Design Considerations for Button BPMs from DESY

Design for ESS and general aspects

Dirk Lipka, MDI, DESY Hamburg, Germany

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Outline

ESS Button BPM design

- 2014 with dissipated power and temperature distribution
- 2015 with dissipated power
- 2016 with requested larger button

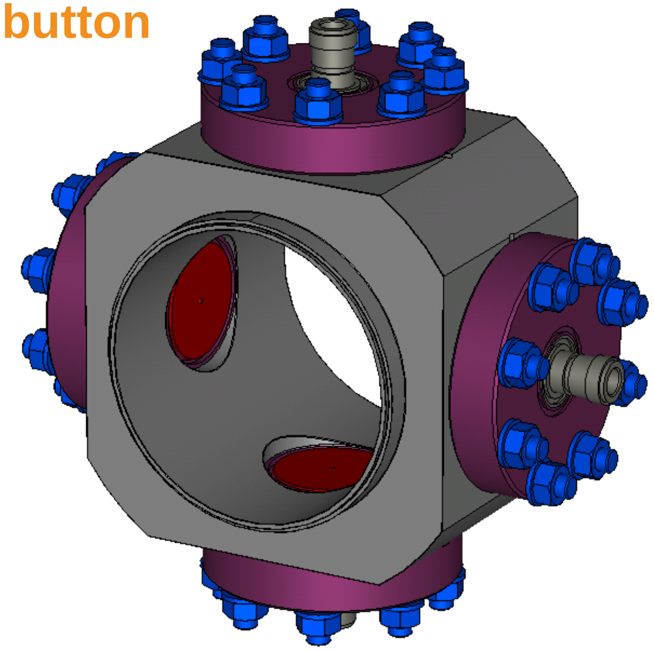
General remarks for heat dissipation

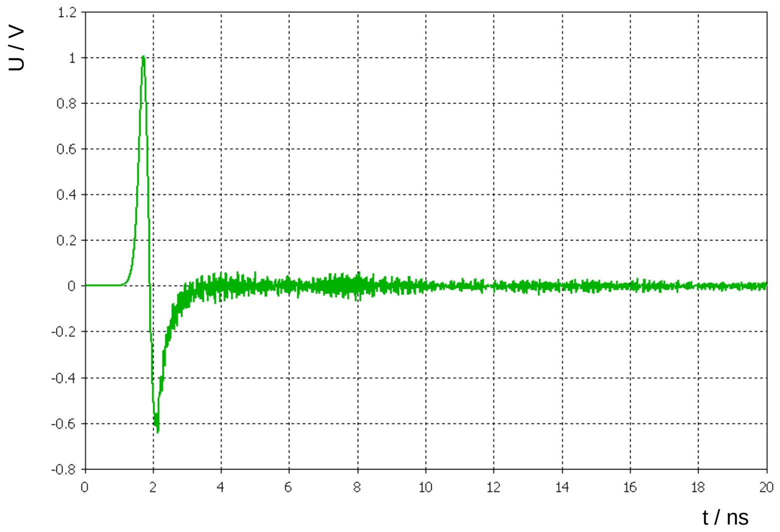
Development of feedthroughs

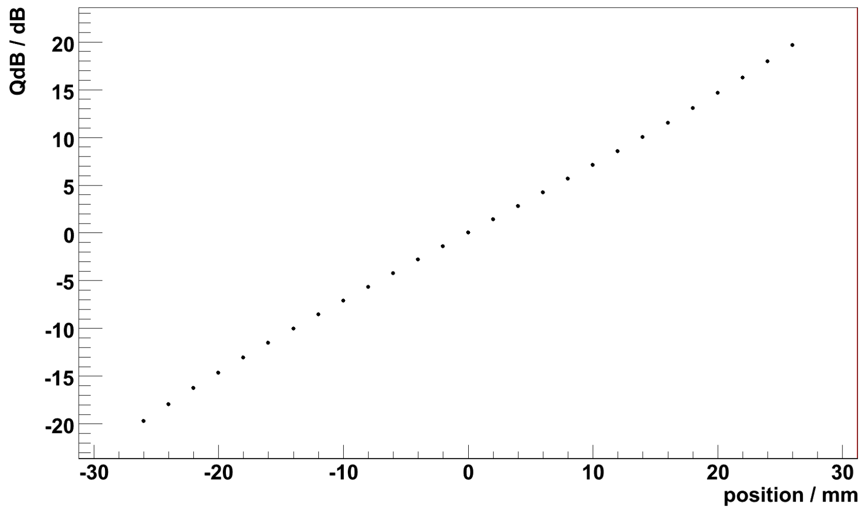
ESS Button BPM design in 2014

Within the process of optimizing the diameter of the button

- A suggestion was made according the shown design with N-connectors
- This was used to simulate signal generation with beam parameters provided by ESS
- Analysis of the signals in frequency domain and calculation of the sensitivity was prepared



