Studies with highly charged ions at Livermore and possible new directions

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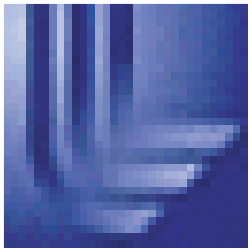


Charge exchange with very highly charge ions at low collision velocity is an unsolved basic physics problem

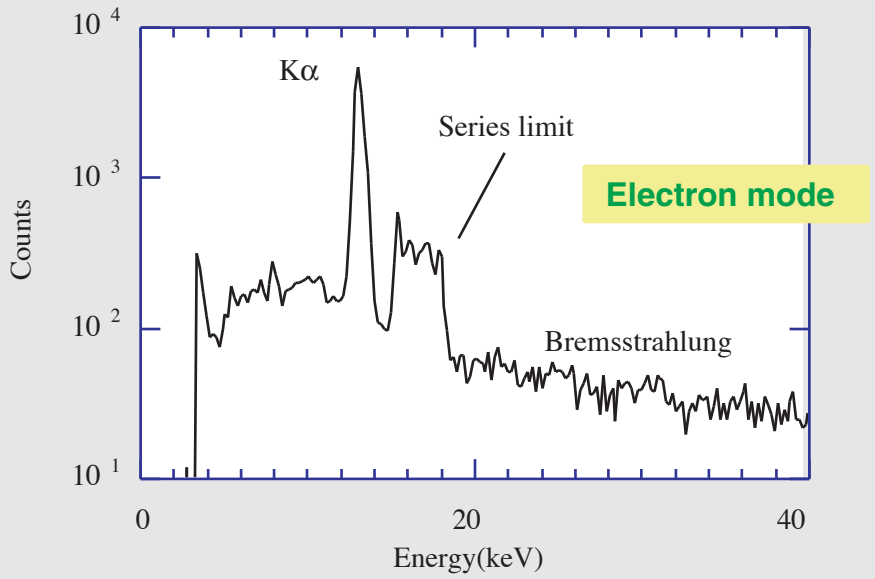
Using the EBIT and SuperEBIT at Livermore we have made numerous studies of the x-ray emission of highly charged ions.

We have encountered distinct problems when the results are compared to theory, which can be traced to an inadequate understanding how the upper levels are populated by charge exchange at low collision energies.

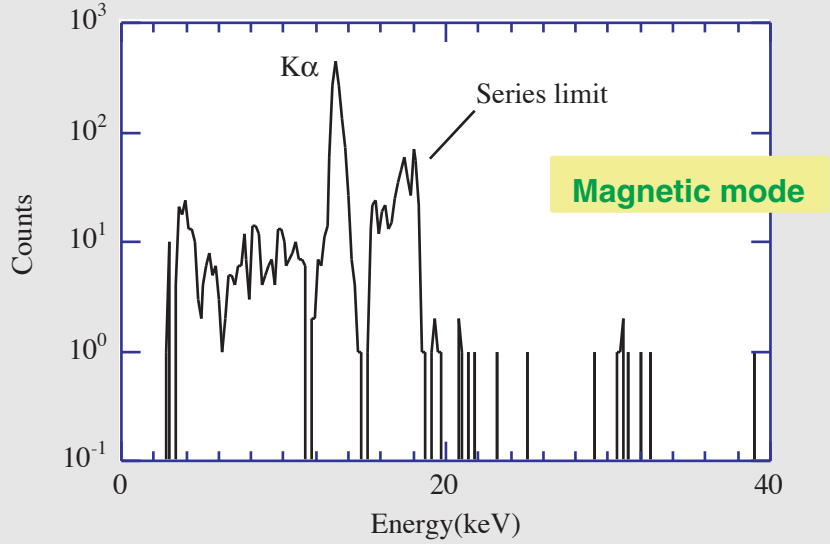
Experiments with the highest possible ions (U^{91+} and U^{92+}) at low collision energy interacting with H, H_2, He, Ar, and various molecular gases are needed to address these problems.

