DarkLight Radiation Backgrounds

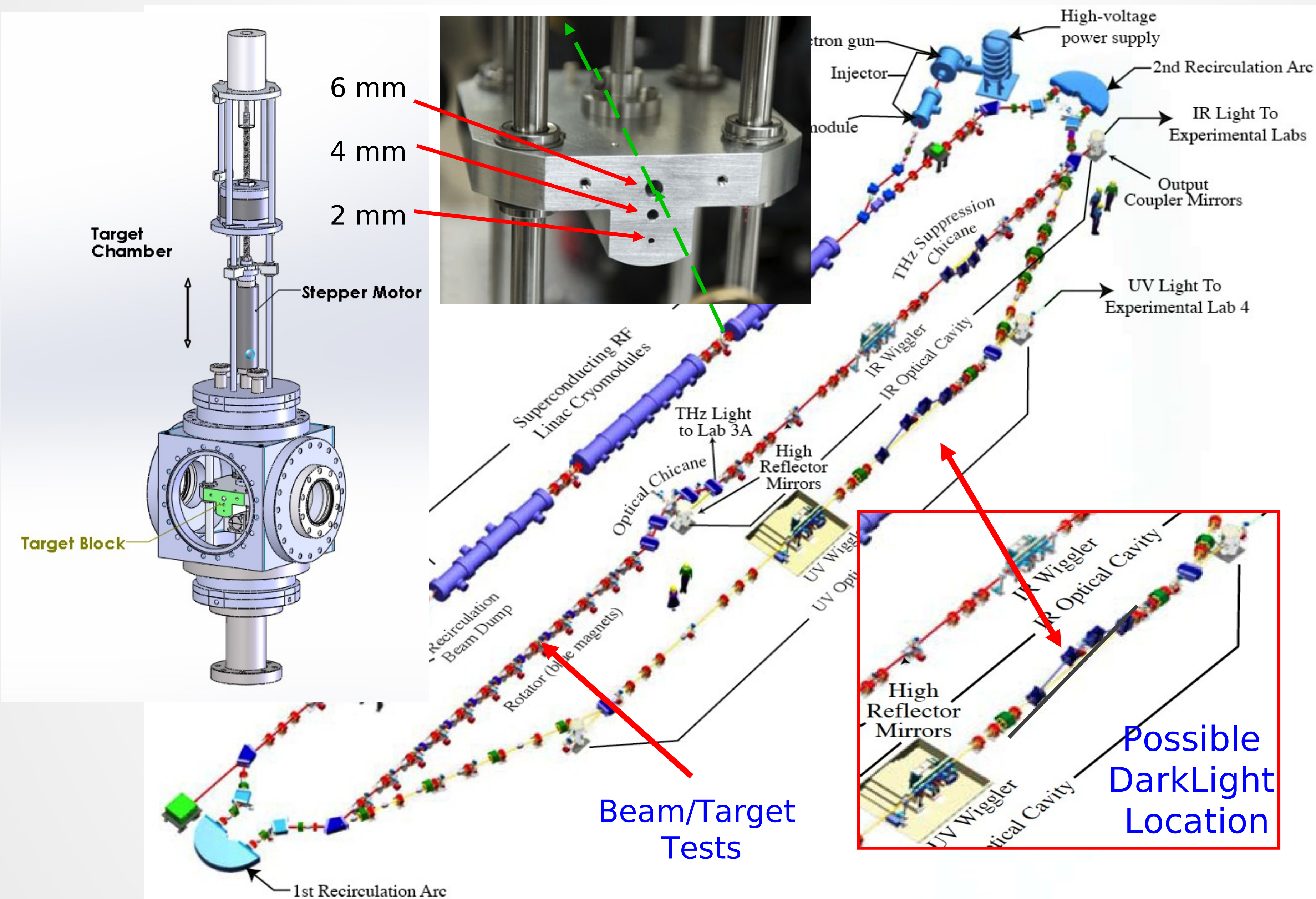
Narbe Kalantarians
Hampton University

PEB Workshop @MIT
15 March 2013

Outline

- The July 2012 beam transmission test (overview)
- Rad background monitoring setup and logging
- Measured neutron and photon monitor dose rates
- Energy spectra from NaI monitors
- Goals for acceptable noise performance in DL trackers
- Conclusions

DarkLight: Beam Tests

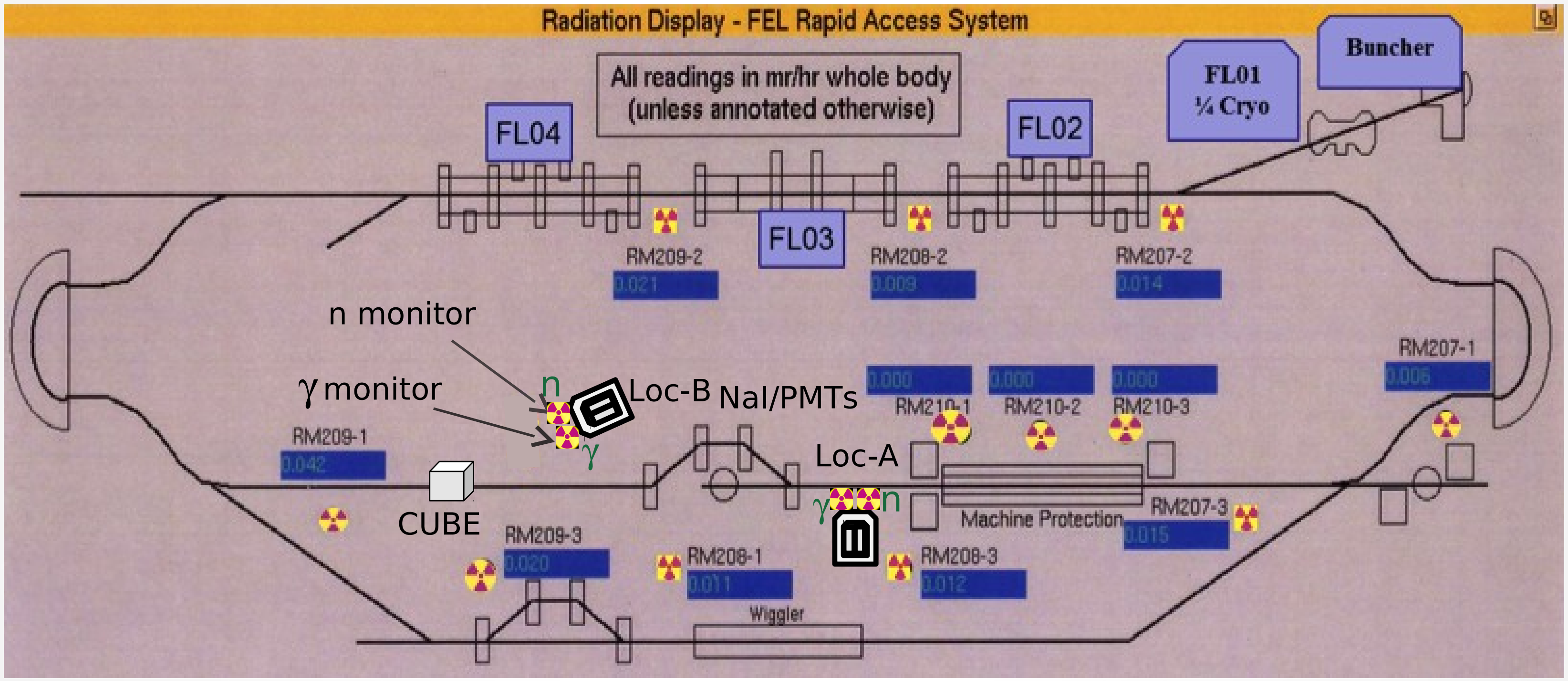


Beam Tests Results

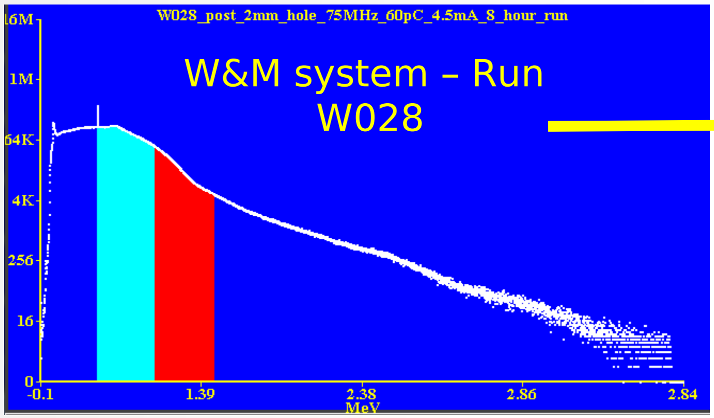
A test e^- beam 100 MeV, 4.5 mA (450 kW power) was successfully transmitted through a 2mm hole, 12.7 cm long, with max loss of 3 ppm for 7 hours. This showed that

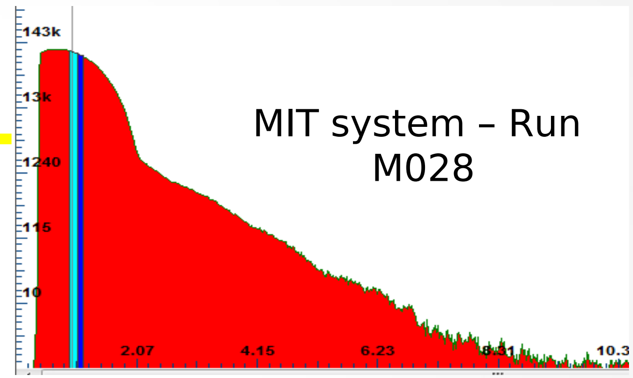
- e^- beam bunch CAN be threaded through a 12.7 cm long, 2 mm hole.
- Halo CAN be minimized.
- The FEL has the stability required for a successful DarkLight experiment.
- Radiation in the vault is manageable.

