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# Isospin influence on the decay modes of systems produced in the $^{78,86}$Kr + $^{40,48}$Ca reactions at 10AMeV

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# Outline

- The Physics Case

- The Experimental Method

- Experimental Results

  - IMF behavior
  - Global features

- Conclusions and Outlook

# Physics case

**Heavy-ion induced reactions with stable and radioactive beams are ideal to explore the response of nuclei under different stress conditions**

**Energy domain E < 15 MeV/A is dominated by fusion processes in competition with binary reactions**

**Both these processes are influenced by many parameters :**

**- nuclear structure and N/Z of the system**

**- angular momentum, dynamical effect -> quasi-fission**

**Decay modes populate the whole mass/charge domain from evaporated light particles up to the symmetric fission fragments, with the IMF in between**

**the decay mechanism are influenced by different parameters :**

**E*, J, N/Z, nuclear structure**

# ISODEC CHIMERA@LNS

## E = 10 AMeV $^{78}Kr + ^{40}Ca \rightarrow ^{118}Ba$ and $^{86}Kr + ^{48}Ca \rightarrow ^{134}Ba$

**Formation of two composite systems that are different for 16 neutrons**

| | $^{118}Ba$ | $^{134}Ba$ |
|---|---|---|
| E*(MeV) | 215 | 270 |
| $V_B$(MeV) | 90 | 87 |
| $(N/Z)_{tot}$ | 1.11 | 1.39 |

**-> possibility to explore the dependence of the formation and decay mechanisms of the composite system on the isospin (N/Z)**

S. Pirrone et al., EPJ 17 (2011) 16010; G. Politi et al., EPJ 21 (2012) 02003;
S. Pirrone et al., AIP Conf. Proc. 1524 (2013) 7;
G. Politi et al., JPS Conf. Proc. to be published 2015;
S. Pirrone et al., Journal of Physics: Conference Series 515 (2014) 012018;

**ISODEC Experiment complements the experiment E457S (GANIL)**
**-> study of the reactions $^{78,82}Kr + ^{40}Ca$ at 5.5 AMeV with the INDRA device**
**same neutron-poor system -> influence of the energy of the entrance channel**

G. Ademard et al., PRC 83 (2011) 054619

# CHIMERA device at INFN-LNS in Catania – ITALY

**4π device**

**1192 Telescopes**

**Si (300μm) - CsI(Tl)**

**Forward part 1°<θ<30°**

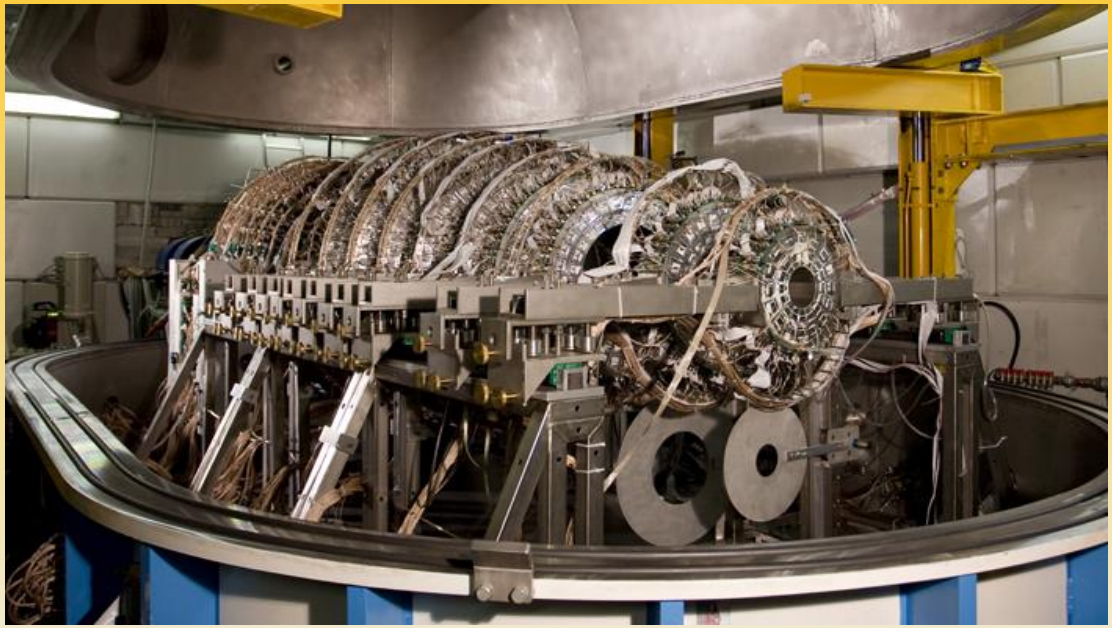
**688 modules**

**9 Rings 100cm<d<350 cm**

**Backward part 30°<θ<176°**

**504 modules**

**Sphere R=40 cm**



A. Pagano et al., NPA681 (2001) 331

**Precise measurement of E, TOF, Velocity, θ, φ**

**Different identification methods: PSD Si, E-ToF, DE/E, PSD CsI**

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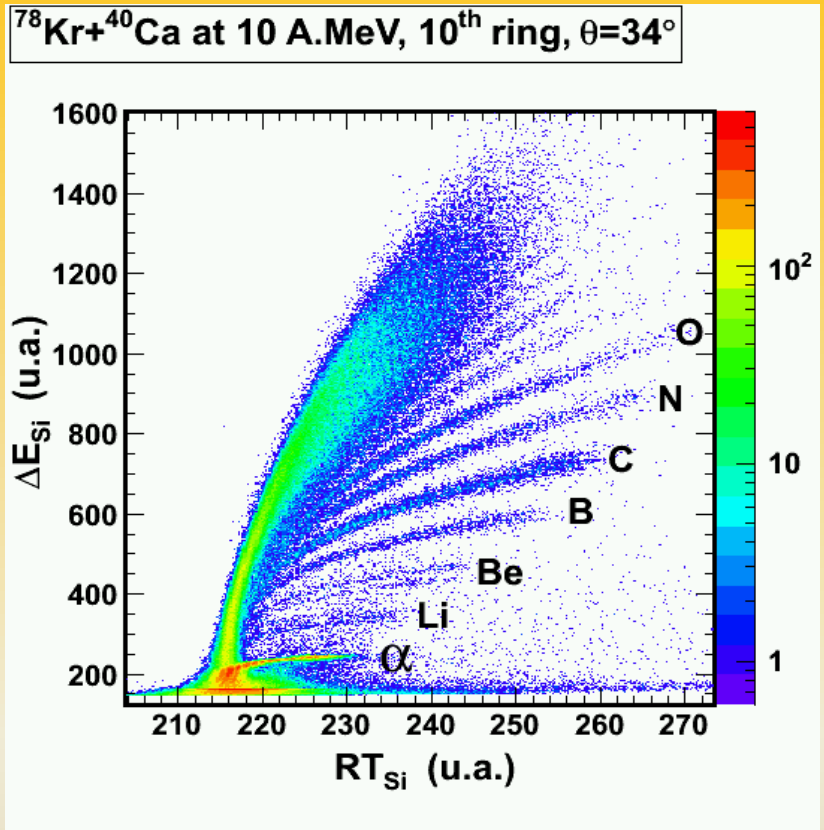
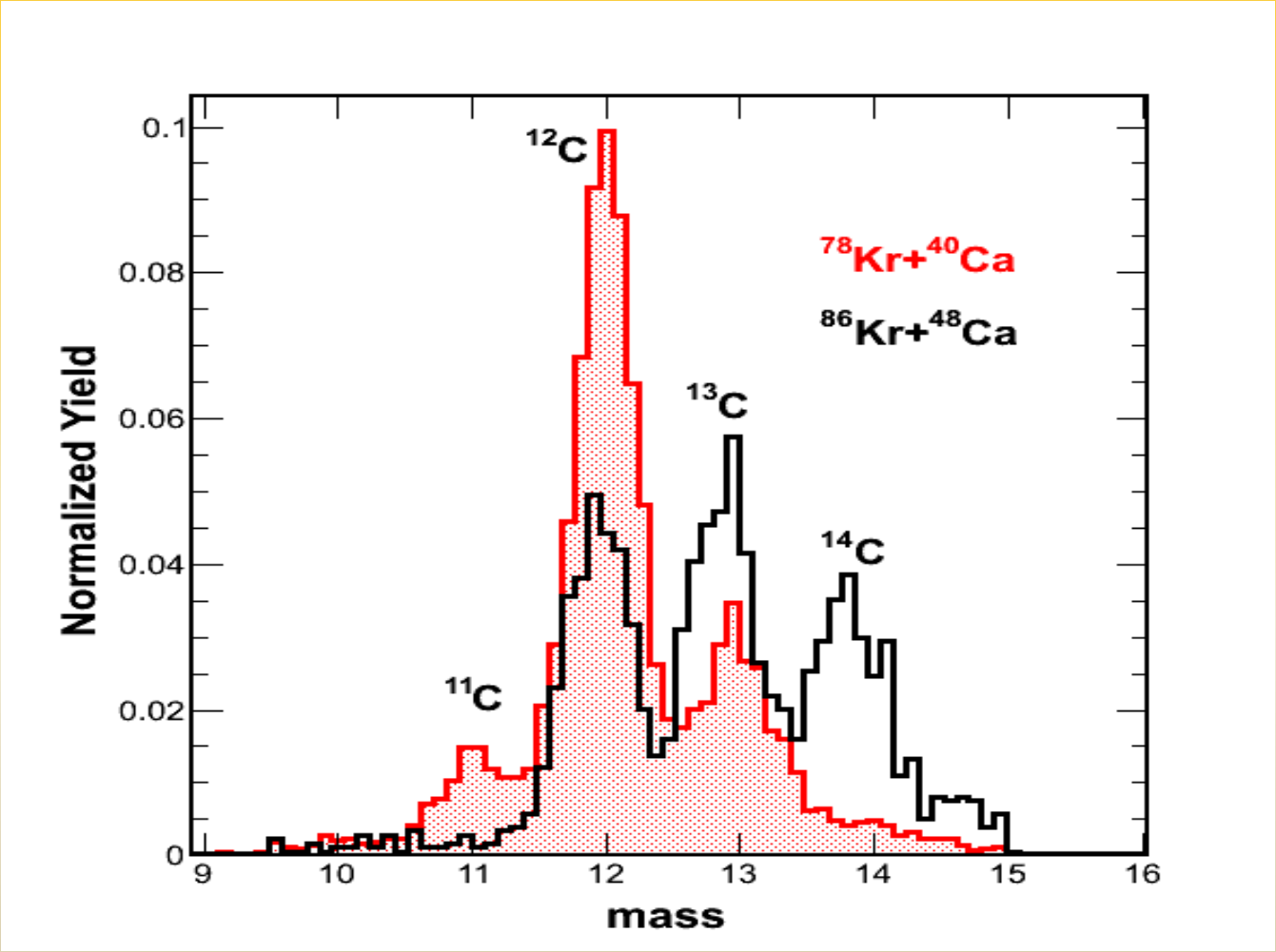



