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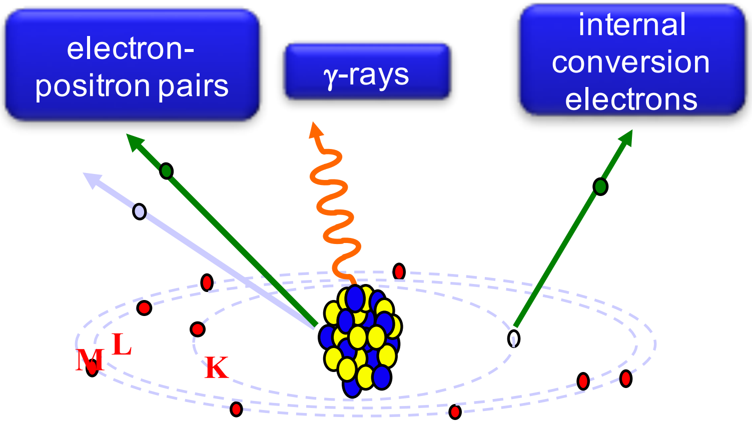
ENSDF analysis and utility codes II
E0 transitions
extension of BrIcc
BrIccEmis

T. Kibèdi (ANU)

Electric monopole (E0) transitions



E0 transitions

- $J^{\pi} \rightarrow J^{\pi}$
- No transfer of angular momentum
- No change in parity
- Single photon emission is not allowed
- For J≠0 E0 can be mixed with E2+M1
- Internal conversion electron emission
- Internal pair emission (E>1.022 MeV)
- Double photon emission (E1+E1; ~10^{-4} 1964Al18)

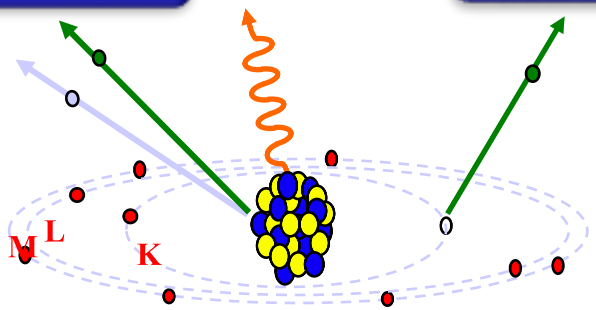
$$0^{+} \xrightarrow{E1} 1^{-} \xrightarrow{E1} 0^{+}$$

Electric monopole (E0) transitions

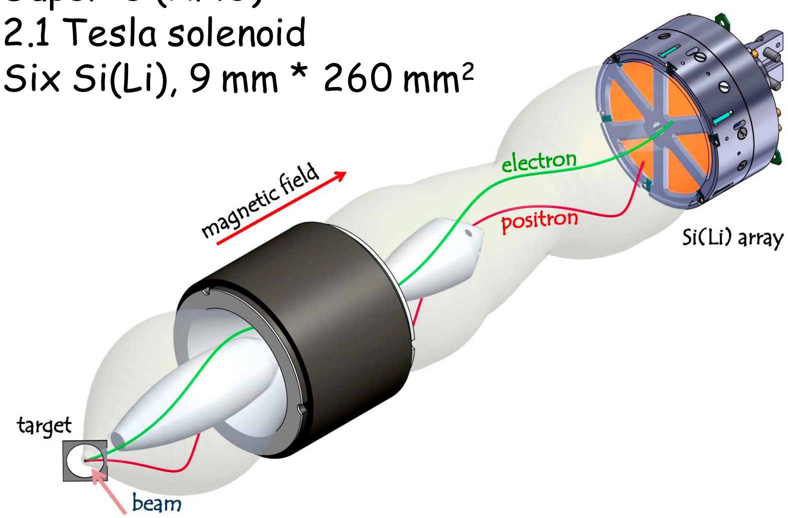
electron-positron pairs

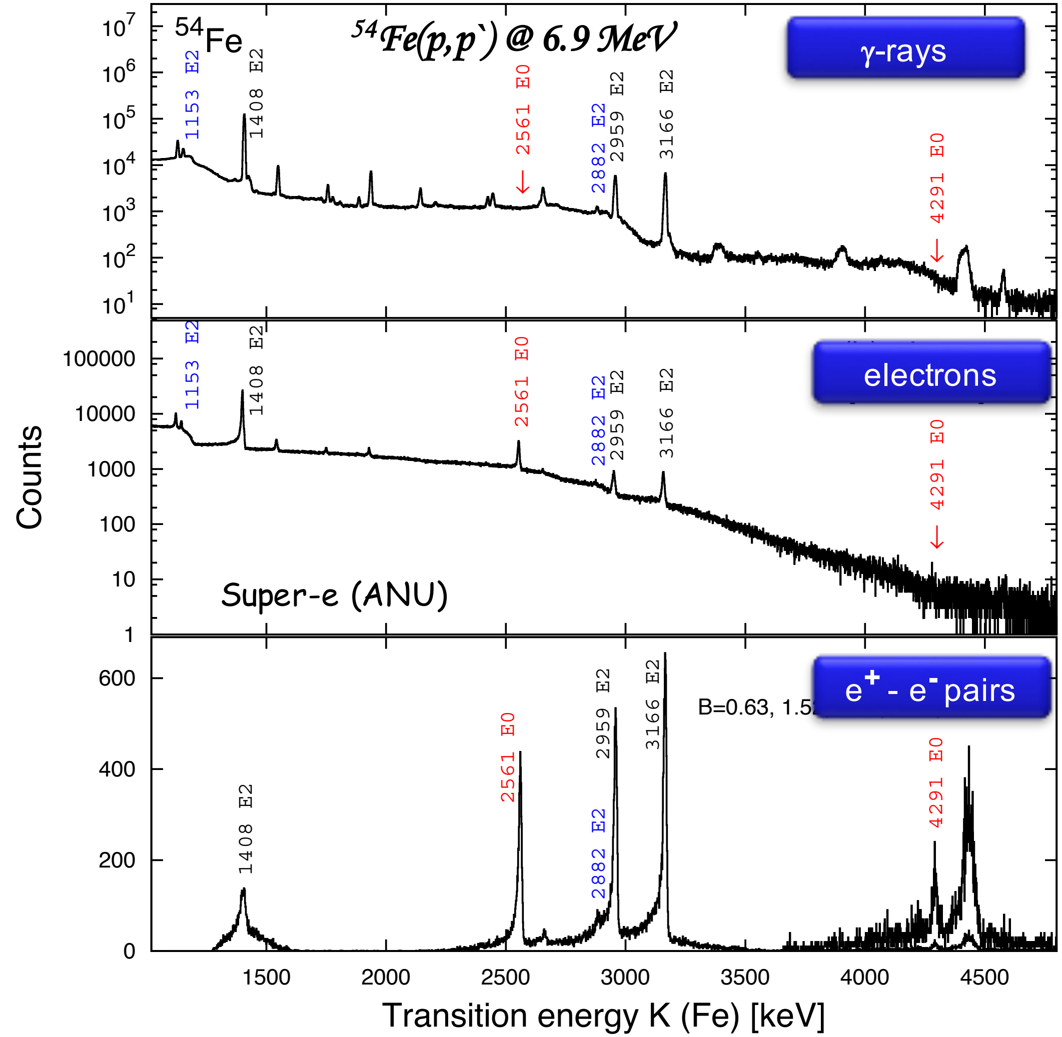
γ-rays

internal conversion electrons

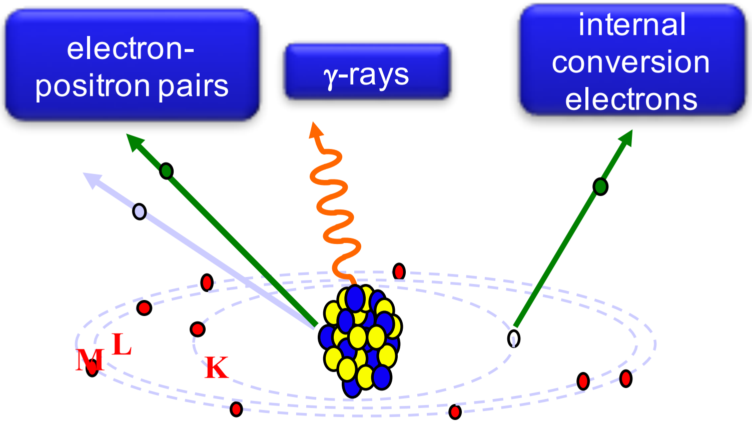


Super-e (ANU)
2.1 Tesla solenoid
Six Si(Li), 9 mm * 260 mm^2





Electric monopole (E0) transitions



BrIcc v2.3S

Conversion Coefficient Calculator

Z (atomic number or symbol): fe

γ-energy (in keV): 2561 Uncertainty

Enter (optional) uncertainty in energy as **x** or **+x-y**

Multipolarity: e0 δ Uncertainty

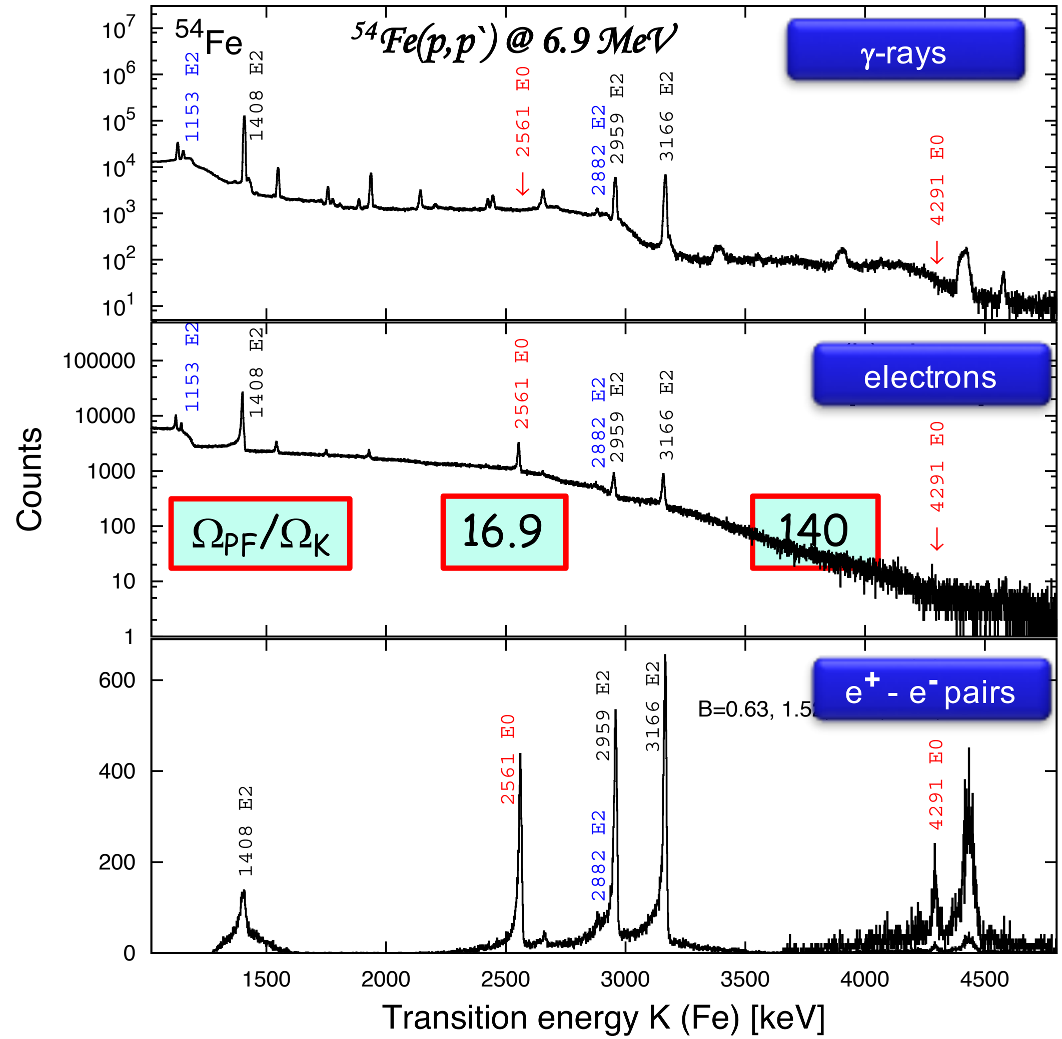
Enter (optional) uncertainty in δ as **x** or **+x-y**

Show Subshells **Data Set** BrIccFO

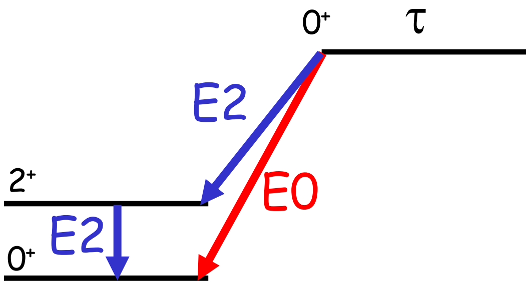
Calculate Reset

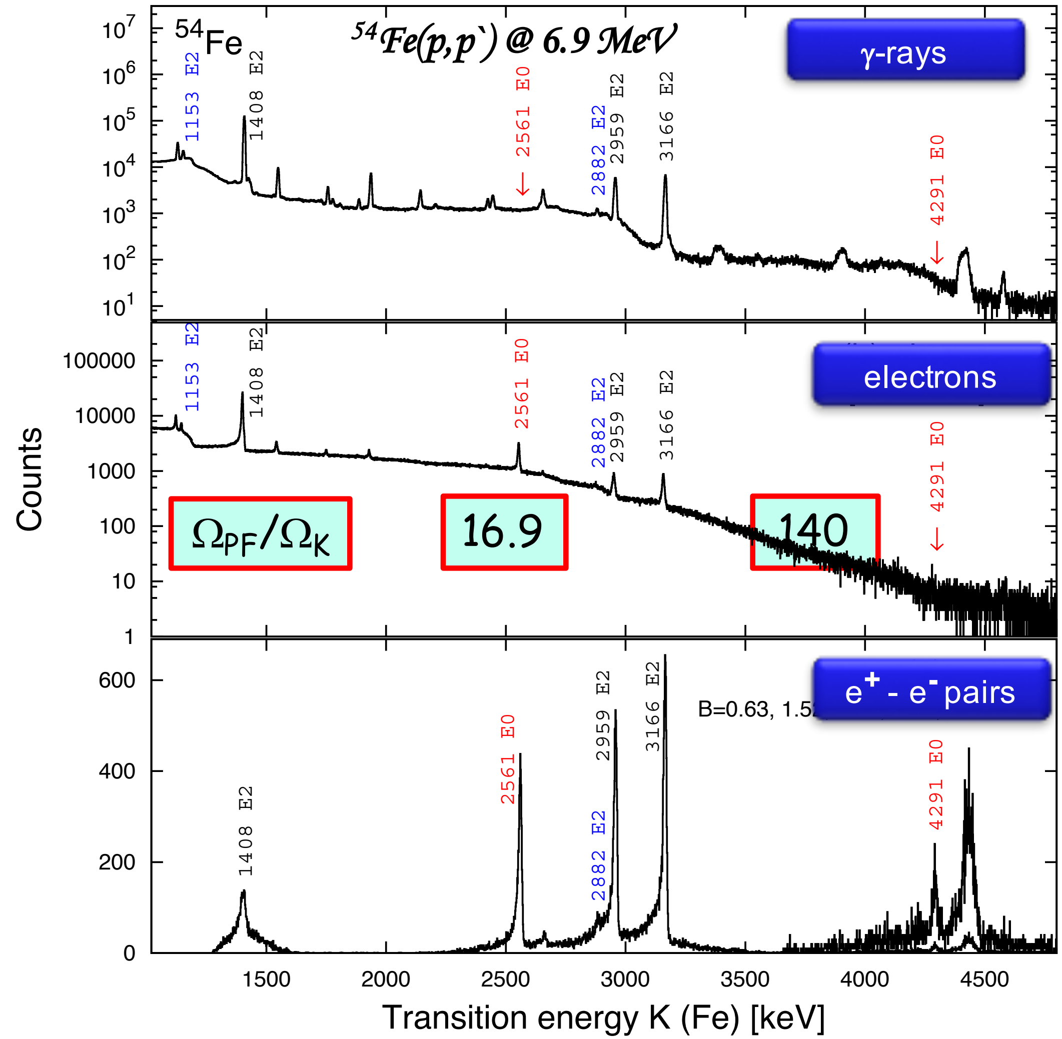
BrIccS v2.3 (9-Dec-2011)
Z=26 (Fe, Iron)
γ-energy: 2561 keV
Data Sets: PaOmg

