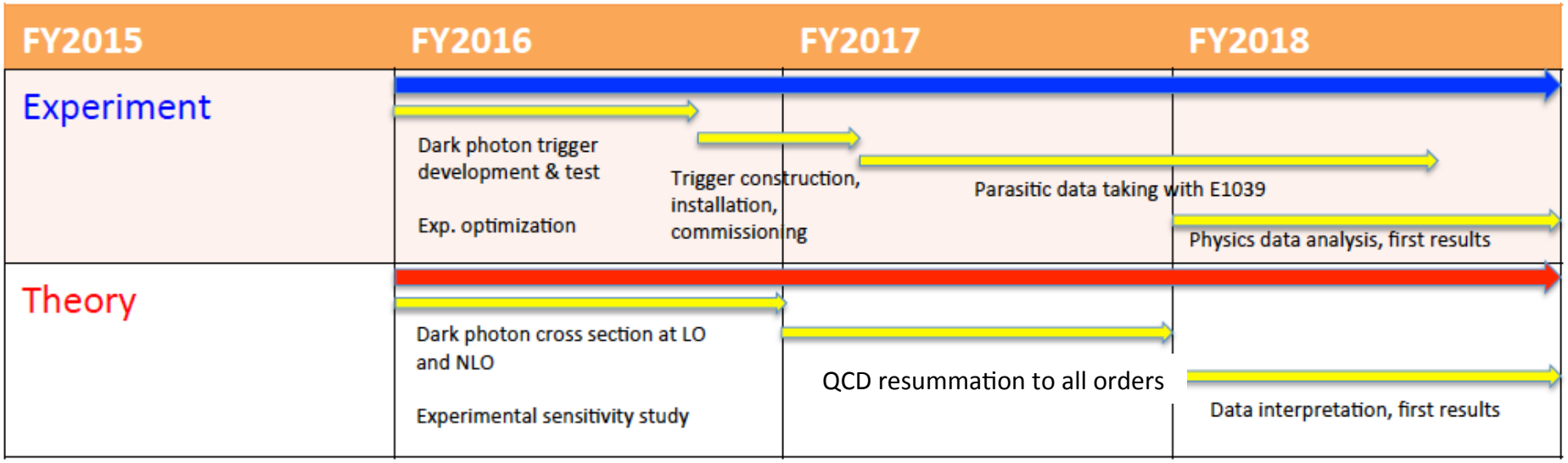
LDRD Tasks & Schedules

FY16: Accomplished all milestones and more!



Today, good work in progress

FY17 Hardware Effort

DAQ Upgrade

V1495 trigger algo implementation & Integration into DAQ

80/20 Al frame and detector assembly & testing @LANL

Safety review and detector installation @FNAL

SiPM readout Integration;

Trigger Commissioning with data

Offline analysis

Data taking, Offline analysis

Manpower:

Kun, PostDoc, Ming, Alex, Andi & Fermilab Engineer/collaborators

Hubert, Pat, Ming, PostDoc, Alex, Fermilab student/collaborators

Additional Engineer & Tech support (w/ $$) could help to reduce the schedule risk

FY-17 DAQ & Trigger Boards V1495 Integration and Commissioning

- DAQ upgrade
  - By the end of November
- V1495 and DAQ integration
  - By mid Feb 2017
- Trigger commissioning
  - By mid March 2017
- Data taking
  - April – July 2017
- Lead persons:
  - Kun, PostDoc (Sho), Ming, Alex, Andi and help from E906 collaboration and other postdocs

FY-17 Trigger Detector Construction & Installation

- Complete assembly and installed by mid of January 2017

- All major hardware in hand
  - Scintillators (at Fermilab)
  - WLSF (at LANL)
  - All 80/20 Al frames at LANL
    - 4 frames completed, 4 more (identical) to go
- Frames assembled at LANL, ship to Femrilab for final assembly in December-January 2016

- Fermilab mechanical structure safety review before installation
  - Kenney to help ?
  - Hubert, Ming
  - By mid of Jan 2017

- Lead persons:
  - Hubert, Ming, Alex, PD and help from Collaboration at Fermilab

SiPM readout and Services

- Fermilab premap cards production
  - Cost: 600 x $40 = $24K
  - By mid January 2017

- Discriminator and LV/HV PS
  - LeCroy 4413 and NIM crates available from Fermilab pool
  - Tested by the end of December
  - Reuse Fermilab HV PS and the 48-ch distribution cards (50~60V, I <500 x 10uA)

