New Collimator Materials in EuCARD^2

Adriana Rossi for the
ColMat-HDED collaboration

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ColMat-HDED

(Collimator Materials for fast High Density Energy Deposition)

- The collimators determine the **LHC impedance**
  - *Tight collimator settings (2012-13) necessary to improve cleaning performance limited beam lifetime.*
- The ***β** reach** is determined by collimation constraints
  - *Retraction between beam dump and horizontal TCTs (BPM collimators) and TCT robustness.*
- LHC challenges: 360MJ design □ 500MJ HiLumi and 1E16 p/y doses in IR7 (betatron cleaning)

➲ Improve **impedance** and **robustness**

- *State-of-the-art material and new design for secondary collimator jaws*
- *Improved robustness at critical locations (like tertiary collimators - close to experimental IRs)*

EuCARD²

ColMat-HDED

(Collimator Materials for fast High Density Energy Deposition)

- Building upon the results of EuCARD and pushing them into a new and even more innovative regime, the collimation WP in EuCARD² will support **progress with material developments for collimators and targets**.
- The new availability of irradiation facility such as HiRadMat (in 2012 at CERN) and M-branch (2011 in GSI), together with well-established irradiation facilities (Kurchatov), will allow to fully characterising promising candi... like metal-diamond and metal-graphite com... new types of silicon carbide.
- Note complementarity with irradiation tests at BLN, different energies and additional materials tested (see A.Bertarelli presentation) within the USLARP program
- These studied have also **a wide range of possible applications** starting from **thermal management for electronics**, to **nuclear industry**, **fusion research**, and **high temperature space applications**.

ColMat-HDED collaboration

(Collimator Materials for fast High Density Energy Deposition)

Main founding to Kurchatov lab.
From CERN Collimation Project

WP11 Objectives

- **Task 11.1. Coordination and Communication**
  (A. Rossi and J. Stadlmann)
  - Define the global system taking inputs from different work-package (WP) tasks
  - Coordinate and schedule WP tasks, to monitor work progress and inform the project management and WP participants
  - Follow up the WP budget and use of resources
  - Prepare internal and deliverable reports

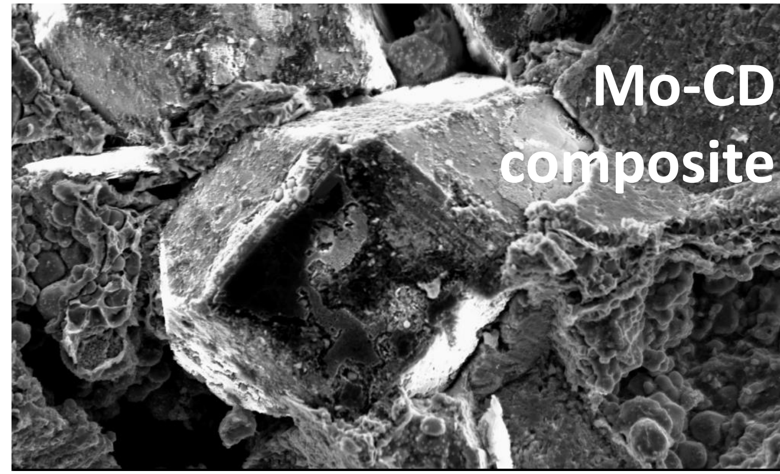
WP11 Objectives

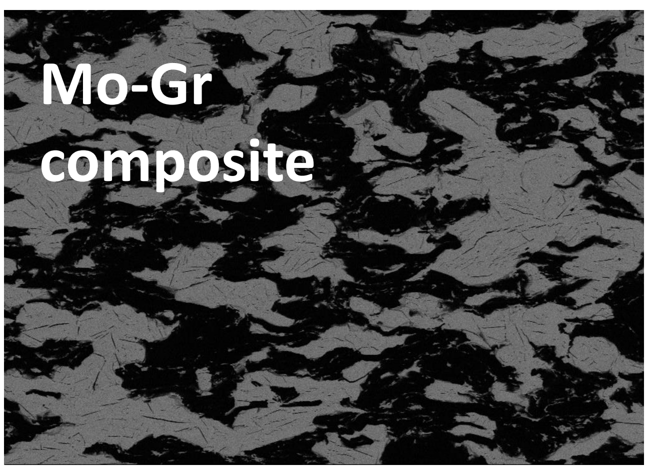
- **Task 11.2. Material testing for fast energy density deposition and high irradiation doses** (A. Bertarelli)

  The collimator robustness and integrity after impact is of great importance in a collimation system. Aim of this task is to review the best modern materials and to perform experimental tests on material robustness and mechanical behaviour.

