Experimental Studies of the Energy Dependence of State-Selective Non-Dissociative Single Electron Capture in He^{2+} on H_2 Collisions

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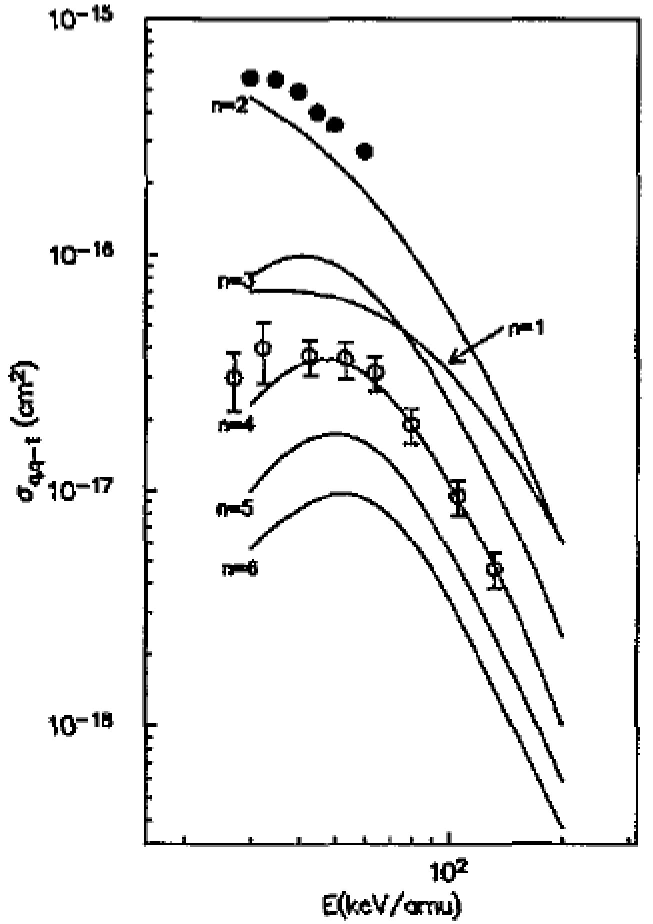

Figure 2. Cross sections for one-electron capture to $He^+(n)$ states as a function of He^{2+} energy. Full curves, CTMC calculations; full circles, $n = 2$ results obtained using present line emission cross sections and the data of Shah and Gilbody (1978)—see text; open circles with error bars, experimental data of Frieling *et al* (1992) for $n = 4$.

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$$He^{2+} + H_2 \rightarrow \begin{cases} He^+(n,l) + H_2^+ \\ He^+(n,l) + H_2^{2+} + e^- \end{cases}$$

Smallness of capture to n = 1

$$\boxed{\sigma(1s) = \sigma(\text{total}) - \sigma(np \rightarrow 1s) - \sigma(2s)}$$

these state-selective electron capture cross sections are needed to help model alpha particle transport and confinement in tokamak fusion plasmas where fast alpha particles are either produced in the D–T fusion reaction or through He neutral beam heating.

Model description for single-electron transfer in slow-ion–H_2-molecule collisions: Studies for H^+, He^{2+}, and C^{4+} projectiles

