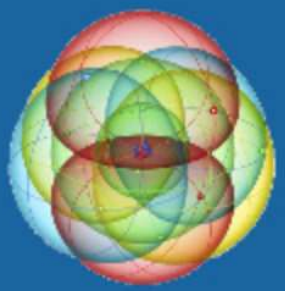
Broader Applications of Nuclear Science and Technology

Graham Peaslee
Department of Physics & Astronomy



NSAC Long Range Plan Town Hall Meeting on Nuclear Structure, Reactions and Astrophysics

November 14, 2022

Nuclear _____

Fill in the blank…

Nuclear Science

What if you asked the public…

Politicians, Funding Agencies, New students…

Nuclear Science

Nuclear Energy

Nuclear Weapons

Nuclear Medicine

Nuclear States…

Known widely for its applications…

Nuclear Science

Fundamental: *Structure, Reactions…*

Applied:

Reactors *Accelerators*

Energy

Weapons

Medicine

Ion Implantation

Art, Archeometry

Trace Elements

Nuclear Medicine

^{99}**Tc** Bone scans
+Myocardial perfusion
+Functional brain imaging
+Immunoscintigraphy
+spleen scans
+diverticulosis

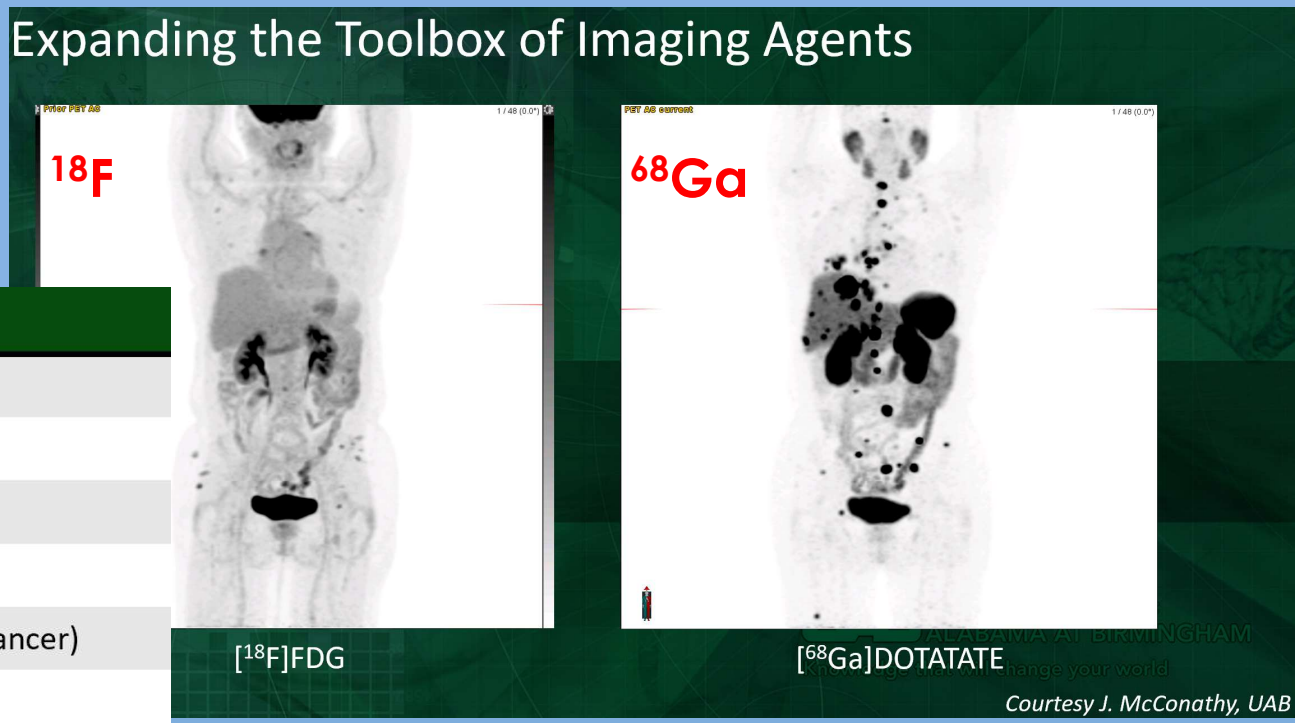
Isotopes: Therapeutic,
Diagnostic,
Theragnostic…

Nuclear Medicine

Expanding the toolbox

From: S. Lapi UAB

Radiopharmaceutical	Use
[^{18}F]FLT	Proliferation
[^{13}N]NH_3	Cardiac blood flow
[^{68}Ga]DOTATATE	SSTR status
[^{18}F]FMISO	Hypoxia
[^{89}Zr]Trastuzumab	HER2 status (breast cancer)
[^{18}F]FET	Amino acid transport
[^{11}C]PiB	Amyloid
[^{18}F]DPA-714	TSPO (neuroinflammation)
[^{68}Ga]PSMA-11	PSMA status (prostate cancer)
[^{89}Zr]Panitumumab	EGFR status (colon cancer)
[^{18}F]AV1451	Tau protein
[^{68}Ga]GZP*	Granzyme B (Immune Activation)
[^{11}C]Acetate	Cardiac Metabolism
[^{89}Zr]Oxine/White Blood Cells*	WBC tracking
[^{18}F]FES	Estrogen receptor
[^{68}Ga]FAP-2286	Fibroblast Activation Protein



Therapeutic,

Diagnostic,

Theragnostic…

Nuclear Medicine

>1500 cyclotrons worldwide
> 200 in US

Medical Accelerators: Therapeutic

Isotope production

Now including a LINAC: FRIB & Isotope Harvesting

Need for more research:

Isotope production on the proton-rich side:

