TDHF Calculations of $^{238}U+^{232}Th$

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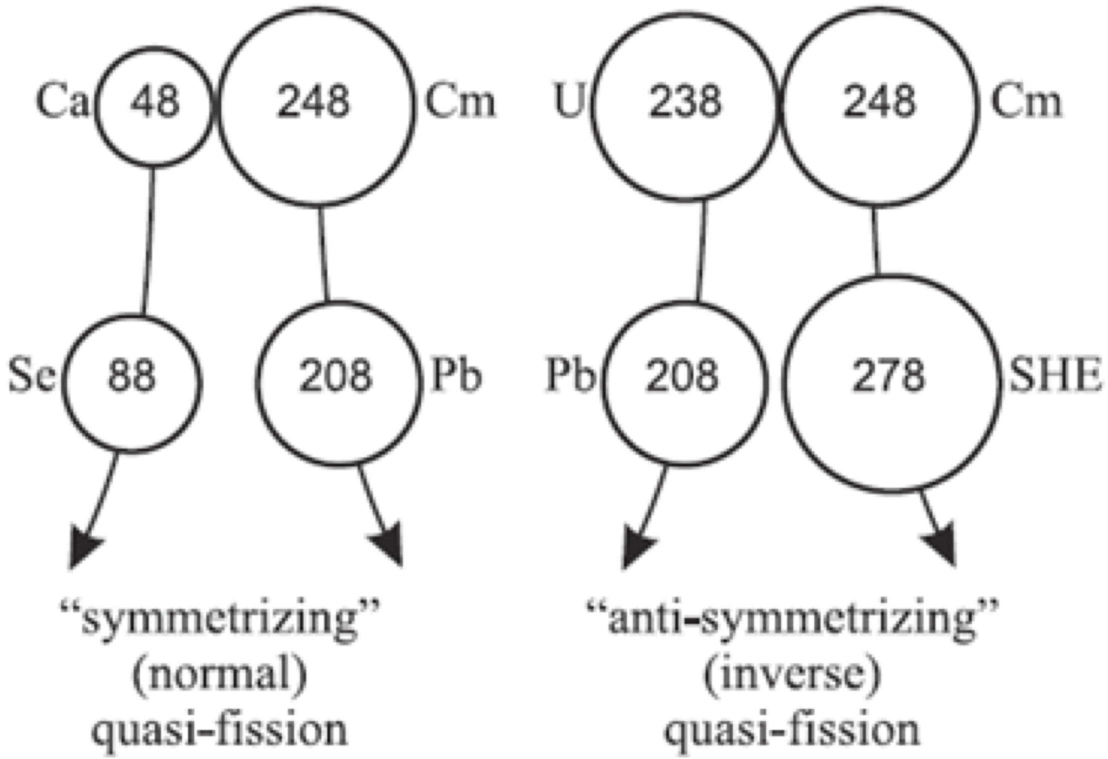
Motivation

- Super heavy elements have been synthesized from heavy element fusion which has resulted in neutron poor super heavy elements.
- Multinucleon transfer is explored to synthesize more neutron rich super heavy elements.
- TDHF is used to simulate the reaction $^{238}U+^{232}Th$ to study multinucleon transfer of heavy elements.

Background

Multinucleon transfer:

- Multinucleon transfer is when nuclei interact, exchange nucleons, and separate as different nuclei.
- Quasi fission is when nuclei exchange nucleons with mass flow from the large nuclei to the smaller nuclei
- Inverse quasi fission is when mass flow is from the smaller nuclei to the heavier nuclei.
- Energies close to the coulomb barrier.

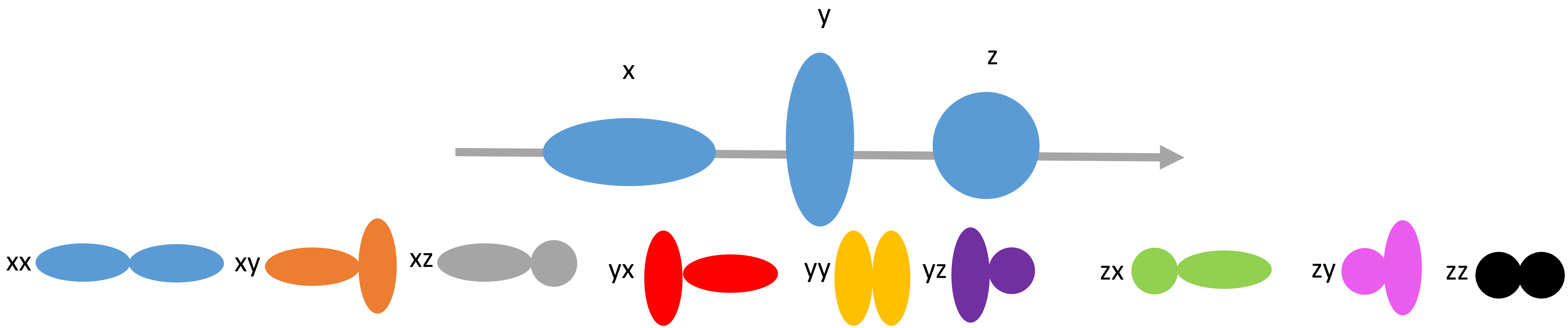


K. Sekizawa et al. Phys. Rev. C 88, 0146114 (2013)
D. J. Kedziora et al. Phys. Rev. C 81 044613 (2010)

Background

Time Dependent Hartree-Fock (TDHF):

- TDHF is a microscopic model
- TDHF generates boundaries for the reaction.
- This is used to study reactions from central to peripheral collisions.
- ^{238}U and ^{232}Th are both deformed nuclei
    - Studying 3 cases.
    - Resulting in 9 different orientation.