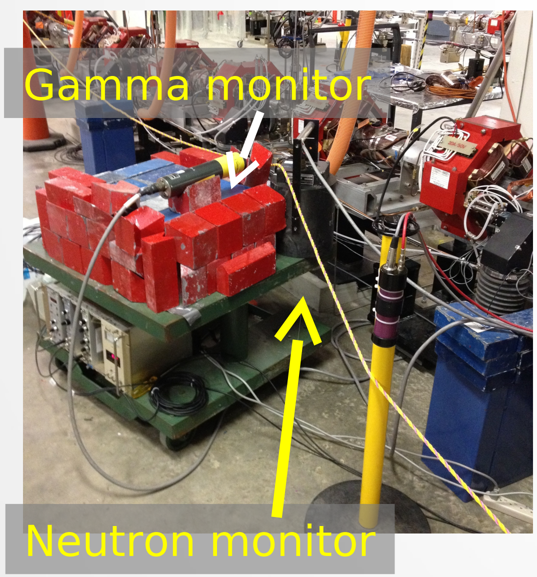
FEL Rapid Access System

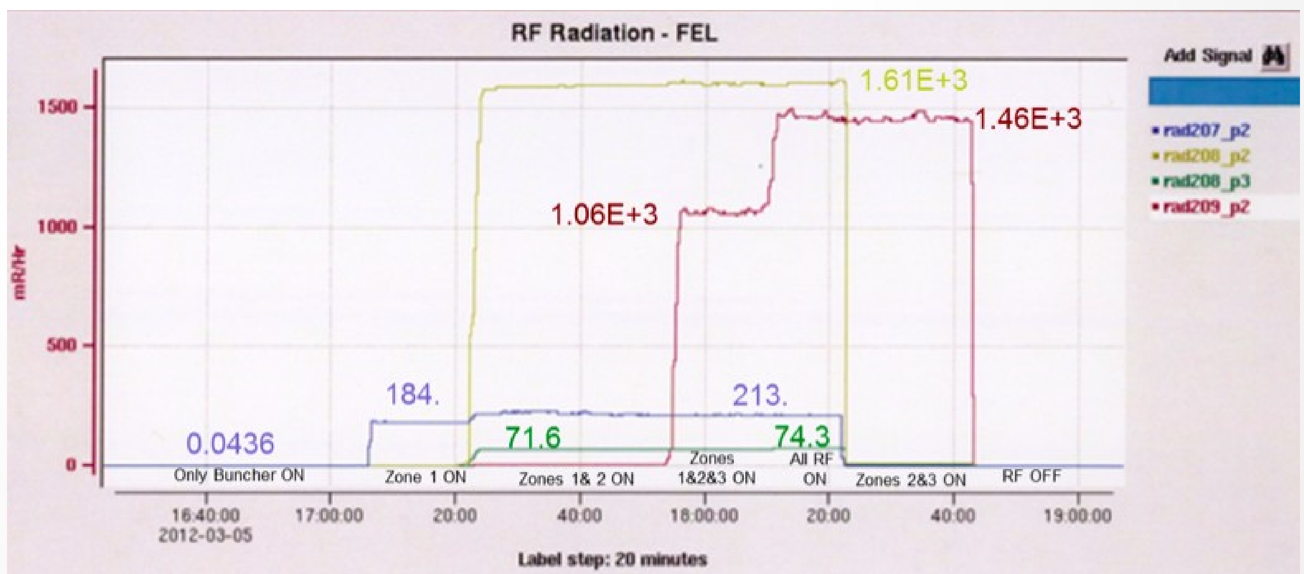


FEL Vault Background Radiation

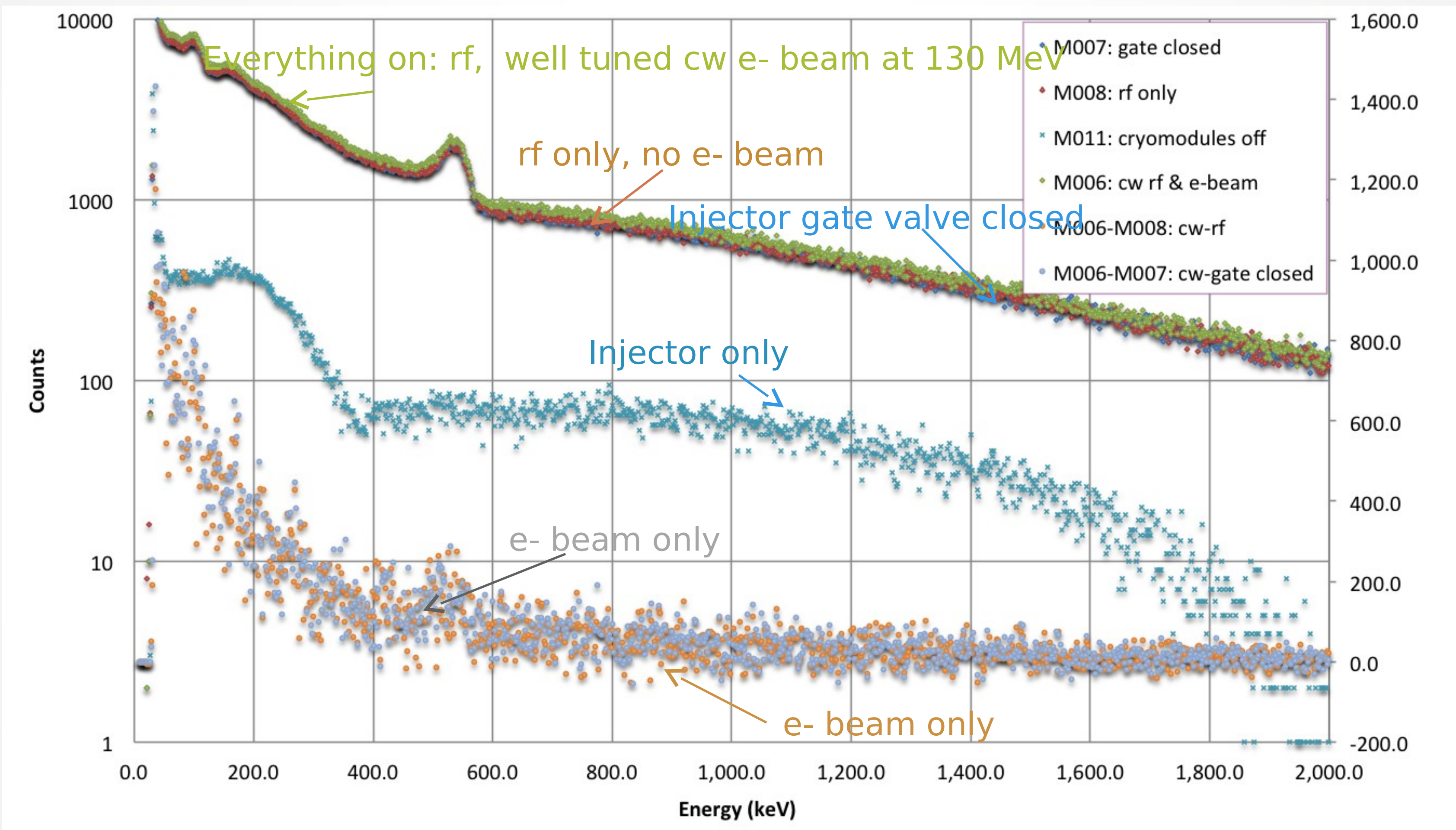






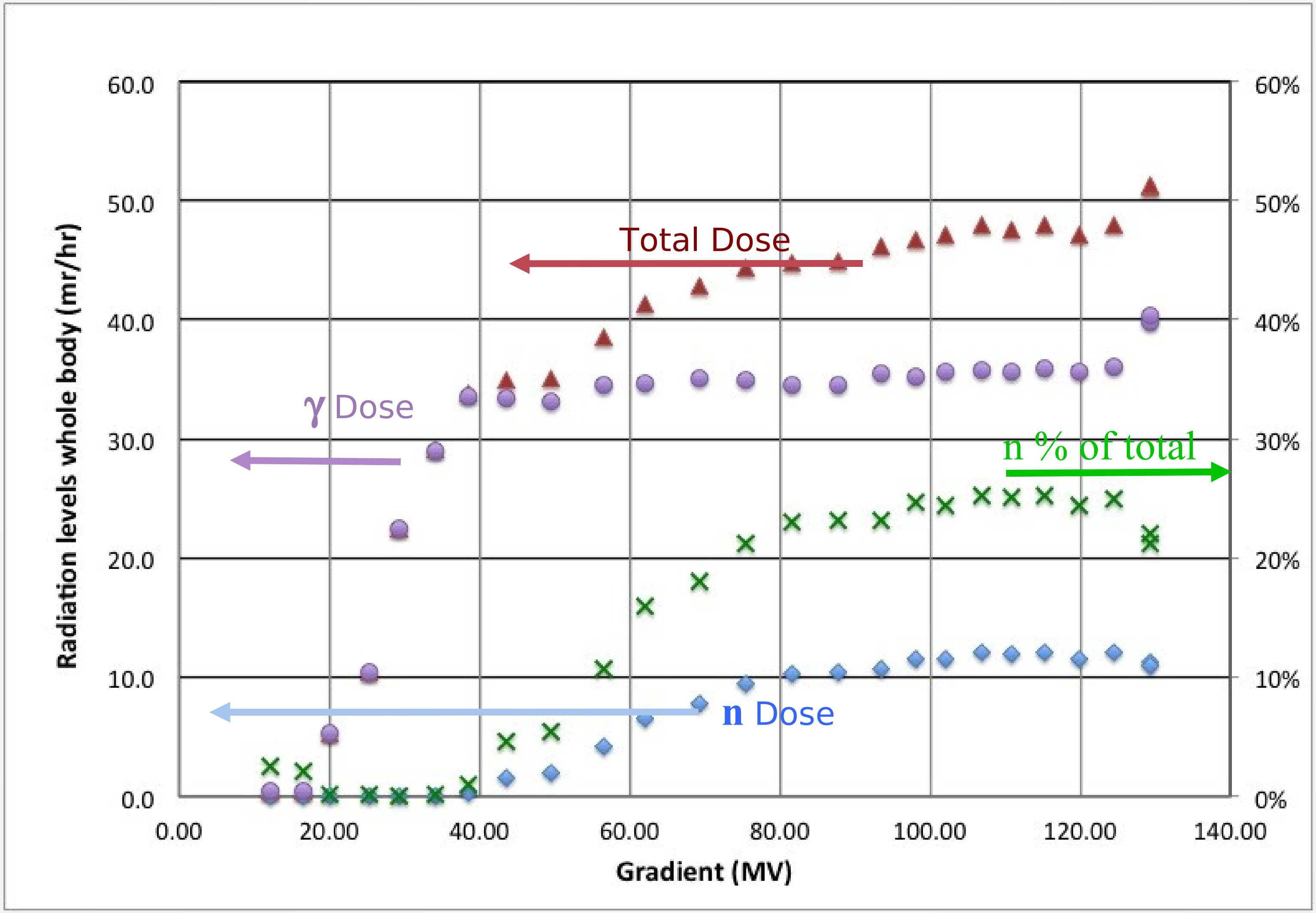


