Isotopic composition of Quasi-Projectile fission fragments on the system ^{40,48}Ca+^{40,48}Ca at 35 MeV/u with FAZIA detector

A. Camaiani

FAZIA-SYM: Scientific Goals

- Study of the symmetry energy of the nuclear Equation of State, as already did in the experimental campaign INDRA + VAMOS

- Coincidence of the QP fragments with IMF and LCP, both emitted at small angles: detailed of the chemical composition

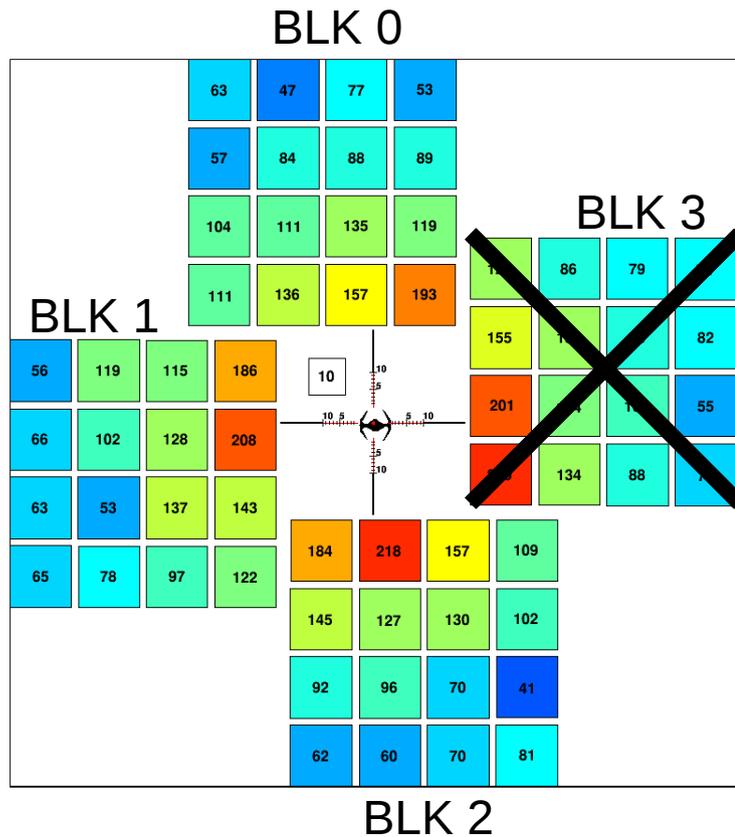- Investigation of the QP Fission-Like events (not originally planned)

FAZIA-SYM Configuration
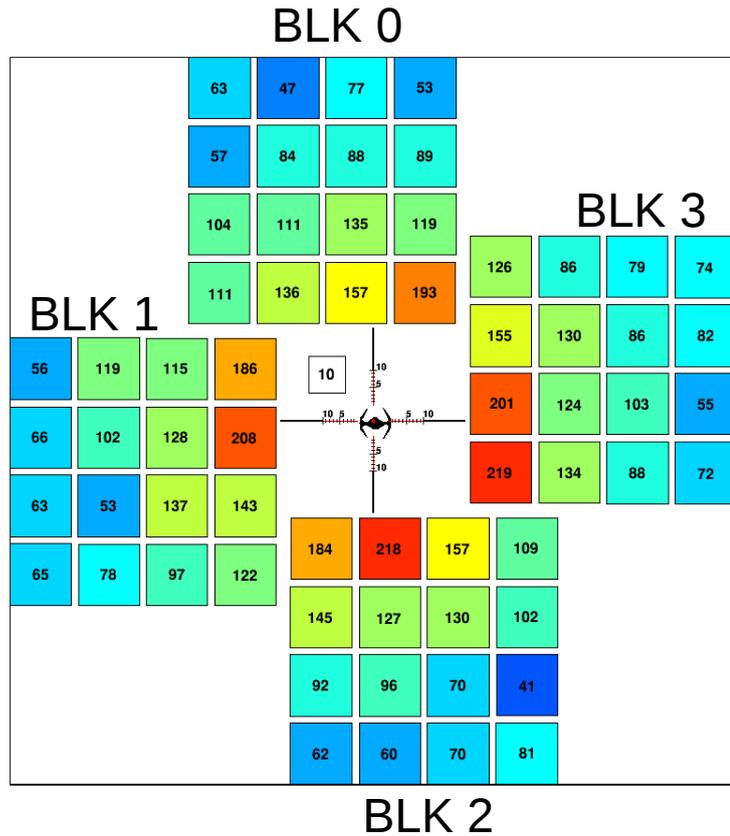
BLK 0

BLK 3

BLK 1

BLK 2

Geometry:

- 4 blocks located aroud the beam axis

- Covered polar angle in lab. frame:
  - $\Theta_{min} = 2°$
  - $\Theta_{max} = 8°$

FAZIA-SYM Configuration

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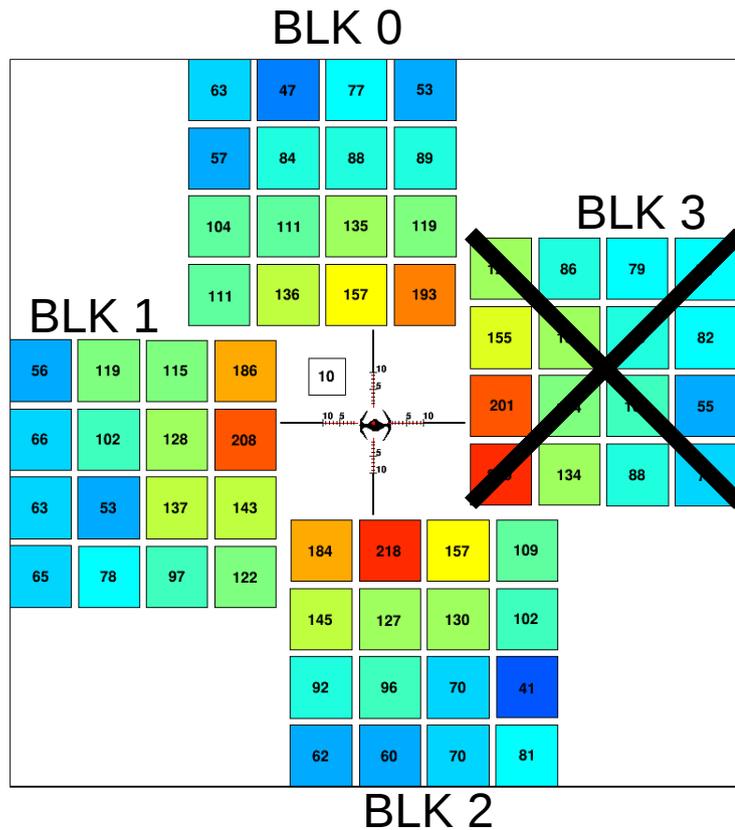
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Working Blocks:

- BLK3 stopped to work during the experiment:
  - **Bias on the event**?
    To be tested with the MonteCarlo Simulations

FAZIA-SYM Configuration

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- 4 blocks located aroud the beam axis

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Working Blocks:

- BLK3 stopped working during the experiment:
  - **Bias on the event**?
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Identification and Energy Calibration:

- Z≥3 well identified both in Z and A and calibrated in energy

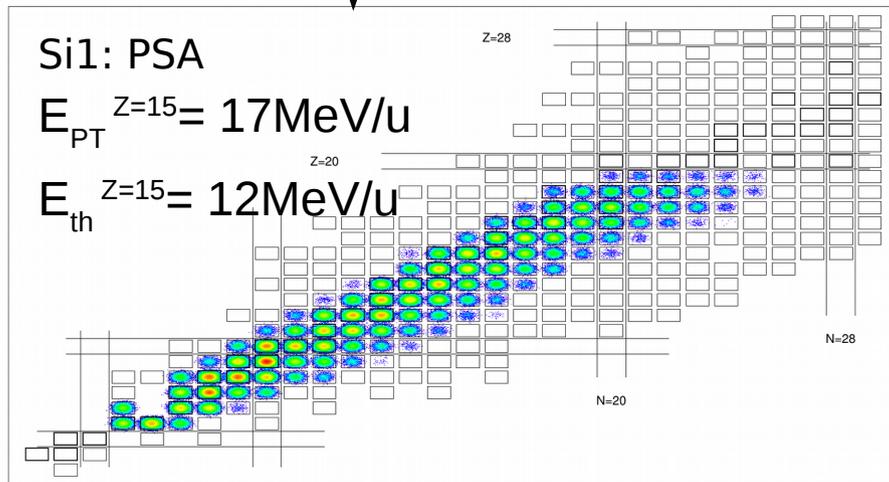- Z≤2 well identified both in Z and A but not calibrated in energy (preliminary)

Simulation:

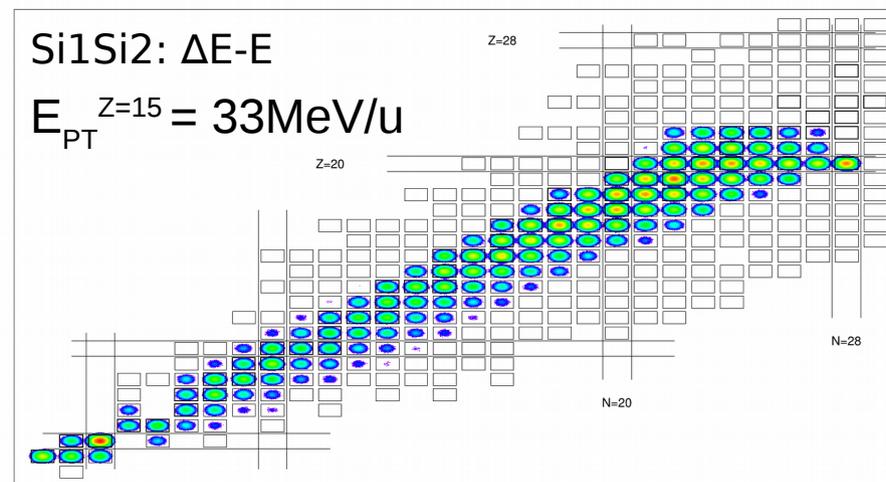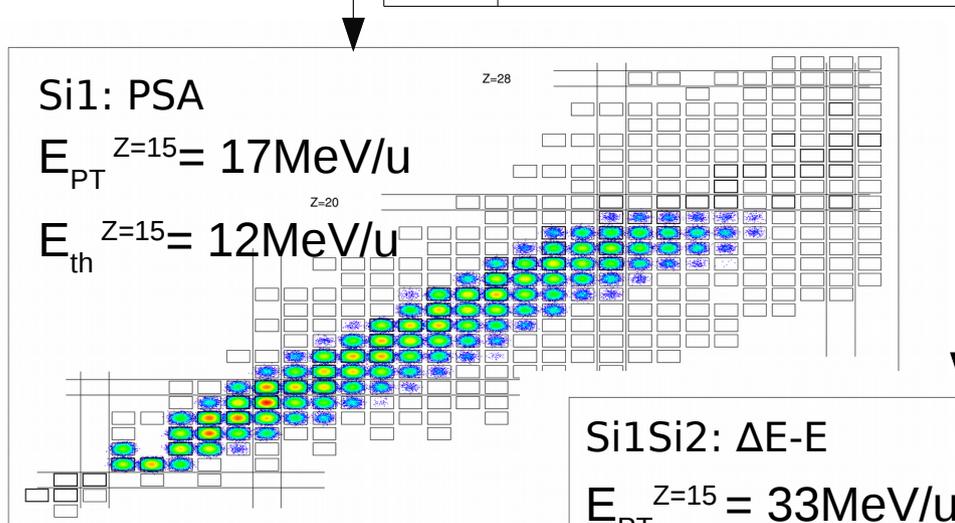- A systematical comparison with AMD+GEMINI is on going but not presented today

