Collimator Materials for High Density Energy Deposition

Report from WP11

1st EuCARD-2 Annual Meeting, DESY Hamburg, Mai 19-23, 2014

Adriana Rossi on behalf

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ColMat-HDED collaboration and beyond

- ColMat-HDED partners

- Partnership agreement with CERN (KN2045)

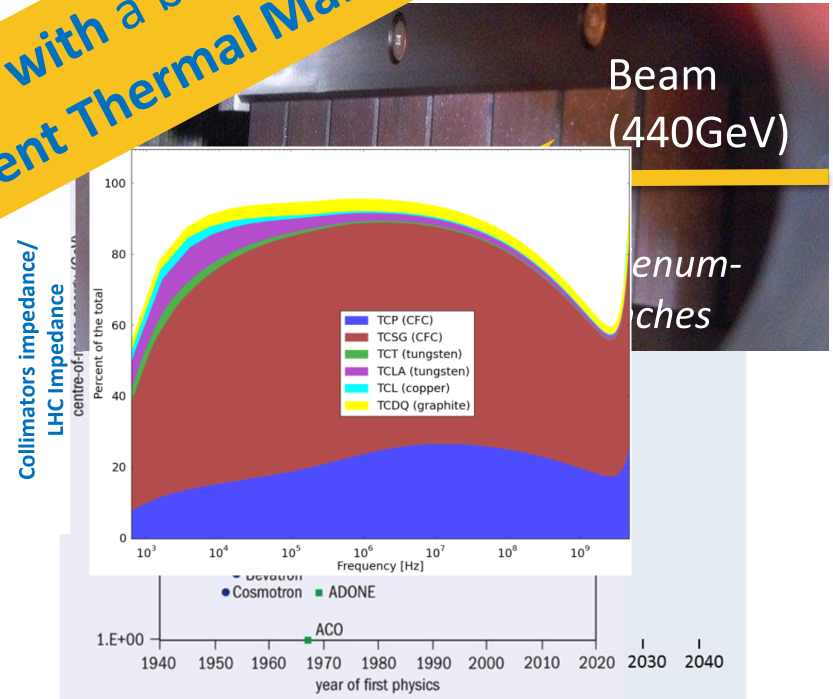
BREVETTI BIZZ

- Collaboration CERN with US-LARP

Motivations

- Accelerator performance with ever increasing beam brig… ess and stored energies pushes **material requirements for col… s** into more challenging grounds: Collimators (and all B… ing Devices) are inherently exposed to extreme …
  - Higher **robustness** (LHC beam energy density up to 15 GJ/mm2, 2-3 orders > oth… machines).
  - Lower **impedance** … give, by far, the hig… machine i… ially leading to se… ities.
  - **Large…** … **to radiation** (1E16 p/… ses in LHC betatron cleaning insertion)
  - **Higher absorption** (clean efficiency for machine protection)

Many requirements **shared with** a broad range of **applications requiring efficient Thermal Management**



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Potential range of applications outside accelerators

Can be further expanded thanks to the tailoring possibilities of Molybdenum-Graphite composites …

Courtesy of A. Bertarelli

Study on Collimation Materials

- Requirements on cleaning and impedance
  - Materials being investigated are **Copper-Diamond** (**Cu-CD**), **Molybdenum-Diamond** (**Mo-CD**).
  - **Molybdenum-Graphite (Mo-Gr)** is particularly appealing for it can be coated with a Mo layer dramatically increasing electrical conductivity , easily machined, has better thermal properties …
  - R&D program still ongoing to further improve physical properties, particularly mechanical strength of **Graphite.**

High-Z Collimators

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ations

Low-Z Collimators

ColMat-HDED

WP11 Objectives

- Task 11.1. Coordination and Communication
  A. Rossi (CERN) and J. Stadlmann (GSI)
- Task 11.2. Material testing for fast energy density deposition and high irradiation doses
  A. Bertarelli (CERN)
- Task 11.3. Material mechanical modelling
  A. Bertarelli
- Task 11.4. Material specification
  A. Rossi

WP11 (and beyond) detailed work

- EuCARD² WP11 ColMat-HDED focusses on further **material developments for collimators and targets**:
  - Producing novel material samples (Brevetti-Bizz, RHP, CERN)
  - Performing irradiation tests in M-branch (from 2011 in GSI) and HiRadMat (from 2012 at CERN), together with well-established irradiation facilities (NRC-KI and BNL) to measure radiation resistance and hardness. (CERN, GSI, UM, KUG, IFIC)
  - Characterising mechanical properties (POLITO and CERN).
  - Simulating mechanical properties (POLITO, NRC-KI, GSI, UM and CERN) and beam induced damage (CERN).
  - Simulating radiation induced damage (NRC-KI, GSI and CERN).
  - Integrating collimators into beam environment to give specifications and validate (CERN, HUD, UNIMAN, RHUL, IFIC).

WP11 results and next

- Ion irradiation tests at GSI.
- Proton irradiation tests at RCC-KI.
- Planned proton irradiation tests at HiRadMat (CERN)
- Thermo-mechanical tests at POLITO.
- Material sample measurements at CERN.

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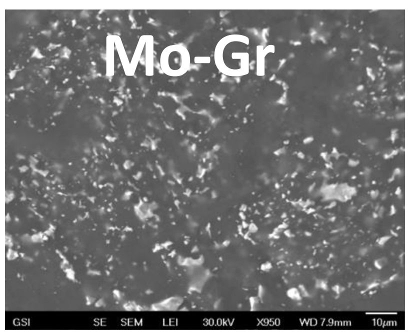
Irradiation tests @GSI

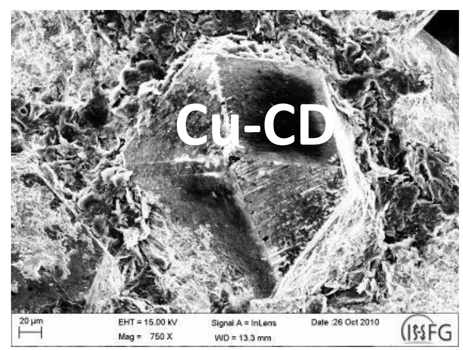
GSI

- Irradiation tests to study ion-induced modifications with ion fluencies and perform.
  U ions at 1.14 GeV, fluencies from 10^{11} to 10^{14} ions/cm^{2}s
- Tests to be continued in July/Sept. with Au and Pb ions and possibly higher energy.

