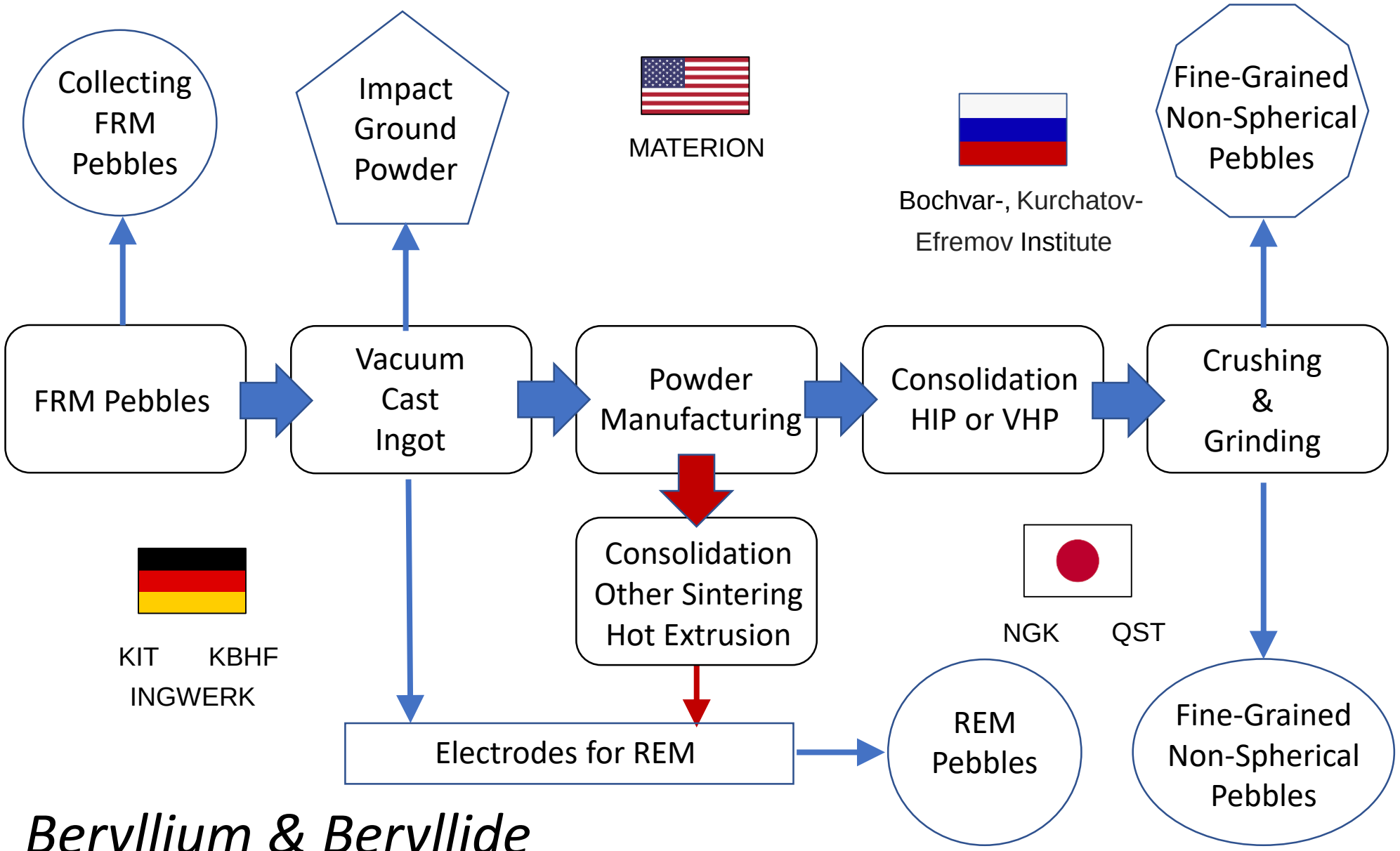

FusNet PhD event 2018
QST
KIT
Karlsruhe Institute of Technology
KBHF
NGK
NGK INSULATORS, LTD.
MATERION
INGWERK
Be4FUSION
Industrial Forum
BeYOND
Communication
KBHF
Innovation
"Spin In" @ KIT
found 2009
MKP
Vision
Club found
2000
GVT
Creation
Engineering
office found
1993
Catch the Star
Without you, FUSION will remain an Experiment,
that is why we have to think BeYOND

