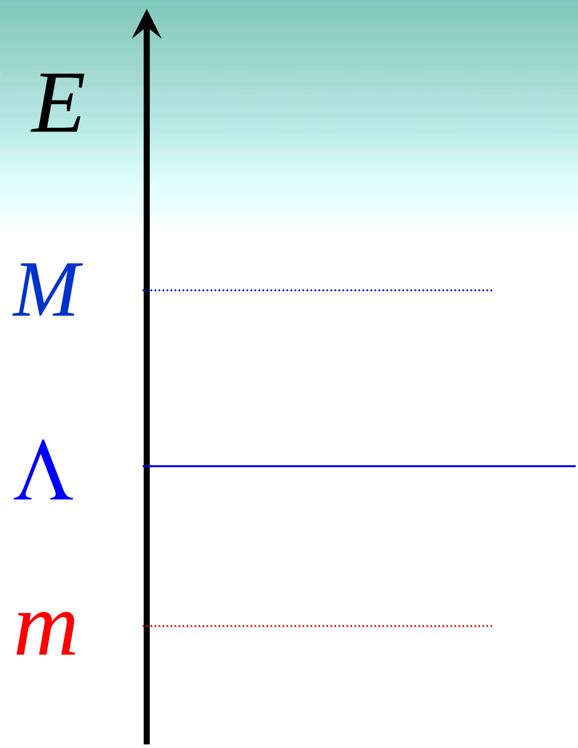
EFT for MBTsts

U. van Kolck
University of Arizona

Supported by US DOE

Weinberg, Wilson, …

EFT



$$Z = \int \mathcal{D}\Phi \, \exp\left(i \int d^4x \, \mathcal{L}_{und}(\Phi)\right)$$

$$\times \int \mathcal{D}\varphi \, \delta\left(\varphi - f_\Lambda(\Phi)\right)$$

$$= \int \mathcal{D}\varphi \, \exp\left(i \int d^4x \, \mathcal{L}_{EFT}(\varphi)\right)$$

$$\mathcal{L}_{EFT} = \sum_{d=0}^{\infty} \sum_{i(d,n)} c_i(M, \Lambda) \, O_i\left((\partial, m)^d \varphi^n\right)$$

most general

underlying dynamics
renormalization-group invariance

local
underlying symmetries

$$\frac{\partial Z}{\partial \Lambda} = 0$$

$$\begin{cases} T = T^{(\infty)}(Q) \sim N(M) \displaystyle\sum_{\nu=\nu_{\min}}^{\infty} \sum_i \tilde{c}_{\nu,i}(\Lambda) \left[\frac{Q}{M}\right]^{\nu} F_{\nu,i}\left(\frac{Q}{m};\frac{\Lambda}{m}\right) \\ \dfrac{\partial T}{\partial \Lambda} = 0 \end{cases}$$

normalization — $N(M)$; non-analytic, from loops — $F_{\nu,i}$

$$\nu = \nu(d, n, \ldots)$$ "power counting"

↳ e.g. # loops *L*

For $Q \sim m$, truncate … … consistently with RG invariance:

$$T = T^{(\bar{\nu})} + \mathrm{O}\left(\frac{Q}{M} T^{(\bar{\nu})}\right)$$

controlled

$$\Lambda \frac{\partial T^{(\bar{\nu})}}{\partial \Lambda} = \mathrm{O}\left(\frac{Q}{\Lambda} T^{(\bar{\nu})}\right)$$

model independent

Nuclear EFTs

Weinberg, vK, ...