FAZIA-SYM: Fragment Identifications

Si1 | Si2 | CsI
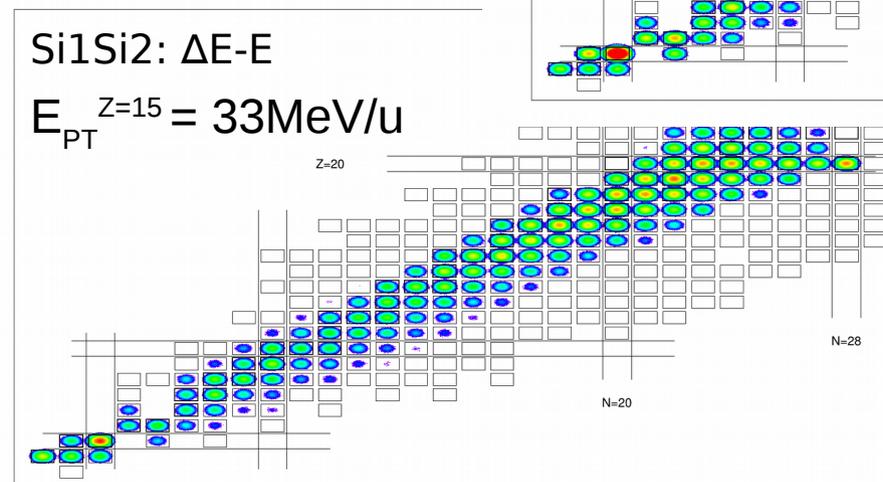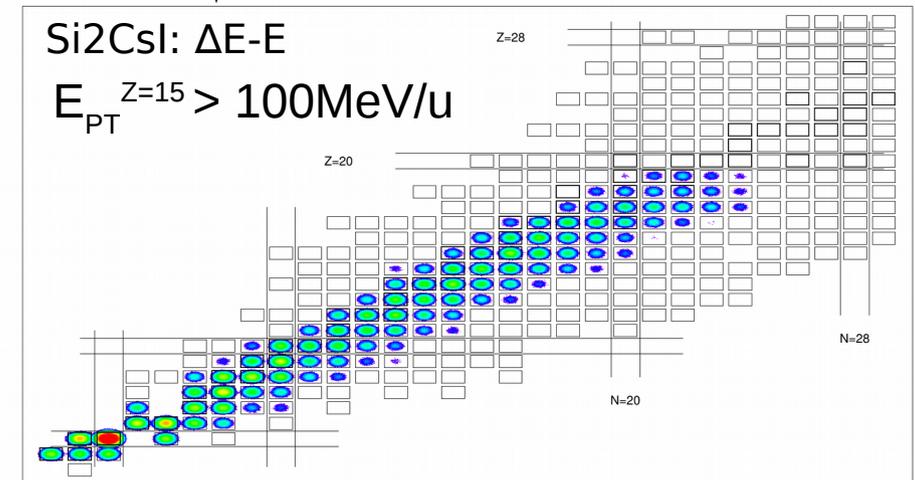
FAZIA-SYM: Fragment Identifications

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Si1: PSA

$E_{PT}^{Z=15} = 17MeV/u$

$E_{th}^{Z=15} = 12MeV/u$

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Si1Si2: ΔE-E

$E_{PT}^{Z=15} = 33MeV/u$

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Si1 | Si2 | CsI

Si1: PSA

$E_{PT}^{Z=15} = 17MeV/u$

$E_{th}^{Z=15} = 12MeV/u$

Si1Si2: ΔE-E

$E_{PT}^{Z=15} = 33MeV/u$

Si2CsI: ΔE-E

$E_{PT}^{Z=15} > 100MeV/u$
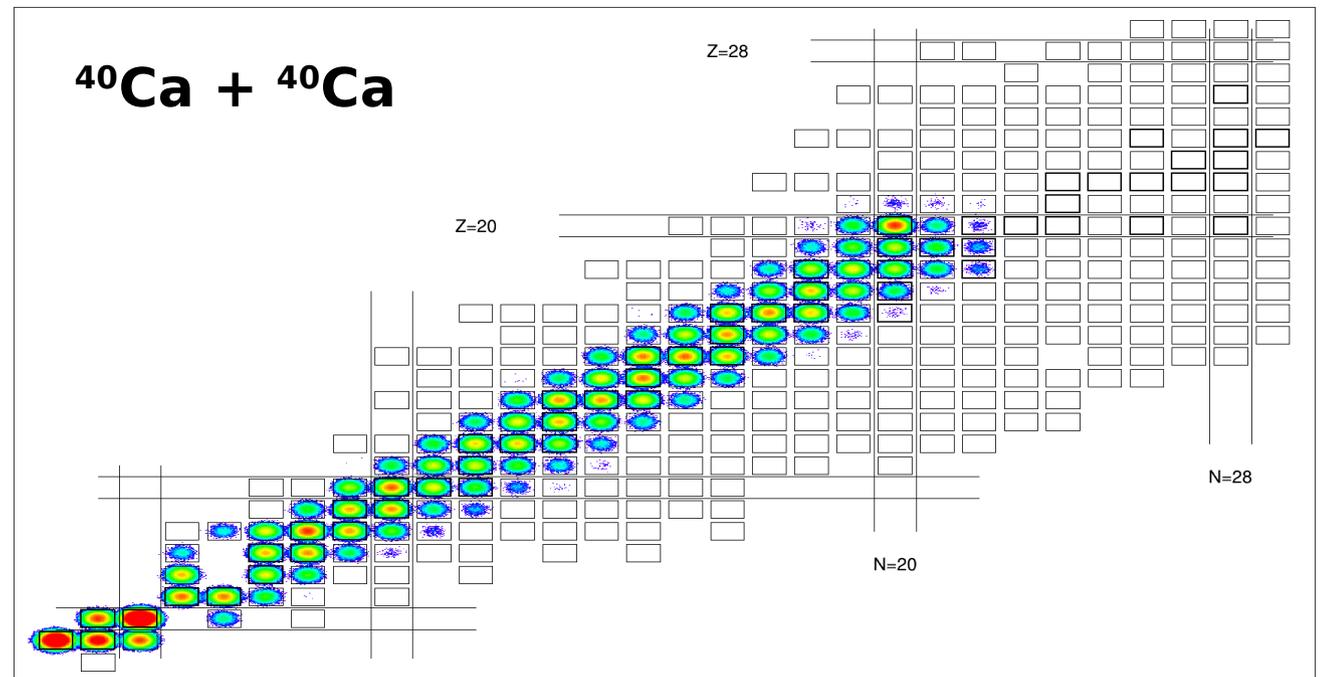
Nuclides Chart Comparison

^{48}Ca + ^{48}Ca

Z=28

Z=20

N=28

N=20
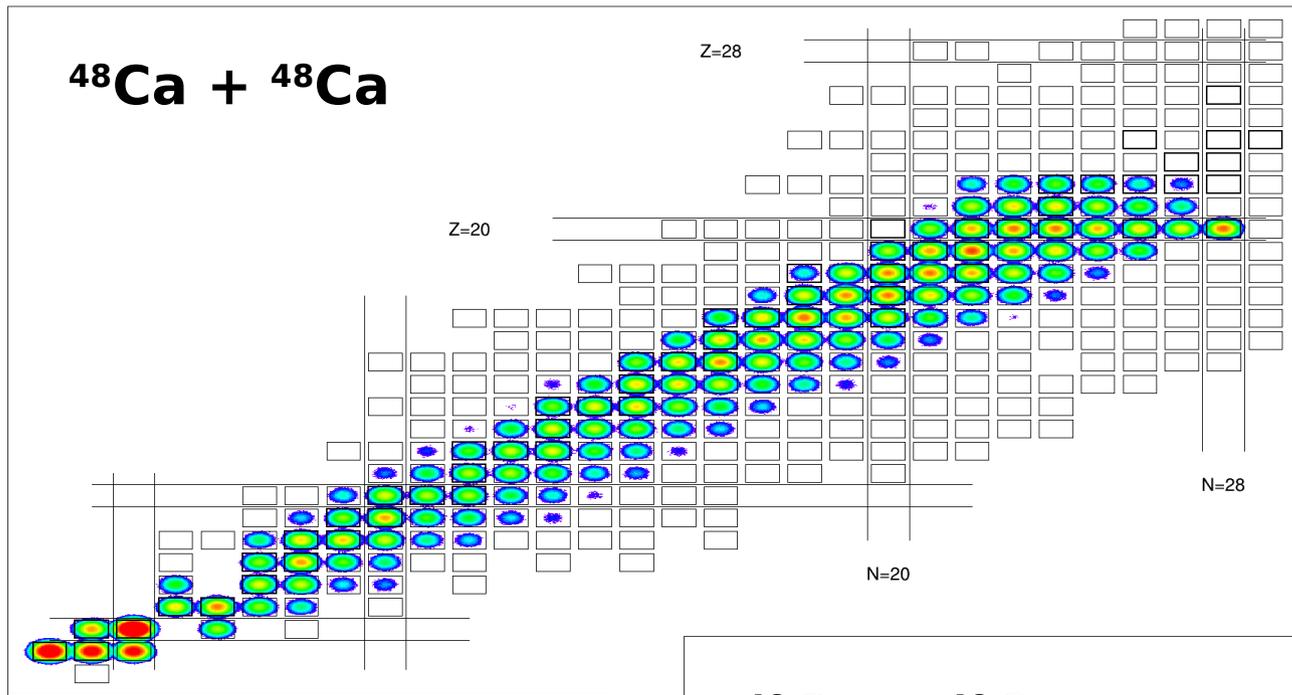
We identify both in Z and A fragments up to projectile charge (Z=20), and even more..

