Searching for a Dark Photon with DarkLight

Ross Corliss
on behalf of the DARKLIGHT Collaboration

DARKLIGHT

Physics and Applications of
High Brightness Beams
March 30, 2016

Massachusetts
Institute of
Technology

DarkLight Collaboration

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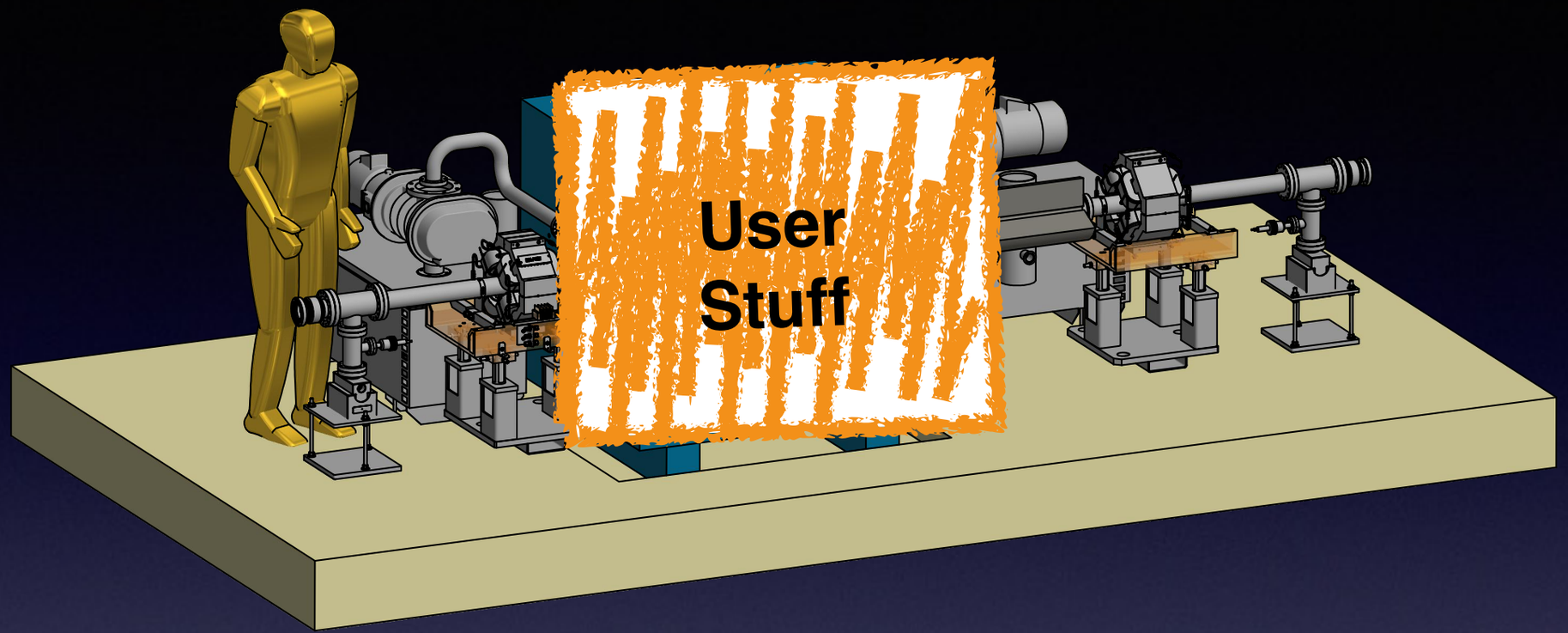
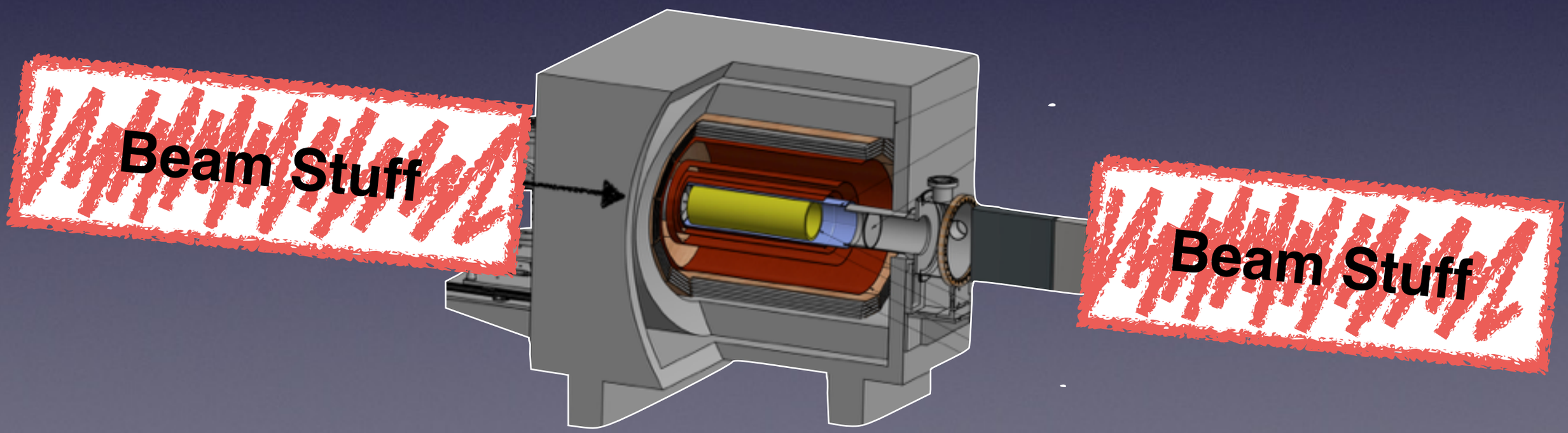
A Beam-User's Disclaimer

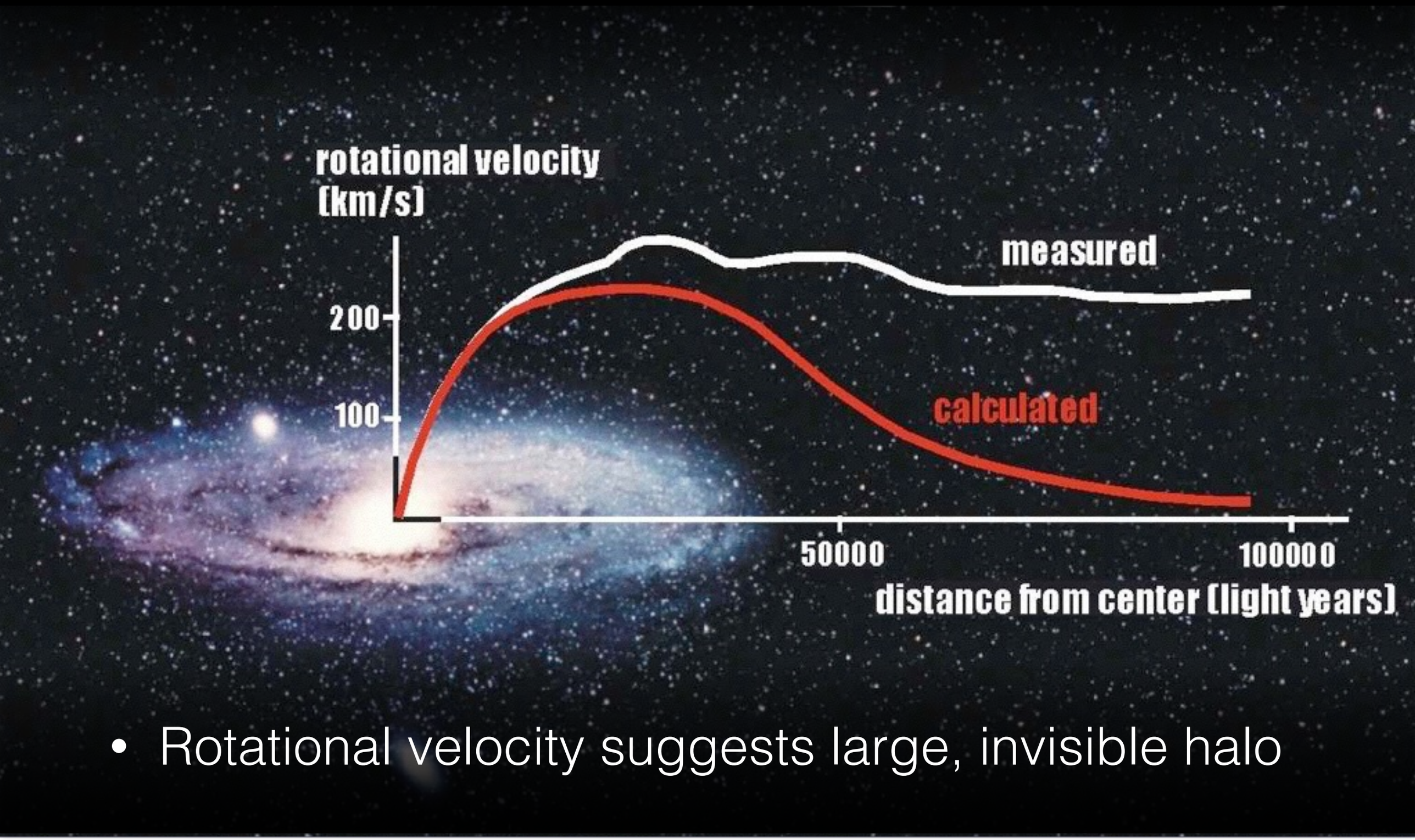




Outline

- Dark Matter and Dark Photons
- Detecting Dark Photons in DarkLight
- Phased Approach to DarkLight

Dark Matter in Galaxies



- Rotational velocity suggests large, invisible halo

Gravitational Lensing

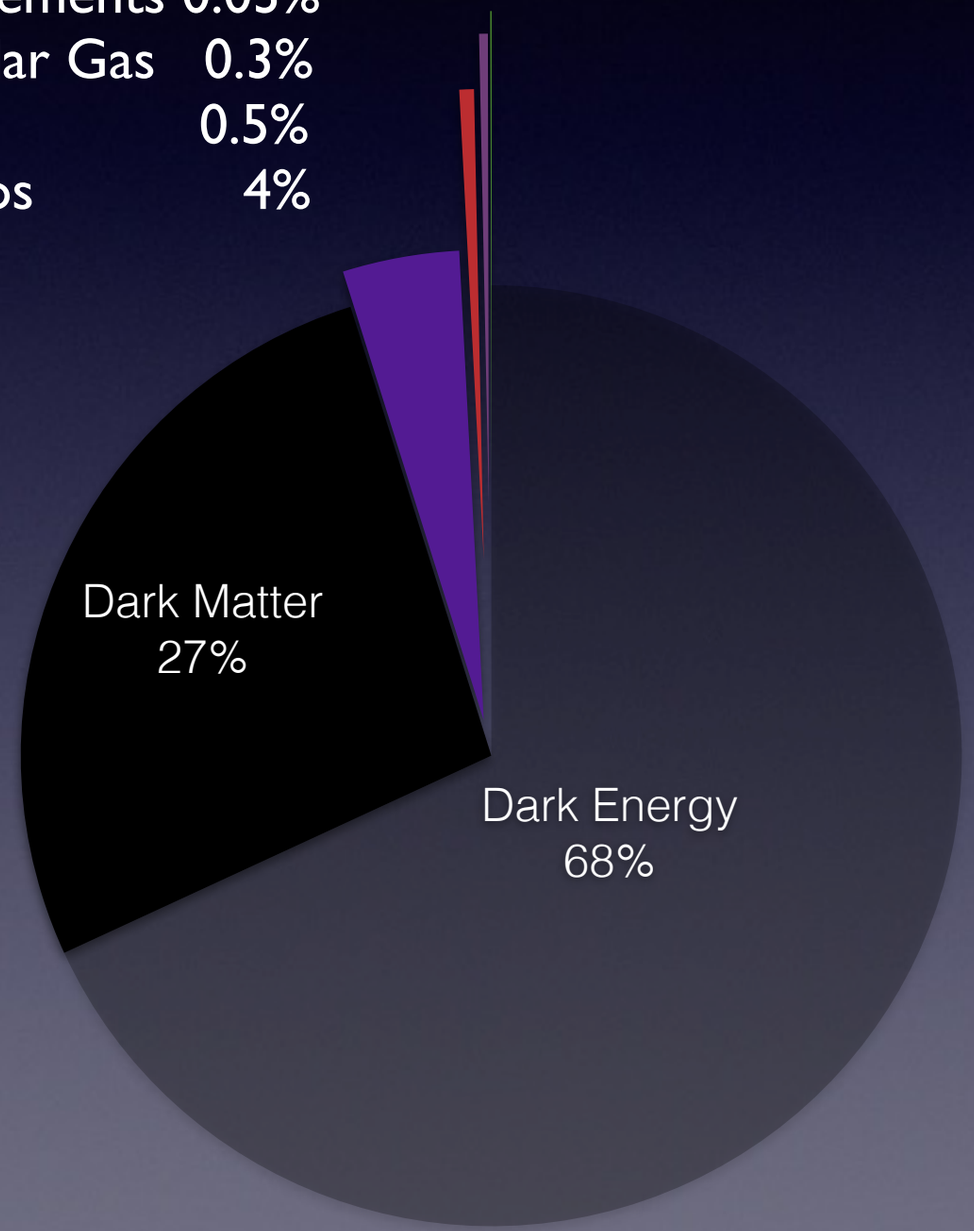
- Foreground objects lens more strongly than visible matter predicts