Production Flowchart

Pure Beryllium



Beryllium & Beryllide

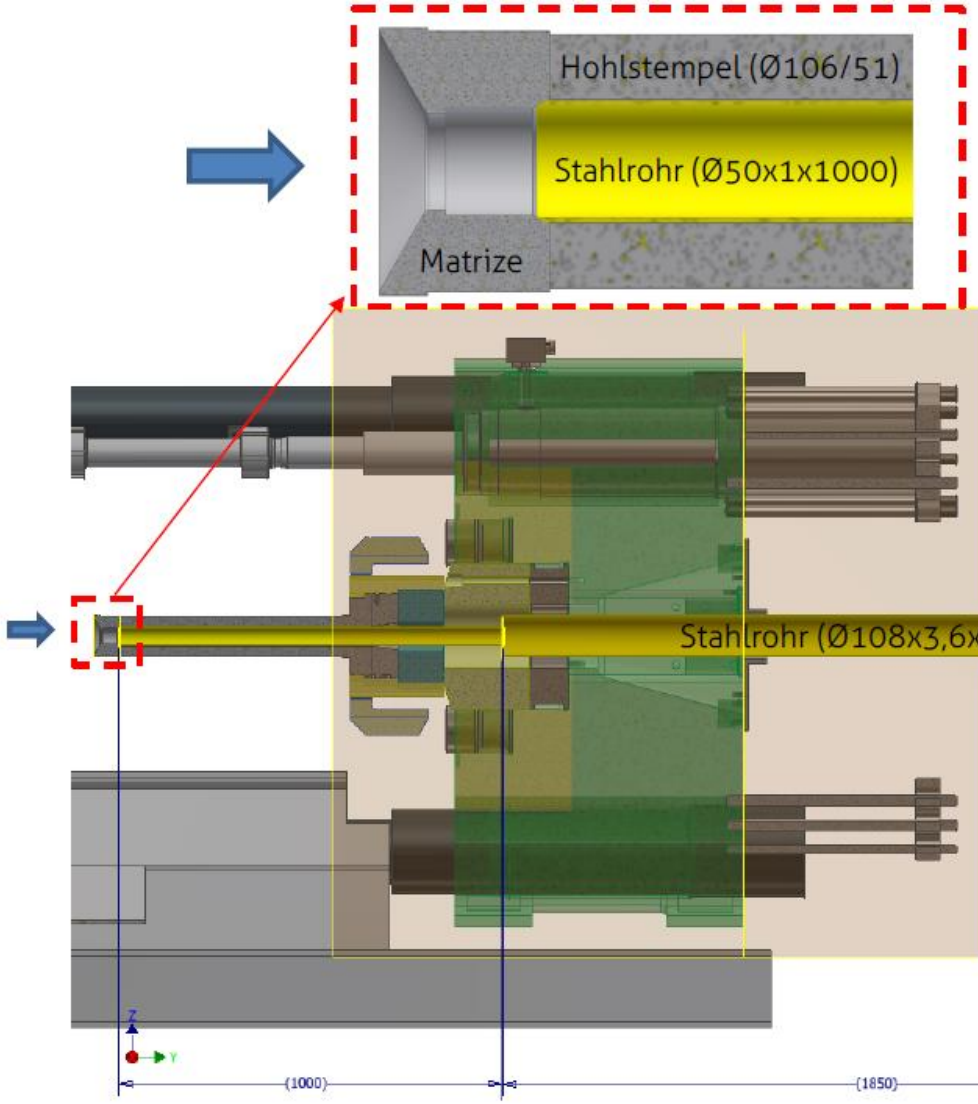
2018, state of the art

- NGK pebbles produced by REM are reference material for a Helium-Cooled-Pebble-Bed-Blanket
- For ITER a water-cooled version of TBM is foreseen but pure Beryllium causes safety problems
- A lot of different Beryllides have been tested and ways to produce them, as well
- The production of pebbles by REM process seems promising for production of ITER amounts
- Beryllides based on Beryllium and Titanium have gone through a long qualification process

