This project has received funding from the European Union's Horizon 2020 Research and Innovation programme under Grant Agreement No 730871.


# Overview and recent developments within Task 14.4

ARIES WP17 2nd Annual Meeting
14 July 2020

Federico Carra, CERN
*With several contributions from the participants to WP14 and WP17*

# WP14.4 milestones and deliverables

| Deliverable Number | Deliverable Title | Lead beneficiary | Type | Dissemination level | Due Date (in months) | Date of completion (in months) |
|---|---|---|---|---|---|---|
| D14.3 | Production of material samples of carbon-based composites and metal-diamond composites | CERN | Demonstrator | Public | **24** | **14** |

**D14.3 : Production of material samples of carbon-based composites and metal-diamond composites**

Production of: 50 samples of carbon-based composites with different production cycles and 30 samples of metal-diamond composites, 20 for high energy impact studies and 10 for luminescence studies

**Completed in M14** (June 2018), to match WP17 milestones and deliverables

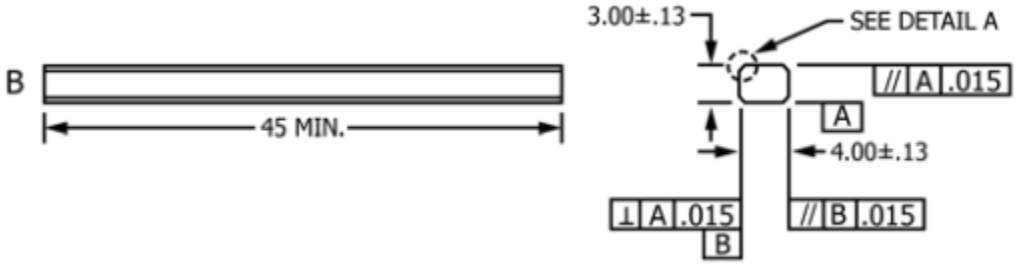
# Deliverable D14.3

- Samples produced with different objectives and **in excess** with respect to the quantity required

| Description | N. samples required | N. samples produced | Composition and envisaged testing method |
|---|---|---|---|
| **Carbon-based specimens for collimators** | 50 | 36 → **61** | Ceramic-graphite for thermomechanical characterization at CERN |
| | | 25 | Molybdenum-graphite for dynamic tests at PoliTo |
| **Metal-diamond specimens for collimators** | 20 | 11 → **28** | Copper-diamond for beam impact tests at CERN HiRadMat facility |
| | | 17 | Copper-diamond for thermomechanical characterization at CERN |
| **Metal-diamond specimens for luminescence screens** | 10 | 10 → **10** | Diamond-based composites with different metallic substrates for testing at CERN and GSI |

# WP17 activities, triggered by ARIES annual meeting 2019 in Budapest

- Ideas discussed at the meeting in Budapest:
  - **Dynamic tests on CuCD Multimat grade (RHP3025-01:10) at PoliTo**: requiring slender rods (twentish with size indicatively 200x10x10 mm3) → waiting for inputs from PoliTo on the size and numbers!
  - **Bending tests at high temperature on the CuCD Multimat grade**: requiring 20 samples with indicative dimensions:




  - **Anisotropy of CuCD**: we are procuring a support (expected in 2 weeks) to test diffusivity of samples size 4.5x5.x5 $mm^3$. 3 samples from RHP already available from MS, can be tested. Measurements could be done before the end of September.
  - **Molybdenum cladding of CuCD blocks instead of Cu**: could we try on a block similar or identical to the one that must be installed in a collimator? Objective: tolerance check, adhesion and thickness of the cladding…
  - **Multimat**: data on RHP CuCD being analysed at University of Malta and CERN

