MPE-PE

- Protection of superconducting circuits – today and tomorrow
- Protection from beam accidents for LHC, HL-LHC, CLIC, FCC and CERN injectors
- Availability of LHC and HL-LHC
- Magnet System and Beam Operation at LHC

- Computer modelling (magnets and beams)
- Development of new methods of protecting sc magnets (CLIQ)
- Development of detectors for beam loss monitoring
- Damage and quench studies
# TE- MPE-PE members

## Staff
1. Zinur Charifoulline
2. Arjan Verweij
3. Bernhard Auchmann
4. Daniel Wollmann
5. Rüdiger Schmidt
6. Michael Jonker

## Fellows
1. Vera Chetvertkova
2. Lutz Hein

## PhD students
1. Emmanuele Ravaioli
2. Michal Maciejewski
3. Scott Rowan
4. Vivien Raginel
5. Florian Burkart
6. Oliver Stein
7. Andrea Apollonio

## Technical students
1. Jonas Blomberg Ghini
2. Deepak Paudel
3. Christian Buhl Sorensen
4. Ondrej Picha
5. Jakub Tytus Janczyk
6. Tobias Griesemer (stagiere until 2/15)

## Summer student 2014
1. G.Rosella
A selection of our activities …..
High Luminosity LHC and Availability

- Pile-up limit by LHC experiments limit maximum luminosity
- Levelling the luminosity to $5 \times 10^{34} \text{ cm}^{-2}\text{s}^{-1}$
- **High availability required** to achieve 200–300 fb$^{-1}$/y ($\times 10$ today)

TE-MPE-PE is strongly involved in studies of availability

This topic concerns all sections
R2E and Availability Workshop
14-17 October 2014
Benjamin Todd, Setting the scene

Run 1:

- HL-LHC: 160 days 25 fb⁻¹
- HL-LHC: 200 days 210 fb⁻¹
- HL-LHC: 260 fb⁻¹
- HL-LHC: 200 days + 20% more availability

Run 2:

- HL-LHC: 300 fb⁻¹

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15/12/2014

Qualitative curves
• **Machine availability:** key factor for integrated luminosity at HL-LHC → fault tracking can provide essential input.

• **R2E: Mitigation → Prevention;** Radiation monitoring in LHC and testing of components (CHARM @ CERN) → requires coordination; maintain experience/knowledge.

• Majority of electronic systems to be replaced before or during HL-LHC → consider R2E + availability, use synergies between teams and with LHC physics experiments.

• New high bandwidth, radiation tolerant communication link required by several systems (QPS, BLMs, …).

• High bandwidth communications links would allow smart electronics outside of radiation areas (no need for smart electronics in rad areas).
Machine Protection from Beam accidents

• **Make sure that beam losses are well understood** (injection, coast, beam dump)
• **Make sure the protection from beam losses is efficient**
  • Dump beams before beam loss would lead to a quench
  • Do not dump beams if beam loss would not lead to a quench
• **Beam loss mechanisms**
  • Very fast transient losses at injection and beam dump
  • Fast beam losses with coasting beam (e.g. UFOs)
  • Slow beam losses during transitions (squeeze, colliding beams)
• **BLM system not designed to monitor very fast transient beam losses**
• **Use diamond detectors and to resolve beam losses on bunch to bunch level** (collaboration with BE-BI)
Beam losses and magnet quenches

**Goal:** Optimal setting of BLM thresholds, among others. Understanding a beam-loss event is iterative. Requires deeper understanding of loss mechanisms, analysis tools, and quench levels.

**Workshop on Beam-Induced Quenches**
September 15-16 at CERN.
50 participants
UFO Modeling – dust falling into the LHC beam

- Semi-analytical models are developed to **predict the likelihood of BLM dumps or magnet quenches due to UFO events** in the arcs after LS1 (based on F.Zimmermann's work).

- The models are validated with Run 1 data.

- First results very promising.
BLM Thresholds

BLM thresholds for cold magnets, warm magnets, and collimators are being updated based on FLUKA models and quench level estimates that were validated by quench tests.
Collaboration with BI: Characterisation of diamond detectors and their use at CERN

• Tests with electron bunches in Frascati, at the BTF facility with different bunch intensities
• 100 um with a diameter of 5 mm and 500 um thick diamond 10*10 mm

F. Burkart, C. Buehl Soerensen, O. Stein, D. Wollmann
Response as a function of number of charged particles through diamond

Response of the diamond detector

100 um with a diameter of 5 mm

Future: Measure abort gap population with diamonds in LHC-IR4.
Verification of protection margins for collimators

Apply closed-orbit bump: Particle trajectories with bump and during MKD misfire are equivalent.

