



# ARTIFICIAL INTELLIGENCE: A LABORATORY FOR NUCLEAR PHYSICS STUDIES



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# INTRODUCTION



- What is Artificial Intelligence?
- Advantages of AI
- History of AI
- Usage areas
- Artificial neural networks
- Deep Learning
- Artificial Intelligence Applications in Nuclear Physics

# What is Artificial Intelligence?



- The human brain can make calculations slow but decision-making fast
- Has past experiences
- Computers can do calculations fast, but not make decisions
- Artificial intelligence is a machine that can make decisions by gaining experience, learning, and generalizing
- Machines that think like humans
- Computer programs, computers, machines that can learn
- Able to predict
- Learning-brain-nervous system

# Advantages

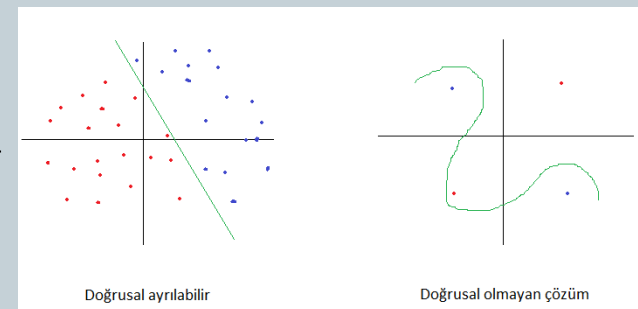


- Humans can forget, artificial intelligence can't
- Easy to transfer information
- Easier and faster to train AI
- Human is emotional, can make inconsistent decisions, artificial intelligence is clear, consistent
- Does not need a mathematical model, no rules
- Can also see unknown relationships between data
- Quick result
- Can be used in any field

# Fundamental History of AI



- Ancient Greek Daedalus, artificial human thought
- 1884 Babage conducted some experiments
- 1940 Heb et al. first artificial neuron in engineering
- 1943 McCulloch and Pitts, the electronic brain
- 1949 Hebbian learning rule
- 1957 Single-layer perceptron
- 1959 Adaline learning algorithm
- 1970 Minsky and Pappert stated 'not applicable to nonlinear problems',
- 1974 Multilayer perceptrons, **solving the XOR problem (CORNER STONE)**
- 1982 Hopfield nets
- 1984 Kohonen, unsupervised learning
- 1986 Back-propagation algorithm
- 1987 The first scientific conference in the world

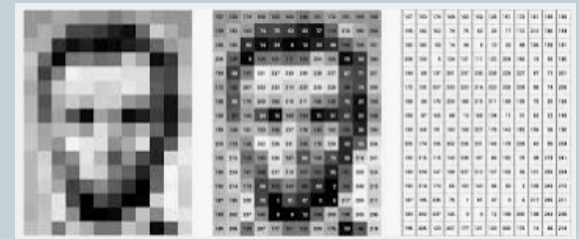
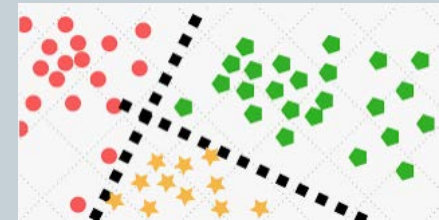


# Usage areas



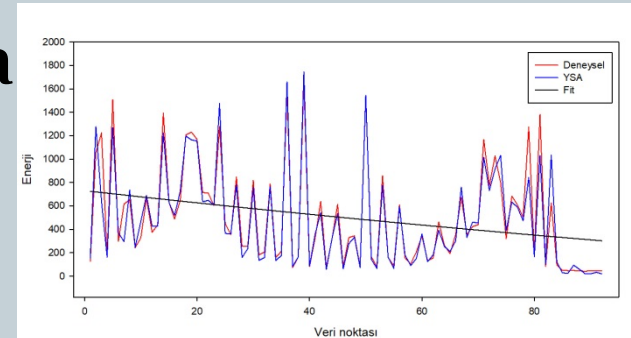
## FORESIGHT – CLASSIFICATION – DATA MERGE AND FILTER – IMAGE PROCESSING

- Space-aviation
- Automotive
- Banking-finance
- Defense
- Electronic
- Machine
- health-medicine
- robotics
- Linguistics
- Traffic
- Contact
- Security
- Image processing
- Meteorology
- **Science**
- Now in every field



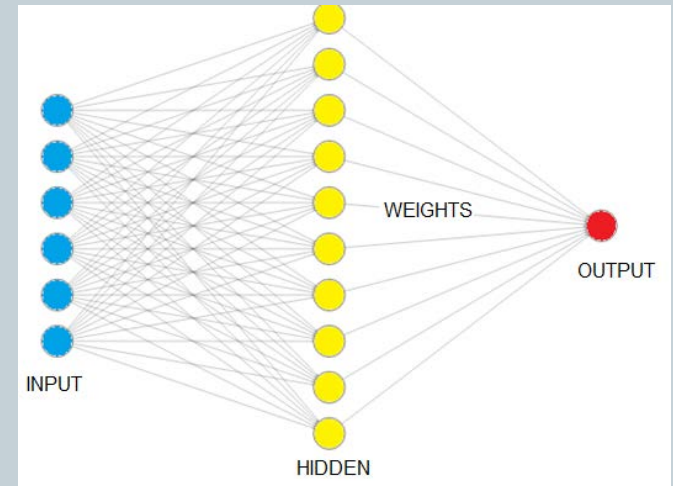
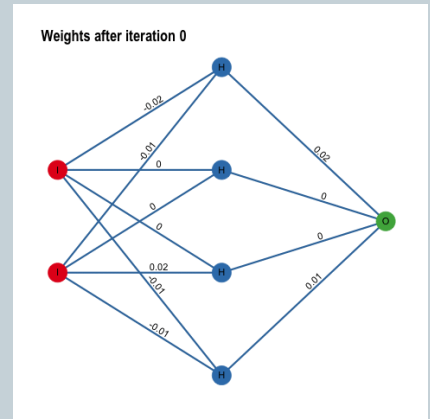
# Artificial Neural Networks (ANN)

