ESGARD – OMIA 10 & 11/09/2007

JRA on Collimators and Materials for High Power Accelerators

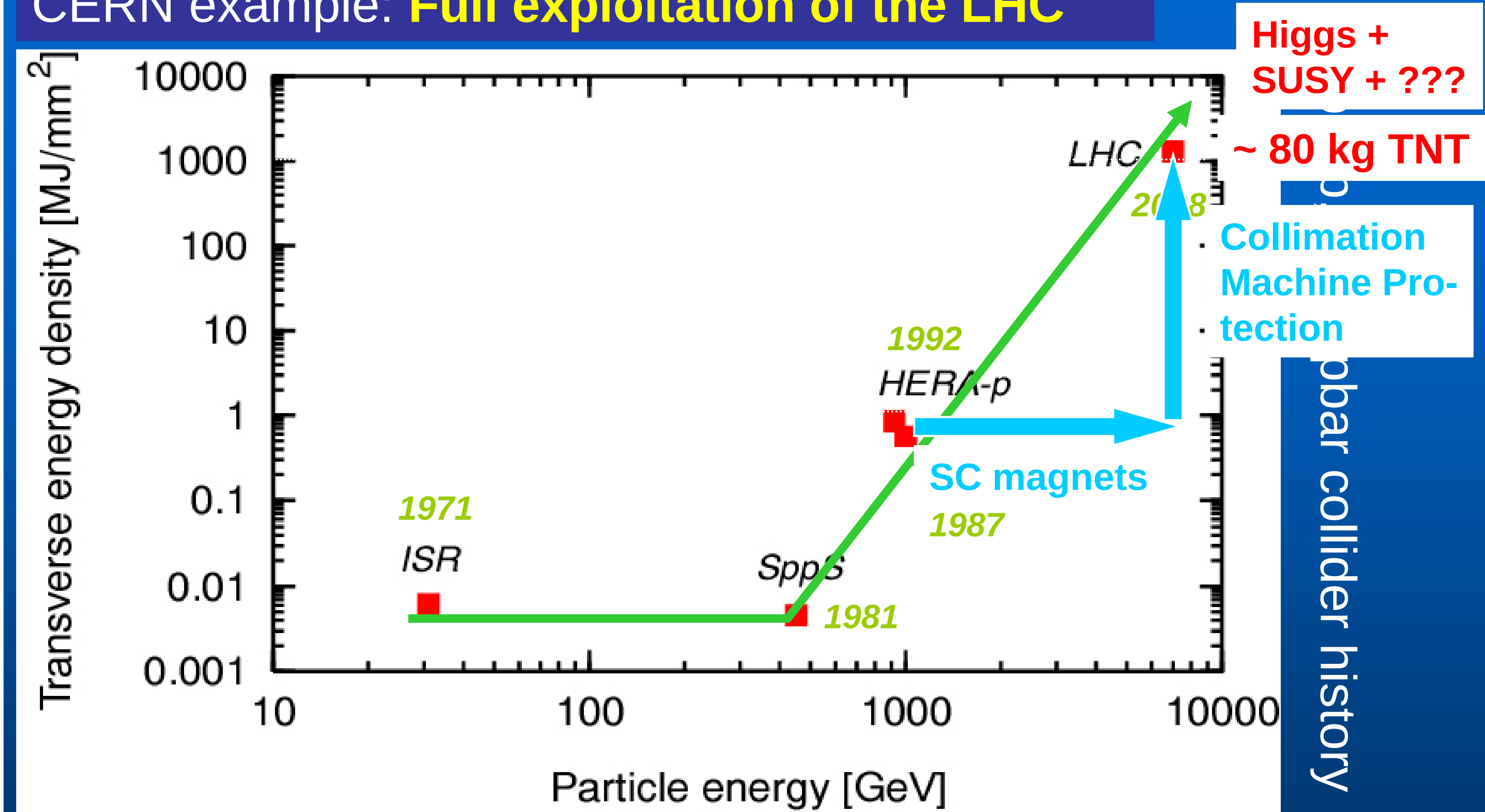
- Motivation
- Work Packages
- Partners & resources

R. Assmann

Motivation

- New accelerators require **outstanding active and passive control of beam loss**:
  - LHC proton beams with unprecedented stored energies.
  - The LHC ion beams face dissociation and fragmentation.
  - The FAIR ion beams face the risk of loss-induced desorption, associated fragments and premature beam decay.
  - The 1 MW PSI operation must minimize beam loss to achieve low activation (same driving limitation for SNS, SPL, J-PARC, …).
- Understand and handle losses: **High-tech collimation and protection systems pursued in the accelerator community**.
- Collaboration and coordination will bring together expertise and will avoid unnecessary duplication of work.

