The Nuclear Structure facility in Bucharest

Dorel Bucurescu

HH-NIPNE-Bucharest

IFIN-HH

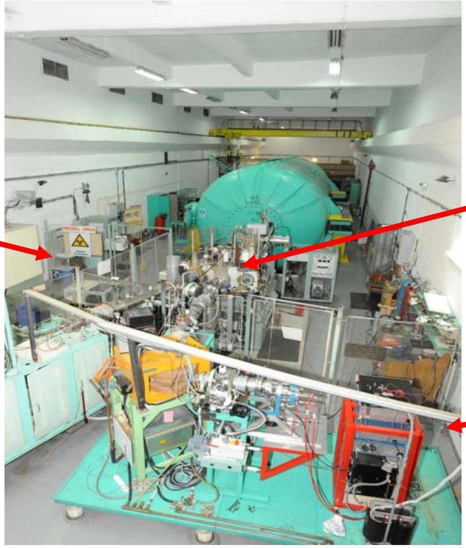
IFIN-HH : Institutul National pentru Fizica si Inginerie Nucleara “Horia Hulubei”

“Horia Hulubei” National Institute for Physics and Nuclear Engineering

Research Infrastructure

- **9 MV TANDEM Accelerator** (High Voltage, commissioned 1973, modernized 2006 – 2010)
  - Best performances for its class
  - Reliability
- Infrastructure for Experiments
  - Modern and competitive
  - Well-suited for complex experiments
  - Flexibility
- Support infrastructure : LN_2 factory, mechanical workshop, etc.

Sputtering negative ion source SNICS II



Negative He ion source (charge exchange on Li)

AMS sputtering negative ion source MC-SNICS II

Modernization program:
Main Accelerator Components

- Pelletron chain charging system
  - improved charging efficiency
  - major increase in reliability
  - maintenance of the Pelletron is done 100% by the TANDEM technicians
- New set of accelerator tubes
  - Titanium electrodes, spiral fields
  - increased reliability and lifetime
- Replacement of: power supplies, fluxmeters, GVM, vacuum system, stabilization system.
- Beam pulsing systems: **nanosecond system** (bunches n·200 ns apart) + **microsecond system** (electrostatic deflection)
- Improvement of ion optics inside the accelerator

  (90-95% transmission at optimum terminal voltage)

Sample of ion beams delivered in 2011

Ion	Charge state	Ion source	Energy (MeV)	Intensity after analyzing magnet (nA)
p	1+	SNICS II	10	300
d	1+	Duoplasmatron	10	1.5
^{4}He	2+	Alpha source	18.6	500
^{6}Li	3+	SNICS II	32	150
^{7}Li	3+	SNICS II	27	25
^{9}Be	4+	SNICS II	28	6
^{10}B	4+	SNICS II	37	8
^{11}B	5+	SNICS II	47	15
^{12}C	6+	SNICS II	57.5	150
^{13}C	6+	SNICS II	54	10
^{15}N	3+	SNICS II	13.5	1
^{18}O	5+	SNICS II	34	90
^{19}F	8+	SNICS II	68	30
^{31}P	7+	SNICS II	65.8	300
^{32}S	5+	SNICS II	48	250
^{36}S	10+	SNICS II	80	20
^{35}Cl	6+	SNICS II	39	200
^{48}Ti	7+	SNICS II	60	10
^{63}Cu	10+	SNICS II	80	60

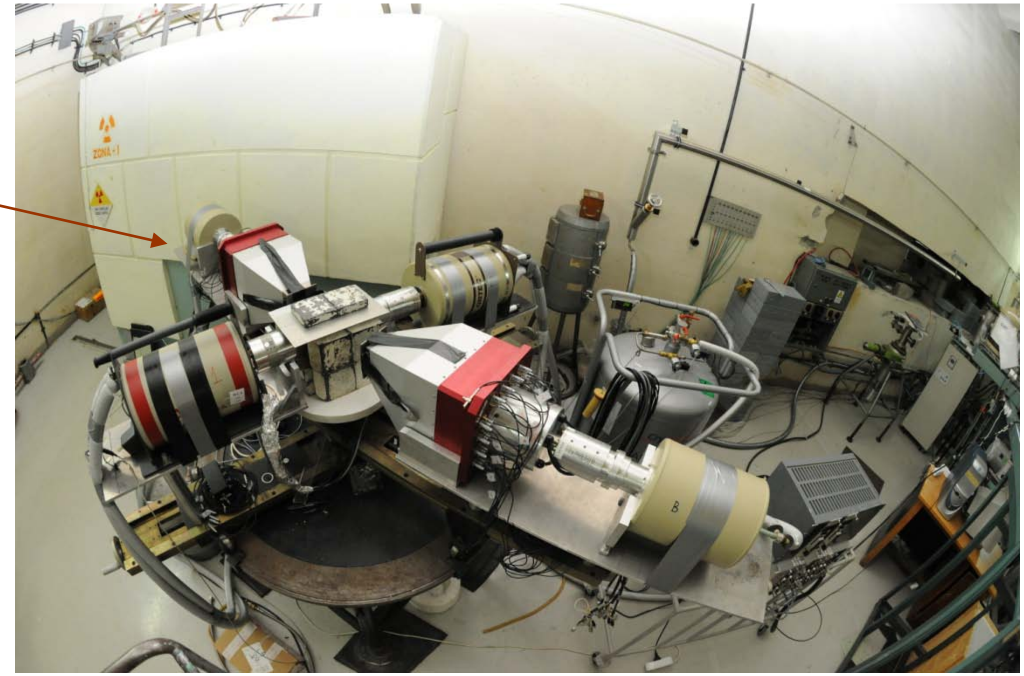
Report of the spring (~march-july) + fall (~sept.-febr.) campaigns / 2011

- 4992 hours (analyzed) beam time delivered for scheduled experiments
- Out of which 1920 (38.5%) hours for experiments proposed by foreign users
- ~500 hours maintenance

Infrastructure for Nuclear Physics experiments : Detectors

Present infrastructure:

- 25 HPGe detectors ~55% efficiency
- two Clover detectors (120% eff.)
- 3 planar Ge (LEP) detectors
- scintillation detectors: 11 $LaBr_3$:Ce, 25 BGO anti-Compton shields
- charged-particle detectors
- neutron (liquid scintillator) detectors
- modern plunger setup (Köln type)
- 2 mini-orange spectrometers for IC el. (Sofia group, under preparation)
- Yale moving tape collector (under installation)



- Mechanics and the reaction chambers allow flexibility in the configuration of the detectors for various experiments

DFN-IFIN: *In-beam* Fast Timing setup
HPGe & $LaBr_3$:Ce array (until may 2012)

- **11 HPGe**
- **4 LEP (planar Ge)**
- **11 $LaBr_3$:Ce**

Ongoing developments

RObaLL array with

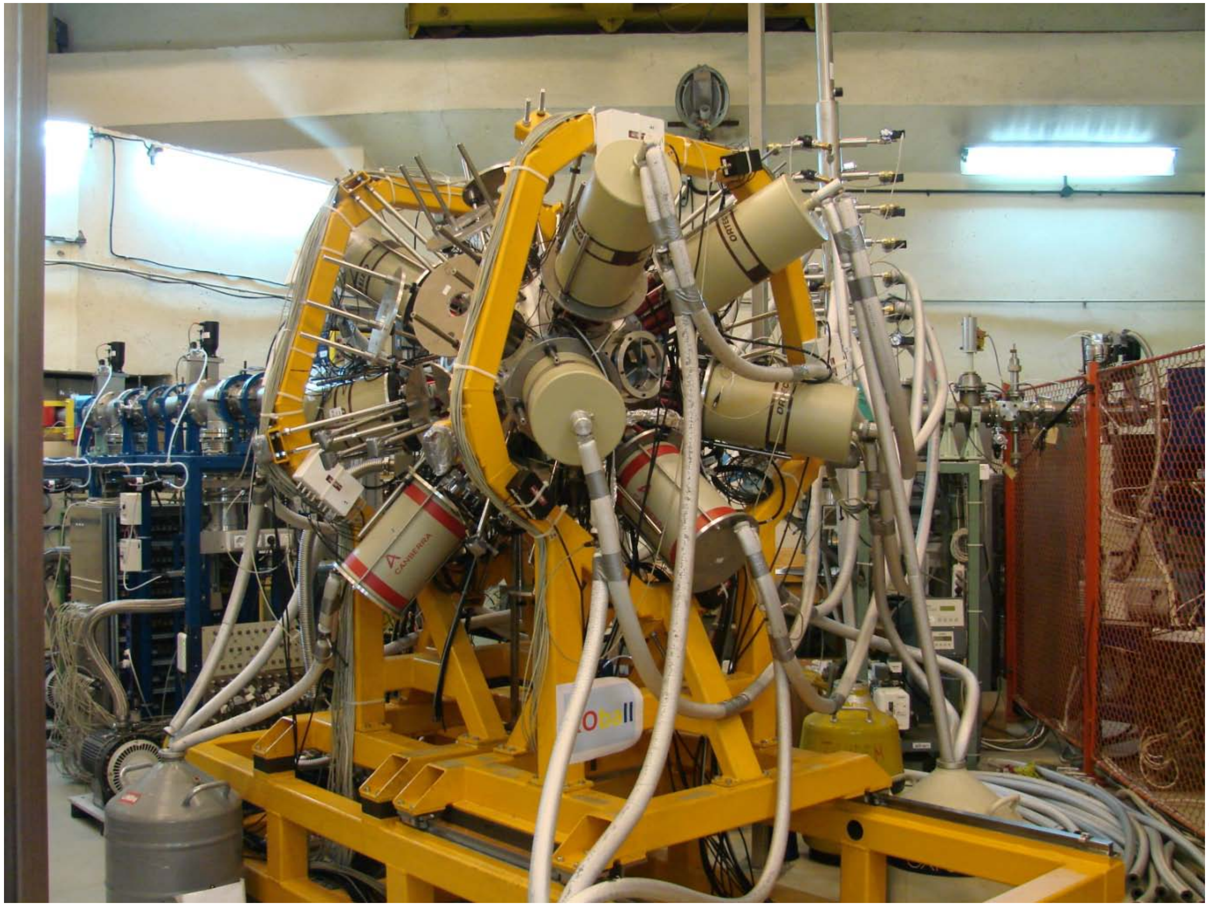
two basic configurations:

-*(i)* ≤ 25 HPGe 55% detectors with BGO anti-Compton shields

- *(ii)* 10-15 HPGe + 10-15 $LaBr_3$:Ce

- Increased granularity
- Increased P/T ratio
- Increased efficiency (Ge: 1-2 %)

Commissioned : June 2012



D.B., ECOS 2012, Como

Research program in γ-ray Nuclear Spectroscopy

- Nuclear structure (level schemes) – niche cases

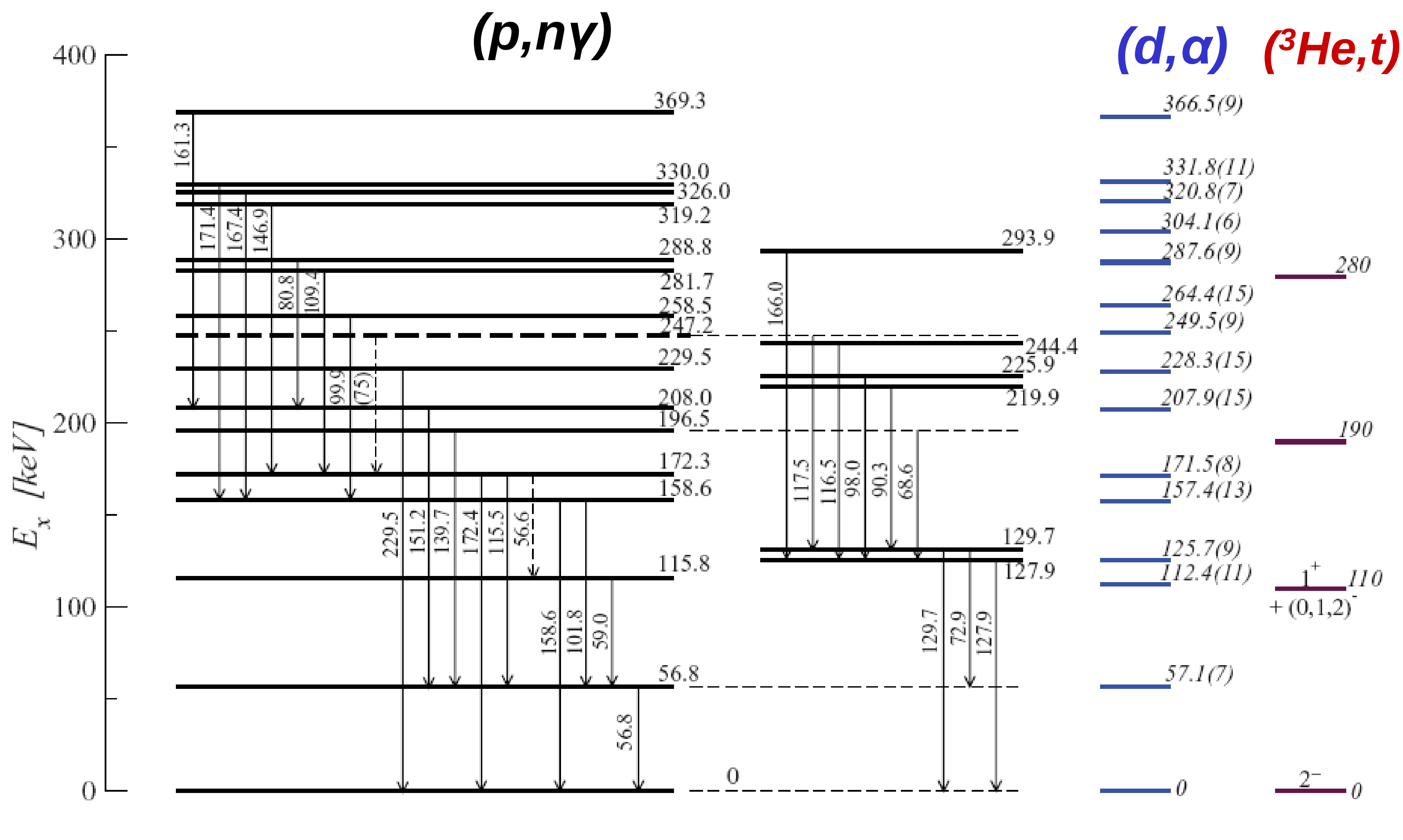
- Measurements of lifetimes of nuclear excited states:
  - in-beam fast timing: ~10 ps - ~10 ns
  - plunger
  - DSAM

- Measurements of reaction cross-sections (activation)

1) Niche case: ^{150}Pm (Z=61,N=89)

- **^{150}Pm** states: intermediate in ββ decay of ^{150}Nd
- Close to critical X(5) point nucleus ^{150}Nd

No excited states known before !



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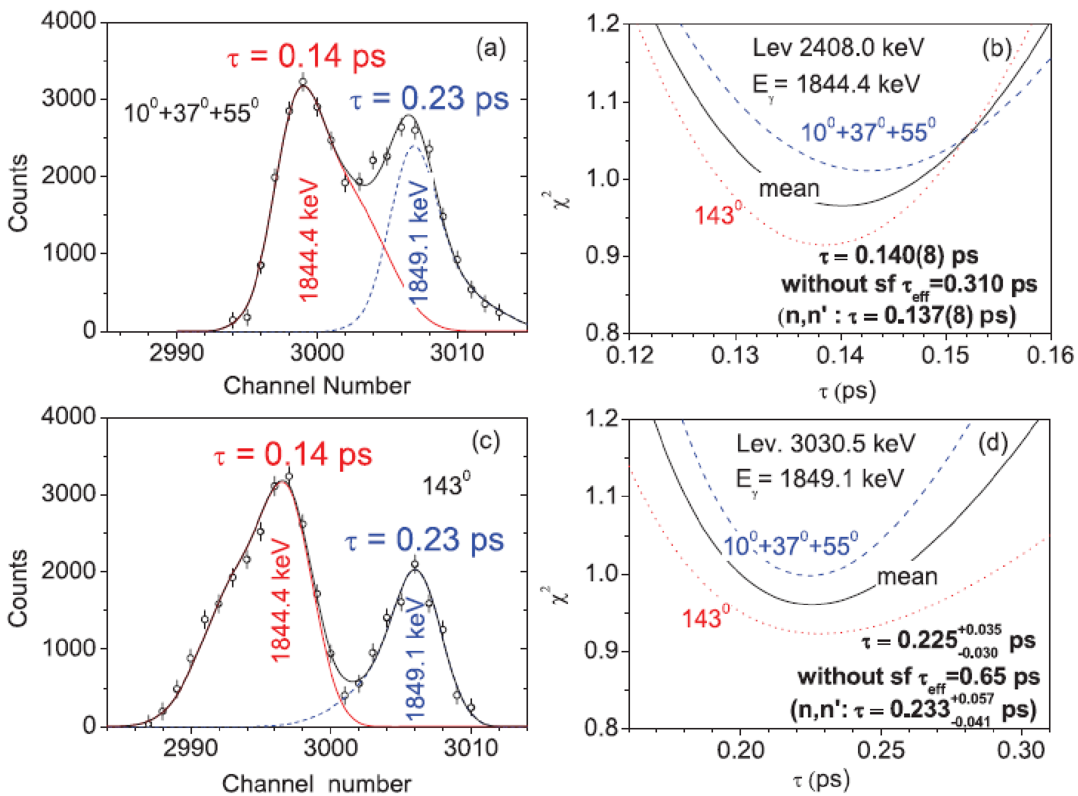
D.Bucurescu *et al.*, PRC85(2012)017304

^{150}Nd(p,nγ) reaction study: *Bucurescu et al.*, **Bucharest tandem**
^{152}Sm(d,α) reaction study : *Bucurescu et al.*, **Q3D München**
^{150}Nd(^{3}He,t) reaction study: *Guess et al., PRC 83(2011)064318*

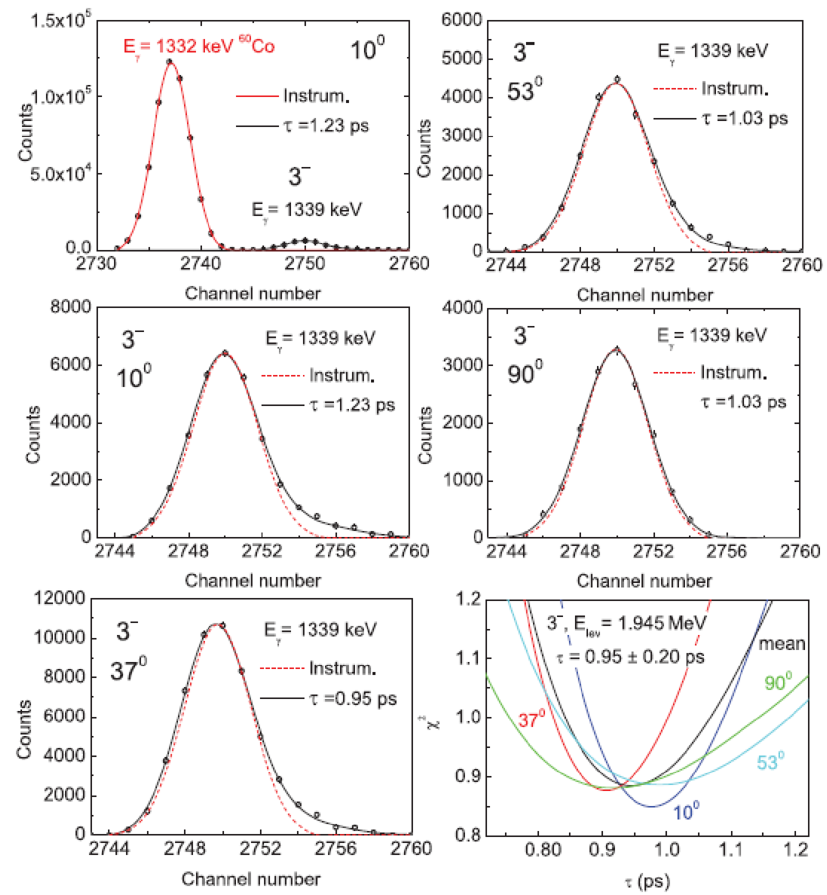
2) DSAM in nonselective reaction (α,nγ)

