Measurement of γ Strength Function and Level Density of ^{138}La at OCL

Oslo Cyclotron Laboratory

Vincent Kheswa
PhD Student

iThemba LABS, Somerset West, South Africa

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Outline

» Introduction

» Experimental Setup

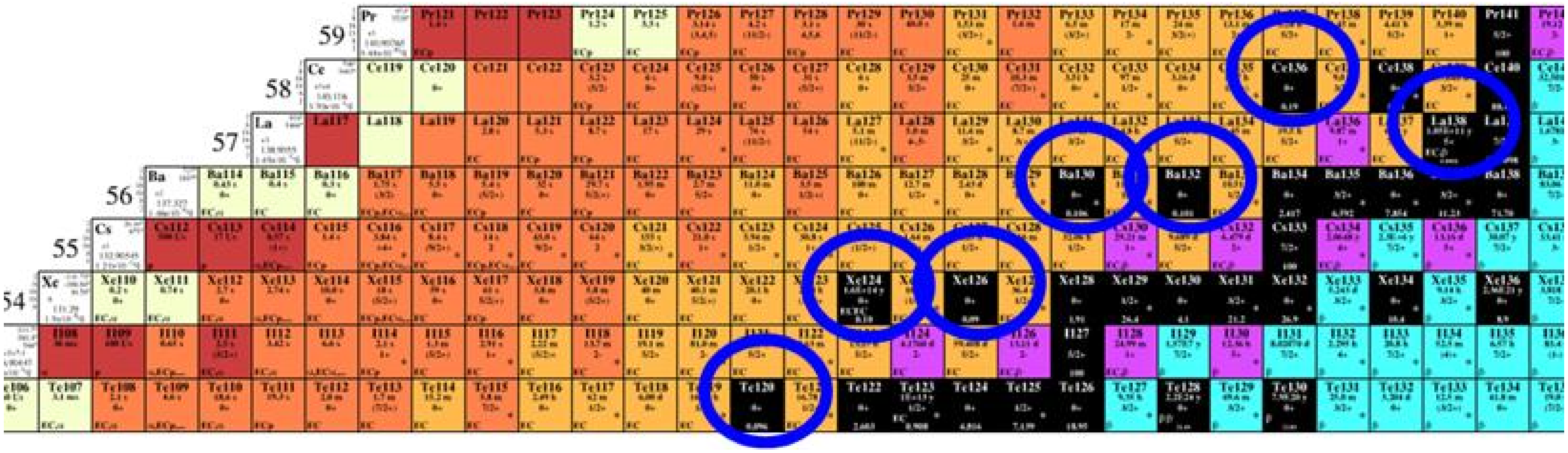
» Preliminary results

» Final Remarks

Introduction

The p-nuclei

- Most nuclei heavier than ^{56}Fe are synthesized in stars by s- and r- processes
- However, 35 p-nuclei, including ^{138}La , are shielded from s- and r- processes by the valley of stability

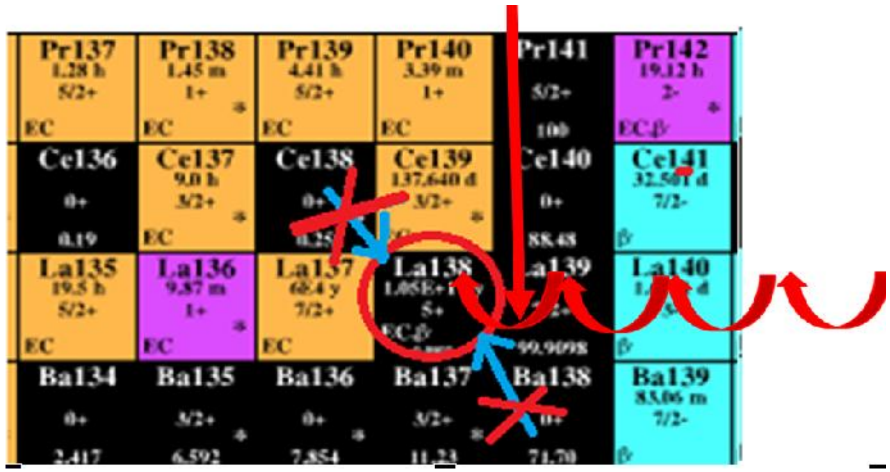


- Hence there exist different mechanisms responsible for synthesis of these nuclei
  - The (p, γ) reaction and / or photo-disintegration
- Very high temperatures and proton density required in this scenario
- Due to high coulomb barrier of heavy nuclei, (p, γ) is negligible for nuclei with Z ≥ 54
- By nature rp terminates at Tellurium due to α-decay
- Photo-disintegration remains the main source for the heavier p-nuclei
  - producing very proton rich nuclei via (γ,n), (γ,α) and (γ,p) reactions

