Investigation of Quasi Fission Dynamics of $^{35}Cl+^{181}Ta$ and $^{35}Cl+^{205}Tl$ reactions

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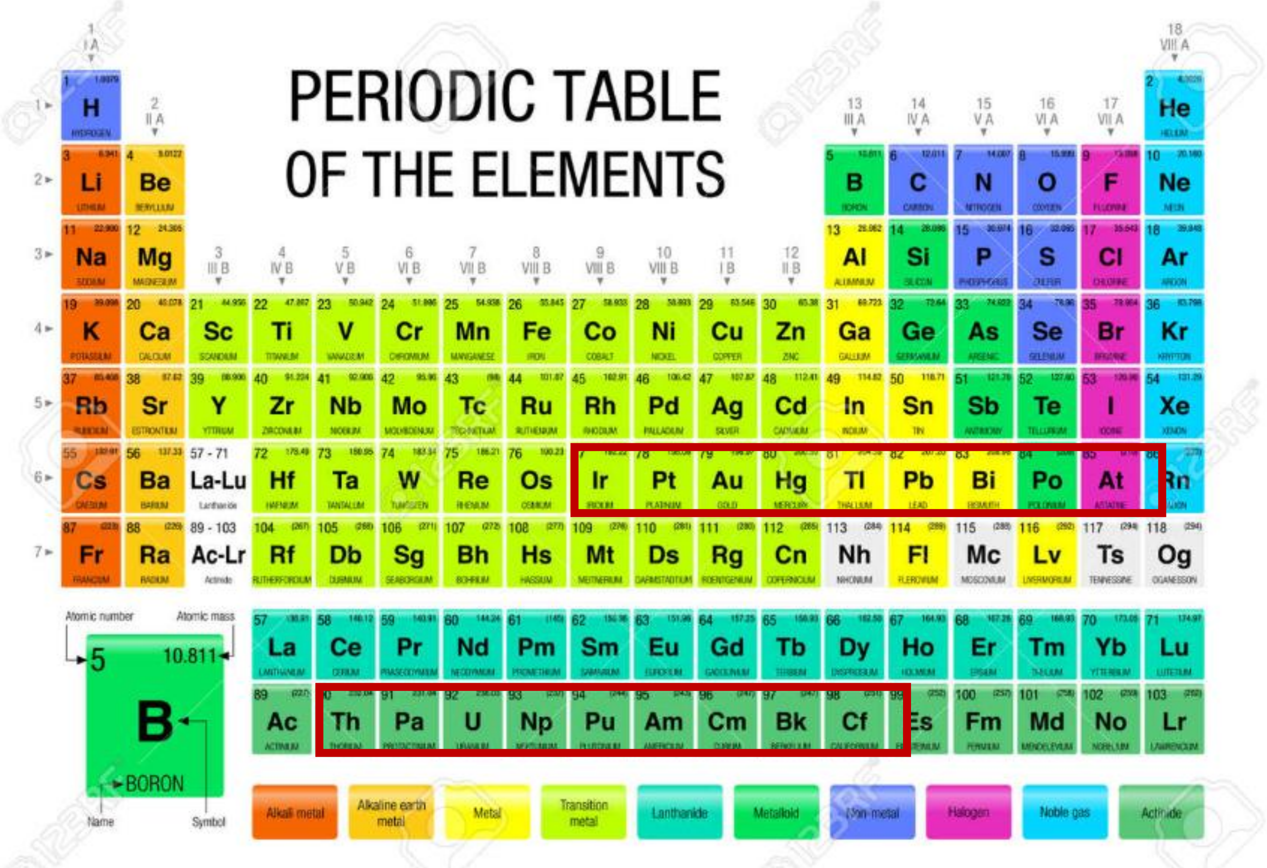
Outline

- ✓ Motivation of the experiment
- ✓Experimental details
- ✓Results
- ✓ Conclusions

Introduction



Accelerator facilities for Nuclear Physics in India

VECC, Kolkata Cyclotron

IUAC, New Delhi, 15 MV pelletron

TIFR, Mumbai, 14 MV pelletron

Higher energies: LINACs at Delhi & Mumbai and K500 Cyclotron in Kolkata

Physics motivation

- **Quasi-fission is a fission like process that hinders the formation of Super Heavy Element (SHE).**

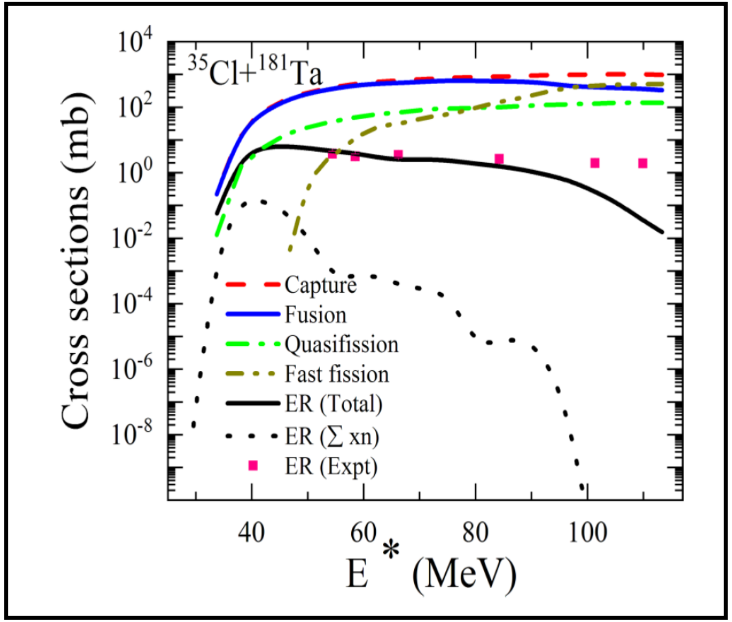
It is important to know dynamics of Quasi Fission (QF) reactions

