The Ultra-pure Ti for the low background experiments (production perspectives)

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The main goal of the activity I

Cryostats, containment tanks, and other mechanical parts of the detector are a very important part of low-background detectors. Due to the large mass, requirements on radiopurity are typically stringent.

The development of a reliable source of strong, radioaclean metal suitable for construction of structural mechanical parts for the next generation of low background detectors is of the crucial importance.

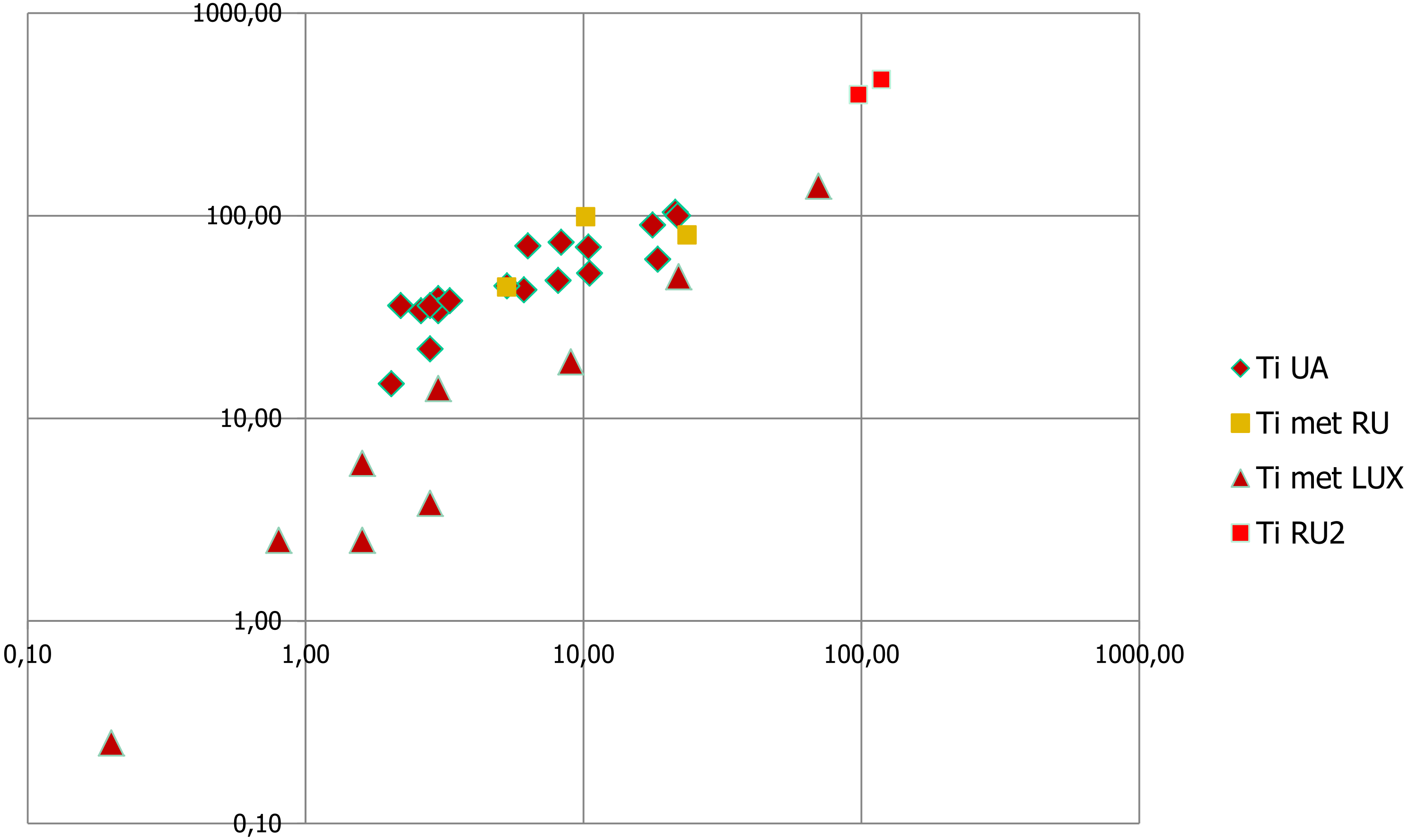
The radioactive contamination has to be lower than 1 mBq/kg of 238U/232Th (0.1 ppb for 238U and 0.25 ppb for 232Th).

Candiidates which already used by different collaborations are:

- Specially selected low background stainless steel
- Electrochemical oxygen-free copper
- Combination of the two
- Specially selected low background metal titanium

The main goal of the activity II

Preliminary analysis of the samples from various sources shows that the levels of contaminations of industrial titanium can be in the range scale from 0.2 to 100 mBq/kg for U/Th.



