What Next meeting at LNGS

(tavola rotonda "Cristalli Radiopuri")

Procurement problems related to scintillating crystals for rare events physics experiments

I. Dafinei

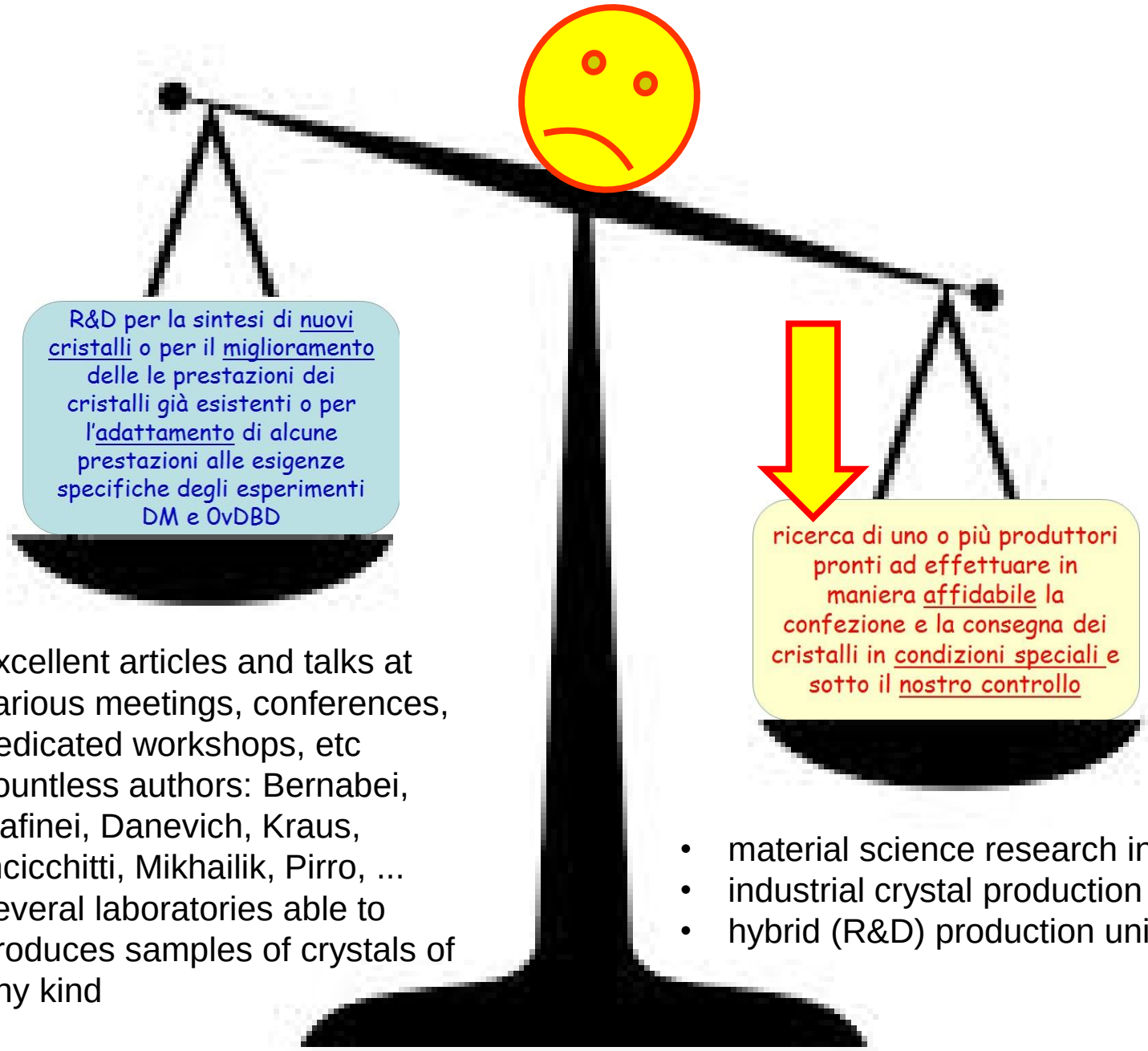
INFN – Roma

chiarimento semantico

la ricerca per cristalli da utilizzare nella fisica degli eventi rari (REP)

