Travelling around GDR phenomena and new detectors with

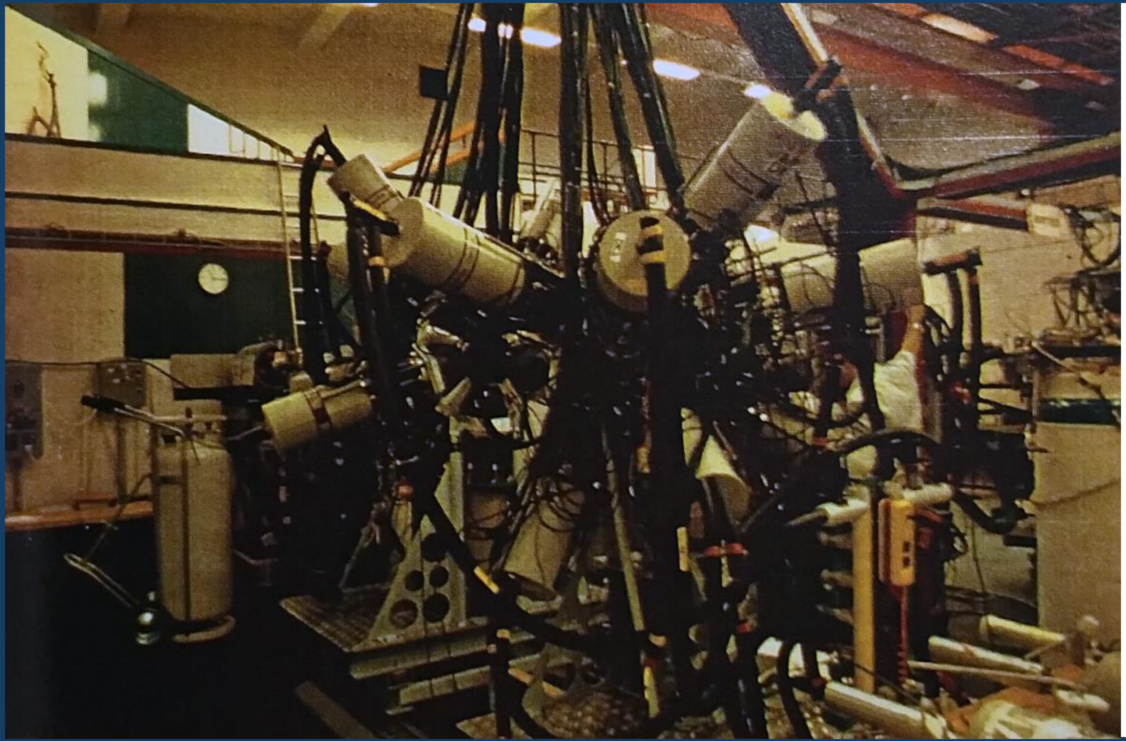
Franco Camera

D. Santonocito - Milano 17-18 oct. 2024

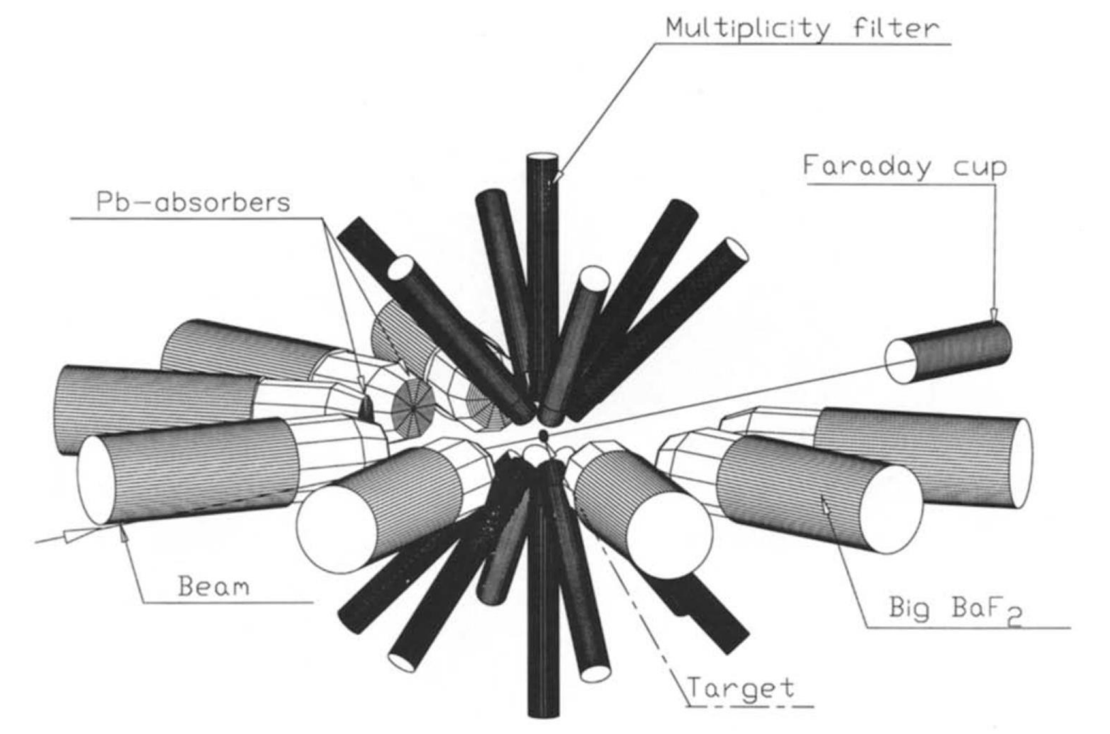
This travel starts at the TANDEM Laboratory of the Niels Bohr Institut in Risø, Denmark

It was beginning of June 1990

NORDBALL



HECTOR

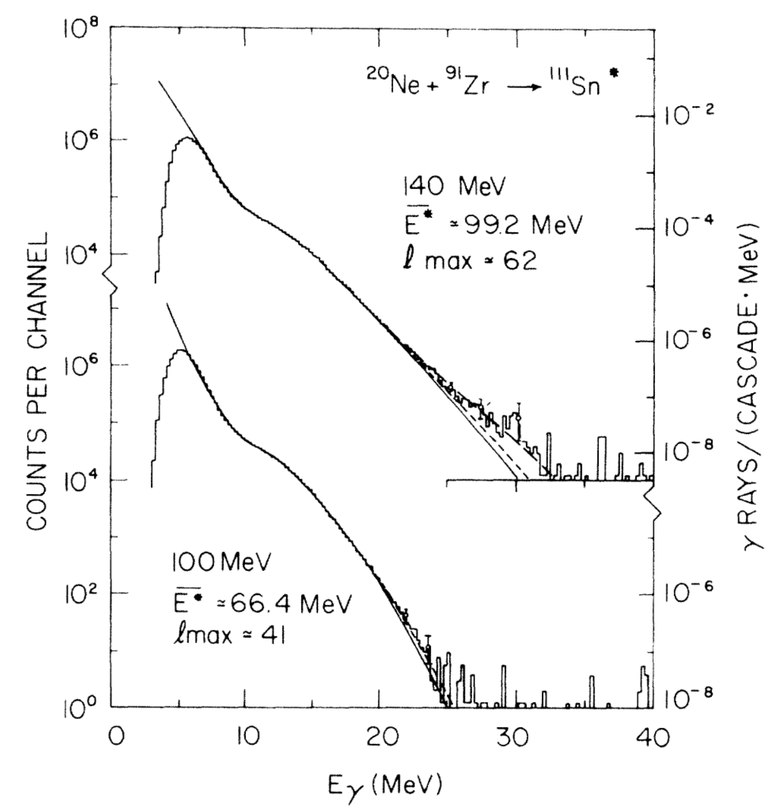


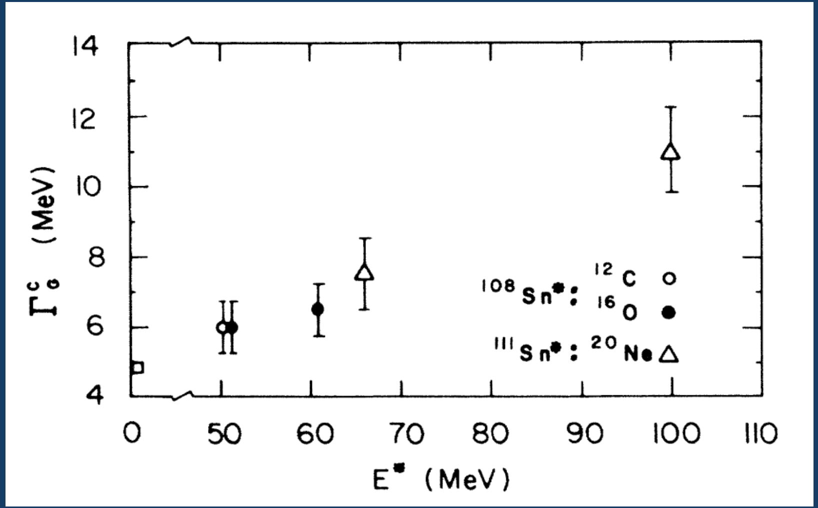
GDR Width evolution at low E*

Reactions	Ebeam	E*	A
^{12}C + ^{96}Ru	63	50	108
^{16}O + ^{92}Mo	73	51	108
^{16}O + ^{92}Mo	84	62	108
^{20}Ne + ^{91}Zr	100	66	111
^{20}Ne + ^{91}Zr	140	99	111

J.J.Gaardhoje et al PRL56(1986)1783 (LBL)

J.J.Gaardhoje et al PRL53 (1984)148 (TANDEM in Risø)



