ALTO
PROPOSAL FOR EXPERIMENT

PAC session :	EXP # (Do not fill in):
March 2015	

Title**:**
Coulomb excitation of super-deformed band in ^{40}Ca

Is it a follow up experiment? [~~Yes~~/No]: If yes, experiment number:

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Short abstract:

The aim of this proposal is to perform Coulomb excitation of ^{40}Ca on a ^{208}Pb target and to extract B(E2) values of electromagnetic transitions. The stable ^{40}Ca beam will be delivered from the IPNO Tandem. A set of reduced transition probabilities in the rotational super-deformed band will be determined. The obtained values will be compared to those extracted from a life time measurement and shell model predictions to confirm the origin electromagnetic structure of ^{40}Ca.

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Beam line (010, 110/PARRNe, 210, 320, 410, 420, 510.)**:**	

Devices needed:	PARRNe		Bacchus		OSCAR		DIESE X		AGAT		LICORNE		BEDO	
(mark with an **X**)	Split Pole		ORGAM		DIESE		ESKIM O		PARIS		CORSET		TETRA	
Other devices (specify):														

Fill in completely:	**Ion(s)**	**Energy (MeV)**	**Intensity (nAe or pps)**	**UT/beam**	**Pulsed beam (yes/no If yes specify time structure)**
Stable beam(s)	1. ^{40}Ca 2. 3.	**168**	12nAe	18	no
RIB beam(s)	1. 2. 3.				
RIB source	1. 2.				

Fill in completely:	**Element / compound**	**Target manufacturer**	
		IPN	other

Targets	**^{208}Pb**		

TOTAL number of beam UTs Requested: 18 (1 UT=8 hours):	Time (UTs) required for setting up the apparatus: 3 Time (UTs) needed for off-beam calibration and dismounting:

Acquisition system: (mark with an **X**)	Tandem		COMET		other									
	X				X									
If other please specify: PARIS ACQ														

SAFETY:	list any hazardous equipment or substances to be used, such as. radioactive target, liquid nitrogen, explosive gas, etc.,:

New devices:	List any NEW devices needed for this experiment which still have to be bought or manufactured:
At what date do you expect these to be available?	

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Special devices:	List any special devices needed for this experiment which would require to be mounted prior to the experiment (special target chambers, detector arrays, etc.):
PARIS array consisting of 2 clusters (9 LaBr3+NaI phoswich detectors each) CEA Saclay LuSIA: double sided silicon strip detector (64 sectors, 32 rings, 16 cm diameter)	
How long will it take to mount the particular device(s) once the area is available to you?	

Status of previous ALTO experiments:	Give the status of previous experiment(s) made by this group in the last 3 years at ALTO: e.g. results from or status of analysis of previous experiments at ALTO, list publications, conference presentations, PhDs awarded etc :

Additional comments:	

PHYSICS MOTIVATION:

The microscopic description of deformation and collective rotation has been a central theme in nuclear structure physics for almost five decades. For nuclei in the lower sd-shell, where the degeneracy of the harmonic oscillator potential remain approximately valid, the connection between deformed oscillator intrinsic states and microscopic wave functions in the laboratory frame was established by Elliot's SU(3) model [1]. For heavier nuclei, however, the spin-orbit interaction brakes the oscillator SU(3) symmetry, and well-developed collective rotation generically involves valence particles/holes in two major shells for both protons and neutrons, making direct shell model diagonalization intractable. Progress in understanding collective rotational motion in these nuclei is thus strongly coupled to the program of identifying approximate symmetries that allow for the inclusion of essential degrees of freedom within an appropriately truncated model space (cf. Refs [2-6]). Such models are ideally tested and refined in cases where the valence space is large enough for collective rotation to develop, yet small enough for full-space shell-model diagonalizations to be performed. Inspection of the single particle energy levels reveals that the N~Z nuclei around $^{40}_{20}Ca_{20}$ are excellent candidates for such studies. The large shell gaps at β_2~0.4-0.6 for particle numbers N,Z = 16, 18, 20 lead to the prediction of super-deformed rotational bands in these nuclei involving valence particles in both the *sd* and *pf* shells, yet with valence space dimensions within the reach of modern shell-model calculations. Thus detailed spectroscopy studies of these A~40 super-deformed bands are important for many aspects.

