Top Quarks, Light Gluinos, and Elements of Snuclear Physics

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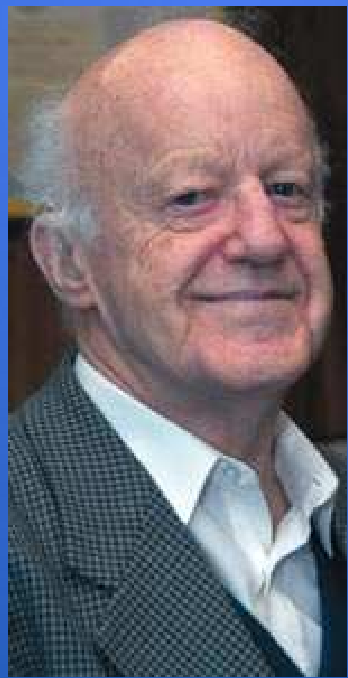
U. of Alabama

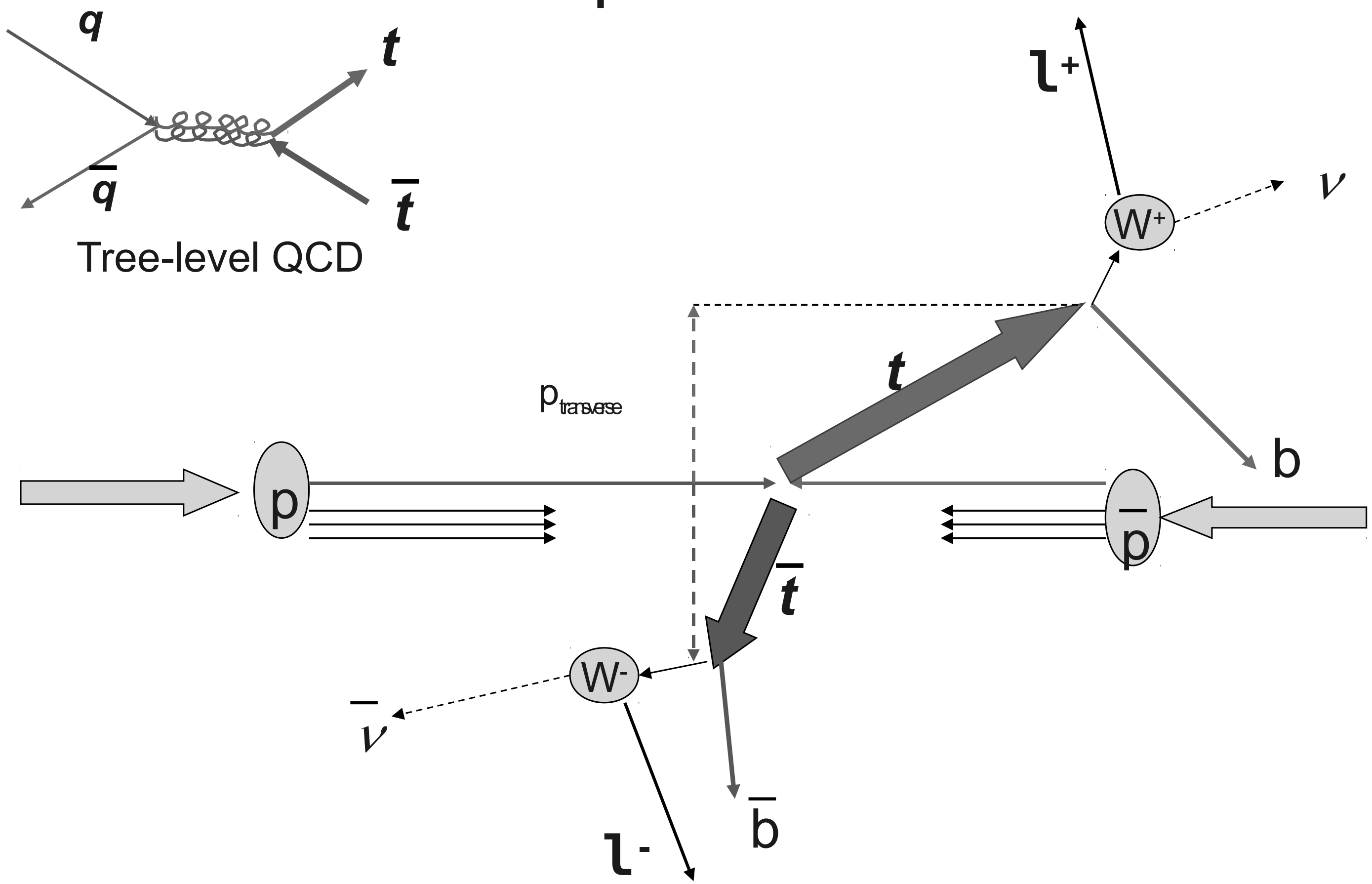
GaryFest, 2010

Second City 1967


Can we make top
quarks at Fermilab?
Yes We Can!



Dilepton events



