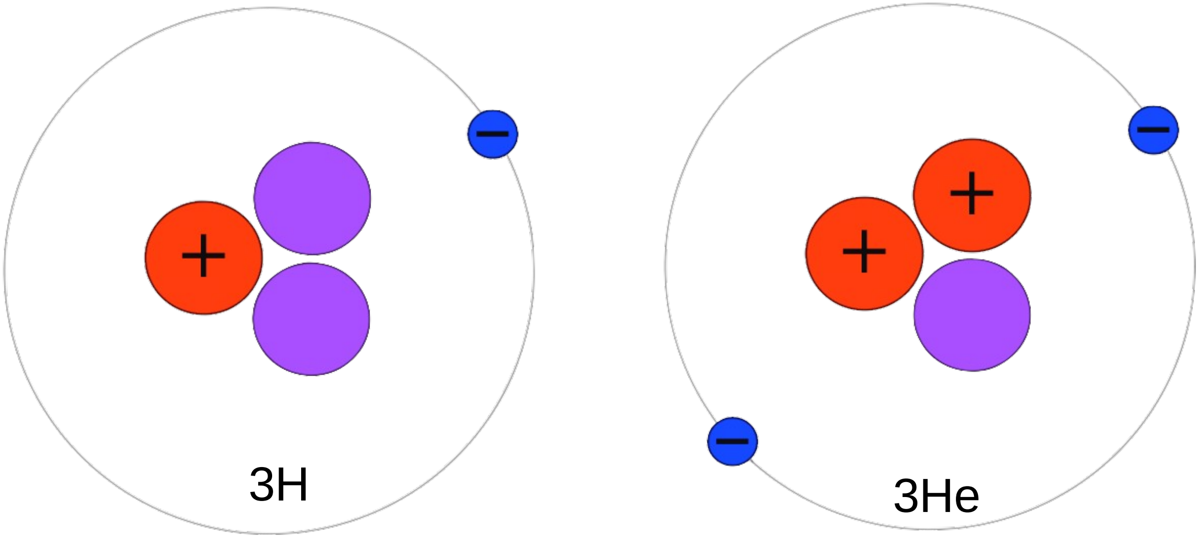
The Hall A Tritium Target Physics Program Overview

Using A=3 Mirror Nuclei to Probe the Nucleon Structure



Buddhini Waidyawansa
(Argonne National Lab)

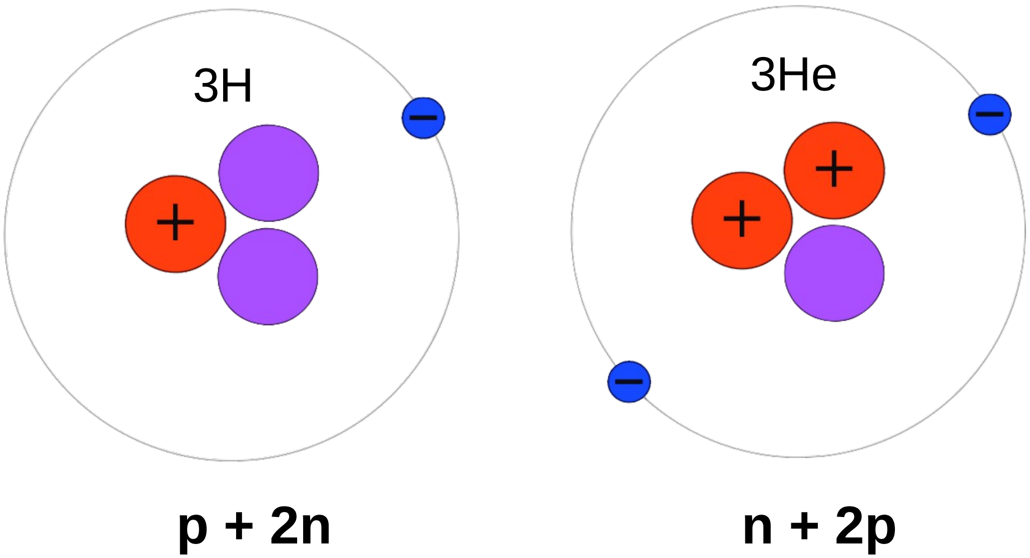
Hall A & C Summer Collaboration Meeting
June 23, 2016

Argonne NATIONAL LABORATORY

Why Mirror Nuclei?

