SeaQuest dark photon search

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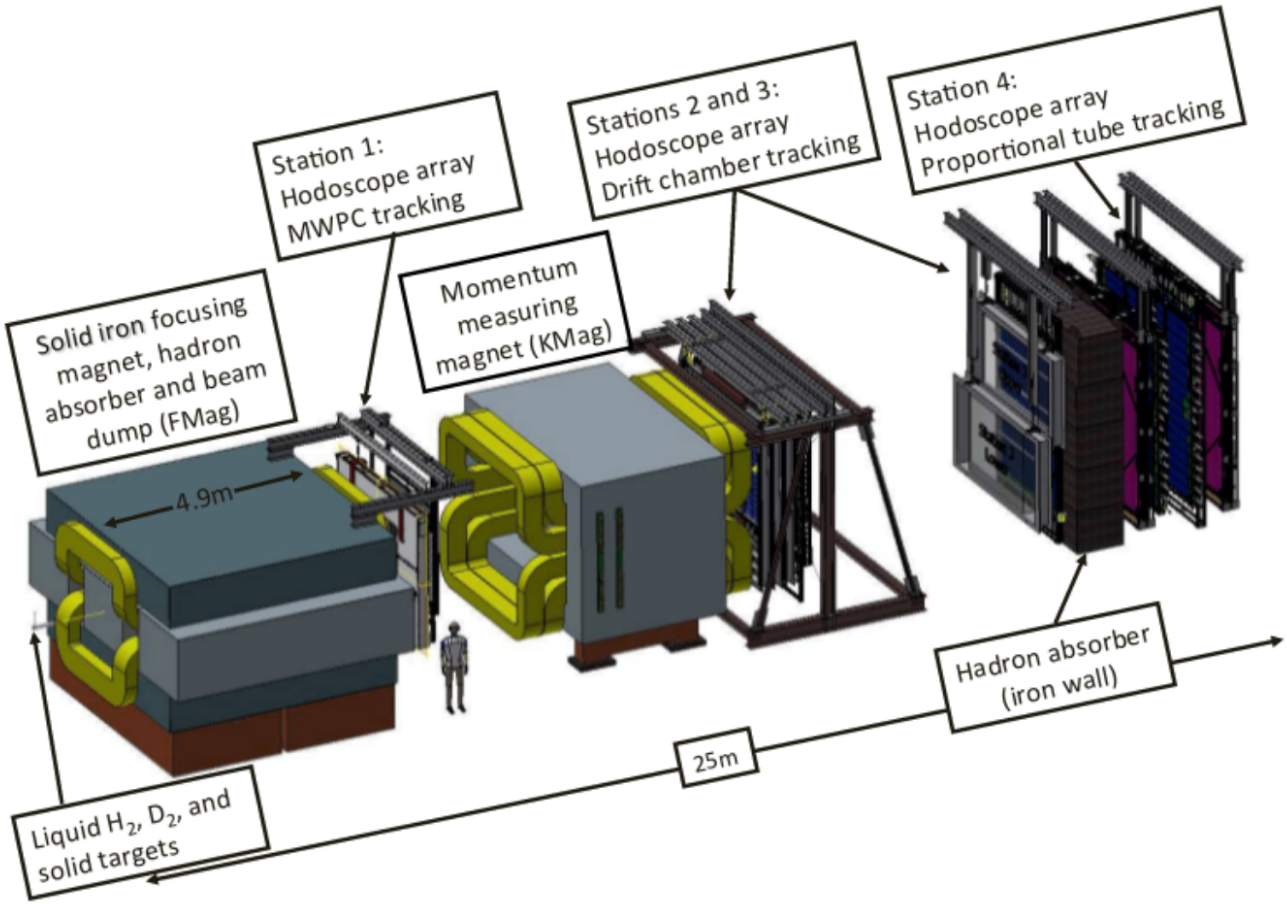
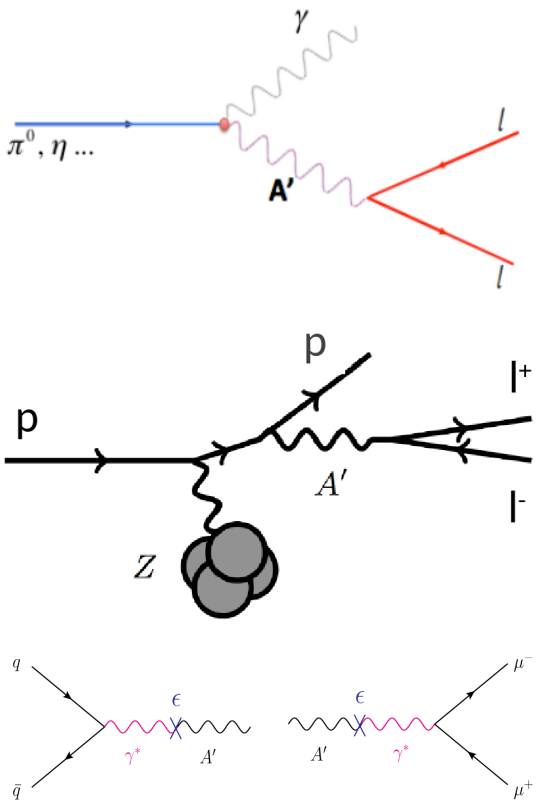
The SeaQuest facility

