Search for long nuclear interaction times in $^{238}U + ^{238}U$ collisions

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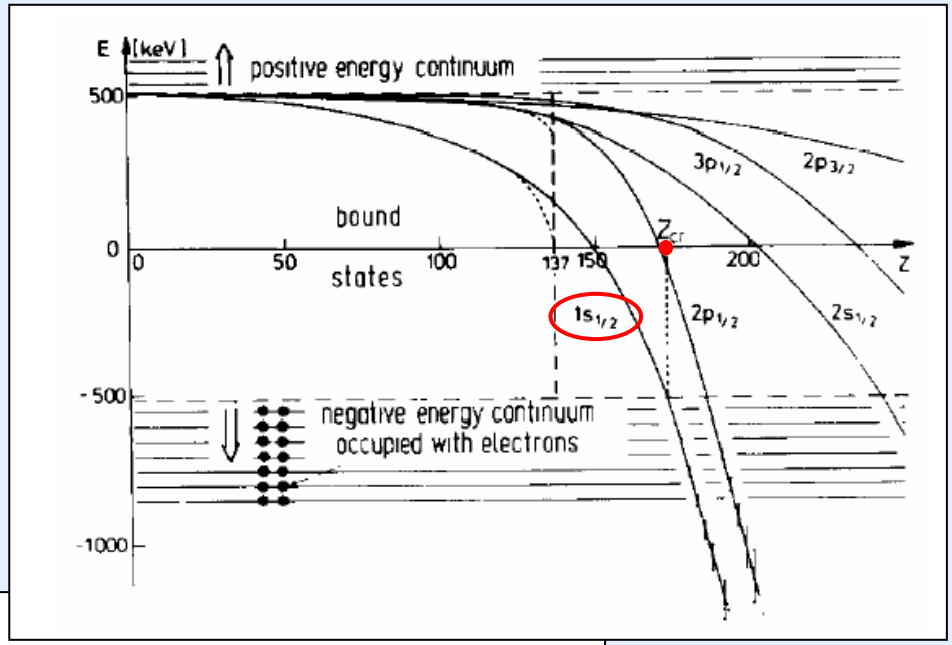
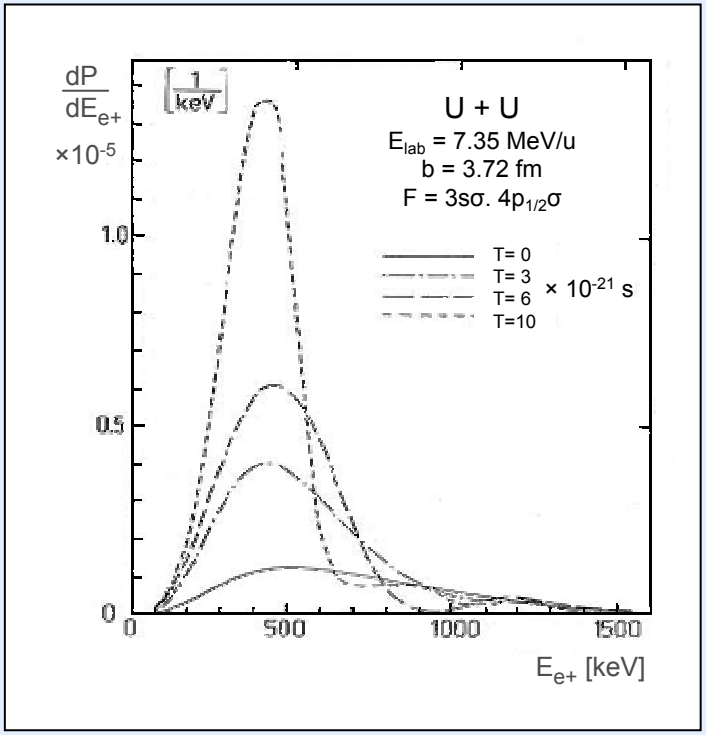
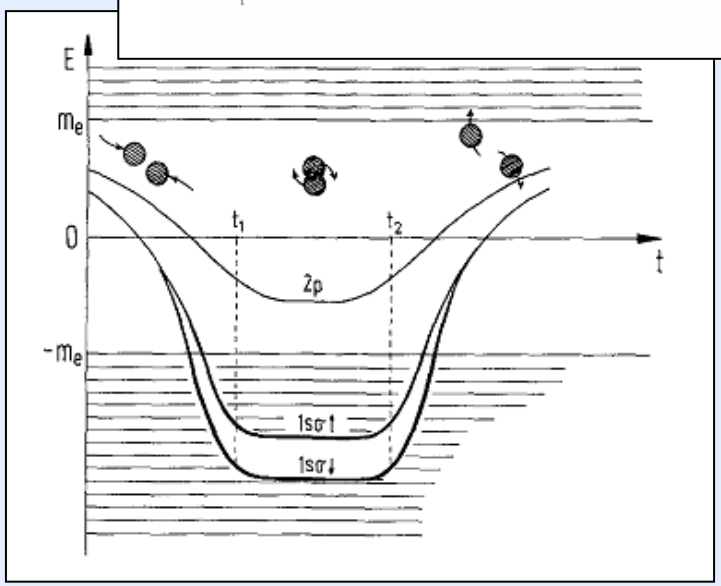
Superstrong fields of giant nuclear systems



