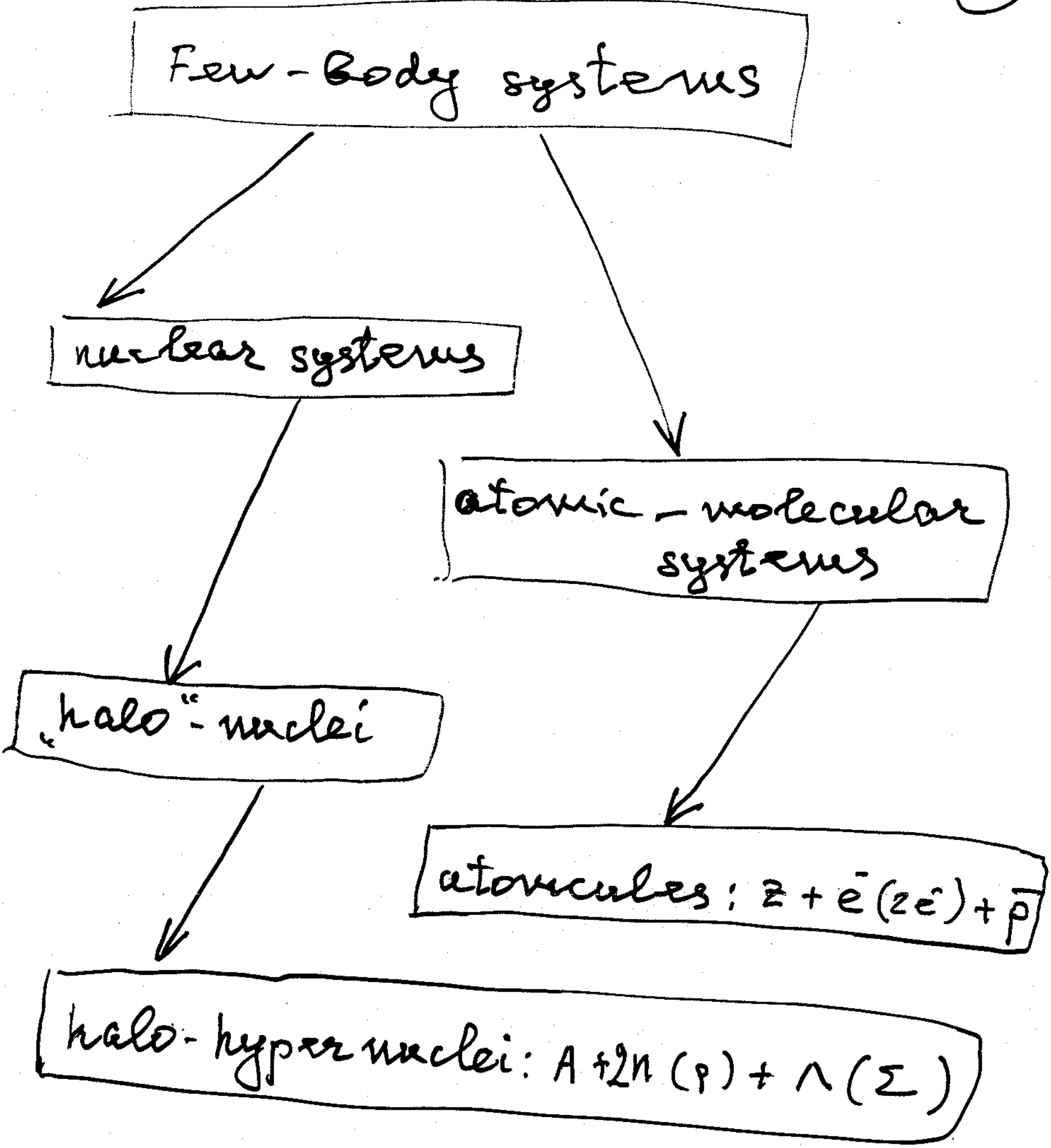