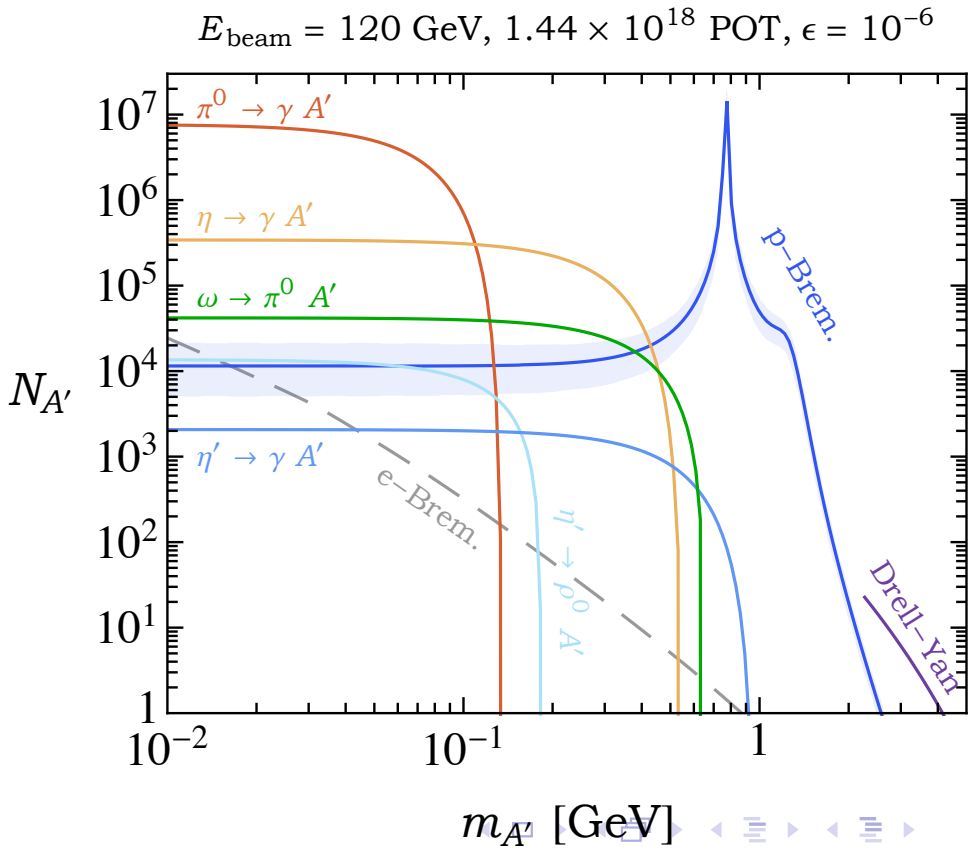
- Fixed target muon spectrometer, Fermilab 120 GeV proton beam
- E906/SeaQuest ended 2017; E1039/SpinQuest (polarized target) takes first beam this year
- Parasitic searches for dark photons approved 2015



