Conflated nuclear mass model

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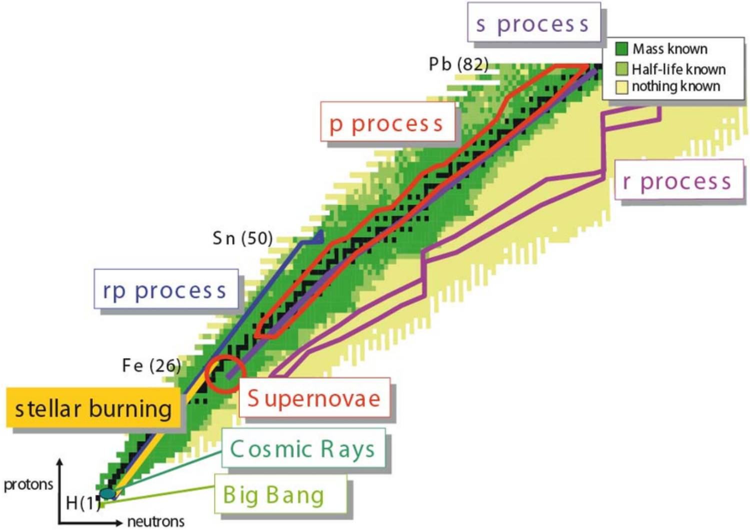
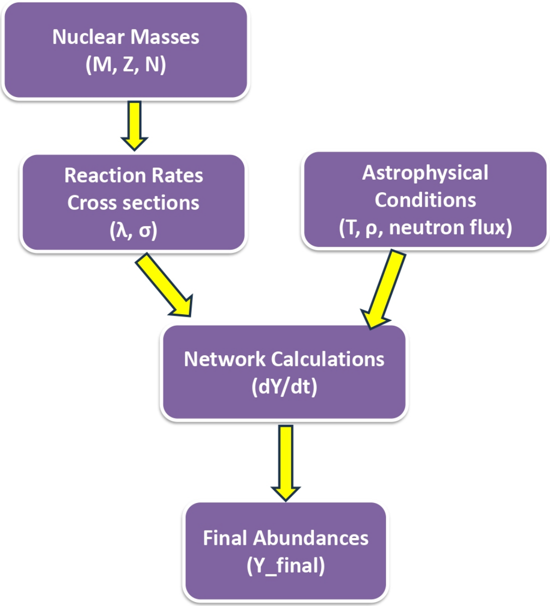

s process
Mass known
Half-life known
nothing known
Pb (82)
p process
r process
Sn (50)
rp process
Fe (26)
stellar burning
Supernovae
Cosmic Rays
Big Bang
protons
H(1)
neutrons

Nucleosynthesis processes

Process	Elements	Astro.site
BBN	H, He, Li	Big Bang
Cosmic rays	Li, Be, B	ISM spallation
Stellar burning	C $\rightarrow$ Fe	Stars
s-process	Zn $\rightarrow$Pb	AGB stars
r-process	Zn $\rightarrow$ U	NS mergers, SN
p-process	Se $\rightarrow$ Hg, p isotopes	SN
rp-process	Sn $\rightarrow$ Te	X-ray bursts

Role of nuclear masses in Nucleosynthesis



90 years of Nuclear mass models

Model Type	Year	Method	RMSE (MeV)
Liquid Drop Model	1935 -1960	Mac.	2.0 – 4.0
SMS	1966–1980	Mic. - Mac.	1.0 – 2.0
FRDM	1992 - 2012	Mic. - Mac.	0.55 – 0.80
Duflo–Zuker	1995–2010	Pheno	0.30 – 0.55
SCMF	2000 - 2020	Mic.	0.55 – 1.0
Mic–Mac (WS4)	2014	W–S mic.	0.30 – 0.40
Machine-Learning	2015–2025	Data Driven	0.15 – 0.35

Components for ML models

List of nuclear features used for learning the nuclear masses

#	Feature	Symbol
1	Proton Number	Z
2	Neutron Number	N
3	Mass Number	A
4	Surface term	$A^{2/3}$
5	Isospin Asymmetry	I
6	Even-Odd Proton Indicator	Z_{eo}
7	Even-Odd Neutron Indicator	N_{eo}
8	Proton Magic Gap	v_Z
9	Neutron Magic Gap	v_N
10	Promiscuity Factor	PF
11	Proton Shell Number	Z_{shell}
12	Neutron Shell Number	N_{shell}

Table: Data sets

Set	Number
train	2028
test	358
extpl	71
2020	2457
new	31

$$M_{model}^{\mathrm{RR}} = M_{\mathrm{Exp}} - M_{model}$$

RR: Raw Residuals

ML method: Gradient Boosting Regressor (GBR)

Conflated of Nuclear mass models

$$
\begin{aligned}
M_m^{\mathrm{RR}}(j) &= M_{\mathrm{Exp}}(j) - M_m(j) \quad \textbf{Raw Residuals} \\
M_m^{\mathrm{CR}}(j) &= M_m^{\mathrm{RR}}(j) - M_m^{\mathrm{ML}}(j) \\
&= M_{\mathrm{Exp}}(j) - (M_m(j) + M_m^{\mathrm{ML}}(j)) \quad \textbf{Corrected Residuals}
\end{aligned}
$$

