Prompt collective oscillations with exotic beams
(a letter of intent for SPES)

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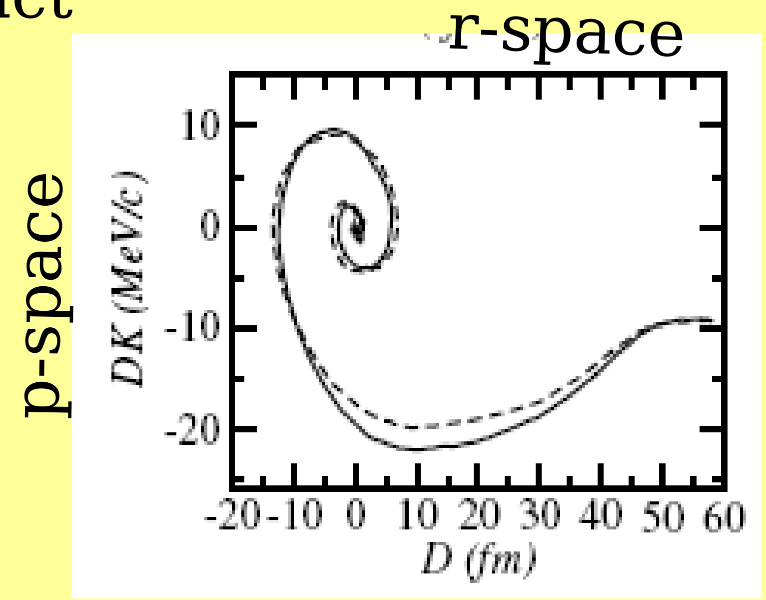
The fast Dynamical Dypole

This is a pre-equilibrium collective oscillation occurring when nuclei with different N/Z interact

The centres of mass of **protons** and **neutrons** don't coincide and a dipole moment oscillation develops in the mean-field of the system



The phenomenon is ruled by:

-the intial dipole moment D(t=0)
-the mean-field dynamics towards the outgoing channel
-the symmetry energy at sub-saturation densities acting as a restoring force for n-p equilibration

V.Baran et al. PRL 87,2001 and PRC79,2009
M.DiToro et al. EPJ A13 2002
C.Rizzo et al ArXiv 1010.2927v1 2010

B.Martin et al. PL B664, 2008
D.Pierroutsakou et al. EPJ A16, 2003
D.Pierroutsakou et al. PRC80 , 2009
A. Corsi et al PL B679, 2009

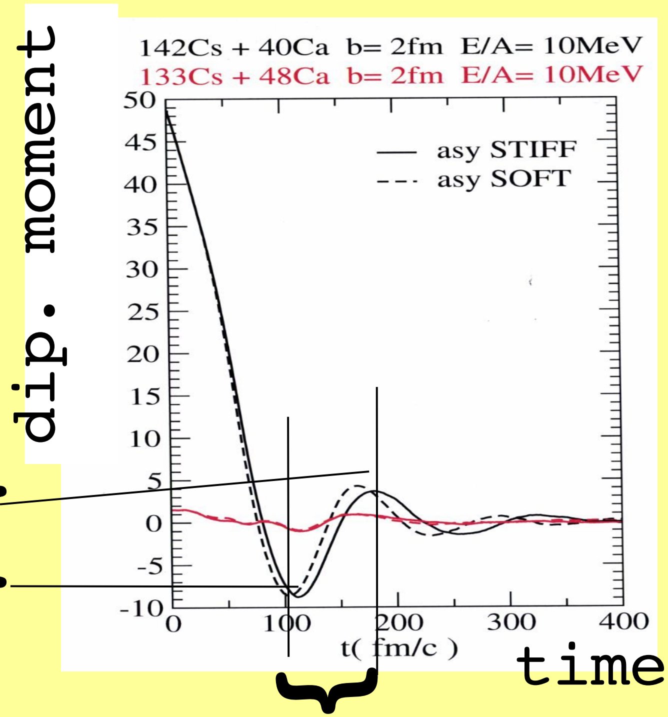
DDR and RIB's

The subject is of general interest among the RIB european facilities

- 2 LOI submitted for the SPES facility: wide interest in this type of physics

- SPES energies are nicely suited to cover the DDR phenomenon

DDR observed in the fusion channel
DDR observed in the DIC channel



SPES

DDR strenght depends on the dipole moment

DDR energy depends on the oscillation frequency (deformation)

