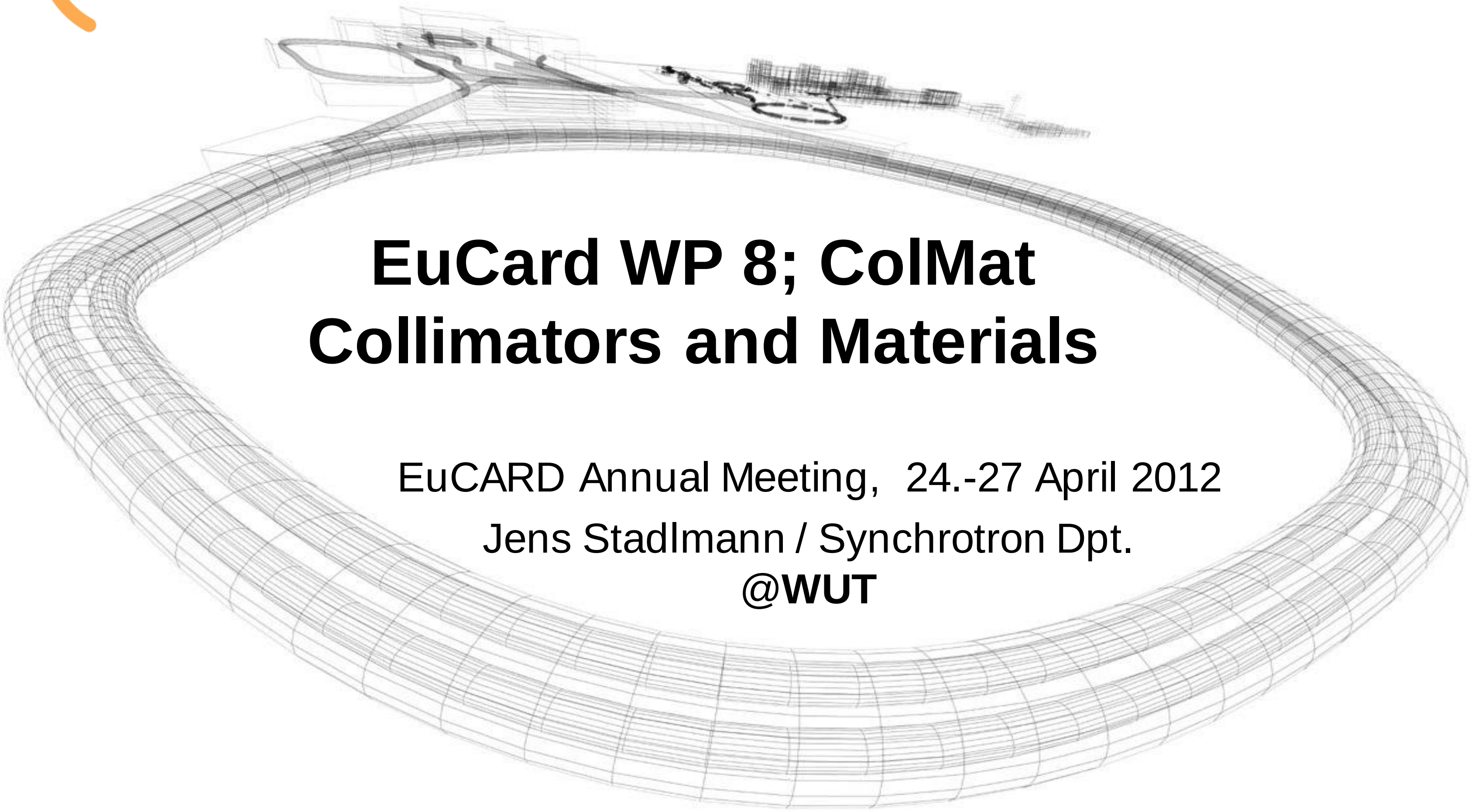


# EuCard WP 8; ColMat
# Collimators and Materials

EuCARD Annual Meeting, 24.-27 April 2012


Jens Stadlmann / Synchrotron Dpt.

**@WUT**

# Overview

- Introduction to WP 8
- Examples of WP 8 activities
  (with one special case picked out)
- Summary and outlook

# WP 8 Tasks

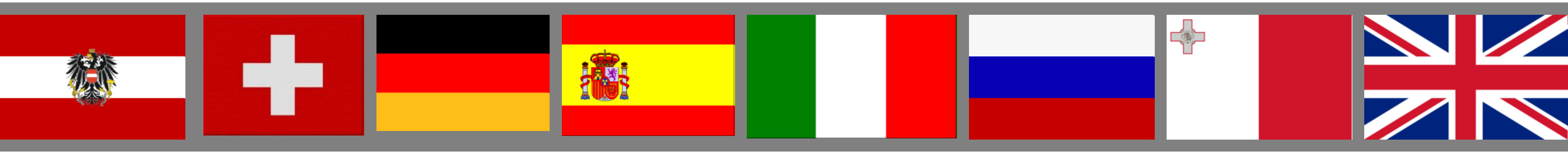
- **8.1** Coordination and Communication

- **8.2** Modeling & Material Tests for Hadron Beams
  **1.** Halo studies and beam modeling
  **2.** Energy deposition calculations and tests
  **3.** Materials and thermal shock waves
  **4.** Radiation damage
  ....