Shell	E(ce)	Ω(E0)
K	2553.89	2.461E+08
IPF		4.151E+09
Tot		4.397E+09
K/Tot		5.597E-02



Electric monopole (E0) transitions





Absolute E0 transition rate

$$\lambda(E0) = \frac{1}{\tau_{E0}} = \lambda_{CE}(E0) + \lambda_{CE}(E0)$$
$$= \rho^2(E0) \times [\Omega_{CE} + \Omega_{PF}]$$

Monopole matrix element ($R = r_o A^{1/3}$)

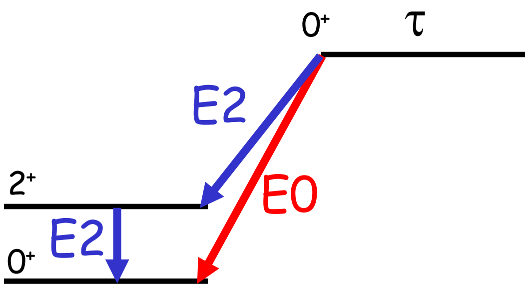
$$\rho(E0) \frac{\langle f|M(E0)|i\rangle}{eR^2}$$

Reduced E0 transition probability

$$B(E0) = \rho^2(E0) \times e^2 R^4$$

How to extract ρ(E0) and B(E0)?

Electric monopole (E0) transitions



Absolute E0 transition rate

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Monopole matrix element ($R=r_oA^{1/3}$)

$$\rho(E0)\,\frac{\langle f|M(E0)|i\rangle}{eR^2}$$

Reduced E0 transition probability

$$B(E0)= \rho^2(E0)\times e^2R^4$$

How to extract ρ(E0) and B(E0)?

E0/E2 Mixing ratio $q_K^2(E0/E2) = \frac{I_K(E0)}{I_K(E2)}$

q^2_K(E0/E2) can be determined from

- ❑ CE and/or PF intensity, E2: Iγ & α_K
- ❑ Use ICC and Ω(E0) values K-shell intensities from other measurements

$$q_K^2(E0/E2) = \frac{I_{PF}(E0)}{I_{PF}(E2)}\times\frac{\Omega_K(E0)}{\Omega_{PF}(E0)}\times\frac{\alpha_{PF}(E2)}{\alpha_K(E2)}$$

X-factor - definition

$$X(E0/E2) = \frac{B(E0)}{B(E2)} = \rho^2(E0)\times e^2R^4/\mathrm{B(E2)}$$

X-factor - experiment

$$X(E0/E2) = 2.54\times10^9\times A^{4/3}\times q_K^2\times\frac{\alpha_K}{\Omega_K}\times E_\gamma^5(MeV)$$

Experimental Monopole matrix element

$$\rho^2(E0) = q_K^2(E0/E2)\times\frac{\alpha_K(E2)}{\Omega_K(E0)}\times\lambda_\gamma(E2)$$

Electric monopole (E0) transitions

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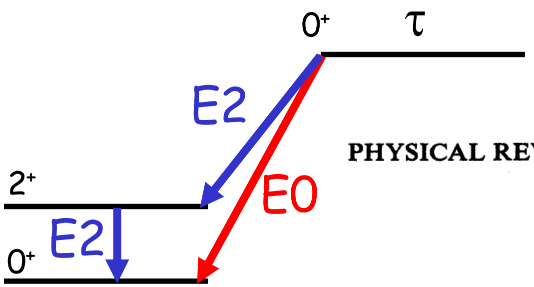

PHYSICAL REVIEW C VOLUME 31, NUMBER 4 APRIL 1985

$E0$ transitions in ^{82}Kr

1985Ze03

A. Zemel, T. Hageman, J. J. Hamill, and J. van Klinken
Kernfysisch Versneller Instituut, 9747 AA Groningen, The Netherlands
(Received 9 October 1984)

The first excited 0^+ state of ^{82}Kr appears to have a noncollective nature, in contrast to the 0_3^+ and other low-spin states in this nucleus. This is corroborated by a conversion-electron measurement of the $0_2^+ \to 0_1^+$ and the $0_3^+ \to 0_1^+$ transitions in ^{82}Kr, following the decay of ^{82}Rb^g. The values $B(E0;0_2^+ \to 0_1^+) = 3.1(5)$ e^2fm^4 and $X_{311} = B(E0;0_3^+ \to 0_1^+)/B(E2;0_3^+ \to 2_1^+) = 0.097(24)$ have been deduced from the intensities of the conversion lines, observed with a mini-orange spectrometer. Previous theoretical and experimental investigations of ^{82}Kr are reviewed.

```
82KR     82RB B+ DECAY (1.2575 M)      1983ME08                   03NDS    200305
82KR   L    1487.62  70+
82KR   E                0.044  3   0.0096 7   6.72   4                  0.054   4
82KRS  E EAV=837.4  33$CK=0.1556  15$CL=0.01804  18$CM+=0.00370  4
82KR   G 711.2      1 0.38     2
82KR   G 1488                       E0                             6.2E-6    6 B
82KRS  G K/K+L+=0.76$  L/K+L+=0.07
82KR  CG             CEK(1488)/CEK(1475)=0.31  3;
82KR2CG CEK(1488)=4.7E-6  5 per 100 82RB (1.273 M) Ducas (1985Ze03).
```

← Should be E2

```python
## python 82Kr_1488E0.py
print "Evaluates E0 transitions from conversion data"
from uncertainties import ufloat
from uncertainties.unumpy import sqrt
from math import pow
##
State='82Kr 1488 E0'
A=82                                       ## atomic mass
Thalf=ufloat(10E-12,3E-12)                 ## half life 10(3) ps
Tau=Thalf/0.6931                           ## mean life
print 'State: ', State
## decay data
qK2_E0E2=ufloat(0.087,0.008)               ## E0/E2 mixing ratio
CK_E2=ufloat(0.001031,0.000015)            ## E2 K-conversion coef.
CC_E2=ufloat(0.001163,0.000017)            ## E2 total conversion coef.
## E2 transition
## intensities are in terms of the I_K(E2)=1
Eg_E2=0.7112                               ## E_gamma [MeV]
IK_E2=1.0                                  ##
IG_E2=IK_E2/CK_E2                          ## I_gamma(E2)
IT_E2=IG_E2*(1+CC_E2)                      ## I_tot(E2)
## E0 transition
IK_E0=IK_E2*qK2_E0E2                       ## E0
WK_E0=8.473E+8                             ## Omega_K(E0)
WT_E0=9.886E+8                             ## Omega_T(E0)
IT_E0=IK_E0*WT_E0/WK_E0                    ## I_tot(E0)
## X-value
X=2.54E+9*pow(A,1.3333)*qK2_E0E2*(CK_E2/WK_E0)*pow(Eg_E2,5)
print '      X(E0/E2)=', X
## Partial E2 photon width
Tau_gE2=Tau*(IT_E2+IT_E0)/IG_E2
## Rho**2
r2_E0=qK2_E0E2*CK_E2/(WK_E0*Tau_gE2)
r_E0=sqrt(r2_E0)                           ## ENSDF: rho(E0) given
print '      rho(E0)=', r_E0
```

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Electric monopole (E0) transitions

96 T. Kibédi, R.H. Spear / Atomic Data and Nuclear Data Tables 89 (2005) 77–100

2005Ki02

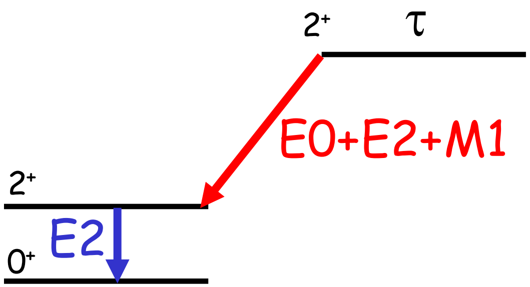
Table 1
Spectroscopic information on $0^+ \rightarrow 0^+$ transitions. See page 95 for Explanation of Table

Nuclide	E_i (keV)	$T_{1/2}$	Transition			q_K^2(E0/E2)		X(E0/E2)	$10^3 \times \rho^2$(E0)	References
			J_i^π–J_f^π	E0 (keV)	E2 (keV)					
$^{72}_{36}Kr_{36}$	671	26.3 (*20*) ns	0_2^+–0_1^+	671	*h*				71 (*6*)	[333]
$^{74}_{36}Kr_{38}$	509	13.3 (*7*) ns	0_2^+–0_1^+	509	53	1.9 (*5*)	*ABE*	0.017 (*4*)	113 (*27*)	[282,300,309,333,334]
$^{78}_{36}Kr_{42}$	1017.2	7.6 (*21*) ps	0_2^+–0_1^+	1017	562.1	0.136 (*6*)	*A*	0.024 (*1*)	47 (*13*)	[262]
$^{80}_{36}Kr_{44}$	1320.5	4.9 (*21*) ps	0_2^+–0_1^+	1320.5	703.9	0.103 (*11*)	*A*	0.023 (*3*)	21 (*10*)	[238]
$^{82}_{36}Kr_{46}$	1487.6	10 (*3*) ps	0_2^+–0_1^+	1488	711.2	0.087 (*8*)	*E*	0.0174 (*16*)	7.3 (*23*)	[182,339]
	2171.7	≈2 ps	0_3^+–0_1^+	2172	1395.1	0.14 (*4*)	*E*	0.10 (*3*)	≈7	[182,339]

ENSDF

```
82KR   L    1487.62  70+
82KR   E                    0.044  3   0.0096 7   6.72   4                   0.054   4
82KRS  E EAV=837.4  33$CK=0.1556  15$CL=0.01804  18$CM+=0.00370  4
82KR   G 711.2      1 0.38     2 E2
82KR   G 1488                    E0                                     6.2E-6    6 B
82KRS  G K/K+L+=0.76$  L/K+L+=0.07
82KR2  G MR2K(E0/E2)=0.087  8$
82KR  CG          CEK(1488)/CEK(1475)=0.31  3;
82KR2CG CEK(1488)=4.7E-6  5 per 100 82RB (1.273  M) decays (1985Ze03).
82KR  CG MR2K(E0/E2)$  from 1985Ze03
82KR  CG          X(E0/E2)=0.0174  16 (1985Ze03)
82KR  CG          RHO(E0)=0.086  13 (1985Ze03)
```

Mixed E0+E2+M1 transitions



As for pure E0, but MR(E2/M1) also needed

Conversion coefficient for atomic shell/PF "i"

$$\alpha_i\,(exp) = \frac{\alpha_i(M1) + (1 + q_i^2)\delta^2\alpha_i(E2)}{1 + \delta^2}$$

E0/E2 Mixing ratio

$$q_K^2(E0/E2) = \frac{I_K(E0)}{I_K(E2)}$$

From α_i(exp) using new BrIccMixing

X-factor - experiment

$$X(E0/E2) = 2.54\times10^9\times A^{4/3}\times q_K^2\times\frac{\alpha_K}{\Omega_K}\times E_\gamma^5(MeV)$$

Experimental Monopole matrix element

$$\rho^2(E0) = q_K^2(E0/E2)\times\frac{\alpha_K(E2)}{\Omega_K(E0)}\times\lambda_\gamma(E2)$$

New Ω(E0) tables

Ω_i(E0) calculations:

K, L1, L2, M1, M2, N1, N2…

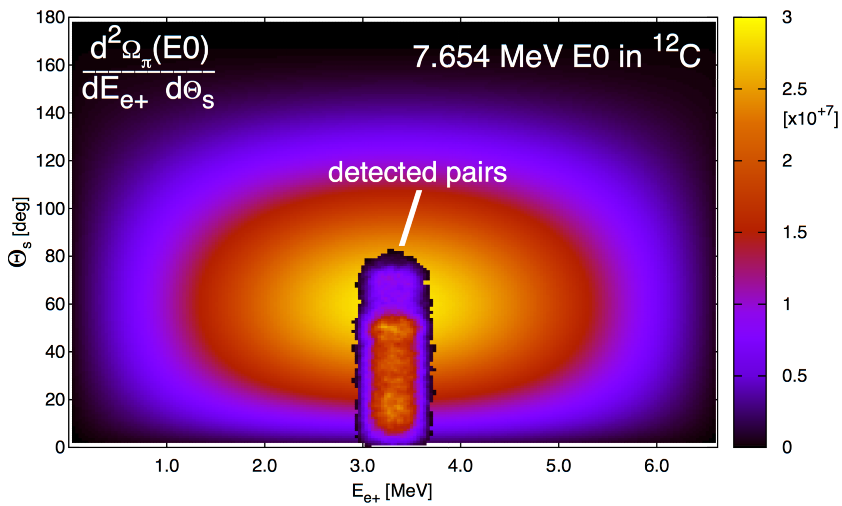
with G. Gosselin, V. Meot, M. Pascal (CEA, France)

