0.3 T.m
☑ Design similar to the super-conducting dipole (HB) of the SHMS

Hall C Horizontal Bend(HB) SC Magnet Cutaway
(shown with HMS Q1)
Usage of flash ADCs

- Continuous sampling of the signal – 4ns window
- Internal buffer for pre-trigger sampling
- FPGA for sampling and bufferizing signal. Also possible to create advanced online processing for trigger system, e.g. cluster finding, ...
- FPGA → real parallel processing → “no” electronic deadtime
High Voltage Base Design

- Adding two high-voltage transistors to the last two dynodes:
  - Drain current and do not change the division ratio
Active bases for PMTs

- The new active base design outperforms the Primex PMT/base by a factor of ~25:
  - Increases the maximum linear count rate: from 30kHz to 1.2MHz
  - Changes the gain stability from ±5% to ±1%
Simulations
Simulation of the calorimeter

- Single photon hitting the small detector in GEMC/GEANT4

Shower spreads in the neighbor crystals, making possible a sub-crystal resolution
Shower profile simulation

3 GeV photon hitting the center of the crystal

Front view

3D view

Side view
Cluster finding algorithm

Simple case: no background

- Find two crystals with greatest energy and with a minimum distance between them
- Make a square cluster using the energetic crystal, in order to maximize energy in the cluster
- Fit a 3D gaussian using crystals in the clusters
Simulating background

- Magnetic field before the detector to reduce charged particles background
Events with two photons from $\pi^0$ decay and background

Considering background
Changes in integration time window
Outlook

- $\pi^0$ calorimeter pre-design tests are ongoing
- MRI/NSF has been submitted in January/2012
- Detector simulations and existing components are being studied