Charge exchange measurements on EBIT

Krypton emission produced by electron-impact excitation



Krypton emission produced by charge exchange

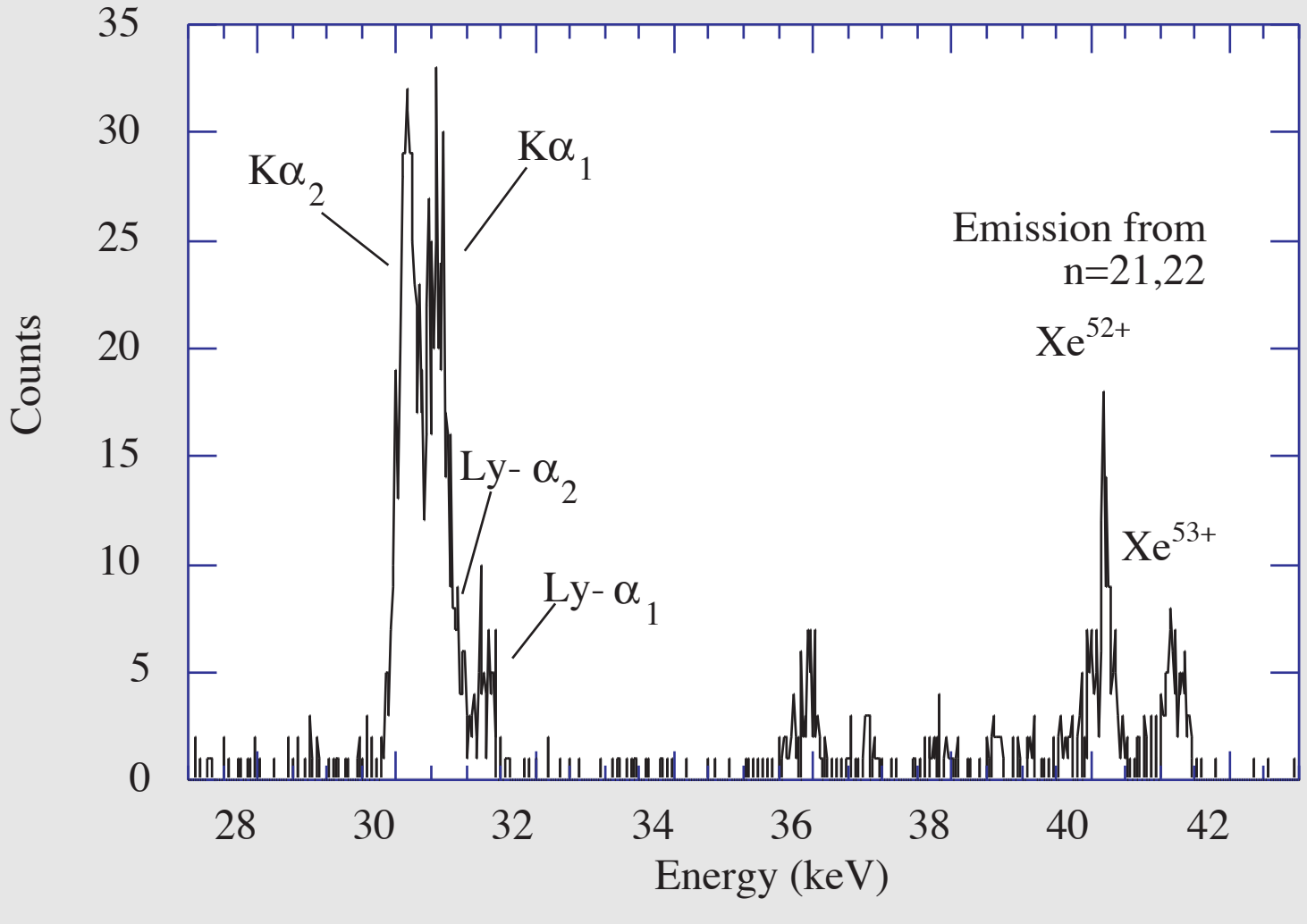


Beiersdorfer et al, RSI 67 (1996) 3818

The charge exchange spectrum has distinct features that set it apart:
The intensity near the series limit is enhanced

Charge exchange measurements on EBIT: K-shell Xe

Xenon emission produced by charge exchange



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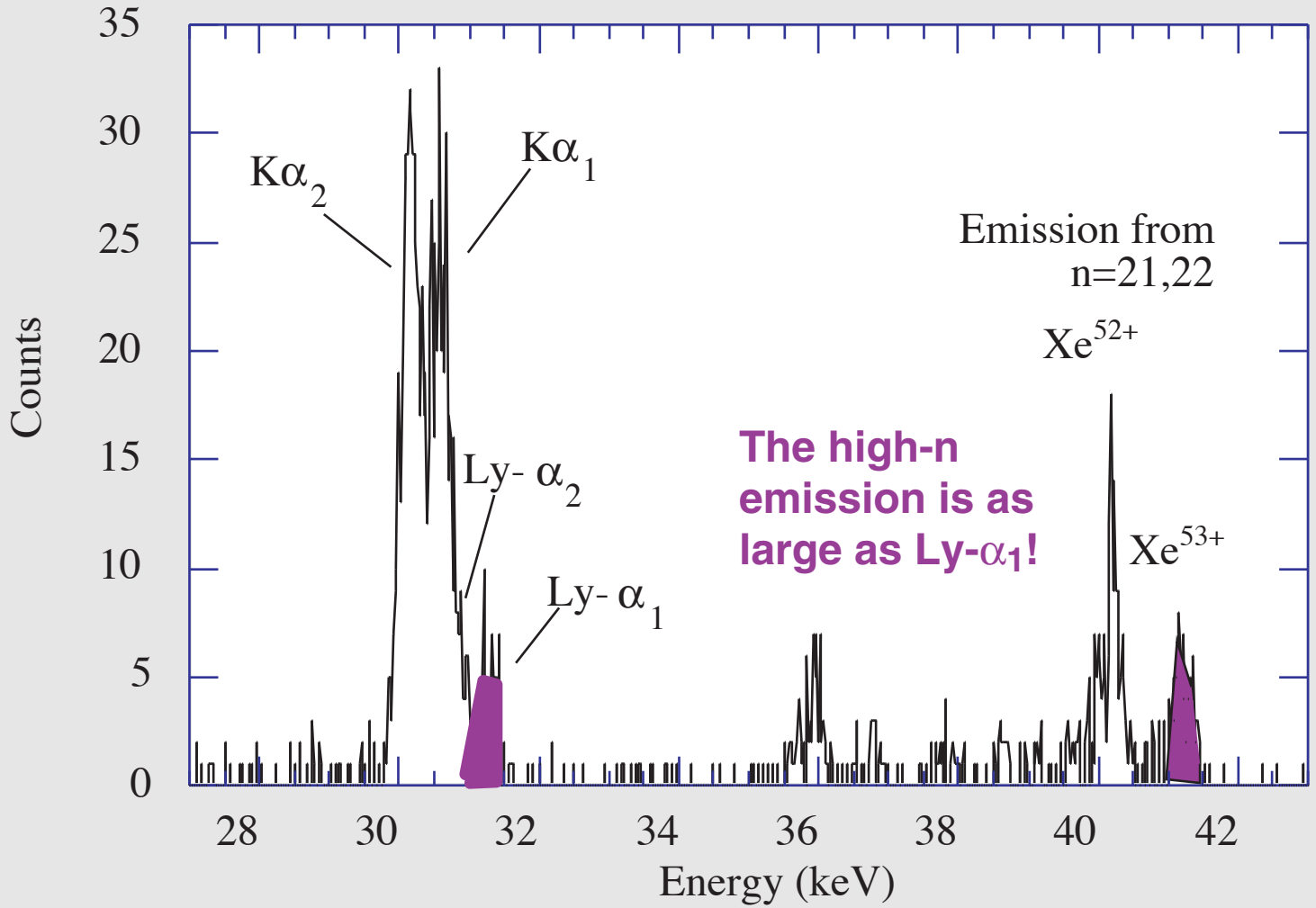
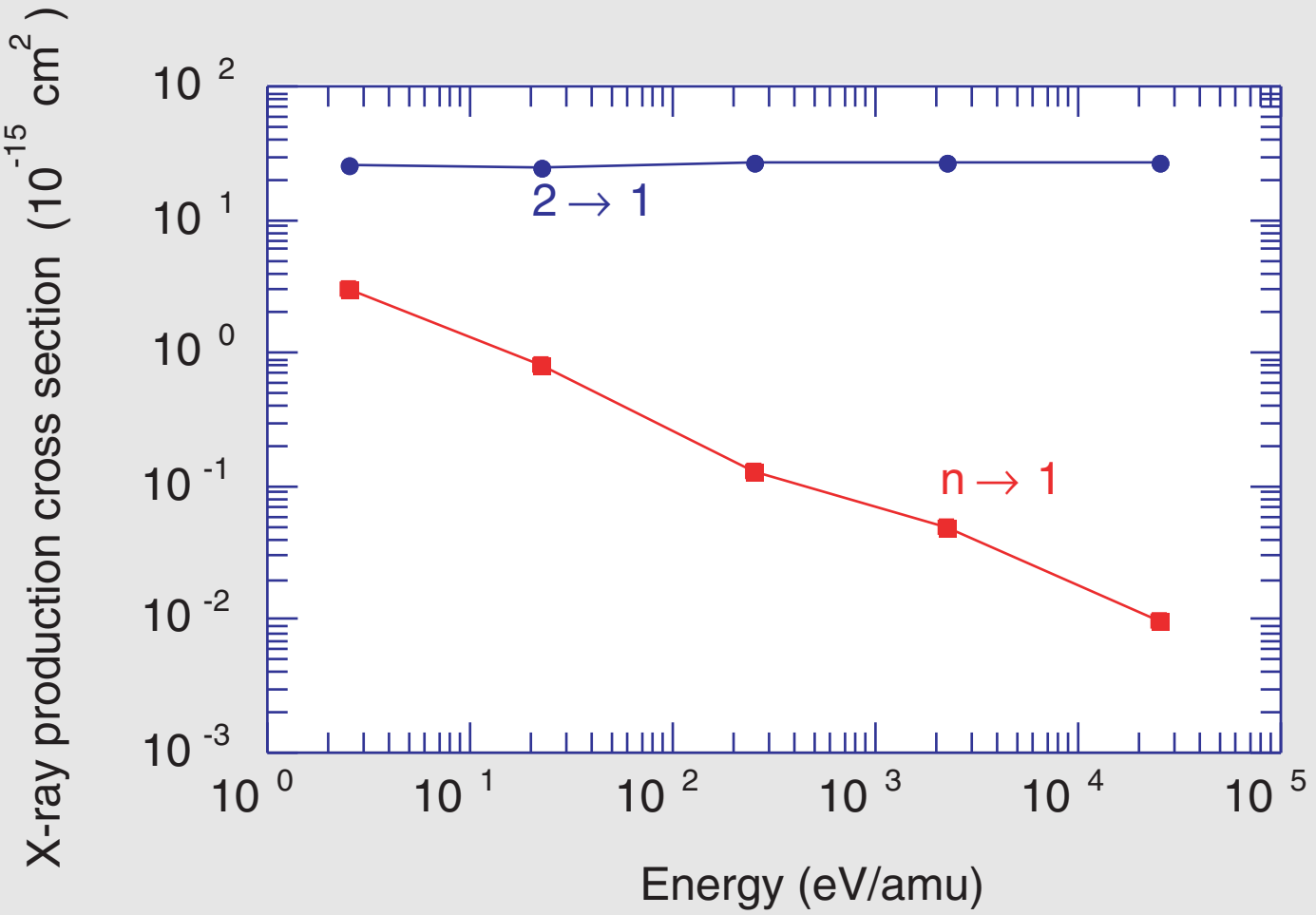
Charge exchange measurements on EBIT: K-shell Xe