Dark Matter

The Standard Model {

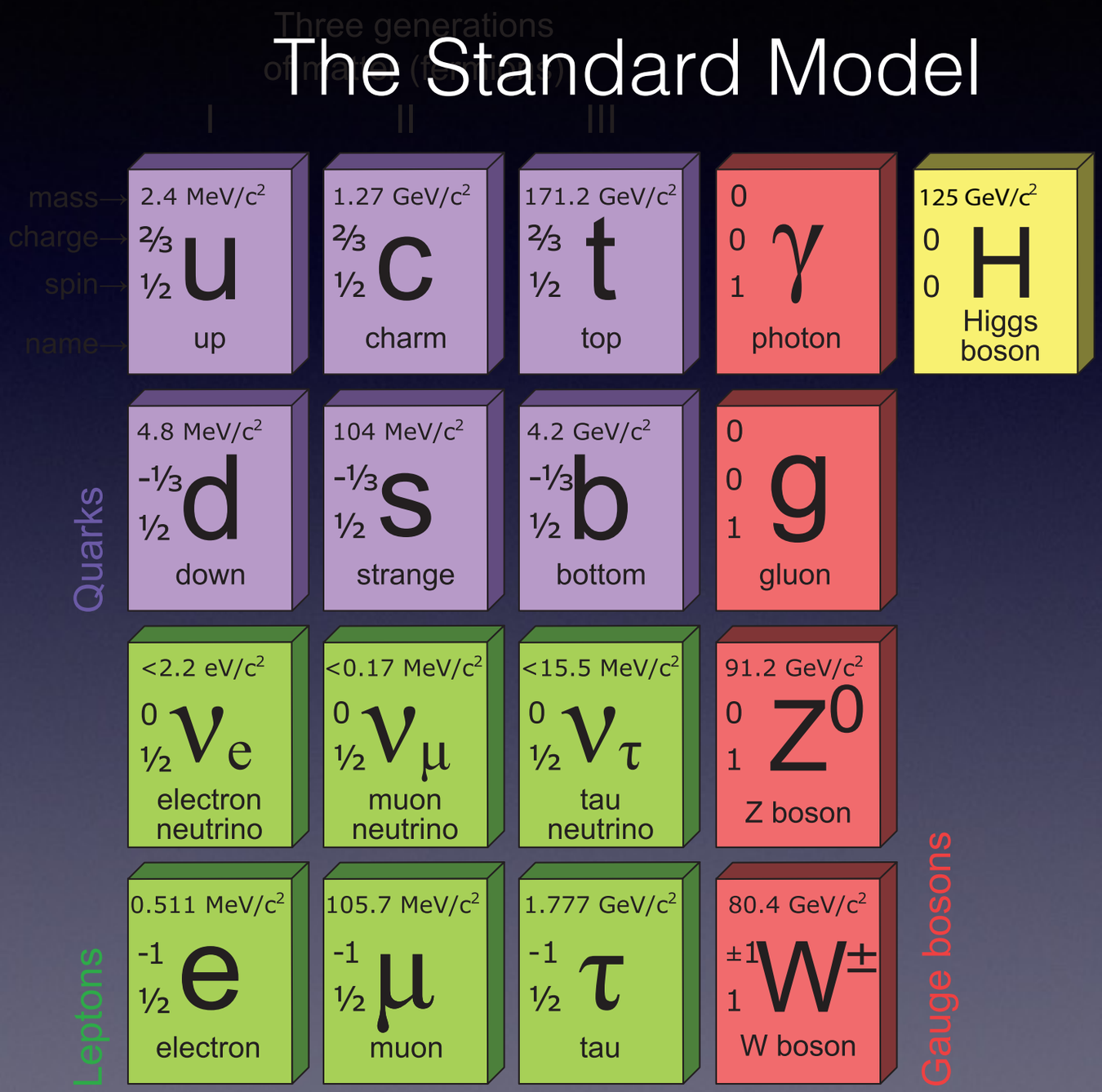
Heavy Elements 0.03%
Interstellar Gas 0.3%
Stars 0.5%
Neutrinos 4%

Something Else {

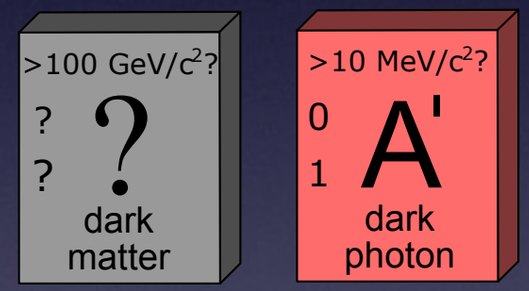


A Dark Sector?

The Standard Model



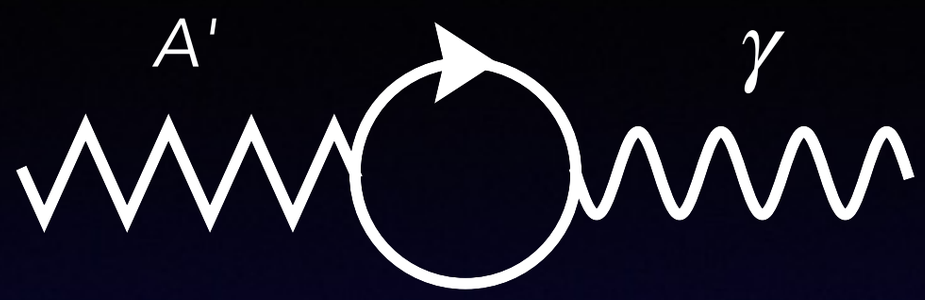
Something Else



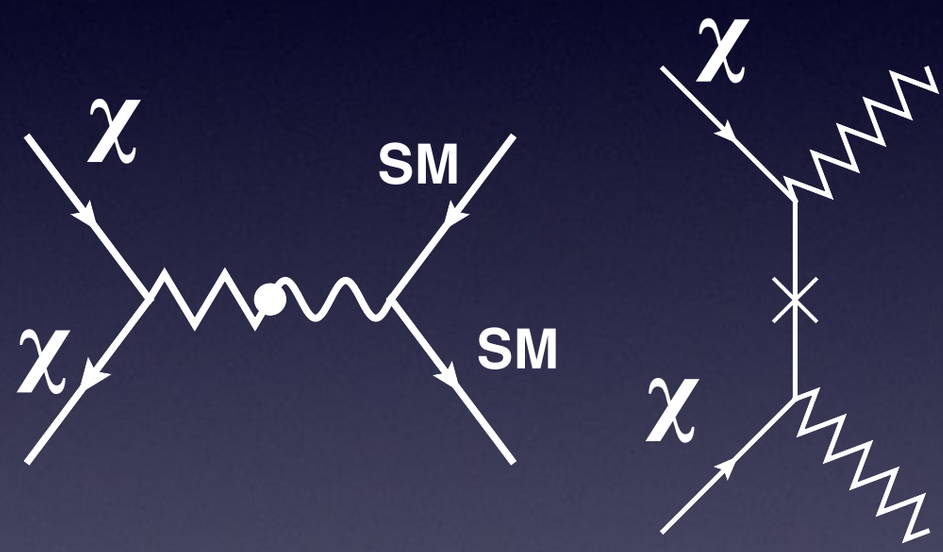
+…?

