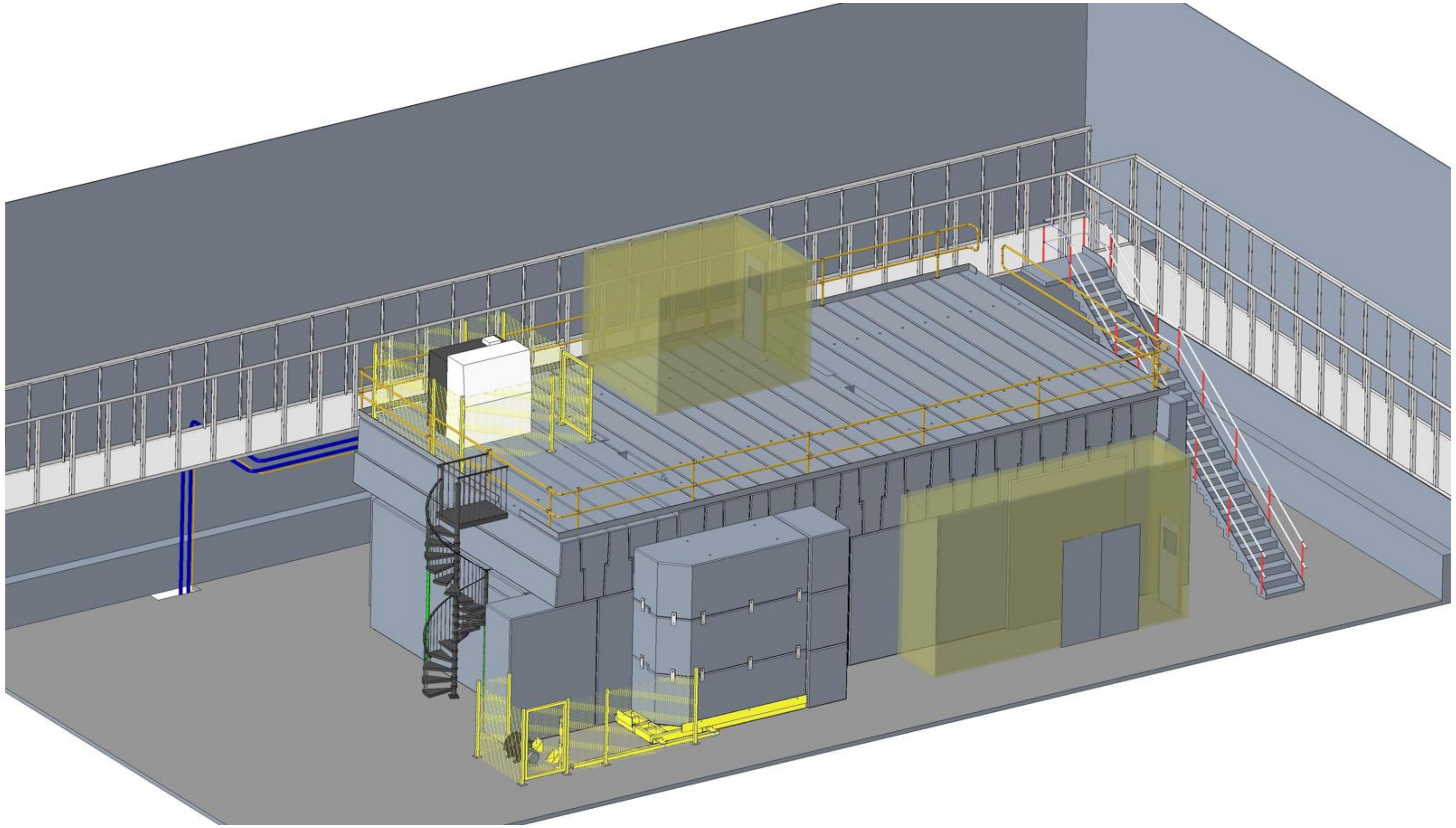
Muon RF conditioning activities in the UK

