Multiple ionization of C_{60} in fast ion collisions and giant plasmon resonance

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A brief outlook

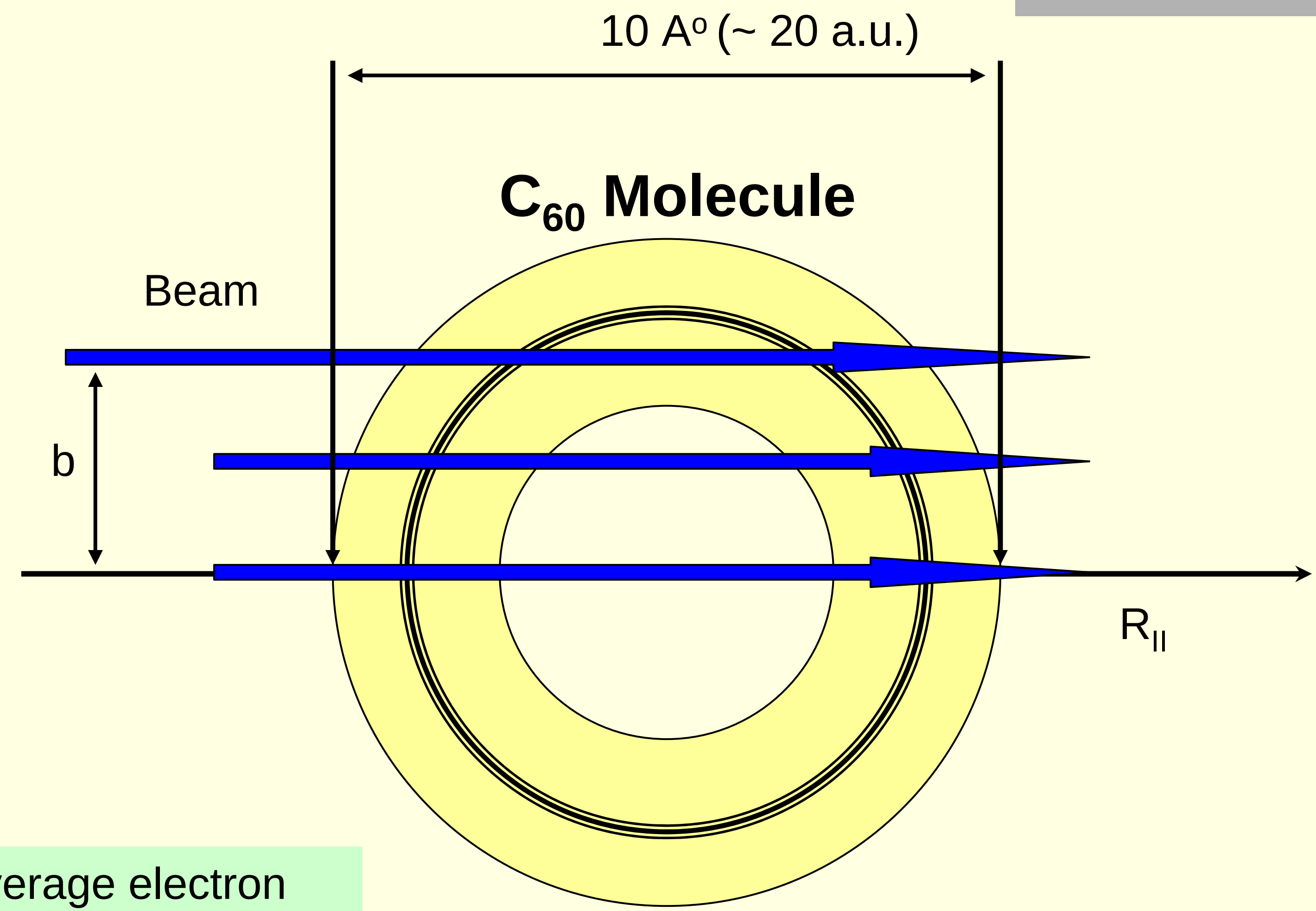
1. Collisions with simple targets: Atomic H, He: ***ION-ATOM***
   e-spectroscopy, Two Center effect, CDW approx.
   (D. Misra et al. PRA, May 2007)
2. Young-type interference in ionization of H_2 **:**
   via Electron Spectra: Deriving oscillations by different techniques:
   i) Atomic H *ii) Asymmetry parameter:*
   (Misra, et al. PRL 92, 2004; and **PRL95, 2005,com/rep)**
   Misra et al. PRA-Rapd comm Dec 2006)
3. *Heavy ion Collisions with* C_{60} *and Collective excitation :* **ION-CLUSTER**

   (a) Solid-like wake-field induced Stark mixing effect : ***Ly X-rays***
   (Kadhane PRL 90, 2003)

   (b) *Multiple ionization and fragmentation of* C_{60} *: ToF recoil-ions :*
   Giant Dipole Plasmon Resonance:
   Single/double ionization ***(Kadhane PRA-Rapd. Comm. April 2007)***
   And also on Triple ionization ***(Kelkar J.Phys. B*** **40 2481** ***June 2007)***

   (d) *Angular distribution of soft electrons, GDPR peak in electron spectrum*
   KLL Auger electron, double K-vacancy in C_{60}*….*
   (Kelkar et al. in Progress)
4. X-ray and inner shell processes………

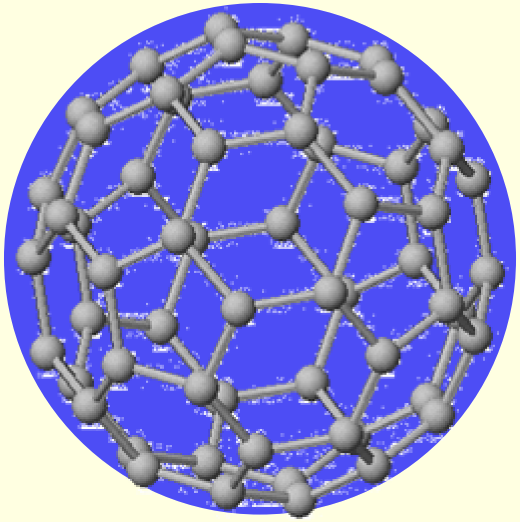
Structure of C_{60}



Average electron density for C_{60} = ~3.3 X 10^{23} cm^{-3}

Ref. : Hadjar *et al,* Phys. Rev. A (2001)