- **Thanks to KIT support we could go a big step towards production conditions in 2018**
- Together with Chris Dorn from Be4FUSION, a white paper “pebble production” was written
- The assumptions were confirmed by our international partners QST, NGK and MATERION

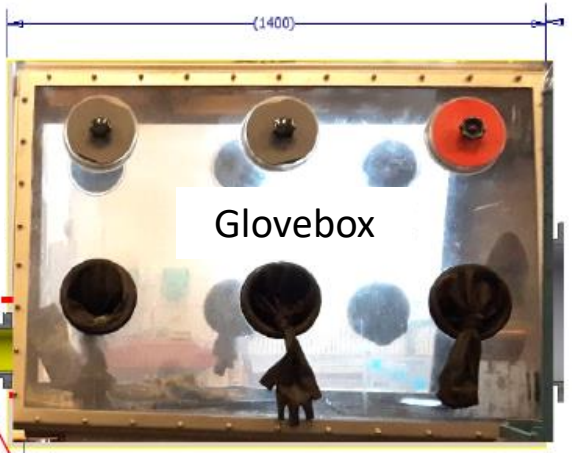
Now, it is about time to involve industry and start a feasibility study

Indirect hot extrusion of Be-Ti capsules



- Taking place at the Research Center for Hot Extrusion
- It is located at the TU-Berlin
- KBHF has provided a Glovebox for safety reasons
- It is in direct connection with the press
- The Bellow can take the backstroke of the machine

Bellow



Results confirm the validity of the assumption

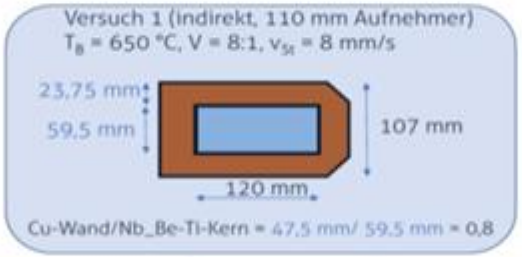
- For ITER it will be possible to produce the relevant amounts of Beryllium and Beryllide pebbles
- Maximum capacity we can get seems to be in the range of 100 Kg/year, depending on price
- MATERION can collect pure Beryllium pebbles from their existing pebble plant by sieving
- In this case the outcome depends on the diameter range but the mentioned amount is realistic
- From what I have seen, in the near future a quantity of 2 Kg/week might be possible by REM
- What has to be tested now, is how the yield of pebbles is depending on the electrode diameter
- **Together with the TU-Berlin we have produced 3 rods with different sizes by hot extrusion**
- We found out that we will reach all limits with a rod of 30 mm diameter and 150 cm length
- It would contain 1.5 Kg Beryllium-Titanium composite, the maximum we can handle at KBHF

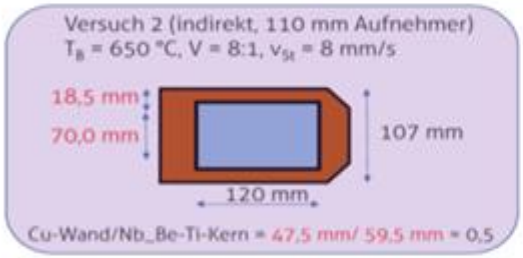
INGWERK a spin-off at TU-Berlin has already offered to produce 100 pieces per year

