Nuclear Mass Predictions with Bayesian Neural Network

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Introduction : Nuclear Mass

Theories of nuclear mass

Macroscopic	**Microscopic**	**Macro-Micro**
LDM	Hartree-Fock-Bogoliubov (HFB)	FRDM Duflo-Zuker (DZ) Moller-Nix (MN)

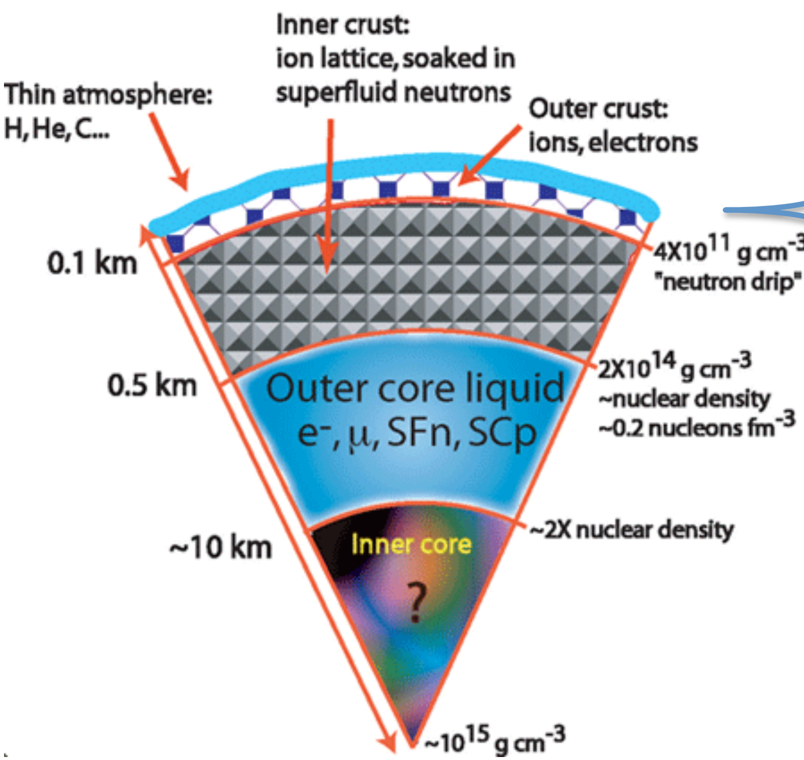
Experiments of nuclear mass

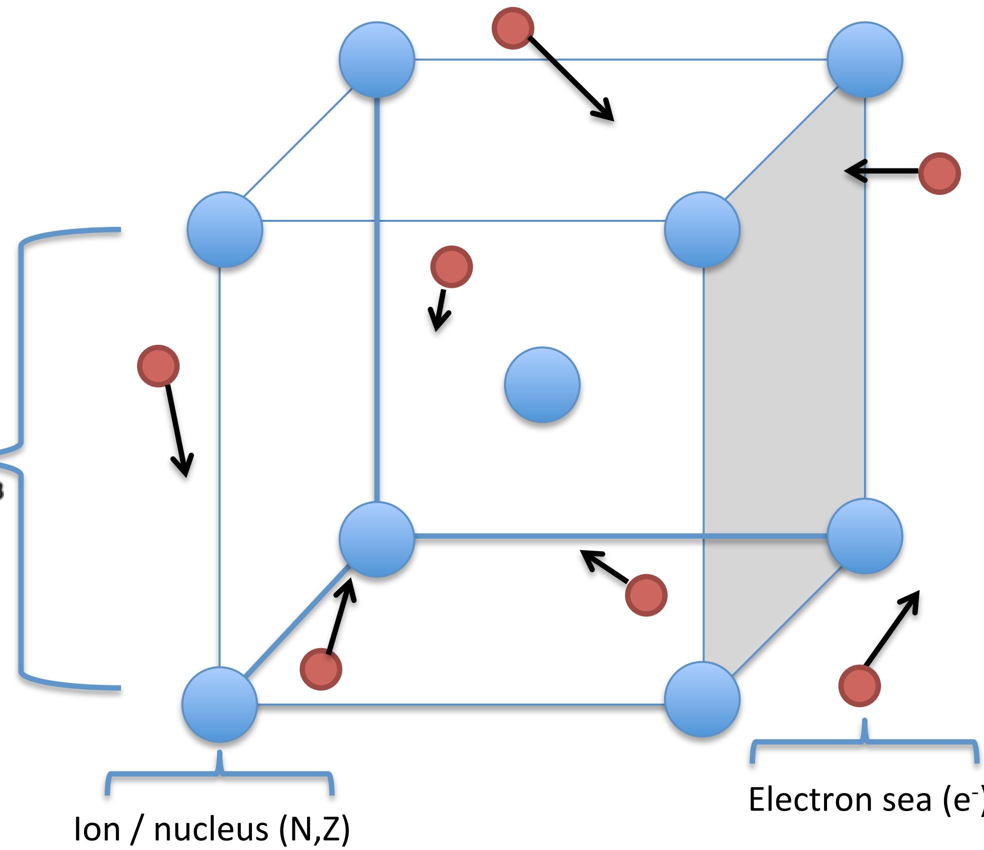
Atomic mass evaluations (AME)

