# Cluster radioactivity studies at S3

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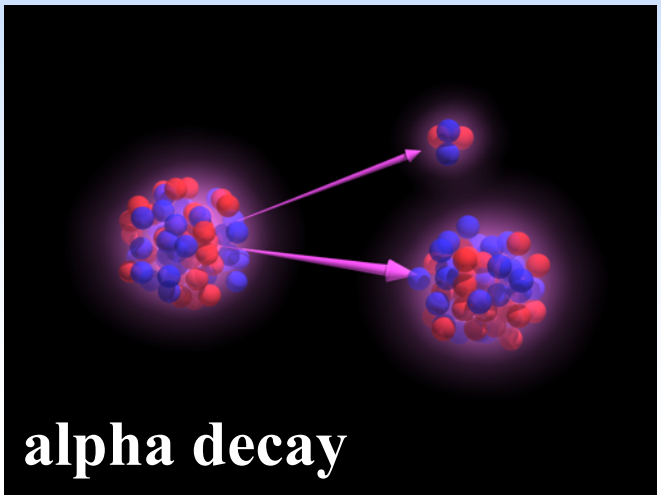
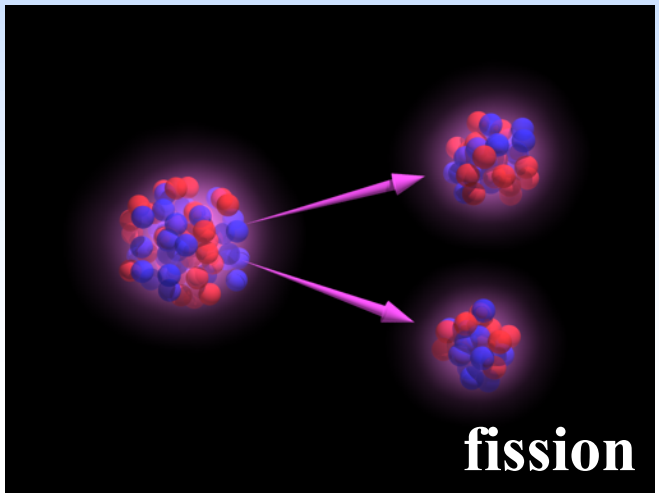
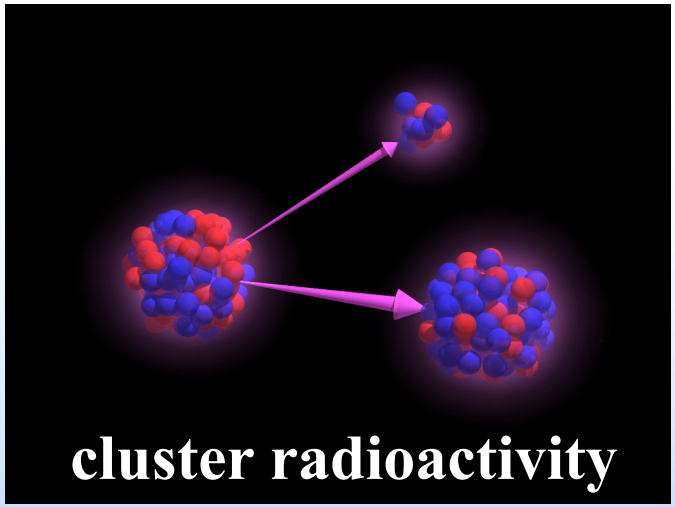
- **Physics case**
- **Predictions**
- **Rates**

