FIssion of Excited Systems at Tandem-Alpi

Percentuali 2010

FI	%	LNL	%	NA	%
N. Gelli	80	M. Cinausero	100	A. Brondi	100
F. Lucarelli	20	G. Prete	100	L. Campajola	30
				A. Di Nitto	100
				G. La Rana	100
				R. Moro	100
				P. Nadtochy	100
				E. Vardaci	100
FTE	1.0		2.0		6.3

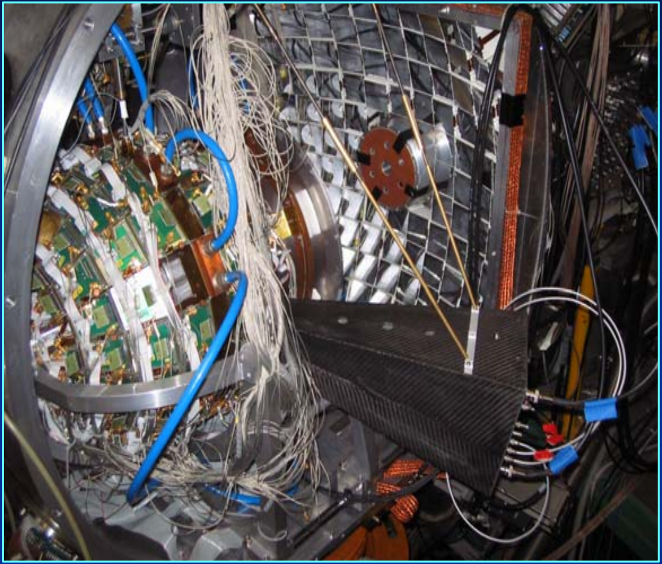
Totale FTE: 9.3

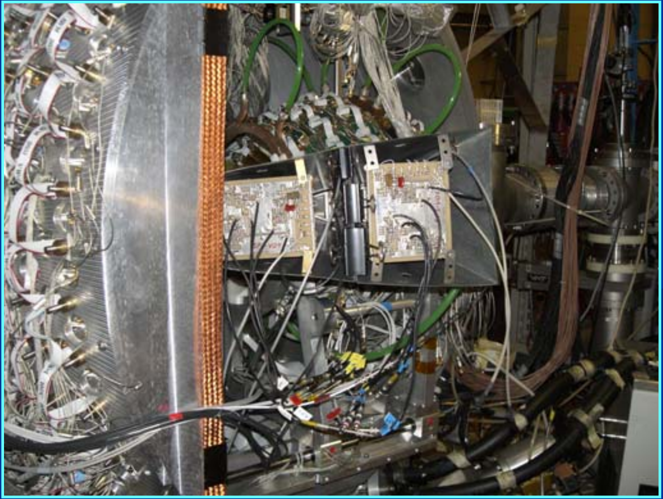
FI.E.S.T.A.

Temi di Ricerca:

1. Dinamica della Fissione in sistemi di fissilità intermedia ;
2. Fissione superasimmetrica;
3. Effetti canale d'ingresso per sintesi superpesanti;
4. Dipendenza dall'isospin della densità dei livelli;
5. Break-up di nuclei leggeri debolmente legati;

Collaborazioni: FLNR, JYFL, ULB





Sistemi Studiati

Fission Dynamics

1. 180MeV $^{32}S + ^{126}Te$ (LCP-FF, LCP-ER)
2. 240-280MeV $^{32}S + ^{100}Mo$ @ JYFL
3. 122 MeV $^{18}O + ^{150}Sm$ @ LNL
4. 200-240 MeV $^{32}S + ^{100}Mo$ @ LNL

Isospin Effects →

5. 180-230 MeV $^{32}S + ^{109}Ag$ @ LNL

Asymmetric Fission →

6. 124 MeV $D + ^{238}U$ @ LNS

SuperHeavy

7. 460-600 MeV $^{86}Kr + ^{208}Pb$ @ JYFL
8. 180-220 MeV $^{36}S + ^{238}U$ @FLNR
9. 320-390 MeV $^{64}Ni + ^{238}U \rightarrow ^{302}120$

Breakup →

10. 31-39 MeV $^{7}Li + ^{208}Pb$

Open Questions in Fusion-Fission

How long is the fission time scale ?