Connecting to the Standard Model

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



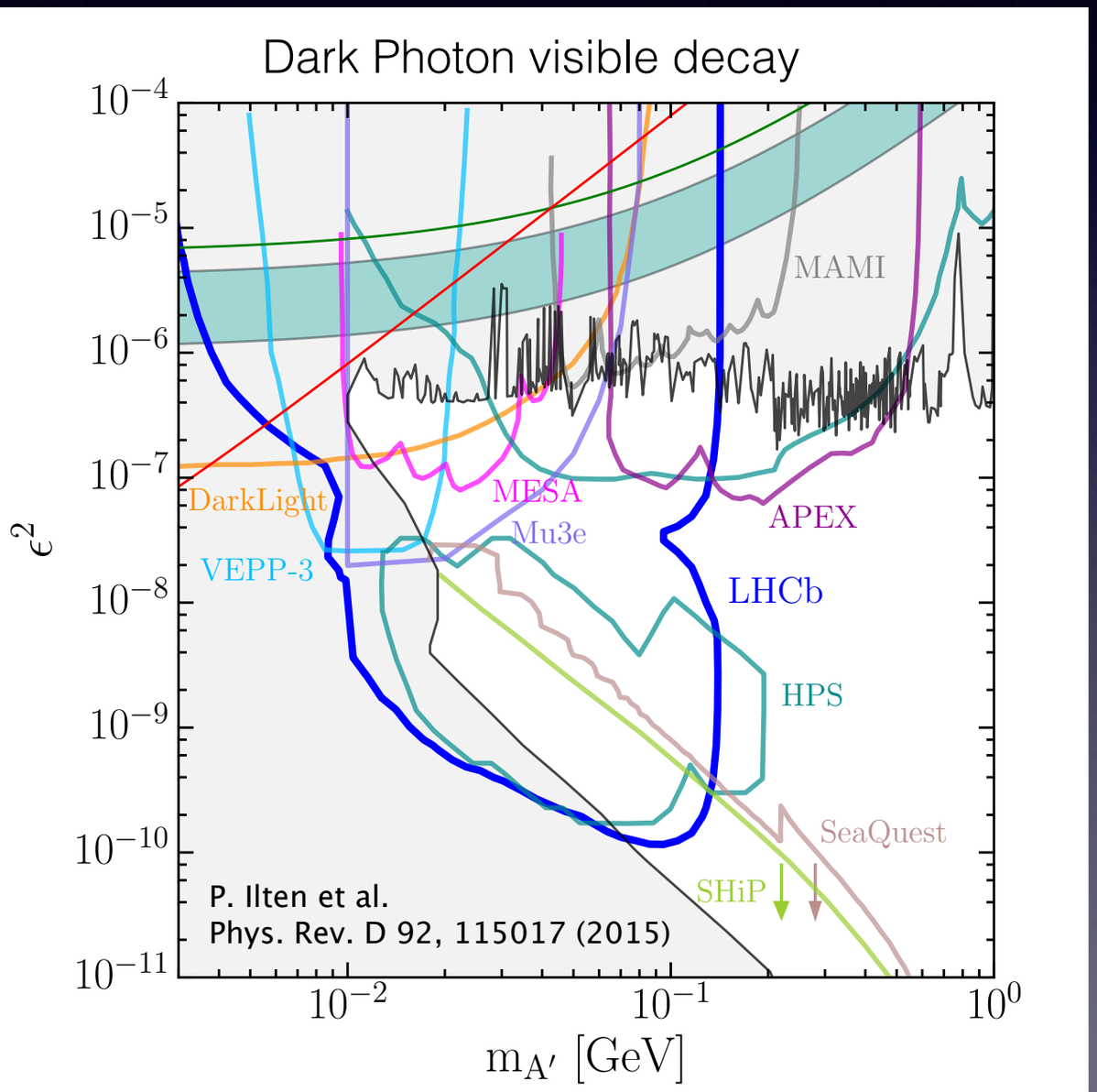
- Mechanism for DM decay

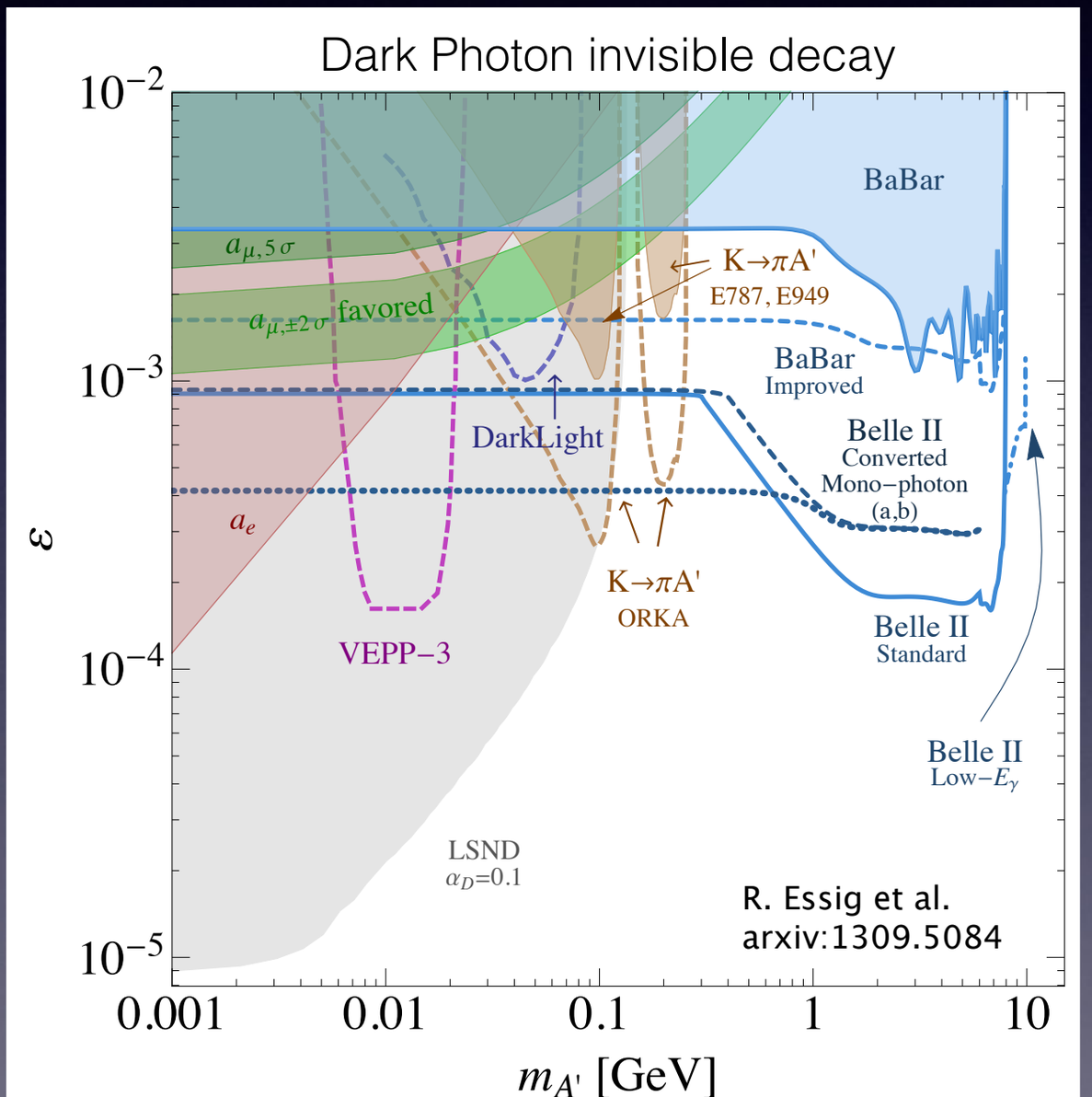


- DM-Agnostic argument:
  No reason not to have new term in Lagrangian:

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

A' Searches


Dark Photon visible decay
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-8}
10^{-9}
10^{-10}
10^{-11}
ϵ^2
MAMI
DarkLight
MESA
Mu3e
APEX
VEPP-3
LHCb
HPS
SeaQuest
SHiP
P. Ilten et al.
Phys. Rev. D 92, 115017 (2015)
10^{-2}
10^{-1}
10^{0}
$m_{A'}$ [GeV]

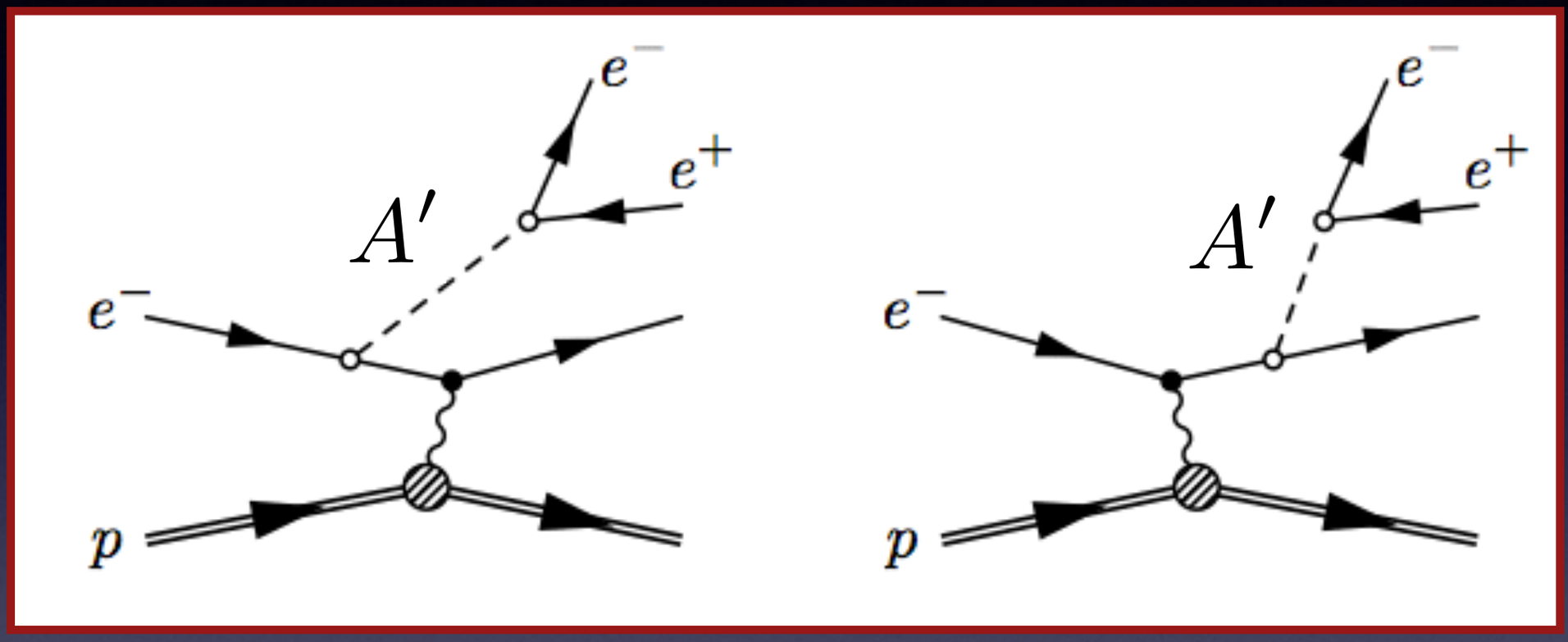

Dark Photon invisible decay
10^{-2}
10^{-3}
10^{-4}
10^{-5}
ε
BaBar
$a_{\mu,5\sigma}$
$a_{\mu,\pm2\sigma}$ favored
K→πA'
E787, E949
BaBar
Improved
DarkLight
Belle II
Converted
Mono−photon
(a,b)
a_e
K→πA'
ORKA
VEPP−3
Belle II
Standard
Belle II
Low−E_γ
LSND
α_D=0.1
R. Essig et al.
arxiv:1309.5084
0.001
0.01
0.1
1
10
$m_{A'}$ [GeV]

DarkLight Concept

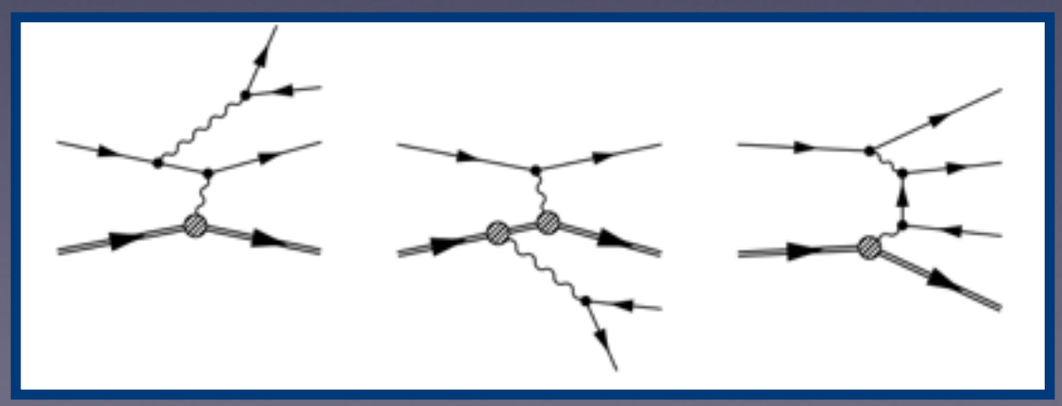
"Detecting A Resonance Kinematically with eLectrons Incident on a Gaseous Hydrogen Target

- 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

Producing A'



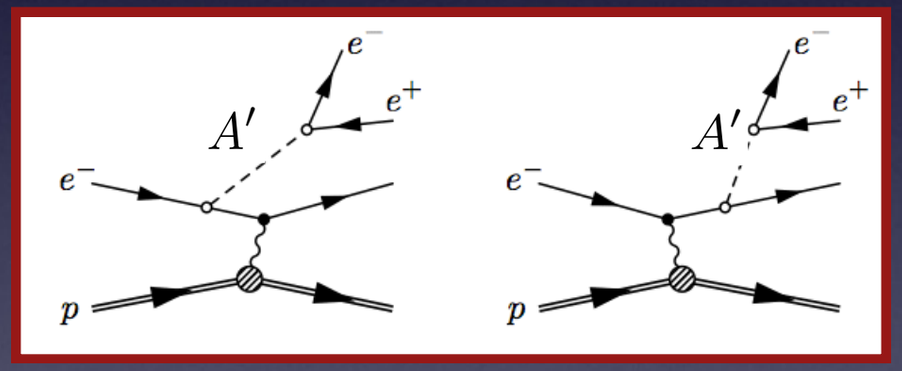
QED Background



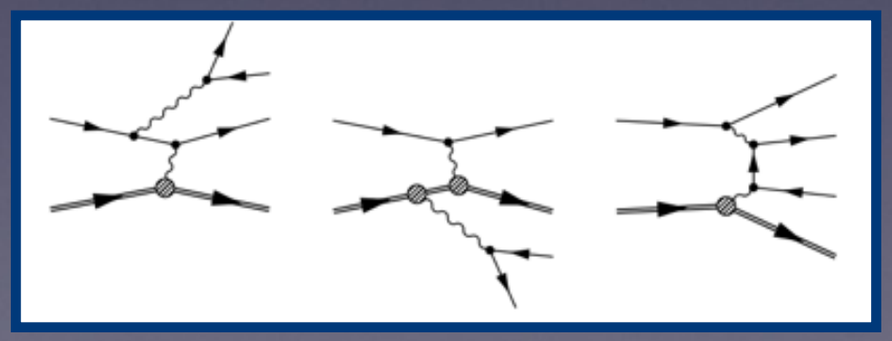
Detecting A'

