

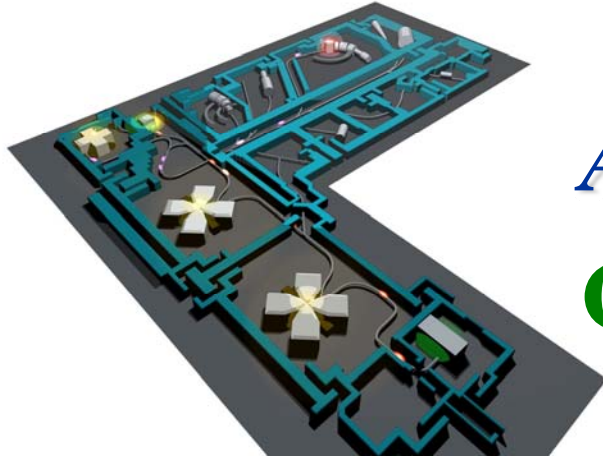
New vista at energies near the Coulomb barrier @ GANIL

From multidimensional tunnelling to exotic shapes at the limits of stability

He to U

A. Navin.

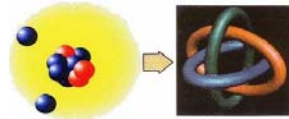
GANIL



N=34,28
Shell closures

$^{6,8}\text{He}$

Borromean nuclei



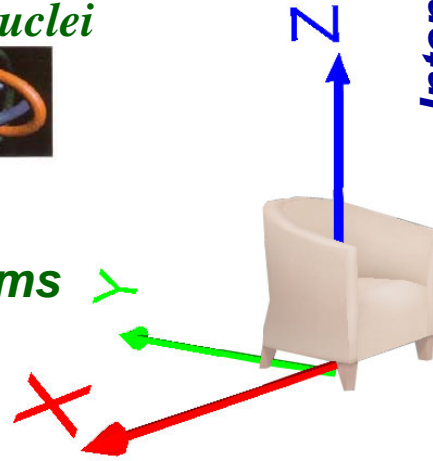
ISOL Radioactive beams

Fragmentation beams

Intense Stable Heavy beams

Spiral2

Intense RIB and more



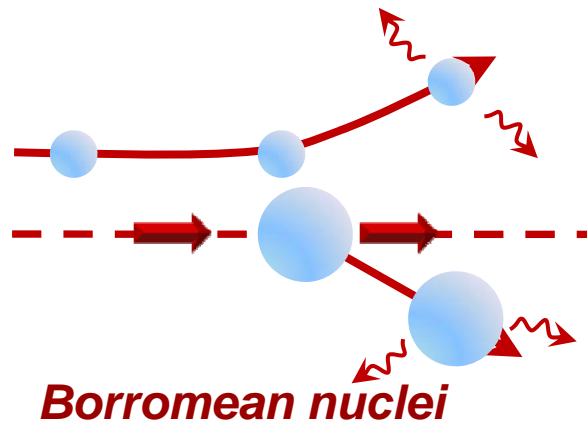
Conclusions

- Measurements at the limits of using light
Radioactive ion beams and heavy stable
beams
- Unexpected shapes and absence of expected
shell closures: new avenues using
VAMOS+Exogam@GANIL in inverse
kinematics
path to SPIRAL2
- Reactions at the Coulomb barrier with
Borromean nuclei the last word?
- Great future at GANIL



Reactions near the Coulomb barrier

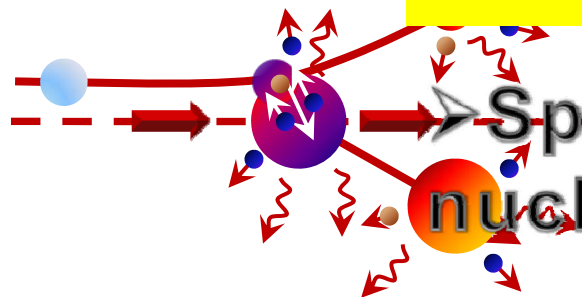
Most intense



Elastic
Quasi elastic

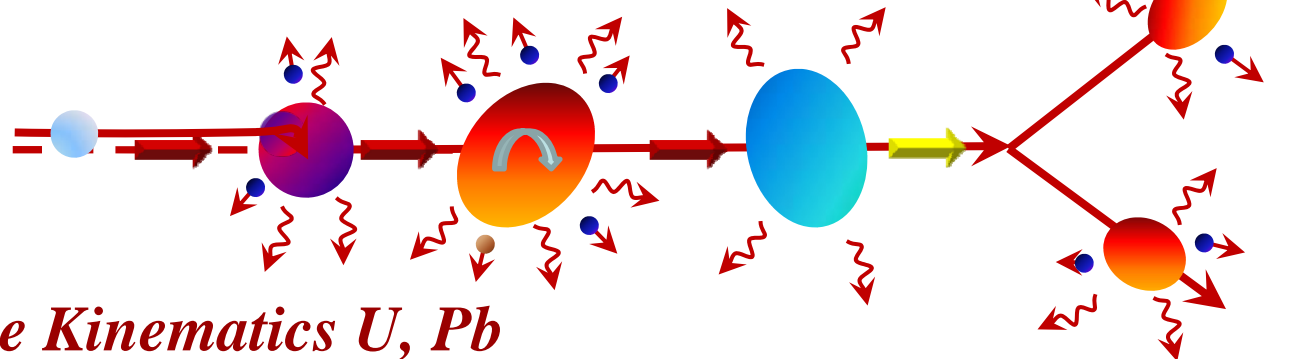
Advantages
Sensitive to structure
High angular momentum

➤ Reactions with exotic nuclei



Spectroscopy of exotic nuclei

Fusion
Fusion fission

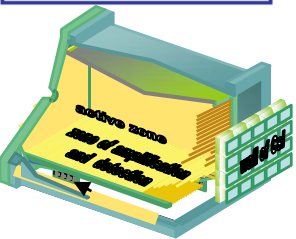


Sensitivity and selectivity
Detectors, beams + great team

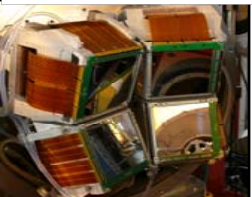
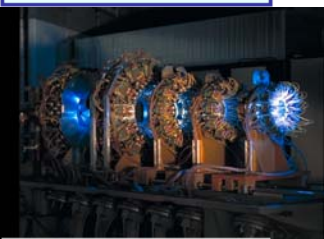