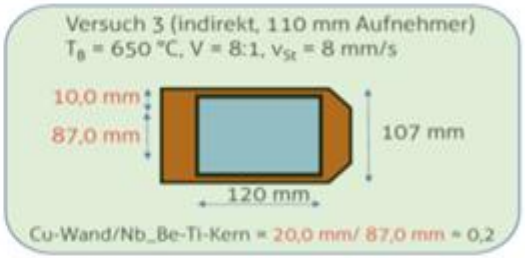
2018, state of the art

Experiments performed to reduce the wall thickness of CuCrZr

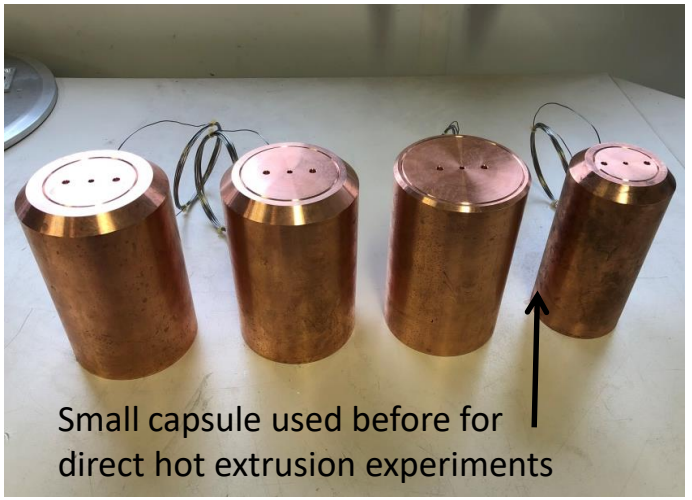
INGWERK







Capsules filled and closed by welding at KBHF facility



Small capsule used before for direct hot extrusion experiments

The integral way of viewing things

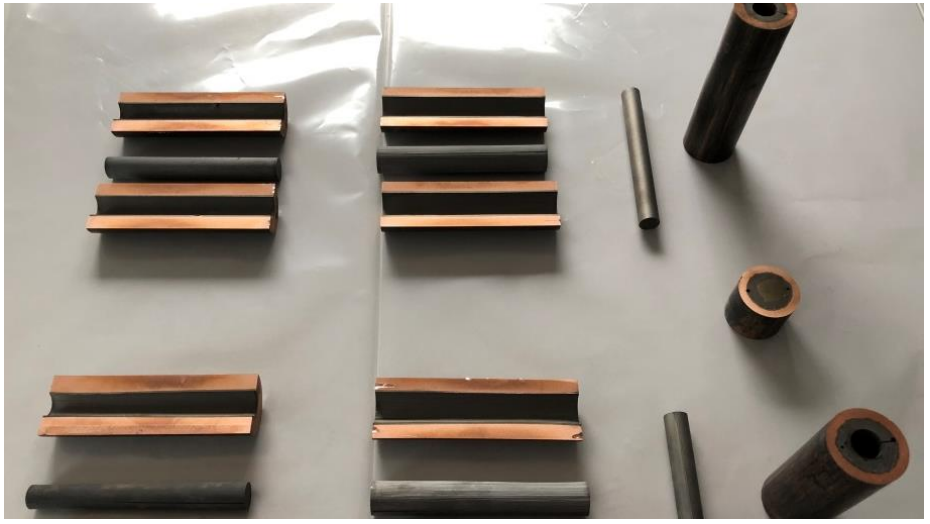
Pure Beryllium:

- A “Shotting-Process”, similar to “melt & spray” was tested at MATERION, but difficult to handle
- There is one other process not yet mentioned but possible: Crushing a block and grinding
- MATERION has “Impact ground” powder available that is produced from cast material
- Our Russian colleagues from Bochvar-Institute have also produced some material in the past
- Russian material has a fine grain structure, because it is crushed from hot-pressed block
- So it might be an option for pure Beryllium in case that tritium release properties are in focus
- BUT: issues for large-scale use that are critical to feasibility in DEMO, will not matter for ITER

