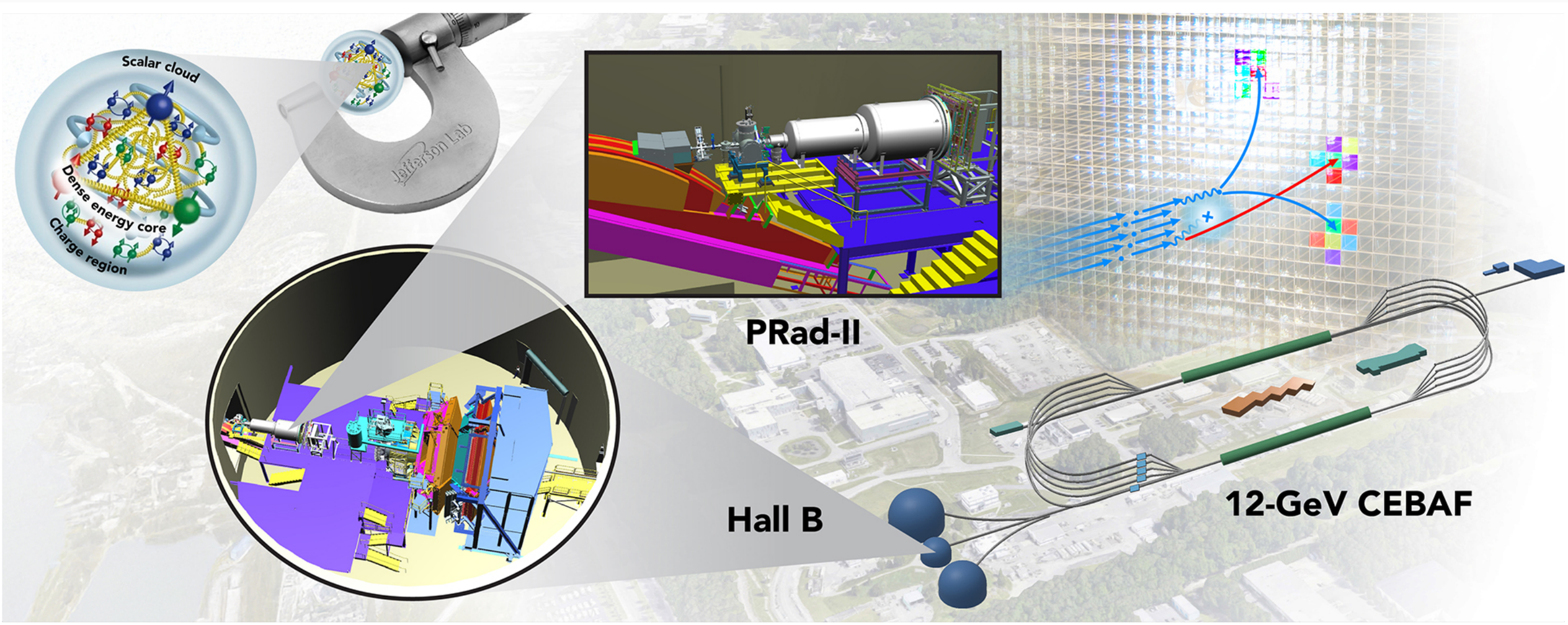
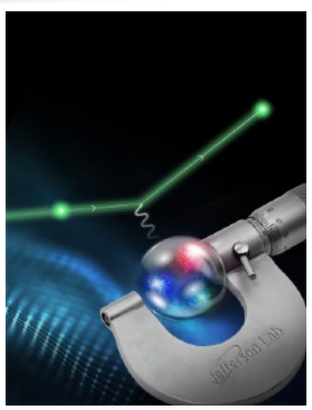
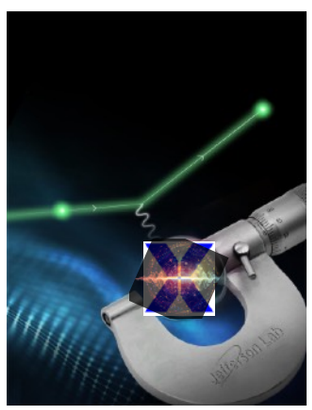
A Magnetic-Spectrometer-Free Forward Angle Physics Program in Hall B

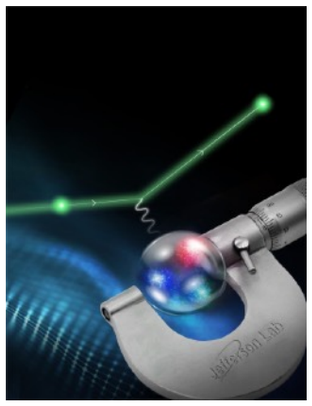






Dipangkar Dutta (Mississippi State)
for the PRad/X17 Collaboration

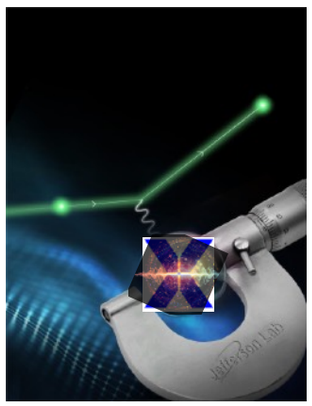
A Magnetic-Spectrometer-Free Forward Angle Physics Program in Hall B



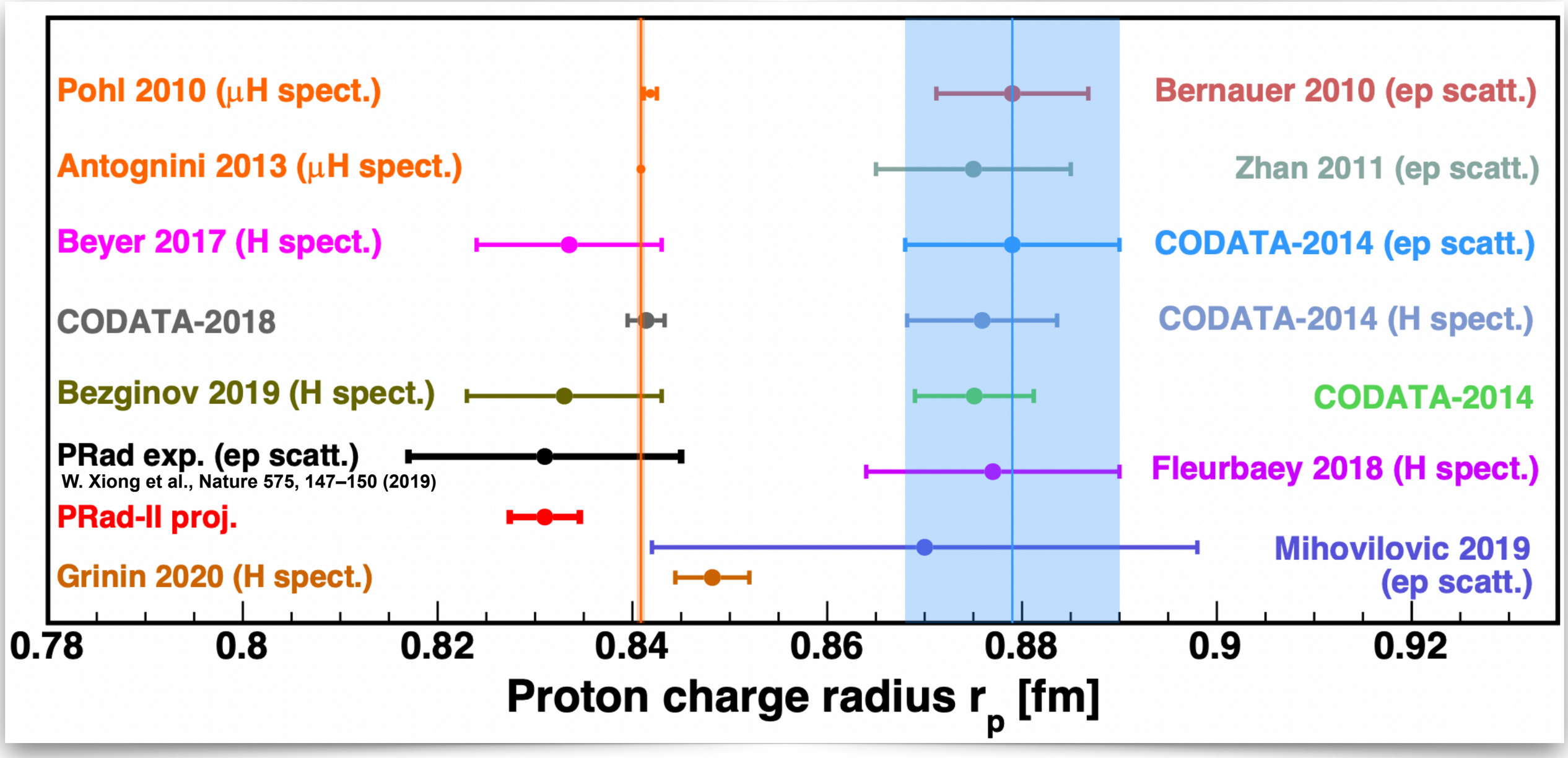
1. Precision charge radii measurement of low-mass nuclei (D, 3He, 4He, …) using the PRad apparatus