- Mimics the human brain-nervous system
- Can learn from the examples and information given
- Like a baby learning to speak
  - After a while, s/he can use the words s/he has not learned and can make sentences. 'I will be a physicist when I grow up'
- Able to adapt what they have learned
- Able to predict future data and events
- Capable of completing missing data
- It's never a 'fitting'



# Artificial Neural Networks (ANN)

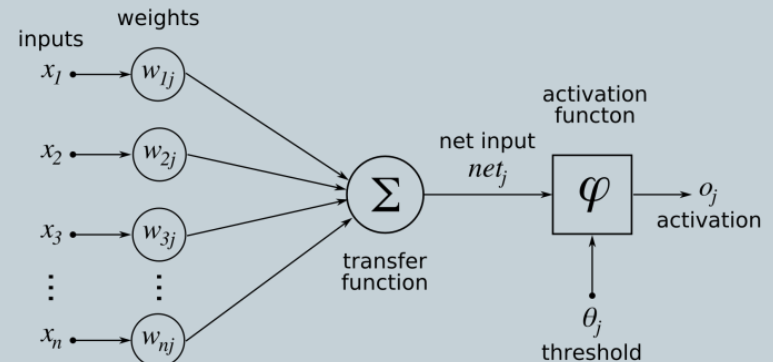
- Neurons
- Input-Hidden-Output layers
- Interneuron Connections
- Assigning appropriate values to the links
- Generating new outputs with these values
- Layers
  - Fully connected
  - Partially connected
  - Feed-forward
  - Bidirectional





# Structure

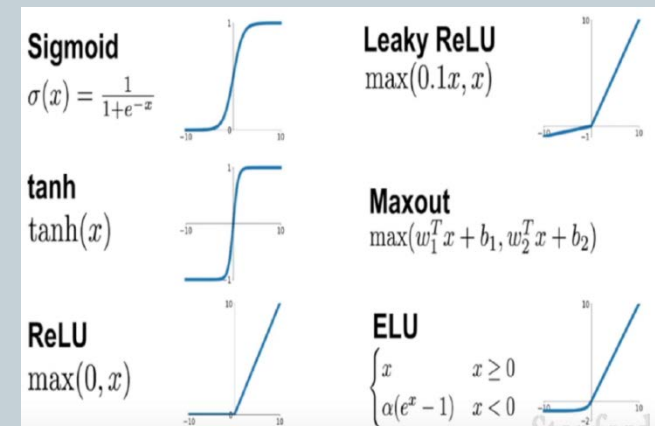
- The inputs of the problem are taken
- Transmitted by multiplying by weights
  - Random starting weight values
- Combined at the neuron input
  - addition, multiplication, take minimum
- Activates before exiting
  - The data is processed, the output to be produced is determined
  - Non-linear function
  - Like sigmoid, tanh, step, relu, sine
- The output of the neuron is produced



# Activation Function



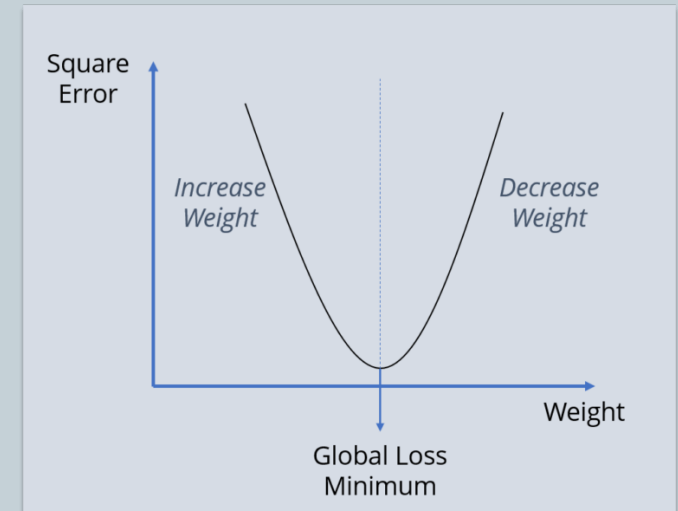
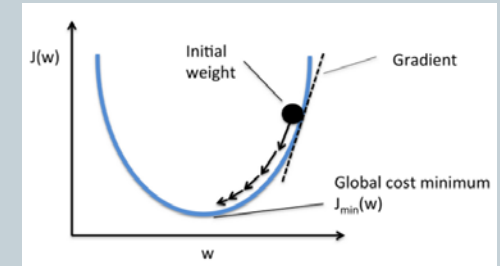
- If the activation function is not applied, the output signal becomes a simple linear function
- By analyzing the net information coming to the cell, it determines the output information that the cell will generate in response to the input information
- Hidden layers and activation functions make artificial neural networks “non-linear”
- Since the derivative of the activation function is also used in feedback networks, a function whose derivative is easy to calculate is chosen so that the calculation does not slow down



# Backpropagation



- Initial weight values are determined randomly
- Our model output is very different from our actual output, ie if the error value is too large
- We have to find a way to train our model
- Backpropagation
- The error in the output propagates backwards to all weights by a certain percentage
- The backpropagation algorithm looks for the minimum value of the error function using the delta rule or gradient descent methods



