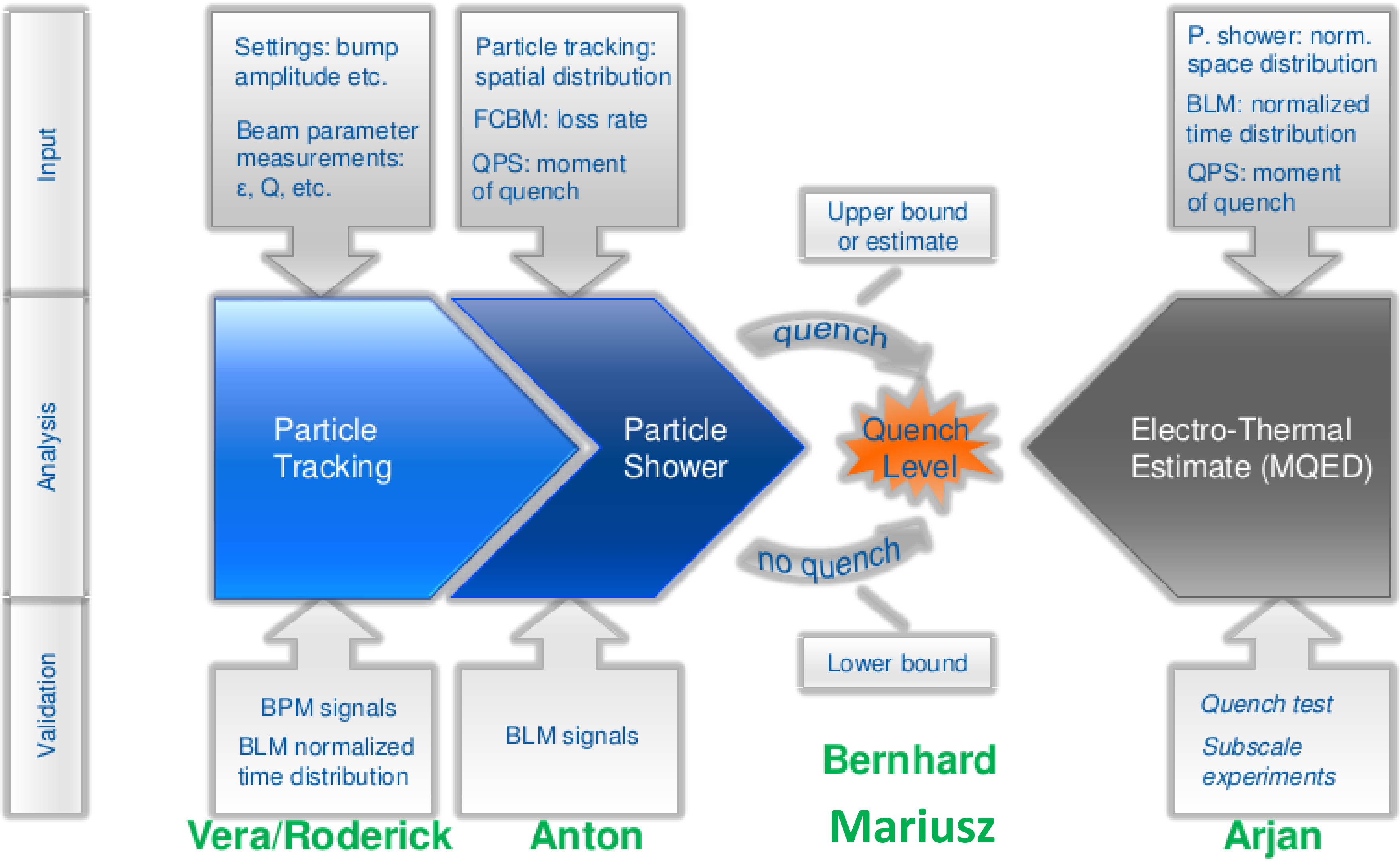
Beam Induced Quench
Session 2: quench test at LHC

B. Dehning, C. Bracco

Quench Test Analysis

What is the energy deposition in the coil at the moment of quench?