Prof Graeme Burt, Lancaster University on behalf of UK Muon RF team



UK RF Team

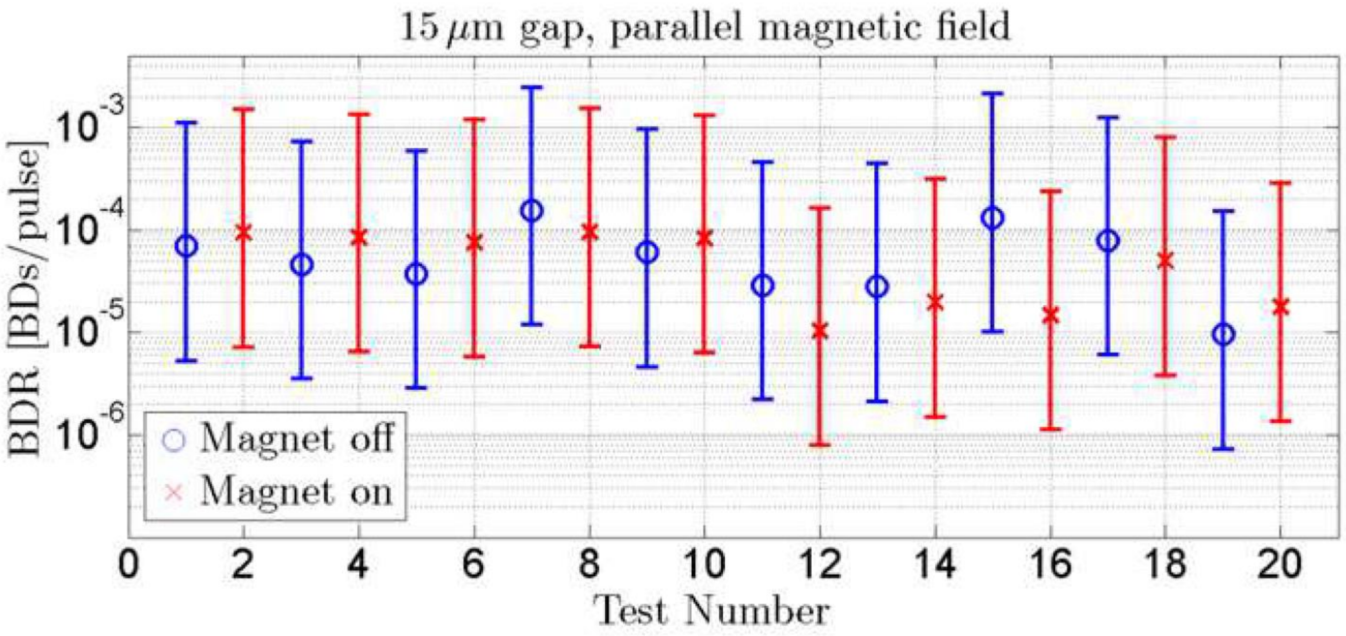
- Lancaster: RF testing & cavity design, Klystron design
- Strathclyde: Physics of breakdown & cavity design
- Southampton: Solenoid Design and construction
- STFC: Mechanical design, controls, lower B field testing on CLARA gun