G. Politi et al., IEEE NSS Conference Record (2005) N28-5

**Precise measurement of E, TOF, Velocity, θ, φ**

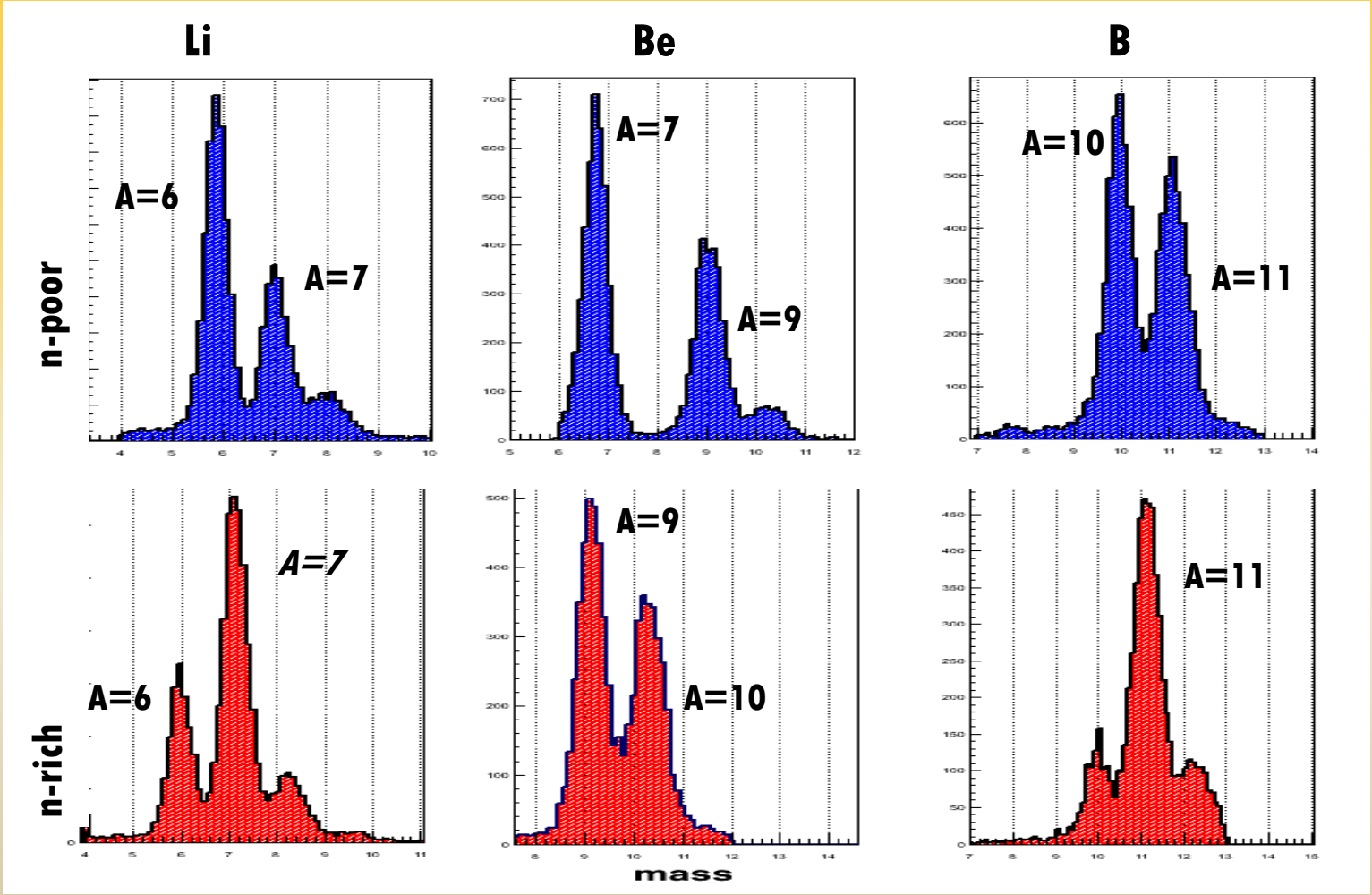
**Different identification methods: PSD Si, E-ToF, DE/E, PSD CsI**

