

# The HPS experiment

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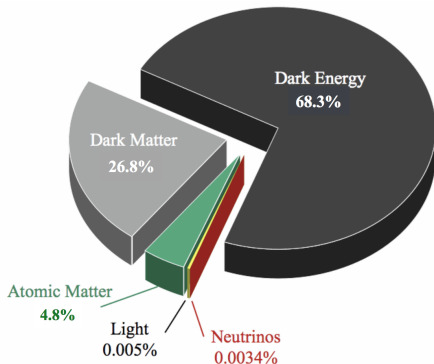
La Sapienza, 24 Set. 2015

## Outline

- ▶ Motivations for searching Heavy Photons
- ▶ Description of HPS setup
- ▶ 2015 Engineering Run
- ▶ Conclusions

# Dark Matter and Dark Sector

Planck



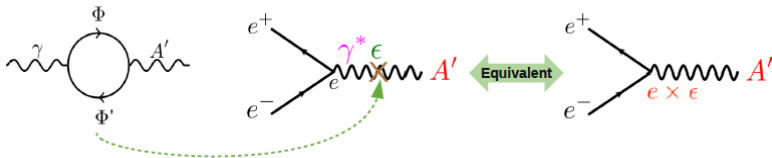
- ▶ DM suggest a *dark sector*
- ▶ Standard Model should be "blind" to new Dark Forces
- ▶ How to look for them?

## The heavy photon $A'$

Consider a theory in which nature contains an additional Abelian gauge symmetry,  $U(1)_D$  [Holdom, Phys. Lett. B166, 1986]

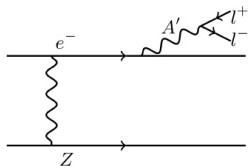
$$\mathcal{L} = \mathcal{L}_{SM} + \frac{1}{4} F'^{\mu\nu} F'_{\mu\nu} + m_{A'}^2 A'^\mu A'_\mu + \frac{\epsilon}{2} F^{Y,\mu\nu} F'_{\mu\nu} \quad (1)$$

This gives rise to a *kinetic mixing term* which produces an effective parity-conserving interaction  $\epsilon e A'_\mu J_{EM}^\mu$  of the  $A'$  to the electromagnetic current, suppressed relative to the electron charge  $e$  by the parameter  $\epsilon$ , which can naturally be in the range  $10^{-12} - 10^{-2}$



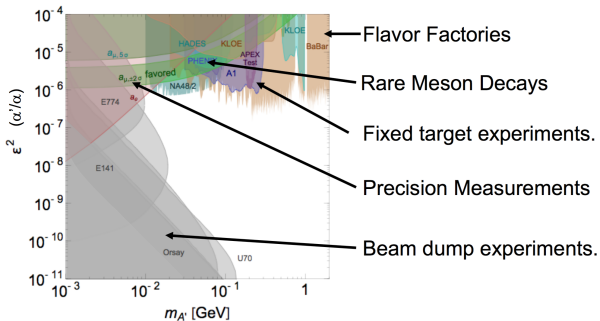
# Search for $A'$ - Current situation

Fixed Target

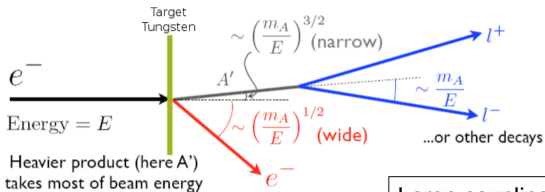


$$\sigma \sim \frac{\alpha^3 Z^2 \epsilon^2}{m^2} \sim \mathcal{O}(10 \text{ pb})$$

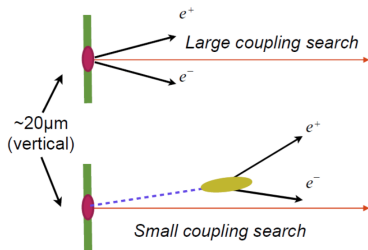
$$\mathcal{O}(ab^{-1}) \text{ per day}$$



# A' search: Bump-Hunt and Vertexing



$A'$  takes most of the incident energy, produced very forward



Large coupling regime:

$A'$  decays in target  $\therefore$  constrain  $e^+e^-$  to originate from beamspot

Search for peak in invariant mass plot

Small coupling regime:

$A'$  decays outside of target  $\therefore$  constrain  $A'$  to originate from beamspot

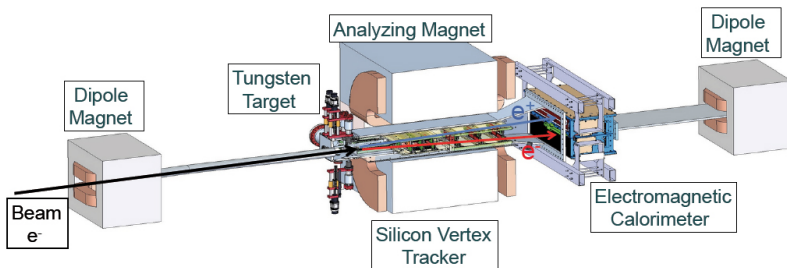
Search for displaced vertex + mass peak

Including recoil  $e^-$  along with  $e^+e^-$  pair would improve mass resolution

# The Heavy Photon Search (HPS) experiment

- ▶ 1 to 6 GeV, 200 nA  $e^-$  on 1% R.L. W target
- ▶ 6 layer Silicon Vertex Tracker (SVT)
- ▶ Electromagnetic Calorimeter (ECal)

