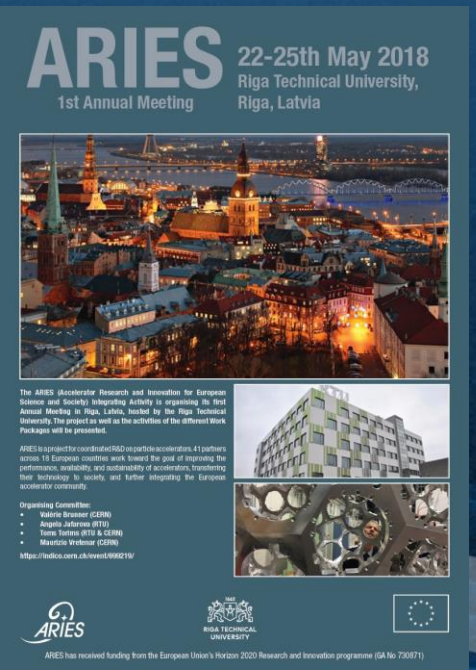
This project has received funding from the European Union's Horizon 2020 Research and Innovation programme under Grant Agreement No 730871.

Development of metallic and ceramic composites for particle accelerators



ARIES 1st Annual Meeting

24 May 2018 | Riga, Latvia

Federico Carra, CERN

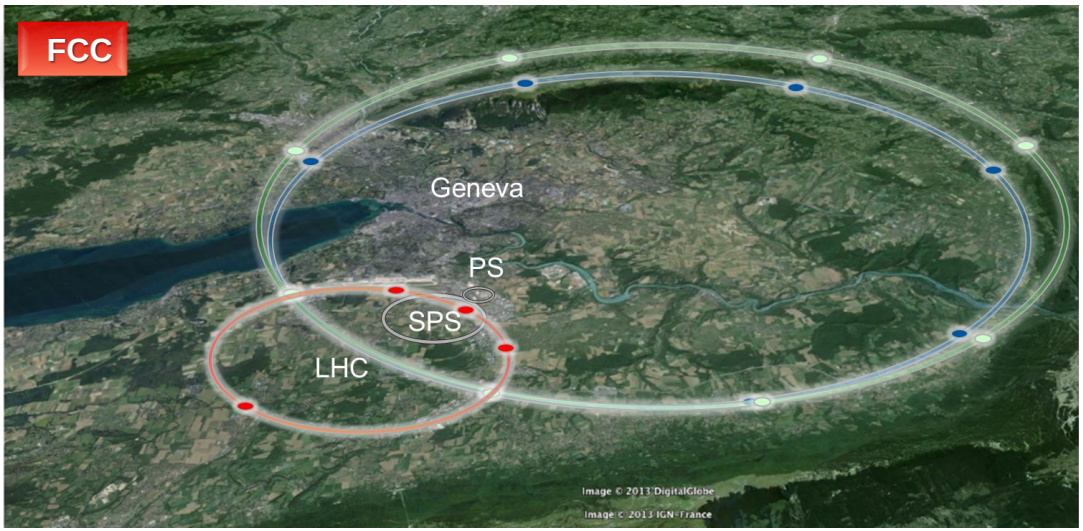
With several contributions from the participants to WP14 and WP17

Outline

- Introduction
- Accelerator applications of advanced composites
  - Beam absorbers
  - Luminescence screens
  - Superconductive thin films
- Wrap-up on WP14.4 status

Introduction: Advanced composites for accelerators

- The energy stored in particle accelerators is expected to significantly increase in the incoming years
- With respect to the LHC, the **HL-LHC will store 2x energy** (700 MJ) and the **FCC-hh more than 20x energy** (8.5 GJ)
- **Novel advanced composites** able to interact with such bright beams are being developed and produced in the scope of WP14 (task 4) and WP17 of ARIES