Wolfgang Fritsch

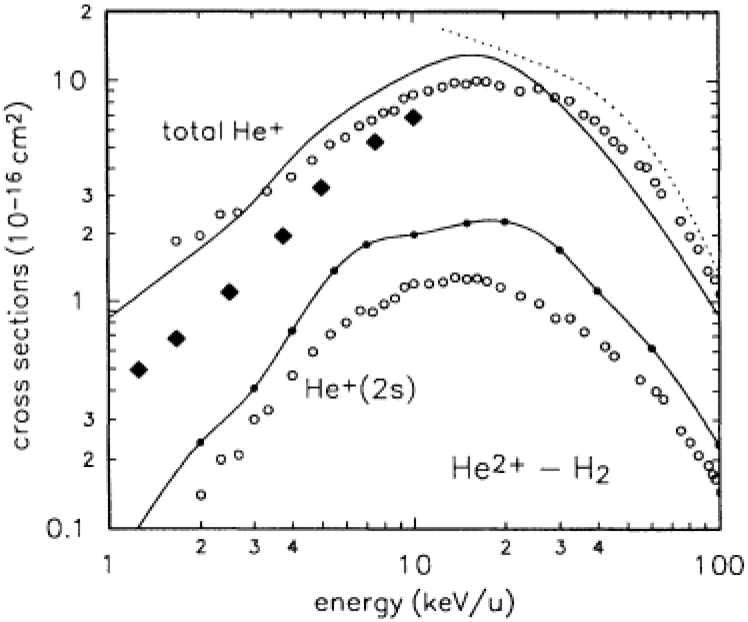


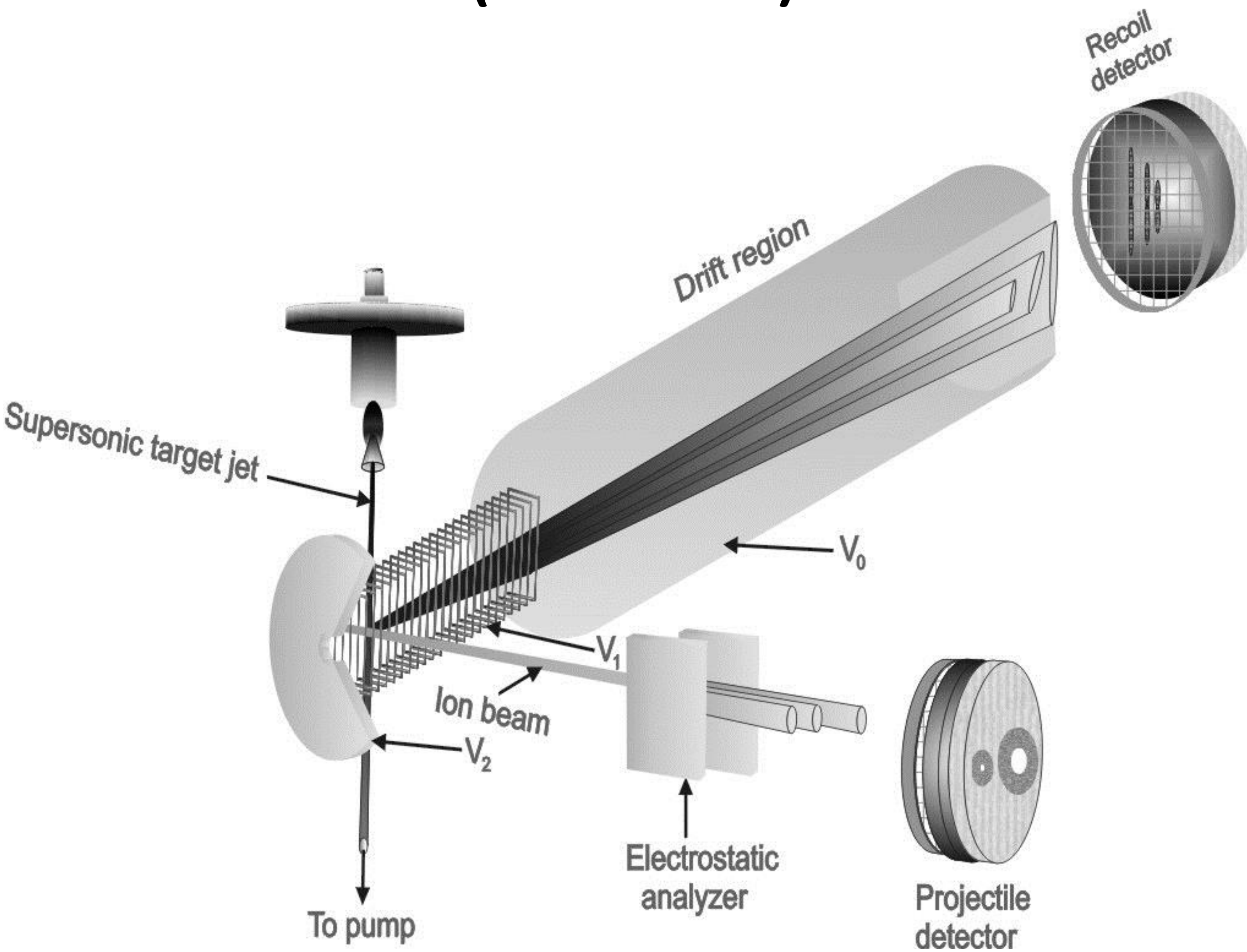
FIG. 6. Calculated transfer cross sections in He^{2+}-H_2 collisions from this work (full lines) are compared to the data by Shah and Gilbody [20] (circles), and to cross sections calculated by Shingal and Lin [8] (dotted line). The upper pair of results are for total He^+ production, the lower pair for $He^+(2s)$ production. The diamonds designate measured cross sections for $He^+(2p)$ production by Ciriè *et al.* [17].

He^{2+}-H_2 collisions