N.B.
All the histograms are normalized to unity

^{40}Ca + ^{40}Ca

Z=28

Z=20

N=28

N=20

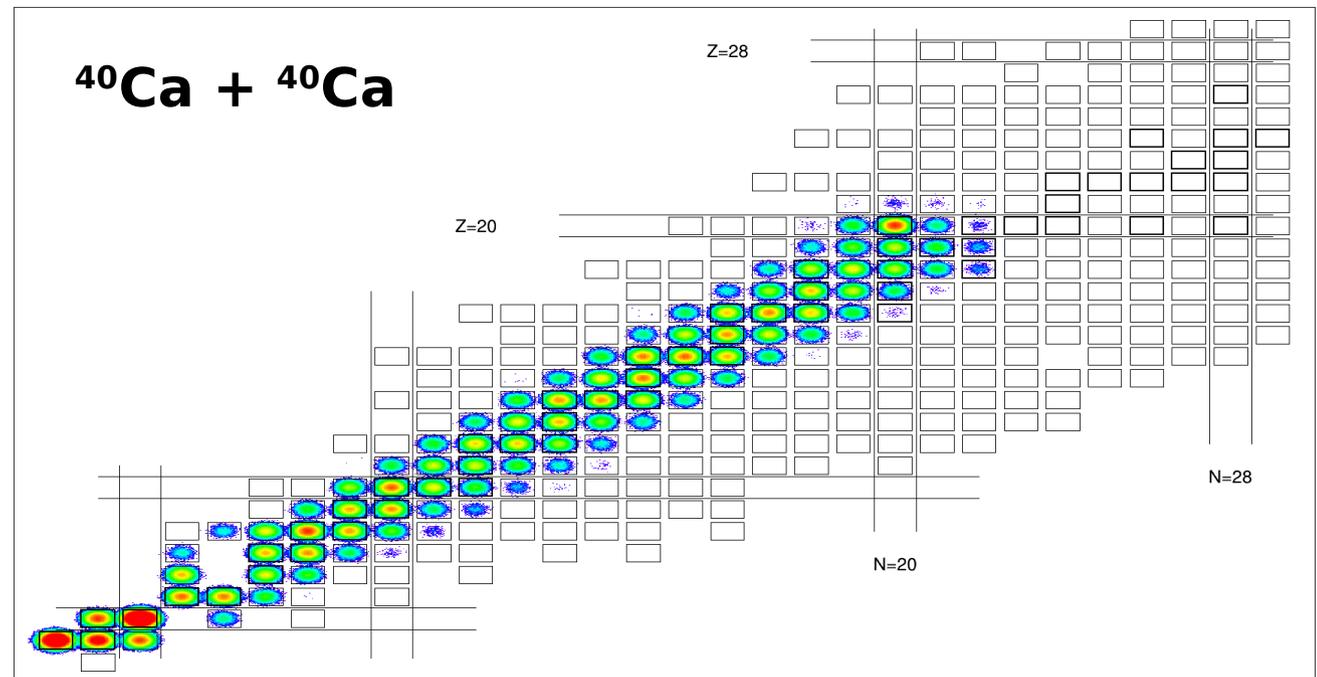# Nuclides Chart Comparison

⁴⁸Ca + ⁴⁸Ca

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Z=20

N=28

N=20
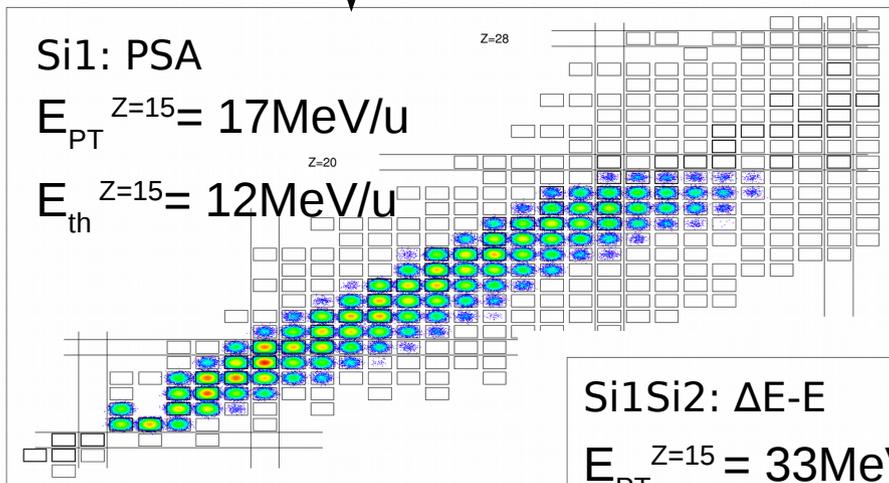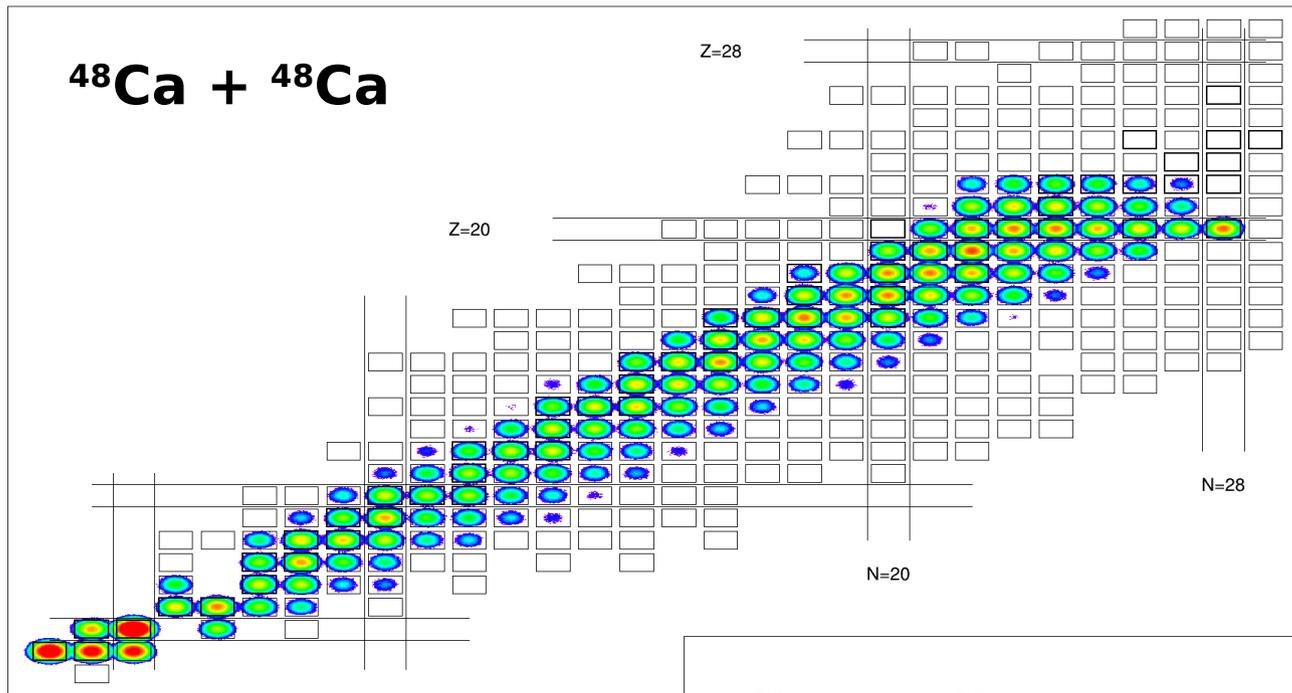
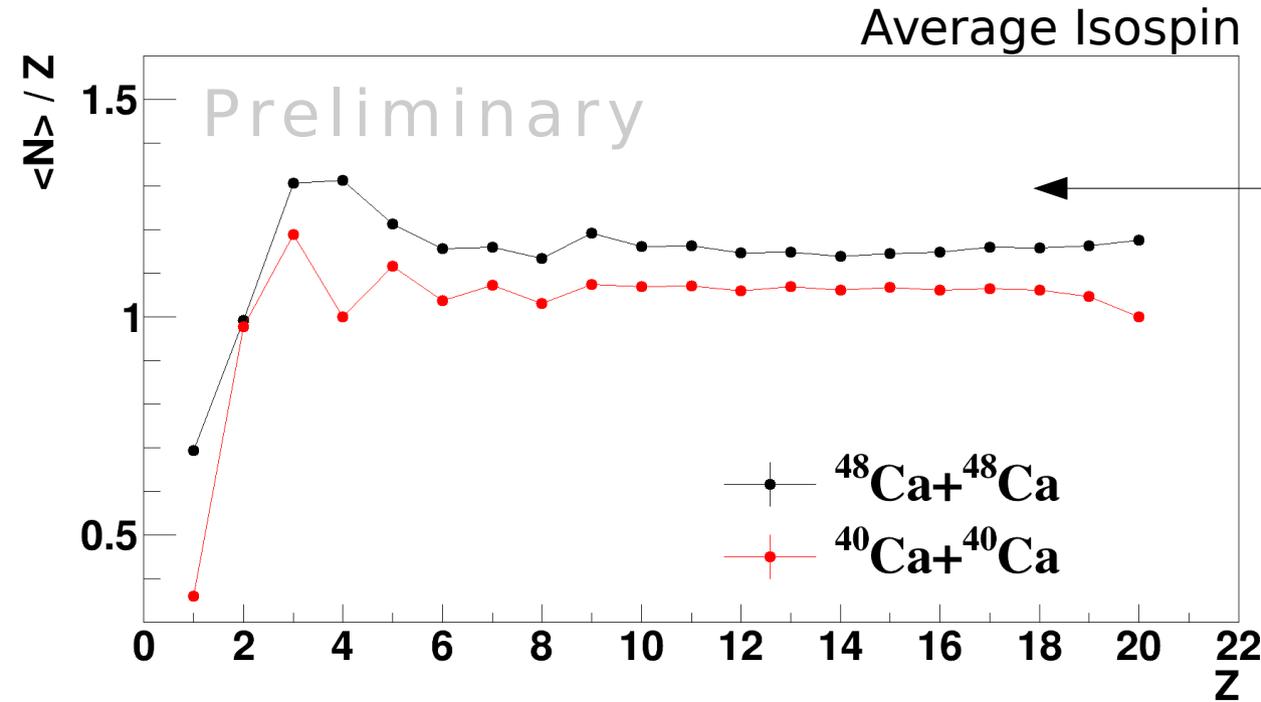We identify both in Z and A fragments up to projectile charge (Z=20), and even more..

