Positron emission in super heavy ion-atom collisions

Decay of the vacuum

GSI-Darmstadt 9.5.2001

Fundamental question:

How behave bound electronic states in supercritical electric fields

or

does the 1sσ state in super heavy ion atom collisions degenerate with the negative energy continuum?

Figure: inner-shell level scheme as function of Z

Figure: excitation processes of vacuum states

Fig. 2. Binding energies of electronic states in atoms as function of nuclear charge Z. At $Z_c = 173$ the 1s-state dives into the negative energy continuum.

Fig. 6. Shows quasi-molecular states of electrons in a heavy-ion collision and indicates various excitation processes: (a and b) ejection of electrons out of the 1s-state, (c) spontaneous positron emission, (d and e) dynamical mechanisms of pair-production involving vacant bound states, (f) direct pair-production (shake-off of the vacuum polarization cloud).

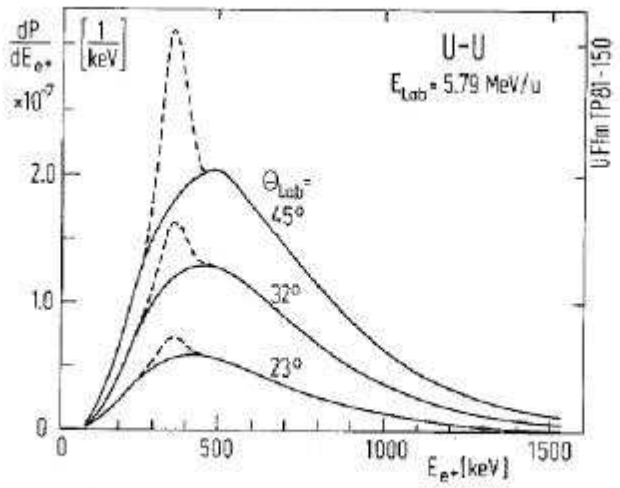


Fig. 22. Spectra of positrons emitted in 5.8 MeV/u U + U collisions in coincidence with a scattered nucleus for three selected lab. ion angles. The fully drawn curves are calculated assuming Rutherford scattering only. The dashed lines show the effect of an additional nuclear reaction with a lifetime $T = 4 \times 10^{-20}$ s. A relative fraction of $q = 2.4 \times 10^{-3}$ reactions per elastically scattered ion (at 45°) has been assumed.

