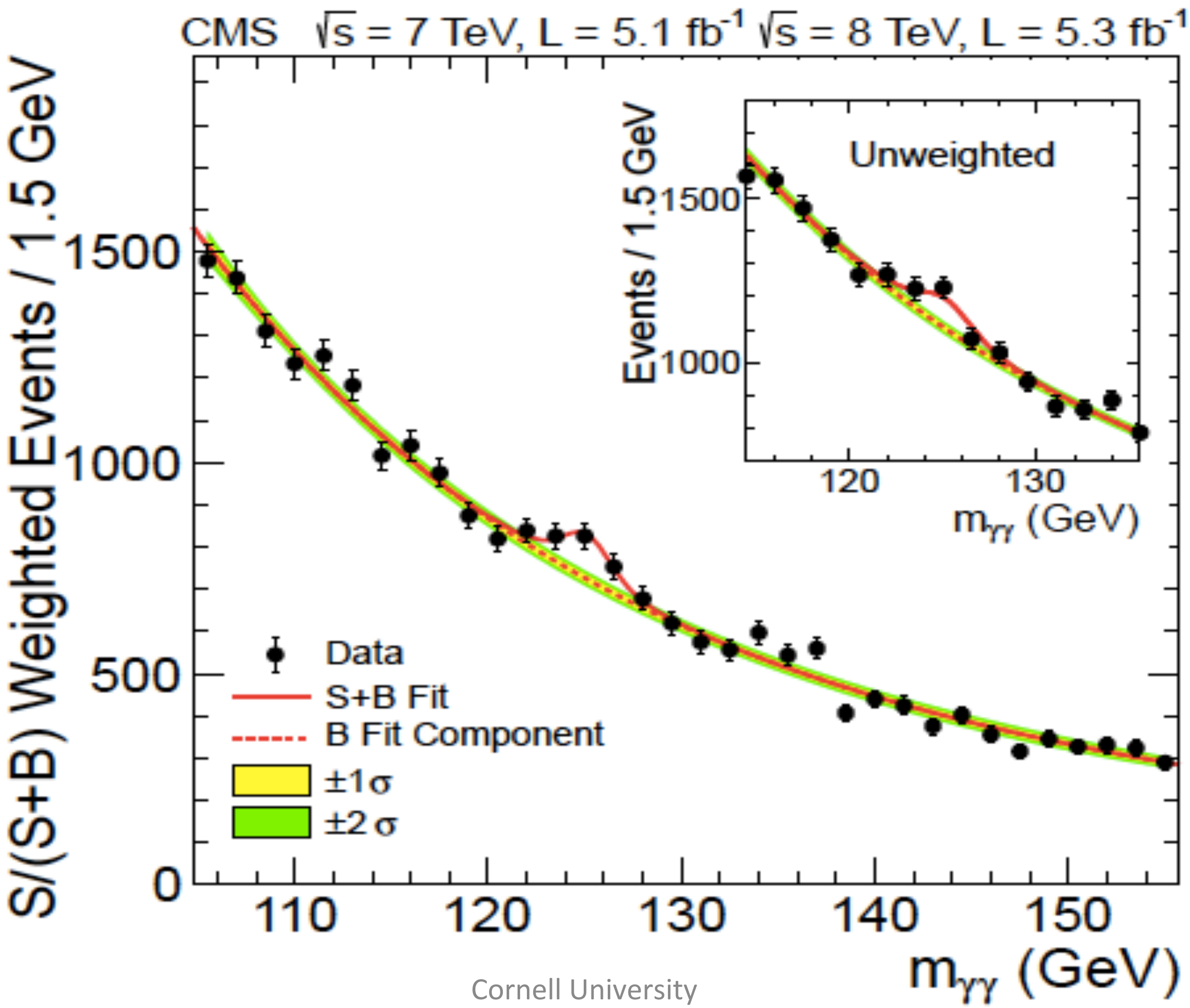
Searching for New Physics at Low Energies: The DARKLIGHT Experiment

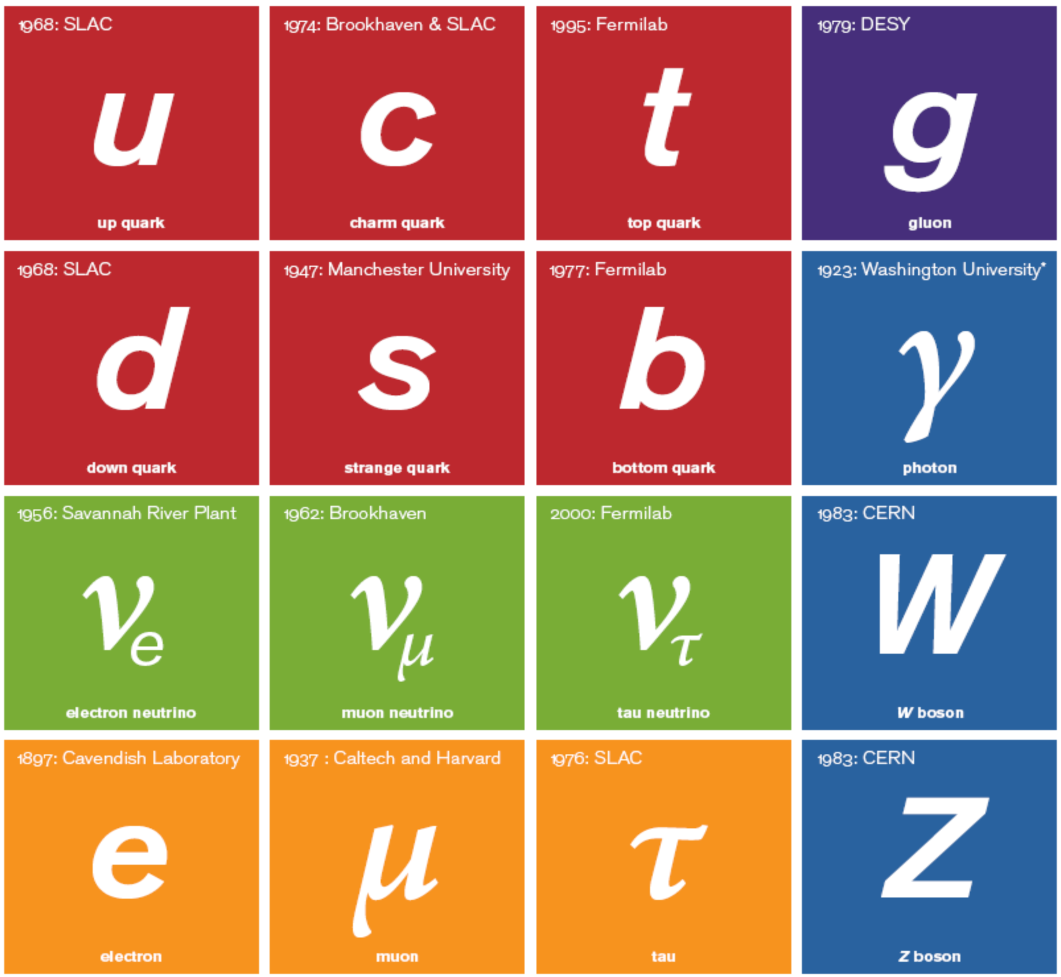
- Introduction
- The DarkLight experiment
- The Path to realization

125 GeV Boson Discovery



Building Blocks of Matter 2013

The Standard Model of Physics

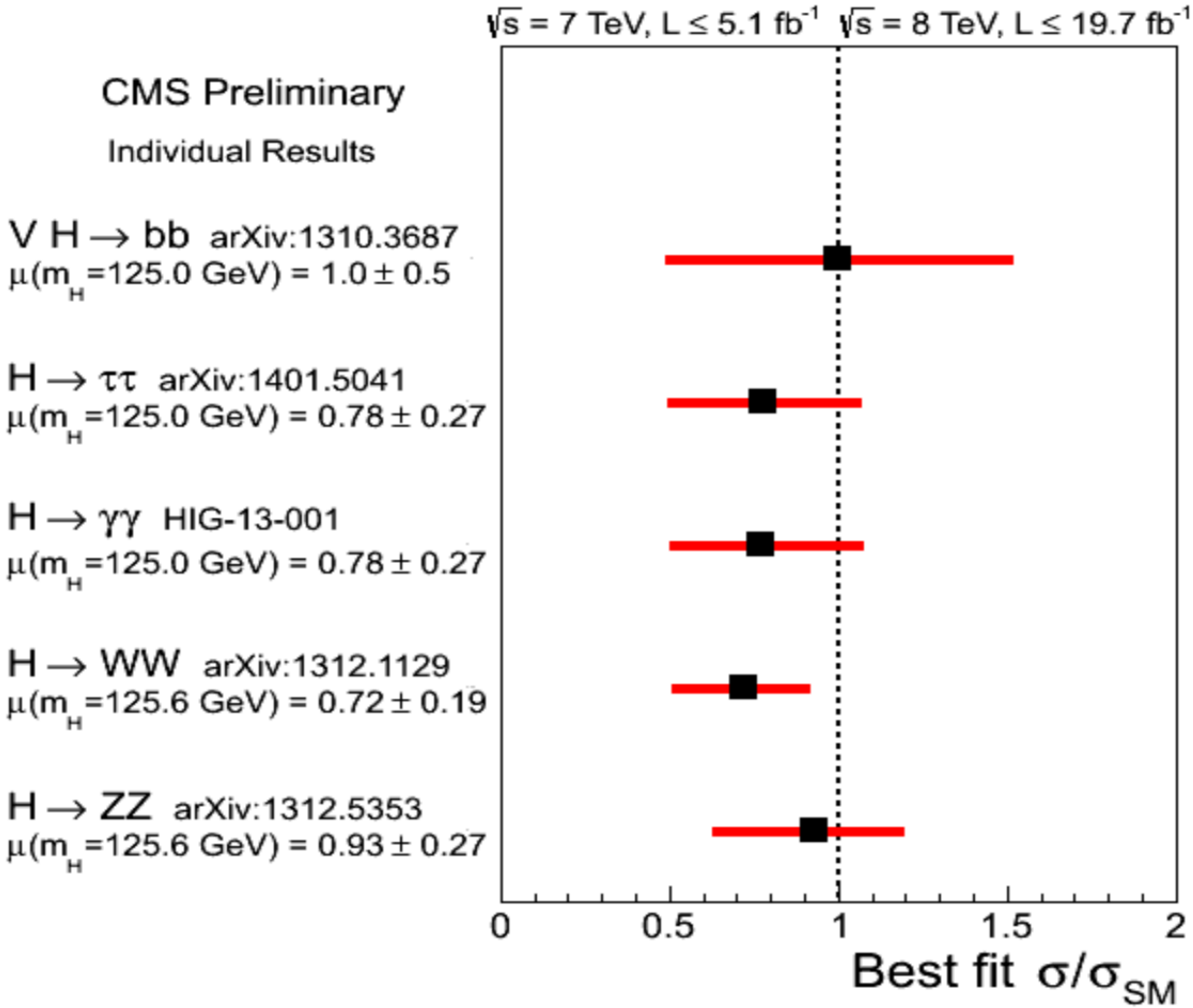


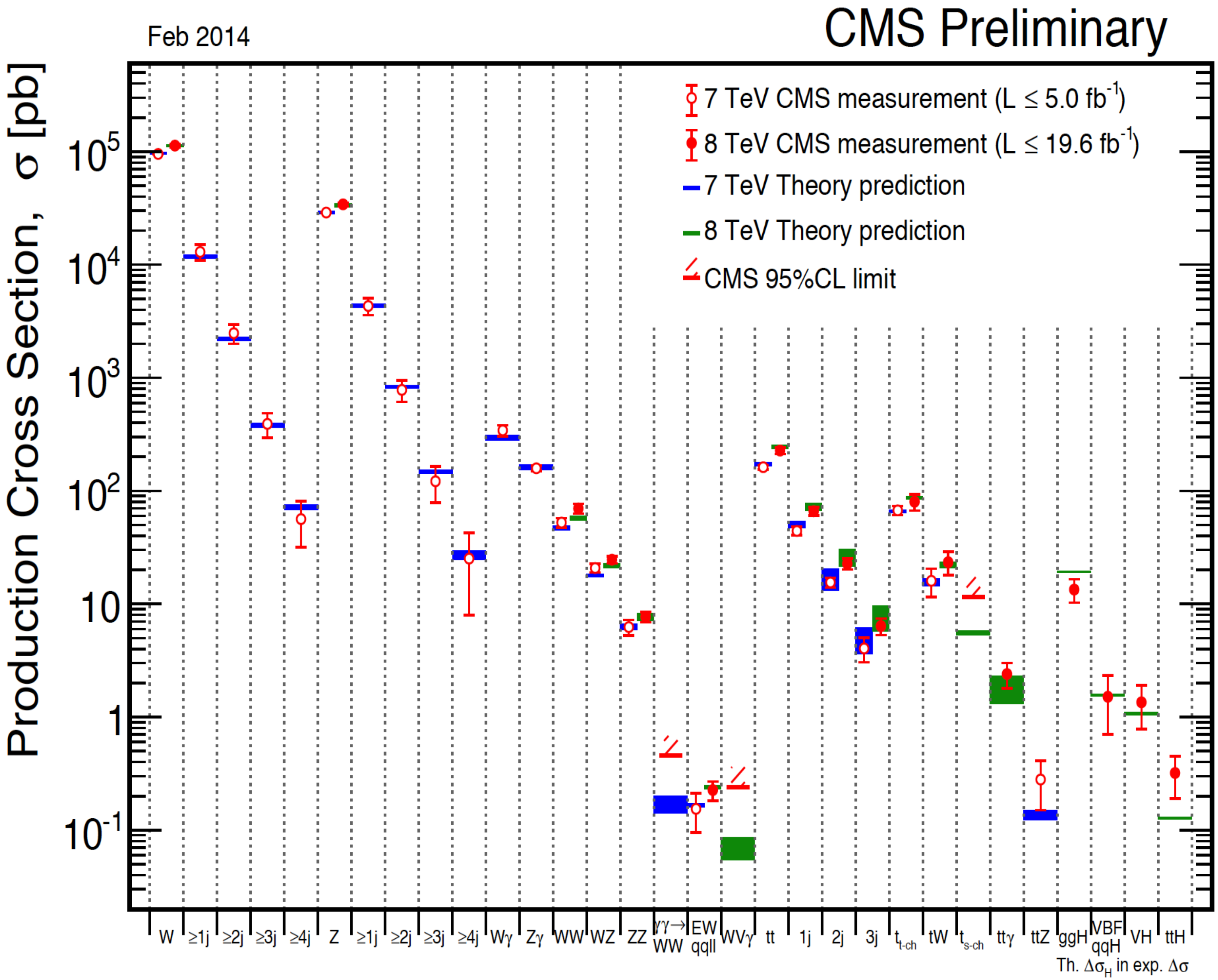
2012: CERN

H

+

Einstein gravity

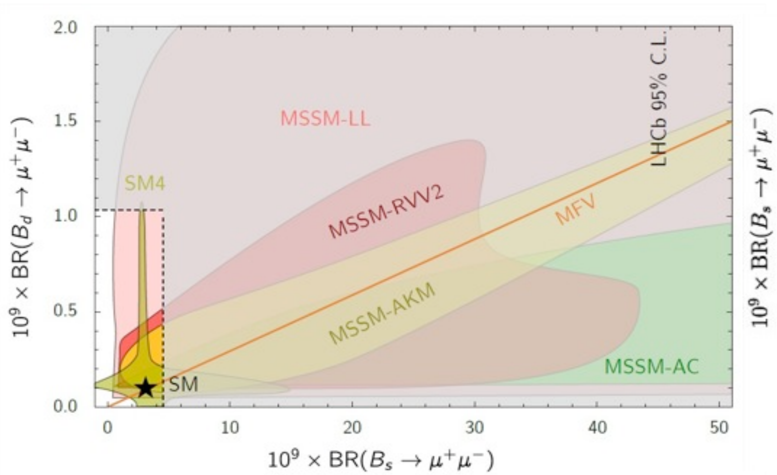

√s = 7 TeV, L ≤ 5.1 fb⁻¹ √s = 8 TeV, L ≤ 19.7 fb⁻¹
CMS Preliminary
Individual Results
V H → bb arXiv:1310.3687
μ(m_H=125.0 GeV) = 1.0 ± 0.5
H → ττ arXiv:1401.5041
μ(m_H=125.0 GeV) = 0.78 ± 0.27
H → γγ HIG-13-001
μ(m_H=125.0 GeV) = 0.78 ± 0.27
H → WW arXiv:1312.1129
μ(m_H=125.6 GeV) = 0.72 ± 0.19
H → ZZ arXiv:1312.5353
μ(m_H=125.6 GeV) = 0.93 ± 0.27
0
0.5
1
1.5
2
Best fit σ/σ_SM

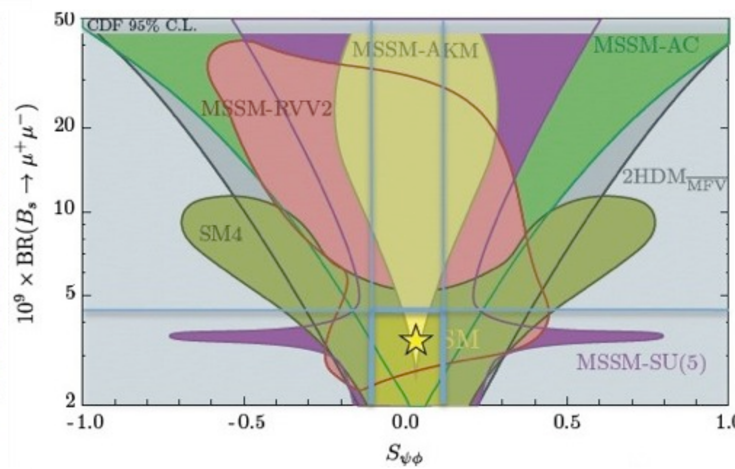

CMS Preliminary
Feb 2014
Production Cross Section, σ [pb]
7 TeV CMS measurement (L ≤ 5.0 fb^{-1})
8 TeV CMS measurement (L ≤ 19.6 fb^{-1})
7 TeV Theory prediction
8 TeV Theory prediction
CMS 95%CL limit
10^5
10^4
10^3
10^2
10
1
10^{-1}
W ≥1j ≥2j ≥3j ≥4j Z ≥1j ≥2j ≥3j ≥4j Wγ Zγ WW WZ ZZ γγ→WW EW qqll WVγ tt 1j 2j 3j t_{t-ch} tW t_{s-ch} ttγ ttZ ggH VBF qqH VH ttH
Th. $\Delta\sigma_H$ in exp. $\Delta\sigma$

LHCb

Constraints from LHCb Observables

(2011 data only)





Parameter space of various extensions to the SM are ruled out just by limits on $\mathcal{B}(B_{d,s} \to \mu^+\mu^-)$ and the CP-violating phase in $B_s \to J/\psi\phi$.

Beyond the Standard Model

- Physicists aim to understand the universe around us in terms of the simplest explanation.
- The Standard Model describes the basic structure of matter and forces, to the extent we have been able to probe thus far.
- Currently, some big questions remain unanswered
  - why so many fundamental particles?
  - how are their masses explained?
  - observed matter-antimatter asymmetry?
  - existence of dark matter and energy
  - reconciliation of gravity with quantum mechanics

Asymptotic safety of gravity and the Higgs boson mass

Mikhail Shaposhnikov

Institut de Théorie des Phénomènes Physiques, École Polytechnique Fédérale de Lausanne, CH-1015 Lausanne, Switzerland

Christof Wetterich

Institut für Theoretische Physik, Universität Heidelberg, Philosophenweg 16, D-69120 Heidelberg, Germany

12 January 2010

Abstract

There are indications that gravity is asymptotically safe. The Standard Model (SM) plus gravity could be valid up to arbitrarily high energies. Supposing that this is indeed the case and assuming that there are no intermediate energy scales between the Fermi and Planck scales we address the question of whether the mass of the Higgs boson m_H can be predicted. For a positive gravity induced anomalous dimension $A_\lambda > 0$ the running of the quartic scalar self interaction λ at scales beyond the Planck mass is determined by a fixed point at zero. This results in $m_H = m_{\min} = 126$ GeV, with only a few GeV uncertainty. This prediction is independent of the details of the short distance running and holds for a wide class of extensions of the SM as well. For $A_\lambda < 0$ one finds m_H in the interval $m_{\min} < m_H < m_{\max} \simeq 174$ GeV, now sensitive to A_λ and other properties of the short distance running. The case $A_\lambda > 0$ is favored by explicit computations existing in the literature.

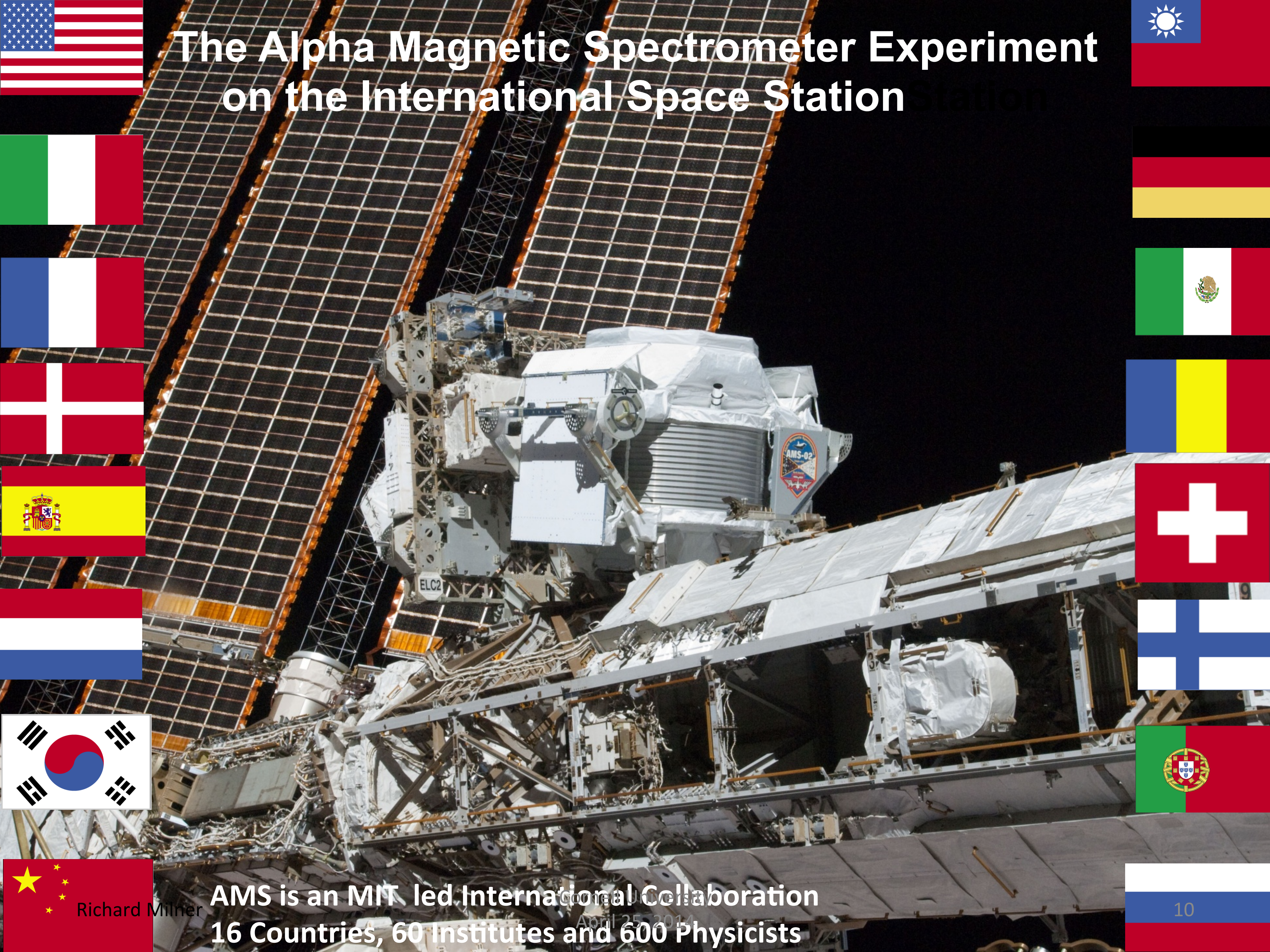
Key words:
Asymptotic safety, gravity, Higgs field, Standard Model
PACS: 04.60.-m 11.10.Hi 14.80.Bn

In this model, all new physics appears below the electroweak scale

What are the Dark forces?