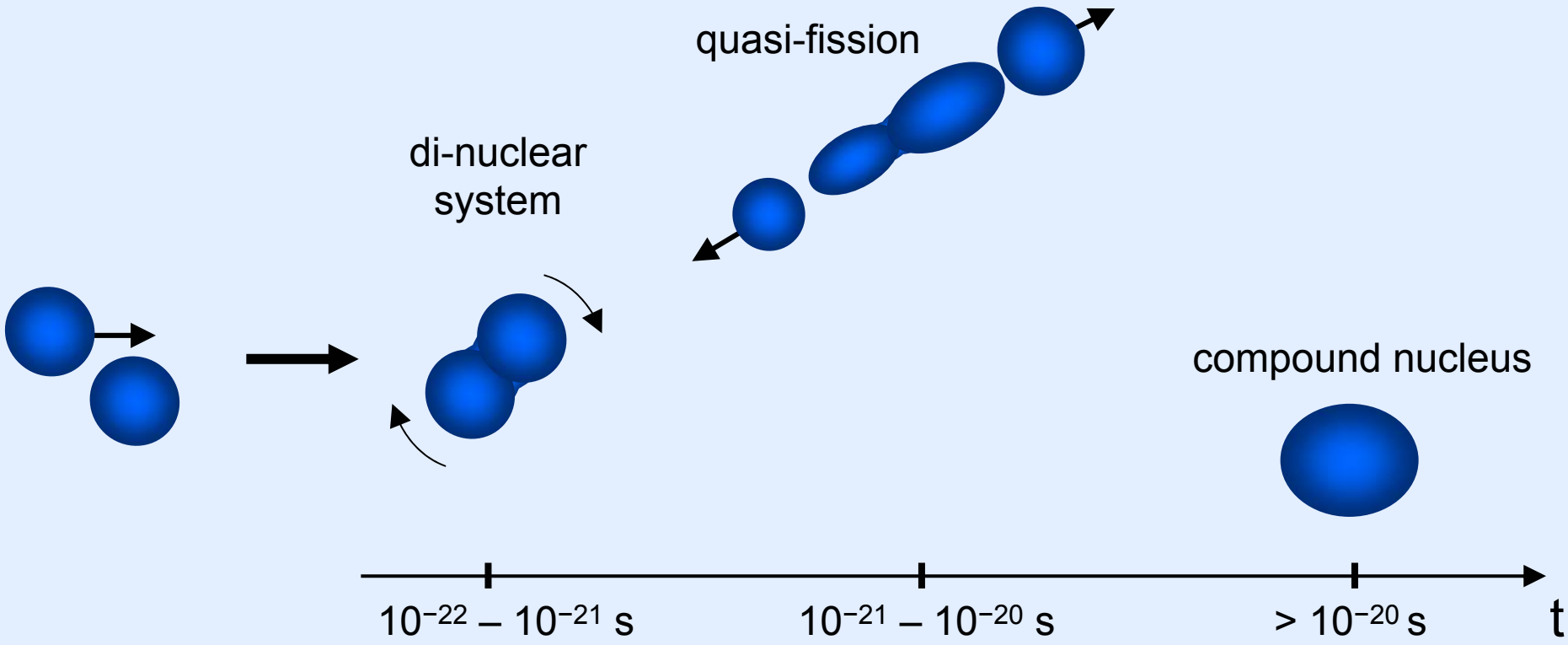
$$E_{e+} = E_B - 2m_e c^2$$





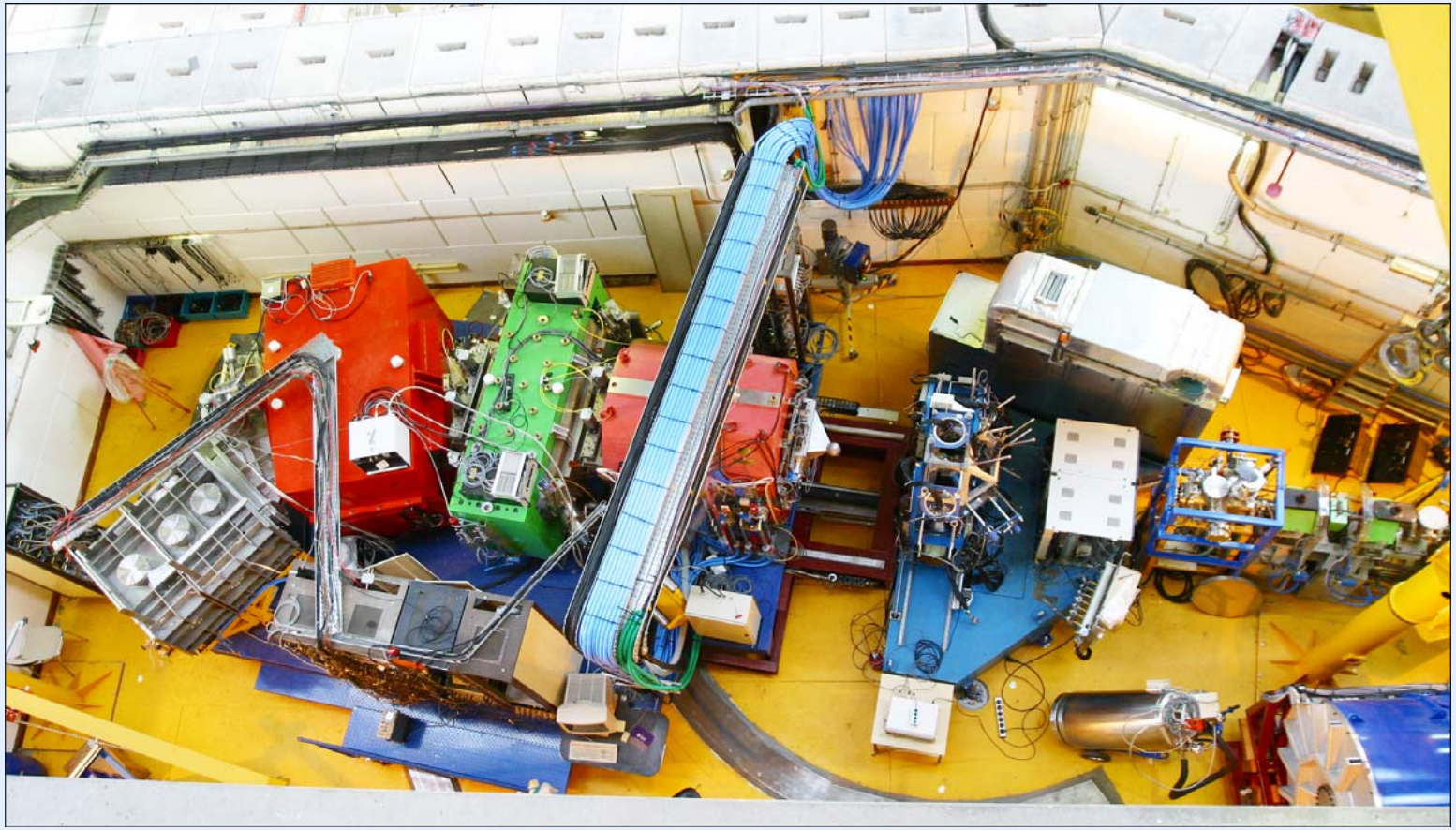
B. Müller and W. Greiner, Physica Scripta 10 A (1974) 170
J. Rafelski, Z. Phys. A 285 (1978) 49
J. Reinhardt et al., Z. Phys. A 303 (1982) 173