CDF Top Analysis

double leptonic events:

$$M_t = 162 \pm 21 \pm 7 \text{ GeV}$$

single leptonic events:

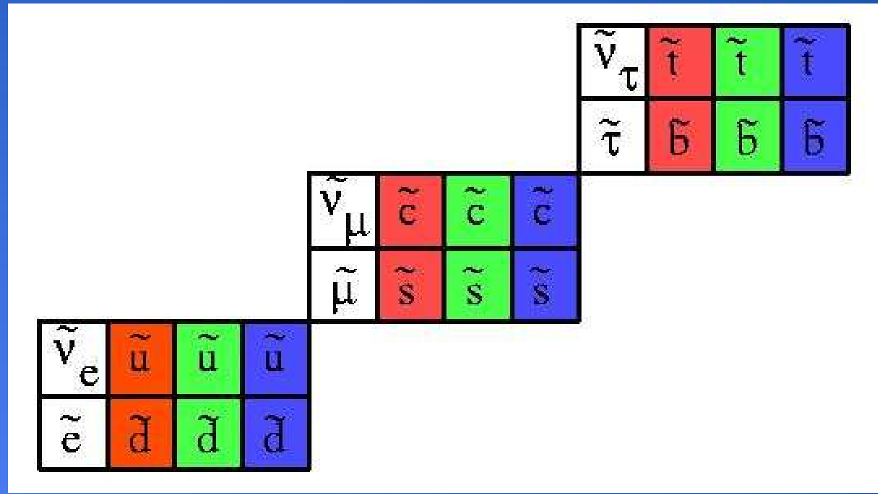
$$M_t = 176 \pm 4.4 \pm 4.8 \text{ GeV}$$

hadronic events: $M_t = 187 \pm 8 \pm 12$ **GeV**

Top Quark Analysis in the Light Gluino Scenario

(LC+GG PR D58, 095012, 1998)

