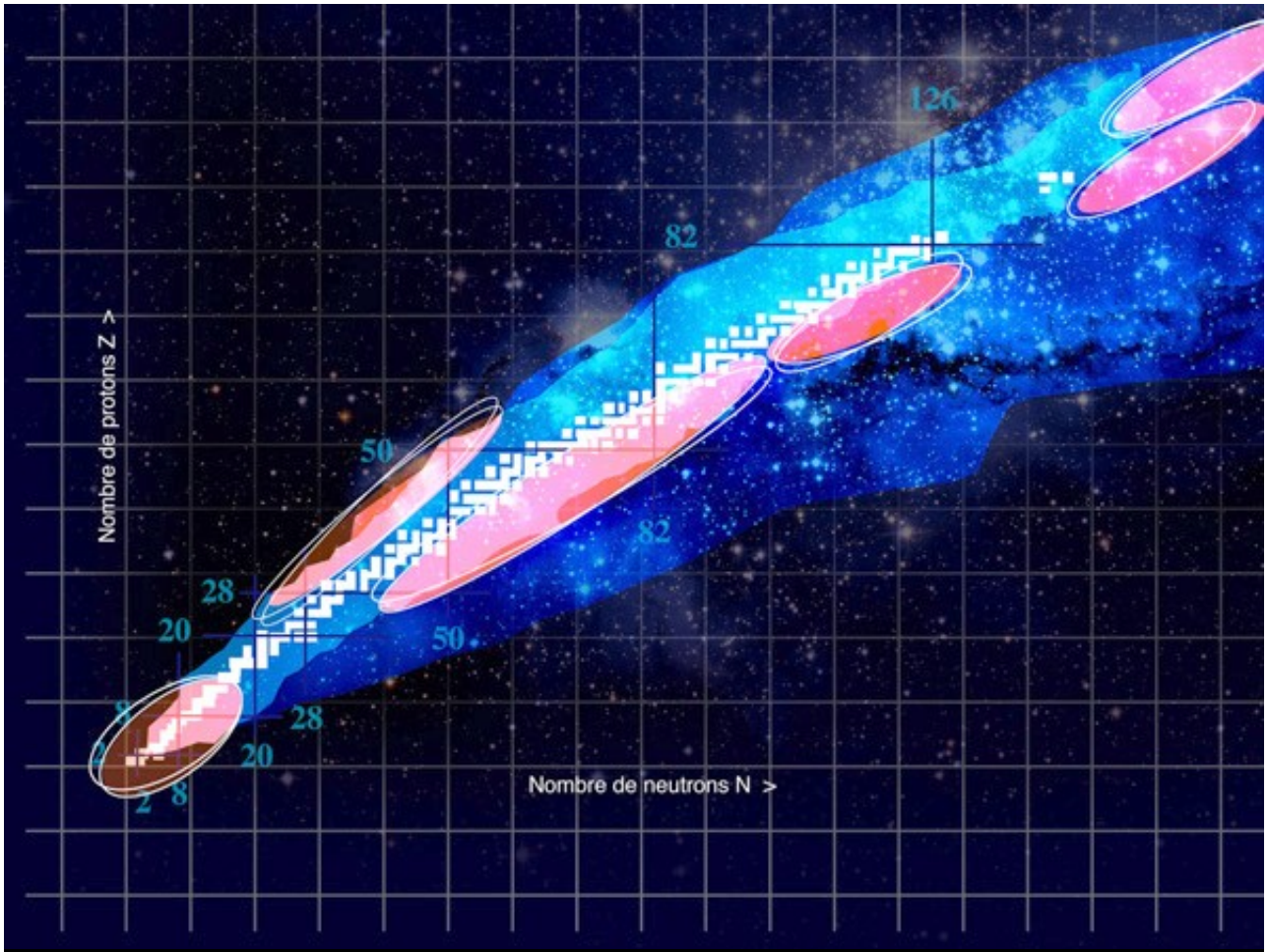
terra incognita



291 i nuclei esistenti sulla Terra

2000 nuclei prodotti in laboratorio

5000-7000 nuclei previsti dalla teoria

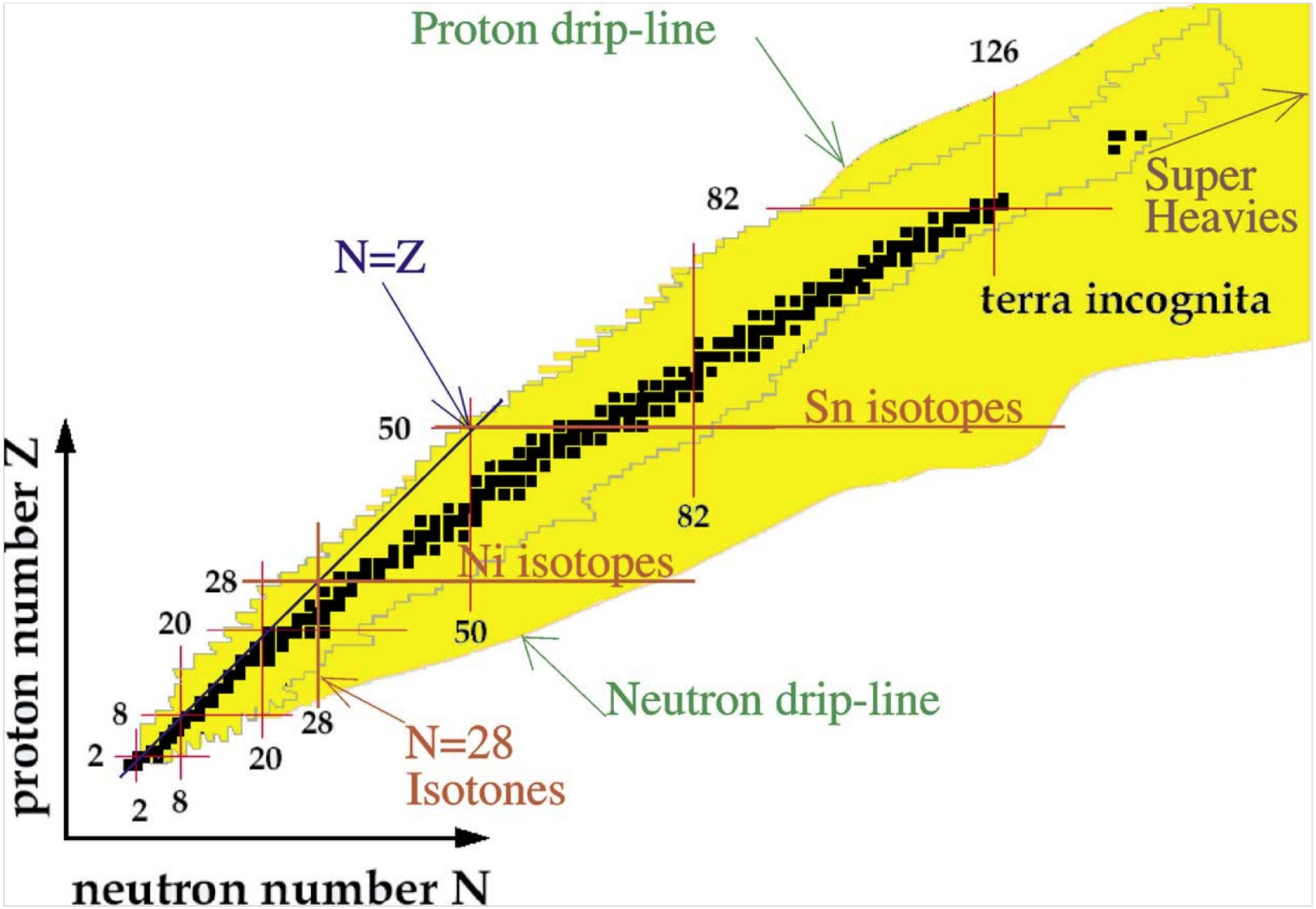


Fig. 1. Chart of nuclei showing in green the ridge of the approximately 250 stable nuclei on the island of several thousand of nuclei bound by the strong interaction but radioactive (yellow area) which constitute a real Terra Incognita since only a few percent of them have been observed up to now (thin line).

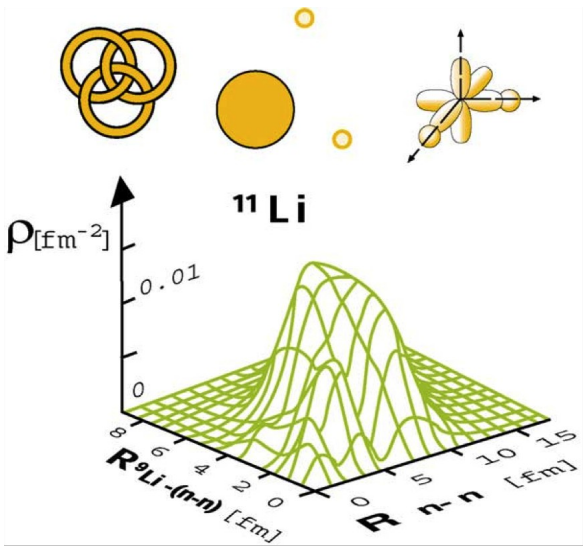


Fig. 11. Predicted probability for a certain distance between ^{9}Li and the neutron pair and the distance between the two neutrons. The peak corresponds to a structure, which resembles to a water molecule (see top). The drawing on the left is the symbols of the Borromee family (adapted from [42]).