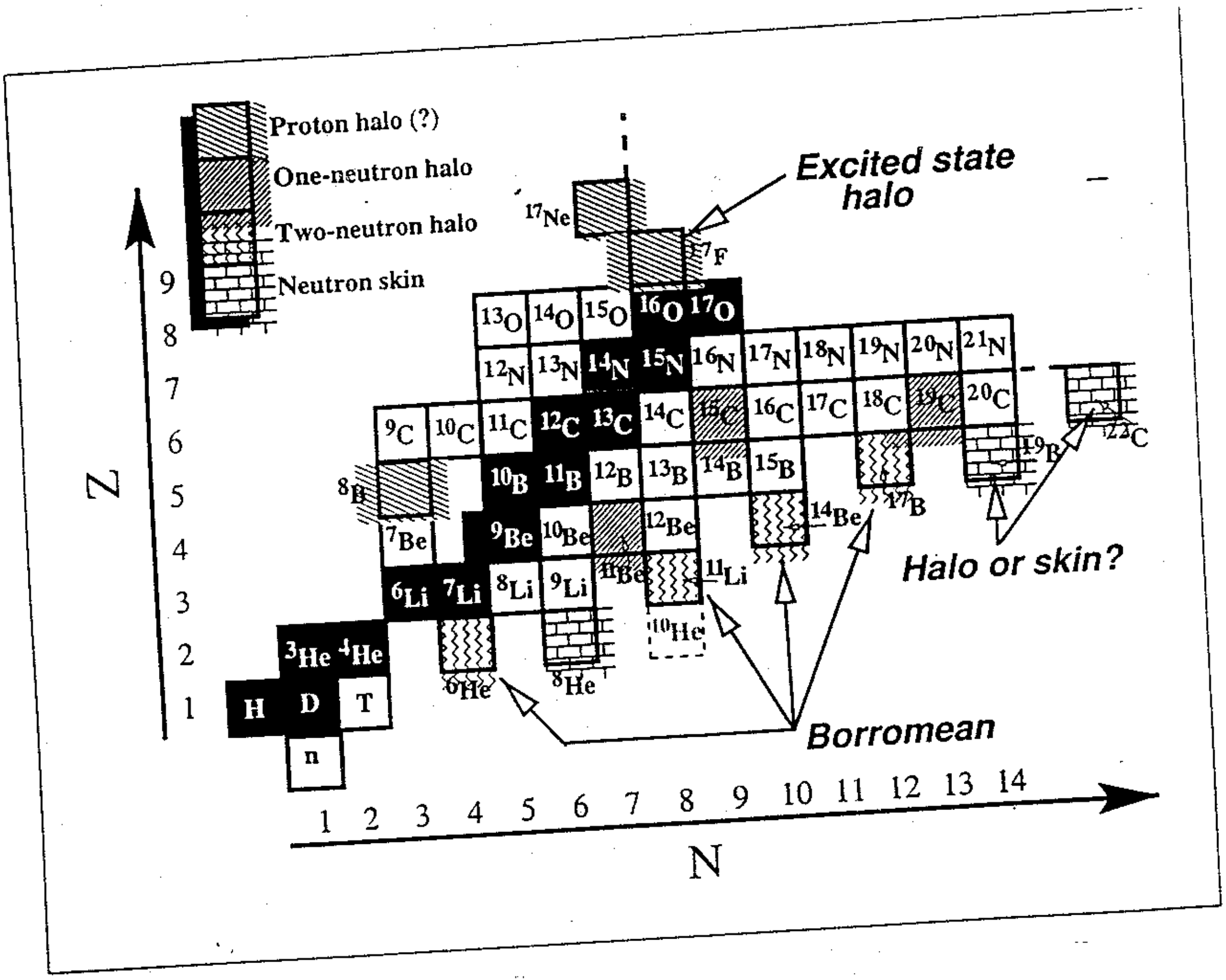