Production and signatures at SeaQuest

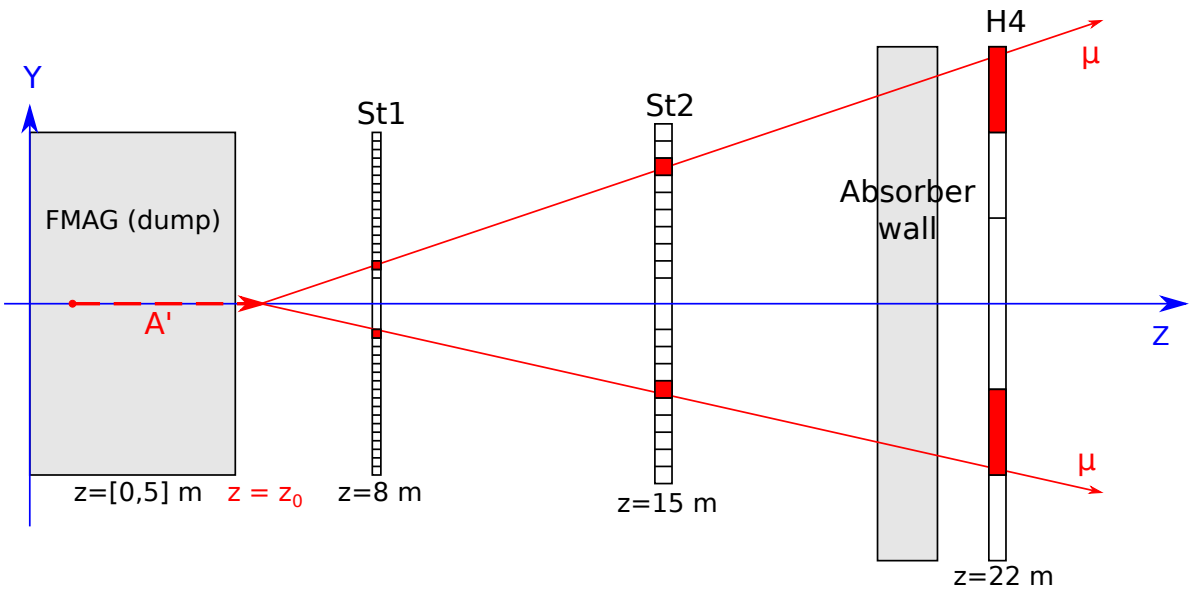
- Three dominant production mechanisms: meson decay, proton bremsstrahlung, Drell-Yan
- Prompt $A' \to \mu^+\mu^-$: bump-hunt
- Displaced $A' \to \mu^+\mu^-$: background suppressed by vertexing
- Displaced $A' \to e^+e^-$: background absorbed in dump





