The Collimation R&D Program

Ralph W. Aβmann
for the ColMat collaboration

Kick off Meeting of EuCARD

CERN - December 5th, 2008

ColMat Participants
(EuCARD WP8 – Joint Research Activity)

ColMat Collaborators

LHC Accelerator Research Program (US government funding):

SLAC NATIONAL ACCELERATOR LABORATORY

BROOKHAVEN NATIONAL LABORATORY

Fermilab

To be approved (German government funding, BMBF):

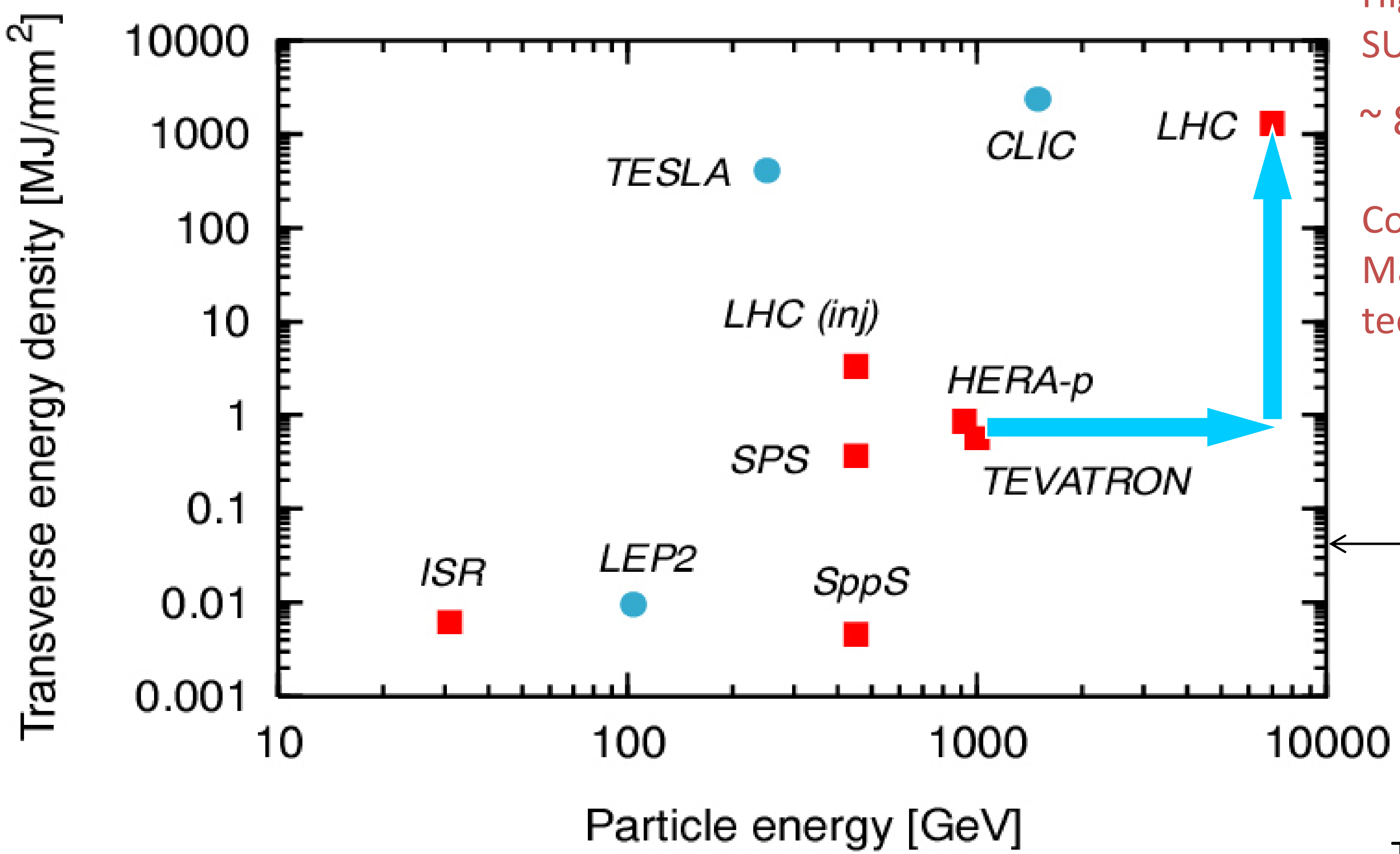
GOETHE UNIVERSITÄT FRANKFURT AM MAIN

TECHNISCHE UNIVERSITÄT DARMSTADT

Objectives Part I

- Coordination and scheduling of the WP tasks.
- Monitoring the work, informing the project management and participants within the JRA.
- WP budget follow-up.
- Design **collimation systems for high-intensity proton and ion beams, adequate for achieving the performance goals of LHC and FAIR.**
- Predict energy deposition from different sources for LHC and FAIR.

The LHC Extrapolation



Higgs +
SUSY + ???

~ 80 kg TNT

Collimation
Machine Pro-
tection

Typical damage
limit for metals

Transverse energy density is proportional to luminosity!

Objectives Part II

- Identify and fully characterize in experiment and simulation materials that are adequate for usage in high power accelerators.
- Predict residual dose rates for irradiated materials and their life expectancy due to accumulated radiation damage.
- Design, construct and test a collimator prototype for upgraded LHC performance.
- Design, construct and test one cryogenic collimator prototype for use in FAIR and possibly LHC.
- Develop crystal engineering solutions for collimation.