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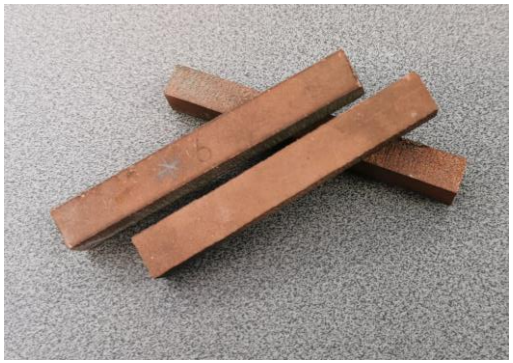
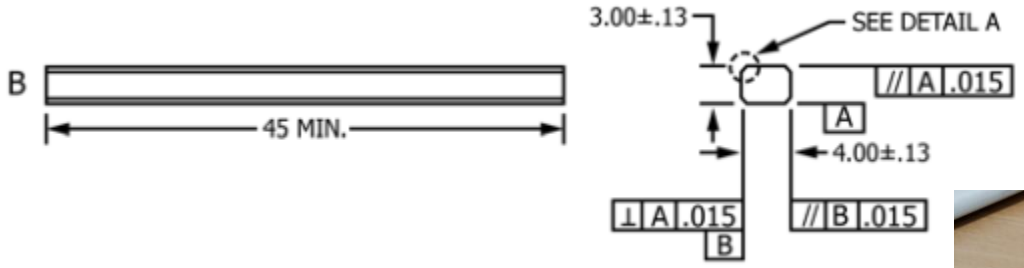


- **3 rods** obtained from Multimat by water-jet (80x10x10) and shipped to PoliTo for some preliminary test with the Hopkinson bar.
- **Result**: due to the bad dimensional tolerances, there is no repeatability of measurements, and the signal is very irregular

- **Proposed actions:**
  1. Prepare a drawing of the required sample, with tolerances (125x10x10, parallelism between faces 0.1-0.2 mm?)
  2. Depending on what remains from RHP budget on this activity
     - A. Prepare 4-5 samples for a new test to confirm that the geometry proposed is ok
     - B. Prepare 20 samples for the complete characterization

# WP17 activities, triggered by ARIES annual meeting 2019 in Budapest

- *Ideas discussed at the meeting in Budapest:*
  - ***Bending tests at high temperature on the CuCD Multimat grade**: requiring 20 samples with indicative dimensions:*




- **25 rods** prepared by RHP in February 2020 and shipped to CERN
- Most of the samples already tested at the CERN MME laboratory!

- **Next actions:**
  1. Analyze the tests done so far and complete the measurements on the remaining samples
  2. Implement the test results in the material model

