Objectives of Task 17.4

A. Lechner (CERN) on behalf of Task 17.4 participants

1st Workshop of ARIES WP17 PowerMat

Nov 28$^{\mathrm{th}}$, 2017

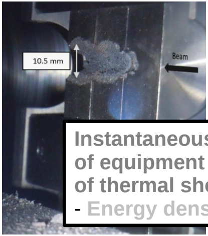
Introduction to Task 17.4

- **Title: Simulation of irradiation effects and mitigation methods**
- **Main goals:**
  - *Quantify Displacement Per Atom (DPA), gas production, nuclear transmutation for equipment in complex accelerator environments*
  - *Provide a relationship with irradiation experiments at lower energies and/or with different particle species, in particular investigate and simulate the material damage induced by irradiation with protons and ions at various energies and doses*
  - *Ideally, relate radiation damage quantities (e.g. DPA) with change of relevant macroscopic material properties*
  - *Assess annealing and temperature-related effects*

  ⇒ *Open to co-operate with other international collaborations such as RaDIATE (Radiation Damage In Accelerator Target Environment)*
- **Participants: CERN, GSI, POLIMI**

A brief reminder: consequences of beam losses

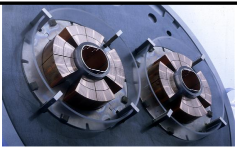
Beam losses in accelerators can have many different consequences...

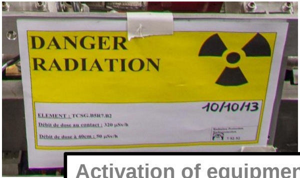


Instantaneous damage of equipment because of thermal shock:
- Energy density

Figure courtesy of A. Bertarelli

Quench of supercond. magnets:
- Energy density (transient losses)
- Power density (steady state losses)





Activation of equipment:
- Residual dose rate
- Induced radioactivity

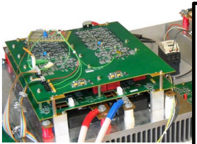


Fig. courtesy of TE/EPC

Radiation effects in electronics:
- High-energy hadron fluence (single event effects)
- Total ionizing dose (cumulative effects)
- Si 1 MeV neutron equiv. fluence (cumulative effects)

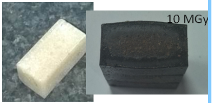


Fig. courtesy of P. Fessia

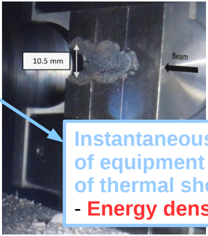
Change of mechanical and physical material properties (on the long term):
- **Displacement per Atom** (non-organic materials)
- **Dose** (insulators)
- **Gas production (H, He) and transmutations**

Focus of Task 17.4

A brief reminder: consequences of beam losses

Can also provide some support for HiRadMat energy deposition studies (although not explicitly mentioned in the Task 17.4 description)

Carried out FLUKA studies for most of the HiRadMat tests discussed yesterday



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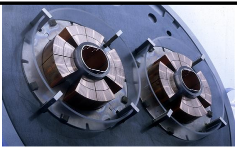

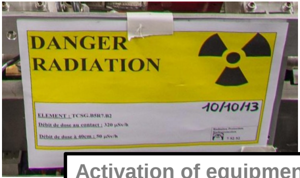

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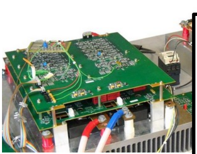

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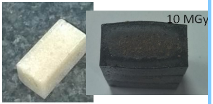

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Focus of Task 17.4

Complex accelerator environment ⇔ irradiation experiments

Example DPA:

- related to **non-ionizing energy loss (nuclear stopping)** of charged particles
- DPA/incident particle depends strongly on **particle species** and **energy**

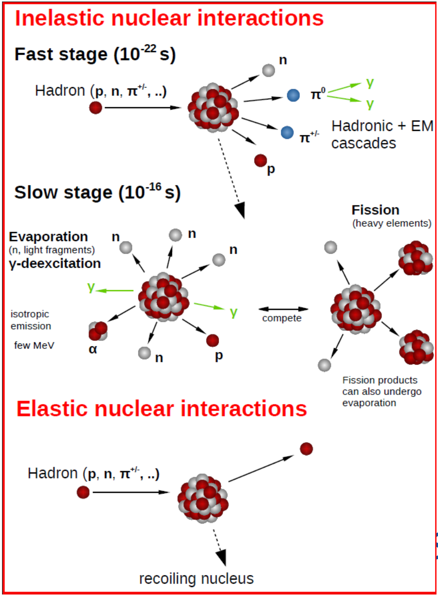
High-energy proton/ion accelerators (GeV-TeV)

