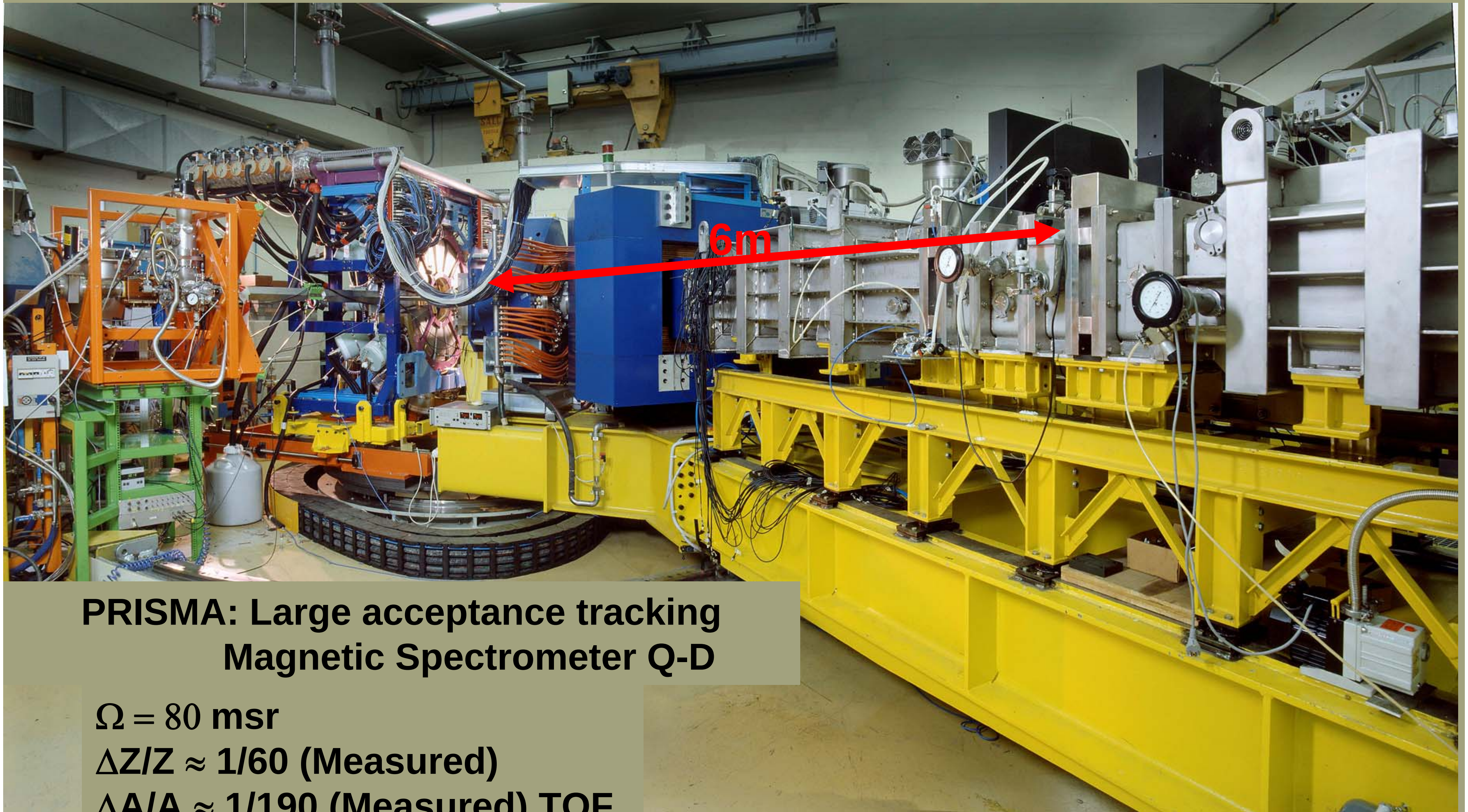
Spectroscopy of n-rich nuclei with CLARA-PRISMA

A.Gadea INFN-LNL
(for the CLARA - PRISMA collaboration)

- **Description of the setup**
- **Grazing reactions as mechanism to study the structure of moderately neutron-rich nuclei**
- **Experimental campaign 2004-2005**
- **Results from n-rich medium mass (A~80) nuclei**
- **CLARA-PRISMA 2006-2007**

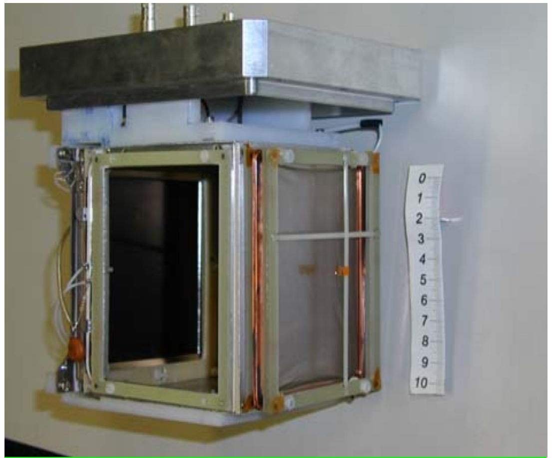


PRISMA: Large acceptance tracking Magnetic Spectrometer Q-D

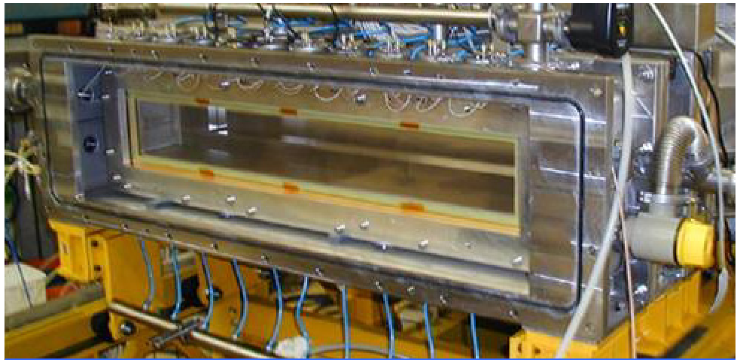
$\Omega = 80$ **msr**
$\Delta Z/Z \approx$ 1/60 (Measured)
$\Delta A/A \approx$ 1/190 (Measured) TOF
Energy acceptance ±20%
$B\rho$ = 1.2 T.m

Note: Dispersion 4cm / 1%, focal plane 1m

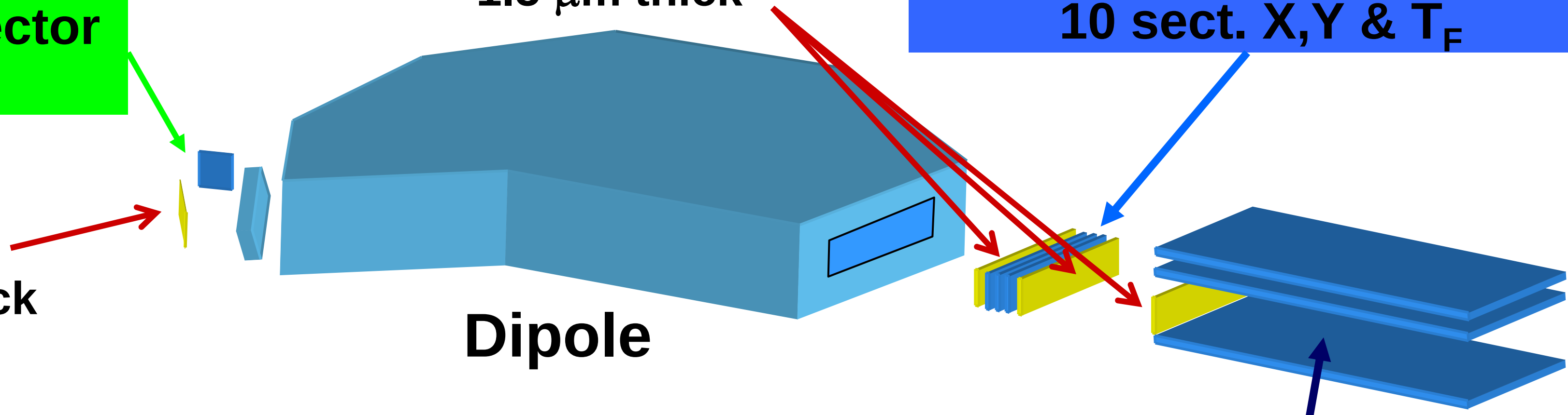
THE PRISMA DETECTORS



MCP Start Detector
X,Y & T_I



MWPPAC Detector
10 sect. X,Y & T_F

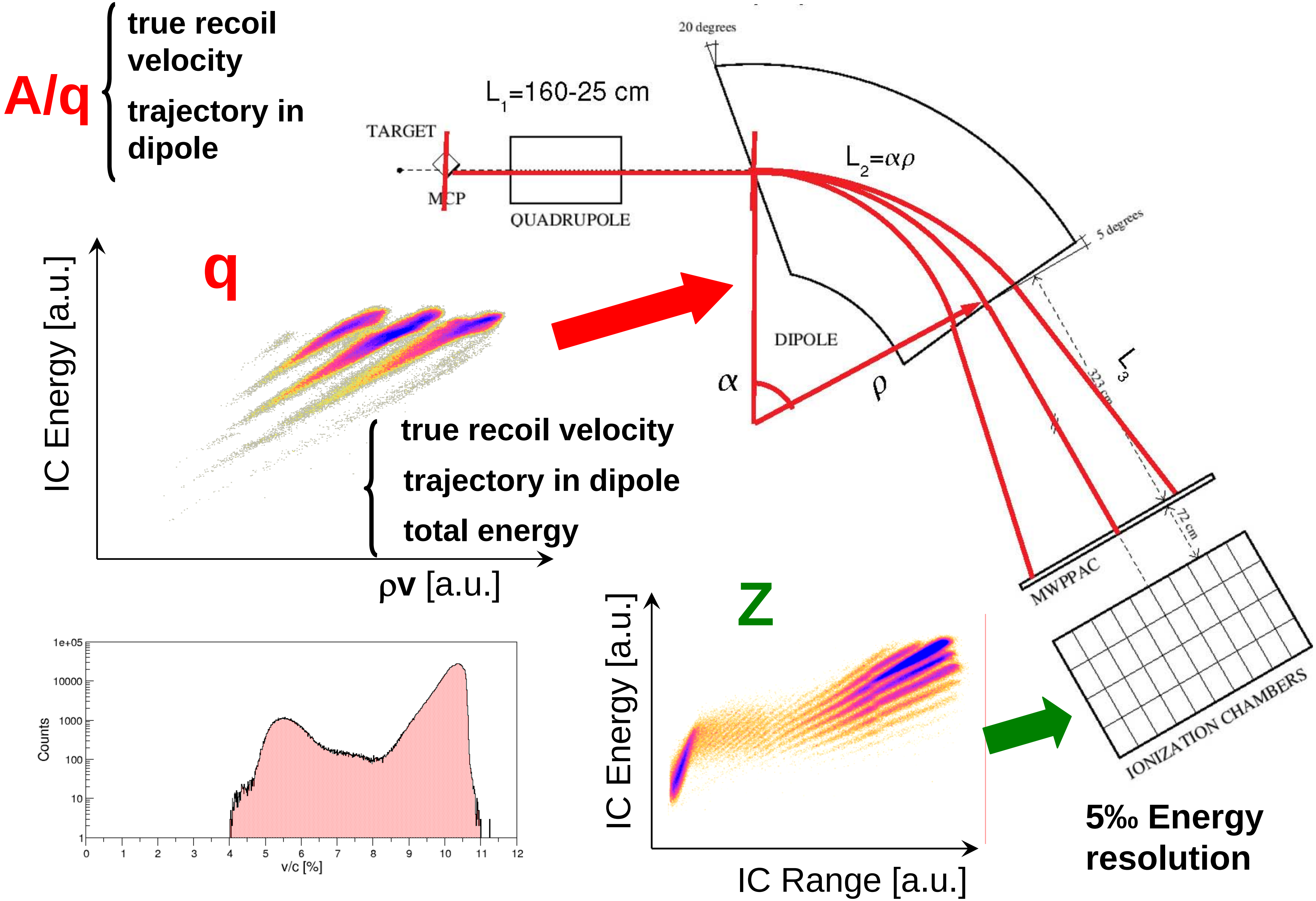


Ionisation
Chamber
10x4 sect. DE - E

Entrance detector position (MCP)
TOF Entrance detector- MWPPAC (~5m)
Focal Plane position MWPPAC + IC
Total Energy and Z (DE/E) from IC

S.Beghini et al. Nucl. Instr. Methods Phys. Res. A551, 364 (2005)

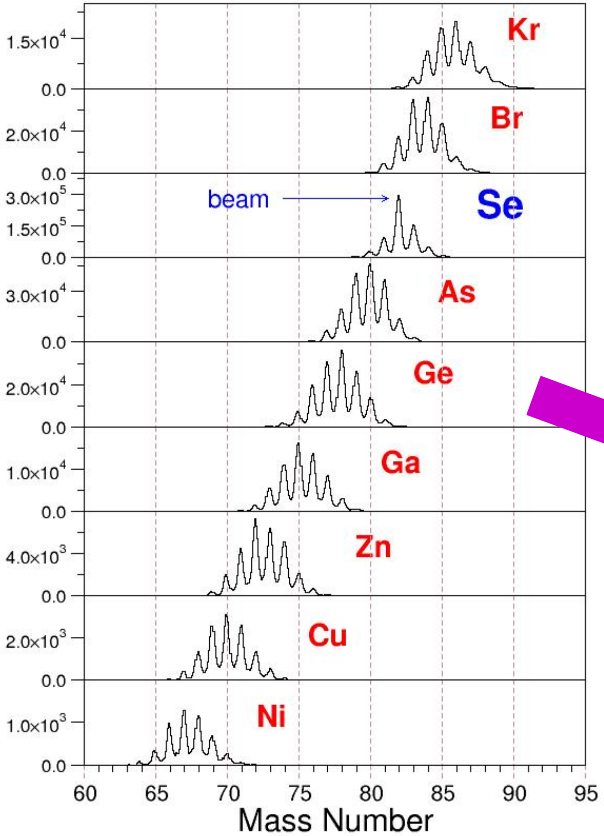
G.Montagnoli et al. Nucl. Instr. Methods Phys. Res. A547, 455 (2005)

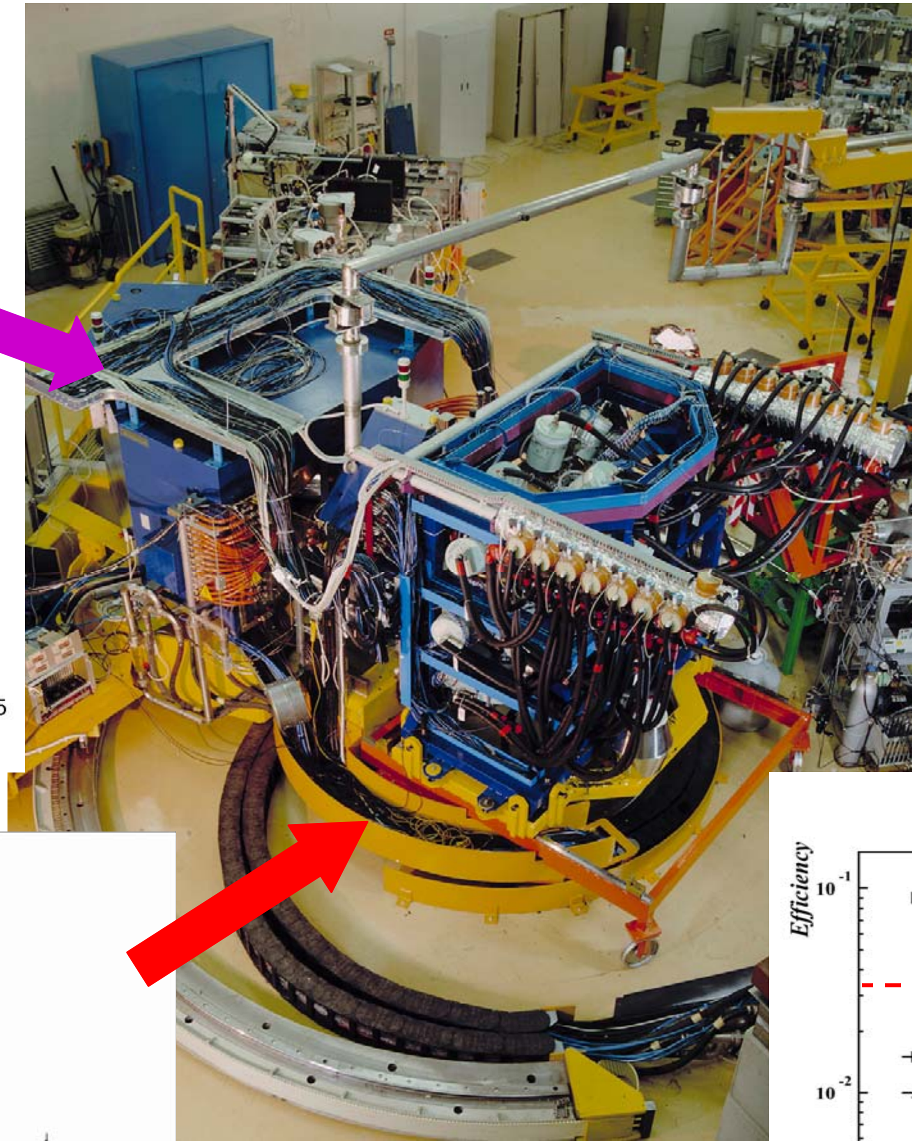


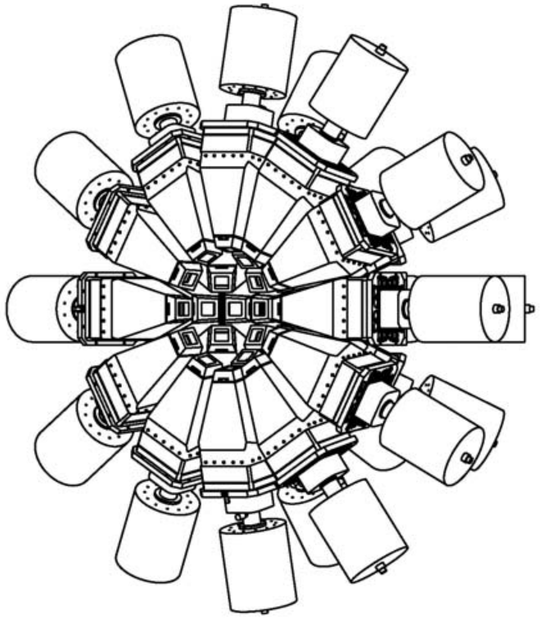
A/q
true recoil velocity
trajectory in dipole
L1=160-25 cm
TARGET
MCP
QUADRUPOLE
20 degrees
L2=αρ
5 degrees
DIPOLE
α
ρ
L3
323 cm
72 cm
MWPPAC
IONIZATION CHAMBERS
q
IC Energy [a.u.]
ρv [a.u.]
true recoil velocity
trajectory in dipole
total energy
Z
IC Energy [a.u.]
IC Range [a.u.]
5‰ Energy resolution
Counts
v/c [%]