Our goal is to investigate a possibility **to manufacture** ultra-pure Ti metal and parts from the metal

Analyzed substances

Ti metal samples

Ti alloys RU, UA

Ti flakes

Ti (iodide refining)

Ti (bromide refining)

Ti containing products

TiO_2 powder

$TiSO_4$ water solution

Ti tetrahloride

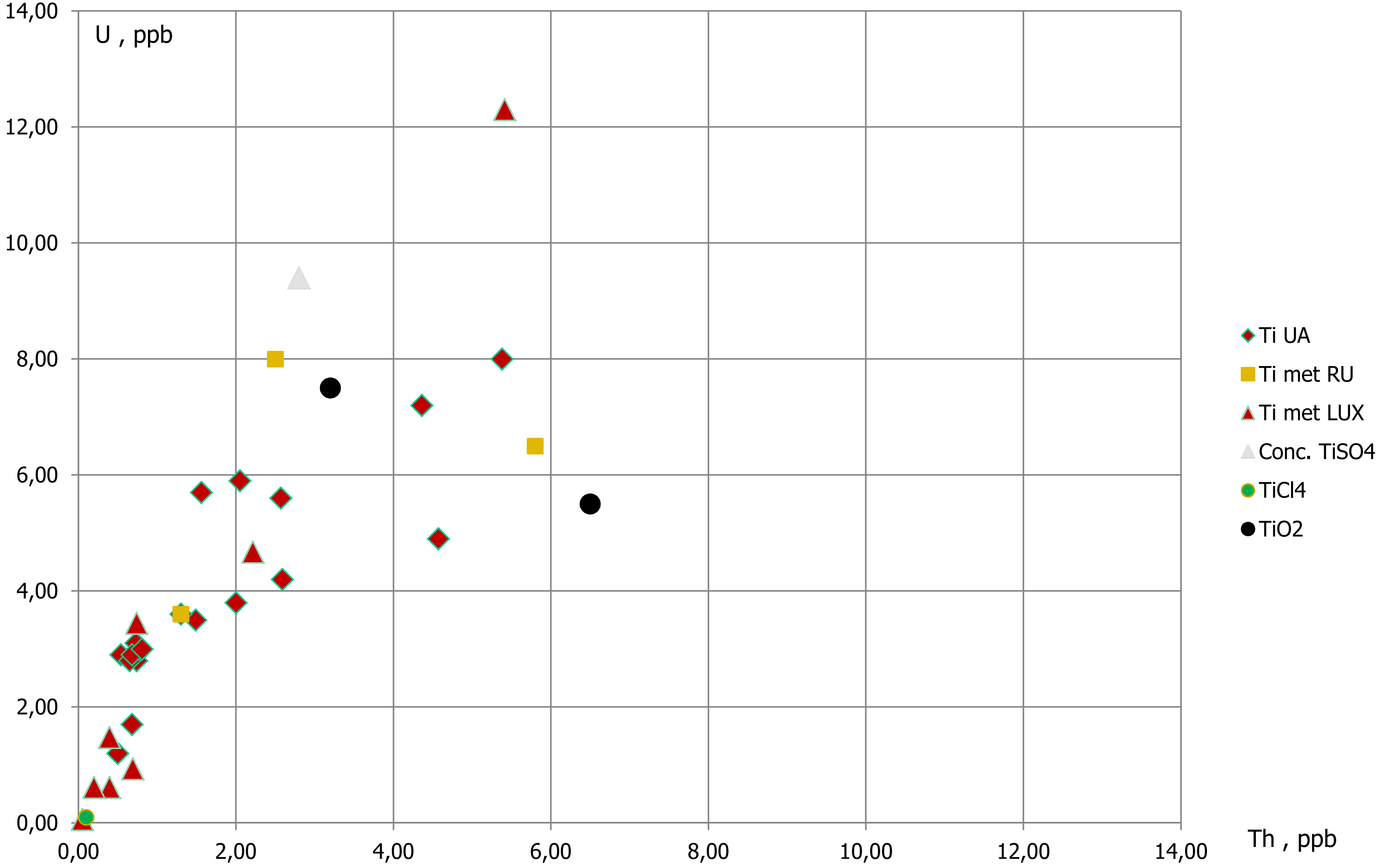
Published data to compare

INR

LUX

XENON

U/Th conc. - below 14 ppb



This work was started within the DarkSide project in 2012

People/organisations involved:

MSU SINP : A.Chepurnov

UCLA: Y.Suvorov

LNGS : A.Ianni, S. Nizi

MSU Chemistry dpt. : I. Seregina

PINP: A. Derbin

TsNIICHERMET: A. Seregin

Institute of Solid State Physics RAS ;

Bauman Technical University (Moscow): I. Shiganov

A. Chub (Solikamsky Magnesium Interprise)

Worldwide Ti industry

- 95% TiO_2 or titanium white (~$200/t)
  - 57% colouring agent for best white colours
  - 21% plastics
  - 14% paper
  - 8% ceramic, catalisators etc.