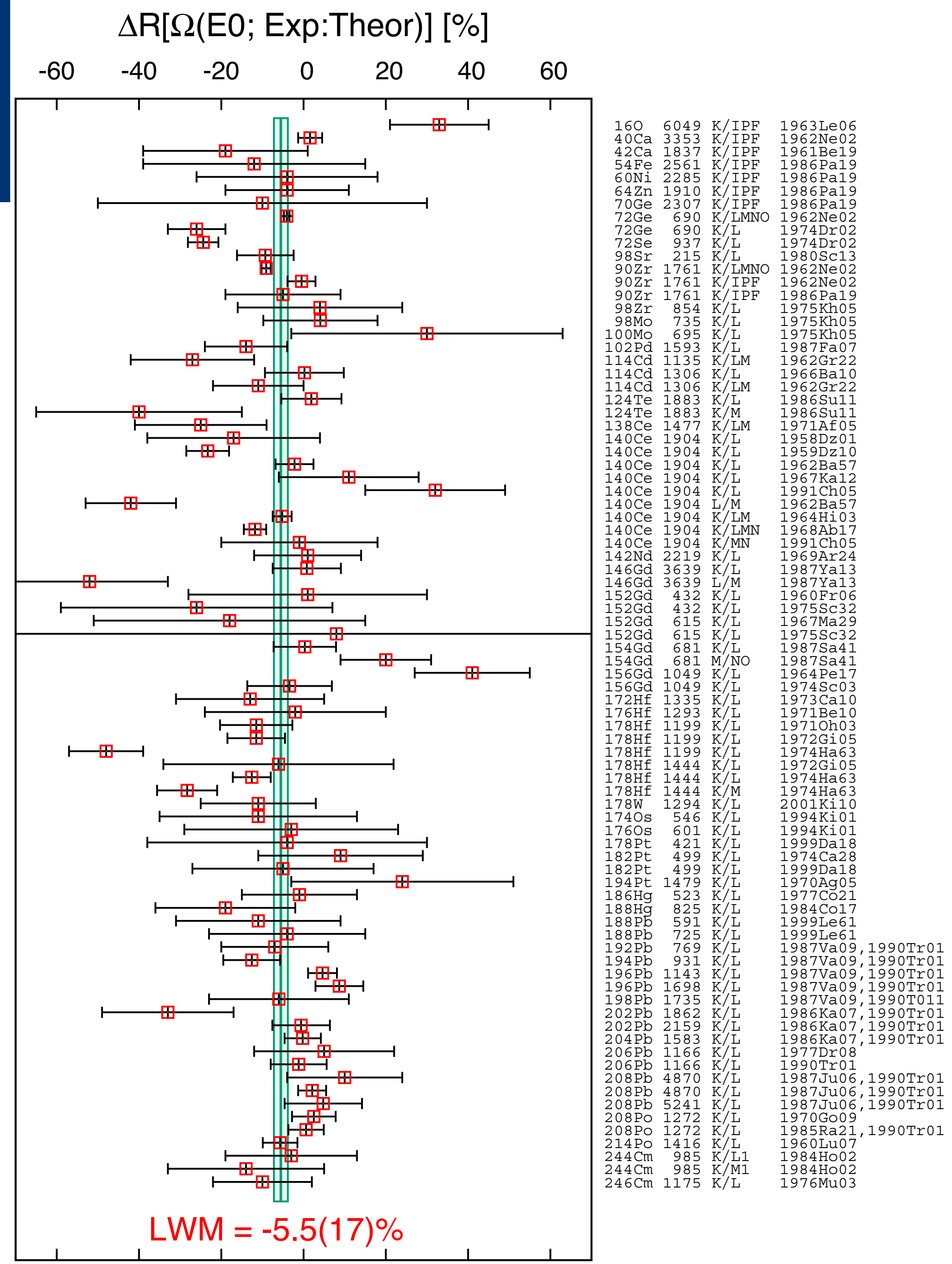
CATAR (Pauli and Raff (Comp. Phys. Comm. 9 (1975) 392).

Modified screening function reduces difference (A.E. Stuchbery, ANU)

Pair Formation

Total as well double differential for pair conversion measurements (T.K. Eriksen, ANU)





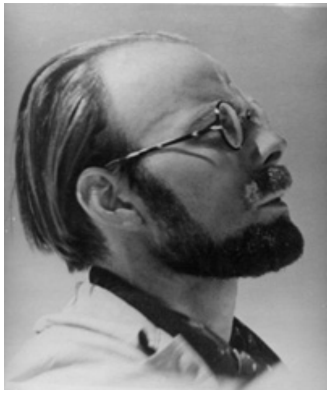
BrIcc V3.0

- Z extended to 126
- New Ω(E0) tables for K, L1, L2, M1, M2 … shells and PF for Z=6-100
- NS_Lib library to parse validate ENSDF records
- Monte Carlo propagation of uncertainties

Technical Meeting on Improvement of Codes used for Nuclear Structure and Decay Data Evaluations, IAEA, 10-13 June 2014 and 5-8 October 2015

```
Z= 54   Xenon              Transition energy: 1400 keV                                      BrIcc v3.0 (10-Jun-2014)
                Omg(E0)                          Conversion Coefficient                     Data Table: BrIccFO
Shell  E_e [keV]  E0         E1        M1        E2        M2        E3        M3        E4        M4        E5        M5
-------------------------------------------------------------------------------------------------------------------------------
Tot               1.729E+10  4.199E-04 1.020E-03 8.226E-04 2.259E-03 1.533E-03 4.196E-03 2.759E-03 7.389E-03 4.875E-03 1.270E-02
K       1365.44   1.499E+10  3.244E-04 8.723E-04 6.975E-04 1.946E-03 1.316E-03 3.600E-03 2.341E-03 6.286E-03 4.038E-03 1.069E-02
L-tot             1.908E+09  3.884E-05 1.068E-04 8.660E-05 2.464E-04 1.737E-04 4.769E-04 3.341E-04 8.804E-04 6.320E-04 1.599E-03
M-tot             2.694E+08  7.807E-06 2.154E-05 1.748E-05 4.990E-05 3.528E-05 9.710E-05 6.842E-05 1.805E-04 1.306E-04 3.303E-04
N-tot             8.489E+07  1.616E-06 4.465E-06 3.615E-06 1.035E-05 7.284E-06 2.012E-05 1.410E-05 3.736E-05 2.684E-05 6.830E-05
O-tot             3.709E+07  2.031E-07 5.632E-07 4.521E-07 1.302E-06 9.023E-07 2.519E-06 1.725E-06 4.645E-06 3.239E-06 8.414E-06
IPF               1.495E-04  4.705E-05 1.455E-05 1.691E-05 5.153E-06                                         4.484E-05
TranEner|ChemSymb|Z+Integer|SUBShell|DATAtable|? for help|EXIT [1400] >
```

The Auger effect
Pierre Auger – Lise Meitner



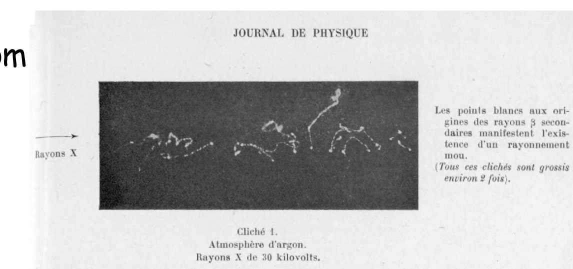
Pierre Victor Auger
(1899 - 1993)

P. Auger, C.R.A.S. 177 (1923) 169-171. 1923:

"When the first [atomic] electron leaves [the atom, ejected by an incident X-ray], as a secondary β-ray, there is a vacancy left in the electronic system of the excited atom. The drop of a more peripheral electron on that level is accompanied by the emission of a characteristic radiation quantum. This quantum may be absorbed in the atom itself, and produce, at the expense of the peripheral levels [the outer electronic shells], a tertiary β-ray . . . The repetition of that process must lead to the production of a fourth order ray; and I in-deed believe I have observed such rays in the case of [gaseous] iodine."

Lise Meitner
(1878- 1968)

First multi-electron tracks from photoionization seen in a cloud chamber.



P. Auger
Journal de Physique et le Radium, **6** (1925) 205.

Auger electrons and X-rays are part of the radiations emitted in nuclear decay!
Not in ENSDF

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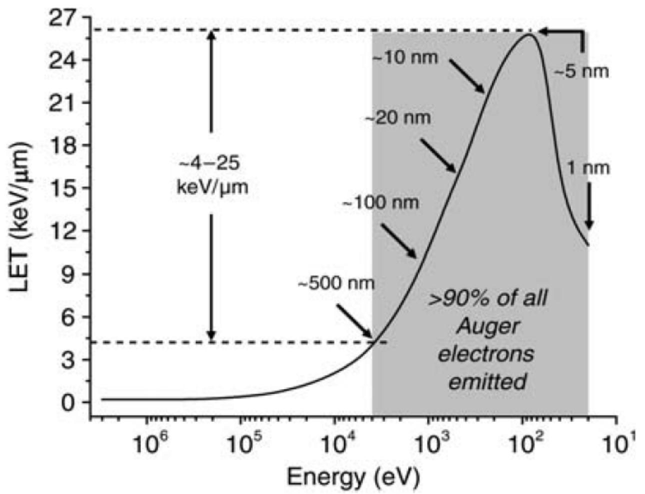
The biological effect of Auger electrons

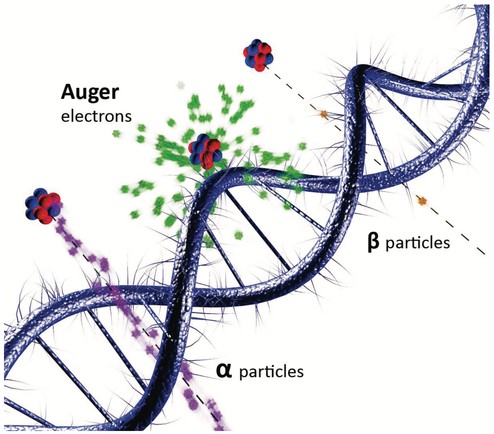
Interaction of ionizing radiation:

- ❑ Spectrum of energy loss
- ❑ Generation of secondary electrons
- ❑ Low energy electrons are the ideal tool
- ❑ Auger electrons from radioisotopes – decay at close proximity to the DNA



Which Isotope?

- ❑ Number of electrons per decay
- ❑ Ratio of X & γ vs. e^- & β
- ❑ Physical vs. effective half life
- ❑ Suitable radiochemistry

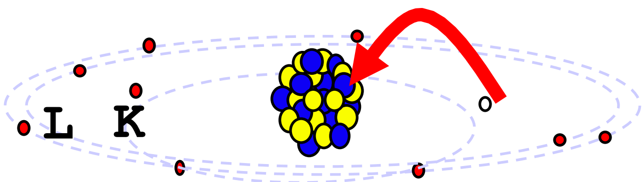


Physics input to dose calculations:

- ❑ Energy loss
- ❑ Radiation spectra

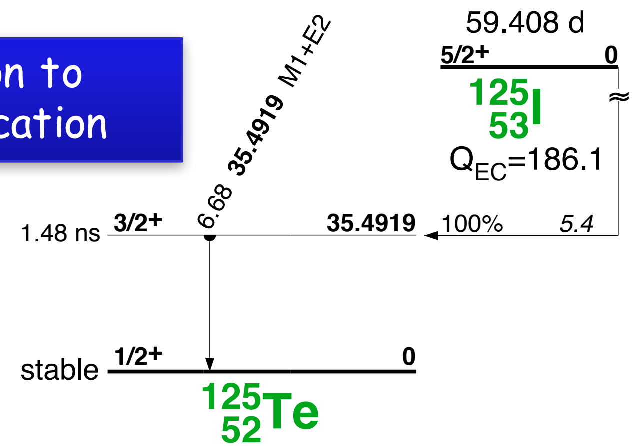
BrIccEmis
Initial vacancy creation

Electron capture



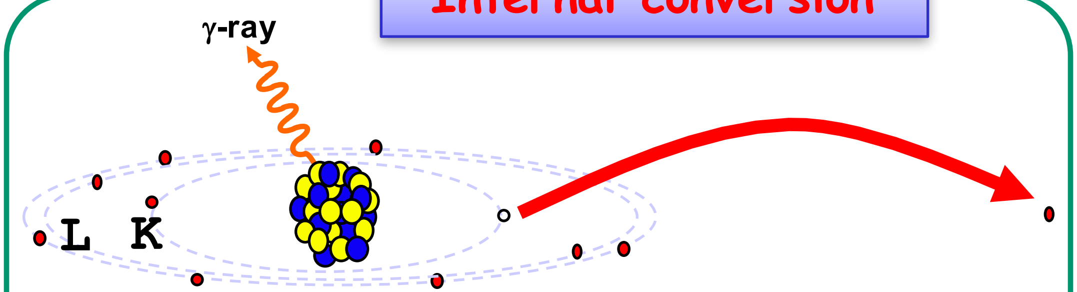
$$ {}^{A}_{Z}X_{N} + e = {}_{Z-1}^{A}X_{N+1} + \nu_e $$

γ-radiation to monitor location



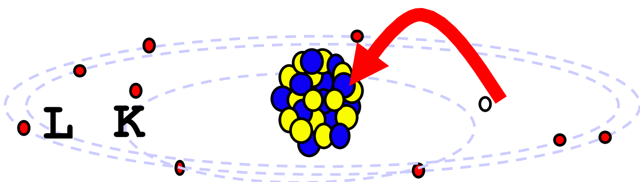
ENSDF - Evaluated Nuclear Structure Data File