- **8.3** Collimator Prototyping & Tests for Hadron Beams
  **1.** Prototyping, laboratory tests and beam tests of room-temperature collimators (LHC type)
  **2.** Prototyping of cryogenic collimators (FAIR type)
  **3.** Crystal collimation

# Participants in WP 8 Task

- AIT
  (Austrian Institute of Technology)
- CERN
  (European Organization of Nuclear Reserach)
- EPFL
  (Ecole Polytechnique Fédérale de Lausanne)
- GSI
  (Helmholtzzentrum für Schwerionenforschung Darmstadt)
- IFIC
  (Instituto de Física Corpuscular, Valencia)
- INFN
  (Istituto Nazionale di Fisica Nucleare)
- Kurchatov Institute
  (Moscow)
- Malta University
- Lancaster & Manchester University
- Politecnico di Torino
- RHUL
  (Royal Holloway University of London)
- NEW: University of Music and Performing Arts, Graz



# The many topics of WP 8

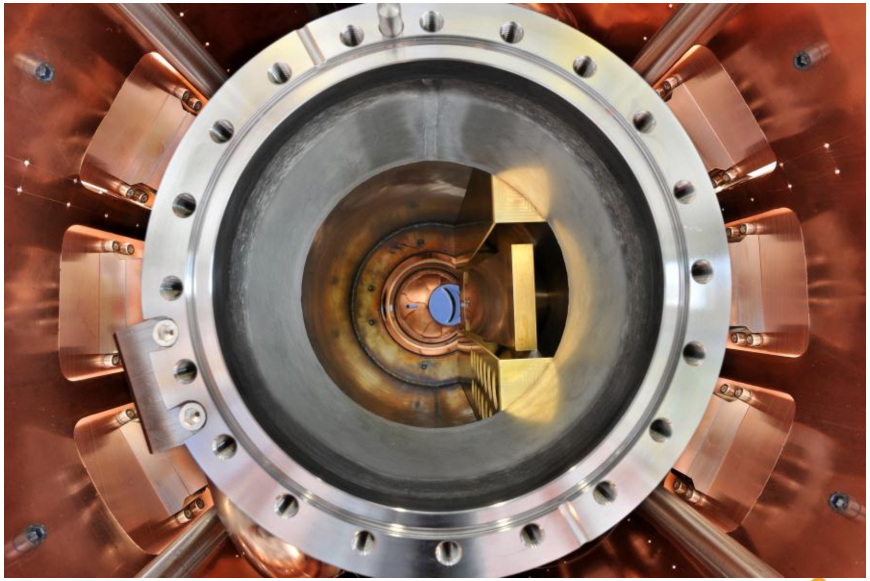
The scope of WP 8 reaches from

- identification of suitable materials for accelerator/collimator design,
- test of material properties,
- simulations of material behavior on beam impact,
- beam simulations and collimator performance to
- actual prototyping an in beam test of collimators for existing and future accelerator facilities.

# Status of LHC and FAIR collimator prototypes

- LHC Phase II collimator
  -> DONE
  (was presented in 2011).

- FAIR cryocatcher
  -> DONE
  (highlight talk by Lars later).



- WP8 activity continuing in material research and simulations.
- Some examples coming up.

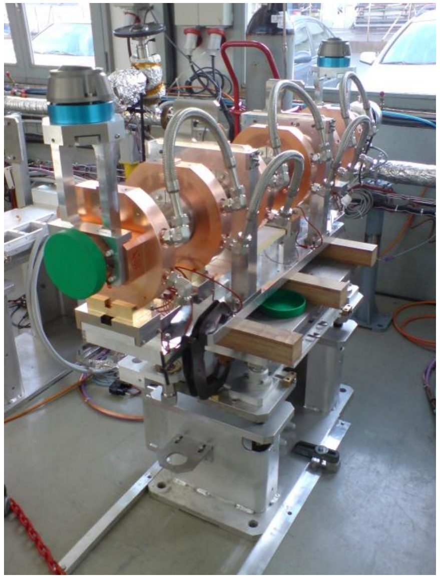
# Beam and halo modeling for LHC

- Simulations and beam measurements on beam halo were performed, aimed to improve the performance of the actual LHC collimation system and to support its upgrade.

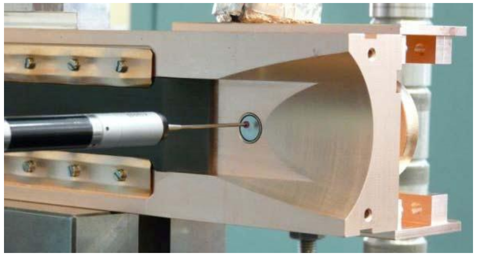
- Some of the many topics include combined betatron and momentum cleaning, misalignment studies and non linear collimation.

- Calculations done with combination from MAD-X + SixTrack + FLUKA

- Studies will continue.



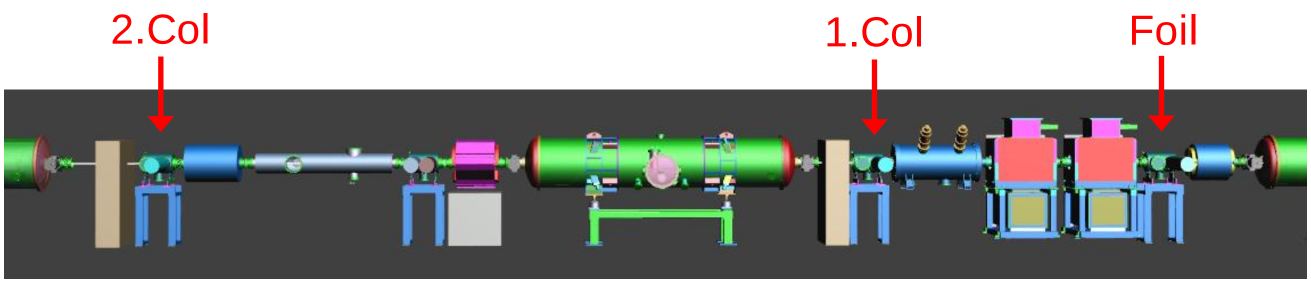
Passive absorber, straight section point 3