In the absence of Coulomb interactions between the protons, a perfectly charge-symmetric and charge-independent nuclear force would result in the binding energies of all the mirror nuclei being identical

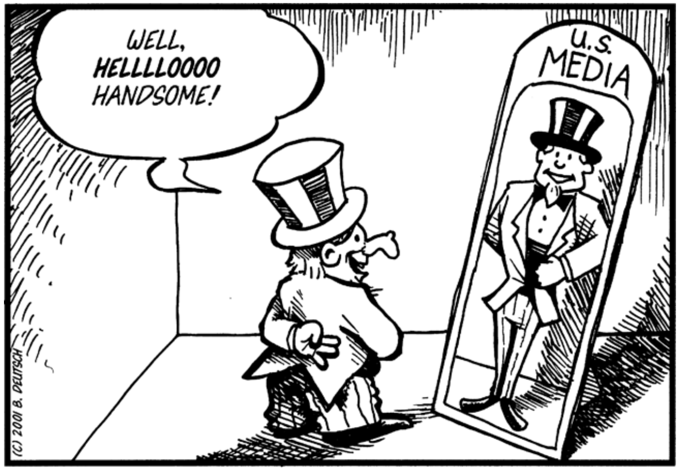
- The are structurally identical.
  - Studying the differences in their properties reveals information about protons and neutrons



Why A=3 Mirror Nuclei?

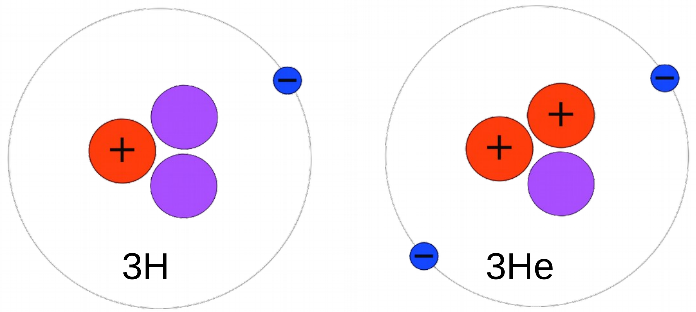
- **Lightest and the simplest mirror system**

- **Differences in the nuclear effects are small**
  - Binding energy
  - EMC effect
- **Nuclear effects cancel in the cross-section ratios**
  - FSI contributions
  - Radiative effects
    - **Cleaner measurements**



THE TRICK IS FINDING THE RIGHT MIRROR

How to Utilize the Mirror Properties (n+2p) vs (p+2n)



Reaction	Cmpare 3He vs 3H	Access	Experiment
DIS e scattering	n+2H vs p+2H	F2p/F2n and d/u	MARATHON

Measurement of deep inelastic ratios from 3H an 3He nuclei (MARATHON)

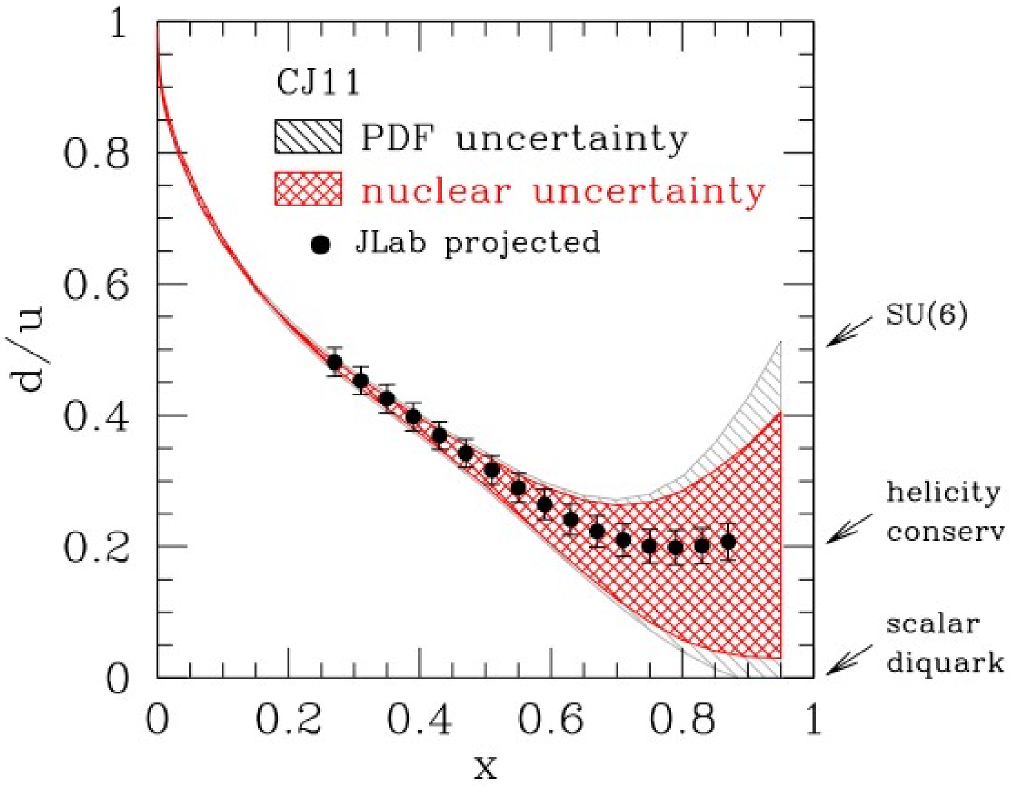
spokespersons: G. Petatos, R. Holt R. Ransome, J. Gomez