CERN example: **Full exploitation of the LHC**



The "new Livingston plot" of proton colliders: Advancing in unknown territory!

A **lot of beam** comes with a **lot of crap** (up to 1 MW halo loss, tails, backgrd, ...)

➔ Collimation. Machine Protection.

RWA

Collimators/absorbers are the sunglasses of an accelerator!

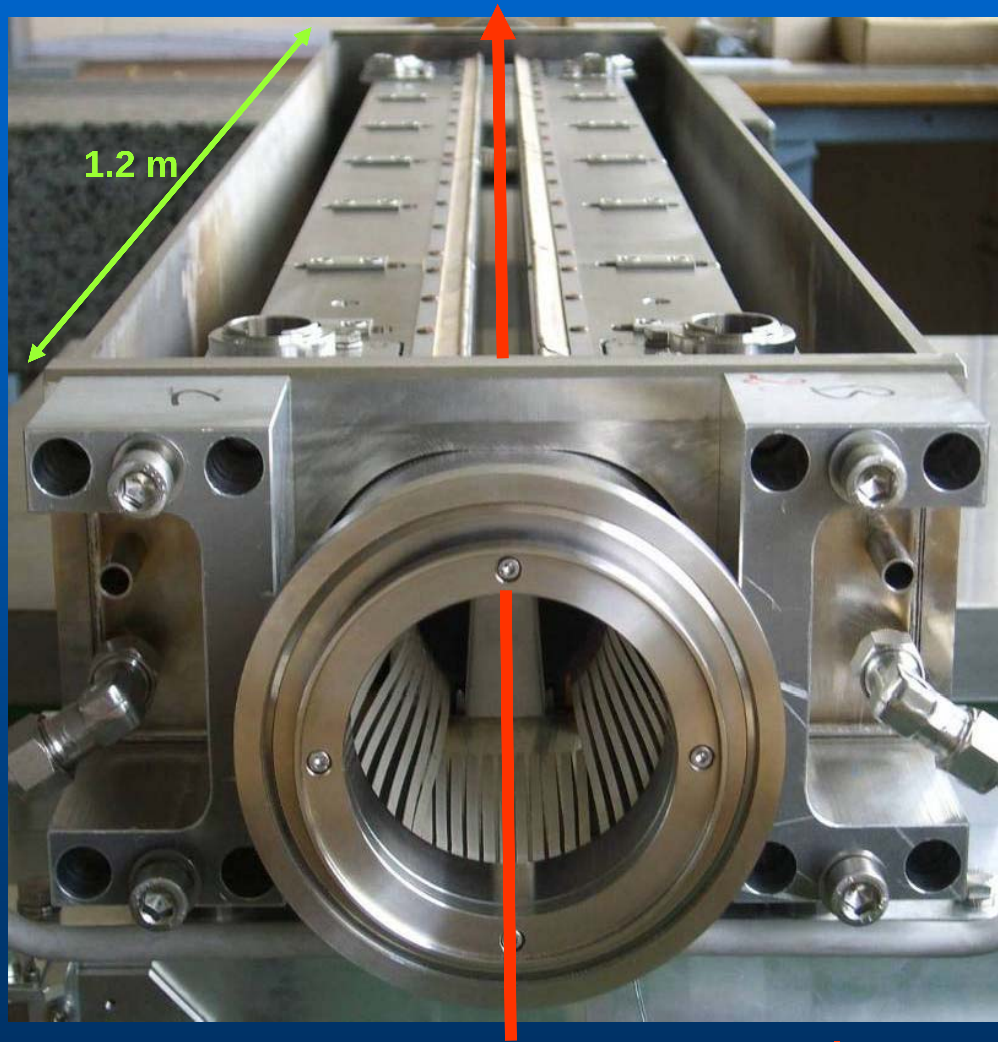
Intercept and absorb unavoidable slow beam losses: >99.99% efficiency goal (LHC, FAIR).

