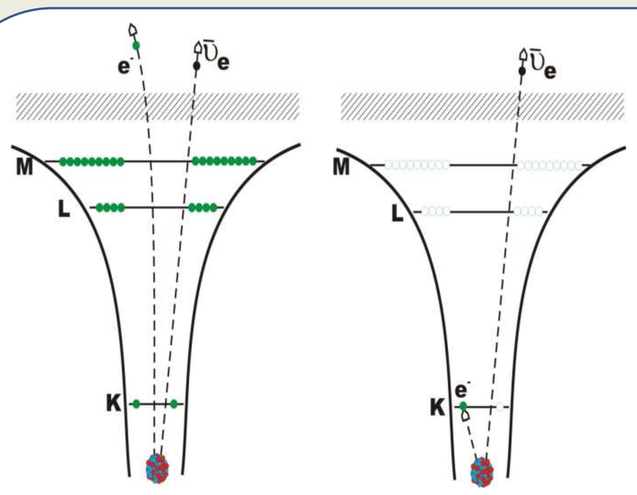
Preparation for the measurement of the bound-state beta-decay of bare ^{205}Tl ions at the ESR

Ragandeep S. Sidhu[1], Fritz Bosch[1], H. Geissel[1], J. Glorius[1], R. Grisenti[1], A. Gumberidze[1], S. Hagmann[1], Ch. Kozhuharov[1], M. Lestinsky[1], S. Litvinov[1], Yu. Litvinov[1], I. Mukha[1], C. Nociforo[1], N. Petridis[1], R. Sánchez[1], M. Sanjari[1], C. Scheidenberger[1], U. Spillmann[1], M. Steck[1], T. Stöhlker[1], K. Takahashi[1], S. Trotsenko[1], H. Weick[1], N. Winckler[1], D. Winters[1], C. Brandau[2], R. Reifarth[3], Ch. Langer[3], D. Atanasov[4], K. Blaum[4], T. Faestermann[5], R. Gernhäuser[5], Paul Kienle[5], M. Najafi[5], M. Pavicevic[6], W. Henning[7], Bradley Meyer[8], D. Schneider[9], K. Leach[10], V. Pejovic[11], B. Boev[12], T. Suzuki[13], T. Yamaguchi[13], S. Naimi[14], F. Suzaki[14], T. Uesaka[14], Y. Yamaguchi[14], T. Ohtsubo[15], B. Sun[16], X. Chen[17], B. Gao[17], X. Ma[17], X. Tu[17], M. Wang[17], H. Xu[17], X. Yan[17], Y. Zhang[17], C. Bruno[18], T. Davinson[18], C. Lederer-Woods[18], P. Woods[18], P. Walker[19], G. Lane[20], I. Dillmann[21], M. Trassinelli[22], S. Torilov[23], R. Cakirli[24], F. Ozturk[24], B. Jurado[25] and W. Korten[26]

[1]*GSI, Darmstadt, Germany;* [2]*Universität Giessen, Gießen, Germany;* [3]*J.W. Goethe Universität, Frankfurt, Germany;* [4]*MPI, Heidelberg, Germany;* [5]*TU Munich, Garching, Germany;* [6]*Salzburg University, Salzburg, Austria;* [7]*Argonne National Laboratory, Argonne, Illinois, USA;* [8]*Clemson University, USA;* [9]*Lawrence Livermore National Laboratory, Livermore, USA;* [10]*Colorado School of Mines, Golden, USA;* [11]*Institute of Physics, Zemun, Pregrevica Belgrade, Serbia;* [12]*University of Štip, FYR Macedonia;* [13]*Saitama University, Saitama, Japan;* [14]*RIKEN Nishina Center, Wako, Tokyo, Japan;* [15]*Niigata University, Niigata, Japan;* [16]*Beihang University, Beijing , China;* [17]*Institute of Modern Physics, Lanzhou, China;* [18]*University of Edinburgh, UK;* [19]*University of Surrey, Guildford, UK;* [20]*The Australian National University, Canberra, Australia;* [21]*TRIUMF, Vancouver, Canada;* [22]*Inst. des NanoSciences de Paris, CNRS UMR7588 and UMPC-Paris 6, France;* [23]*St. Petersburg State University, Russian Federation;* [24]*University of Istanbul, Turkey;* [25]*CNRS, IN2P3, CENBG, France;* [26]*IRFU, CEA, Université Paris-Saclay, France*

