Grupo de Física Nuclear Experimental

Decay Studies

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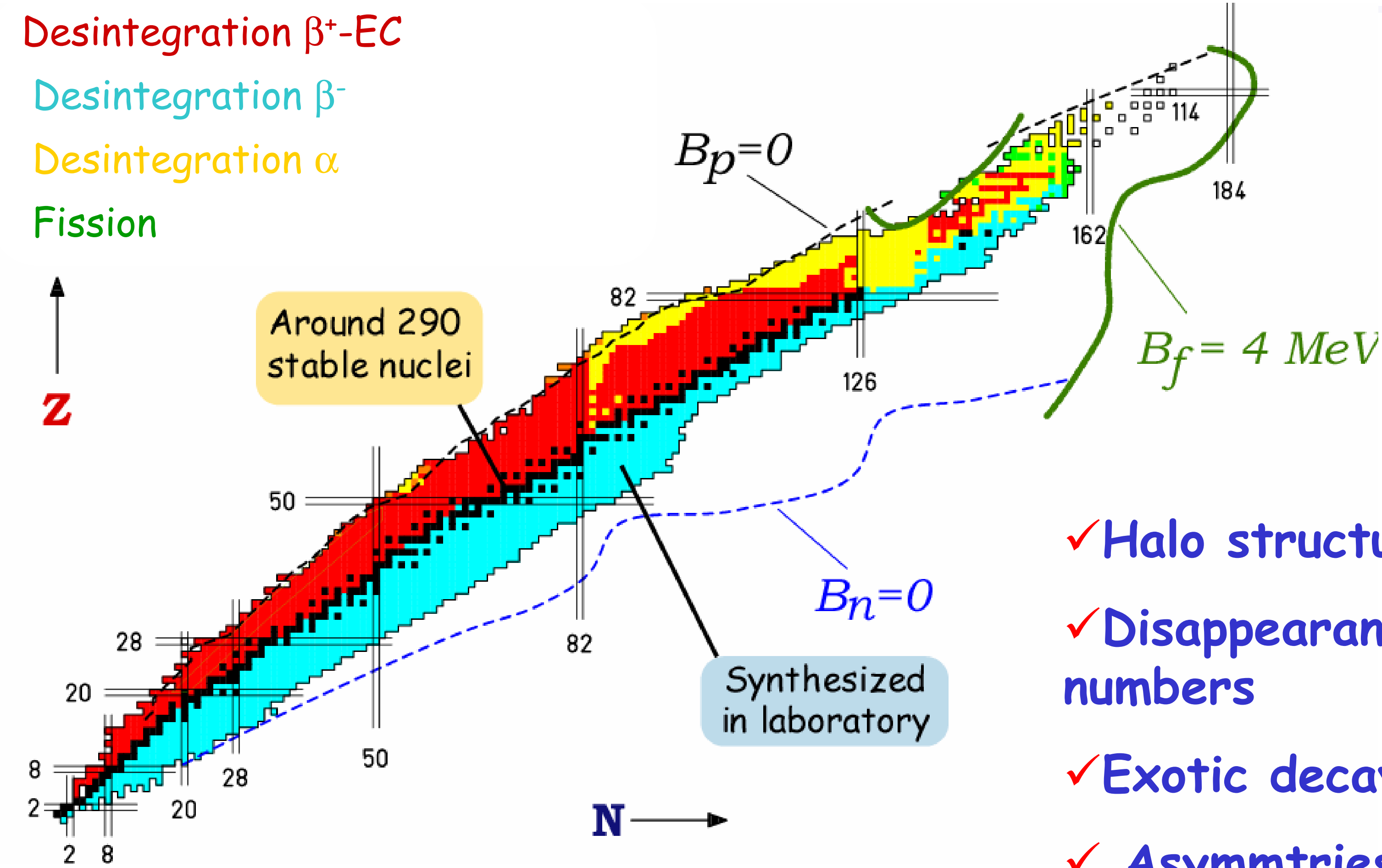
Overview

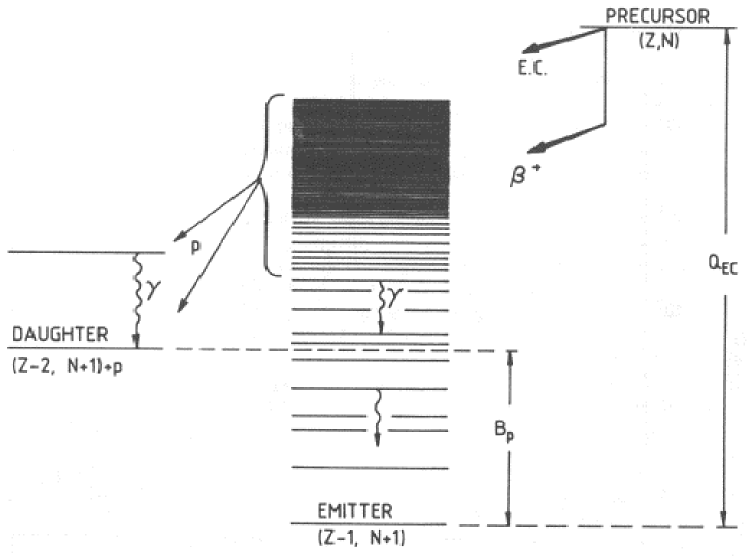


Near the drip lines

- ✓**Halo structure**
- ✓**Disappearance of magic numbers**
- ✓**Exotic decays**
- ✓ **Asymmtries**
- ✓**Order to Chaos**

Beta-delayed Particle Emission

- **1916** **Rutherford & Wood** βα [*Philos. Mag.* ***31*** *(1916) 379*]
- **1963** **Barton &Bell** identified ^{25}Si as **βp**



- The intensity of the particle depends of:
  1-Beta intensity of the precursor
  2-Probability of particle emission versus γ

$$I_p^{if} = I_\beta^{i} \frac{\Gamma_p^{if}}{\Gamma^{if}}$$

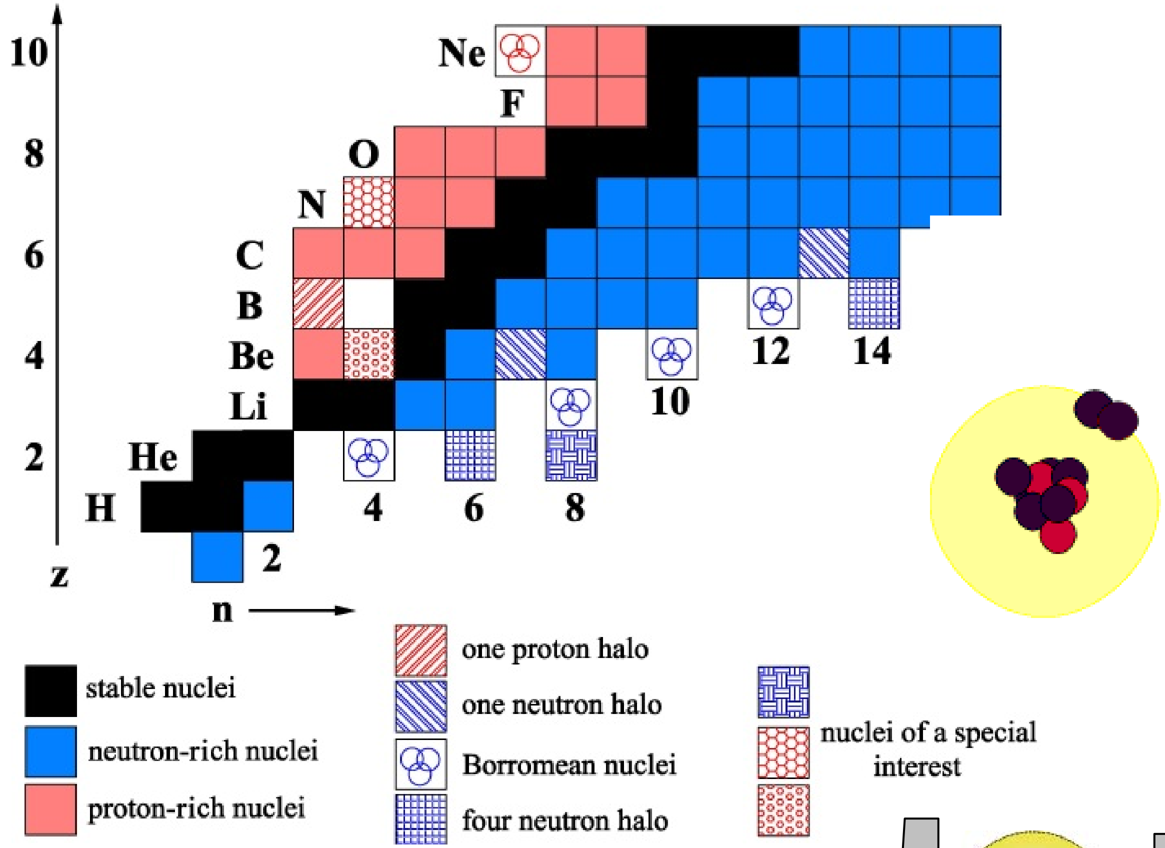
E, Γ

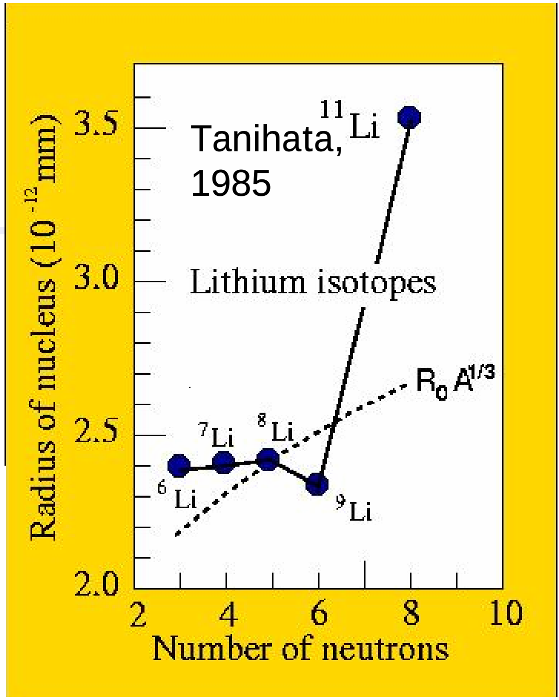
Level density

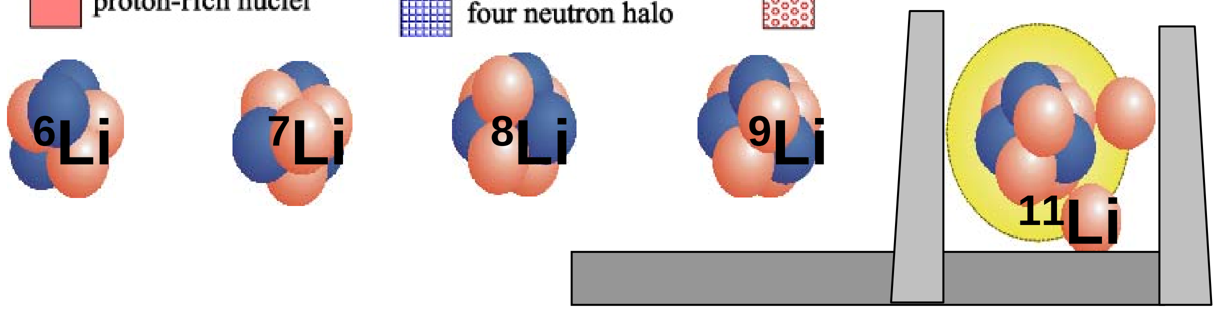
Spin, Isospin

β-decay properties

Halo nuclei



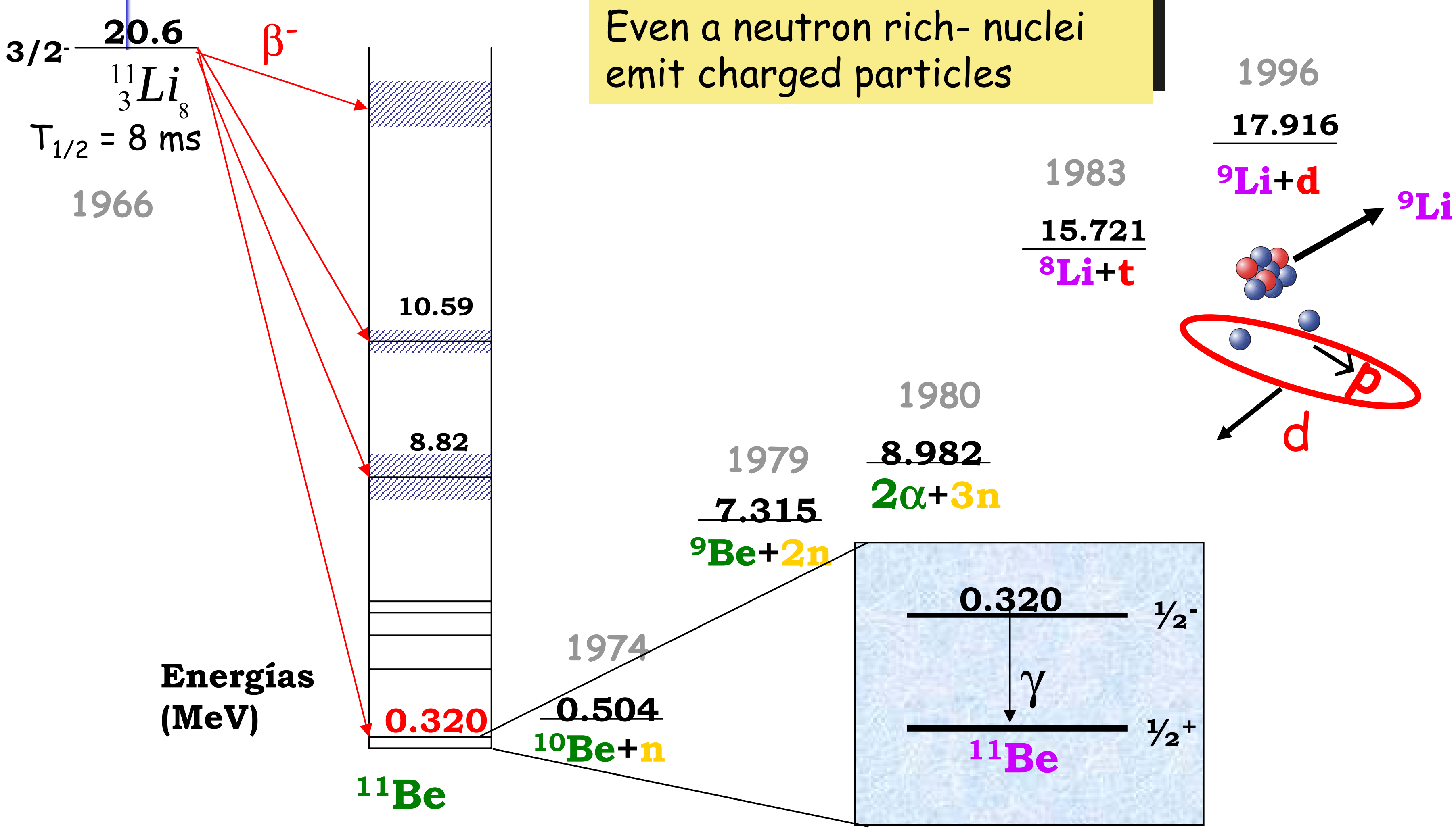




- ✓Energy threshold effect
- ✓Highlight by nuclear reactions
- ✓Effects in beta decay