- Cables
  - Recycle from previous Fermilab experiments
    - Lemo cables, 550
    - 34-ch ribbon cables
    - By mid of January 2017

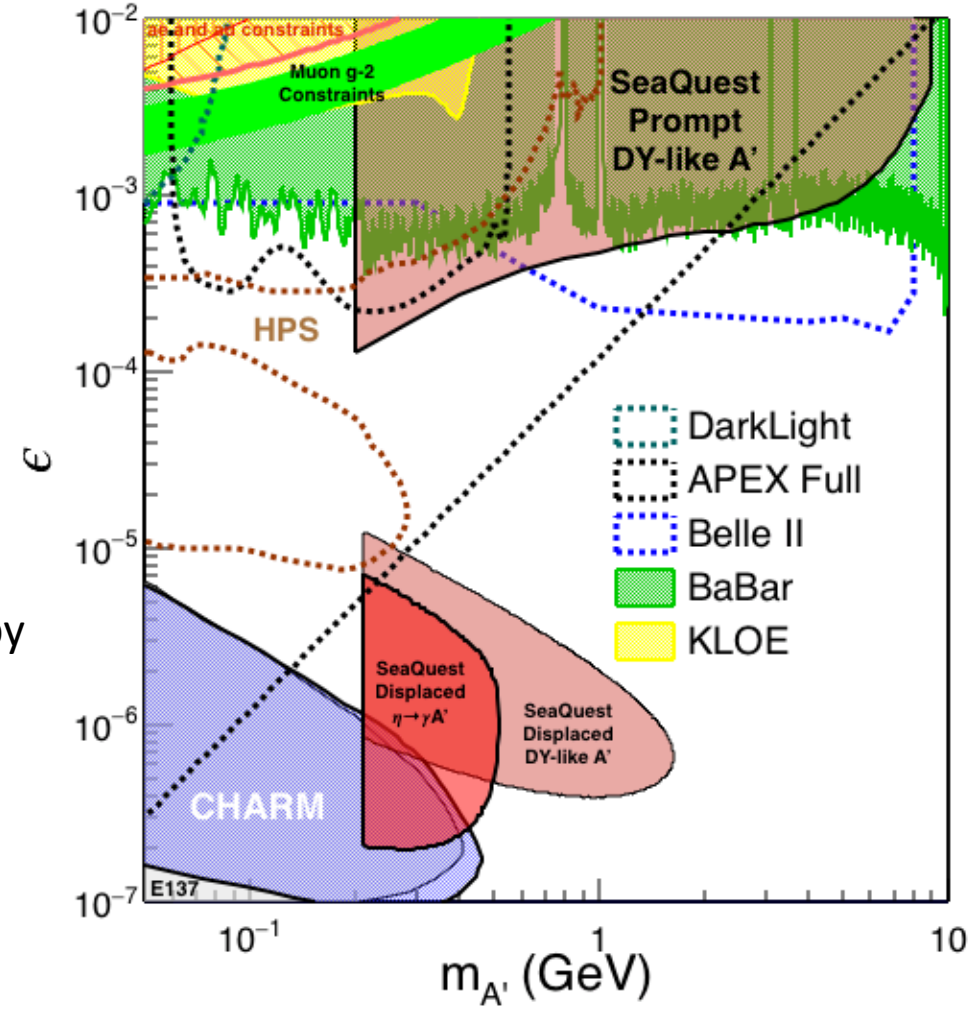
- V1495 and VME crate and Controller CPU
  - In hand, need to update firmware based on E906 trigger code
  - Integration starts early December, complete by mid Feb 2017

- New Taiwan TDCs
  - Being produced in Taiwan
  - available by the end of March 2017, partial delivery possible
  - Good to have items, but not absolutely needed for trigger

- Lead persons:
  - Ming, PD/Sho, Kun, Pat and Fermilab Engineer/Collaborators

Updated Sensitivity from the Expected the E906 2017 Trial Run

- April – July 2017, assuming 4-month (120 days) of parasitic running
- For prompt-DY-like dark photon search, the lowest ε reach is proportional to 1/sqrt(Lumi) (Lumi, the integrated luminosity)
- For displaced dark photon search, the case is more complicated:
  - The upper limit is primarily limited by the decay length (kinematics) as most data statistics will be in this region, and not very sensitive to the change of statistics
  - The lower bound is primarily limited by the cross section/statistics and thus is proportional to 1/sqrt(Lumi)