Applied Radiation and Isotopes 178 (2021) 109935 2021

Contents lists available at ScienceDirect

Applied Radiation and Isotopes

journal homepage: www.elsevier.com/locate/apradiso

A heavy-ion production channel of ^{149}Tb via ^{63}Cu bombardment of ^{89}Y

John T. Wilkinson [a,*], Kendall E. Barrett [b], Samuel J. Ferran [c], Sean R. McGuinness [a], Lauren A. McIntosh [d], Mallory McCarthy [d], Sherry J. Yennello [d], Jonathan W. Engle [b], Suzanne E. Lapi [c], Graham F. Peaslee [a]

Avoiding ^{149m}Tb production

2021 www.nature.com/scientificreports

scientific reports

^{16}O+ ^{nat}Cu instead of:
p + ^{78}Se
α + ^{75}As

OPEN

Heavy-ion production of ^{77}Br and ^{76}Br

Sean R. McGuinness✉, John T. Wilkinson & Graham F. Peaslee

Need for more research:

The problems with ^{44}Sc isotope production

Physical characteristics of relevant Sc radioisotopes

Radionuclide	Half-life	Decay mode	Energy of particles or photons (keV)
^{43}Sc	3.89 h	β^+	1198
			825
		γ	372
^{44g}Sc	3.97 h[a]	β^+	1475
		γ	1157
^{44m}Sc	58.6 h	γ	271
			1002
			1126
			1157
^{46}Sc	83.79 d	β^-	357
		γ	889
			1121
^{47}Sc	3.35 d	β^-	600
			439
		γ	153
			1120

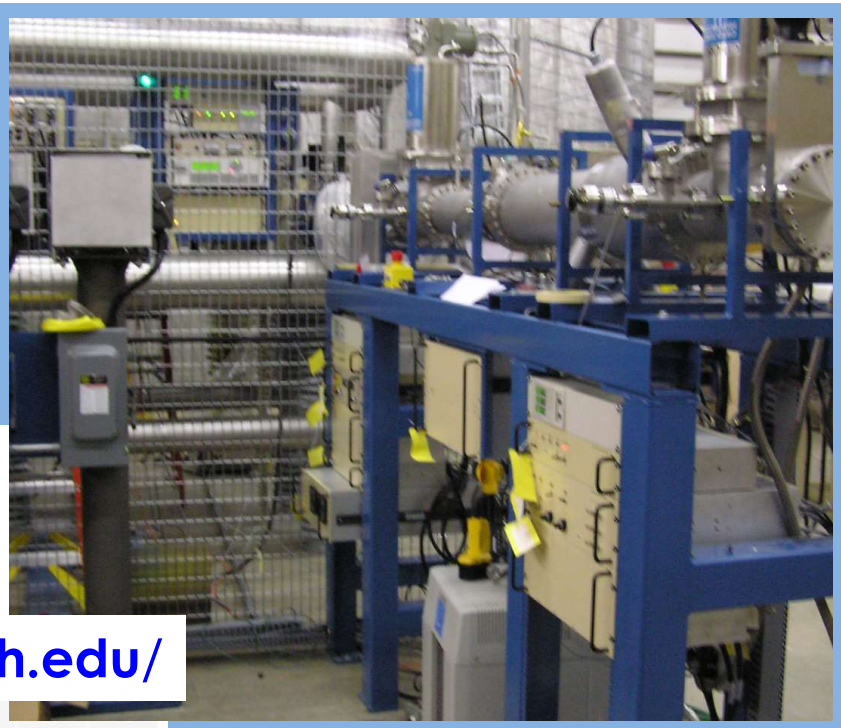
2022 ^{27}Al(^{19}F,p2n)….

^{46}Ti (p,α)….

^{44}Ca(p,n)….

Ion Implantation

Materials modifications



Ion Beams Produced in the 400 kV NEC Implanter

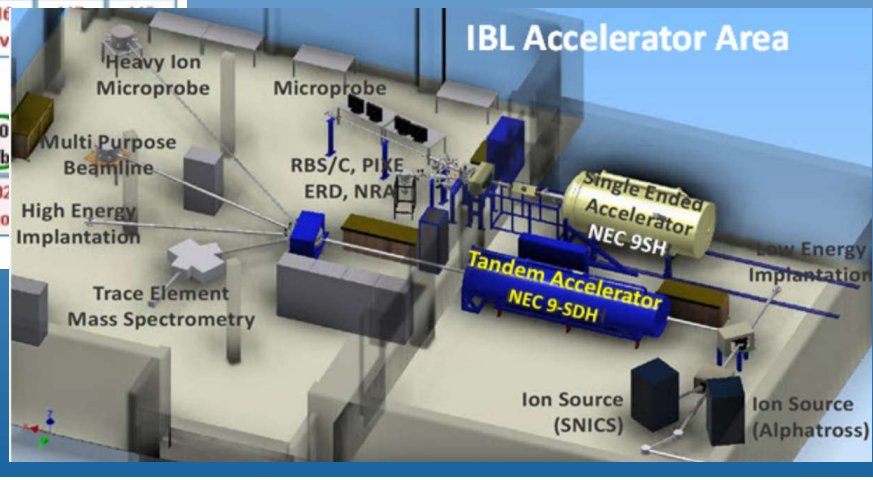
○ Ions implanted (42)

https://mibl.engin.umich.edu/

Group	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Period 1	1 H																	2 He
2	3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
3	11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
4	19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
5	37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
6	55 Cs	56 Ba	57-71	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
7	87 Fr	88 Ra	89-103	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg	112 Cn	113 Uut	114 Fl	115 Uup	116 Lv		

57 La	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb
89 Ac	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No