(τ_f = 5 -500x10^{-21}s)

Is dissipation

1. *one-body* or *two-body like?*
2. dependent on the *shape?*
3. dependent on the *temperature ?*

…Our answers…

We have arguments to conclude that:

1. The Statistical Model approach is inadequate;
2. Dissipation is *one-body like;*
3. Dissipation is dependent on the *shape.*

E. Vardaci et al. EPJ A43, 2010
P. Nadtochy et al., Phys. Lett. B 685 (2010) 258
A. Di Nitto, Ph.D. Thesis, Napoli, INFN site

Where do we base our conclusions on ?

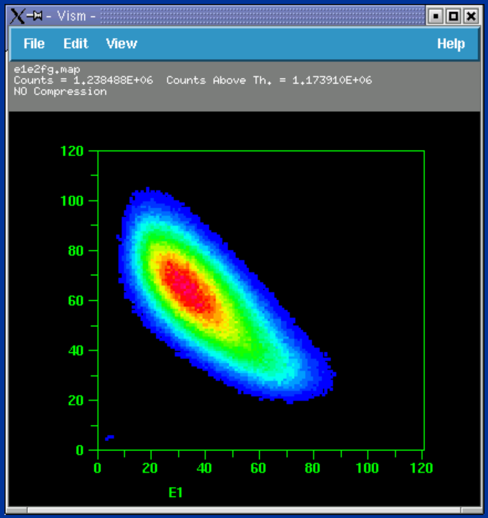
...Our answers...

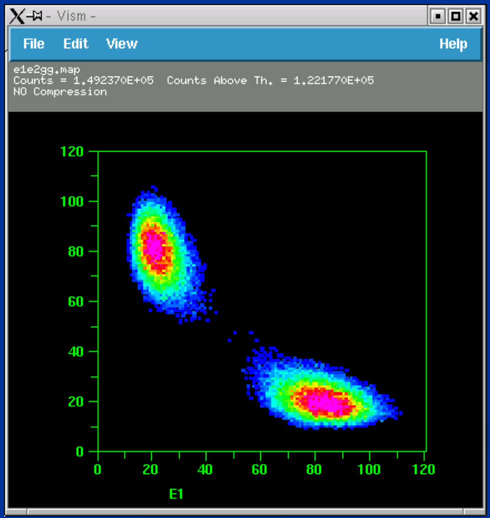
1. 3-D Langevin stochastic approach
2. Studies on systems of Intermediate Fissility
3. Large set of obervables

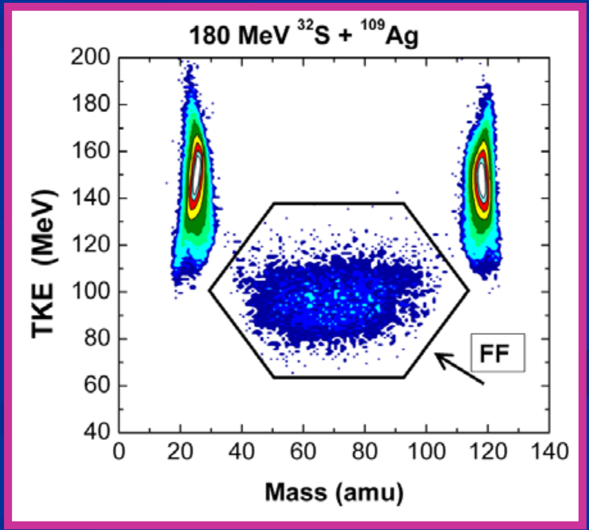
What observables ?

