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

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2. Lutz Hein

Summer student 2014

1. G.Rosella

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)

CERN | 60 YEARS / ANS CERN

A selection of our activities …..

High Luminosity LHC and Availability

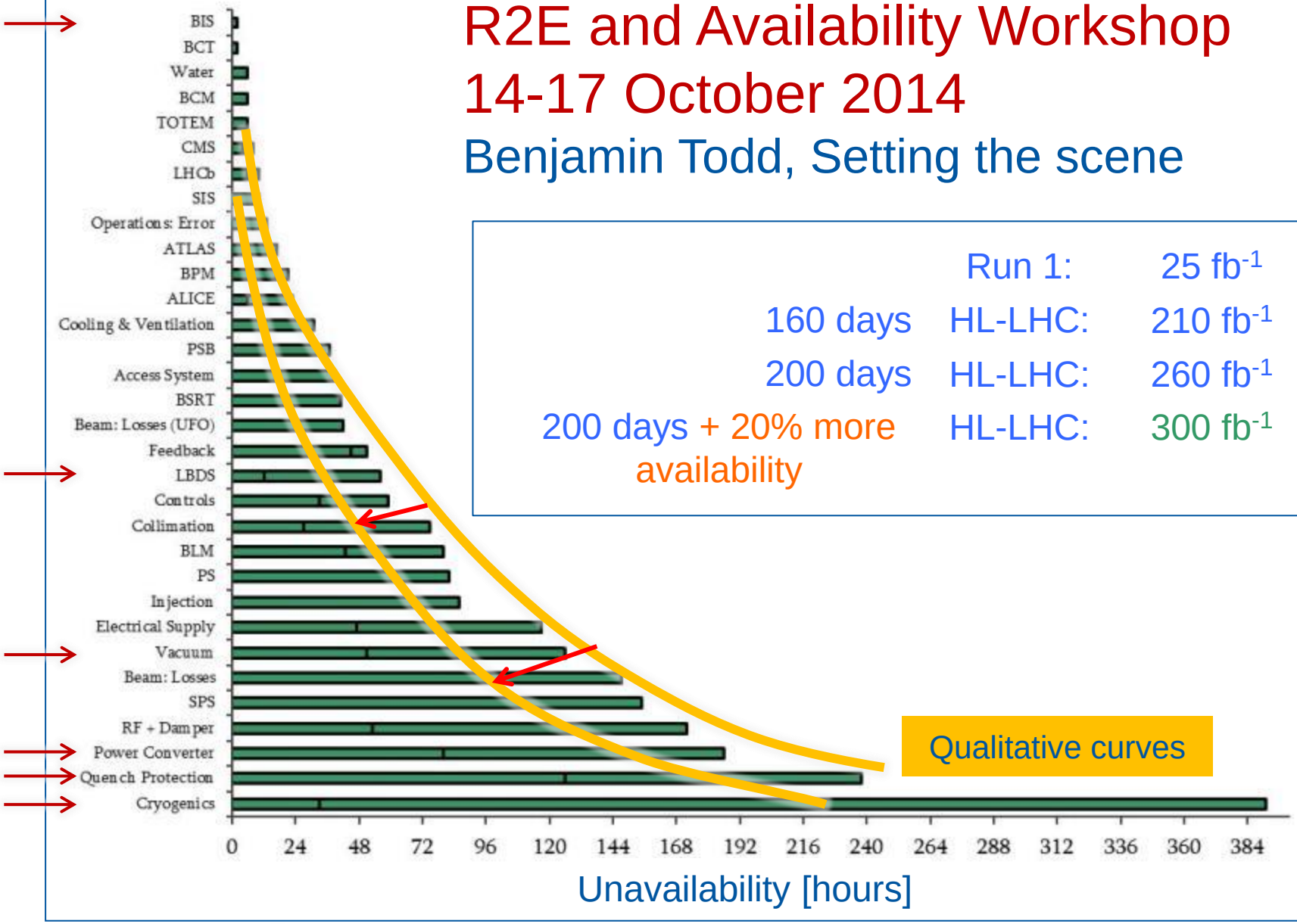
- Pile-up limit by LHC experiments limit maximum luminosity
- Levelling the luminosity to **$5x10^{34}$ $cm^{-2}s^{-1}$**
- **High availability required** to achieve 200–300 fb^{-1}/y (×10 today)

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:	25 fb^{-1}
160 days	HL-LHC:	210 fb^{-1}
200 days	HL-LHC:	260 fb^{-1}
200 days + 20% more availability	HL-LHC:	300 fb^{-1}

Conclusions (MPE)

LMC 3/12/2014

- **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)