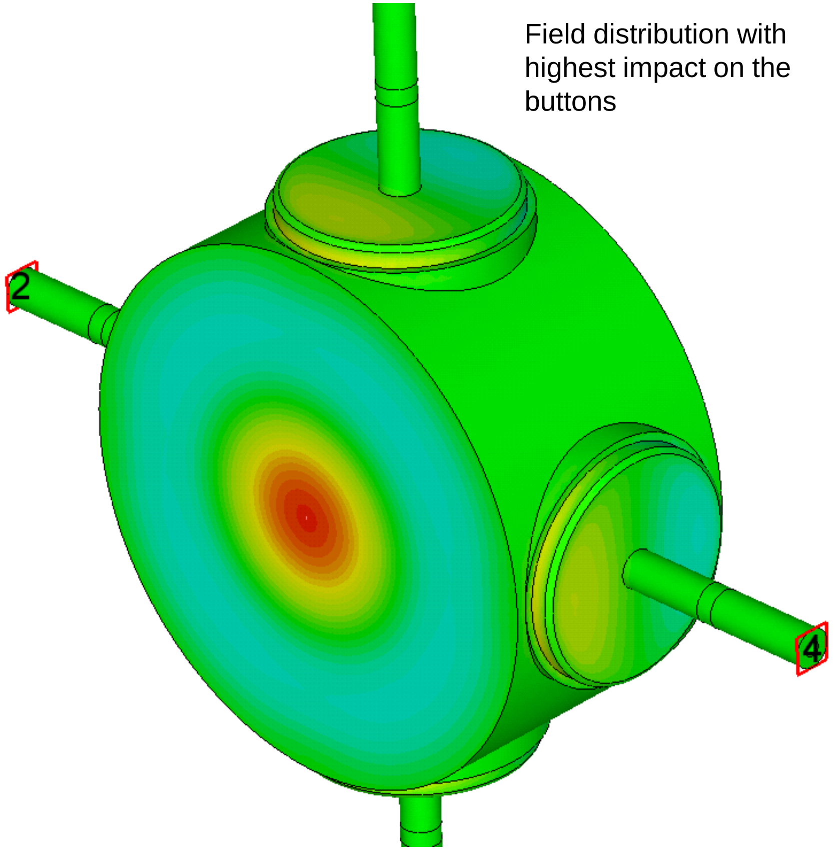




ESS Button BPM design in 2014

Dissipated power

- Simulated resonances power will be transferred to the buttons and could heat it, see figure on the right, this a mode at about 5 GHz with highest impact.
- The dissipated power is: $P = f_{Macropuls} t_{pulselength} f_{Bunchrepetition} Q^2 \, k_{loss}$, with $f_{Macropuls}$=14 Hz, $t_{pulselength}$=2.86 ms, $f_{Bunchrepetition}$= 352 MHz, Q = 178 pC.
- The loss factor k_{loss} are a result of wakefield simulation which considers the geometry and the bunch length. With the shortest bunch length the largest loss factor results to be 0.69 V/pC.
- This results in a maximum dissipated power of 0.307 W per BPM, temperature simulation next slide.