Stop quark slightly above top can lead to the observed pattern.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τ̃ b̃ b̃ b̃
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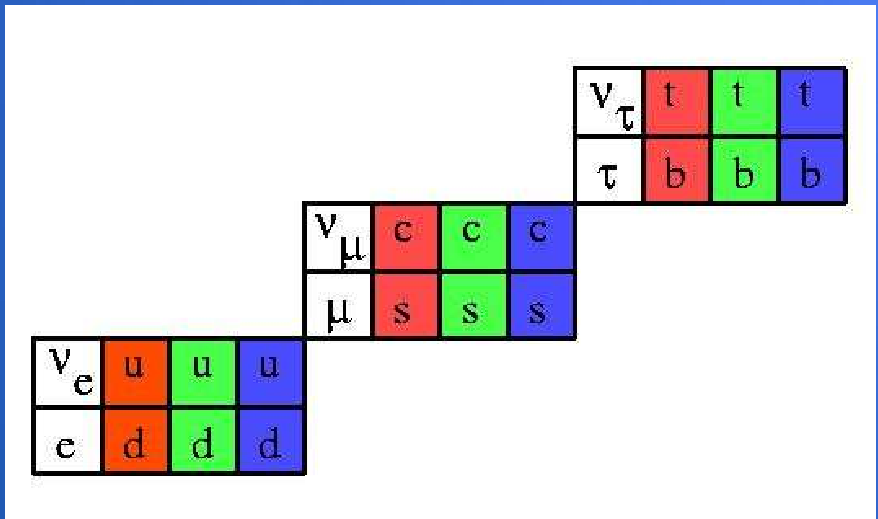