# WP17 activities, triggered by ARIES annual meeting 2019 in Budapest

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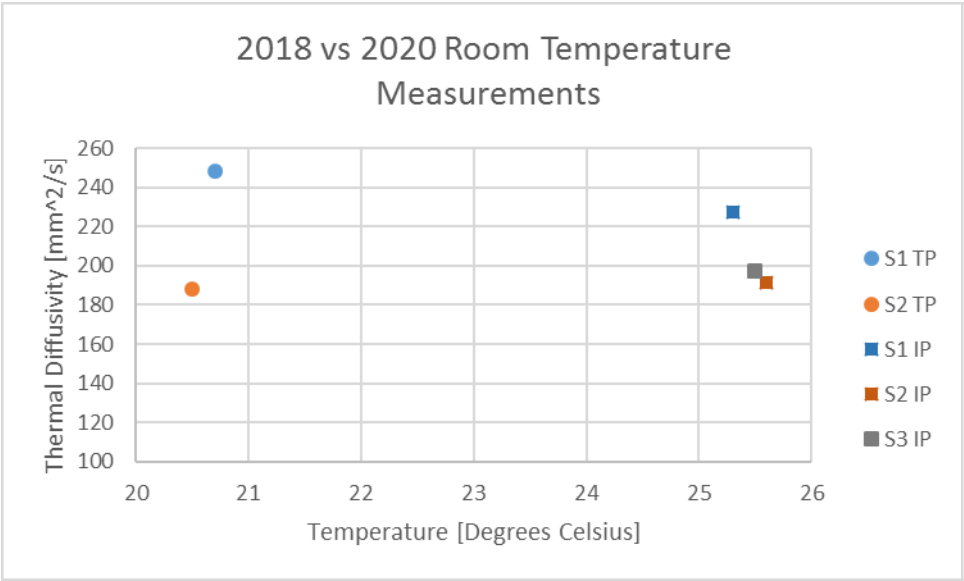
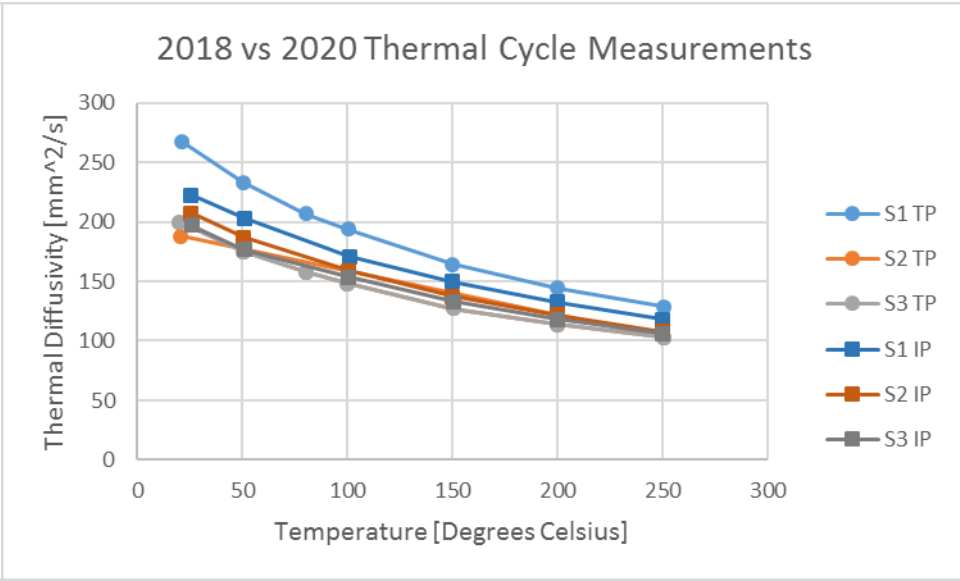
  - ***Anisotropy of CuCD**: we are procuring a support (expected in 2 weeks) to test diffusivity of samples size 4.5x5.x5 mm$^3$. 3 samples from RHP already available from MS, can be tested. Measurements could be done before the end of September.*

- **3 samples 4.5x5x5** prepared and tested at the Mechanical Laboratory
- **No anisotropy was found for the material**, confirmation of expectations and previous models!



# WP17 activities, triggered by ARIES annual meeting 2019 in Budapest

- *Ideas discussed at the meeting in Budapest:*
  - ***Molybdenum cladding of CuCD blocks instead of Cu**: could we try on a block similar or identical to the one that must be installed in a collimator? Objective: tolerance check, adhesion and thickness of the cladding…*

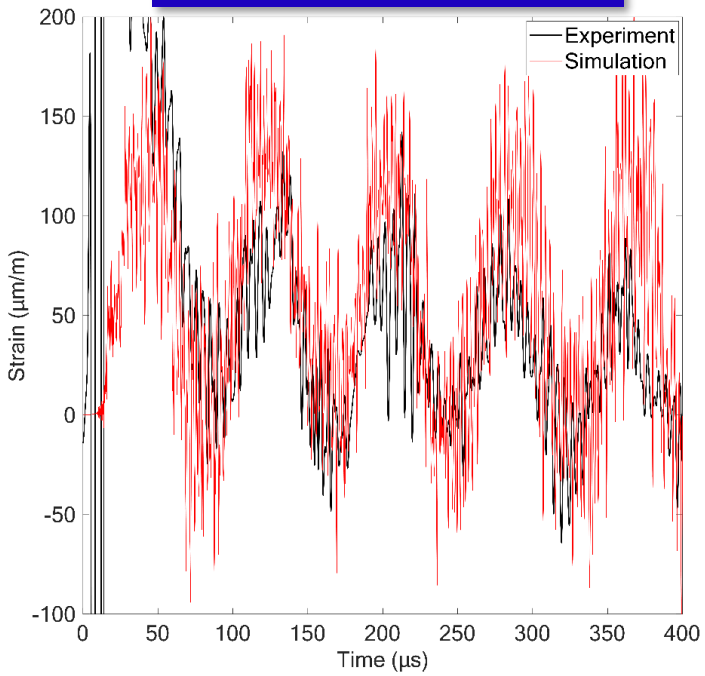
- **Discussed in August 2019 with RHP during meeting at CERN**, but no actions started so far in this sense.

