Search for Dark Photons in the SeaQuest E906 Experiment

Arun Tadepalli[1], Roy Holt[2], Ron Gilman[1]
[1]Rutgers University
[2]Argonne National Laboratory

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- Dark matter and standard model coupling
- The SeaQuest spectrometer
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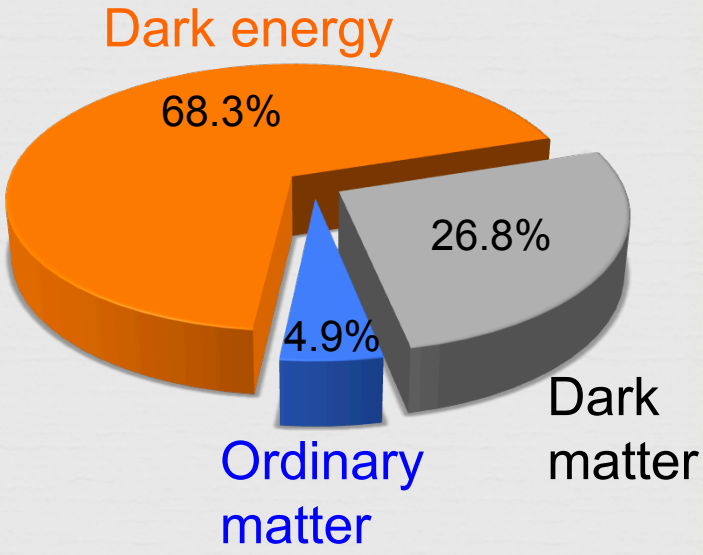
What's the matter?

Dark matter is:

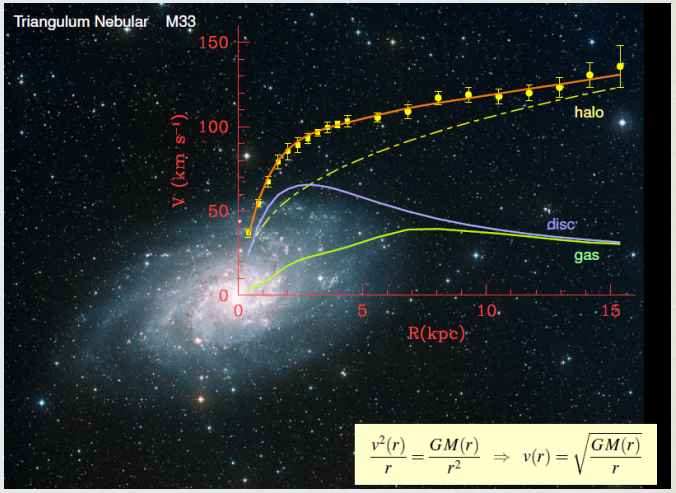
- one of the greatest unsolved mysteries of modern physics
- a central element for cosmology and astronomy
- about 27% of the energy density of the Universe



Evidence for Dark matter

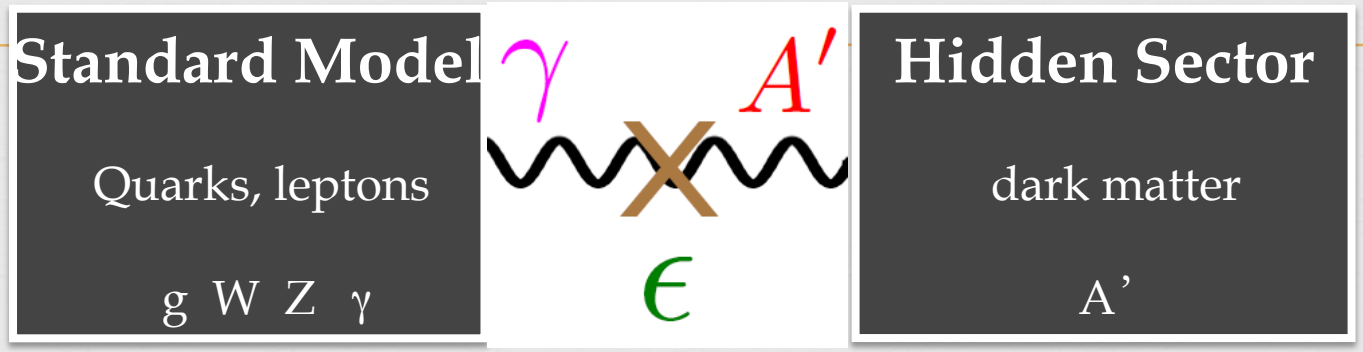
- Indirect:
  - Rotation curves of galaxies
  - Gravitational lensing
  - Surveys of cosmic microwave background
  - Positron excess in the universe
  - Gamma ray excess from the galactic center
  - …
- Direct:
  - …

