

IS452 - Coulomb Excitation in the Light Hg Region

Andrew Petts and Nick Bree

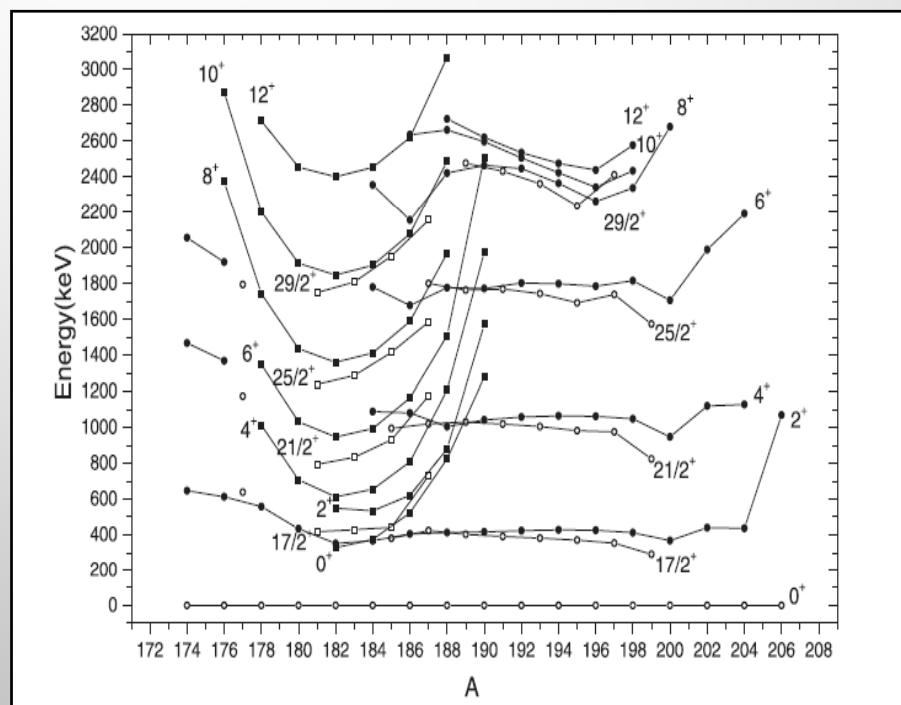
For the IS452 Collaboration



Overview

- Background Physics
- Coulomb excitation of $^{184,186,188}\text{Hg}$ - Initial Campaign
- Coulomb excitation of $^{182,184,186,188}\text{Hg}$ - Latest
- Further Work

Background Physics



R. Julin et al. J. Phys. G: Nucl. Part. Phys. 27 (2001) R109–R139

- Shape coexistence observed in light Hg region
- Neighbouring Pb shows same phenomena due to intruder states $\pi(2p-2h)$ and $\pi(4p-4h)$ excitations
- Evolution and microscopic origin of shape coexistence in region not clear
- Degree of mixing between configurations unknown