Vault Photon Radiation

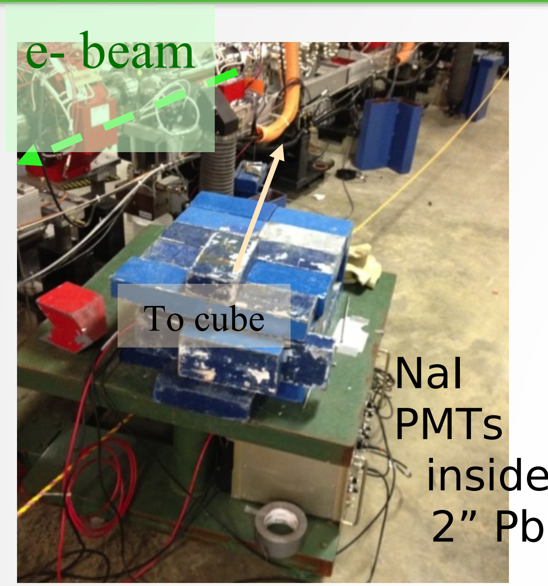


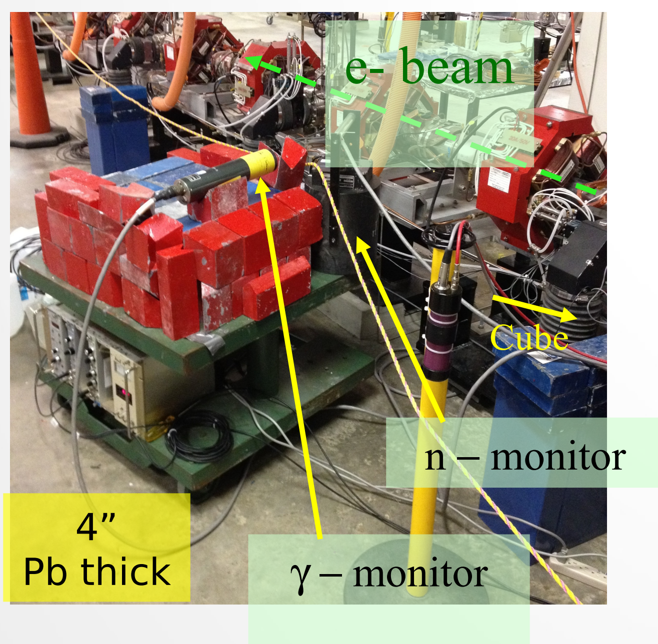
Tuned e- beam

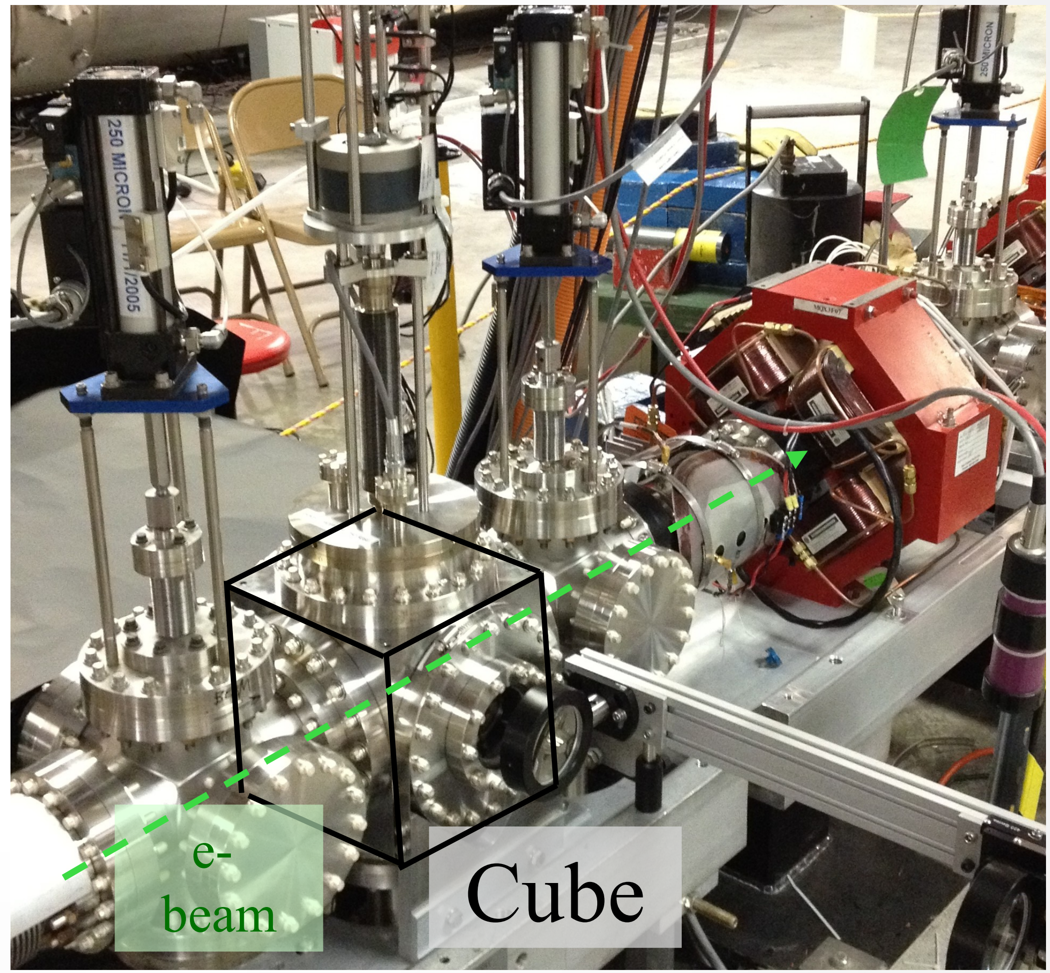
FEL Vault Radiation Levels vs. Total RF Gradient