R&D per la sintesi di nuovi cristalli o per il miglioramento delle le prestazioni dei cristalli già esistenti o per l'adattamento di alcune prestazioni alle esigenze specifiche degli esperimenti DM e 0vDBD

ricerca di uno o più produttori pronti ad effettuare in maniera affidabile la confezione a gande scala e la consegna di cristalli in condizioni speciali e sotto il nostro controllo



- excellent articles and talks at various meetings, conferences, dedicated workshops, etc
- countless authors: Bernabei, Dafinei, Danevich, Kraus, Incicchitti, Mikhailik, Pirro, ...
- several laboratories able to produces samples of crystals of any kind

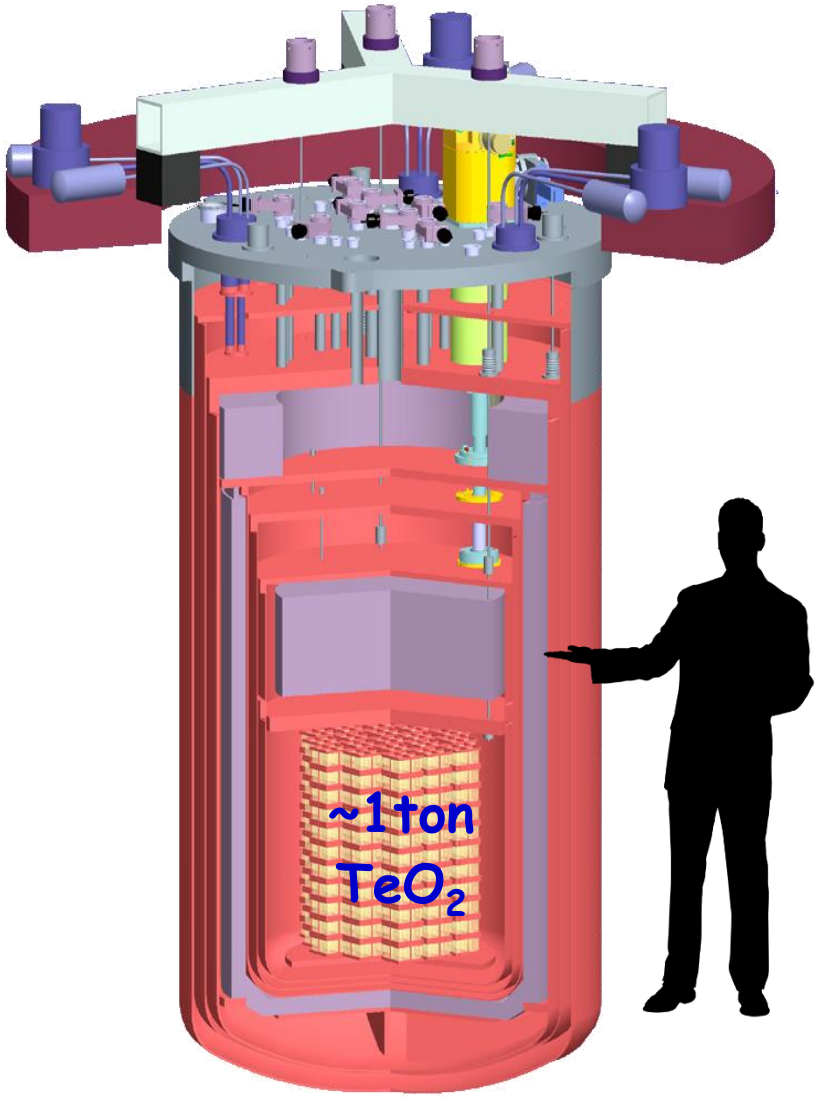
- material science research institutes: ?
- industrial crystal production units: ?
- hybrid (R&D) production units: ?

brevi cenni storici

- the history of crystals procurement for REP comes from far, it was preceded by the activities related to the production of scintillating crystals for HEP. The latter was quite a successful experience (though lately not everybody agrees on this matter …)
- REP physiscists have to understand how did it work and why was it possible also because they are seen at a first approach by the crystal growers community as people coming from the same field and treated as such. Nevertheless the differences are huge:
    - different characteristics
    - different production conditions
    - different production scale
- INFN pathfinder in the field: DAMA, CUORE, GERDA, CREST, etc.

