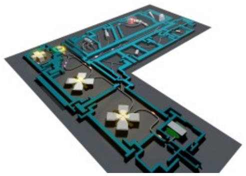
Nuclear Physics Highlights from Stable Ion Beam Facilities ECOS -2011-2014

A.Navin

Grand Accélérateur National d'Ions Lourds, France



Julin Rauno

JYVÄSKYLÄN YLIOPISTO
UNIVERSITY OF JYVÄSKYLÄ

Georgi Iulian, Iolanda+

GANIL spiral2

Fanny,Maurice,Christelle,John +

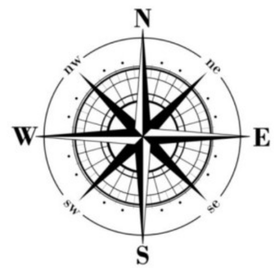
IPN
INSTITUT DE PHYSIQUE NUCLÉAIRE
ORSAY

GSI Dieter

ŚRODOWISKOWE LABORATORIUM
CIĘŻKICH JONÓW

Pawel
Krzysztof

Adam



Giacomo,Lorenzo

INFN

Laboratori Nazionali di Legnaro

Istituto Nazionale di Fisica Nucleare
Laboratori Nazionali del Sud

Stefano Romano +

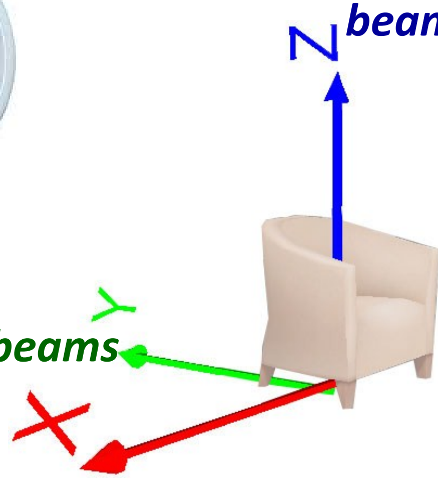
NuPECC ENSAR ECOS

ALTO-IPN - Orsay/FRANCE
GANIL - Caen/FRANCE
GSI - Darmstadt/GERMANY
IFJ - Cracow/POLAND
JYFL - Jyväskylä/FINLAND
LNL-INFN - Legnaro/ITALY
LNS-INFN - Catania/ITALY
SLCJ - Warsaw/POLAND

Inputs from the various labs
Work from many institutions

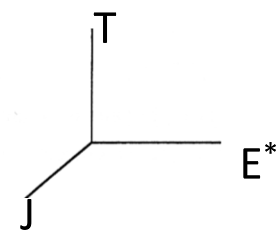
Plan of the talk

Intense Stable beams



ISOL
Radioactive beams

Fragmentation beams



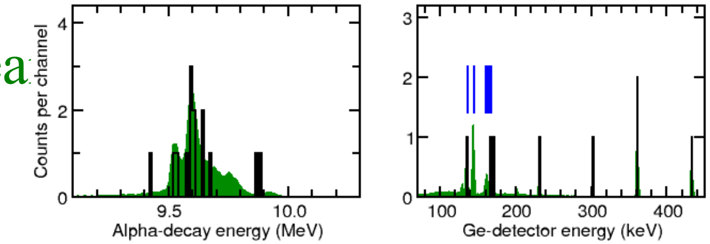
A variety of Physics Q's (suggested by the labs)

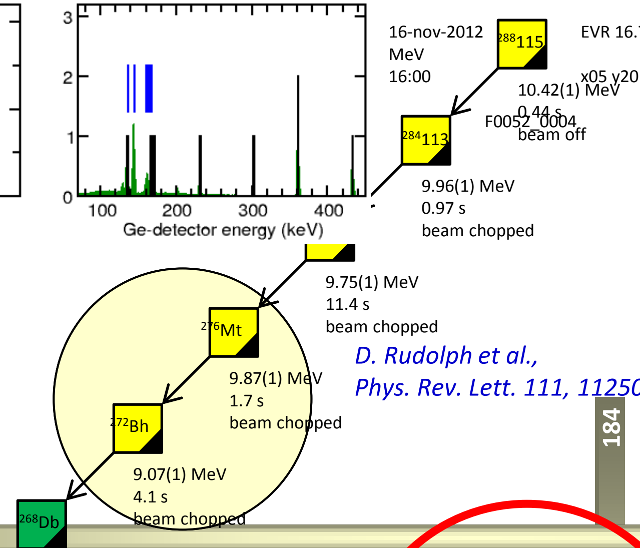
Tools and phenomena Selectivity and sensitivity

Tomorrow ?

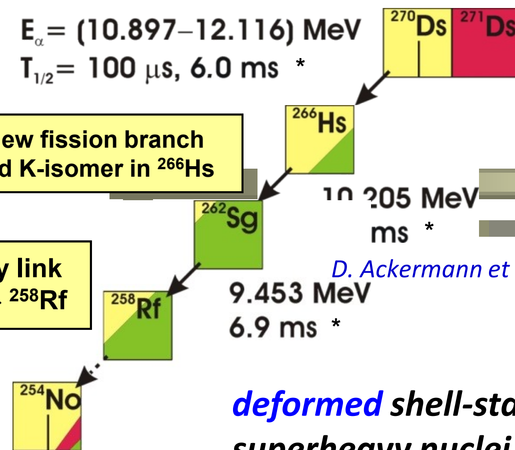
SHE resea

- SHE Synthesis
  - hot fusion: confirmation at LBNL and GSI for Z=112, 114, 115, 116, 117
  - first attempt to fix Z via X-ray detection for $^{288}115$
- nuclear structure features of superheavy nuclei
  - new approaches
  - precise masses for nobelium and lawrencium from SHIPTRAP → E_{bind}
  - laser spectroscopy beyond fermium





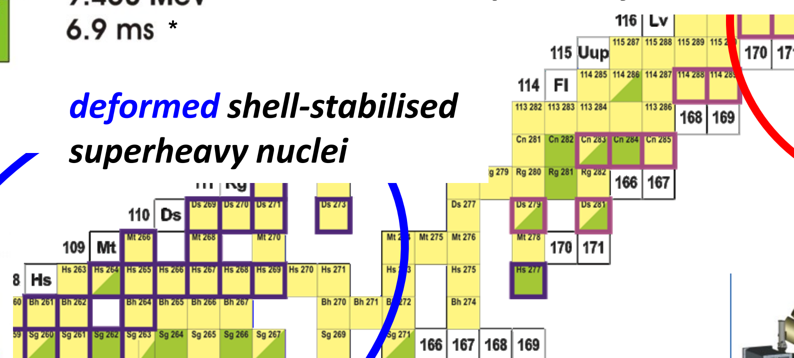
D. Rudolph et al., Phys. Rev. Lett. 111, 112502

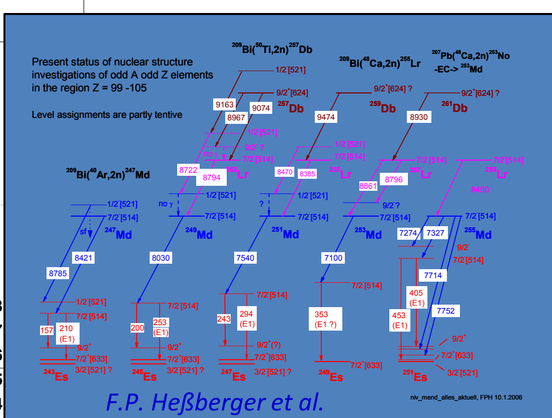


D. Ackermann et al.

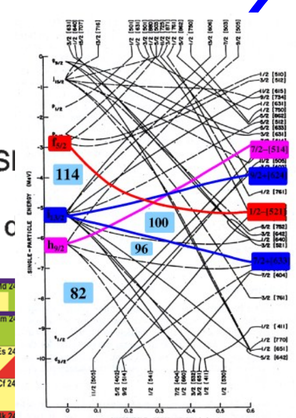
***spherical** shell-stabilised superheavy nuclei*

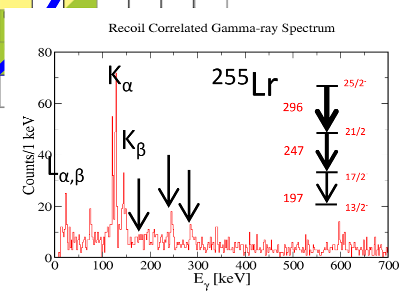
***deformed** shell-stabilised superheavy nuclei*

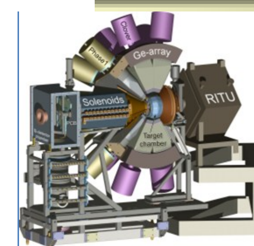




F.P. Heßberger et al.



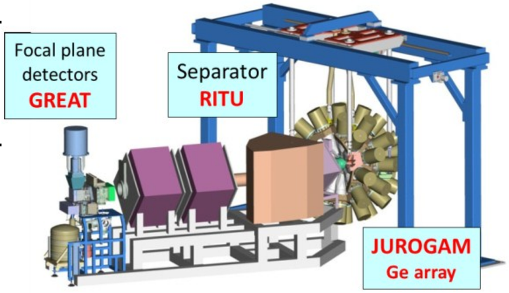




M. Sandzelius et al., Zakopane 2014

Calc.: A. Sobiszewski

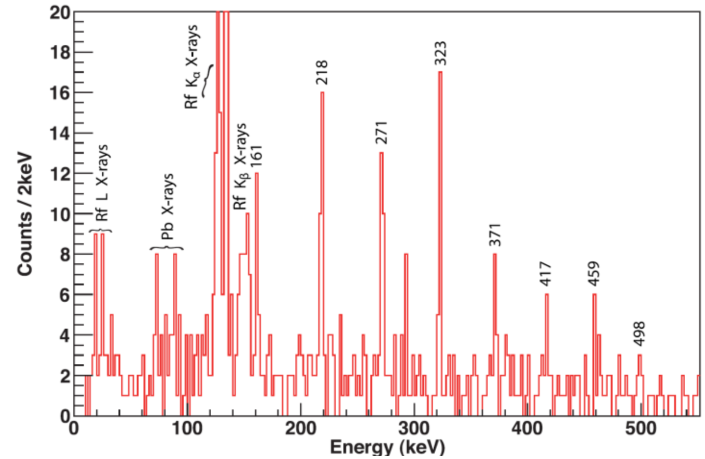
Shell-structure and pairing interaction in superheavy nuclei:
Rotational properties of the Z=104 nucleus ^{256}Rf

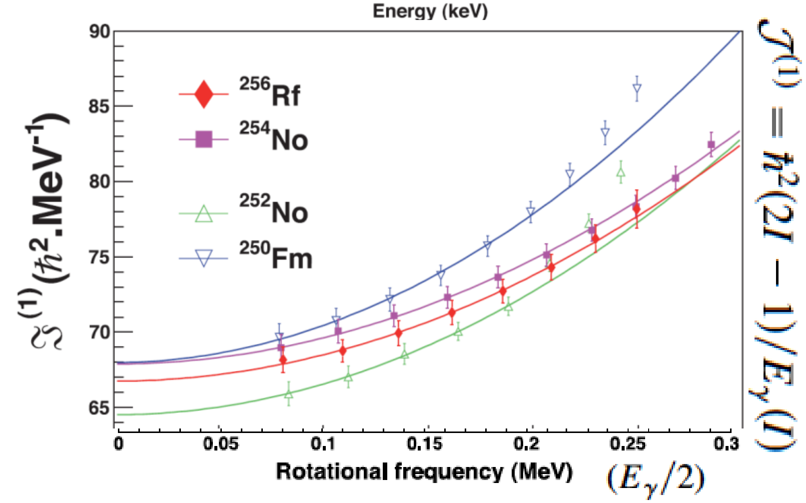


JYFL - Jyväskylä

At the high-Z limit of in-beam spectroscopy:

- $^{208}Pb(^{50}Ti,2n)^{256}Rf$ - 17nbarn
- Gammapool detectors + RITU-GREAT
- High rates with digital electronics
- Strasbourg contribution in beam development





c At a deformed shell gap, the pairing correlations are weakened, which in turn leads to a larger moment of inertia. This seems to be borne out by the behavior of the moments of inertia ı

available. It might also be expected that if there is a significant shell gap at $Z = 104$, that the moment of inertia of ^{256}Rf would be larger than that of the isotone ^{254}No.

Selected for a Viewpoint in Physics
PRL 109, 012501 (2012) PHYSICAL REVIEW LETTERS week ending 6 JULY 2012

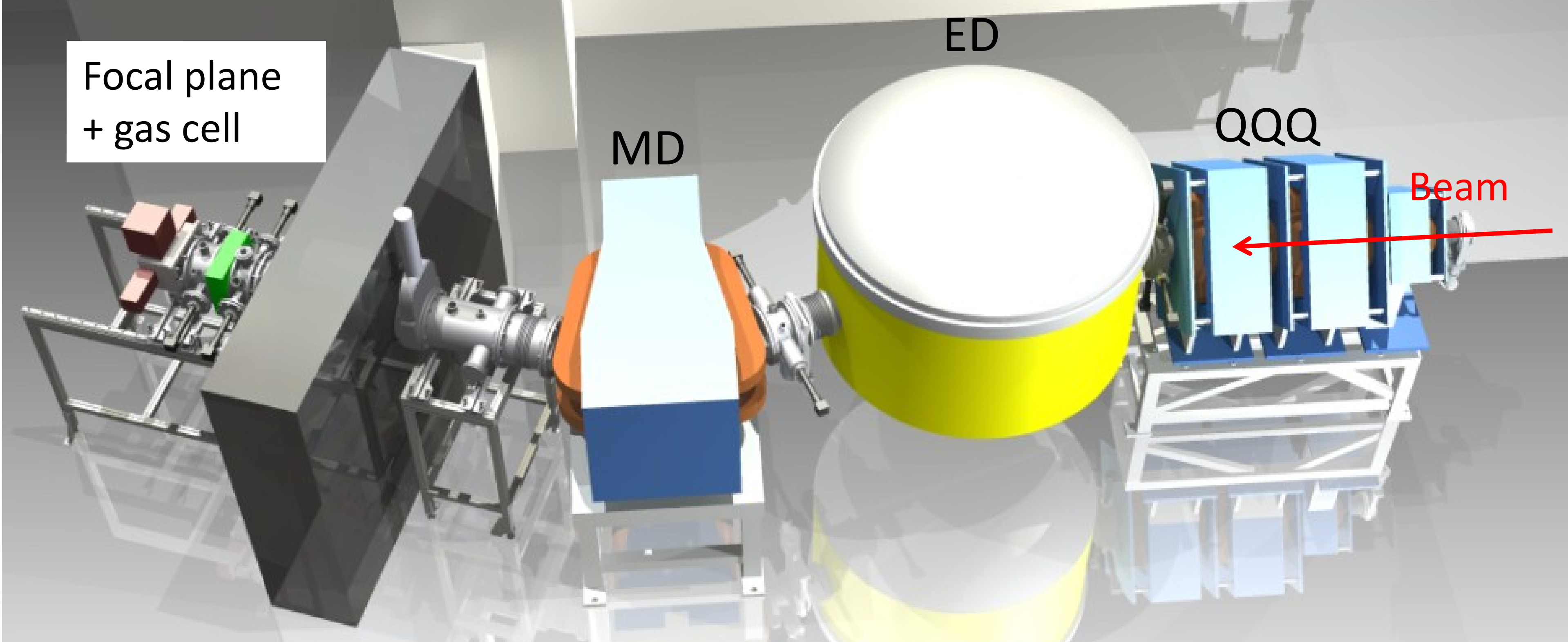
Shell-Structure and Pairing Interaction in Superheavy Nuclei: Rotational Properties of the Z=104 Nucleus ^{256}Rf

P. T. Greenlees [1,*] J. Rubert [2] J. Piot [2] B. J. P. Gall [2] L. L. Andersson [3] M. Asai [4] Z. Asfari [2] D. M. Cox [3] F. Dechery [5]

$J^{(1)}$ → no Z = 104 shell gap

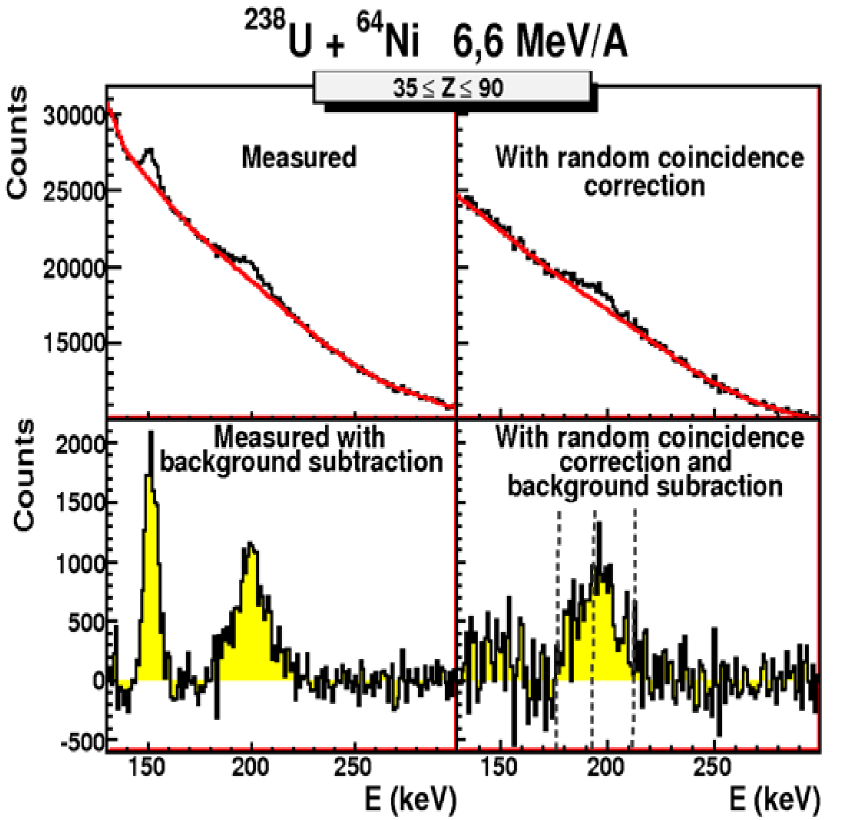
JYFL – Jyväskylä: MARA ready soon

A new vacuum-mode separator – MARA
→ better mass selection in RDT experiments



- Solid angle acceptance (central m/q and energy) 10 msr
- Typical transmission ~12% per charge state

Fission life-times : a link towards the production of SHE



M .O. Frégeau et al., Phys. Rev. Lett. 108, 12270 (2012)

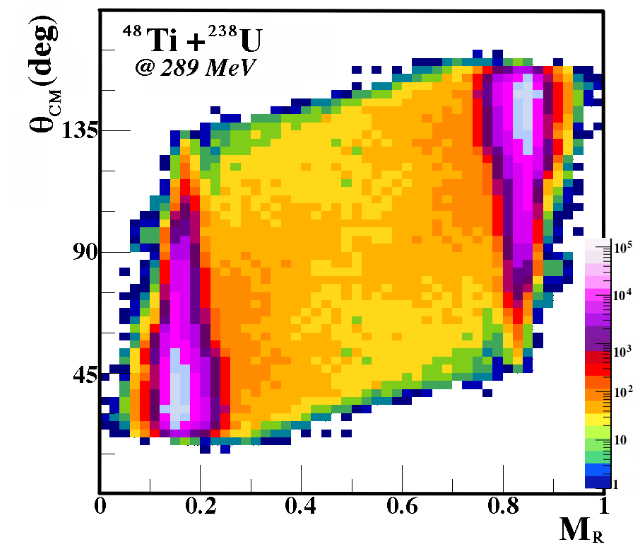
- ***X_K fluorescence of the atom with 120 protons has been observed.***
- ***Compound nucleus lifetime of the order of the K-vacancy lifetime (~10^{-18}s)***

New Collaboration:

GANIL-IPNO-SPhN?-ANU

Measure in coincidence with X-rays

The angular distribution of fragments

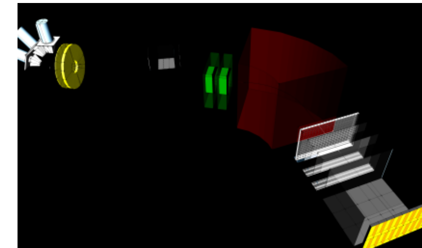


- Determination of the fusion components on 4π from X-ray fluorescence

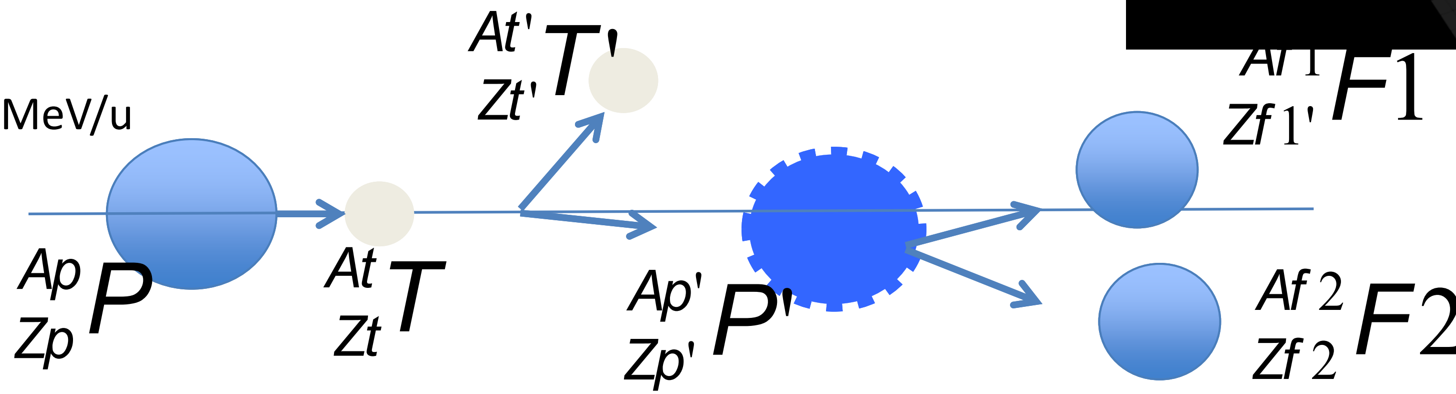
Reconcile the most probable fission times inferred from angular distributions with the average fission times inferred from direct measurements

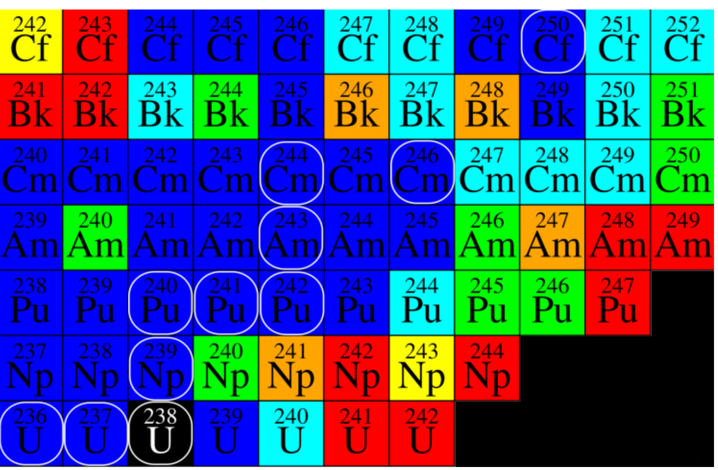
Transfer-induced fission in inverse kinematics @ GANIL

F. Farget et al., GANIL

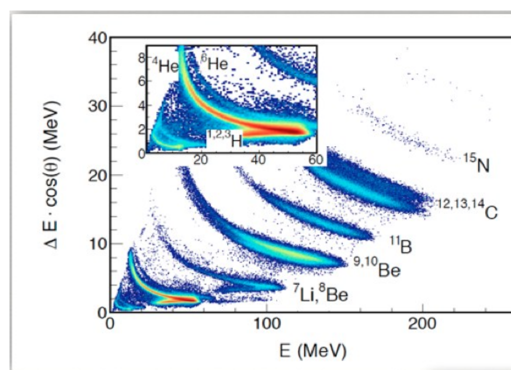


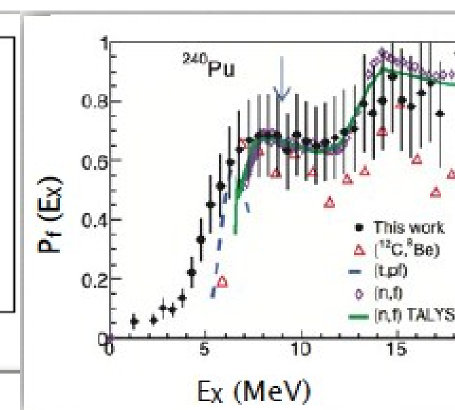
$^{238}U + ^{12}C$ @ 6.1 MeV/u





- 10 actinides produced
- E* distribution
- Full resolution in (Z,A) of fragments
- TKE

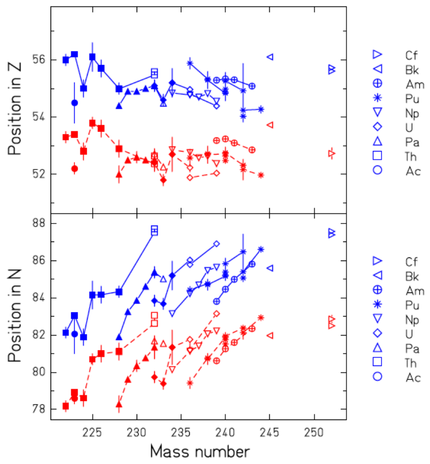


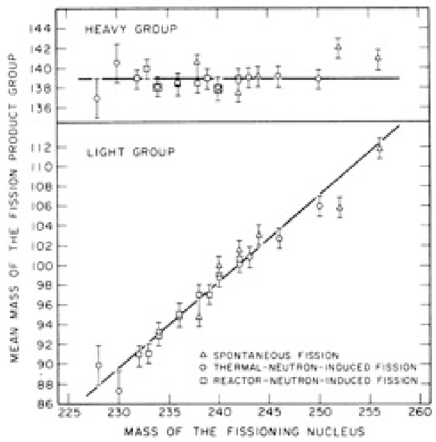


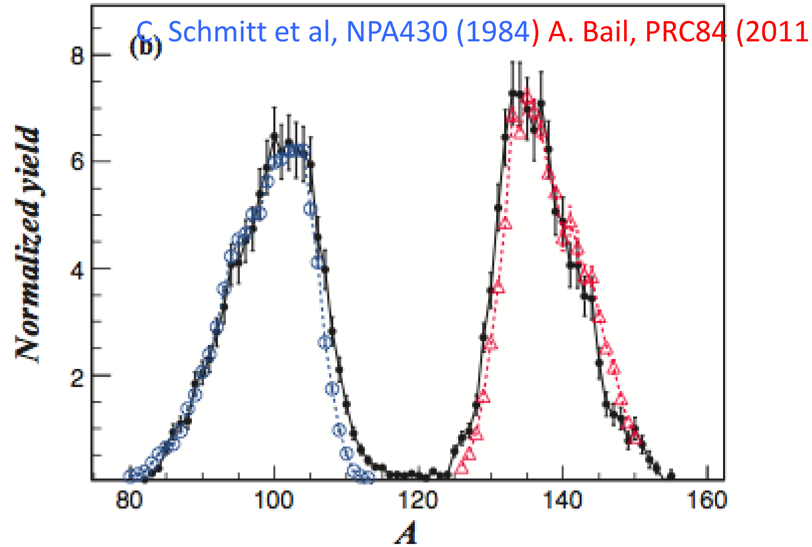
Applications reactor heat, radio toxicity control

Isotopic distribution of fission fragments : Open Questions

F. Farget et al., GANIL

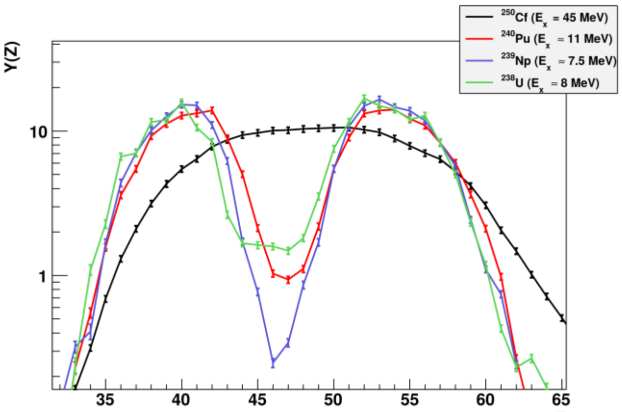


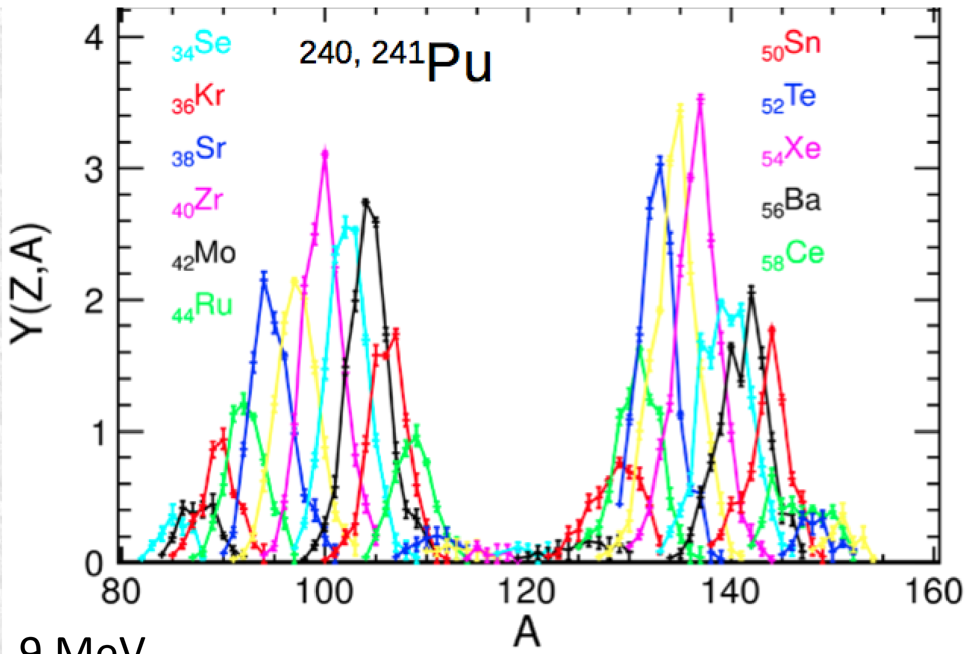




Z=54: N=82;86-90

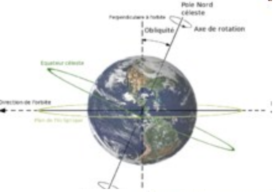
M. Caamaño et al., PRC 88 (2013) 024605

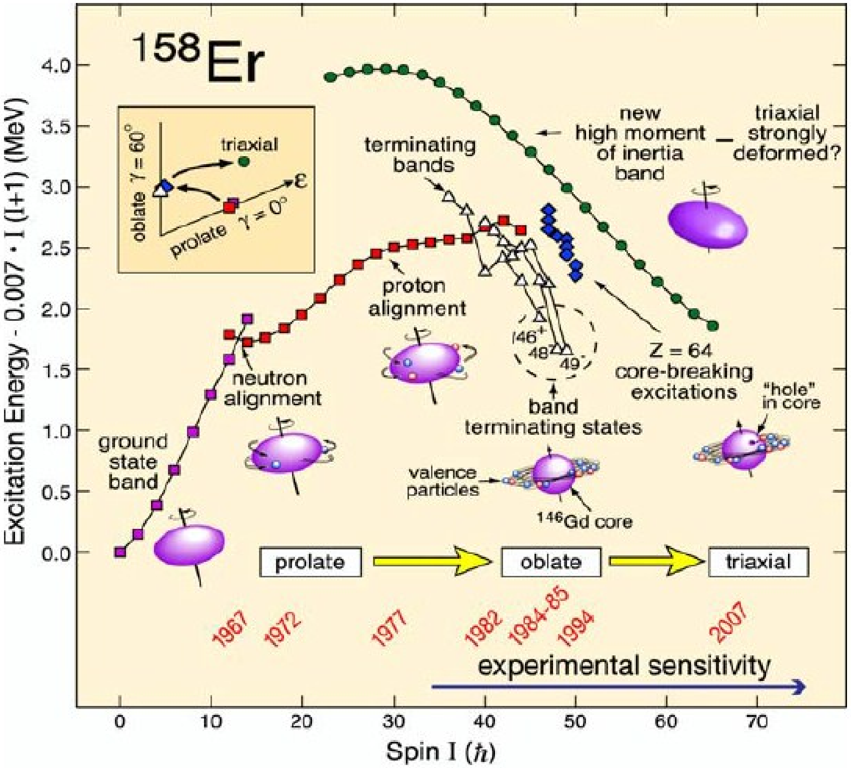




9 MeV

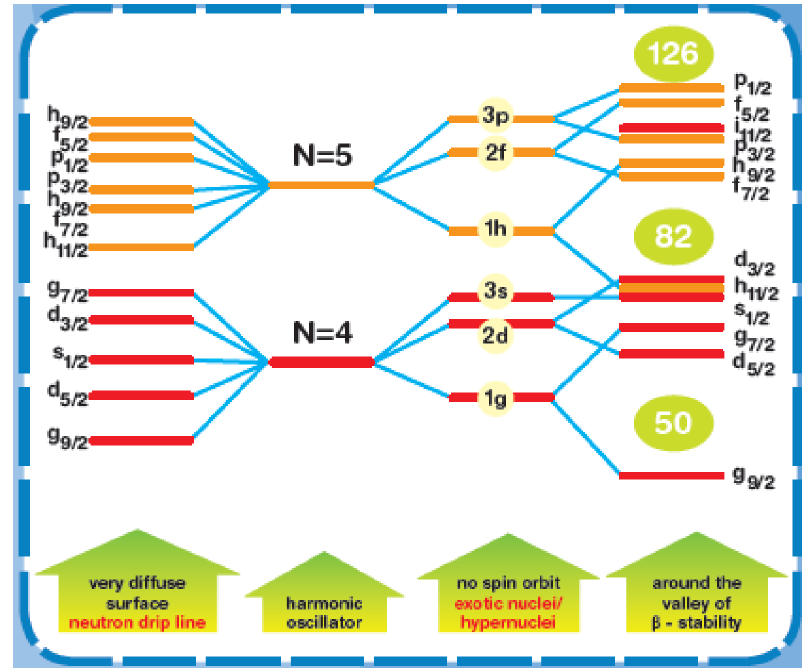
What happens when an exotic nuclei undergoes fast rotation
Is this the next question we want to address

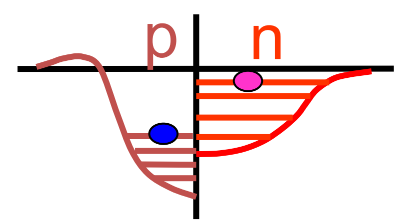


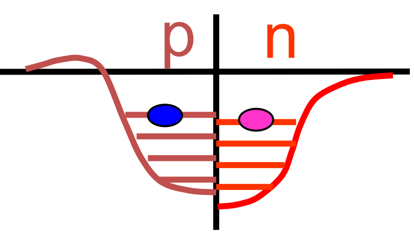


AIP Conf. Proc. 1498, 84 (2012)

+

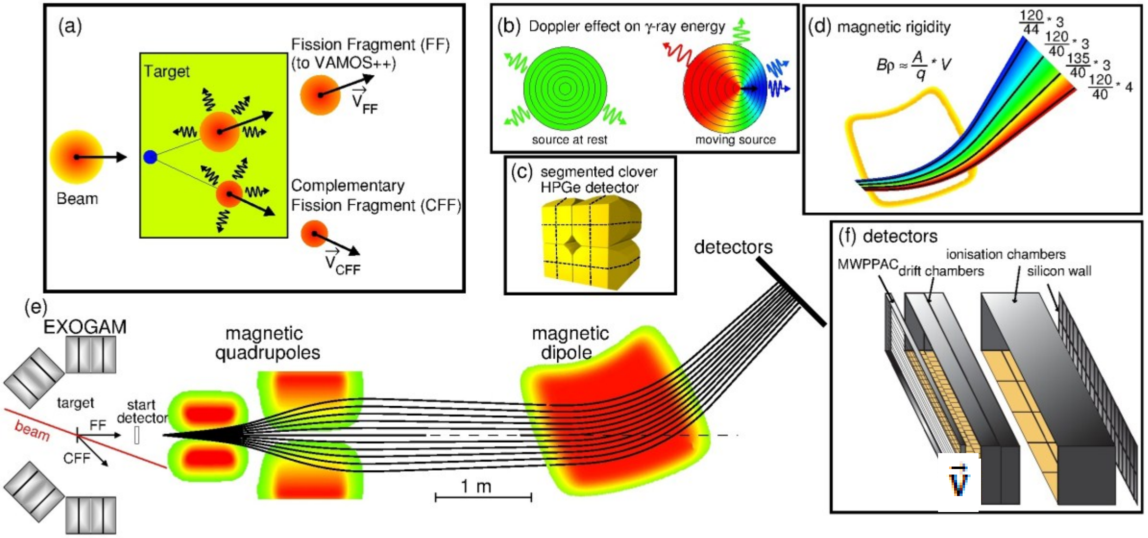


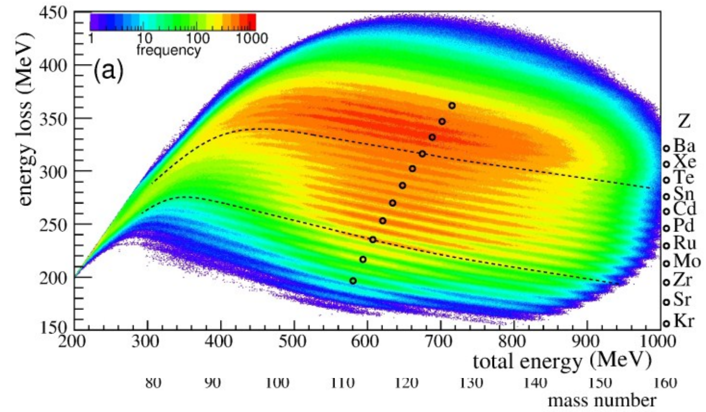


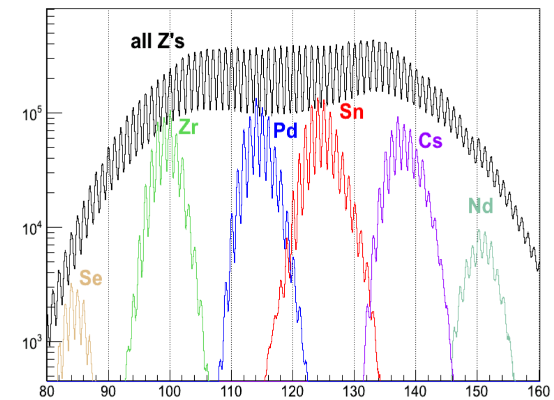


Look for new "effects"
With the next level of sensitivity

Prompt spectroscopy of M and Z identified fission frag







$^{238}U+^{9}Be$ at 6 Mev/U

Tomorrow AGATA@GANIL

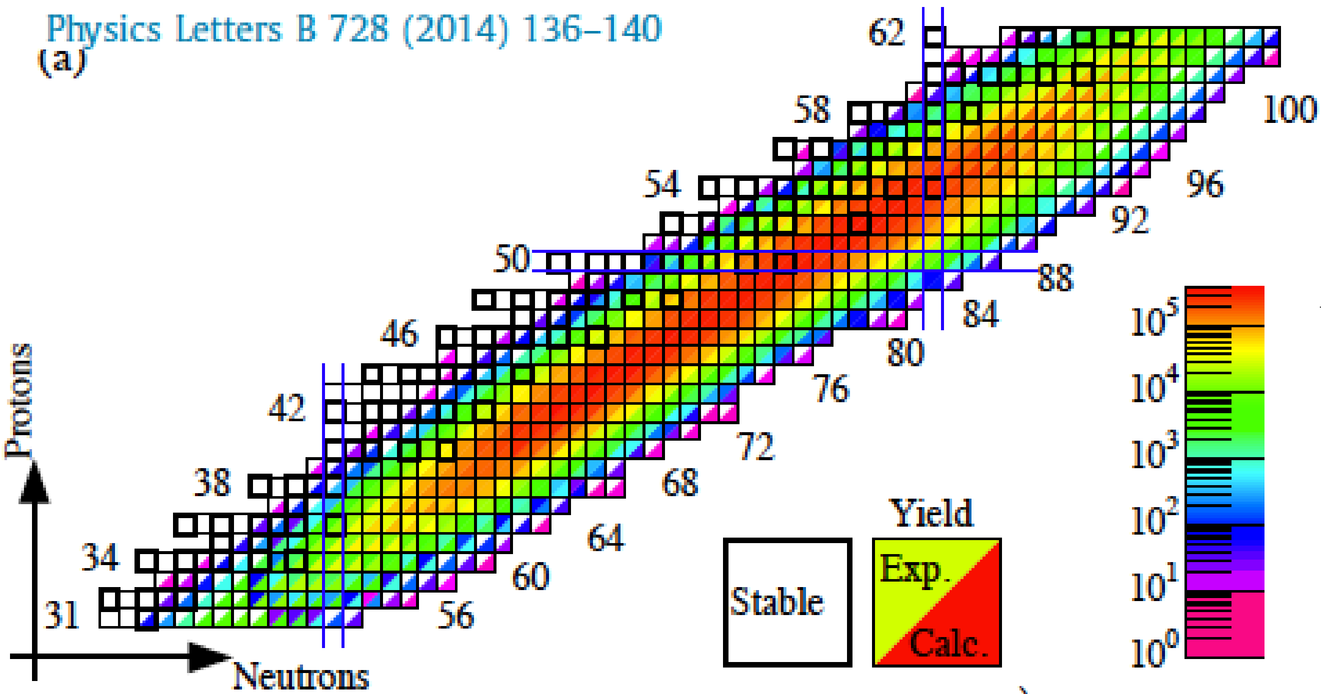
Thus uniquely identify M and Z
Doppler correction for the emitted γ rays
$\vec{V}$ of the fragment & angle of the segment of the clover detector