- The universe appears to be filled with cold, dark matter, which could be a relic particle that interacts through known forces or possibly via new forces beyond the Standard Model.
- There are several hints from astrophysical measurements of dark matter annihilation products, *e.g.*
  - WMAP haze: excess microwave emission around the galactic center
  - Cosmic positron energy distribution: may be sensitive to dark matter annihilation in the e^+ energy range of 10 to 1000 GeV (Turner and Wilczek 1990)
- Experiments are producing new data.

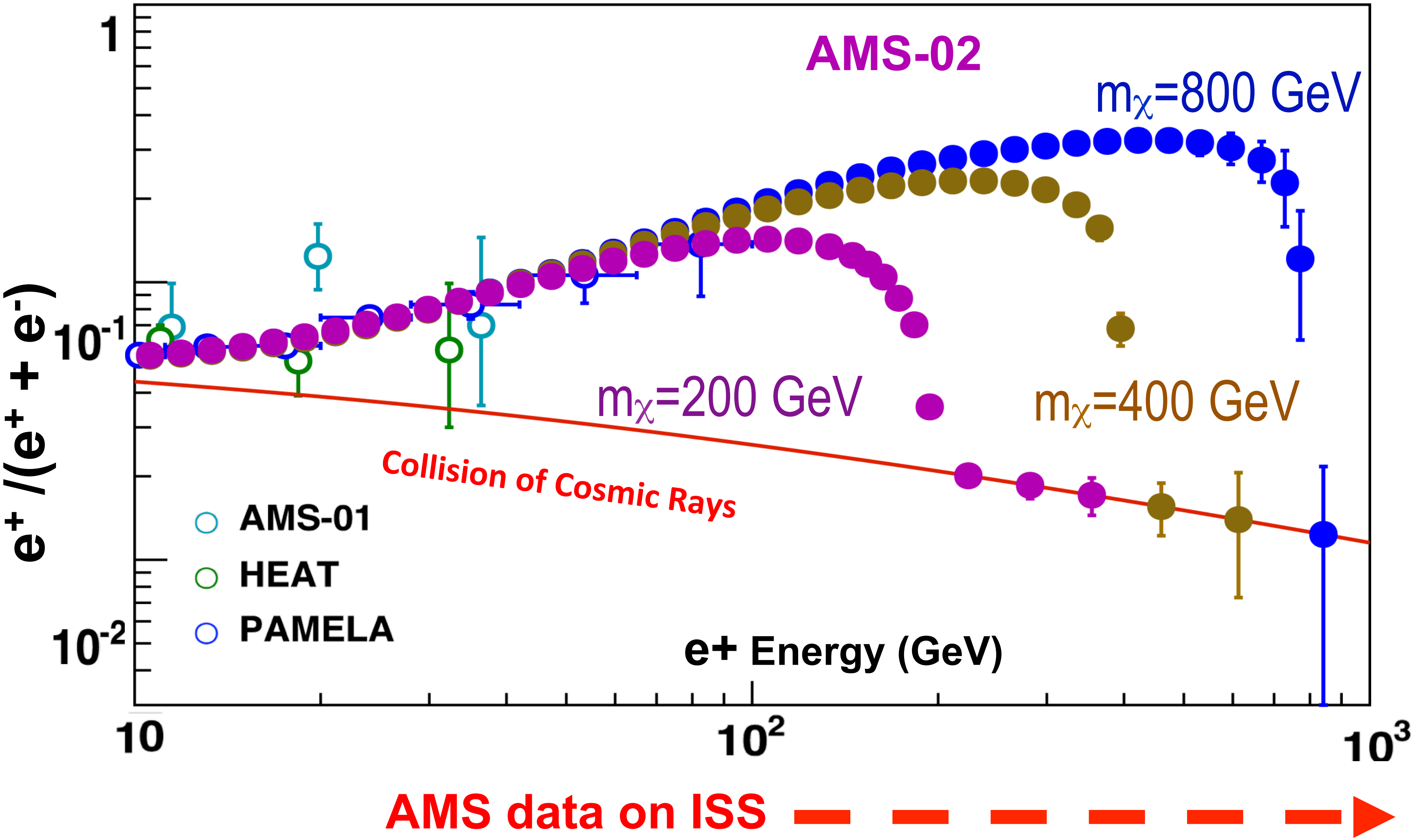
The Alpha Magnetic Spectrometer Experiment on the International Space Station

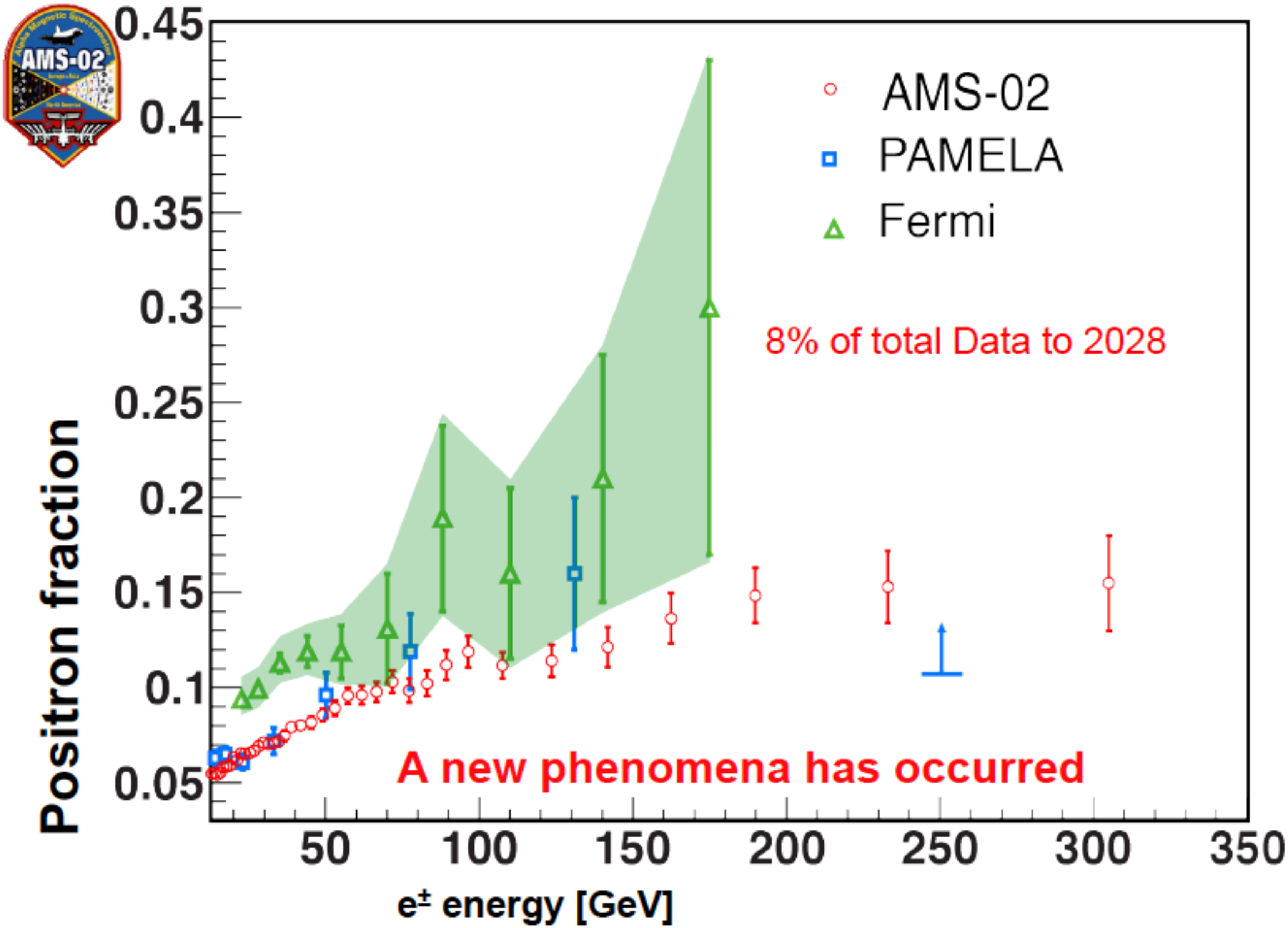


AMS is an MIT led International Collaboration

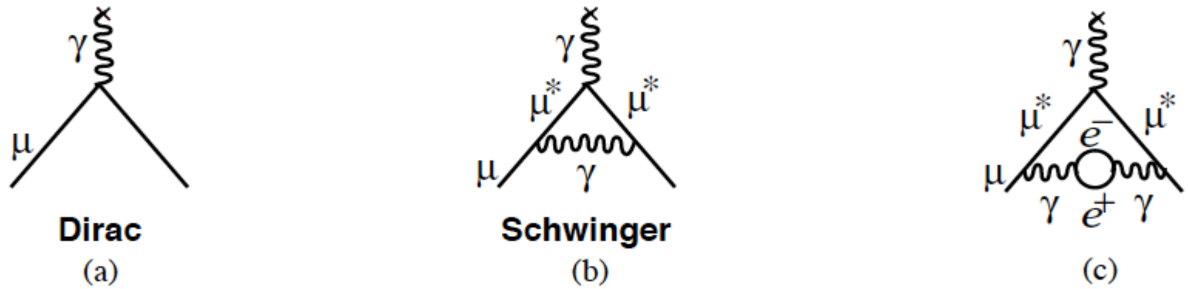
16 Countries, 60 Institutes and 600 Physicists

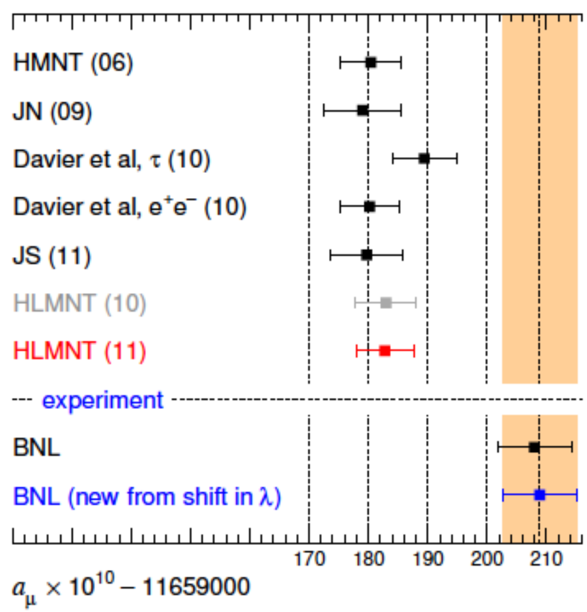
Detection of High Mass Dark Matter from ISS




AMS-02
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
Positron fraction
AMS-02
PAMELA
Fermi
8% of total Data to 2028
A new phenomena has occurred
50
100
150
200
250
300
350
e± energy [GeV]

Anomalous magnetic moment of the muon

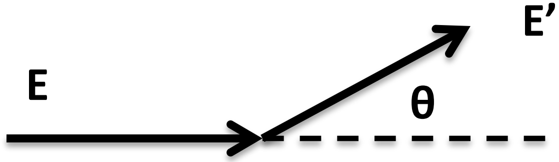




208±6.3

Figure 1: Standard Model predictions of a_μ by several groups compared to the measurement from BNL (from Ref. [4]).

Elastic electron-proton scattering

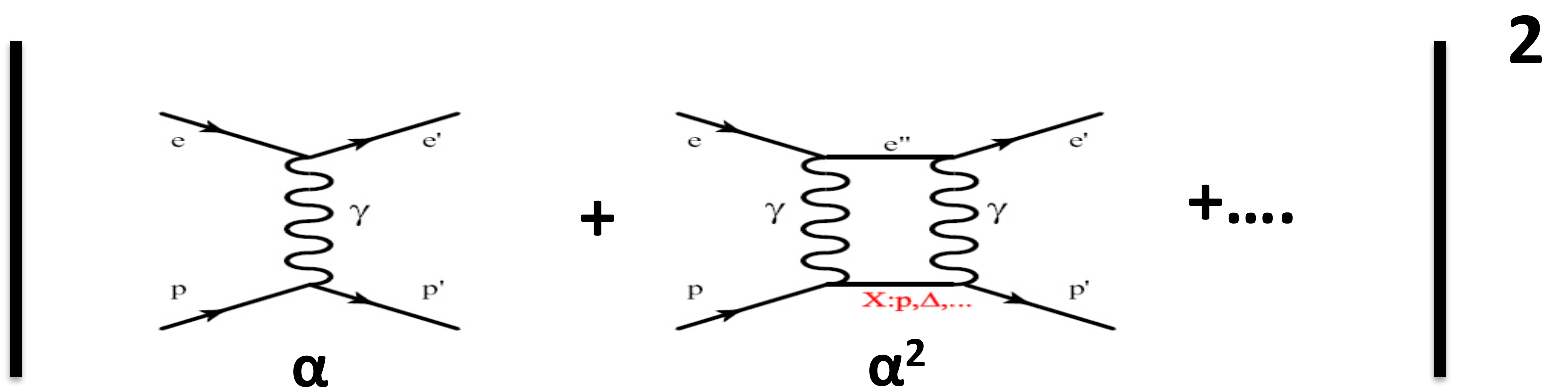


e+ p ⟶ e’ + p’

Q^2=4EE’ $\sin^2 \theta/2$

Q^2=$2M_p$(E-E’)

- Fundamental process in hadronic physics
- Described in QED (α= 1/137) by a perturbative expansion



Elastic scattering cross section

In the one-photon exchange approximation, the cross section is a product of the Mott cross section and the form factor functions

$$\left(\frac{d\sigma}{d\Omega}\right)_{Mott} = \frac{\alpha^2}{4E^2}\frac{1}{\sin^4\frac{\theta}{2}} \cdot \cos^2\frac{\theta}{2} \cdot \frac{E'}{E}$$

$$\frac{d\sigma/d\Omega}{(d\sigma/d\Omega)_{Mott}} = S_0 = A(Q^2) + B(Q^2)\tan^2\frac{\theta}{2}$$

$$= \frac{G_E^2(Q^2) + \tau G_M^2(Q^2)}{1+\tau} + 2\tau G_M^2(Q^2)\tan^2\frac{\theta}{2}$$

$$= \frac{\epsilon G_E^2 + \tau G_M^2}{\epsilon(1+\tau)}, \qquad \epsilon = \left[1 + 2(1+\tau)\tan^2\frac{\theta}{2}\right]^{-1}$$

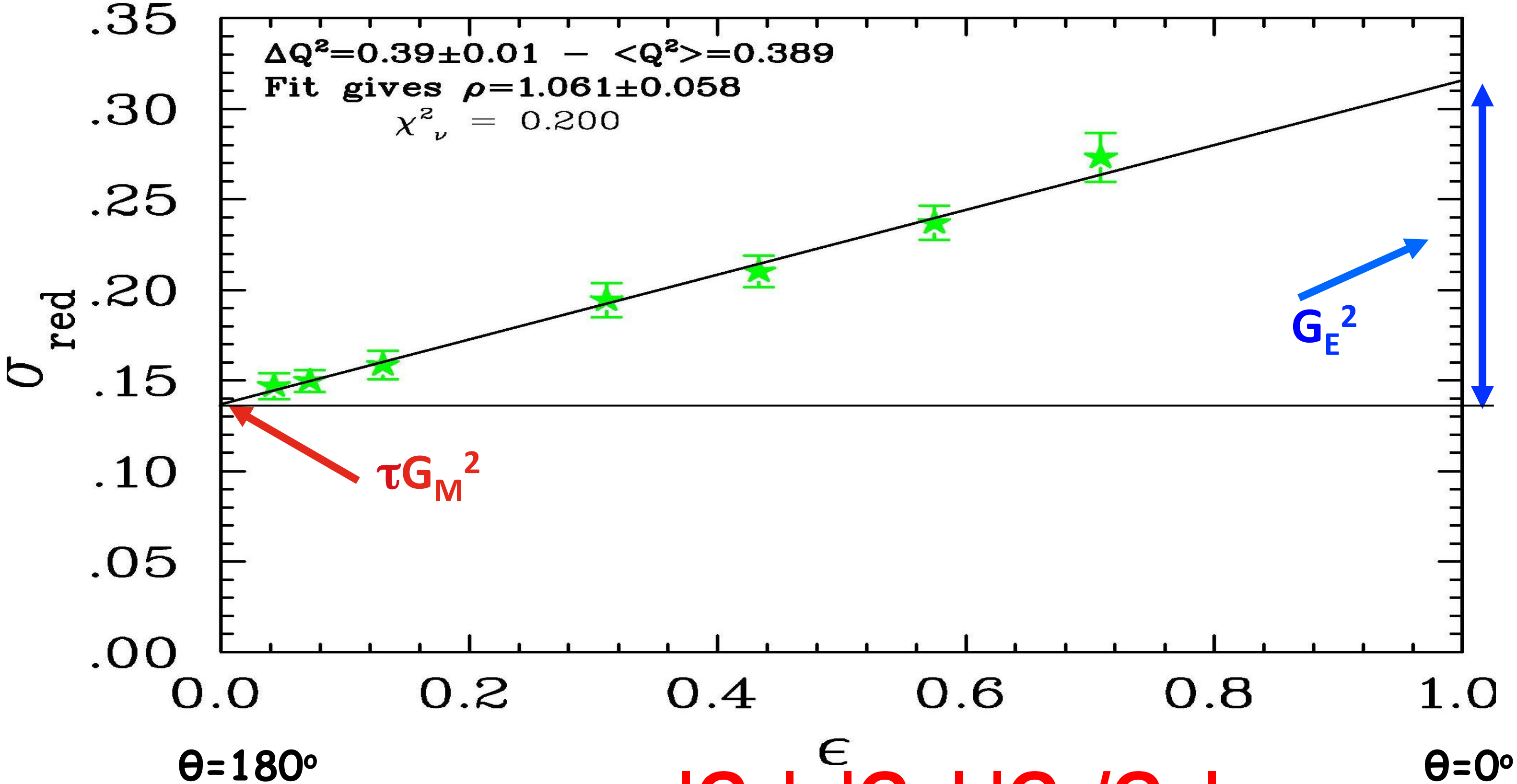
$$\tau = \frac{Q^2}{4M_p^2}$$

ε =relative flux of longitudinally polarized virtual photons

Form Factors from Cross section (Rosenbluth Method)

One can define the reduced cross section σ_{red}

$$\sigma_{red} = \varepsilon G_E^2 + \tau G_M^2$$



➔**Determine** $|G_E|, |G_M|, |G_E/G_M|$

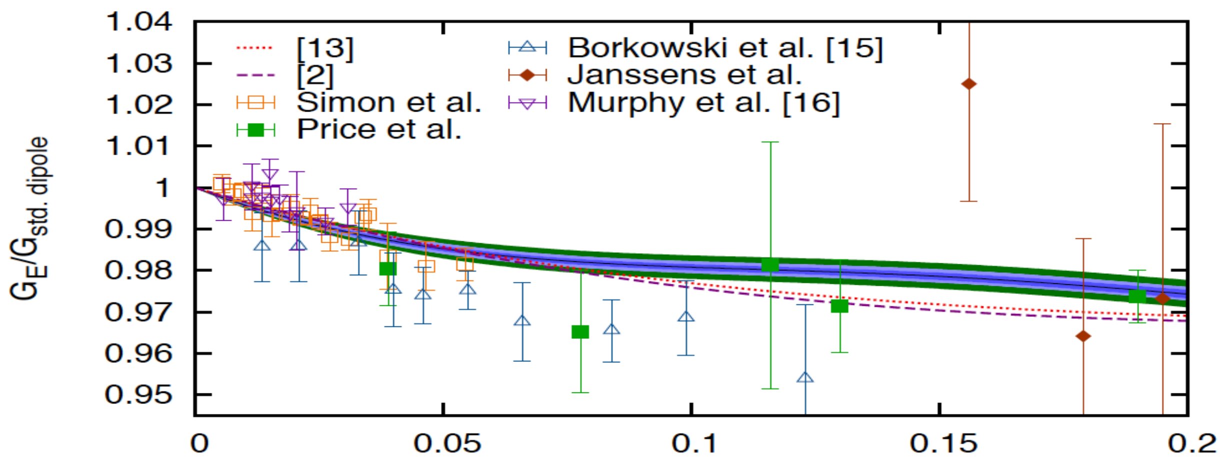
Proton charge radius determined from elastic electron scattering data

The charge and magnetic rms-radii are given by

$$G_E^p(q^2) = 1 + \frac{q^2}{6}\langle r^2\rangle_E^p + \ldots$$

$$\left\langle r_{E/M}^2 \right\rangle = -\frac{6\hbar^2}{G_{E/M}(0)} \frac{\mathrm{d}G_{E/M}(Q^2)}{\mathrm{d}Q^2}\bigg|_{Q^2=0} .$$

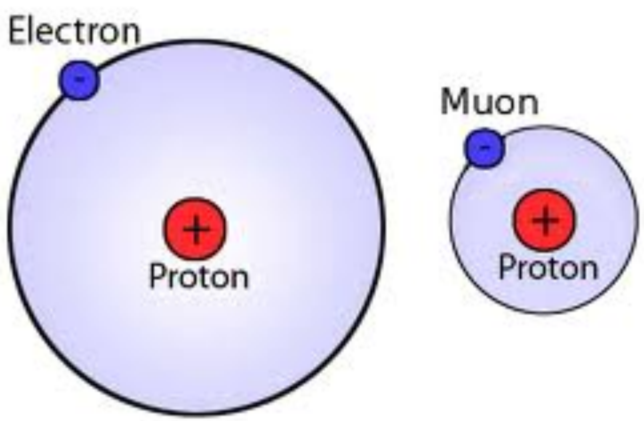
Determined from elastic electron scattering data on proton at low Q^2

