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Status of task 17.3 and publications on Shocks and Vibrations

2nd Annual Meeting of Aries WP17

Lorenzo Peroni (POLITO)

Task 3 description

Task 3: Dynamic testing and online monitoring

Testing of material samples in a broad range of environments:

- Mechanical testing in quasi-static and dynamic conditions, at various temperatures
- Tests under very high power laser and particle beams
- Irradiation tests with online monitoring of properties evolution
- Hydrodynamic simulations of experiments - constitutive models, spall strengths for new materials

Participants: CERN, ELI-NP, GSI, POLIMI, POLITO

Milestones

Milestone number[18]	Milestone title	WP number[9]	Lead beneficiary	Due Date (in months)[17]	Means of verification
MS58	Organisation of PowerMat kick-off meeting (Task 17.1)	WP17	1 - CERN	6	Agenda, summary report
MS59 ✓	Irradiation campaigns at GSI for radiation hardness studies (Task 17.3)	WP17	23 - POLITO	27	Report to StCom
MS60 ✓	Irradiation effects analysis (Task 17.3)	WP17	1 - CERN	36	Report to StCom
MS61	Comparative compendium of materials developed (Task 17.2)	WP17	1 - CERN	40	Report to StCom
MS62	Dissemination of R&D results on novel materials for accelerator and societal applications (Task 17.5)	WP17	12 - GSI	46	Report to StCom

ARIES

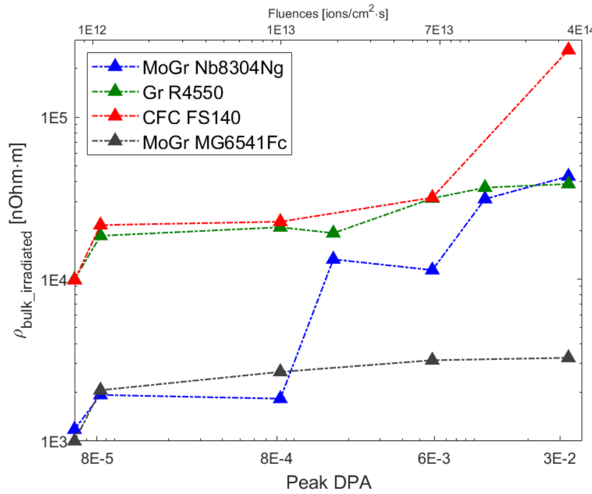
Deliverables

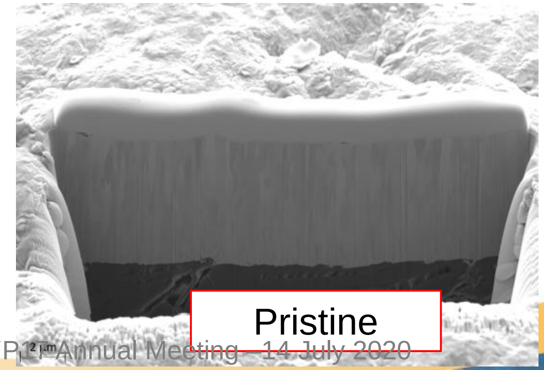
Deliverable Number[14]	Deliverable Title	Lead beneficiary	Type[15]	Dissemination level[16]	Due Date (in months)[17]
D17.1	Material characterization	1 - CERN	Report	Public	12
D17.2	Irradiation effect simulations	1 - CERN	Report	Public	44
D17.3	Irradiation test results	23 - POLITO	Report	Public	46

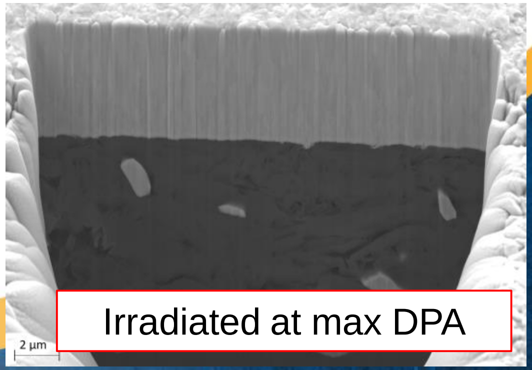
Task 17.3 – Material Testing: Irradiation at GSI UNILAC

Assessment of radiation damage to graphitic materials induced by 4.8 MeV/u Ca ions: **electrical resistivity** and **coating microscopy** analysis