Collective excitation in C_{60}

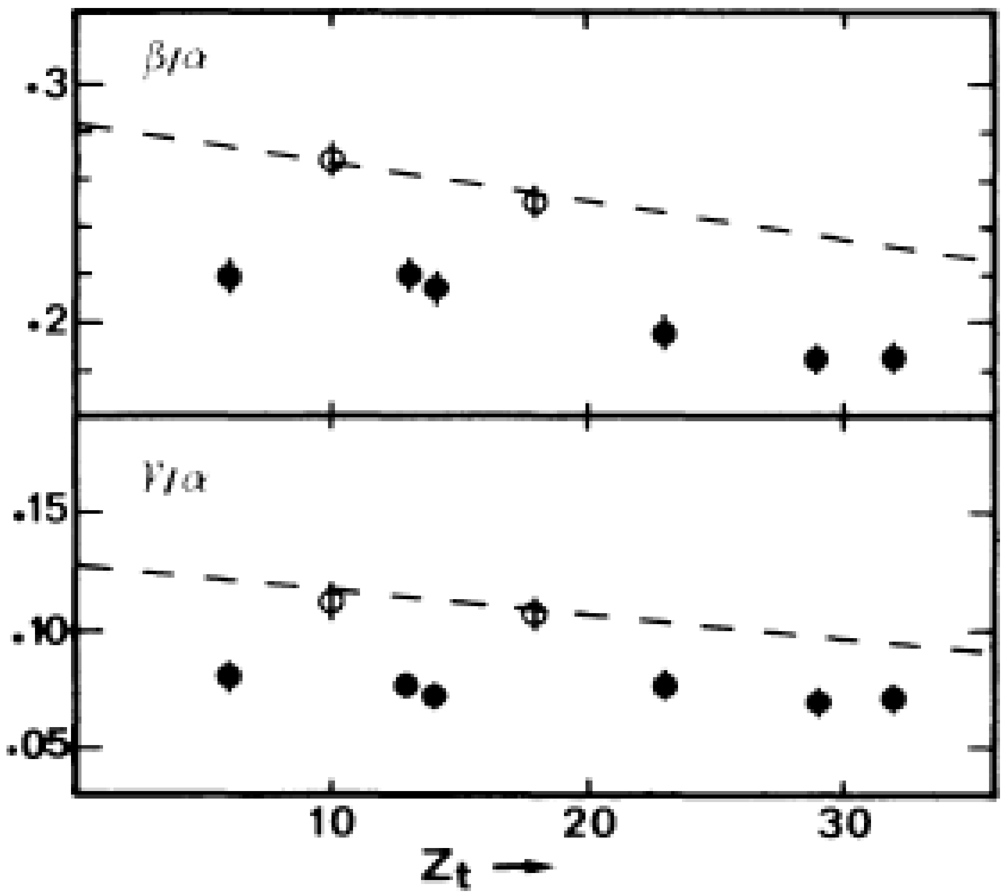


Frequency ~ 10^{15} Hz

Energy ~ 20 eV

Predicted by Bertsch et. al. (1991)
Measured by Hertel et. al. (1992)

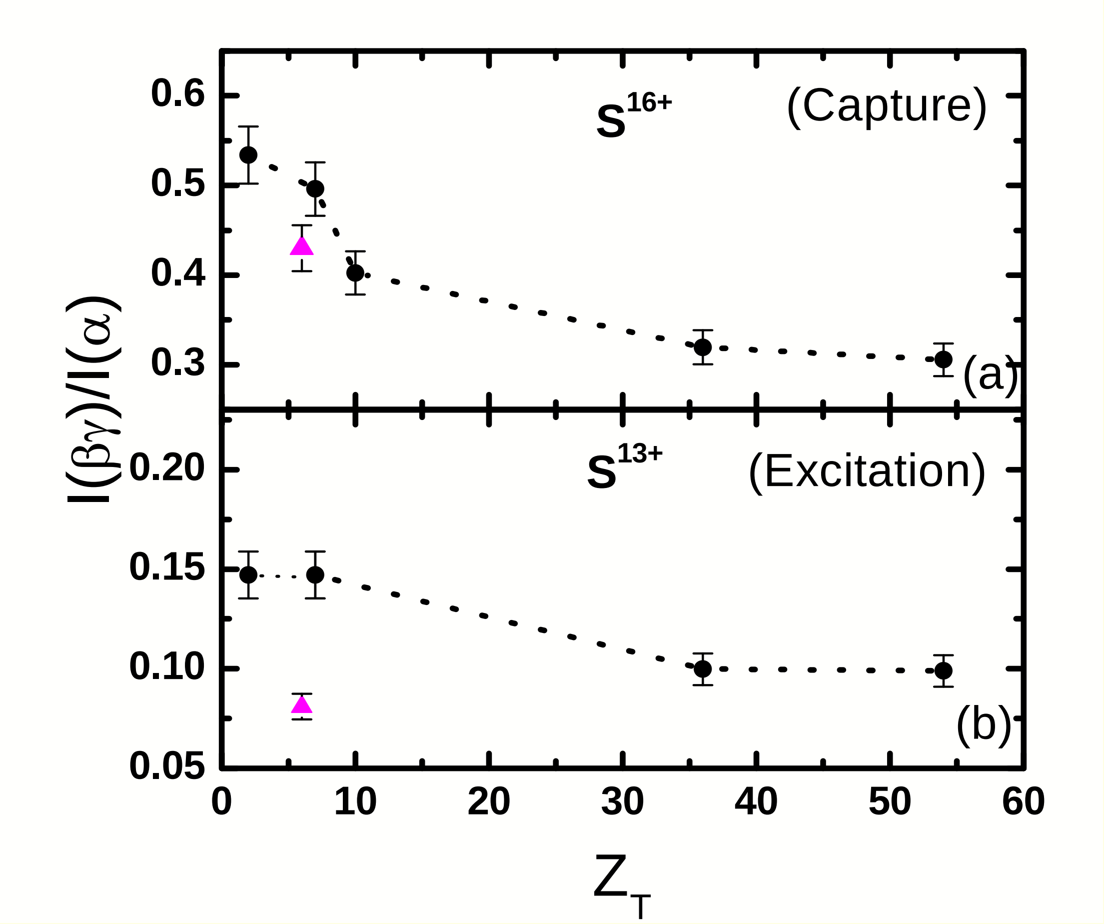
2.8 GeV Kr^{36+} on Gas and Solid targets



$\tau_d \sim 10^{-15}$ s

Ref. : Rozet *et al,* Phys. Rev. Lett (1987)

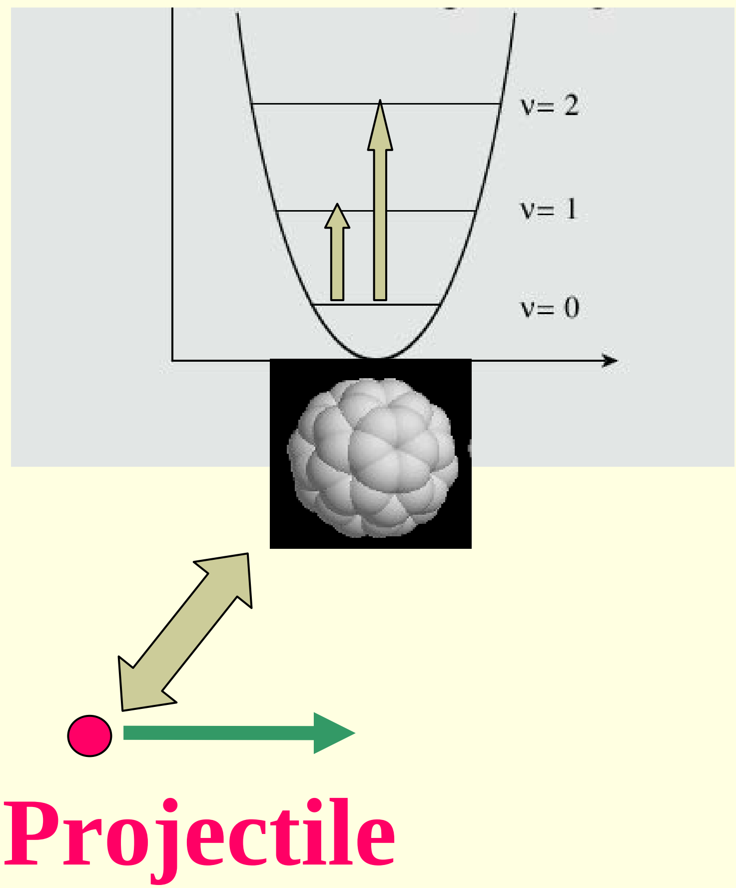
120 MeV S^{16+} on Gas and C_{60} targets:



Ref. : Umesh Kadhane *et al,* Phys. Rev. Lett (2003)

If plasmon excitation can influence the projectile. Then what is the influence of such excitation on the target itself?