60% of TiO_2 is produced through $TiCl_4$

- 5% Ti sponge (~$8000-10000/t) - Ti alloys (~$30000/t)
  - alloys and non-ferrous alloys with Ti addings - parts for machinery mainly for aerospace industry, nuclear power plants, submarines, cutting tools etc.

100% of sponge is produced through $TiCl_4$

Natural mineral raw materials of Ti.

Ores:

Ilmenite I (FeO *TiO_2) - 43,7-52,8 % TiO_2.

Rutile, Anatase, Brookite 94,2-99,0 % TiO_2

Loparite 38-41 % TiO_2

Perovskite 59 % TiO_2

Titano-Magnetite

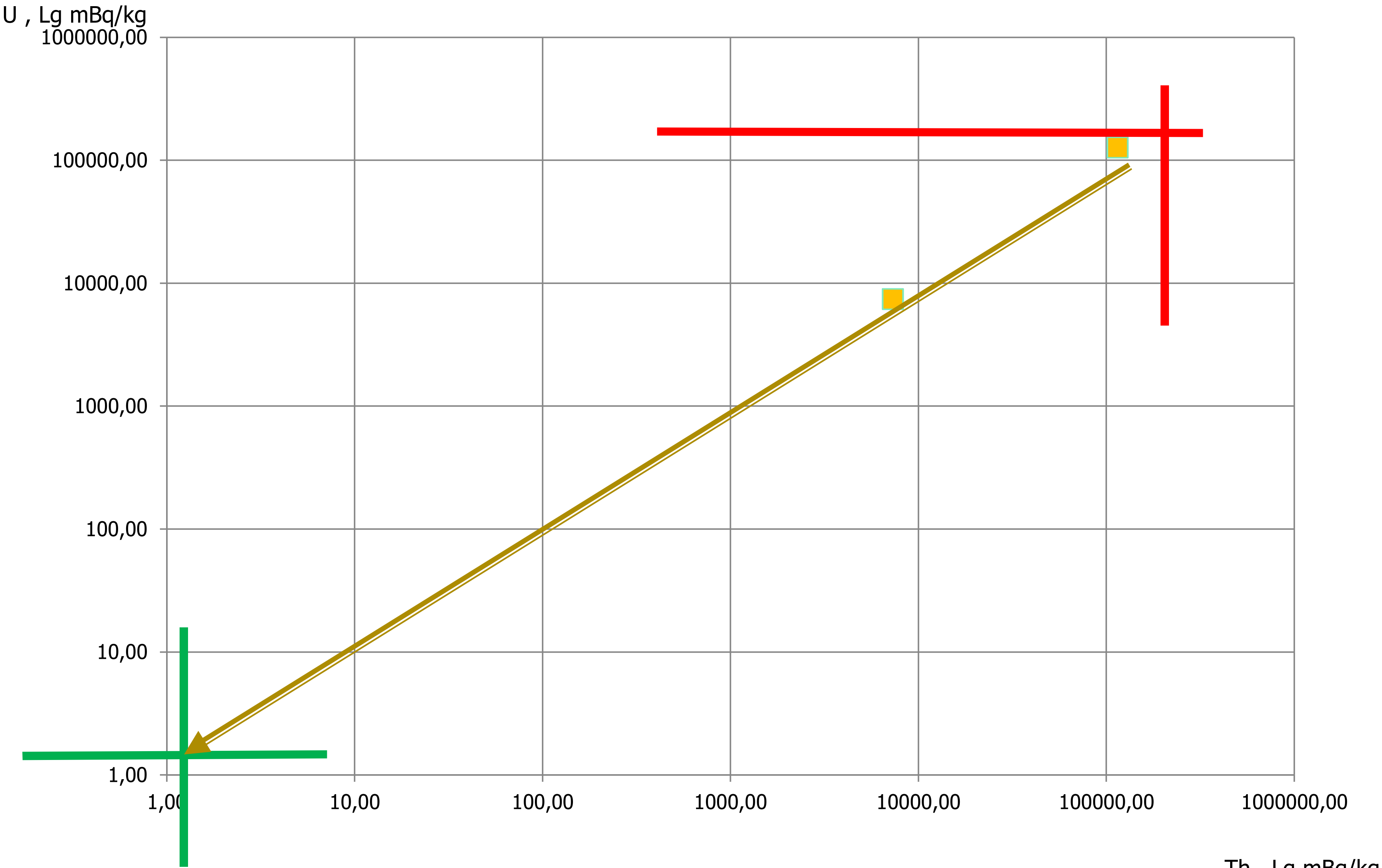
beaches and alluvial sands - commercial development worldwide but <20% of world resources