FY-17 Plan Summary

- Complete DAQ and Trigger upgrade for E906 Run-5
  - By March 2017
  - Parasitic data taking April – July, 2017 with E906
  - Lead people: Kun, PD(Sho), Andi and Fermilab collaboration (Engineer and students)

- Trigger detector construction at LANL and Fermilab
  - Mechanical structure safety calculation and documentation (LANL student Kenney?)
  - Fermilab safety review (by the end of 12/2016)
  - Ship to Femrilab in mid of January 2017
  - Installation (mid of January 2017)
  - Lead people: Hubert(10%), Ming(10%), PD(50%), Fermilab student(50%)

- Readout electronics & LV/HV services
  - Femrilab preamps production (by mid January 2017)
  - LeCroy 4413 from Fermilab, tested (by Mid Dec, 2017)
  - Lemo cables (520) and 17-ch ribbon cables (35)
  - Trigger detector installation and commissioning (Feb 2017)
  - Lead people: Ming, PD(Sho), Pat and collaboration (Fermilab and ANL)
-
- V1495 trigger look-up table implementation
  - MC simulation, Collaboration (Univ. Of Michigan)
  - PD (Sho), Kun

- Integration and commissioning trigger electronics system
  - Feb – March, 2017
  - PD(sho), Kun, Ming and collaboration

- Data taking and analysis

- Manppwer on project:
  - Kun(20%), PD(50%), Hubert(10%), Ming(10%), PD(50%), Fermilab student(50%) and Fermilab collaborators
  - Help from Andi, Pat and other PDs from the team ,

FY-18+ Plan

- Continue parasitic data taking with polarized Drell-Yan (E-1039) experiment in FY18 – FY19 as originally proposed.

- Carry out the first physics analysis using 2017 data and publish preliminary results

- Write a full Dark Photon and Dark Higgs Search proposal to Fermilab PAC for future dedicated runs with upgraded detector for many years to come
  - Include adding Electro Magnetic Calorimeter (EMCal) to measure low mass dark photons below dimuon mass threshold (200MeV, current lower mass limit on dark photon search)
  - Dedicated runs with much higher luminosity beyond 2017
  - Obtained two "free" EMCal sectors from PHENIX experiment at RHIC

- Received strong support from Fermilab PAC, Director and the Dark Sector Physics community on such proposal

Note on Fermilab future beam schedule:

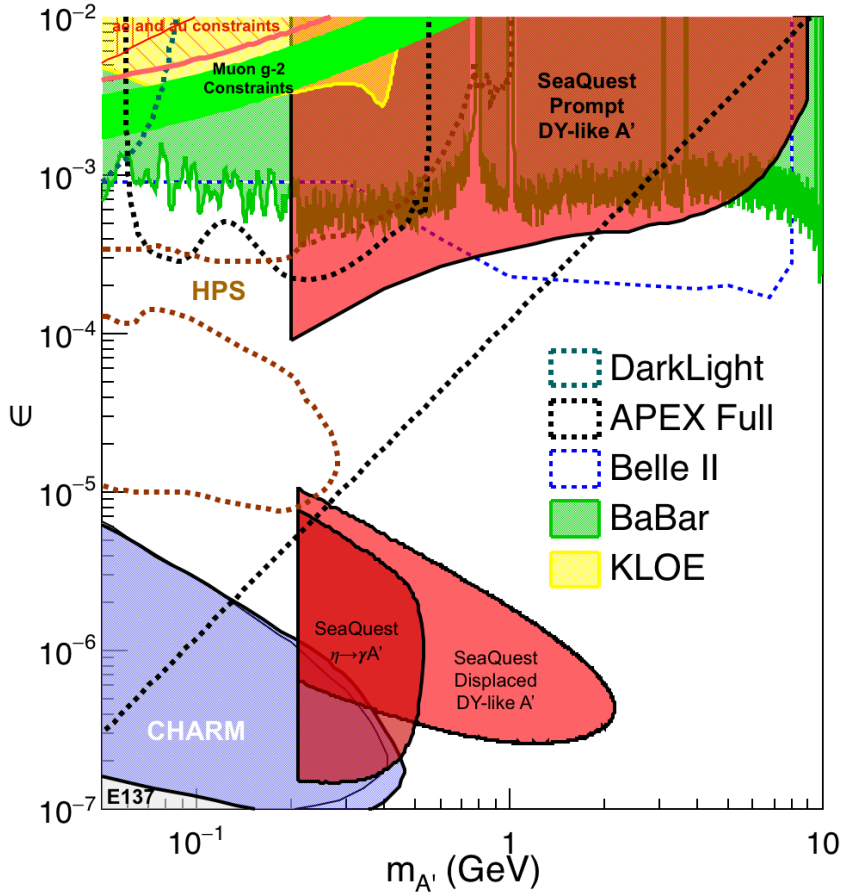
E1039 was originally planned to start data taking in ~May 2017, for two years. Recent changes of Fermilab's run plan due to limited budget requires additional external fund to install the polarized target and run the experiment. There is an on-going discussion between DOE–Fermilab to run E-1039 after summer 2017. A decisions will be made by DOE in January 2017.