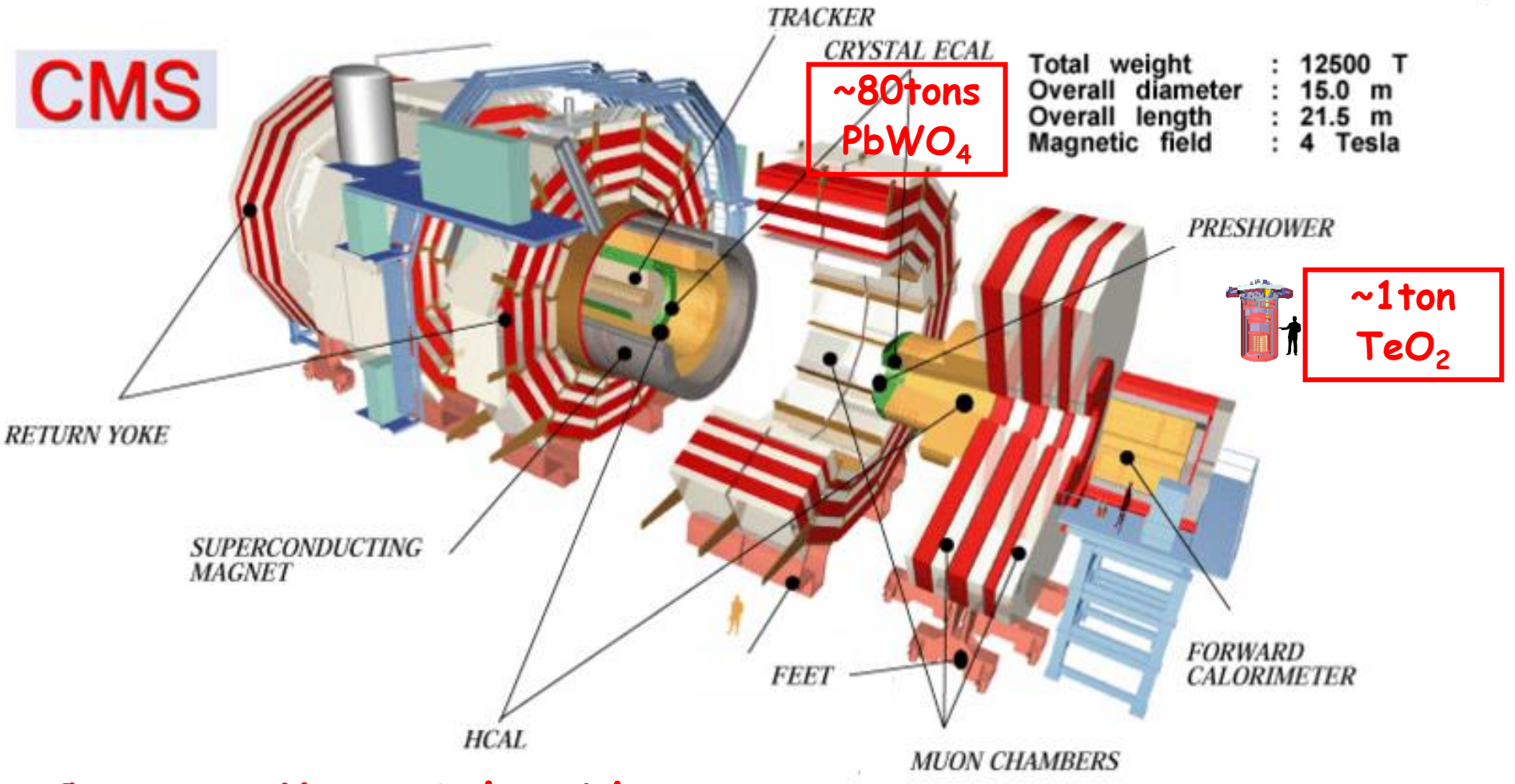
technological challenge

CUORE



~1 ton
TeO_2

technological challenge



Compact Muon Solenoid

crystal production for REP

R&D activity for new/improved crystals

very rich litterature

(expression of the greatest interest of the scientific community on this topic)