Beryllide:

Only REM meets the criteria so far, the question is what can be done to simplify the production

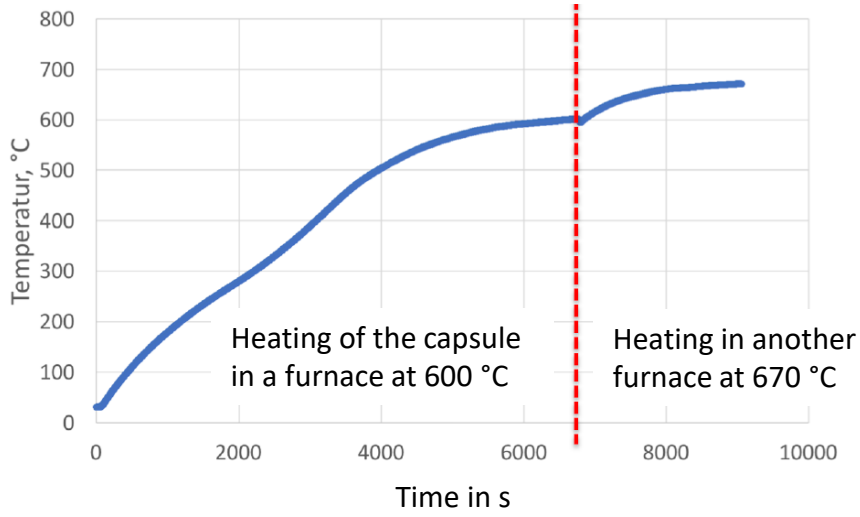
Results confirm the validity of the assumption

