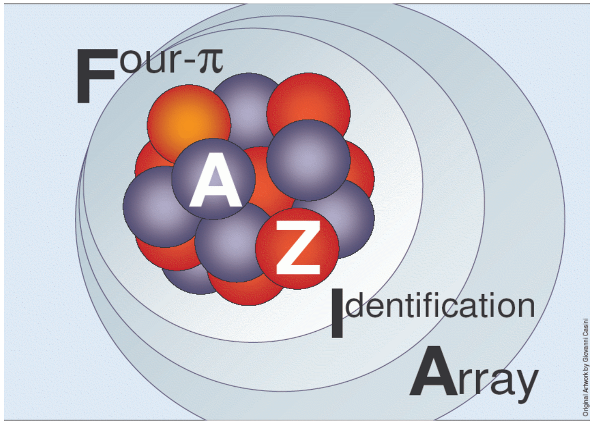
Isospin dynamics and nucleon exchanges with Fribs

LOI for the Fribs facility at the LNS



Giovanni Casini
for the
FAZIA collaboration

LNS USER GROUP

Catania, july 10th 2009

Outline:

- **what is FAZIA**
- **what is FRIBS: you know very well !**
- **what are some physics ideas compatible (?) with FRIBS**

What is FAZIA

(see http://fazia.in2p3.fr)

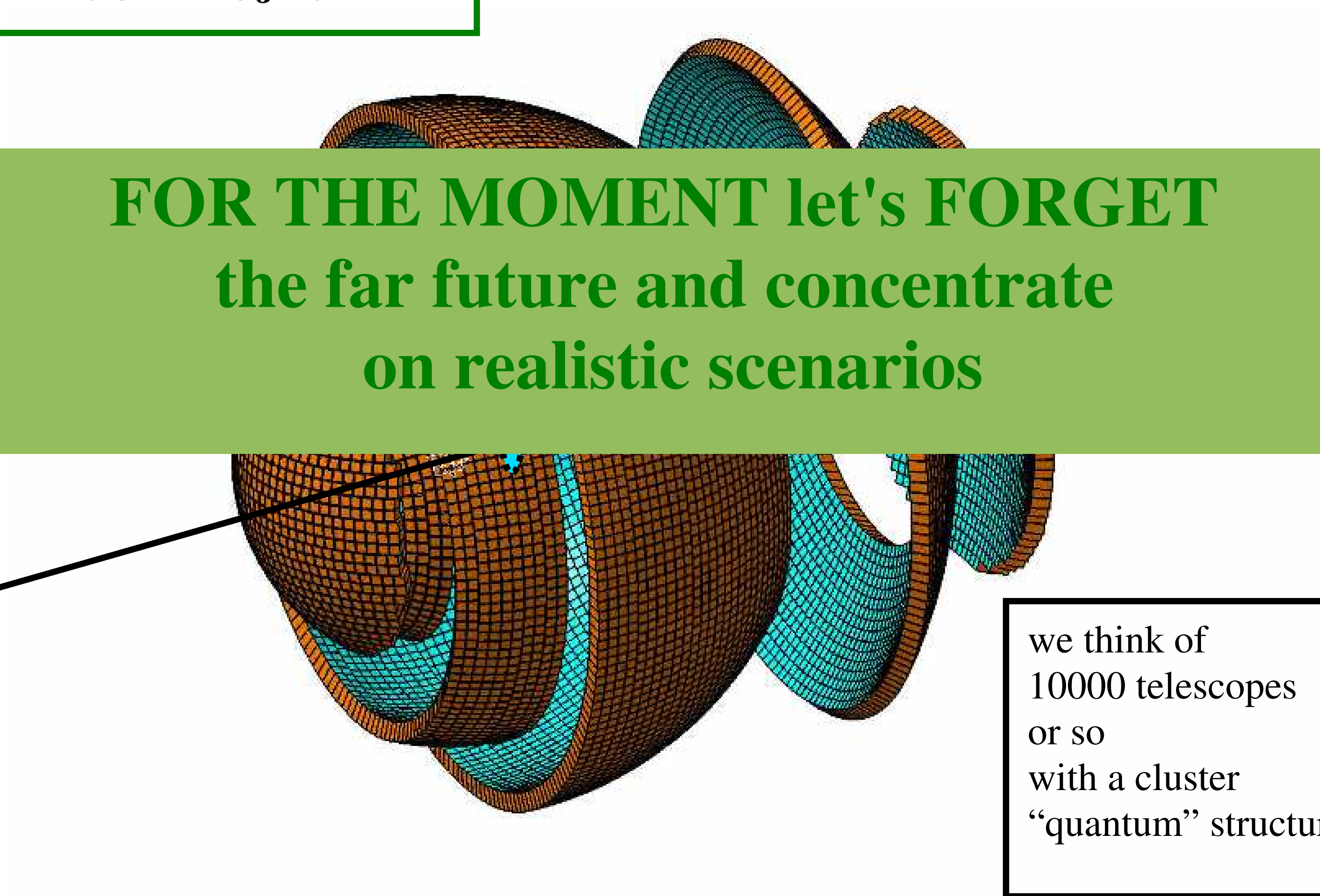
Fazia is an international collaboration mainly composed of French and Italian researchers with important contributions by Romanian, Polish and Spanish groups.

- **The long term project is to build a highly efficient array for charged products, to be used to study the properties of excited nuclear matter and the reaction dynamics, with both EXOTIC and STANDARD beams at energies from the Coulomb barrier to Fermi domain**

- **The middle term program (under discussion) is to build for good physics a sizeable telescope array (100-200 detectors) including the main features and original solutions of the final set-up, but intended to be coupled with other large arrays in operation. The first marriages are scheduled with INDRA and GARFIELD which are under the responsibilitiy of the biggest FAZIA components but all scientific plans can be considered together other groups**

What is FAZIA

A HUGE PROJECT……



FOR THE MOMENT let's FORGET the far future and concentrate on realistic scenarios

beam

target

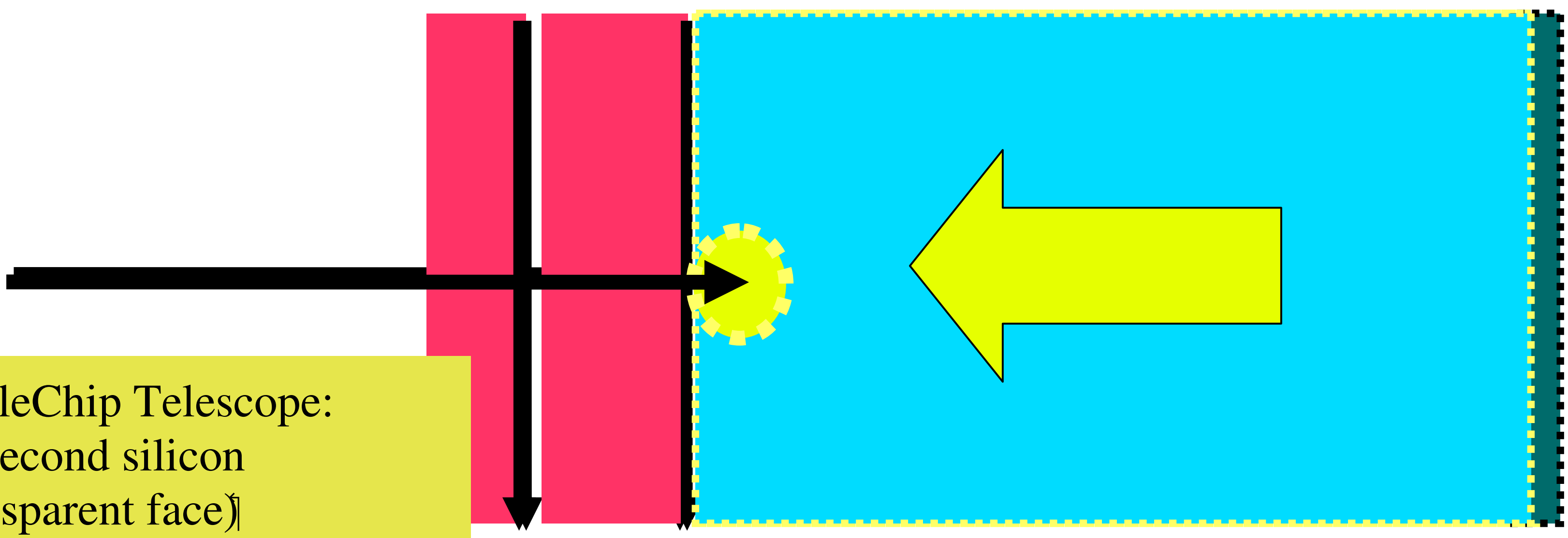
we think of
10000 telescopes
or so
with a cluster
"quantum" structure

What is FAZIA

In the last years Fazia made an intense R&D on detectors and on signal analysis techniques
Presently, the basic module is a telescope 20x20 mm^2 front face.
Si-Si-CsI(Tl) thickness: 300+500 micron Si; 4cm CsI(Tl)