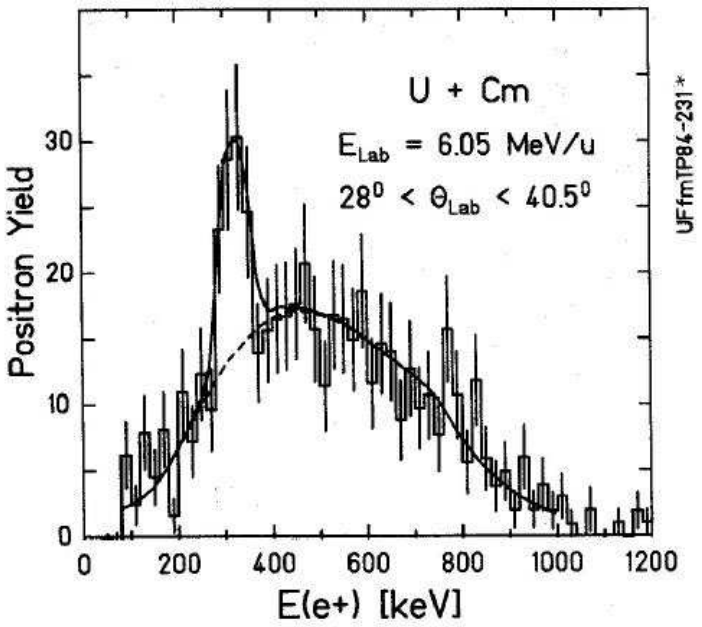


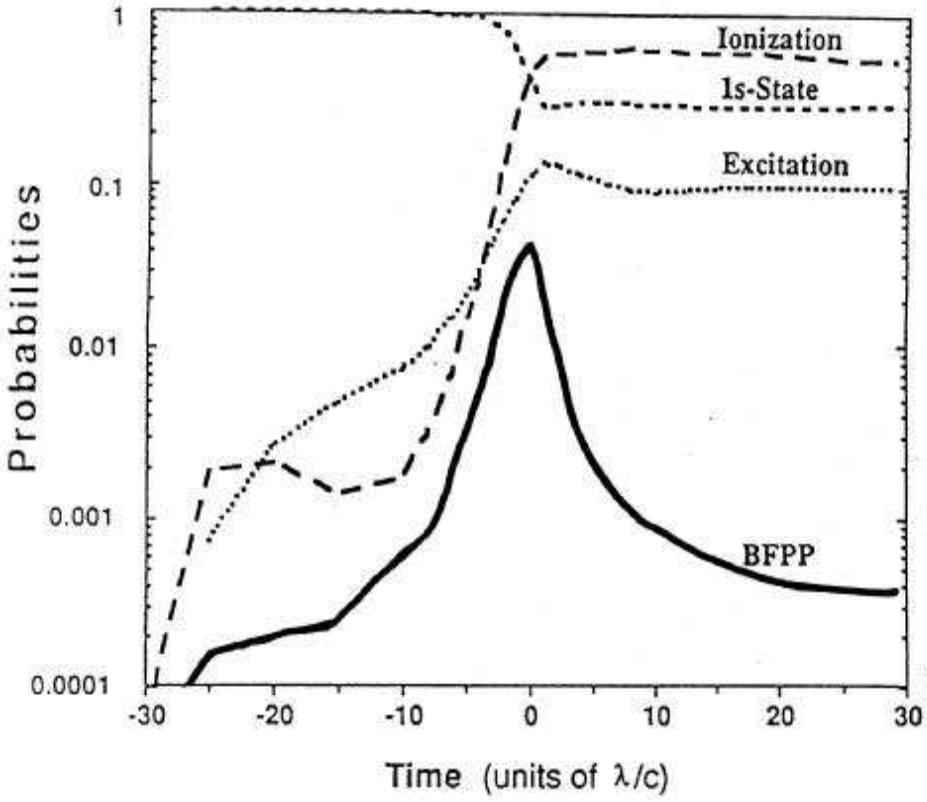
Fig. 23. The U + Cm positron spectra at 6.05 MeV/u[63] show a remarkable structure in the selected region of scattered particles. Theoretical results (at $E_{lab} = 5.8$ MeV/u, folded with the detector efficiency) are compared with the experimental positron yield. The line structure can be explained by a nuclear reaction component with a delay time $T = 10^{-19}$ s and an admixture ratio $q = 10^{-3}$.

experimental problem:

1. create 1sσ vacancy during collision after passing distance of closest approach (Tenzer 16)

Momberger, Belkacem und Sorensen [Europhys.Lett. 32 (1995)]

Au + U, E_{Lab} = 0.93 GeV/Nukleon, b = 0



pair production with captu

2. strong dynamically induced virtual photon

field =>dynamically induced pair creation

3. nuclear background etc.