Highly collective rotational structures have now been identified in a few A~40 nuclei such as ^{40}Ca [7], ^{36,38}Ar [8-10] and ^{42}Ca[11]. In the last case the deformation of the band build on the 0_2 state was measured with the Coulomb excitation technique. The high value of beta ~ 0.7 shows similarity of the low energy structure in ^{42}Ca to the super-deformed band in ^{40}Ca (see Fig.1). A measurement of B(E2) value for the unobserved 2_{sd}->0_{sd} transition and determination of the 0^+ band-head deformation are advantages of the proposed Coulomb excitation method. The low-spin behaviour of these bands is distinctive as compared to SD bands in other mass regions.

In the case of ^{40}Ca the known B(E2) values have been deduced from lifetime measurements using the Doppler-shift attenuation method [12]. The proposed experiment would provide an alternative and independent way of extracting these values. Another advantage of Coulomb excitation is to extract the relative signs of the interband transition matrix elements, which deliver an additional information on coupling of SD and yrast bands.

PROPOSED EXPERIMENT AND OBSERVABLES:

In the experiment a ^{208}Pb target (1mg/cm2) will be bombarded with a beam of ^{40}Ca delivered by the IPNO tandem at Orsay with an incident energy of 168 MeV (the 11^+ charge state and 14 MV high voltage at the terminal). The beam energy was chosen to be as high as possible while still fulfilling the Cline safe energy criterion [13].

The scattered ^{40}Ca projectiles will be detected at backward angles in the LuSIA - CEA Saclay double sided silicon strip detector (64 sectors, 32 rings, 16 cm diameter). The particle detection setup will cover an angular range from 120 to170 degrees in the laboratory frame to maximise the Coulomb excitation probability. The heavy-ions detector was successfully used for the series of COULEX measurements preformed during the MINORCA campaign at IPNO in January 2015.

High energy gamma-rays will be detected in coincidence with the scattered ^{40}Ca using the PARIS array. For this proposal it was assumed that 2 PARIS clusters (9 $LaBr_3$+NaI phoswich detectors each) will be placed at the distance of 15 cm from the target to reach the 3.5 % efficiency of the 6 MeV gamma-ray detection[14]. The

HPGe high resolution gamma ray detection array ORGAM will be used additionally to register a medium energy (500-1500 keV) gamma-ray transitions in the yrast band.

