

lundi 7 octobre 2013

# **Heavy Photon Search**

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## **The Hidden Sectors**

#### → Hidden sectors

- → The universe may include Hidden Sectors
  - *i.e. particles and forces that don't couple directly to the Standard Model*
- → Dark matter may be part of a hidden sector
- Hidden sectors would be detectable through gravity and "portals"

The *photon portal*, through which the SM photon mixes with the hidden sector photon, can allow our world to interact with the hidden sector

# → The heavy photon (A') is a conjectured new particle that can mix with SM photon

- → U(1) boson
- **→** Small coupling to electrons (reduced by ε)
- It can be massive !



#### → Why assume there are more U(1)'s in Nature?

- String theories and other BSM theories generate hidden sectors with additional U(1)'s
- → Given that only 4% of the universal mass-energy is wellaccounted for, there is plenty of room!

#### → The experimental side:

- → Could explain discrepancies between direct dark matter searches (CDMS & XENON100 vs DAMA/LIBRA & CoGeNT)
- Observation of unexpected flux of positrons can be explained by a coupling of A' to DM
- → Could help solve the muonic g-2 discrepancy  $(3\sigma)$



# **The Heavy Photon Search**

- Where to look for heavy photon ?
  - ➔ Masses from few MeV to a GeV
  - Vector boson
  - **→** Small coupling to electrons (reduced by ε)



# →So hidden sector photons couple weakly to electric charge and our world.

In particular, they couple weakly to electrons, so they can be radiated by electrons, and they can decay into e+e-



# **Production of the Heavy Photon**

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→ Important QED backgrounds



FIG. 4: Sample diagrams of (left) radiative trident ( $\gamma^*$ ) and (right) Bethe-Heitler trident reactions that comprise the primary background to the  $A' \to l^+ l^-$  search.

#### Use thin nuclear target reduces hadronic backgrounds and multiple scattering

→ High beam intensity with thin target cause heat problems



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Momentum and Vertex

# **HPS Experimental Setup**



**Trigger and Particle ID** 



# **Trigger Algorithm**

#### → Cluster finding

→ Look at energy deposit for all 3x3 configurations of crystal

#### → Topological Selection

- Energy sum, time coincidence, energy difference, coplanarity and energy slope
- → The Maximum rate for electronics is 43 kHz
- → Evaluation using Monte-Carlo Simulation
  - → Reproduce bunches of electrons
  - → Simulation also helped determine trigger cuts

Sample	Rate (kHz)
1.1 GeV beam background	$15.7 \pm 0.4$
1.1 GeV beam background+tridents	$18.3 \pm 0.4$
2.2 GeV beam background	$11.2 \pm 0.3$
2.2 GeV beam background+tridents	$15.8 \pm 0.4$
6.6 GeV beam background	$10.2 \pm 0.3$
6.6 GeV beam background+tridents	$12.6 \pm 0.4$
6.6 GeV beam background+tridents+pions (FLUKA)	$13.4 \pm 0.4$
6.6 GeV beam background+tridents+pions (G4)	$13.5\pm0.4$

TABLE XVIII: Trigger rates using various background samples, with statistical uncertainties.



# **HPS Test Run**



- The main goal was to validate the critical assumptions made in our simulations for rates and occupancies
  - Most of trigger rates come from multiple Coulomb scattered electrons
  - Correct simulation of the electromagnetic background is crucial for the design of the experiment
  - Two simulation tools, GEANT4 and EGS5 gave different results in the rate estimates

→ The other goal of the test run was to demonstrate the feasibility of the proposed apparatus and data acquisition





## **Silicon Vertex Tracker**

# → Will be installed in in the vacuum inside the analyzing magnet

- First layer is located at 10 cm from the target,
- the silicon in the first layer is only 0.5 mm from the center of the beam
- Layer number 1 23 4 5 6 nominal z, from target (cm) 102030 507090 Stereo Angle (mrad) 100100 100505050Bend-plane resolution  $(\mu m)$  $\approx 60 \approx 60 \approx 60 \approx 120 \approx 120 \approx 120$ Non-bend resolution  $(\mu m)$  $\approx 6$  $\approx 6$  $\approx 6$  $\approx 6$  $\approx 6$  $\approx 6$ Number of sensors 8 8 8 4 4 4 Nominal dead zone in y (mm)  $\pm 1.5 \pm 3.0 \pm 4.5 \pm 7.5 \pm 10.5 \pm 13.5$ Module power consumption (W) 6.96.96.9 13.8 13.8 13.8
- → Silicon will be actively cooled to retard radiation damage
- → The sensors have 60 µm readout pitch

The sensors are read out continuously at 40 MHz





# **Electromagnetic Calorimeter**





#### The calorimeter in details

- → We have 442 PbWO4 crystals (from CLAS IC) and a mechanical structure for them
- → Light amplified with Avalanche Photo-Diodes
- → Thermal box keeps the calorimeter at 18 degree Celsius
- → All the detector electronics is updated
- Addition of a light monitoring system composed of LEDs
  placed in front of the crystals
- Most of this work is done in IPN Orsay



## **Detection of the Heavy Photon**

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#### Search based on a bump hunt

→ Looking for a peak in the large QED background

#### →Supplemented by displaced vertex

→ Reduce drastically the QED background







# **HPS performance**

#### →Reach of the experiment for the simple bump hunt and the displaced vertex methods







Scientific program with a wide reach

- → Search for A'
  - → Linked to dark matter, cosmology and precision QED
- → Search for true muonium
  - → Linked to precision QED and QCD hadronization
- → Development & Constructions 2013-2014
- → Data taking in the Hall B at the end of 2014 and during 2015
  - → 3 months approved by PAC
  - → But only 1 month of running planned for 2014-2015 run

#### → CLAS12 should be running mid-2016Data taking in 2015

- → IPN Orsay is committed to the ECal
  - → Update mechanics and electronics
  - → Construction of a light monitoring system