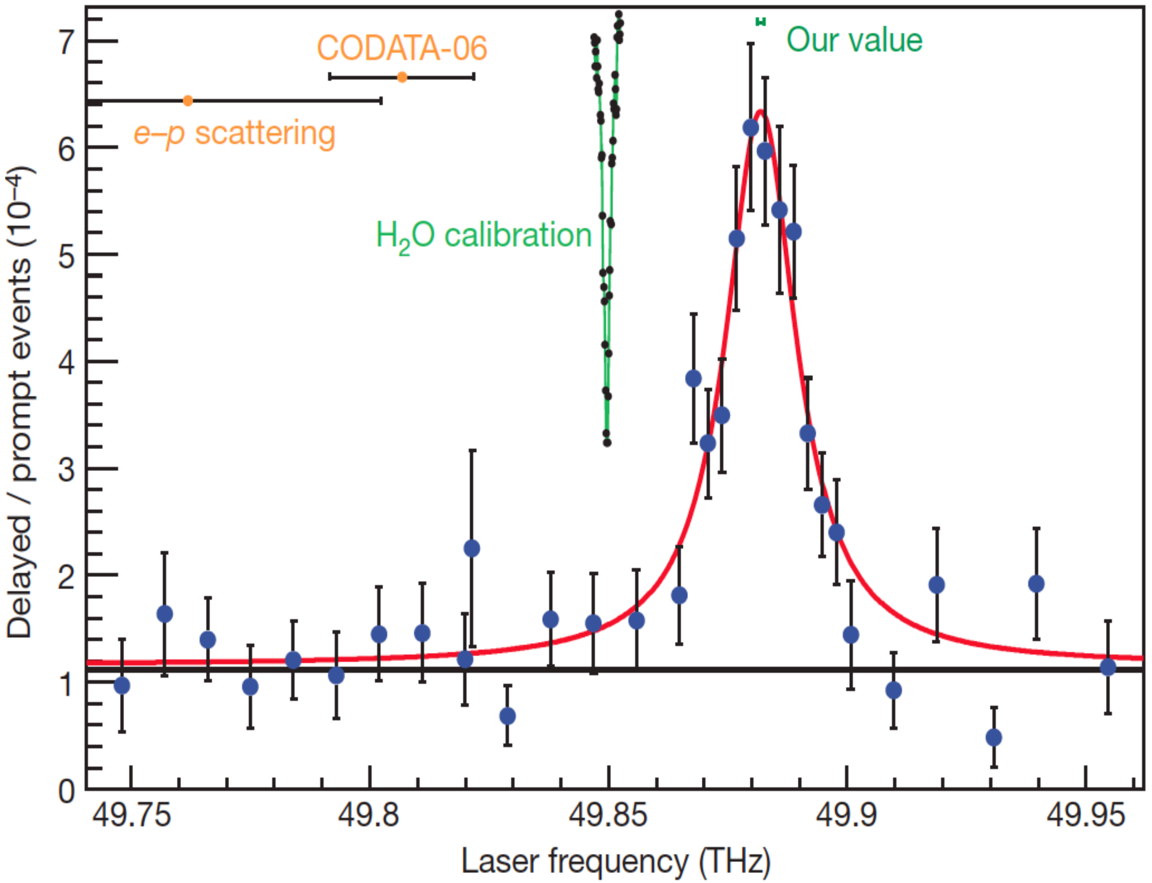


CODATA value, $r_E^p = 0.8768(69)$ fm

The size of the proton

Randolf Pohl[1], Aldo Antognini[1], François Nez[2], Fernando D. Amaro[3], François Biraben[2], João M. R. Cardoso[3], Daniel S. Covita[3,4], Andreas Dax[5], Satish Dhawan[5], Luis M. P. Fernandes[3], Adolf Giesen[6]†, Thomas Graf[6], Theodor W. Hänsch[1], Paul Indelicato[2], Lucile Julien[2], Cheng-Yang Kao[7], Paul Knowles[8], Eric-Olivier Le Bigot[2], Yi-Wei Liu[7], José A. M. Lopes[3], Livia Ludhova[8], Cristina M. B. Monteiro[3], Françoise Mulhauser[8]†, Tobias Nebel[1], Paul Rabinowitz[9], Joaquim M. F. dos Santos[3], Lukas A. Schaller[8], Karsten Schuhmann[10], Catherine Schwob[2], David Taqqu[11], João F. C. A. Veloso[4] & Franz Kottmann[12]





Discrepancy!

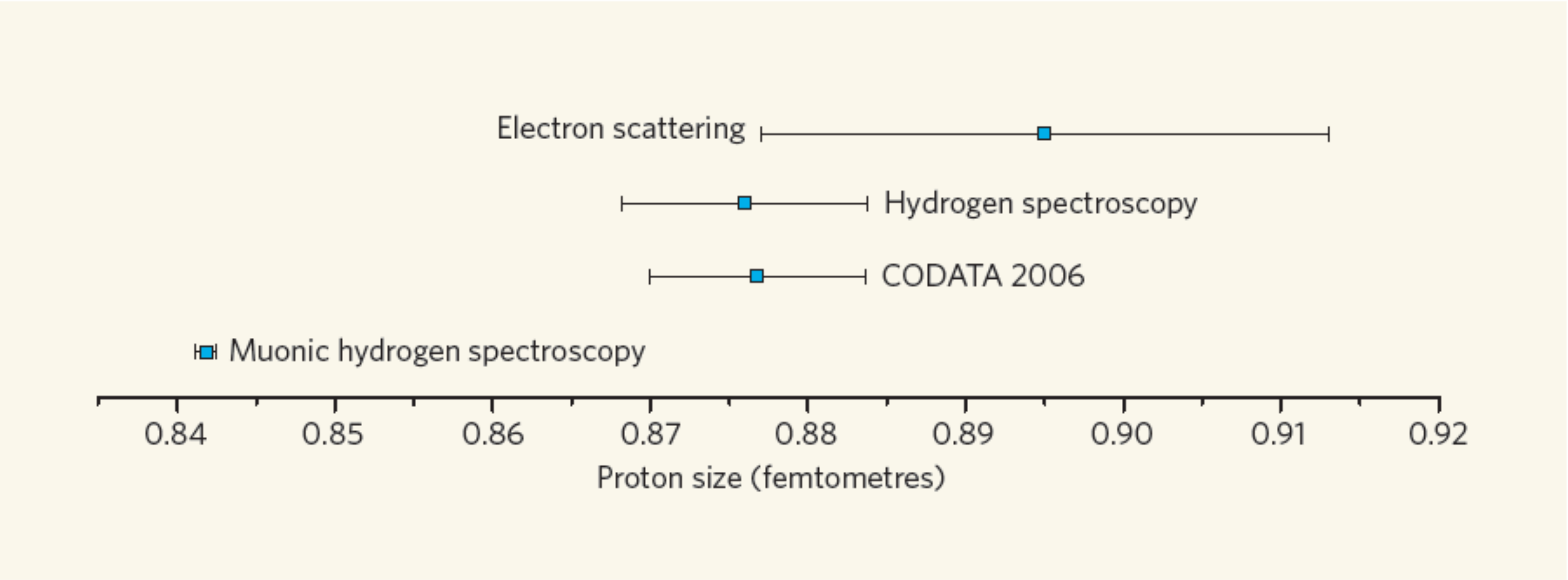


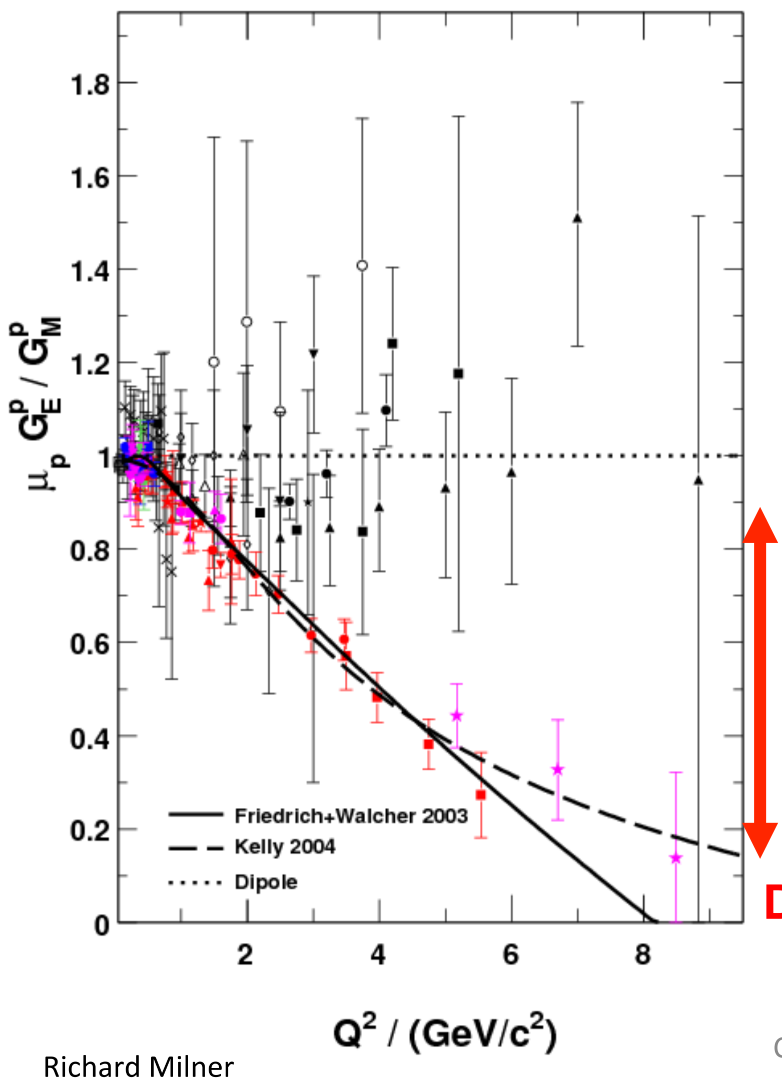
Figure 2 | Size of the proton. A comparison of the results of different methods used to measure the proton size is shown: electron scattering[5], hydrogen spectroscopy, the combination of these (both from the CODATA 2006 review[6]), and Pohl and colleagues' new measurement[1] derived from muonic hydrogen spectroscopy. The bars indicate an uncertainty of one standard deviation. The discrepancy of about five standard deviations between the muonic hydrogen result and the CODATA result, which summarizes all previous work, is clear.

Possible resolutions

- Elastic electron-proton scattering data are not correct : new experiments being planned

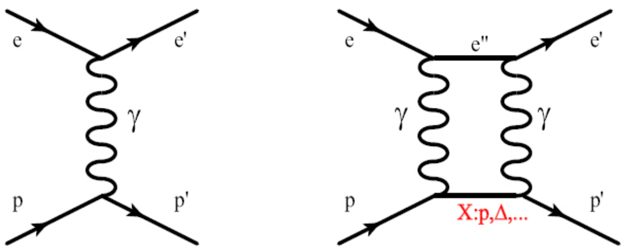
  inc. lower Q^2, comparison of muon and electron scattering
- Lamb shift determination of the charge radius is not correct
- They are not measuring the same quantity
- There is new physics beyond the Standard Model

Proton Form Factor Ratio



Jefferson Lab 2000

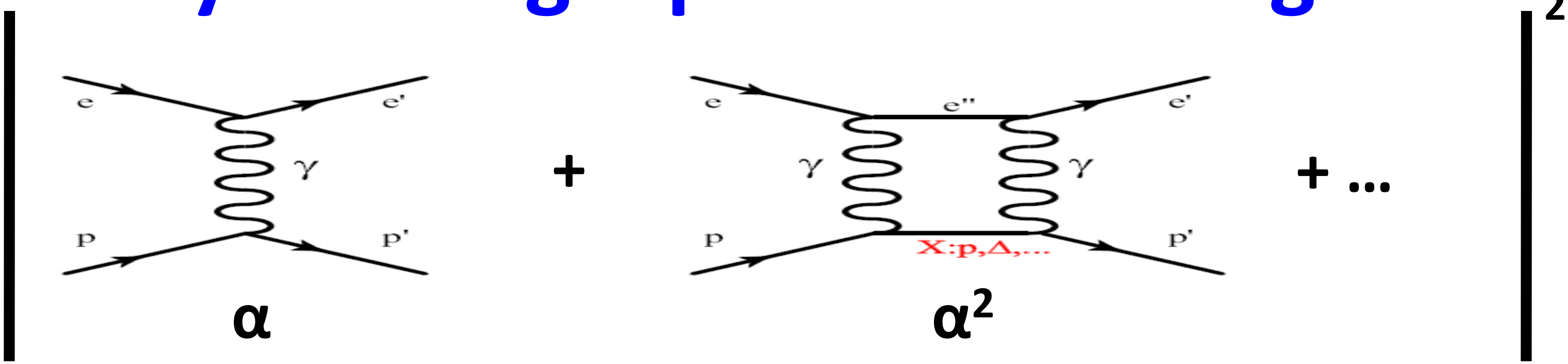
- All Rosenbluth data from SLAC and JLab in agreement
- Dramatic discrepancy between Rosenbluth and recoil polarization technique
- Contribution of multi-photon exchange widely accepted explanation of discrepancy



Dramatic discrepancy!

>800 citations

Definitive determination of contributions beyond single photon exchange



$$\sigma = (1\gamma)^2\alpha^2 + (1\gamma)(2\gamma)\alpha^3 + ...$$

$$e^- \Longleftrightarrow e^+ \Rightarrow \alpha \Longleftrightarrow -\alpha$$

$$\sigma(\text{electron-proton}) = (1\gamma)^2\alpha^2 - (1\gamma)(2\gamma)\alpha^3 + ..$$

$$\sigma(\text{positron-proton}) = (1\gamma)^2\alpha^2 + (1\gamma)(2\gamma)\alpha^3 + ..$$

$$\frac{\sigma(e^+p)}{\sigma(e^-p)} = 1 + (2\alpha)\frac{2\gamma}{1\gamma}$$

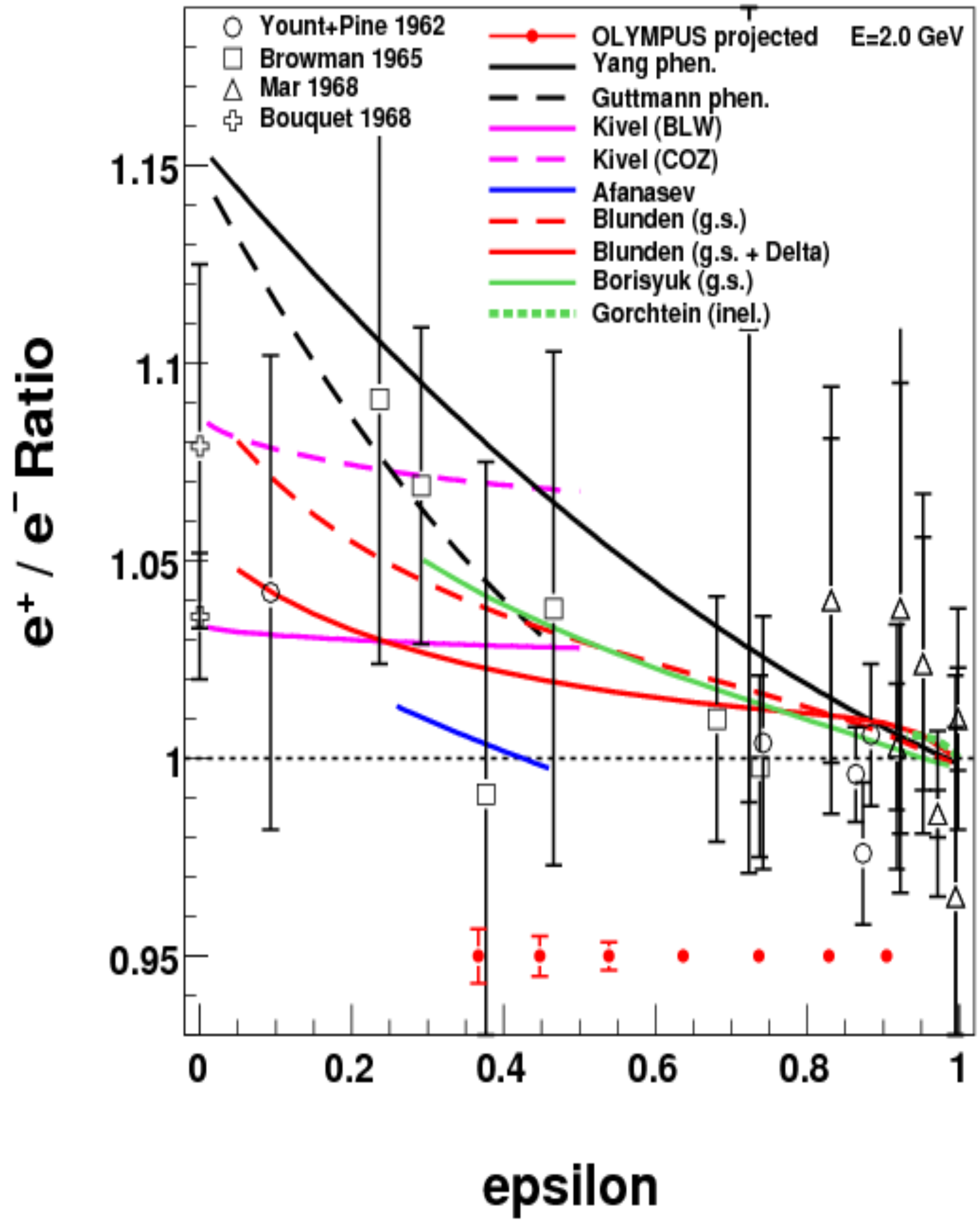
Arizona State University, USA
DESY, Hamburg, Germany
Hampton University, USA
INFN, Bari, Italy
INFN, Ferrara, Italy
INFN, Rome, Italy
Massachusetts Institute of Technology, USA
Petersburg Nuclear Physics Institute, Russia
Universität Bonn, Germany
University of Glasgow, United Kingdom
Universität Mainz, Germany
University of New Hampshire, USA
Yerevan Physics Institute, Armenia

The OLYMPUS Experiment

- Electrons/positrons (100mA) in multi-GeV storage ring DORIS at DESY, Hamburg, Germany
- Unpolarized internal hydrogen target (buffer system) 3×10^{15} at/cm^2 @ 50 mA → $L = 10^{33}$ / (cm^{2}s)
- Large acceptance detector for e-p in coincidence: utilized existing BLAST detector from MIT-Bates
- Redundant monitoring of luminosity:
  Pressure, temperature, flow, current measurements
  Small-angle elastic scattering at high epsilon / low Q^2
  Symmetric Moller/Bhabha scattering

- **Measured ratio of positron-proton to electron-proton unpolarized elastic scattering with goal of ≈1% stat.+sys.**

Projected uncertainties



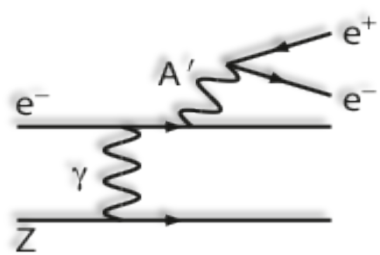
- 2 GeV incident beam energy
- Luminosity = 2 x 10^{33} cm^{-2} s^{-1}
- 500 hours each for e+ and e-
- 3.6 fb^{-1} integrated luminosity

Schedule

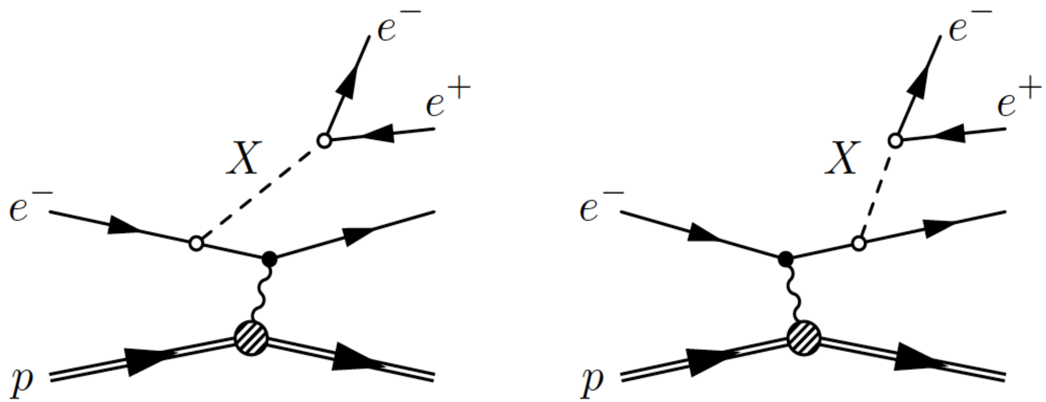
• OLYMPUS proposed	09/2008
• OLYMPUS approved and funded	01/2010
• Experiment roll-in	07/2011
• First data taking run	02/2012
• Second data taking run	10-12/2012
• Post-experiment survey and field mapping	02-04/2013
• Data analysis	in progress

New Dark Gauge Forces

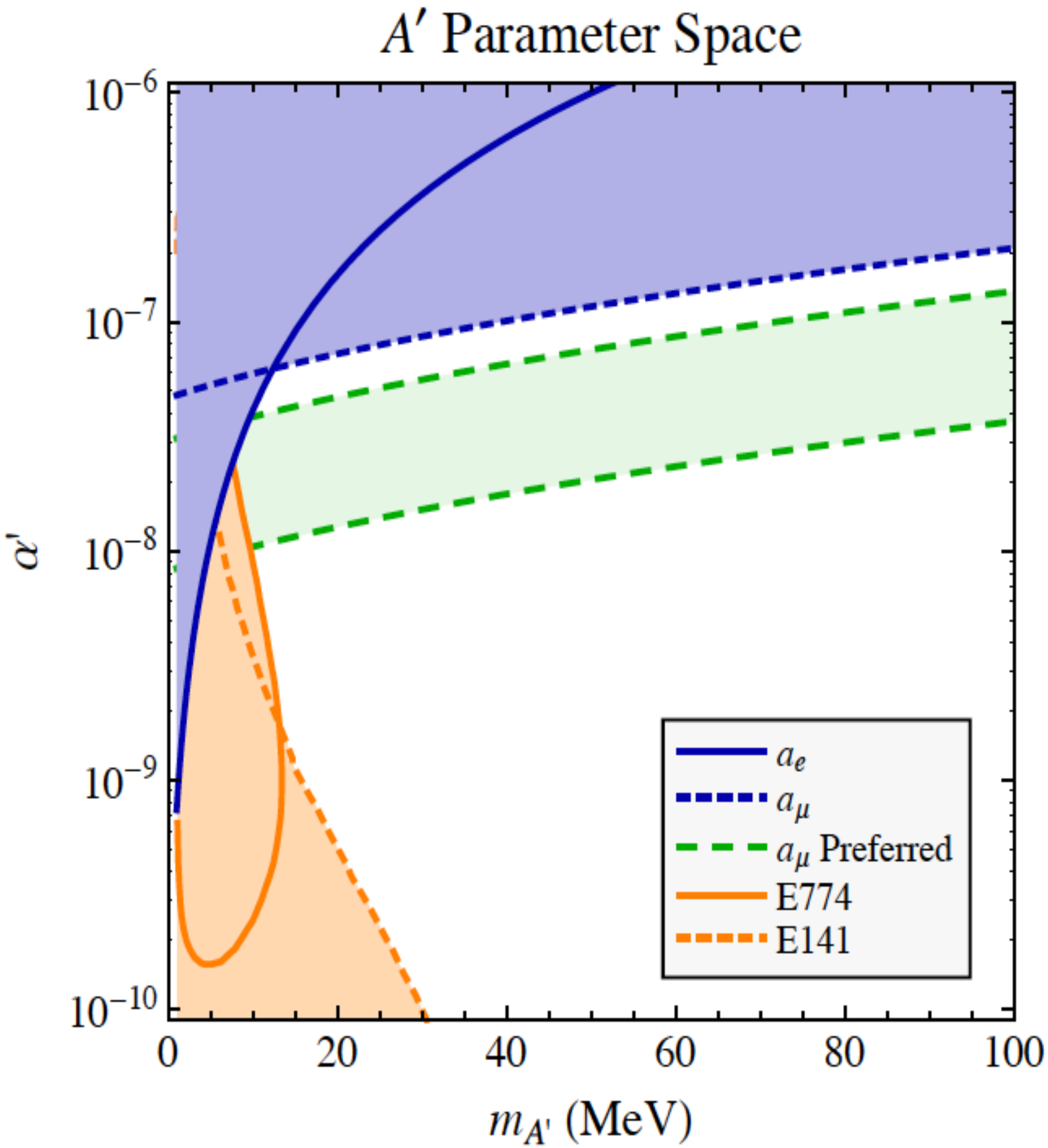
- New dark Abelian forces can couple to the SM hypercharge through the kinetic mixing operator $\frac{\epsilon}{2} F^{Y}_{\mu\nu} F'^{\mu\nu}$, where $F'_{\mu\nu} = \partial_{[\mu} A'_{\nu]}$
- ≈ MeV to GeV scale mass for the A' gauge boson
- A' can be produced in collisions with charged particles and can decay to electrons or muons
- Production cross-section $\sigma_{A'} \sim 100 \text{ pb} \left(\epsilon/10^{-4}\right)^2 (100\,\text{MeV}/m_{A'})^2$
- Decay length $\gamma c\tau \sim 1 \text{ mm} \, (\gamma/10) \left(10^{-4}/\epsilon\right)^2 (100\,\text{MeV}/m_{A'})$
- $\alpha' = \epsilon^2 \alpha_{\text{EM}}$
- Look for evidence of A' in the presence of QED radiation