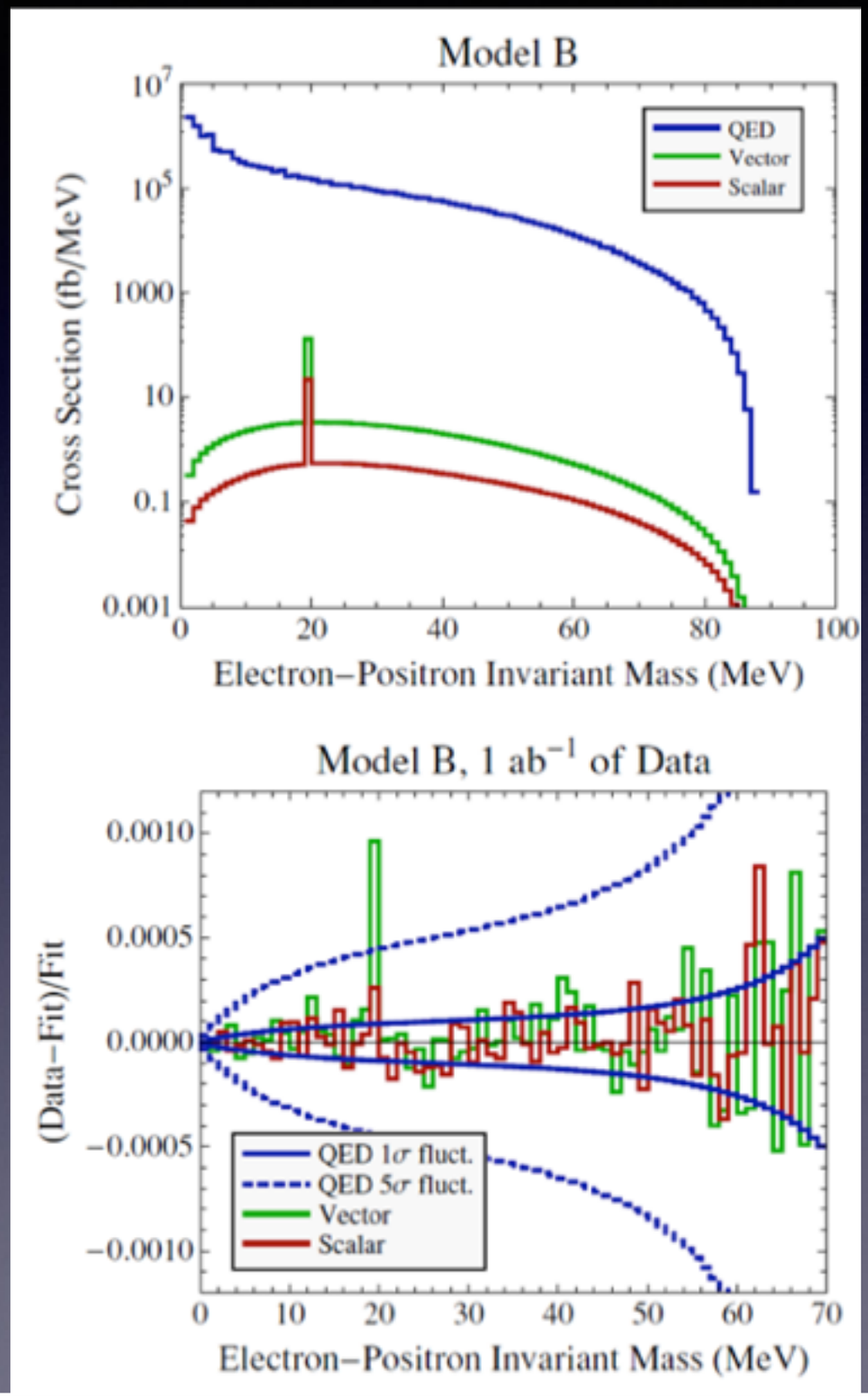
- Search for resonance in e^+e^- pairs
- High statistics help overcome irreducible background

A' Signal

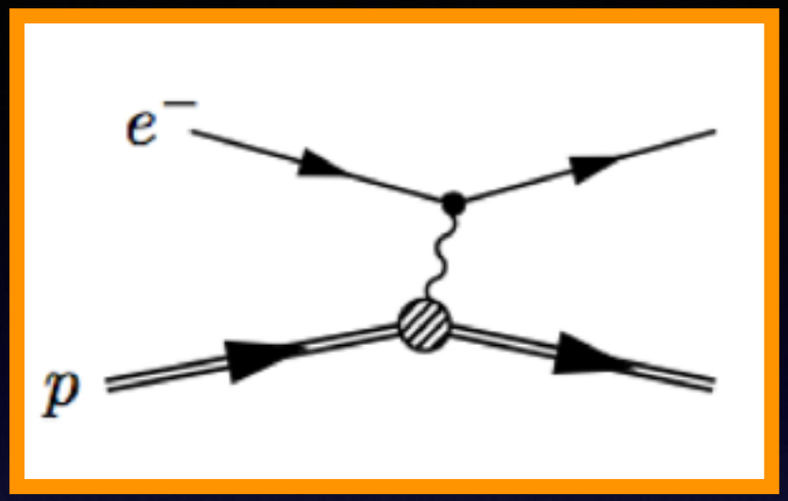


QED Background





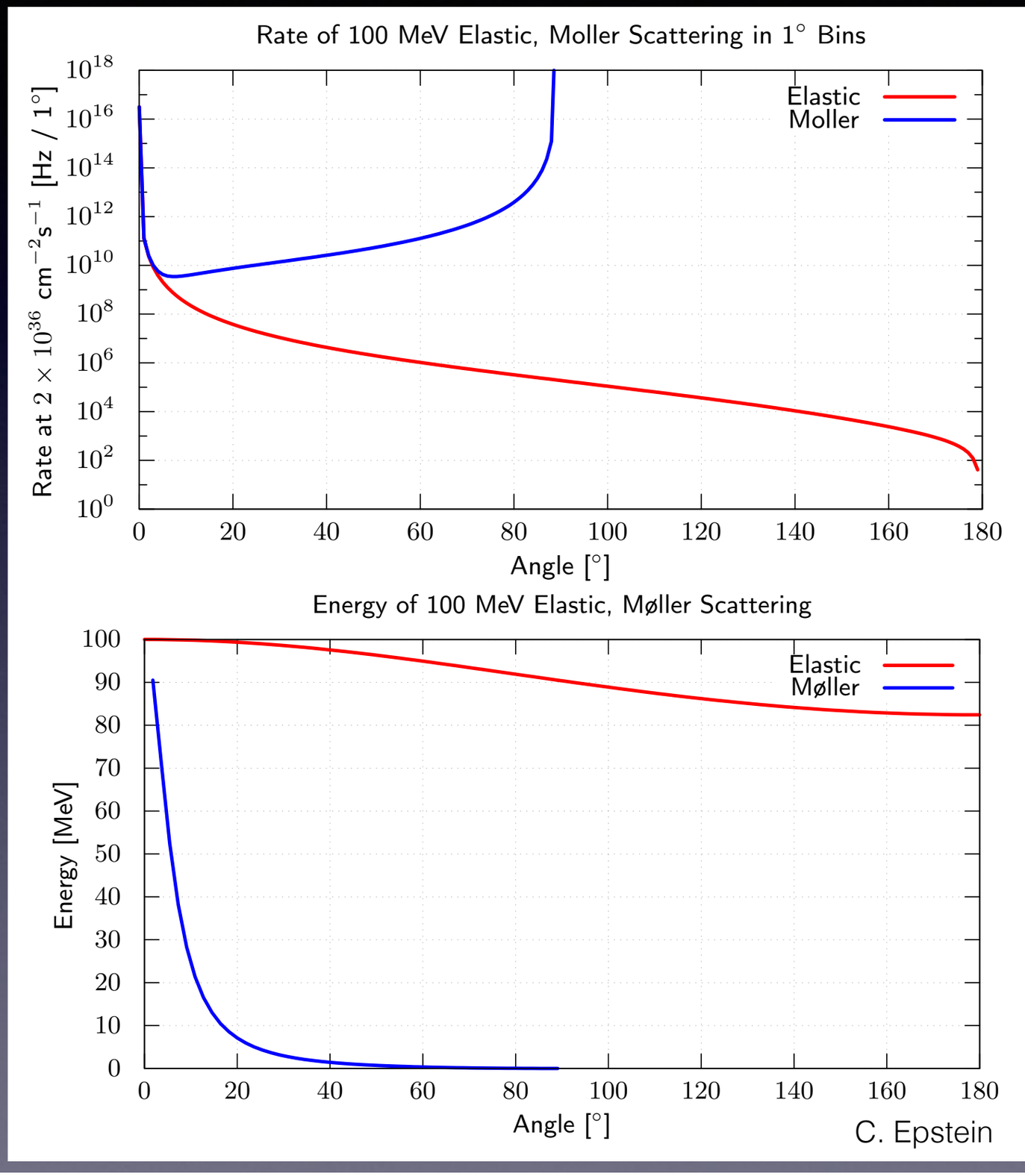
Standard Model Environment



- 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

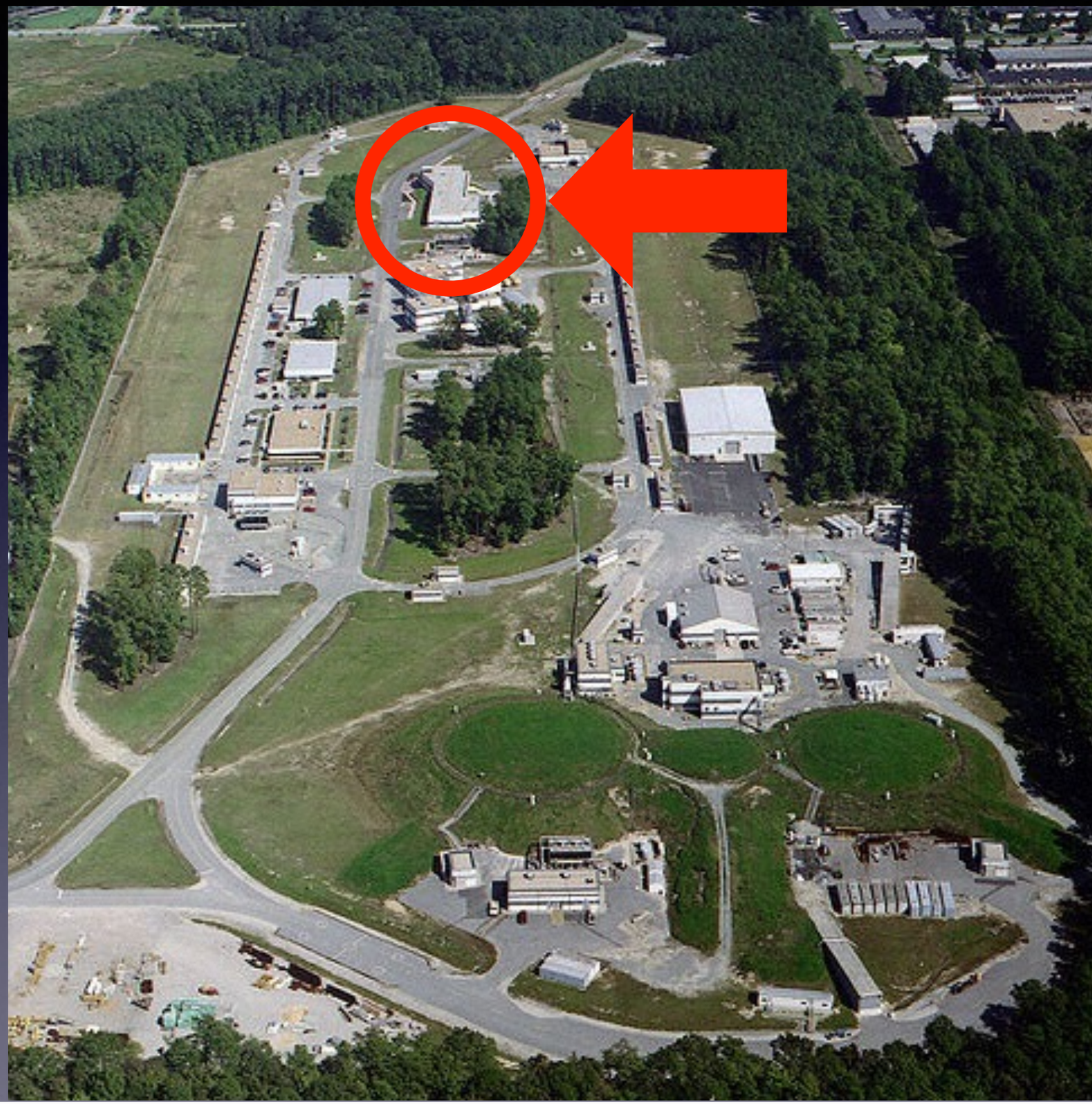
1. Linac+Fixed Target?
   Target thickness unlimited ✔
   Beam intensity too low ✘

2. Storage Ring + Internal Target?
   Target must be thin ✘
   Beam intensity high ✔

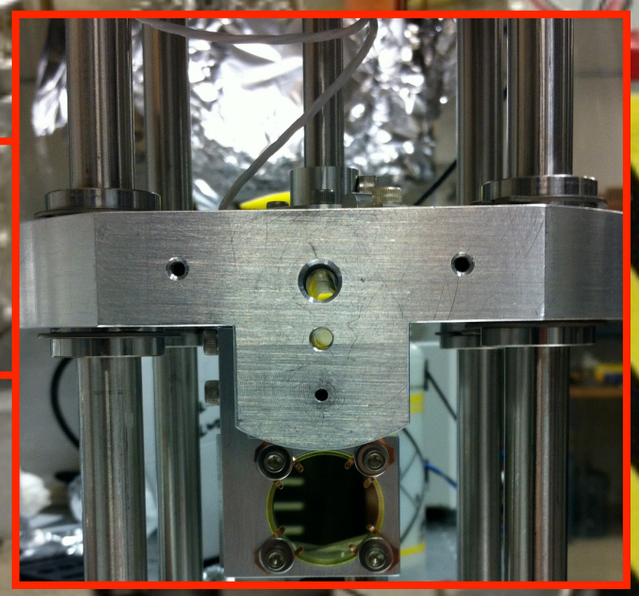
3. **ERL** + Internal Target?
   Target somewhat limited ✔ ...but unproven
   Beam intensity high ✔