- Irradiation test (TNA) in March/April 2019 on coated and bare samples at **DPA levels comparable to end-of-life HL-LHC**. **Examination** started already **~2 months later** thanks to low residual dose
- **Electrical Resistivity**
  - DC measurements with the 4-probe method and multi-layer model
    Bulk **resistivity increasing faster in more ordered materials**; MoGr with fibres more radiation resistant
  - Coatings resistivity worsening significantly less in pulsed-mode (HIPIMS) compared to DC-mode (DCSM)
- FIB-SEM investigation of **Mo coating/bulk interface**
  - Columnar and dense structure kept after irradiation
  - The coating-bulk interface is continuous, no evidence of coating detachment; no cracks



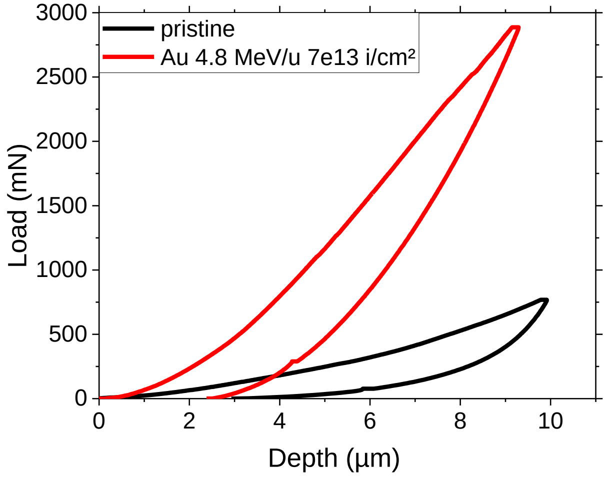


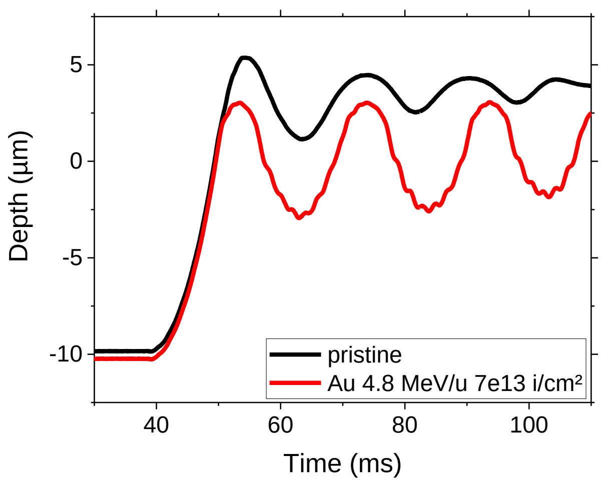


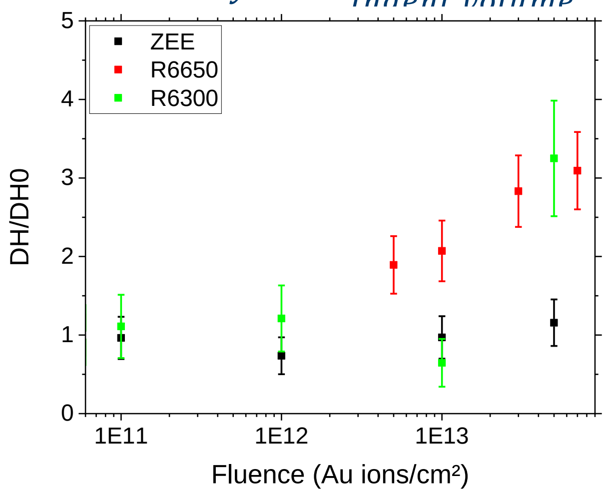
Task 17.3 – Material Testing: Irradiation at GSI UNILAC

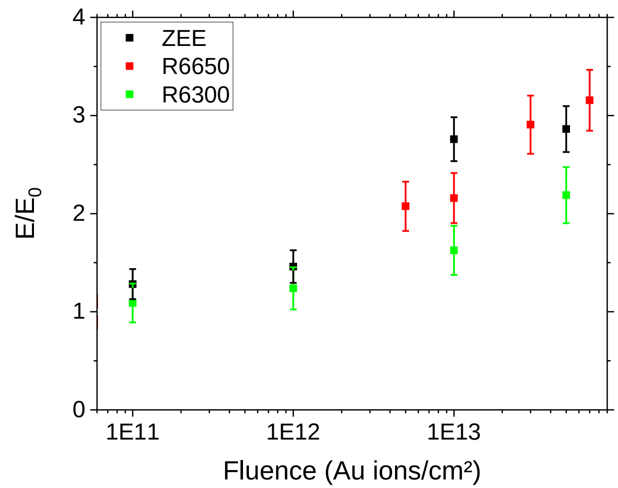
Assessment of hardening of graphitic materials (3 Graphites grades, 2 suppliers) induced by 4.8 MeV/u Au ions (early 2020) by quasi-static and dynamic techniques