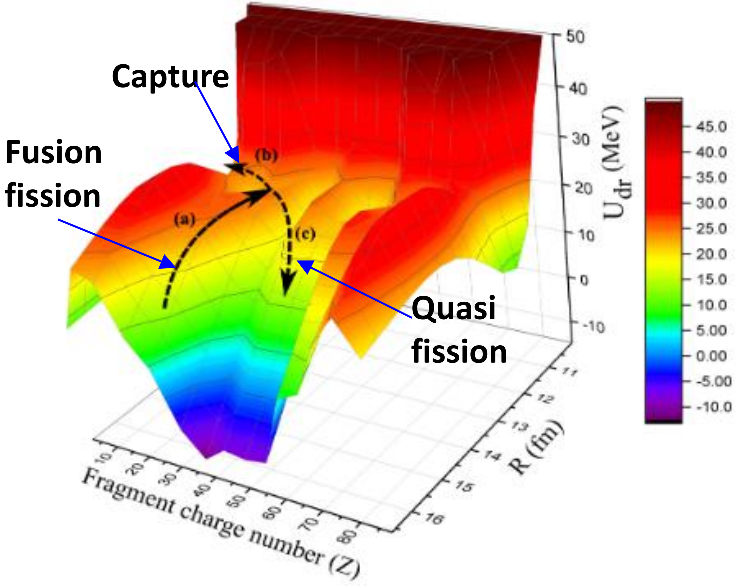
- **We study the dynamics of quasi-fission reactions both for HE and SHE using mass distributions as the experimental probe.**

A.Chaudhuri, A. Sen, T.K. Ghosh et al; Phys. Rev. C 94, 024617 (2016)
Kozulin, Knyazheva, T.K. Ghosh, Sen et al; Phys. Rev. C. 99, 014616 (2019)
A Sen, T.K. Ghosh, Kozulin et al; Phys. Rev. C. 105, 014627 (2022)

- There are scarcity of reliable theoretical models that efficiently predicts the amount of QF in a reaction. However, any new models that are being developed, needs to be tested experimentally.

Motivation

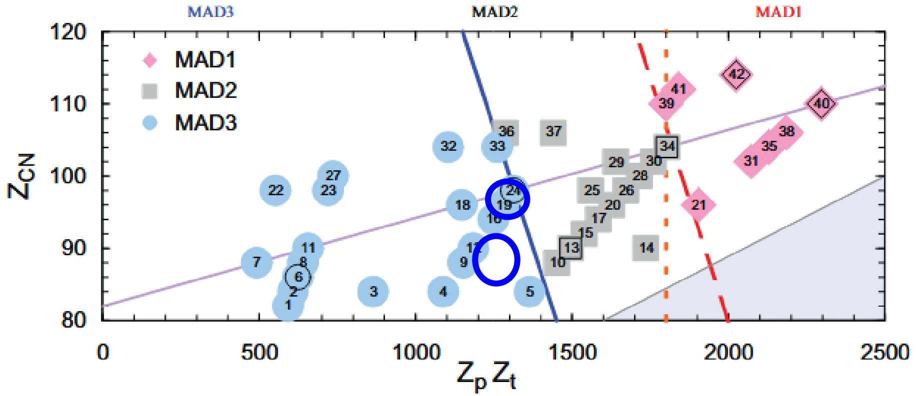


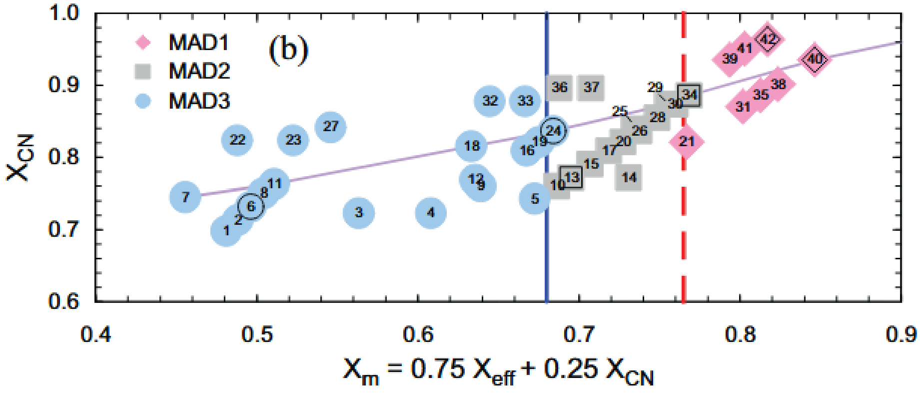


- The DNS model predicts quasi-fission (QF) in the $^{35}Cl + ^{181}Ta$ reaction.
- In order to validate the DNS model predictions, we conducted an experiment to explore quasi-fission (QF) dynamics in this reaction.