CLARA: Clover Detector array

A & Z identification







25 Euroball Clover detectors (from the EU GammaPool)

for Eγ= 1.3MeV

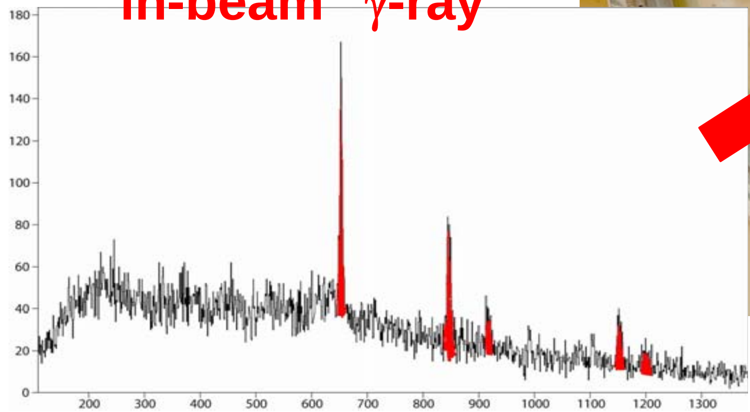
Efficiency ~ 3 %

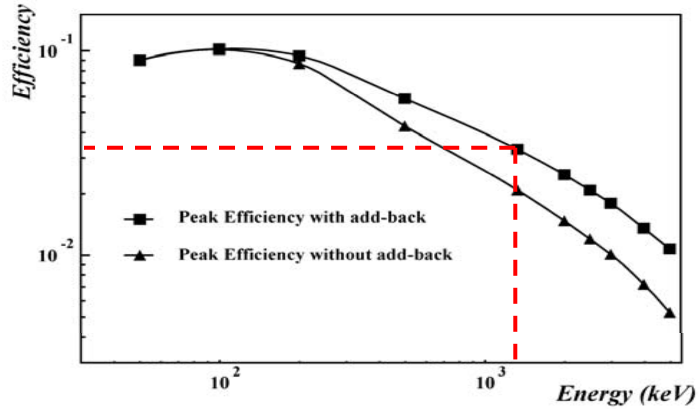
Peak/Total ~ 45 %

FWHM < 10 keV

(at v/c = 10 %)

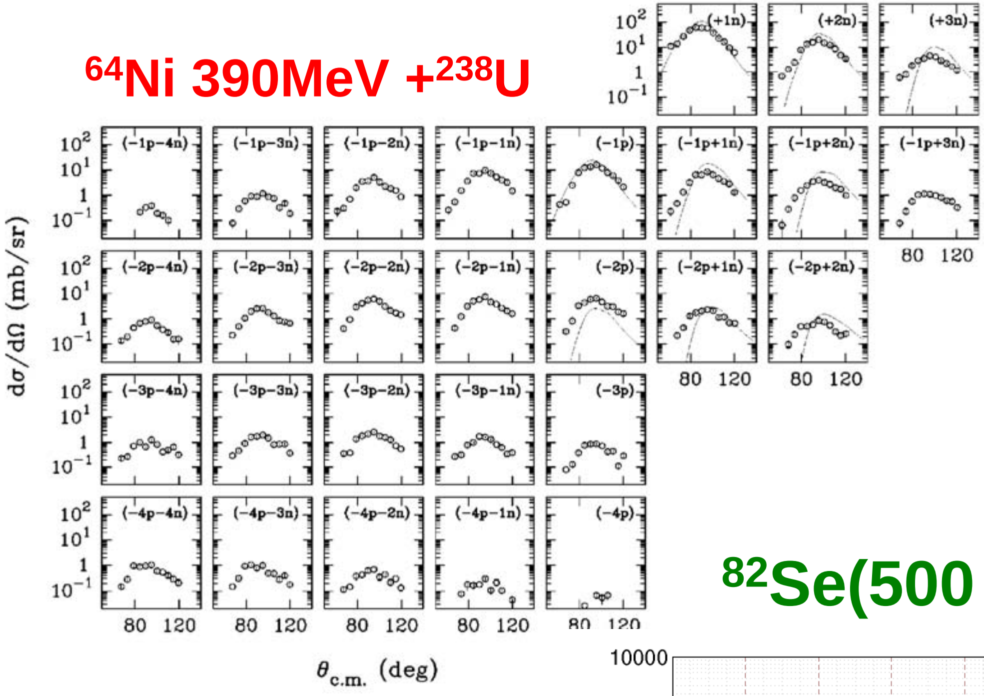
"in-beam" γ-ray





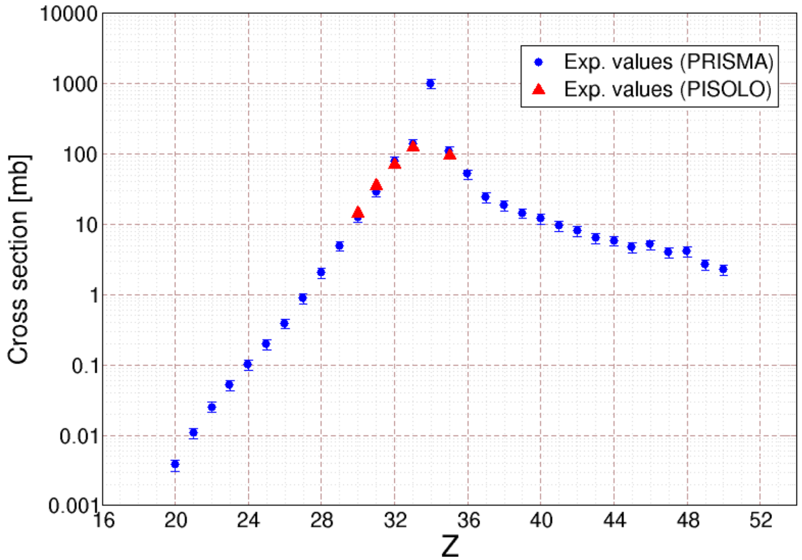
Grazing reactions as a tool to study n-rich nuclei

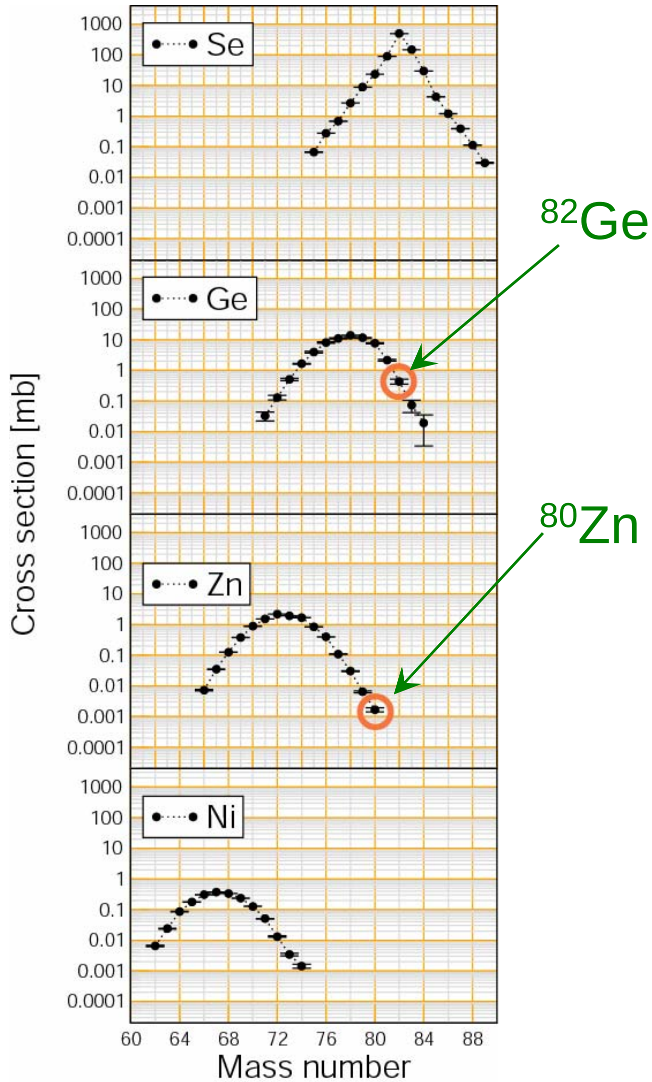
^{64}Ni 390MeV +^{238}U



L.Corradi et al.,
Phys.Rev.C59 (99)261
Theory: G.Pollarolo

^{82}Se(500 MeV) + ^{238}U

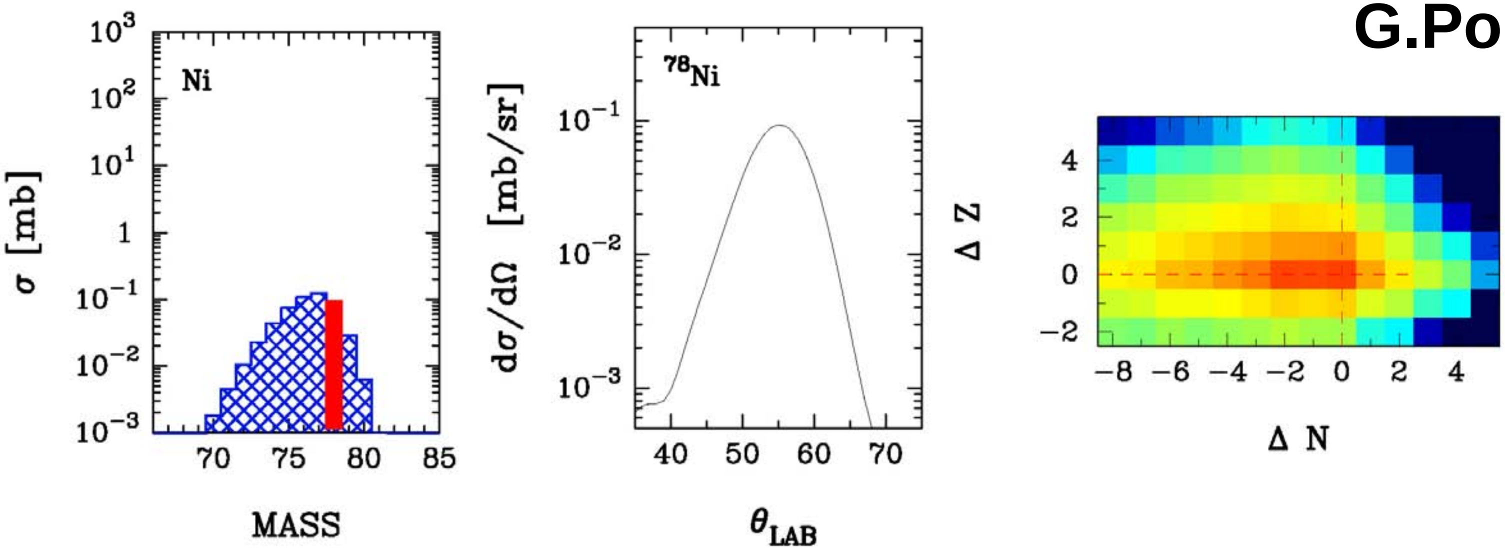




Transfer with Radioactive Beams at Coulomb barrier Energies

$^{80}Zn + ^{238}U$ (460 MeV)

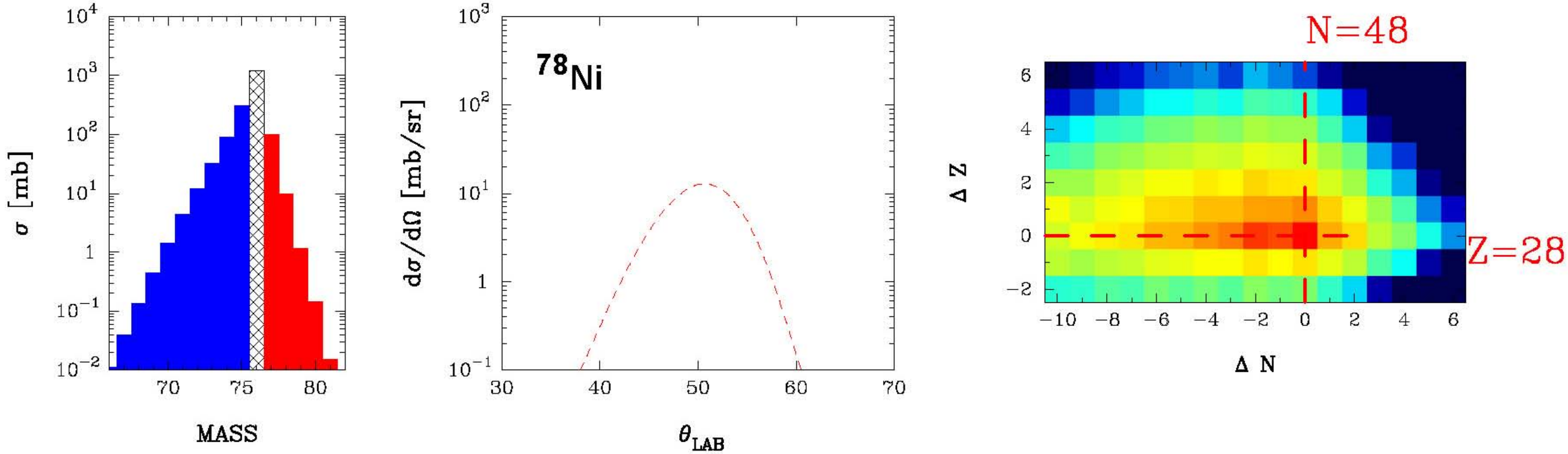
Calculations by G.Pollarolo



dσ/dΩ=100μb

dσ/dΩ=10mb

$^{76}Ni + ^{238}U$ (450 MeV)



Experimental campaign Spring 2004 – End 2005

- *Search for excited states in neutron rich Mg, Si and S.* ($^{36}S + ^{208}Pb$)
X.Liang, Paisley F.Azaiez, Orsay (R.Chapman talk)

- *Nuclear spectroscopy of neutron rich nuclei in the N=50 region* ($^{82}Se + ^{238}U$)
G.Duchene, Strasbourg, G.de Angelis, Legnaro

- *Spectroscopy of deformed neutron rich A ~ 60 nuclei* ($^{64}Ni + ^{238}U$)
S.M.Lenzi, Padova, S.J.Freeman, Manchester (N.Marginean talk)