- **Microindentation**
  - Young's modulus rises up to 300 %
- **Dynamic hardness test**
  - indenter accelerated towards sample surface with a constant force
  - strain rates at the surface ~ 10^4 s^{-1}
  - observation of velocity and penetration on the surface; differences between grades detected
  - calculation of dynamic hardness $H_{dyn} = \frac{(E_{kin,in} - E_{kin,out})}{Indent\ volume}$



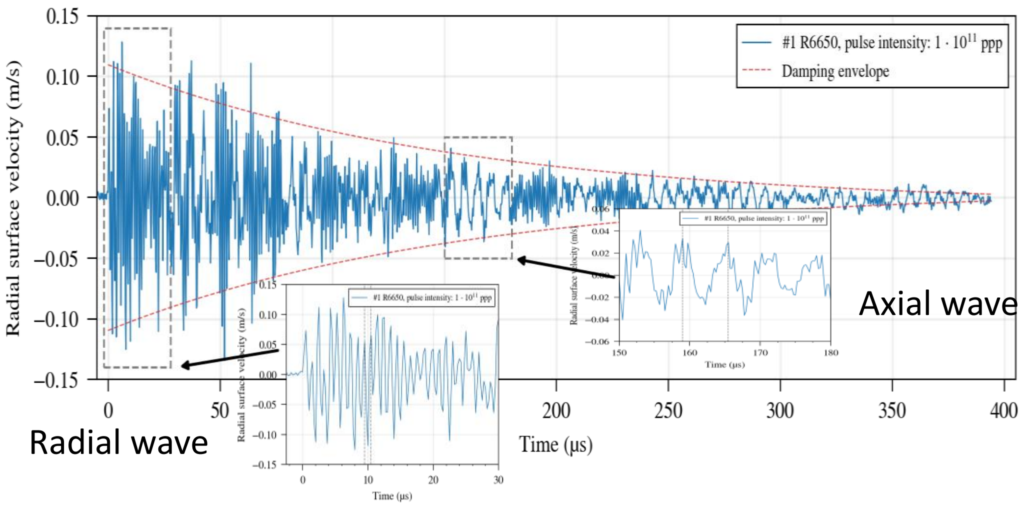


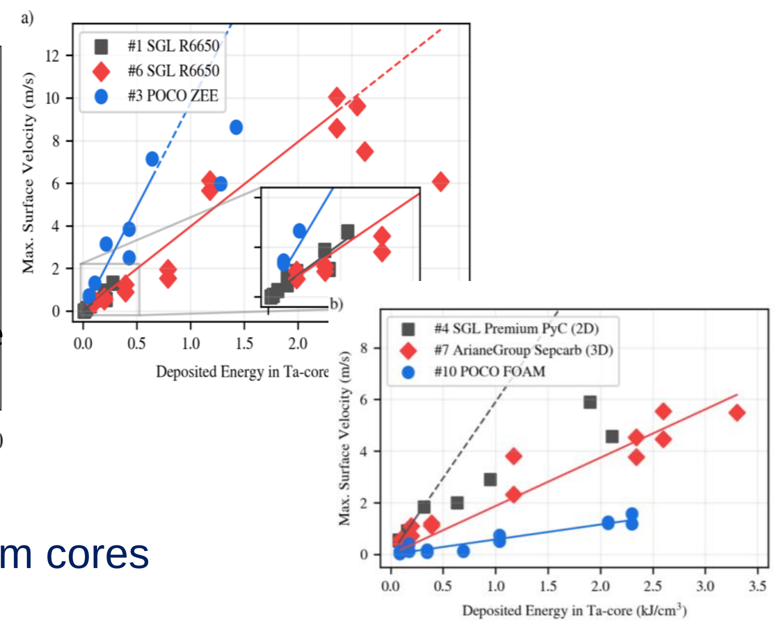




Task 17.3. Material Testing: FlexMat @ HiRadMat

- ***Aim:*** Testing of dynamic response of target and beam dump materials to proton beam impact
- ***Since last reporting***: detailed analysis of response of different graphitic materials at high strain rates-using Ta core drivers