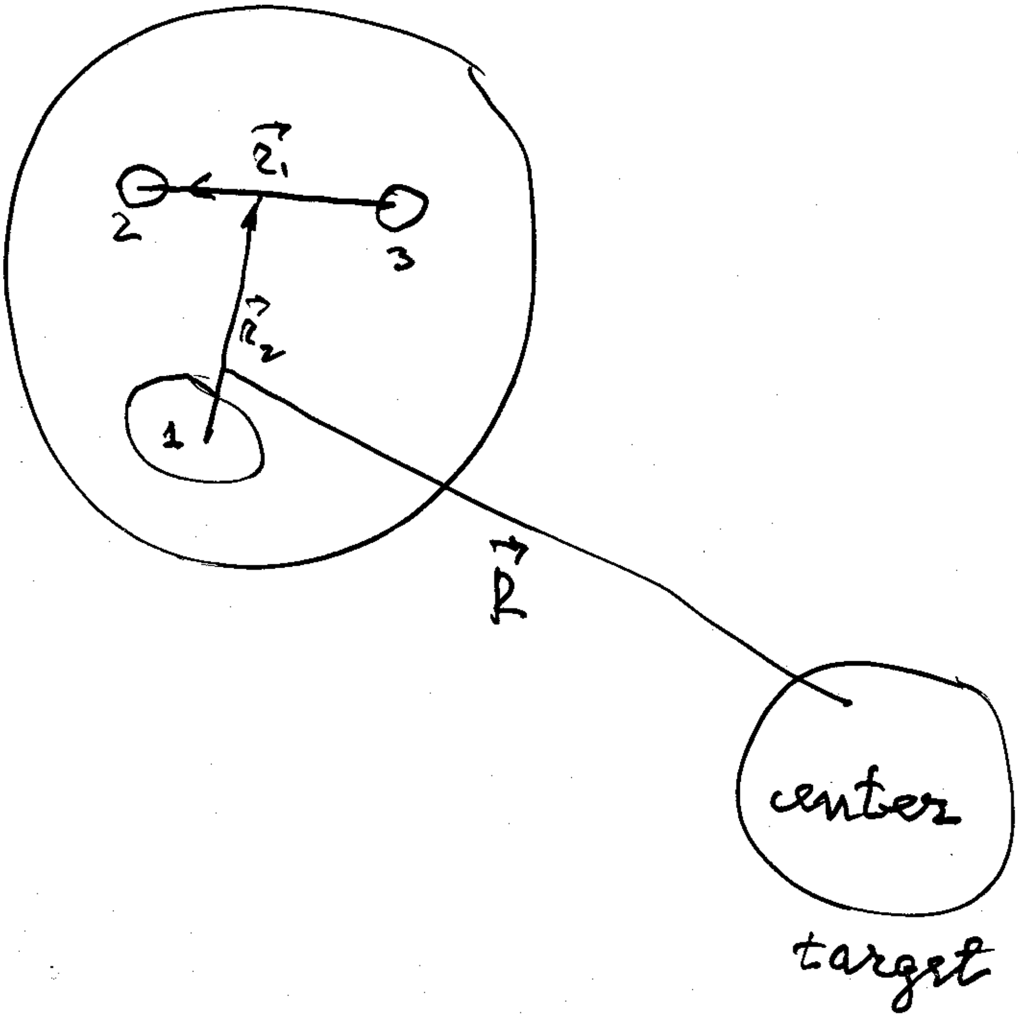

