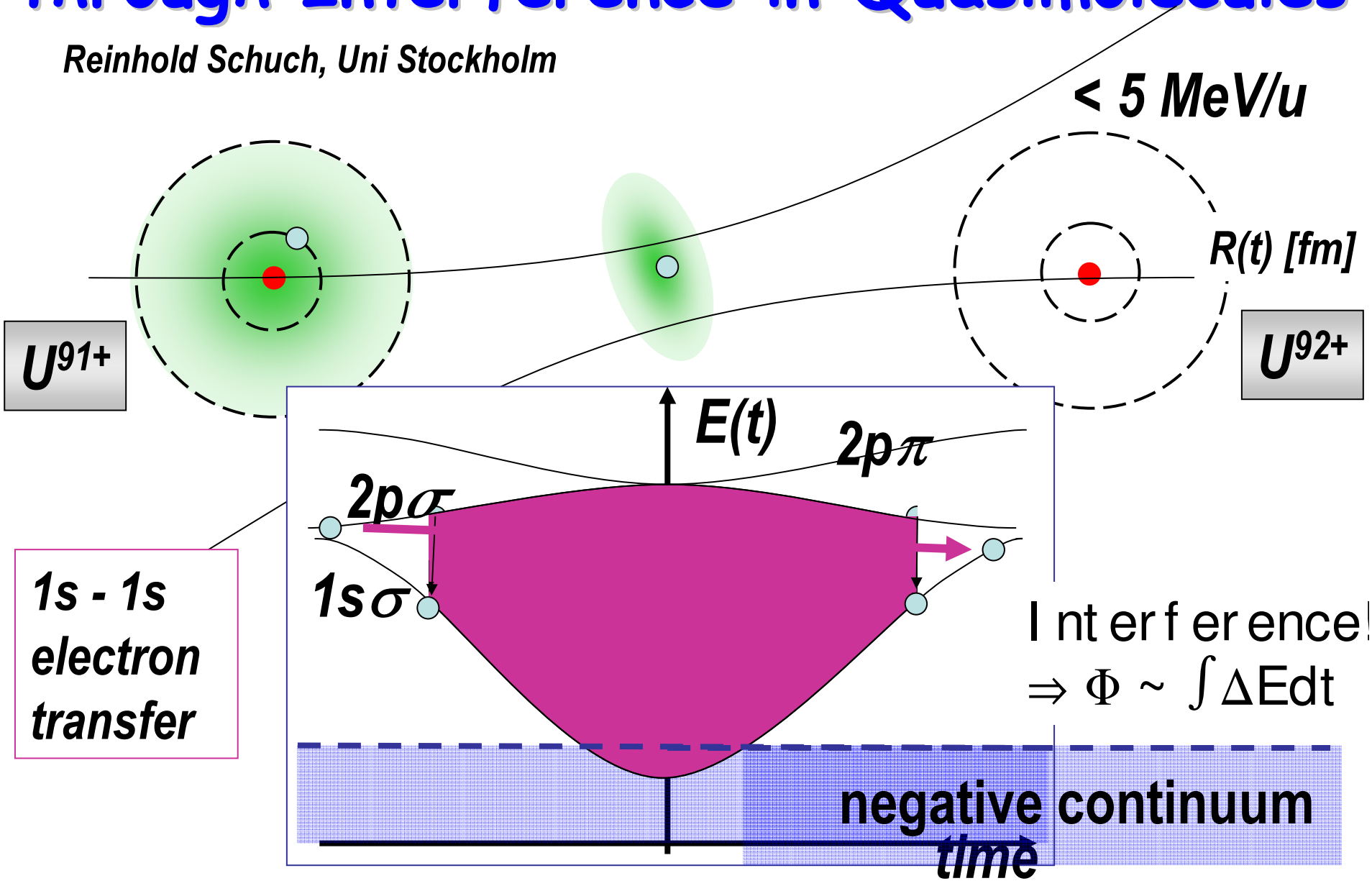
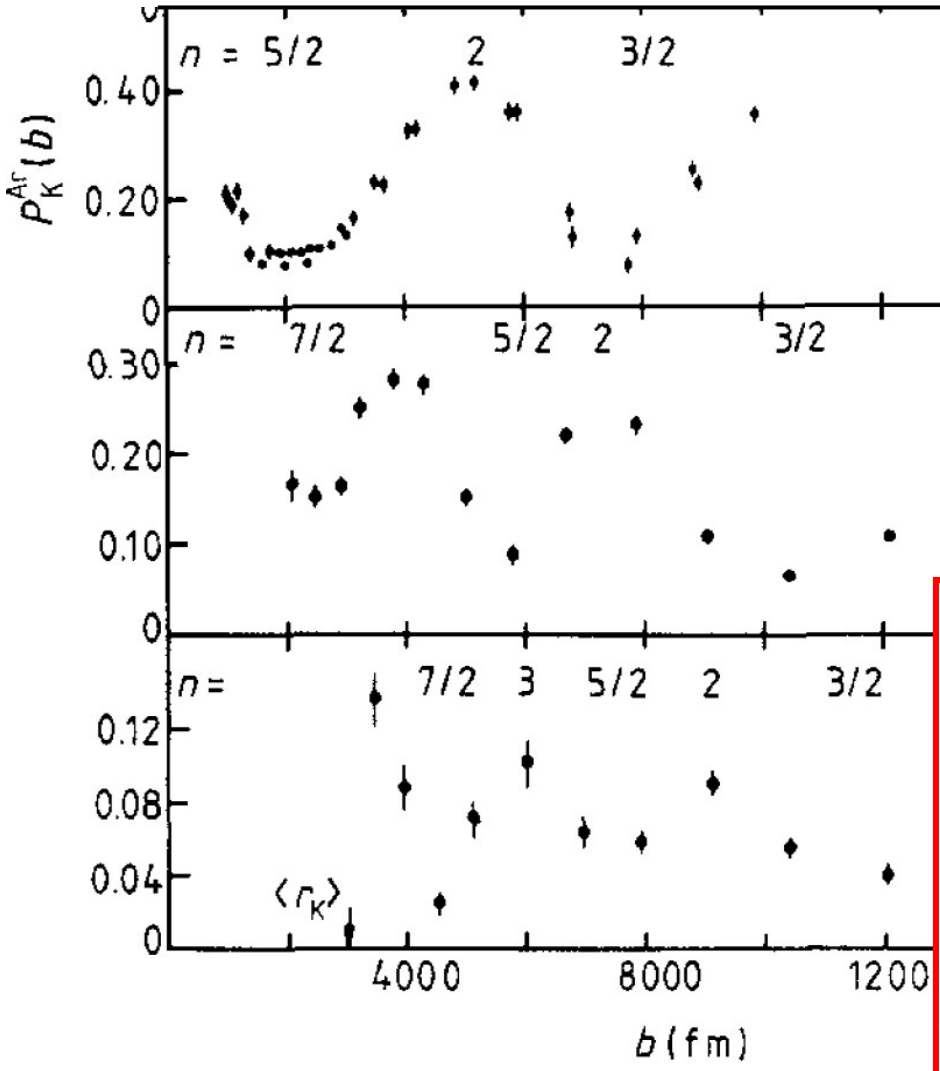
Spectroscopy of Super-heavy Atoms through Interference in Quasimolecules

