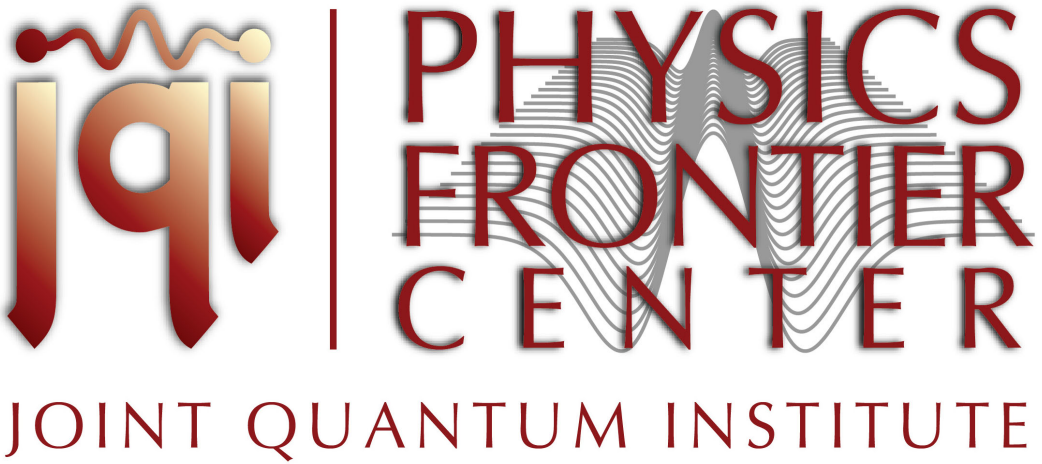


Francium after 80 years.

Les Houches,
April 2019

Luis A. Orozco
www.jqi.umd.edu

NIST

United Nations
Educational, Scientific and
Cultural Organization

International Year
of the Periodic Table
of Chemical Elements

This presnetation is available at:

http://www.physics.umd.edu/rgroups/amo/orozco/results/2019/Results19.htm

FrPNC Collaboration (Winter 2018-2019)

Seth Aubin; College of William and Mary, USA.
John A. Behr, Matt R. Pearson, Alexander Gorolov, Mukut R. Kalita; TRIUMF, Canada.
Victor V. Flambaum; University of New South Wales, Australia.
Eduardo Gómez; Universidad Autónoma de San Luis Potosí, México.
Gerald Gwinner SPOEKESPERSON Tim Hucko, Michael Kossin, ; University of Manitoba, Canada.
Luis A. Orozco; University of Maryland, USA.
Yanting Zhao; Shanxi University, Taiyuan, China.

Work supported by NRC, TRIUMF, and NSERC from Canada, DOE, and NSF of USA, and CONACYT of México.

ОПЫТЪ СИСТЕМЫ ЭЛЕМЕНТОВЪ.

ОСНОВАННОЙ НА ИХЪ АТОМНОМЪ ВѢСѢ И ХИМИЧЕСКОМЪ СХОДСТВѢ.

		Ti = 50	Zr = 90	? = 180.
		V = 51	Nb = 94	Ta = 182.
		Cr = 52	Mo = 96	W = 186.
		Mn = 55	Rh = 104,4	Pt = 197,1.
		Fe = 56	Ru = 104,4	Ir = 198.
		Ni = Co = 59	Pl = 106,6	Os = 199.
H = 1		Cu = 63,4	Ag = 108	Hg = 200.
	Be = 9,4	Mg = 24	Zn = 65,2	Cd = 112	
	B = 11	Al = 27,4	? = 68	Ur = 116	Au = 197?
	C = 12	Si = 28	? = 70	Sn = 118	
	N = 14	P = 31	As = 75	Sb = 122	Bi = 210?
	O = 16	S = 32	Se = 79,4	Te = 128?	
	F = 19	Cl = 35,6	Br = 80	I = 127	
Li = 7	Na = 23	K = 39	Rb = 85,4	Cs = 133	Tl = 204.
		Ca = 40	Sr = 87,6	Ba = 137	Pb = 207.
		? = 45	Ce = 92		
		?Er = 56	La = 94		
		?Yt = 60	Di = 95		
		?In = 75,6	Th = 118?		

Д. Менделѣевъ

The periodic table of elements

Reihen	Gruppo I. — R^1O	Gruppo II. — RO	Gruppo III. — R^2O^3	Gruppo IV. RH^4 RO^2	Gruppo V. RH^3 R^2O^5	Gruppo VI. RH^2 RO^3	Gruppo VII. RH R^2O^7	Gruppo VIII. — RO^4
1	H=1							
2	Li=7	Be=9,4	B=11	C=12	N=14	O=16	F=19	
3	Na=23	Mg=24	Al=27,3	Si=28	P=31	S=32	Cl=35,5	
4	K=39	Ca=40	—=44	Ti=48	V=51	Cr=52	Mn=55	Fe=56, Co=59, Ni=59, Cu=63.
5	(Cu=63)	Zn=65	—=68	—=72	As=75	Se=78	Br=80	
6	Rb=85	Sr=87	?Yt=88	Zr=90	Nb=94	Mo=96	—=100	Ru=104, Rh=104, Pd=106, Ag=108.
7	(Ag=108)	Cd=112	In=113	Sn=118	Sb=122	Te=125	J=127	
8	Cs=133	Ba=137	?Di=138	?Ce=140	—	—	—	— — — —
9	(—)	—	—	—	—	—	—	
10	—	—	?Er=178	?La=180	Ta=182	W=184	—	Os=195, Ir=197, Pt=198, Au=199.
11	(Au=199)	Hg=200	Tl=204	Pb=207	Bi=208	—	—	
12	—	—	—	Th=231	—	U=240	—	— — — —

Periodic Table of Elements

based on Mendeleev's Periodic Law

0	I	II	III	IV	V	VI	VII	VIII		
	H 1.01									
He 4.00	Li 6.94	Be 9.01	B 10.8	● C 12.0	N 14.0	O 16.0	F 19.0			
Ne 20.2	Na 23.0	Mg 24.3	Al 27.0	Si 28.1	P 31.0	● S 32.1	Cl 35.5			
Ar 40.0	K 39.1	Ca 40.1	Sc 45.0	Ti 47.9	V 50.9	Cr 52.0	Mn 54.9	● Fe 55.9	Co 58.9	Ni 58.7
	● Cu 63.5	Zn 65.4	Ga 69.7	Ge 72.6	As 74.9	Se 79.0	Br 79.9			
Kr 83.8	Rb 85.5	Sr 87.6	Y 88.9	Zr 91.2	Nb 92.9	Mo 95.9	Tc (99)	Ru 101	Rh 103	Pd 106
	● Ag 108	Cd 112	In 115	● Sn 119	Sb 122	Te 128	I 127			
Xe 131	Ce 133	Ba 137	● La 139	Hf 179	Ta 181	W 184	Re 180	Os 194	Ir 192	Pt 195
	● Au 197	● Hg 201	Ti 204	● Pb 207	Bi 209	Po (210)	At (210)			
Rn (222)	Fr (223)	Ra (226)	● Ac (227)	● Th 232	● Pa (231)	● U 238				

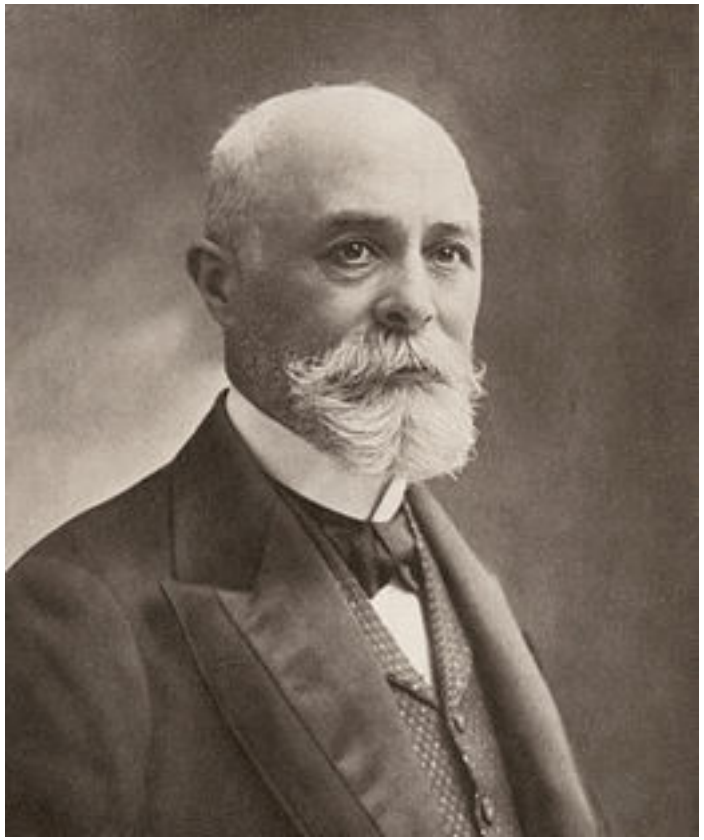
Dobereiner's triads

Known to Mendeleev

● Lanthanide series
● Actinide series
● Known to Ancients

The dashed line says it is a missing element
He moved the elements around to make their chemical properties similar.
Named eka- and predicted some properties for those elements missing but that should fit under.
That is why people would start looking for eka-caesium

Radioactivity: Something probabilistic in nature



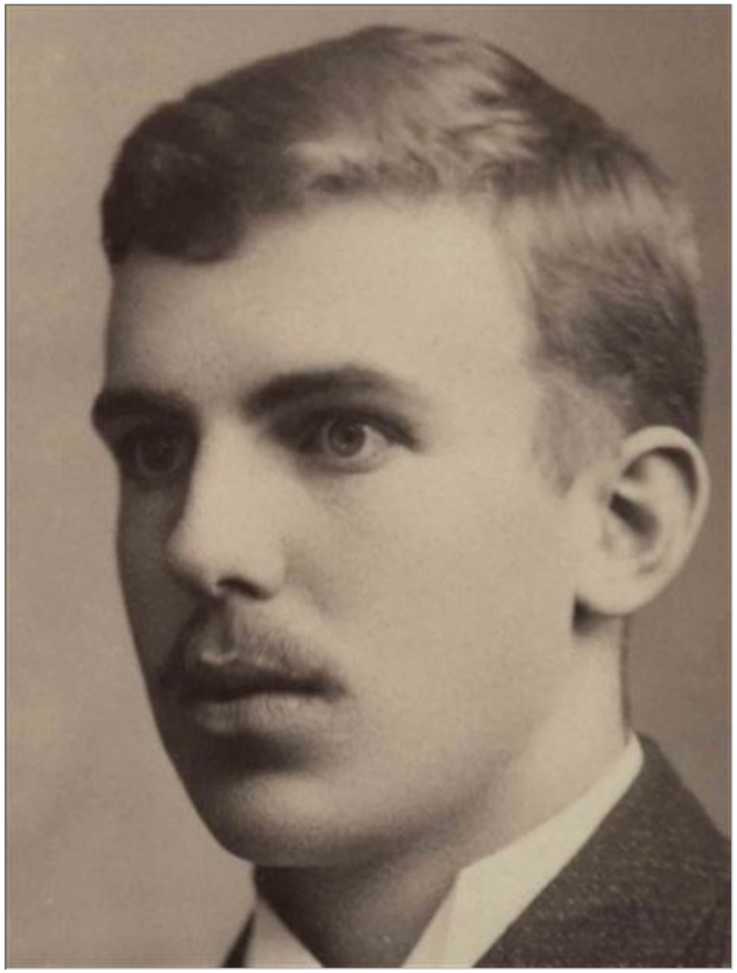
Henry Becquerel

February 27 1896

Pierre Curie

Marie Curie

Rutherford discovers there are two kinds of rays in radioactivity (α, β)