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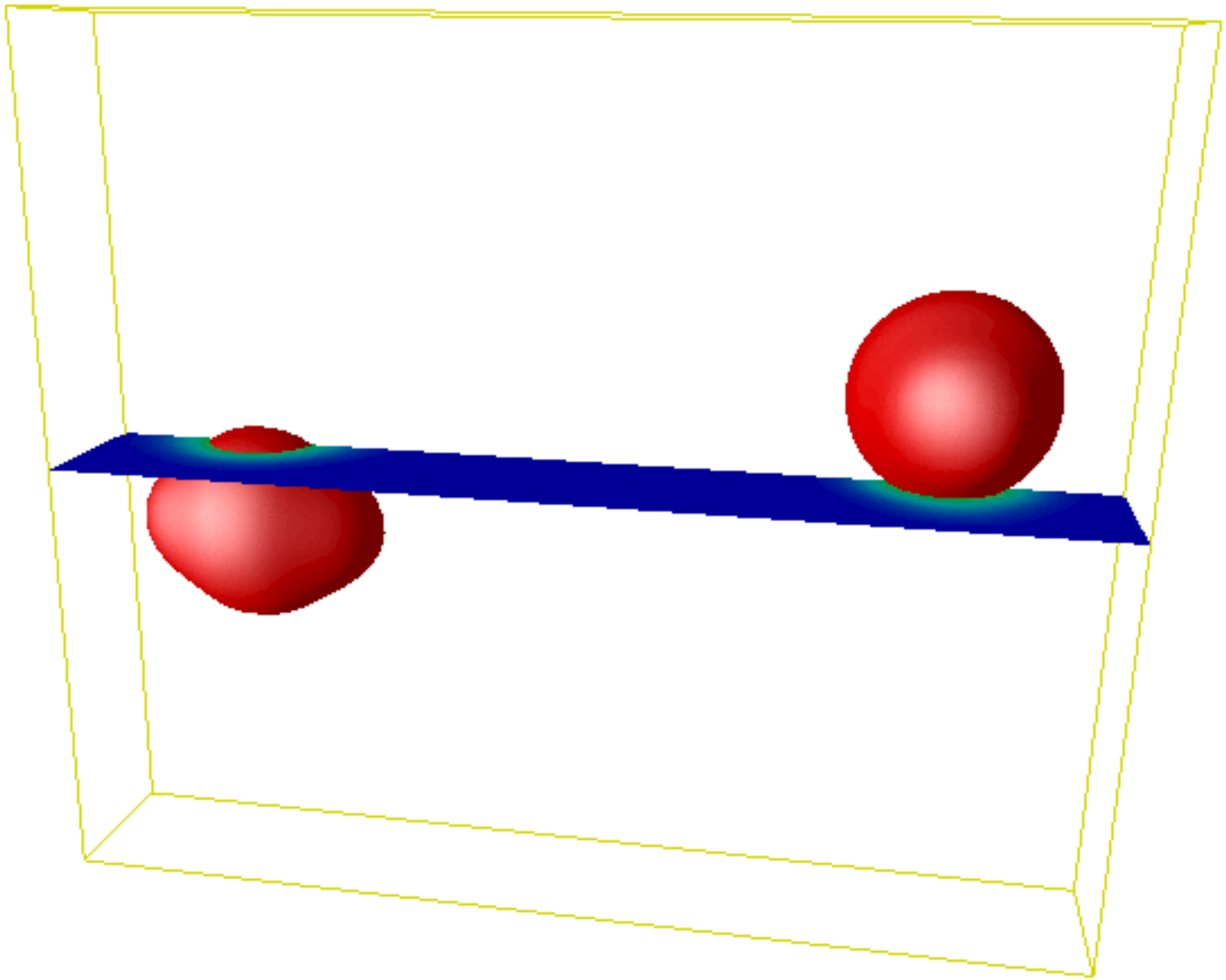
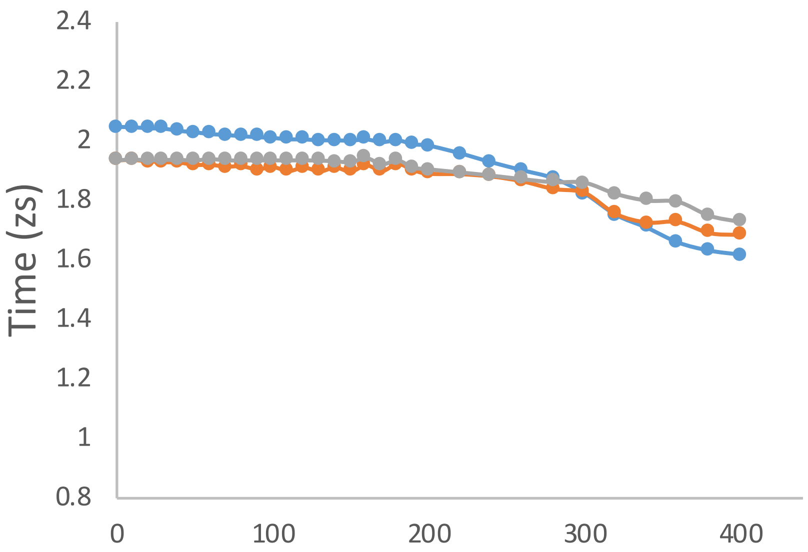
Example reaction:

- U and Th come into contact
- Neck forms and nucleons transfer
- The nuclei rotate to conserve angular momentum
- Separate as two new nuclei