- All shower particles can contribute to DPA
- In particular **recoils from nuclear interactions**, but also **EM showers**

Task 17.4: provide relationship ⇕

Irradiation experiments to probe effects of radiation damage in materials

- Often with **much lower-energy** protons, neutrons, ions (with different fluences)
- Example MeV protons/ions: DPA mainly through nuclear stopping of **primaries**



Simulation tool at hand: FLUKA Monte Carlo code

Powerful simulation tool to quantify relevant quantities like DPA, gas production in complex radiation environments

Standard shower code for CERN accelerators (LHC, HL-LHC, SPS, PS, ...), also used at many other facilities

1 A GeV ^{208}Pb + p reactions Nucl. Phys. A 686 (2001) 481-524

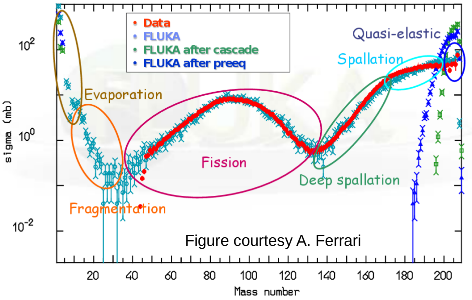


Figure courtesy A. Ferrari

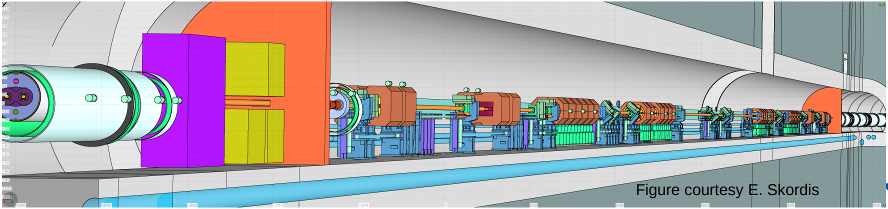


Figure courtesy E. Skordis

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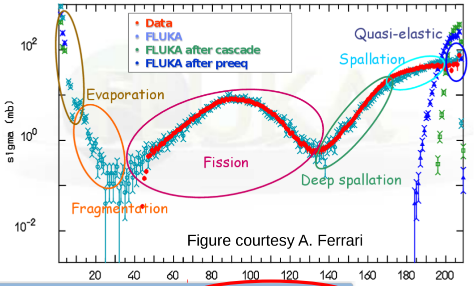


Figure courtesy A. Ferrari

Task 17.4 - Modelization of radiation-induced damage in FLUKA and material damage estimates for CERN injectors and future facilities *Jose Antonio Briz Monago*

Some details on modeling approaches (and limitations) + examples for CERN facilities

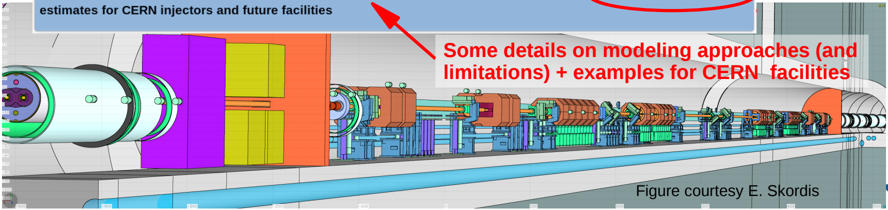
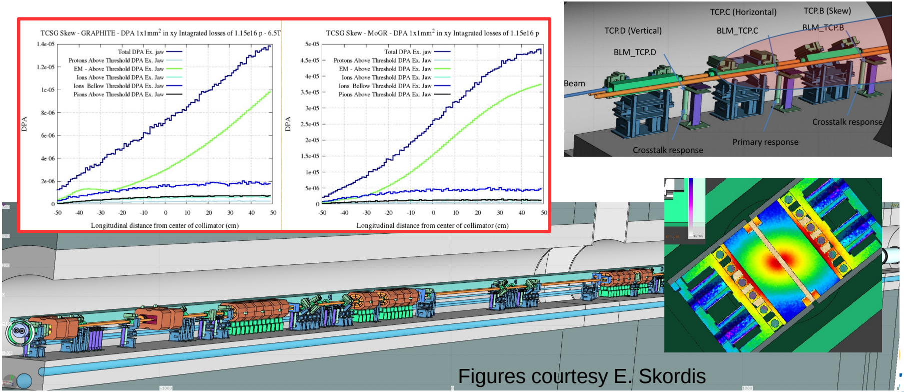


Figure courtesy E. Skordis

DPA calculations for HL-LHC collimators

Multi-turn **particle tracking** in accelerator lattice (SixTrack-FLUKA coupling) ⇒ Detailed **shower simulations** in accelerator components like collimators (FLUKA)



Figures courtesy E. Skordis

See E. Skordis et al, "FLUKA estimation of DPA for ion irradiation and update on IR7 DPA calculations for LHC operations", EuCARD2 WP11 Topical Meeting Collimator Materials for Fast High Density Energy Deposition , Malta, 2016.