Microstructural studies – SEM



BREVETTI BIZZ



RHP TECHNOLOGY

Courtesy of M. Tomut

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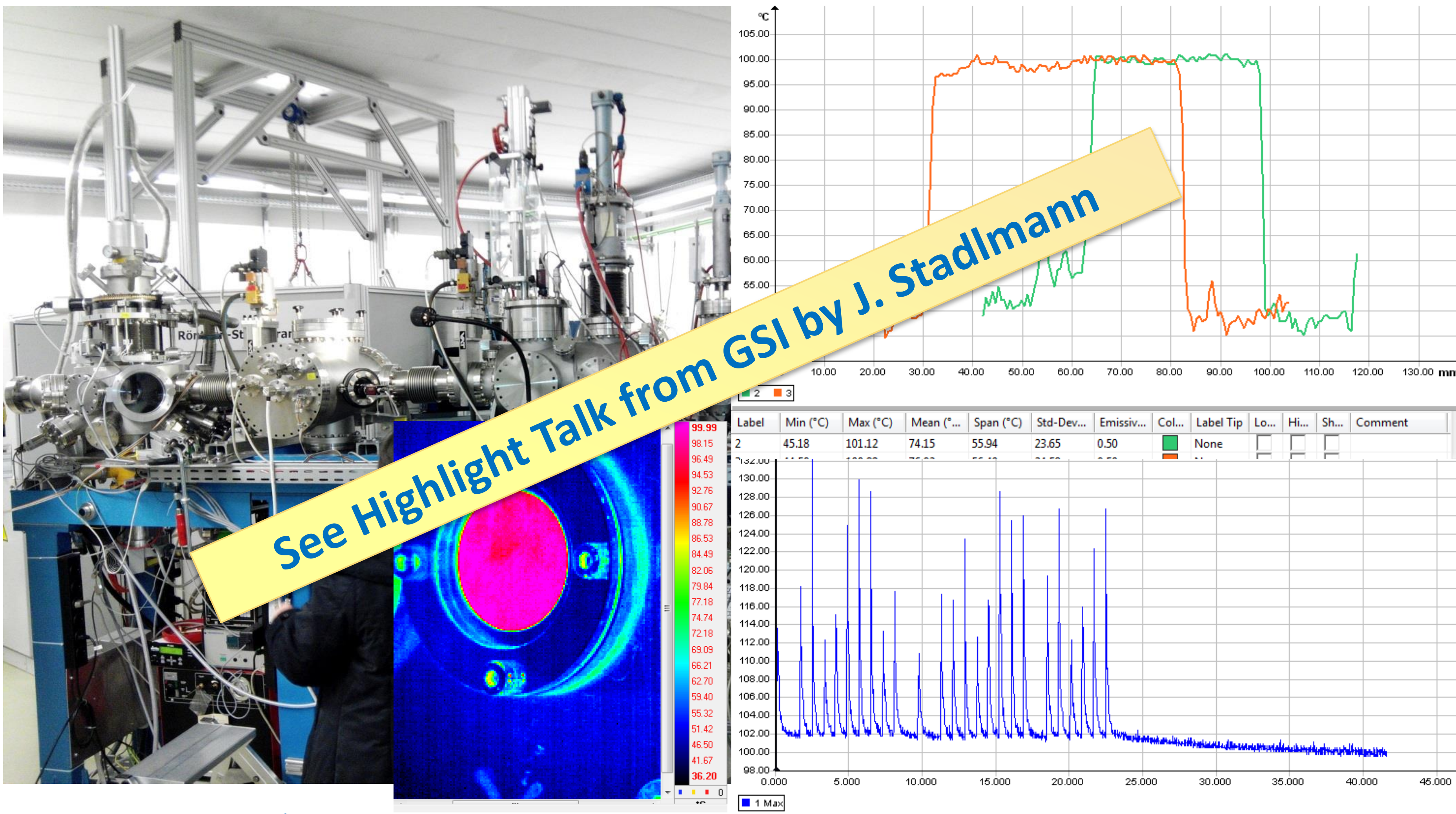
Irradiation tests @GSI



See Highlight Talk from GSI by J. Stadlmann

Desy – May '14

Courtesy of M. Tomut

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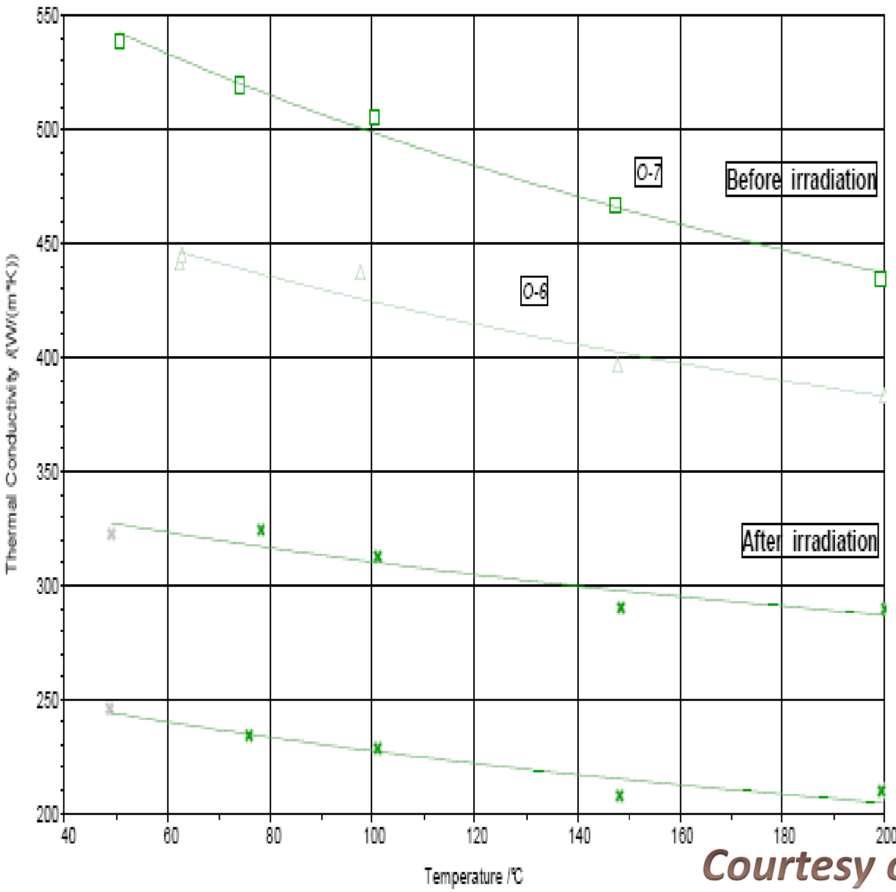
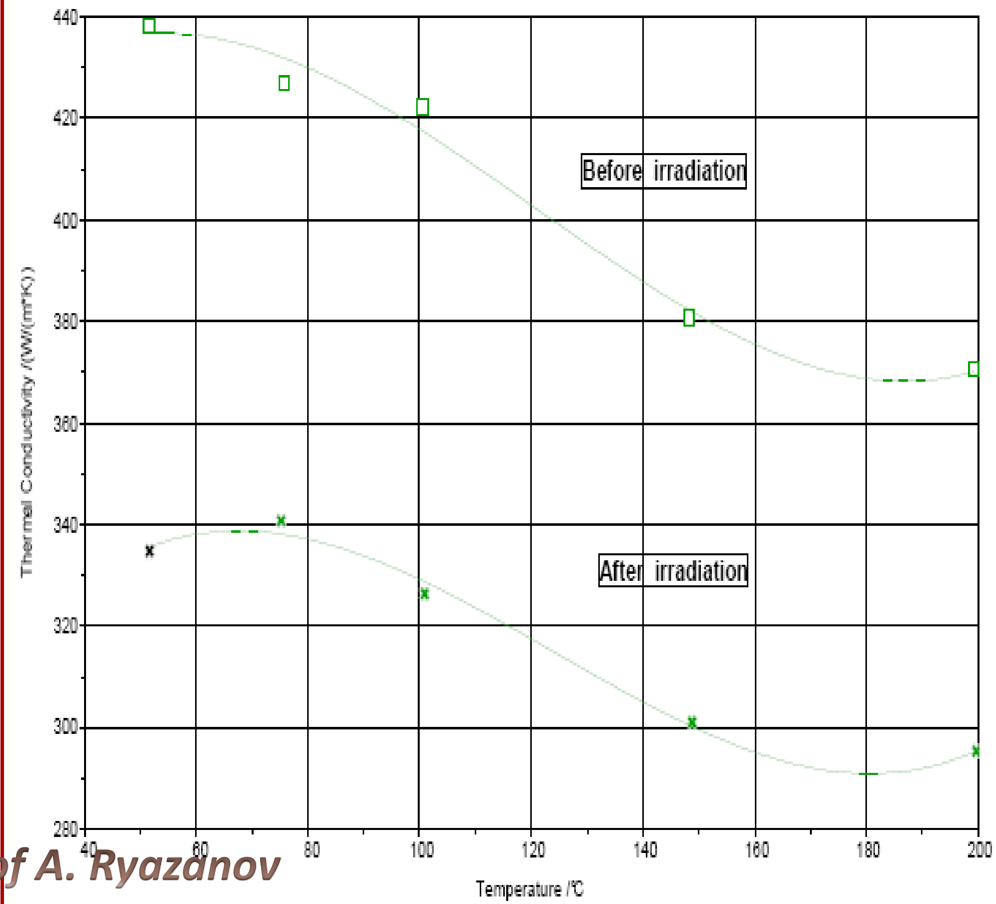
Irradiation tests @ NRC-KI