BPM button in collimator allows precise adjustment

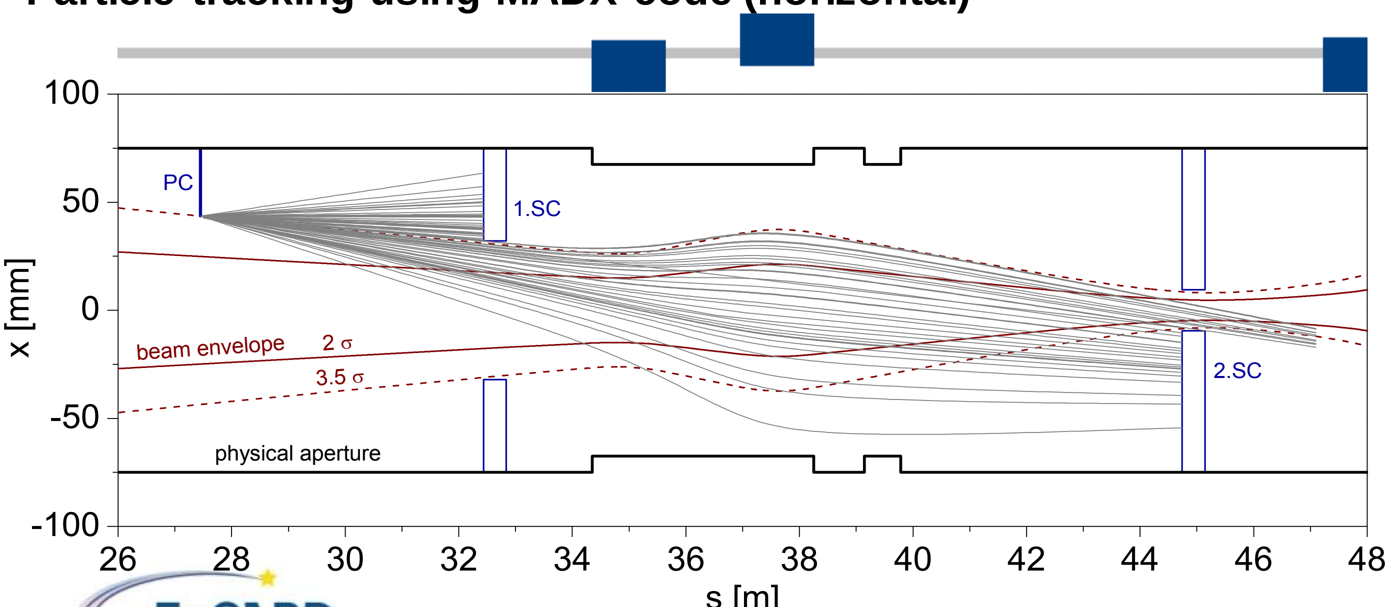
# Two stage collimation system in SIS 100

Primary collimator (thin foil) acts as a scatterer of the halo particles.
Secondary collimators (bulky blocks) are necessary to absorb the scattered particles.




Sector 1, straight
(SIS100 → SIS300 transfer)

**Particle tracking using MADX code (horizontal)**



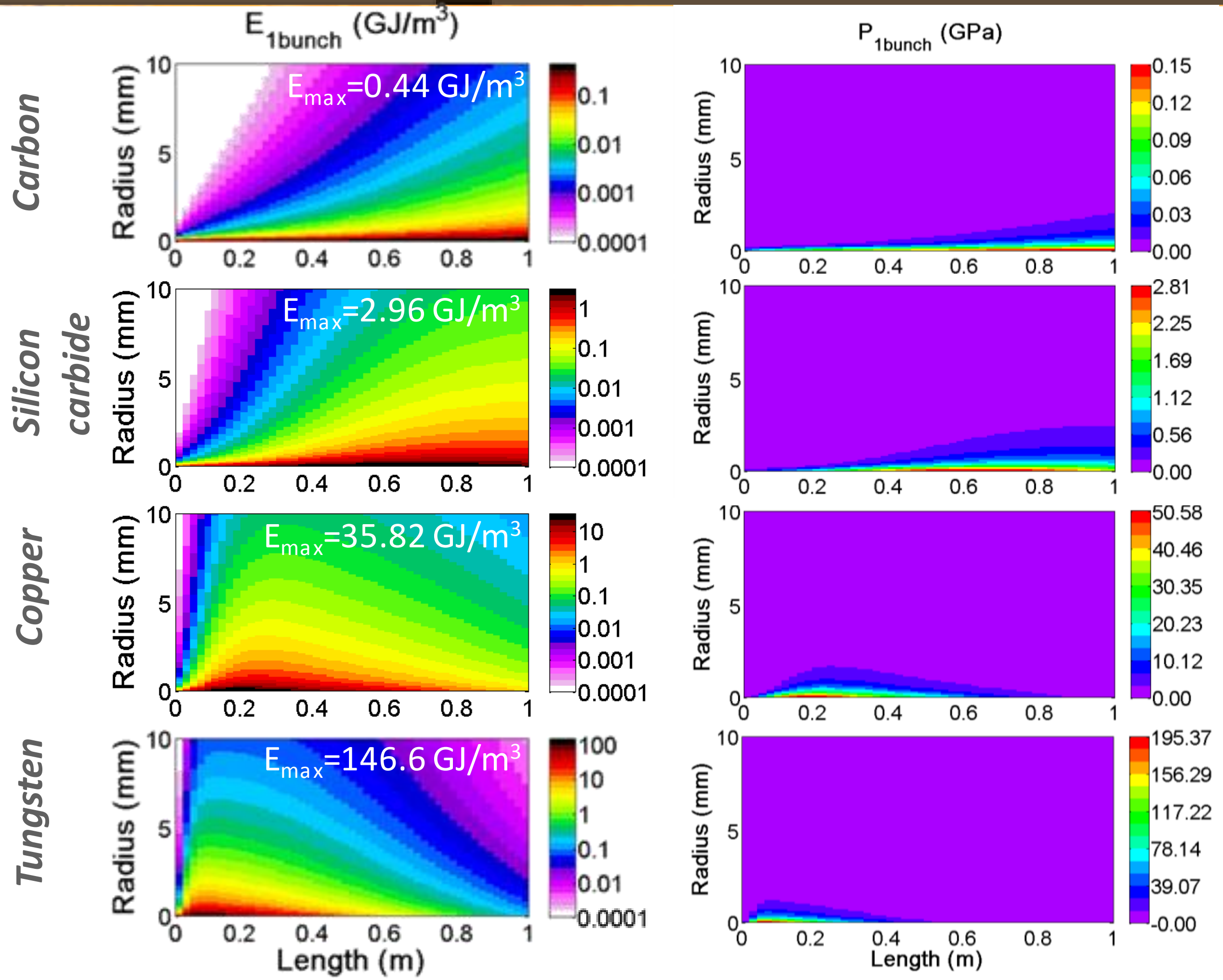

Collimation efficiency:
~ 80 %

*tuning not yet performed!*

# Simulation of beam impact

- Several studies on accidental beam impact on collimators or other accelerator components are performed in the ColMat work package.
- Simulations are being benchmarked with experiments at HiRadMat now leading to even better theoretical models.
- The latest paper on beam impact by N.A. Tahir et. al. predicts ranges of up to 25 m in solid carbon for the impact of an LHC beam (ask me for a copy).

