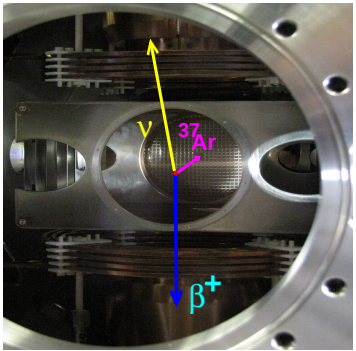
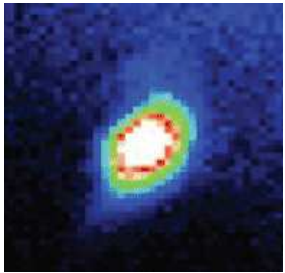
John D'Auria, the relativistic chemistry of francium, and MeV-mass ν's



Otto Häusser, Peter Jackson, and John D'Auria started TRIumf's Neutral Atom Trap "TRINAT"



M. Kalita and T. Hucko showed recent Fr physics results Monday

- JDA's interest: Chemistry of francium for its own sake
  S-states are sucked in by relativity
- We tried to trap ^{226}Fr with TRINAT at TISOL
  Searched for MeV-mass ν's instead

TRIUMF

"Traps for Antimatter and Radioactive Nuclei" 1993

Organizers:
J. D'Auria,
D. Gil,
A. Yavin

'1st TRINAT meeting'
JD'A, JB Apr'94 APS meeting:

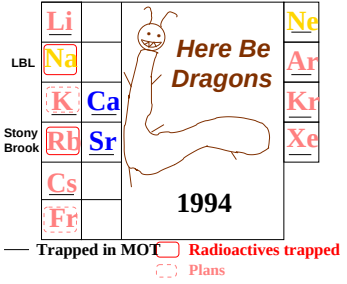
JD'A: We wanna trap Fr and study it for its own sake

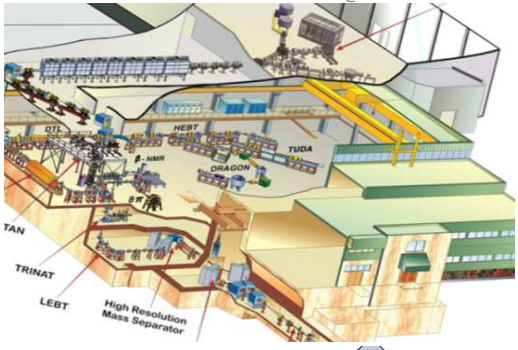
JB: I thought we were mostly doing β-ν correlations?

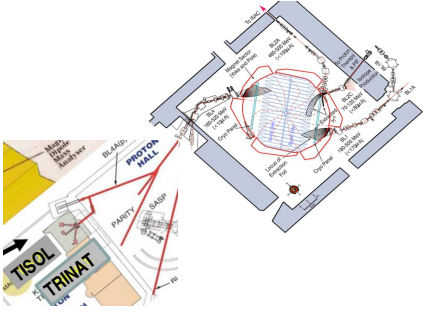
JD'A: Eh, that's Otto (cough)

T. Goldman HI 1993 tossing $\bar{p}$ at ceiling
D'Auria HI 81 275 1993 TISOL
Behr, Orozco, Sprouse, Gwinner et al.
HI 81 197 (1993) but I didn't go ("$")☹.
I did read the conference summary:
O.Hausser HI 81 197 (1993) ☺:

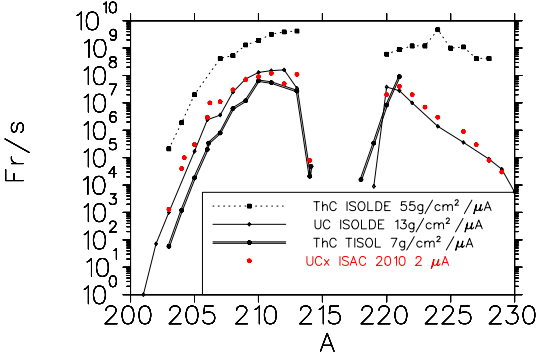
- **We trapped ^{79}Rb at Stony Brook**
- **Otto hired me (4th choice) for TRINAT**