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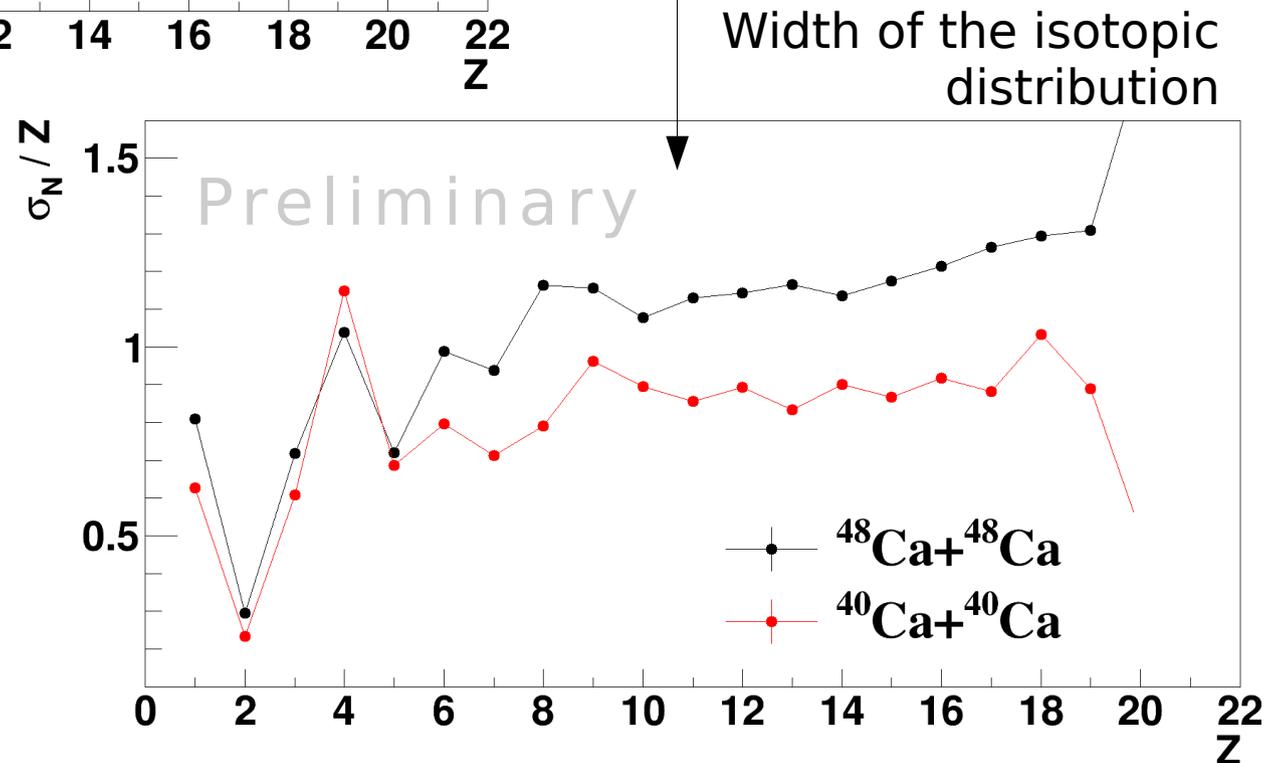Different isotopes population
for a given Z:

• on average

• on width

⁴⁰Ca + ⁴⁰Ca

Z=28

Z=20

N=28

N=20

Isotope Population Comparison

Average Isospin

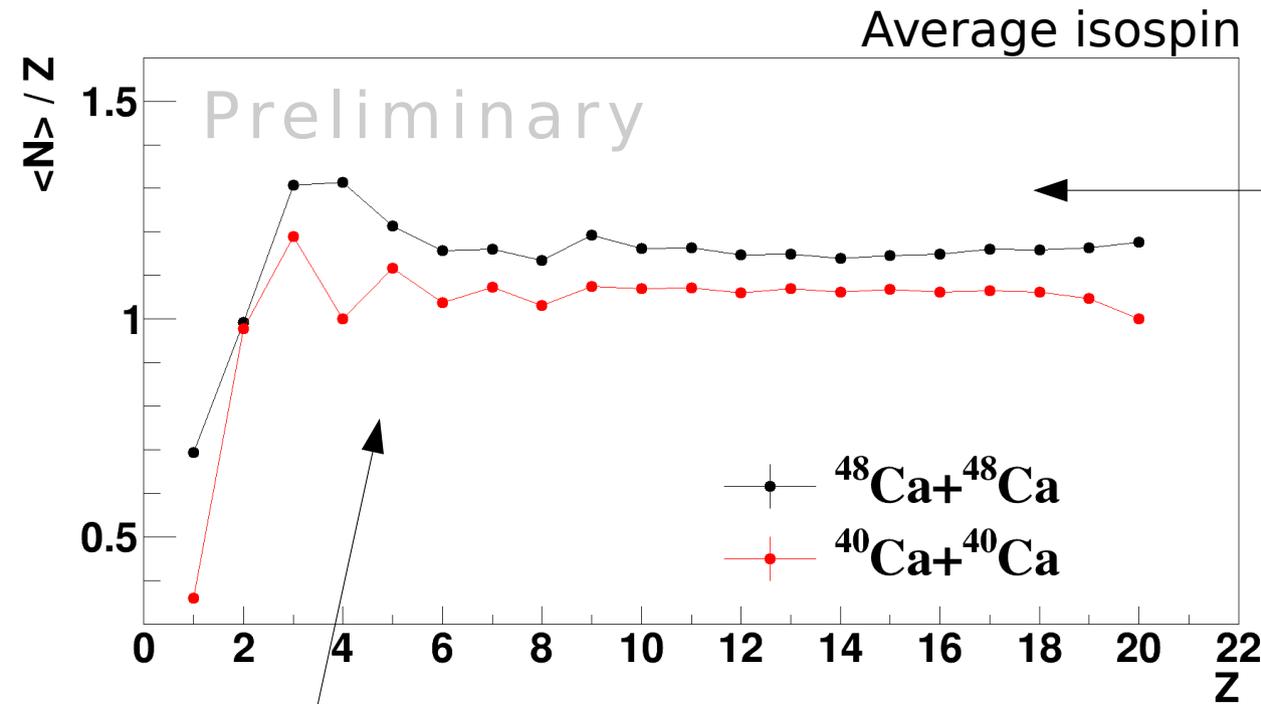
As expected:

- Greater average isospin in the $^{48}Ca+^{48}Ca$ system

- Larger number of isotopes populated in the $^{48}Ca+^{48}Ca$ system

Width of the isotopic distribution

Isotope Population Comparison

Average isospin

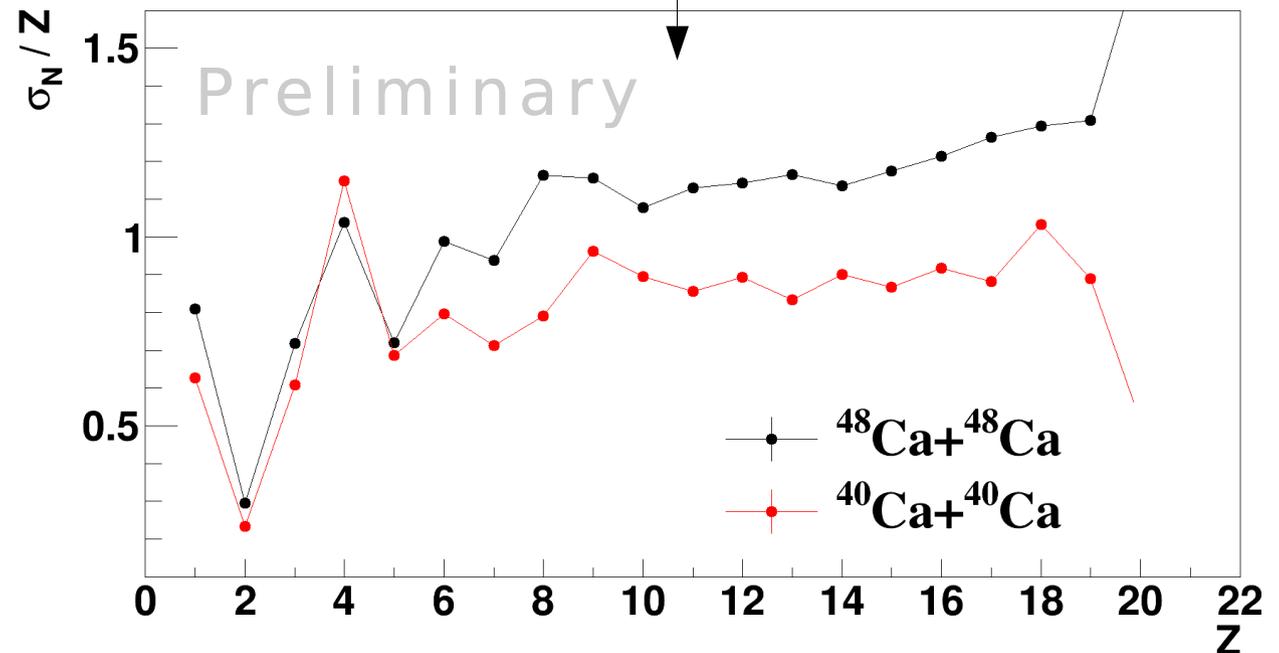
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Width of the isotopic distribution
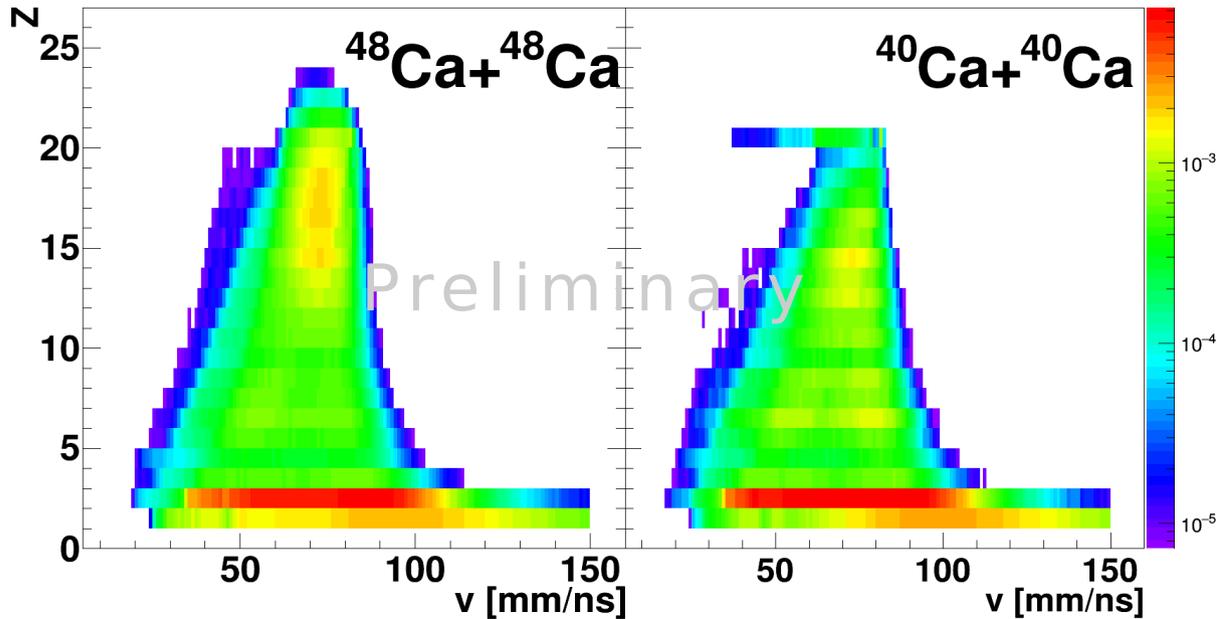
Odd-Even effect
in the light fragment
region for the ^{40}Ca+^{40}Ca