^{119}Sn(α,nγ)^{122}Te @ 15 MeV, v/c≈0.3%



C.Mihai et al.,
PRC81(2010)034314
$t_{1/2}$ for 24 levels, J ≤ 10

^{115}Sn(α,nγ)^{118}Te @ 15 MeV, v/c≈0.3%



C.Mihai et al.,
PRC83(2011)054310
$t_{1/2}$ for 12 levels, J ≤ 8

^{117}Sn(α,nγ)^{120}Te @ 15 MeV
$t_{1/2}$ for 30 levels, J ≤ 12, in preparation

Collaboration with Dr. A.Pasternak, Sankt Petersburg

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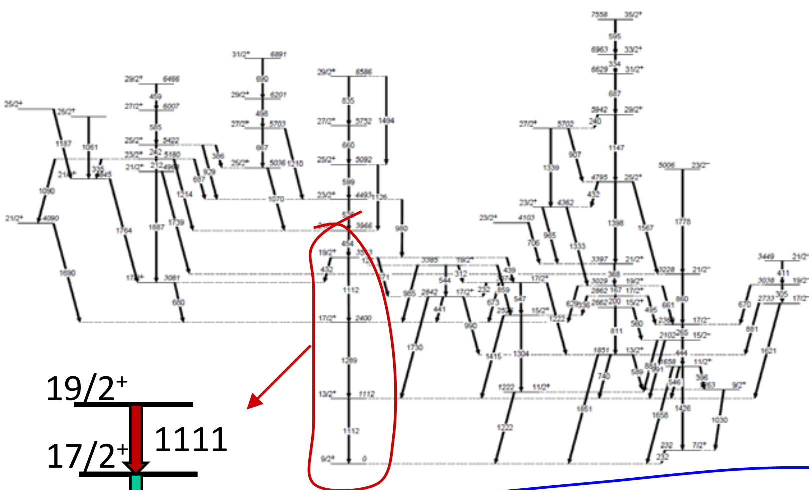
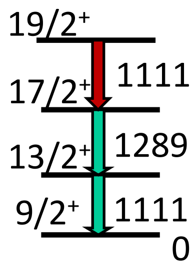
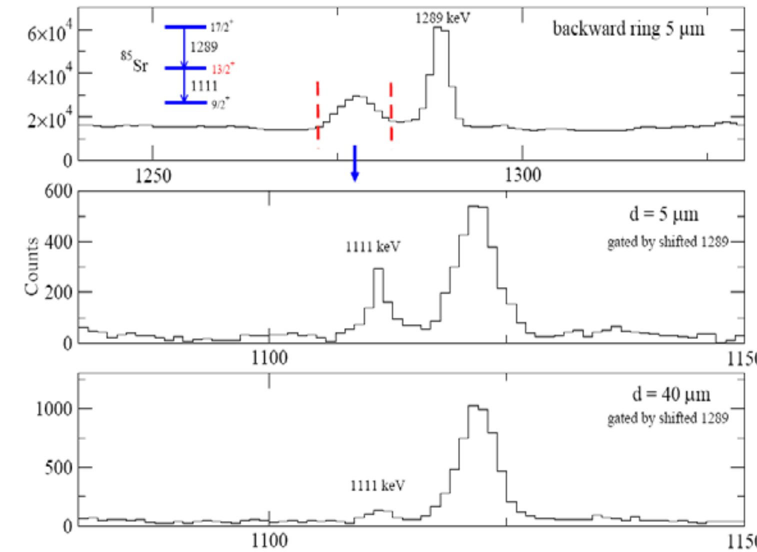
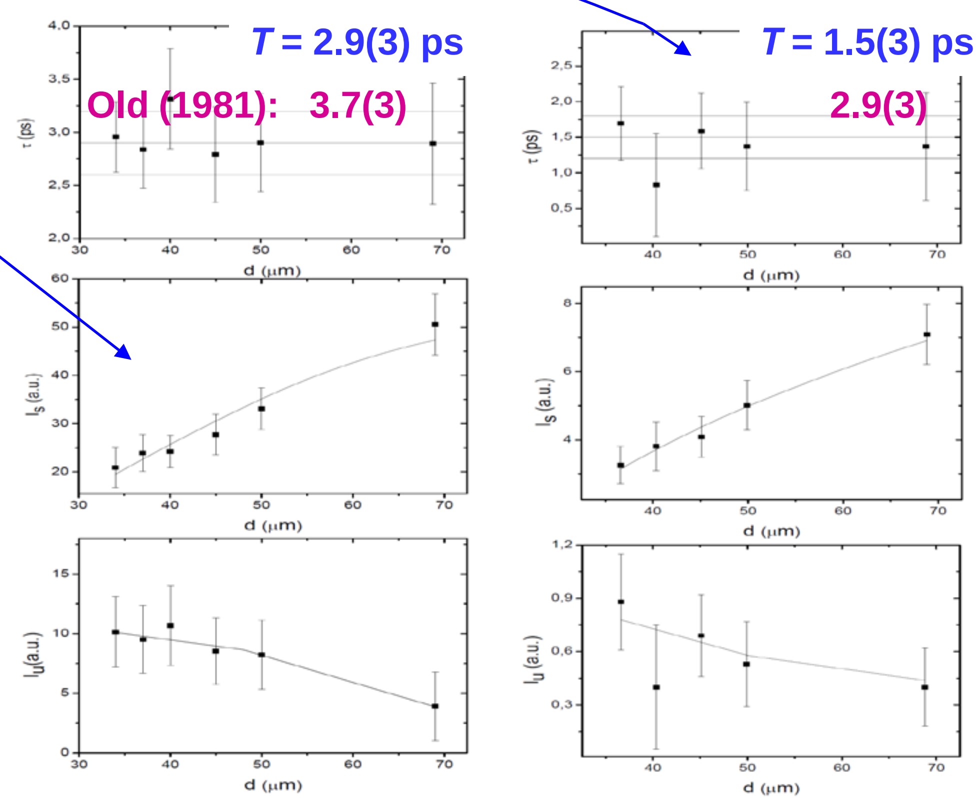
3) Plunger measurements

$^{76}Ge(^{13}C,4n)$ ^{85}**Sr** @56 MeV





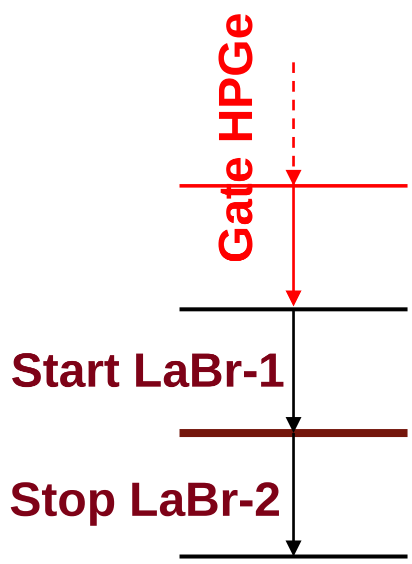




C.Mihai *et al.*, preliminary

D.B., ECOS 2012, Como

4) Fast timing in-beam measurements



$LaBr_3(Ce)$

$E_{\gamma 1} - E_{\gamma 2} - \Delta t_{12}$

$LaBr_3$:Ce detectors:

- Best energy resolution achievable with scintillators
- Timing comparable with BaF_2 : 100-300 ps depending on the crystal size
- May be used to measure lifetimes in the ~40 ps – few ns range

Suitable for ***in-beam*** experiments

- Many detection elements which must **behave identically**
- Careful off-line energy matching and **correction of the CFD time walk with energy** → similar time response of all elements (fast detectors)
- **Coupling with other kind of detectors**