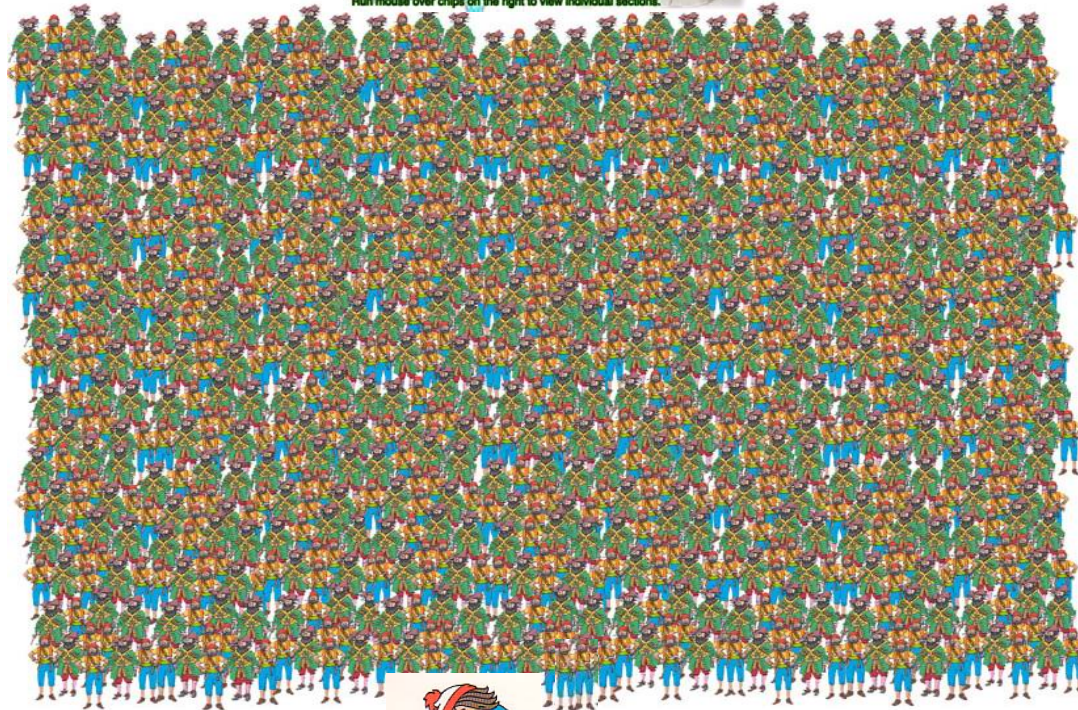
MAYA



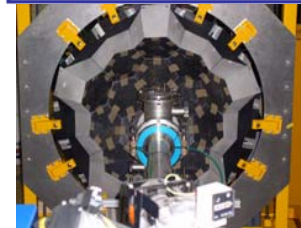
INDRA



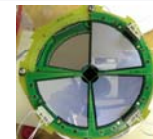
TIARA★★★



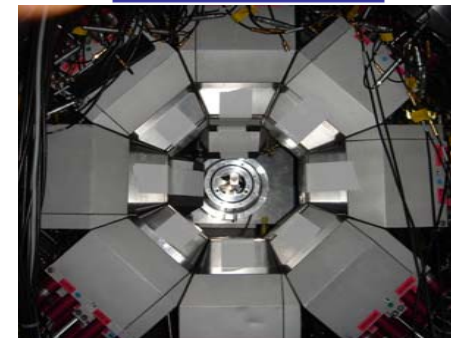
Neutron Wall



Nameless

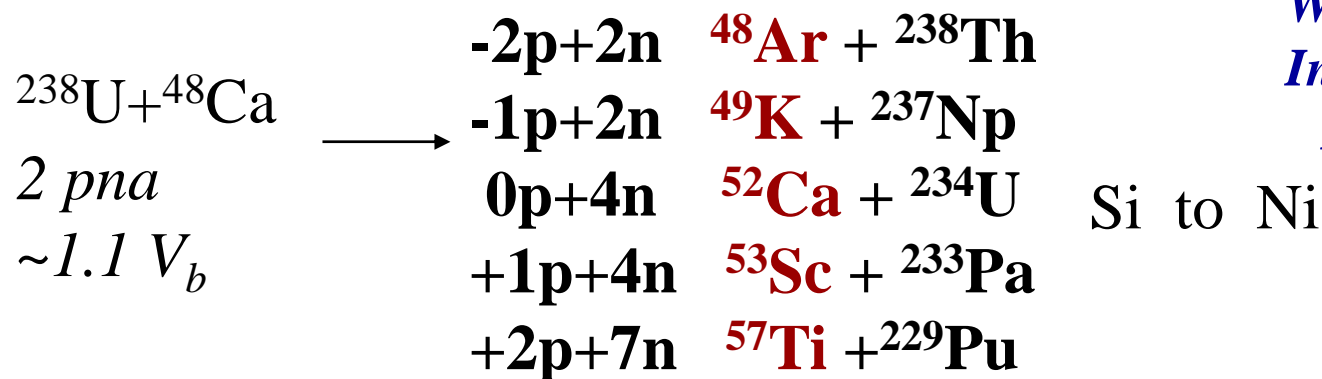


EXO GAM



Reaching new frontiers with Deep inelastic reactions at GANIL

Been there done it Cracow-ANL-MSU, Legnaro

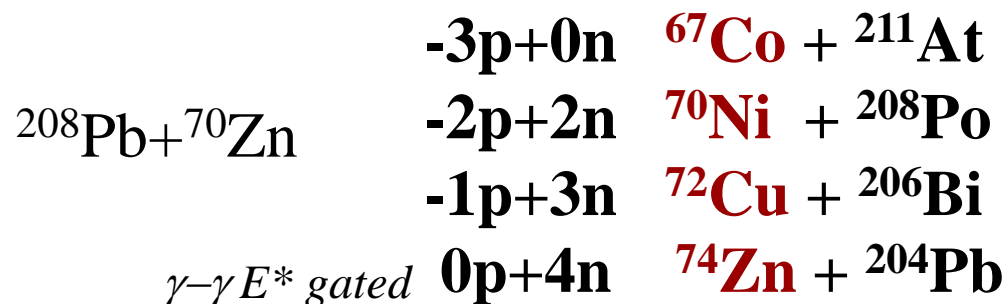


We do it our way
Inverse kinematics
Advantegous

Expensive and
rare stamps



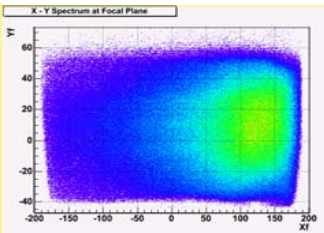
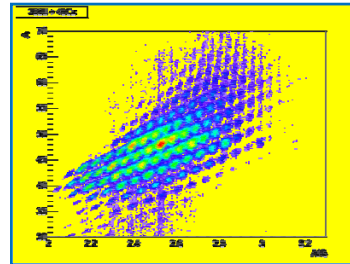
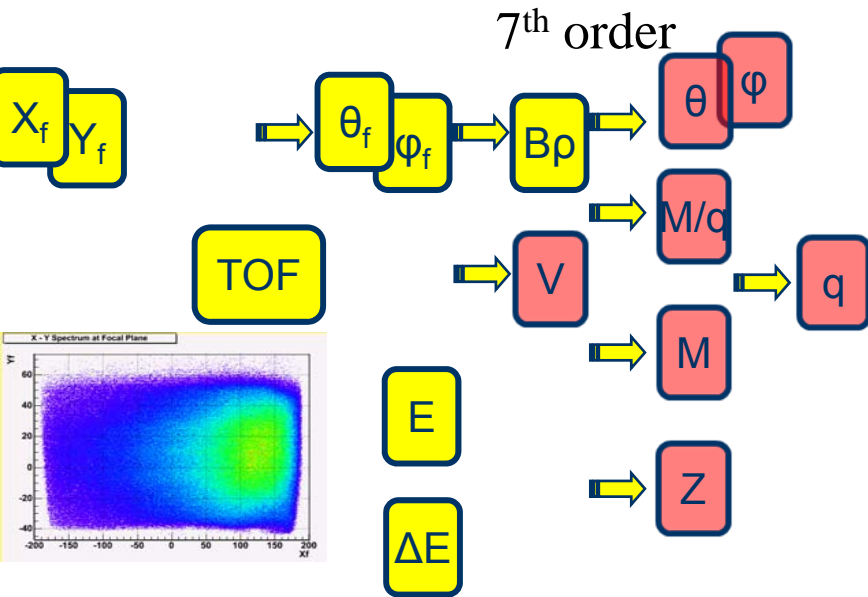
3.8M\$



What's the question?

Levels schemes Neutron rich nuclei
 Single particle and collective states + life times

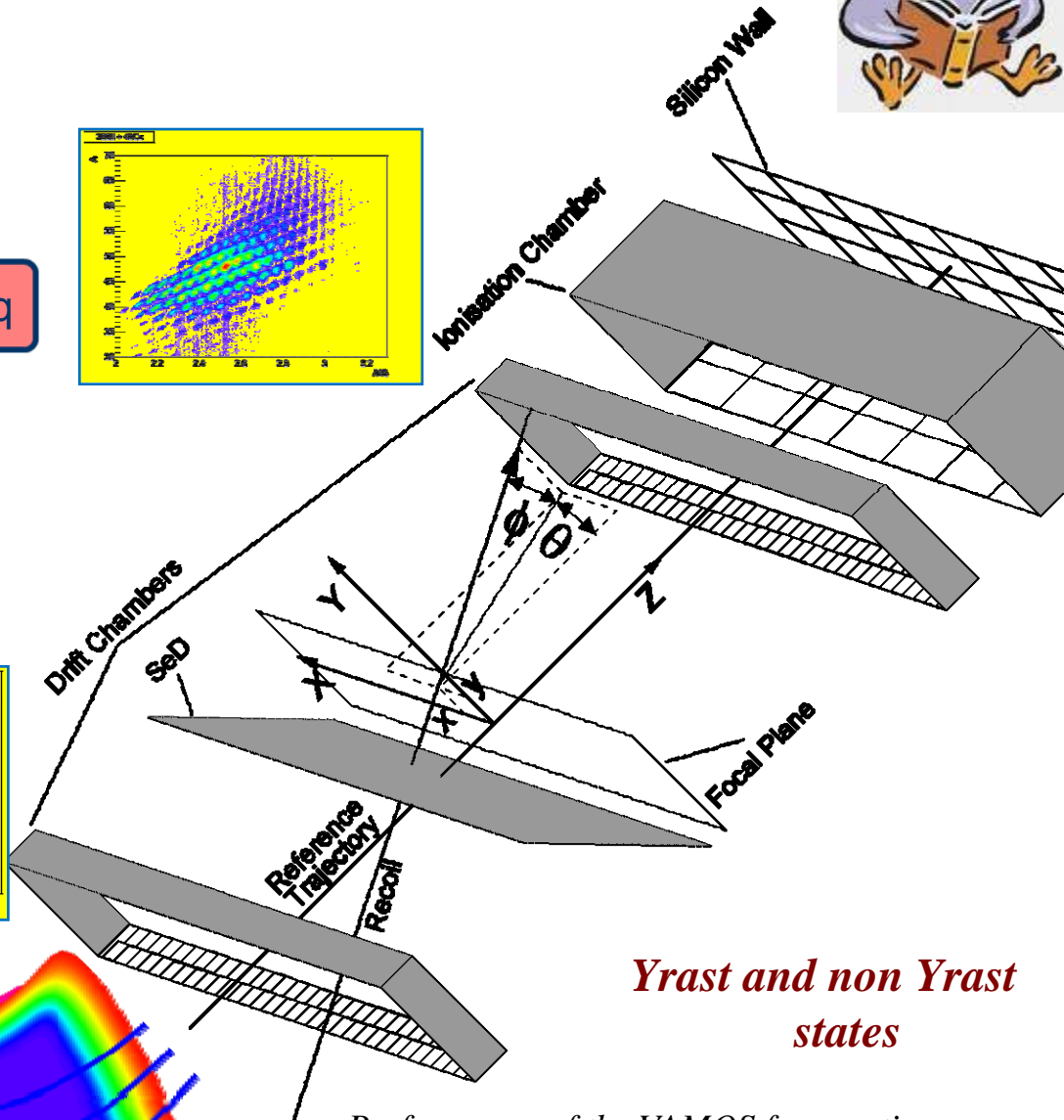
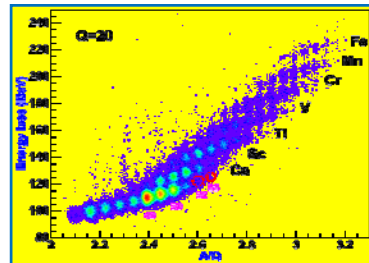
Software spectrometer