2. X17 type search experiments with electron beam

3. High sensitivity search experiments with a positron beam



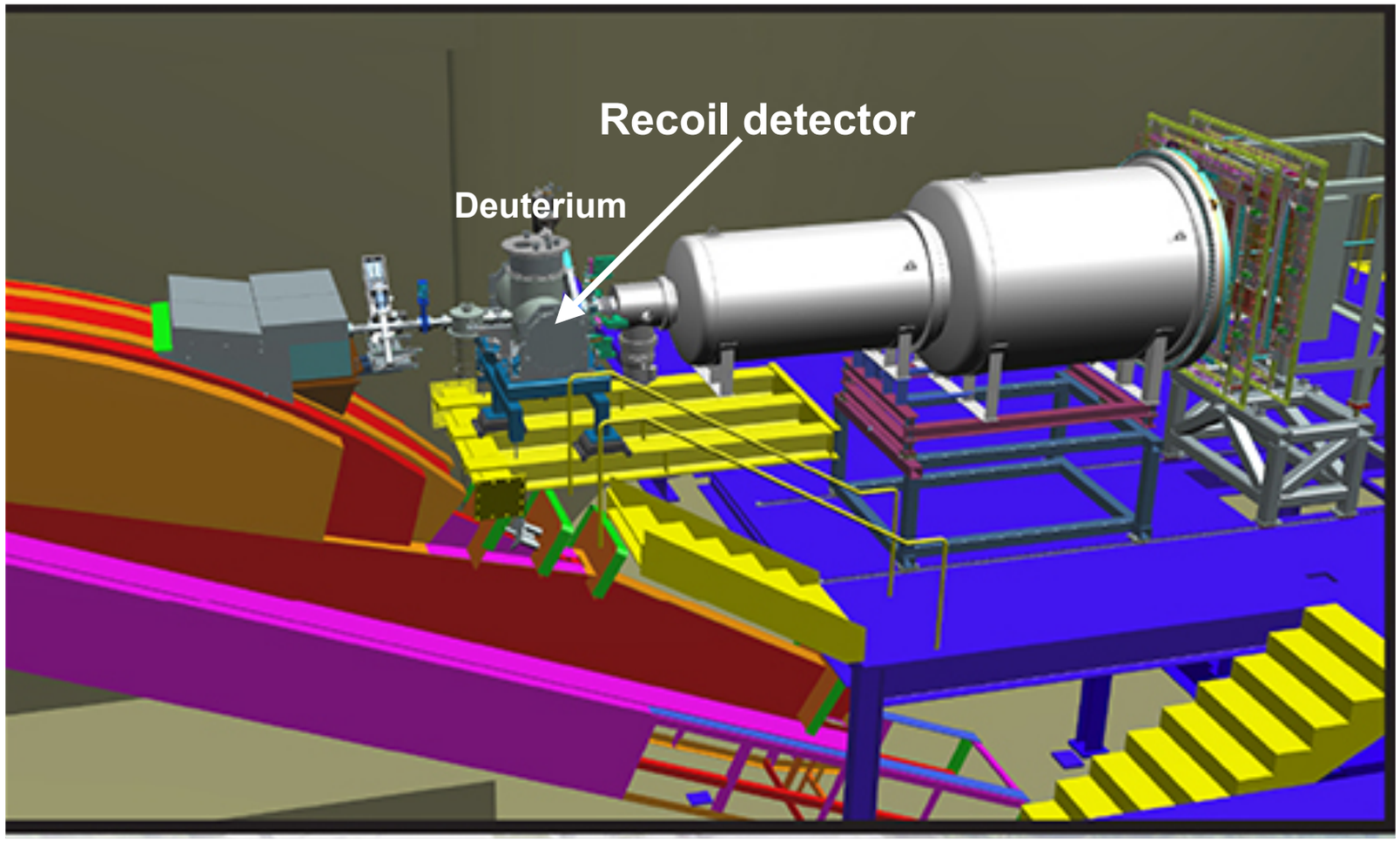
Magnet-Free Technique: Proven by PRad, Confirmed by PRad-II



PRad-II significantly surpassed PRad in many performance parameters

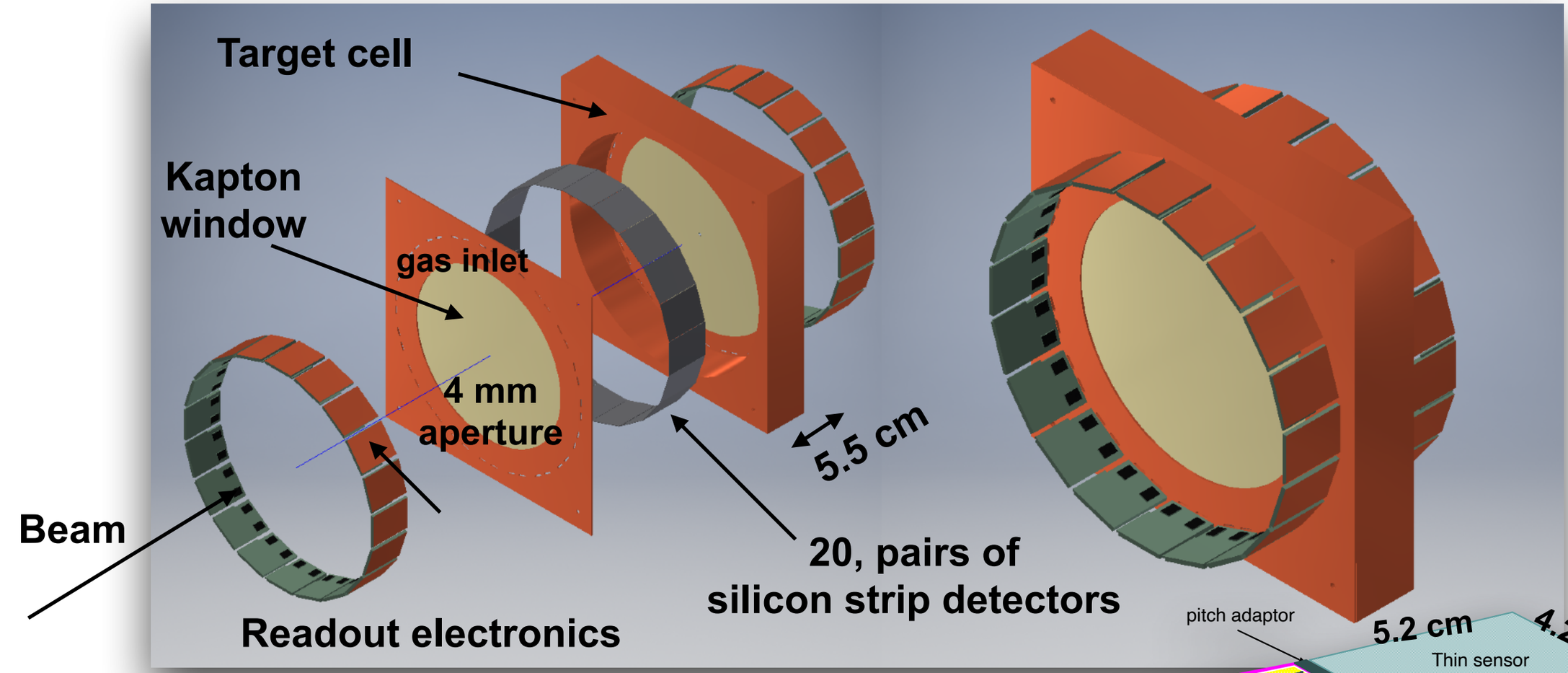
	PRad-II	PRad
Vacuum Chamber	**0.012 mTorr**	0.5 mTorr
H_2 cell /chamber pressure	**1030 / 4.3 mTorr**	470 / 2.7 mTorr
H_2 gas flow	**1300 sccm**	600 sccm
H_2 gas density	**5.5 x 10^{18} H/cm^2**	2 x10^{18} H/cm^2
Beam current	**up to 700 nA**	50 nA
Luminosity	**2.6 x 10^{31} /cm^2**	6 x 10^{29} /cm^2
Beam background	**~ 2% of *ep* events**	~10 - 30% of *ep* events
DAQ rates	**20-25 kHz**	4-5 kHz
GEMs	**2-planes with tracking**	1-plane, no tracking
Veto counter (Q^2 range)	**~ 10^{-5} GeV^2**	~ 10^{-4} GeV^2
HyCal	only $PbWO_4$ **+ FADC readout**	$PbWO_4$ + Pb-glass

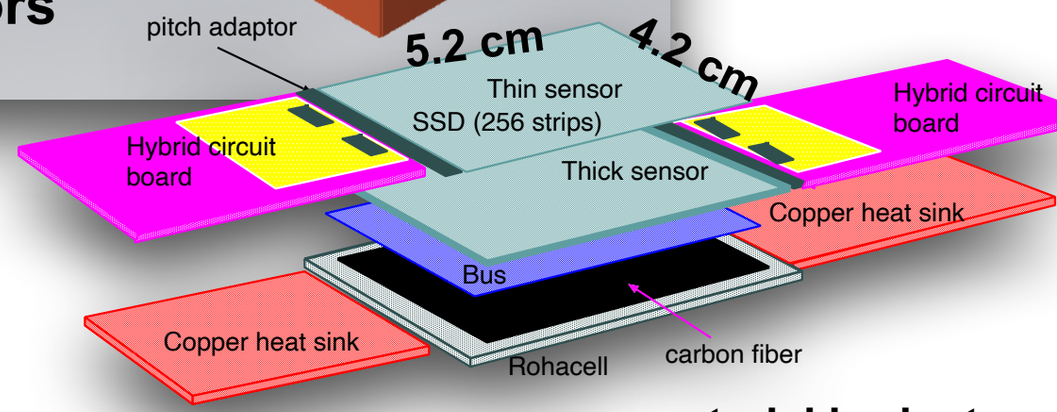
DRad: a natural extension of the magnetic-spectrometer-free technique



- High resolution $PbWO_4$ calorimeter (magnetic spectrometer free)
- Windowless, high density gas flow target (reduced backgrounds)
- Simultaneous detection of elastic and Møller electrons (control of systematics)
- Vacuum chamber with one thin window, & two GEM chambers (better resolution)
- Q^2 range of $2x10^{-4} – 5x10^{-2}$ GeV^2 (lower than all previous electron scattering expts.)
- Add a cylindrical recoil detector for ensuring elasticity of reaction.
- Precise extraction of the charge form factor and charge radius r_D

The elasticity of e-D scattering will be ensured with a cylindrical Si-strip-based recoil deuteron detector.