A. Navin and M. Rejmund
McGraw-Hill Yearbook of Science & Technology (2014) pg

Fission fragment spectroscopy

Towards The next frontier of Nuclear Physics: High Spin ***and*** Isospin

Physics Letters B 728 (2014) 136–140



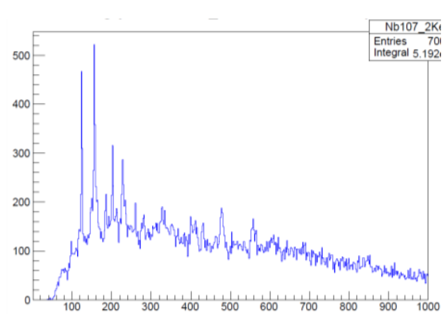
Limit of Mass distb^n from

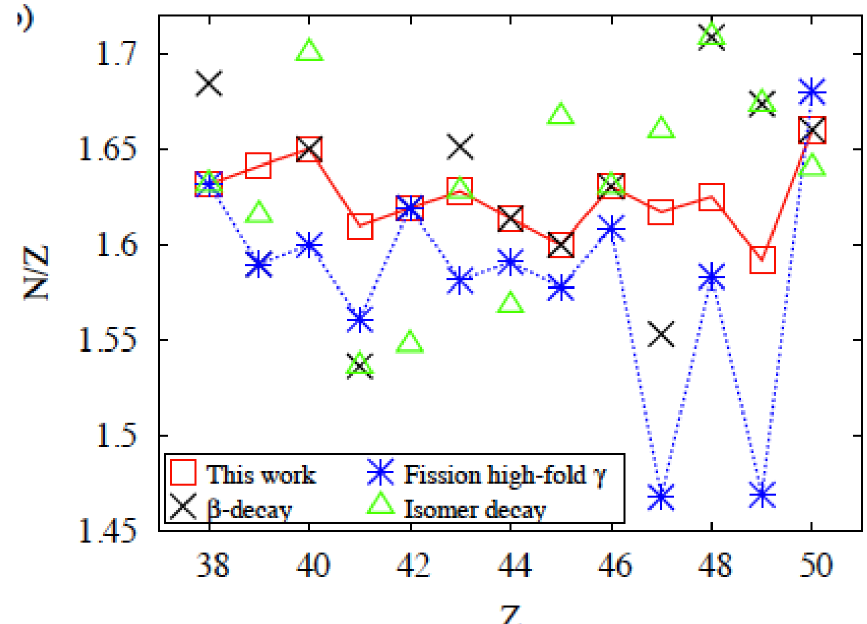
The Fission mechanism

Not acceptance

Measurements of Yields and Gamma rays

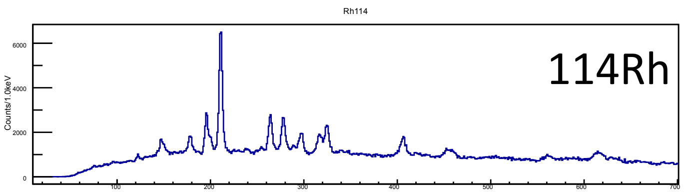
FF yields as low as ~2.5 ·10^{-5} measured (^{106}Zr)

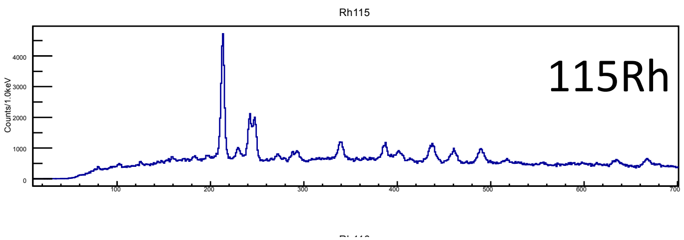


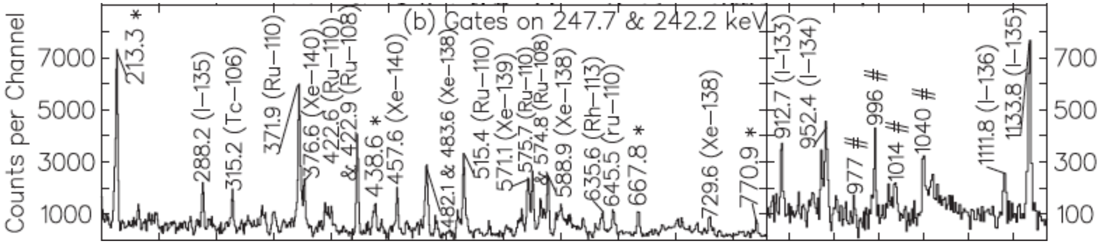


II)

Neutron Rich $_{45}$Rh







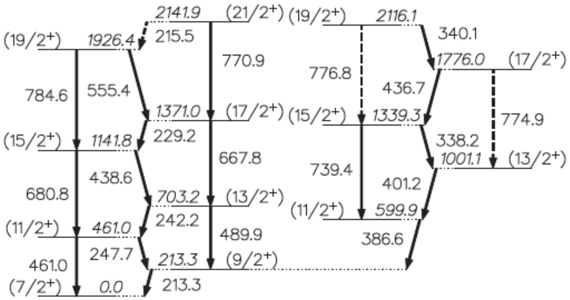
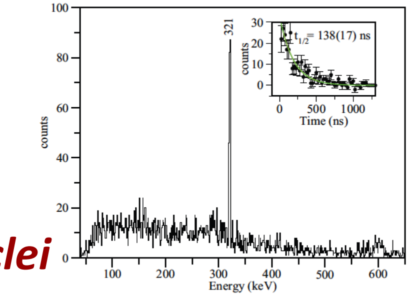


FIG. 1. A high-spin level scheme of ^{115}Rh built in the present

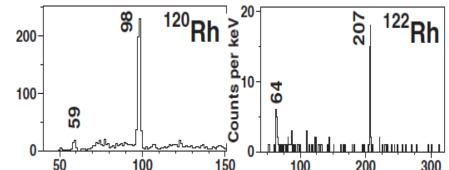
γ- spectroscopy till ^{115}Rh (Cf γ-Sphere γ–γ–γ–γ)
S.H. Liu et al., PRC 84 014304 (2011)

Isomer 138ns ^{117}Rh (GSI)
S. Lakovski et al. PRC 88 024302 (2013)

0.29, 0.82 μsecs ^{120,122}Rh
D. Kameda et al., Phys. Rev. C 86, 054319 (201



regular and simple patterns
that emerge
in the structure of complex nuclei

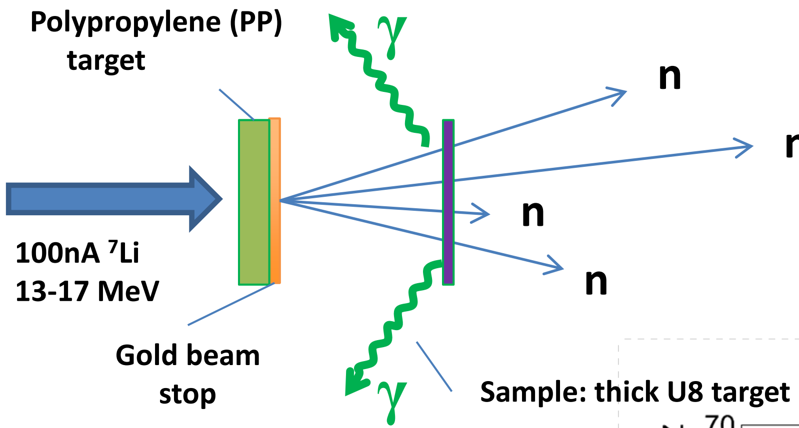


Work in progress

Lithium Inverse Cinematiques ORsay Neutron source

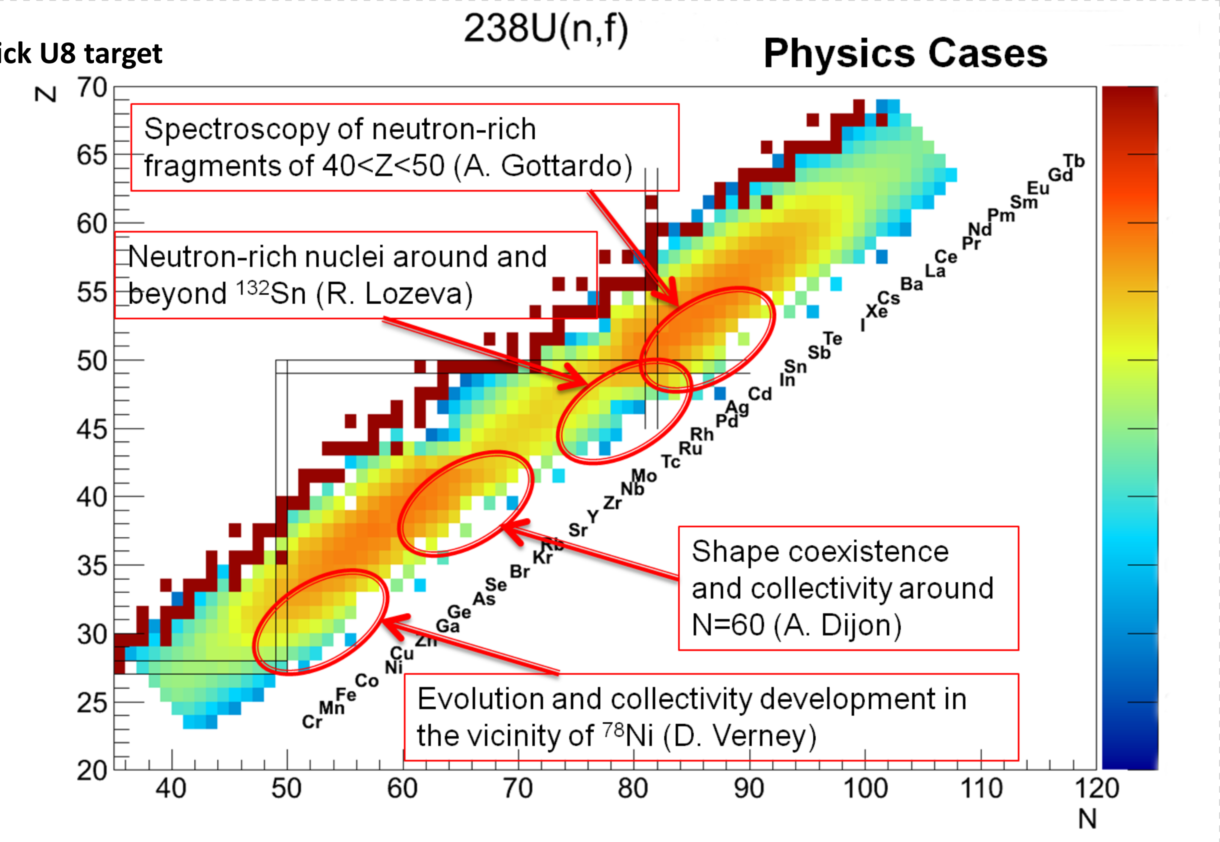
LICORNE

First LICORNE – ORGAM coupling: January 2014



- Isomer tagging of fission partners
- H2 to replace PP target
- following experiment at IPN : ORGAM and Miniball (MINORCA)

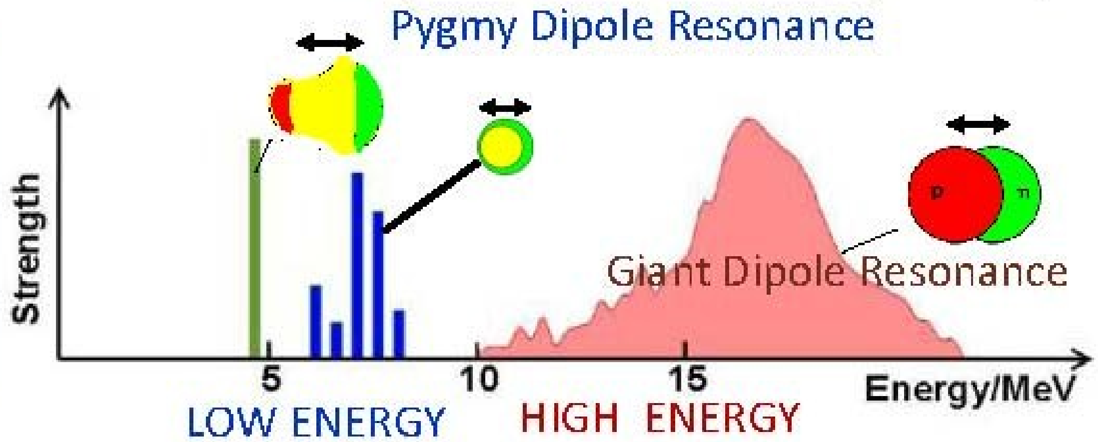
Intense focused monoenergetic neutron source:
10^7 n/s/steradian



Isoscalar Component of the PDR for Nuclei with n-excess

Nuclear Structure information from the Low Energy part of the Electric Dipole response

The relevant energy window for (γ,n) reactions in the stellar photon bath is located in the vicinity of the PDR.

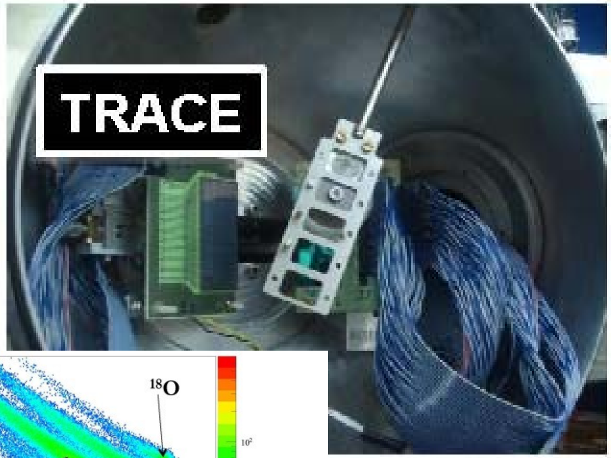


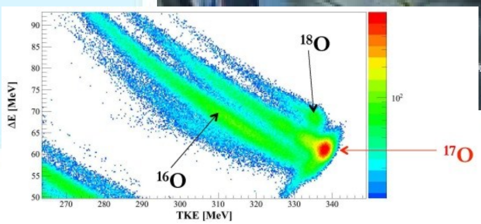
Inelastic scattering of ^{17}O @ 20 MeV/u on different targets + γ-rays in coincidence

TWO EXPERIMENTS PERFORMED:

- Studied Nuclei: **208Pb 90Zr**
  R. Nicolini (Università di Milano /INFN)
  D.Mengoni (Università di Padova/INFN)

- Studied nuclei: **208Pb, 124Sn,140Ce**
  M. Kmiecik (IFJ PAN Kraków) ,
  F. Crespi (Univ. di Milano/INFN)



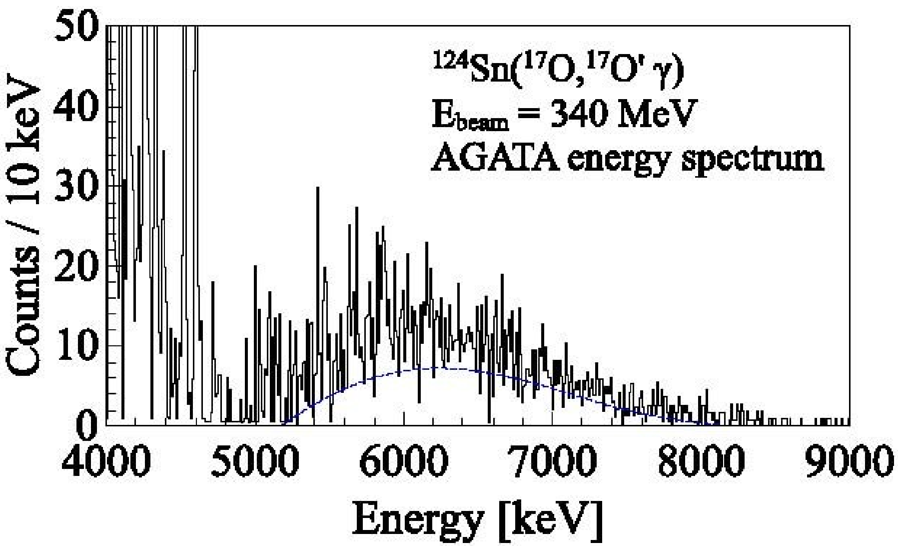


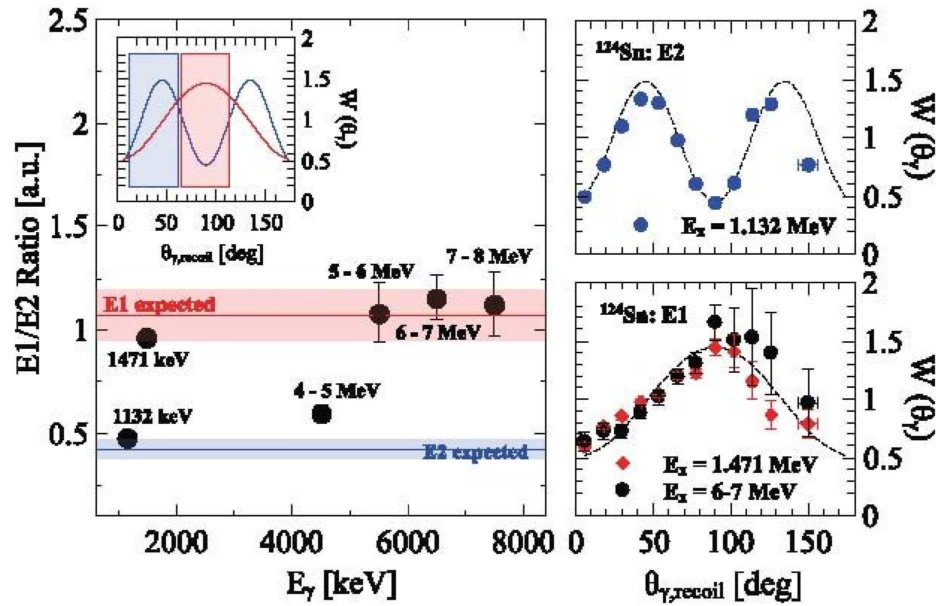
F.C.L. Crespi et al., EPJ WoC, INPC 2013

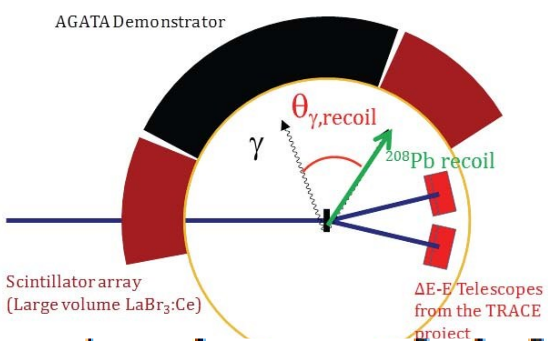
Pygmy Dipole Resonance in ^{124}Sn by inelastic scattering of ^{17}O
L. Pellegri Phys. Lett. B (in press)

Dominant Isoscalar excitation: n and p transition densities are **in phase** inside the nucleus, at **the surface only the n-part survives**

Inelastic scattering: Interaction Surface Peaked (^{17}O)





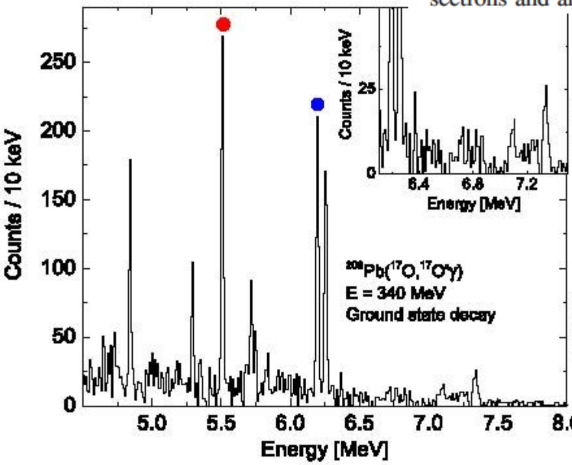


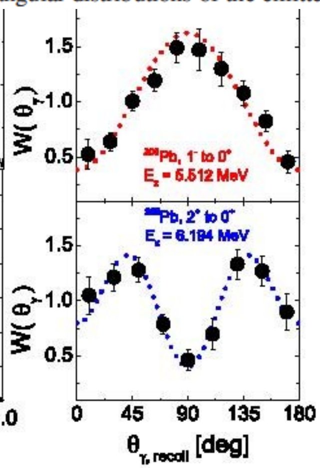
. The emitted γ rays were detected with high resolution with the AGATA demonstrator array and the scattered ions were detected in two segmented ΔE–E silicon telescopes.