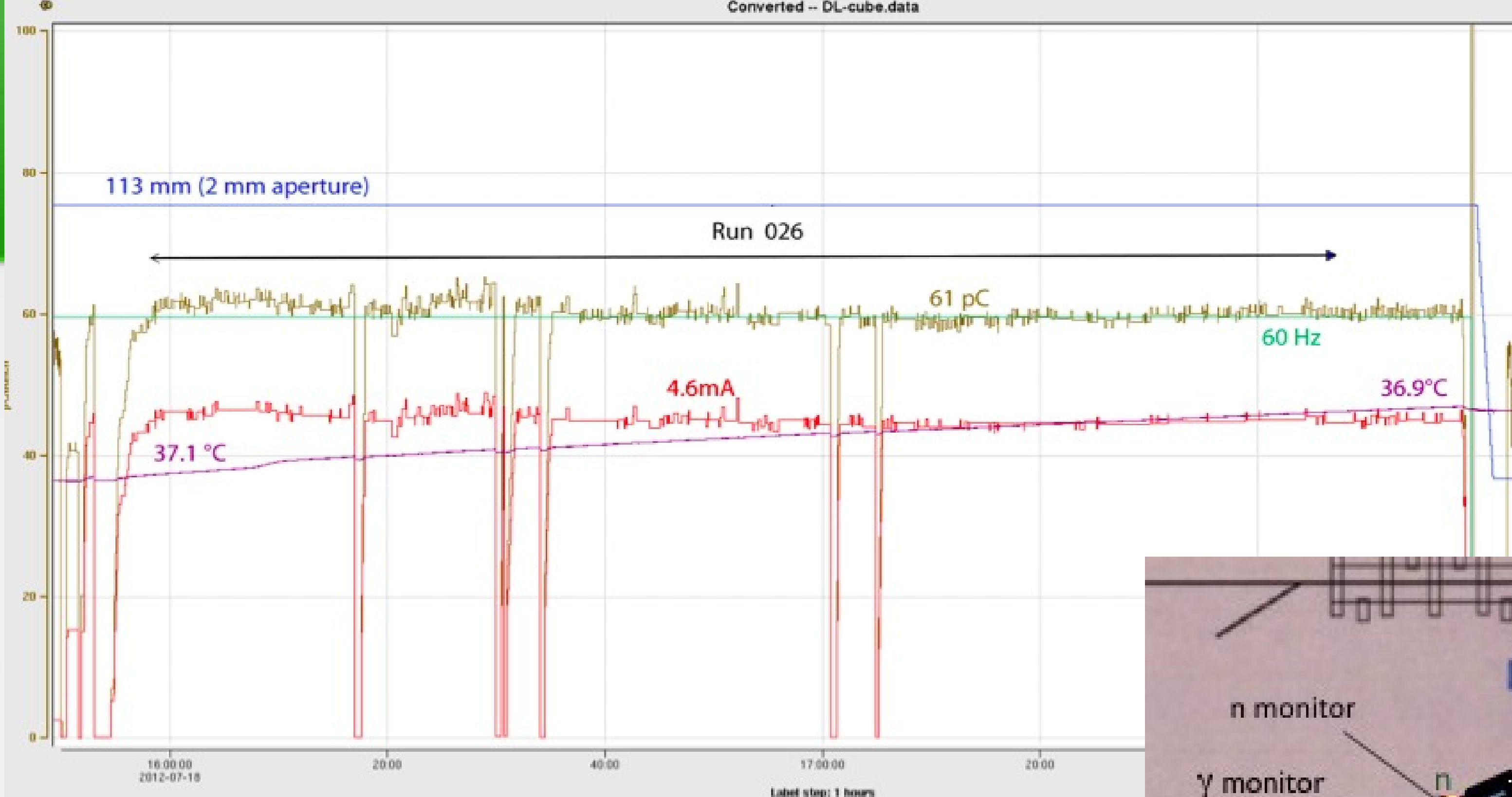
FEL Beam-Target Tests & Radiation Measurements

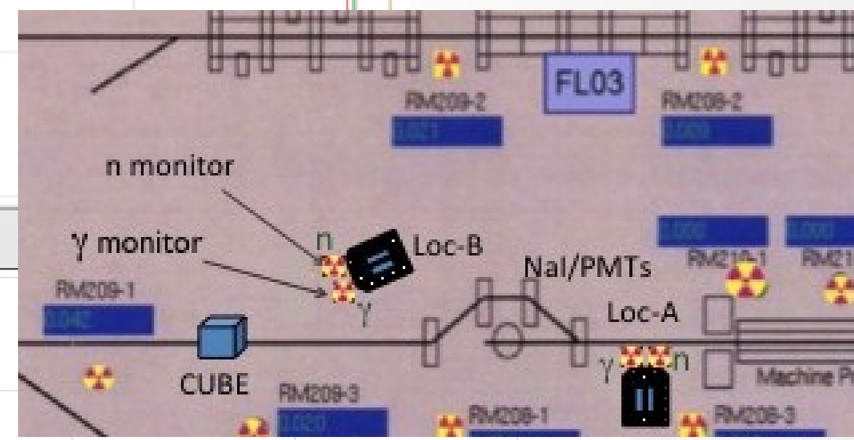


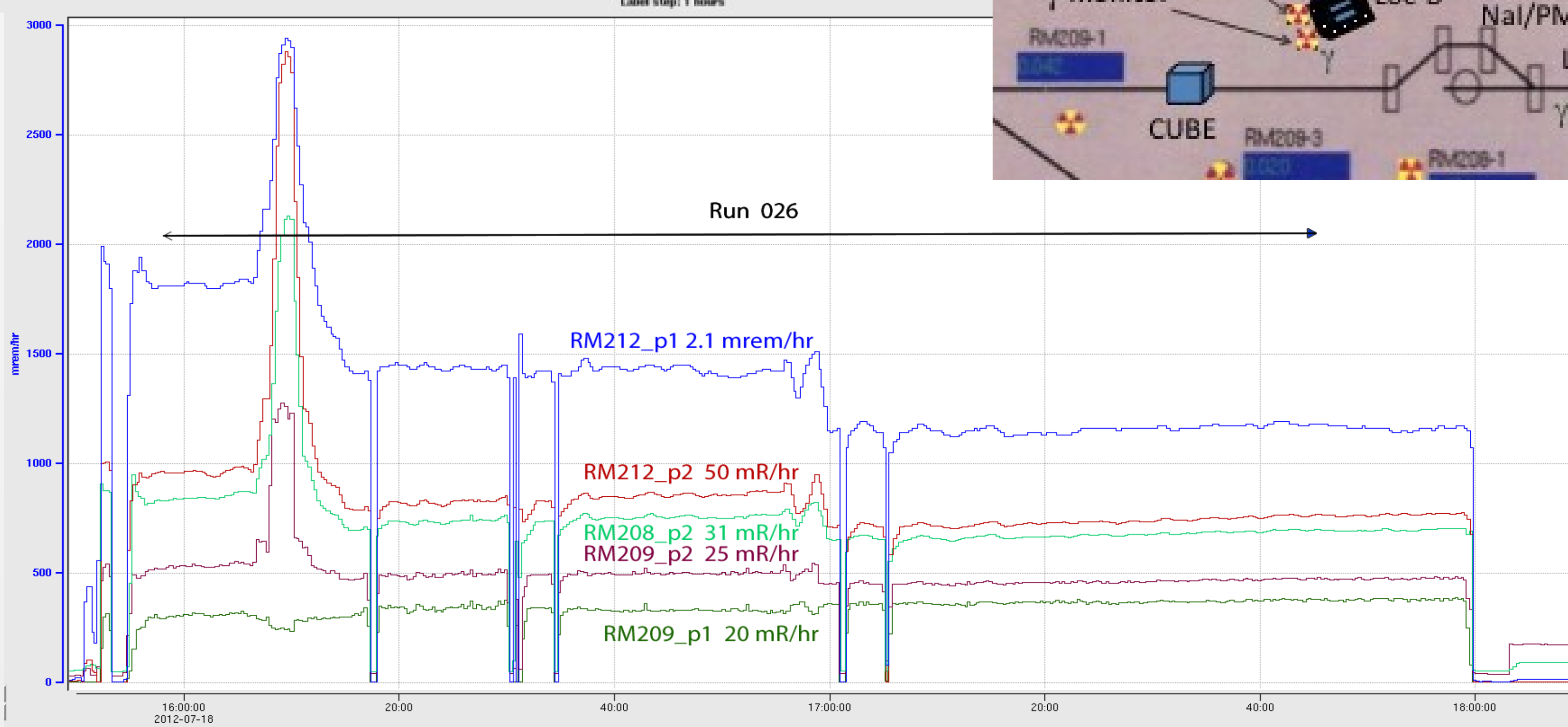




DL Run 26 Location B







TPC Tracker with Background Noise

- DarkLight design calls for
  - I. GEM-TPC lepton tracker
    - a) Inner radius 5 cm, outer radius 30 cm
    - b) Approximately 10,000 channels
  - II. Single layer silicon microstrip detector
    - a) 4 cm from the beam
- To move ahead with design of DarkLight
  - I. Need to understand the effect of backgrounds on these devices
    - a) From beam interaction with the target
    - b) From the FEL machine itself (vault backgrounds)
  - II. Estimate performance of trackers with different levels of noise
  - III. Estimate potential radiation damage to inner silicon tracker and electronics

I.