Xenon emission produced by charge exchange



The x-ray spectrum depends on collision energy

Predicted emission of K-shell lines in xenon based on CTMC calculations (Olson)



Perez et al, JPhysB 34 (2001) 3063

The emission from n>2 levels increases as the collision energy drops

The x-ray spectrum depends on collision energy

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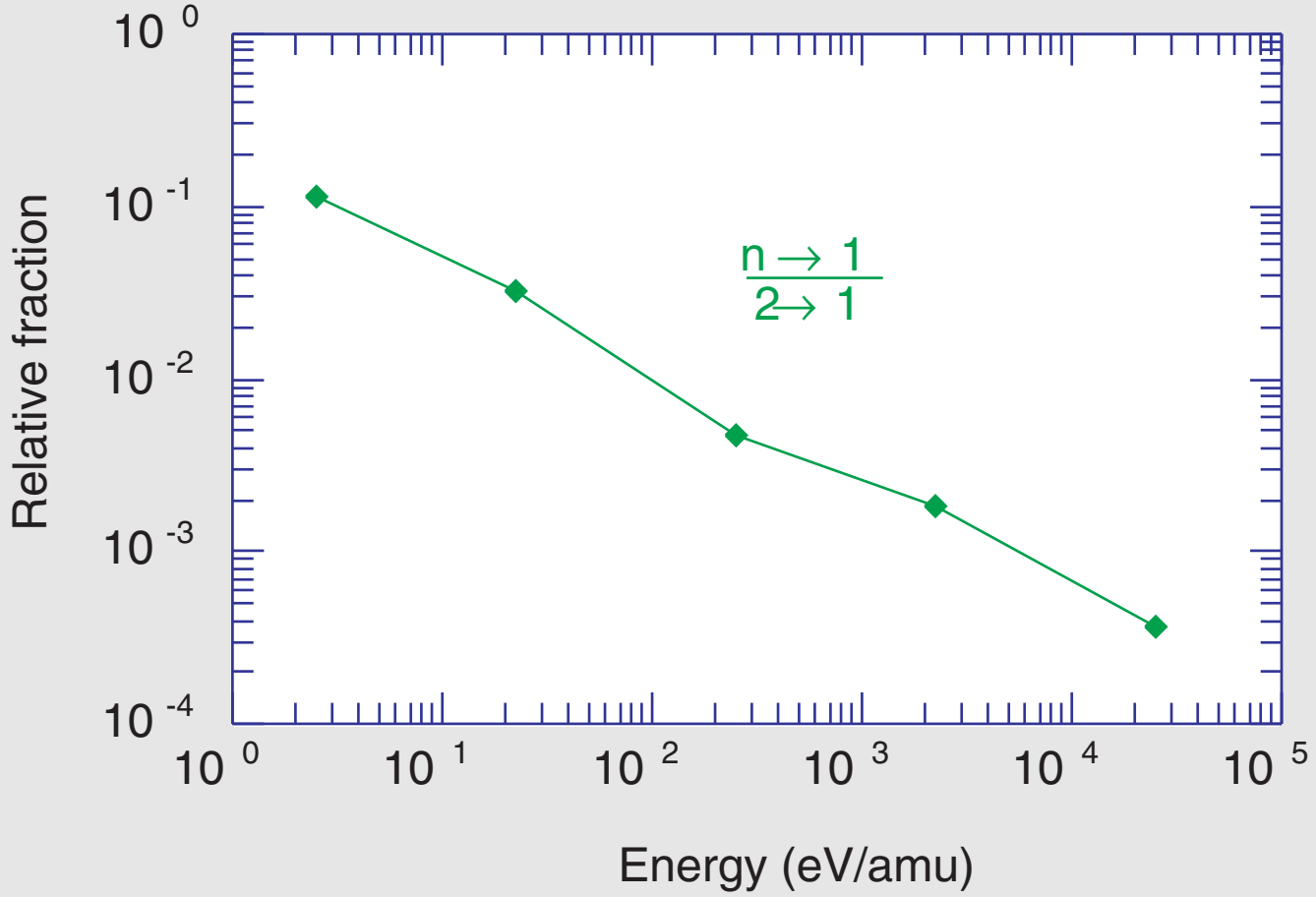