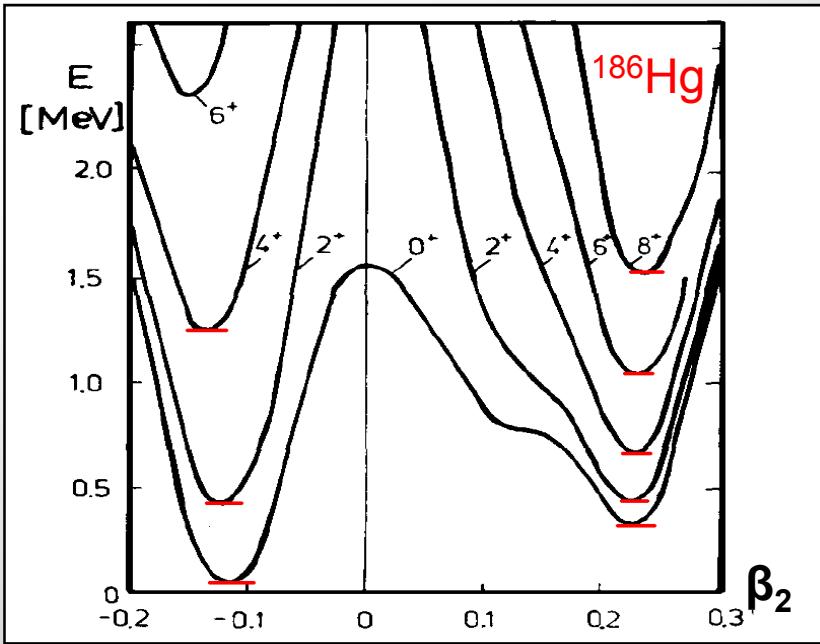


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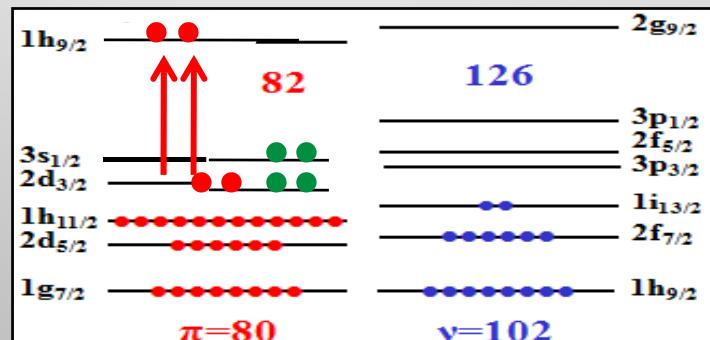
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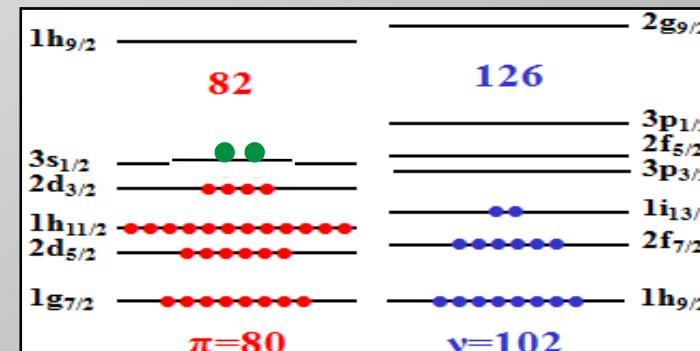
Background Physics



- Weakly deformed prolate and oblate bands in even-even Hg isotopes predicted to be $\beta \approx 0.25$ and $\beta \approx -0.15$
- Prolate states associated with excitations of four protons across Z=82 shell gap $\pi(2\text{p}-4\text{h})$ configuration
- Oblate states associated with $\pi(0\text{p}-2\text{h})$ configuration



Prolate Hg



Oblate Hg

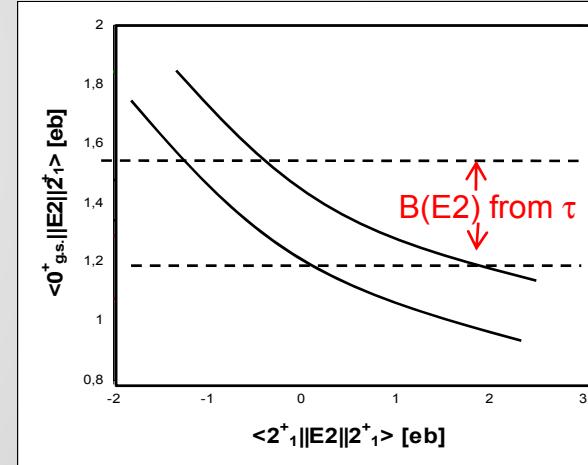
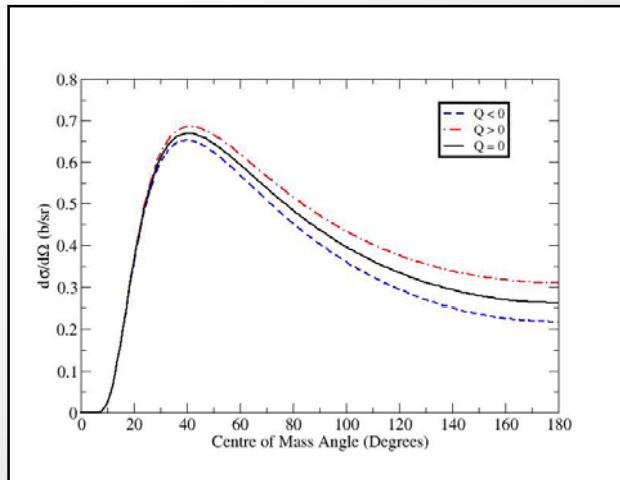