The He^{2+}-H_2 collisions, electron transfer is known to populate mainly the $He^+(n=2)$ states, similarly as in the He^{2+}-H system [1,17–19]. For the close-coupling calculations with the $L=0$ assumption, we have chosen a basis which includes, besides the initial state, the $n=2$ capture states as products of the $He^+(n=2)$ states with the 1s (1.0945) state of the remaining electron at the location of the molecule. Also pseudostates have been included in

the calculations of this work include, in an explicit manner, only the He^+ $n=2$ transfer states

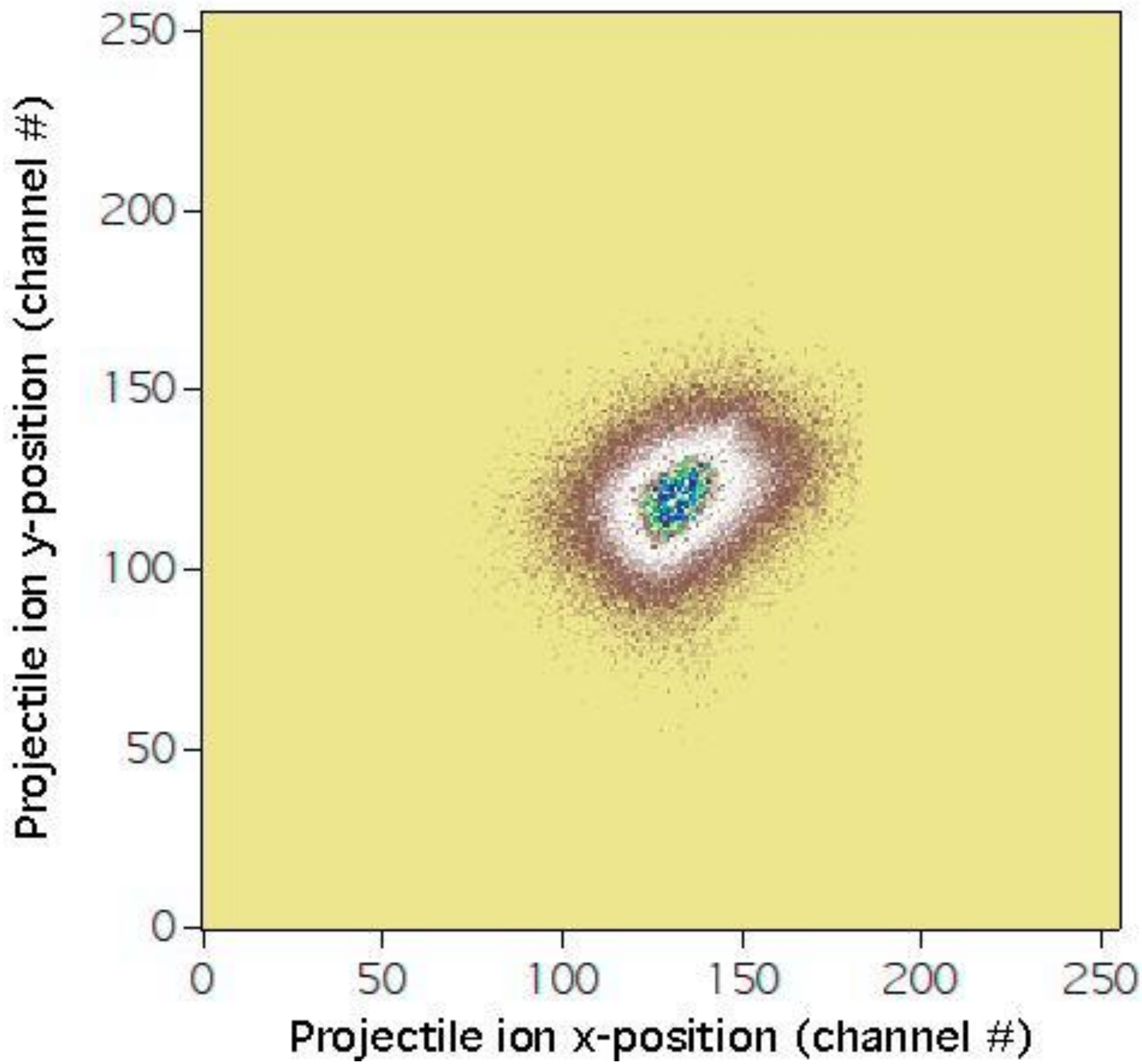
Cold Target Recoil Ion Momentum Spectroscopy (COLTRIMS)

