BPM vacuum sealing aspects

Michal Krupa

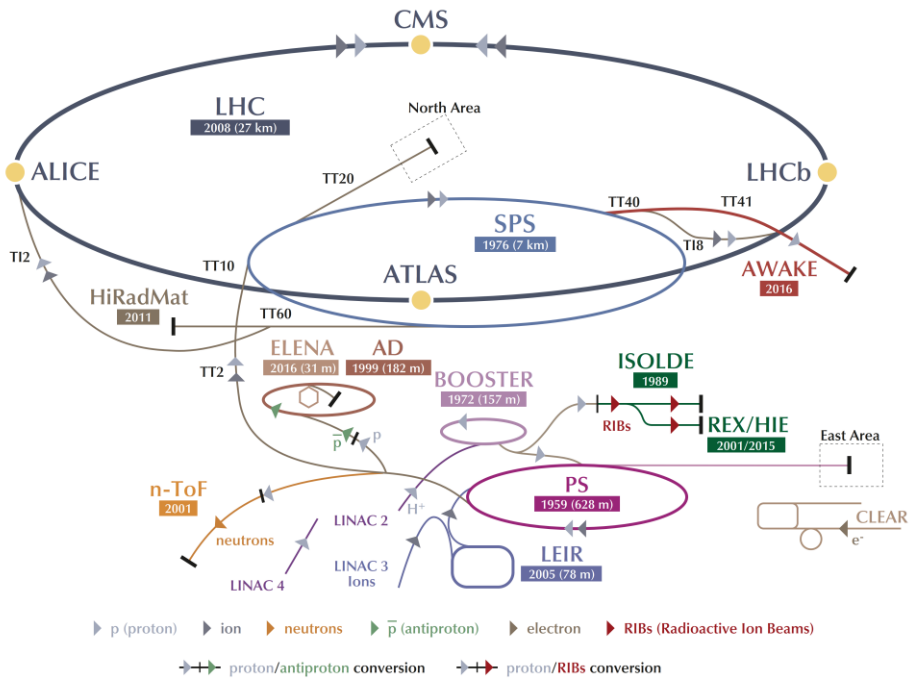
02/05/2019
BPM button design and manufacturing workshop

Outline

- Overview of BPM feedthroughs and buttons experience from CERN
- Available sealing techniques
- Flange and body material
- Connector type