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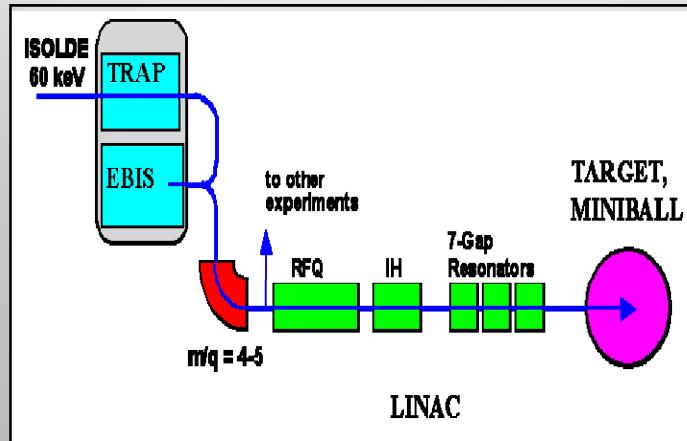
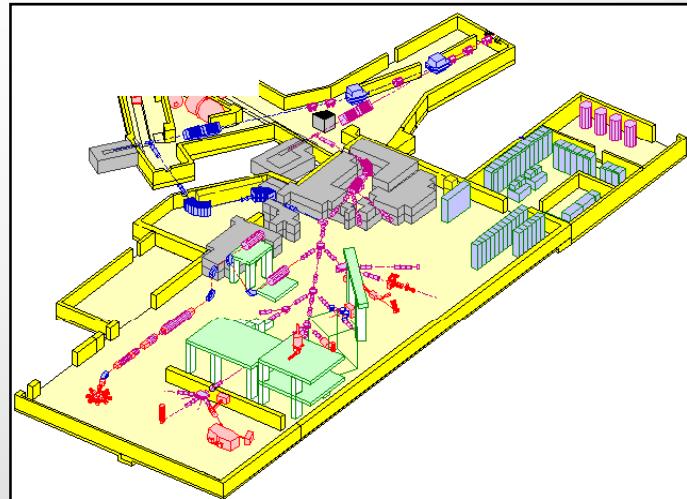
Background Physics – Hurst Analysis



- Exploits Coulex cross section dependence on quadrupole moment
- Matrix elements varied to reproduce experimental yields
- Diagonal matrix elements and size and sign of quadrupole moment obtained with Coulex

$$P_{2+} \propto \langle 0^- | |E2| |2^+ \rangle^2 \cdot [1 - \langle 2^+ | |E2'| |2^+ \rangle f(\xi)]$$

Experimental Details - REX-ISOLDE



- ISOLDE provides > 600 isotopes. Half lives down to ms. Intensities up to 10^{11} pps
- PS booster provides 1GeV or 1.4Gev protons which impinge upon molten primary target
- ISOLDE delivers 1^+ ions at 60 keV.
- REXTRAP – penning trap used during charge breeding
- EBIS – Charge breeds ions to $m/q \sim 4-5$
- REX – Linac accelerates ions that have passed through mass separator to 0.8 – 3.2 Mev/u

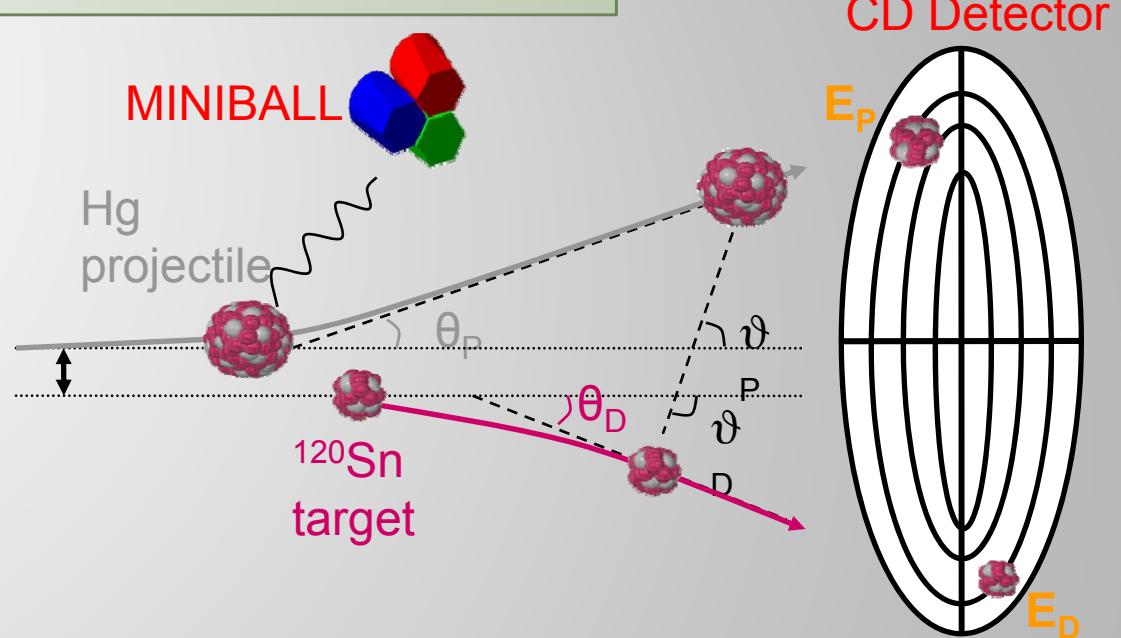
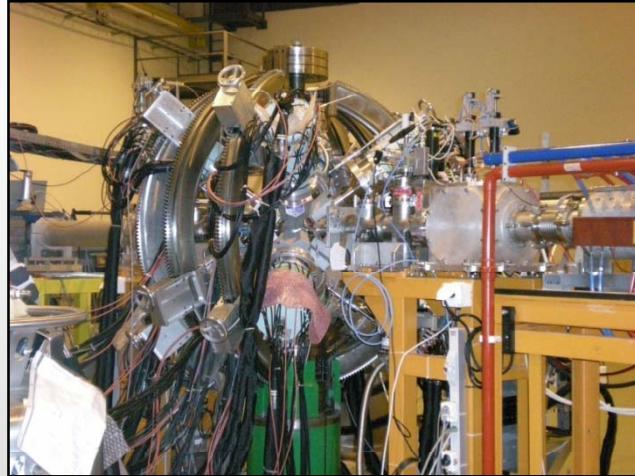