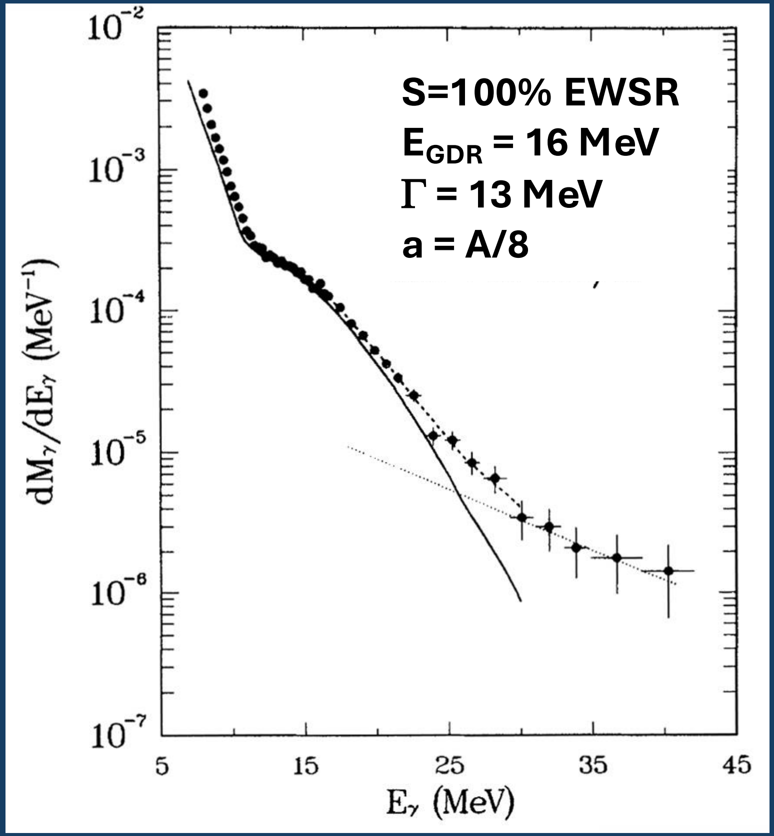


Statistical model calculation using CASCADE code:

- **Strength = 100% EWSR**
- **Γ increasing with E***
- **Egdr constant with E***

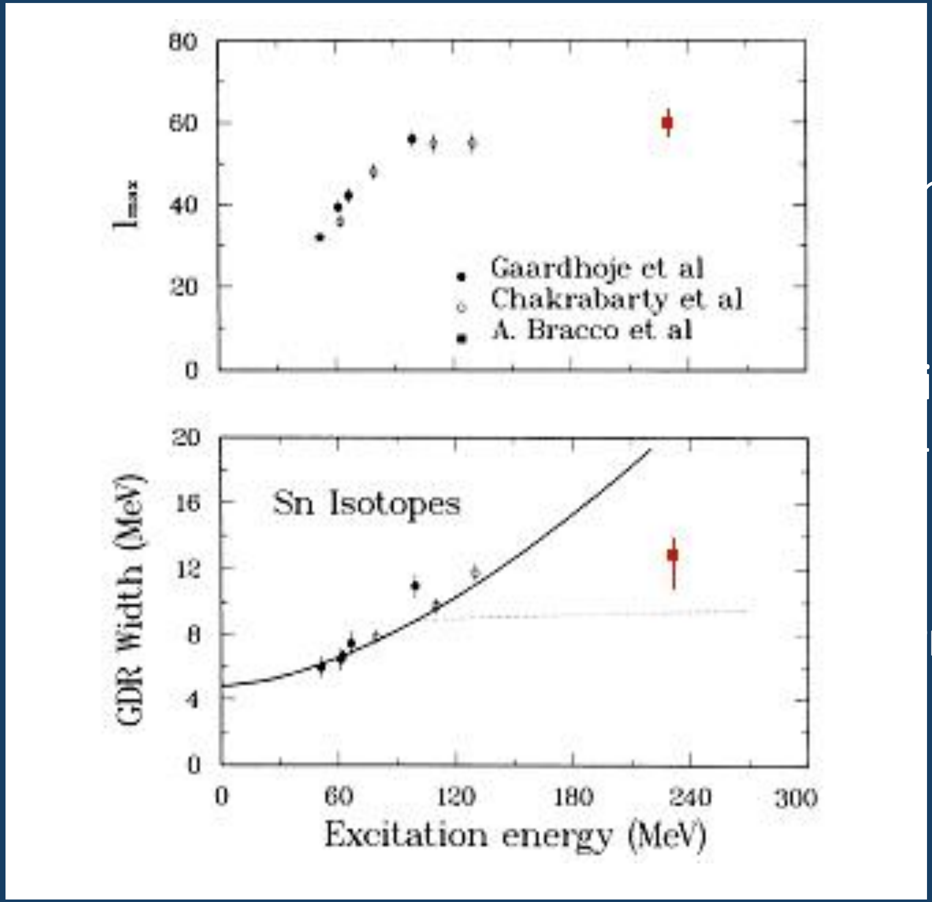
Study of GDR properties for T > 2 MeV

Reaction: ^{40}Ar+^{70}Ge @ 10 MeV/A



A. Bracco et al. PRL62(1989)2080 (Grenoble)

Hot nuclei (^{110}Sn) were populated at E* ≈ 230 MeV
Gamma-rays were measured in coincidence with Evaporation Residues (using PPAC)



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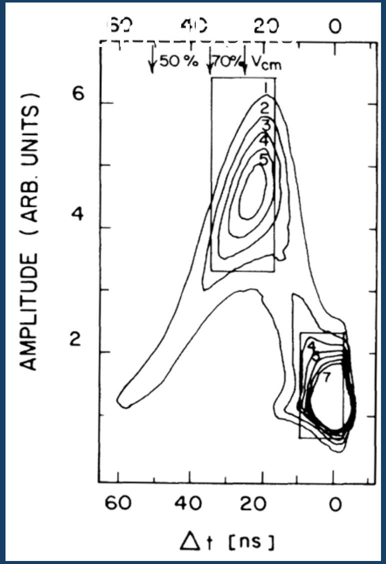
The first evidence for a GDR width saturation at about 13 MeV due to saturation of transferred angular momentum.

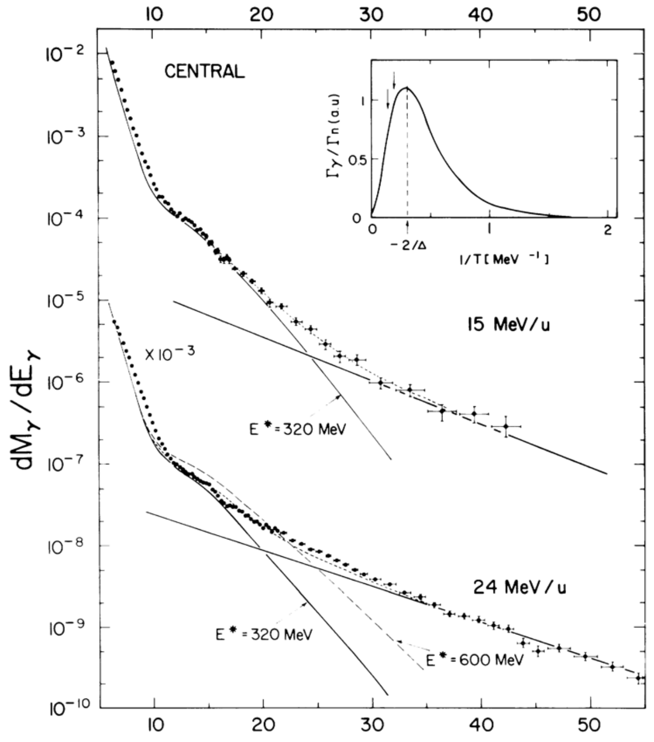
Quenching of the GDR in Hot nuclei

First evidence of a GDR quenching was observed by Gaardhoje et al. in 1987 studying the reactions ^{40}Ar + ^{70}Ge 15*A* and 24*A* MeV

Fusion events selected through measurements using PPAC (DE-T)
Hot systems populated at E* ≈ 320 and E* ≈ 600 MeV
Large distribution in momentum transfer

Residue
ToF





J.J. Gaardhoje et al PRL59 (1987)1409

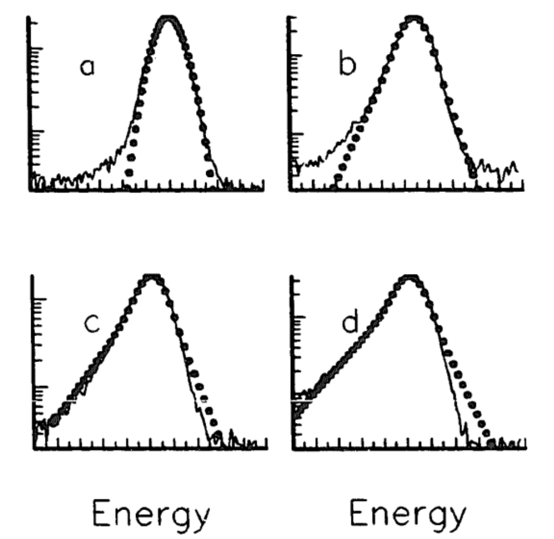
At E* = 320
Gamma spectrum reproduced assuming for the GDR:

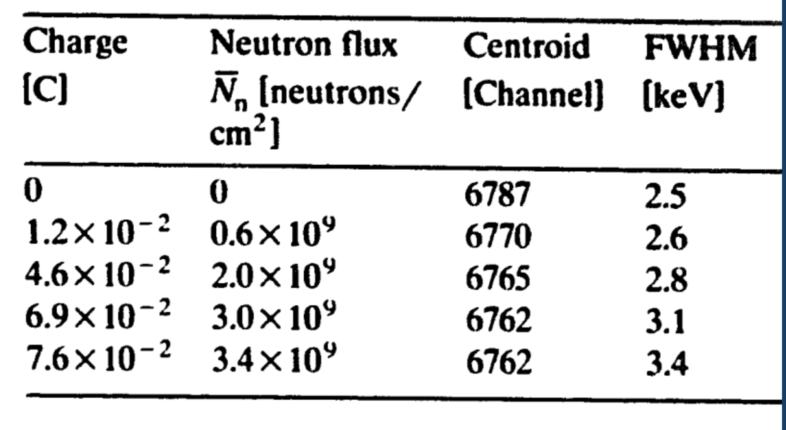
- Strenght: 100%
- E_{GDR} = 15.5 MeV
- Width = 15 MeV