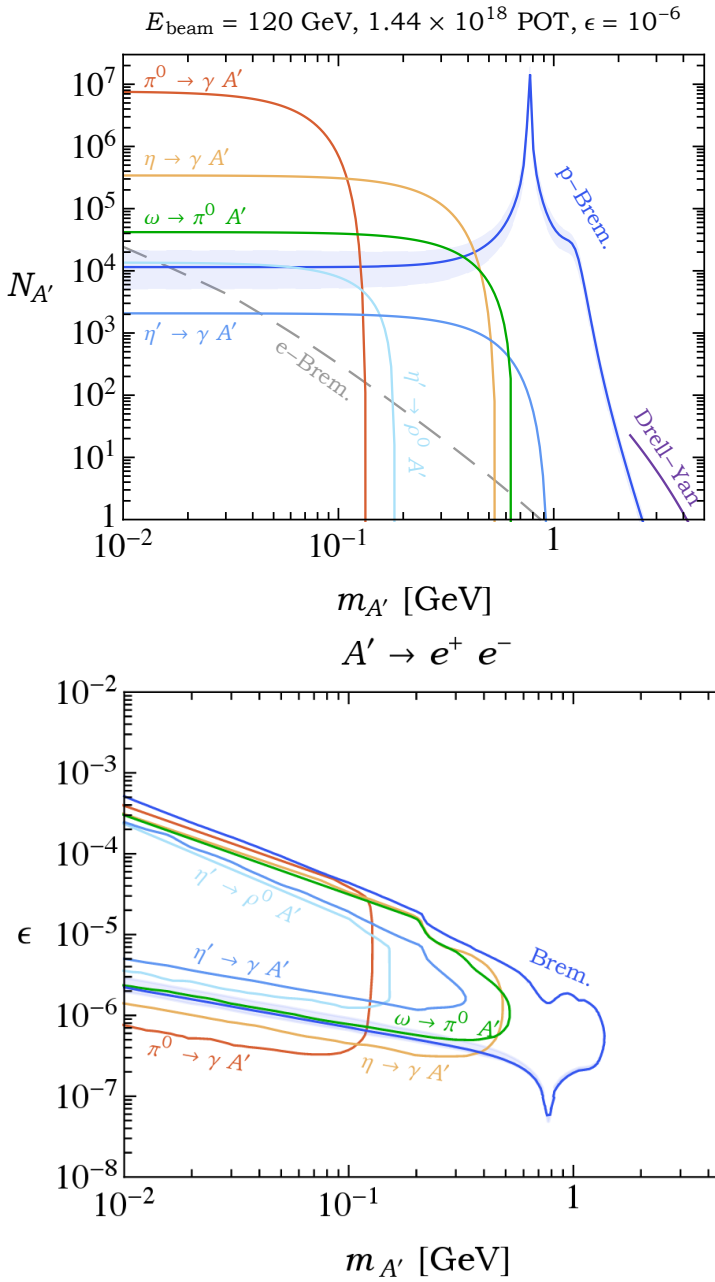
SeaQuest search for dark photons

- Dimuons in main SeaQuest dataset
  - Bump-hunt at high mass (ongoing effort)
- Dimuon displaced-vertex trigger
  - Commissioned 2017, physics data soon
- Dielectron trigger
  - EMCal for electron PID (in planning)



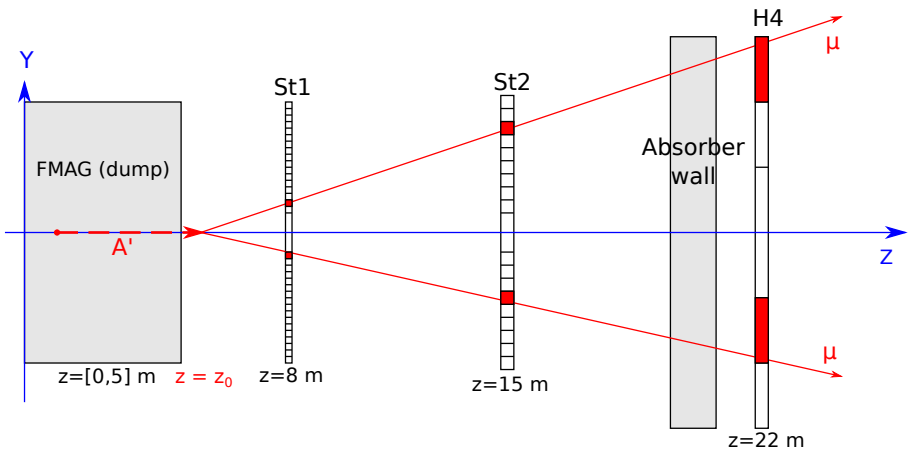
Why SeaQuest?

