# Elementary Nuclear Physics Laboratory course

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$10^{-14}$ meters

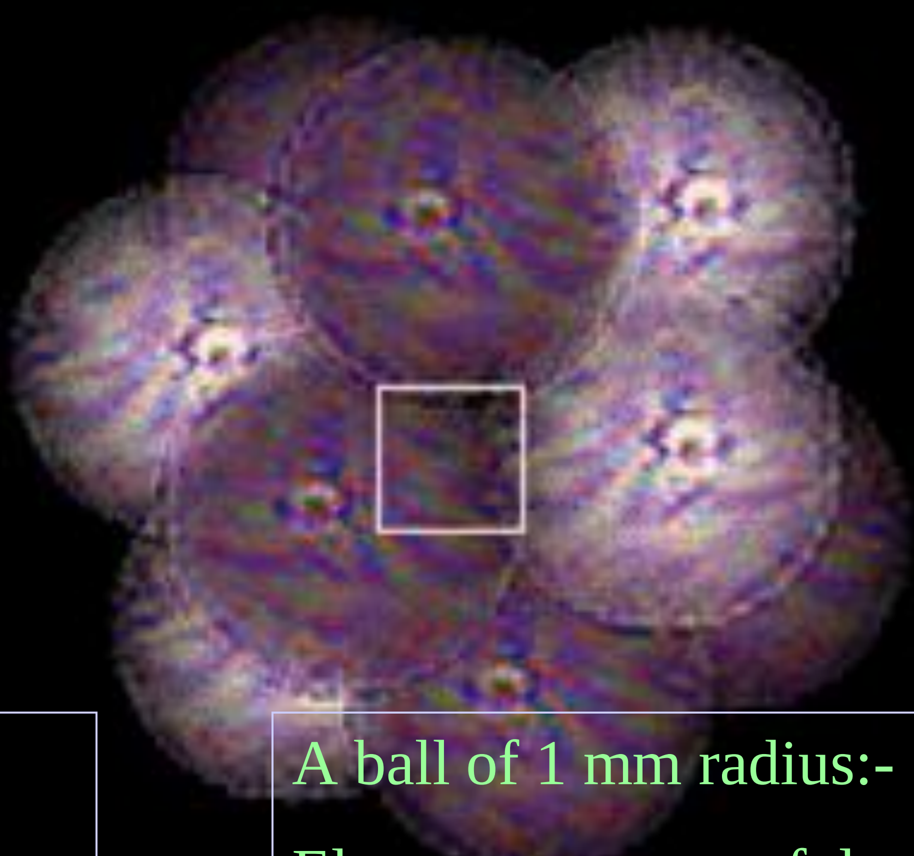
10 femtometers

$10^{-14}$ m :

radius of nucleus

$10^{-10}$ m :