BPMs at CERN

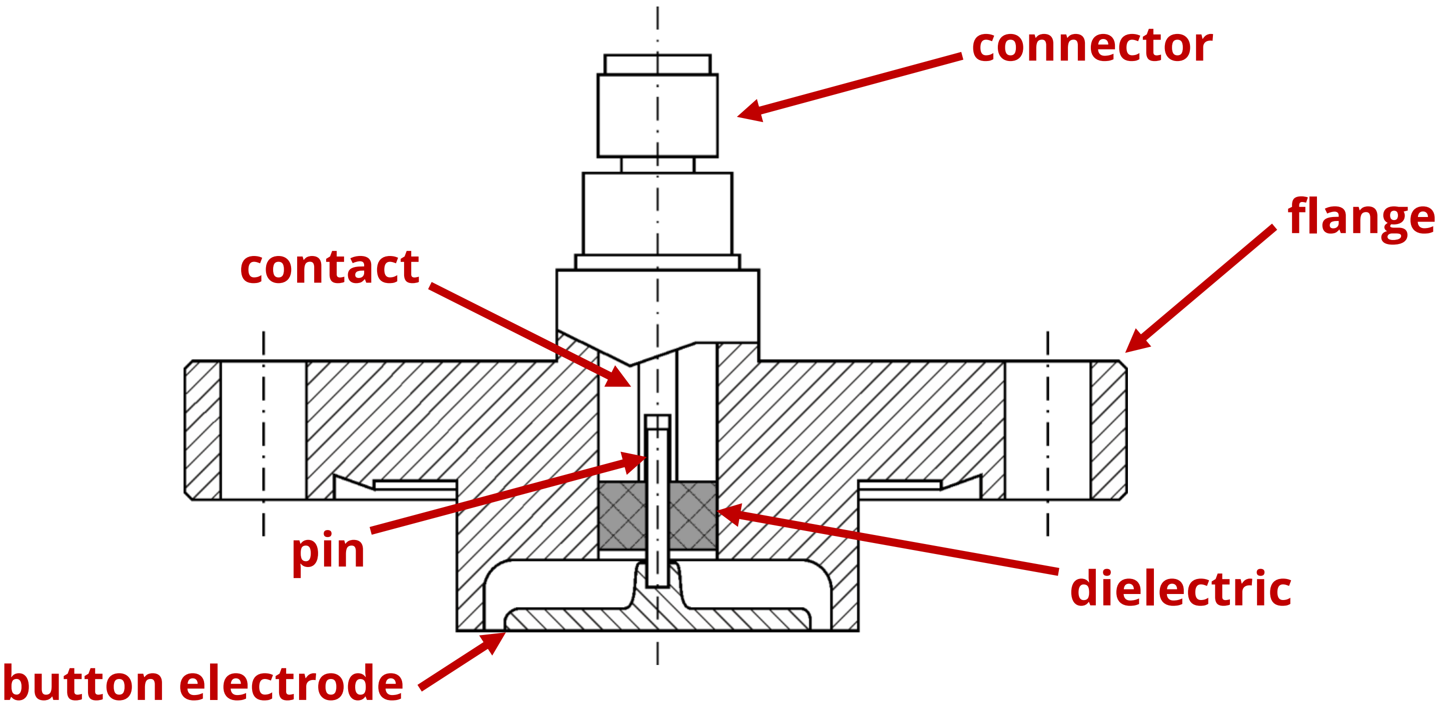
- 8 accelerators, 2 decelerators, 8 experimental areas
- Around 60 km of tunnels
- 2000+ BPMs of ~ 50 types
- BPMs physically quite large
- Long-term plans of even larger accelerators
  - FCC: 2000 BPMs
  - Full CLIC: 50,000 BPMs



BPM feedthroughs at CERN

- Broad range of requirements
  - Frequency: 100 MHz ÷ 10 GHz
  - Vacuum levels: 10^{-8} mbar ÷ 10^{-12} mbar
  - Operating temperature: -270°C ÷ +400°C
  - High-temperature bake-out
  - Radiation tolerance: 0 Gy ÷ 20 MGy (2 GRad!)
  - Order size: 10 units ÷ 1000s units
  - Varied connector type, flange type, materials etc.
  - Wide variety of acceptance criteria
- No “one size fits all” solution possible

Typical BPM feedthrough / button

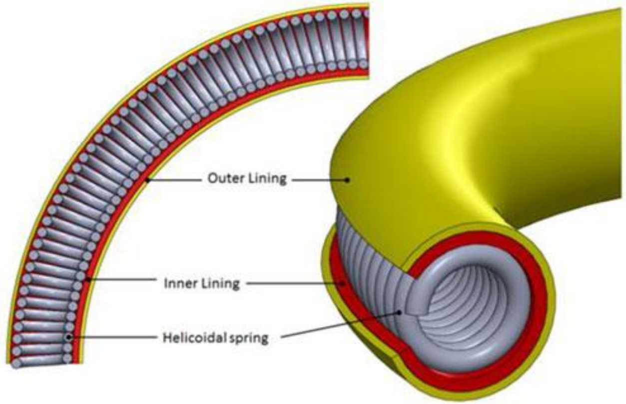


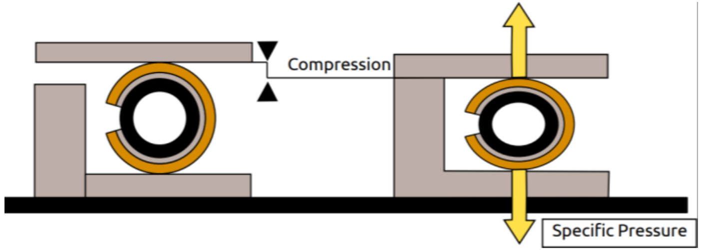
Vacuum sealing by welding or brazing

- Non-detachable connection to the BPM body
- Potentially excellent vacuum seal
- Never done at CERN for BPMs
- Very difficult to replace the feedthrough
- Very difficult to align the feedthrough