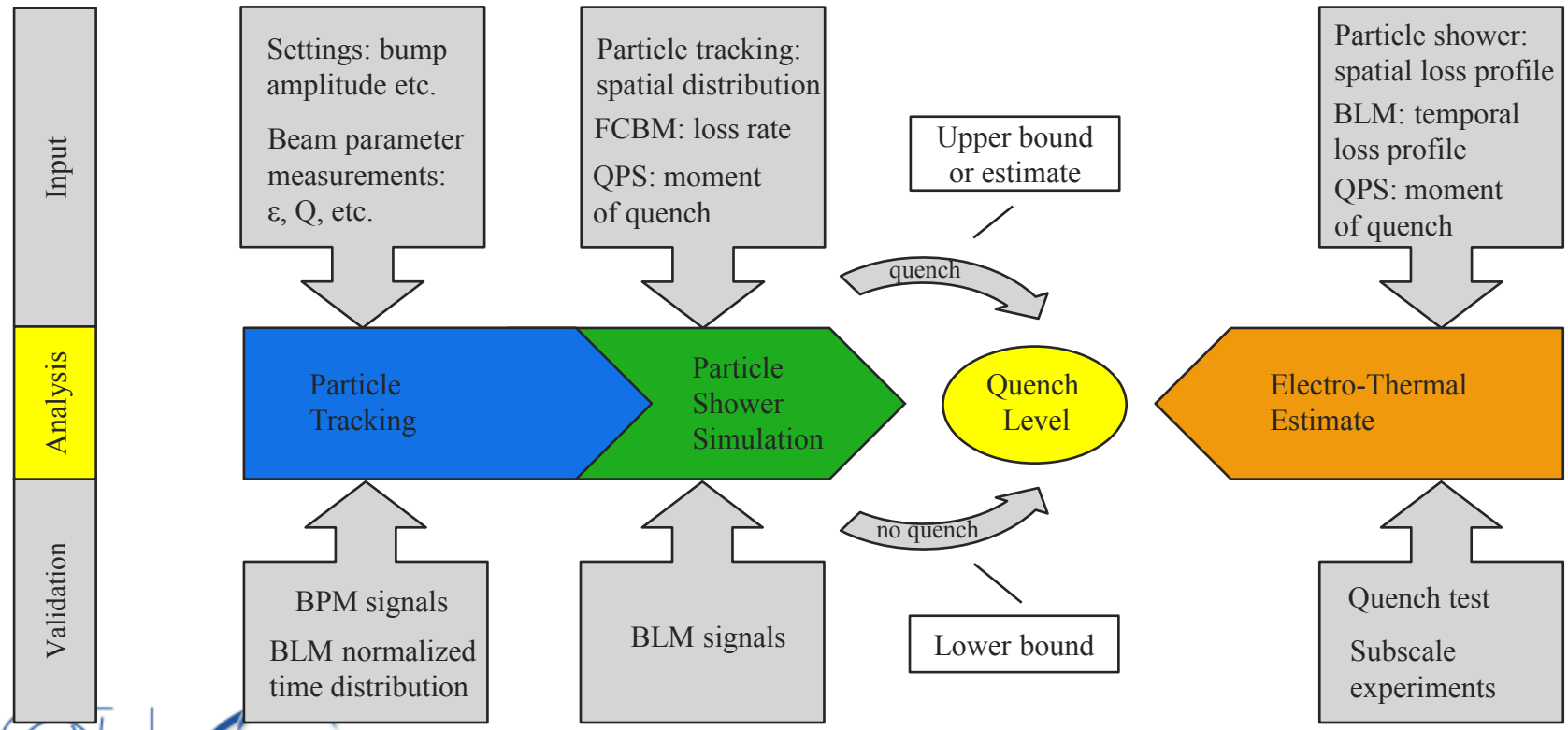
Beam losses and magnet quenches

Goal: Optimal setting of BLM thresholds, among others.

Understanding a beam-loss event is iterative.

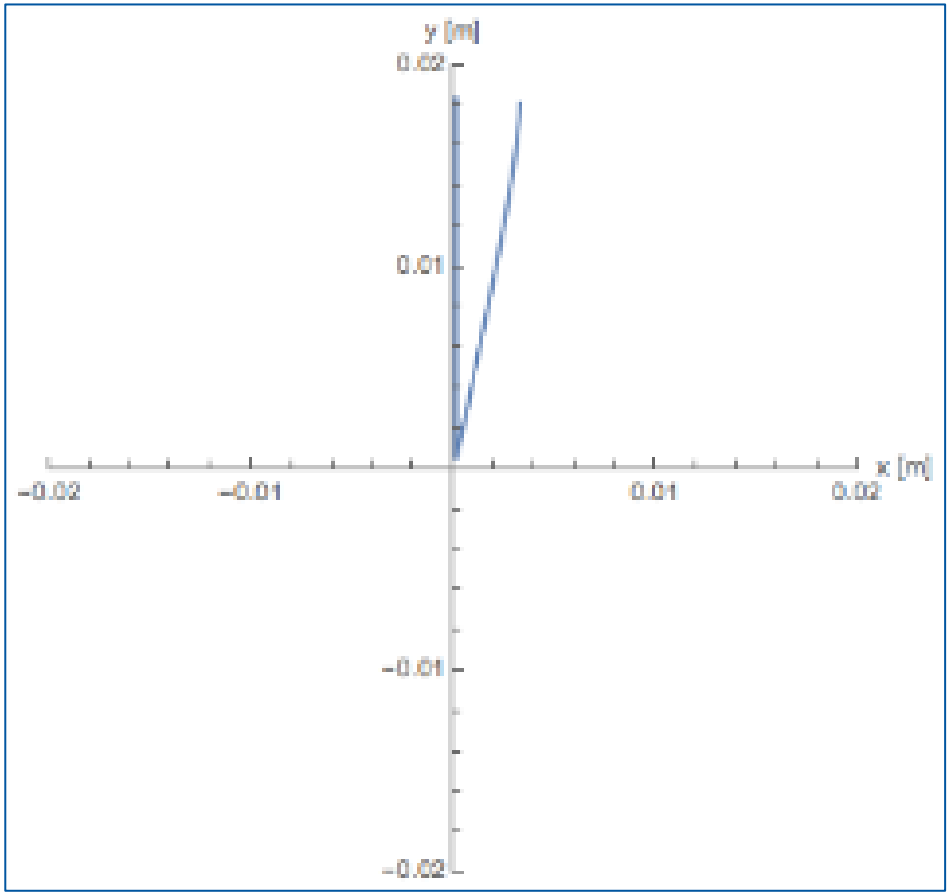
Requires deeper understanding of loss mechanisms, analysis tools, and quench levels.

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.Zimmermanns work).
- The models are validated with Run 1 data.
- First results very promising.