The fast Dynamical Dypole

Features and Signatures of this oscillation

-increase with N/Z asymmetry in colliding nuclei

-resonance energy lower than thermal GDR (lower frequency ω due to larger deformations)

- ”*rise and fall*” with E_{bomb} : weak DDR strenght with low decelarations (energies); weak DDR strenght with too high energies as other fast processes (e.g. particle emissions) quench the collective excitation

- angular distribution for DDR photons: “oscillating dipole” shape, normal to the emission axis which rotates during the collisions (a rotating gamma-flash)

- reduction of the DDR strenght for mass-symmetric collisions due to the slower dynamics (?)

SPES-ALPI:

Looking for DDR in fusion reactions

Experimental method

direct comparison of fusion reactions for two systems, the one iso-symmetric (null signal case) the other one iso-asymmetric (fast dipole emission expected)

estimate the absolute strenght and compare to the predicted values to contrain the stifness of the Symmetry Energy assumed in the EOS

SPES-ALPI

Looking for DDR in fusion reactions

$^{133}Cs + ^{48}Ca \to ^{181}Re$ 6-12 AMeV (N/Z=1.42,1.40)
$^{141,142}Cs + ^{40}Ca \to ^{181,182}Re$ 6-12 AMeV (N/Z=1.56,1.58,1.00)

$^{132}Sn + ^{40}Ca \to ^{172}Yb$ E=6-12 AMeV (N/Z= 1.64,1.00)
$^{124}Sn + ^{48}Ca \to ^{172}Yb$ E=6-12 AMeV/u (N/Z= 1.48,1.40)
[^{94}Kr(*) + $^{78}Se \to ^{172}Yb$ E=6-12 AMeV/u (N/Z= 1.61,1.29)]

$^{132}Sn + ^{58}Ni \to ^{190}Pt$ E=6-12 AMeV (N/Z= 1.64,1.07)
$^{124}Sn + ^{58}Ni \to ^{182}Pt$ E=6-12 AMeV/u (N/Z= 1.48,1.07)

$^{124}Sn + ^{56}Fe \to ^{180}Os$ E=6-12 AMeV (N/Z= 1.48,1.15)
$^{90}Kr + ^{90}Zr \to ^{180}Os$ E=6-12 AMeV/u (N/Z= 1.50,1.25)

^{90}Kr intensities ok : $8.7 \cdot 10^7$ pps
^{94}Kr intensities too low?: $5.5 \cdot 10^5$ pps
^{132}Sn intensities ok : $3.1 \cdot 10^7$ pps
$^{141,142}Cs$ intensities ok: $2 \cdot 10^8$ and $2 \cdot 10^7$ pps

(*) 94Kr beam is also part of the PARIS Coll. LOI for Spiral2, 2006

SMF predictions for the proposed systems at SPES

by M.Colonna

ASYMMETRIC MASS SYSTEMS

A isospin symmetric

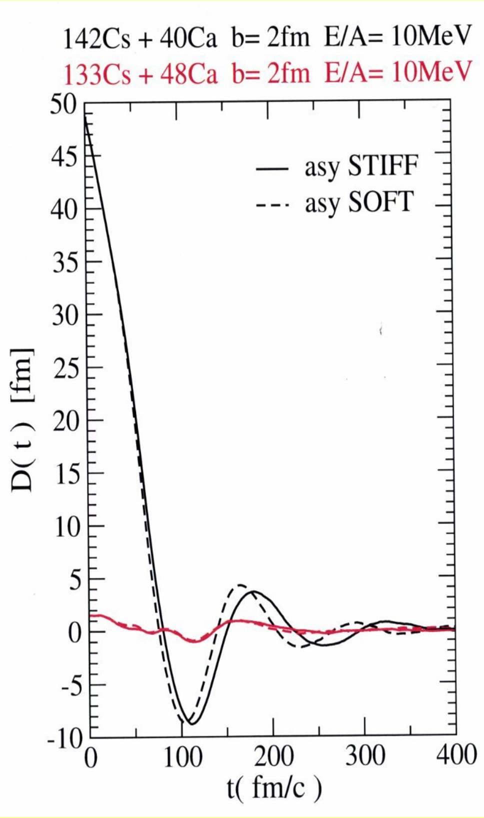
^{133}Cs+^{48}Ca-->^{181}Re 6-12 AMeV (N/Z=1.42,1.40)