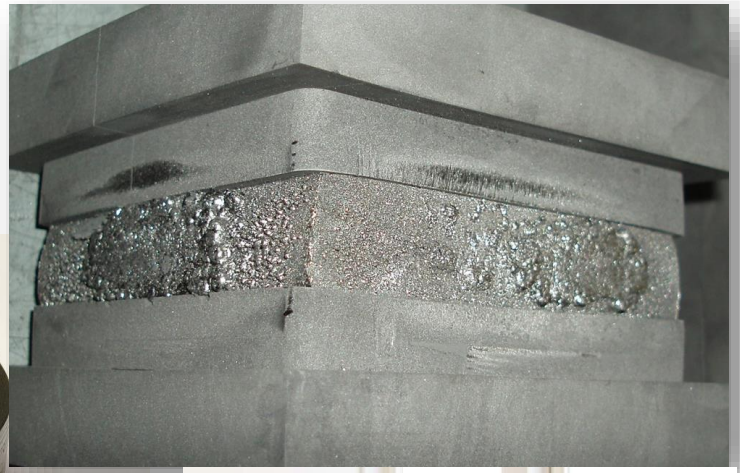


Introduction: Advanced composites for accelerators

- Material production takes place at **RHP (AT)** and **Brevetti Bizz (IT)**
- **State-of-the-art techniques** are adopted to manufacture the composites
  - Spark plasma sintering
  - Rapid hot pressing
  - Liquid-phase sintering
  - Additive manufacturing
  - …and more!

RHP TECHNOLOGY

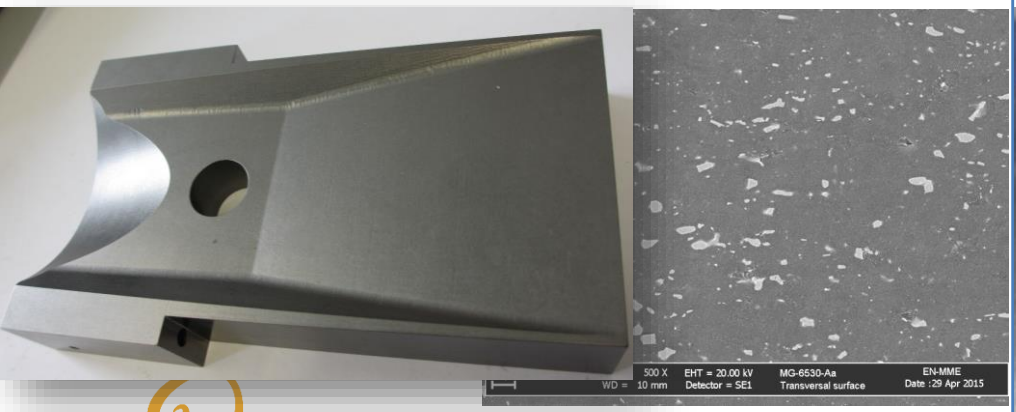
BREVETTI BIZZ



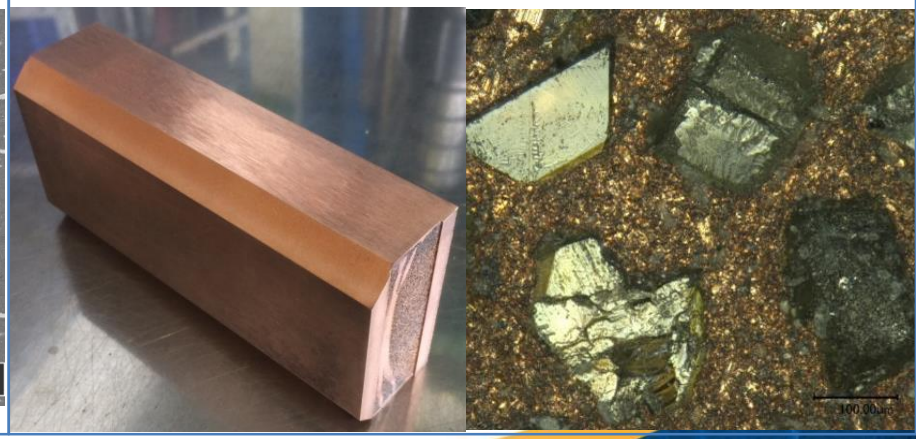
Accelerator applications: beam absorbers

- Beam absorbers and beam intercepting devices, such as **LHC collimators**, require materials with a wide set of properties (thermal shock resistance, thermal and electrical conductivity, radiation hardness, outgassing, …)
- Materials currently adopted (graphite, CFC, high-ρ metals) **cannot satisfy all these requirements**
- Composites built at **RHP** and **Brevetti Bizz** combine properties of carbon allotropes and metals: **Molybdenum-graphite (MoGr)** and **Copper-diamond (CuCD)**

MoGr: ρ ~2.5 g/cm^3, transverse isotropy with respect to the sintering plane. Outstanding thermal conductor (800 W/m/K). Easily machinable.