- **Proposed action:**
  1. If RHP budget allows: produce a “simplified” collimator block (parallelepiped 125x45x25) with Mo cladding on the two 125x45 faces, trying to achieve good position tolerance of one face wrt the other. **Mo layer thickness (post-machining): target ≤ 0.5 mm (ideally 0.2-0.3 mm**, less is impossible if diamonds are up to 0.2mm!).

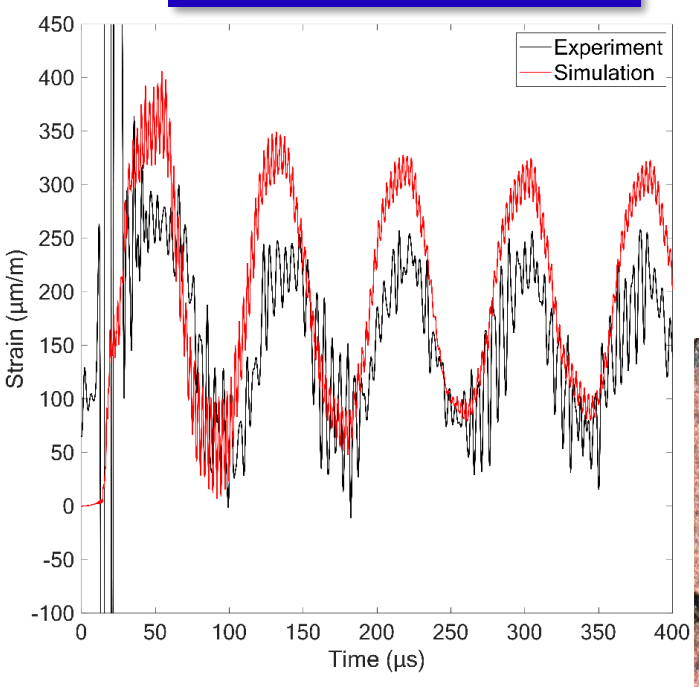
# WP17 activities, triggered by ARIES annual meeting 2019 in Budapest

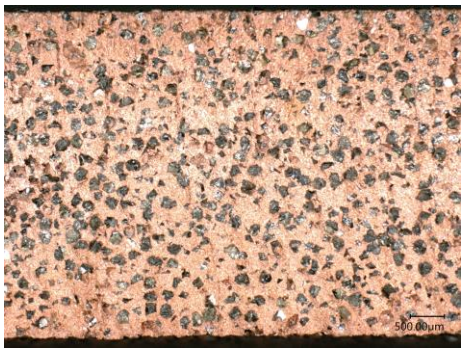
- *Ideas discussed at the meeting in Budapest:*
  - ***Multimat**: data on RHP 3434 CuCD being analysed at University of Malta and CERN*
- **Paper prepared by M. Portelli**, submitted to the special issue in “Shock and Vibrations” ✓
- Contains characterization of the material and benchmarking against beam impact scenario (Multimat).