Regardless of the outcome of DOE's decision on the polarized Drell-Yan running at Fermilab, we plan to write a full proposal to have a dedicated dark photon and dark Higgs program beyond 2017 using Fermilab High Intensity Frontier Facility, also seeking additional fund from DOE NP and HEP

Projected Sensitivity with 2-year Parasitic Run with Polarized Drell-Yan E-1039 Experiment

- Parasitic run with polarized Drell-Yan
  - 2018-2019

Assuming 2-yr (400 days) of parasitic running



If additional fund available in FY17…

- Given the uncertainty of future run beyond 2017 at Fermilab, it would be very helpful to have additional $$ and technical resource support to speed up the DAQ/ trigger upgrade to take maximal amount of data out of current 2017 E906 run

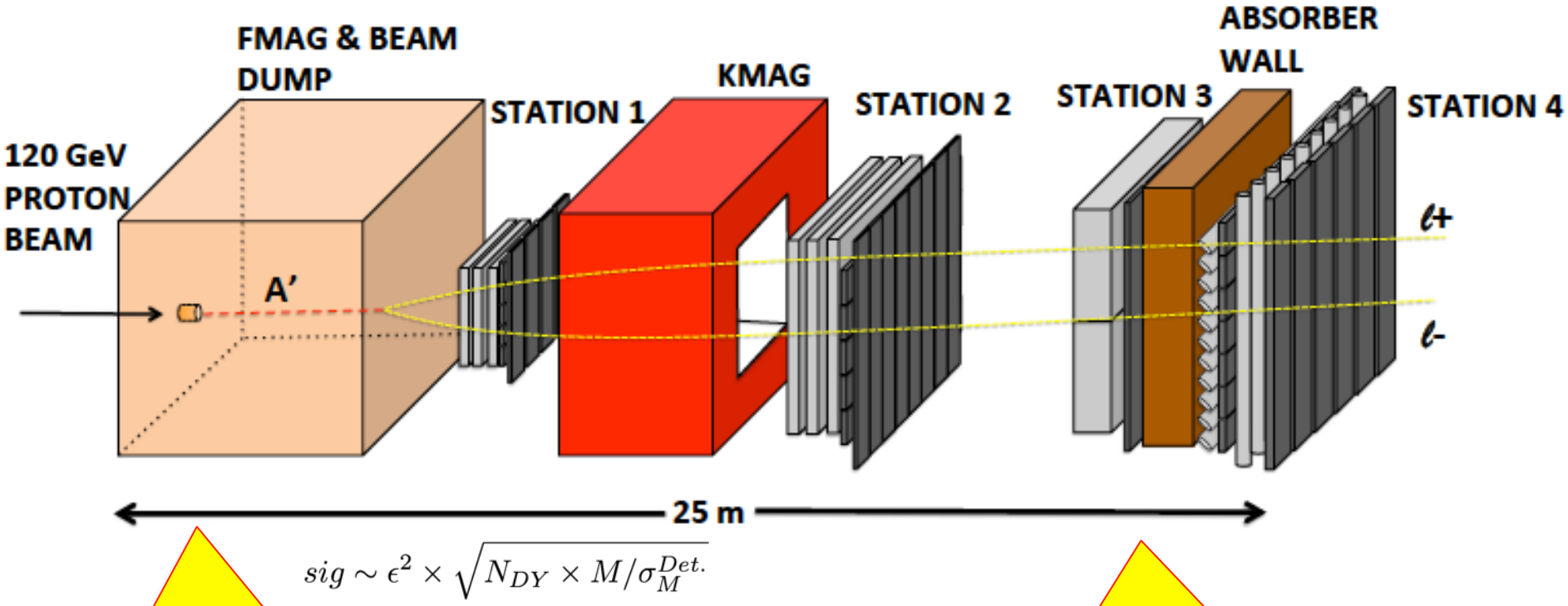
- More manpower could be used to speed up assembly, trigger algorithm development, testing readout and installation, in particular in the following tasks:
  - Trigger logic FPGA programing support
  - Electronic tech to help SiPM readout, LV/HV, installation and debugging
  - Mechanical engineer to complete the safety document for the Fermilab review