- particle - FF coincidences
- particle - ER coincidences

8πLP + Trigger for ER and FF

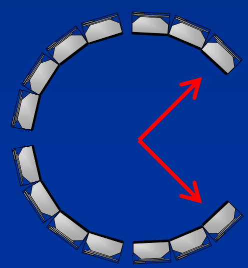






Out-Of-Plane Multiplicity Spectra

ring G

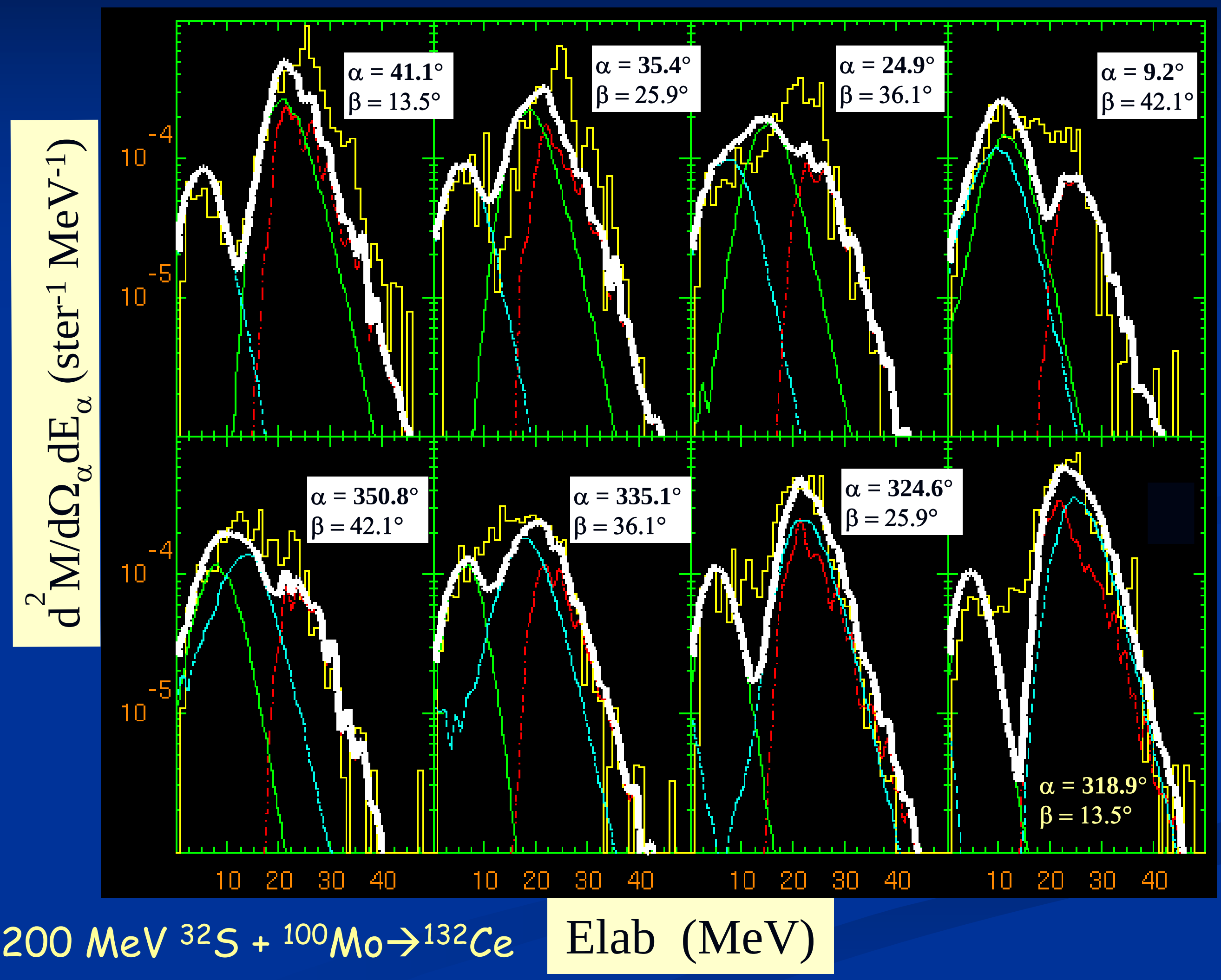


α = in-plane angle
β = out-of-plane angle

CS

F1

F2



200 MeV ^{32}S + ^{100}Mo → ^{132}Ce

What did we do?

