E12–14–009: Ratio of the electric form factor in the mirror nuclei ^{3}He and ^{3}H

(The ^{3}He – ^{3}H Charge Radius Difference)

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Hall A Winter Meeting

December 9, 2014

Measuring $\langle r^2 \rangle$

- **Absolute methods**

  Elastic electron scattering

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- **Relative method**

  Isotopic shifts

Proton Radius Puzzle

Proton radius extracted from all three methods

ep:	0.879	$\pm$ 0.009	fm
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Just for laughs...

Deuterium radius

eD:	2.130	$\pm$ 0.010	fm
μH + Iso. Shift:	2.12771	$\pm$ 0.00022	fm
μD (prelim):	2.128		fm

Why Tritium? Why Now?

Experimentally, large uncertainties & discrepancies

arXiv:1412.2603 – new radii and moments of ^{3,4}He

Lightest isotope with excess neutrons (skin?)

	$\langle r^2 \rangle_{^3\mathrm{H}}$	$\langle r^2 \rangle_{^3\mathrm{He}}$
SACLAY	1.76(9)	1.96(3)
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"Because the ^3H (tritium) charge radius currently has large errors, in my opinion the single most valuable measurement to be undertaken for nuclear physics purposes would be the tritium-hydrogen (^3H-^1H) isotope shift"

J.L. Friar
Precision Physics of Simple Atomic Systems (2003)

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^{3}H:^{3}He connects the hydrogen, helium chains

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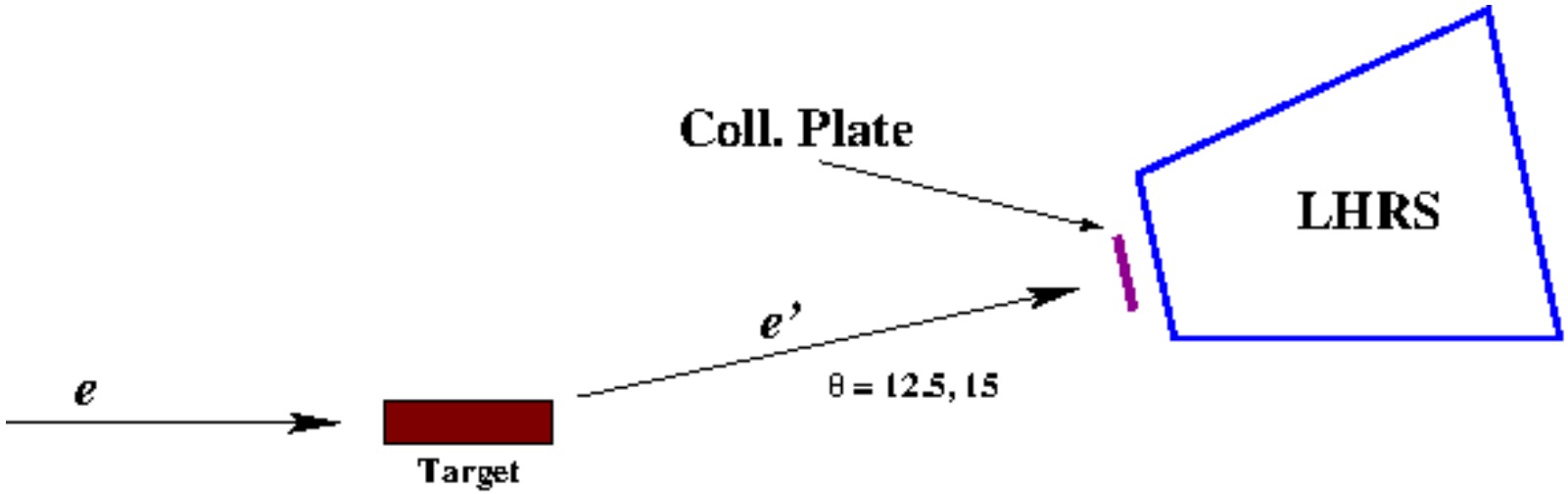
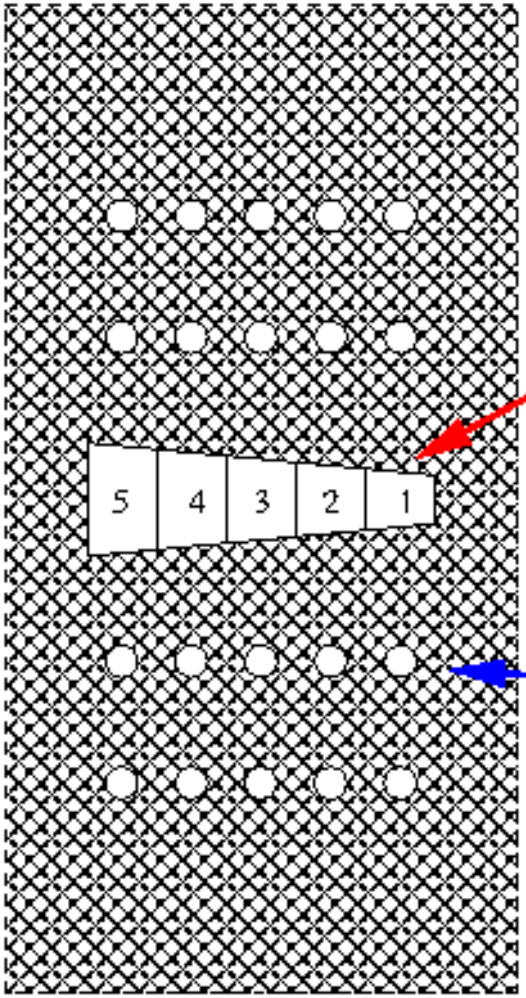
Experimental Setup