Spring loaded seals

- Plastic deformation of seal jacket
  - Greater ductility than the flange material
- A lot of advantages
  - Somewhat reusable
  - Proven cryogenic performance
  - “Arbitrary” shape
  - Reasonably forgiving material choice
  - Available commercially

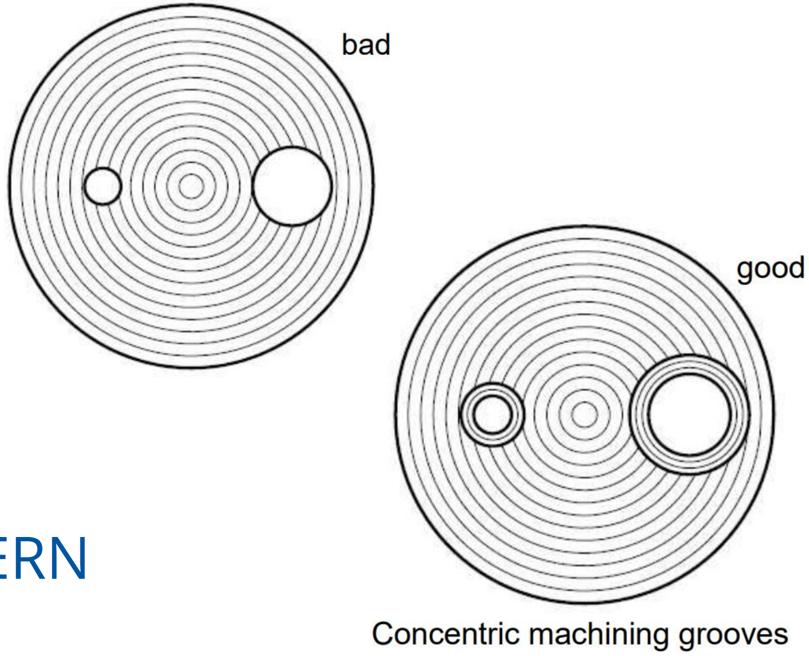




Figures courtesy of: TECHNETICS GROUP

Spring loaded seals

- Not a perfect solution
  - Relatively expensive
  - Limited supply chain
  - Controlled surface quality
  - Special machining
- Historically the go-to solution at CERN
  - Presently avoided



Figures courtesy of: VAT Vacuum Valves

Conflat flanges

- Metal gasket sandwiched between two precisely-machined knife edges
- Extremely versatile
  - Industry standard
  - Excellent UHV performance
  - Working over a vast temperature range
  - Complete in-house production possible
  - Fully adaptable
  - Exotic gasket materials for special applications
  - Custom shapes possible (e.g. rectangular)

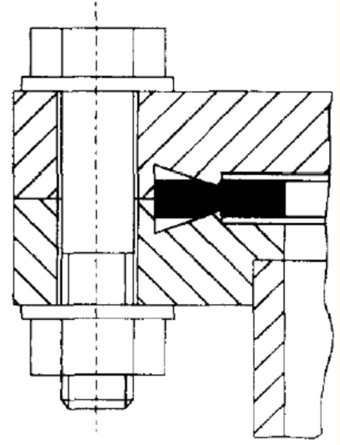
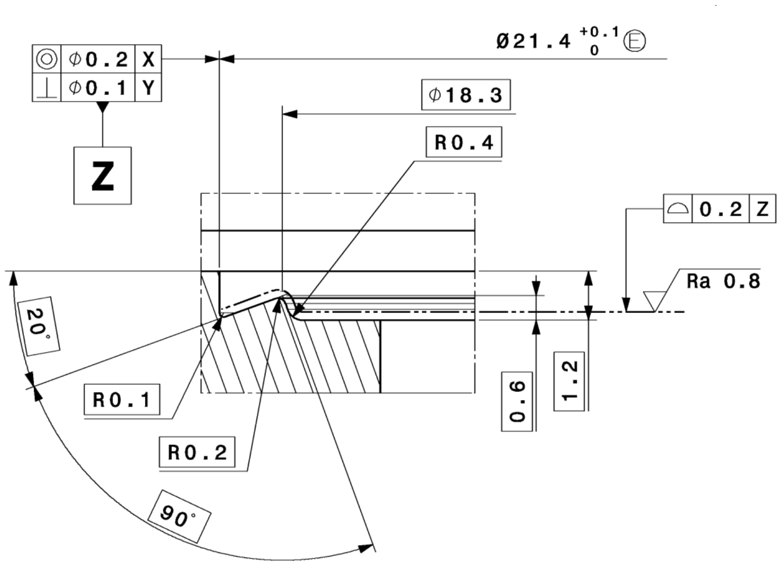