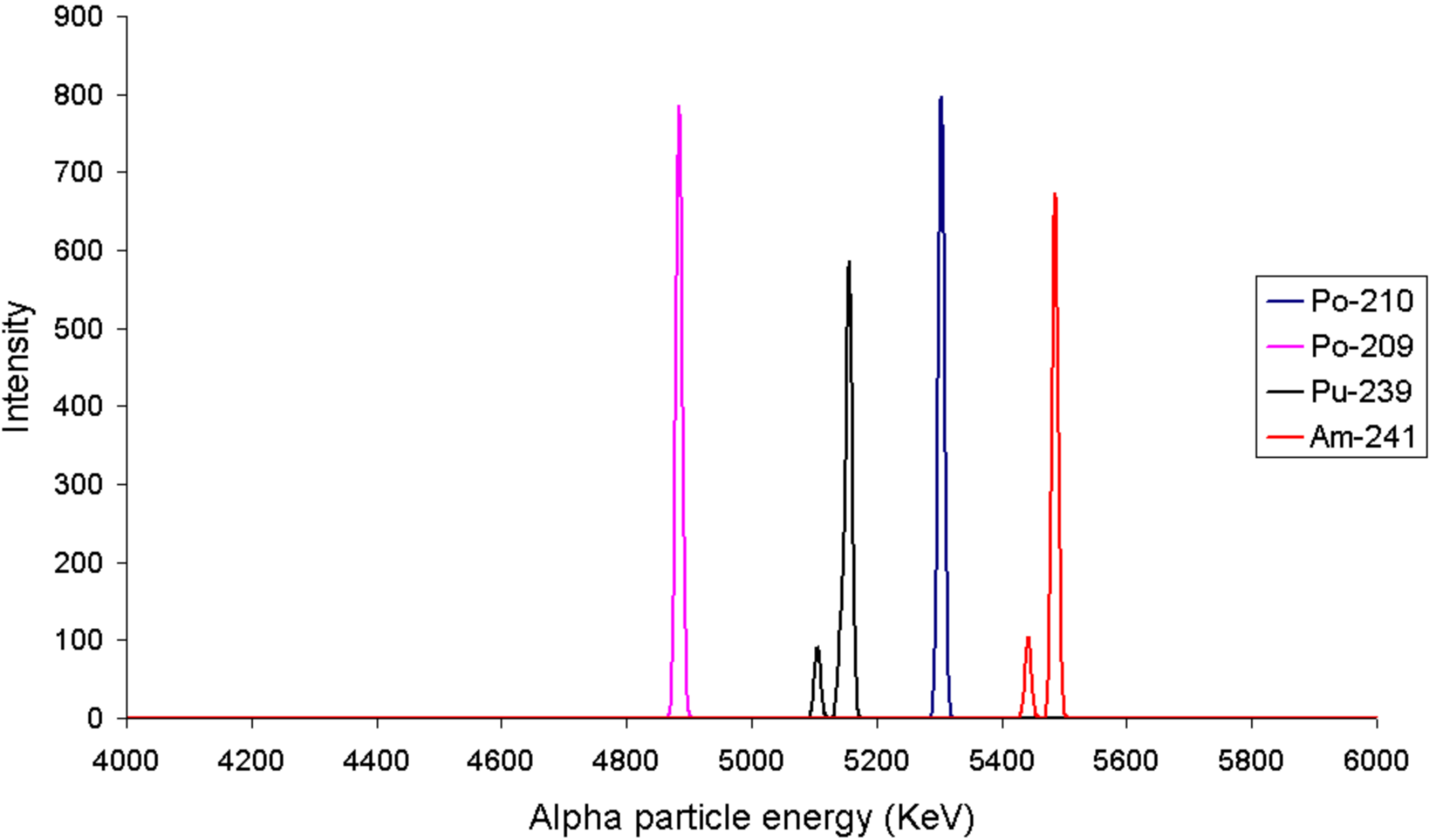


Ernest Rutherford

Rutherford determines ~1910

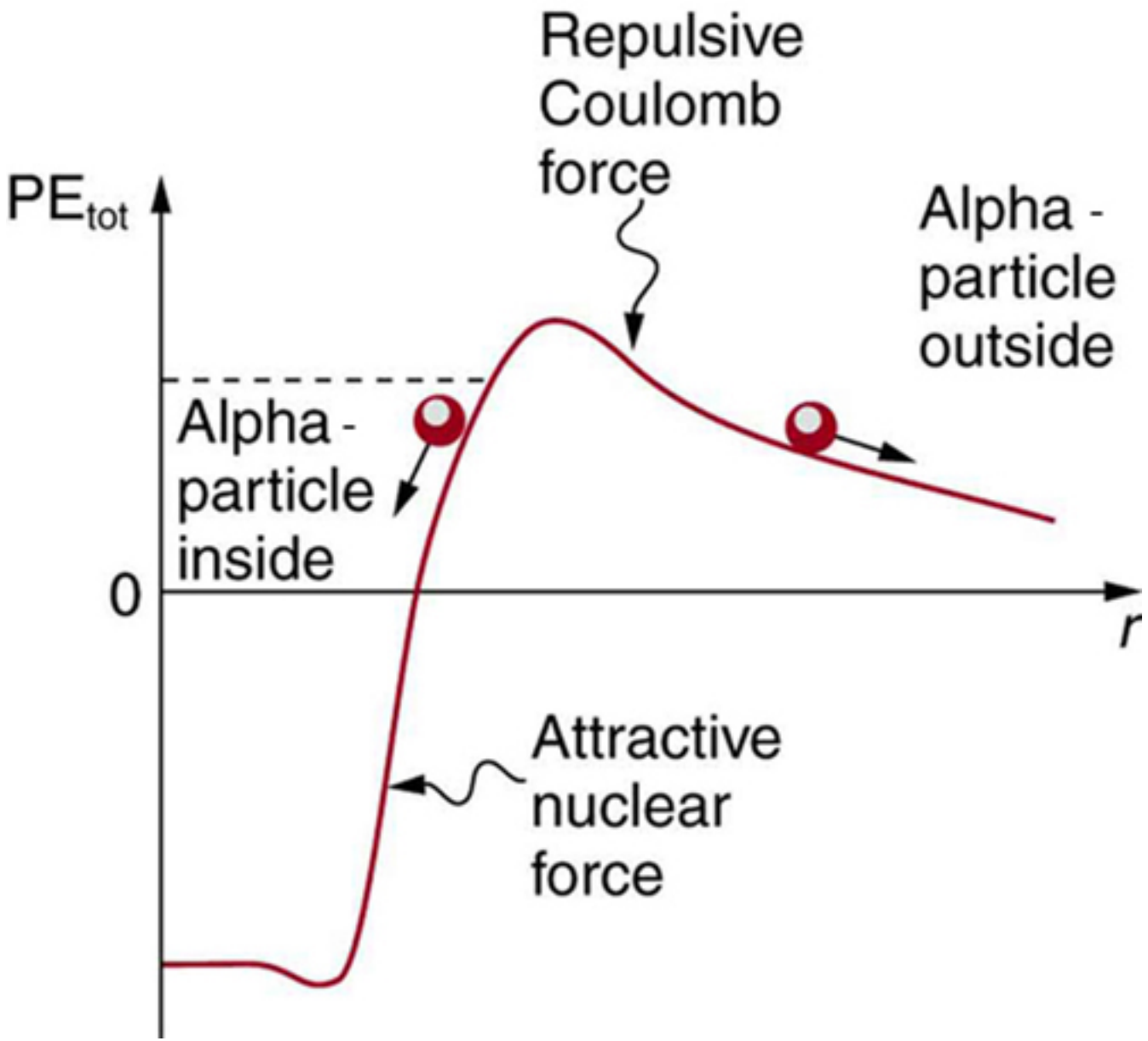
- Alpha particle is a helium nucleus
- Beta particle is an electron

Alpha decay spectra



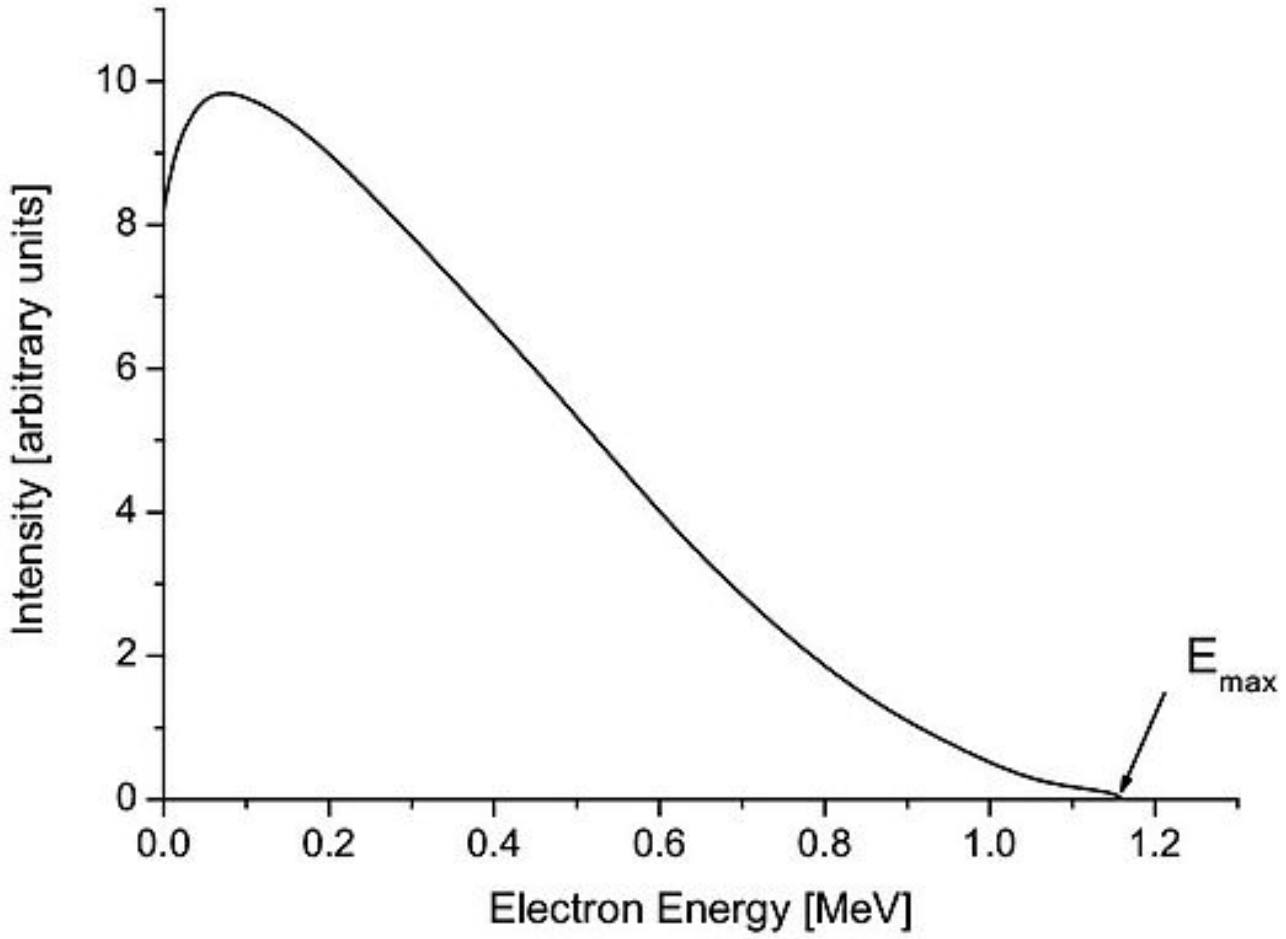
1928 George Gamow explains alpha decay as a tunneling process

Tunneling of alpha particles



Beta decay:

Lise Meitner y Otto Hann (1911), Jean Danysz (1913) and James Chadwick (1914) measure thee spectrum of beta decay and it shows a continuum of energies.

