Schedule for Fall 2015

- **Tue 2015/09/15 5:00pm**
  Michael / Status of TREK, OLYMPUS, MUSE, DarkLight, C-GEN
- **Tue 2015/09/22 5:00pm**
  Narbe / Deuteron fits
- **Tue 2015/09/29 5:00pm**
  ?
- **Tue 2015/10/13 5:00pm**
  APS/DNP2015 rehearsals
- **Tue 2015/10/20 5:00pm**
  APS/DNP2015 rehearsals
- **Tue 2015/11/03 5:00pm**
  Leke
- **Tue 2015/11/17 5:00pm – (MK at J-PARC)**
  ?
- **Tue 2015/12/01 5:00pm – (MK at PSI)**
  ?
- **Tue 2015/12/08 5:00pm – last meeting**
  ?

Status of OLYMPUS, TREK, MUSE, DarkLight, C-GEN

Michael Kohl

Hampton University, Hampton, VA 23668
Jefferson Laboratory, Newport News, VA 23606

* Presently supported by NSF grants PHY-1436680, 1505934, and DOE DE-SC0012589, SC0013941

A framework of new experiments

- Two-photon exchange in lepton scattering
  OLYMPUS @ DESY to compare
  e^+p and e^-p elastic scattering

- Test of lepton flavor universality
  TREK/E36 @ J-PARC to compare
  $K^+ \rightarrow e^+ \nu$ / $\mu^+ \nu$ decays

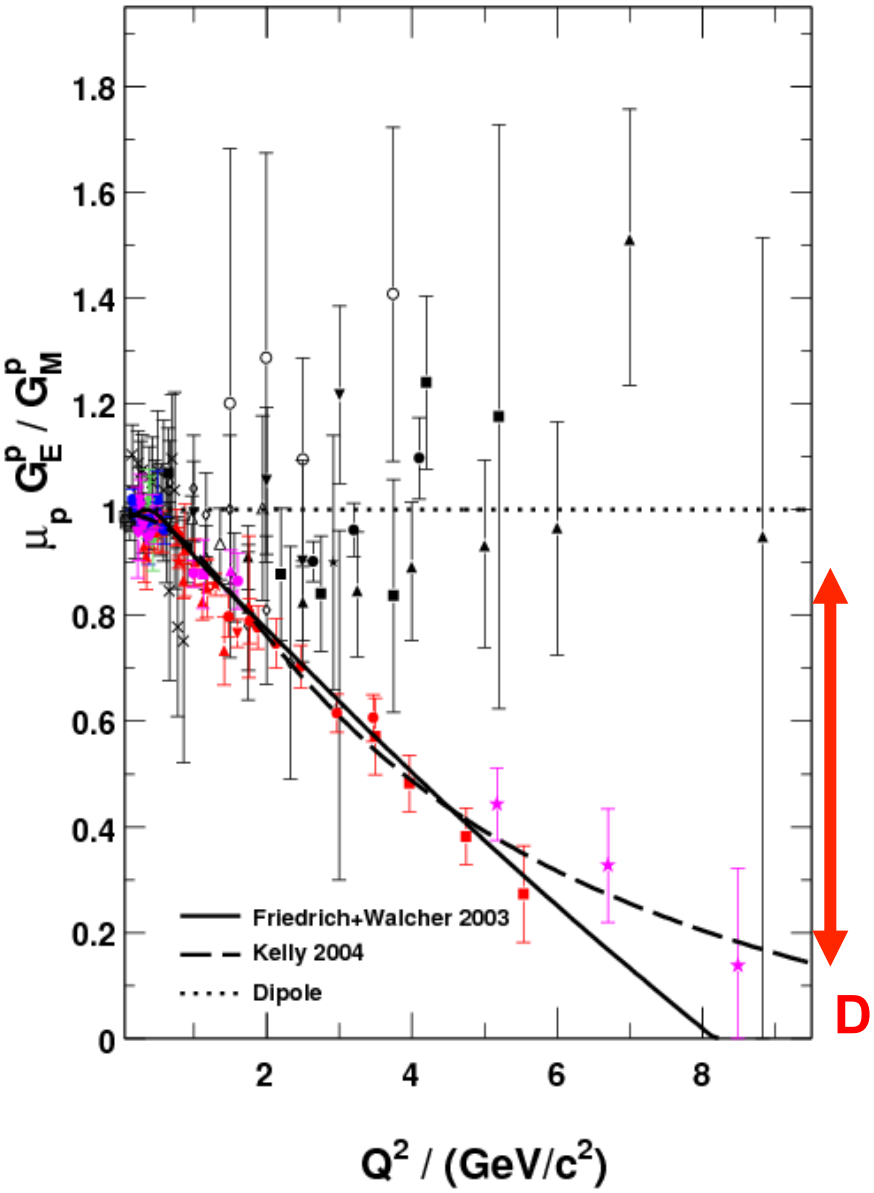
- The proton charge radius puzzle
  MUSE @ PSI to compare
  $\mu^\pm p$ and $e^\pm p$ elastic scattering

The nine muses

- Search for a gauge boson $m_{A'}$ = 10-90 MeV/c^2
  DarkLight @ JLAB to reconstruct the
  decay of $A' \rightarrow e^+ e^-$ in $e^- p \rightarrow e^- p e^+ e^-$

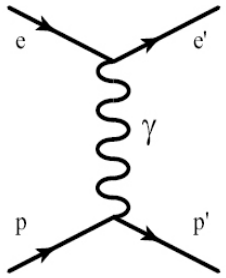
- Measurement of the neutron electric form factor
  via neutron recoil polarization in quasielastic
  deuteron electrodisintegration with C-GEN @ JLAB

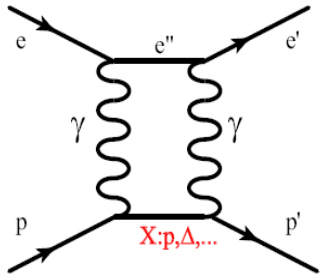
Proton form factor ratio



Jefferson Lab 2000–

- All Rosenbluth data from SLAC and Jlab in agreement
- Dramatic discrepancy between Rosenbluth and recoil polarization technique
- Multi-photon exchange considered best candidate

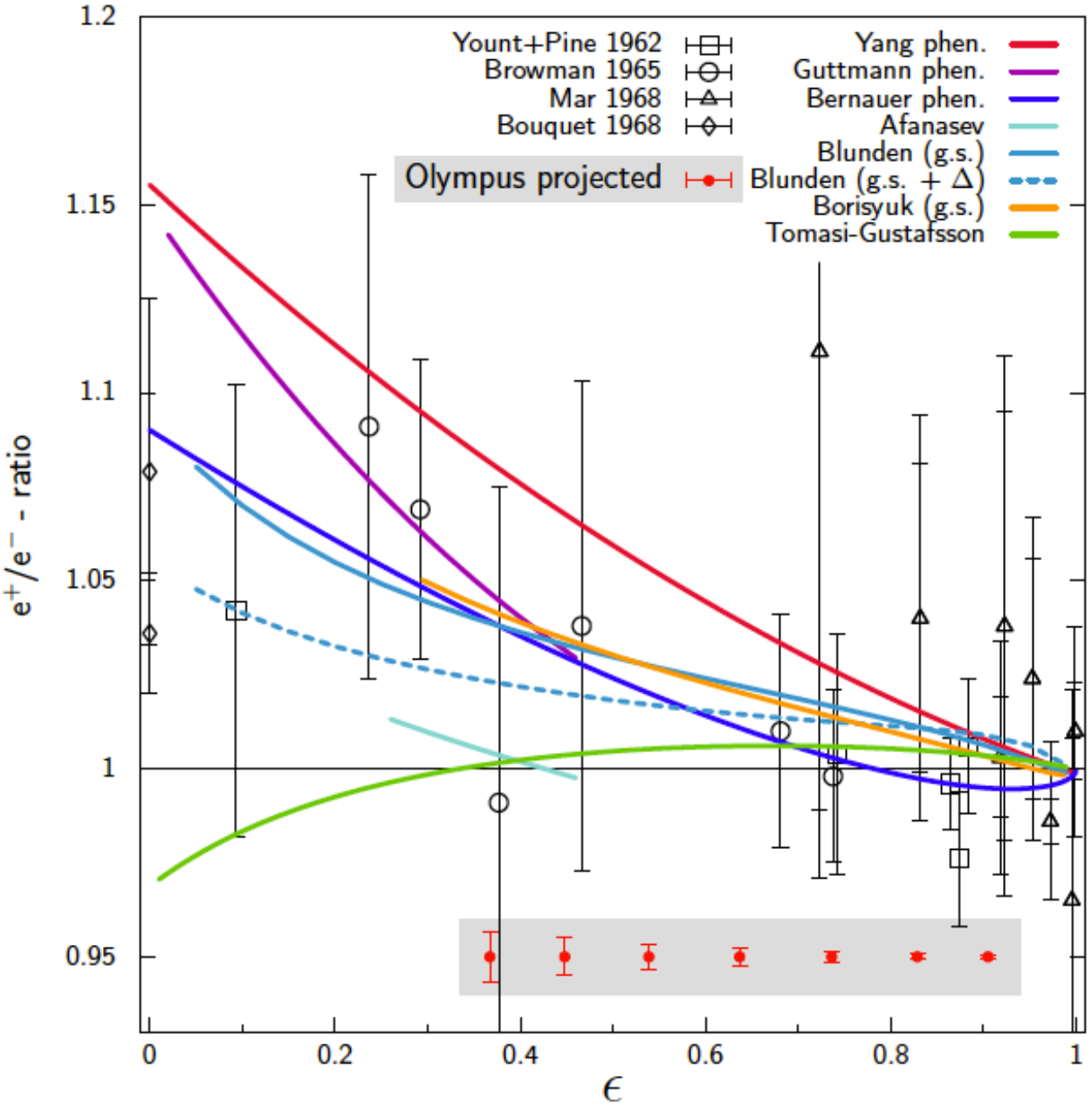




Dramatic discrepancy!

>800 citations

Projected results for OLYMPUS



Data from 1960's

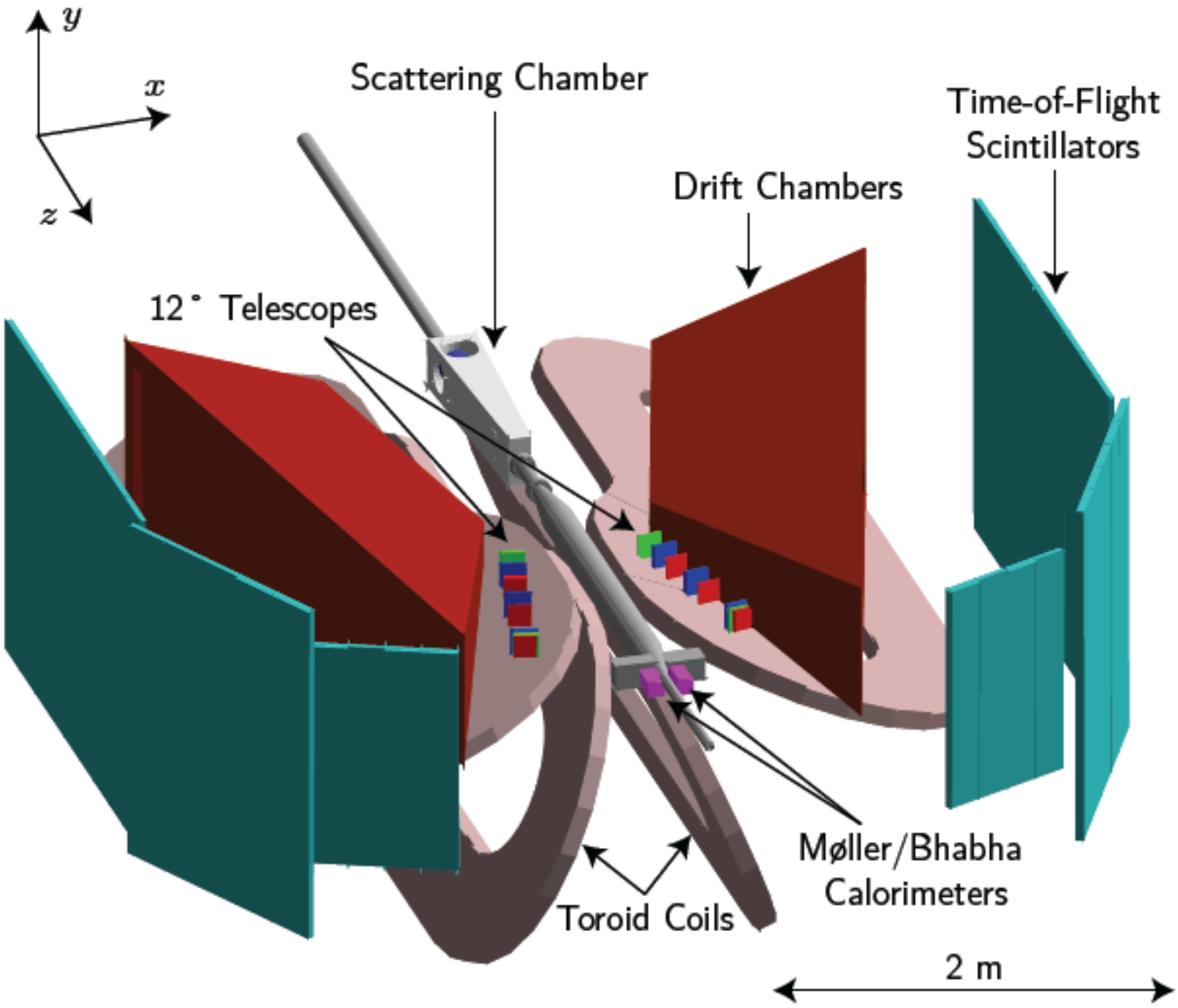
Many theoretical predictions with little constraint