- Procurements of small items
  - Fiber-SiPM adaptors
  - Lemo and ribbon cables
  - Big frame to hold 4-frames per plane, detector pre-installation safety review

- Move PHENIX two EM Calorimter sectors from BNL to Fermilab, installed at SeaQuest after summer 2017.
  - Free from PHENIX, a ~$2M detectors, with PMTs and HV PS
  - Shipping cost ~$10K

E-1067 Future Upgrade: New Idea

2018 ~ 2025+



$$sig \sim \epsilon^2 \times \sqrt{N_{DY} \times M/\sigma_M^{Det.}}$$

Add tracking detectors close to "target" to improve mass resolution

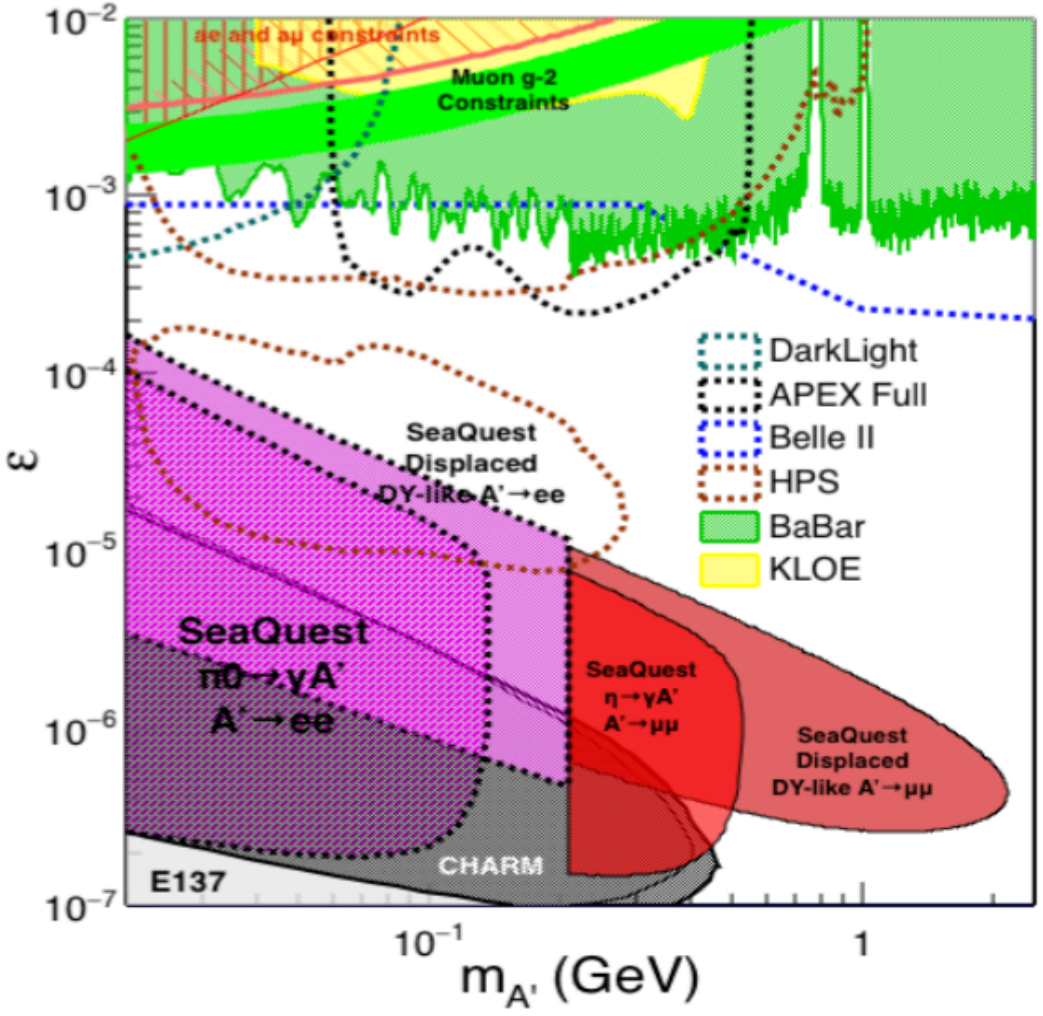
Add EMCal (recycled from PHENIX at RHIC) to identify $e^{+/-}$, $h^{+/-}$, $\pi^{+/-}$