F. Zwicky, ApJ 86 (1937) 217, V. Rubin et al, ApJ 238 (1980) 471

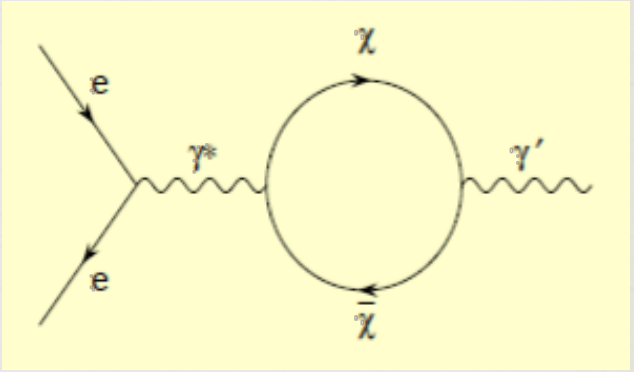


- Dark matter interpretations of astrophysical anomalies
- Indicates that dark matter couples to ordinary matter more than gravitationally

Dark sector and Standard model coupling



- Dark sector could interact with the standard model sector via a hidden gauge boson (A′ or “dark photon” or “para photon” or “hidden photon”)
- Dark photons can provide a portal into the dark sector
- Dark photons could couple to standard model matter with $\alpha' = \alpha\ \varepsilon^2$



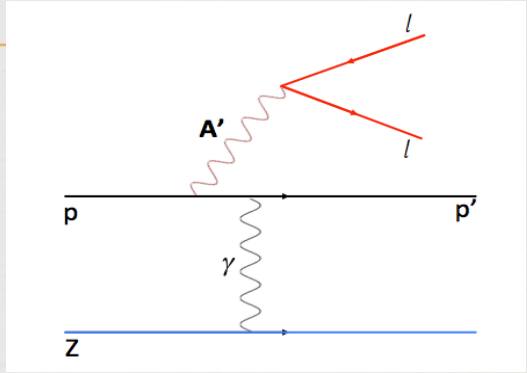
A′ produced via a loop mechanism

$$\mathcal{L} \supset -\frac{1}{4}F^{\mathrm{SM}}_{\mu\nu}F^{\mu\nu}_{\mathrm{SM}} - \frac{1}{4}F^{\mathrm{hidden}}_{\mu\nu}F^{\mu\nu}_{\mathrm{hidden}} + \frac{\varepsilon}{2}F^{\mathrm{SM}}_{\mu\nu}F^{\mu\nu}_{\mathrm{hidden}} + m^2_{\gamma'}A^{\mathrm{hidden}}_{\mu}A^{\mu}_{\mathrm{hidden}}$$

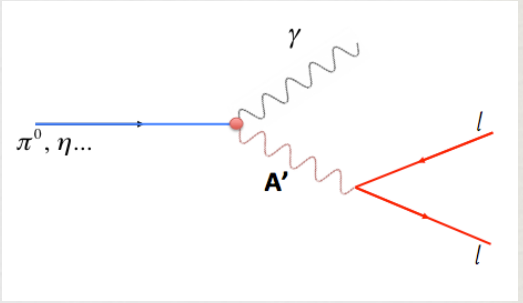
B. Holdom, PLB **166** (1986) 196
J. D. Bjorken et al, PRD **80** (2009) 075018