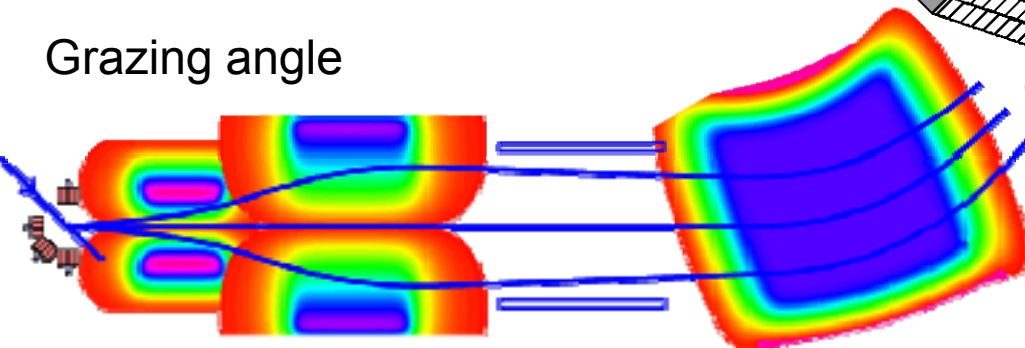
$$M/q \sim B\rho \times \text{TOF}$$

$$M \sim E \times \text{TOF}^2$$

$$Z \sim E \times \Delta E$$



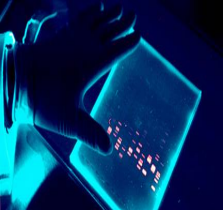
Grazing angle



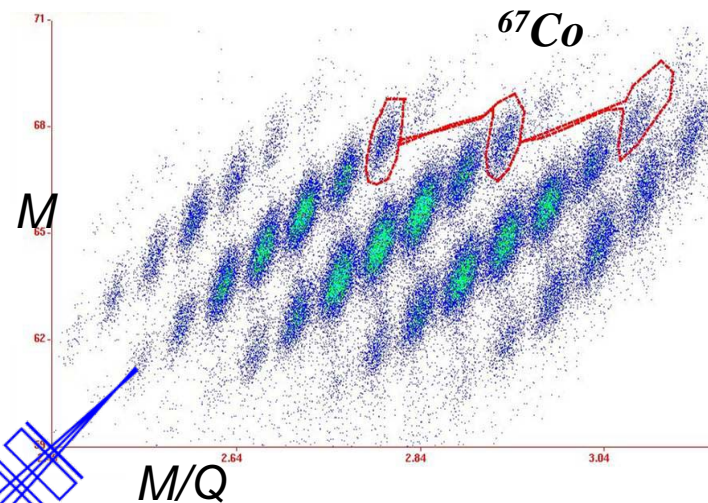
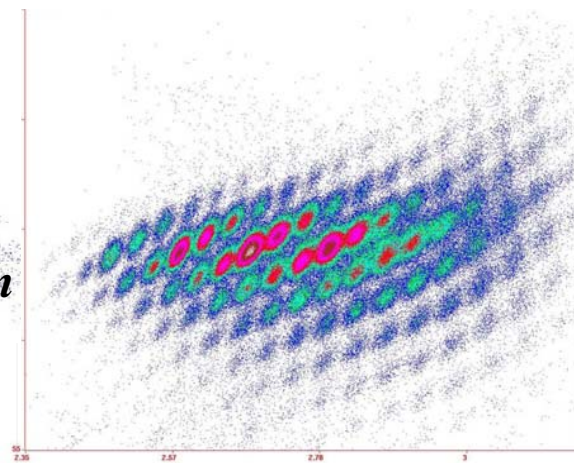
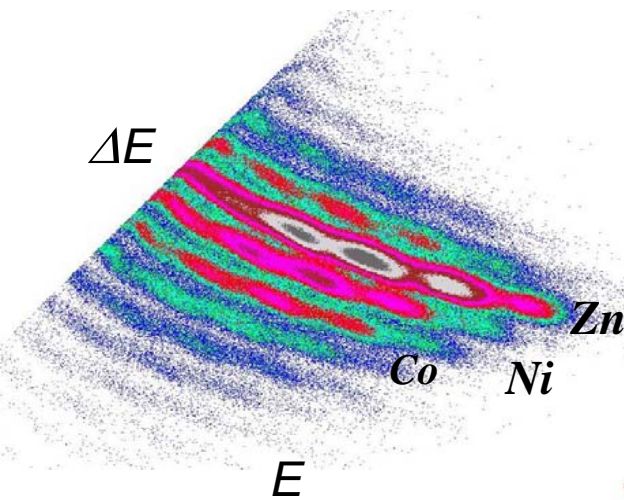
Yrast and non Yrast states

Performance of the VAMOS for reactions near the Coulomb barrier

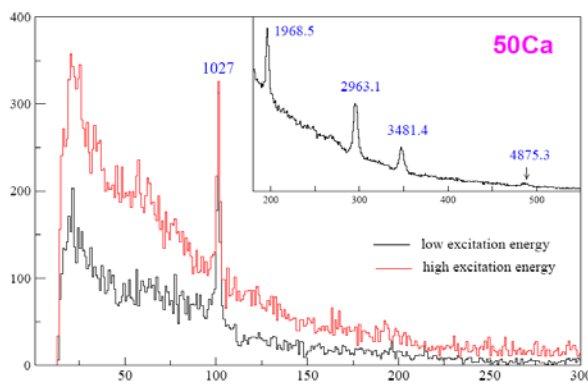
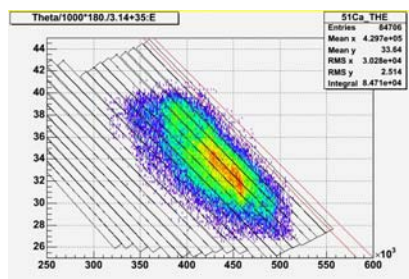
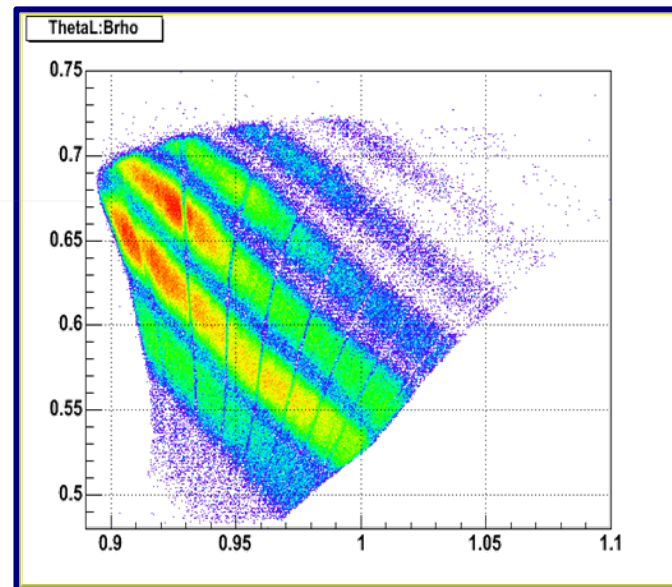
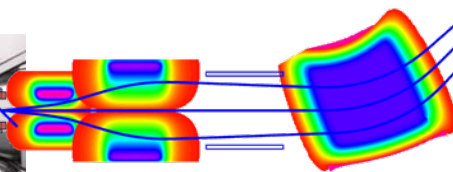
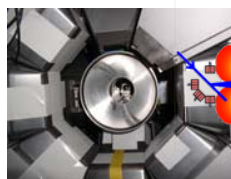
NIMA 593, 343 (2008)



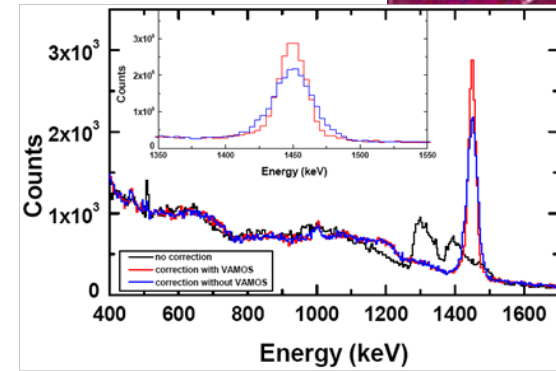
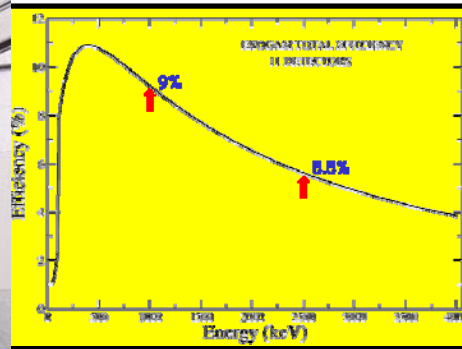
Who am I