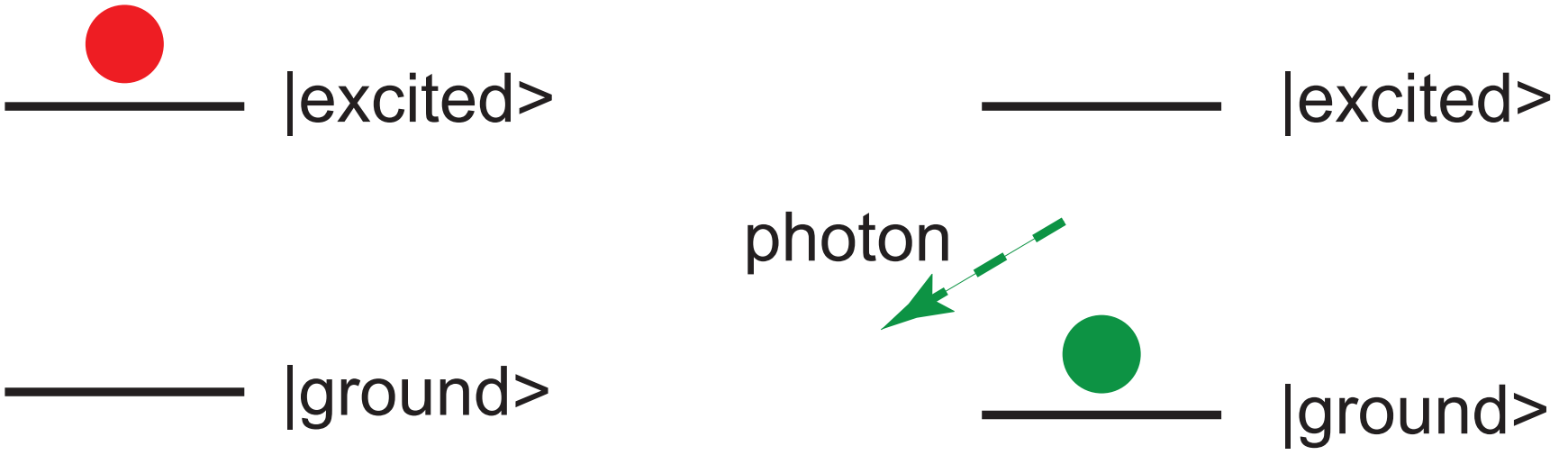


^{210}Bi

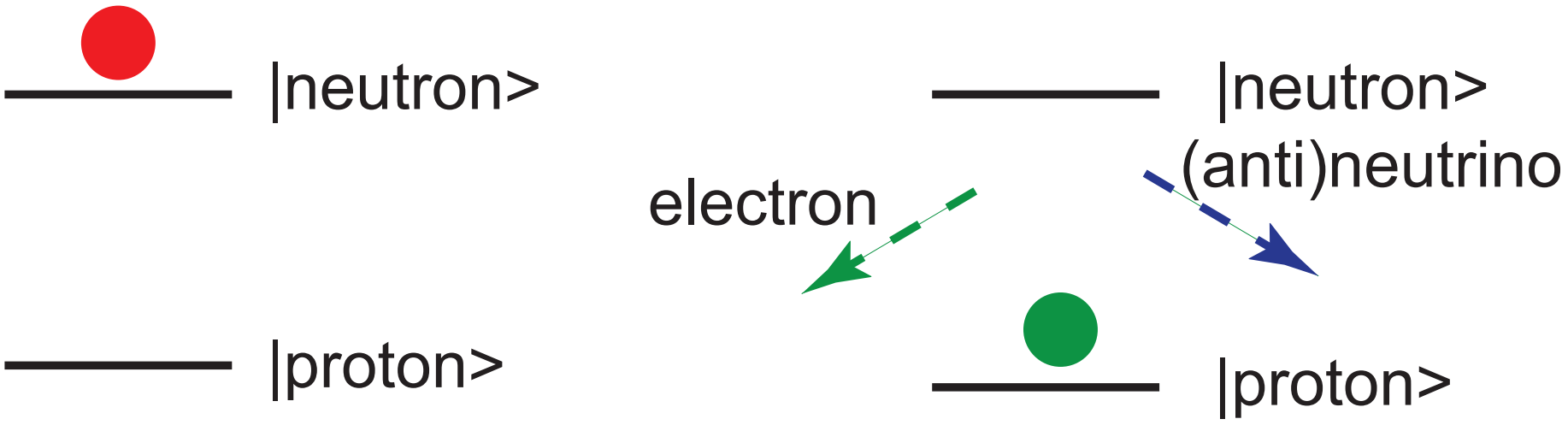
Beta decay theory by Enrico Fermi in 1934, it is just spontaneous emission.

Enrico Fermi

Spontaneous emission



Beta decay

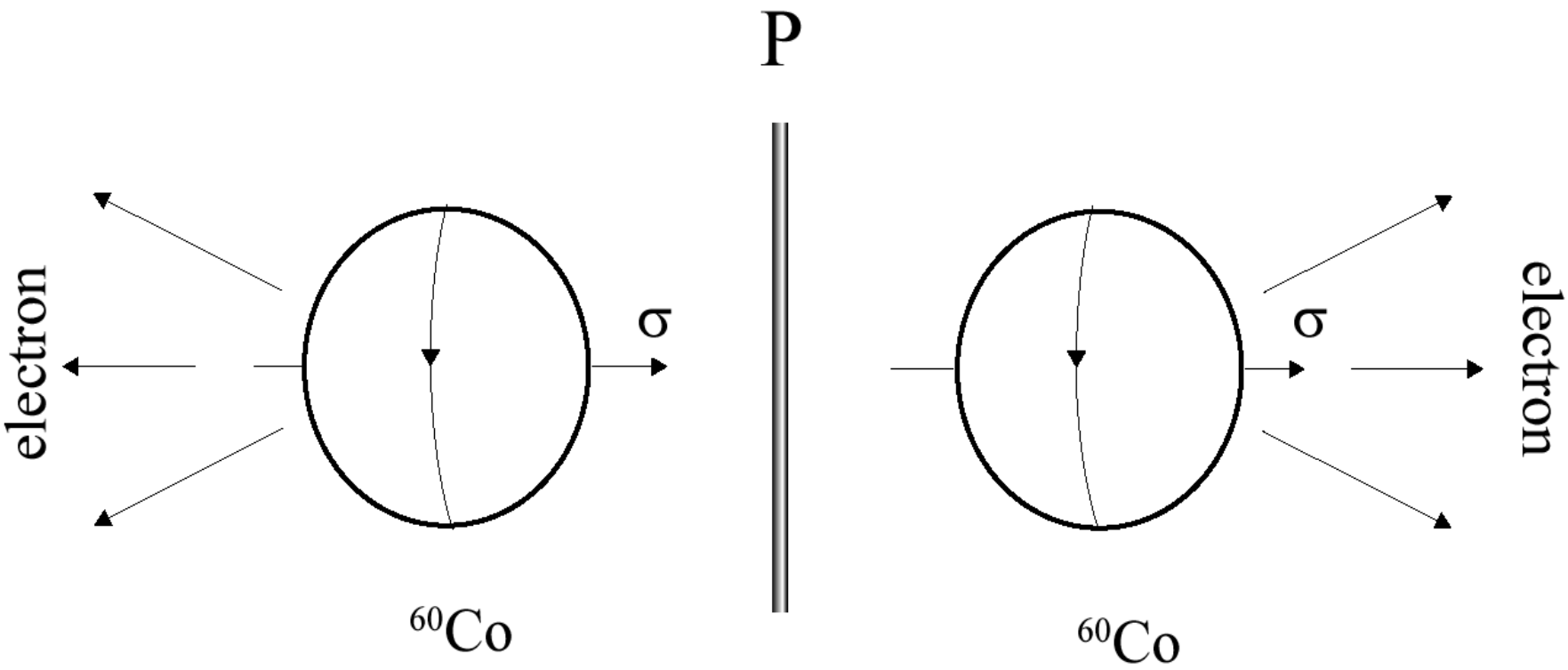


- The weak interaction changes the “flavor” of a particle: a neutron becomes a proton.
- The inverse process a proton becomes a neutron is the beginning of the solar cycle.
- The weak interaction does violates partity.

Nature does not have Parity symmetry.

Change x to −x; y to −y and z to −z

From right hand to left hand



The discovery of Francium

First report of eka-caesium

D. K. Dobroserdov, a soviet chemist, claim to have found eka-caesium. In 1925 he observed weak radioactivity in a sample of K and incorrectly concluded that eka-caesium was contaminating the sample (it came from ^{40}K)
He published his predicttions of the properties of eka-caesium, which he named Russium after his home country. He abandoned any pursue of element 87.

In 1926 Gerald J. F. Druce and Frederick H. Loring (UK) analyzed X ray spectra of manganese sulfate and presumed to see eka-caesium, they proposed alkalinium.

Time Magazine February 1930

Science: Alabamium

Monday, Feb. 17, 1930

Of the 92 elements which the late great Russian Dmitri Ivanovitch Mendelèeff (1834-1907) predicates with his Periodic Law, 16 have been discovered since 1894.* Two remain to be isolated—eka-iodine and eka-cesium.† Last week Dr. Fred Allison and Edgar Jackson Murphy of Alabama Polytechnic Institute at Auburn, Ala., reported that they had "evidence of considerable weight for the presence" of eka-cesium in certain salts they had reduced from lepidolite, a form of mica, and pollucite, a mineral consisting chiefly of cesium, aluminum and silicon. When they break down their salts they will get a...

(They wanted to call it Virginium). Report retracted later.

Horia Hulubei and Yvette Cauchois analyzed pollucite (the mineral that was analyzed by Fred Allison) in 1936 using X ray spectra and they presumed they were from element 87, They announced it and proposed Moldavium. By 1937 there was criticism of their work but they were supported by J. B. Perrin who sided with them, but later changed his mind.