Collective excitation model



- The target is considered as a harmonic oscillator with resonance at GPE frequency.
- Single GPE leads to single ionization and double GPE leads to double ionization.
- The model shows week velocity dependence but strong projectile charge state dependence.

(Introduced by LeBrune *et al* 1996.)

Energy Loss by the projectile

$$\Delta\varepsilon = \frac{2q^2e^4}{mv^2b^2}\left[\xi^2 K_1^2(\xi) + \frac{\xi^2}{\gamma^2} K_0^2(\xi)\right]$$

Where :

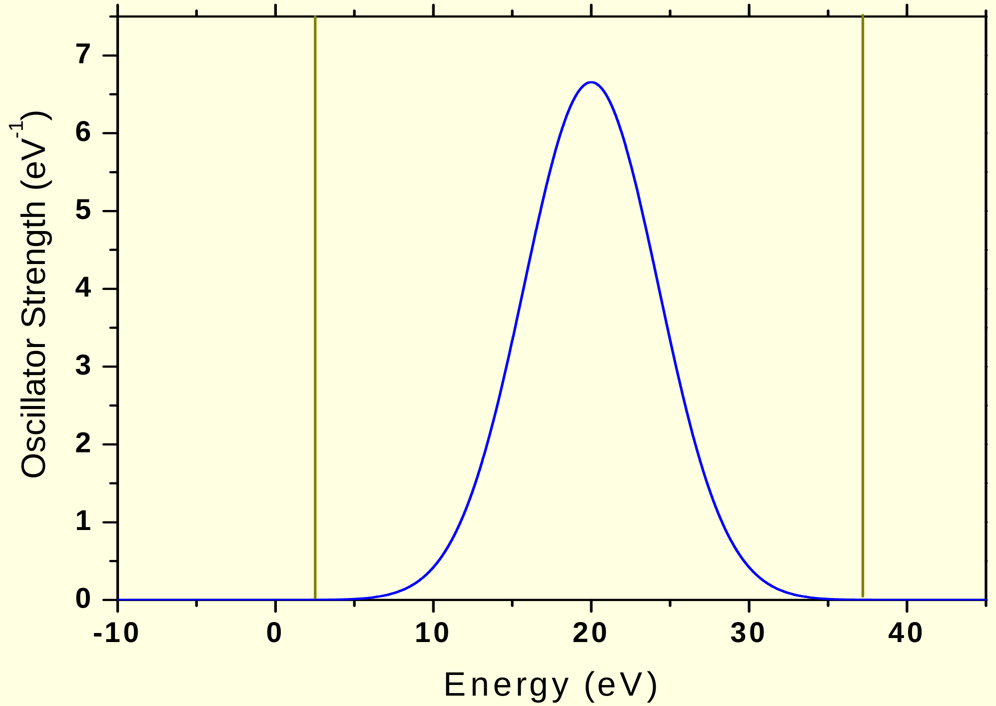
$$\xi = \frac{2\pi E b}{vh}$$

K_i = i^{th} order Modified Bessel Function

Oscillator strength function *f(E)*

$$f(E) = \frac{71}{\sqrt{2\pi\lambda}} \exp\left[-\frac{(E-20)^2}{2\lambda^2} \right]$$

Where, $$\lambda = \frac{10}{2.35} eV$$



Integrated Generalised Oscillator strength for C_{60} = 71

Ref. : Bertsch et al, Phys. Rev. Lett. 67, (1991),2690

The effective number of Plasmons excited, N(b) is given as :

$$N(b) = \int_0^\infty \frac{f(E)}{E} \Delta\varepsilon dE$$

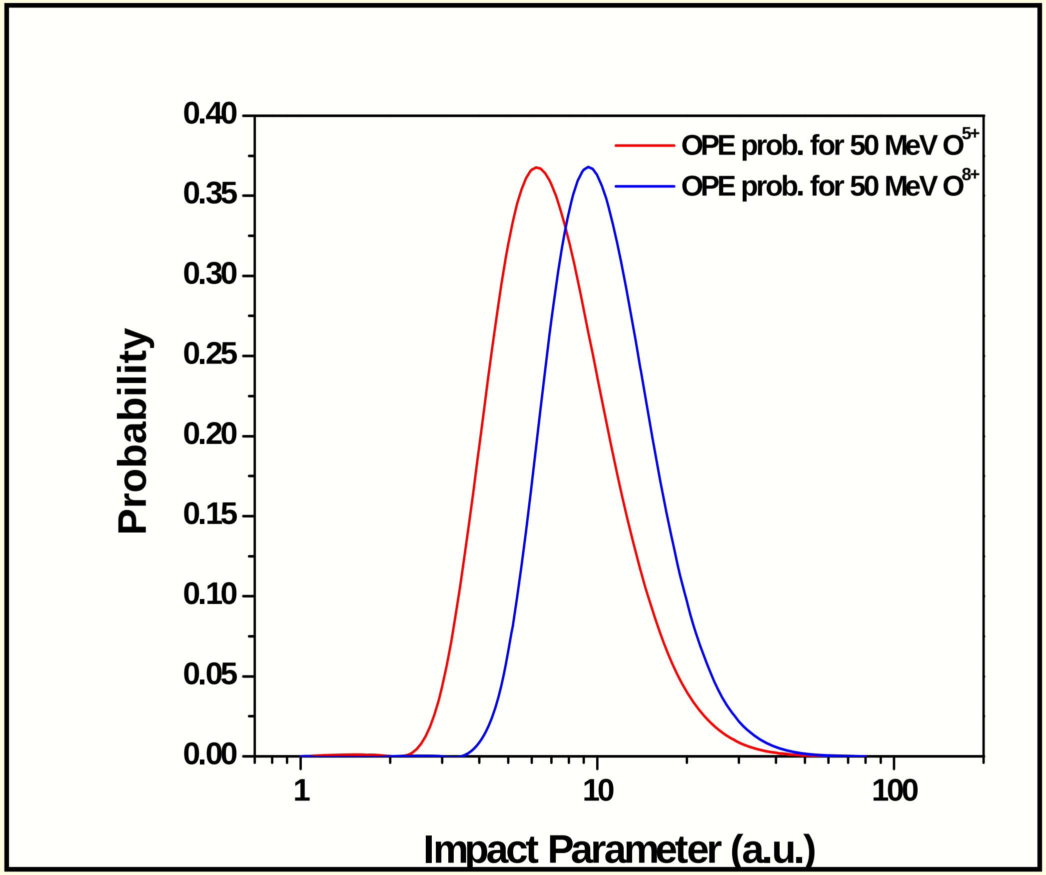
The Probability of “n” plasmon excitation is given by the Poisson statistics as:

$$P_n(b) = \frac{[N(b)]^n}{n!} \exp[-N(b)]$$

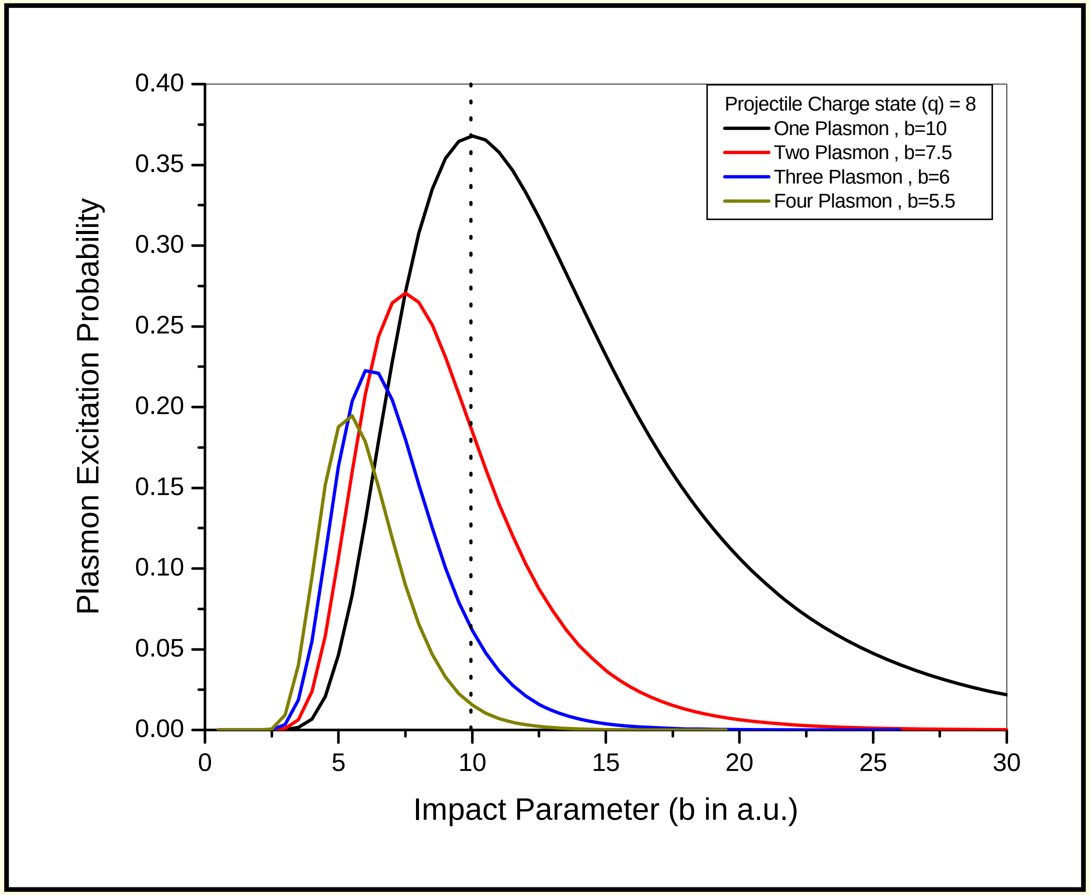
“n” plasmon excitation cross sections:

$$\sigma_n(pl) = 2\pi \int b \frac{(N(b))^n}{n!} e^{-N(b)} db$$

One Plasmon Excitation probability Vs. impact parameter



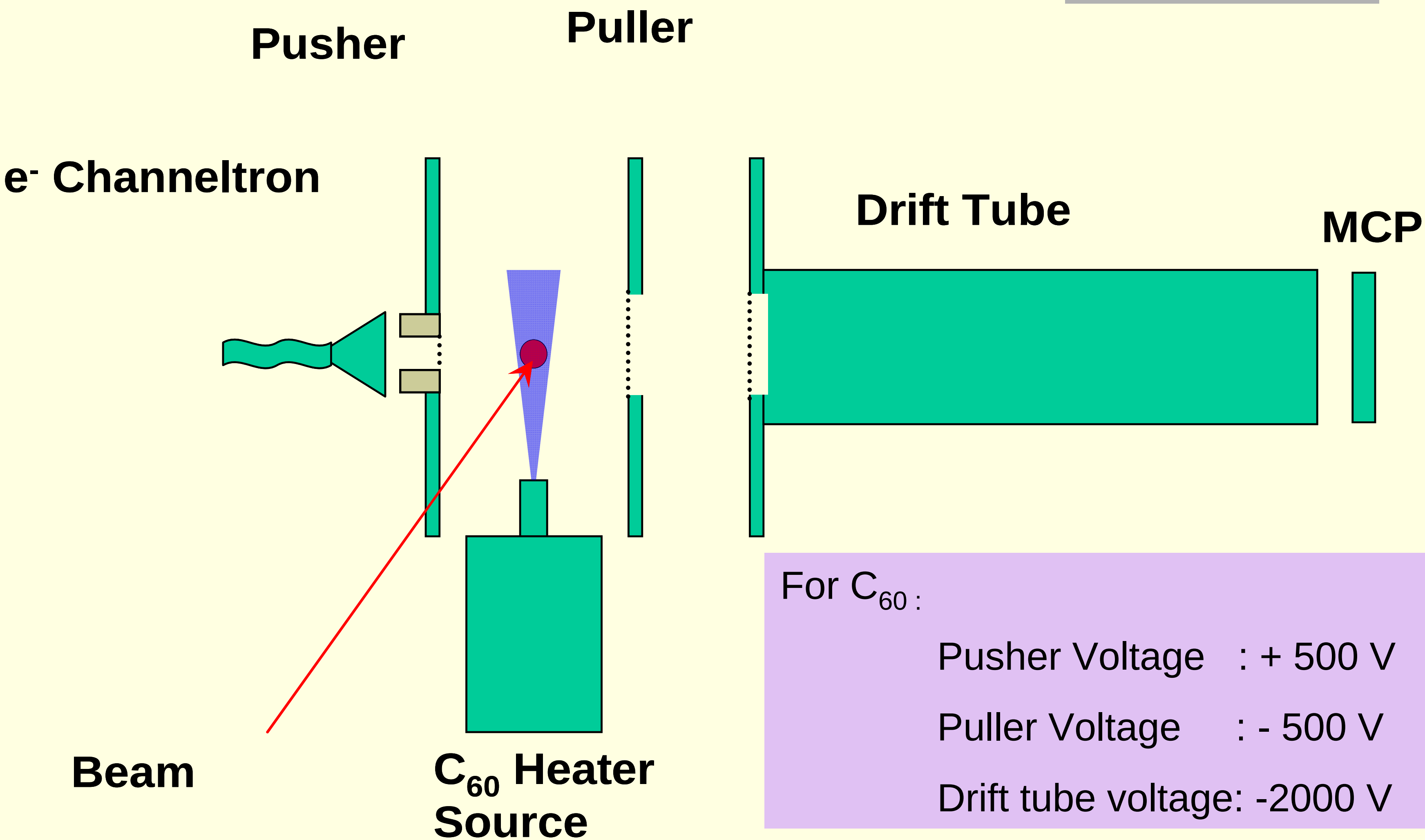
Multi Plasmon Excitation probability Vs. impact parameter