Possible A′ production mechanisms

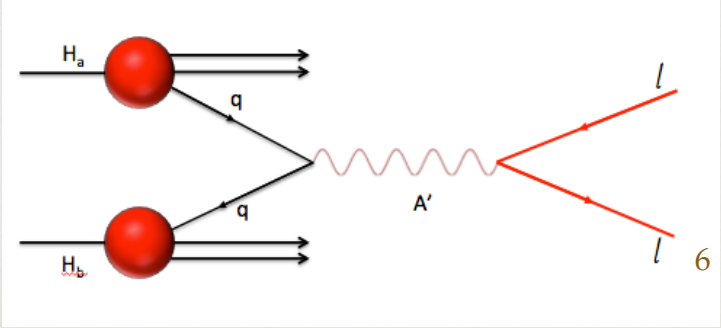
- Proton Bremsstrahlung



- η … decay



- Dark Drell-Yan process

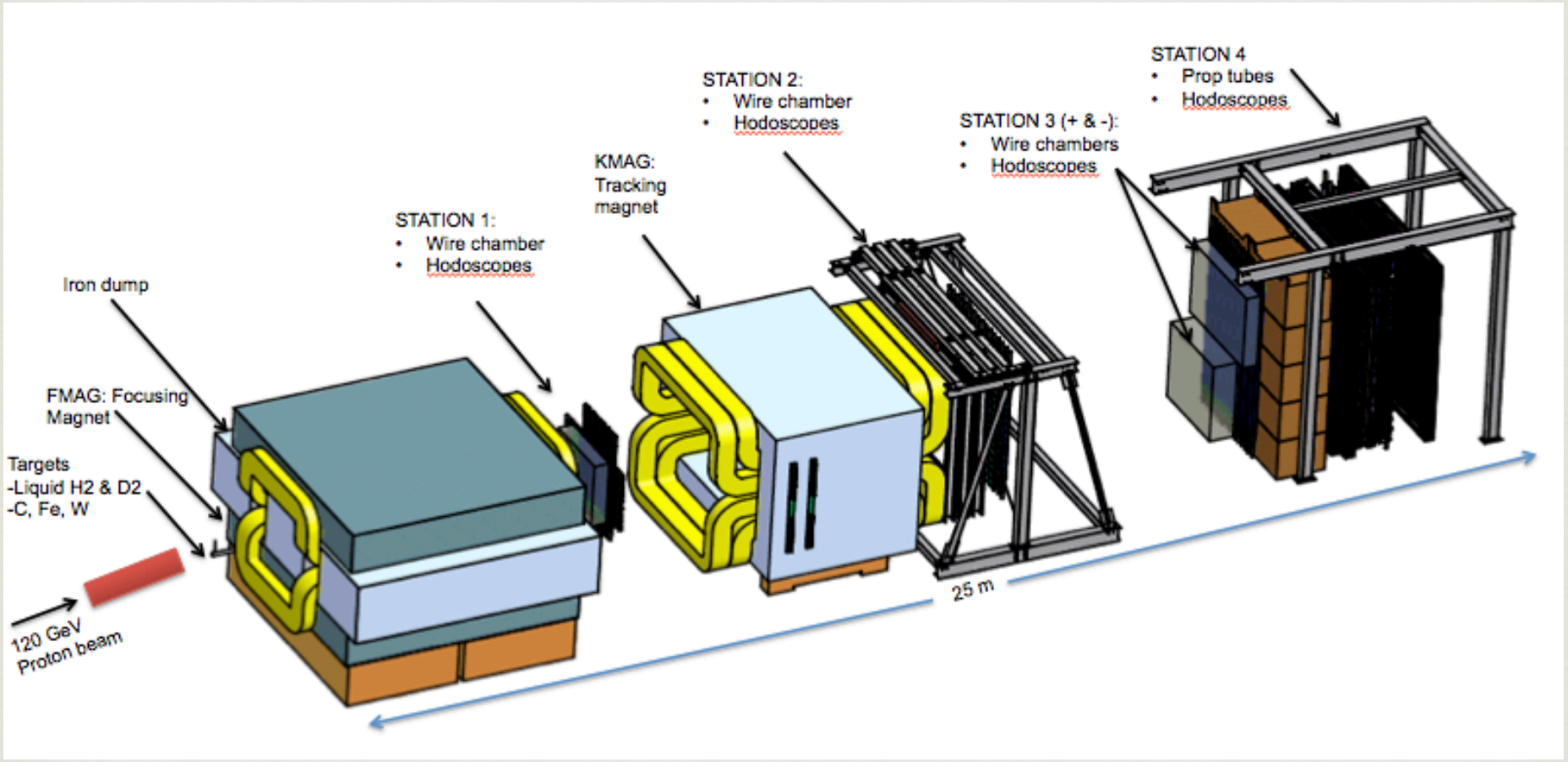


The SeaQuest E906 Experiment

- 120 GeV proton beam from the Main Injector at Fermilab.
- Fixed target Drell-Yan experiment
  - Liquid H2, Liquid D2, C, Fe, W, none and empty flask.
- Optimized for studying high rate di-muons to study the nucleon sea