- Measure DIS from 3H, 3He and 2H
- Construct EMC cross-section ratios

$$R(^3\mathrm{H}) = \frac{F_2^{^3\mathrm{H}}}{F_2^p + 2F_2^n} \quad R(^3\mathrm{He}) = \frac{F_2^{^3\mathrm{He}}}{2F_2^p + F_2^n}$$

- Extract
  - F2n/F2p and d/u ratios
- Mirror symmetry makes ratios independent of nuclear effects

$$\frac{F_2^n}{F_2^p} = \frac{2\mathcal{R} - F_2^{3He}/F_2^{3H}}{2F_2^{3He}/F_2^{3H} - \mathcal{R}} \qquad \frac{F_2^n}{F_2^p} = \frac{1+4(d/u)}{4+(d/u)}$$



Precise extraction of F2n/F2p, d/u ratio independent of nuclear effects

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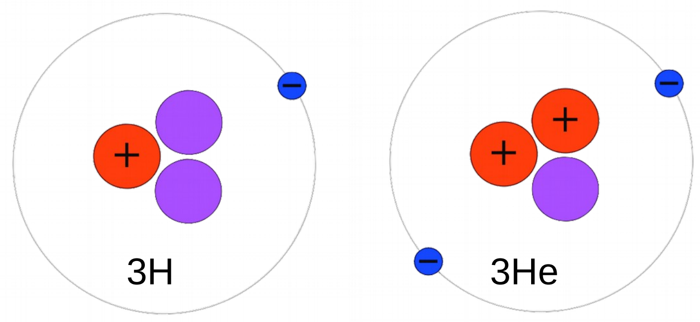


Reaction	Cmpare 3He vs 3H	Access	Experiment
DIS e scattering	n+2H vs p+2H	F2p/F2n and d/u	MARATHON
QE e scattering	2(pn)+(nn) vs 2(pn)+(pp)	Isospin structure of 2N-SRC	SRC @ x>1

Isospin dependance of 2N-SRC (E12-11-112)