bedrock deposits in ores belong to the intrusive rock >80% of world resources

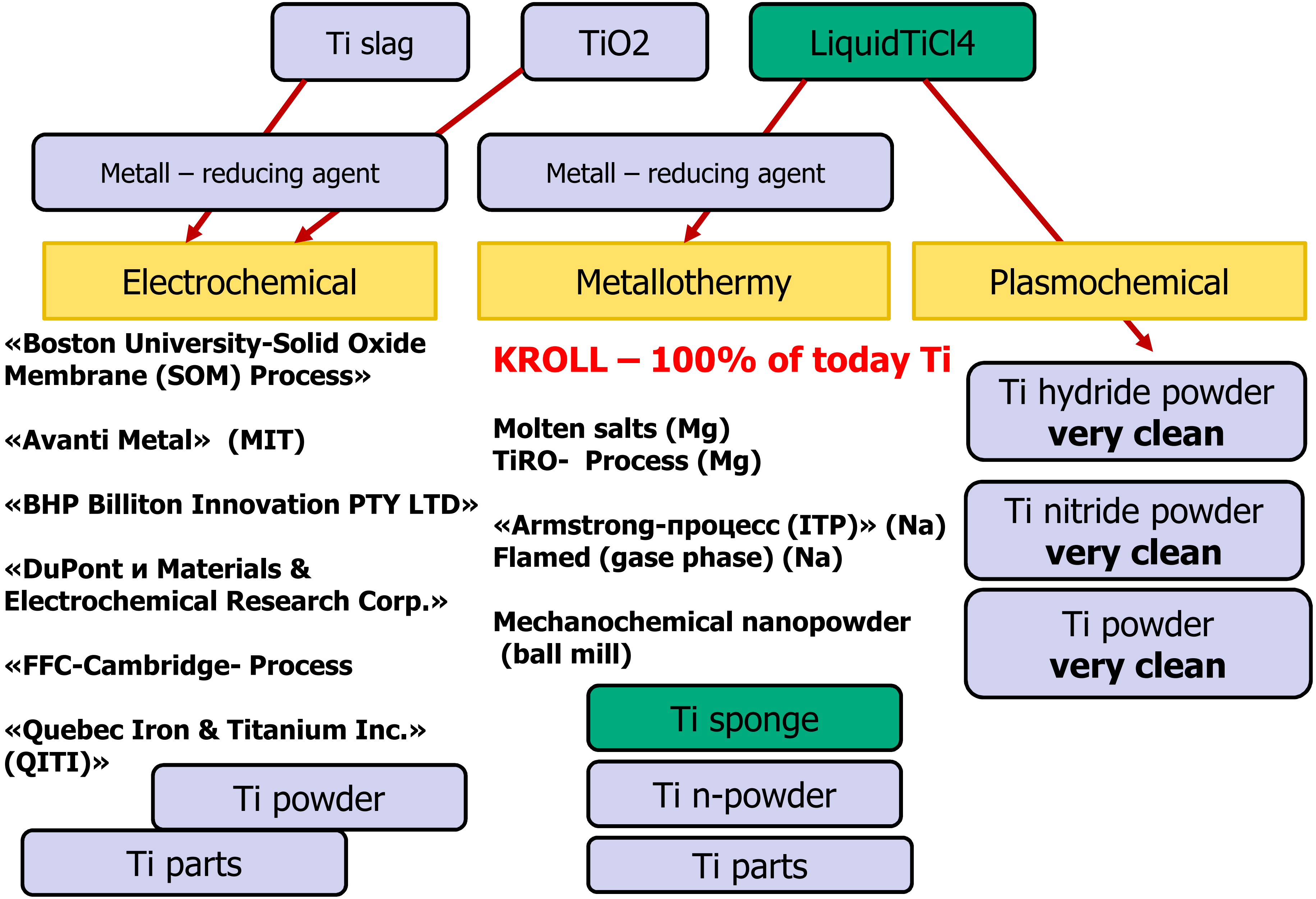
<u>Natural concentration of U/Th</u> "gabbro" U - 0.6*10-4% Th - 1.8*10-4% or
"syenite" U – (4.1-10.3)*10-4% Th – (7.2-28.3)*10-4%