3D Langevin approach + Statistical Model

Karpov, Nadtochy et al.

Phys.Rev. C63, 2001

LILITA_N97 for light particle evaporation along trajectories

3D-Langevin Eq.   1/2

Fission is treated as a stochastic diffusive process driven by inertia and dissipation

$$M\frac{dv}{dt} = -\beta v + F(t)$$

$$\left\langle F_i(t)F_j(t')\right\rangle = D^2\delta_{ij}\delta(t-t')$$

$$D^2 = 2\beta T$$

$$m\frac{d^2q}{dt^2} = -\frac{\partial V}{\partial q} - \beta m\frac{dq}{dt} + \sqrt{\beta T}\, f(t)$$

q_1 = deformation

q_2 = neck size

q_3 = mass asymmetry

Inertia Tensor

Friction Tensor

Karpov, Nadtochy et al. Phys.Rev. C63, 2001

200 MeV ^{32}S + $^{100}Mo \rightarrow ^{132}Ce$

ER channel   Prescission

	p_{ER}	α_{ER}	p_{PRE}	α_{PRE}	σ_{FF} mb	σ_{ER} mb	σ_{M} a.m.u	σ_{TKE} MeV	TKE MeV
Ks=1, a=A/6	1.2	0.56	0.052	0.030	143	793	14.9	7.3	82.0
μ=0.24TP, a=A/6	1.2	0.57	0.048	0.028	125	811	14.6	6.7	79.6
Exp.	0,90 (0.14)	0,56 (0.09)	0,055 (0,007)	0,038 (0,005)	130 (13)	828 (50)	15.4 (1.1)	11.4	90.9

Reasonable overall good agreement with *full one-body dissipation*.

A. Di Nitto, Ph.D. Thesis, Napoli, INFN site

180 MeV ^{32}S + $^{126}Te \rightarrow ^{158}Er$

	p_{ER}	α_{ER}	n_{PRE}	p_{PRE}	α_{PRE}	σ_{FF}(mb)
Ks=1, a=A/9	0.26	0.34	1.77	0.032	0.021	186
Exp.	0,375 (0.033)	0,234 (0.08)	1.7 (0.5)	0,034 (0.005)	0,020 (0.003)	195 (20)

C.N.	τ_d (zs)	t_f^{MAX}(zs)	$<t_f>$ (zs)
^{158}Er	9	50	850

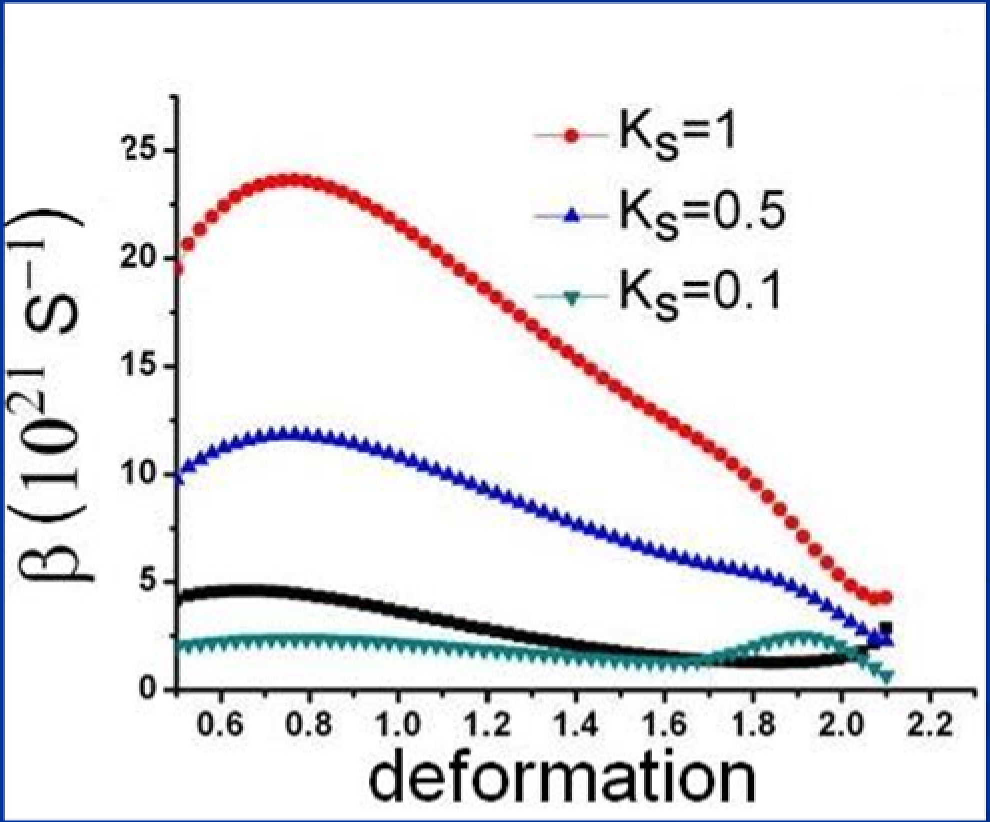
Best overall agreement with full one-body dissipation, as in ^{132}Ce nuclei.