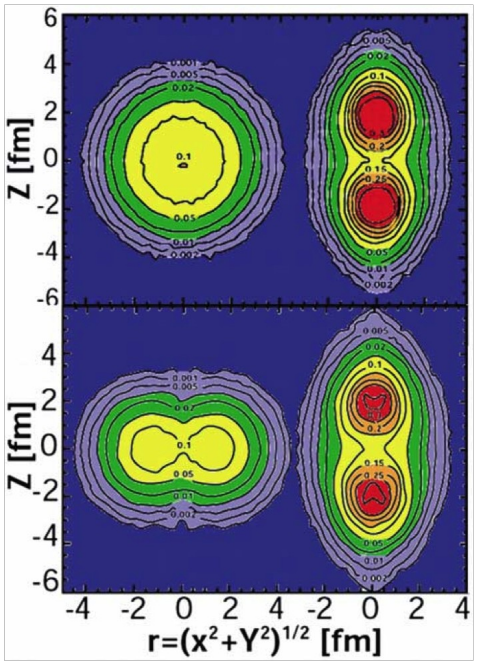


Fig. 12. Ab initio quantum calculations using Monte Carlo techniques of the density contours of 8Be first $0+$ (top) and $4+$ (bottom). The left part is in the laboratory frame while the right part corresponds to the intrinsic frame (adapted from [45]).

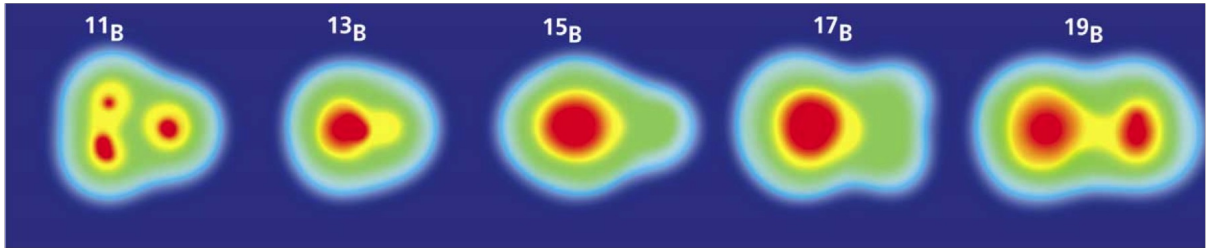


Fig. 13. Anti-symmetrized molecular dynamics calculation of the ground state of light nuclei showing a strongly clustered system (adapted from [41]).

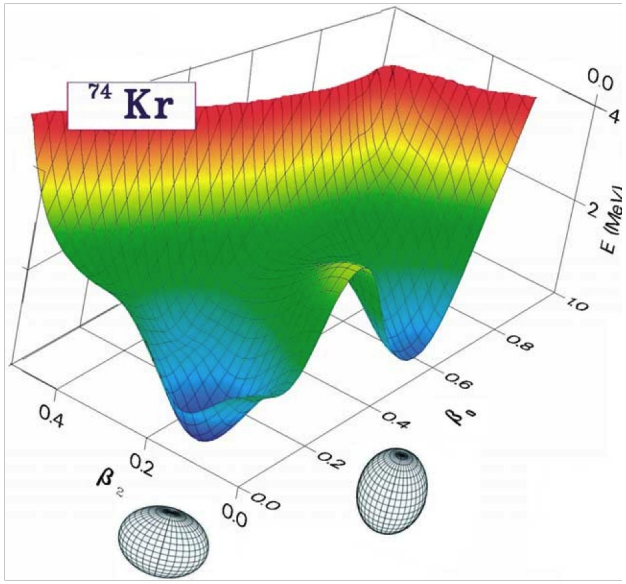


Fig. 14. Hartree–Fock–Bogoliubov calculation of the energy of a ^{74}Kr nucleus as a function of its deformation. The two deep minima correspond to two isomeric states with different shapes (shown below) (adapted from [28]).

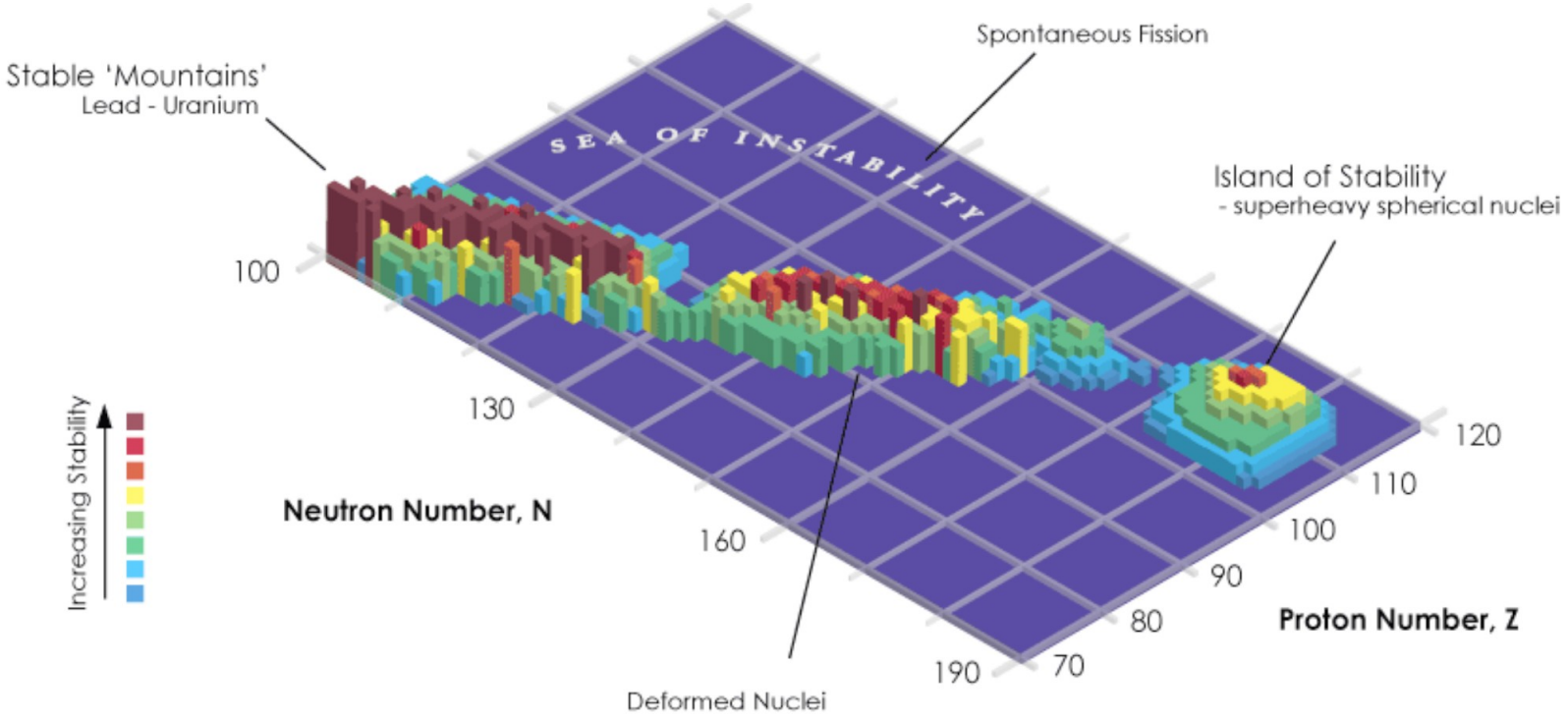
Gruppo	1	2	3		4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Periodo																			
1	1 H																		2 He
2	3 Li	4 Be												5 B	6 C	7 N	8 O	9 F	10 Ne
3	11 Na	12 Mg												13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
4	19 K	20 Ca	21 Sc		22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
5	37 Rb	38 Sr	39 Y		40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
6	55 Cs	56 Ba	57 La	*	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
7	87 Fr	88 Ra	89 Ac	**	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg	112 Cn	113 Uut	114 Uuq	115 Uup	116 Uuh	117 Uus	118 Uuo

* **Lantanoidi**	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu
** **Attinoidi**	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr

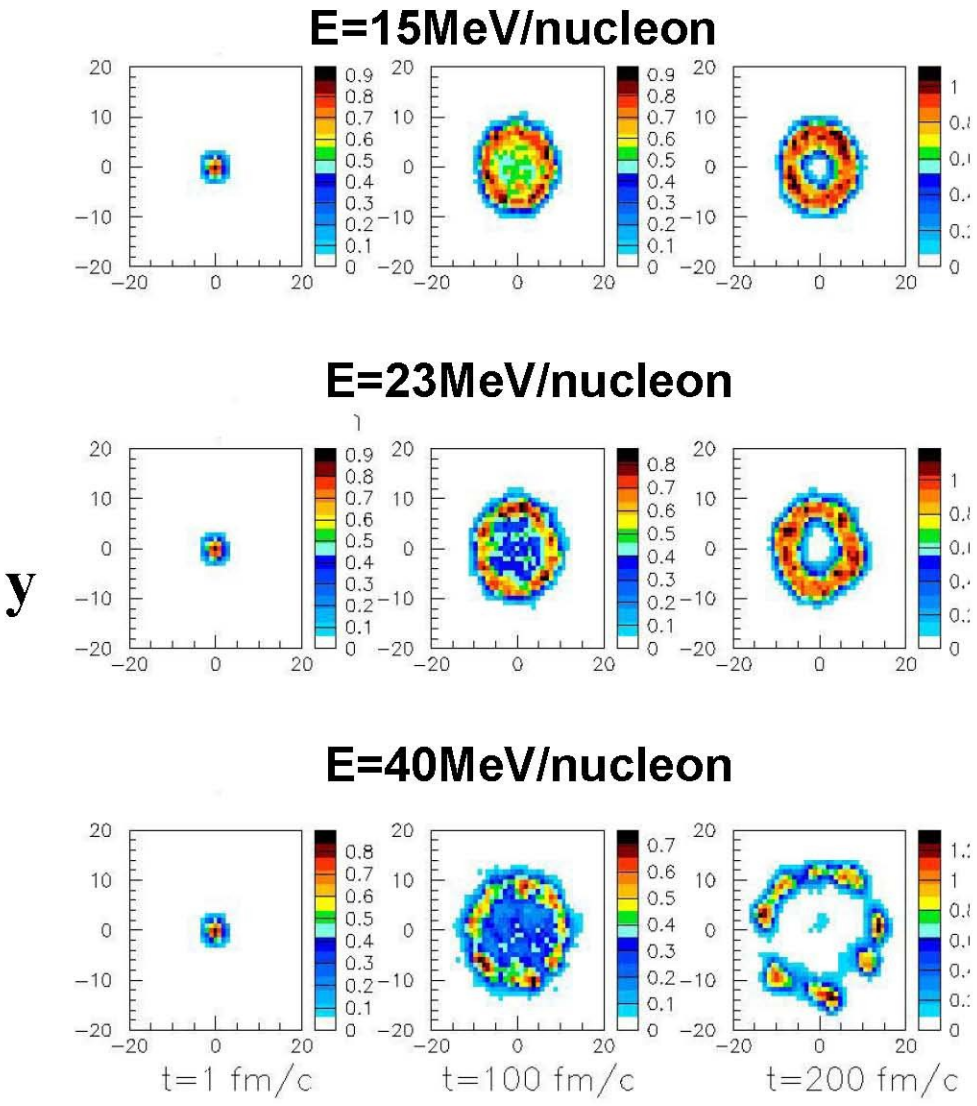
Serie chimiche della tavola periodica				
Metalli alcalini	Metalli alcalino terrosi	Lantanoidi	Attinoidi	Metalli del blocco d
Metalli del blocco p	Semimetalli	Nonmetalli	Alogeni	Gas nobili

Legenda per i colori dei **numeri atomici**:

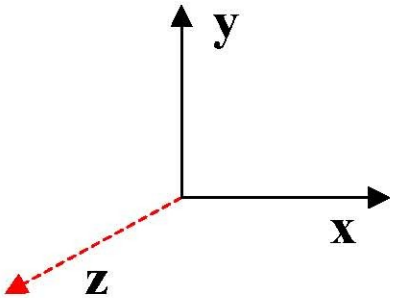
- gli elementi numerati in blu sono liquidi a $T = 298$ K e $p = 1$ bar;
- quelli in verde sono gas a $T = 298$ K e $p = 1$ bar;
- quelli in nero sono solidi a $T = 298$ K e $p = 1$ bar;
- quelli in rosso sono artificiali e non sono naturalmente presenti sulla Terra (sono tutti solidi a $T = 298$ K e $p = 1$ bar). Il tecnezio è presente in minime quantità nelle miniere di uranio e nelle giganti rosse.
- quelli in grigio non sono ancora stati scoperti


Stable 'Mountains'
Lead - Uranium
Spontaneous Fission
SEA OF INSTABILITY
Island of Stability
- superheavy spherical nuclei
100
130
160
190
70
80
90
100
110
120
Neutron Number, N
Proton Number, Z
Increasing Stability
Deformed Nuclei

Simulation results for central collisions of Au+Au



K=200MeV

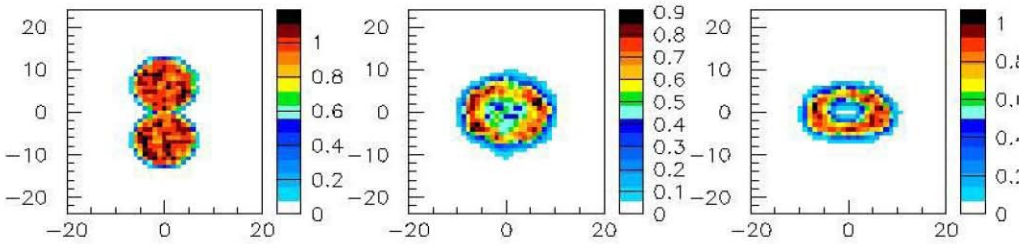


BUU calculations

x

Simulation results for central collisions of Au+Au

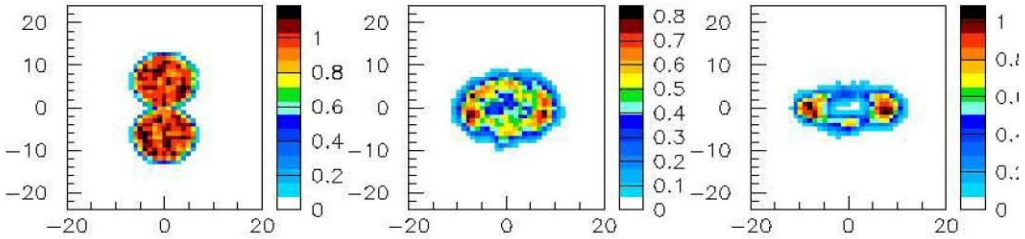
E=15 MeV/nucleon

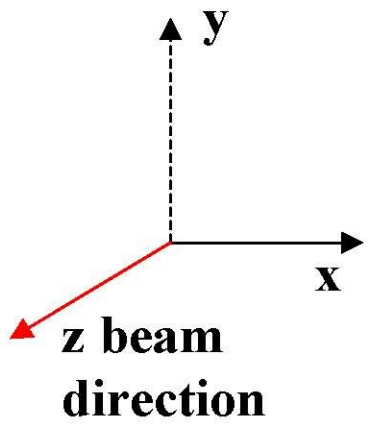


K=200MeV

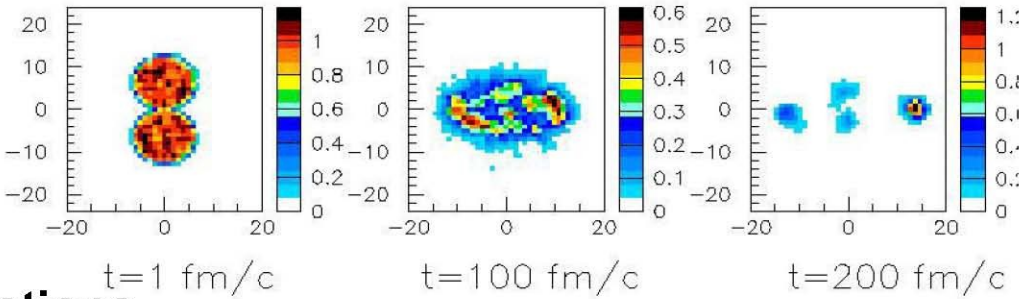
E=23 MeV/nucleon

z





E=40 MeV/nucleon



BUU calculations

x

Boltzmann – Uehling – Uhlenbeck model

The BUU transport equation for the nucleonic one-body density distribution function *f* = $f(\vec{r},\vec{p},t)$ **is given by:**

$$\left[\frac{\partial}{\partial t}+\vec{\upsilon}\nabla_r-(\nabla_r U)\nabla_p\right]f(\vec{r},\vec{p},t)=-\frac{1}{(2\pi)^3}\int d^3\vec{p}_2 d^3\vec{p}_{2'}\,d\Omega\frac{d\sigma}{d\Omega}\upsilon_{12}$$
$$\left\{f\,f_2\left(1-f_{1'}\right)\left(1-f_{2'}\right)-f_{1'}f_{2'}\left(1-f\right)\left(1-f_2\right)(2\pi)^3\,\delta^3\left(\vec{p}_1+\vec{p}_2-\vec{p}_{1'}-\vec{p}_{2'}\right)\right\}$$

$d\sigma/d\Omega$ **- nucleon-nucleon cross section**

v_{12} **- relative velocity for the colliding nucleons,**

U - mean-field potential consisting of the Coulomb potential and a nuclear potential with isoscalar and symmetry terms.

The potential field is approximated by

$$U(\rho,\tau_z)=A\left(\frac{\rho}{\rho_0}\right)+B\left(\frac{\rho}{\rho_0}\right)^{\sigma}+(1-\tau_z)V_c+V_{n,p}^{asy}(\rho,\delta)$$