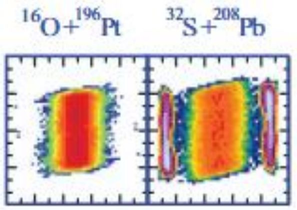
Nasirov et al., Phys. Lett. B 686, 72 (2010), Phys. Rev. C102,034613(2020)

Motivation

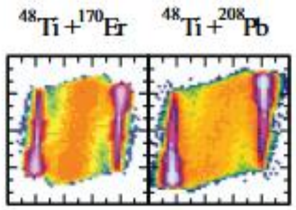




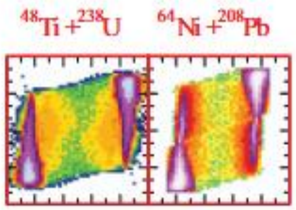
Reaction	$Z_p Z_t$	Z_{CN}	X_{CN}	X_m
$^{35}Cl + {}^{181}Ta$	1241	90	0.780	0.661
$^{35}Cl + {}^{205}Tl$	1377	98	0.834	0.696



MAD3



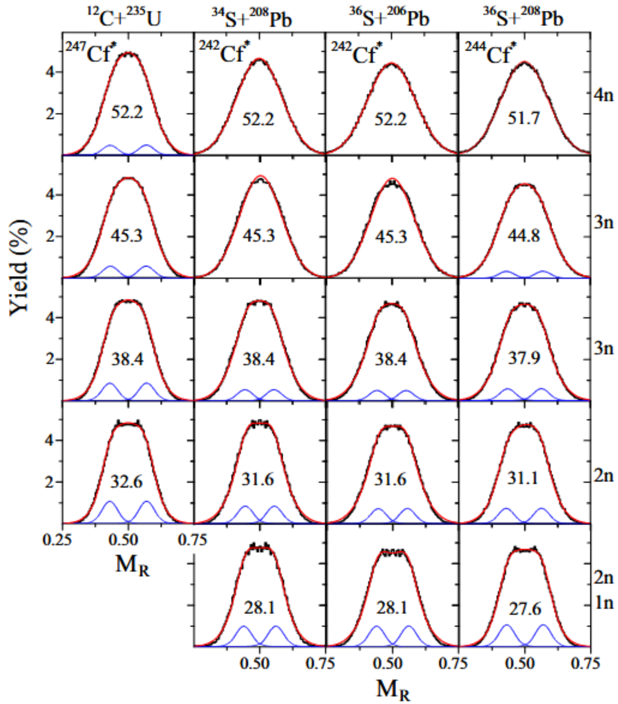
MAD2



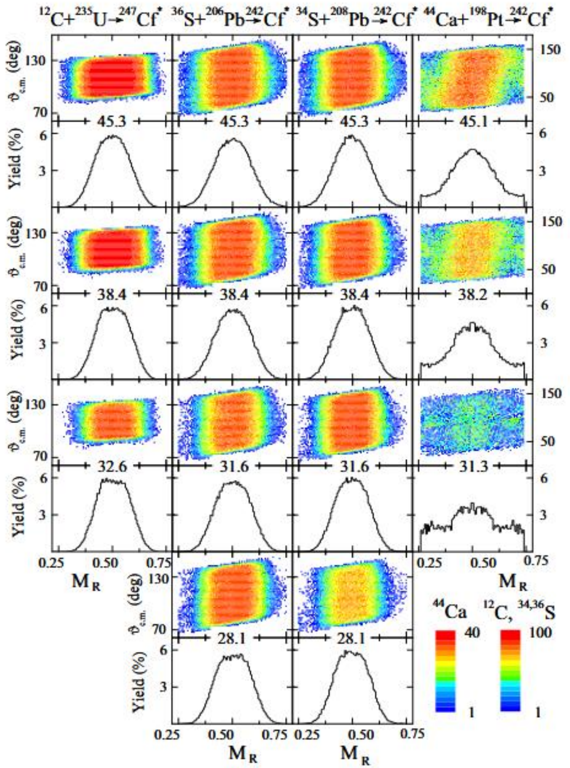
MAD1

R. du Rietz, et al., PHYSICAL REVIEW C 88, 054618 (2013)

Motivation



No Mass angle correlation



- ➢ The ER yield for $^{34}S + ^{208}Pb$ is suppressed by ~10 times compared to $^{36}S + ^{206}Pb$.
- ➢ Both the reactions show very similar flat-topped fission mass spectra.

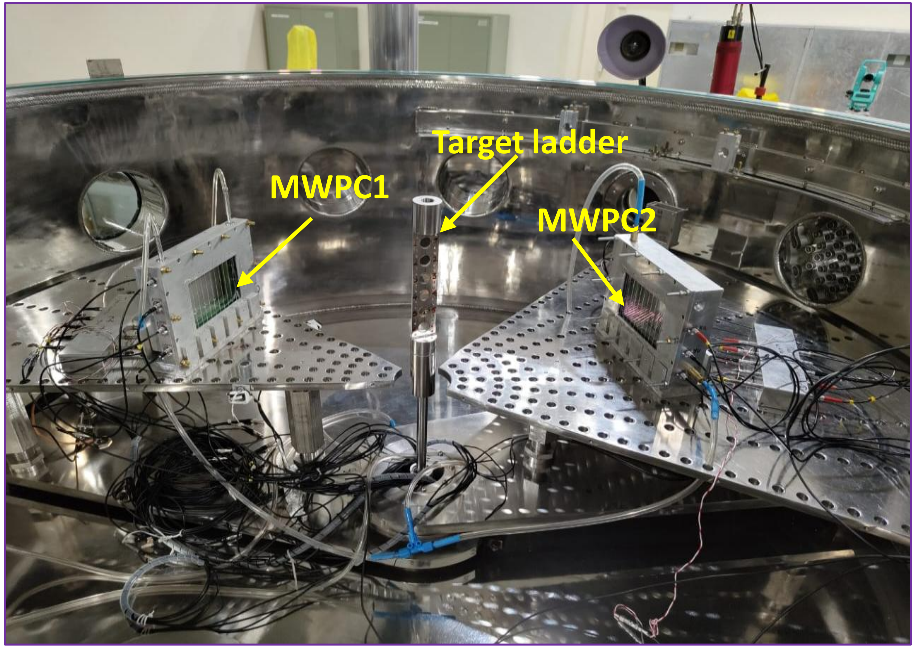
- ✓ Mass distributions deviate from a single Gaussian shape.
- ✓ Implies quasifission is influenced by shell effects even at ~45 MeV excitation energy.