Conflated of Nuclear mass models

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M_m^{\mathrm{RR}}(j) &= M_{\mathrm{Exp}}(j) - M_m(j) \quad \textbf{Raw Residuals} \\
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&= M_{\mathrm{Exp}}(j) - (M_m(j) + M_m^{\mathrm{ML}}(j)) \quad \textbf{Corrected Residuals}
\end{aligned}
$$

$$
\begin{aligned}
\bar{M}^{\mathrm{CR}}(j) &= \sum_{m=1}^{12} w_m M_m^{CR}(j) \quad \textbf{Weighted avarage} \\
w_m &= \frac{\left(\frac{1}{\sigma_m^{\mathrm{CR}}}\right)^2}{\sum_{k=1}^{12}\left(\frac{1}{\sigma_k^{\mathrm{CR}}}\right)^2}
\end{aligned}
$$

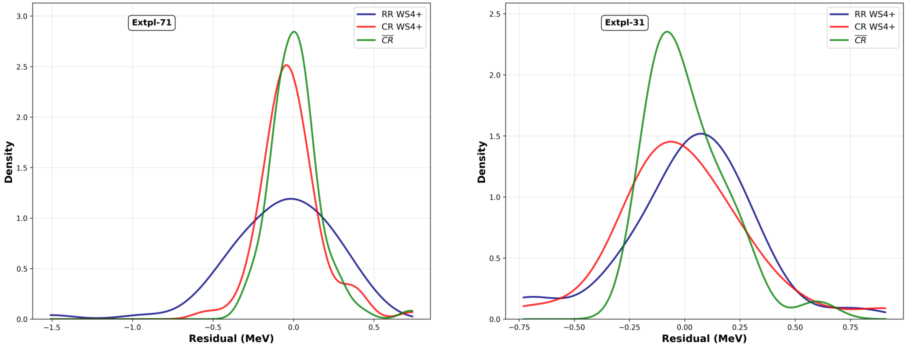
with σ_m^{CR} is the RMSE for a given nuclear mass model with corrected residuals:

$$
\sigma_m^{\mathrm{CR}} = \sqrt{\frac{1}{N_d}\sum_{j=1}^{N_d}(M_m^{\mathrm{CR}}(j))^2}
$$

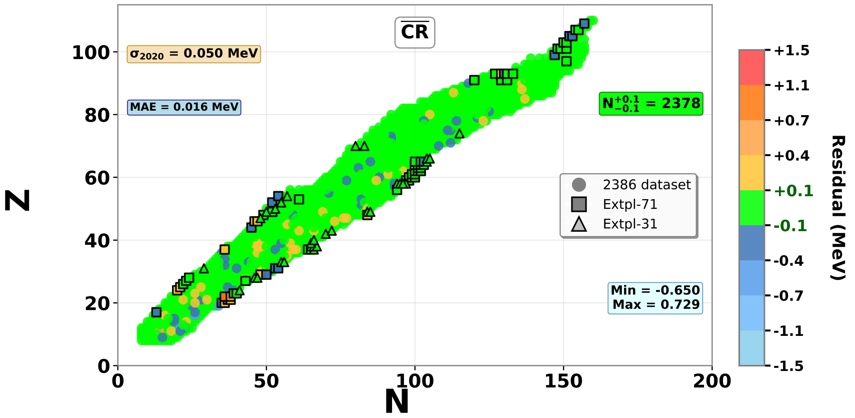
Results

Models	Extpl-71	Extpl-31	2020	Weights
WS4	0.2213	0.3666	0.0670	0.1348
WS4+	0.1902	0.2940	0.0513	0.2607
frdm	0.2911 0	.3024	0.0830	0.0933
DZ(28)	0.2056	0.2769	0.0762	0.0976
UNEDF1	0.4908	0.3464	0.1375	0.0350
RMF	0.5494	0.4937	0.1547	0.0273
HFB31	0.5156	0.6905	0.1444	0.0322
Gogny	0.3265	0.2942	0.1235	0.0341
bskg03	0.2829	0.2101	0.0856	0.0828
KTUY05	0.2844	0.2558	0.0793	0.1048
UNEDF0	0.5277	0.3694	0.1241	0.0611
BW2	0.3886	0.4706	0.1255	0.0364
Average	**0.1585**	**0.1677**	**0.0507**	

Distribution of Residuals



Nuclear chart



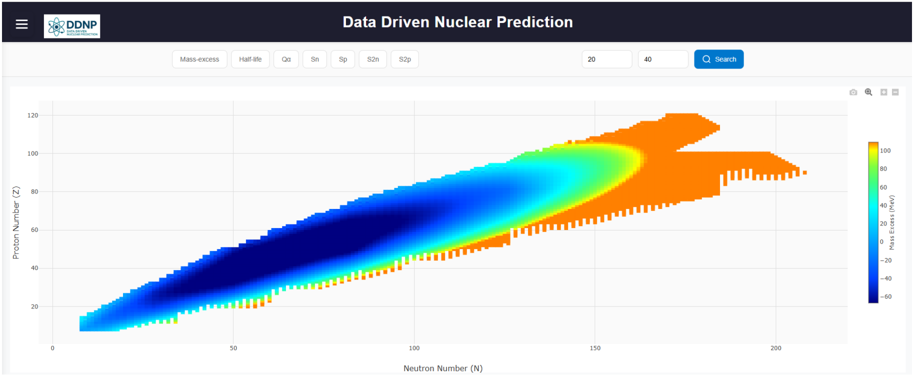


Figure: Homepage of ddnp.in showing the interactive nuclear chart with ELMA-based predictions.

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