1988, 1993, 1995, 2003, **2012**

Motivation : Why Mass?

Neutron star outer crust





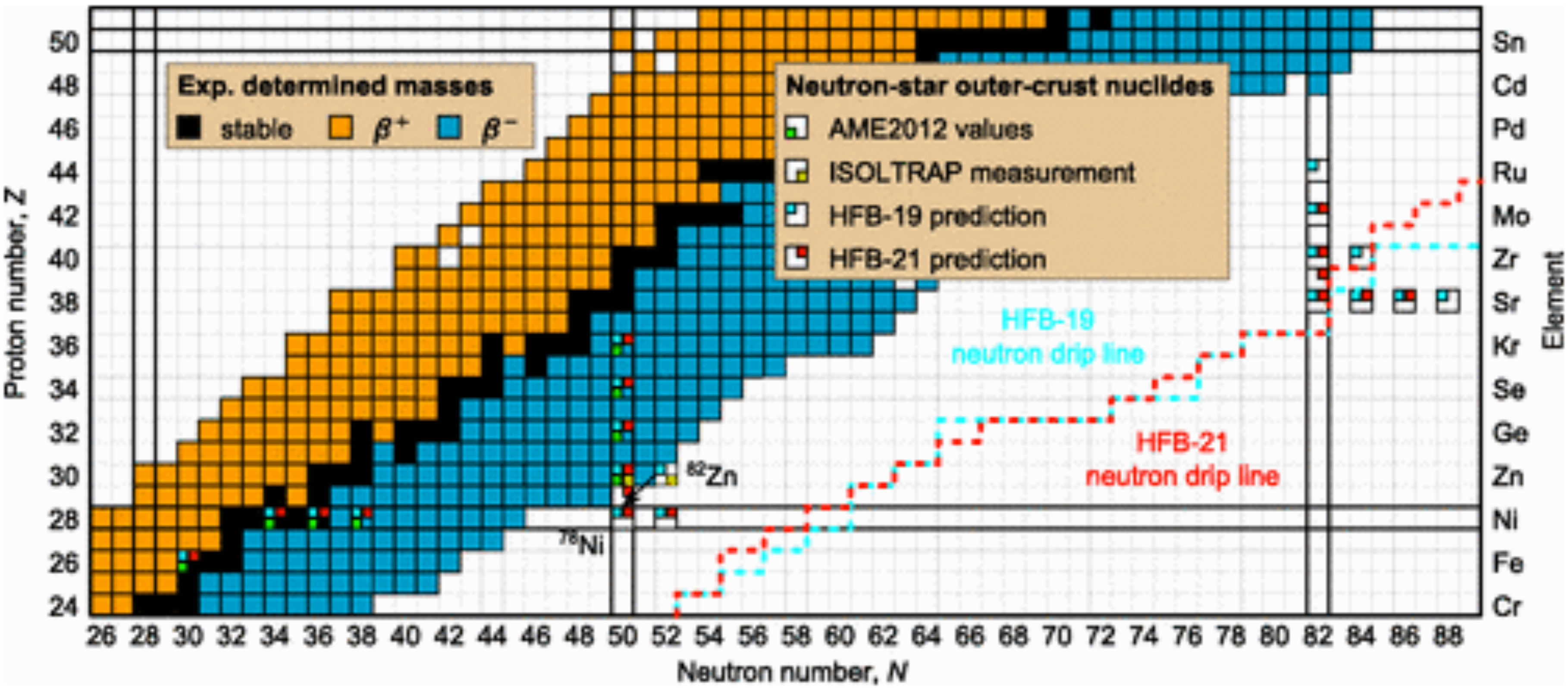
Energy = Mass + Degeneracy + Lattice

Composition

?

