Nuclear Statistical Equilibrium based on mean-field nuclear functional: application to Proto-Neutron Stars

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1 NSE

2 Energy of clusters

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NSE vs SNA

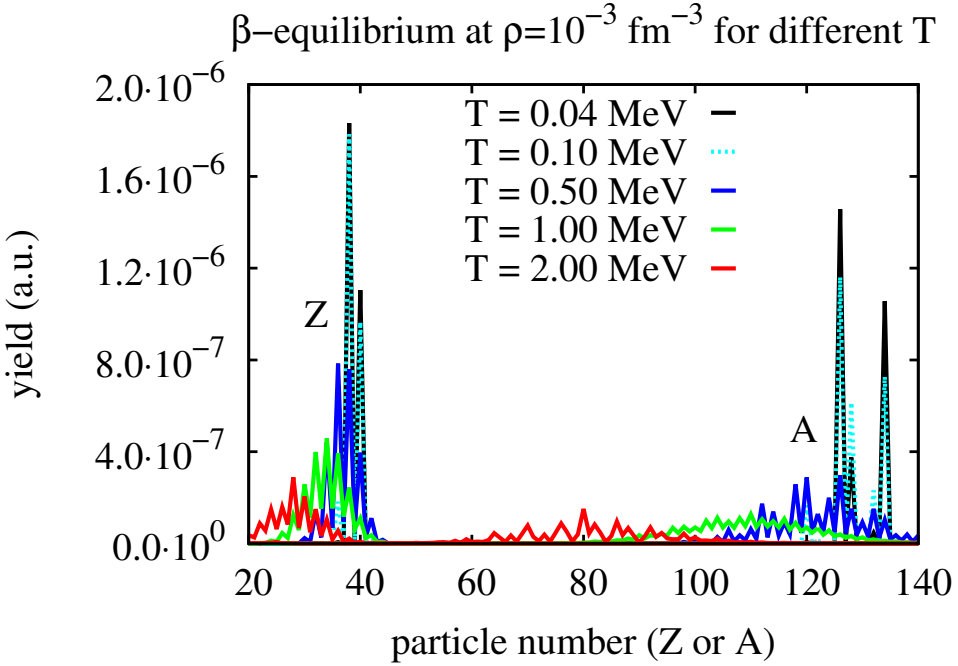
- $T = 0$: $\min[E_{WS}/V_{WS}] \rightarrow$ one single nucleus
- Finite temperature: SNA $\rightarrow \min[F_{WS}/V_{WS}]$

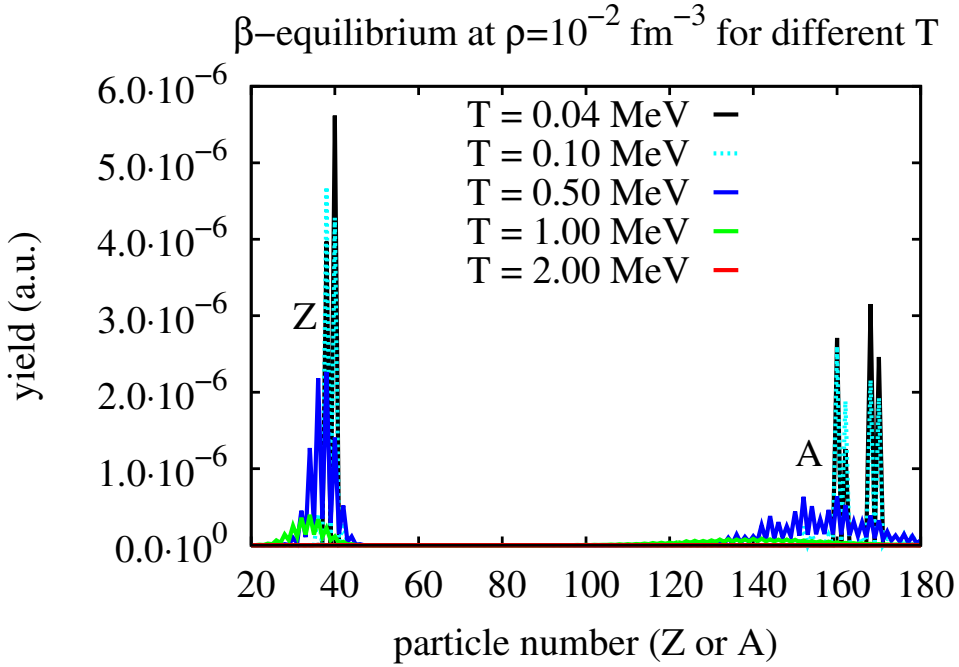
  (*J.M. Lattimer and F. Douglas Swesty*, NPA 535, 331 (1991), *H. Shen et al.*, NPA, 435 (1998))
- Beyond SNA: statistical distribution of WS cells

  $\rightarrow P_{WS} \propto \exp\left[\beta(F_{WS}/V_{WS} - \mu_B\rho_B - \mu_3\rho_3)\right]$