A' Production



- Search below pion threshold: no inelastic contributions
- Detect complete final–state: e+p ➔ e'+p+e^+e^-
- Dark photon decaying to e^+e^- pair would show up as a peak on the radiative tail from QED processes
- Invariant mass of the peak gives the mass of the dark photon



Experimental constraints:

- Beam dump axion experiments at SLAC and Fermilab in 1980s
- Any muon (g-2) discrepancy with SM can be explained by a dark photon
- Low mass, high coupling region particularly interesting

DARKLIGHT

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

J. Balewski, J. Bernauer, J. Bessuille, B. Buck, R. Corliss, R. Cowan, K. Dow, C. Epstein, P. Fisher, E. Ihloff, Y. Kahn, J. Kelsey, R. Milner, C. Moran, L. Ou, R. Russell, B. Schmookler, J. Thaler, C. Tschalär, C. Vidal

Massachusetts Institute of Technology, MA

S. Benson, G. Biallas, J. Boyce, J. Coleman, D. Douglas, R. Ent, P. Evtushenko, H. C. Fenker, C. Gould, J. Gubeli, F. Hannon, J. Huang, K. Jordan, R. Legg, M. Marchlik, W. Moore, G. Neil, M. Shinn, C. Tennant, R. Walker, G. Williams, S. Zhang

Jefferson Laboratory, VA

R. Alarcon, R. Dipert

Arizona State University, AZ

R. Beck, R. Schmitz, D. Walther

Bonn University, Germany

I. Albayrak, M. Carmignotto, T. Horn

Catholic University, DC

K. Brinkmann and H. Zaunig

Giessen University, Germany

T. Gunter, N. Kalantarians, M. Kohl

Hampton University, VA

A. Deshpande

Stonybrook University, NY

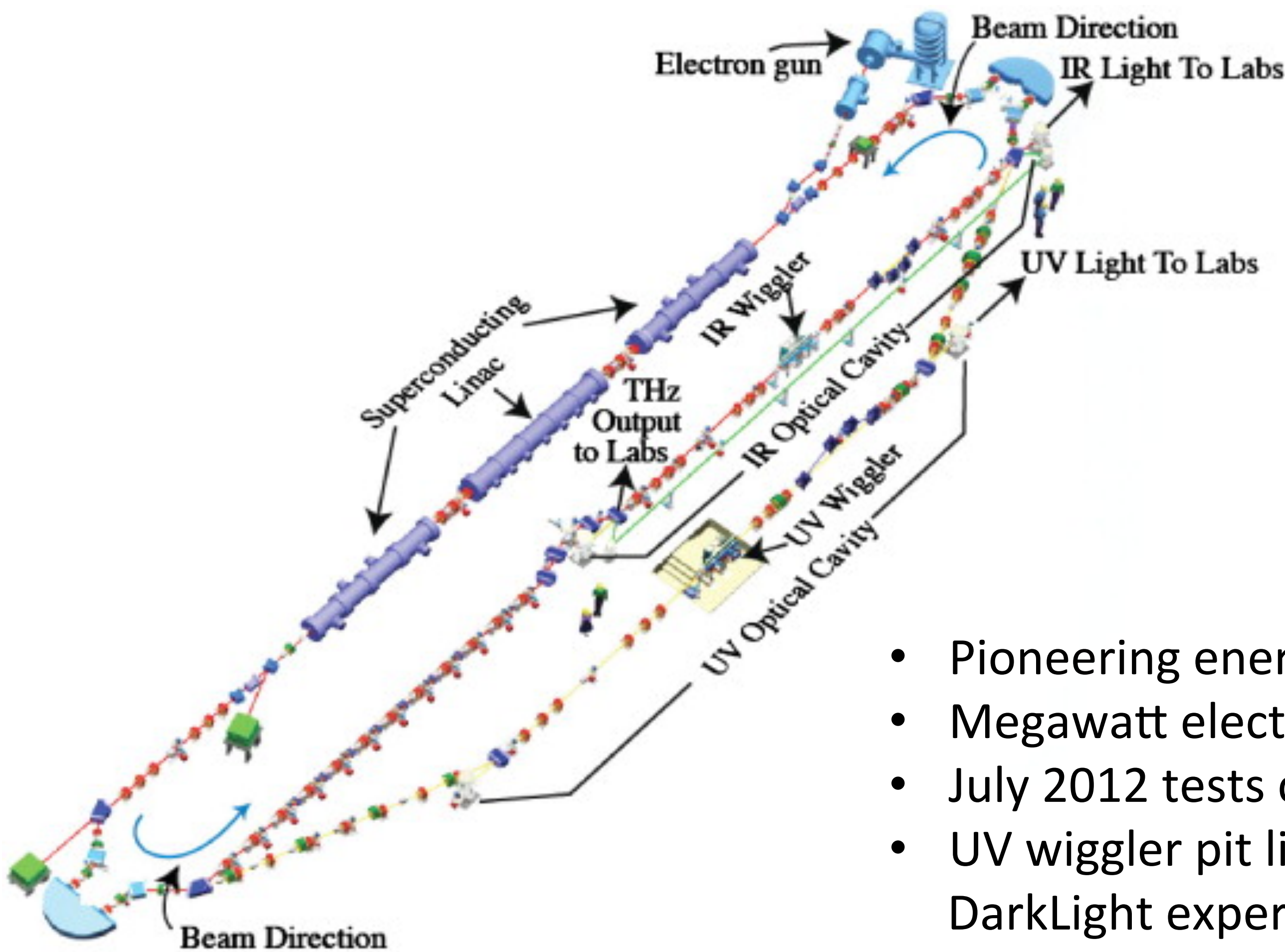
D.S. Gunarathne, C.J. Martoff, D.L. Olvitt, B. Surrow, X. Li

Temple University, PA

Experimental considerations

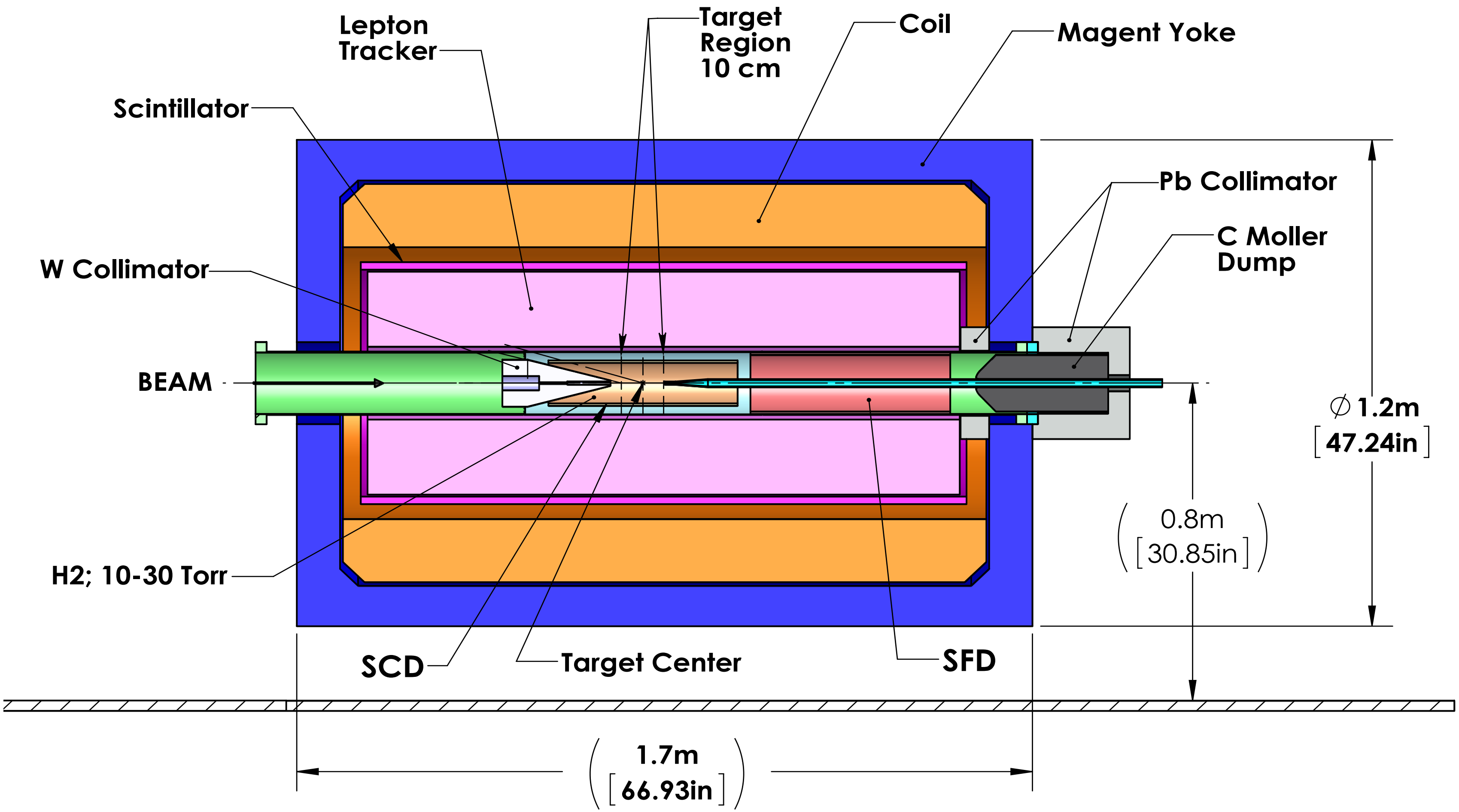
- Elastic electron-proton scattering at about 100 MeV
- Stay below pion threshold to keep final state simplest
- Demand detection of complete final state: scattered electron, recoil proton, and e+e- pair from A' decay => gas target so that the 1-5 MeV recoil proton can escape and be detected
- Require high luminosity: gas target of 10^{19} cm^{-2} and 10 mA of electrons so that one can make a definitive measurement in 1 month
- JLab FEL is world's only such accelerator: 1 MWatt of power
- Energy recovering linac
- Final state leptons have energy from 10 to 100 MeV => multiple scattering dominates resolution => thin material thicknesses
- Gas target of 10^{19} cm^{-2} is challenging; actually pushing to 4 x 10^{19} cm^{-2}

JLab Free Electron Laser

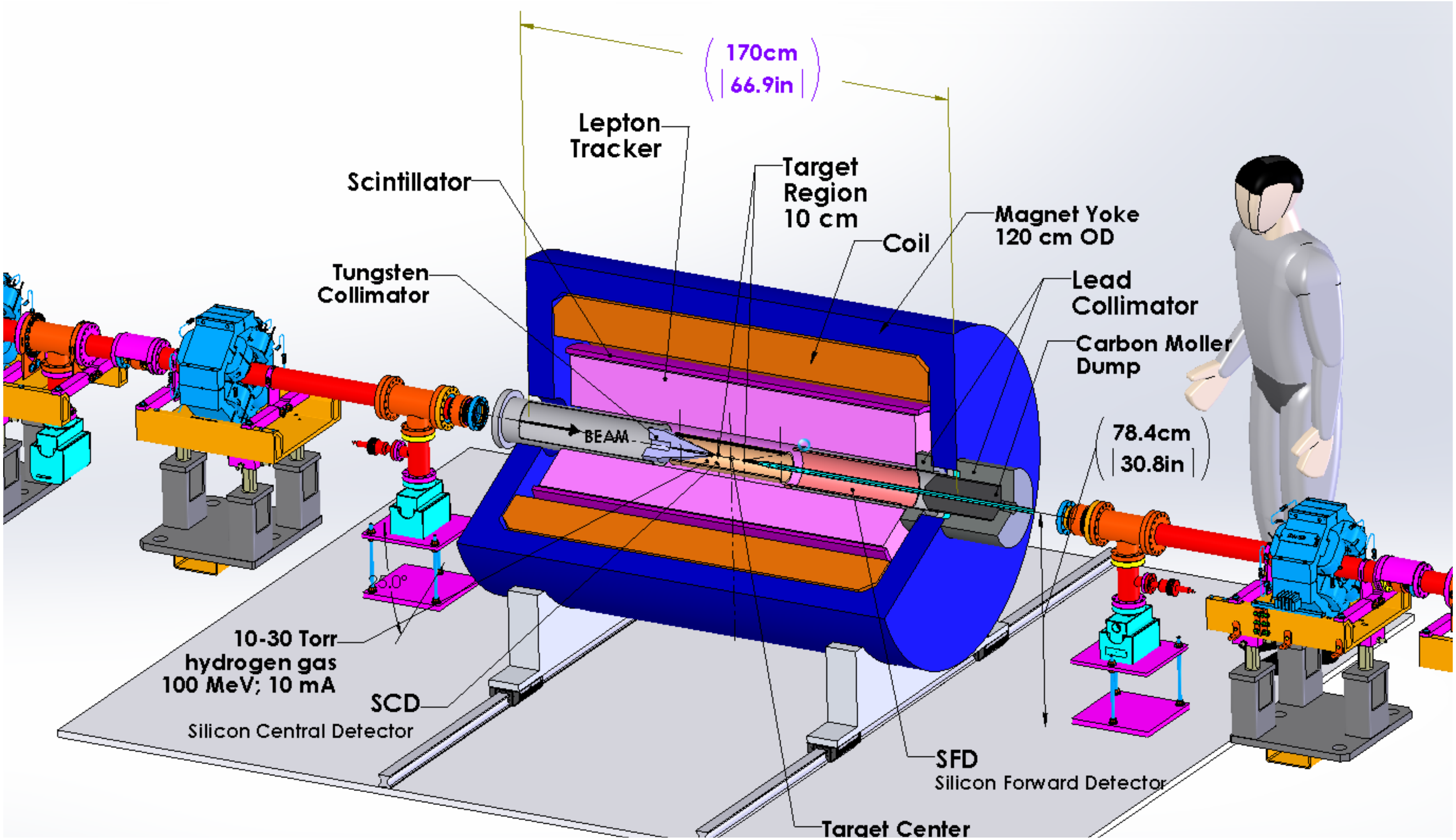


- Pioneering energy-recovering linac
- Megawatt electron beams at 100 MeV
- July 2012 tests carried out in IR region
- UV wiggler pit likely location of DarkLight experiment

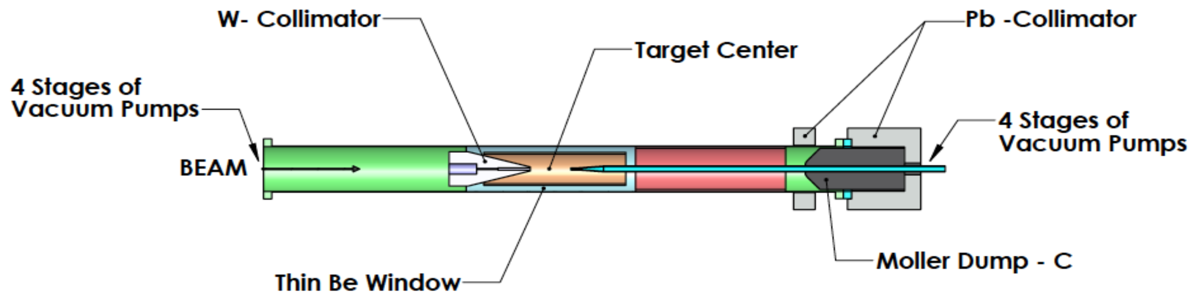
DARKLIGHT Detector



DARKLIGHT Layout



DARKLIGHT Target

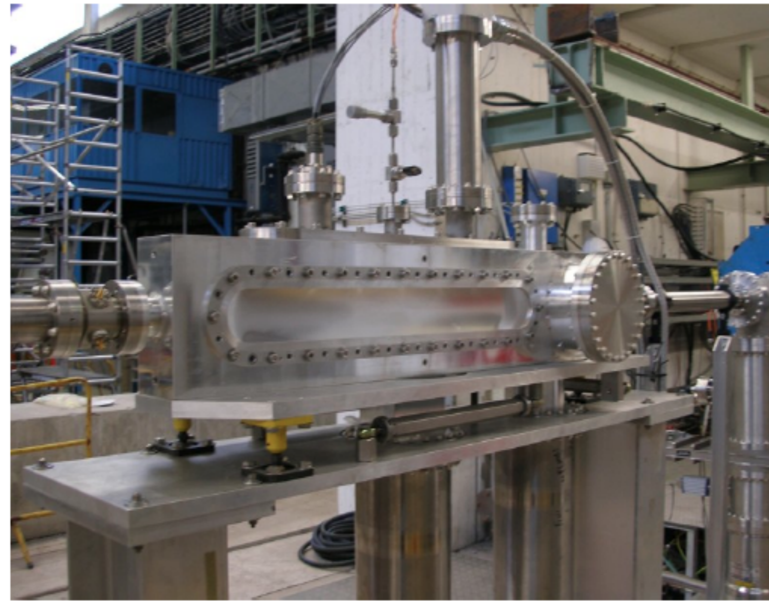


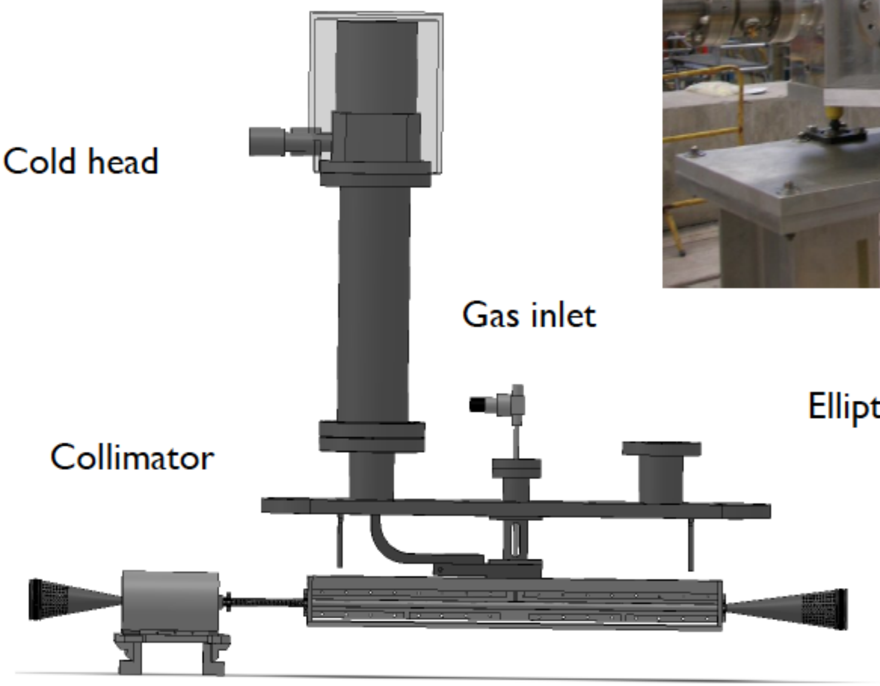
- Hydrogen target realized by flowing gas through narrow apertures
- Aperture diameter: 2 mm
- Aperture length: 50 mm
- Thickness: 10^{19} hydrogen atoms cm^{-2}
- Flow rate: 24 Torr-liter s^{-1}
- Viscous subsonic flow regime
- Multiple stages of differential pumping required
- Plasma windows under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

OLYMPUS Target

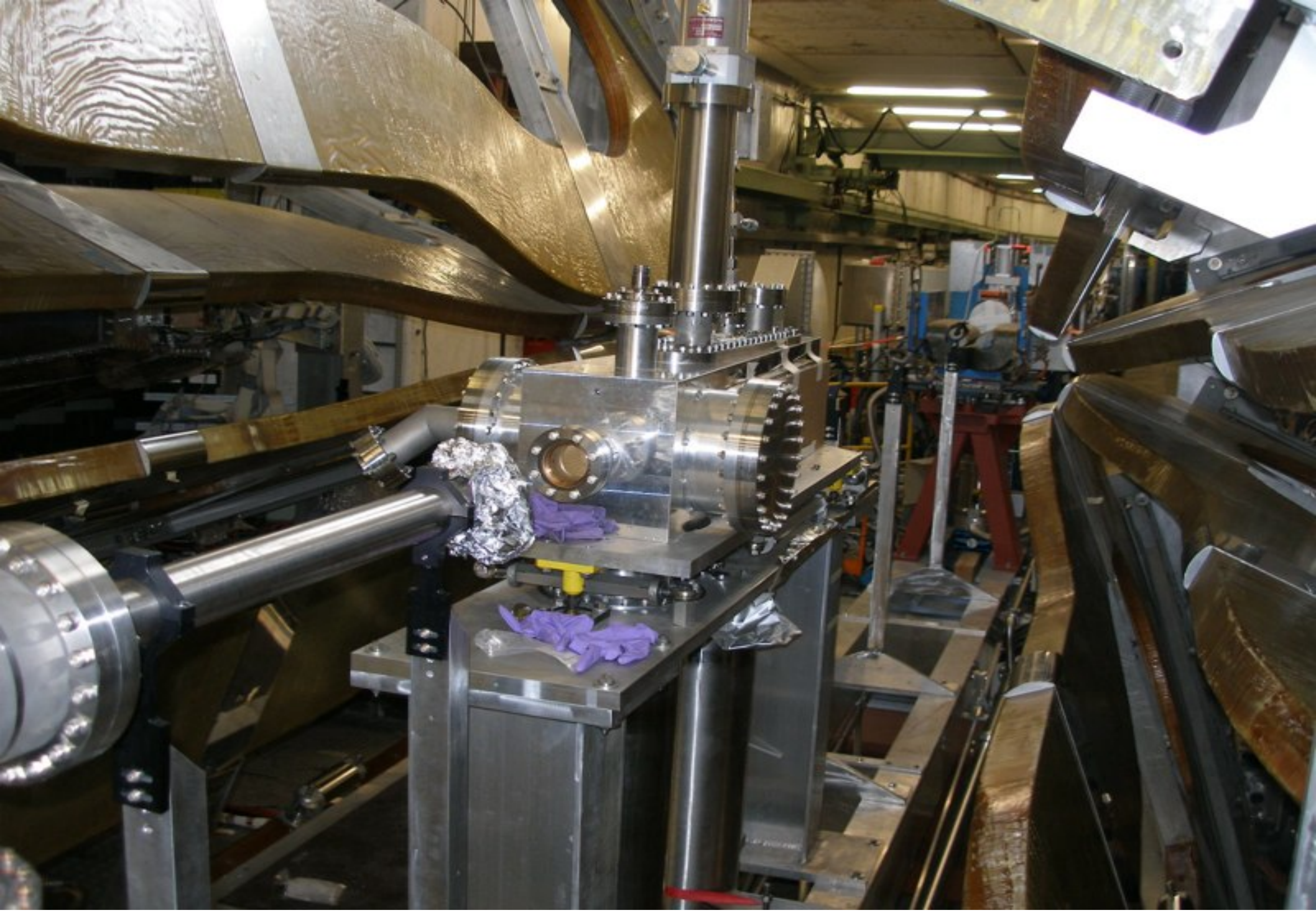
Target chamber, beamline, and vacuum system