T. Rauscher, Proceedings of Science, 059 (2010),
S.E. Woosley et al., Ap. J. 356, 272 (1990).

Introduction

^{138}La is a special case



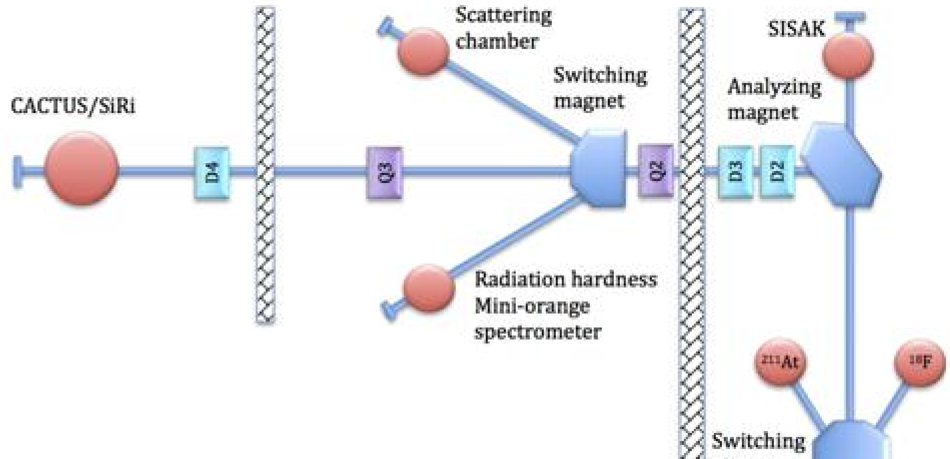
- Photo-disintegration cannot satisfactorily explain the observed abundance of ^{138}La
- More exotic reactions e.g ^{139}La(ν, n)^{138}La or ^{138}Ba + νe -->^{138}La must be considered
- Neutrino induced reactions can explain the observed abundance of ^{138}La
- However (γ, n) processes cannot be ruled out due to high errors in their rate predictions, which are due to limited knowledge and uncertainties in nuclear level densities, γ-ray strength function and neutron optical potentials which are critical input parameters for rates calculation

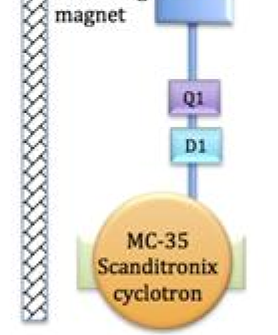
→ **Hence we measured the** nuclear level densities and γ-ray strength function **using the Oslo Method**

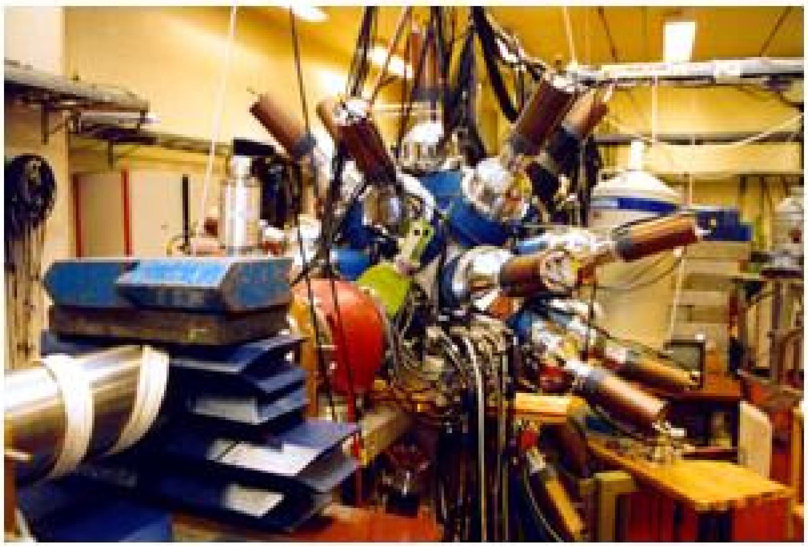
S. Goriely et al., A&A 375, 35 (2001).

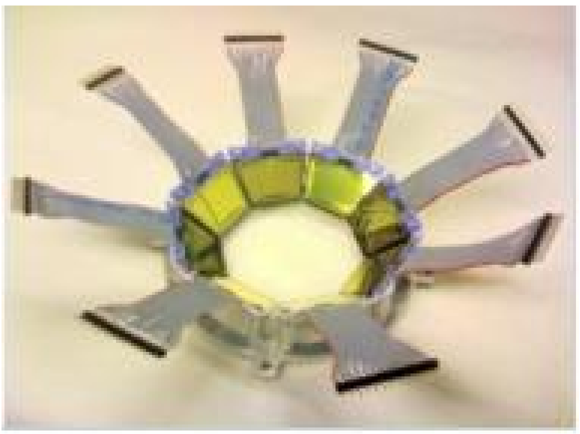
Experimental Setup

- Beam time: first half of February 2013
- ^{3}He beam at 38 MeV
- ^{139}La(^{3}He,^{4}He)^{138}La









