Th-232(d,4n)Pa-230 cross section measurements at ARRONAX facility

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UNIVERSITÉ DE NANTES

ECOLE DES MINES DE NANTES

Outline

- Motivations
- Experimental set-up and data measurements
- Results and comparisons
- Conclusions and outlooks

Motivations

Innovative radionuclides: **PET** imaging, β^- and α targeted **radiotherapy**

α RIT: binding an α emitter to an antibody **to target** and **destroy** tumor cells
- high LET
- important cytotoxic effect
- minimizing damage

^{226}Th: **novel therapeutic** nuclide, a **more potent** α emitter for leukemia than ^{213}Bi (46 min)
- decay: 4 α cascade, 27.7 MeV
- generator system: ^{230}U(21 d)/^{226}Th(31 min)

Production routes: ^{231}Pa(p,2n)^{230}U ^{232}Th(p,3n)^{230}Pa → ^{230}U   **^{232}Th(d,4n)^{230}Pa → ^{230}U**

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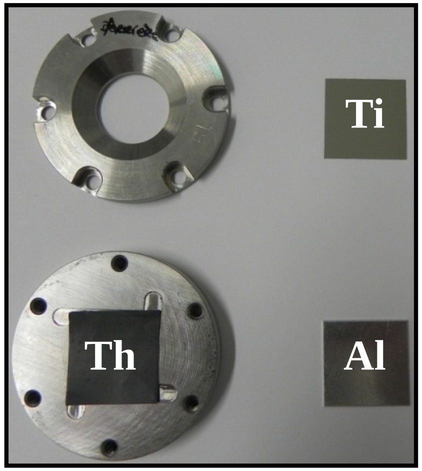
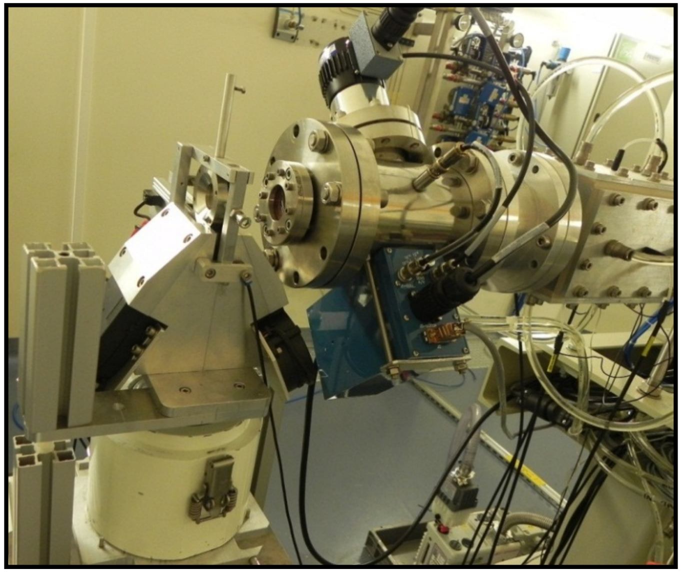
Experimental set-up and data measurements

Stacked-foil technique:

- target / monitor / degrader **pattern**
- **thin** foils



Capsule and foils



Nice III and beam line

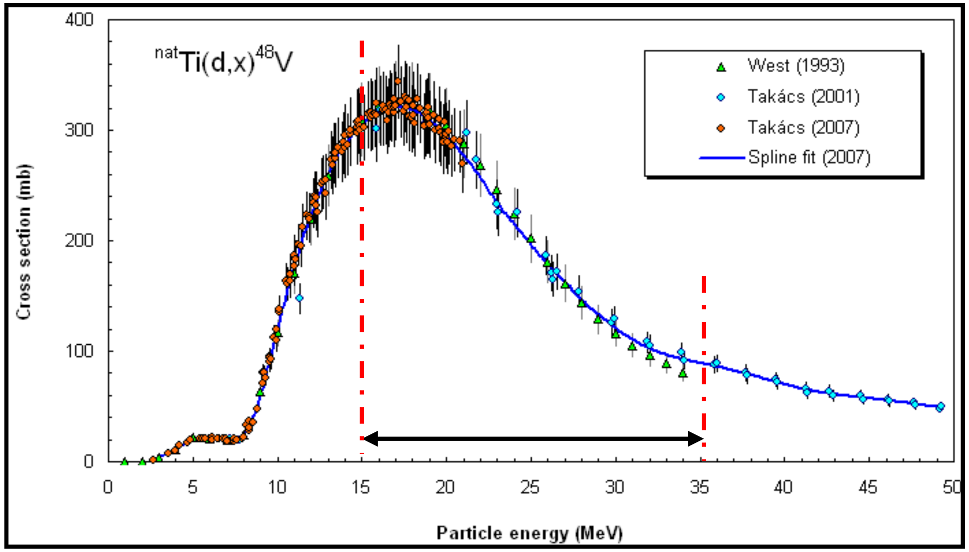
Activity and cross section:

$$\sigma = \frac{Act\,.\,A}{\Phi\,.\,\mathcal{N}_A\,.\,\rho\,.\,e\,.\,(1 - e^{-\lambda.t})}$$

Use of a monitor foil:

$$\sigma = \sigma'.\frac{Act\,.\,A\,.\,\rho'\,.\,e'\,.\,(1 - e^{-\lambda'.t})}{Act'\,.\,A'\,.\,\rho\,.\,e\,.\,(1 - e^{-\lambda.t})}$$

- error on e, e': ≤ 1%
- error on t: negligible



IAEA recommended cross section

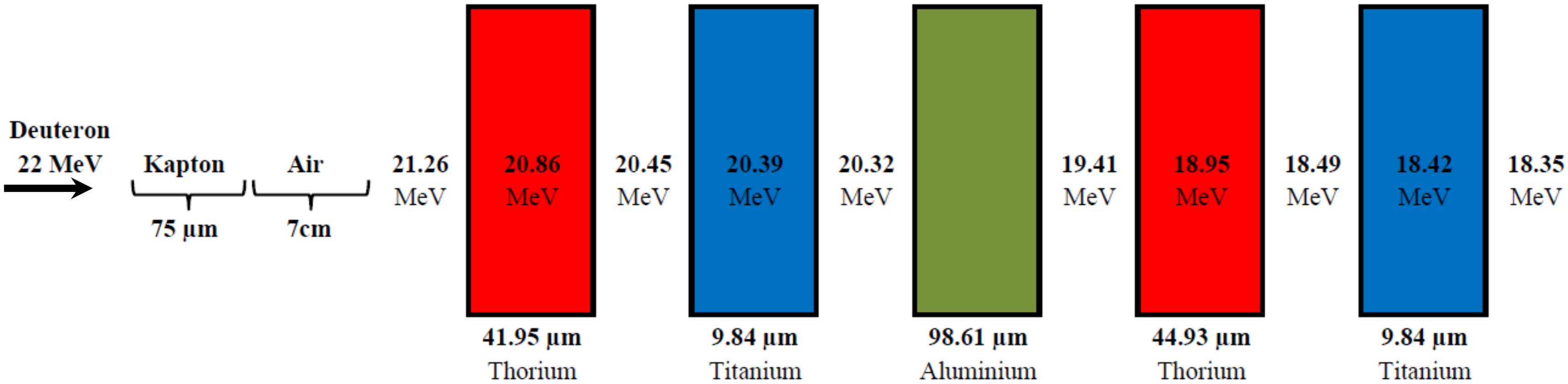
IAEA recommended cross sections:

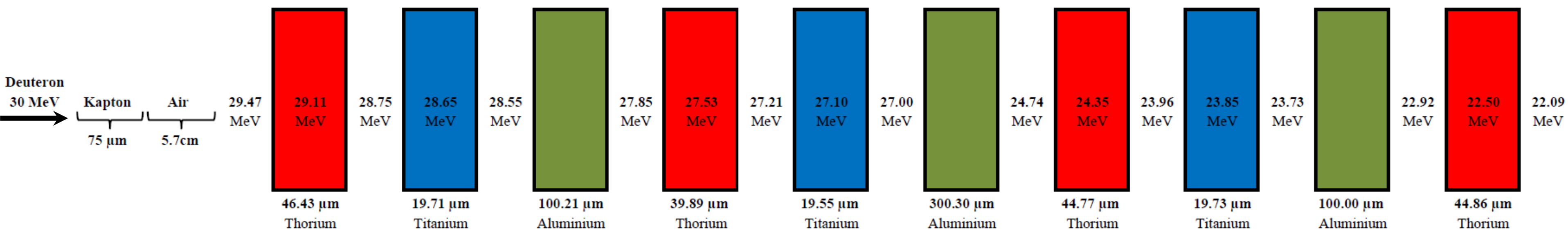
- 5 reactions available for deuteron beam
  - ^{27}Al (2), ^{nat}Fe (1), ^{nat}Ni (1) and
- **^{nat}Ti(d,x)^{48}V**
  - error on σ: ≤ 12%

Stacked-foil set-up

2 stacks irradiated

- **deuteron beam**: 22 and 30 MeV - **intensity**: 100 nA - **irradiation time**: 30 min





- **6 energy points**: 18.95 – 20.86 – 22.50 – 24.35 – 27.53 – 29.11 MeV for ^{230,232,233}Pa