Time scale of nuclear reactions



large mass re-arrangement — large kinetic energy loss — long interaction times

The experiment
VAMOS spectrometer, GANIL



determination of A and Z by measuring E, ΔE and TOF

resolution: ΔA/A = 2%, ΔZ/Z = 8%

Experimental parameters

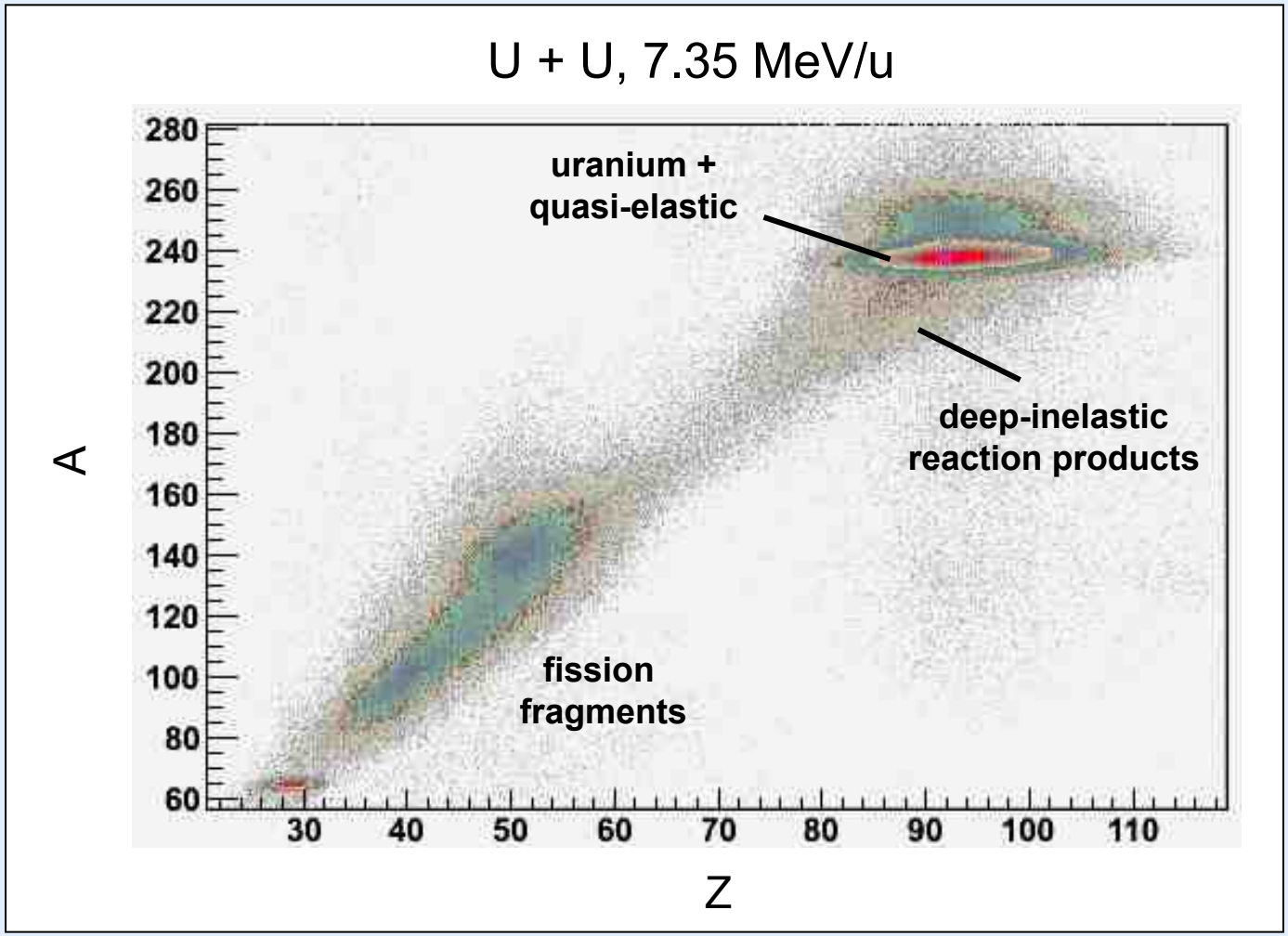
beam: ^{238}U, ~0.5 pnA

energy: 6.09, 6.49, 6.91, 7.1, 7.35 MeV/u

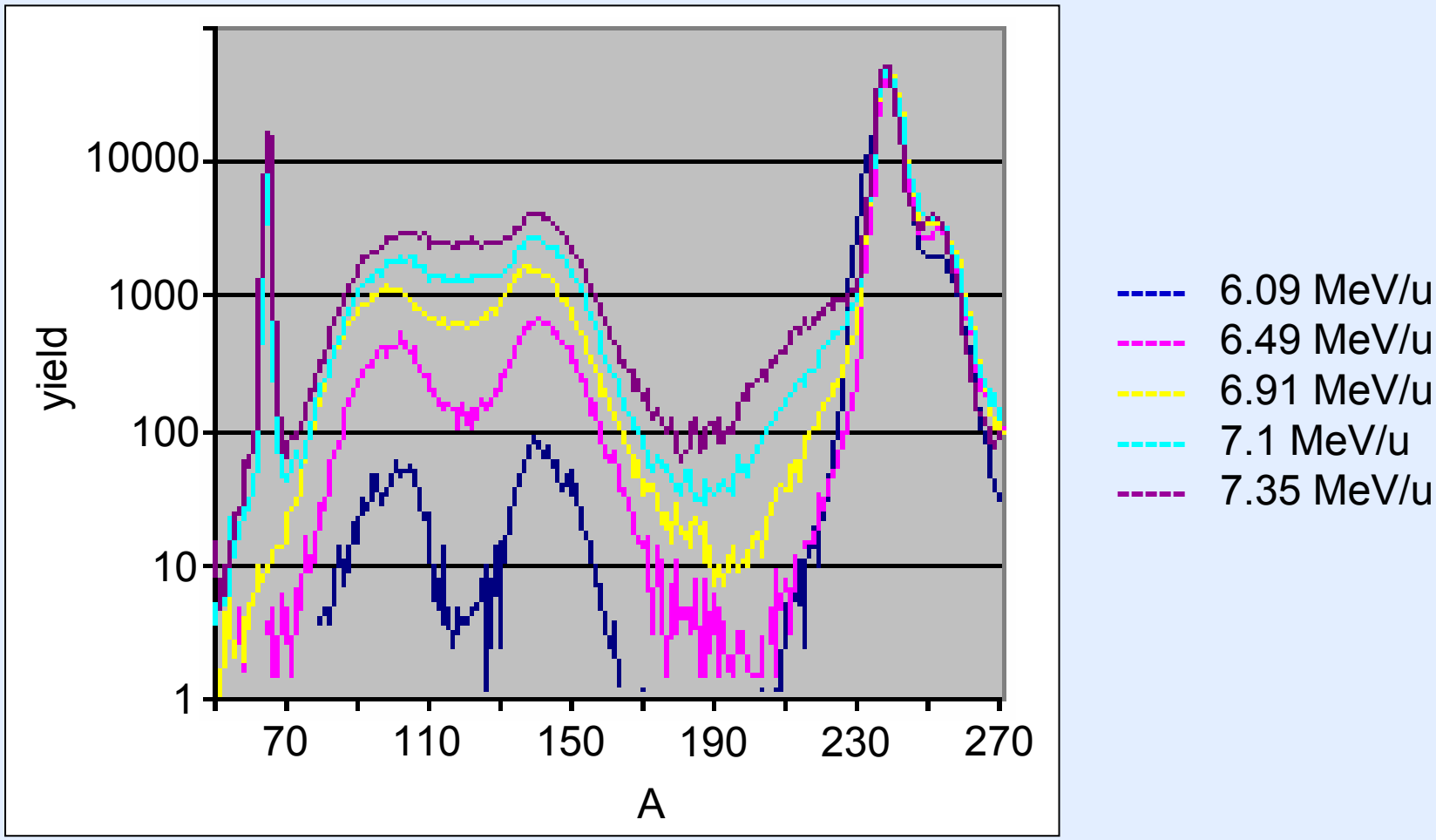
target: 500 μg/cm^2 metallic uranium

