EUROPEAN ORGANISATION FOR NUCLEAR RESEARCH

# Status report to the INTC Committee on: *"Thallium isobaric contamiants of neutron-deficient Polonium beams from UCx-RILIS units at ISOLDE"*

## related to the CERN-INTC-2008-027 proposal: *"Shape coexistence measurements in even-even neutron-deficient Polonium isotopes by Coulomb excitation, using REX-ISOLDE and the Ge MINIBALL array."*


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# Abstract

In the May 2008 INTC meeting, we proposed to study the transition from the vibrational-like character of the heavier Po isotopes to the shape coexistence mode observed in the lighter Po isotopes, by using post-accelerated neutron-deficient $^{198,200,202}$Po beams from REX-ISOLDE and the "safe"-energy Coulomb excitation method. The Committee endorsed the physics case of the proposal but did not recommend it yet for approval by the Research Board until yields for the Po and Tl isotopes as well as their release has been tested. In this document, based on T.E. Cocolios *et al.* measurements [1] and T. Stora *et al.* internal report [2], **the requested release and yield characteristics are reported. The obtained results comfirm the feasability of the proposed experiment.**

# 1 Release and yields characteristics of neutron-deficient Po isotopes

The neutron-deficient Polonium isotopes yields have been recently measured at ISOLDE by T.E. Cocolios and collaborators [1]. The isotope chain $^{193-198,200,202,204}$Po was produced by spallation reactions of the 1.4 GeV CERN-PS Booster proton beam impinging on a $UC_x$ target (50 g.cm$^{-2}$) and by specific RILIS ionisation. Some of the values obtained are presented in Tab. 1 (the even-even isotopes cases).

| Isotope | Half life [s] | Yields [ions/$\mu$C] |
|---|---|---|
| $^{194}$Po | 0.392 | $2.7\times10^{3}$ |
| $^{196}$Po | 5.8 | $4.8\times10^{5}$ |
| $^{198}$**Po** | **105** | $\mathbf{1.2\times10^{7}}$ |
| $^{200}$**Po** | **690** | $\mathbf{6.4\times10^{6}}$ |
| $^{202}$**Po** | **2682** | $\mathbf{1.7\times10^{7}}$ |
| $^{204}$Po | 12708 | $1.1\times10^{7}$ |

TAB. 1 – Polonium yields published in reference [1].

The yield is defined as the ratio of the ion beam intensity to the primary beam current and is expressed in units of ions/$\mu$C :

$$Y = \frac{N_{0i}}{N_p \times 1.6.10^{-19}}.10^{-6} \int_{t=0}^{\infty} P_i(t,\lambda_i)dt \qquad (1)$$

with

$$P_i(t,\lambda_i) = exp(-\lambda_i t).P_{\lambda_r,\lambda_f,\lambda_s,\alpha}(t) \qquad (2)$$

$$P_i(t,\lambda_i) = exp(-\lambda_i t)[(1 - exp(-\lambda_r t)).[\alpha.exp(-\lambda_f t) + (1-\alpha).exp(-\lambda_s t)]] \qquad (3)$$

$N_{0i}$ corresponds to the number of ions created in one proton pulse. $N_p$ is the number of protons per pulse. $P_i(t,\lambda_i)$ corresponds to the release fraction [3]. For the polonium isotopes, the release curve constants are given in Tab.1. $\lambda_i$ refers to the decay constant of the radioactive element i.

| Constants | Measurement with UC356 /RILIS (tungstène) |
|---|---|
| **tr (s)** | 18.1 |
| **tf (s)** | 4.67 |
| **ts (s)** | 568 |
| $\alpha$ | 0.984 |

TAB. 2 – Three exponential release curve constants of Polonium isotopes deduced from the August 2007 run [4].

**In the CERN-INTC-2008-027 proposal, the yields values presented in Tab. 1 were used to estimate the required beam time**, in order to reach less than 10% uncertainty on the measurements of the Coulomb excitation differential cross section and provide both the transition and diogonal matrix elements for these nuclei.

As mentioned in the proposal, surface ionized contaminants from the hot cavity can however be produced, and more particulary isobaric neutron-deficient Thallium isotopes ($^{198,200,202}$Tl) in the present case.

# 2 Release and yields characteristics of neutron-deficient Tl isotopes

The release and yield characteristics for $^{190}$Tl and $^{192}$Tl have been measured this year on the UC382 (standard ISOLDE UCx target, 46g/cm$^2$ depleted U) unit at a target/line temperature of 2040/2120°C. Both the target and line temperatures are the nominal figures for constant Radioactive Ion Beam production over several physics shifts. The UC382 unit was mounted with a Tantalum ionizing cavity. The parameters of the 3-exponential function (eq. (3)) used to fit the data and the measured yields are shown in Tab. 3 and Tab.4, respectively, and compared to the reference data reported in the ISOLDE database [5,6].

| Constants | Present measurement with UC382 / surface (Ta) | Previous measurement with UC202 / RILIS (Nb) |
|---|---|---|
| **tr (s)** | 0.0 | 0.045 |
| **tf (s)** | 2.277 | 0.6 |
| **ts (s)** | 37.991 | 5.7 |
| $\alpha$ | 0.98 | 0.98 |

TAB. 3 – Three exponential release curve constants of Thallium isotopes obtained with UC382/surface [2] and UC202/RILIS [5,6].

| Isotope | Present yield measurement (ions/$\mu$C) UC382 / surface (Ta) | Previous yield measurement (ions/$\mu$C) UC202 / RILIS (Nb) |
|---|---|---|
| $^{190}$Tl | $4\times10^6$ | $8.1\times10^7$ |
| $^{192}$Tl | $5\times10^6$ | $9.6\times10^7$ |

TAB. 4 – $^{190}$Tl and $^{190}$Tl yields measured with UC382/surface [2] and UC202/RILIS [5,6].