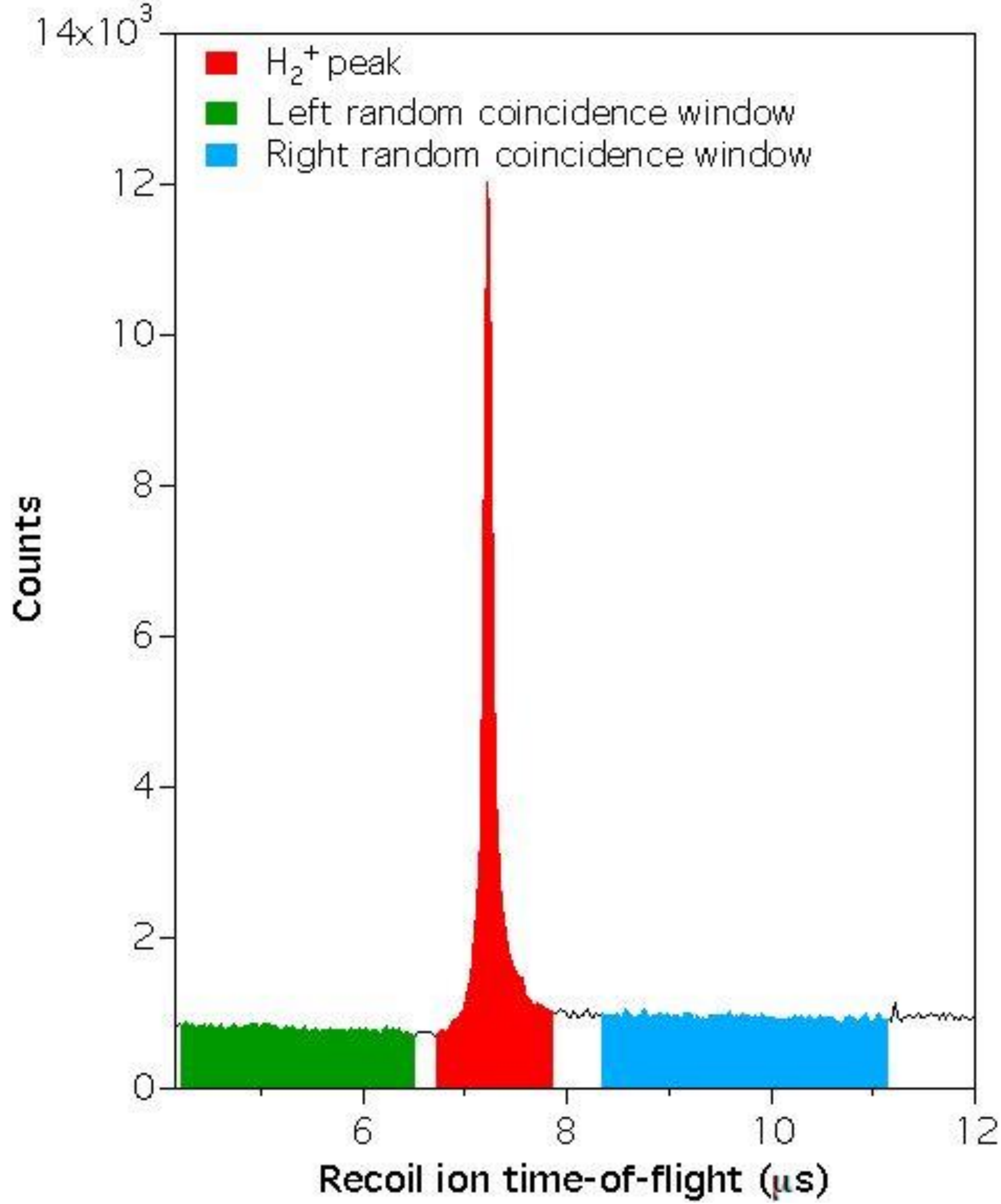


$$Q \approx -(P_{long}\, v + i v^2/2)$$

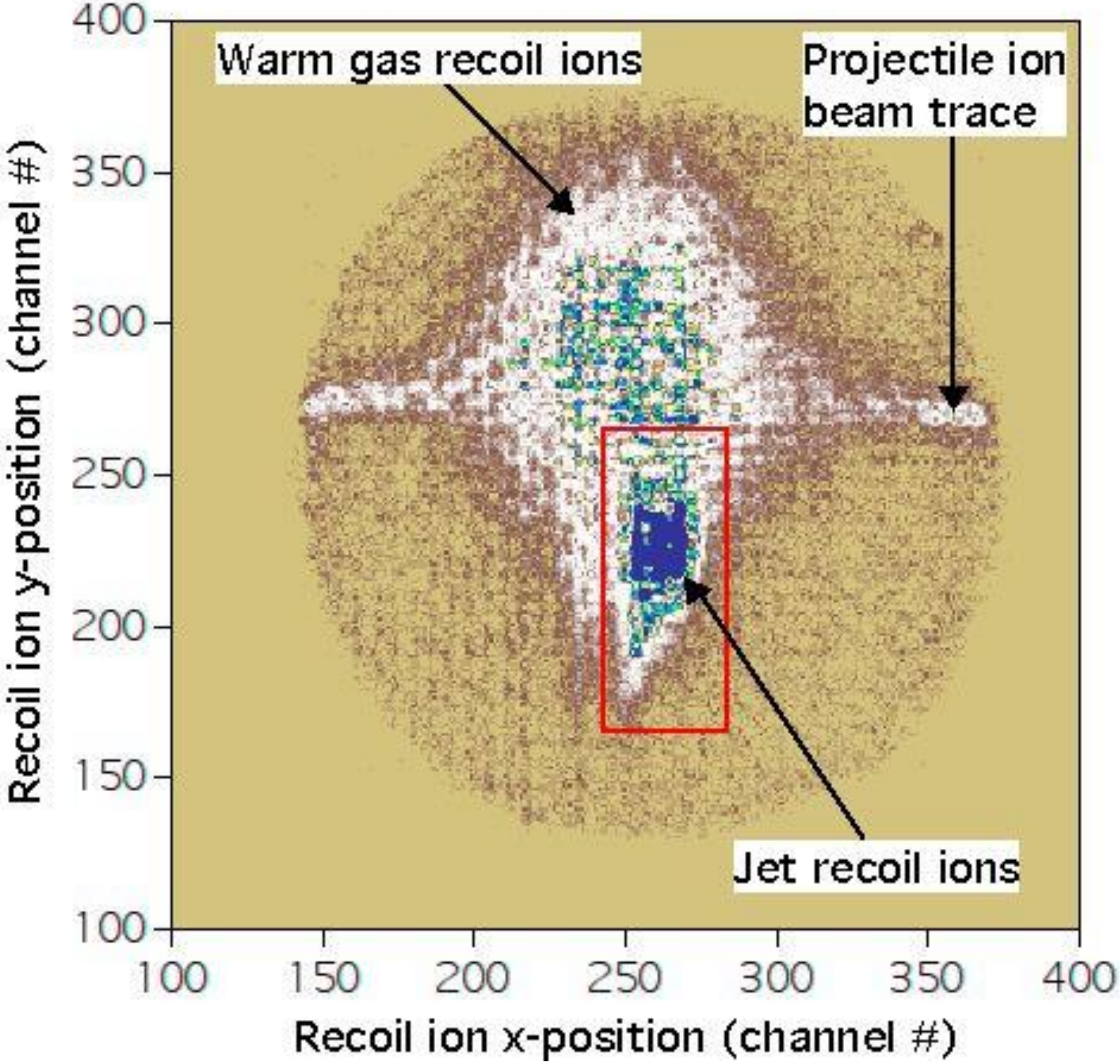
Scattered He^{+} projectile ions

(150 keV $He^{2+} + H_2$)