# Machine Learning



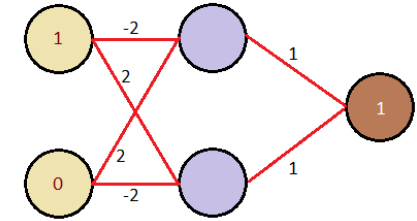
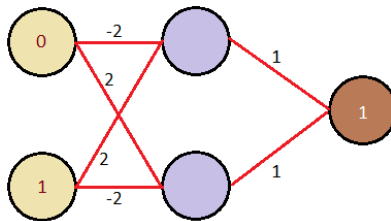
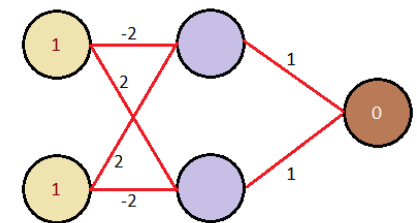
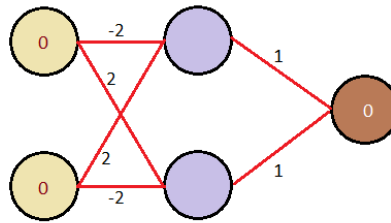
- **Supervised**
  - Desired outputs are also given
  - It is constantly compared with the output of the network
  - An accepted threshold error value
  - Final weights
- **Unsupervised**
  - Desired outputs are not given
  - Outputs are classified
  - Final weights
- **Reinforced**
  - The desired output is not given
  - Goodness of results after each output production cycle
  - An accepted threshold error value
  - Final weights



# XOR Problem



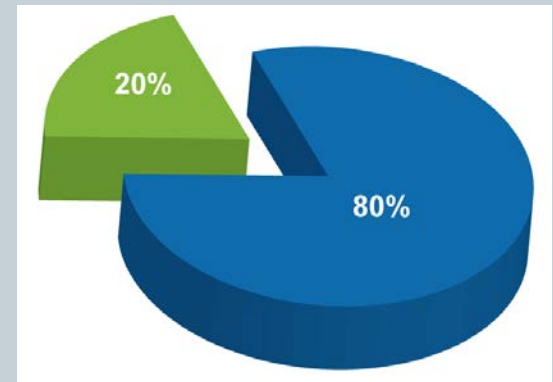
- A basic non-linear problem
- Cannot be solved with a single layer
- Multiple layers required
- Threshold value +1



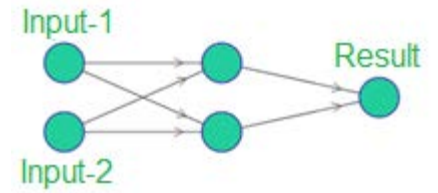
# Basic Stages



- **Training with a portion of all data (80%)**
  - Digitization is possible
  - random selection
  - No memorization required
  - Weights are improved with each cycle
  - Weights below the error threshold
- **Test with remaining data (20%)**
  - Final weights
  - Output of the network
- As training improves, test results go farther than desired
- If the training is one-to-one with the desired, memorization has taken place
- It is important to determine the most appropriate hidden layer



# A Simple Example



## TRAINING DATA

Input-1	Input-2	Result	ANN Result
2	3	6	6,968197
4	2	8	8,228104
3	5	15	14,99255
4	3	12	11,2995
6	2	12	11,59457
6	4	24	23,54598
8	2	16	16,50363
9	3	27	27,14061
3	8	24	23,19126
2	9	18	17,99816
7	5	35	35,005
5	9	45	44,40249
6	8	48	45,83007
4	9	36	37,14064
8	4	32	31,25021
6	6	36	37,85414

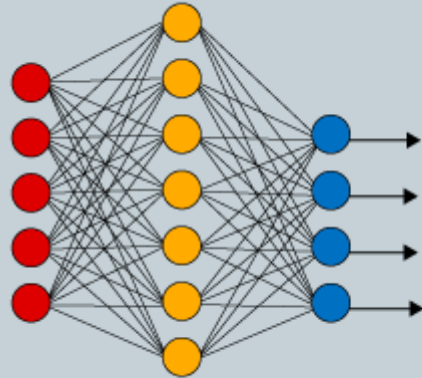
## TEST DATA

18	13	234	48,7149974
12	23	276	25,7898617
12	23	276	25,7898617
14	16	224	50,2758755