J. Khuyagbaatar et al; Phys Rev C 91, 054608 (2015)

Experiment at TIFR, Mumbai, India

Reaction: $^{35}Cl + ^{181}Ta \longrightarrow ^{216}Th^*$

Reaction: $^{35}Cl + ^{205}Tl \longrightarrow ^{240}Cf^*$



✓ **The experiment was carried out at BARC-TIFR LINAC-Pelletron facility, Mumbai**

Motivation

We measured the mass distributions in the reactions:

Target is deformed

$^{35}Cl + ^{181}Ta \Rightarrow ^{216}Th^*$

$^{35}Cl + ^{205}Tl \Rightarrow ^{240}Cf^*$

Target is spherical

Measurement of ER at IUAC

Laveen et al; Phys Rev. C 102, 034613 (2020)

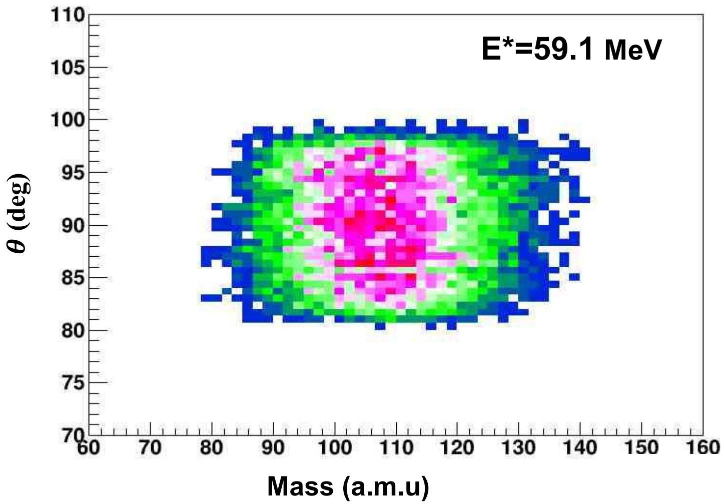
Details of the reaction parameters

Reaction	$^{35}Cl + ^{205}Tl$	$^{35}Cl + ^{181}Ta$
β_2 projectile	-0.234	-0.234
β_2 target	0.000	0.255
ZpZt	1377	**1241**
X_{CN}	0.834	0.780
Ent. Channel magicity	0	0
Mass asymmetry	0.708	0.676