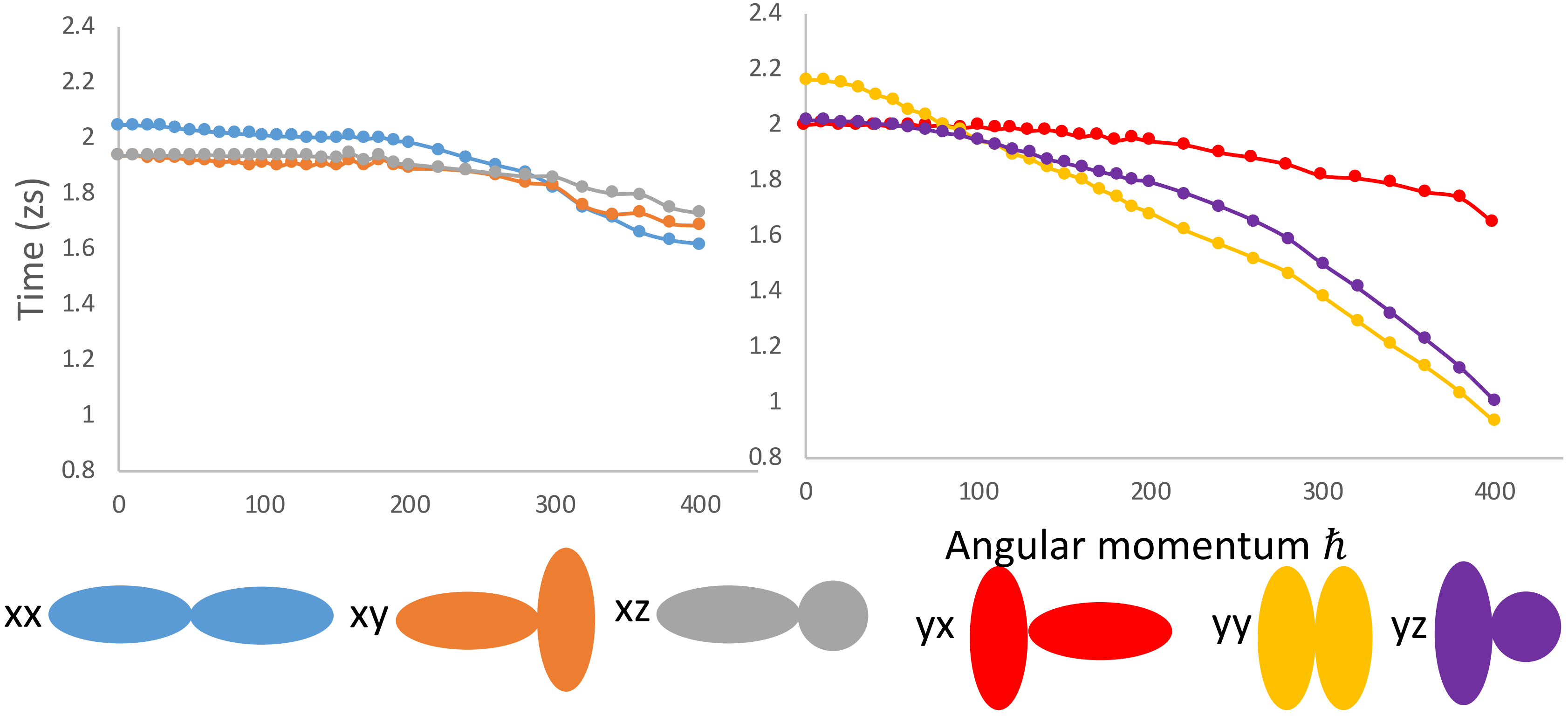
Contact Time



Angular momentum $\hbar$

- The reaction is consider to be in contact when the neck density is > 0.016 u/fm³.
- Various combinations of orientations.

Contact Time



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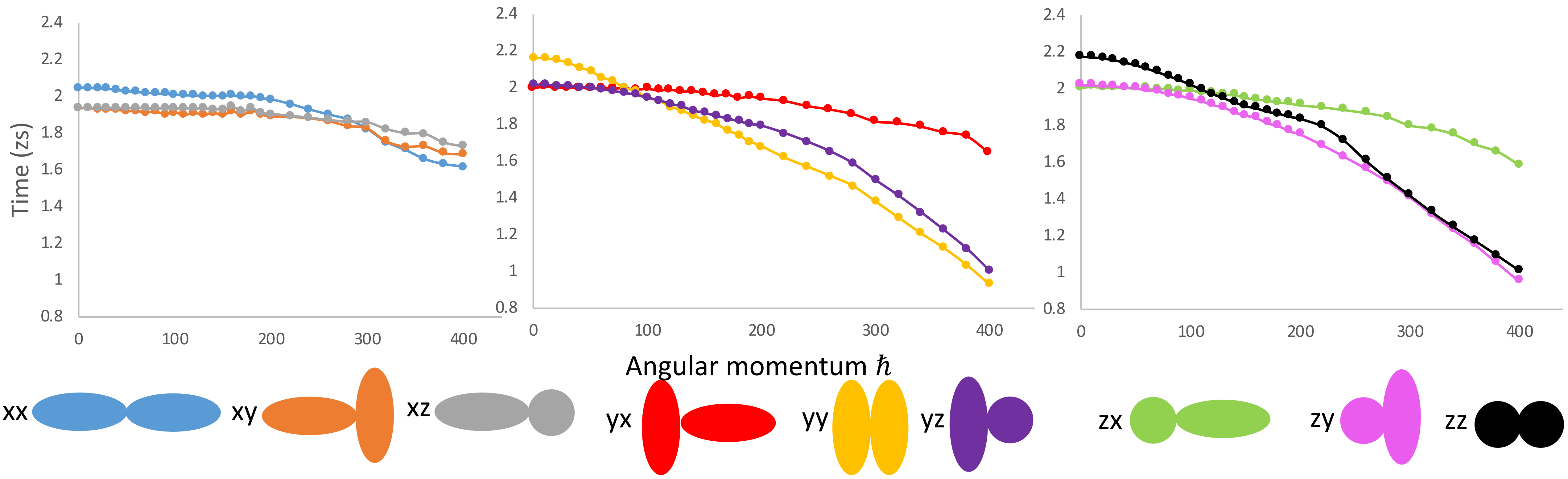
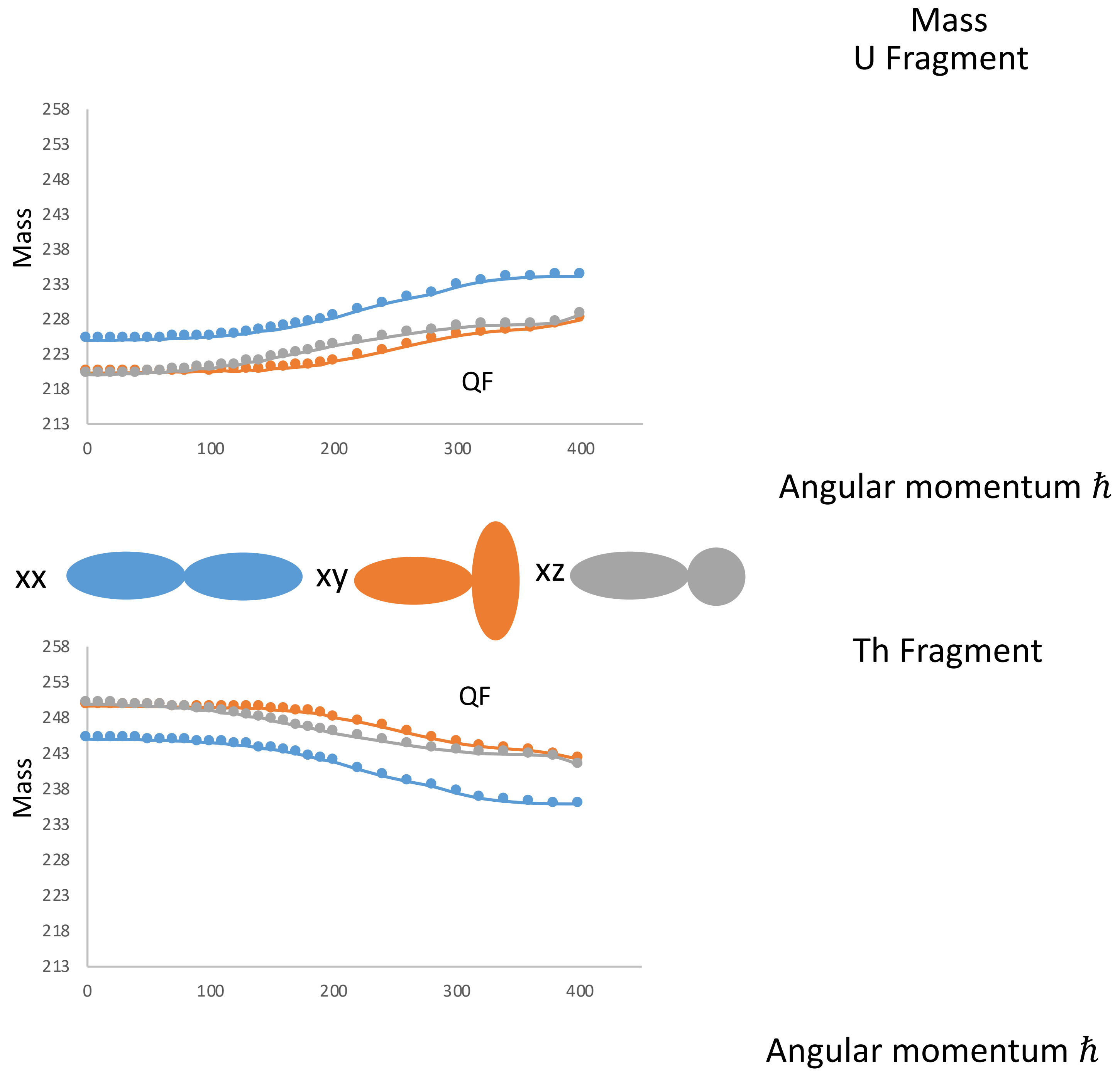