More work is needed to reproduce the multiplicities in the ER channel.

A. Di Nitto, Ph.D. Thesis, Napoli, INFN site

Viscosity coefficient is dependent on the shape

Ks=1, that supplies the best reproduction of data, shows a nuclear viscosity strongly dependent on the shape. The maximum value assumed is 24 x $10^{21}s^{-1}$ for nearly spherical shapes, at the beginning of fission process.



β assumed independent from temperature.

3D-Langevin Eq. 2/2

Some recent results:

1. Light particle multiplicities are the most sensitive observable for the dissipation strength
2. Fission rate and multiplicities dependence on the dimensionality of the model
3. Strong effects isospin related

P. Nadtochy et al., Phys. Lett. B 685 (2010) 258

Next step

- ✓ Fission time scale;
- ✓ Strength and Nature of dissipation: one-body or two-body;

3. Dependence of the viscosity on the temperature and on the shape.

How is $\beta(T)$ studied ?

1. Excitation function of the light particles and/or GDR-γ ray multiplicities.
2. Comparison with models

Present studies suggest different ways to correlate viscosity and temperature.

Usually an insufficient set of observables is used and the models are not well constrainted.

Dependence of β on the temperature

The use of systems of intermediate fissility is relevant because':

1. Viscosity may depend on fissility
2. More constraints on the models

Where can we start from?