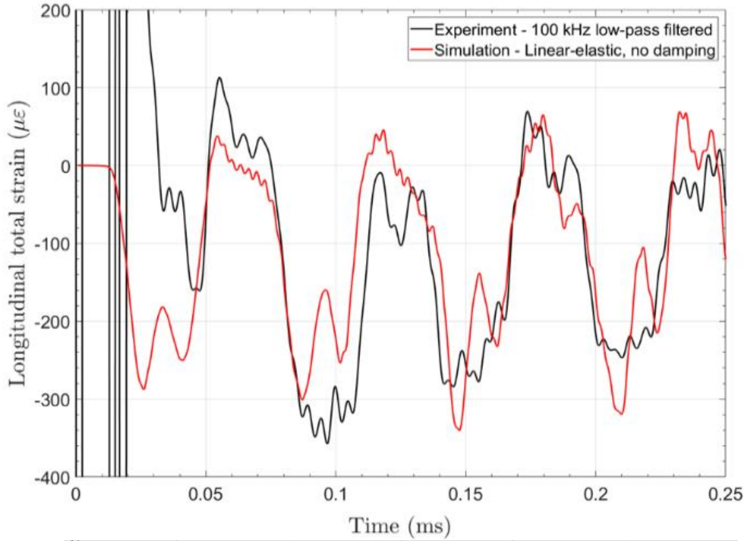


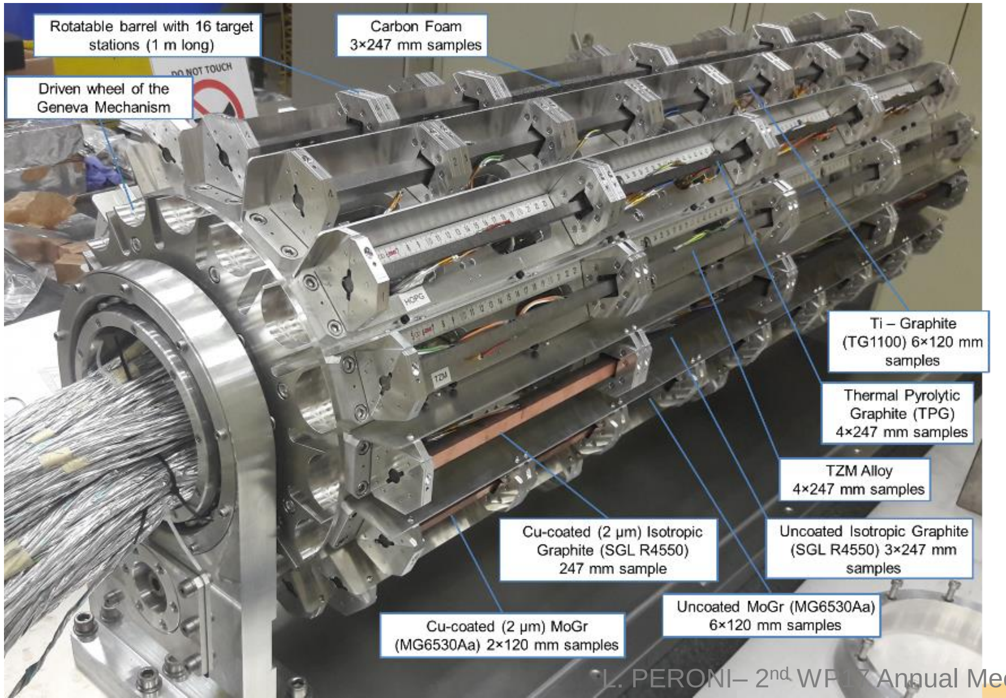
- Short-pulse 440 GeV proton beam impact on Tantalum cores embedded in different graphitic shells
- Identification of beam-induced radial & axial pressure waves
- Extraction of material parameters in dynamic loading conditions with FE simulations
- Identified load limits for failure of the graphitic shells by deviation from monotonic increase with increasing energy deposition density