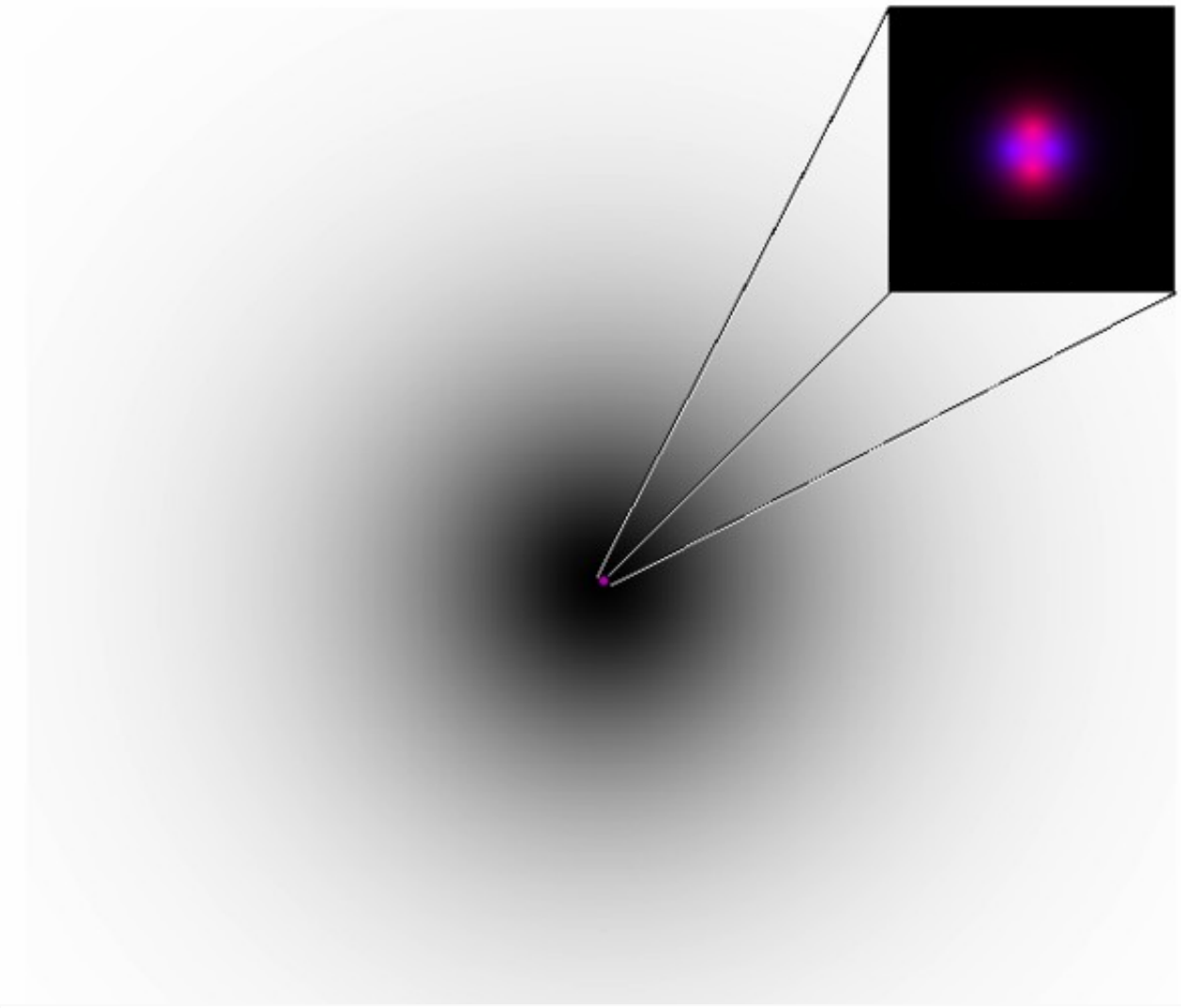
ρ_0 - normal nuclear matter density,

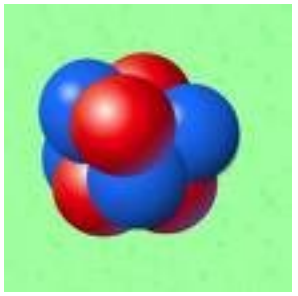
ρ, ρ_n , ρ_p - nucleon, neutron, and proton densities,

τ_z - equals 1 or -1 for neutrons or protons, respectively.

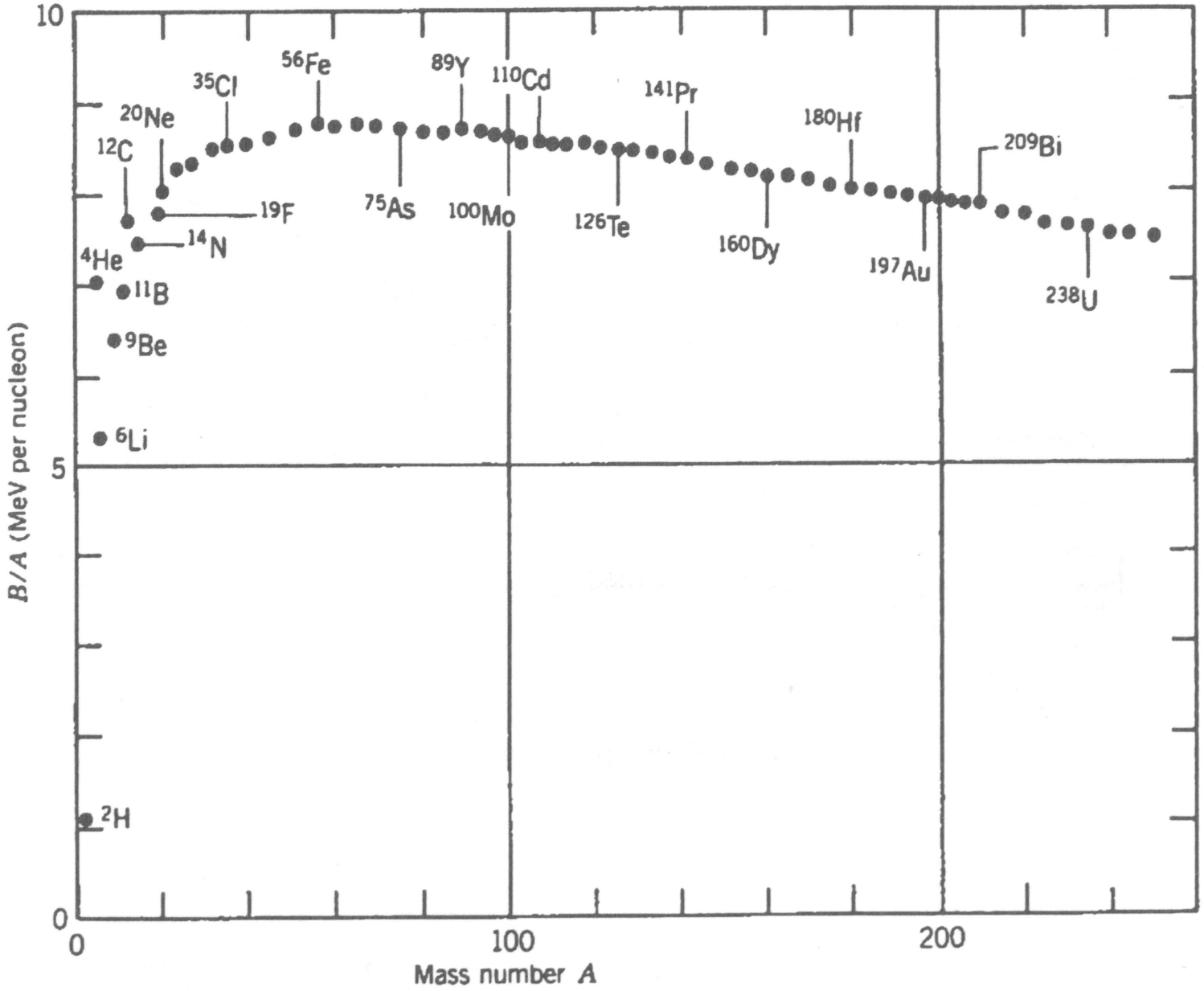
$\delta = (\rho_n - \rho_p) / (\rho_n + \rho_p)$ – asymmetry parameter

EOS	A[MeV]	B[MeV]	σ	K[MeV]
STIFF	-124.69	74.24	2	380
SOFT	-356	306.1	7/6	200





R_a	10^{-10} m = 0,1 nm
R_N	10^{-15} m = 1 fm
se R_a	cm
R_N	km


10
5
0
0
100
200
B/A (MeV per nucleon)
Mass number A
56Fe
89Y
110Cd
35Cl
20Ne
12C
141Pr
180Hf
209Bi
19F
75As
100Mo
126Te
160Dy
197Au
14N
238U
4He
11B
9Be
6Li
2H

$$m_N \approx A(amu)$$

$$V_N = \frac{4}{3}\pi r_0^3 A$$

$$n = \frac{A}{\frac{4}{3}\pi r_0^3 A} \approx 0{,}17 \text{ fm}^{-3}$$

$$\rho_0 = \frac{m_N}{V_N} = \frac{amu}{\frac{4}{3}\pi r_0^3} \approx$$

$$\approx \frac{1{,}66 \times 10^{-27}}{4{,}2 \times 1{,}5 \times 10^{-45}} \; kg\, m^{-3} \approx$$

$$\approx 2{,}6 \times 10^{17} \; \frac{kg}{m^3} \equiv 2{,}6 \times 10^{14} \; \frac{g}{cm^3} \equiv 2{,}6 \times 10^{8} \; \frac{t}{cm^3}$$

$$\frac{1}{2} m_n \upsilon^2 = kT = \left(1{,}38 \times 10^{-23}\right)\,(293)\ \mathrm{J} \approx$$

