

# Technical Review of Beam Position Button Design and Manufacture

Alun Morgan





- Manufacturing issues for buttons for the DDBA diamond upgrade.
- A full machine upgrade will require ~ 1000 buttons.
- One shot per machine.
- Many machine upgrades proposed for the next decade.
- There seemed to be a lack of manufacturers

The **aim** of the workshop was to bring together:

- representatives from the accelerator community
- potential button manufacturers,
- system integrators

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**PMB**  
ALCEN

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**CeramTec**  
THE CERAMIC EXPERTS

**allectra**  
A future with vacuum

 **Testbourne Ltd**  
Products for Research, Development & Industry

**NTG**

SCIENTIFIC INSTRUMENTS  
**EINEL**

 **BC-TECH AG**  
GLAS - METALL - DURCHFÜHRUNGEN

 **FMB Berlin**

**Ep3e**

  
**SOLCERA**  
Advanced Materials

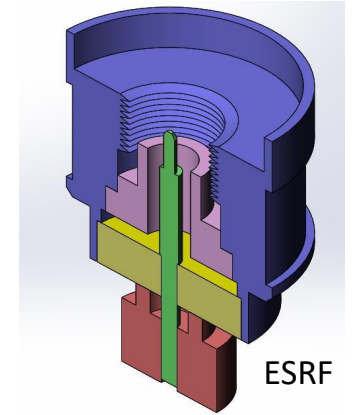
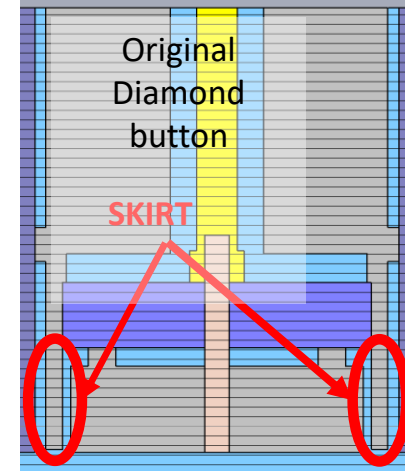
- Very successful
- manufacturers were able to be very open about their processes.
- Detailed discussions on the limitations of the various technologies.
- The facility representatives got a feel for the strengths of the various companies, and how each would approach the problem.
- Manufacturers realised that the customer demand in the next decade was not just 10s but 1000s of units.

- There is a general move away from having a ‘skirt’.

A skirt:

- Simplifies installation
- Mitigates against poor installation tolerances
- Causes additional wake loss and heating.

- **Non cylindrical button shapes** are being investigated.



## BPM design considerations

Smaller chamber dimension → **small button head** : Wakefield ↓ and signal ↓

Mitigate internal reflection → **Impedance matching within the button structure**

Mitigate signal inference between bunches. → **Low Permittivity insulator**

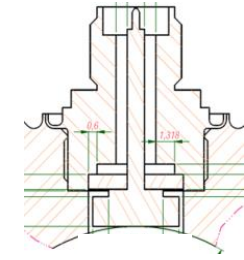
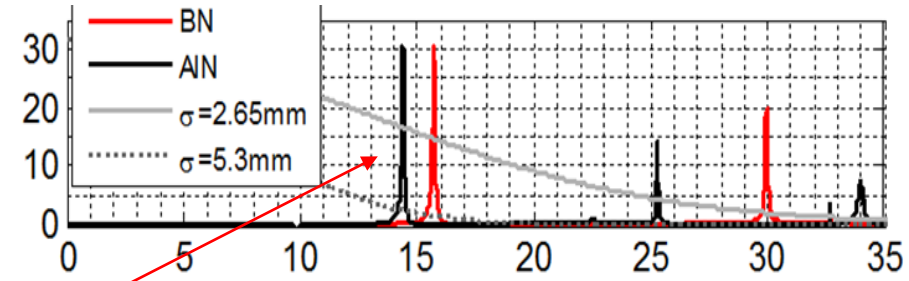
Trapped mode in gap → **Reduce the gap**

- 100μm **OK**
- 50μm **Challenging**
- 25μm **Not yet**



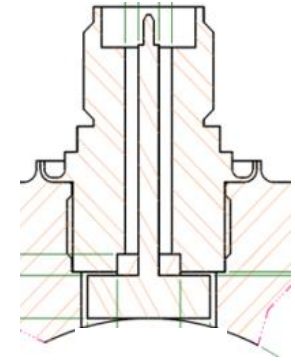
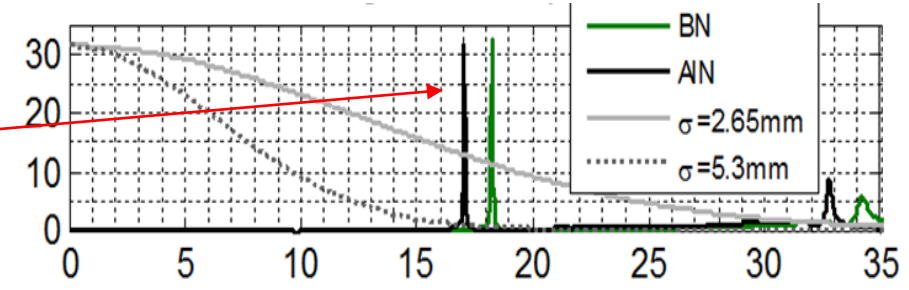
Moving the frequency higher reduces wake loss

Real Longitudinal impedance ( $\Omega$ )