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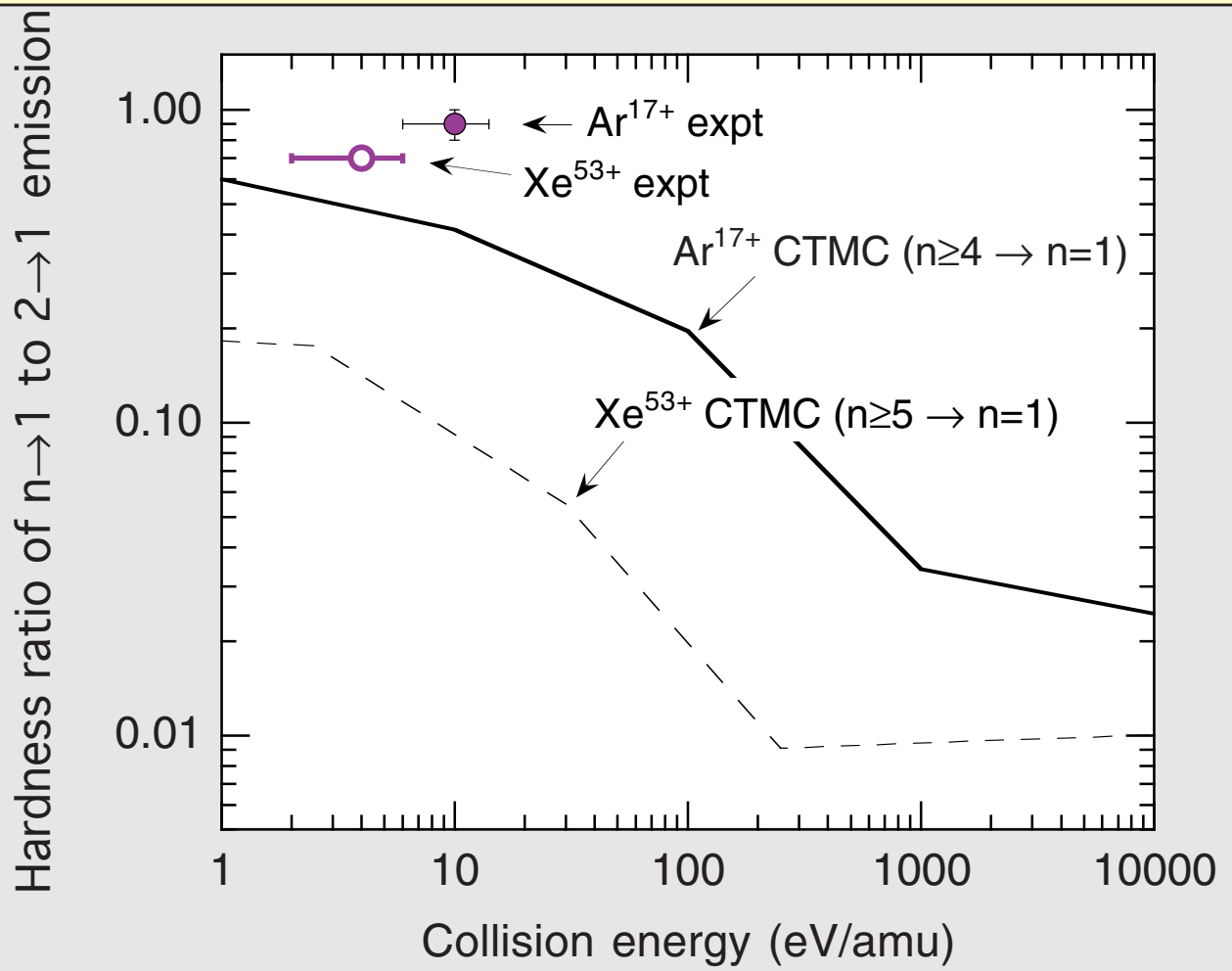
The emission from n>2 levels increases as the collision energy drops