UNT Ion Beam Laboratory

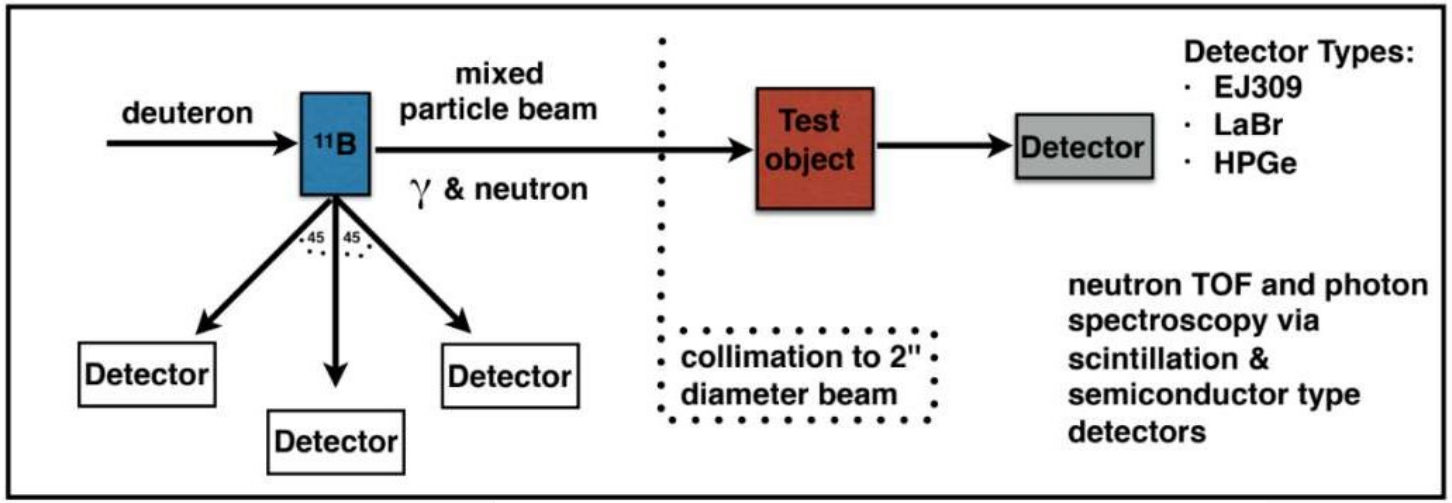


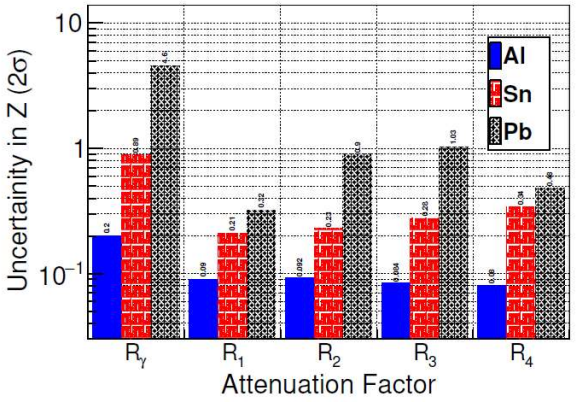
DHS: Tomography with neutron beams

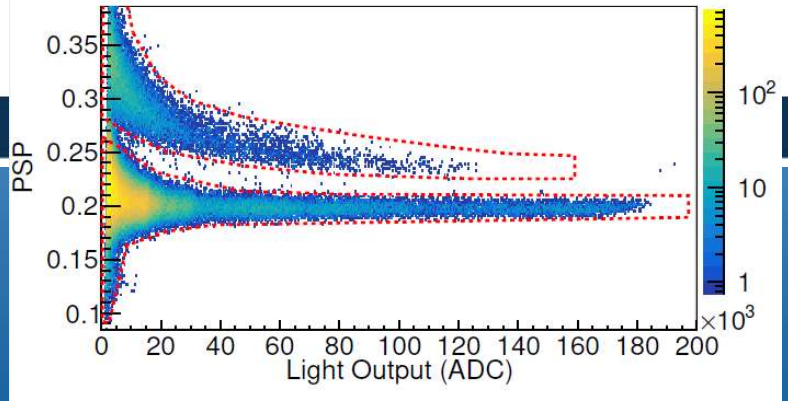
PHYSICAL REVIEW APPLIED **11,** 044085 (2019)

High-Contrast Material Identification by Energetic Multiparticle Spectroscopic Transmission Radiography

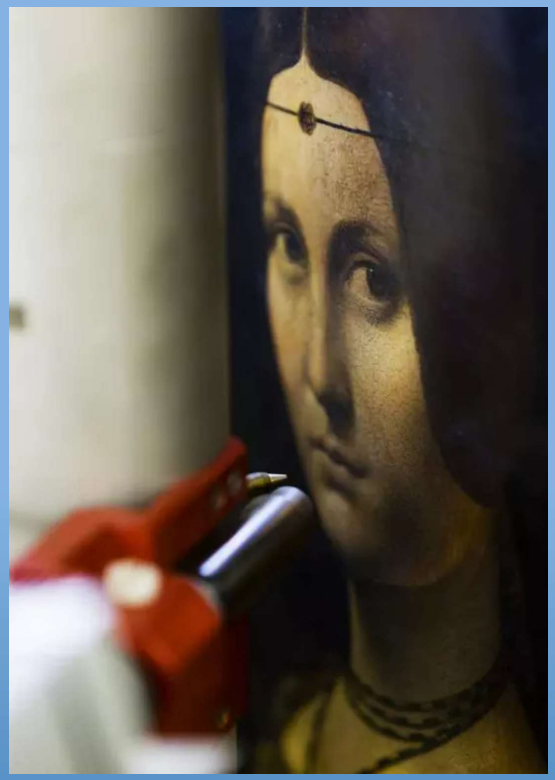
J. Nattress,[1,*,†] T. Nolan,[1] S. McGuinness,[2] P. Rose,[3,†] A. Erickson,[3] G. Peaslee,[2] and I. Jovanovic[1]