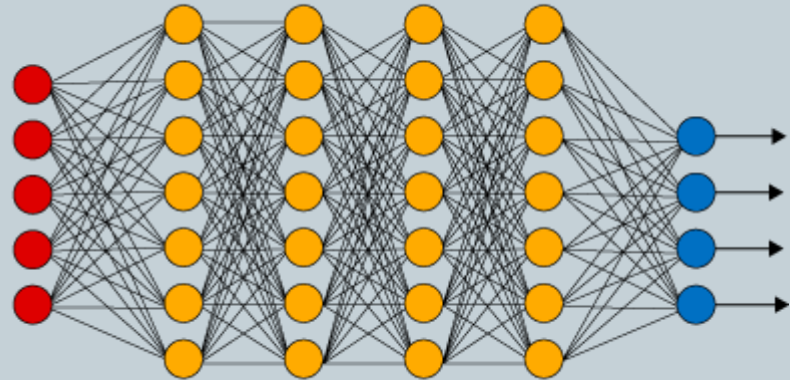
# Deep Learning



Simple Neural Network



Deep Learning Neural Network



● Input Layer

● Hidden Layer

● Output Layer

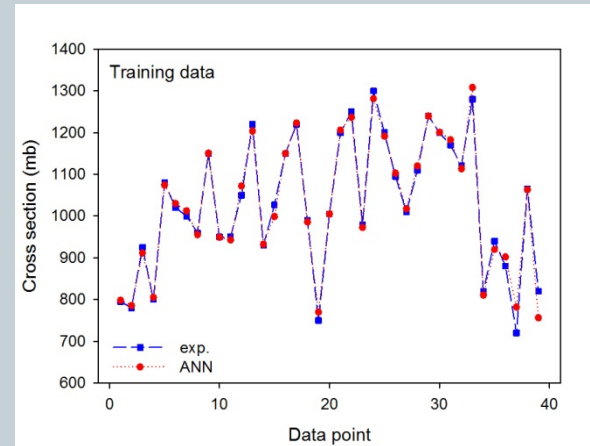
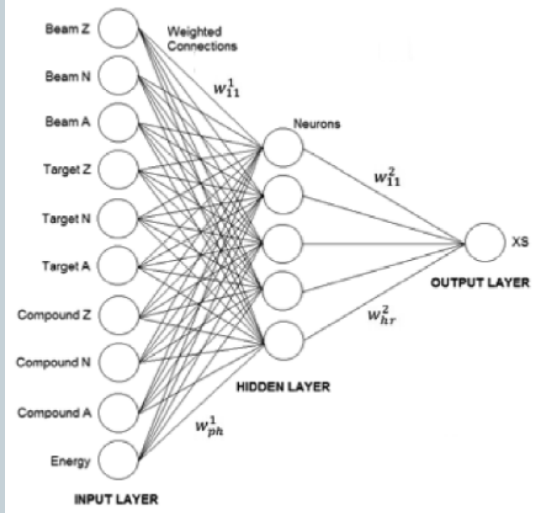
- Existing experiences were given to the machine through parameters
  - Red is apple, yellow is lemon
  - If it is round, it is apple, if it is oval, it is lemon
  - Deep learning can learn these differences on its own
- Creates its own rules
- Does not require basic human skills



# Applications in Nuclear Physics



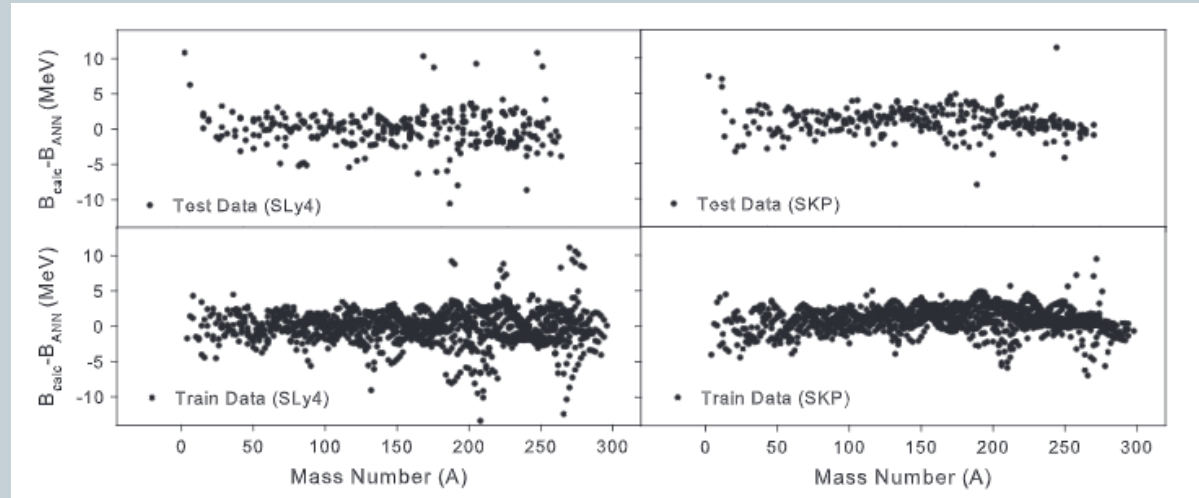
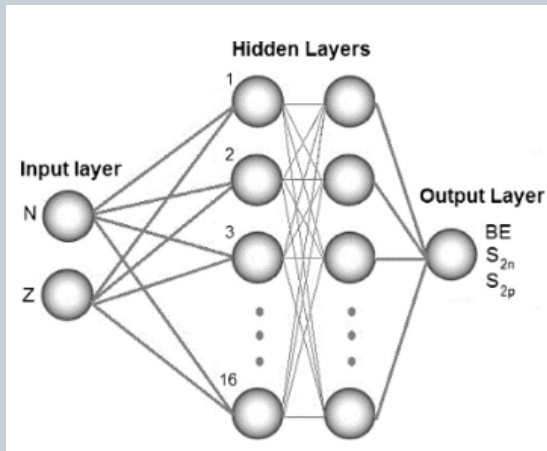
## ● Cross-sections for Nuclear Fusion Reaction (S.Akkoyun)



Beam			Target			Compound			E <sub>cm</sub> (MeV)	Cross-section (mb)		
Z	N	A	Z	N	A	Z	N	A		Exp.	ANN	PACE
3	4	7	6	6	12	9	10	19	16.3	975(50)	928*	901
4	5	9	14	14	28	18	19	37	23.8	950(90)	1093	1140
5	5	10	7	7	14	12	12	24	35.2	1045(40)	1229	808
6	7	13	6	6	12	12	13	25	18.0	960(19)	840	1056
6	6	12	12	12	24	18	18	36	33.7	1200(78)	1085	1064
6	6	12	12	14	26	18	20	38	37.0	1300(70)	1218	1098
6	6	12	14	14	28	20	20	40	34.5	960(40)	1147	1102
7	8	15	13	14	27	20	22	42	45.0	1200(50)	1142	1130
8	8	16	6	6	12	14	14	28	20.8	1060(10)	1055*	1015
8	8	16	14	14	28	22	22	44	38.8	1050(40)	1032*	1091
8	8	16	14	15	29	22	23	45	39.0	1260(1 0 0)	1136	1116
9	10	19	14	16	30	23	26	49	44.5	1235(1 4 0)	1181*	1204*
12	12	24	12	12	24	24	24	48	39.3	1050(36)	1091	958
14	14	28	14	16	30	28	30	58	42.8	820(27)	731	826*
14	14	28	12	12	24	26	26	52	38.0	760(23)	919	791