Measurements compared to theory

Line ratios measured for Ar^{18+} and Xe^{54+} colliding with Ar and Xe

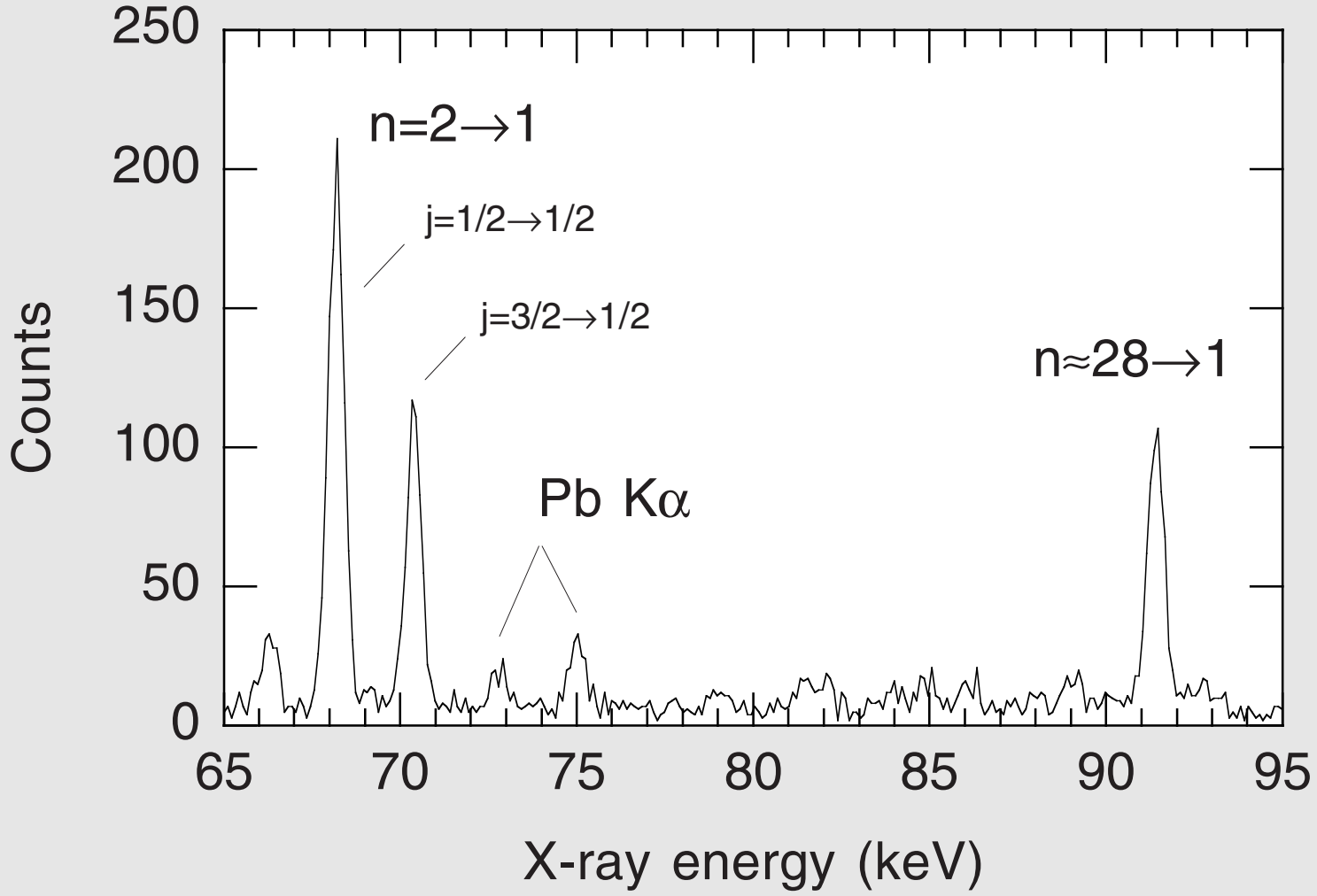


Beiersdorfer et al, PRL 85 (2000) 5090

There are clear differences with theory

Heliumlike spectra of very high-Z ions also show enhanced emission from high-n levels

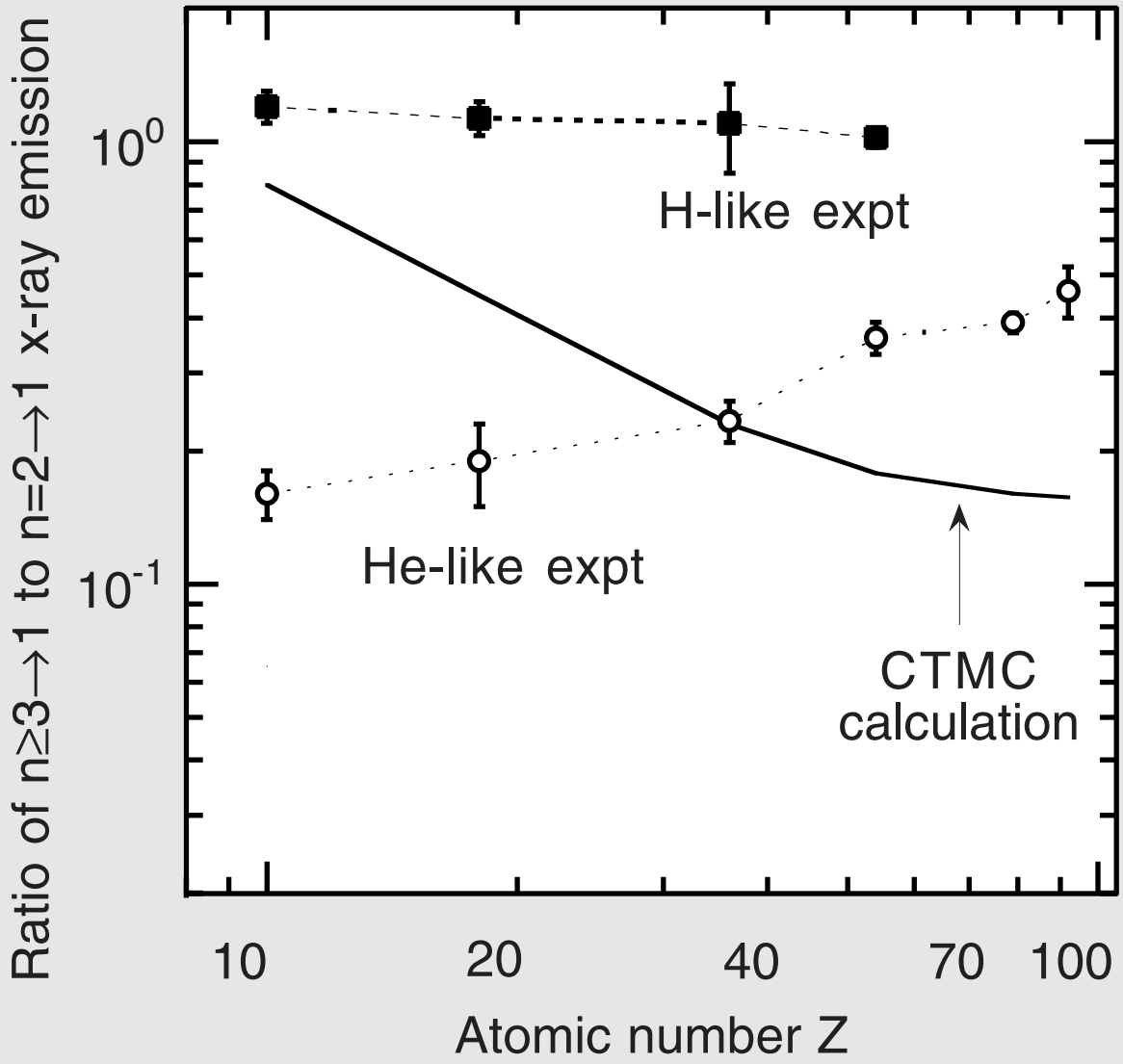
X-ray emission from heliumlike Au^{77+} produced by charge exchange