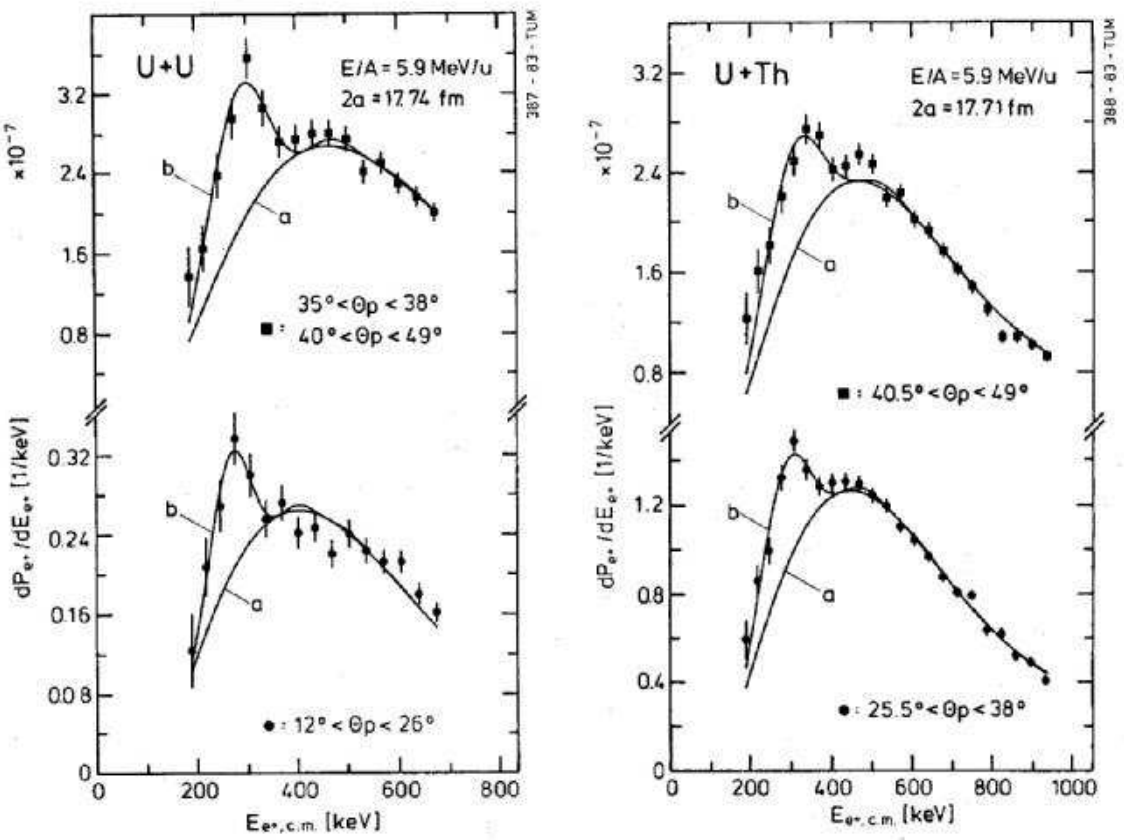


Fig. 24. Positron spectra of U + U and U + Th collisions measured by C. Kozhuharov, P. Kienle *et al.* (cf. Fig. 16) at two different scattering angle windows. Line (a) represents spectra expected from Rutherford trajectories, line (b) includes in addition positrons from a giant nuclear complex living for several times 10^{-20} s (Fits by U. Mueller).

resumee: *new* experiments (GSI and Argonne) show no evidence for line structure due to spontaneous decay

**(pure Coulombic trajectory
and even with nuclear stacking time)**

Desireable *key* experiment for *decay of vacuum* effect:

must vary and controle the key parameter:
$1s\sigma$ vacancy probality $P^{1s\sigma}(b,R,t)$

this never done so far

in all experiments so far projectile charge state $q<<Z^p-2$

thick solid targets used => charge state distribution $q<Z^p-2$

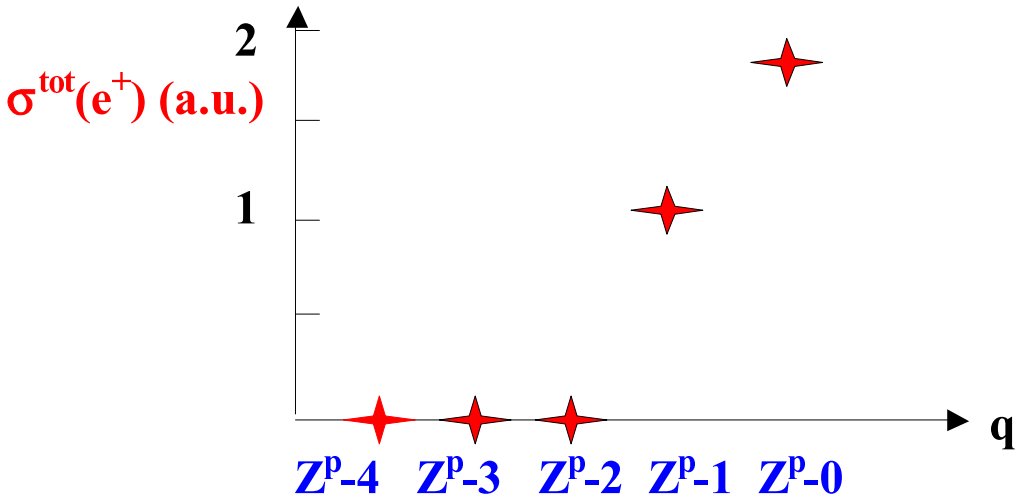
⇨ **incoming ion has no $1s\sigma$ vacancy**

proposal experiment:

vary projectile charge state from q= Z^p-3 to Z^p

q	Z^p-3	Z^p-2	Z^p-1	Z^p-0
$P^{1s\sigma}$(b,Rmin,t)	$<10^{-4}$	$<10^{-4}$	10^{-2}	2.10^{-2}
$\sigma^{tot}(e^+)$ a.u.	$<10^{-3}$	$<10^{-2}$	1	2