Discovery of Francium as a product of alpha decay of actinium in 1939 (Margarite Perey)

Eka-caesium (Mendeleeff)

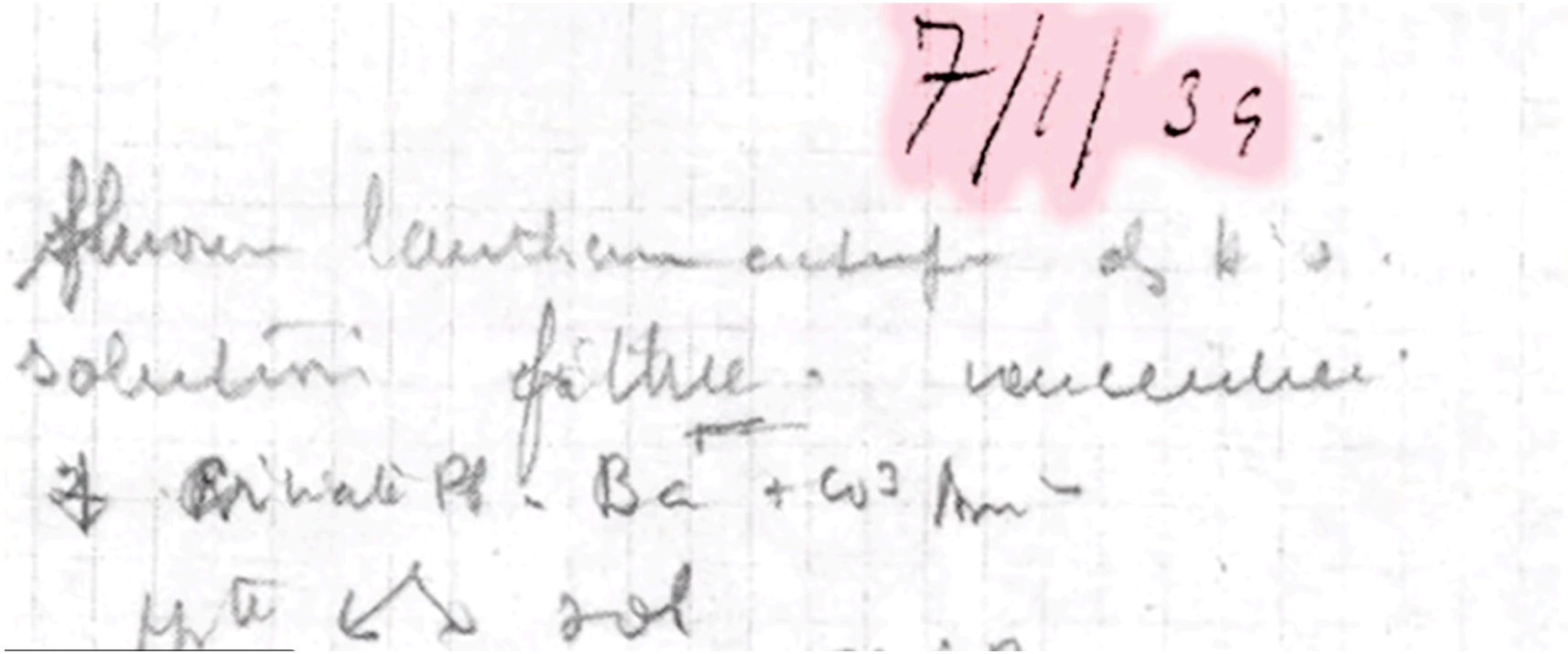
Margarite Perey, Institute du Radium, Paris~1939

Margarite Perey (1909-1975)

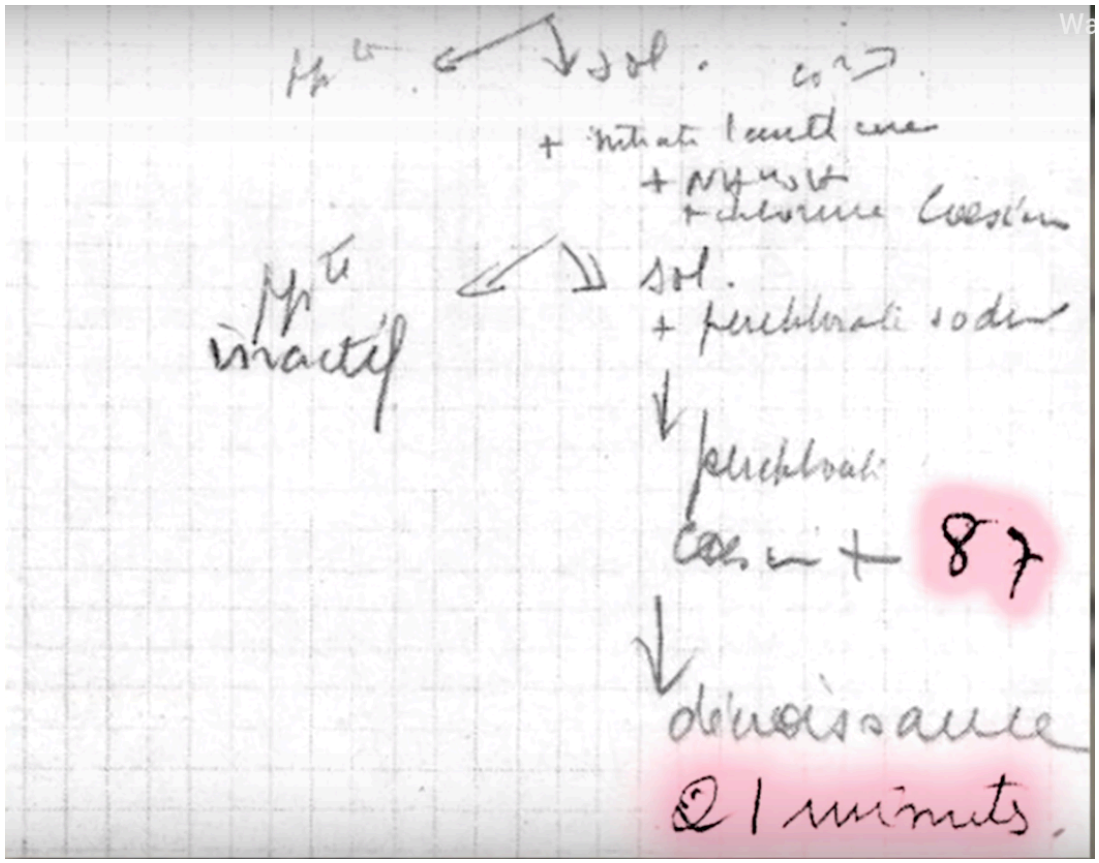
- Studied for chemical laboratory technician.
- She wanted to study medicine.
- Contracted by Mme. Marie Curie to purify substances, the Radium Institute wanted to purify minerals to extract actinium (discovered in 1899).
- Purified a mineral with lanthanum containing actinium.

Margarite Perey (1909-1975)

- She discovered that the actinium sample purified had two decays after she finished the purification, one at 220 KeV corresponding to actinium and the other at 80 KeV of the daughet with half-life of 21 minutes.
- Saw that the activity behaved like an alkali as it precipitated with some cesium salts.



- She was given a fellowship to study and received her doctorate in 1946.
- Professor at Strasbourg.
- First woman elected as a corresponding member of the French Academy of Sciences (1962).



Veronique Greenwood, “My Great-Great-Aunt Discovered Francium. And It Killed Her.” New York Times Magazine Dec. 3, 2014

Comptes rendus a L'Academie de Sciences, **208**, 87 (1939)

RADIOACTIVITÉ. — *Sur un élément* 87, *dérivé de l'actinium.*
Note de M^lle^ **Marguerite Perey**, présentée par M. Jean Perrin.

Afin de connaître avec précision l'évolution de l'activité du rayonnement β émis par l'actinium privé de ses dérivés, nous en avons suivi l'accroissement, en nous efforçant de mesurer le plus tôt possible après la dernière purification l'activité β propre à l'actinium, avant que celle de ses successeurs intervienne.

The origin of the name

- 1939 Perey proposes Actinium K
- 1946 Perey proposes Catium (Objected by Irène Joliot Curie)
- 1949 Francium (Fa later changed to Fr) making the second element named for the country (Gallium).

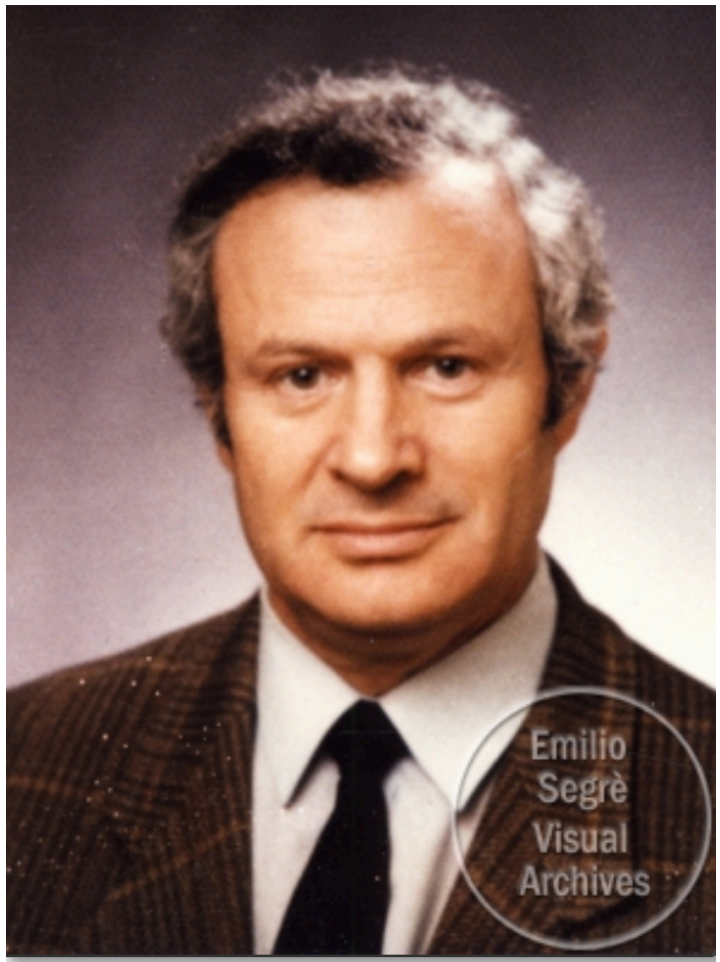
The entrance to atomic physics

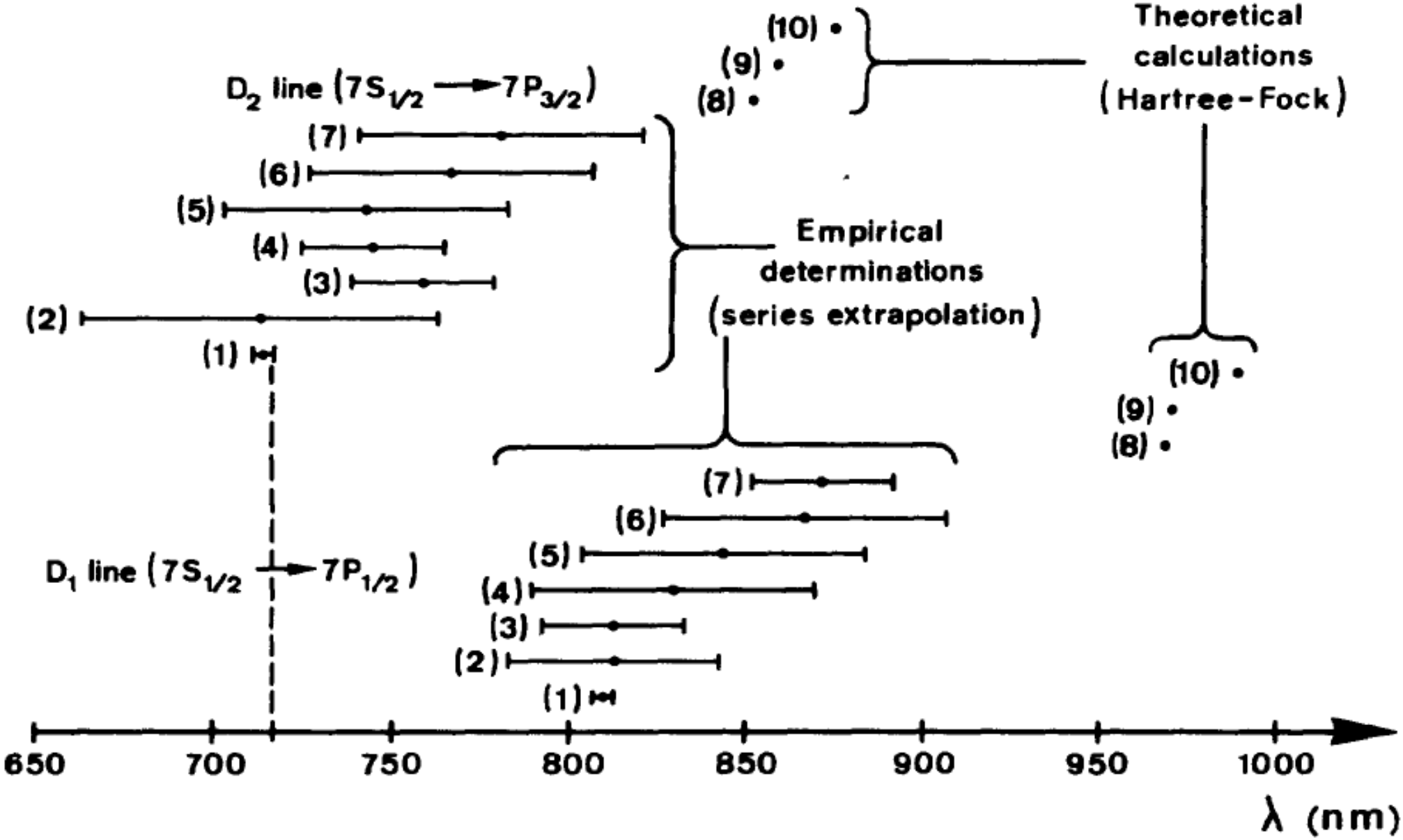
SPECTROSCOPIE ATOMIQUE. — *Première mise en évidence d'une transition optique dans l'atome de francium.* Note (*) de Sylvain Liberman, Jacques Pinard, Hong Tuan Duong, Patrick Juncar, Jean-Louis Vialle, Pierre Jacquinot, Membre de l'Académie, Gerhard Huber, François Touchard, Stephan Büttgenbac' Annie Pesnelle, Catherine Thibault, Robert Klapisch et Collaboration ISOLDE.