Radiation Background Types

- Divide backgrounds into two classes
  I. Directly from beam halo interaction with the test cube
  II. General vault backgrounds from the machine
      a) Not associated with beam interaction with test cube
- Vault backgrounds were studied earlier in 2012
- Dose rates are typically < 100 mr/hr for photons and neutrons combined
  I. Away from the RF cavities, near the IR line
  II. Small compared to rates from interaction of beam with target cube but not negligible
  III. Estimate in progress of additional shielding needed (if any)
  IV. Used 4” of Pb shielding.

Photon Flux Estimates with Test-Cube

- Photon flux estimates from data taken during the beam test with the NAI/PMT detectors are shown in the table (next slide)
  - I. Fluxes are at 1.9 m downstream of cube target and 0.8 m to the side of the beamline
  - II. For photons from 100 keV to 15 MeV
  - III. Does not include photons below 100 keV
    - a) Limited by NAI/PMT thresholds and live time
    - b) Lower energy photon rate much higher but of less importance
- Neutron fluxes are smaller
  - I. But not negligible and need further study
- Measurements limited to single location downstream of the test cube
  - I. Need more data about angular distribution of backgrounds inside the detector

NaI Count Rate: 0.5-1.5 MeV

Aperture/running condition	**Count Rate (Inside Pb Shielding)**
6 mm @ 75 MHz, 60 pC/pulse	1.13×10^{3} cm^{-2} sec^{-1}
4 mm @ 75 MHz, 60 pC/pulse	1.91×10^{3} cm^{-2} sec^{-1}
2 mm @ 75 MHz, 60 pC/pulse	5.04×10^{3} cm^{-2} sec^{-1}
RF only, no beam	1.97×10^{2} cm^{-2} sec^{-1}

MIT NaI; live-time 50%

NaI Count Rate: 0.5-1.5 MeV

Aperture/running condition	**Count Rate (Inside Pb Shielding)**
6 mm @ 75 MHz, 60 pC/pulse	6.02×10^{3} cm^{-2} sec^{-1}
4 mm @ 75 MHz, 60 pC/pulse	9.26×10^{3} cm^{-2} sec^{-1}
2 mm @ 75 MHz, 60 pC/pulse	1.23×10^{4} cm^{-2} sec^{-1}
RF only, no beam	1.39×10^{3} cm^{-2} sec^{-1}

W&M NaI; live-time 20% (some saturation)

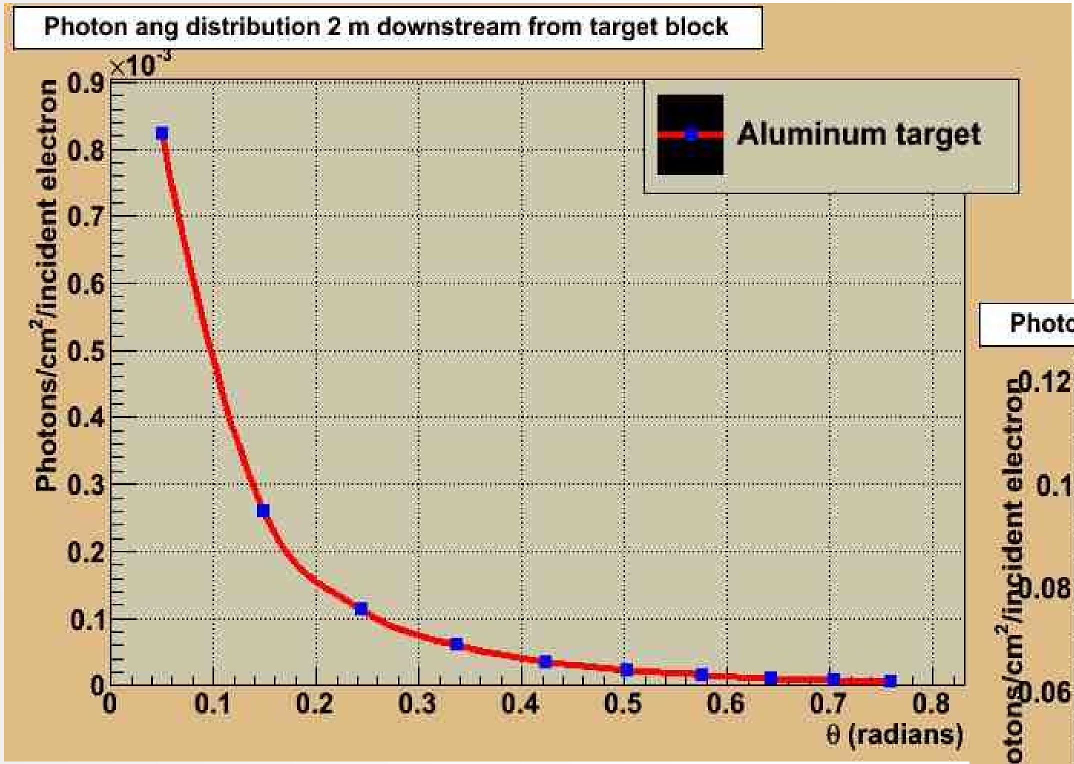
Background Simulation Studies

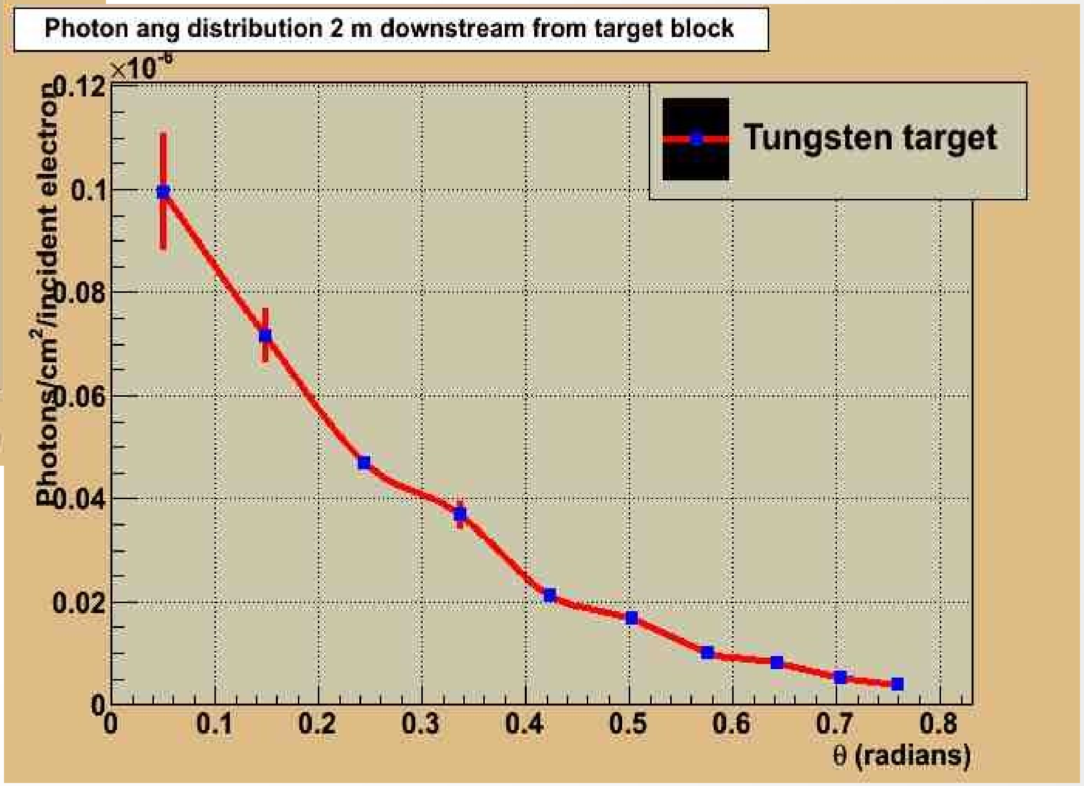
I. FLUKA/FLUGG simulation study is underway