### Step-Shaped BPM Button

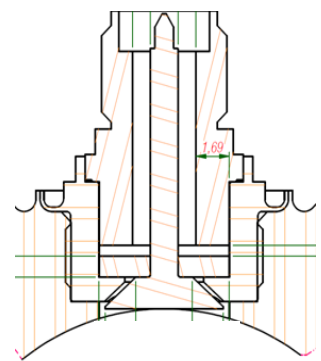
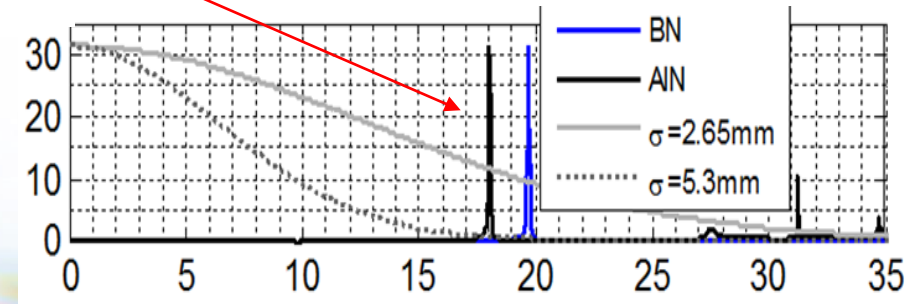
Based on the geometry style implemented at ALBA.



### Flat BPM Button

Reduced ceramics dimensions

← 37% wake loss reduction



### Bell-Shaped BPM Button

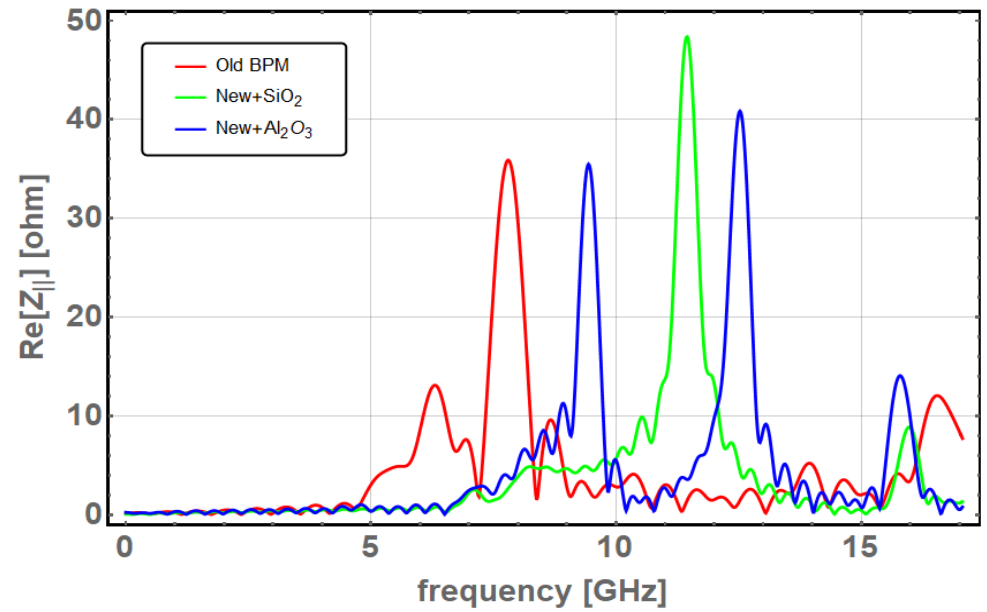
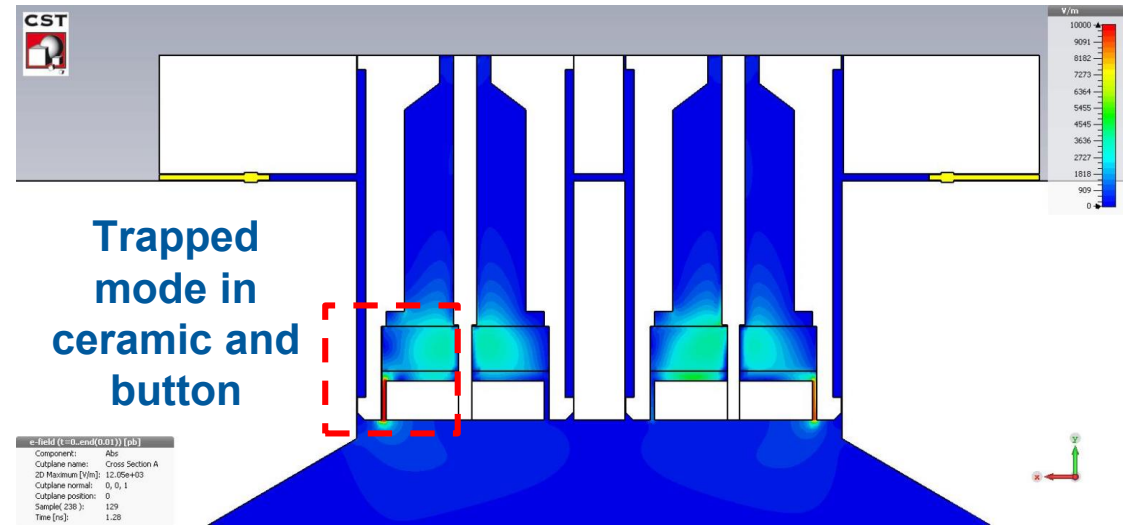
Conical profile shifts the HOMs to higher frequencies