Temperature dependence of thermal conduction of the Cu-CD before and after irradiation with p+ at 30 MeV and doses of

(a) 10^{17} p/cm² **(b) 10^{18} p/cm²**

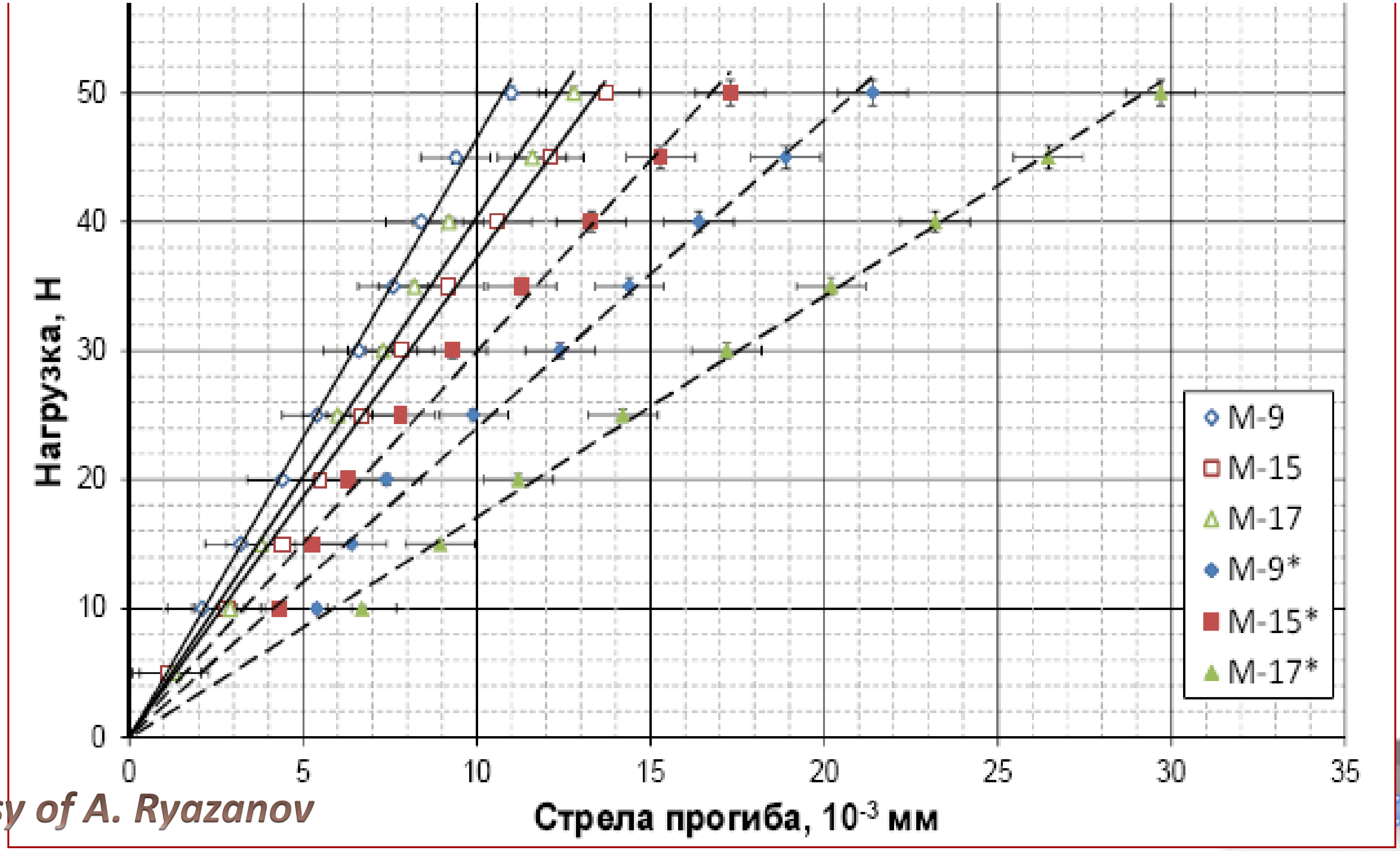




Courtesy of A. Ryazanov

Irradiation tests @ NRC-KI

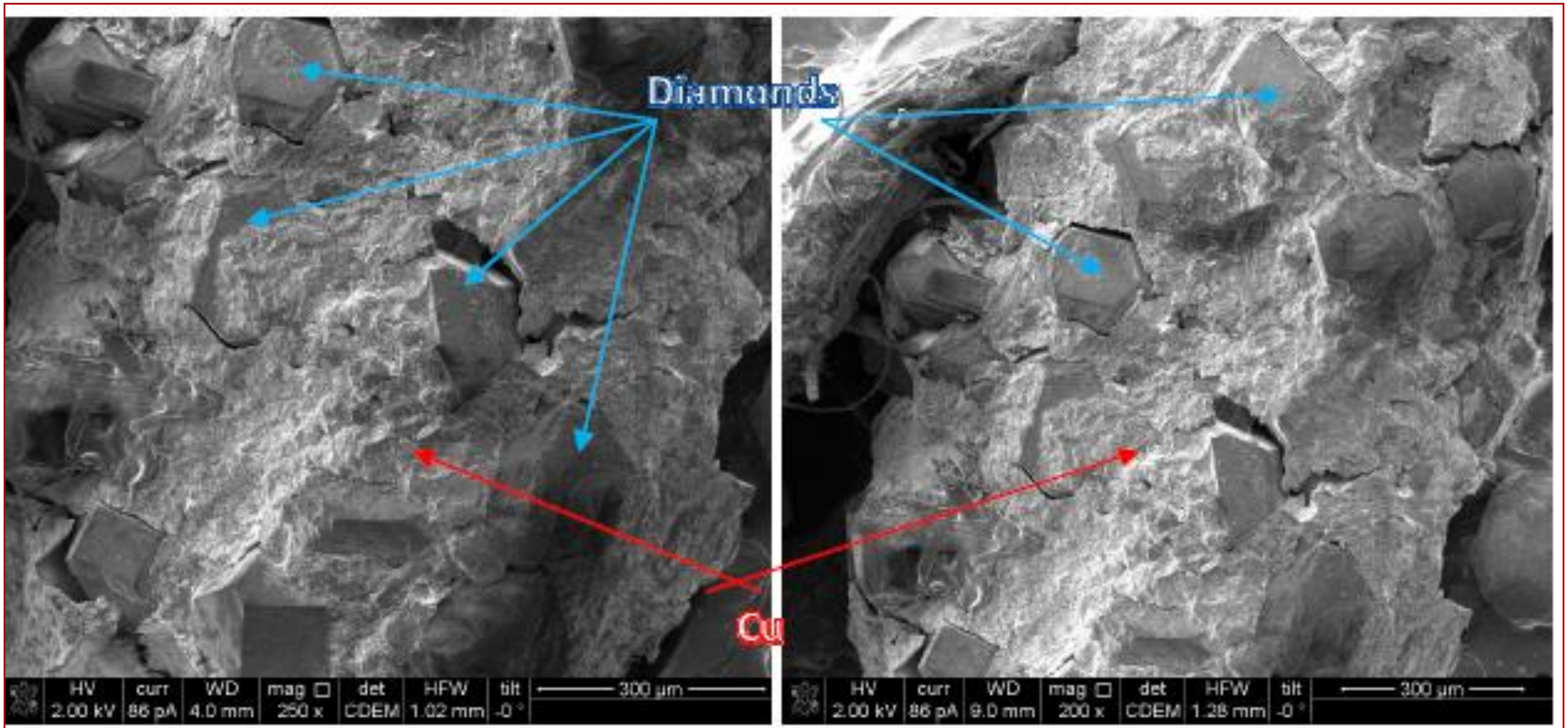
Measurements of the "load - deformation" curves of the initial (◊, □, Δ) and irradiated (♦, ■, ▲) of Cu-CD (M-9, M-15, M-17) after second irradiation by p+ at 30 MeV and dose of 10^{18} p/cm^2



Courtesy of A. Ryazanov

Irradiation tests @ NRC-KI

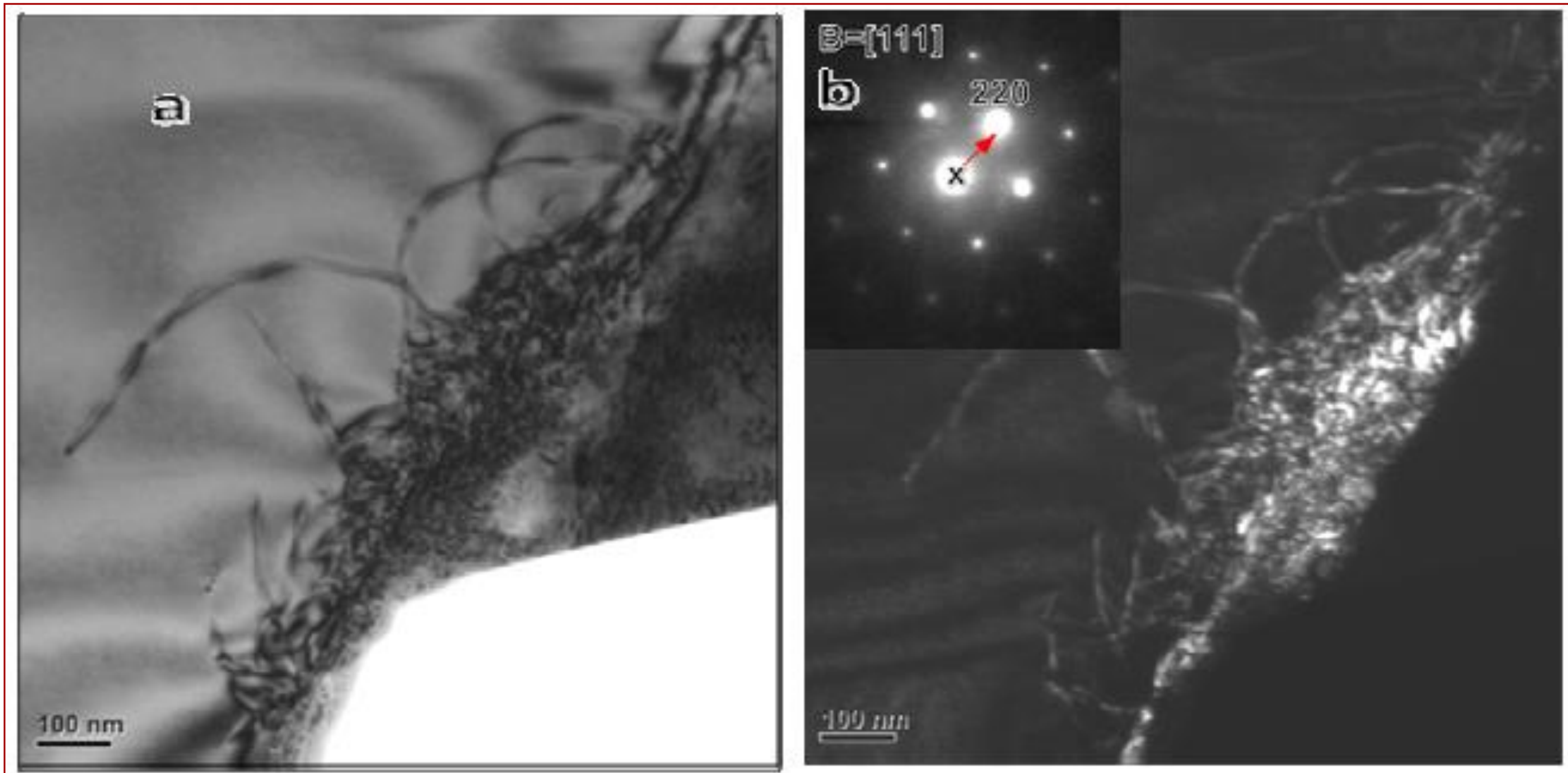
SEM images of the Cu-CD composite after p+ irradiation at 30 MeV and dose of 10^{17}p/cm^2 with (a) – high and (b) – low magnifications



(a) (b)