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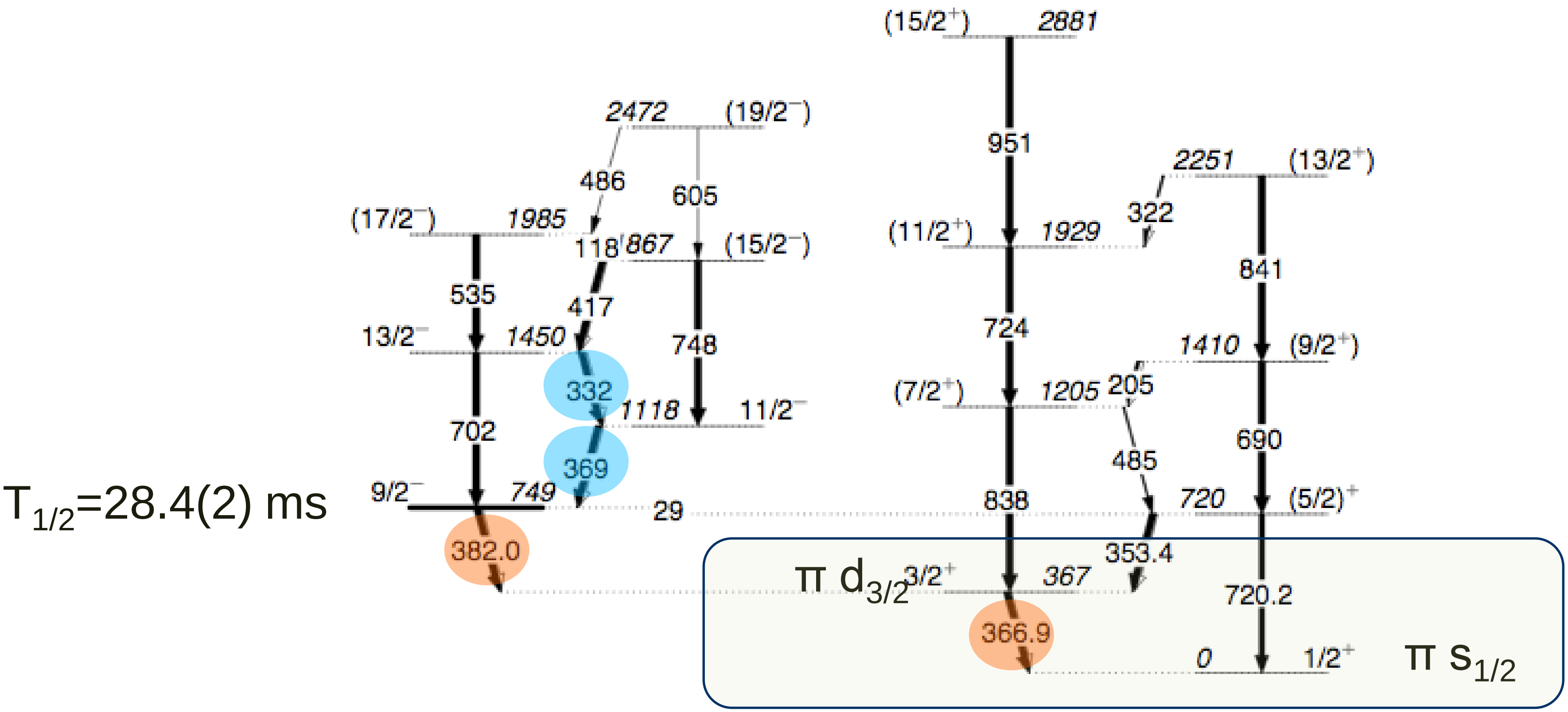
a) - Fast-timing test case: ^{199}Tl

N.Mărginean *et al.*,
EPJA46(2010)329

$^{197}Au(\alpha,2n)^{199}Tl$ @ 24 MeV

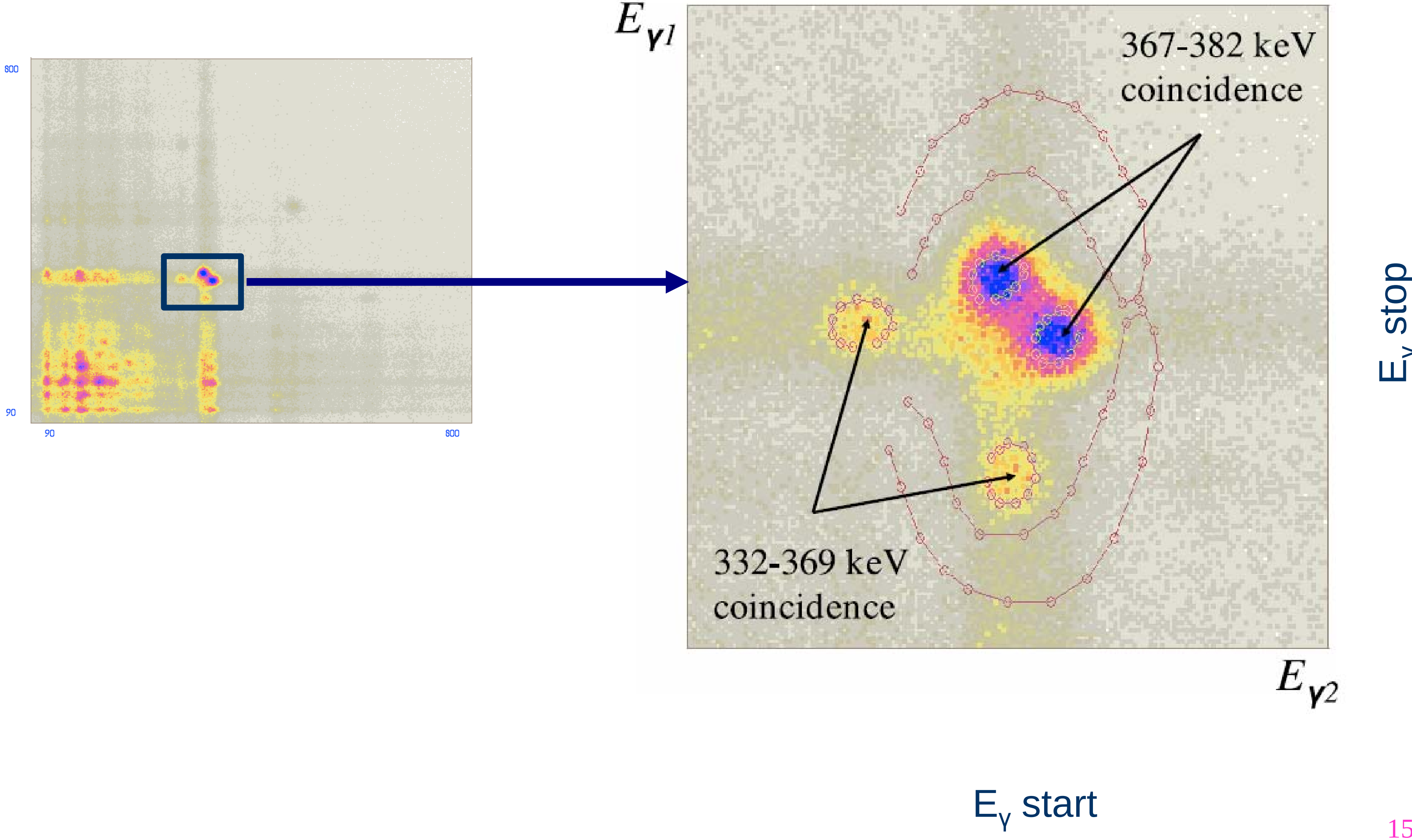
8 HPGe and 5 $LaBr_3$:Ce detectors



If g.s. and 367 keV state have pure single-particle configurations, one expects lifetime of several hundreds of picoseconds for the 367 keV level