  - R&D focuses on Metal Matrix Composites (MMC) with Diamond or Graphite reinforcements as they have the potential to combine the properties of Diamond or Graphite (high k, low ρ and low CTE) with those of Metals (strength, γ , …).
  - Perform experimental tests on material robustness and mechanical behaviour after highly energetic beam impact and high thermal stresses measuring heating and shock waves.
  - Perform irradiation and characterisation of property changes of collimator materials.

Material sintering, some examples



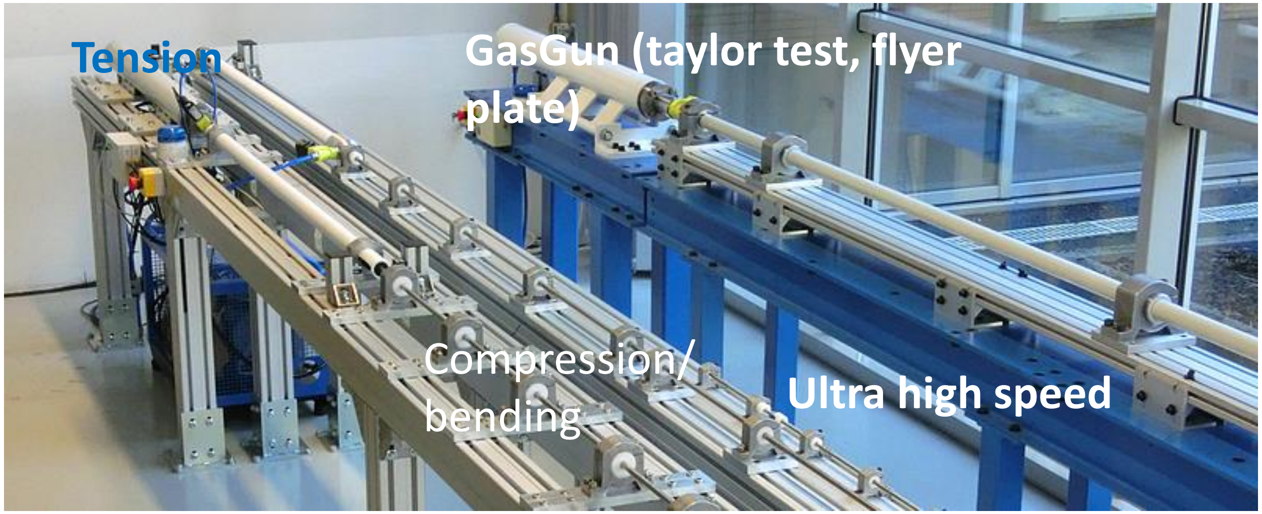


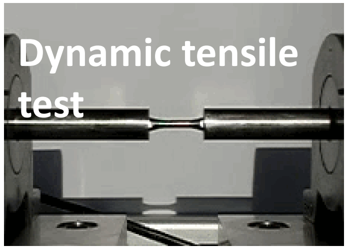