**Different isotopic composition and relative richness of the Carbon for the two systems**

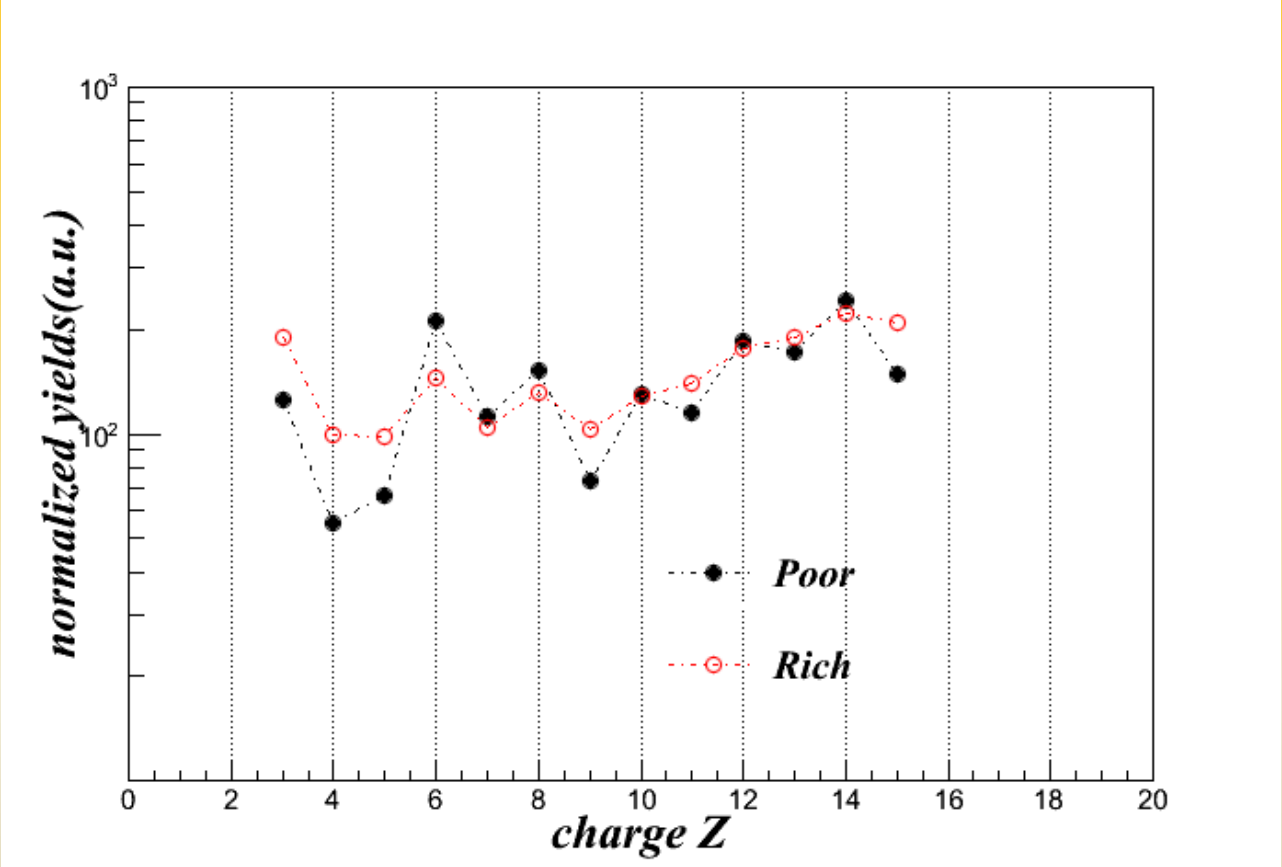



E. De Filippo, A. Pagano, EPJA681 (2014) 32

## Mass distributions of different Z for the n-poor system $^{78}Kr + ^{40}Ca$ and for the n-rich system $^{86}Kr + ^{48}Ca$ at $\theta_{lab} = 21°$



## Charge Yields for IMF of the reactions $^{78,86}$Kr + $^{40,48}$Ca in the range $\theta_{Lab}$ = 10°- 16°

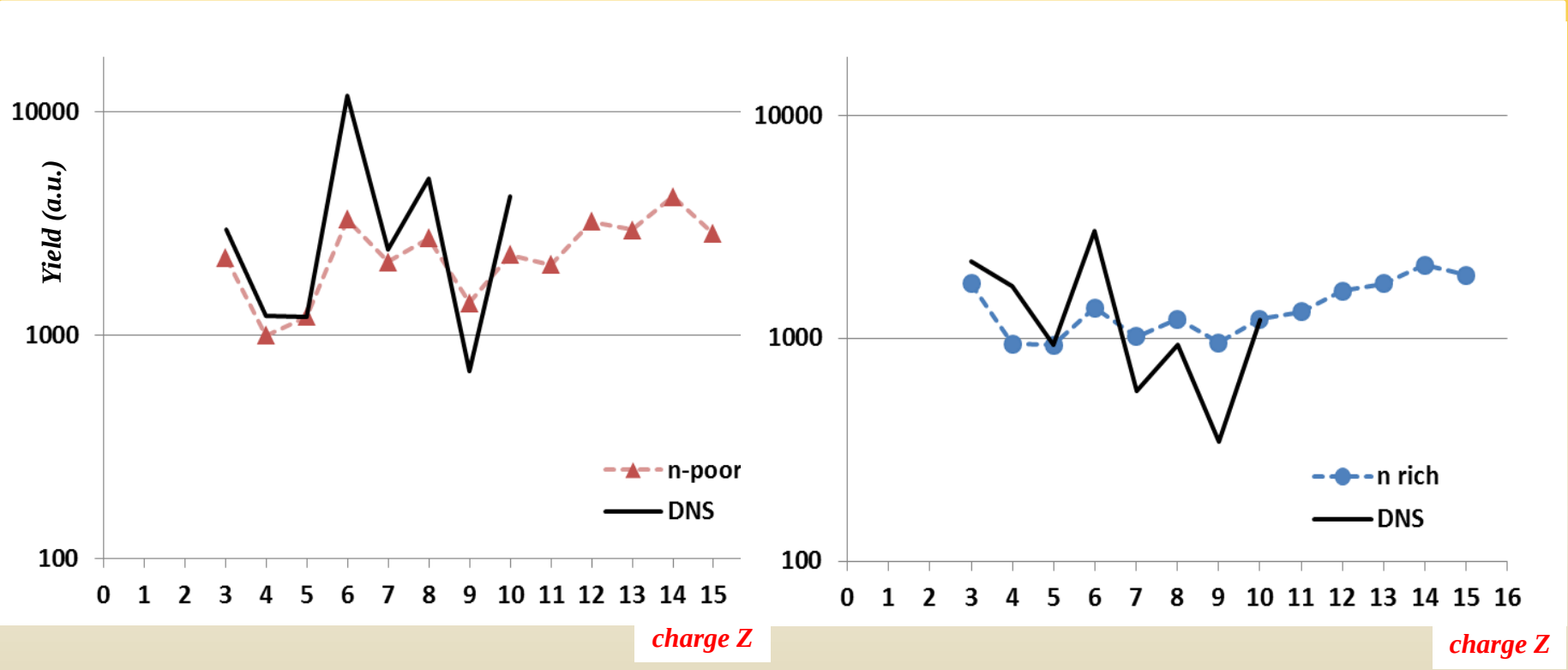



**The IMF yields exhibits an odd-even staggering, that is more pronounced for the n-poor system**

**In agreement with**: I. Lombardo et al., PRC 84 (2011) 024613
G. Casini et al., PRC 86 (2012) 011602

## *Preliminary* comparison with DiNuclear System (DNS) code

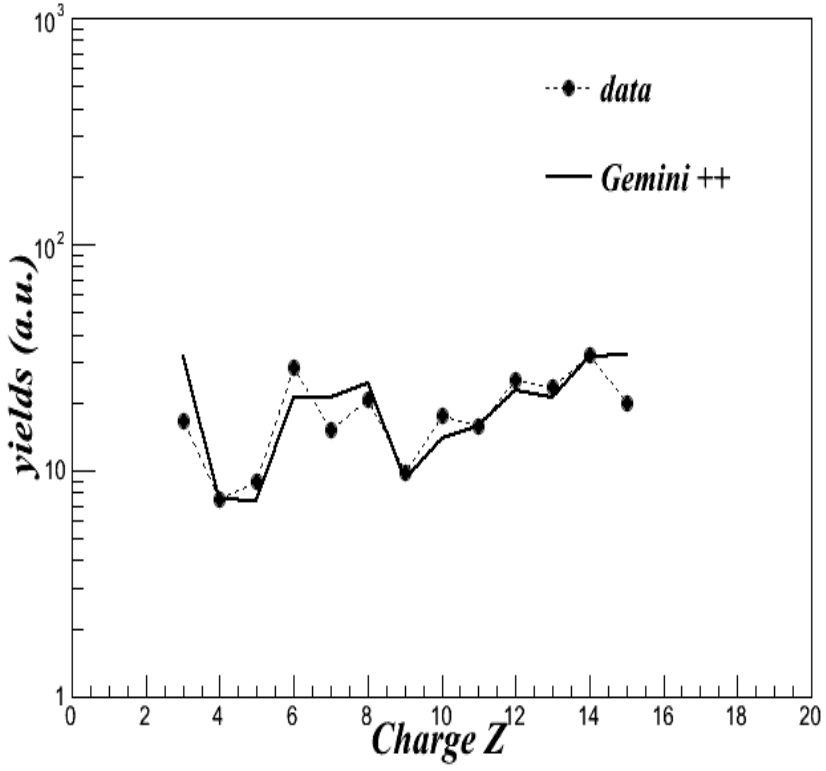
S.A. Kalandarov et al., PRC 82 (2010) 044603