← 50% wake loss reduction

Courtesy of Henrique de Oliveira Caiafa Duarte

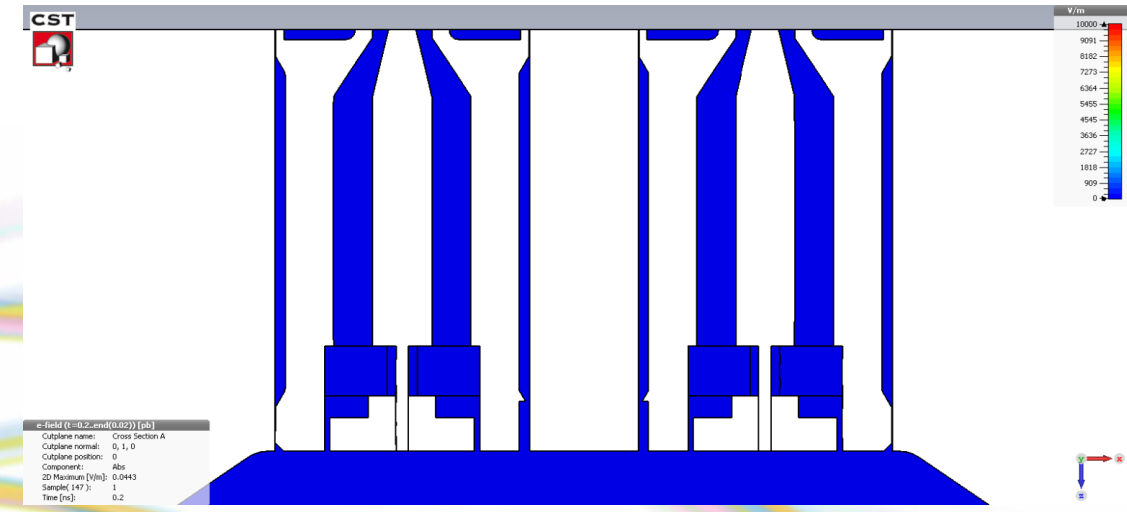


Original design

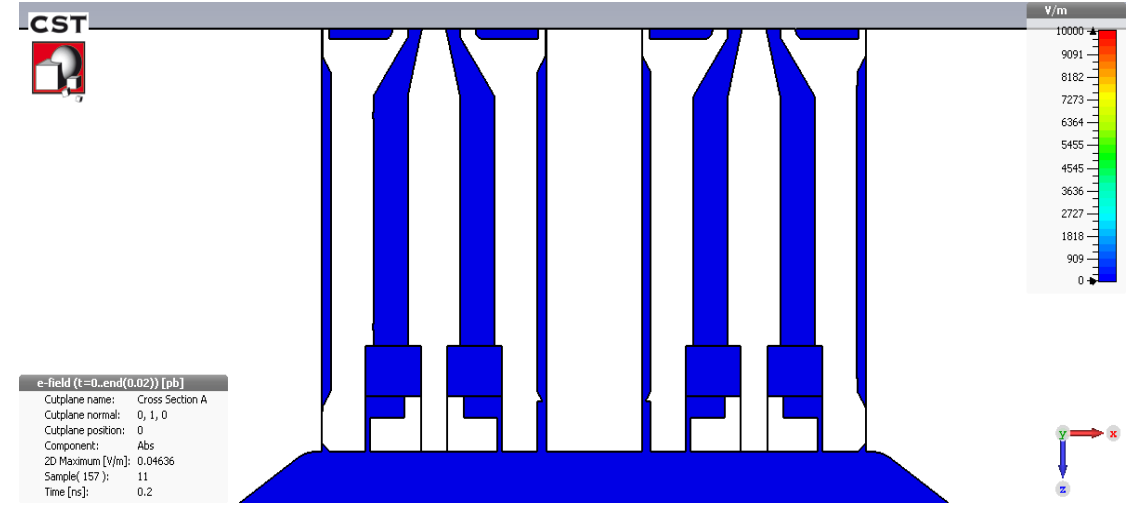


Courtesy of  
**A. Schälicke,**  
**J.-G. Hwang**

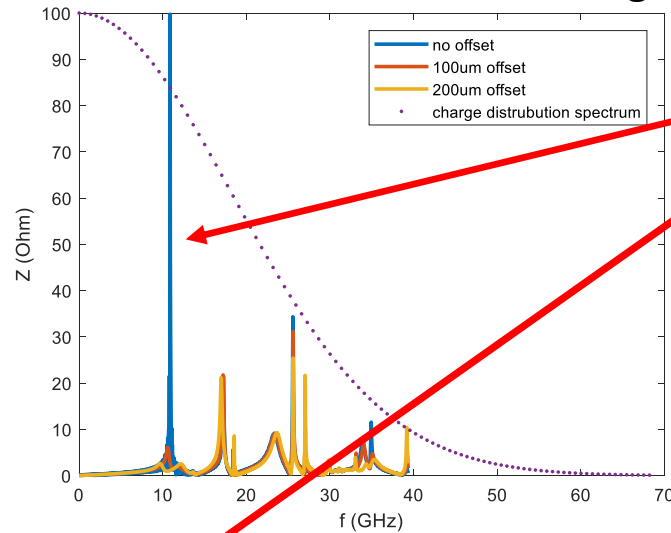
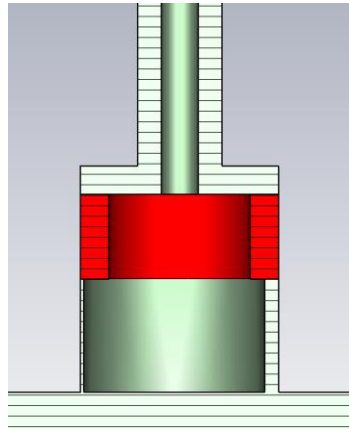
Aluminium Oxide (Al<sub>2</sub>O<sub>3</sub>)  $\epsilon_r = 9-9.8$