Isospin character of low-lying pygmy states in ^{208}Pb via inelastic scattering of ^{17}O

F.C.L. Crespi et al., PRL 113, 012501 (2014)

The properties of pygmy dipole states in ^{208}Pb were investigated using the ^{208}Pb(^{17}O, ^{17}O'γ) reaction at 340 MeV and measuring the γ decay with high resolution with the AGATA demonstrator array. Cross sections and angular distributions of the emitted γ rays and of the scattered particles were measured. The



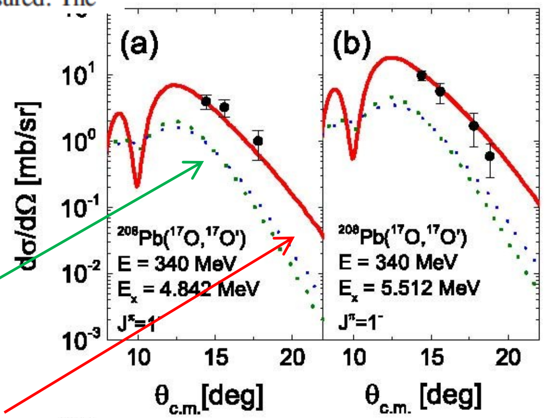


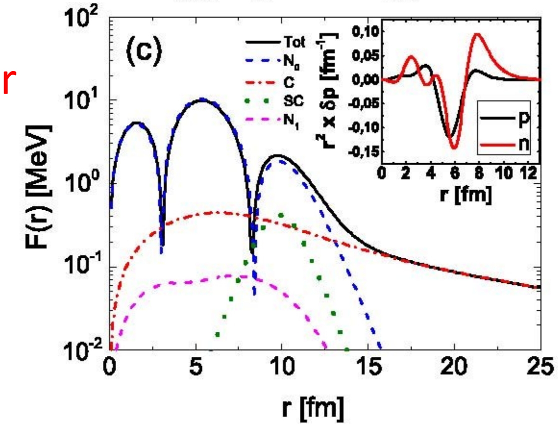
$^{208}Pb(^{17}O,^{17}O)^{208}Pb^*$

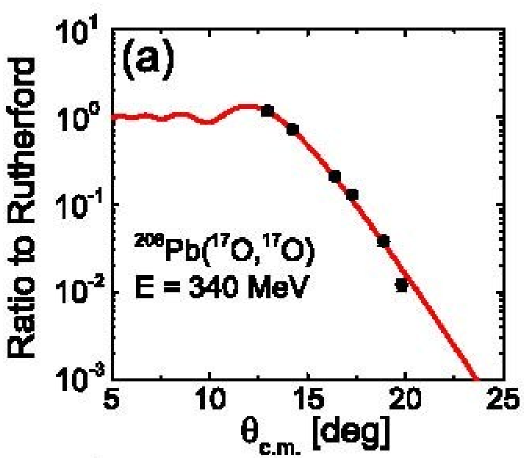
E1 at 4.85 MeV and 5.54 MeV

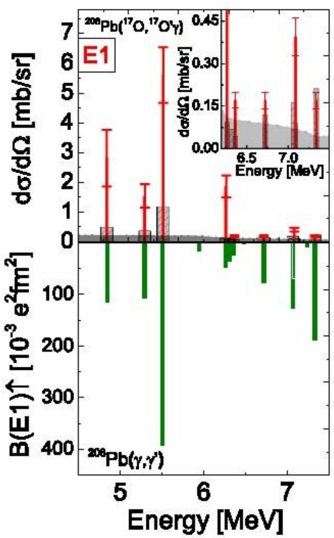
Phenomenological form factor, isovector

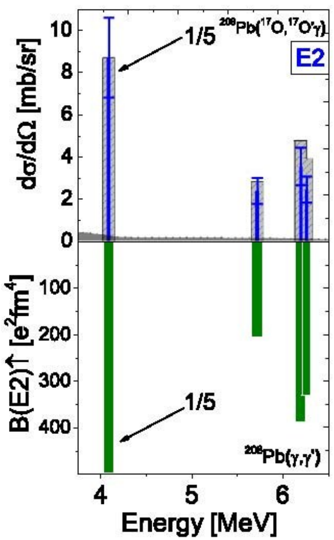
nuclear contribution microscopic form factor











Nuclei with n-excess show low-lying dipole strength with strong isoscalar component

PRL 113, 012501 (2014) PHYSICAL REVIEW LETTERS week ending 4 JULY 2014

Isospin Character of Low-Lying Pygmy Dipole States in ^{208}Pb via Inelastic Scattering of ^{17}O Ions

. The $E1$ transitions cross sections for ^{208}Pb were analyzed for the first time using a microscopic form factor and the isoscalar potential was found to depend on the presence of the neutron skin. A

Doctopic: Experiments ARTICLE IN PRESS PLB:30434

Physics Letters B ••• (••••) •••–•••

Contents lists available at ScienceDirect

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www.elsevier.com/locate/physletb

ELSEVIER

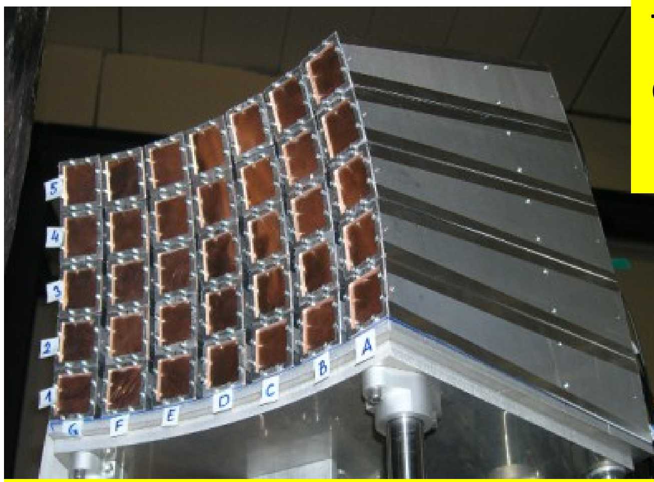
Pygmy dipole resonance in ^{124}Sn populated by inelastic scattering of ^{17}O

For the 1^- states a DWBA analysis based on a microscopically calculated form factor was performed and showed a sensitivity to the surface part of the transition density. Being the transition density dominated on the surface by the neutron component one can deduce that the pygmy states ^{124}Sn are associated with the excitation of surface neutrons, mainly those in the neutron skin. Therefore in the future it will be very interesting to perform these studies on the isotopic chain of Sn and other neutron-rich nuclei also using other probes as protons at medium energy.

Cyclotron Center Bronowice
Institute of Nuclear Physics Polish Academy of Sciences
Krakow, Poland

A) Study of collective modes excited by high-energy protons

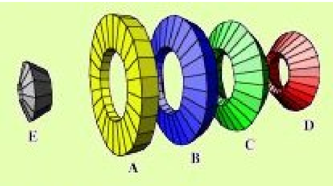
1. **HECTOR** array to measure high energy gamma-rays



2. **KRATTA** array (triple CsI telescopes) at forward direction to measure the energy of inelastically scatter protons

3*. **PARIS** Demonstrator for PDR measurements with high-resolution, in coincidence with KRATTA

** - in dedicated campaigns*



Hot GDR study in nuclei in the mass region A~120-132 with MEDEA at LNS

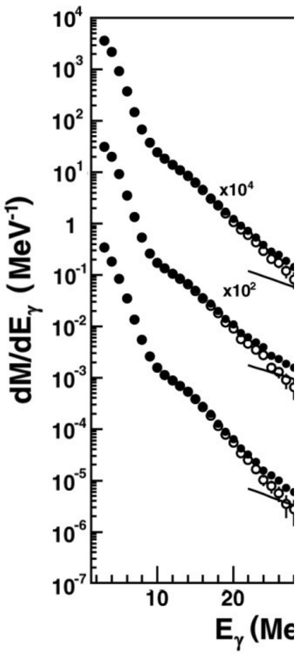
	E^*	A_{res}
$^{116}Sn+^{12}C$ 17*A* MeV	150	124
$^{116}Sn+^{12}C$ 23*A* MeV	190	123
$^{116}Sn+^{24}Mg$ 17*A* MeV	270	132

Onset of the quenching of the Giant Dipole Resonances at high excitation energies

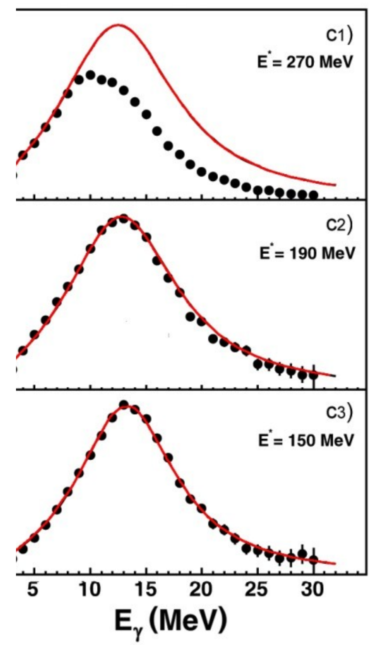
D.Santonocito[a], Y.Blumenfeld[b], C. Agodi[a], R.Alba[a], G. Bellia[a),c], R. Coniglione[a], F. Delaunay[b)*], A. Del Zoppo[a], P. Finocchiaro[a], F. Hongmei[a], V. Lima[b], C. Maiolino[a], E. Migneco[a),c], P.Piattelli[a], P. Sapienza[a], J.A. Scarpaci[b)†], O.Wieland[d]

The evolution of the Giant Dipole Resonance properties in nuclei of mass A = 120-132 has been investigated in an excitation energy range between 150 and 270 MeV through the study of complete and nearly complete fusion reactions. Evidence of a quenching of the GDR gamma yield was found at 270 MeV excitation energy.

A limiting excitation energy for the collective motion of about ***E*/A ~ 2 MeV/A*** *was exctracted.*



ao mass $A \sim 132$. Evidence of a limiting excitation for the collective motion was also extracted in nuclei of mass $A = 60 \div 70$ but the value of about $E^*/A \simeq 5$ MeV, differs significantly from the ones measured for nuclei in the mass region $A = 105 \div 135$ suggesting the existence a mass dependence of the limiting excitation energy per nucleon, for the collective motion. Interesting similarities in trend and absolute values can be found when comparing the limiting excitation energy for the collective motion with the energy at which the plateau of the caloric curve sets in, indicating the onset of liquid-gas phase transition. This feature suggests a possible link between GDR disappearance and liquid-gas phase transition which deserves further investigation from both theoretical and experimental points of view. In particular extending the systematics of the GDR to hot nuclei with $A = 160 \div 180$ could provide further information on the possible link between GDR disappearance and liquid-gas phase transition and therefore shed additional light on the mechanism responsible for the GDR quenching.



a) Solid symbols re... reactions. Open symbols represent the spectra after bremsstrahlung subtraction.

b) Statistical gamma spectra compared to CASCADE calculations shown as red lines.

c) Linearized Spectra compared to Lorentzian function used in the calculation for each reactions.

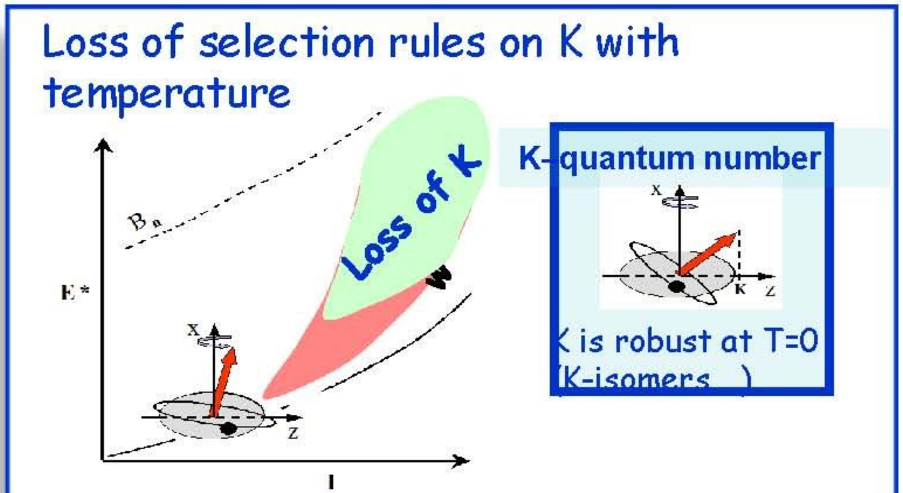
^{174}W: ORDER-TO-CHAOS TRANSITION

HIGH TEMP

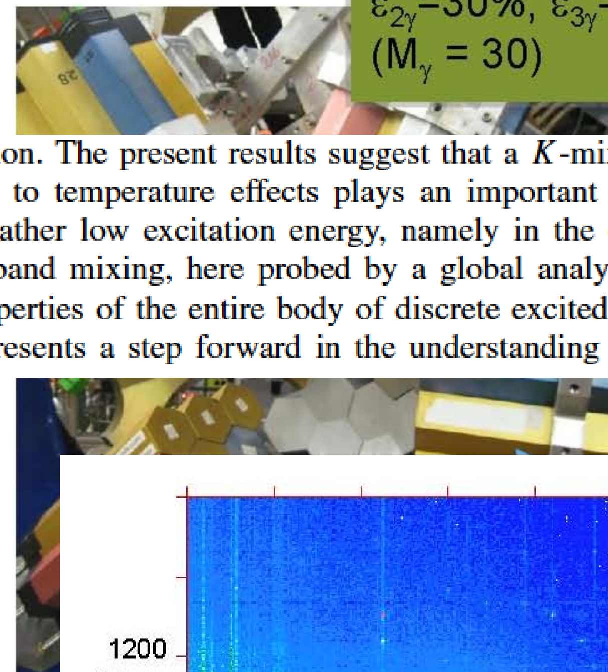
QUASI-CONTINUUM γ-γ MATRICES

HIGH TEMP

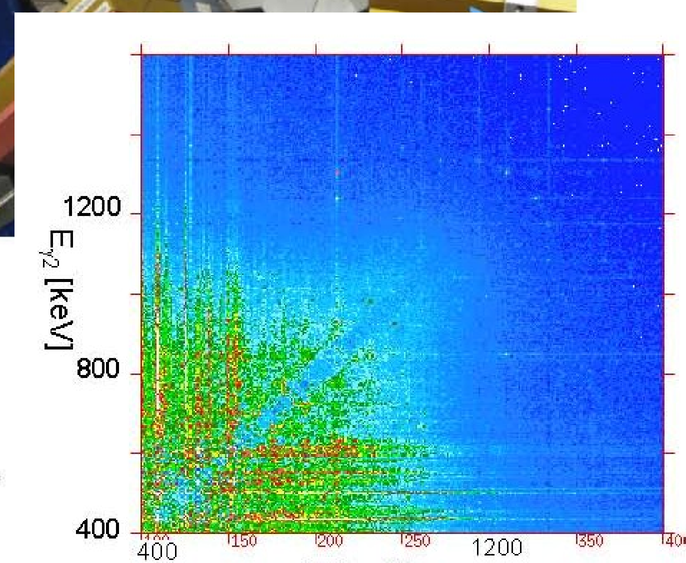
High-Spin Fusion Evaporation
^{50}Ti on ^{128}Te @ 217 MeV, I ≥ 60ħ



4 Triple Clusters
2 and 3 folds:
$\varepsilon_{2\gamma}$=30%, $\varepsilon_{3\gamma}$=10%
(M_γ = 30)



region. The present results suggest that a *K*-mixing process due to temperature effects plays an important role already at rather low excitation energy, namely in the onset region of band mixing, here probed by a global analysis of decay properties of the entire body of discrete excited bands. This represents a step forward in the understanding of the basic



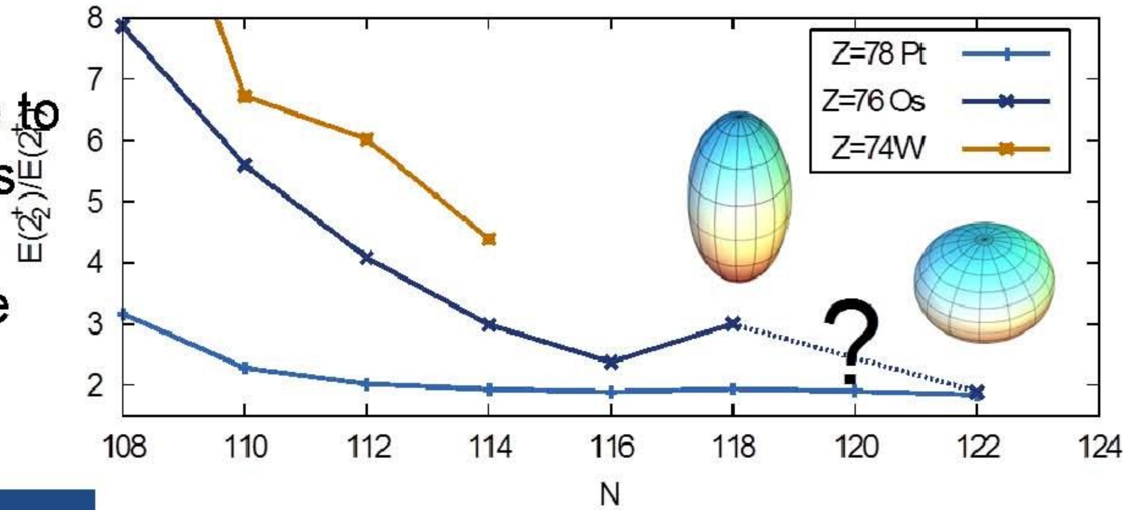
Goal: populate ^{174}W at the **highest possible spins** (≥60ħ), in order to make the **statistical fluctuation analysis of the ridge-valley structures in the γ-γ matrices**, to estimate the number of low-*K* and high-*K* bands and their correlation