Protect against failures (protection).

Robustness: Collimators to **survive the intense beams** (shock impacts, radiation damage) and allow good beam vacuum.

Material studies are crucial!

Pretty good sun-glasses (filter factor >1000)…



The 99.99% challenge!

Work packages: *(draft – final commitments in written proposal)*

WP1 – Management and communication

WP2 – Collimation modeling and studies

WP3 – Material & high power target modeling and tests

WP4 – Collimator prototyping & testing for warm regions *(CERN coord?)*

- **Task 1** – Scrapers/primary collimators with crystal feature
- **Task 2** – Phase 2 secondary collimators

WP5 – Collimator prototyping & testing for cryogenic regions *(GSI coord?)*

WP6 – Crystal implementation & engineering *(CERN/INFN coord?)*

Options:

Option1 – Absorbers for machine protection

Option2 – Magnetic collimators

Limitation: Beam intensity for protons and ions *(limit at ~½ of nominal LHC intensity?)*

Problem: Losses in dispersive, super-conducting arc regions (LHC and FAIR)

impedance limitation with initial collimators, issues with multi-stage cleaning efficiency, single-diffractive scattering, ion fragmentation, dissociation

Hardware:
- WP4-I, WP6 (scrapers/primary collimators with crystal feature)
- WP4-II (improved secondary collimators, phase 2)
- WP5 (cryogenic collimators at loss locations – FAIR, LHC upgrade)
- Option 2 (magnetic collimators for additional deflection of halo particles)

Limitation: Maximum ion luminosity *(limit at > ½ nominal LHC ion luminosity?)*

Problem: Losses of collision products in super-conducting arcs (physics).

Hardware: WP5 (cryogenic collimators at loss locations – FAIR, LHC upgrade)

Limitation: Protection, availability, component lifetime.

Problem: Absorption efficiency and robustness of absorber.

Hardware: Option 1 (improved absorber design)

WP1: Management & Communication

Goals:

- **Management of the JRA**
- **Organization of communication inside and dissemination outside the JRA (publications, internet etc.)**
- **Link with other JRAs as well as with other European projects and integration of the relevant results**
- **Coordination of the technical debates and conclusion on suitable technologies**

WP2: Collimation Modeling & Studies

Subjects:

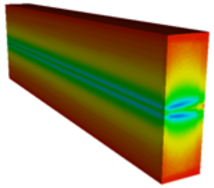
- **Study of collimation and protection concepts (collimation in cryogenic regions, crystal-enhanced collimation, non-linear collimators, magnetic collimators, …).**
- **Studies and review of beam loss.**
- **Simulation of collimation performance and comparison with experiments.**
- **Modeling of beam impact on collimators/absorbers/… and energy deposition.**
- **Specification of improved collimators and absorbers.**

WP3: Material & High Power Target Modeling and Tests

Subjects:

Heavy usage of beam test facility

- Experimental evaluation of materials
  - Mechanical, electrical and thermal properties
  - Radiation damage
  - Engineering aspects (manufacturing, machining, tolerances)
  - Damage threshold and damage extent
  - Vacuum properties
- Modeling of materials
  - Thermo-mechanical behavior under beam load
  - Thermal shock resistance
  - Damage
- Selection of materials for improved collimators and absorbers
- Support for material questions on assembled collimators



Workshop on Materials for Collimators and Beam Absorbers

Search

3-5 September 2007 | CERN

- Home Page
- List of registrants
- Timetable
- Call for Abstracts
  - View my abstract(s)
- Book of abstracts [PDF]
- Contribution List
- Speaker index

Home

This workshop will focus on collimators and beam absorbers for High Energy Hadron Accelerators, with the energy stored in the beams far above damage limit. The objective of the workshop is a better understanding of the technological limits imposed by mechanisms related to beam impact on materials. The issues to be addressed at the workshop are listed below.

