$\frac{F_2^n}{F_2^p}$ and EMC Ratios from MARATHON

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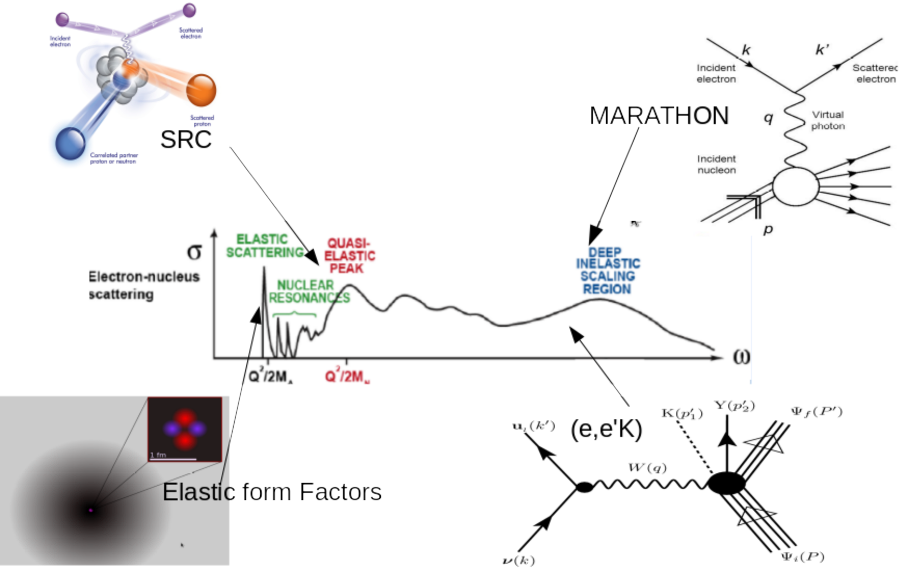
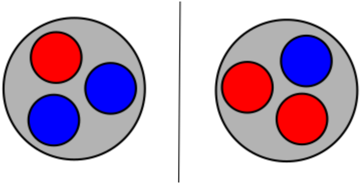
Tritium Experiments



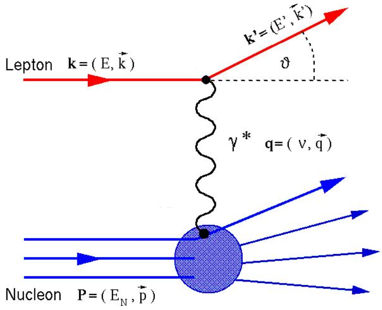
MARATHON

MeAsurement of $F_2^n/F_2^p, d/u$ RAtios and $A = 3$ EMC Effect in Deep Inelastic Electron Scattering off the Tritium and Helium MirrOr Nuclei.



- Lightest and simplest mirror system
  - Number of protons in ^3H = neutrons in ^3He
- Differences in the nuclear effects are small
- Improve the current measurement and understanding of F_2^n/F_2^p ratio
- Restrict the assumptions and parameters made in the model calculations of the down to up quark distribution ratio

Deep Inelastic Scattering (DIS)



- $Q^2 \equiv 4EE' sin^2 \frac{\theta}{2}$
- $X_{Bj} = \frac{Q^2}{2\nu M}$
- $\sigma_{eN} = \frac{\alpha^2}{eE^2 sin^4(\frac{\theta}{2})}[\frac{F_2}{\nu} cos^2 \frac{\theta}{2} + \frac{2F_1}{M} sin^2 \frac{\theta}{2}]$
- $W^2 = 2M\nu + M^2 - Q^2$
- $W^2 > 4 \rightarrow$ DIS