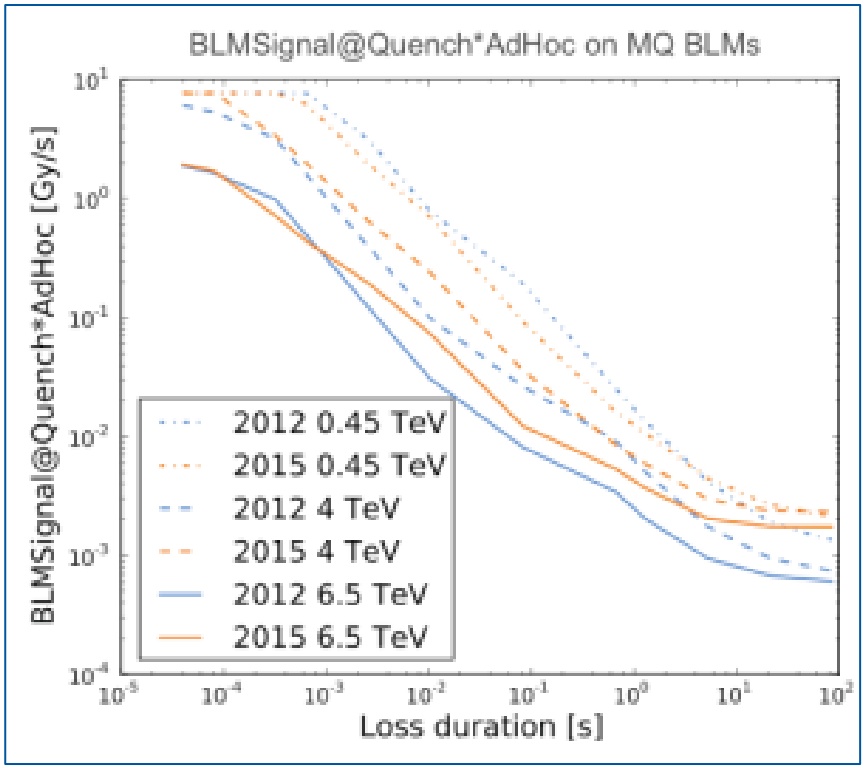


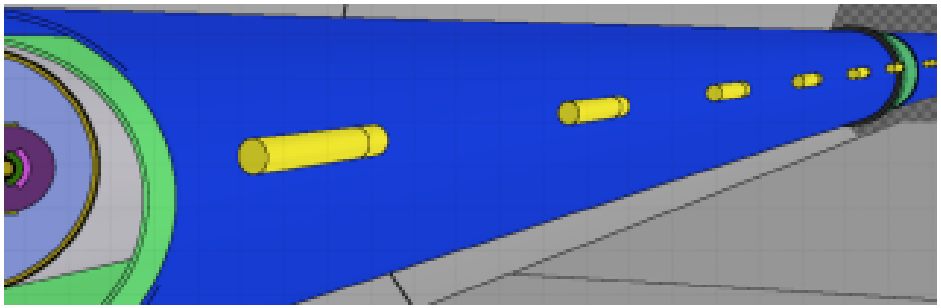
Macro-particle trajectory

B.Auchmann, S.Rowan

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.





FLUKA model of DS dipole

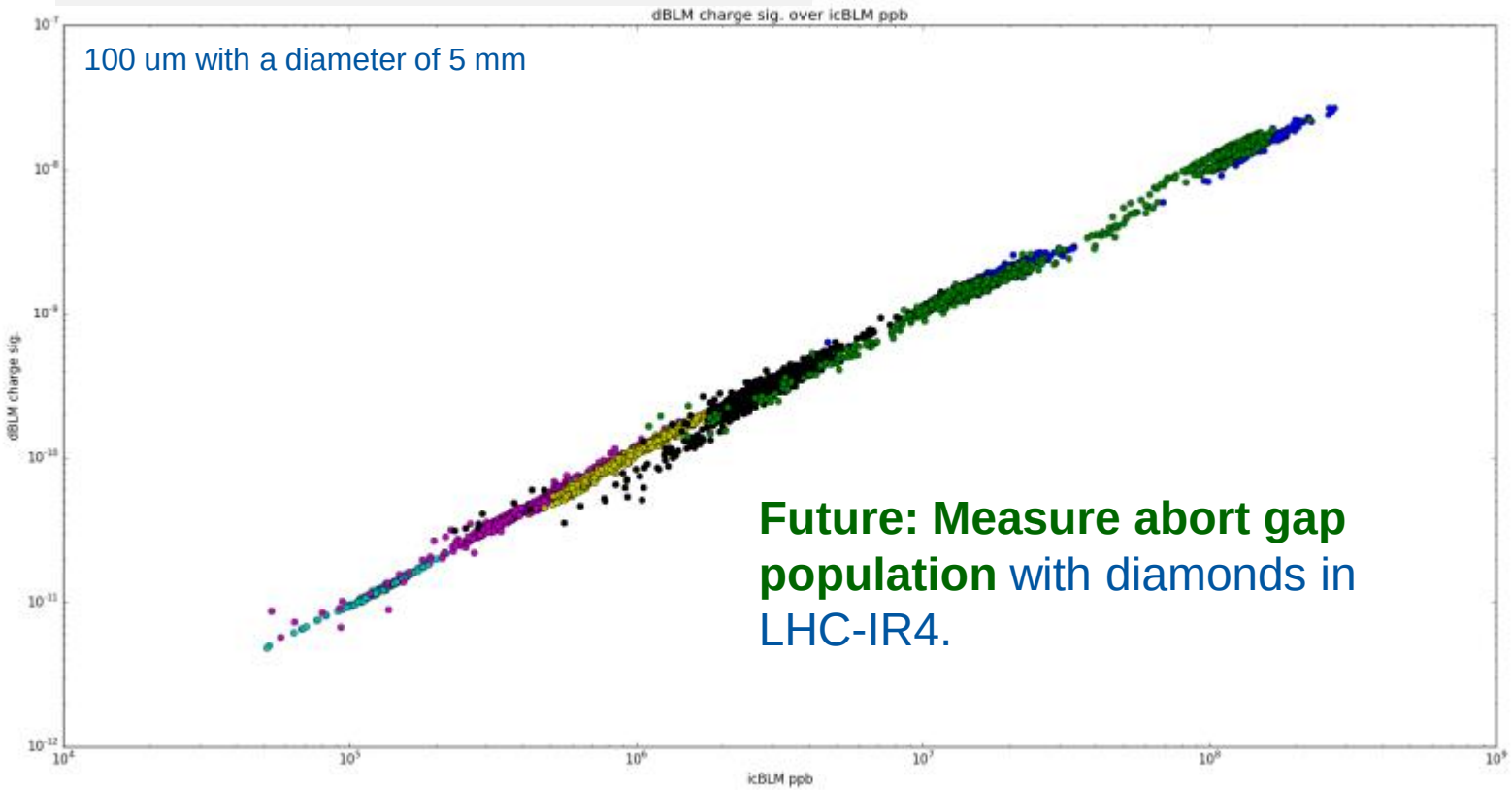
Collaboration with BI: Characterisation of diamond detectors and their use at CERN