Field distribution with highest impact on the buttons

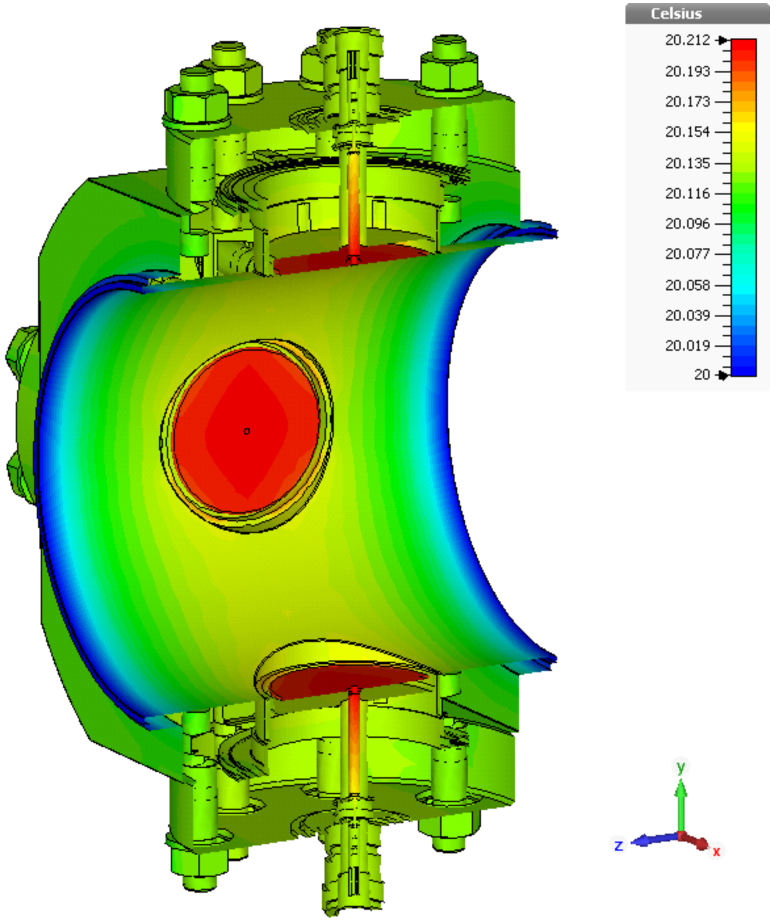
ESS Button BPM design in 2014

Temperature distribution with more detailed design

- Input of temperature simulation: field distribution from previous slide scaled to calculated max. dissipated power, thermal conductivity and radiation according material properties, without cooling only at the end of tube fixed temperature of 20°C: corresponds to worst configuration

- Result: max. temperature rise of 0.21K

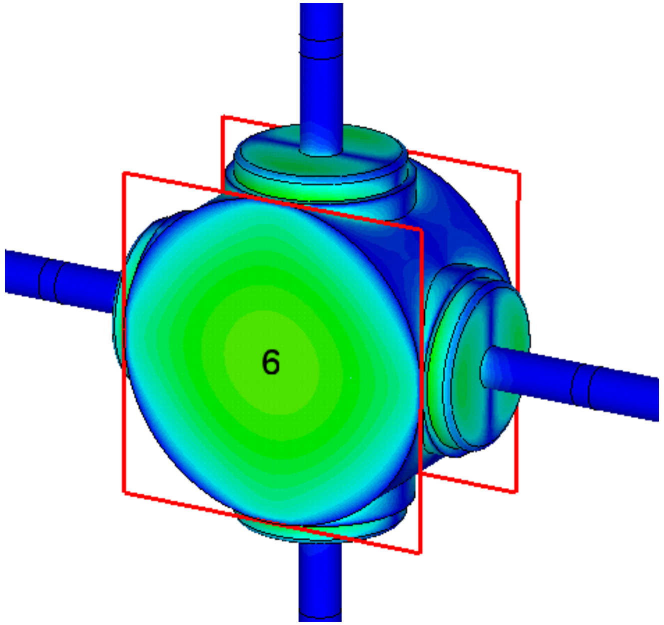
- Temperature increase is small because the duty factor $(f_{Macropuls} t_{pulselength})$ of ESS is small compared to a synchrotron. Therefore more attention has to be taken for accelerators with high duty factors.