Sylvain Liberman
(1934-1988)

Found the D2 line of Fr (718 nm), working at CERN.

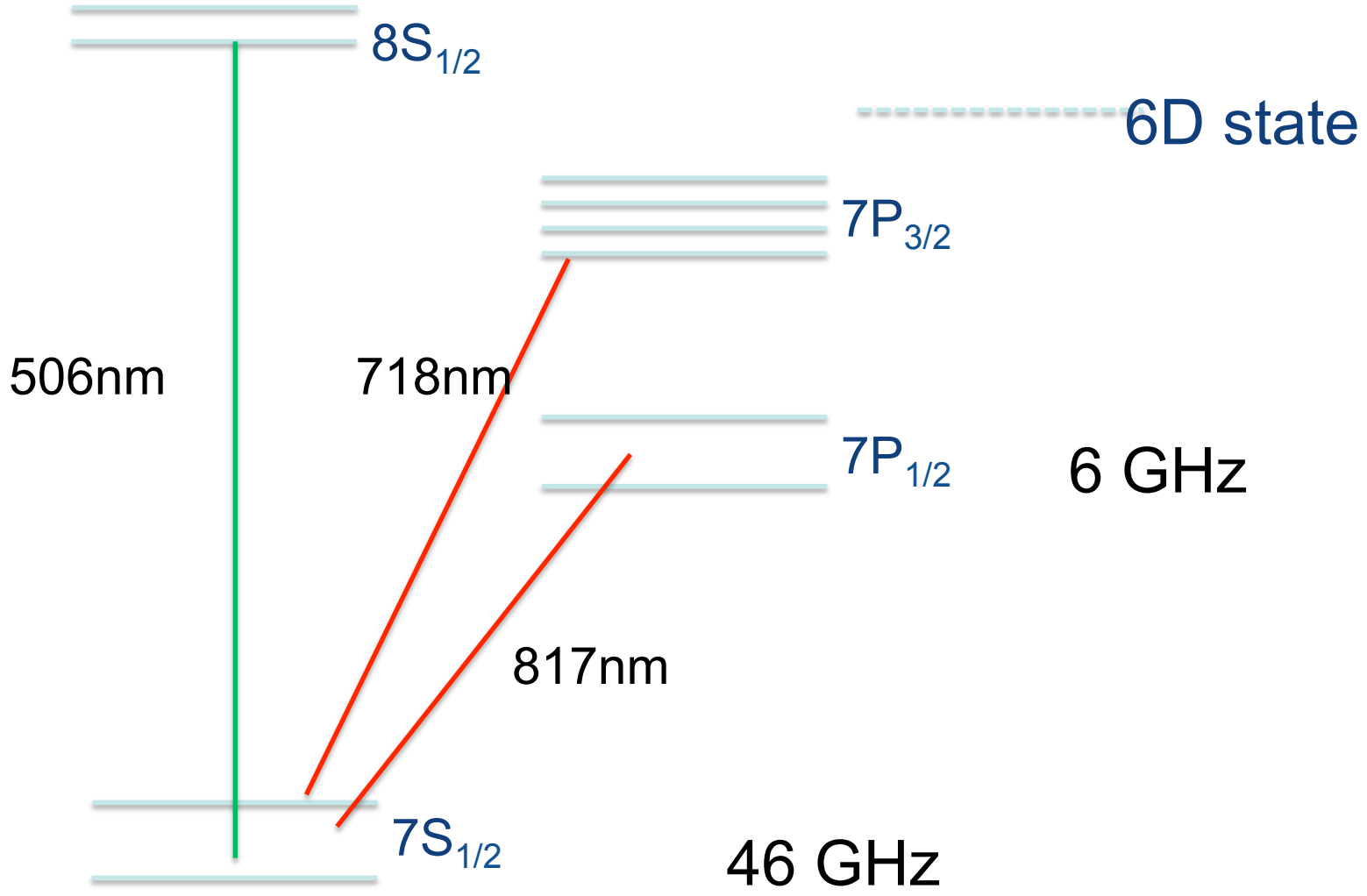
Try to find a Euro coin between Paris and Marseille





A highly sensitive method of detection coupled with a laser atomic beam experiment using on-line-produced Fr isotopes, has permitted finding and measuring the first optical resonance line of this element and its wavelength: $\lambda = 717.97 \pm 0.01$ nm. A high-resolution optical study has been undertaken, which has led to the determination of the hyperfine structure and isotope shifts for isotopes of mass number 208 to 213.

Francium Atomic Energy Levels

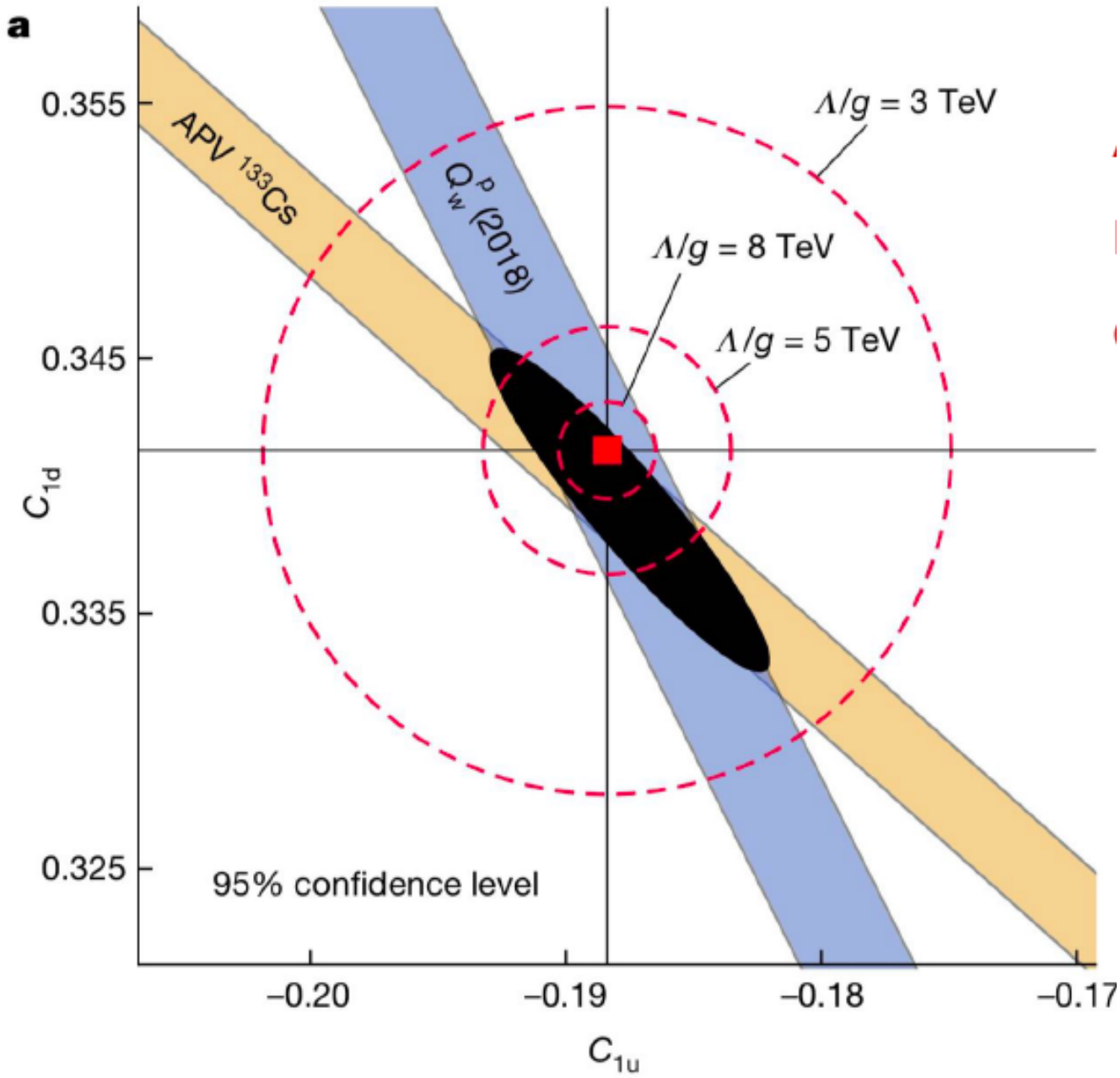


Francium at Stony Brook

Measure Atomic Parity non Conservattion and compare to predictions of the SM and study if the weak interaction gets affected by the presence of lots of nucleons.