# Example: Comparison between different materials




One 7 TeV protons bunch $1.15 \times 10^{11}$ protons

The proton energy loss and the maximum position is strongly "material" dependent

**A beam of LHC has 2808 bunches!**

362 MJ energy/beam sufficient to melt 500 kg copper

# MERLIN simulations in WP8

*Rob Appleby, Adina Toader, Maurizio Serluca, James Molson (Manchester)*
*Roger Barlow, Haroon Rafique (Huddersfield)*

MERLIN: a modern, flexible C++ library for accelerator simulations.

The groups is:

•Checking LHC collimation results obtained using sixtrack. Comparing loss maps.

• Improving the models of elastic and diffractive scattering in collimators with assistance from friendly theoretician Sandy Donnachie. At last, a use for the Pomeron!

• Obtaining large increases in computation speed using multiple cores

• Maintaining and updating the Merlin code on the SourceForge repository

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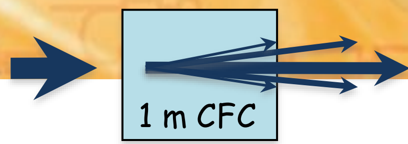
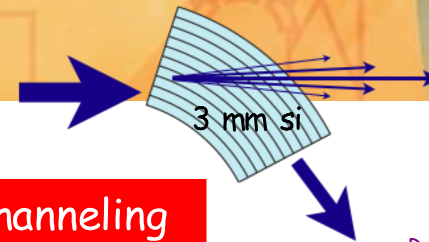
# Crystal assisted collimation




amorphous

$\langle\theta\rangle_{MCS} \cong 3.6\mu rad$ @ 7 TeV

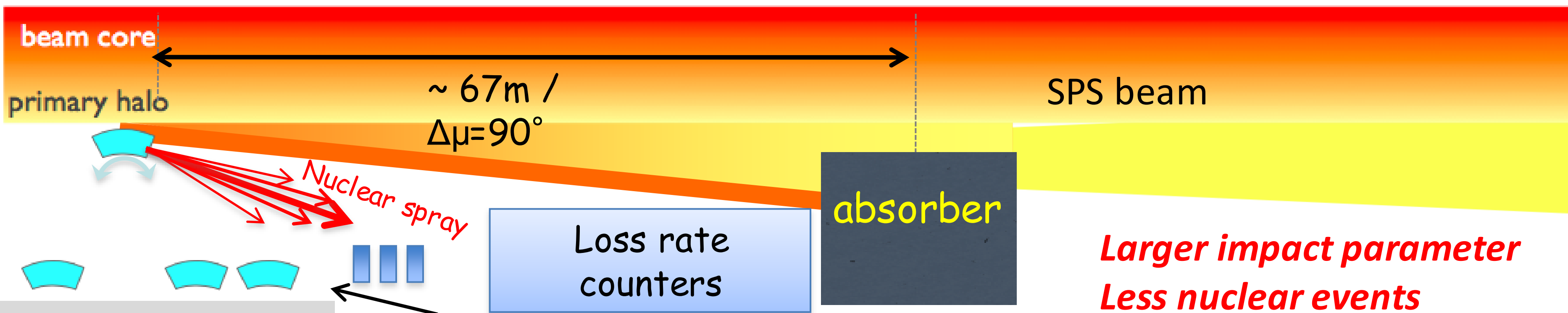



$\theta_{ch} \cong \alpha_{bending}$

channeling

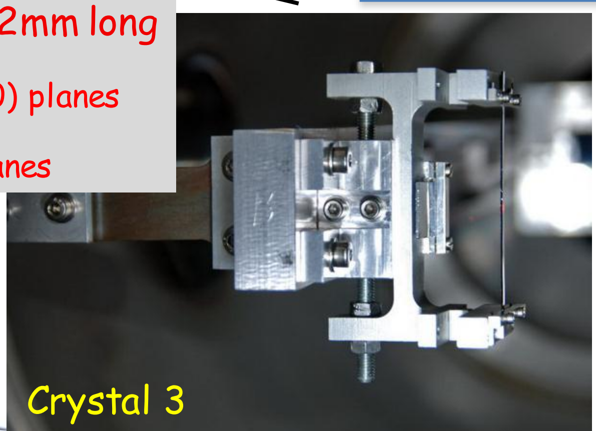
$\theta_{optimal}$ @7TeV $\cong$ 40 μrad

R. W. Assmann, S. Redaelli, W. Scandale, "Optics study for a possible crystal-based collimation system for the LHC", EPAC06




Strip crystal 2mm long

- Bent along (110) planes
- Equidistant planes




***Larger impact parameter***

***Less nuclear events***

***Less impedance***

Strip crystal manufactured in INFN Ferrara

Mechanical holder to impart proper curvature (~150 μrad)