Reinhold Schuch, Uni Stockholm



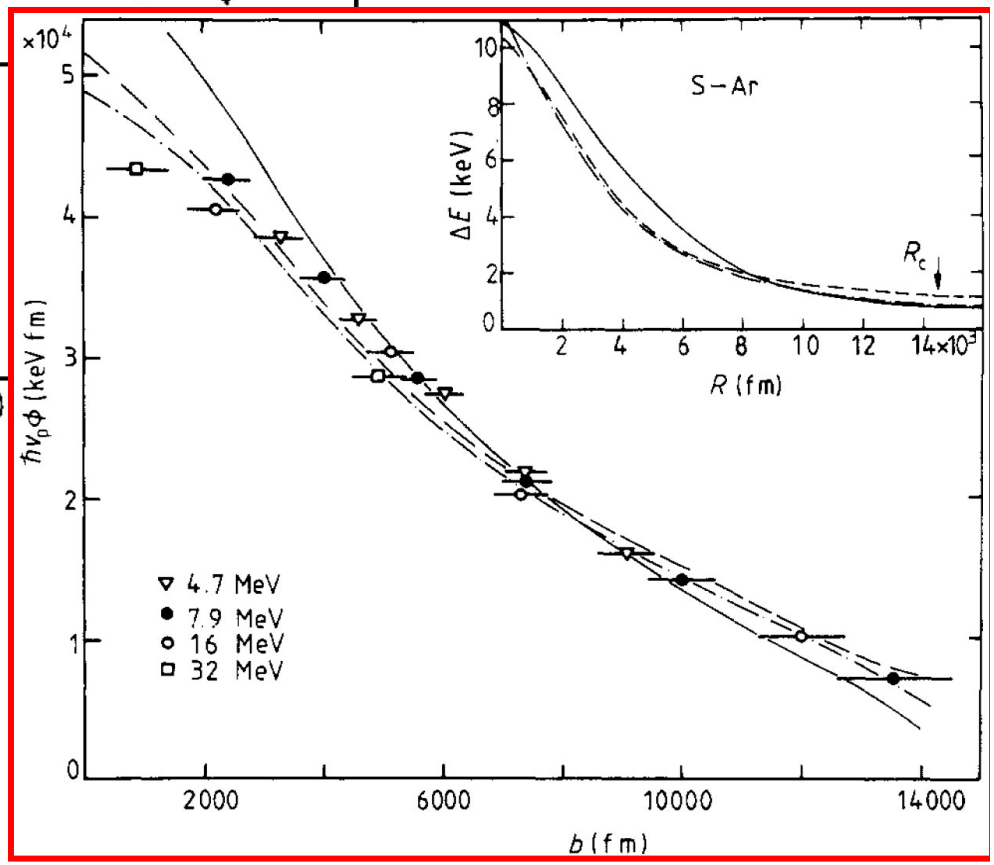


S^{15+} - Ar

$$\dot{a}_1(t) = -a_2(t) M_{12} \exp \mathrm{i}/\hbar \left(\int_{\infty}^{t} (A - \Delta E)\, \mathrm{d}\tau + Bt \right)$$

$$\dot{a}_2(t) = a_1(t) M_{12} \exp -\mathrm{i}/\hbar \left(\int_{-\infty}^{t} (A - \Delta E)\, \mathrm{d}\tau + Bt \right)$$

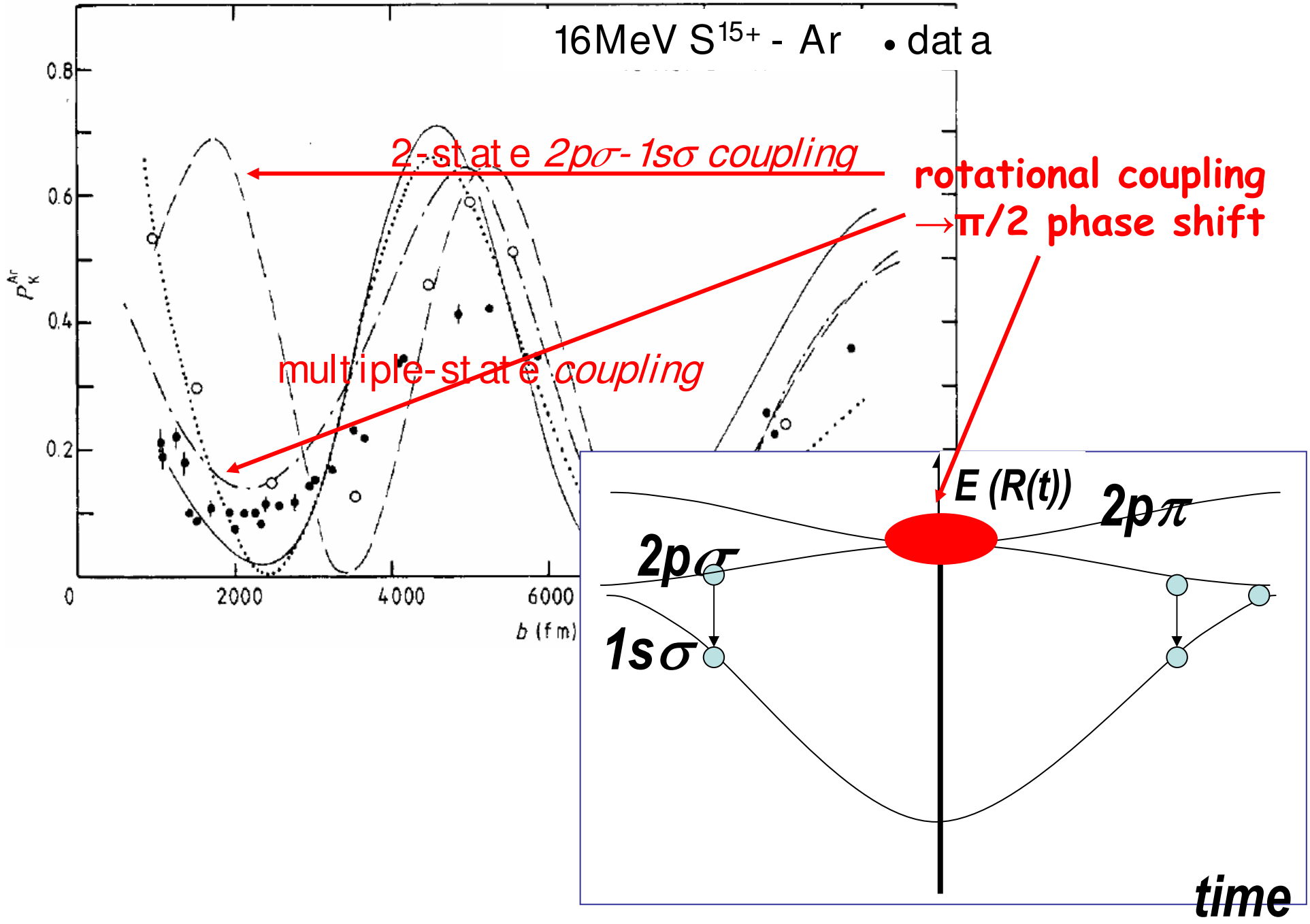
$$\hbar v_p \phi = \int_{b}^{R_c} \Delta E(R)\, R\, \mathrm{d}R (R^2 - b^2)^{-1/2}$$



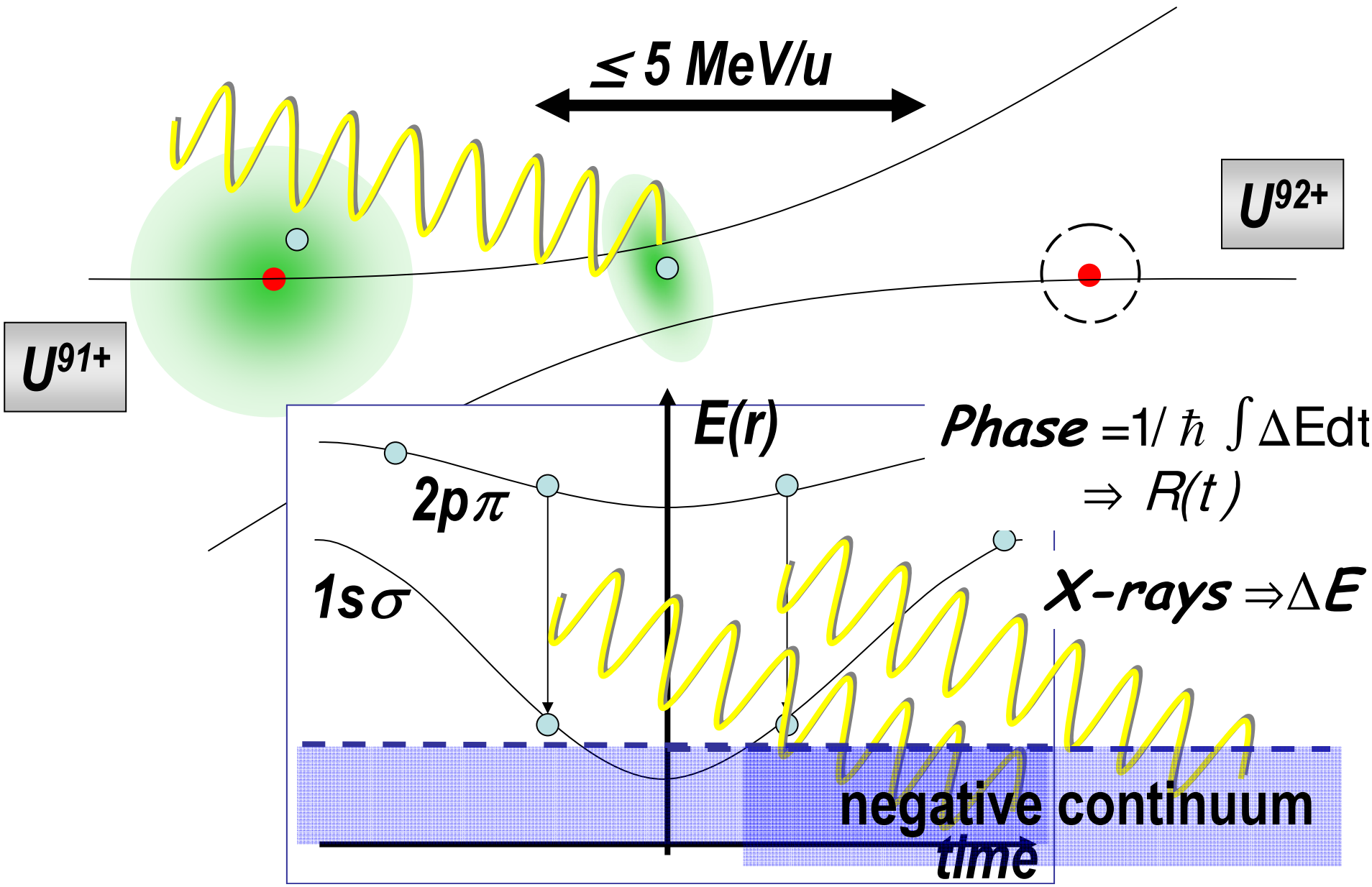
1sσ-2pσ binding energy differences as function of R