spokespersons: P. Solvignon, J. Arrington, D. Day, D. Higinbotham

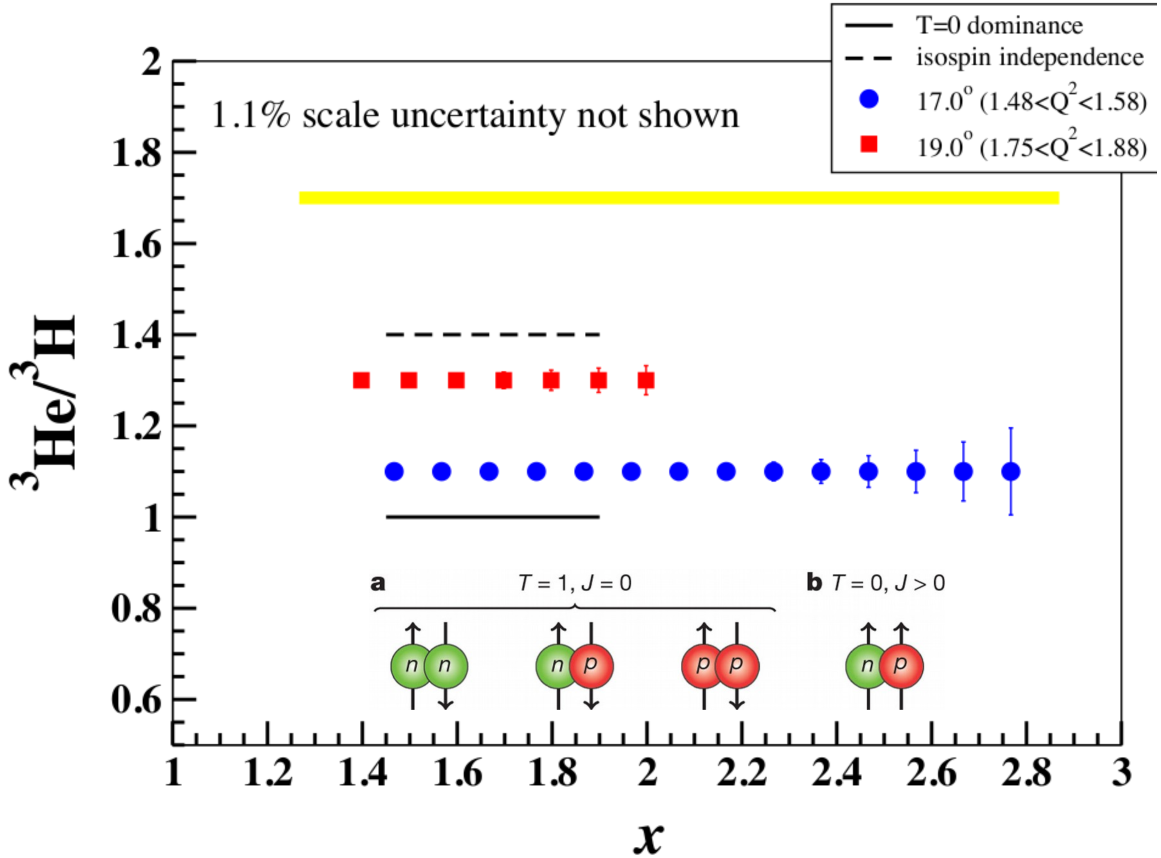
- Measure inclusive QE scattering from 3H and 3He
- Extract 2N-SRC ratios asuming

Isospin independent

$$\frac{\sigma_{^3He}/3}{\sigma_{^3H}/3} = \frac{(2\sigma_p + 1\sigma_n)/3}{(1\sigma_p + 2\sigma_n)/3} \xrightarrow{\sigma_p \approx 3\sigma_n} 1.40$$

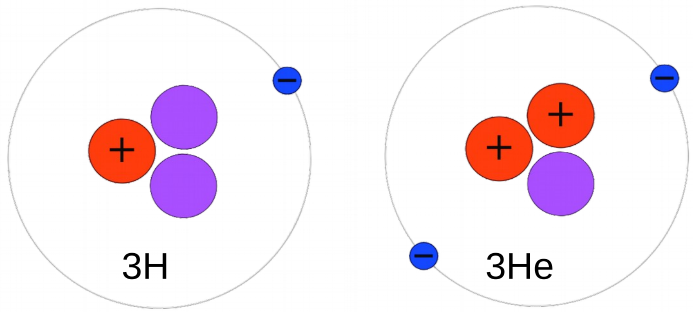
Full n-p dominance (T=0)

$$\frac{\sigma_{^3H}/3}{\sigma_{^3He}/3} = \frac{(2\,pn + \cancel{1\,nn})/3}{(2\,pn + \cancel{1\,pp})/3} = 1.0$$



Precision measurement of the isospin dependance in the 2N-SRC region (x>1)

How to Utilize the Mirror Properties (n+2p) vs (p+2n)