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Experimental Details - MINIBALL



- MINIBALL – HPGe array consisting of 8 triple cluster units with 6 fold segmentation. Full energy peak efficiency $\varepsilon_{\text{ph}} > 7\%$ at 1.3 MeV.
- 7keV FWHM at $E\gamma = 1.3$ MeV with $v/c = 0.045$ and $\theta = 90^\circ$
- CD Detector – DSSD in four separate quadrants.
- Angular range of $15^\circ - 53^\circ$. Position, Energy loss and Particle ID info given.



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Experimental Details - Initial Campaign

- Was the heaviest post accelerated radioactive beam to date using the ISOL process
- First experimental program to probe low lying states in Hg – Pb region using Coulomb excitation
- 0.19% efficiency through REX – 10% what we expected!
- Use of ^{120}Sn and ^{107}Ag targets – cross normalisation.

Isotope	Charge state	Intensity@Miniball
^{184}Hg	43+	3×10^3 pps
^{186}Hg	43+	2.0×10^5 pps
^{188}Hg	44+	2.5×10^5 pps

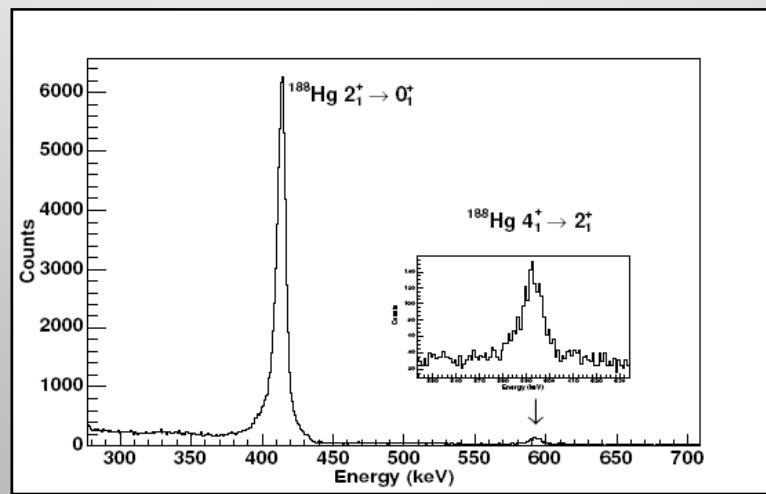
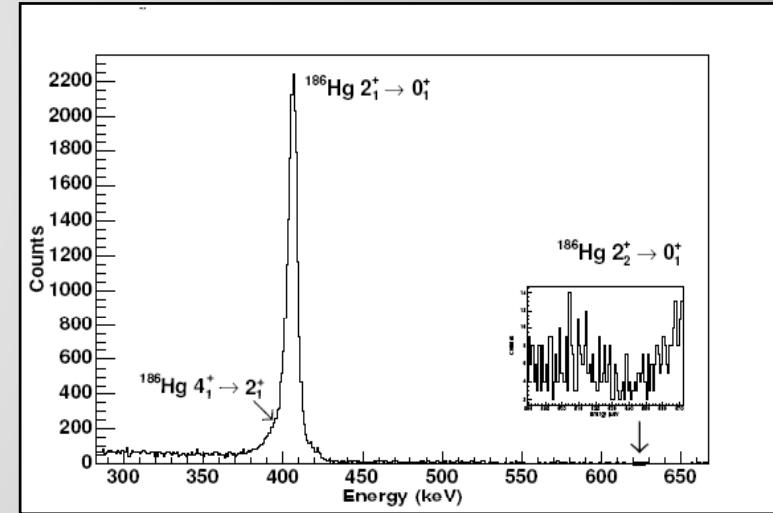
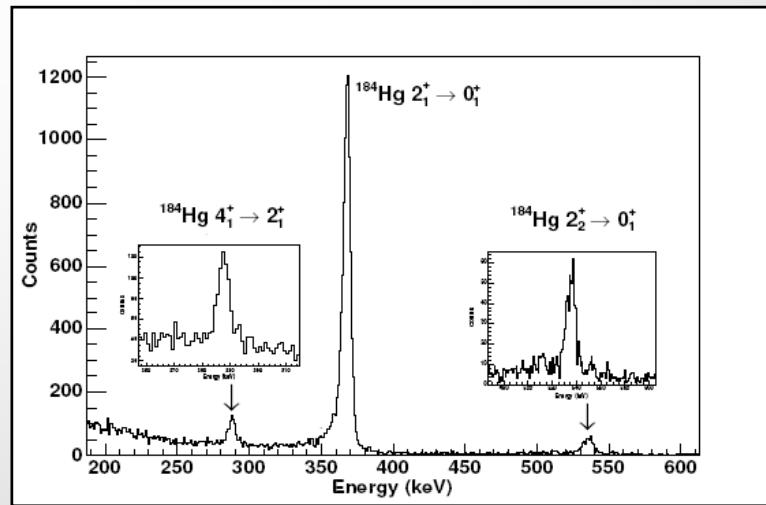