- The reaction is consider to be in contact when the neck density is > 0.016 u/fm^3.
- Various combinations of orientations.
- Longest time approximately 2.2 zs or 650 fm/c
- The orientations have a large impact on the reactions.



Mass
U Fragment
Mass
258
253
248
243
238
233
228
223
218
213
0
100
200
300
400
QF
Angular momentum ħ
xx
xy
xz
Th Fragment
Mass
258
253
248
243
238
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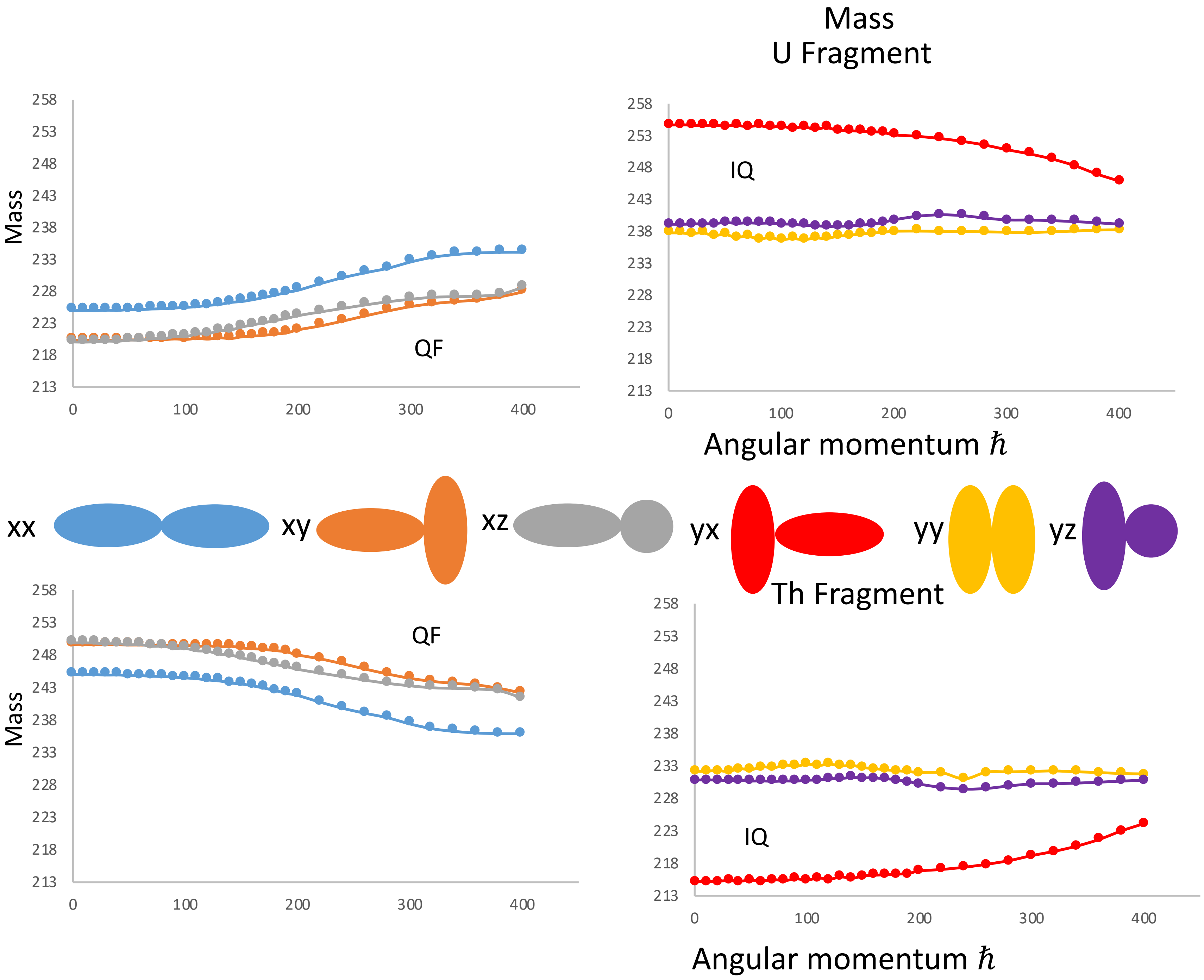