ντ t t t
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νμ c c c
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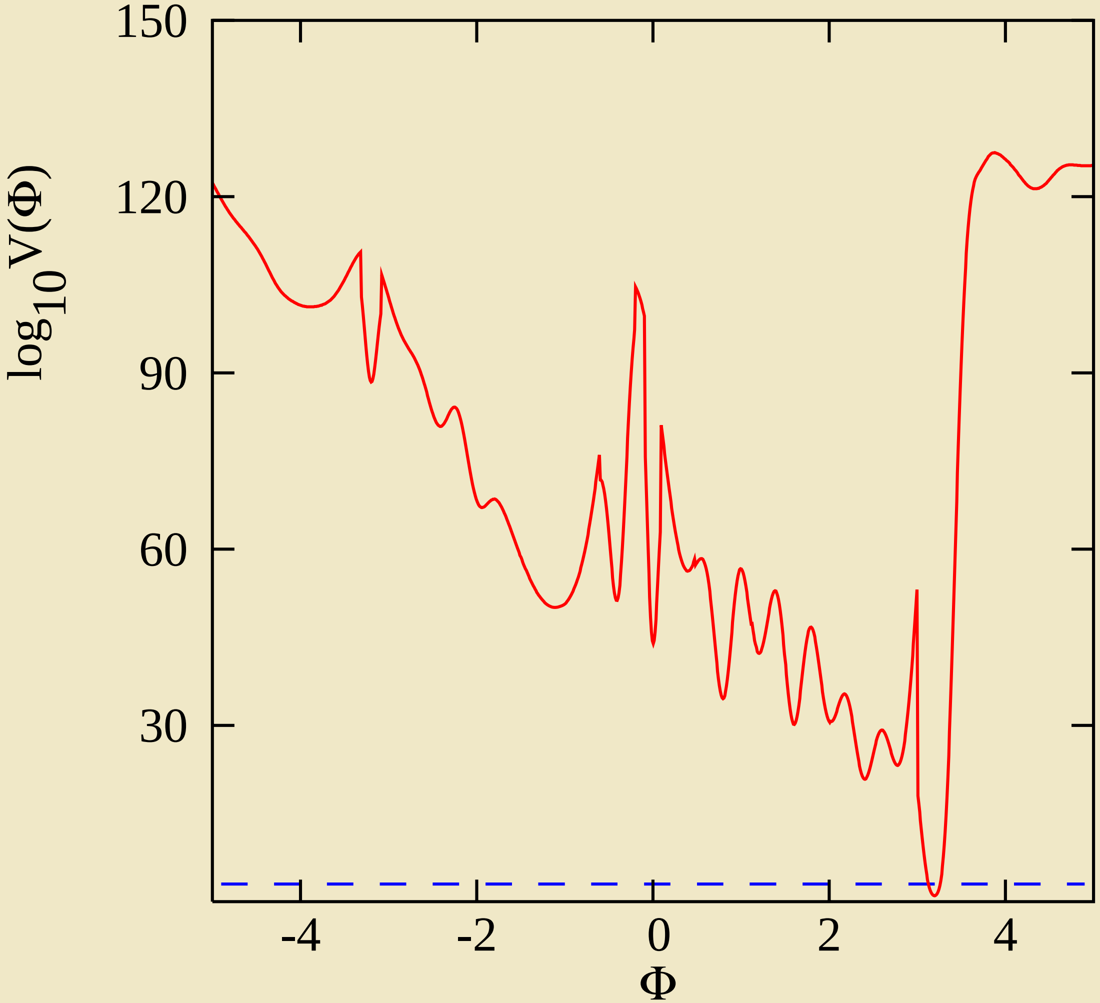
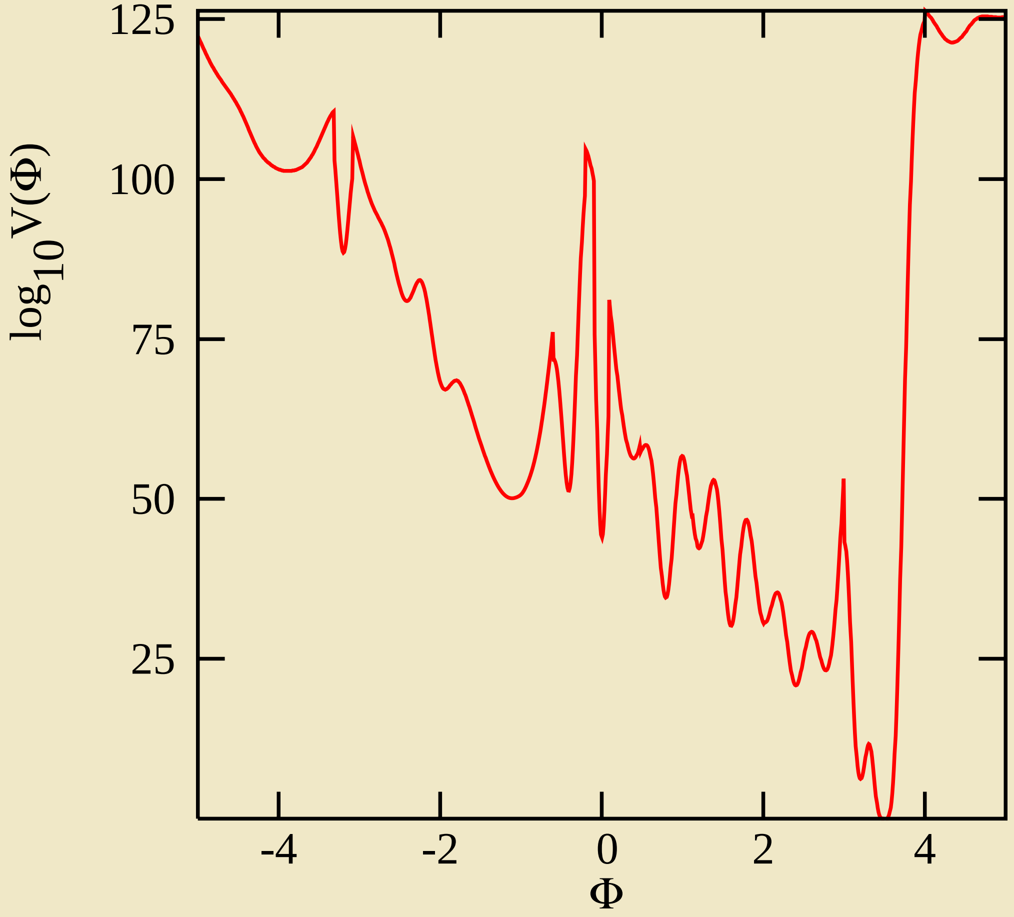
The String Landscape



