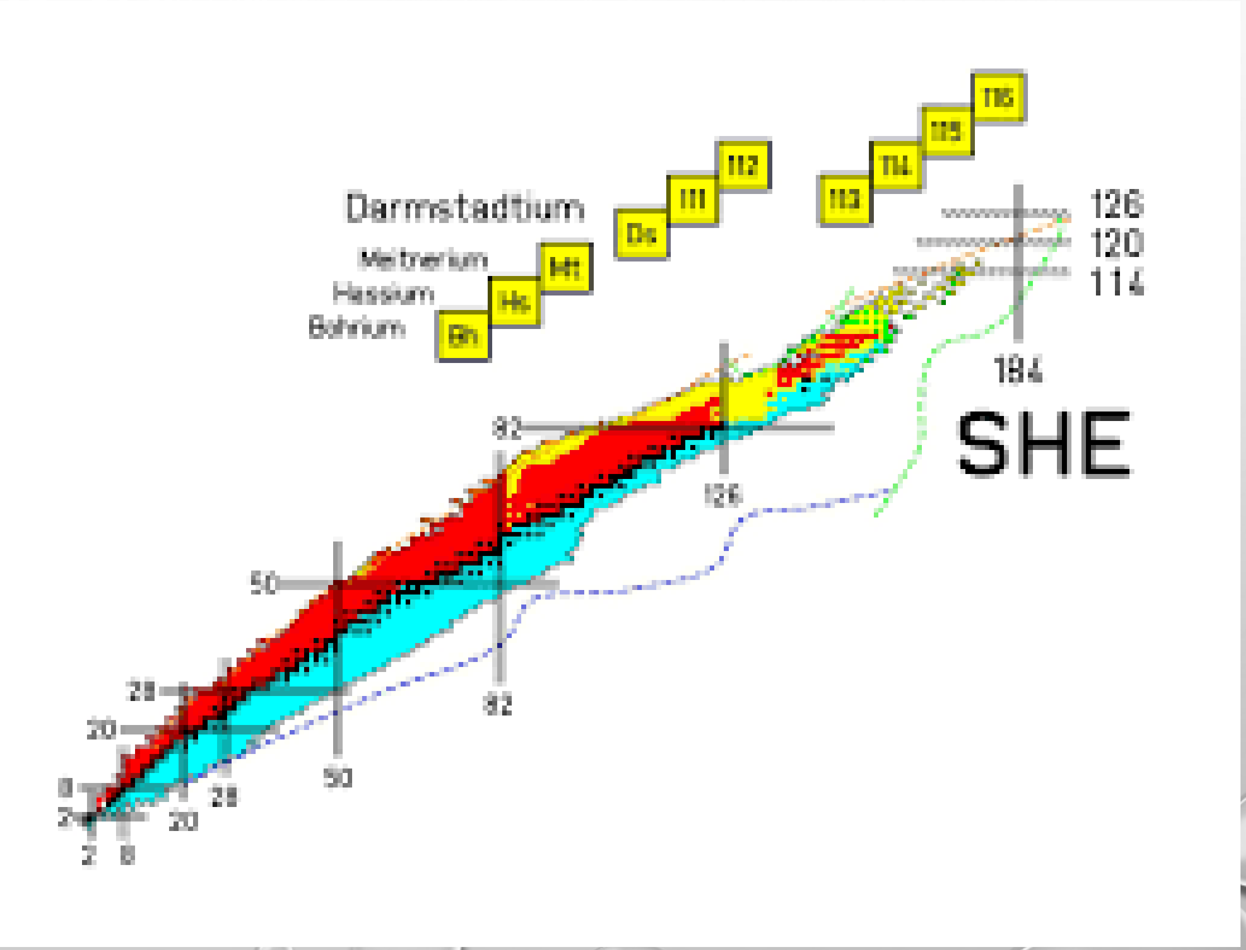
NEUTRON EMISSION FROM SPONTANEOUS FISSION OF HEAVY ELEMENTS AT FLNR

BY: TOKOZANI V.N MTETWA

SUPERVISOR: A. SVRIKHIN

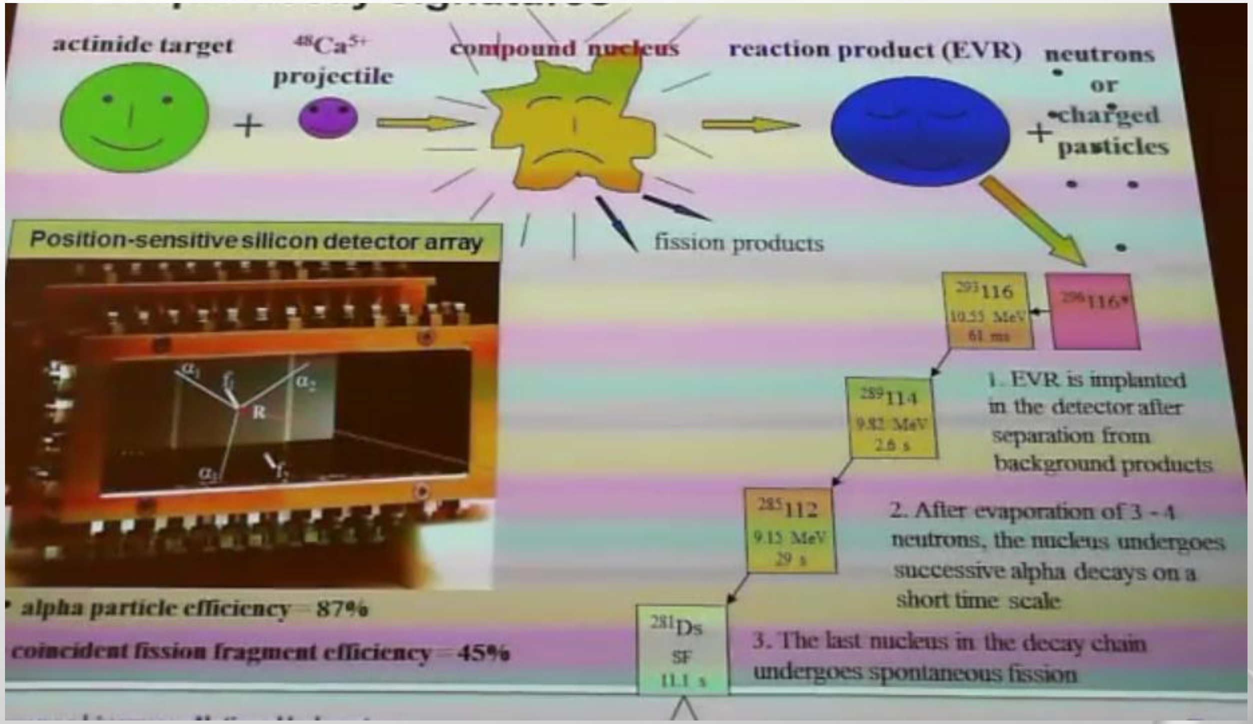
SUPER HEAVY ELEMENTS

- SUPER HEAVY ELEMENTS(SHE) ARE ELEMENTS WITH A LARGE NUMBER OF PROTONS IN THEIR NUCLEUS. THESE ELEMENTS HAVE MORE THAT 100 PROTONS AND ARE UNSTABLE;
  - THEY DECAY RADIOACTIVELY TO LIGHTER NUCLEI WITH A CHARACTERISTIC HALF LIFE
  - THEY HAVE ONLY BEEN MADE ARTIFICIALLY, AND BECAUSE OF THEIR SHORT HALF-LIVES, RANGING FROM A FEW MINUTES