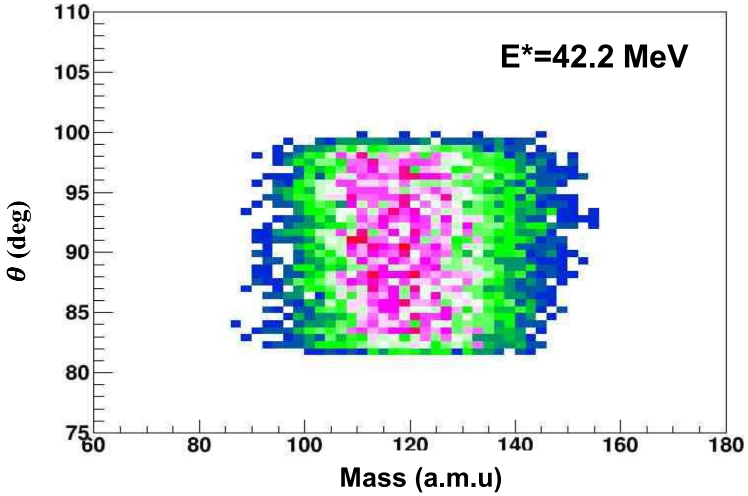
Results of $^{35}Cl+^{181}Ta$

Mass Angle correlation

$^{35}Cl+^{181}Ta \longrightarrow ^{216}Th^*$

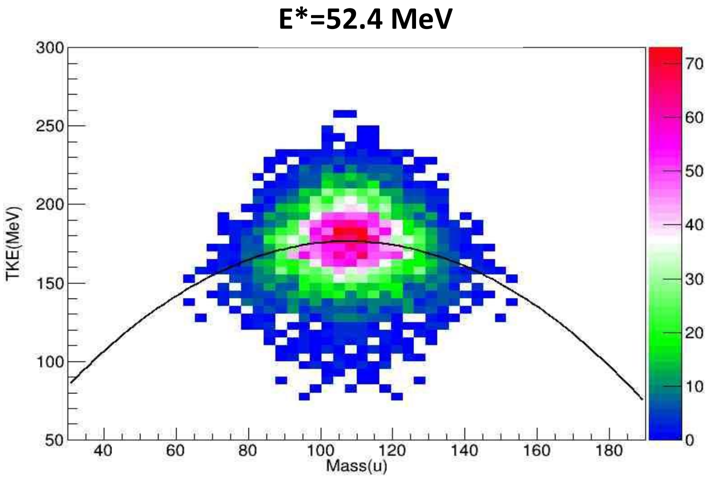


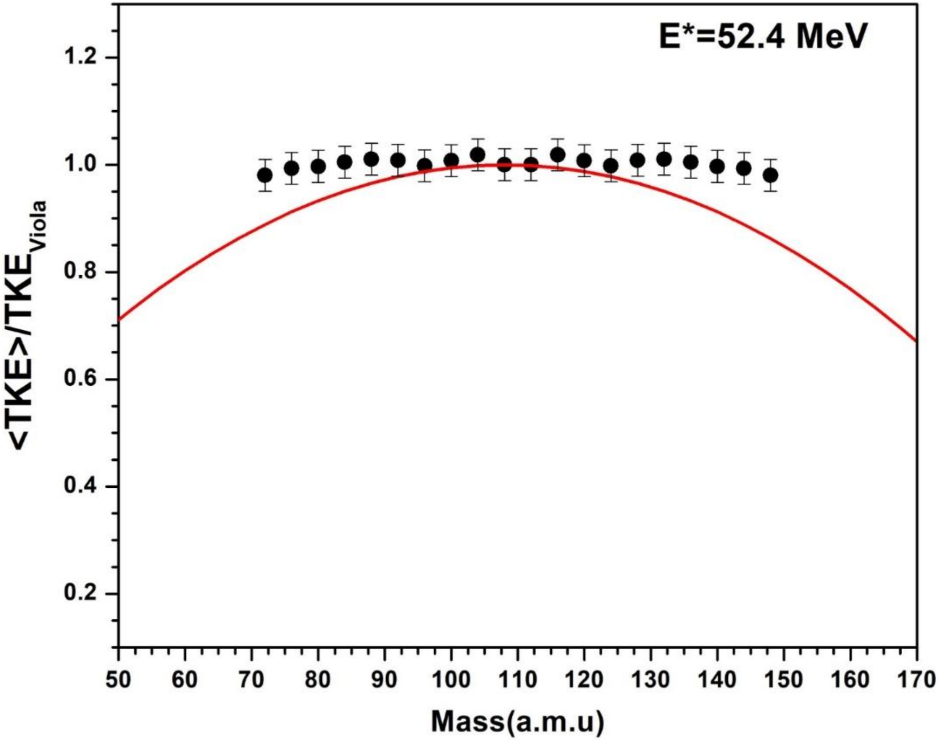
$^{35}Cl+^{205}Tl \longrightarrow ^{240}Cf^*$



No significant mass angle correlation for both the systems

Mass-TKE correlations (^{35}Cl + ^{181}Ta)

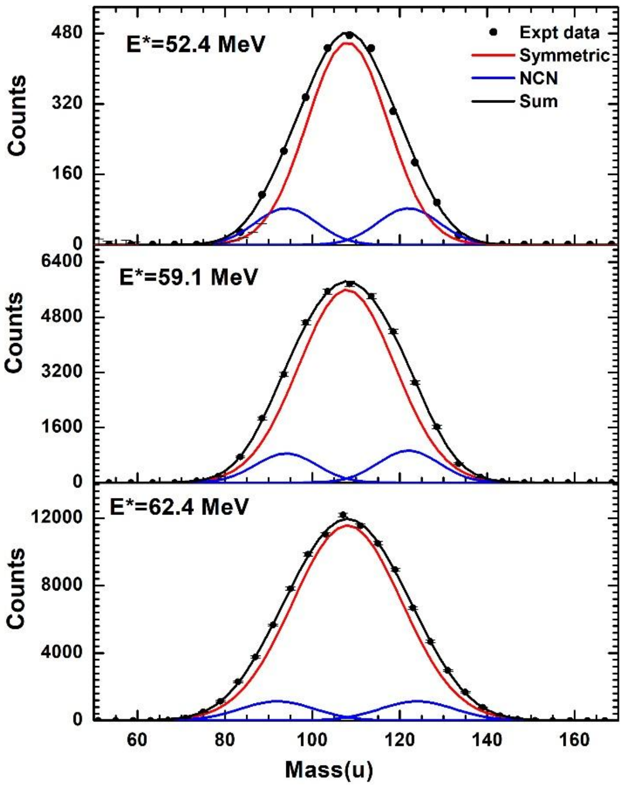


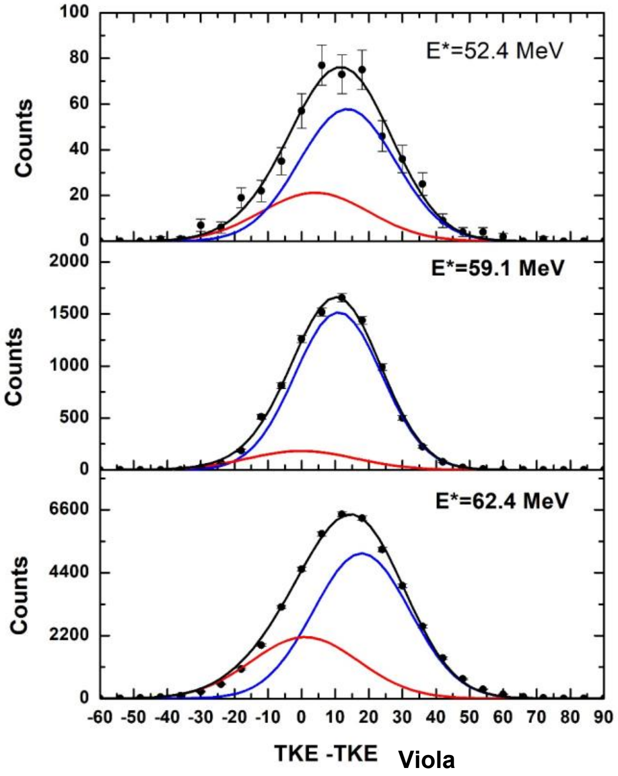


- Admixture of NCN fission is evident from measured Mass–TKE correlations.

Deviation from LDM may be due to quasi-fission or shell effects.