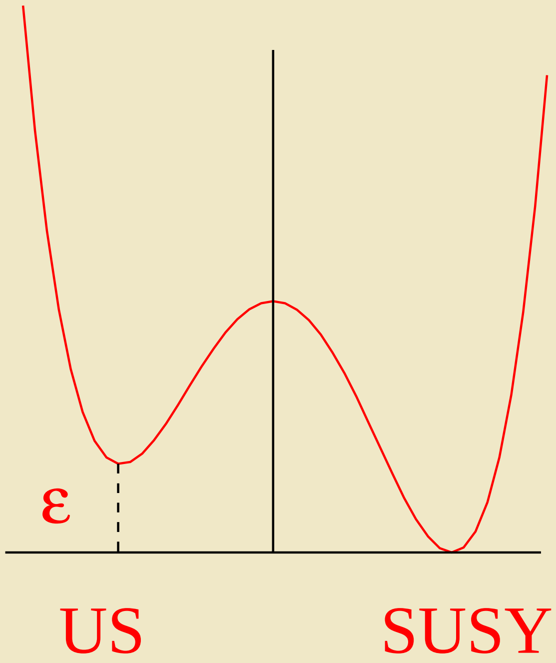
An exact susy ground state in the string landscape?

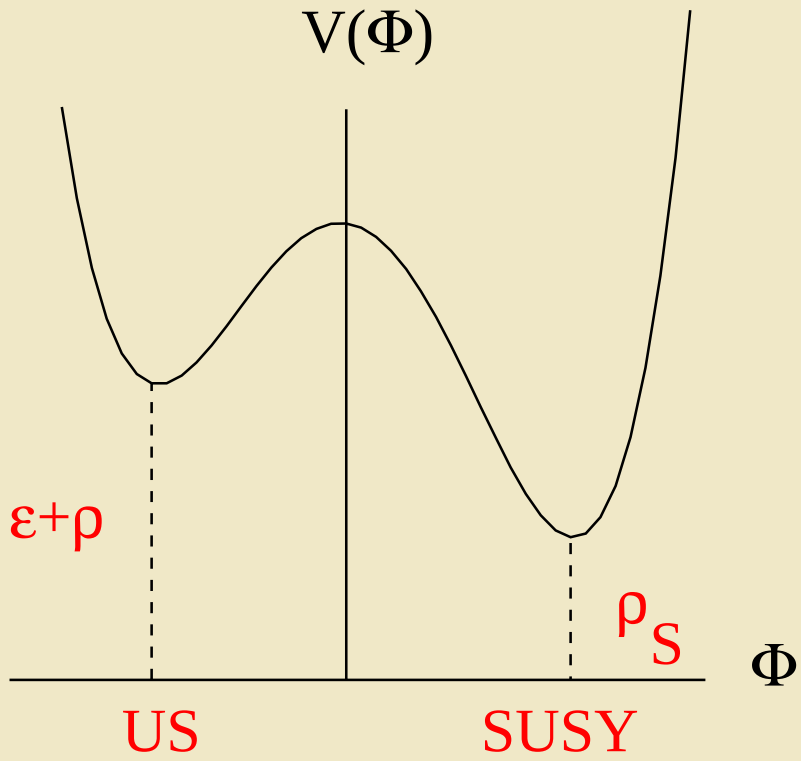


Vacuum Decay

Coleman-DeLuccia

dense matter analog





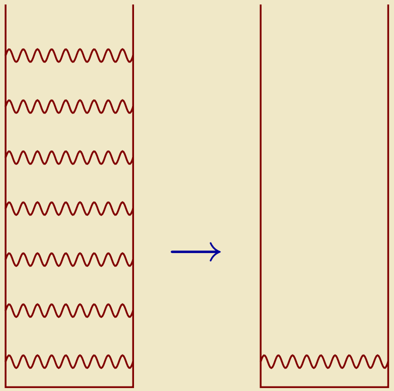
vac energy density ε = 3560 MeV/m^3

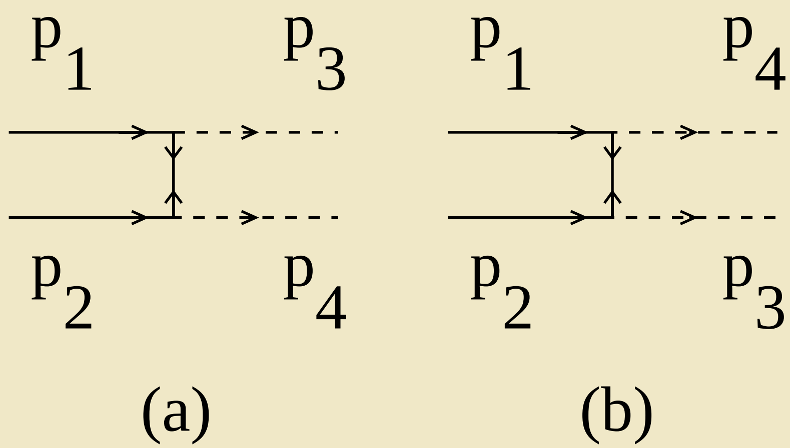
In dense matter $\epsilon \rightarrow \epsilon + \rho - \rho_s = \epsilon + \Delta\rho$