OLYMPUS:

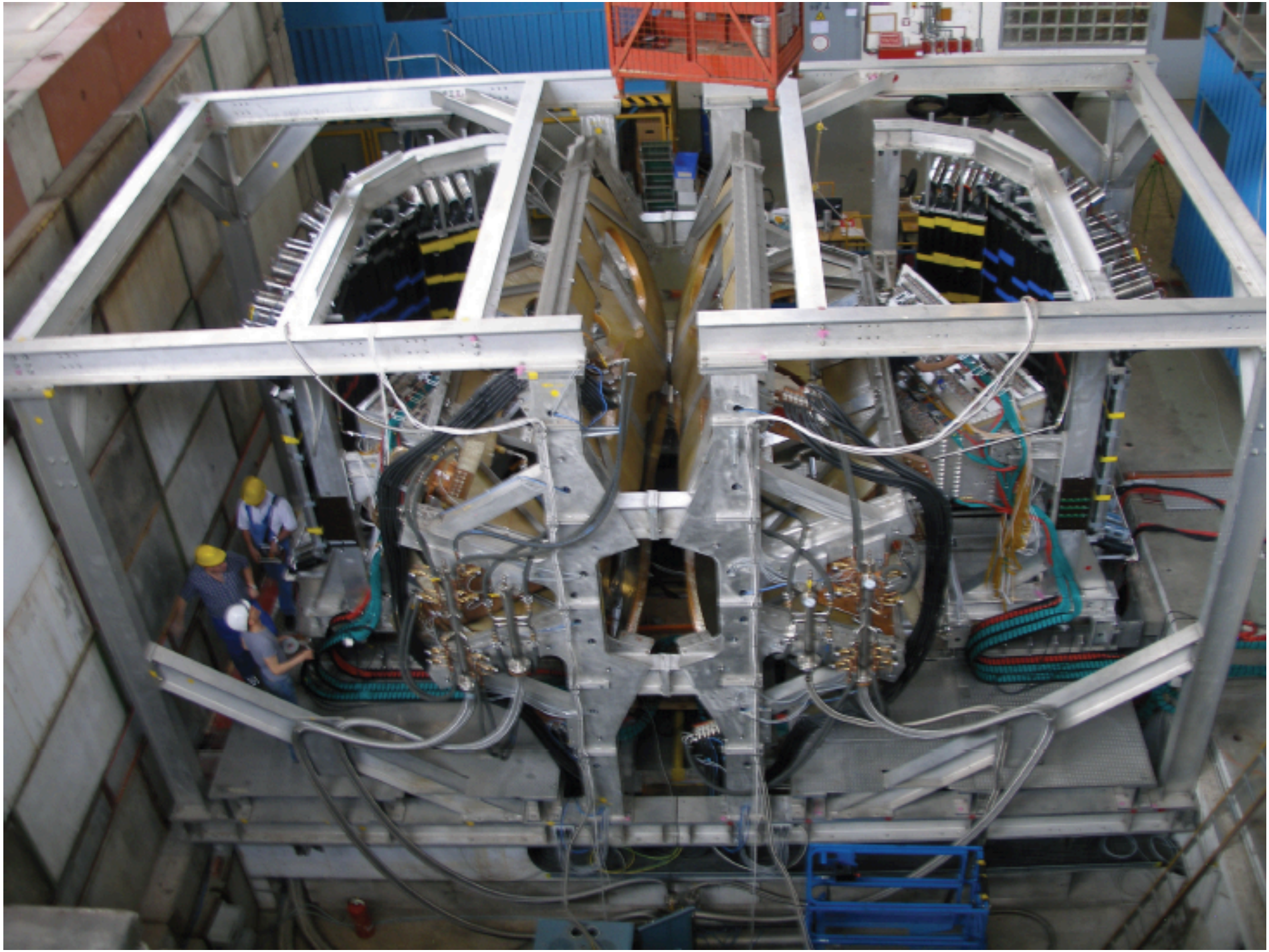
- **E= 2.0 GeV**
- **$0.4 < Q^2/(GeV/c)^2 < 2.2$**
- **Acquire 3.6 fb^{-1} for <1% projected uncertainties**

Data taking completed in 2012
Acquired > 4 fb^{-1}

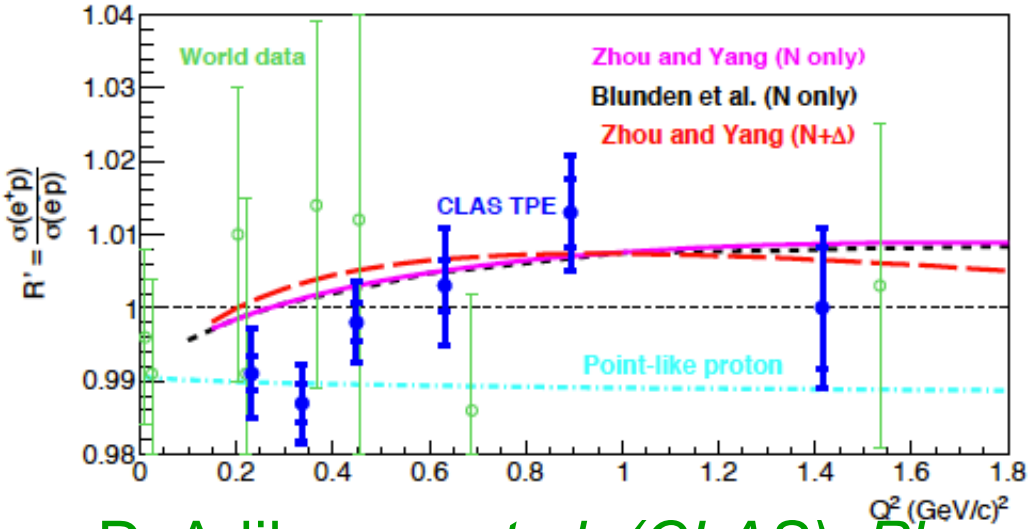
OLYMPUS detector

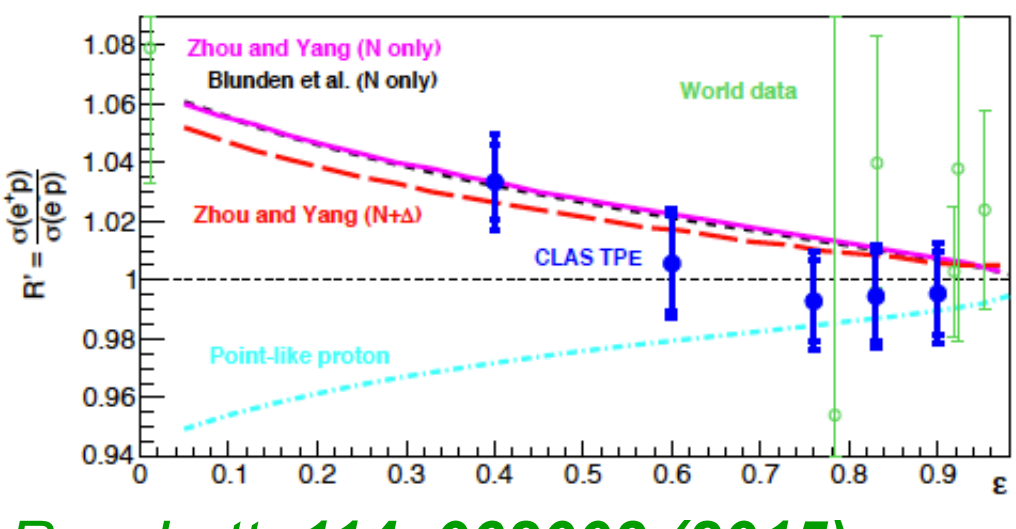


OLYMPUS detector

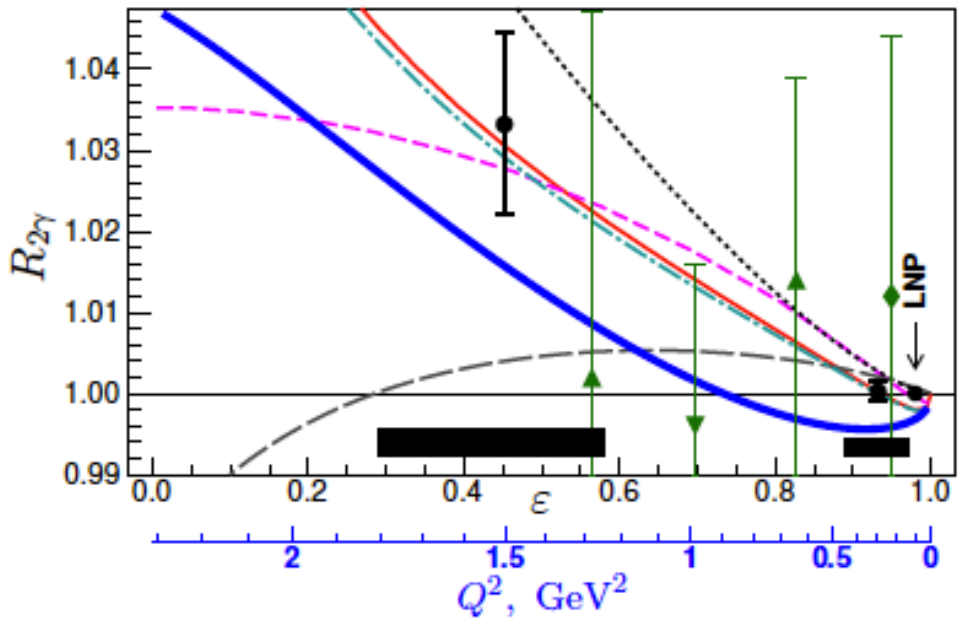


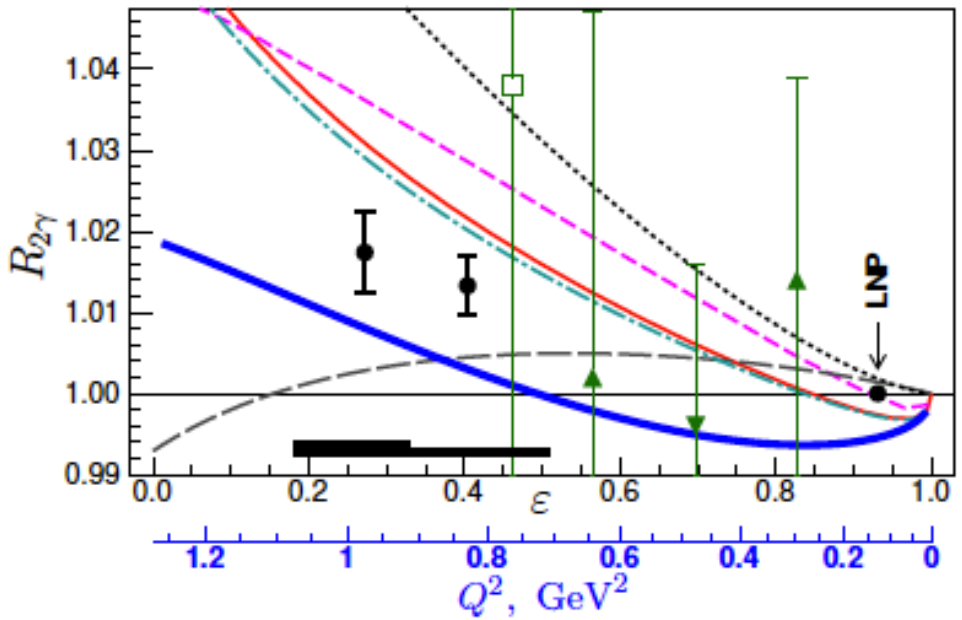
CLAS and VEPP-3





D. Adikaram *et al. (CLAS), Phys. Rev. Lett.* ***114, 062003 (2015)***





I.A. Rachek *et al. (VEPP-3), Phys. Rev. Lett.* ***114, 062005 (2015)***

OLYMPUS activities and status

- Two-photon exchange remains controversal
- Results from TPE experiments at Jlab and Novosibirsk ot definitive