Fused silica (SiO<sub>2</sub>)  $\epsilon_r = 3.74$



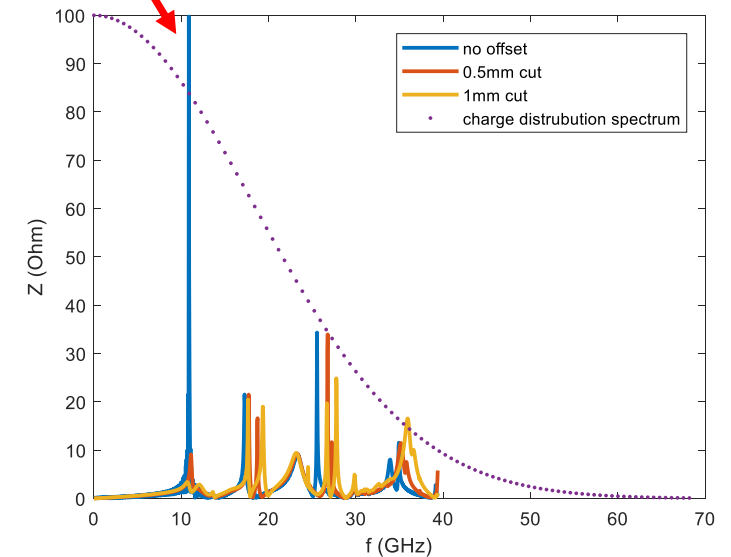
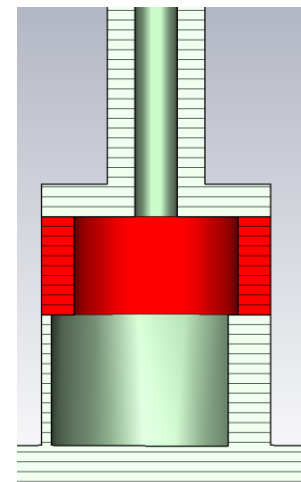
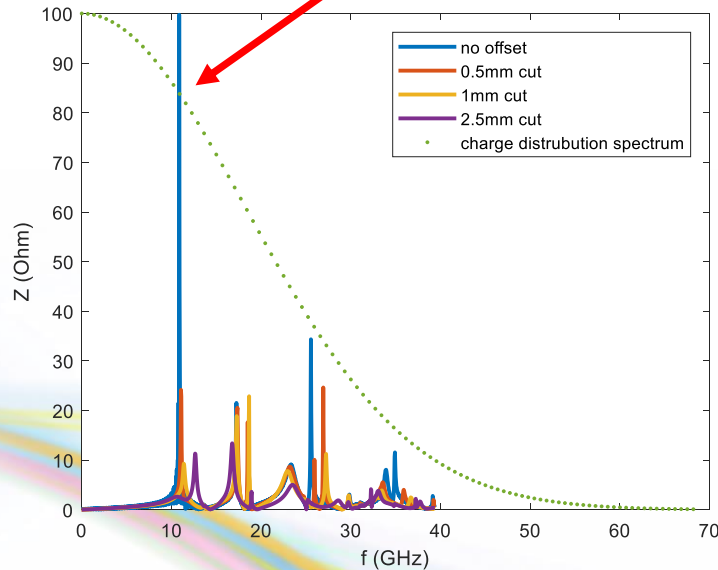
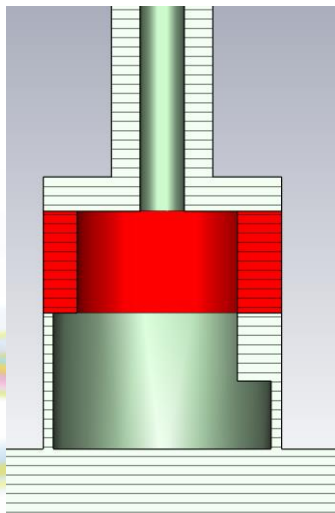
Button non centered in the vacuum chamber housing.