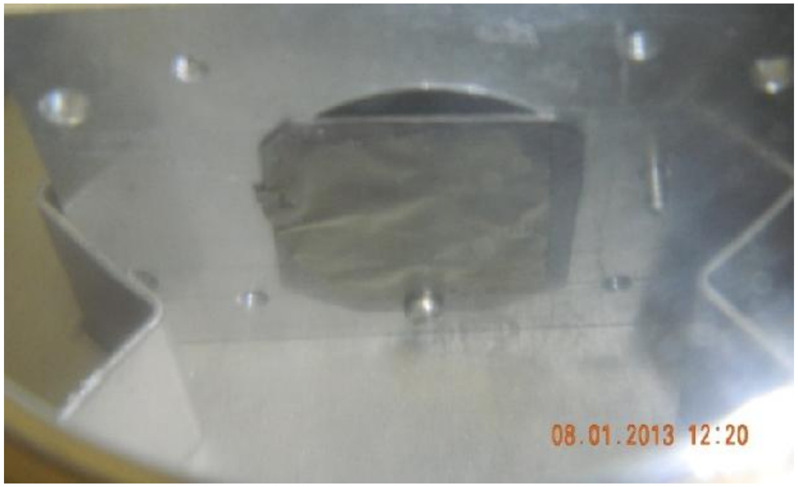
- CACTUS array, 26 NaI γ-ray detectors

- SiRi array, 64 Si telescope detectors (particle identification)
- At 40 – 54º with respect to the beam

Experimental Setup

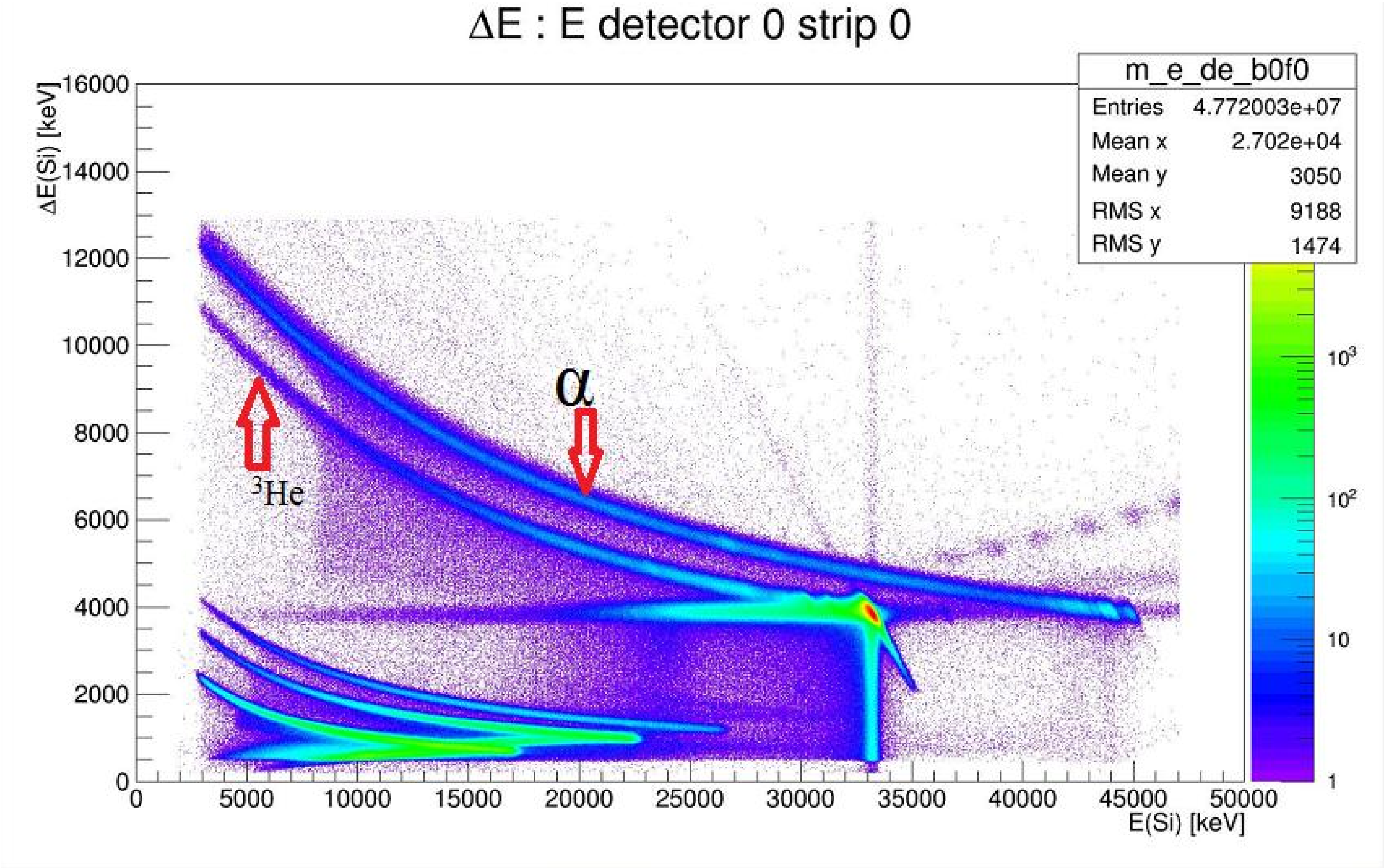
La target and experimental challenges

- 2.5 mg/cm^2 ^{Nat}La (99.9% 139La) targets provided by iTL. (N.Y. Kheswa): 5 samples shipped to Oslo (only 3 survived)
- Elemental La oxidizes easily!
- First transportation in a vacuum-tight container (2 samples) was unsuccessful
- The foil used during the measurement was instead transported in Argon and silica gel (which absorbs moisture)
- The scattering chamber was filled with Argon during the target mounting operation