Mass Distributions and TKE distributions ($^{35}Cl + ^{181}Ta$)



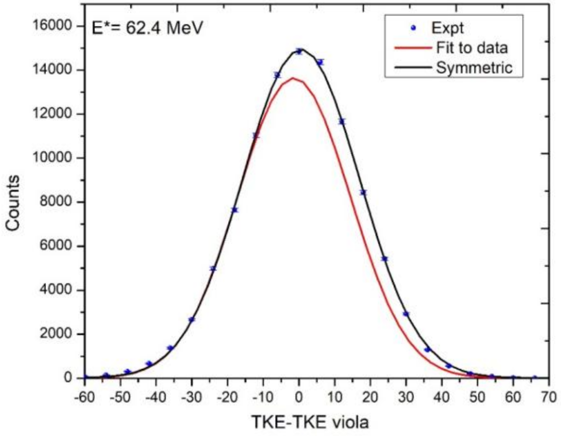


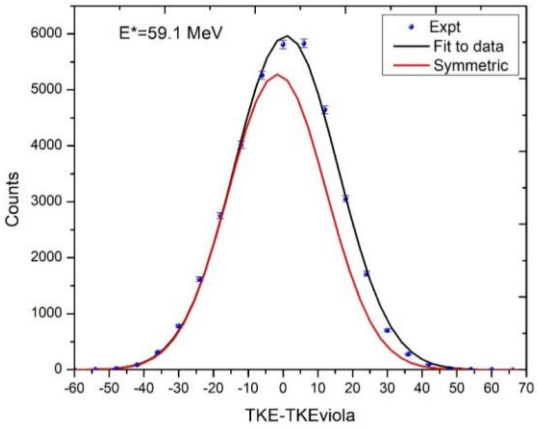
- ✓ Large mass distribution width → requires FF and NCN components
- ➢ **NCN component decreases as excitation energy increases.**

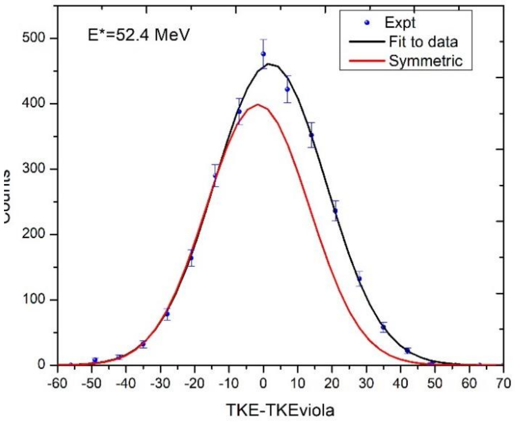
TKE of asymmetric fragments (120–140) u.

- ✓ Deviates from single Gaussian; TKE of NCN is higher than CN.

Total Kinetic Energy Distribution of Fission Fragments

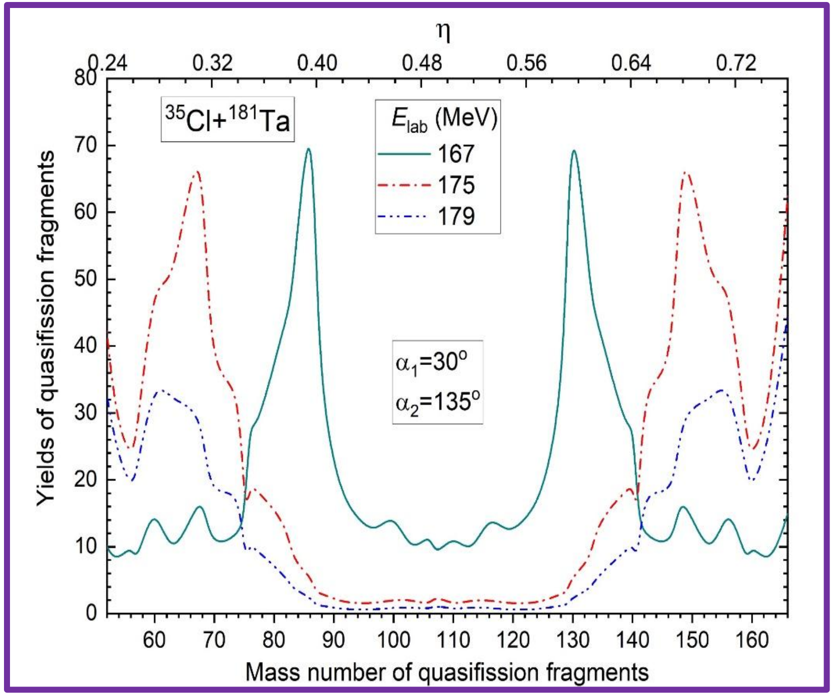






- ✓ **Approximately 21%, 13%, and 9% of NCN component shows up at excitation energies of 52.4, 59.1, and 62.4 MeV respectively.**
- ✓ **Percentage of NCN decreases with increasing excitation energies.**

Di-Nuclear System (DNS) Model Calculation



Percentage of Quasi Fission:

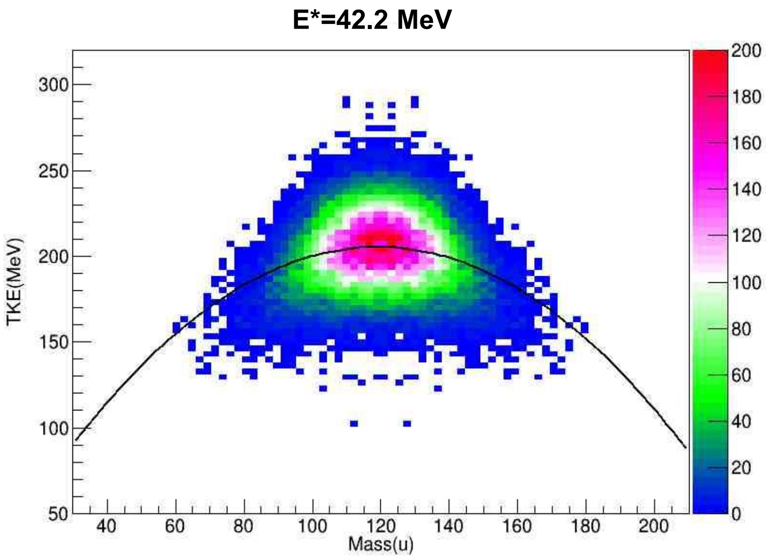
E_{lab} (MeV)	167	175	179
Ratio	0.21	0.11	0.09