Figure courtesy of: Atlas Technologies

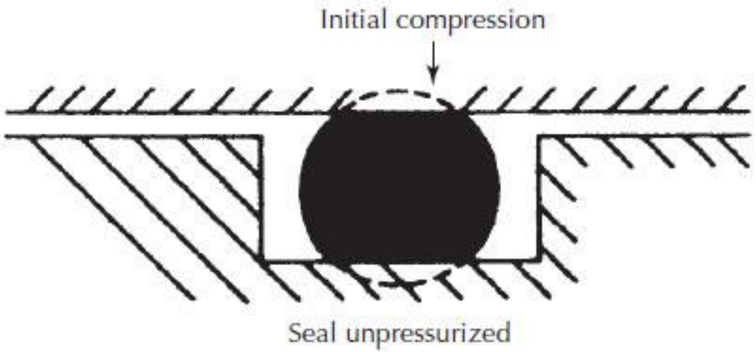
Conflat flanges

- More complicated than spring loaded seals
  - High-precision machining required
  - Fragile knife edges
  - Single-use gasket
  - Very difficult to re-machine
- Present default solution for new designs at CERN



Rubber gaskets

- Similar in concept to spring loaded seals
- Much simpler implementation: O-ring
- Reusable
- Variety of materials available
  - Application specific choices possible
- Economical choice with limitations
  - Outgassing at high temperatures
  - Risky at low temperatures
  - Limited tolerance to radiation
- Used at CERN but not directly on BPMs



Flange material choice

- 316LN – golden standard for feedthrough flanges
  - Low-carbon, nitrogen-enhanced 316
  - Very hard, resistant to corrosion
  - Low inclusion contents
  - Non-magnetic
  - Proven performance over a huge temperature range
- Expensive and hard to procure
  - CERN tries to help
- Even higher quality
  - VAR / ESR
  - 3D forging

Flange material choice

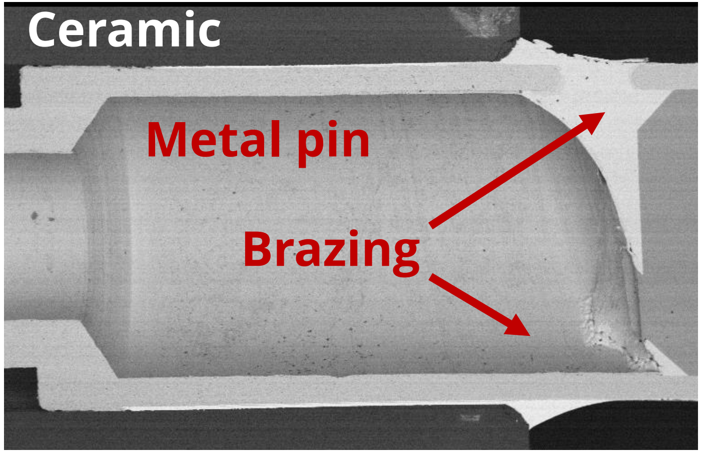
- 304L – in some cases good alternative
  - Low-carbon 304
  - Resistant to corrosion
  - Higher inclusion contents
  - Magnetic – high local μ_r
  - Brittle at low temperatures
- Readily available on the market
- At CERN used for vacuum vessels