Setup of LHC Quench Experiments
M. Sapinski, BLM team CERN

- Note 44+GEANT+FLUKA simulations used as reference before LHC startup to set up BLM thresholds
- Quench tests 2010/2011:
  - **Orbit bumps**: **steady state losses, Quenched**
  - **Wire scanner: intermediate loss,** Q**uenched**!
  - **Collimation induced quench tests**: **steady state losses**, change tune across resonance and losses at collimators. **0.5 MW power on primary collimators for 1s, no quench either with protons or ions**
- 2013 tests in preparation to operation at **6.5 TeV**.
  - **Steady state losses** at collimation: beam power to **1 MW** and longer losses , **No quench**!
  - **Orbit bump** (steady state with ADT): **20 s steady state losses** on magnet, Q**uenched**
  - **Fast losses at injection: quench at 2500 A**. **Quenched**
- Conclusions:
  - Well know technique and good tools/results
  - UFO still far from desirable results
  - ADT (feedback kicker magnet) extremely useful during 2013 tests!!

Particle Tracking for Orbit-Bump Quench Tests at LHC
Vera CHETVERTKOVA, MP team CERN

- Bump around quadrupole – aperture limit, either increase the bump or excite the beam (ADT and MKQ)
- **MADX thin lens tracking model** (1 cm resolution), **aperture as black absorber** (no scattering back).
- **Measured beam parameters** (energy, tune and beam profile), **orbit**, **MKQ and ADT strengths** (tuned wrt BPM readings to simulate the real measured orbit).
- Results:
  - **Small dependence** on **tune**, **emittance** and **bump amplitude** on **peak loss** for **ms** time scale losses
  - **Longitudinal distribution of lost particles** depends on **bump increase speed**, **diffusion speed** (ADT gain) and **aperture limitations**
  - Input to **FLUKA**: dependence on **spatial and angular distribution**!

Check contribution of sextupoles!

Particle-Tracking for Collimation Studies
Roderik Bruce, Collimation team CERN

- Collimation system designed to intercept 500 kW - 85 W/m leakage to cold magnets
- **4 TeV test quench test: 5.8 MJ at collimators and no quench** (not far from model according to latest calculations). Extrapolation to higher energy!
- Quench test:
  - Settings defined with SixTrack simulations (200 turns, 6e6 halo particles, no diffusion)➔ much more **relaxed settings** than in operation
  - Good agreement between simulated and measured loss maps (qualitatively non quantitatively: only primary protons tracked with SixTrack). After adding FLUKA simulations very good agreement!
- Ongoing work: **better halo modeling** (impact parameter) and **scattering routine**. Coupling between SixTrack and FLUKA (very important for ions!).
- Other codes explored: MERLIN and BDSIM (HighLumi)

Particle shower simulations for LHC quench tests: methodology, challenges and selected results
Anton Lechner, FLUKA team CERN

- Input: **impact distribution** of protons on chamber, collimators, wires. Output: **energy density map** in **SC coils** and/or **BLM signals** (per p+ lost, need **normalization**: measurements!). Comparison measured and simulated BLM, energy density and quench limit.
- Methodology: realistic 3D geometry models of different components ➔ **peak energy density and power density** for **fast and steady –state** regime respectively.
- BLM: model and **accurate positioning** (strong dependence of losses on BLM position!). Dose normalized by measured proton loss rate.
- Results:
  - Dependence on **orbit and emittance**. Good agreement (20%) with BLM.
  - WS test: issue: vibrations and wire sublimation ➔ empirical correction applied
  - Orbit bumps: 20% agreement with BLMs for ms test. Not so good agreement for steady-state losses, **very sensitive to details** like surface roughness.
  - Collimation test at 4 TeV: 500-600 m machine to be modeled! Very good agreement with BLM measurement only for first test ➔ **strong dependency on surface roughness**. Studies ongoing to improve geometry.
- Summary and conclusions:
  - good opportunity for benchmarking with BLMs!
  - FLUKA only way to estimate energy deposition, no direct measurement is possible

Electro-thermal simulations of superconductors in case of beam losses
Arjan Werveij, MP team CERN

- 3D model **for Rutherford cables** available but a simplified **1D model** along a single strand is sufficient provided the **non uniformity** of several parameters (field, voids volume and contact, losses) along the strand is included.
- QP3 model: **He adjacent to each conductor section + insulating layer and He bath**. Different heat flows inside the cable and the heat from the beam losses are modeled. **Challenging** modeling the **heat flow** contribution from the **voids**
- Errors: local cable variations (fast losses), non-uniform current distribution, incorrect models (i.e. fishbone efficiency for steady-state), etc.. **Biggest uncertainties for intermediate loss duration phenomena** (unknown transient heat transfer in cable voids, in particular for spiky losses: time of quench?).