- installed and operational January, 2011

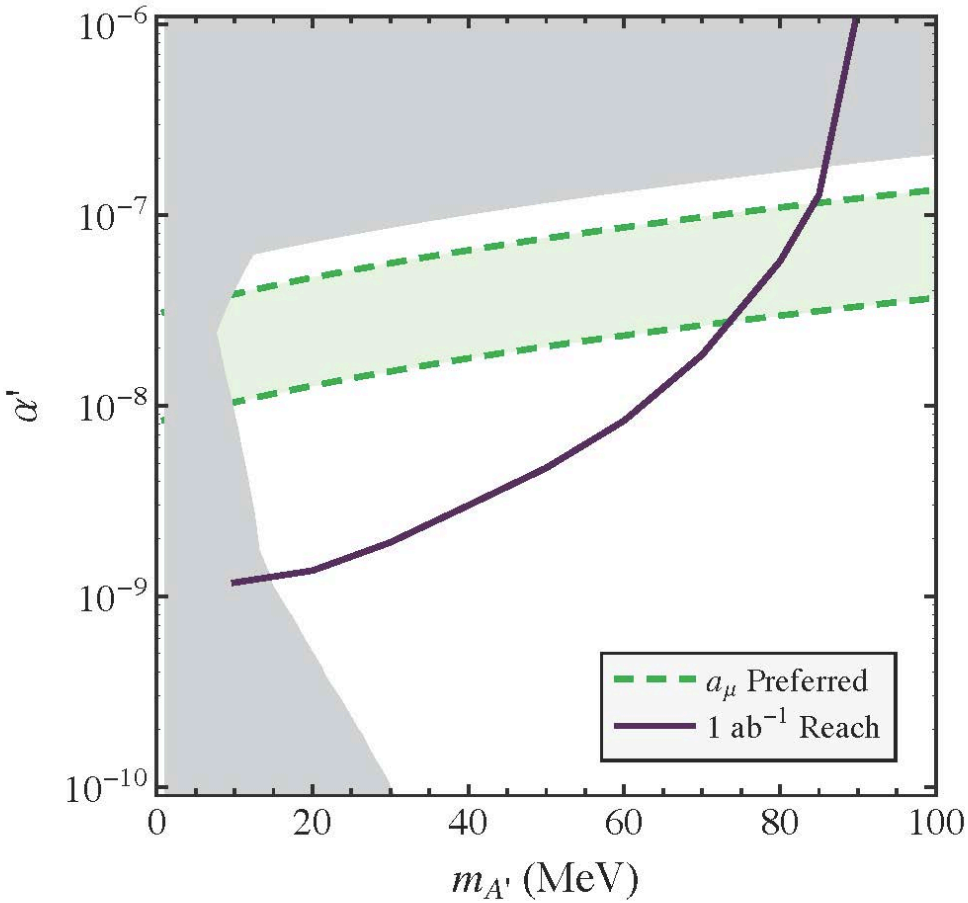




Ferrara, Italy



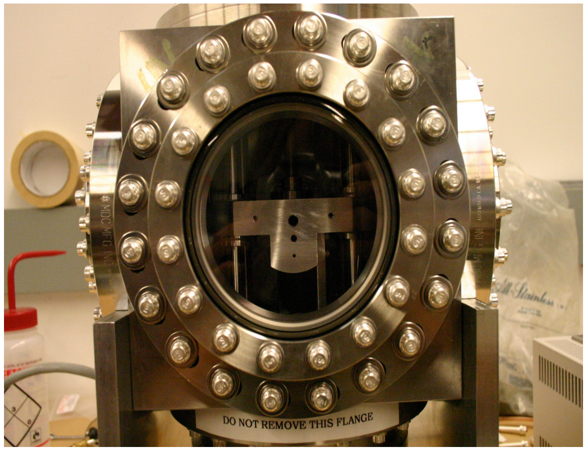
DARKLIGHT Sensitivity



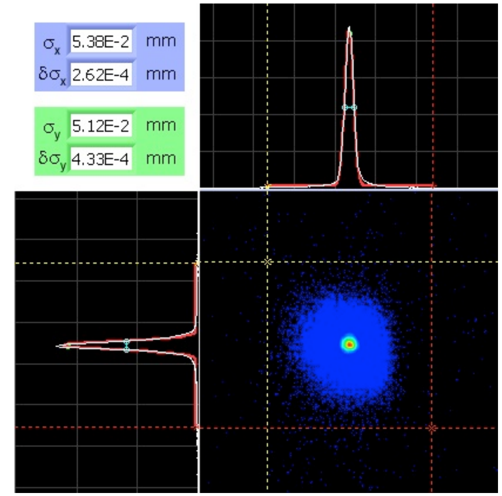
- Precision test of QED radiative processes in electron-proton elastic scattering as $Q^2 \rightarrow 0$
- Completely calculable
- Complete reconstruction of final-state
- 5σ discovery limit
- 1 ab^{-1} attained in several months of data taking with 10 mA at 100 MeV on 10^{19} cm^{-2} target
- Green region is present muon (g-2) result explained by a dark force

Freytsis, Ovanesyan, and Thaler
JHEP **1001**, (2011) 111

Successful beam test in July 2012



Target system designed and constructed at Bates R&E Center



- A test beam of 4.3 mA, 100 MeV (430 kWatt of e-beam power) was successfully transmitted through a 2 mm hole, 127 mm long, with a maximum loss of about 3 ppm for seven hours.
- Halo can be minimized and radiation in vault is manageable.
- The FEL has the stability required for DarkLight.
- Three papers written on test: *Phys. Rev. Lett*. **111**, 164801 (2013)
  Nucl. Instr. Meth. **A729**, 233 (2013)
  Nucl. Instr. Meth. **A729**, 69 (2013)

PRL **111,** 164801 (2013) PHYSICAL REVIEW LETTERS week ending 18 OCTOBER 2013

Transmission of Megawatt Relativistic Electron Beams through Millimeter Apertures

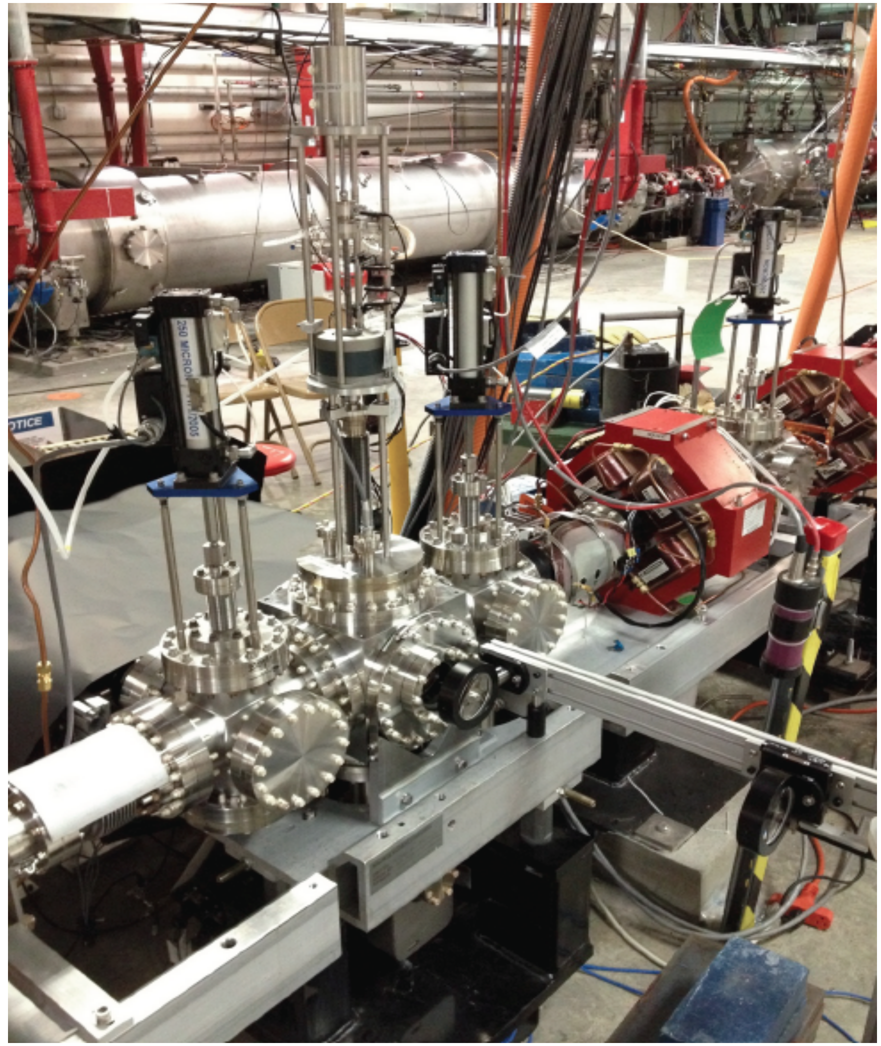
R. Alarcon,[4] S. Balascuta,[4] S. V. Benson,[2] W. Bertozzi,[1] J.R. Boyce,[2] R. Cowan,[1] D. Douglas,[2] P. Evtushenko,[2] P. Fisher,[1] E. Ihloff,[1] N. Kalantarians,[3] A. Kelleher,[1] R. Legg,[2] R.G. Milner,[1] G.R. Neil,[2] L. Ou,[1] B. Schmookler,[1] C. Tennant,[2] C. Tschalär,[1] G.P. Williams,[2] and S. Zhang[2]

[1]*Laboratory for Nuclear Science, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139, USA*
[2]*Free Electron Laser Group, Thomas Jefferson National Accelerator Facility, Newport News, Virginia 23606, USA*
[3]*Department of Physics, Hampton University, Hampton, Virginia 23668, USA*
[4]*Department of Physics, Arizona State University, Tempe, Arizona 85287, USA*
(Received 30 April 2013; published 16 October 2013)

High-power, relativistic electron beams from energy-recovering linacs have great potential to realize new experimental paradigms for pioneering innovation in fundamental and applied research. A major design consideration for this new generation of experimental capabilities is the understanding of the halo associated with these bright, intense beams. In this Letter, we report on measurements performed using the 100 MeV, 430 kW cw electron beam from the energy-recovering linac at the Jefferson Laboratory's Free Electron Laser facility as it traversed a set of small apertures in a 127 mm long aluminum block. Thermal measurements of the block together with neutron measurements near the beam-target interaction point yielded a consistent understanding of the beam losses. These were determined to be 3 ppm through a 2 mm diameter aperture and were maintained during a 7 h continuous run.

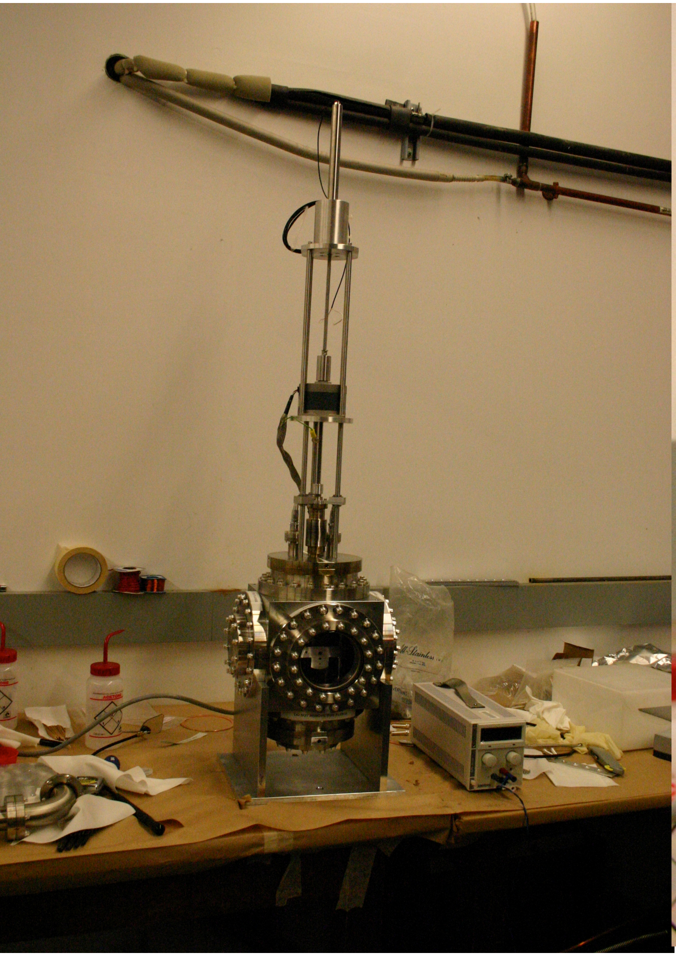
DOI: 10.1103/PhysRevLett.111.164801 PACS numbers: 41.60.Cr, 41.75.Fr, 41.85.−p