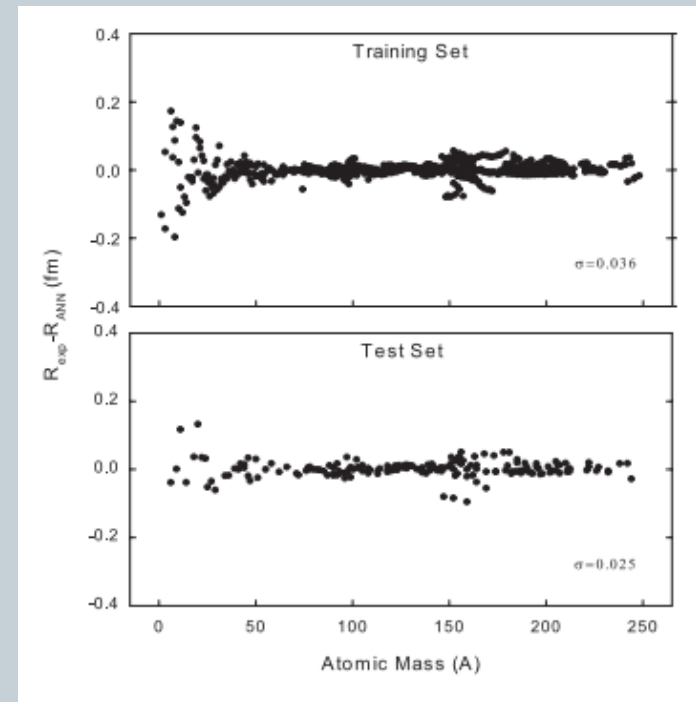
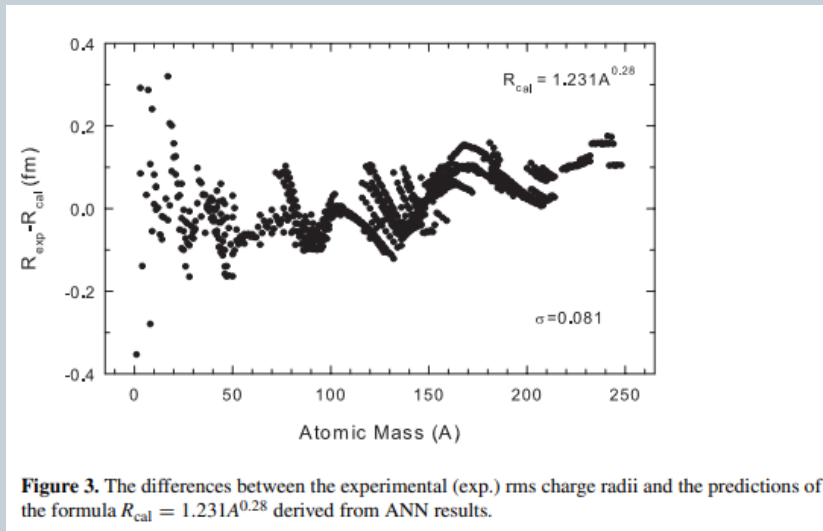
# Applications in Nuclear Physics

## ● Binding Energies of Atomic Nuclei (T.Bayram, S.Akkoyun, S.O. Kara)



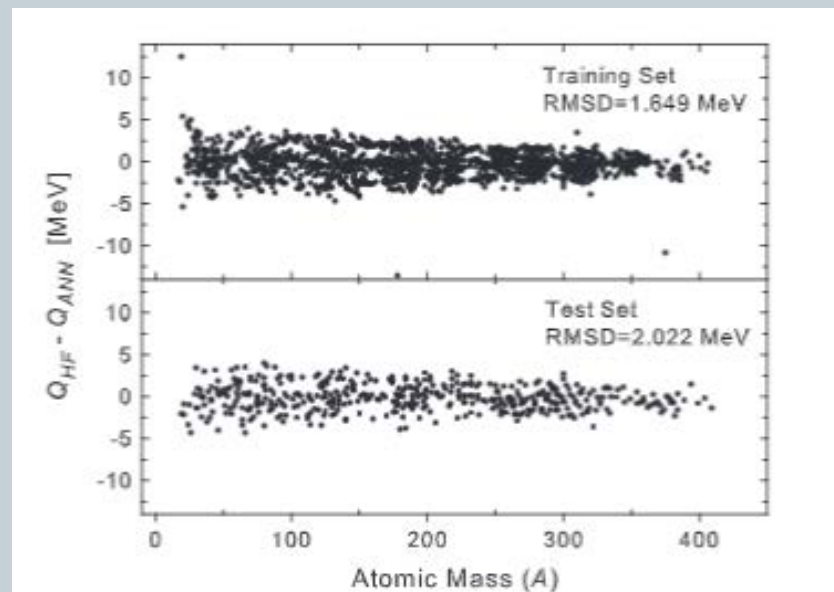
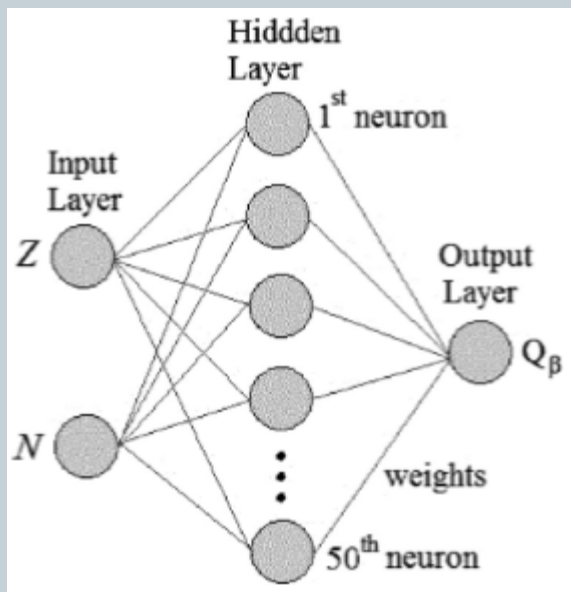
# Applications in Nuclear Physics