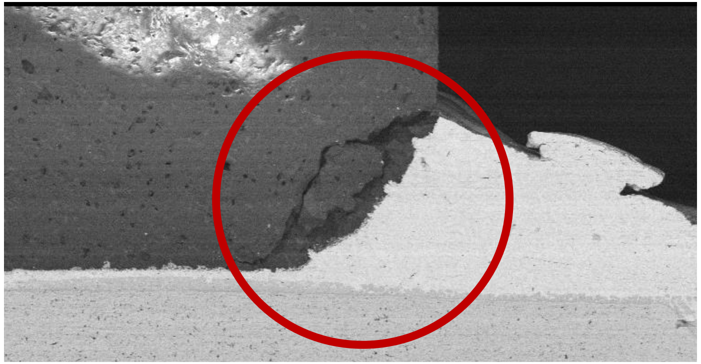
Flange material choice

- Titanium – in principle a good choice
  - Very hard, resistant to corrosion
  - Non-magnetic
- Limited experience at CERN
  - Expensive
  - Different thermal expansion coefficient than BPM body
  - More complicated acceptance tests

Ceramic seals

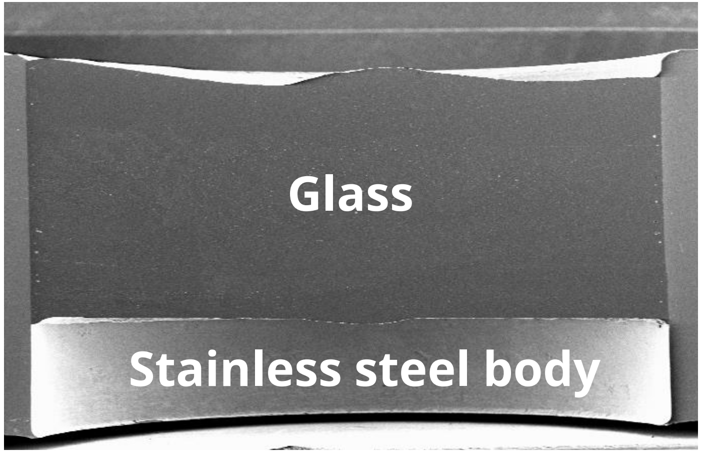
- Popular solution
- $\varepsilon_r > 9$ – limited RF performance
- Prone to cracks and fissures at cryogenic temperatures
- Less expensive than glass seals