Events Selection

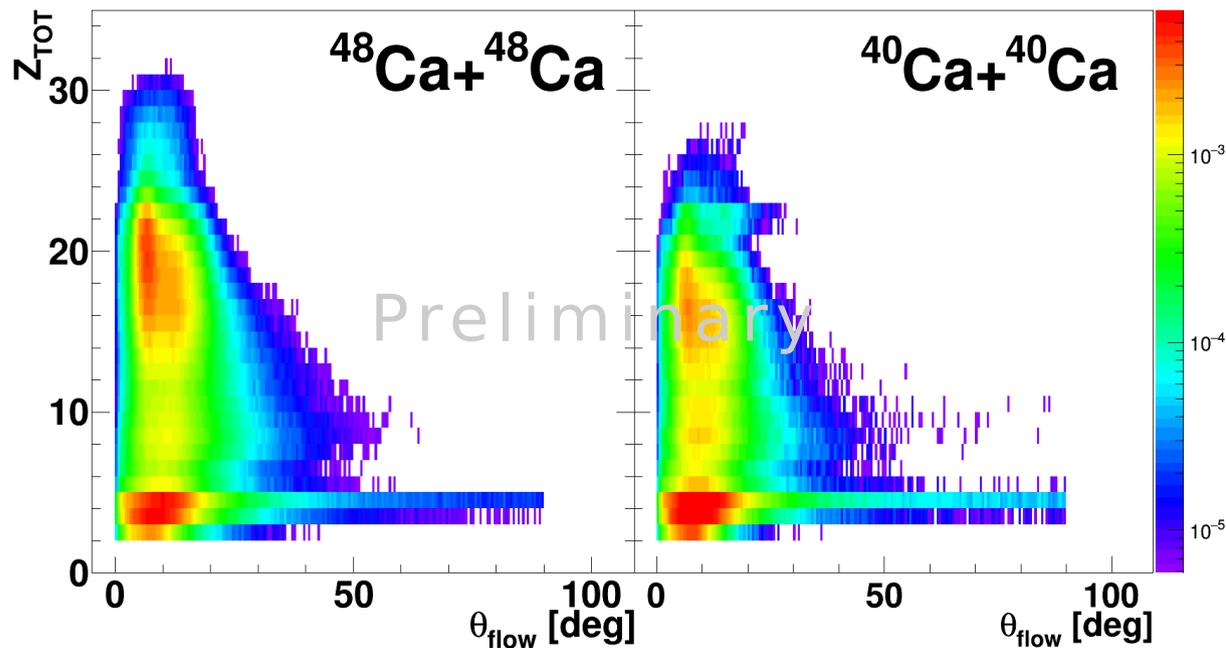Events with multiplicity >1

$^{48}Ca + ^{48}Ca$: $32 * 10^6$ Events
$^{40}Ca + ^{40}Ca$: $3.6 * 10^6$ Events

but only 8% has at least one fragment with $Z \geq 3$

N.B.
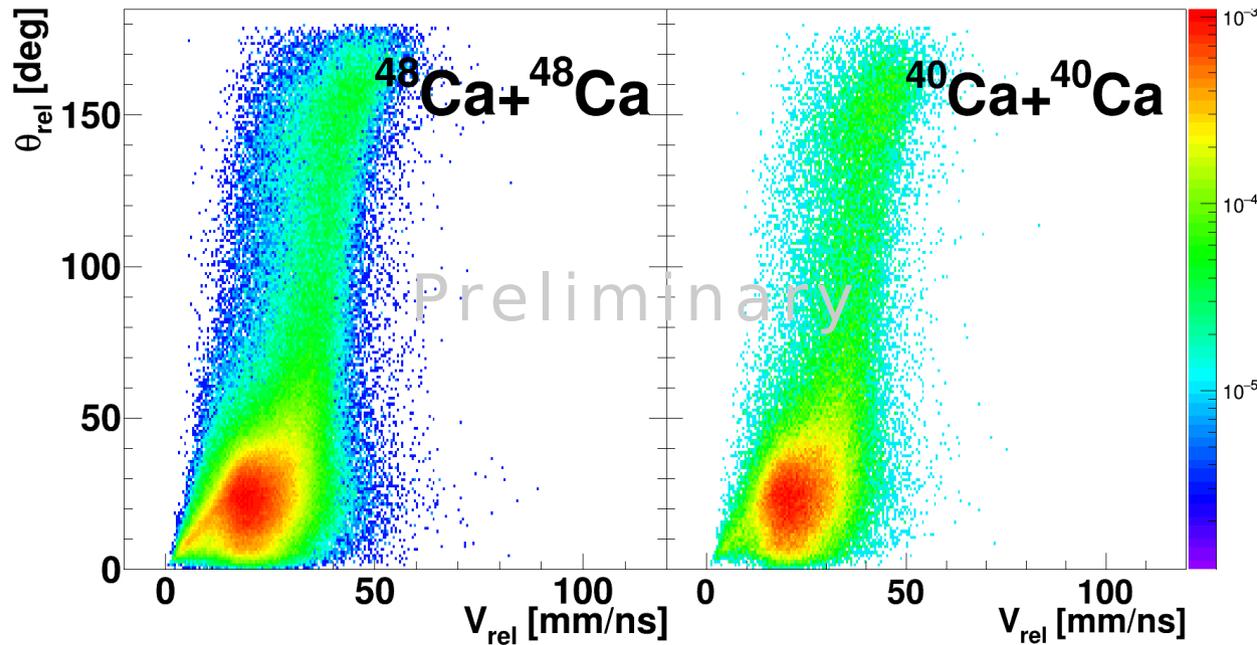All the histograms are normalized to unity

Peripheral Events:
$Z_{TOT} > 8$
$2° < \theta_{flow} < 20°$

No Central Events can be observed in the data:
(large Z_{TOT} and θ_{flow})

QP Fission-Like Events Selection

^{48}Ca+^{48}Ca

^{40}Ca+^{40}Ca

Preliminary

QP Events:
$Z_{BIG} \geq 12$
$Z_{small} = 3, 4$ or LCP

QP Fission-Like Events:
$Z_{small} \geq 5$
$Z_{BIG} + Z_{small} \geq 12$
V^{CM}_1 & $V^{CM}_2 > 0$
$\Theta_{rel} < 50°$

^{48}Ca + ^{48}Ca: $1.6 * 10^5$ Events
^{40}Ca + ^{40}Ca: $4.5 * 10^4$ Events
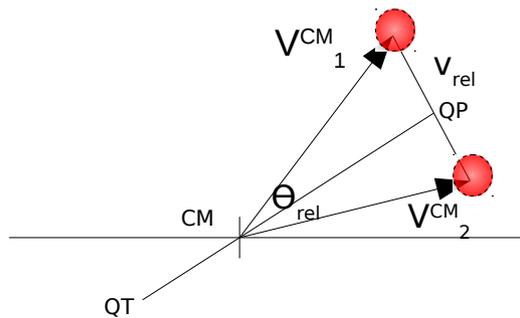
QP Fission-Like Events
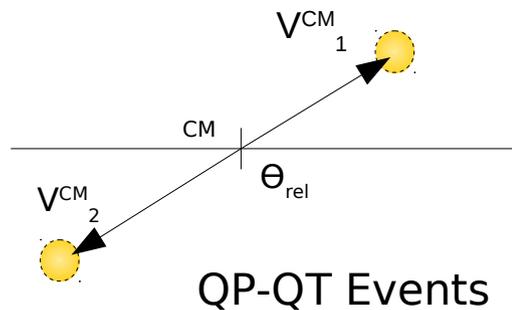
QP-QT Events

No Events in which both QP and QT are detected

Fission-Like Events: Characterization
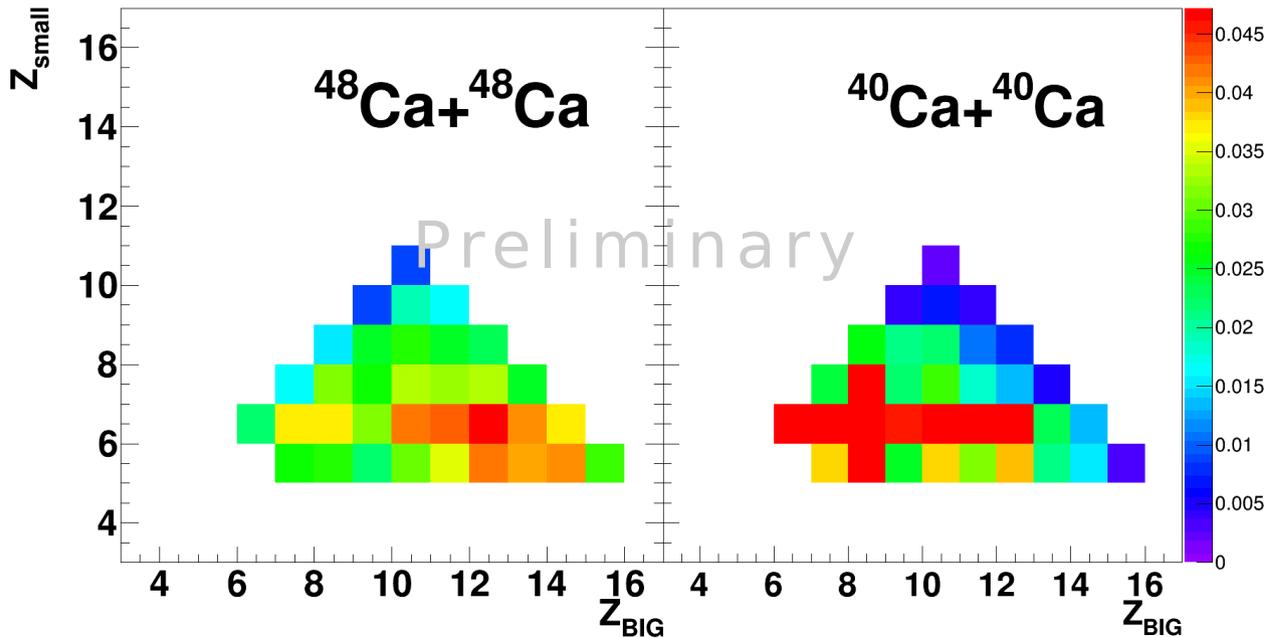
Preferred fission couples involve Z=6 and 8, expecially in $^{40}Ca+^{40}Ca$ system

$$\eta = \frac{Z_{BIG} - Z_{small}}{Z_{BIG} + Z_{small}}$$

Different behaviour:

$^{40}Ca+^{40}Ca \rightarrow$ favours symmetric fission

$^{48}Ca+^{48}Ca \rightarrow$ flatter and wider distribution

N.B.
All the histograms are normalized to unity
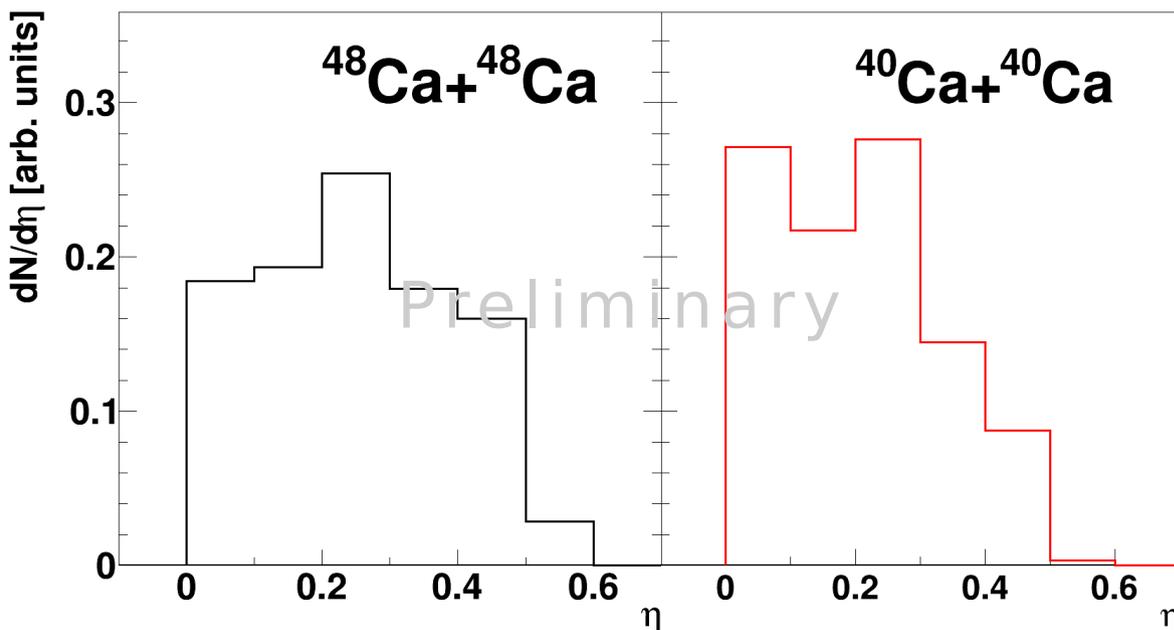
Fission Fragments: Composition

Average isospin

Z_{BIG}

Preliminary

$^{48}Ca+^{48}Ca$

$^{40}Ca+^{40}Ca$

Z_{small}

Preliminary
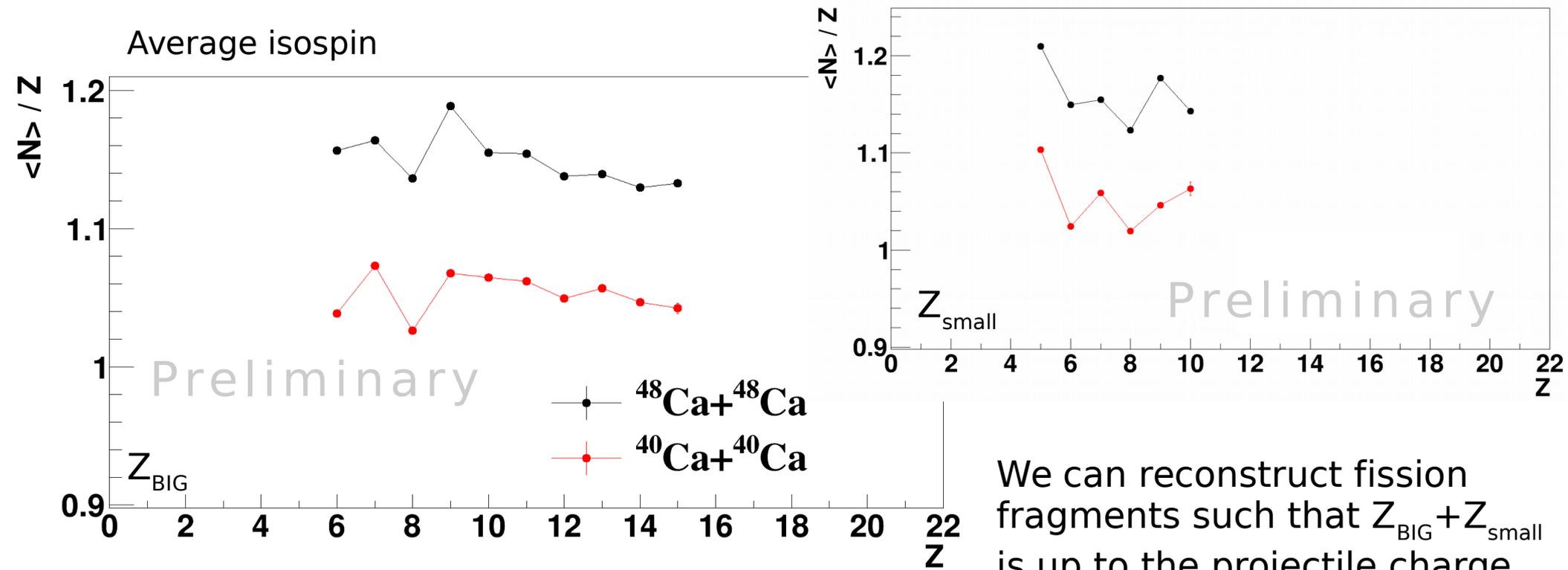
Different n-richness for the two systems

We can reconstruct fission fragments such that $Z_{BIG}+Z_{small}$ is up to the projectile charge (Z=20)

Slight odd-even effect for Z≤10

Flat <N>/Z for Z>10

Fission Configuration

A. Jedele et al.,
Phys. Rev. 062501-2 Lett. 118 062501 (2017)
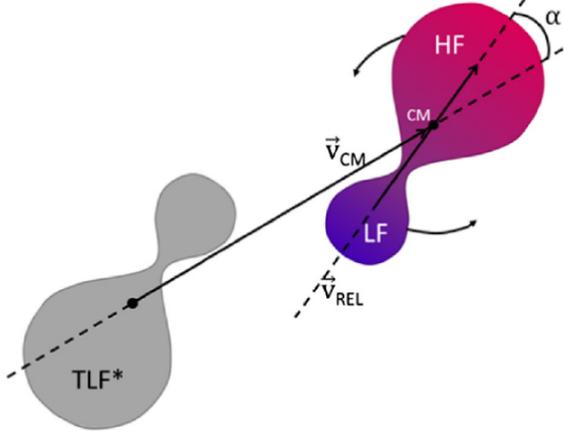
Alpha : Angle between the V_{rel} and V^{CM}_{QP}
Can be used as a clock for fission events.

Small Alpha values indicate relatively fast fission;

Large Alpha values indicate relatively slow fission;

$^{70}Zn+^{70}Zn$ 35 MeV/u,
A. Rodriguez Manso PRC95, 044604, 2018

---- η=0.3
.... η=0
——— All η
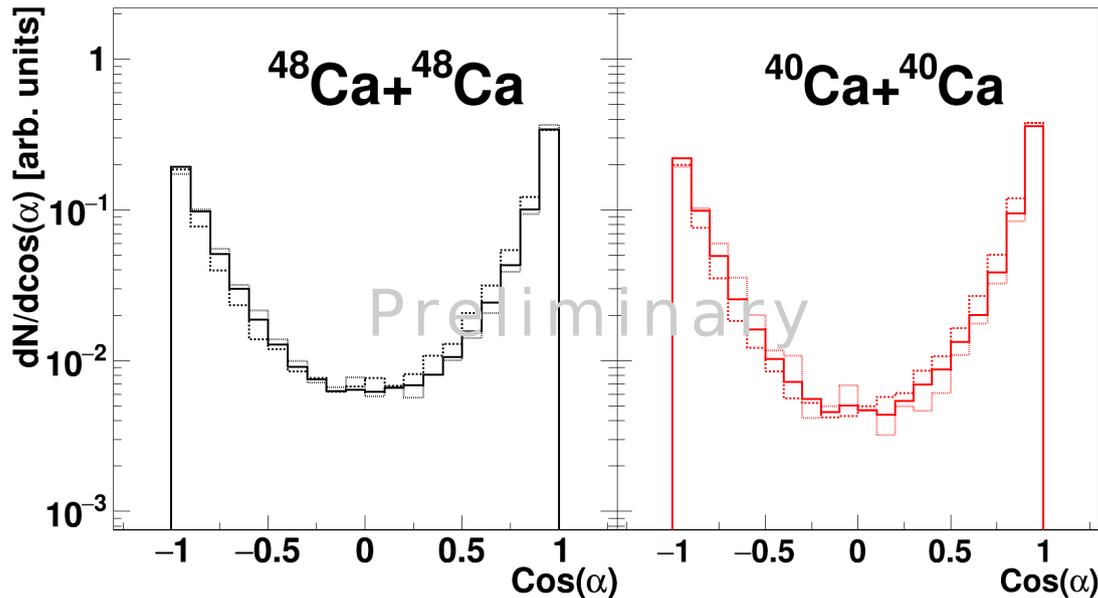
The isospin evolution of the fission fragments as a funtion of the α angle has been recently observed

No preferred fission:
it does not change as the fission asymmetry changes

Are we biased the events due to the geometry?
(AMD+GEMINI)