Internal conversion

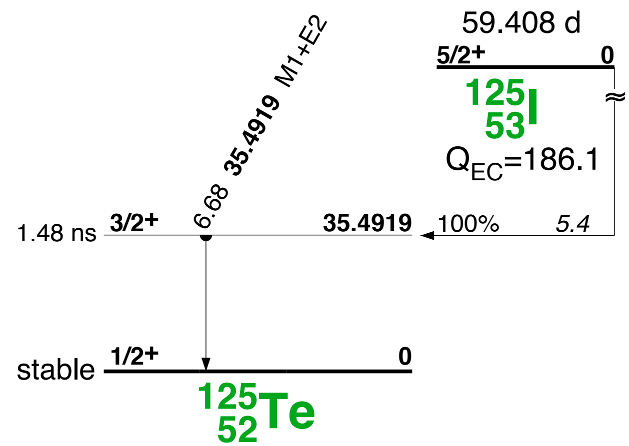


Electron capture

Electron capture



$$ {}^{A}_{Z}X_{N} + e = {}^{A}_{Z-1}X_{N+1} + \nu_{e} $$



Electron capture rates

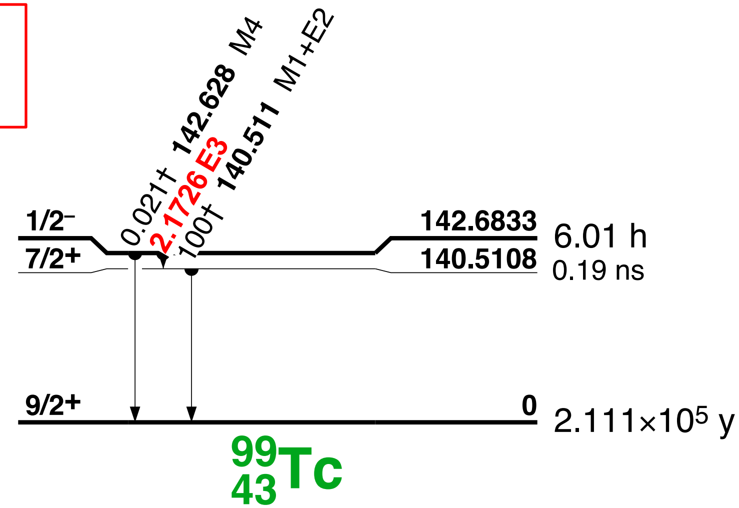
$P_K+P_L+P_M+P_N+P_O=1$

E. Schonfeld, PTB-6.33-95-2 (1995)

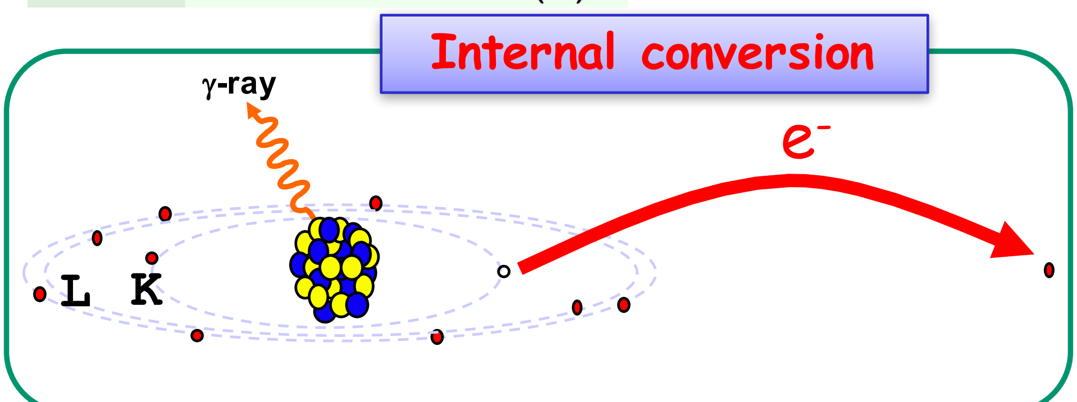
Internal conversion

Shell	E(ce)	E3
Tot		1.370E10 (20)
M1	1.63	2.26E6 (4)
M2	1.73	3.37E9 (5)
M3	1.75	5.98E9 (9)
M4	1.92	1.100E9 (16)
M5	1.92	1.655E9 (24)
M-tot	1.78	1.211E10 (17)
N1	2.10	5.00E5 (7)
N2	2.13	4.92E8 (7)
N3	2.14	8.77E8 (13)
N4	2.17	9.11E7 (13)
N5	2.17	1.350E8 (19)
N-tot	2.14	1.596E9 (23)
O1	2.17	3.49E4 (5)
O-tot	2.17	3.49E4 (5)

Conversion coefficient $= N(e^-)/N(\gamma)$

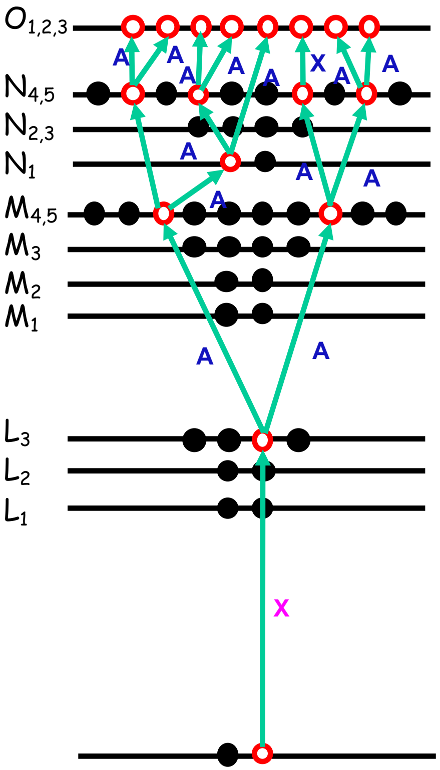


- ICC ~1.3% accurate
- Z=5-110; 1-6000 keV; E0, E1-E5, M1-M5
- All subshells



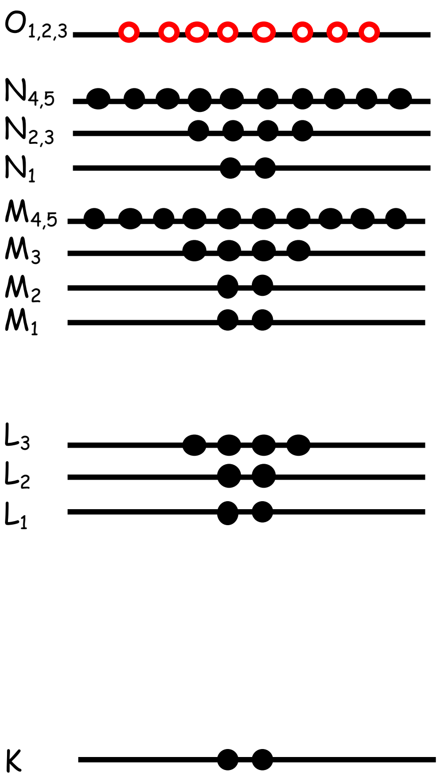
T. Kibedi, et al, NIM Nucl. Instr. and Meth. **A589** (2008) 202

Propagation of the vacancies



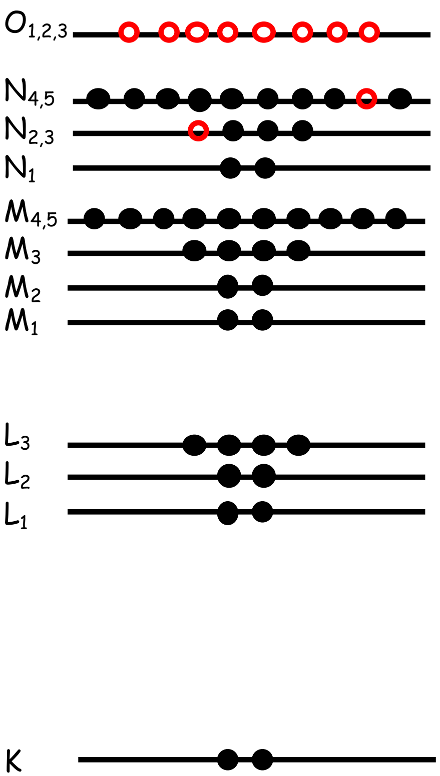
- X-ray or Auger electron emission to fill vacancy
- Multi step, stochastic process; Monte Carlo
- Transition energies and transition probabilities are needed for every propagation step
- Transition energies from Dirac-Fock atomic model
  - RAINE code (Band 2002) No QED or Breit corrections
- Transition rates from EADL (Perkins 1991)
  - Calculated for single initial vacancies
  - No shaking or double Auger process
- Krause-Carlson correction to transition rates to take into account multiple vacancies

Propagation of the vacancies

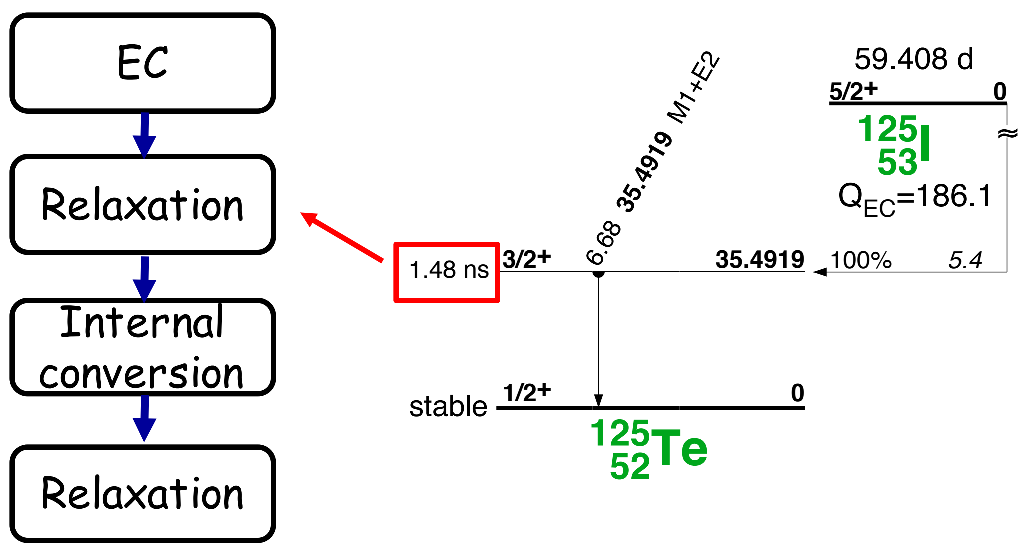


- X-ray or Auger electron emission to fill vacancy
- Multi step, stochastic process; Monte Carlo
- Transition energies and transition probabilities are needed for every propagation step
- Transition energies from Dirac-Fock atomic model
  - RAINE code (Band 2002) No QED or Breit corrections
- Transition rates from EADL (Perkins 1991)
  - Calculated for single initial vacancies
  - No shaking or double Auger process
- Krause-Carlson correction to transition rates to take into account multiple vacancies
- STOP: Vacancy in valence shell / no transition is possible

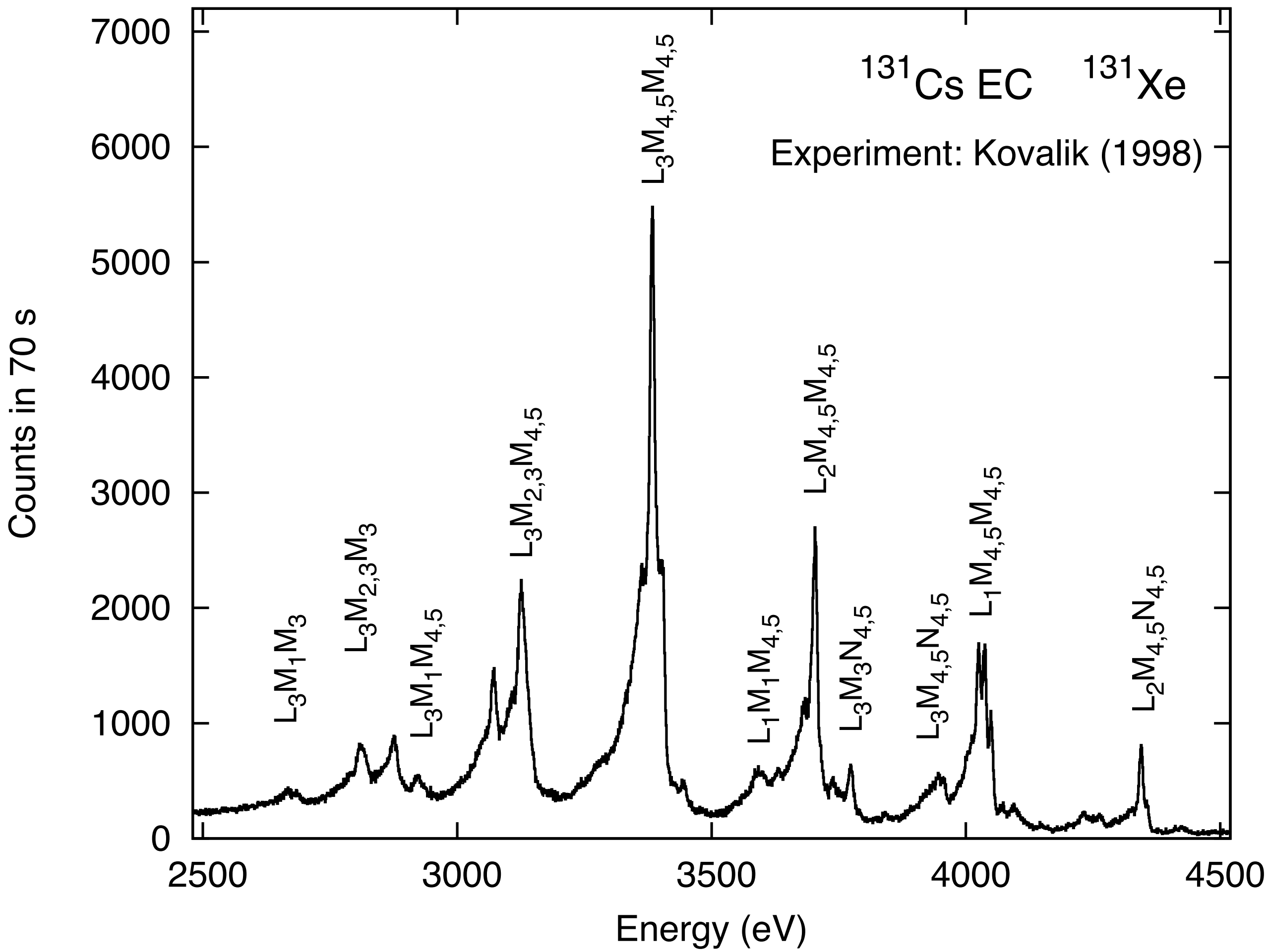
Fast vs. slow neutralization

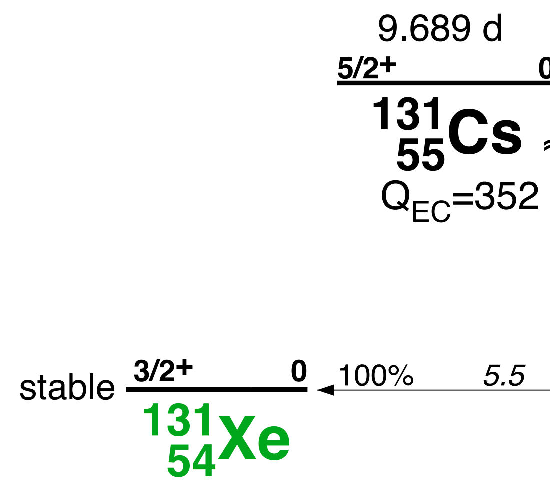


- Is the atom ISOLATED or in CONDENSED PHASE?
- Condensed phase: vacancies filled from environment (Charlton and Booz 1981, Humm 1984, Howell 1992)
- Auger cascade very fast: 10^{-14} to 10^{-16} s
- Neutralization is a slow process (Pomplun 2012)
- BrIccEmis: fast neutralization and option
  Correct treatment: condensed physics model