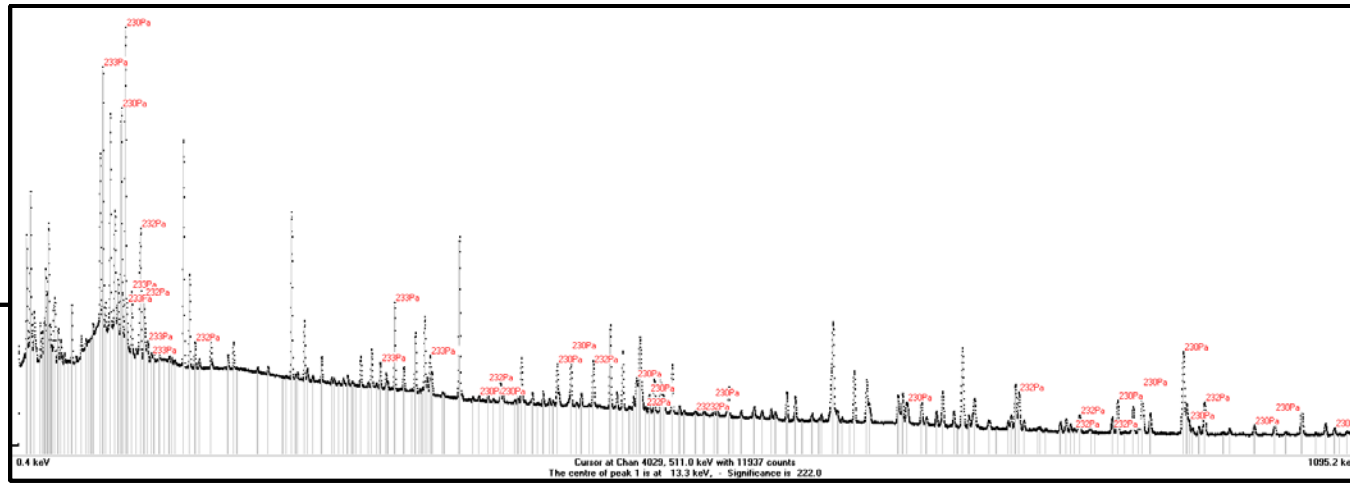
Data measurements

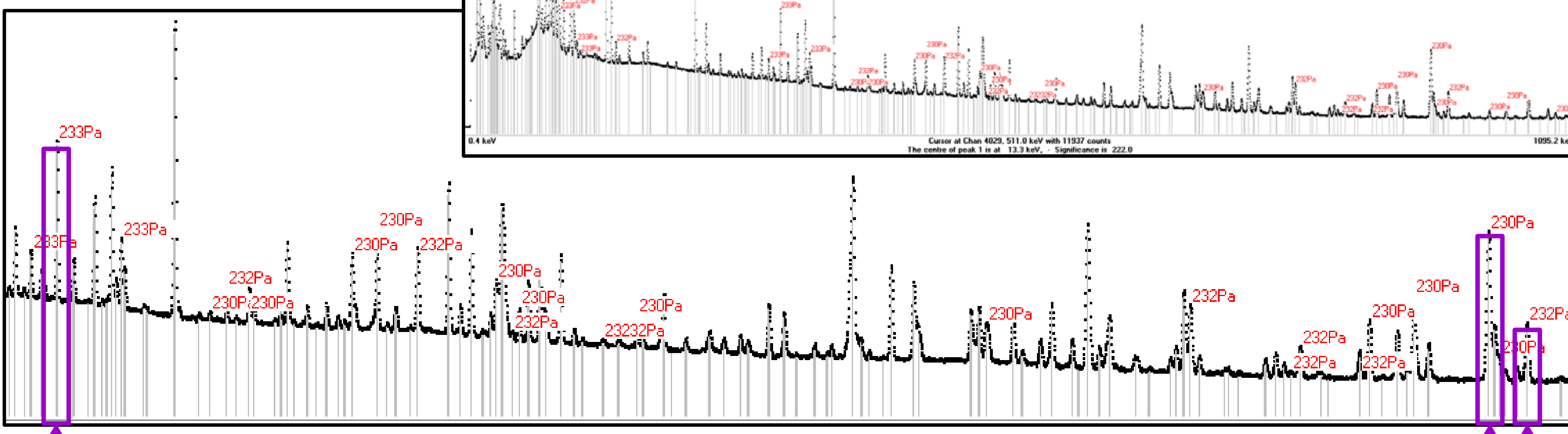
Gamma spectroscopy:

- **HPGe** coaxial detector
- Dead time: < 10% (sum peak)
- Activity values: FitzPeaks
- $T_{1/2}$, E_γ, I_γ: Lund/LBNL, NNDC

- γ spectra recorded on **8192 channels**
- FWHM: 1.04 keV at 122 keV (^{57}Co)
  1.97 keV at 1332 keV (^{60}Co)
- Energy and efficiency calibrations : Co and Eu

- **Target and monitor**:
  - ✓ counted twice
  - ✓ during > 24 hrs
  - ✓ 2 week delay