- *Pair transfer effects in $^{90}Zr+^{208}Pb$* L.Corradi, Legnaro ($^{90}Zr + ^{208}Pb$)

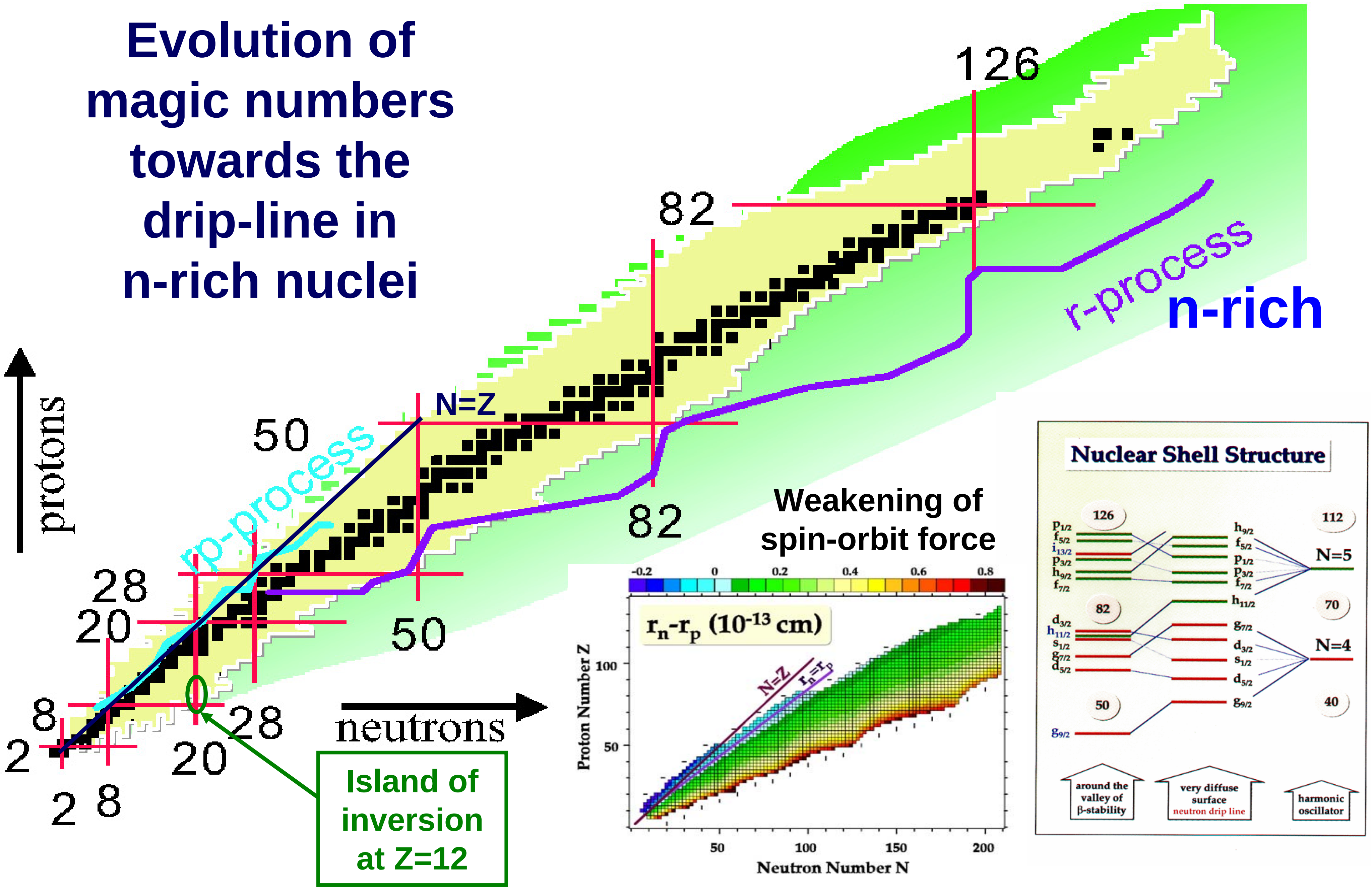
- *Identification of the 6+ state in ^{54}Co* A.Gadea, Legnaro ($^{54}Fe + ^{54}Fe$)

- *Resonances in 24Mg+24Mg and molecular states in 48Cr* ($^{24}Mg + ^{24}Mg$)
F.Haas, Strasbourg (F.Hass talk)

- *Excited states in ^{31}S.* D.R.Napoli, M.Marginean, Legnaro ($^{32}S + ^{58}Ni$)

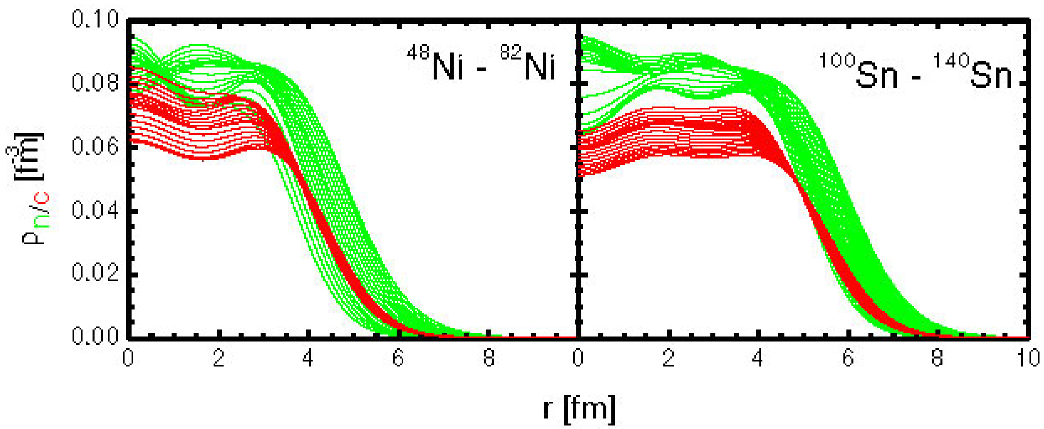
- *Decay properties of pairing vibration states populated in transfer reactions* S.Szilner, Zagreb ($^{40}Ca + ^{96}Zr$)

- *Large angle scattering of $^{40}Ca + {}^{X}Zr$.* G.Montagnoli, Legnaro ($^{40}Ca + {}^{xx}Zr$)

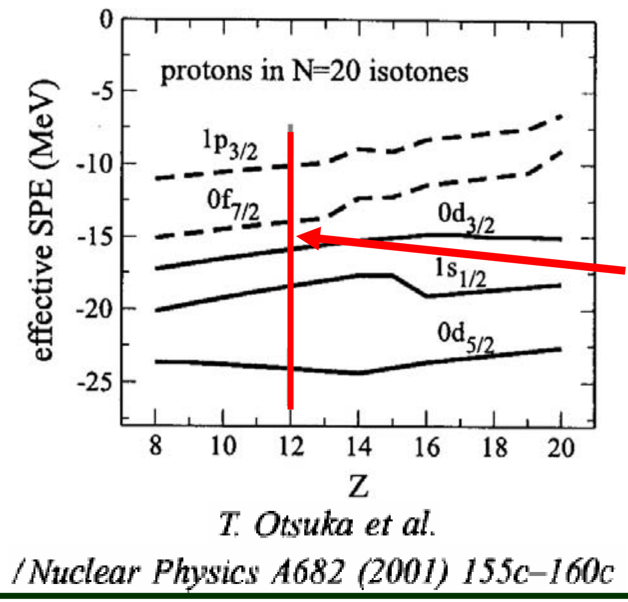

Evolution of magic numbers towards the drip-line in n-rich nuclei
protons
neutrons
rp-process
r-process
n-rich
N=Z
126
82
82
50
50
28
28
20
20
8
8
2
2
Island of inversion at Z=12
Weakening of spin-orbit force
r_n-r_p (10^{-13} cm)
-0.2
0
0.2
0.4
0.6
0.8
N=Z
r_n=r_p
Proton Number Z
Neutron Number N
100
50
50
100
150
200
Nuclear Shell Structure
126
112
N=5
82
70
N=4
50
40
around the valley of β-stability
very diffuse surface
neutron drip line
harmonic oscillator

N=20 and N=50 Shell Gaps

weakening of the spin-orbit force?



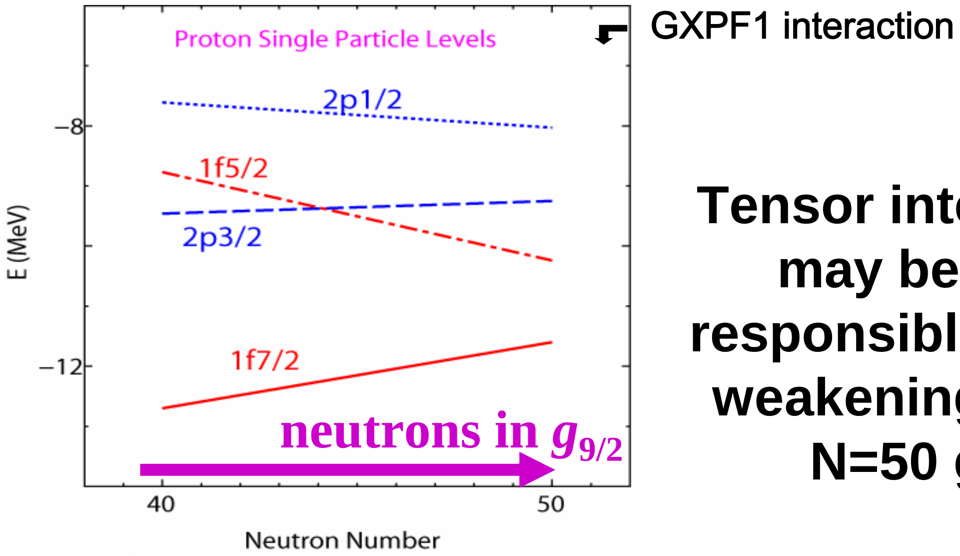
DDRH Field Calculations by F.Hofmann, C.M.Keil, H.Lenske, Phys.Rev.C64(01)034314.



N=20: ^{32}Mg

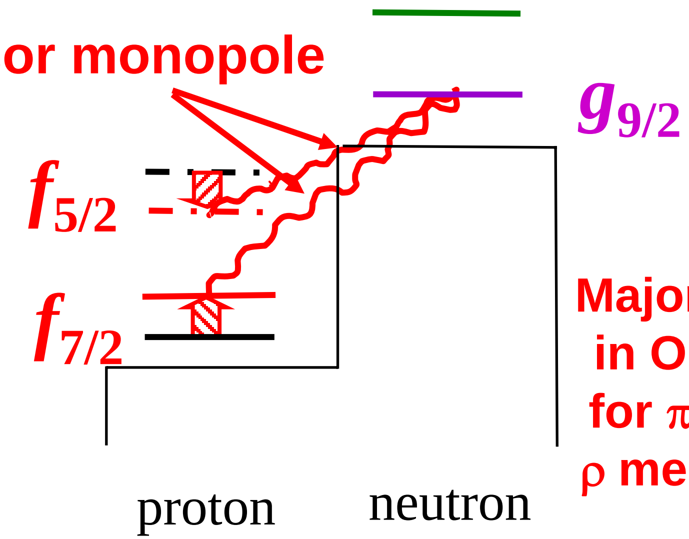
Island of inversion (due to residual interaction)

B(E2): GANIL, RIKEN, REX-ISOLDE, NSCL



T. Otsuka et al. Zakopane 2004

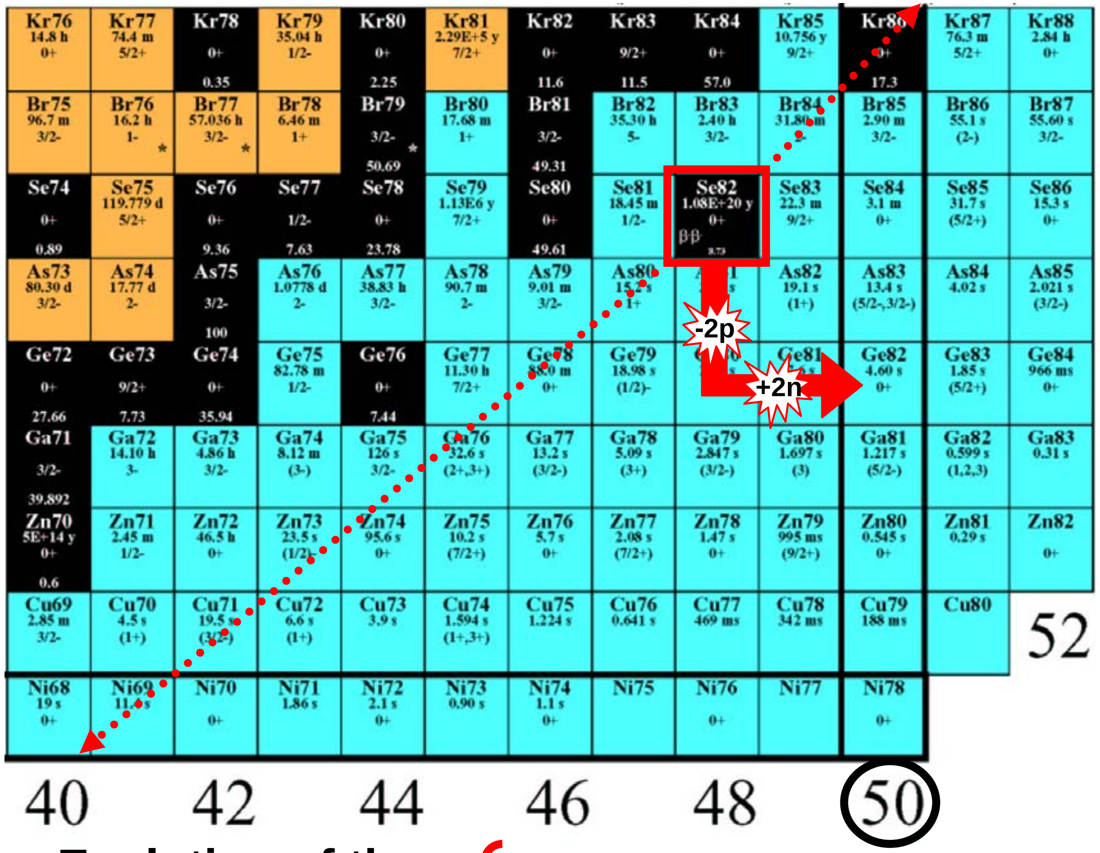
Tensor interaction may be also responsible for the weakening of the N=50 gap