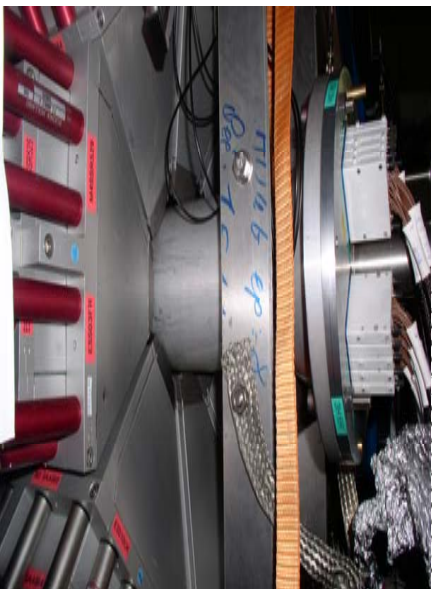
Z resolution verified around 50



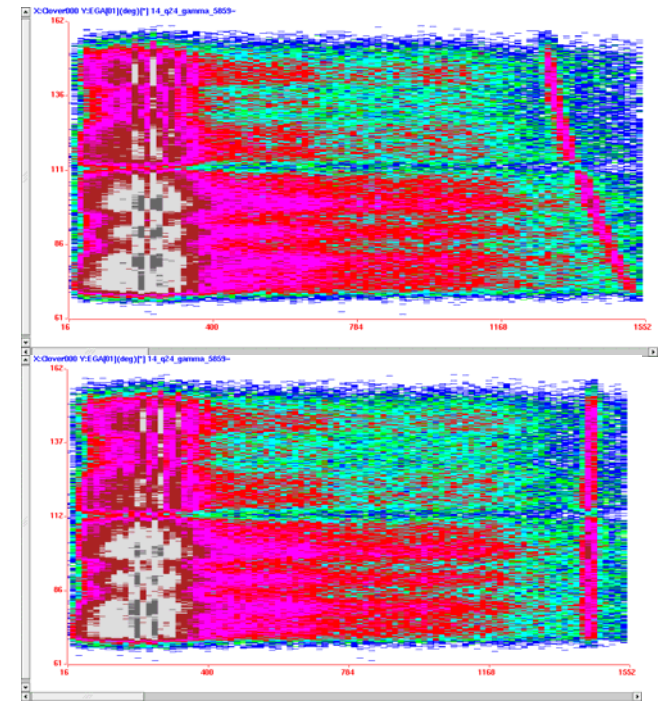
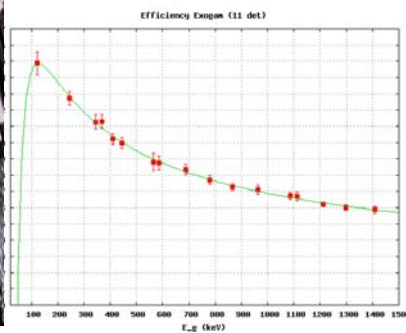
Brho



4K triggers 25 % deadtime



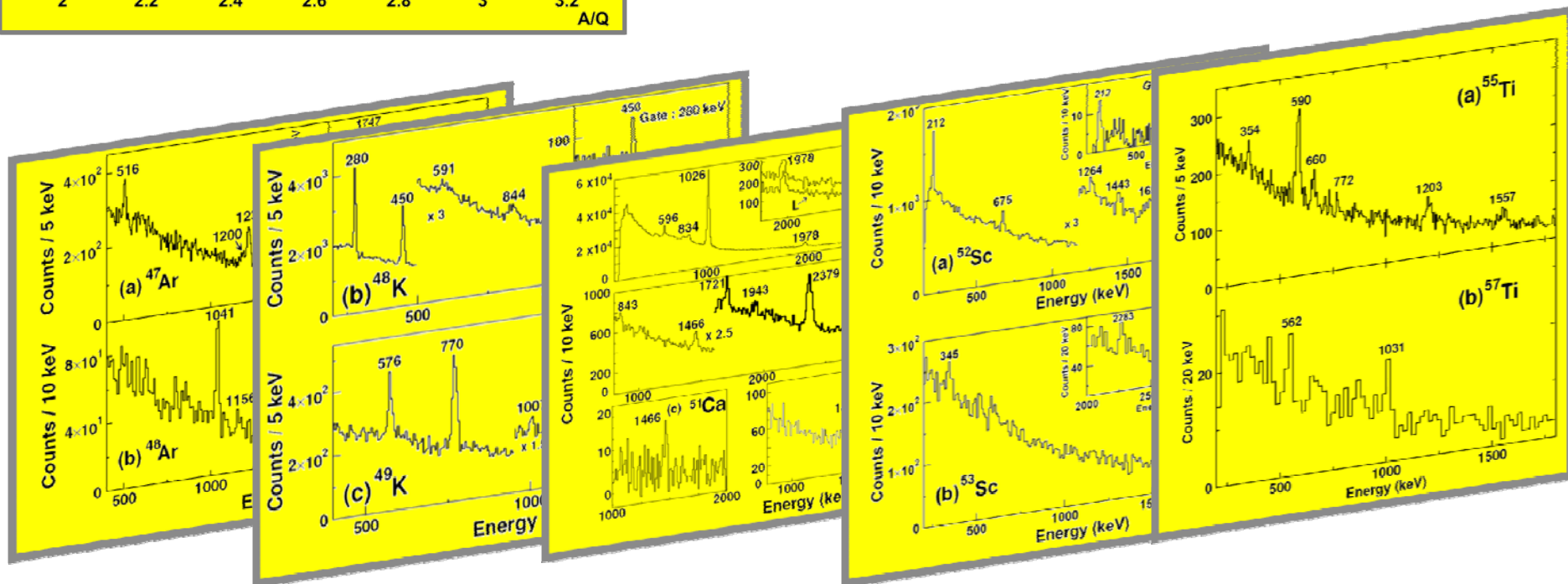
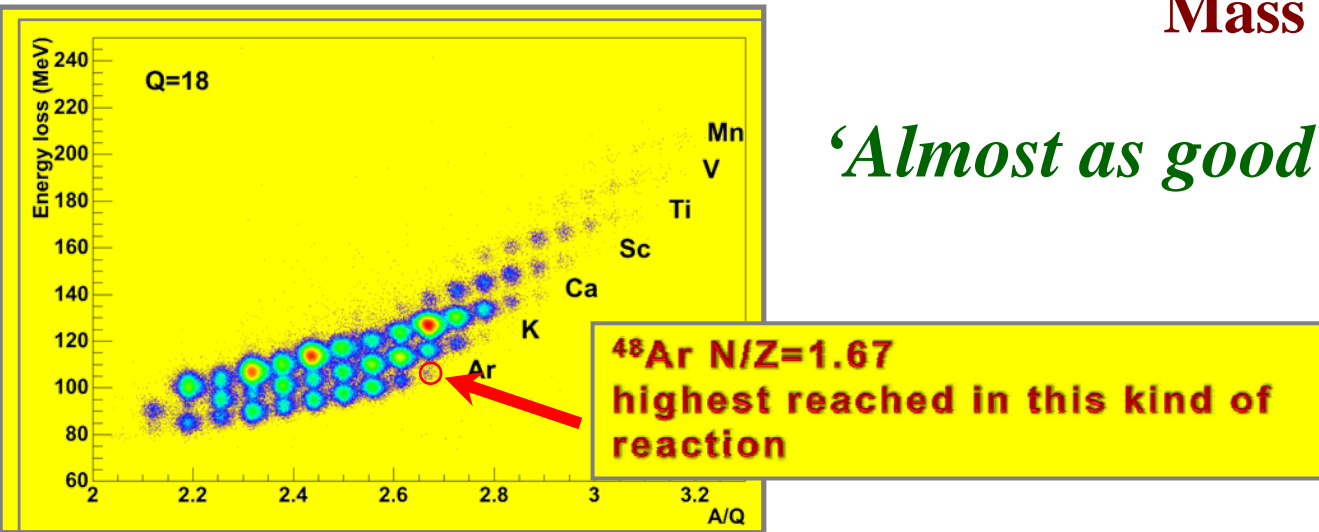
12 detector array