Task Structure ColMat

Task 1 → **ColMat Coordination and Communication.**

R. Assmann (ColMat coordinator) & J. Stadlmann (deputy)

Task 2 → **Modelling, Materials, Tests for Hadron Beams.**

A. Bertarelli

Task 3 → **Collimator Prototyping & Testing for Hadron Beams.**

P. Spiller, R. Assmann

Description Task 2.1

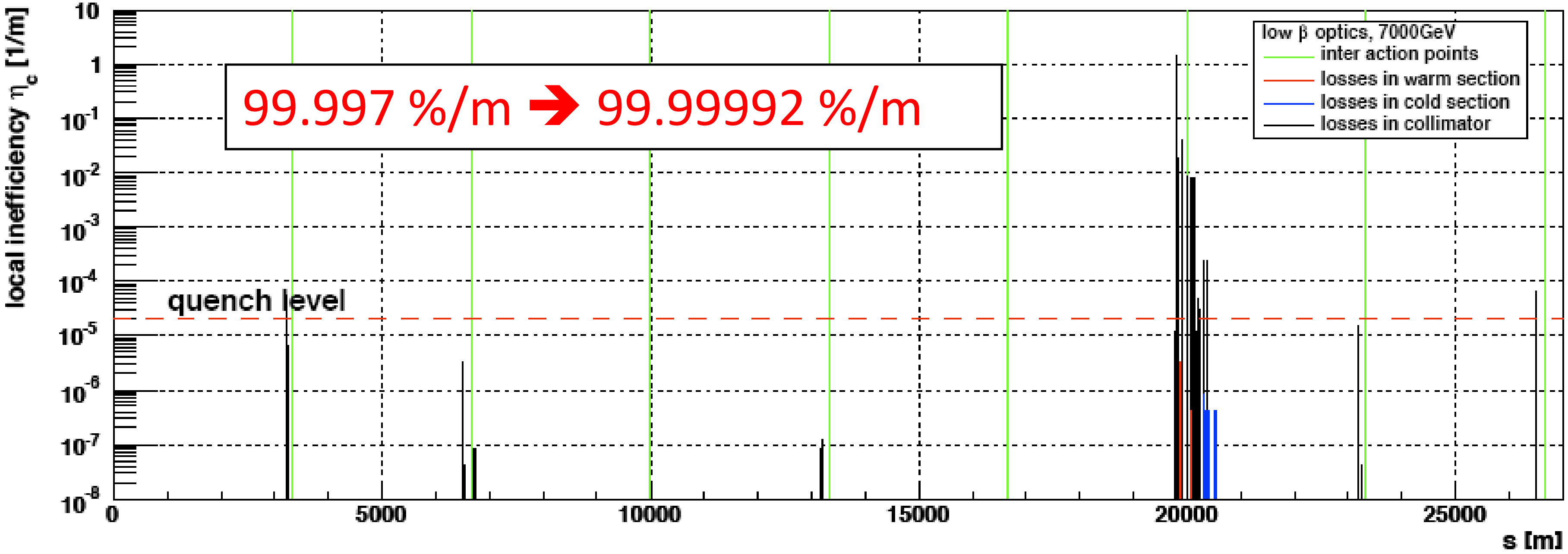
- *Task 2. Modelling, Materials, Tests for Hadron Beams.*
  - **Sub-task 1: Halo studies and beam modelling.**
    - Nature, magnitude and location of beam losses in modern accelerators.
    - Dynamics of the beam halo and proper diffusion models.
    - Design and optimization of multi-stage collimation systems.
    - Simulation of multi-turn collimation processes, including nuclear interactions of halo particles in the collimator materials.
    - The following institutes contribute to this work: **CERN, GSI, CSIC, INFN, ULANC, UM and UNIMAN.**

Collimation study for FAIR synchrotrons SIS100&300

- review of beam loss mechanisms (charge exchange, halo formation);
- estimates of the residual activation and the radiation environment around the catchers and collimators (catchers are to clean the vacuum chamber from the charge-exchanged beam ions and collimators for intercepting the halo particles);
- design of two stage collimation system for protons;
- feasibility study of two-stage collimation system for partially stripped heavy ions for SIS100;
- feasibility study of two-stage collimation system for fully stripped high-energy heavy ions for SIS300;

LHC Collimation Efficiency

T. Weiler & R. Assmann



Inefficiency reduces by factor 30 with innovative cryogenic collimators.

Caution: Further studies must show real feasibility of this proposal (energy deposition, heat load, integration, cryogenics, beam2, …). Just a concept at this point.

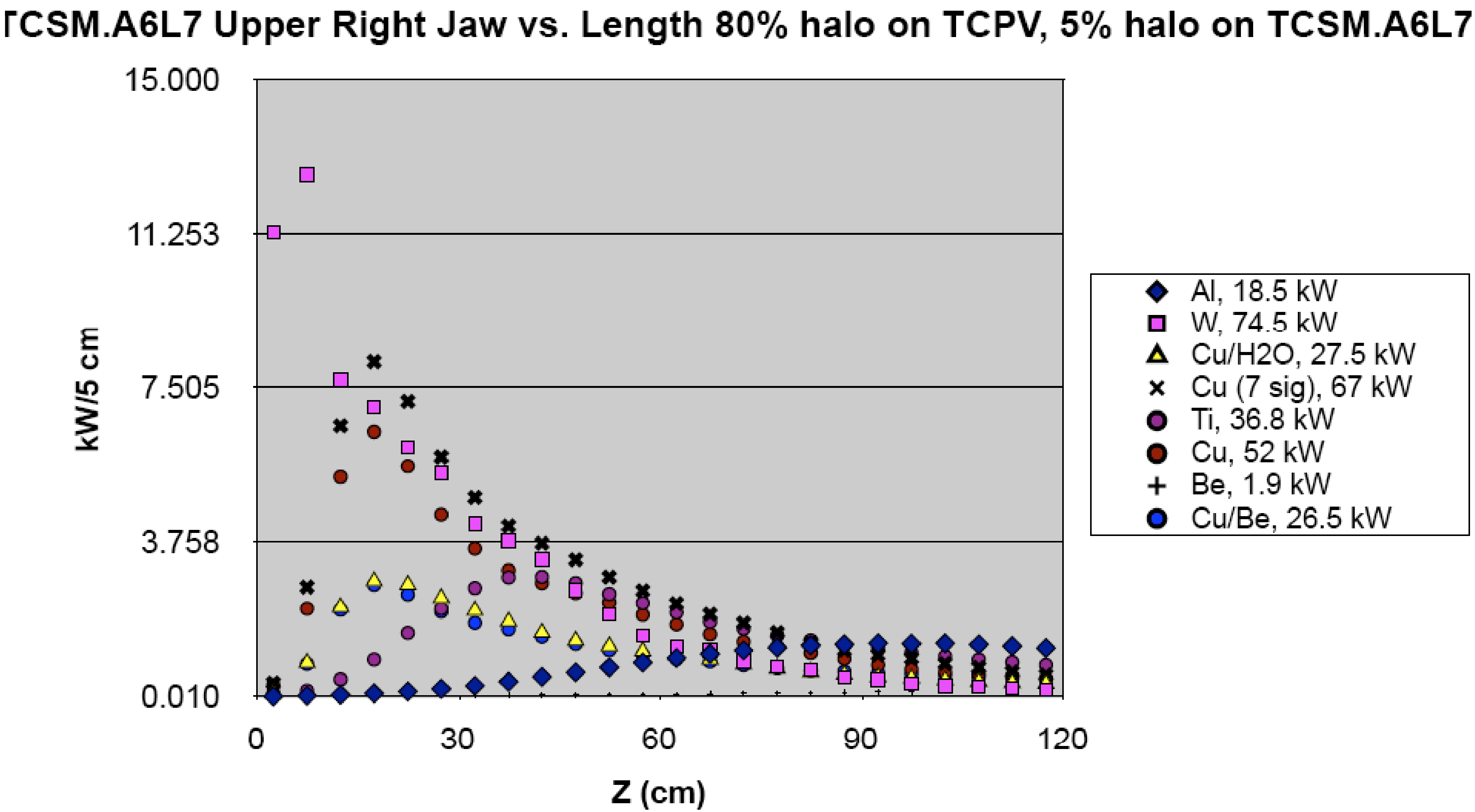
Cryogenic collimators for LHC studied with GSI in Germany (➔ FAIR).