CERN

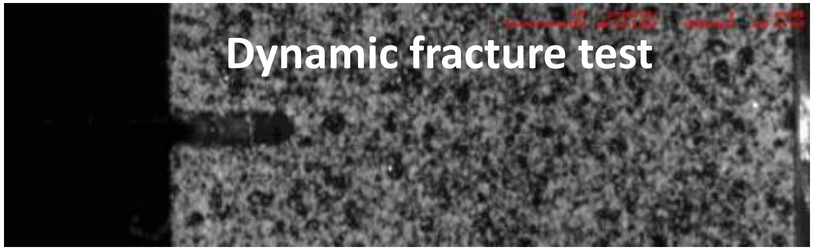
BREVETTI BIZZ

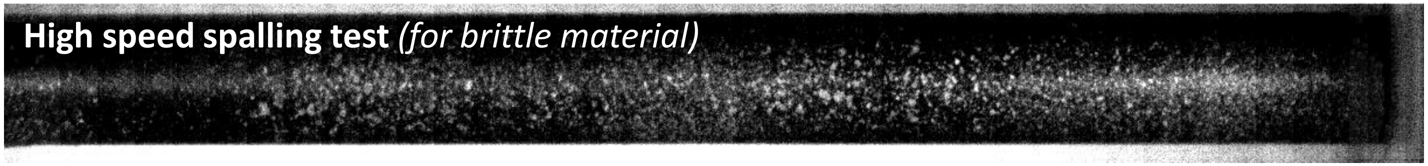
Courtesy of A. Bertarelli

Material testing, some examples



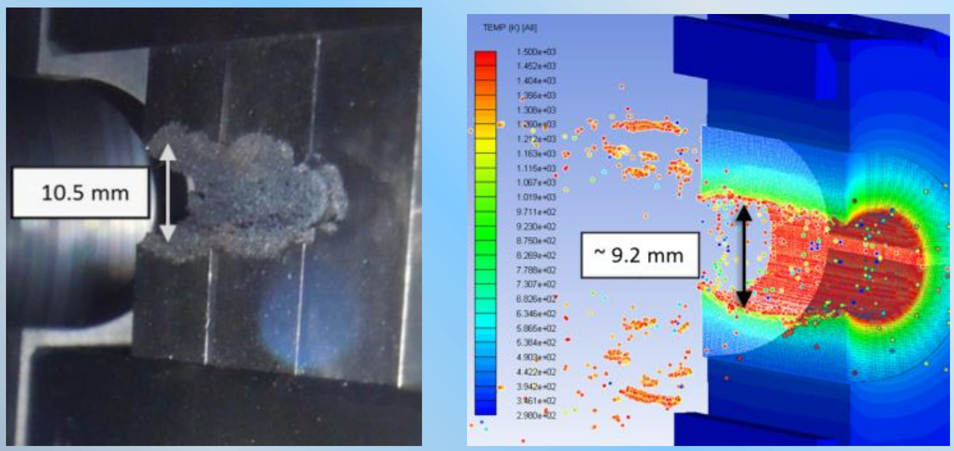






Courtesy of M. Scapin and L. Peroni

Material testing, some examples



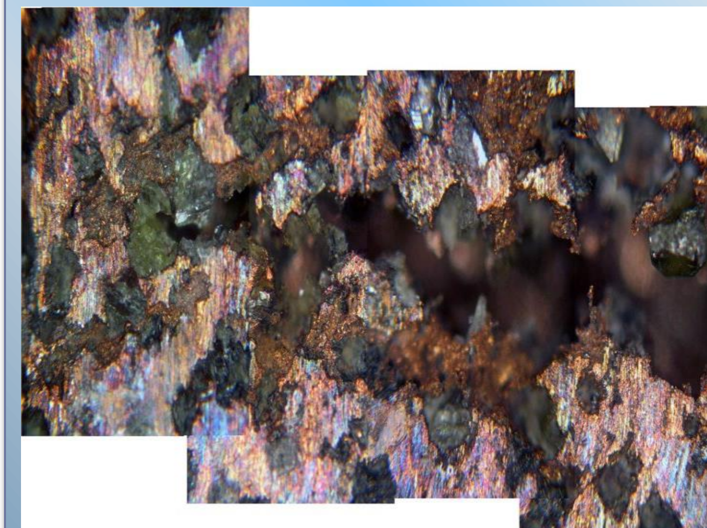
Post-mortem observation of Inermet® 180 samples and simulated after irradiation in HiRadMat at 440GeV (A. Bertarelli IPAC’13)

- HiRadMat tests show that an acoustic monitoring of collimator sections in the LHC is a promising tool for post-mortem analysis of beam induced damage in solid materials.