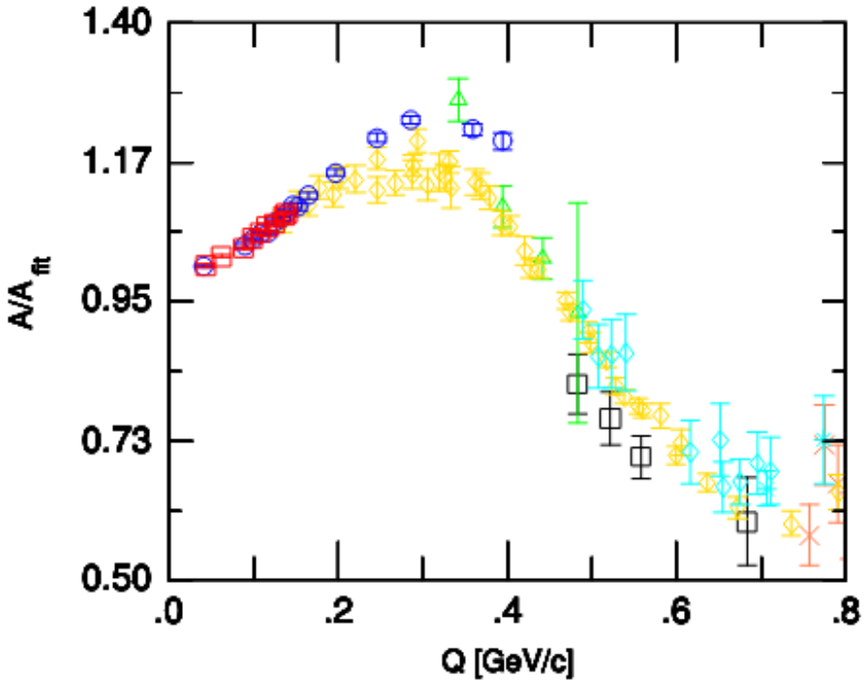
Based on CLAS12 Barrel Si tracker (SVT)

- consists of 20 panels of twin, single-sided Si-strip detectors (size; 42x52 mm^2);
- thickness: inner, ≈ 200 μm, outer ≈ 300 μm (to be optimized);
- 20 segment arrangement with R=13 cm radius (to be optimized);
- 256 strips on each segment, angular resolution: δφ ≤ 5 mrad, δθ ≤ 20 mrad
- Passivation layer ~ 0.1 μm (can be as low as 0.01 μm).

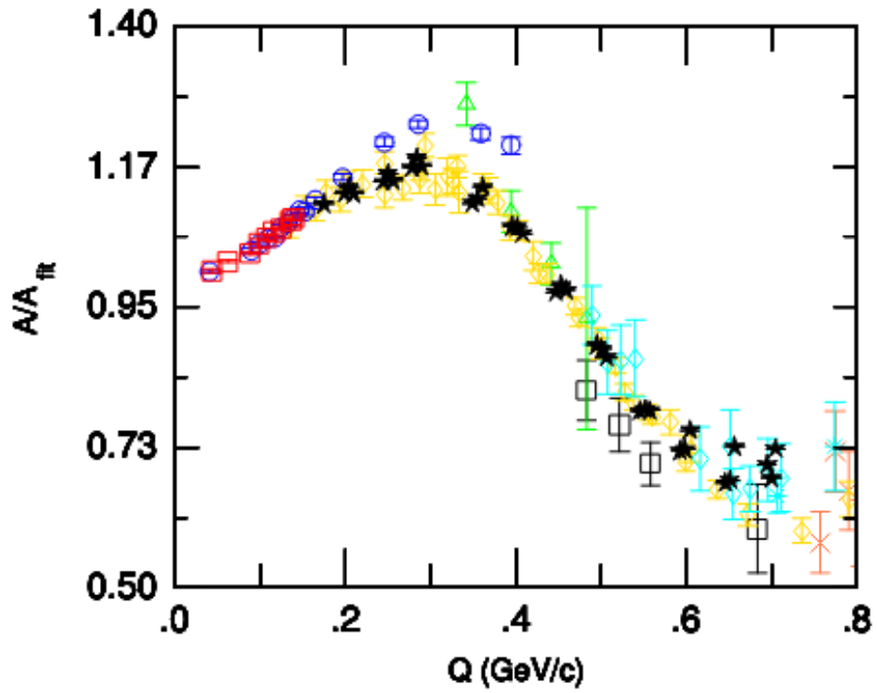
material budget < 1% r.l.

There is a urgent need for high precision *e-D* scattering cross section and charge form factor data

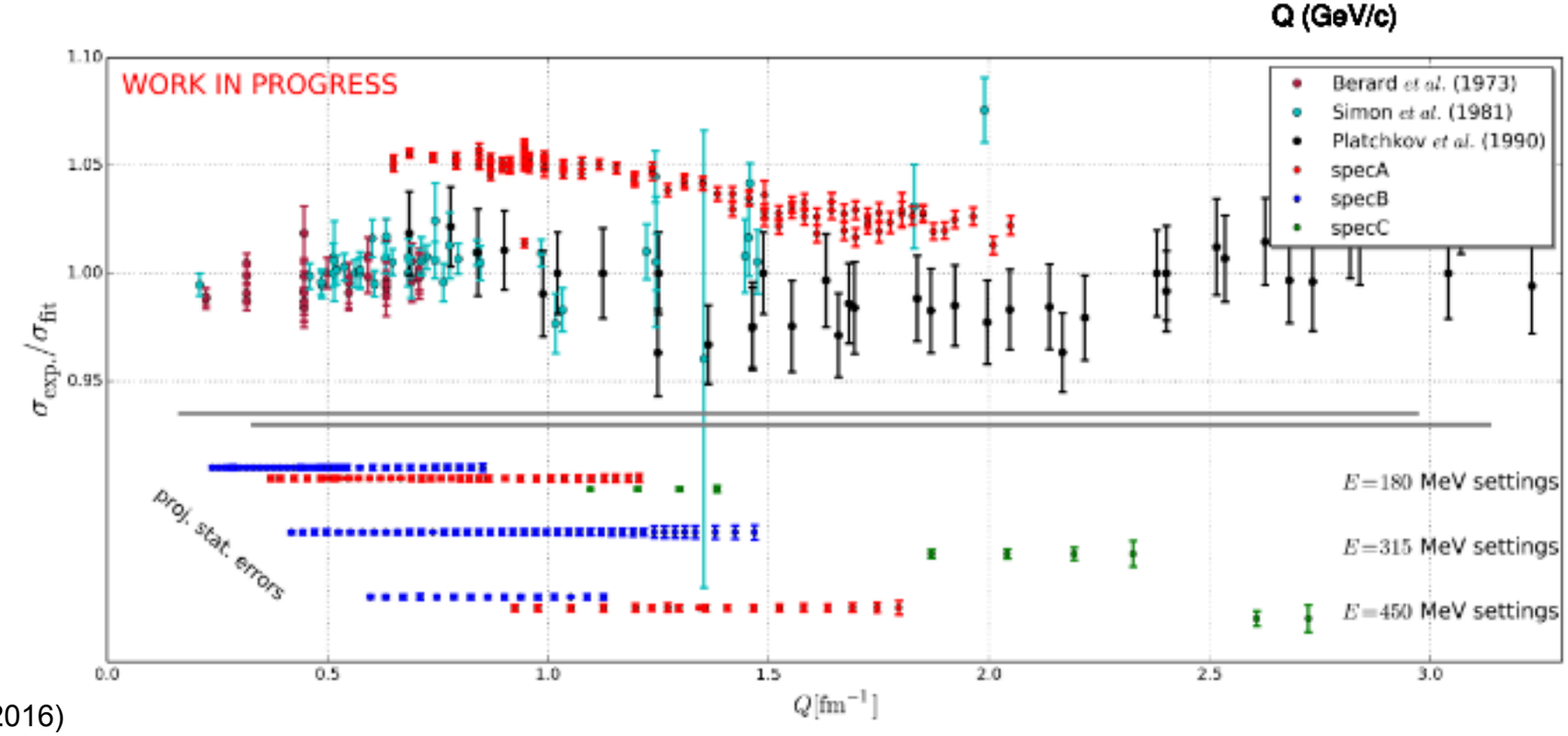
Figs. from Byungwuek Lee's PhD thesis (LEDEx experiment @ JLab)



Experiment	Q (GeV/c)	Symbol	Year and Reference
Monterey	0.04 - 0.14	□	1973 [8]
Mainz	0.04 - 0.39	○	1981 [9]
Saclay ALS	0.13 - 0.84	◇	1990 [10]
Orsay	0.34 - 0.48	△	1966 [11]
Stanford	0.48 - 0.88	□	1965 [12]
DESY	0.49 - 0.71	◇	1971 [13]
CEA	0.76 - 1.15	×	1969 [14]
JLab Hall C	0.81 - 1.34	★	1999 [15]
JLab Hall A	0.83 - 2.44	□	1999 [16]
SLAC E101	0.89 - 2.00	+	1975 [17]