Natural Ti concentrate has natural U/Th radioactivity which depends on the source of the concentrate which is impossible to trace on the stage of Ti metal production

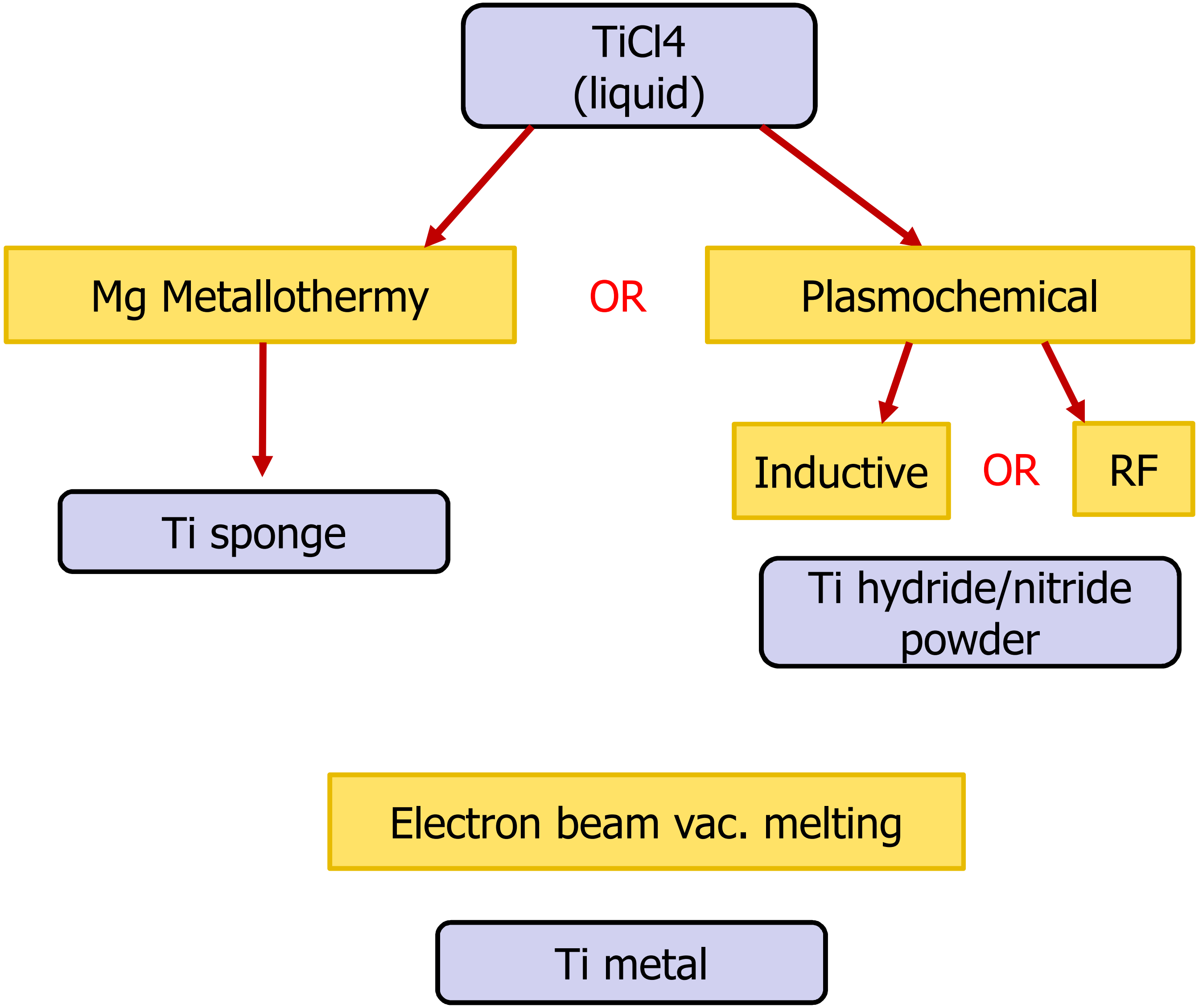
Radiopurity goal is 5 orders of magnitude !