SLAC/CERN Data Interpretation in QPM

- Nachtmann inequality satisfied: $1/4 \leq F_2^n / F_2^p \leq 4$
- For $x \rightarrow 0$: $F_2^n/F_2^p \rightarrow 1$: Sea quarks dominate with:

$$u + \bar{u} = d + \bar{d} = s + \bar{s}$$

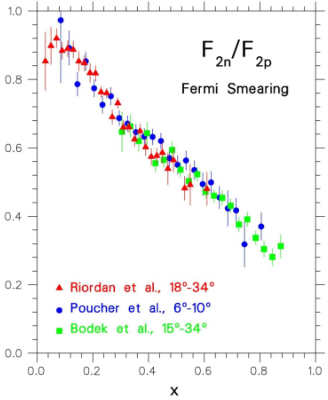
- For $x \rightarrow 1$: $F_2^n/F_2^p \rightarrow 1/4$: High momentum partons in proton (neutron) are up (down) quarks, and:

$$s + \bar{s} = 0$$

- For medium and high x, safe to assume that (with d and u denoting now quark plus antiquark distributions):

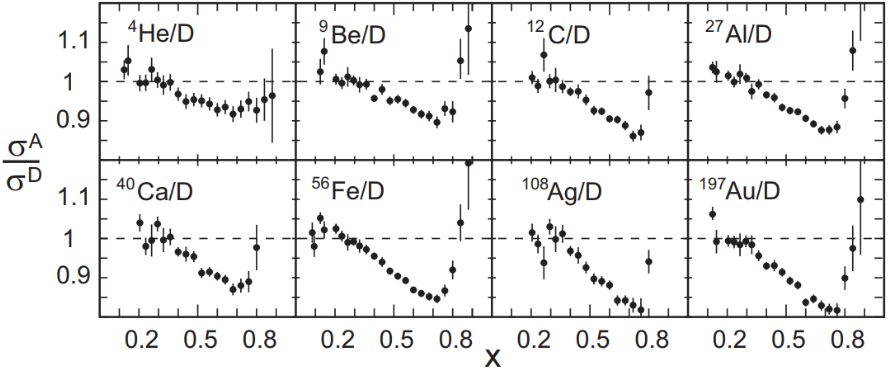
$$\frac{F_2^n}{F_2^p} = \frac{[1 + 4(d/u)]}{[4 + (d/u)]}$$

Makis Petratos



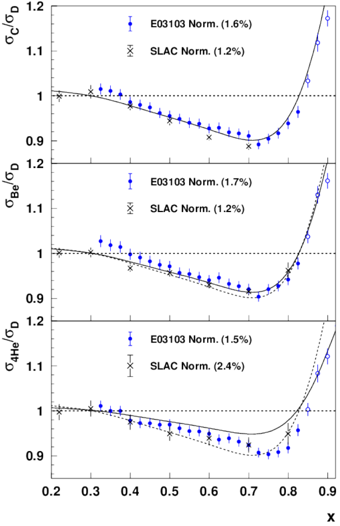
EMC Effect

SLAC experiment E139 [J. Gomez et al., 1994] .

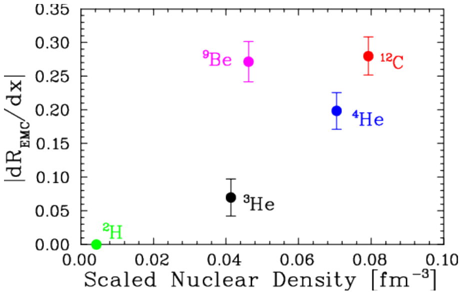


EMC Effect

JLab experiment E03103
[J.Seely, A. Daniel et al]



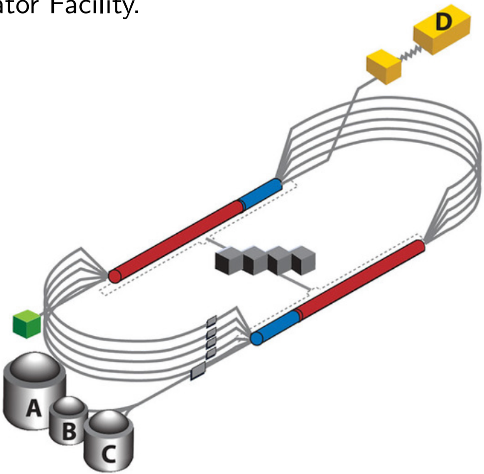
EMC as a function of Nuclear Density.
[J.Seely, A. Daniel et al]