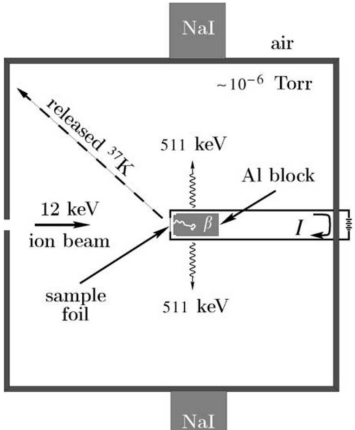
TRINAT at TISOL: A good match for surface ion source for alkali production



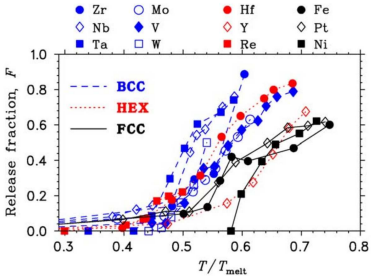
- Developed stopper/neutralizer (flexible beamtime)
- Trapped ^{37}K and measured isotope shift (flexible beamtime)
- Tried to trap ^{226}Fr

'Simpler chemistry': 1997 Neutralizer development

One day the trap was not working ☹, so we scrounged foils and tried out release:

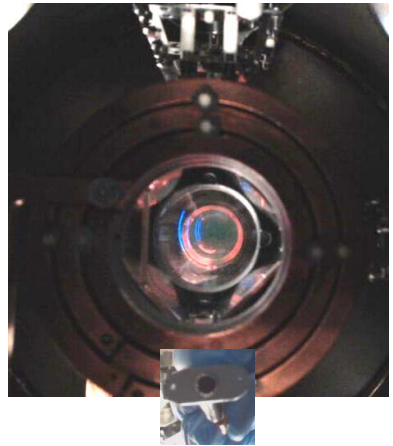


Best release from BCC



Melconian et al 2005 NIMA

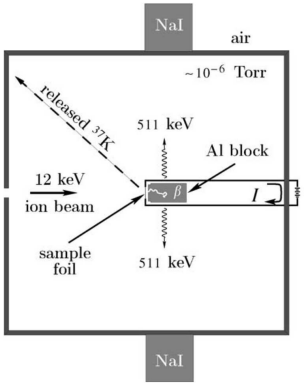
Miedema and Dorleijn Surf. Sci. 95 (1980) 477: adsorption enthalpy related to bulk properties like T_{melt} and work function →



Zr won

We tried lower-T foils →

lower-T foils

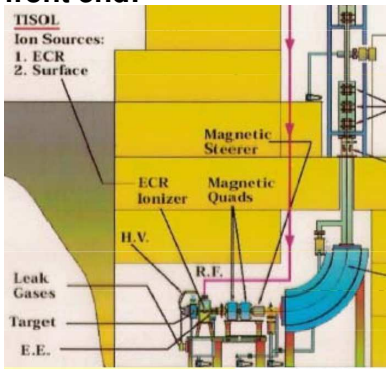


When Gorelov and I blew up the Lithium foil and went to lunch, JD'A cleaned box

Al didn't work either

further backup from JD'A

J.B.'s only visit to TISOL front end:



One day, vacuum valves closed.

After 8 hrs: 5 Rem/hr

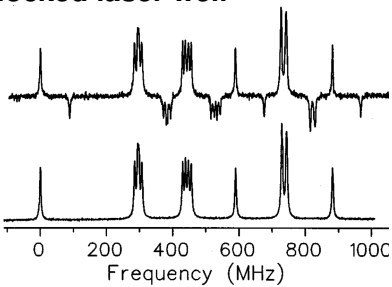
P.M. reconnaissance: Polyethelyne (auxiliary) tubing cracked

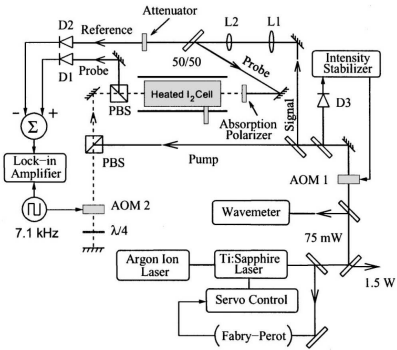
J.B. capped the PolyFlo (50 sec), knocked over the cooling fan.