Irradiation tests @ NRC-KI

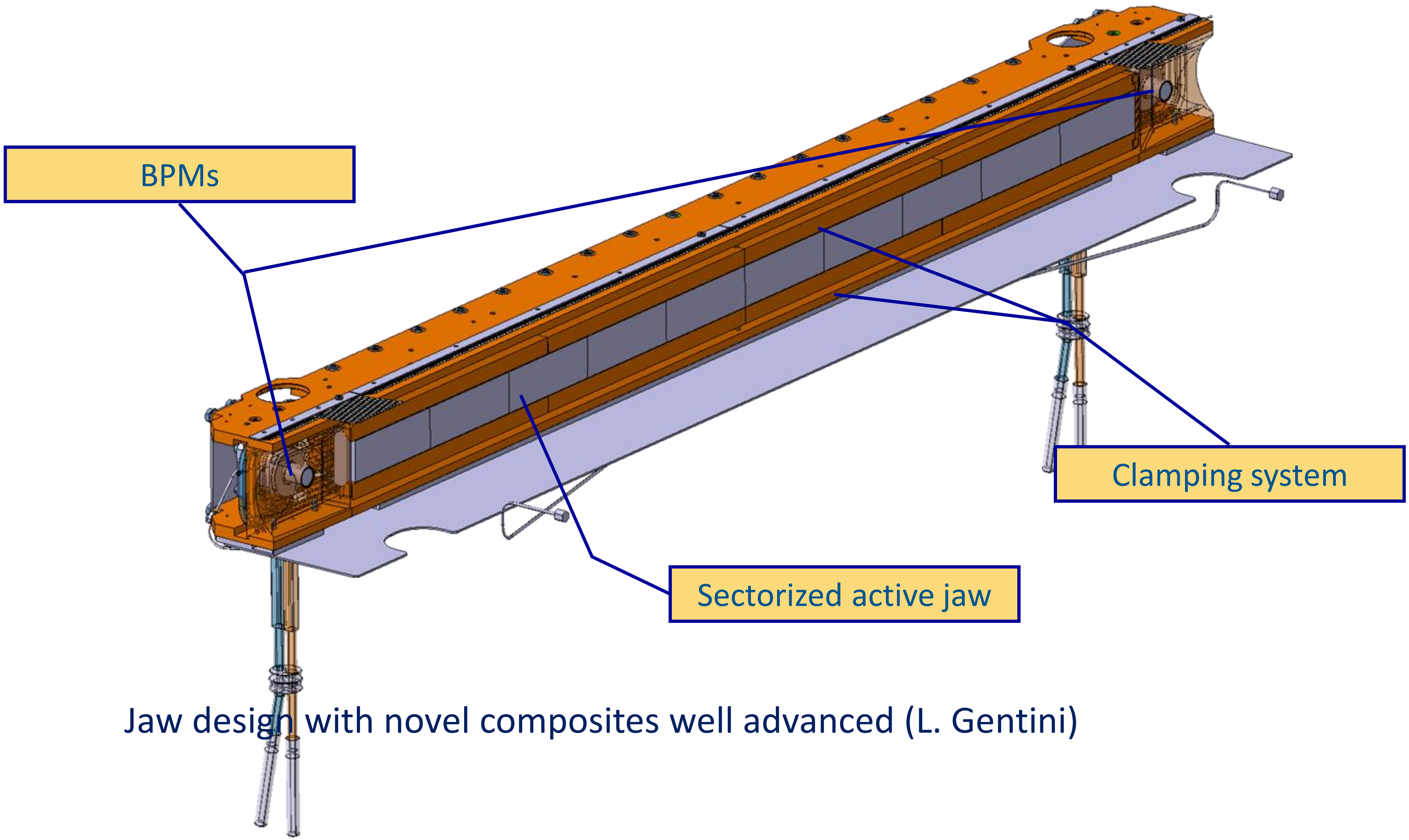
Bright field (a) and dark field (b) TEM images of dislocations near the surface of diamond precipitate after p+ irradiation at 30 MeV at 10^{18} p/cm^2. The SADP is in the inset of (b).



Courtesy of A. Ryazanov

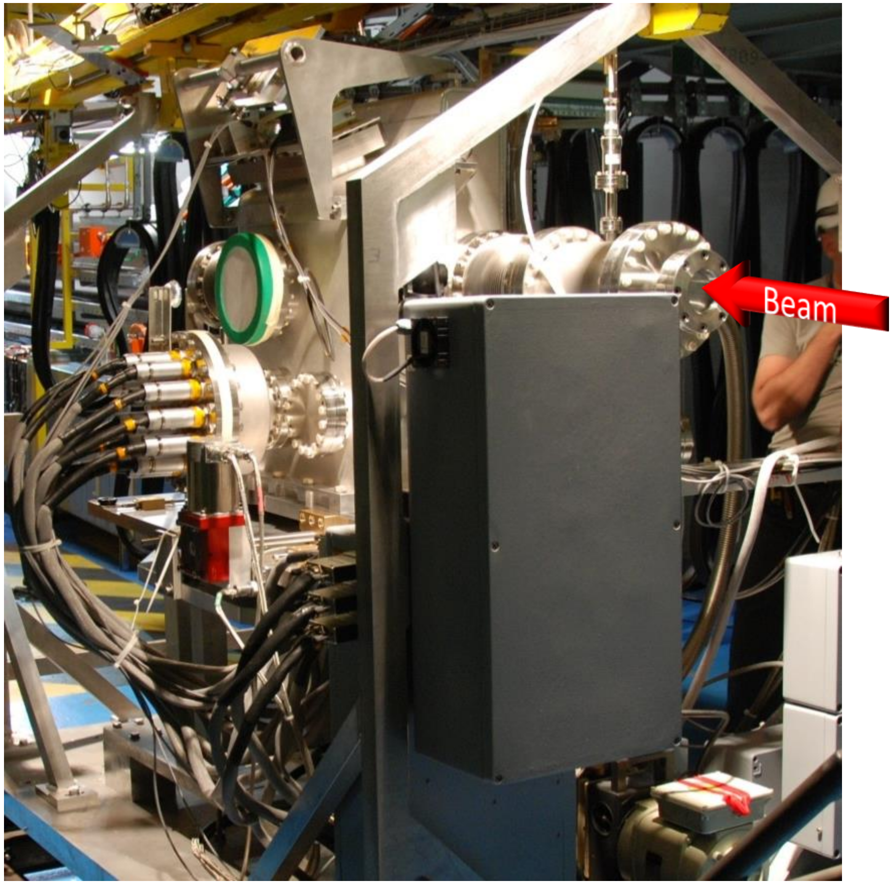
(a) (b)

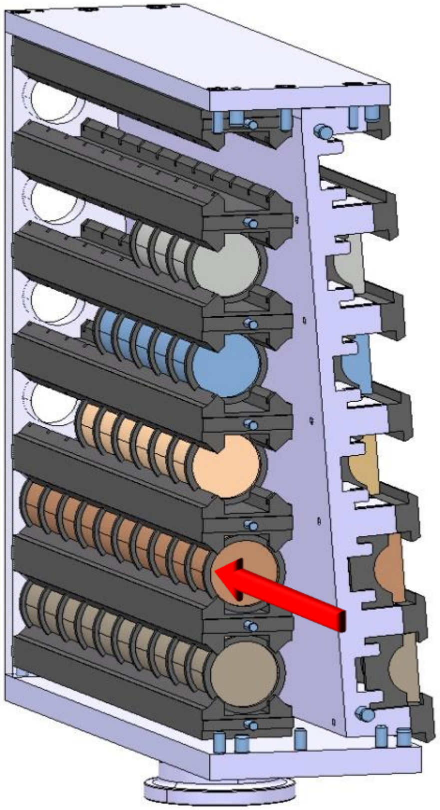
Future irradiation tests in HiRadMat @ CERN



Jaw design with novel composites well advanced (L. Gentini)

Future HiRadMat tests





High Intensity Samples (Type 2)

- Strain measurements on sample outer surface;
- Fast speed camera to capture fragment front formation and propagation;
- Temperature measurements;
- Sound measurements.