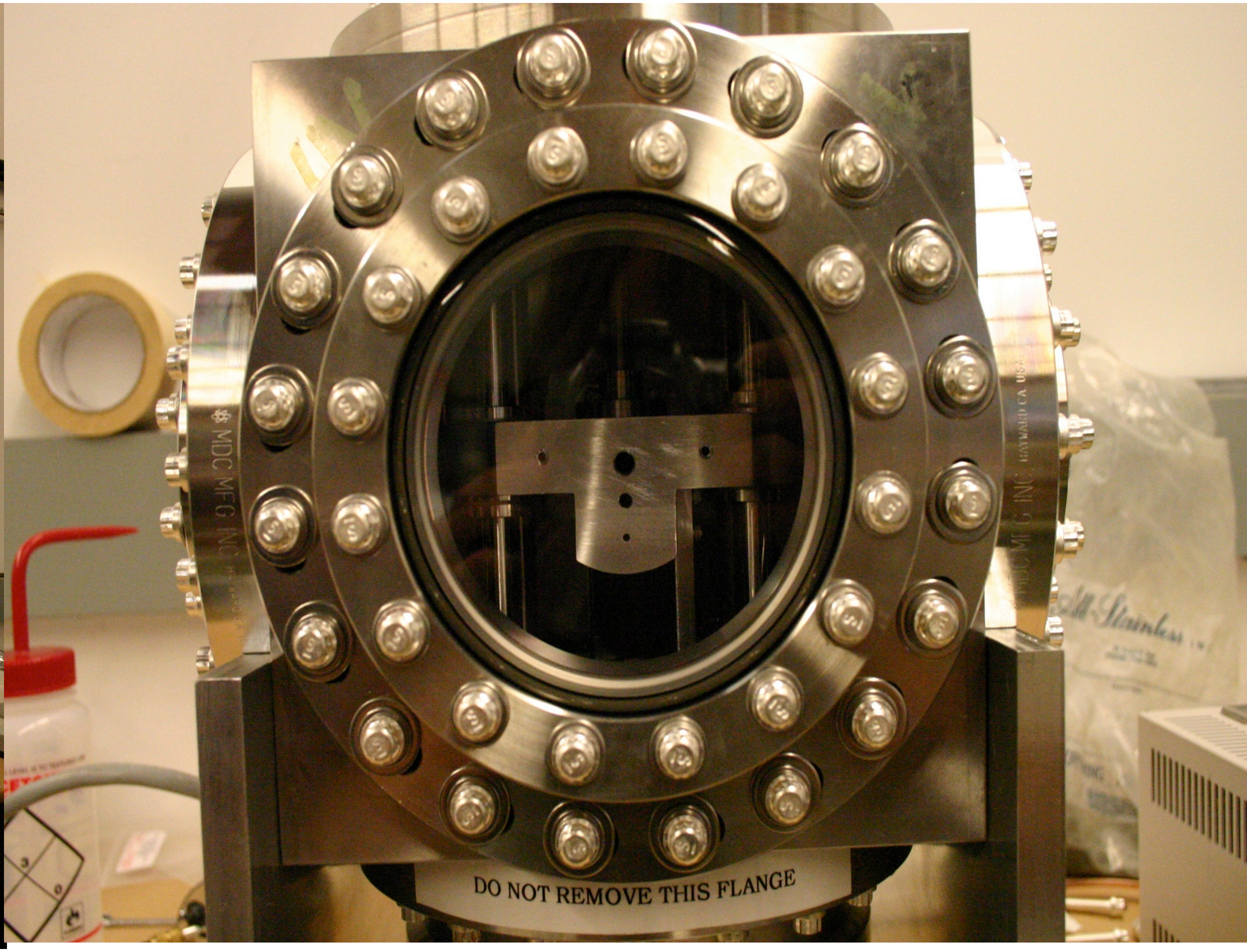
FEL vault



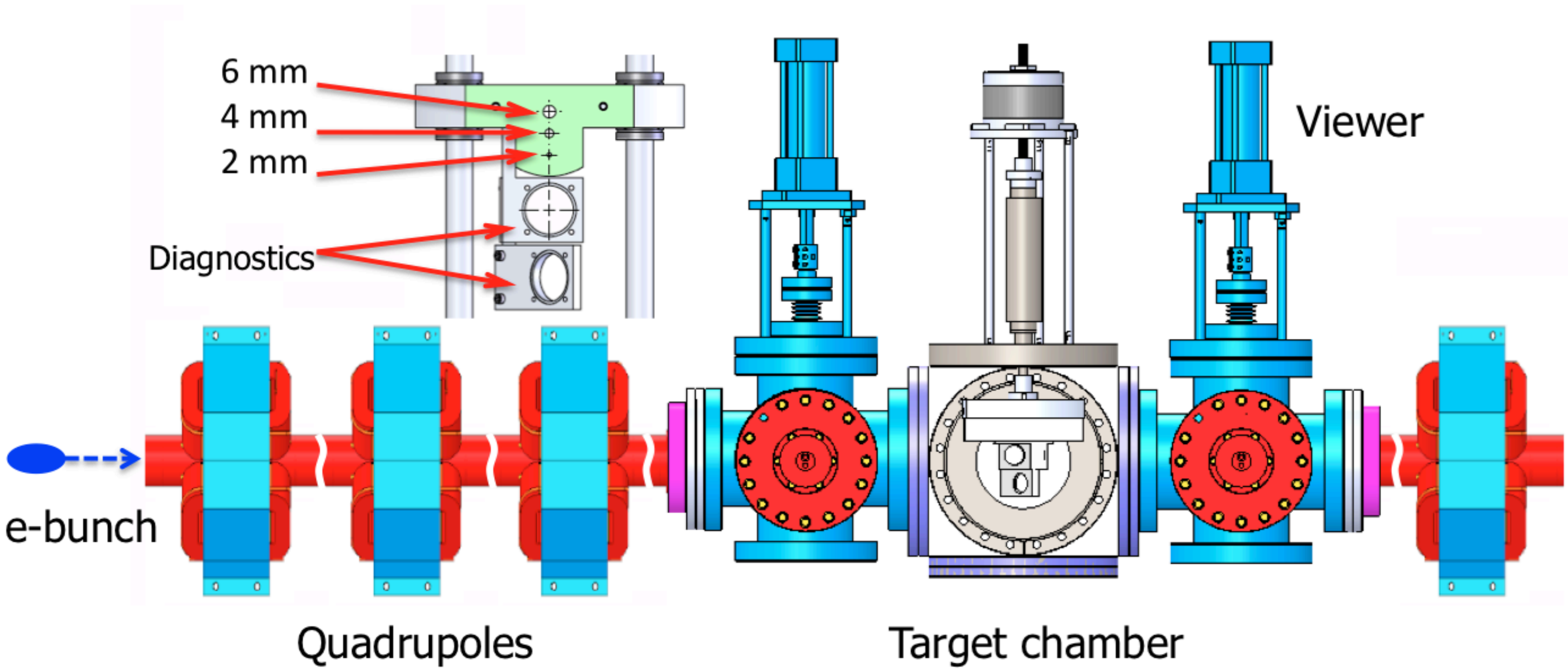
Test target

designed and constructed at the MIT-Bates R&E Center

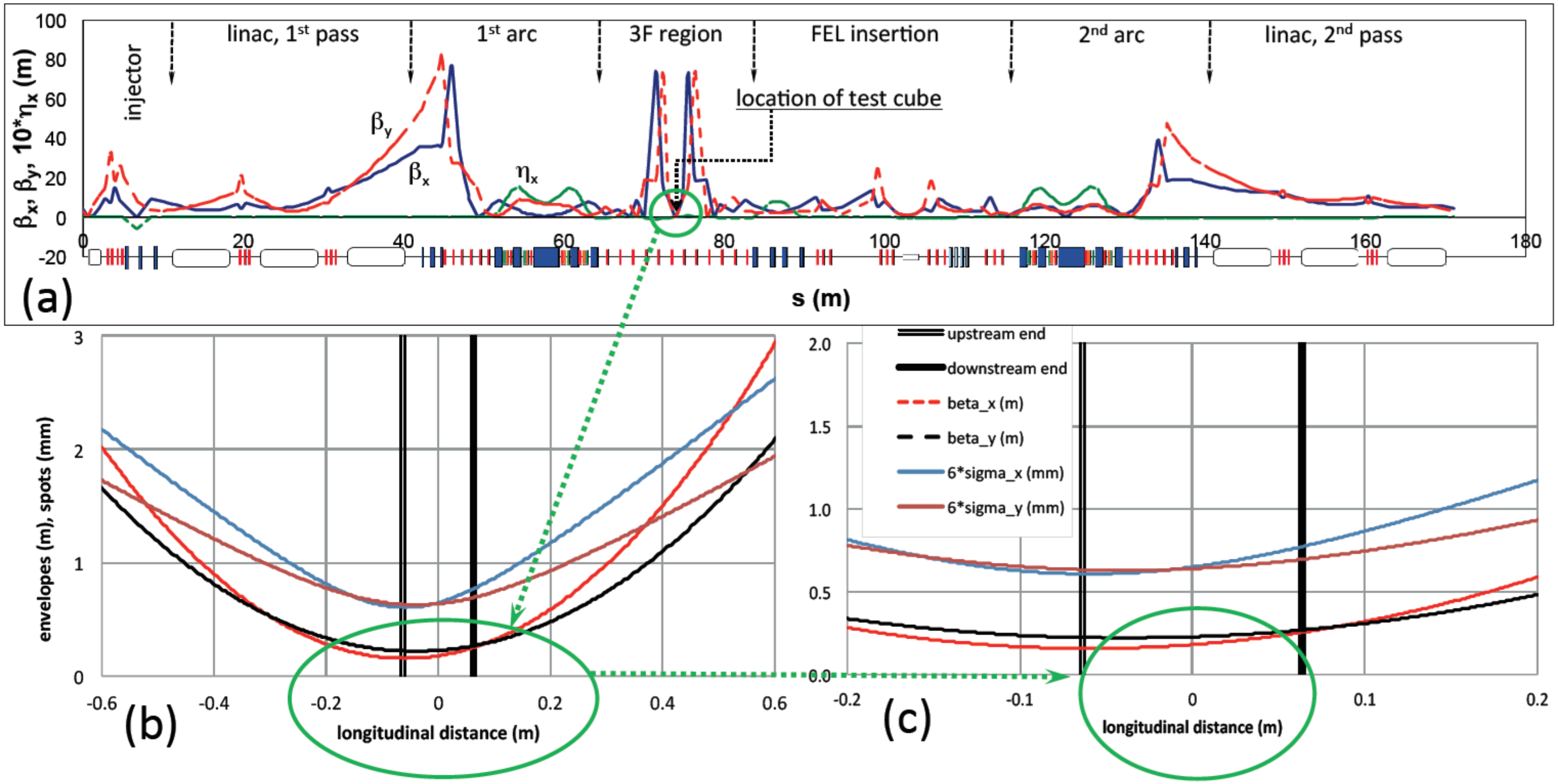




Test layout

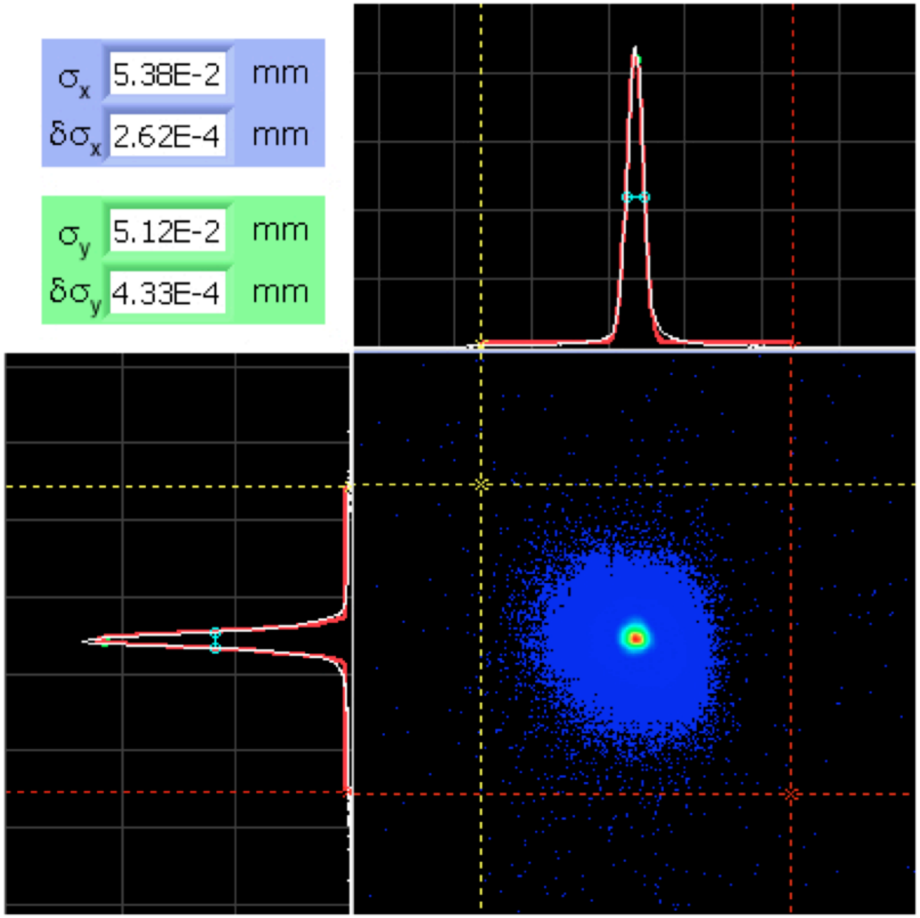

6 mm
4 mm
2 mm
Diagnostics
Viewer
e-bunch
Quadrupoles
Target chamber

Beam optics

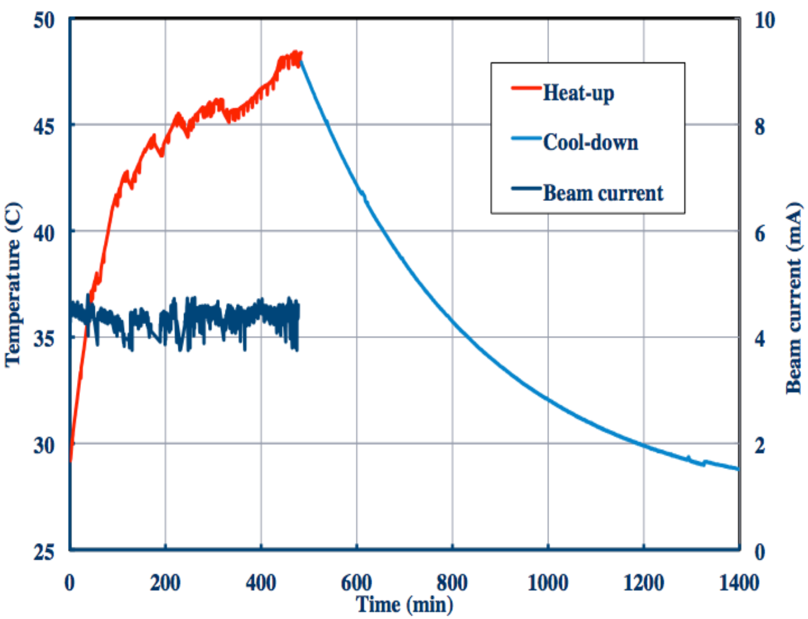


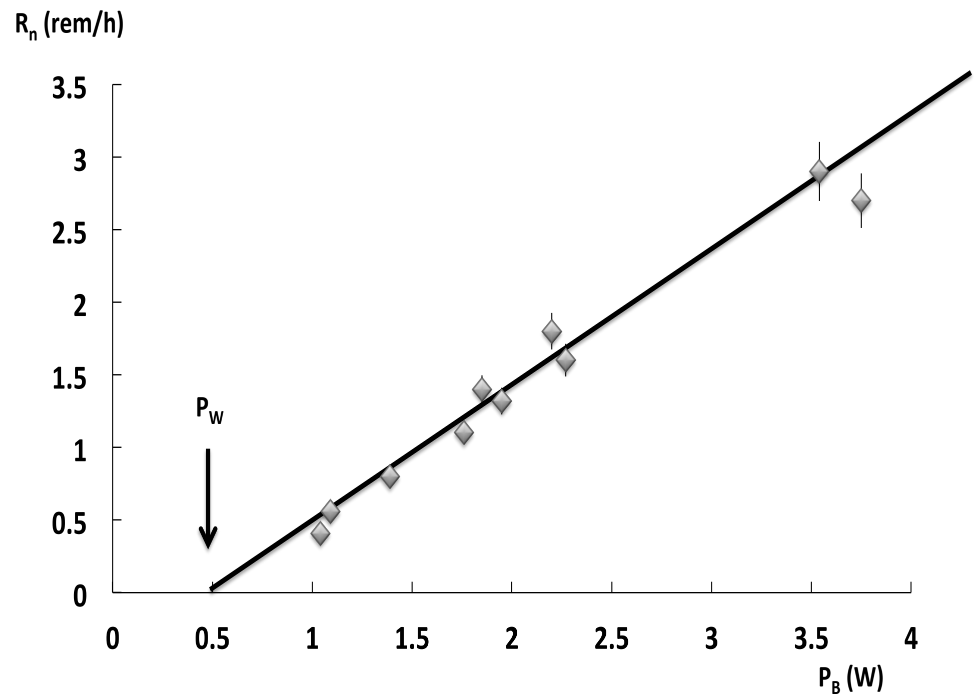
(a)
injector
linac, 1st pass
1st arc
3F region
FEL insertion
2nd arc
linac, 2nd pass
location of test cube
β_y
β_x
η_x
β_x, β_y, 10*η_x (m)
s (m)
(b)
envelopes (m), spots (mm)
longitudinal distance (m)
(c)
upstream end
downstream end
beta_x (m)
beta_y (m)
6*sigma_x (mm)
6*sigma_y (mm)
longitudinal distance (m)

Bright, clean Megawatt 100 MeV electron beam



Power deposition inferred from thermal and neutron production measurements





Test results

Aperture	Average beam loss	Neutron dose rate	Photon dose rate	Photon flux
6 mm	2.5 ppm	261 mrem/hr	13 R/hr	1.2×10^7 cm^{-2} sec^{-1}
4 mm	3.0 ppm	435 mrem/hr	19 R/hr	1.8×10^7 cm^{-2} sec^{-1}
2 mm	6.0 ppm	900 mrem/hr	60 R/hr	4.8×10^7 cm^{-2} sec^{-1}

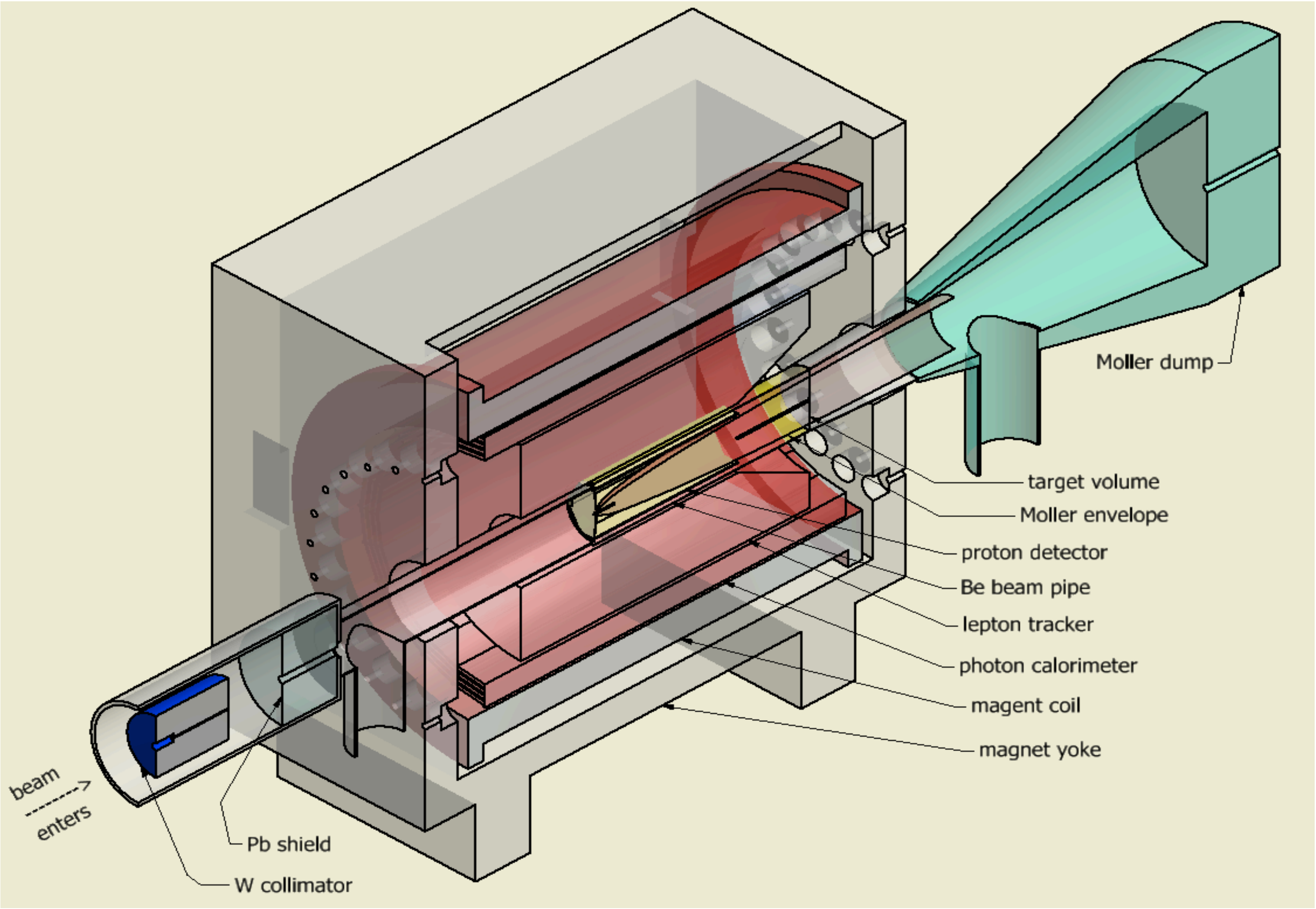
Table 1: Beam loss and average radiation backgrounds observed for each aperture, averaged for each run. Photon and neutron backgrounds are at 2 m downstream of the target cube and 1 m to the side of the beam line. Photon flux measurements are estimates from NAI/PMT recorded spectra in photon energy range 100 keV to 15 MeV.

- A test beam of 4.5 mA, 100 MeV (450 kWatt of e-beam power) was successfully transmitted through a 2 mm hole, 10 cm long, with a maximum loss of about 7 ppm for seven hours.
- Halo can be minimized.
- The FEL has the stability required for a successful DarkLight experiment.
- Radiation in the vault is manageable.

Existing solenoidal magnet from E906 at BNL

- Constructed in Japan: see thesis by J.P. Nakano, U. of Tokyo (2000)
- E906 carried out at AGS D6 line
- 0.5 Tesla maximum field
- Inner diameter 712 mm
- Magnet with power supply now located at Stony Brook University

Optimized design in progress



Design process

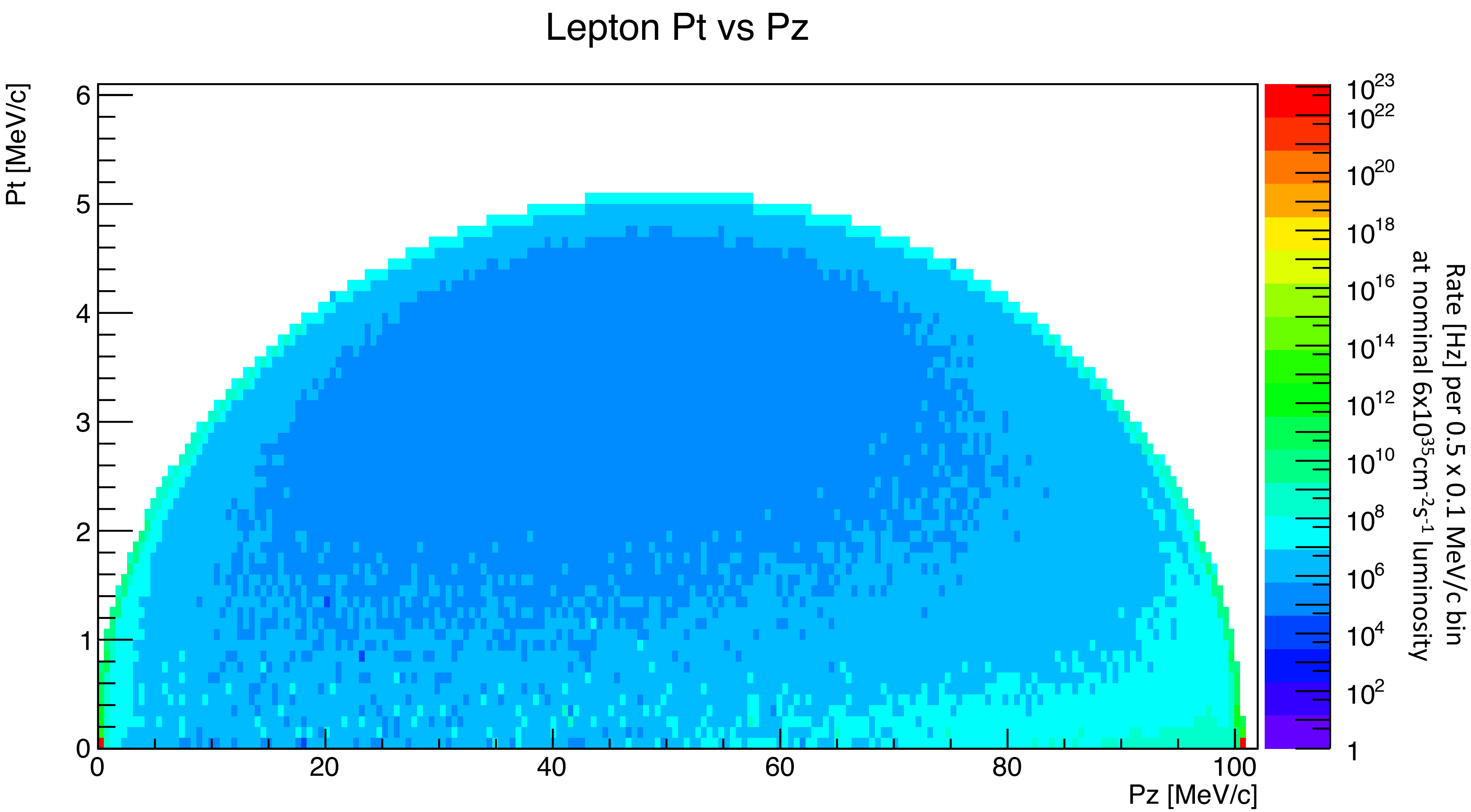
- Full Geant4 computer simulation coordinated by Jan Balewski (MIT)
- Physics processes:
  - elastic electron-proton scattering
  - Moller scattering
  - their associated radiative processes
- Detailed experimental geometry:
  - windowless gas target
  - existing solenoidal magnet
  - realistic 3 D magnetic field map from OPERA
  - Moller dump
  - lepton tracker
  - recoil proton detector
  - photon veto detector
- Simulations are used to optimize the design of the experiment.

Development of a Radiative Møller Generator

- Under development by Charles Epstein (MIT) :
  a Monte Carlo event generator for the radiative corrections to Møller scattering
- Improves understanding of background processes
  - Møller rate is exceptionally high and must be understood

- Produces two types of events:
  - Elastic e-e events with cross-section corrected for the emission of soft photons (Tsai, 1960)
  - Hard single-photon bremsstrahlung events (exact first-order calculation)

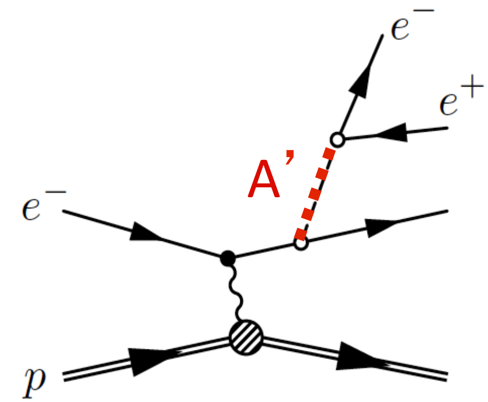
Radiative Møller Event Distribution

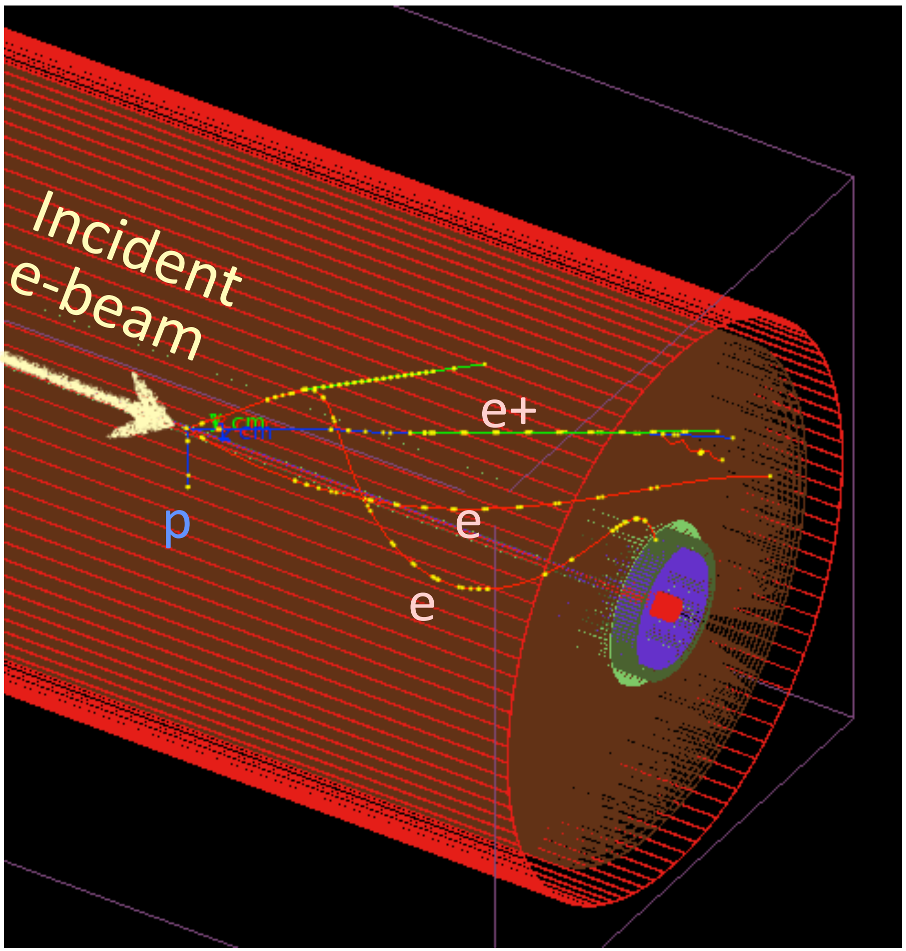


- Thorough vetting underway – comparison with data?
- Code will be made available after sufficient verification