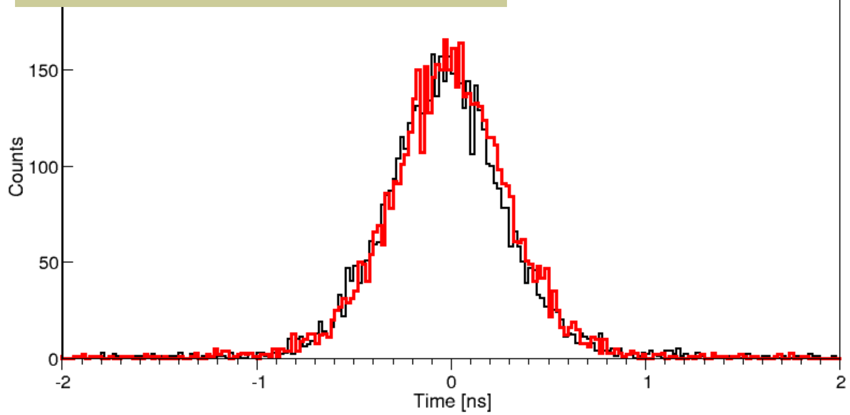
Lifetime of the 367 keV, 3/2$^+$ level

Eγ-Eγ-Δt cube with $LaBr_3$:Ce detectors

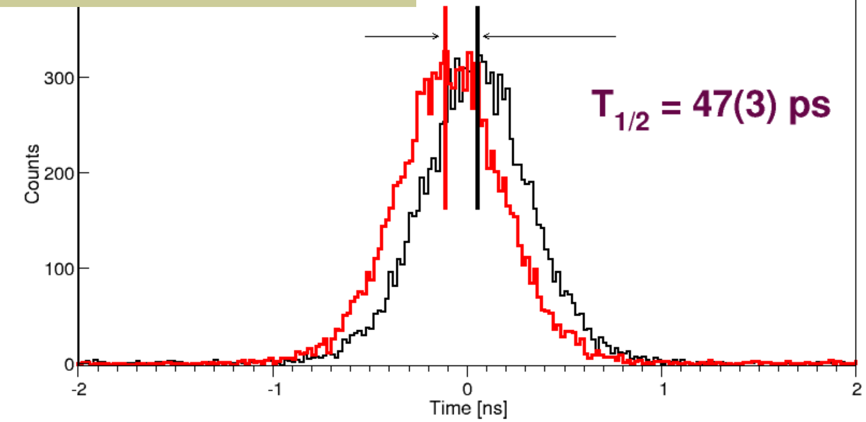


Lifetime of the 367 keV, $3/2^+$ level

332-369 keV coincidence
Fast transitions



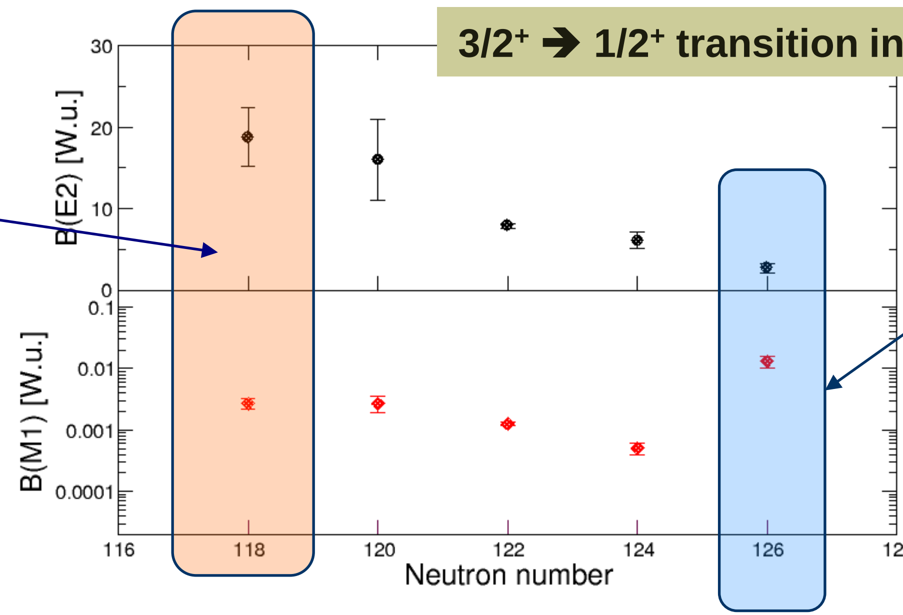
367-381 keV coincidence
Centroid shift



$3/2^+ \rightarrow 1/2^+$ transition in odd-A Tl isotopes

Present data

Increased collectivity
of the two states



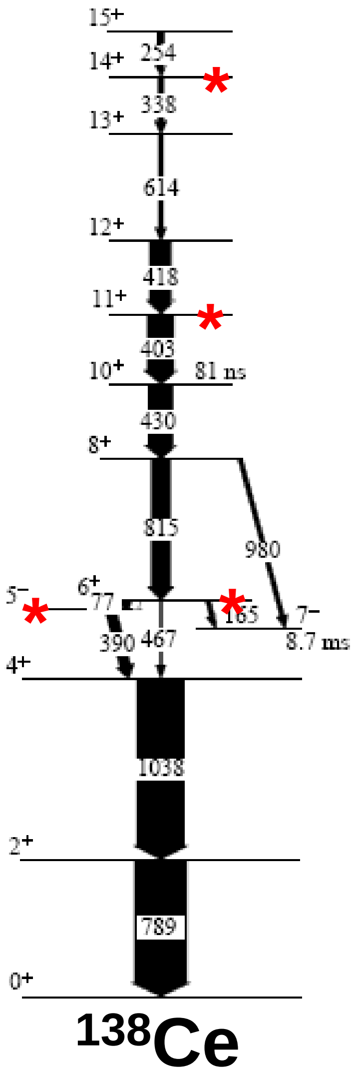
One hole in doubly-magic ^{208}Pb
Single-particle states

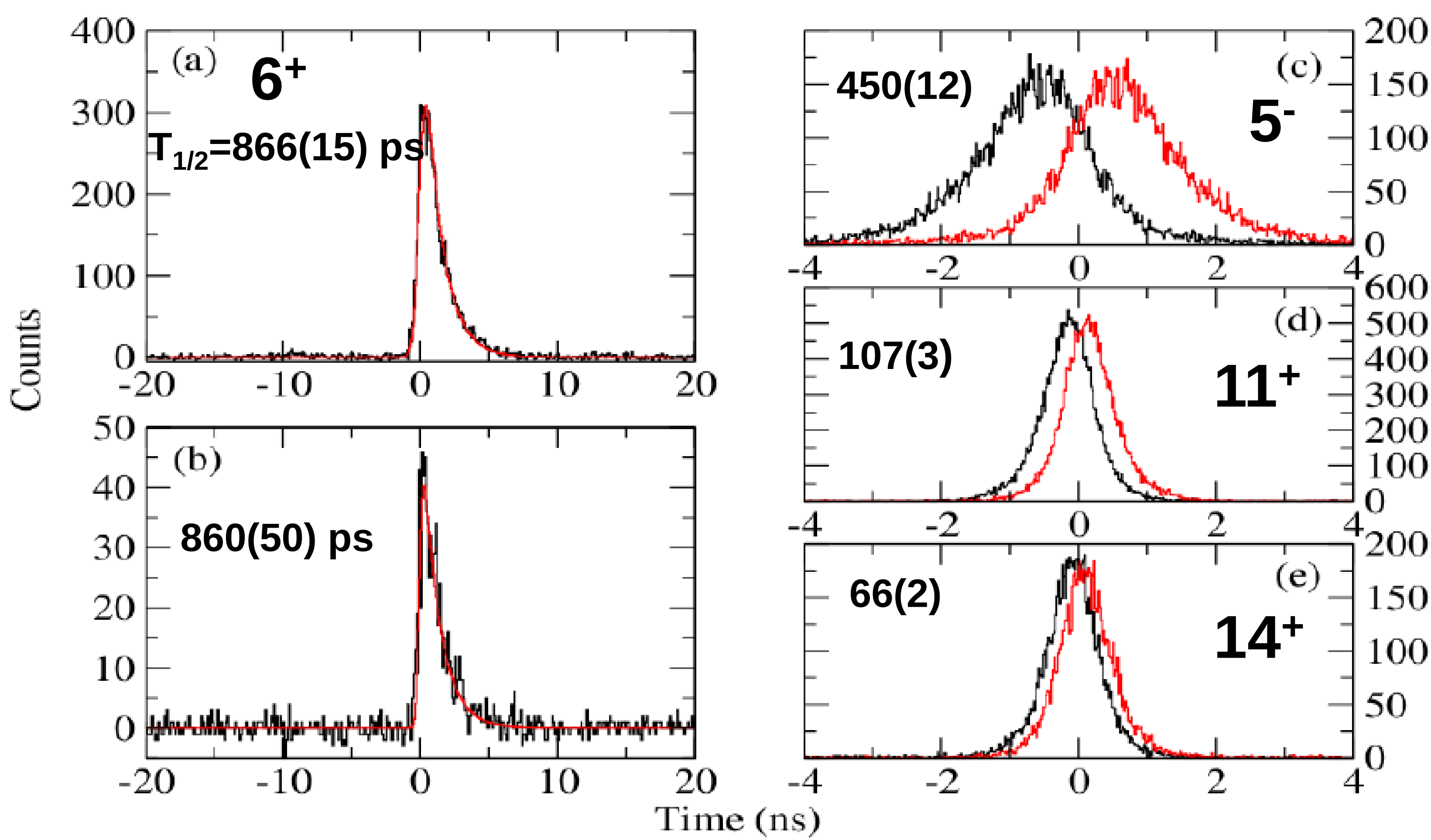
b) - Fast timing technique: wide range

^{138}Ce Z=58, N=80

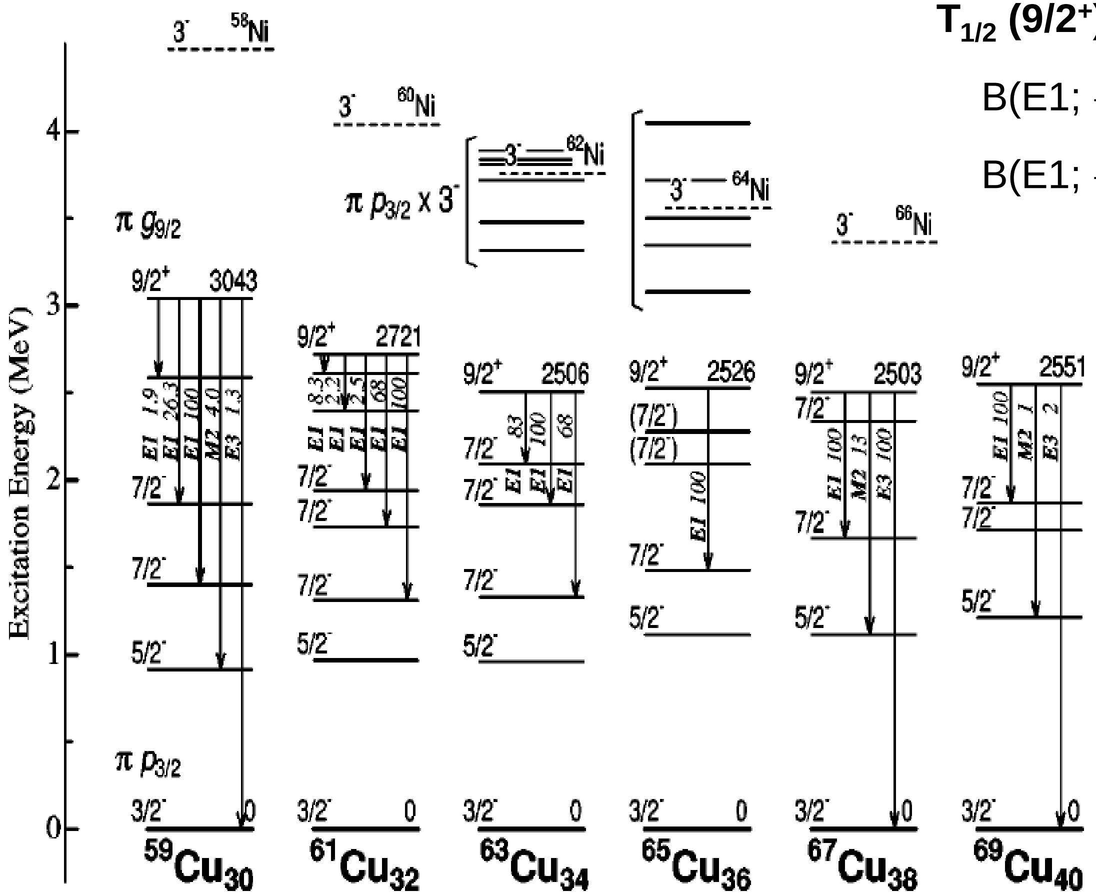
T. Alharbi *et al.*
Rutherford Centennial Conference, August 2011

^{130}Te(^{12}C,4n)^{138}Ce @ 56 MeV   Tandem + det. array IFIN





c) - Fast timing: E1 and E3 transitions in Cu isotopes



	^{59}Cu	^{61}Cu	^{63}Cu
$T_{1/2}$ (9/2$^+$) [ps]	0.80(35)	> 2.8	1.5 +3/-2
B(E1; →7/2$^-_1$)	9x10^{-5}	< 9x10^{-5}	9x10^{-5}
B(E1; →7/2$^-_2$)	7x10^{-5}	< 6x10^{-5}	4x10^{-4}

Asai et al, PRC 62(2000)054313

^{67}Cu : $T_{1/2}$(9/2$^+$) < 300 ps

B(*E*3;2503 keV) > 11 W.u.