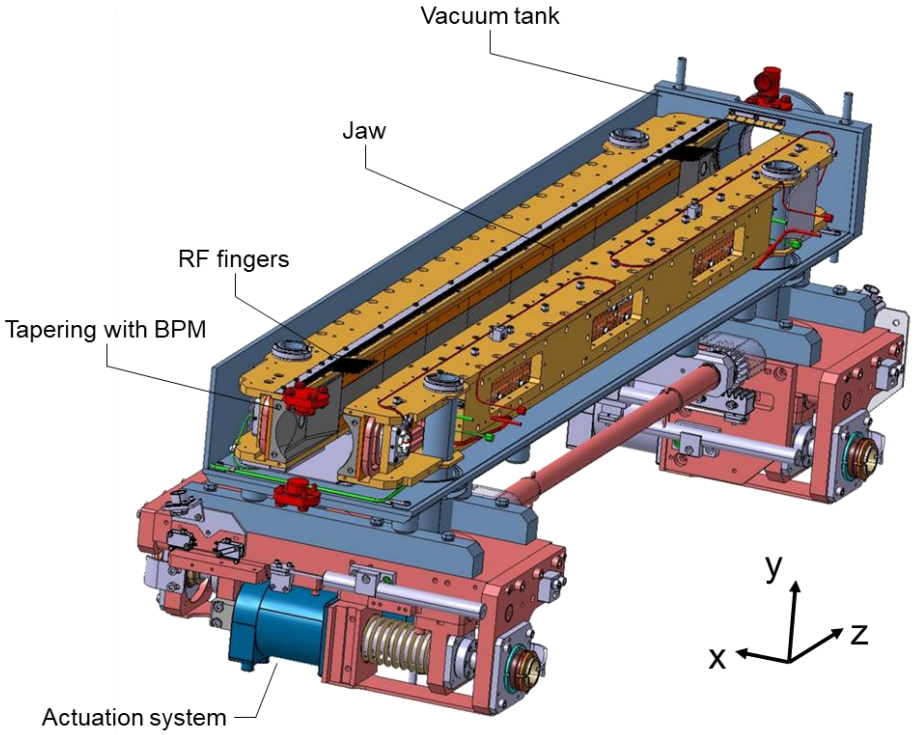


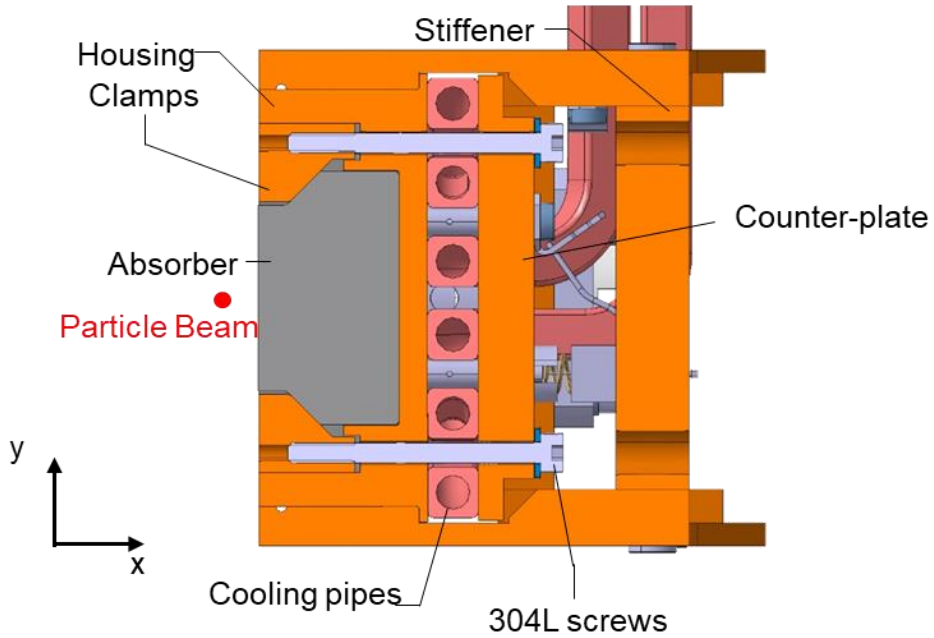
CuCD: ρ ~5 g/cm^3, isotropic. Copper matrix with diamond reinforcement. Very good thermal and electrical conductor. High hardness and mechanical properties, difficult to machine.



