Searching for a Dark Photon with DarkLight

Ross Corliss
on behalf of the DARKLIGHT Collaboration

DARKLIGHT

New Vistas in Low-Energy
Precision Physics
April 5, 2016

Massachusetts
Institute of
Technology

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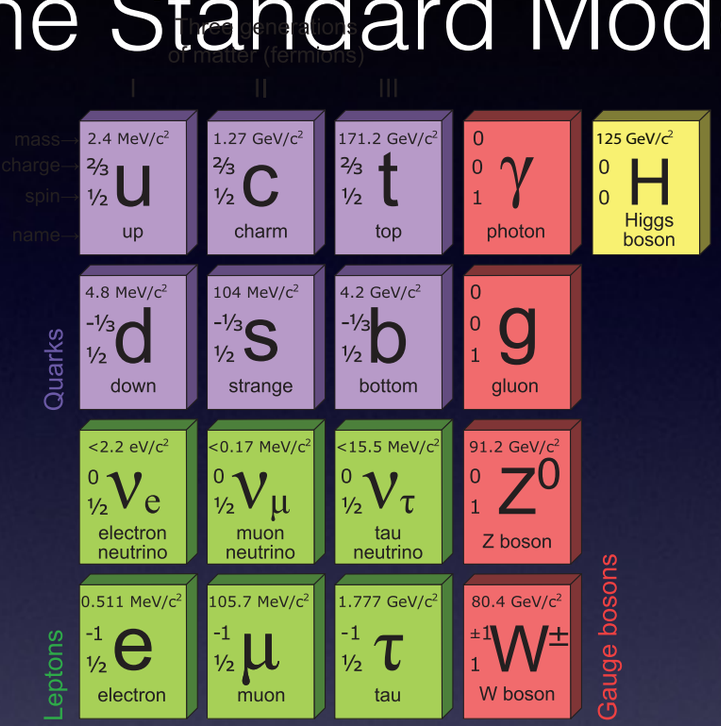
Dark Matter

The Standard Model



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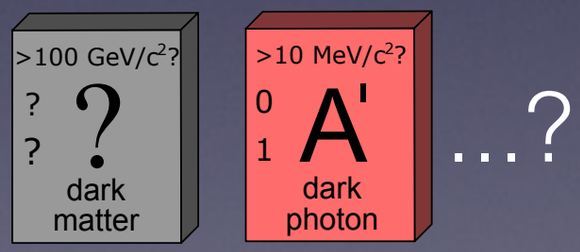
Heavy Elements 0.03%
Interstellar Gas 0.3%
Stars 0.5%
Neutrinos 4%

Something Else



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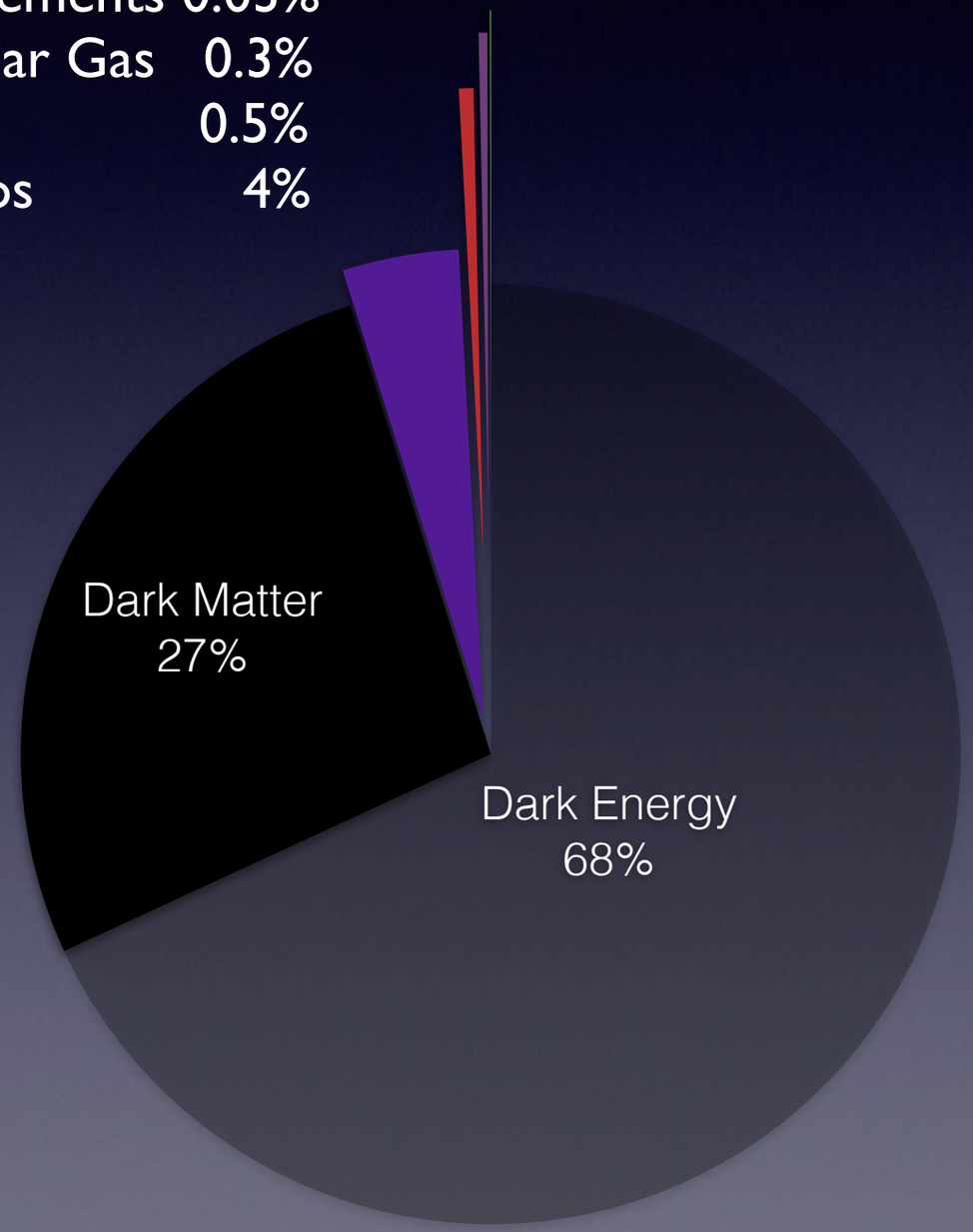
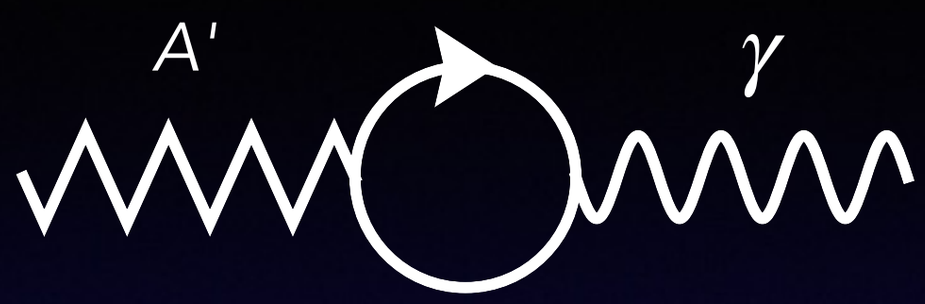
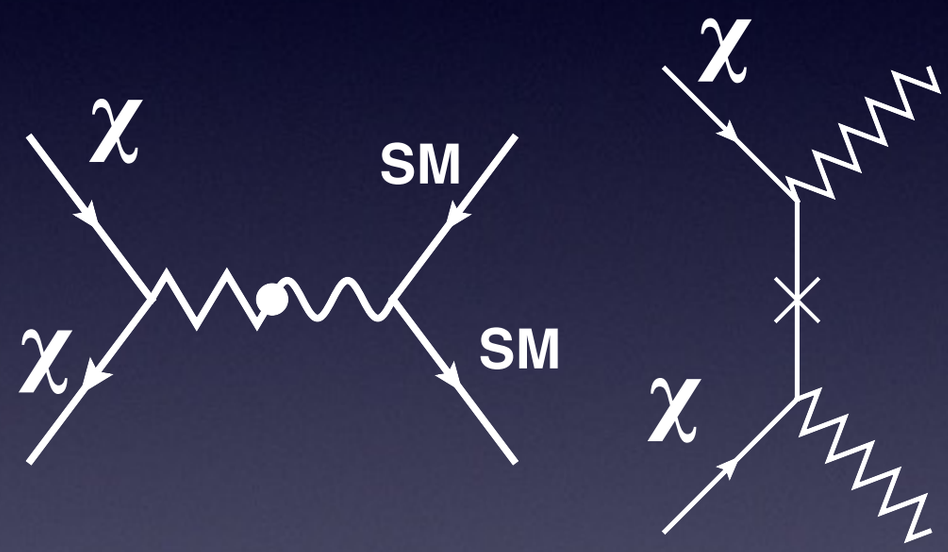


Dark Photons into Standard Model

- A' can kinetically mix via heavy intermediary
  (A' inherits small ϵ coupling to SM particles)