- OLYMPUS data taken in February and October-December 2012
- Calibration measurements (survey and field mapping) in 2013
- Large analysis and simulation effort –
  7 graduate students from MIT (4), ASU (1), HU (1), Mainz (1)
- Full implementation of radiative effects in Montecarlo

- Collaboration meetings in March 2015 at ASU and August 2015 at MIT
- First results to be released at DNP2015 in Santa Fe and at EINN2015 in Cyprus

- Final results in 2016

TREK

- **TREK Program**
  - **E06: Search for Time Reversal Symmetry Violation**
  - **E36: Test of Lepton Universality**
  - **Search for Heavy Neutrinos**
  - **Search for Light Bosons**

  } Lower intensity

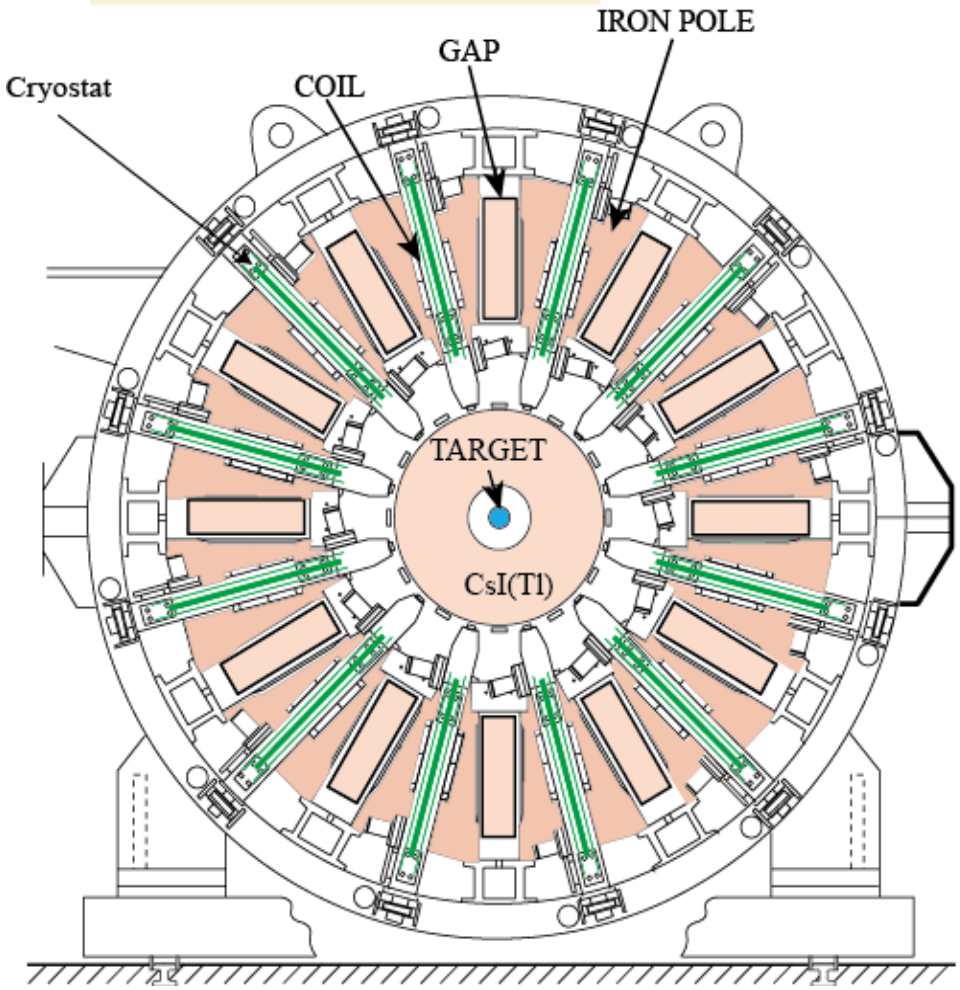
- **TREK Apparatus**
- **Status & Schedule**

Scheduled to run in fall 2015
Commissioned April-June 2015

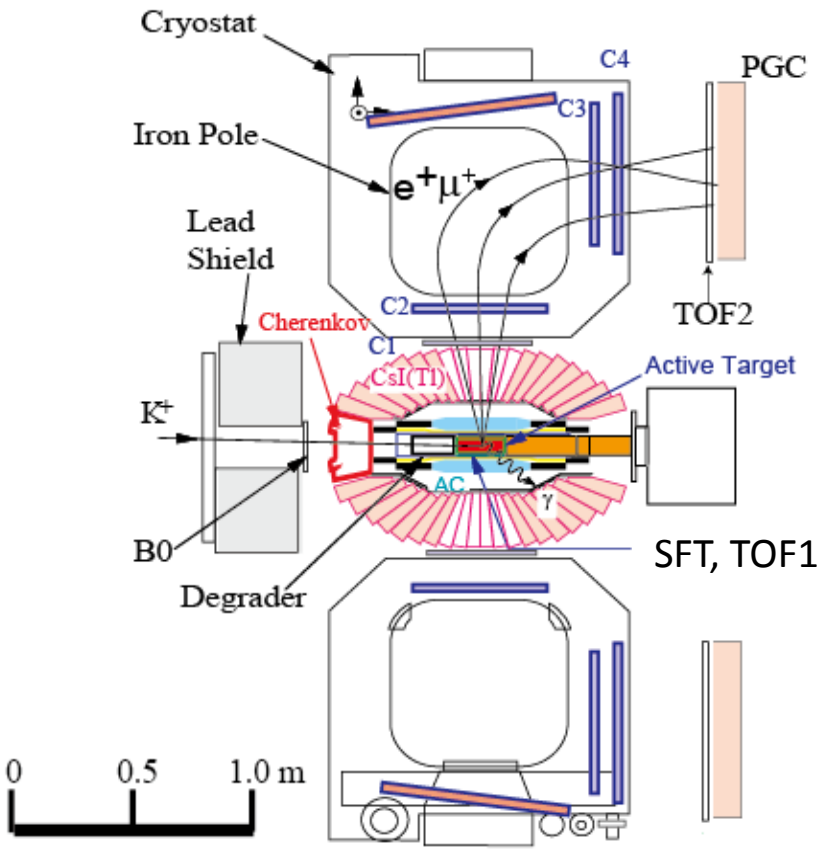
http://trek.kek.jp

The TREK apparatus for E36

End View



Side View



Reasonable upgrade of KEK-PS E246

Stopped K method

- K1.1BR beamline
- Fitch Cherenkov
- K^+ stopping target

Tracking

- MWPC (C2, C3, C4）
- Spiral Fiber Tracker(SFT)

PID

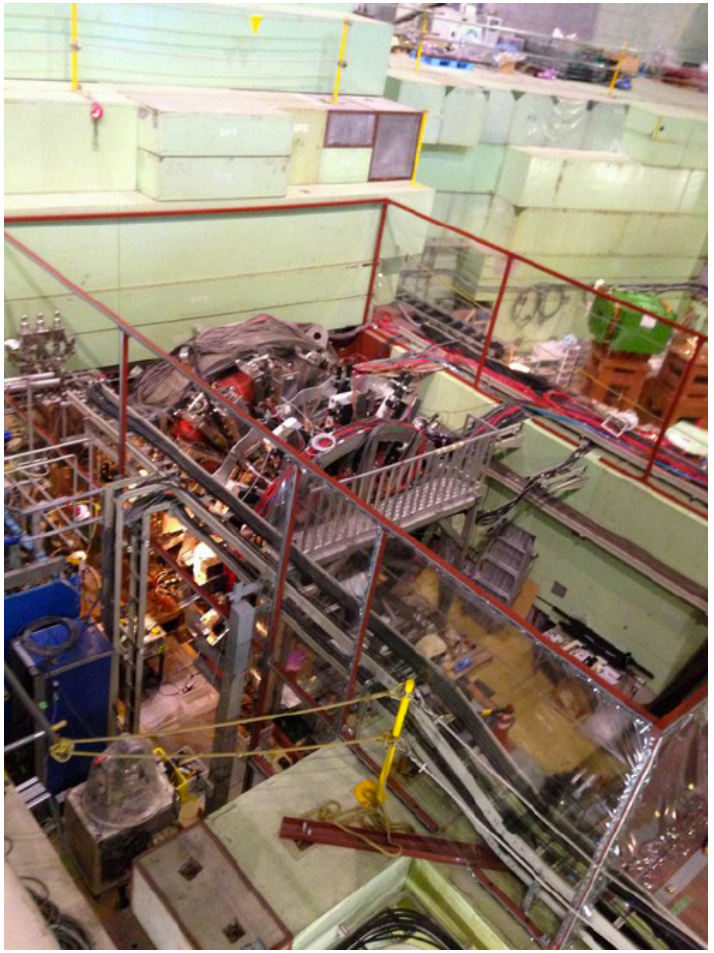
- TOF1,2
- Aerogel Cherenkov (AC)
- Pb glass counter (PGC)

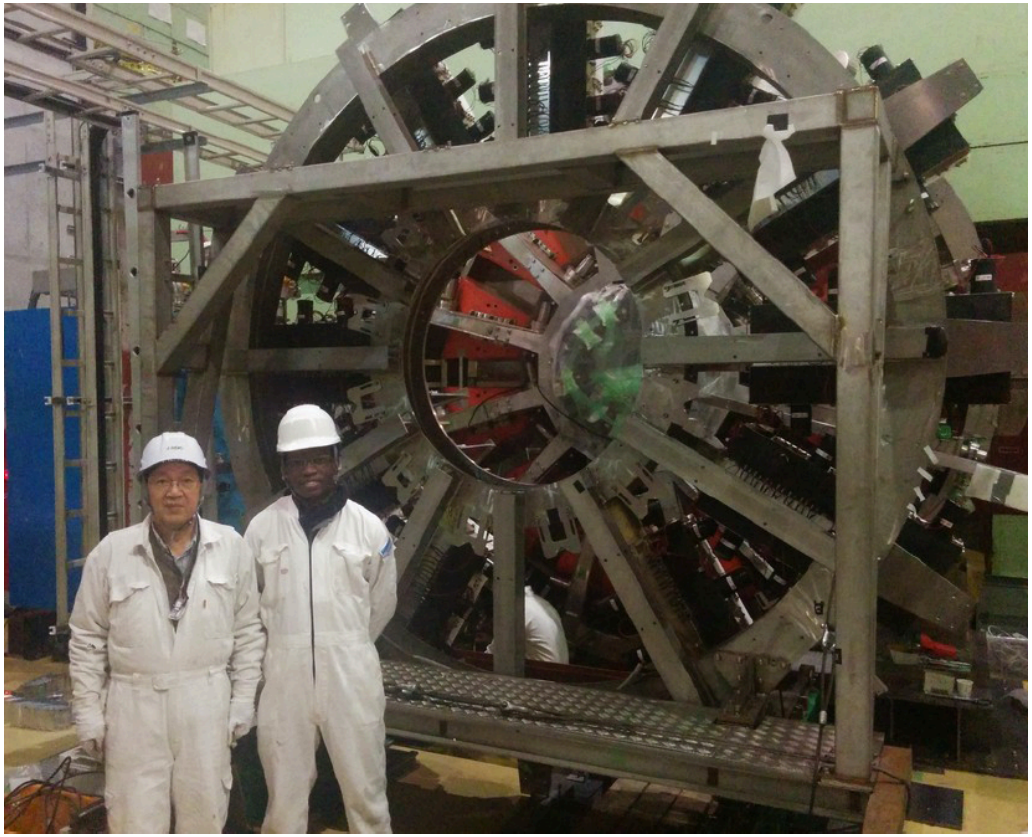
Gamma ray

- CsI(Tl)