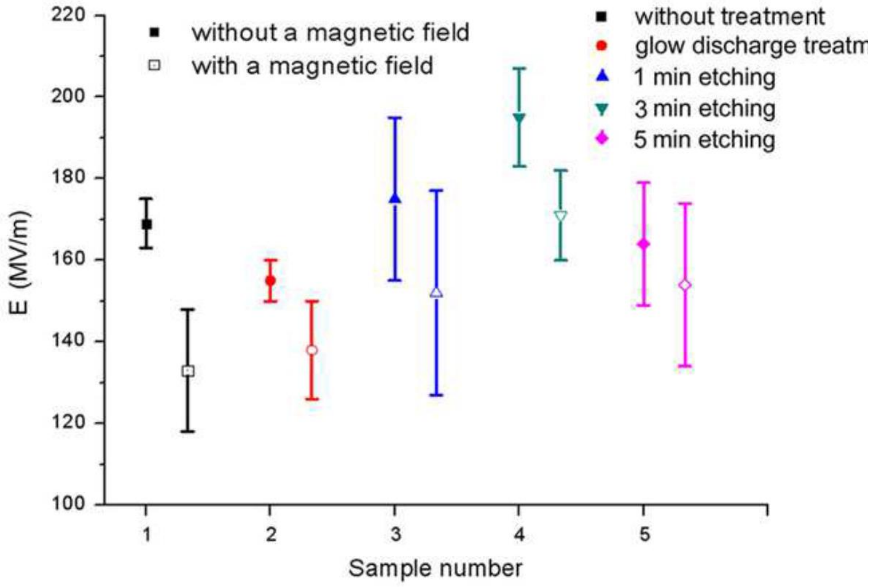
Discharges in Magnetic Fields

- In RF cavities magnetic fields (B-fields) have been noted to
  - Increase dark current
    - diamond machining of surfaces and surface preparation crucial for reducing dark current
    - magnetic field can focus dark current into a beamlet causing more damage
  - Require re-conditioning of cavities
  - May inhibit conditioning and limit peak E field
  - Increase risk of arcing which can happen extremely rapidly (ns scale)
- In DC vacuum breakdown, B – fields have been noted to improve diode insulation BUT also:
  - Increase number of active emission sites
    - suppression of the screening effect
  - Enhance optical emissions from the cathode flare plasma
  - Suppress material polishing in short pulse driven systems
- The MICE/MAP experience significantly reduced breakdown/multipaction issues with coating on critical components (exposed areas of the RF couplers).

DC spark gap experiments in 0.5 T field

Small gap studies at CERN showed no difference in BDR while larger gap studies at IAP showed a 10-20% reduction in the breakdown voltage with the magnetic field



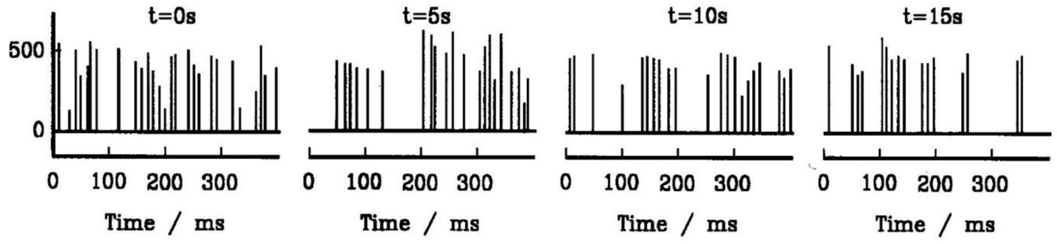


S. Lebedynskyi, O. Karpenko, R. Kholodov, V. Baturin, Ia. Profatilova, N. Shipman, W. Wuensch, DC vacuum breakdown in an external magnetic field, Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment, Volume 908, 2018,

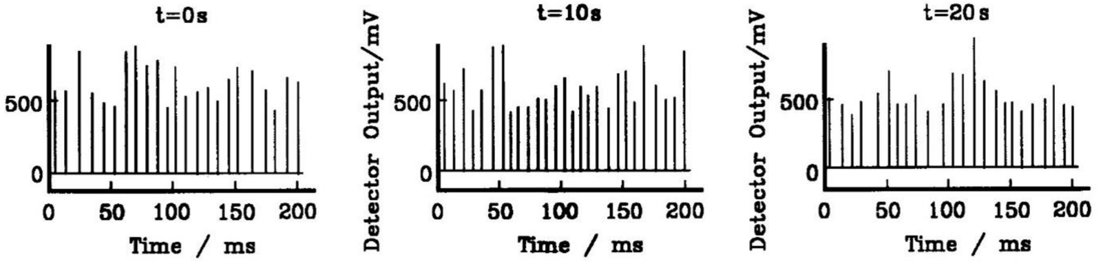
Links to DC Vacuum Spark Dynamics (Spark *et al*)