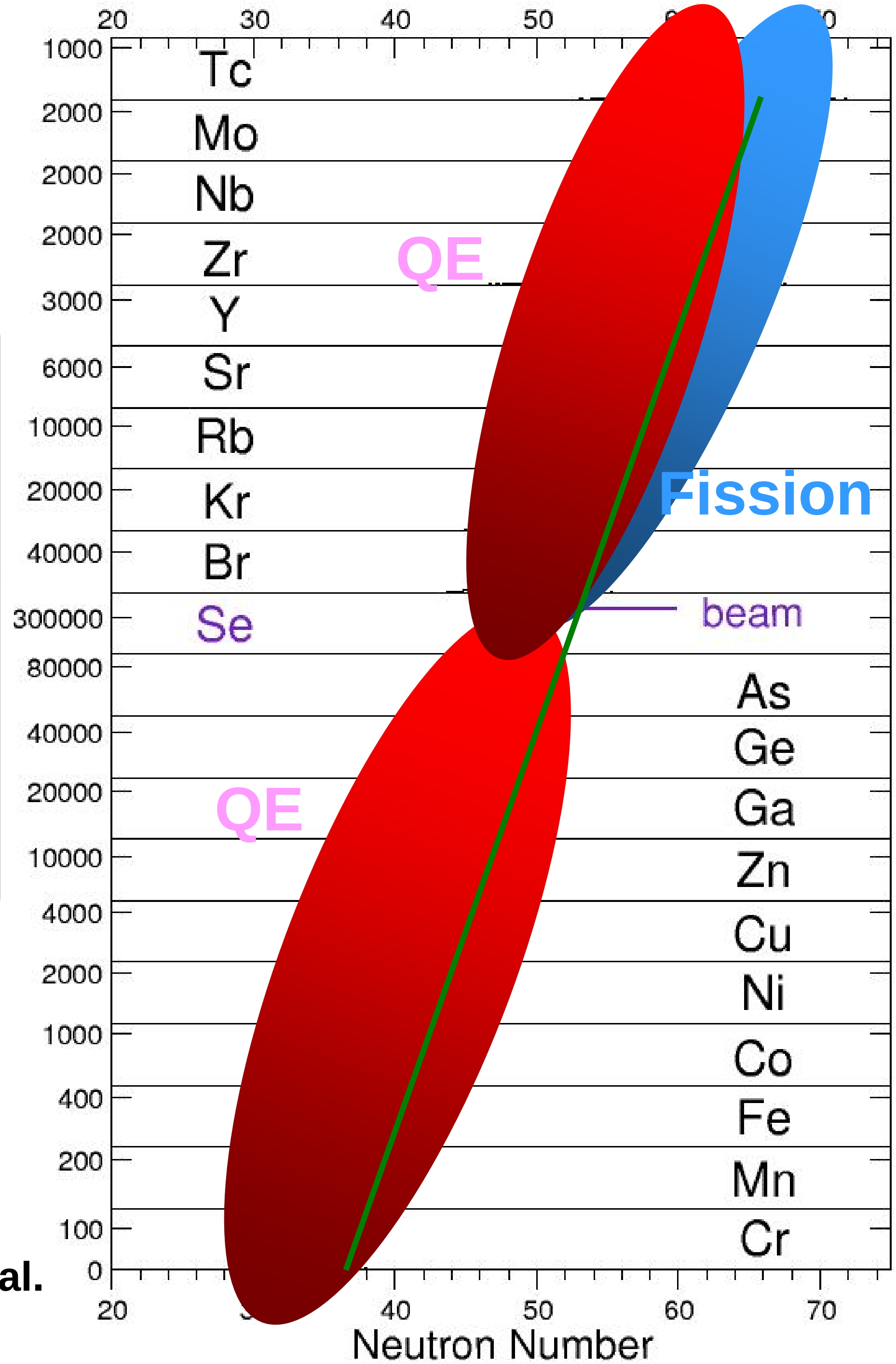


Major role in OBEP for π and ρ mesons

^{82}Se + ^{238}U E=505 MeV (ALPI)
4 days, PRISMA at θ_G=64°

G.deAngelis, G.Duchêne
Analysis: N.Marginean



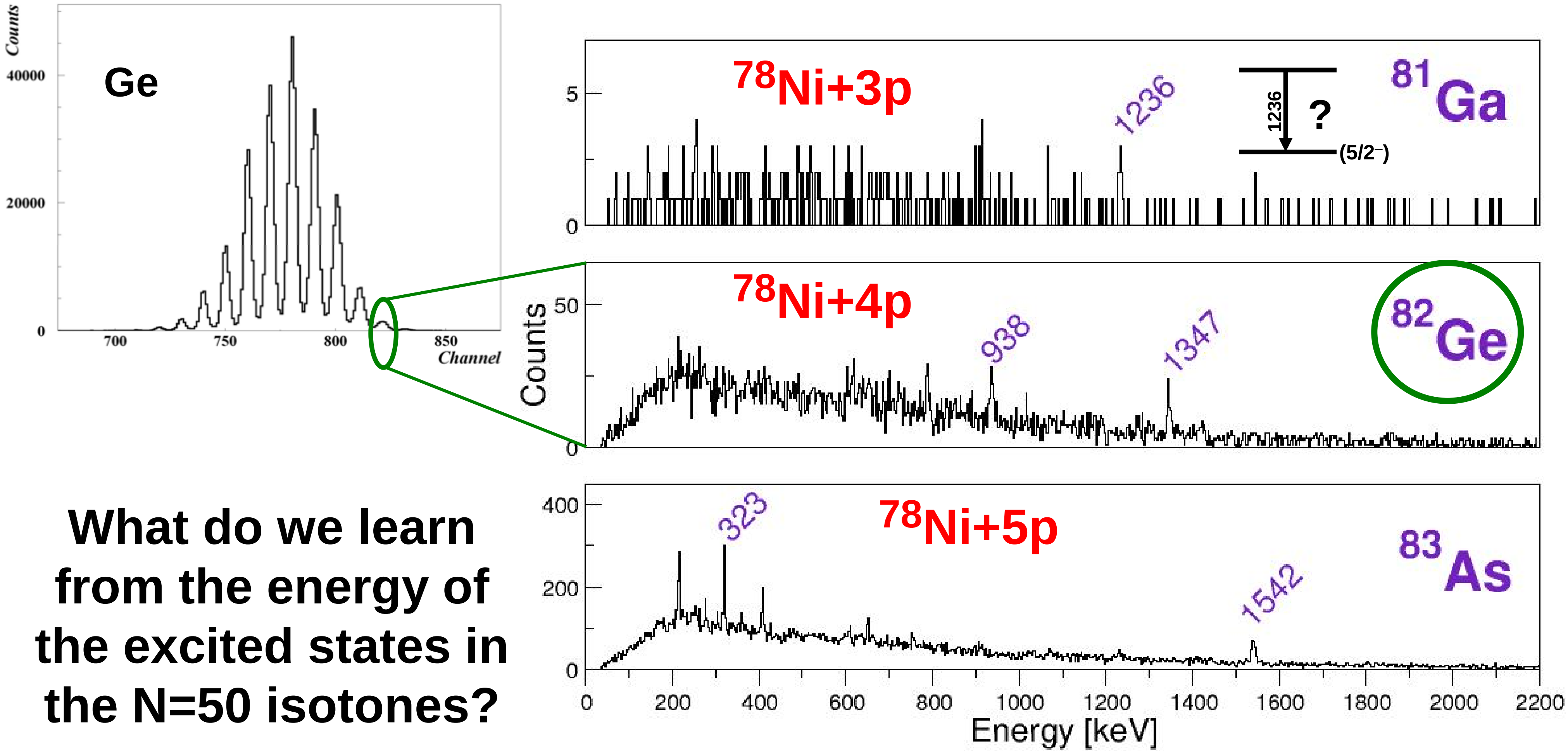


Evolution of the N=50 shell: Searching for the shell gap quenching

Z=32: INM, R.C.Nayak et al. PRC 60 (1999) 064305

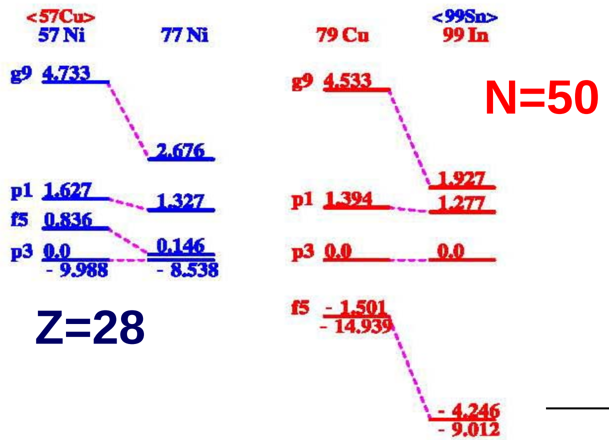
Z=24-26: RMF, L.S.Geng et al. nucl-th/0402083

Spectroscopy of the N=50 Isotones



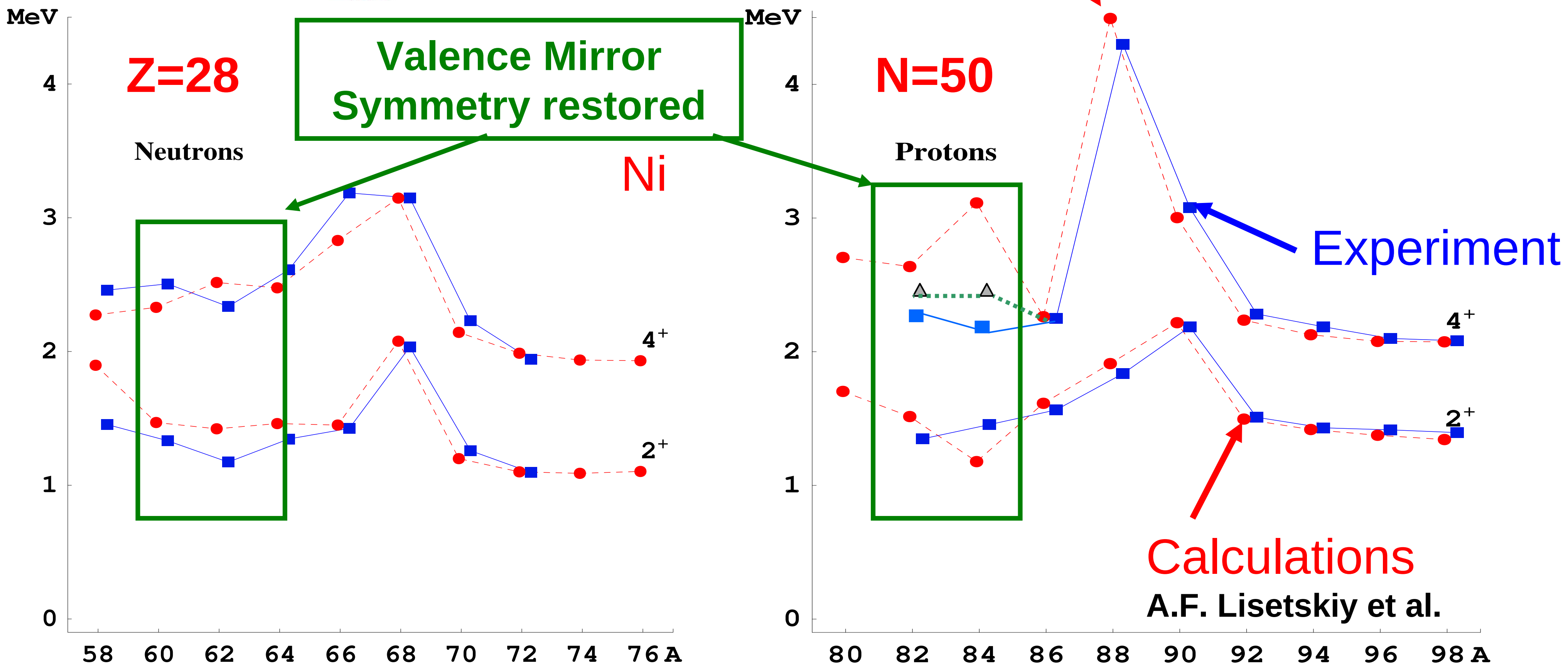
What do we learn from the energy of the excited states in the N=50 isotones?

G.deAngelis, G.Duchêne, et al. Analyzed by N.Marginean



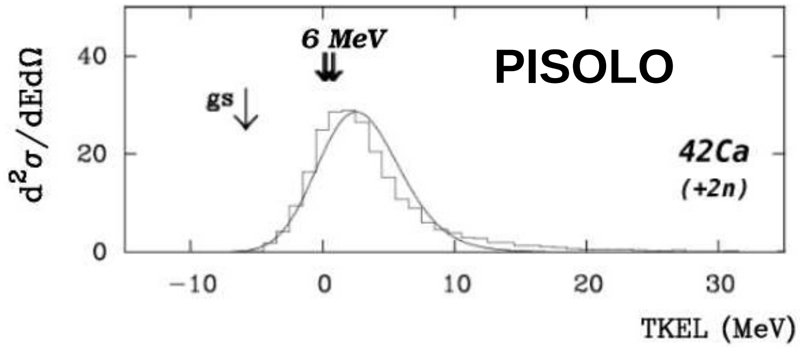
N=50 Shell gap stable at Z=32 !

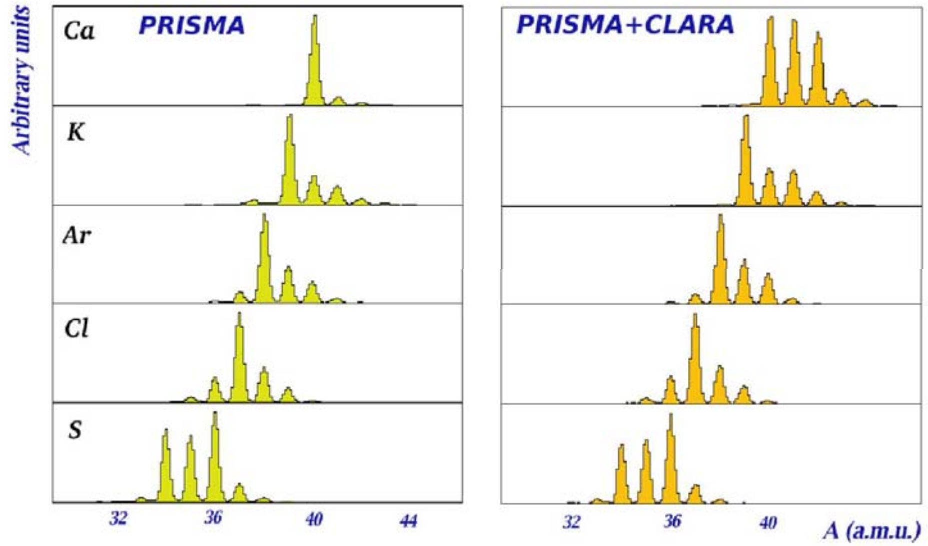
Interactions taking into account the monopole migration



A.F. Lisetskiy, B.A.Brown, M. Horoy, H. Grawe nucl-th0402082 (G-Matrix based on Bonn-C)

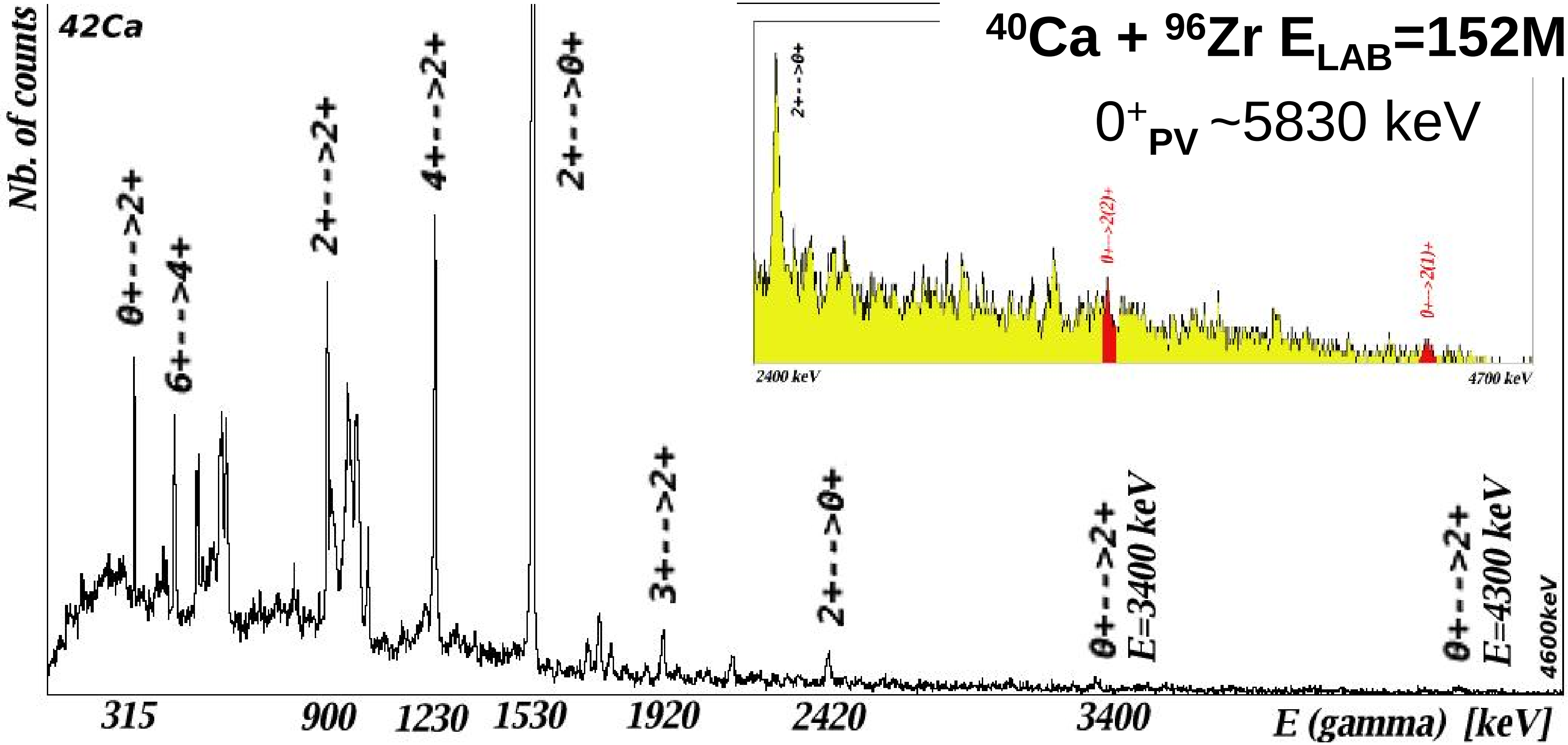
Pairing-vibration states in ^{42}Ca
S.Szilner (LNL and Zagreb)