TREK/E36 installation

- Completed detector installation in April 2015
- Electronics were set up and tested
- Conditioning of MWPCs



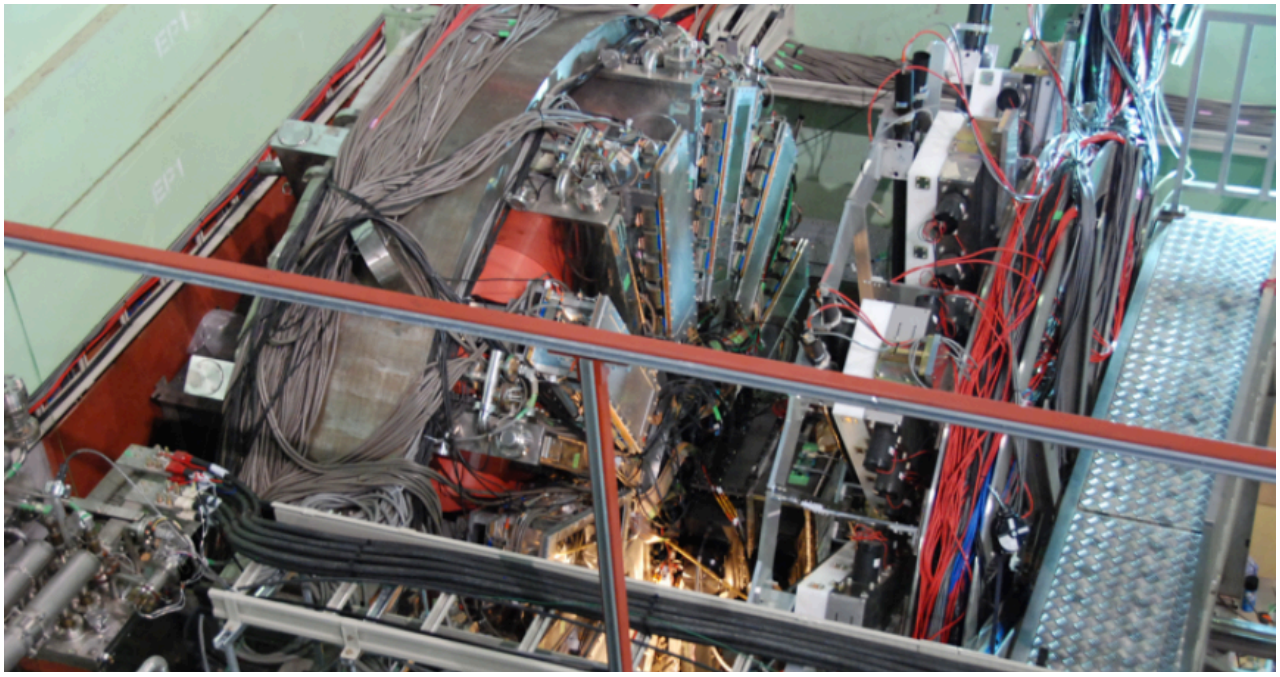


- Commissioning of TGT+TOF1+SFT with cosmic rays
- Check-out of all detectors with beam
- Commissioning of toroidal magnet

Bishoy Dongwi (Hampton Univ.)

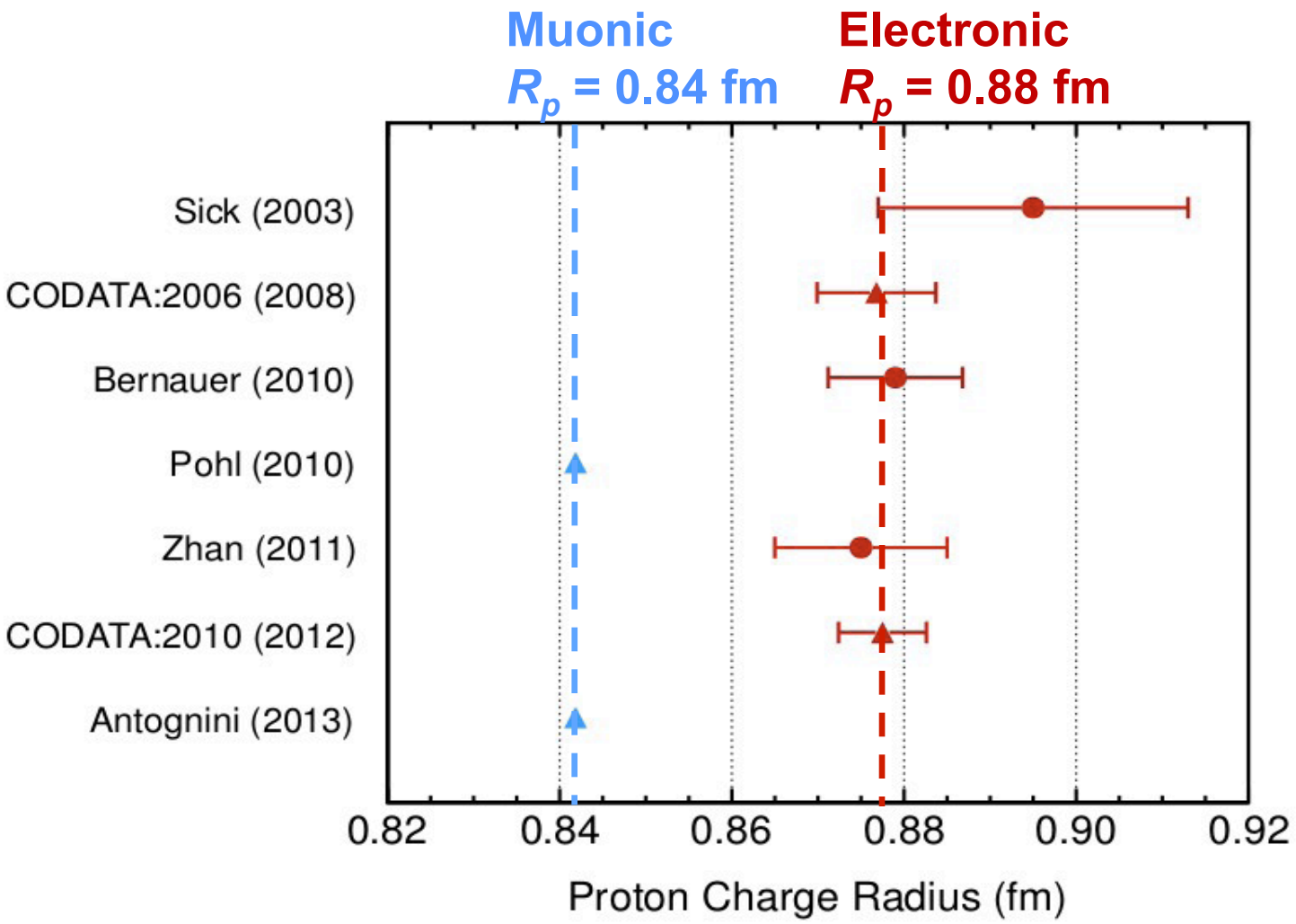
Activities and schedule

- Detector preparation November 2014 – April 2015
- First commissioning run April 8 (24) – May 7, 2015
- Second commissioning run June 3 – 26, 2015
- PAC20 July 15-17, 2015
- Improvements to the system in summer 2015
- **Production run October 14 – November 24, 2015**
- **Review end of October / early November**
- **Possible run extension until December 24**



The proton radius puzzle

- >7σ (4%) discrepancy between **muonic** and **electronic** measurements
- High-profile articles in Nature, NYTimes, etc.
- Puzzle unresolved, possibly New Physics



▲ Spectroscopy

● Scattering

R_P = 0.84184(67) fm

R_P = 0.875(10) fm

R_P = 0.8775(51) fm

R_P = 0.84087(39) fm

MUon Scattering Experiment (MUSE) at PSI

Use the world's most powerful low-energy separated e/π/μ beam for a direct test if μp and ep scattering are different:

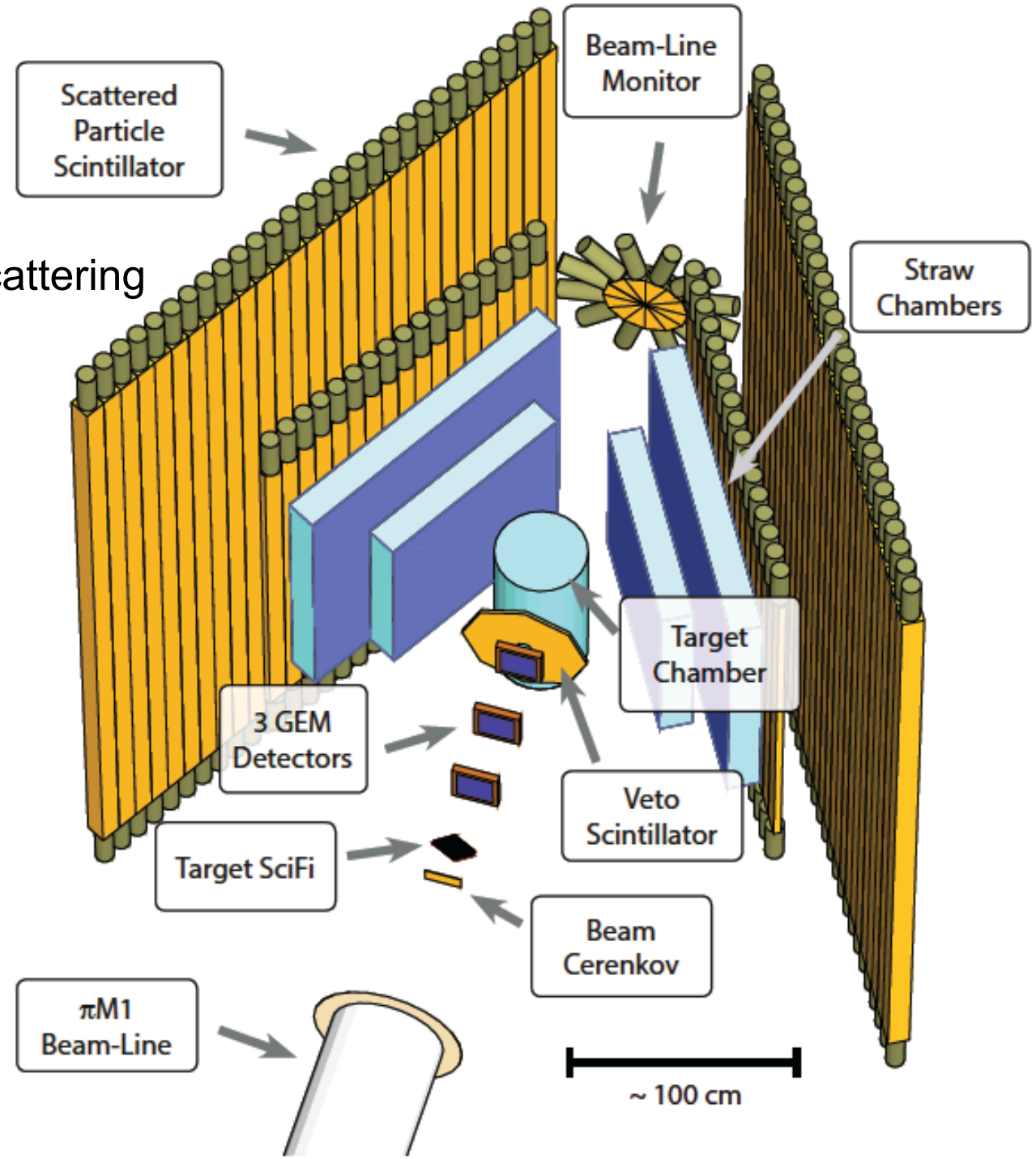
- **Simultaneous, separated beam of (e+/π+/μ+) or (e-/π-/μ-) on liquid H_2 target**
  → Separation by time of flight
  → Measure absolute cross sections for ep and μp
  → Measure e+/μ+, e-/μ- ratios to cancel certain systematics
- **Directly disentangle effects from two-photon exchange (TPE) in e+/e-, μ+/μ-**
- **Multiple beam momenta 115-210 MeV/c to separate G_E and G_M (Rosenbluth)**