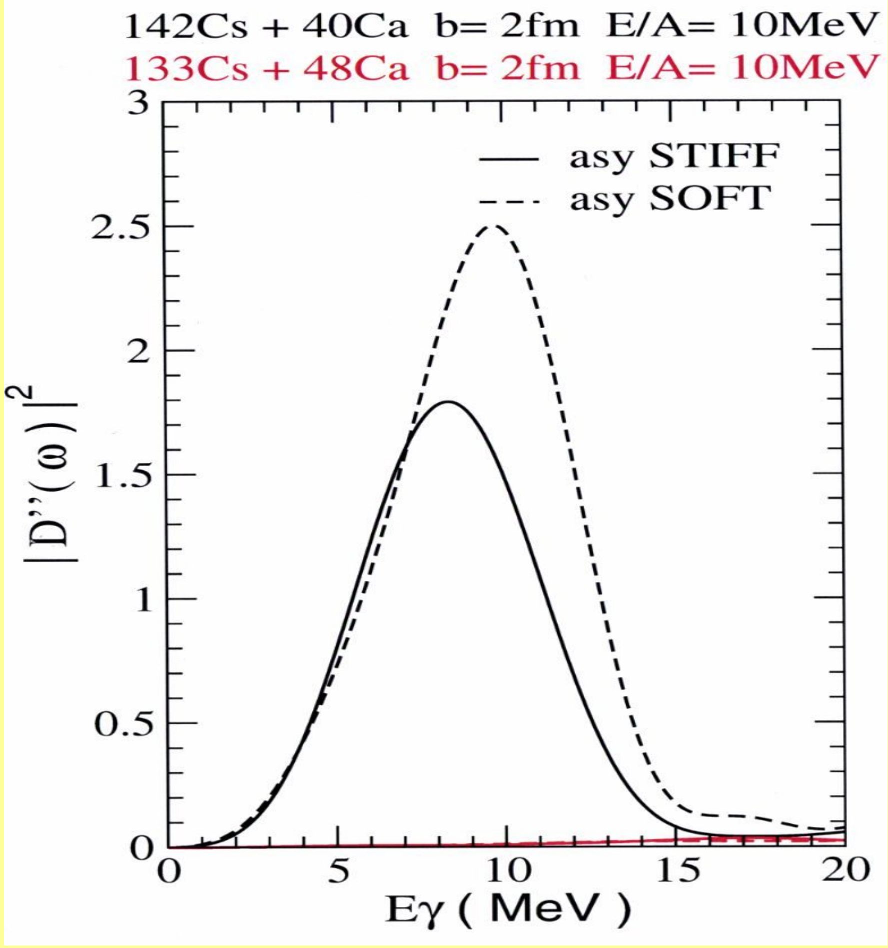
B isospin asymmetric

^{141,142}Cs+^{40}Ca-->^{181,182}Re 6-12 AMeV (N/Z=1.56,1.58,1.00)

SYS A is iso-symmetric: very low initial dipole moment D_0=1.2 fm

SYS B is iso-asymmetric: 'huge' initial dipole moment D_0=36 fm





SMF predictions for the proposed systems at SPES

by M.Colonna

...also SYMMETRIC MASS SYSTEMS

C isospin symmetric

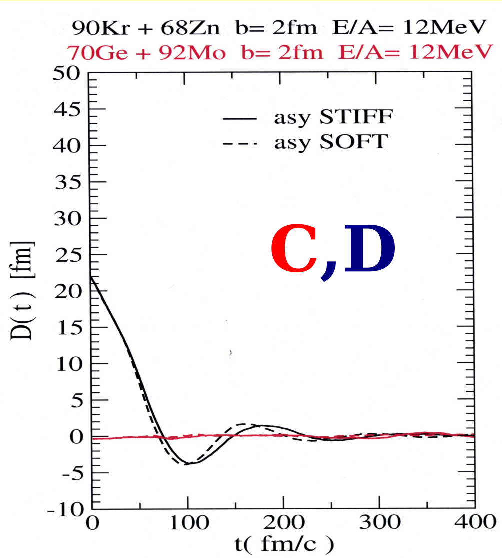
^{70}Ge+^{92}Mo-->^{162}W E=6-12 AMeV (N/Z= 1.19,1.19)