- **Atomic Radius** (S.Akkoyun, T.Bayram, S.O. Kara, A.Sinan)
  - Error 0.07 according to the formula produced from ANN
  - Error 1.42 according to common formula



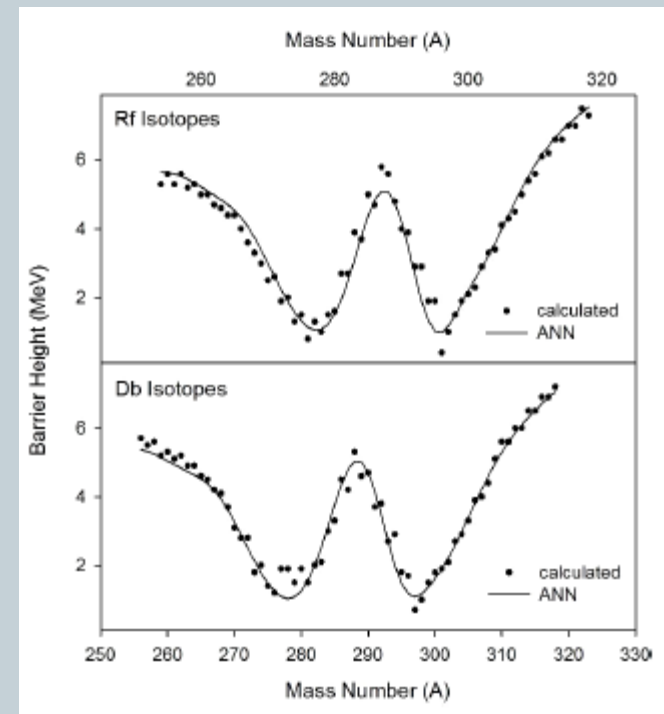
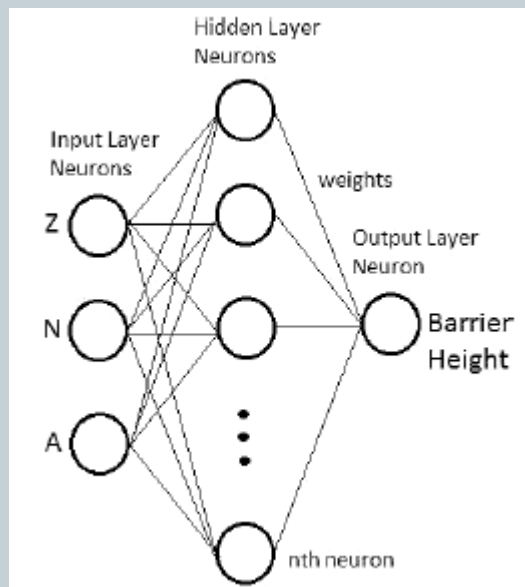
# Applications in Nuclear Physics

- Beta decay energies of atomic nuclei (S.Akkoyun, T.Bayram, T.Turker)



# Applications in Nuclear Physics

- Fission barrier height (S.Akkoyun, T.Bayram)

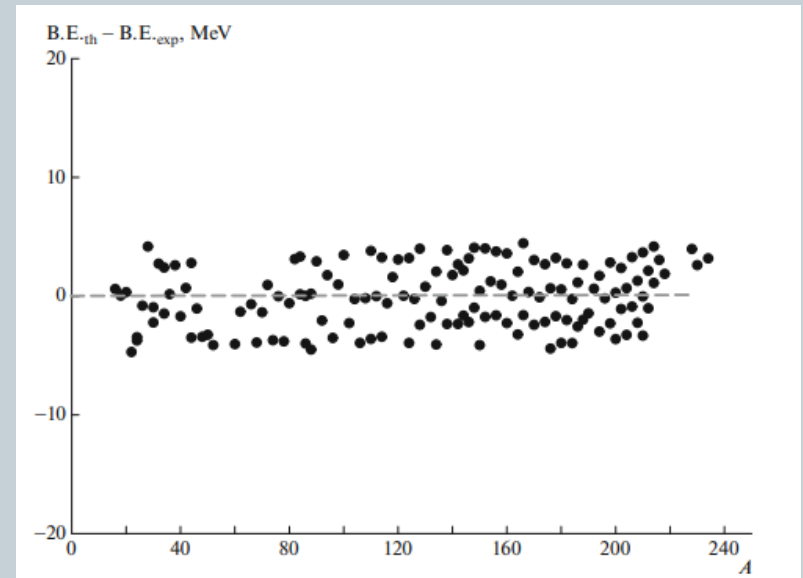
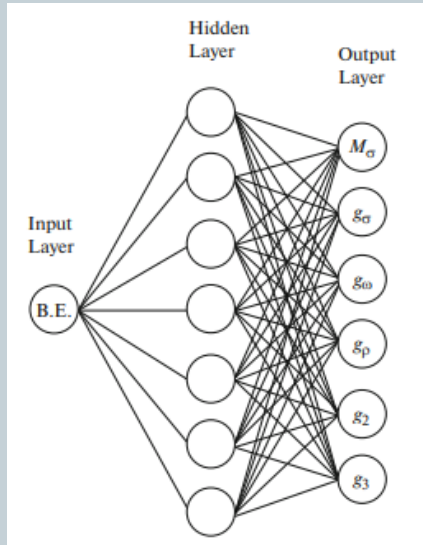