- SeaQuest also takes advantage of a paired spectrometer to search for dark photons

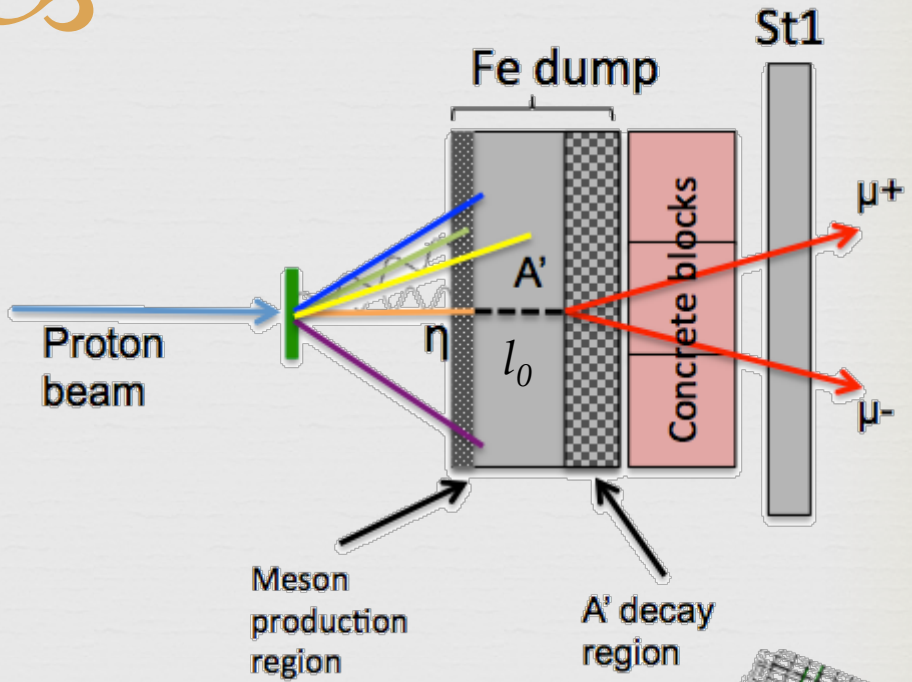

SeaQuest
E906
Experiment

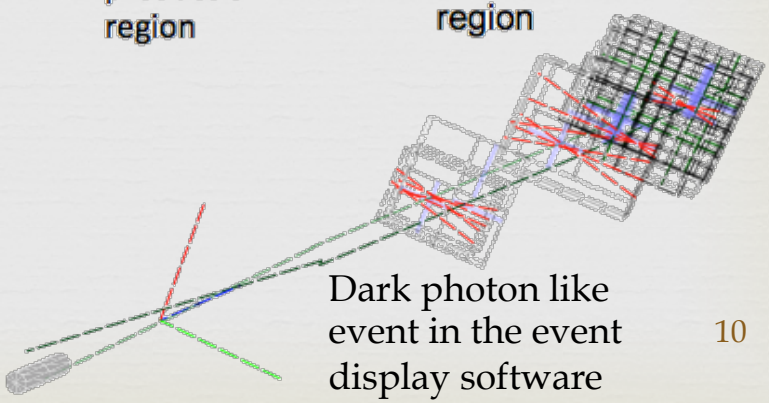
SeaQuest Spectrometer



SeaQuest A′ search strategy

- A′ generated by η decay and/or proton Bremsstrahlung in the Iron beam dump
- A′ could travel a distance l_0 without interacting
- A′ decays into di-leptons
- Reconstructed di-lepton vertex is displaced, downstream of the target in the beam dump