  I. Using similar technology as used for the 2011 Atlas cavern backgrounds study

- Goals
  I. Simulate beam interaction with test cube target
    a) Compare measurements from July beam test with simulation results
  II. If reasonable agreement, re-run simulation with DarkLight inner detector geometry
    a) Obtain estimates of photon and neutron background rates
      i. As function of energy and angle
- Understand implications of simulation for the detector design
  I. As noted in the beam test executive summary document, several avenues for improvement of running conditions and reduction of backgrounds exist
  II. It will likely be important to take advantage of these to obtain the lowest background rates feasible

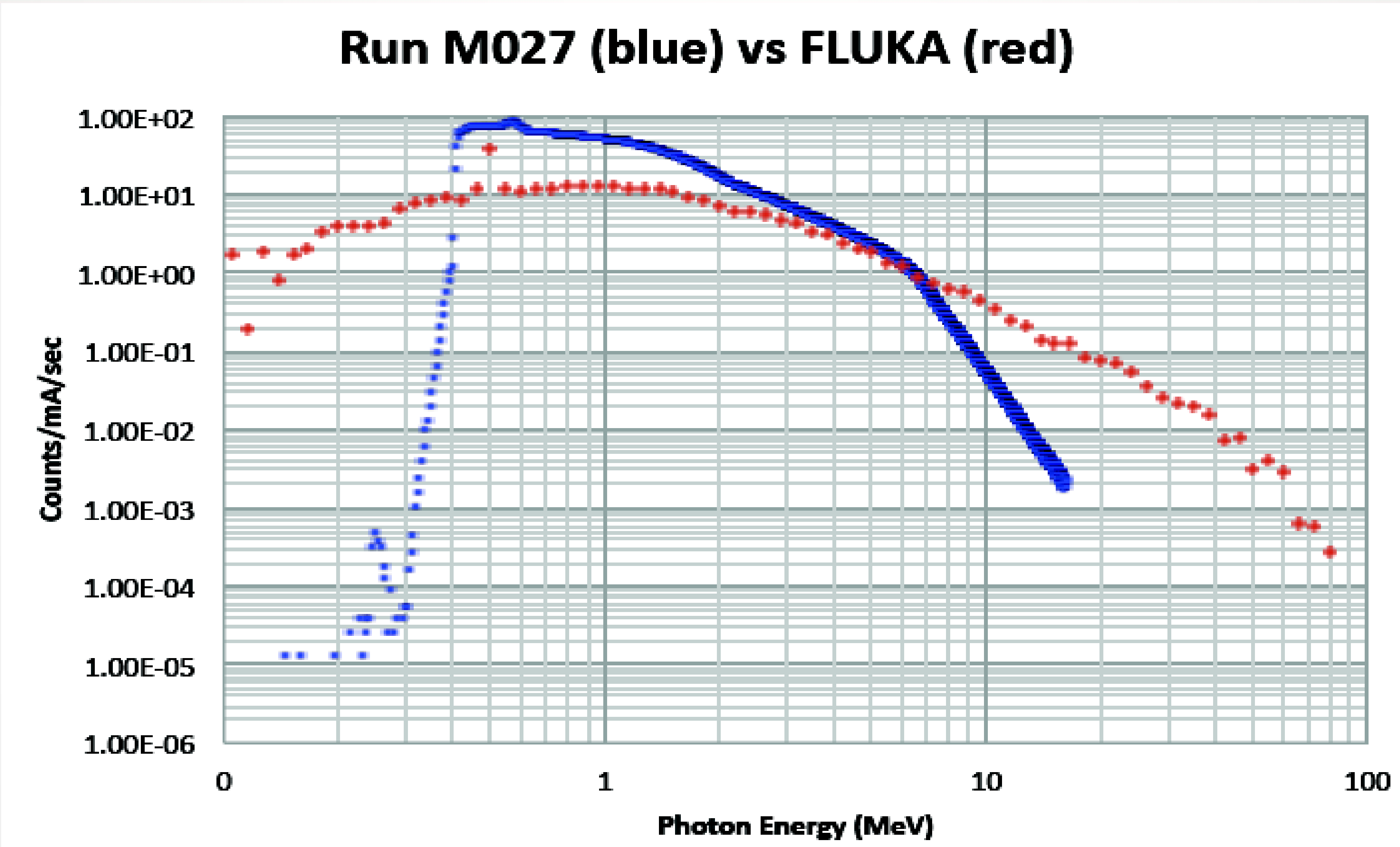
FLUKA Study





Flux ratio for W/Al ~10^{-4}

FLUKA Study



FLUKA counts are those incident on NaI, inside shielding

Background from Collimator

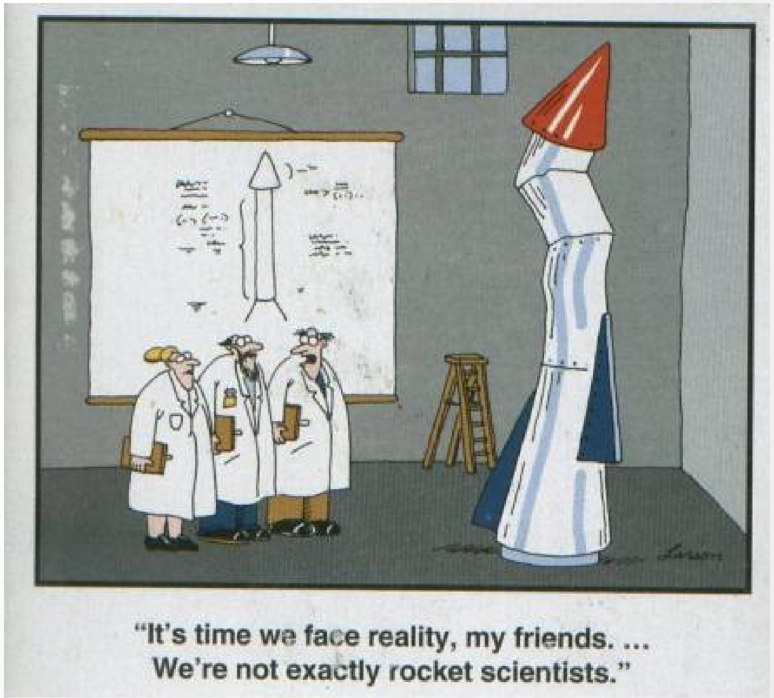
- Neutrons
  I. 100 MeV, 10 mA e- beam acting on W produces 2.5×10^{15} neutrons/s .
  II. Beam halo 5 ppm, intercepted by W, would produce enough neutrons to create 6.25×10^{7} secondaries at 5% yield.

- Electrons
  I. Multiple scattering halo e-, from W-entrance, calculated -> 40 mrad.
  II. Fraction of halo scattered depends on radius *R* of halo
    a) ~ few percent for $R > 0.2$ mm, decreases as *R* increases.
    b) We measured 5ppm, for 100 MeV & 10 mA, deposits ~5×10^{8} e-/s in dump.

* C. Tschalaer's D.L. T.N.

Radiation Backgrounds Team

- J. R. Boyce, R. F. Cowan, J. Kossler, E. Long, B. Schmookler, NK.
- Plus a lot of good work by A. Kelleher.