Beiersdorfer et al, PRL 85 (2000) 5090

Measurements compared to theory

Line ratios measured as a function of Z show biggest differences with CTMC calculations for highest Z



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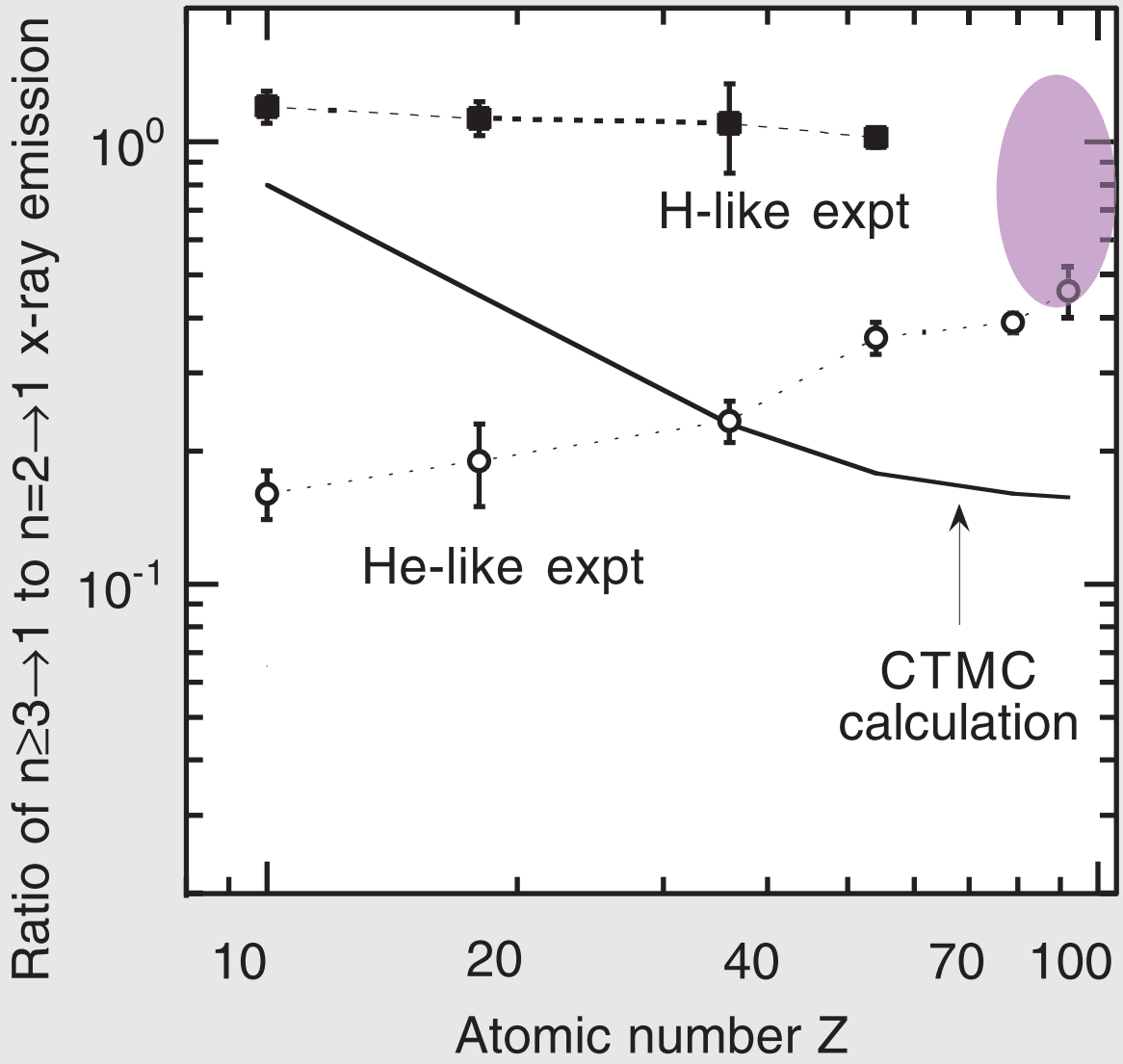
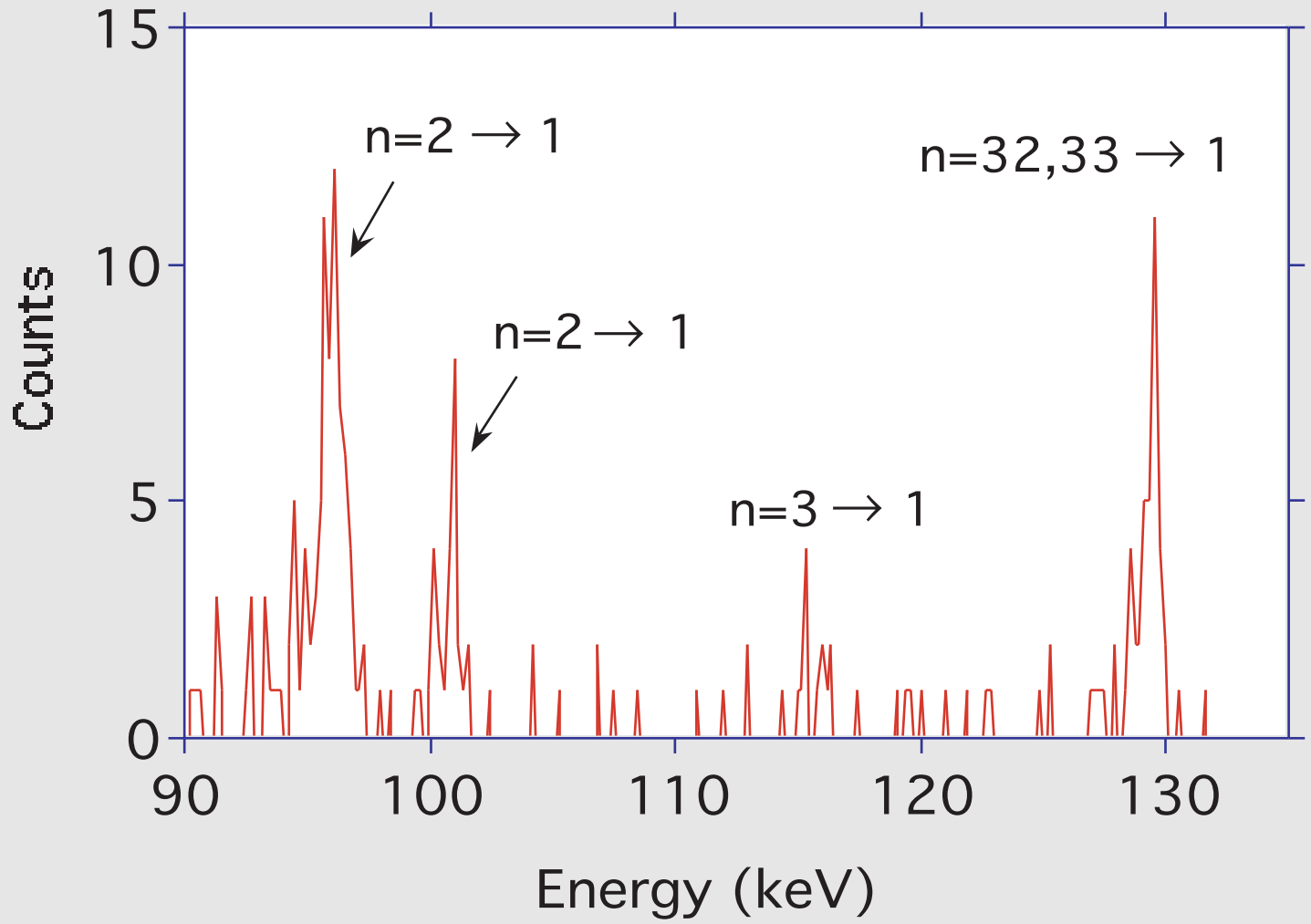