Environmental Applications



PIXE Art verification

AGLAE: Accélérateur Grand Louvre d'analyse élémentaire

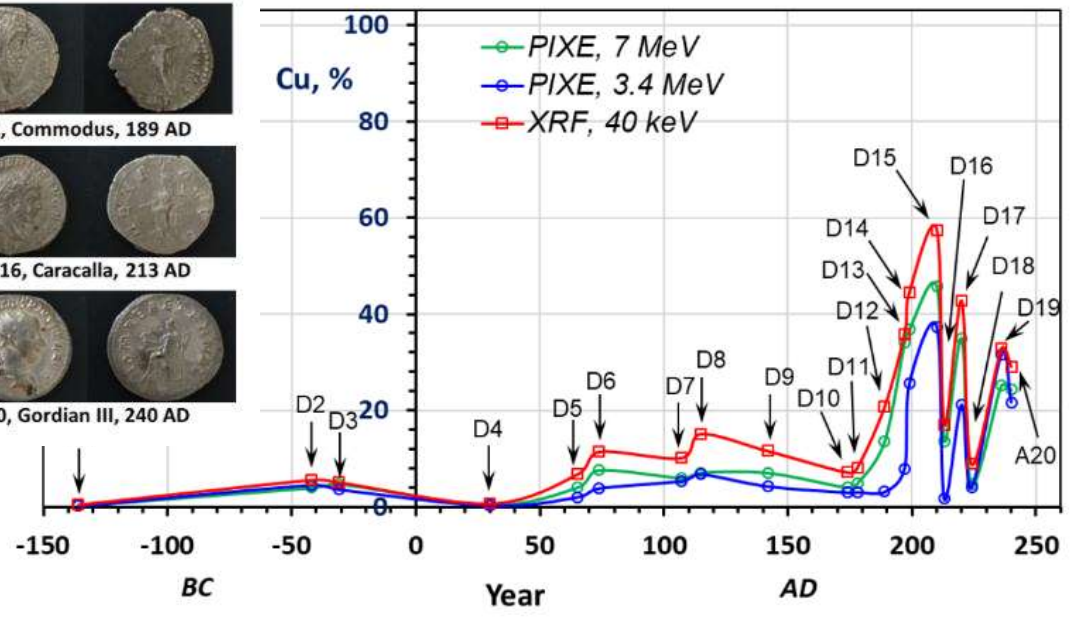
Applied Surface Science
Volume 493, 1 November 2019, Pages 818-828

Full length article

Surface manipulation techniques of Roman denarii

Khachatur Manukyan, Cecilia Fasano, Ashabari Majumdar, Graham F. Peaslee, Mark Raddell, Edward Stech, Michael Wiescher

Differential PIXE



Environmental Applications

Radiocarbon dating via AMS

Historical Radiocarbon via AMS

Climate Research: UC-Irvine

3700 yo : Ötzi the Iceman

Pharma Applications

Use sensitivity of AMS (10^{-18} moles ^{14}C) to trace carbon pharmacokinetics in human subject trials…

LLNL 250 kV SSAMS spectrometer for biomedical ^{14}C measurements

ELSEVIER

Identification and Quantification of Drugs, Metabolites, Drug Metabolizing Enzymes, and Transporters (Second Edition)

Concepts, Methods, and Translational Sciences

2020, Pages 185-210

Chapter 6 - AMS in drug development: Exploring the current utility of AMS and future opportunities for absolute bioavailability and ADME investigations

Absorption, Distribution, Metabolism and Excretion.

