Instrumentation Physics Cases and for EURISOL DF, the next step towards EURISOL

SPES and PARIS

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The actors:

- SPES
- PARIS

Ref: 170516_gp_programma SPES_CSN3
Report SPES WP_B0
version 1.0
May 18, 2017

The physical phenomenon:

- gamma decay of the HOT IVGDR

The physics cases:

- Dynamic Dipole
- Isospin Mixing
- ....

SPES

4. MAIN SPES MILESTONES

Cyclotron SAT	Jul 2017
Cyclotron operation training	Dec 2017
Installation of the UCx lab	2017-2018
Installation Charge Breeder (including dedicated sources) and Medium Resolution Mass Spectrometer	2017-2019
Installation of TIS and FE in ISOL1	2018
1+ beam line to Tape System	2018
SPES ISOL system test	Spring 2019
ISOL commissioning to Tape System	Summer 2019
Installation RFQ	2019
Low energy exotic beams to the Tape System	End of 2019
Installation of two new cryostats equipped with 8 high-beta RF cavities	End of 2019 - beginning of 2020
Experimental campaigns with low energy exotic beams	2020-2021
Installation of the transport beam line from 1+ to CB	2020
Installation HRMS	2021
Exotic beams reaccelerated by RFQ-ALPI	2021
Commissioning of HRMS	2022

NOW

Ebeam ≈ 40 keV

SPES

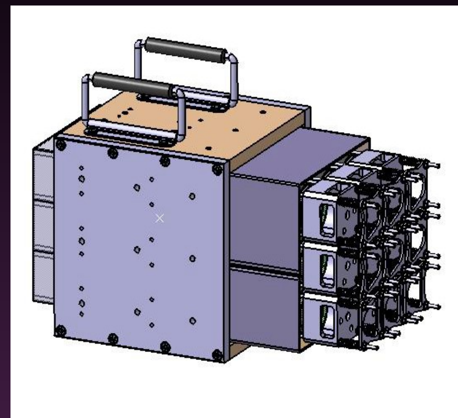
Table 1.1: Low energy SPES beams - REPORT: G.Prete, A.Andrighetto, F.Gramegna Note 8 maggio 2017.

NOTES	Beam	Purity	Target	Source	Reference to LoI
First beam produced at SPES	^{26}Al		SiC		No LoI at present
	^{26}Si		SiC		No LoI at present
Beams at high selection	^{83}Ge	100	UCx	LIS	1+ (LoI n. 27)
	^{84}Ge	100		LIS	1+ (LoI n.10, 27)
	^{80}Ga	100		LIS	1+ (LoI n. 27)
	^{82}Ga	100		LIS	1+ (LoI n. 10, 27)
	^{110}Ag	100		LIS	1+ (LoI n. 38)

Table 6.3: Charge states available for post-acceleration at SPES (intensities after the SPES-CB).

Species	Intensity [pps]	Available Charge States
^{94}Rb	7E8	15+,16+,21+
^{130}Sn	3.9E8	19+,29+
^{132}Sn	7.5E7	19+,21+,23+
^{132}Sb	9.5E7	19+,21+,23+
^{132}Te	2.1E9	19+,21+,23+
^{134}Te	8.5E9	27+,31+
^{138}Cs	5.5E8	20+,22+,23+,26+,30+,31+

PARIS



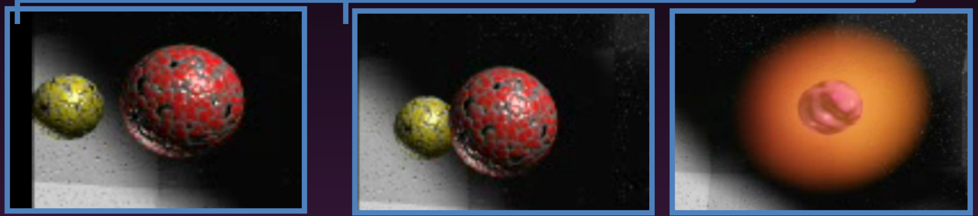
PARIS is a detector array which can:

- provides excellent time resolution
- provides the multiplicity information
- provides large efficiency for high energy γ-rays

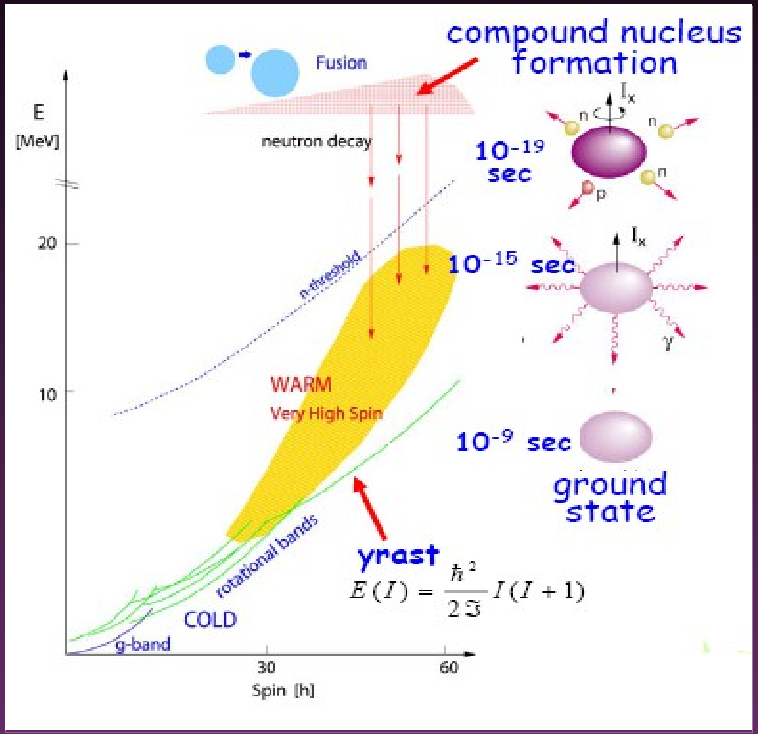
- Excellent for the measurement of the gamma decay of hot IVGDR from CN nuclei
  - Physics case 1
    - Dynamical Dipole – LOI SPES
  - Physics case 2
    - Isospin Mixing

Dynamical Dipole Emission

t=0s **t=10-24s CN formation** **t=10-21s CN statistical decay**



Thanks to J. Grebosz

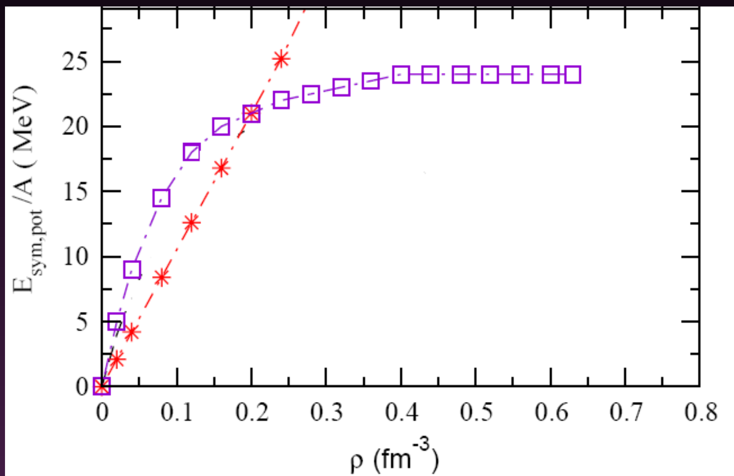


Dynamical Dipole emission	CN statistical decay GDR decay

In a fusion reaction, if the colliding nuclei have a different N/Z ratio, a charge equilibration process takes place. The related neutron-proton motion has the features of a collective oscillation and it is associated to a γ emission, the so called **Dynamical Dipole (DD)** emission.