Accelerator applications: HL-LHC collimators

- **MoGr**, thanks to its low density, is proposed to replace CFC in **primary and secondary collimators**. Other compositions are also under development.
- **CuCD** is denser and represents a more robust option for **tertiaries**, currently in W-alloy
- Both materials **can be coated** to further enhance the surface thermal and electrical exchange

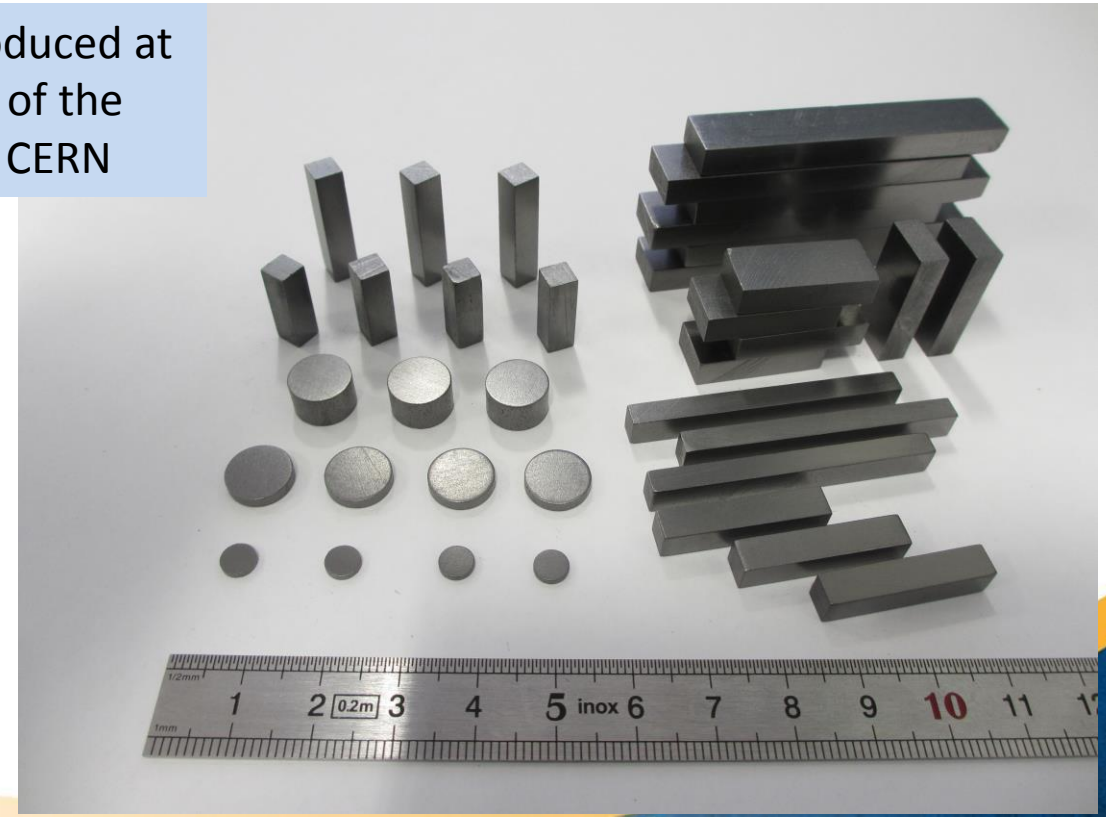




Accelerator applications: HL-LHC collimators

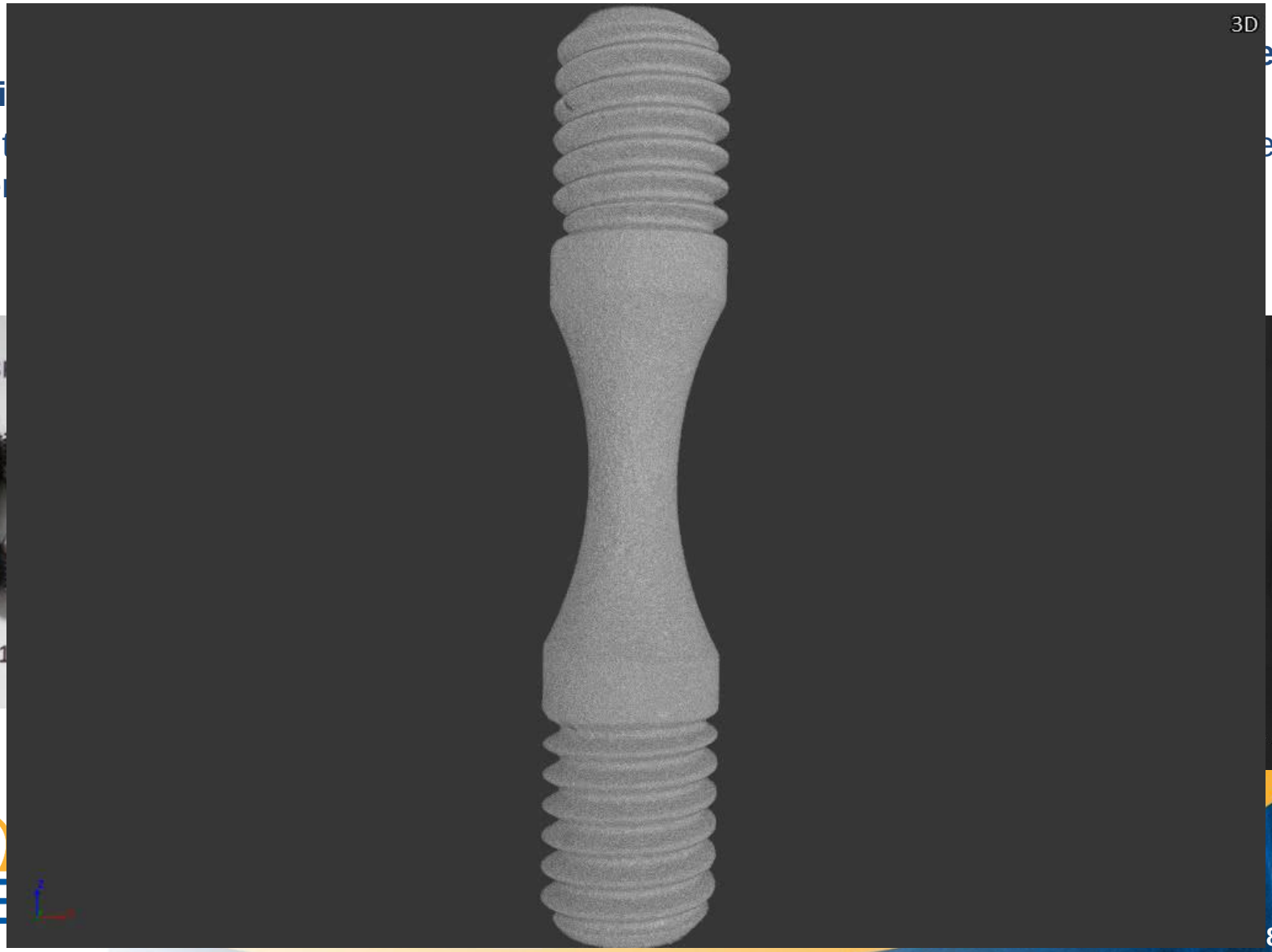