The reference data were obtained with laser ionized Tl isotopes from the UC202 unit equipped with a Nb cavity. The unit was operated at a target/line temperature of 2000/2100°C, very similar as those used for the present tests on UC382. **There is a difference of x20 between the yields obtained with UC382/surface and UC202/RILIS**. This matches the x20 factor quoted in ref [5] obtained with UC202 for laser over surface ionized Tl yields.

However, there is a significant difference in the tf and ts components of the release function, by a x4-6 factor. **We do not expect any difference in the release functions between surface and laser ionized Tl beams**. While **there might be some impact of the cavity material (Nb vs Ta)**, it seems rather more probable that the release function quoted in ref [5] was obtained **from a release curve truncated after 10s** (on $^{195}$Tl) and displaying some scattered data points originating from laser fluctuation.

The previously reported release curve parameters are therefore believed to be relevant for Tl isotopes with half lifes of less than 10s at mass 184 and below, and the new one reported here is believed to **better describe the Tl beam impurities in the 190-200 mass region**.

# Conclusion

In the CERN-INTC-2008-027 proposal, we made yields assumption of $5\times10^{6}$ions/$\mu$C for $^{198,200,202}$Tl and used the released curve obtained with UC202/RILIS (Nb). With the present release and yields measurements, we can now have a better estimation : the **Tl isobaric impurities** with UC356 /RILIS (Ta) are therefore expected to match the figures of the Tl yields with UC356 /RILIS (Nb)[5,6], **decreased by a factor 1/20**. In Tab. 5, we summarize the expected Po yields and Tl impurities for the proposed experiment. **The $^{198,200,202}$Po beams purities should be at least of 98% (see also Fig.1).** Using the RILIS for the experiment, identification and normalisation will be provided by the laser on/off method.

**The obtained results underline thus the feasability of the proposed experiment**. Thereby, the proposers ask the CERN-INTC-2008-027 proposal to be recommended for approval by the Research Board.

| Mass Number A | Expected Po yields (ions/$\mu$C) | Expected Tl yields (ions/$\mu$C) |
|---|---|---|
| 198 | $1.2\times10^{7}$ | $1.5\times10^{5}$ |
| 200 | $6.4\times10^{6}$ | $1.0\times10^{5}$ |
| 202 | $1.7\times10^{7}$ | $<1.0\times10^{5}$ |

TAB. 5 – Expected Po yields [1] and Tl isobaric impurities [2].

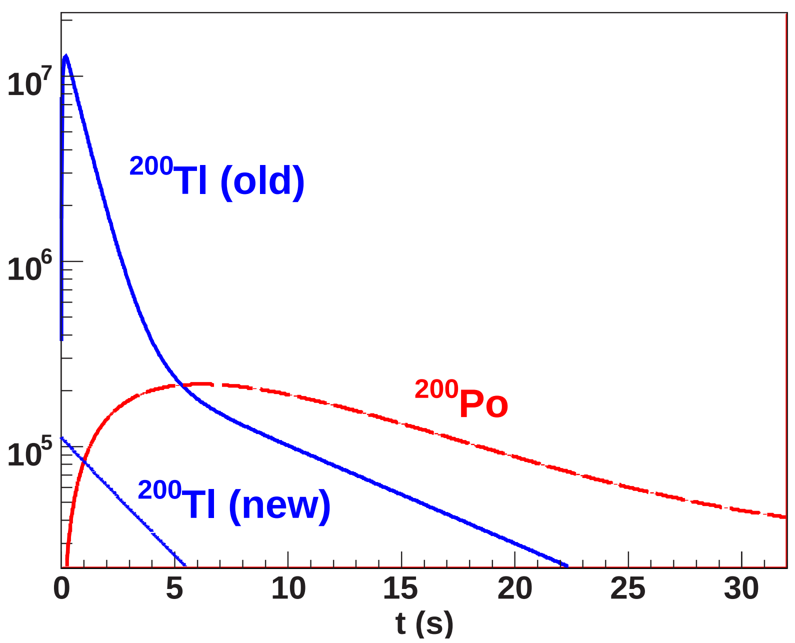


FIG. 1 – *$^{200}$Po and $^{200}$Tl release curves, considering one proton pulse of $N_p$=2$\times$10$^{13}$ only; where t corresponds to the time since proton impact.*

# References

[1] T.E. Cocolios *et al.*, Nucl. Instr. and Meth. B, in press, corrected proof available online 19 June 2008. Proceedings of the EMIS 2007 conference (2008).
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[3] J. Lettry *et al.*, Nucl. Instr. and Meth. B 126 (1997) 130.
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