angular acceptance: (35 ± 7)°

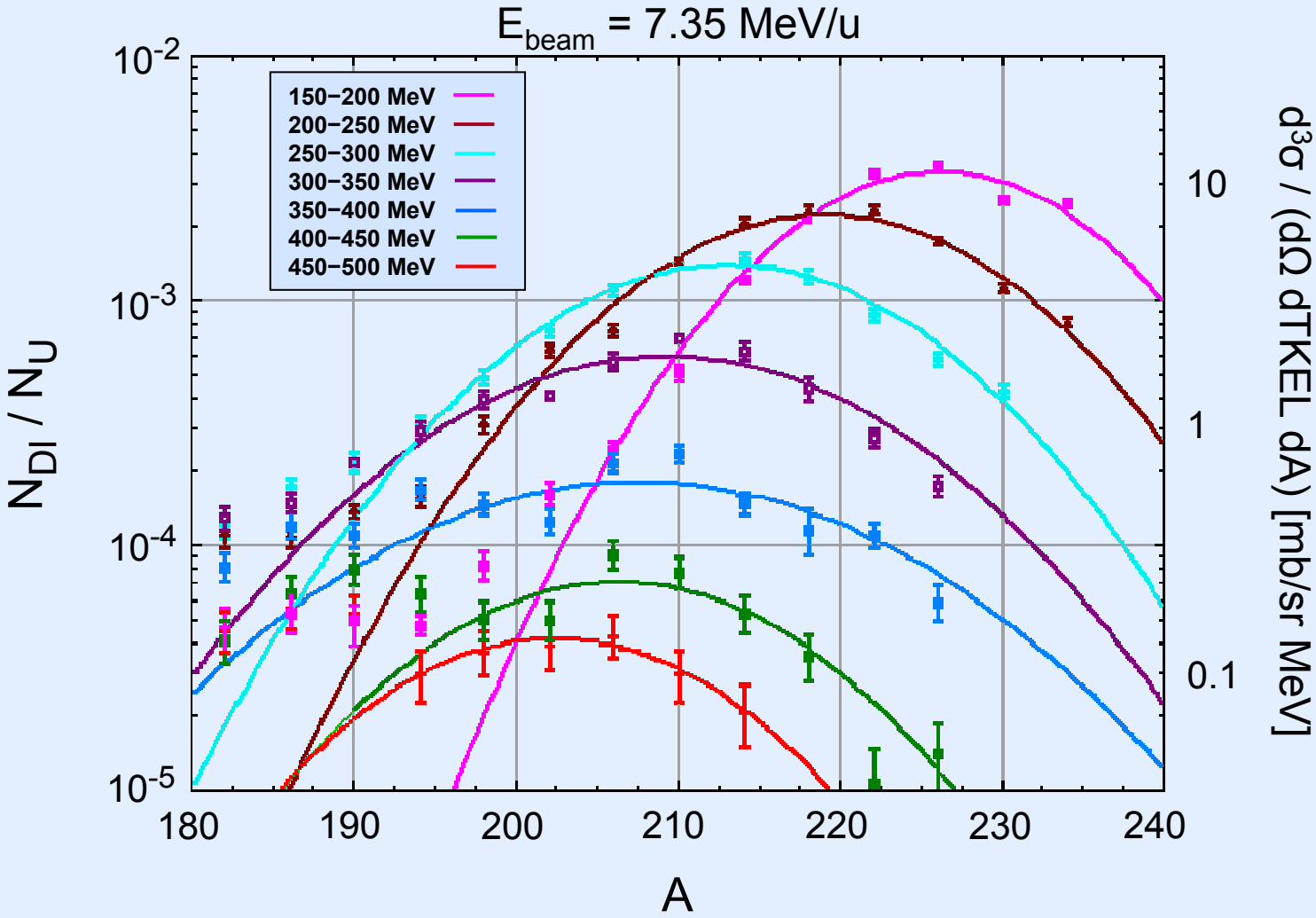
Reaction products from ^{238}U + ^{238}U collisions



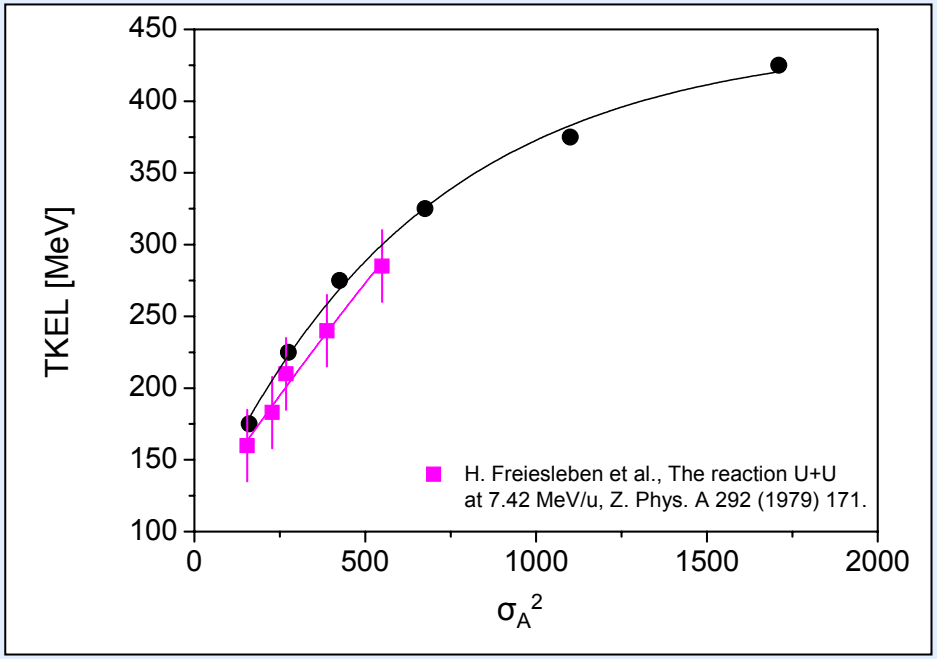
Mass spectra from ^{238}U + ^{238}U collisions