14 MV UD BARC-TIFR Pelletron

3.125 MeV/u and 5 MeV/u O^{q+} (q = 4 to 8)
2.33 MeV/u Si^{q+} (q = 6, 10 to 14)

Time of Flight (ToF) set up



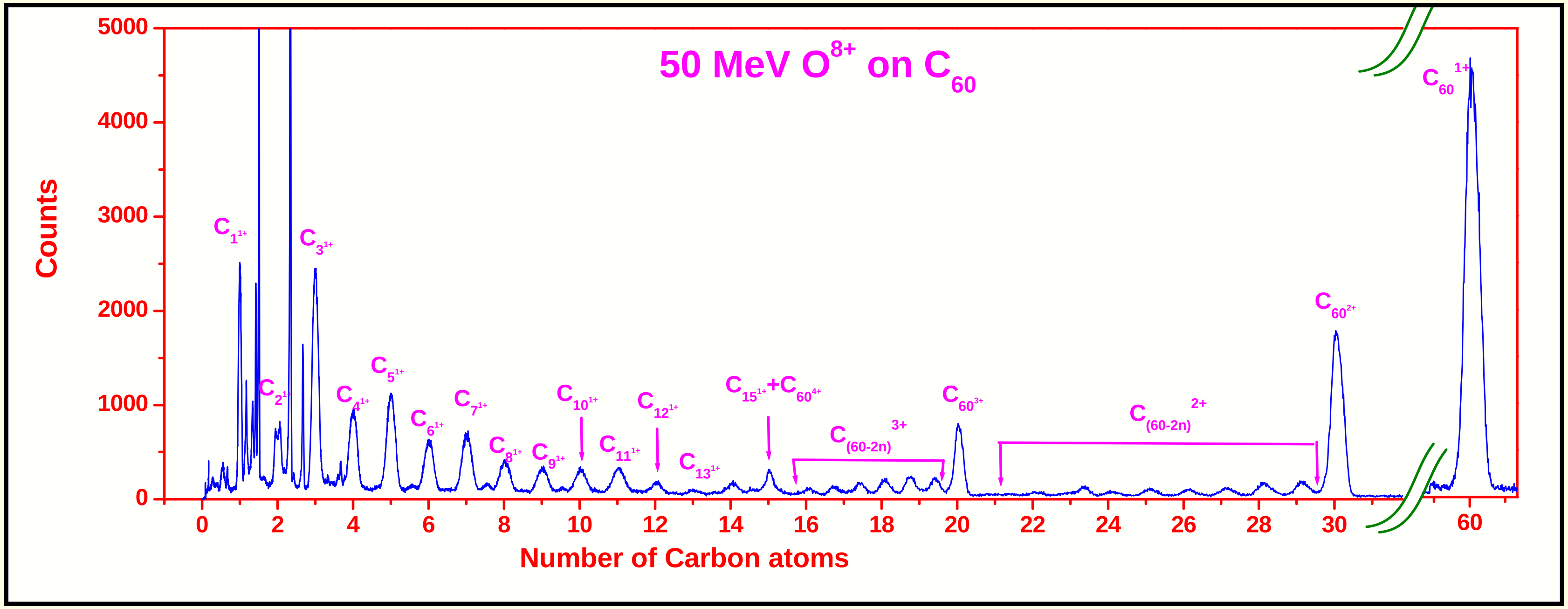
For C_{60} :