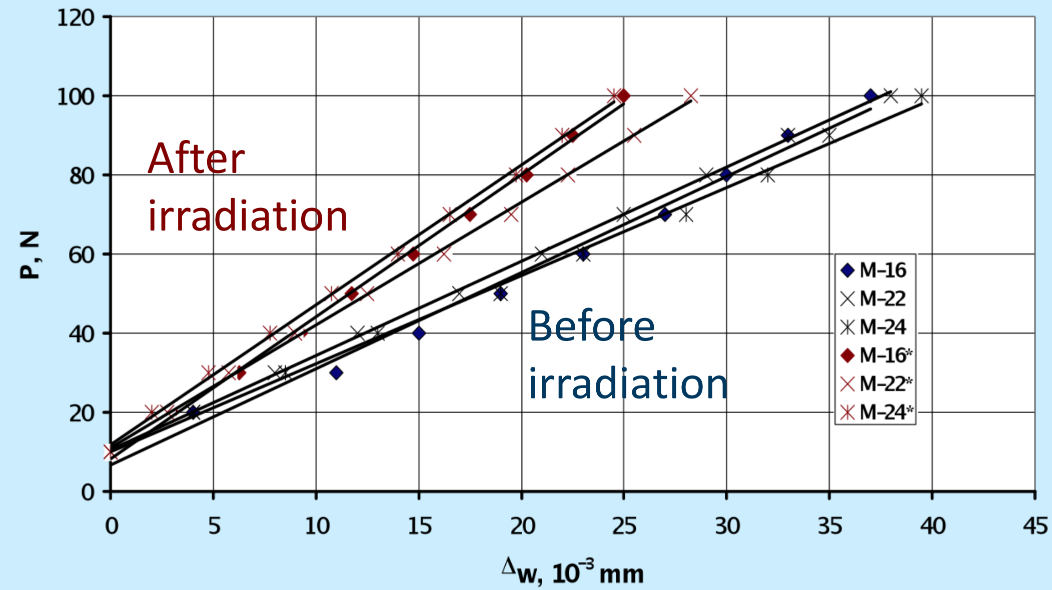
ColMat-HDED

EuCARD²

Material testing, some examples



Cracks in Cu-D material after 30 M
beam irradiation

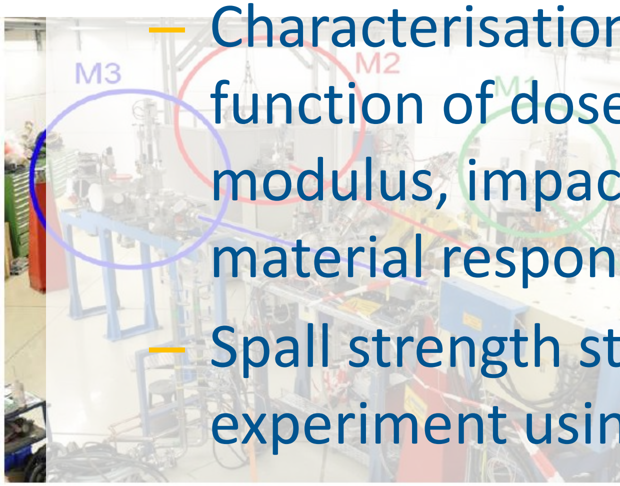


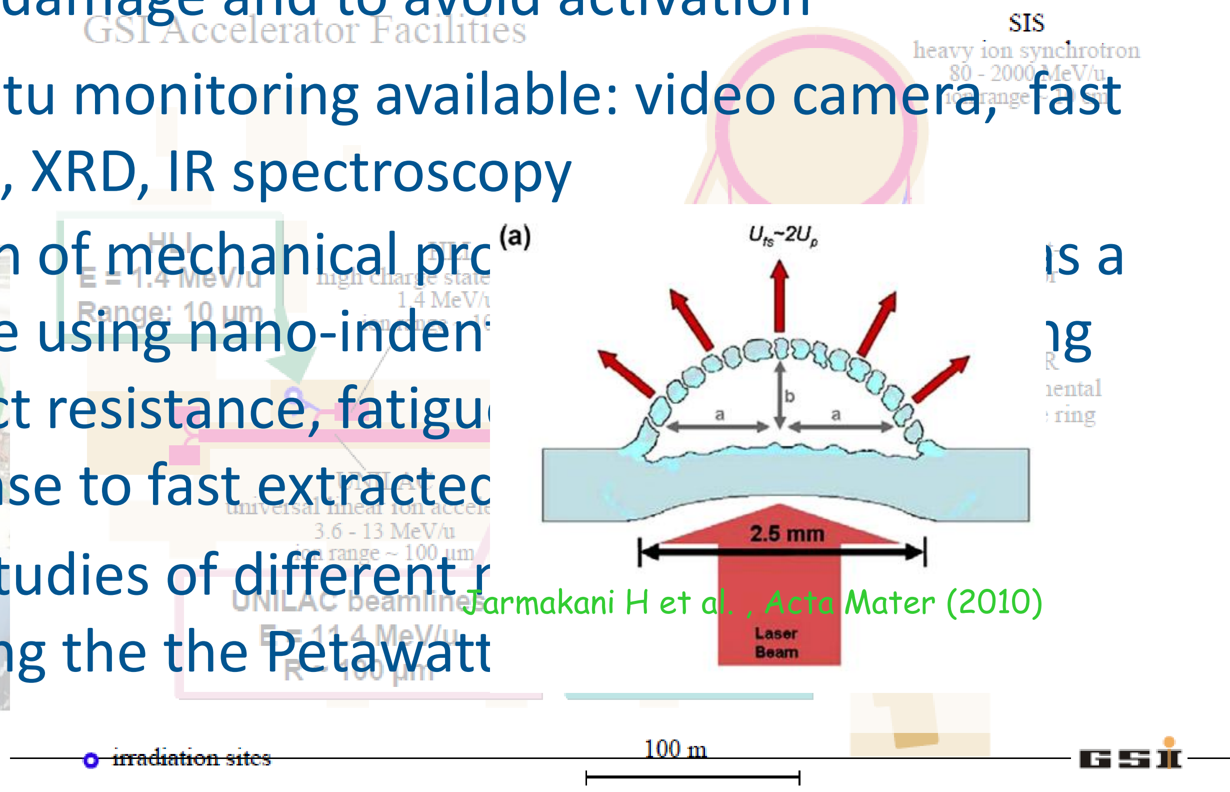
Deformation curves for unirradiated and 30 MeV proton irradiated Cu-D , fluence $\Phi = 10^{17} p/cm^2$