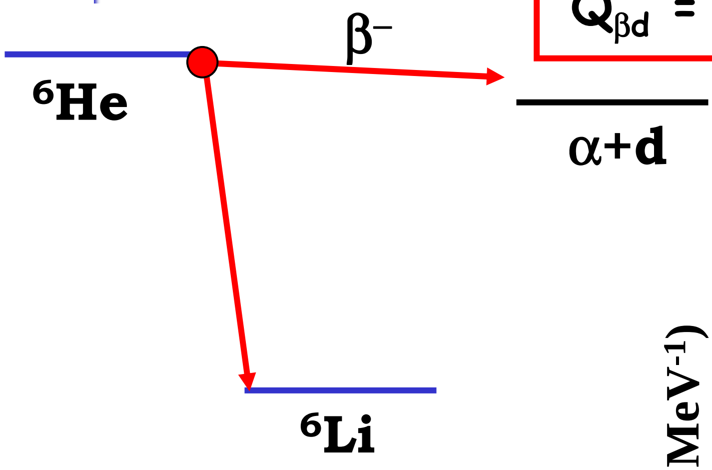
Beta decay of an exotic nuclei

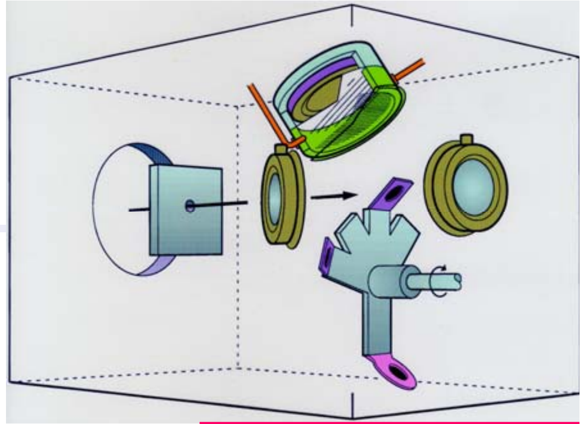
Even a neutron rich- nuclei emit charged particles



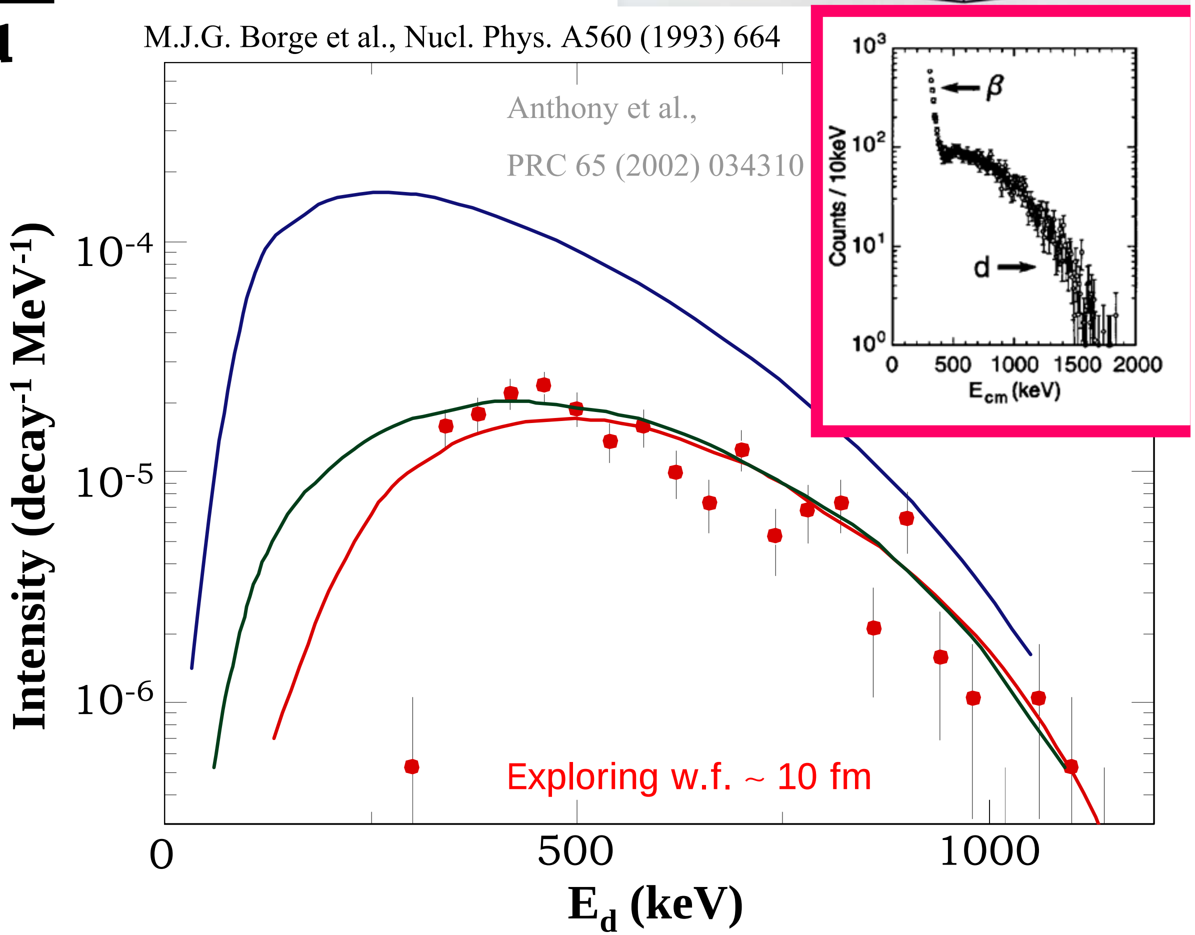
Beta-delayed deuterons

$$Q_{\beta d} = 3.007 - S_{2n} \text{ MeV}$$





M.J.G. Borge et al., Nucl. Phys. A560 (1993) 664

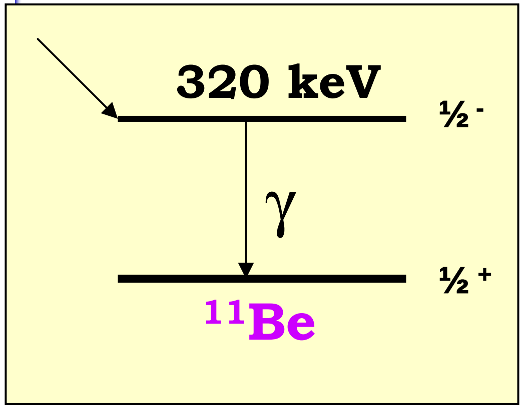


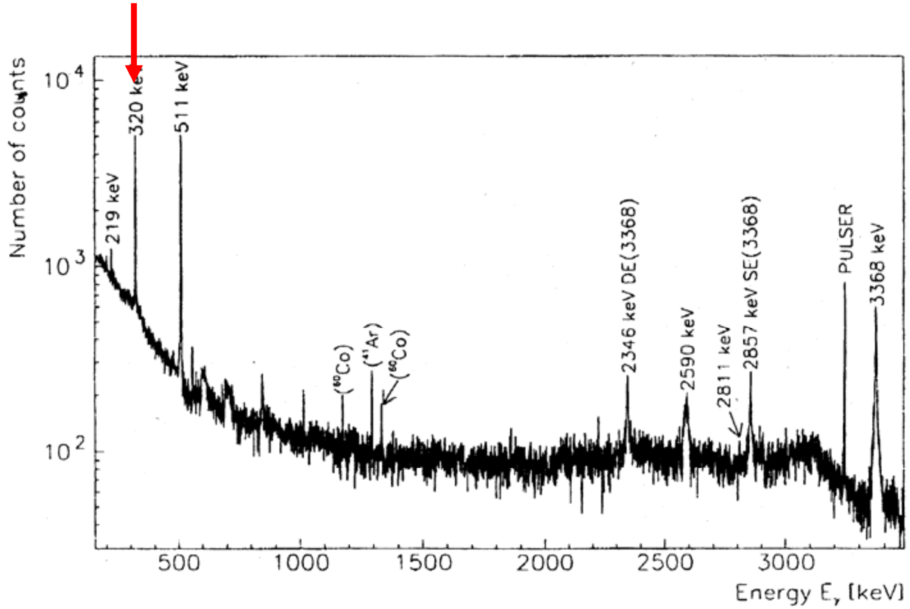
M.V. Zhukov et al., PRC47 (1993) 2937

D. Baye et al., Prog. Th. Phys. 91 (1994) 271

F.C. Baker, Phys. Lett. B 322 (1994) 17

^{11}Li, gamma rays





M.J.G. Borge et al., PRC55 (97) R8

N. Aoi et al., NPA616 (97) 181c

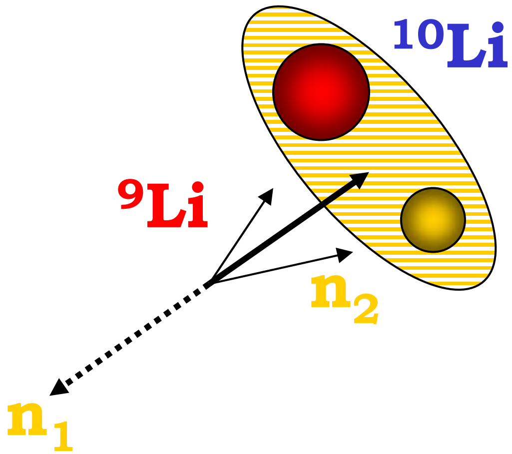
D. Morrisey et al., NPA627 (97) 222

Q = 20.62 MeV, $T_{1/2}$= 8.2 ms
b(320) = 6.3(6) %
log *ft* = 5.73

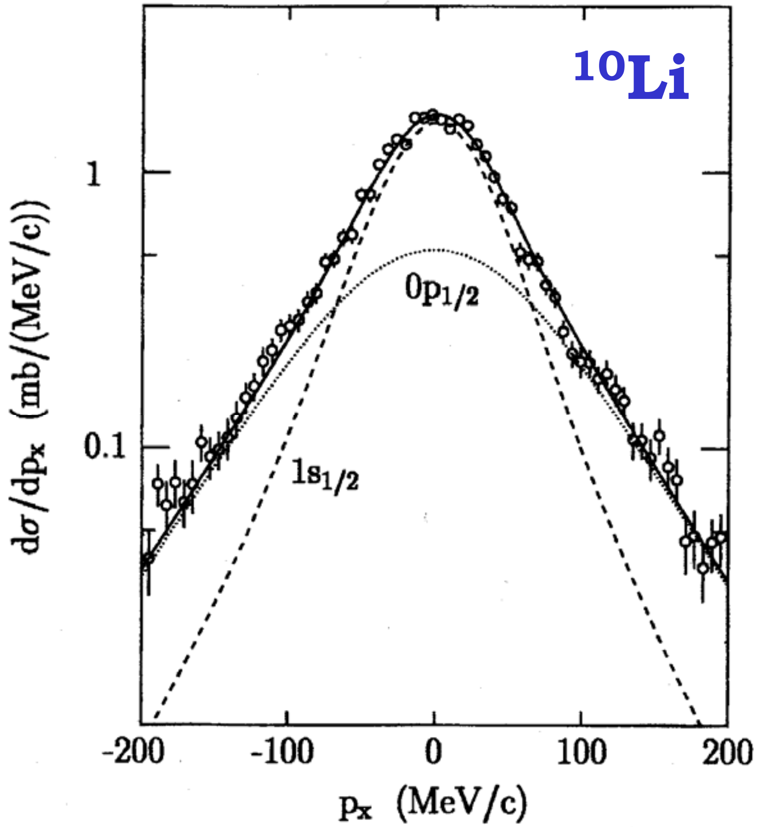
$(1s_{1/2})^2/(0p_{1/2})^2 \sim 1$

^{11}Li (284 MeV/u) + C ⟶ ^{9}Li + n @ GSI

See presentation of Thomas Nilsson



H. Simon et al., PRL 83 (1999) 496

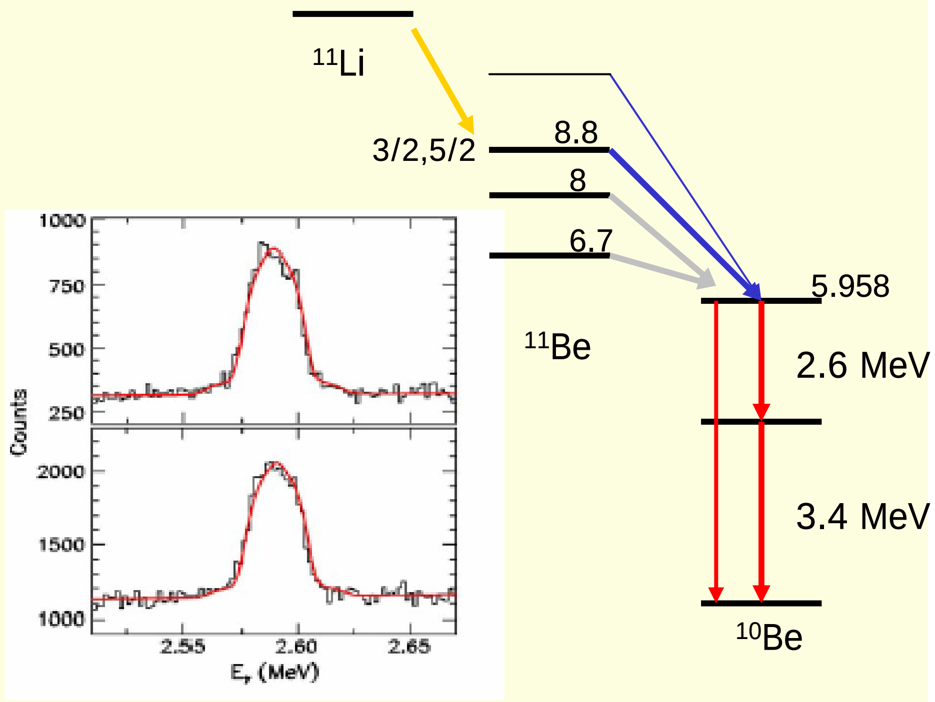


Single-particle momentum distributions, Hankel functions

$(1s_{1/2})^2$ = 45(10) %

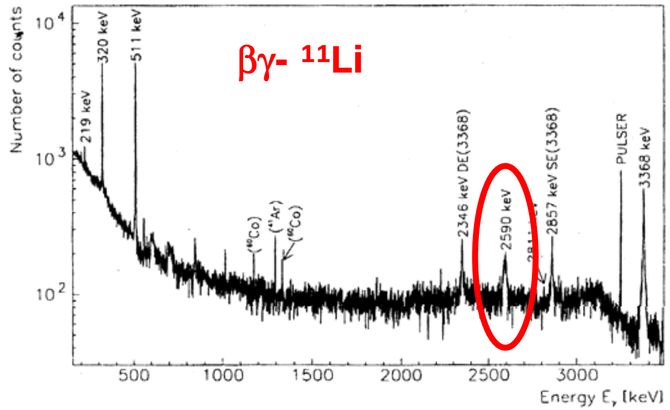
in the ^{11}Li g.s

Energy, spin & $T_{1/2}$ from γ-line shapes in ^{11}Li decay



Fynbo, NPA 736 (2004) 39

Controversial interpretation of βn in ^{11}Li ⇒ New Method



Doppler broaden γ-lines (βnγ)