TO JUST A FEW MICROSECONDS (EXCEPT FOR DUBNIUM, WHICH HAS A HALF LIFE OF OVER A DAY), THEY ARE EXTREMELY HARD TO STUDY



HOW TO MAKE SHE

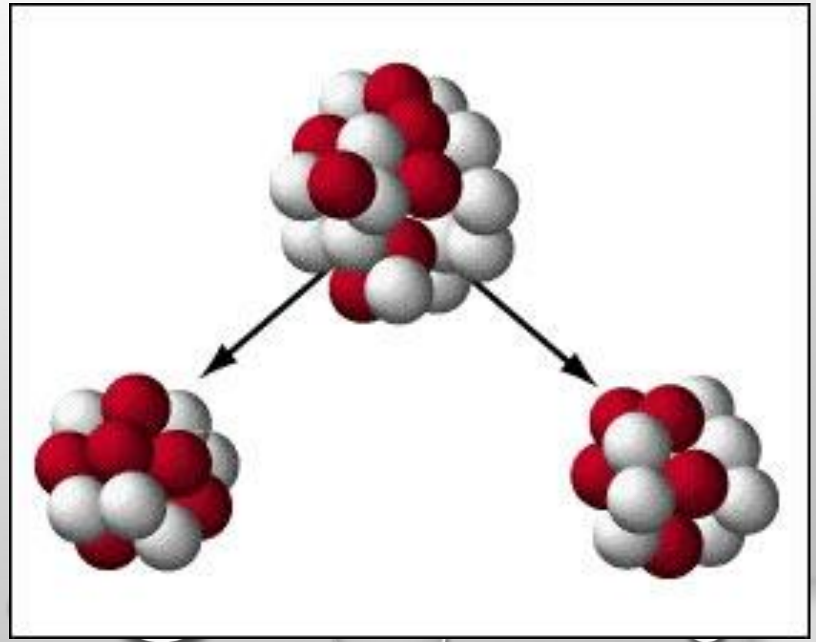
- ALL OF THE ELEMENTS WITH A > 92 HAVE BEEN DISCOVERED IN THE LAB.
- TAKE TWO LIGHTER NUCLEI THAT CONTAIN THE NUMBER OF PROTONS IN THE ELEMENT YOU WANT TO MAKE AND THEN ADD THEM TOGETHER BY:
- ACCELERATING ON OF THE NUCLEI TO VERY HIGH ENERGIES AROUND 10% OF THE SPEED OF LIGHT AND FIRING IT AT THE OTHER NUCLEUS.
- IF THE NUCLEI STICK ON IMPACT A SUPER HEAVY ELEMENT IS CREATED