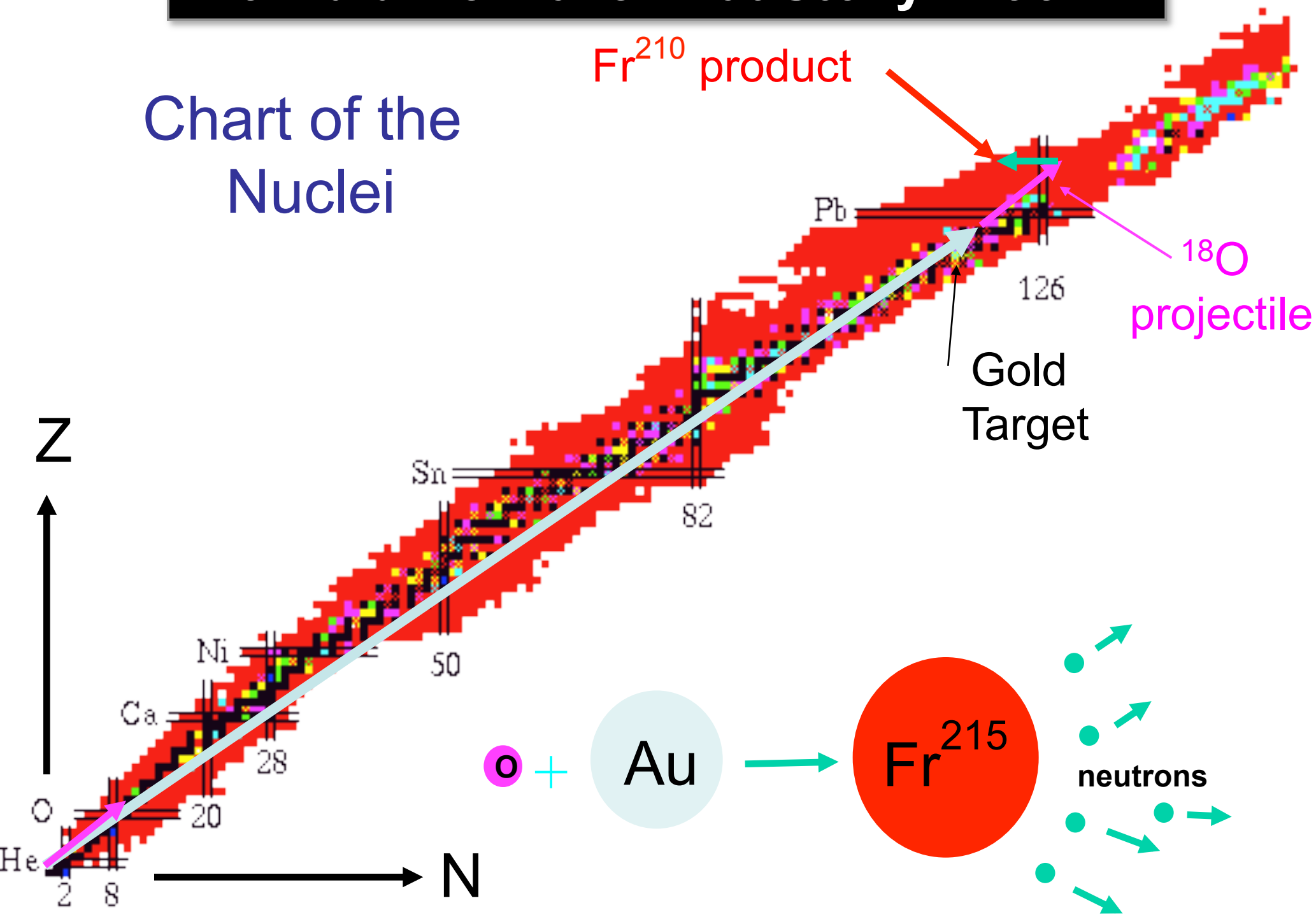
Use a heavy atom (Buchiats) as the measurements scale faster than Z^3 and $Z^{8/3}$

Weak PV electron-quark couplings



Q_{weak} 2018

How did we make Fr at Stony Brook ?

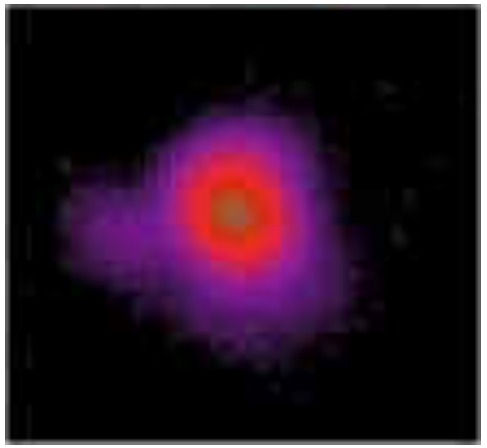


A Brief History of Francium at Stony Brook

1991-94: Construction of 1st production and trapping apparatus.

1995: Produced and Trapped Francium in a MOT.

1996-2000: Laser spectroscopy of Francium.



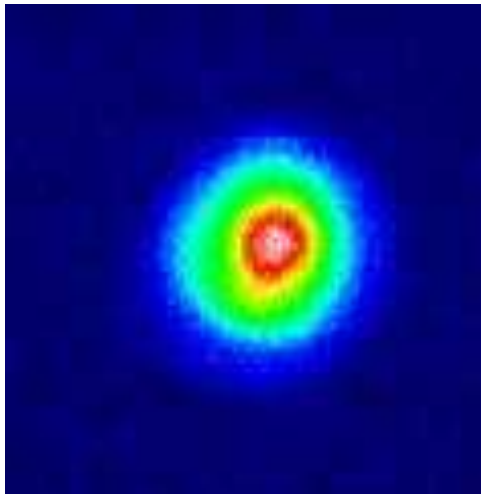
2,000 atoms Fr MOT

2000-2002: High efficiency trap.

2003: Spectroscopy.

2004: Lifetime of 8S level.

2007: Magnetic moment ^{210}Fr .



250,000 atoms Fr MOT

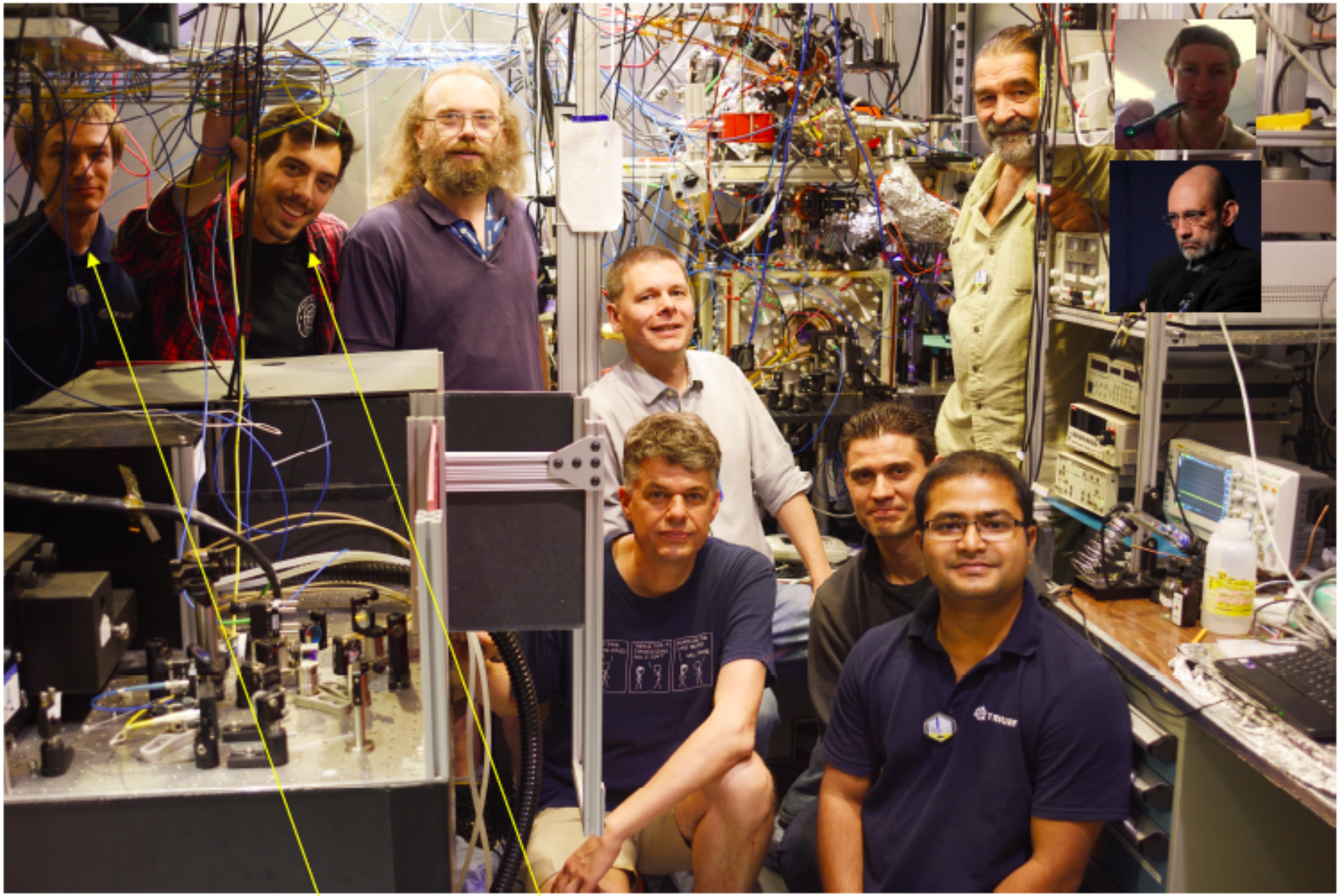
Francium at TRIUMF

FrPNC Colaboration (Winter 2018-2019)

Seth Aubin; College of William and Mary, USA.
John A. Behr, Matt R. Pearson, Alexander Gorolov, Mukut R. Kalita; TRIUMF, Canada.
Victor V. Flambaum; University of New South Wales, Australia.
Eduardo Gómez; Universidad Autónoma de San Luis Potosí, México.
Gerald Gwinner SPOEKESPERSON Tim Hucko, Michael Kossin, ; University of Manitoba, Canada.
Luis A. Orozco; University of Maryland, USA.
Yanting Zhao; Shanxi University, Taiyuan, China.

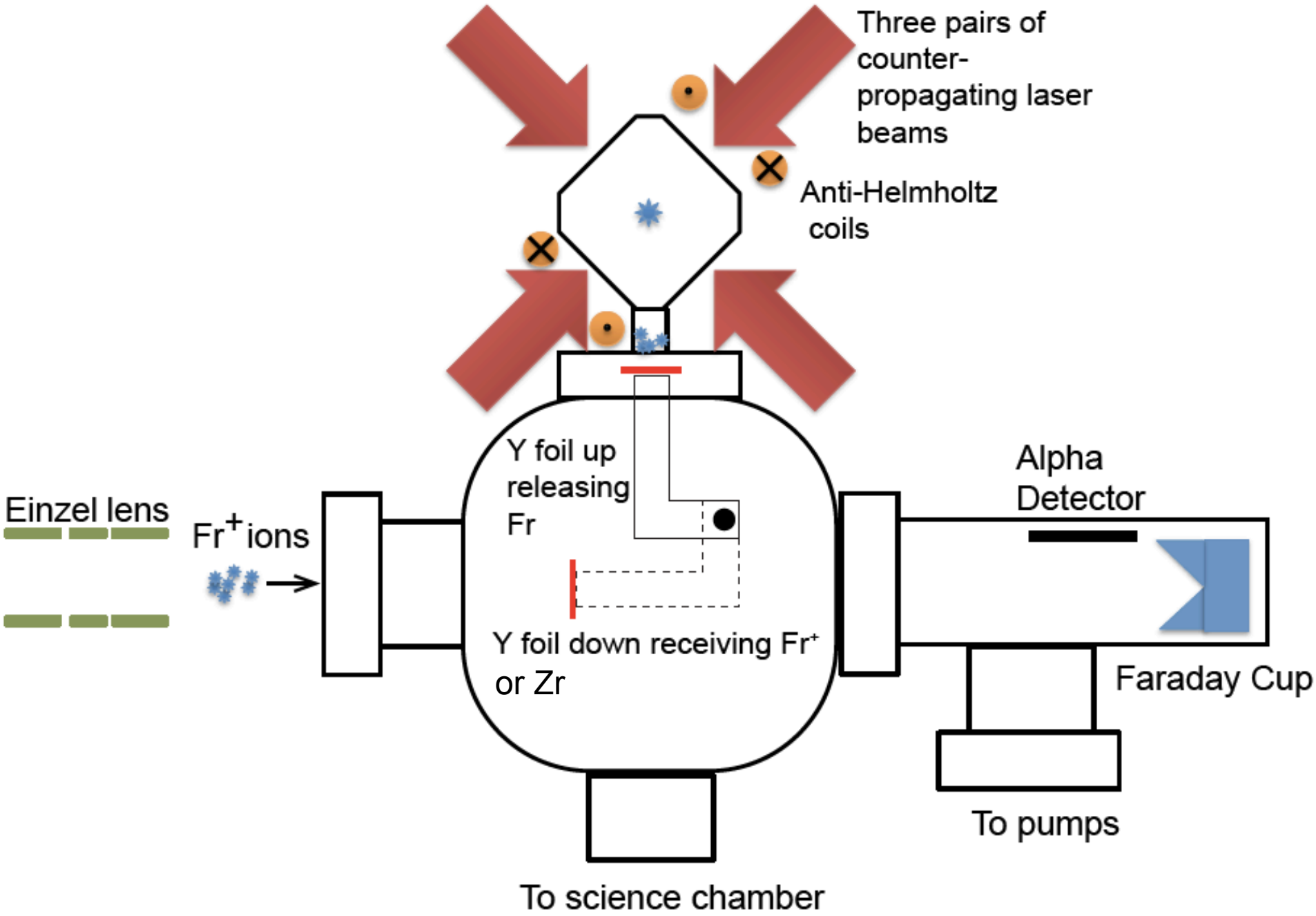
Work supported by: NRC, TRIUMF, and NSERC from Canada, DOE, and NSF of USA, y CONACYT from Mexico.