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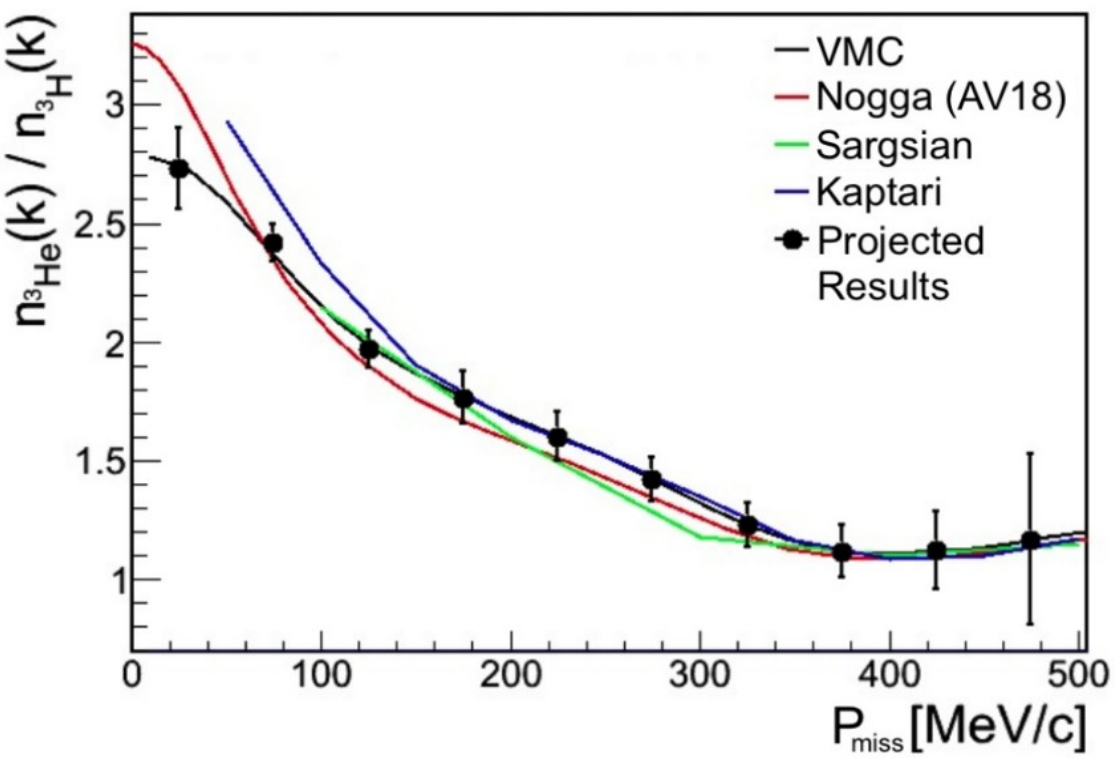
QE e scattering	2(pn)+(nn) vs 2(pn)+(pp)	Isospin structure of 2N-SRC	SRC @ x>1
	(p+2n) vs (2p+n)	n(k) of protons	(e,e'p)

Proton and Neutron Momentum Distributions in 3H and 3He (E12-13-012)

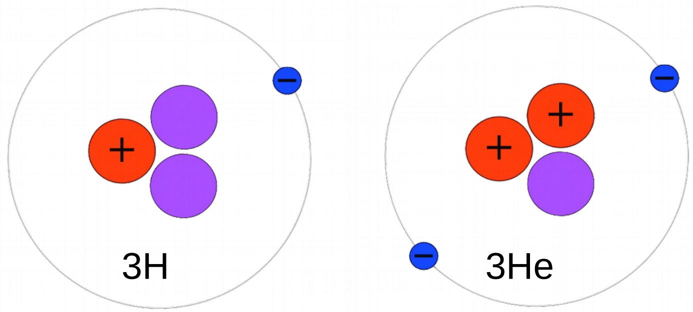
spokespersons: O. Hen, L. Weinstein, S. Gilad, W.Boeglin

- Measure the quasi elastic (e,e'p) reaction on 3H and 3He
  - First measurement of 3H(e,e`p)
  - First measurement of 3He(e,e`p) with minimized effects from FSI
- Measure cross-section sensitive to ground state momentum distributions
- Will show kinetic energy of minority (p in 3H_ > kinetic energy of majority (p in 3He)



First high precision model independent extraction of nuclear momentum distribution ratio

How to Utilize the Mirror Properties (n+2p) vs (p+2n)