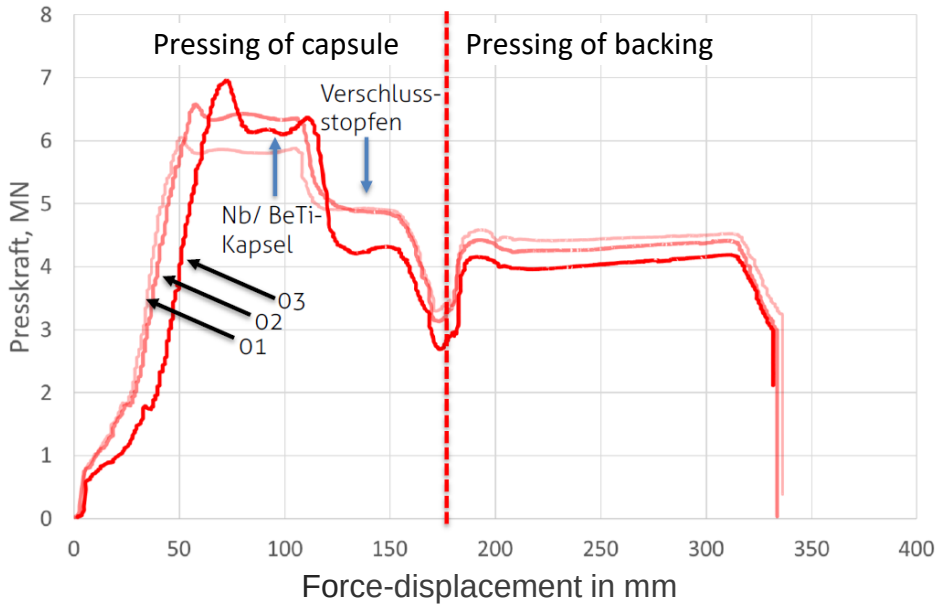


Results from our hot extrusion campaign

INGWERK

Heating curve and comparison of the total forces



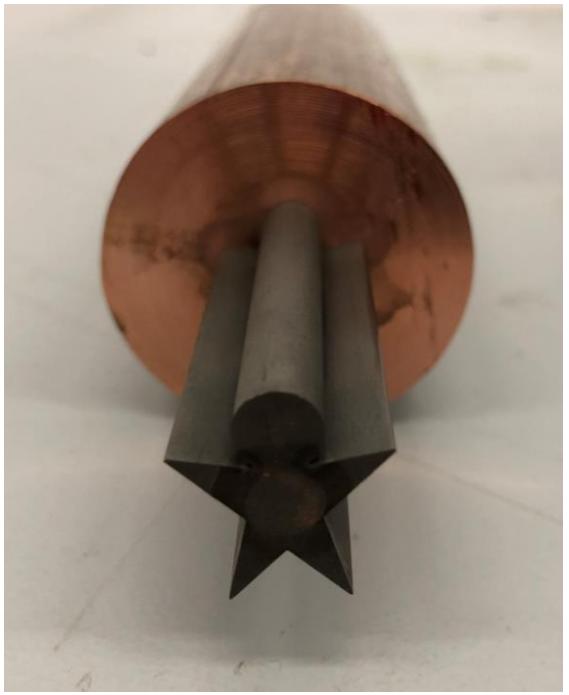


Increasing Be-Ti fraction leads to an increasing pressing force and the decreasing off the stationary press area (reason: increasing compaction energy)

Curve number 03:

- Maximum pressure force 7 MN is reached with the 27/28 mm core
- Homogeneous hot extrusion of the Niobium capsule containing the Be-Ti powder mixture
- Increasing of the press force when the end of the inner capsule is reached

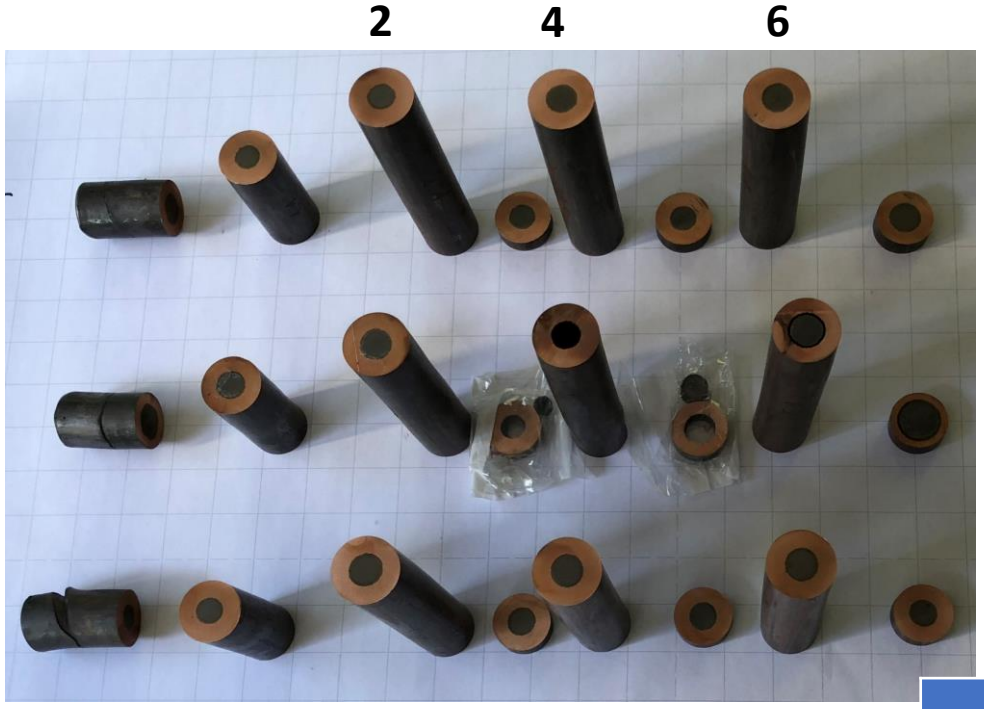
Electrodes produced by wire eroding



- QST has offered to produce 200g of Be-Ti pebbles for tests that will be performed at KIT
- Therefore the hot extruded material has been machined by electrical discharge wire erosion
- We have cut electrodes with 10, 15 and 20 mm diameter out of the Be-Ti-Composite
- We have send them to Japan to be used for REM-Methode, short before this FusNet event
- Just as a test we have cut out an even more complex structure by wire erosion, it works as well!