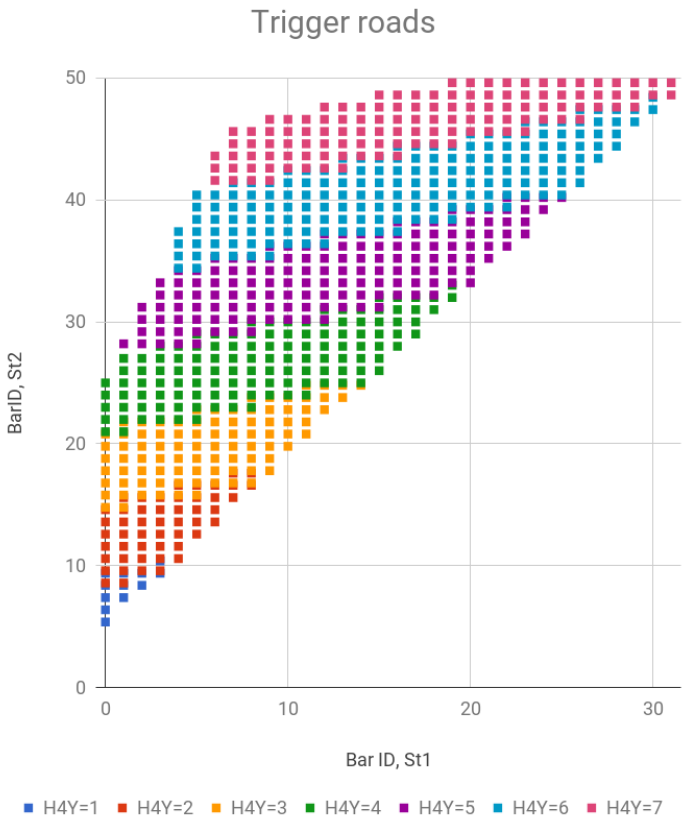
- Most fixed-target dark photon experiments have thin targets or thick beam dumps (100s of meters)
- SeaQuest has:
  - Thin dump, just thick enough to absorb beam backgrounds
  - High beam energy (boosts the A', so $\gamma c\tau$ gets through the dump)
  - Proton beam: many production channels and wide mass coverage
- Strong support from theory groups for a broad dark sectors program at SeaQuest (arXiv:1804.00661)



Trigger logic

- Two levels of CAEN V1495 FPGA boards: identify displaced tracks, trigger on pairs
- L1: three-way coincidence within each quadrant
  - Identify displaced tracks ($z_0 \in [400, 650]$ cm) in each quadrant using roads
- L2: two-out-of-four coincidence between opposite-sign quadrants





Installation and commissioning

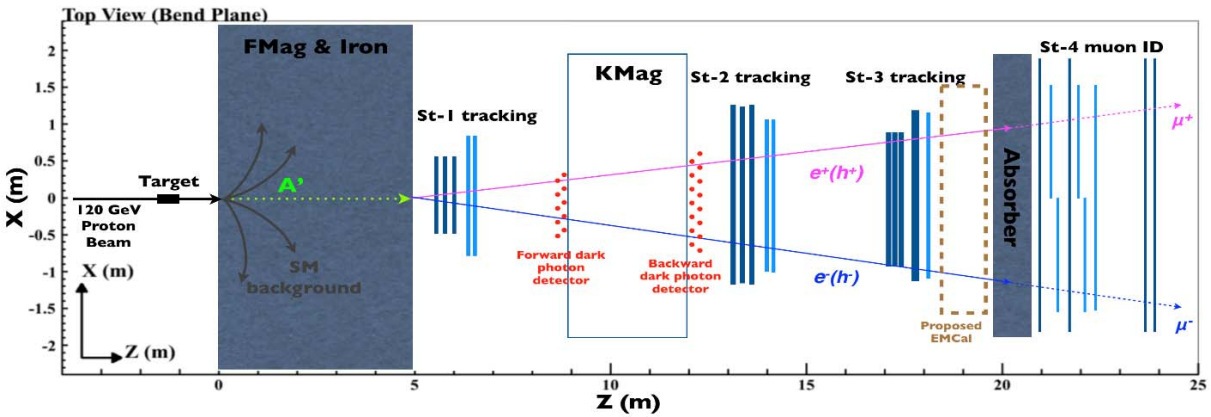
- Trigger hodoscopes installed spring 2017
- Detectors and trigger electronics tested and timed in
- 5 days of data taken with the displaced vertex trigger before summer shutdown
  - Confirmed expected trigger rate, and got lots of random-triggered data for trigger optimization
  - Incorrect trigger delay: no drift chamber tracks