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QE e scattering	2(pn)+(nn) vs 2(pn)+(pp)	Isospin structure of 2N-SRC	SRC @ x>1
	(p+2n) vs (2p+n)	n(k) of protons and neutrons	(e,e'p)
Elastic e scattering	2(pn)+(nn) vs 2(pn)+(pp)	Difference in charge radii Form factors	Elastic

Charge Radii of 3H and 3He (E12-14-009)

spokespersons: J. Arringtone, L. Myers, D. Higinbotham

- Measure elastic scattering cross-section ratio of 3H to 3He
  - Extract the relative charge radius
- One time opportunity for 3H at JLab
-

	$<r^2_{rms}>_{3H}$ (fm)	$<r^2_{rms}>_{3He}$ (fm)	ΔR_{rms} (fm)
GFMC	1.77(1)	1.97(1)	0.20 (1)
χEFT	1.756(6)	1.962(4)	0.21 (7)
SACLAY	1.76(9)	1.96(3)	0.20 (10)
BATES	1.68(3)	1.97(3)	0.30(3)
Atomic	--------	1.959(4)	--------

GFMC, χEFT: Precise (~1%) theoretical calculations

SACLAY, BATES: Large uncertainties and discrepancy in measurements

Improve precision of ΔR_{rms} by factor of 3-5 over SACLAY to check existing theory and experimental results

(Piarulli et al., Phys. Rev. C 87 014046)

Experiment Lineup

- **E12-06-118** : Measurement of deep inelastic ratios from 3H/3He (MARTHON)
- **E12-11-112** : isospin dependance of short range correlations in x>1 region
- **E12-14-011** : Proton neutron momentum distributions in A=3 nuclei
- **E12-14-009** : 3H – 3He charge radius difference from elastic scattering

Require the Jlab Tritium target

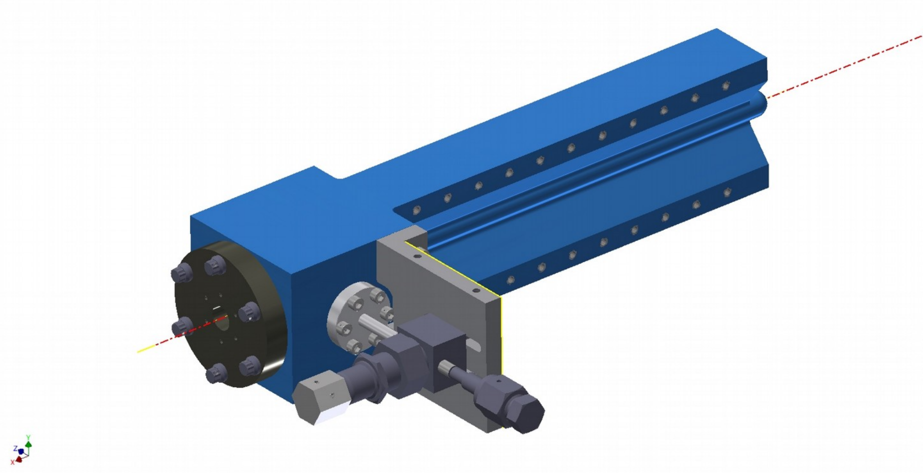
Tritium Gas Targets @ electron accelerators

Lab	Year	Quantity (kCi)	Thickness (g/cm^2)	Current (µA)	Power loss (mW/mm)
Stanford	1963	25	0.8	0.5	3.2
MIT-Bates	1982	180	0.3	20	47.7
SAL	1985	3	0.02	30	4.8
JLab	**(2016)**	**1**	**0.08**	**20**	**12.7**

- Jlab radioactivity very low
- JLab luminosity ~ **2.0 x 10^{36} tritons/cm^2/s**

Jlab Tritium Target

First tritium target @ JLab



- **Thin Al windows**
  - Beam entrance: 0.010”
  - Beam exit: 0.011”
  - Side windows: 0.018”
  - 25 cm long cell at ~200 psi T_2 gas

- **Tritium cell filled and sealed at Savannah River National Lab**
  - Purity: 99.9% T_2 gas, main contaminant is D_2
  - 12.32 y half-life: after 1 year ~5% of ^3H decayed to ^3He

- **Administrative current limit: 25 μA**

Summery

- Four experiments to study the nucleon structure using 3H and 3He mirror symmetry
  - Elastic to Deep inelastic kinematics
  - Nucleon structure functions, charge radii, momentum distributions and SRC
  - Excellent candidates to test theory calculations

- The collaboration is eagerly waiting to take data in the Spring of 2017!