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Preliminary Results - $^{184,186,188}\text{Hg}$ Spectra



- Able to obtain $\langle 0^+ || E2 || 2^+ \rangle$ and $\langle 2^+ || E2 || 2^+ \rangle$ for all three nuclei
- Should obtain to obtain $\langle 2^+ || E2 || 4^+ \rangle$ for $^{184,188}\text{Hg}$ and $\langle 0^+ || E2 || 2_2^+ \rangle$ for ^{184}Hg
- Magnitude and sign of quadrupole moment obtainable for all three nuclei



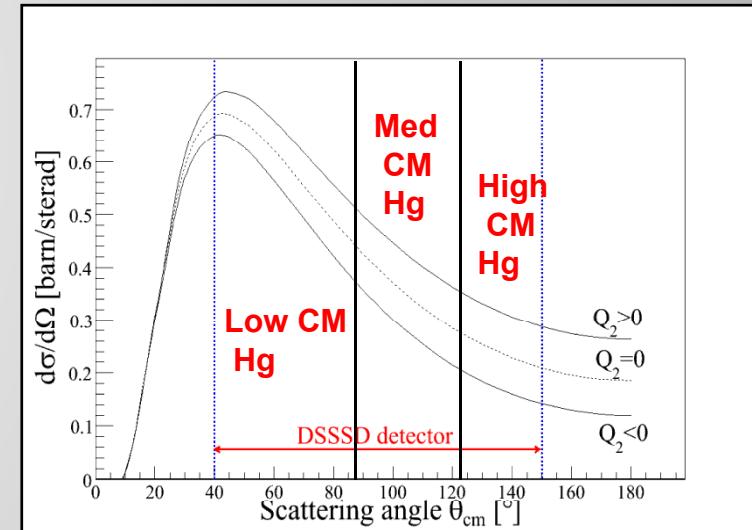
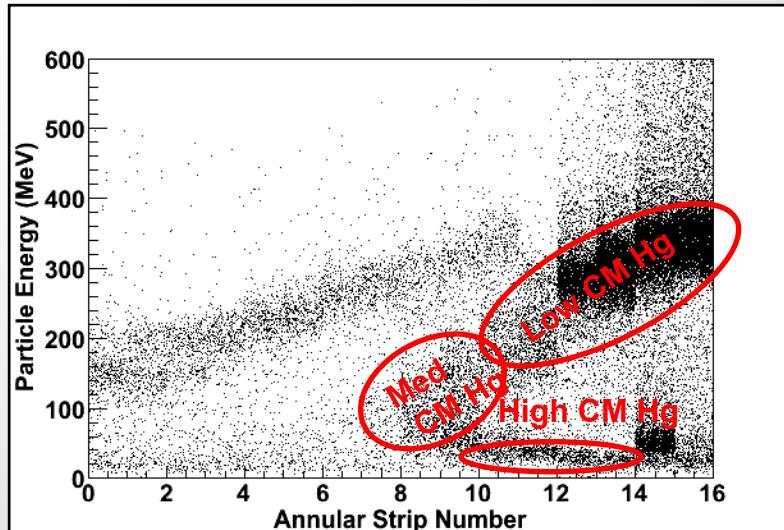
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Preliminary Results - ^{186}Hg analysis