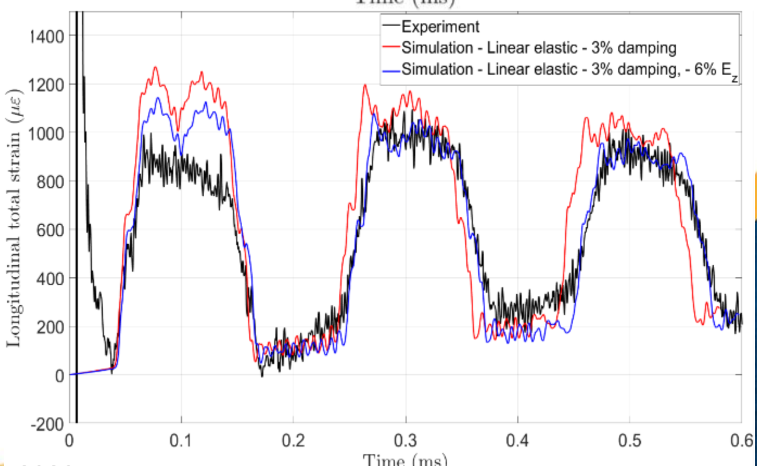
Task 17.3 – Material Testing: MultiMat @ HiRadMat

Post-processing of **MultiMat** acquired data and comparison to advanced simulations ongoing (CERN, POLITO, UOM):

- In general good agreement, particularly for isotropic materials
- Elastic constants of several materials updated (e.g. CFC, CuCD)
- Role and extent of internal damping assessed
- Some unexpected failures (SiC and TZM) analyzed and (partly) explained