Coming to Hall A in spring of 2017!

Physics
with
Tritium

MARATHON
(DIS)
Neutron to proton structure
function ratio
d/u ratio
EMC ratio

X>1
(QE)
Isospin dependance
of 2N and 3N SRC

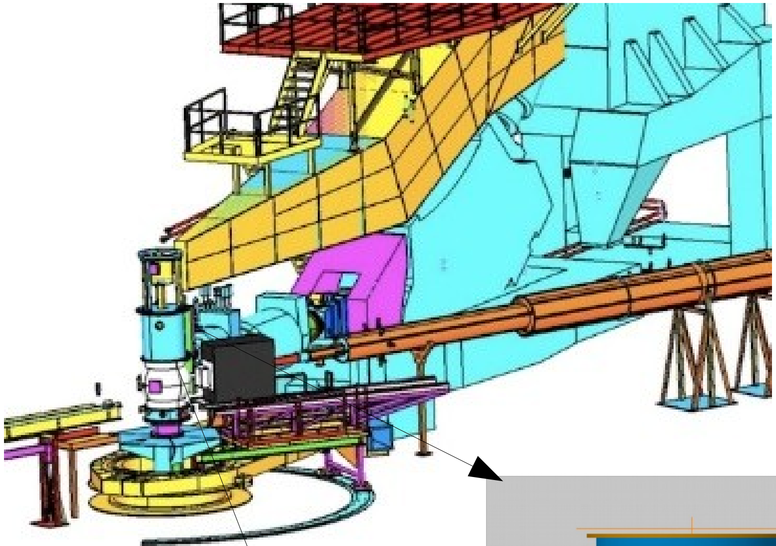
(e,e`p)
(QE)
Ground state
n and p momentum
distributions

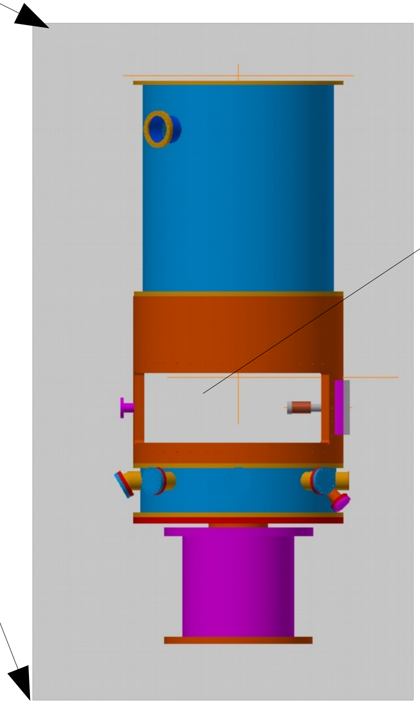
Elastic

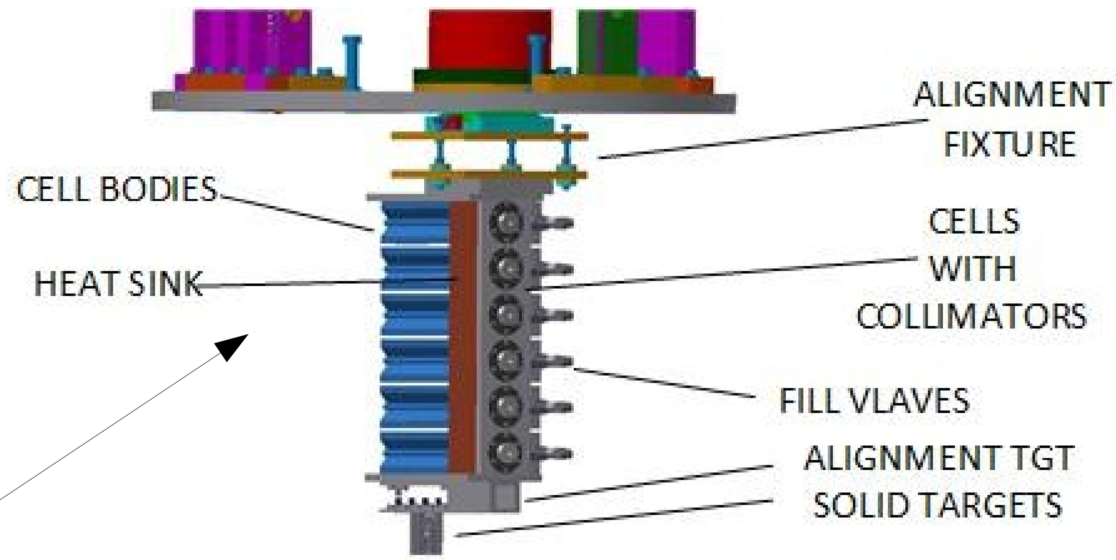
Charge radii of A=3 nuclei
Electric form factors