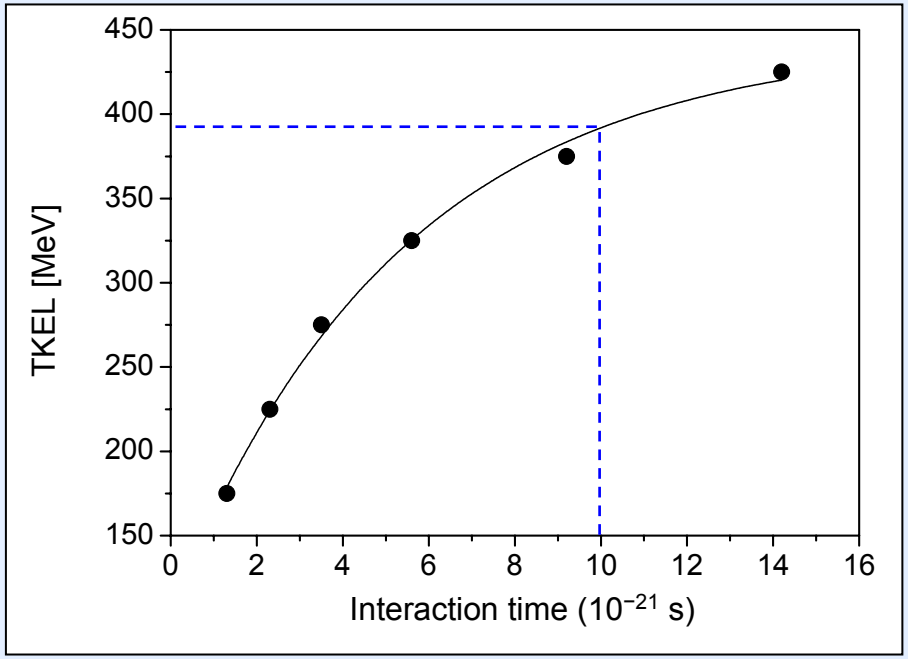


Yield of deep-inelastic reaction products for different TKEL bins



Estimate of nuclear interaction times
Diffusion model of C. Riedel, W. Nörenberg et al.





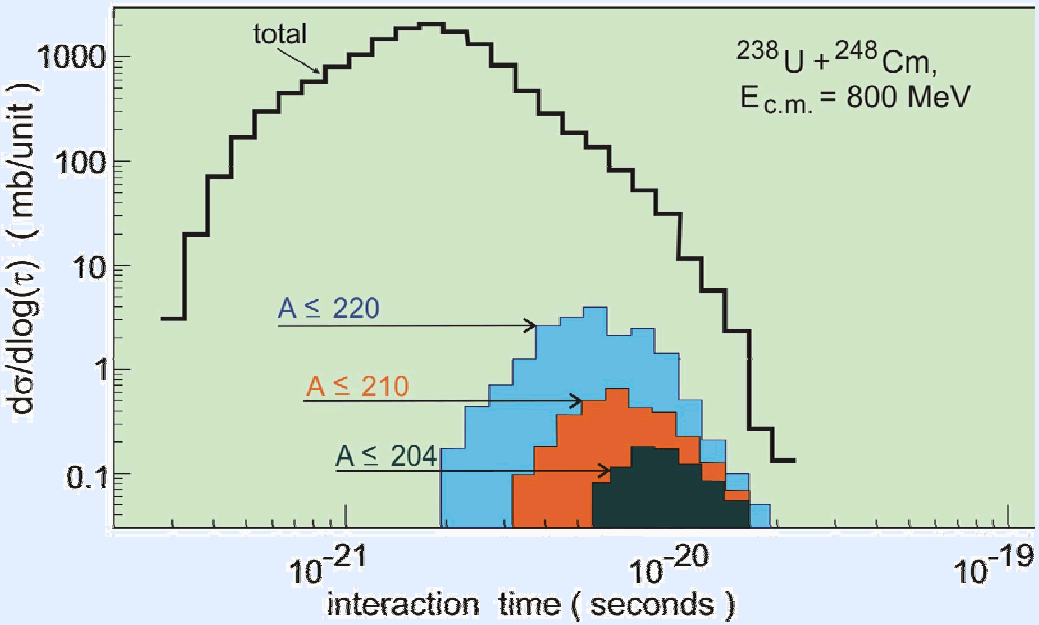
$$\sigma_A^2 = D_A \cdot t_{int}$$

σ_A^2: variance

$D_A = D_Z / (Z/A)^2$: mass diffusion coefficient

$D_Z = 0.9 \cdot 10^{22}$ s^{-1}, U+U, 7.5 MeV/u (C. Riedel, W. Nörenberg, Z. Phys. A 290 (1979) 385)