LERF at Jefferson Lab

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



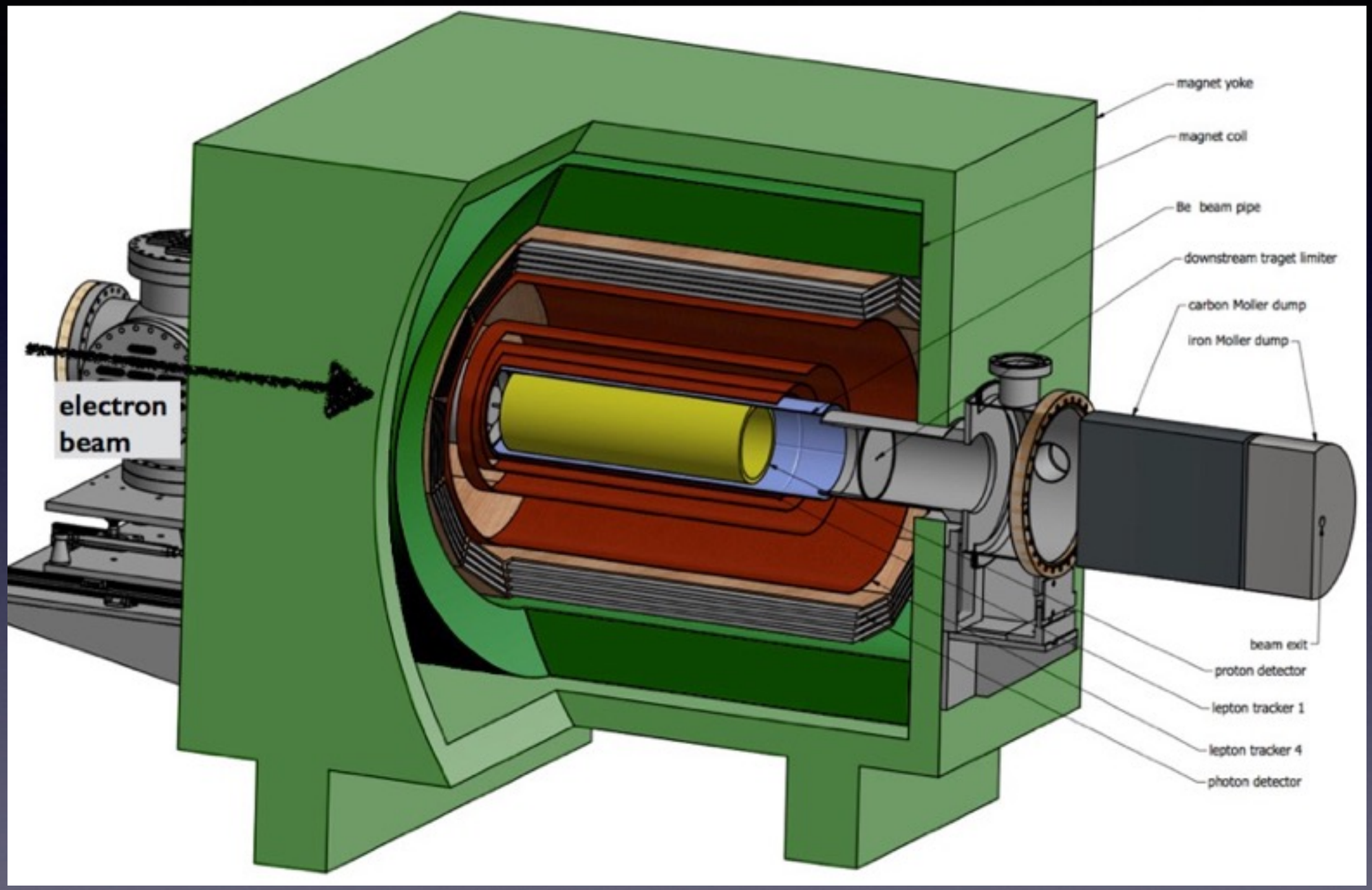
LERF at Jefferson Lab



- 2012 beam test showed precision steering possible

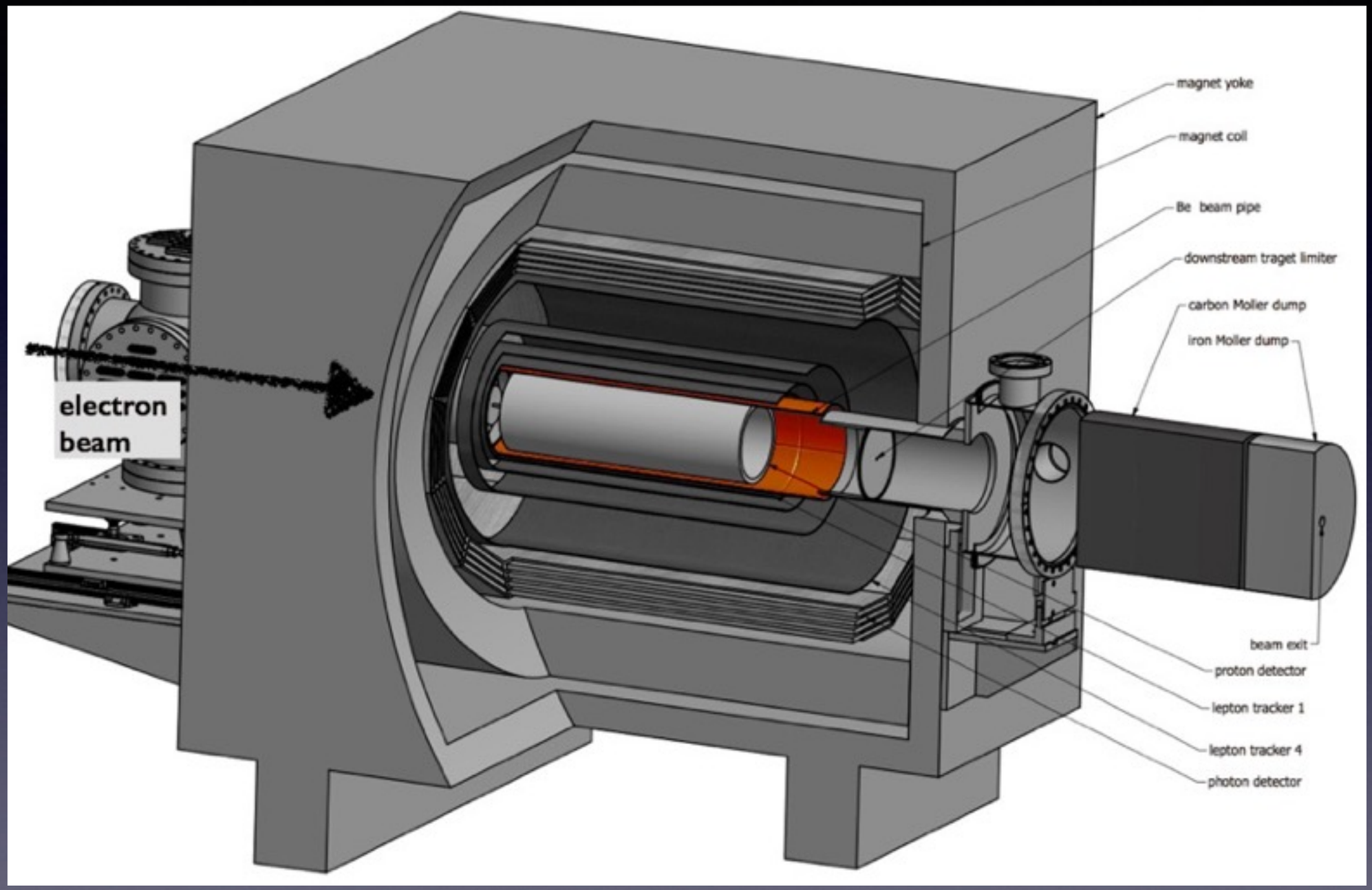
Phys. Rev. Lett. 111, 165801 (2013)
Nucl. Instr. Meth A729, 233 (2013)
Nucl. Instr. Meth. A729, 69 (2013)