^{131}Cs EC – Auger spectrum





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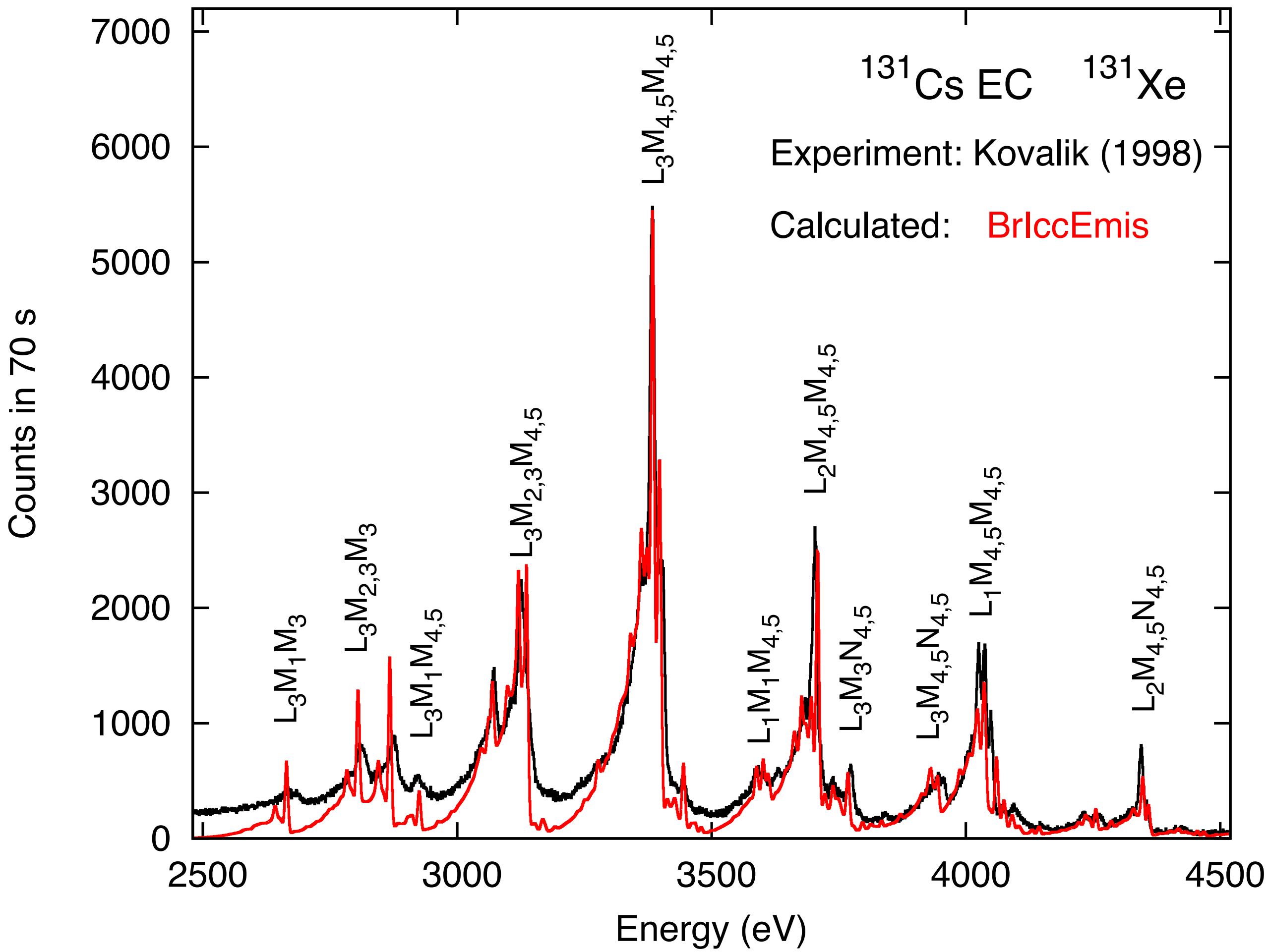

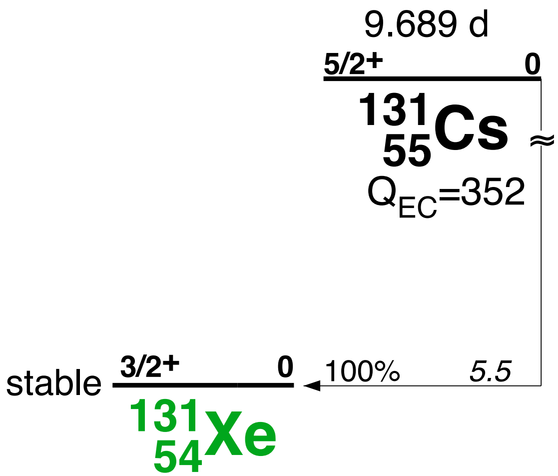

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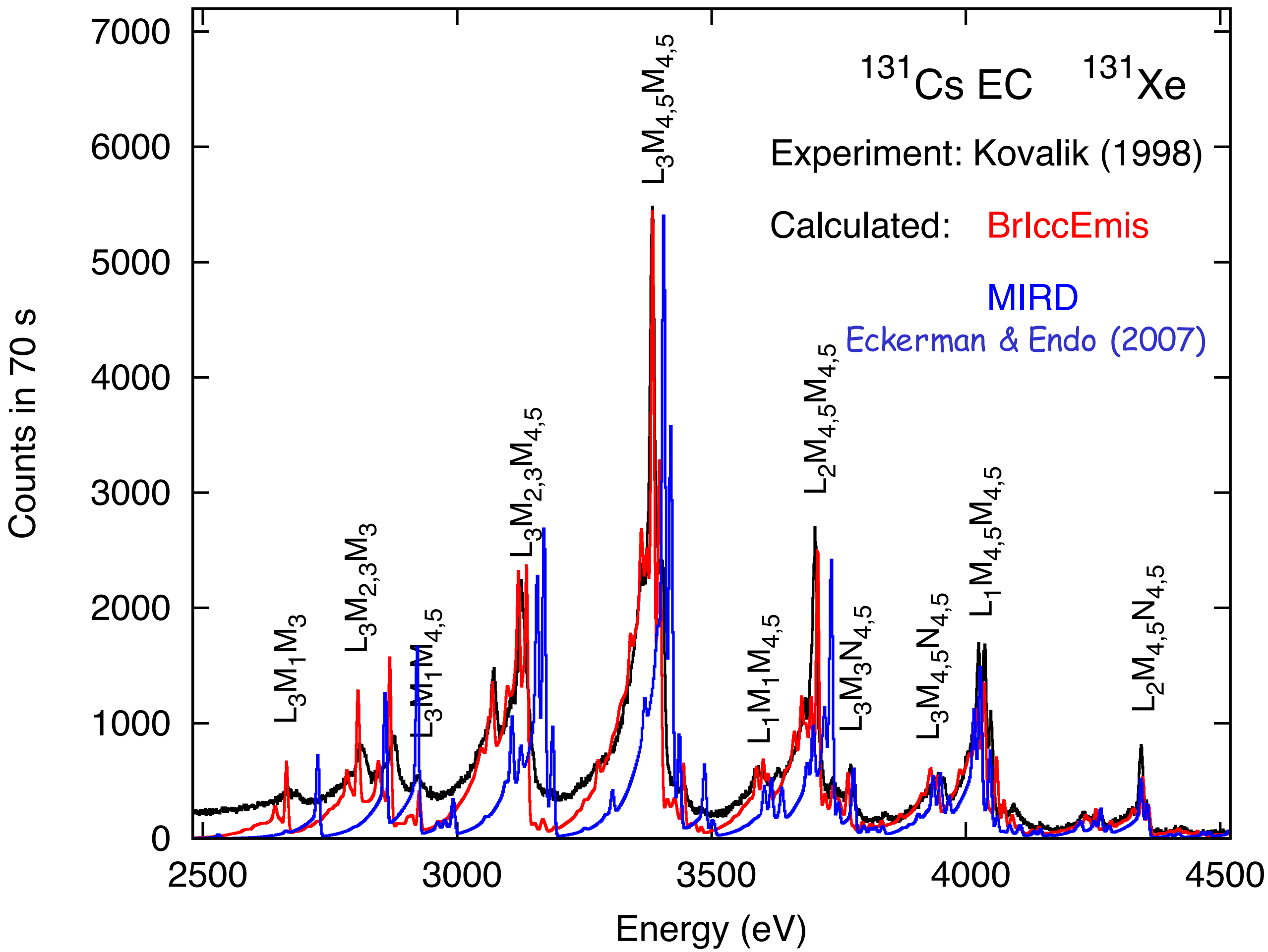

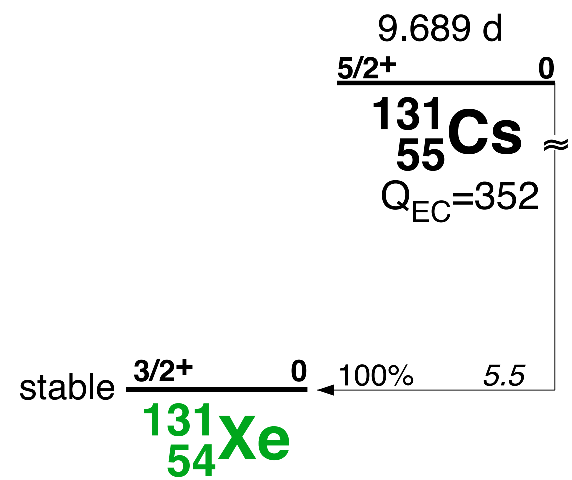

^{125}I – low energy Auger electron measurements

nature materials | LETTERS
PUBLISHED ONLINE: 15 JUNE 2015 | DOI: 10.1038/NMAT4323

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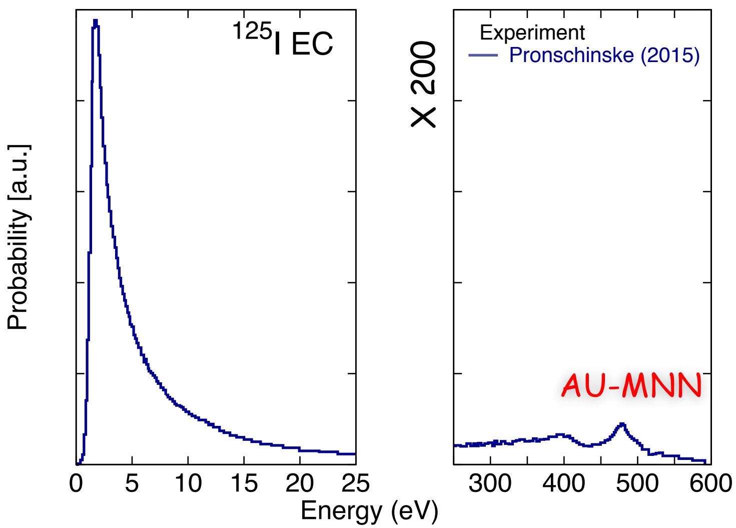
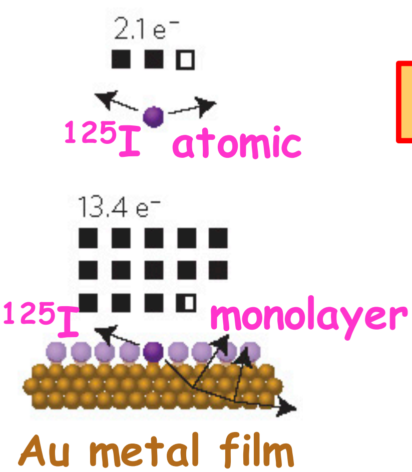
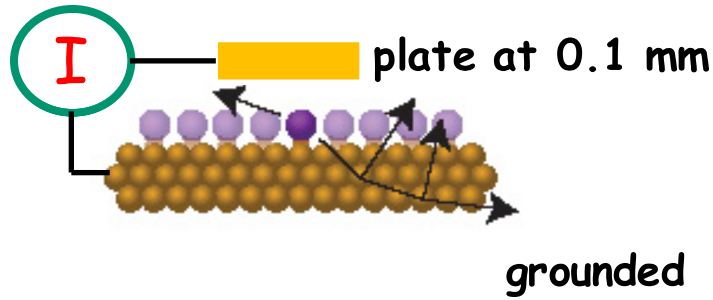




-10 V on plate: ΔI = 11.8 pA



Auger spectrum: 5-channel concentric hemispherical electron energy analyser

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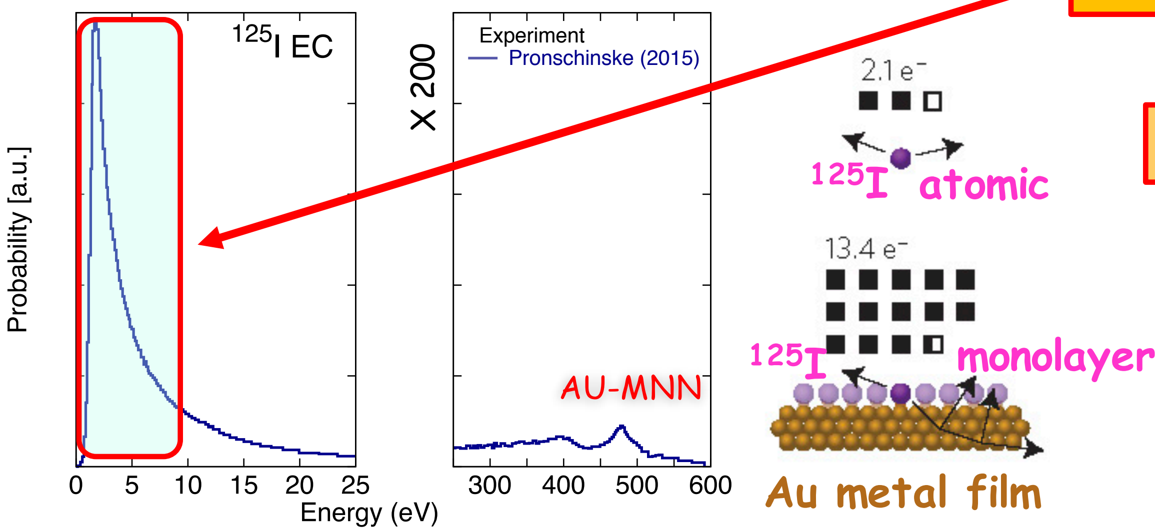
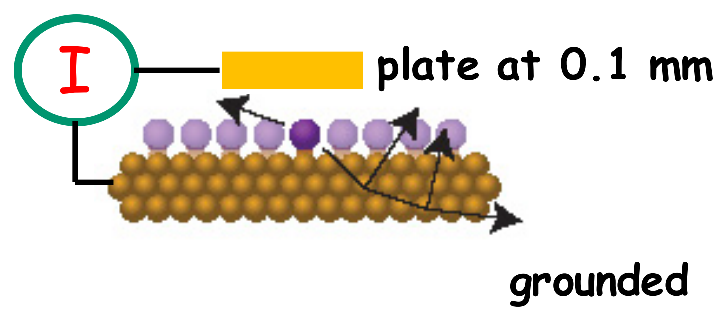