MUSE experiment layout

- Beam particle tracking
- Liquid hydrogen target
- Scattered lepton detection

Measure $e^{\pm}p$ and $\mu^{\pm}p$ elastic scattering
p = 115, 153, 210 MeV/c
Θ = 20° to 100°
Q^2 = 0.002 - 0.07 $(GeV/c)^2$
ϵ = 0.256 - 0.94

Challenges
- Secondary beam with π background
- Non-magnetic spectrometer
- Background from Møller scattering and muon decay in flight



MUSE activities and status

- Proton puzzle alive and well in 2015

- R&D program with DOE support
- Improvement of the GEM telescopes:
  modified geometry; speed-up of data acquisition
- Test beamtimes in June and July 2015
- Mini-workshop with PSI PAC subcommittee in July 2015

- Technical design report October 2015
- Collaborative funding proposal at NSF in Nov. 2015 – NSF mid-scale
- Next test beamtime December 2015
- PAC January 2016

- Full funding by mid-2016
- Construct MUSE 2016-2017
- Data taking 2x 6 months in 2018-2019

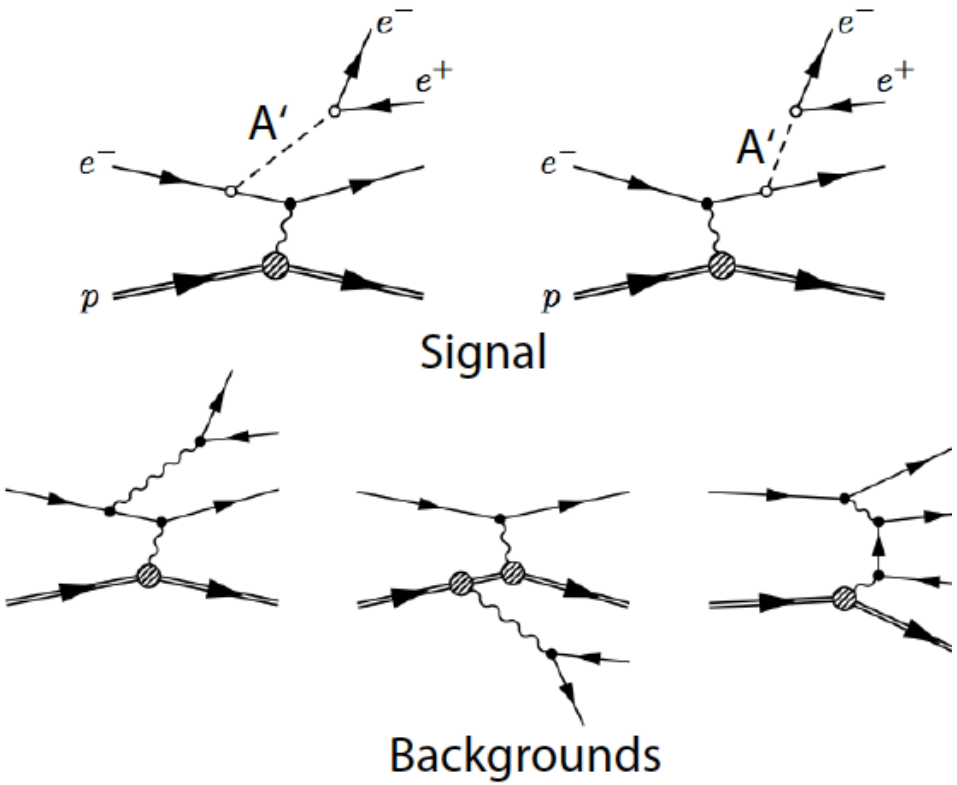
DarkLight

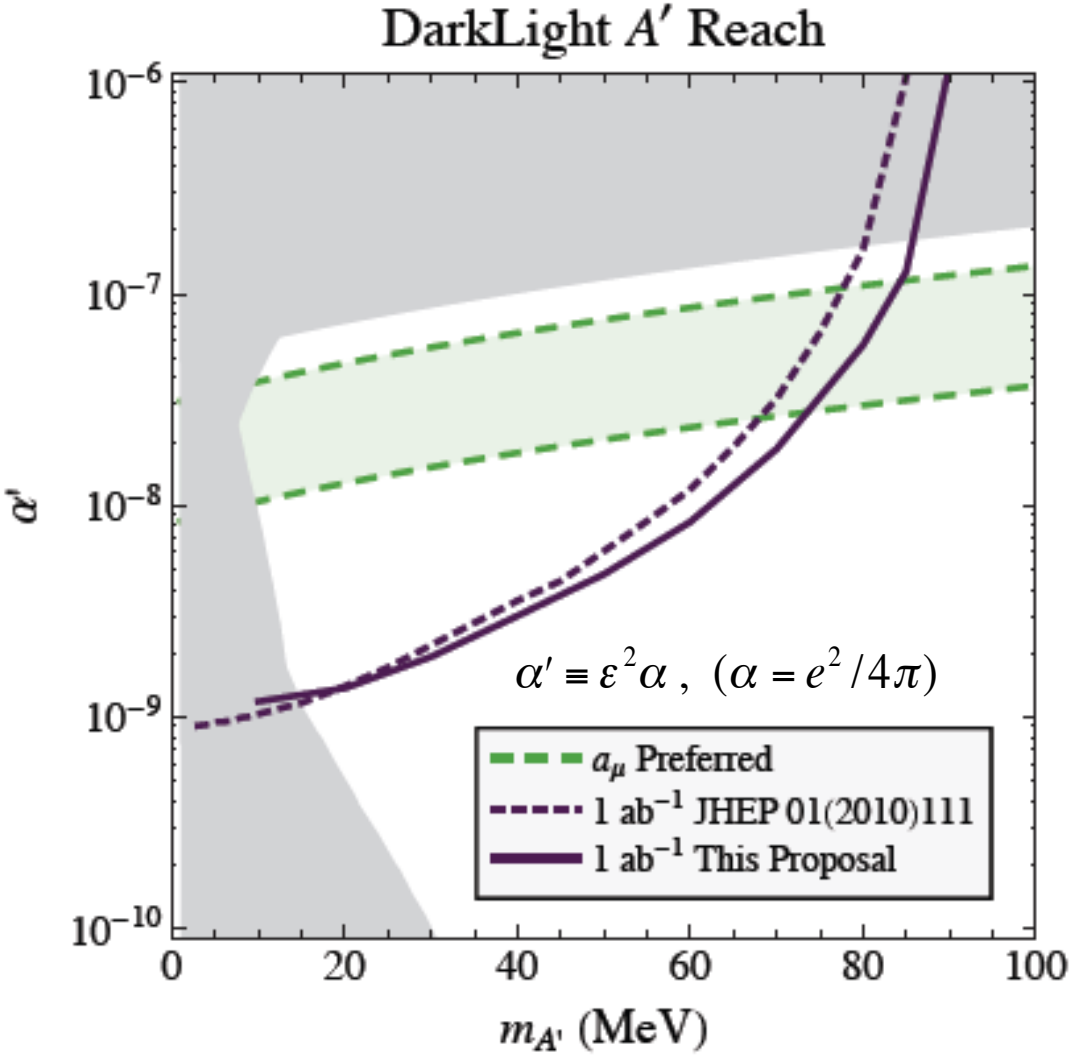
Jefferson Lab

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

DarkLight sensitivity: visible decay

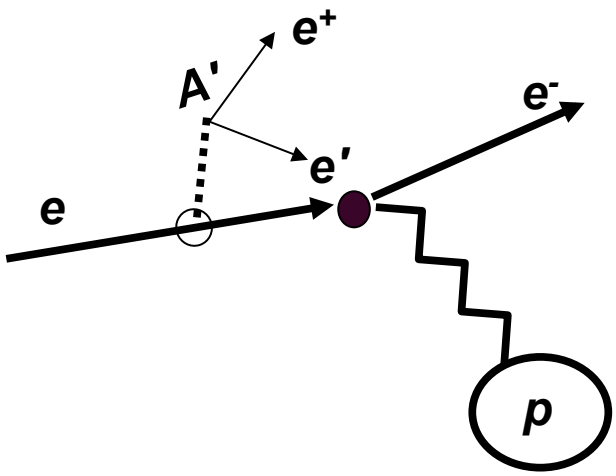
Goal: Explore $e^+ e^-$ invariant mass spectrum from 10-90 MeV using the process $e^- p \rightarrow e^- p\ e^- e^+$

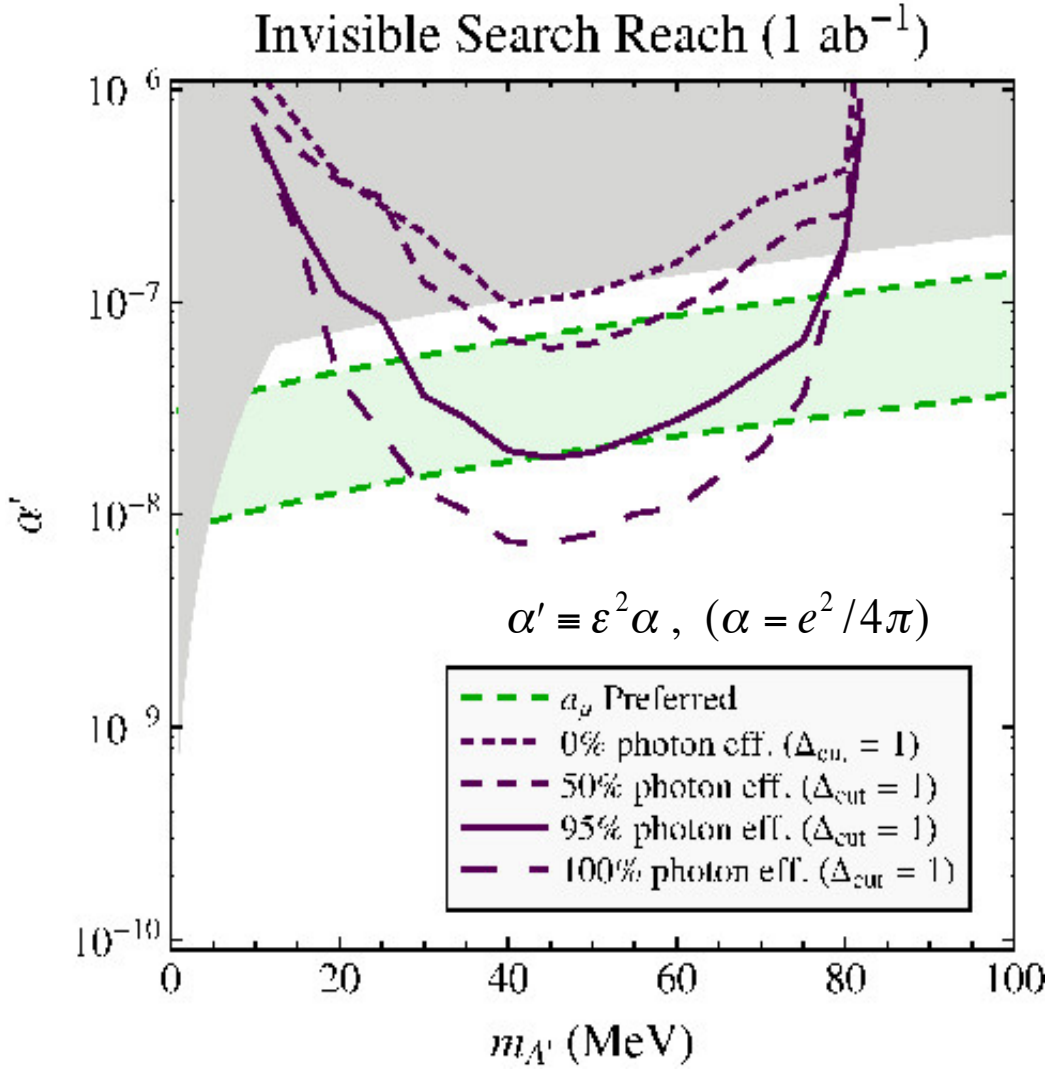




DarkLight sensitivity: invisible decay

- *ep → epA' ("invisible")* observe only final state electron and proton,
- Backgrounds' kinematics different enough that they can be controlled
- Requires photon veto *ep → epγ*