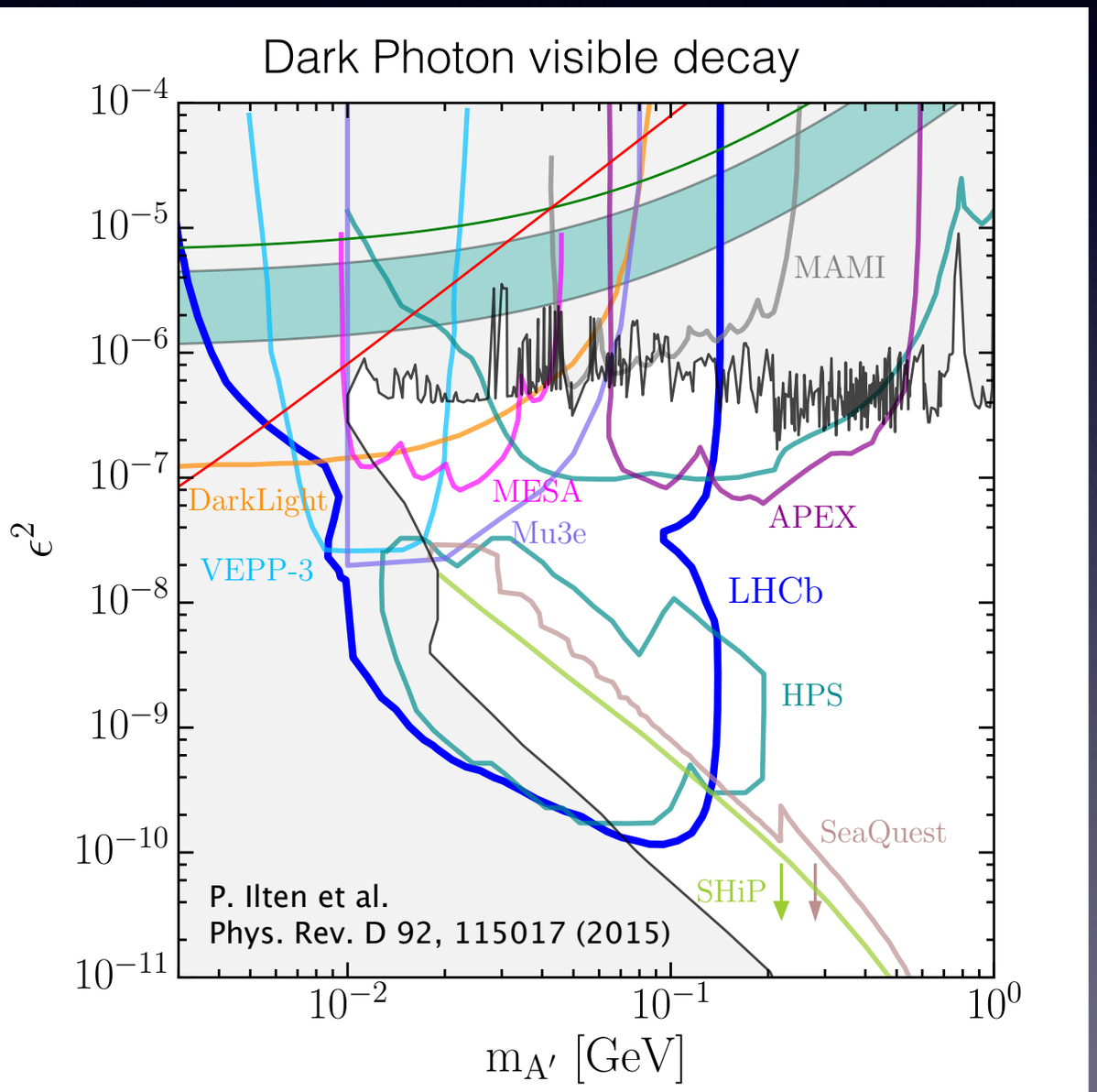
- Mechanism for DM decay

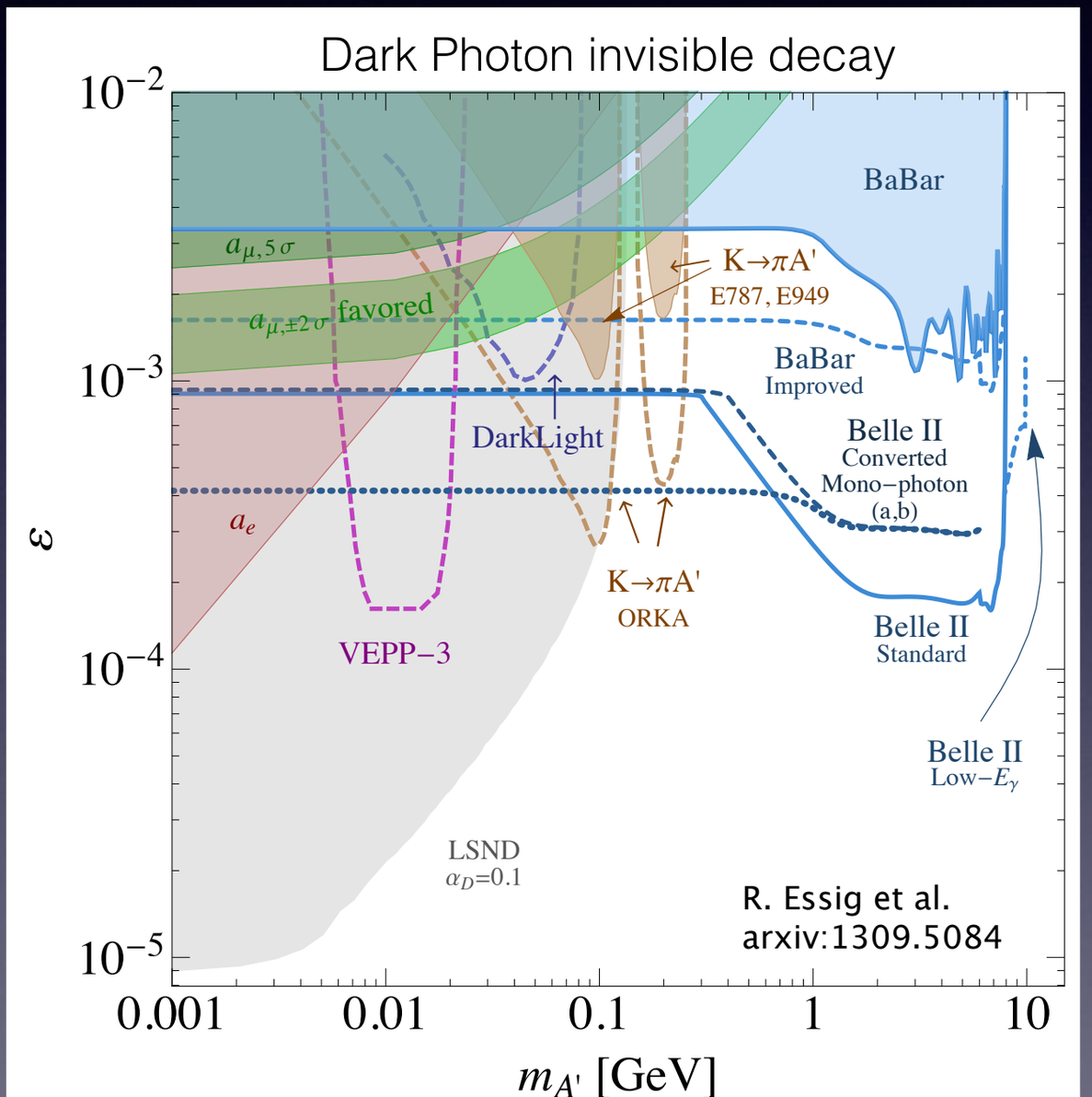


- DM-Agnostic argument:
  No reason not to have new term in Lagrangian:

$$\frac{\epsilon}{2} F_{\mu\nu} F'^{\mu\nu}$$

A' Parameter Space





DarkLight Concept

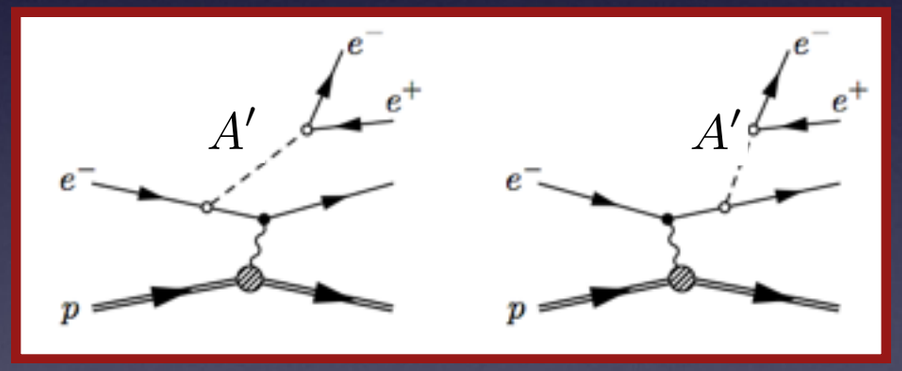
"Detecting A Resonance Kinematically with eLectrons Incident on a Gaseous Hydrogen Target

- High intensity electron beam on dense gas target to overcome small coupling (~ab^{-1}/mo)
- At 100 MeV to rule out pion production
- With solenoid and tracking for complete reconstruction of final state

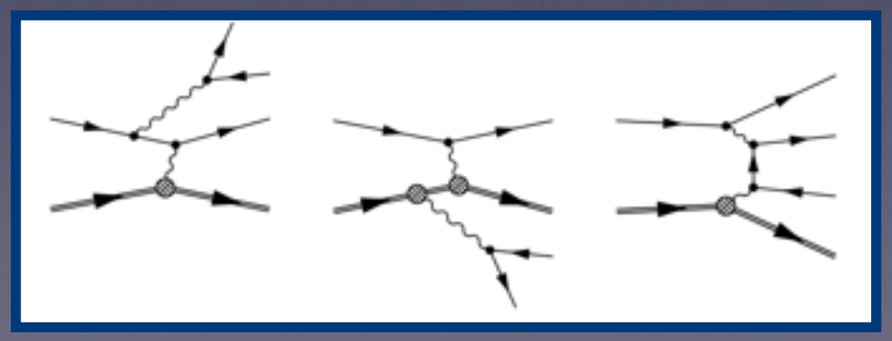
Detecting A'

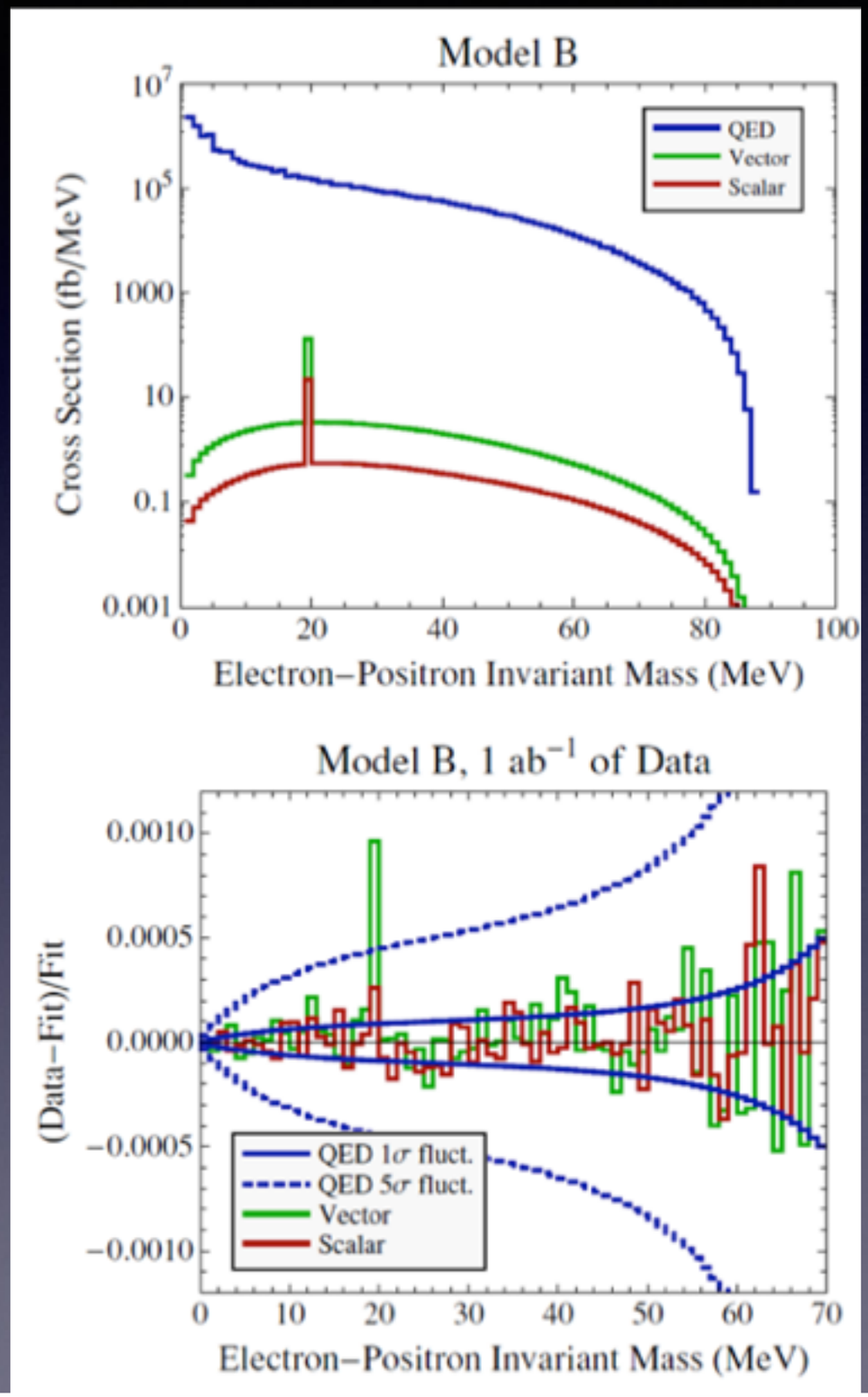
- Search for resonance in e^+e^- pairs
- High statistics help overcome irreducible background

A' Signal

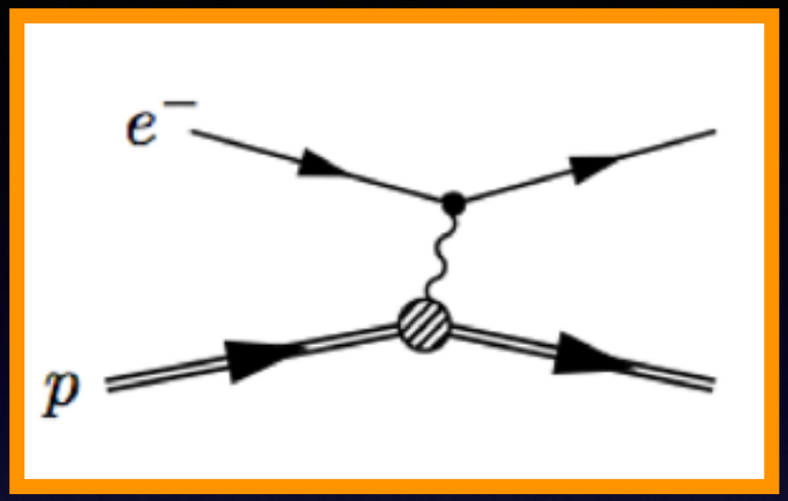


QED Background





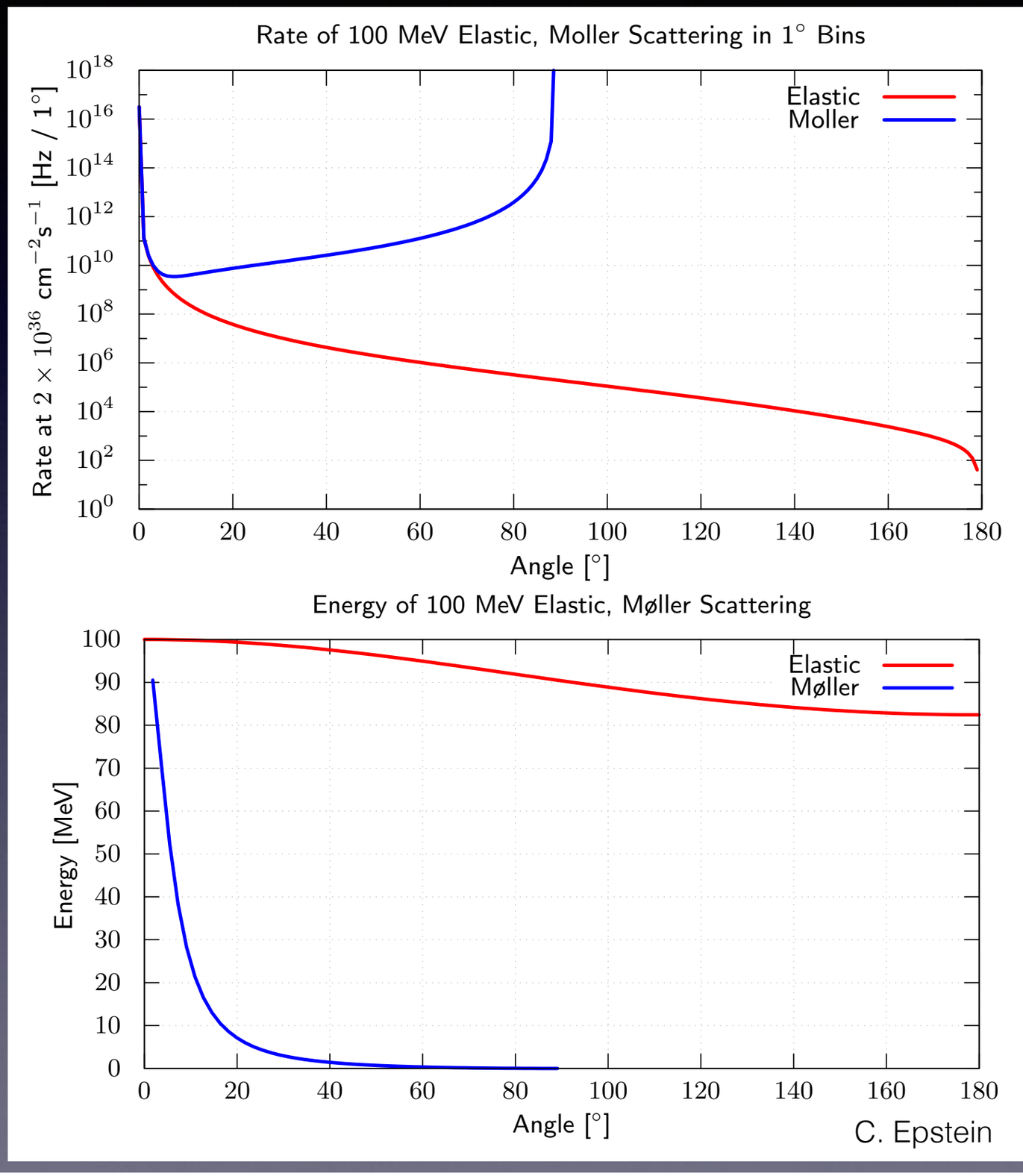
Standard Model Environment



- Luminosity= 2×10^{36} $cm^{-2}s^{-1}$

- Total Møller rate 2°-5°
  ~ 30 GHz (E<100 MeV)
- Total Elastic rate 2°-5°
  ~ 30 GHz (E~100 MeV)