Six fold increase in E_e < 10 eV

-10 V on plate: ΔI = 11.8 pA



Tufts University, MA, USA

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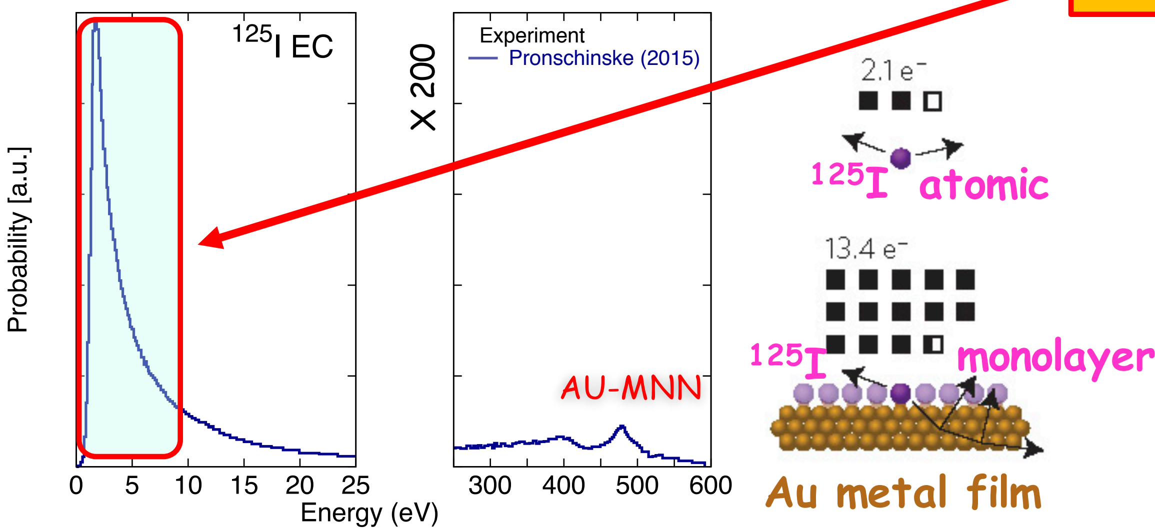

Line	<E> [eV]	Yield/decay
C-K MMX	1.433	90
Aug-MXY	377	3.308
C-K NNX	27	1.803
Aug-NXY	38	1.655

E. Pomplun et al,
Radiat. Res. 111 (1987) 533.

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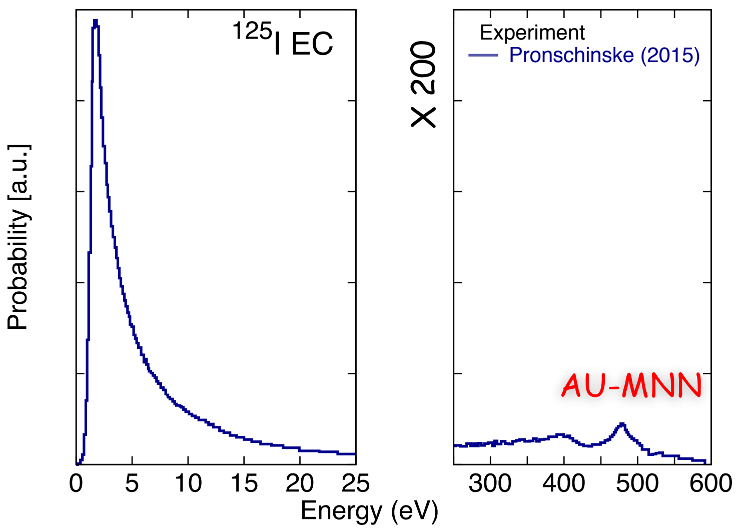

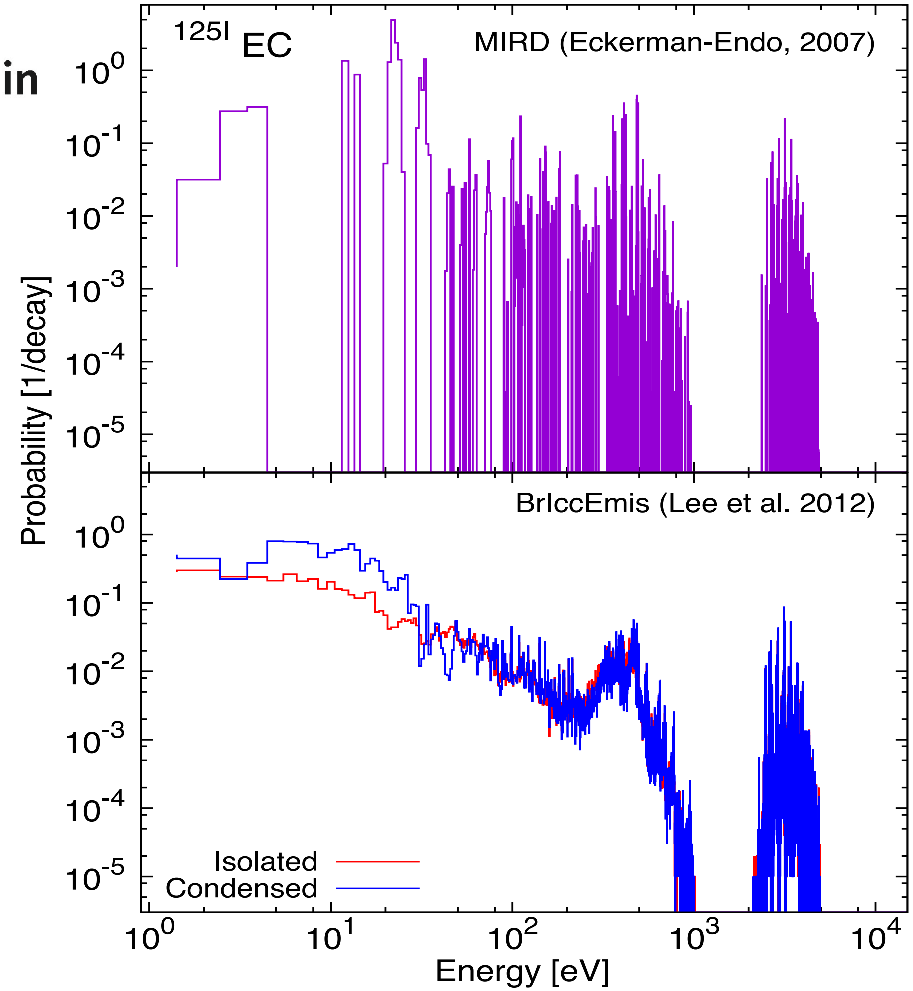

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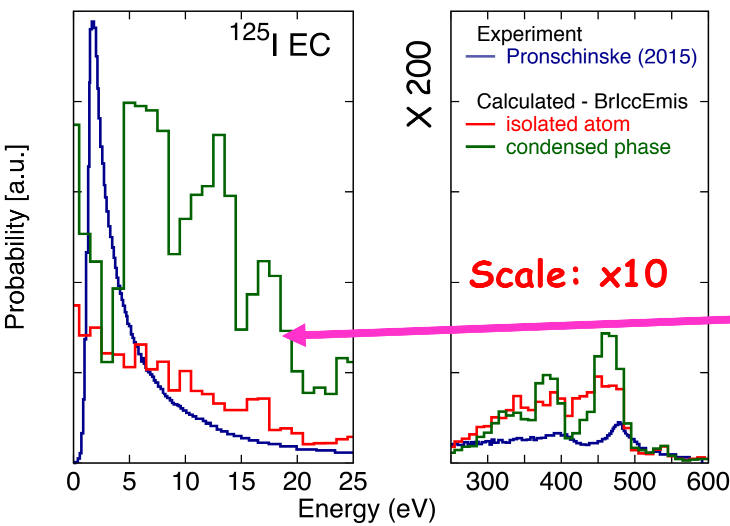

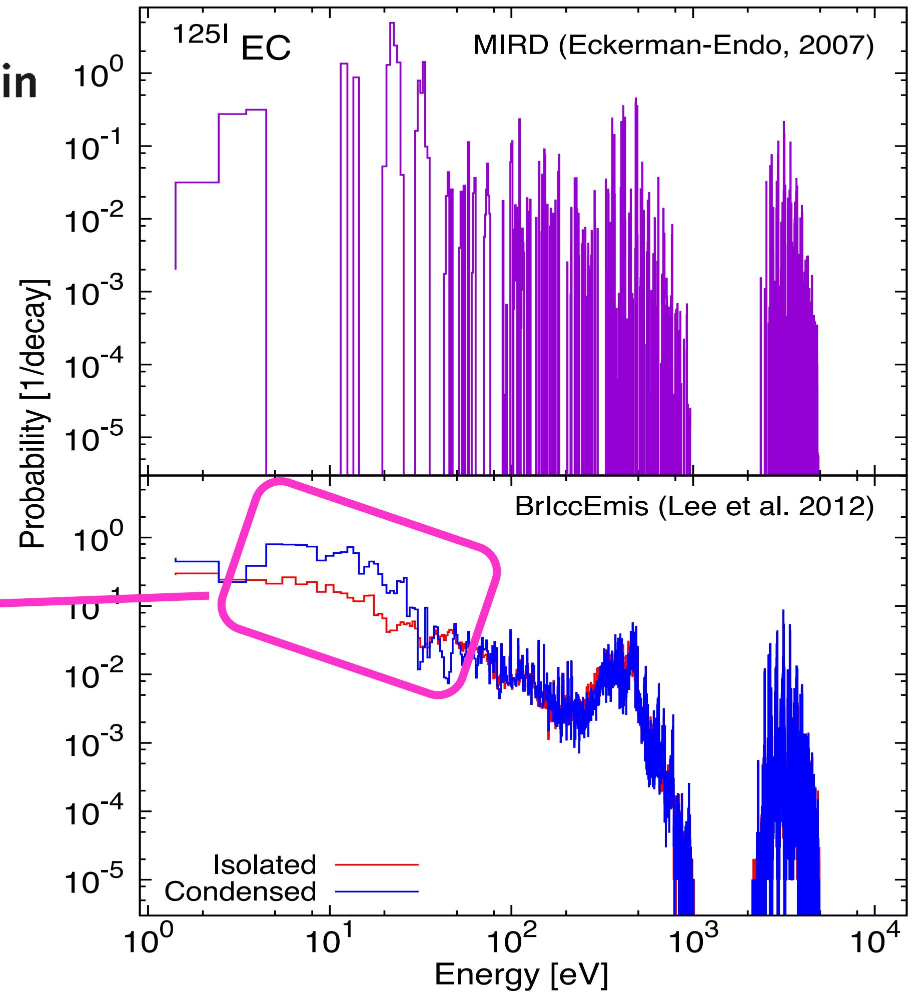

Correct treatment: condensed physics model!

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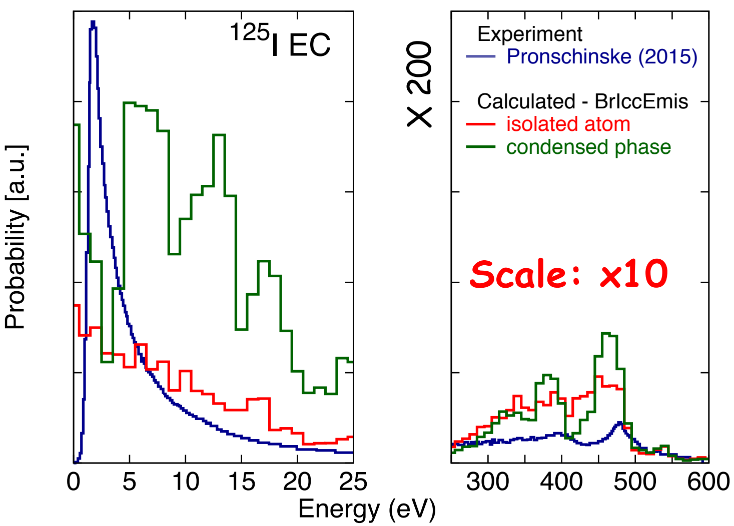

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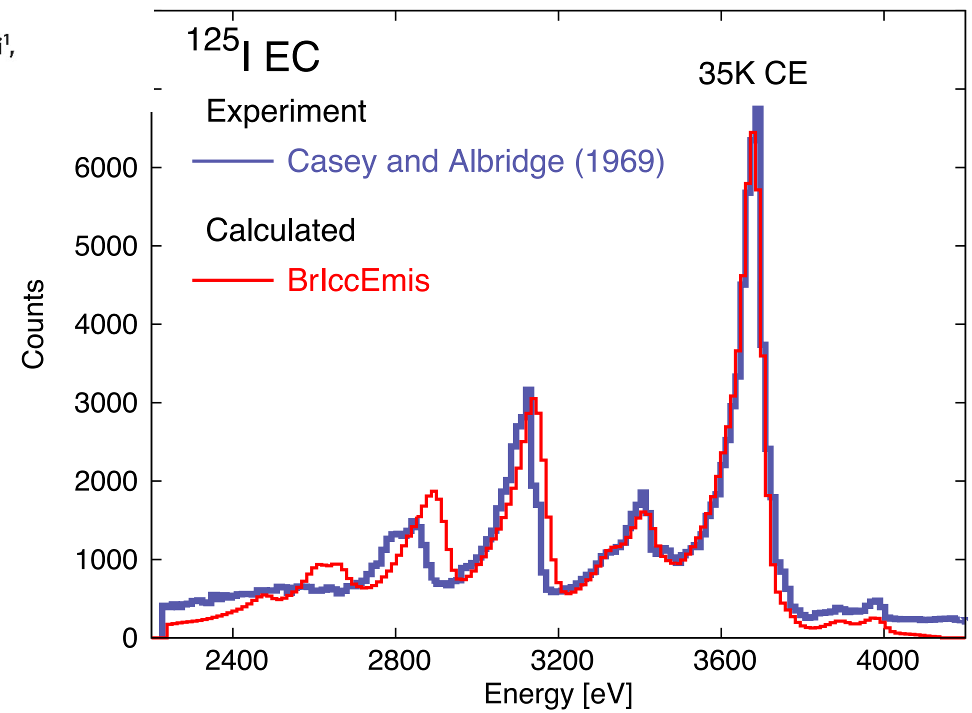

W.R. Casey, R.G. Albridge, Z. Phys. 219 (1969) 216

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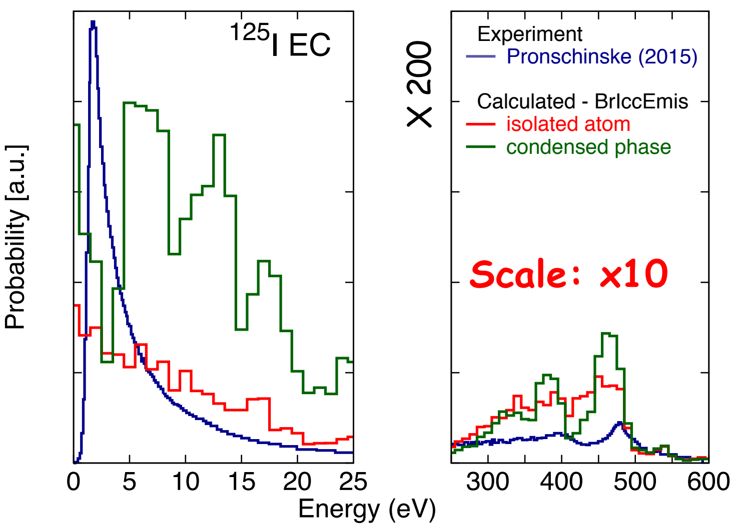