**First physics with S3, IRFU Saclay, 27-30 March 2017**

# Cluster emission ..... 1984




**emitted clusters:**
$^{14}$C, $^{20}$O, $^{23}$F,
$^{22,24,25,26}$Ne,
$^{28,29,30}$Mg,
$^{32,34}$Si

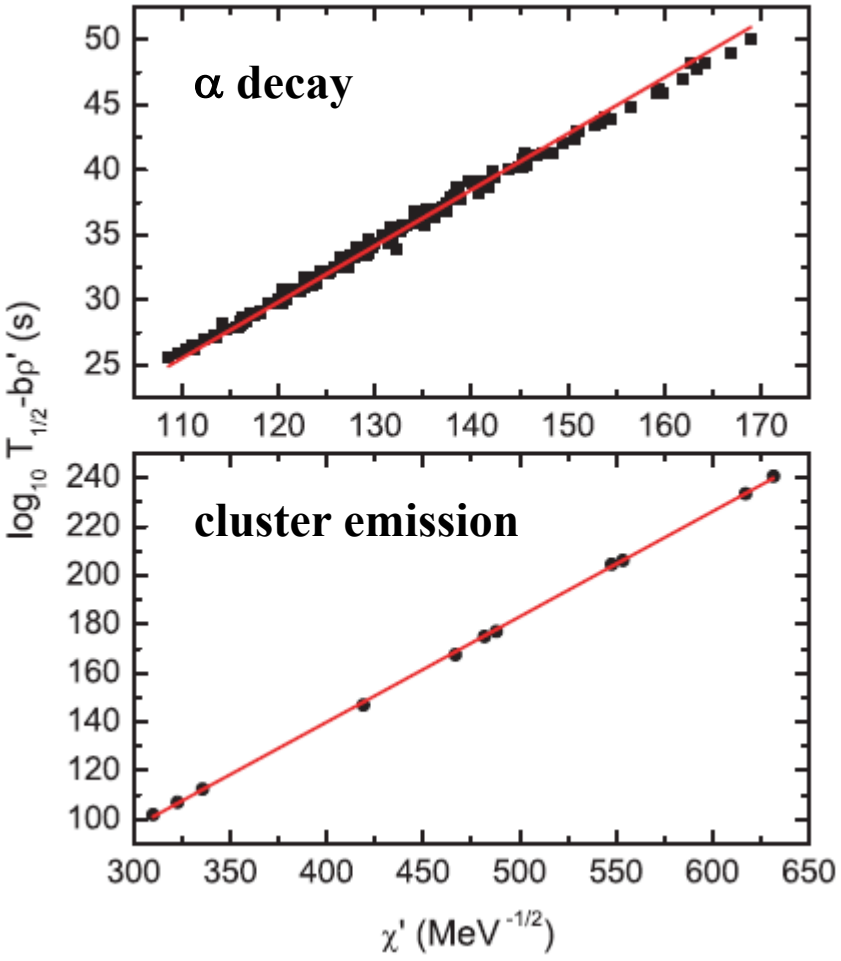
**cluster emitters:**
$^{221}$Fr …. $^{242}$Cm

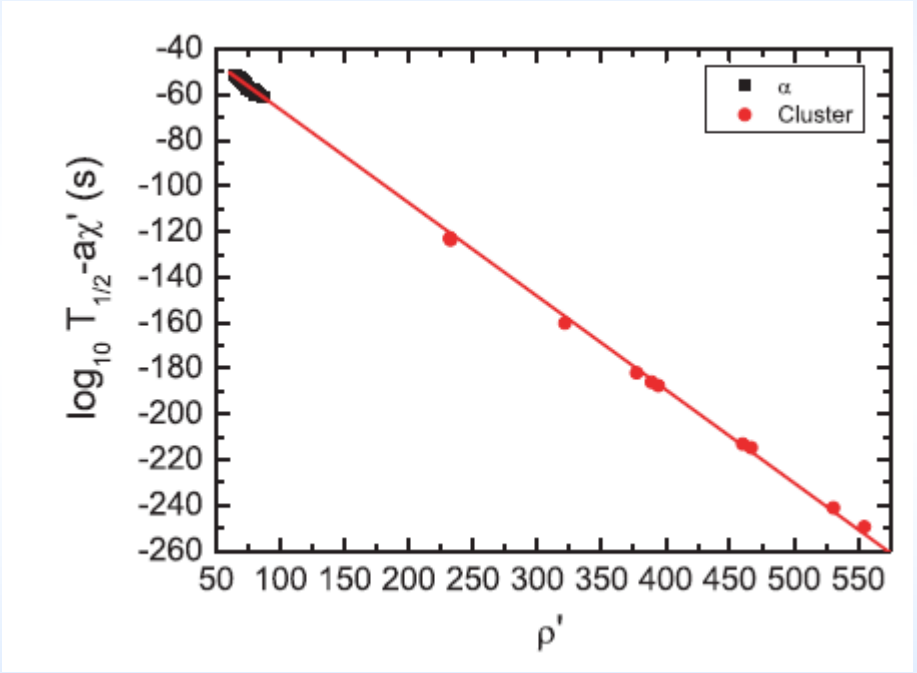
**daughter nuclei:**
$^{208}$Pb region
➔ large binding

**Physics:**
- first!
- cluster pre-formation
- super-allowed α decay

- A. Sandulescu, D.N. Poenaru, and W. Greiner, 1980
- H.J. Rose and G.A. Jones,1984

# Prediction of half-lives




Qi et al., PRC 80, 044326 (2009)