- MoGr, similar ceramic graphite and CuCD are characterized in the frame of WP17:
  - Thermophysical characterization at the CERN mechanical lab
  - Dynamic testing at Politecnico di Torino
  - Beam-impact response at HiRadMat (CERN)
- **Samples of complex shapes produced in the scope of WP14.4**

Graphite-ceramic specimens produced at Brevetti Bizz; characterization of the thermophysical properties at CERN



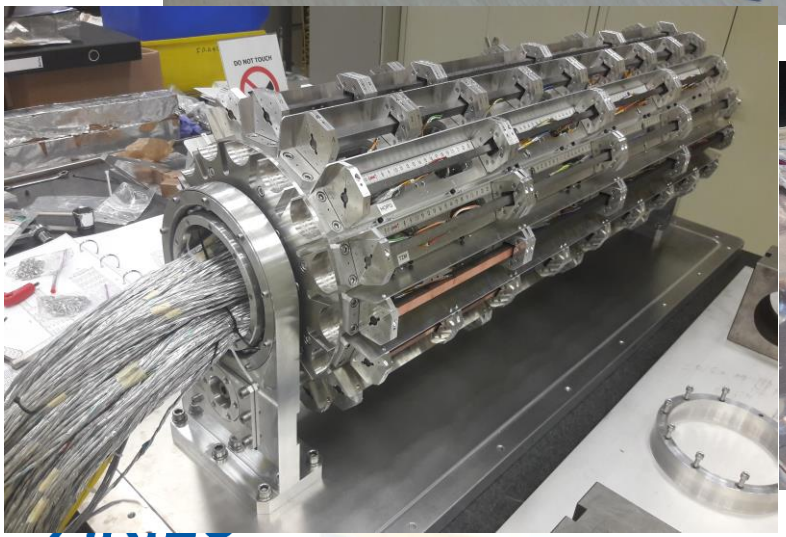
Accelerator applications: HL-LHC collimators