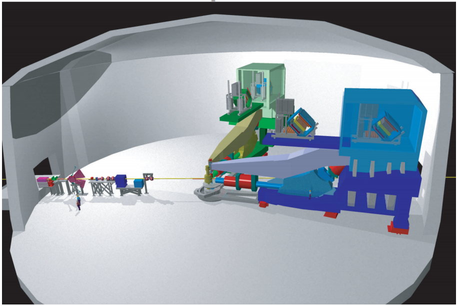
Scaled by $\frac{(A-1)}{A}$

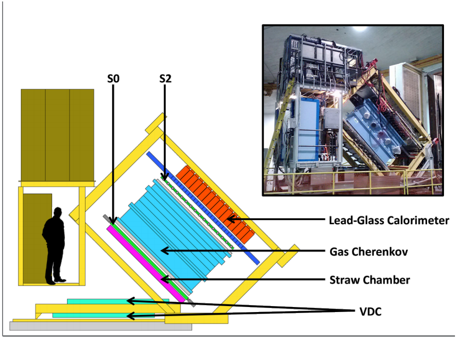
CEBAF

The Continuous Electron Beam Accelerator Facility (CEBAF) at Thomas Jefferson Accelerator Facility.



Hall A & The HRSs





Systematics: ^3H Decay

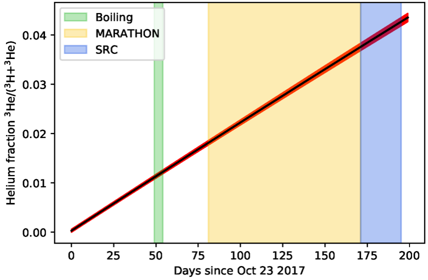
$^3H \rightarrow ^3He$

$$\tau(^3H) = 4500 \pm 8 days$$

$$c = \frac{\eta_{^3He}}{\eta_{tot}}$$

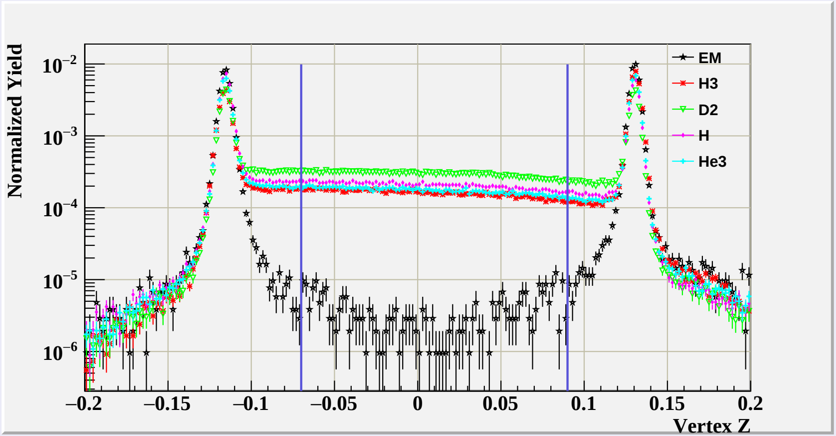
$$\sigma_{^3H} = \left(\frac{\sigma_{tot}}{\sigma_{^3He}}\right)\left(\frac{1}{1-c}\right) - \left(\frac{1}{1-c}\right)$$