At E* ≈ 600 MeV the spectrum was nearly identical to the one at 320 MeV

Possible interpretation in terms of loss of collectivity due to different mechanisms

Initial Publications





Charge [C]	Neutron flux $\bar{N}_n$ [neutrons/cm^2]	Centroid [Channel]	FWHM [keV]
0	0	6787	2.5
1.2×10^{-2}	0.6×10^{9}	6770	2.6
4.6×10^{-2}	2.0×10^{9}	6765	2.8
6.9×10^{-2}	3.0×10^{9}	6762	3.1
7.6×10^{-2}	3.4×10^{9}	6762	3.4

Measurement of the Giant Dipole Resonance γ-Decay

Nuclear Instruments and Methods in Physics Research A314 (1992) 544–546
North-Holland

NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH
Section A

Effects of neutron exposure on the energy resolution of Ge(Hp) detectors

F. Camera [a,b], A. Bracco [a,b], S. Leoni [a,b], G. Lo Bianco [a,b], B. Million [b] and E. Rebesco [a]
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Received 29 August 1991

The energy resolution of a high purity Ge detector with an efficiency of 70% was measured after it was exposed to increasing integrated fluxes of fast neutrons. The latter were produced by the reaction $p+{}^{nat}Cu \rightarrow Zn+n$ at an incident laboratory energy of 6 MeV. The energy resolution was found to be increased by ~30% after irradiation by an integrated flux of 3×10^9 neutrons/cm^2.

1. Introduction

Ge detectors are used in γ spectroscopy because of their extremely good energy resolution (~2.0 keV at 1 MeV). One of the major uses is the in-beam measurement of gamma rays produced by compound fusion reactions between heavy ions. In addition to gamma rays these reactions produce several neutrons (one for every ~10 MeV of excitation energy) which can be absorbed in the Ge crystal. The structural damage caused by neutrons consists of the creation of trapping levels between the valence and conduction bands. As a consequence, the electron–hole pairs, created by the photon interaction in the active volume of the detector, are trapped during their drifting to the electrodes. This effect results in the broadening of the full energy peak and in the appearance of a low energy tail. It is therefore important to measure the value of the integrated neutron flux that such detectors can stand before their energy resolution becomes unacceptable.

So far the Ge detectors which where used in nuclear spectroscopy studies through heavy ion fusion reactions had an efficiency of 20 to 40%. For detectors of this size the neutron damage of the crystal becomes important after approximately 10^9 neutrons/cm^2. In spite of large fluctuations among these detectors one can say that the FWHM becomes in average larger by a factor of the order of 1.3.

Only recently very efficient HpGe detectors (of the order of 70%–80%) became available and several groups are constructing arrays with this type of detectors. It is therefore very important to know how they are damaged by fast neutron bombardment.

In the present paper we report on a measurement made to determine how the energy resolution of a large HpGe detector (~70%) is affected by irradiation with fast neutron fluxes. The detector is manufactured by the company Intertechnique of Strasbourg. The shape of the crystal is that of a cylinder with a diameter of ~8 cm and a length of ~7 cm. The first 3 cm are tapered to an angle of 10°. The cryostat was especially designed to keep the detector to a temperature lower than 85 K. In fact, the energy resolution of the HpGe detectors that have been irradiated seems to be [1] extremely dependent on the operating temperature. An increase of only a few degrees over 85 K causes a dramatic increase in the radiation damage sensitivity of the detector.

2. The measurement

The energy resolution of the HpGe detector was measured before it was exposed to neutrons using a ^{60}Co source. The signal from the preamplifer was sent to a Tennelec TC244 Spectroscopy Amplifier with pile up rejection and the chosen shaping time was 4 µs. Before the test started a reference spectrum was taken. With a counting rate of 1 kHz the FWHM of the 1332 keV line of ^{60}Co was 2.5 keV. The detector was then irradiated with neutrons produced by the reaction: $p+{}^{nat}Cu \rightarrow Zn+n$ with an incident proton energy of 6

Measurement to determine how the energy resolution of a large HpGe detector (~ 70%) is affected by irradiation with fast neutron fluxes

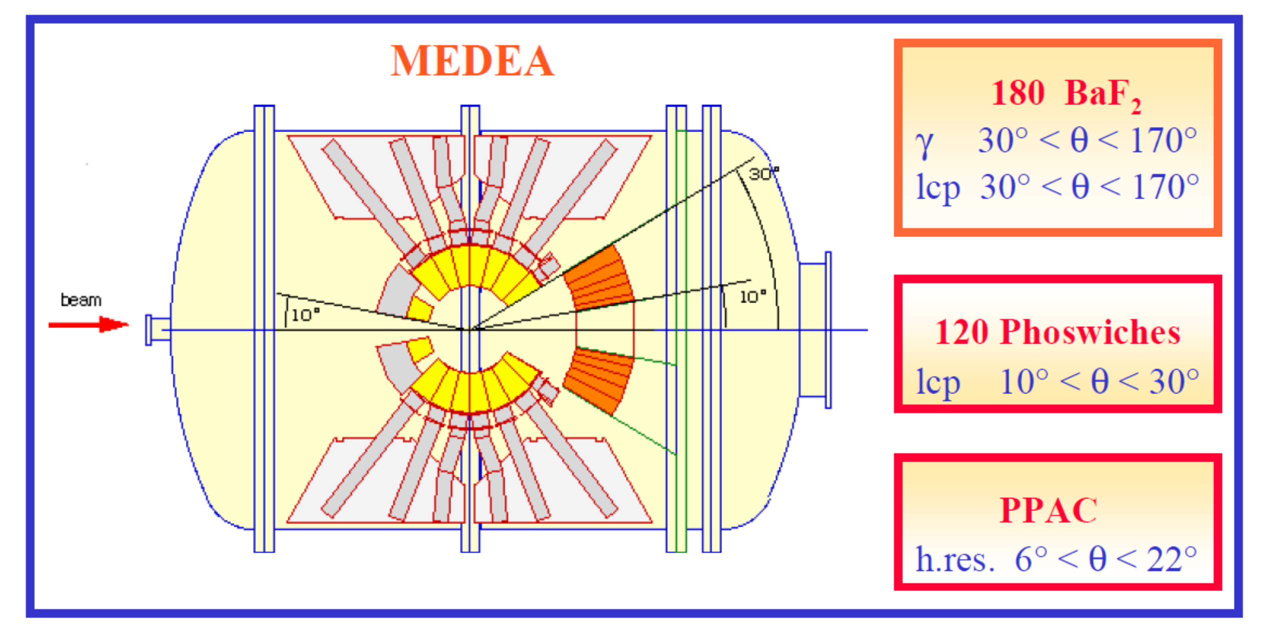
Angular anisotropy $a2(E\gamma)$ for ^{110}Sn at E* = 92 MeV and I~ 60h

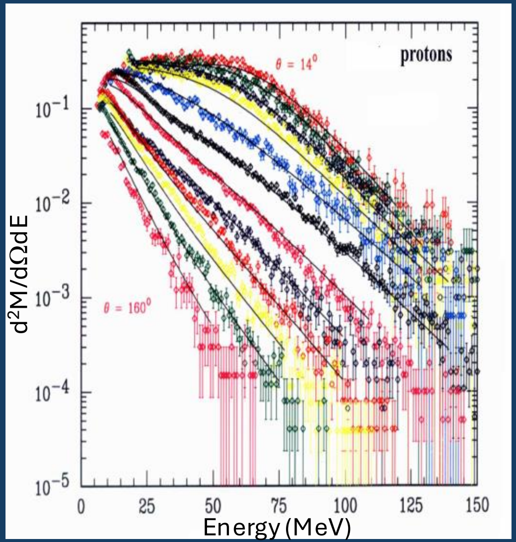
My Activities @ LNS – Catania

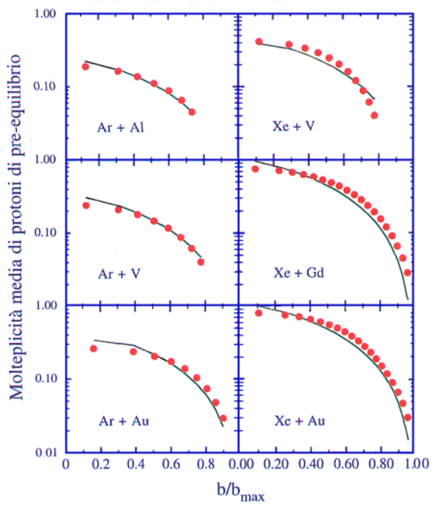
Intermediate energy heavy ion collisions Studies using MEDEA setup in GANIL and LNS

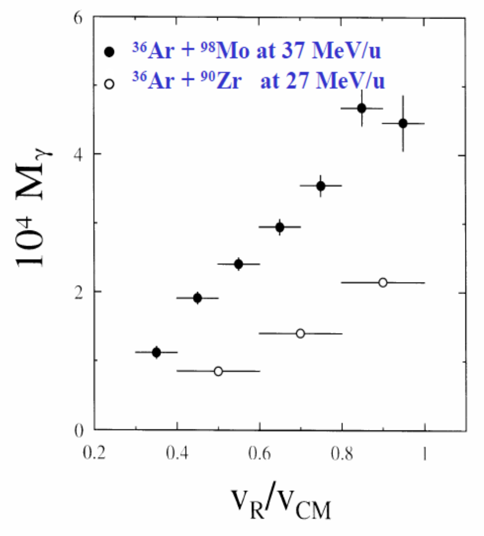
Characterization of the pre-equilibrium emission:

- High energy protons
- High energy gamma-rays



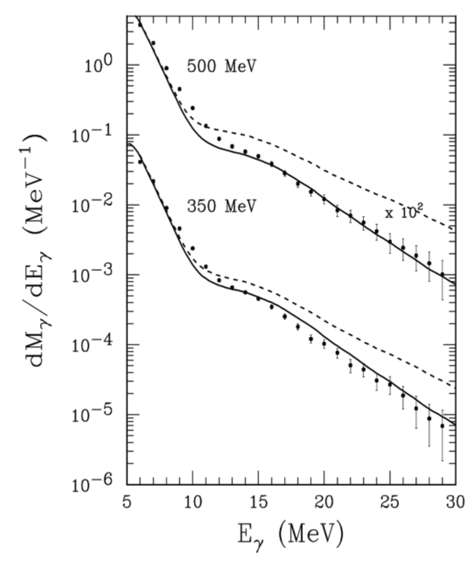






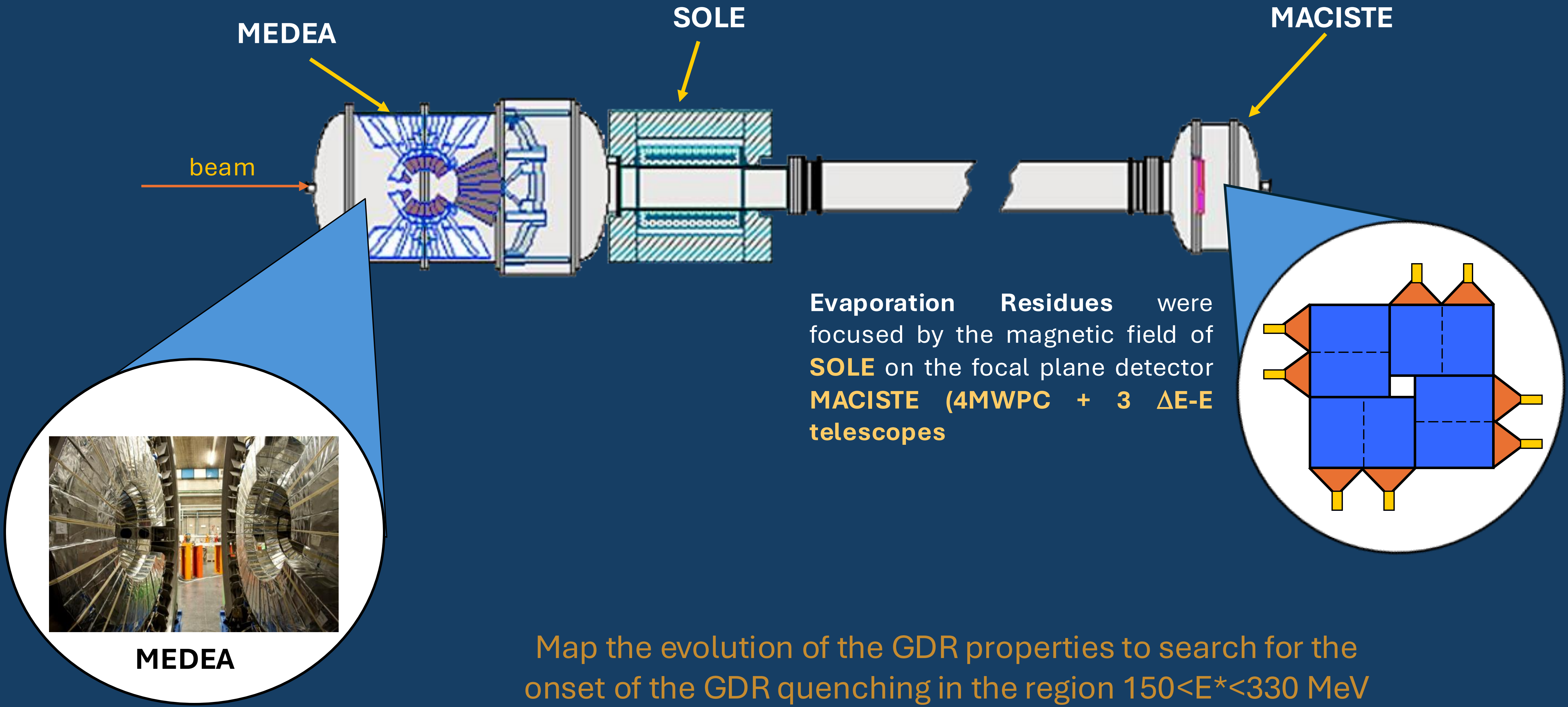
GDR quenching
^{36}Ar + ^{90}Zr @ 27 MeV/A

The γ-ray multiplicity saturation was consistent with a disappearance of the GDR strenght above E* = 250 MeV



My real start in the GDR business (2002-2003)

Build SOLE + Maciste setup to complement MEDEA



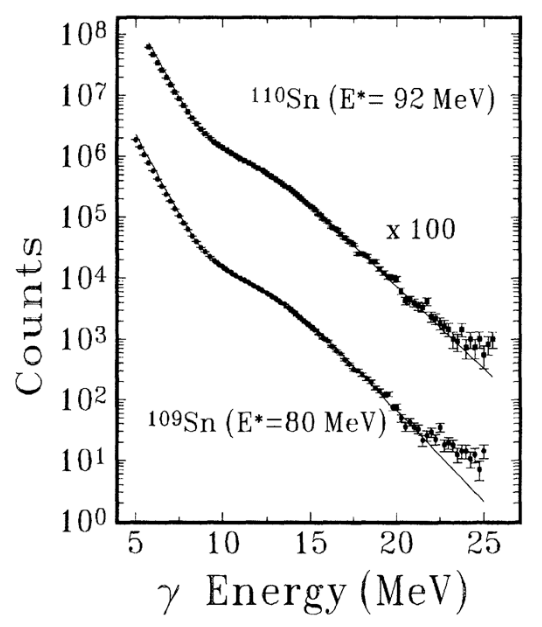
Evaporation Residues were focused by the magnetic field of **SOLE** on the focal plane detector **MACISTE (4MWPC + 3 ΔE-E telescopes**

Map the evolution of the GDR properties to search for the onset of the GDR quenching in the region 150<E*<330 MeV

Hot GDR properties scenario up to 2006

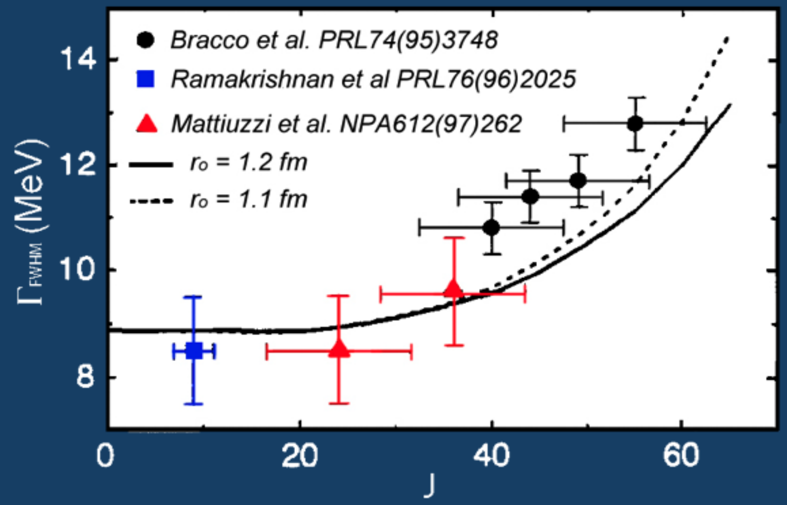
Most of the activities were focused on the GDR Width evolution with Temperature and Spin

GDR Width evolution: J-dependence



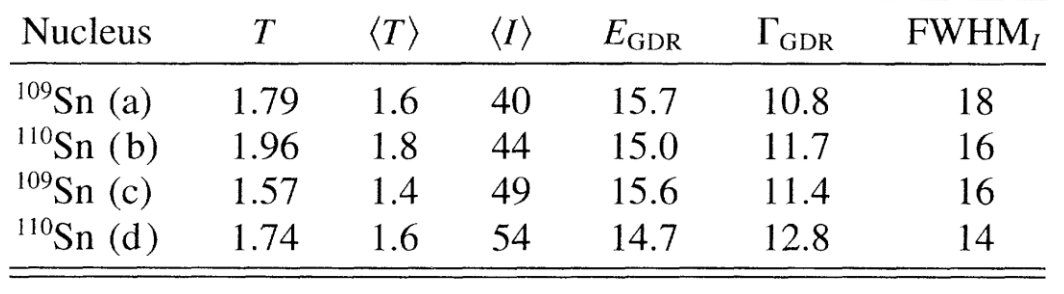
A. Bracco et al PRL74 (1995) 3748

Previous work was extended populating ^{106}Sn nuclei at E* = 8 MeV and lower J using ^{58}Ni+^{48}Ti @ 260 MeV