Courtesy of CAMS

Environmental Applications

PIGE Analysis of ^{19}F

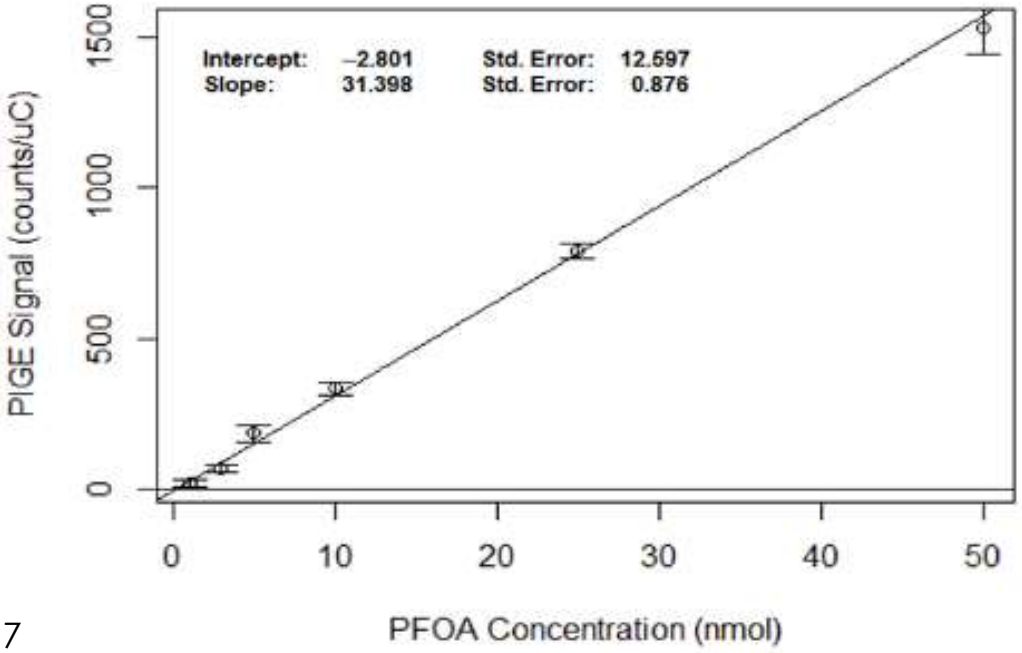
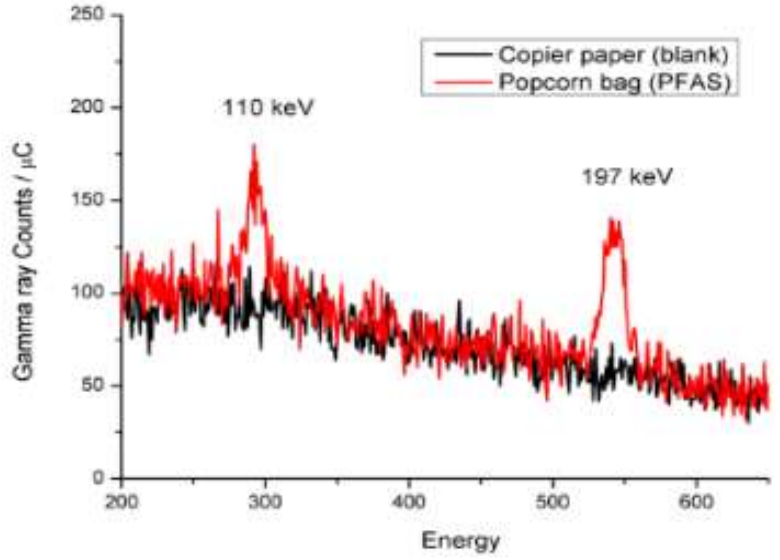
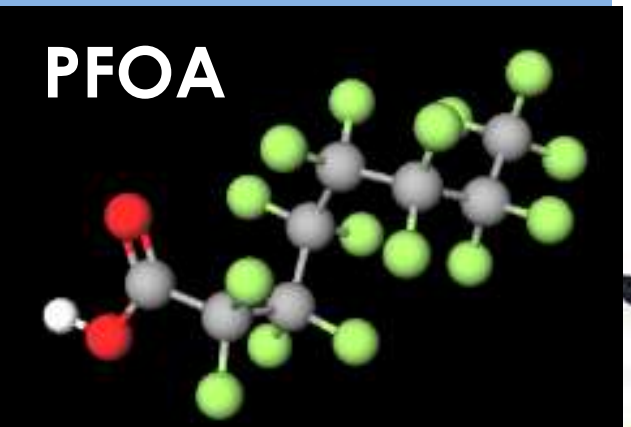
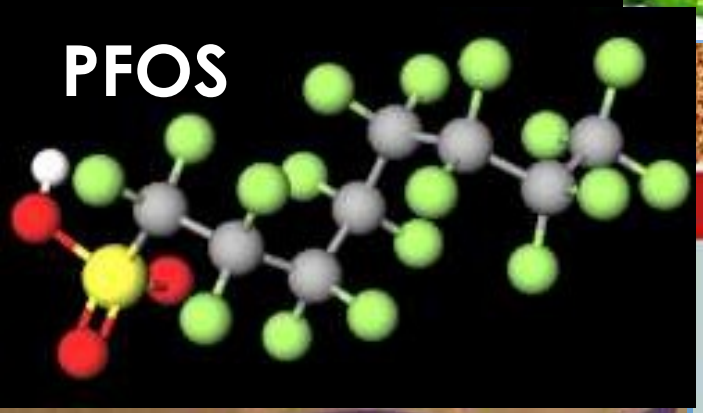


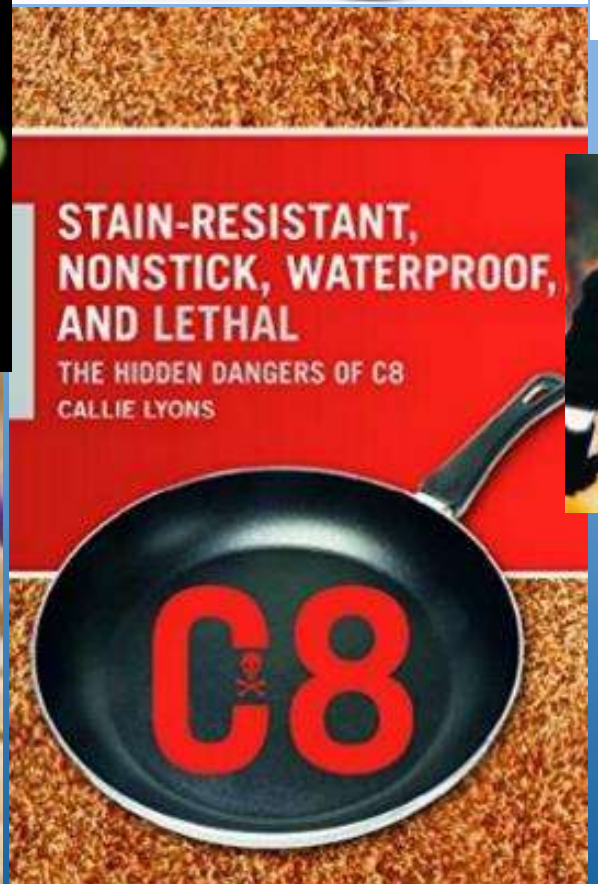
Fig. 3: PFAS-coated paper sample compared with uncoated paper. Irradiation time of 180 second with 9 nA of 3.4 MeV protons.