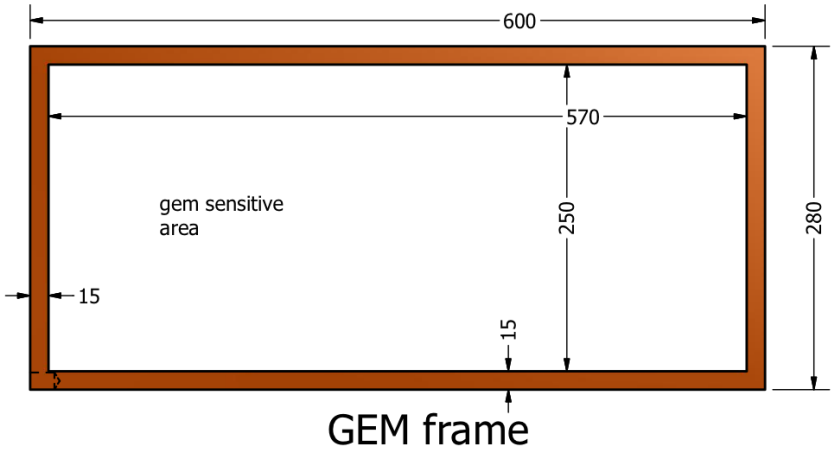
Kahn, Thaler Phys. Rev. D **86** (2012) 11501

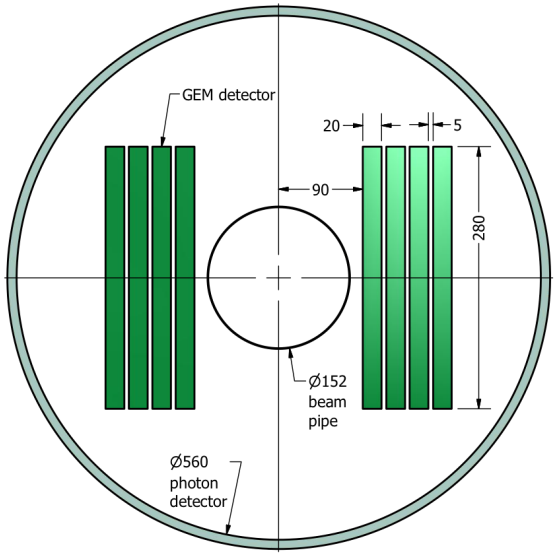
DarkLight dark photon search

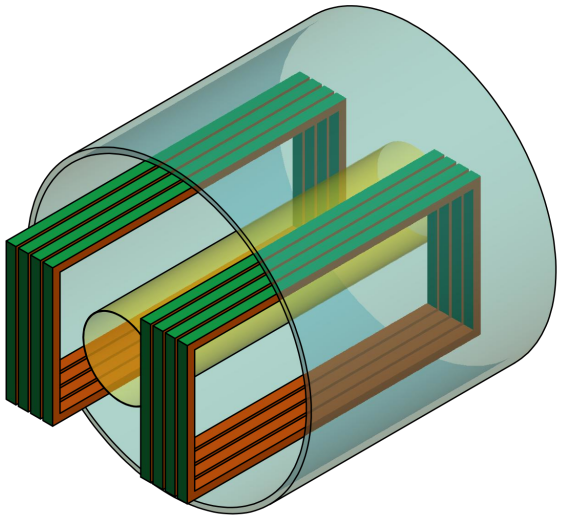
- Dark photons (universal coupling) well motivated by dark matter observations (astronomical, direct, positrons) in combination with g_μ-2 anomaly
- To be run at the Low Energy Recirculator Facility (LERF) at Jefferson Lab
- Search for visible decays modes of $A' \rightarrow e^+e^-$ in $ep \rightarrow epA' \rightarrow epee$
- Search for invisible decays $A' \rightarrow X$ in $ep \rightarrow epX$
- DarkLight sensitive to dark photons with masses < 100 MeV/c^2 in the region of the g_μ-2 welcome band
- DarkLight phase I:
  Funded (NSF-MRI) in 2014, HU responsible for lepton tracker
  Prepare to run phase 1a/b in 2016 and phase 1c in 2017
- DarkLight phase II:
  Ultimate reach, design in progress, 2018+

GEMs for DarkLight Phase-I at JLAB

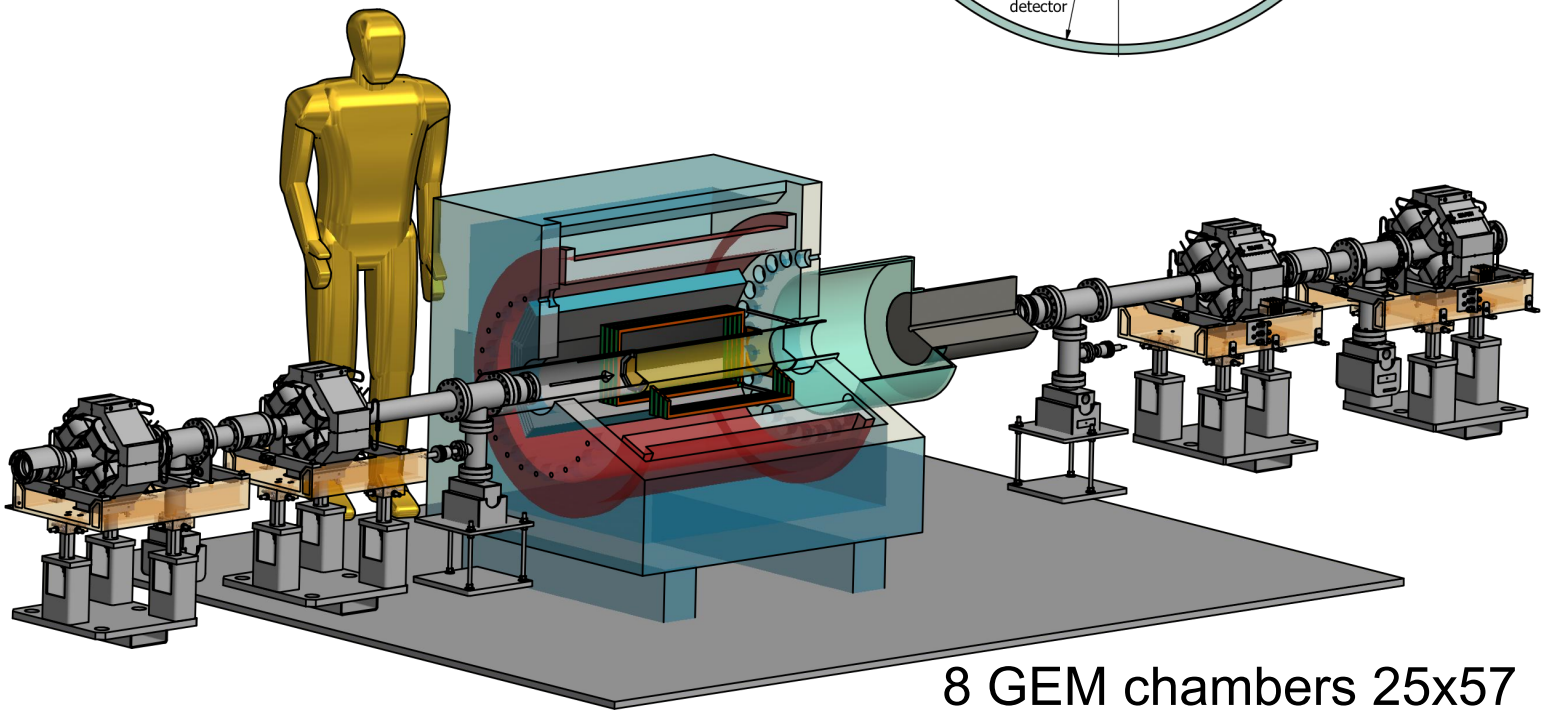
For lepton tracking in ep->epee







J. Balewski



8 GEM chambers 25x57

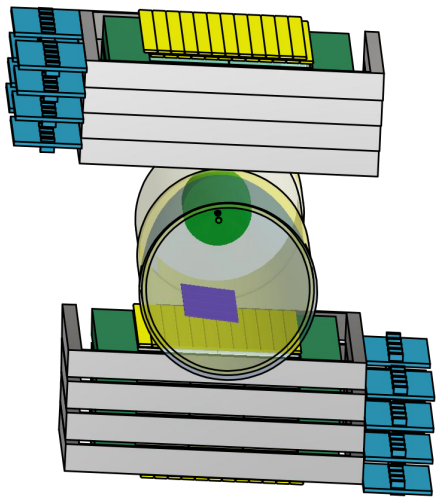
Total no. of channels **20,480**

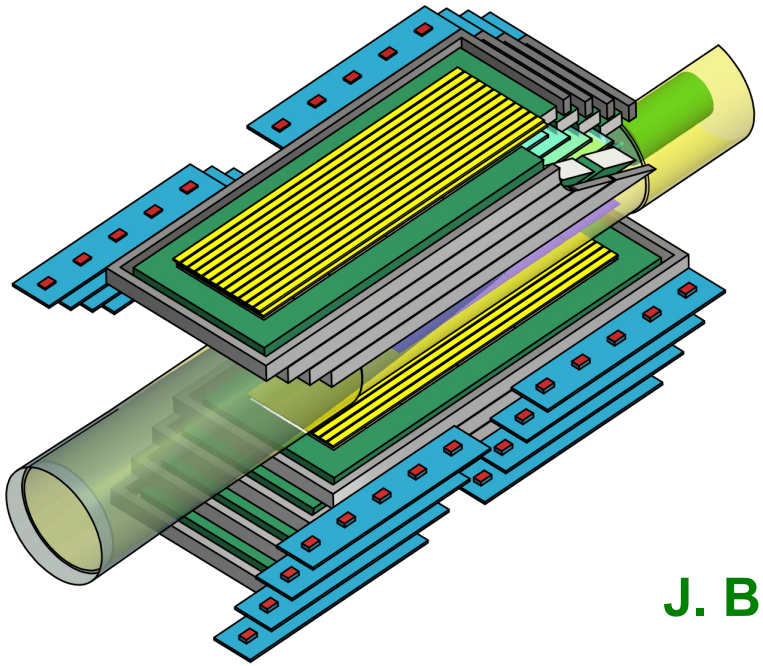
Total cost ($$) **320,000**

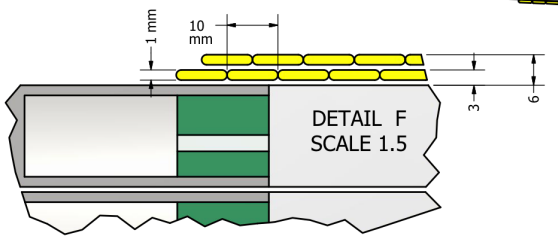
NSF/MRI award 2014 (HU)

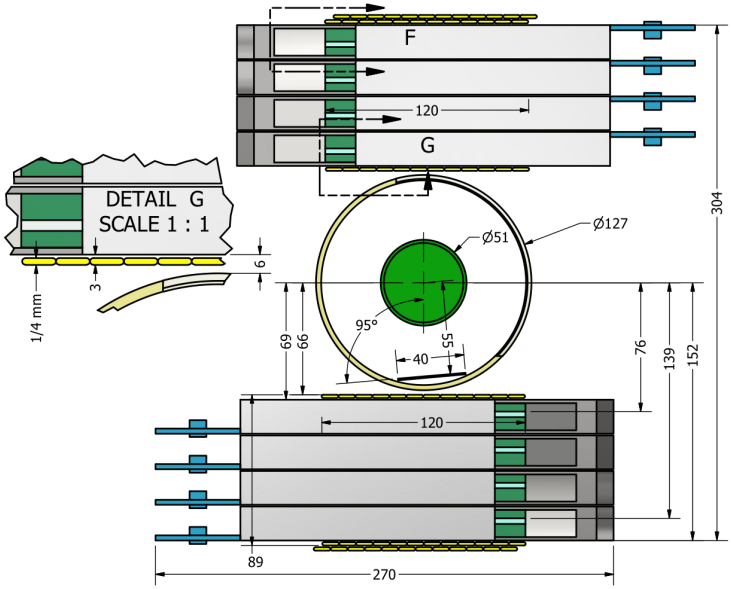
GEMs for DarkLight Phase-Ic at JLAB (MRI)