Beta Decay Helium Fraction



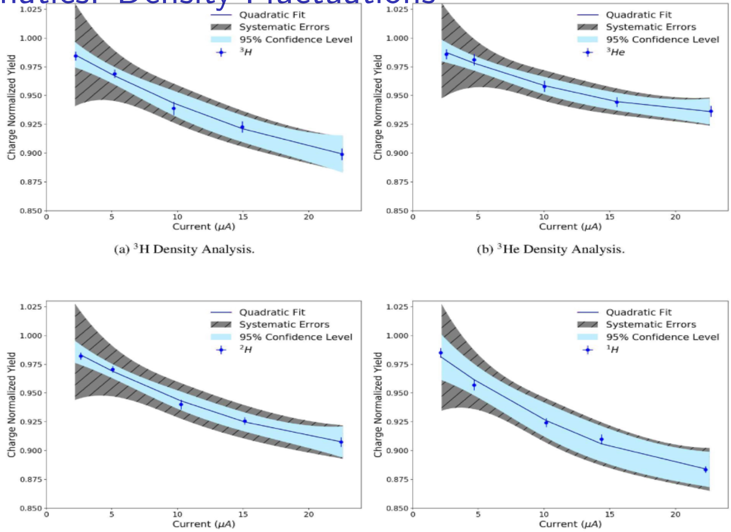
Tyler Kutz

Systematics: Endcaps



- Extract ratio of the normalized yield from the gas cell to that of the empty cell

Systematics: Density Fluctuations



(a) ^{3}H Density Analysis.

(b) ^{3}He Density Analysis.

(c) ^{2}H Density Analysis.

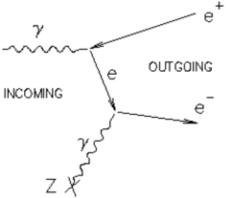
(d) ^{1}H Density Analysis.

[S.N.Santiestebana et. al]

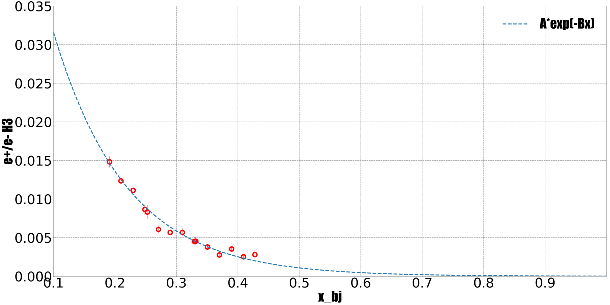
Charge Symmetric back ground

- γ decay into an e^+e^- pairs
- Pair produced $^-$ by detecting e^+
- Extraction based on fit to Exponential function

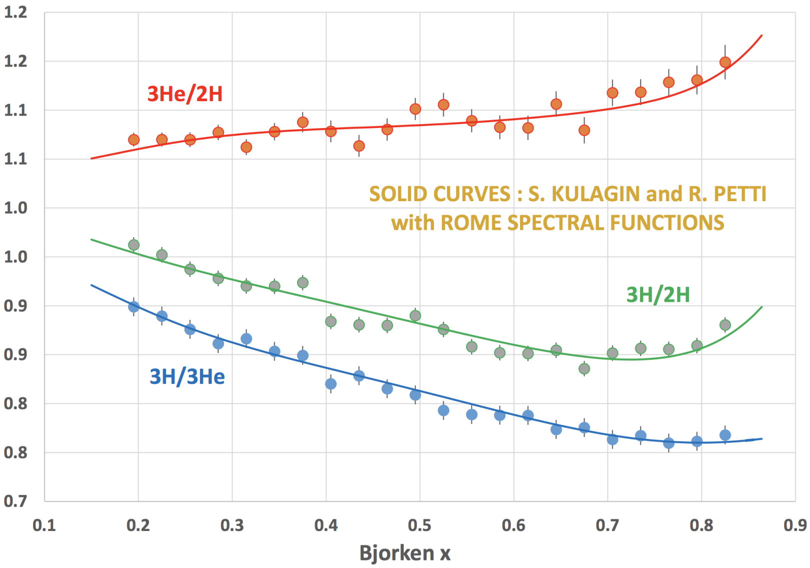
Pair Production



Tritium positron contamination. Credit: Tong Su



Ratio of Yields



Extracting F2 ratio

- Form the "SuperRatio" of EMC-type ratios for A=3 mirror nuclei:

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

- Solve above equations for the $A=3$ structure function ratio:

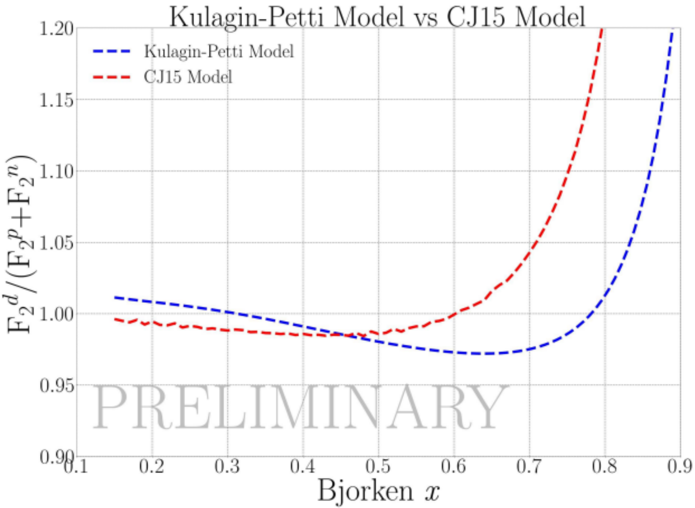
$$\frac{\sigma^{^3He}}{\sigma^{^3H}} = \frac{F_2^{^3He}}{F_2^{^3H}} = R^* \frac{2F_2^p + F_2^n}{F_2^p + 2F_2^n}$$

- Solve for the nucleon F_2 ratio and calculate it, using R^* from a reliable theoretical model (value of R^* is very close to unity with small uncertainty), and the measured $A=3$ DIS cross section ratio:

$$\frac{F_2^n}{F_2^p} = \frac{2R^* - \sigma^{^3He}/\sigma^{^3H}}{2\sigma^{^3He}/\sigma^{^3H} - R^*}$$

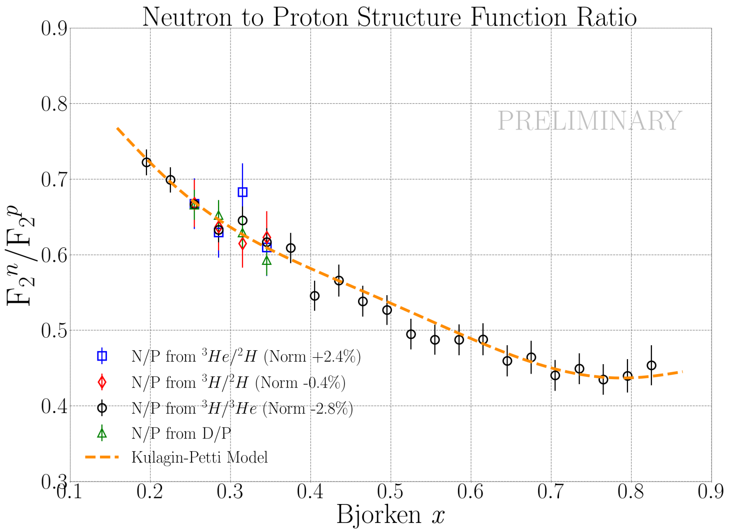
- Iterate the process until it converges to a stable F_2^n/F_2^p ratio.