A well assessed recipe but with **many innovative solutions**:

e.g. there is the alternative on the scintillation READOUT



SingleChip Telescope:
the second silicon
(transparent face)
acts as a Photodiode

What is FAZIA

about **CsI(Tl) detectors**:

a) home-made full digital electronics via fast ADC sampling (14bit@100MhZ) and DSP-FPGA

b) Pulse Shape Analysis (PSA) for light particles (digital fast-slow)

c) high performance low-noise charge preamplificators

d) identification and control of the critical construction parameters; strong contacts with several manufacturers (GB, Amcrys, Scionix)

e) optimum doping Tl concentration for H.I. light response;
Tl conc. via PIXE measurements in Florence

f) read -out choice via PD or via SCT technique

IMPORTANT ASPECTS for GOOD PSA:

- **Tl doping concentration**
- **wrapping procedures**

What is FAZIA

About **Silicon detectors**:

a) home-made full digital electronics via fast ADC sampling (14bit@100MhZ) and DSP-FPGA

b) Digital Pulse Shape Analysis (PSA), digit-energy and digit-time

c) high performance low-noise current-charge preamplificators

d) identification and control of the critical construction parameters; strong contacts with Silicon manufacturers (FBK, Canberra, Topsil)

e) reduction of peripheral dead-layers (now 0.3mm)

f) performances vs. radiation dose

g) syncronization via a unique reference signal; time-offset via LASER flashes

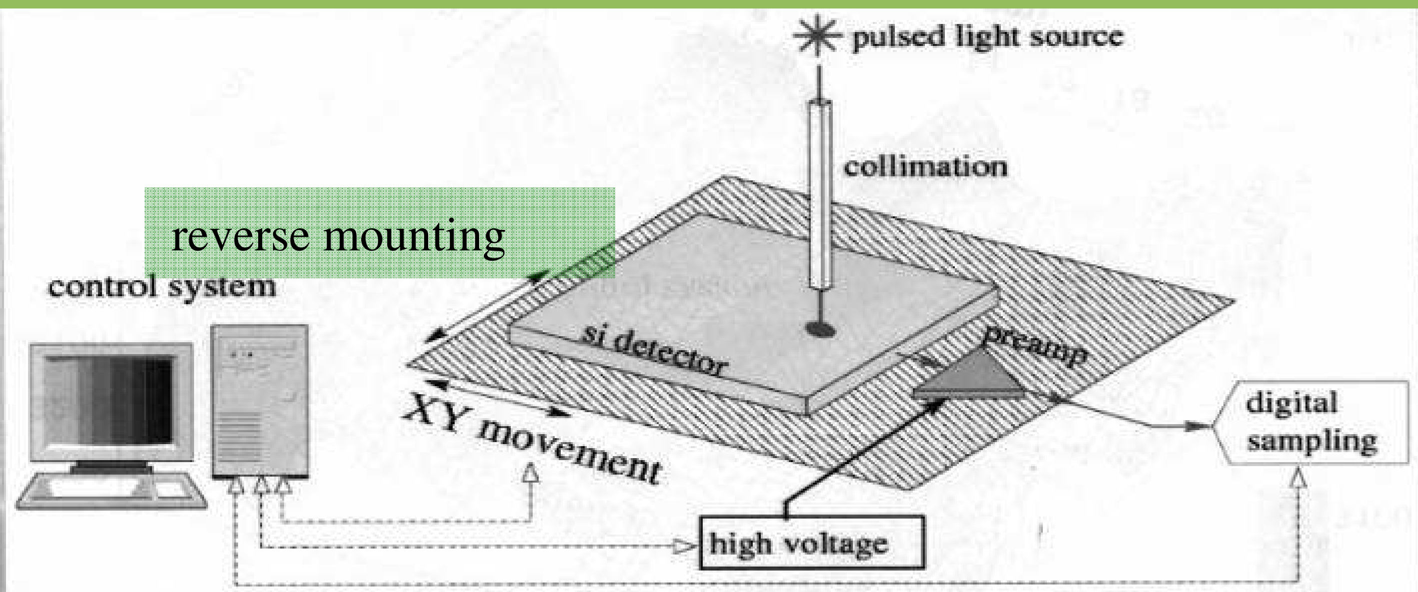
VERY IMPORTANT ASPECTS for GOOD PSA (till now):

- **doping homogeneity (uniform resistivity)**
- **avoid "channeling" (mask the crystalline nature to incoming particles)**

The good uniformity

Uniformity of the doping atoms plays a role in PSA (see Pausch IEEE-NS 44, 1997)

Original method for an easy control of chip local resistivity in LAB
L.Bardelli et al NIM A 602 (2009), 501-505



The detector is mounted on a XY movement.

Both the XY support and the HV are computer controlled.

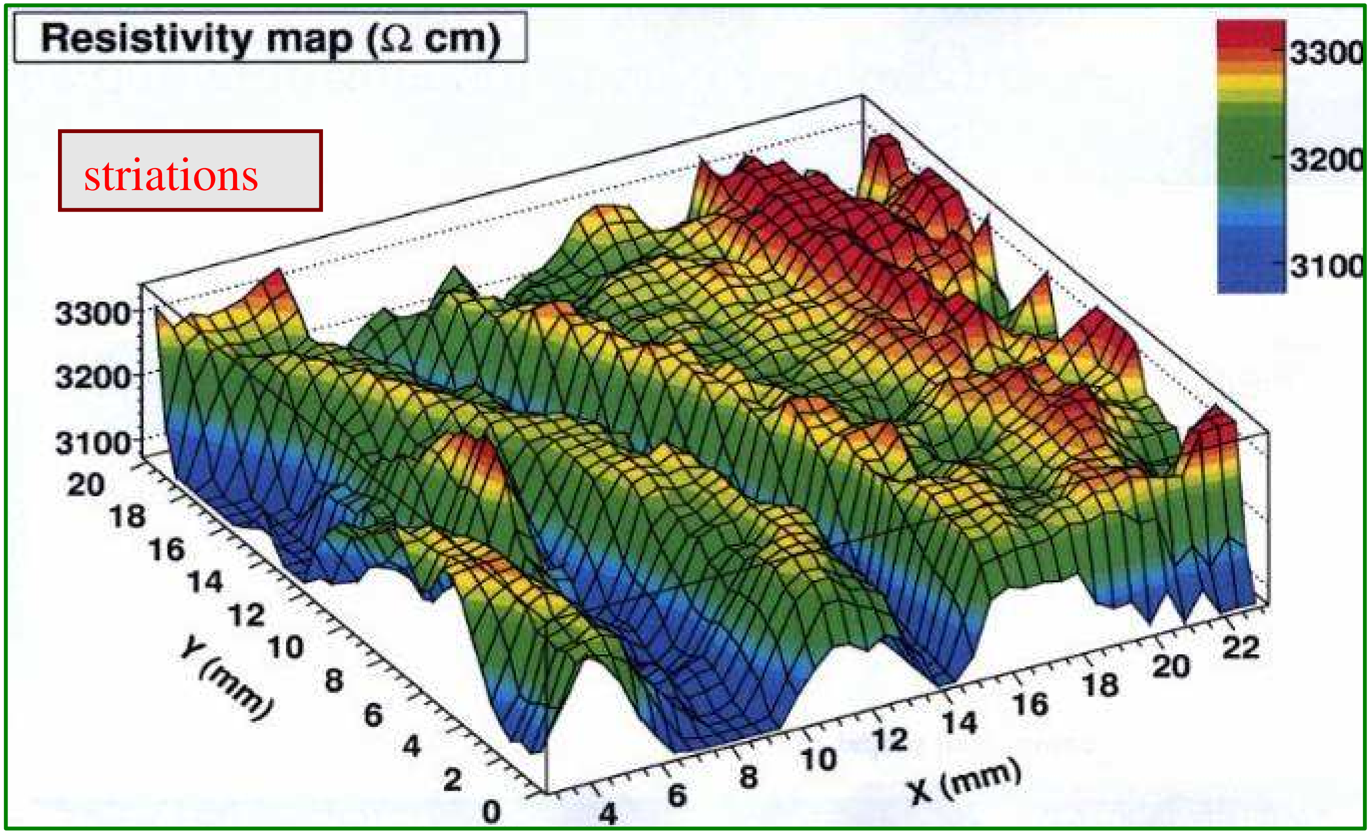
Shapes are collected with a digitizer (Florence DSP card)

-Rise-time *tr* from digitized shapes vs. bias voltage
-saturation of *tr* defines V_{depl} for each X,Y
-resolution 1mm
-about 150min to get a complete scan for a 400mm2 chip

The good uniformity

Uniformity of the doping atoms plays a role in PSA (see Pausch IEEE-NS 44 1997)

mountains and valleys appear in the chip!



-high sensitivity

-fast selection of the best crystals for the experiments

-(effective) interaction with Si-lingot producers.