Q ↑

QCD — symmetries: Lorentz, ~~B~~, ~~P~~, ~~T~~, chi~~r~~al

~1 GeV — $M_{QCD} \sim m_N, m_\rho, 2\pi F_\pi, \ldots$

pionful (or chiral) EFT — NR nucleons + pions, NR deltas

$$V_{LO} \square C\delta\left(r_i - r_j\right) + OPE_{ij}$$

~150 MeV — $M_{nuc} \sim F_\pi, 1/r_{NN}, m_\pi, \ldots$

pionless (or contact) EFT — NR nucleons

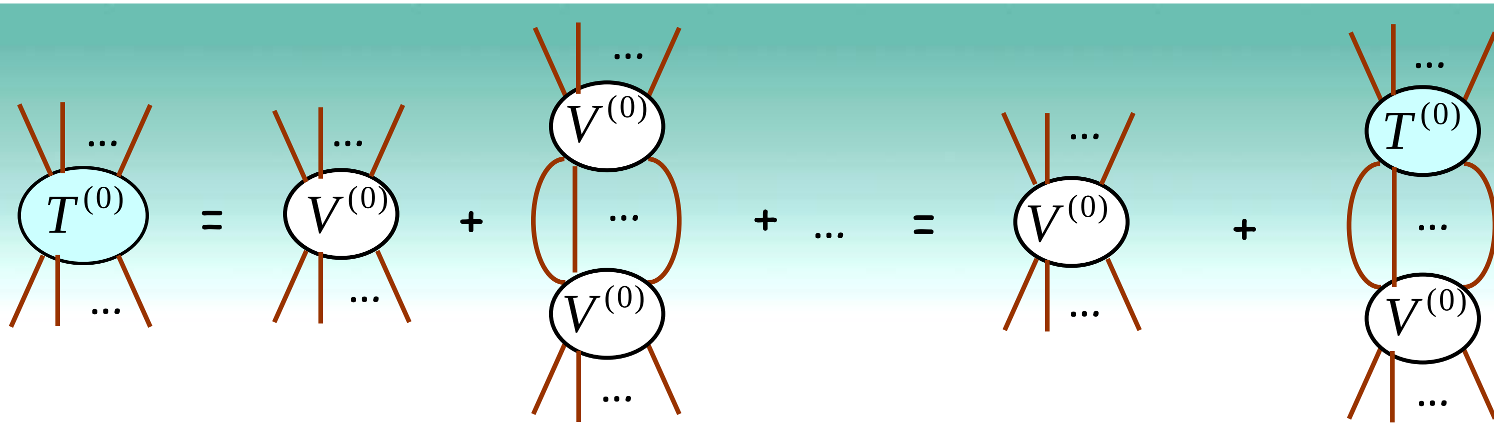
~100 MeV — $M_{cor} \square \sqrt{m_N E_{cor}}$

$$V_{LO} \square C\delta\left(r_i - r_j\right) + D\delta\left(r_i - r_j\right)\delta\left(r_j - r_k\right)$$

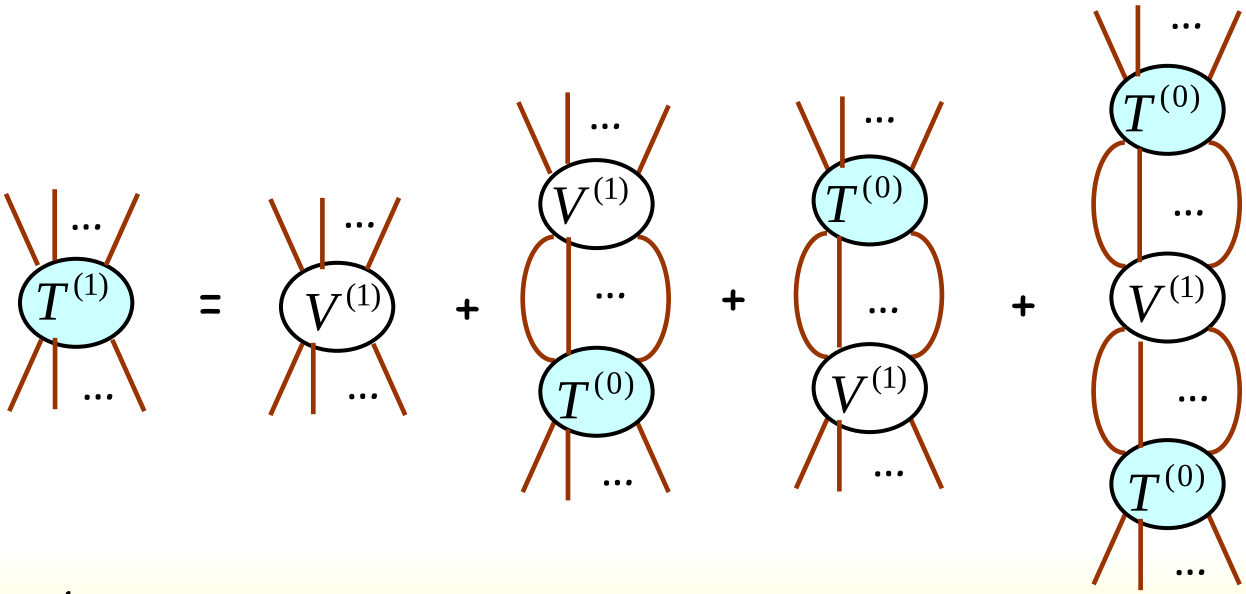
~30 MeV — $\aleph \sim 1/a_{NN}$

halo (or cluster) EFT — NR nucleons + clusters

$$V_{LO} \square \frac{1}{a + bE_{ij}^2}\delta\left(r_i - r_j\right) + ?$$



$$\left(T+V^{(0)}\right)\left|\psi^{(0)}\right\rangle = E^{(0)}\left|\psi^{(0)}\right\rangle$$



$$E^{(1)} = \left\langle\psi^{(0)}\right|V^{(1)}\left|\psi^{(0)}\right\rangle$$

smaller

etc.