Motivation : Crustal Nuclei

Outer crust by HFB



<u>The constituents in multicolor</u>

Frameworks : Bayes' Theorem

Bayes' probabilities

Likelihood

Posterior → $$P(A \mid B) = \frac{P(B \mid A)P(A)}{P(B)}$$ ← Prior

Example : Ebola Test

P -> positive ; E -> Ebola

$$p(E) = 0.01$$

$$p(P|E) = 0.9$$

$$p(E|P) = \frac{p(P|E)p(E)}{p(P)}$$

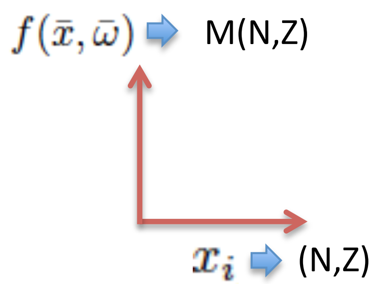
$$p(E|P) = \frac{0.9 \times 0.01}{(0.9 \times 0.01) + (0.1 \times 0.99)} = 0.083$$

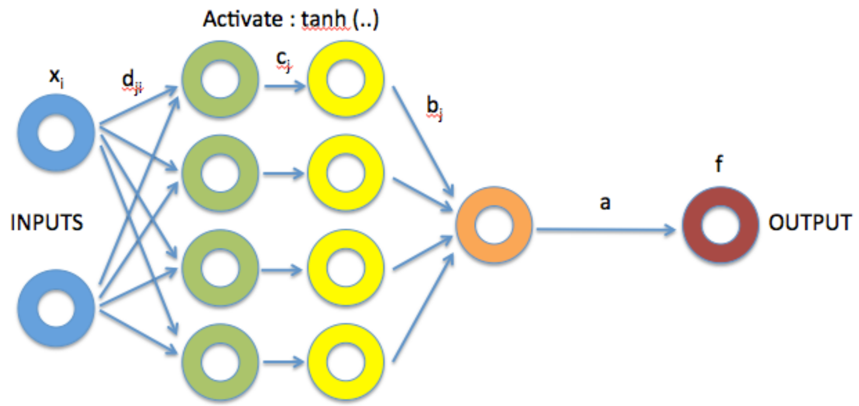
Frameworks : Neural network

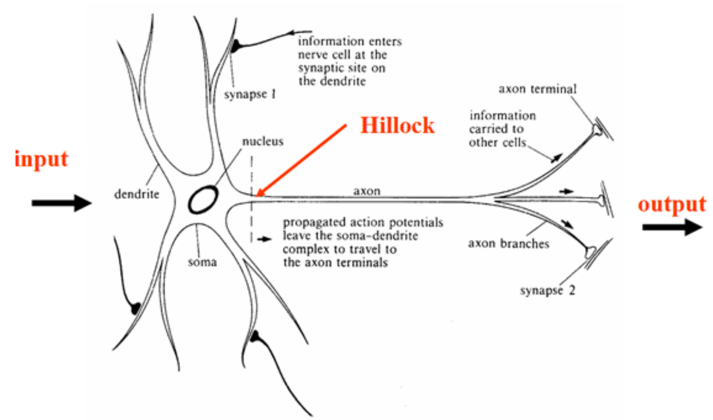
Neural Network

Basis function

$$f(\bar{x},\bar{\omega}) = a + \sum_{j=1}^{H} b_j tanh(c_j + \sum_{i=1}^{I} d_{ji}x_i)$$