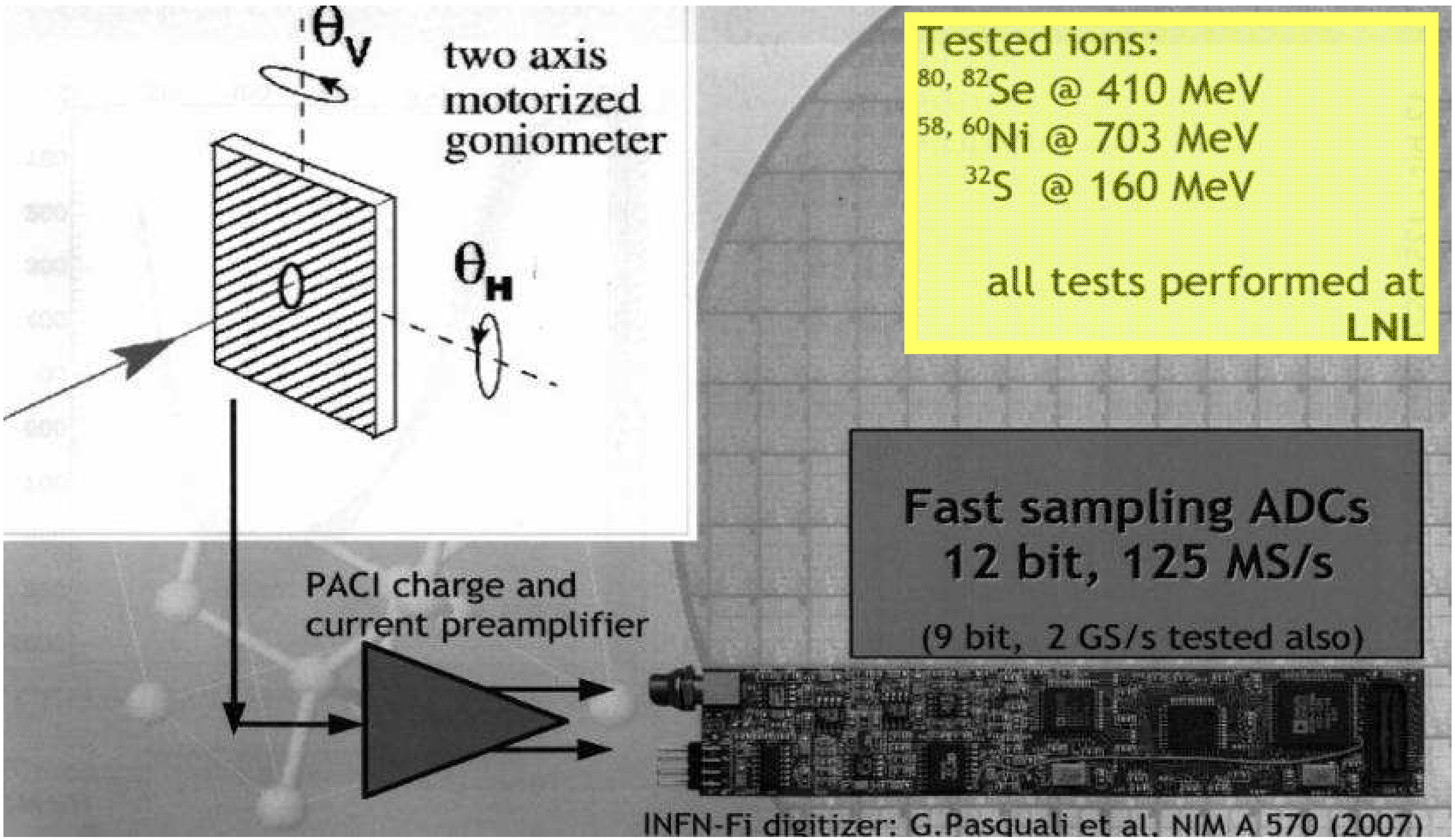
At present, our **best nTD crystals have uniformities within 1.3% at 4200 Ohm*cm**

L.Bardelli et al NIM A 602 (2009), 501-505 for FAZIA

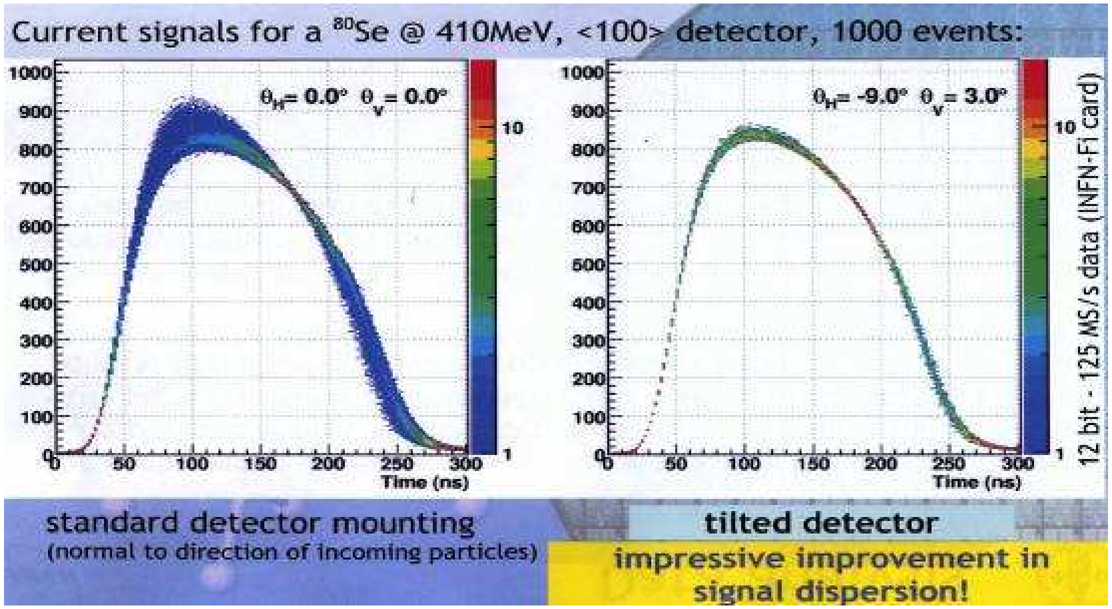
The channeling issue

Due to the crystalline nature, Silicon detectors manifest effects vs. orientation
Many works exist, some of them with heavy-ions but a few with energetic species

A dedicated experiment was performed at LNL



The channeling issue

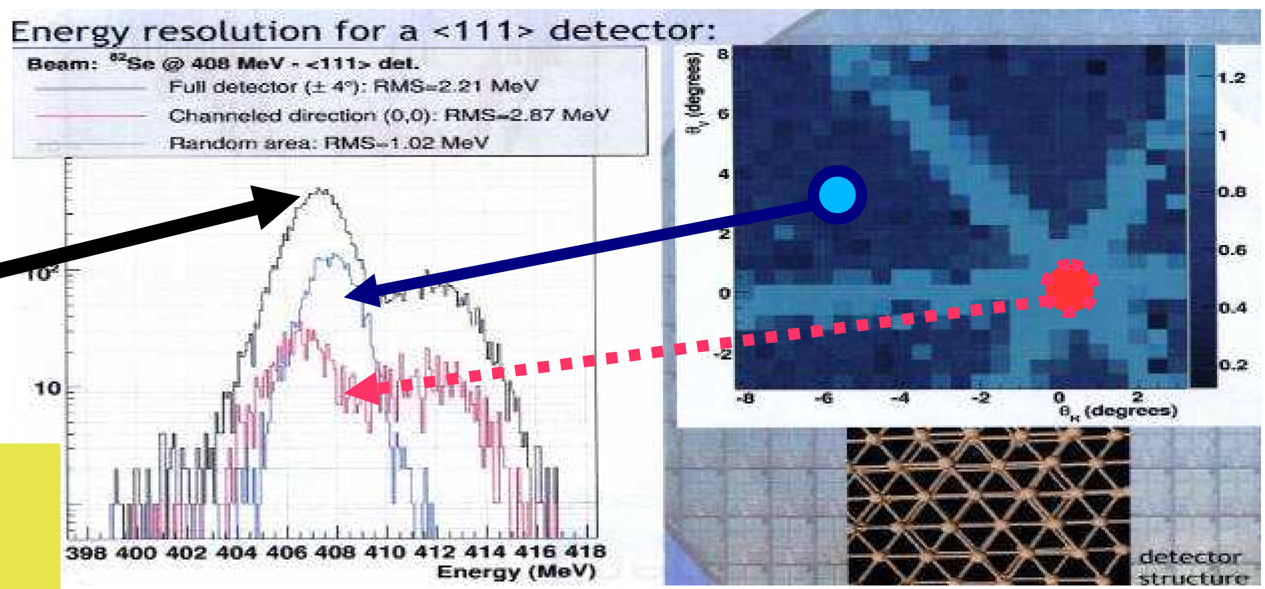


Fluctuactions of signal shape strongly decrease for 'random' orientation (right)

^{80}Se ions at 410MeV
<100> detector
reverse mounting

^{82}Se ions at 408MeV
<111> detector
reverse mounting

entire detec.



Strong effect also on 'usual'
Energy spectra

When channeling and homogeinity are under control...

PSA for stopped ions: 14bit 100MS/s 1.3GeV RANGE

The same detector
but **well oriented**

RANDOM

A good detector **badly oriented**

1/10 of the FULL RANGE!

500micron DETECTOR
1.5% doping uniform.