The "Forever" Chemicals: PFAS







ENVIRONMENTAL Science & Technology LETTERS

> 39,900 downloads to date

> 350 citations

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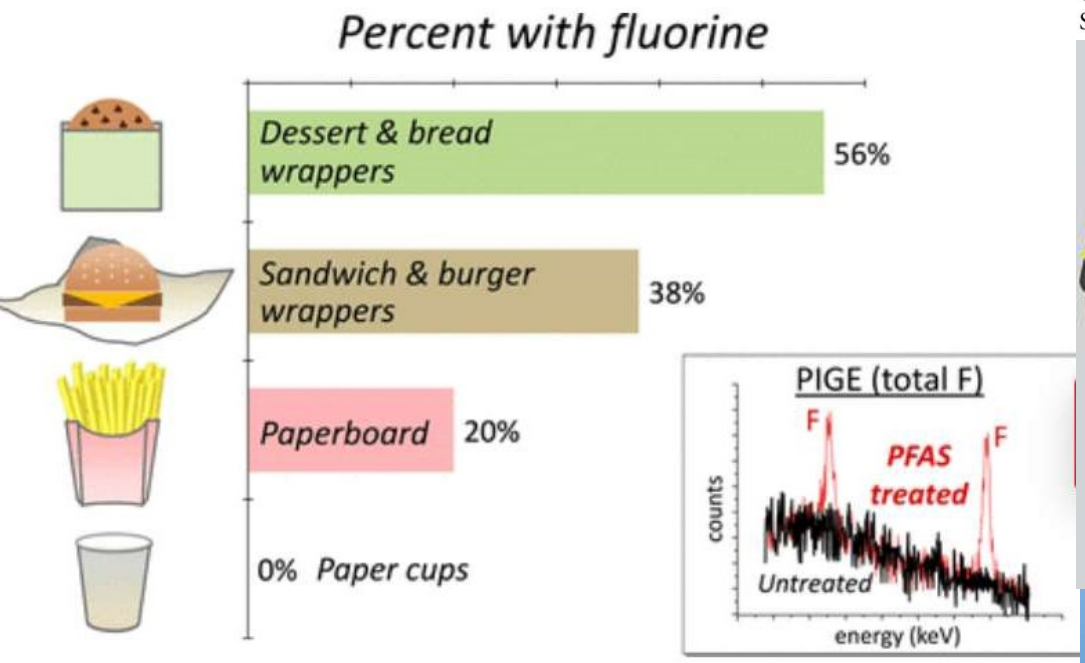
2017

Fluorinated Compounds in U.S. Fast Food Packaging

Laurel A. Schaider,*[†] Simona A. Balan,[‡] Arlene Blum,[§,∥] David Q. Andrews,[⊥] Mark J. Strynar,[#] Margaret E. Dickinson,[▽] David M. Lunderberg,[▽] Johnsie R. Lang,[○] and Graham F. Peaslee[@]



ENVIRONMENTAL Science & Technology LETTERS

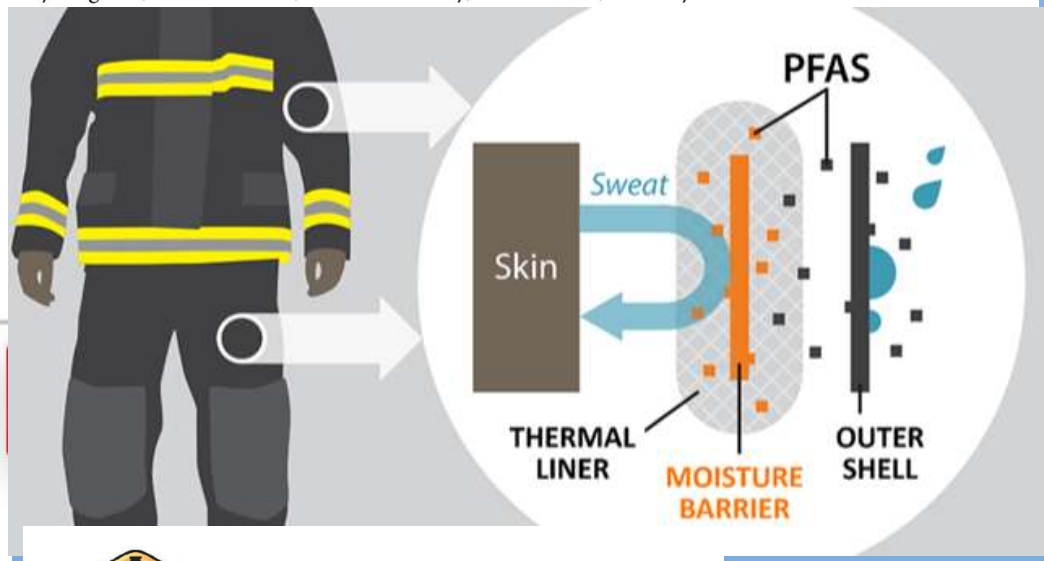
2020

pubs.acs.org/journal/estlcu

Letter

Another Pathway for Firefighter Exposure to Per- and Polyfluoroalkyl Substances: Firefighter Textiles

Graham F. Peaslee,* John T. Wilkinson, Sean R. McGuinness, Meghanne Tighe, Nicholas Caterisano, Seryeong Lee, Alec Gonzales, Matthew Roddy, Simon Mills, and Krystle Mitchell



INTERNATIONAL ASSOCIATION OF FIRE FIGHTERS

NEWS RELEASE

1750 New York Ave. NW, Washington, D.C. 20006 www.iaff.org

For immediate release

International Association of F
University of Notre Dame stu
substances (PFAS) in fire figl

The research studies conducted b
the IAFF as they provide the data
fire fighters are most exposed to c

Dr. Peaslee's latest research ackr
PFAS from the use of AFFF, valid
firefighting and training. Dr. Peasl
another viable source of exposure

His research has provided new int
these chemicals could transfer fro
in direct contact with skin. This is
from PPE and present a risk of ex

This research, in addition to the nu
information to make changes to pr
the safety and health of our 320,0
understand the full impact of this c
fighters' gear.