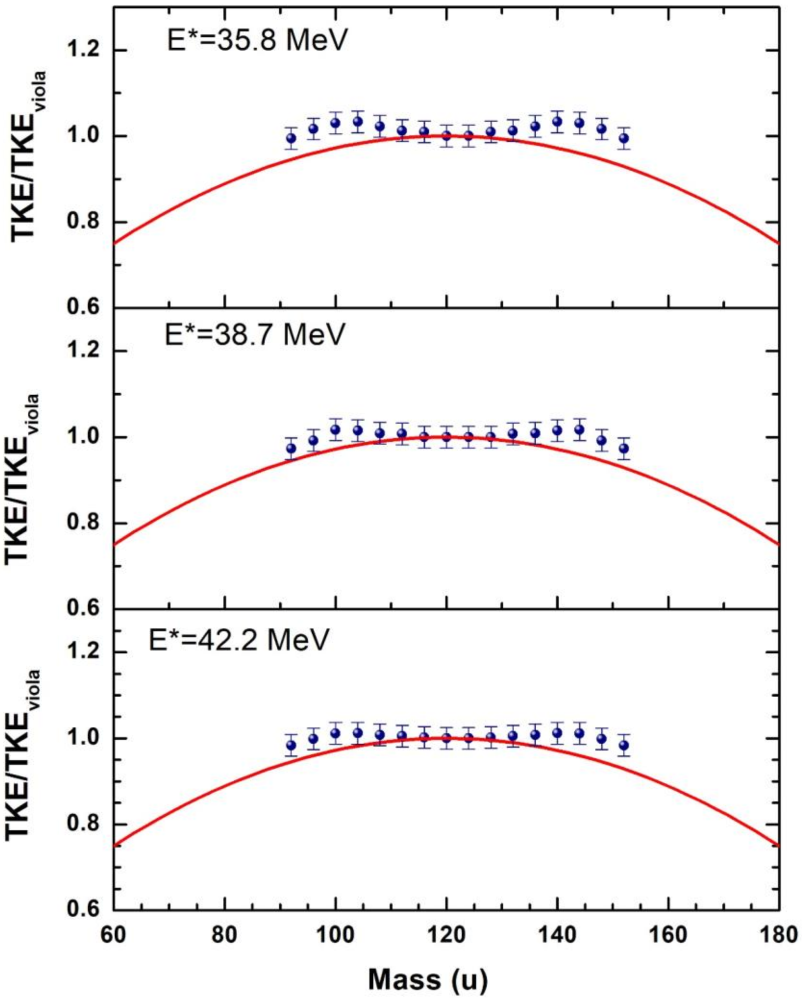
- **Experimental QF yields show good agreement with DNS model calculations.**

Calculation by Nasirov, JINR, Dubna

Results of $^{35}Cl+^{205}Tl$

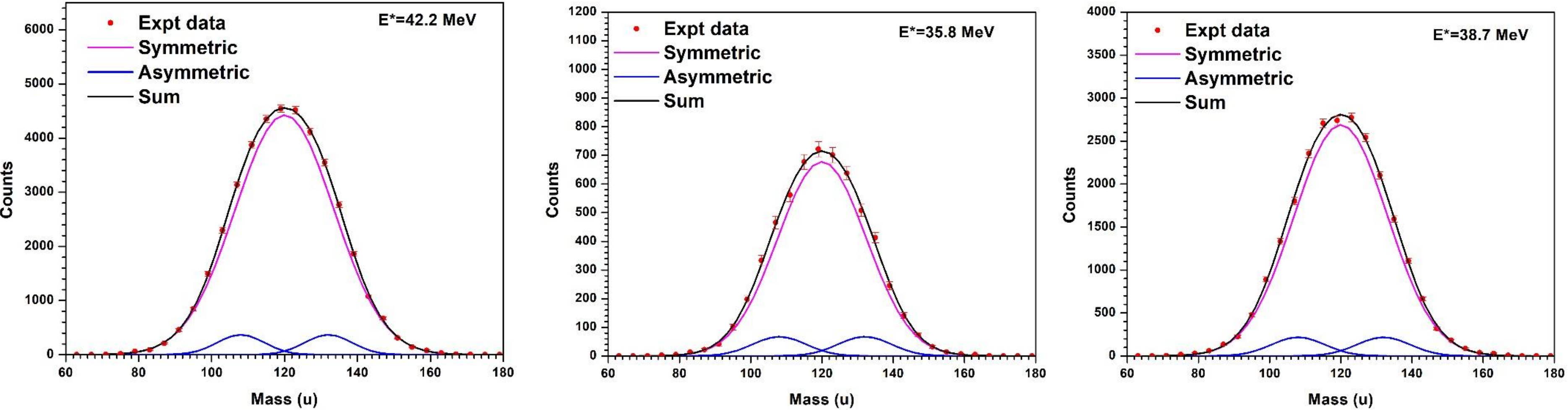
Mass-TKE correlations (^{35}Cl + ^{205}Tl)





Deviation from LDM may be due to quasi-fission or shell effects

Mass Distributions of $^{35}Cl + ^{205}Tl$



➢ Mass distribution shows two components: fusion–fission (FF) and NCN /shell effects.