Angular momentum ħ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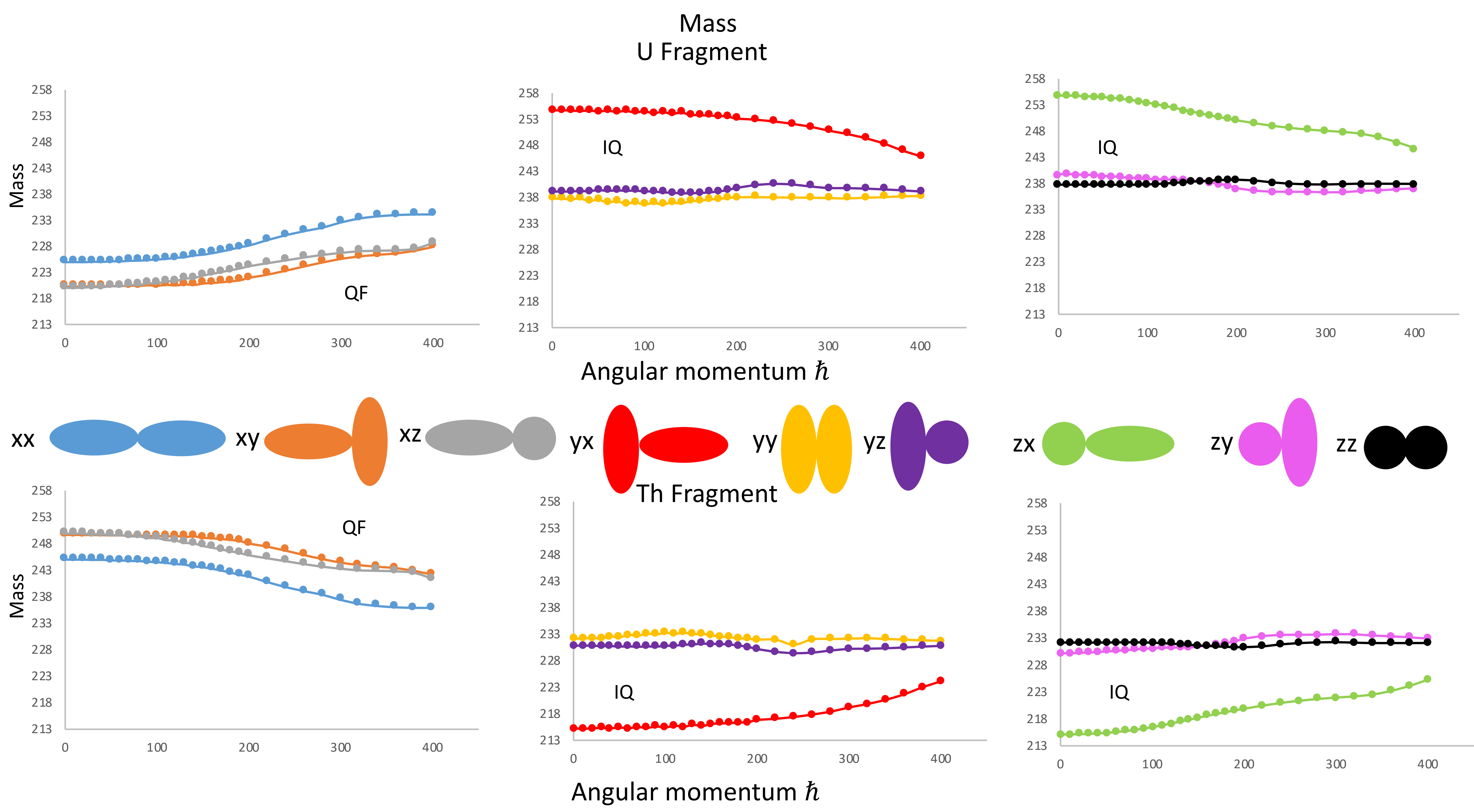
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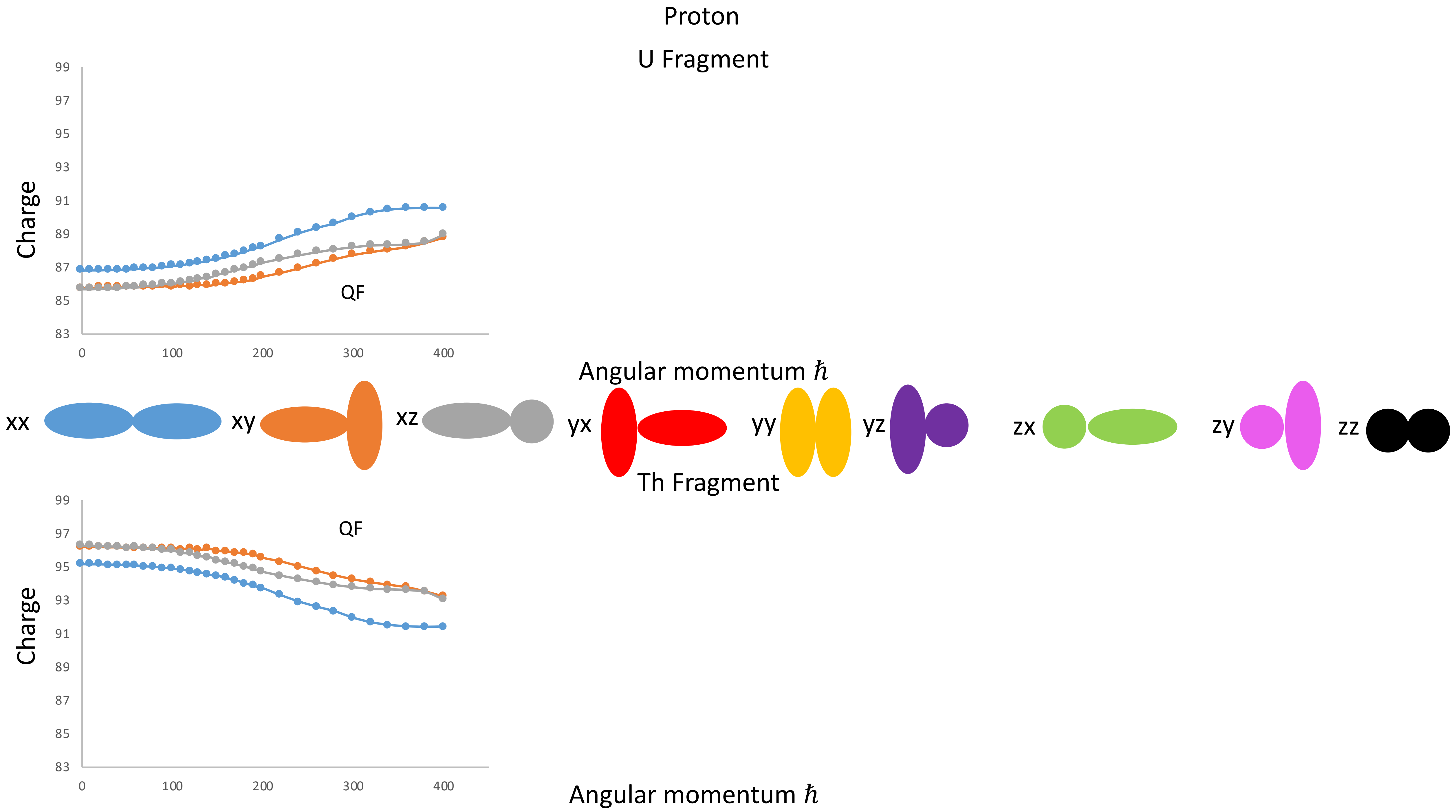
Proton
U Fragment
Charge
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QF
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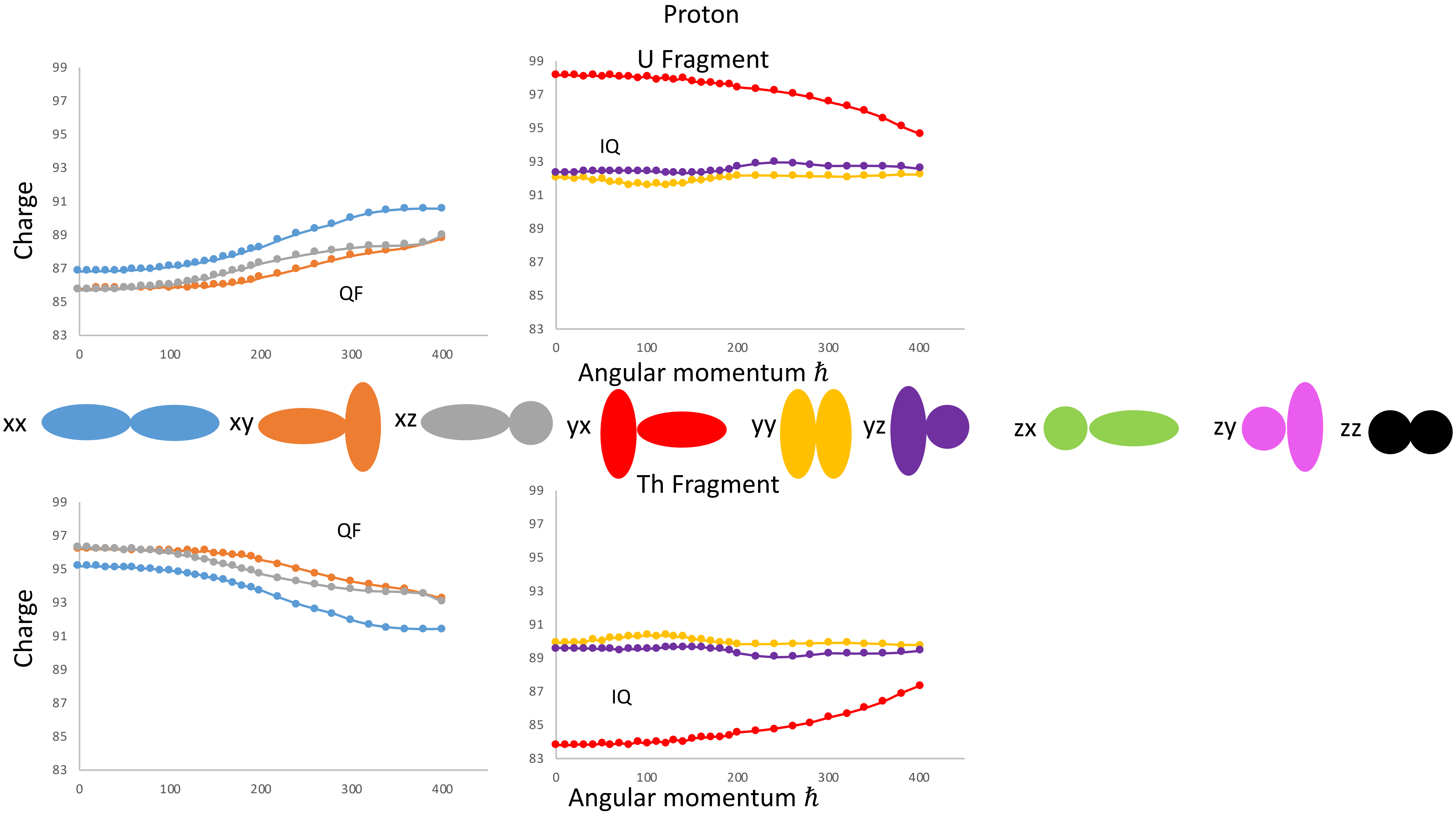