SPONTANEOUS FISSSION

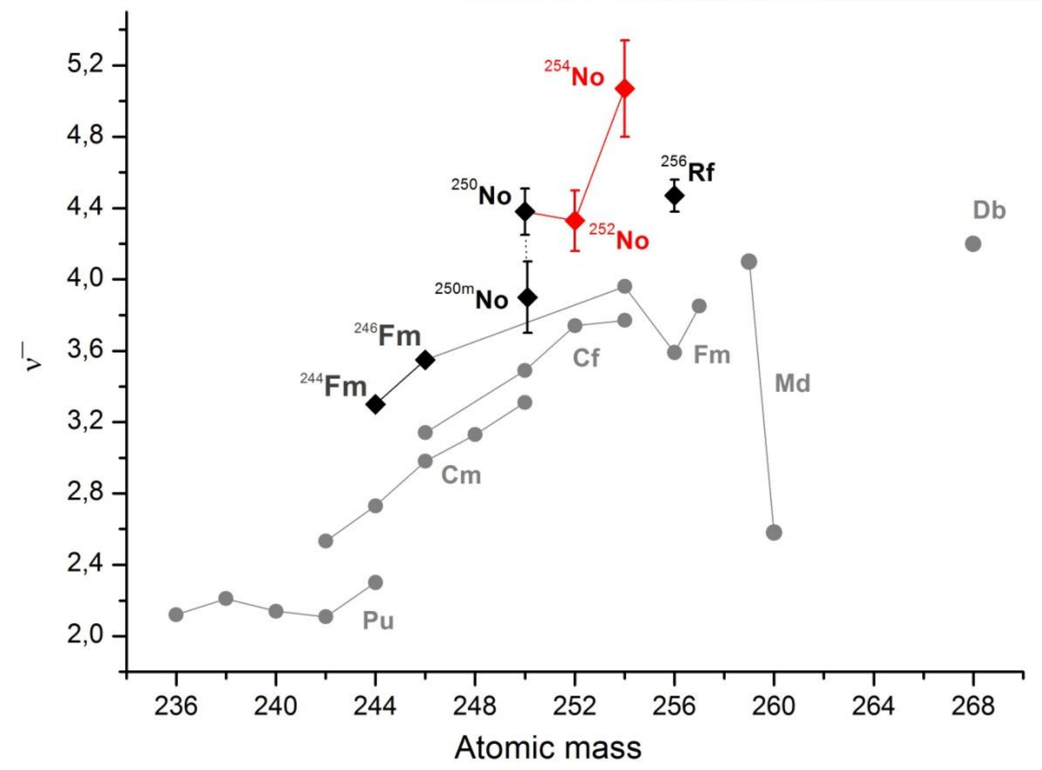
- SPONTANEOUS FISSION(SF) IS A FORM OF RADIOACTIVE DECAY FOUND IN HEAVY ELEMENTS
- SF WAS DISCOVERED BY PETRZHAK AND FLEROV [1939] IN ^{238}U
- THE NUCLEUS WILL SPLIT INTO TWO NEARLY EQUAL FRAGMENTS AND SEVERAL FREE NEUTRONS
- A LARGE AMOUNT OF ENERGY IS ALSO RELEASED

- MOST ELEMENTS DON'T DECAY FROM SF UNLESS THE THEIR MASS NUMBER IS GREATER THAN 230.



MULTIPLICITY OF PROMPT NEUTRONS FROM SF

- THE NUMBER OF NEUTRONS EMITTED DURING FISSION DIRECTLY DEPENDS ON THE DEGREE OF EXCITATION OF FISSION FRAGMENTS AND THUS PLAYS AN IMPORTANT ROLE IN THE RESTORATION OF THE REACTION ENERGY BALANCE AND AIDS THE EXPLORATION OF THE NUCLEAR PROPERTIES
- THE MEAN NUMBER OF NEUTRONS PER SPONTANEOUS FISSION IS A UNIQUE CHARACTERISTIC OF THE NUCLEUS