✓ **The peak of the heavy fragments corresponds to mass ≈132.**

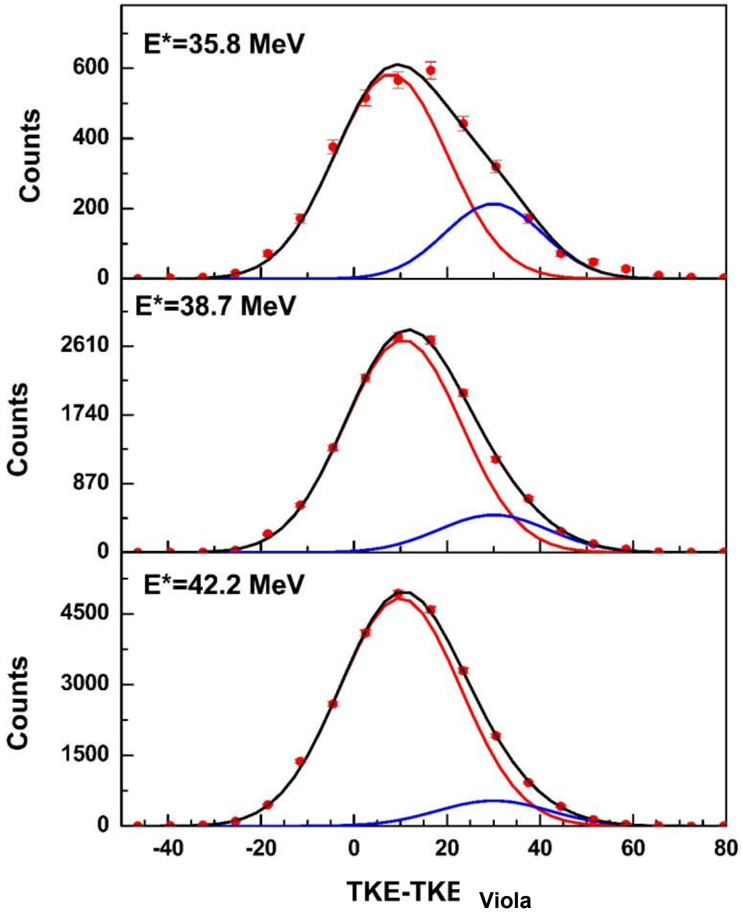
✓ **To investigate further it is important to measure the TKE distributions.**

TKE Distributions of $^{35}Cl + ^{205}Tl$

✓ **TKE distributions deviate from single Gaussian.**

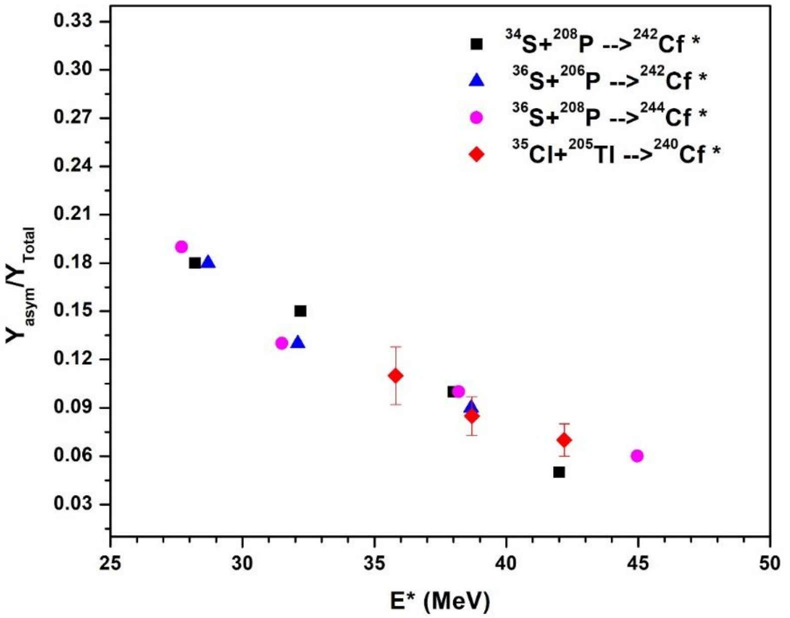
✓ **Deviation observed on high-energy side at all excitation energies.**

✓ **Does this originate from shell effects of asymmetric fragments or NCN events?**



$^{35}Cl + ^{205}Tl$

Fraction of Mass asymmetric fission component



Reaction	$^{35}Cl + ^{205}Tl$	$^{34}S + ^{208}Pb$	$^{36}S + ^{206}Pb$	$^{36}S + ^{208}Pb$
β_2 projectile	-0.234	-0.235	0.000	0.000
β_2 target	0.000	0.000	0.000	0.000
ZpZt	1377	1312	1312	1312
Ent. Channel magicity	0	2	2	3
Mass asymmetry	0.780	0.718	0.702	0.705
$\Delta(N/Z)_{Ent}$	0.472	0.412	0.262	0.287
α_{BG}	0.900	0.897	0.897	0.895

- ✓ **Asymmetric fraction decreases with excitation energy for all reactions.**
- ✓ **Variations in isospin show no clear influence on Asymmetric fraction.**

- ✓ **The observed asymmetry is likely due to shell effects or slow quasi-fission, with no dependence on the entrance channel.**

Conclusion

- ✓ The observed mass distributions of $^{35}Cl + ^{181}Ta$ and $^{35}Cl + ^{205}Tl$ deviate from LDM predictions, indicating the presence of quasi-fission or the emergence of asymmetric fission.
- ✓ No significant mass-angle correlation is observed in both the reactions.
- ✓ Analysis of the mass and energy distributions deviate from single Gaussian for both the reactions.
- ✓ The percentage of quasi-fission for $^{35}Cl + ^{181}Ta$, calculated using the DNS model, is 21%, 11%, and 9% at excitation energies of 52.4, 59.1, and 62.4 MeV, respectively. Our results are in good agreement with the DNS model calculations.
- ✓ The percentage of quasi fission decreases with increasing excitation energy for $^{35}Cl+^{181}Ta$.
- ✓ For $^{35}Cl + ^{205}Tl$ reaction the observed asymmetry is likely due to shell effects or slow quasi-fission, with no dependence on the entrance channel.

Thank You

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