Best way to understand difference: look at highest-Z ions (U^{90+} can be a place holder for bare U^{92+})

Beiersdorfer et al, PRL 85 (2000) 5090

Heliumlike U spectrum shows strongly enhanced emission from high-n levels

X-ray emission from heliumlike U^{90+} produced by charge exchange



Schweikhard et al, NIM B 142 (1998) 245

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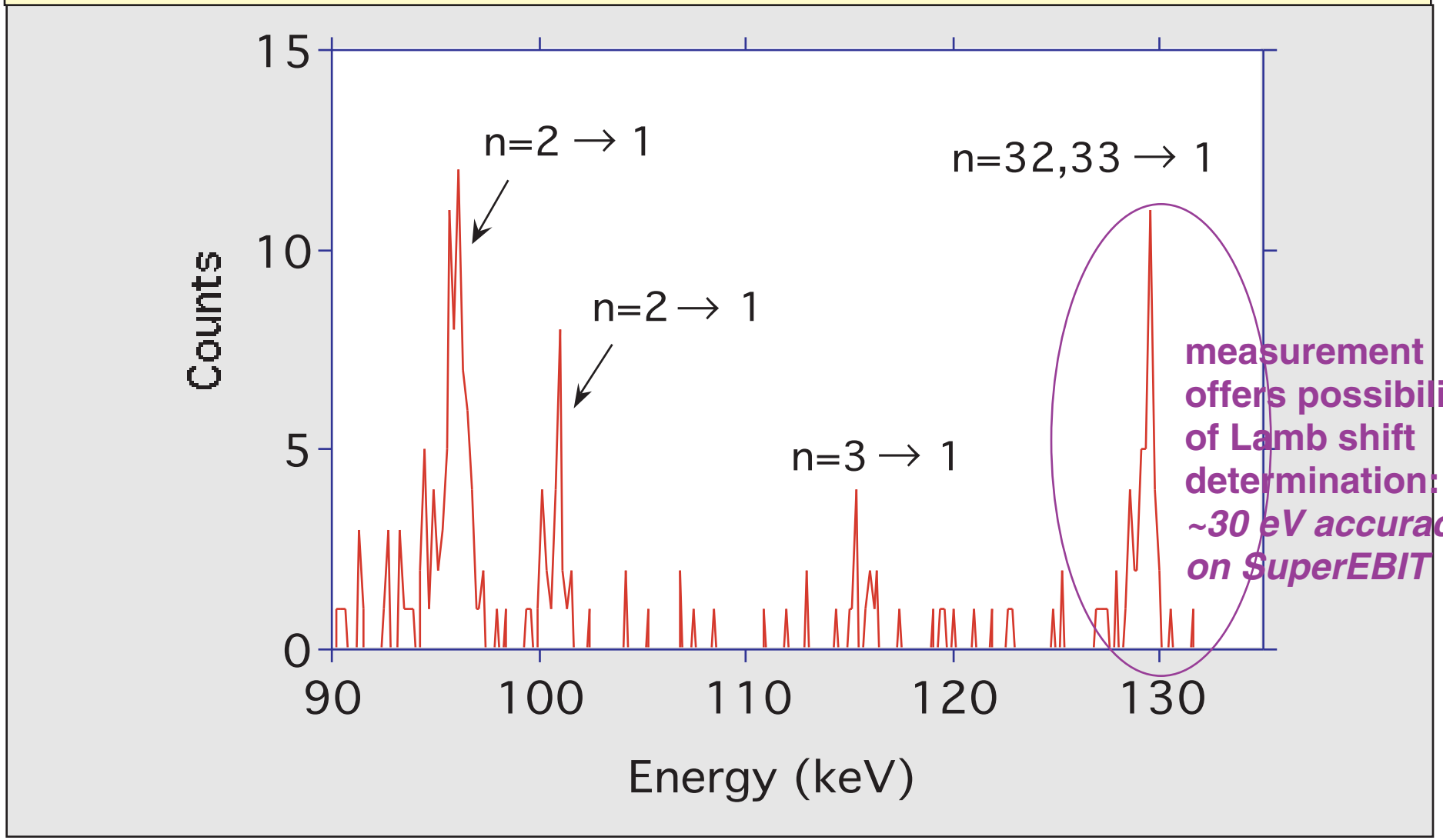
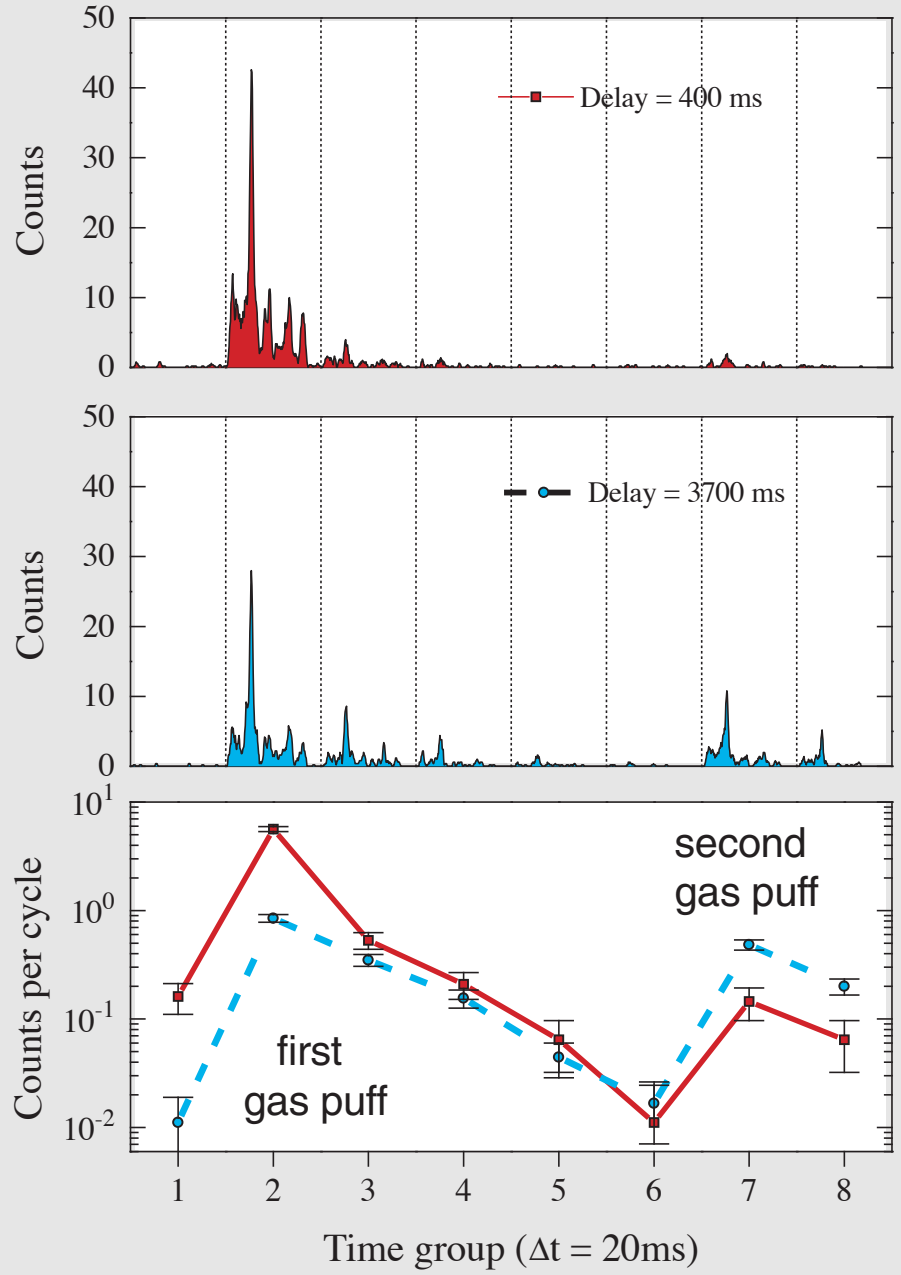
X-ray emission from heliumlike U^{90+} produced by charge exchange



measurement offers possibility of Lamb shift determination: ***~30 eV accuracy on SuperEBIT***

Strong gas puffs enhance signal to noise



Gas puff is used to put most CX signal in a short time bin to enhance signal from U^{90+}

Schweikhard et al, NIM B 142 (1998) 245

Second gas puff was used to find out, if any ions were left in the trap

Summary

Charge exchange produced x-ray emission at low collision energies is not well understood

New measurements with bare (He-like as a place holder) and H-like U are needed as benchmarks for improving theory

Measurements should include collision studies with H, H_2, He, Ar, and various molecular gases to assess the variation of the value of n_c and of the role of multi-electron capture

Ideally, all decay branches should be measured simultaneously:
K-shell (~100 keV), L-shell (~30 keV), M-shell (~6 keV), N-shell (~1 keV) ...