radius of first electron orbit



A ball of 10 cm radius:-

Electron :- a ball-bearing at a distance of 100000 cm = 1km of radius 1mm

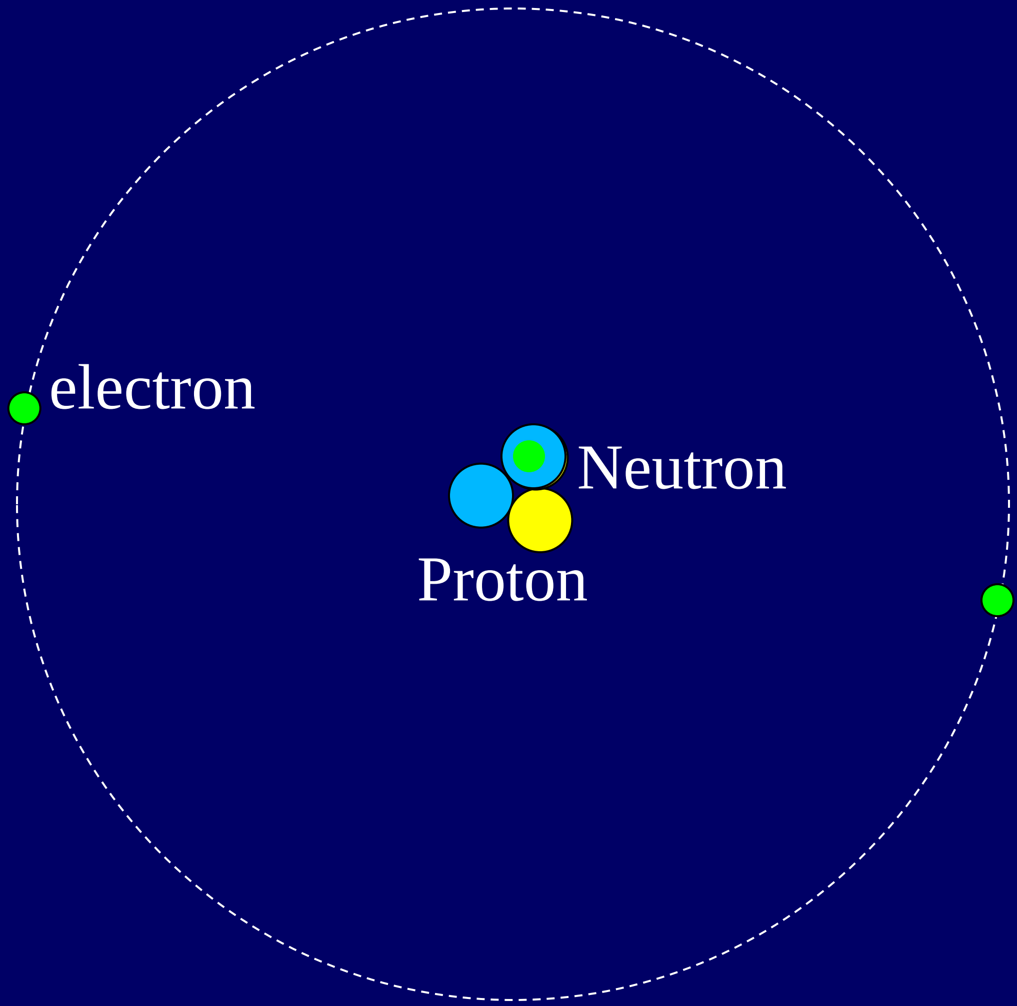
A ball of 1 mm radius:-

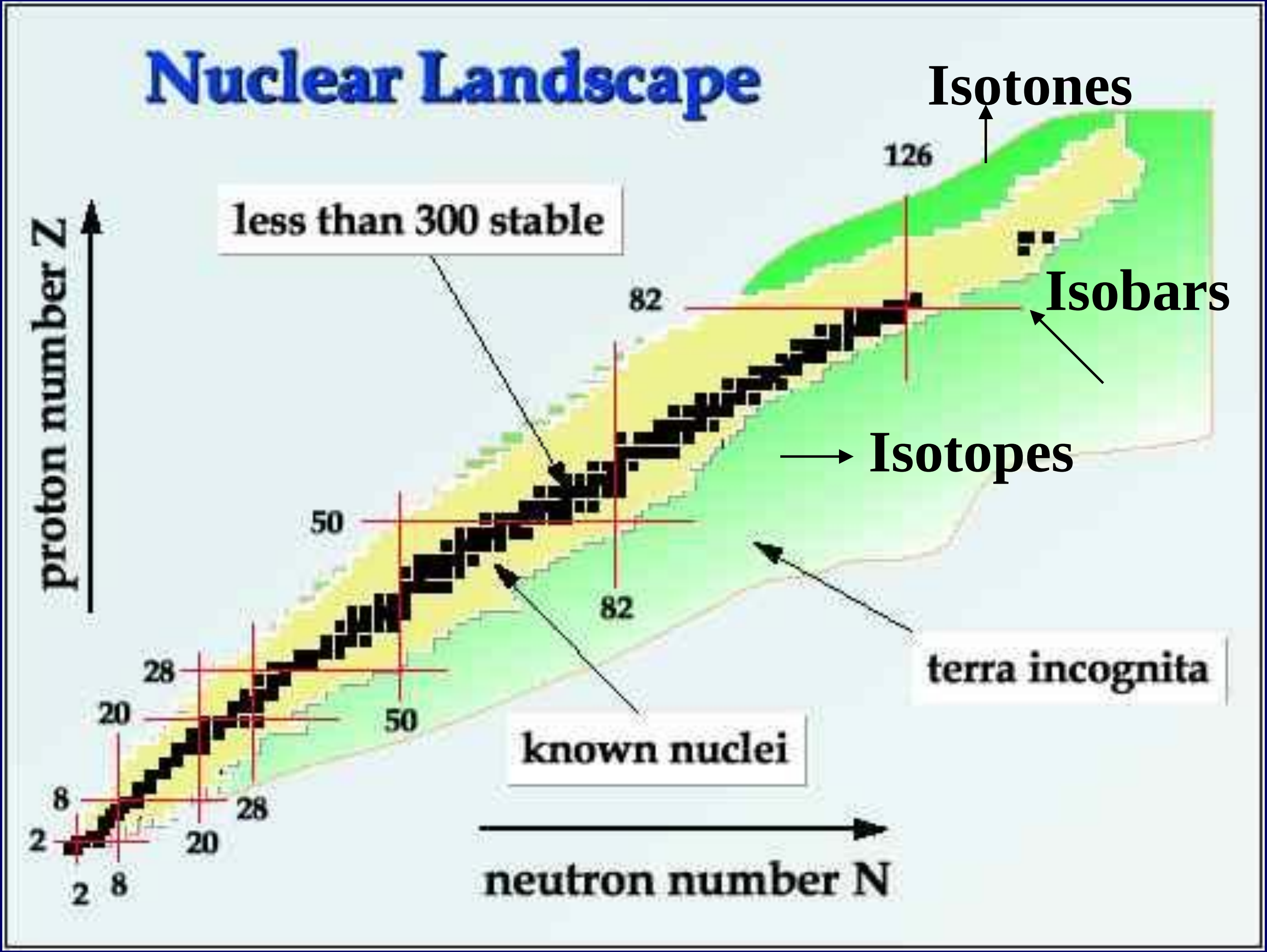
Electron :- a spec of dust at a distance of 1000 cm = 10 m of radius .01mm

Deutrron (stable)

Tritium ( 12.3y)

$^{3}$He (stable)