R.S. J.Phys.B17,2319('84)

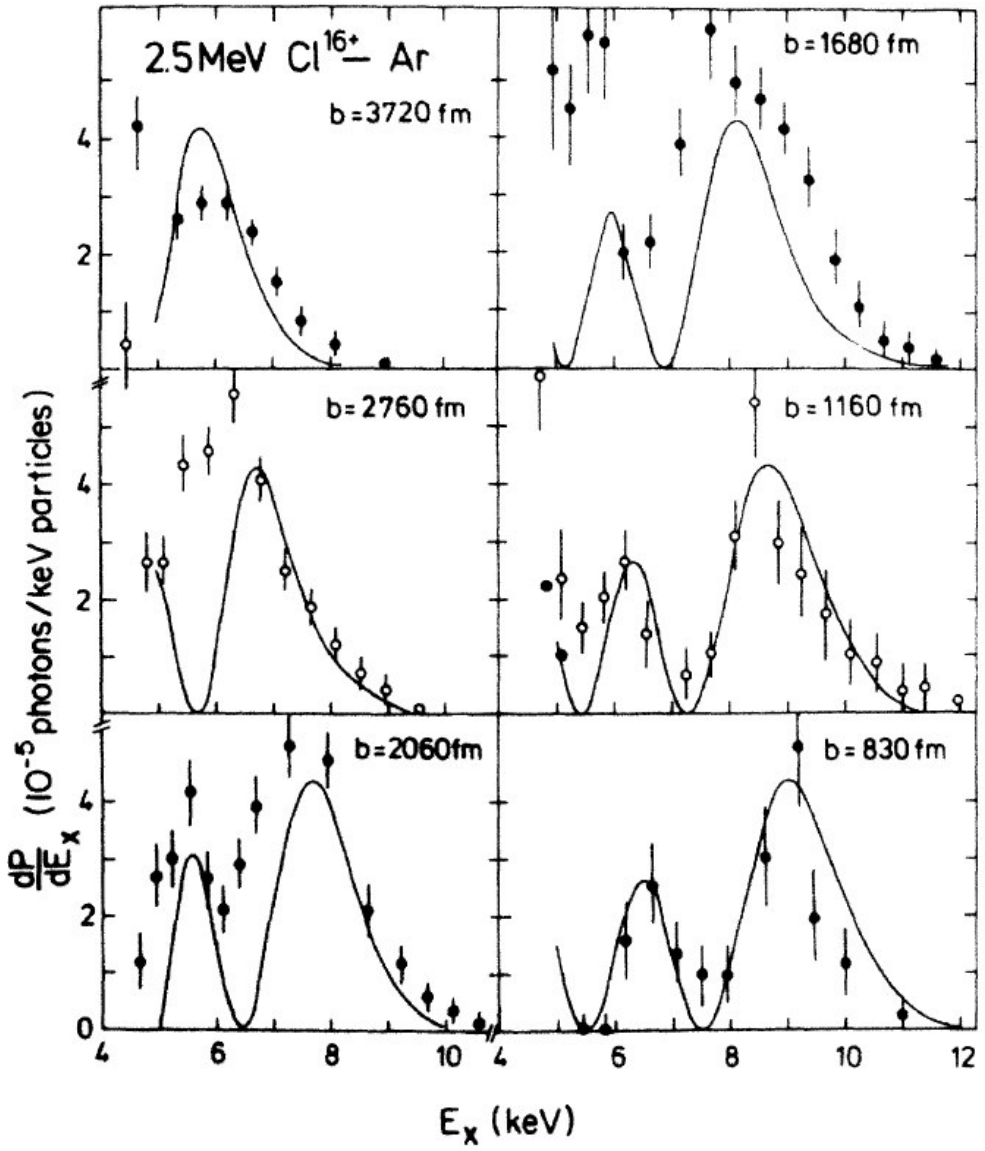
Level of model calculations

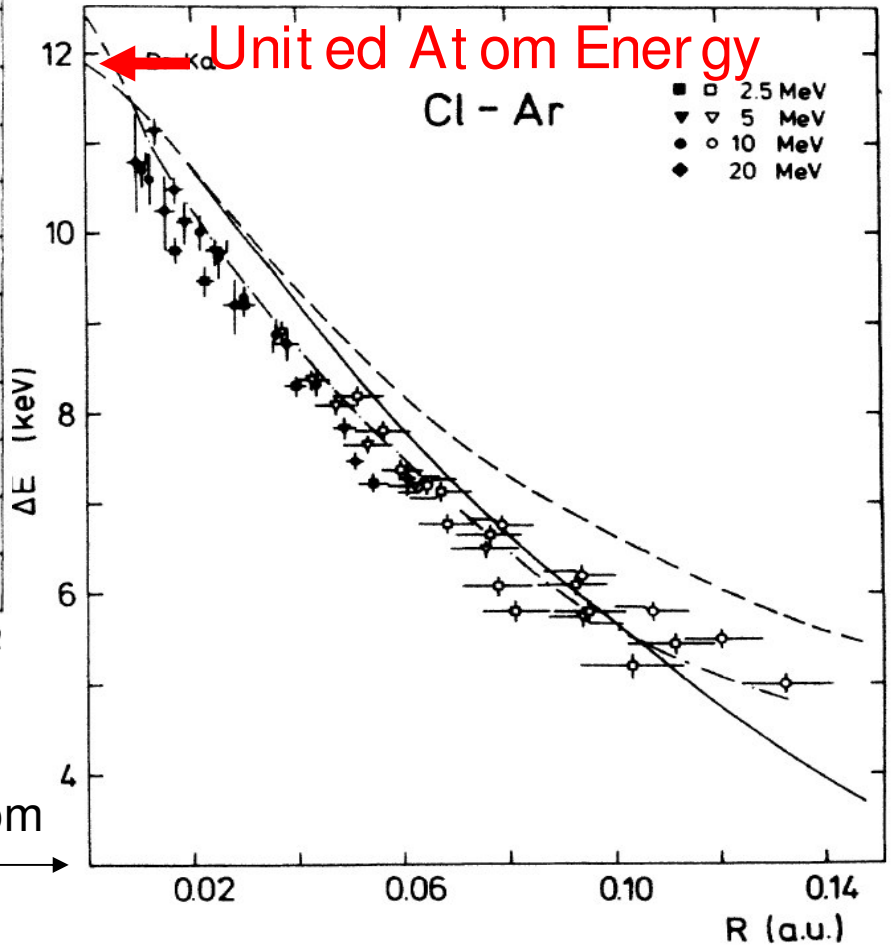


X-ray Emission from Quasimolecule



Test Case Cl^{16+} - Ar (Z_{ua} =35) goal U^{91+} - U (United atom Z=184) for Super Critical Fields,