Estimate of nuclear interaction times
model of V. Zagrebaev



$t_{int} \sim 10^{-20}$ s

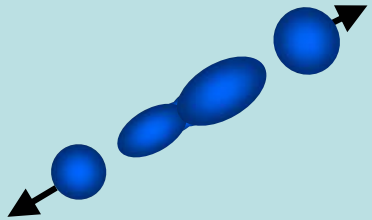
A ≤ 204

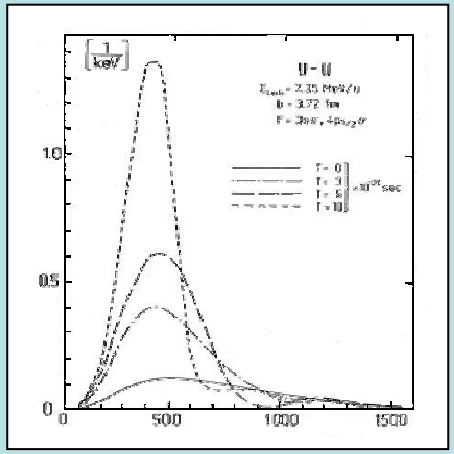
TKEL < 200 MeV

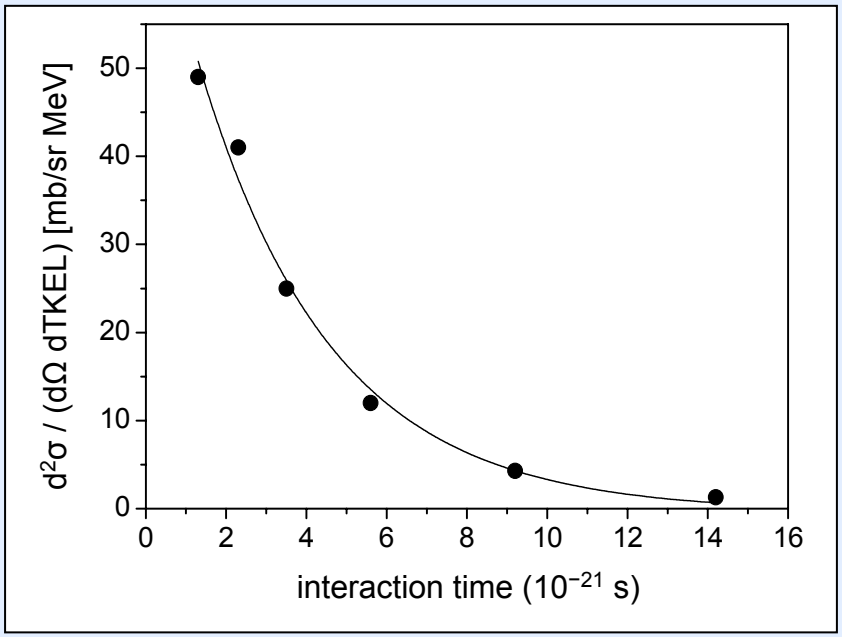
large mass re-arrangement — large kinetic energy loss — long interaction times

Cross sections

quasi-fission reactions with mean interaction times of ~10^{-20} s can be used as a trigger in the search for spontaneous e^+ emission