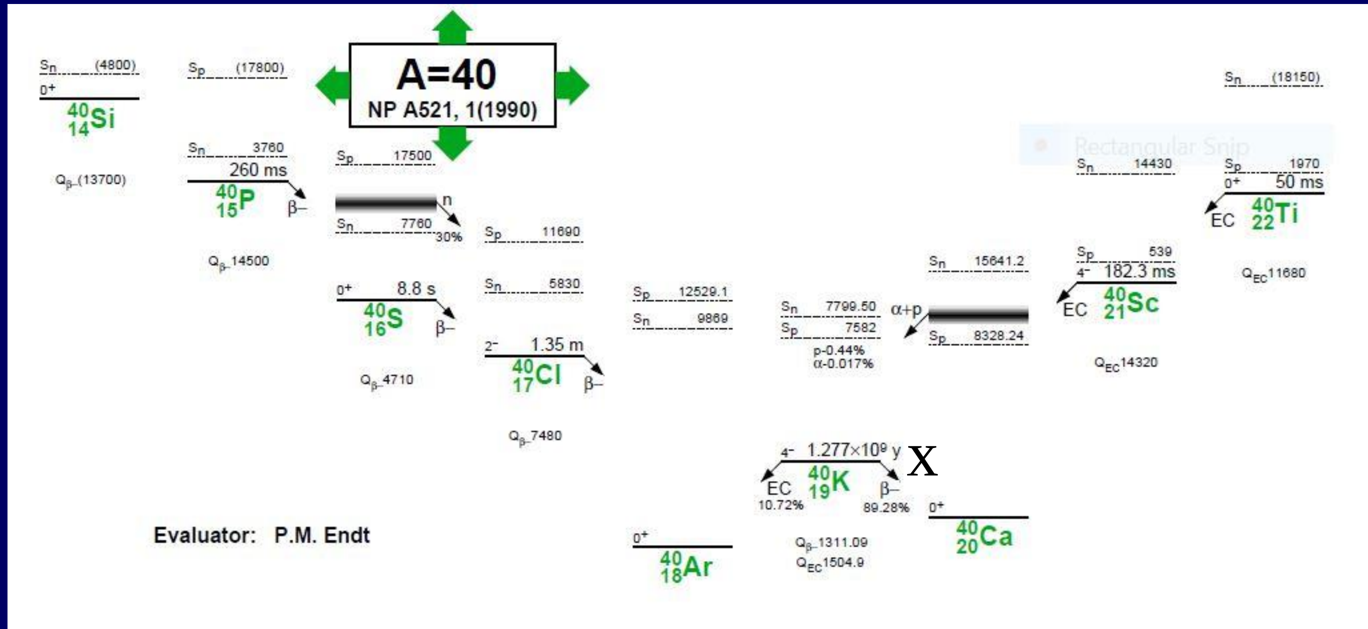


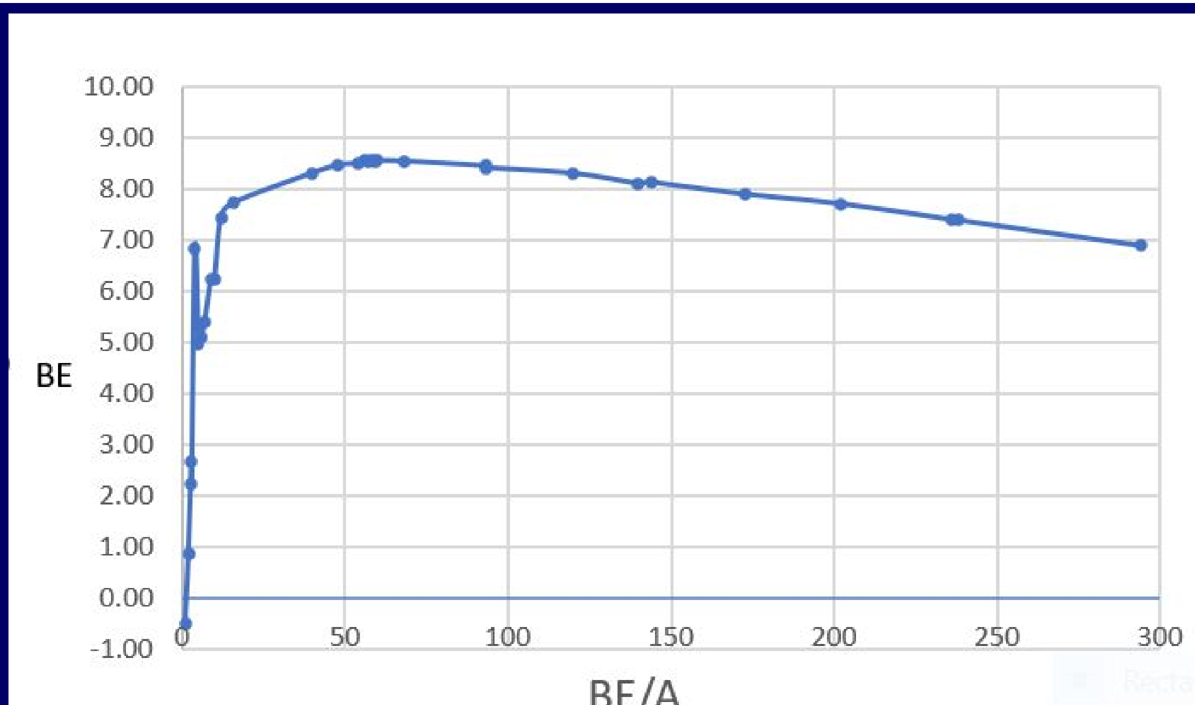



Odd Z Odd N :- 9 Even Z Odd N :- 57

Odd Z even N :- 52 Even Z Even N :- 167

Total :~ out of about 3300 isotopes


A=40
NP A521, 1(1990)
Evaluator: P.M. Endt
40 14 Si
40 15 P
40 16 S
40 17 Cl
40 18 Ar
40 19 K
40 20 Ca
40 21 Sc
40 22 Ti
260 ms
8.8 s
1.35 m
1.277×10⁹ y
182.3 ms
50 ms
EC
β−
10.72%
89.28%
X


BE
BE/A
10.00
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
-1.00
0
50
100
150
200
250
300