CHANNELED

L.Bardelli et al.
NIM A 605 (2009), 353

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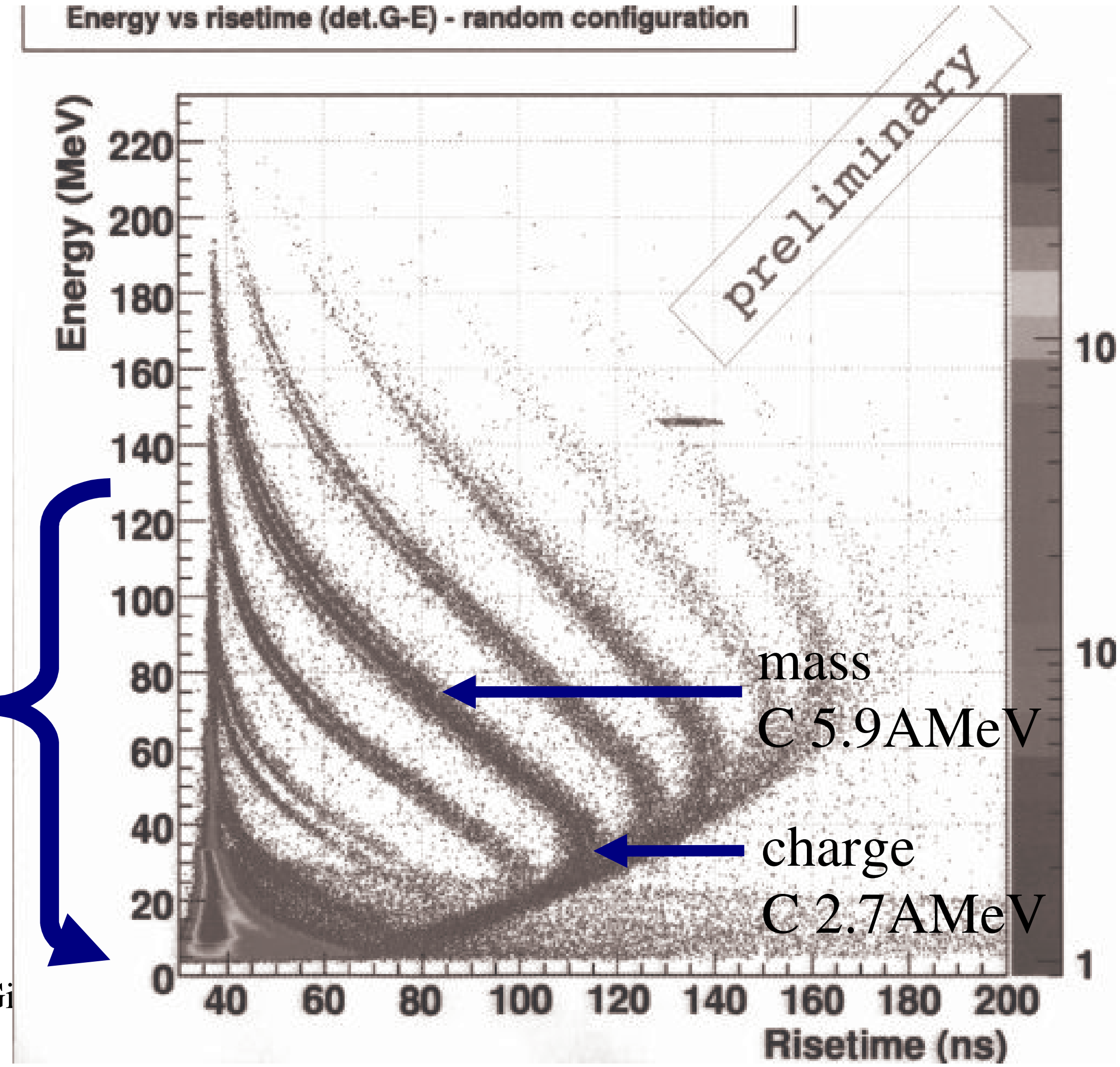
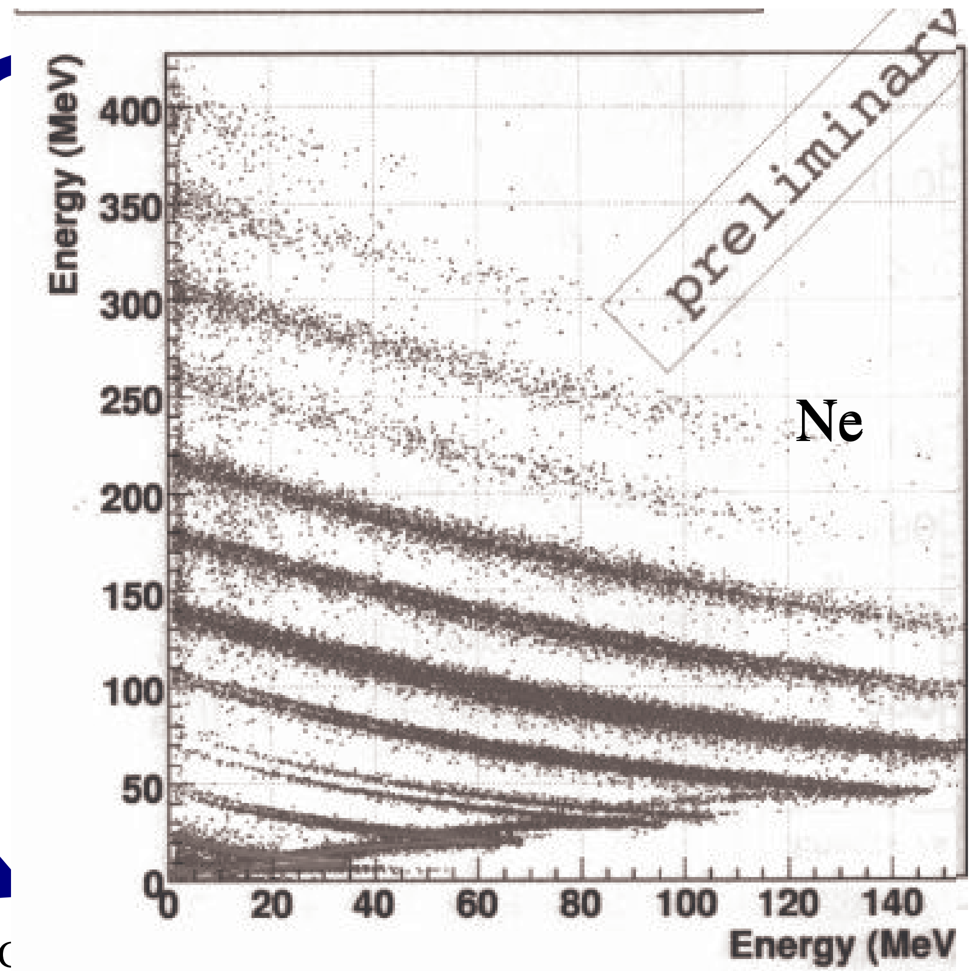


When channeling and homogeinity are under control...

Digital DE-E(CsI) method: 14bit 100MS/s
DE with 4.2GeV RANGE!

The same detector
badly oriented
but well oriented
detector with
good homogeineity
RANDOM

1/10 of the FULL RANGE!



L.Bardelli et al.
NIM A 605 (2009), 353

Next week a new test at LNS

^{129}Xe ions at 35AMeV on several targets will permit the first high energy test of the FAZIA telescopes (the previous ones were all at LNL)

Aspects to be studied

- DPSA at high energy
- fix the current range needed for the PREAMP
- fix the question: do we need current and charge ?

- SCT or PD for CsI(Tl)
- radiation demage and PSA
- timing performances in reverse or direct mounting

Physics

2006: FAZIA presented a **letter of intent for SPIRAL2** at GANIL

The physics is divided in different issues and, of course, contains topics which are of high interest in this field and which the authors have long experience in.

- **Limiting temperature in hot iso-asymmetric systems**
- **N/Z dependence of nuclear level densities**
- **Two- and multi-particle correlation studies and validity of statistical theories (see also SPES TDR 2008)**
- **Accessing the nuclear symmetry energy from fragment isotopic distributions**
- **Studies on Esym with dissipative peripheral collisions**

Physics (a selection for DIC)

Validity of the transport models (or other models)
in explaining as a function of the impact parameter:

1) excitation of QP,QT in dissipative collisions mass and charge drift of QP,QT (alias the story of isospin in peripheral collisions)

2) mass and charge fluctuations of QP,QT (nucleon vs. cluster exchanges)

3) influence of the iso-asymmetry in induced fission channel

Some REFERENCES
(DIC QP,QT oriented)

- *Isospin Experiments with stable beams*

A.Marchetti et al. PRC 48(1993),266
H.Madani et al PRC 51(1995),2562
D.Shapira et al. PRC 55(1997),2448
J.L.Wile et al. PRC 47(1993),2135
A.Cabrera et al. PRC 68(2003)034613
M.Korolija et al PRC 52(1995)3074
M.Veselsky et al. NP A765(2006) 252
R.K.Gupta et al. nucl-ex/0410016v1

- *New studies 'on' and 'for' RIB*

M.Di Toro et al. NP A787(2007) 585c
E.Bonnet et al. arXiv:0808.2885v1 (2008)
M.Colonna et al. NP A805(2008) 454c
A.S.Zubov et al. EPJ A33(2007) 223
J.F Liang et al. EPJ Sp.Top 150(2007) 35
M.Veselsky et al. NP A781(2007) 521
G.A.Souliotis et al. NP A588(2004) 35
V.Baran et al. LOI for FRIBS