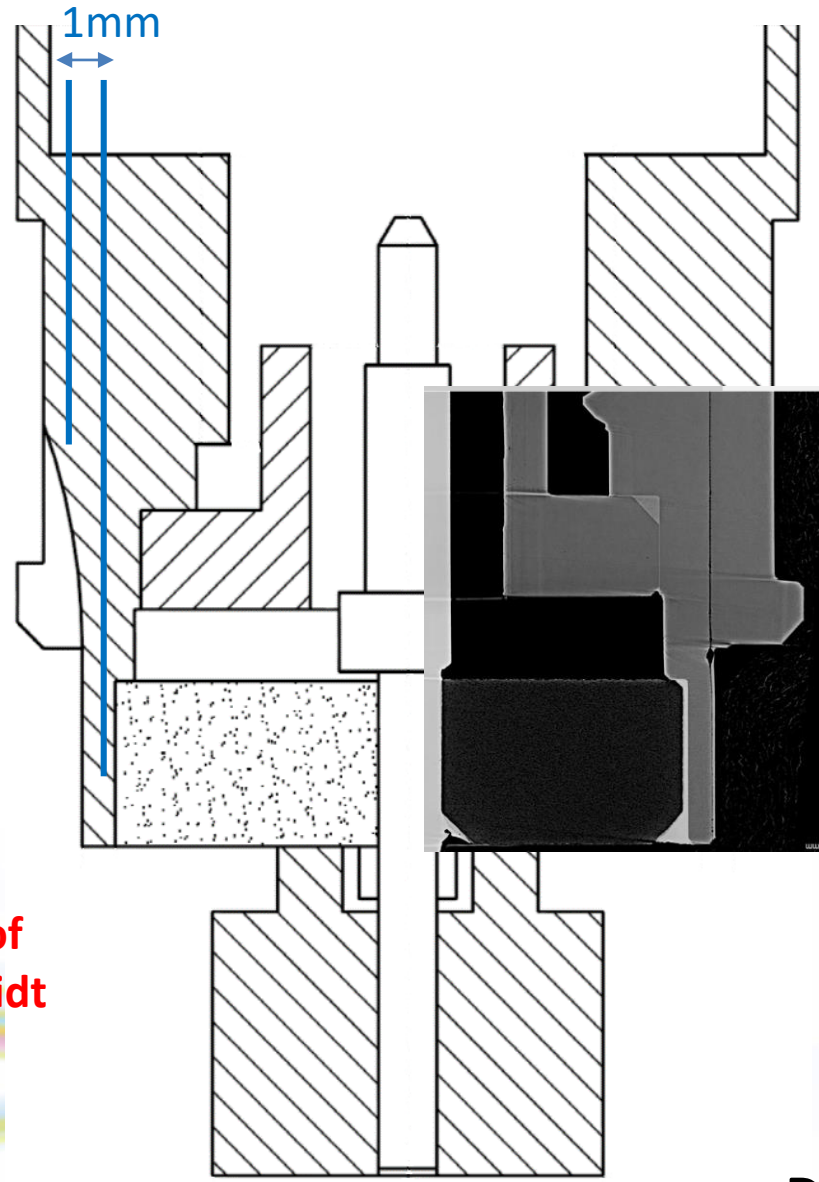
**11GHz resonance strongly damped for all geometries**

Courtesy of  
F. Marcellini

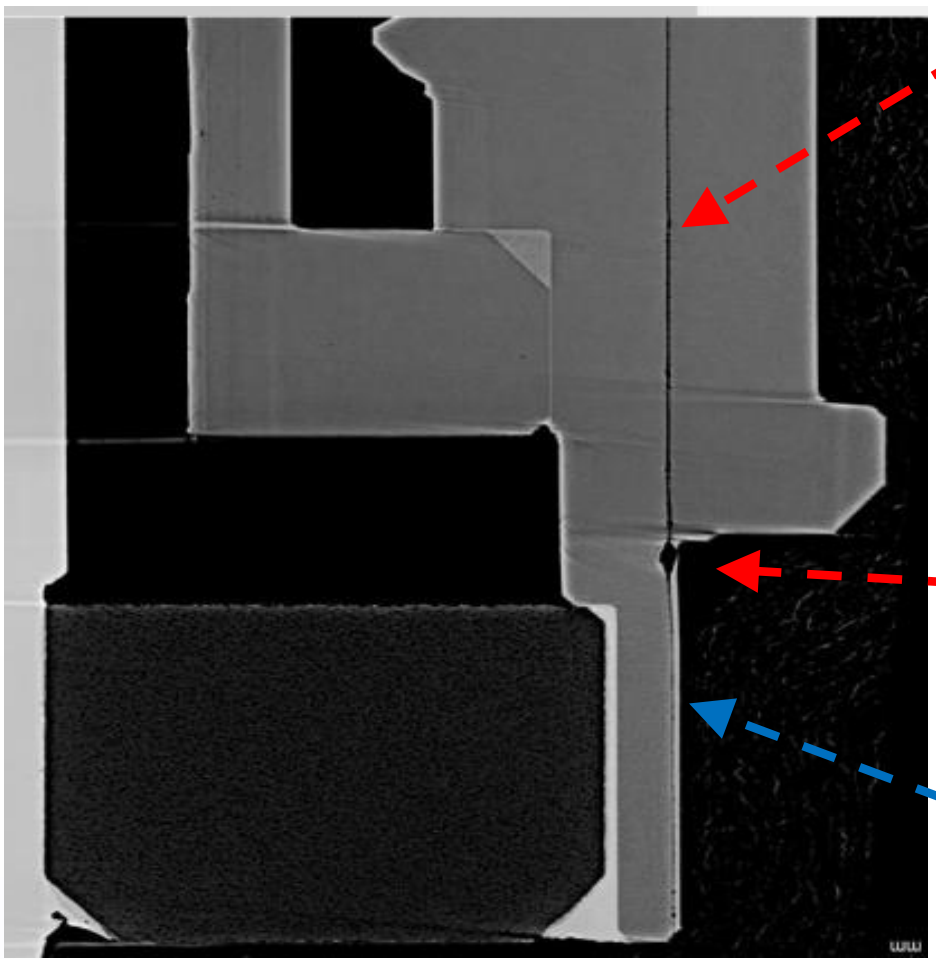
Also cutting the button along the rotation axis produces a similar beneficial effect.