Pusher Voltage : + 500 V

Puller Voltage : - 500 V

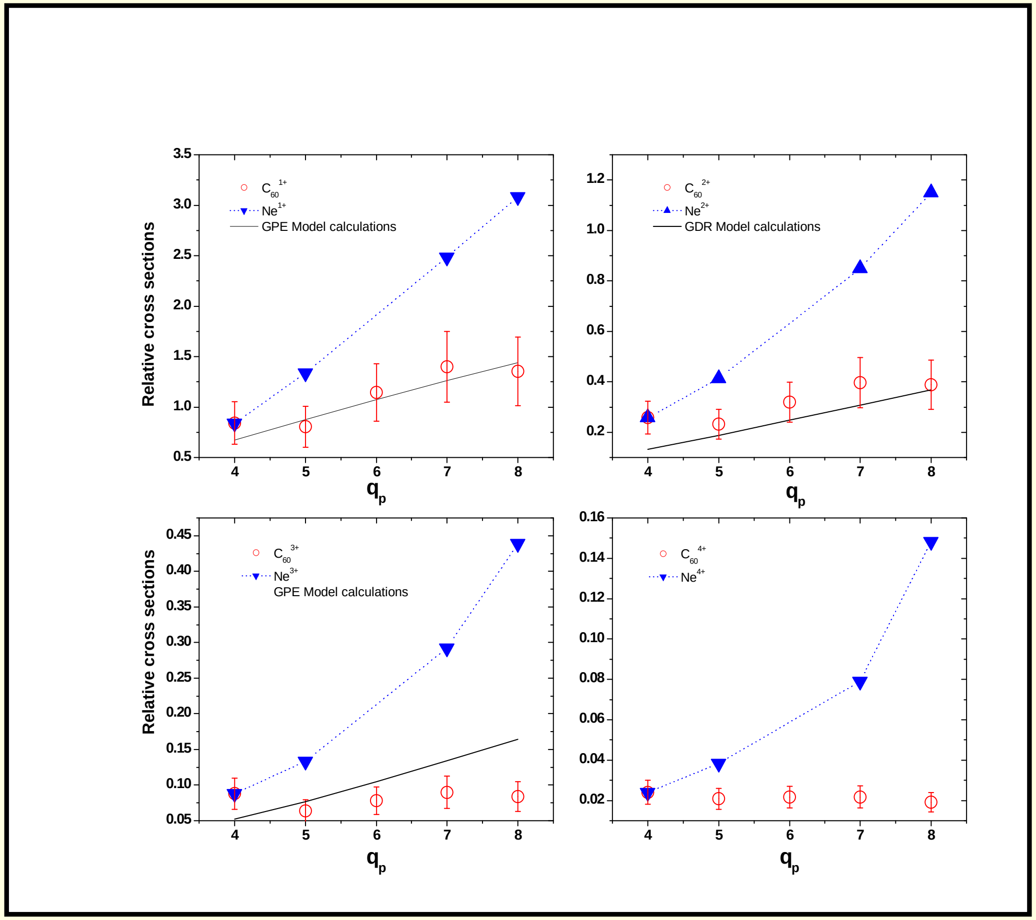
Drift tube voltage: -2000 V

ToF Spectrum of C_{60}



Temp. of C_{60} heater = ~ 400 ^oC

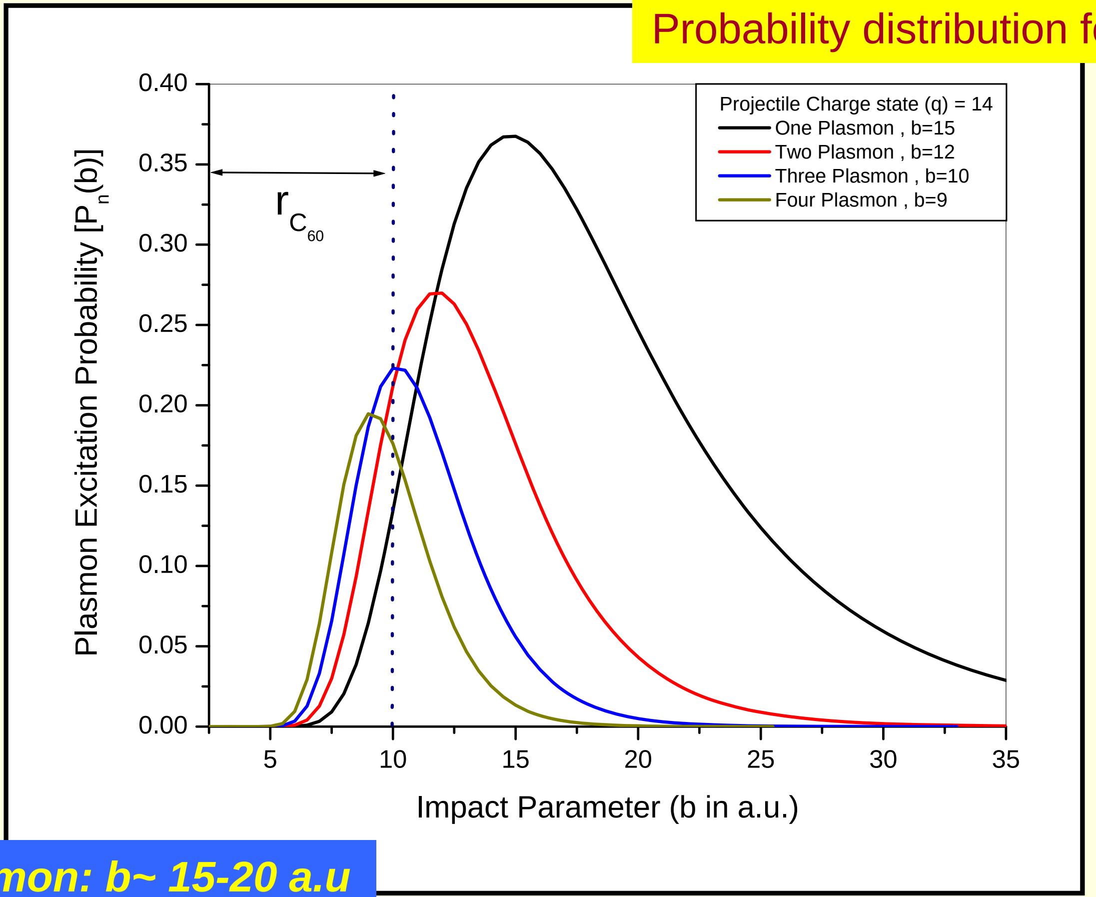
Comparison with ion-atom case



Kadhane *et. al.* Phys. Rev. A (Rapid comm.) 2007

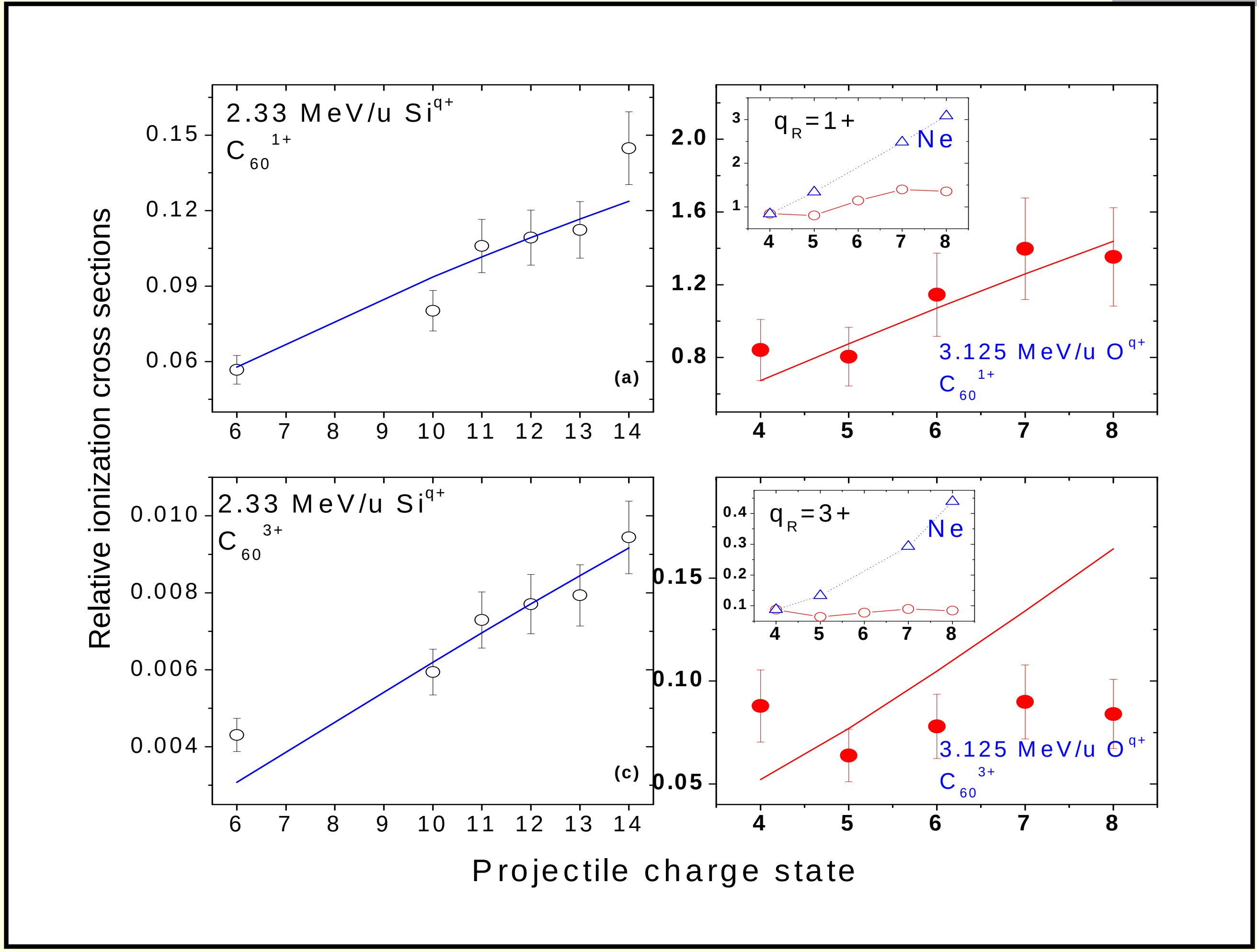
Multi Plasmon Excitation probability Vs. impact parameter :

Probability distribution for q=14+



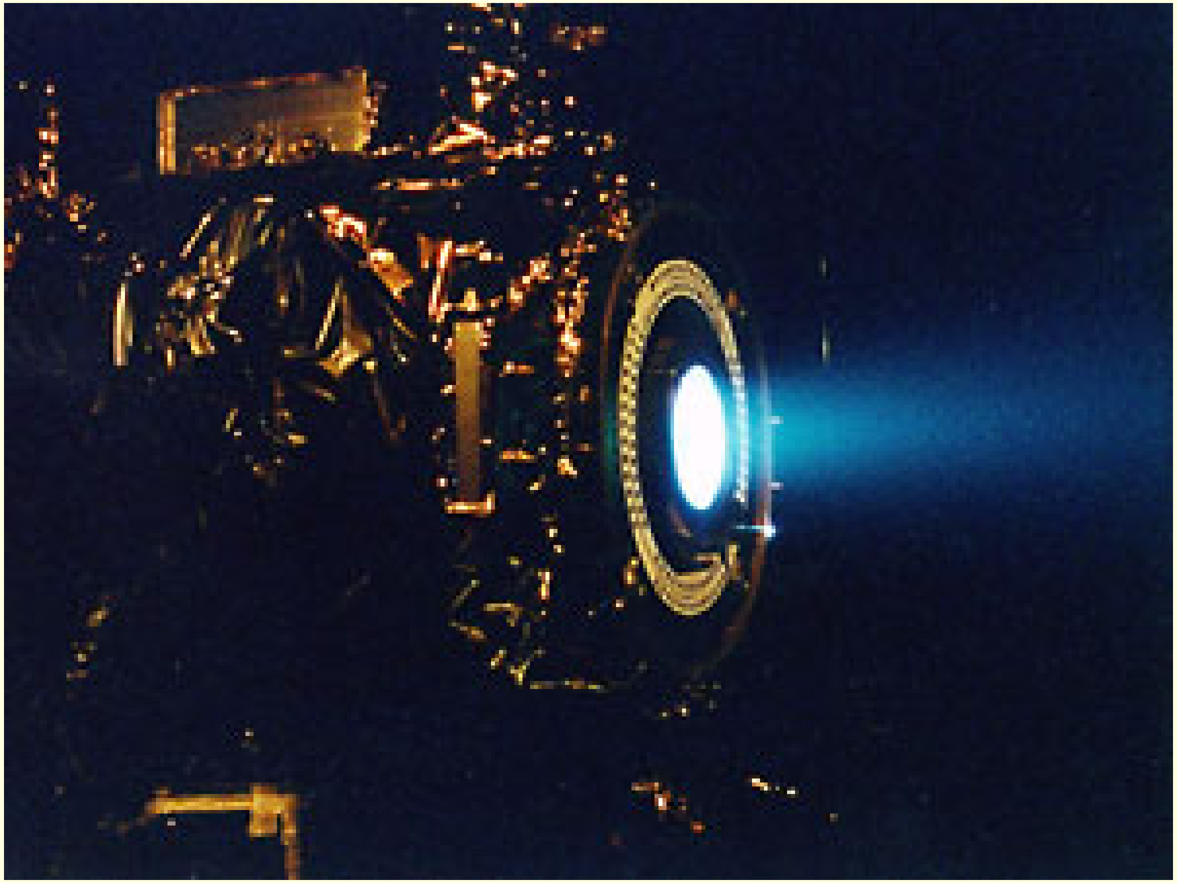
1 plasmon: b~ 15-20 a.u
4 plasmon: b~ 8-10 a.u