➡ Want full reconstruction of final state to suppress these



Target and Beam

- Need high luminosity and low-density target

1. Linac+Fixed Target?
   - Target thickness unlimited ✓
   - Beam intensity too low ✗

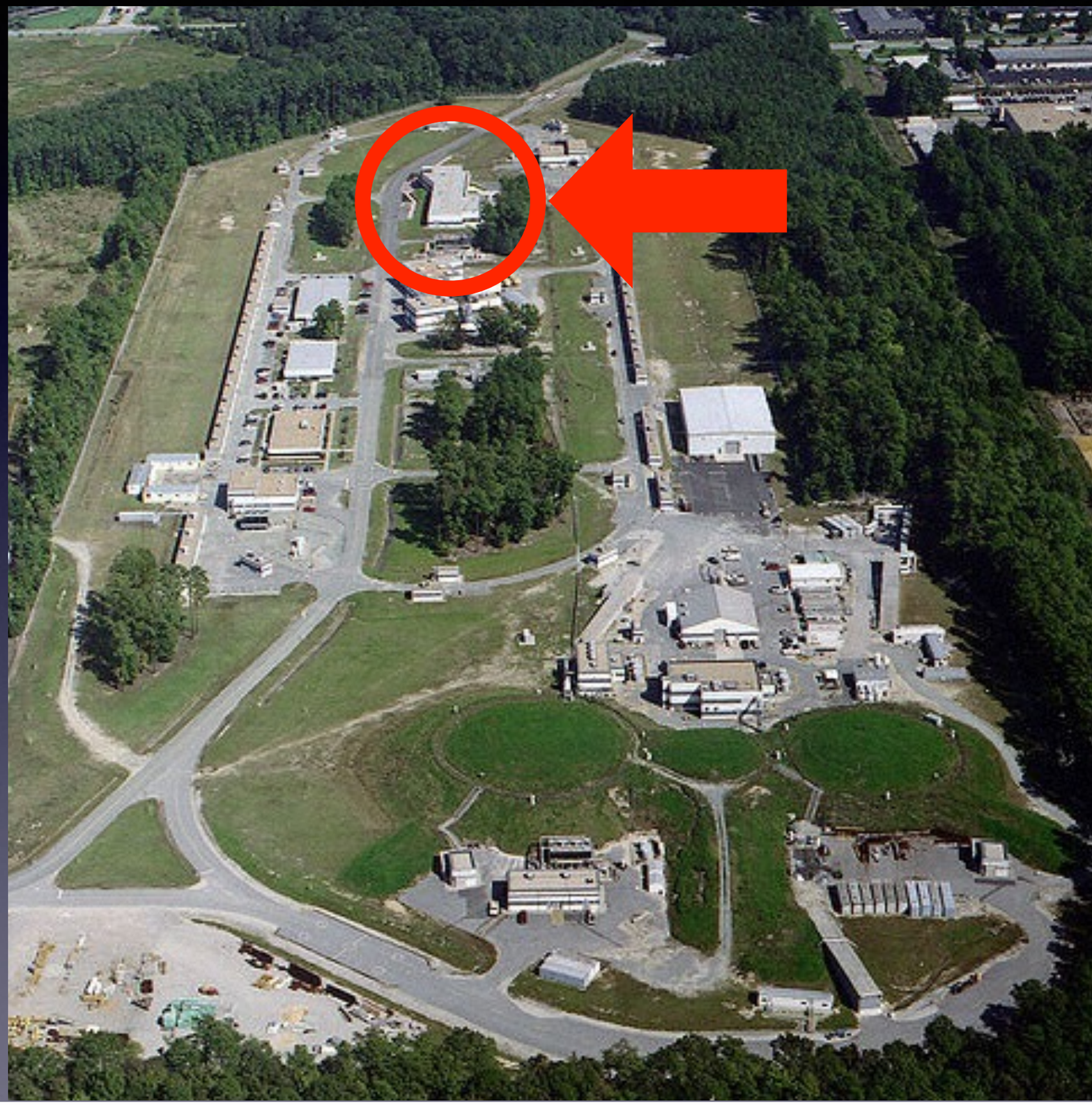
2. Storage Ring + Internal Target?
   - Target must be thin ✗
   - Beam intensity high ✓

3. **ERL** + Internal Target?
   - Target somewhat limited ✓
   - Beam intensity high ✓

...but unproven

LERF at Jefferson Lab

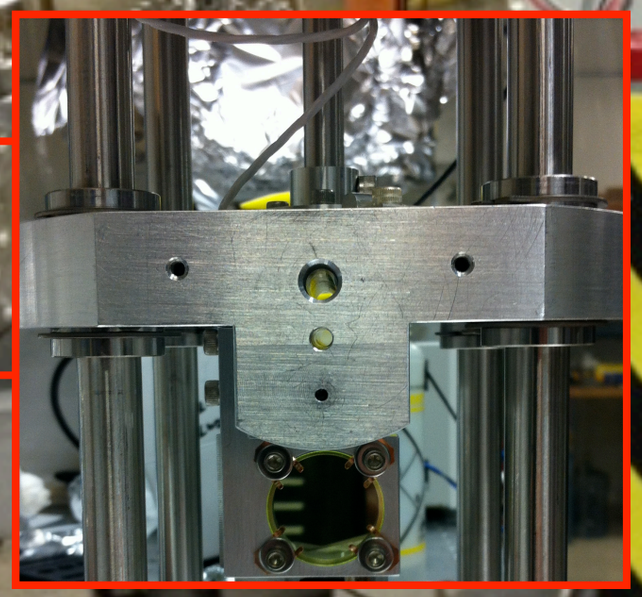
- JLab's Low Energy Recirculating Facility (LERF) e^- beam
  5mA. ~10^{16}e/s at 100MeV



LERF at Jefferson Lab

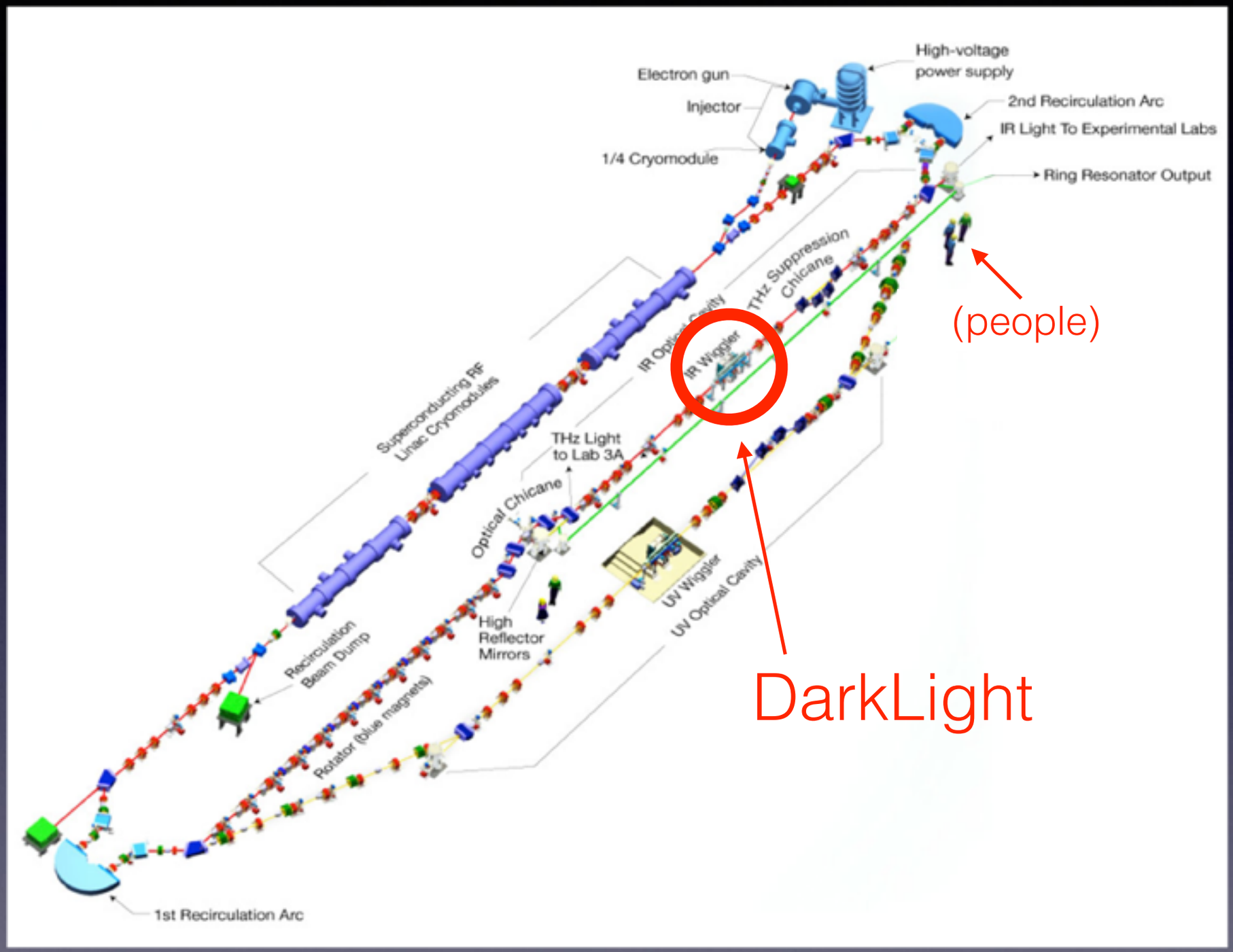
- 2012 beam test showed precision steering possible

  Phys. Rev. Lett. 111, 165801 (2013)
  Nucl. Instr. Meth A729, 233 (2013)
  Nucl. Instr. Meth. A729, 69 (2013)

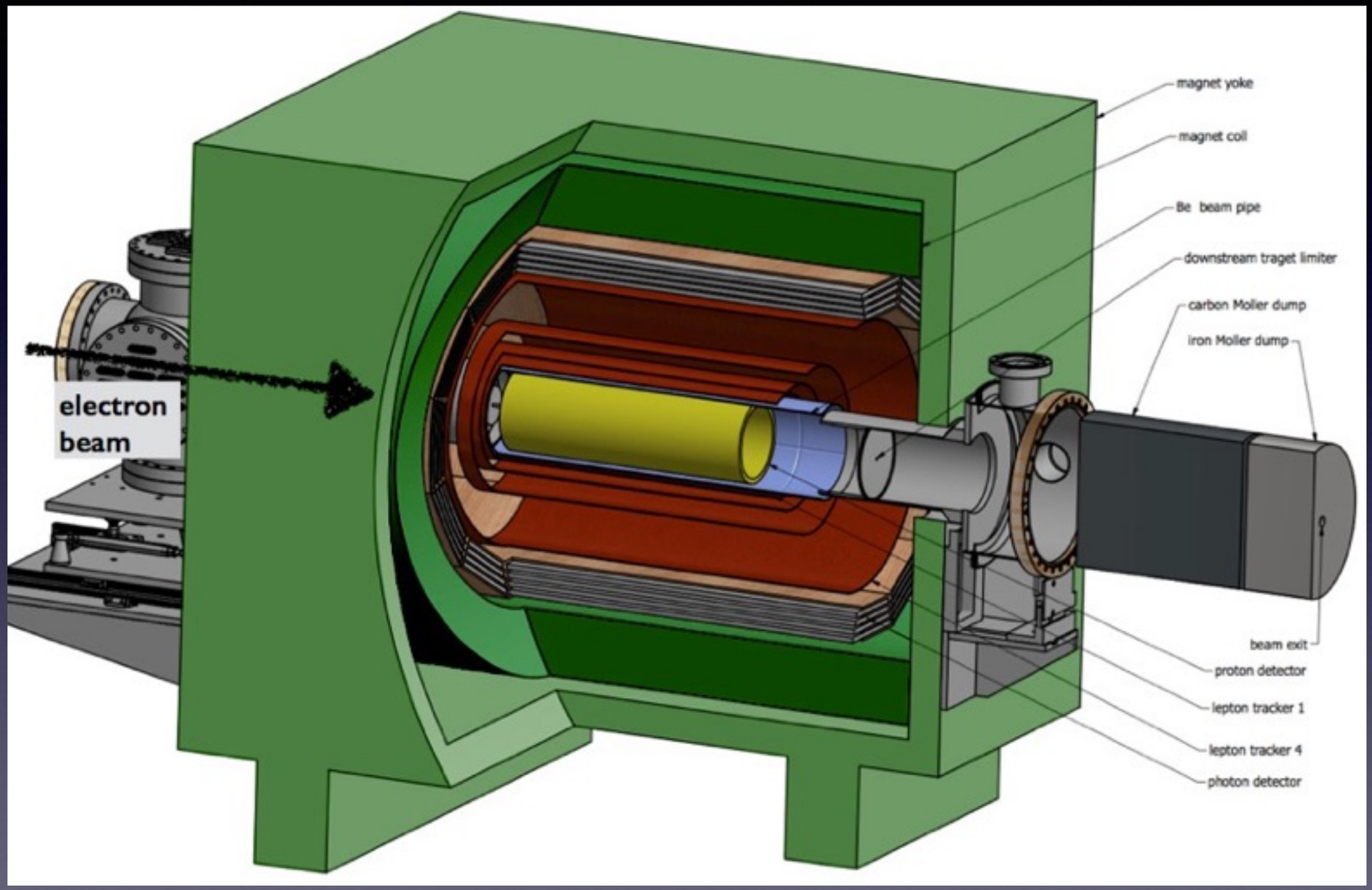


- 6, 4, and 2 mm aperture with few ppm losses.