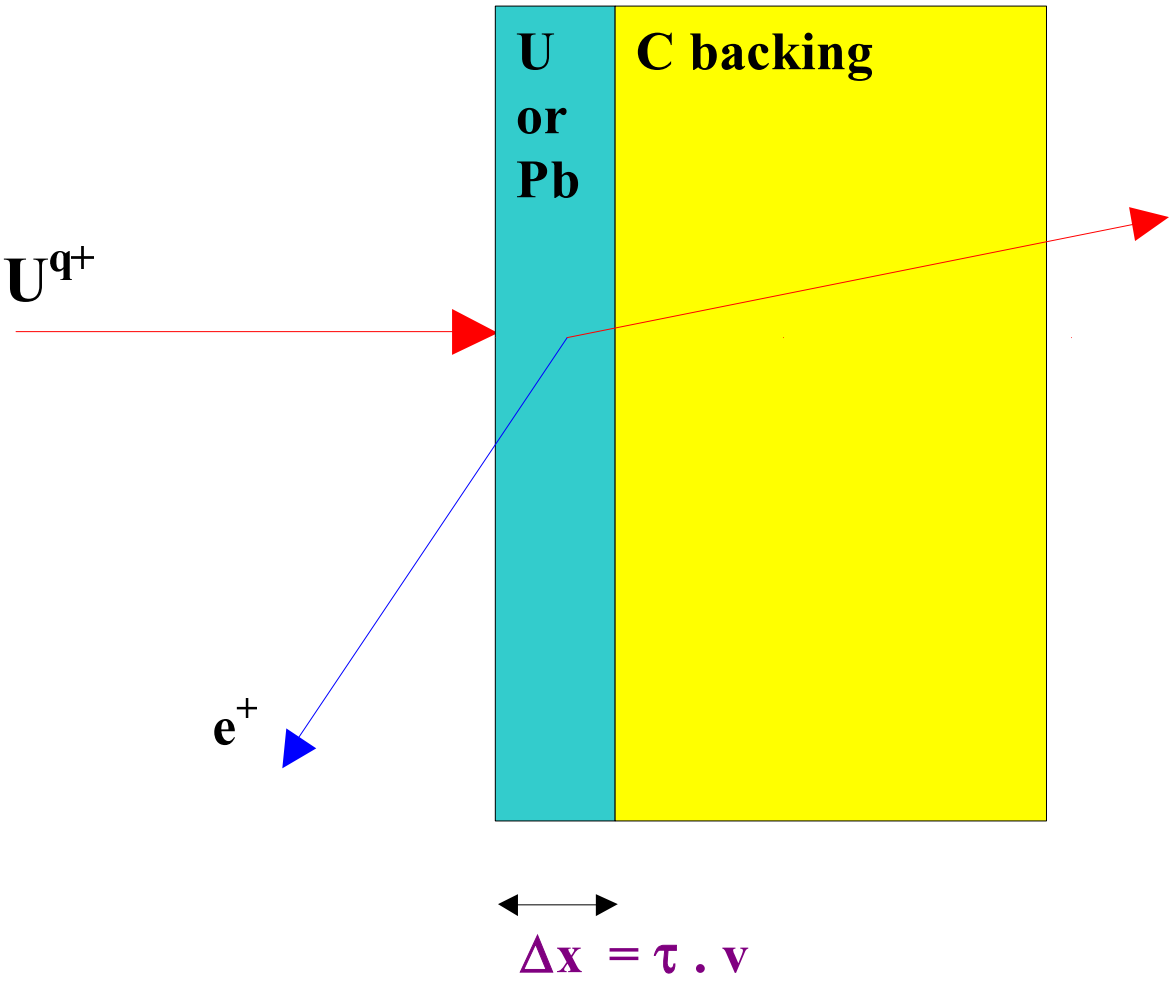
Expectations:



Problem:

when H-like U projectile penetrates target
=>
K - vacancy filling within 10^{-17}sec

Need special sandwhich target:



$\tau = 10^{-17}$sec is K vacancy life time in solid

at 6MeV/u => Δx = 2 atomic layers
at 600MeV/u => Δx = 20 atomic layers

expected positron yield => 511keV yield per ion:

q	Z^p-3	Z^p-2	Z^p-1	Z^p-0
$P^{1s\sigma}$(b,Rmin,t)	$<10^{-4}$	$<10^{-4}$	10^{-2}	2.10^{-2}
$\sigma^{tot}(e^+)$ barn	$<10^{-1}$	$<10^{-1}$	10	20

511 keV detection rate:

$$\Delta N^{e+} = N^p\, N^T\, \sigma^{tot}(e^+)\quad \Delta\Omega(511keV)/4\Pi$$

$$= N^p\, .10^{-8}/sec$$

Collaborators:

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