- MoGr
  Hopki
- Also
  cluste



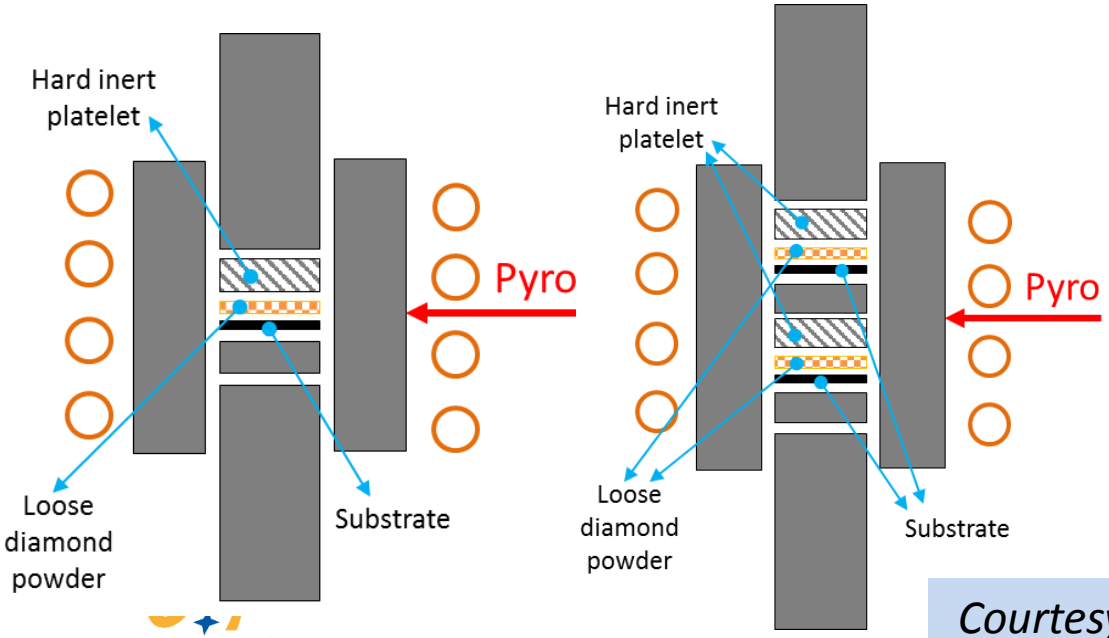
Accelerator applications: HL-LHC collimators

- Slender rod specimens of MoGr and CuCD, coated and uncoated, for beam-impact tests at HiRadMat (**HRMT36 – Multimat**) → see talk from M. Pasquali



Accelerator applications: luminescence screens

- The addition of diamond particles to metallic substrates is a technique exploitable in the construction of beam instruments such as **luminescence screens**
- **Diamonds act as scintillators** upon interaction with incident high energy beam. Requirements:
  - Smaller diamond particle size -> higher resolution of the incident beam
  - Smaller Z-number of the substrate -> lesser interaction between high energy beam and substrate material
  - Tougher substrate -> higher resistance to induced heat / sputtering damage



- **Production at RHP by induction hot pressing** in the scope of WP14.4
- Substrates investigated: **Ti and Al alloys, Ti composites**
- Influence of **diamond powder size, type and purity** under study

Courtesy of D. Grech, RHP

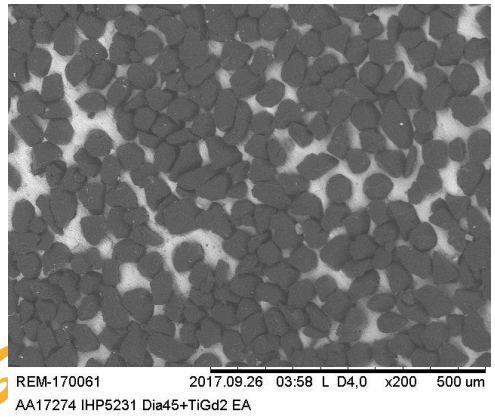
Accelerator applications: luminescence screens

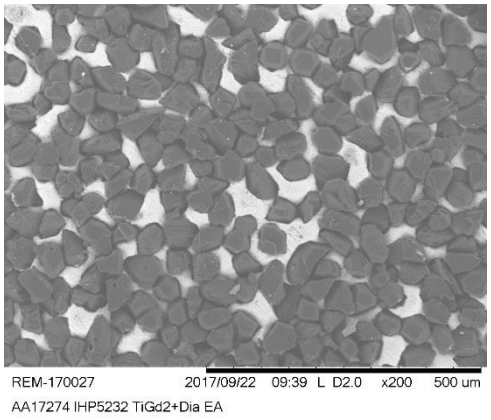
- Several specimens produced so far at RHP, **10 of those under testing at GSI and CERN**