- Decay of exotic neutron rich light nuclei
- Depends of energy of neutron
- $T_{1/2}$ of the bound state

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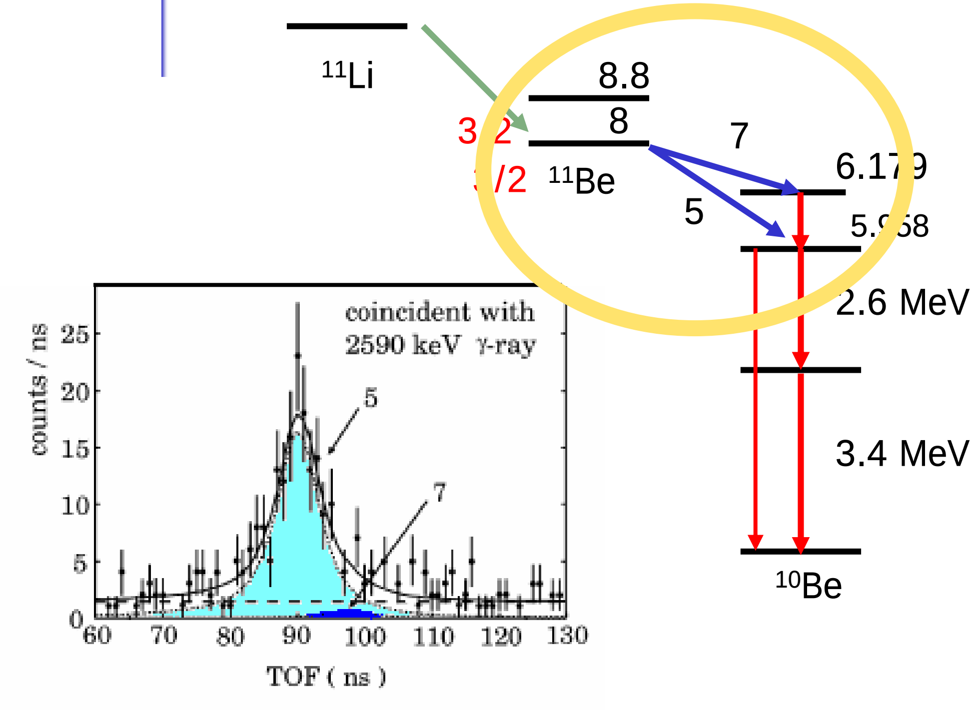
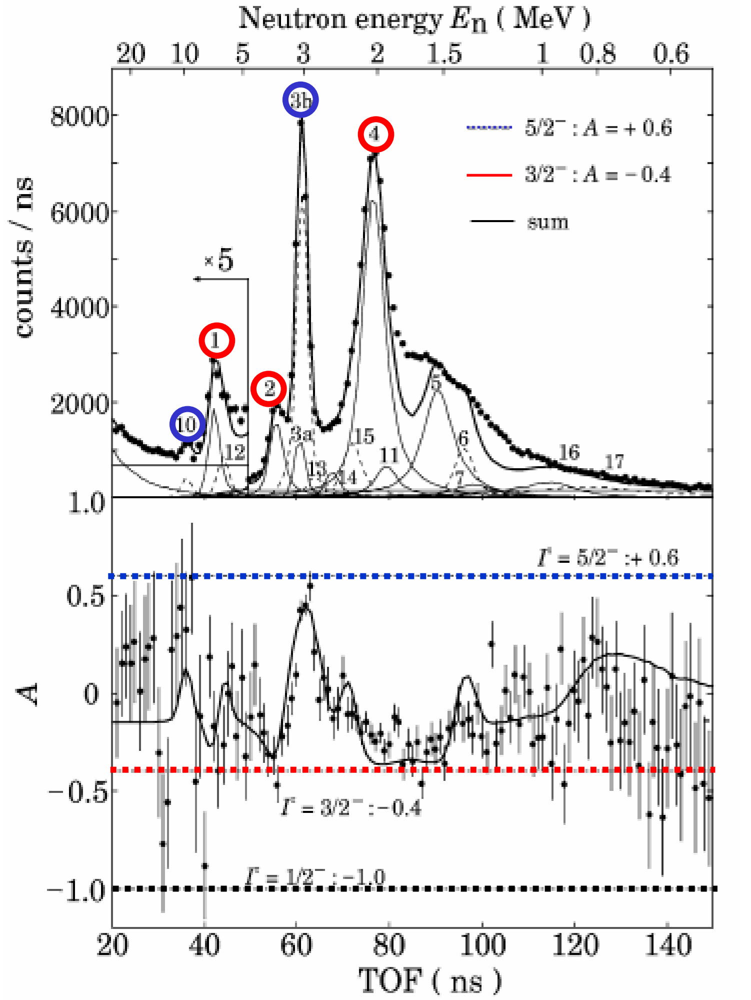
Polarized radioactive beams: ^{11}Li @ TRIUMF





Hiriyama, Phys. Lett. B 611 (2005)239

- Spin polarized ^{11}Li beam
- βγ, βn, βγn coincidences
- Spin and parities of 7 levels in ^{11}Be assigned.

Mirror Asymmetry & Systematics

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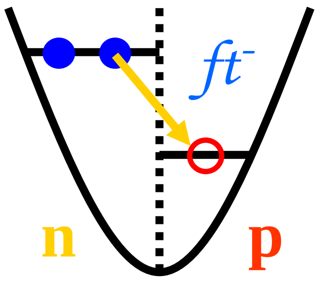
$\beta^+ \;: p \rightarrow n + e^+ + \nu$

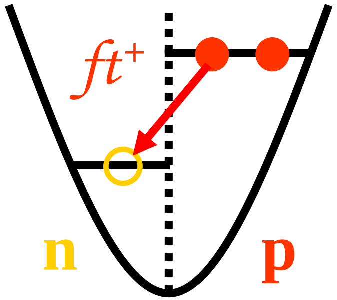
$\beta^- : n \rightarrow p + e^- + \bar{\nu}$

$\text{E.C.} : p + e^- \rightarrow n + \nu$

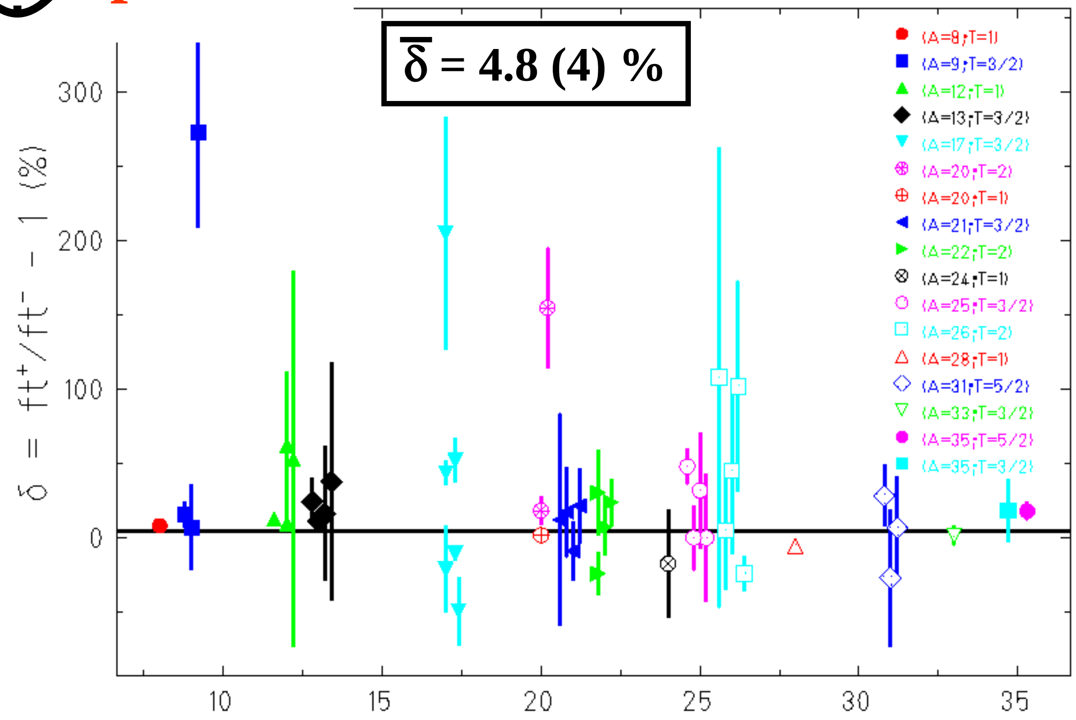
$$\delta = \frac{ft^+}{ft^-} - 1$$

$$\delta = \delta_{nuc} + \delta_{SCC}$$





Thomas et al., AIP Conf. Proc 681, p. 235



- **Allowed Gamow-Teller transitions (log(ft)<6)**
  - →**17 couples of nuclei**
  - →**46 mirror transitions**

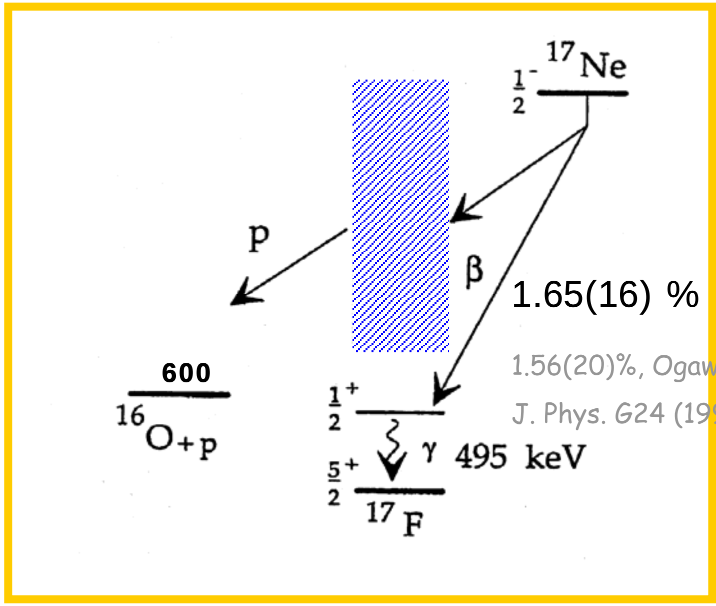
Average asymmetry δ :

11 (1) % in the 1p shell (A<17)

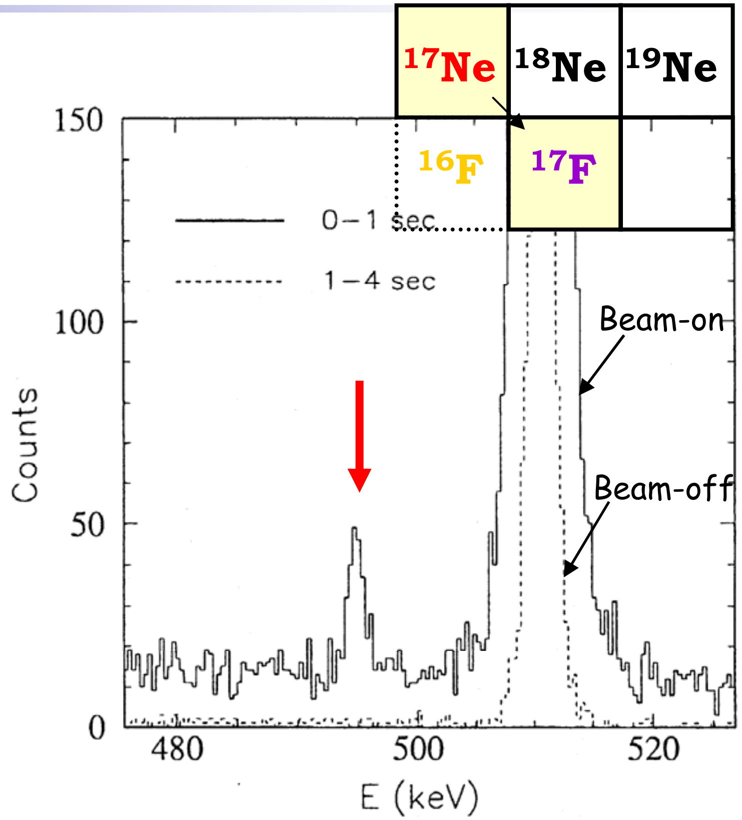
0 (1) % in the (2s,1d) shell (17<A<40)