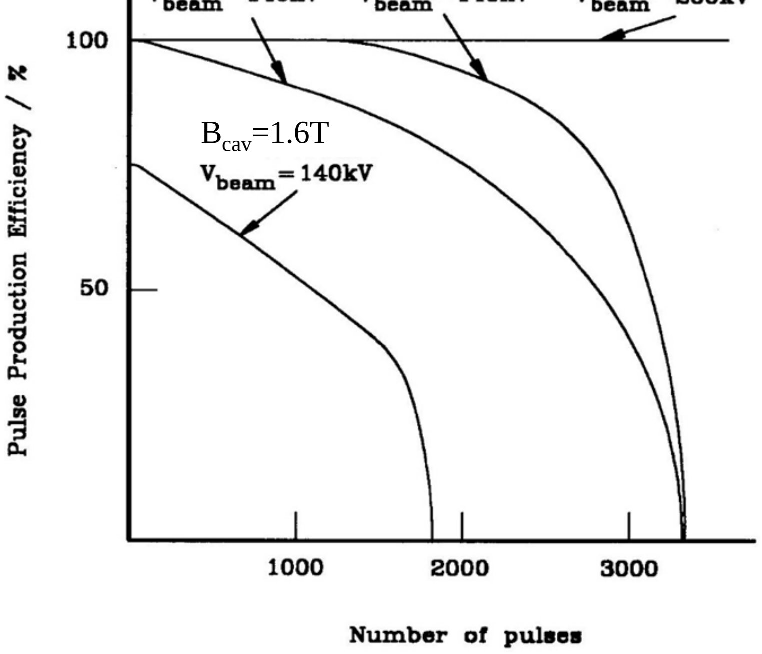
- Spark, Cross, Phelps and Ronald [4] investigated high PRF cathode erosion in vacuum arcs
  - Showed sensitivity of ‘critical field’ and ‘cathode polishing’ of knife edge emitters to B-field