Mattiuzzi et al , NPA612(1997) 262

Different J intervals selected through low γ-ray

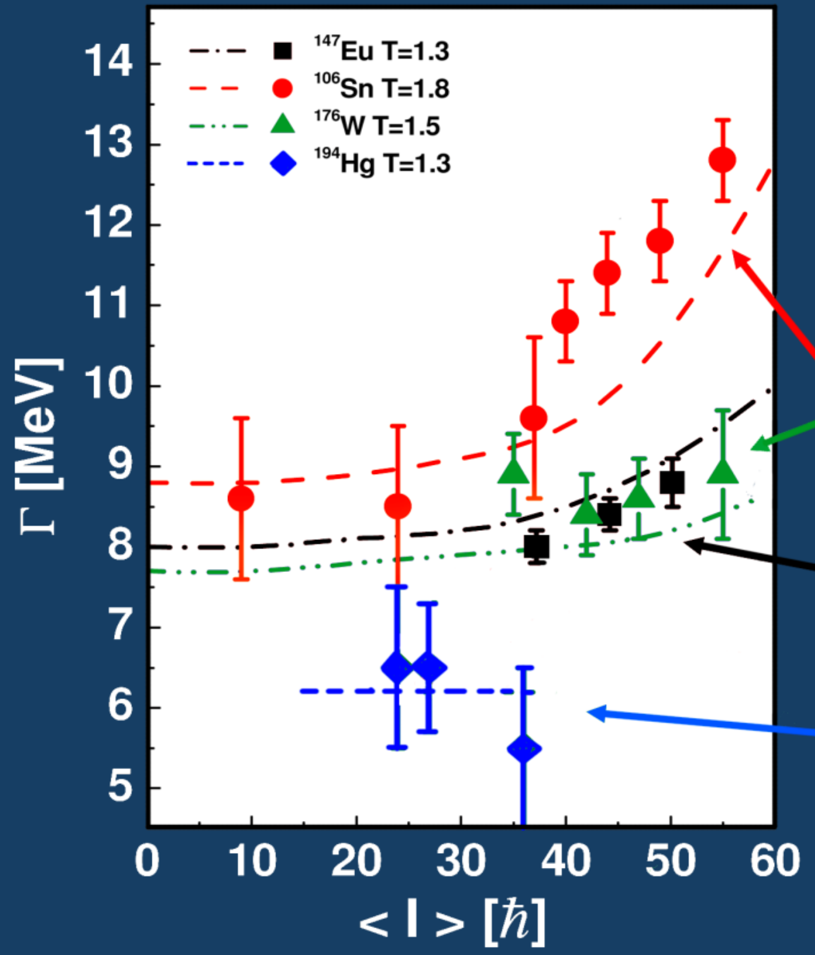


Nucleus	T	$\langle T \rangle$	$\langle I \rangle$	E_{GDR}	Γ_{GDR}	FWHM$_I$
^{109}Sn (a)	1.79	1.6	40	15.7	10.8	18
^{110}Sn (b)	1.96	1.8	44	15.0	11.7	16
^{109}Sn (c)	1.57	1.4	49	15.6	11.4	16
^{110}Sn (d)	1.74	1.6	54	14.7	12.8	14

The width of the GDR is roughly constant for J < 35h, increasing rapidly for higher angular momenta. Good agreement with theoretical calculations within TSFM

GDR Width evolution: J-dependence

Measurement in different mass regions.
Width increase depends on the system A → J value at which the increase takes place goes up with A.
Deformation is driven by rotational frequency



M. Mattiuzzi et al.
NPA612 (1997) 262

M.Kmiecik et al.
NPA674 (2000) 29

Camera et al.
PR.C60 (1999)014306

Basic assumptions of TSFM work in describing the data trend:

Dipole vibration coupled to the ensamble of nuclear deformations characterising the nucleus at finite T and J.

Width increase with J reflects the increase in the splitting of GDR components associated to increase in deformation induced by rotation.

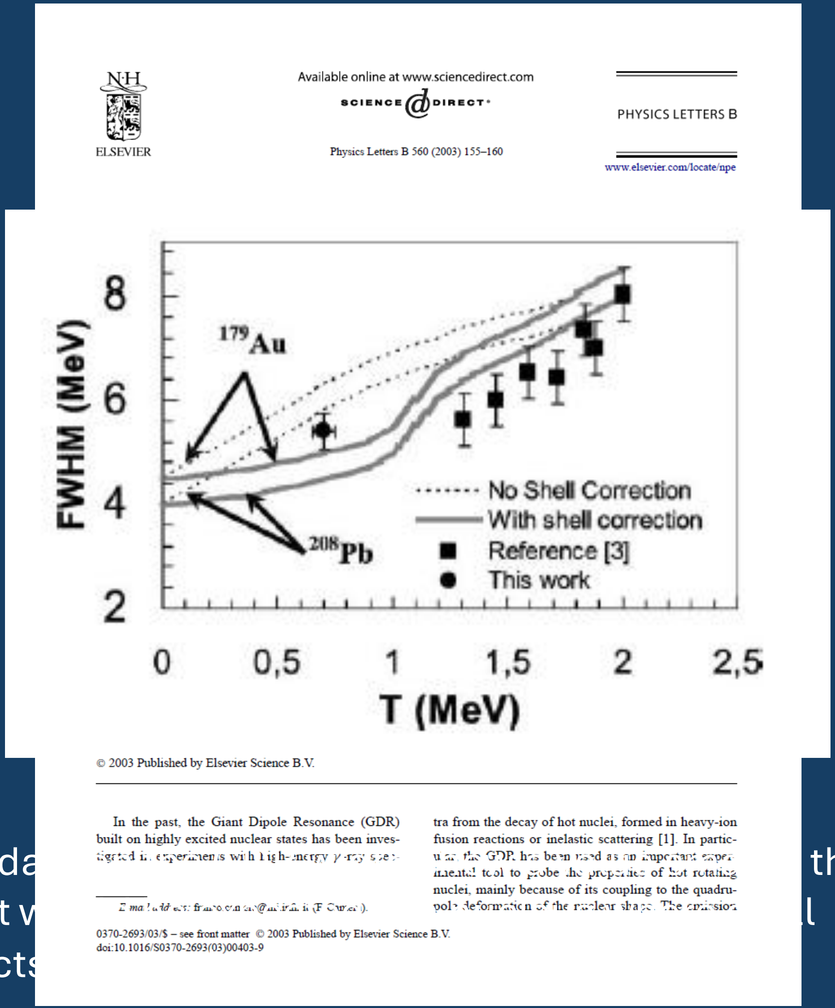
GDR Width evolution: T-dependence

GDR width in ^{179}Au at very low T

^{90}Zr + ^{89}Y → ^{179}Au @ E* = 20 MeV

^{90}Zr beam @ 352 MeV

Probe nuclear shapes in the region of temperature *T* = 0.5 – 1 MeV to investigate how shell effects decrease with increasing temperature.



Available online at www.sciencedirect.com

Physics Letters B 560 (2003) 155–160

PHYSICS LETTERS B

www.elsevier.com/locate/npe

In the past, the Giant Dipole Resonance (GDR) built on highly excited nuclear states has been investigated in experiments with high-energy γ-ray spectra from the decay of hot nuclei, formed in heavy-ion fusion reactions or inelastic scattering [1]. In particular, the GDR has been used as an important experimental tool to probe the properties of hot rotating nuclei, mainly because of its coupling to the quadrupole deformation of the nuclear shape. The emission

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0370-2693/03/$ – see front matter © 2003 Published by Elsevier Science B.V.
doi:10.1016/S0370-2693(03)00403-9

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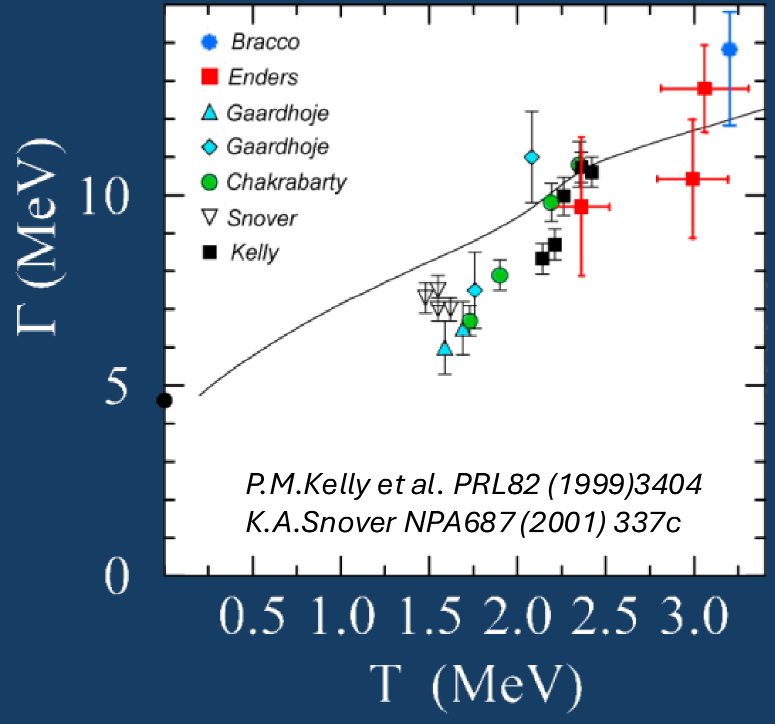
effects

Study of GDR properties for T > 2 MeV

GDR width in ^{132}Ce hot nuclei up to T= 4 MeV

Investigation of the problem required new data:

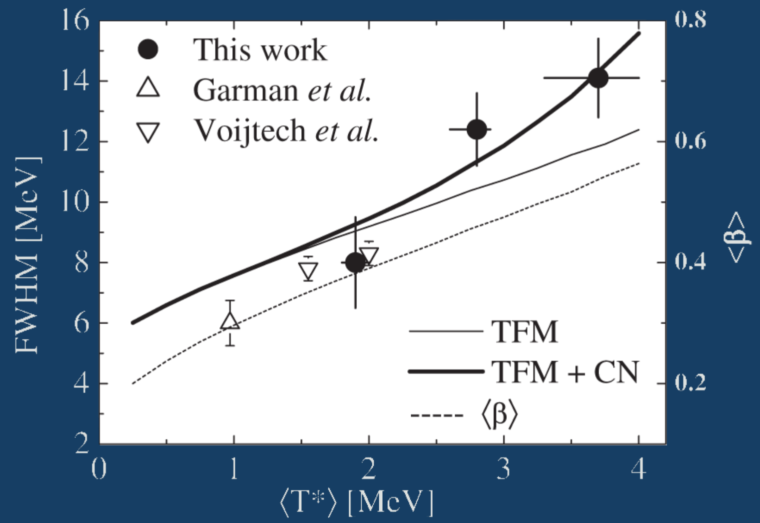
- a good control on the pre-equilibrium emission



P.M.Kelly et al. PRL82 (1999)3404
K.A.Snover NPA687 (2001) 337c

Pre-equilibrium corrections applied to GDR width in the A ~ 120 systematics at high T.