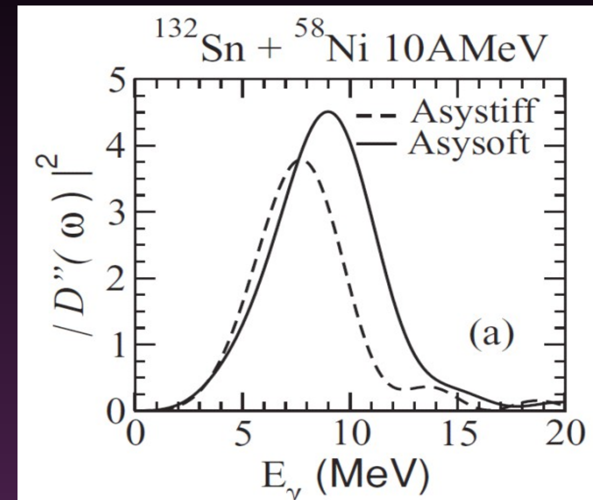
S.Flibotte et al. PRL 77(1996)1448, A.Giaz et al PRC 90(2014)014609, C.Parascandolo et al PRC(2016)044619

Physical Motivation



Sensitivity to:

Symmetry term of nuclear equation of state



V. Baran et al. PRC 79 (2009), 021603

It is like a measurement of the gamma decay of IVGDR built on a CN

- suitable for PARIS

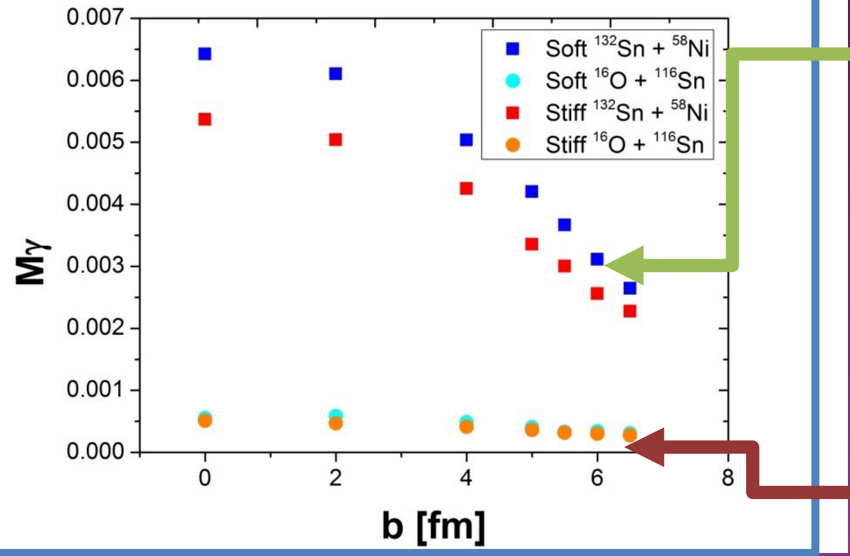
The Reaction 132Sn+58Ni

The dipole moment :D(0) = 45.4 fm (in 16O +116Sn D(0) = 8.6 fm)

The Mγ for 132Sn+58Ni is **one order of magnitude larger** than the Mγ for 16O +116Sn.

Comparison between the DD γ yield from **BNV** between:

132Sn + 58Ni and 16O + 116Sn



Exotic Beam

132Sn + 58Ni :