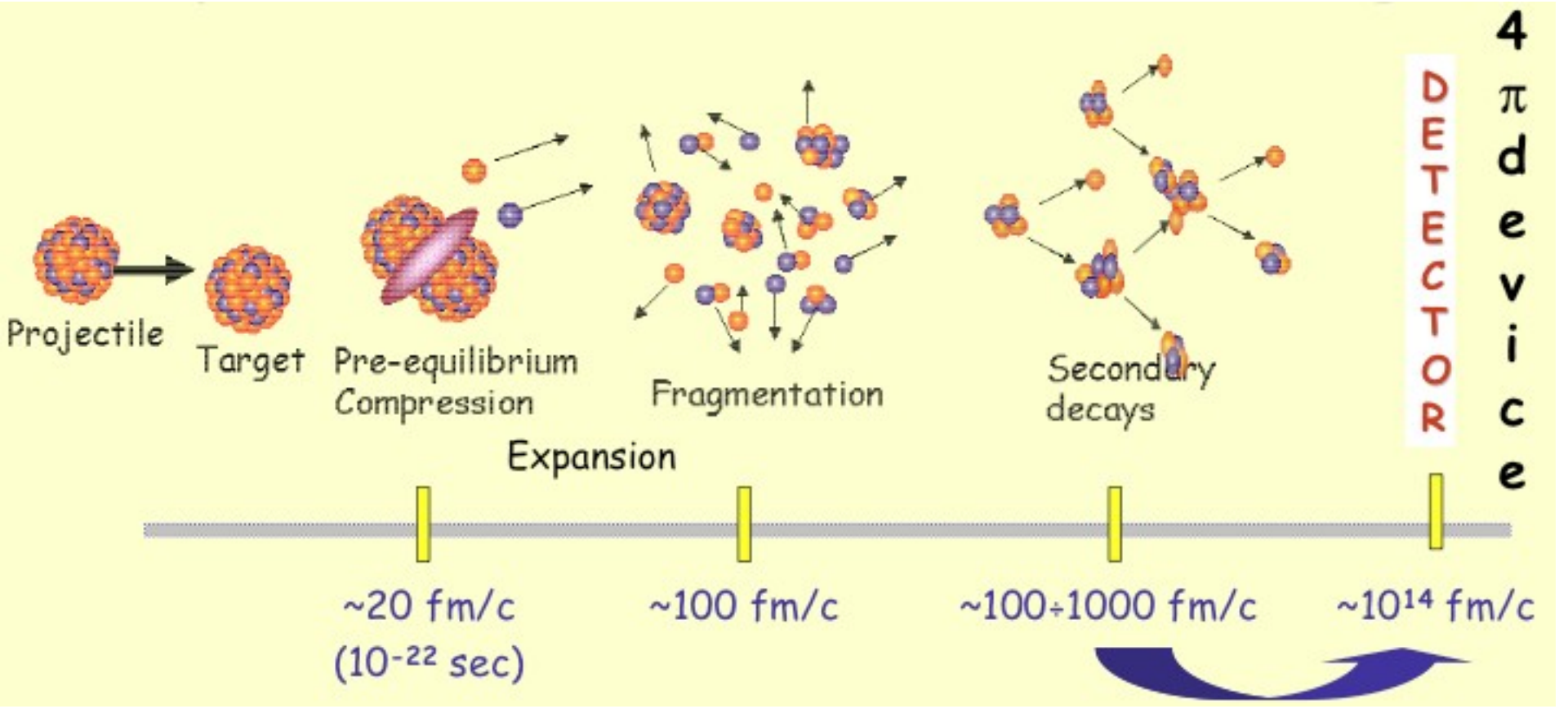
$$\approx 4 \times 10^{-21}\ \mathrm{J} \approx\ 25 \times 10^{-3}\ \mathrm{eV}$$

$$\upsilon = \sqrt{\frac{2kT}{m_n}} \approx \sqrt{\frac{8 \times 10^{-21}}{1{,}66 \times 10^{-27}}}\ \frac{m}{s} \approx 2{,}2 \times 10^{3}\ \frac{m}{s}$$

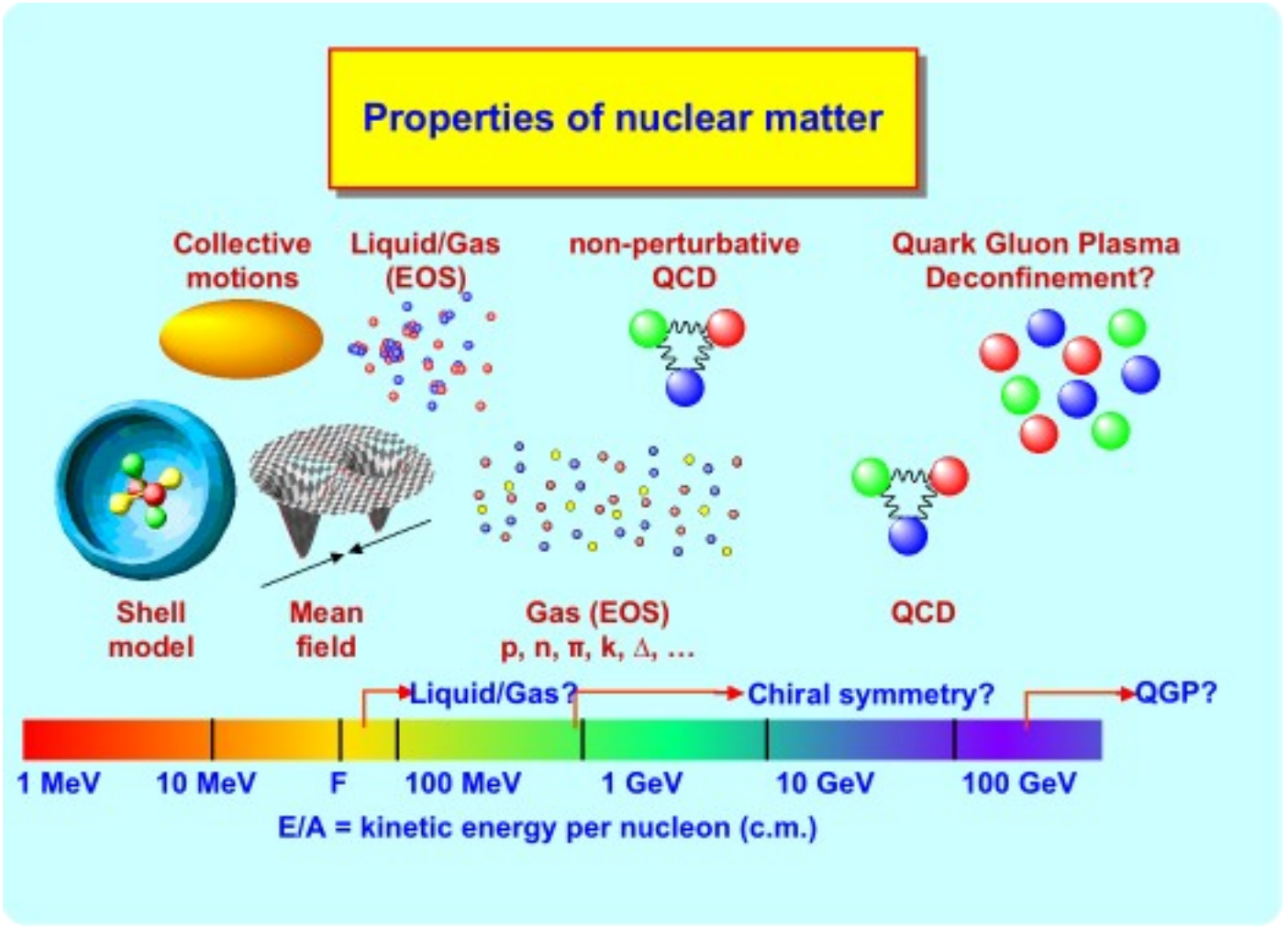
$$E^* \approx 1\ MeV$$

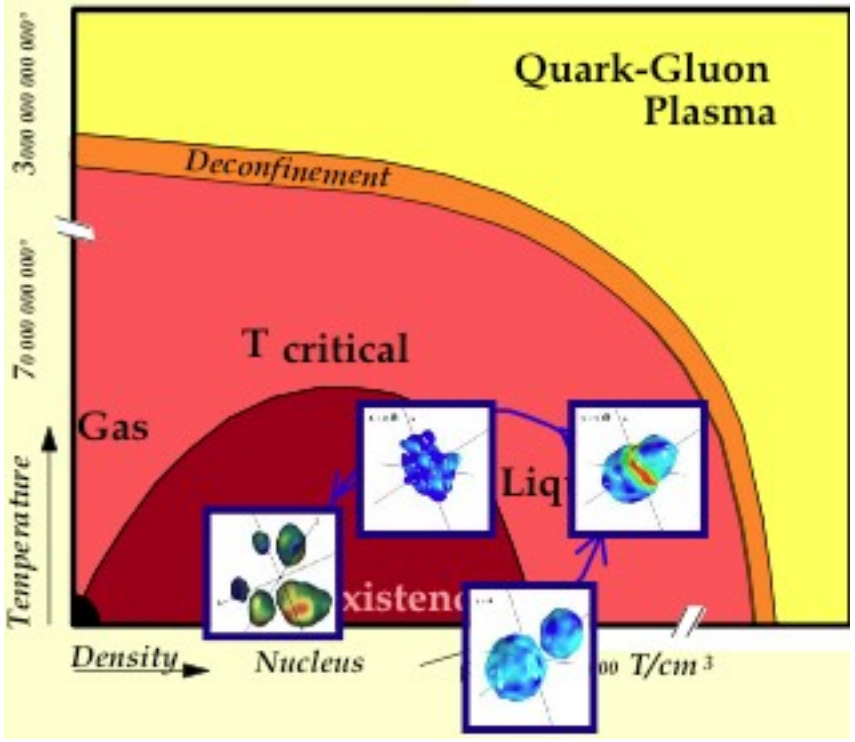
$$\Downarrow$$

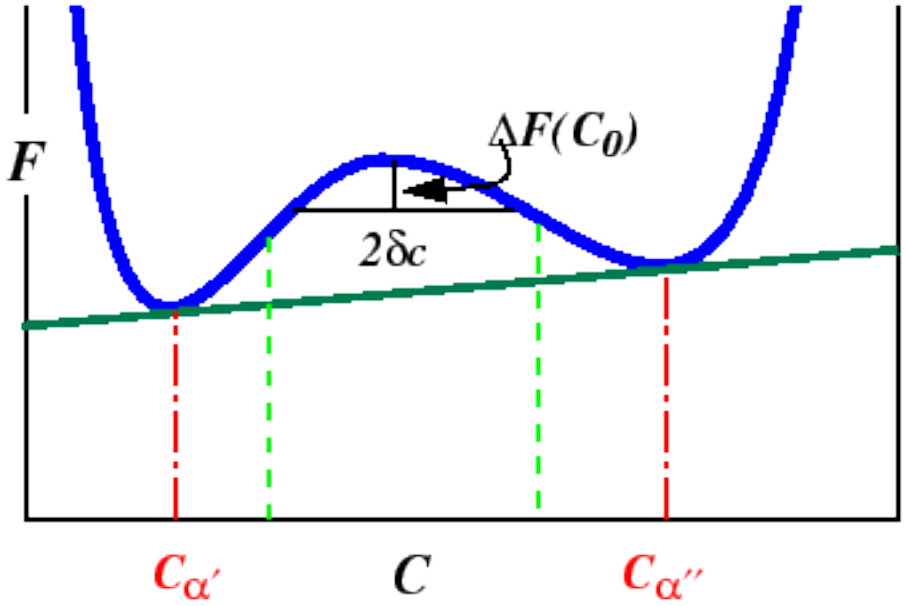
$$T \approx 11{,}6 \times 10^{9}\ K \qquad\qquad \upsilon \approx 1{,}4 \times 10^{7}\ \frac{m}{s}$$