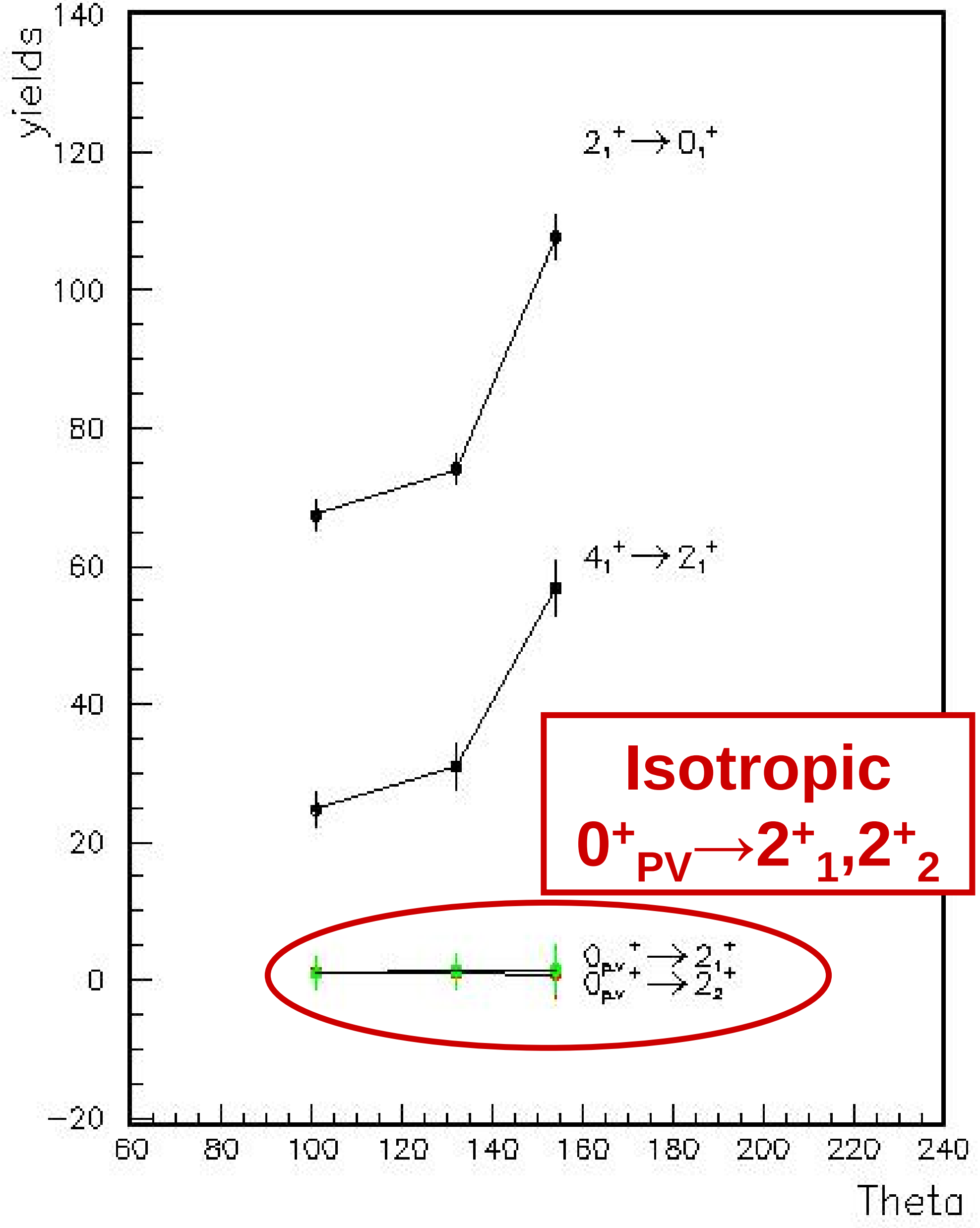


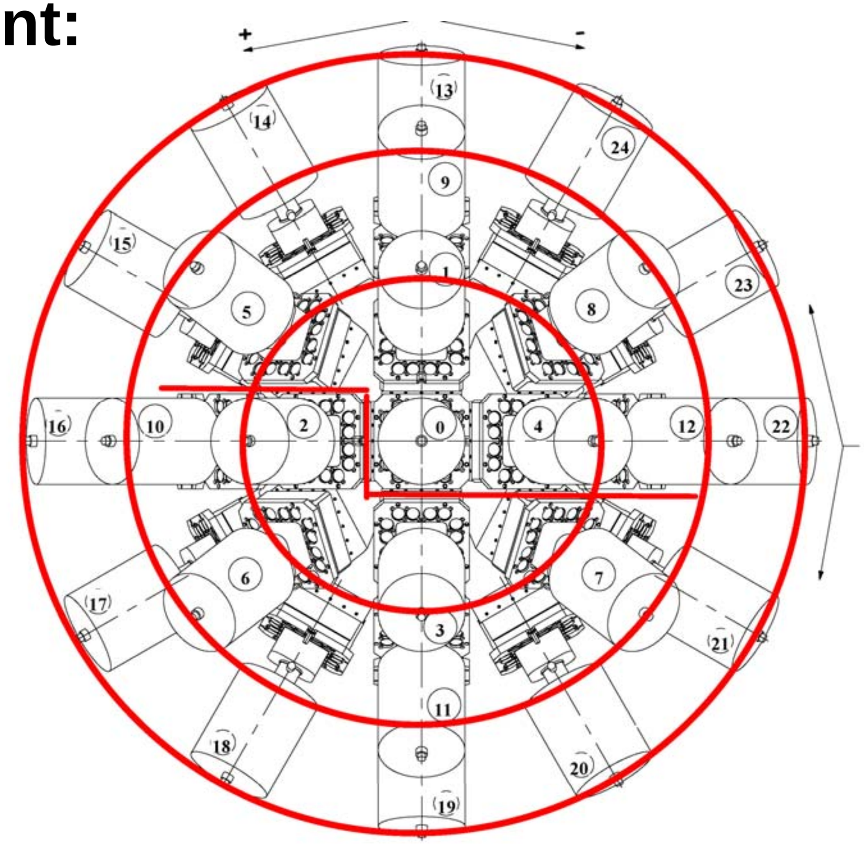
^{40}Ca + ^{96}Zr E_{LAB}=152MeV

0^+_{PV} ~5830 keV



Angular Distribution measurement:





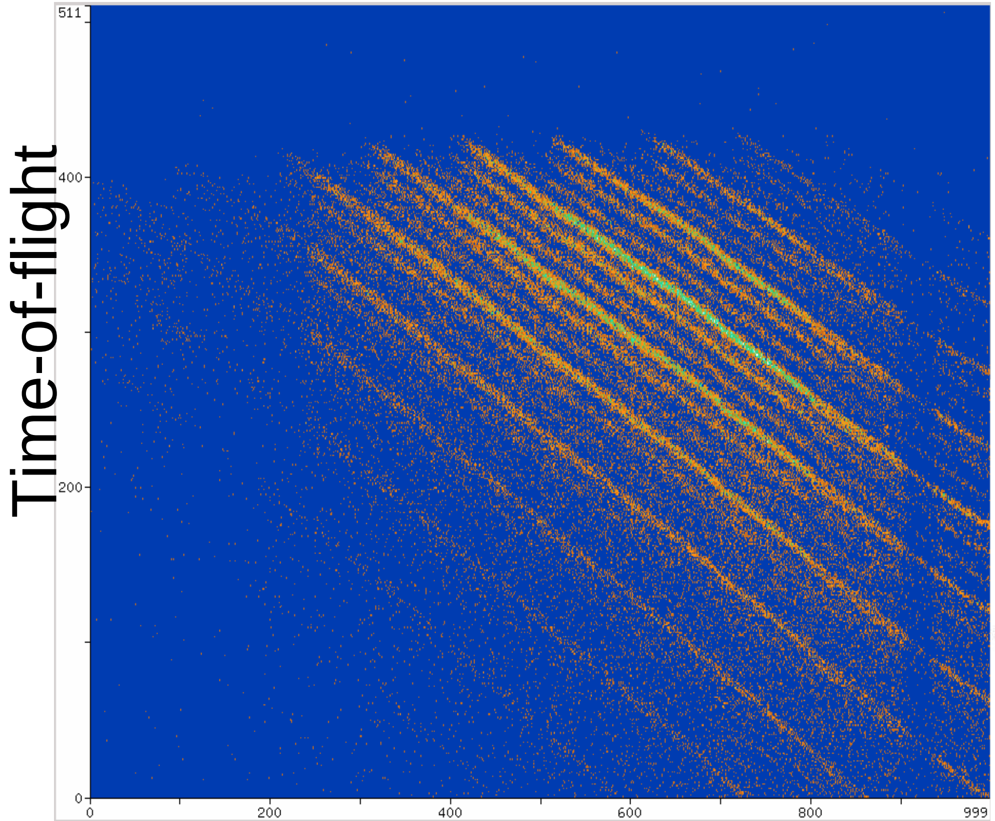
Angular Distribution of $4^+ \rightarrow 2^+$ and $2^+ \rightarrow 0^+$ transitions indicates: $\sigma/J \sim 0.3$

S.Szilner, LNL & Zagreb

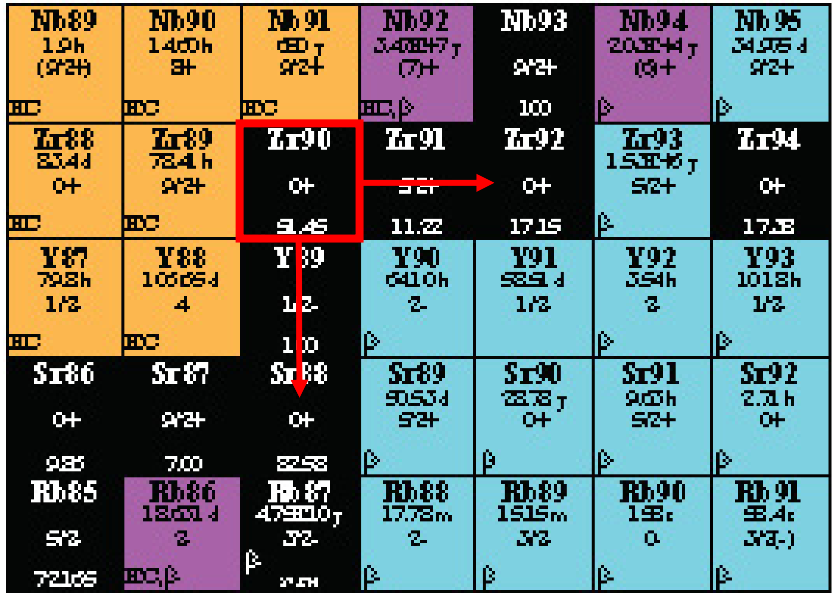
^{90}Zr 560MeV + ^{208}Pb

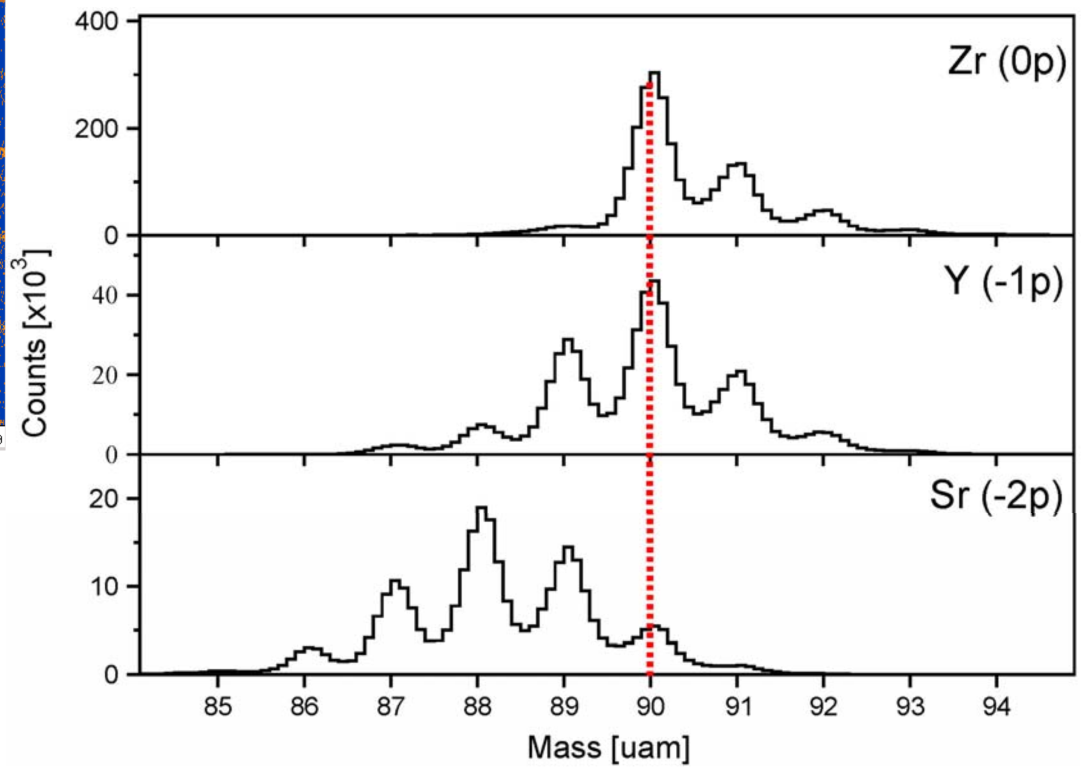
1 day beam time

L.Corradi, C.A.Ur, et al.