1. V. B. Mikhailik and H. Kraus, Performance of scintillation materials at cryogenic temperatures, Phys. Status Solidi B 247, No. 7, 1583–1599 (2010) / DOI 10.1002/pssb.200945500
2. F. A. Danevich, Development of Crystal Scintillators From Enriched Isotopes for Double β Decay Experiments, IEEE Trans.Nucl.Sci., Vol. 59, No. 5, October 2012, 2207
3. Rita Bernabei et al., DAMA experiment related articles
4. V. Shlegel, E. Galashov, et al. (NIIC Novosibirsk) works on oxyde crystals
5. S. Galkin, V.D. Ryzhikov, et al. (ISMA Kharkiv) works on AIIBVI crystals
6. .....

serial production of crystals for rare event physics application…

… not so many examples :-(

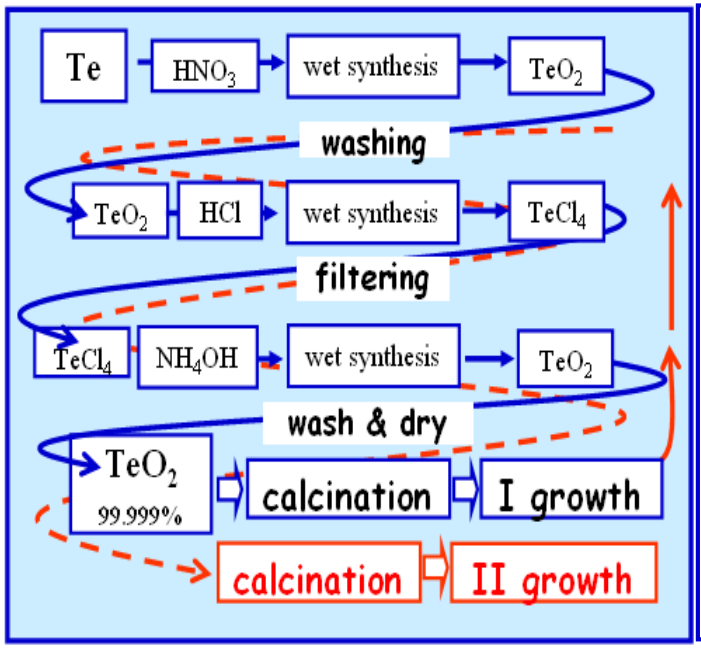
large scale production

CUORE case

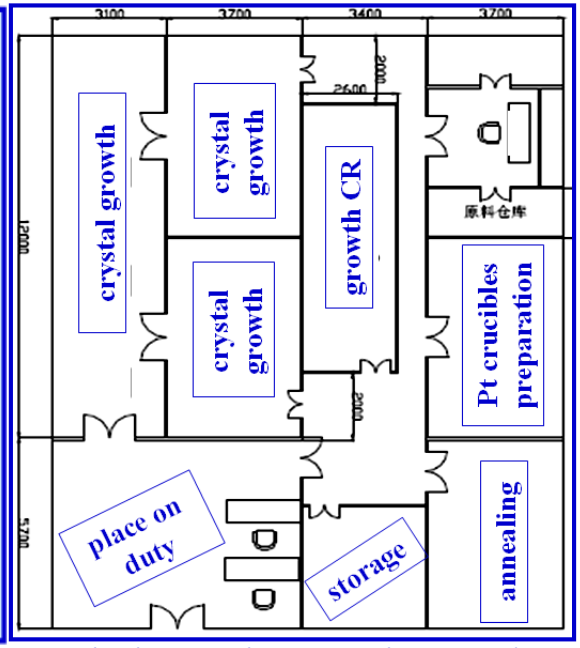
- *C. Arnaboldi et al., J.Cr.Gr. 312 (2010), pp. 2999-3008*
- *I. Dafinei, RPSCINT 2009*

only 2-3% crystals can be measured

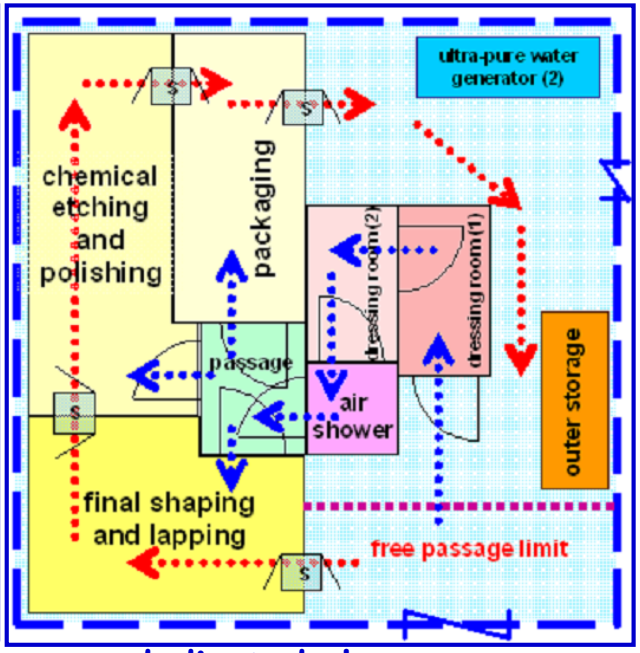
precautionary principle: raw materials, reagents, intermediary products, processes and procedures