Symmetric reactions used to populate hot nuclei of ^{132}Ce at E* = 100, 150 and 200 MeV



Wieland et al. Phys. Rev. Lett. 97(2006)012501

In mass region A ~ 130 the GDR Width increases with T

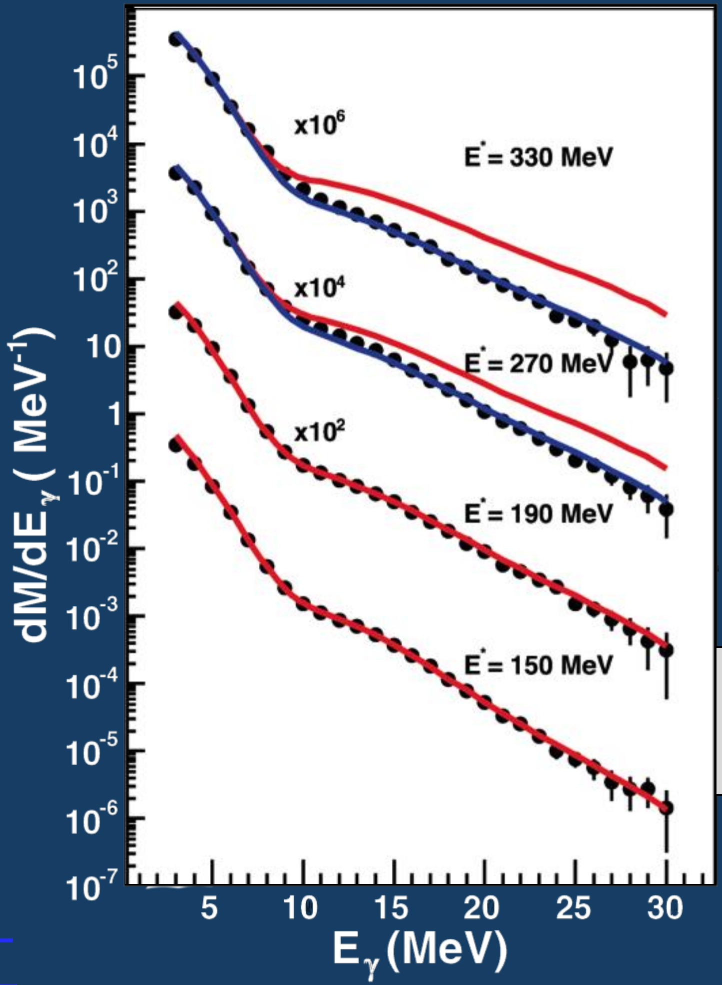
The trend can be reproduced including compound nucleus lifetime within the TFM calculation

GDR quenching

Evolution of the GDR properties up to E* = 330 MeV with MEDEA

Reactions studied: ^{116}Sn + ^{12}C, ^{24}Mg @ 17 MeV/A

^{116}Sn + ^{12}C, ^{24}Mg @ 23 MeV/A



CASCADE at 150 MeV A=124
CASCADE at 190 MeV A=123
CASCADE at 270 MeV A=132
CASCADE at 330 MeV A=128
GDR inputs:

- 100% EWSR
- E_{GDR} = 14
- Γ_{GDR} = 11 – 13 (increases with E*)
- a = a(T) (Ormand et al PRC40(1989)1510)

E* = 270 MeV E_{cut} = 230 MeV
E* = 330 MeV E_{cut} = 240 MeV

Physics Letters B 782 (2018) 427–432

Contents lists available at ScienceDirect

Physics Letters B

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Mapping the demise of collective motion in nuclei at high excitation energy

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ABSTRACT

High energy gamma-rays from the ^{116}Sn + ^{24}Mg reaction at 23A MeV were measured using the MEDEA detector at LNS – INFN Catania. Combining this new data with previous measurements yields a detailed view of the quenching of the Giant Dipole Resonance as a function of excitation energy in nuclei of mass A in the range 120 ÷ 132. The transition towards the disappearance of the dipole strength, which occurs around 230 MeV excitation energy, appears to be remarkably sharp. Current phenomenological models give qualitative explanations for the quenching but cannot reproduce its detailed features.

Studies of the Giant Dipole Resonance (GDR) built on excited states have provided a wealth of information on the dynamics of nuclei at finite temperature [1–3]. One remaining open problem in the study of the evolution of GDR properties as a function of excitation energy is the origin of the suppression of the GDR gamma yield at high excitation energies. This effect was observed, for the first time, in the study of ^{40}Ar + ^{70}Ge @ 24A MeV reaction [4] where hot nuclei around 600 MeV excitation energy were populated and the gamma-ray spectrum measured in coincidence showed a sizeable strength reduction compared to standard statistical model calculations. The spectrum could be reproduced assuming an excitation energy $E^* = 320$ MeV suggesting the interpretation of the disappearance of the GDR with increasing excitation energy and the existence of a limiting temperature for the collective motion in nuclei with mass A ~ 100.

Further evidence for the suppression of the GDR γ yield at very high excitation energies in the same mass region was then found by different experimental groups investigating the reactions ^{40}Ar + ^{92}Mo at 21A and 26A MeV [5], ^{36}Ar + ^{90}Zr at 27A MeV [6] and ^{36}Ar + ^{98}Mo at 37A MeV [7] where hot nuclei were populated in an energy domain ranging from 260 to about 550 MeV. These results showed the limits of applicability of the standard statistical scenario in the description of the GDR decay from a very hot system, pointing to the need of a theoretical explanation for the quenching mechanism. A simplified approach to reproduce the gamma-ray spectra was to introduce a sharp ad hoc suppression of the gamma emission above a given excitation energy, the so called cutoff energy. In the analysis of the 27A MeV data the authors reproduced the spectra extracted at all the excitation energies using the same energy value of 250 MeV for the cutoff [8] which led the authors to conclude that $E^*/A \sim 2.2$ MeV represents a limit for the existence of the dipole vibration for $A \sim 110$ nuclei [8].

Different theoretical models developed to explain the GDR behaviour at high excitation energy basically follow two main ideas,

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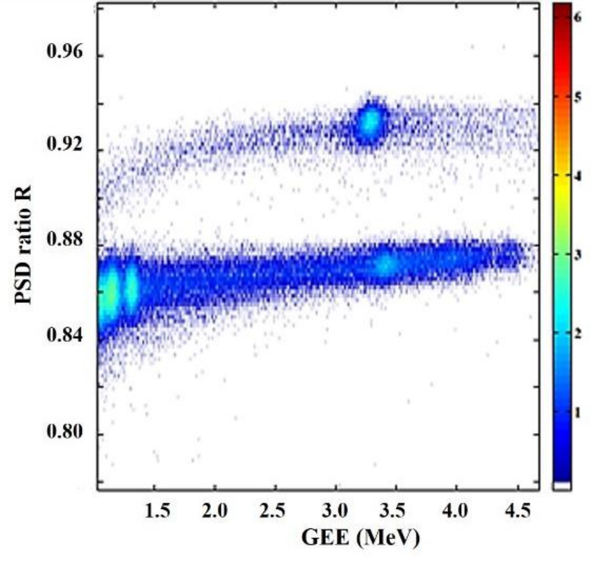
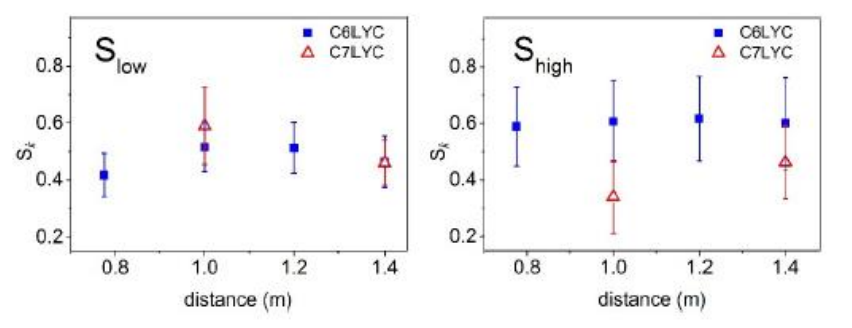
https://doi.org/10.1016/j.physletb.2018.05.052

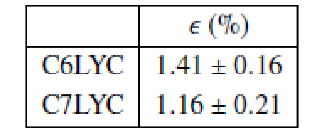
- A surprisingly abrupt onset of the GDR quenching is observed which cannot be reproduced by any of the existing models.
- Data are better reproduced assuming a yield suppression model