LERF

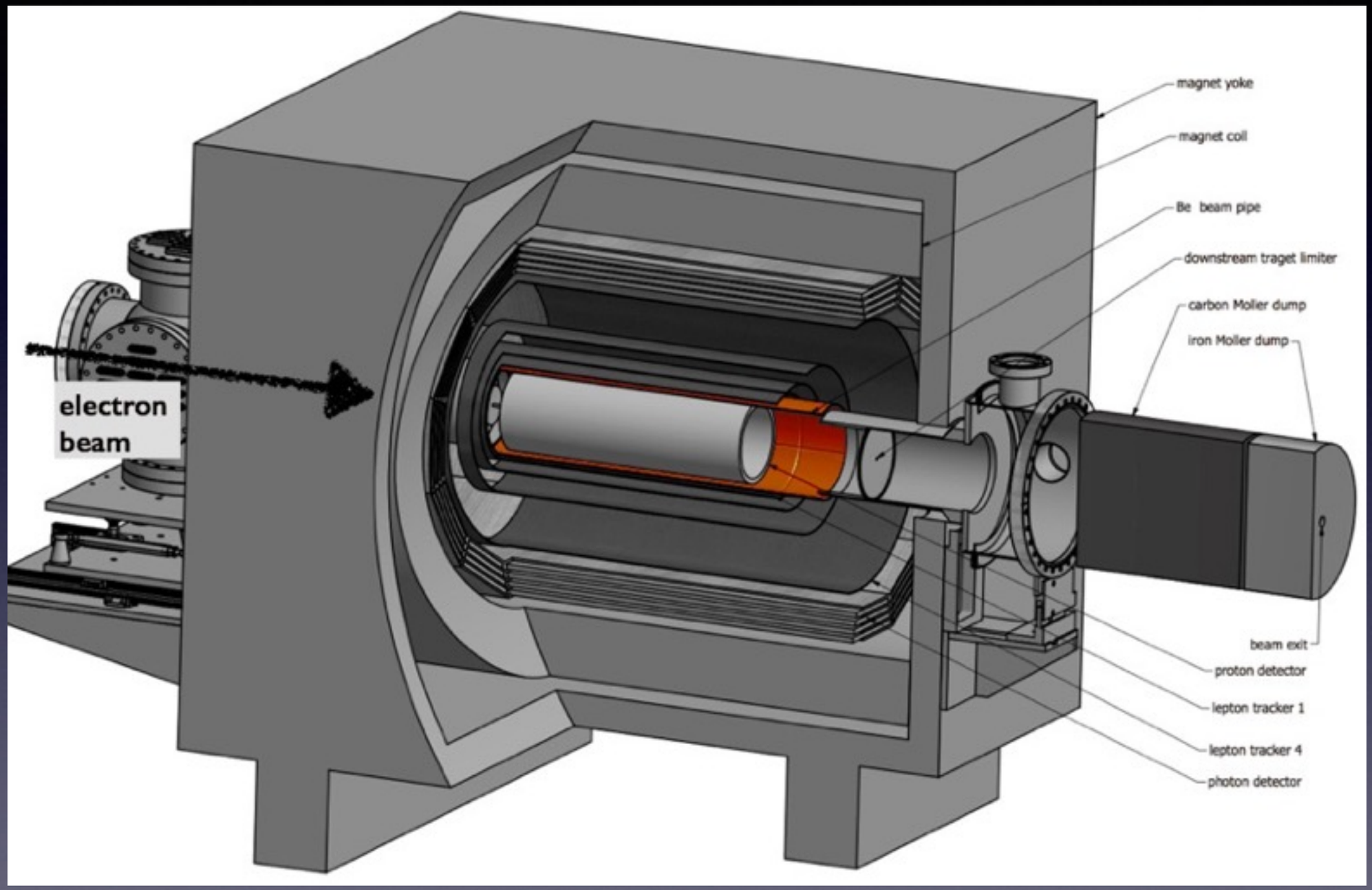

High-voltage
power supply
Electron gun
Injector
2nd Recirculation Arc
IR Light To Experimental Labs
1/4 Cryomodule
Ring Resonator Output
THz Suppression
Chicane
IR Optical Cavity
IR Wiggler
(people)
Superconducting RF
Linac Cryomodules
THz Light
to Lab 3A
Optical Chicane
UV Wiggler
UV Optical Cavity
High
Reflector
Mirrors
Recirculation
Beam Dump
Rotator (blue magnets)
DarkLight
1st Recirculation Arc

DarkLight Design



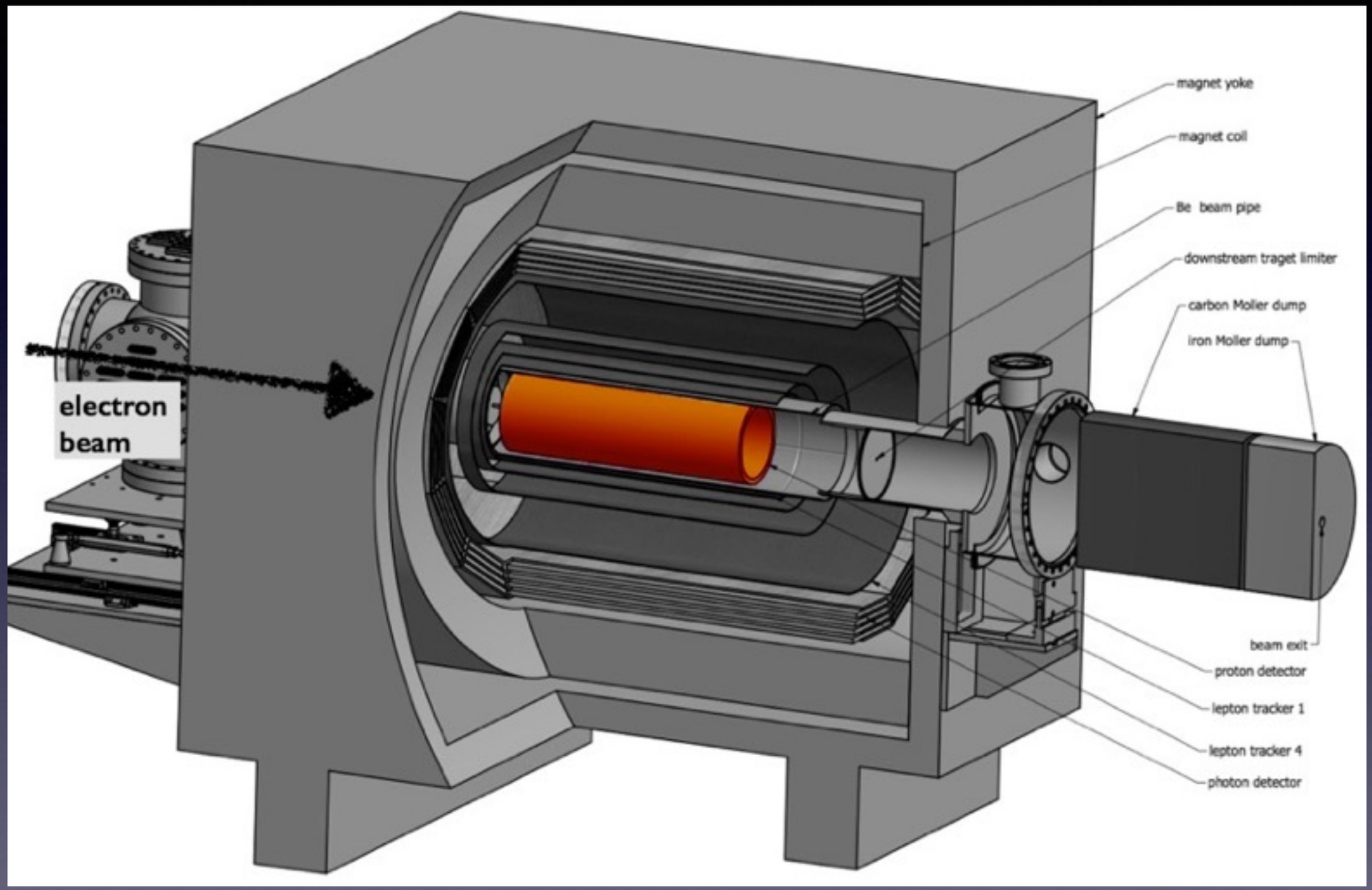
- Cylindrically symmetric detector

DarkLight Design



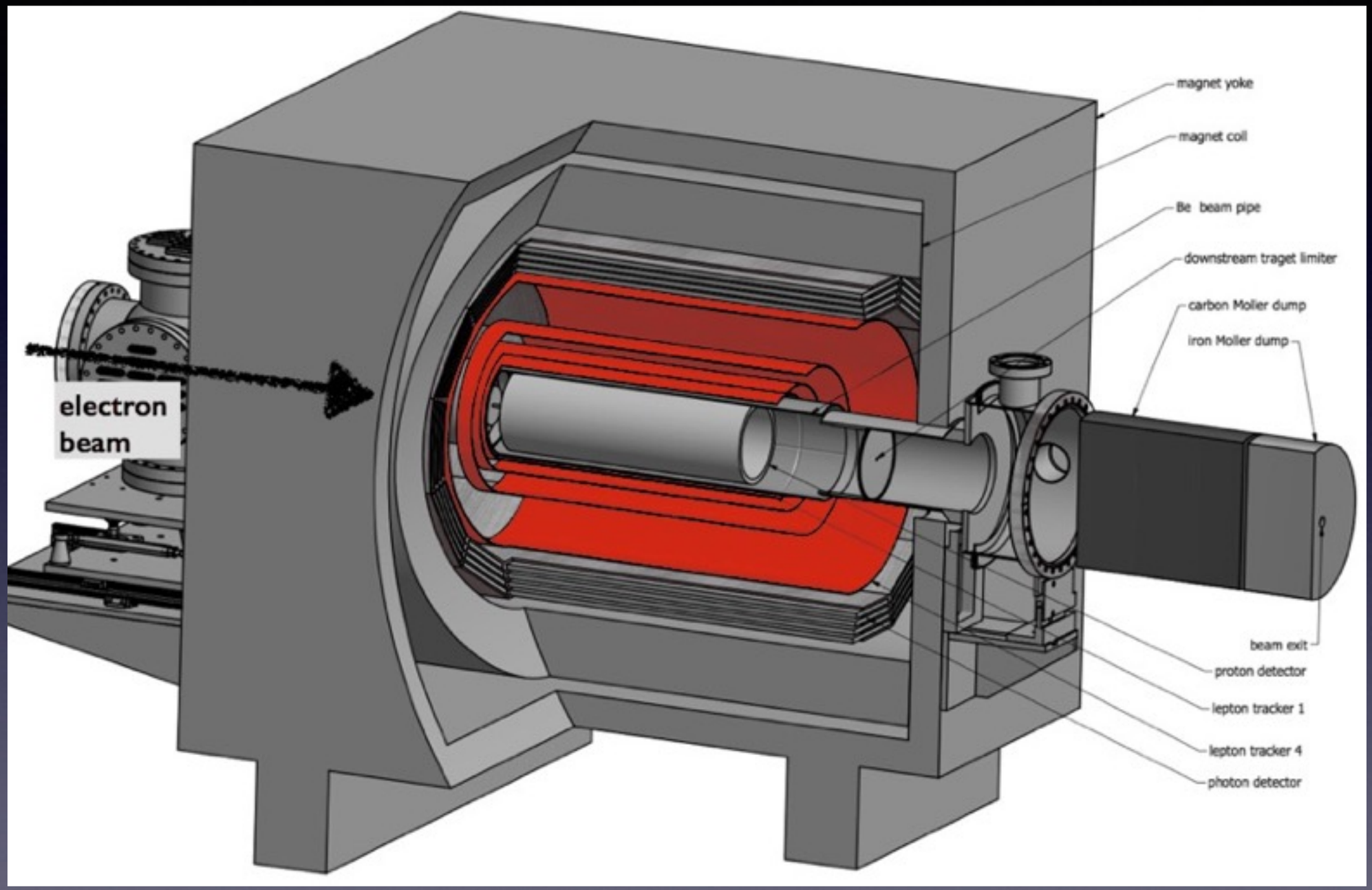
- Windowless, thin-walled target cell with ~few Torr

DarkLight Design



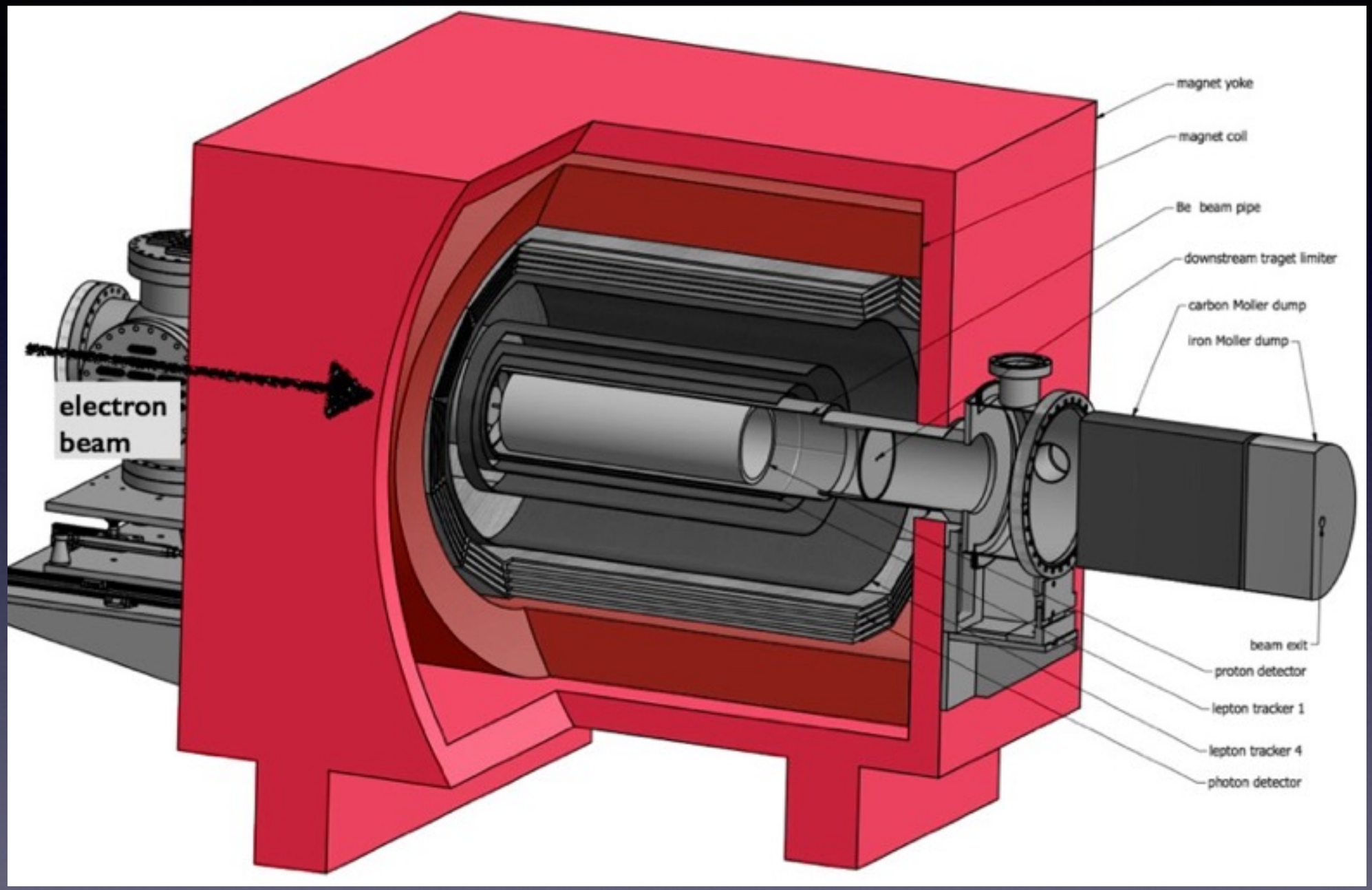
- Silicon detector inside target cell for recoiling proton