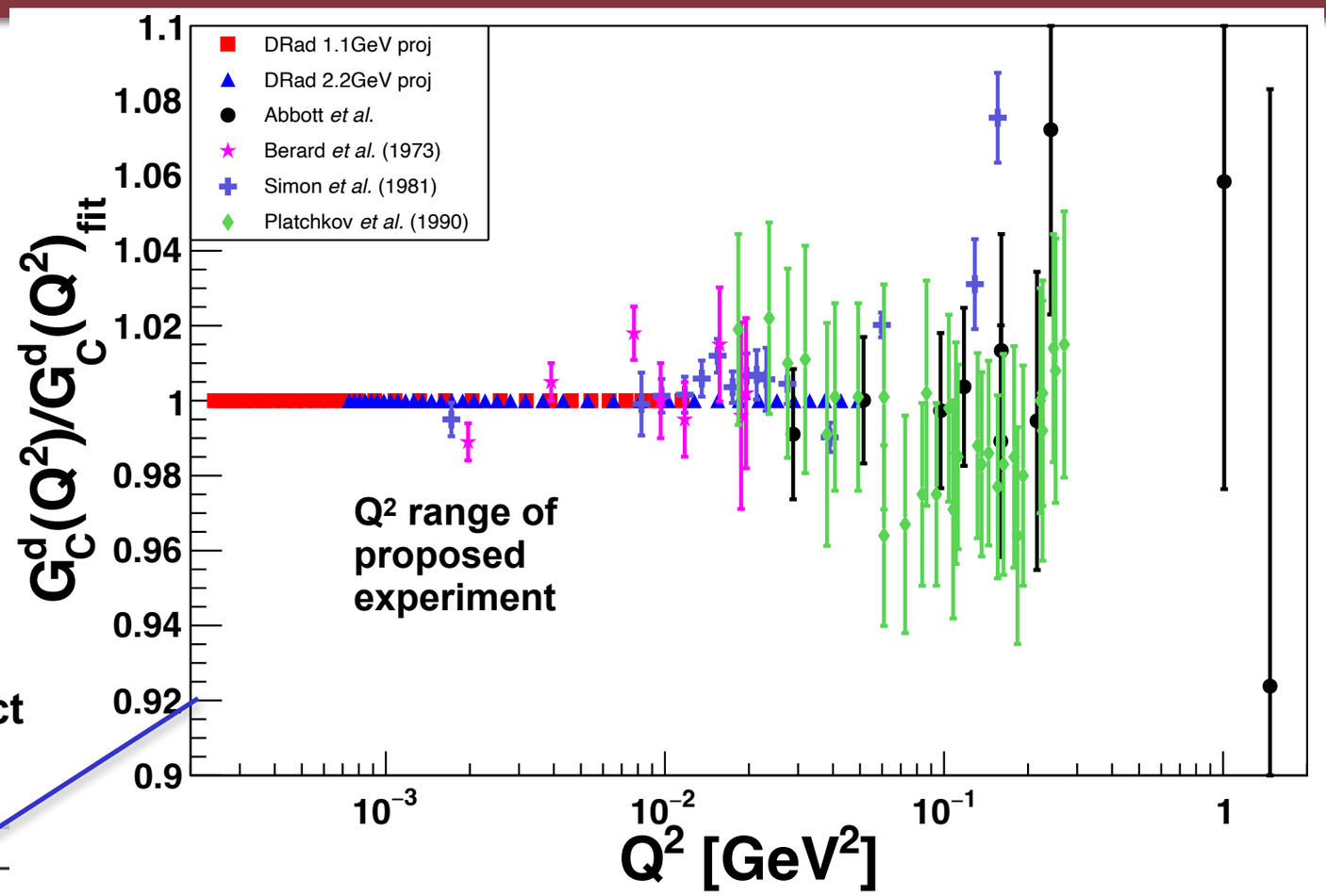
More recent experiment at Mainz



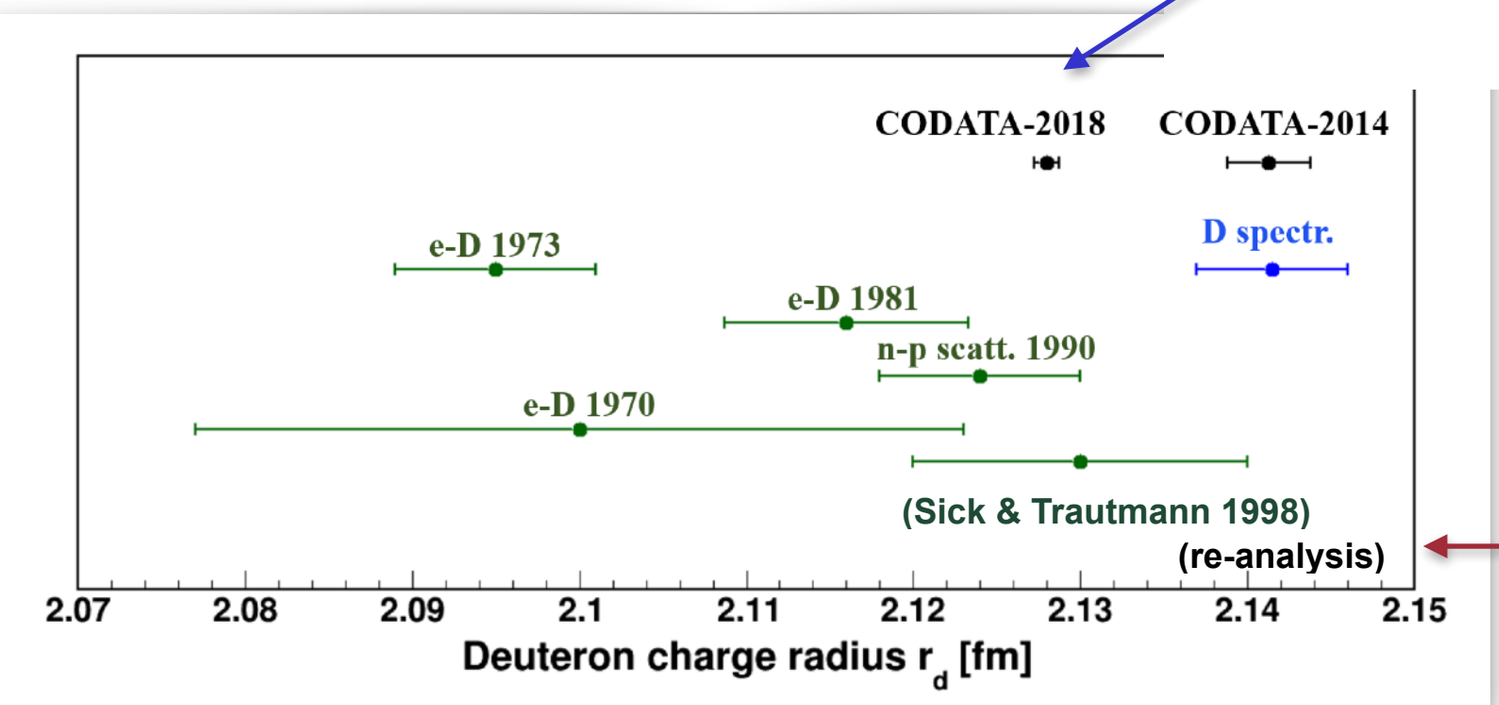
B.S. Schlimme, et al. EPJ W of C, 113, 04017 (2016)

The program will provide precision Deuteron charge radius and much more

- existing data from old methods
- large uncertainty
- all used magnetic spectrometer method
- normalized *eD* to *ep* cross section
- large bgd. from target windows