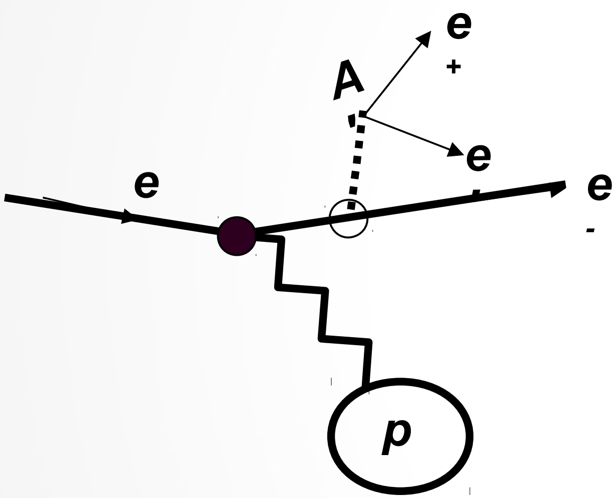


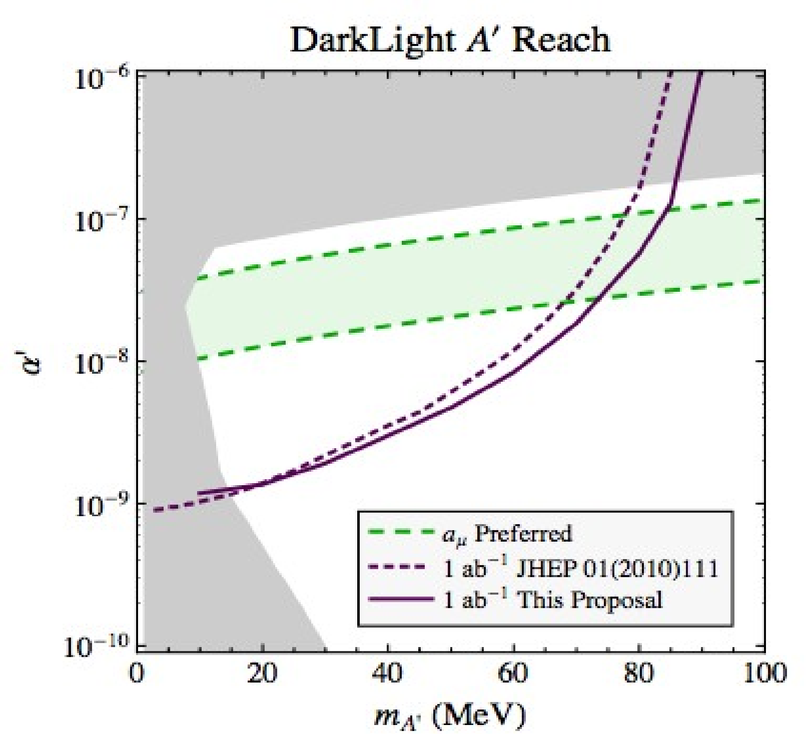
Support Slides

DarkLight: Goal

Detecting **A** **R**esonance **K**inematically with eLectrons **I**ncident on a **G**aseous **H**ydrogen **T**arget

A Search for new light bosons using the Jefferson Lab FEL facility.





$$\alpha' \equiv \varepsilon^2 \alpha\,,\ \ (\alpha = e^2/4\pi)$$

Goal: Explore e^+-e^- invariant mass spectrum using the process $e^- + p \rightarrow e^- + p + e^- + e^+$

High Intensity, Low Energy Electron Beam

Using JLab's FEL on Thick Hydrogen Gas Target

==> Luminosity: 1 ab^{-1}/month

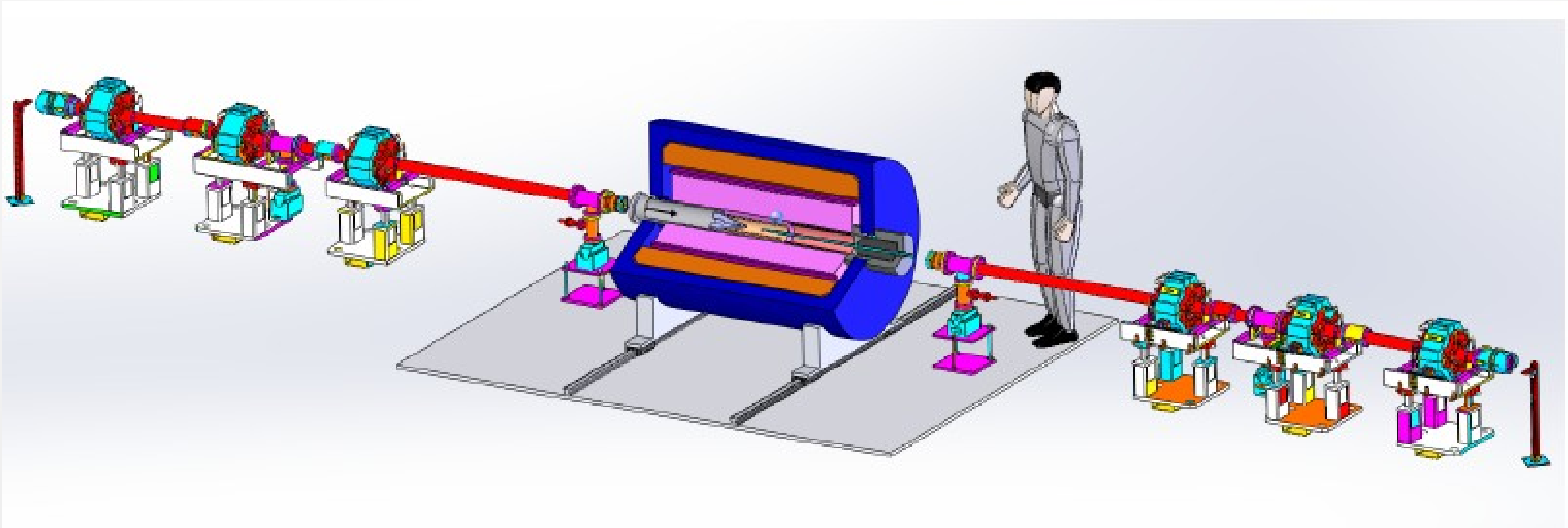
(Formal request ~60 days)

"Dark Force Detection in Low Energy e-p Collisions"
[Freytsis, Ovanesyan, Thalar: arXiv:0909.2862 (JHEP 1001;111)]

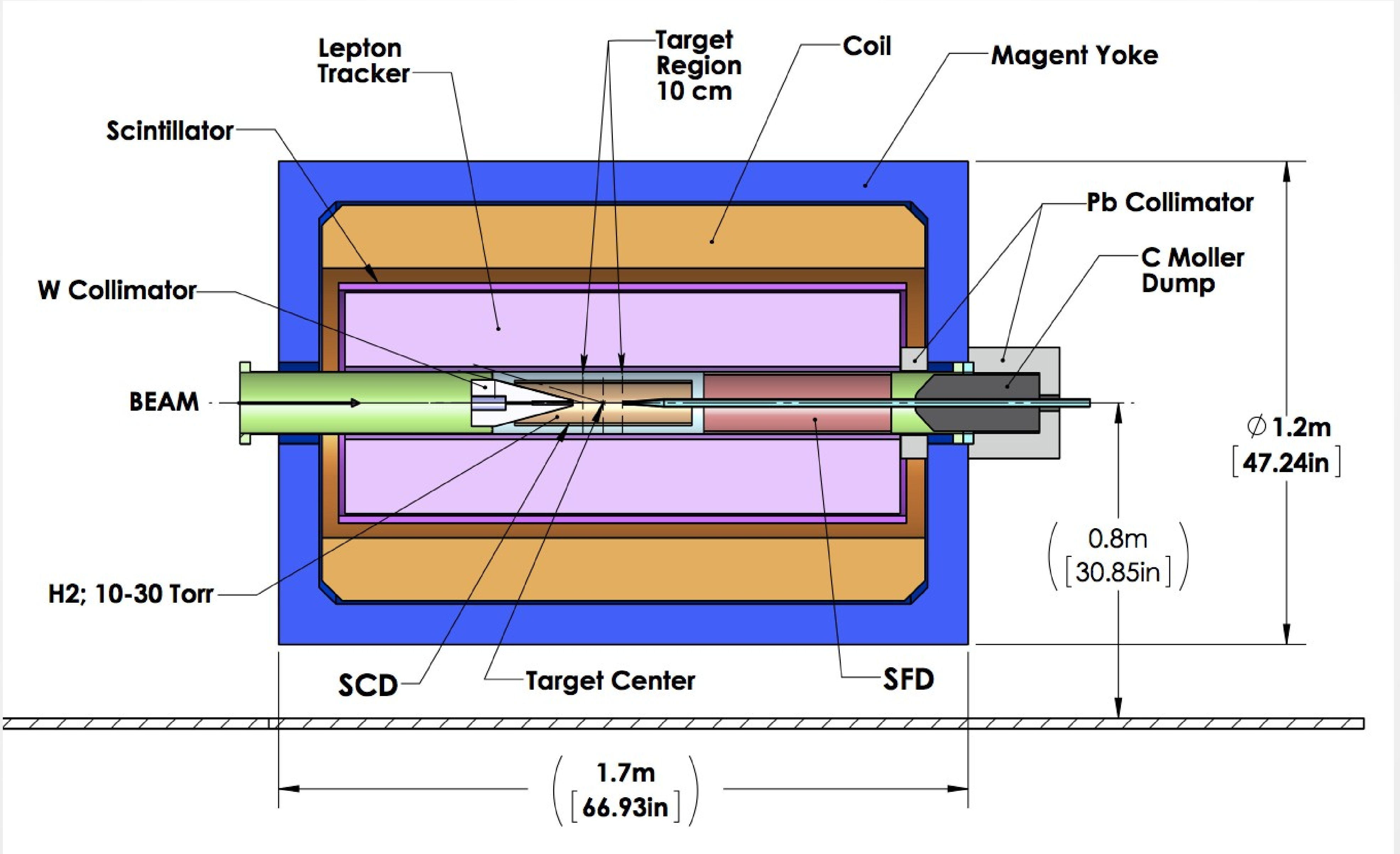
DarkLight: Components

DarkLight has 4 primary components:

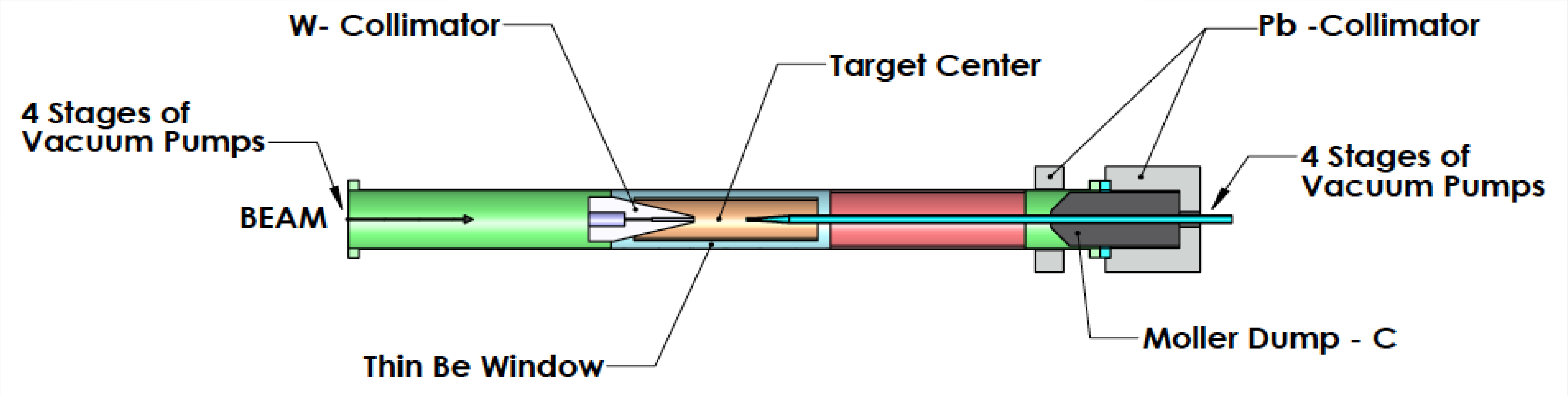
- Target – Differentially pumped hydrogen gas target $10^{19}/cm^2$, 10 cm long.
- Silicon proton detector - ~3.5 cm from beam, single layer of silicon micro-strip detector. Measure energy and angle of recoil proton.
- Lepton tracker – 10-25 cm radius TPC, based on PANDA design.
- Magnet – Solenoid provides 0.5 T B-field to focus Moller e^- and measure lepton momentum and direction.



DarkLight: Schematic

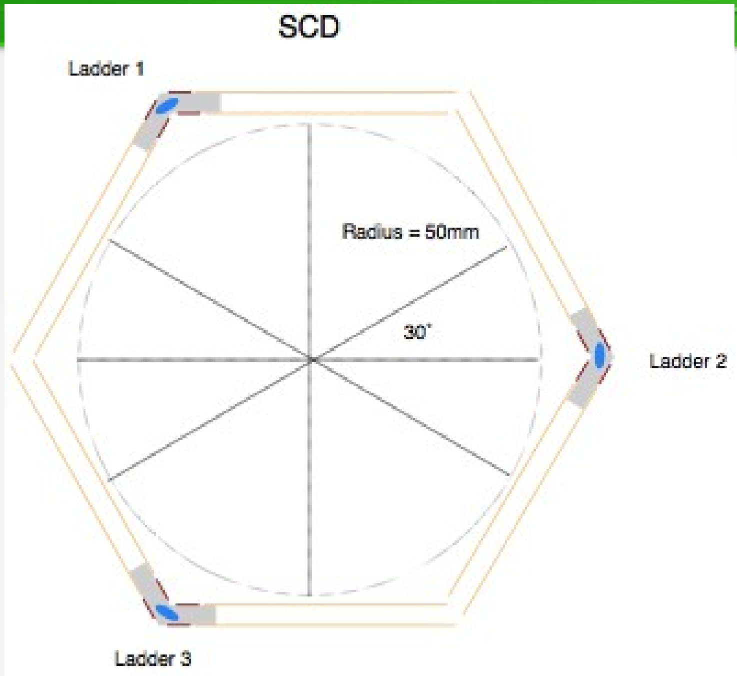


DarkLight: Target

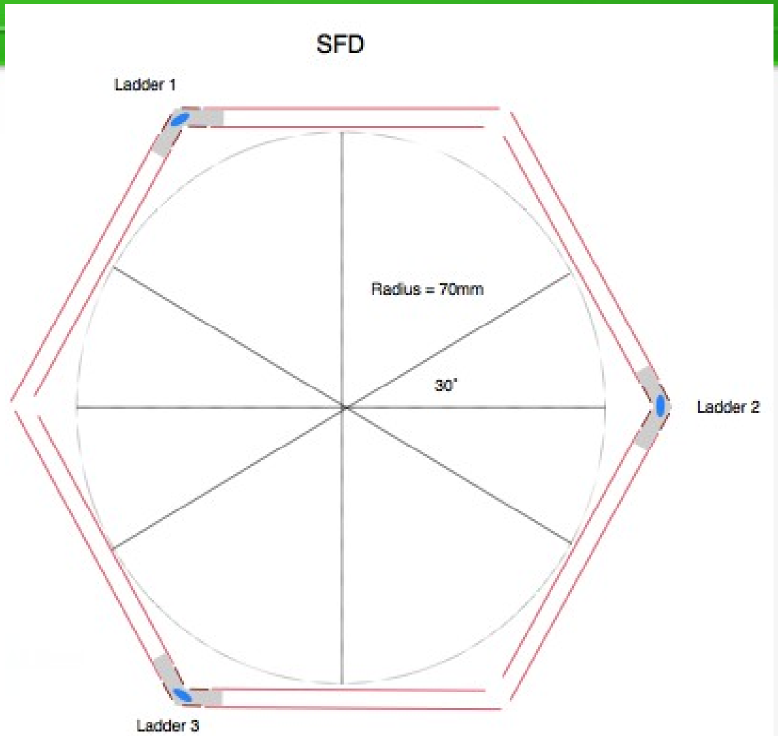


- Hydrogen target realized by flowing gas through narrow apertures
- Aperture diameter: 2 mm
- Aperture length: 50 mm
- Thickness: 10^{19} Hydrogen atoms cm^{-2}
- Flow rate: 24 Torr-liter s^{-1}
- Viscous subsonic flow regime
- Multiple stages of differential pumping required
- Plasma windows under consideration

DarkLight: Central & Forward Detectors



- Radius: 50mm
- Φ-coverage: 360°
- θ-coverage: 17° - 163°
- Number of ladders: 3
- Ladder length: 430mm
- Sensor dimensions: 56.5mm X 60.0mm / 52.5mm X 60.0mm
- Sensor thickness: 300µm
- Total number of sensors: 84
- Power dissipation: 0.3W per chip / 50W per ladder
- Radiation tolerance of sensors: 1MRad
- Radiation tolerance of readout chip: >>1MRad



- Radius: 70mm
- Φ-coverage: 360°
- θ-coverage: 6.1° - 19°
- Number of ladders: 3
- Ladder length: 458mm
- Sensor dimensions: 78.5mm X 64.0mm / 72.5mm X 64.0mm • Number of sensors: 28 per ladder
- Sensor thickness: 300µm
- Total number of sensors: 84
- Power dissipation: 0.3W per chip / 50W per ladder
- Radiation tolerance of sensors: 1MRad
- Radiation tolerance of readout chip: >>1MRad

DarkLight Specs

$M_{A'}$ 1 MeV (< 1% Rad. Length)

Incident electron energy 100 MeV

Scattered lepton angle 25-165 deg

Scattered lepton energy 10-100 MeV

Recoil proton angle 6-163 deg

Recoil proton energy 1-6 MeV

Position: 250 μm

Elastic rate within acceptance 10 MHz

Trigger Rate ~ kHz

Jlab FEL Capabilities

	Near Term Capability, Dec. 2013	Full Capability	Internal Target (Near Term)
	external target	external target	internal target
E (MeV)	80-320	80-610	80-165
P_{max} (kW)	100	300	1650
I (mA)	0.31-1.25	0.5-3.75	10
f_{bunch} (MHz)	750 / 75	750 / 75	750 / 75
Q_{bunch} (pC)	1.67-0.4 / 16.7-4	5-0.67 / 50-6.7	13.5 / 135
$\varepsilon_{transverse}$ (mm-mrad)	~1 / ~3	~2 / ~5	~3 / ~10
$\varepsilon_{longitudinal}$ (keV-psec)	~5 / ~15	~10 / ~25	~15 / ~50
Polarization	No	Up to 600 μA	No
	750 MHz drive laser; single F100	12 GeV RF drive; three F100s	12 GeV RF drive; three F100s

Possible Timeline

Year Focus	2012	2013	2014	2015	2016
FEL beam & Radiation limits					
Finalize Design Secure funding					
Technical Review Start Construction					
Detector Commissioning					
DarkLight data taking begins					