First identification of a proton-halo state

Rolfs, NPA217(73)29



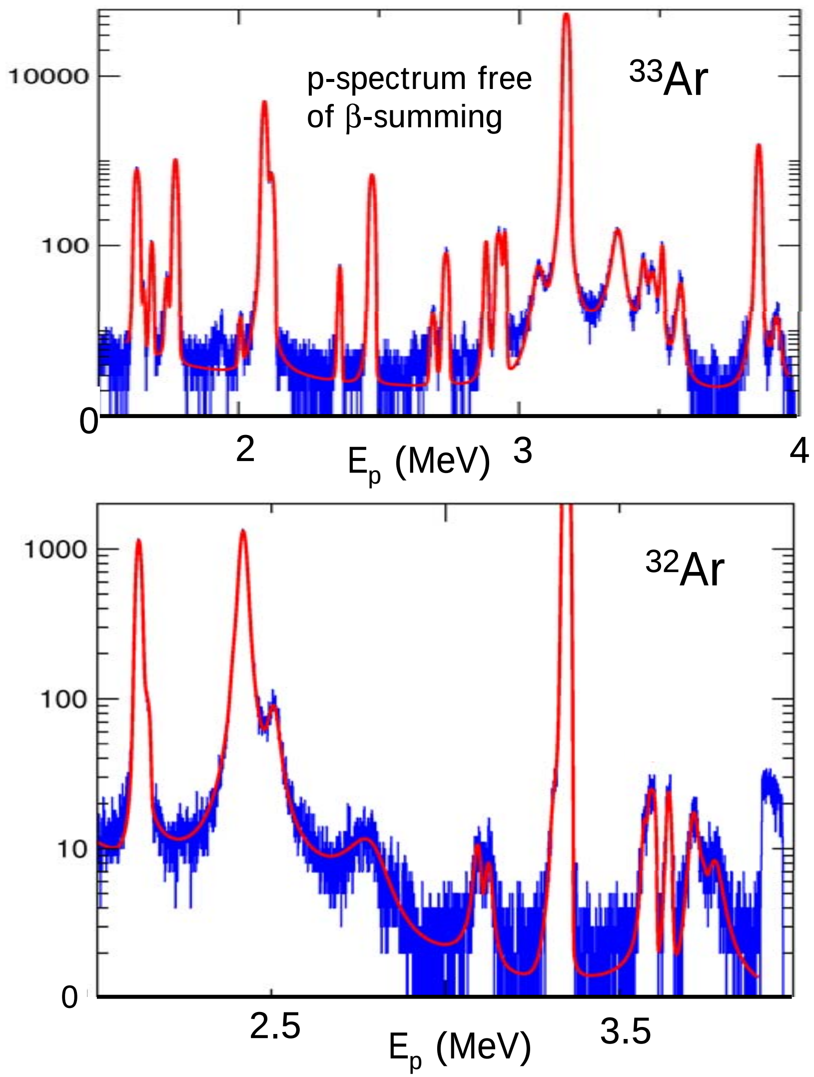
$\delta = ft^{+}/ft^{-} - 1 = -0.55(09)$



Borge et al., PLB317(93)25

Asymmetry ⟷ Halo Structure

Electron-Neutrino Correlations



Study of the proton line shape

- Physics beyond the SM

(see presentation of O. Naviliat-C)

- Isospin mixing in Fermi decays
- Configuration mixing
- Level interferences
- Spin assignment
- Excitation energies

Schardt & Riisager, Z. Phys. A 345 (1993) 265

Adelberger & Garcia, Hyp. Int 129 (2000) 237

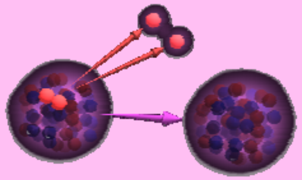
Exotic Radioactivities

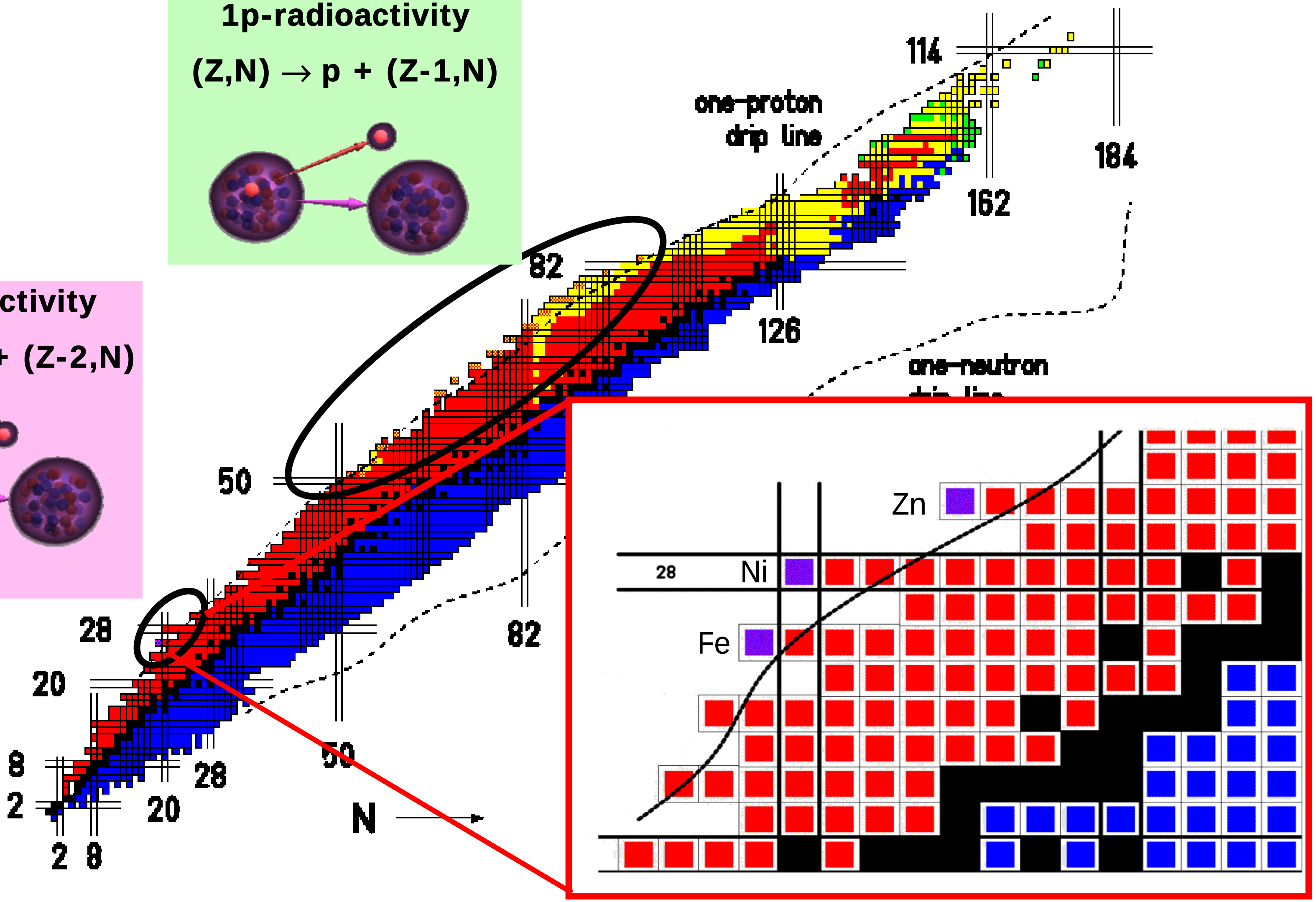
1p-radioactivity

(Z,N) $\rightarrow$ p + (Z-1,N)

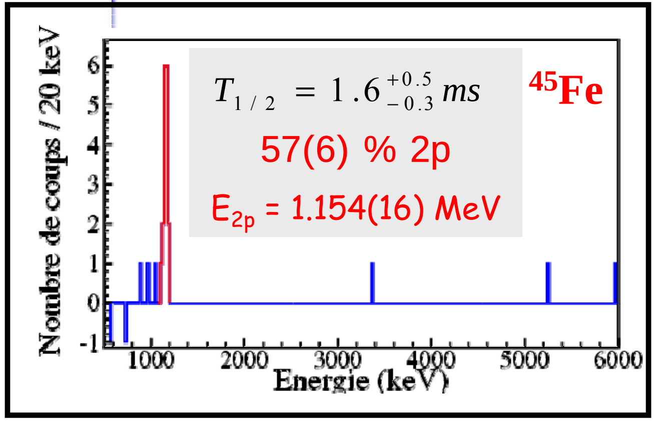
2p-radioactivity

(Z,N) $\rightarrow$ 2p + (Z-2,N)





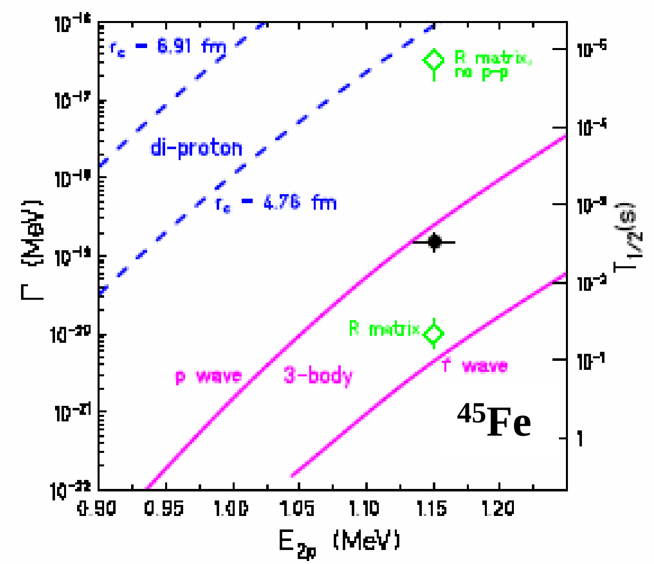
Status of 2p-radiaoctivity



Giovinazzo et al., PRL 89 (2002) 102501

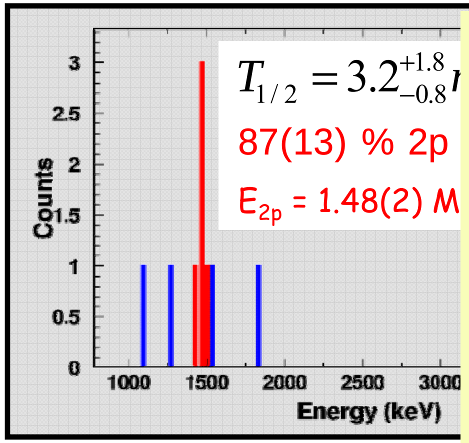
GANIL

Fragmentation reactions ^{58}Ni-beam

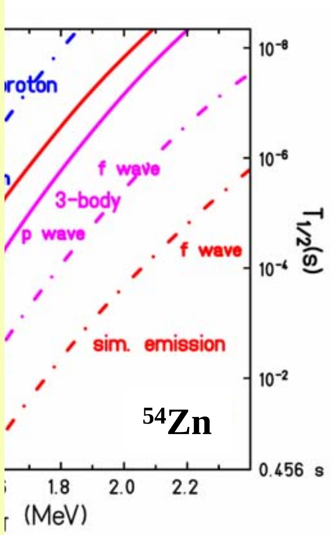


Dossat, PRC, submitted

Agreement with 3-body



Blank et al., PRL 94 (2005)



Next Steps:

- Search for new two-proton emitters

  ^{48}Ni , ^{59}Ge .....

- Detailed study of the decay process

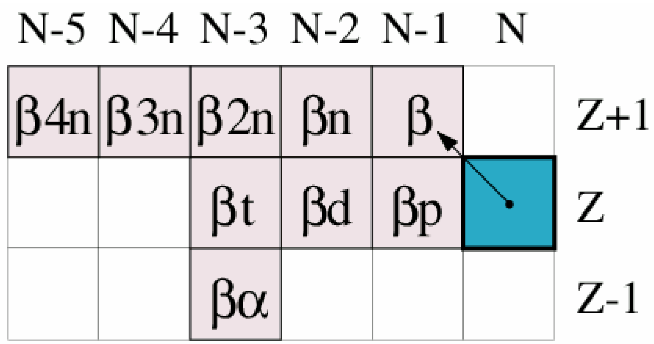
  Measurement of proton-proton correlation:

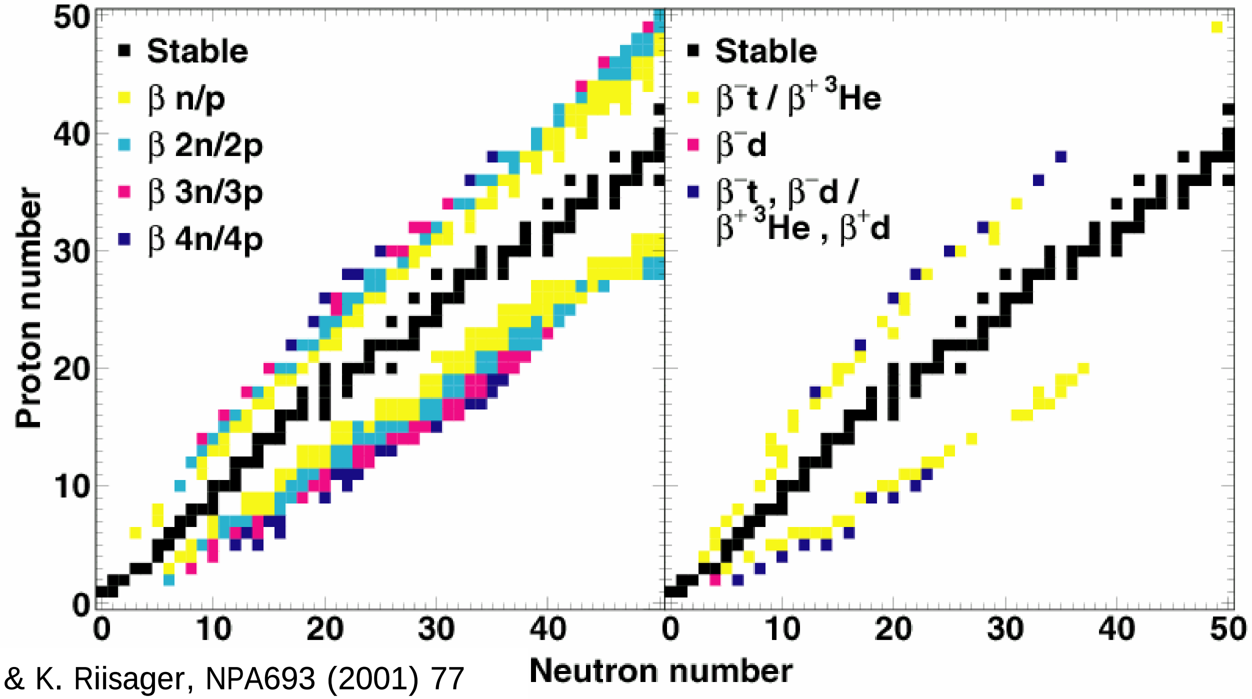
✓ p-p angle

✓ Individual proton energies

✓ Modelling of the 2p resonance

Beta delayed particle emitters

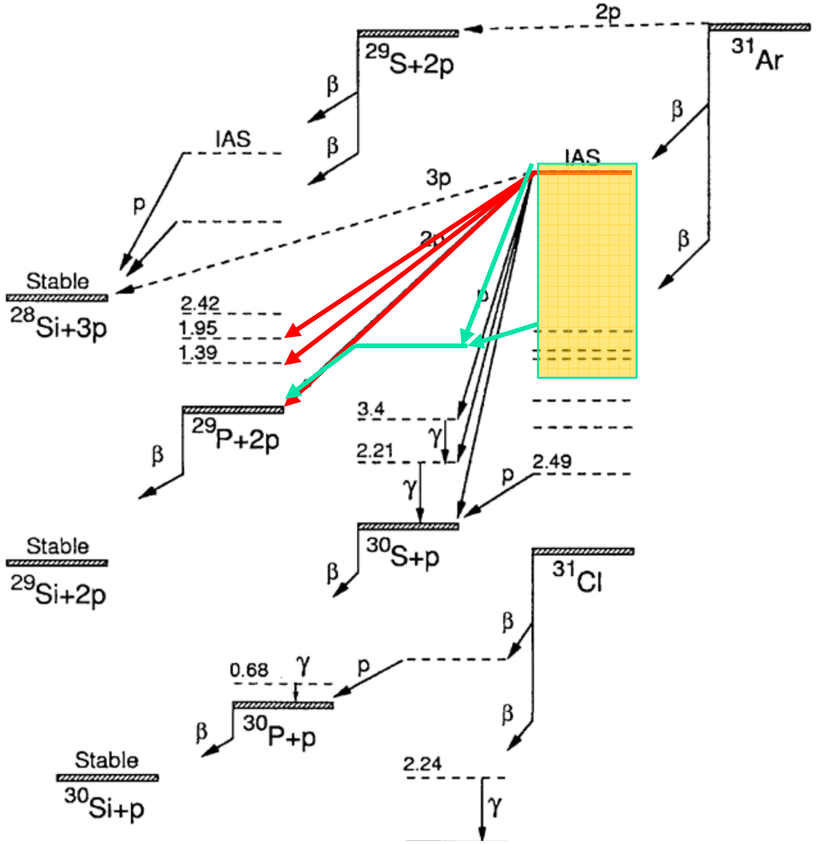




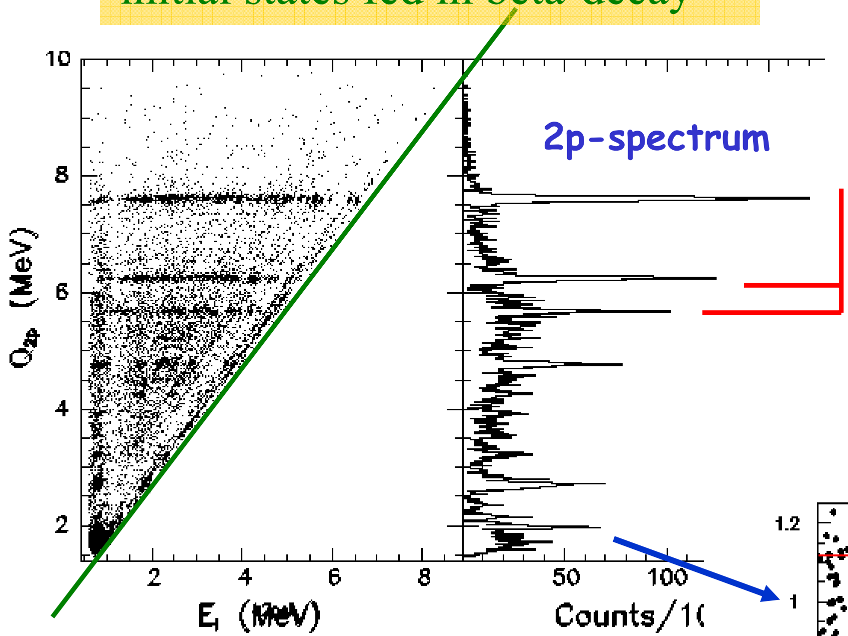
B.Jonson & K. Riisager, NPA693 (2001) 77

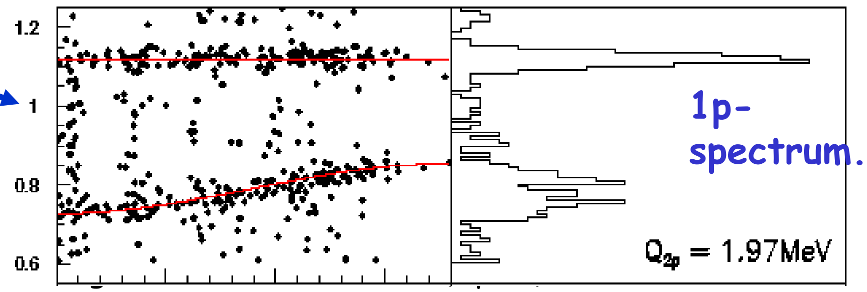
^{31}Ar β-2p emitter

Decay of IAS through
2p emission



Diagonal from decays via single intermediate state from many initial states fed in beta-decay

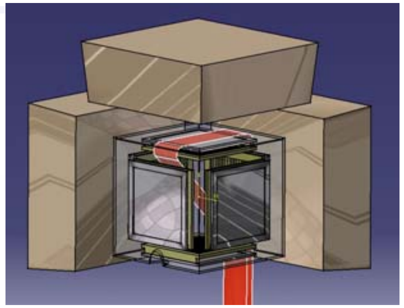




Best candidate for correlated 2p-emission

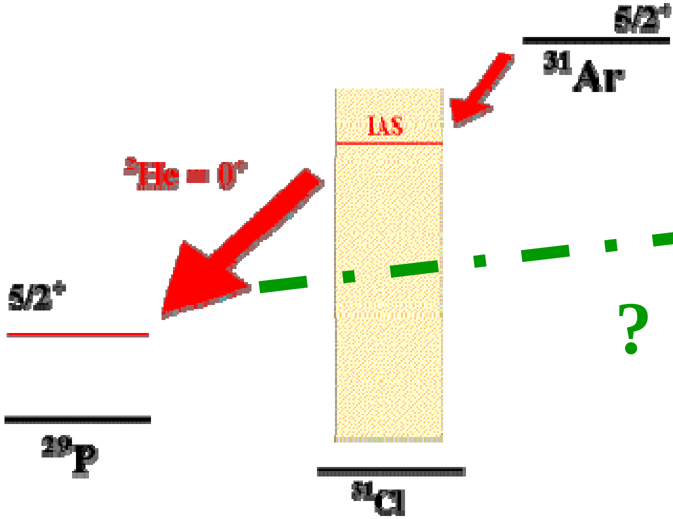
Search at the limit of 0.01% for

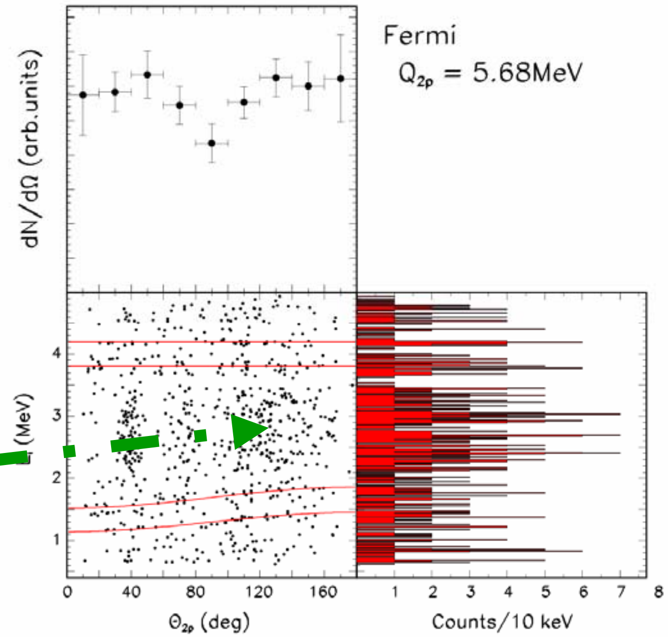
direct β 2p emission and **β3p –emission**



Improvements in comparison to previous ISOLDE experiment:

- ✓Double coincidences a factor of 30 better
- ✓Triple coincidence a factor 70 better
- ✓Energy cut-off down to →100 keV



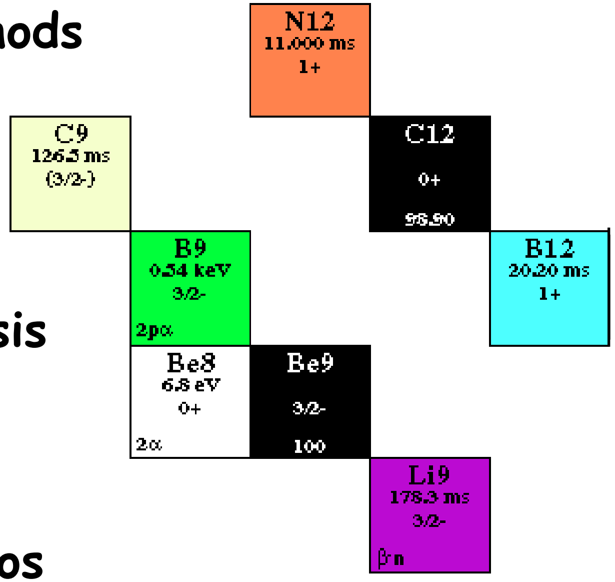


Why to Study Light Nuclei ?

- Exact" A-body calculations possible for A≤12

  Green Funtion Monte-Carlo methods

  Non-core Shell-model



- Crucial for bridging A=5 and A=8 gaps in

  Big Bang and Stellar nuclear synthesis

  The α(αn,γ)9Be + 9Be(α,n)^{12}C

  Competes with triple-α in n-rich scenarios

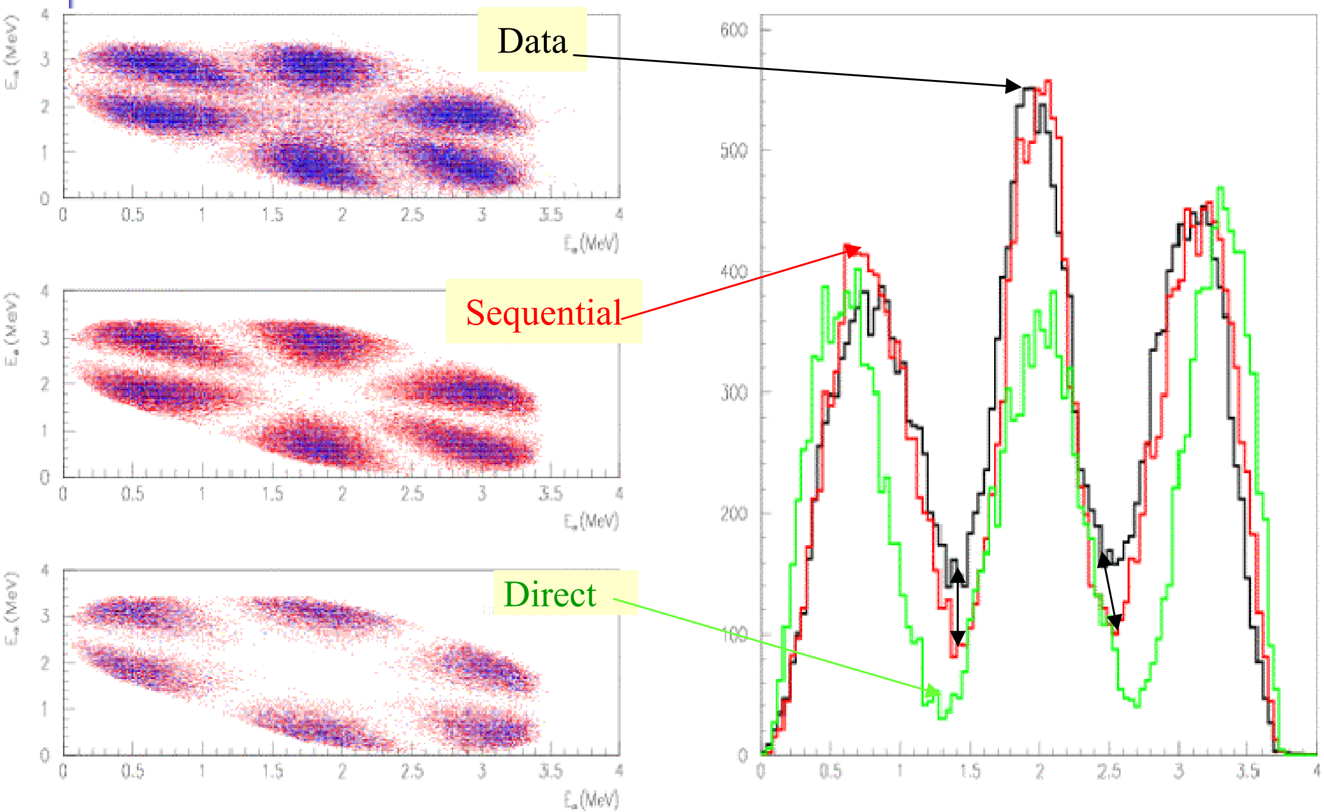
  Importance of the α +n↔^{5}He(α, γ)^{9}Be

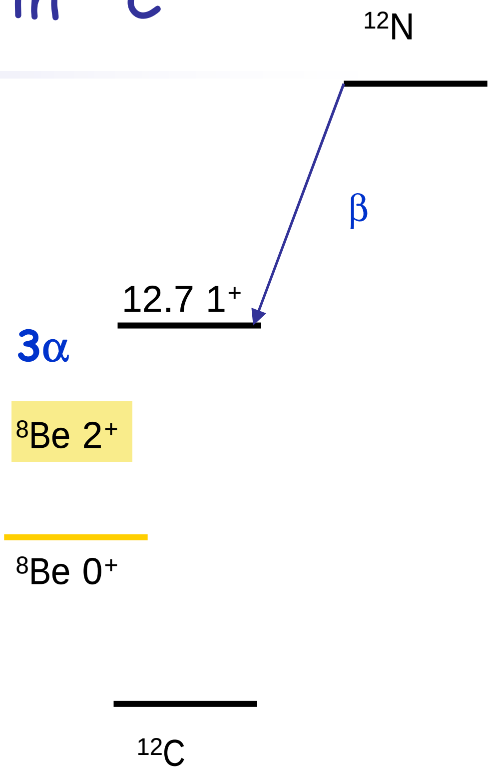
- Experimentally β-decay provides

  Clean way to feed unbound states

  Break-up mechanism not fixed by kinematics

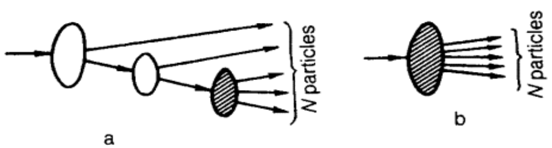
3α break up of the 12.71 MeV state in ^{12}C





Break-up mechanism ?