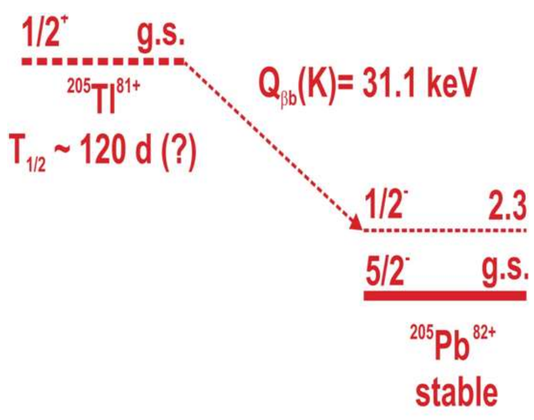
Abstract

Bound-state beta-decay (β_b) accompanied by the emission of a monochromatic antineutrino, was first predicted by Daudel et al [1] in 1947 and then discussed in detail by Bahcall [2]. The first direct observation of the bound-state beta decay (β_b decay) was done in 1992 by Jung et al [3] with the use of bare $^{163}Dy^{66+}$ ions stored in the heavy ion storage ring ESR at GSI. In the present study we aim at measuring the bound-state beta-decay rate of fully-ionized ^{205}Tl, which is needed to determine the matrix element for the electron capture decay from the 2.3 keV excited state in ^{205}Pb to the ground state of ^{205}Tl. This matrix element is important for constraining of neutrino capture probability into the 2.3 keV state of ^{205}Pb [4] and for modelling of the s-process [5] in the Hg-Pb region. The experiment proposal has been approved by the GSI program advisory panel. We aim at conducting the experiment in 2018, when the accelerator complex of GSI will restart its operation.

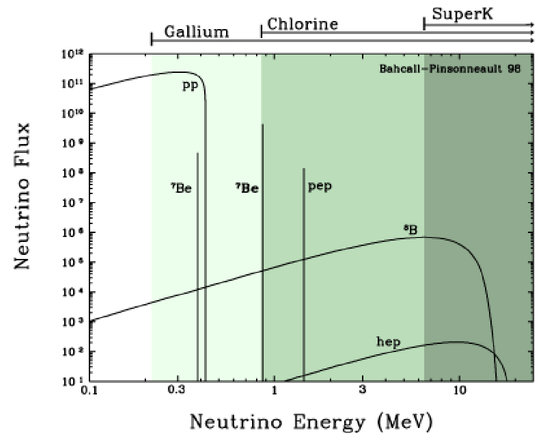


Continuum state beta decay.

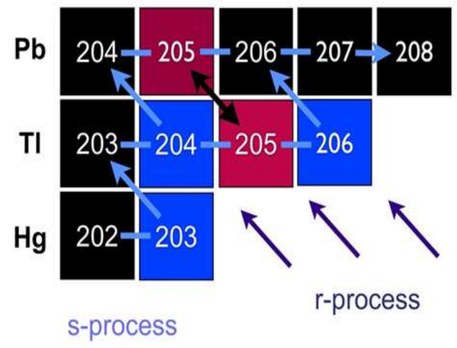
Bound state beta decay.



Bound-state beta-decay of fully stripped $^{205}Tl^{81+}$ to $^{206}Pb^{82+}$.