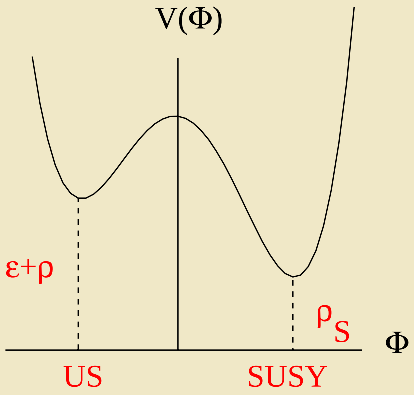
$$\frac{d^2P}{dt d^3r} = A_C \, e^{-\frac{27\pi^2 S^4}{2\,\hbar\, c\, \epsilon^3}} \longrightarrow A_C \, e^{-\frac{27\pi^2 S^4}{2\,\hbar\, c\,(\epsilon + \Delta\rho\, c^2)^3}}$$

Bose-Fermi degeneracy + pair conversion process

$\rightarrow$ significant energy release

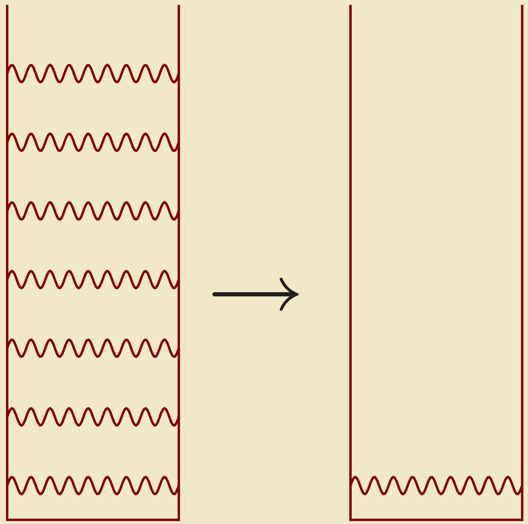






$$f + f \rightarrow \tilde{f} + \tilde{f}$$

Energy release in a transition to exact susy



$$\Delta\rho = \rho\frac{\Delta E}{A\,M_n\,c^2} = \frac{1}{2}\left(\left(\frac{2\,N}{A}\right)^{5/3} + \left(\frac{2\,Z}{A}\right)^{5/3}\right)\frac{3\,(9\pi)^{2/3}}{40}\frac{\hbar\,\rho}{M_n\,c\,R_0} \approx 0.02\rho$$

for comparison, standard hydrogen fusion into Helium: $\Delta\rho = .007\rho$

standard triple alpha process: $\Delta\rho = 5.6 \cdot 10^{-4}\,\rho$

$$
\begin{aligned}
M(Z,A) \; &= \; m_N\, N + m_P\, Z - a_V\, A + a_S\, A^{2/3} + a_C\, \frac{Z^2}{A^{1/3}} \\
&+ \; a_A\, \frac{(N-Z)^2}{A} + \delta\, \frac{\cos(\pi\, Z)\cos^2(\pi\, A/2)}{\sqrt{A}}
\end{aligned}
$$

An excellent fit to hundreds of nuclear masses is defined by the coefficients

$$
\begin{aligned}
a_V &= \; 15.67\, MeV \\
a_S &= \; 17.23\, MeV \\
a_C &= \; 0.714\, MeV \\
a_A &= \; 23.3\, MeV \\
\delta &= \; -11.5\, MeV
\end{aligned}
$$

Assume entire $(N - Z)^2$ term is due to Pauli Principle and therefore absent in a susy world.