Extracting F2 ratio

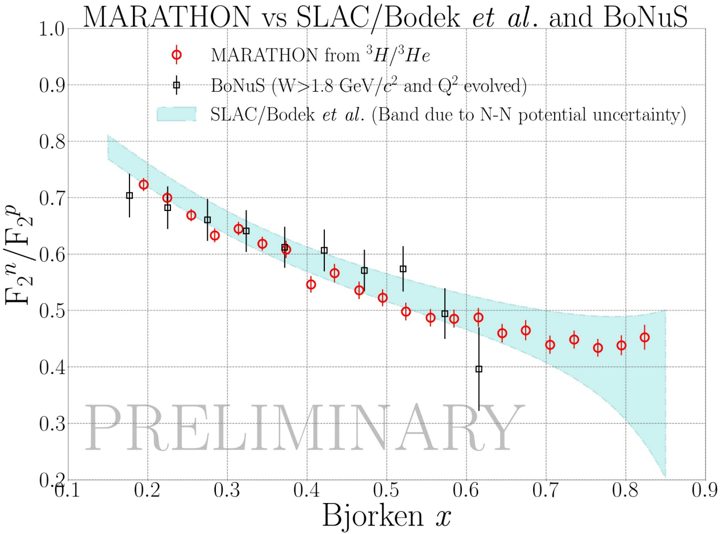


plot credit: Tong Su

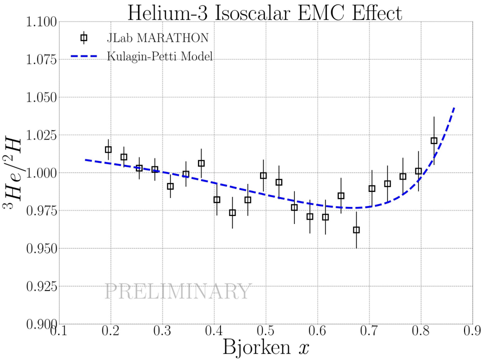
$\frac{F_2^n}{F_2^p}$ for D/p and $^3H/^3He$

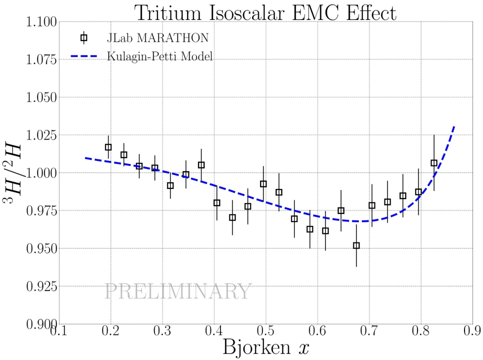


$\frac{F_2^n}{F_2^p}$


MARATHON vs SLAC/Bodek et al. and BoNuS
MARATHON from $^3H/^3He$
BoNuS (W>1.8 GeV/c^2 and Q^2 evolved)
SLAC/Bodek et al. (Band due to N-N potential uncertainty)
F_2^n/F_2^p
Bjorken x
PRELIMINARY
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9

EMC Effect





- ^3H normalized by -0.4%
- ^3He normalized by 2.4%
- Isoscalar corrections from MARATHON F_n(n/p)

Thank you!!

- MARATHON students
- Tritium collaboration
- Hall A Collaboration
- Nadia Fomin and Doug Higinbotham
- DOE and JSA