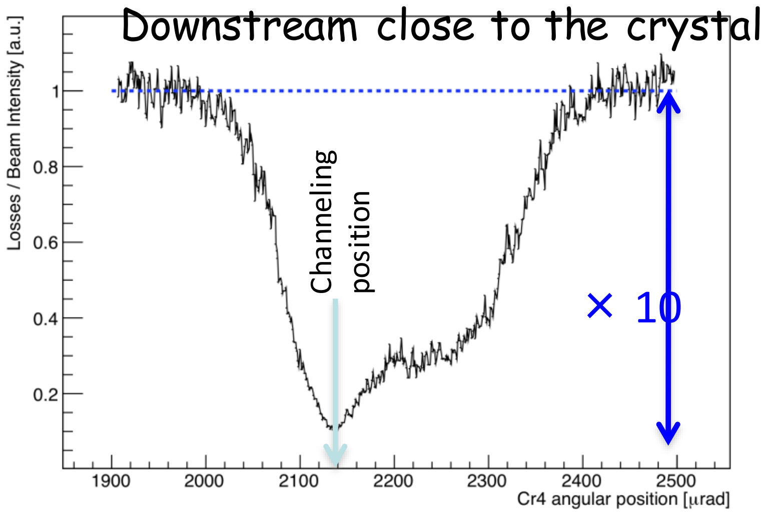
Installed in SPS and tested

# Reduction of secondary interaction

Crystal acting as primary aperture

Crystal rotated in a continuous scan

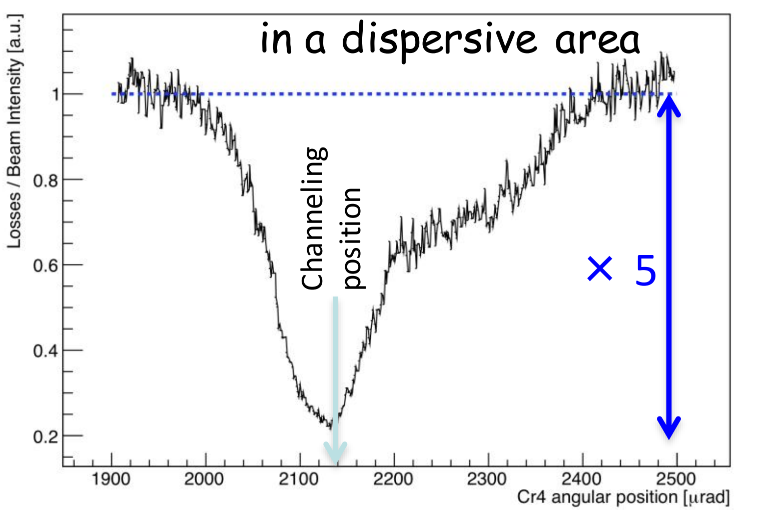
Reduction of recorded secondary interaction close to crystal in channeling condition!




Off-momentum particles produced in the secondary absorber.

Intercepted with scatterer in a dispersive area

Observed a substantial reduction!




Tests done with 120 GeV proton beam and Pb ion beam, similar results

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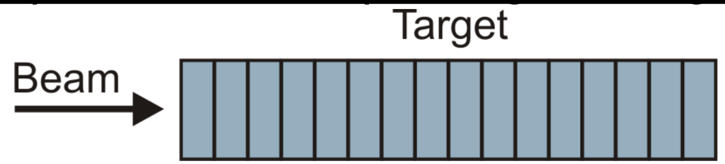
# Activation of collimator materials by heavy ions

## Irradiation experiments performed in 2011

Targets: graphite, carbon-composite
Beams: 500 MeV/u $^{181}$Ta ions, 500 MeV/u $^{238}$U ions

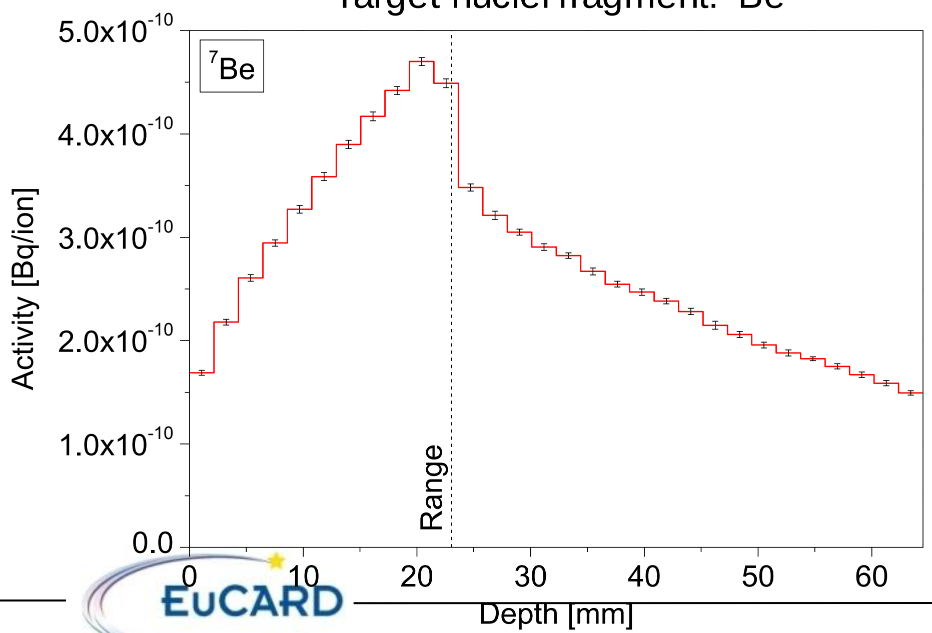
## Experimental setup & target configuration