Isospin Content of Fission Pairs

For the 48Ca+48Ca, looking also fragment with Z=3 and Z=4...
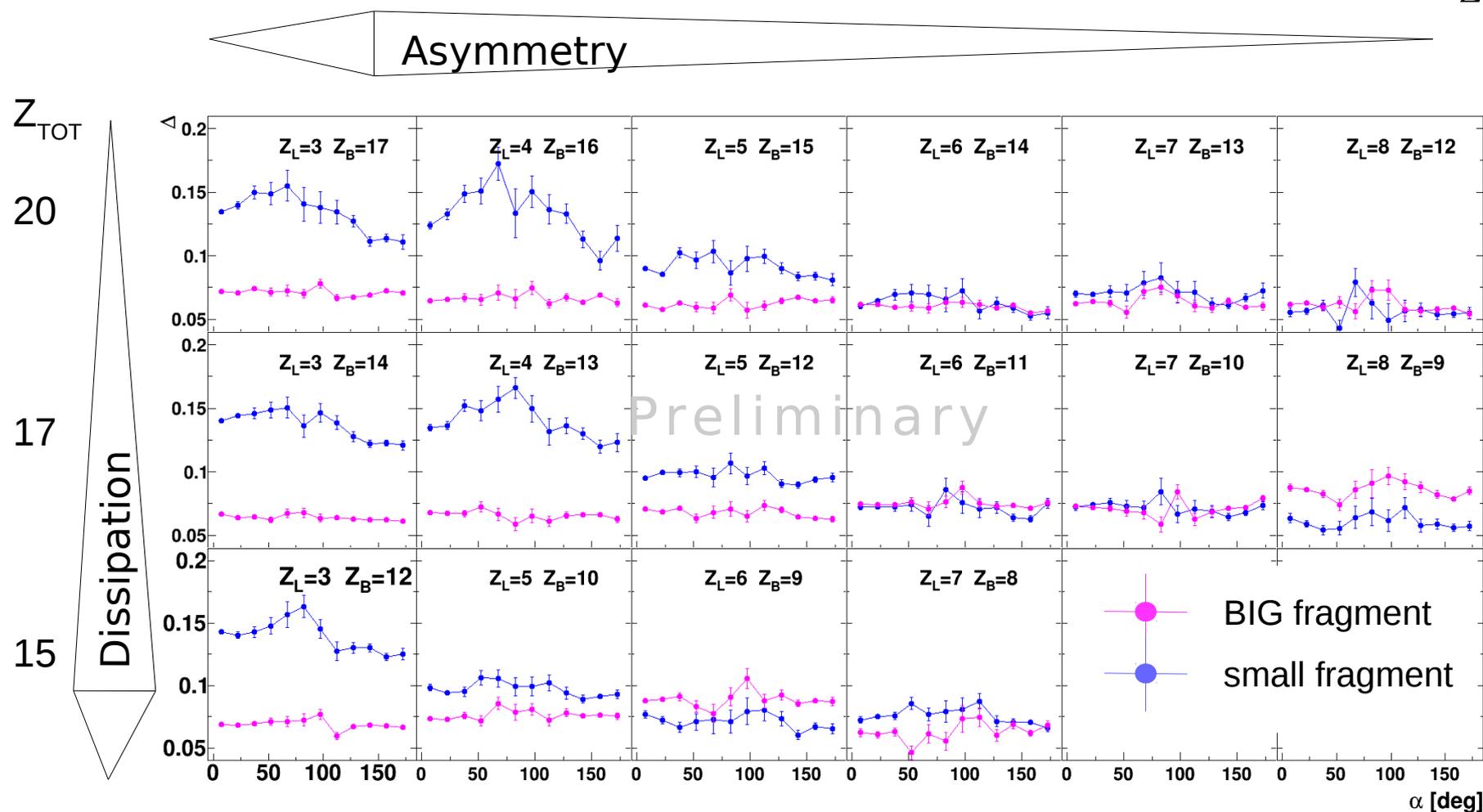
$$\Delta = <\frac{N-Z}{Z+N}>$$

Asymmetry

Z_{TOT}

Dissipation

For each class of events with a fixed dissipation, an equilibration is visible when the asymmetry decreases, but there are no signs of equilibration (slight signs for Z=3,4?) as the α increases (but it was seen in ^{70}Zn$+^{70}$Zn 35 MeV/u, A. Rodriguez Manso PRC95, 044604, 2018).

Can it be related to the smaller syze of the system? Is this due to the fact that the Z_{TOT} is close to Z of the projectile (i.e. peripheral collision)?

Fission: Some structure effects?

Fixing the Z_{BIG} fragments we can explore the $\Delta = < \dfrac{N-Z}{Z+N} >$ as a function of the Z_{small}

$$\Delta = < \frac{N-Z}{Z+N} >$$

Z_{BIG}

10

11

Preliminary

12

BIG fragment

small fragment
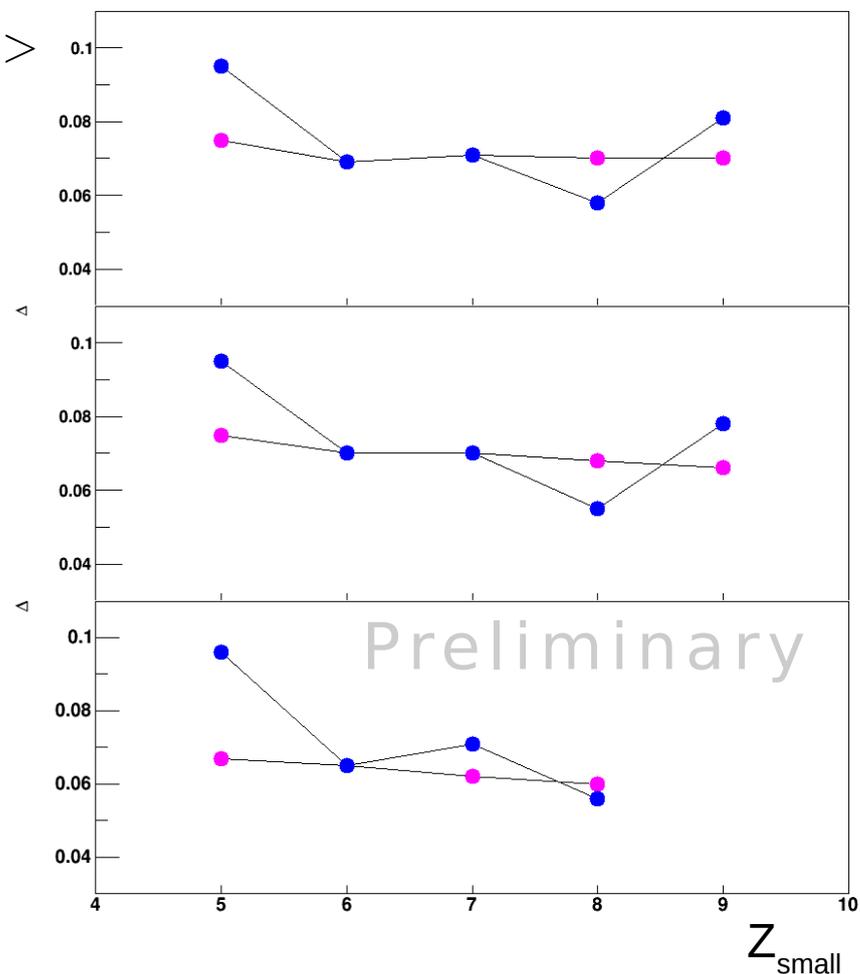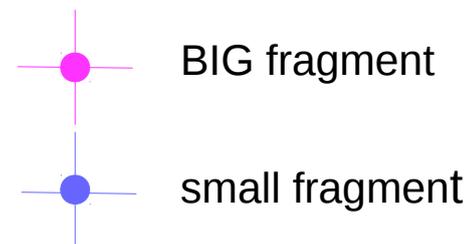
When Z_L=6, 8 a sudden decrease in the Δ with respect to the the previous pair;
On the other side there is a sudden increase when Z_L=9;

It's also present in $^{70}Zn+^{70}Zn$ 35 AmeV, Fig.9 Manso et al., PRC95, 044604

Fission: Some structure effects?

And they are present (even more) in the ^{40}Ca + ^{40}Ca reaction...

$$\Delta = < \frac{N-Z}{Z+N} >$$
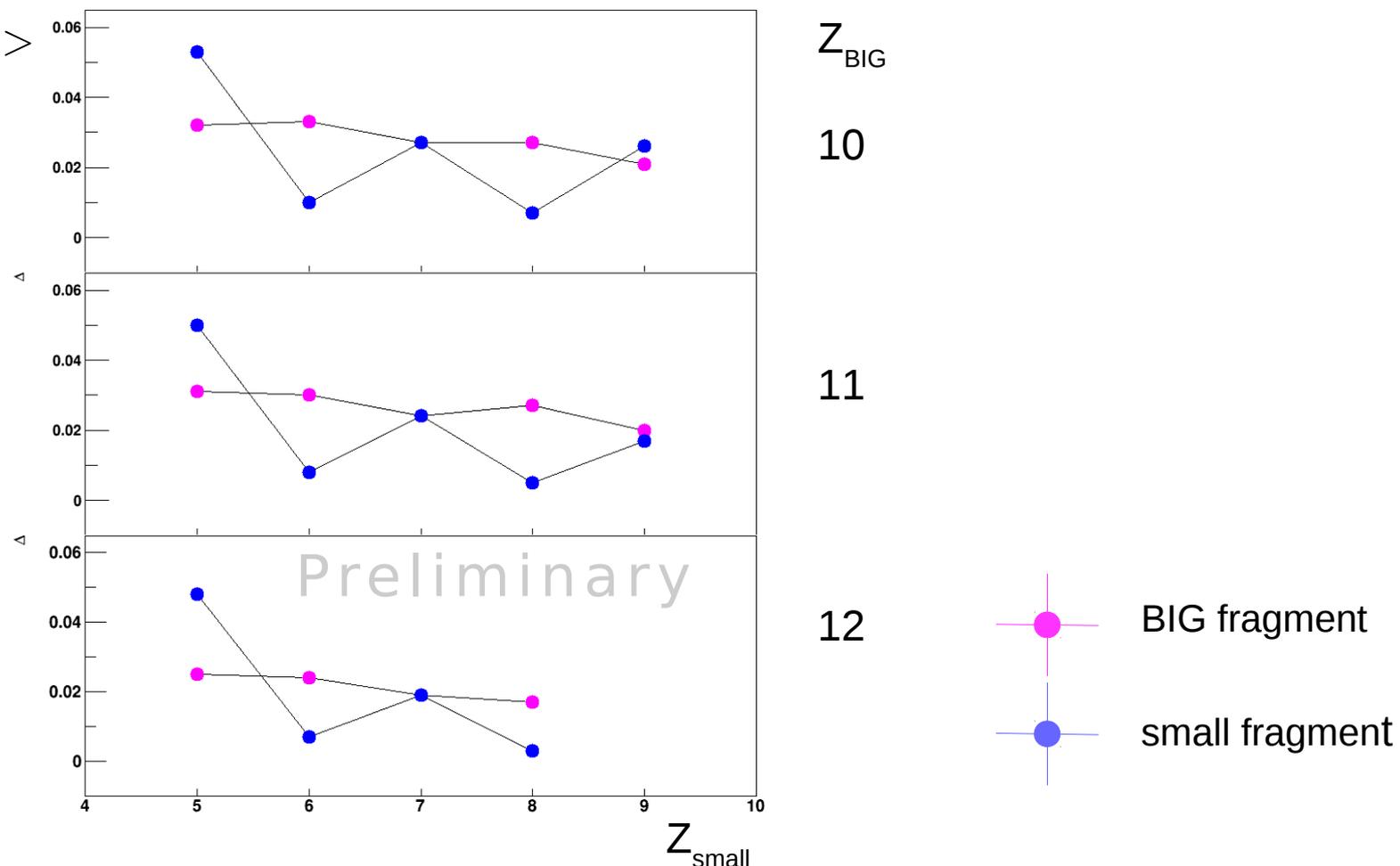

Z_{BIG}

10

11

Preliminary

12

BIG fragment

small fragment

Z_{small}

It seem that the odd-even effect is more evident with respect to the ^{48}Ca+^{48}Ca system.