Description Task 2.2

- *Task 2. Modelling, Materials, Tests for Hadron Beams.*
  - **Sub-task 2: Energy deposition calculations and tests.**
    - Showering models with protons and ions in the relevant energy range.
    - Modelling of the accelerator geometry and materials.
    - Energy deposition calculations for various operational assumptions.
    - Calculation of residual dose rates.
    - Modelling radiation-induced displacements per atom (dpa).
    - The following institutes contribute to this work: **CERN and GSI.**

FLUKA Results - Power Deposited vs. Length

- Ist secondary collimator
- Various materials

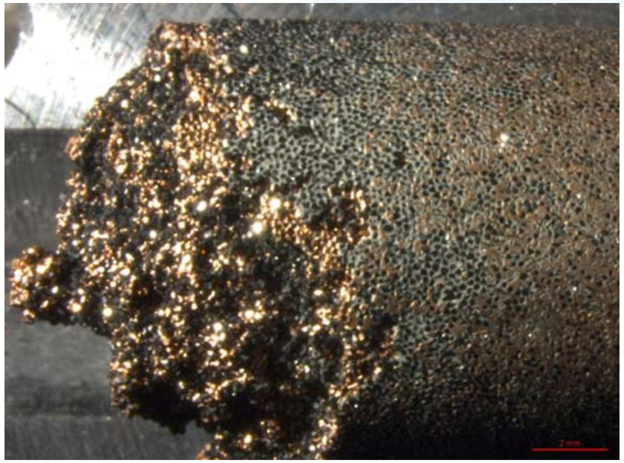


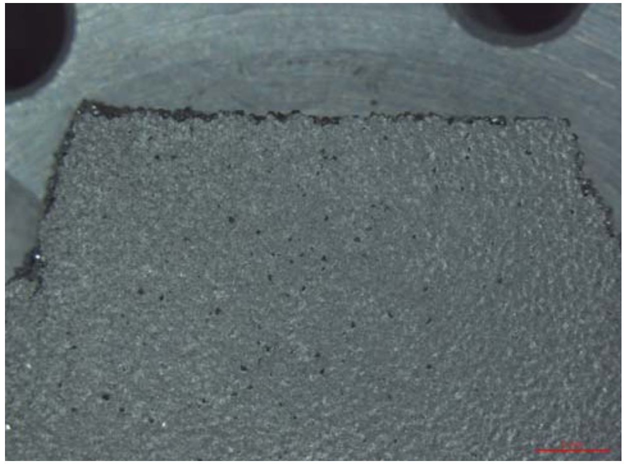
Description Task 2.3

- *Task 2. Modelling, Materials, Tests for Hadron Beams.*
  - **Sub-task 3. Materials and thermal shock waves.**
    - Selection of candidate materials for usage in high intensity accelerators. This includes also special materials, like modern composite materials and crystals.
    - Mechanical, electrical and vacuum characterization of materials.
    - Simulations of thermal shock waves due to impacts of beam particles.
    - Experimental tests on material resistance to beam-induced thermal shock waves.
    - Modelling of beam shock-induced damage of accelerator materials.
    - The following institutes contribute to this work**: ARC, CERN, GSI, EPFL, RRC KI and POLITO.**

Diamond Composites

- Preliminary tests of UHV compatibility
  - Two samples of Cu-D and Al-D proposed by L. Weber at EPFL.
    - Ready available, irregular shape
  - Outgassing tests made by I. Wevers
    - Cu-D: 2×10^{-12} torr·l·s^{-1}·cm^{-2}
    - Al-D: 10^{-11} torr·l·s^{-1}·cm^{-2}
    - Preliminary results compatible with standard UHV use
- Further steps
  - Functionally interesting?
  - Study feasibility of required dimensions
  - Tests foreseen
    - Thick coating for machining
    - Brazing to ceramics and to copper
    - Radiation effect on properties
    - Other…