- **Material quality**
- **Sealing technology**
- **Mechanical tolerances**
- **Testing and inspection**
- **Cables and calibration**



Courtesy of  
Kees Scheidt



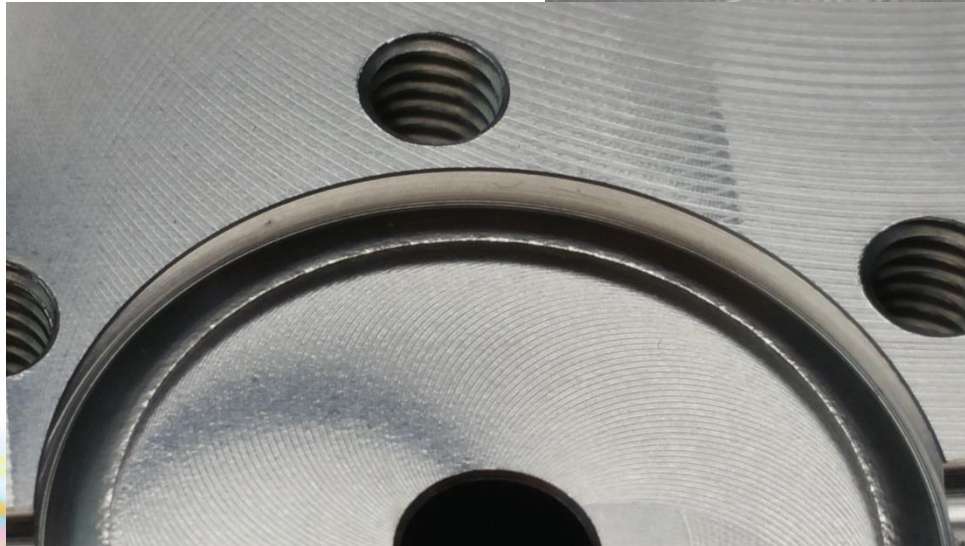
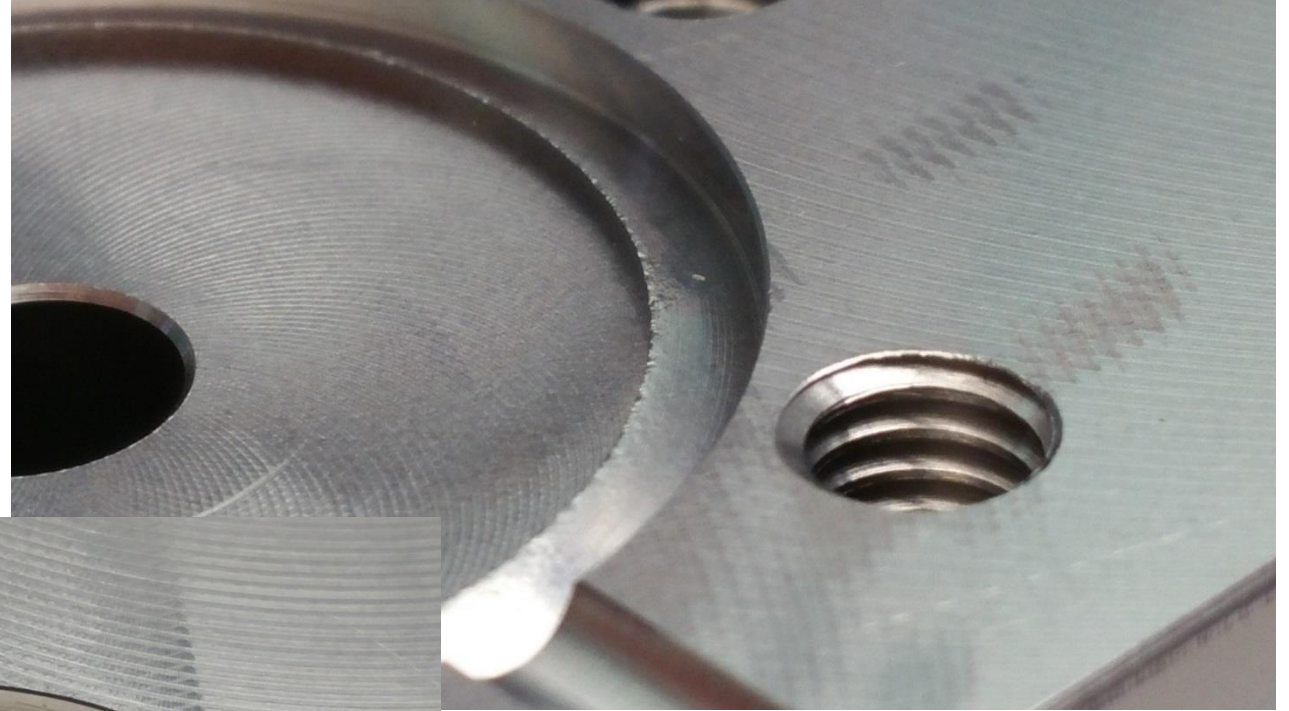
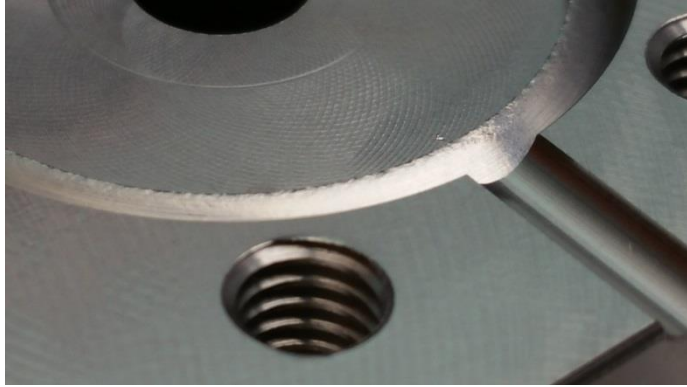
The crack/pipe/channel  
traverses the full depth  
of the steel outer-body

Big cavity

The crack changes  
angle/orientation  
after the cavity

Due to micro channel defects in the bulk.