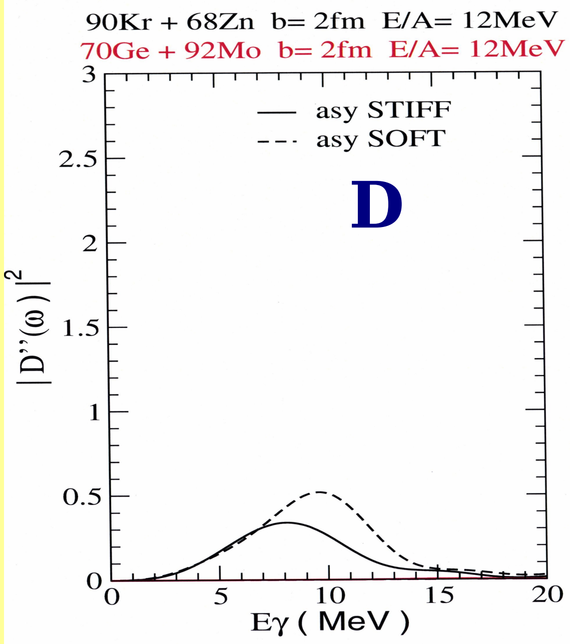
D isospin asymmetric ^{90}Kr+^{68}Zn -->^{158}Dy E=6-12 AMeV/u (N/Z= 1.50,1.26)

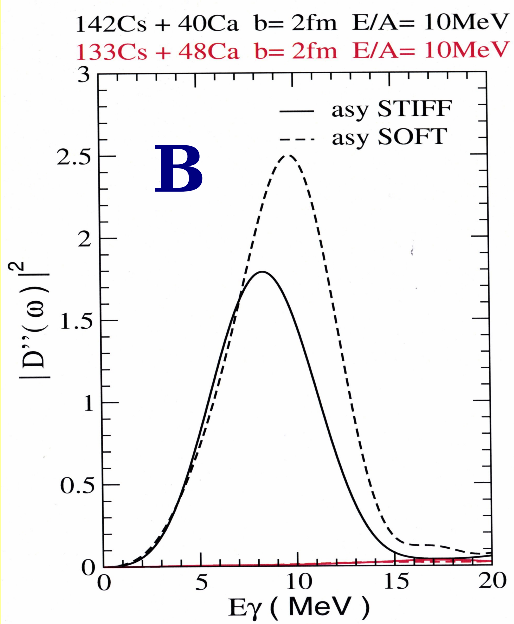
SYS C is iso-symmetric: **very low initial dipole moment 0.25fm (null signal)**

SYS D is iso-asymmetric: **large initial dipole 18.3fm**

DDR is weaker due to the slower dynamics for symmetric entrance channels







Possible future equipments

Modern Apparatus with fast digital electronics

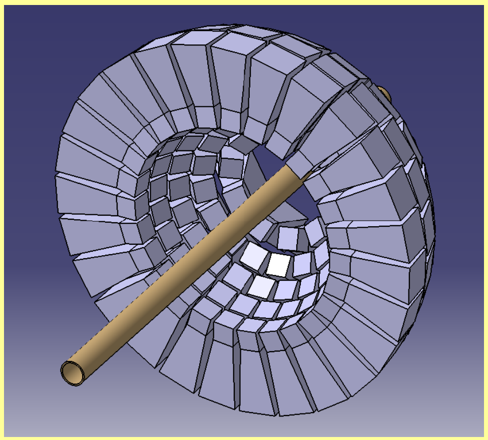
1- powerful selective ER detector (Phoswiches, Gas detector, FAZIA telescopes)

2- light charged particle array (GARFIELD chambers, FAZIA telescopes, others...)