Displaced dimuon plans

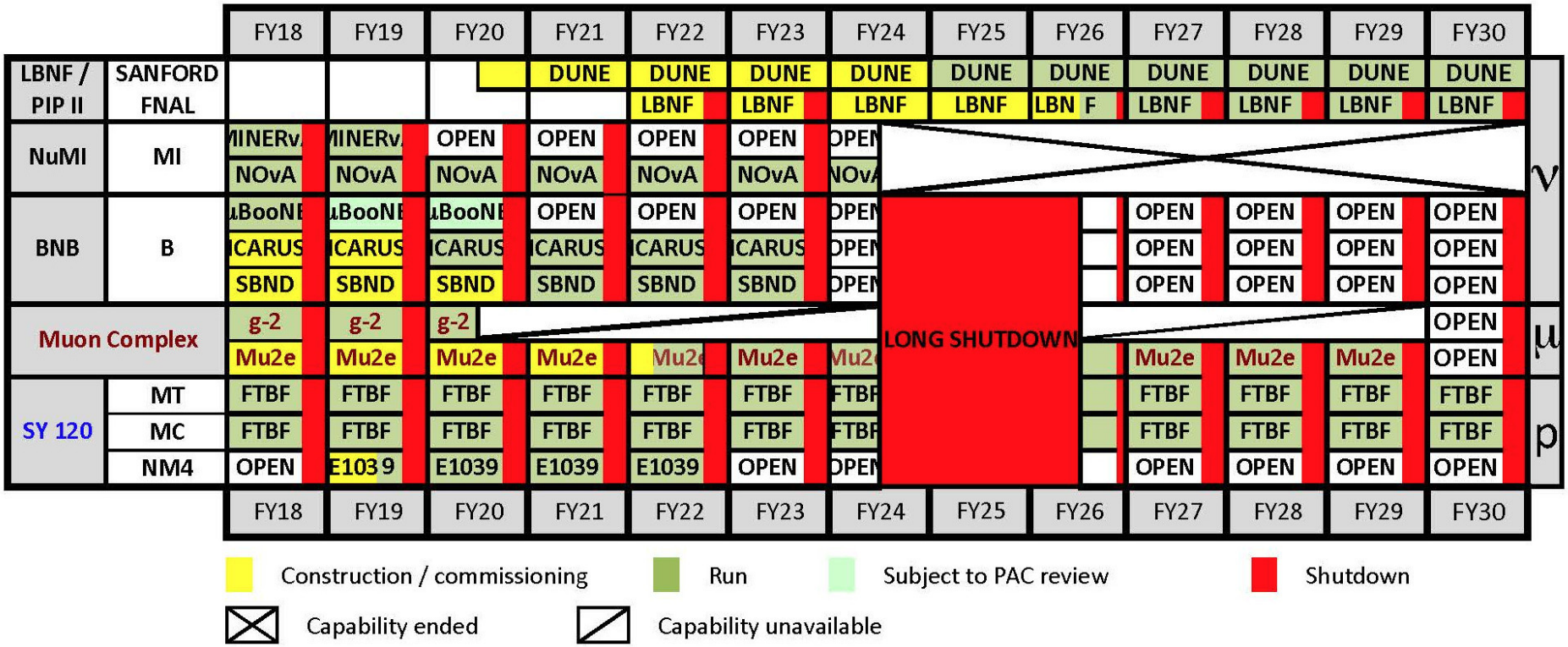
- Bad hodoscope channels repaired last year, hardware is ready to go
- Trigger logic should be optimized using real background data and improved signal MC
- Run dimuon dark photon search during E1039 commissioning and running
- Analysis should get a result quickly
  - Shoot for initial result (from first year's data) late 2019/early 2020

EMCal upgrade for dielectron trigger

- One PHENIX EMCal sector: 2×4 m^2 wall of Pb-scintillator shashlyks
- Simple energy threshold can trigger on non-MIP particles
- Track matching enables electron ID (reject $K_L^0 \to \pi^{\pm} e^{\mp} \nu_e$ mis-ID background)
- Requires some spectrometer reconfiguration — must be installed after E1039 is done