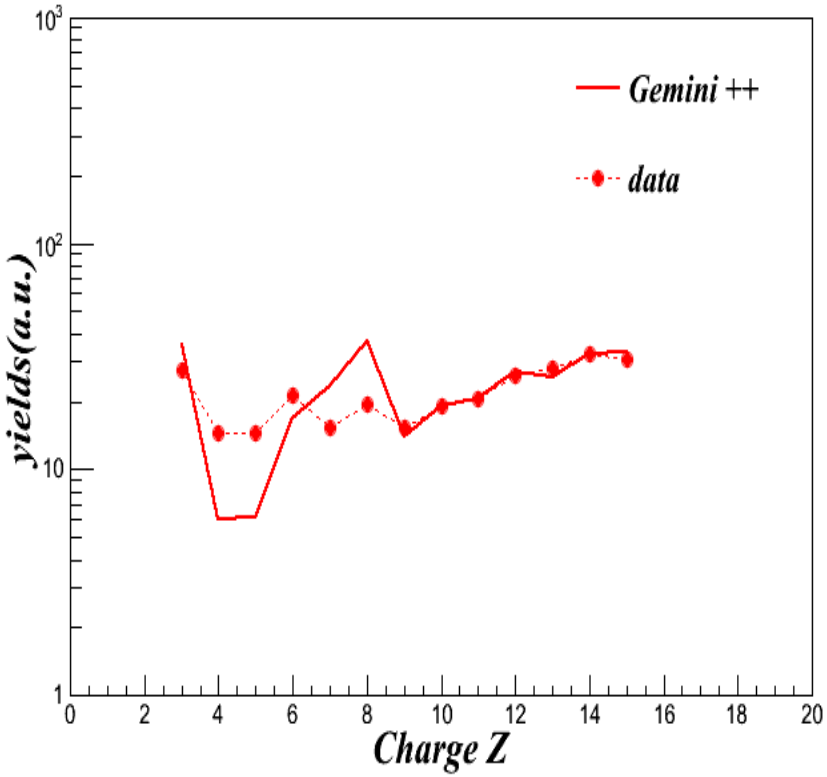



**Simulation performed for the TOTAL cross section and normalized at Z=5**

**DNS seems to reproduce slightly better the n-poor system**

## *Preliminary* comparison with Gemini ++ code

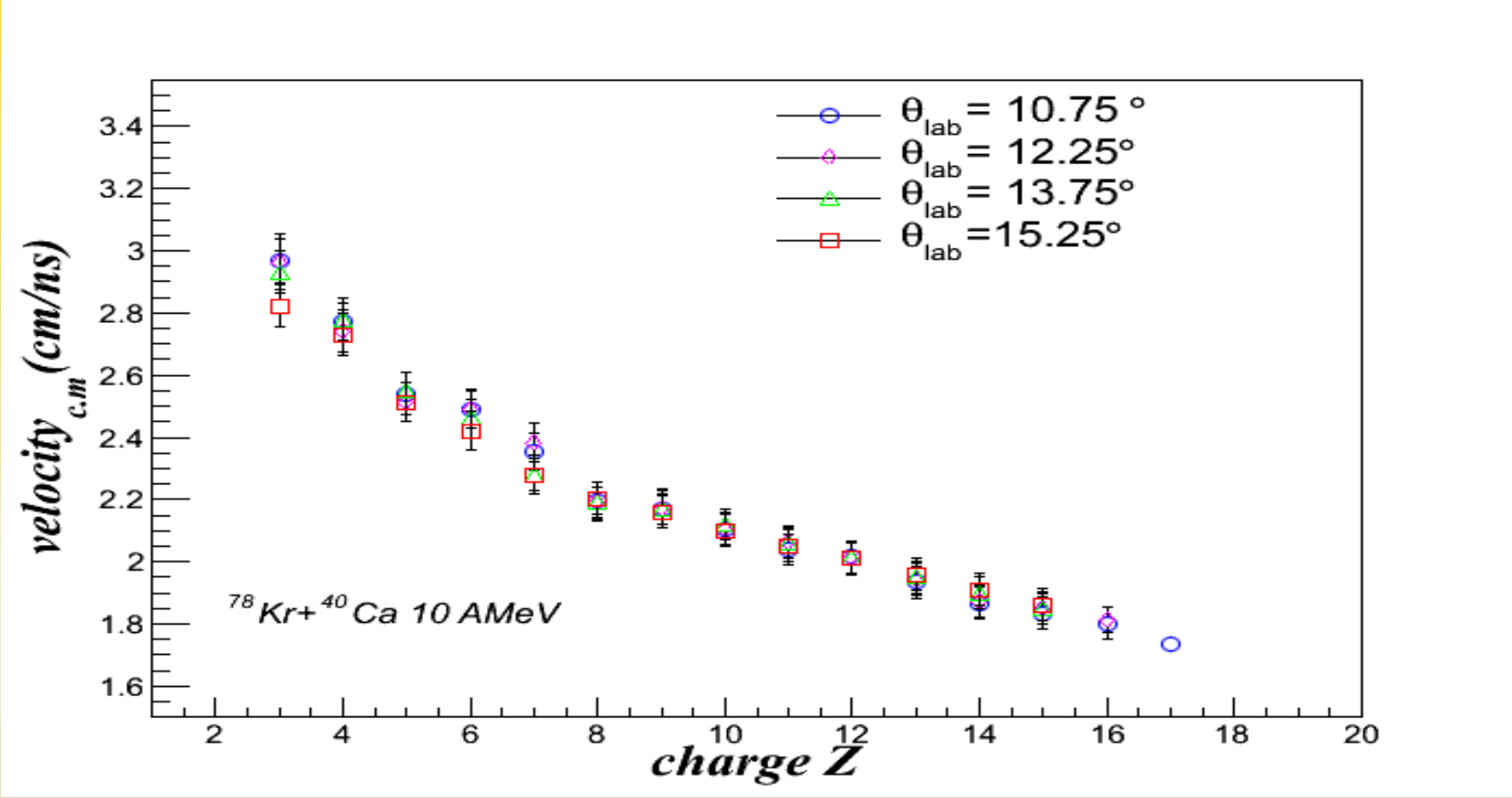



**Simulation performed for the TOTAL cross section and normalized at Z=14**

**Gemini++ seems to reproduce slightly better the n-poor system**

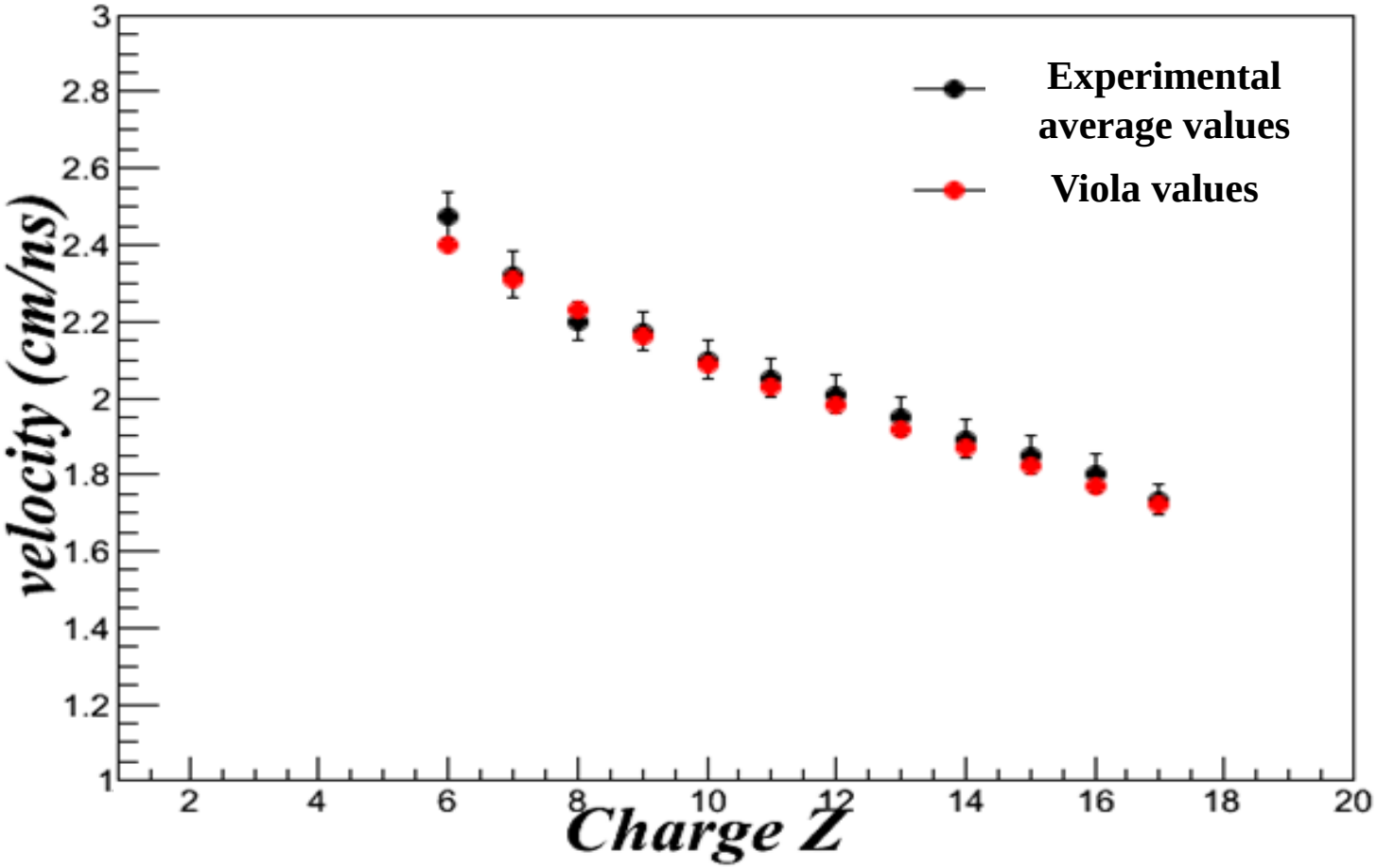
**Average velocity for Z= 3-17 in the center of mass frame for different Z and at different $\theta_{lab}$**