- Data separated into three angular ranges
- Angular ranges all sensitive to quadrupole moment
- Data only included if kinematic branches are separable



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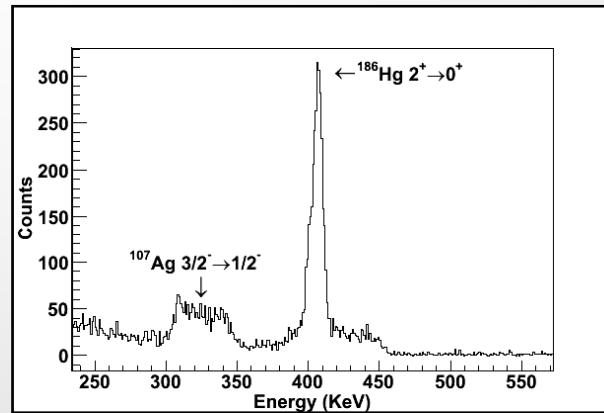
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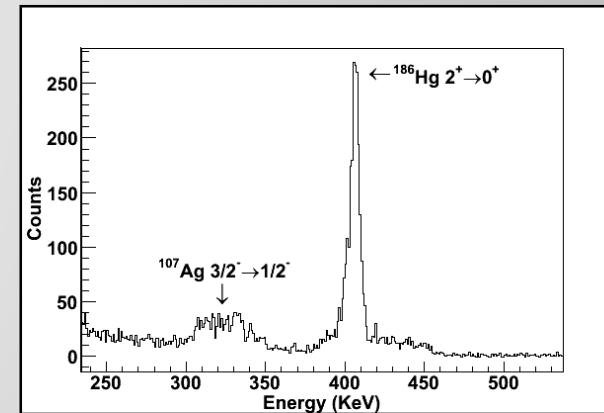
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Preliminary Results - ^{186}Hg Yields

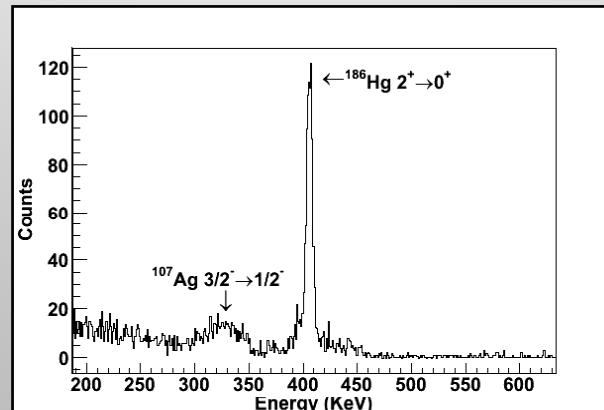
Low COM Range



Med COM Range



High COM Range



COM Range	Hg Yield	Ag Yield
Low	2966 ± 57	1221 ± 49
Med	1939 ± 46	786 ± 23
High	824 ± 22	373 ± 21



Preliminary Results - ^{186}Hg Gosia minimization

```
EXPT
3,80,186
-47,107,524.1,22.75,3,1,0,0,360,1,1
-47,107,524.1,32.95,3,1,0,0,360,0,1
-47,107,524.1,32.,3,1,0,0,360,0,1
CONT !use INR, for independent normlisat
LCK,
0,0
WRN,3.
PRT,
4,0
2,0
5,2
```

```
OP,INTG
5,7,400.,525.,21.,28.
400,430,460,490,525
14.,18.,21.,24.,27.,30.,32.
5,7,400.,525.,30.5,35.5
400,430,460,490,525
31.,31.5.,32.,32.5.,33.,34.,35.8
5,7,400.,525.,22.5,33.5
400,430,460,490,525
20.,24.,28.,32.,33.,34.,35.05
5
400,430,460,490,525
```

Matrix elements from
Proetel et al, 1974, Physics Letters B, 48, 102

$$\begin{aligned}<2^+_1||E2||0^+_1> &= 1.18 \pm 0.11 \text{ eb} \\<2^+_2||E2||0^+_2> &= 3.55 \pm 1.32 \text{ eb} \\<4^+_1||E2||2^+_2> &= 3.37 \pm 0.69 \text{ eb} \\<4^+_1||E2||2^+_1> &= 2.13 \pm 0.40 \text{ eb}\end{aligned}$$