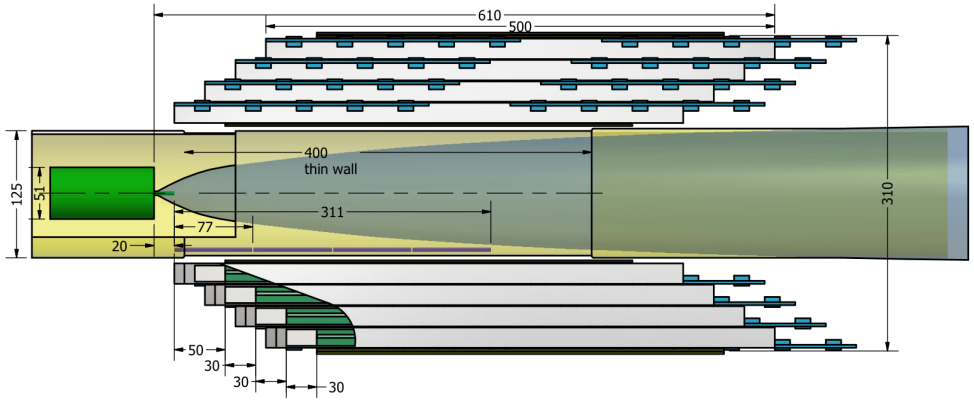
For lepton tracking in ep->epee









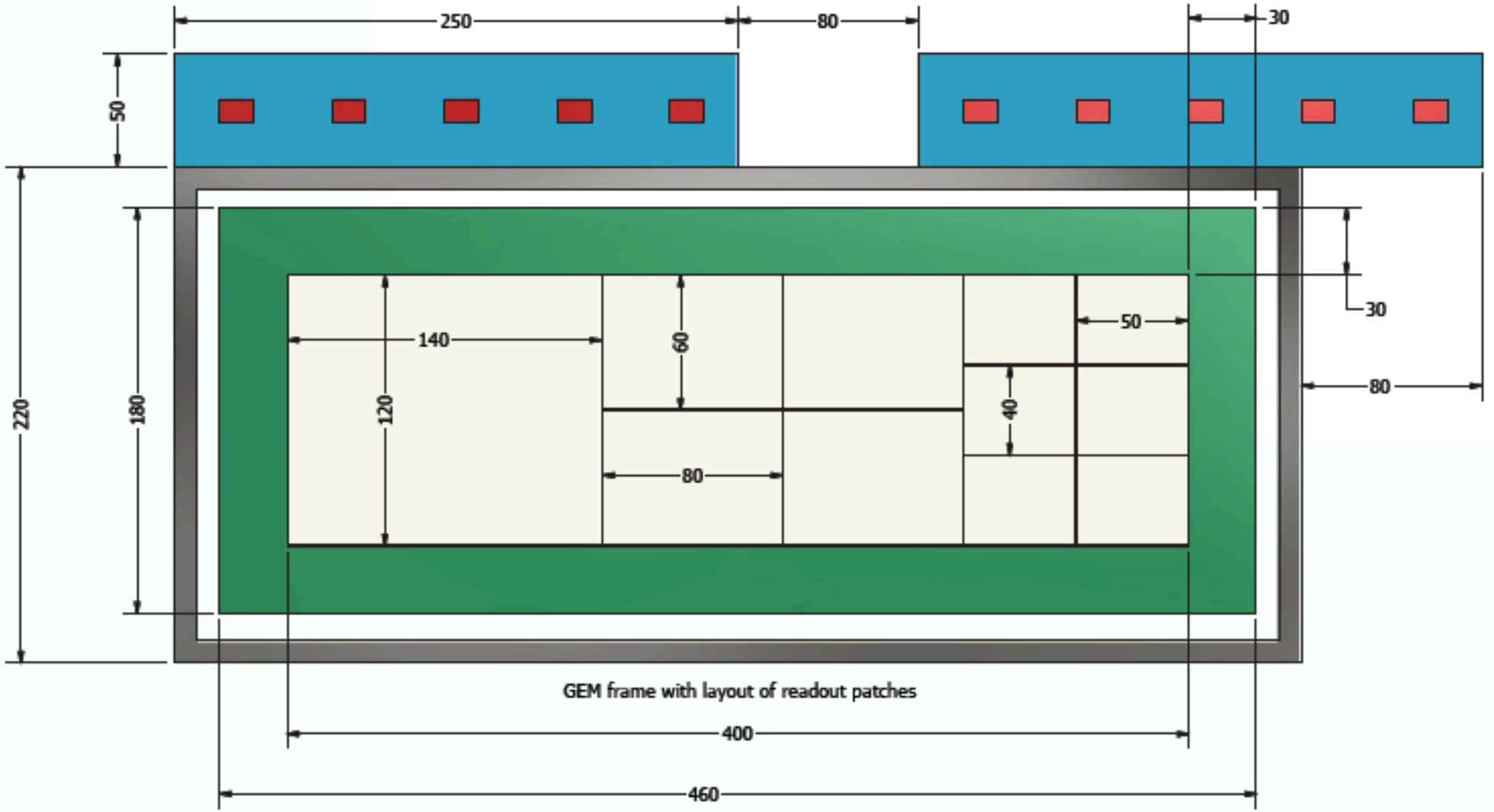


J. Balewski

DRAWN Jan Balewski	4/9/2015		
CHECKED		TITLE	
QA			
MFG			
APPROVED		SIZE C	DWG NO full asmb verC2 2D REV
		SCALE	SHEET 1 OF 1

GEMs for DarkLight Phase-Ic (MRI)

For lepton tracking in ep->epee

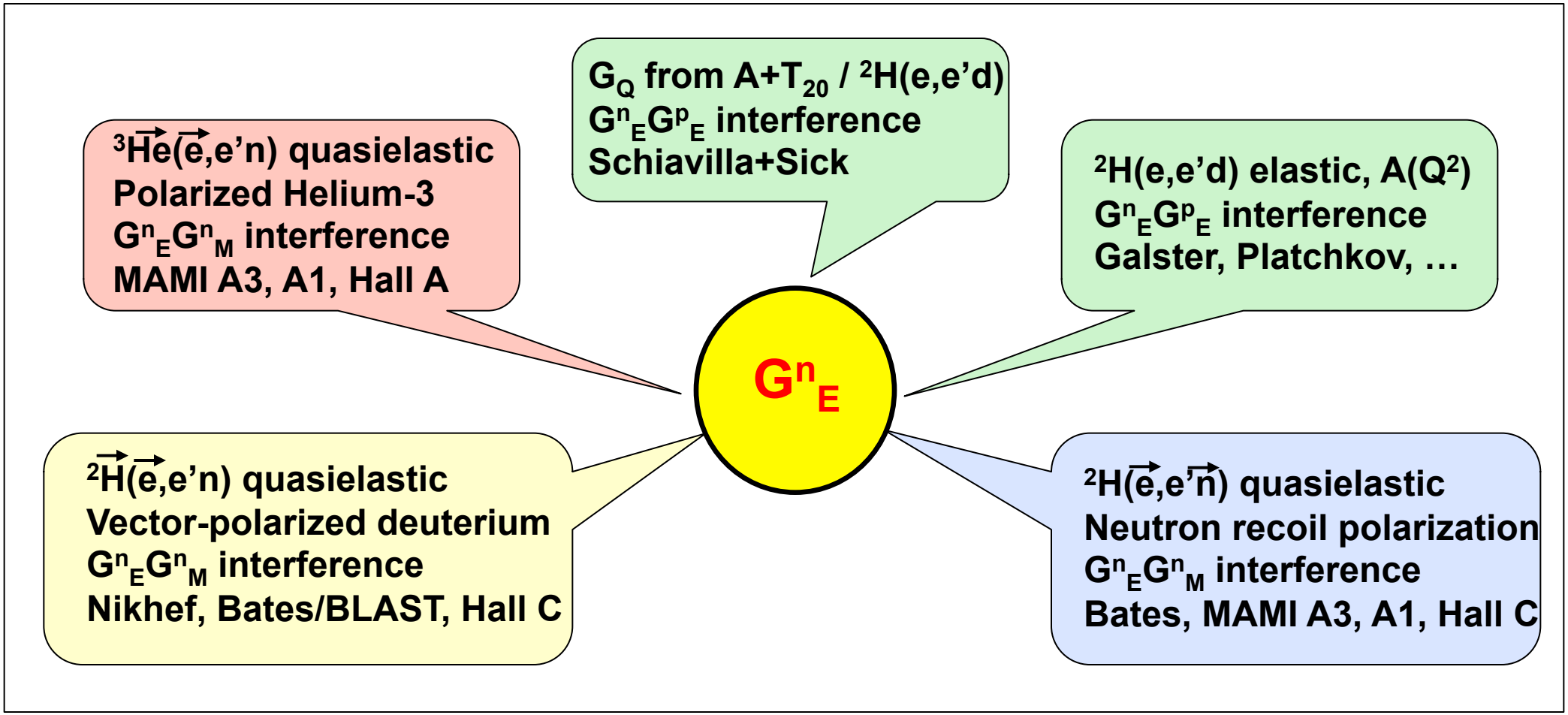


8 GEM chambers 12x40 (as of June 2015)
Readout tiles, size adjusted constant elastic flux
Total no. of channels **10,880**

J. Balewski

G^n_E in absence of a free neutron target

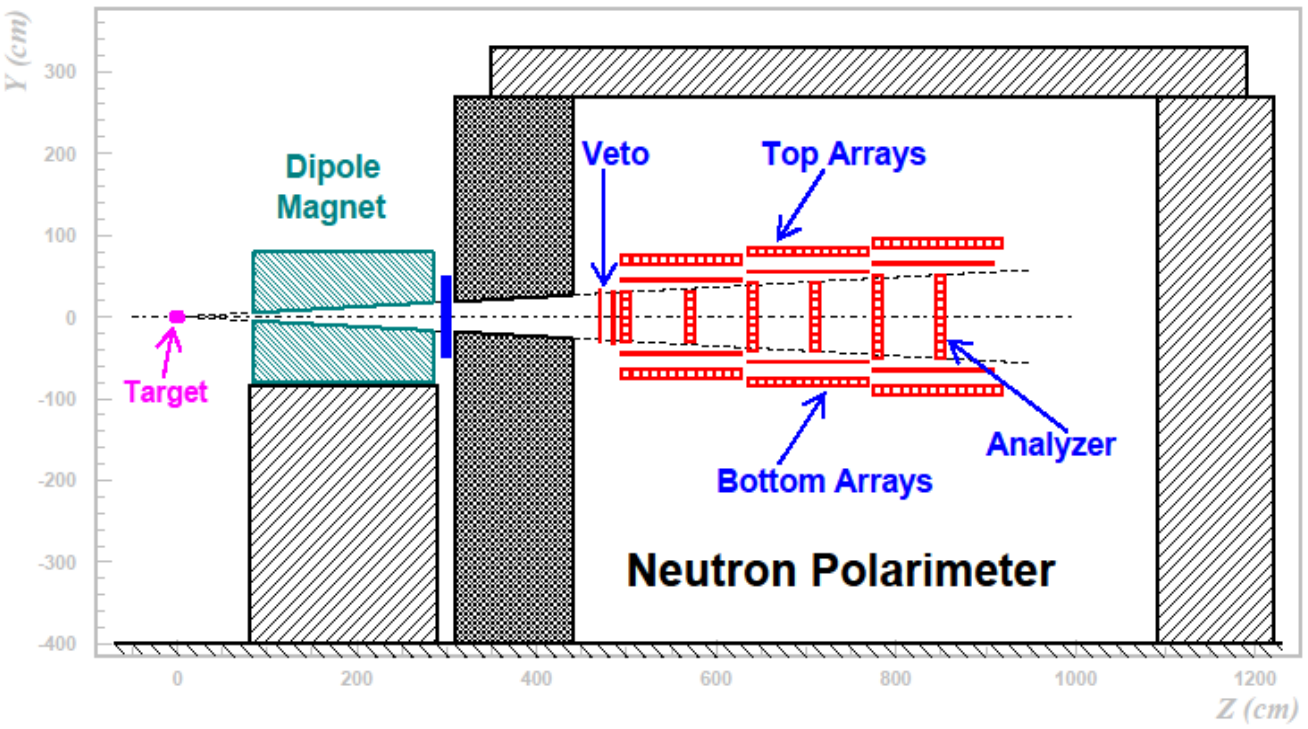
- Form factors are fundamental quantities describing spatial structure
- Knowledge of G_{En} still limited to $Q^2 = 3.4$ (GeV/c)^2
- No free neutron target → elastic and quasi-elastic scattering
- Nuclear corrections (FSI, MEC, …)
- Use interference to amplify smallness of G^n_E