**Velocity seems to be independent of the emission angle for all the fragments**

**-> high degree of relaxation of kinetic energy**

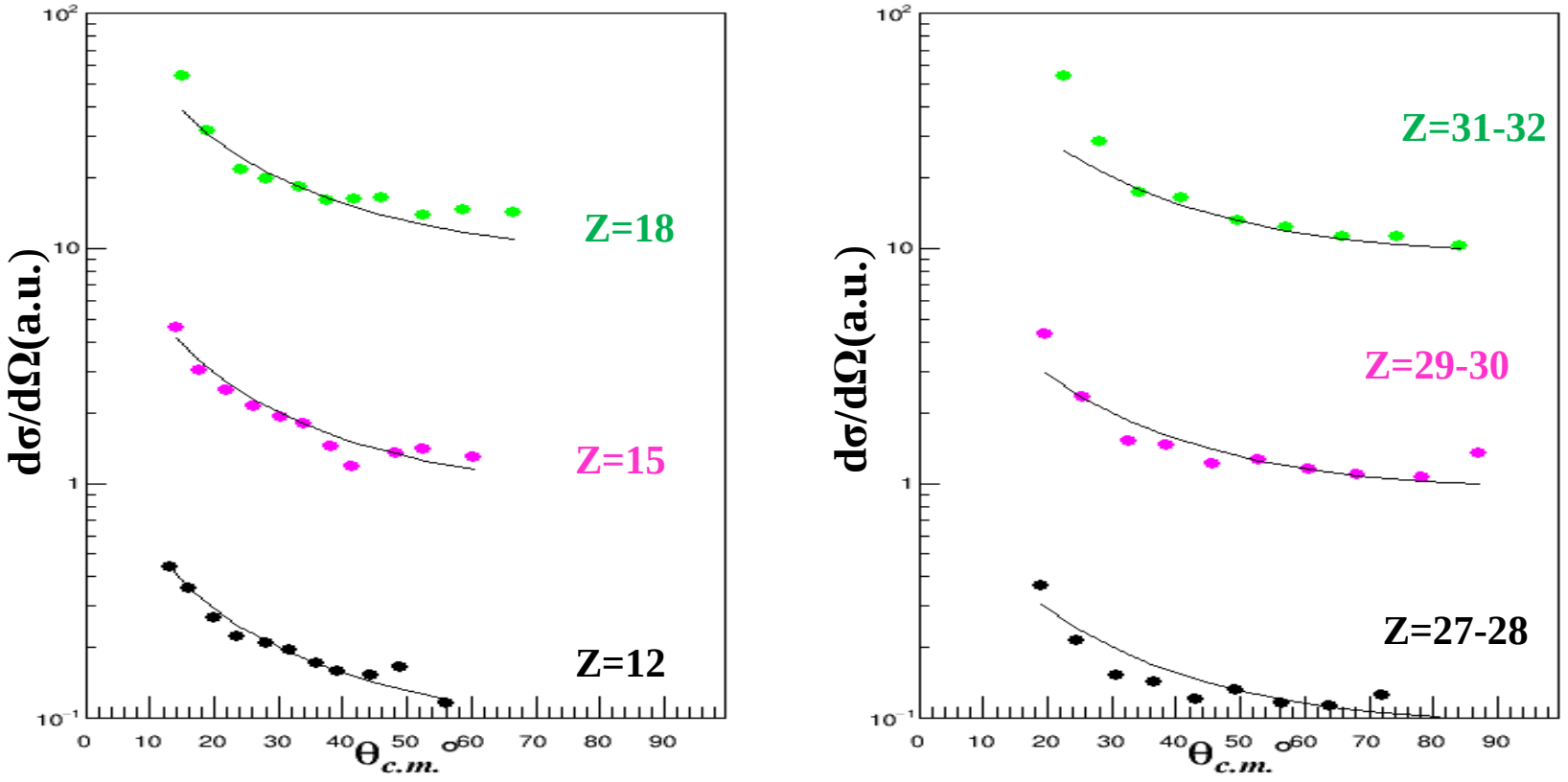
**Signature of a binary process dominated by the Coulomb interaction between the considered fragment and its complementary partner**




**Average values of the experimental velocity ( from $\Theta_{lab}=10.75^0$ to $\Theta_{lab}=15.25^0$) in the center of mass frame compared to the values obtained with the systematic of Viola, with the correction for the asymmetric fission** D.J. Hinde, NPA472 (1987) 318