used to extract charge radius

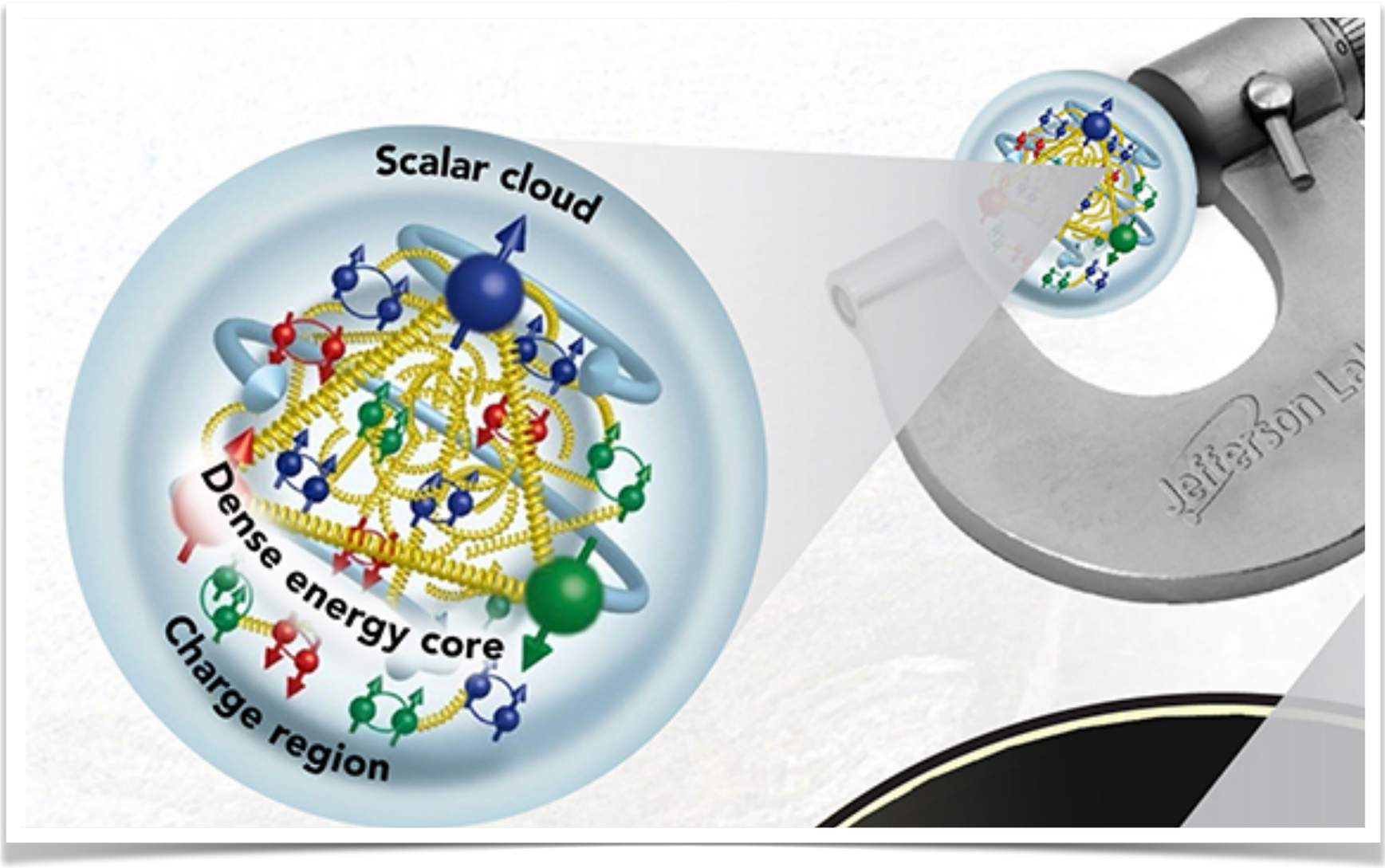


Most recent extraction of charge radius is a reanalysis of old data.

Situation points to an urgent need for a new high precision *eD* experiment

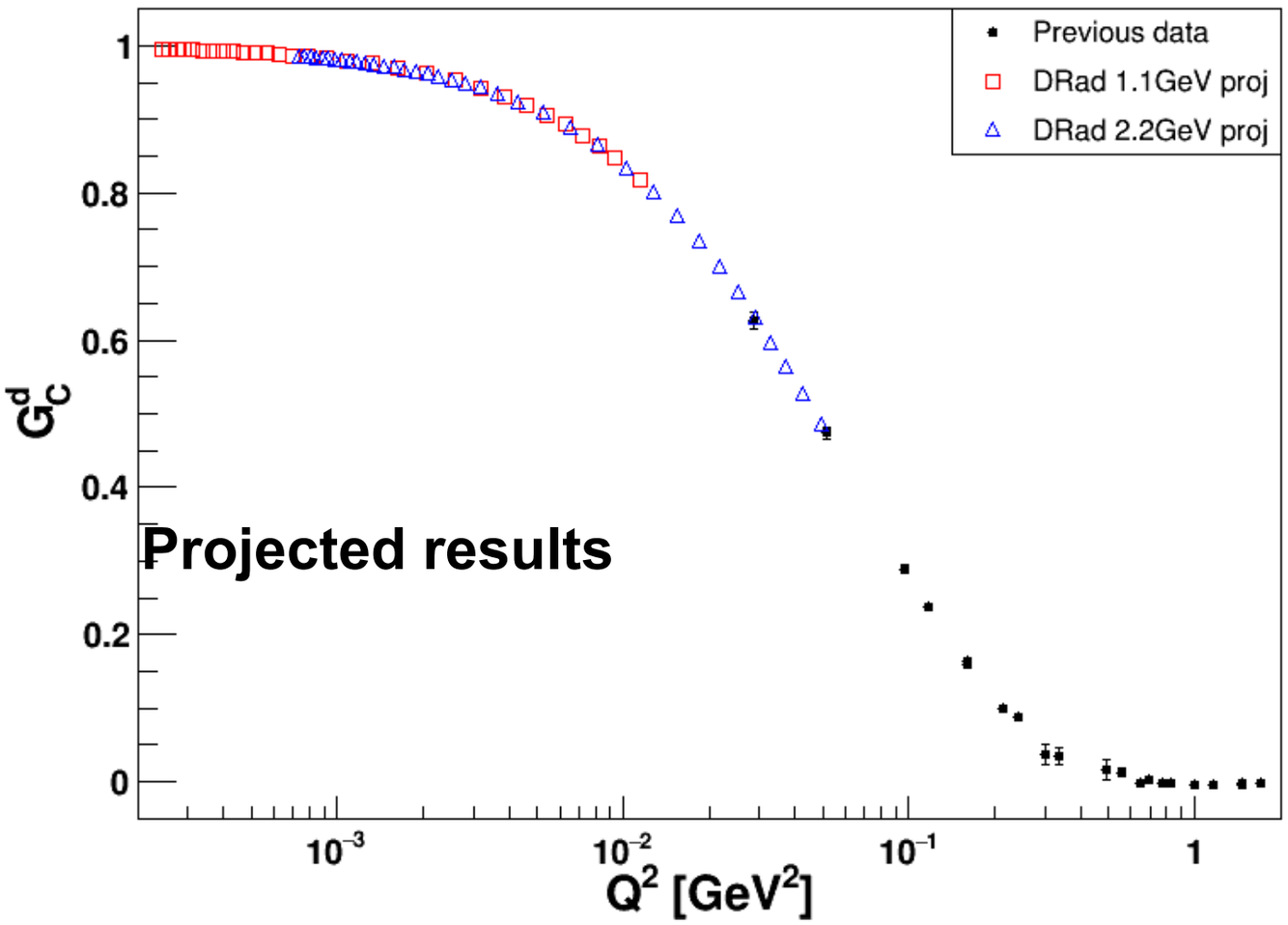
The deuteron "structure radius" is the point-nucleon matter radius and a direct test of χEFT

$$r_{str}^2 = r_d^2 - r_p^2 - r_n^2 - 3/4m_p^2$$



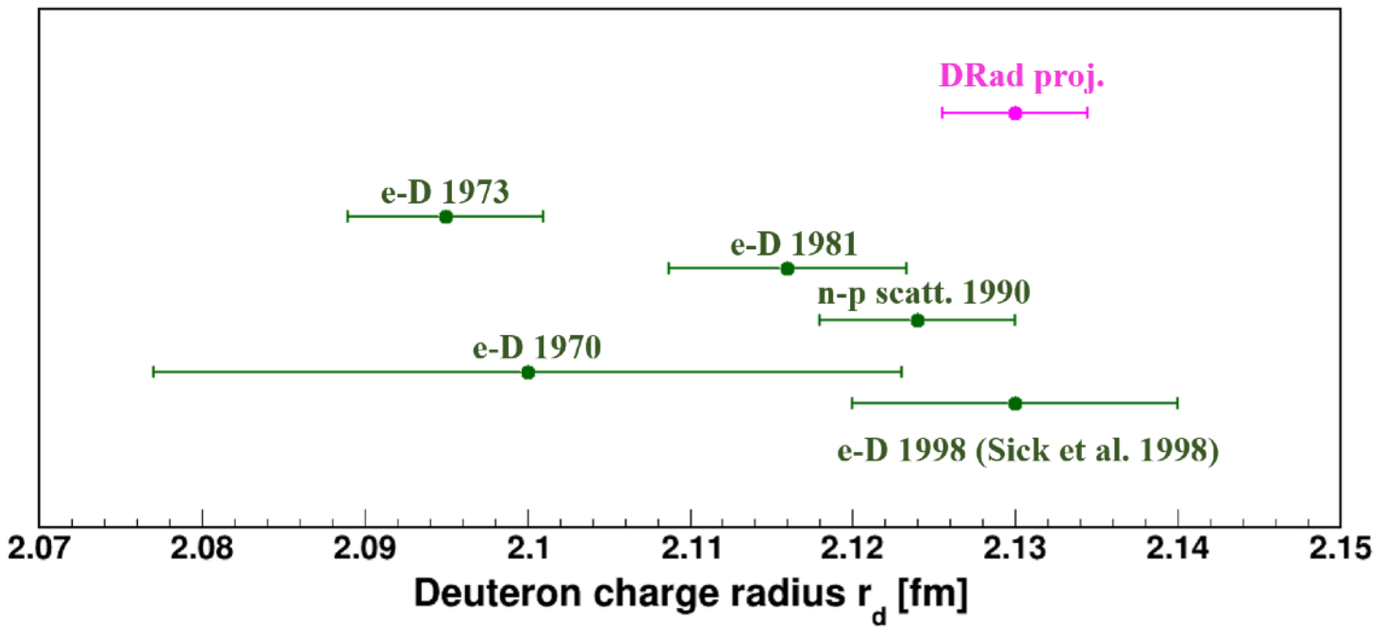
PRad, DRad charge radii and the J/Ψ based mass radius measurement will provide contrasting physics with a precise anchor for lattice calculations.