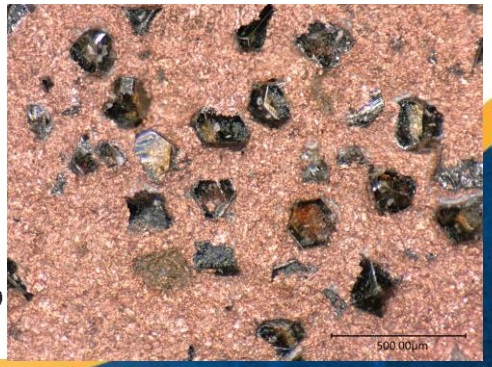
**1 bunch on CuCD**




**12 bunches on CuCD**



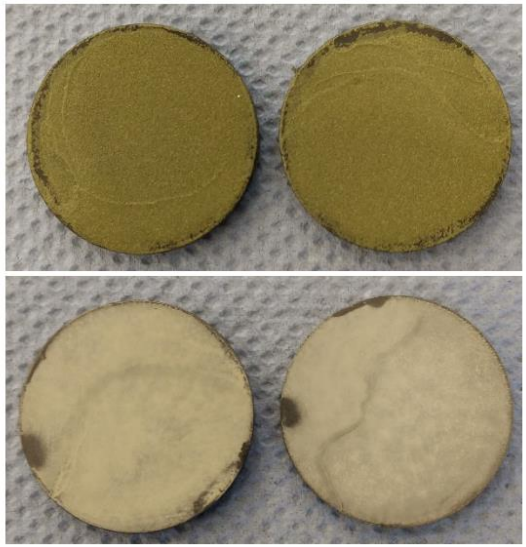





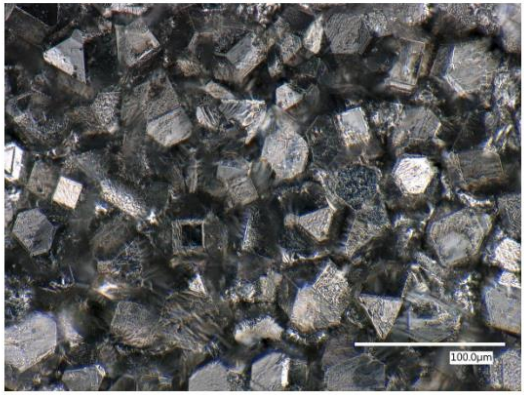
# Luminescence

- After the 10 samples produced for the deliverable, **other 21 samples produced** in the past year.

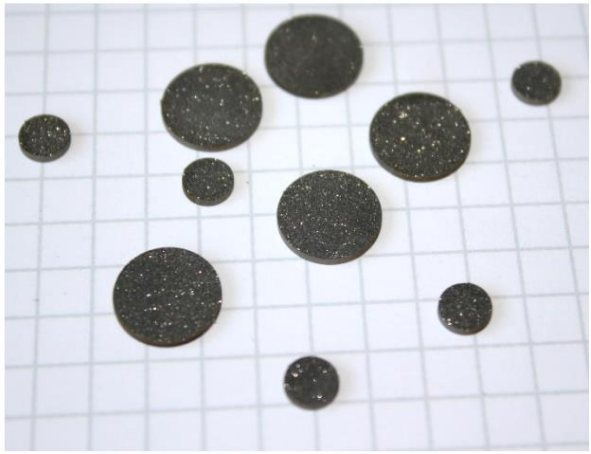
- **Base materials**: Cu / Ti grade 2 / Ti grade 5
- **Diamond size**: 1 / 3 / 10 / 45 micron



(a)




(b)



(c)

**Figure 4 Diamond-Ti luminescent screens (a) before hotpressing (b) depth profile of embedded diamonds (c) samples extracted from larger hotpressed sample**

# Summary of WP14.4 activities post - D14.3

- 4 samples of $MgB_2$ on metal substrate (January 2019)
- 5 samples of $MgB_2$ on metal substrate (22 March 2019) → much better results
- 19 samples of $MgB_2$ on Cu and $Al_2O_3$ (December 2019)

**$MgB_2$**

- 1 additional sample within D14.3 (5 made instead of 4, we can add IHP5527-A to the total production)
- 16 samples for luminescence, spray-deposited diamonds on Cu (February 2019)
- 4 samples for luminescence, diamonds on Ti grade 2, good diamond particle distribution (March 2019)