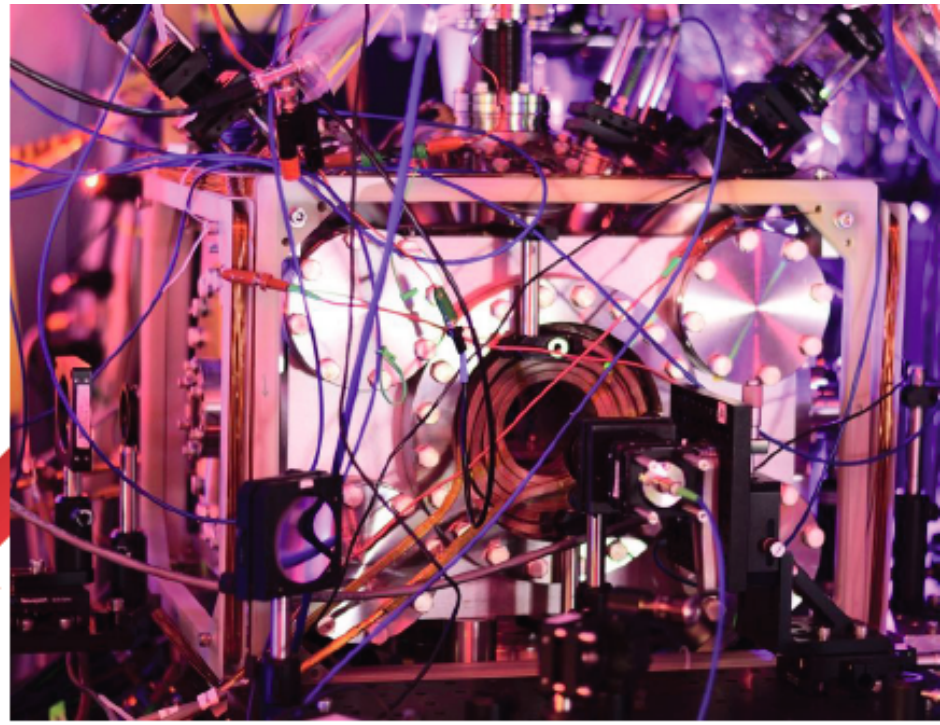
ISAC I hall en TRIUMF, Francium Trapping Facility

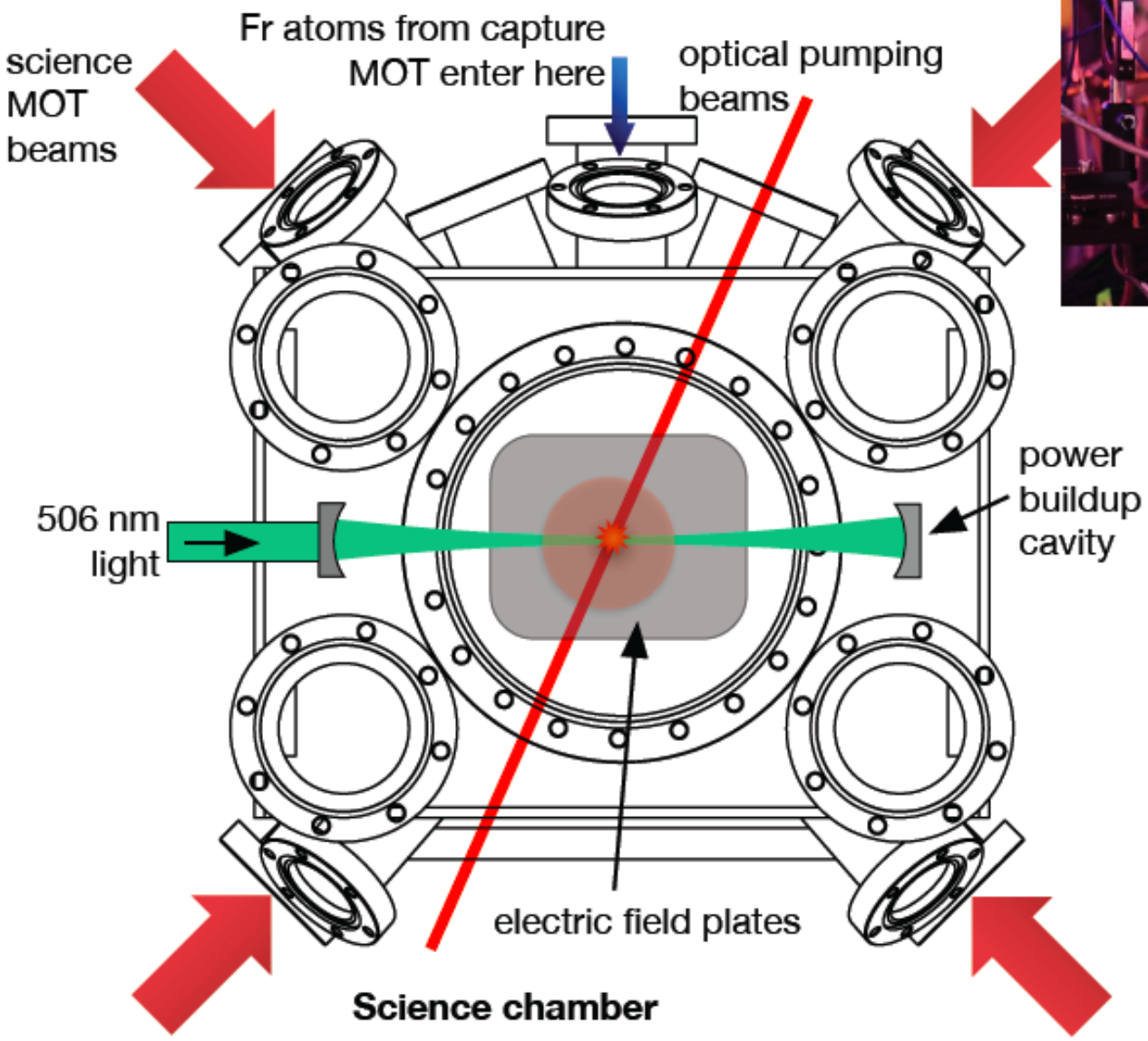


From Left to right: Michael Kossin, Austin deHart, Matt Pearson, Seth Aubin, Gerald Gwinner, Eduardo Gomez, Mukut Kalita, Alexandre Gorelov, John Behr, Luis Orozco.