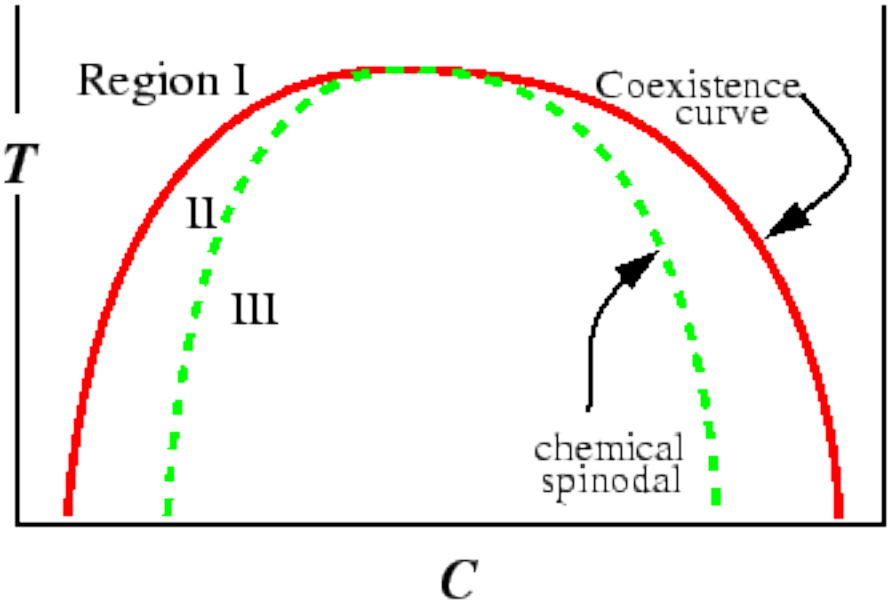


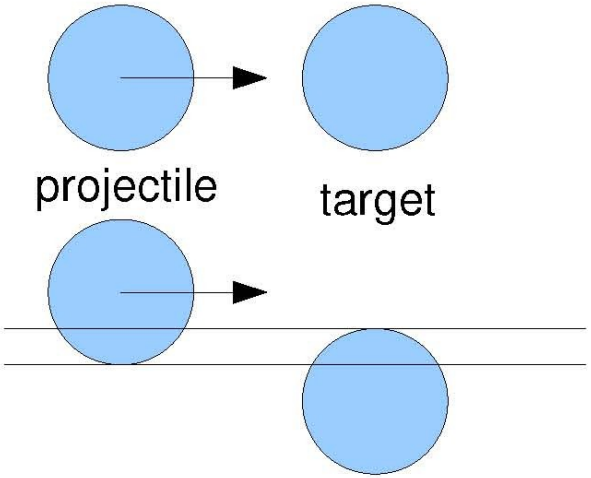
$$t_N \rightarrow \frac{fm}{c} = \frac{10^{-15}}{299\ 792\ 458} \approx 3{,}3 \times 10^{-24}\ s$$

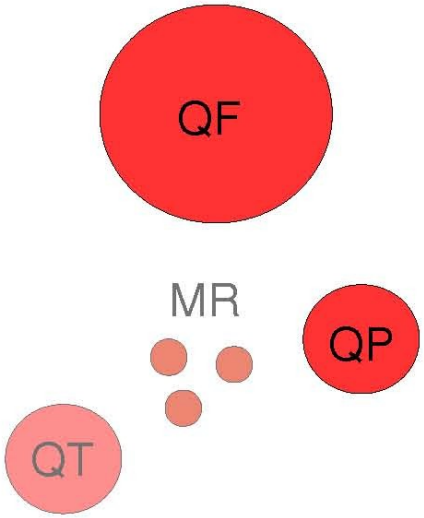

Properties of nuclear matter
Collective motions
Liquid/Gas (EOS)
non-perturbative QCD
Quark Gluon Plasma Deconfinement?
Shell model
Mean field
Gas (EOS)
p, n, π, k, Δ, …
QCD
Liquid/Gas?
Chiral symmetry?
QGP?
1 MeV
10 MeV
F
100 MeV
1 GeV
10 GeV
100 GeV
E/A = kinetic energy per nucleon (c.m.)


Quark-Gluon
Plasma
Deconfinement
T critical
Gas
Liq
Temperature
Density
Nucleus
T/cm 3