B_{cav}=1.6T, V_{beam}=140kV



B_{cav}=4.5T, V_{beam}=140kV

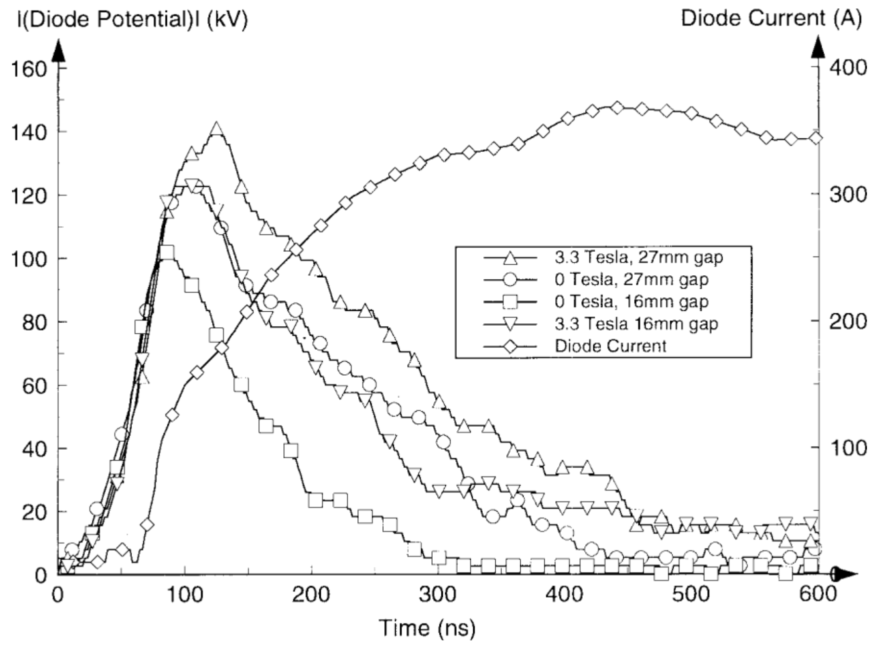




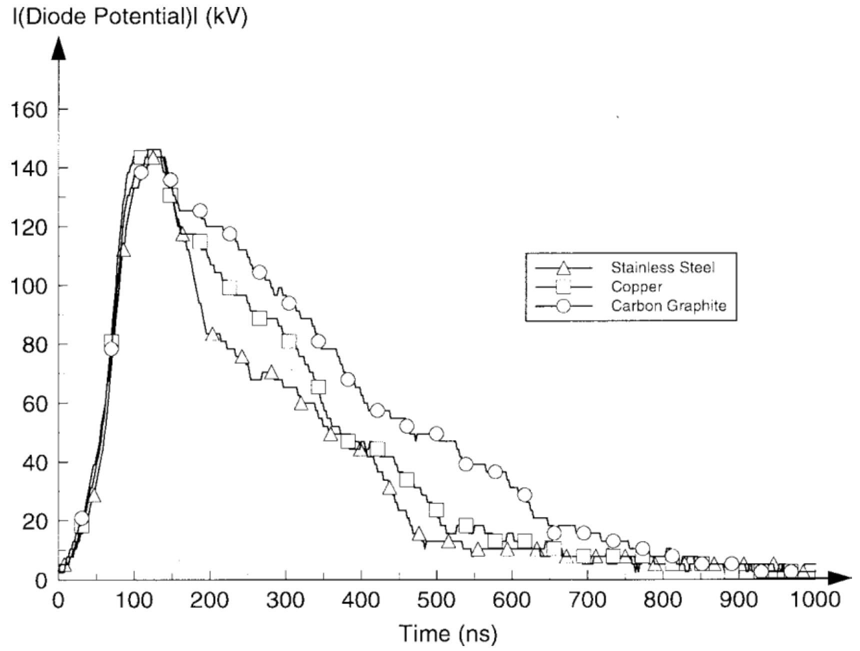
[4] S.N. Spark, A.W. Cross, A.D.R. Phelps A.D.R. and Ronald K. ‘Megawatt, 330Hz PRF tunable gyrotron experiments’, Int. J. of Infrared and Millimeter Waves. 15, No12, pp2003-2017, 1994.

Links to DC Vacuum Arc Dynamics (Ronald *et al*)

- Influence of the diode gap spacing & the B-field on the collapse of the diode potential
  - Material stainless steel



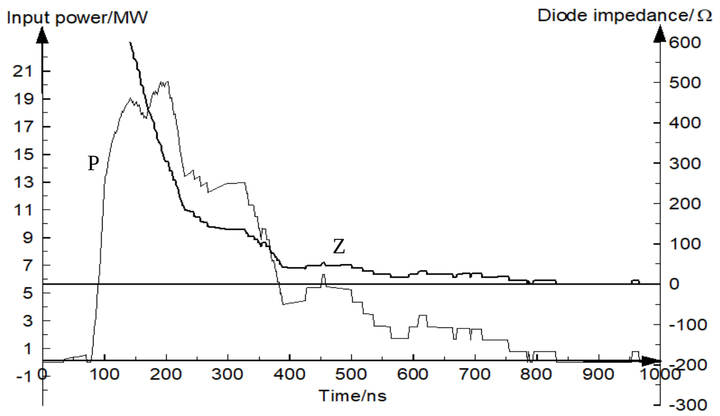
- Influence of material on rate of collapse of diode potential
  - Anode-cathode gap 27mm
  - B-field 0 Tesla

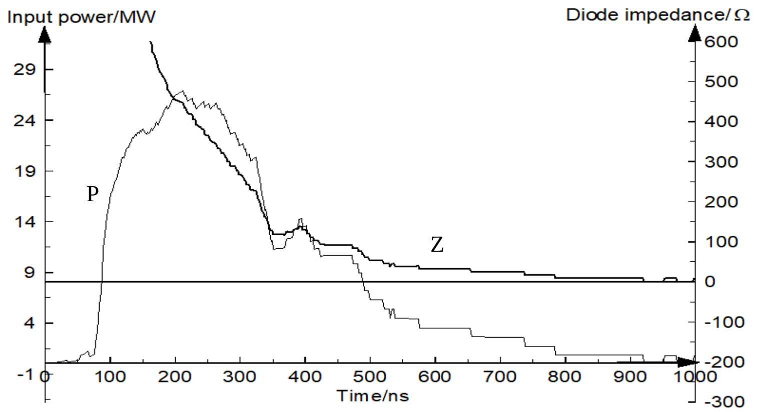


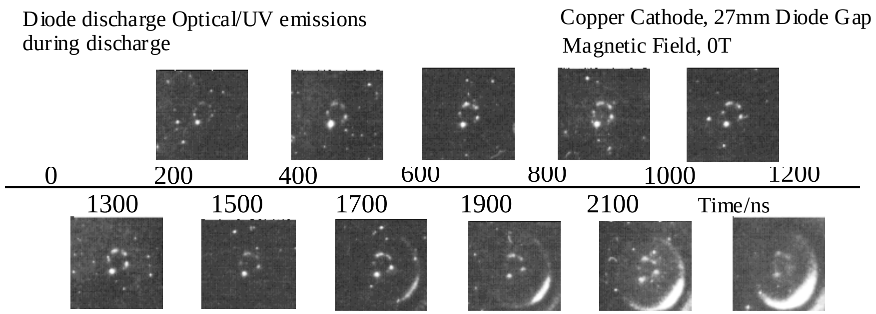
[5] K. Ronald, A.W. Cross, Alan D. R. Phelps et al “Explosive Cathode Experiments”, IEEE Trans. on Plasma Science, **26**, No 3, June 1998