Displaced Low Mass Dark Photons

with EMCal upgrades

- Detector upgrades
  - EMCal: $e^{+/-}$
  - HCal: $\pi^{+/-}$
  - Recycle from other experiments, PHENIX/RHIC etc
- DAQ upgrade
  - 100+ kHz
- Timeline of runs
  - 2018+
- Detector configuration
  - Access low mass region with optimized Fmag settting

Projection: POT 1.4 x 10^{18}

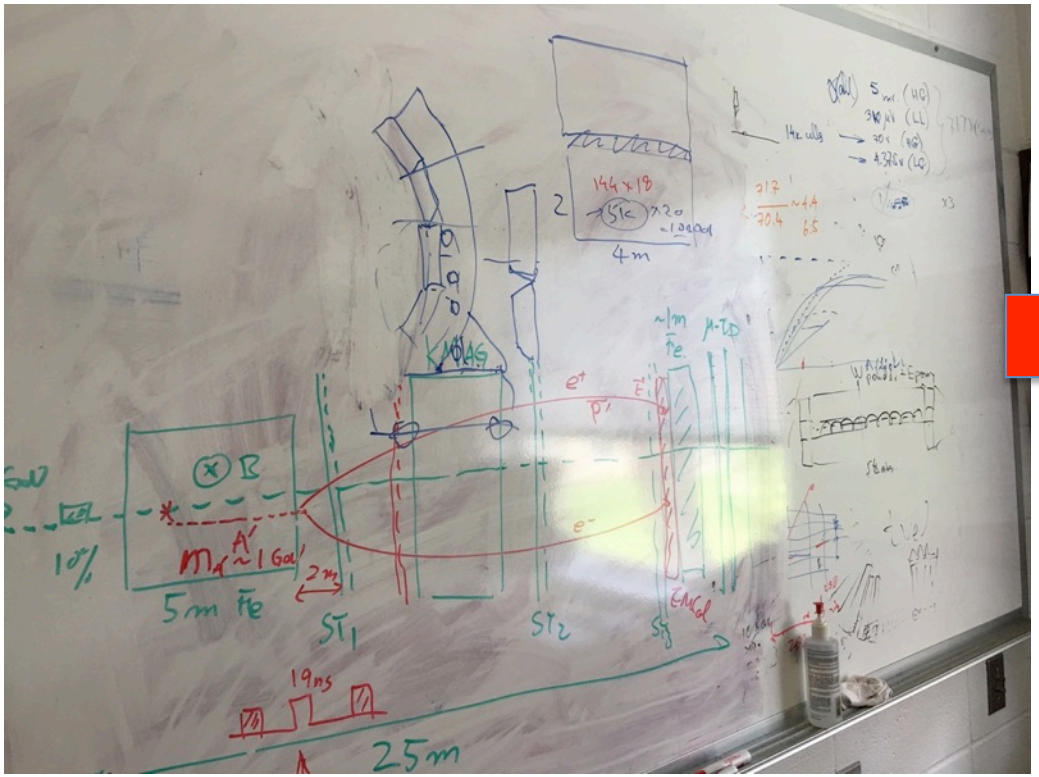


EMCal Identified from PHENIX/RHIC

- 2 EMCal sectors are available from PHENIX experiment at RHIC, ~end of 2016
  - one EMCal sector is made of:
    - 2m x 4m, 18 (3x6)super modules
    - Super module = 36 modules; Module = 4 towers
    - 36 x 4 x 18 = 2592 channels
    - Could gang 2x2 (or 3x3) into one ADC/TDC readout

Available in summer 2017 for installation at Fermilab

- *dE/E = 8.1%/sqrt(E) + 2.1%*
- *dT < 200 ps*
- *Excellent e/pi separation*



Projected Dark Higgs Sensitivity

POT:1.4x10^{18} (Phase-I)

- Dimuons with downstream displaced decay vertices
- Limited sensitivity to "prompt" large mixing case due to small cross-section
- Dark Higgs or dark photons?
  - Dimuon kinematic and angular distributions
- Phase-II
  - Dedicated high luminosity runs optimized for low mass acceptance, mass<3GeV

Y. Zhang (2015)