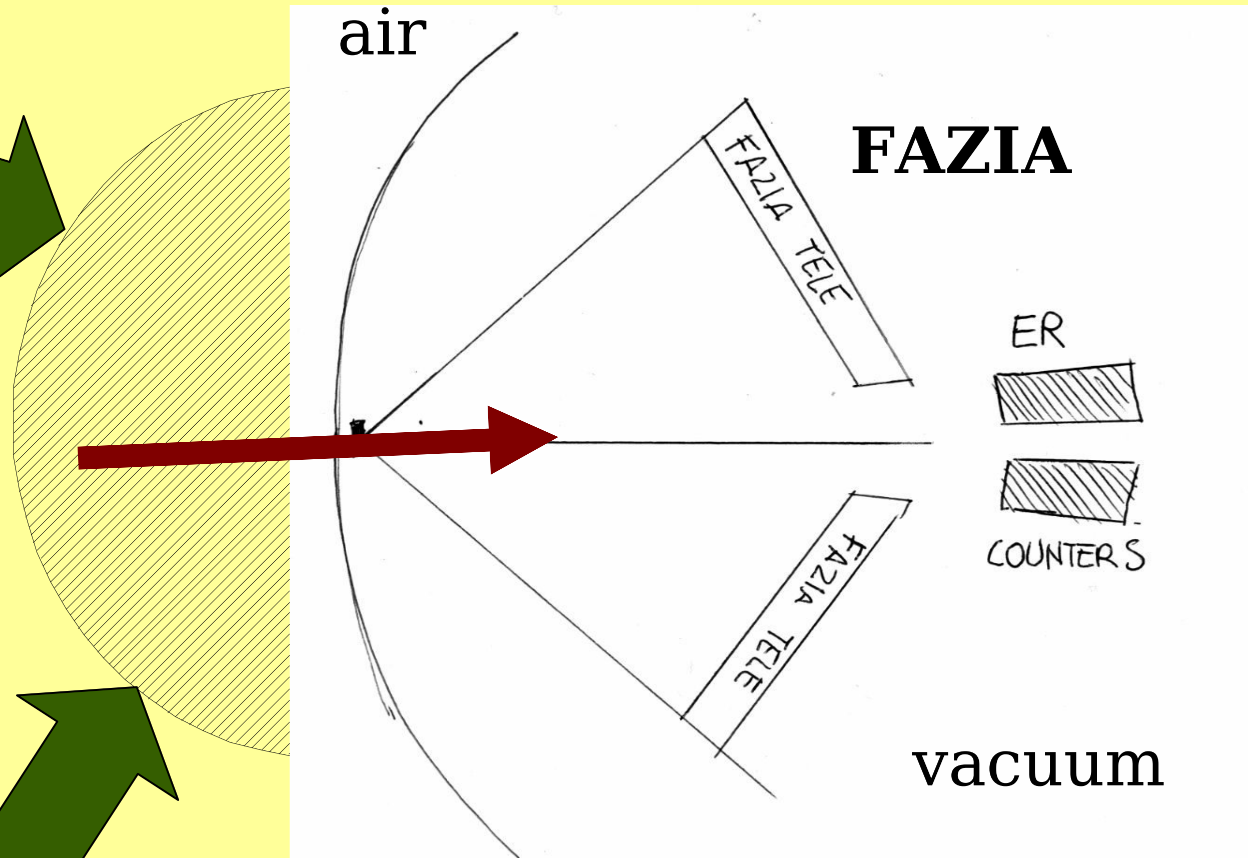
3 -efficient energetic gamma-rays detectors (AGATA, PARIS emisphere or emicube, HECTOR big crystals)

Note: the gamma detectors like AGATA, PARIS should stay in air, while HECTOR BaF_2 can also be operated under vacuum; the in-air mounting constrains the gamma arrays to back emisphere (less sensitivity to ang.distribution) but allows for larger effciencies

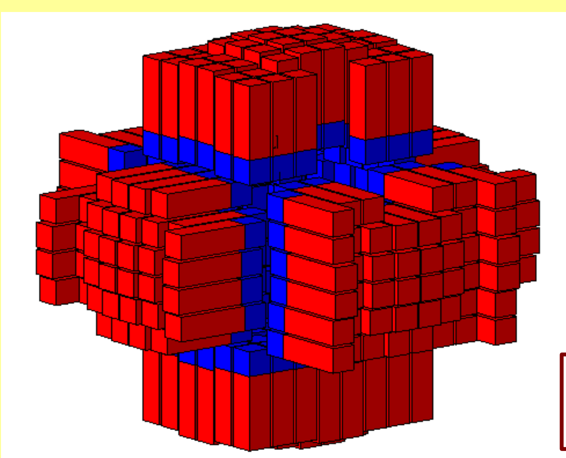
...thinking of a possible SPES experiment



PARIS emisphere?