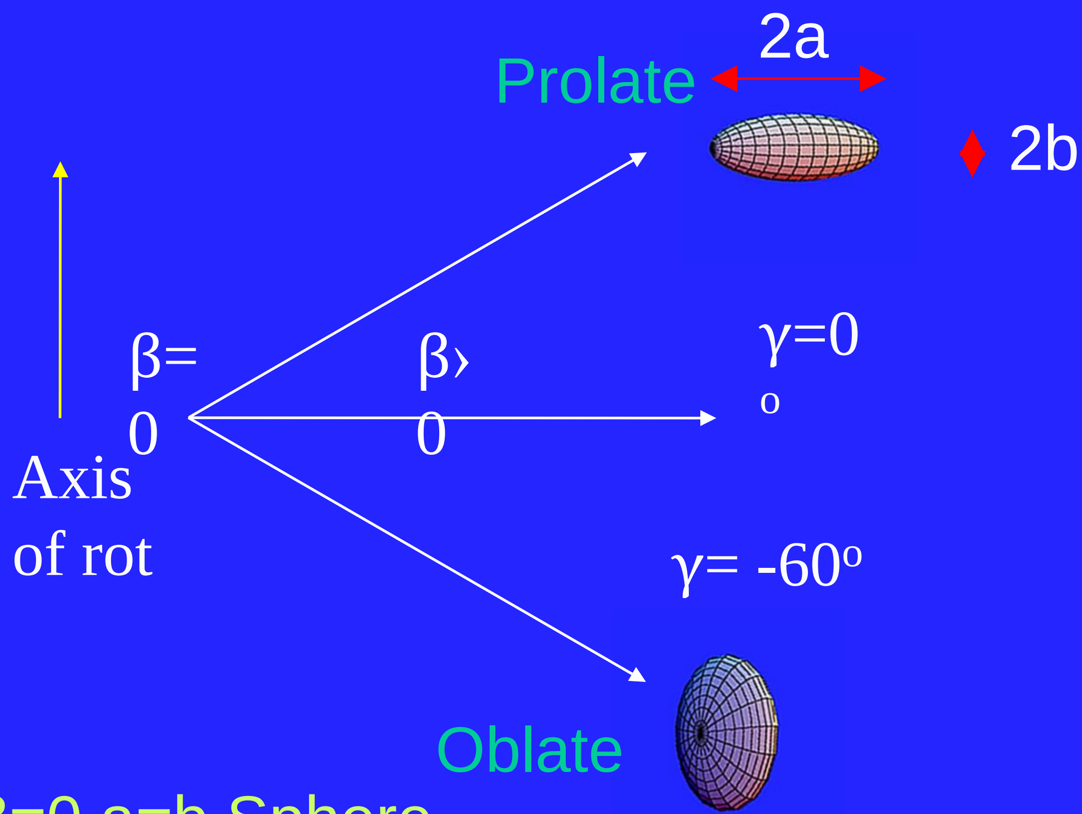
# Forces in nature

- Gravity ; 1/r ;1 unit
- Weak interaction
- Electromagnetic ; 1/r ; $10^{19}$ units
- Nuclear force ; ~ $e^{-\mu r} / r$ ; $10^{38}$ units ; *Extremely short ranged*

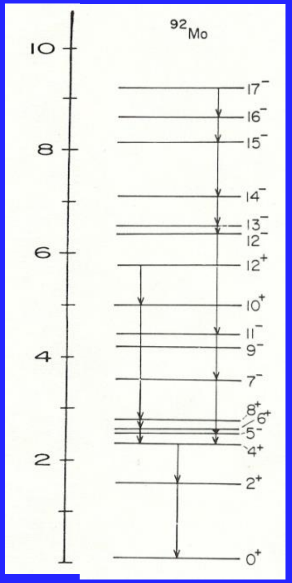
# Nuclear Force

- The basis of formation of starts and other heavenly bodies
- Nuclei to touch each other for fusion to trigger, but cross-section?
- Stellar dust →star →white dwarf/neutron star/blackhole
- Supernova explosions leading to heavy elements
- Solar energy sources to several phenomena on earth