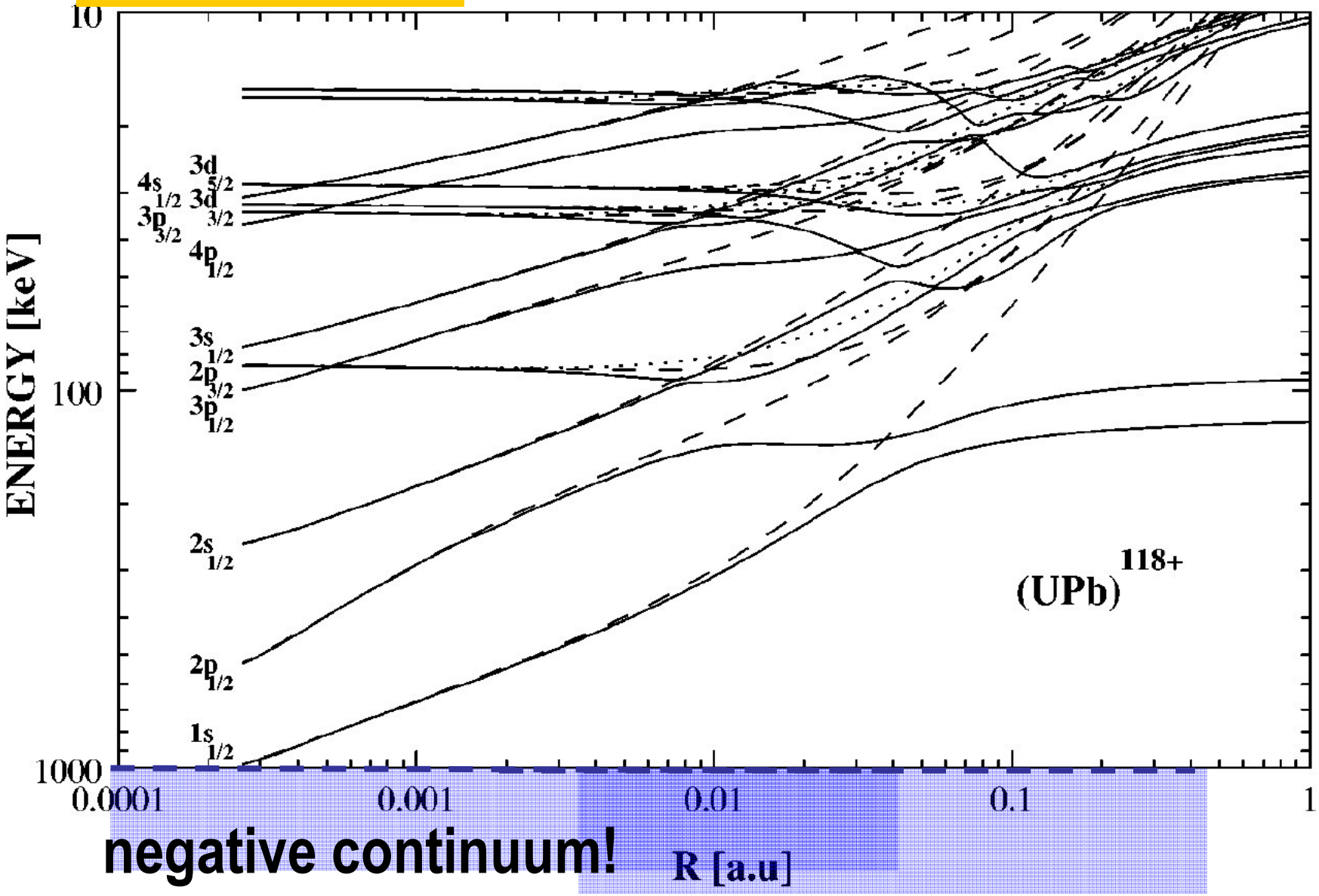


separated atom energies →

R. S. et al., PRA**37**, 3313, '88

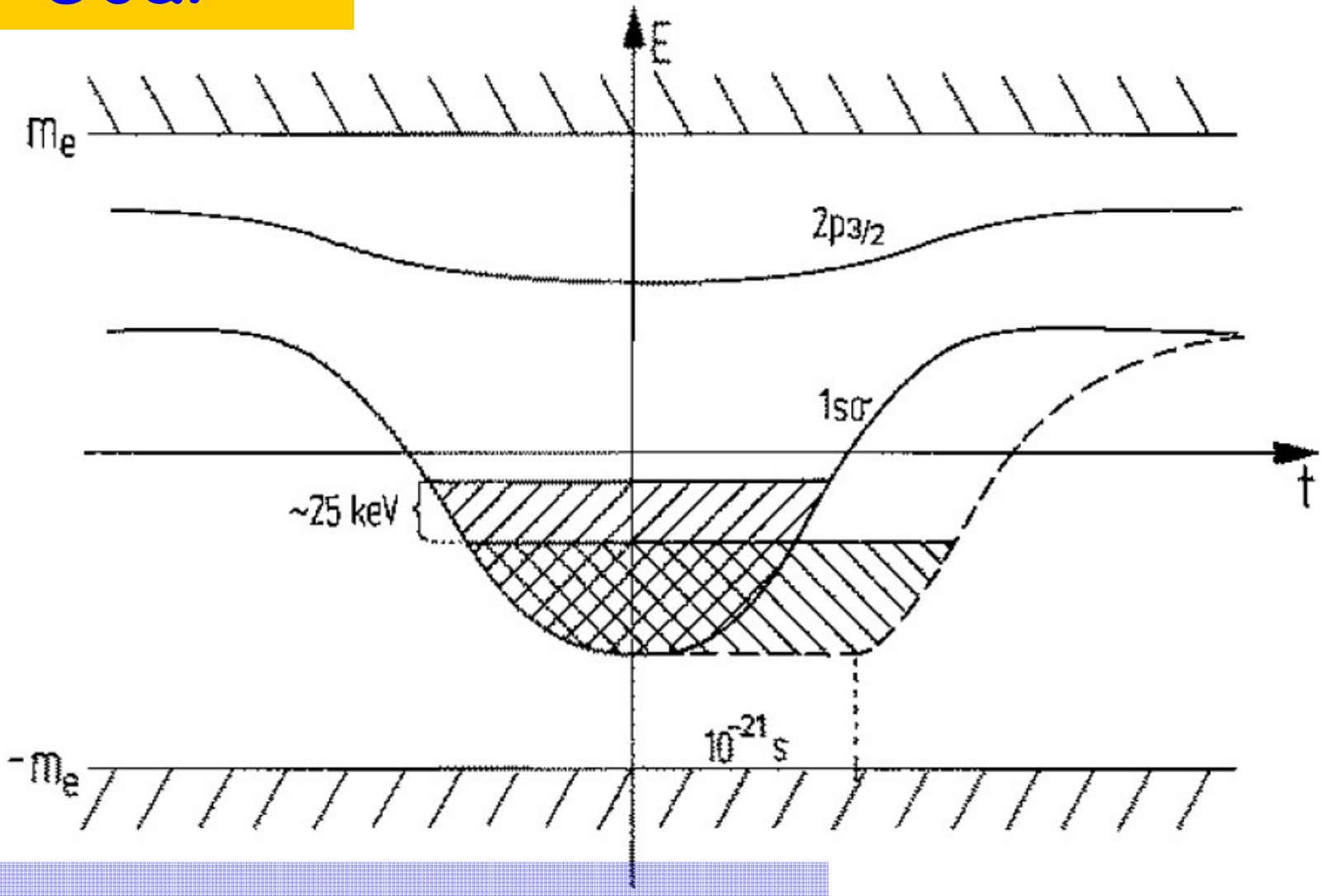
FIG. 9. Transition energies between $1s\sigma$ and $2p\pi$ MO states

Goal:



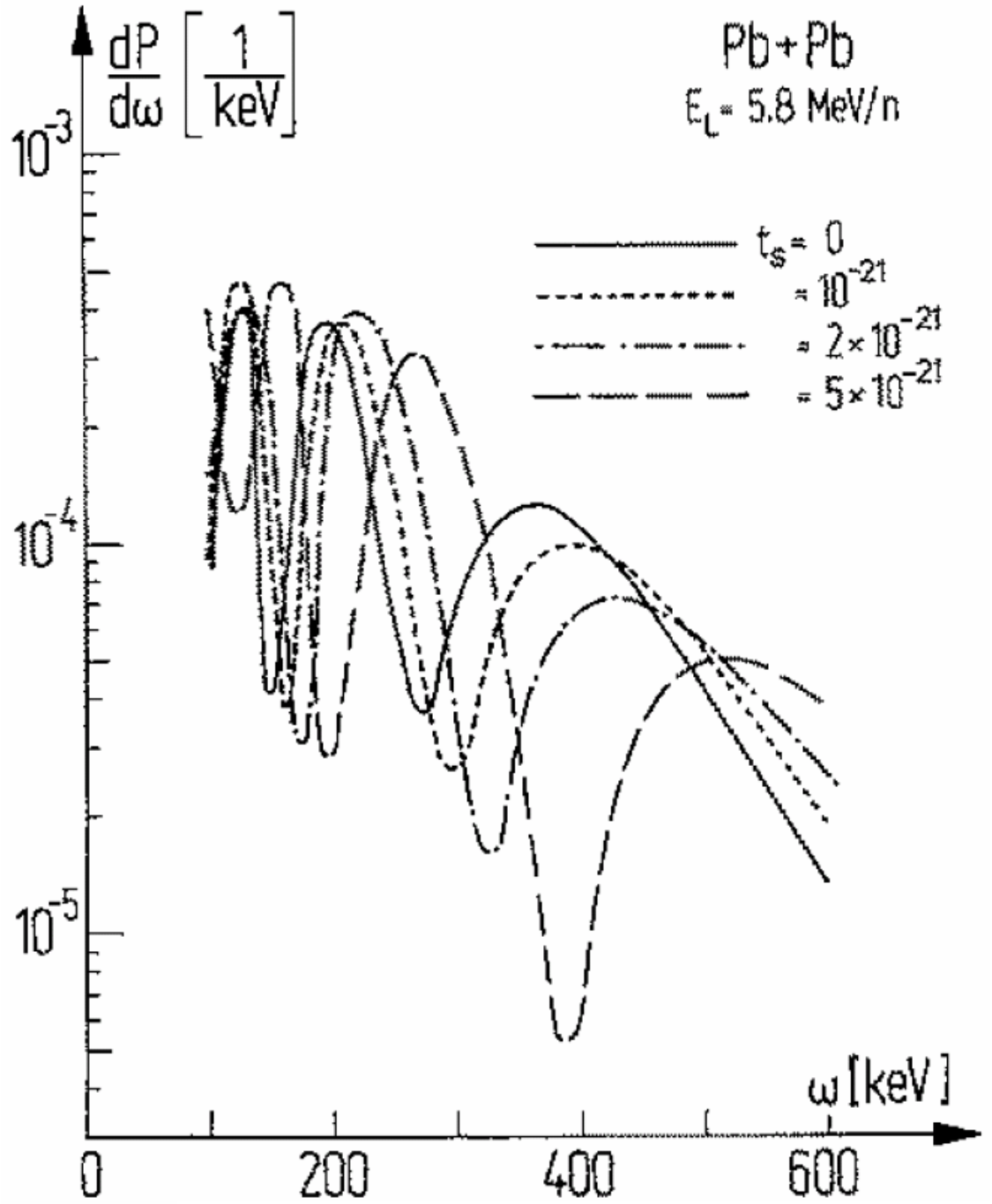
K. Schulze, B. Fricke et al. P.Rev.A59,1578('98)