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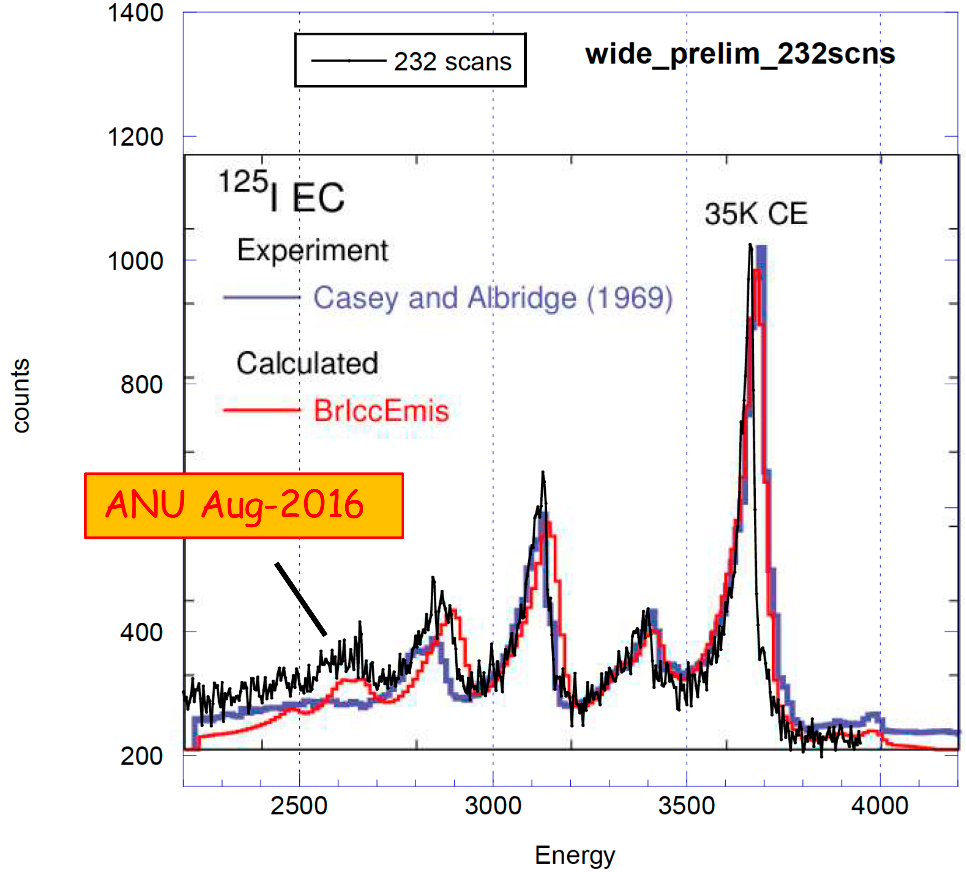

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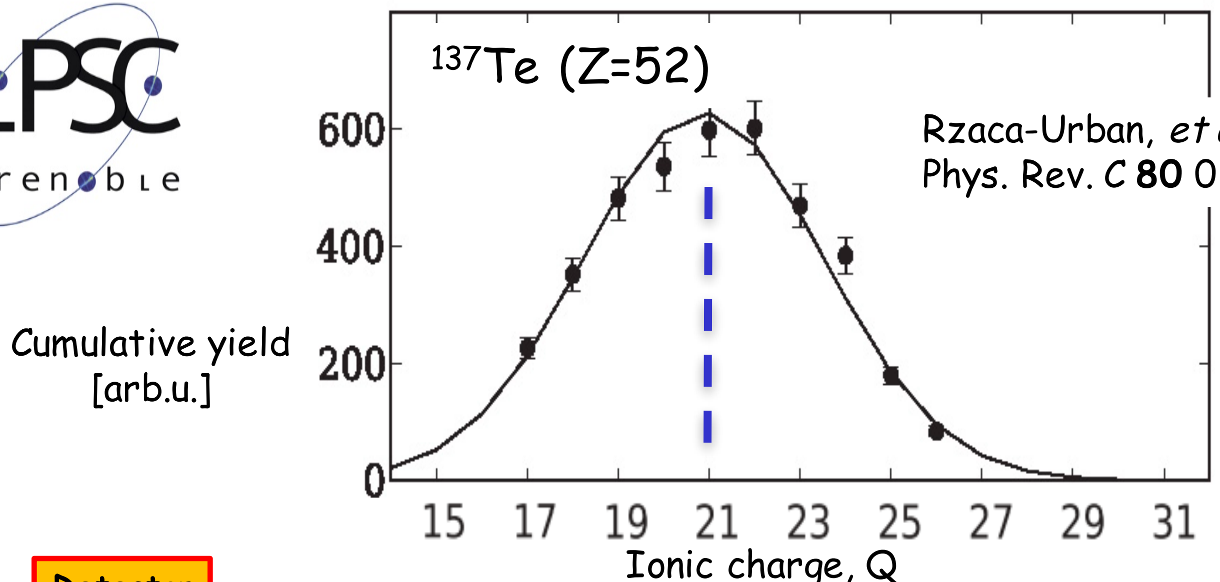
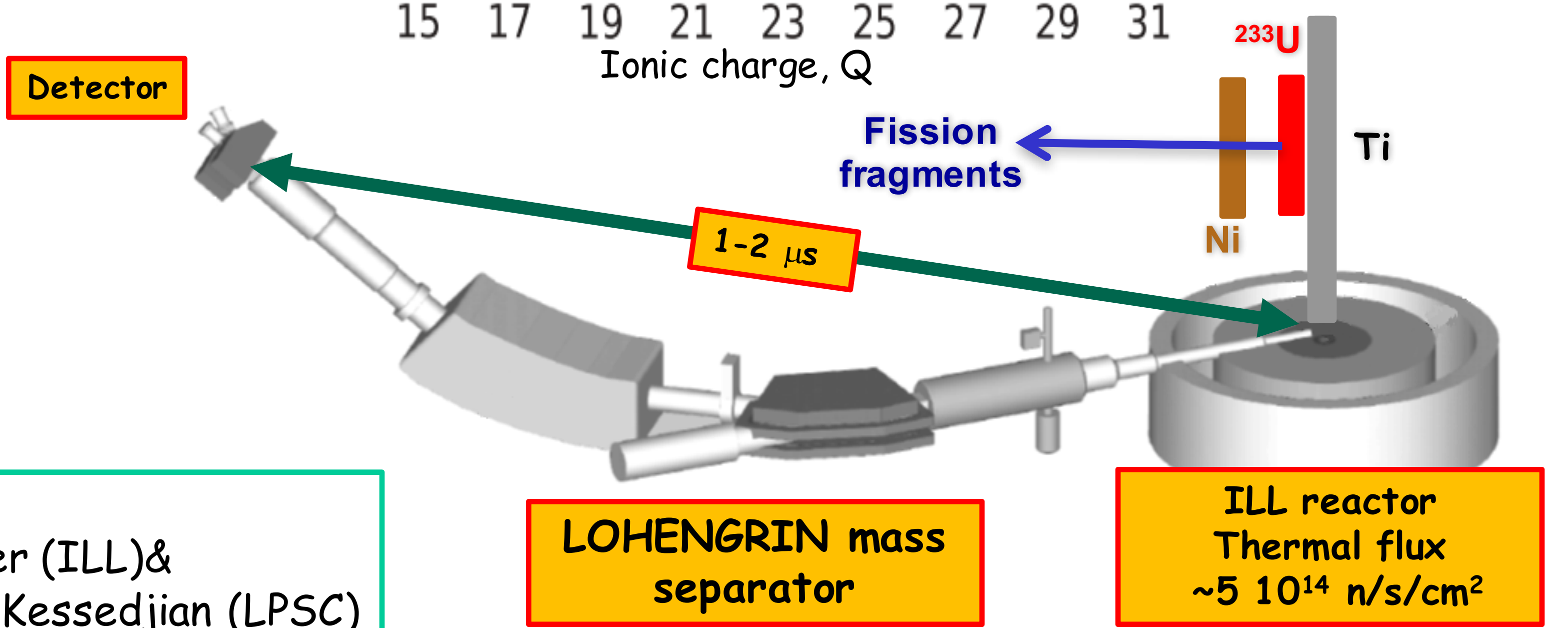
Charge state distribution of fission isomers

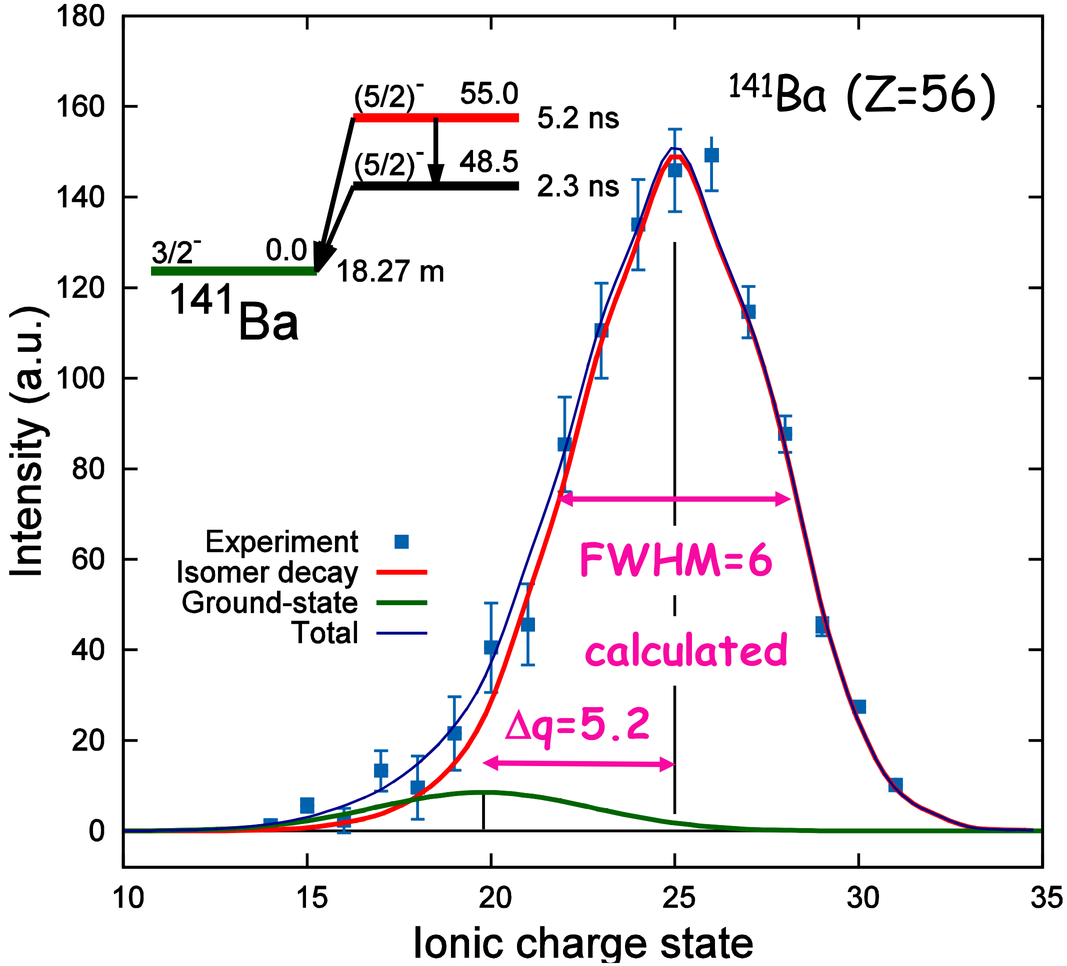




Collaboration:
Ulli Köster (ILL)&
Grégoire Kessedjian (LPSC)

Charge state distribution of fission isomers

- 55.0 keV isomeric state decays in flight
- Auger cascade increases ionization state by ~5 units of charge



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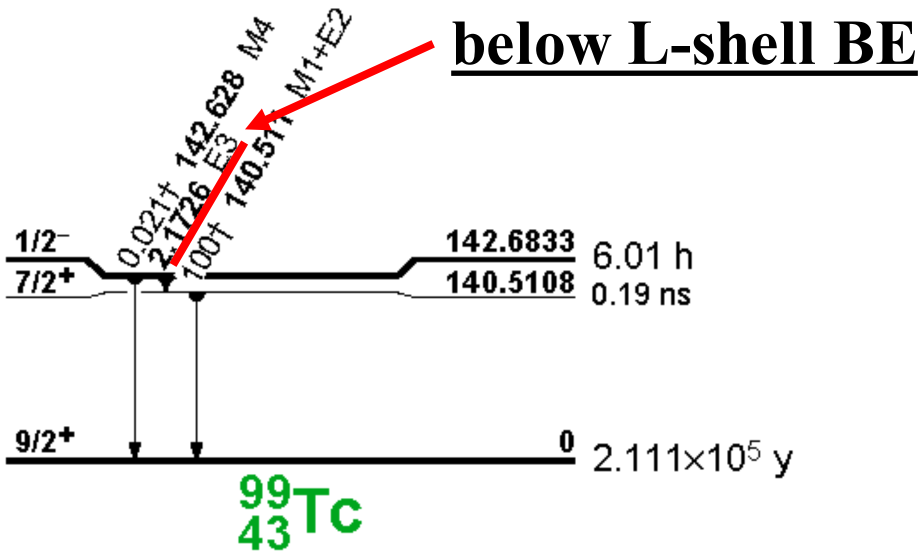
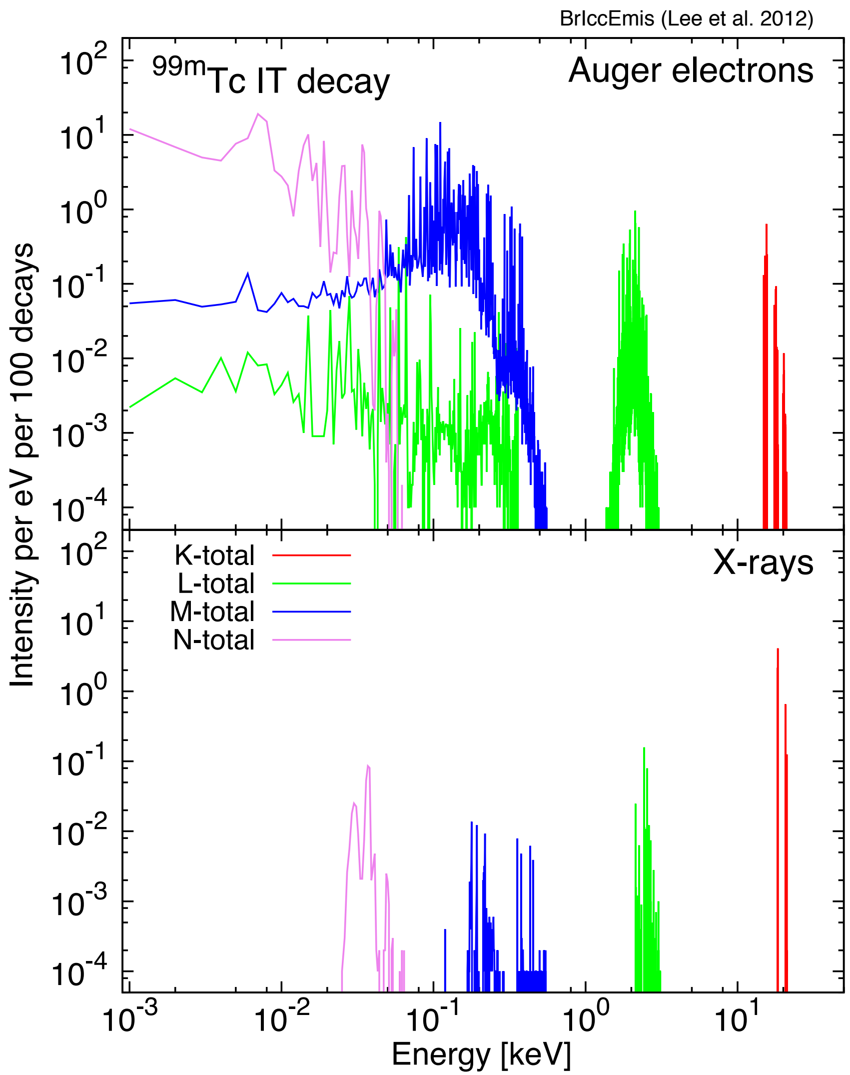
99mTc
Used for ~30M medical procedures every year



1 photon per 1.37×10^{10} decays!