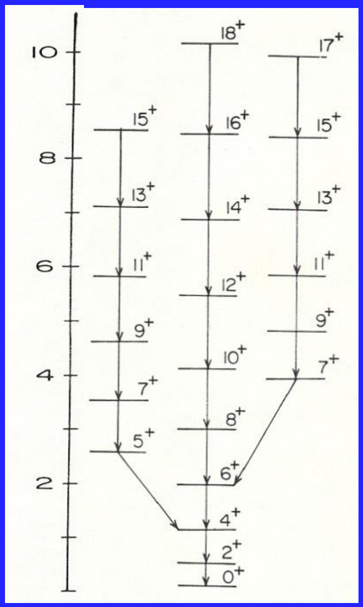
$\beta=3(a-b)/(3a-b)$




$\beta\approx 0$



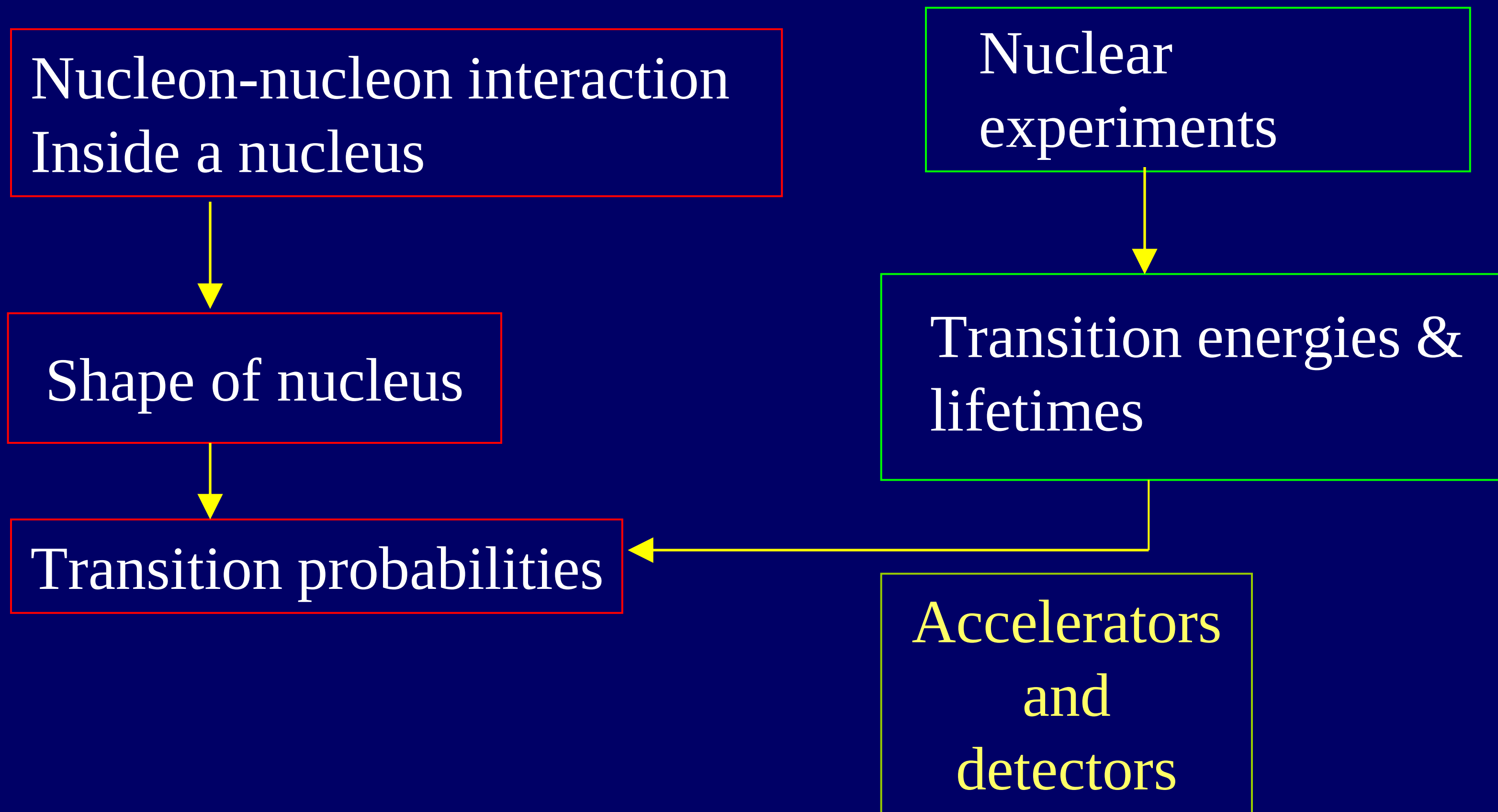

$\beta>0$




$\beta=0$ a=b Sphere

$\beta=0.6$ a=2b Superdeformation

$\beta=0.8$ a=3b Hyperdeformation


Nucleon-nucleon interaction
Inside a nucleus
Nuclear
experiments
Shape of nucleus
Transition energies &
lifetimes
Transition probabilities
Accelerators
and
detectors