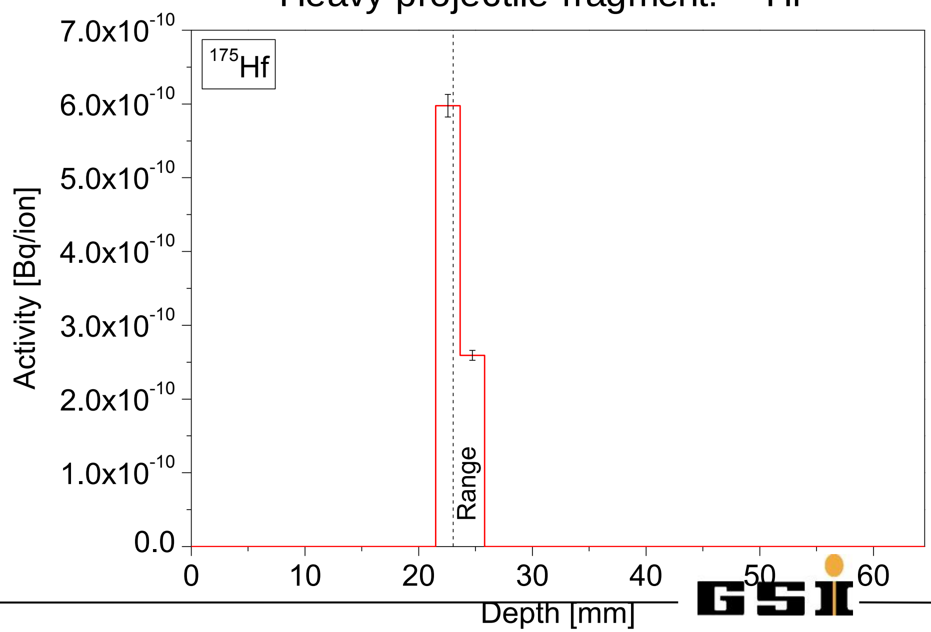

- the target consists of several individual plates
- drawn up for depth profiling of the residual activity

## Depth profiles of the residual activity (500MeV/u $^{181}$Ta beam $\rightarrow$ graphite target)

Target-nuclei fragment: $^{7}$Be




Heavy projectile-fragment: $^{175}$Hf

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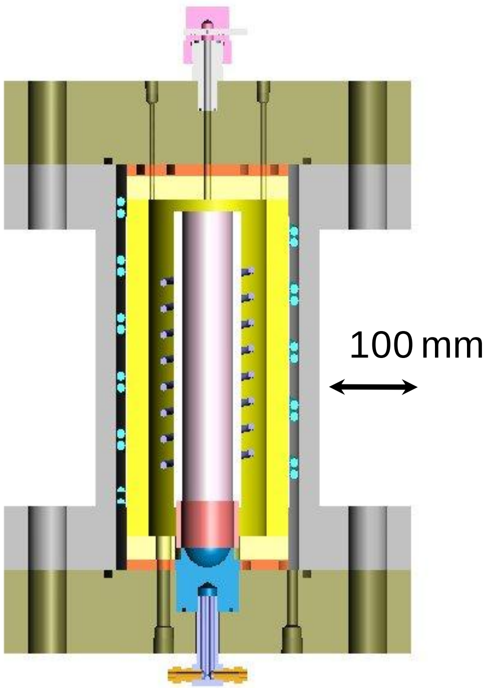
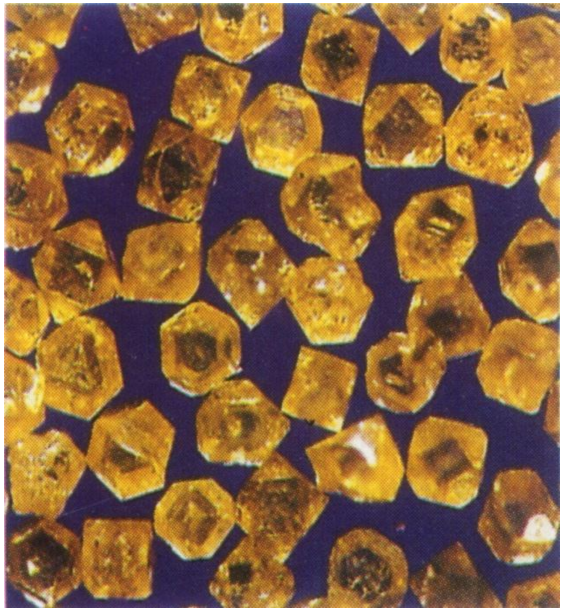
# A "tale of diamonds": Diamond Composite Material




• Cold wall vessel
(250 bar, 200°C)
Inner side of the wall in contact with a water cooled heat shield

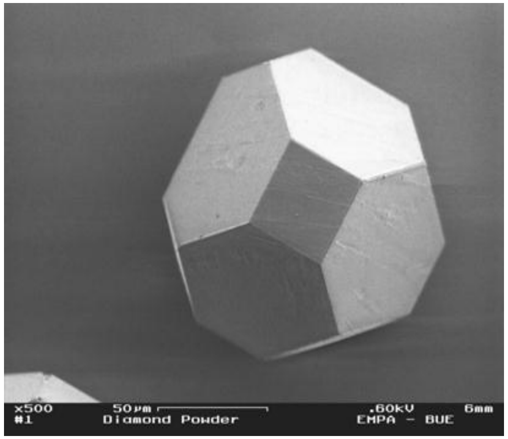
• Induction heating
(using a graphite susceptor)

• primary vacuum pump
(0.1 mbar)