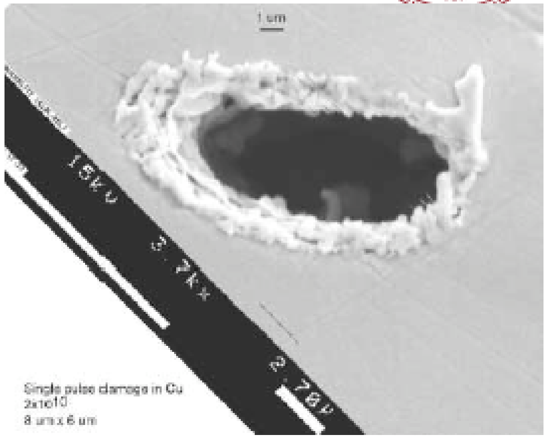


5mm

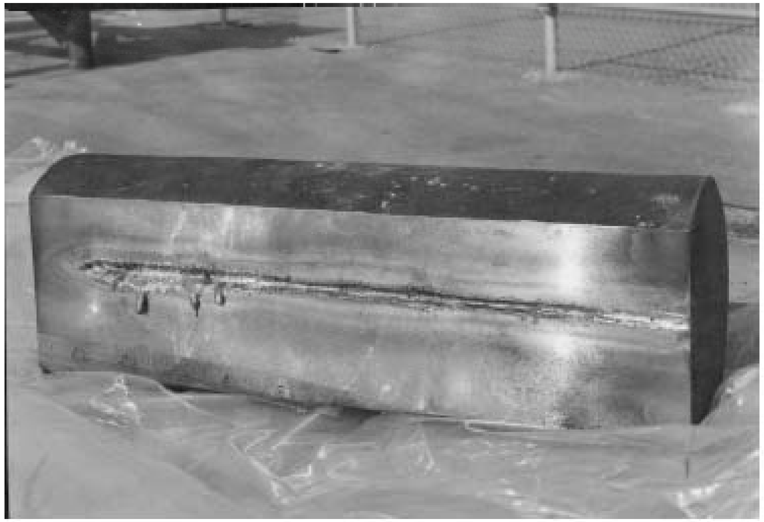
G. Arnau Izquierdo
CERN

Exact Nature & Extent of Damaged Region still not really known well. We need beam tests with prototype.

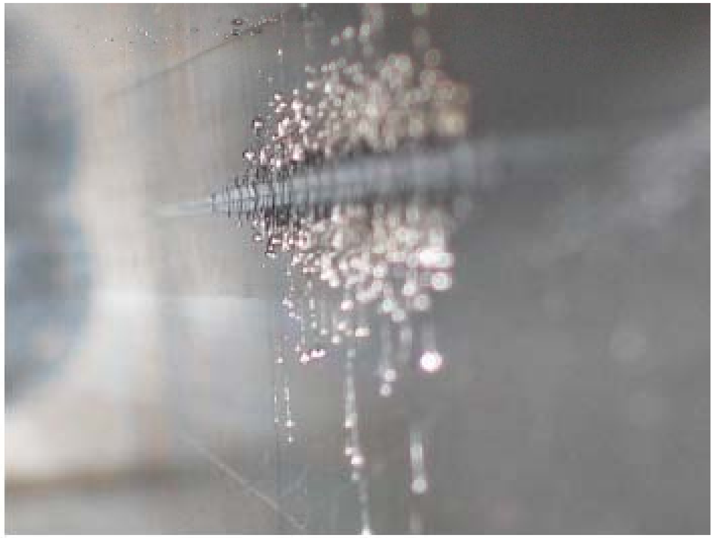
Thin Cu sample in FFTB electron beam at SLAC
Hole = Beam Size



2000um 500 kW 20 GeV e- beam hitting a 30cm Cu block a few mm from edge for 1.3 sec (0.65 MJ)



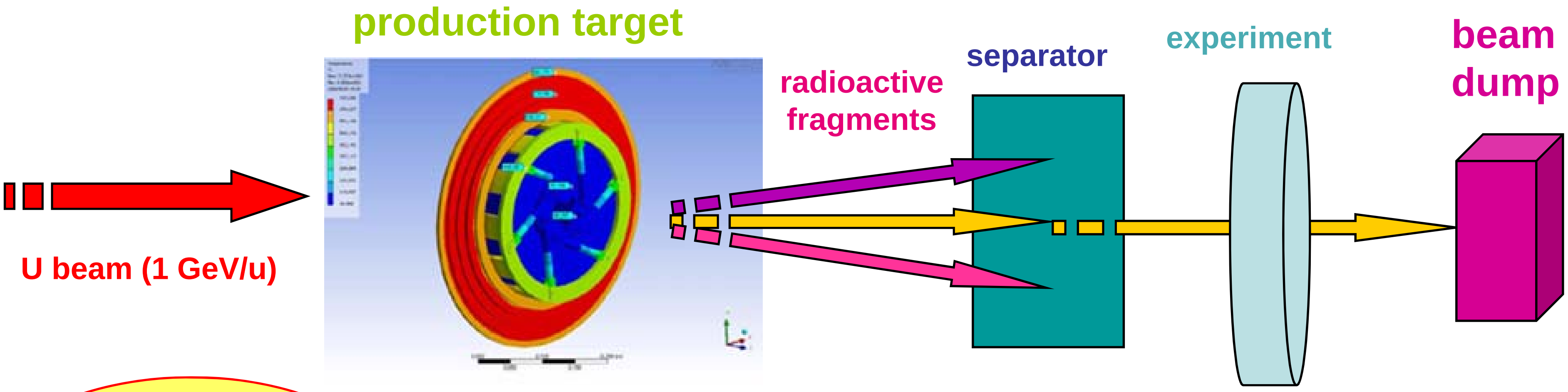
FNAL Collimator with .5 MJ



Description Task 2.4

- *Task 2. Modelling, Materials, Tests for Hadron Beams.*
  - **Sub-task 4: Radiation damage.**
    - Experimental tests on material resistance to beam-induced radiation.
    - Modelling of radiation damage for accelerator materials.
    - Prediction of material life expectancy in accelerator environment.
    - The following institutes contribute to this work: **CERN, GSI and RRC KI.**

Graphite as Super-FRS target and beam catchers
Long term radiation effects?



graphite at T_{target} ~ 700 C

~10^{17} ions/cm^2 per year

radiation damage?
- volume changes
- embrittlement
- crack formation
- decrease in
- heat conductivity

planned investigations
(on ion-irradiated samples)
- microscopy (SEM, AFM,...)
- spectroscopy (Raman, PAS)
- profilometry
- mechanical tests
- thermal tests
- model calculations