DarkLight Design



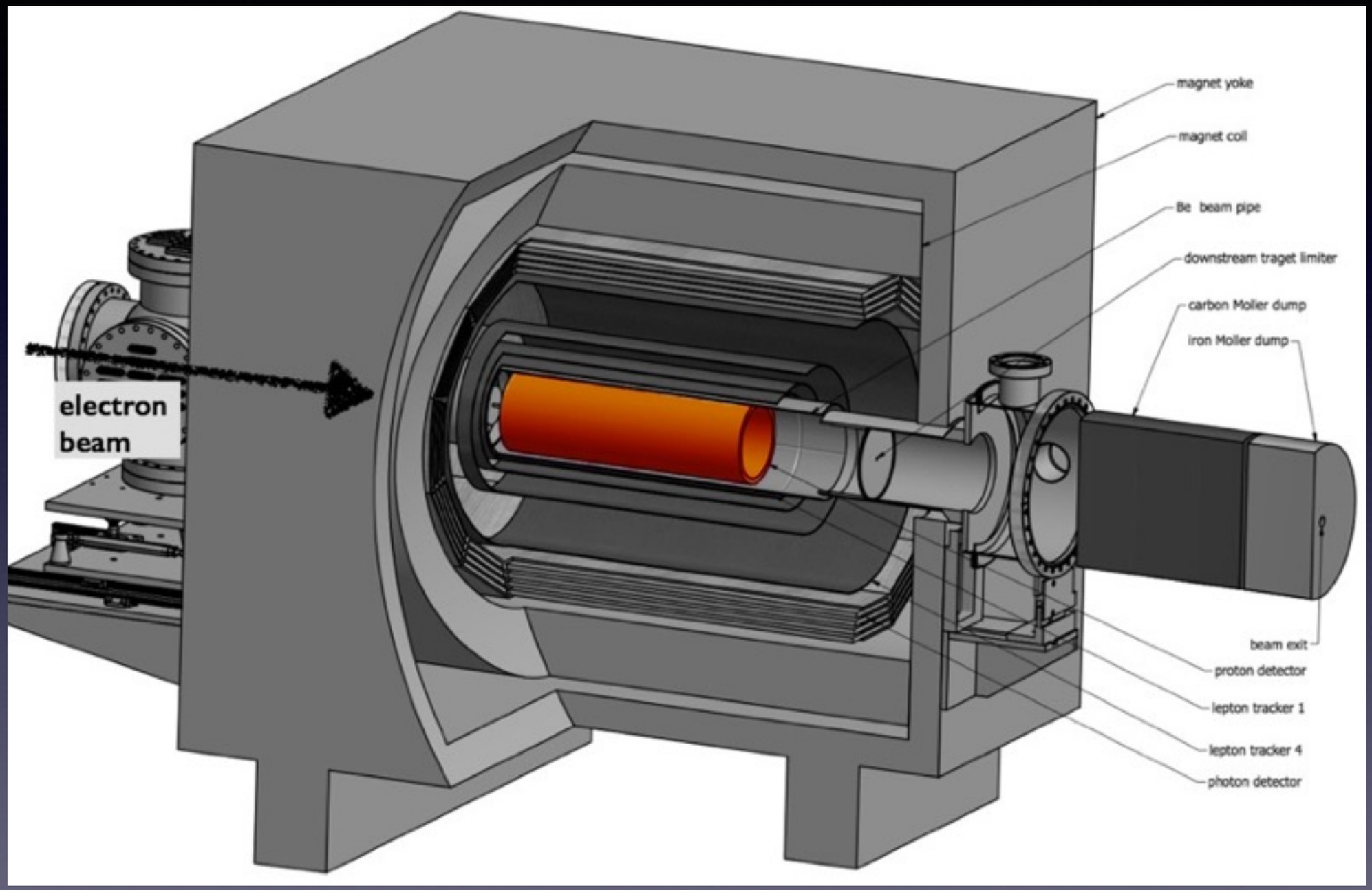
- Cylindrically symmetric detector

DarkLight Design



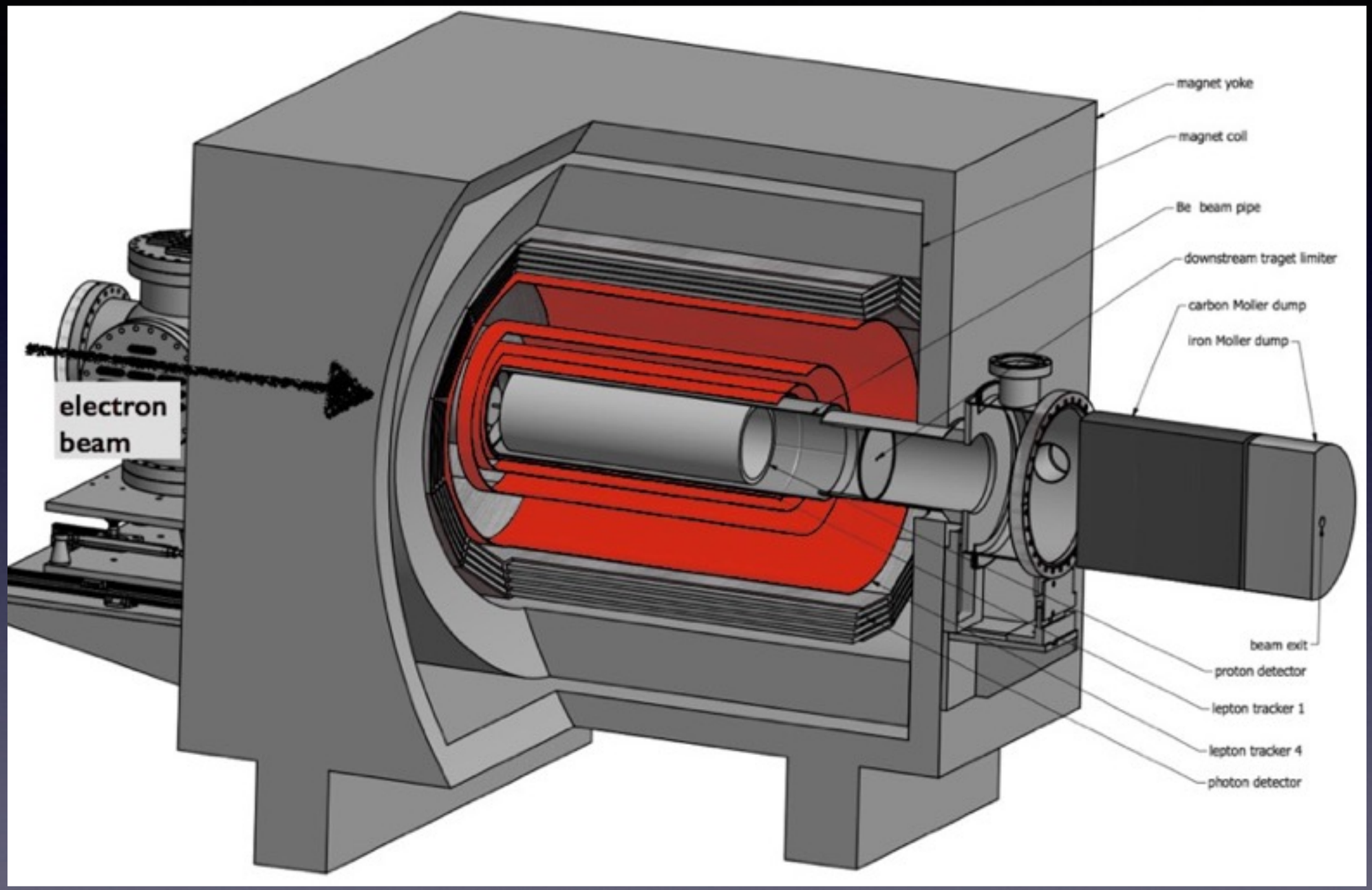
- Windowless, thin-walled target cell

DarkLight Design



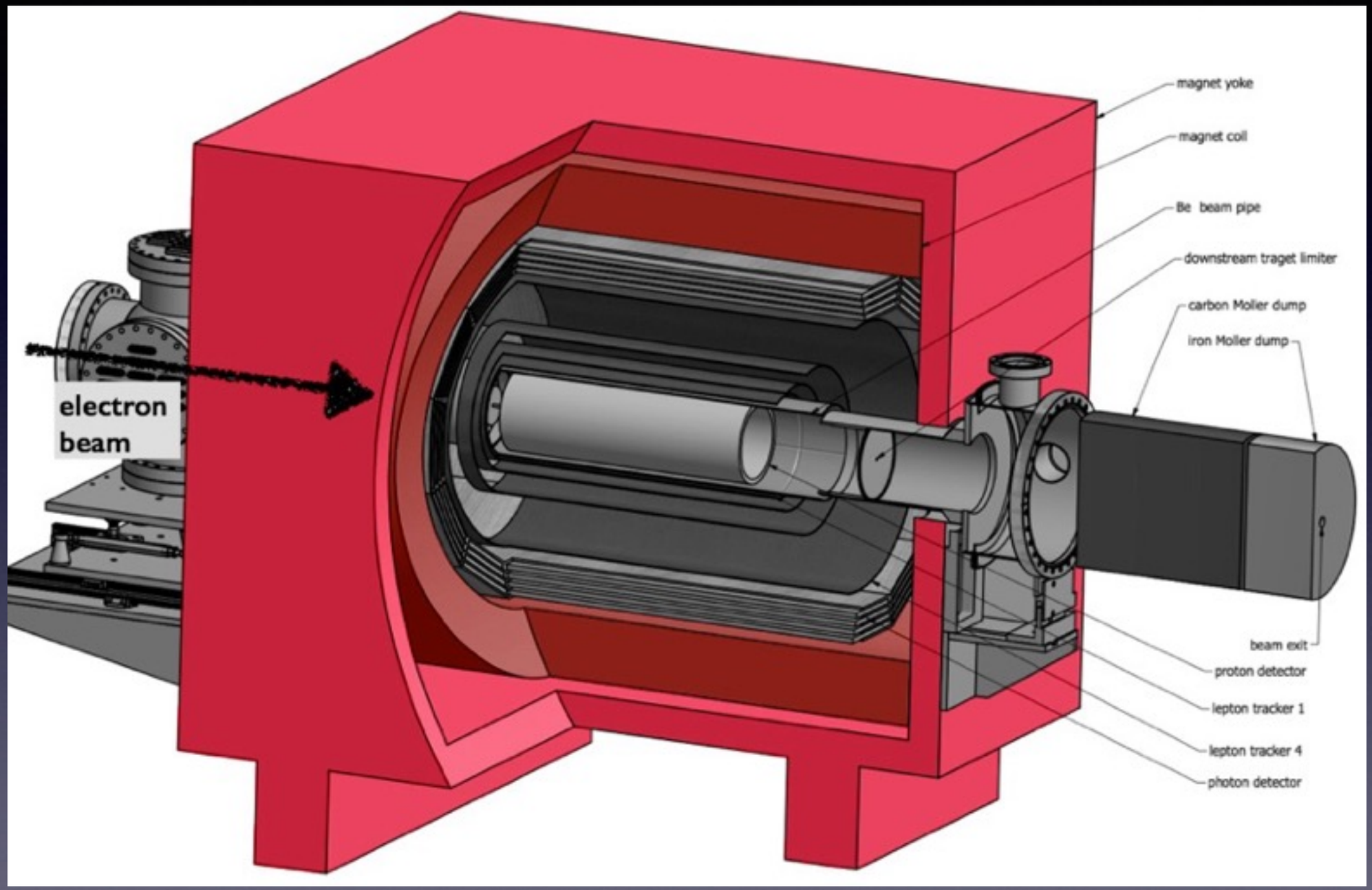
- Silicon detector inside target cell for recoiling proton

DarkLight Design



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

DarkLight Design



- Solenoid and yoke for momentum reco. and Møllers

Phased Approach

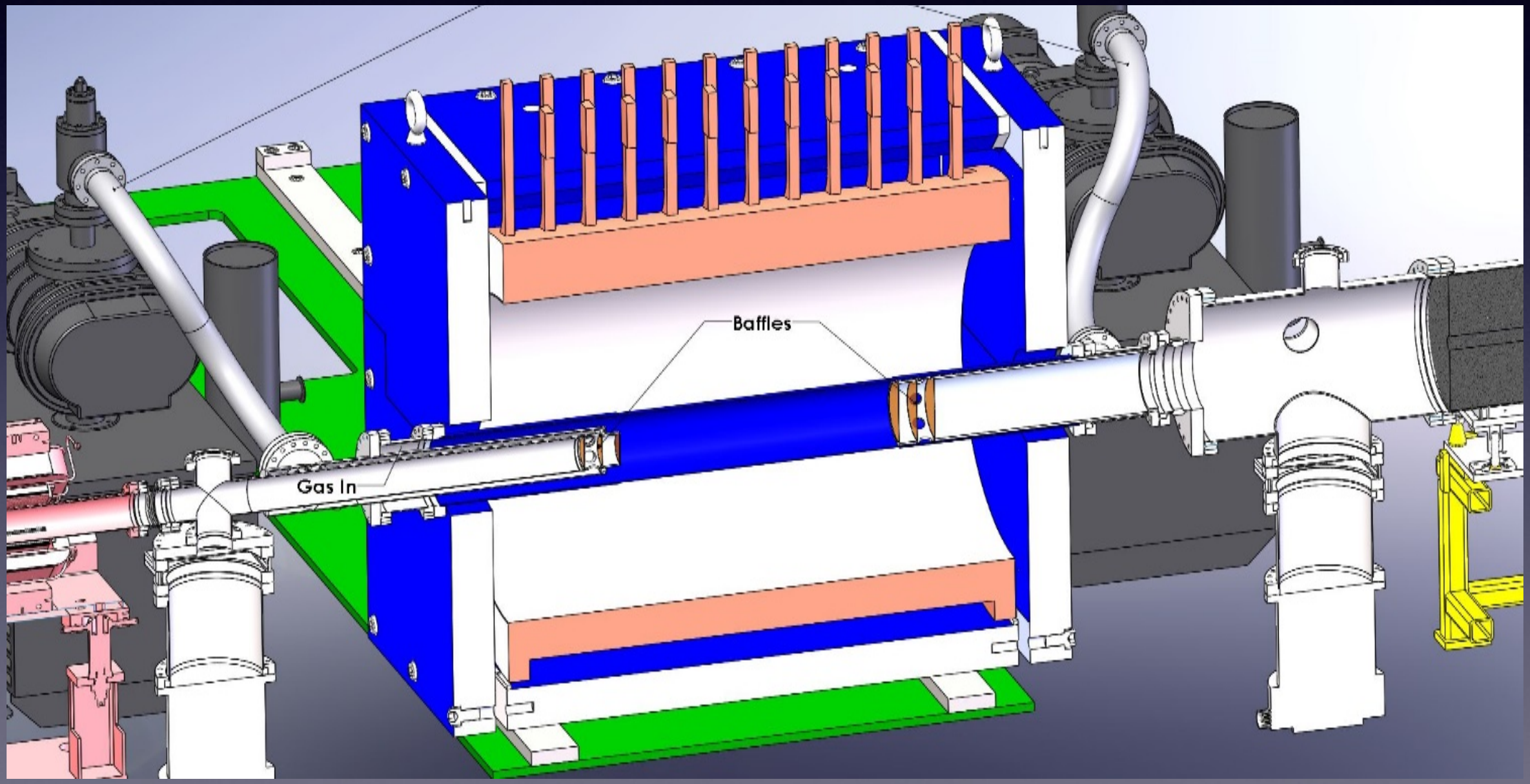
- 1A: Learn to operate LERF with Solenoid + Target
- 1B: Measure radiative Møller rates (spectrometer design)
- 1C: Proof-of-principle with partial coverage detector in solenoid