Metal Ti, production cycles



Selected production cycle



Mg Metallothermy

Ti sponge separation, final stage

Sponge block ready for cutting

“Solikamsky Magnievy Zavod”

Solikamsky Magnesium Interprise

Multistage electron beam vacuum melting

Current results

- $TiCl_4$ is selected as candidate and very promising start product It seems that it is available from the market with proper quality

- TiO_2 is selected as spare candidates but it use should be additionally investigated

- two technologies for tetra chloride restoring is under studying

1) Mg metallotermy, via sponge stage (under investigation)

2) plasma chemistry reactor (via nitride or hydrate powder)

    -inductive (less clean, more performance)

    -Rf (more expensive, more clean, less performance)

-- laser cut & welding in Ar atmosphere

Conclusion

It seems to be possible to improve existing production cycles to manufacture ultrapure Ti and avoid selection procedure in future

Next steps

- More Ti metal samples and Ti-containing substances are coming and will be tested
- Lab scale production cycle should be testes
- Contaminations during the mechanical processing should be studied after the samples will be ready

Tasks

1. Investigation of the current Ti production cycle status

- Selection of titanium production cycle with clear U/Th contaminations migration
- Improvement if necessary (and possible) a production cycle which guaranty necessary level of contaminations due to its controllable migration.
- To develop new or reconstruct existing Ti production plant of the scale which match the ultra pure Ti needs.

2. To manufacture necessary parts from ultra pure titanium.

To develop procedure and organize mechanical workshop to manufacture the separate mechanical parts from ultra pure titanium and avoid extra contaminations on this stage.

Ti sponge/alloys trends
(as a reflection of global industrial trends)

“Titanium is a steel of XXI century” soviet academician I.P. Bardin

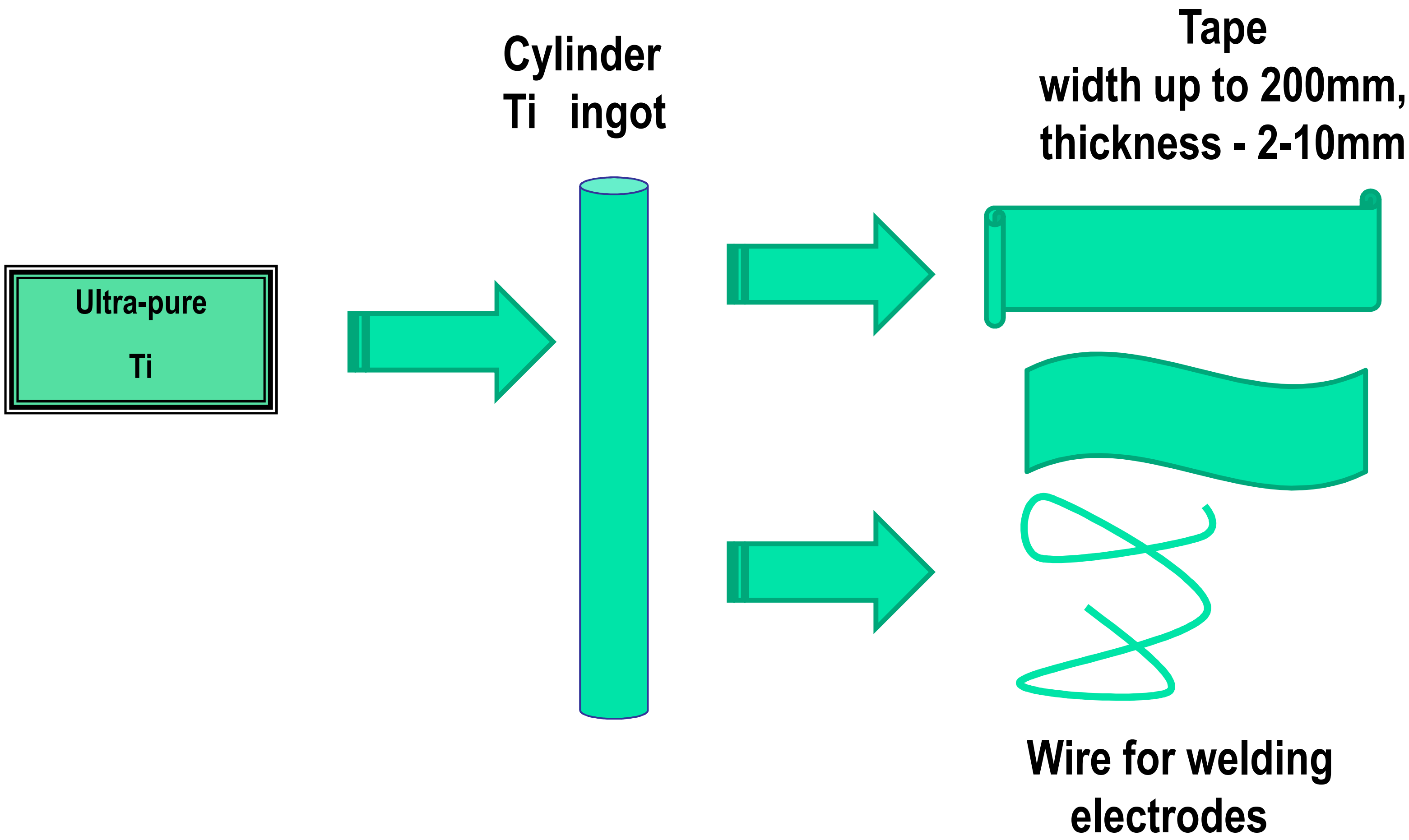
- Development of the new Ti processes to reduce self-cost and to replace stainless steel which self-cost couldn’t be reduced and will increase only (Energy consumption efficiency due to less energy for production and less weight of the product (transport systems etc.))