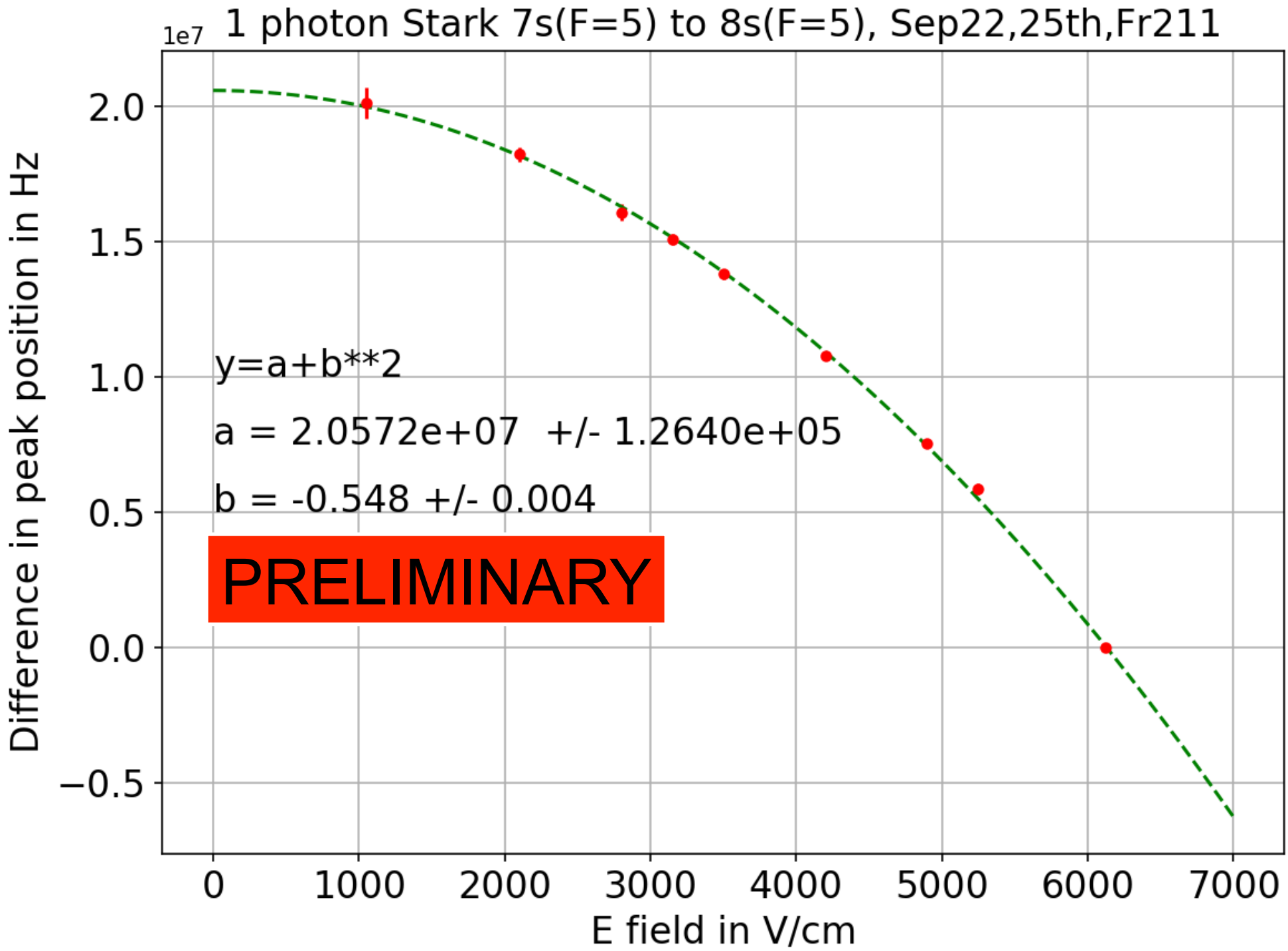
Fr Trapping Facility capture MOT



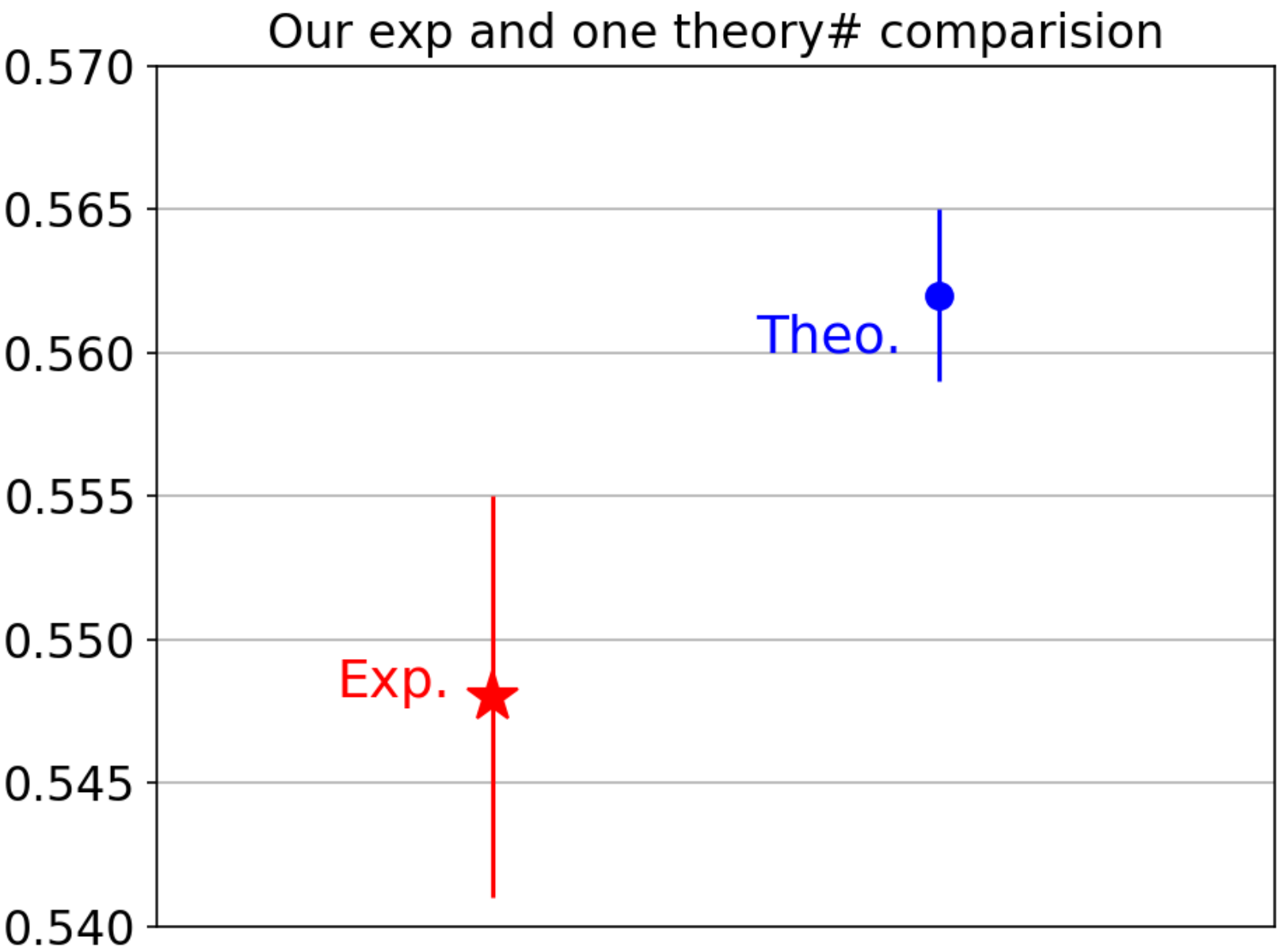



science
MOT
beams
Fr atoms from capture
MOT enter here
optical pumping
beams
power
buildup
cavity
506 nm
light
electric field plates
Science chamber

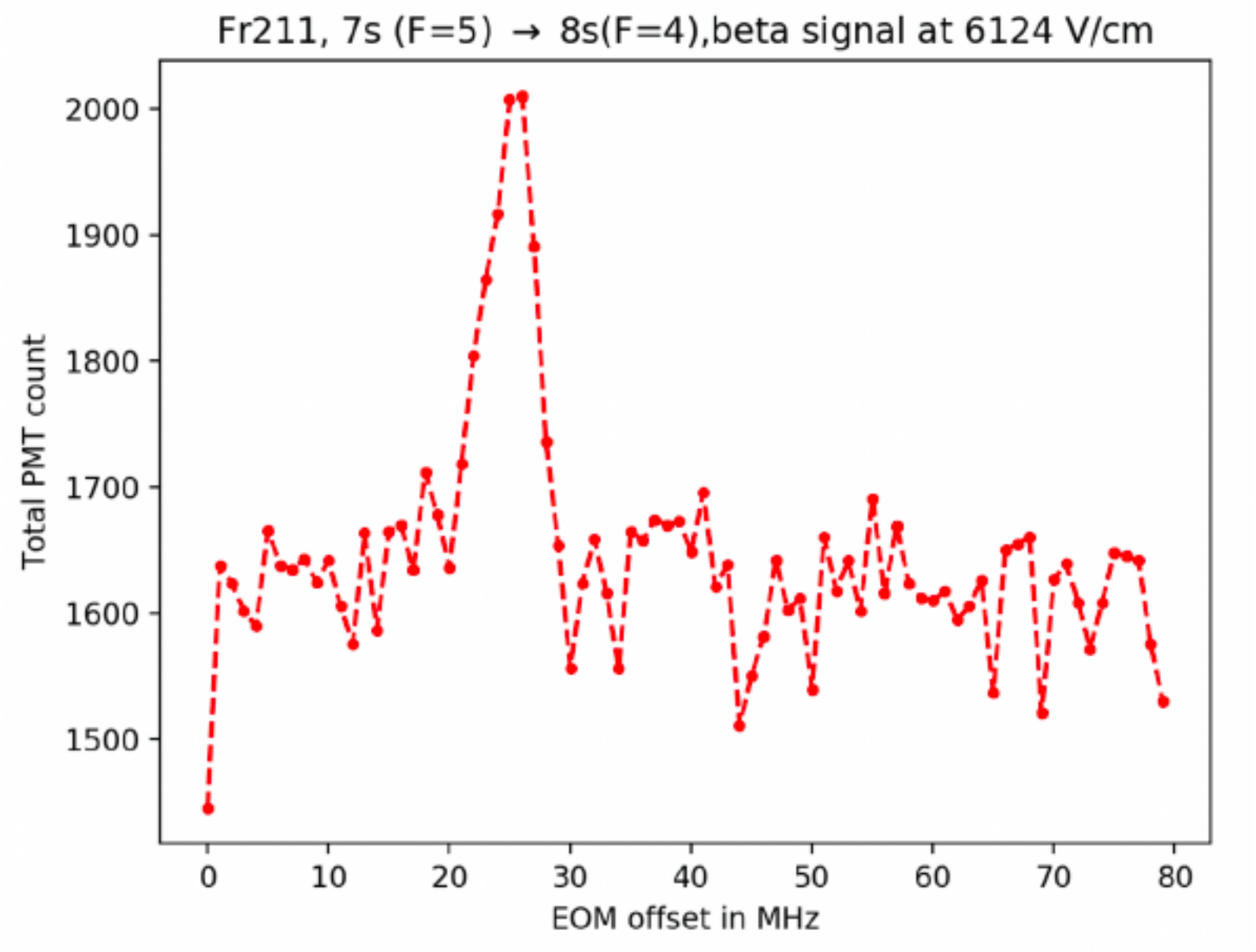
α (scalar) static polarizability in 7s to 8s



Preliminary α static polarizability in 7s to 8s

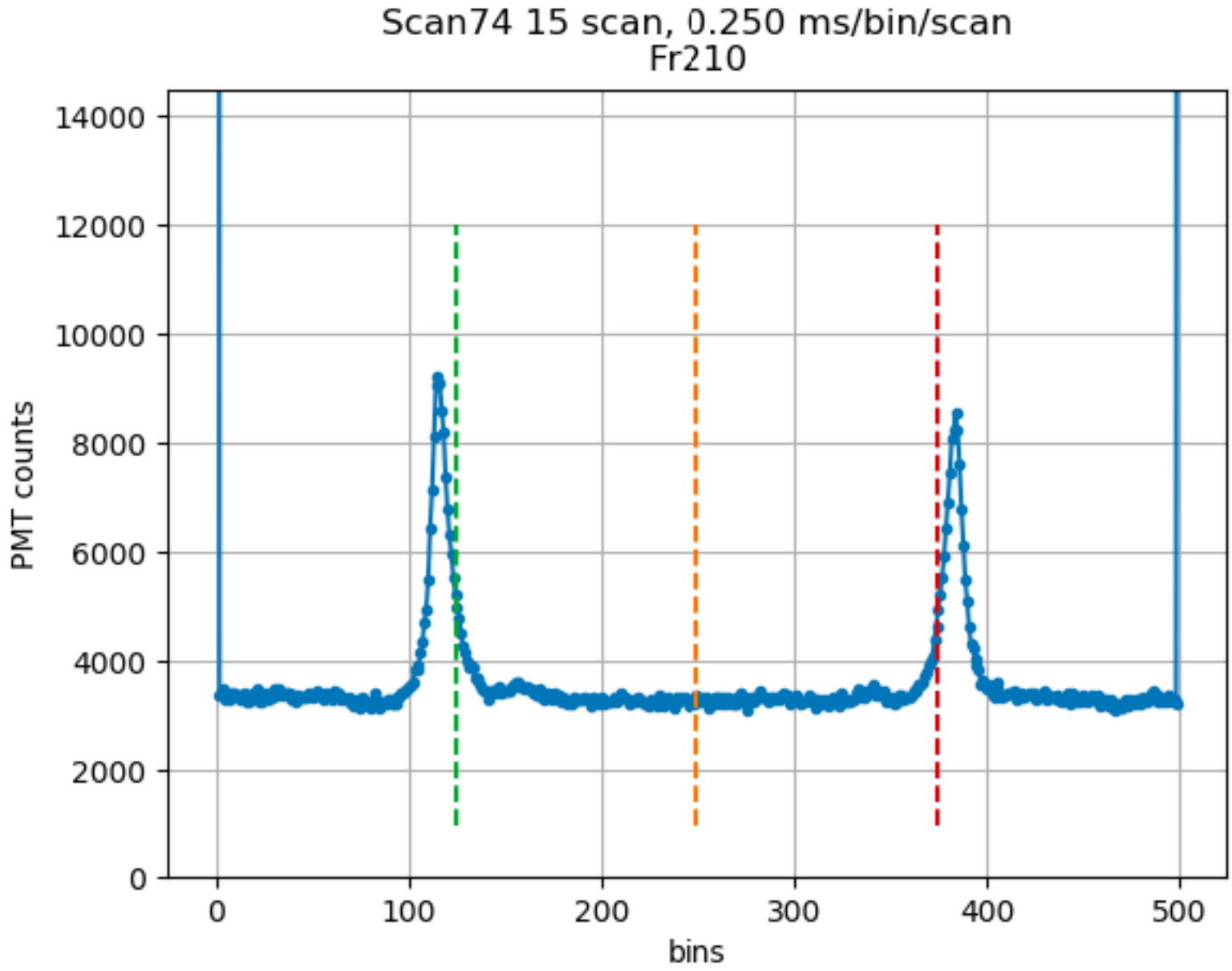


Observation of the ß (vector) Stark induced 7s-8s



10^9 To 10^{10} times weaker than a typical E1 transition.

December 2018 run: Observation of 7s hyperfine splitting in a few Fr isotopes



- We understand quantitatively the Fr atom. Energy levels, lifetime, hyperfine splitting, isotope shifts, etc.

- DC Stark induced transition 7s to 8s for scalar polarizability (measured) and for vector polarizability (observed).

- Closer to Weak interaction studies.

Thank you very much
and
Happy 80th birthday to Francium