# How does photon interact with matter

Photo-electric effect

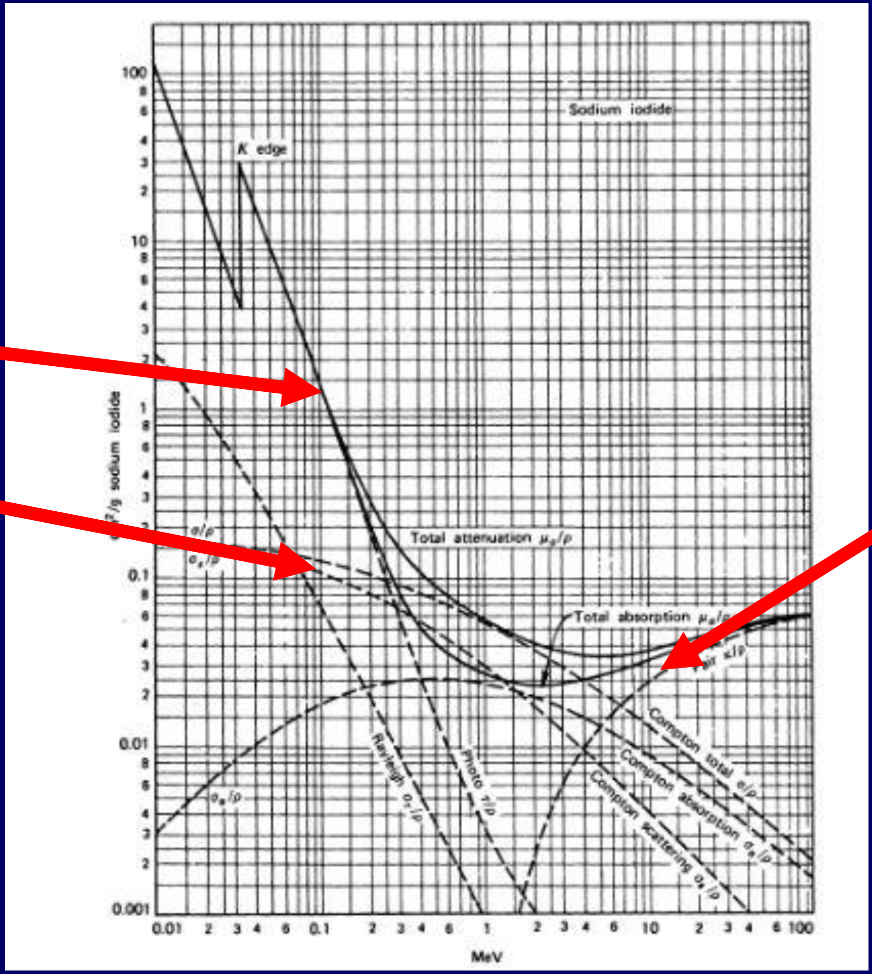
Compton

Pair-production

PE

COMPTON

PP




EURISYS MESURES

The study of gamma-ray interaction with matter: Leads to

a) Nuclear medicine

b) imaging techniques

c) Food irradiation programmes

d) Higher quality agricultural products

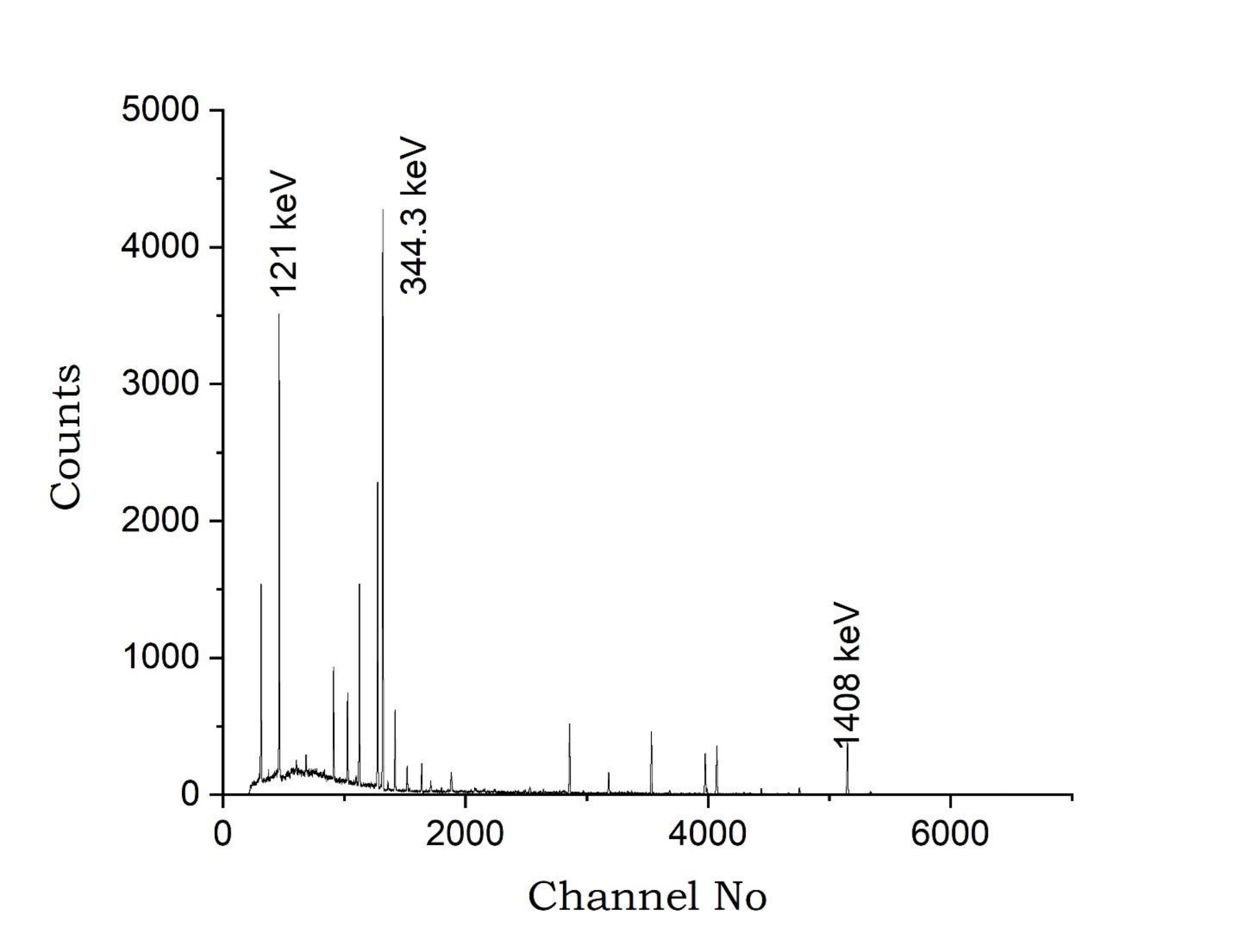
The radioactive decay studies lead to techniques like carbon dating

# Health effects

| No | Dosage mSv/year | Dosage mR | Possible health effects |
|---|---|---|---|
| 1 | 15 | 1,500 | Prescribed upper limit for individual in 1 year |
| 2 | 100 | 10,000 | No detectable effects/ first sign of increased risks of cancer |
| 3 | 400 | 40,000 | Radiation sickness, immediate med attention is required |
| 4 | 2,000 | .2 mil | Sever poisoning, maybe fatal, skin burns/cataracts ( Case in New Delhi last year) |
| 5 | 4,000 | .4 mil | Risk of death sever |
| 6 | 8,000 | .8 mil | fatal |
| 7 | 10 | 1000 | Fukushima max dose / hour |
| 8 | 87000 | 8.7 mil | Fukushima max dose / year |