DarkLight Design



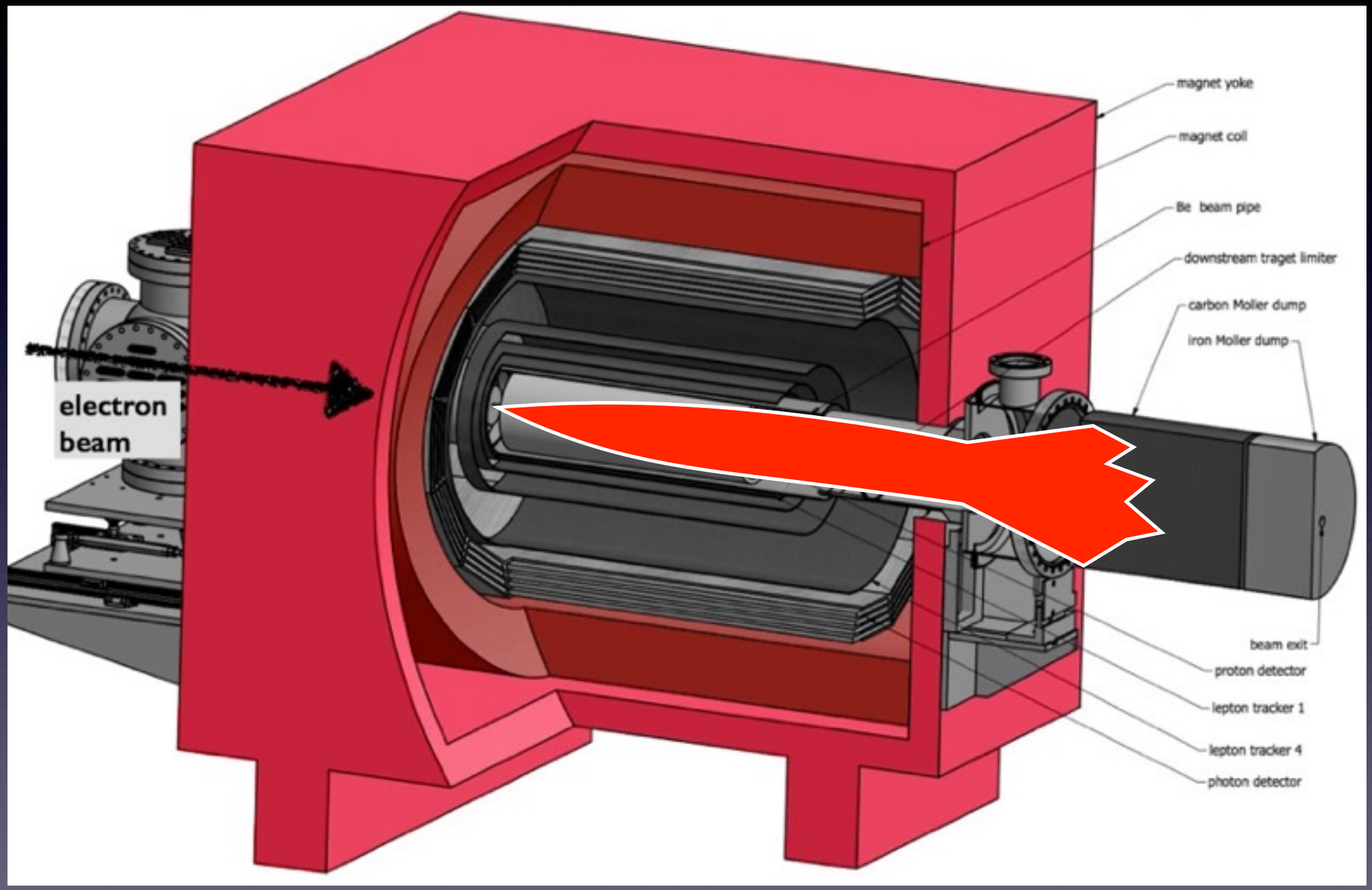
- Cylindrical tracking layers for e^+ / e^-

DarkLight Design



- Solenoid and yoke for momentum reconstruction

Moller Envelope



- Field also controls Møllers

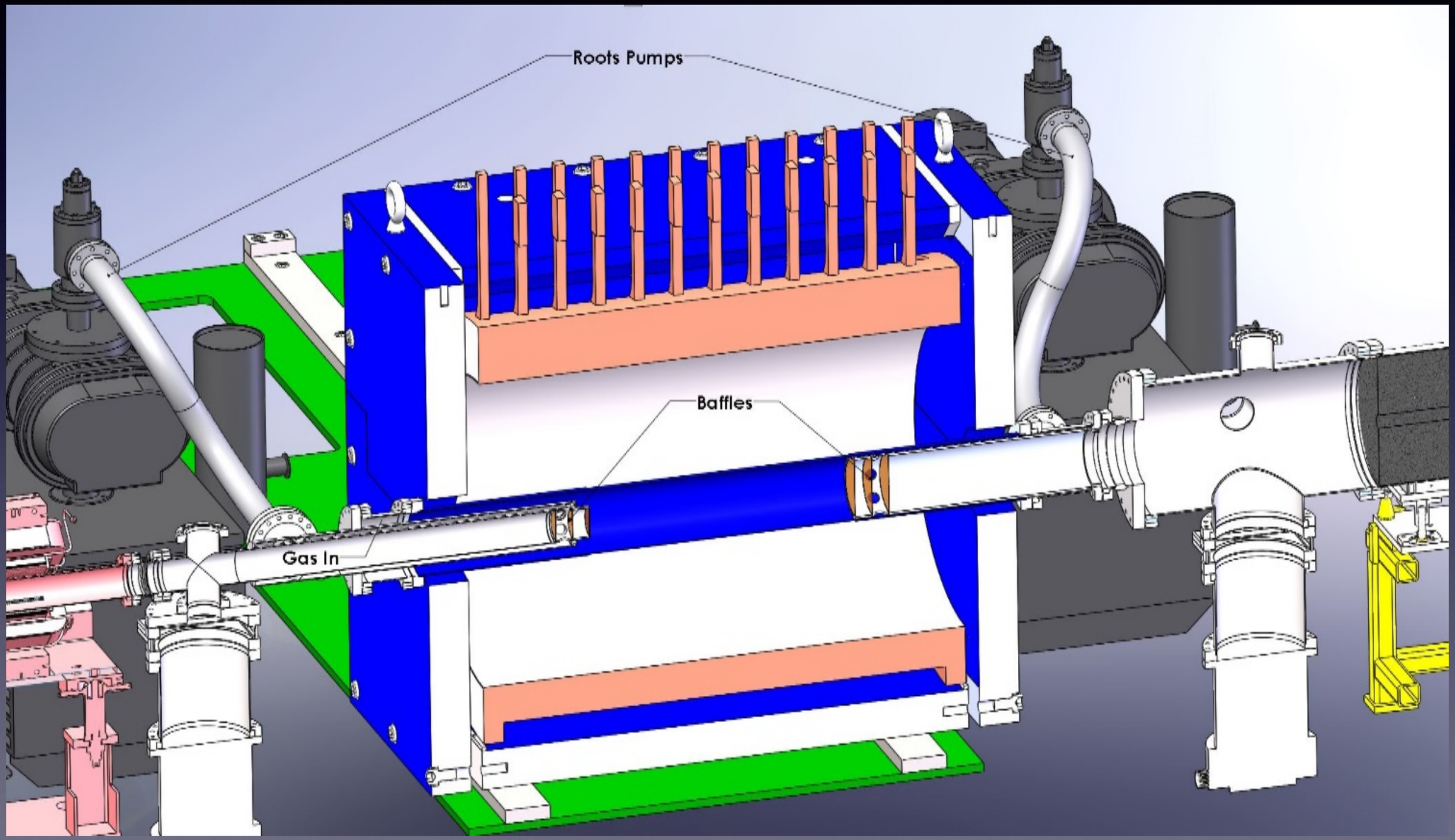
Phased Approach

Funded:

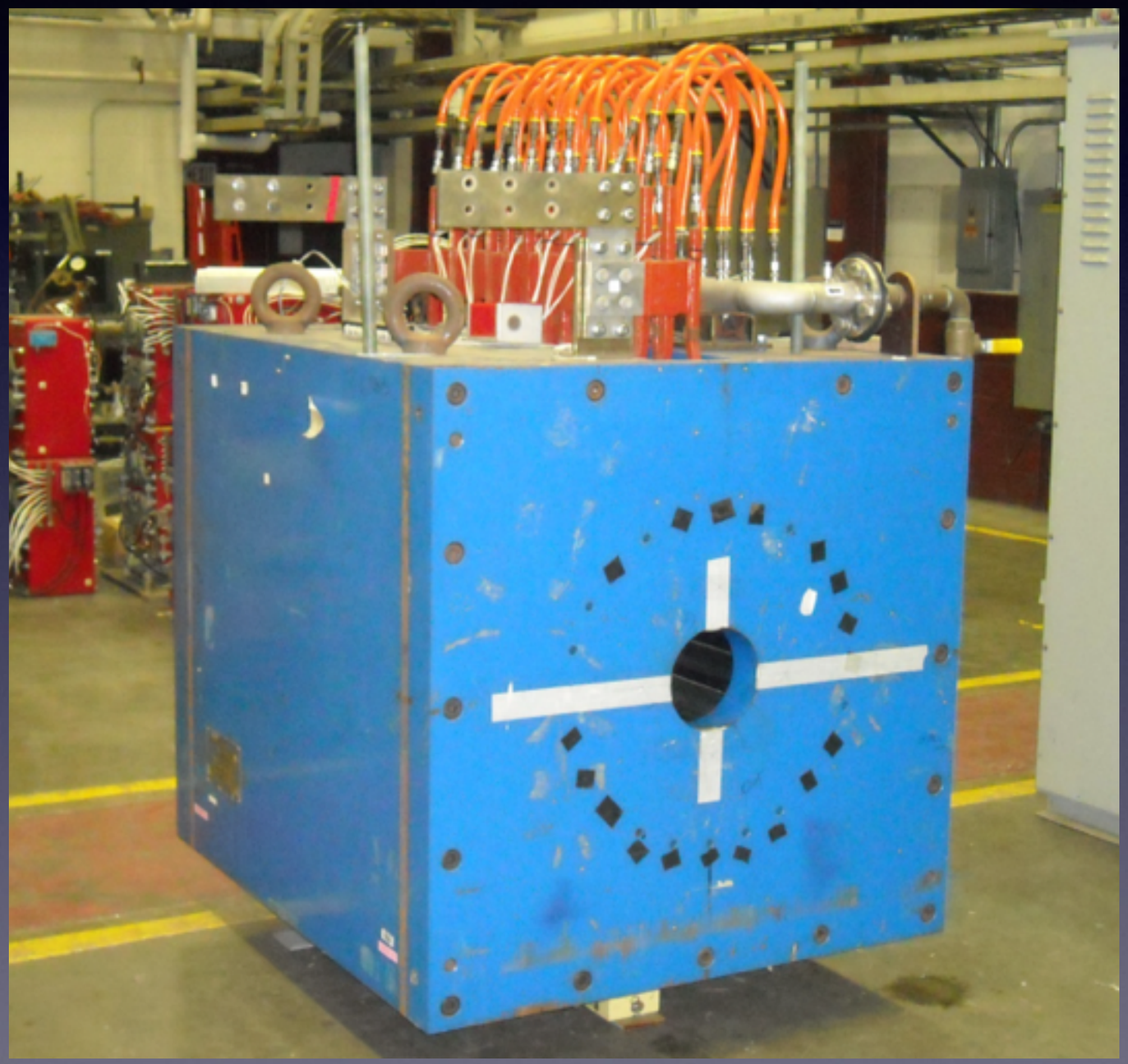
- 1A: Learn to operate LERF with Solenoid + Target
- 1B: Measure radiative Møller rates (spectrometer design)
- 1C: Proof-of-principle with partial coverage detector in solenoid
- 2: High-statistics measurement with full DarkLight detector