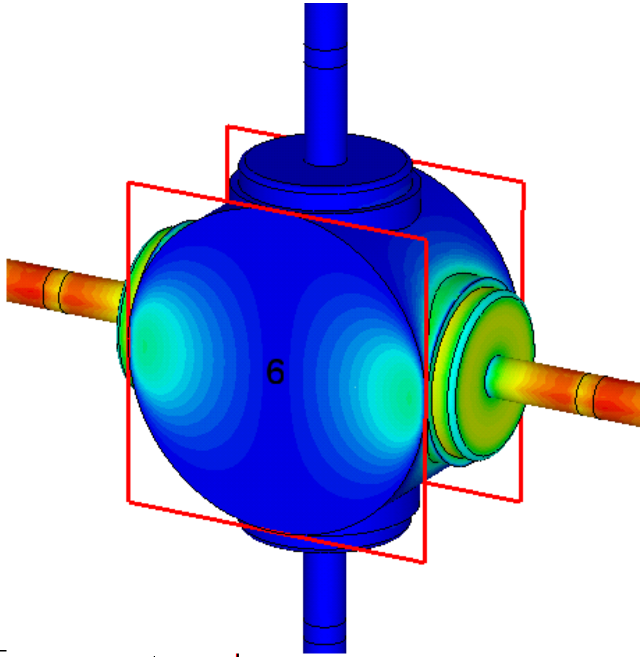
ESS Button BPM design in 2015

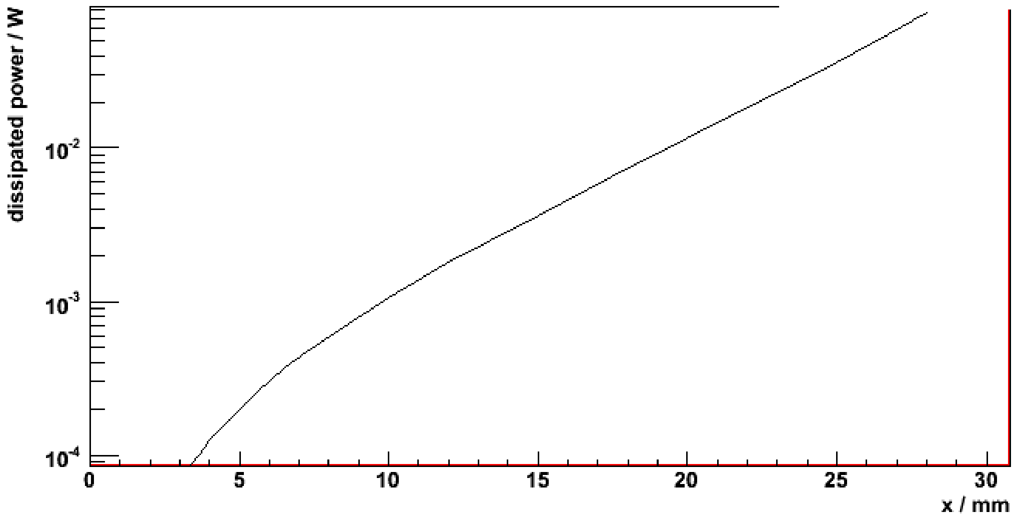
Dissipated power for second design

- The field distribution of the mode with highest dissipated power and symmetric mode is shown, k_{loss} = 549.2 V/nC results in 0.245 W at a frequency of 3.77 GHz (not harmonics of bunch repetition rate) and centered beam



- A dipole mode is produced too, see field distribution, at a frequency of 3.09 GHz (not harmonics of bunch repetition rate)