dedicated TeO2 synthesis facility @ Kunshan Chemical Plant



dedicated crystal growth facility @ SICCAS Jiading



dedicated clean room SICCAS/INFN @ Jiading

dedicated production protocols
- -environment conditions
- -equipment and infrastructures
- -materials handling

dedicated measurement protocols
- -dimensions
- -crystal perfection
- -radio-purity

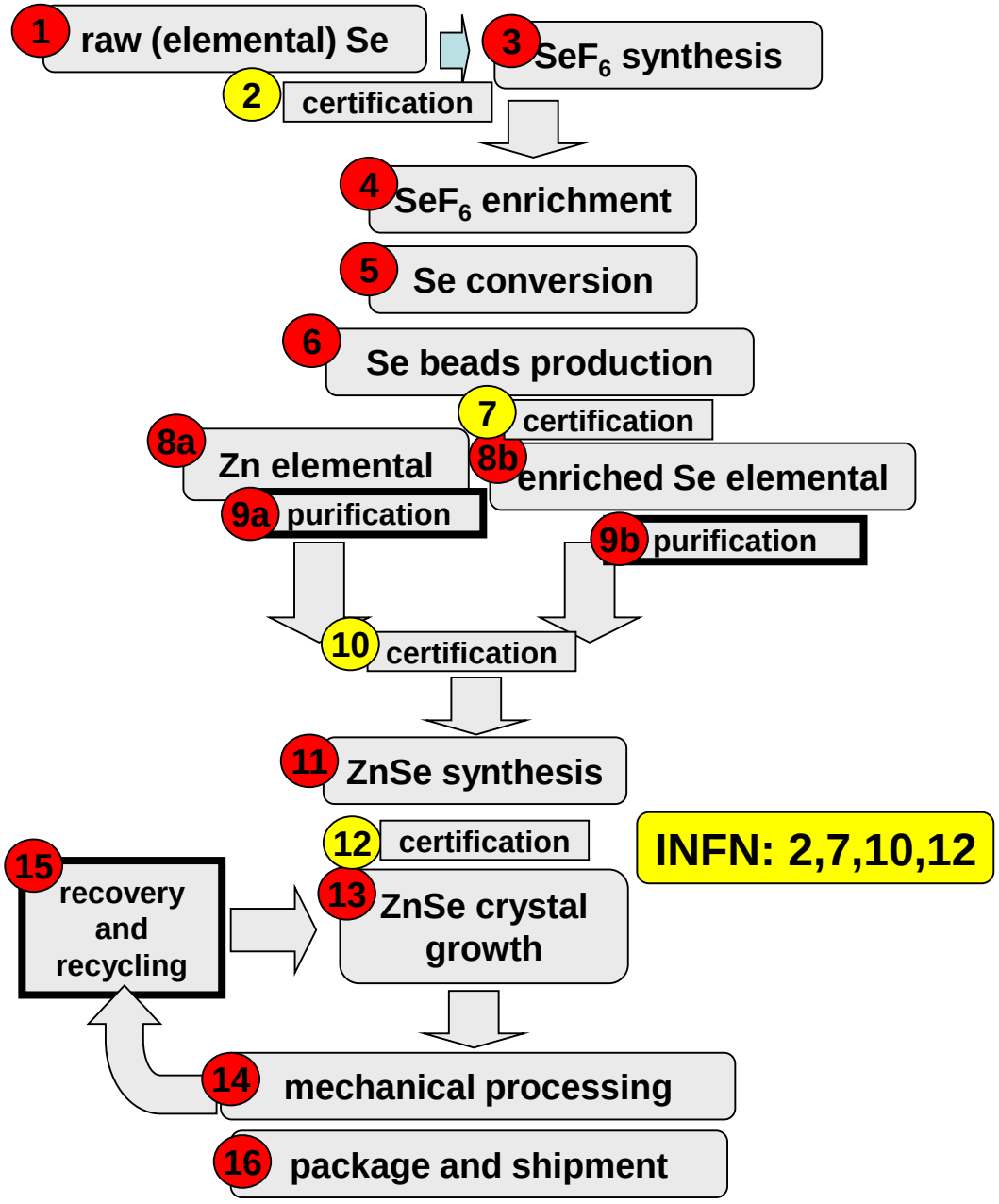
perspective of scintillating crystals

- question:
  - is it feasible a similar enterprise in the case of scintillating bolometers?
- answer:
  - TeO_2 crystal was a lucky case:
    - industrial scale production already existed
    - easy implementation of improvements imposed by DBD application
    - long term existing market for high quality crystals
  - scintillating crystals for DBD is a more complex case:
    - no scintillating material for DBD use was produced at large scale till now
    - some of the problems to be addressed were solved in the case of TeO_2 crystal production
    - work still needed for a reliable production
    - the use of enriched materials demands very low loss coefficients in all phases of the production
    - lack of reliable producer

$Zn^{82}Se$ case

main requests:

- raw materials of high purity:
  - chemical (ppm level)
  - radio.chemical (below ppt level)
- efficient synthesis of the compound
  - high yield
  - high quality (chem. and phys.)
  - good reproducibility
- crystal growth
  - high yield
  - high quality (crystal perfection)
  - high light output at very low temperature



summary

- “search for crystals” means nowadays finding reliable producers. In this respect INFN had a successful experience (beginner's luck?) with CUORE crystals produced by SICCAS, China. It was learned in this occasion (also in contrast to other subsequent cases) that the very strict control of production conditions is important but also the management/sales politics of the producer (openness/readiness to cooperate) and the local political/bureaucratic background play a fundamental role.

- concerning the crystals needed for the next generation detectors:
  - first (relatively) large scale enrichment at a western company (Urenco)
  - several promising materials (oxides and AIIBVI compounds)