DPA calculations for HL-LHC collimators

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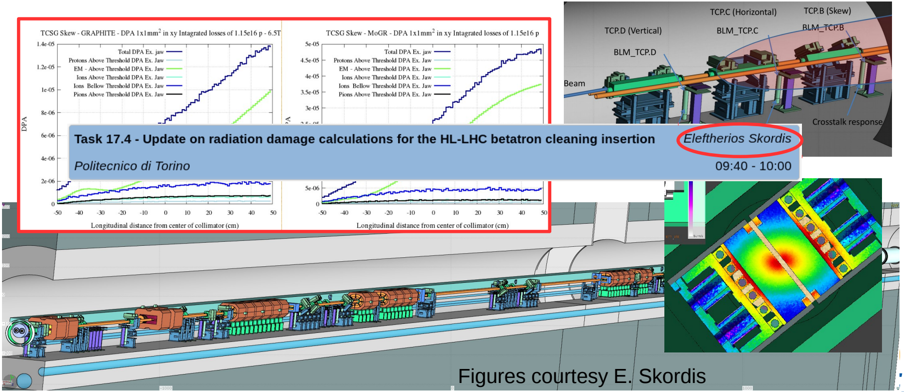
⇒

Detailed **shower simulations** in accelerator components like collimators (FLUKA)



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Objectives of Task 17.4

- **Goal:**
  - *Quantify Displacement Per Atom (DPA), gas production, nuclear transmutation for equipment in complex accelerator environments*

- **Objectives:**
  - *FLUKA calculations quantifying the long-term radiation damage for FAIR targets, beam dumps/catchers*
    - ⇒ *By GSI team, with guidance/help from CERN FLUKA team*
    - ⇒ *Details and timeline: to be defined with Marilena*

Task 17.4 - Requirements for radiation damage simulations regarding FAIR targets, beam dumps/catchers and previous experiments at GSI — *Marilena Tatiana Tomut*

  - *FLUKA calculations quantifying the long-term radiation damage for HL-LHC collimators*
    - ⇒ *By CERN FLUKA team, continuation of work which started in EuCARD2*
    - ⇒ *Should include absorber materials (CfC, MoGR) and coatings (Mo etc.)*
    - ⇒ *Updated loss predictions for HL-LHC based on operational experience in LHC Run 2*
    - ⇒ *Timeline: ongoing, expect results within 6 months*

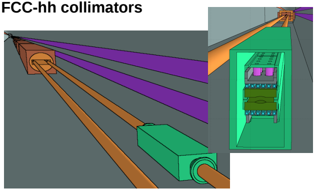
Task 17.4 - Update on radiation damage calculations for the HL-LHC betatron cleaning insertion — *Eleftherios Skordis*
Politecnico di Torino — 09:40 - 10:00

Objectives of Task 17.4

- **Goal:**
  - *Quantify Displacement Per Atom (DPA), gas production, nuclear transmutation for equipment in complex accelerator environments*

- **Objectives:**
  - *FLUKA calculations quantifying the long-term radiation damage for FCC collimators*
    - ⇒ *By CERN FLUKA team*
    - ⇒ *By-product of FCC collimation studies (within FCC project)*
    - ⇒ *Timeline: first results within the next 12 months*

FCC-hh collimators

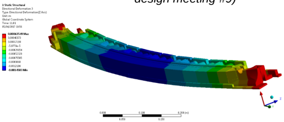


About a factor 15 higher wrt to LHC (6.5 TeV, 500 kW power losses)

Collimator Jaws	Secondaries [kW]
TCSG_A6L	233.6
TCSG_B5L	8.2
TCSG_A5L	35.7
TCSG_D4L	27.6

A factor of 2-2.5 higher than LHC

Radiation damage will also be much higher than for LHC



Figures courtesy of M.I. Besana and F. Carra (FCC collimation design meeting #9)