## Angular distributions in the center of mass frame for fission fragments

n-poor

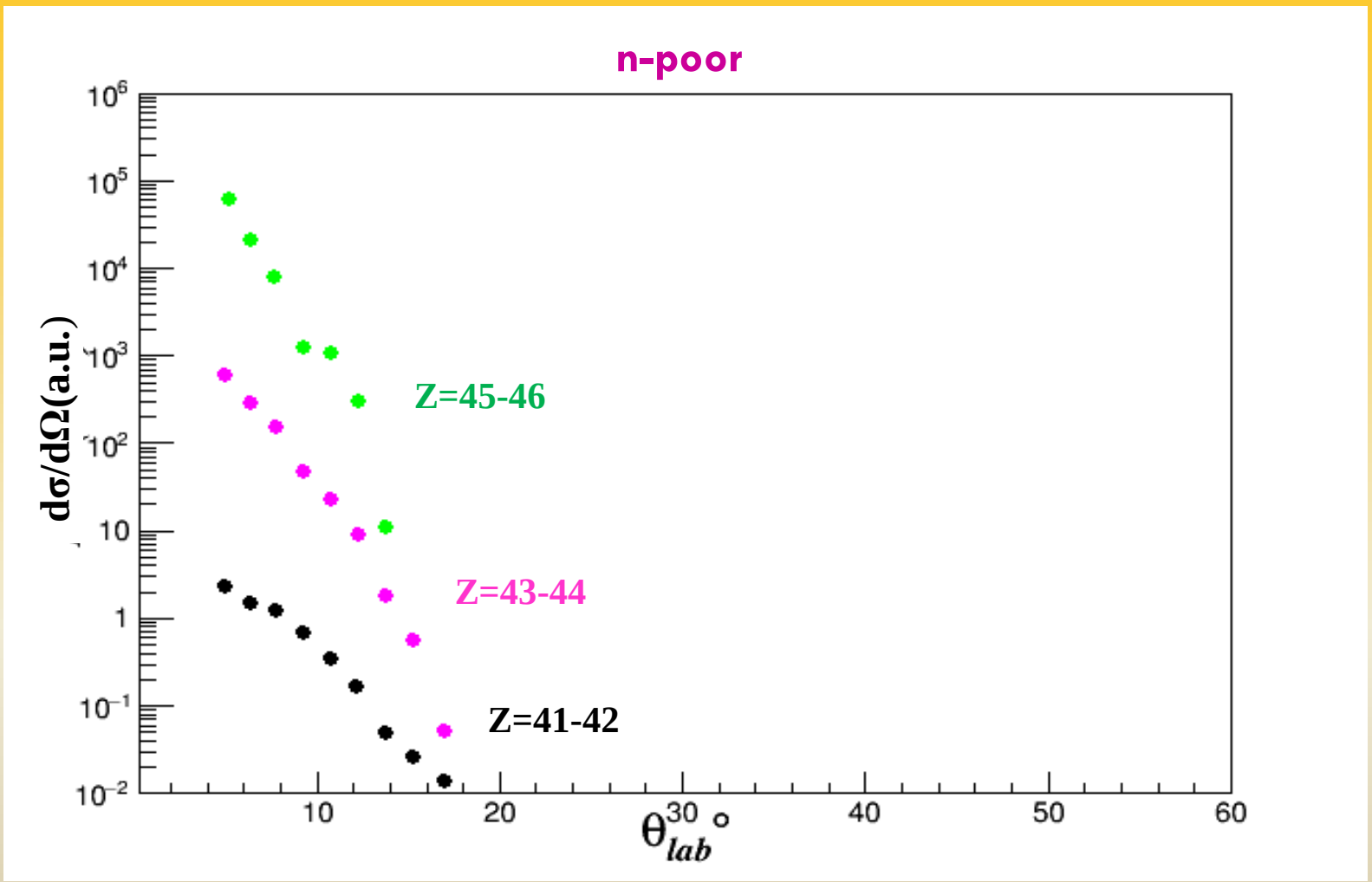



1/sinθ fit -> high degree of relaxation

Production via a long lived system

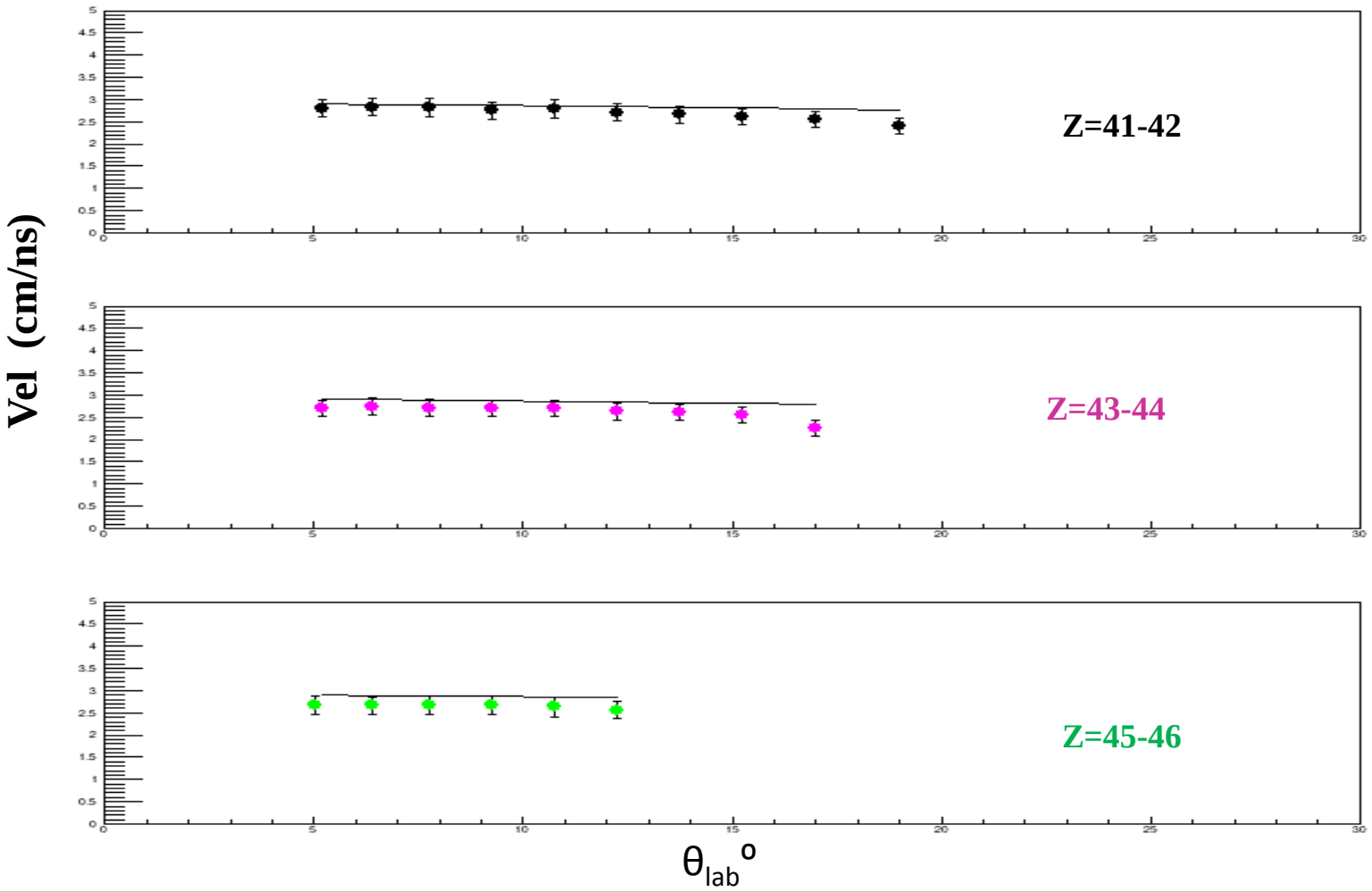
Similar results for the n-rich system

## Angular distributions in the laboratory frame for groups of Z (from Z=41-42 up to Z=45-46)




**These angular distributions are