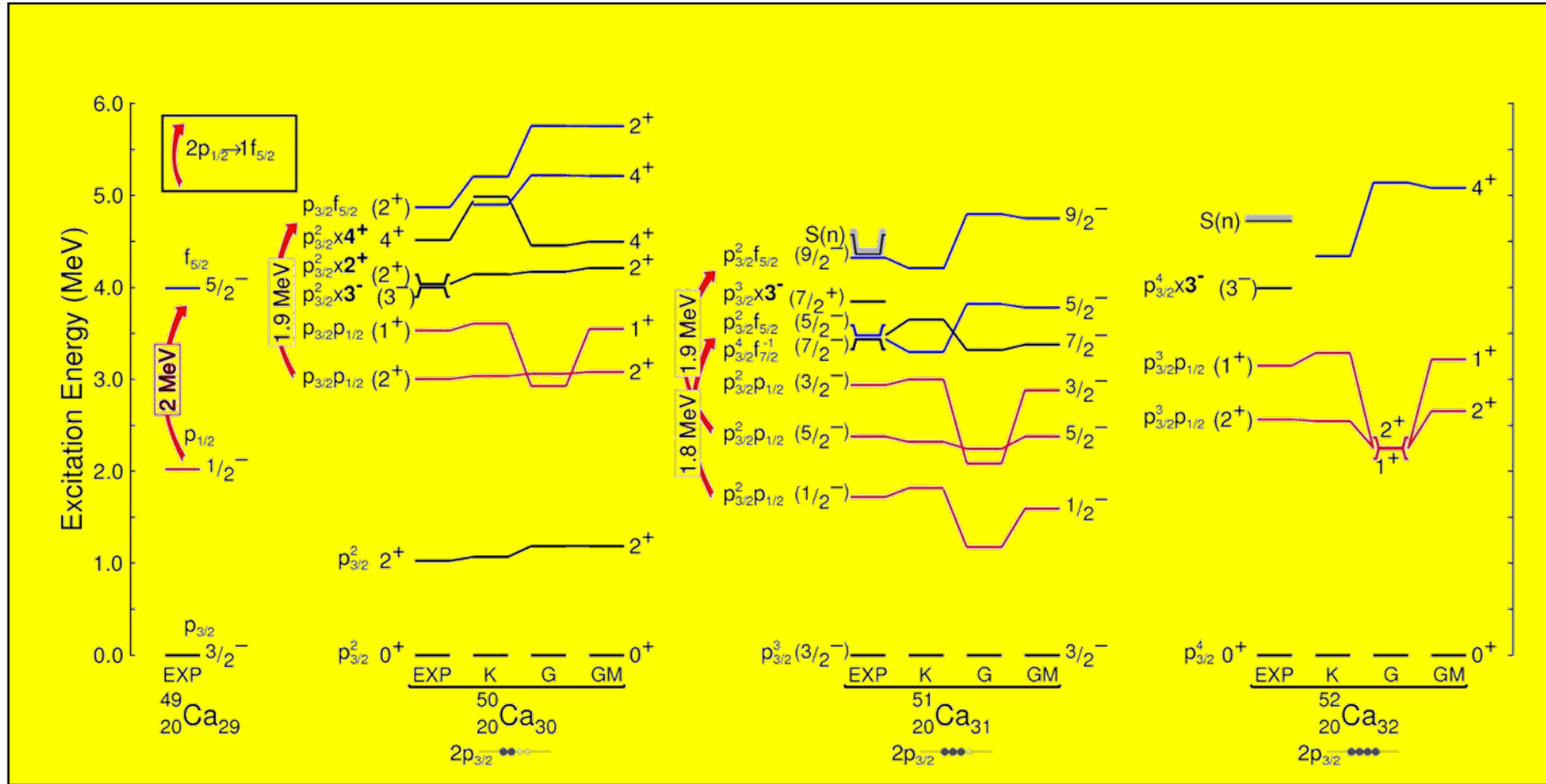


Mass at ISOLDE

‘Almost as good’ as beta decay’



New Shell gap at $N=34$?



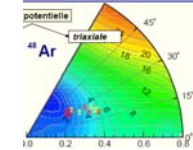
$$\langle p_{3/2} p_{3/2}, 1+ | V | p_{3/2} p_{3/2}, 1+ \rangle$$

*M. Rejmund, S. Bhattacharya, A.N et al.
Phys Rev C 76 021304 (R) 2007.*

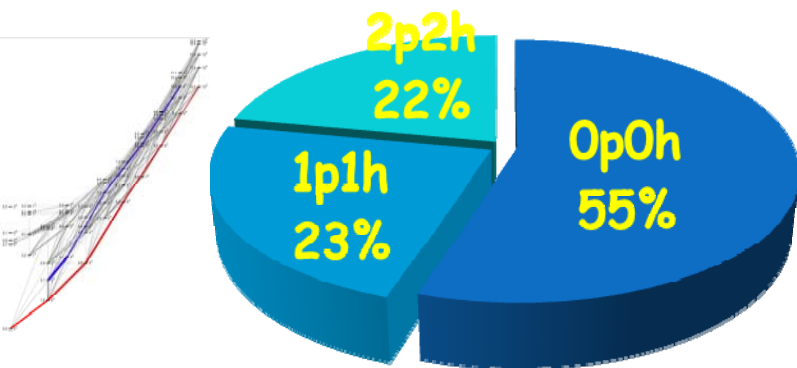


Signatures of triaxial shapes

Davydov et al NPA 8 (1958) 237, Davydov et al NPA 20 (1960) 499



Number of particle-hole excitations across N=28



Shell model calculations
Alfredo Poves, Fredrick Nowascki
E. Caurier

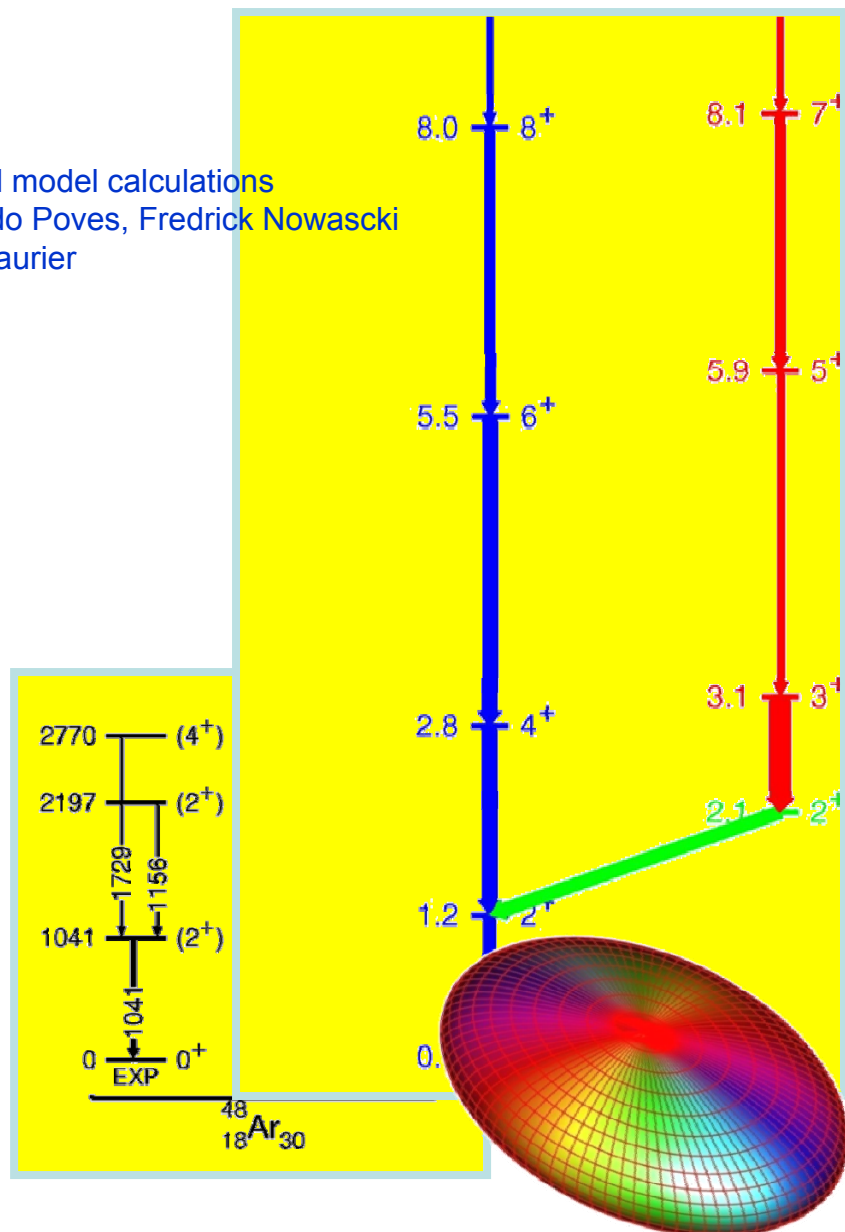
Presence of correlations, cross shell excitations.

Existence of deformed shapes N~28, ⁴²Si

Rotational spectra only slightly effected by violation of axial symmetry

Appearance of new rotational states 2,3,4....

Lowering of these states with increase in deviation from axial symmetry.