Courtesy of A. Bertarelli

Studies @POLITO

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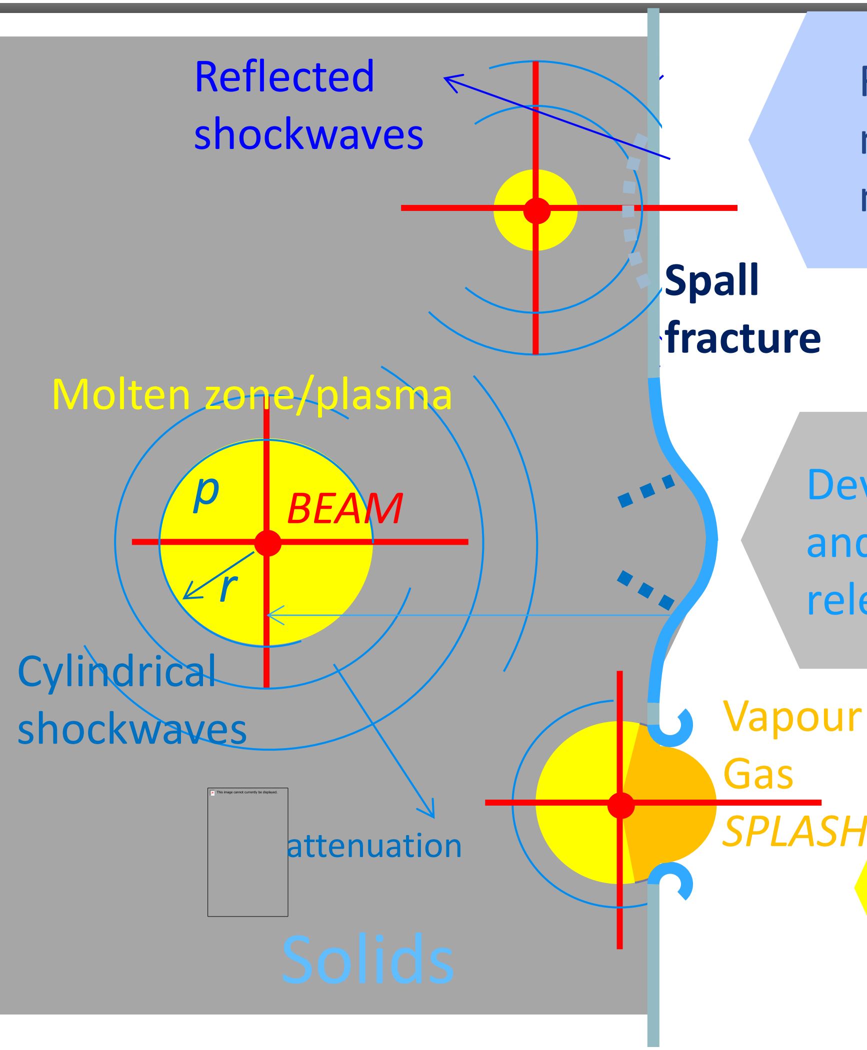
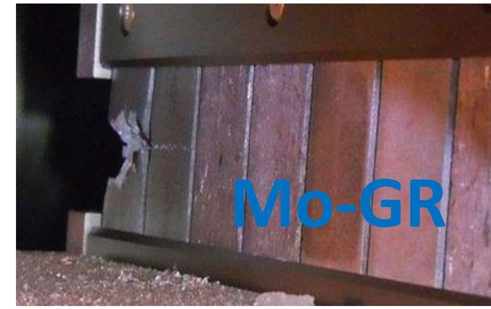
DIMEAS

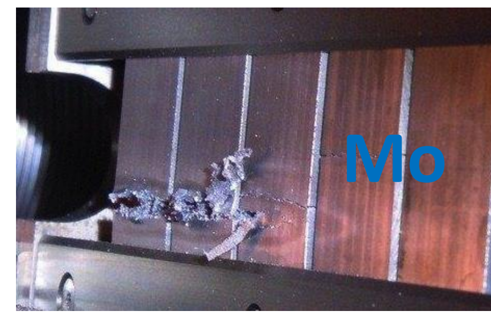


Fracture analysis of novel composites materials

Development of strength and failure models for relevant materials

Contributions to the development of Equations of State for relevant materials





Courtesy of L. Peroni

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EuCARD² Improved @POLITO

Strength and failure models – Gasgun

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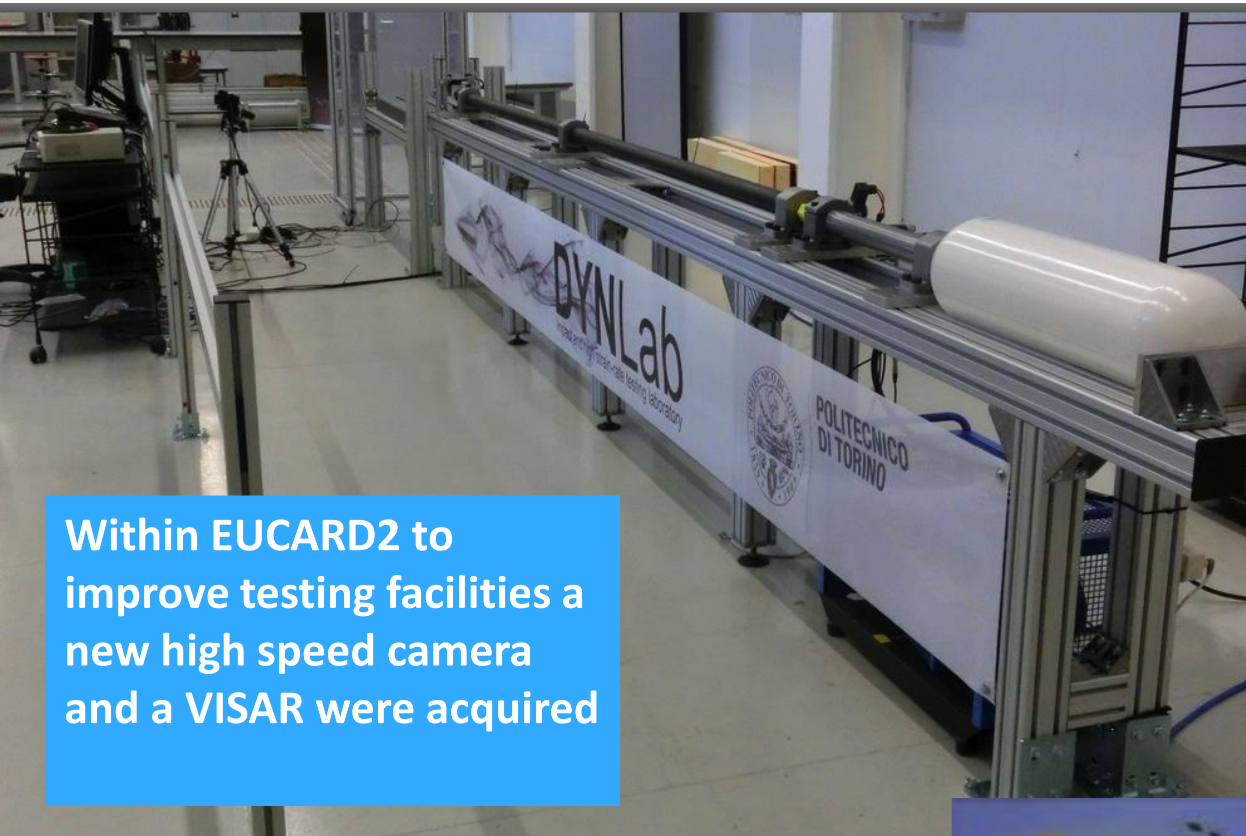