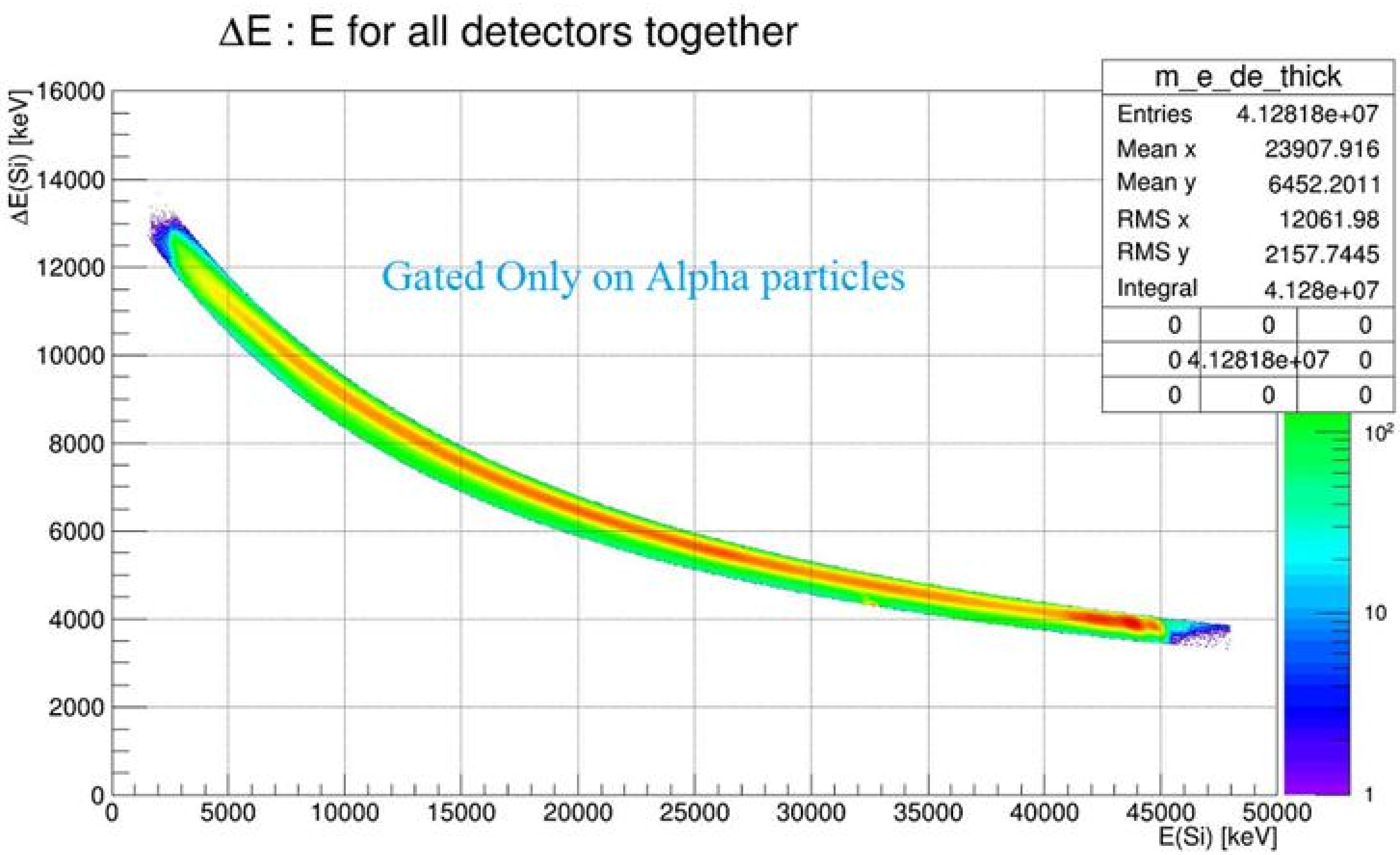


Analysis

Ungated ΔE vs E for particle identification



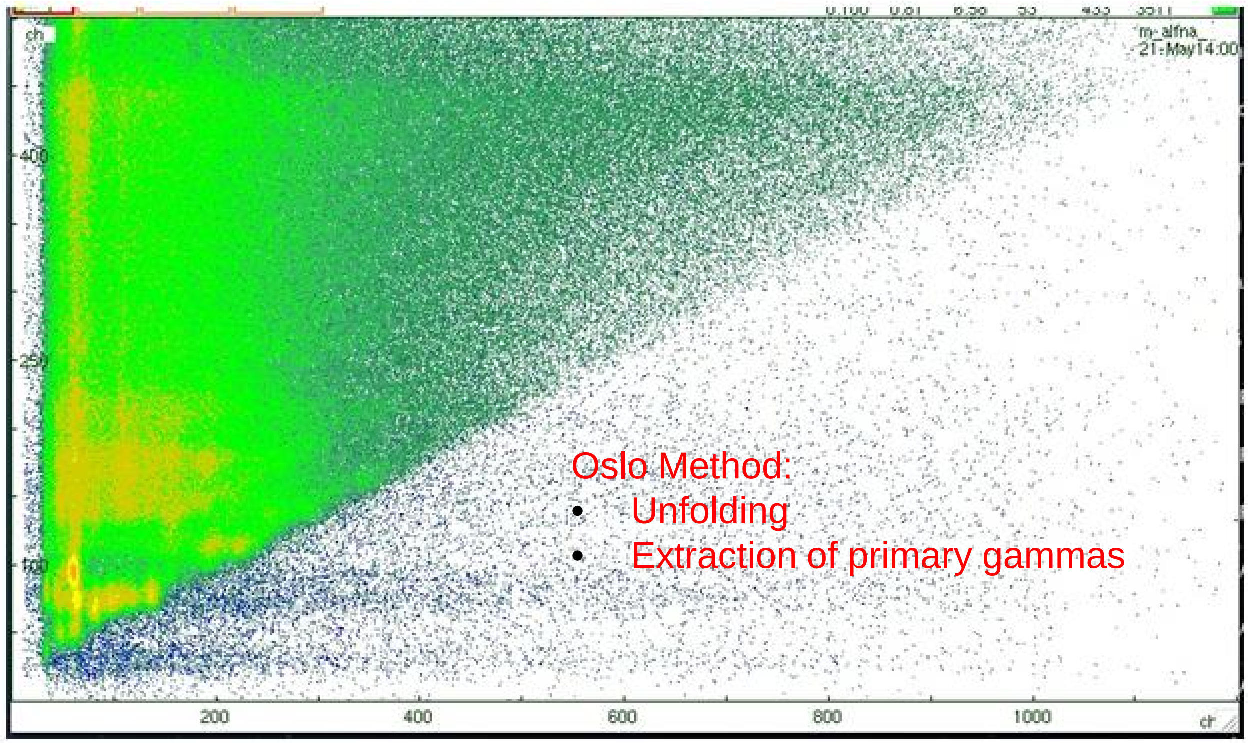
Analysis
Gated E:ΔE Plot



Analysis
Particle - γ coincidence matrix

- From Q-value and kinematics of the reaction