- Setup ∼same as MARATHON and SRC
- Targets: ^{3}H, ^{3}He as well as ^{1}H, ^{2}H, empty cell and ^{12}C
- Beam: 1.1 GeV, 5 μA **for 1.5 days**
- Special collimator plate

Collimator Plate



Collimator Plate
– reduce overall rate
– equalize rate in bins

Holes allow for simultaneous optics

Kinematics with LHRS

θ_{HRS} [deg]	p_{HRS} [GeV/c]	Q^2 [GeV^2]	^{3}H Rate [Hz/bin]	^{3}He Rate [Hz/bin]
12.5	1.07	0.049–0.065	210	510
15.0	1.07	0.072–0.091	60	125

- Only **one** momentum setting
  - Works for ^{3}H, ^{3}He as well as ^{1}H, ^{2}H, ^{12}C
  - ^{1}H, ^{12}C data for systematics cross check
- Count rates are HUGE!
  - $I_{\text{beam}} \sim 5\mu$A
  - Even with losses, 10^5 counts/bin/hr

Non-target Scattering

1) Scattering from windows
   - Dedicated, empty target runs
   - Vertex cuts

2) 1.1 GeV beam halo
   - Heating and scattering concerns
   - If needed, reduce raster size

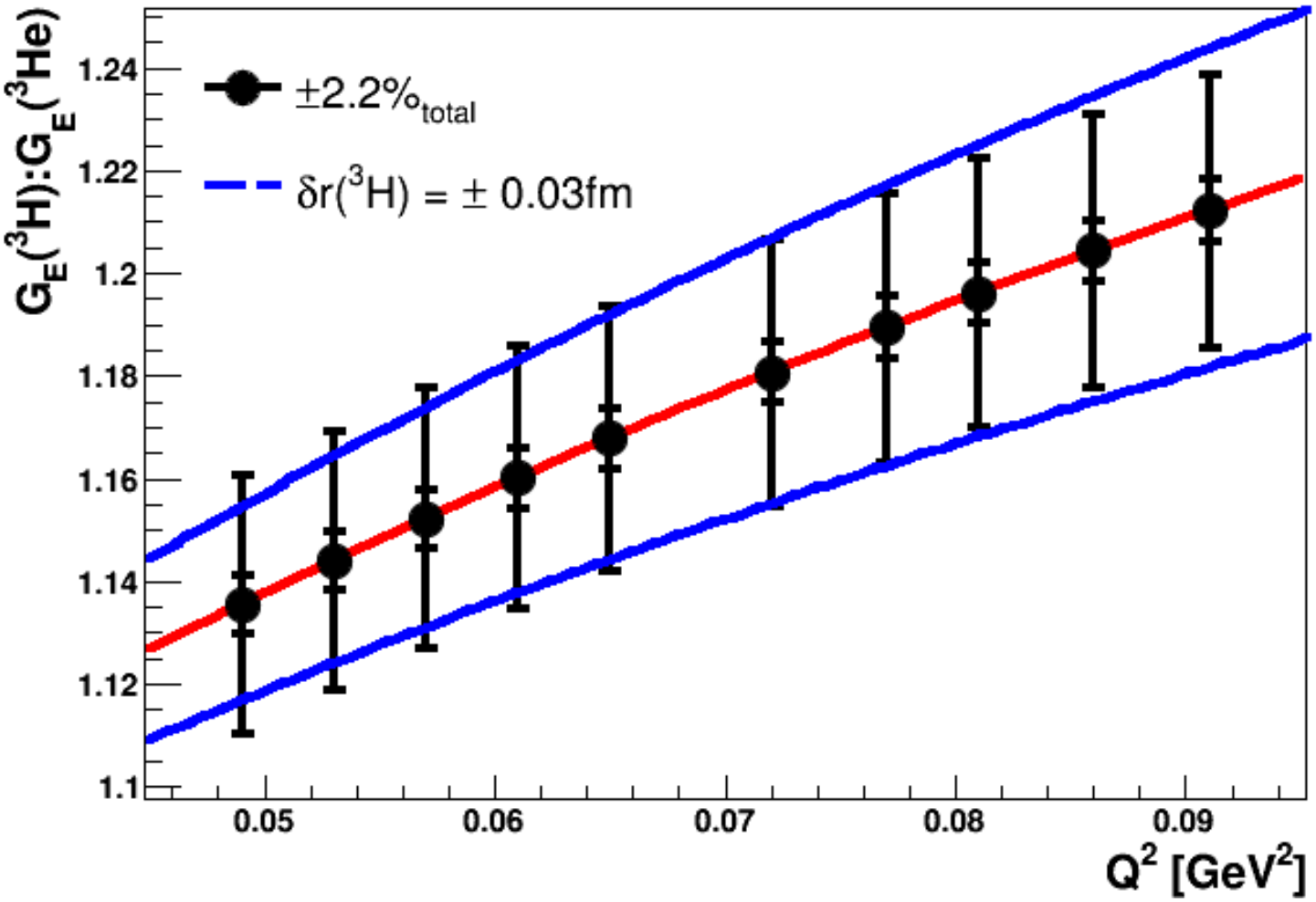
3) Rescattering from target walls
   - Simulations: small absolute effect, cancellation

4) Rescattering from collimator plate
   - Software cuts, ^{12}C comparison

Error Budget

Statistics	0.4%
Charge	<0.5%
Relative target thickness	**1.5–2%**
Deadtime, efficiency, etc	<0.5%
G_M subtraction	0.4%
Radiative corrections	0.5%
Coulomb correction, TPE	0.4%
Total	**1.8–2.2%**