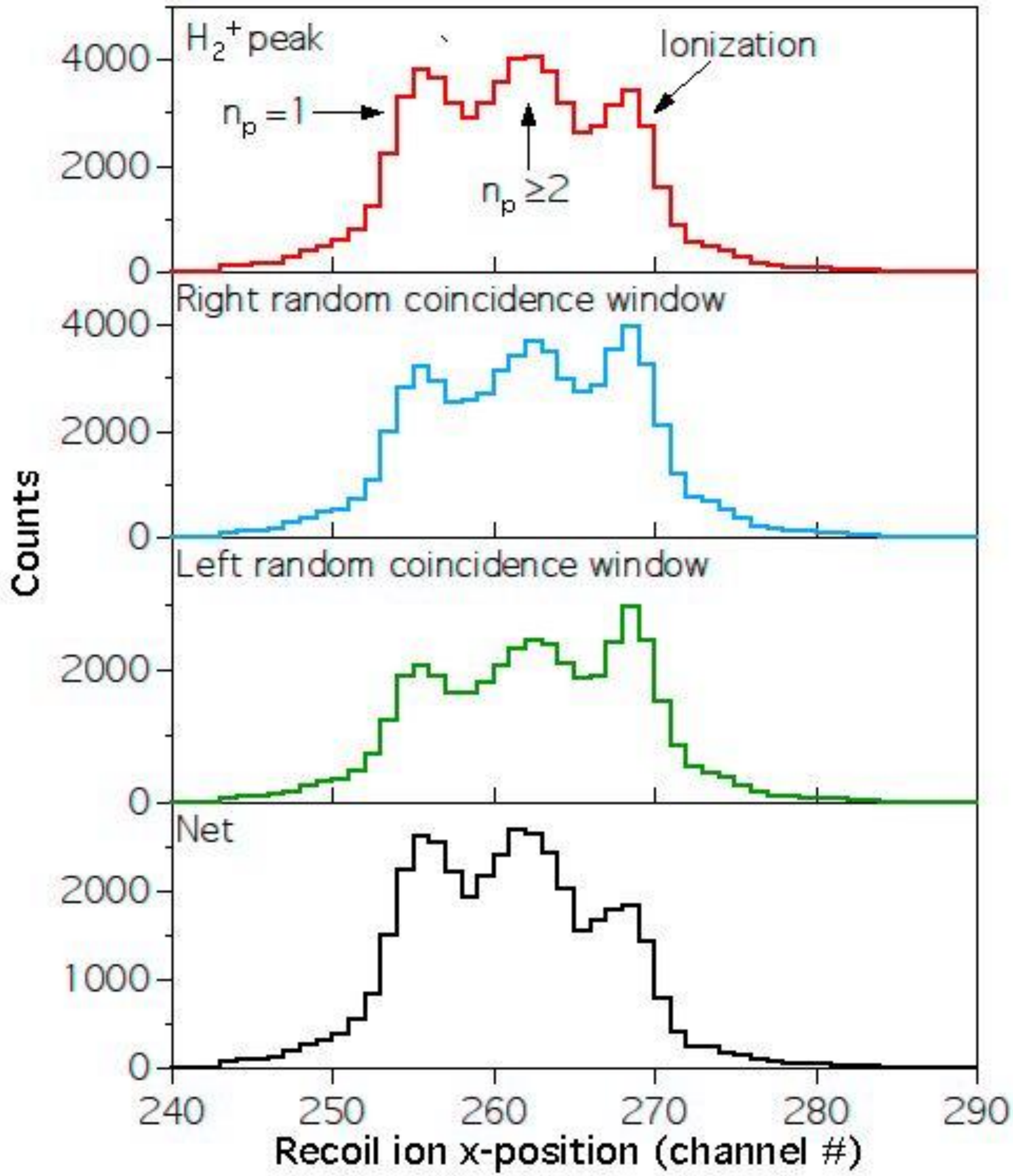




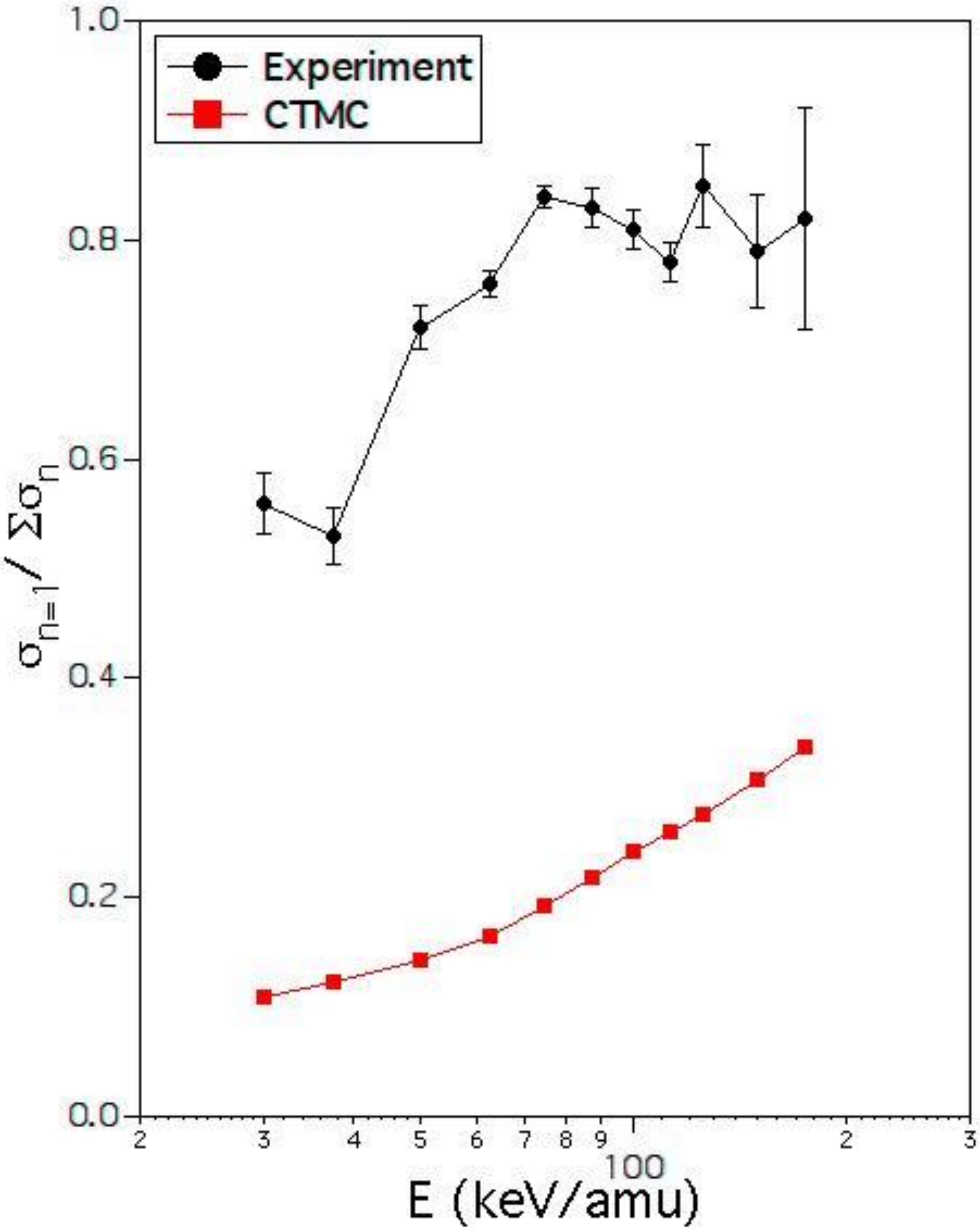
H_2^+ peak
Left random coincidence window
Right random coincidence window
14x10³
12
10
8
6
4
2
0
Counts
6
8
10
12
Recoil ion time-of-flight (μs)



Warm gas recoil ions
Projectile ion beam trace
Jet recoil ions
Recoil ion y-position (channel #)
Recoil ion x-position (channel #)
100
150
200
250
300
350
400



H_2^+ peak
Ionization
$n_p = 1$
$n_p \geq 2$
Right random coincidence window
Left random coincidence window
Net
Counts
Recoil ion x-position (channel #)
0
1000
2000
4000
240
250
260
270
280
290