γ rays used to extract production cross section of ^{230,232,233}Pa

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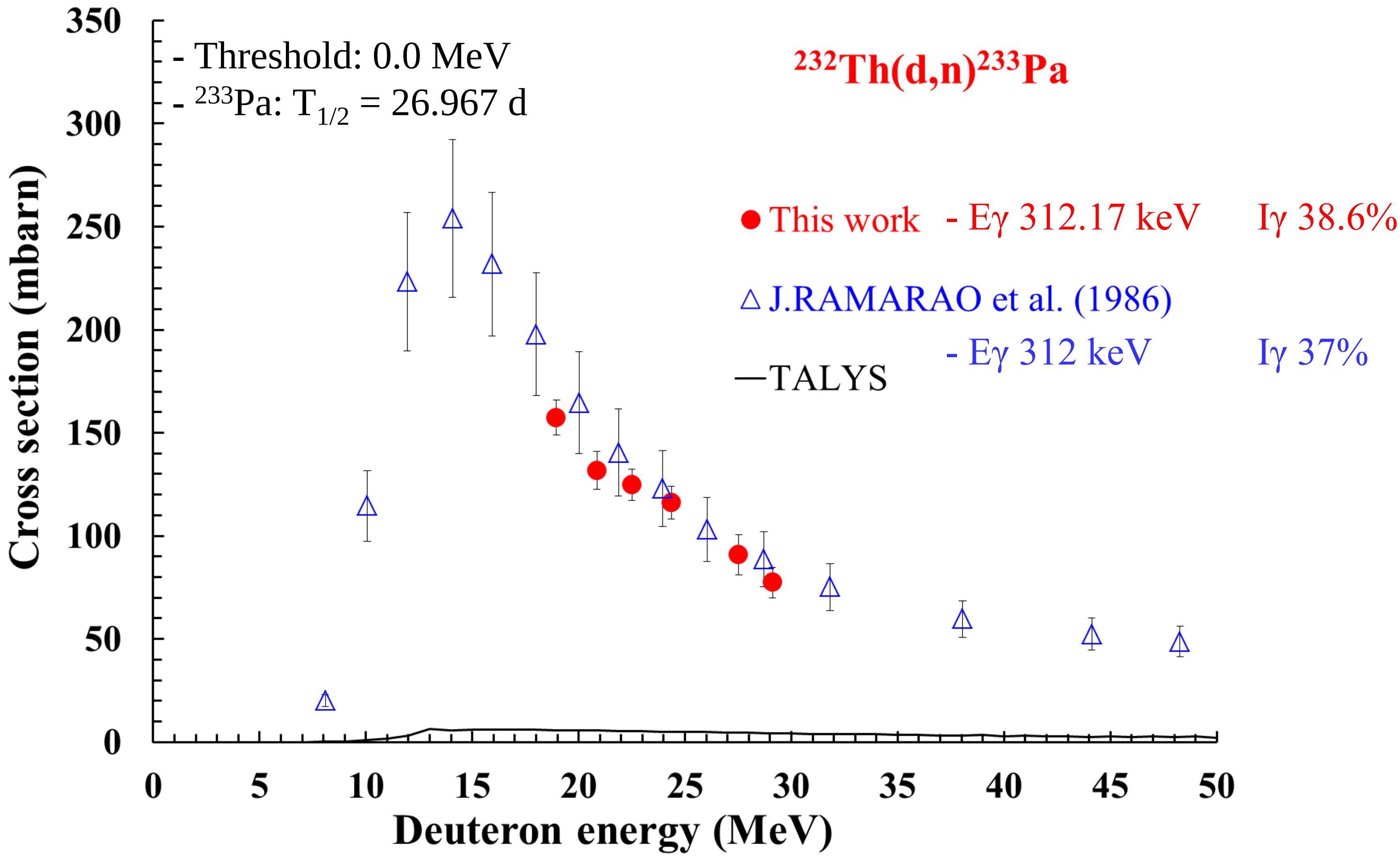
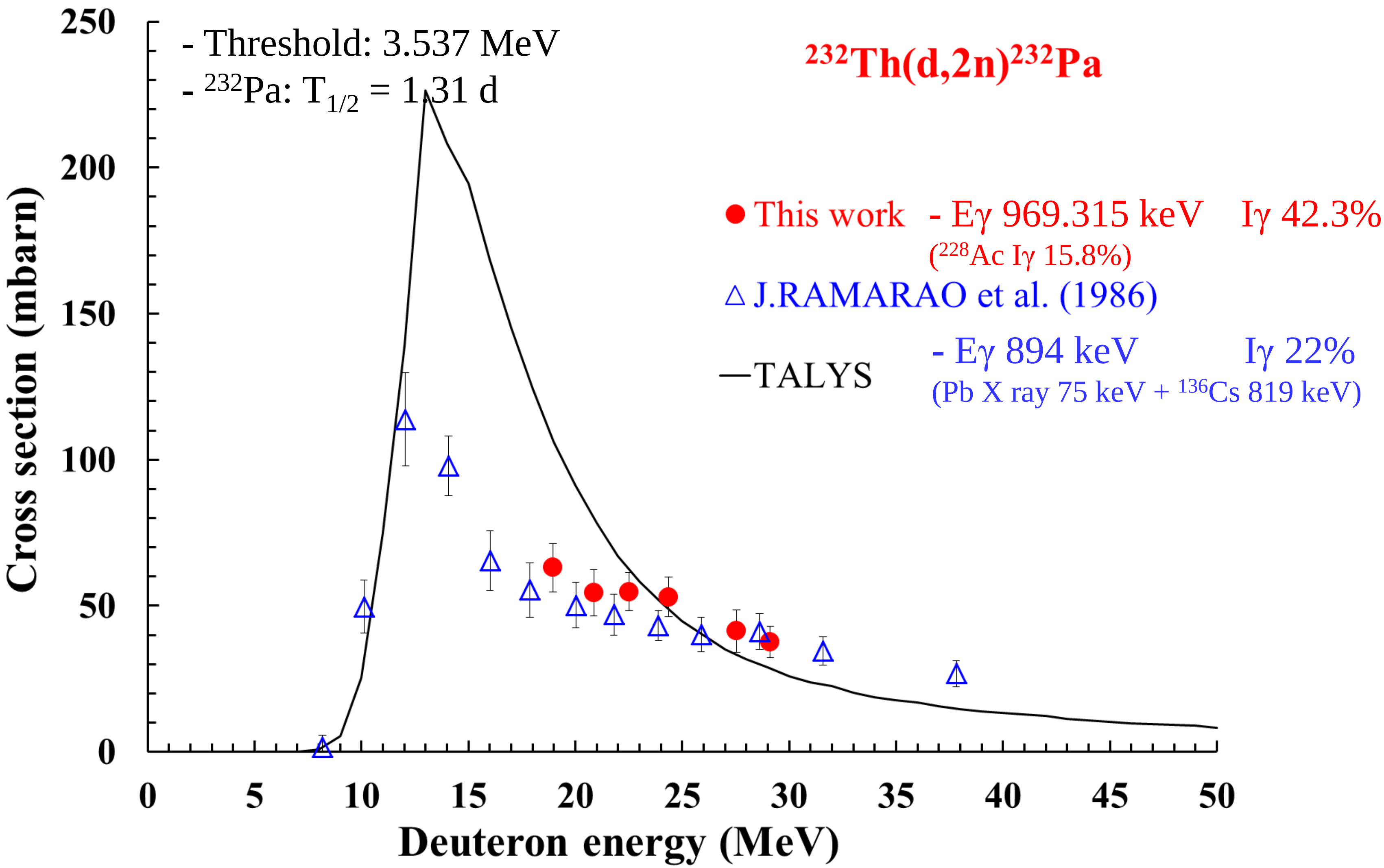
Results and comparisons