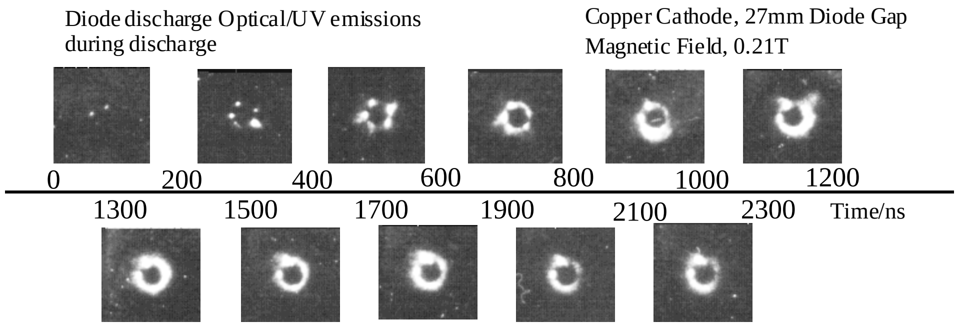
Links to DC Vacuum Arc Dynamics (Ronald *et al*)

- Ronald et al [5] investigated pulsed vacuum arcs
  - Showed sensitivity of cathode flare plasma (distribution and intensity) to B-field in knife edge emitters