By further increasing the bump amplitude and successive moving out of the collimators in the region of interest, the accurate positioning of the collimators and there protection level can be validated.

V. Chetverkova

IP6 (MKD/TCDQ) → IP5 (TCT/triplet) with closed orbit bump – Preparation for ATS optics
CLIQ – Coupling-Loss Induced Quench (EU Patent EP13174323.9, June 2013)

**Solution** for protecting new generation high field superconducting magnets

**Repair option** for operating magnets with failing quench-heater (existing LHC circuits)

**CLIQ** quenches magnet by oscillating magnet current, generating **coupling losses** (=heat) in the conductor.

- **easier** implementation and repair,
- **faster** quench initiation,
- lower **hot-spot, temperature,**
- lower **failure risk.**

**Tested on the MQXC2 quadrupole magnet** (NbTi, 2 m long)
- **-20% quench load with respect to QH**
- **-65 K hot-spot temperature**

**Tested on the HQ02 quadrupole magnet** (Nb$_3$Sn, 1 m long)
- **-45% quench load**
- **Entire coil quenched in <10 ms!**

E. Ravaioi et al., MT23, 2013.
E. Ravaioi et al., EUCAS11, 2013.
E. Ravaioi et al., Cryogenics, 2014.

E. Ravaioi, A. Verweij
FCC accidental beam impact on equipment

- Simulations by coupling of FLUKA with BIG2 (F.Burkart, N.Tahir GSI) – take very long

- 40 TeV, sigma = 0.2 mm, 25 ns, 1e11 protons/bunch

After the impact of 8 bunches
FCC accidental beam impact on equipment

Preliminary estimation: range of beam is between 150 and 200 m
Projects and studies

- **HL-LHC**: Machine protection (work package 7 for HL-LHC)
  - Availability, damage tests and other activities

- **FCC**
  - Availability: with teams from Finland (Tampere) and collaborators from Stuttgart: **LHC to be used as reference**

- **CLIC**: Machine protection, risk analysis and proposals for machine protection system, studies of availability
Thanks to all the Team
spare
Proton energy deposition for different energies

- 50 MeV
- 100 MeV
- 200 MeV
- 500 MeV
- 1 GeV
- 2 GeV
- 5 GeV
- 10 GeV
- 20 GeV
- 50 GeV
- 100 GeV
- 200 GeV
- 400 GeV
- 1 TeV
- 7 TeV
- 450 GeV
- 26 GeV
- 100 MeV
- 200 MeV
- 40 TeV
Workshop on Beam-Induced Quenches

September 15-16 at CERN.
50 participants from BNL, CEA, CERN, GSI, KEK.

Topics:
- Experience from SC accelerators.
- Analysis of beam-induced quenches in the LHC (quench tests).
- Experimental and modeling work on heat transfer in SC cables.
- Feedback to BLM thresholds.

Organizers: B. Auchmann, A. Lechner, B. Salvachua, M. Sapinski

Proceedings: E. Todesco

Presentation proposed within MSC seminars

http://indico.cern.ch/events/BIQ2014
Applications of diamond detectors in LHC and elsewhere for machine protection

1. **Calculating abort gap population** by measuring shower particles from beam gas interactions in the BGI in IR4.
2. **Identification of loss pattern** during beam dump measuring scattered particles close to the TCDQ.
3. Measuring of **IP2/IP8 injection losses**.
4. Measuring **global losses in IP7** close to collimators, in particular the losses from UFOs, for each bunch.
5. Use detectors in HiRadMat for damage studies.

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T. Baer
Monitoring of Abort Gap Population with dBLMs

- Two diamond detectors to eliminate signal from other beam.
- Detection rate increases linearly with intensity of un-bunched beam and vacuum pressure.
- Higher abort gap populations can be detected faster and more accurately.
- Low un-bunched beam intensities → integrate over whole circumference
- High un-bunched beam intensities → “gate” on abort gap.
Beam induced damage of sc magnets

• What is the limit (e.g. in J/cm³)?
• Frequent questions: e.g. what mask is required to protect D1 from full beam impact on the TDI injection absorber? What is the “safe” intensity for beam at injection and collision energy?
• Only one (very old paper) with a limit that appears extremely low
• Needs studies: PhD student started recently, discussions with TE-MSC and EN
• Experimental programme on beam induced damage being studied, HiRadMat beam time requested