# Applications in Nuclear Physics



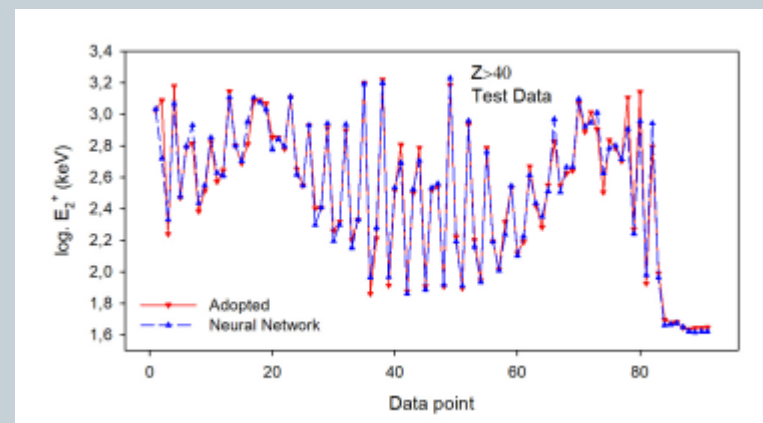
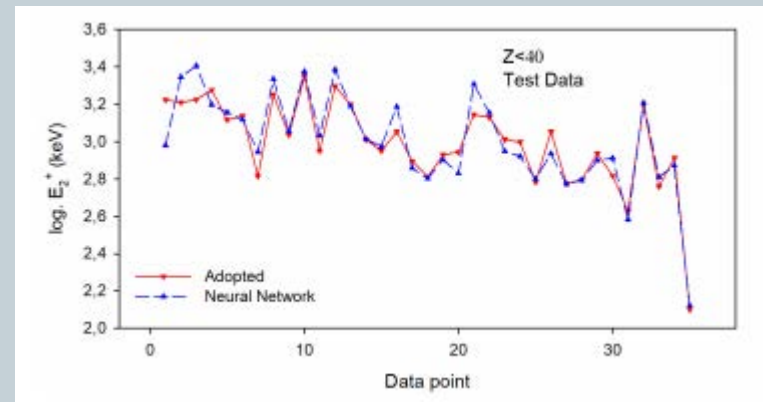
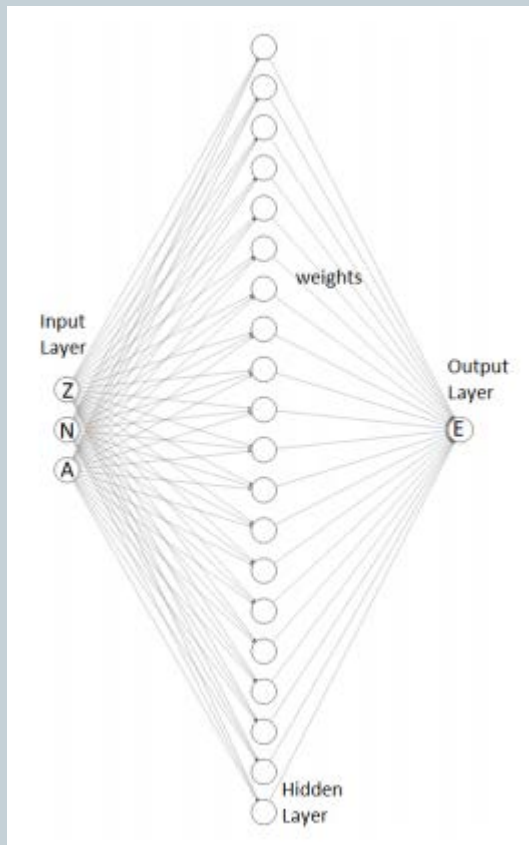
- Improvement of RMF model parameters (T.Bayram, S.Akkoyun, S.Senturk)

$$\begin{aligned}
 L = & \bar{\psi}(i\gamma^\mu\partial_\mu - M)\psi + \frac{1}{2}\partial^\mu\sigma\partial_\mu\sigma - U(\sigma) \\
 & - g_\sigma\bar{\psi}\sigma\psi - \frac{1}{4}\Omega^{\mu\nu}\Omega_{\mu\nu} + \frac{1}{2}m_\omega^2\omega^\mu\omega_\mu \\
 & - g_\omega\bar{\psi}\gamma^\mu\psi\omega_\mu - \frac{1}{4}R^{\mu\nu}R_{\mu\nu} + \frac{1}{2}m_\rho^2\rho^\mu\rho_\mu \\
 & - g_\rho\bar{\psi}\gamma^\mu\tau\psi\rho_\mu - \frac{1}{4}F^{\mu\nu}F_{\mu\nu} \\
 & - e\bar{\psi}\gamma^\mu\frac{1-\tau_3}{2}A_\mu\psi,
 \end{aligned}$$