DESY has noticed a reduction in hardness of the steel they use for knife edge flanges. This has caused failure of multiple parts.



“orange skin” on CF 16 flange  
made of 316 LN ESR

**Courtesy of  
Silke Vilcins**

Some of this is attributed to changes in the steel market leading to confusion of what today's certification means compared to 10 years ago.

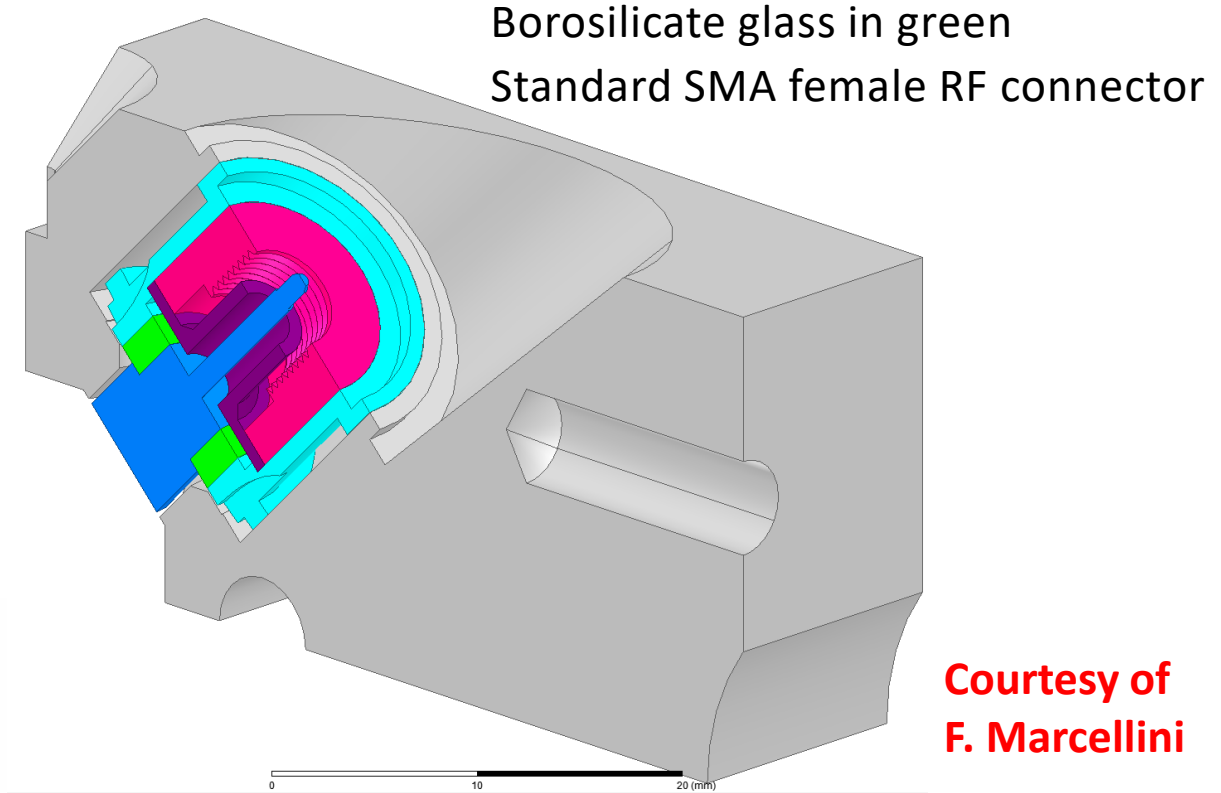
- Facilities now need to take more care in specifying the grade of material. **Certain steel qualities are not as good as they were in the past. Users have examine the specs & certificates**
- Facilities also need to investigate the melting and extrusion techniques used to form the starting block as these can interact to cause a problem while each step alone is benign.

## SwissFEL cavity BPM feedthroughs



Button BPM with borosilicate glass as dielectric insulator

1500 borosilicate glass feedthroughs have been produced for the cavity BPMs of the SwissFEL accelerator.

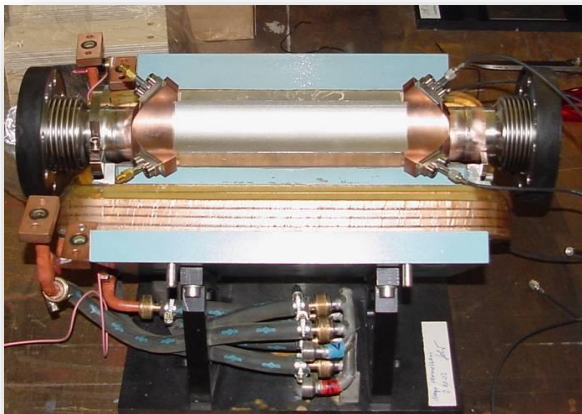


Courtesy of F. Marcellini

Ordered 8 prototypes.

The purpose is to test the manufacturing quality, mechanical tolerances and reproducibility, NEG coating, heating...