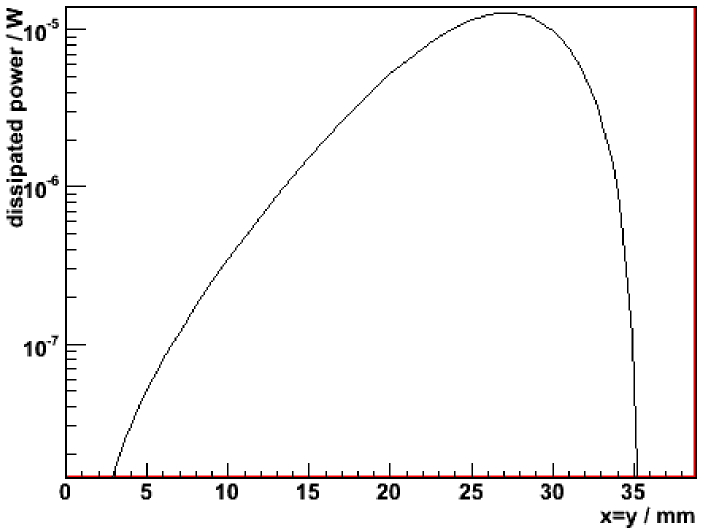


- The power is below 0.1 W per BPM for maximum offset

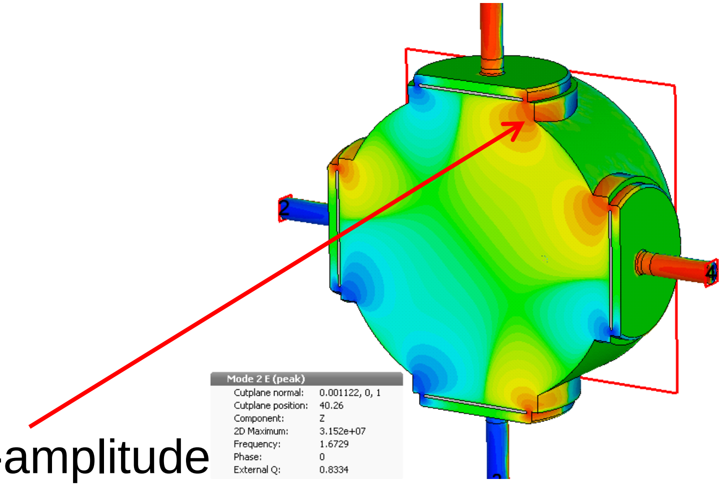
ESS Button BPM design in 2016

ESS requests to increase the button diameter

- Loaded resonance frequency f_L = 1.75 GHz, near to harmonics of f_L/352 MHz=4.97, unloaded resonance frequency is 1.67 GHz
- External quality factor = 0.833, results in a decay time of $\tau=Q/(\pi f_L)$=151.6 ps, bunch spacing of 2.84 ns is factor 19 larger, therefore this mode is already decayed when following bunch arrives monitor



- Beam through max. z-amplitude (near button corner) results in P_{max} = 5 mW
- Therefore maximum dissipated power still negligible



E-field z-component amplitude distribution

General remarks for heat dissipation

Until here only a linear accelerator was considered

- The low dissipated power is caused by a low duty factor of the beam current because of a linear accelerator
- Synchrotron and continuous wave operation of linear accelerators produce much higher duty factor
- Smaller beam pipes will cause a more dense induced power
- Smaller beam pipes cause smaller BPMs with relative similar requirements, therefore mechanical tolerances will decrease accordingly
- Shorter bunches induces higher frequencies with higher dissipated power
- Harmonic resonances to bunch repetition rates enhance dissipated power

Development of feedthroughs

Experience of the development for BPMs

Requirements on the feedthrough:

- (General requirements of the BPM system has to be provided by the accelerator coordinators)
- Signal transmission should be provided for each feedthrough with similar properties; variation of attenuation or reflection in the feedthrough should be avoided which will cause individual electrical offsets
- Reflection of signals in the feedthrough can influence resonances in BPM, especially for cavity BPMs where the external quality factor can be influenced
- Reflections in the feedthrough can increase the heat dissipation

Result

Design the button and BPM with the company together to maintain

- Similar feedthrough properties and
- Good transmission and
- Low reflections in a wide frequency range

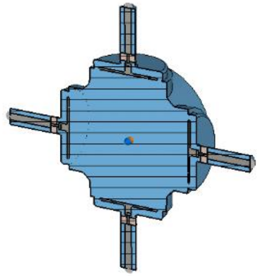
Questions to companies:

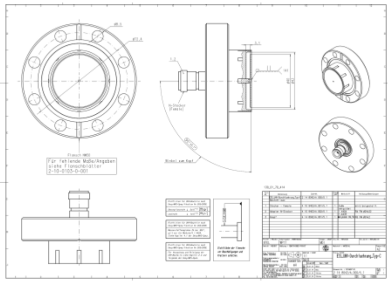
- Values of dielectric constant of feedthrough isolator (data sheet or measured) including tolerances
- Process of production which limits design

Development of feedthroughs

Experience of the development for BPMs

Requirements → Simulations and Design → Construction → Discussion with companies → Prototyping





→ Quality Controls → Maybe Redesign → Series production → Quality Controls →

Feedthroughs under test head on

-Vacuum checks
-Cryogenic checks
-Visual checks

Button BPM feedthrough transmission measurement with reference (Lab measurements)

-Vacuum checks
-Cryogenic checks
-Visual checks

Sorting → Ready for installation

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Development of feedthroughs

Quality Management efforts
Plan, Do, Check, Actions ...

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Quality steps on the feedthrough production:

- Descriptions of Items, incl. Change and Configurations-Management (Quality Management)
- Detailed technical drawings and 3D model-files (Quality assurance)
- Descriptions of production process (workflow and steps) and work place instructions (Quality assurance)
- Process and material Documentation (Quality assurance)
- Inspection of incoming parts (Quality control)
- Supplier Audits (Quality Management)
- Determination of quality properties (Quality assurance)
- Determination of rework (Quality Management)
- Implementation of tools for effectiveness of running processes (Quality Management)
- Testing incoming parts (Quality control)
- Documentation of quality checks (visual controls, vacuum test, cryogenic test, checking RF properties, shock tests...) (Quality assurance)
- Agreement of “Jour-fix” Dates (Quality control)
- Agreement of delivering schedule (Quality Management)
- Create a start-up meeting (Quality Management)

Development of feedthroughs

Ready parts waiting for shipment

Thanks a lot...any questions

Contact

DESY. Deutsches Elektronen-Synchrotron

www.desy.de

Dirk Lipka
Machine Diagnostics Instrumentation (MDI)
Dirk.Lipka@desy.de