The estimated total uncertainties is about a factor of 2 better than the best extraction to date



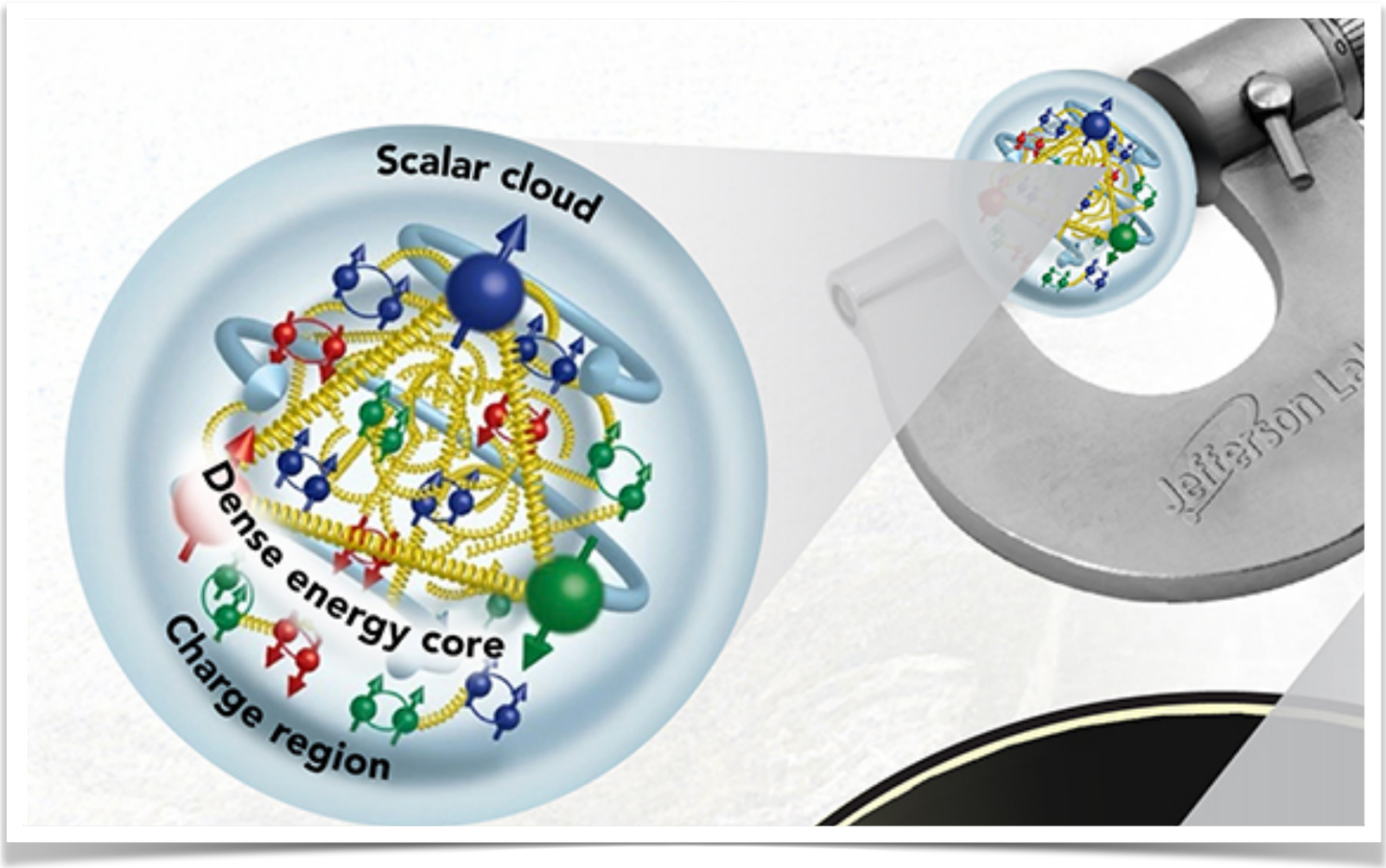
Estimated from 10,000 mock data sets smeared by systematic and statistical uncertainties.

systematic uncertainty
= $(R_{smear} - R_{unsmear})/R_{unsmear}$



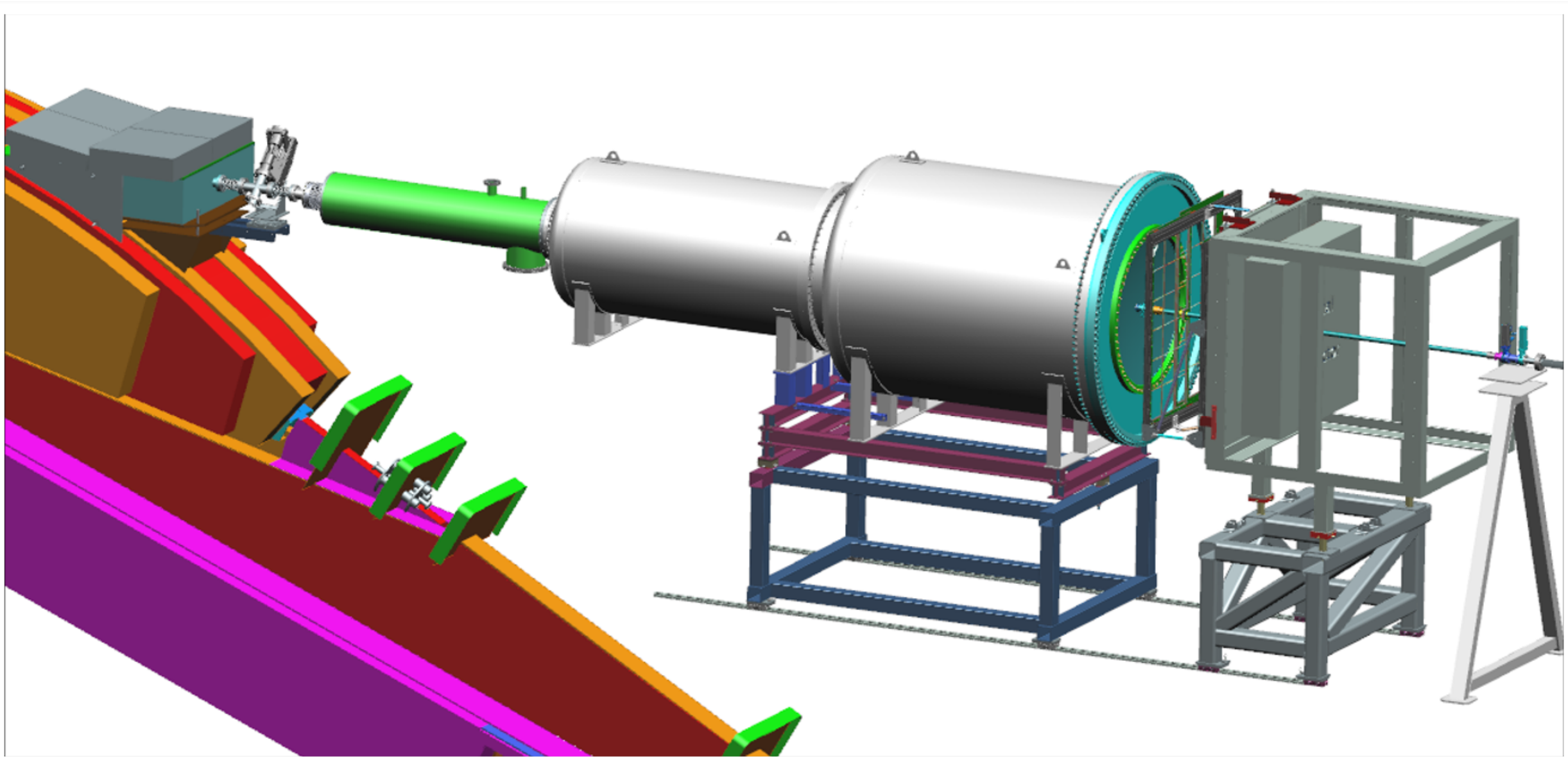
^{4}He is the natural reference nucleus for a nuclear charge-vs-mass comparison

^{4}He is spin-0 and isospin-0: Its charge radius therefore fixes its matter radius directly.