Goal:



nuclear sticking times!

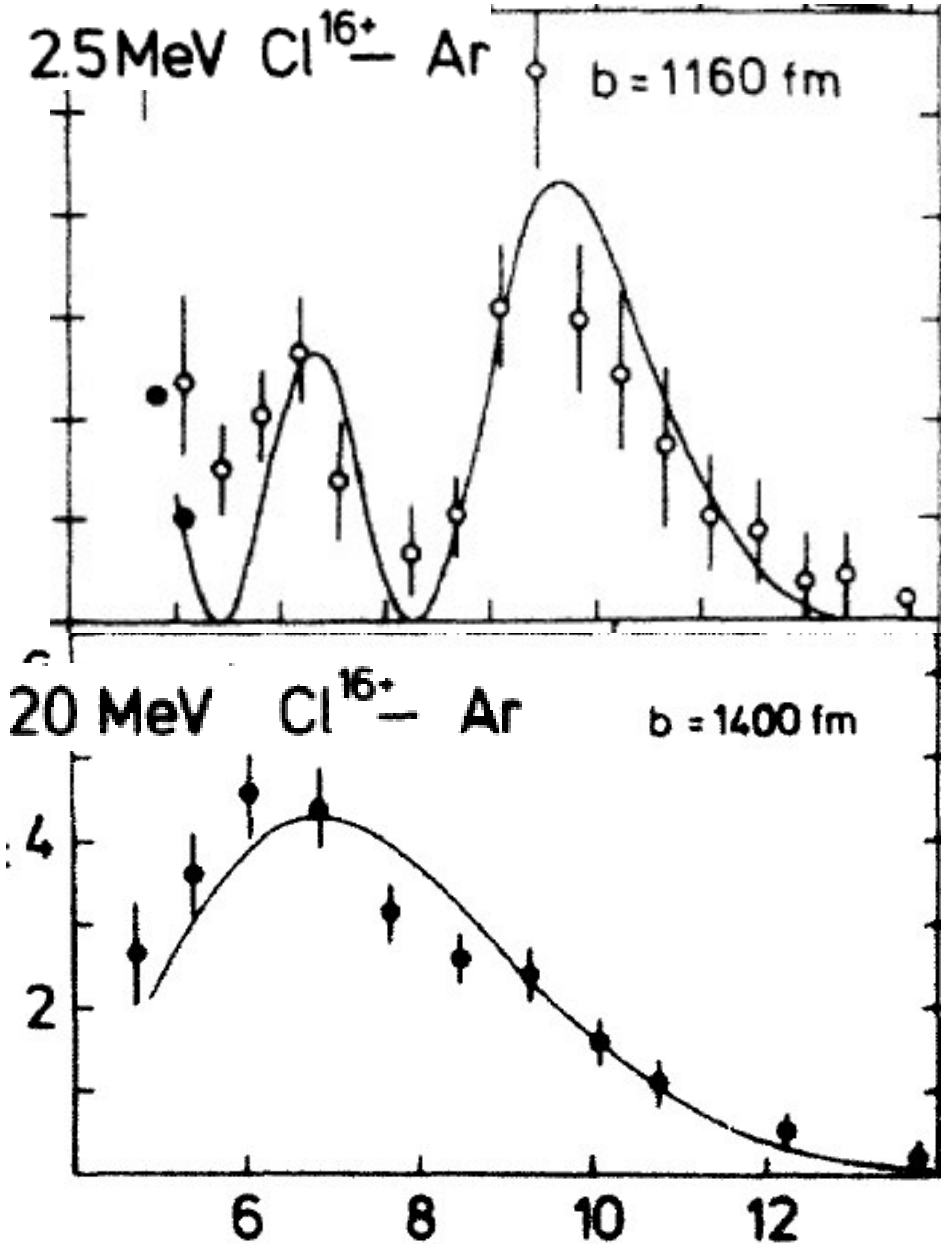
calculation:



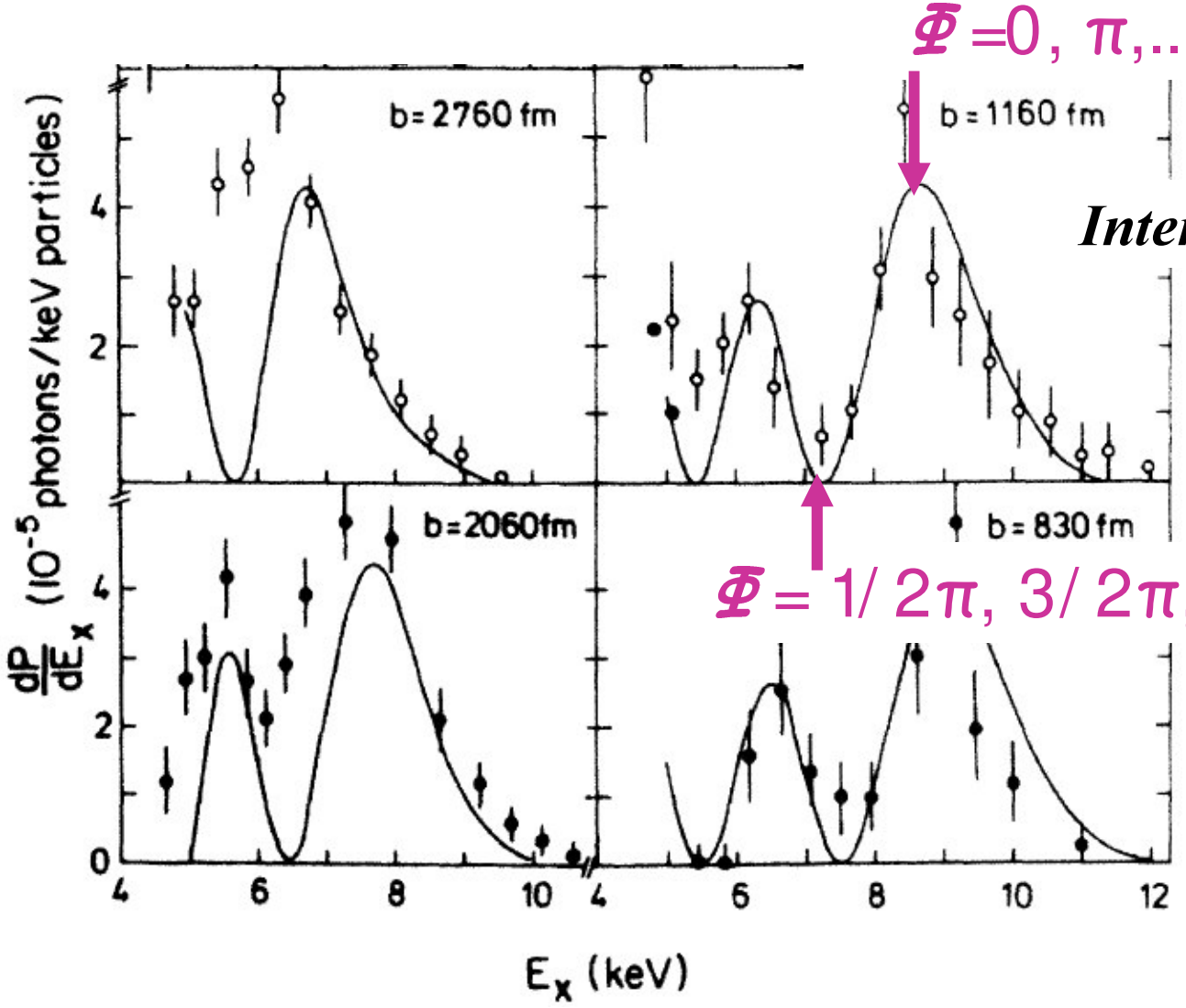
J. Kirsch*, B. Müller, and W. Greiner Z. Phys. D – Atoms, Molecules and Clusters 1, 47–50 (1986)

collision broadening:

$\Delta E\,\Delta t = \hbar$ and $\Delta E_x \ll E(1s\sigma) \Rightarrow$
$\Delta t = 10^{-18}$keVs/keV ($E(1s\sigma)$
$\cong$1MeV) with R$\cong 10^{-12}$m $\Rightarrow$
$v/c \cong 10^{-2} \Rightarrow$ MeV/u



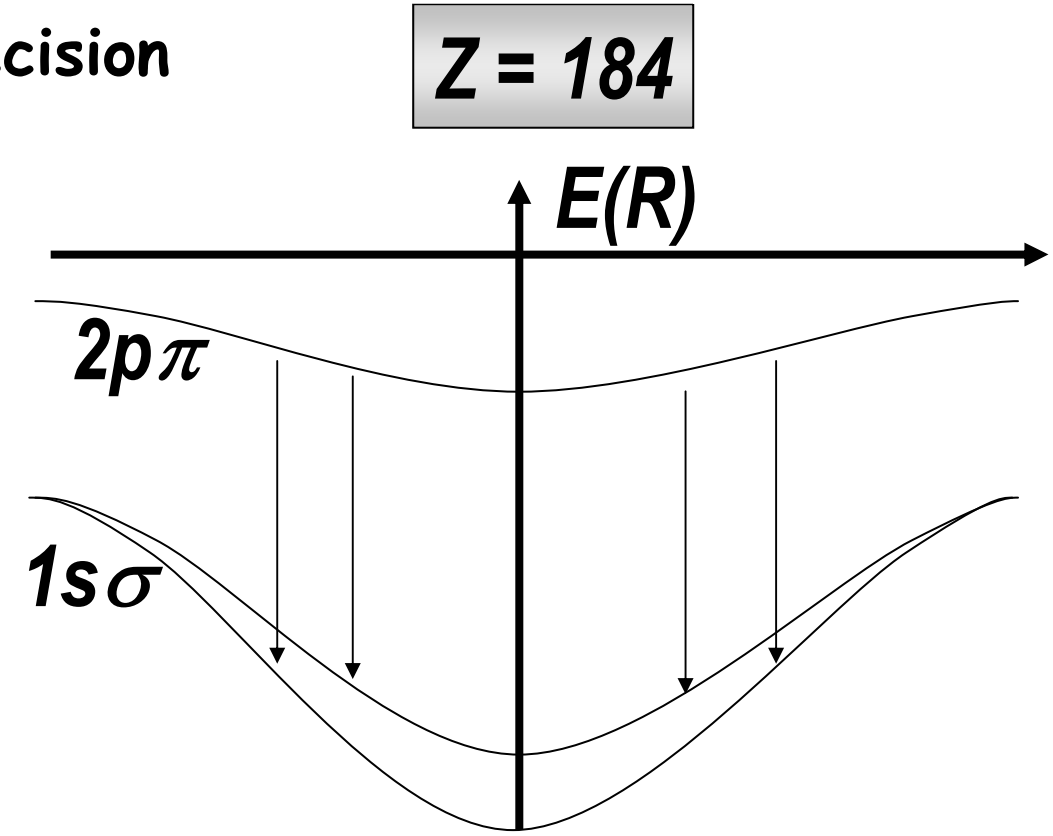
Spectral Shape and Phase Values



$$\Delta\phi = \frac{\pi}{2} \simeq t_{\text{mid}} \mid \omega_{\text{max}} - \omega_{\text{min}} \mid$$

$$\omega_{if}(t_{\text{mid}}) = \tfrac{1}{2}(\omega_{\text{max}} + \omega_{\text{min}})$$

Expected Precision



with $\Delta\Phi/\Delta E_x = 2/\hbar\ t(E_x) = 2/\hbar\ t(R)$ *and*

with $\Delta E(1s\sigma) \cong \Delta E_x \Rightarrow \Delta E(1s\sigma) = \Delta\Phi\ \hbar/2t(E_x)$

assume $\Delta\Phi \cong 0.5$

$\Rightarrow \Delta E(1s\sigma) = 20\ keV$ for E_x up to 500 keV

A few experimental parameters, ESR and later NESR

gas target $\cong 10^{13}$ A/cm^2

Solid angle $\cong \Omega/4\pi = 30\%$

P(400 keV) $\cong 3\ 10^{-5}$ /keV

P(200 keV) $\cong 3\ 10^{-4}$ /keV

$\Delta\sigma_{Rutherf} \cong 10^{-22}$ cm^2

with beam Intens. 10^{10} U^{91+}/s

$\Longrightarrow$ **count rate $\Delta N/\Delta E$ (400 keV) 2 / (h keV)**

extracted beam from (N)ESR:

10^{10} at 5 MeV/u cooled, cycle 100 sec

beam intensity 10^6 U^{91+}/s

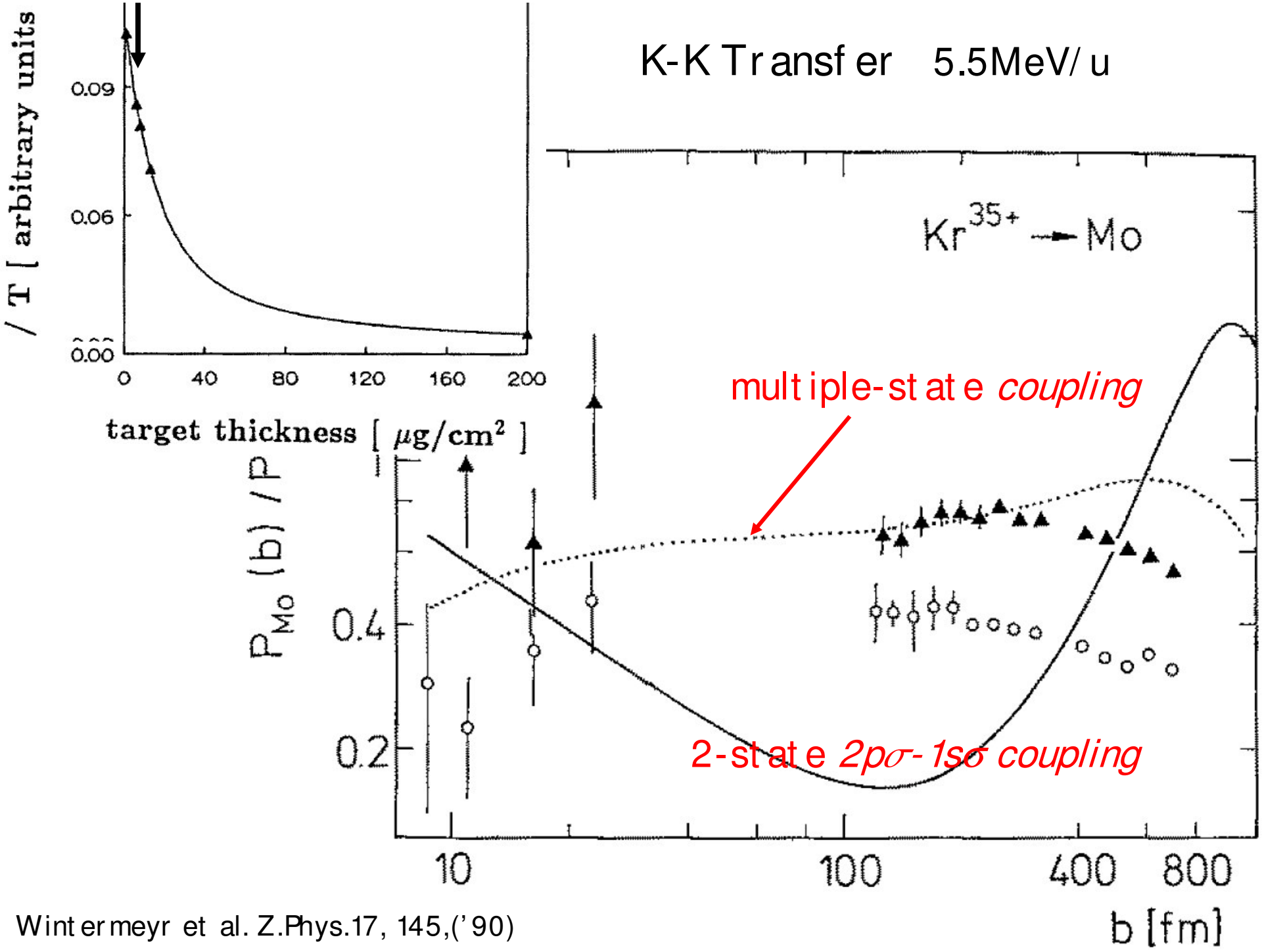
solid target 10^{16} A/cm^2

KK transfer

$\sigma_{KK} \cong 10^{-21}$ cm^2

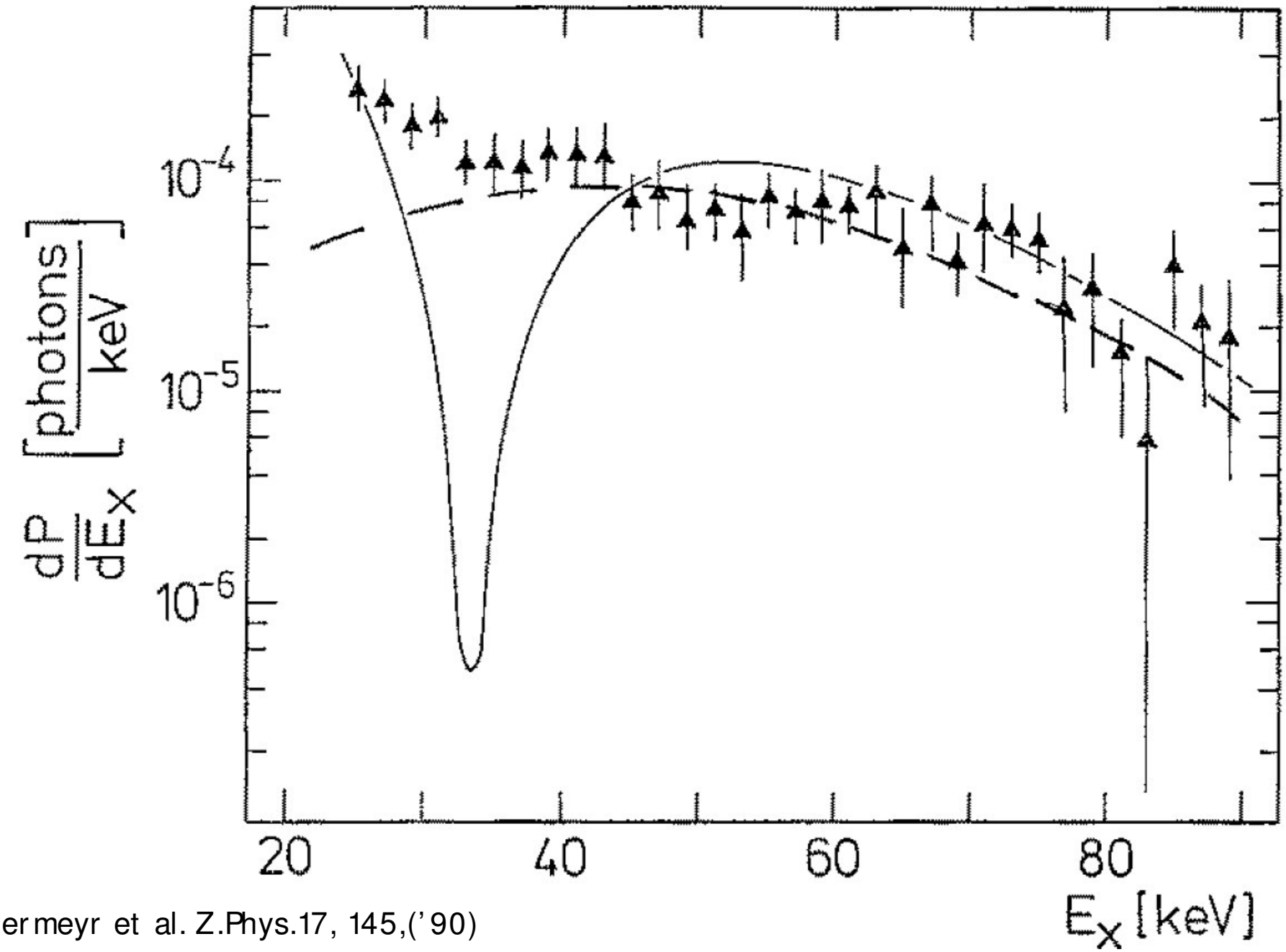
charact. X-ray coincidence rate 2- 10 /s

essential: 1s vacancy needs to survive into the close collision $\rightarrow$ dilute gas target $\Leftrightarrow$ dense solid target multiple collisions occur



Wintermeyr et al. Z.Phys.17, 145,('90)

Quasimolecular X rays 5.5MeV/u Kr^{35+} - Mo



Wintermeyr et al. Z.Phys.17, 145,('90)