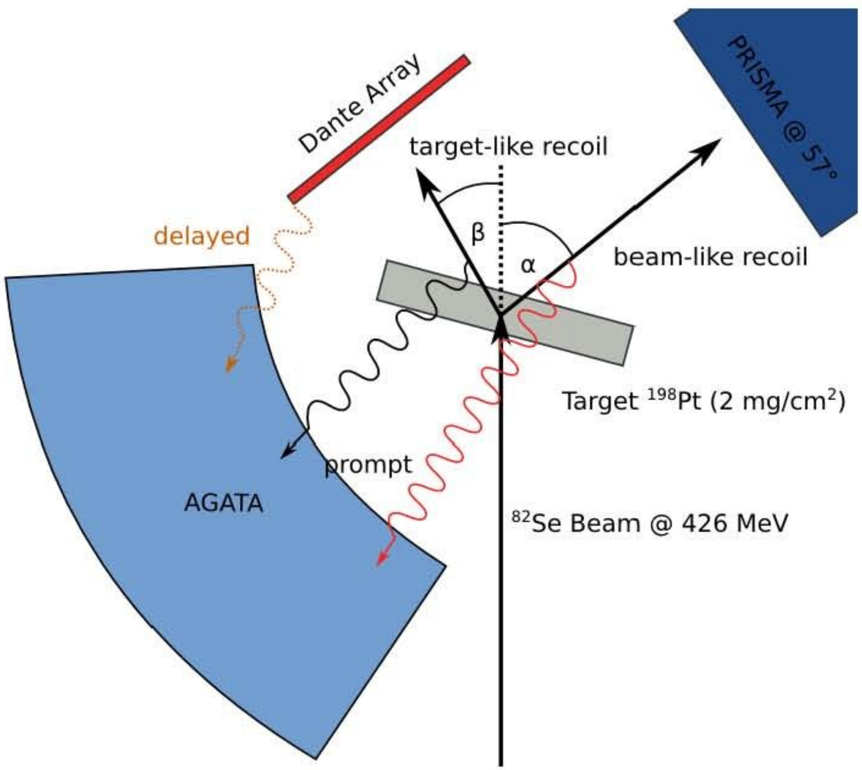
PHYSICAL REVIEW C **88**, 034312 (2013)

V.Vandone et al. **Global properties of *K* hindrance probed by the *γ* decay of the warm rotating ^{174}W nucleus**

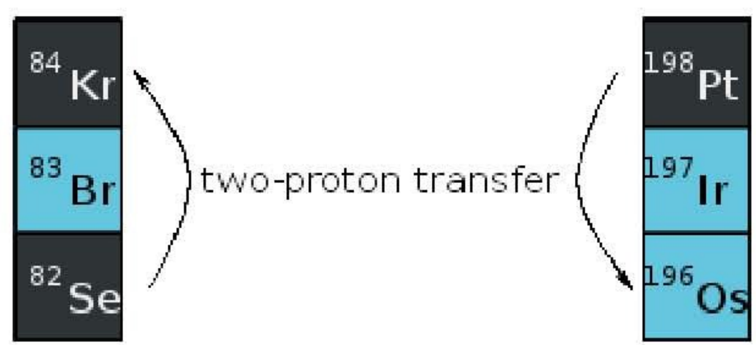
SHAPE TRANSITION IN THE OS ISOTOPES

- ❑Shape transoton from prolate to oblate deformed nuclei in the Os isotopes
- ❑ ^{194}Os suggested to be prolate
- ❑^{198}Os shows oblate character

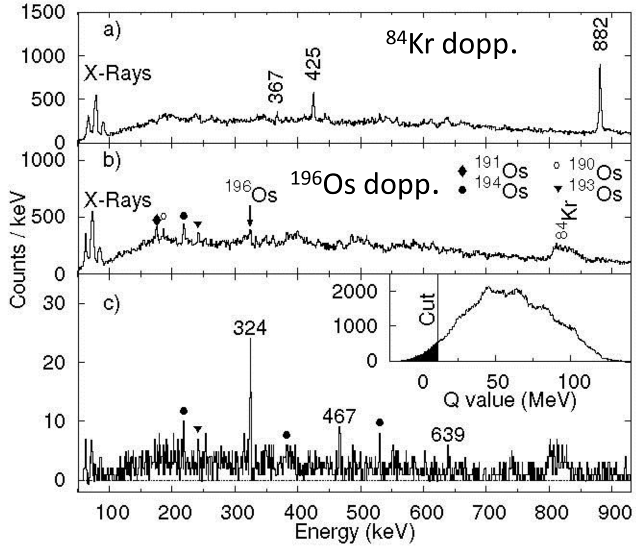


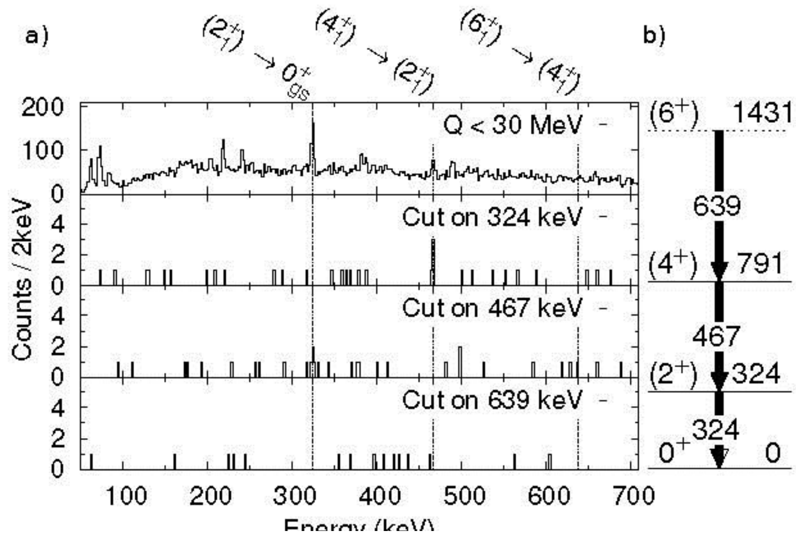


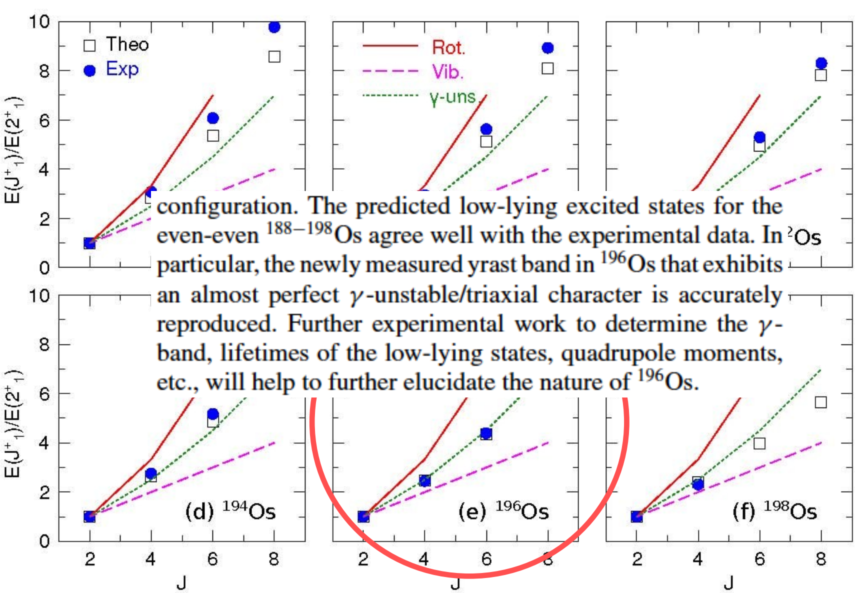
- ❑ Binary Partner Method
- ❑ ^{82}Se(^{198}Pt, ^{196}Os)^{84}Kr @ 426 MeV
- ❑Detect lighter beam-like recoil in PRISMA
- ❑ Reconstruct Spectrum for ^{196}Os



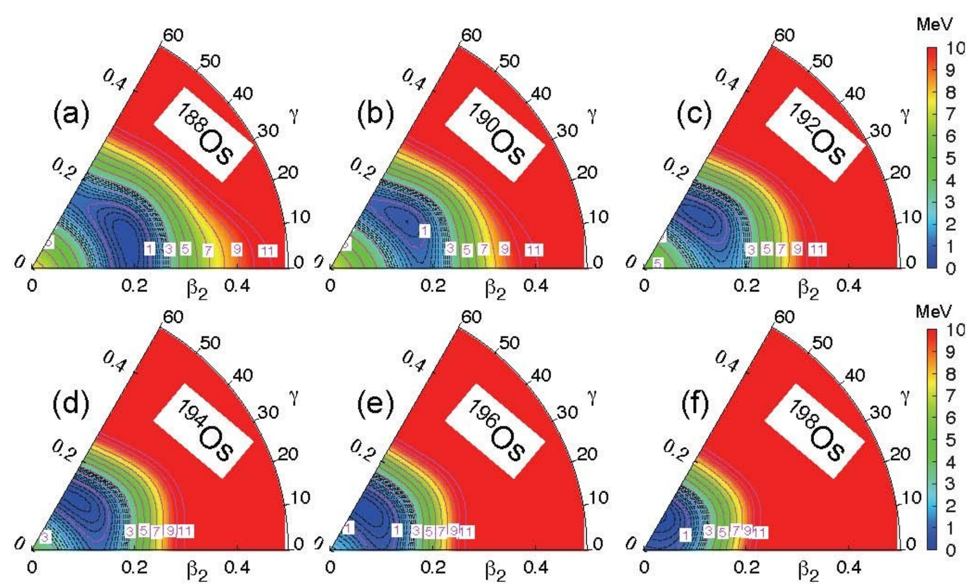
Shape evolution in the n-rich Os isotopes: prompt γ-ray spectroscopy of ^{196}Os
P.R. John et al. PRC 90 021301 (2014) rapid comm.







configuration. The predicted low-lying excited states for the even-even $^{188-198}$Os agree well with the experimental data. In particular, the newly measured yrast band in ^{196}Os that exhibits an almost perfect γ-unstable/triaxial character is accurately reproduced. Further experimental work to determine the γ-band, lifetimes of the low-lying states, quadrupole moments, etc., will help to further elucidate the nature of ^{196}Os.

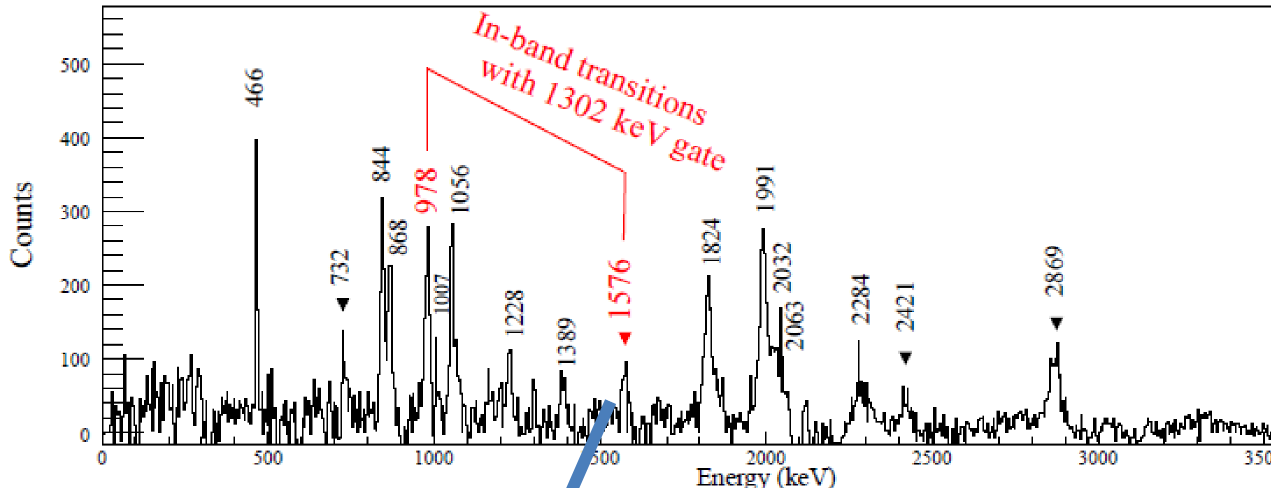


Beyond mean field with generator coordinate method
Mixing particle num. and ang. Mom. projected states

Superdeformation in A~40 nuclei

E. Ideguchi (RCNP, Osaka Univ.) – January 2013

Search for superdeformed bands in ^{35,36}S, ^{40}Ar via ^{18}O + ^{26}Mg -> ^{44}Ca*



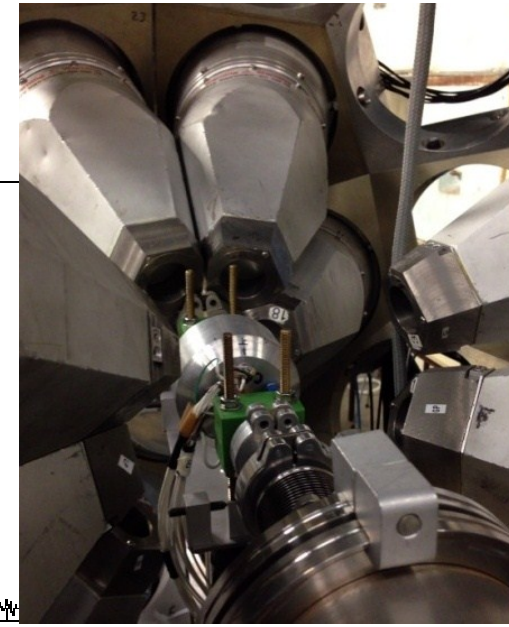


Fig. 1. γ-ray energy spectrum gated 1302-keV transition. The 1576-, 1302- and 978-keV transitions belong to the same band transition. The peaks labeled with the triangles are new transitions of ^{35}S.

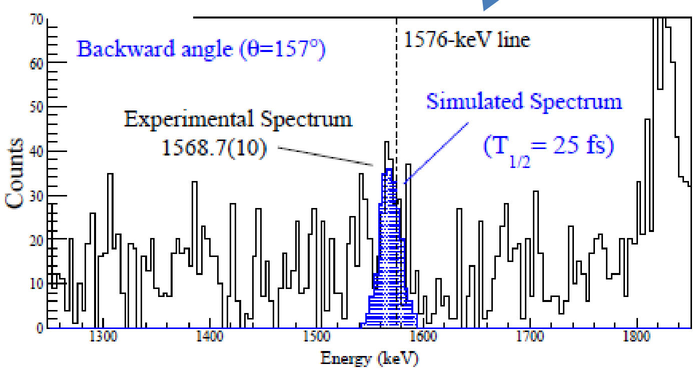


Fig. 2. Comparison between experimental and simulated spectra for the residual Doppler shifted 1576-keV peak in the forward and backward angles of the germanium detectors.

Investigations of the orbitals responsible for superdeformation in the mass region, f7/2, nearby are important to infer the existence of superdeformed states in ^{32}S.

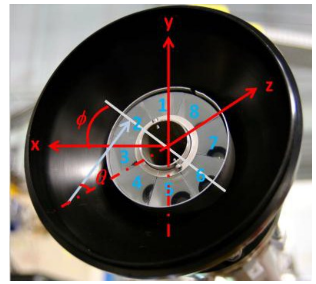
The de-excitation of the superdeformed band was observed from $19/2^-$ to $7/2^-$.The superdeformed band structure was highlighted by the measurement of half-life and relative intensities of the intra-band transition. The $f_{7/2}$ negative parity intruder orbital seems to be responsible for the negative

Shintaro GO (RCNP, Osaka University), ARIS2014 Proceedings

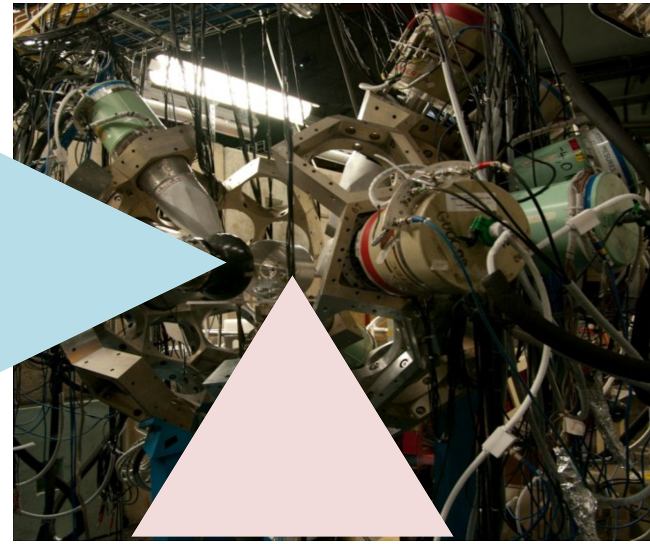
Time Dependent Recoil In Vacuum on H-like ions: ^{24}Mg - revisited

G. Georgiev (CSNSM), A.E. Stuchbery (ANU), Dec. 2012

- *Experiment:* High accuracy (< 2%) model independent (*B from first principles*) g-factor value for short-lived (ps) excited states
- *Theory:* g-factors of the 2^+ states in N=Z nuclei should be slightly higher than 0.5

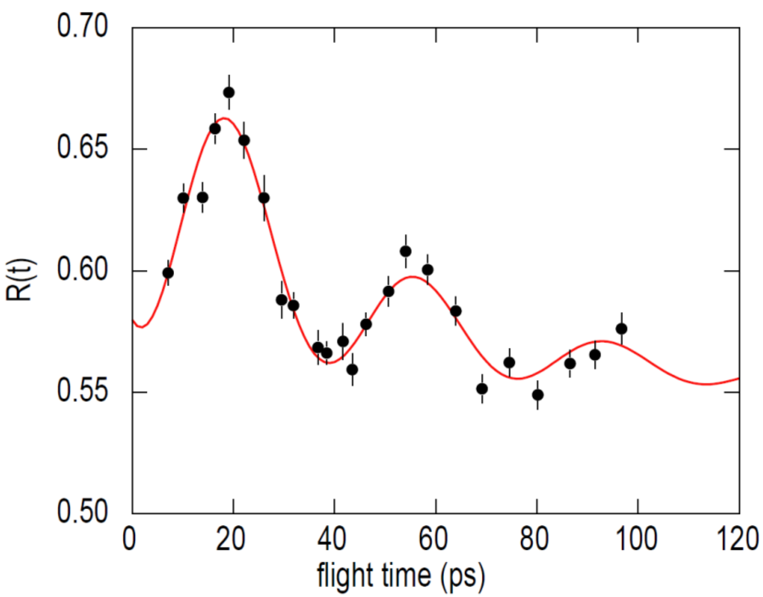


8-fold segmented annular detector

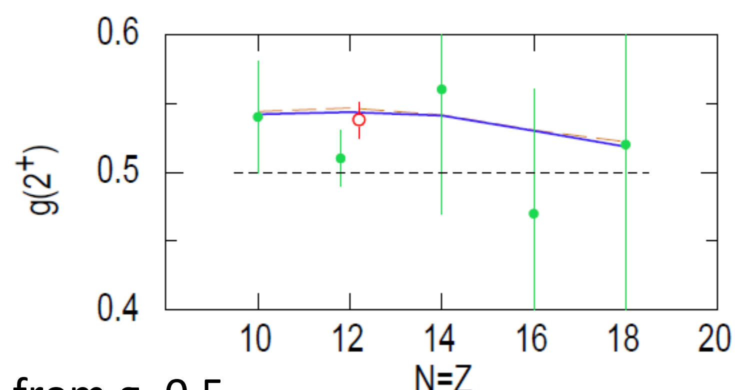


^{24}Mg+^{93}Nb coulex

OUPS (Orsay Universal Plunger System)



A. Kusoglu, A. Stuchbery, G. Georgiev *et al.*



Our result: first experimental evidence of deviation from g=0.5

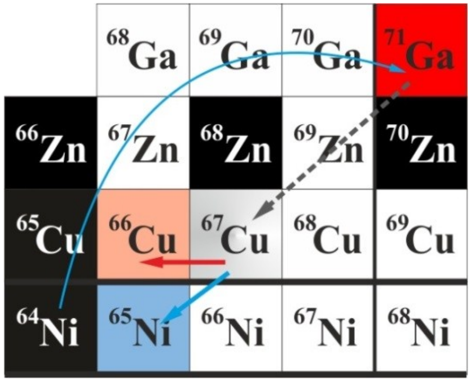
→ stringent test of the nuclear theories