- 2: High-statistics measurement with full DarkLight detector

Phase 1A

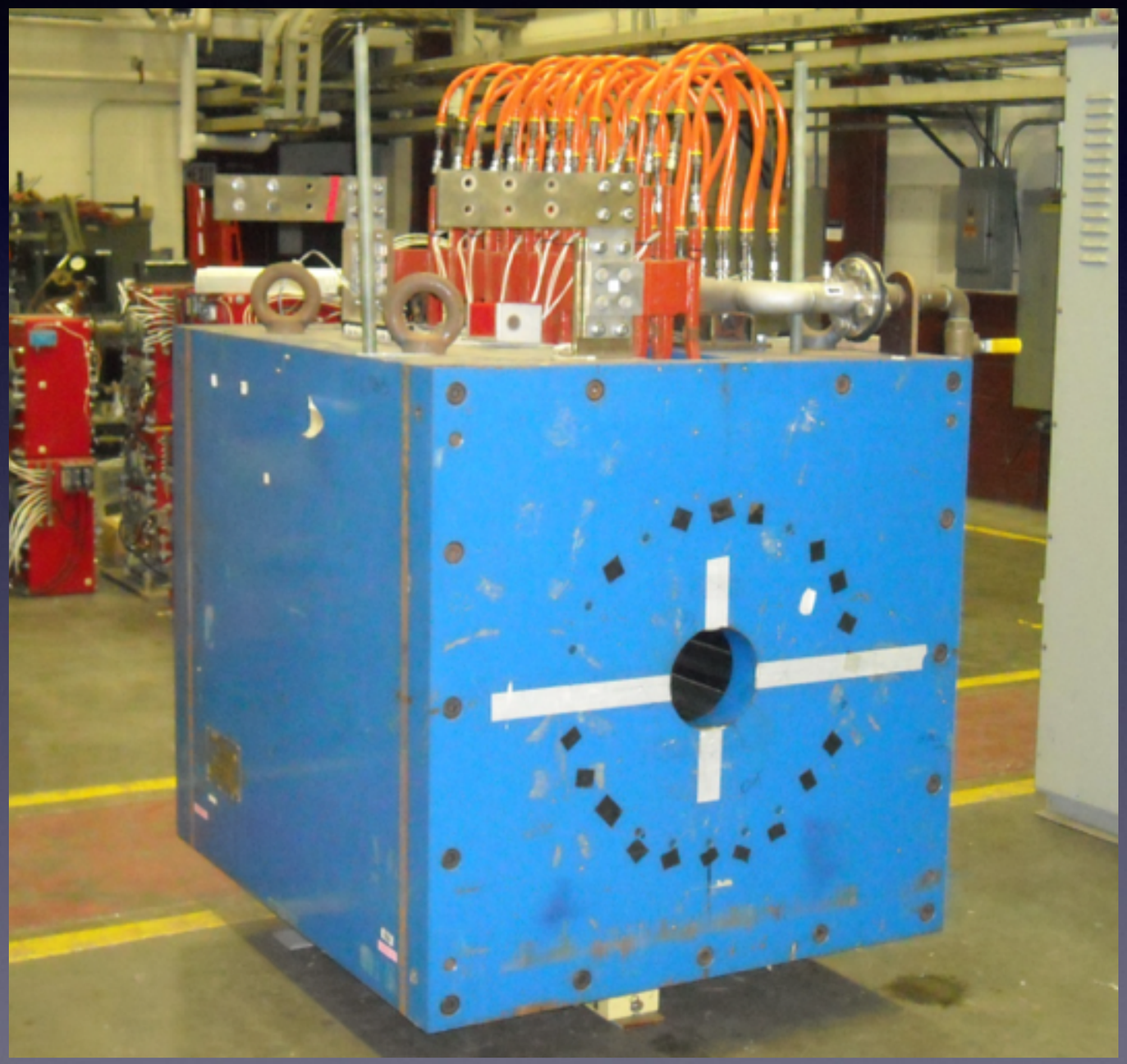
- 1A: Learn to operate LERF with Solenoid + Target