We are truly looking at non-dissociative SEC

No assumptions
No indirect inferences

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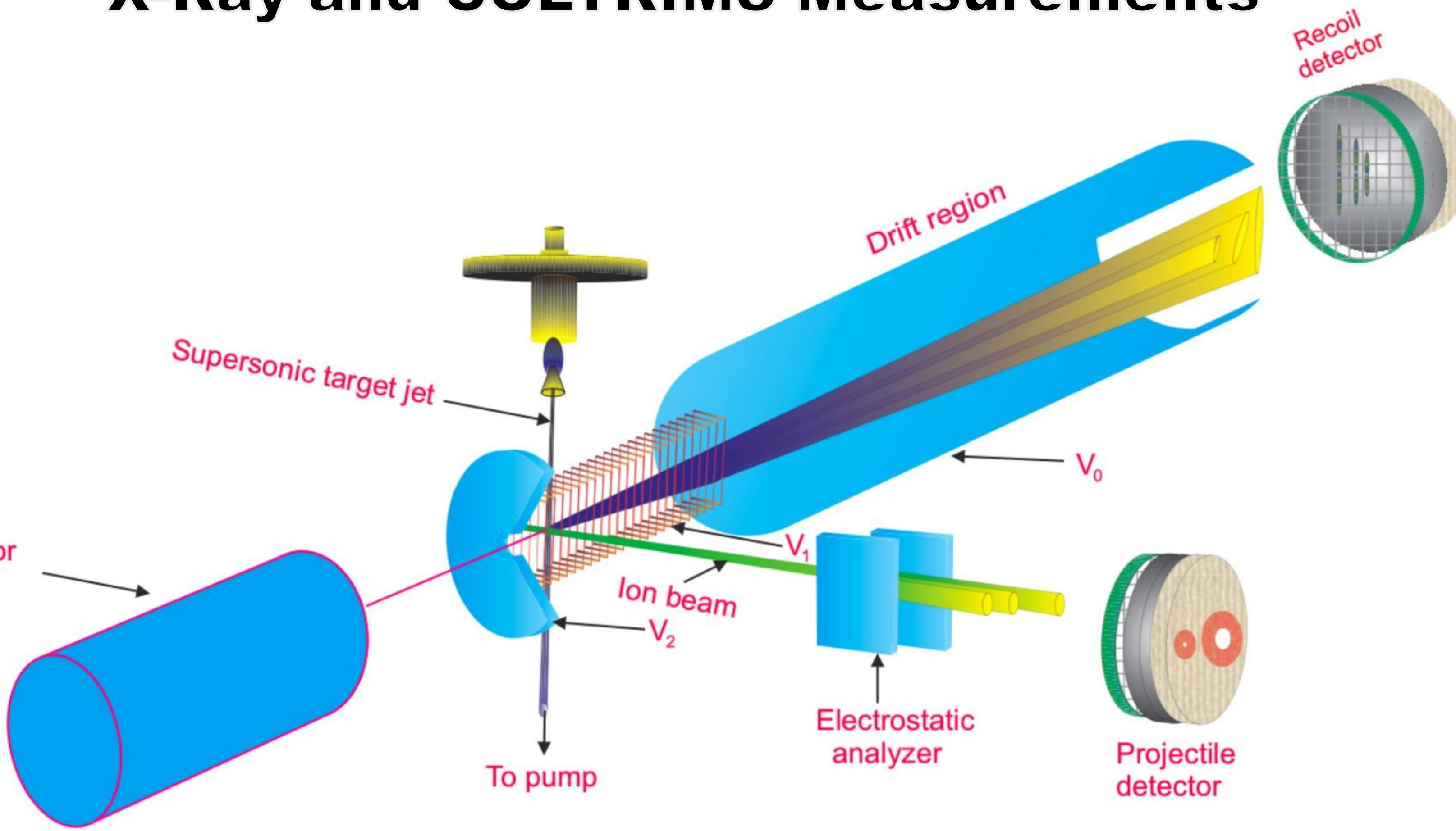
Charge Exchange Studies Using Simultaneous X-Ray and COLTRIMS Measurements



The Astrophysical Journal, 629:L125–L128, 2005 August 20

ON THE SIGNIFICANCE OF THE CONTRIBUTION OF MULTIPLE-ELECTRON CAPTURE PROCESSES TO COMETARY X-RAY EMISSION

R. Ali,[1] P. A. Neill,[2] P. Beiersdorfer,[3] C. L. Harris,[4] M. J. Raković,[5] J. G. Wang,[6] D. R. Schultz,[7] and P. C. Stancil[8]
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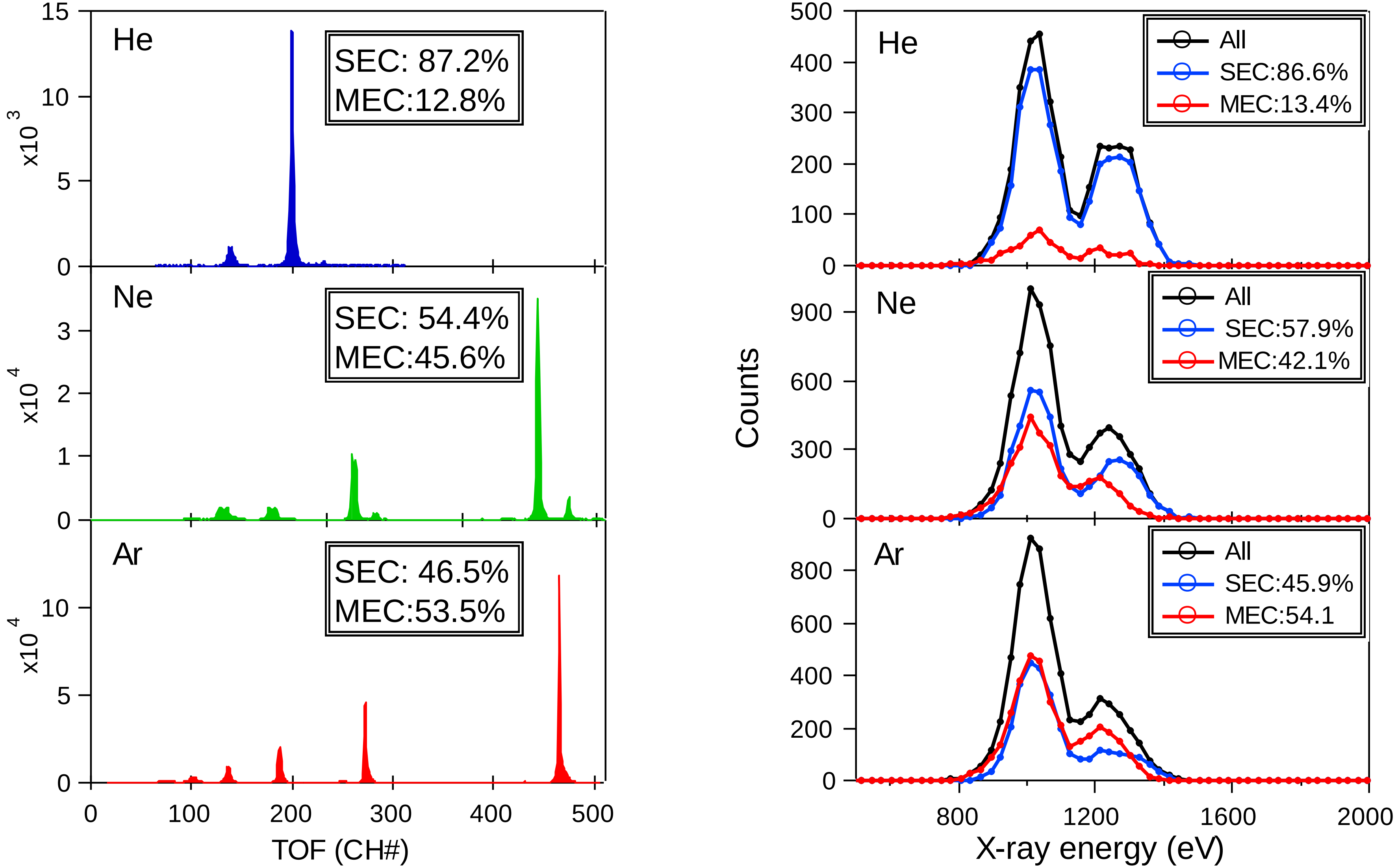