E_{ex}

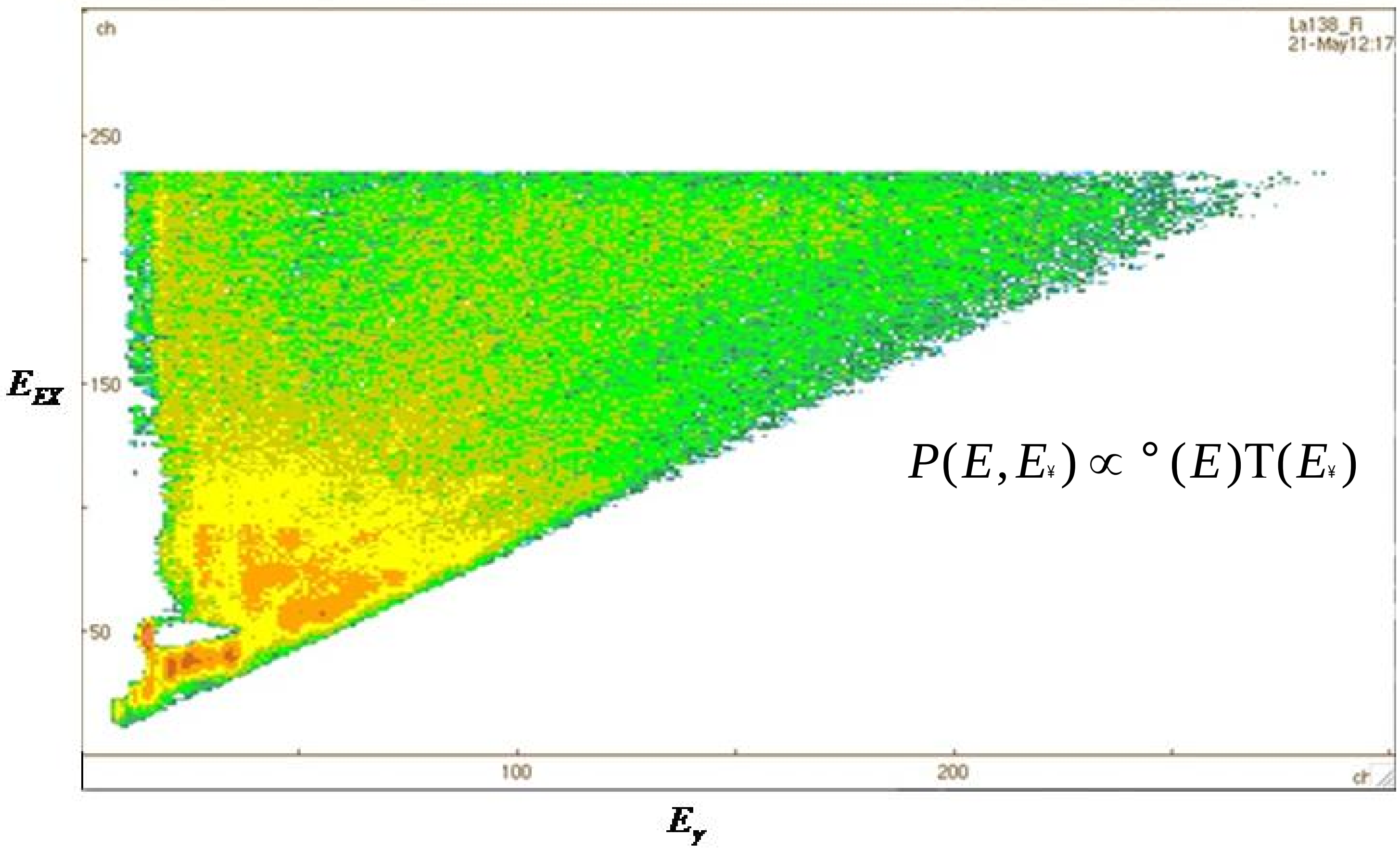


Oslo Method:
- Unfolding
- Extraction of primary gammas

E_{γ}

- Gammas in coincidence with particles

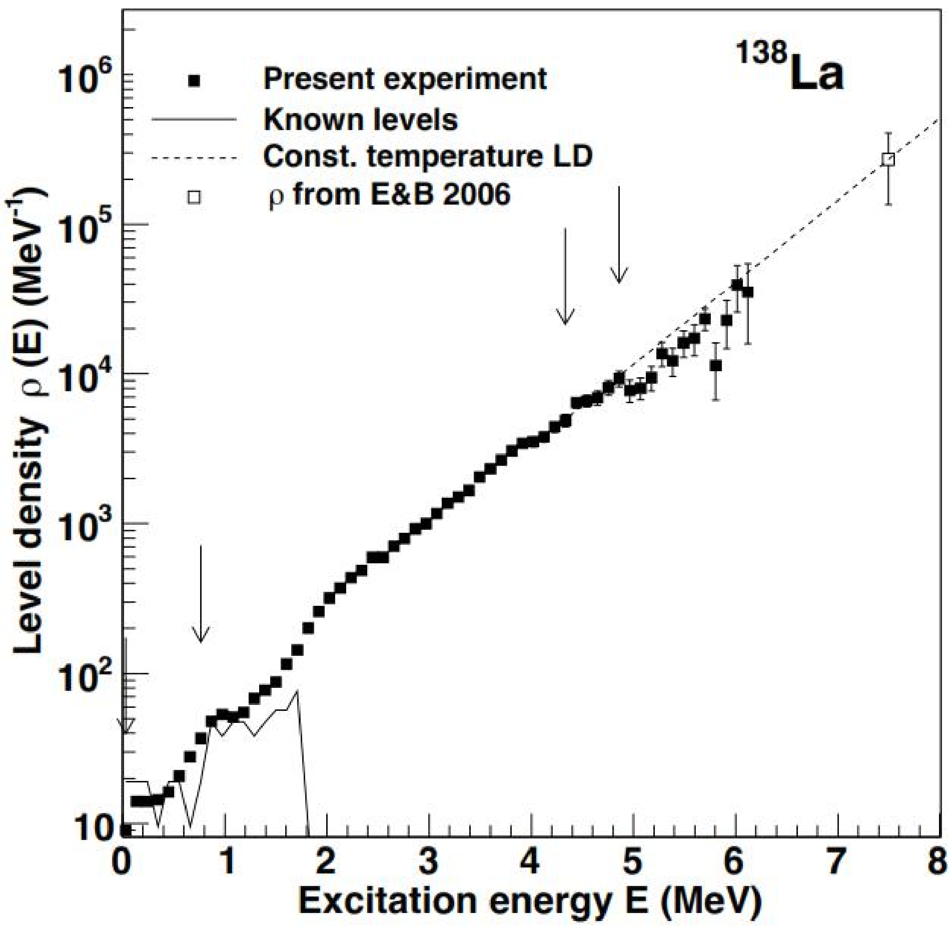
Analysis
First Generation Matrix



$$P(E,E_\gamma) \propto \rho(E)\mathcal{T}(E_\gamma)$$

Preliminary Results

Level Density of La138



- ρ(S_n) calculated using BSFG model:

$$\circ(S_n) = \frac{\exp\left[2\sqrt{a(S_n - E_1)}\right]}{12\sqrt{2}\pm * a^{1/2}(S_n - E_1)^{5/4}}$$