Materialforschung GSI (R. Neumann, M. Tomut, C. Trautmann) & TU-Darmstadt (W. Ensinger, M. Krause)

Description Task 3.1

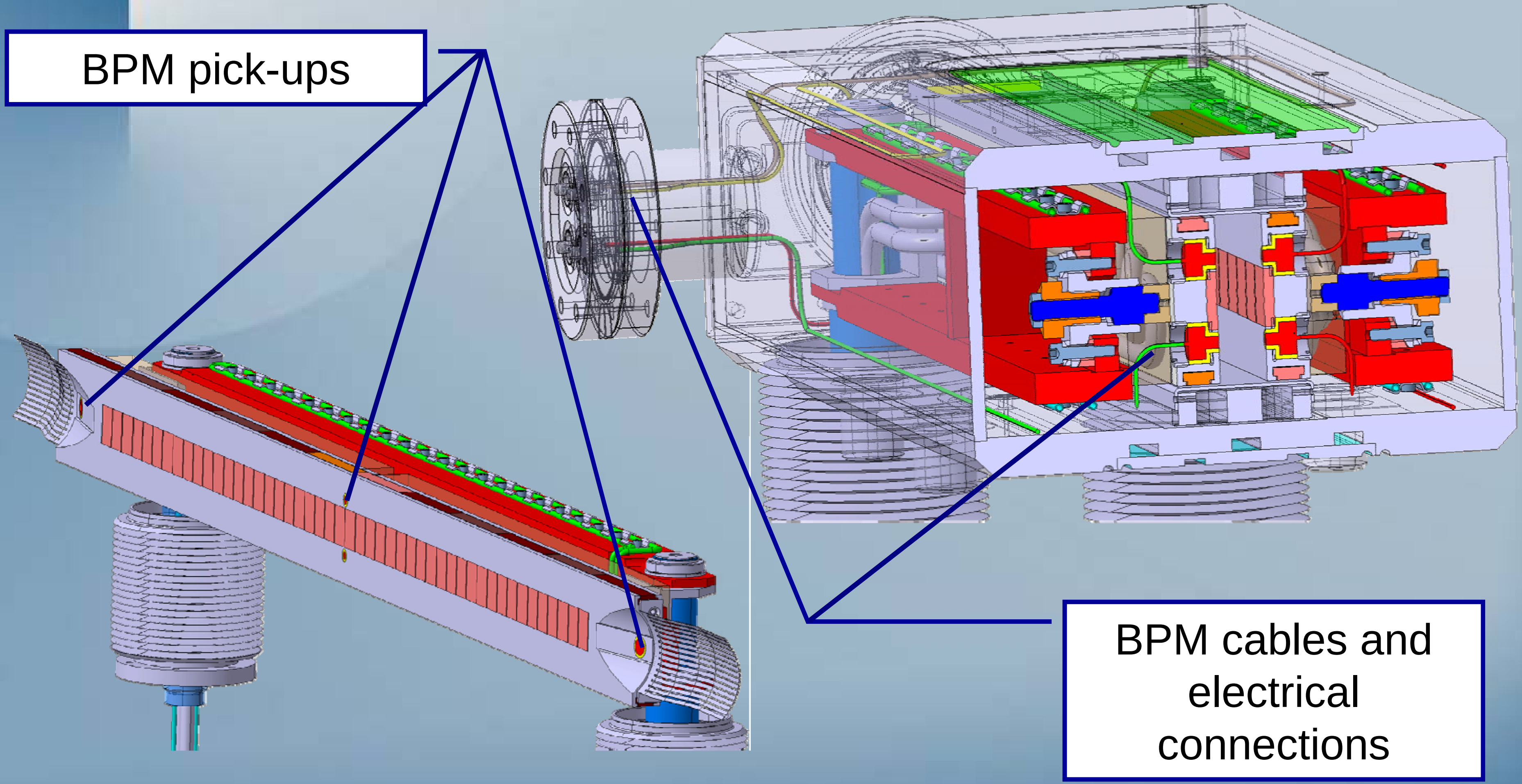
- *Task 3. Collimator Prototyping & Testing for Hadron Beams.*

  – **Sub-task 1: Prototyping, laboratory tests and beam tests of room-temperature collimators (LHC type).**

  – The following institutes contribute to this work: **CERN, INFN. Collaboration with BNL, FNAL and SLAC** in the United States.

BPM integration

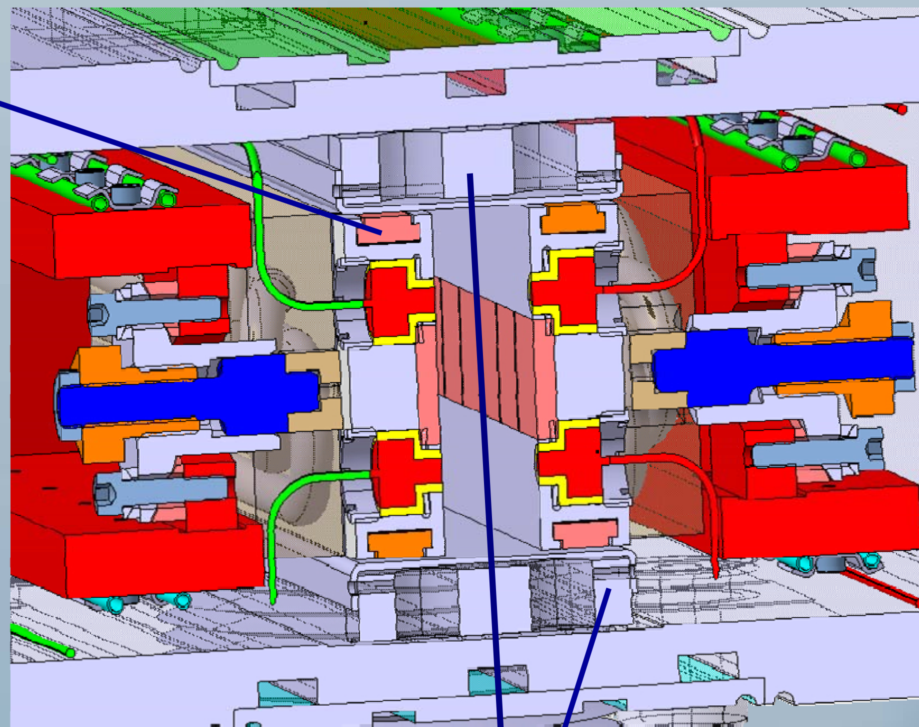
Integration of BPMs into the jaw assembly gives a clear advantage for set-up time