- Radiative decays of doubly excited states have been discussed for over two decades.
- Not a single charge exchange x-ray spectral model has invoked the ATR mechanism or direct radiative decays.
- A serious disconnect not only between the atomic physics and spectral modeling communities.

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Charge-transfer-induced x-ray spectra in collisions of Ne^{10+} with He and Ne atoms

L. Liu,[1] J. G. Wang,[1] and R. K. Janev[2,3]

For the Ne^{8+} (4l,4l') doubly excited states the authors did not consider the radiative stabilization of these states at all and stated:

"The two-electron capture to the n = 4 shell, however, does not considerably (if at all) contribute to the radiative cascade producing the n = 4 x-ray spectra due to the predominant Auger decay of the doubly excited (4l,4l′) state."

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Charge-exchange x-ray spectra: Evidence for significant contributions from radiative decays of doubly excited states

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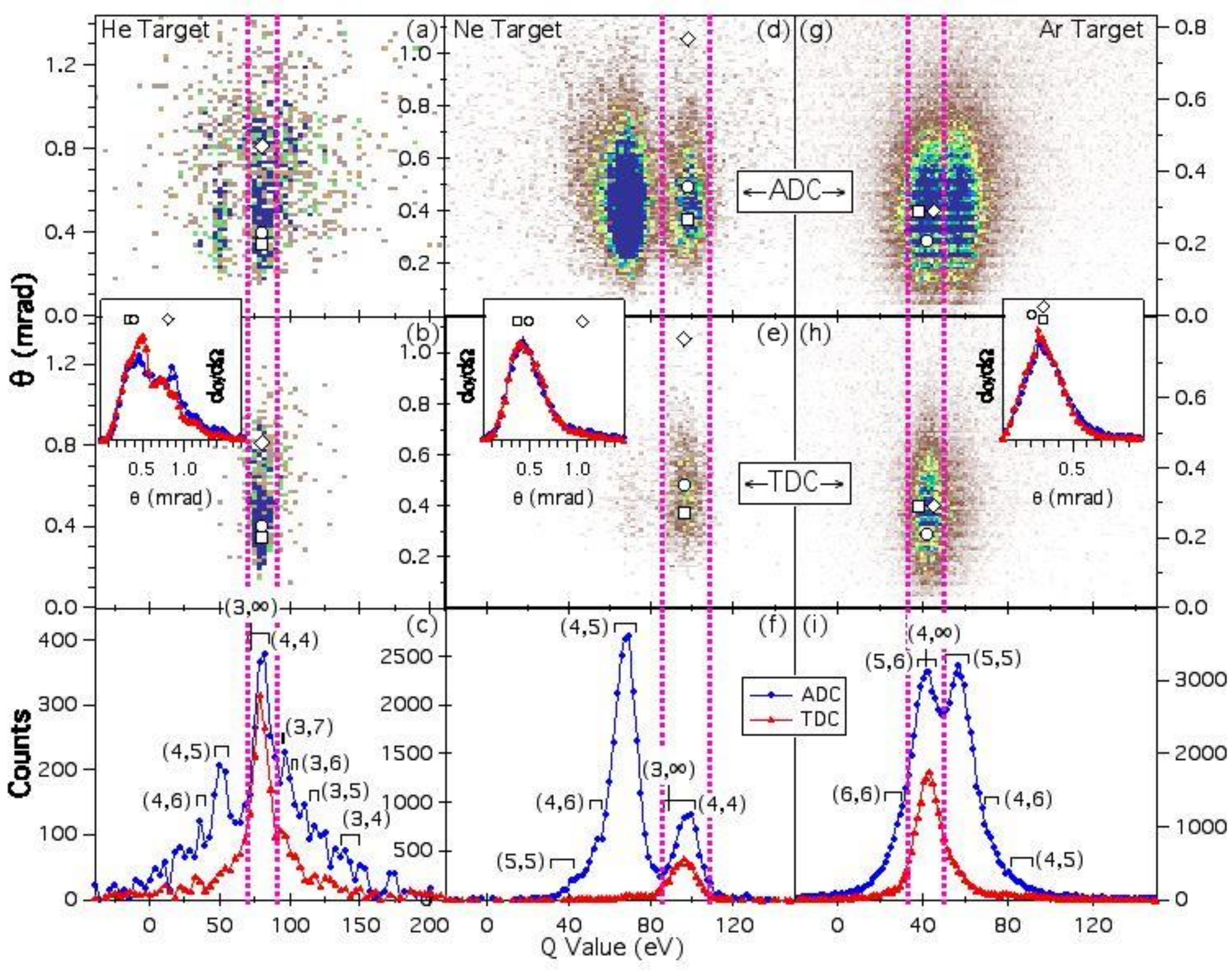
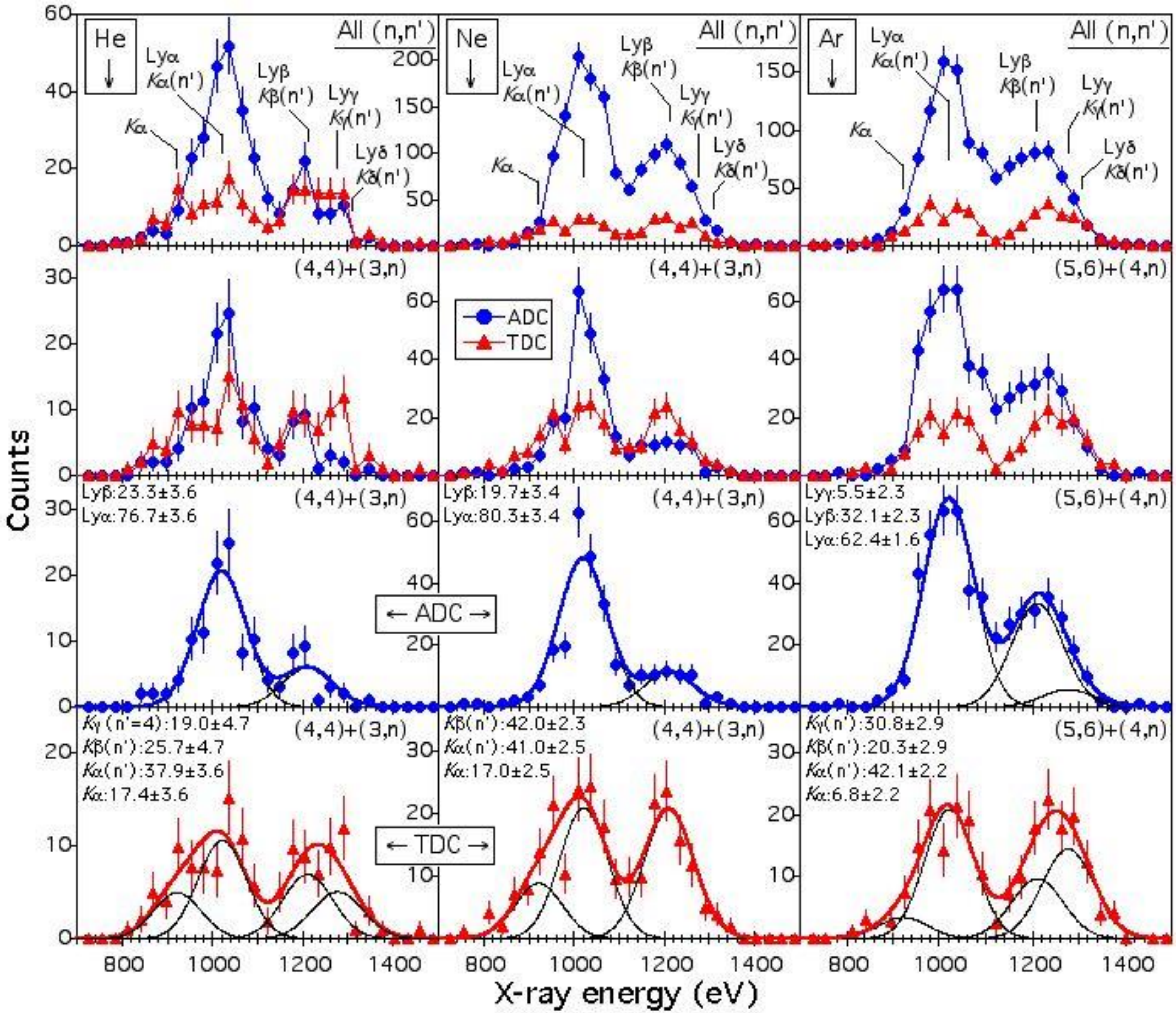