B(*E*1;833 keV) > 1.1x10^{-6} W.u.

If B(E1) in ^{67}Cu is ~ 10^{-5} W.u.,
then B(E3) >> 11 W.u.

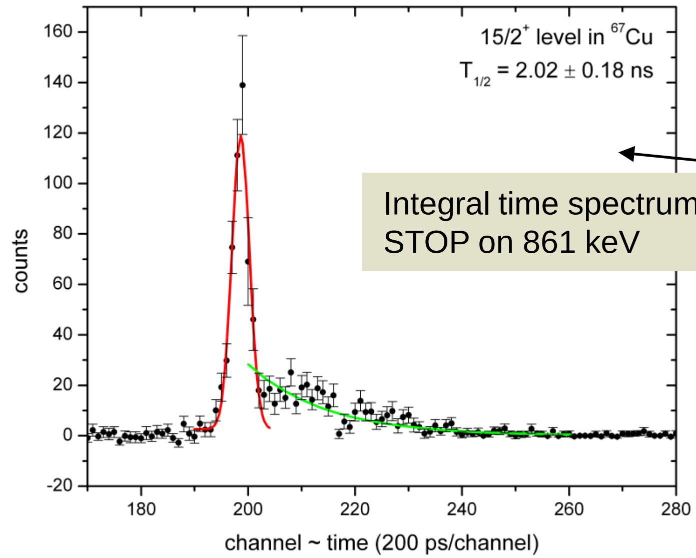
In ^{63,65}Cu, B(E3;9/2$^+$ →3/2$^-$) ≈ 20 W.u.

^{67}Cu: 9/2$^+$ has large $\pi g_{9/2}$ component (from transfer reactions)

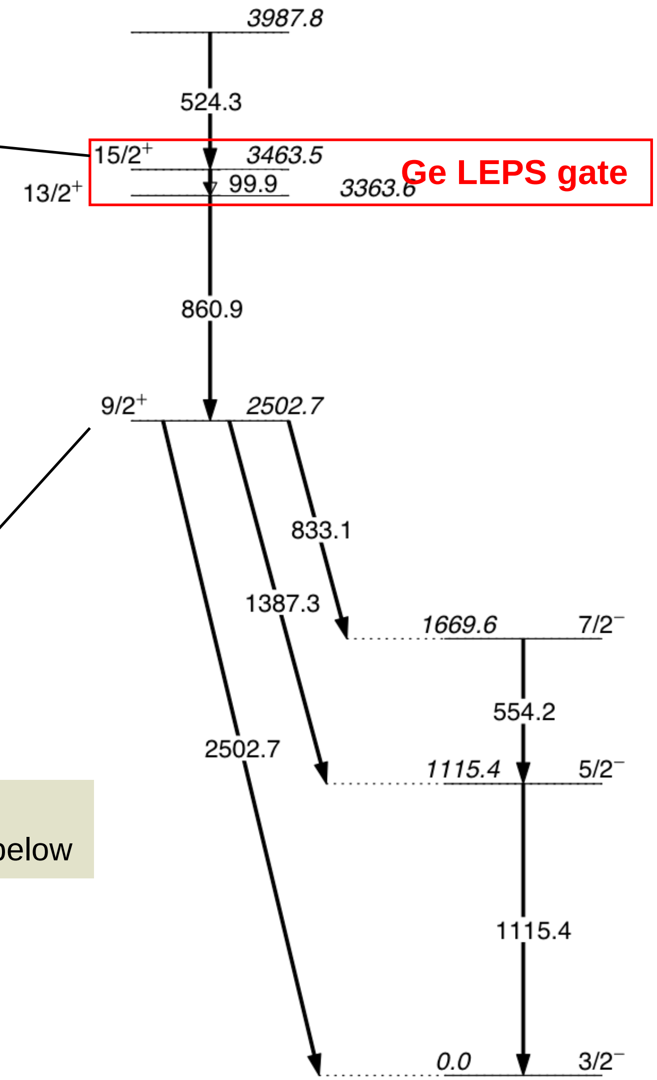
E3 $\pi g_{9/2} \rightarrow \pi p_{3/2}$ enhanced by particle-octupole vibration coupling?

Lifetime of positive-parity states in ^{67}Cu

C. Niță *et al.* (to be published)



Integral time spectrum with STOP on 861 keV



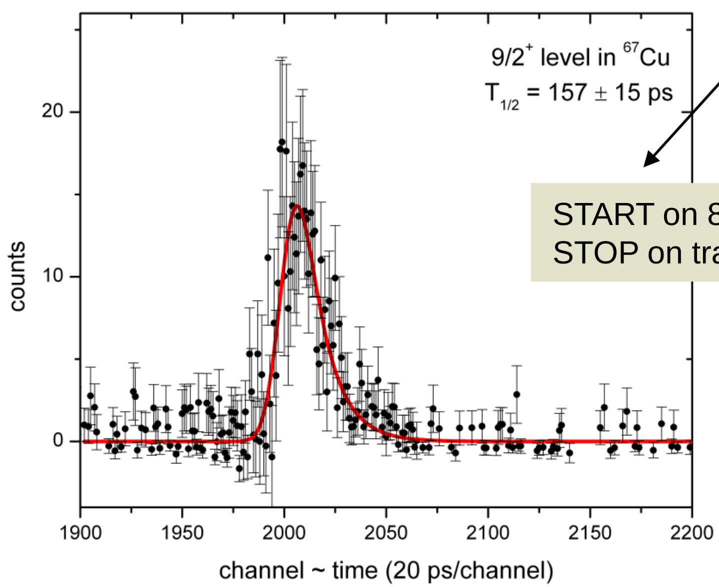
^{64}Ni(α,p)^{67}Cu

E_{α}= 18 MeV

5 HP-Ge (55% rel. eff.)

4 HP-Ge planar detectors

8 $LaBr_3$:Ce



START on 861 keV
STOP on transitions below

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E1/E3 transition strengths in ^{67}Cu

C. Niță *et al.* (to be published)

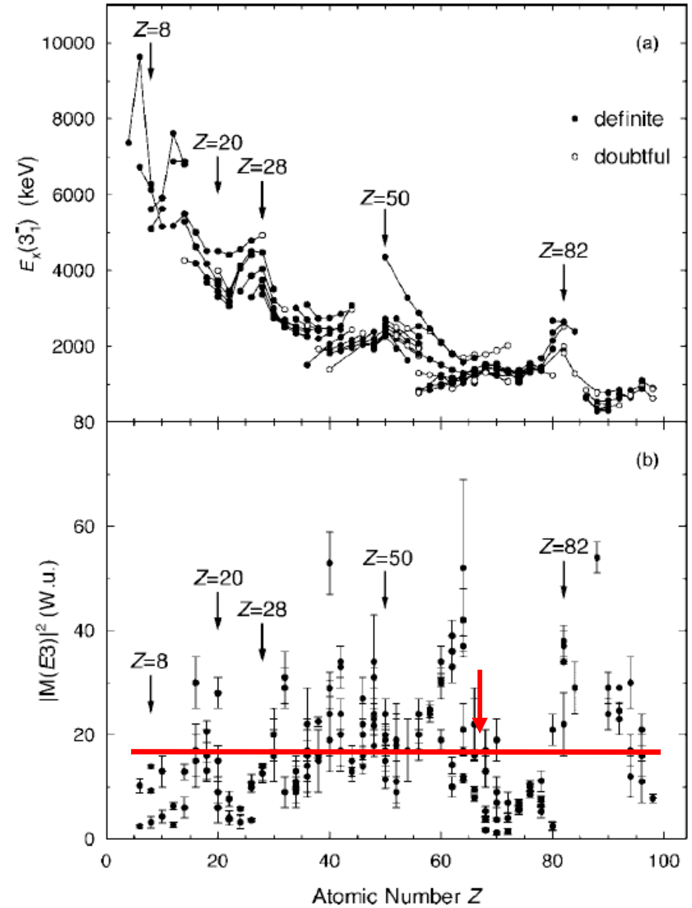
	^{59}Cu	^{61}Cu	^{63}Cu
$T_{1/2}$ ($9/2^+$) [ps]	0.80(35)	> 2.8	1.5 +3/-2
B(E1; $\rightarrow 7/2^-_1$)	9×10^{-5}	$< 9\times10^{-5}$	9×10^{-5}
B(E1; $\rightarrow 7/2^-_2$)	7×10^{-5}	$< 6\times10^{-5}$	4×10^{-4}

^{67}Cu B(E1; $\rightarrow 7/2^-_1$) = $2.6(3)\times10^{-6}$ W.u.

$T_{1/2}(9/2^+)$ = 157(15) ps

^{67}Cu B(E3; $9/2^+ \rightarrow 3/2^-$) = 17(2) W.u.

T. Kibédi and R.H. Spear
Atomic Data an Nuclear Data Tables 80(2002)35-82



In ^{63,65}Cu, B(E3;$9/2^+ \rightarrow 3/2^-$) ≈ 20 W.u. (from (α,α'), (p,p'), (e,e')).