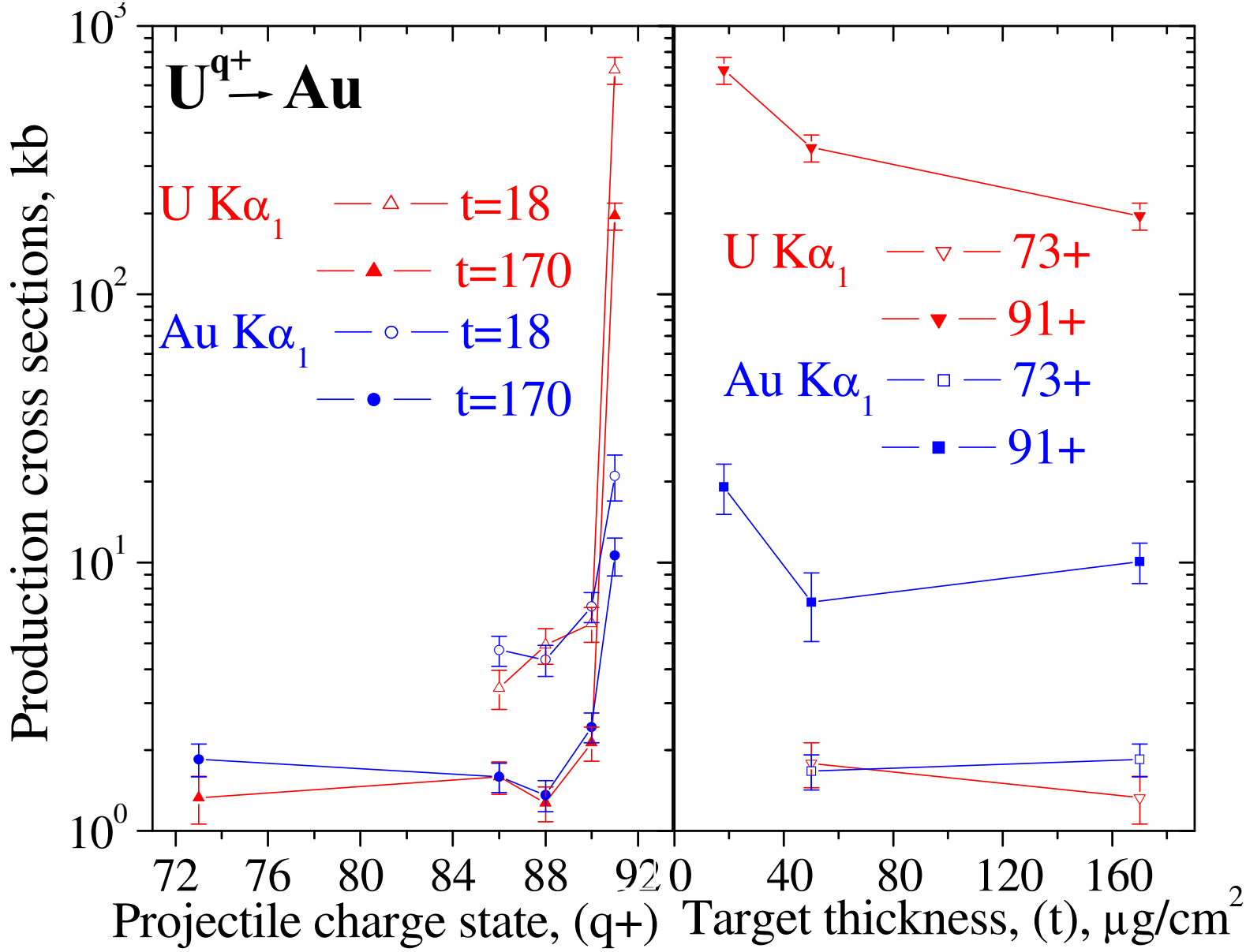


Fig.1 U & Au Kα$_1$ emission cross sections

P.Verma, A. Bråunig-Demian, P.Mokler et al. NIM235,309, 2005

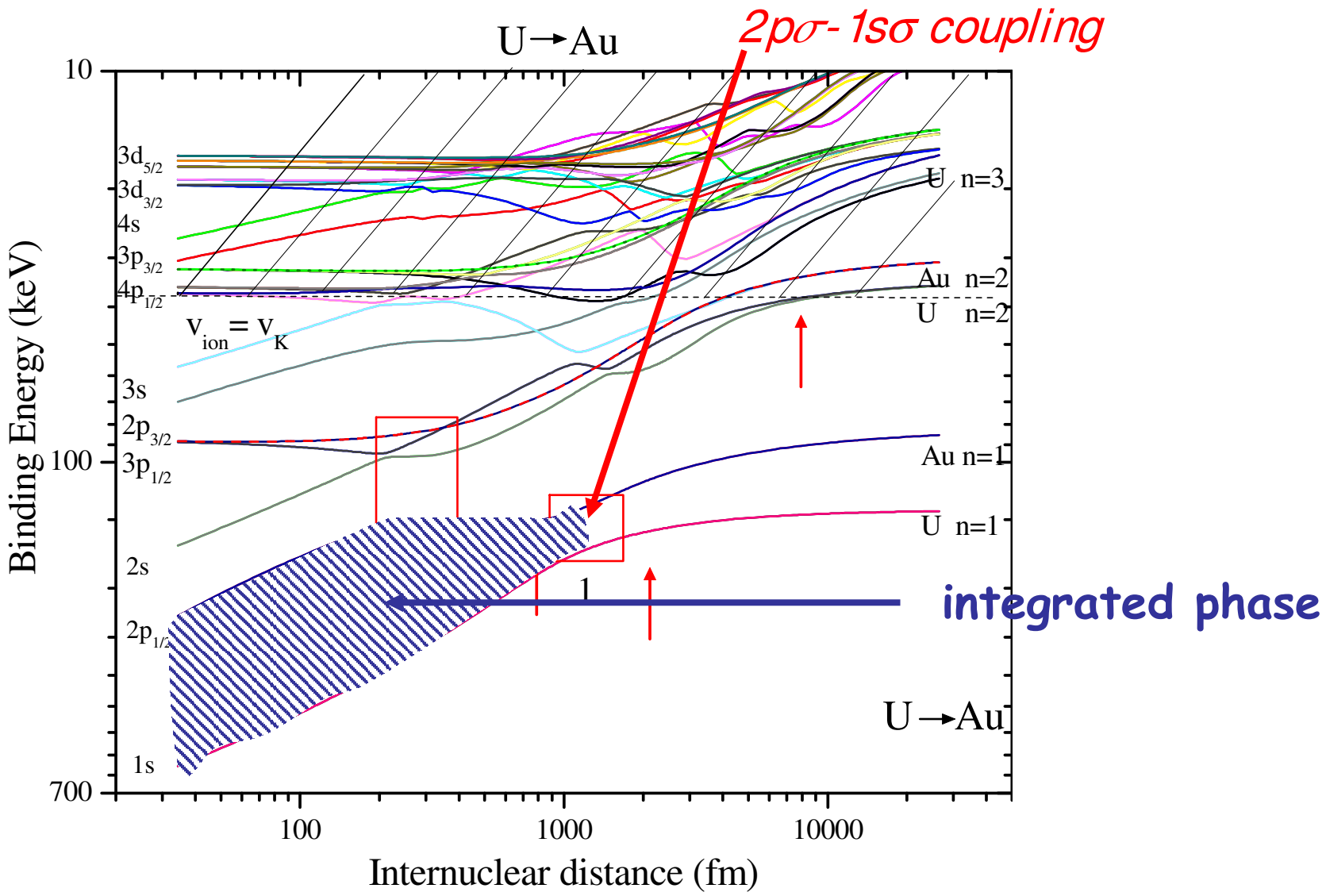


Fig. 6.6. Adiabatic level diagram for the asymmetric U-Au collision system. All the electrons above the region for vion = vK, i.e. shaded

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10^{10} at 5 MeV/u cooled, cycle 100 sec

extracted beam intensity 10^6 U^{91+}/s

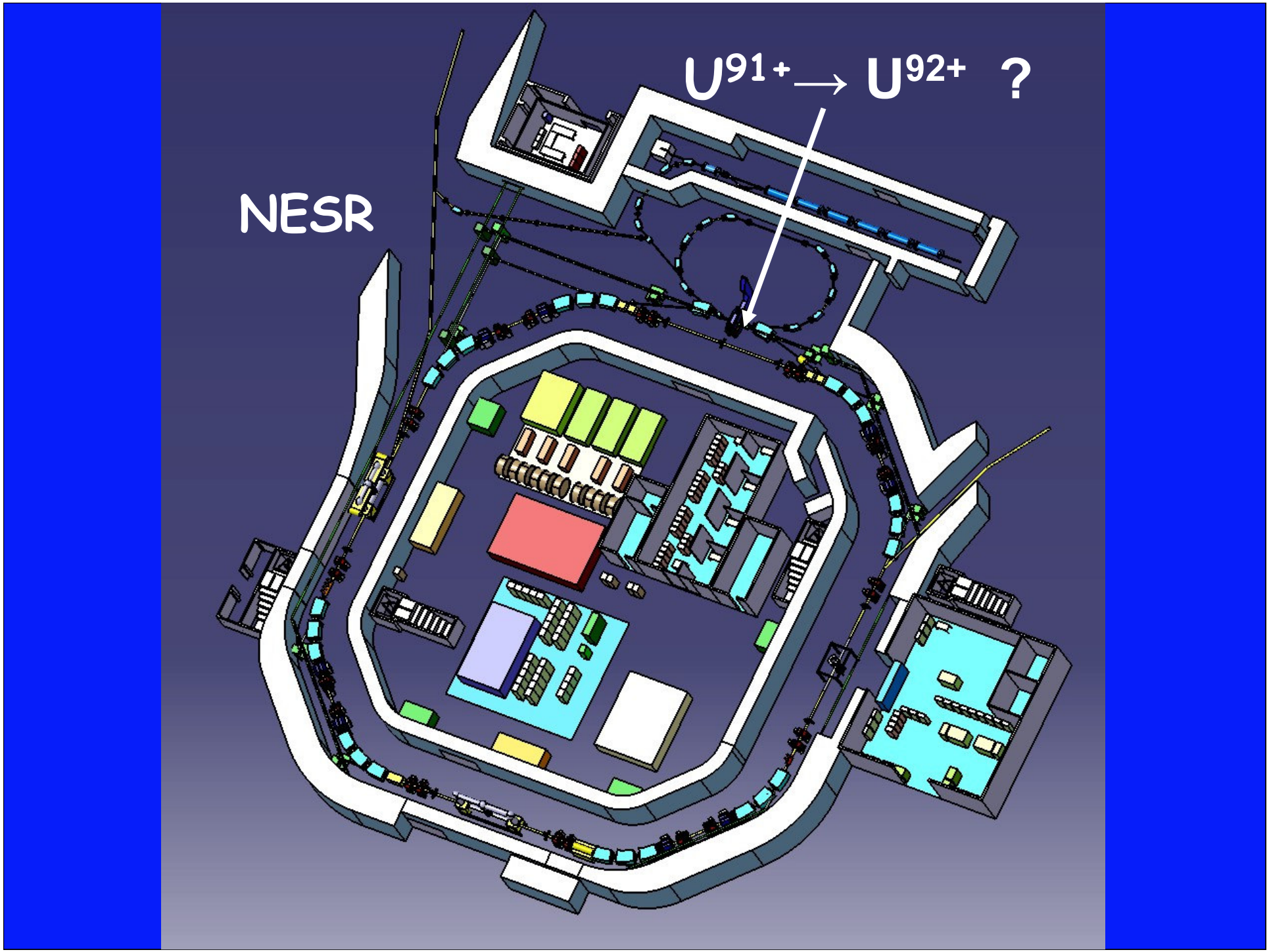
solid target 10^{16} A/cm^2

KK transfer

$\sigma_{KK} \cong 10^{-21}$ cm^2

charact. X-ray coincidence rate 2- 10 /s

essential: 1s vacancy seems to survive into the close collision also in dense thin solid target $\rightarrow$ start-up experiments!


$U^{91+} \rightarrow U^{92+}$?
NESR

Collaborators

MPI + Uni Heidelberg:
***G. Nolte, H.*Ingwersen, G.Wintermeyr, R. Hofmann, J. Ullrich, ...**

Gesellschaft für Schwerionenforschung (GSI) Darmstadt:
F. Bosch, S. Hagmann, D. Liesen, P. Mokler, Th. Stöhlker,....

University Frankfurt:

H. Schmidt-Böcking, K. Stiebing, M. Jäger,....

I. Tserruya *(Weizman Institute)*

K. Jones, B. Johnsson *(Brookhaven Nat.Lab.)*

M. Schulz (Missouri-Rolla)

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+ new collaboration partners:
P. Indelicato(Paris), Y. Yamasaki (RIKEN,Tokyo),