Charge-exchange collisions of slow Ne^{10+} ions with He, Ne, and Ar targets were studied with simultaneous x-ray and cold-target recoil-ion-momentum spectroscopy proving the contribution of several mechanisms to the radiative stabilization of apparent (4,4) doubly excited states for He and Ne targets and of (5,6) states for Ar. In particular, the stabilization efficiency of the mechanism of dynamic auto-transfer to Rydberg states is confirmed. Moreover, we present evidence for direct radiative decays of (4,4) states populated in collisions with He, which is an experimental indication of the population of so-called unnatural-parity states in such collisions. These mechanisms lead to the emission of x-rays that have considerably higher energies than those predicted by current spectral models and may explain recent observations of anomalously large x-ray emission from Rydberg levels.



He Target
Ne Target
Ar Target
(a)
(b)
(c)
(d)
(e)
(f)
(g)
(h)
(i)
←ADC→
←TDC→
θ (mrad)
dσ/dΩ
θ (mrad)
Counts
Q Value (eV)
ADC
TDC
(3,∞)
(4,4)
(3,7)
(3,6)
(3,5)
(3,4)
(4,5)
(4,6)
(5,5)
(4,∞)
(5,6)
(6,6)



He
Ne
Ar
All (n,n')
Lyα
Kα(n')
Lyβ
Kβ(n')
Lyγ
Kγ(n')
Lyδ
Kδ(n')
Kα
(4,4)+(3,n)
(5,6)+(4,n)
ADC
TDC
Lyβ:23.3±3.6
Lyα:76.7±3.6
Lyβ:19.7±3.4
Lyα:80.3±3.4
Lyγ:5.5±2.3
Lyβ:32.1±2.3
Lyα:62.4±1.6
← ADC →
← TDC →
Kγ(n'=4):19.0±4.7
Kβ(n'):25.7±4.7
Kα(n'):37.9±3.6
Kα:17.4±3.6
Kβ(n'):42.0±2.3
Kα(n'):41.0±2.5
Kα:17.0±2.5
Kγ(n'):30.8±2.9
Kβ(n'):20.3±2.9
Kα(n'):42.1±2.2
Kα:6.8±2.2
Counts
X-ray energy (eV)