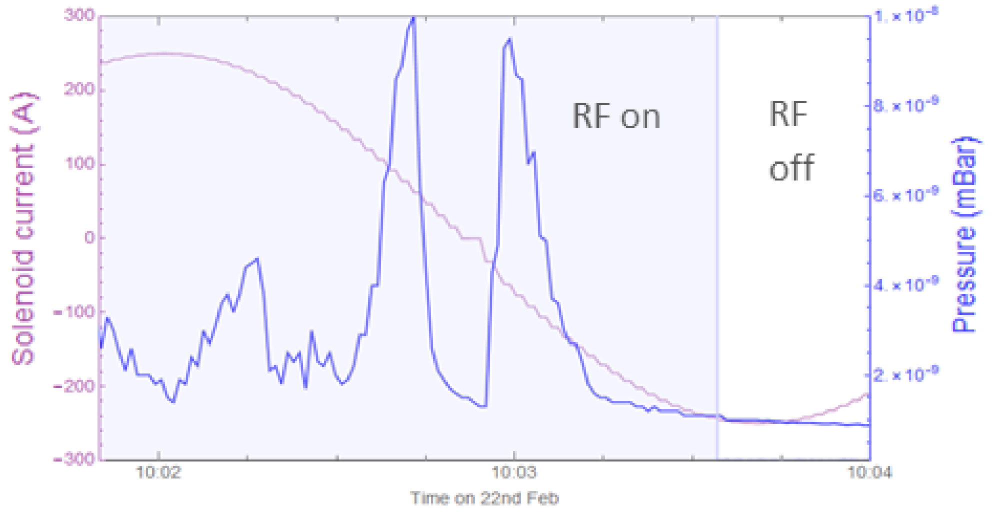


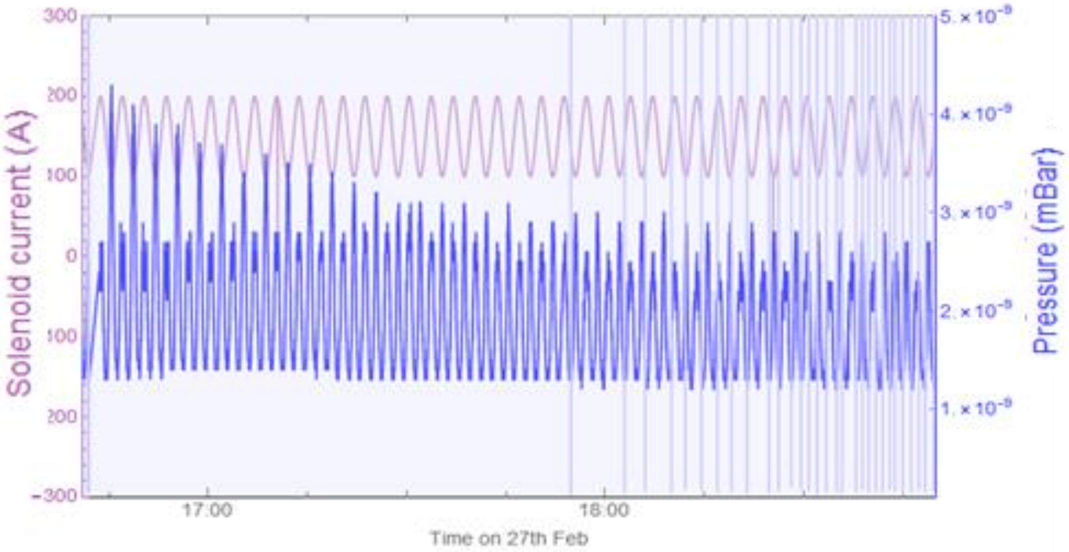


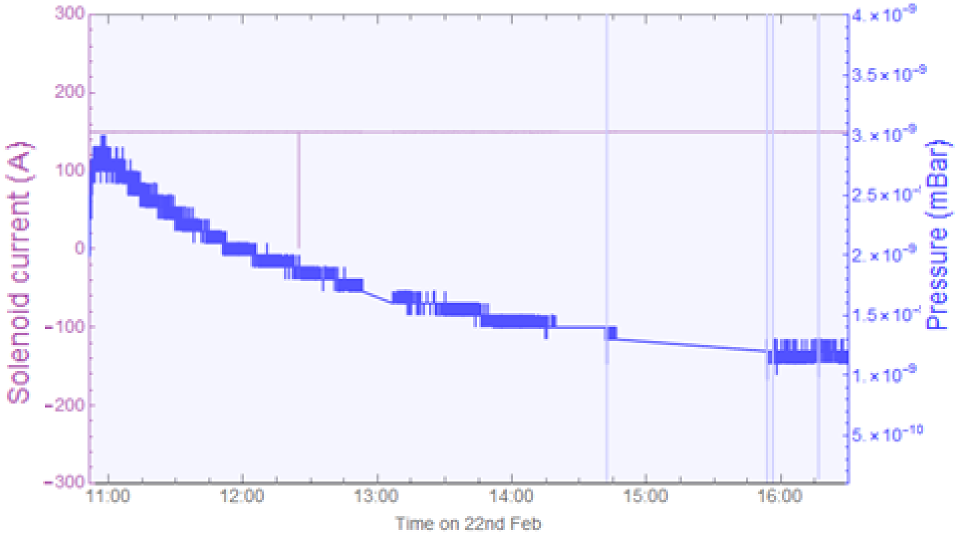
[5] K. Ronald, A.W. Cross, Alan D. R. Phelps et al "Explosive Cathode Experiments", IEEE Trans. on Plasma Science, **26**, No 3, June 1998