# diamond Feedthroughs made by glass ceramic - DESY



Button BPM's @ PETRA III



Courtesy of Silke Vilcins



- **The lower dielectric constant of the glass makes it attractive.**
- **Designs may require longer pins, but scale to smaller diameters.**
- **Welding**
  - **Manufacturers suggest 30mm between weld and seal.**
  - **Facilities experience -> 15mm is possible.**

- **Continuous communication.**
- Make sure that the company you're working with *really* understands what you want.
- Make sure that all subgroups *really* understand what you want.
- Detailed reporting combined with in-house testing.

Tighter tolerances can worsen resonance problems of the machines as a whole.

- “Any specifications placed on the drawings, need to be able to be measured.”
- Facilities need to have robust in house testing capability.
- Each button needs to a unique identifier.
  - Laser marking

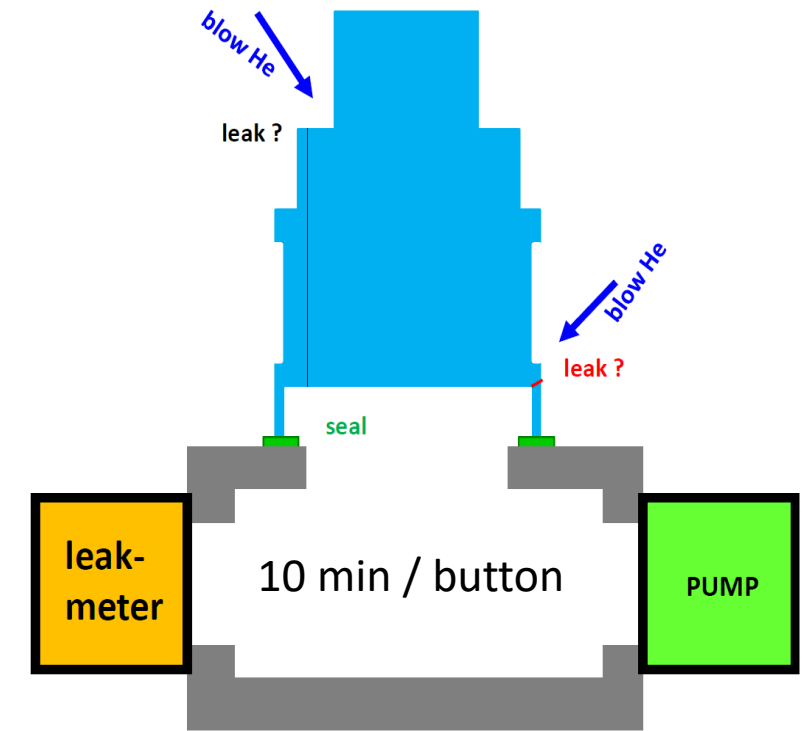
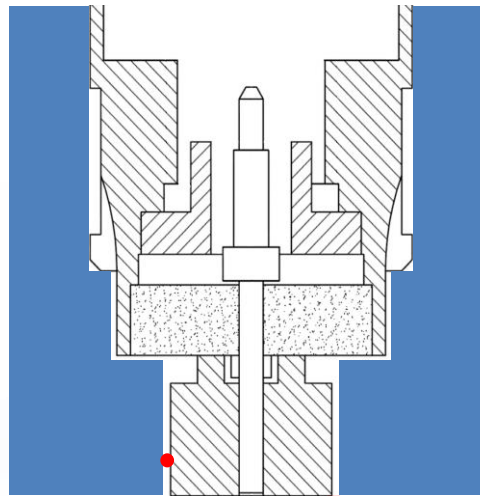
**Metallic particles in the gap.**

NEG?

Removed with:

Nitrogen jets

Clearing with current



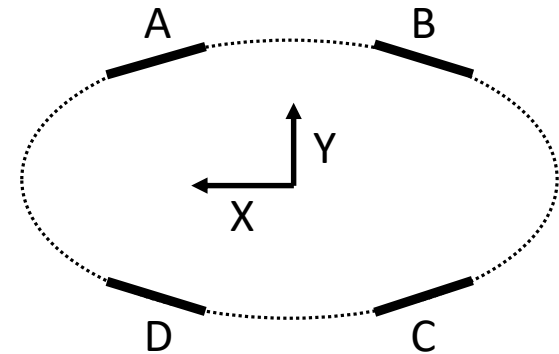
ESRF button leak testing setup

**Long term stability** is becoming increasingly important, however “Ultimate stability” needs to be tempered with user requirements.

- ESRF are developing an improved cable testing system, which is undergoing lab tests
- LNLS use a 4 in 1 cable to mitigate environmental variations.
- **Measure Q** to look for cable changes over time.

$$X = \frac{(A + D) - (B + C)}{(A + B + C + D)} \quad Y = \frac{(A + B) - (C + D)}{(A + B + C + D)} \quad Q = \frac{(A + C) - (B + D)}{(A + B + C + D)}$$

Q is insensitive to position movement so can better identify individual channel variations over time.



- Ideally the next generation of systems will have **in situ online calibration**.
- Some parts of the BPM electronics are moving into the tunnel.
  - for better signal to noise,
  - to use active calibration techniques.

- There are several different threads of design which are coming through which are independently improving things, but could also be combined for further benefits.
- Glass sealing technology is of increasing interest for new machines. Especially as buttons are getting smaller.
- Take great care over material quality specification.
- Continuous communication with suppliers give the best chance to achieve the required tolerances.
- However in-house testing capability is still strongly advised.
- Each button needs to be traceable through the entire process.
- There will be more electronics in the tunnel.
  - Improved signal to noise
  - Active calibration
  - Increased risk of radiation damage

Thank you to all the participants of the  
workshop

And to you for your attention