Comparison of model with the data

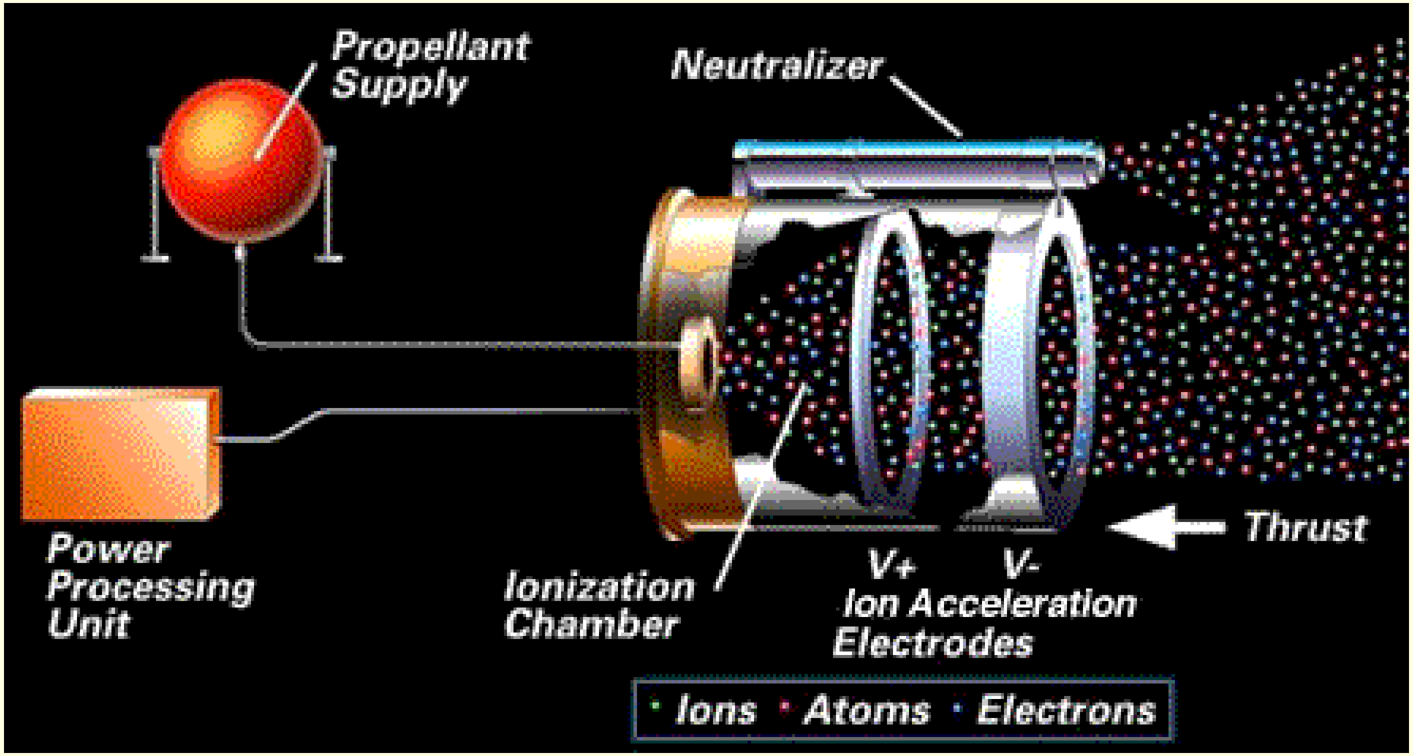


Kelkar *et. al.* J. Phys. B 2007

Application???



Application????



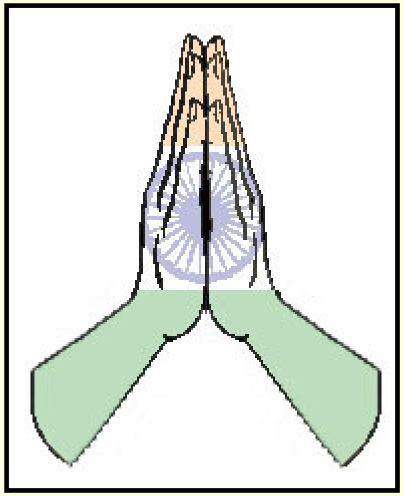
Conclusion

- SI and DI are dominated by GPE for O.
- Qualitative agreement for single and multiple ionization with GPE model for Si.
- *Indication of 3- plasmon excitations for triple ionization: Observed 1st time.*
- Need for a general model involving coupling among ionization, fragmentation and evaporation channels.

References:

Kadhane et. al. Phys. Rev. Letts. **90**, 093401 (2003)
Kadhane et. al. NIMB **205,** 661 (2003)
Kadhane et al. PRA **75** 041201(R) (2007)
Kelkar et al. JPB **40** 2481 (2007)
Kelkar et al. NIMB **256** 114 (2007)