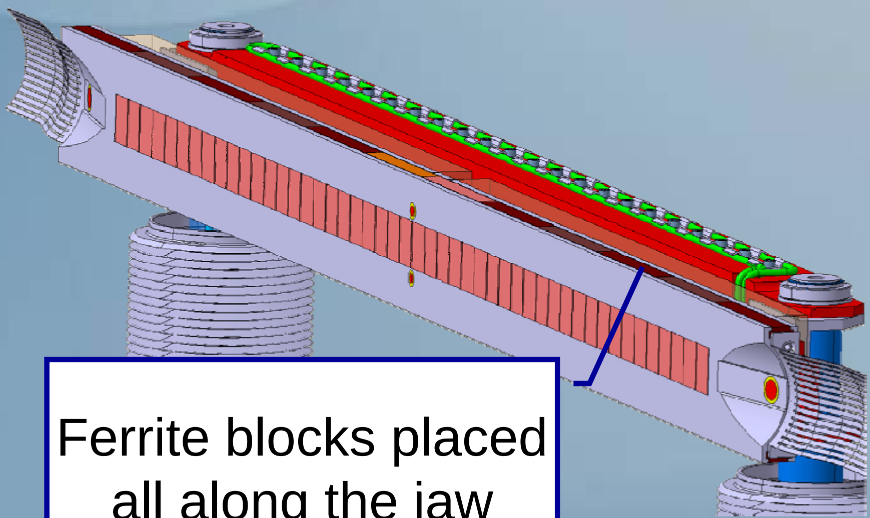


RF contacts

RF stability provided by ferrite blocks and metallic rails (no sliding contacts)