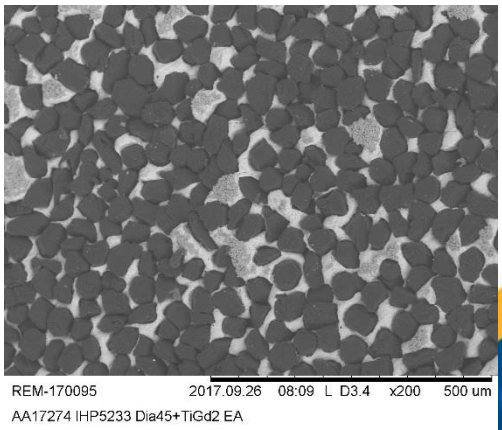
IHP5231-A
900°C/5min/30MPa

IHP5232-A
900°C/15min/30MPa

IHP5233-A
900°C/30min/30MPa



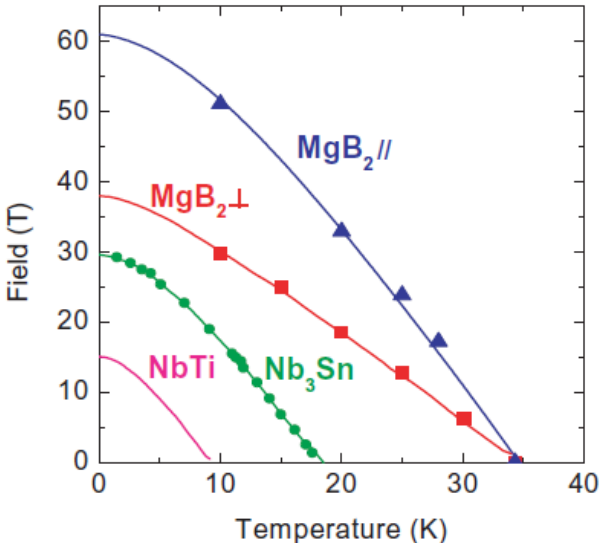


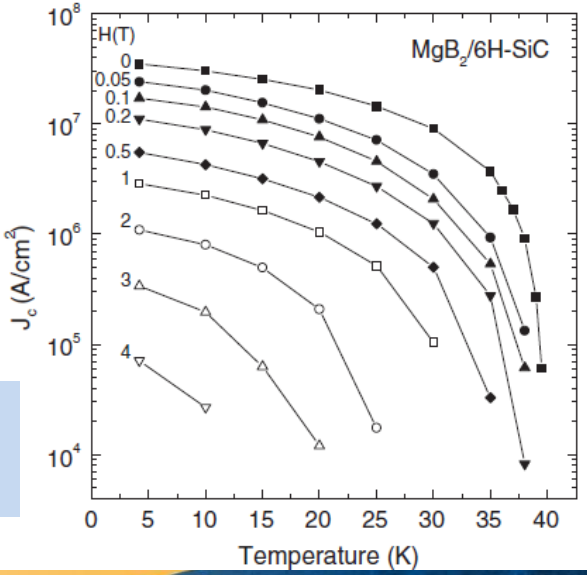


Courtesy of D. Grech, RHP

Accelerator applications: HTS thin films on metallic substrates

- **High Temperature Superconductors (HTS)** seem the best choice for future accelerators in need of high magnetic fields
- Already adopted in the LHC for current leads, next step is to use them in “hybrid” configuration magnets
- Thin-HTS deposition on metallic substrate: technology of interest for **SRF cavities and beam pipes**
- Several fields of application also **outside accelerators** (medicine, green energy, nuclear waste transmutation, wind turbines, …)