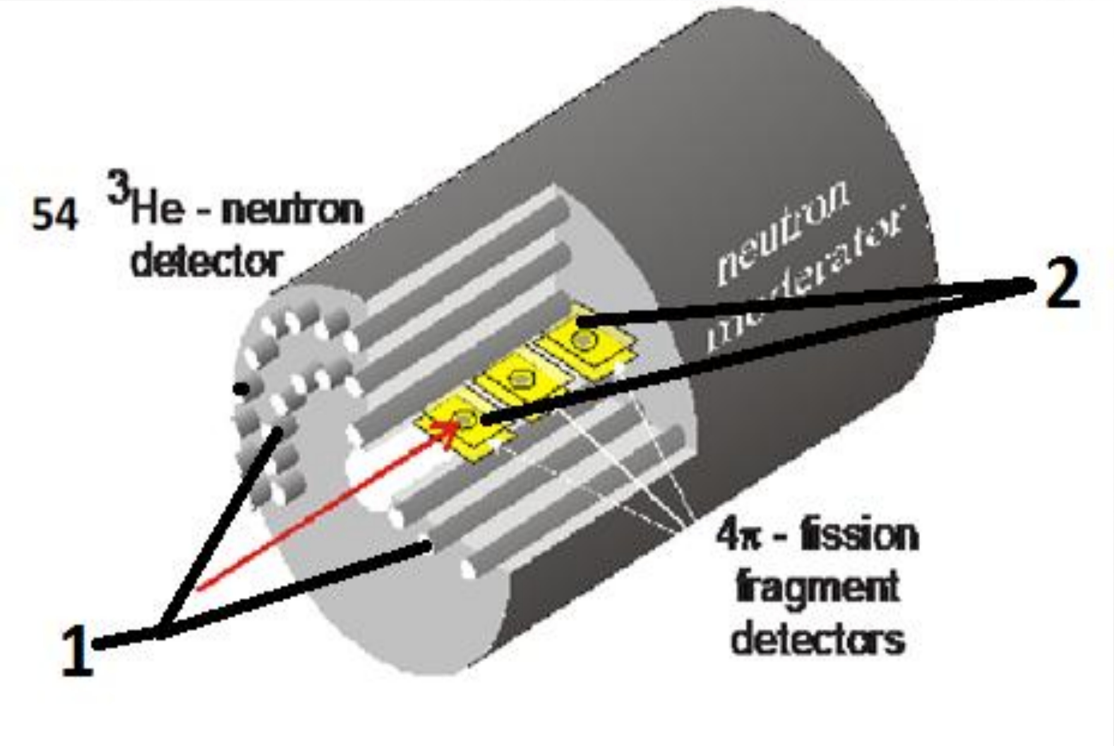
AIM OF THE EXPERIMENT

- THE MAIN GOAL OF OUR PROJECT WAS PREPARING THE DETECTION SYSTEM FOR EXPERIMENTS AIMED TO INVESTIGATION OF NEUTRON PROPERTIES OF SPONTANEOUS FISSIONING HEAVY NUCLEI.

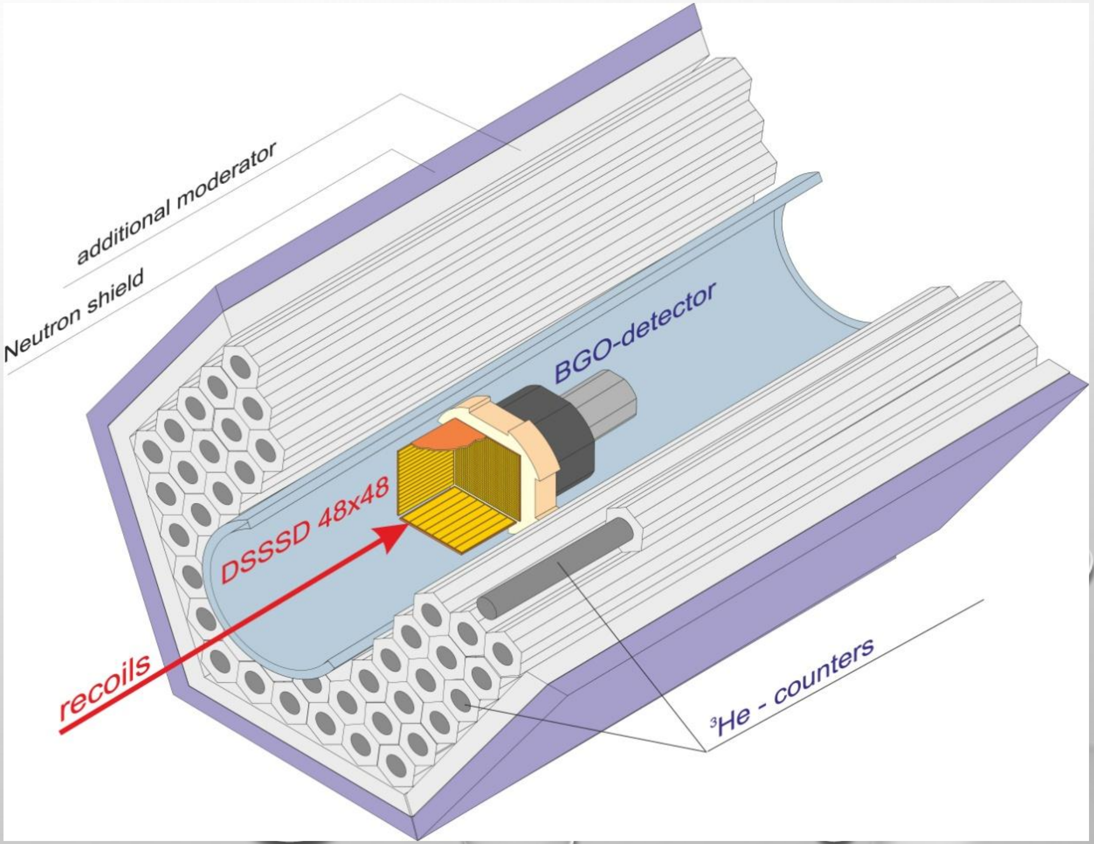
    - CALIBRATION OF SI DETECTOR WITH A ALPHA-SOURCES

    - DETERMINING EFFICIENCY OF NEUTRON DETECTOR

EXPERIMENTAL SETUP



Neutron detector using for “on-line” experiments aimed to study properties of exotic short-lived SF-nuclei producing at the SHELS separator



Helium-3 based neutron detector using for “off-line” experiments aimed to study SHE (this project)

DETECTION OF SPONTANEOUS FISSION

- USING SILICON DETECTOR
  - PASSIVATED IMPLANTED PLANAR SILICON (PIPS) DETECTOR IS A PRODUCT OF MODERN SEMICONDUCTOR TECHNOLOGY.
  - IT HAS 8 SEPARATE SOURCES USED TO CALIBRATE THE DETECTOR