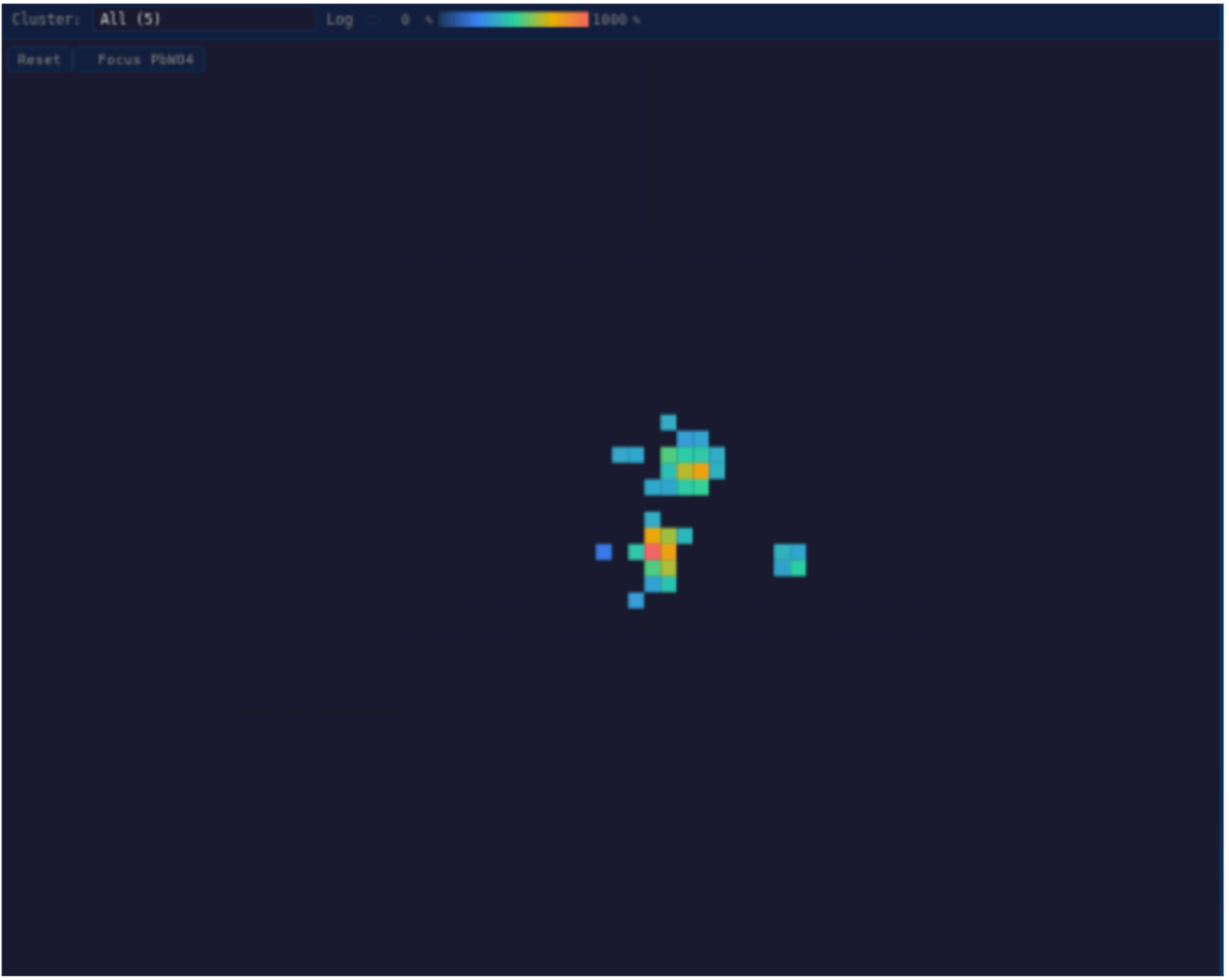
DRad setup can be used for ^{3}He and ^{4}He charge radii measurements, providing nuclear-structure input for muonic helium, and e vs μ validation

The X-17 apparatus provides a unique window into the 0.5 - 105 MeV, e-to-μ mass desert

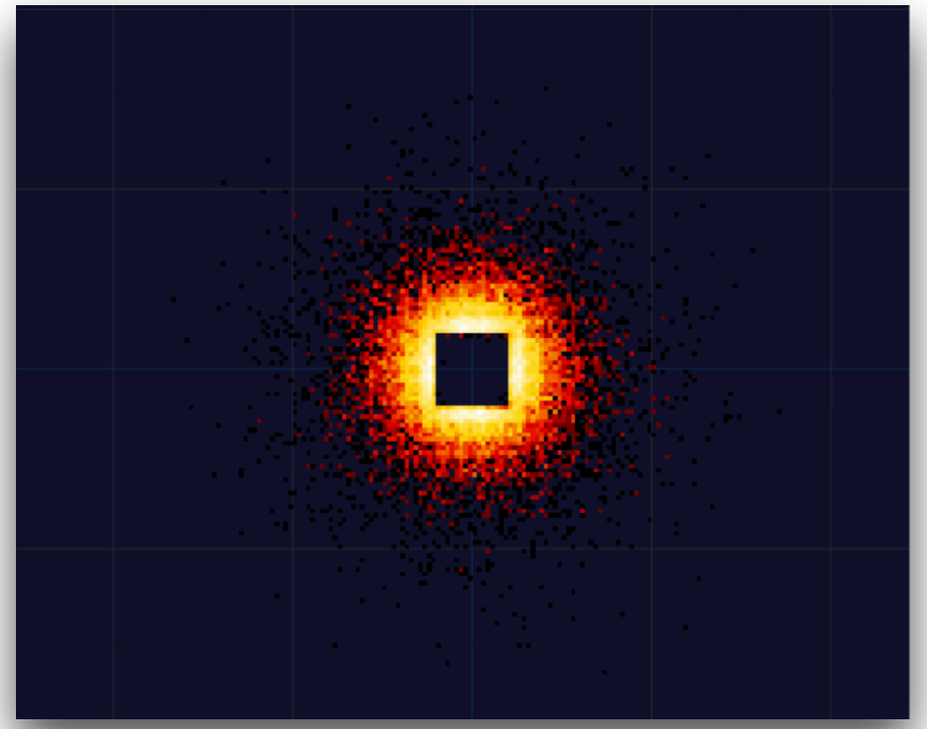


The X-17 experiment demonstrated the advantage of the magnetic-spetrometer-free method