CA Gets Tougher On PFAS Chemicals Under Ting Bill Signed By The Governor

FOR IMMEDIATE RELEASE:

Thursday, September 29, 2022

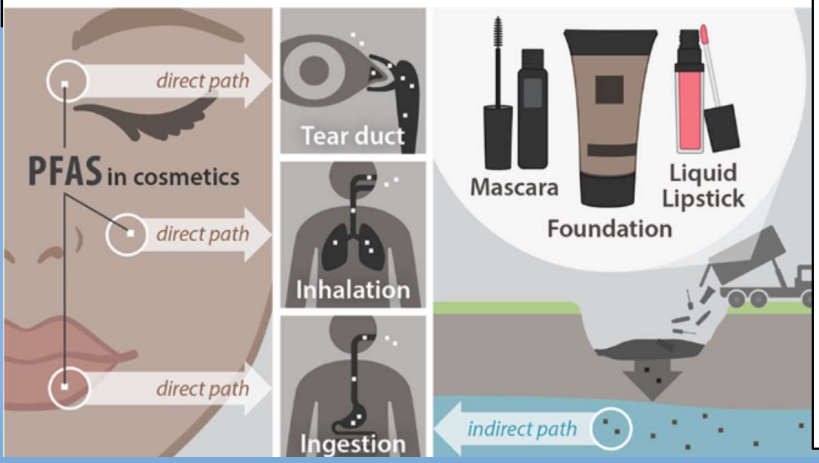
> 99,000 downloads to date
> 50 citations

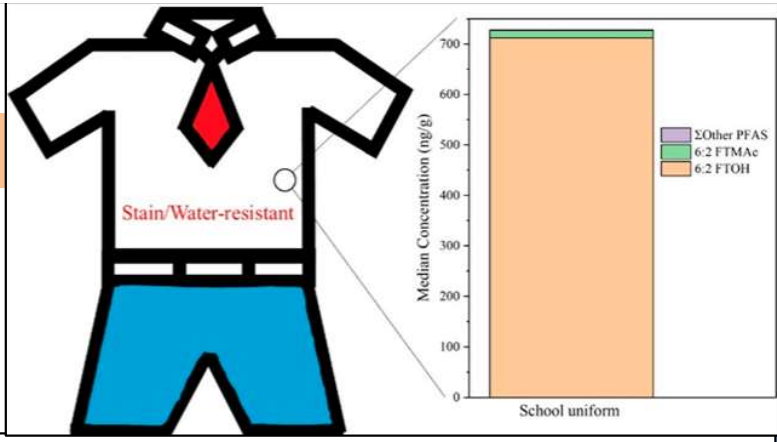
ENVIRONMENTAL Science & Technology LETTERS
2021
pubs.acs.org/journal/estlcu
Letter

Fluorinated Compounds in North American Cosmetics

Heather D. Whitehead, Marta Venier, Yan Wu, Emi Eastman, Shannon Urbanik, Miriam L. Diamond, Anna Shalin, Heather Schwartz-Narbonne, Thomas A. Bruton, Arlene Blum, Zhanyun Wang, Megan Green, Meghanne Tighe, John T. Wilkinson, Sean McGuinness, and Graham F. Peaslee*

Cite This: *Environ. Sci. Technol. Lett.* 2021, 8, 538–544 Read





ENVIRONMENTAL Science & Technology
2022
pubs.acs.org/est
Article

Per- and Polyfluoroalkyl Substances in North American School Uniforms

Chunjie Xia, Miriam L. Diamond, Graham F. Peaslee, Hui Peng, Arlene Blum, Zhanyun Wang, Anna Shalin, Heather D. Whitehead, Megan Green, Heather Schwartz-Narbonne, Diwen Yang, and Marta Venier*

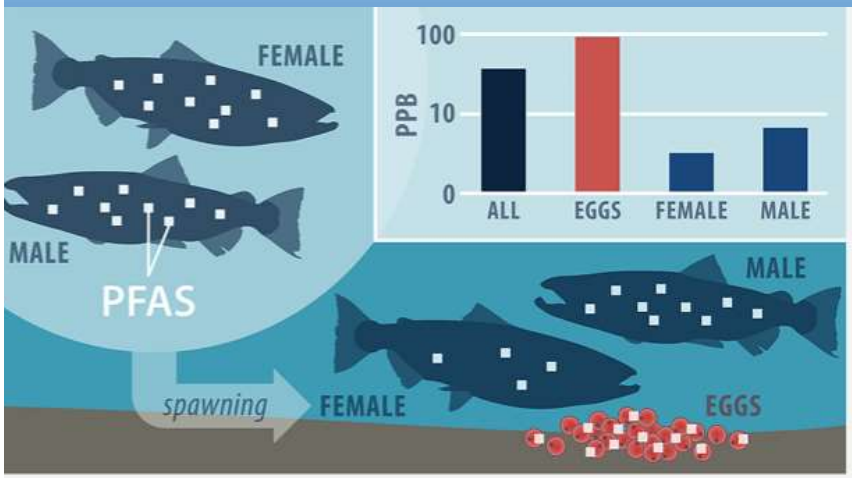
Cite This: *Environ. Sci. Technol.* 2022, 56, 13845–13857 Read Online

ENVIRONMENTAL Science & Technology LETTERS
2022
pubs.acs.org/journal/estlcu
Letter

Maternal Offloading of Per- and Polyfluoroalkyl Substances to Eggs by Lake Michigan Salmonids

Whitney M. Conard,* Heather D. Whitehead, Keegan J. Harris, Gary A. Lamberti, Graham F. Peaslee, and Amy A. Rand