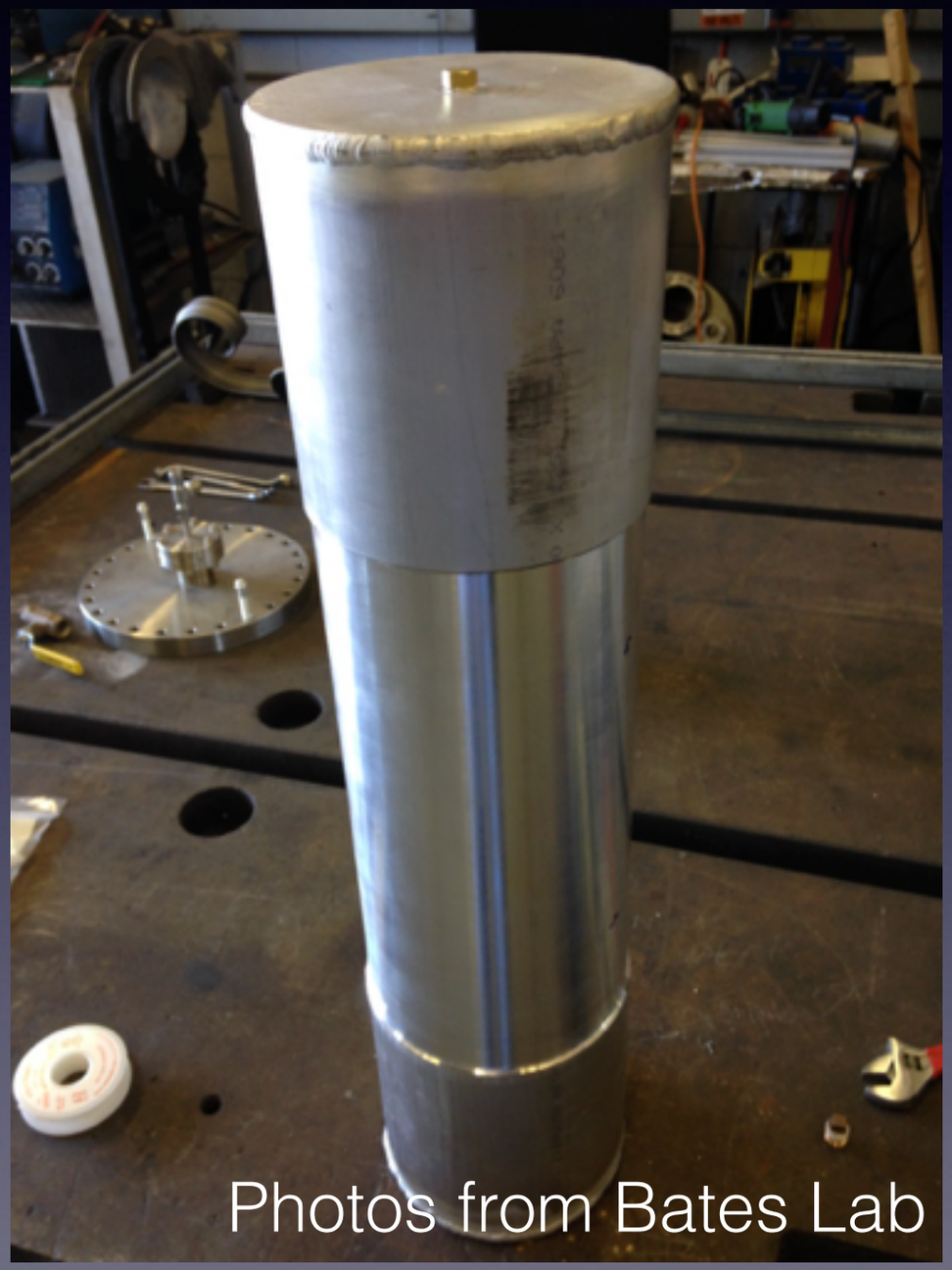
➡ few Torr gas, 0.5 Tesla field



Phase 1A Beam Interaction

- 1A: Learn to operate LERF with Solenoid + Target





Photos from Bates Lab

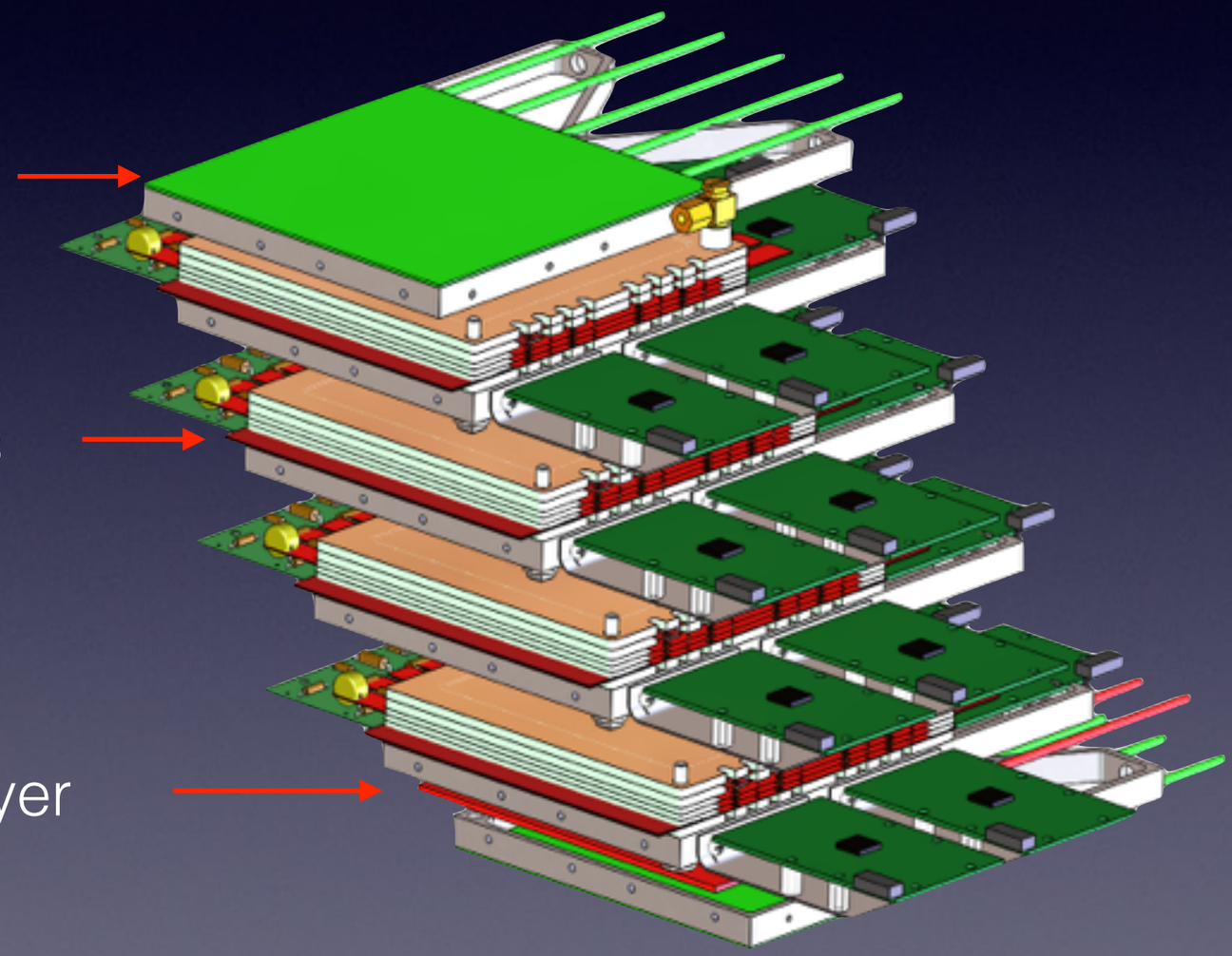
Phase 1A Detector

- Measure rates and evaluate detector performance

Scintillating strips

GEM tracking layers

Scintillating Fiber layer



Phase 1A Detector

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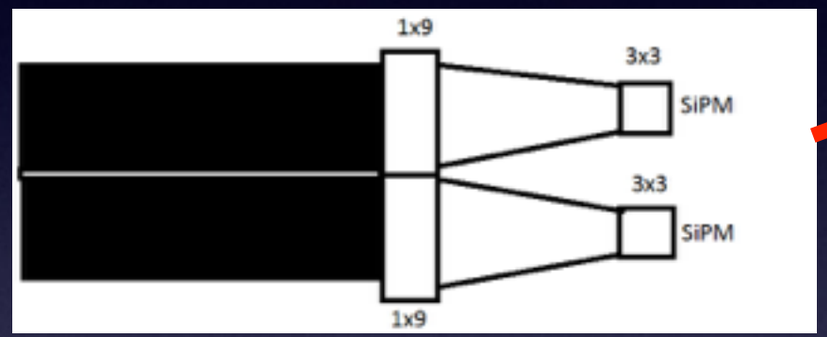
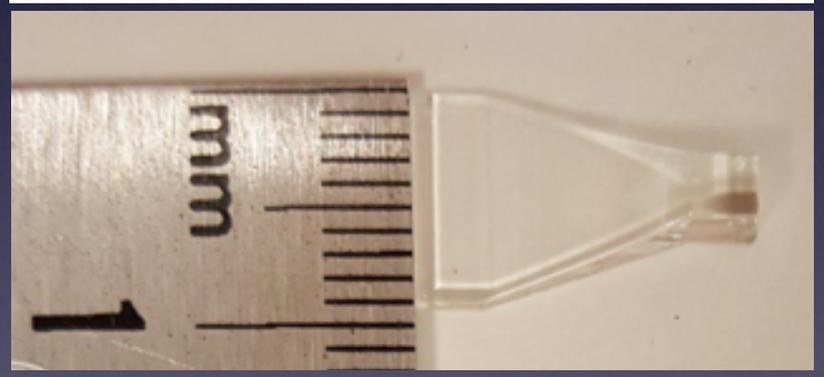
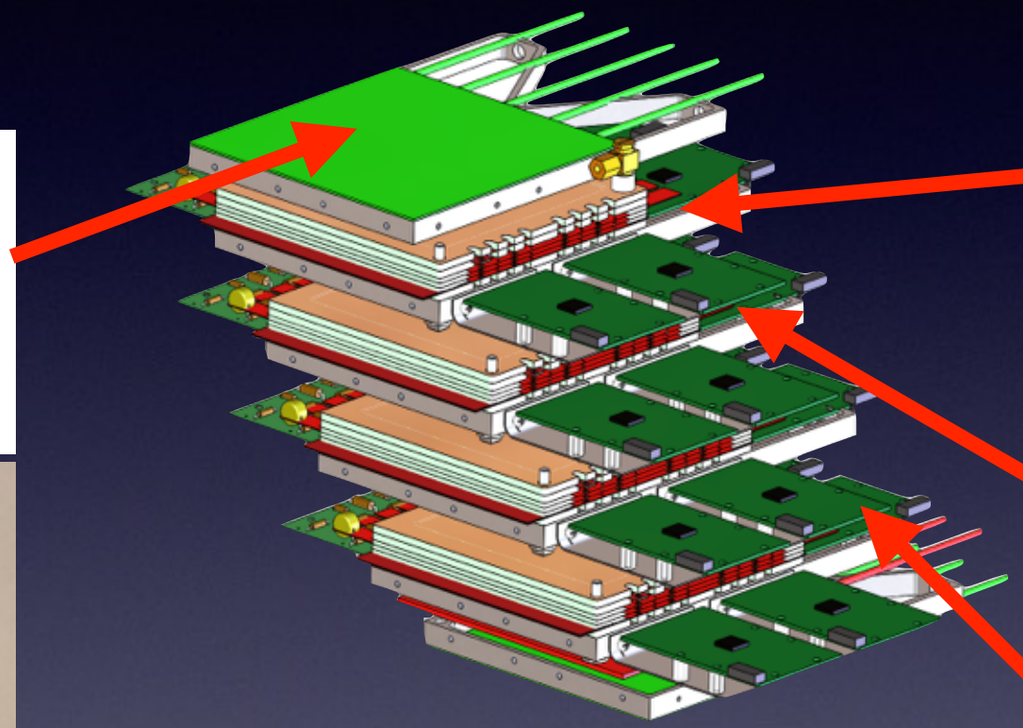
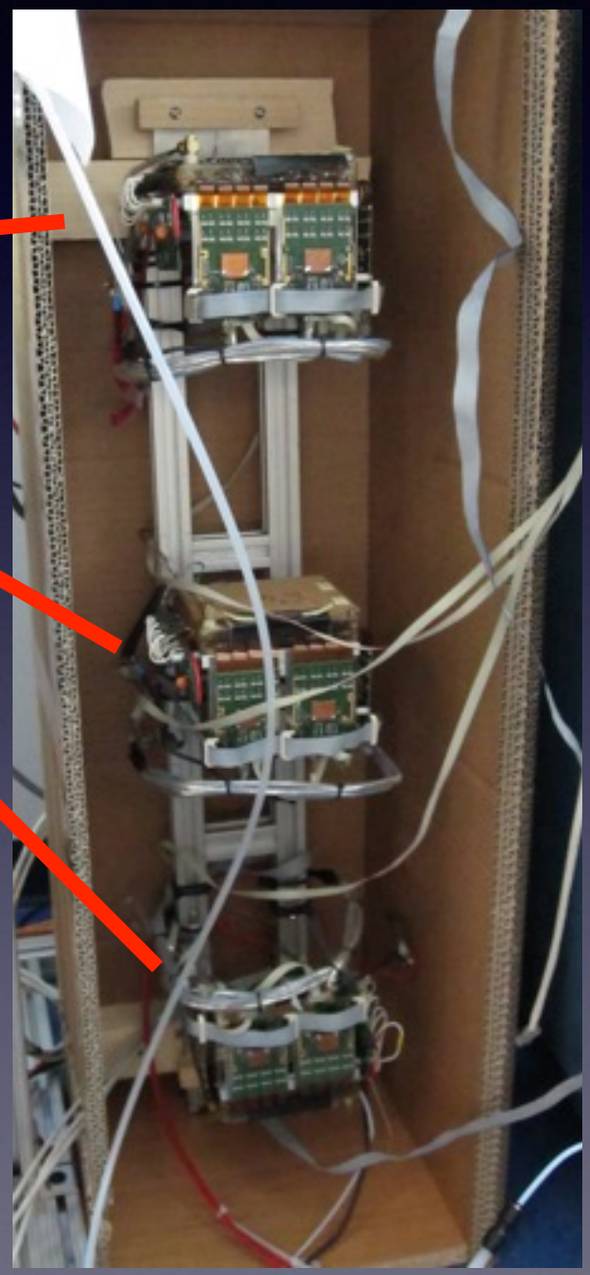


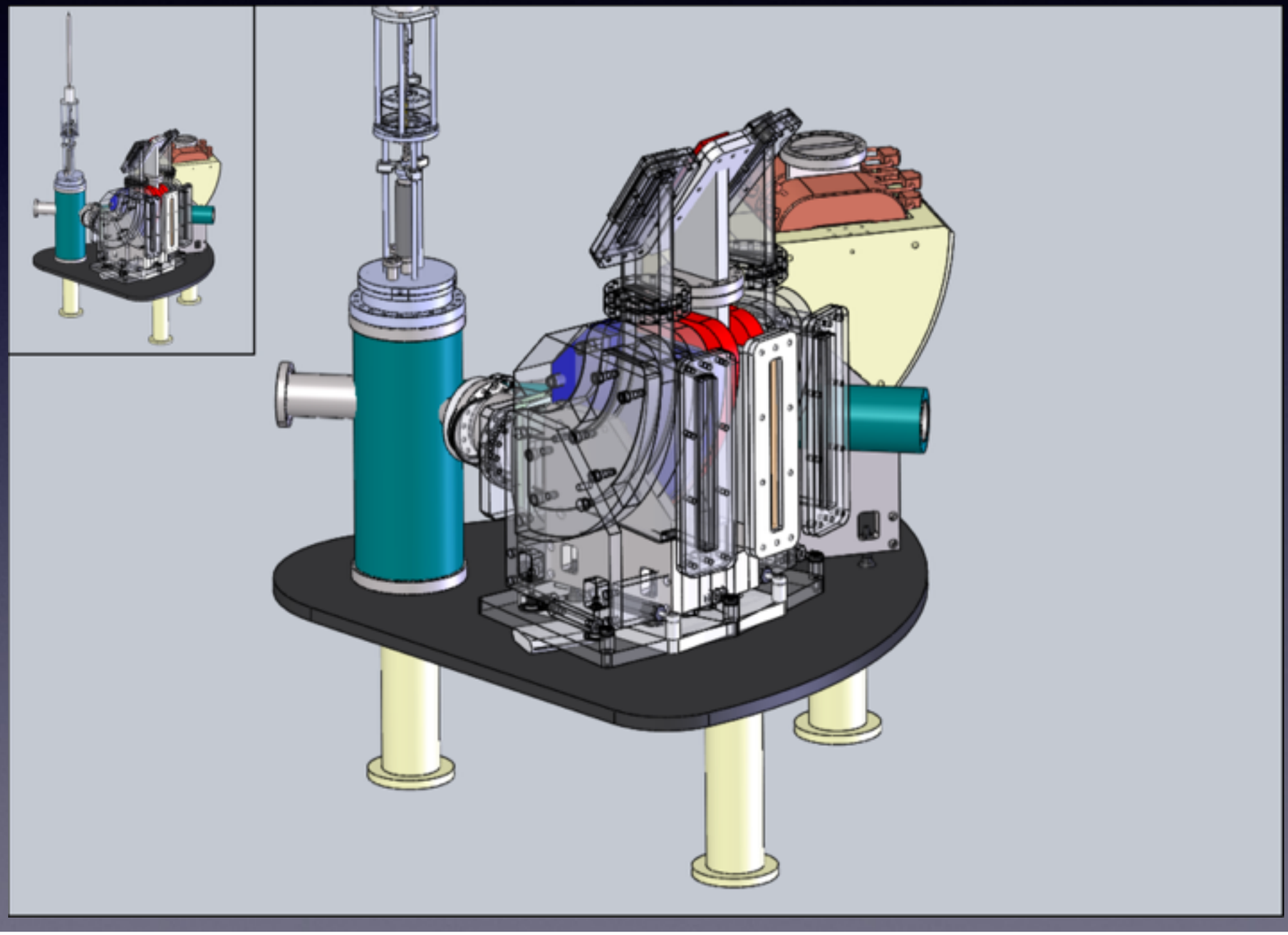






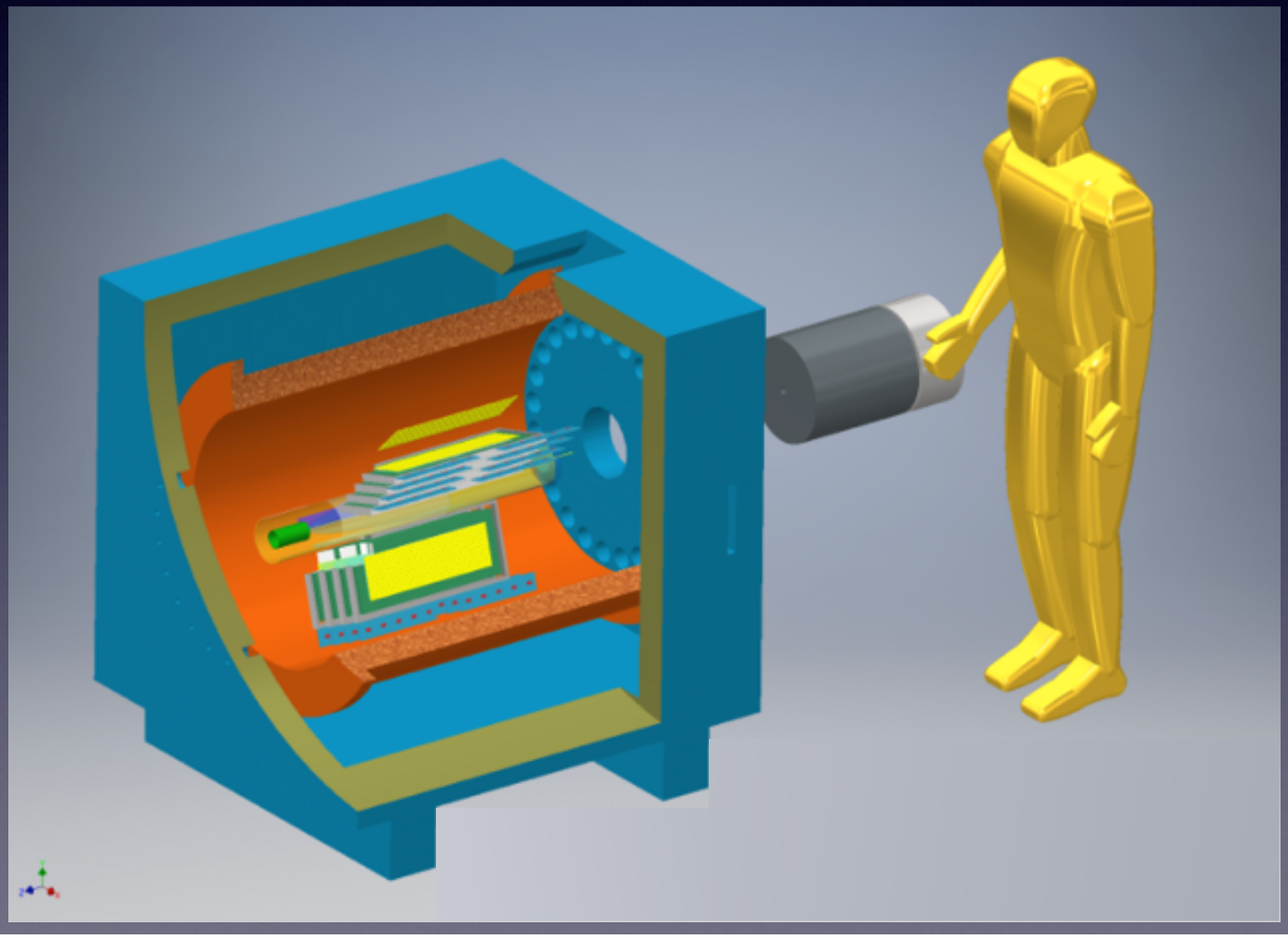
Phase 1B

- Measure radiative Møller rate using dedicated spectrometers



Phase 1C

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



Summary

- Dark photon may provide window to 'Dark Sector'

- High luminosity essential for search

- 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.