JD'A fixed the fan

1997 Attempt to trap ^{226}Fr at TISOL

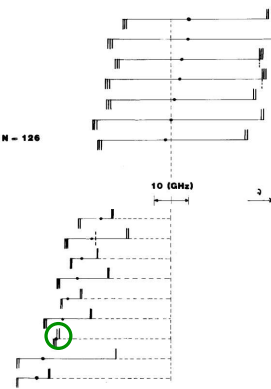
Dube and Trinczek JOSA B
Iodine saturation spectr.
locked laser well





Coc (Orsay/ISOLDE) PLB
1985 hyperfine structure

Fr	Half life	Spin
207	14.8s	9/2
208	59.6s	7
209	50s	9/2
210	192s	6
211	186s	9/2
212	1200s	5
213	34.6s	9/2
214	5×10^{-3}s	
215	0.09×10^{-6}s	
216	0.7×10^{-6}s	
220	27.4s	1
221	294s	5/2
222	864s	2
223	1308s	3/2
224	198s	1
225	236s	3/2
226	48s	1
227	148.2s	1/2
228	39s	2



- ^{226}Fr frequencies covered by existing AOM's
- ThO+egg white$\rightarrow$'ThC' was fine (chef JD'A) but low yields for 226, β decay geometry collected few photons
- EEC: 'If you're going to do this, you have to do it right'

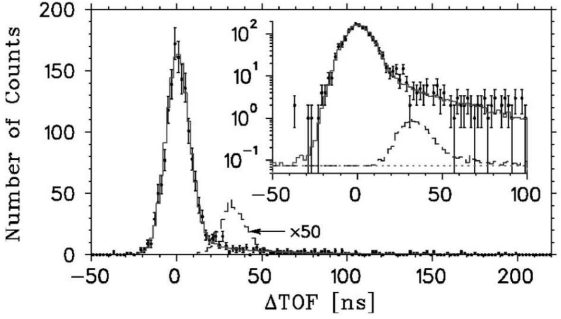
Francium trapped at ISAC ☺ 15 years later

MeV-mass ν's and cosmology

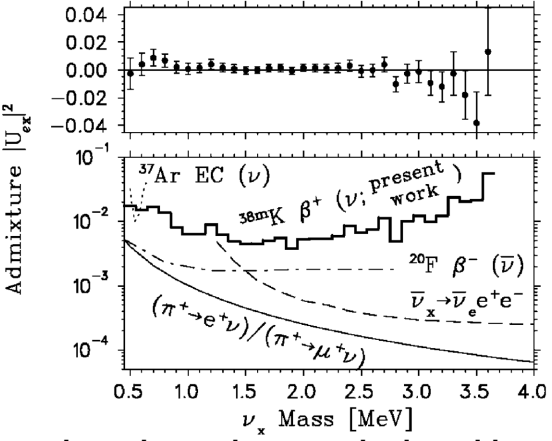
Trinczek... JD'A et al PRL 2003

Would produce slower nuclear recoils in

$^{38m}K \rightarrow {}^{38}Ar + \beta^+ + \nu$



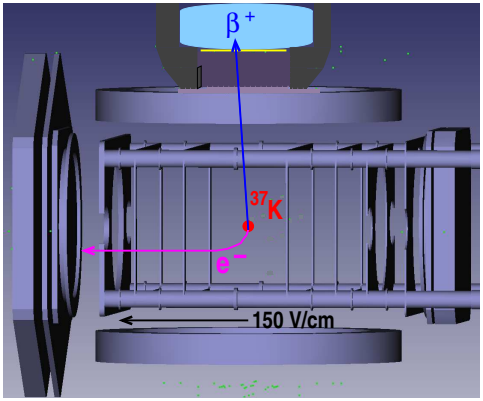
Limits are in PDG

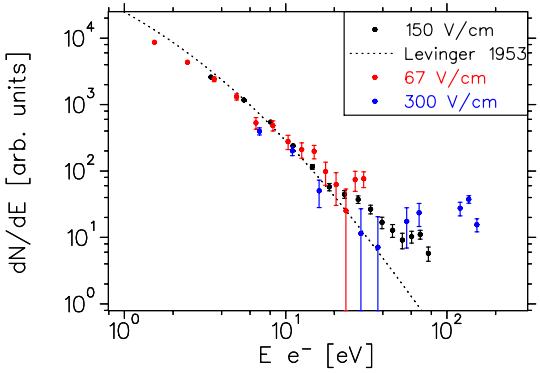


Gelmini PRL 2004 Such ν's don't overclose the universe in cosmologies with low reheating temperature (MeV's, enough to make BBN)

Low-energy e^- 'shakeoffs' from ^{37}K β^+ decay

JD'A+J. Vincent: Can TRINAT trap rhodium and measure e^- energies? No, but:





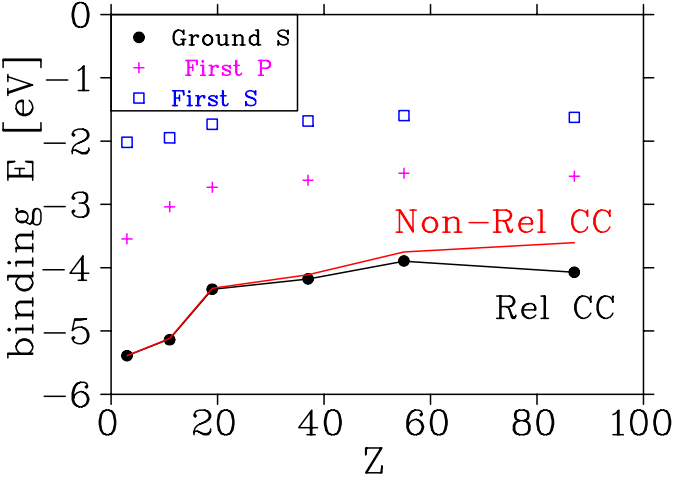
Levinger '53: hydrogenic ψ's, with K/Ar E_{bind}, n^*

Some higher-energy shakeoff e^-, but very few above threshold for double-strand DNA breaks, $\sim$ 25 eV [Friedland Rad Res 150 172 (1998)]

Relativity and ionization potentials of alkalis

Relativity binds S states tighter. Consequences include:

Au is gold **Hg is a liquid** **ekaRn Z=118 may have e^- affinity > 0**



Relativity has $\sim$ 10% effect on Fr ionization potential [Relativistic version of Coupled Cluster theory: (E. Eliav, U. Kaldor, Y. Ishikawa, Phys Rev A 50 (1994) 1121)]

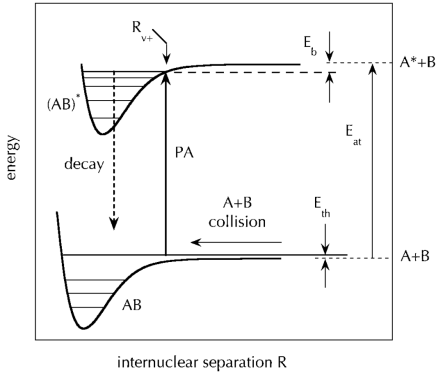
Cold chemistry: Photoassociation $\rightarrow$ Fr_2 molecular dimers

- **Excite one atom to a P state, making a dipole interaction with the other.**

C_3 molecular potential $\rightarrow$ quantitative info on $\langle s||E1||p\rangle$ to interpret atomic PNC interpretation.

Stony Brook (Orozco, Gomez, et al.) looked for Fr_2 and FrRb, did not see.

Aymar et al. JPB 39 2006 predict: greater Fr spin-orbit coupling $\rightarrow$ different dimer potential than Rb_2, Cs_2: similar rates, but fewer Fr_2 molecules near g.s.

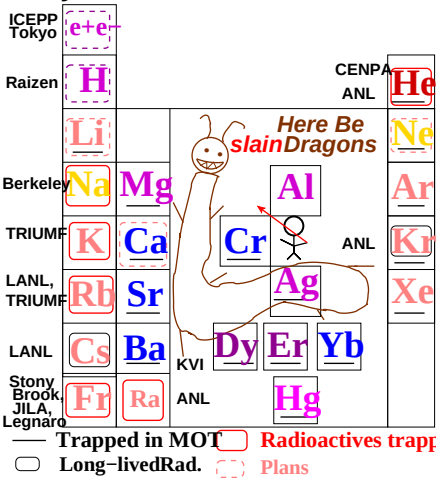


Jones et al. RevModPhys 2006

Most efficient probe by far is photoionization, so TRINAT may be a better facility than FranciumTrappingFacility to do this.

John D'Auria, the relativistic chemistry of francium, and MeV-mass ν's

Many radioactive MOT's now



TRINAT testing phase needed regular beamtime from TISOL

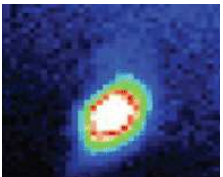
JD'A and TRINAT:

J.D'A, Buchmann, Dombsky, Jackson, Sprenger, JB, 1997 NIMB on TISOL

J.B. PRL 1997 Trapping 37K

Melconian NIMB 2005 NIMA

Trinczek PRL 2003



M. Kalita and T. Hucko showed recent Fr physics results Monday CAP