Sequential or ***Direct***



... mainly sequential

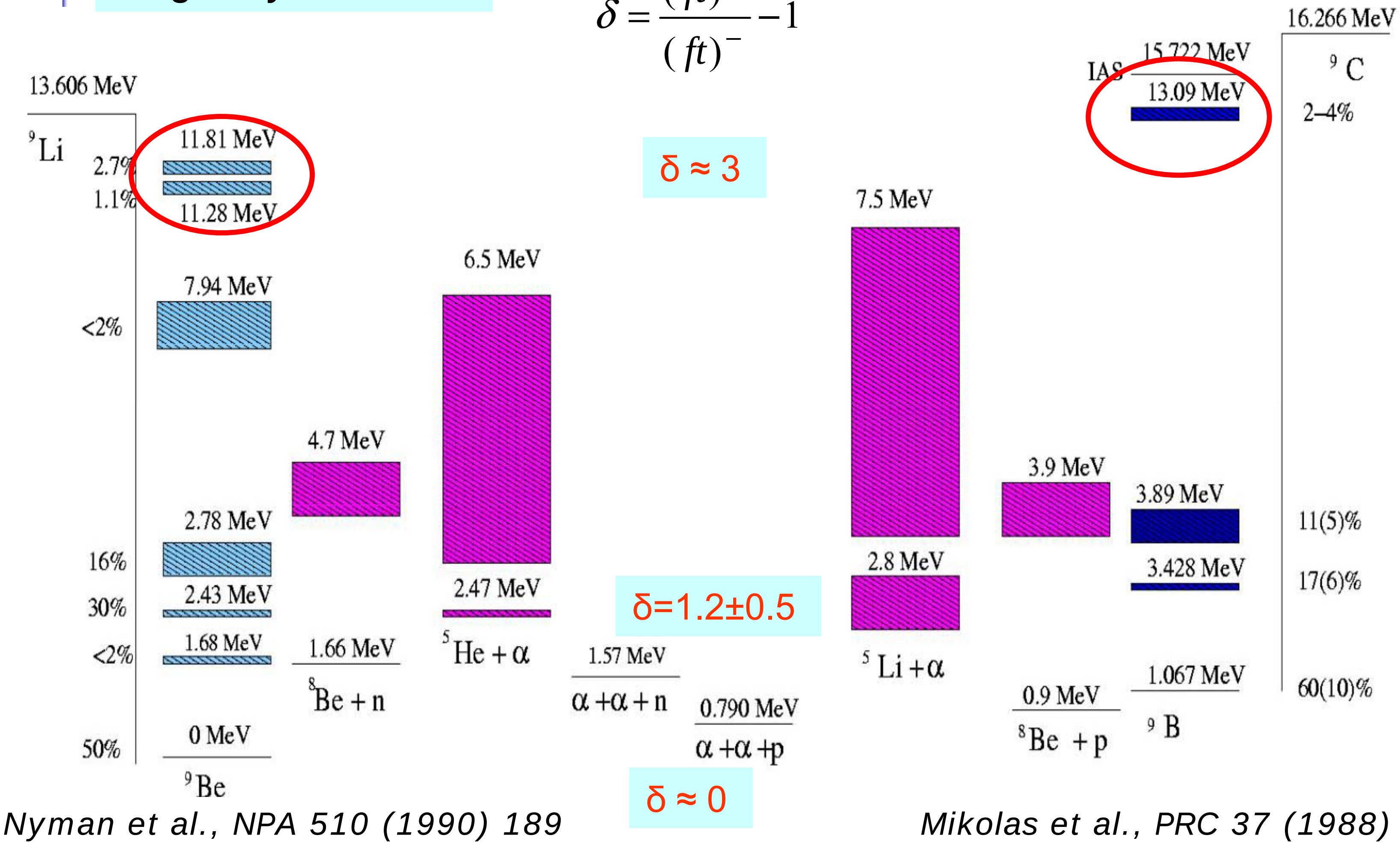
+ Coulomb int. between the 3 α

Fynbo et al, Phys. Rev. Lett. 91(2003) 082502

A = 9 Isobar

Large asymmetries

$$\delta = \frac{(ft)^+}{(ft)^-} - 1$$

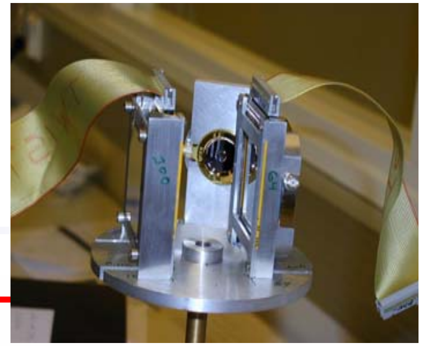


Nyman et al., NPA 510 (1990) 189

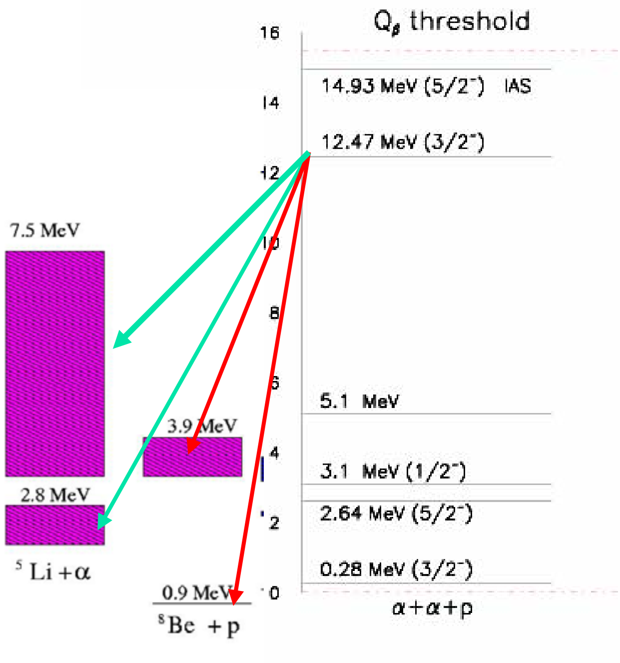
Mikolas et al., PRC 37 (1988) 766

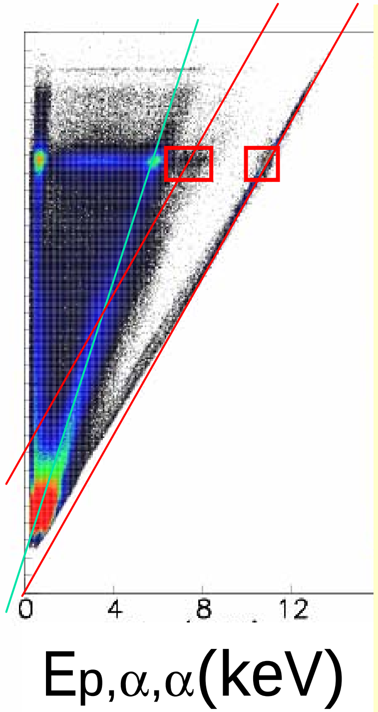
F. Ajzenberg-Selove, NPA 490 (1988) 1

^{9}B States fed in β-decay of ^{9}C



$$E_{sum} = \frac{M_{recoiling} + M_{first}}{M_{recoiling}} E_{first} + x \begin{cases} = 92\ \text{keV}\ (9/8)\ \text{for}\ ^{8}Be(0^{+}) \\ \approx 2\ \text{MeV}\ (9/5)\ \text{for}\ ^{5}Li(3/2^{-}) \\ = 3.0\ \text{MeV}\ (9/8)\ \text{for}\ ^{8}Be(2^{+}) \end{cases}$$





- Sequential Decay of 12.2 MeV State via ^{8}Be(gs), ^{8}Be(2^{+}), ^{5}Li(gs) and ^{5}Li(1/2)
- R-Matrix-formalism applied.
- MC-simulations to account for efficiencies of each channel
- Results E: 12.19(4) MeV

  Γ: 450(20) keV

  J: 5/2

  B_{GT}: 1.20(15)

UC Bergmann, NPA 692 (2001)427

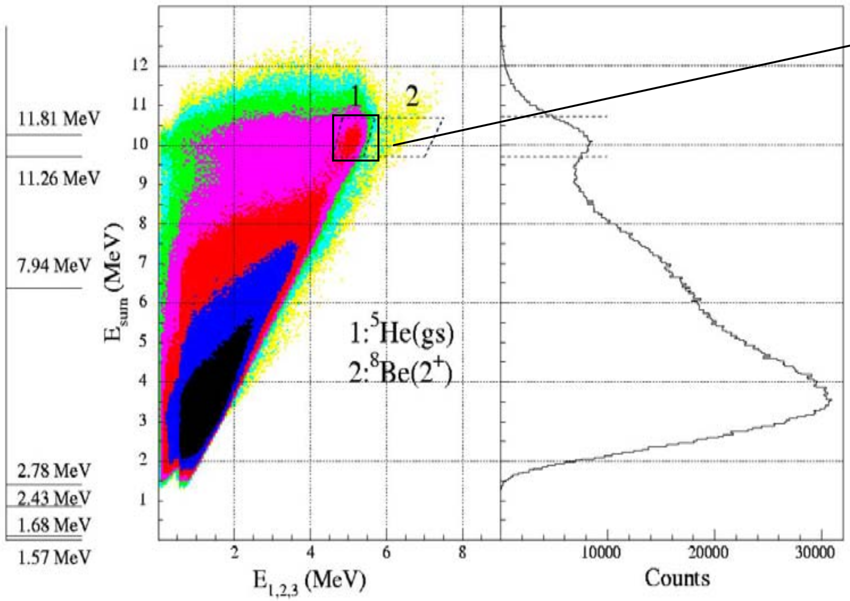
Beta feeding to the 11-12 MeV region in ^{9}Be

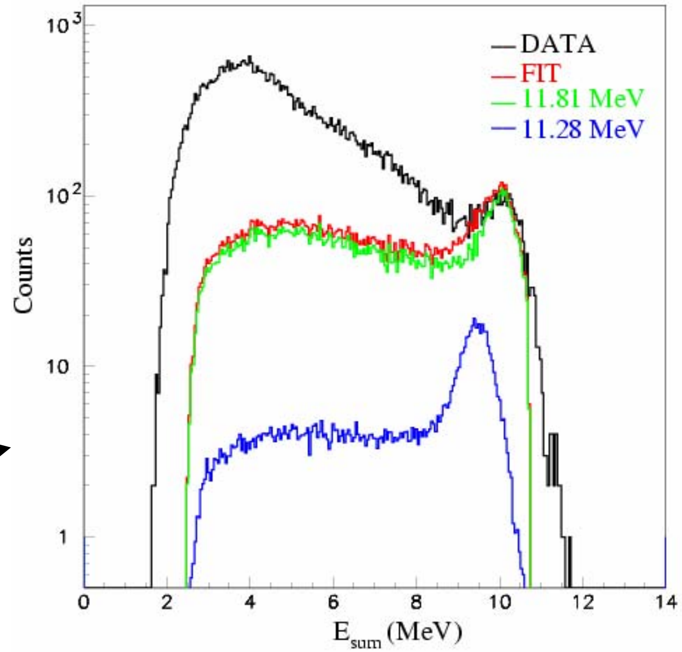
Fit of the high energy peak gating on the $^{5}He(3/2^{-})$ channel

11.81 MeV state → 91±10%

11.28 MeV state → 9 %

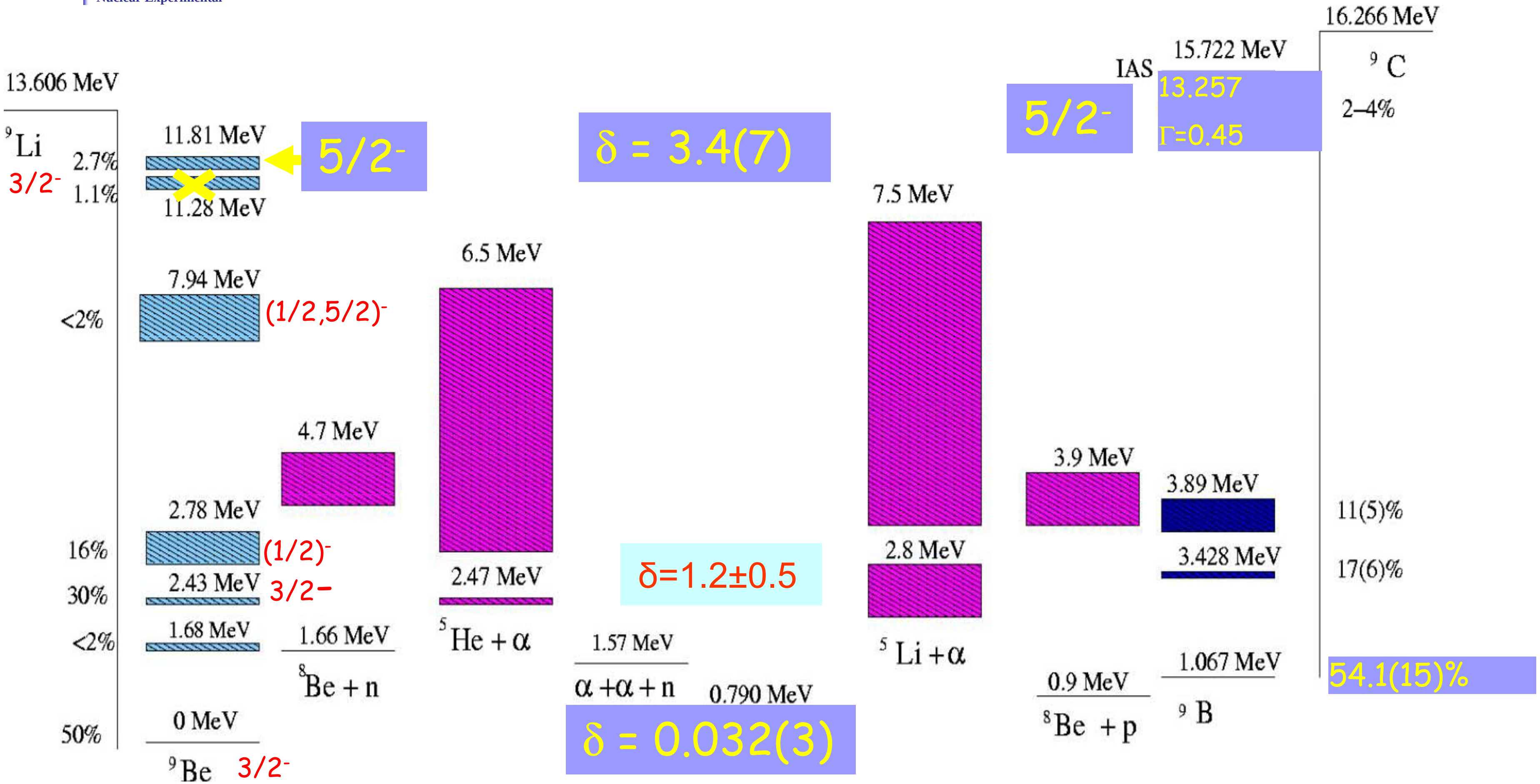
(e,p)-scattering on ^{9}Be assumed J = 7/2