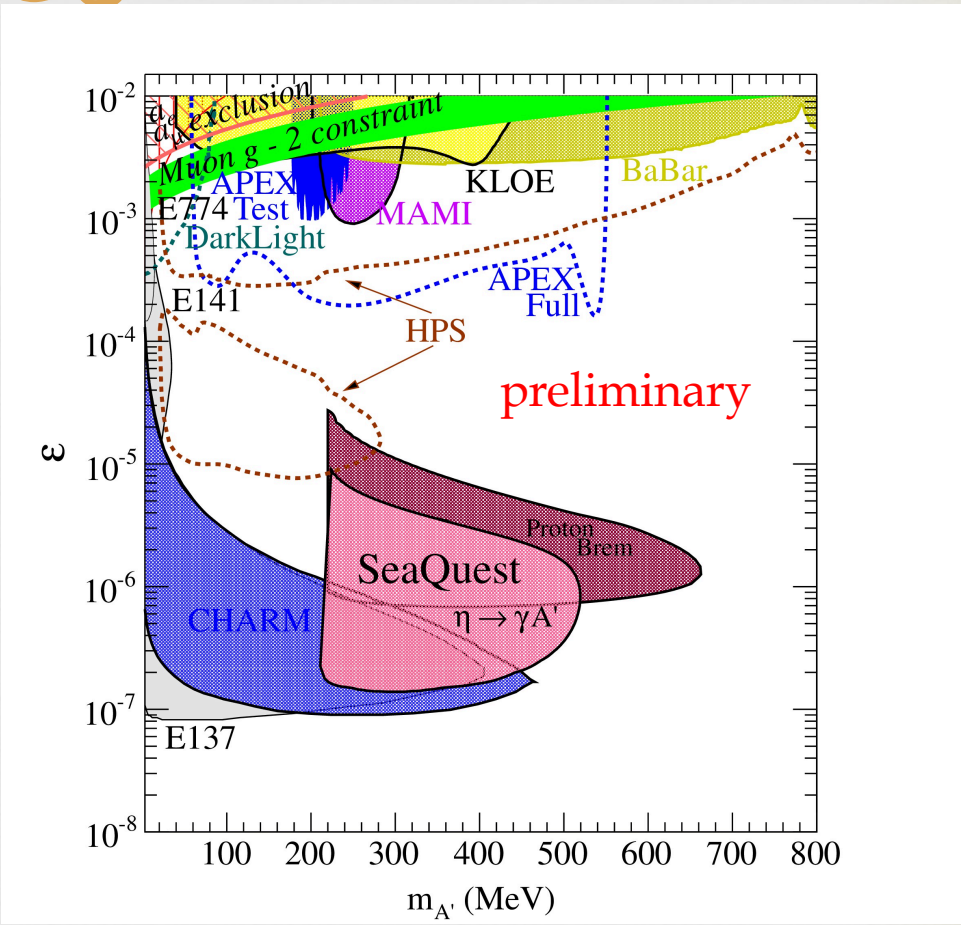
Dark photon like event in the event display software