F
ΔF(C0)
2δc
Cα′
C
Cα″


Region I
Coexistence
curve
II
III
chemical
spinodal
T
C





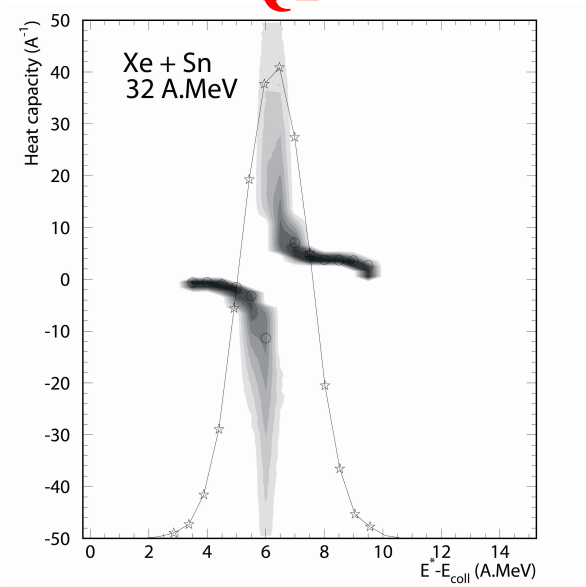
Central collisions

Quasi-Fusion (QF) sources

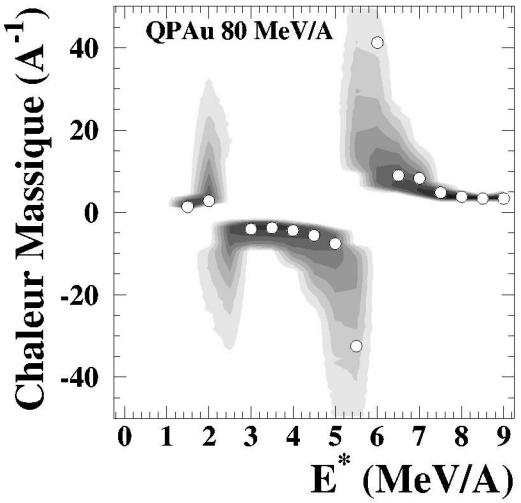
Peripheral collisions

Quasi-Projectile (QP) sources

QF

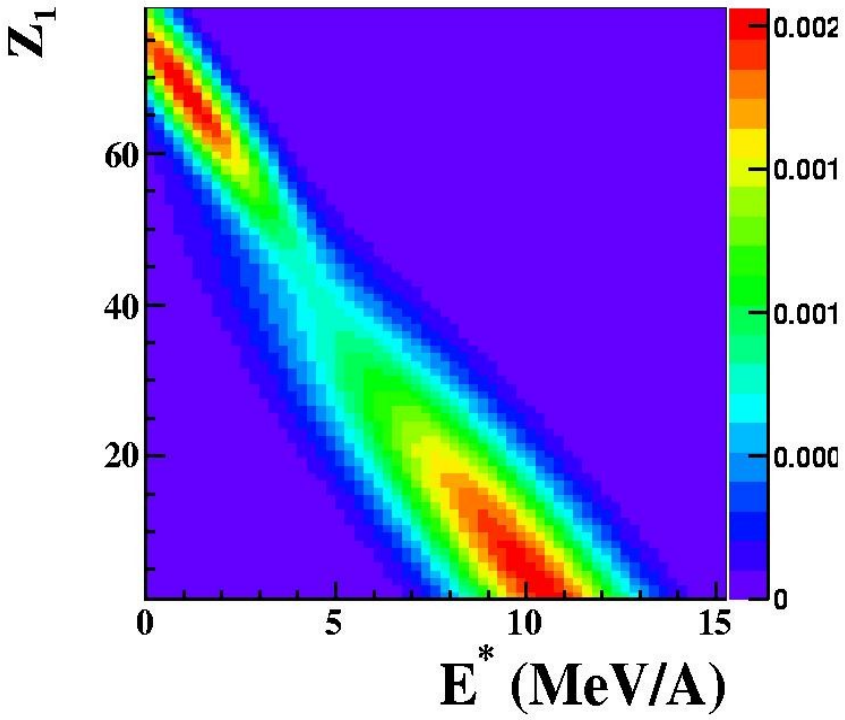


QP



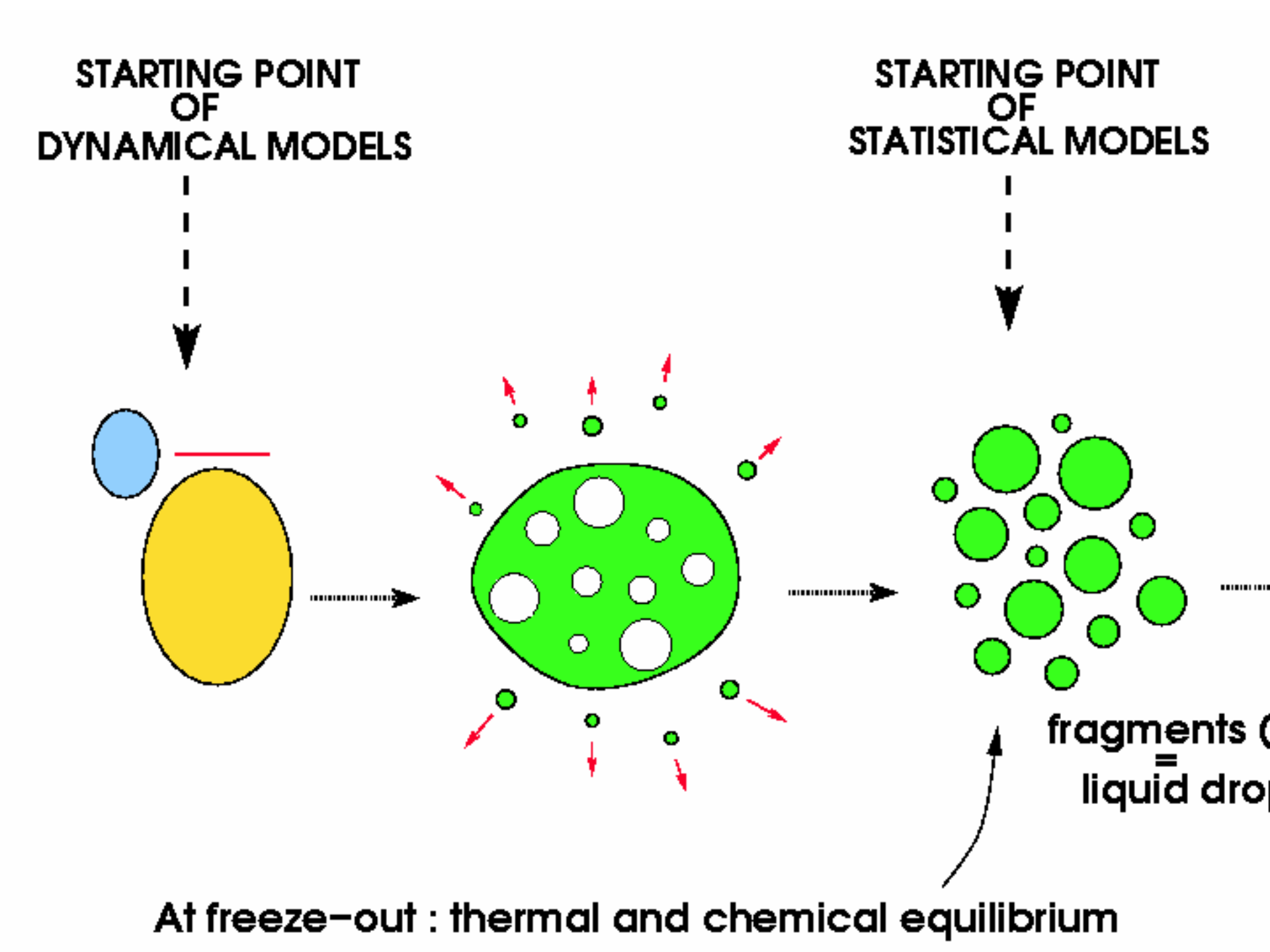
Negative heat capacity

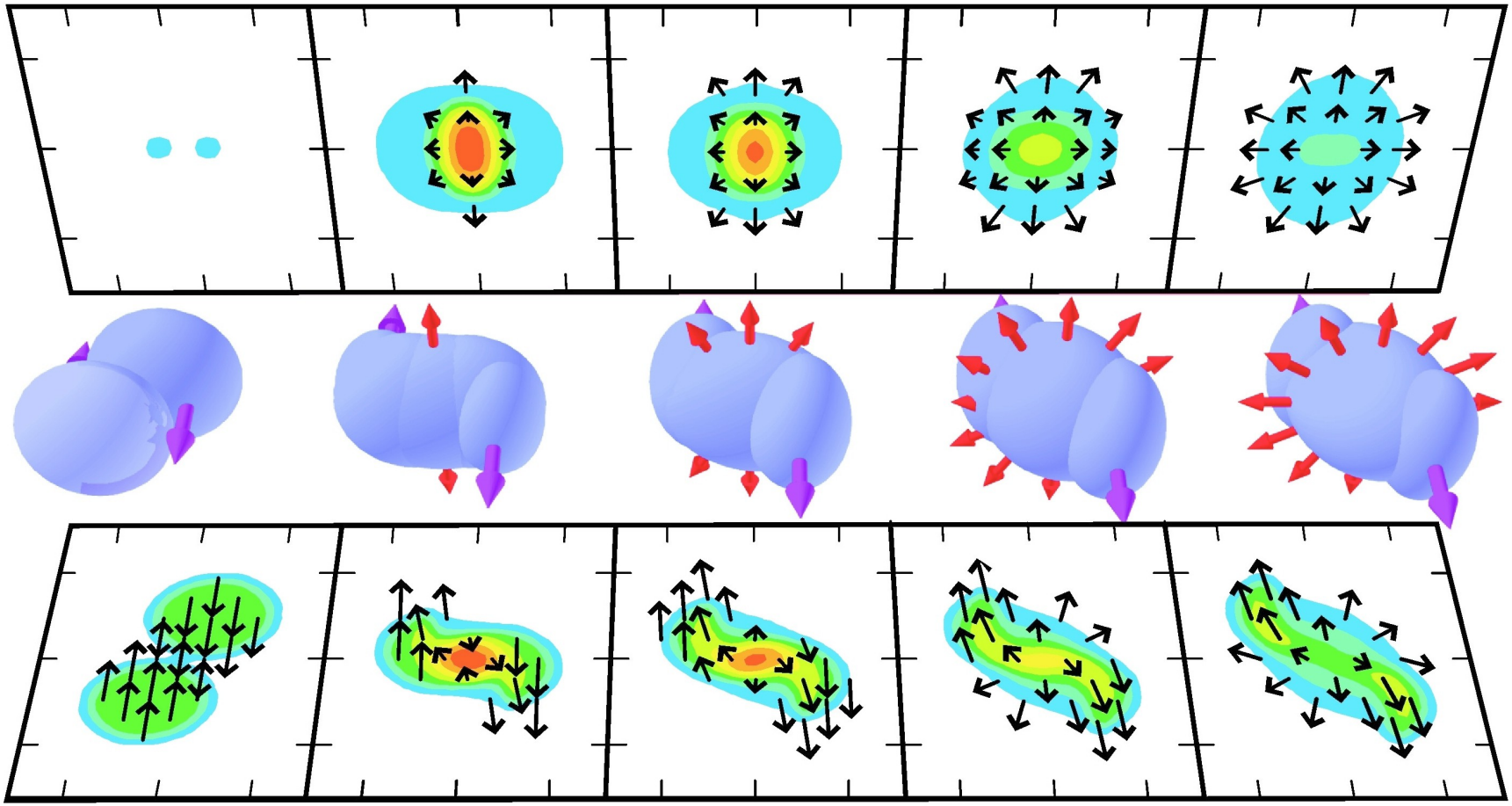
Bimodal behavior of the heaviest fragment distribution as signature of a first order phase transition in finite systems

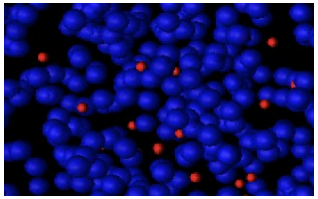


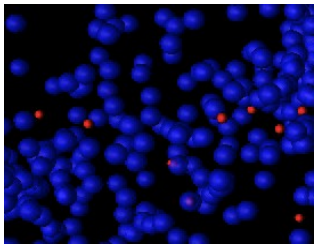
latent heat of the phase transition for heavy nuclei Z ~ 70

$(E_G\text{-}E_L) \sim 8.1\ (\pm 0.4)_{stat}\ (\pm 1.2 - 0.9)_{syst}$ AMeV

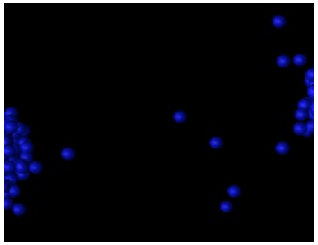

STARTING POINT
OF
DYNAMICAL MODELS
STARTING POINT
OF
STATISTICAL MODELS
fragments (
=
liquid dro
At freeze-out : thermal and chemical equilibrium