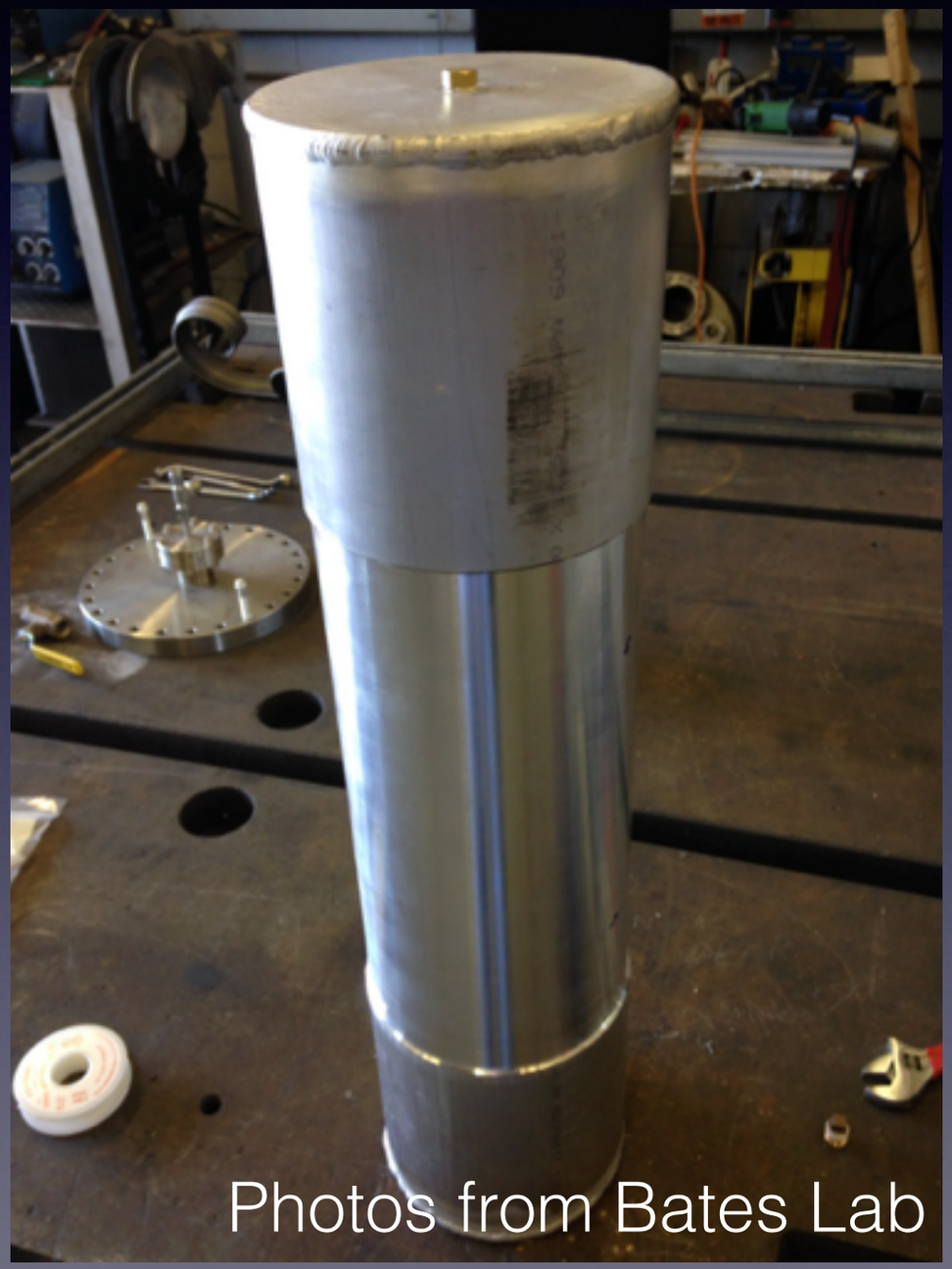
Phase 1A

- ~Torr target with baffles, 0.5 T solenoid



Phase 1A Beam Interaction

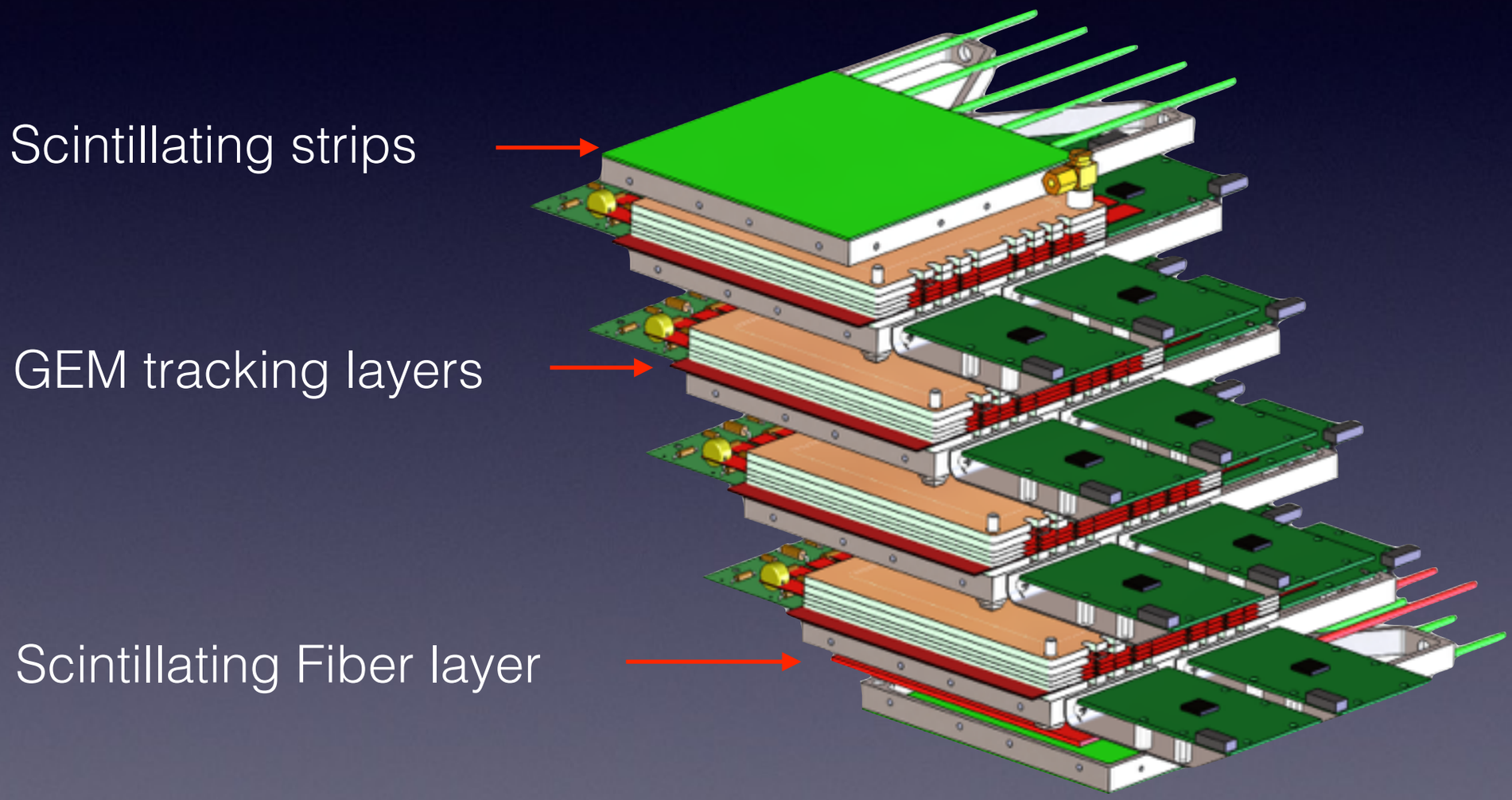




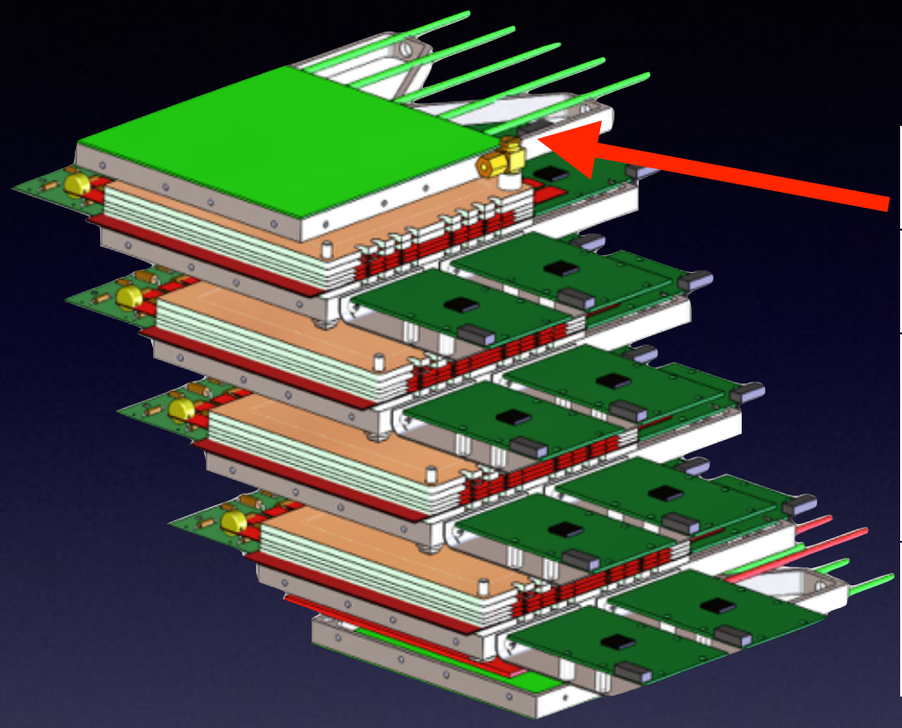
Photos from Bates Lab

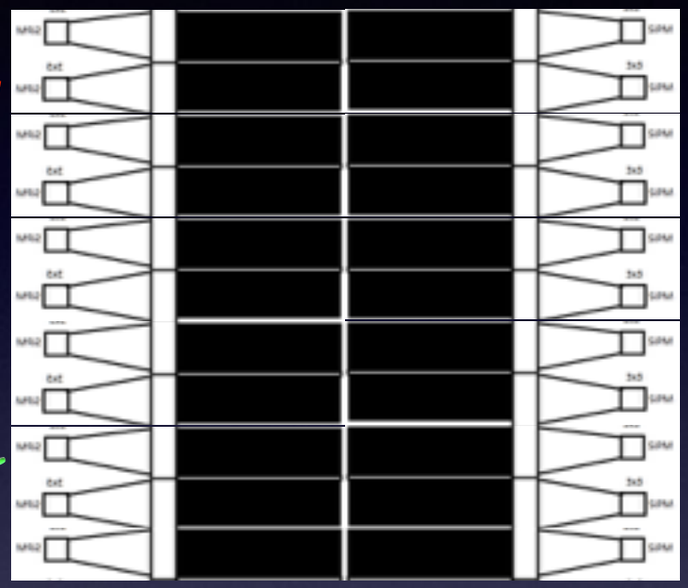
Phase 1A Detector

- Measure rates and evaluate detector performance

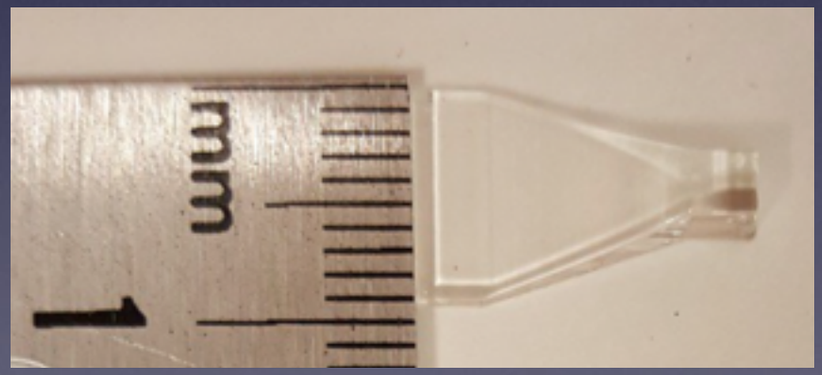


Phase 1A Trigger Paddles

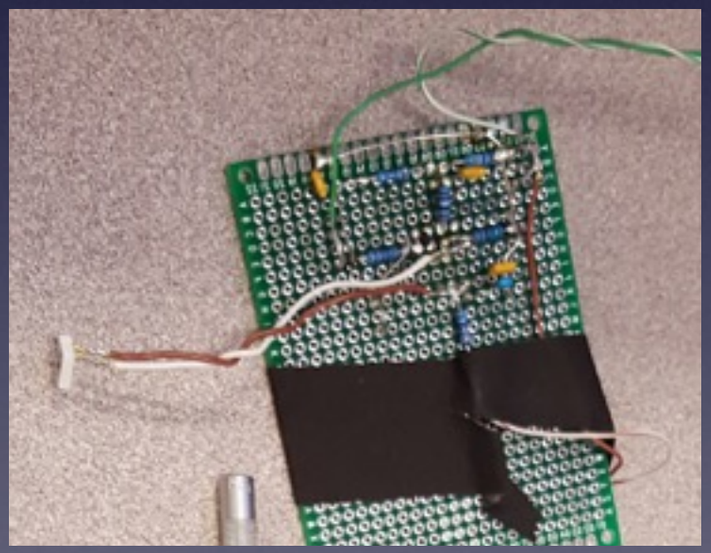




9x 1mm Scintillating Fibers
+ Acrylic Paint