# New island of cluster emission: above Sn-100

- best candidates: $^{12}C$ emission from $^{114}Ba$ and $^{112}Ba$

| Emitter | Cluster | $Q_\alpha$ (MeV) | $T_{1/2}(\alpha)$ (s) | $Q_{12C}$ (MeV) | $T_{1/2}(^{12}C)$ (s) | $T_{1/2}(\beta)$ (s) |
|---|---|---|---|---|---|---|
| $^{112}Ba$ | $^{12}C$ | 4.65 | 0.01 | 21.37 | 335 | 0.04 |
| $^{114}Ba$ | $^{12}C$ | 3.53 | 725 | 18.98 | $10^7$ | 0.43 |
| $^{114}Ba$(exp) | $^{12}C$ | 3.60(3) | 44 | 19.02(3) | | $0.395^{+0.160}_{-0.089}$ |

case of $^{114}Ba$: $10^7 / 0.43 = 2.3 * 10^7$ events

case of $^{112}Ba$: $335 / 0.01 = 3.4 * 10^4$ events

Qi et al., PRC 80, 044326 (2009)

# S3 experiment rates: α decay

**$^{114}$Ba: α decay**

- **$^{58}$Ni beam: 248 MeV, 2.2 pμA, target: $^{58}$Ni 1mg/cm2**
- **cross section: 0.2 μb (exp.: $0.2^{+0.13}_{-0.09}$ μb, 0.15(9) μb)**
- **transmission: 0.5**

**➔ 15 pps**

- **$BR(\alpha)_{predicted} = 6*10^{-4}$ ➔ 0.5 α decays per min**
- **$BR(\alpha)_{experiment} = 9*10^{-3}$ ➔ 8 α decays per min**

**$^{112}$Ba: α decay**

**$^{58}$Ni beam: 280 MeV, 2.2 pμA, target: $^{58}$Ni 1mg/cm2**

- **cross section: ~ 0.1 nb**
- **transmission: 0.5**

**➔ 0.01 pps**

- **BR(α) = 0.8 ➔ 0.5 α decays per min**

# S3 experiment rates: $^{12}C$ cluster decay

**$^{114}Ba$:**

- **$^{58}Ni$ beam: 248 MeV, 2.2 pμA, target: $^{58}Ni$ 1mg/cm2**
- **cross section: 0.2 μb**
- **transmission: 0.5**

**➔ 15 pps**

- **BR($^{12}C$) = $4*10^{-8}$ ➔ 1 $^{12}C$ decay in 20 days**

**$^{112}Ba$:**

**$^{58}Ni$ beam: 280 MeV, 2.2 pμA, target: $^{58}Ni$ 1mg/cm2**

- **cross section: ~ 0.1 nb**
- **transmission: 0.5**

**➔0.01 pps**

- **BR($^{12}C$) = $2*10^{-5}$ ➔ 1 $^{12}C$ decay in 60 days**

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**$^{58}Ni$ beam: 280 MeV, 11 pμA, target: $^{58}Ni$ 1mg/cm2**

**$^{114}Ba$: ➔ 1 $^{12}C$ decay in 4 days**

**$^{112}Ba$: ➔ 1 $^{12}C$ decay in 15 days**

# Possible experiments

**First experiments with S3 focal plane detectors:**

- **$^{114}$Ba:**
  - **confirm results from GSI and JYFL**
    - **identify α – α – α decay chain**
    - **improve precision on half-life and BR**
    - **search for cluster decay?**
      - **➔ Only with higher primary beam intensity…**

- **$^{112}$Ba:**
  - **search for α – α – α decay chain**
  - **determination of Q value for $^{12}$C emission**
  - **new determination of cluster BR**

**➔ ➔ following experiments depend on results**

**➔ ➔ development of dedicated setup?**

**➔ TPC?**

# Conclusions

- $^{114}$Ba:
  - improve existing results
  - search for $^{12}$C decay maybe with higher intensity

- $^{112}$Ba:
  - search for $\alpha - \alpha - \alpha$ decay chain
  - search for cluster radioactivity depends on $Q_{12C}$

Thank you
for
your attention

# New island of cluster emission: above Sn-100

- best candidates: $^{12}C$ emission from $^{114}Ba$ and $^{112}Ba$

| Emitter | Cluster | $Q_\alpha$ (MeV) | $T_{1/2}(\alpha)$ (s) | $Q_{12C}$ (MeV) | $T_{1/2}(^{12}C)$ (s) | $T_{1/2}(\beta)$ (s) | $Q_{2p}$ (MeV) | $T_{1/2}(2p)$ (s) |
|---|---|---|---|---|---|---|---|---|
| $^{110}Xe$ | $^{12}C$ | 3.89 | 0.164 | 15.73 | $10^{13}$ | 0.2 | | |
| $^{112}Xe$ | $^{12}C$ | 3.33 | 300 | 14.28 | $10^{17}$ | 2.7 | | |
| $^{112}Ba$ | $^{12}C$ | 4.65 | 0.01 | 21.37 | 335 | 0.04 | 1.912 | $10^{6}$ |
| $^{114}Ba$ | $^{12}C$ | 3.53 | 725 | 18.98 | $10^{7}$ | 0.43 | | |

Qi et al., PRC 80, 044326 (2009)