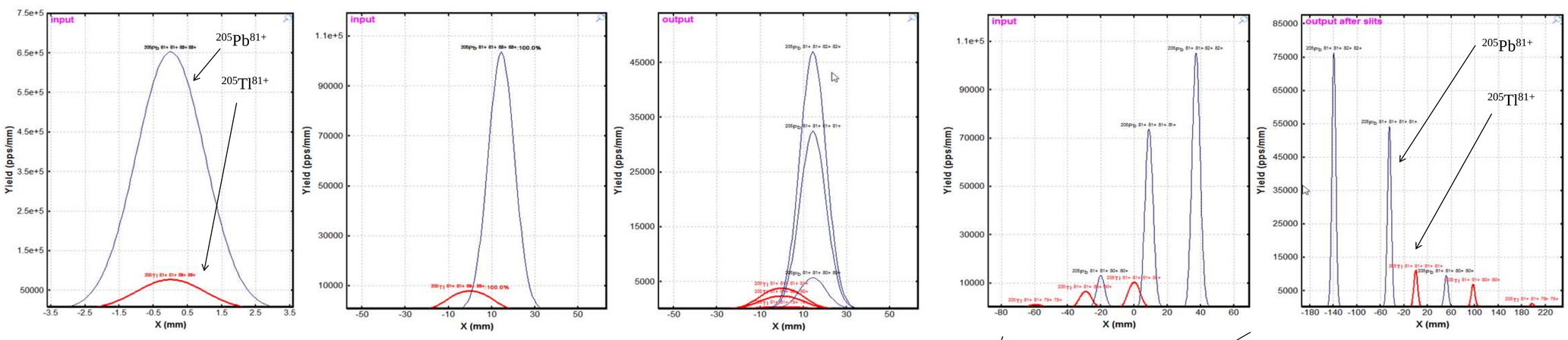


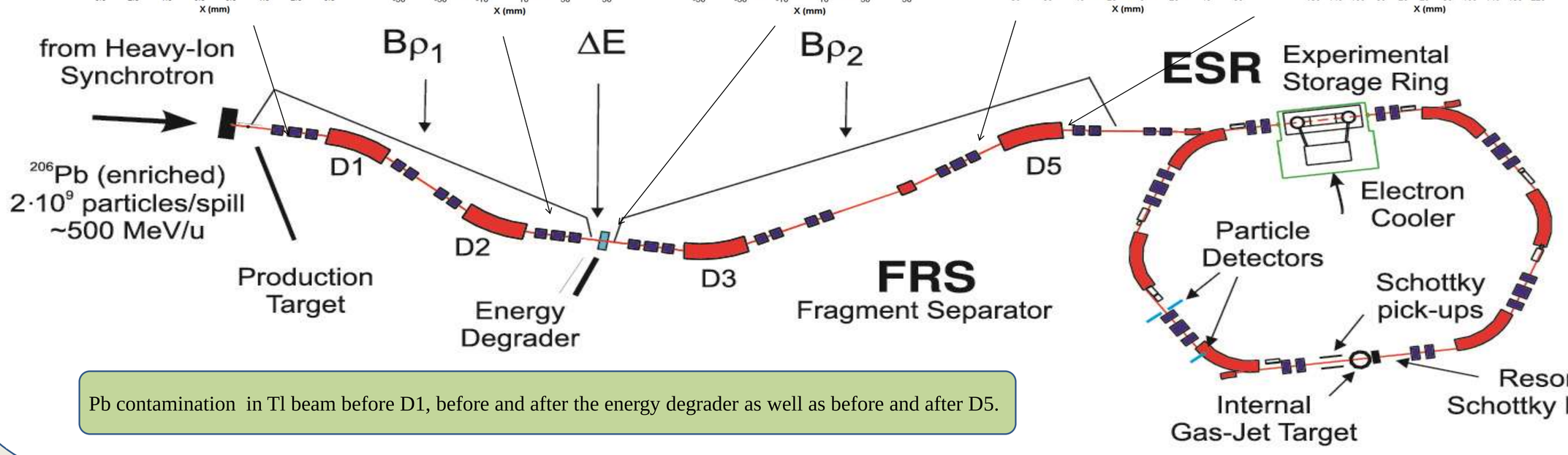
Solar Neutrino flux
Capture reaction transforming the Tl nucleus into Pb nucleus, with an energy threshold of 52 keV could be used to study the pp-neutinos from the sun [4].



Pb/Tl pair, a sensitive tool to study the conditions at the very end of the s-process [5].

Preparation of bare $^{205}Tl^{81+}$ beam and it's separation from the contaminant $^{205}Pb^{81+}$:





Pb contamination in Tl beam before D1, before and after the energy degrader as well as before and after D5.

Decay of $^{205}Tl^{81+}$:

- For the design value of stored bare Tl ions and a very cautiously estimated bound-state beta deacy half-life of 1 year, we expect about 40 bound-state beta decays within a storage time of 1 hour.
- $^{205}Tl^{81+}$ and $^{205}Pb^{81+}$ have a mass difference of 52 keV and cannot be directly resolved by mass spectrometry.
- After some waiting, a strong Ar internal gas jet is used to strip off the electron from Pb daughter ions.
- Experiment to be done similar to the one on $^{187}Os/^{187}Re$ [6].

[1] R. Daudel, M. Jean and M. Lecoin, J. Phys. Radium ***8****, 238 (1947).*
[2] J. N. Bahcall, Phys. Rev. ***124****, 495 (1961).*
[3]M. Jung et al., Phys. Rev. Lett. ***69****, 15 (1992).*
[4]M.K. Pavicevic et al., Nucl. Instr. and Meth. ***A 621****, 282 (2010).*
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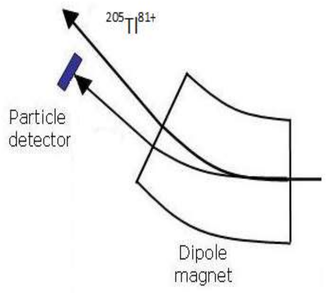
[6]F. Bosch et al., Phys. Rev. Lett ***77****, 5190 (1996).*

Separation of $^{205}Tl/^{205}Pb$:

$^{205}Pb^{81+}$ ions produced in the β_b decay of $^{205}Tl^{81+}$ can be separated in magnetic rigidity by removing the bound electron from the $^{205}Pb^{81+}$. For the latter an internal Ar gas-jet is switched on for a short time.

Detection:



The ions can be identified either by a particle detector installed after the dipole magnet downstream the gas-jet or by non-destructive Schottky mass spectrometry. The latter has a very high sensitivity down to single stored ions.

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