Is this due to some structure effects on these nuclei?

Conclusions

- The first (and preliminary) results from the FAZIA-SYM experiment has been presented, with a particular focus on the fission of the Quasi-Projectile in the reactions ^{40,48}Ca + ^{40,48}Ca at 35 MeV/u

- As espected, the reactions show different isotope populations both in the average isospin and in the width.

- Exploring the fission of the Quasi-Projectile we observed:
  - Wider fission fragments Z distribution for the ^{48}Ca+^{48}Ca
  - Almost symmetrical splits are preferred for the ^{40}Ca+^{40}Ca

  - Equilibration of the isospin as a funtion of the asymmetry of the fission pairs is observed for each class of events with a fixed dissipation

  - Some structure effects (strong variation of <N>/Z) are clearly observed when the fission pairs involve Z=6,8,9, both for ^{48}Ca+^{48}Ca and ^{40}Ca+^{40}Ca

  - No Isospin dependence as a function of the α angle:

This set of results will be checked with the help of transport simulation, also including a replica of the apparatus filter: indeed our limited acceptance can introduce some deformation of the observables that have to be severely verified

Thank you for your attention

Backup Slides

AMD: <N>/Z v.s v^{CM}_z for primary fragments

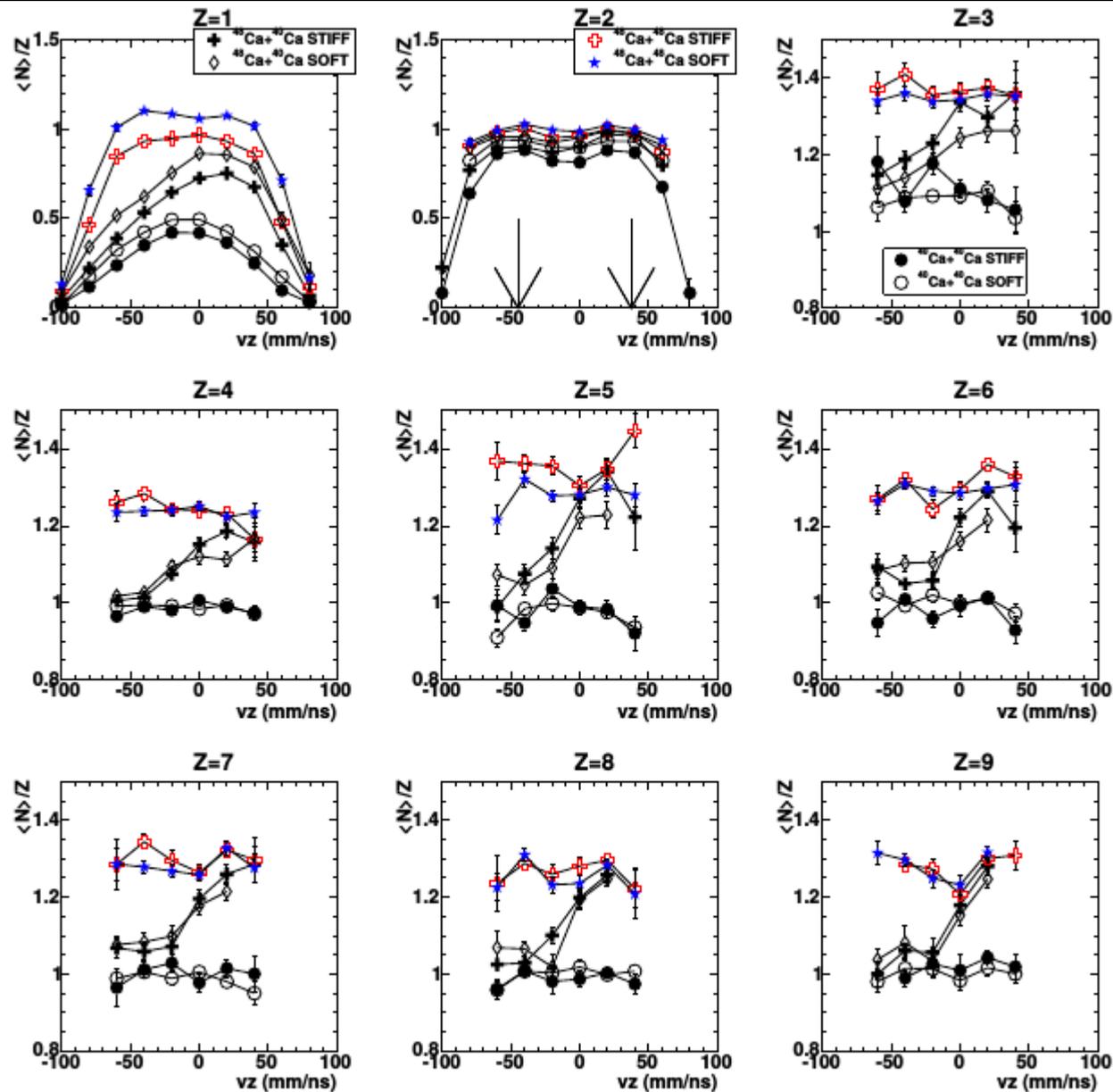

Figure 13. Average isospin of all the ejectiles (QP and QT excluded) emitted in DIC events with $b \geq 7$ fm as a function of the c.m. velocity along the beam axis (0 is the centre of mass). Each panel refers to a different element. The arrows in panel Z=2 correspond to the target and projectile velocities, respectively

Isospin Content of Fission Pairs

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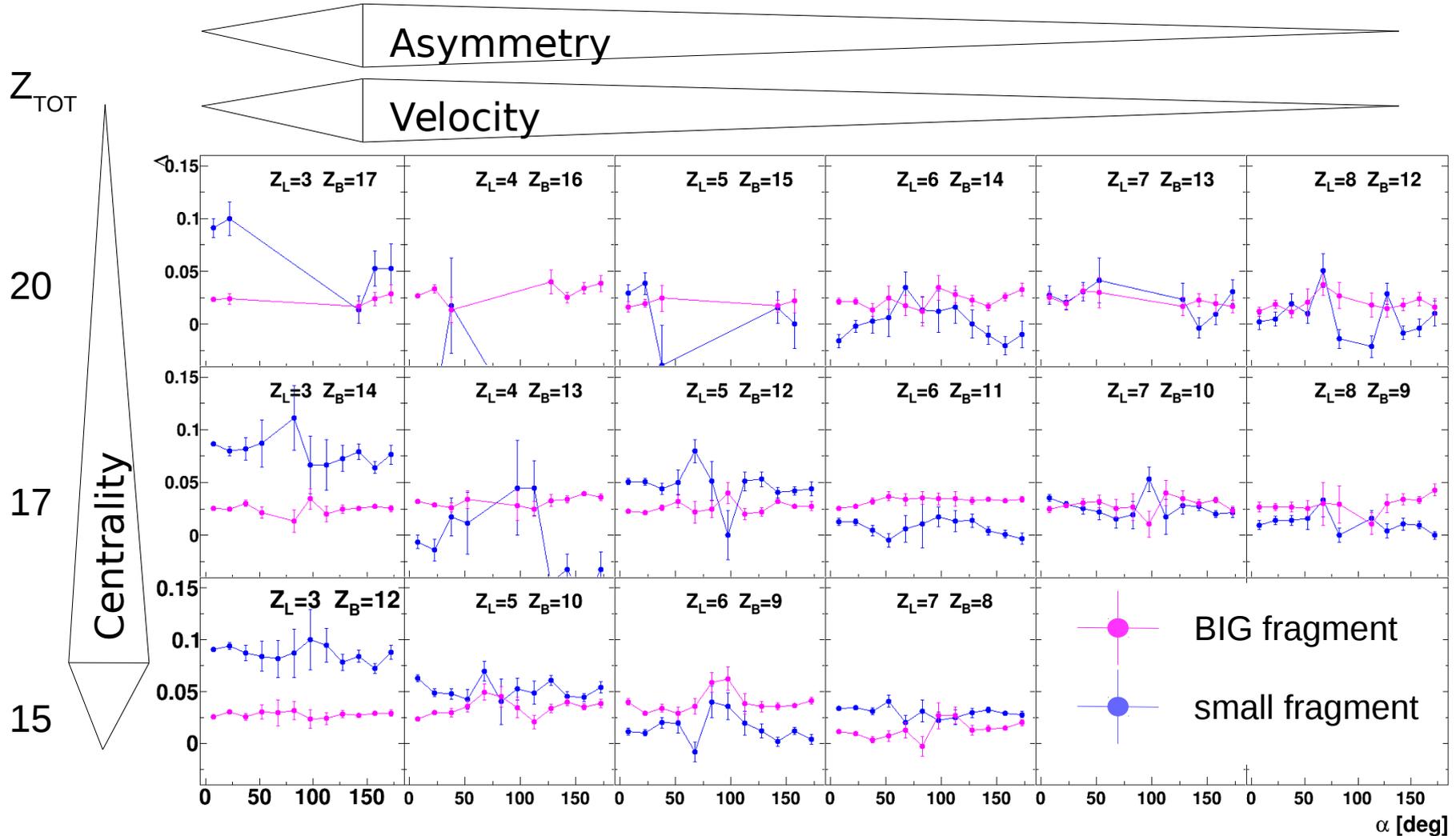
Despite the low statistic for some pairs, it seems that the same observed equilibration, as the fission asymmetry, is present.

Fission Fragments: $\langle N\rangle/Z$ v.s v^{CM}_z