Isospin Dynamics and its influence on nuclear excitation

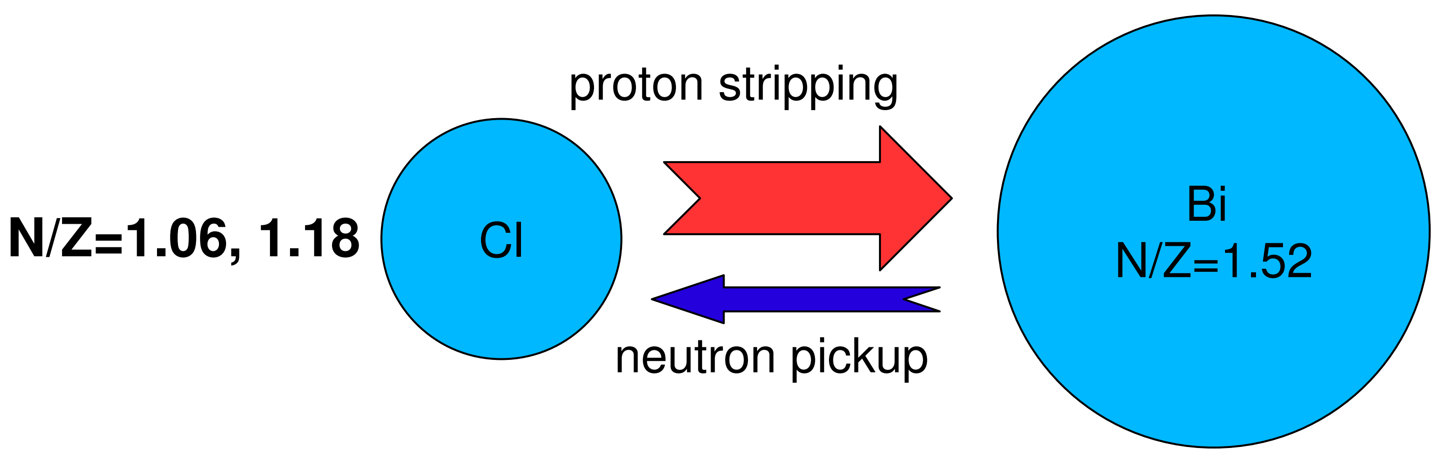
Nuclear Excitation, nucleon exchanges and isospin

Nucleon Exchange Model (NEM) + Statistical Evaporation Models

Experimental Evidences for Asymmetric Reactions

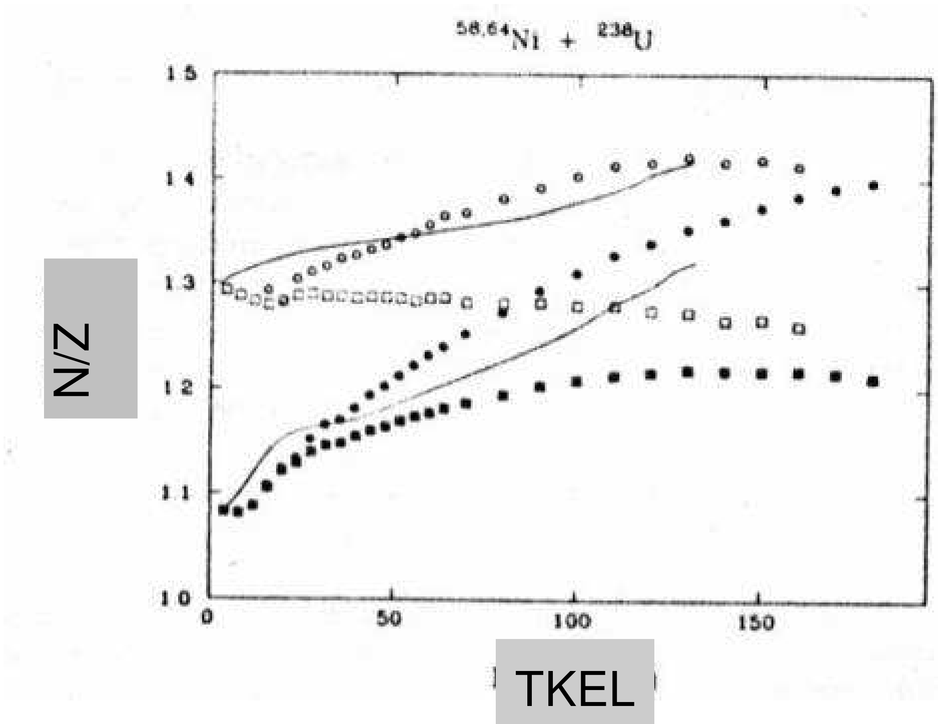
$^{37}Cl+^{40}Ca$, $^{37}Cl+^{209}Bi$ at 7.3MeV/u
$^{35}Cl+^{209}Bi$ at 15 MeV/u

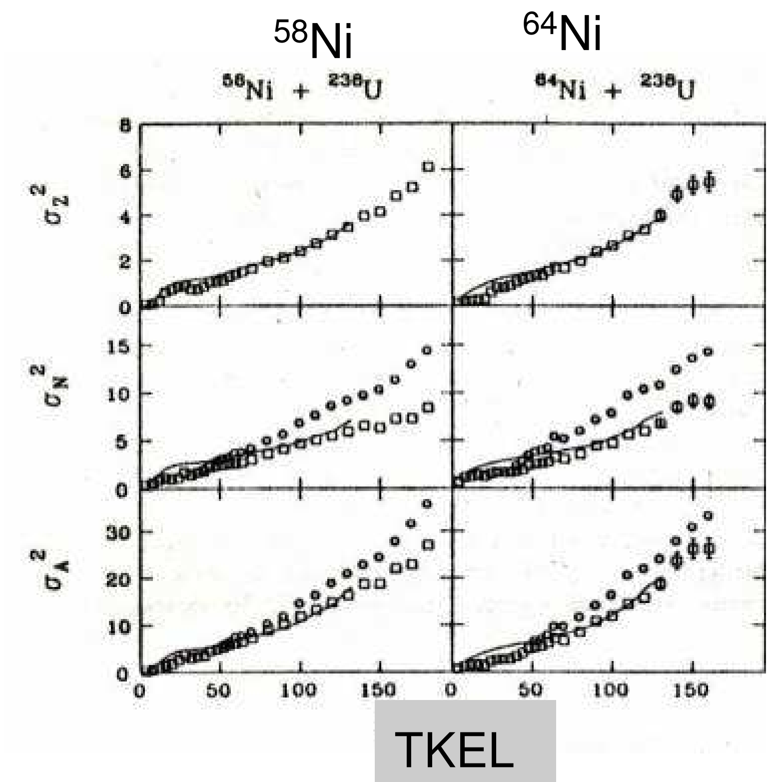
"Strong drift" towards larger mass asymmetries. QP get lighter and lighter and more n-rich. It tends to the global N/Z values for more violent collisions



Experimental evidences

R.Planeta et al PRC 38(1988)195
^{58,64}Ni+^{238}U at 8.5 MeV/u (N/Z=1.07,1.29 +1.59)
NEM (vers. Randrup) reasonably describe drift and widths