- 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

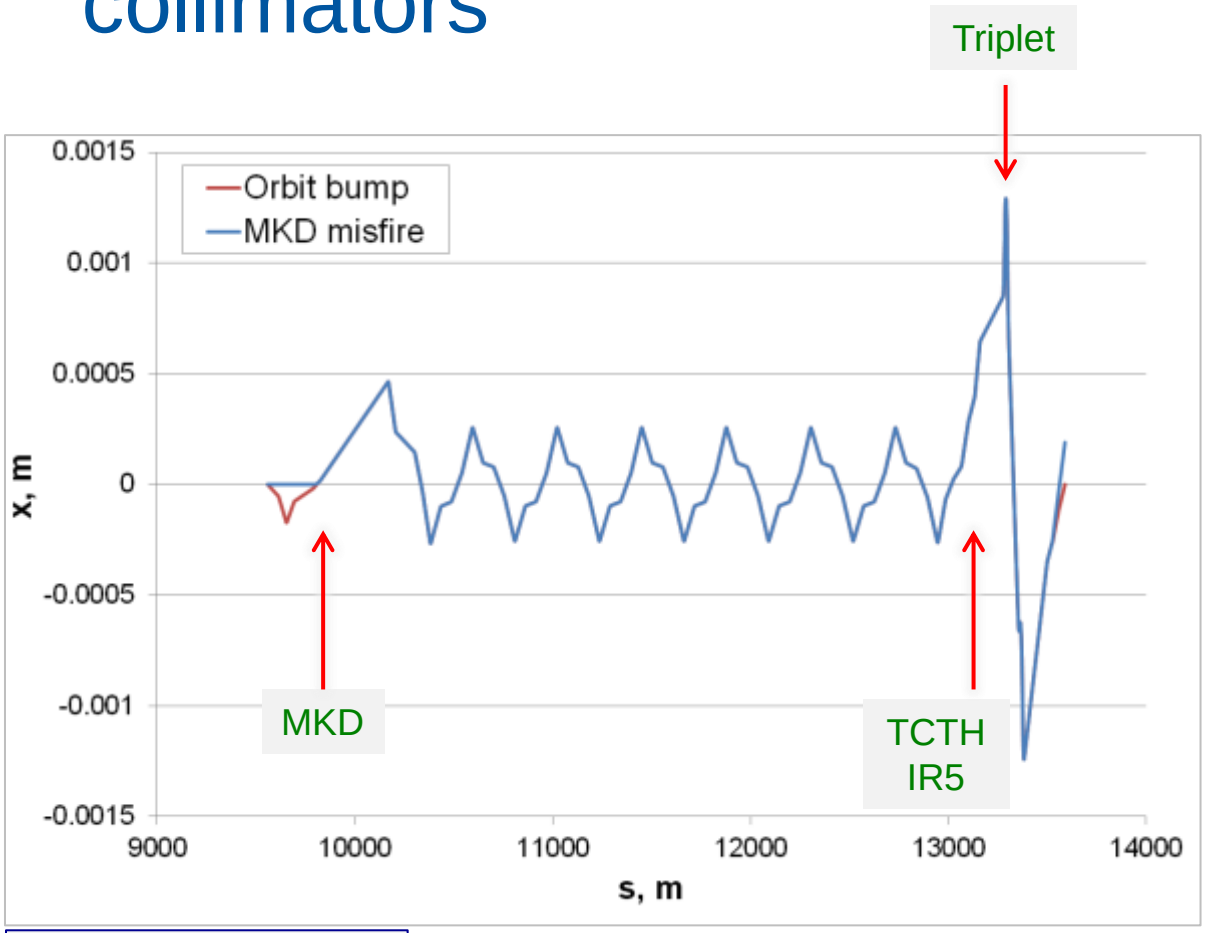
Response of the diamond detector



10^4 10^5 10^6 10^7 10^8 10^9

Electrons per pulse through diamond detector

Verification of protection margins for collimators



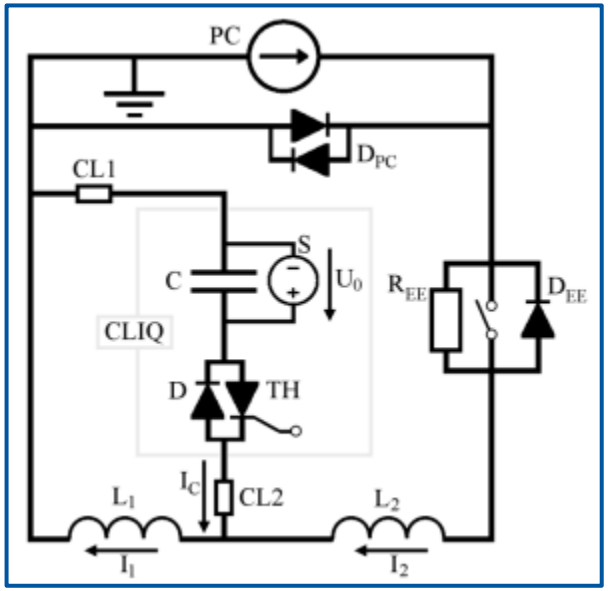
V.Chetverkova

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.

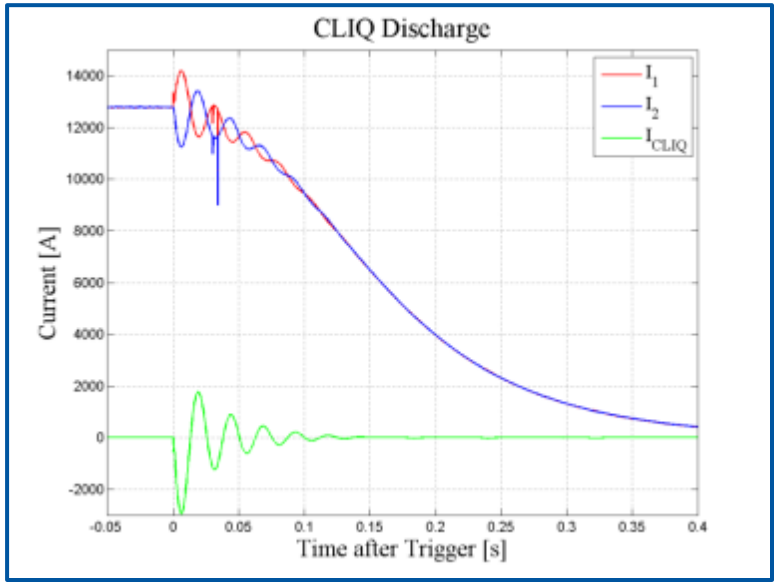
IP6 (MKD/TCDQ) → IP5 (TCT/triplet) with closed orbit bump – Preparation for ATS optics

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**.