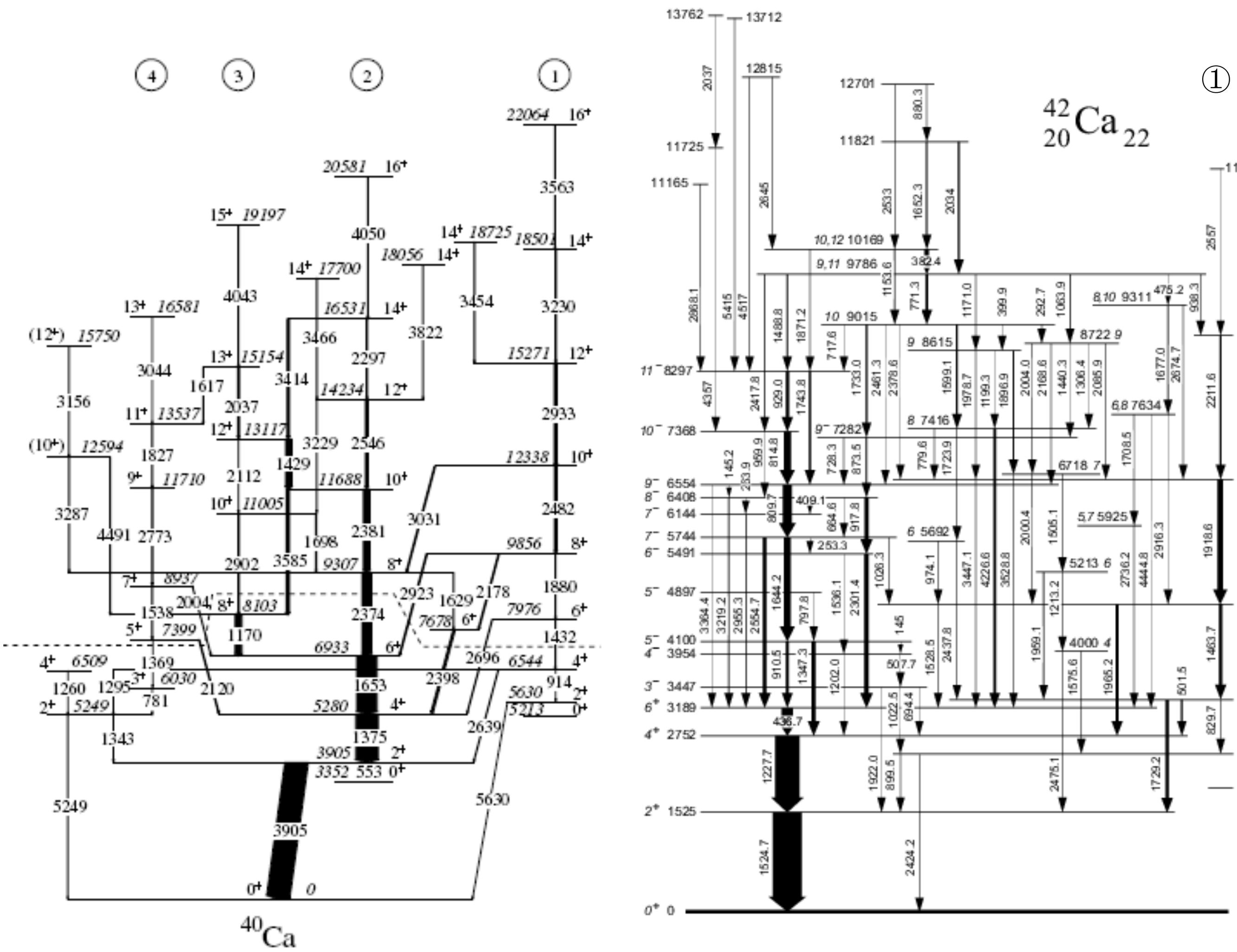

Fig.1. Left: The level scheme of ^{40}Ca [7]; right: the level scheme of ^{42}Ca [15]. The SD band in ^{40}Ca and highly deformed band in ^{42}Ca are indicated with ①.

Gamma-rays of Coulomb excited states in ^{40}Ca will be emitted in flight which will require Doppler corrections to be applied based on the particle detector readout.

To achieve a basic goal of the experiment decays of 0_{sd} and 2_{sd} states have to be observed. Population of the 0^+_{sd} state in the Coulomb excitation measurement should be more preferable than by compound nucleus reaction. This level can't be populated through the decay of excited states lying above because the high energy gamma transitions are much more probable than a low energy inband transition.

Expected in the experiment gamma ray yields were calculated using the GOSIA Coulomb excitation code [16] taking into account known nuclear structure data concerning ^{40}Ca. The expected counting rates in the PARIS detectors are shown in the Table 1.

The excitation of 4^+_1 level is the weakest possible to be observed in the proposed experiment. The energy of the in-band decay is very close to the 1308 keV line. The use of the high resolution HPGe array ORGAM will help to determine intensities of these both decays. The intensity of 0_{sd} ->2_1 inter band transition is important because it describes the Coulomb excitation of the SD band head.

Table 1. Calculated counting rates of the Coulomb excited ^{40}Ca decays measured with 2 PARIS clusters.

Transition	Energy [keV]	Counts/day	Total
2_1->0_{gs}	3905	8400	42000
2_{sd}->0_{gs}	5630	400	2000
0_{sd} ->2_1	1308	1250	6250
4_1->2_1	1375	100	500
2_{sd}->0_2	2639	60	300

BEAM REQUEST:

In order to achieve the accuracy better the 5 % in the weakest line of the 2_{sd} decay we request 5 days of in-beam data taking (15 shifts) and 1 day (3 shifts) for the particle detector setup.

References :

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