# Health effects

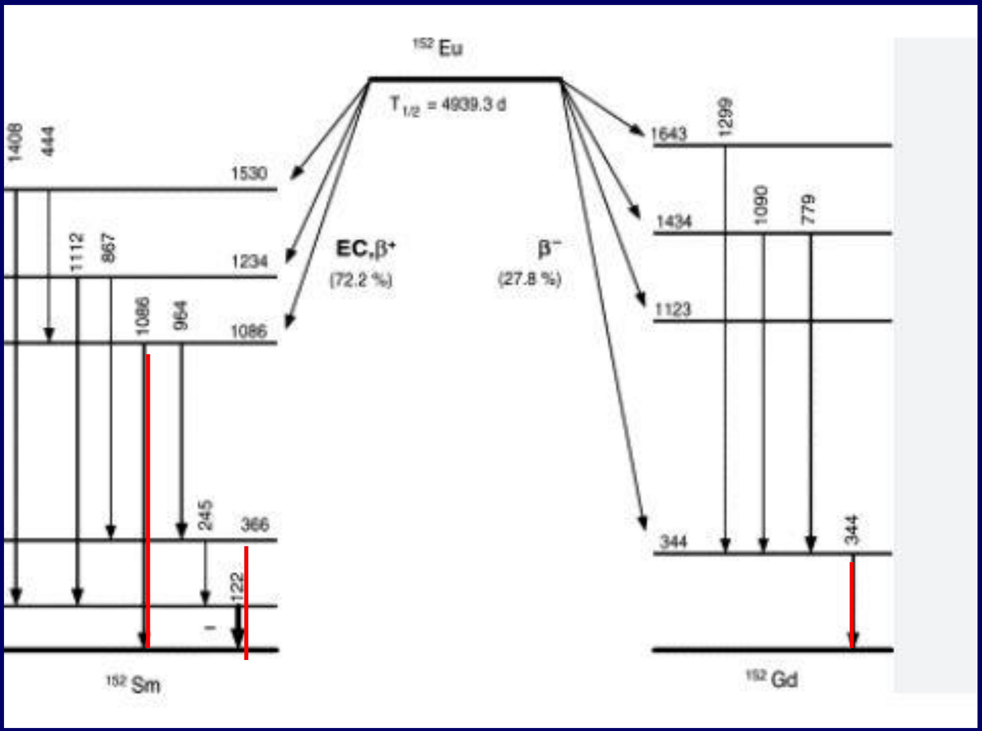
- What happens when radiation hits body
- Radiation can ionize atoms inside body by knocking out electrons from atoms
- Gamma and neutrinos pass through the body. Relatively less harmful
- Beta radiation locally more harmful. Short range
- Neutrons 2-11 times more ionizing, but very few natural sources around. Very little neutron radiation from such accidents
- Alpha particles 20 times more ionizing/dangerous. Extremely local. Some hazards in this kind of accident. Smoking.




$$E = a + b \times x + c \times x^2$$

Usually c is negative

C ≈ $10^{-4}$ to $10^{-6}$ x b




| Eg | Ig |
|---|---|
| 121.7817 3 | 28.58 6 |
| 244.6975 8 | 7.583 19 |
| 295.9392 17 | 0.447 5 |
| 344.2785 12 | 26.5 4 |
| 367.7887 16 | 0.861 5 |
| 411.1163 11 | 2.234 4 |
| 443.965 3 | 2.821 19 |
| 563.990 7 | 0.489 6 |
| 678.623 5 | 0.471 4 |
| 688.670 5 | 0.857 8 |
| 778.9040 18 | 12.942 19 |
| 867.378 4 | 4.245 19 |
| 919.330 3 | 0.427 6 |
| 964.079 18 | 14.605 21 |
| 1085.869 24 | 10.207 21 |
| 1112.074 4 | 13.644 21 |
| 1212.948 11 | 1.422 6 |
| 1299.140 10 | 1.623 8 |
| 1408.006 3 | 21.005 24 |