Courtesy of A. Ryazanov

Material testing, some examples

- Material irradiation at M-branch – UNILAC GSI
  - Energies close to Bragg peak to maximize energy deposition and damage and to avoid activation
  - Online and in-situ monitoring available: video camera, fast IR camera, SEM, XRD, IR spectroscopy
  - Characterisation of mechanical pro ... as a function of dose using nano-inden ... ng modulus, impact resistance, fatigu ... material response to fast extracted
  - Spall strength studies of different r ... experiment using the the Petawatt





Jarmakani H et al. , Acta Mater (2010)

Courtesy of M. Tomut

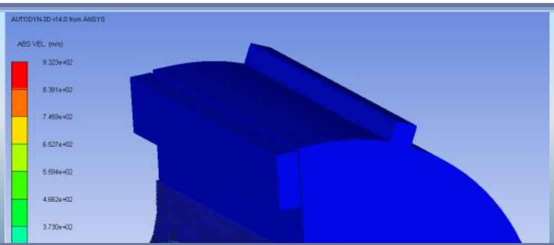
WP11 Objectives

- **Task 11.3. Material mechanical modelling** (A. Bertarelli)
  Theoretical modelling of new materials and composites, the calculation of energy deposition following accidents and the modelling of shock-induced and radiation damage.
  - Model and theoretically characterize new materials and composites for collimation, and provide parameters for stress analysis.
  - Model energy deposition and shock-induced damage following abnormal beam loss events.
  - Model radiation damage.
  - Compare results with experimental data.