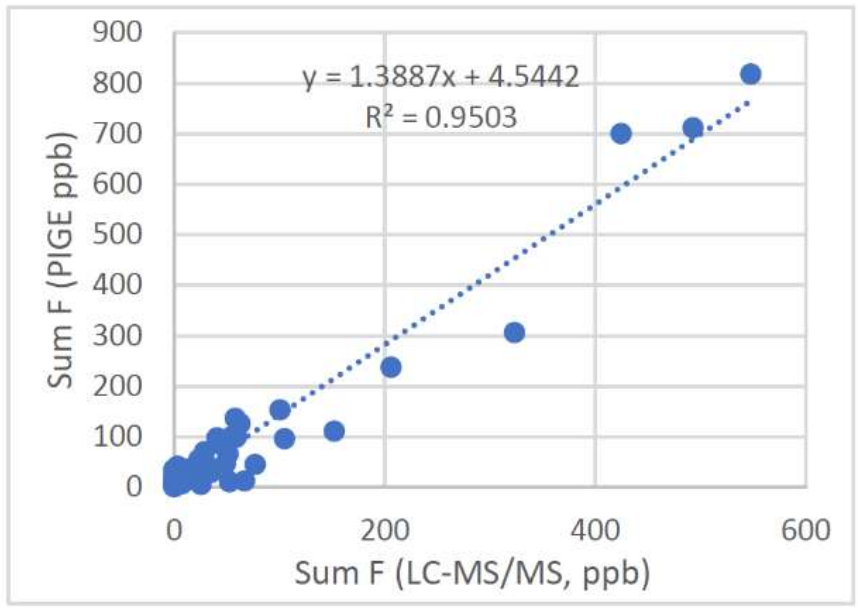
Cite This: https://doi.org/10.1021/acs.estlett.2c00627 Read Online



Environmental Applications

ESTCP

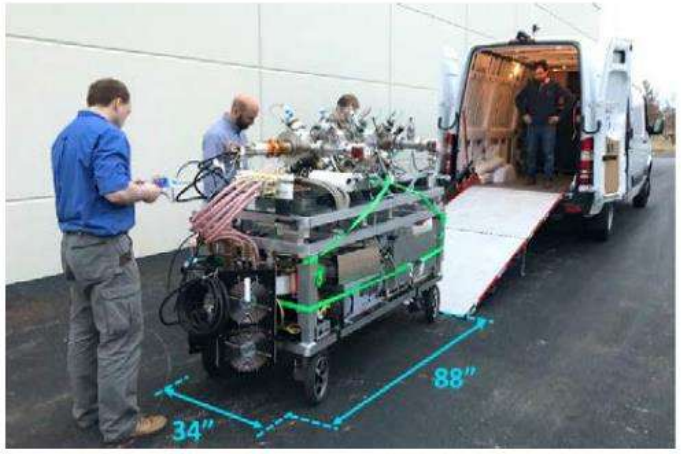
PIGE Screening Data: Groundwater (range of ppb Fl from multiple sample depths)



Field-Deployable PIGE Analysis

SERDP
DOD ▪ EPA ▪ DOE

starfire industries



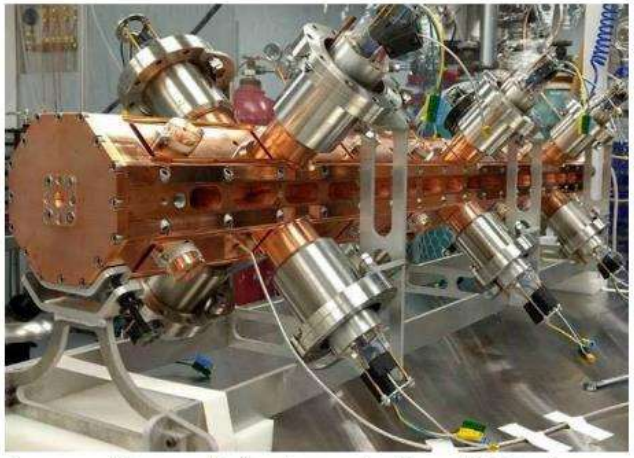
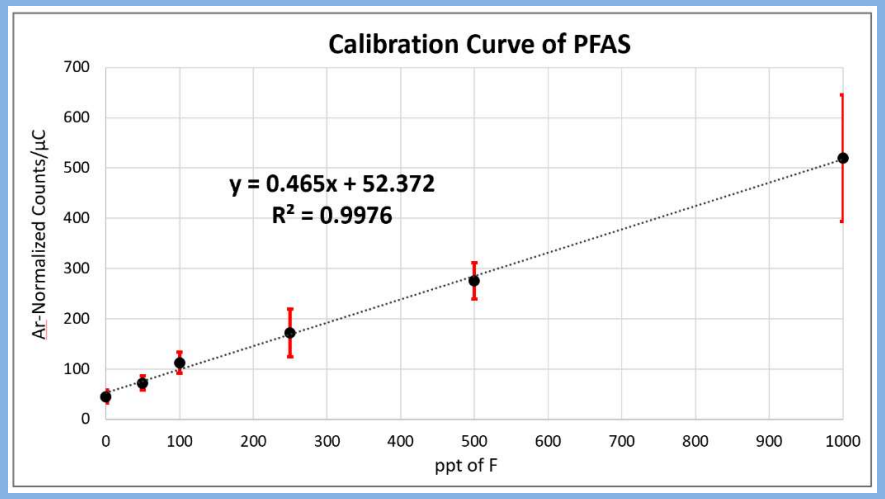


***Figure S4**: (Left) Centurion™ Mk1 system being loaded into a van for transport to an off-site demonstration >1000 miles away. (Right) The compact RFQ LINAC itself (shown assembled with Starfire's patent-pending RF power injectors) is approximately 4' long and can be modified for energies between 1—5 MeV.*

Environmental Applications

Field-deployable Solid-Phase Extraction/PIGE

GAC felt



PIGE analysis of ^{19}F : Screening for PFAS

High sensitivity in drinking water:
MDL <20 ng/L for 4.0 L samples

IDEA CENTER

Commercialization: Forever Analytical Services, LLC

The role of funding agencies…

Provide stable funding opportunities for basic research in nuclear science…

However, Federal budgets are rarely increasing and we are increasingly asked what is the purpose/benefits of basic research?

Including a small mix of applied nuclear science in the funding portfolio will increase visibility, attract students and can take advantage of current events to increase funding streams…

gpeaslee@nd.edu