Obtained matrix elements from minimization

$$\begin{aligned}<2^+_1||E2||0^+_1> &= 1.18 \pm 0.16 \text{ eb} \\<2^+_1||E2||2^+_1> &= 2.31 \pm 0.31 \text{ eb}\end{aligned}$$

Oblate $\beta_2 = -0.14 \pm 0.03$



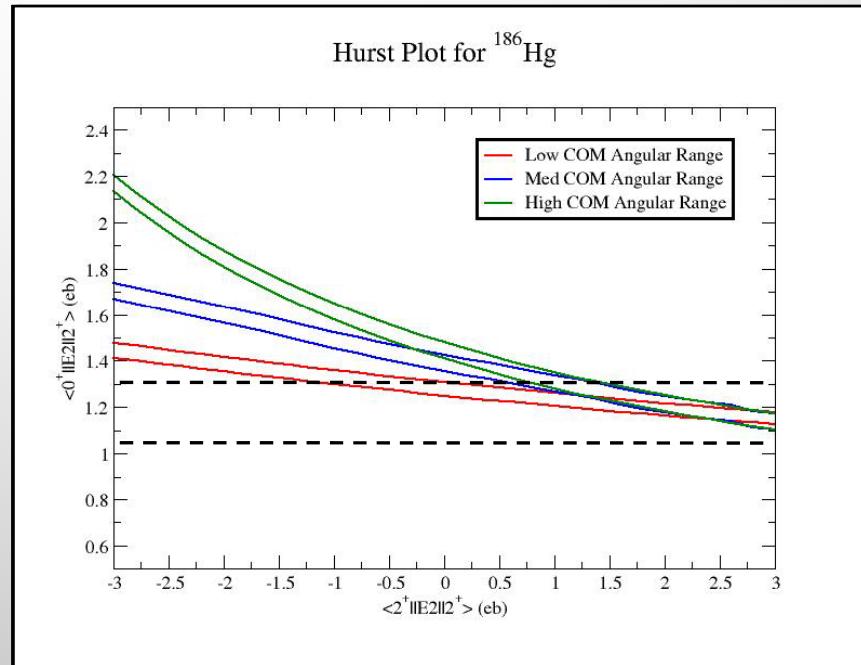
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Preliminary Results - ^{186}Hg Hurst analysis



- Cross normalised to ^{107}Ag

$$\sigma_{\text{cr}}(\text{Hg}) = \sigma_{\text{cr}}(\text{Ag}) \cdot \left(\frac{e_r(\text{Ag})}{e_r(\text{Hg})} \cdot \frac{W_r(\text{Ag})}{W_r(\text{Hg})} \cdot \frac{N_r(\text{Hg})}{N_r(\text{Ag})} \right)$$

- Three distinct angular ranges chosen
- $\langle 2^+_1 || E2 || 0^+_1 \rangle$ and $\langle 2^+_1 || E2 || 2^+_1 \rangle$ varied by hand to reproduce Yield in each angular range

Results

$$\langle 2^+_1 || E2 || 0^+_1 \rangle = 1.8 \pm 0.8 \text{ eb}$$

$$\langle 2^+_1 || E2 || 2^+_1 \rangle = 2.32 \pm 1.1 \text{ eb}$$

Oblate $\beta_2 = 0.14 \pm 0.06$



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Experimental Details - Second Campaign

- Increased efficiency through REX
- The production and delivery of ^{182}Hg now possible
- Increased yields for $^{184,186,188}\text{Hg}$ - more stats!
- Use of $^{112,114}\text{Cd}$ targets. See both target and projectile excitation this time - Gosia analysis much easier.

Isotope	Intensity@Miniball	Previous Intensity@Miniball
^{182}Hg	4.9×10^3 pps	N/A
^{184}Hg	1.0×10^5 pps	3×10^3 pps
^{186}Hg	2.5×10^5 pps	2.0×10^5 pps
^{188}Hg	3.1×10^5 pps	2.5×10^5 pps