Within EUCARD2 to improve testing facilities a new high speed camera and a VISAR were acquired

- ✓ Light Gasgun for Taylor, flyer-plate and ballistic impacts tests

- ✓ 2 high speed video cameras (max **1 Mfps**) and 1 VISAR (Velocity Interferometer System for Any Reflector), PVDF sensors

Courtesy of L. Peroni

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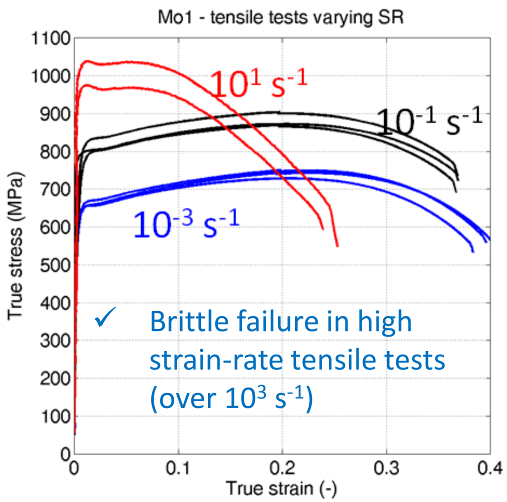
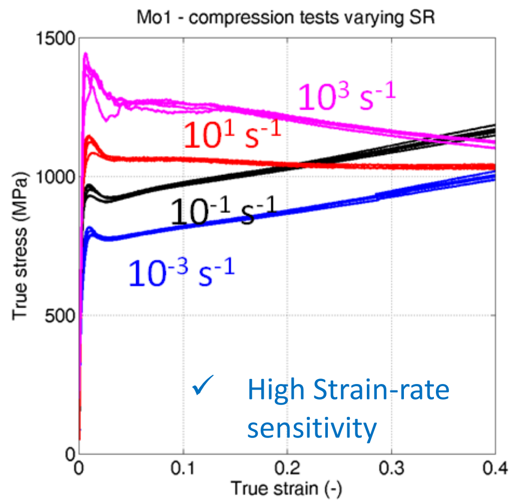
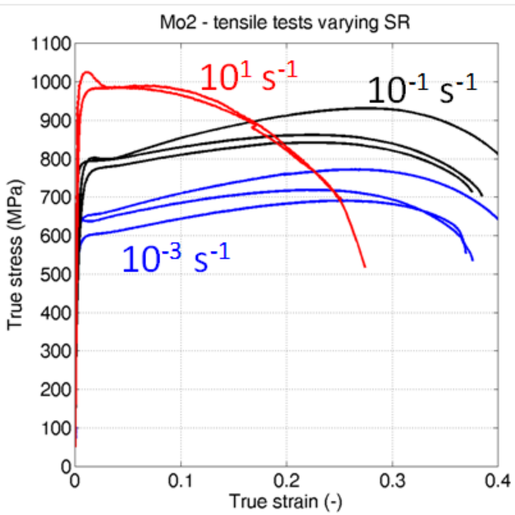
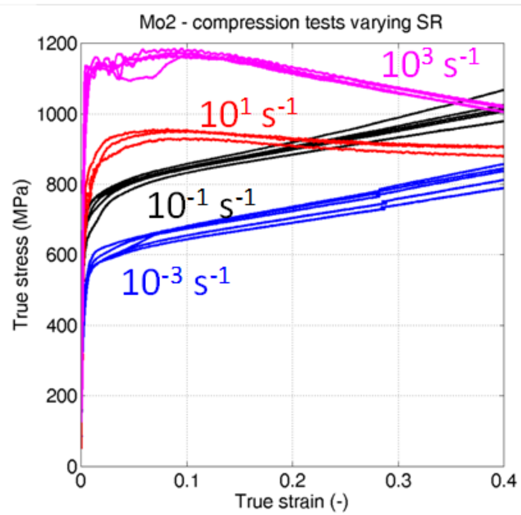
Tests @POLITO









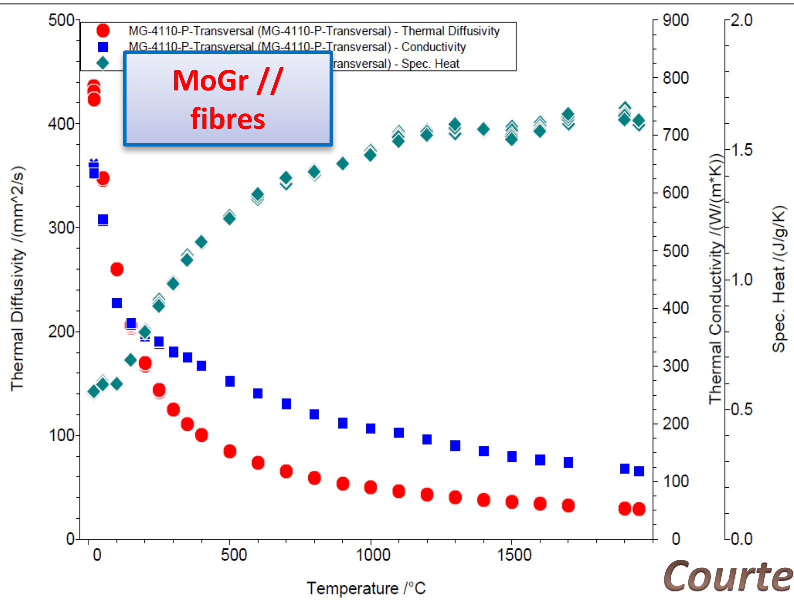
Courtesy of L. Peroni

2 Grades:
Mo1 (Plansee);
Mo2 (China)

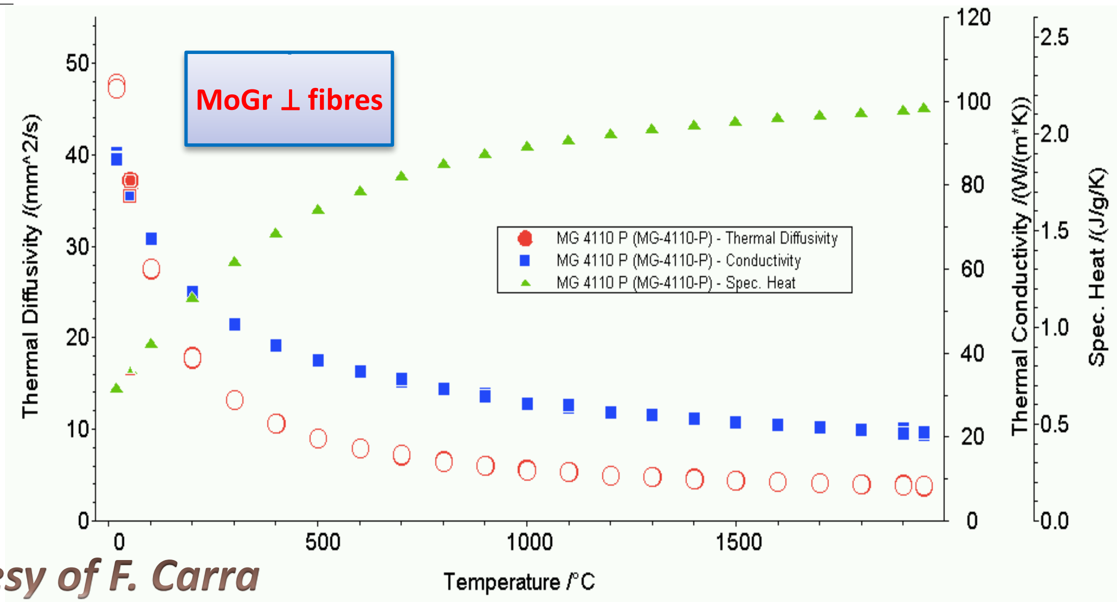
Metals produced via powder technology could exhibit brittle behaviour especially at high strain-rates probably due to the change of failure mechanism between ductile damage and transgranular fracture. These aspects must be deeply investigated.