Examples of mechanical modelling

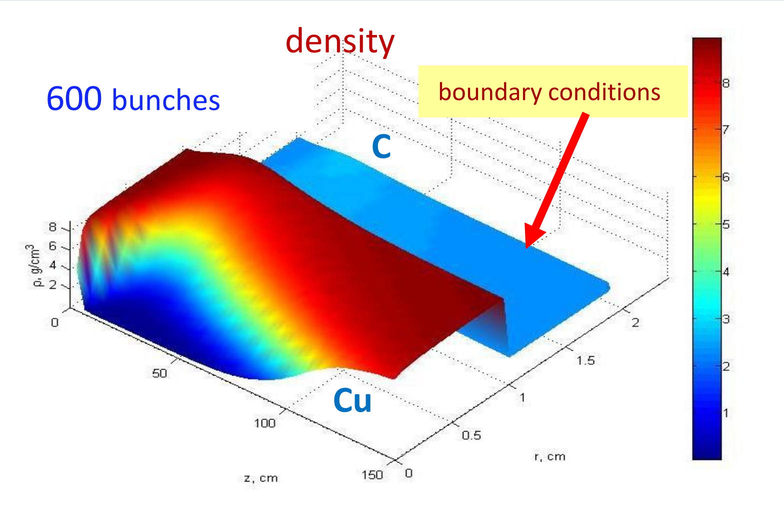
ColMat-HDED

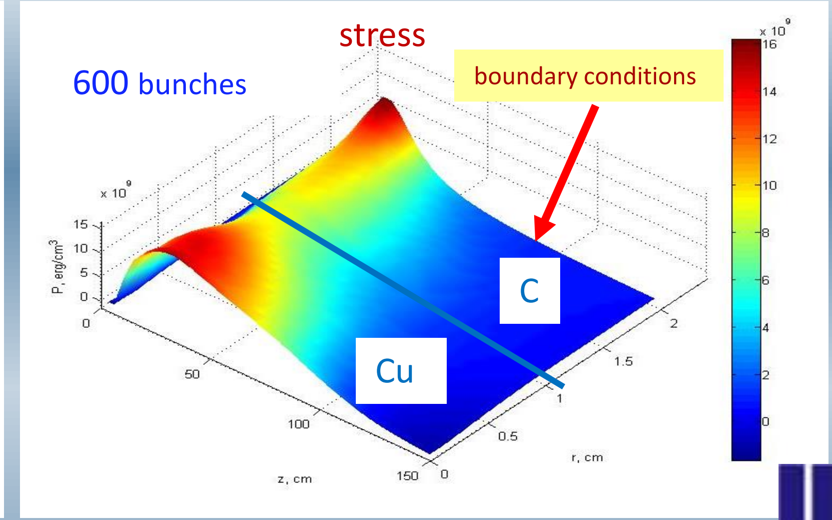
Extensive Complex Calculations of Beam-induced Shockwaves with advanced non-linear tools (**Hydrocodes – Autodyn**)



SPH (Smooth Particle Hydrodynamics) material fragmentation and particle projection, material density

Modelling of shock wave formation in assembled Cu - D materials ("sandwich structures") at 450 GeV proton beam 600 bunches (15 000ns)); *wave reflection* (boundary conditions)





WP11 Objectives

- **Task 11.4. Material specification** (A. Rossi)

  The increasing beam intensity in accelerators requires ever better cleaning efficiency, and lower collimator impedance. Aim of this task is to evaluate the potential, advantages and disadvantages of materials and report on comparative assessment of beam simulation codes

  - Simulate the potential of new collimator materials like silicon carbide and metal-diamond compounds for collimation of hadron beams and iterate on material specifications to address the needs of future accelerator developments.

Examples of material spec

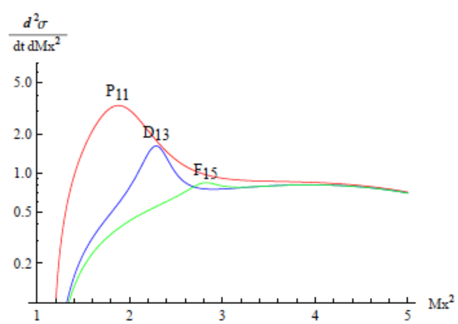
Baryon resonance region

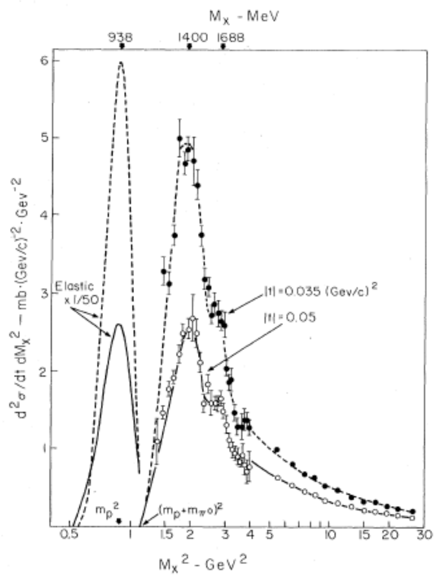
s have proton
rials:

diffractive

ttering,

MERLIN





- Cross Sections for "Diffractive" $p + p \longrightarrow p + X$ from 100 to 400 GeV (PRL, V34, 1975)
- Diffraction Dissociation of High-Energy Protons in p-d Interactions (PRL, V12, 1975)

Examples of material spec

- SixTrack – Merlin – FLUKA are being compared
- New material cross sections have to be implemented: not easy for composite
- *Simulations to design absorbers behind crystals*

WP11 Deliverables

- ColMat-HDED web pages published: Online resources for ColMat-HDED will be continuously updated to provide the collimator community with information such as relevant events and publications (Task 11.1) [month 6]
- Results on simulations of new materials and composites: Calculation of energy deposition and modelling of shock-induced and radiation damage following beam losses in new materials (Task 11.3) [month 40]
- Report on comparative assessment of beam simulation codes (Task 11.4) [month 40]
- Irradiation test results: Beam impact on new material and composite (Task 11.2) [month 48]
- Results on characterisation of new materials and composites: Produce new materials and measurements mechanical characteristics (Task 11.3) [month 48]

THANK YOU FOR YOUR ATTENTION