Current Change → Magnetic Field Change → Coupling-Losses (Heat) → Tempe-rature Rise → QUENCH

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

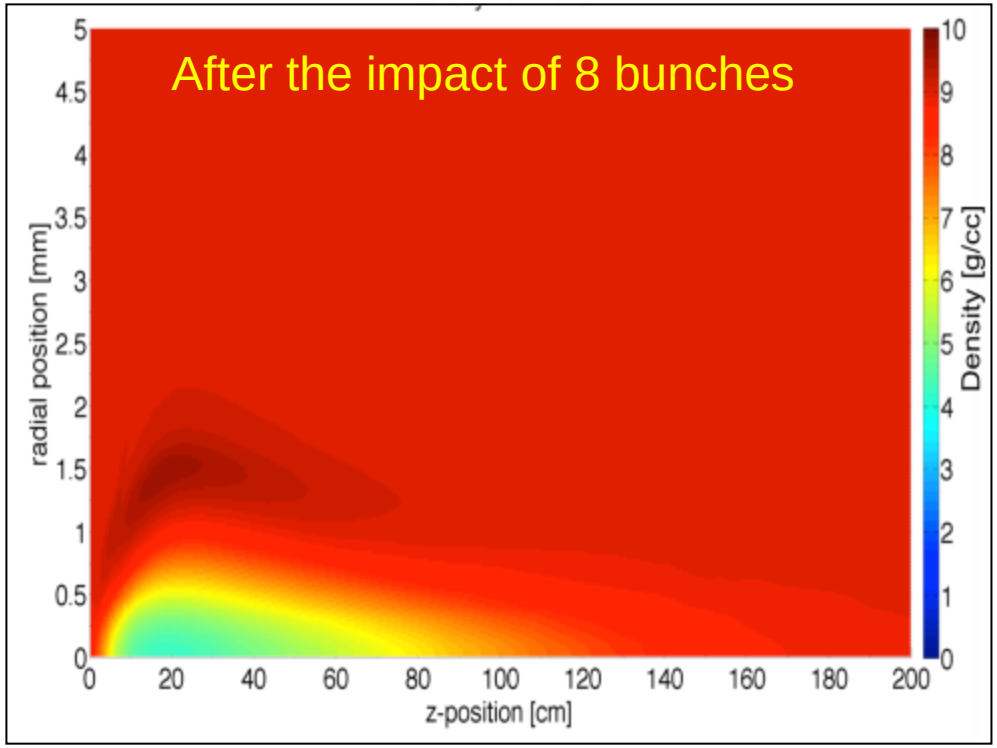
Tested on the **HQ02** quadrupole magnet (Nb_3Sn, 1 m long)
-45% quench load
Entire coil quenched in <10 ms!

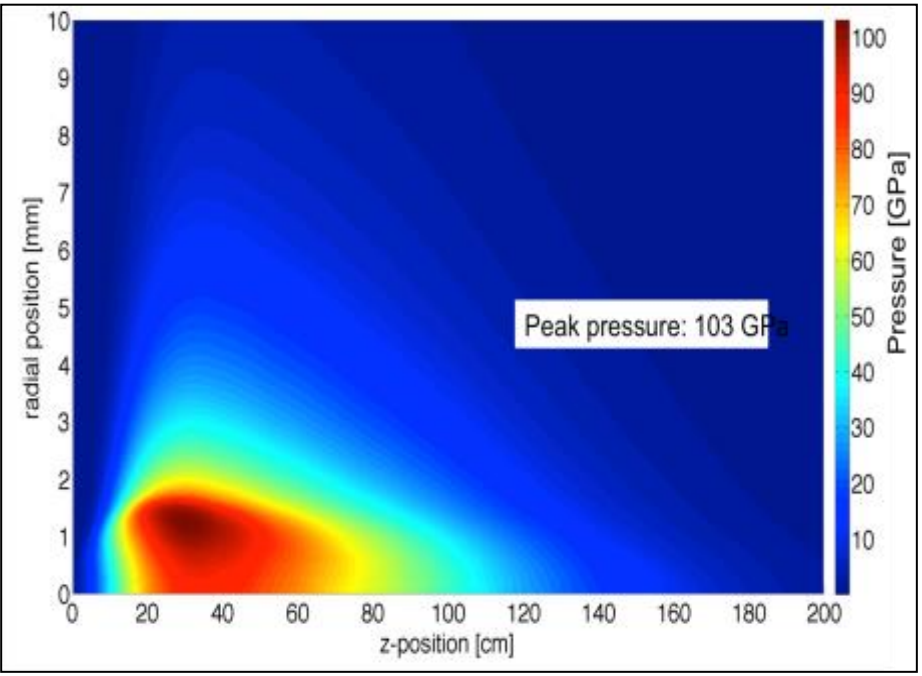
EU Patent EP13174323.9, June 2013.
E. Ravaioli et al., MT23, 2013.
E. Ravaioli et al., EUCAS11, 2013.
E. Ravaioli et al., CHATS-AS, 2013.
E. Ravaioli et al., Cryogenics, 2014.
E. Ravaioli et al., SuST, 2014.