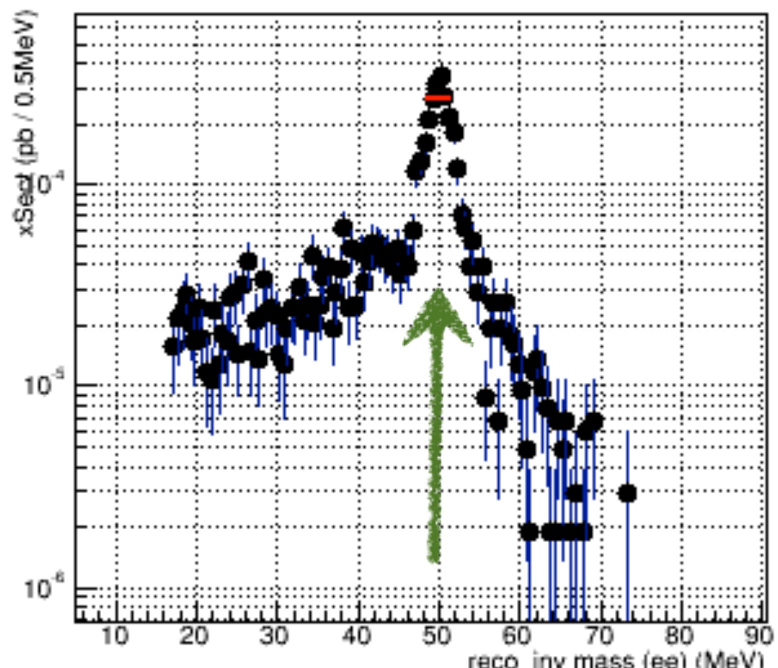
DARKLIGHT

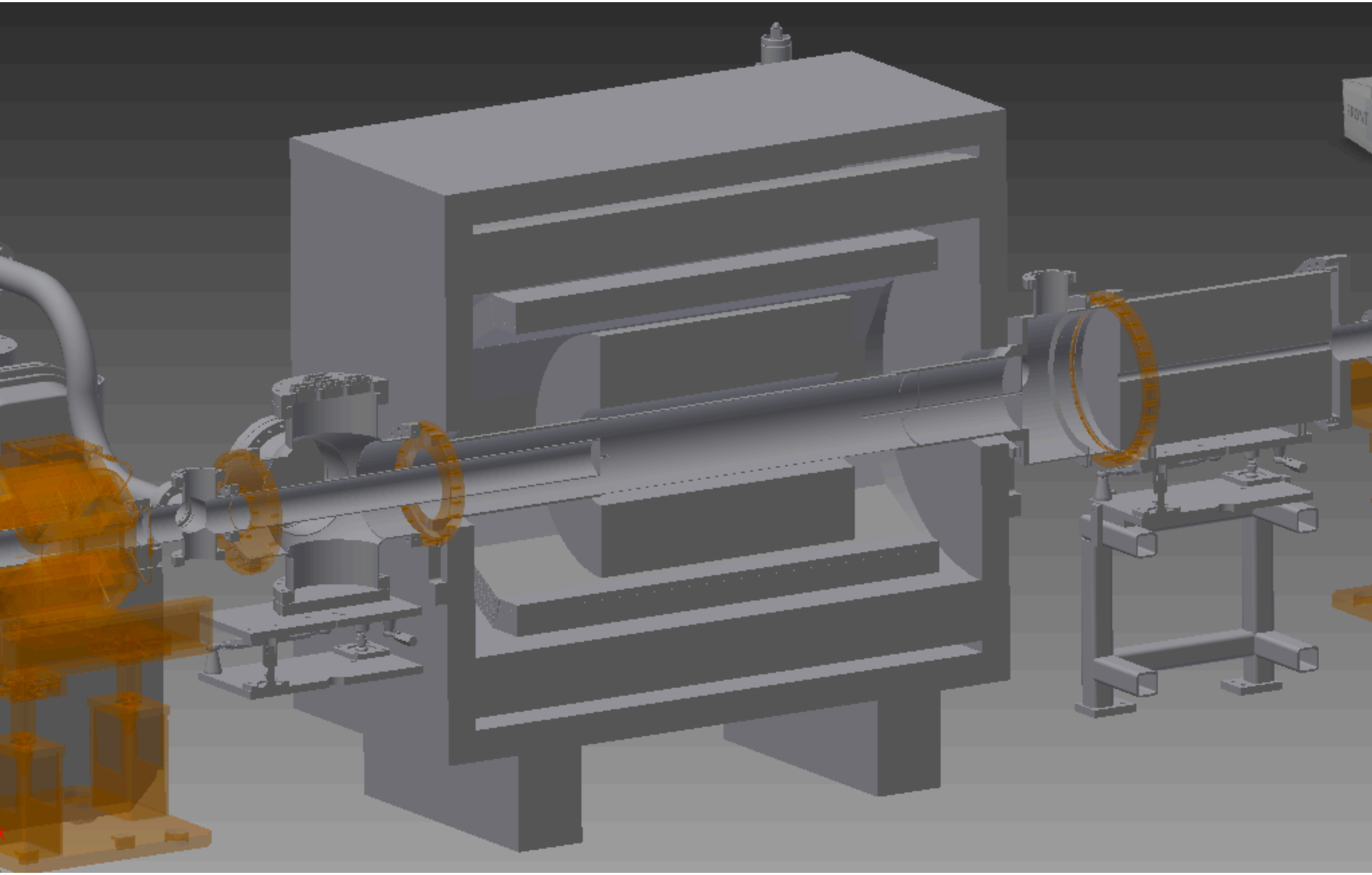
e p → e- p A’ (30 MeV) →e+ e-



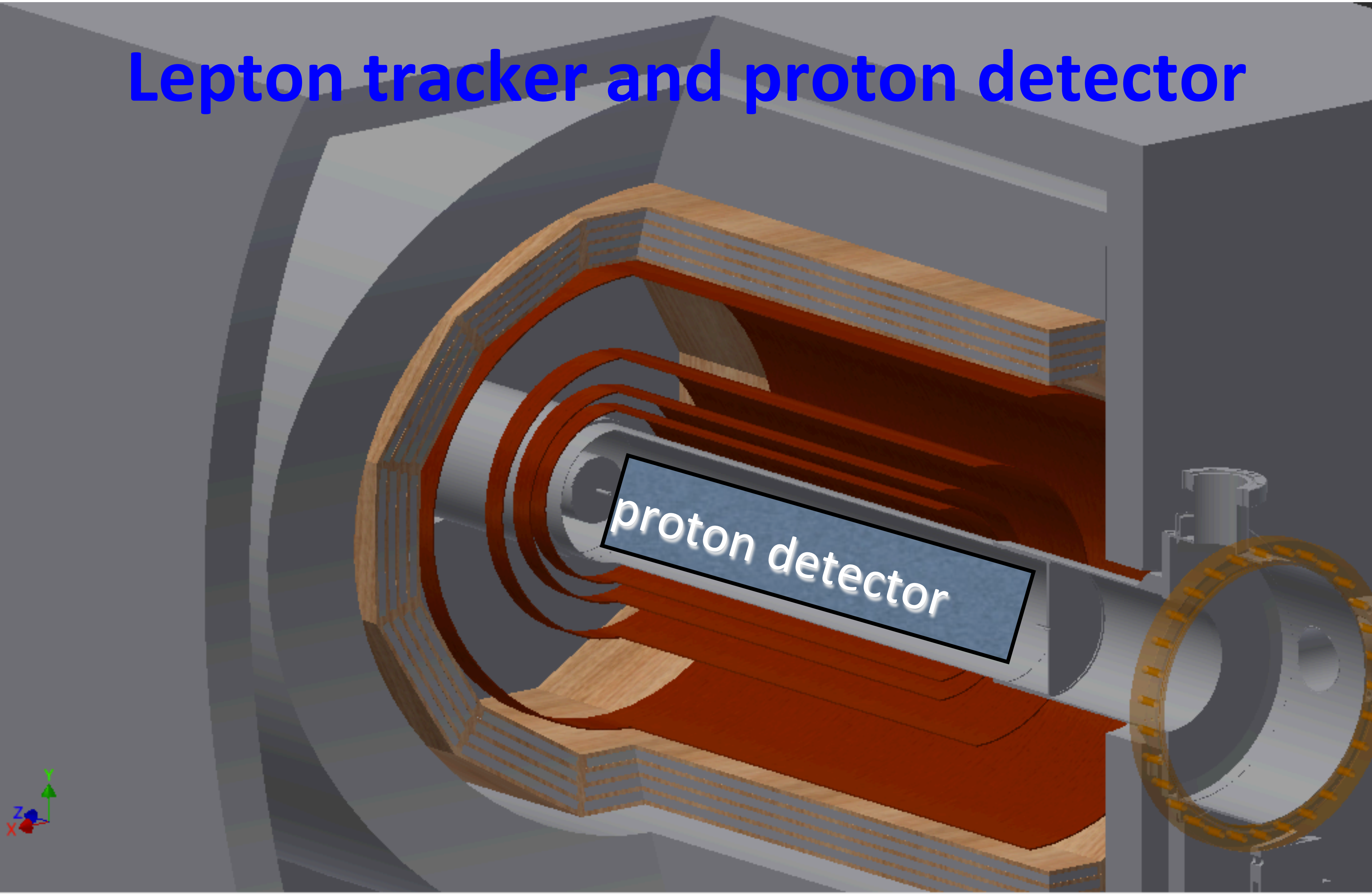


reconstructed **A’ signal**
assumed mass of A’ =50 MeV



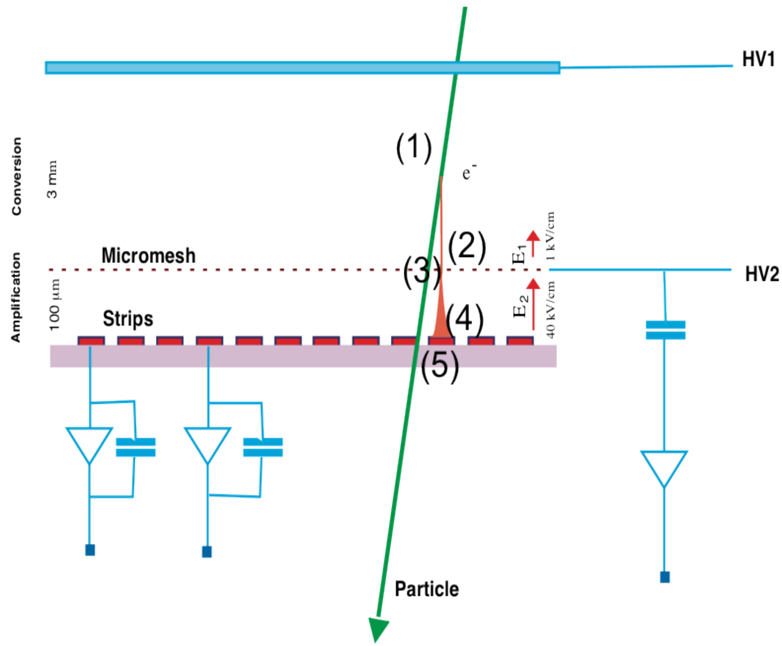


Lepton tracker and proton detector

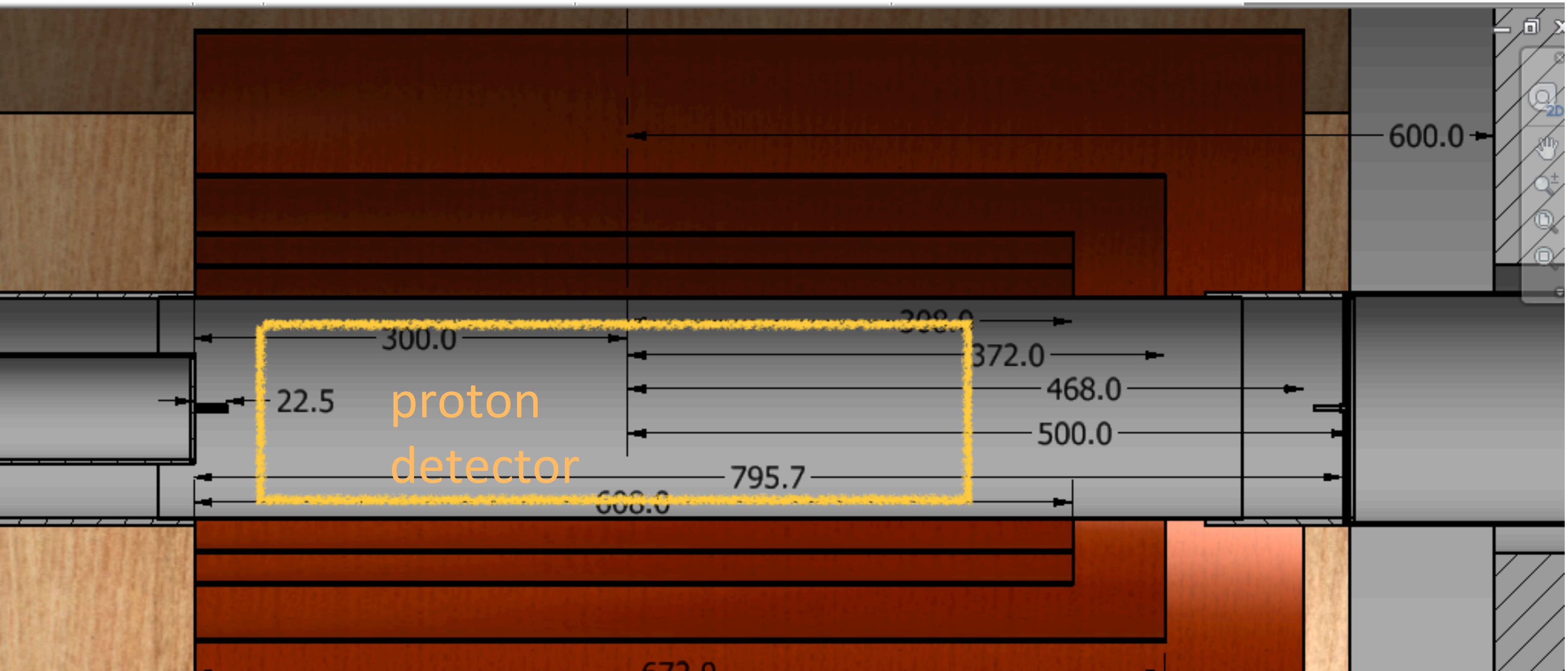


Current specifications

- Lepton tracker
  - 4 cylindrical layers
  - 0.3% rad. l. per layer
  - Micro-Mesh Gaseous Structure leading candidate
  - approx. 30,000 channels
- Proton detector
  - 300 micron silicon
  - 0.3% rad. l. inc. sensor and cables
  - 1 mm thick Be beampipe (0.3% rad. l.)
  - approx. 1,000 channels
- Photon detector
  - lead-scintillator sandwich
  - 1000 channels
- Luminosity
  - 2.5 x 10^{36} cm^{-2} s^{-1} (4 times design)



Event Rates

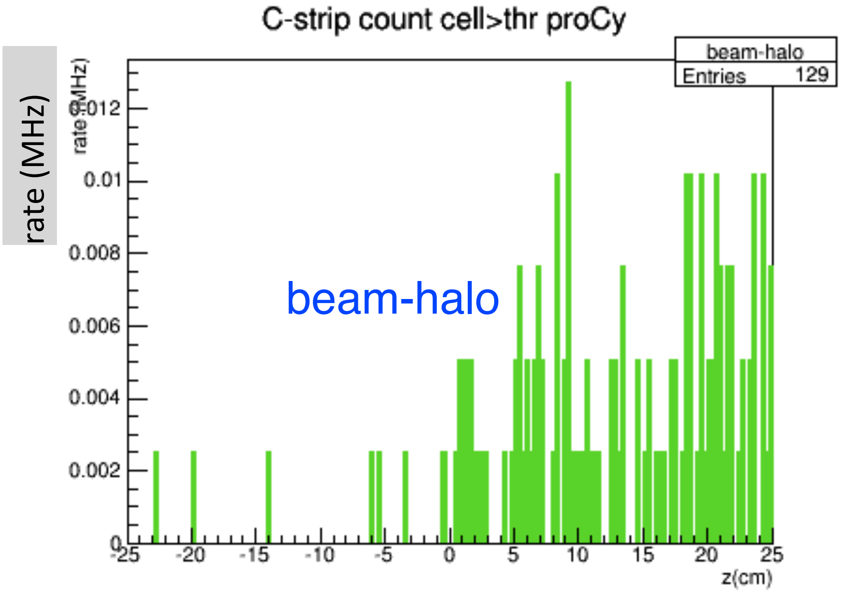


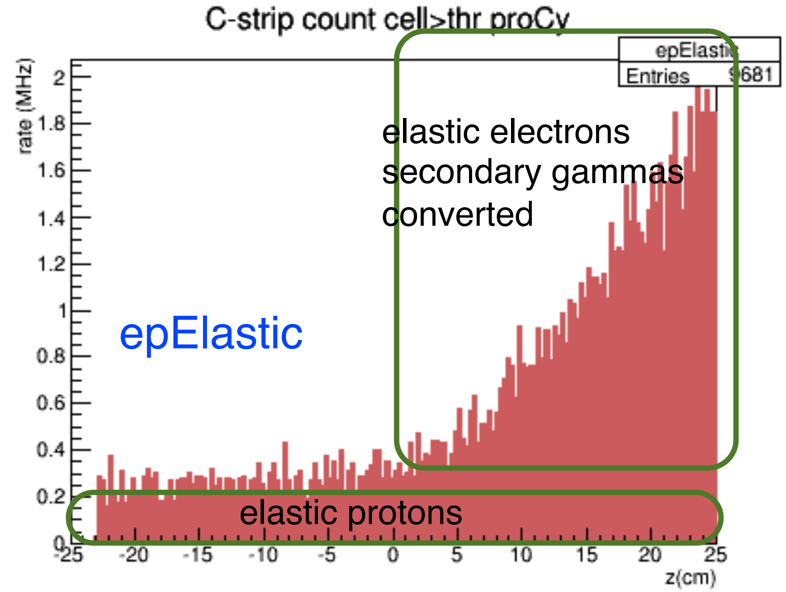
epElastic totXsect(cm2)=6.5e-24 for theta=[0.002 0.9] rad
[totXsect]*2.5e36 → **1.6 e13 Neve/sec** @ DL-2 nominal lumi

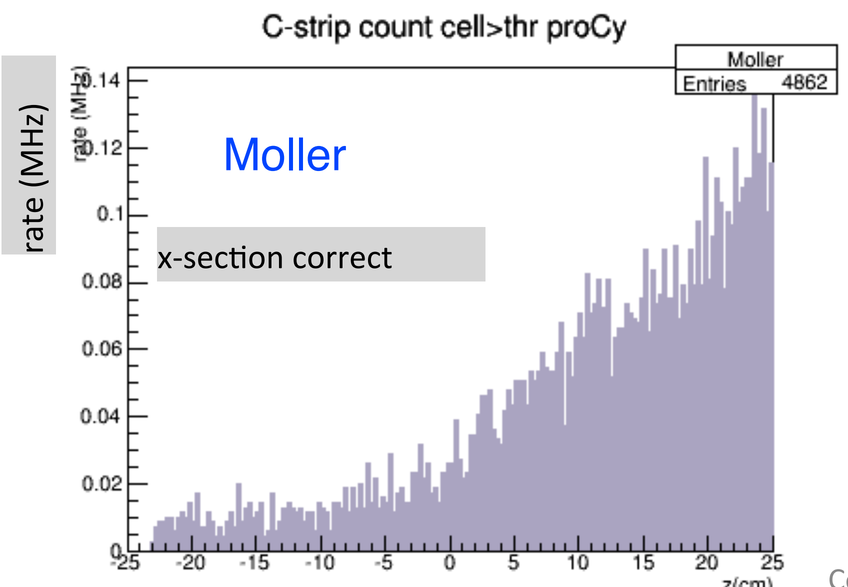
Moller totXsect(cm2)=6.9e-25 for theta=[0.002 0.9] rad
[totXsect]*2.5e36 → **8.7e13 Neve/sec** @ DL-2 nominal lumi

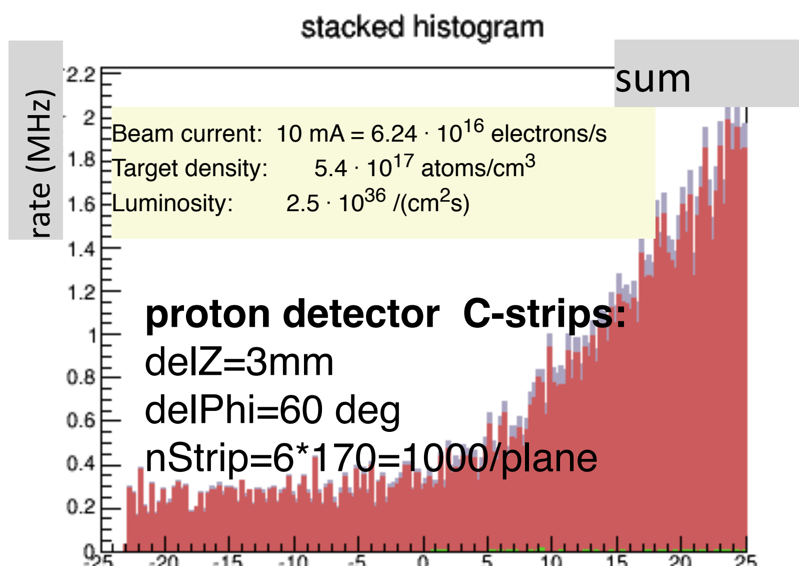
beam halo 3ppm * 6.24e16 → **1.9e1 Neve/sec** @ DL-2 nominal lumi