Few-Body systems
nuclear systems
atomic-molecular systems
„halo"-nuclei
atomcules: z + e⁻(2e⁻) + p̄
halo-hypernuclei: A+2n (p) + Λ(Σ)

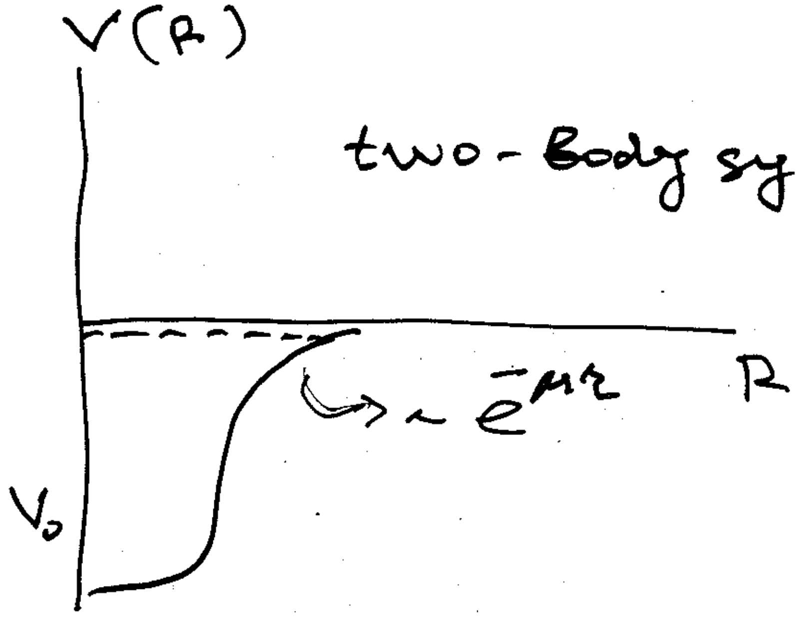


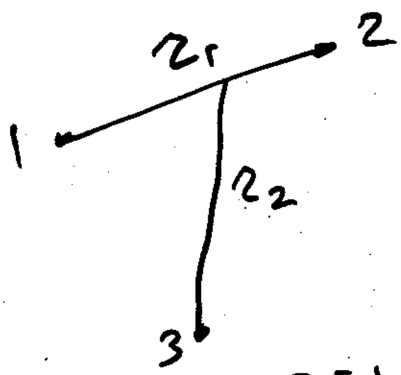
Proton halo (?)
One-neutron halo
Two-neutron halo
Neutron skin
Excited state halo
Halo or skin?
Borromean
Z
N

3-body projectile (cluster)

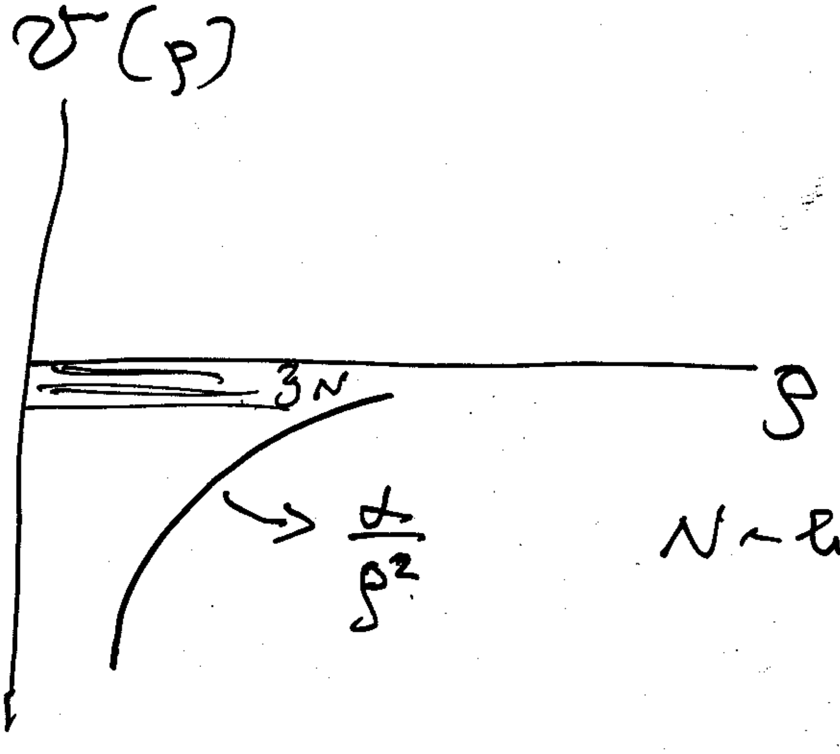


Efimov systems.





$$\rho = \sqrt{r_1^2 + r_2^2}$$



$$N \sim \ln \frac{|a|}{r_0}$$

Peculiarities of halo-systems

1. Short range interaction and long tail in w.f.: $\bar{r} \sim 5-6$ fm
   $\bar{r}_d \sim 3.8$ fm
   (Probaly not Efimov-type systems)
2. Weak Binding and few-Body nature:
   $^6He \Rightarrow \alpha + n + n$
3. Strong infl**u**ence of continuum
4. Strong recoil effects in the reactions due to few-cluster structure

Physics to be extracted: exotic substructures like:

$N_1 n + N_2 p$

$N_1 n + N_2 p + \Lambda(\Sigma)$

core

New generation of facilities:

ISOL, SPIRAL-GANIL,
REX-ISOLDE, ISAC-TRIUMF,
HRIBF (Oak-Ridge)

How to study halo-nuclei?