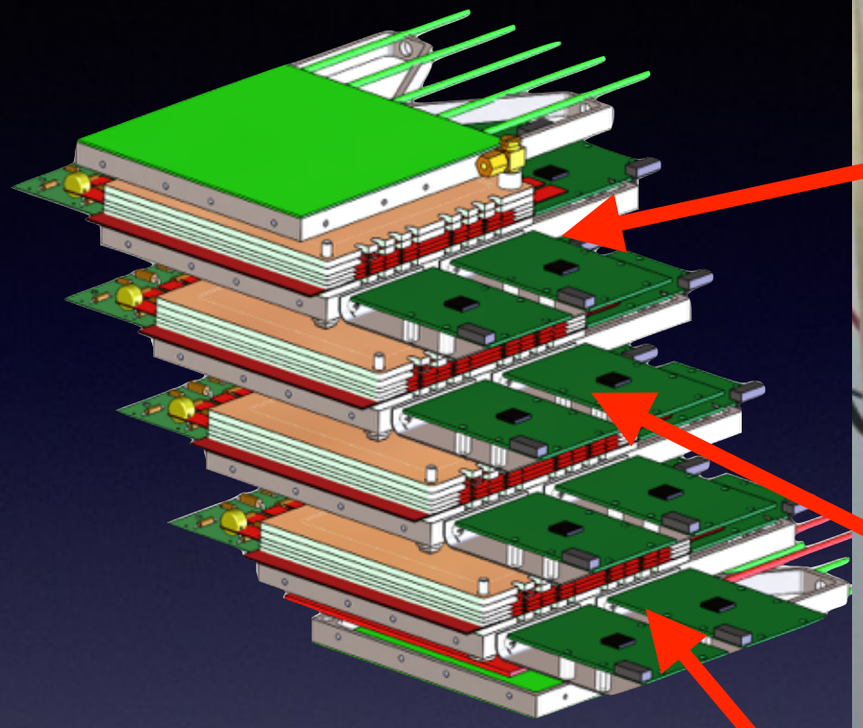


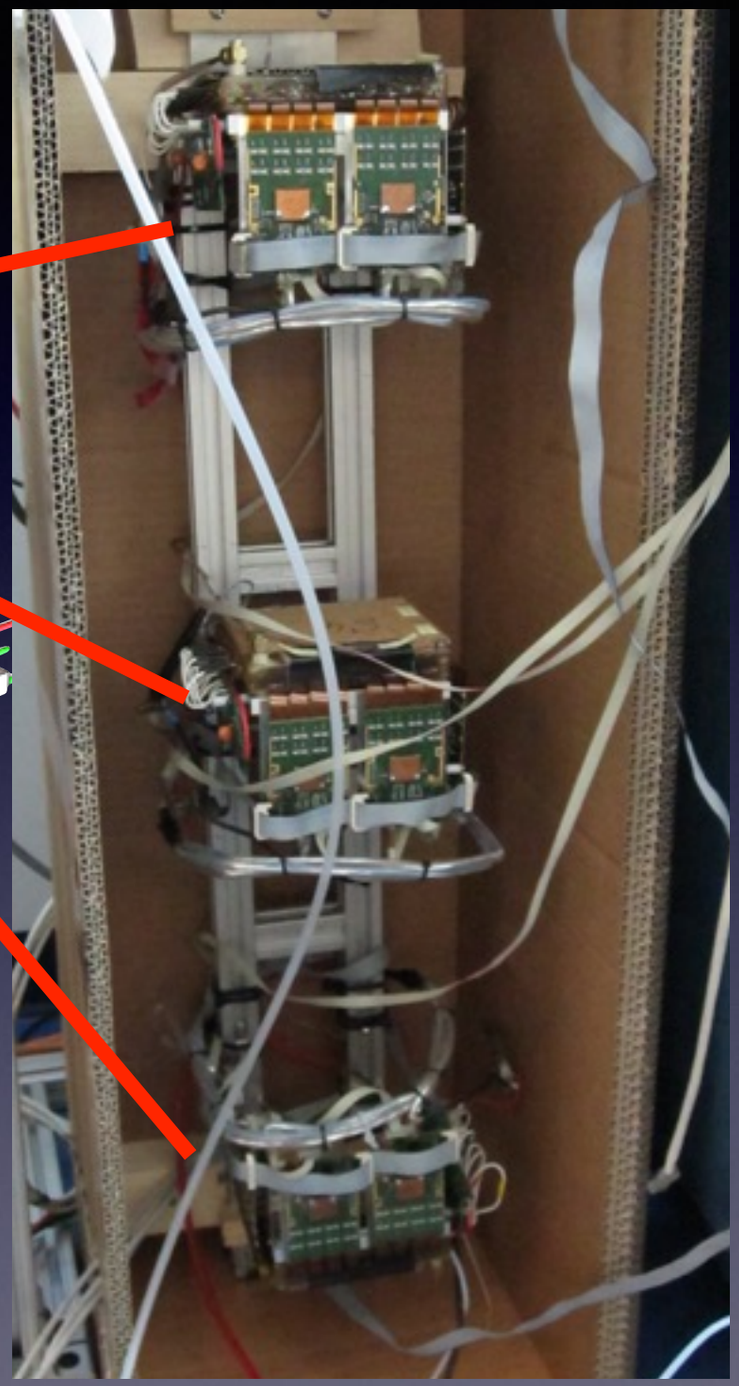
3D-printed Lightguide



3x3mm SiPM
+ Amplifier

Phase 1A GEM Telescope

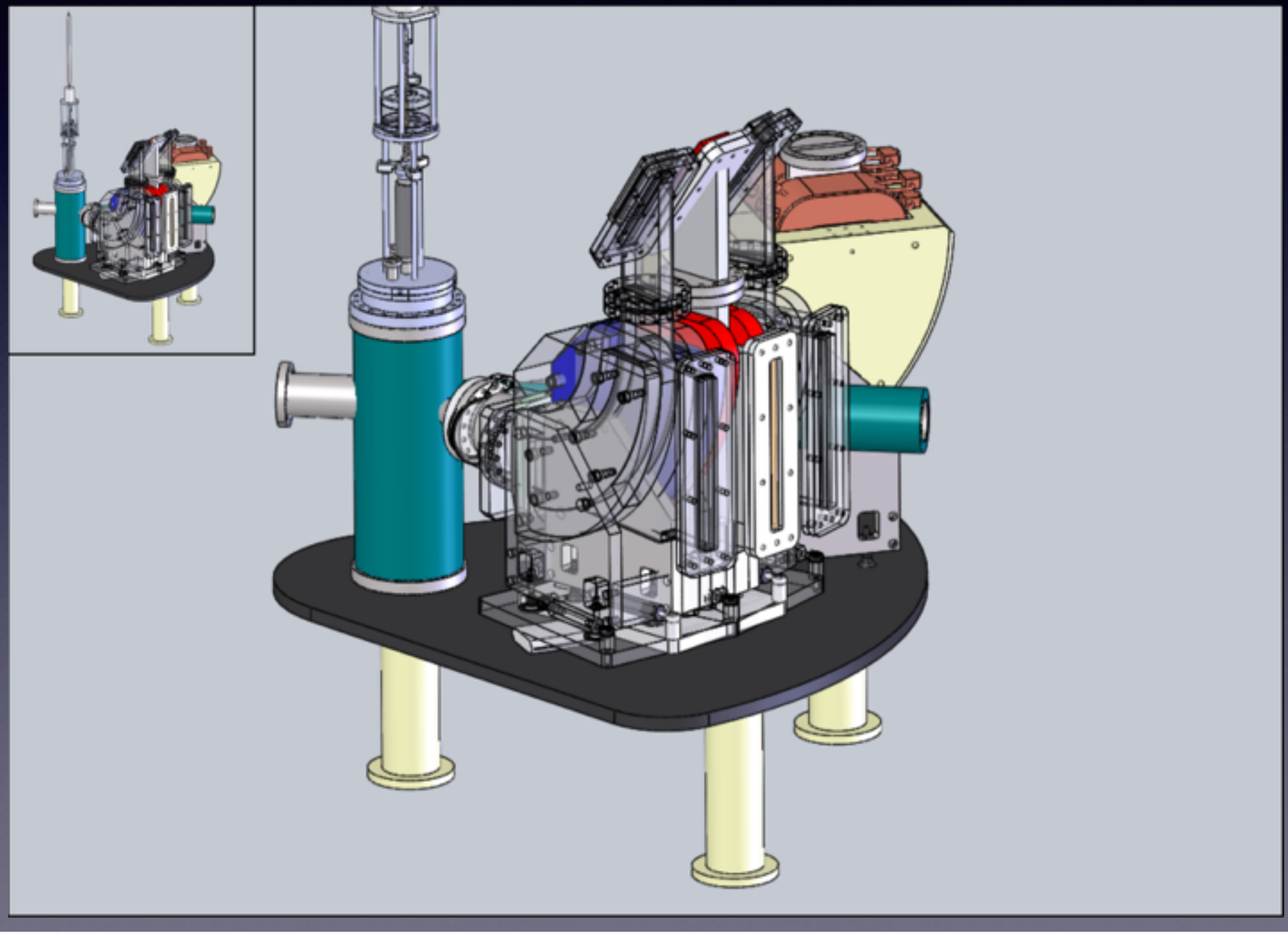




10 cm x10 cm OLYMPUS
Triple-GEM detectors

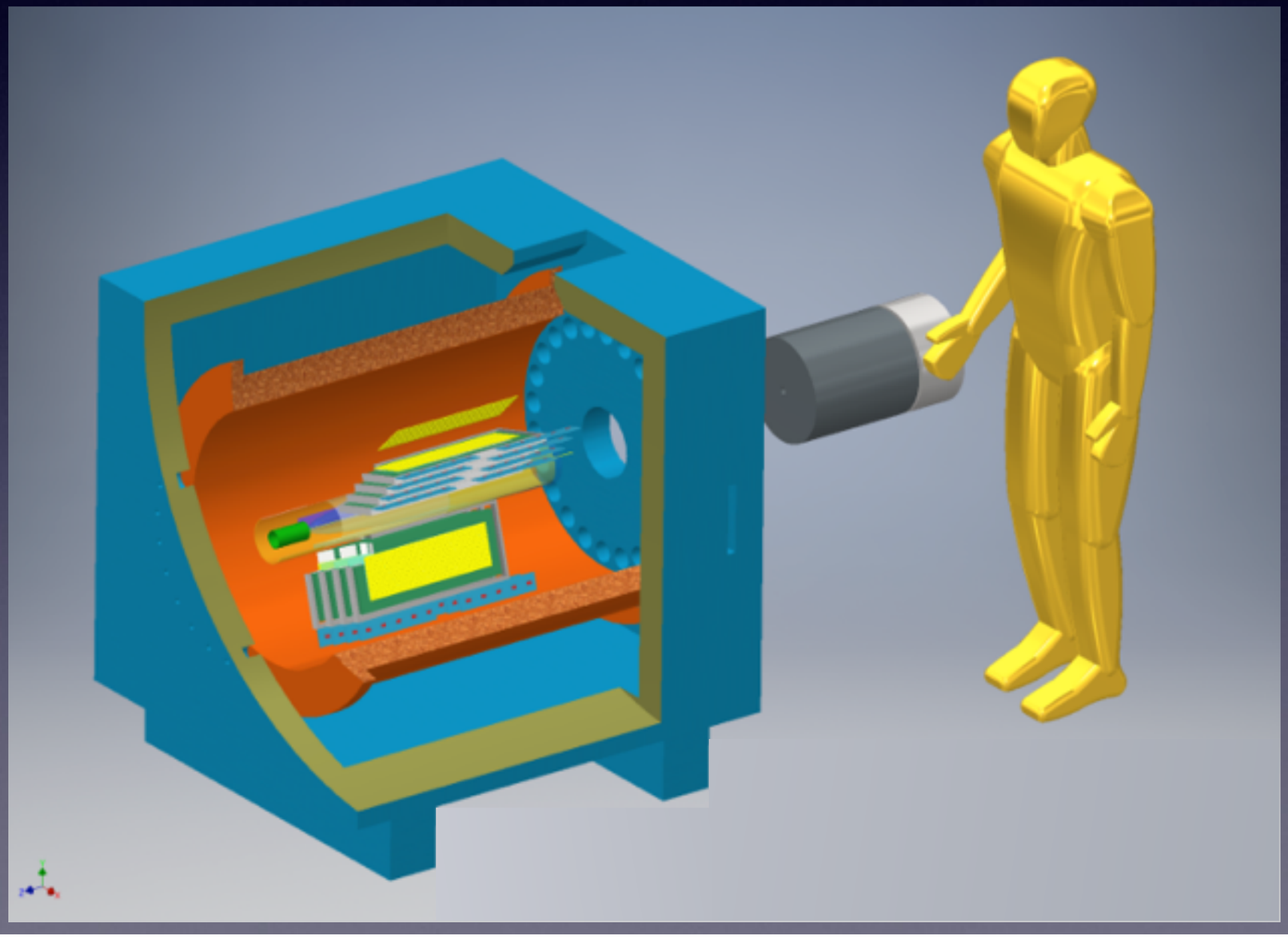
Phase 1B

- Measure radiative Møller rate using dedicated spectrometers



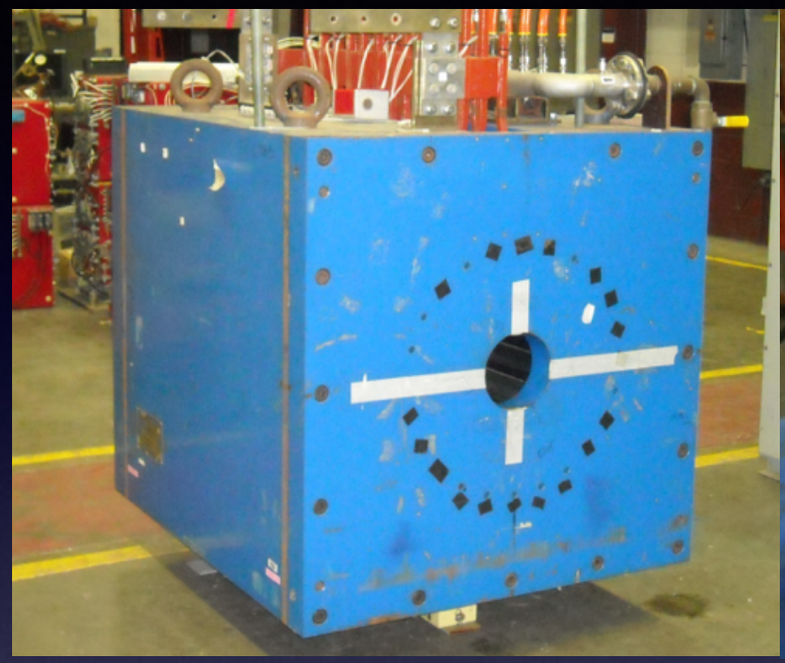
Phase 1C

- Proof-of-principle for A' search
- Partial coverage (detectors similar to 1A)
- Triggered readout

