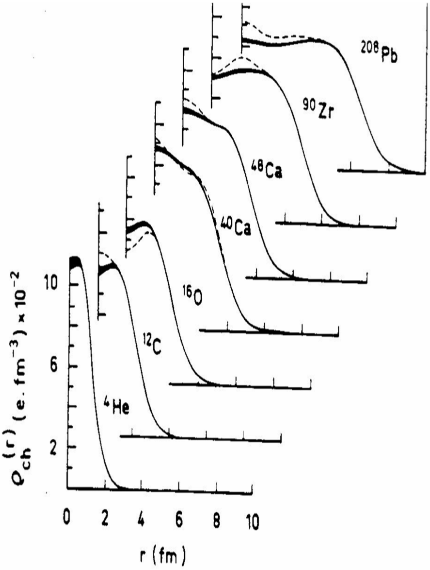
What do (ordinary) nuclei look like?

- Charge densities of magic nuclei (mostly) shown
- Proton density has to be "unfolded" from $\rho_{\text{charge}}(r)$, which comes from elastic electron scattering
- Roughly constant interior density with $R \approx (1.1\text{–}1.2\,\text{fm}) \cdot A^{1/3}$
- Roughly constant surface thickness

$\Longrightarrow$ Like a liquid drop!



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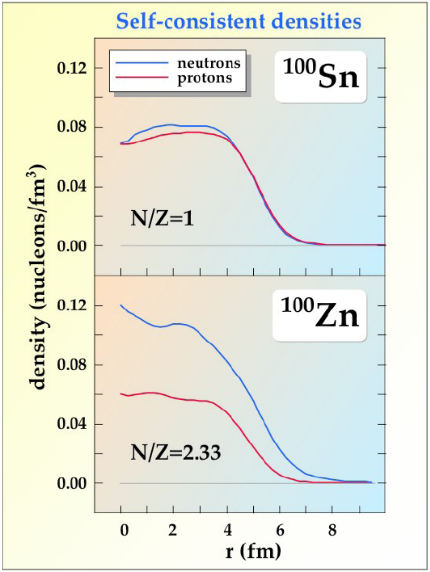
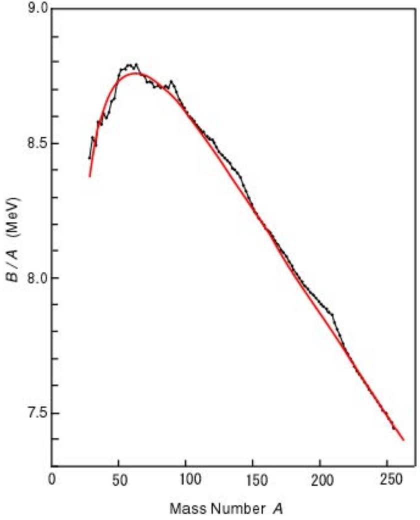


Semi-empirical mass formula $(A = N + Z)$

$$E_B(N,Z) = a_v A - a_s A^{2/3} - a_C \frac{Z^2}{A^{1/3}} - a_{\rm sym} \frac{(N-Z)^2}{A} + \Delta$$

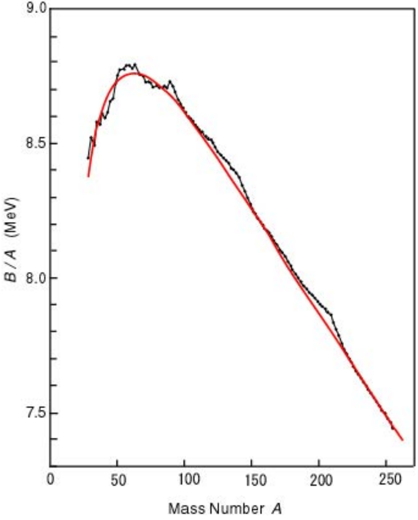
- Many predictions!
- Rough numbers: $a_v \approx 16\,\text{MeV}$, $a_s \approx 18\,\text{MeV}$, $a_C \approx 0.7\,\text{MeV}$, $a_{\rm sym} \approx 28\,\text{MeV}$
- Pairing $\Delta \approx \pm 12/\sqrt{A}\,\text{MeV}$ (even-even/odd-odd) or 0 [or $43/A^{3/4}$ MeV or …]
- Surface symmetry energy: $a_{\rm surf\ sym}(N-Z)^2/A^{4/3}$
- Much more sophisticated mass formulas include shell effects, etc.



Semi-empirical mass formula per nucleon

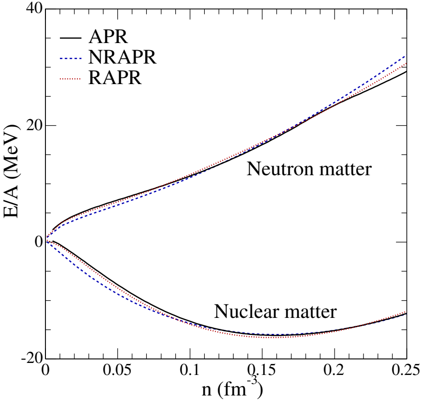
$$\frac{E_B(N,Z)}{A} = a_v - a_s A^{-1/3} - a_C \frac{Z^2}{A^{4/3}} - a_{\rm sym} \frac{(N-Z)^2}{A^2}$$

- Divide terms by $A = N + Z$
- Rough numbers:
  $a_v \approx 16\,$MeV, $a_s \approx 18\,$MeV,
  $a_C \approx 0.7\,$MeV, $a_{\rm sym} \approx 28\,$MeV
- Surface symmetry energy:
  $a_{\rm surf\ sym}(N-Z)^2/A^{7/3}$
- Now take $A \to \infty$ with Coulomb $\to 0$ and fixed N/A, Z/A
- Surface terms negligible



Nuclear and neutron matter energy vs. density

[Akmal et al. calculations shown]



- Uniform with Coulomb turned off
- Density n (or often ρ)
- Fermi momentum $n = (\nu/6\pi^2)k_F^3$
- Neutron matter ($Z = 0$) has positive pressure
- Symmetric nuclear matter ($N = Z = A/2$) saturates
- *Empirical* saturation at about $E/A \approx -16\,\text{MeV}$ and $n \approx 0.17 \pm 0.03\,\text{fm}^{-3}$