Dates: from 03 September 2007 14:00 to 05 September 2007 18:15

Location: *CERN*
Geneva, Switzerland
Room: **40-S2-D01**

Chairs:
Ralph W. ASSMANN (CERN) - ORGANIZING COMMITTEE
Wim WETERINGS (CERN) - ORGANIZING COMMITTEE
Nikolai V. MOKHOV (Fermilab) - ORGANIZING COMMITTEE
Alessandro BERTARELLI (CERN) - ORGANIZING COMMITTEE
Peter SPILLER (GSI) - ORGANIZING COMMITTEE
Rudiger SCHMIDT (CERN) - Chairman
Małgorzata MACUDA (CERN) - Workshop Secretary
Caroline CAZENOVES (CERN) - Workshop Secretary

Additional info: A detailed agenda will soon be made available. We are planning to reserve a large fraction of the workshop time for comments and discussions.

WORKSHOP TOPICS:

- The problems encountered for systems used in different accelerators will be presented together with the solutions adopted. What materials are being used? What led to the choice of these materials? What are the limits of the present solutions?
- Why will more robust devices be needed in the future? What is the perspective in the framework of new or upgraded machines?
- The relevant parameters for beam impact on the material will be discussed, such as deposited beam energy, beam power and time structure of the beam impact.
- What material parameters are relevant, such as specific heat capacity, enthalpy, Young's modulus, yield stress, coefficient of thermal expansion, thermal conductivity? What are the relevant figures of merit? Are the bulk or microscopic parameters the relevant ones, particularly for composite and anisotropic materials?
- What materials are most suitable, e.g. robust and with low electrical resistance? Other parameters such as anisotropy of materials and secondary electron yield? Are there new materials on the horizon?
- What happens in case of shock impact (time constant ~µs or ~ns) and continuous impact (time constant ~s)? What are the relevant physics effects to be considered?
- What are the limits of the domain of application of the classical thermoelastic/plastic theory with respect to the Hydrodynamic theory of Shock Waves?
- What happens to the material beyond melting / vaporisation temperature? (example: beam tunneling through materials).
- What is the design limit based on, e.g., maximum temperature? When do we require renewable/disposable/sacrificial devices?
- What is the status of the codes for energy deposition calculations? When do calculations for shock impact with mechanical engineering codes (e.g., ANSYS, AUTODYN, LS-DYNA) break down? What are the domains of validity for simulation?
- How to compare the results from different codes, possibly for some (simple) test cases to be defined?
- What experimental evidence and experience with benchmarking exists?
- How to formulate an equation of state for materials in advanced codes?
- What are the short- and long-term effects of radiation? What is the effect of the total dose on material properties, and on equation of state? Is there an effect of the dose rate?
- DPA (displacements per atom) is a measure of the material irradiation. Is this a universal measure for different radiation fields? Is there a temperature dependence during radiation? What about annealing? Can this be used to 'repair' devices?
- What tests of materials are possible? What to test? Where to test? How to analyse test results? Test bench at SPS?

➔ Workshop last week provided important input and support…

WP4: Collimator prototyping & testing for warm regions

Subjects:

- **Goals:**
  - Reduce collimator-induced impedance.
  - Improve multi-stage cleaning efficiency.
  - Improve operational ease (beam diagnostics in jaws).
  - Maintain robustness against shock and radiation damage.
  - Upgrade of primary collimator to overcome problem of single-diffractive scattering in these collimators.
  - Scraper design for removing beam.
  - Bent crystal for enhancing efficiency.
- **Work flow:**
  - Conceptual design
  - Mechanical design
  - Prototyping
  - Laboratory tests
  - Beam tests

WP5: Collimators in Cryogenic Regions

Subjects:

- **Goals:**
  - **Catch losses locally in super-conducting regions.**
  - **Address losses originating from local processes (beam-gas, collisions, ions, …).**
- **Work flow:**
  - **Prototyping (GSI/FAIR design)**
  - **Laboratory tests**
  - **Beam tests**
  - **Eventual design adaptation to LHC conditions**

WP6: Crystal Implementation and Engineering

Subjects:

- **Goals:**
  - **Enhance cleaning efficiency by complementing primary collimators with bent crystals.**
- **Work flow:**
  - **Study and construction of bent crystals and their assembly onto a support.**
  - **Study and construction of infrastructure, required for implementation of crystal collimation (goniometers, diagnostics, operational tools, …)**
  - **Support for implementation into an LHC scraper or collimator.**

Option 1: Absorbers for Machine Protection

Subjects:

- **Goals:**
  - Improve passive machine protection in the LHC in view of LHC upgrades.
- **Workflow:**
  - Adapt exisiting sandwich absorber for beam tests.
  - Beam tests to explore damage limit.
  - Improvement of design.
  - Prototype of improved absorber.
  - Laboratory tests.
  - Beam tests.