Theory – Prediction

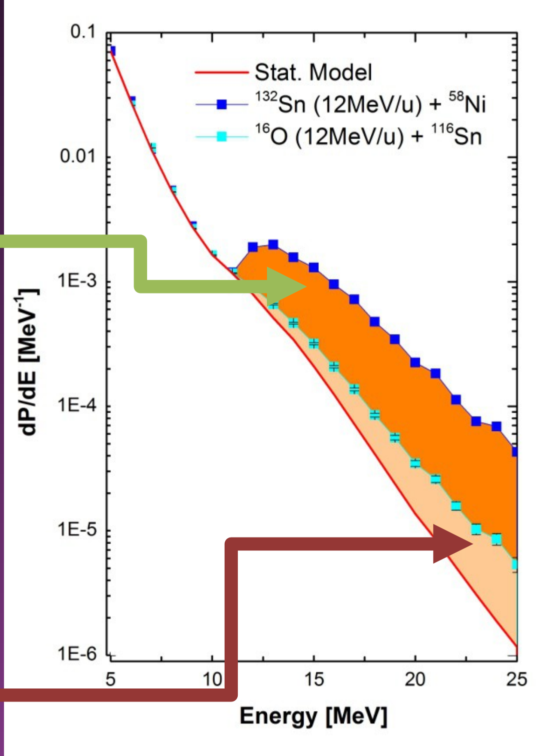
Alternative case:

68Ni +58Ni

D(0) = 21.2 fm

Now: 160 + 116Sn :

Theory – exp. Data



A.Giaz PRC-90(2014)014609 and A. Giaz PHD thesis

Prompt collective oscillations with exotic beams

Letter of intent for the SPES-ALPI facility

SPES exotic beams for science

Reaction	N/Z	CN
$^{124}Sn+^{58}Ni$	1.48 - 1.07	^{182}Pt
$^{124}Sn+^{64}Ni$	1.48 - 1.29	^{182}Pt
$^{132}Sn+^{58}Ni$	1.64 - 1.07	^{190}Pt

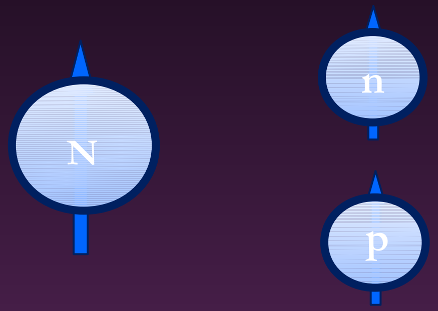
Reaction	N/Z	CN
$^{124}Sn+^{48}Ca$	1.48 - 1.40	^{172}Yb
$^{132}Sn+^{40}Ca$	1.64 - 1.00	^{172}Yb

^{132}Sn: the “monster” resonance

Isospin Mixing

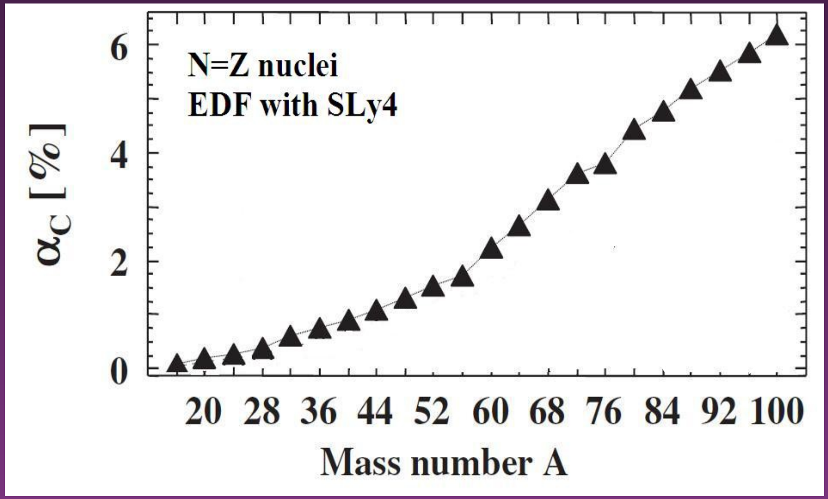
Heisenberg introduces a new quantum number, the **Isobaric spin (Isospin) I**, to specify whether a particle in the nucleus is a proton or a neutron