  (*Ad. R. Raduta and F. Gulminelli*, PRC 82, 8065801 (2010), *M. Hempel and J. Schaffner-Bielich*, NPA 837, 210-254 (2010))

Distribution of clusters for PNS





1 NSE

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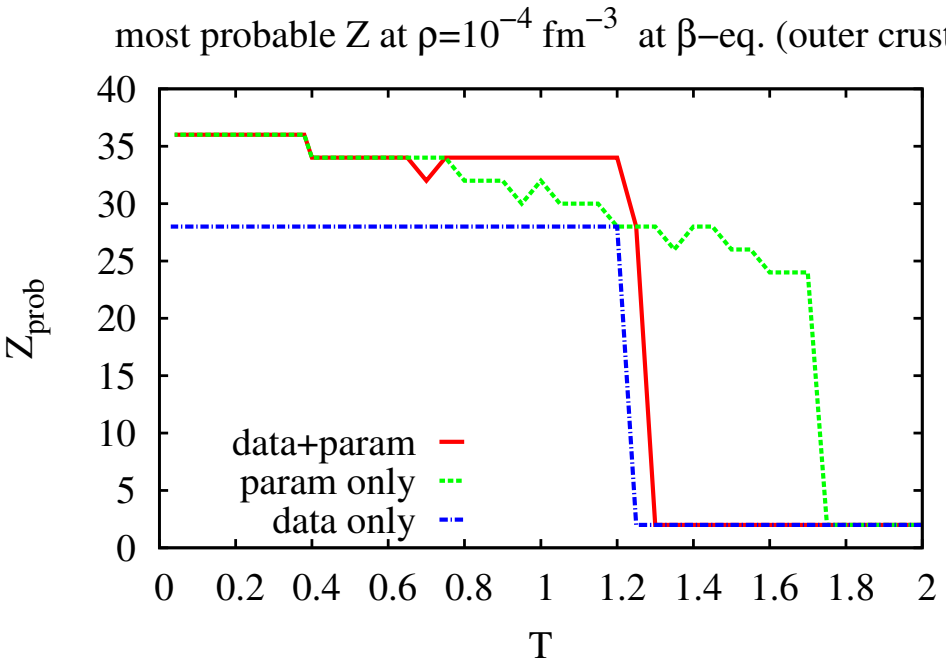
Energy of clusters

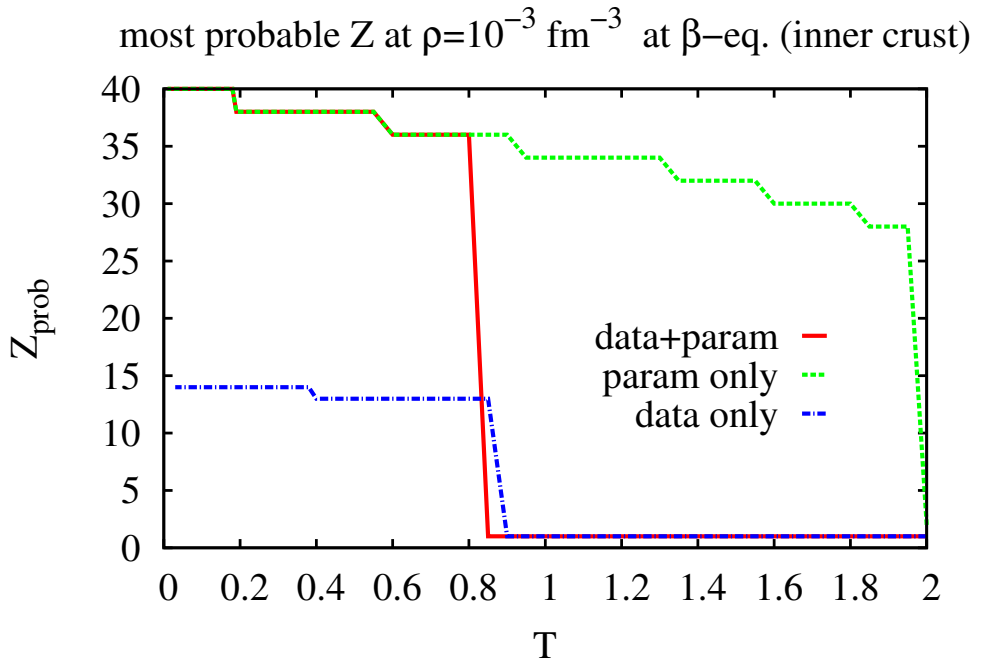
- $P_{WS} \propto \exp\left[\beta(F_{WS}/V_{WS} - \mu_B\rho_B - \mu_3\rho_3)\right]$
- $F_{WS} = E_{WS} - TS_{WS}$
- $E_{WS} = E^{vac}_{nucl}(A,Z) + \mathcal{E}_{gas}(V_{WS} - V_{cl}) + E_{coul} + \delta E_{surf}(A, Z, \rho_{gn}, \rho_{gp})$
  - if the mass data exist: $E^{vac}_{nucl}(A,Z)$ given by the measurement
  - if not: parametrization with coefficients fitted from HF

$$E^{vac}_{nucl}(A,Z) = -a_v A + a_s A^{2/3} + \frac{a^a_v}{1 + a^a_v/(a^a_s A^{1/3})}\frac{(N-Z)^2}{A}$$