  - difficult implementation of large scale production
    - technological constraints (relatively large dimensions, chemical purity, radio-purity, high reproducibility, high production yield)
    - potential producers have extremely unstable managements and are located in countries with very heavy bureaucracy

cristalli per REP

- scarso interesse dell'industria di settore (reagenti e materiali speciali) a causa delle richieste troppo spinte e la mancanza di un possible mercato per tali prodotti

- poco interesse per la ricerca di settore: non ha sufficiente rilevanza "scientifica" il fatto di aver migliorato la (radio)purezza di un cristallo con tre ordini di grandezza sotto la soglia richiesta in qualsiasi altro campo "di interesse" (industriale, medicale, sicurezza, etc.)

how to proceed?

chi vuole fare un esperimento REP basato su cristalli, deve avere la propria unità di produzione cristalli e materiali speciali

minimo necessario per una tale struttura:

- unità di stoccaggio (sotterranea): simile alla PSA di CUORE
- unità di produzione materiali e dispositivi speciali (in superficie):
  - preparazione/condizionamento delle materie prime
  - crescita cristalli e trattamenti termici post crescita
  - produzione dispositivi speciali (evaporatore per deposizione di film sottili)
  - lavorazione meccanica dei cristalli (taglio lucidatura)

dettagli tecnici:

- apparecchiature: forno ad atmosfera controllata per reazioni chimiche in fase solida; forno per reazioni di sintesi; ; impianto no.1 crescita Czochralski in atmosfera controllata (Ø15mm); impianto no.1 crescita Czochralski in atmosfera controllata (Ø80mm); impianti crescita Bridgman in atmosfera controllata (impianto purificazione “zone melting” in atmosfera controllata; evaporatore per deposizione di film sottili; macchine da taglio (a filo e a disco); lappatrici; cappa chimica aspirante; pompe da vuoto; attrezzature di laboratorio chimca; attrezzature per imballaggio sotto vuoto, etc
- utenze speciali: impianto elettrico di potere previsto di gruppo continuità; impianto ventilazione e impianto di scarico per cappe chimiche; impianto produzione acqua demineralizzata ed ultrapura; camera pulita (classe 100, S = 5x5 m2)