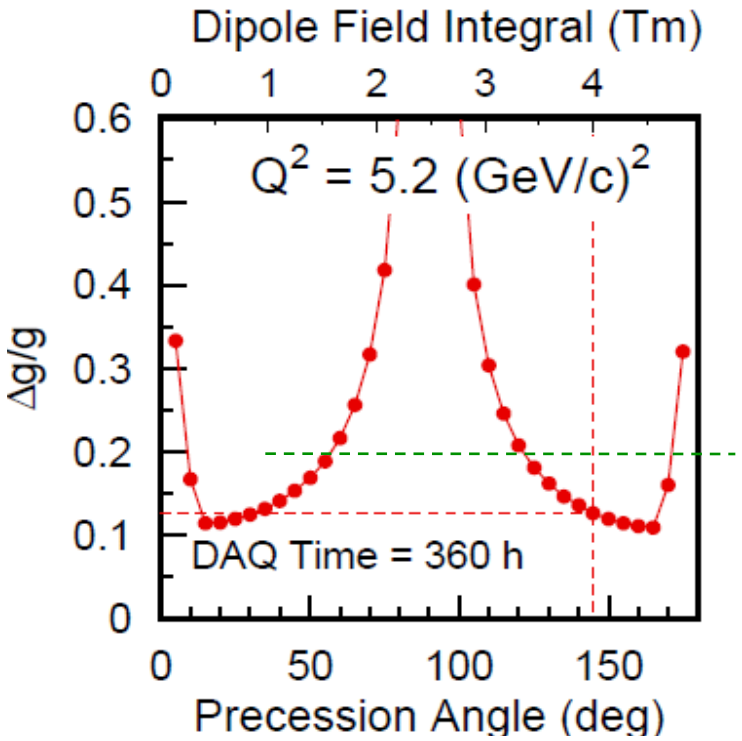


Neutron electric form factor G^n_E

- **Measurements of G_{En} in high Q^2 range provide important insight**
  - **Complete set of form factors in region with small pion cloud contributions**
  - **Extraction of isoscalar and isovector form factors**
  - **Flavor decomposition of up, down quark contributions (neglect strange quarks)** *[Cates (2011) ; Qattan and Arrington et al. (2012)]*
  - **Model-independent extraction of neutron infinite-momentum frame [IMF] transverse charge density** *[Miller (2007) ; Venkat et al. (2010)]*
  - **Important comparisons to QCD-based calculations**
    - **Lattice QCD: isovector form factor (G_{Ep}-G_{En}) cancels disconnected diagrams**
    - **Region of interest for Dyson-Schwinger Equation calculations**
- **Polarized $^3\vec{He}(\vec{e},e'n)$ (E12-09-016) will extend G_{En} to Q^2 = 10 (GeV/c)^2**
  - **Systematics limited**
  - **Significant systematics due to larger proton backgrounds, worse inelastic/ quasielastic separation, beam and target polarization uncertainty**
- **Recoil polarization in $^2H(\vec{e},e'\vec{n})$ (E12-11-009) will provide complementary data with smaller (and very different) systematics up to Q^2 = 7 (GeV/c)^2**
  - **Statistics limited**
  - **Cleaner, better control of systematics**
  - **Nuclear corrections smaller than in ^{3}He**

Precession magnet



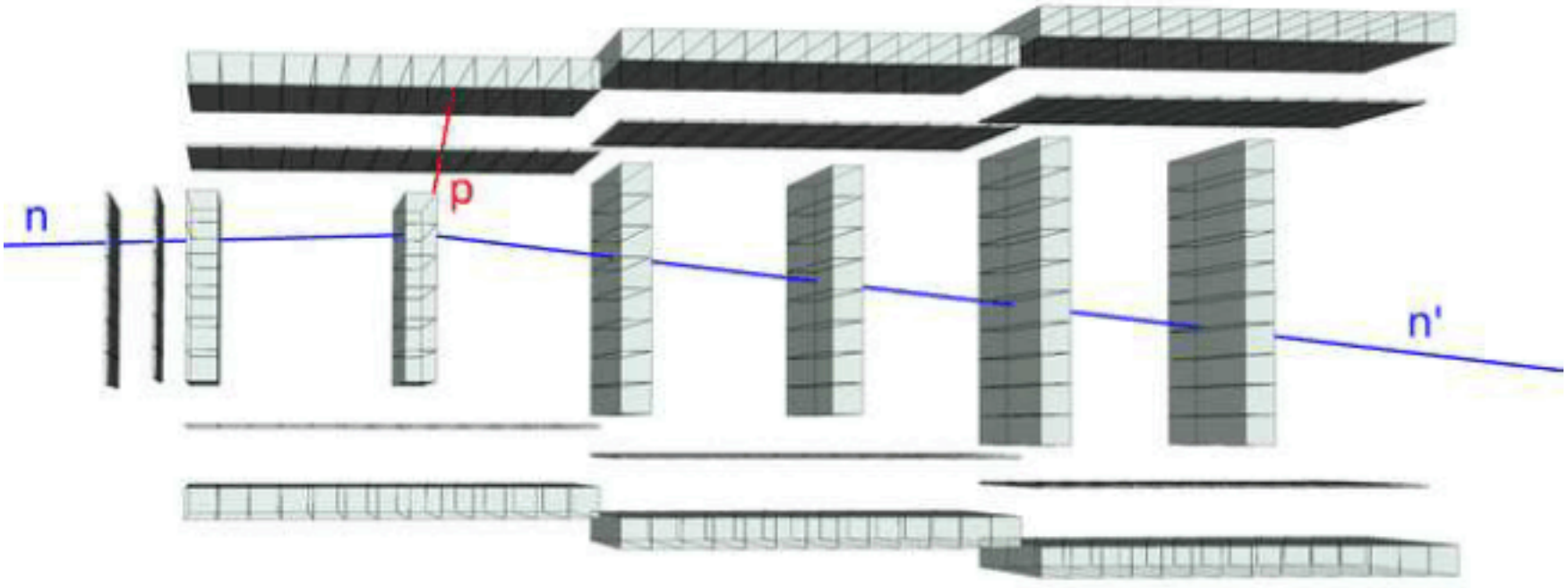


where, $g \equiv G_E/G_M$

- Field serves two functions
  - precess the neutron spin to maximize detected asym (low *or* high field OK, but 'medium' == no good)
  - suppress charged backgrounds from target (*need high-field*)
- Optimal B·dl : 4.3 T·m
  - Double magnet solution with Charybdis + 48D48 for >4.0 T·m

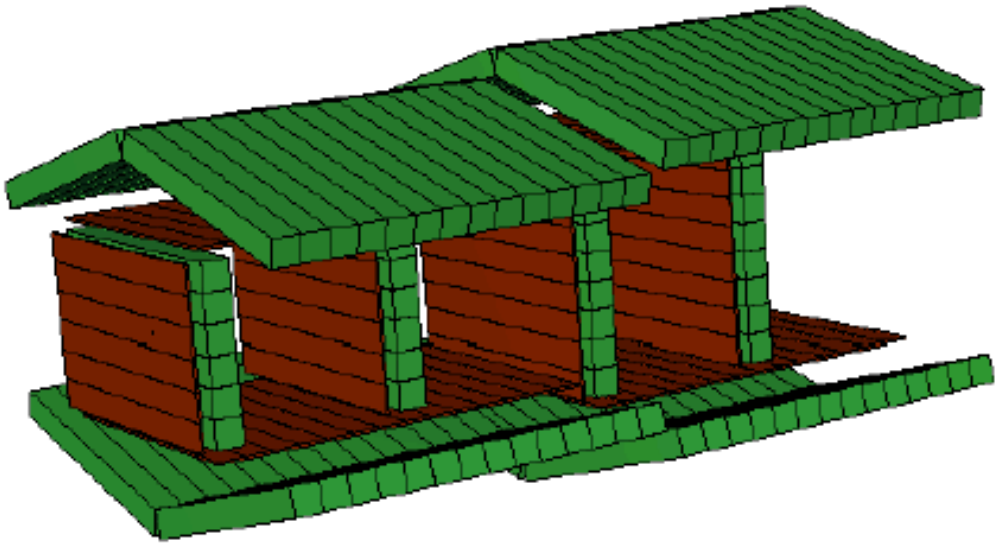
New neutron polarimeter

- Design and further improvements by A. Semenov / Regina
- Scintillator R&D by Will Tireman / Northern Michigan U.
- Planning for MRI proposal (HU, NCA&T, SUNO, NMU)



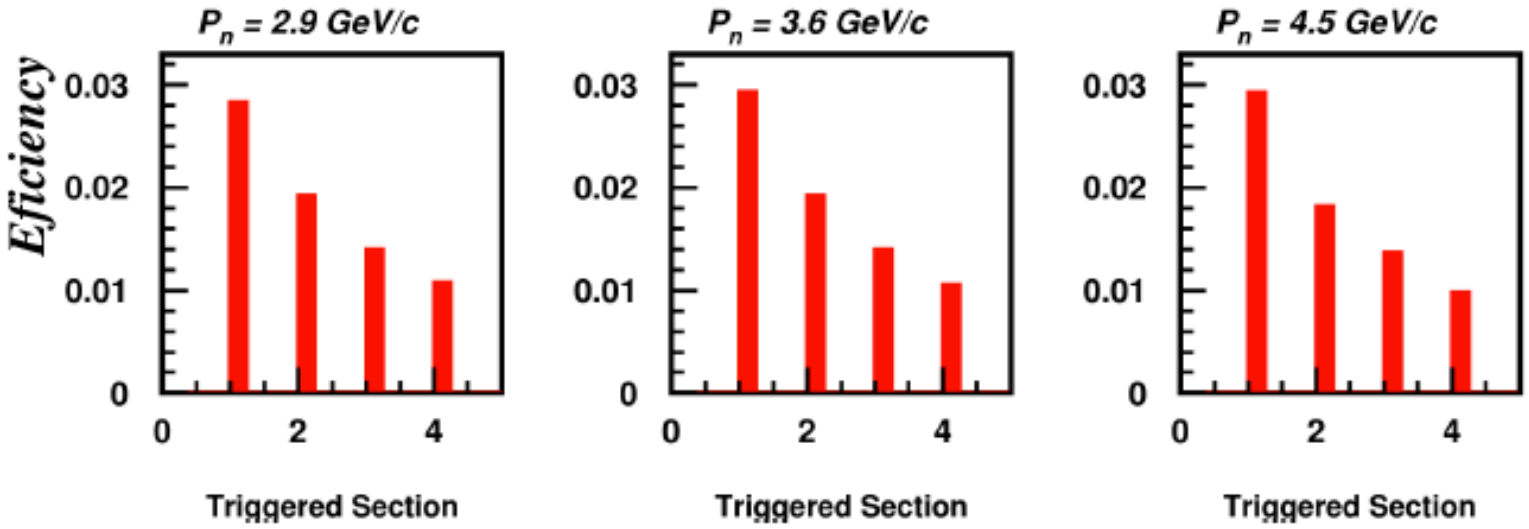
PAC37 version

New neutron polarimeter



Simulation:
Fluka 2011.2.9 + MCEEP-generated flux of neutrons

Visible increase of polarimeter efficiency even with only 4 sections in the polarimeter



A. Semenov

Activities and schedule

- PAC43: SBS proposal in Hall A based on charge exchange reaction
- PAC: only one GEn experiment via deuteron electrodisintegration with neutron recoil polarization

- Workshop in late 2015 or early 2016

- Optimization of existing design with Geant4 simulation
- Forward charged particle tracker for CHX (GEMs?)
- Alternative polarimeter designs?

- Funding and construction 2016-2018
- Running 2019 or 2020