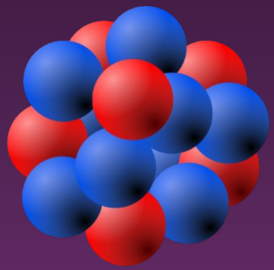
I = 1/2



Iz = +1/2

Iz = -1/2





Iz = (N –Z)/2

Iz| ≤ I ≤ (N+Z)/2

g.s.: I = Iz

N=Z nucleus **I = Iz=0**

Isospin Mixing

- Isospin is not a observable quantity to be measured
- Electromangnetic transitions and weak interaction can be used to test isospin invariance
- Searching for transitions that are forbidden by isospin conservation

E1 γ transition (only in N=Z nuclei)

It is a hot GDR measurement

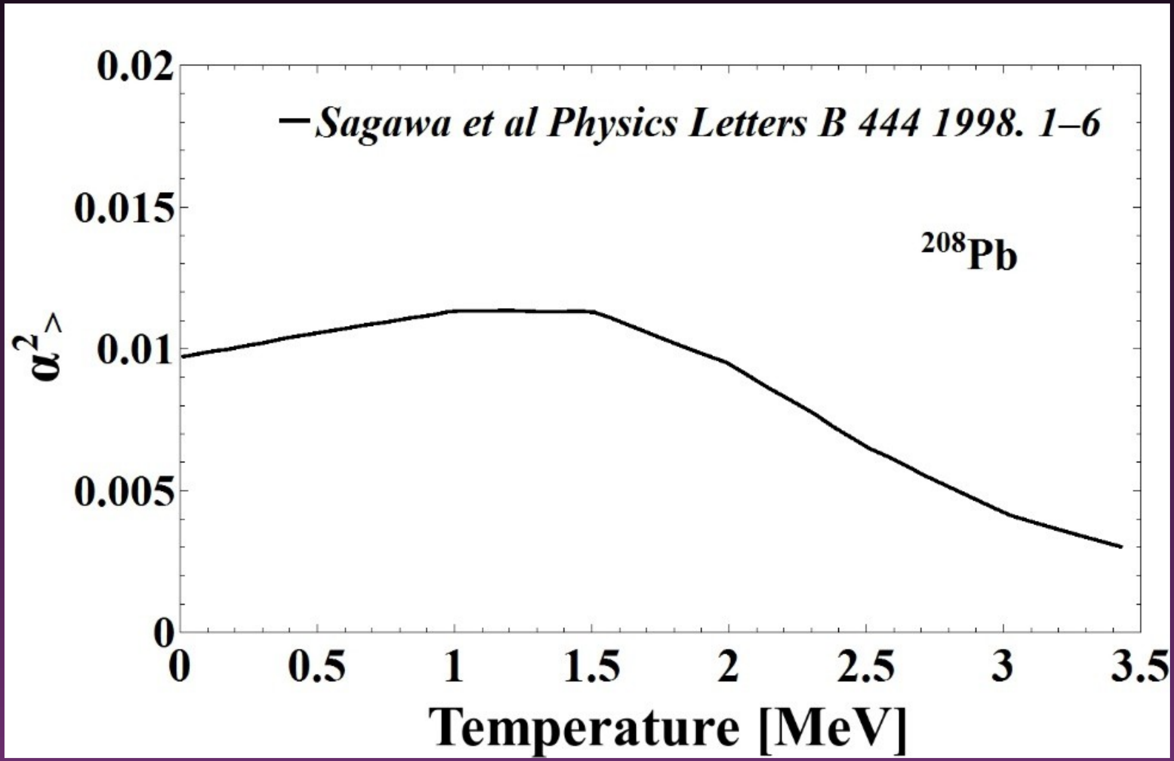
- suitable for PARIS

Isospin Mixing was intensively studied in the past at Univ. of Washington and at Warsaw

- A. Behr et al. Phys. Rev. Lett. 70(1993)3201
- M. Kicinska-Habior et al. NPA 731(2004)138
- M. Kicinska-Habior Acta Physica Polonica B 4(2005)1133

Isospin Mixing

Breaking of Isospin symmetry: Compound Nuclei



Coulomb spreading width

$$\alpha^2 \simeq \frac{\Gamma^{\downarrow}}{\Gamma_{CN}} \simeq \frac{\tau_{CN}}{\tau_{MIX}}$$