- Rice in cost and depletion of mineral resources which makes Ti production less profitable and increase its cost.

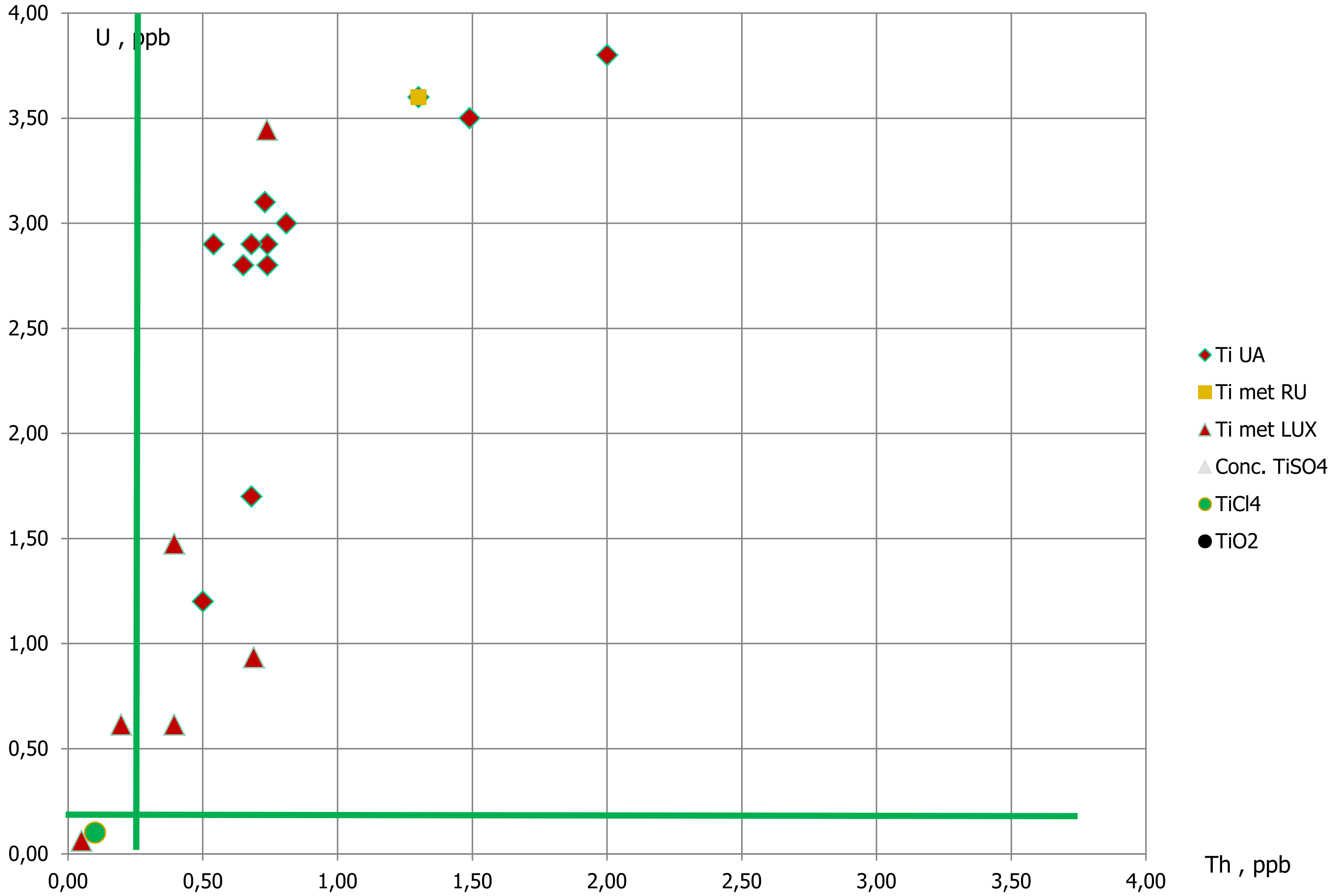
- Ti alloys recycling processes development