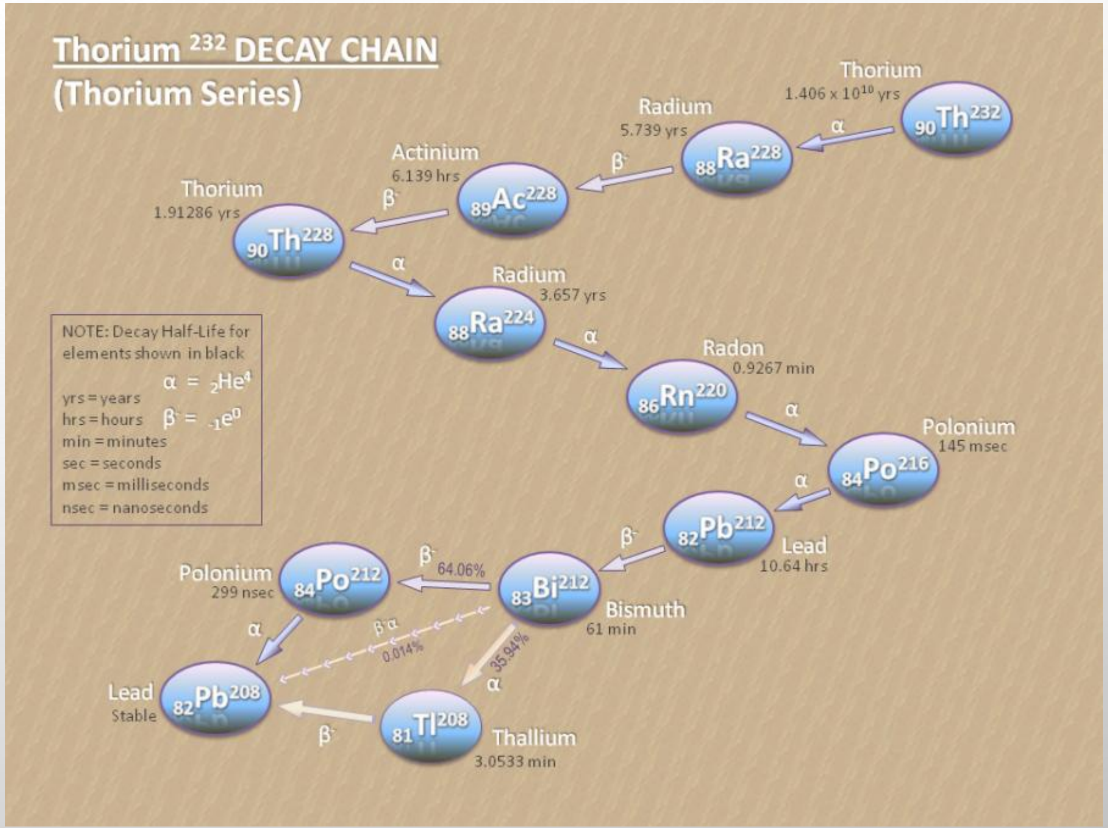
ALPHA SOURCE

Thorium^{232} Decay Chain (Thorium Series)

RE: www.periodictable.com

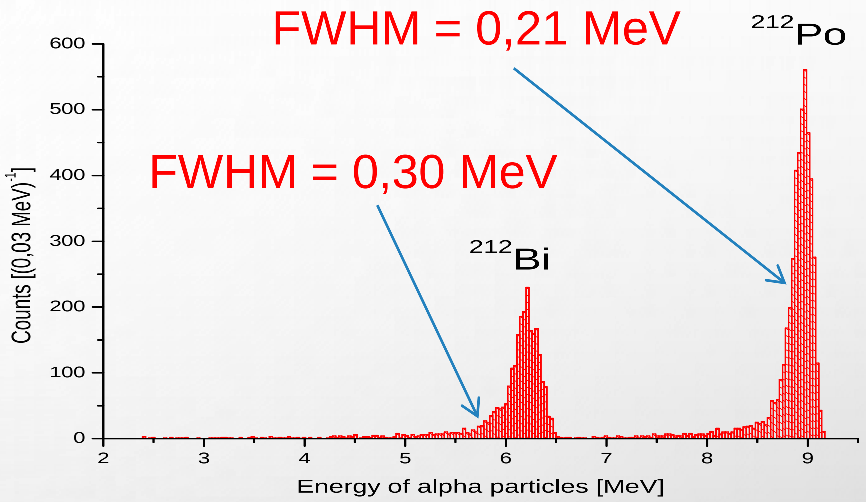
The 4n+2 chain of Th^{235} is commonly called the "Thorium Series". This table shows the naturally occurring elements in this series.