**Luminescence**

- 3 CuCD rods for SHPB tests
- 3 CuCD samples for anisotropy measurements
- 25 CuCD rods for high-T bending tests

**Collimation**

# WP14.4: production goals for ARIES

- The **full scope of the production throughout 4 years** include:
  - **Production objectives**:
    - 30 samples of $MgB_2$ on metal substrate (28)
    - 50 samples of CuCD (59)
    - 40 samples of metal-diamond composite for luminescence studies (31)
    - 50 samples of carbide-graphite or metal-graphite composites (61)
    - 1 large size block of carbide-graphite or metal-graphite composite with tight mechanical tolerance to proof industrialisation (0% – R&D ongoing)

**RHP**

**BrevettiBizz**

- **So far so good!**

# Open activities with Brevetti Bizz (WP14/17)

- **Three items agreed for production**

1. **1 plate MG-6671Fc** dimensions 150x100x26, BB offer n. 351-CE/18 (16/10/18), DAI 7518253 (WP17 budget)
   - 5%vol pitch (Rutgers Carbores P, density ~1.3 g/cm3, particles ~60 micron)
   - 4.5%vol Mo, 0.55%vol Ti, 84.95%vol graphite Asbury 3260, 5%vol short fibres CYTEC Ø10x250 um
2. **25 samples of MG-6541Fc** for dynamic tests with Hopkinson bar, letter of commitment 23/10/17 (WP14 budget)
   - 25 samples of MG-6403Fc already produced
   - Raw plate material and sample shape can be updated to current needs, input from WP17 needed on this!
3. **1 piece of big size with fine machining to prove industrialization** (WP14 budget)
   - 1 tapering-like? Which material? Inputs needed from WP17 and from this meeting

# Conclusions

- Production efforts in 2019 focused on the synthesis of **$MgB_2$-coated samples**, with promising results (not in the scope of this meeting).
- Nevertheless, **significant advancements also on WP17-related activities**.
- In particular, thanks to the samples produced within WP14, **the characterization of the RHP 3434 grade will be the most in-depth performed so far for CuCD** → hopefully also including strain-rate effects!
- On the luminescence screen side, we are ready for further inputs from GSI.
- $MgB_2$ and luminescence samples: numbers counted so far are only the tested samples. Produced samples are actually already above the production targets **→ question to RHP: to prepare a table not only with the tested samples, but with those produced overall**
- Only a fraction (10%) of the production targets remaining, most important is the **large-scale component with Brevetti Bizz.**

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# Budget

| Beneficiary short name* | Person - months | Monthly personnel costs | Personnel direct costs | Travel direct costs | Equipment and consumables | Other direct costs | Sub-contracting costs | Material direct costs | Total direct costs | Total indirect costs** | Total costs (direct + indirect) | EC requested funding |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CERN | 3.00 | 8'000.00 | 24'000.00 | 3'000.00 | 0.00 | | | 3'000.00 | 27'000.00 | 6'750.00 | 33'750.00 | 9'312.50 |
| Bizz Brevetti | 6.00 | 3'500.00 | 21'000.00 | 5'000.00 | 50'000.00 | 10'000.00 | | 65'000.00 | 86'000.00 | 21'500.00 | 107'500.00 | 60'000.00 |
| RHP | 6.00 | 3'500.00 | 21'000.00 | 5'000.00 | 110'000.00 | 10'000.00 | | 125'000.00 | 146'000.00 | 36'500.00 | 182'500.00 | 91'250.00 |
| Total | 15.00 | 59'365.00 | 66'000.00 | 13'000.00 | 160'000.00 | 20'000.00 | 0.00 | 193'000.00 | 259'000.00 | 64'750.00 | 323'750.00 | 160'562.50 |