Nevertheless we have to get rid of this step in the production to get to a scalable process by …

Optimizing the roundness of the core material



120° was our standard for most tests but it seems that 90° or 150° is giving better results.

Rotation tests at 5.000 RPM should be performed with the dismantled rods to find out which length stays mechanically stable and courses low “good” or acceptable vibrations.

	2 A	2 B	4 A	4 B	6 A	6 B
I y	12,2	11,8	12,3	12,3	12,4	13,3
I x	12,8	11,2	12,7	12,5	12,2	13,8
II y	11,8	10,6	12,3	12,2	12,0	18,2
II x	12,4	10,6	12,4	12,2	12,3	18,9
III y	12,4	10,7	12,0	12,2	11,4	11,5
III x	12,9	11,3	12,5	12,5	12,5	12,1

Converting Composite to Beryllides by HIP

Beryllium Alloys: Hot Extruded material, still within the CuCrZr layer is cut and encapsulated again
These capsules are evacuated or Electron Beam (EB) welded and Hot Isostatic Pressed (HIP)
An experimental matrix with different temperatures and Beryllides is being performed now
First Results with Be-Ti show a high dense single phase Beryllide at temperatures around 1000°C

For the production of Electrodes this step is not necessary, it is only performed as R&D for DEMO

Production of Beryllides by Hot Isostatic Pressing

- If the electrodes must be cut in shape, maybe a direct HIP of a block might be cheaper, but we have to find the right conditions
- Beryllide can swell very strong (maybe because of the Kirkendall-Effect)
- At Brush Wellman (now MATERION) similar swelling effects were seen in the 70ies when they sintered Beryllides under vacuum conditions
- This can course serious safety problems especially in a HIP facility
- Beryllides are very brittle and it might be not a workable solution to get electrodes for REM
- In addition, a re-melting might course segregation of Be-Ti in the pebble
- HIP might be a more effective solution if DEMO uses blocks or rods

Near to end shape solutions might be the best way to get parts for DEMO

Future aims of KBHF concerning Blanket Technology

Short-Term, 2020 (ITER-Production):

- Test of the produced rods: Rotation at 5000 rpm, mechanical stability versus length
- Test production of a rod with maximum length (1500 mm), diameter (30 mm) and uniform shape
- *Getting the support for starting a pilot production of Beryllide-Pebbles for the use in ITER TBMs*
- "White Paper" concerning DEMO production possibilities together with Chris Dorn (Be4FUSION)
- Optimization of the KALOS Facility as a model for a Lithium-Ceramic-Pebble pilot production

If there is interest we could even offer a PhD "praxis transfer" event with the support of FusNet

Middle-Term, 2025 (DEMO-Production):