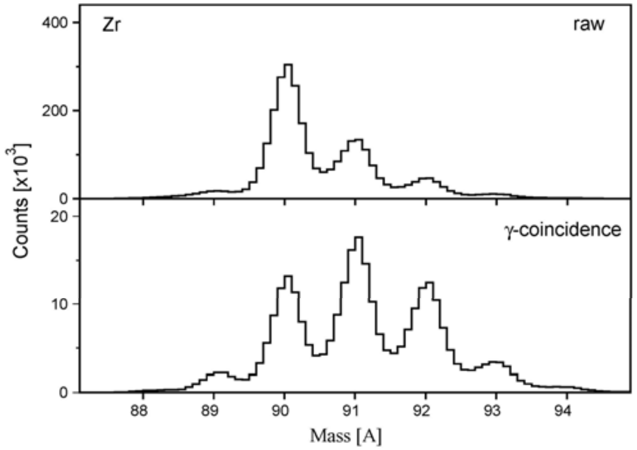


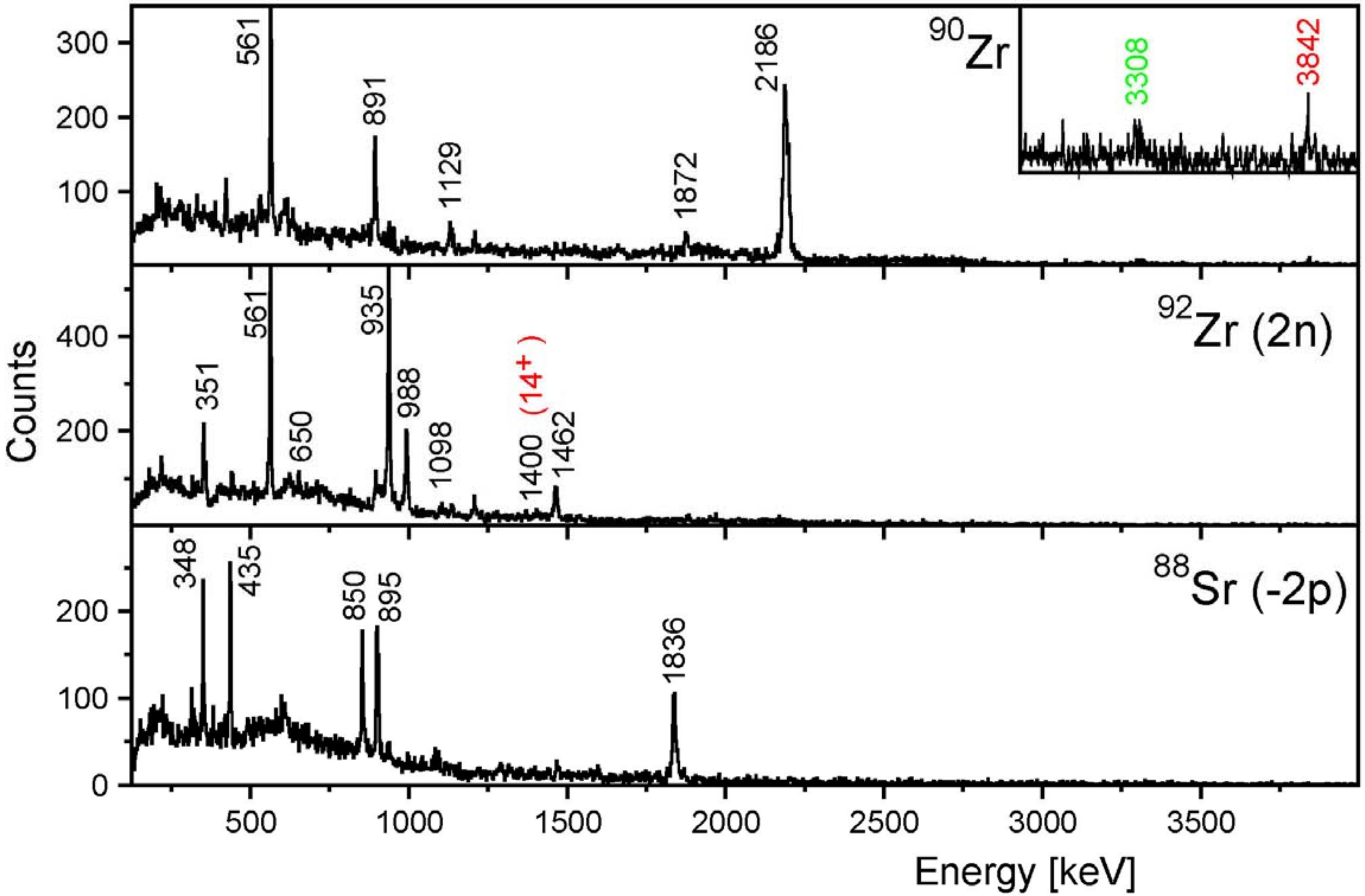
Distance along focal plane

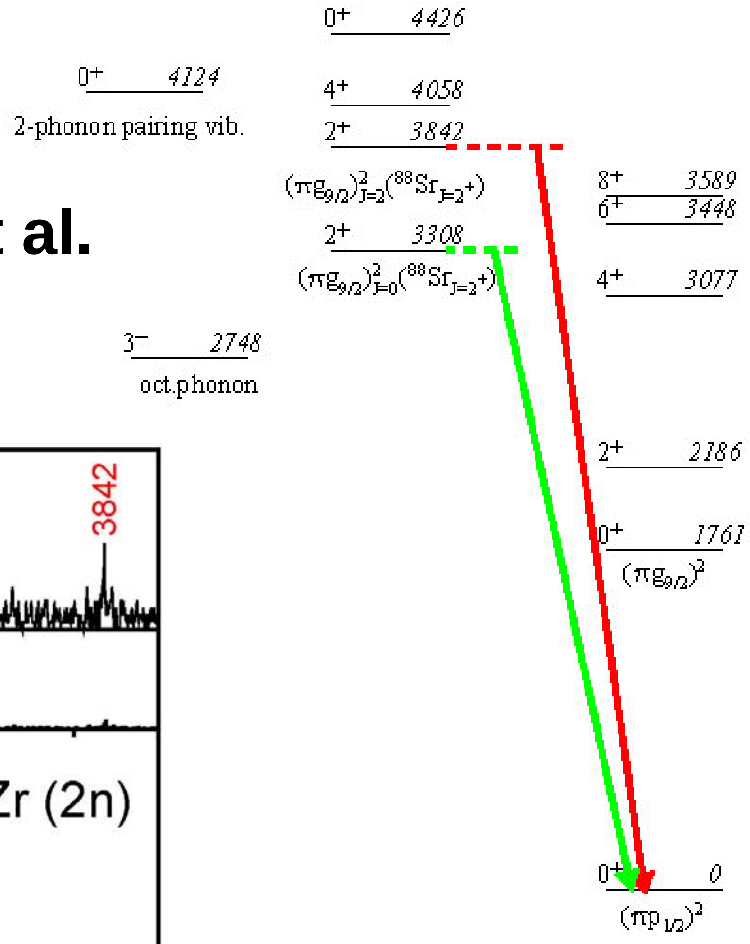




^{90}Zr 560MeV + ^{208}Pb
L.Corradi, C.A.Ur et al.







Level Scheme from: $^{90}Zr(n,n`\gamma)$ P.E.Garrett et al., Phys.Rev.C68 (2003)024312

CLARA-PRISMA 2006-2007

Drawback of the setup: low efficiency for γ–γ–PRISMA coincidences: Development of complementary ancillary devices for Doppler correction.

Measurement of γ–PRISMA coincidences (Identification) and γ–γ–ancillary coincidences (γ–γ coincidences with Doppler correction).

DANTE: MCP array, developed in collaboration with FLNR Dubna, in phase of commissioning.

Development of the Differential Plunger RDDS technique for CLARA-PRISMA in collaboration with IKP-Koeln.

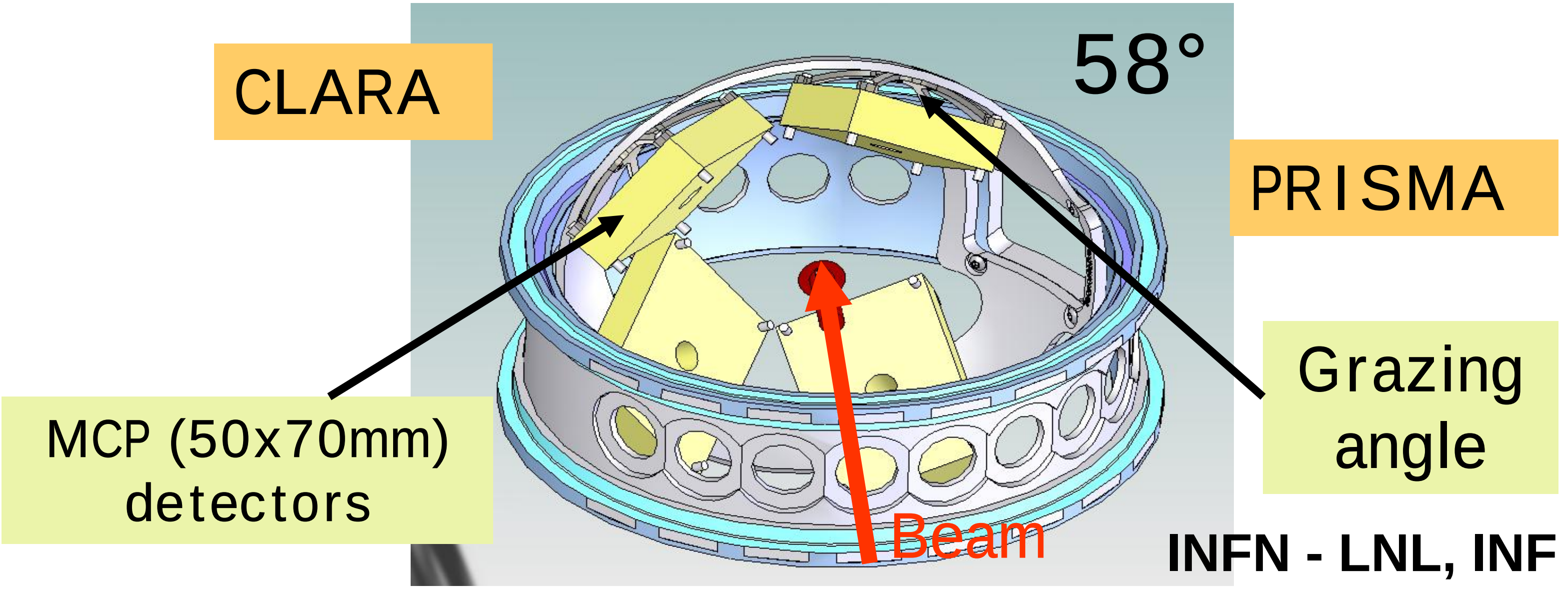
Development of a new focal-Plane detector for PRISMA based on SeD (collaboration U.K. - INFN)

Heavier beams from ALPI linac with the new positive ion injector PIAVE.

DANTE

(**D**etector **A**rray for multi **N**ucleon **T**ransfer **E**jectiles)

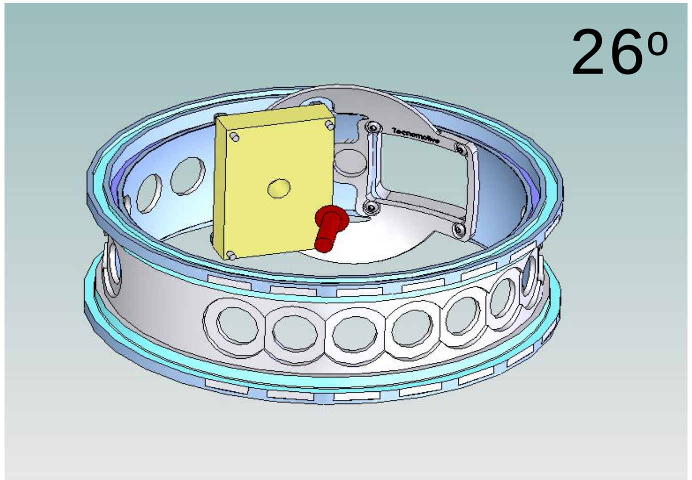
- **Start detector of PRISMA ⇒ No possible to place PPACs**
- **Limited efficiency of the PRISMA-CLARA setup ⇒ No γ-γ coincidences.**
- **DANTE (heavy ion detector based on MCP) reveals the position interaction of the recoils ⇒ Doppler correction.**
- **DANTE placed at the grazing angle, has a high efficiency ⇒ γ-γ coincidences ⇒ No need of an extra GASP experiment to build up a level scheme.**

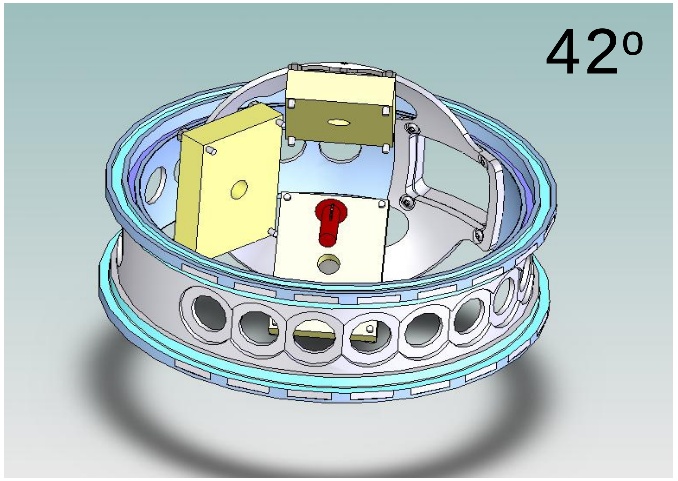


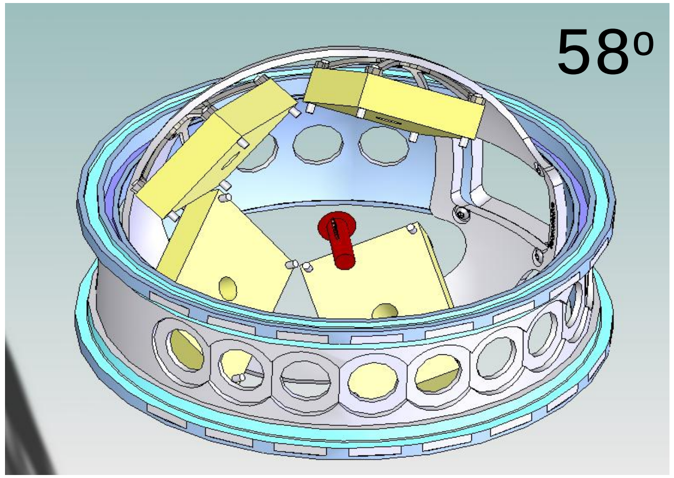
INFN - LNL, INFN - Milano, INFN - Padova, JINR - Dubna

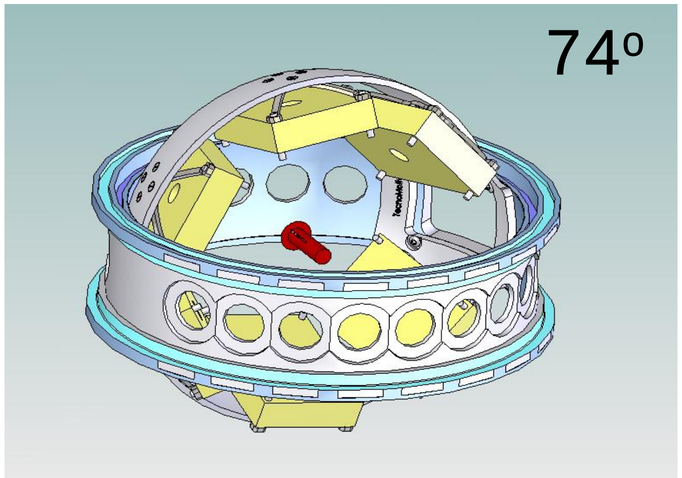
Versatility of DANTE

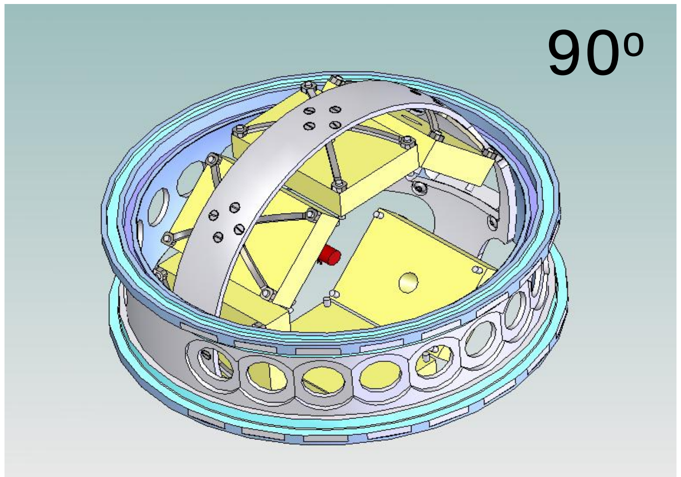
The DANTE configuration will depend on the grazing angle of the reaction of interest