धन्यवाद



ACKNOWLEDGMENT

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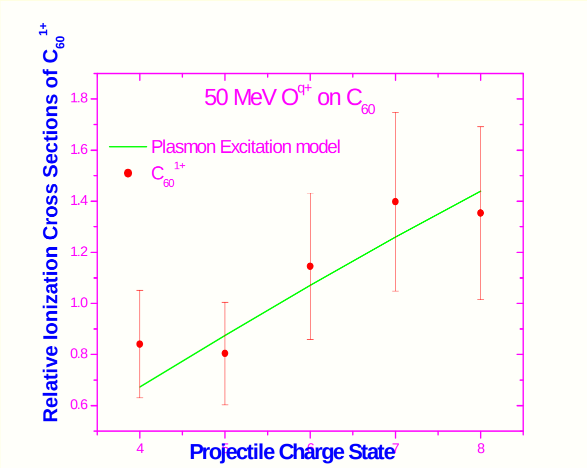
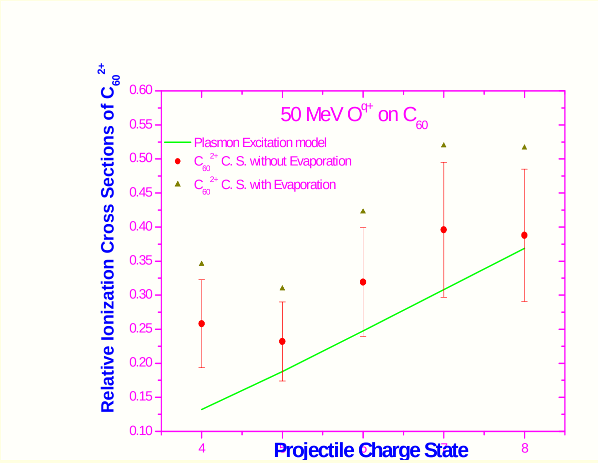
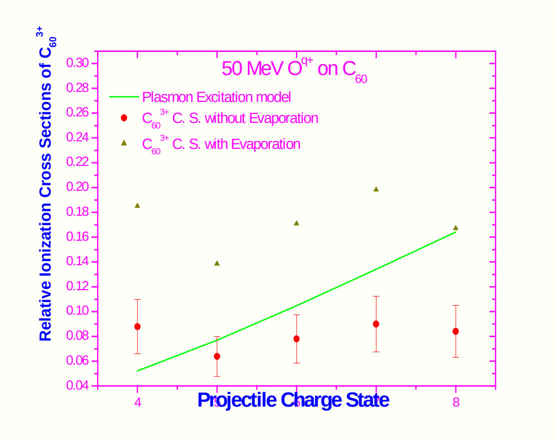
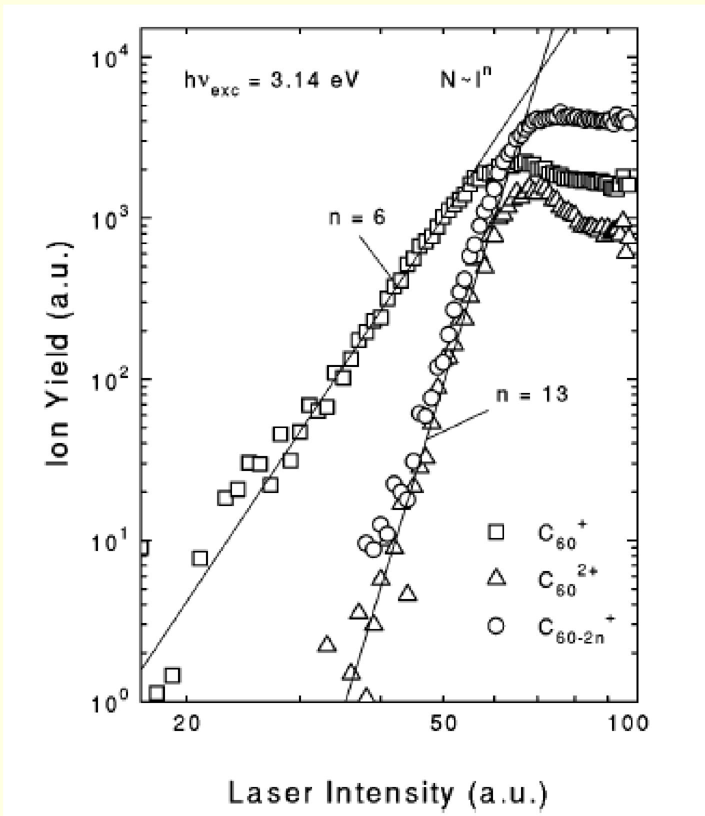
Comparison of plasmon excitation model with data

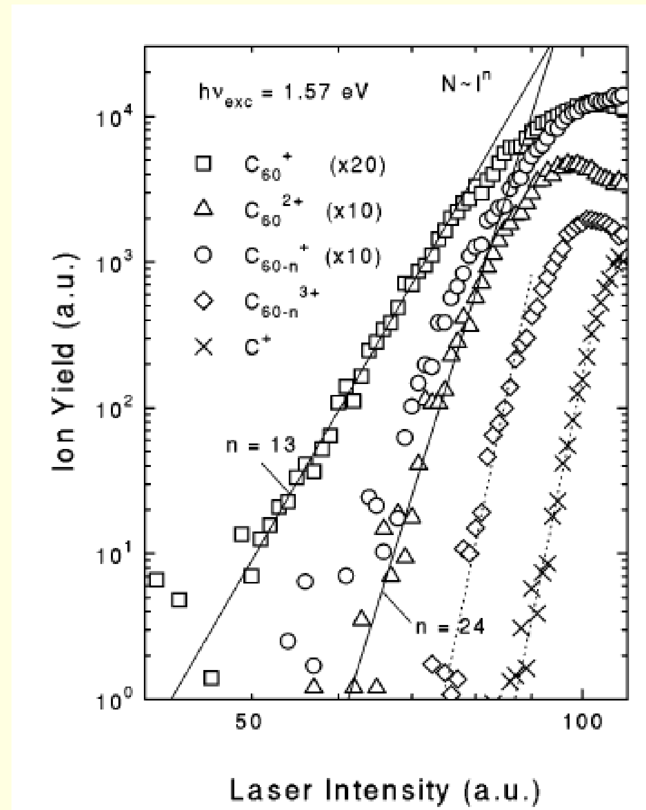






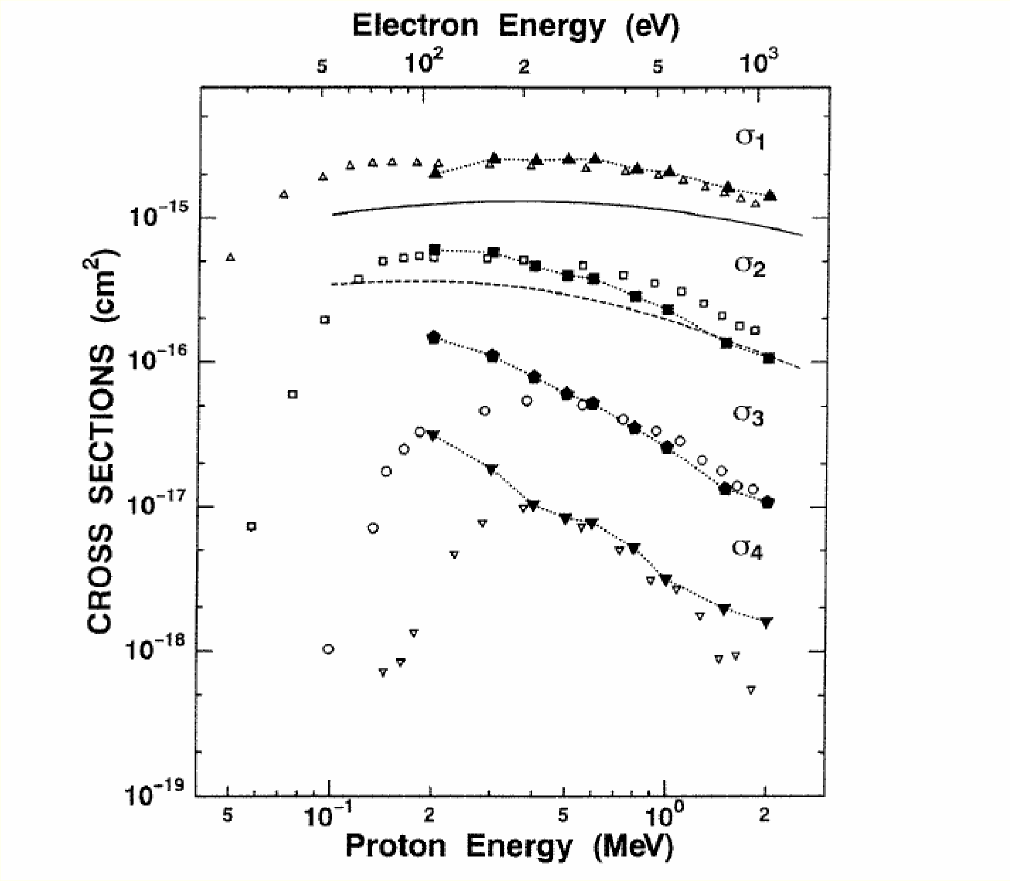
Equivalence of Plasmon excitation and ionization:





Ref. : Hunsche *et al,* Phys. Rev. Lett. (1996)

Testing the model



Week v_p dependence

Tsuchida *et. al.* J. Phys. B 1998