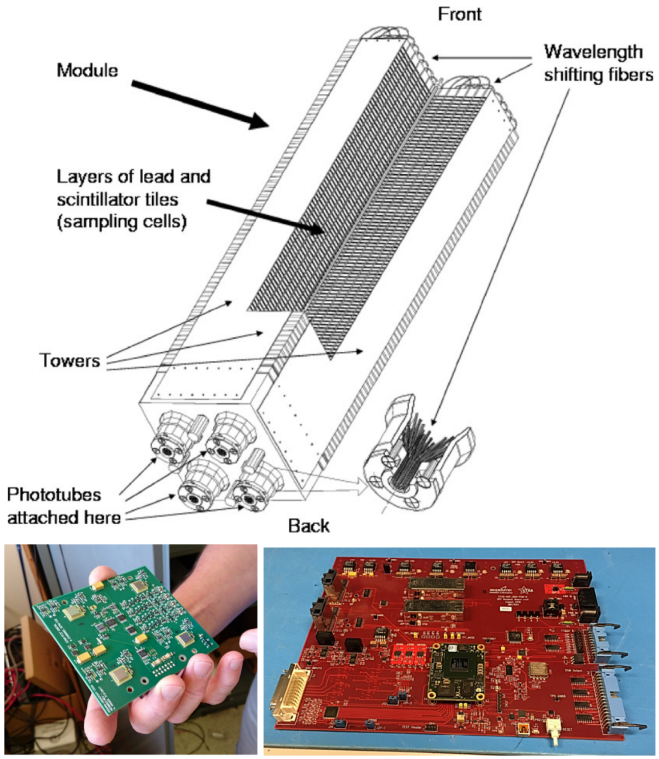
SeaQuest after E1039



- NM4 is unscheduled after E1039: new NP program possible, or dedicated HEP dark sectors program?
- Dark photon searches can run in either scenario

EMCal hardware status

- The two best sectors have been transferred (on paper) to LANL
- We have the full PHENIX readout system; investigating whether it can be directly reused for SeaQuest
  - Time structure (10 MHz vs. 53 MHz) is the main concern, but pileup is negligible
  - Alternative: STAR is developing an SiPM-based readout system with the same modules
- We have a set of EMCal modules, with the full electronics chain, at LANL



EMCal upgrade plans

- Install a small number of modules in SeaQuest to measure background rates
- Develop MC to understand our efficiency for triggering on electrons
- Brainstorm additional dark sector searches possible at SeaQuest, possibly with additional hardware or spectrometer reconfiguration
- Work on a letter of intent, gather HEP collaborators

A Letter of Intent to Search for Dark Sectors with the EMCal Upgrade of the SeaQuest Experiment at Fermilab*

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Abstract

In 2017, the parasitic dark sector physics search experiment SeaQuest/E1067 successfully installed and commissioned a new displaced dark photon di-muon trigger along with 10-fold improvement in SeaQuest DAQ bandwidth during the last run of the SeaQuest/E906 experiment. This upgrade allows the SeaQuest experiment to search for dark photons (and, more in general, for new displaced dark particles decaying into muons) in the mass range from 200 MeV to about 10 GeV, in a parasitic operation mode with the E906 and the upcoming E1039 experiments. Given the recent stage-II approval of the E1039 polarized fixed target experiment and the success of the dark photon trigger upgrade, we propose to further expand the dark sector physics program to particles with a mass below 200 MeV (di-muon mass limit) down to about 1 MeV, a two orders of magnitude improvement. This will be achieved via adding a new electromagnetic calorimeter (EMCal), recycled from the PHENIX experiment at BNL, before the station-4 muon identification absorber for electron identification. With this EMCal upgrade, SeaQuest will have an unprecedented discovery reach for a large set of New Physics models predicting resonant and non-resonant electron signatures. Leveraging the existing SeaQuest experiment, we will be able to carry out a very broad dark sector physics program, first parasitically with the E1039 polarized fixed target experiment at Fermilab in 2019-2021, and second with a dedicated experiment after the EMCal upgrade. These two phases of the experiment will produce world best and most timely searches for uncharted models with new dark particles in the mass range from about 1 MeV to 10 GeV.

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Help!

- “Our” theorists are very excited about SeaQuest and will support us, but the experimental side needs help
- I’m going to SENSEI (direct detection, low-mass DM), E1039 is already very tight on manpower
- Our immediate need is manpower for dimuon trigger optimization and analysis, then EMCal studies
  - Half a grad student would make a big difference, with an immediate payoff
- E1039 would love it if someone could help with detector commissioning while working on dark sector physics
- LANL group has no funding to work on this right now, though we have proposals in the pipe:
  - LANL LDRD
  - DOE HEP US-Japan program