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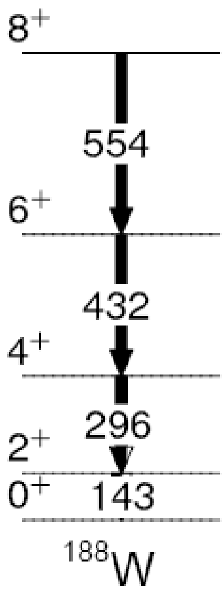
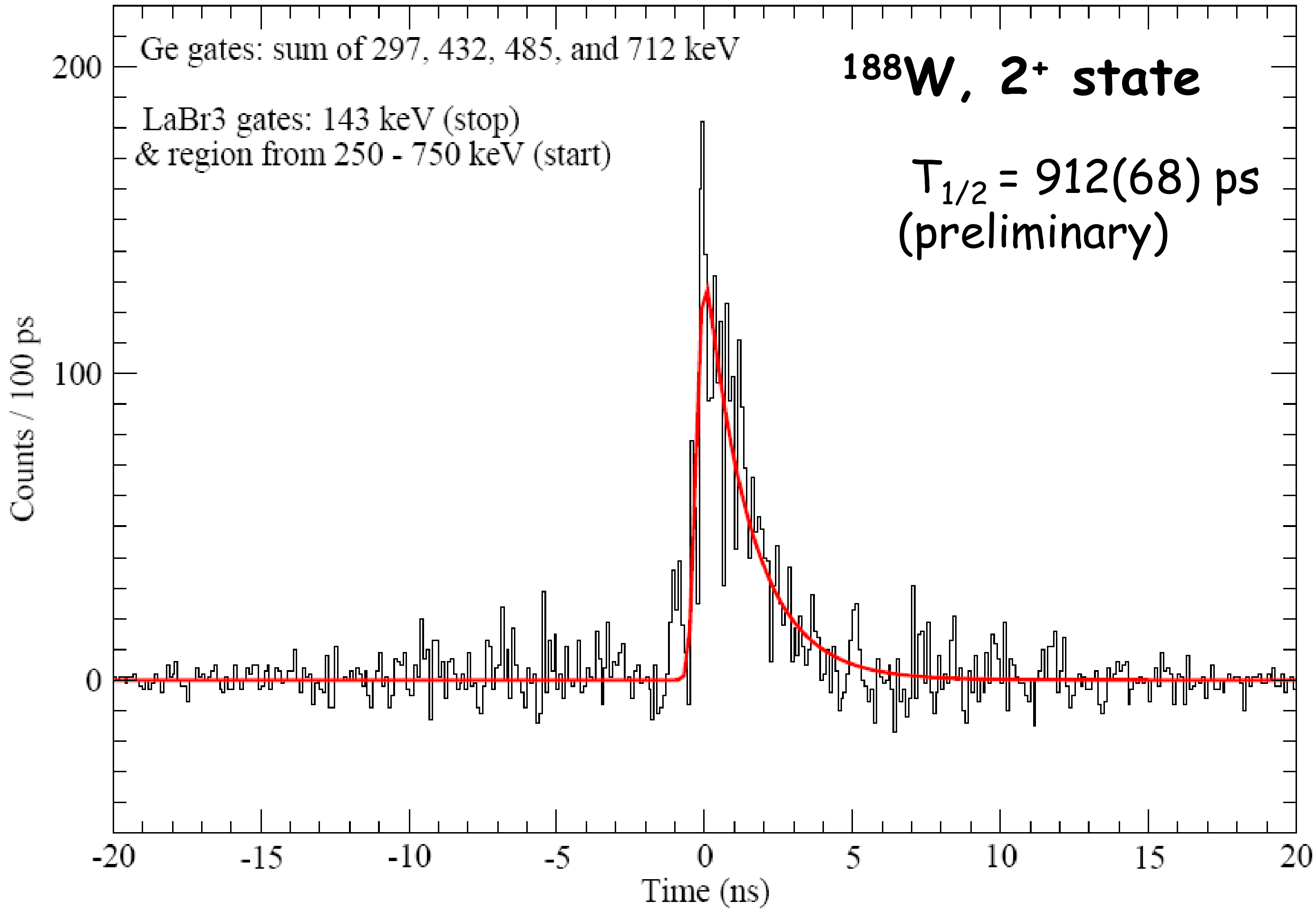
d) - Fast timing: Lifetime of 2_1^+ state in ^{188}W

P.Mason *et al.*, preliminary

^{186}W(^{7}Li,αp)^{186}W @ 32 MeV

(incomplete fusion + low-energy transfer)





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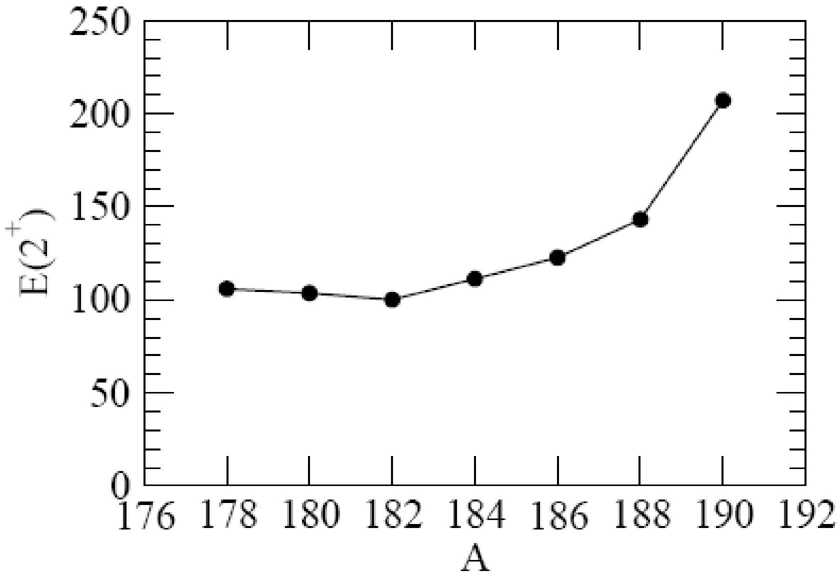
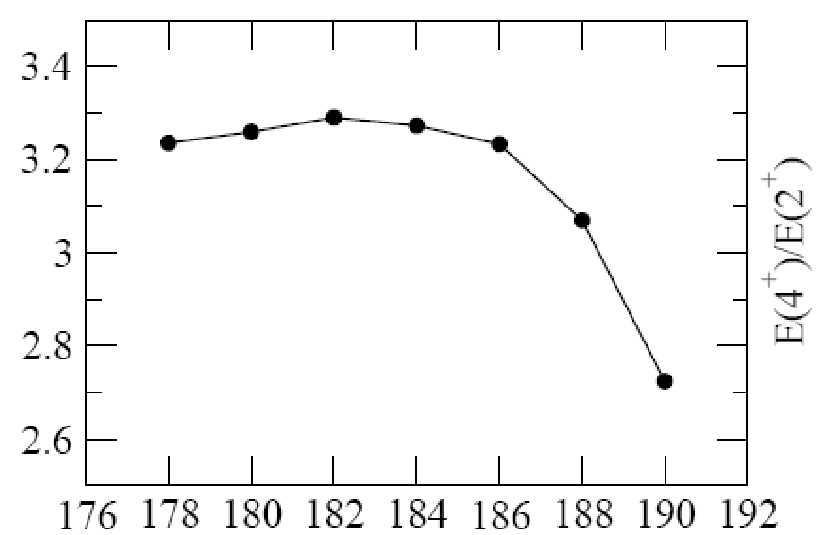
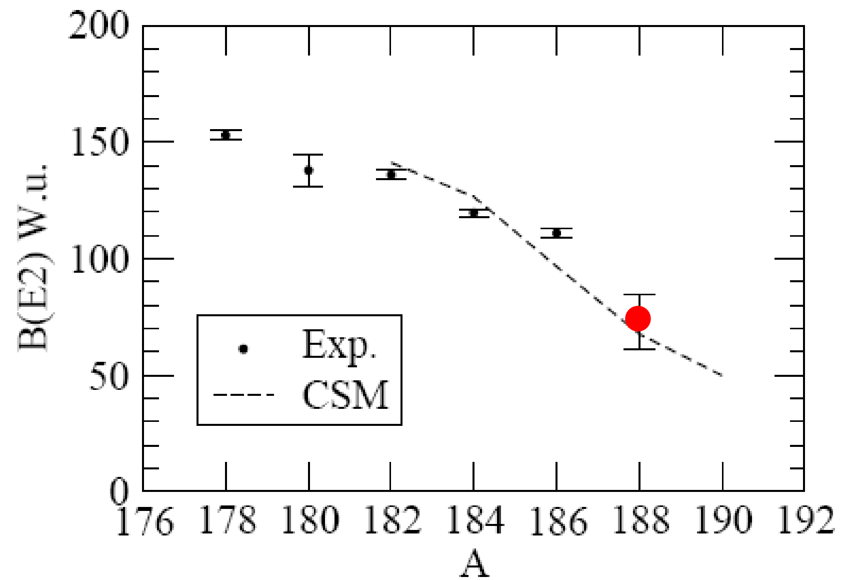
P.Mason, D.Delion, *et al.*, preliminary