Backup Slides

Tritium Target Ladder



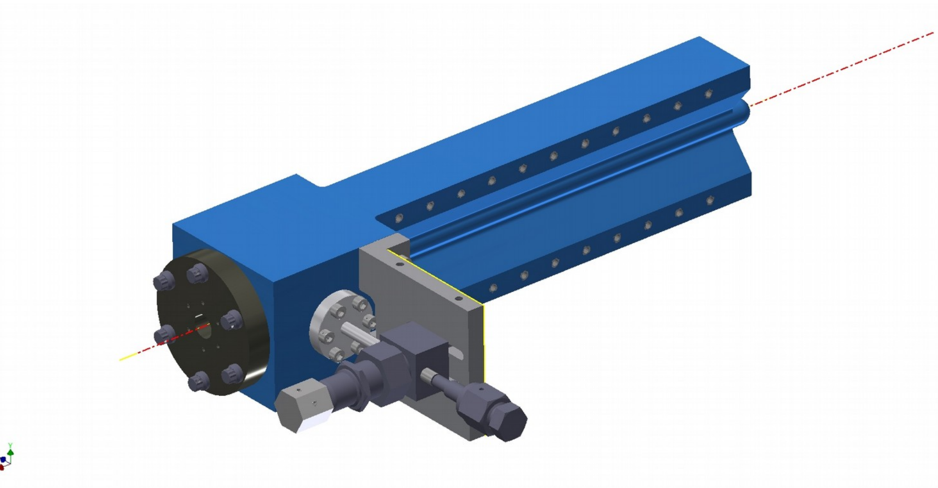




TARGET LADDER ASSEMBLY

JLab Tritium Target

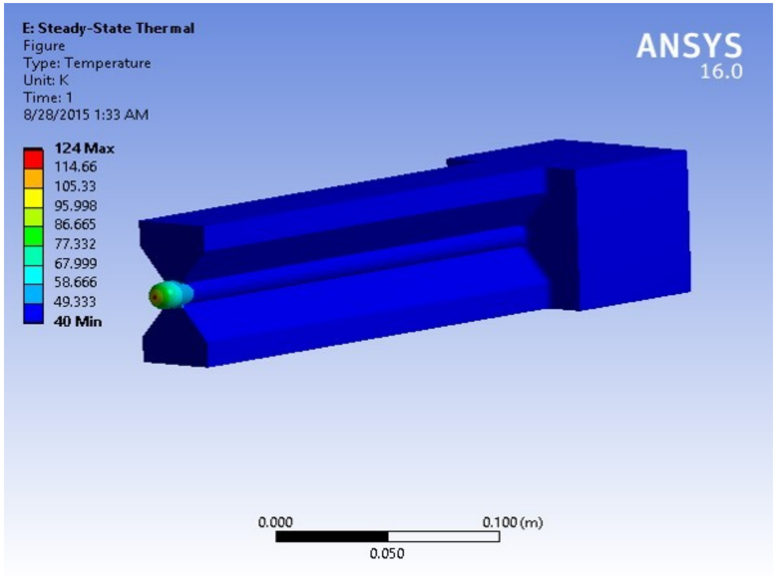
- **Design**



Main Body and Entrance
Window made of ASTM B209
AL 7075-T651

090 Ci of T2 (0.1 g)
~ 200 psi @295 K
L = 25 cm and ID = 12.7 mm
Volume = 34 cc

- **Beam Heating**



$I_{beam} = 20\mu A$ Max beam current
$A_{raster} = 2x2mm^2$ min raster

3W in Entrance
3.3 W in Exit
$T_{max} = 125K$ on exit
$T_{max} = 120K$ on entrance