Only the participation of the 11.81 MeV state in ^{9}Be for the beta feeding is considered

A = 9 isobar



Nyman et al., NPA 510 (1990) 189

Mikolas et al., PRC 37 (1988) 766

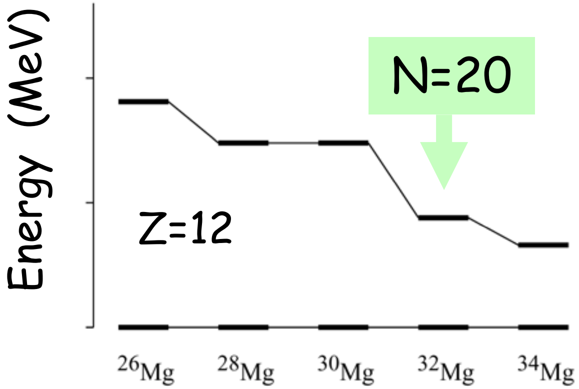
PLB576 (2003)55

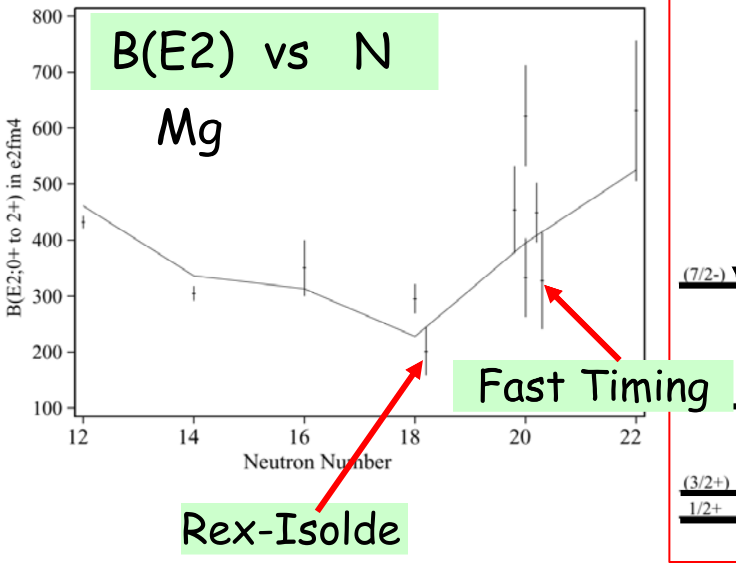
F. Ajzenberg-Selove, NPA 490 (1988) 1

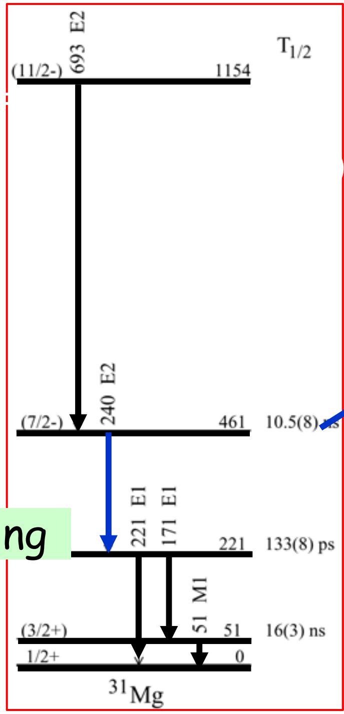
NP A692(2001)427

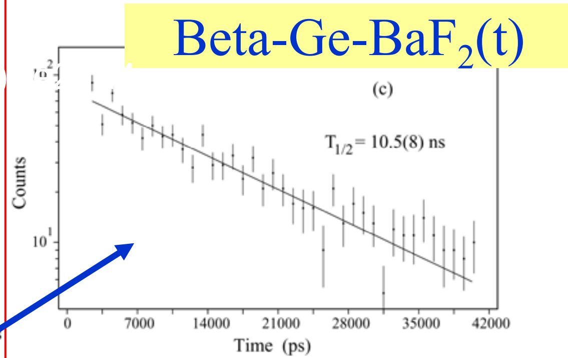
Island of Inversion
Fast timing technique

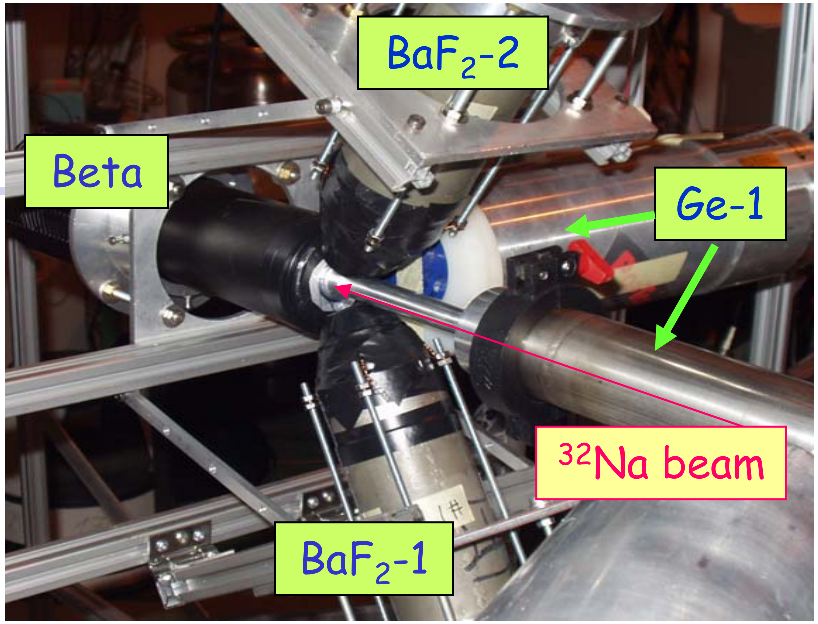
H. Mach, ENAM2004











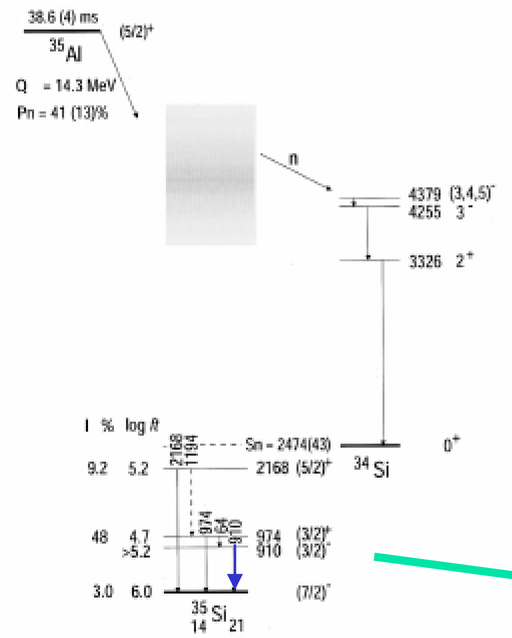
^{31}Mg 1p1h B(E2;7/2$^-$ →3/2$^-$) = 67(6) e^{2}fm^4

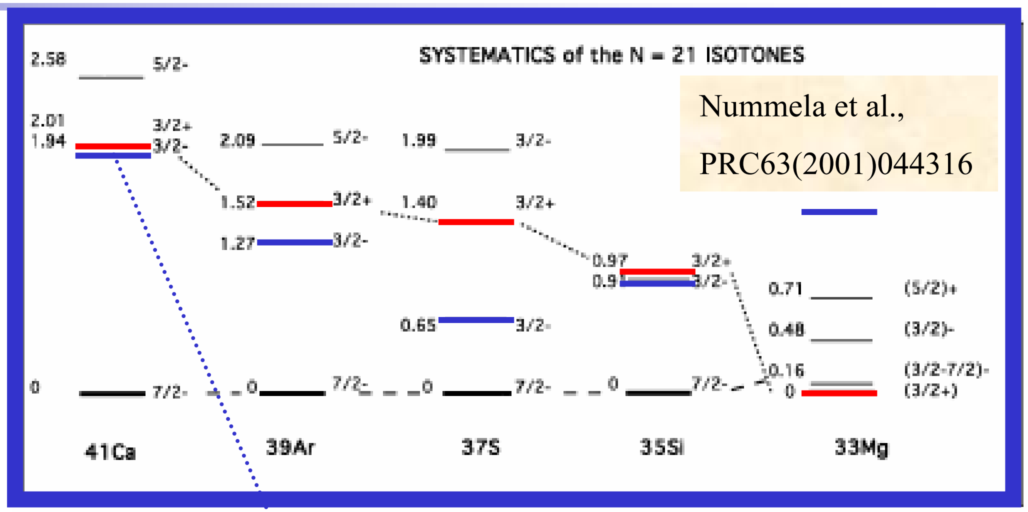
Mach, EPJA25,s01(2005)149

^{30}Mg normal B(E2; 2$^+$ → 0$^+$) = 40(9) e^{2}fm^4

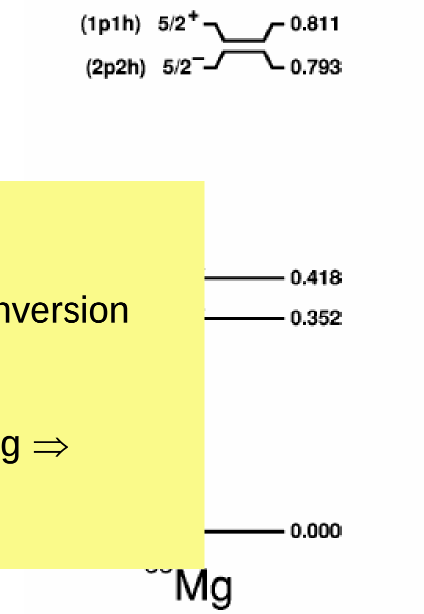
Scheit, PRL 94(2005) 172501

Intruder states & shape coexistence





Position of 3/2- state
in N = 21 isotones

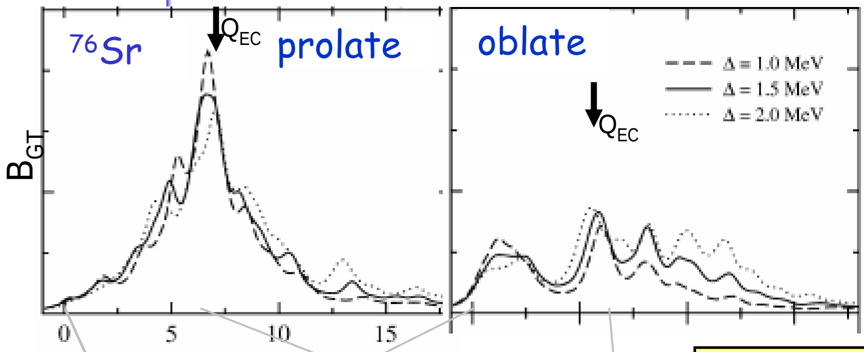


Nummela etal., PRC6

Fix the single p
energy for the
effective *sd-pf*
interaction

- Shell Model describe well by intruder states the Island of Inversion and the deformed region around ^{32}Mg.
- Predicts vulnerability of N= 28 closure for ^{44}S, ^{42}Si and ^{40}Mg ⇒ confirmed for ^{44}S (Sohler, PRC66 (2002) 054302))

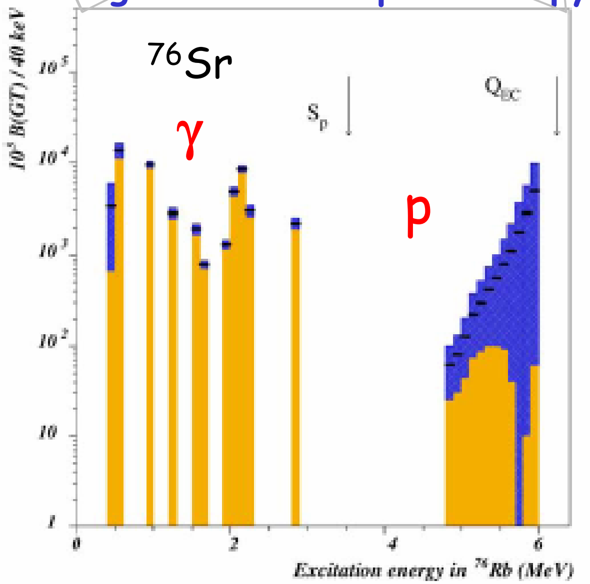
Deformation & Gamow-Teller distribution



Sarriguren NPA 691(2001)631

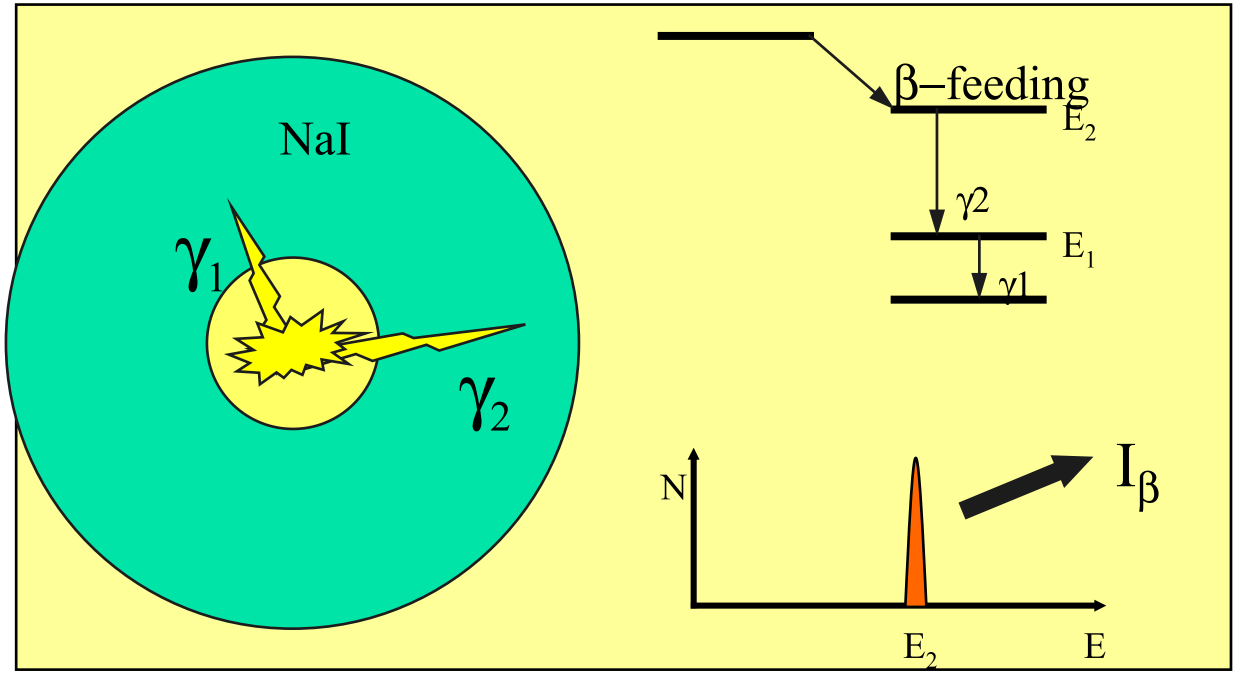
$$\int \frac{I_\beta(E)}{f(Q_\beta - E)T_{1/2}} \Delta E = \frac{1}{6147 \pm 7} \left(\frac{g_A}{g_V}\right)^2 \sum_{Ef<Q\beta} B(GT)_{i \to f}$$