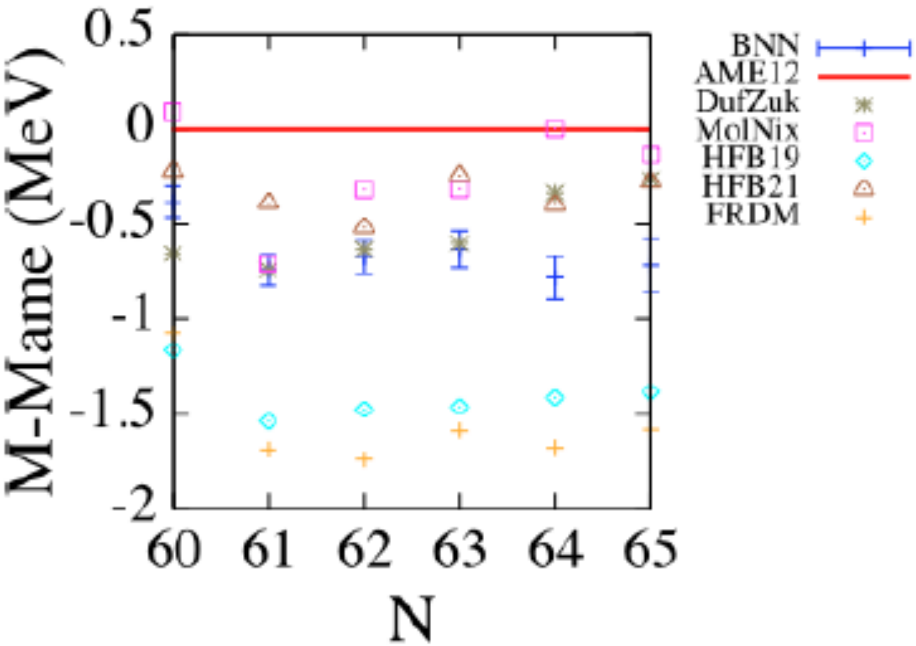


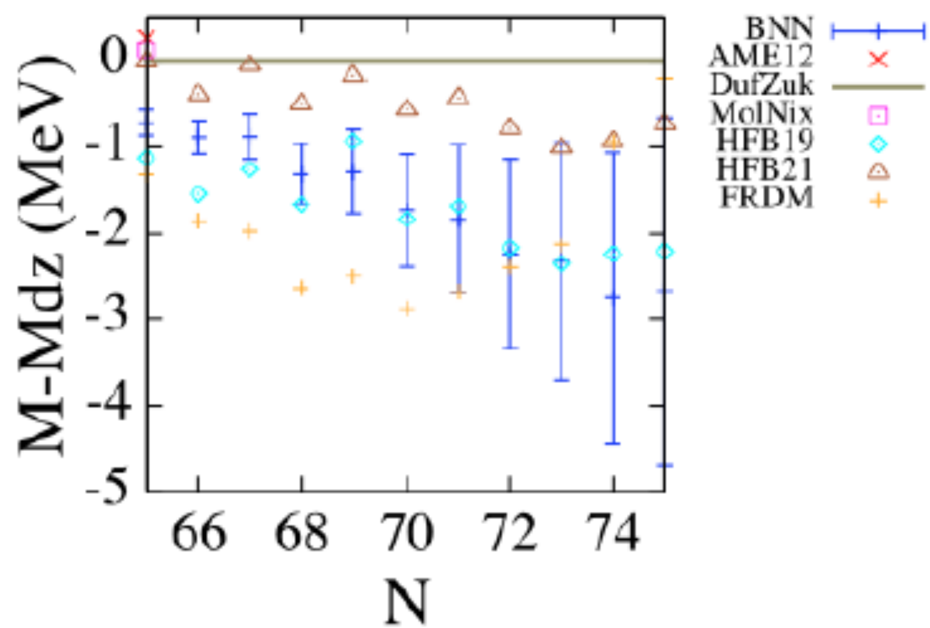




Results : BNN Predictions

LDM with BNN on Krypton isotopes





At outer crust region :

20<N<84 and 20<Z<50

Model	LDM	DZ	MN	FRDM	HFB19	HFB21
$\sigma_{rms}^{(pre)}$(MeV)	3.233	0.528	1.006	0.848	0.743	0.639
$\sigma_{rms}^{(post)}$(MeV)	0.532	0.303	0.479	0.432	0.412	0.398
$\Delta\sigma/\sigma_{rms}^{(pre)}$	0.84	0.43	0.52	0.49	0.45	0.38

Outlook

- Significance of nuclear mass prediction in Astrophysics :
  Outer crust of neutron star
  r-process

- Bayesian approach for data fitting

- Neural network as basis for any smooth function

- Potential use of BNN for many other nuclear observables

Thank You