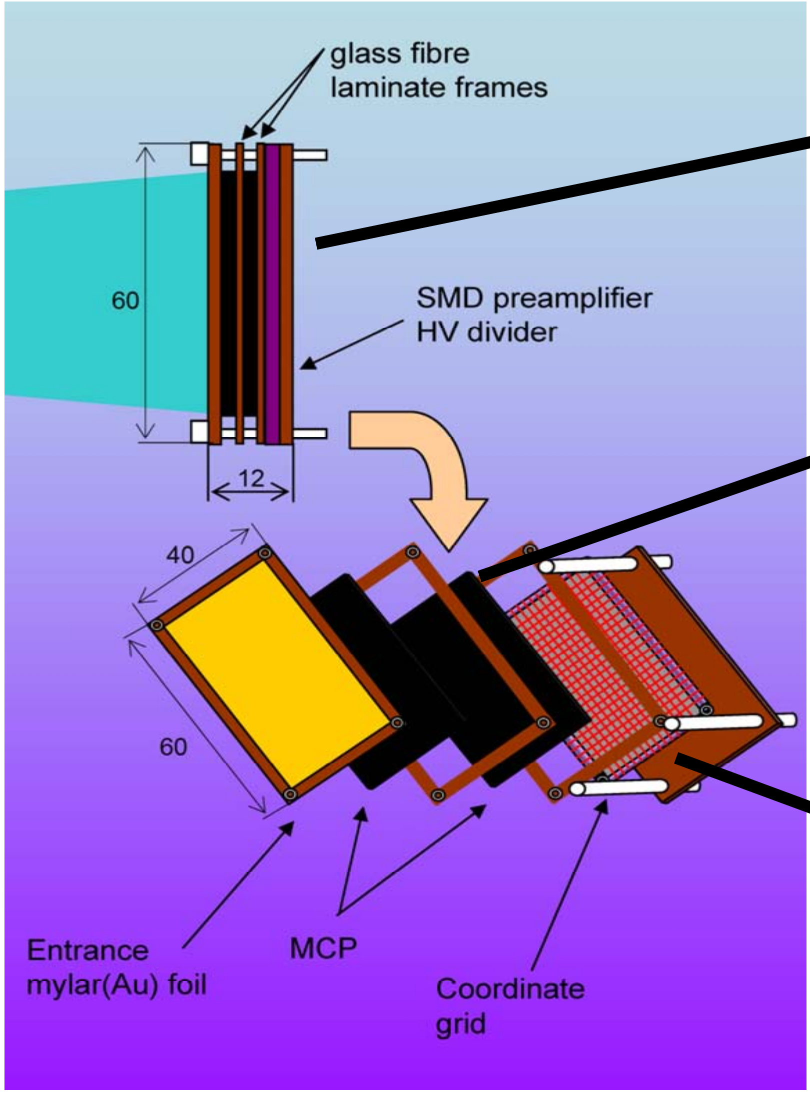




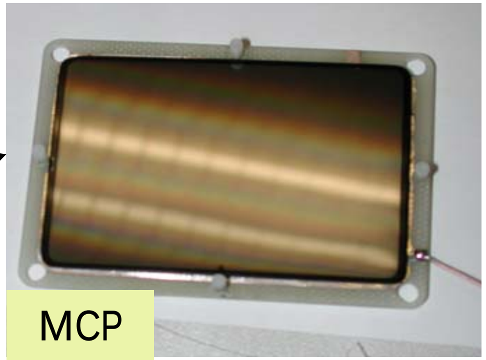




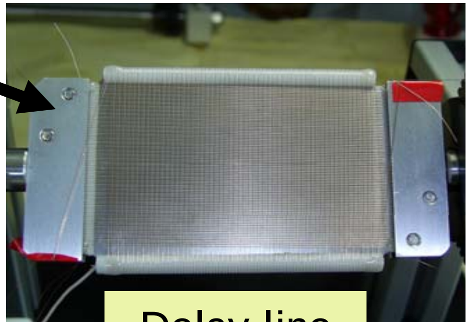
The DANTE detectors



Preamplifier in vacuum

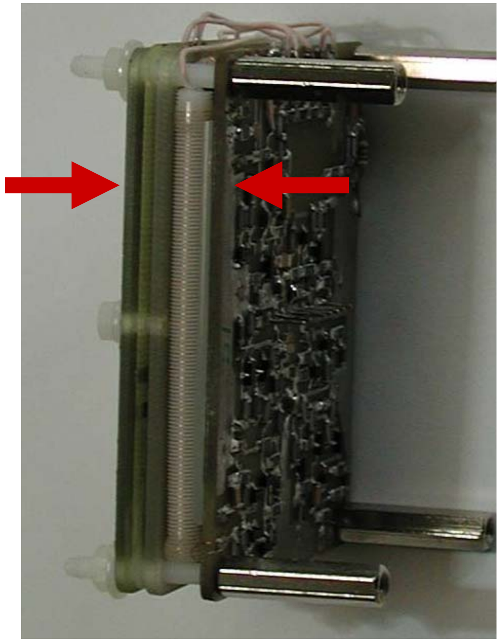


MCP



Delay line

Thickness:13mm

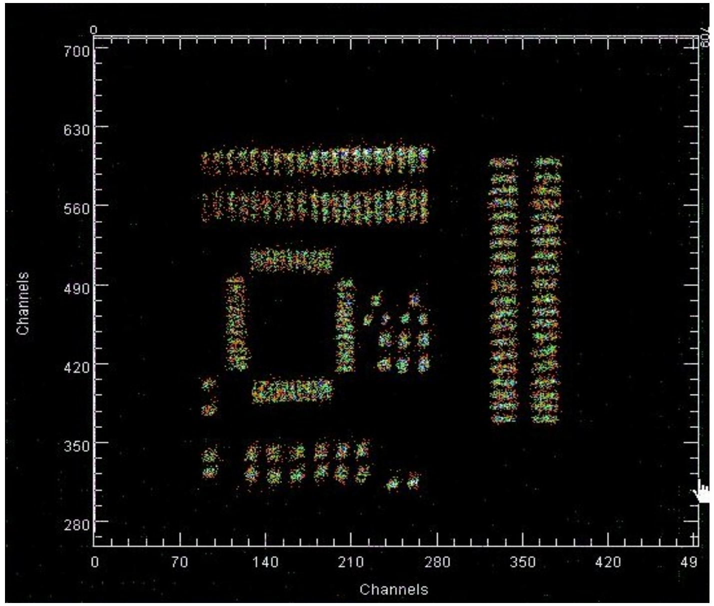


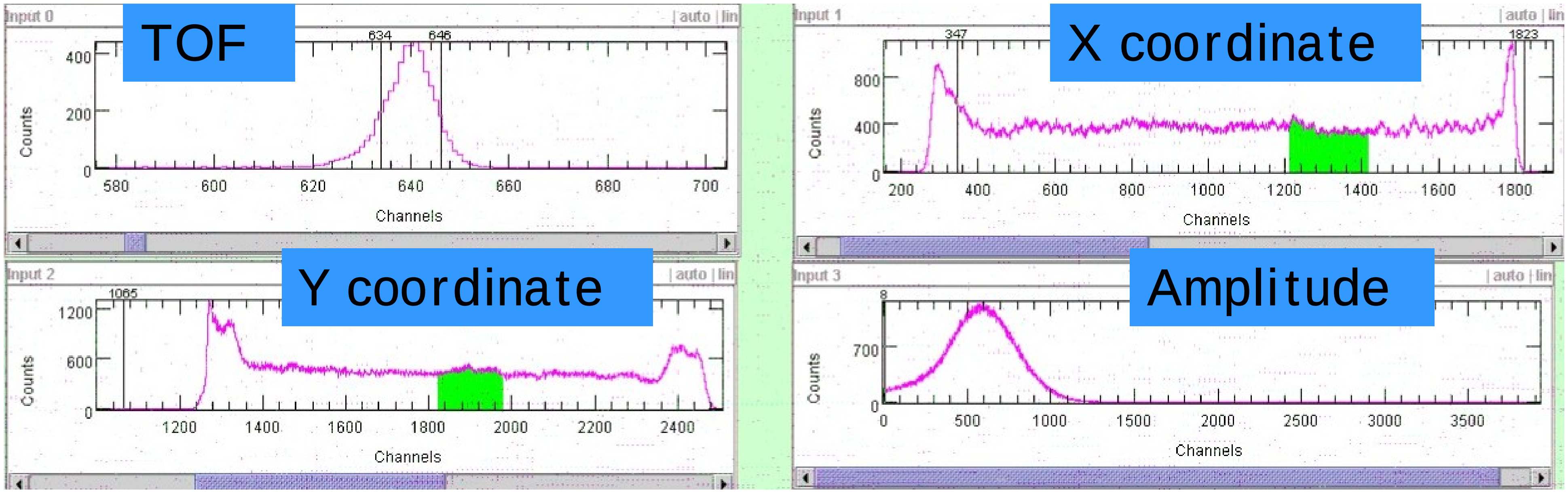
Lateral section of the first DANTE prototype

Test of the DANTE detectors

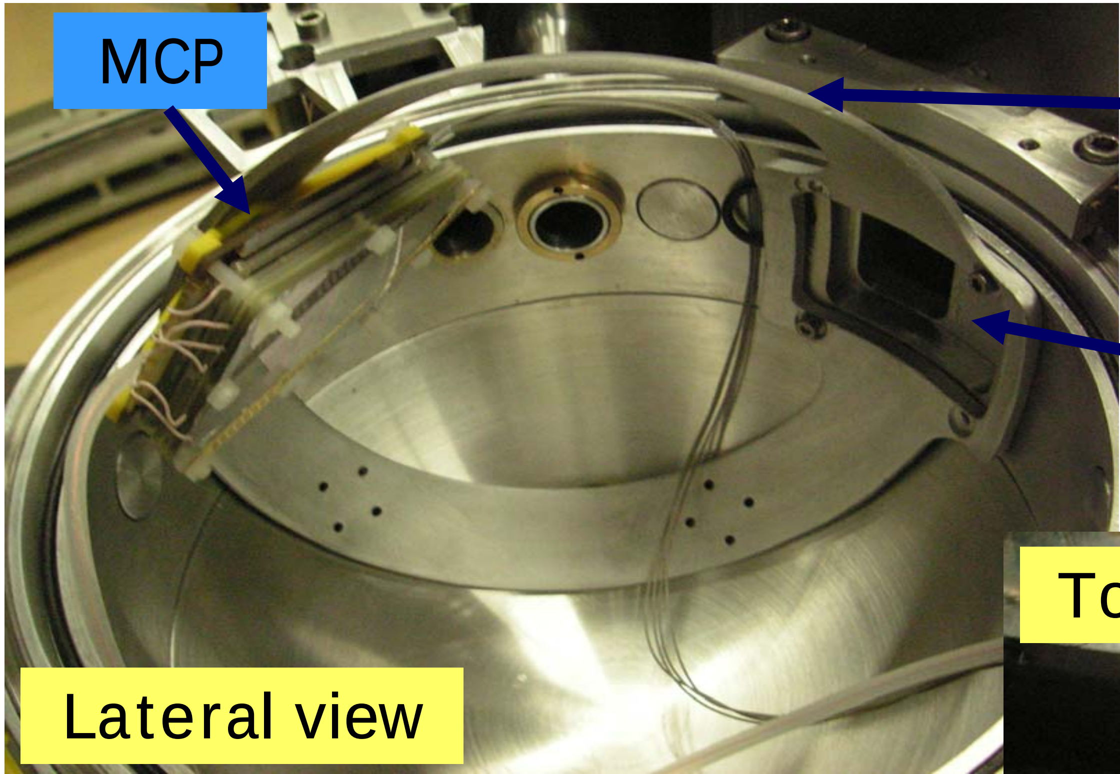
<u>Test done with an α source</u>

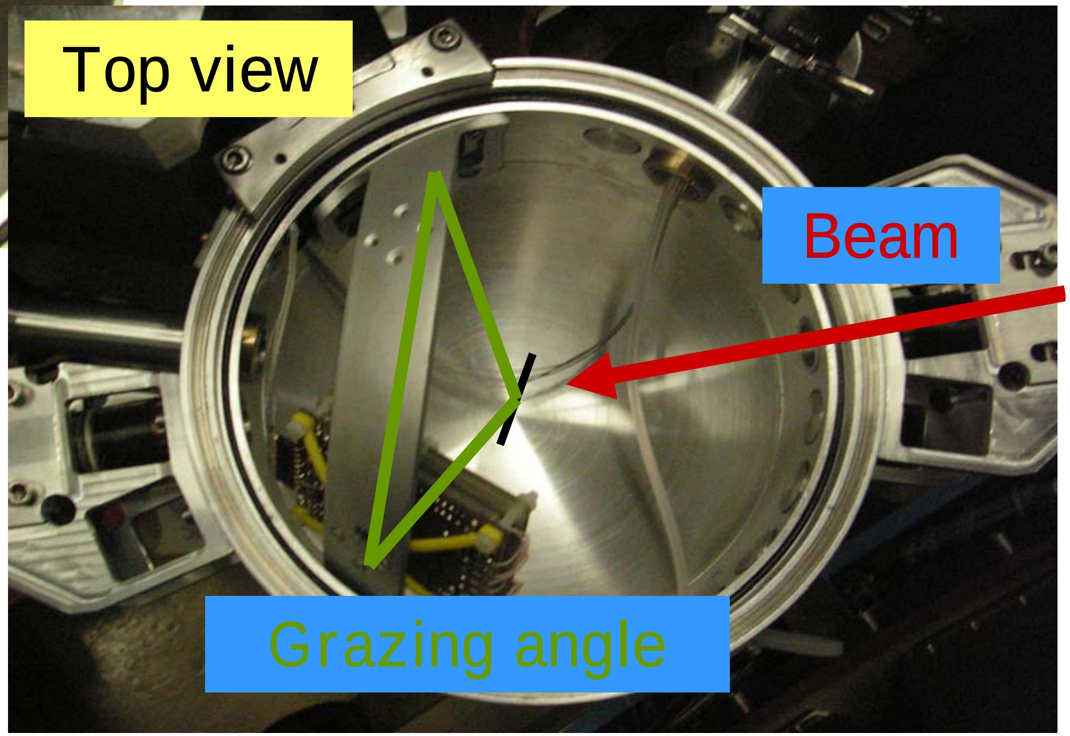
- Time resolution 130ps (TAC-ADC)
- Position resolution <1mm
- High counting rate
- High noise rejection