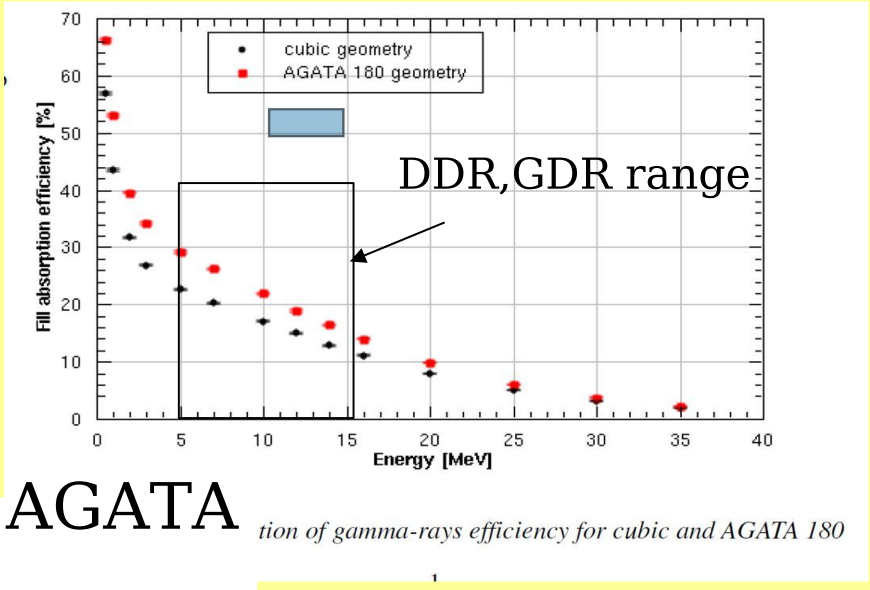
part of
AGATA?

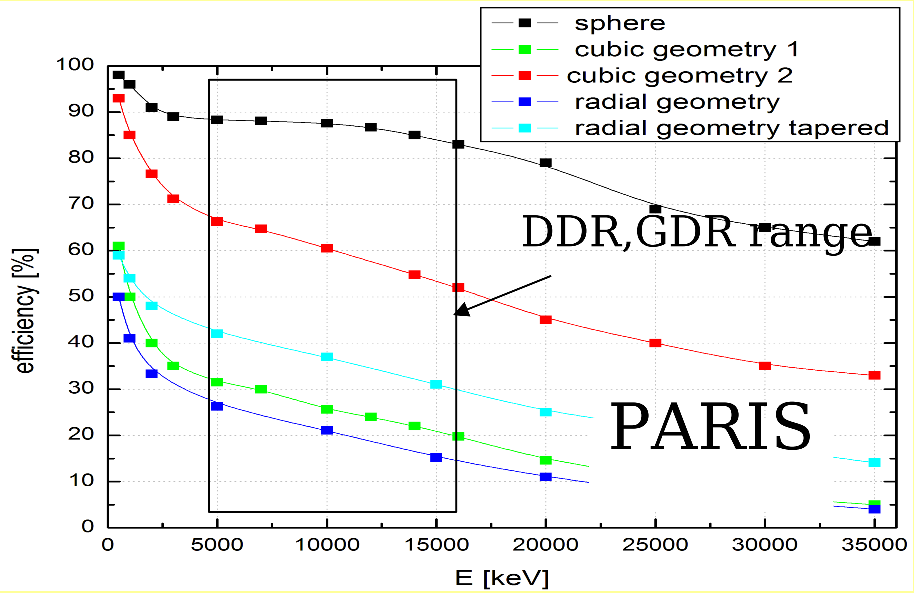


PARIS emicube?

suggestions are WELCOME!

Using "monster" gamma-arrays…





..this type of measurements seem FEASIBLE at SPES

- assumed efficiency: 10% for DDR gammas
- beam intensities: $3*10^7$ pps (SPES: 132Sn, 133Cs, 90Kr)
- target thickness: 0.5mg/cm2 (Ni,Zn)
- Fusion Cross Section (1barn) and DDR emission probability (some 10^{-3} for ^{132}Sn+^{58}Ni taken from C.Rizzo ArXiv 1010.2927v1 nucl-th 2010)

total fusion rate: 170 Hz; ER efficiency: (12%)

detected fusion rate: 20Hz

DDR+ER coinc. measured rate: about $4\text{-}6*10^{-3}$ Hz, overall; in the bin of the maximum about $0.8*10^{-3}$ Hz.

Therefore to have 200 count/MeV at the DDR peak max : about 3-4 days