Ferrite blocks ensure beam stability without sliding contact





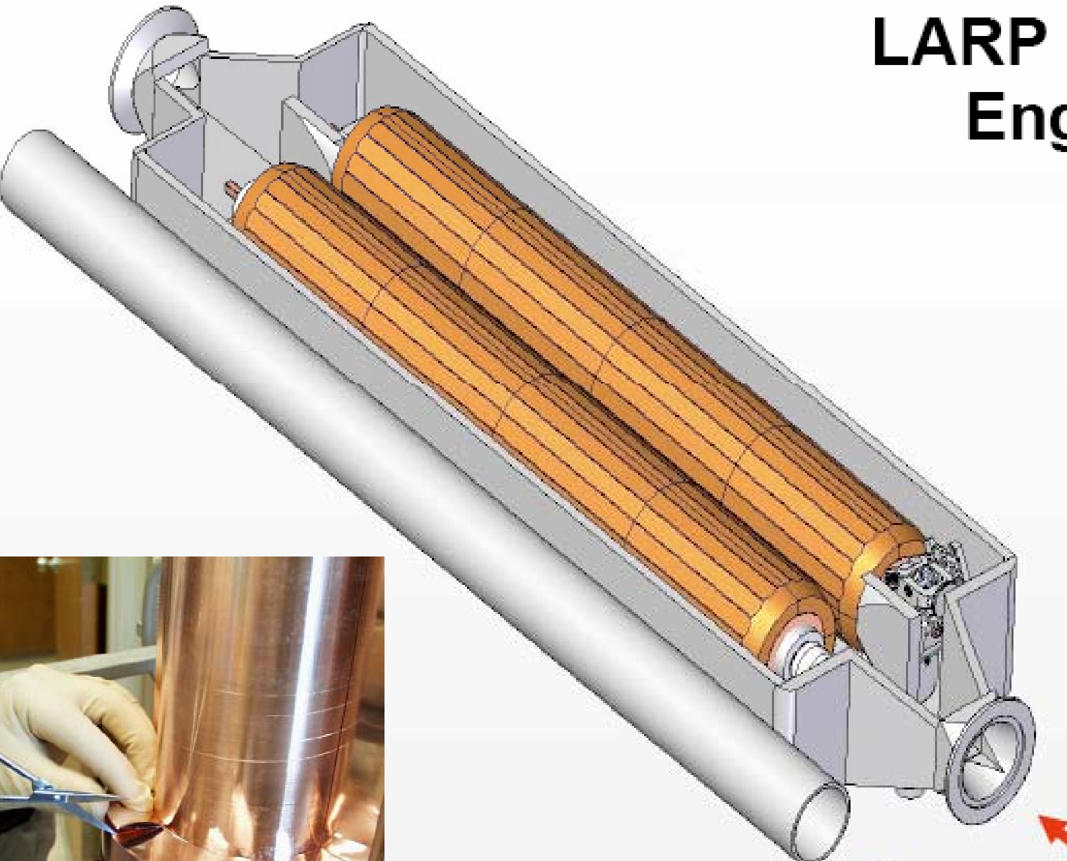
Ferrite blocks placed all along the jaw

Metallic rail

LARP

US LHC Accelerator Research Program

BNL - FNAL- LBNL - SLAC



LARP Phase
Engineerin

Jeff S
SLA

beam

bea

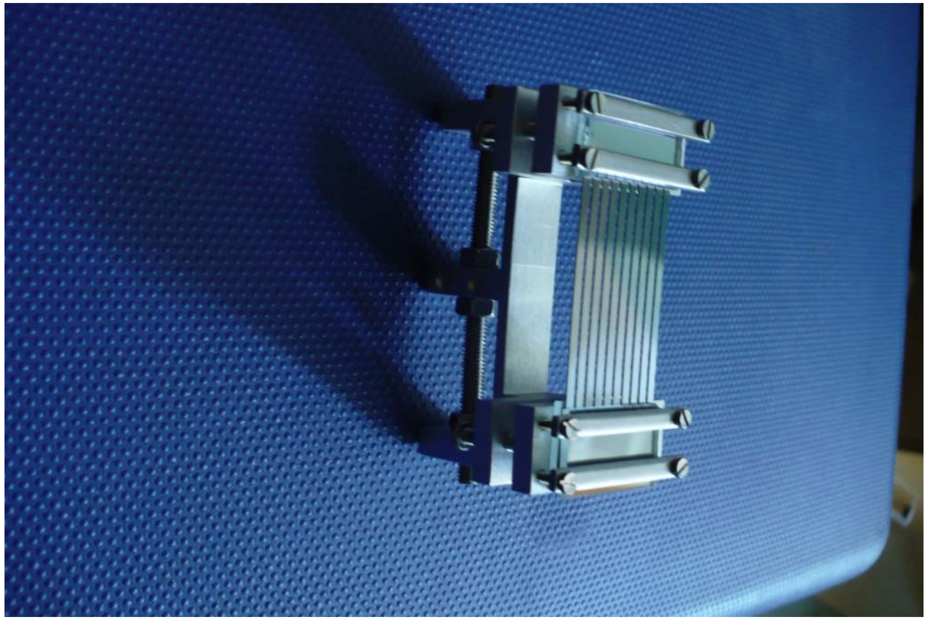
CERN

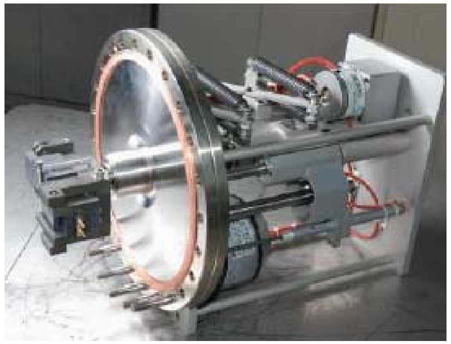
Eric Doyle, Lew Keller, Steve Lundgren, Tom Markiewicz, Reggie Rogers & Jeff Smith

Crystal Engineering

Built at INFN – Ferrara in collaboration with IHEP - Protvino

multistrip crystal (IHEP and INFN-Ferrara)





Bent crystals as possible way to improve cleaning efficiency.

R&D topic with ongoing conceptual tests in Tevatron and SPS.

Once successful, include crystals for LHC collimation.

→ W. Scandale and INFN

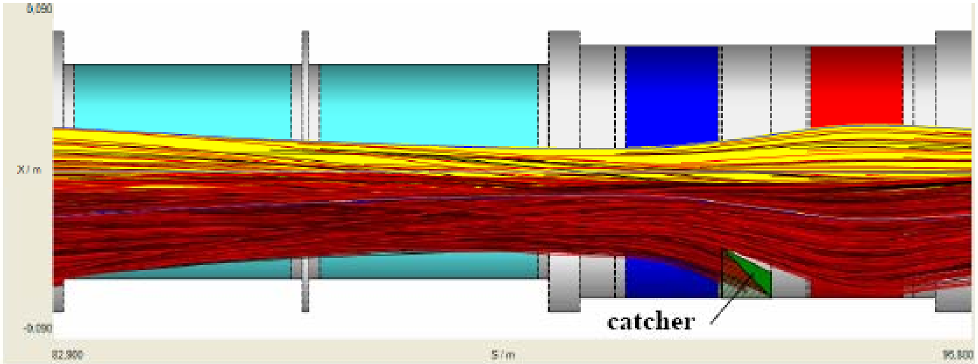
Description Task 3.2

- *Task 3. Collimator Prototyping & Testing for Hadron Beams.*

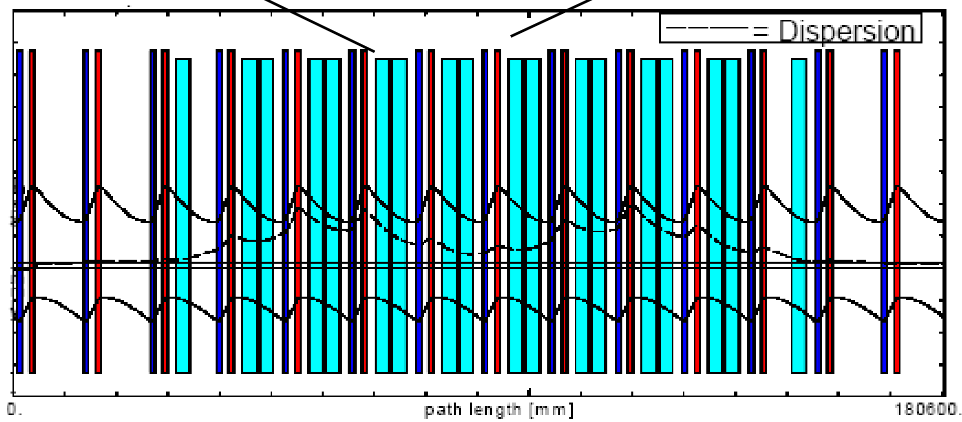
  - **Sub-task 2: Prototyping of cryogenic collimators (FAIR type).**
  - The following institutes contribute to this work: **GSI, CERN**.