Systematics of W isotopes



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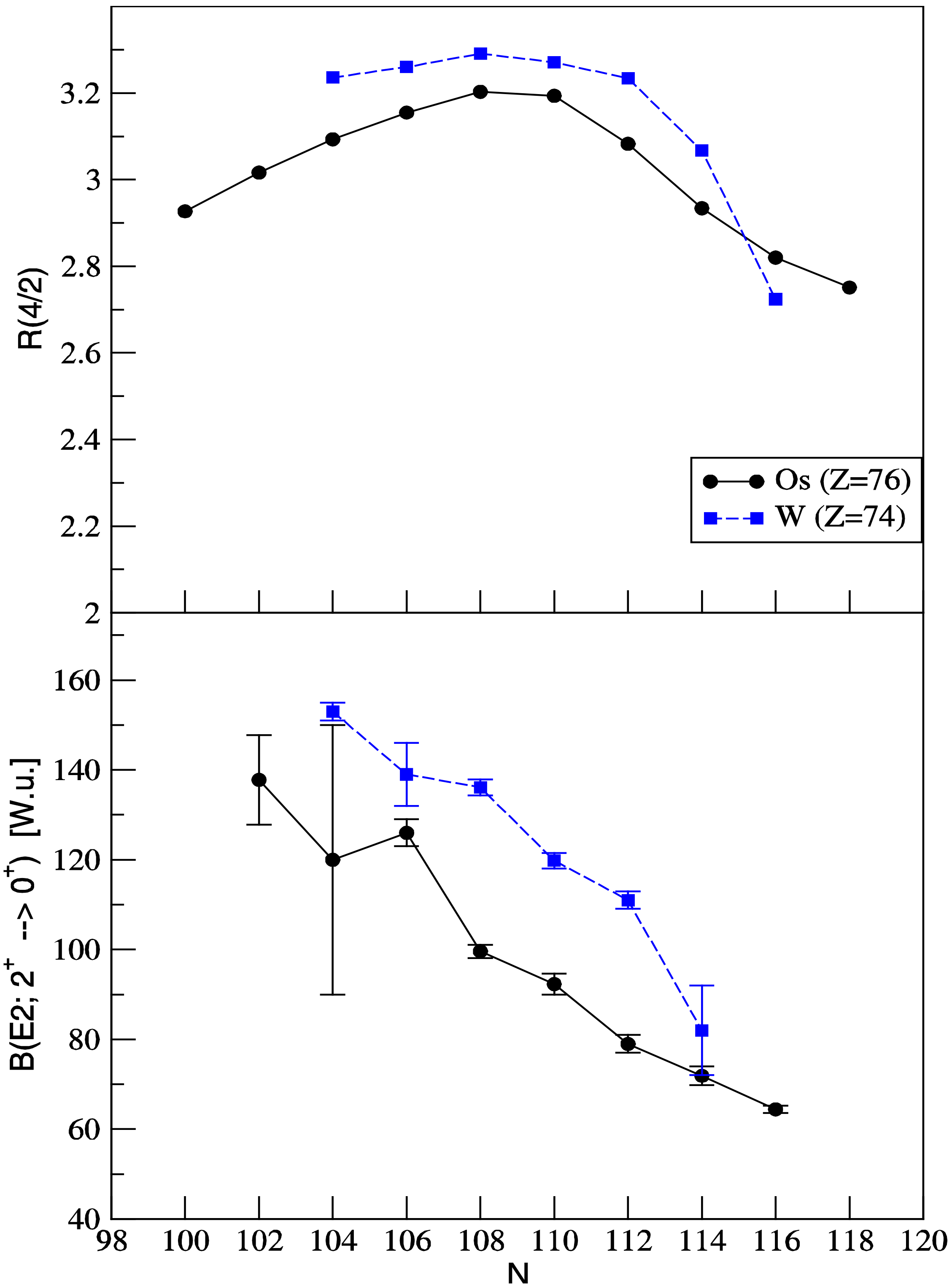

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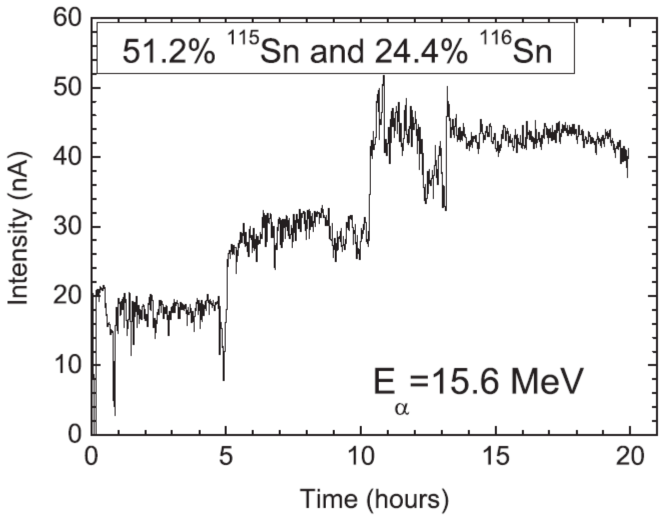
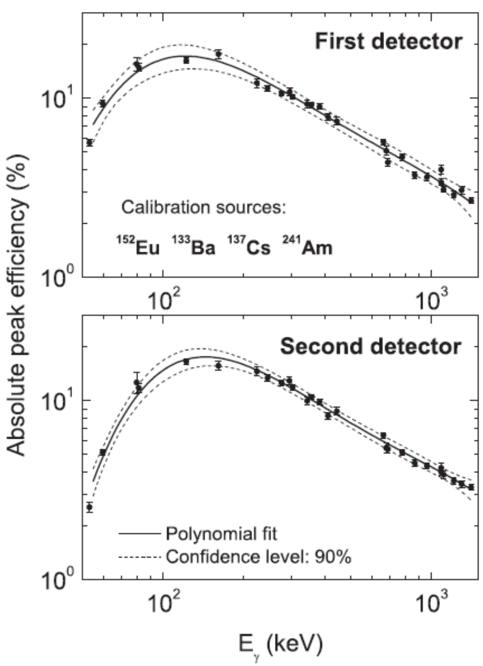
5) Reaction cross-sections of astrophysical interest

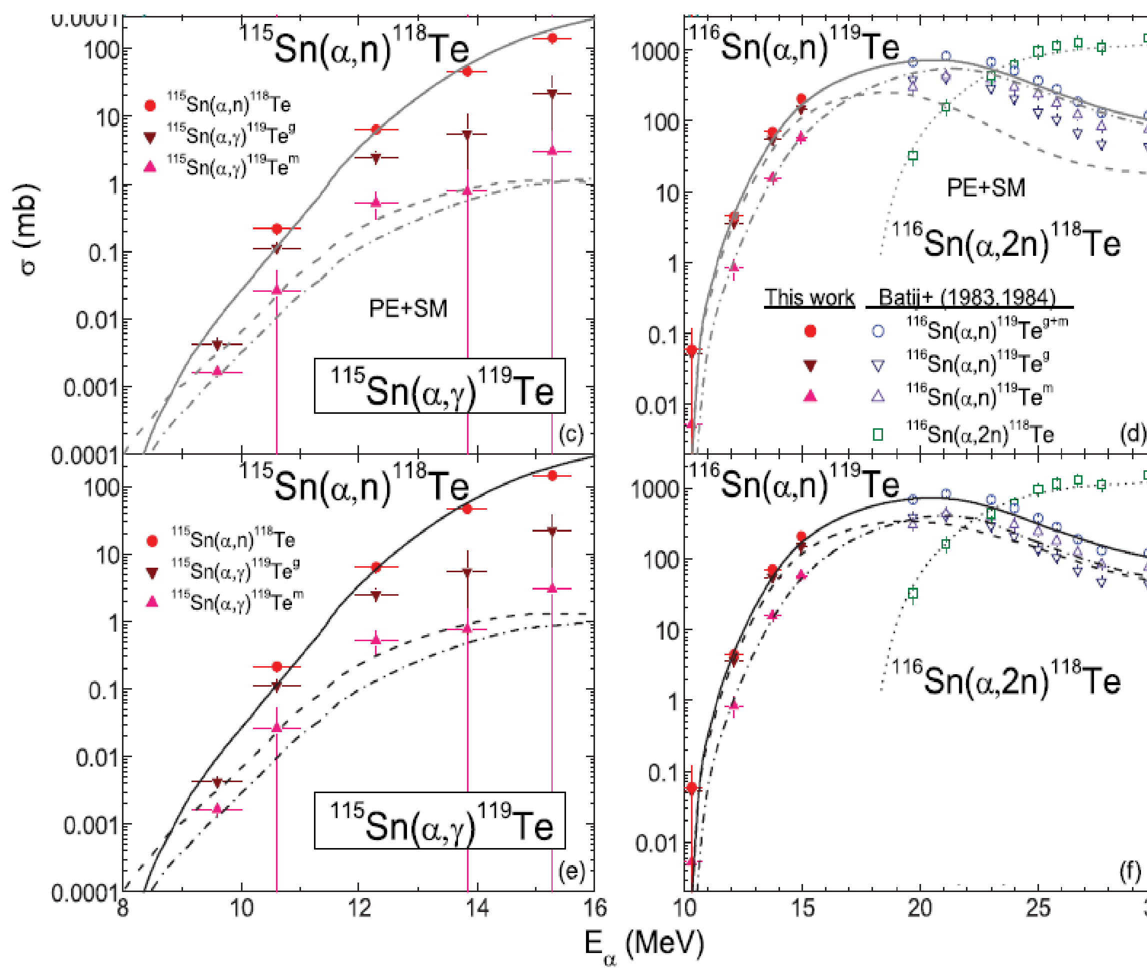
^{115}Sn(α,γ), (α,n)

D.Filipescu *et al.*, PRC83(2011)064609

Target stack activation technique







D.B., ECOS 2012, Como

Summary

- 9 MV TANDEM accelerator in Bucharest completely modernized

  Provides good currents, continuous and wide-range pulsed beam for a large number of ion species

- Experimental infrastructure: modern and competitive, developing

  HPGe+$LaBr_3$ γ-ray ball, well suited for nuclear lifetime measurements (in-beam DSAM, plunger, and fast timing)

- Facility + research program: good basis to attract young people

- We are active in international collaborations and offer good support for external groups coming to our laboratory

  Proposals of experiments are being submitted to an international PAC twice a year (~february and ~july).

http://www.nipne.ro http://tandem.nipne.ro

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R. Wadsworth

USA

P. Bender
U. Garg
V. Werner

*

The present structure of PAC is as follows:

Chair:

Dr. Gheorghe Căta-Danil (cata@tandem.nipne.ro)

Members:

Dr. Dimiter Balabanski
Dr. Norbert Pietralla
Dr. Attila Krasznahorkay
Dr. Lionel Thome
Dr. Nicolae Marius Mărginean

Secretary:

Dr. Dan Gabriel Ghiță (dghita@tandem.nipne.ro)

Applied Physics (~30-50% from the available beamtime)

- **Materials analysis with : RBS/Channeling (Rutherford backscattering / channeling); NRA (Nuclear Reaction Analysis); ERDA (Elastic Recoil Detection Analysis); PIXE (Particle Induced X-Ray Emission)); PIGE (Particle Induced γ-ray Emission)**
- **AMS (Accelerator Mass Spectrometry) – tritium in Tokamak blankets.**

Together with other users, this program will continue at the new accelerators (under commissioning): 3 MV Tandetron (analysis of materials), and 0.5-1.0 MV Tandetron (^{14}C AMS).