Selected Diamond Grid

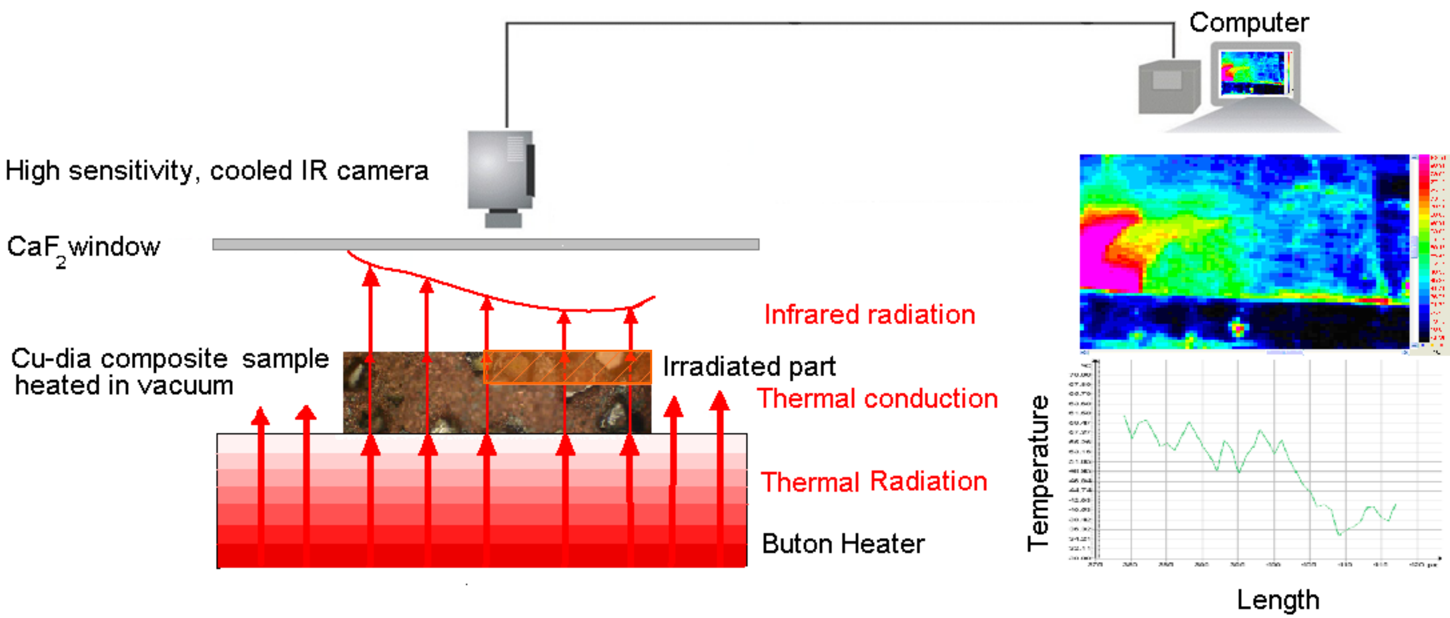
- Mono-crystalline diamond
- Low nitrogen level
- Relatively large size (>100µm)




Résistance et Ténacité

# Radiation hardness of ion- exposed Cu-diamond material: Thermal conductivity

- Mid-infrared imaging tests of thermal conductivity degradation in copper-diamond composites exposed to high doses of 4.8 MeV/u $^{197}$Au ions at UNILAC accelerator, at GSI



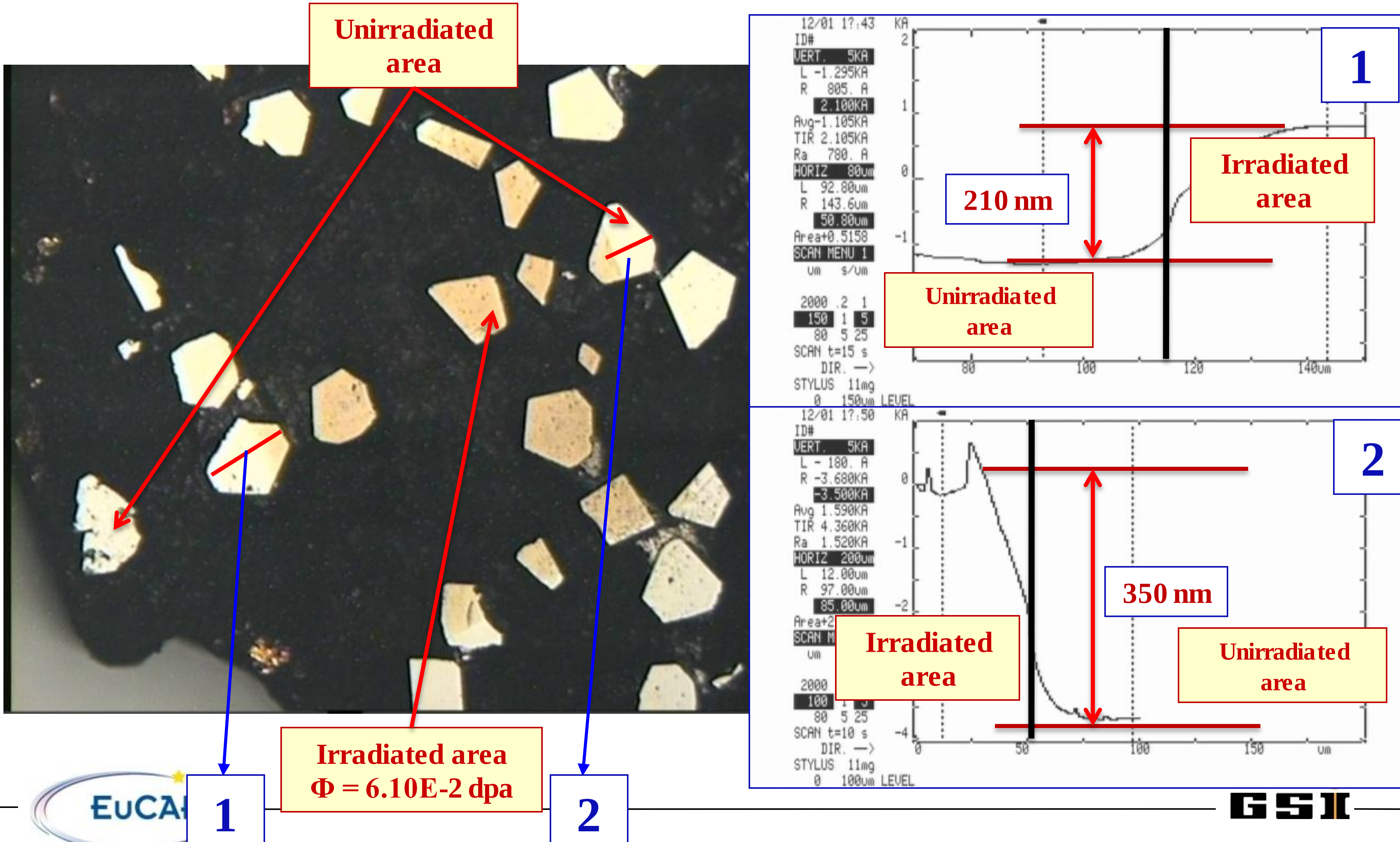
# Experimental and theoretical studies of the effects of irradiation on Cu-Diamond composites