  - *Further radiation damage studies for future CERN machines to be assessed*
    - ⇒ *By CERN FLUKA team*
    - ⇒ *E.g. HL-LHC dump, FCC dump, HE-LHC collimation/dump etc.*
    - ⇒ *Timeline: expect some results (HL-LHC dump, FCC dump) within the next 6 to 12 months*

ARIES

Objectives of Task 17.4

- **Goals:**
  - *Provide a relationship with radiation experiments at lower energies and/or with different particle species, in particular investigate and simulate the material damage induced by irradiation with protons and ions at various energies and doses*
  - *Ideally, relate radiation damage quantities (e.g. DPA) with change of relevant macroscopic material properties*

- **Objectives:**
  - *Analysis of previous ion-implantation experiments carried out at GSI*

    ⇒ *By GSI team, with guidance/help from CERN FLUKA team*

    ⇒ *Details and timeline: to be discussed with Marilena*

Task 17.4 - Requirements for radiation damage simulations regarding FAIR targets, beam dumps/catchers and previous experiments at GSI	*Marilena Tatiana Tomut*

  - *Definition of the requirements for the GSI irradition campaign of CERN samples in 2018 (see presentation of Marilena yesterday)*

    ⇒ *Ion species, fluence, equivalence with damage in LHC collimators*

    ⇒ *DPA simulations by CERN FLUKA team*

    ⇒ *Timeline: soon*

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- **Goals:**
  - *Provide a relationship with radiation experiments at lower energies and/or with different particle species, in particular investigate and simulate the material damage induced by irradiation with protons and ions at various energies and doses*
  - *Ideally, relate radiation damage quantities (e.g. DPA) with change of relevant macroscopic material properties*
- **Objectives:**
  - *Establish a correlation, empirical and ideally also theoretical, between the microscopic effects of radiation and the degradation of macroscopic properties of thin films (coatings)*
    - ⇒ *PhD project set up by CERN and POLIMI*
    - ⇒ *Irradiation of coated samples in 2018 BLIP run in collaboration with RaDIATE collaboration*
    - ⇒ *DPA estimates by CERN FLUKA team, in collaboration with RaDIATE collaboration*

Task 17.4 - Plans and contributions for radiation damage studies by POLIMI	*Marco Beghi*
Politecnico di Torino	10:40 - 11:00

Task 17.4 - CERN's activities within the RaDIATE Collaboration	*Claudio Leopoldo Torregrosa Martin*
Politecnico di Torino	10:20 - 10:40

- **Deliverables:**
  - *Task 17.2) Comparative compendium of the developed materials [month 40]*
  - *Task 17.4) Report on simulations on irradiation effects [month 44]*
  - *Task 17.3) Irradiation test results: Beam impact on new material and composite [month 48]*
  - *Task 1.4) Production of material samples (as large as possible for each industry to demonstrate workability) [month 24]*

Milestones

- **Milestones:**
  - *Task 17.1) Organisation of PowerMat kick-off meeting, with publication of talks on Web [month 6]*
  - *Task 17.2) Material characterisation , with publication of results on Web [month 18-24]*
  - *Task 17.3) Irradiation, with publication of report on web [month 27]*
  - *Task 17.4) Irradiation effects analysis, with publication of report on web [month 36]*
  - *Task 17.5) Report on studies, with publication of report on web, [month 46]*
  - *Task 1.4) Prepare first samples [month 12]*

The agenda at a glance

Task 17.4 - Objectives of Task 17.4	*Anton Lechner*
Politecnico di Torino	08:40 - 09:00
Task 17.4 - Requirements for radiation damage simulations regarding FAIR targets, beam dumps/catchers and previous experiments at GSI	*Marilena Tatiana Tomut*
Task 17.4 - Modelization of radiation-induced damage in FLUKA and material damage estimates for CERN injectors and future facilities	*Jose Antonio Briz Monago*
Task 17.4 - Update on radiation damage calculations for the HL-LHC betatron cleaning insertion	*Eleftherios Skordis*
Politecnico di Torino	09:40 - 10:00
Coffee Break	
Politecnico di Torino	10:00 - 10:20
Task 17.4 - CERN's activities within the RaDIATE Collaboration	*Claudio Leopoldo Torregrosa Martin*
Politecnico di Torino	10:20 - 10:40
Task 17.4 - Plans and contributions for radiation damage studies by POLIMI	*Marco Beghi*
Politecnico di Torino	10:40 - 11:00
Task 17.4 - Discussion on objectives, actions and deliverables of Task 17.4	
Politecnico di Torino	11:00 - 11:45

Thanks to all speakers!