1. Total crossection
→ vialation of scaling
$\sqrt{\langle r^2 \rangle} \not\sim A^{1/3}$

2. Elastic + inelasting scattering,
example: ${}^{6}He + {}^{12}C$

3. Breakup processes,
example: ${}^{7}Be + {}^{208}Pb \to \alpha + {}^{3}He + {}^{208}Pb$

4. Knockout reactions:
(core + n) + target → core + n + target
projectile
example: ${}^{9}Be({}^{12}Be, {}^{11}Be){}^{8}Be\,n$

5. Transfer reactions (recent history)

$$A(X,Y)B$$

$$A = B + v$$

$$Y = X + v$$

6. Fusion,

$$^{11}Li + ^{208}Pb$$

$$^{11}B + ^{12}C$$

7. Charge exchange and photonuclear reactions,

examples:

$$^{6}Li(n,p)^{6}He$$

$$^{14}Be(n,p)^{14}B$$

$$^{6}Li(t,^{3}He)^{6}He$$

$$\gamma(\pi^{\pm}) \rightarrow {}^{6}Li(\gamma,\pi^{+})^{6}He$$

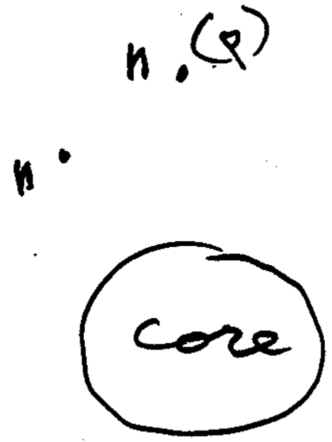
$$^{17}O(\gamma,\pi^{-})^{17}F(\tfrac{1}{2}^{+}, 0.495)$$

Nonmesonic decay hypernuclei
(due to transition $\Lambda N \to nN$)

$$\Gamma_n/\Gamma_p \equiv \Gamma(\Lambda n \to nn)/\Gamma(\Lambda p \to np) \quad \text{in } {}^5_\Lambda He,\ {}^{12}_\Lambda C$$

3-body weak transitions:

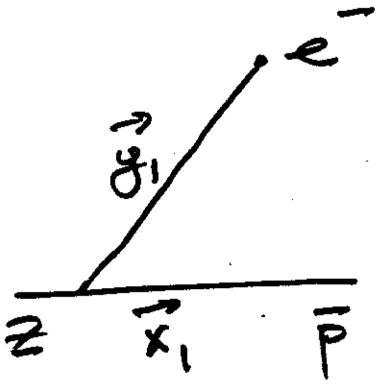
$$\Lambda n p \to n n p$$



Atomcules, peculiarity.

$Z + e^- (2e^-) + \bar{p}$ for $Z=2$, $\tau \sim 10^{-6}$ sec.

Coulomb-Fourier transformation



$$H = -\Delta_{\vec{x}} - \Delta_{\vec{y}} + \frac{n_1}{x_1} + \frac{n_2}{x_2} + \frac{n_3}{x_3}$$

$$H(\vec{p}, \vec{p}') \equiv \langle \varphi^0_{p_1} \varphi^c_{k_1} | H | \varphi^0_{p_1'} \varphi^c_{k_1'} \rangle \Rightarrow$$

where

$$\varphi^0_{\vec{p}_1}(y_1) = \frac{1}{(2\pi)^{3/2}} e^{i \vec{p}_1 \vec{y}_1}$$

$$\varphi^c_{\vec{k}_1}(x_1) = \frac{1}{(2\pi)^{3/2}} e^{i \vec{k}_1 \vec{x}_1} e^{-\pi \gamma_1 /2} \Gamma(1 + i\gamma_1).$$

$$\Phi(-i\gamma_1, 1, i k_1 \xi_1)$$

$\gamma_1 = n_1/2k_1$ - Sommerfeld parameter

$\xi_1 = x_1 - (\vec{x}_1 \cdot \vec{k}_1)$

$$\Longrightarrow (\kappa_1^2 + p_1^2)\,\delta(\bar{\kappa}_1 - \bar{\kappa}_1')\,\delta(\bar{p}_1 - \bar{p}_1') + W_2(\bar{p}, \bar{p}') + W_3(\bar{p}, \bar{p}')$$

$$W_j(\bar{p}, \bar{p}') \approx \frac{n_j}{|\bar{p} - \bar{p}'|^2}\, \mathcal{L}_j(\bar{p}, \bar{p}')$$

$$\mathcal{L}_j(\bar{p}, \bar{p}') = \lim_{\lambda \to +0} \int d\bar{x}_1\, e^{i \bar{\varepsilon}_j \vec{x}_1 (\bar{p} - \bar{p}') - \lambda x_1}\, \psi^{c*}_{\bar{\kappa}_1}(\vec{x}_1)\, \psi^{c}_{\bar{\kappa}_1'}(\bar{x}_1)$$