1. Our 3-D successful model
2. The 8πLP 4π setup for LCPs

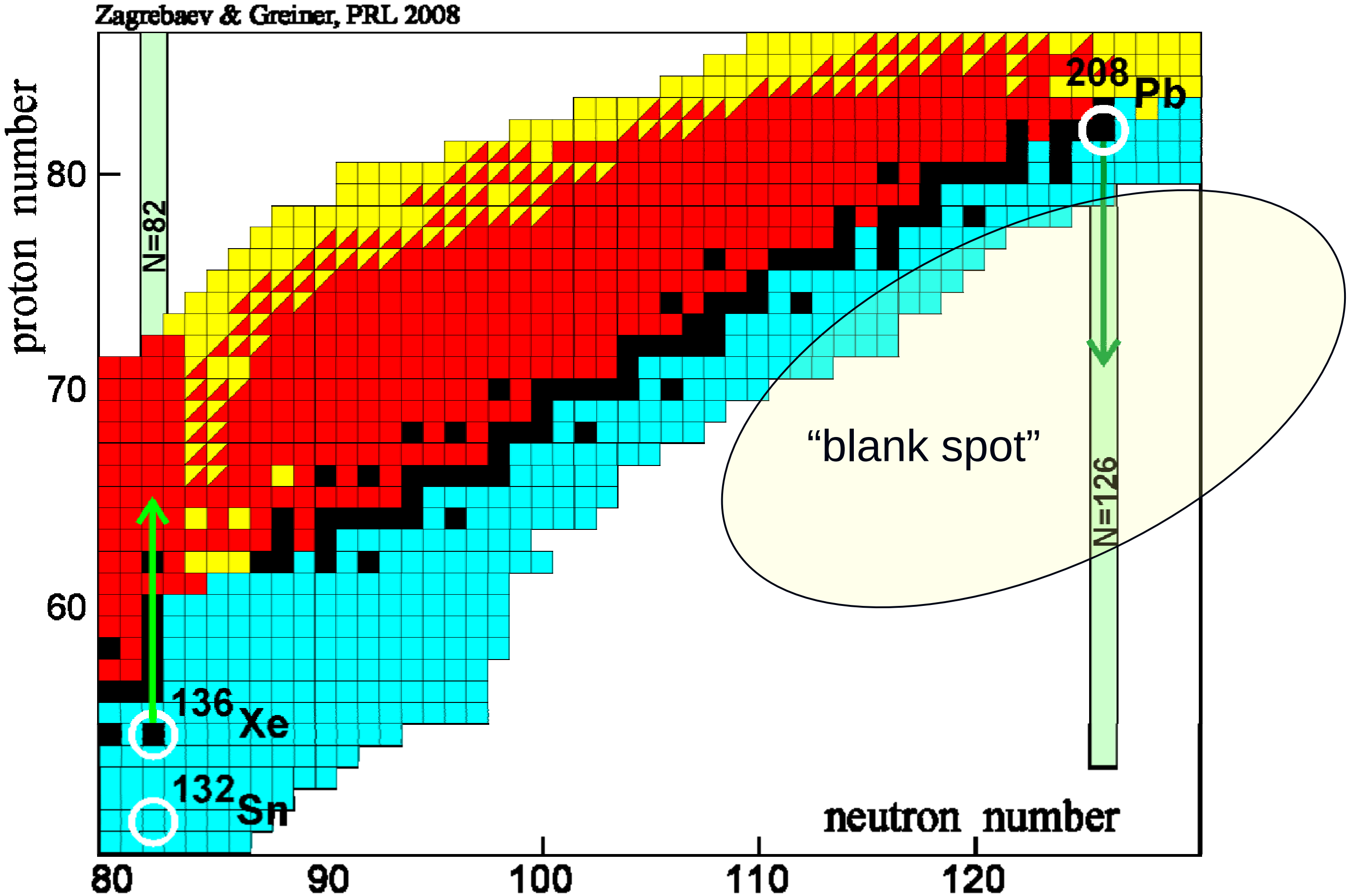
Possible Systems

	$^{40}Ca + ^{84}Sr$				$^{40}Ca + ^{106}Cd$			
E_x (MeV)	E_{lab} (MeV)	L_{fus} ($\hbar$)	σ_{fus} (mb)	σ_{fiss} (mb)	E_{lab} (MeV)	L_{fus} ($\hbar$)	σ_{fus} (mb)	σ_{fiss} (mb)
90	140.9	73	944	265	170	70	660	246
120	171	73	776	180	199.6	70	564	190
150	200.5	73	663	142	229	70	433	156

Production of new heavy neutron-rich nuclei located along the closed neutron shell N=126 in the reaction $^{136}Xe+^{208}Pb$

We propose to measure mass and charge distributions of fragments formed in the reaction $^{136}Xe+^{208}Pb$ at low incident energies and, thus, estimate the possibility for production and study of heavy neutron-rich nuclei located in unexplored area of the nuclear map.