More than 10 different new technologies of Ti metal production are under development now worldwide

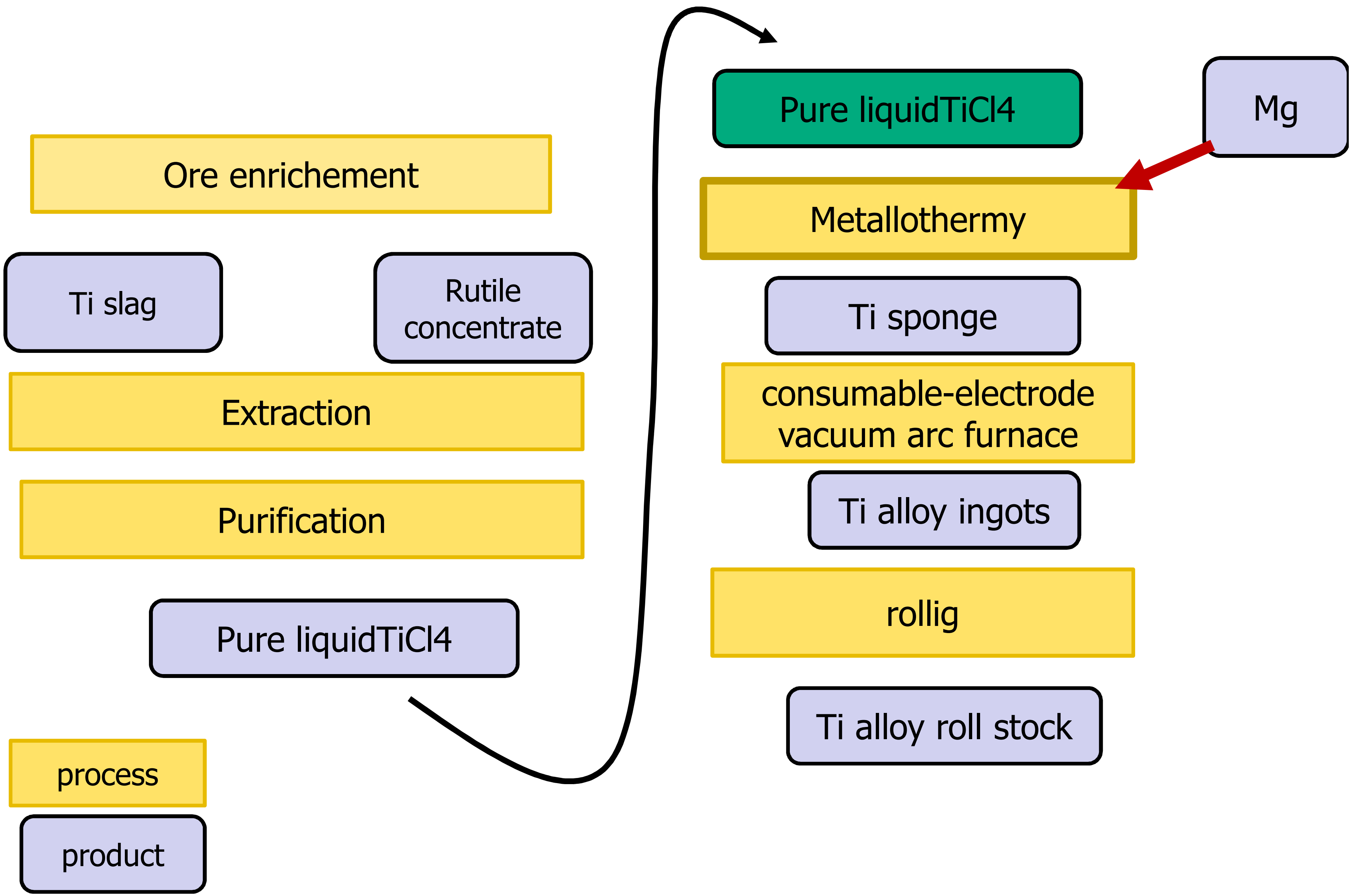
Mechanical processing



U/Th conc. - below 4 ppb



Metal Ti, industrial standard cycle (Kroll)



What are the natural sources of Ti.

Volnogorsky GOK(Ukraine), belongs to «VSMPO-AVISMA Corporation» (Russia)

Ilmenite

Rutile concentrate