Expected Results



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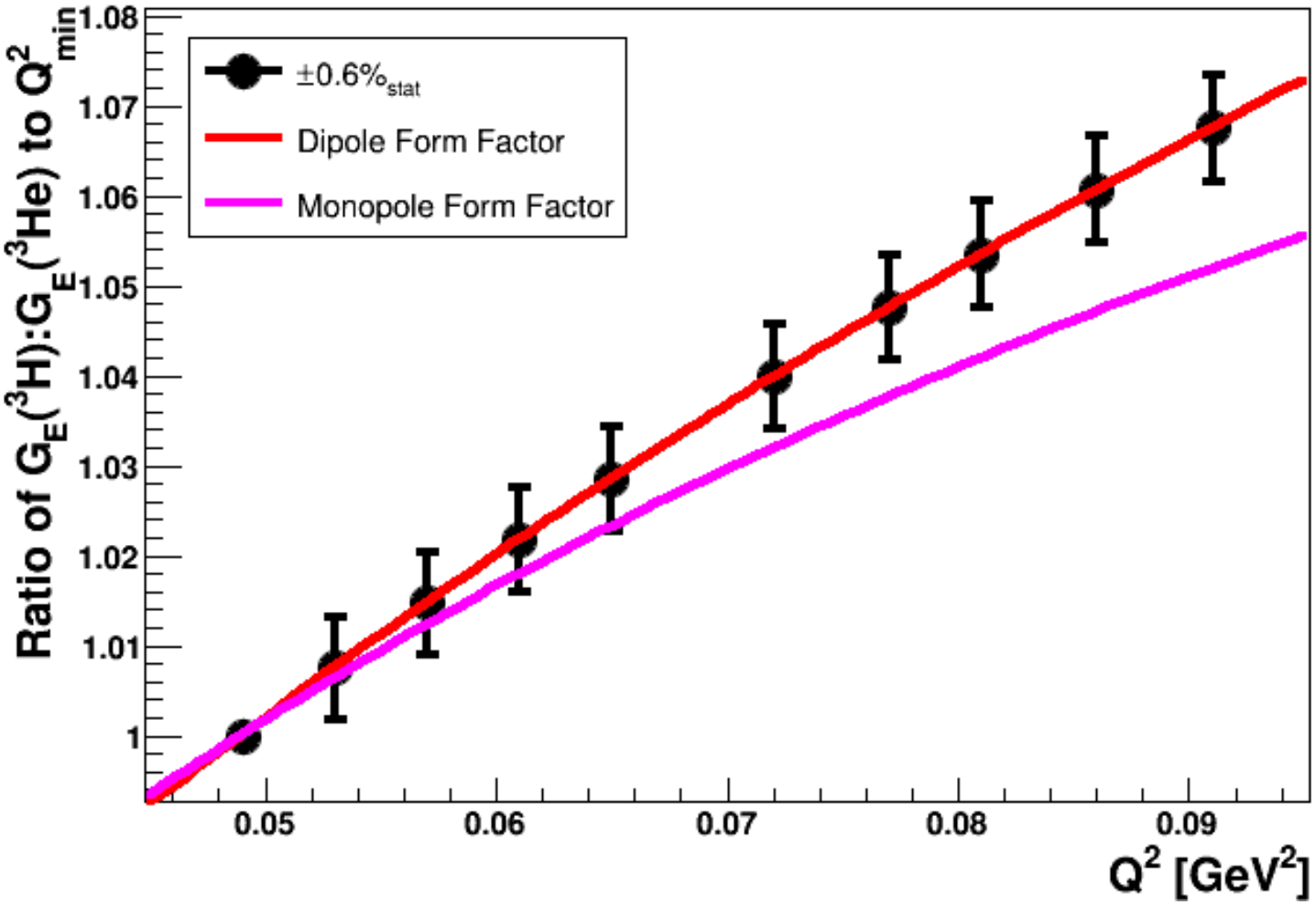

The Wrap-Up

- **1.5 day experiment**
  Single-arm, two angles, single p setting
  ^{1}H, ^{2}H, ^{3}H, ^{3}He, and ^{12}C

- 2% measurement of $G_{\mathrm{E}}(^{3}\mathrm{H})$:$G_{\mathrm{E}}(^{3}\mathrm{He})$
  $\langle r^2 \rangle_{^{3}\mathrm{He}} - \langle r^2 \rangle_{^{3}\mathrm{H}} \approx (0.20 \pm 0.03)$ fm
  Reduction in uncertainty by ~3x

- *"[T]his proposal offers an opportunity to perform an interesting measurement, which will provide valuable input to theoretical calculations, and will enable their further progress."* – JLab Theory Advisory Committee

- **Best chance to measure the ^{3}H radius**

Thank you!

Beamtime Allotment

Description	Time
Accelerator scaling to 1.1 GeV	4 hr
BCM calibration and luminosity scans	2 hr
Optics and acceptance studies with collimator	4 hr
Production running at 12.5° (1.5 hrs/target)	9 hr
Target changes at 12.5°	1 hr
Move spectrometer from 12.5° to 15.0°	2 hr
Optics and acceptance studies with collimator	4 hr
Production running at 15.0° (1.5 hrs/target)	9 hr
Target changes at 15.0°	1 hr
Total Beam Time Request	**1.5 PAC Days**

Target Contribution

1) Scattering from windows
   - Dedicated, empty target runs
   - Vertex cuts at ±10 cm