Production on new heavy nuclei in the region of N=126



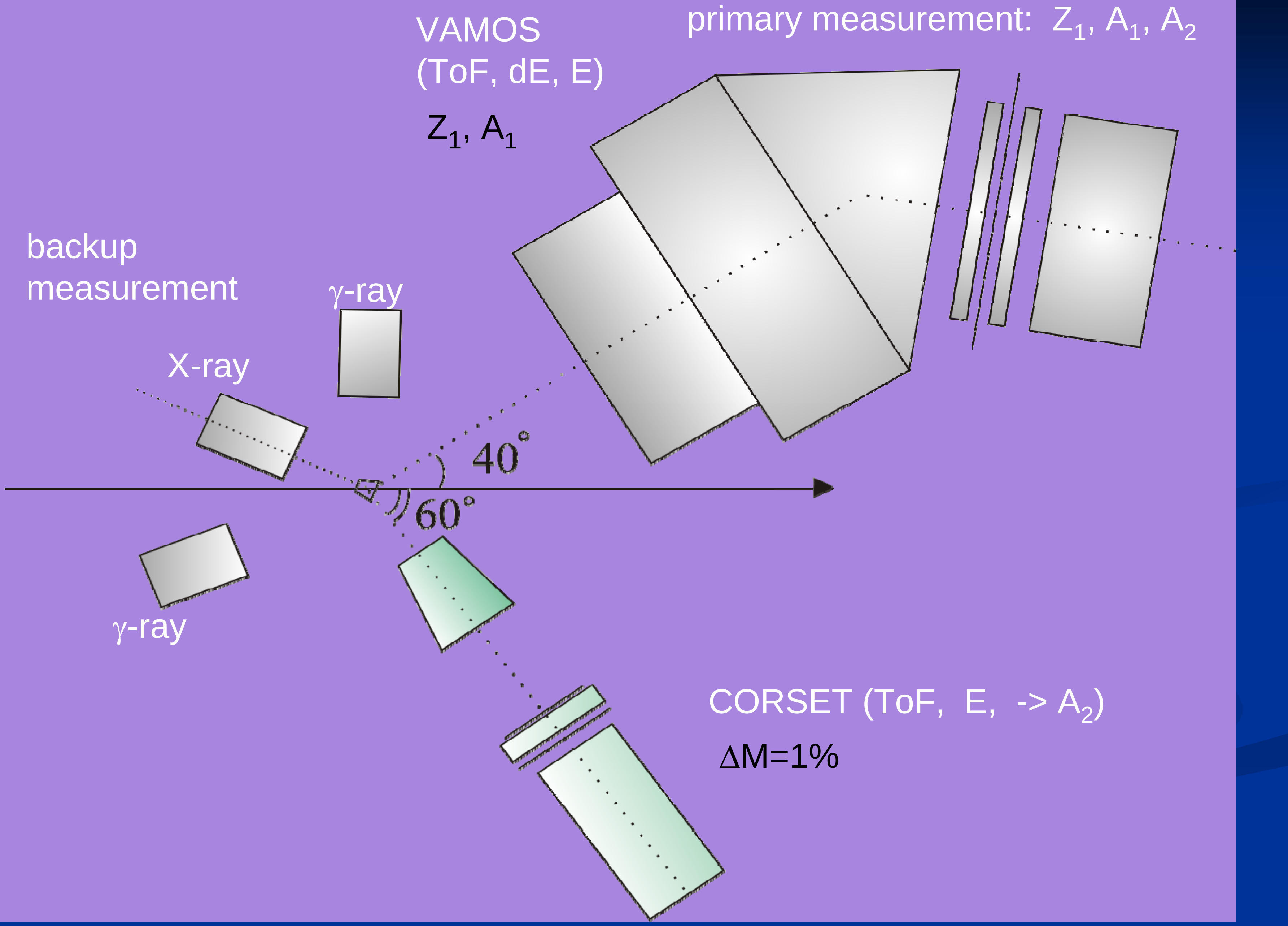
proton transfer along the neutron closed shells:

$^{136}Xe_{N=82} + {}^{208}Pb_{N=126} \rightarrow {}^{136+\Delta Z}X_{N=82} + {}^{208-\Delta Z}Y_{N=126} + Q \approx 0$

Reactions with $Q \approx 0$ are very favorable for proton transfer

The use of ^{132}Sn is even better !

Experimental Setup



Fission process: Isospin and Nucleosynthesis

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Piano Finanziario

Piano finanziario globale: ≈100 keuro in due anni per:

- Interventi di manutenzione apparato 8pLP (inv+consumo)
- 3 Turni di misura
- Consumo e spese per missioni

Sedi partecipanti: **Firenze, LNL, Napoli**