The JLab MARATHON Tritium Collaboration

D. Abrams, H. Albataineh, **S. Alsalmi**, D. Androic, K. Aniol, W. Armstrong, J. Arrington, H. Atac, T. Averett, C. Ayerbe Gayoso, X. Bai, **J. Bane***, **S. Barcus**, A. Beck, V. Bellini, H. Bhatt, D. Bhetuwal, D. Biswas, D. Blyth, W. Boeglin, D. Bulumulla, A. Camsonne, **M. Carmignotto**, **J. Castellanos**, J-P. Chen, C. Ciofi degli Atti, E. O. Cohen, S. Covrig, K. Craycraft, **R. Cruz-Torres**, B. Dongwi, M. Duer, B. Duran, D. Dutta, N. Fomin, E. Fuchey, C. Gal, T. N. Gautam, S. Gilad, K. Gnanvo, T. Gogami, J. Gomez, C. Gu, A. Habarakada, **T. Hague***, O. Hansen, M. Hattawy, **F. Hauenstein**, O. Hen, D. W. Higinbotham, R. Holt, E. Hughes, C. Hyde, H. Ibrahim, S. Jian, S. Joosten, A. Karki, B. Karki, A. T. Katramatou, C. Keppel, M. Khachatryan, V. Khachatryan, A. Khanal, D. King, P. King, I. Korover, S. A. Kulagin, **T. Kutz***, N. Lashley-Colthirst, G. Laskaris, **S. Li**, W. Li, **H. Liu***, S. Liuti, N. Liyanage, D. Lonardoni, R. Machleidt, L.E. Marcucci, P. Markowitz, **E. McClellan**, D. Meekins, W. Melnitchouk, S. Mey-Tal Beck, Z-E. Meziani, R. Michaels, M. Mihovilovič, V. Nelyubin, **D. Nguyen**, N. Nuruzzaman, **M. Nycz***, R. Obrecht, M. Olson, L. Ou, V. Owen, E. Pace, **B. Pandey**, V. Pandey, A. Papadopoulou, M. Paolone, S. Park, M. Patsyuk, S. Paul, G. G. Petratos, R. Petti, E. Piasetzky, R. Pomatsalyuk, S. Premathilake, A. J. R. Puckett, V. Punjabi, R. Ransome, M. N. H. Rashad, P. E. Reimer, S. Riordan, J. Roche, F. Sammarruca, G. Salmè, **N. Santiesteban**, B. Sawatzky, J. Segal, E. P. Segarra, B. Schmookler, A. Schmidt, S. Scopetta, A. Shahinyan, S. Širca, N. Sparveris, **T. Su***, R. Suleiman, H. Szumila-Vance, A. S. Tadepalli, L. Tang, W. Tireman, F. Tortorici, G. Urciuoli, M. Viviani, L. B. Weinstein, B. Wojtsekhowski, S. Wood, **Z. H. Ye**, Z. Y. Ye, and J. Zhang.

More than 140 Collaborators

Red-Boldfaced Names: Tritium Program grad students; **starred**: MARATHON Ph.D. students

Blue-Boldfaced Names: Tritium Program postdoctoral associates

The JLab MARATHON Tritium Collaboration

Forty Five Institutions (in no particular order): University of Virginia; Texas A & M University; Kent State University; University of Zagreb; California State University, Los Angeles; Argonne National Laboratory; Temple University; The College of William and Mary; University of Tennessee; Massachusetts Institute of Technology; INFN Sezione di Catania; INFN Sezione di Roma, INFN Sezione di Pisa; Mississippi State University; Hampton University; Florida International University; Old Dominion University; Jefferson Lab; University of Perugia; Tel Aviv University; University of Connecticut; Tohoku University; Columbia University; Cairo University; Ohio University; Stony Brook, State University of New York; Syracuse University; Nuclear Research Center-Negev, Beer-Sheva; Institute for Nuclear Research of the Russian Academy of Sciences; University of New Hampshire; University of Regina; Columbia University; Facility for Rare Isotope Beams, Michigan State University; Los Alamos National Laboratory; University of Idaho; University of Pisa; Jožef Stefan Institute, University of Ljubljana; Johannes Gutenberg-Universität Mainz; Saint Norbert College; Center for Neutrino Physics, Virginia Tech; University of South Carolina; Kharkov Institute of Physics and Technology; Norfolk State University; Rutgers University; Artem Alikhanian National Laboratory; Tel Aviv University; Northern Michigan University; University of Illinois, Chicago.

Twelve Countries: Armenia, Canada, Croatia, Egypt, Germany, Israel, Italy, Japan, Russia, Slovenia, Ukraine, United States.

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