very strongly forward peaked as it is expected for the evaporation residues.**

## Extracted centroids $V_{ER}$ for the evaporation residues vs laboratory angle compared to $V_{CN}$*cos $\theta_{lab}$

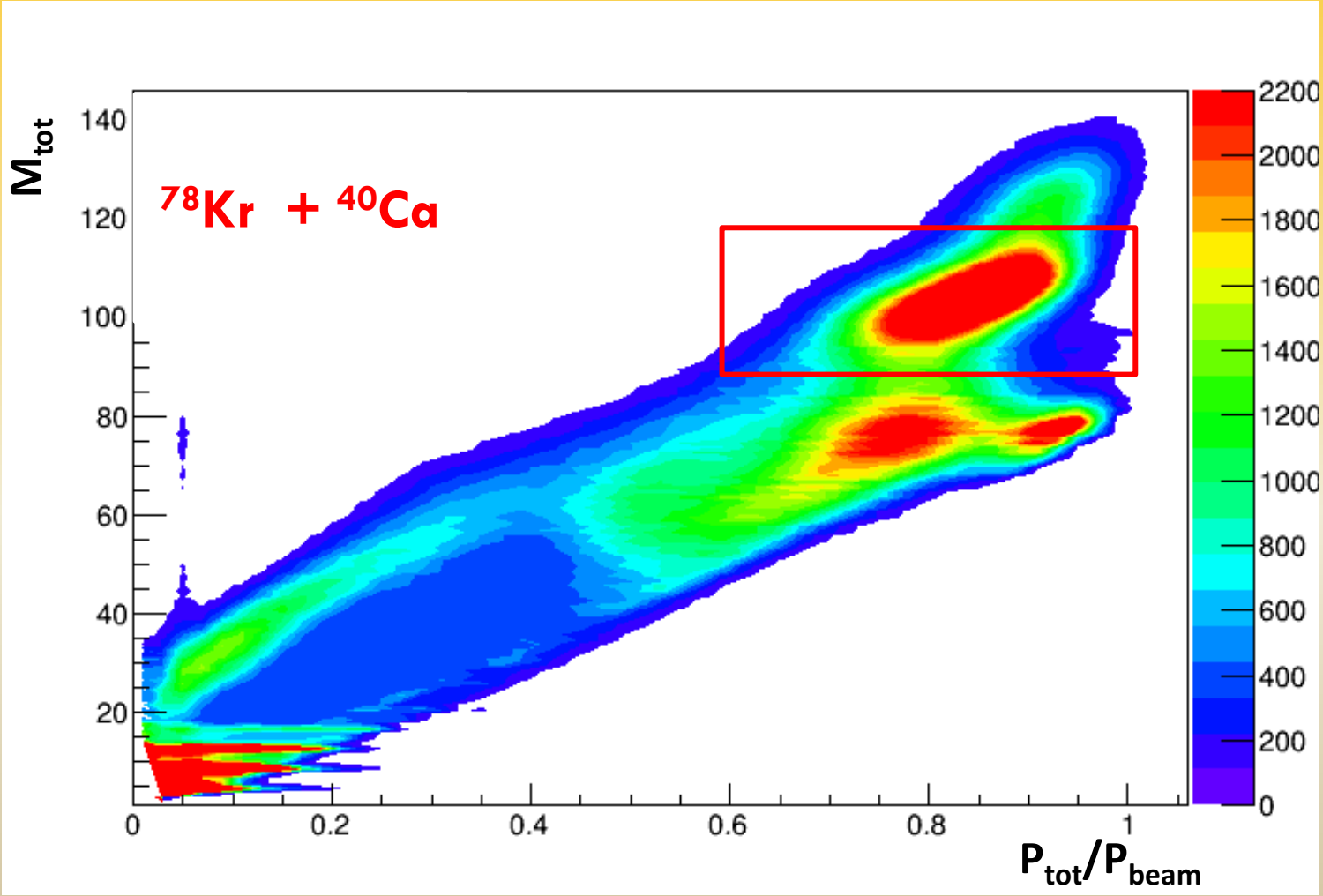


**$M_{tot}$ –$P_{tot}$ plot for complete events selection:**

**Multiplicity≥2**

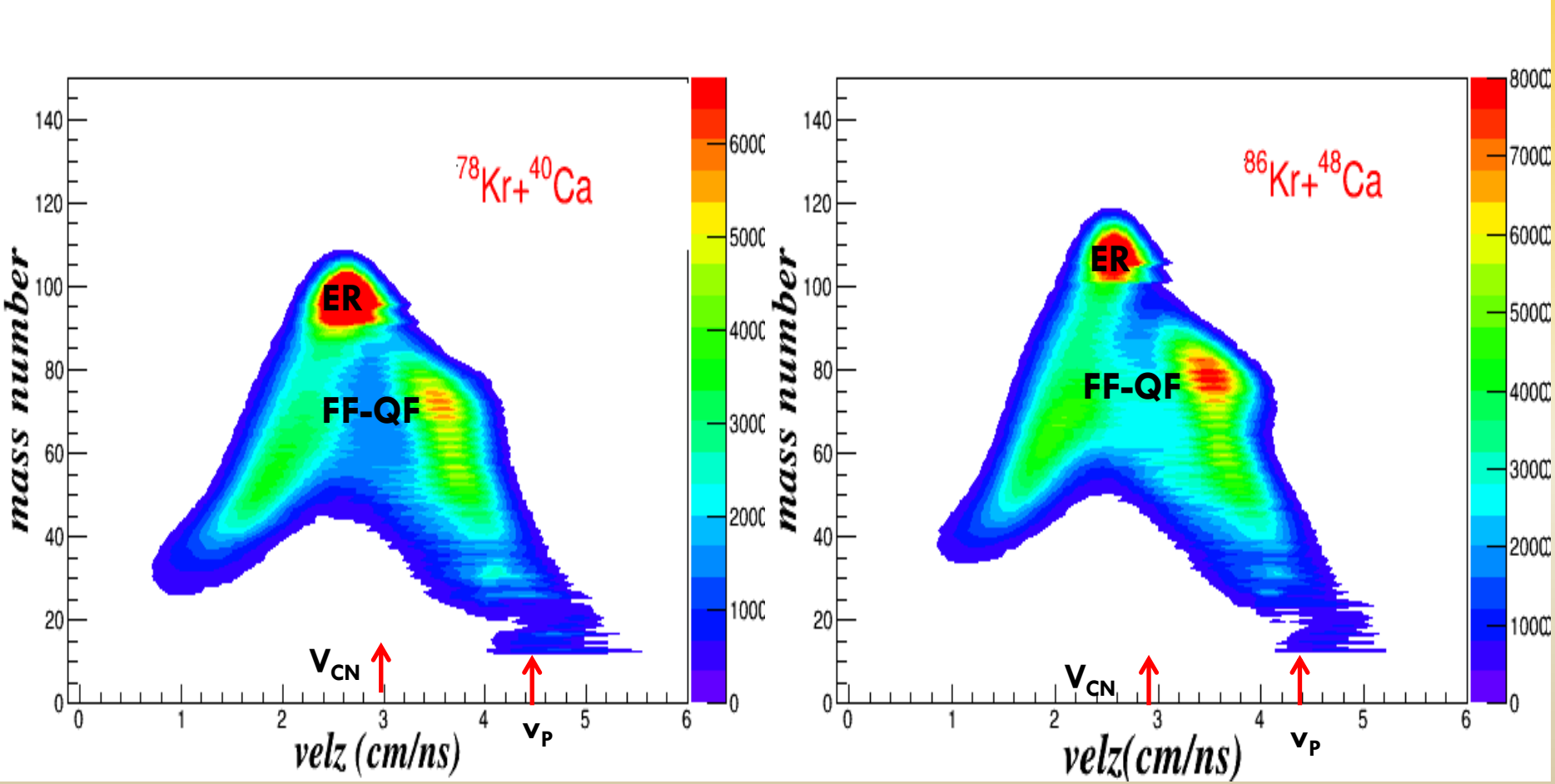
**$0.8\ M_{CN} \leq M_{tot} \leq 1.1\ M_{CN}$**