High resolution spectroscopy



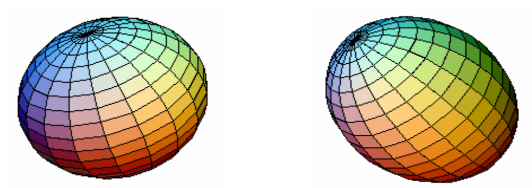
Dessagne EJPA20 (2004) 405

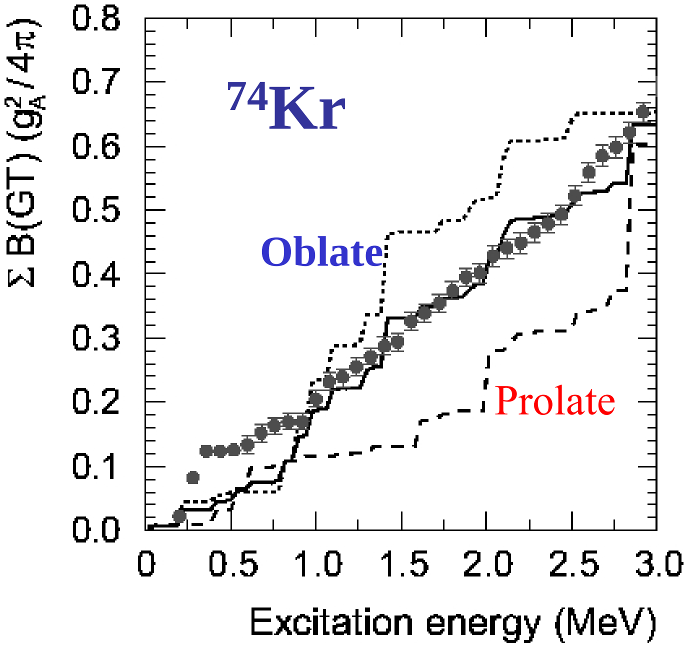
Total Absorption spectrometry



Mass ~70 : Strong Deformation & Shape Coexistence

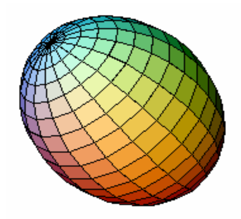
^{74}Kr, shape admixture

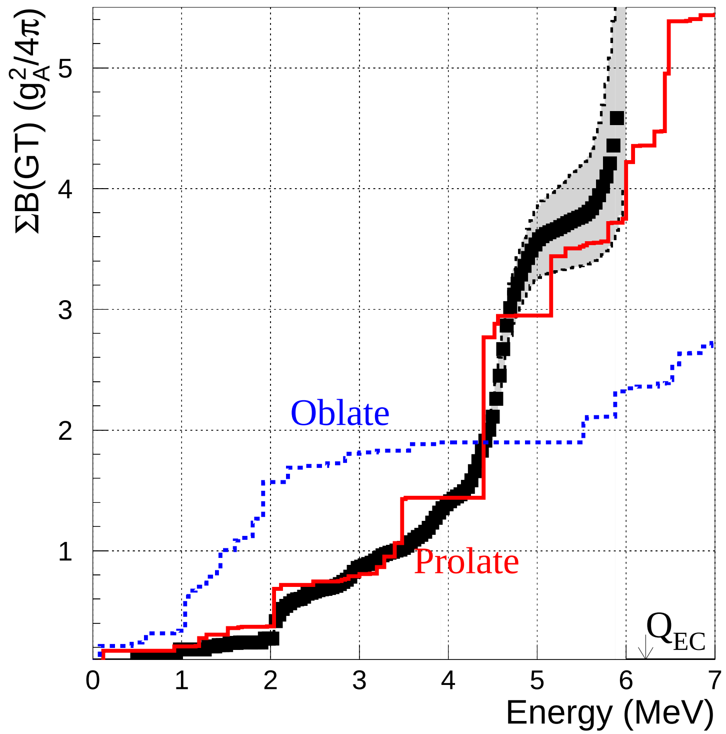




Poirier et al., PRC 69 (2004) 034307

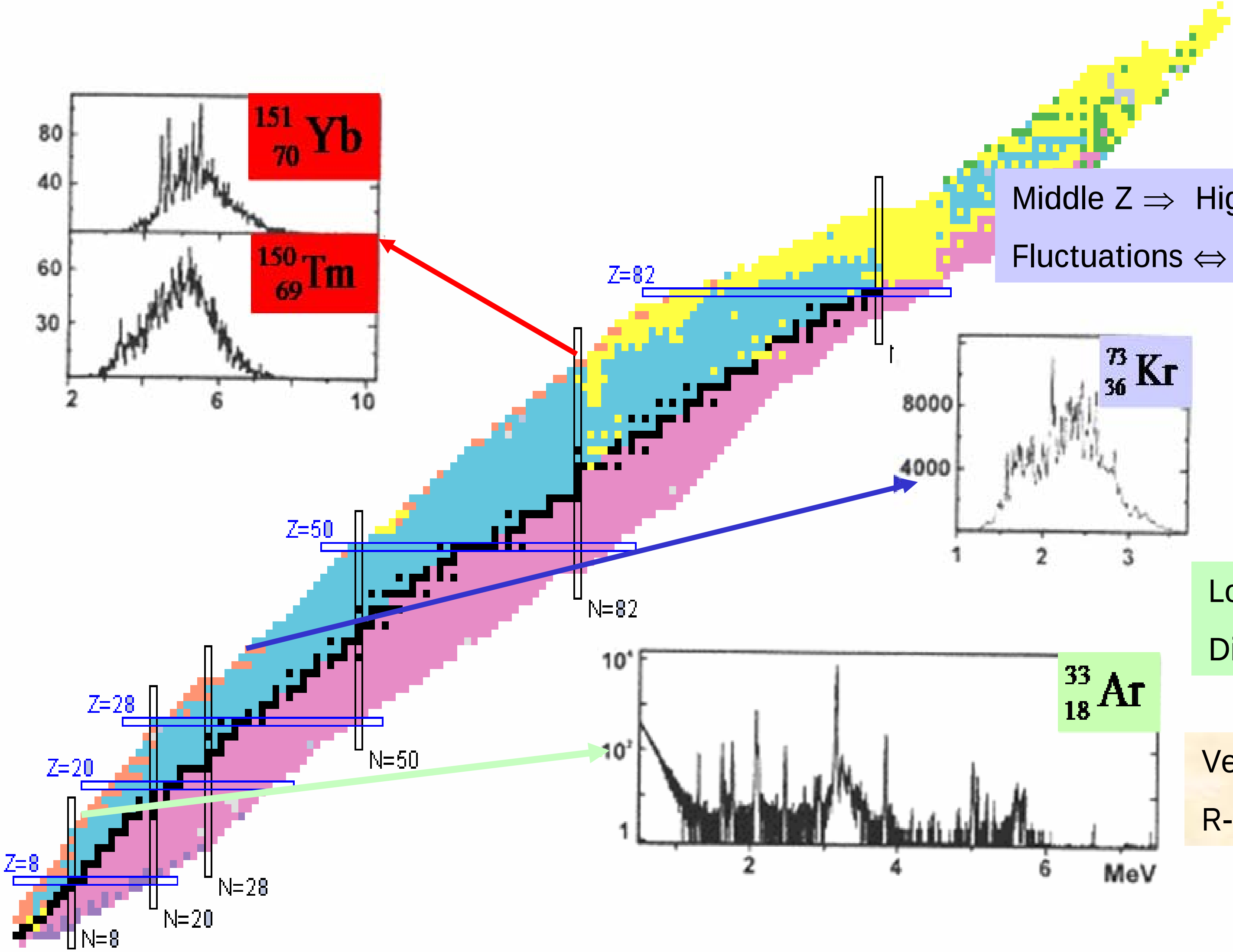
^{76}Sr clearly prolate





Nácher et al., PRL 92 (2004) 232501

Transition from order to Chaos



Middle Z ⇒ High Density Narrow States

Fluctuations ⇔ Porter Thomas Distribution

Low Z ⇒ Narrow States

Direct structure information

Very low Z ⇒ Broad States

R-Matrix description: E, Γ

Summary

- Decay mechanism: ^{2}H, ^{2}He, 3p, halo-core
- Exotics decays
- Asymmetries: ^{9}C, ^{9}Li Unknown
  ^{17}Ne, ^{17}N halo structure
- Shapes, island of inversion
- Sign of deformation from GT-distribution
- Level densities → Fluctuations → Chaos
  ↓
  Relevant for astrophysics

Outlook

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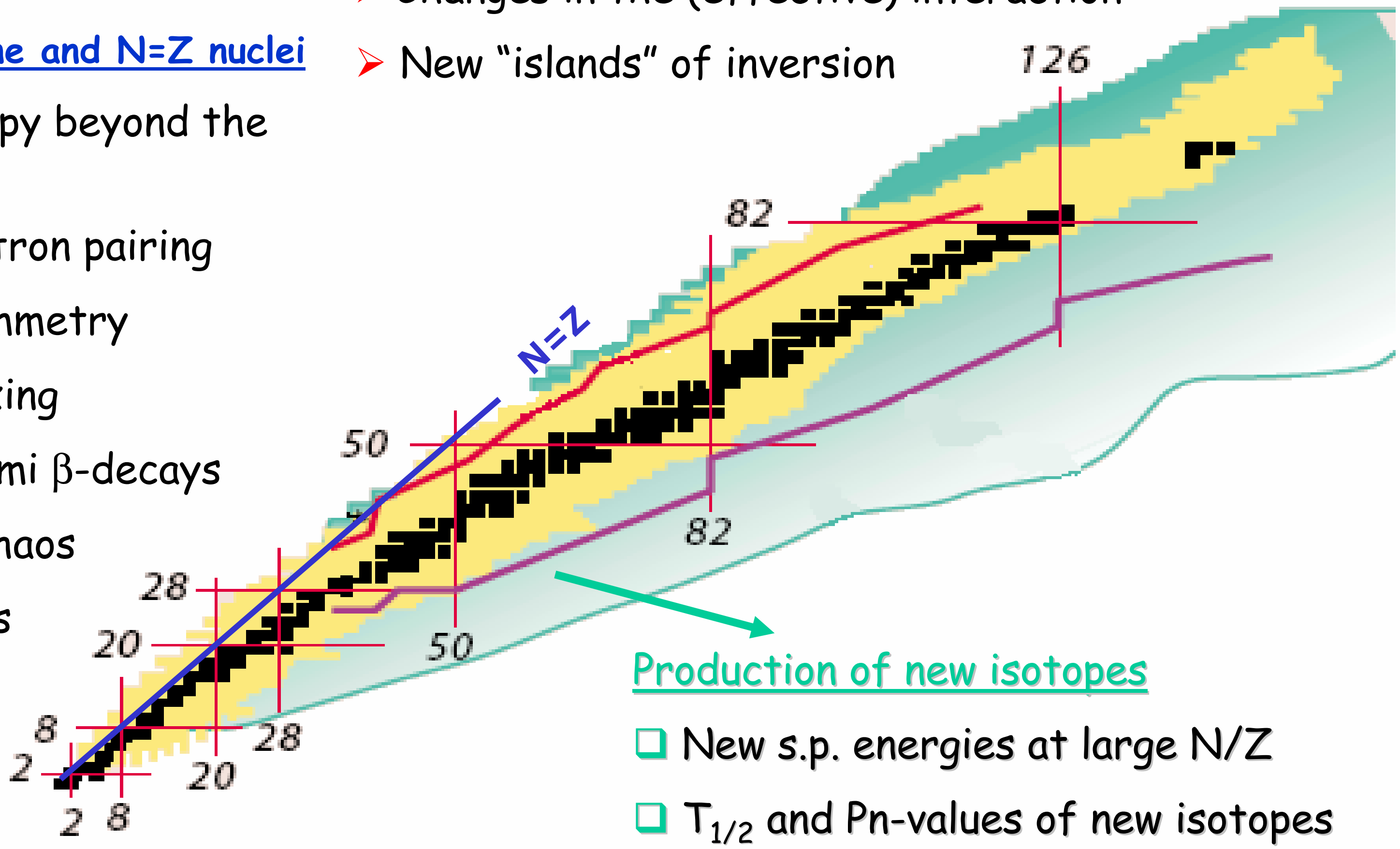
Shell structure @ drip lines

- Changes in the (effective) interaction
- New "islands" of inversion

Proton drip line and N=Z nuclei

- Spectroscopy beyond the drip line
- Proton-neutron pairing
- Isospin Symmetry
- Isospin Mixing
- GT and Fermi β-decays
- Order to chaos
- Γ_p / Γ_γ ratios



Production of new isotopes

- New s.p. energies at large N/Z
- $T_{1/2}$ and Pn-values of new isotopes

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October 1492

Many Thanks to all colleagues that generously send me some recent talks or papers

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Karsten Riisager

Berta Rubio

Jean C. Thomas

Piet Van Duppen.....

Thanks for your Attention!!

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Nuclear Experimental