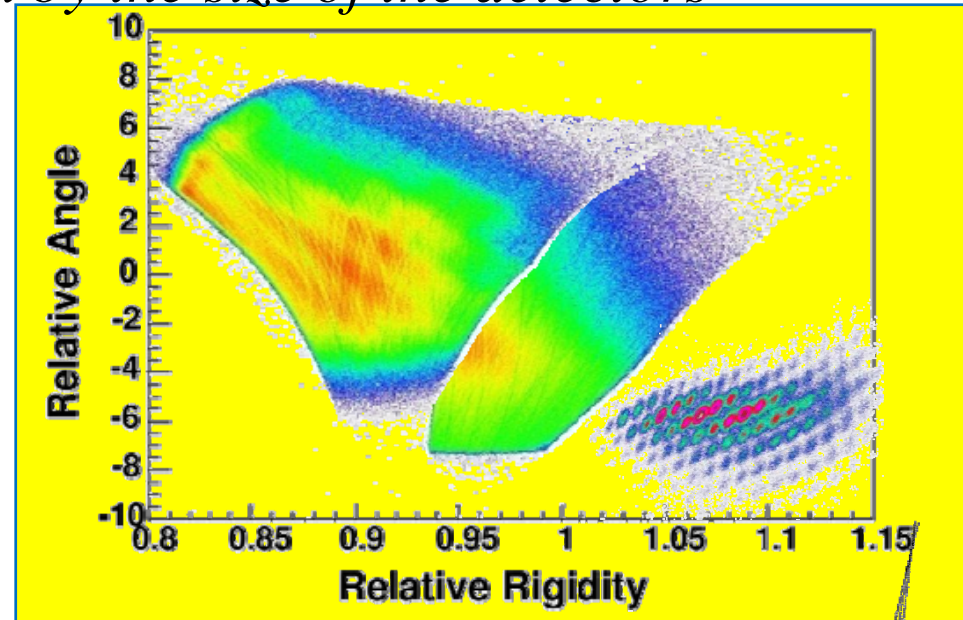
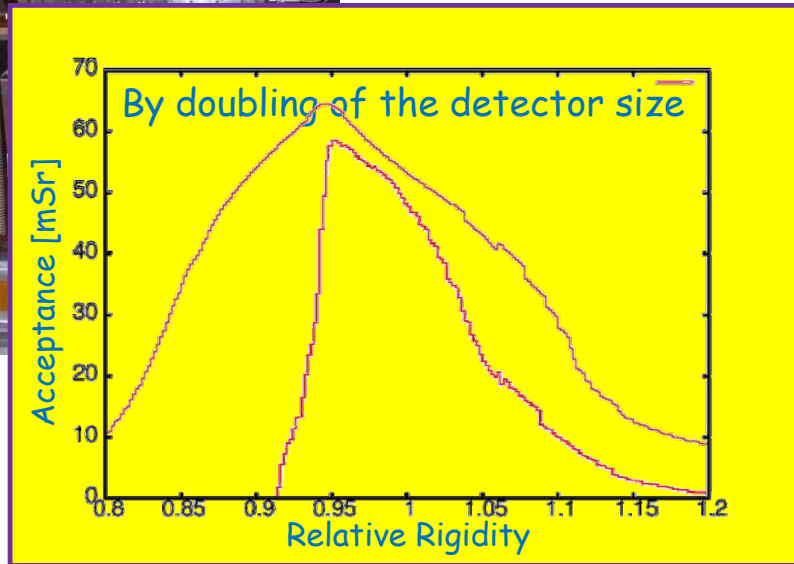
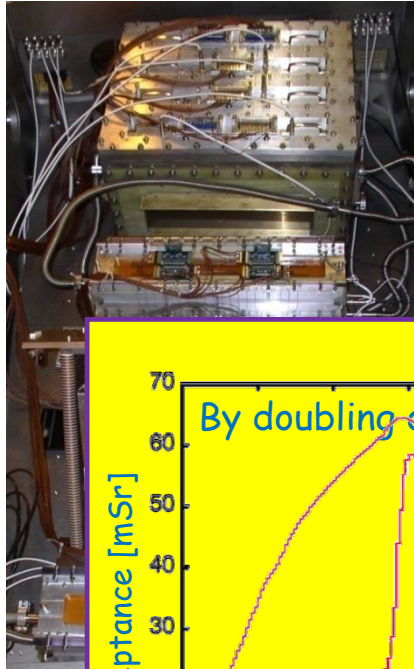


S. Bhattacharyya, M. Rejmund, A.N et al.

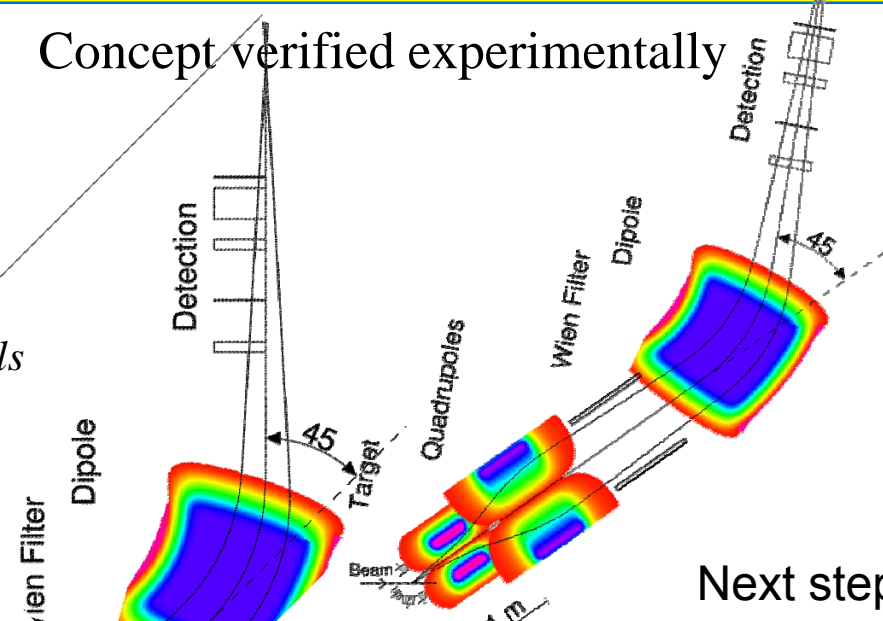
Phys. Rev. Letts 101 032501 (2008)

Improvements of sensitivity

Acceptance limited by the size of the detectors



Concept verified experimentally



Full digital electronics for Inner , Outer and shield signals
High counting rate > 50 kHz/crystal

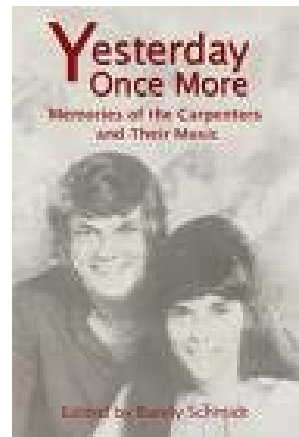
Agata demonstrator at GANIL

Next step

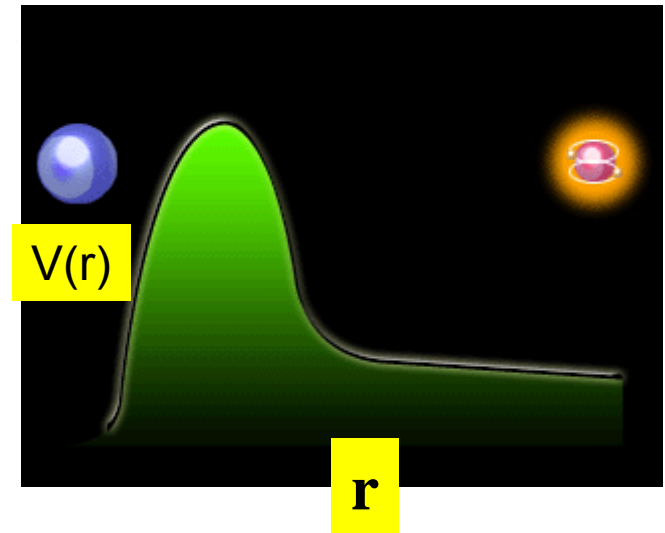
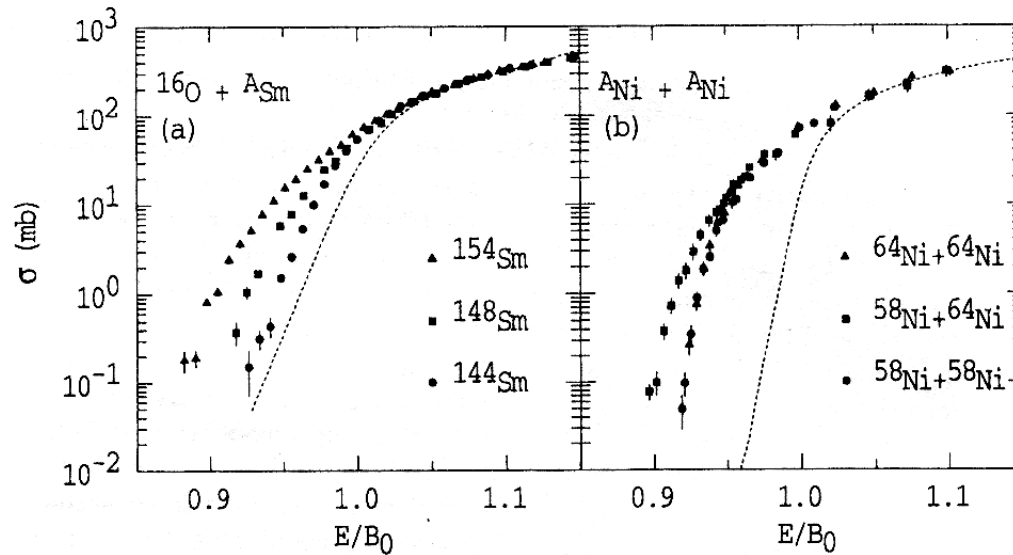


The fission route towards neutron rich nuclei
M,Z,Q tagged gamma spectroscopy
SPIRAL2