Hydrogen	$Z = 1$	$1 < A < 19$
Helium	$Z = 2$	$3 < A < 88$
Lithium	$Z = 3$	$8 < A < 243$
Berylium	$Z = 4$	$21 < A < 518$
Boron	$Z = 5$	$45 < A < 946$
Carbon	$Z = 6$	$82 < A < 1562$
Nitrogen	$Z = 7$	$136 < A < 2400$
Oxygen	$Z = 8$	$209 < A < 3494$
Fluorine	$Z = 9$	$304 < A < 4878$

Atomic weights of the stable isotopes of low-lying elements in the exact susy limit of the MSSM. Elements up to He^4 would have the same masses as in the standard model.

Alternatively, assume there is a non-Pauli related $(N-Z)^2$ term and the Pauli related piece is as given by the Fermi gas model:

$$M(Z,A) = m_N\, N + m_P\, Z - \tilde{a}_V\, A + a_S\, A^{2/3} + a_C\, \frac{Z^2}{A^{1/3}} + \tilde{a}_A\, \frac{(N-Z)^2}{A} + \delta\, \frac{\cos(\pi Z)\cos^2(\pi A/2)}{\sqrt{A}} + E_P \quad .$$

The Pauli energy, E_P, in the Fermi gas model is

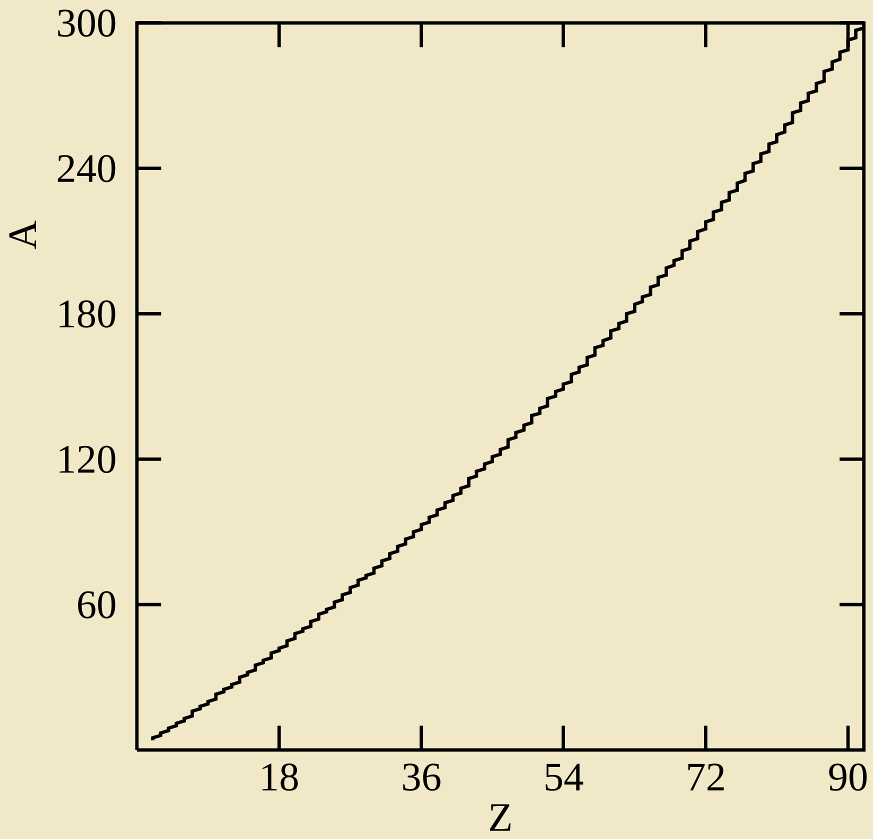
$$E_P = \frac{3\, A\, (\hbar\, c)^2}{80 M_N\, R_0^2}(9\pi)^{2/3}\left[(2Z/A)^{5/3} + (2(A-Z)/A)^{5/3}\right]$$
$$= 20.0 MeV\, \frac{A}{2}\, \left[(2Z/A)^{5/3} + (2(A-Z)/A)^{5/3}\right]$$
$$\approx A \cdot 20.0 MeV + \frac{(Z-N)^2}{A} \cdot 11.5 MeV + \ldots$$

$$\tilde{a}_V = a_V + 20.0\,MeV = 35.6\,MeV$$
$$\tilde{a}_A = a_A - 11.1\,MeV = 12.2\,MeV$$