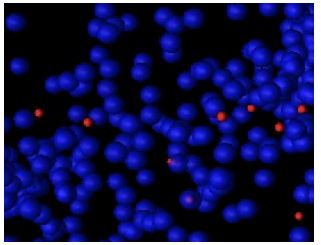


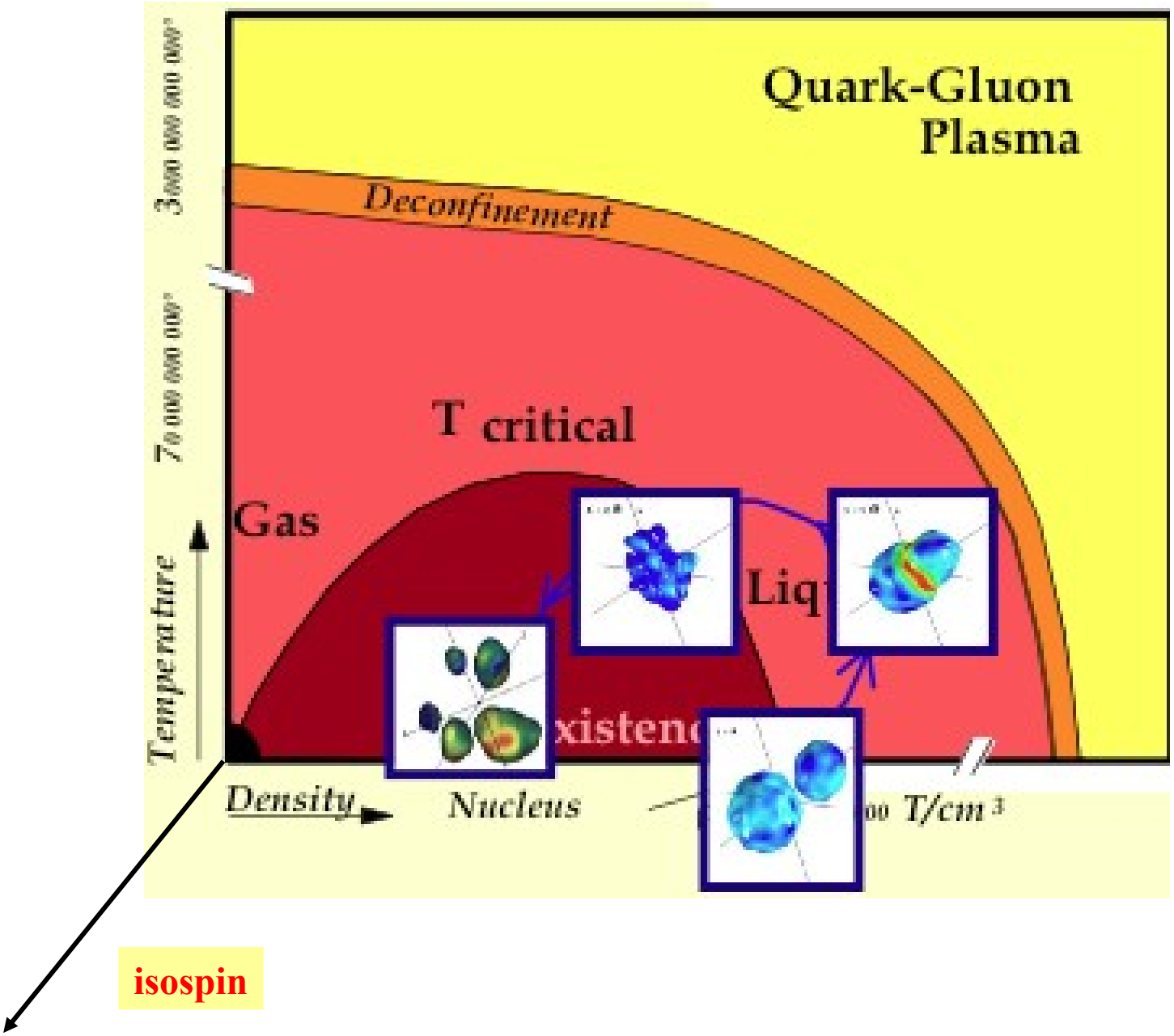




Au+Au @ E= 1A.GeV



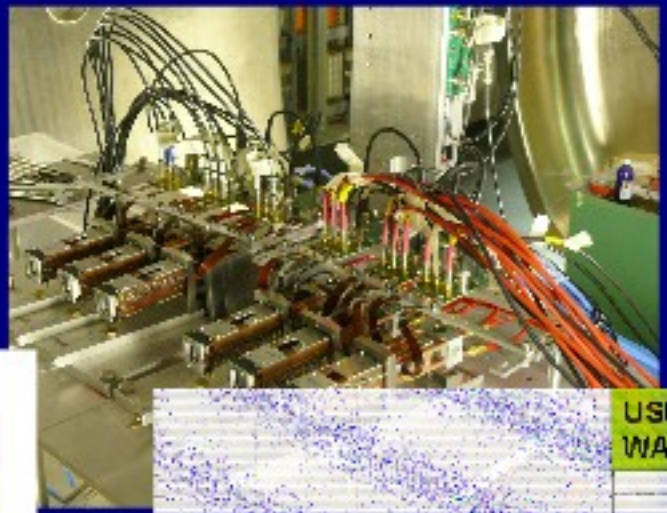


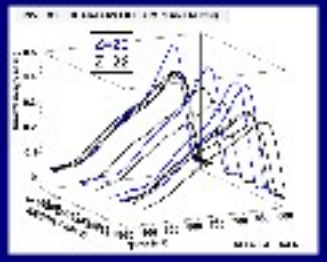

Quark-Gluon
Plasma
Deconfinement
T critical
Gas
Liq
Temperature
Density
Nucleus
T/cm 3
isospin

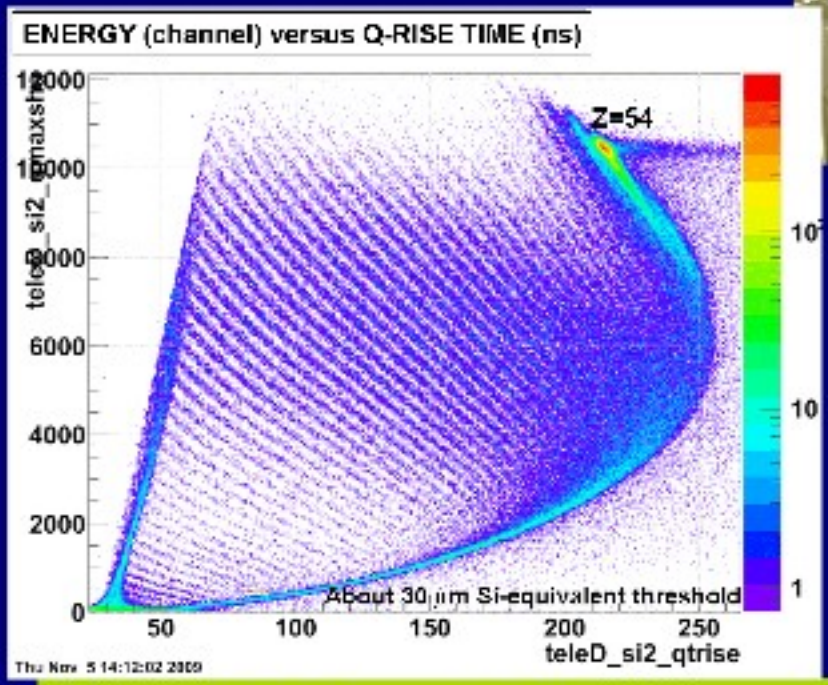
FAZIA collaboration

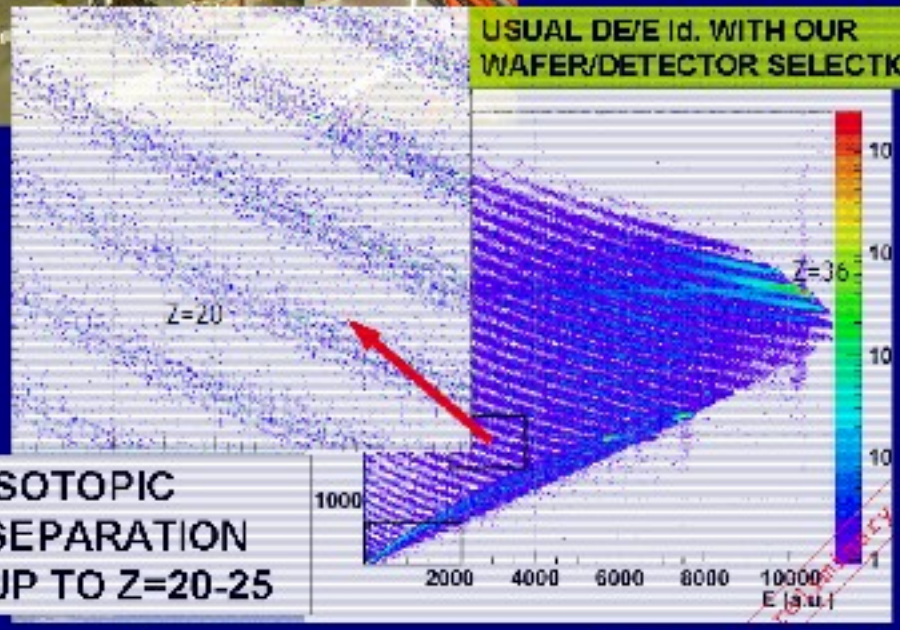
FAZIA PHASE-I prototype
R&D Experiment
(LNS-Nov. 2009)

^{129}Xe+Ni 35 A.MeV









Z identification up to Z=54
with ONE detector by Pulse Shape Analysis

Spiral2
TASK 5.3 SPIRAL2PP