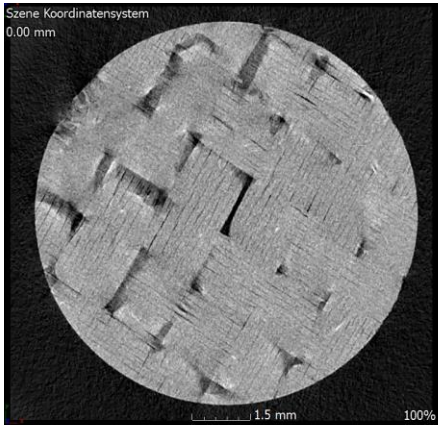




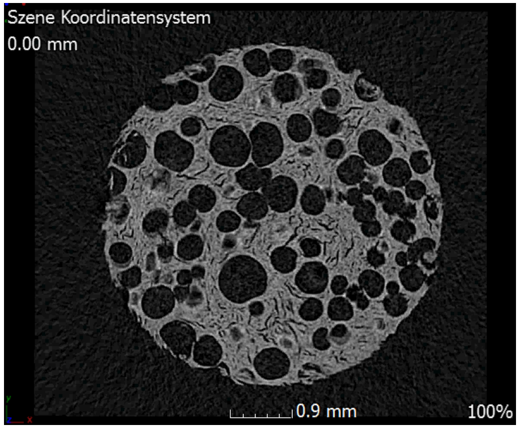
Task 17.2 and 17.3 – Highlights

X-ray tomography

2D CFC



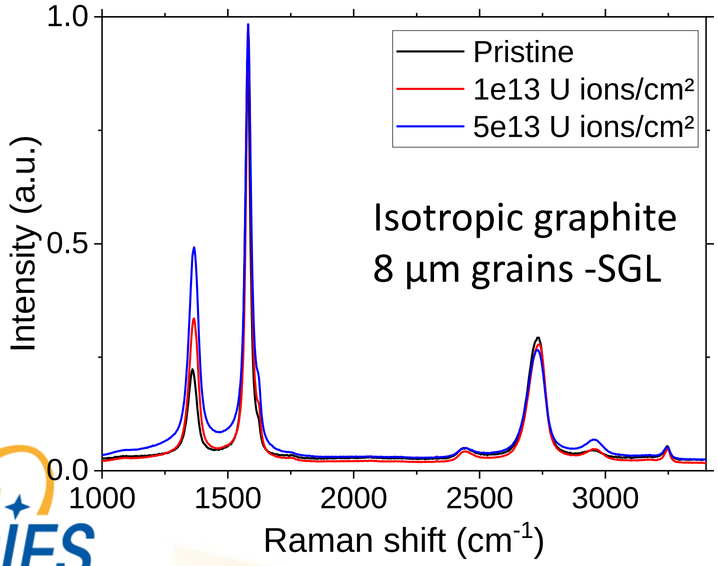
POCO Foam



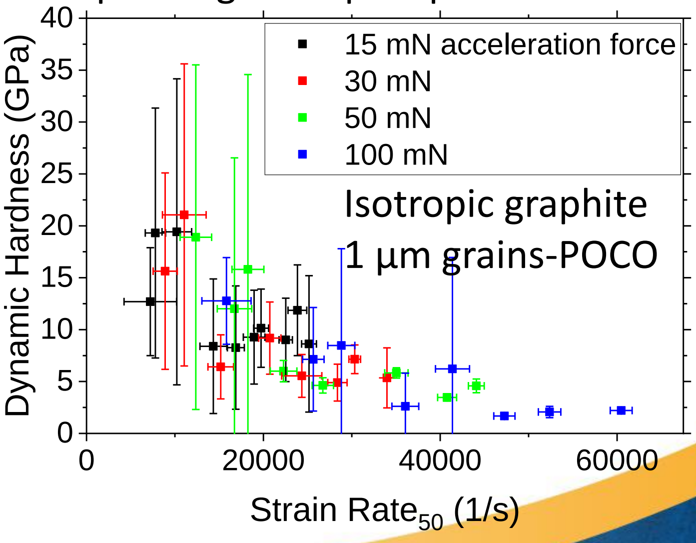
GSI

Nanoindentation, nanoimpact
Fatigue testing
Creep
Poisson ratio measurements
Laser Flash analysis
Thermomechanical analysis
X Ray Diffraction

Raman spectroscopy



Nanoimpact with varying Strain Rate depending on impact parameters



Special Issue

Journal metrics

Acceptance rate	36%
Submission to final decision	92 days
Acceptance to publication	38 days
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APC	**$2200**

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Shock and Vibration

Hindawi

Special Issue on
Structural and Wave Propagation Effects in High-Energy Particle Impacts

CALL FOR PAPERS

When subatomic particles or ions interact with matter, they tend to transfer part of their energy to the medium they traverse. The energy deposited in the material produces a dynamic response of the structure, entailing stress waves and vibrations, or even the failure of the component, with effects comparable to a simultaneous action of dynamic mechanical and thermal loads. These phenomena may severely affect the integrity and functionality of the impacted equipment. The correct understanding and prediction of beam-induced shock and damage is therefore extremely important in the design of any component exposed to direct interaction with intense and energetic particle beams. However, it could also be of inspiration for many other civil and aerospace applications in which the structures are subjected to similar scenarios, such as mechanical and high-velocity impacts, explosions, or thermally induced vibrations. Moreover, impacts with high-energy particle beams allow researchers to investigate material behavior in extreme conditions that cannot be replicated with laboratory-controlled experiments. For example, the HiRadMat facility at the European Organization for Nuclear Research (CERN) could potentially be a useful tool for the shock community to validate theoretical and numerical models and to evaluate the structural integrity of components, with potential applications not strictly related to the particle accelerator field.

This special issue aims to publish original research in the field of high-energy particle beam interaction from a shock and vibration perspective. Papers concerning the assessment of induced shockwaves and their structural effects on mechanical components will be considered. Contributions that discuss the development and validation of experiments, alongside analytical and numerical tools for the analysis of wave propagation and dynamic loading scenarios, are particularly welcome. This special issue also encourages researchers to submit review articles that overview the state of the art and seek to stimulate and support continuing efforts in studying the macroscale mechanical and hydrodynamic responses induced on materials and in evaluating structural integrity.

Potential topics include but are not limited to the following:

- Mechanics and behaviors of materials in high-energy impacts from a shock and vibration perspective
- Analysis of elastoplastic shock wave generation and propagation in matter
- Modeling and simulation of structural effects during particle beam interaction with matter
- Development and validation of novel material models and/or equations of state for high-energy impact applications from a shock and vibration perspective
- Development of innovative experimental techniques for testing and characterizing materials and structures under extreme shock conditions
- Data acquisition and signal processing in high-energy impact and shock experiments

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Submission Deadline
Friday, 11 September 2020

Publication Date
January 2021

ARIES

Only 3 submitted papers…

Shockwave propagation in particle accelerator scenarios
Martina Scapin
Submitted 2019/12/09
Editor assigned, reviewers invited

Dynamic Response of Graphitic Targets with Tantalum Cores Impacted by Pulsed 440-GeV Proton Beams
Pascal Simon, Philipp Drechse, Peter Katrik, Kay-Obbe Voss, Philipp Bolz, Fiona J. Harden, Michael Guinchard, Yacine Kadi, Christina Trautmann, Marilena Tomut
Submitted 2020/06/14
Editor assigned, reviewers invited

Thermomechanical Characterisation of Copper Diamond and Benchmarking with the MultiMat experiment
Nicholas J. Sammut, Pierluigi Mollicone, Michele Pasquali, Federico Carra, Alessandro Bertarelli, Jorge Guardia Valenzuela, Oscar Sacristan De Frutos, Marcus Portelli,
Submitted 2020/07/08

All the submitted papers have at least one of the authors which is also a guest editor for the SI