Courtesy of M. Losasso, CERN

Accelerator applications: HTS thin films on metallic substrates

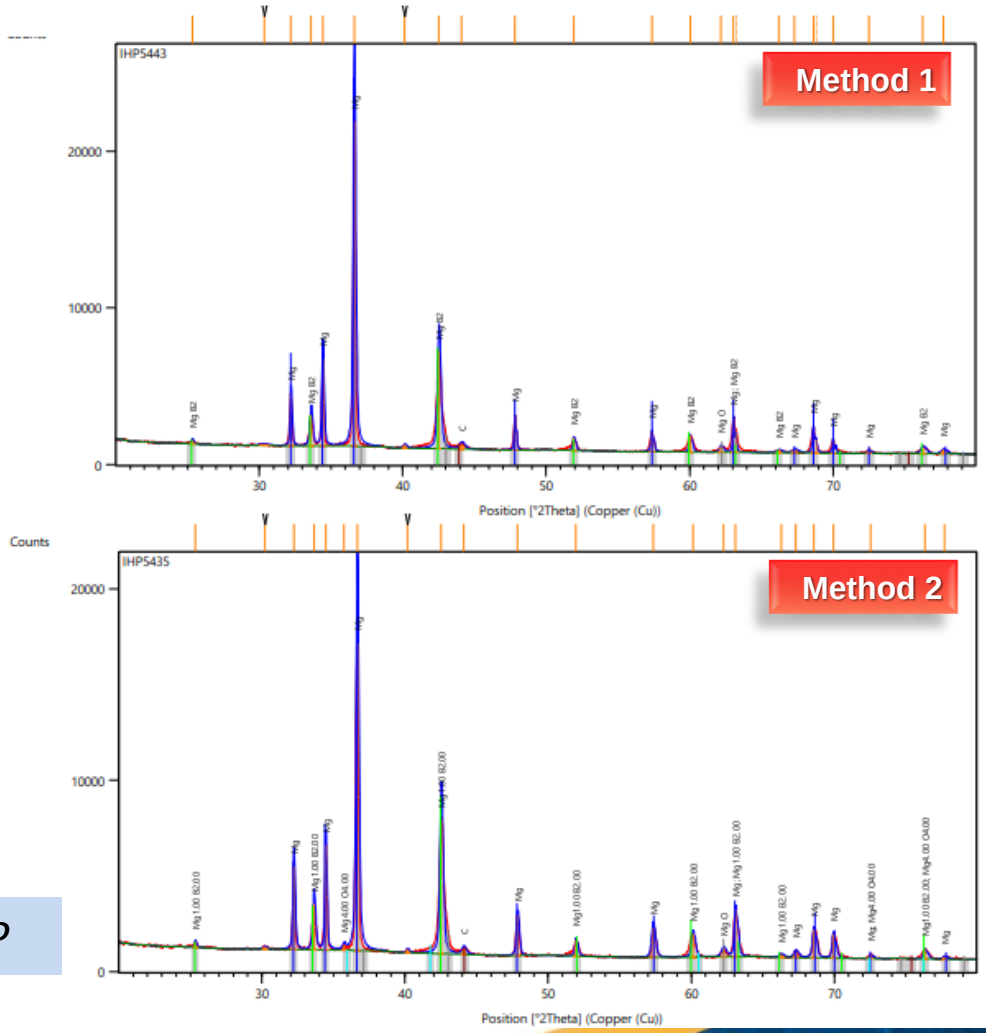
- At RHP (WP14.4): development of **MgB_2 layers on metal substrates** (*e.g.* copper)
- Aim is to synthetize the MgB_2 powder, characterize it, and deposit it on a substrate by means of 3D printing → Plasma Transferred Arc (PTA)

- Direct synthesis of MgB_2 from precursors:
  1. Mg + 2B → stoichiometric
  2. Mg + 2B → 5wt% excess of B
- Procedure
  - Cold pressing of powders
  - Pellet preparation at 650°C, 2h under vacuum
  - Densification
  - XRD analysis of the phases

Courtesy of D. Grech, RHP

Accelerator applications: HTS thin films on metallic substrates

- **Better results obtained with the 2nd method (excess of B)**
- However, no pure MgB_2 shyntesis (major phase is Mg, then MgB_2, with traces of MgO and C)
- Next steps
  - Increase the B content (10wt%)
  - Inductive hot pressing for the same T and t, under a pressure of 30 MPa



Courtesy of D. Grech, RHP

WP14.4 milestones and deliverables

- All the samples produced are part of D14.3

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

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

Our goal: complete it by 2018, to match WP17 milestones and deliverables

Almost completed! Only missing 10 CuCD samples, already produced at RHP, under shipping

WP14.4 milestones and deliverables

- The full scope of the production throughout 4 years include:

  - **Production objectives**:
    - 30 samples of MgB_2 on metal substrate (0% – R&D ongoing)
    - 30-50 samples of CuCD (40%)
    - 40 samples of metal-diamond composite for luminescence studies (25%)
    - 50 samples of carbide-graphite or metal-graphite composites (100%)
    - 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!**

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

Thank you for your attention!

Backup slides

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

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