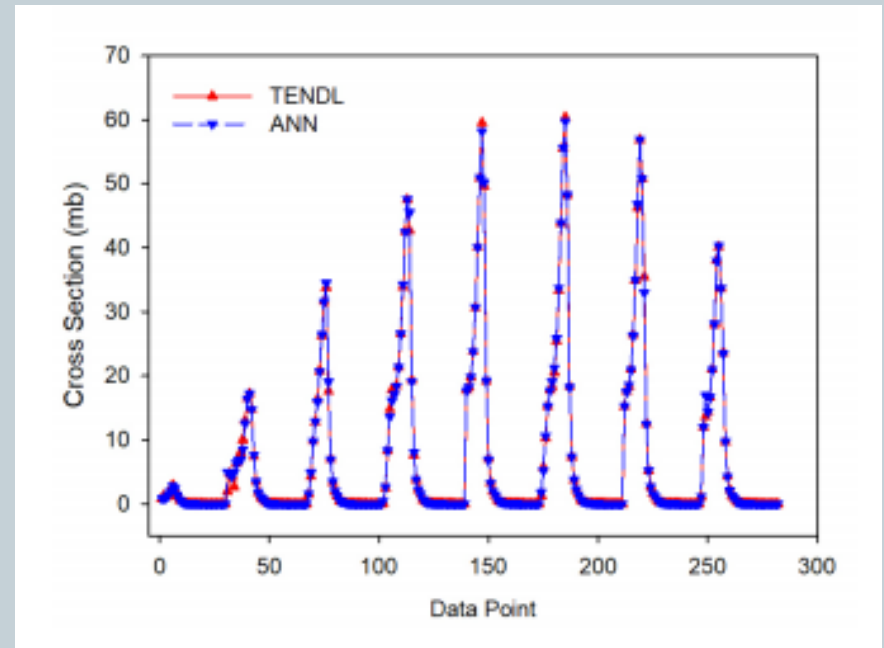
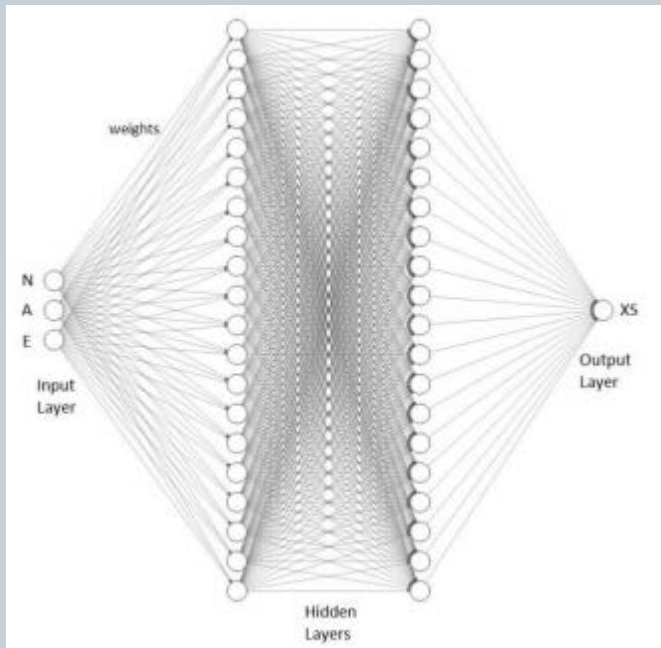
# Applications in Nuclear Physics

- First 2+ excited state energy (S.Akkoyun, Y.Torun, H.Kaya)



# Applications in Nuclear Physics

- Photonuclear reaction cross section on Ca isotopes (S.Akkoyun)



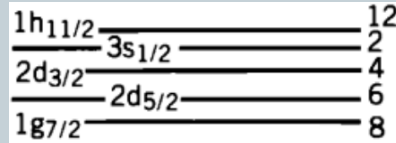


# Applications in Nuclear Physics



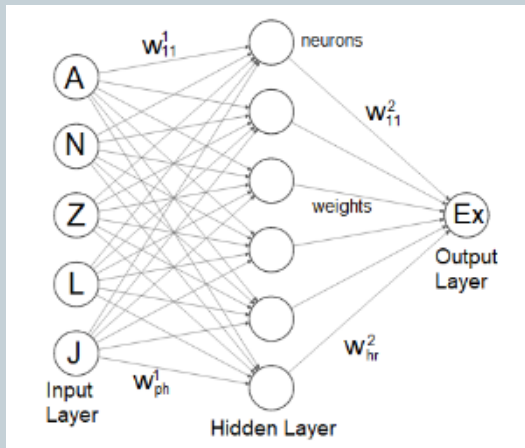
- Determination of neutron single particle energies for the Sn-101 isotope

$$H = E_0 + \sum_i \varepsilon_i a_i^\dagger a_i + 1/2 \sum_{ijkl} \langle ij|V|kl \rangle a_i^\dagger a_j^\dagger a_l a_k$$



E(level) (keV)	XREF	J $\pi$ (level)
0.0	AB	(5/2 <sup>+</sup> )
171.7 6	B	(7/2 <sup>+</sup> )

J $\pi$ (level): From shell-model interpretation



J $\pi$	Experimental	sn100pn	Set-1	Set-2	Set-3
5/2 <sup>+</sup>	0	0	0	0	0
7/2 <sup>+</sup>	199.7	139	213	165	171
9/2 <sup>+</sup>	1194.0	1385	1265	1244	1303
11/2 <sup>+</sup>	1393.8	1451	1366	1371	1420
13/2 <sup>+</sup>	1848.7	1999	1817	1970	2001
13/2 <sup>+</sup>	1915.6	2148	2046	2065	2124
15/2 <sup>+</sup>	2030.7	1976	1823	1924	1973
15/2 <sup>+</sup>	2167.0	2270	2120	2288	2300
17/2 <sup>+</sup>	2203.5	2267	2142	2312	2323

# Thank you very much



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