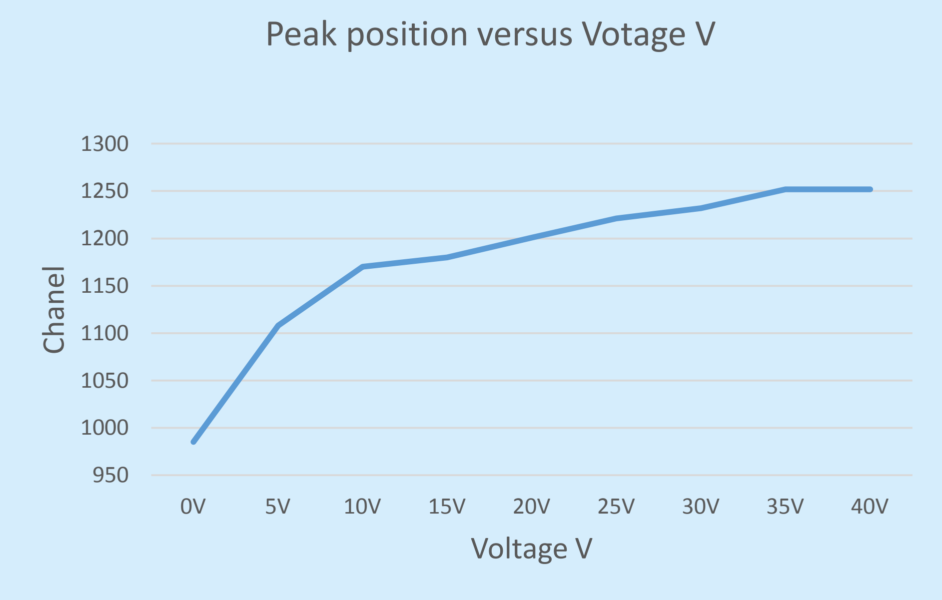
Nuclide	Element Name	Historic Name	Decay Mode	Half Life	MeV	Product of Decay
$_{90}Th^{232}$	Thorium - 232	*Thorium*	α	1.406 x 10^{10} yrs	4.0816	$_{88}Ra^{228}$
$_{88}Ra^{228}$	Radium - 228	*Mesothorium 1*	$β^-$	5.739 yrs	0.045811	$_{89}Ac^{228}$
$_{89}Ac^{228}$	Actinium - 228	*Mesothorium 2*	$β^-$	6.139 hrs	2.12379	$_{90}Th^{228}$
$_{90}Th^{228}$	Thorium - 228	*Radiothorium*	α	1.91286 yrs	5.52008	$_{88}Ra^{224}$
$_{88}Ra^{224}$	Radium - 224	*Thorium X*	α	3.657 yrs	5.78885	$_{86}Rn^{220}$
$_{86}Rn^{220}$	Radon - 220	*Thoron*	α	0.9267 min	7.52626 0.71484	$_{84}Po^{216}$
$_{84}Po^{216}$	Polonium - 216	*Thoium A*	α	145 msec	6.90632	$_{82}Pb^{212}$
$_{82}Pb^{212}$	Lead - 212	*Thorium B*	$β^-$	10.64 hrs	0.56991	$_{83}Bi^{212}$
$_{83}Bi^{212}$	Bismuth - 212	*Thorium C*	$β^-$ 64.06% α 35.94% $β^-$ α 0.014%	61 min	2.25213 6.20726 11.20624	$_{84}Po^{212}$ $_{81}Tl^{208}$ $_{82}Pb^{208}$
$_{84}Po^{212}$	Polonium - 212	*Thorium C'*	α	299 nsec	8.95412	$_{82}Pb^{208}$
$_{81}Tl^{208}$	Thallium - 208	*Thorium C"*	$β^-$	3.0533 min	4.99898	$_{82}Pb^{208}$
$_{82}Pb^{208}$	Lead - 208		—	Stable	—	—

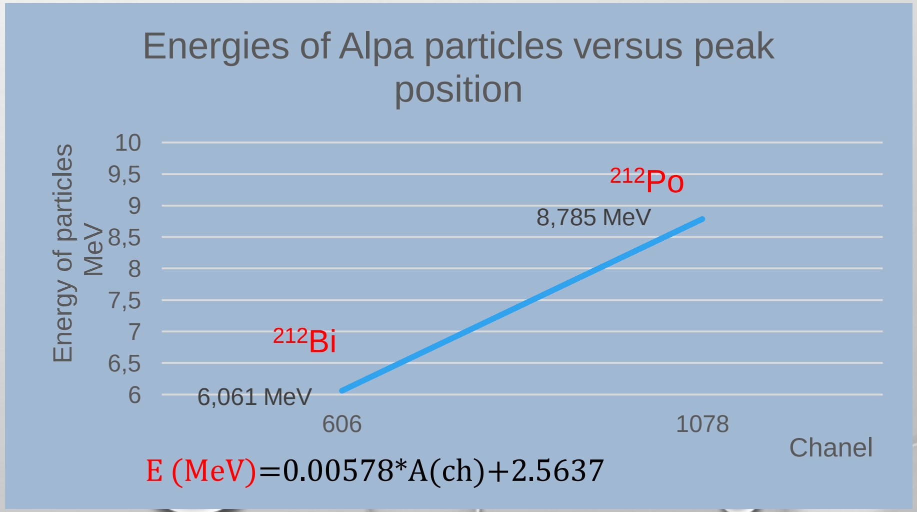


CALIBRATION OF DETECTOR WITH ALPHA SOURCES

- WE MEASURED ACTIVE EMITTERS , WHICH WERE PLACED IN A VACUUM . WE EVALUATED THE RESULTS OF EACH SENSOR AND THEN WE EVALUATED BEST MEASURED VALUES.