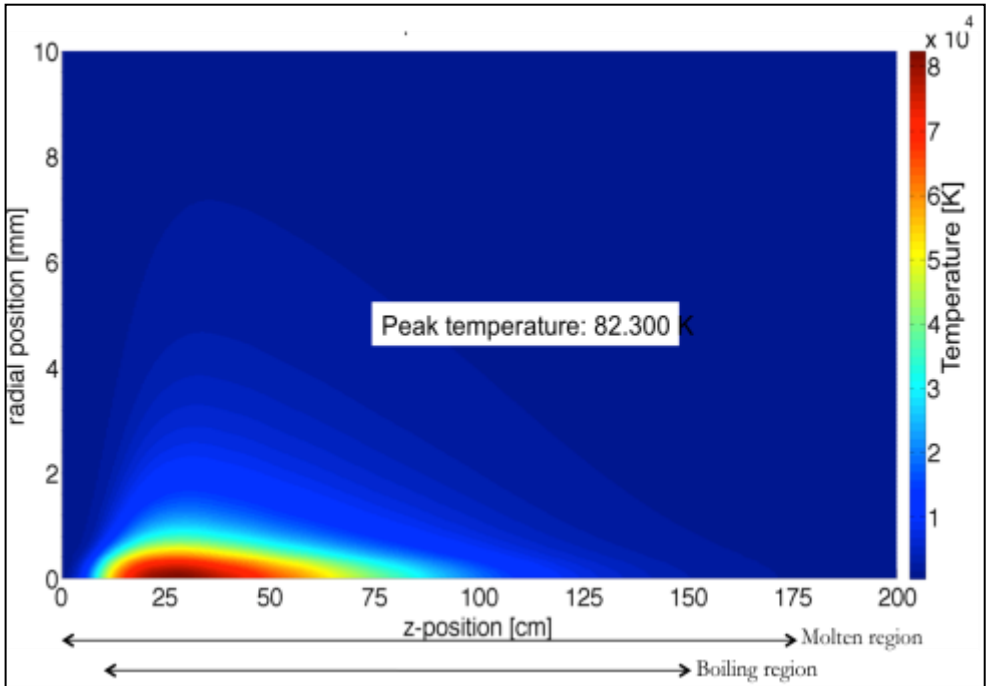
E. Ravaioli, A. Verweij

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

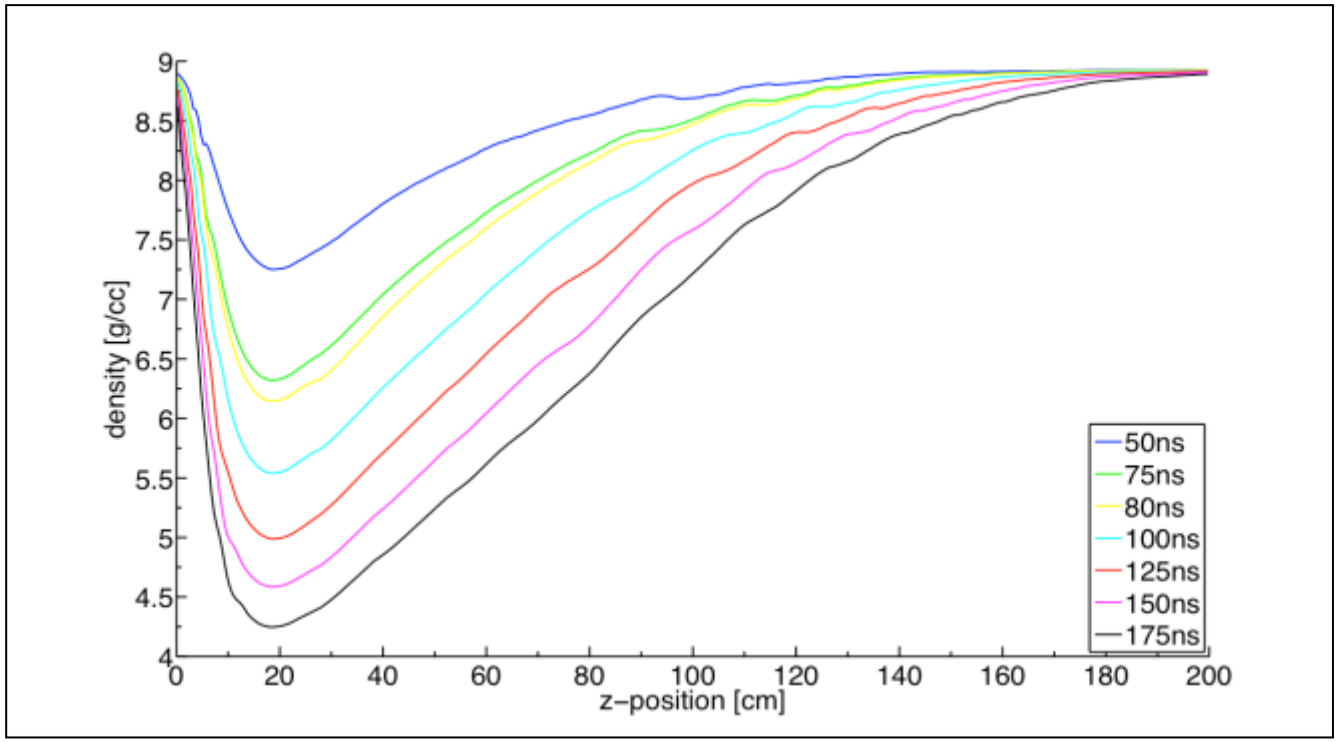






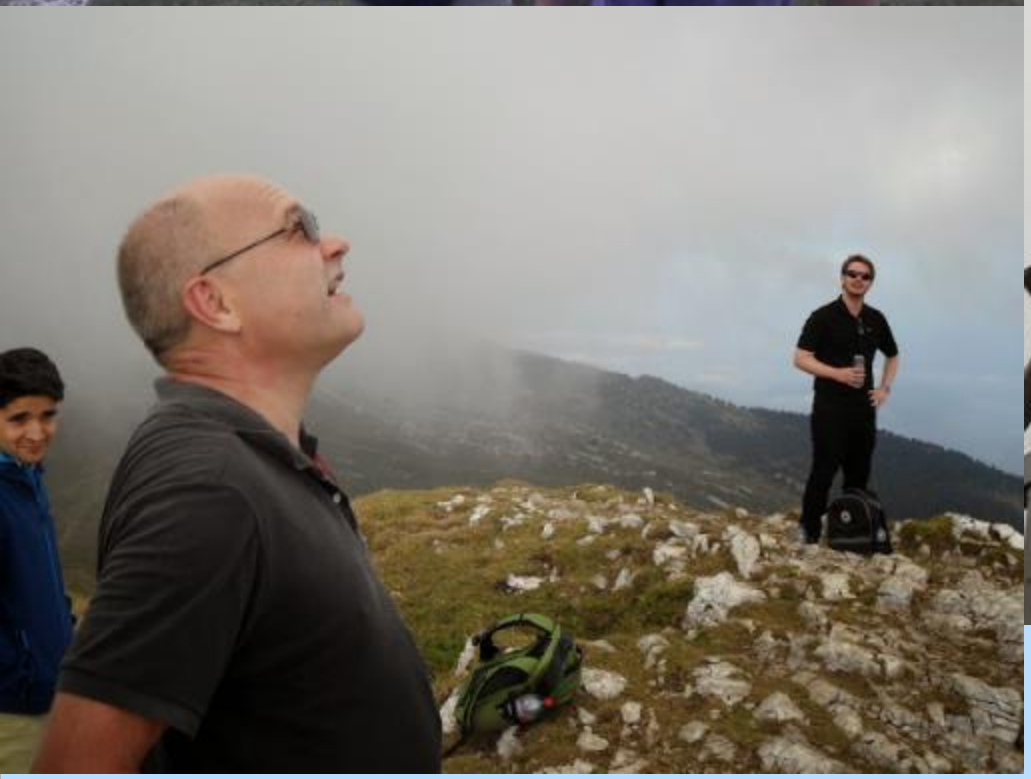
FCC accidental beam impact on equipment

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



Projects and studies

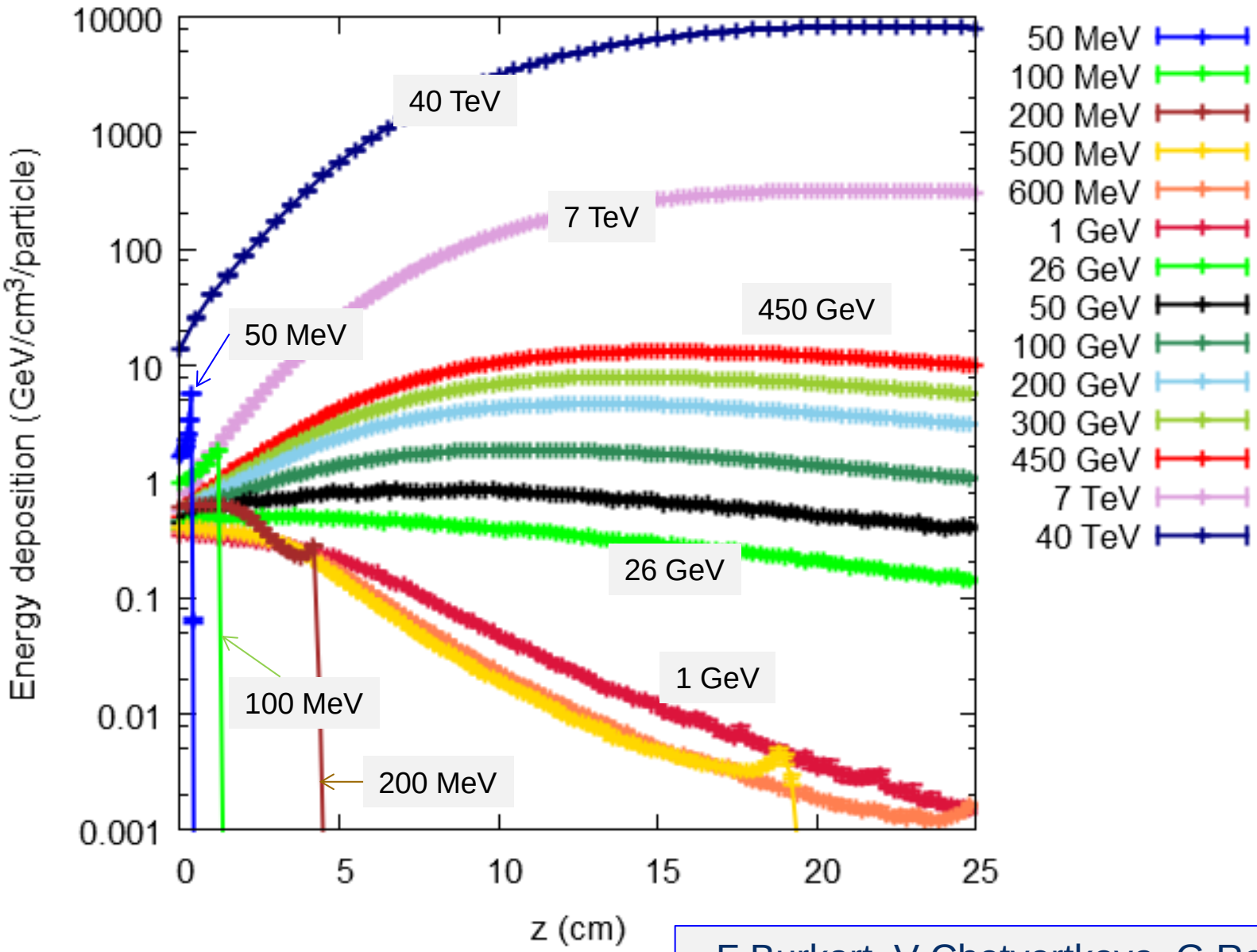
- HL-LHC: Machine protection (work package 7 for HL-LHC)
  - Availability, damage tests and other activities
- FCC