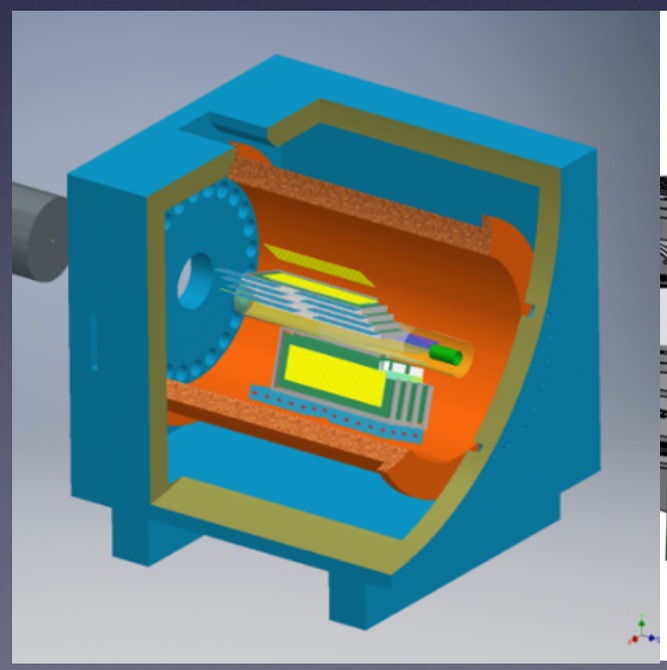


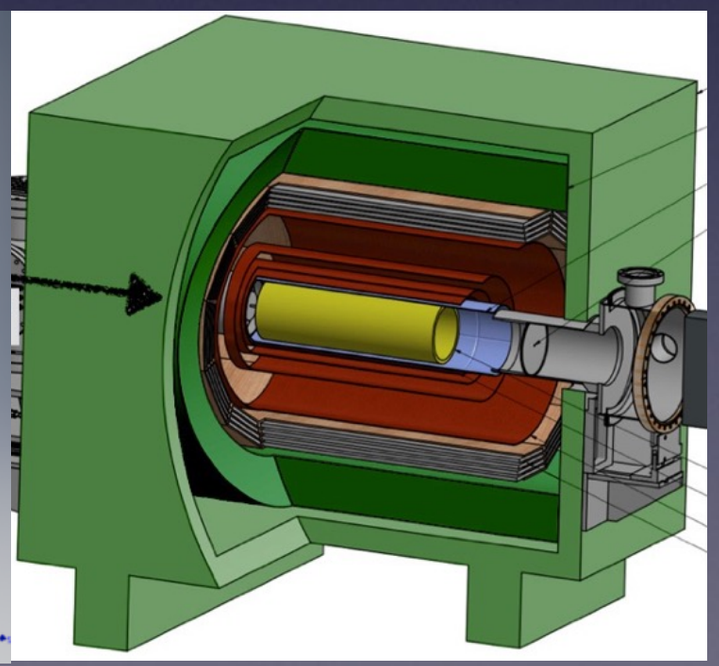
Outlook

- Summer 2016 / Near term:
  - First internal target / solenoid in an ERL
  - First measurements of radiative Møllers at this energy

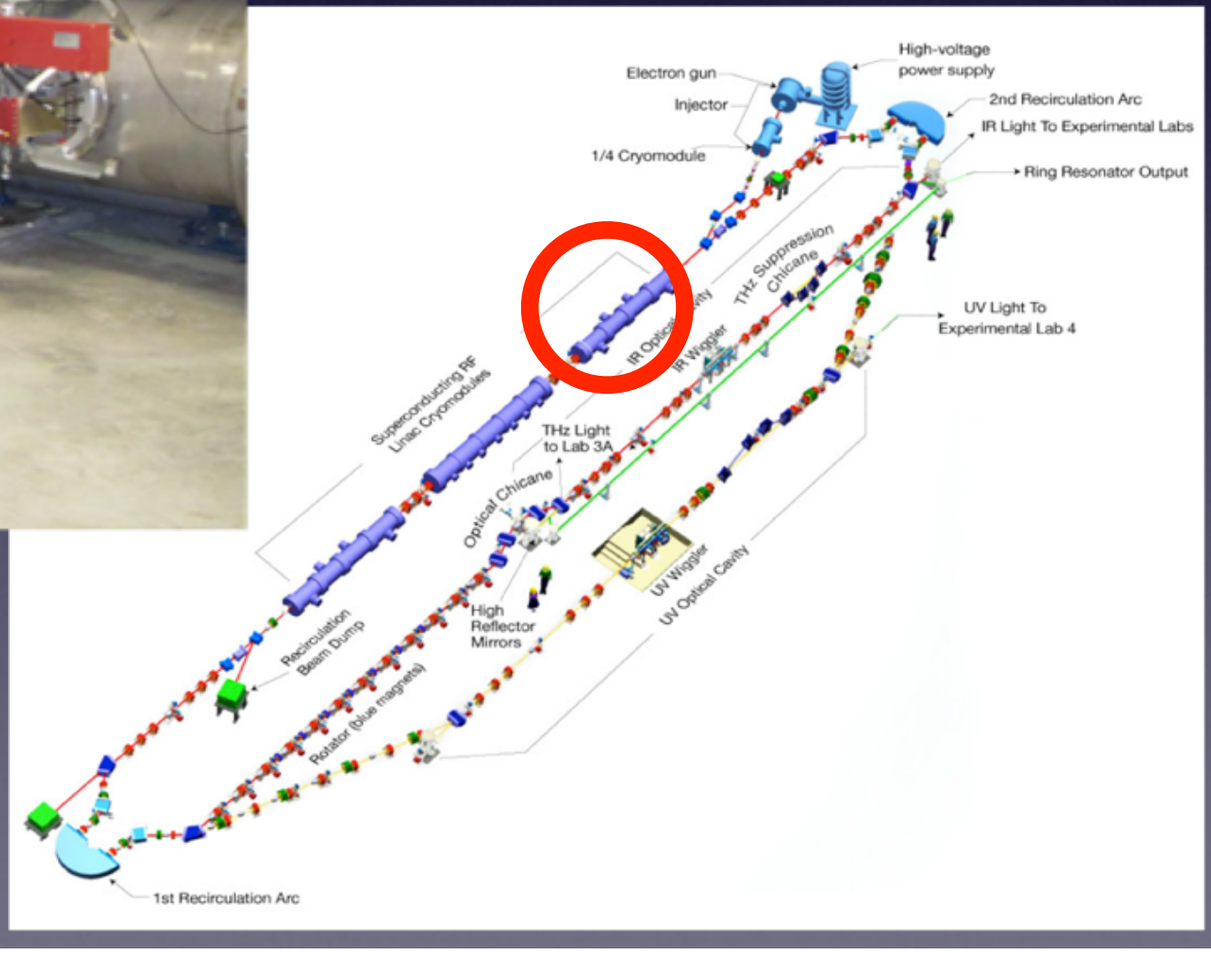


- Later:
  - Simulations and design work underway for phase 1C as well as future phase 2.

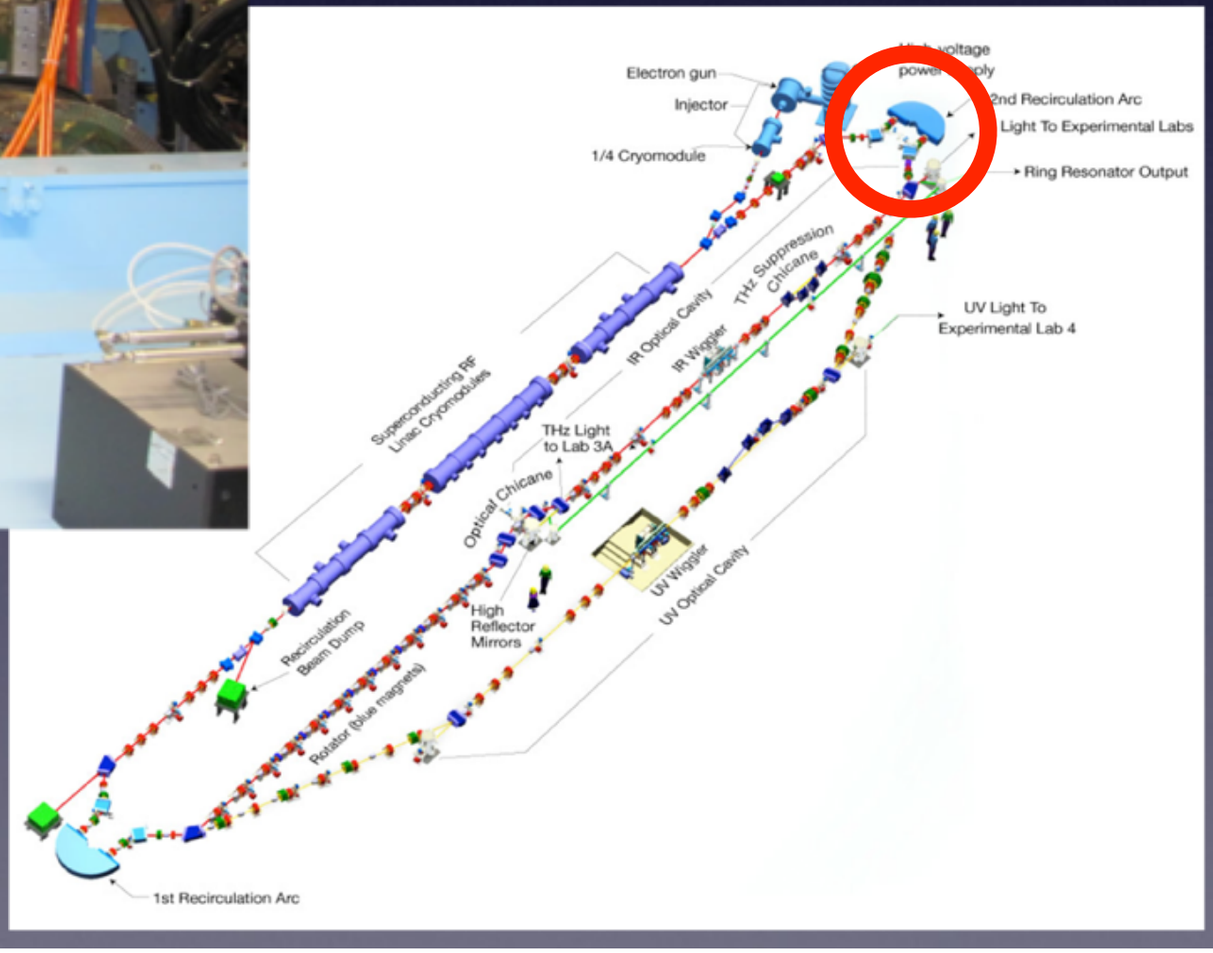




LERF Tour


High-voltage
power supply
Electron gun
Injector
1/4 Cryomodule
2nd Recirculation Arc
IR Light To Experimental Labs
Ring Resonator Output
THz Suppression
Chicane
UV Light To
Experimental Lab 4
IR Optical Cavity
IR Wiggler
Superconducting RF
Linac Cryomodules
THz Light
to Lab 3A
Optical Chicane
High
Reflector
Mirrors
UV Wiggler
UV Optical Cavity
Recirculation
Beam Dump
Rotator (Blue magnets)
1st Recirculation Arc

LERF Tour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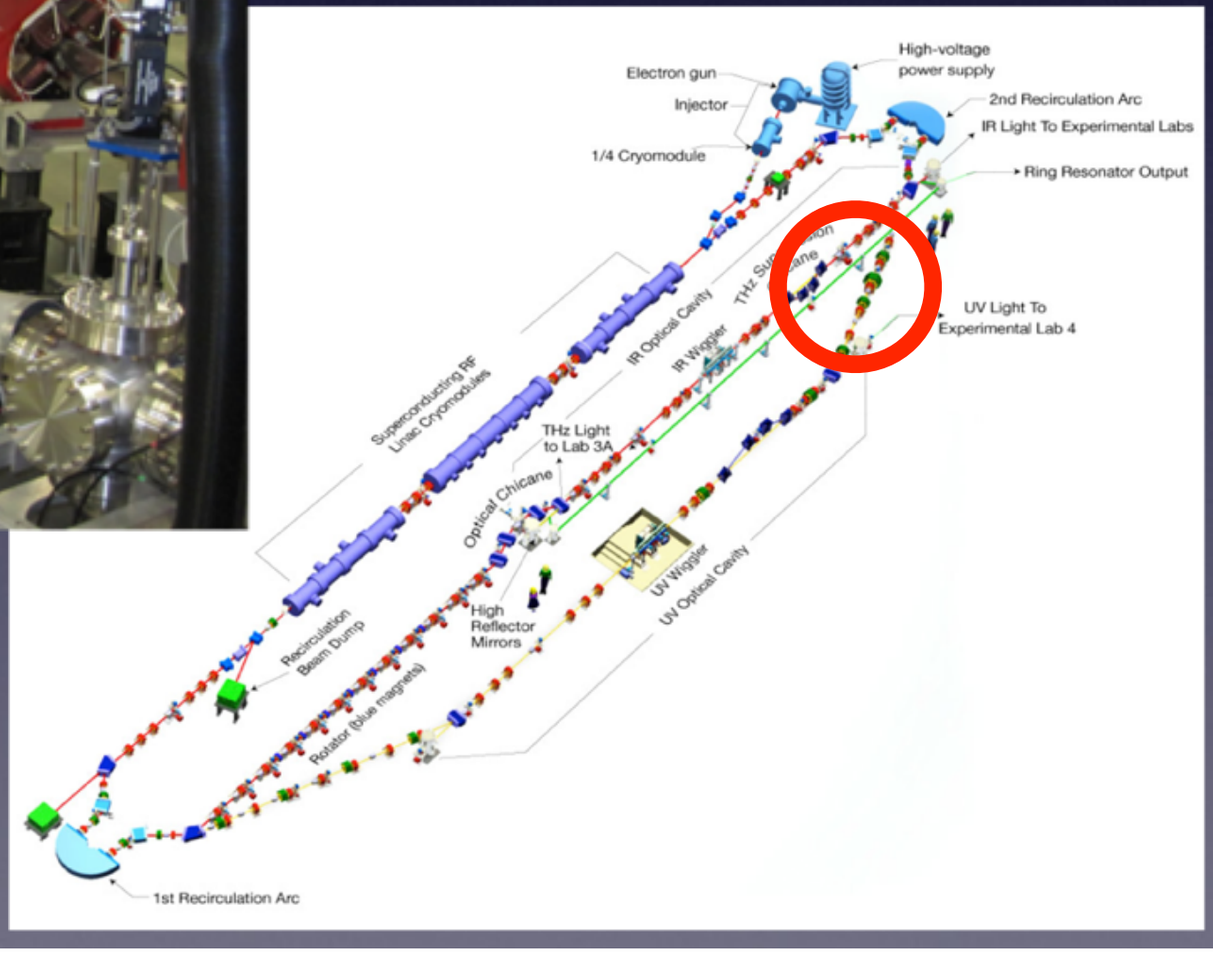
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