Proton
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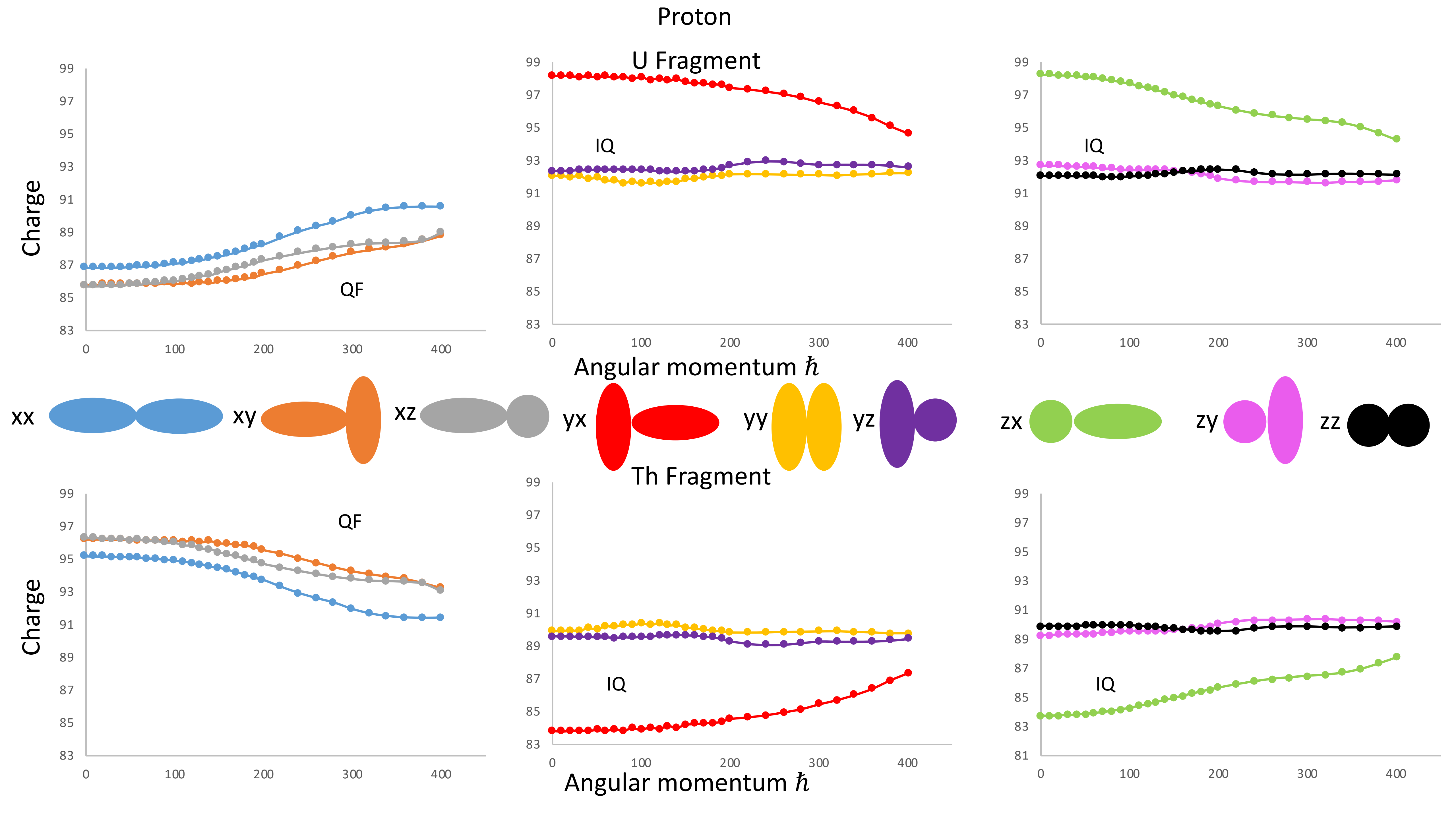