SPIRAL1
Most intense beams
Of He ++



Tunneling through a multi-dimensional barrier

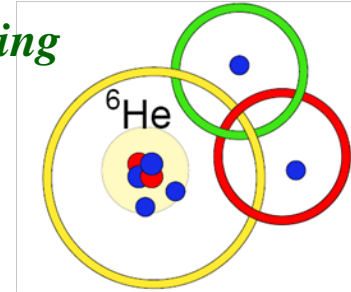


In general $V(r, \xi_1, \xi_2, \xi, \dots)$ Coupled channel problem

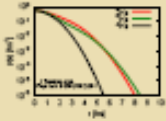
Large size enhancement in fusion cross section
Weak binding breakup suppression of fusion

How does the intrinsic structure of nuclei affect the tunneling

Borromean nuclei He



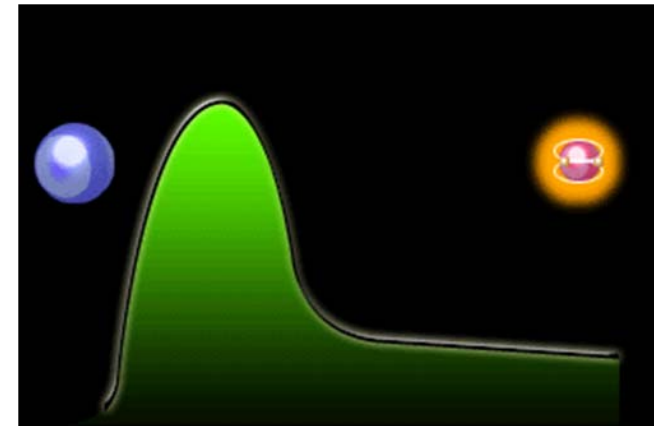
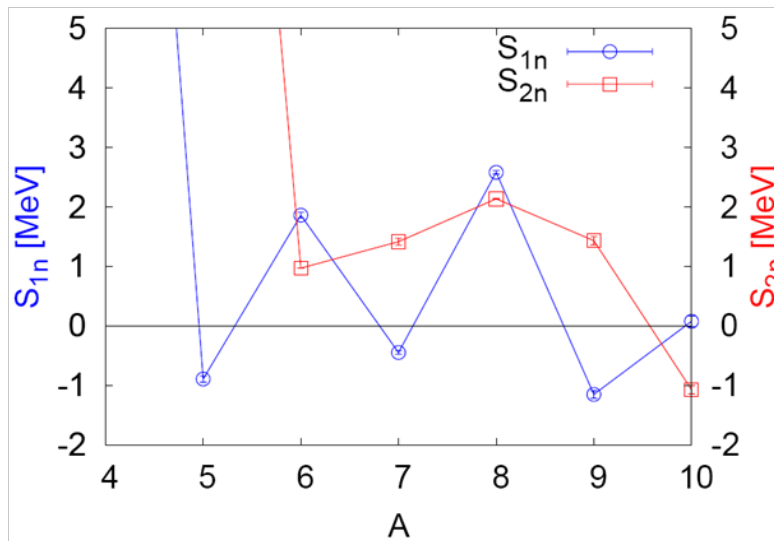
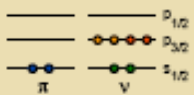
Halo nucleus



Borromean Structure

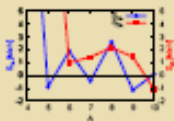


G.S. Configuration

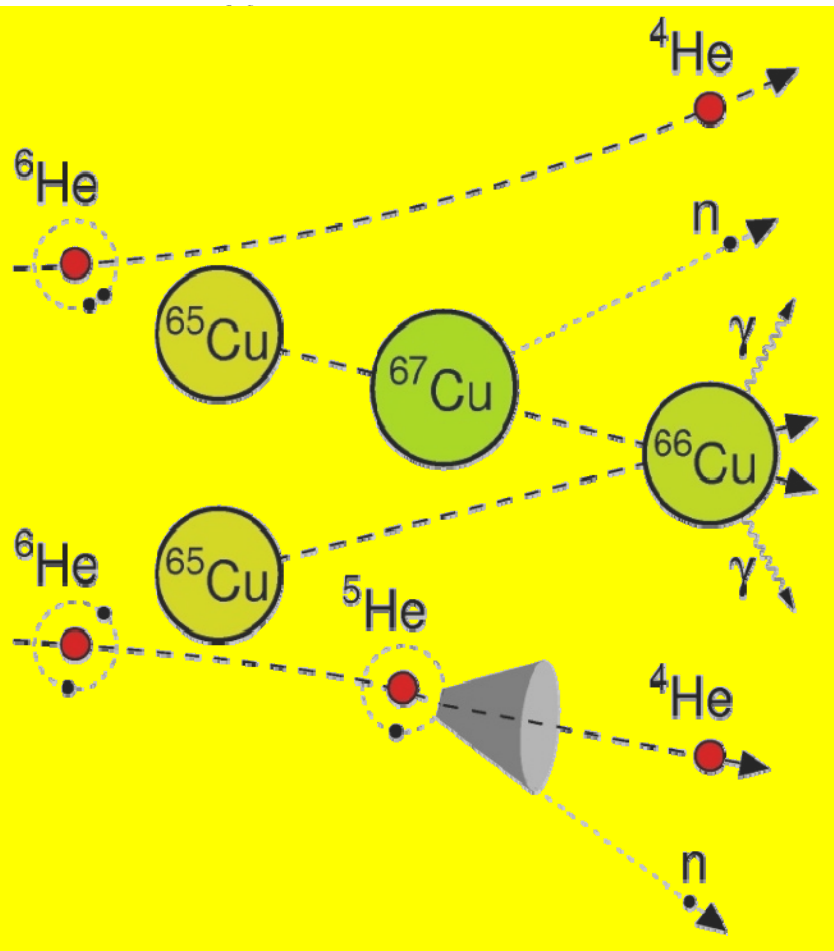


Measure all reactions elastic, transfer, fusion

Weakly Bound



one and two neutron transfer



◎ ^6He

- > Borromean
- > Radioactive
- > $I \sim 4 \times 10^7$ pps

◎ ^5He unbound

◎ Need of triple coincidences

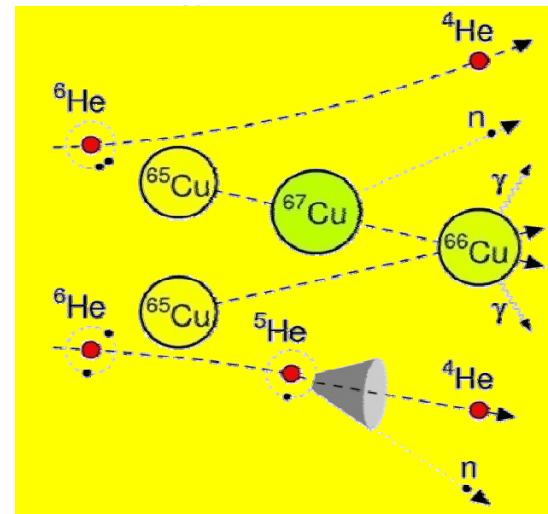
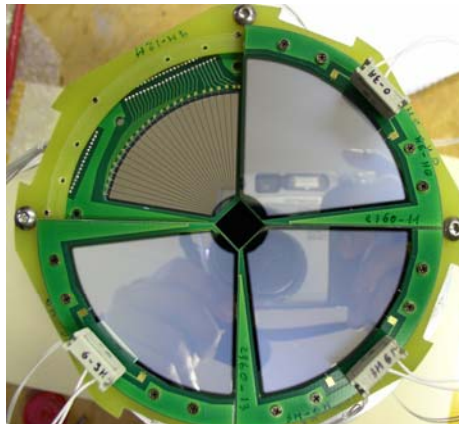
- > γ , n , α