Compound nucleus decay width

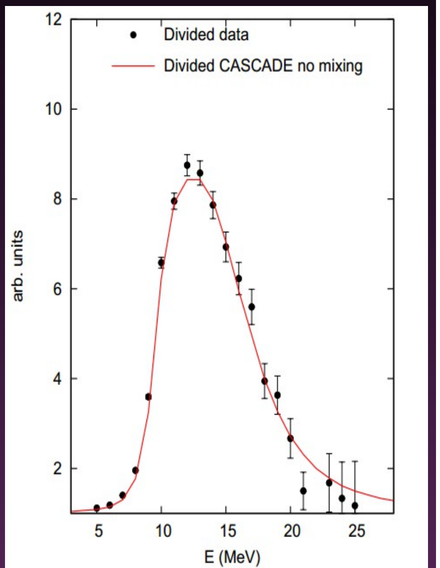
$$\alpha^2_{I_0+1} \sim \frac{\Gamma^{\downarrow}_{\mathrm{IAS}}}{\Gamma^{\uparrow}_{\mathrm{CN}}(T) + \Gamma_{\mathrm{IVM}}}$$

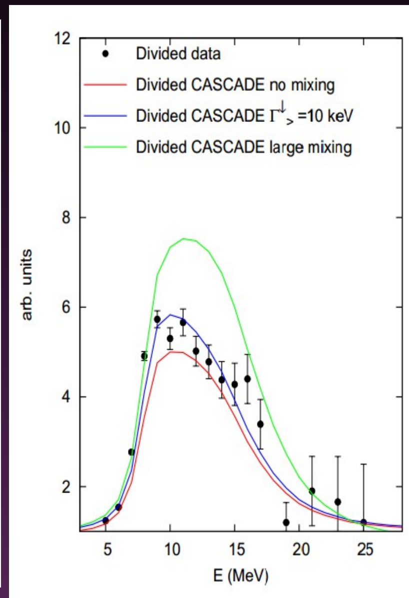
Colo' et al .PRC 54(1996)- Sagawa et al Physics Letters B 444 1998. 1–6