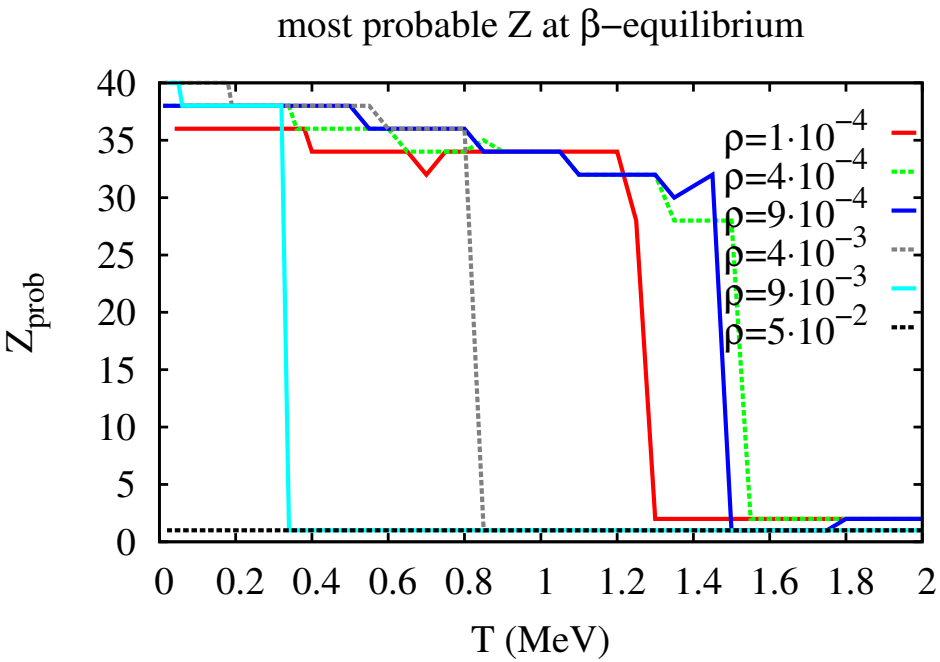
P. Danielewicz and J. Lee, Nucl. Phys. A 818 (2009)

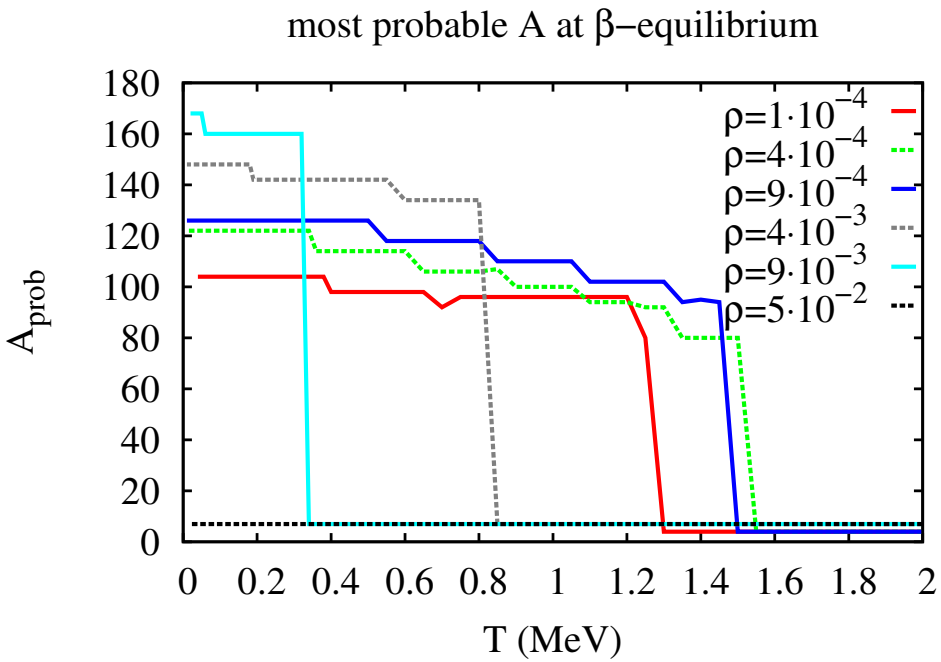
Importance of data AND functional





Evolution of representative clusters





Summary and perspectives

- Nuclear Statistical Equilibrium:
  distribution of clusters, even at very low temperatures
- Vacuum cluster mass:
  - → Experimental mass:
    - Outer part of the outer crust
    - Inner crust at high temperature to allow light clusters (resonances)
  - → Functional:
    - Inner part of the outer crust: beyond the known nuclei
    - Inner crust at low temperature:
      beyond the dripline (unable to experimentally measure)