◎ Challenge



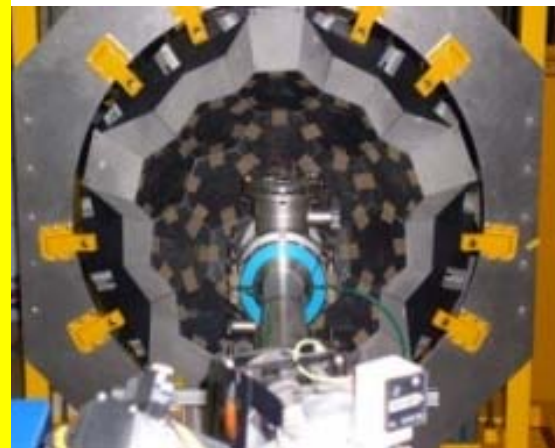
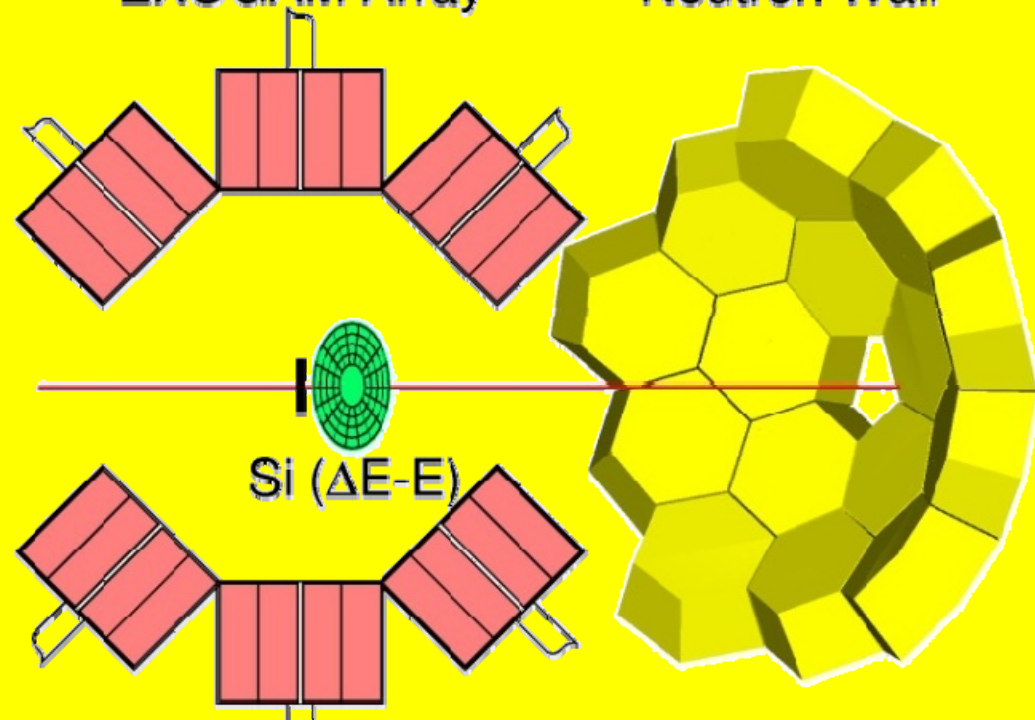
*A. Chatterjee, A. N et al.
Phys. Rev. Letts 101, 032701 (2008)*

one and two neutron transfer



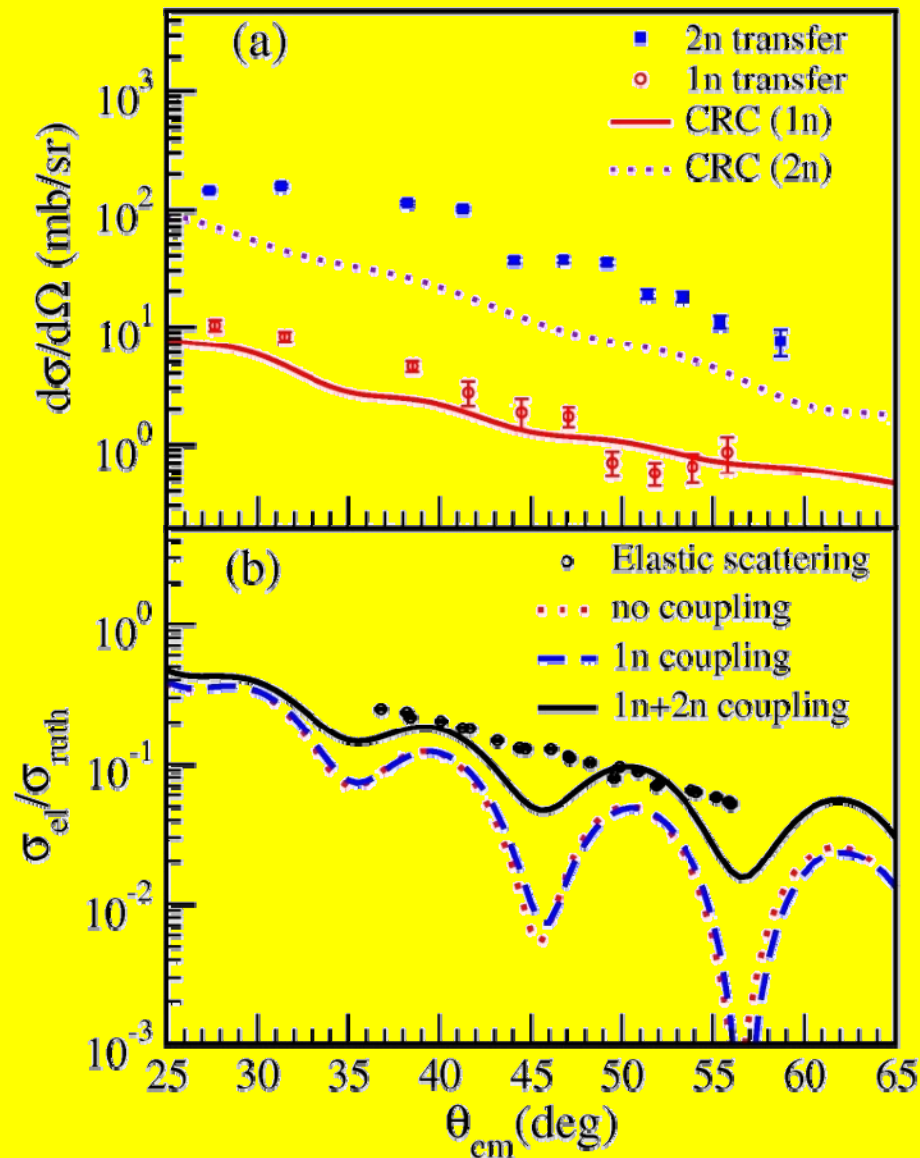
EXOGRAM Array

Neutron Wall

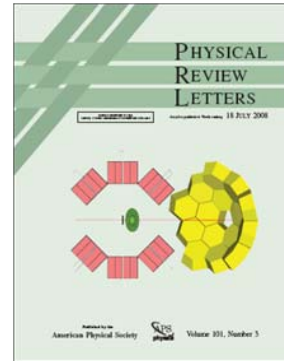


*A. Chatterjee, A. N et al.
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one and two neutron transfer

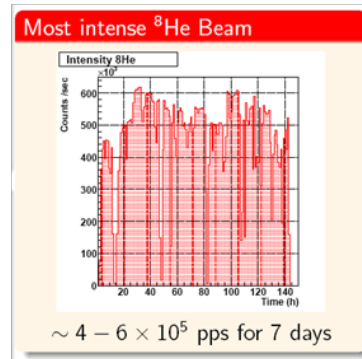
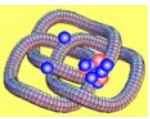


- > Large transfer cross section
- > Large ratio between one and two neutron transfer
- > Important role of the dineutron configuration



A. Chatterjee, A. N et al.
 Phys. Rev. Letts 101, 032701 (2008)

Reactions with Double Borromean Nuclei around the Coulomb barrier?



• ${}^8\text{He} + {}^{65}\text{Cu}$ and

${}^8\text{He} + {}^{197}\text{Au}$

In beam measurements

off beam measurements

Particle-gamma-n

X-gamma coinc (new)

A. Lemasson et al (in prep)

A. Lemasson et al. NIMA (in press)

Elastic scattering,

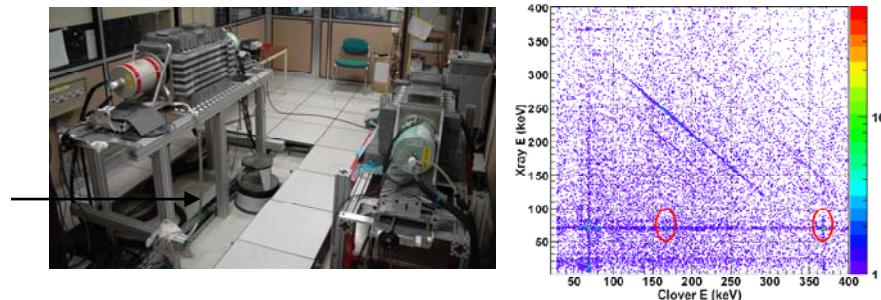
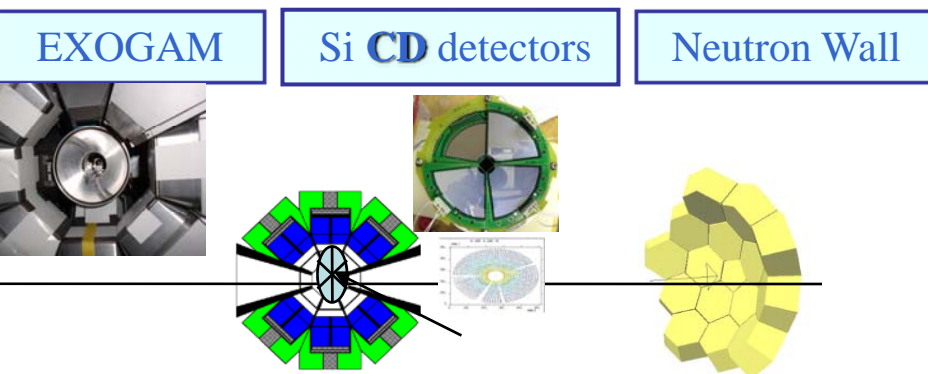
(1+2)n angular distributions

Total (1+2)n transfer cross sections.

Above barrier Fusion cross sections

Sub barrier fusion cross sections

0.5mb equivalent to pb SHE but with γ



Results ^8He

- *Comming soon in a journal close to you!!*
Not for the web



*The woods are lovely dark and deep,
But we have miles to go before we sleep,
Miles to go before we sleep.....
Robert Frost*

*HI REX
SPIRAL 2*