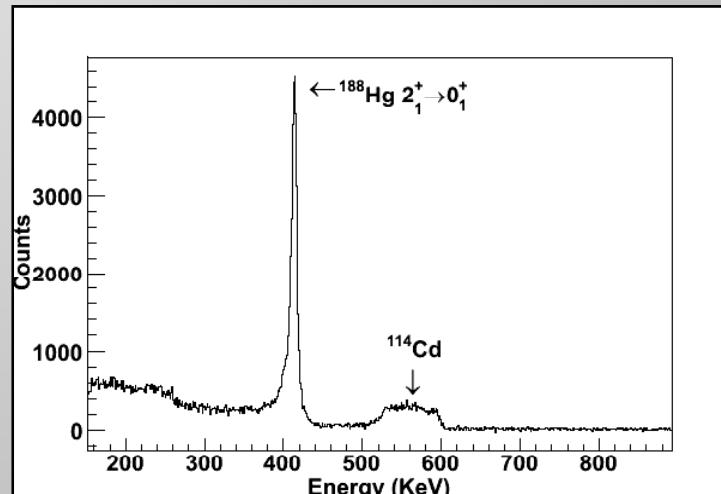
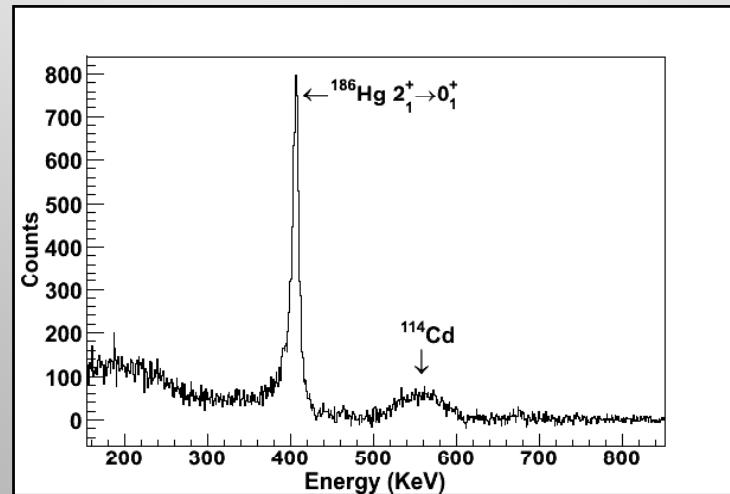
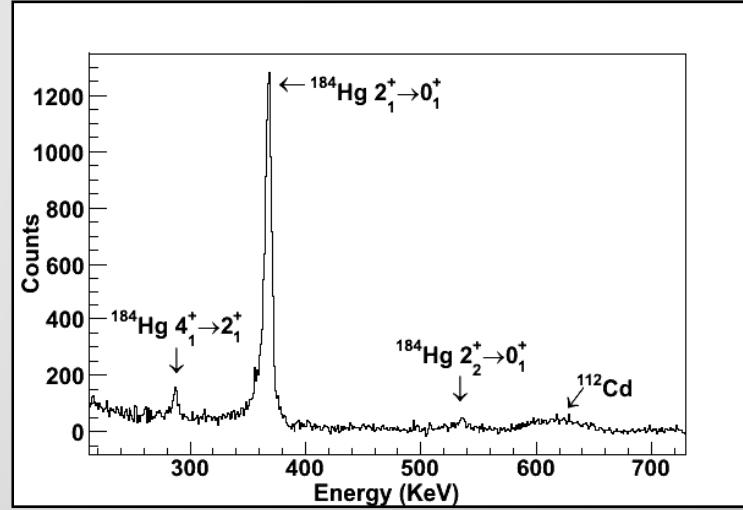
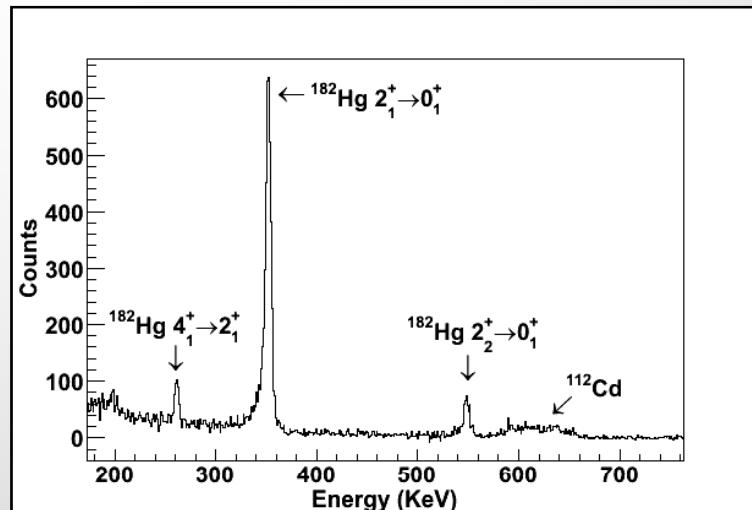


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Preliminary Spectra - Second Campaign



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Further Work

Lifetime Analysis

- Lifetime measurements of $^{184,186,186}\text{Hg}$ proposal accepted by Argonne PAC ~ April 2009

Coulex Analysis

- Further analysis of $^{184,186,188}\text{Hg}$
- Comparison of obtained results with results from new run with Cd targets
- ^{182}Hg Coulex data under analysis



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