The theoretical and experimental characterization of radiation damage to composite materials is difficult at best. Several tests and first theoretical studies on changes after radiation in Cu-Diamond materials have been performed including:

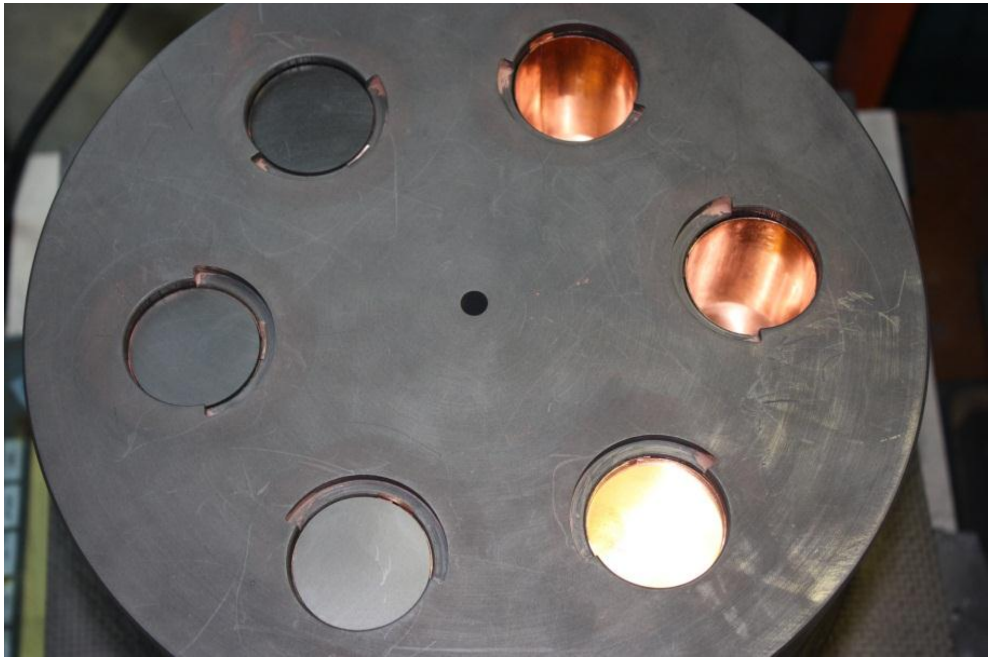
1. radiation-induced deformation (radiation swelling)
2. radioactive isotope composition
3. thermal expansion coefficient
4. temperature conductivity in Cu-Diamond
5. dependence of specific heat
6. change of electrical resistivity
7. mechanical properties and Joung's modulus changes

**National Research Center" Kurchatov Institute"**

# Measurements of Radiation Swelling in Irradiated Copper-Diamond Samples by 26 MeV Carbon Ions



# Cu-Diamond at HiRadMat

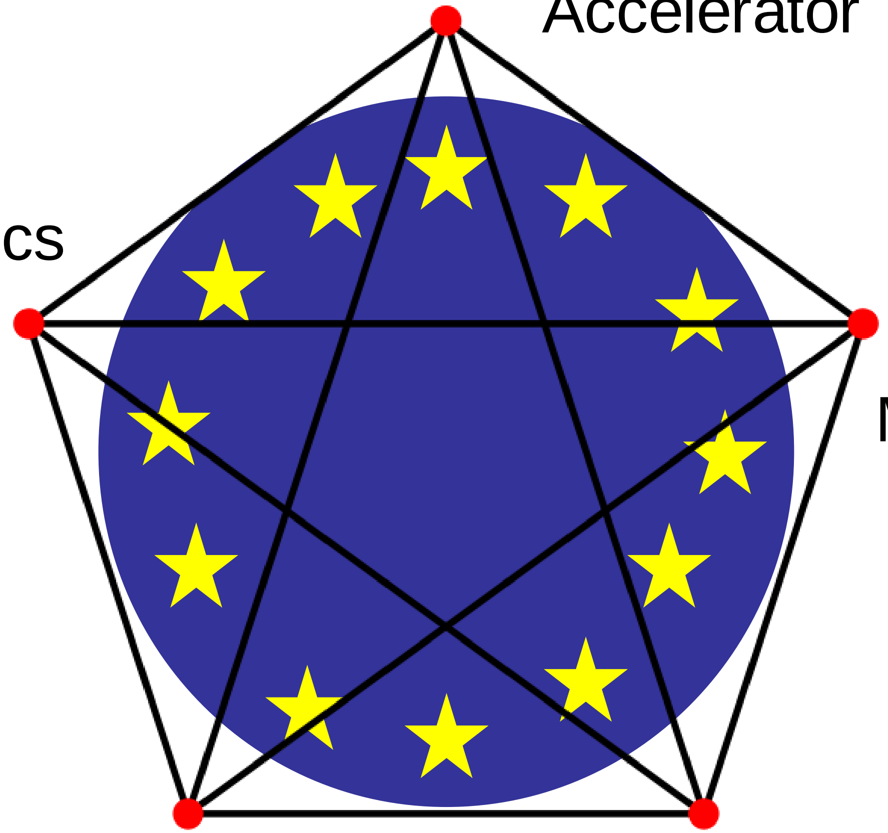
 

The new material is to be tested with SPS beam an the HiRadMat facility.

# Diamond composite materials in ColMat

- We started out with questions about basic properties like "can we actually make them in sufficient size".
- Material characterizations: Mechanical, irradiation...
- Handling of the composite materials in simulations
- Now it is actually considered for the next generation of collimators (-> highlight talk by A. Bertarelli)

# Bonds formed by materials and collimators




**Interdisciplinary collaborations between labs have been established**

# Conclusion

- The major "hardware" deliverables have been build keeping the WP8 well within schedule.
- Beside the excellent results obtained by the many participants many really new interdisciplinary collaborations have been formed.

Thank you for your attention and all my collaborators for their work an input to this talk.