Proton
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Angular momentum ℏ
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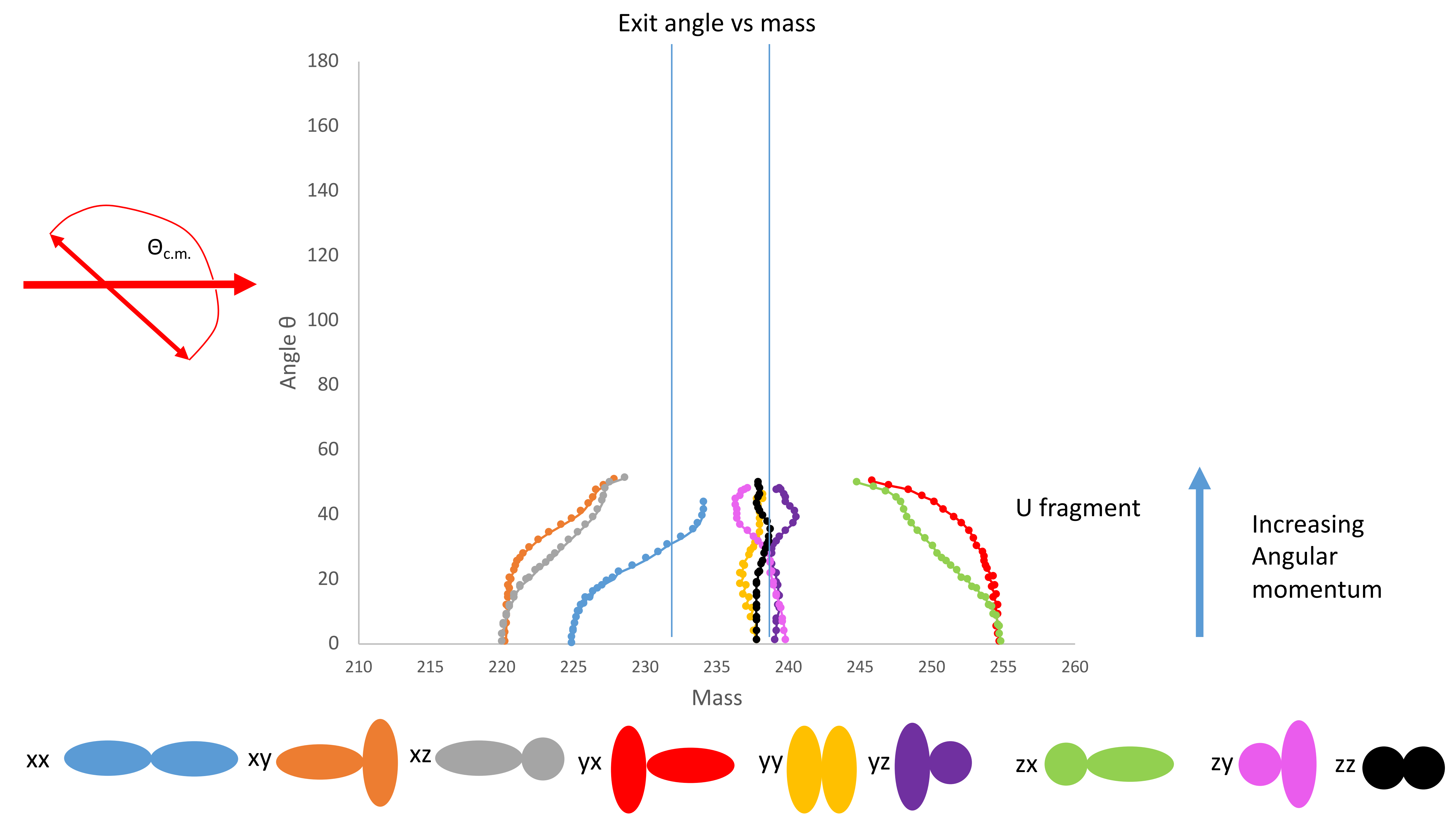