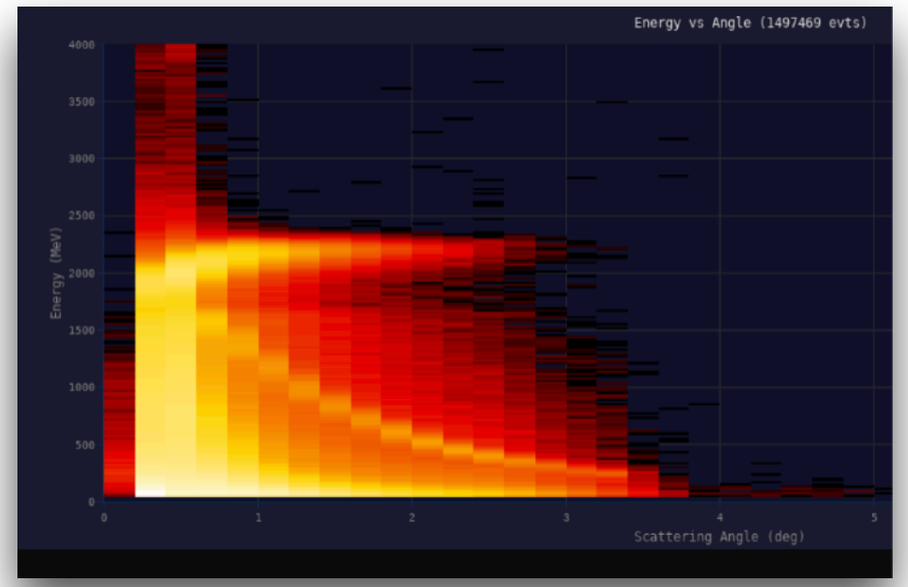
3 nA on Ta target



one 3-cluster event on the HyCal



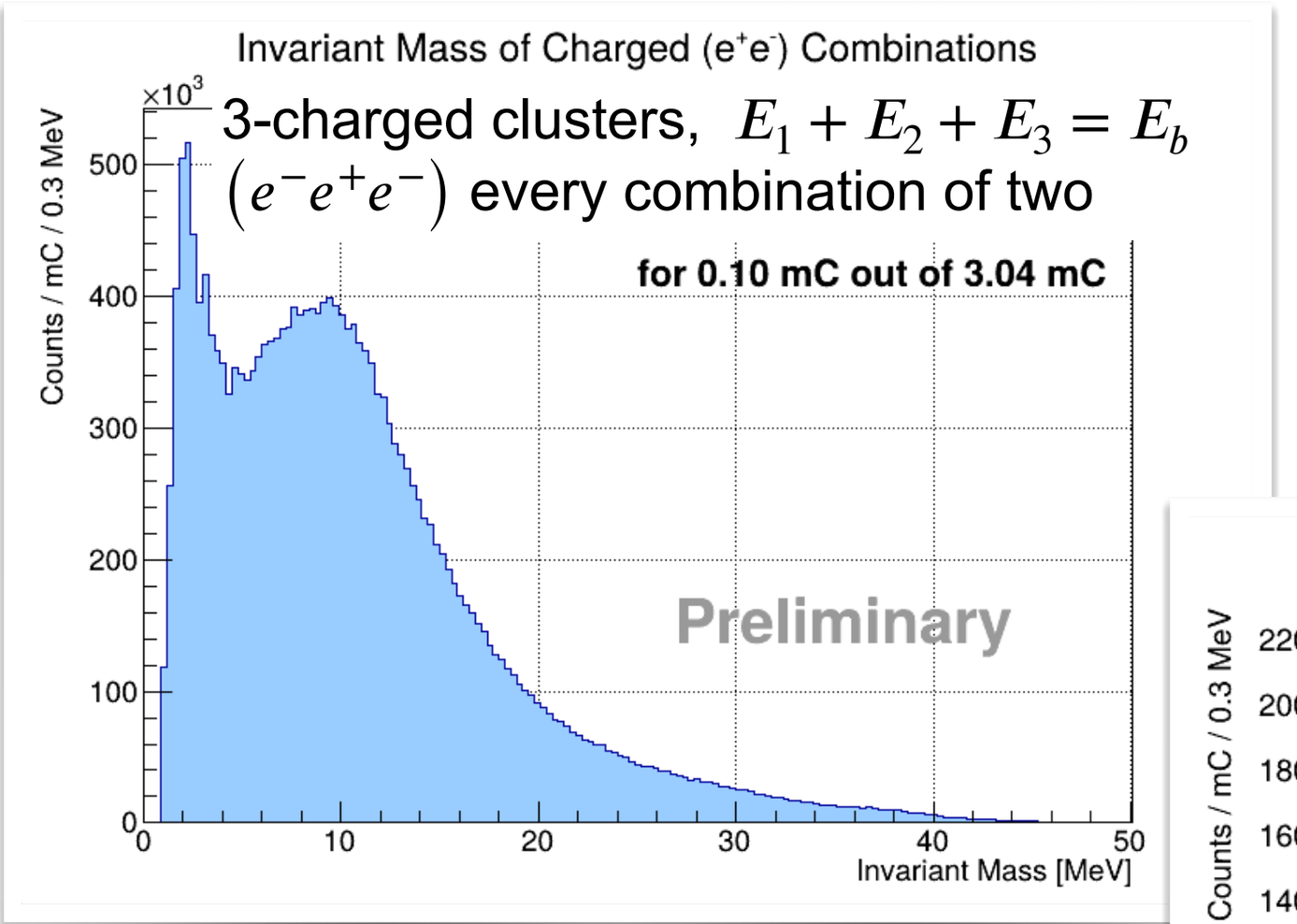
distributions of clusters on the HyCal

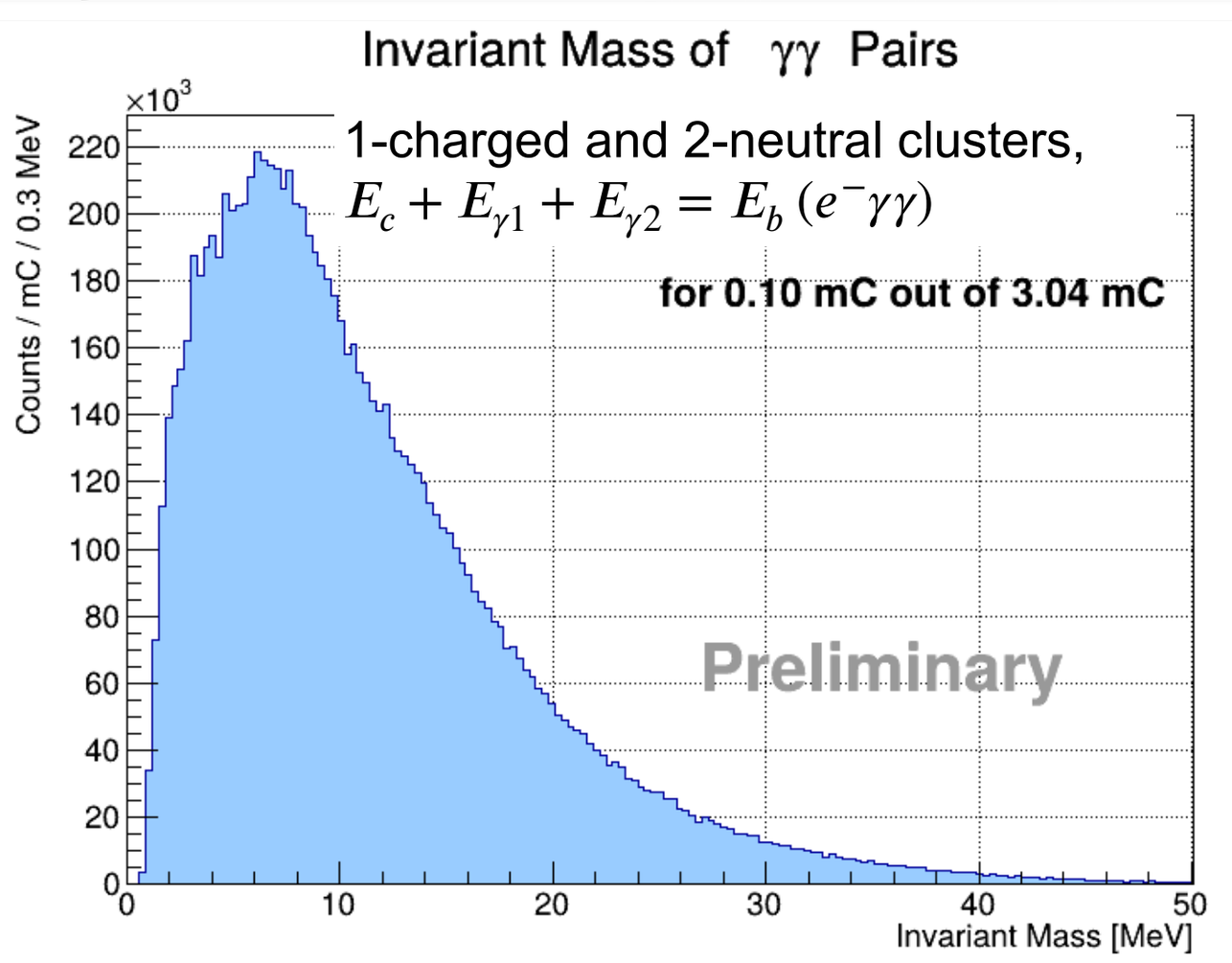


Energy (MeV)

Angle (deg)

The invariant mass spectra demonstrated the first detection of all final state particles

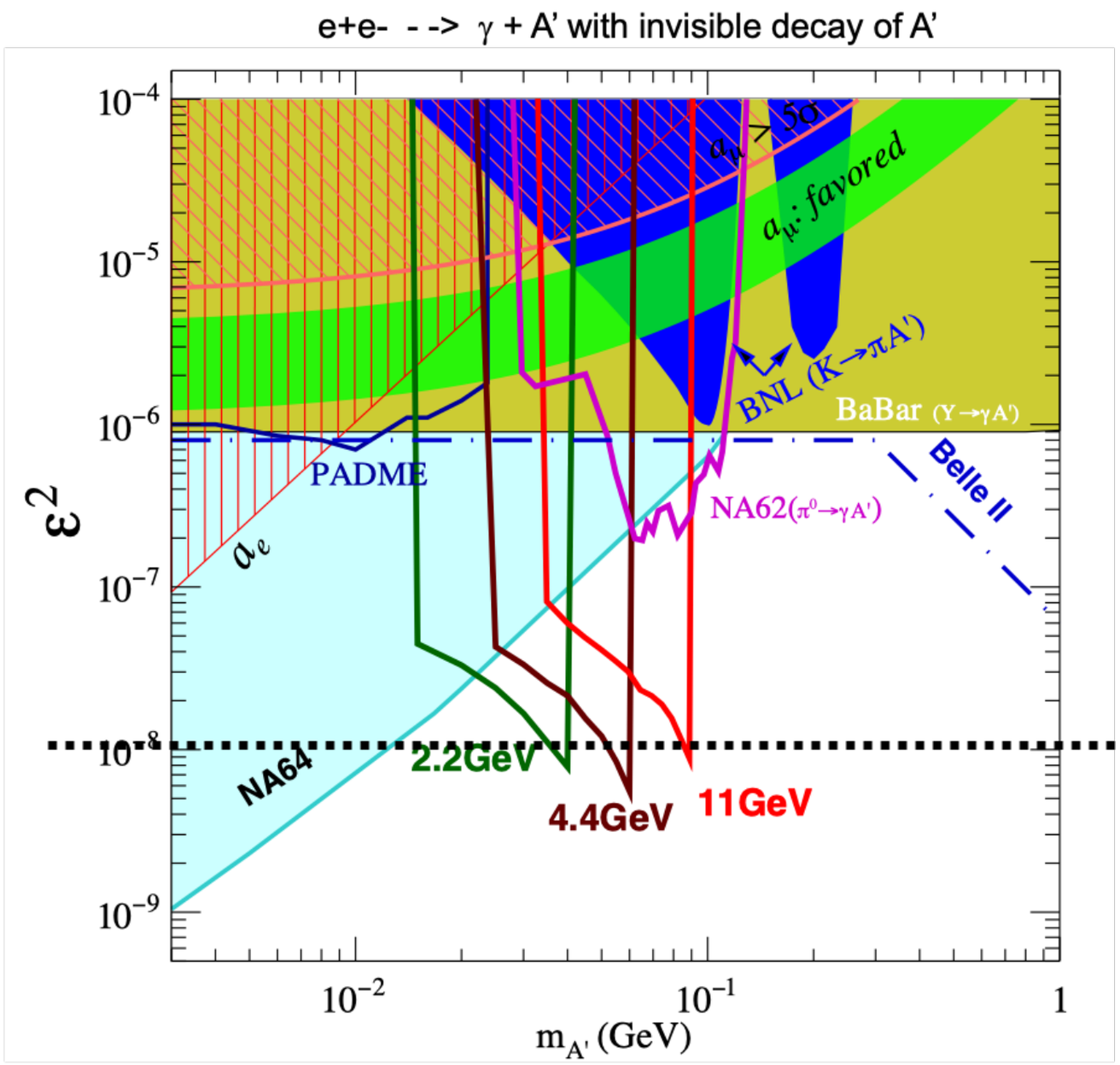




Additional statistics would provide discovery potential/ sharpen limits

The JLab positron beam with PRad setup would provide additional unique dark photon searches

Allows one photon detector probing A' decays to invisible particles



Positron A' collaboration : B. Wojtsekhowski et al., conditionally approved by PAC-52

image from B. Wojtsekhowski

Summary

- The PRad experiment demonstrated the novel magnetic-spectrometer-free technique in electron scattering.
- The recently completed PRad-II has reconfirmed the method and improved on it
- The same technique along with a recoil detector would allow high precision measure of deuteron and helium charge radii.
- These would provide unique tests of theory and unique input to the charge-vs-mass radius comparison.
- The X17 experiment demonstrated the advantages of the magnet-free technique and provides a unique opportunity to explore the e-to-μ mass desert.
- The JLab positron beam will allow additional new dark photon search for invisible decays.

This work was supported by US DOE grant DE-FG02-07ER41528