Collimators for the suppression and control of desorption gases for high intensity operation with intermediate charge state heavy ions in the FAIR SIS100

Desorption Catcher		
Absorber wedge		
Length	m	0.6
Density	kg/m³	8
Material		Copper
Low desorption coating		100 nm Ni, 100 . 200 nm Au
Temperature	K	50 .. 100 K
Weight	kg	2.3
Alignment tolerance	mm	0.5
Heat release from the beam	W	< 10
Chamber		
Aperture	mm²	135 x 65
Chamber shape		rectangular
Operation temperature	K	4.5
Cooling power	W	100
General		
Length of module	m	0.7
No. of modules per superperiod		8
Total no. of collimators		48



11 Cryo-collimators per arc of SIS100



One of six arcs of SIS100

The lattice structure of SIS100 has been optimized to achieve a peaked distribution for ionization beam loss enabling an efficient use of cryo-collimators

Cryogenic FAIR Collimator

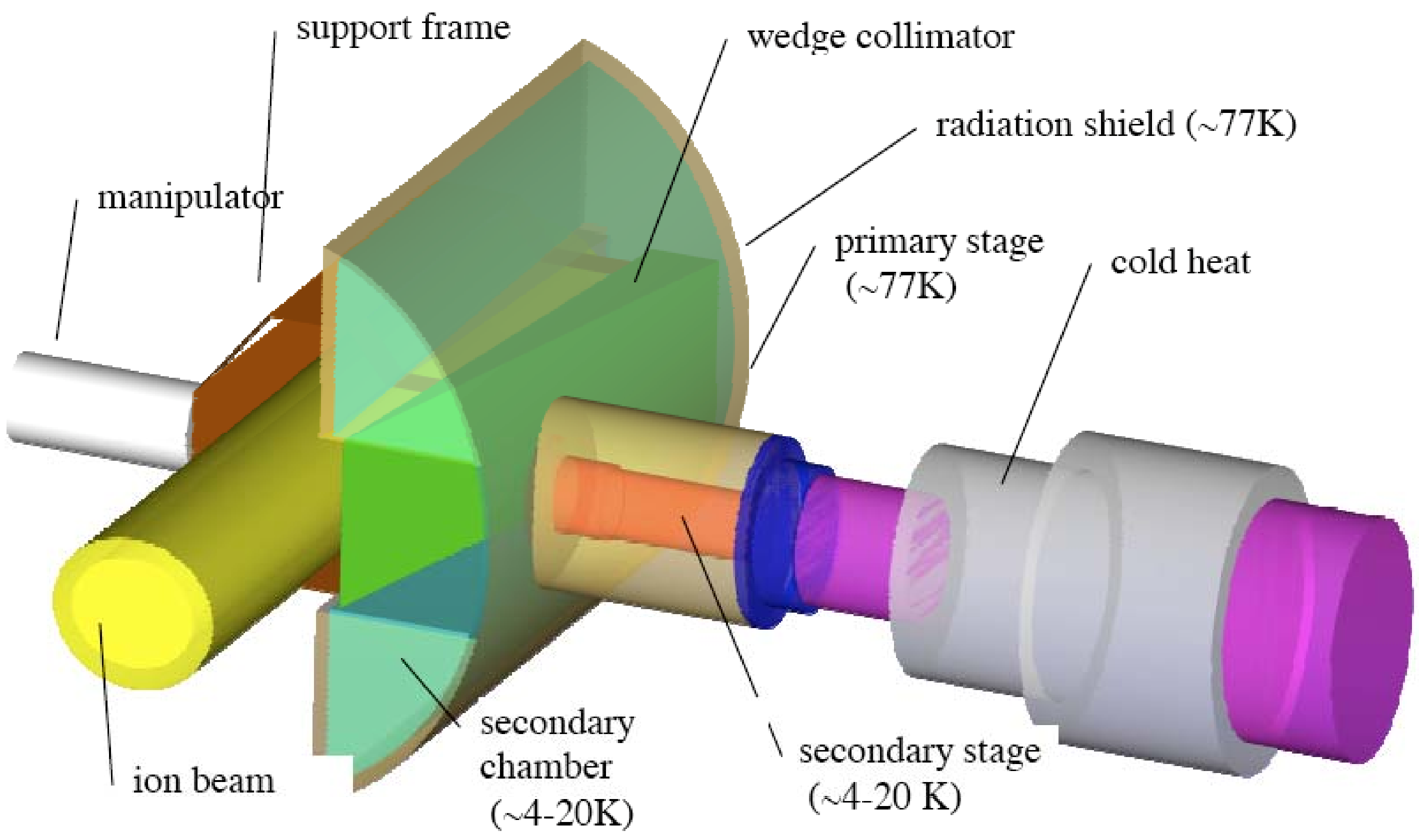


FIGURE 2: Proposed collimator for SIS18 with ion beam, support frame and secondary chamber/heat shield.

P. Spiller, K. Blasche, B. Franczak, J. Stadlmann, and C. Omet

Milestones - Schedule

Mile-stone	Description/title	Nature	Delivery month	Comment
8.1.1	1st annual ColMat review meeting	O	M12	
8.1.2	2nd annual ColMat review meeting	O	M24	
8.1.3	3rd annual ColMat review meeting	O	M36	
8.1.4	Final ColMat review meeting	O	M48	
8.2.1	Functional specification LHC of beam loss and collimator design	R	M12	Simulations and design completed.
8.2.2	Upgrade LHC collimator specification	R, D	M24	Materials characterized and tested. Review of results and specification.
8.2.3	Functional specification FAIR of beam loss and collimator design	R	M12	Simulations and design completed.
8.3.1.1	LHC type collimator designed	R	M20	warm collimator
8.3.1.2	LHC type collimator constructed	P	M26	
8.3.1.3	LHC type collimator tested	R	M30	
8.3.2.1	FAIR type collimator designed	R	M24	cryogenic collimator
8.3.2.2	FAIR type collimator constructed	P	M36	

Deliverables - Schedule

Deliverables of tasks	Description/title	Nature	Delivery month
8.1.1	ColMat web-site linked to the technical and administrative databases	O	M48
8.1.2	Collimator specification for LHC upgrade parameters	R	M24
8.1.3	Collimator specification for FAIR	R	M24
8.2.1	Report on modelling and materials	R	M36
8.3.1	One primary collimator with optional crystal feature, tested with beam	P	M42
8.3.2	One cryogenic collimator, tested with beam	P	M30

Conclusion

- Reaching the intensity frontier (LHC and FAIR) requires major advances in materials close to beam, collimation concepts and engineering.
- ColMat brings together unique expertise from different fields to make these advances possible, at fastest possible speed. Synergy effects…
- EU support allows pursuing innovative and inherently risky paths.
- Looking forward to very productive work over next years…

Thanks…

Jaw and cooler: Design options

…depending on RF and cleaning efficiency specifications…