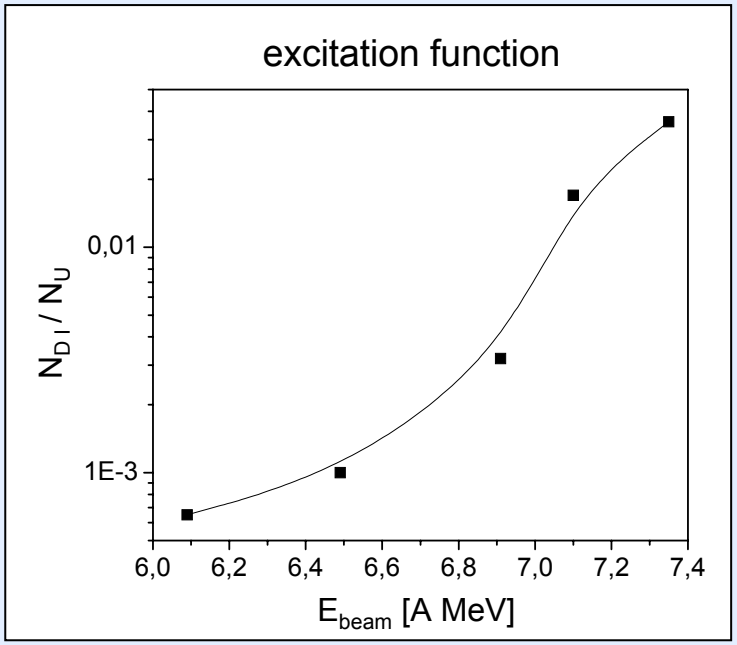


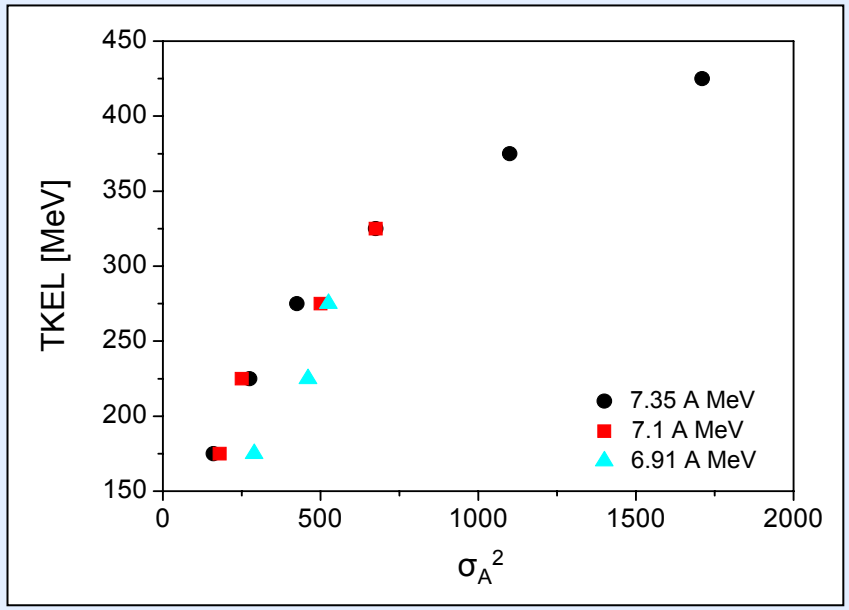
TKEL = 450 – 500 MeV

$t_{int} \sim 10^{-20}$ s

$d^2\sigma / (d\Omega\, dTKEL) \sim 0.5$ mb/sr MeV

The beam energies 6.09 − 7.1A MeV





The longest interaction times we expect at 7.35A MeV ($t_{int} = \sigma_A^2 / D_A$)

Further investigations (I)

Investigation of nuclear interaction times for ...

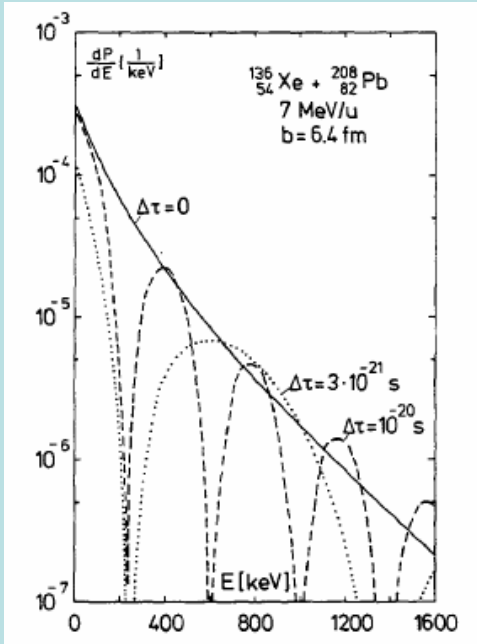
- E_{beam} > 7.35A MeV
- smaller scattering angles / impact parameters
- better statistics to search for events with TKEL > 500 MeV

Independent cross check of the interaction times

- delta electron spectroscopy

  → oscillations in the energy spectrum with the width

  $\Delta E = h/\Delta t$



J. Reinhardt et al., Z. Phys. A 292 (1979) 211

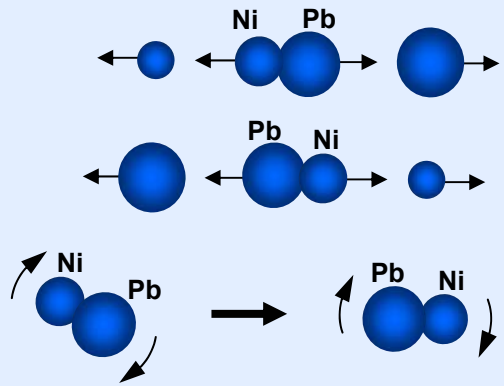
Further investigations (II)

Investigation of nuclear interaction times at SHIP

- ► detection at 0º with respect to the beam
- ► measurement of the velocity spectrum

− "visibility" of the rotation of a di-nuclear system
− lower limit of nuclear interaction times

cm system

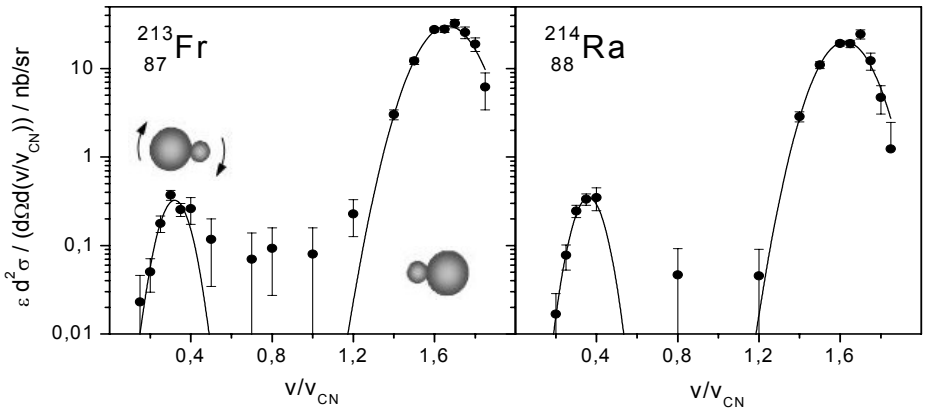


$\omega = 2\pi / T = \hbar L / \Theta$

grazing collision:
b = 4 fm
L = 130 h
$\theta_{rot} \geq 160°$

T (360°) = 6×10^{-21} s
T (≥160°) ≥ 3×10^{-21} s

QF products from ^{64}Ni + ^{207}Pb at 5.9A MeV



Spontaneous e^+ production with merged beams