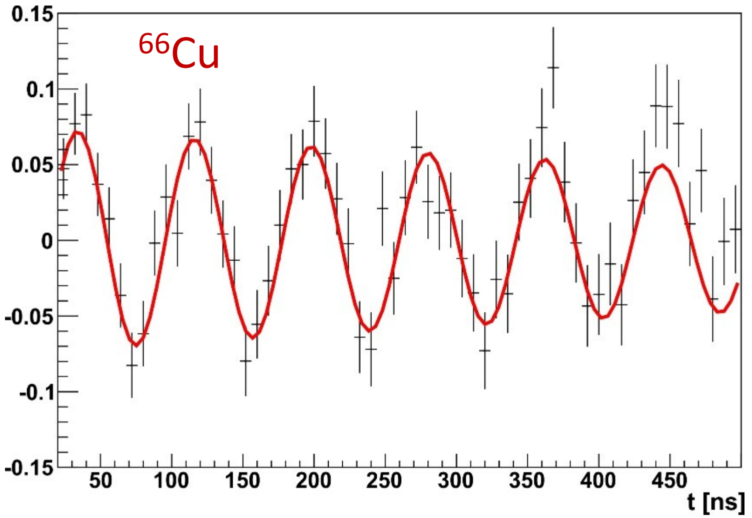
Nuclear spin orientation in incomplete fusion reactions

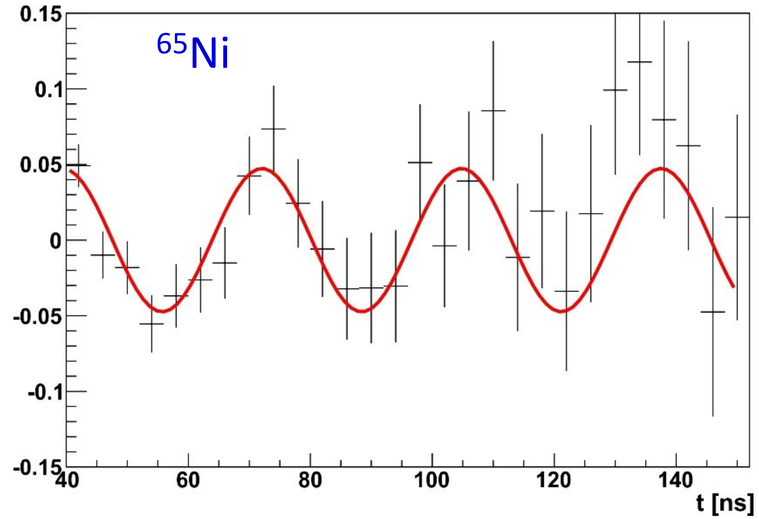
G. Georgiev (CSNSM) Dec. 2013

Nuclear spin orientation – a must for nuclear moments studies

- Fusion-evaporation reactions – **25 % - 75 %** alignment
- Projectile-fragmentation - **8 % - 13 %**
- Direct reactions (single-nucleon transfer) **~ 13 %**
- **Incomplete fusion** (multi-nucleon transfer?) – ???







Amplitude = 8 (1) %

Spin alignment = 23 (3) %

Amplitude = 4.8 (8) %

Spin alignment = 12.5 (20) %

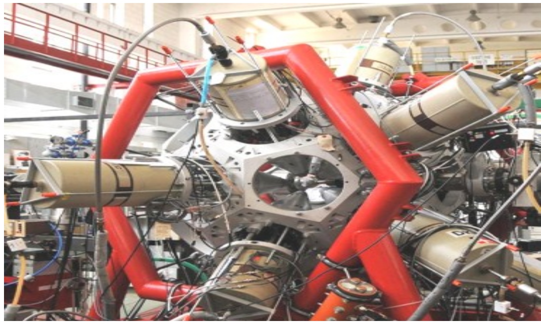
Results:

- considerable spin alignment in ^{7}Li induced reactions;
- dependence on the number of transferred nucleons?

$^{7}Li+^{64}Ni$
Triton 1n ,
triton1pn

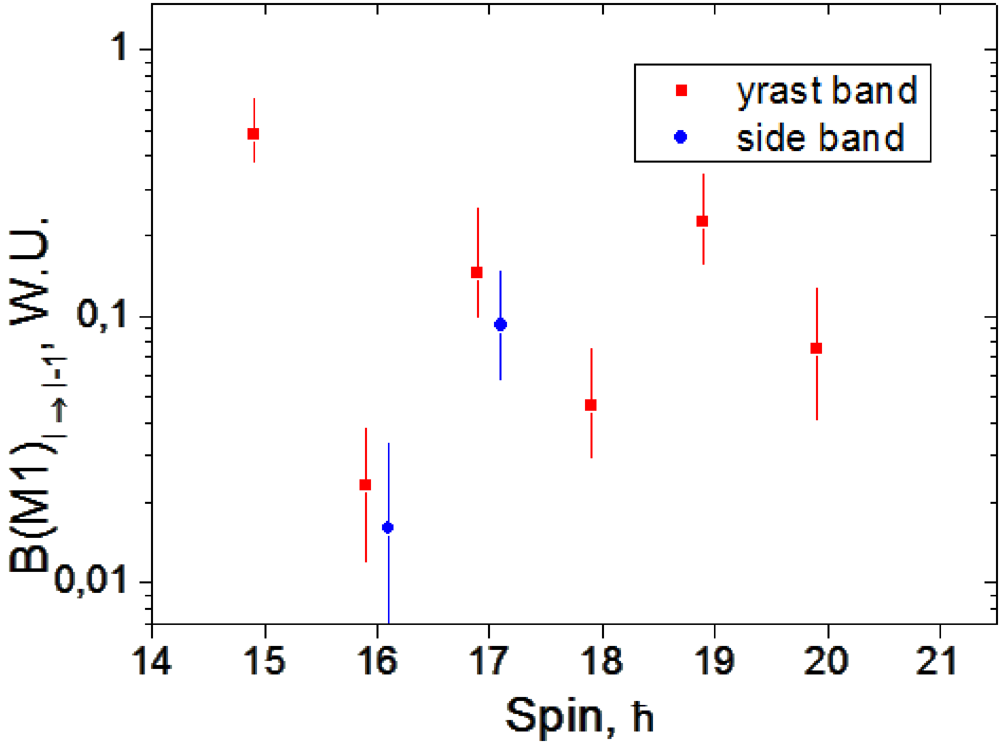
Spontaneous chiral symmetry breaking in ^{124}Cs

The central European Array for Gamma Levels Evaluation



- Experiment - EAGLE [1] array.
- DSA method measurement leading to B(M1) and B(E2) determination.
- Spontaneous chiral symmetry breaking [2] is proven if one can see two rotational bands (chiral partner bands) with similar reduced transition probabilities, (B(M1) and B(E2)).

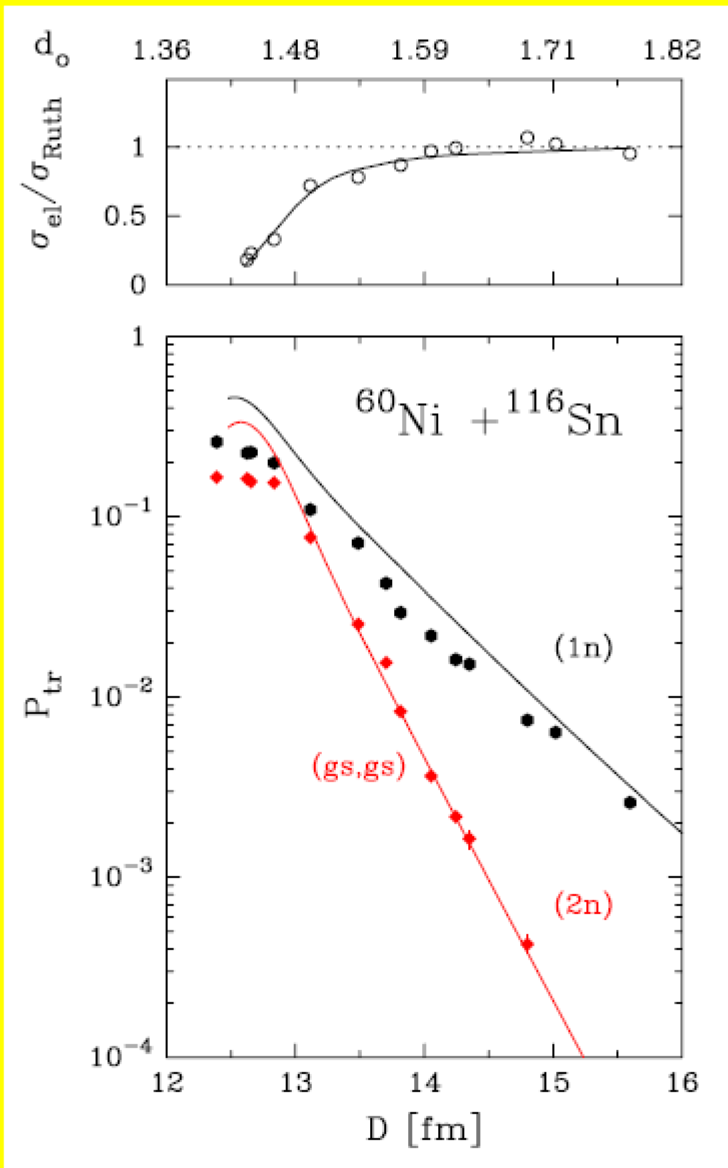
Preliminary results for ^{124}Cs - B(M1) in partner bands.



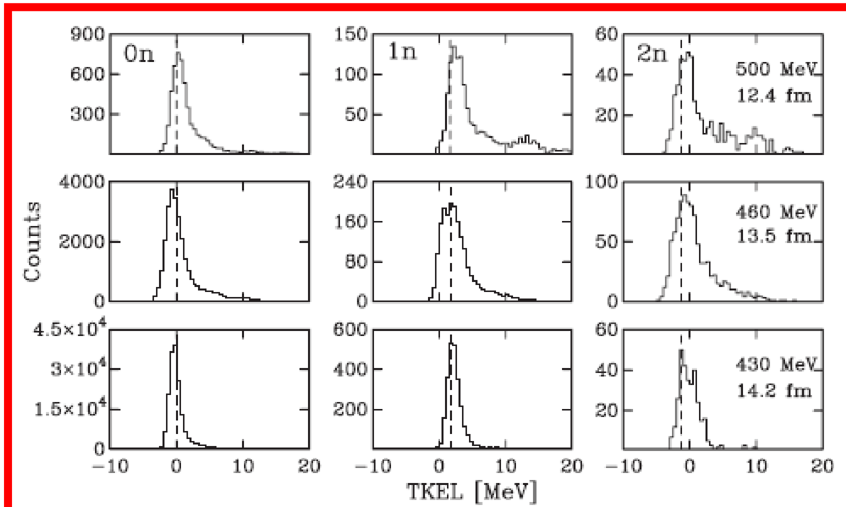
[1] J. Mierzejewski et al., NIM A 659, 84 (2011).

[2] E. Grodner et al., Eur. Phys. J A27, 325 (2006).

Neutron pair transfer in $^{60}Ni+^{116}Sn$ far below the Coulomb barrier



Transfer strength very close to the g.s. to g.s. transitions

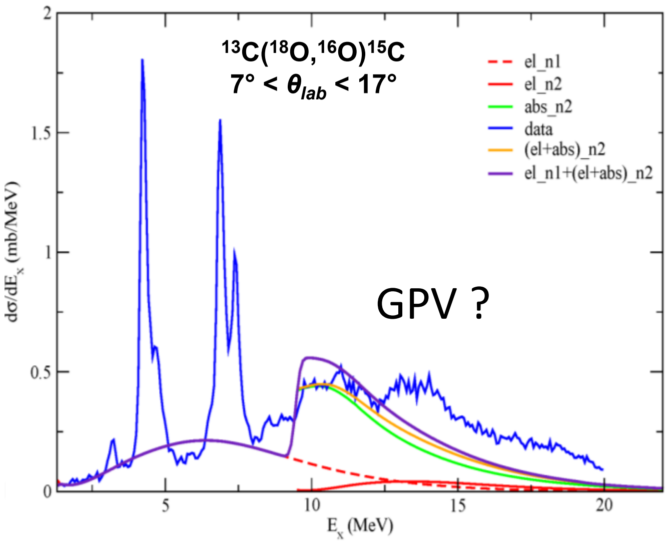


The experimental transfer probabilities are well reproduced, for the first time with heavy ion reactions, in absolute values and in slope by microscopic calculations which incorporate nucleon-nucleon pairing correlations

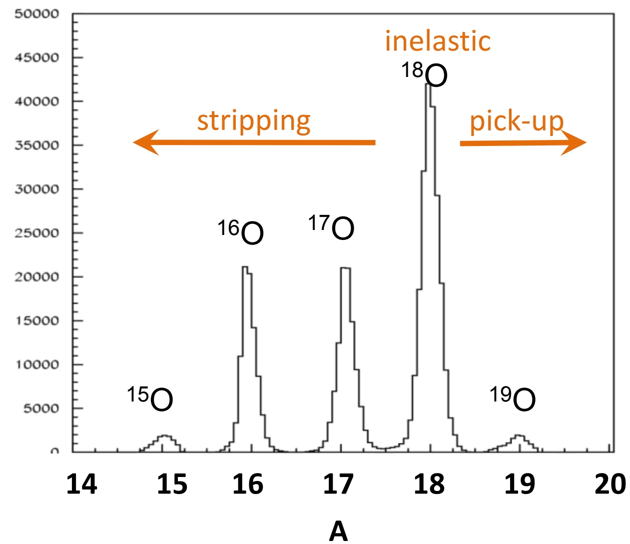
D.Montanari et al., PRL113(2014)052501

Pairing correlations with MAGNEX

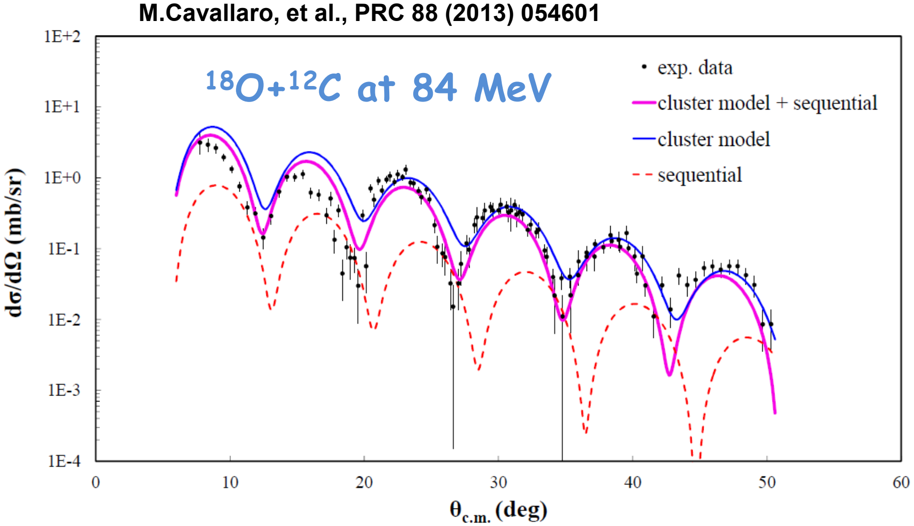
F.Cappuzzello, et al., PLB 711 (2012) 347-352



$^{18}O+^{13}C$ at 84 MeV



M.Cavallaro, et al., PRC 88 (2013) 054601

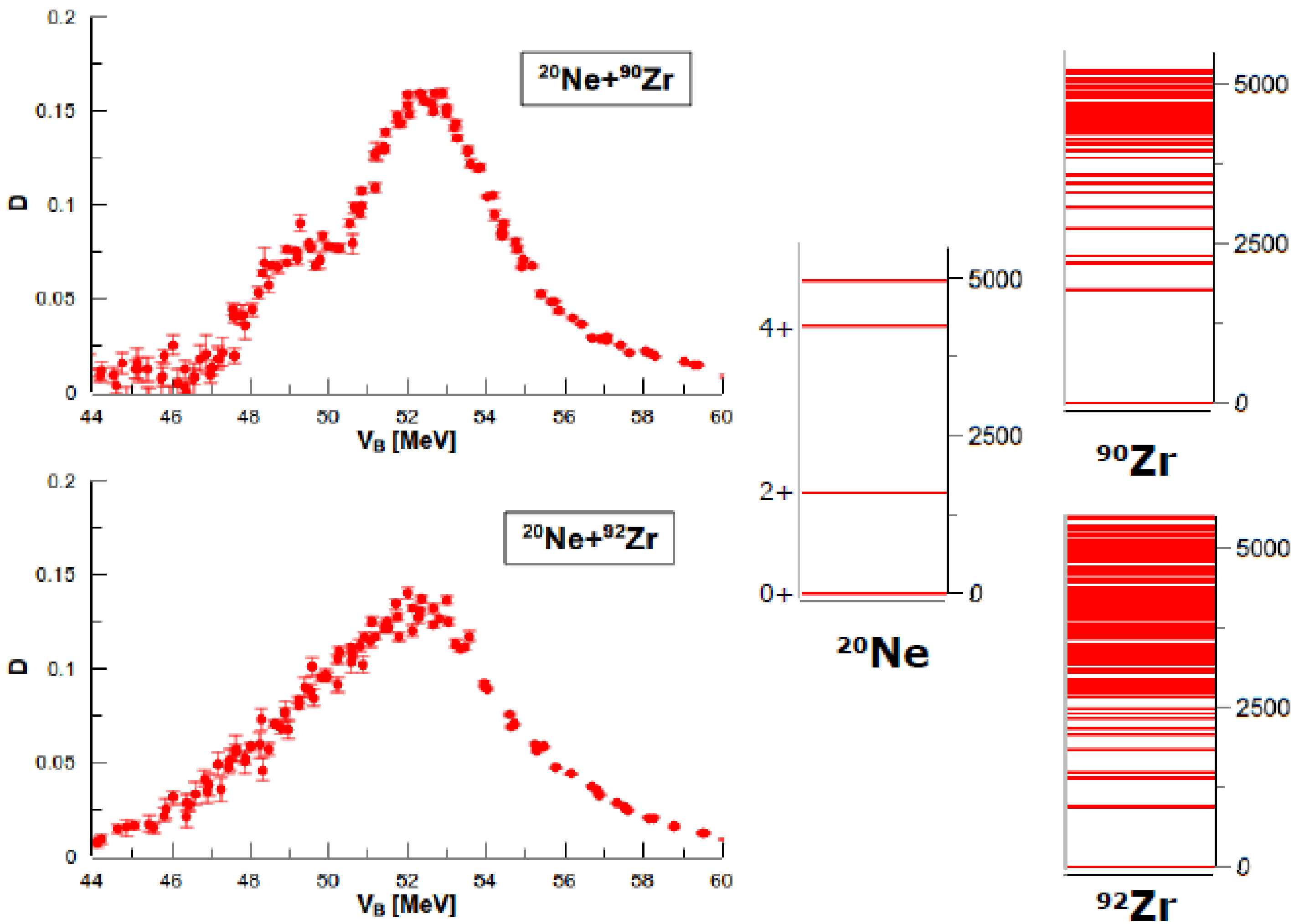


- ✓ Major physics output, observation of GPV (?) **correlated two-neutron transfer**, determination of **pair spectroscopic amplitude**

D.Carbone Thesis (2013) and manuscript submitted

Barrier distributions for fusion

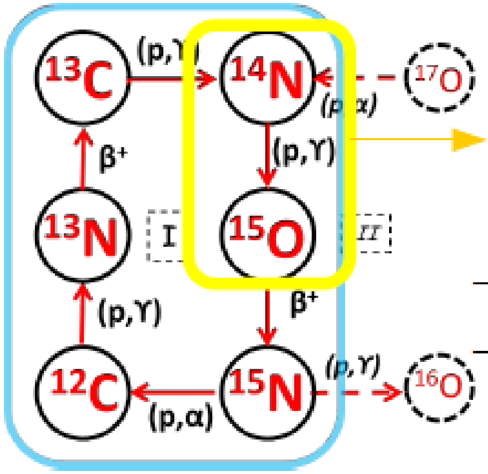
ŚRODOWISKOWE LABORATORIUM
CIĘŻKICH JONÓW