Option 2: Magnetic Collimators

Subjects:

- **Goals:**
  - **Additional deflection with magnetic fields.**
  - **Overcome problem of dissociation and fragmentation in primary collimator for ion beams and single-diffractive scattering for p beams.**
- **Workflow:**
  - **Conceptual design of a magnetic collimator.**
  - **Mechanical design**
  - **Prototyping**
  - **Laboratory tests**
  - **Beam tests**

Partners and Resources

- Detailed program **being worked out**.
- Limited effort so far:
  - CERN is driving this proposal.
  - CERN resources fully focused on completing the LHC for first operation.
  - In particular, completion of initial collimation system for March 2008 is our (my) highest priority.
- **Final proposal will be prepared for January 2008**, taking into account output from this meeting.
- **The written proposal will include final participation and commitments**.
- The information presented is based on preliminary discussions and expressions of interest. To be formalized in next months!

Participating Institutes and Resources (preliminary)

Institute	WP1 Management & communication budget (k€)	WP2 Collimation studies & modeling budget (k€)	WP3 Materials, tests, modeling & radiation budget (k€)	WP4-1 Scraper/primary collimator with crystal feature budget (k€)	WP4-2 Secondary collimator (phase 2) budget (k€)	WP5 Cryogenic collimator budget (k€)	WP6 Crystal implementation and engineering budget (k€)	Total budget (k€)	Option 1 Absorbers for machine protection	Option 2 Magnetic collimators	Total option
CERN	200	600	600	700	900	120	120	3240	900	980	1880
GSI	80	200	130	0	0	500	0	910	200	70	270
PSI	20	0	130	0	150	0	0	300	0	0	0
EPFL	25	0	230	0	0	0	0	255	25	25	50
Turin Polytechnic	25	0	180	0	0	0	0	205	25	25	50
Plansee company	20	0	100	0	0	0	0	120	15	15	30
Austrian Research Center ARC	20	0	100	0	0	0	0	120	15	15	30
Alicante University	10	0	40	0	0	0	0	50	10	10	20
Milano University	20	100	0	0	0	0	0	120	200	200	400
INFN	50	30	90	30	0	0	160	360	0	0	0
John Adams Insitute	20	300	0	0	0	0	0	320	35	35	70
Total	**490**	**1230**	**1600**	**730**	**1050**	**620**	**280**	**6000**	1425	1375	**2800**

Draft (one possibility) – detailed split and commitments are under discussion!

➔ Not funded through FP7.

Collaborating Institutes (preliminary)

Institute	WP1	WP2	WP3	WP4-1	WP4-2	WP5	WP6
	Management & communication	**Collimation studies & modeling**	**Materials, tests, modeling & radiation**	**Scraper with crystal**	**Improved secondary collimator (phase 2)**	**Cryogenic collimator**	**Crystal implementation and engineering**
BNL							
FNAL							
IHEP Protvino							
JINR Dubna							
Kurchatov							
Protvino							
SLAC							

Strong support and interest at CERN and in the world-wide community:

➔ **White paper** project on phase 2 collimators (CERN resources)

➔ Collaboration with the US (BNL, FNAL, SLAC) through **LARP program**

➔ **FP7 – connect and integrate with relevant European R&D efforts**

Program Summary

- Proposed JRA addresses challenges for **high-intensity, ultra-clean accelerators**!
- Work packages and deliverables (materials, prototype collimators) defined for:
  - Full exploitation and upgrade of the **LHC**.
  - Collimation needs of the **FAIR project**.
  - Expect strong **spin-off from and for other projects** and ongoing R&D efforts.
- Final description only once detailed commitments and boundary conditions have been received.
- Budget request:
  - Limited core program: **6 MEuro** (strongly reduced to match target)
  - Core options: **2.8 MEuro**
- Preliminary network:
  - 11 participating institutes, universities and companies in 6 European countries.
  - 7 collaborating institutes, in the United States (funded by the DOE through LARP) and Russia (funded in direct agreements).
- Schedule will be defined with compatibility for 1) LHC exploitation and upgrade and 2) FAIR construction.