# What's next after ARIES? → IFAST (2021/24)

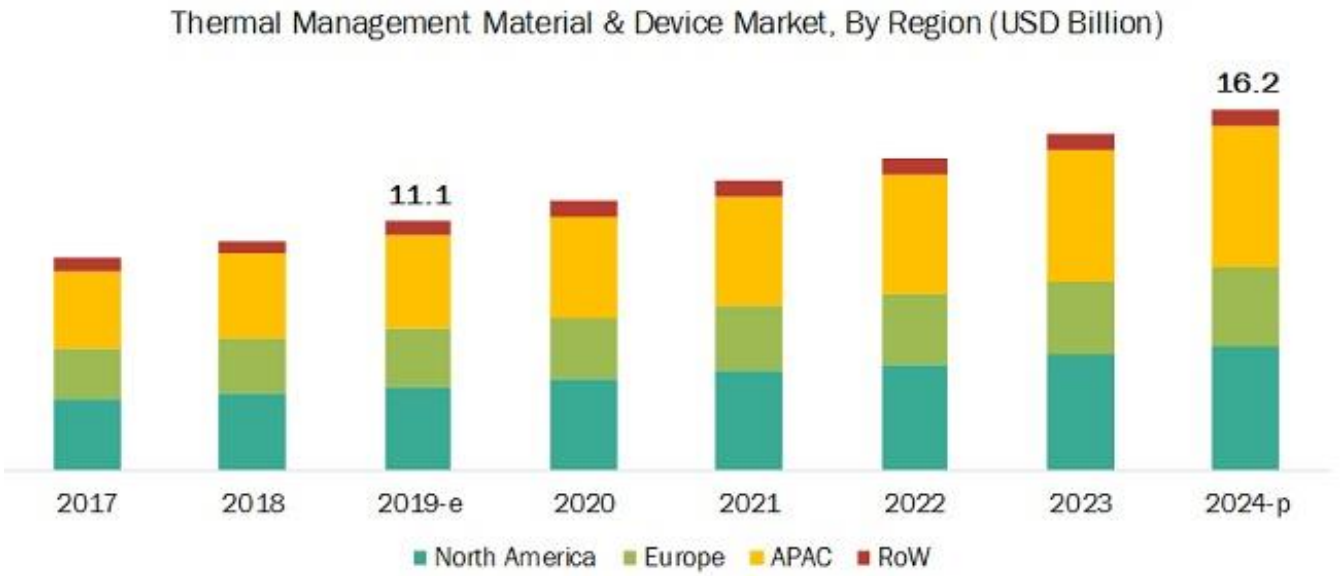


Figure 1 – Expected figures for the development of the thermal management market in the next years, source: https://www.marketsandmarkets.com/Market-Reports/thermal-management-market-155049228.html

**Task 4.4: Large scale Carbide-Carbon Materials for multipurpose applications** M1 – M48 **F. Carra**

Promote the use of carbide-carbon materials (CCM) in future particle physics facilities and open up the market to commercial applications, by and decreasing the final production costs of the raw material.

# What's next after ARIES? → IFAST

**Task 4.4: Large scale Carbide-Carbon Materials for multipurpose applications** M1 – M48 **F. Carra**

**CERN, Nanoker (ES)**

Promote the use of carbide-carbon materials (CCM) in future particle physics facilities and open up the market to commercial applications, by:

- increasing the maximum achievable volume of CCM components
- decreasing the final production costs of the raw material

The first stage of the work will involve the definition by CERN of technical specifications for the CCM to be produced. After this stage, NNK will work in parallel on two paths:

- put in place a system to allow producing two plates per machine cycle of minimum cross-section 400 $cm^2$ and minimum thickness 3 cm. This increased sintering capacity will result in a cost reduction.
- investigate CCM alternative to MoGr, requiring lower sintering temperatures, and produce single plates per machine cycle with a volume up to 1800 $cm^3$. The decreasing of the sintering temperature will result in a cost reduction. The material volume reached will meet the targets.

CERN will perform characterization campaigns on the materials produced to ascertain the fulfilment of the specification. Last stage of the work will include a precise machining of the raw plates from NNK, to obtain functional pieces with fine mechanical tolerances.

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# Thank you for your attention!