Thermo-mechanical measurements @CERN

- **State-of-the-art machines** purchased by CERN to measure thermal properties of advanced materials
- **Temperature range**: T_{room} up to **2000 ˚C** (lower limit **-180 ˚C** with ad-hoc setup)
- **Laser-Flash**: thermal diffusivity, specific heat and thermal conductivity
- **Dilatometer**: Coefficient of thermal expansion

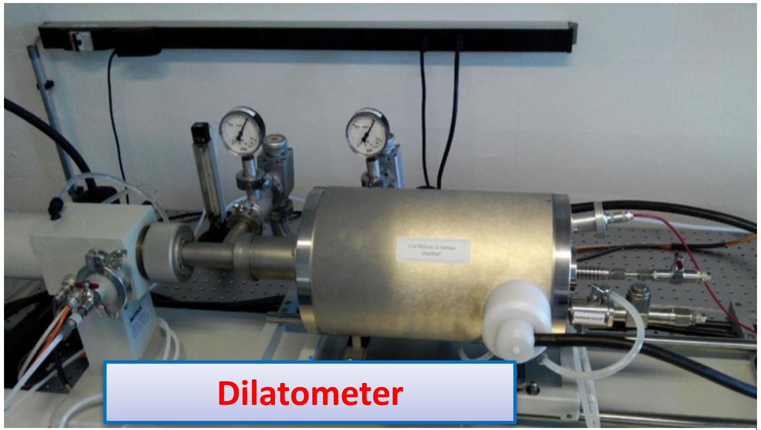


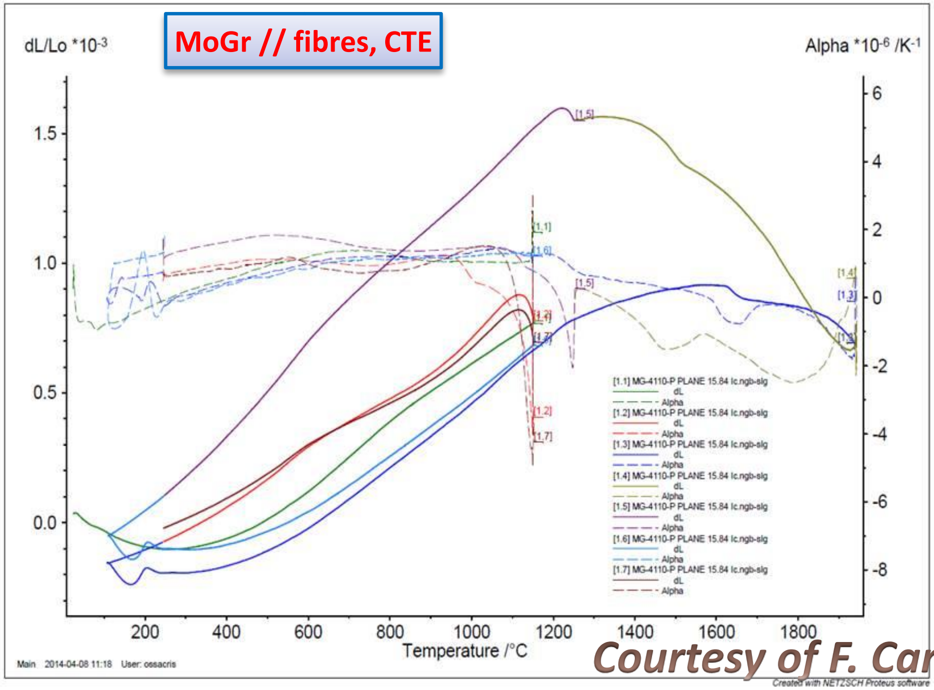
Courtesy of F. Carra

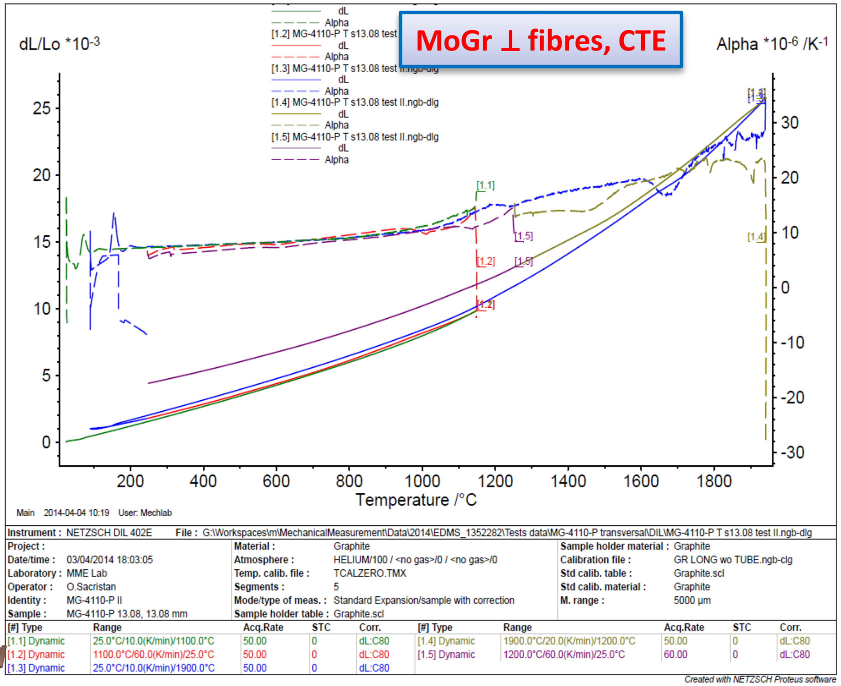


Method to measure material properties @CERN

- **CTE measurements: measurements performed in the two directions, after heating/cooling cycles**
- **Dotted lines: CTE**
- **Continuous lines: linear expansion**







Courtesy of F. Carra

WP11 Status Report

- **To date milestones achieved:**
  - Irradiation of first samples (some results already available!)
    - Sample preparation
    - Lab characterisation

  Extensive work already carried out at several institutes and future work being prepared. Simulations will follow.

- **Data analysis and simulations ongoing**

THANK YOU FOR YOUR ATTENTION

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