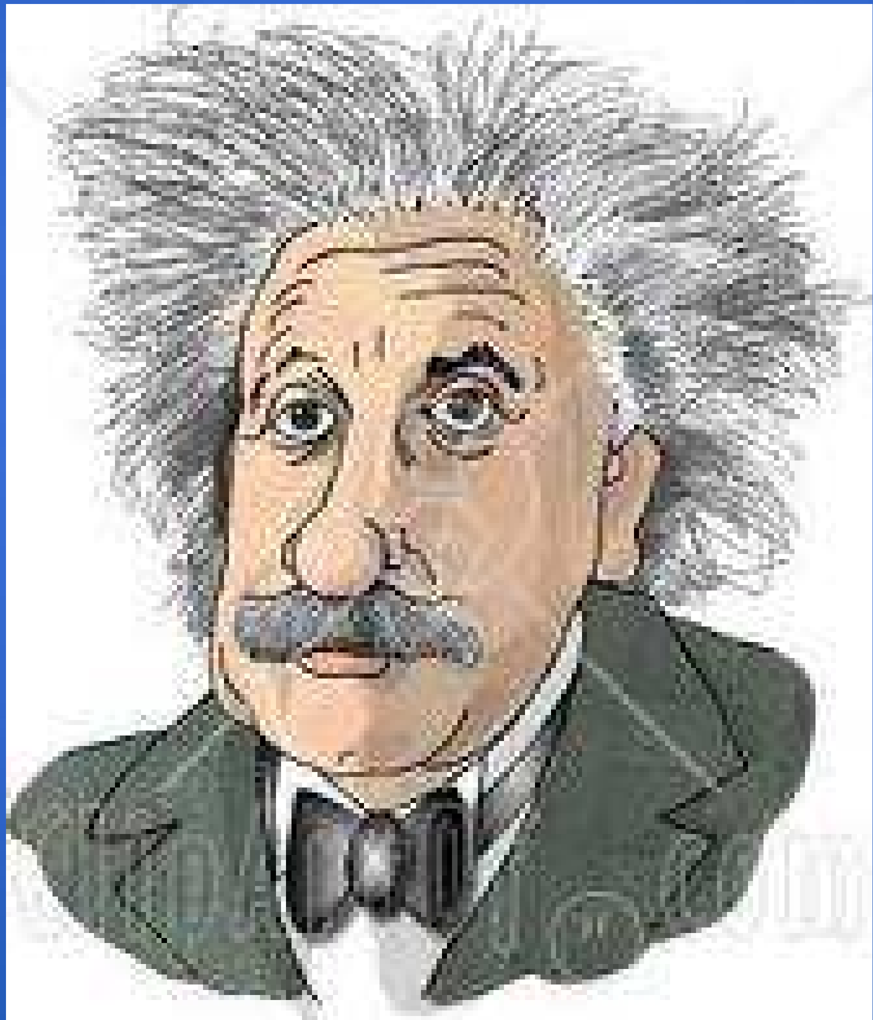
Discarding the δ term above its minimum and the E_P term, the suggested ground state mass for a susy nucleus of atomic number Z and atomic weight A is

$$M_s(Z,A) = m_N\,N + m_P\,Z - \tilde{a}_V\,A + a_S\,A^{2/3} + a_C\,\frac{Z^2}{A^{1/3}} + \tilde{a}_A\,\frac{(N-Z)^2}{A} - \frac{11.5\,MeV}{A^{1/2}} \quad .$$

Stable susy nuclei in the Z, A plane



Happy Birthday, Gary!



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