  - Availability: with teams from Finland (Tampere) and collaborators from Stuttgart: **LHC to be used as reference**
- CLIC: Machine protection, risk analysis and proposals for machine protection system, studies of availability



Thanks to all the Team

spare

Proton energy deposition for different energies



F.Burkart ,V.Chetvertkova, G.Rosella

Workshop on Beam-Induced Quenches

September 15-16 at CERN.

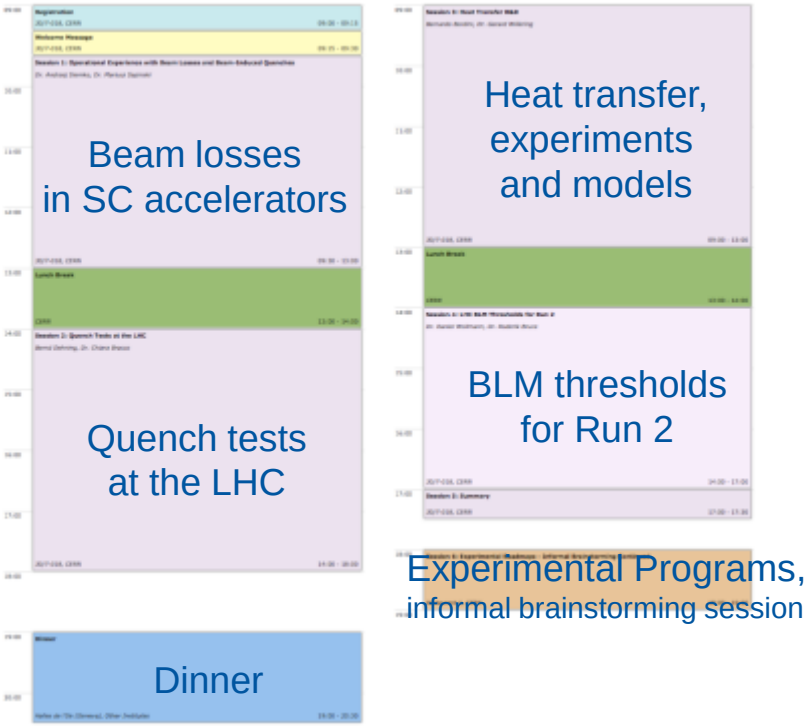
50 participants from BNL, CEA, CERN, GSI, KEK.