Exit angle vs mass
Θc.m.
Angle θ
180
160
140
120
100
80
60
40
20
0
210
215
220
225
230
235
240
245
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255
260
Mass
U fragment
Increasing
Angular
momentum
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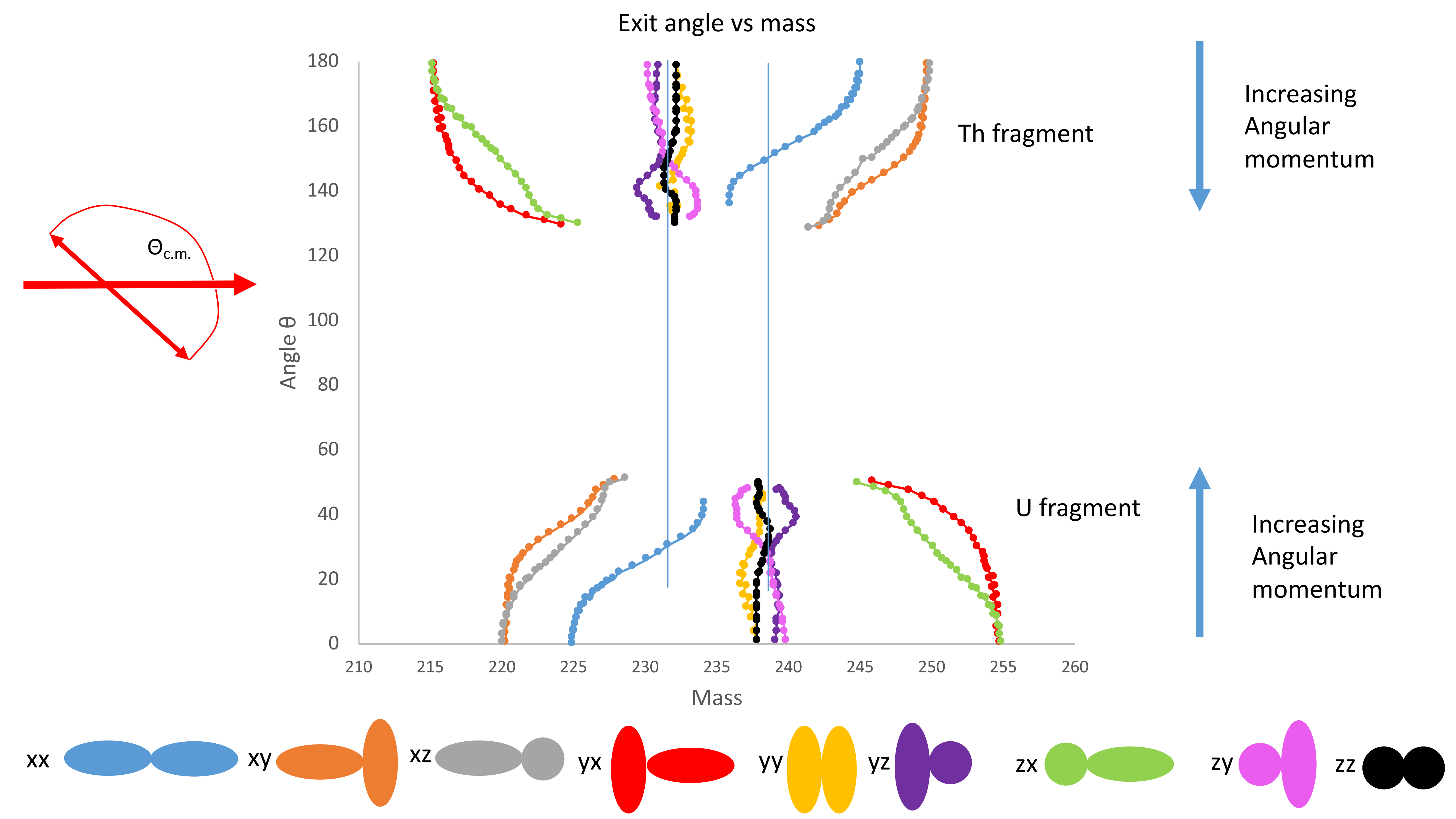
xy
xz
yx
yy
yz
zx
zy
zz



Exit angle vs mass
Θc.m.
Angle θ
180
160
140
120
100
80
60
40
20
0
210
215
220
225
230
235
240
245
250
255
260
Mass
Th fragment
U fragment
Increasing Angular momentum
Increasing Angular momentum
xx
xy
xz
yx
yy
yz
zx
zy
zz

Conclusion

- Resulting fragments depend on orientations of the starting reactants.
- Reactions show the greatest transfer of nucleons occur at the lowest angular momenta.
- Products show greatest mass transfer of 17 nucleons , 11 neutrons, 6 protons.
- TDHF gives expectation values.

Thank You

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S. Wuenschel et al. Phys. Rev. C 97, 064602 (2018)
K. Sekizawa et al. Phys. Rev. C 88, 0146114 (2013)
D. J. Kedziora et al. Phys. Rev. C 81 044613 (2010)
A. Wakhle. Thesis (2013)