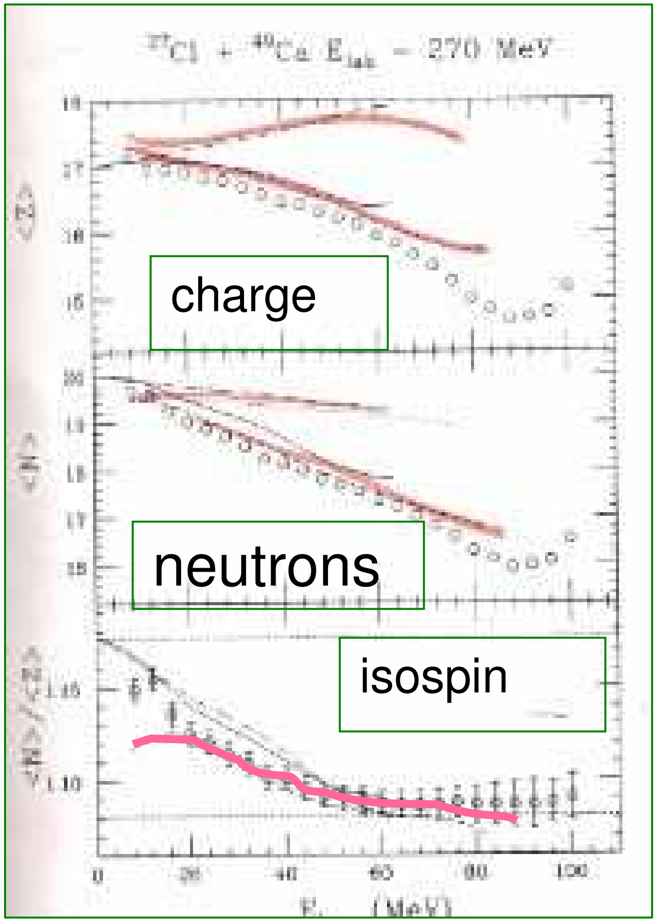


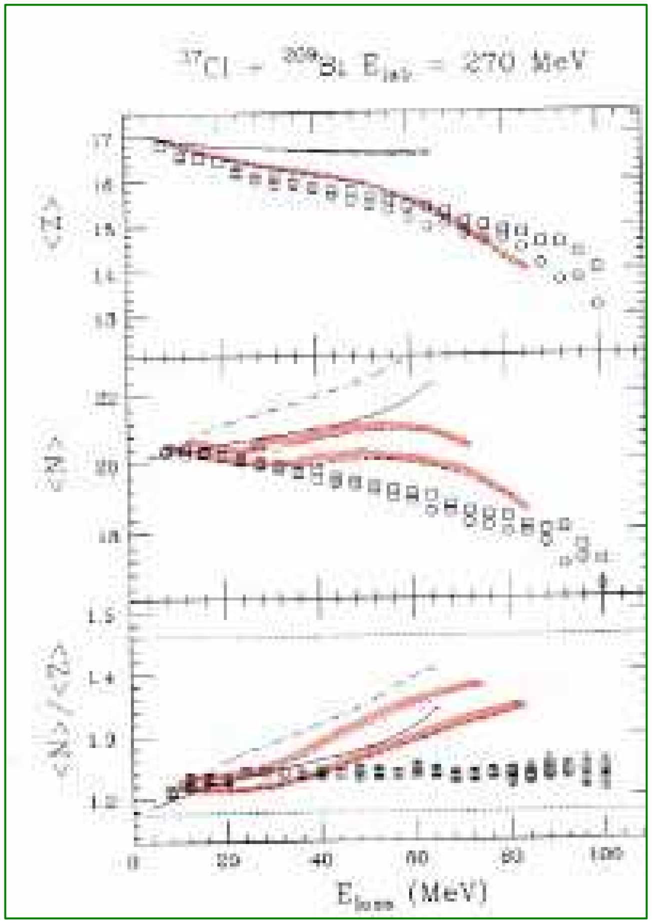


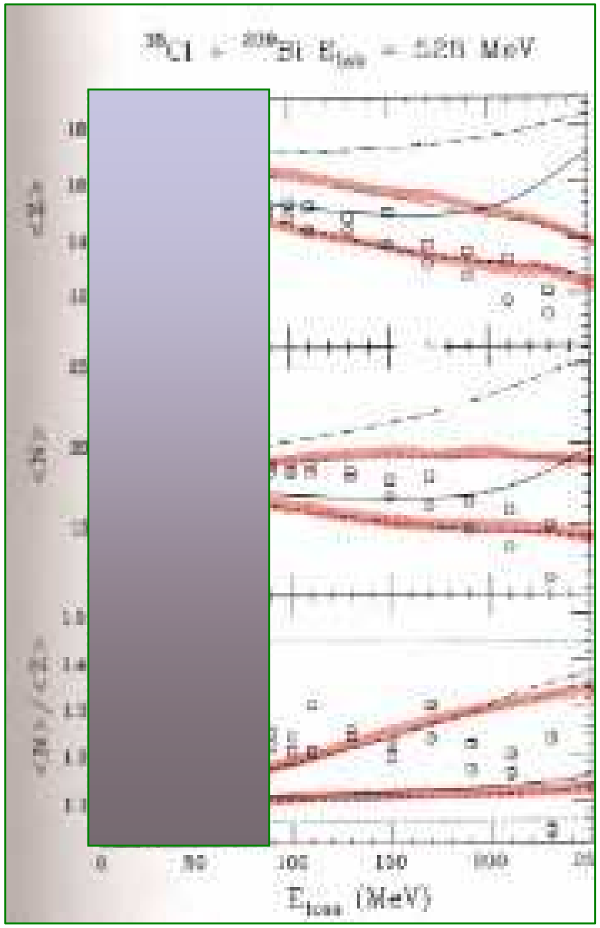
Also H.Madani et al (PRC 51(1995)2562) found a rather good agreement between NEM and data from ^{56}Fe+^{165}Ho at 12,15 MeV/u (N/Z=1.00 + 1.47)

Experiments & Predictions: average values

A.Marchetti et al. PRC 48(1993),266





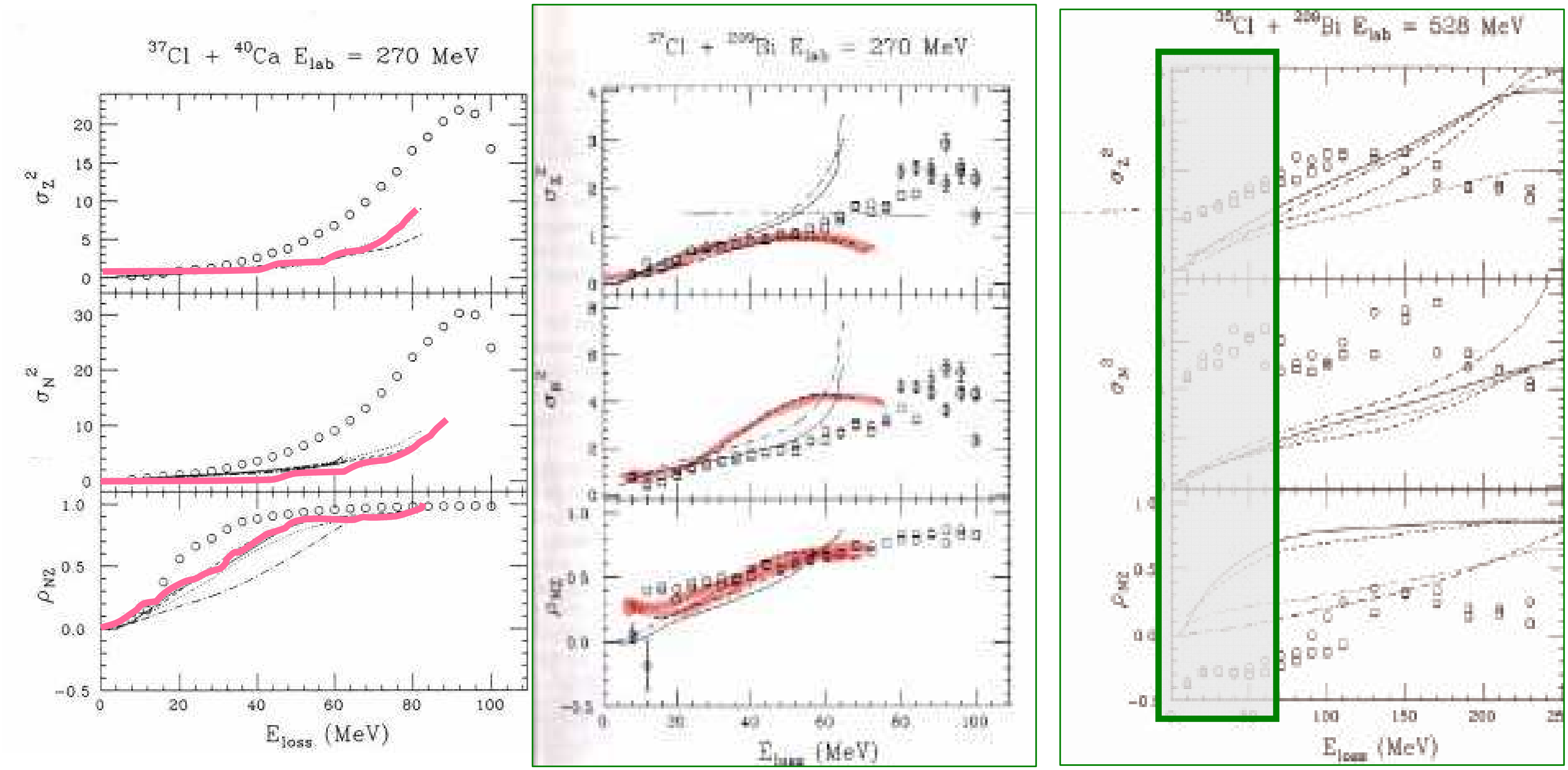


primary and secondary quantities : NEM from T.Got (pink)

experimental points (open symbols)