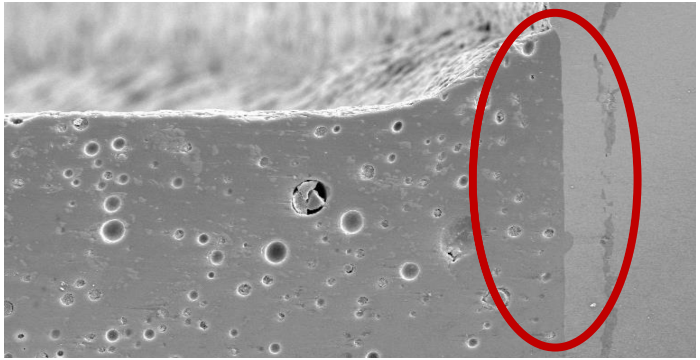




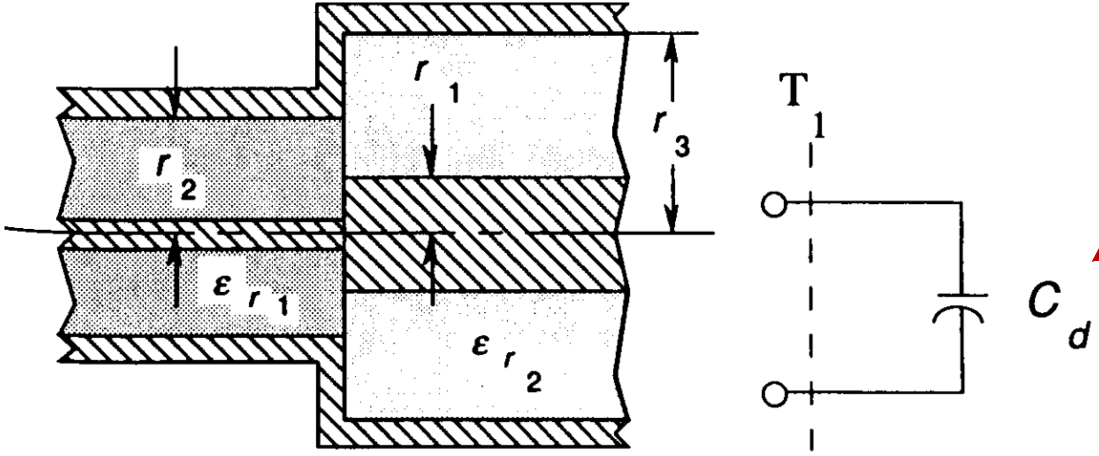
Glass-to-metal seal

- Less popular than ceramic seals
  - Limited number of suppliers
- ε_r ~ 4 – good RF performance
- Excellent adhesion to all surface blemishes
- Can be expensive





Importance of ε_r



$$C_d \cong 2.0\, \varepsilon_{r1}\, \pi\, r_1\, C'_{d_2} + 2.0\, \varepsilon_{r2}\, \pi\, r_2\, C'_{d_1}$$

Figure courtesy of: Handbook of transmission line design

Virtually impossible to do broadband compensation

CERN now offers 3D electromagnetic simulations for our contracts (NDA)

Central pin material

- Pin material proposed by the supplier
  - Strong and stable in temperature
  - Inconel seems to be the de facto standard
- Contact material specified by CERN
  - Strong and flexible (spring effect)
  - Good conductivity
  - 100s of mating cycles required
  - Secure fixing to the pin: welding preferred
  - Gold-plated CuBe (e.g. C17410)

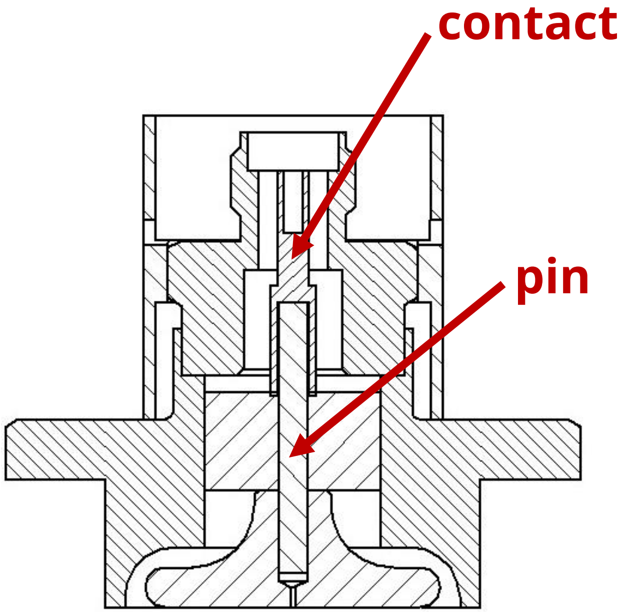


Figure courtesy of: SLAC

Connector type

- Type N advantages
  - Robust
  - Easy to handle
  - Bulky
- SMA advantages
  - Optimised for high frequencies
  - Smaller footprint
- So far only standard gender connectors used at CERN
  - Benefits of the reverse polarity?

Some example acceptance criteria

- All feedthroughs undergo vacuum acceptance tests
  - Performed by the Vacuum Group at CERN following their procedures, normally a large number simultaneously
- When appropriate the feedthrougs are subject to
  - RF characterisation with dedicated tooling and equipment
  - Cryogenic tests (usually LN2)
  - Mechanical tests
  - Metallurgical tests
  - Microscopic examination

Conclusions

Thank you for your attention

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CERN