99mTc

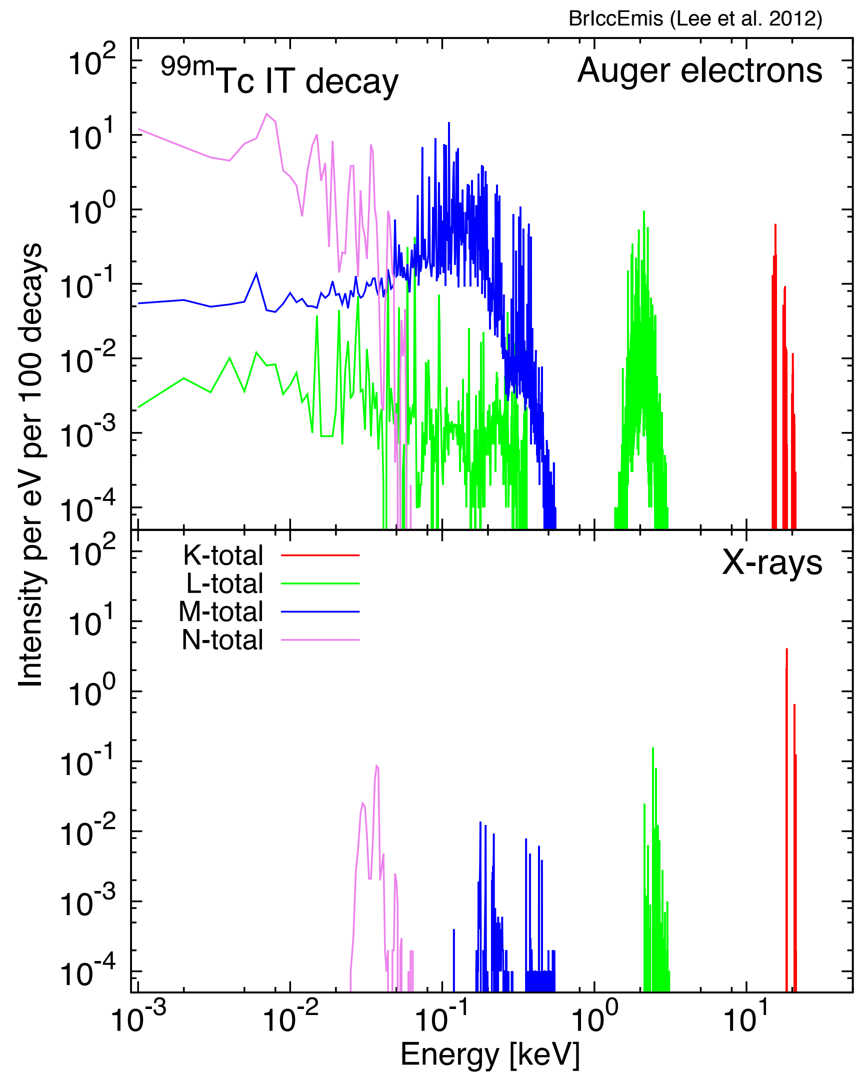
Used for ~30M medical procedures every year

ELECTROMAGNETIC TRANSITIONS ==================

# Trans	Energy[keV]	Prob.[per 100 decays]
G - 1	140.511(1)	88.80(20)
K - 1	119.467	8.86(17)
L - 1	137.673	1.080(19)
M - 1	140.126	0.196(4)
N - 1	140.480	0.0311(6)
G - 2	2.1726(15)	7.23E-9(11)
M - 2	1.7879	87.5(11)
N - 2	2.1422	11.54(16)
G –	142.6831(11)	0.0238(4)
K - 3	121.6391	0.693(16)
L - 3	139.8455	0.216(3)
M - 3	142.2984	0.0422(6)

SIMULATED TOTAL ENERGY RELEASED PER DECAY========

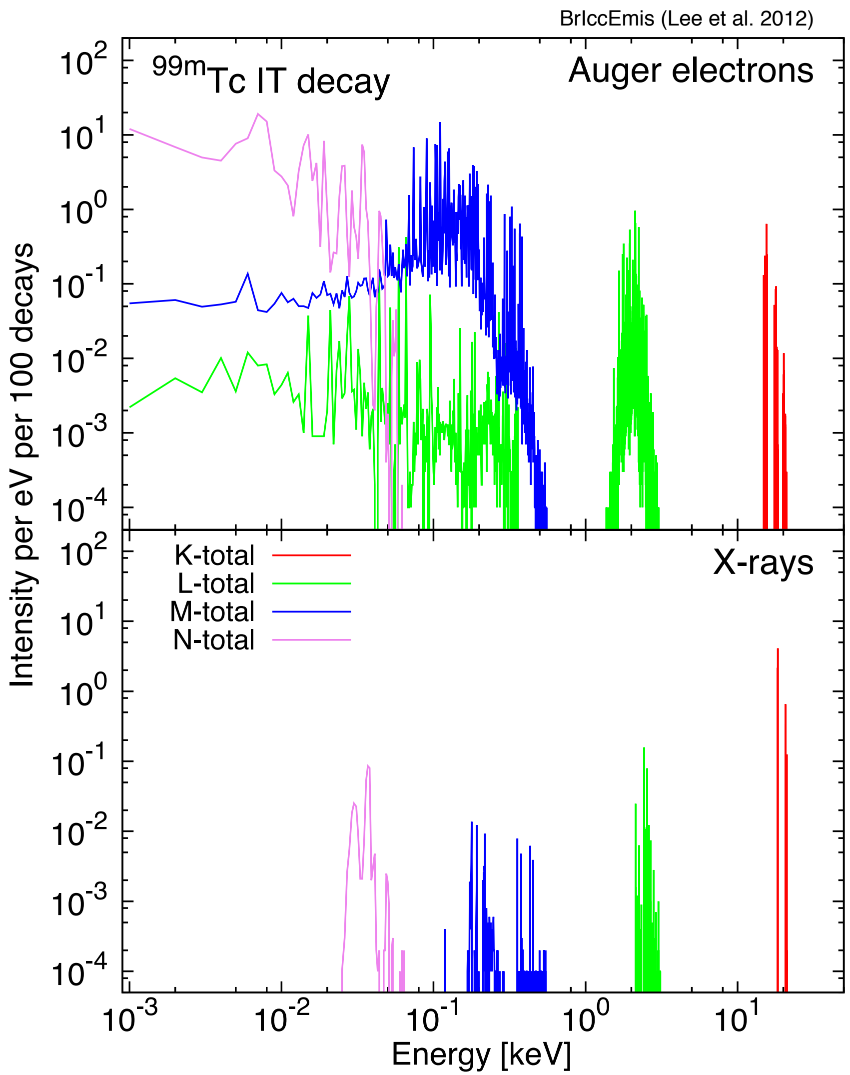
# Trans	Energy[keV]
Gamma-Rays:	125.9386
CE electrons:	15.4571
X-rays:	1.4110
Auger electrons:	0.8358



99mTc

Used for ~30M medical procedures every year

AUGER transition types:	417		
#	Energy		
# Trans	Mean[keV]	95% Conf. range	Prob.[per 100 decays]
Auger_Tot	0.2362	[0.0008 : 1.9763]	3.538E+02
Auger_Ktot	16.1483	[14.8777 : 18.3536]	2.117E+00
Auger_KLL	15.3674	[14.8777 : 15.6103]	1.496E+00
Auger_KLX	17.8437	[17.4479 : 18.3536]	5.733E-01
Auger_KXY	20.2619	[19.9579 : 20.7831]	4.770E-02
Auger_Ltot	1.7686	[0.0350 : 2.4734]	1.249E+01
CK_LLM	0.0530	[0.0055 : 0.0652]	9.476E-01
CK_LLX	0.1386	[0.0146 : 0.3484]	8.894E-01
Auger_LMM	2.0138	[1.6629 : 2.2682]	9.219E+00
Auger_LMX	2.3236	[2.0927 : 2.5832]	1.381E+00
Auger_LXY	2.6491	[2.5275 : 2.9347]	5.450E-02
Auger_Mtot	0.1390	[0.0491 : 0.3198]	1.818E+02
CK_MMX	0.1039	[0.0339 : 0.1544]	7.128E+01
Auger_MXY	0.1616	[0.0623 : 0.3318]	1.105E+02
Auger_Ntot	0.0130	[0.0004 : 0.0355]	1.574E+02
SCK_NNN	0.0108	[0.0002 : 0.0289]	7.152E+01
CK_NNX	0.0148	[0.0010 : 0.0433]	8.592E+01



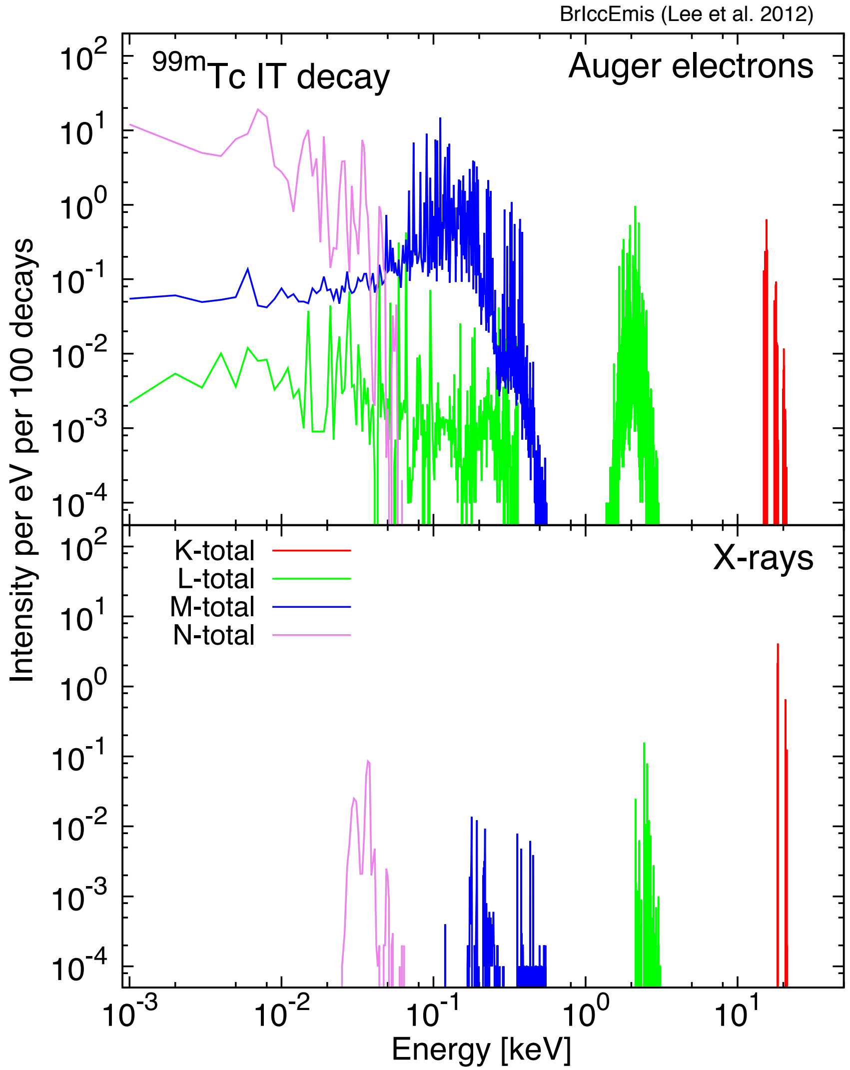
New ENSDF card(s) to hold atomic radiations.
Immediately before the P/N/G/L card
Only for decay data sets

99mTc

Used for ~30M medical procedures every year

X-ray transition types: 50

# Trans	Energy Mean[keV]	95% Conf. range	Prob.[per 100 decay]
X-ray tot	16.8459	[0.0367 : 20.6725]	8.376E+00
X-ray Ktot	18.7556	[18.3018 : 21.0567]	7.457E+00
X-ray KL2	18.3018	[18.3018 : 18.3018]	2.153E+00
X-ray KL3	18.4207	[18.4207 : 18.4207]	4.111E+00
X-ray KM	20.6663	[20.6519 : 20.6725]	9.982E-01
X-ray KM2	20.6519	[20.6519 : 20.6519]	3.403E-01
X-ray KM3	20.6725	[20.6725 : 20.6725]	6.532E-01
X-ray KN	21.0614	[21.0567 : 21.0638]	1.940E-01
X-ray KN2	21.0567	[21.0567 : 21.0567]	6.800E-02
X-ray KN3	21.0638	[21.0638 : 21.0638]	1.257E-01
X-ray Ltot	2.4651	[2.1331 : 2.6918]	4.869E-01
X-ray Mtot	0.2616	[0.1727 : 0.4706]	1.016E-01
X-ray Ntot	0.0351	[0.0278 : 0.0403]	3.304E-01



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Summary and outlook

Future plans

- Atomic transitions energies and rates from Grasp2K/RATIP and MCDFGME (ANU-Malmo-Lisbon collaboration)
- Low energy (100 eV to 4 keV) Auger electron measurements to benchmark calculations
- Condensed phase physics input to incorporate environmental effects

Collaborators

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Argonne National Laboratory, USA
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Karolinska Institutet, Stockholm, Sweden
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Joint Institute for Nuclear Research
Alois Kovalik
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