Experiments & Predictions: variances and correlations

A.Marchetti et al. PRC 48(1993),266

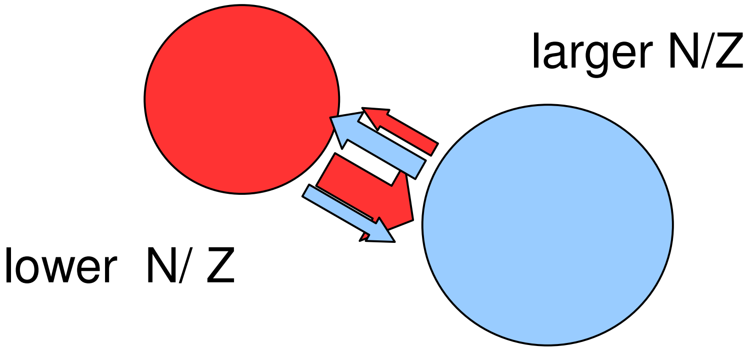


symmetric system: NEM ok at low TKEL but fails at high TKEL

^{37}Cl+Bi: NEM T.Got 'ok' for Z but not for N

^{35}Cl+Bi: low quality data but it seems that NEM if of scarce reliability

proton and neutron flows

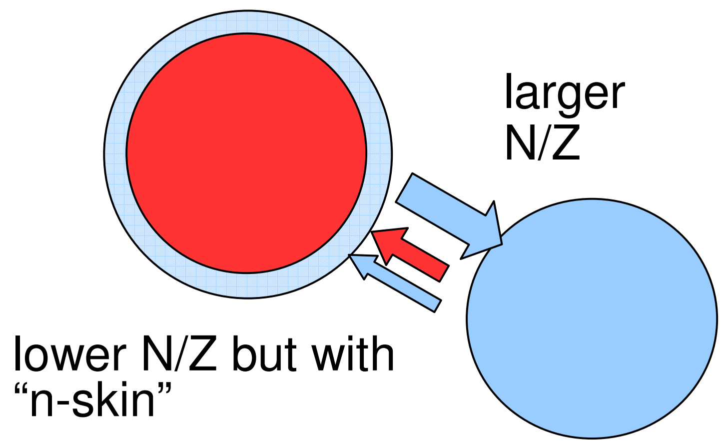


This is the normal situation. The two fluxes tend to N/Z equilibration

Possible inversion of the process of isospin equilibration

This is the particular situation which could occur for peripheral reactions between n-rich nuclei

(Veselsky et al. NP A765(2006) 252)



nuclear periphery and deep-inelastic reactions

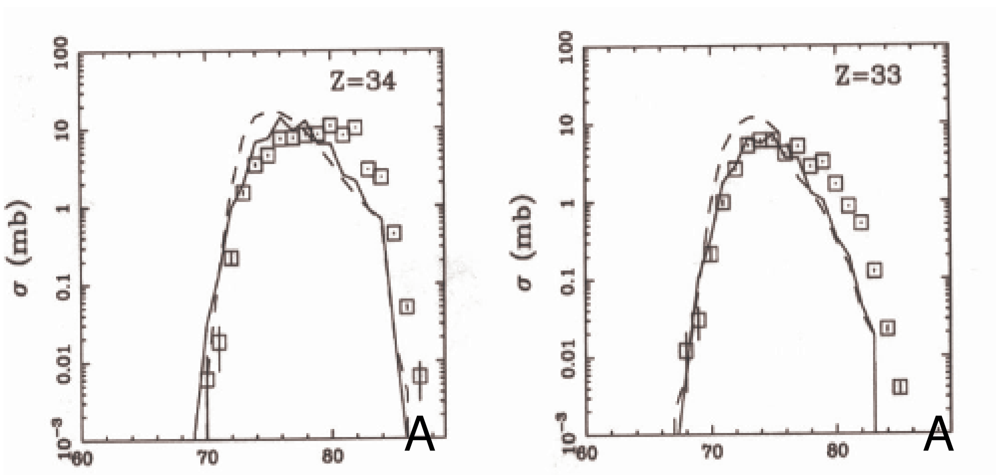
an INTERESTING CASE:

M.Veselsky et al. NP A765(2006) 252, NP A781 (2007), arXiv:0801.4140v2

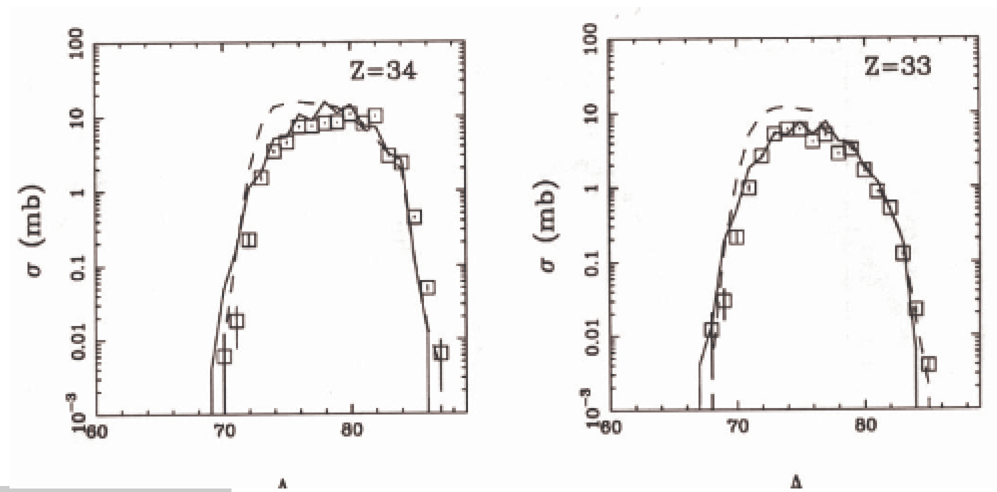
^{86}Kr+^{64}Ni a 25MeV/u (1.39,1.29)

Deep inelastic scattering (+ evaporation)
measurements of QP (A,Z) and LCP
framework: NEM+Gemini (o SMM)

Abundant n-rich QP: process for N/Z equilibration reversed in peripheral (almost grazing) collisions?



standard NEM



modified NEM

Kr QP mass

Fast neutron (or proton) emission and isospin dynamics

For n(p)-rich nuclei neutron(proton) emission is favoured. If neutrons(protons) are quickly emitted (before the interaction sets in), one sees changes in the forthcoming evolution.

- **Compound Nucleus or QP <u>is not</u> so iso-asymmetric;**
  CN (or QP+QT) momentum <u>is less</u> than the total one;
- **the interaction occurs between nuclei with <u>N/Z less asymmetric</u> and this can reduce isospin effects**

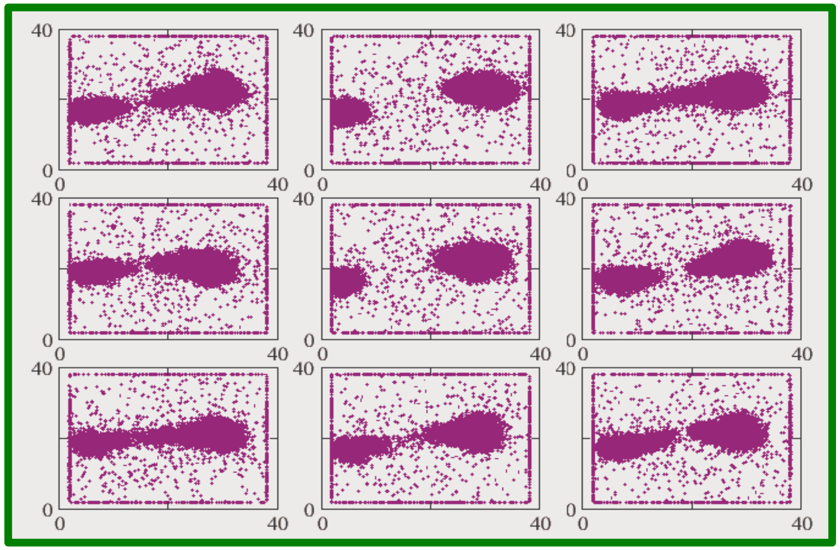
indication of this fact for an n-rich case

M.Veselsky et al. arXiv:0801.3140v2

In $^{40,48}Ca + ^{27}Al$ at 45AMeV, the caloric curves of the CN and other observables measured in the two cases don't reveal differences. Fast emitted neutrons escape and don't deposit energy inside the system

Surface instabilities and Sequential Fission

M. Di Toro et al. NP A 787 (2007), 585c studied the reactions induced by the "special" n-rich ***^{132}Sn also at low energies***



^{132}Sn+^{64}Ni a 8,10 MeV/u

Calculations BNV with ingredient E_{sym} ASYstiff o ASYsoft. The first recipe favours **a more dissipative neck** which allows larger elongations (e.g. greater quadrupole or octupole deformations).

-more yield of sequential fission?
-stronger neck LCP (or IMF) emission?