Recent papers: E. Piasecki et al. PRC 85 (2012) 054604 and 054608

NAP

Stellar burning rates and $^{14}N(p,g)^{15}O$ reaction



slowest reaction => it determines the rate of the CNO cycle

→ age of globular clusters

→ *Solar Composition Problem*

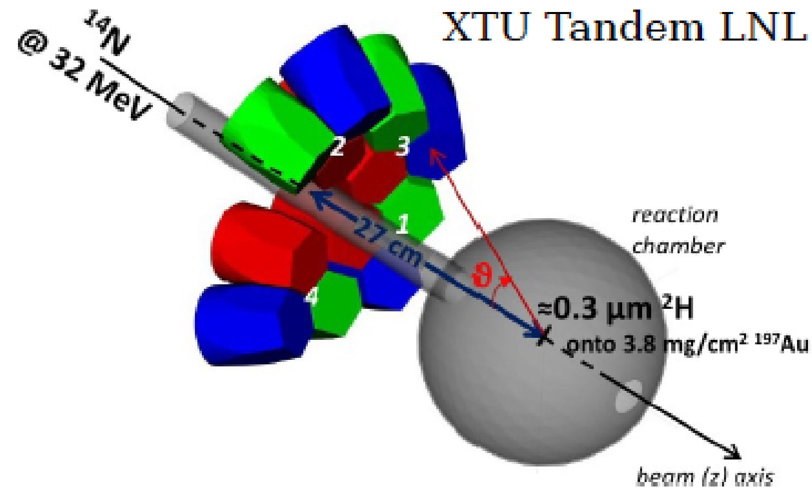
The sub-threshold resonance corresponding to the <u>first excited 3/2$^{\pm}$ state in ^{15}O</u> is predicted to play a dominant role when extrapolating the cross-section to the Gamow peak region

width of the resonance <=> lifetime of the nuclear state

First application of the high gamma energy resolution and position sensitivity of AGATA to investigate ≈fs nuclear level lifetimes

Lifetime measurement of the 6.79 MeV state in ^{15}O with the AGATA Demonstrator

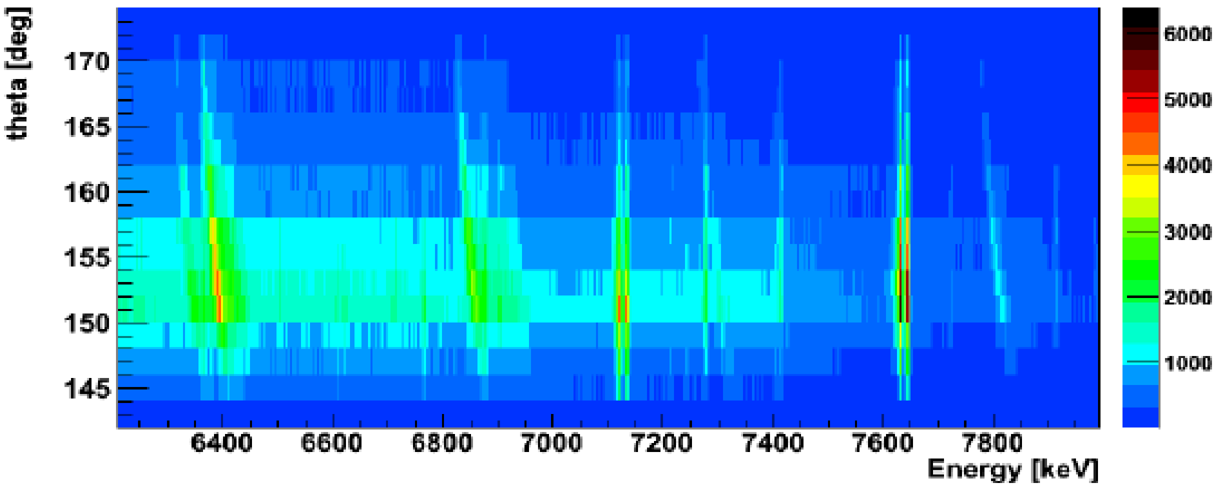
^{14}N (32 MeV) + ^{2}H, XTU Tandem LNL



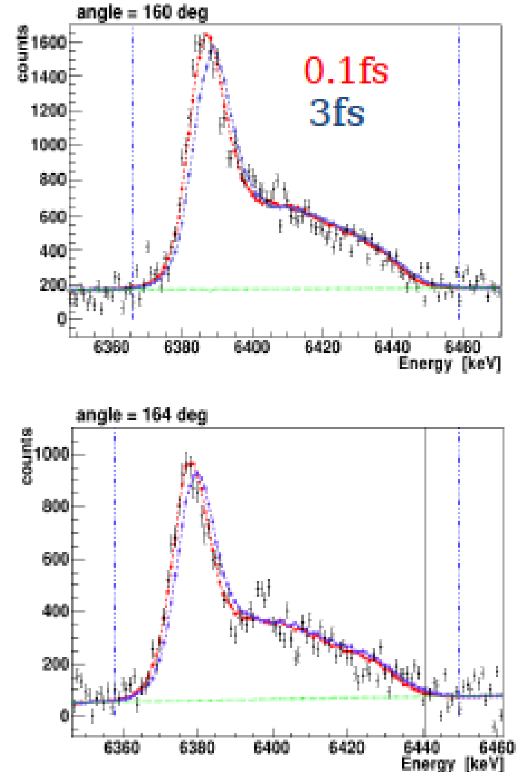
4	asymmetric triple-clusters
12	36-fold **segmented** HPGe

first interaction point and γ energy event-by-event: Lineshape analysis with a few degrees resolution

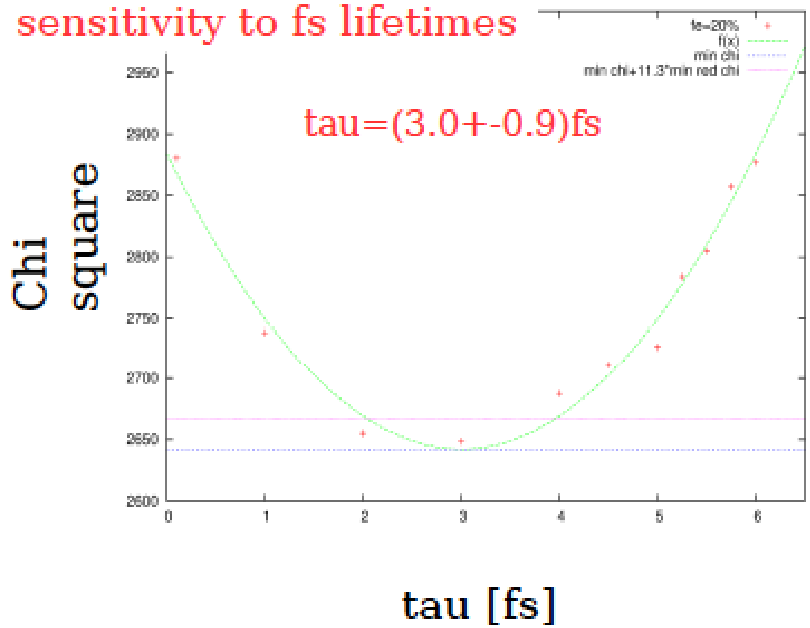
Energy vs theta first interaction point



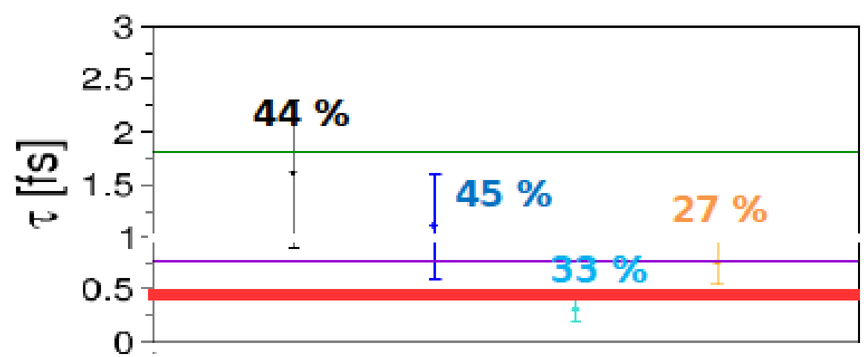
Lineshape analysis for the 6.79 MeV state in ^{15}O



8.31 MeV level in ^{15}N: sensitivity to fs lifetimes

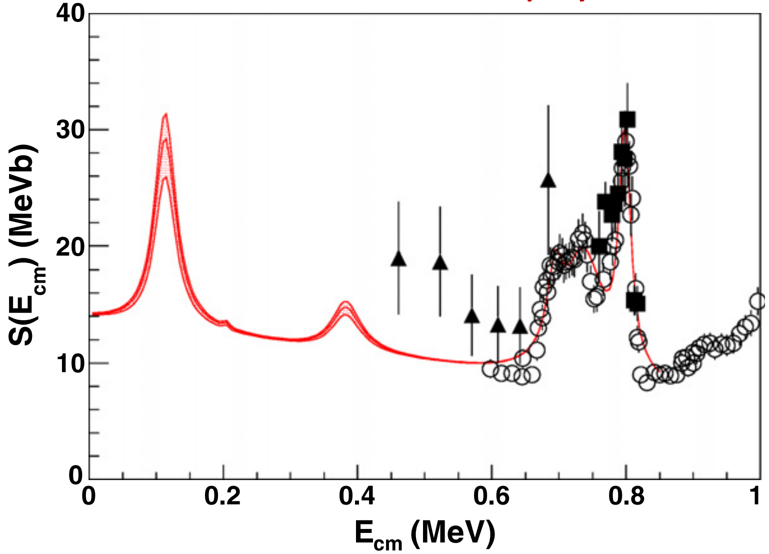


New upper limit on the lifetime of the 6.79 MeV state in ^{15}O



C. Michelangelo (pvt Comm)

Nuclear astrophysics @ LNS – Trojan Horse Method Applications



THM is an indirect method that allow to extract nuclear information of a two-body reaction, even at astrophysical energies, by means of the quasi-free contribution in an appropriate three-body reaction.

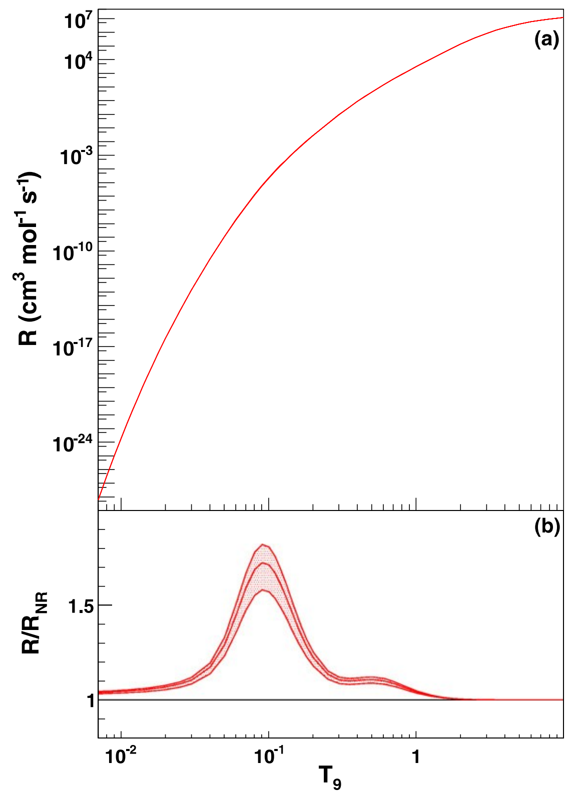
$$A + x \rightarrow C + c, \quad A + a \rightarrow C + c + b.$$

$^{19}F(p,\alpha)^{16}O$ (two-body reaction) studied at LNS via $^{19}F(d,\alpha n)^{16}O$ (three-body reaction)
At 50 MeV @Tandem

Red line Rmatrix based on THM data
Points, direct measurements

First time in Gamow window (<500 keV)

Reaction rate is calculated in the AGB star temperature window for the first time.
The ratio to the NACRE evaluation is reported in panel b



THE ASTROPHYSICAL JOURNAL LETTERS, 739:L54 (6pp), 2011 October 1

A. Tumino et al . Acta Phys.Pol. B45, 181 (2014)

PHYSICAL REVIEW C 88, 062802(R) (2013)

Search for new resonant states in ^{10}C and ^{11}C and their impact on the cosmological lithium problem

F. Hammache, N. de Sereville, I. Stefan

Primordial nucleosynthesis (BBN) is one of the three evidences for the Big-Bang model

When $T < 10^9$ K → BBN starts

- Production of D, ^3He, ^4He, ^7Li
- Abundances depend on baryonic density

Metal poor halo dwarf stars

D, ^3He, ^4He, observations agree with predictions (BBN + CMB)

^7Li problem: $(^7Li/H)_{BBN} / (^7Li/H)_{obs} = 4$

Possible explanations:

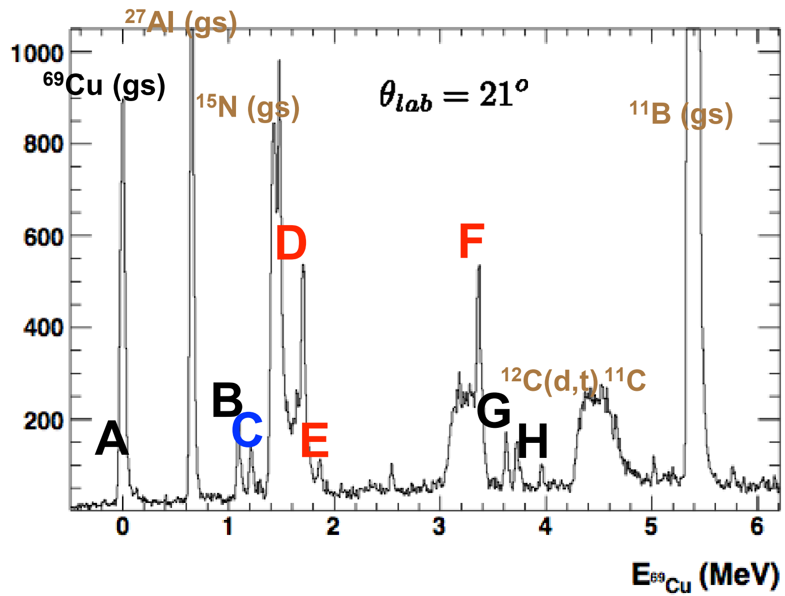
- Physics beyond standard model: super-symmetry, constant variation, ….
- Observations: can ^7Li be uniformly destroyed in the Splite plateau region?
- Nuclear physics: ^7Li produced by ^7Be EC & $^3He(^4He,\gamma)^7Be$ known better than 15%

Last proposed solution studied with SPLITPOLE @ IPN Orsay

Finally, our two results concerning ^{10}C and ^{11}C compound nuclei put an end to the various discussions concerning the missing resonant states in these nuclei, which were thought to partially or totally solve the ^7Li problem [19–21] and exclude $^7Be + ^3He$ and $^7Be + ^4He$ reaction channels as responsible for the observed ^7Li deficit.

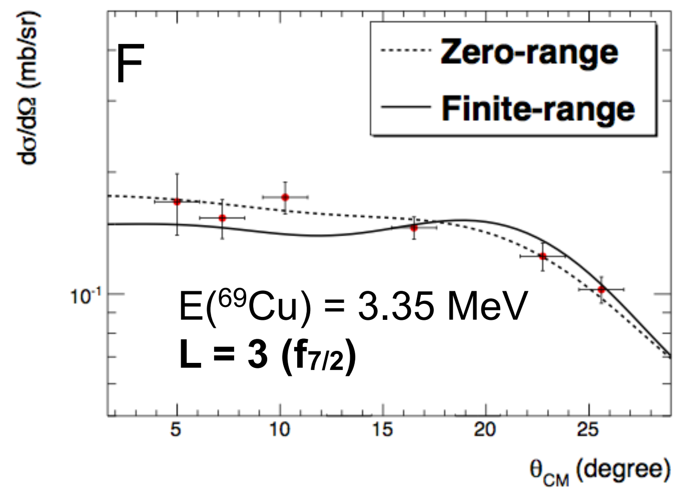
Direct kinematics ^{70}Zn(d,^{3}He)^{69}Cu with 27 MeV deuteron beam and SPLITPOLE spectrometer

Part of the program: Systematic of the evolution for $f_{7/2}$ proton-hole strength from stability to ^{78}Ni ?



Excitation energy of ^{69}Cu measured with splitpole.
Letters correspond to states in ^{69}Cu

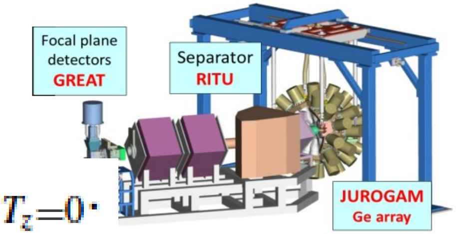
Angular distribution for the f state



E (MeV)	L (J^π)	C^2S (ZR)	C^2S (FR)
0	1 ($3/2^-$)	1.40(15)	1.50(17)
1.10	-	-	-
1.23	3 ($5/2^-$)	0.80(11)	0.70(10)
1.71	3 ($7/2^-$)	2.00(11)	2.50(14)
1.87	3 ($7/2^-$)	0.40(10)	0.50(10)
3.35	3 ($7/2^-$)	1.60(10)	2.40(15)
3.70	2 ($3/2^+$)	1.90(25)	1.50(20)
3.94	0 ($1/2^+$)	0.70(06)	0.70(10)

New part of the $f_{7/2}$ strength: $\sum f_{7/2} = 5.40$ or 67%

JYFL - Jyväskylä

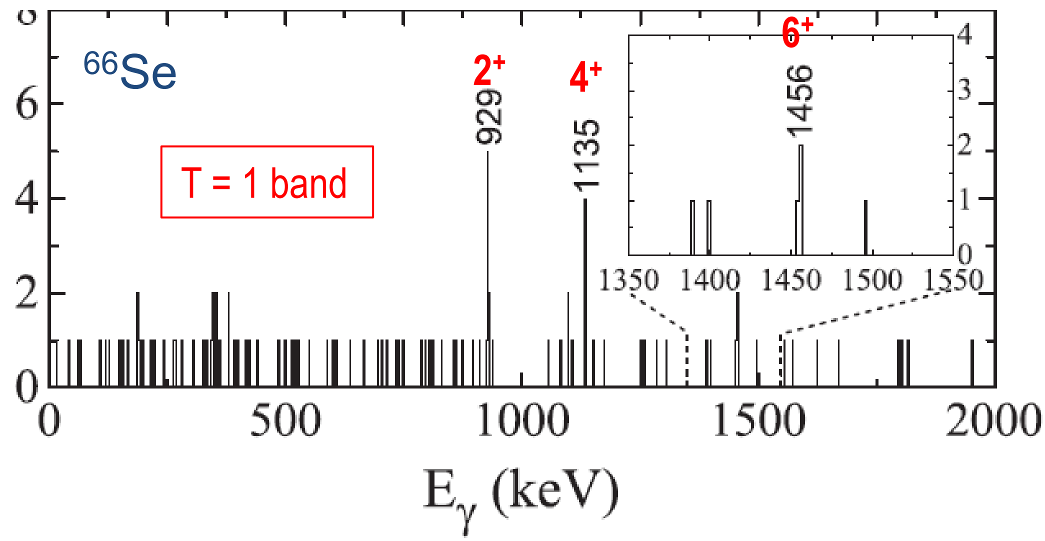


$$\mathrm{TED}_{J,T} = E^*_{J,T,T_z=-1} + E^*_{J,T,T_z=+1} - 2E^*_{J,T,T_z=0}.$$

Spectroscopy of proton-rich ^{66}Se up to $J^\pi = 6^+$: Isospin-breaking effect in the A = 66 isobaric triplet

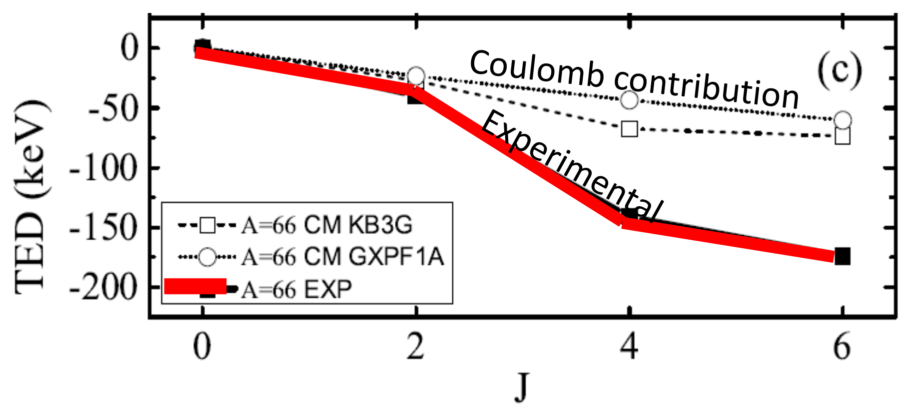
Recoil-beta tagging study:

- ^{40}Ca(^{28}Si,2n) ^{66}Se ~ 200nb
- UoY Tube Charged-particle veto
- ^{66}As isomer veto-tagging



TED=Triple Energy Differences
for the A = 66 T=1 triplet

Isospin non-conserving contribution is needed !