Rate vs. z at proton detector

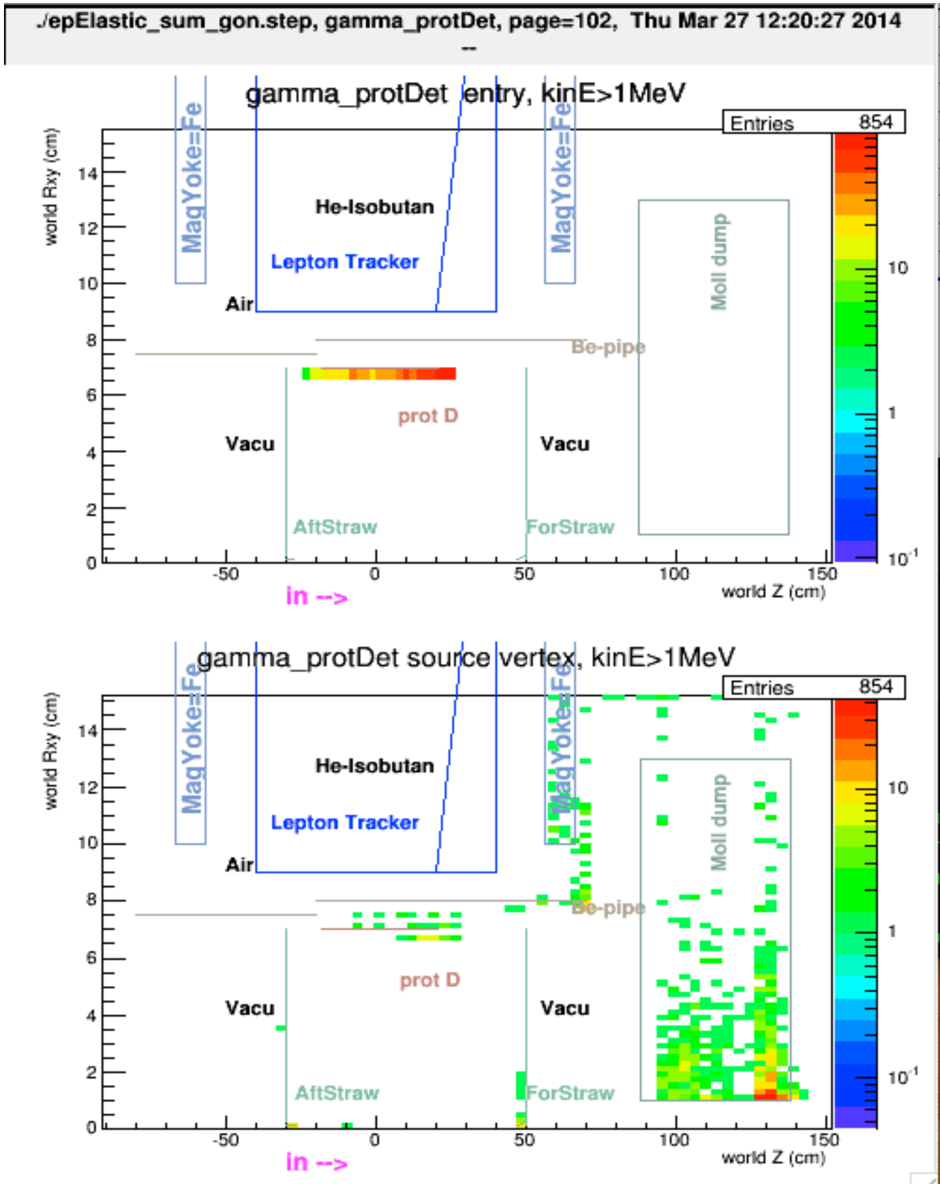


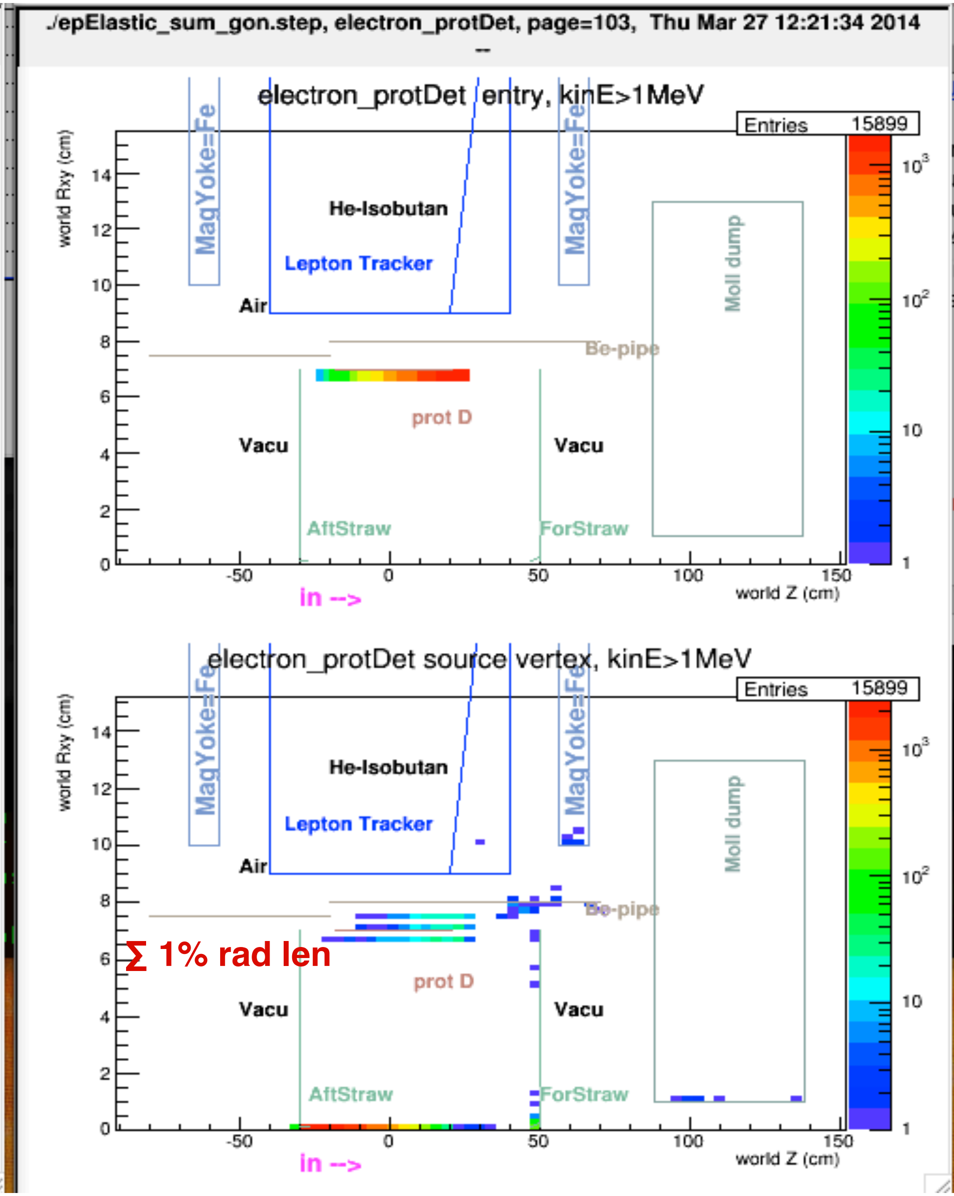




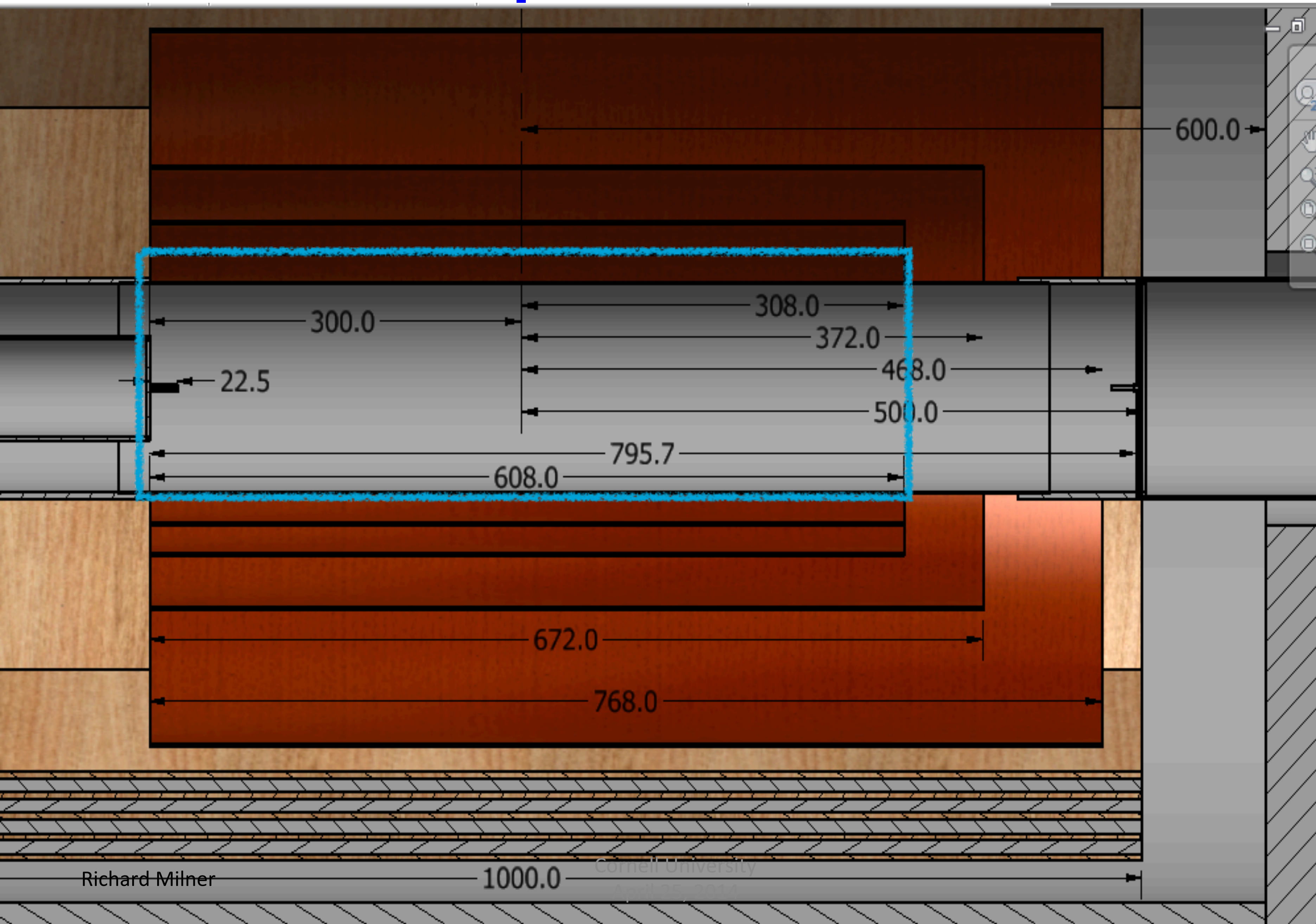


Photons and electrons entering lepton tracker

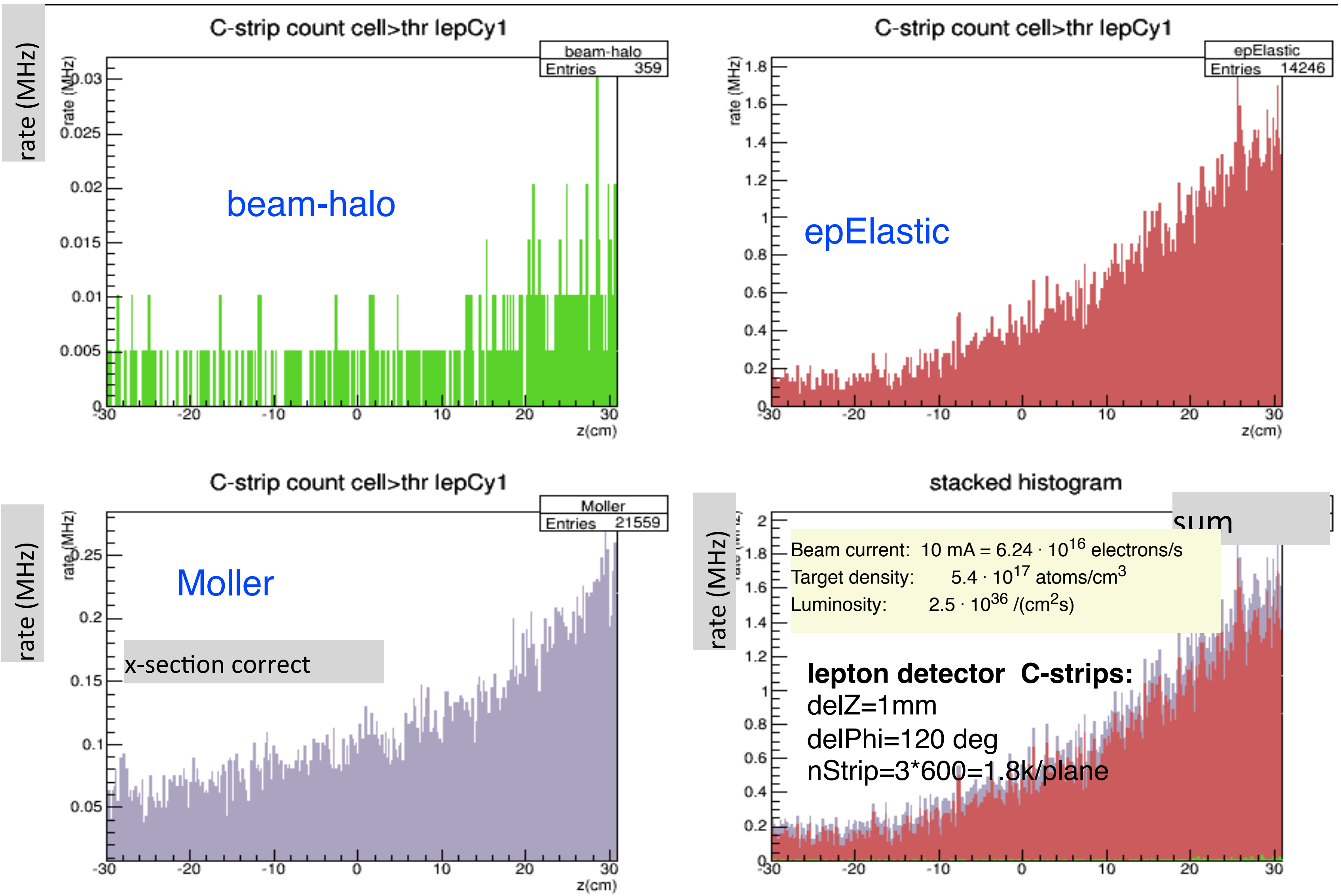




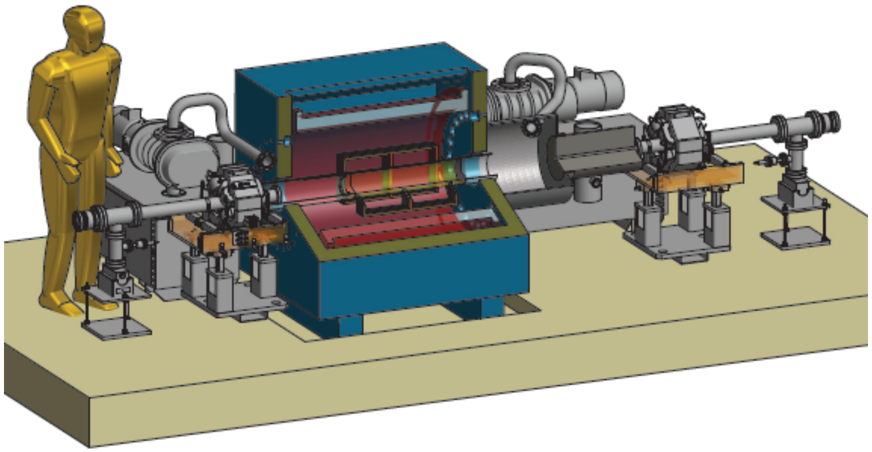
Lepton Tracker



Rates vs. z at lepton detector



DARKLIGHT streaming DAQ

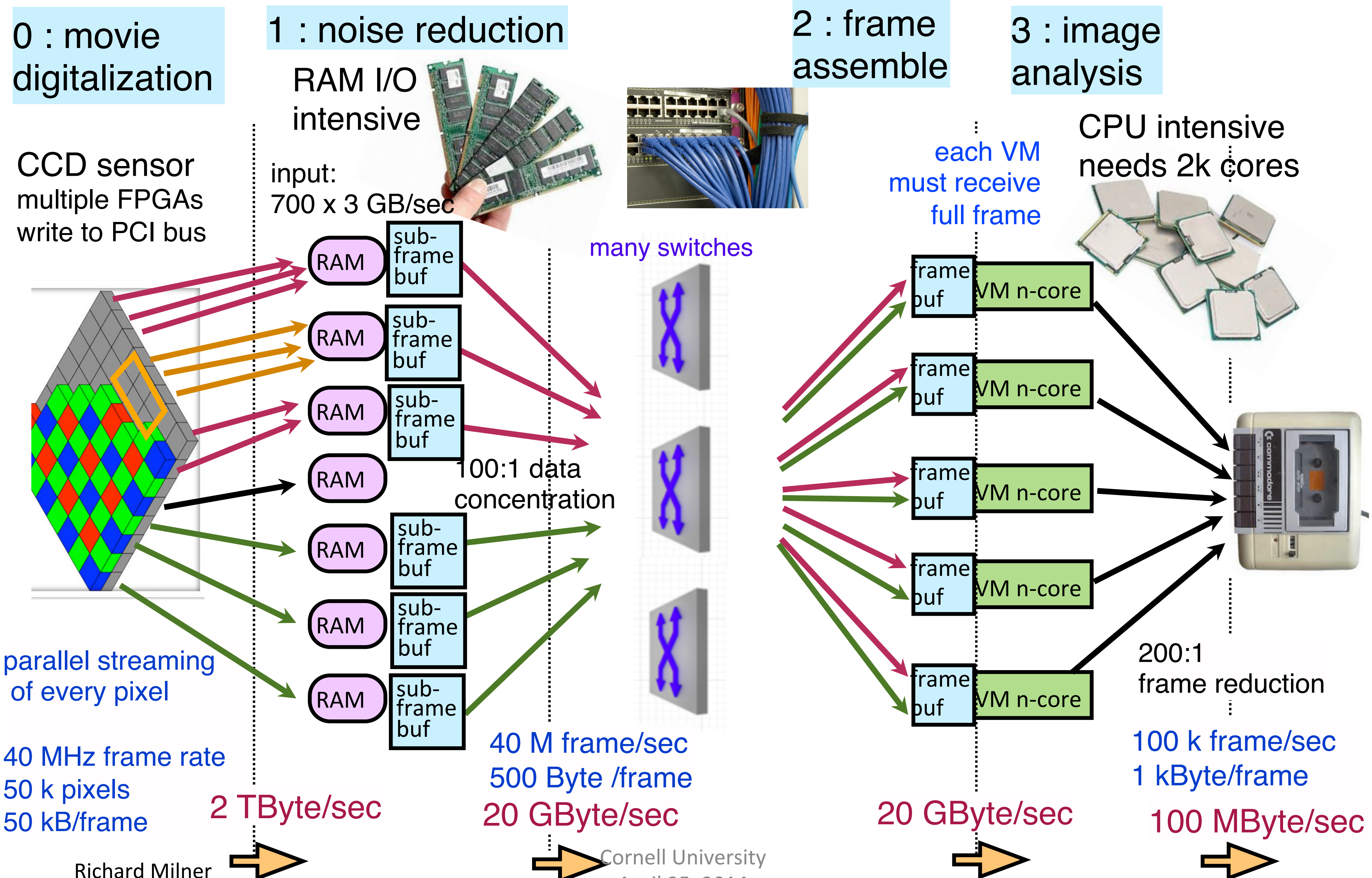


DarkLight experiment @ JLAB , assume:
- streaming of 50k x 1Byte channels at 40 MHz
- input raw data rate 2TByte/sec

Step A: noise reduction
Step B: frame assembly
Step C: image recognition

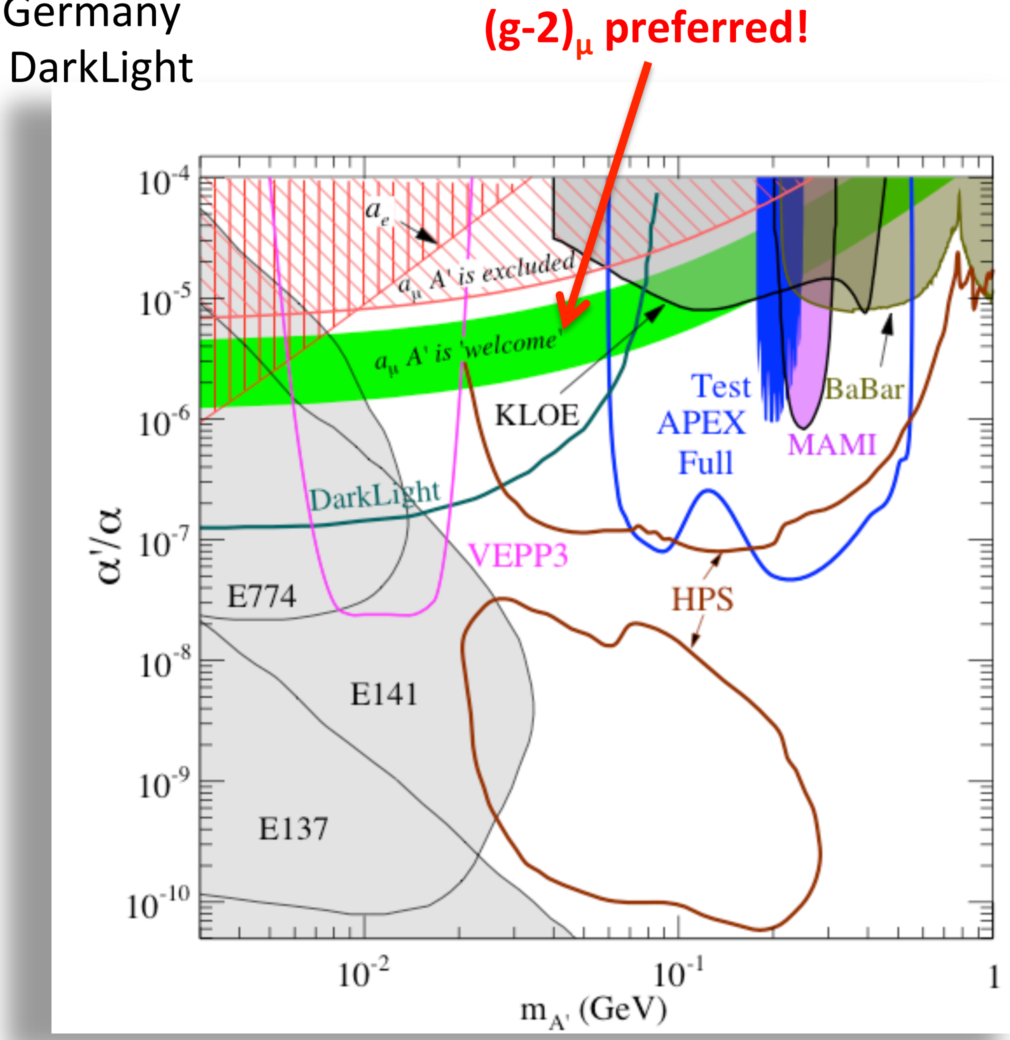
1.make movie at 40 MHz
2.read every pixel in parallel
sparse DATA [pixel ID][time bin]
1.recombine complete frames,
transpose: DATA [time bin] [pixel ID]
1.distribute frames over CPUs
2.analyze images in parallel
3.keep only interesting frames w/ dark-matter events

DarkLight streamed data acquisition (sDAQ)



New experimental program

- MAMI at Mainz, Germany
- JLab: APEX, HPS, DarkLight



Workshop to Explore Physics Opportunities with Intense, Polarized Electron beams with Energy up to 300 MeV

MIT, Cambridge, MA
March 14-16, 2013

With the availability of intense, polarized linac beams in the energy range up to 300 MeV, new types of experiments can be considered. The workshop is open to all good ideas but we solicit abstracts in the following categories:

- **Parity violating electron scattering at low Q^2**
- **Search for dark photons**
- **Precision nucleon structure**
- **Nuclear physics, inc. astrophysical reactions**
- **Technology: facilities, high power targets, high intensity polarized electron sources, precision electron polarimetry, optimized detectors and high brightness beam diagnostics**

Organizing Committee:

Kurt Aulenbacher (U. Mainz)
Roger Carlini (JLab) (Co-chair)
Achim Denig (U. Mainz)
Roy Holt (ANL)
Peter Fisher (MIT)
Krishna Kumar (UMass, Amherst)
Frank Maas (U. Mainz) (Co-chair)
Bill Marciano (BNL)
Richard Milner (MIT) (Co-chair)
George Neil (JLab)
Marc Vanderhaeghen (U. Mainz)

For information contact:

http://web.mit.edu/lns/PEB_Workshop/
Email: *pebworkshop@mit.edu*

Supported by: MIT, Johannes Gutenberg Universität Mainz, Jefferson Lab – Thomas Jefferson National Accelerator Facility

DARKLIGHT Schedule

- DarkLight proposal approved at JLab PAC 39 in June 2012 with "A" scientific rating, conditional upon successful test being completed
- Test successfully completed in July 2012
- Full scientific approval granted in May 2013
- Detailed simulations in progress to finalize design: lepton tracker, trigger and readout
- OLYMPUS target was shipped back to MIT in summer 2013 to allow start on development of DarkLight target
- Existing 0.5 T solenoid at Stony Brook University (A. Deshpande)
- Anticipate it will take about 3 years to realize the experiment
- Envisage further beam tests at the FEL with prototype target and detectors
- International interest in using technology to address other important scientific problems: workshop to explore physics opportunities took place at MIT on March 14-16, 2013

Summary

- The search for new physics beyond the Standard Model must take place at all energy scales.
- There are some indications for a dark photon in the mass range below 1 GeV.
- DarkLight is designed to search for such a dark photon in the mass range 10 to 100 MeV/c^2 by carrying out a precision test of QED where the complete final-state is detected.
- MRI proposal submitted to NSF to mount phase-I DarkLight experiment. If funded, this can begin in 2015.
- Full experiment design with cost to be completed summer 2014.
- Could begin data taking as early as 2017.