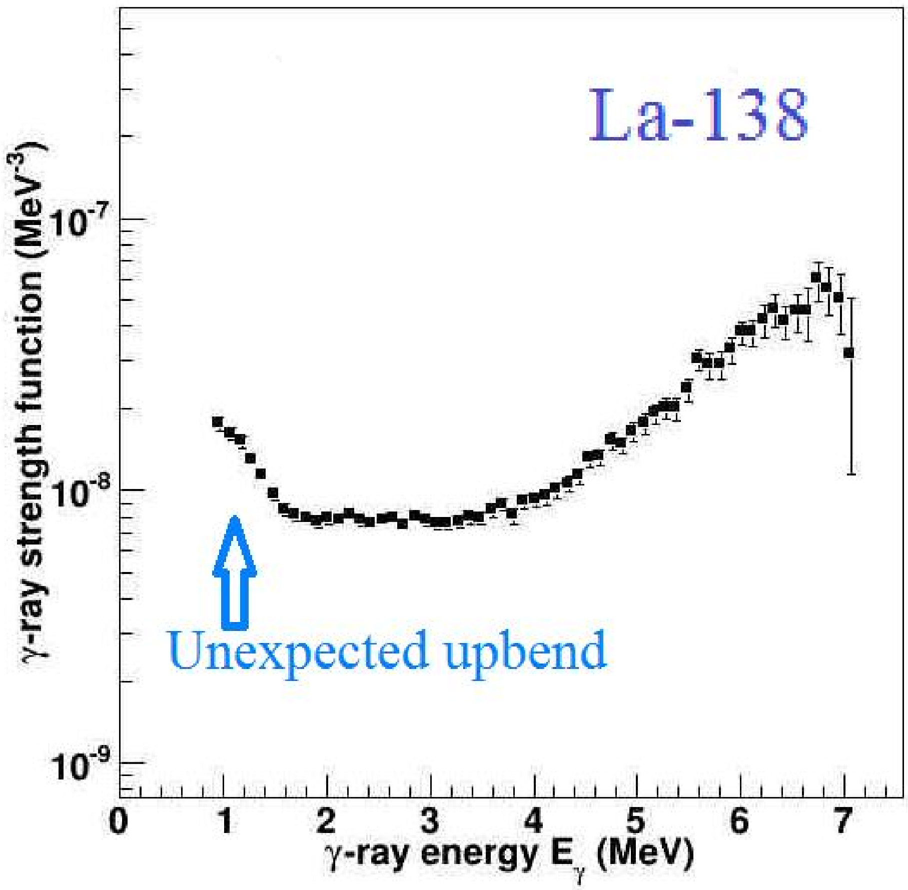
and

$$\pm^2 = 0.0146A^{5/3}\frac{1+\sqrt{1+4a(U-E_1)}}{2a}$$

T. von Egidy and D. Burcurescu, PRC 72, 044311(2005)

Preliminary Results

Photon Strength Function of ^{138}La

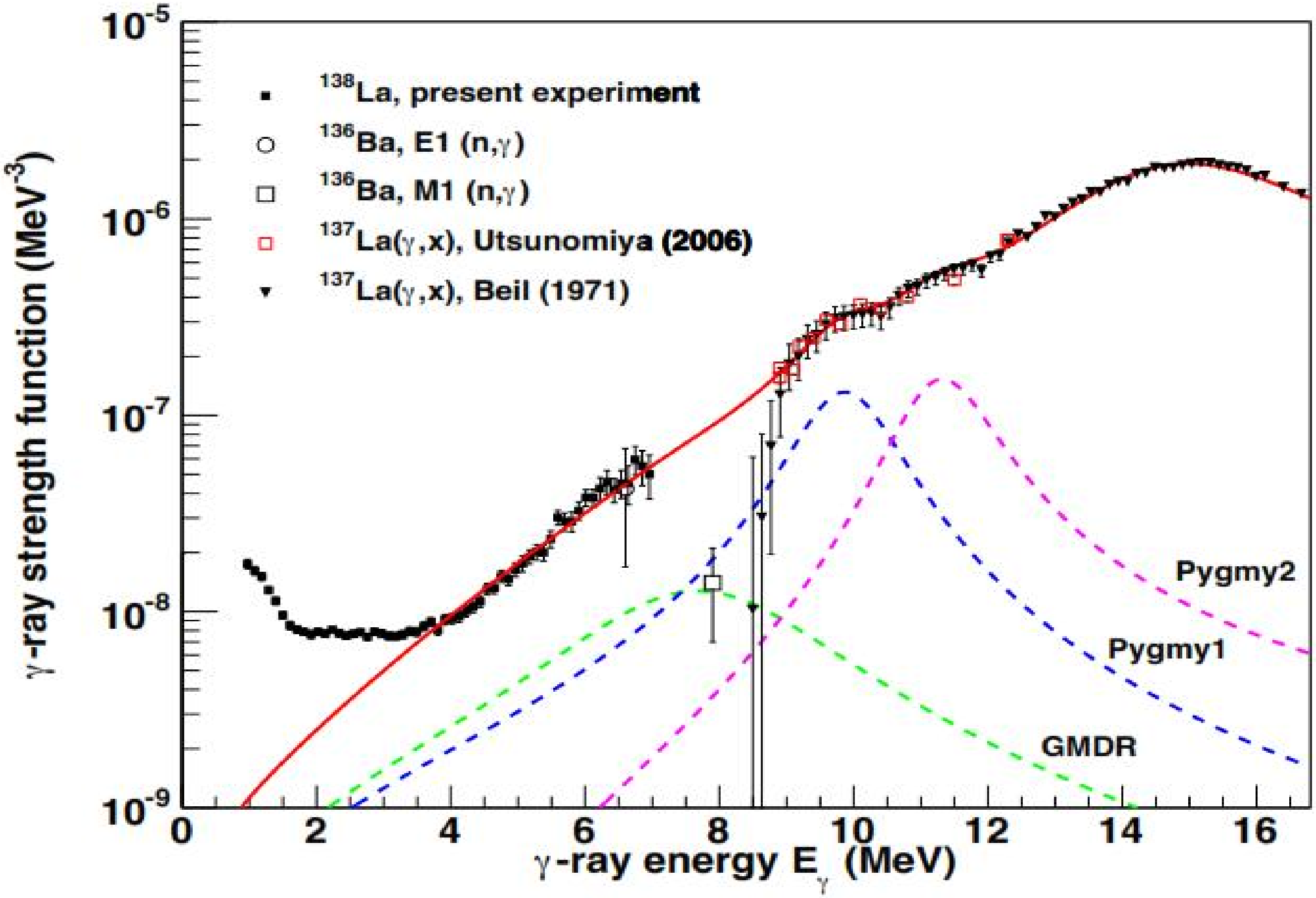


- Pronounced low energy enhancement

- ***First observation of the low-energy enhancement above mass A~106!!!!!!!***

Preliminary Results

Comparison with GDR Model and Experimental data



Clearly there is a low energy enhancement !!!!!!!!!!!