## Heavy Photon Search Beamline and Detectors



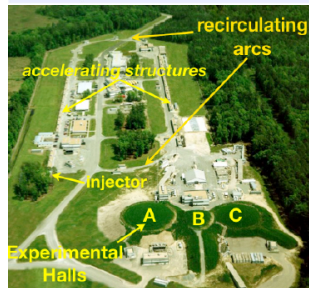
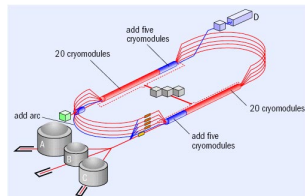
# HPS Construction

- ▶ Conceived, built and installed HPS detector in about 14 months
- ▶ The HPS test detector [NIM A, Volume 777, 21 March 2015, Pages 91-101]
- ▶ Upgrade  $PbWO_4$  Ecal installed September 2014
- ▶ Improved six-layer Si Vertex Tracker installed February 23, 2015

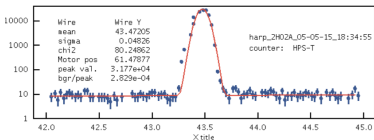
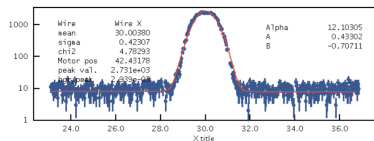


# 2015 Engineering Run

- ▶ 2015 Engineering Run
- ▶ in HallB at Jefferson Lab
- ▶ 1.1 GeV, 200 nA beam
- ▶ Commissioned HallB beamline, SVT, ECal, trigger, DAQ
- ▶ took data with SVT at  $\pm 1.5$  mm and  $\pm 0.5$  mm from beam



# Beam Quality

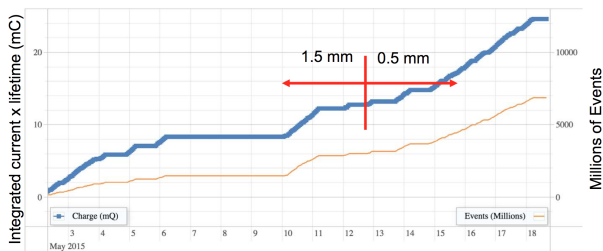


HPS requires high-quality, stable beam.

Small beam size:

▶  $\sigma_x \approx 300$  to  $500 \mu m$

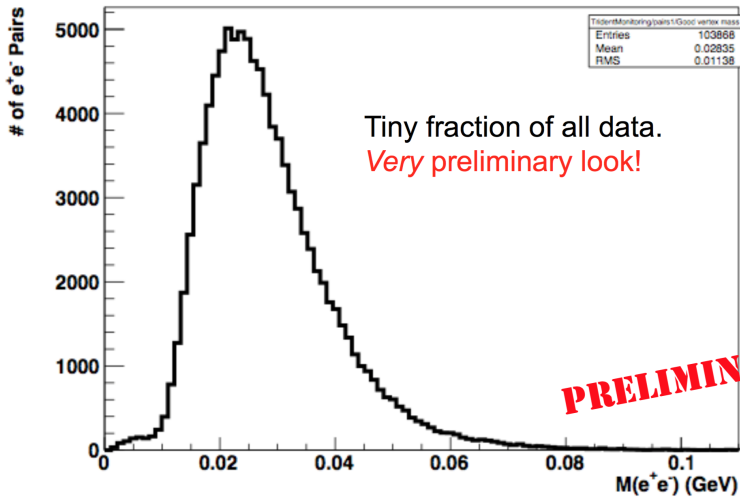
▶  $\sigma_y \approx 15$  to  $50 \mu m$



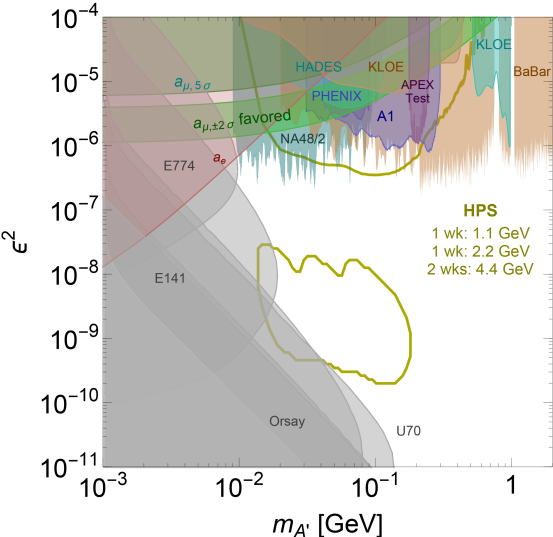
# Data!

- ▶ Took over 5 billion events with single electron and pairs triggers
- ▶ Detector and data acquisition system performed as expected
- ▶ Currently analyzing a 10% of the data to calibrate the detector response
  - ▶ Time
  - ▶ Energy
  - ▶ Position

# $e^+e^-$ Pairs Mass Distribution



# Expected HPS Reach



## Conclusions

- ▶ HPS is a new experiment at JLAB, dedicated to searching for heavy photons with masses 10-200 MeV and couplings  $10^{-3} < \epsilon < 10^{-5}$  in unexplored regions of parameter space.
- ▶ Invariant mass and vertexing signatures let HPS achieve sensitivity to very small values of the  $A'$  coupling. Using invariant mass alone, HPS covers  $\epsilon^2 > \text{few} \times 10^7$  for  $10 < mA' < 200$  MeV.
- ▶ HPS is installed in Hall B at JLAB and recently completed a successful engineering run, exercising all aspects of the experiment.