- Same trend
- TALYS 1.4, default parameters
- Difference explained by the Iγ update since 1986
- Very low cross section, far from the experimental data

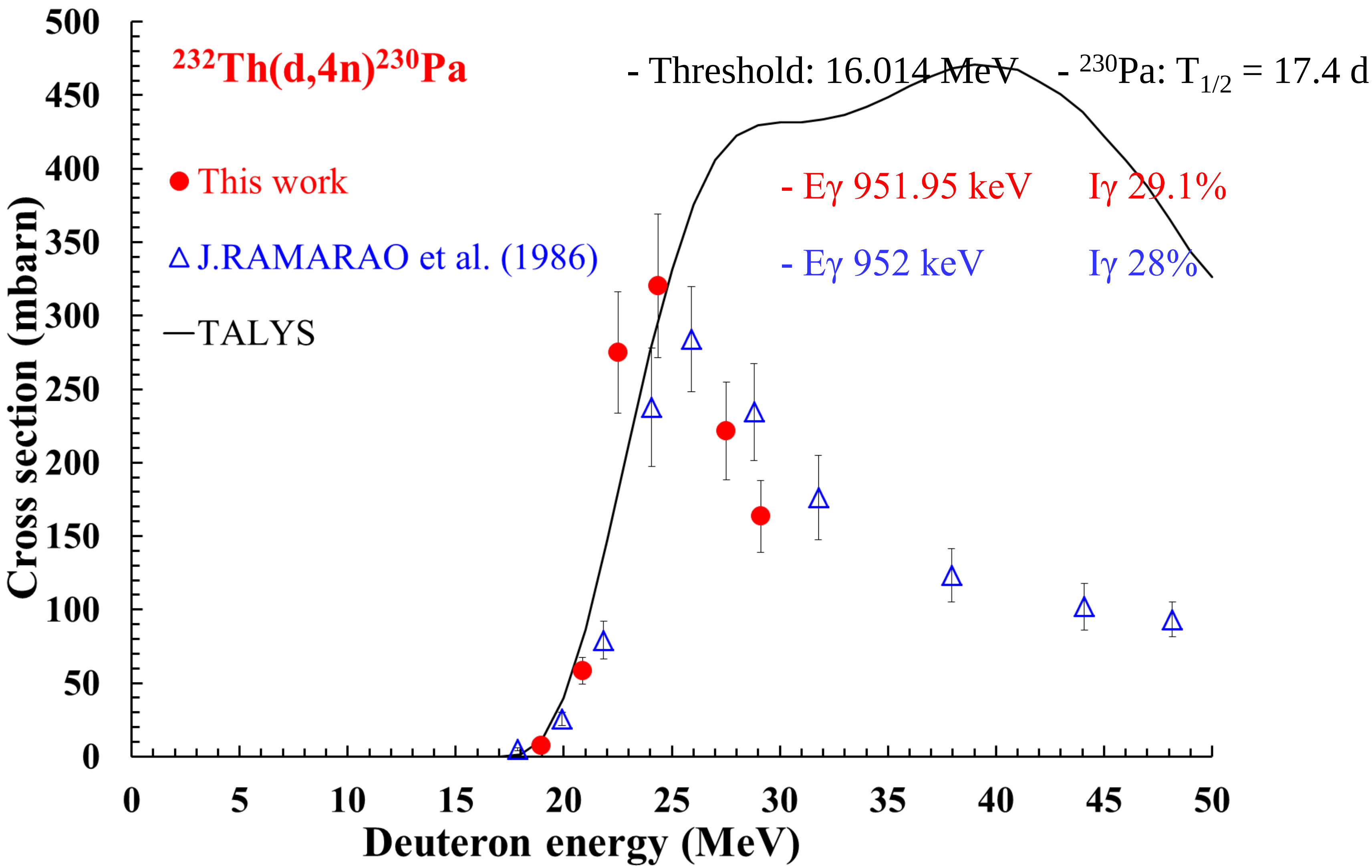
Results and comparisons



- Same trend
- Difference explained by γ line choosen and the I_γ update in database since 1986

- TALYS 1.4, default parameters
- Not in agreement with data even if the shape is not too bad

Results and comparisons



- Same trend but a small energy shift and a maximum value slightly higher
- Difference not explained by the Iγ update in database since 1986

- TALYS 1.4, default parameters
- Neither the shape nor the maximum value are reproduced

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Conclusions and outlooks

Conclusions:

✓ **New data** sets obtained: ^{232}**Th(d,xn)** ^{230,232,233}**Pa**

- compared with J. Rama Rao et al.
  - ^{232,233}Pa: same trends, influence of the branching ratio values
  - ^{230}Pa: same trend, higher amplitude, shift in energy

- compared with TALYS calculations
  - default parameters, no satisfactory results

✓ Also **new data** sets extracted from the monitors: ^{nat}**Ti(d,x)**^{43,44,44m,46,47,48}**Sc**

Outlooks:

✓ **Yield** estimation in Bq/A.h

✓ **Production route** comparison:
- yields
- contaminants
- chemistry

✓ **TALYS** parameter tuning:
- optical models (5)
- level density models (5)
- pre-equilibrium models (4)

Innovative radio-isotope program for PET imaging, β^- and α targeted radiotherapy at ARRONAX is ongoing: ^{82}Sr/^{82}Rb – ^{44}Sc – ^{64}Cu, ^{47}Sc – ^{67}Cu, ^{211}At…

Thank you for your attention

Acknowledgments to the ND 2013 organization committee

^{232}Th(d,4n)^{230}Pa cross-section measurements

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