Asystiff:

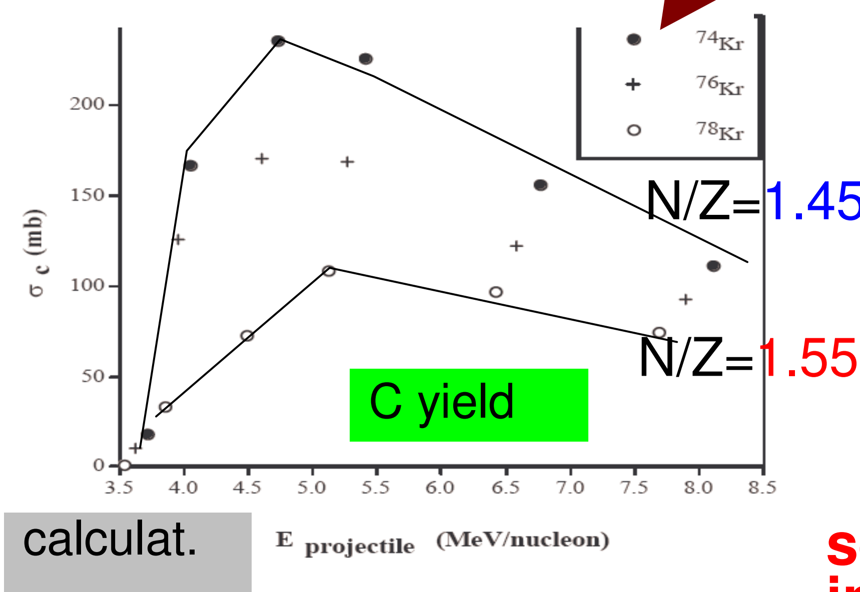
-larger residue deformations (more fast fission events)

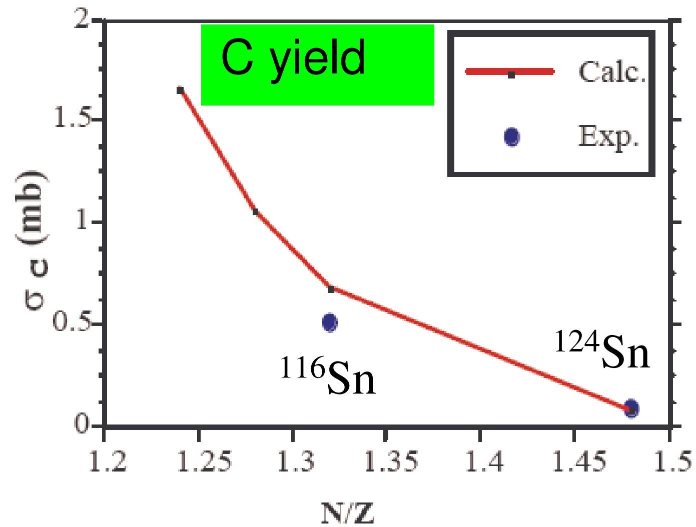
from Di Toro
Talk given at the Conference.
Kazimiers september 2007

‘Standard' and Sequential Fission: Different behavior with isospin?

- Thermal asymmetric fission (IMF emission) increases for hot n-poor nuclei due to Coulomb instabilities

Kr+Ca -> fusion-fission





He+Sn -> FUSION fission

Question:

sequential fission (dynamical) is influenced by deformation and by neck properties: a larger neck makes this split more favourable (n-rich)

the biggest problem...

Very low intensities and countrates!

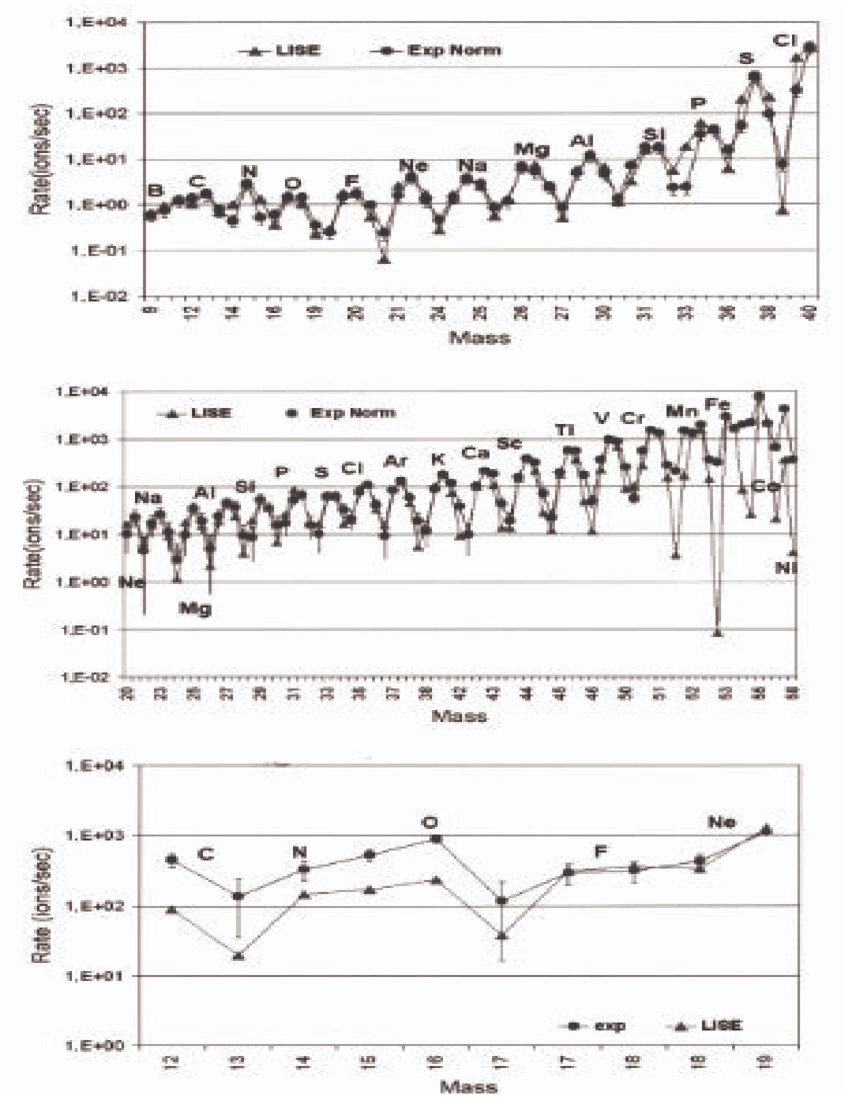
reaction rates around 0.1-1cps

Experimental run lasting 100days or so?

browsing Fribs Theses...

An attempt to estimate some countrates

Normalization: 700enA from CS (best present result, G.Cardella 23.3.2009)
Target 1mg/cm2 Efficiency = 1 Tagging:perfect



Reaction	Isotope	Rate (ions/sec)
$^{12}C+^{9}Be$	^{12}N	61.3±3
	^{10}C	29.0±2
	^{8}B	8.8±1
$^{40}Ar+^{9}Be$	^{39}Cl	237±7
	^{36}S	95.8±3
	^{34}P	43±2
	^{31}Si	22±1
$^{58}Ni+^{27}Al$	^{55}Co	259±6
	^{53}Fe	97±4
	^{54}Fe	54±3
	^{53}Mn	49±3
	^{51}Mn	66±3
	^{51}Cr	42±2
	^{49}Cr	18±1.5
$^{20}Ne+^{9}B$	^{21}Na	10.8±2.0
	^{18}Ne	4.2±0.5
	^{17}F	2.0±1
	^{15}O	5.5±1
	^{13}N	0.52±0.1
	^{11}C	1.0±0.8

Table 4.1: Production rates at the final focus of the fragment separator for the variou fragmentation reaction investigated. The production rates are normalized to a primar beam current I_0 of 100 epA.

E.Rapisarda
PHD Thesis

secondary beam intensities

neutron rich reactions
40Ar+9Be reaction, primary current 700enA

		N/Z
^{39}Cl	$1.6*10^{6}$ pps	1.29
^{36}S	$0.6*10^{6}$ pps	1.25
^{34}P	$0.3*10^{6}$ pps	1.27
^{31}Si	$1.5*10^{5}$ pps	1.21

partner beam

	N/Z
^{37}Cl	1.18
^{32}S	1.
^{31}P	1.07
^{28}Si	1.

proton rich reactions
58Ni+27Al reaction, primary current 700enA

		N/Z
^{55}Co	$1.8*10^{6}$ pps	1.04
^{53}Fe	$0.6*10^{6}$ pps	1.04
^{54}Fe	$0.3*10^{6}$ pps	1.08

partner beam

	N/Z
^{59}Co	1.19
^{58}Fe	1.23

proton rich reactions
20Ne+9Be reaction, primary current 700enA

		N/Z
^{18}Ne	$2.9*10^{4}$ pps	1.0

partner beam

	N/Z
^{20}Ne	1.22

QUESTIONS for everybody here:

what about $^{64}Ni+^{27}Al$ reaction? n-rich production? rates?
what about $^{64}Ni+^{30}Si$ reaction? n-rich production? rates?
what about ^{32}Ar production?

Giovanni Casini FIRENZE

neutron rich reactions
40Ar+9Be reaction, primary current 700enA

		N/Z
39Cl	$1.6*10^6$ pps	1.29
36S	$0.6*10^6$ pps	1.25
34P	$0.3*10^6$ pps	1.27
31Si	$1.5*10^5$ pps	1.21

partner beam

	N/Z
37Cl	1.18
35Cl	1.06
32S	1.
31P	1.07
28Si	1.

proton rich reactions
58Ni+27Al reaction, primary current 700enA

		N/Z
55Co	$1.8*10^6$ pps	1.04
53Fe	$6.8*10^5$ pps	1.04
54Fe	$3.8*10^5$ pps	1.08

partner beam

	N/Z
59Co	1.19
58Fe	1.23

EXAMPLES

53,58Fe or 35,37,39Cl or 32,36S + heavy t.: iso-drift and excitation

35,37,39Cl + 92,100Mo: dynamical fission

11Be,11B +heavy t.: non-participating n-halo

32Ar,40Ar + 92,100Mo: iso-equilibration and excitation, fission, n-p preeq.

energy	CS current enA	grazing deg	reaction rate hZ	elastic rate 0.1-1 deg hZ	
35	700	5.6	0.23	705	
45	700	4.3	0.23	426	
45	700	3.3	15	16632	
45	700	5.3	18	49300	