**$0.6 \leq p_{tot}/p_{beam} \leq 1$**

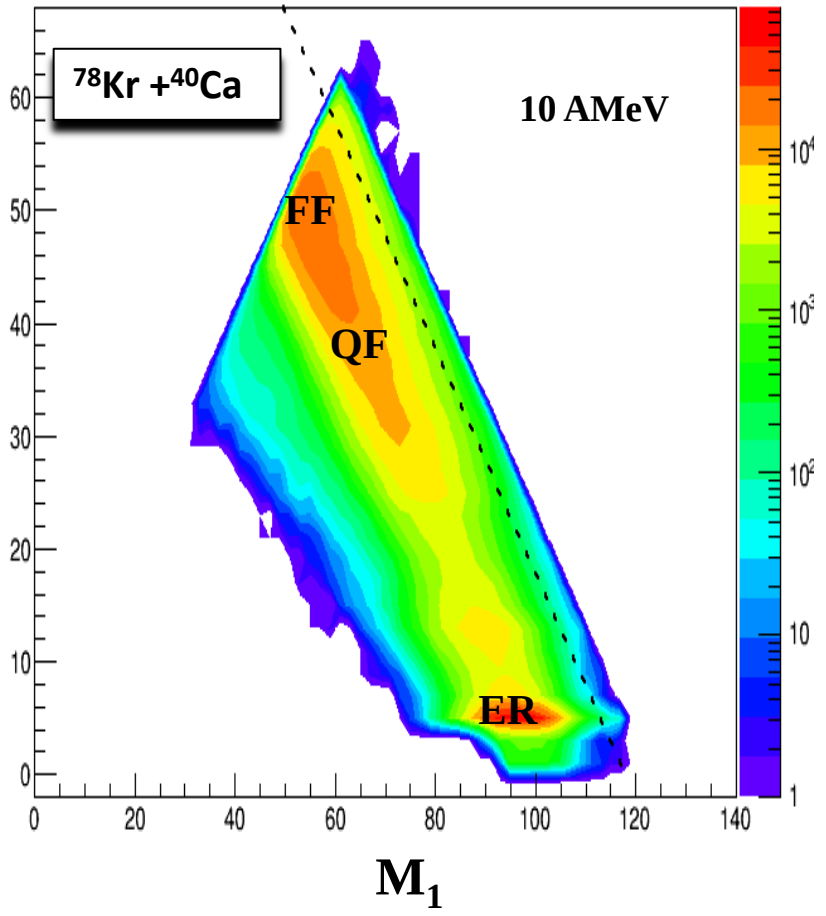


## *Global features*

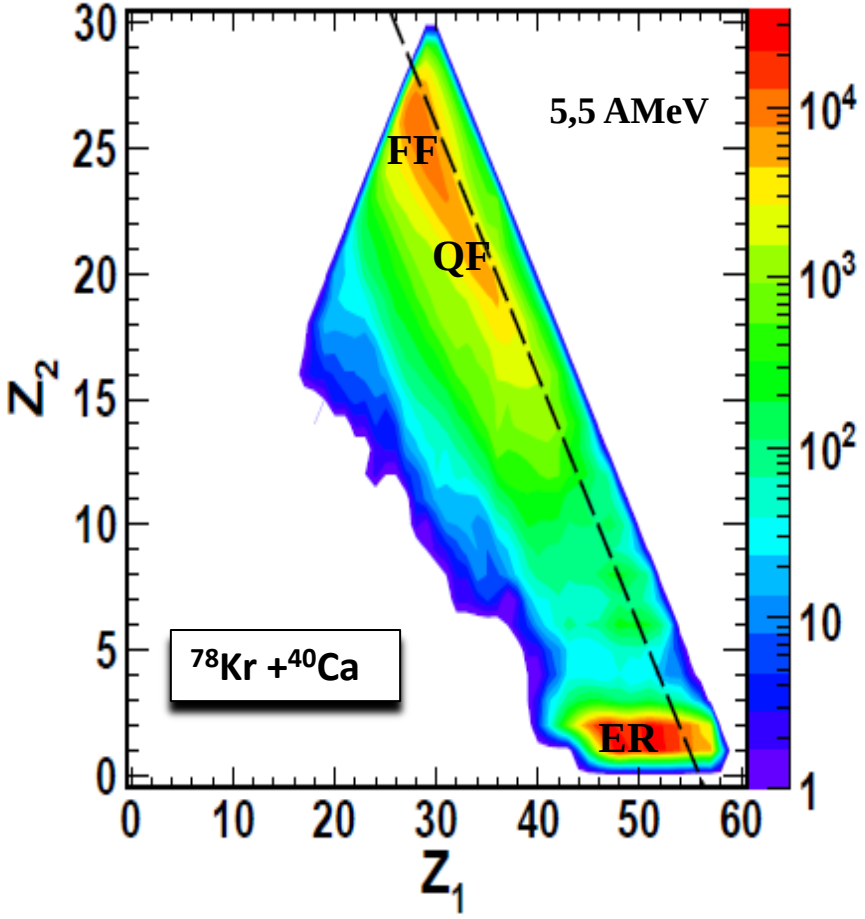
**Plot mass-vparallel of the reaction products with complete events selection**
**-> important information on the competition between the reaction mechanism**
**->very preliminary analysis seems to show that there is a higher ER/FF ratio for n-poor system compared to the n-rich one**



**ISODEC experiment**

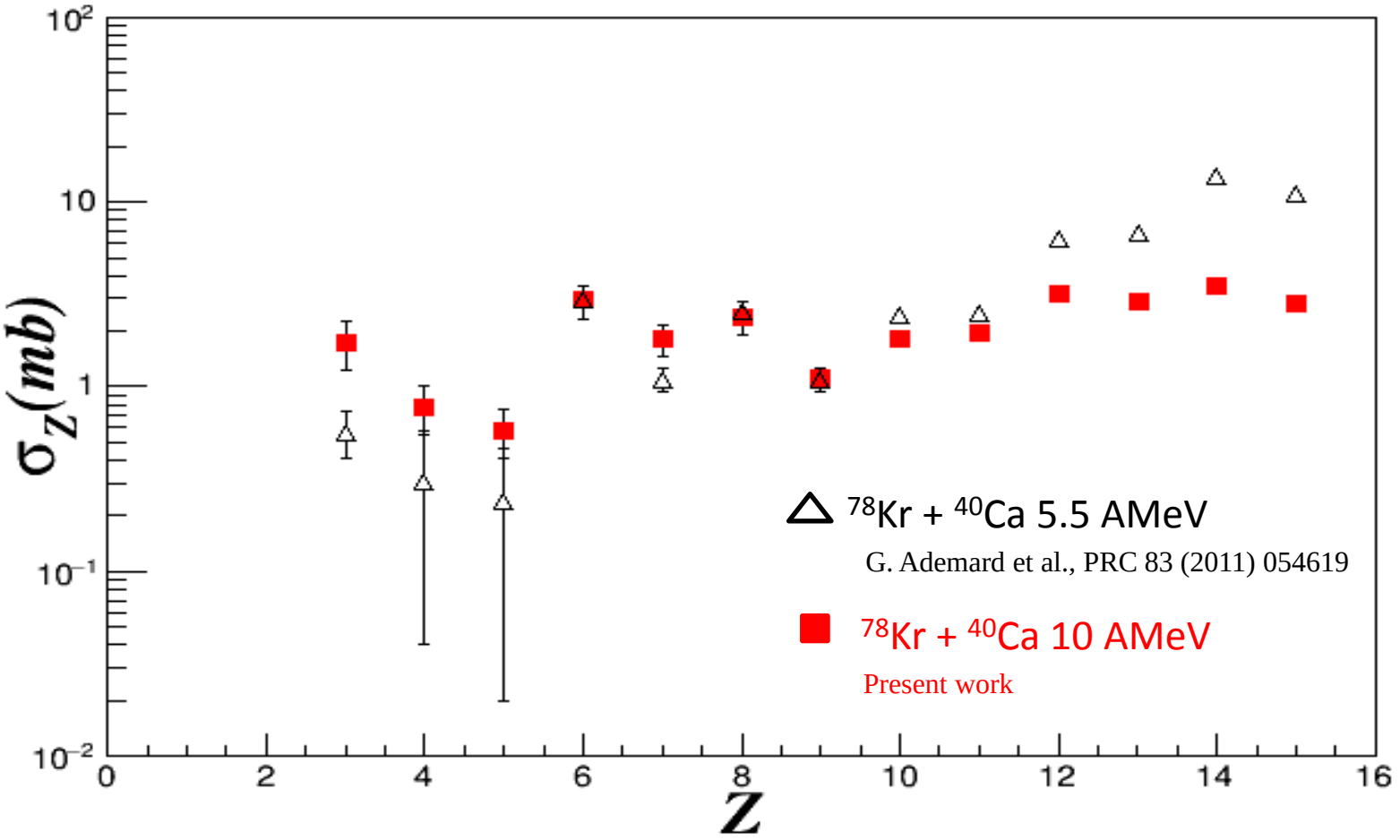



**E457S experiment**




**Preliminary comparison with the INDRA results of the reaction $^{78}$Kr +$^{40}$Ca at 5.5 AMeV**

G. Ademard et al., PRC 83 (2011) 054619




**Very Preliminary comparison with the production cross section of the IMF in the reaction $^{78}$Kr +$^{40}$Ca at two different energies**

# Conclusions

**The results of the analysis of the reactions $^{78,86}$Kr + $^{40,48}$Ca at 10 AMeV are presented:**

**The kinematical characteristics and the angular distributions of the fragments detected seem to indicate for both reactions a high degree of relaxation of the composed system**

**The IMF cross section is more flat for the neutron –poor system at the higher energy**

**The results put in evidence the influence of the neutron enrichment of the entrance channel on:**

**- Different isotopic composition and relative richness of the reaction products for the two systems.**

**- Odd - even effect, Staggering, in the IMF charge distributions**
**-> stronger for the n-poor system.**

**- Sizeable differences for the different reaction channels:**
**FF, QF and ER -> there is a higher ER/FF ratio for n-poor system compared to the n-rich one**

# Outlook

**Data analysis are in progress :**

**Cross sections calculations for different mechanisms to confirm this first qualitative observation**

**Study of the Coincidence between LCP-FF, LCP-ER ,LCP-IMF**

**More precise comparisons with theoretical predictions to provide indications on the isospin influence on the reaction mechanism and fragments production**

# Outlook

**For a comparison with the results obtained with the stable beams ,**

**a LOI was presented at the " Second SPES International Workshop at INFN-LNL " in May 2014 by using radioactive beams**

**for studying the reactions:**

$$^{92}Kr + ^{40,48}Ca \quad 10\ AMev \quad ^{132,140}Ba^* \quad E^* \sim 320\ MeV$$

**These reactions lead to the formation of CN with N/Z =1.5 greater then the ratio obtained with stable beams.**

**-> study of the evolution, with isospin asymmetry, of the reaction dynamics and competition between different decay modes**

**-> interplay between nuclear structure and reaction mechanism in the emission process**

# EXOCHIM – ISODEC collaboration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