Detectors

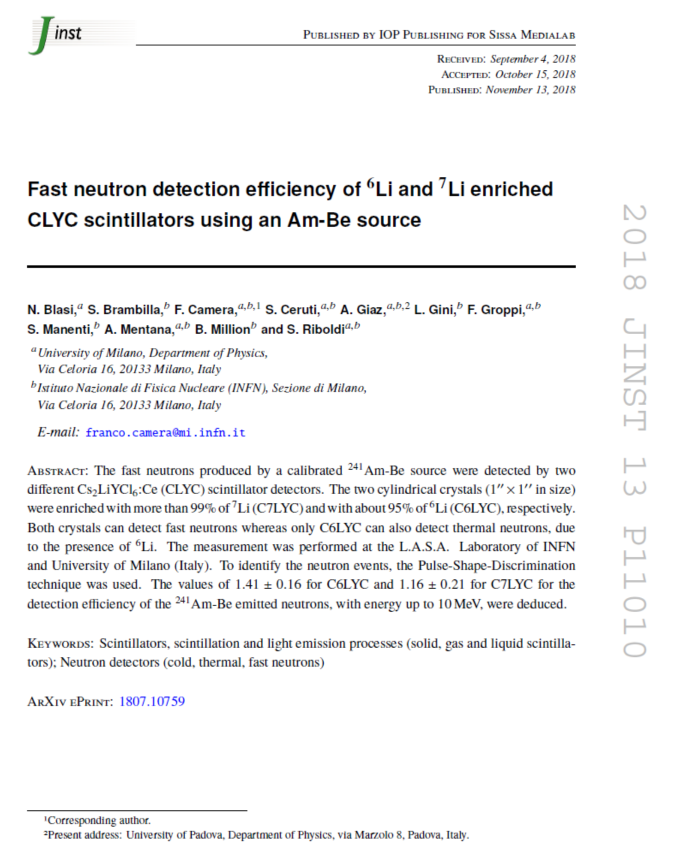
CLYC







	ϵ (%)
C6LYC	1.41 ± 0.16
C7LYC	1.16 ± 0.21



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Fast neutron detection efficiency of ^{6}Li and ^{7}Li enriched CLYC scintillators using an Am-Be source

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Abstract: The fast neutrons produced by a calibrated ^{241}Am-Be source were detected by two different Cs_2LiYCl_6:Ce (CLYC) scintillator detectors. The two cylindrical crystals (1″ × 1″ in size) were enriched with more than 99% of ^{7}Li (C7LYC) and with about 95% of ^{6}Li (C6LYC), respectively. Both crystals can detect fast neutrons whereas only C6LYC can also detect thermal neutrons, due to the presence of ^{6}Li. The measurement was performed at the L.A.S.A. Laboratory of INFN and University of Milano (Italy). To identify the neutron events, the Pulse-Shape-Discrimination technique was used. The values of 1.41 ± 0.16 for C6LYC and 1.16 ± 0.21 for C7LYC for the detection efficiency of the ^{241}Am-Be emitted neutrons, with energy up to 10 MeV, were deduced.

Keywords: Scintillators, scintillation and light emission processes (solid, gas and liquid scintillators); Neutron detectors (cold, thermal, fast neutrons)

ArXiv ePrint: 1807.10759

2018 JINST 13 P11010

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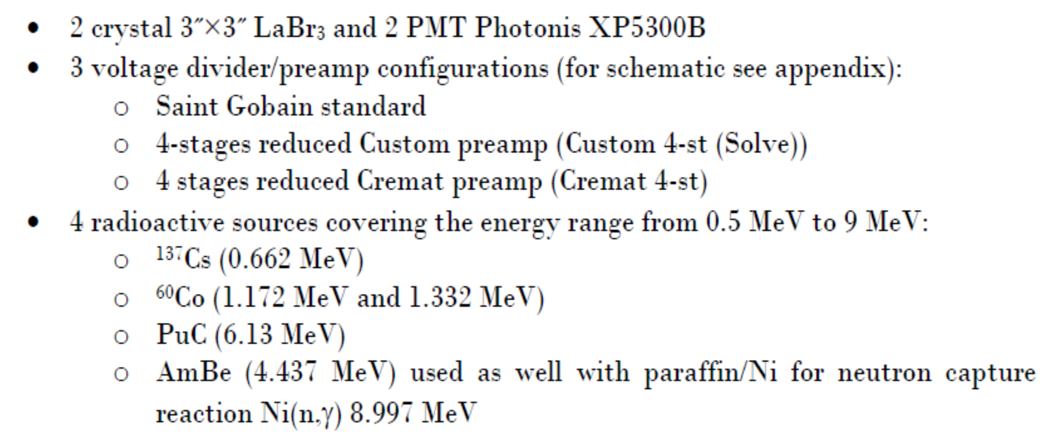
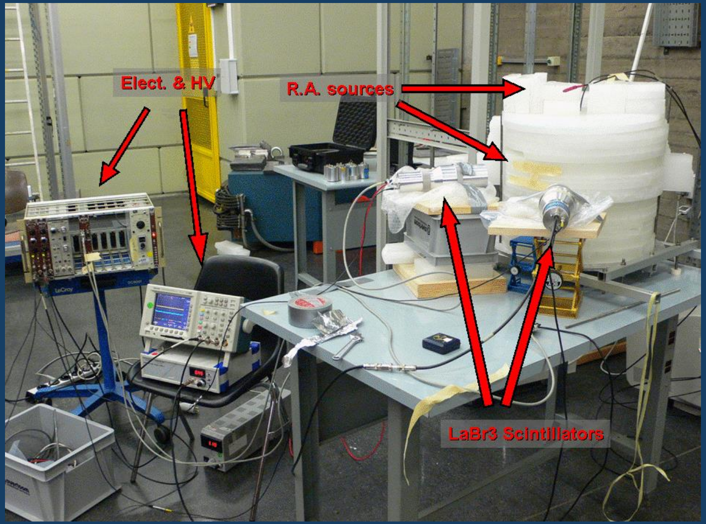
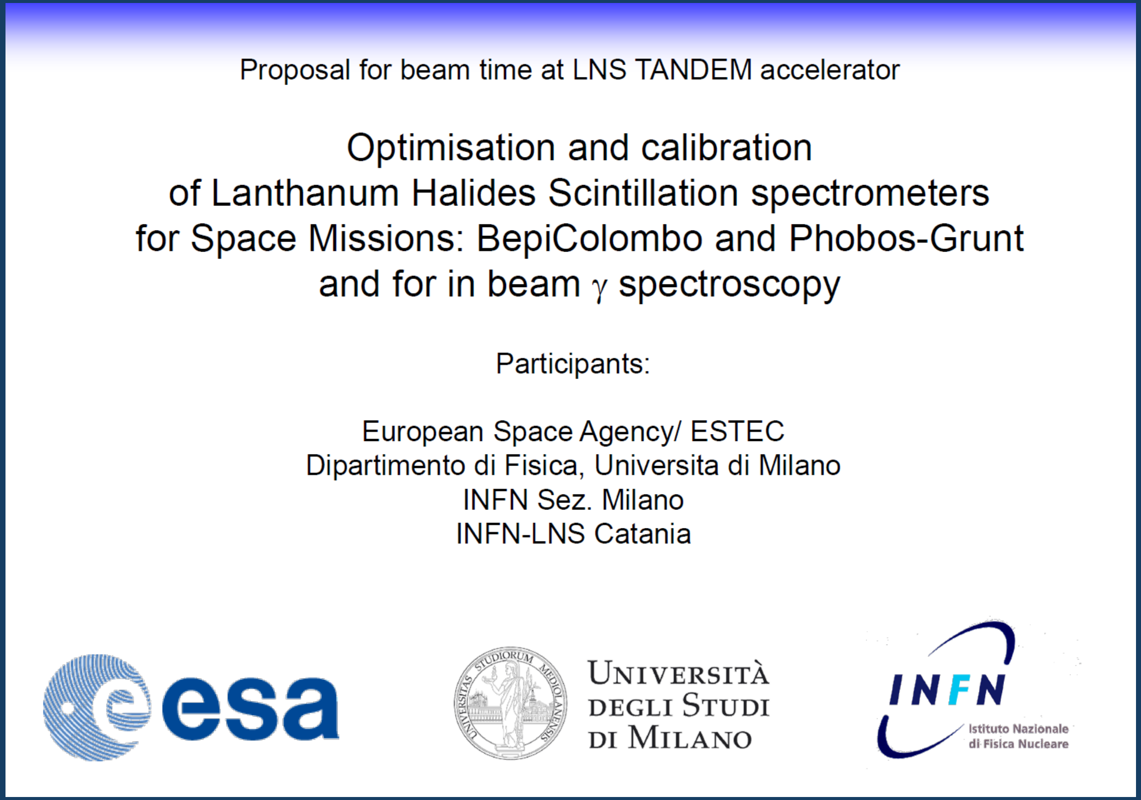
LaBr3 characterization at the LNS

Many test of LaBr3 crystals were performed at the LNS using sources: AmBe, PuC, AmBe+Ni



- 2 crystal 3″×3″ LaBr$_3$ and 2 PMT Photonis XP5300B
- 3 voltage divider/preamp configurations (for schematic see appendix):
  - Saint Gobain standard
  - 4-stages reduced Custom preamp (Custom 4-st (Solve))
  - 4 stages reduced Cremat preamp (Cremat 4-st)
- 4 radioactive sources covering the energy range from 0.5 MeV to 9 MeV:
  - ^{137}Cs (0.662 MeV)
  - ^{60}Co (1.172 MeV and 1.332 MeV)
  - PuC (6.13 MeV)
  - AmBe (4.437 MeV) used as well with paraffin/Ni for neutron capture reaction Ni(n,γ) 8.997 MeV





Proposal for beam time at LNS TANDEM accelerator

Optimisation and calibration
of Lanthanum Halides Scintillation spectrometers
for Space Missions: BepiColombo and Phobos-Grunt
and for in beam γ spectroscopy

Participants:

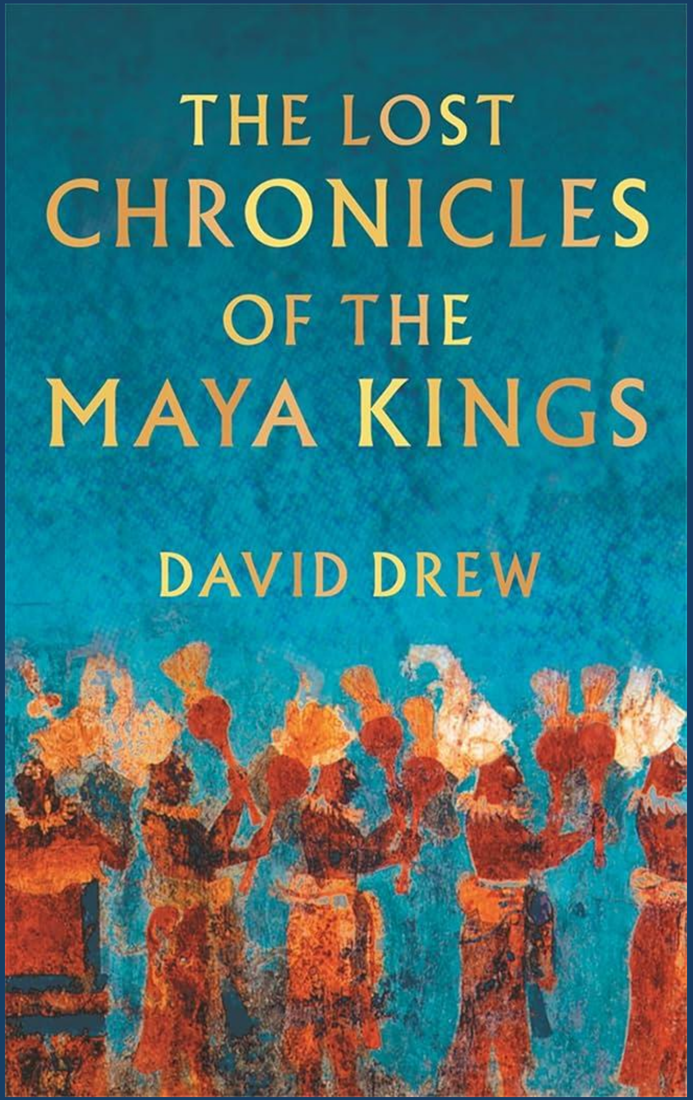
European Space Agency/ ESTEC
Dipartimento di Fisica, Universita di Milano
INFN Sez. Milano
INFN-LNS Catania

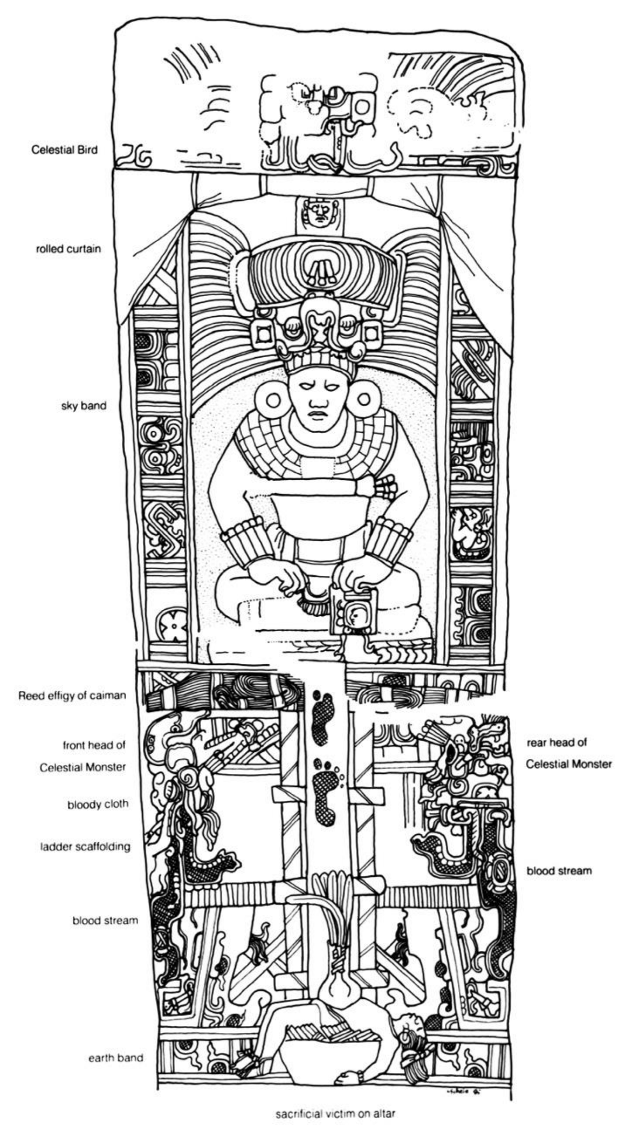
esa
Università degli Studi di Milano
INFN Istituto Nazionale di Fisica Nucleare

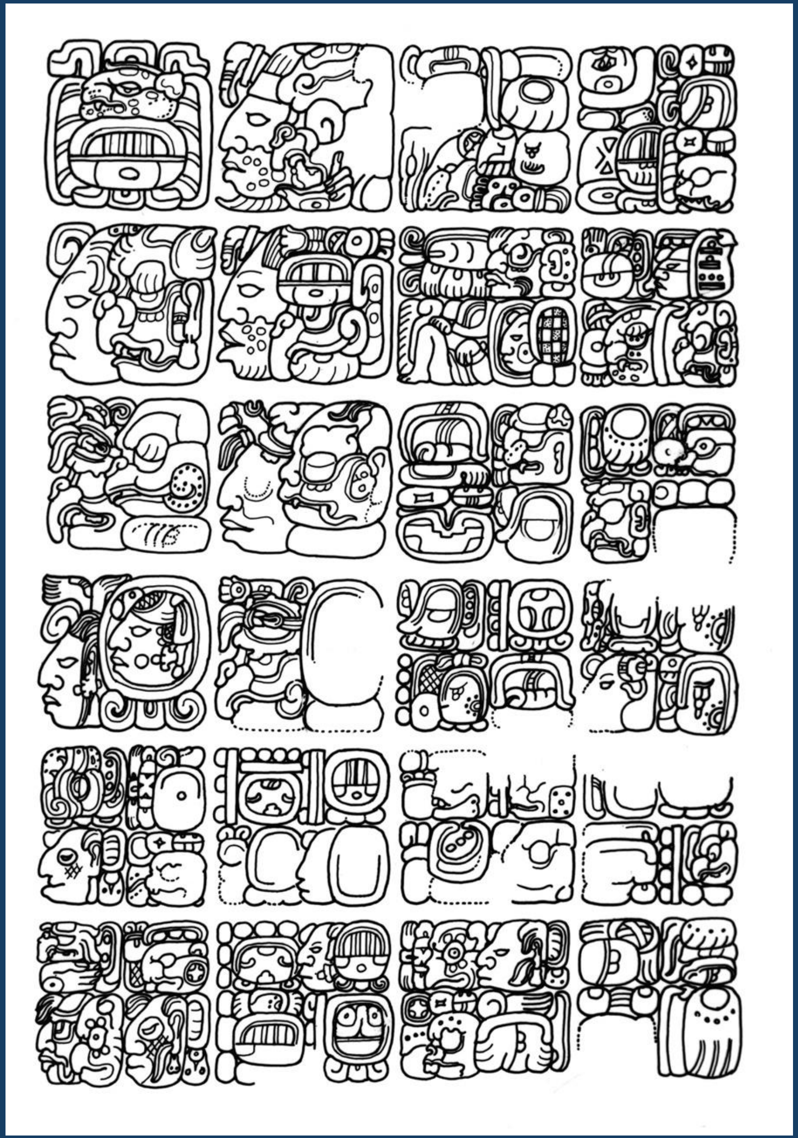
CSN3

CSN 3

Maya Archeology





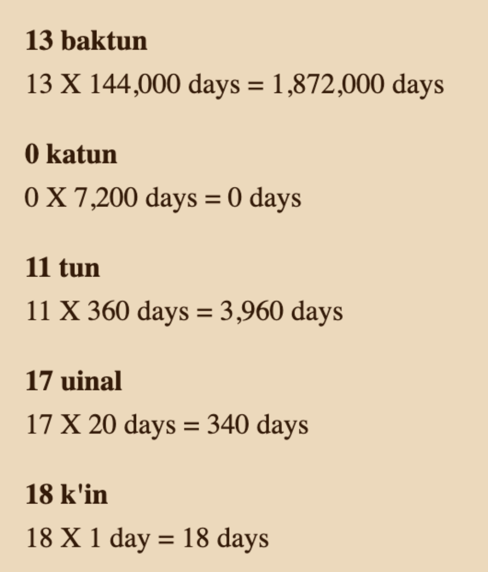


Celebrating events using Maya Writing system

- Date
- Name
- Sentence

17 october 2024

13.0.11.17.18
6 Etz’nab’
1 Sak’



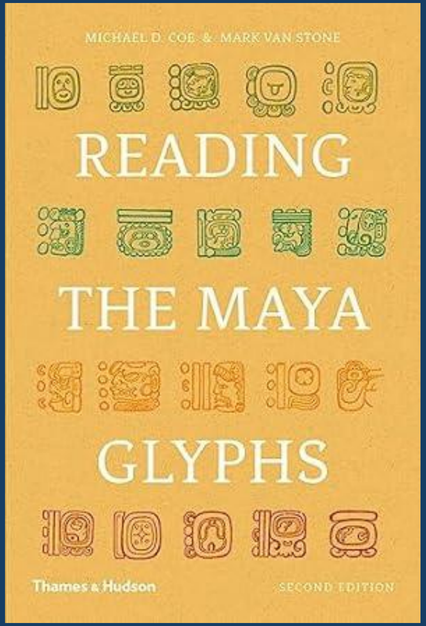
13 baktun
13 X 144,000 days = 1,872,000 days

0 katun
0 X 7,200 days = 0 days

11 tun
11 X 360 days = 3,960 days

17 uinal
17 X 20 days = 340 days

18 k'in
18 X 1 day = 18 days



MICHAEL D. COE & MARK VAN STONE
READING
THE MAYA
GLYPHS
Thames & Hudson
SECOND EDITION

HAPPY BIRTHDAY !!