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

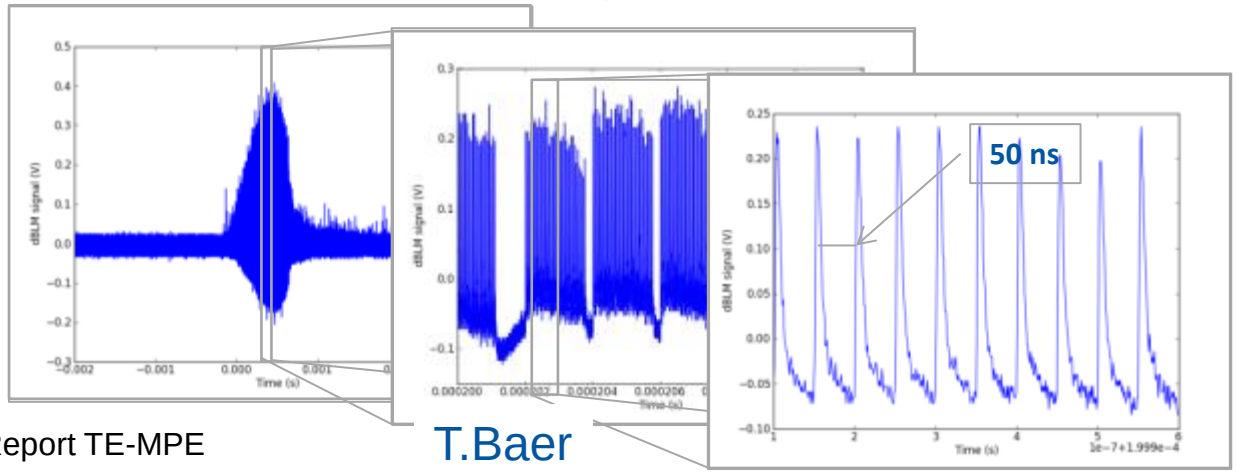


http://indico.cern.ch/events/BIQ2014

Presentation proposed within MSC seminars

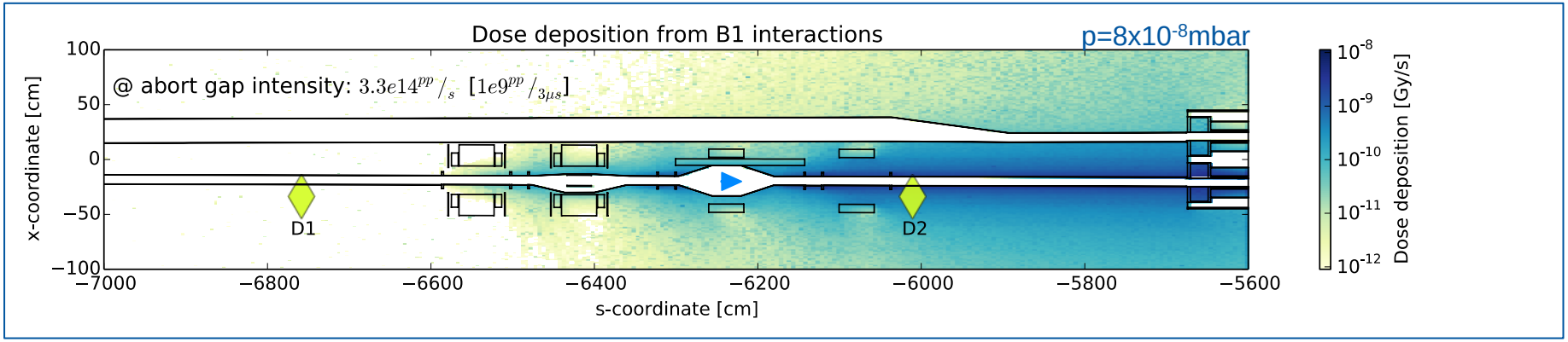
Applications of diamond detectors in LHC and elsewhere for machine protection

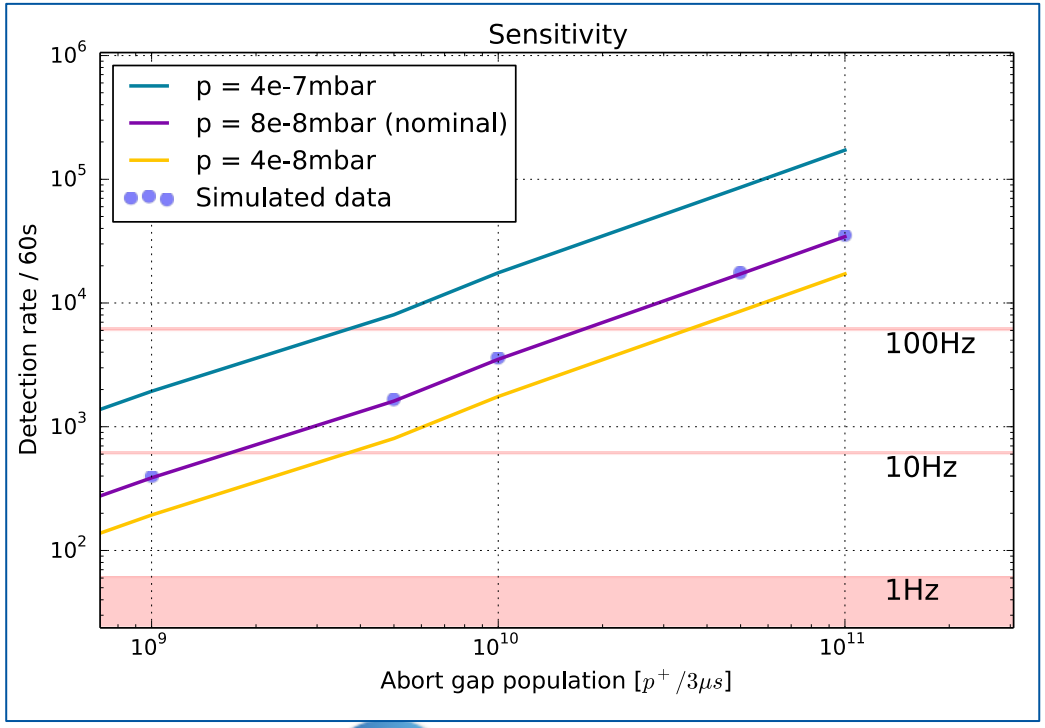
1. **Calculating abort gap population** by measuring shower particles from beam gas interactions in the BGI in IR4.
2. **Identification of loss pattern** during beam dump measuring scattered particles close to the TCDQ.
3. Measuring of **IP2/IP8 injection losses**.
4. Measuring **global losses in IP7**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



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.

C. Buehl Soerensen, O. Stein, D. Wollmann

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