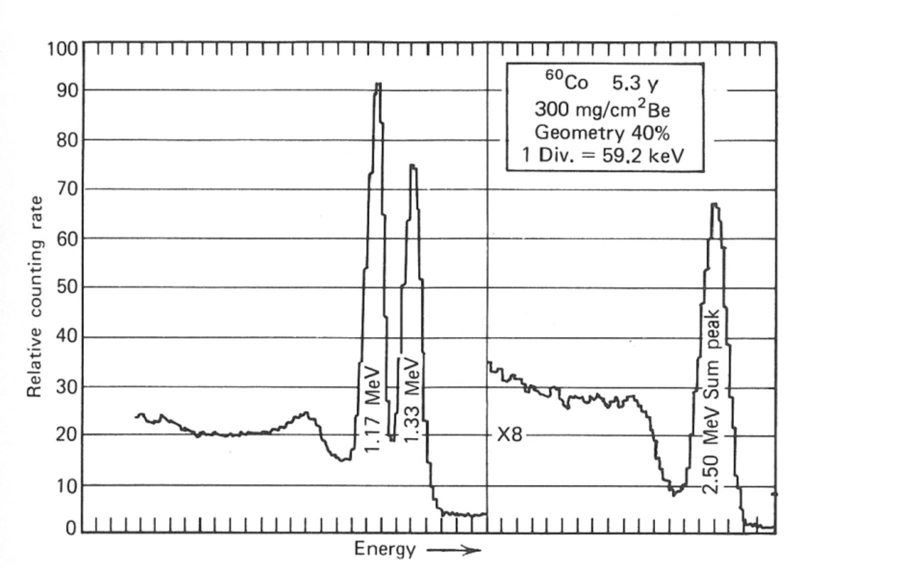
Table 1.1: Intensities of data

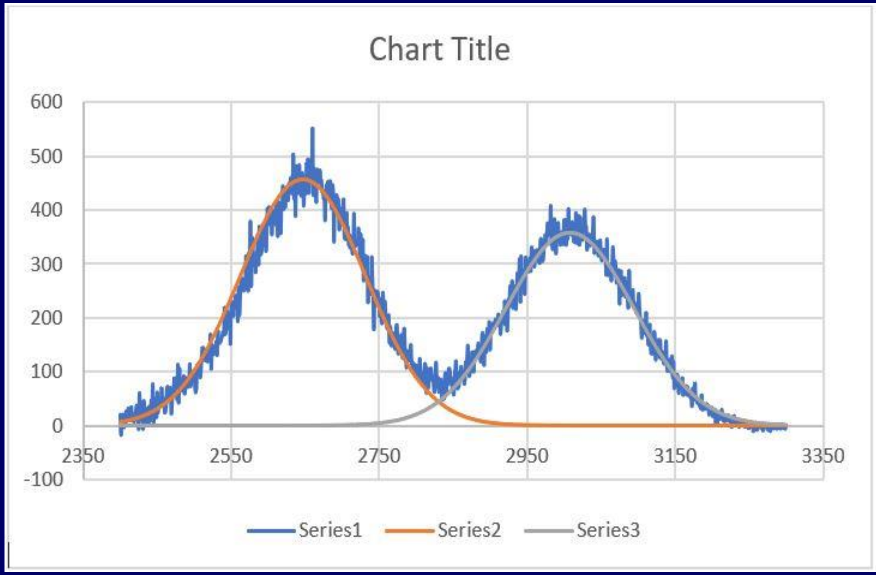
| $E_\gamma$ (keV) | $I_g$ | $\alpha_k$ | Total Intensity |
|---|---|---|---|
| 121.78 | 28.58 | 1.155 | 61.6 |
| 1085.8 | 10.27 | 0.0026 | 10.3 |
| 344.28 | 26.5 | 0.04 | 27.6 |
| Total | | | 99.46 |

# Scintillation Detectors

- But PMT 20 % eff, Photo cathode ~12 % eff :- implying average excitation energy 0.1 keV
- 1 keV  ~ 40 photons
- 1.1 MeV = 40,000 photons
- Random statistics: error = $\sqrt{N}$ = ~ 3.5% error
- Energy resolution around 7% for NaI(Tl), 13 % for $BaF_2$ and 16 % for BGO

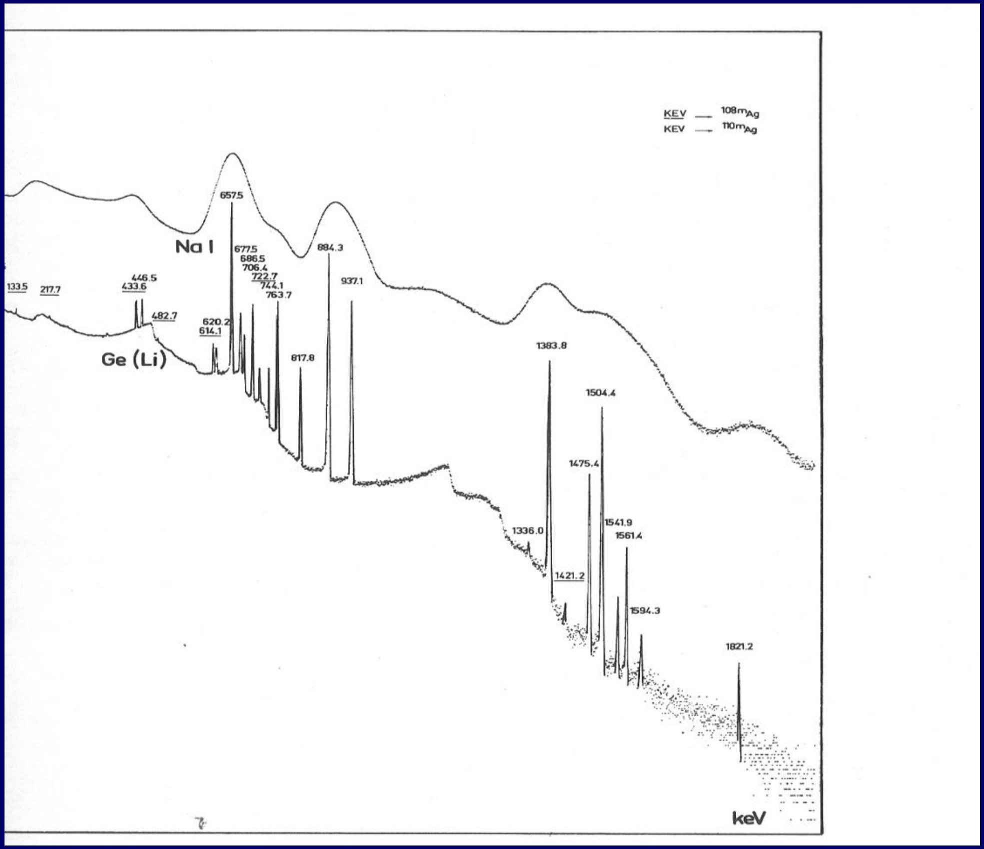
# $^{60}$Co spectrum in a NaI(Tl) Detector



# Comparision of NaI(Tl) and HpGe detector spectra

Counts




Energy

# Analysis

- Calibrate the channel using E=a+bx for $^{152}Eu$ data provided.
- Resolution:Plot data and Gaussian simultaneously. Measure and minimize to find best centroid and FWHM.
- Similarly, find calibration and resolution for Cs(I) detector data collected in lab manually without any readymade softwares .
- Background subtraction.