Conclusions and outlook

• To better understand the natural abundance of the "p-nuclei" and in particular 138La, more precise production rates have to be determined: Experimental data on PSF and LD as input parameters are needed.

•A $^{139}La(^{3}He, \alpha)^{138}La$ experiment has been successfully performed in February 2013 at OCL.

•Preliminary results on PSF and LD have been extracted: an unexpected up-bend at low energy in the PSF have been observed for the first time in nuclei heavier than ***A~106***!!!

• Next steps: comparison with more experimental data and models.

PSF and LD for ^{139}La via the $(^{3}He, ^{3}He\gamma)$ reaction.

Plans for neutron capture measurements to extract PSF via TSC analysis.

Acknowledgements

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- The following people for participating on the experimental work:

B.V. Kheswa[1], M. Wiedeking[1], F. Giacoppo[2], M. Guttormsen[2], A. Görgen[2], A. C. Larsen[2] ,T. Renstrøm[2], S. Siem[2], P. E. Koehler[2], T. K. Eriksen[2], E. Sahin[2], T. Tornyi[2], M. Klintefjord[2], T. W. Hagen[2], S. Rose[2], F. Bello[2]

[1]iThemba LABS, Somerset West, South Africa
[2] SAFE, University of Oslo, Oslo, Norway

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Thank You All

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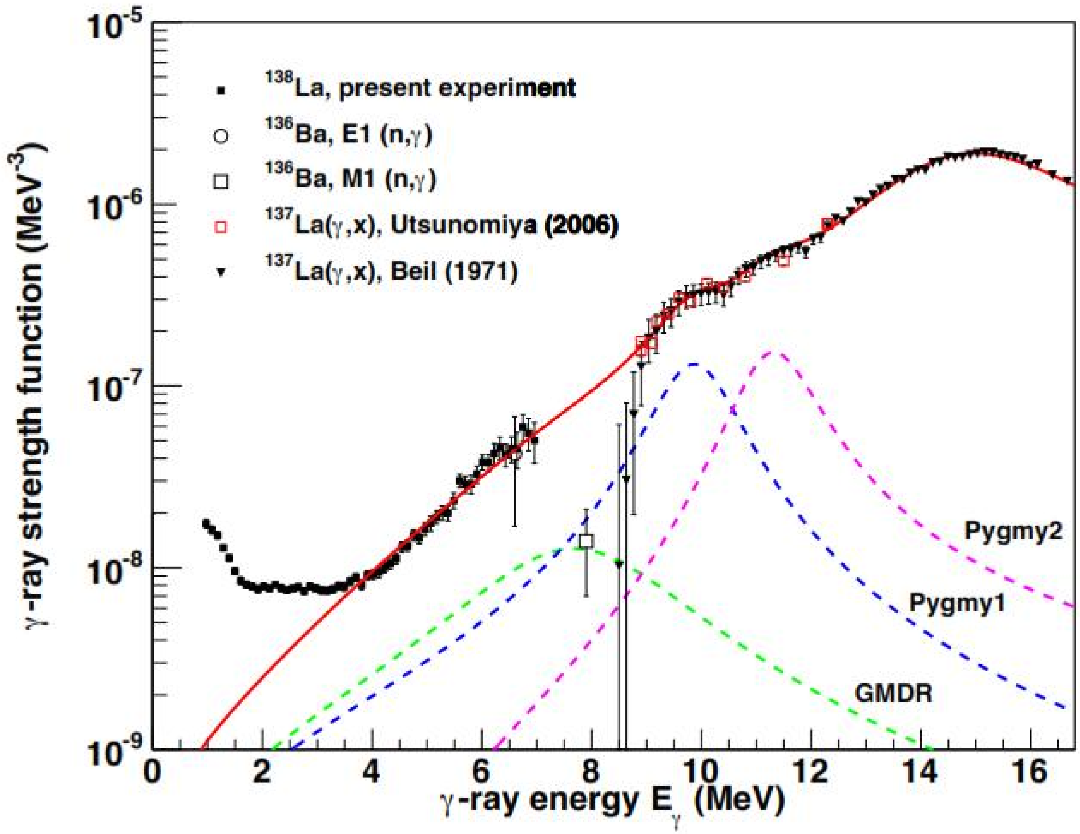
Preliminary Results

Comparison with GDR Model and Experimental data



- *Pygmy1 and Pygmy2 are E2 and E1 resonances*
- *Models:*
  - *Spin-flip Model for GMDR*
  - *Isoscalar Model for Pygmy1*
  - *EGLO for GEDR and Pygmy2*

Clearly there is a low energy enhancement !!!!!!!!!!!