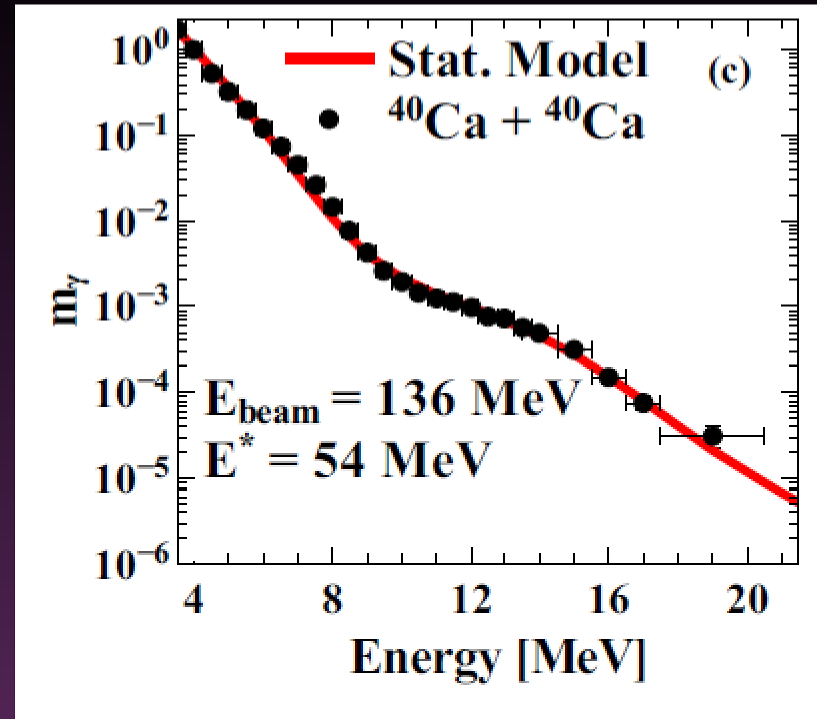
GARDFIELD & HECTOR

80Zr–HECTOR+

E* = 84 MeV   T = 3 MeV







Γ↓=10±3 keV
α2 = 0.013 ±0.004

Γ↓=12±3 keV, α2=0.046±0.007

- **Γ↓ does not change with T**
- **α2 is larger at T = 2 MeV**

A.Corsi et al. PRC 84, 041304(R) (2011)

S:Ceruti et al. PRL 115(2015)222502

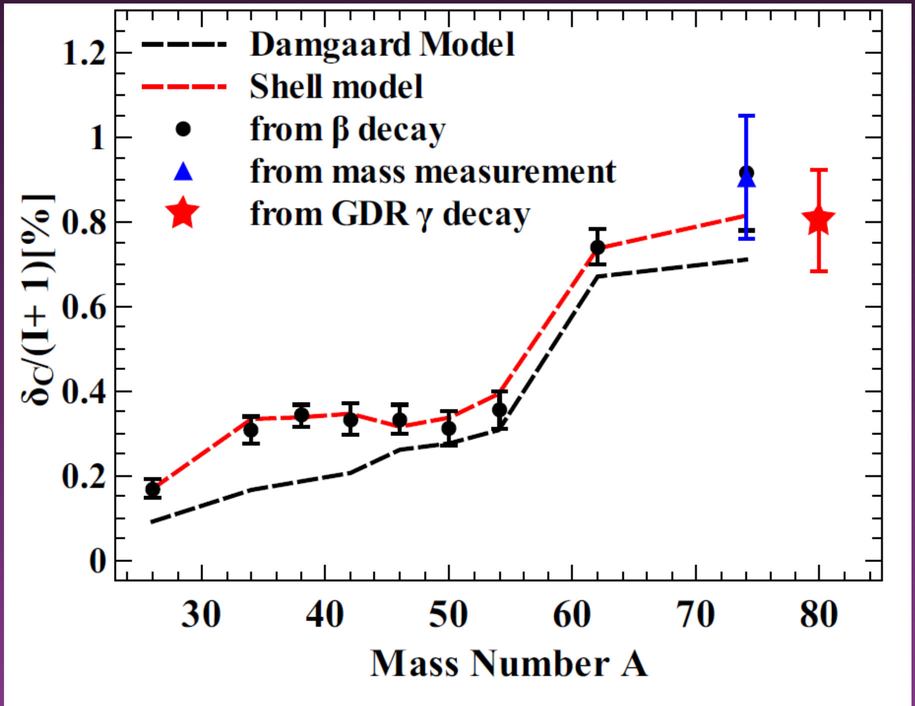
Beyond nuclear structure: CKM matrix

$$Ft \equiv ft(1+\delta_R)(1-\delta_C)$$

Many parametrizations are present in literature to describe **δC** behaviour. Auerbach proposed:

$$\delta_{\mathrm{C}} = 4(\mathrm{I}+1)\frac{\mathrm{V}_1}{41\xi \mathrm{A}^{2/3}}\alpha^2$$

Isospin mixing



I.S. Towner and J.C. Hardy PRC 82, 065501 (2010)

Conclusion

The physics cases of

- the measurement of the Dynamical Dipole emission
- the measurement of the Isospin Mixing at zero temperature
- ……………………………………….

requires the measurement of

- High energy gamma rays
- The multiplicity of the gamma radiation
- Excellent time resolution

→ **PARIS**

Requires the use of radiactive beams

- 132Sn is a good candidate for the Monster D.D
- N=Z nuclei are required for Isospin Mixing

→ **SPES**

Thanks to

PARIS collaboratorions
Milano and Kracow HECTOR and HECTOR+ collaborations
SPES, Galileo and Garfield collaborations

Thank you for the attention