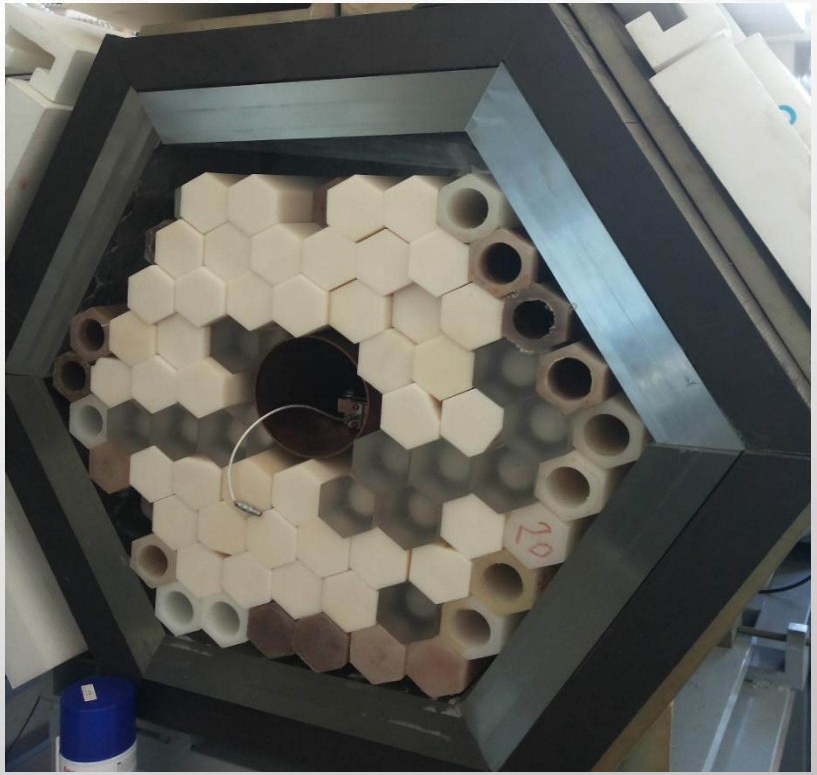






NEUTRON DETECTOR

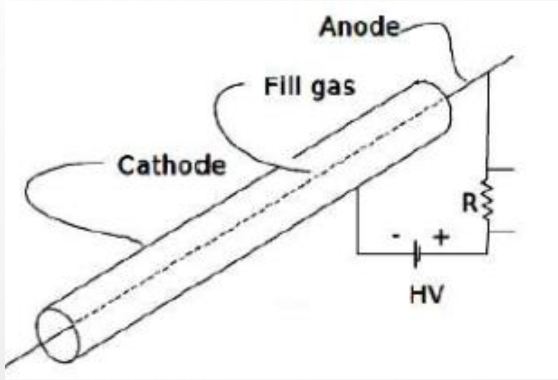
- *NEUTRON DETECTION IS THE EFFECTIVE DETECTION OF NEUTRONS ENTERING A WELL-POSITIONED DETECTOR.*
  - NEUTRONS CAN BE DETECTED USING HELIUM-3-FILLED GAS PROPORTIONAL COUNTERS. A TYPICAL COUNTER CONSISTS OF A GAS-FILLED TUBE WITH A HIGH VOLTAGE APPLIED ACROSS THE ANODE AND CATHODE. OUR DETECTOR USES 54 COUNTERS
  - THE NEUTRON COUNTERS ARE COVERED BY PLATES OF PLEXIGLAS AND POLYETHYLENE, BOTH 5 CM THICK, TO SLOW DOWN AND CAPTURE BACKGROUND NEUTRONS FROM THE OUTSIDE OF THE NEUTRON COUNTER. IT ALLOWS US TO REDUCE THE NEUTRON BACKGROUND BY ONE ORDER OF MAGNITUDE.
  - THE NEUTRON DETECTOR IS ALSO SURROUNDED WITH ^{10}B , WHICH IS USED FOR THE ABSORPTION OF NEUTRONS DUE TO THE HIGH NEUTRON-CROSS-SECTION IN IT



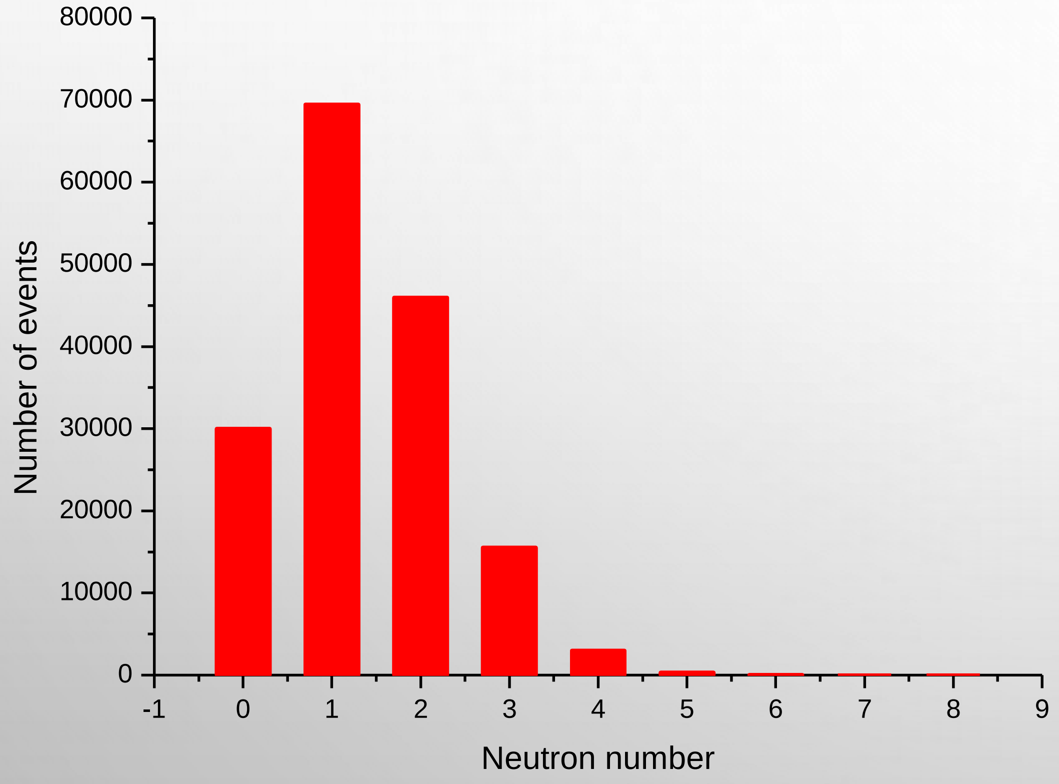
HELIUM-3 COUNTERS

- NEUTRONS ARE NON-IONIZING PARTICLES ⟹ WE DETECT THEM UNDIRECTLY
- ^{3}HE REACTS BY ABSORBING THERMAL NEUTRONS
- REACTION USED IN HELIUM COUNTERS: **$^3He + n \longrightarrow {}^3H + p + 0.764$ MEV**
- NEUTRONS FROM SF HAVE ENERGIES 1 – 1,5 MEV, NECESSARY TO SLOW THEM DOWN WITH HYDROGEN-RICH MATERIAL (POLYETHYLEN, PLEXYGLASS), CALLED MODERATOR