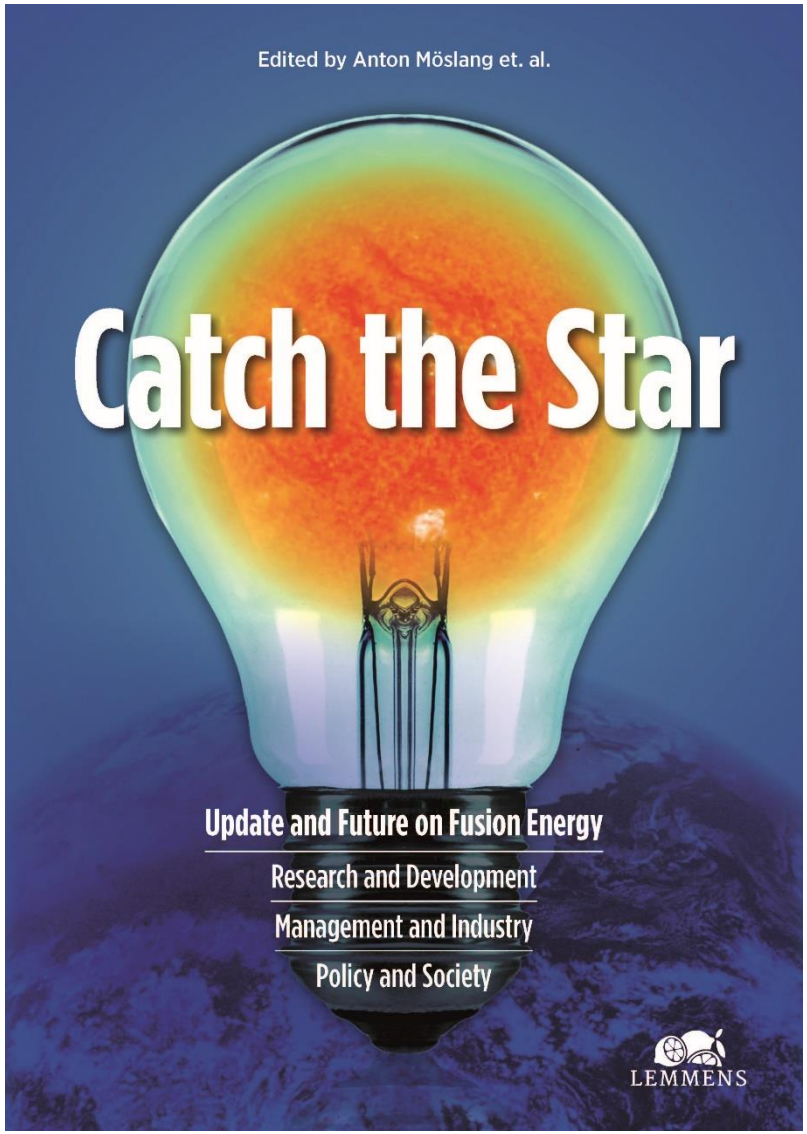
- Research work towards "Rapid Prototyping" of Beryllides for the production of DEMO amounts
- *Getting the financial support for a Laser-Sintering-Device for the use with Beryllium*
- R&D work on the Laser-Sintering of complex structures made of Beryllides

Long-Term, 2030 (Blanket Handling Facility at KIT):

- There is no other facility than KBHF available for the filling of TBMs located closer to ITER
- KIT has the HELOKA facility and the capability to test TBMs before sending to ITER
- *Changing GODZILLA for the filling of TBMs from our international partners, as well*

KALOS - Test Facility for producing Lithium-Ceramics

“Always aim for the Moon, even if you miss, you'll land among the stars.” Friedrich Nietzsche



Q: Publication – why?

A: Good timing for PR to the 2025 ITER goal!

Q: Wide of the articulated topics?

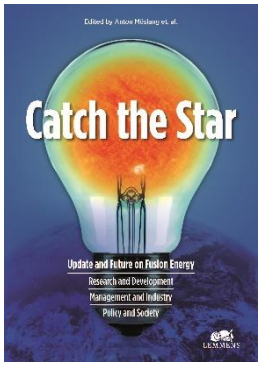
A: From energy sources, politics, industry & science relations and basic research to a publication format addressing experts and media in all areas of relevance

Q: Timeline?

A: Editorial work from January to June 2019, publication timeframe end of 2019/early 2020 maybe accompanied by a conference/expert meeting in New York

Edited by Anton Möslang et al. Published by Lemmens Media, Berlin-Washington; Project Manager: Aniceto Goraieb

The Idea behind – 3 outlines:



- We aim to *collect the relevant stakeholder opinions* on Fusion Energy as a main source of the future world of an infinite supply.

- We want to *structure and nurture* the international debate on Fusion Energy.

- We intend to offer a *sound science style* but an simultaneously *understandable writing* for a broad audience of stakeholders.