Loss duration	Adiabatic	4.5 K 1.9 K potted	1.9 K non-potted
Short	green	green	green
Intermediate	green	blue	red
Steady-state	green	blue	blue

green	Error <20%
blue	Error <50%
red	Error up to a factor 4

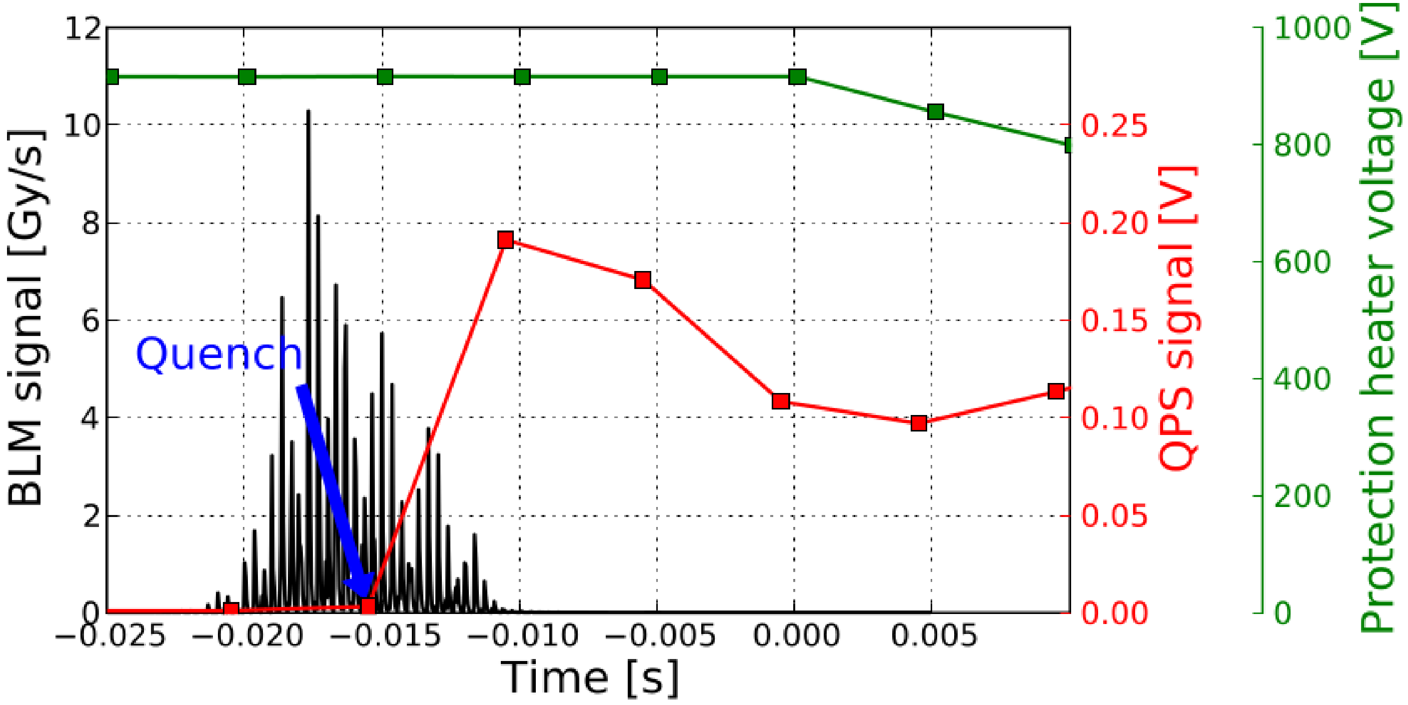
- BLM thresholds for ions shall be reviewed?
- Steady state: important effect of singularities. Can we really trust the model?
- Possible being fully independent from FLUKA?

Lessons Learnt from Quench Tests at the LHC
Bernhard Auchmann, MP team CERN

- Short-duration losses:
  - Large Kick: very good agreement between FLUKA and QP3 calculations
- Intermediate losses:
  - WS: several uncertainties, still agreement within error margin
  - Orbit bump: large uncertainty on moment of quench, good agreement with BLMs and FLUKA). QP3 calculations giving much lower values (x4 Still very dependent on assumptions and used parameters. Doubts on extrapolation to 6.5 TeV.
- Steady state losses:
  - Orbit bump (real steady state): good agreement including surface roughness and with/without fish-bone cooling. Scale model to different magnets (different insulation schemes).
- Future tests for intermediate losses:
  - Orbit bump tests in different magnets (ADT)

Lessons Learnt from Quench Tests at the LHC
Bernhard Auchmann, MP team CERN

- Better instrumentation , oscilloscope to catch moment of quench
- Warm dipole magnet current change to create orbit bump - few ms loss peak at collimation.



In principle we should aim to understand beam-induced quenches in all aspects to within 20% - though it may still take some time to get there.

Quench test simulation