^{3}He proportional counters

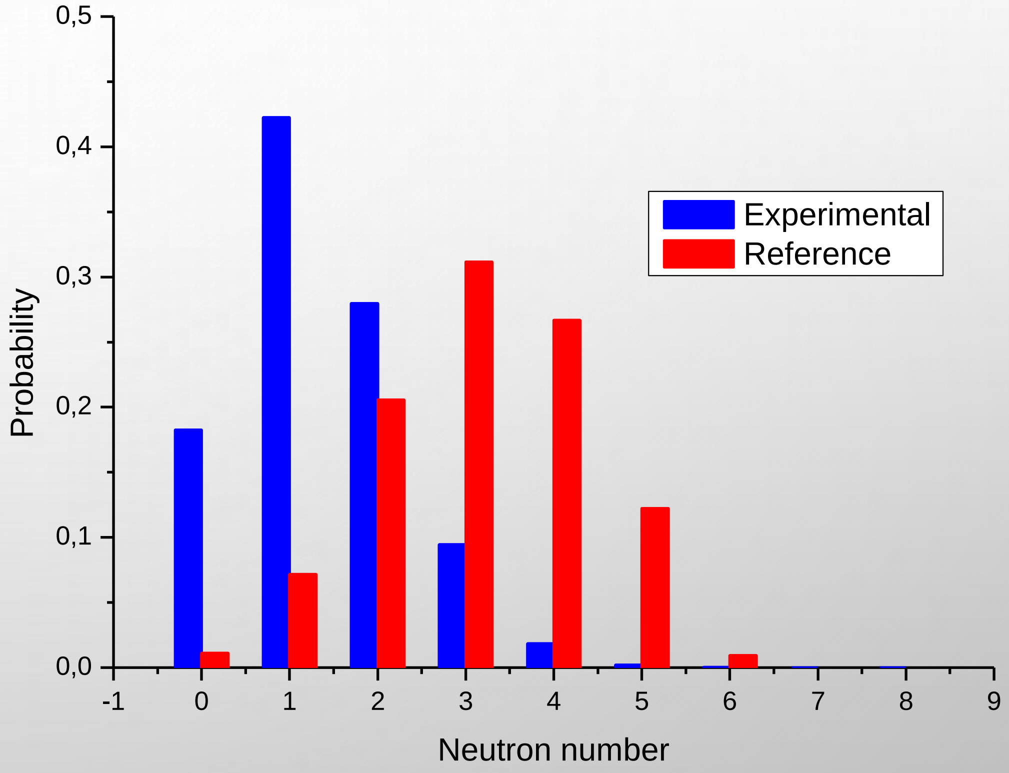


MULTIPLICITY AND PROBABILITY



THE MULTIPLICITY DISTRIBUTION OF EMITTED NEUTRONS FROM SPONTANEOUS FISSION OF ^{248}CM

THE EXPERIMENTAL AND REFERENCE PROBABILLITY DISTRIBUTION OF EMITTED NEUTRONS FROM SPONTANEOUS FISSION OF ^{248}CM



THE EFFICIENCY OF NEUTRON DETECTOR

TO DETERMINE THE DETECTOR EFFICIENCY, WE CALCULATED SOME RATIOS BETWEEN THE NUMBERS OF EMITTED NEUTRONS, AND THEN WE COMPARED THESE RATIOS WITH SOME KNOWS RATIOS. WE OBTAINED DIFFERENT EFFICIENCY FOR EACH RATIO, AND THEN WE CALCULATED THE AVERAGE EFFICIENCY.

Number of neutrons	Ratio	Efficiency (%)	Average efficiency (%)
N_1=97226	N_1/N_2=1.5111	40	39.4
N_2=64341	N_1/N_3=4.4658	39	
N_3=21771	N_2/N_3=2.9553	39	
N_4=4214	N_3/N_4=5.1665	40	
N_5=476	N_2/N_4=15.2684	39	

The efficiency of our detector

CONCLUSION

- WE CALIBRATED THE SI DETECTORS WITH ALPHA SOURCES OF KNOWN ENERGIES (^{212}BI AND ^{212}PO) FROM THORIUM DECAY CHAIN:

  E (MEV)=0.00578*A(CH)+2.5637

  RESOLUTION (FWHM) ≈ 2.5% (210 KEV FOR ^{212}PO ALPHAS)

- WE COLLECTED 230903 SPONTANEOUS FISSION EVENTS AND REGISTERED 310750 PROMPT NEUTRONS EMITTED BY ^{248}CM-SOURCE. THE EFFICIENCY OF NEUTRON DETECTOR WAS DETERMINED TO BE **39,4±1%**

THANK YOU