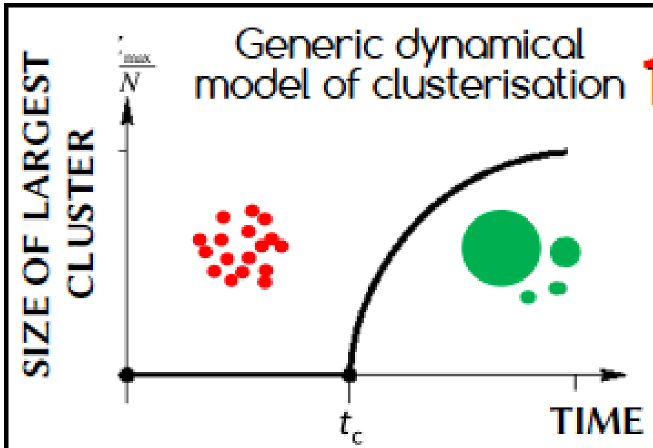
PHYSICAL REVIEW C 88, 041308(R) (2013)

Spectroscopy of proton-rich ^{66}Se up to $J^\pi = 6^+$: Isospin-breaking effect in the $A = 66$ isobaric triplet

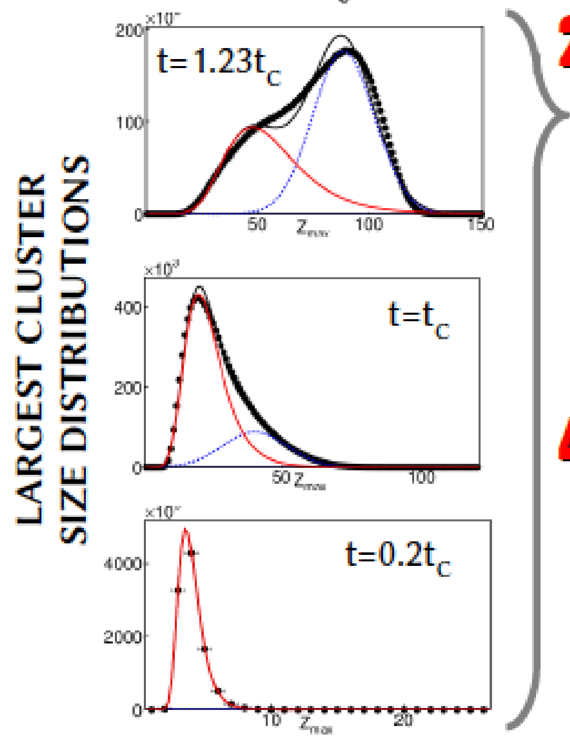
P. Ruotsalainen,[1,*] D. G. Jenkins,[2] M. A. Bentley,[2] R. Wadsworth,[2] C. Scholey,[1] K. Auranen,[1] P. J. Davies,[2] T. Grahn,[1] *Timescale of the multifragmentation is directly reflected in the shape of the largest fragment charge/mass distribution*

INDRA collaboration
+M. Ploszajczak (GANIL)
+R. Botet (LPS Orsay)

D. Gruyer et al., Phys. Rev. Lett. 110, 172701 (2013)

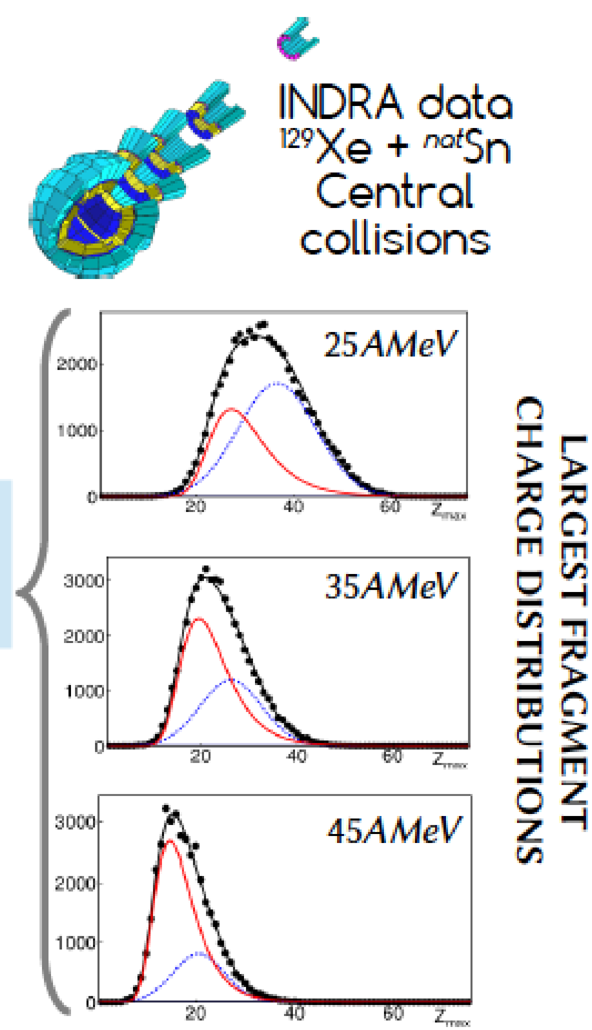


1 The *Smoluchowski equations* describe a generic clusterisation process **(lumps forming in soup)**



2 Largest cluster size distribution evolves with time

3 In data, largest fragment charge distribution evolves with beam energy



4 Similarity between model and data indicates time-scale decreases with increasing bombarding energy

$\Rightarrow$ *increasing radial flow*
(nuclear lumps forming in expanding nuclear soup)

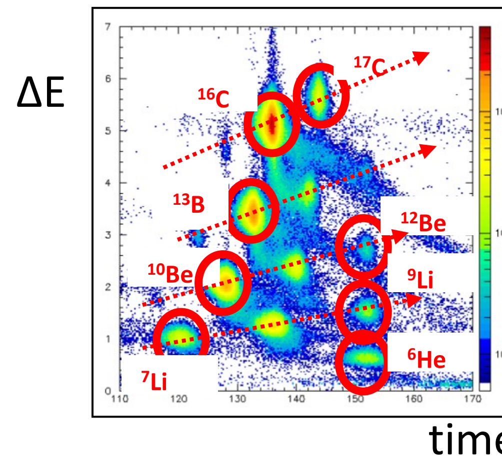
Studies of heavy ions reactions with the CHIMERA@LNS

- Reaction Dynamics at Fermi energy (*)
- EOS - density dependence of the symmetry term (**)
- Reactions and Structure with Radioactive Fragmentation Beam (***)
- Correlation and interferometry : FARCOS (****)

DSSD(300+1500+CsI)

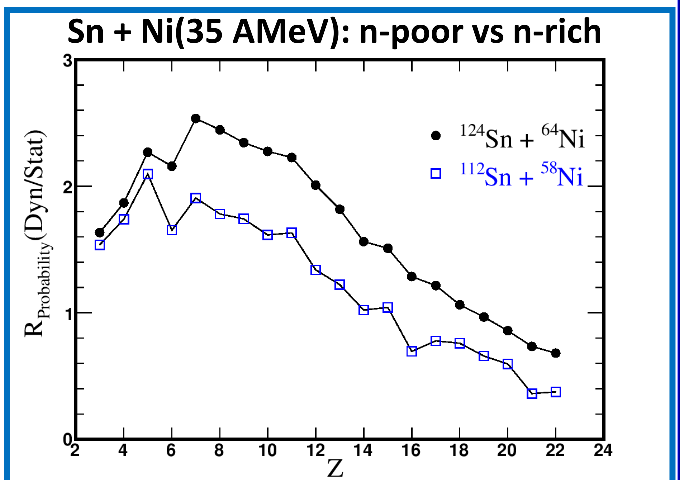
(***) In-Flight RIB production

IT NEEDS HIGH INTENSITY BEAMS



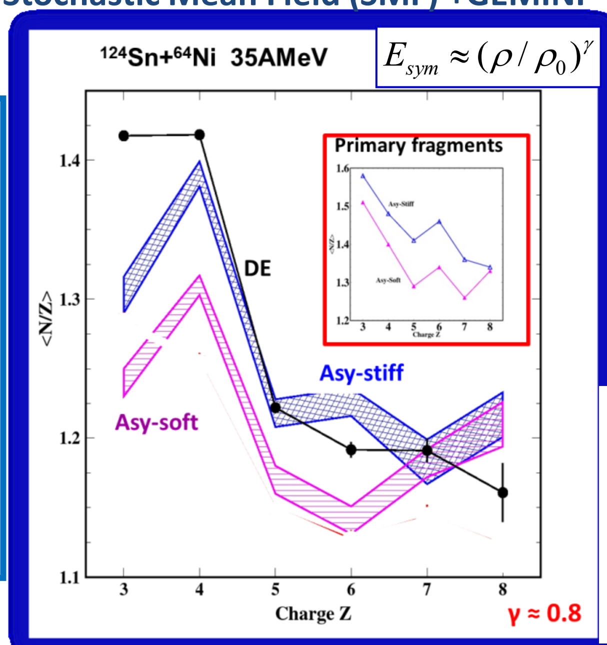
(*) Dyn/Stat Fission:

Size or Isospin effects?



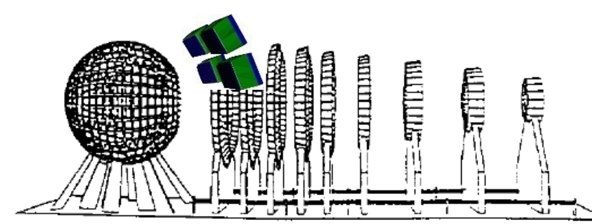
P. Russotto et al. , submitted, PRC (2014)

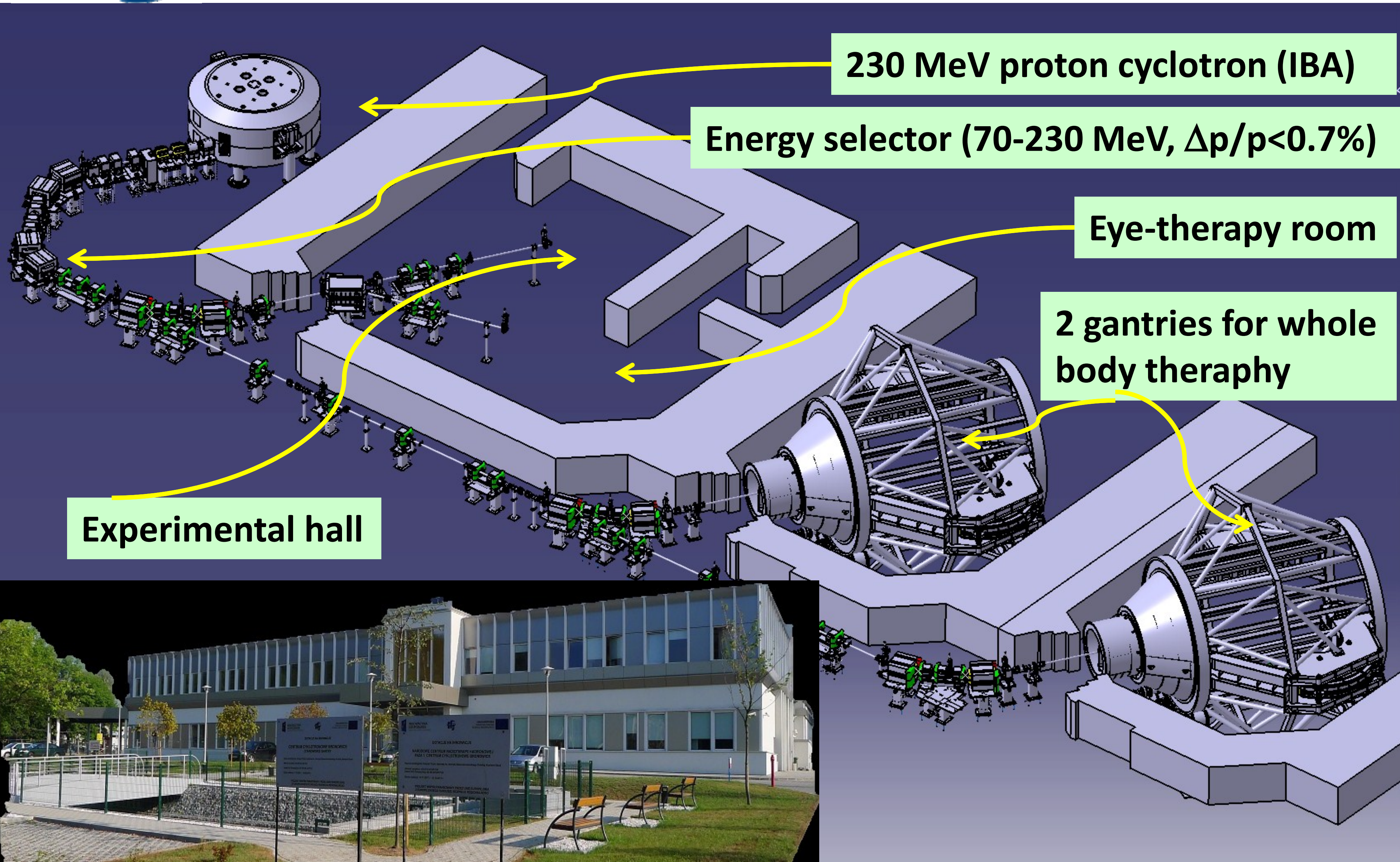
(**)Comparison of IMF data with Stochastic Mean Field (SMF) +GEMINI



E.De Filippo et al, PRC86 014610 2012

(****) CHIMERA + FARCOS correlator




230 MeV proton cyclotron (IBA)
Energy selector (70-230 MeV, Δp/p<0.7%)
Eye-therapy room
2 gantries for whole body theraphy
Experimental hall

B) Study of the dynamics of few-body systems

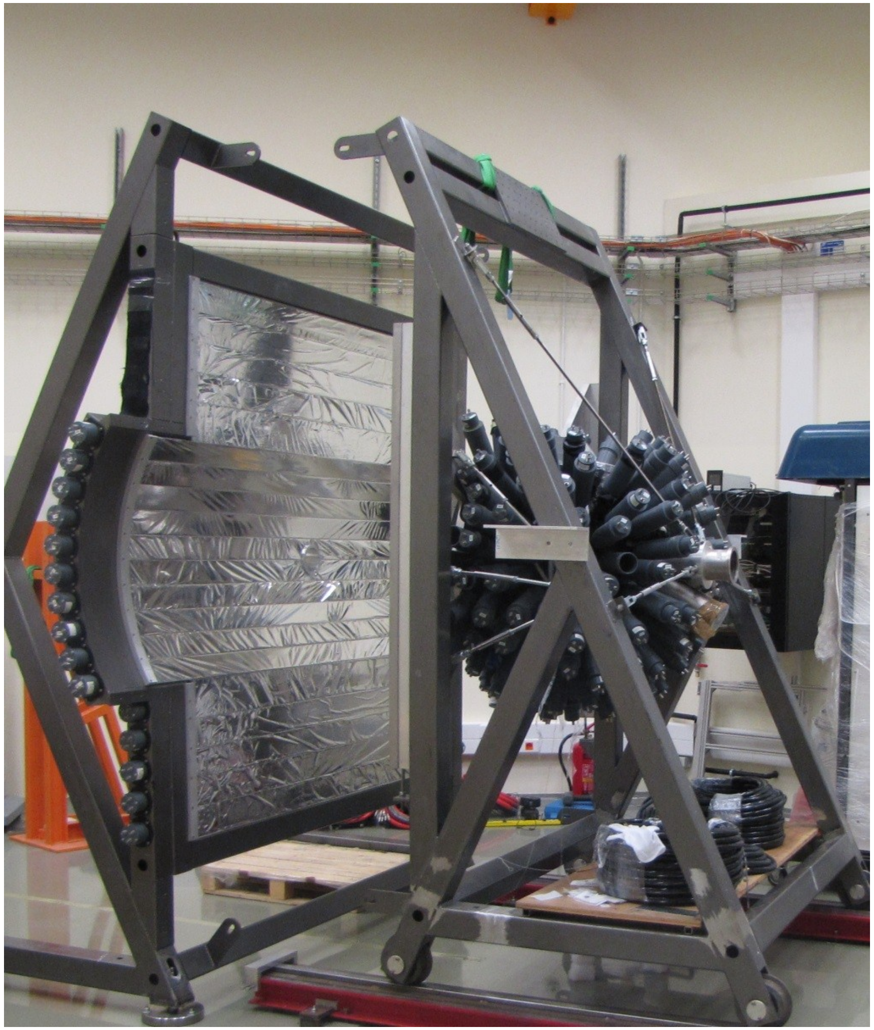
1. **Detector BINA (moved from KVI Groningen) for light nuclei reactions studies**

Wall:

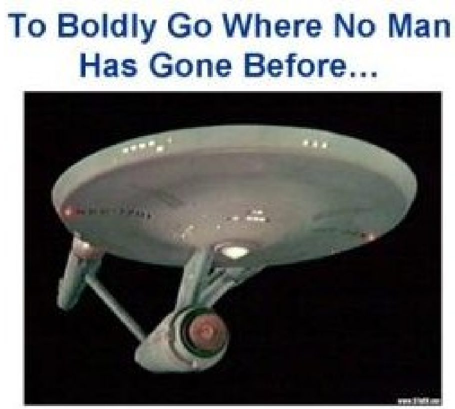
- MWPC (3 planes)
- ΔE (24 x 2 mm)
- E (20 x 120 mm)

Ball:

- Phoswich (149 x 90/30 mm)



CCB Krakow and HIL Warsaw are in the ENSAR2 H2020 project as TNA facility



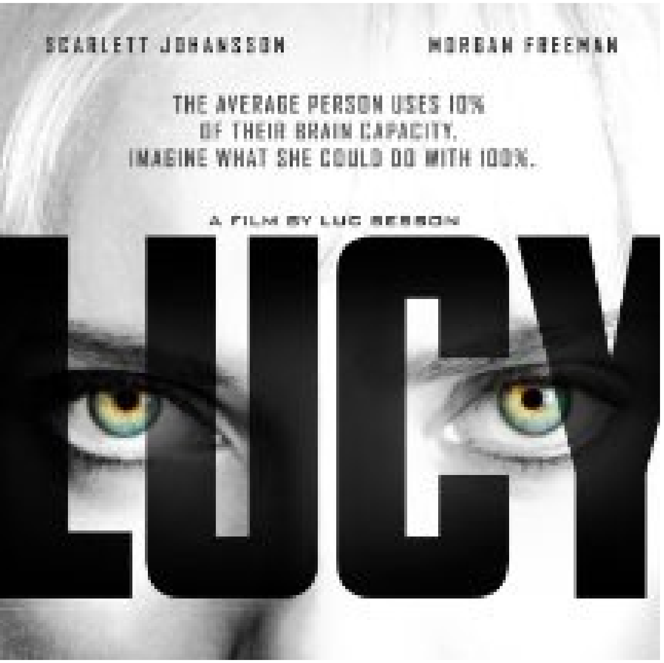
ECOS: a Path to …

What can we different that we cannot do today?

What are the physics questions that we specifically that we want to address for which we need very intense stable beams ?

What are the things we need to think and develop (other than the machine)

(Other speaker are going to answer this)



Evolution to revolution