A′ sensitivity region for SeaQuest

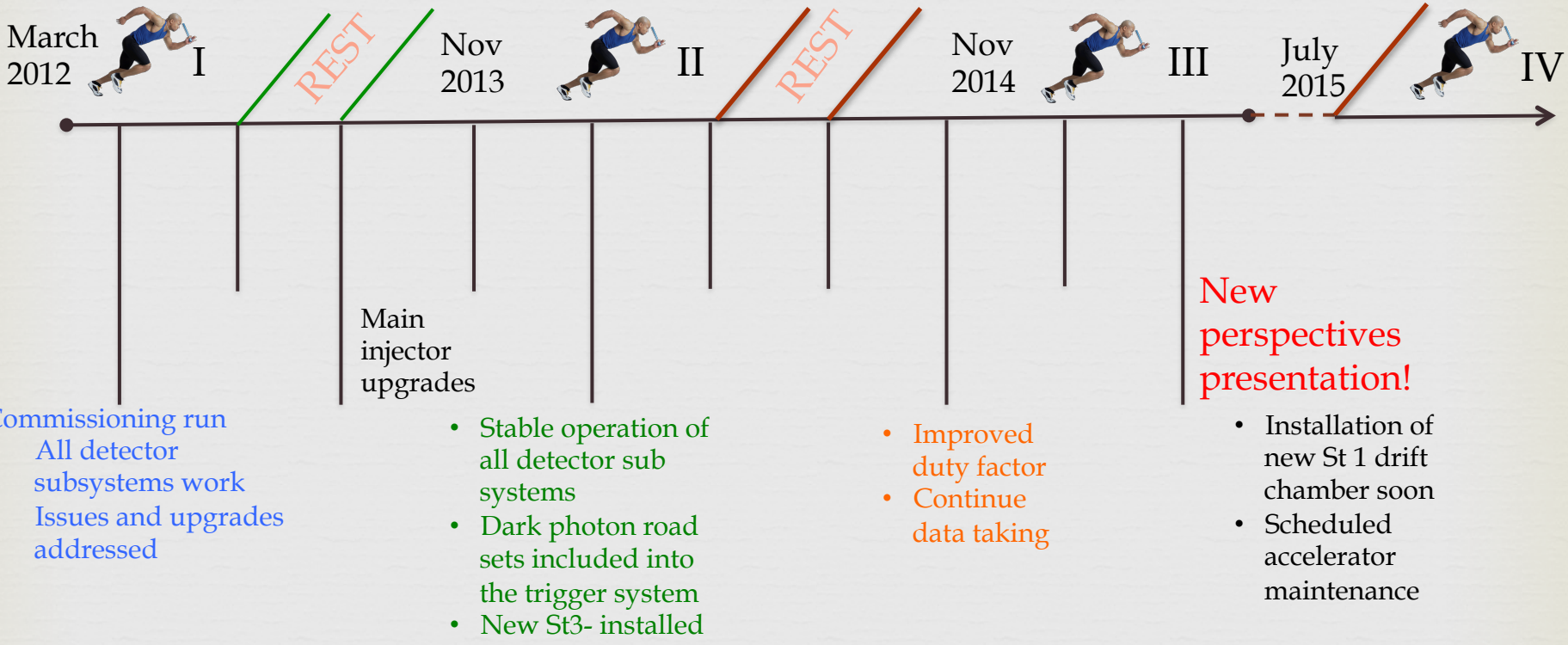
$$l_o \approx \frac{0.8\,cm}{N_{eff}}\left(\frac{E_o}{10\,GeV}\right)\left(\frac{10^{-4}}{\varepsilon}\right)^2\left(\frac{100\,MeV}{m_{A'}}\right)^2$$

J. D. Bjorken et al, PRD **80** (2009) 075018

- E_0 = energy of the A′
- N_{eff} = no. of available decay products
- l_0 = distance that A′ travels before decaying
- ε = coupling constant between standard model and dark sector
- $m_{A'}$ = mass of A′



Timeline of SeaQuest



- SeaQuest has finished a successful RUN II
- SeaQuest is now taking more data in RUN III – Analysis underway
- SeaQuest will take more data in RUN IV with new detector components

Summary and outlook

- Indirect evidence for dark matter is overwhelming. Direct detection is pending…
- Dark photons could provide a portal into the dark sector.
- SeaQuest takes advantage of the η decay, proton bremsstrahlung and Drell-Yan processes to search for dark photons.
- A preliminary estimate has been made of the range of dark photon ε and mass parameters to which SeaQuest is sensitive.
- SeaQuest is currently taking data with a trigger that has some acceptance to dark photon decays.
- Exciting time ahead!


DON’T BE AFRAID OF THE DARK!