DANTE inside the reaction chamber

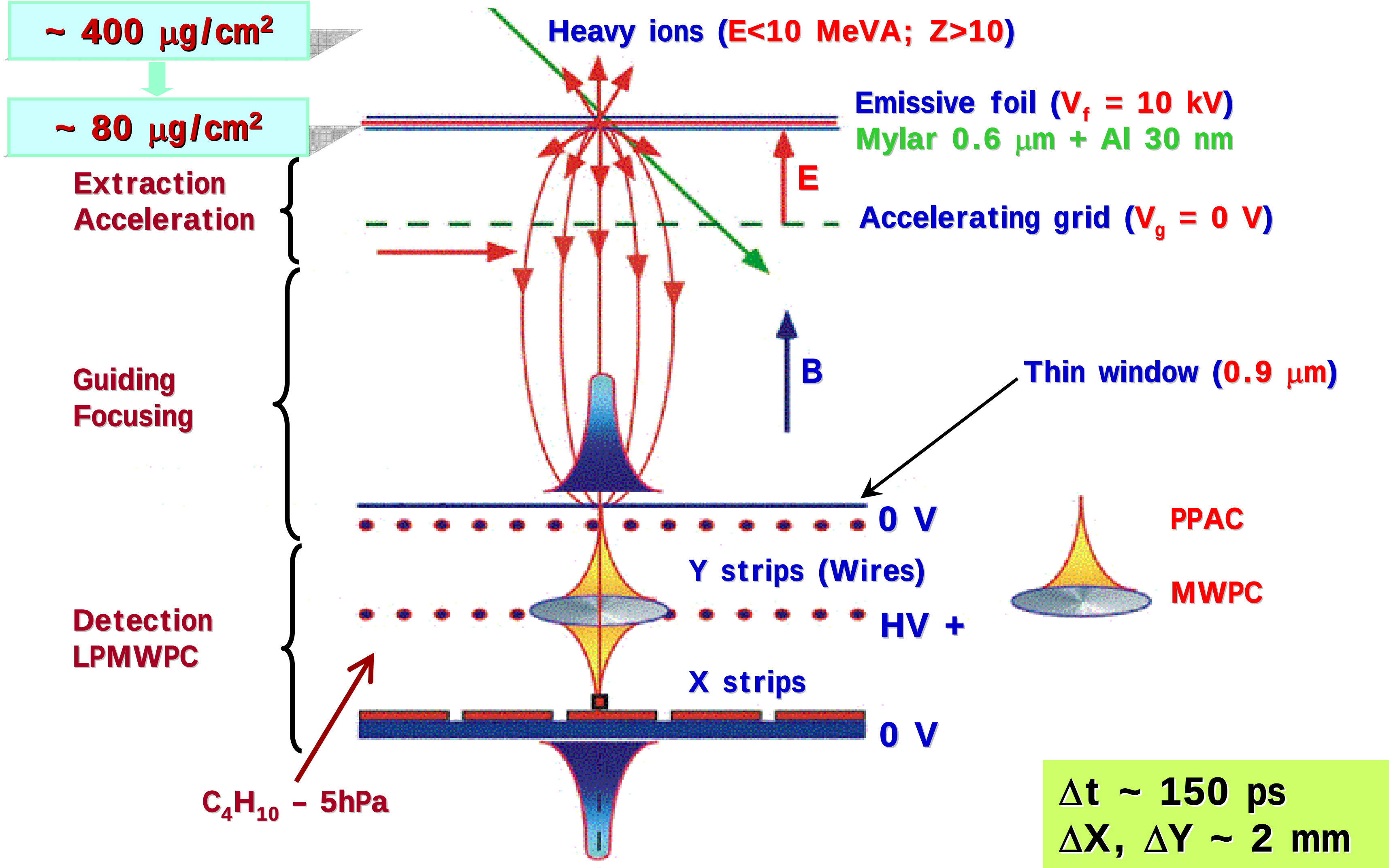




Reaction chamber of
CLARA-PRISMA

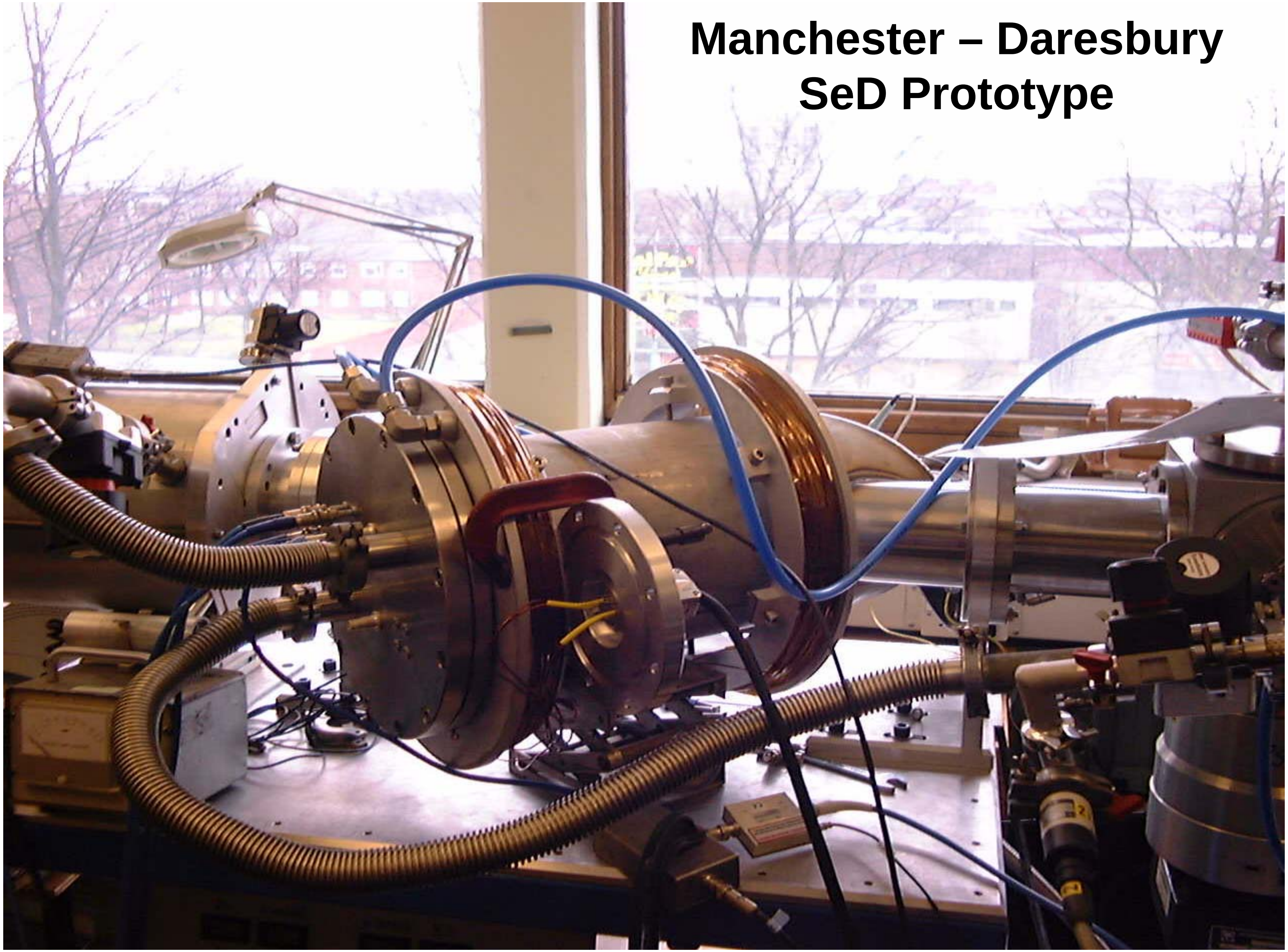
Development of a new FPD for PRISMA

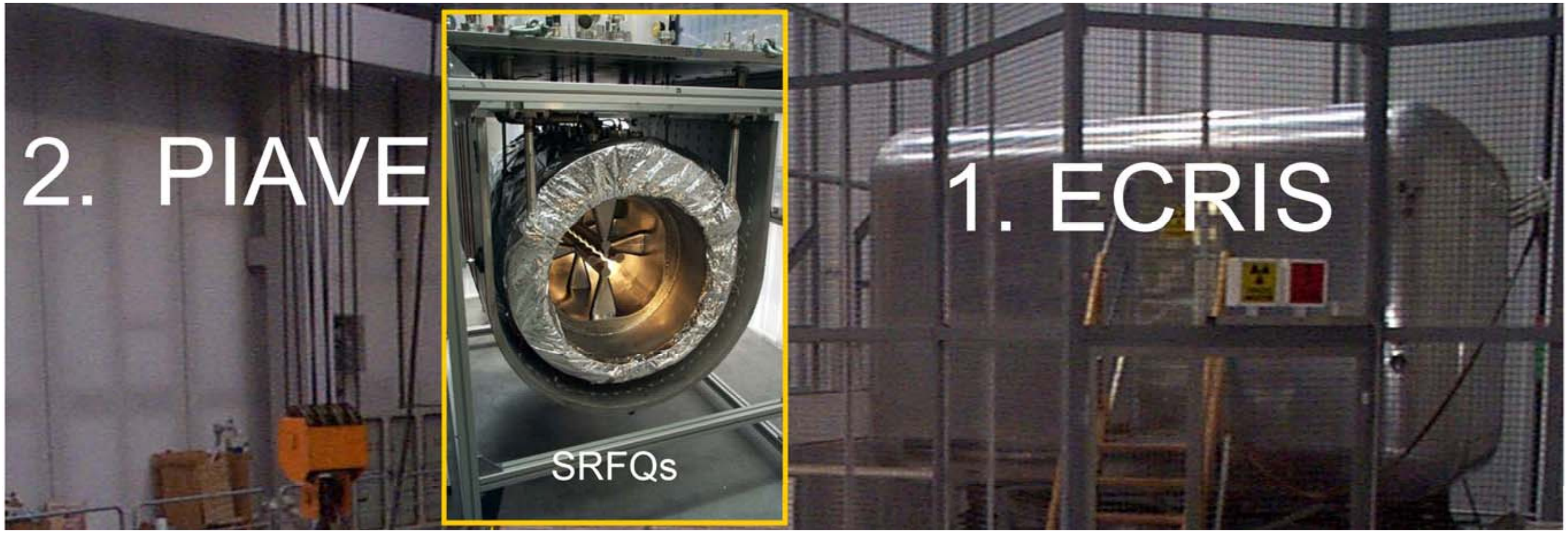
New FPD for low energy HI ➡ Se-D

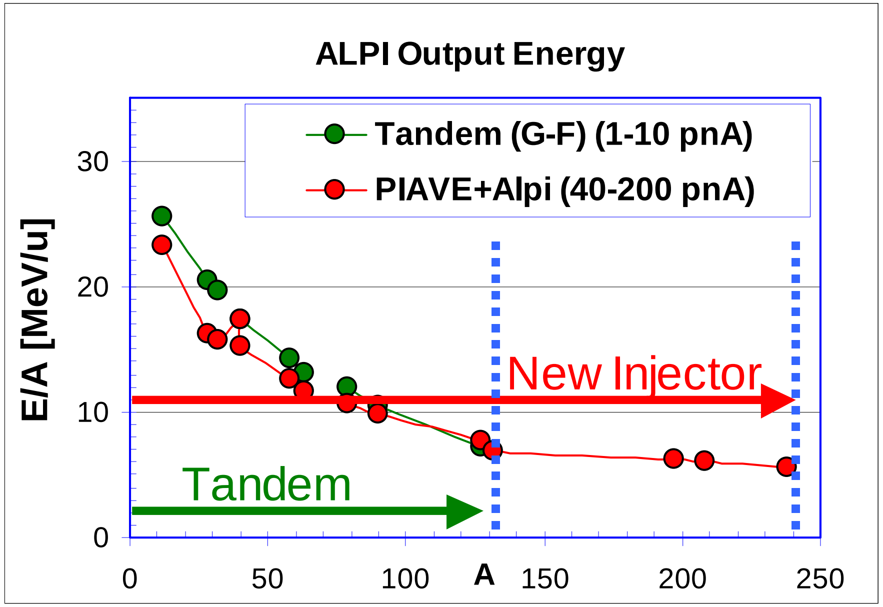


Collaboration of several U.K.groups
Manchester – Daresbury - Paisley

Manchester – Daresbury SeD Prototype

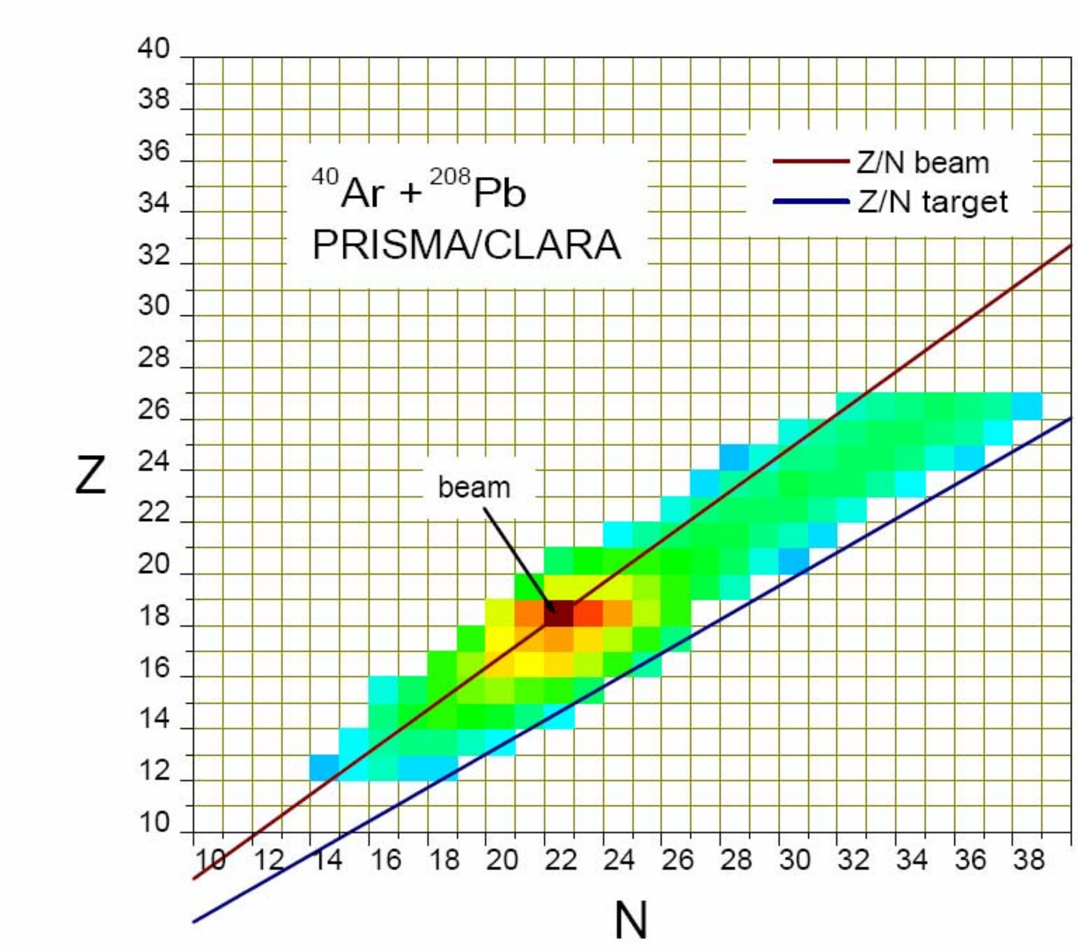


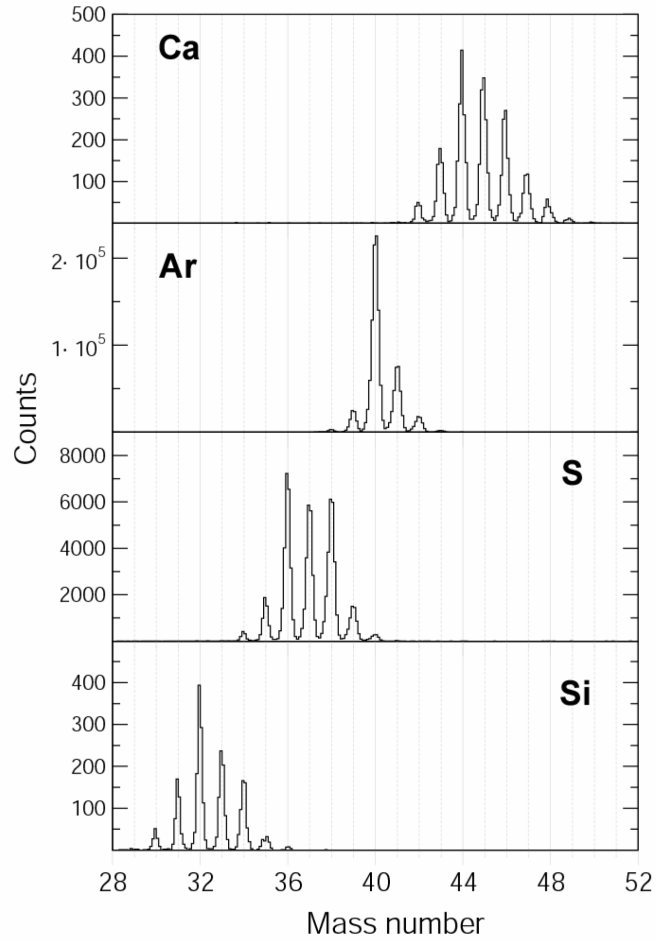




Positive ion injector ECRIS + PIAVE commissioned
Last quarter 2005 - first quarter 2006: Ne, Ar and Kr beam delivered to the experimental areas for test.
PIAVE beams for users expected second semester 2006.

^{40}Ar (238 MeV) PIAVE-ALPI beam test
CLARA-PRISMA, January 2006



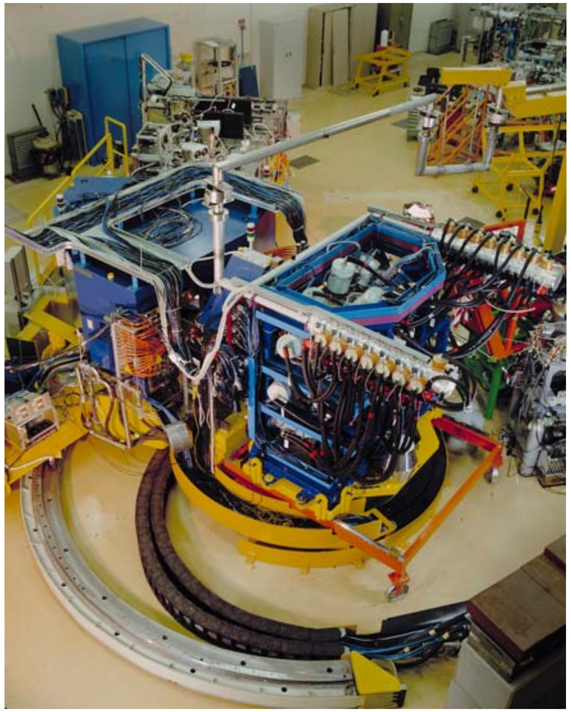


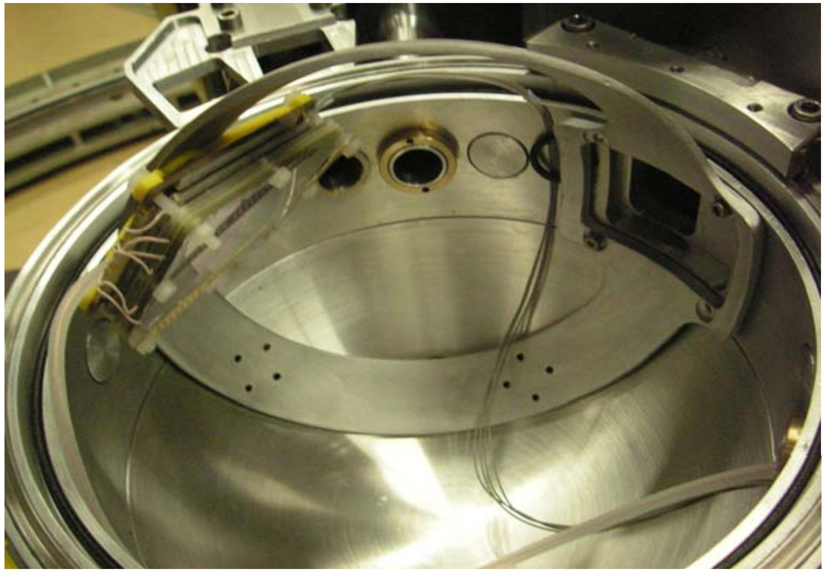
Analysis by N.Marginean

Outlook:

-Spectroscopy with grazing reactions, using the combination of a gamma- array and a large acceptance spectrometer (as CLARA-PRISMA), provides valuable structure information on moderately n-rich nuclei.

-Differential RDDS technique is being developed in collaboration with IKP-Koeln, commissioning next month.





-CLARA is being upgraded with an ancillary array to perform “in beam” $\gamma-\gamma$ coincidences with Doppler correction.

-New SeD based FPD for PRISMA are under development (U.K. – INFN)

-Is foreseen to start the use of the CLARA-PRISMA setup with the medium-mass and heavy beams from PIAVE-ALPI during the second semester 2006.

The CLARA-PRISMA collaboration

- France

IReS Strasbourg
GANIL Caen

- U.K.

University of Manchester
Daresbury Laboratory
University of Surrey
University of Paisley

- Germany

HMI Berlin

GSI Darmstadt

- Italy

INFN LNL-Legnaro
INFN and University Padova
INFN and University Milano
INFN and University Genova
INFN and University Torino
INFN and University Napoli
INFN and University Firenze
University of Camerino

- Spain

University of Salamanca

- Romania

Horia Hulubei NIPNE Bucharest