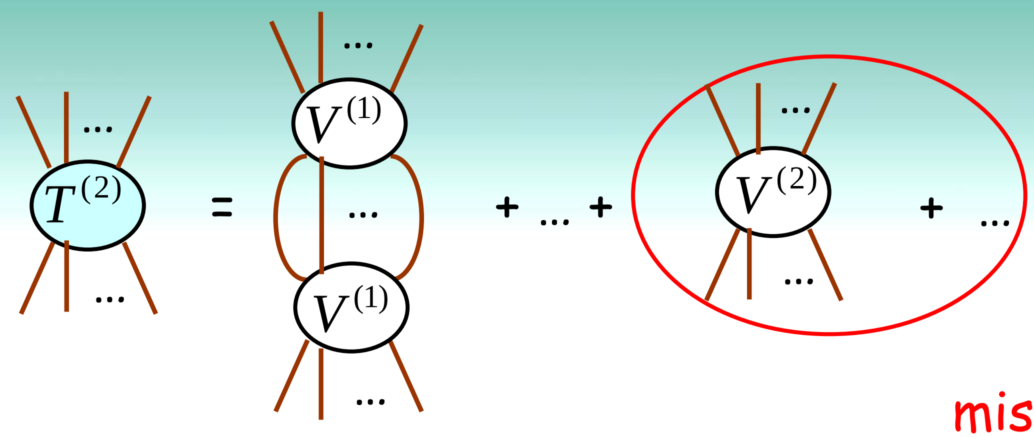
RG

delta functions smeared by regulator

(non-local)

AN forces tied to
{ 2N force
regulator

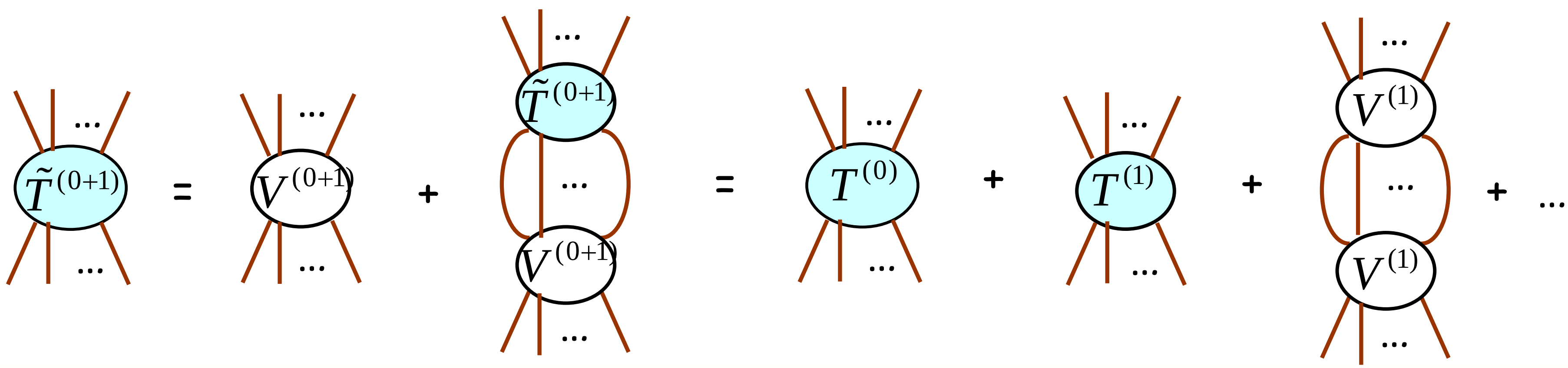
(similar for currents)



$$E^{(2)} = \sum_n \frac{\langle \psi^{(0)} | V^{(1)} | \psi_n^{(0)} \rangle \langle \psi_n^{(0)} | V^{(1)} | \psi^{(0)} \rangle}{E^{(0)} - E_n^{(0)}} + \langle \psi^{(0)} | V^{(2)} | \psi^{(0)} \rangle$$

missed

sum even smaller



$$\Rightarrow \quad T = \tilde{T}^{(\bar{\nu})} + O\left(f\left(\frac{\Lambda}{M}\right) \tilde{T}^{(\bar{\nu})} \right) \qquad \Lambda \frac{\partial \tilde{T}^{(\bar{\nu})}}{\partial \Lambda} = O\left(\tilde{T}^{(\bar{\nu})}\right)$$

uncontrolled

model dependent

How can we do MBT with EFT?

- Where in A does the pionless EFT break down?
  After that, we need the pionful EFT.

- Where in A do exact MBTs run out of gas?
  After that, does another (cluster?) EFT applies?

$QCD \neq QED$

nuclear physics ≠ chemistry

"And so my fellow theorists:
ask not what EFT can do for you,
ask what you can do for EFT."