VELA gun Solenoid effects

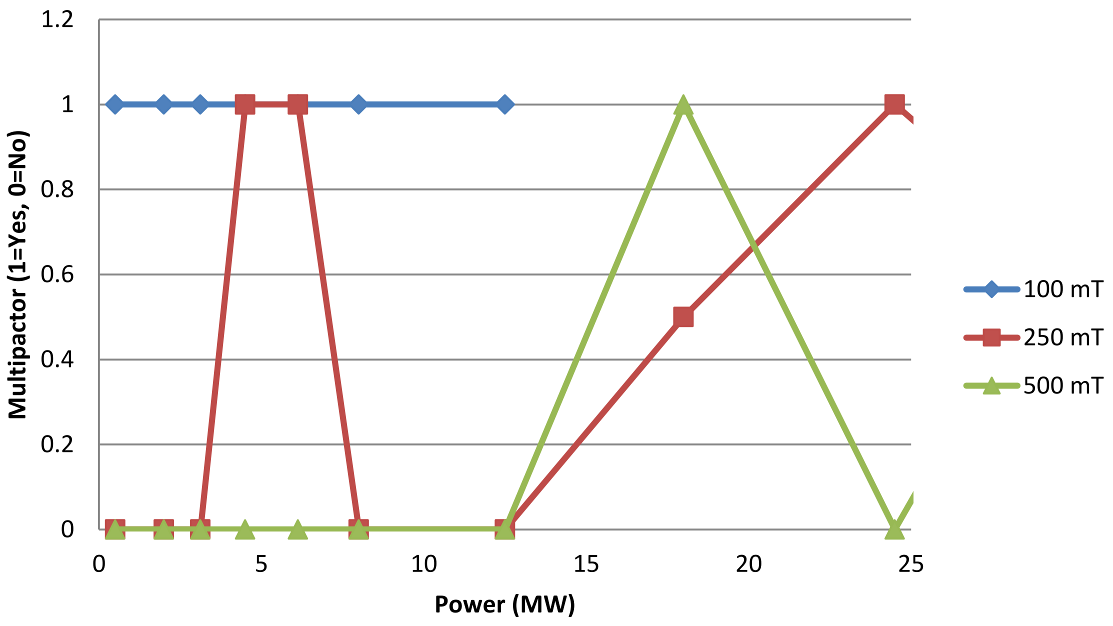
- Oscillation from -250 A to + 250 A caused vacuum spikes up to 1 x 10^{-8} mBar.
- Solenoid switch on to 150 A caused pressure increase to 2.7 x 10^{-9} mBar. Which recovered slowly.
- Solenoid oscillation from 100 to 200 A (0.3 T) caused decaying oscillation of the pressure.

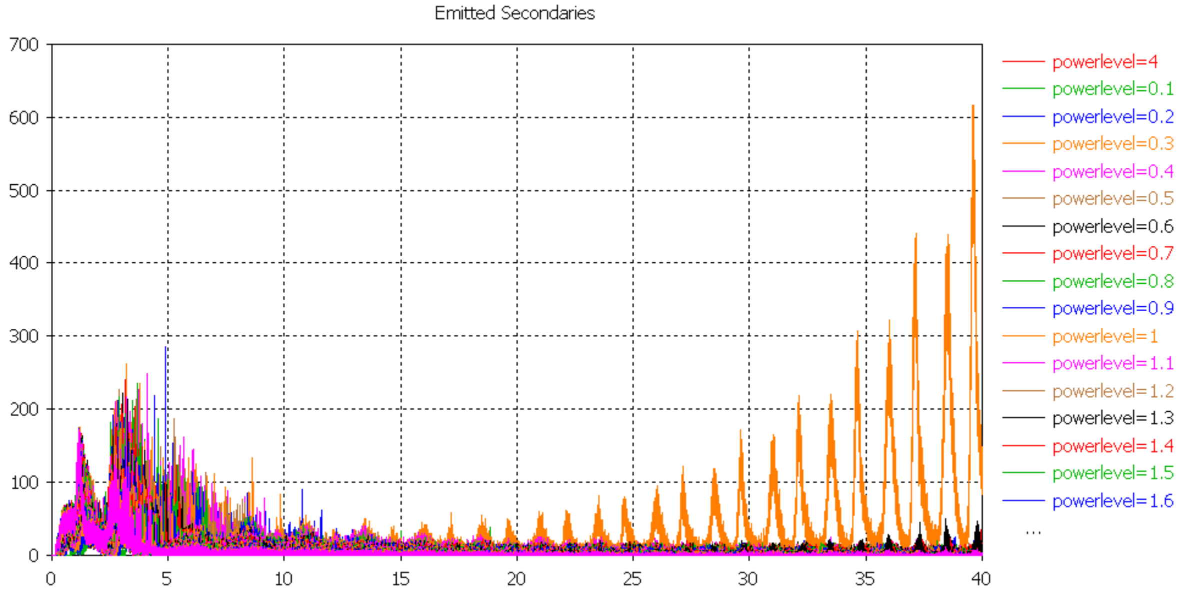






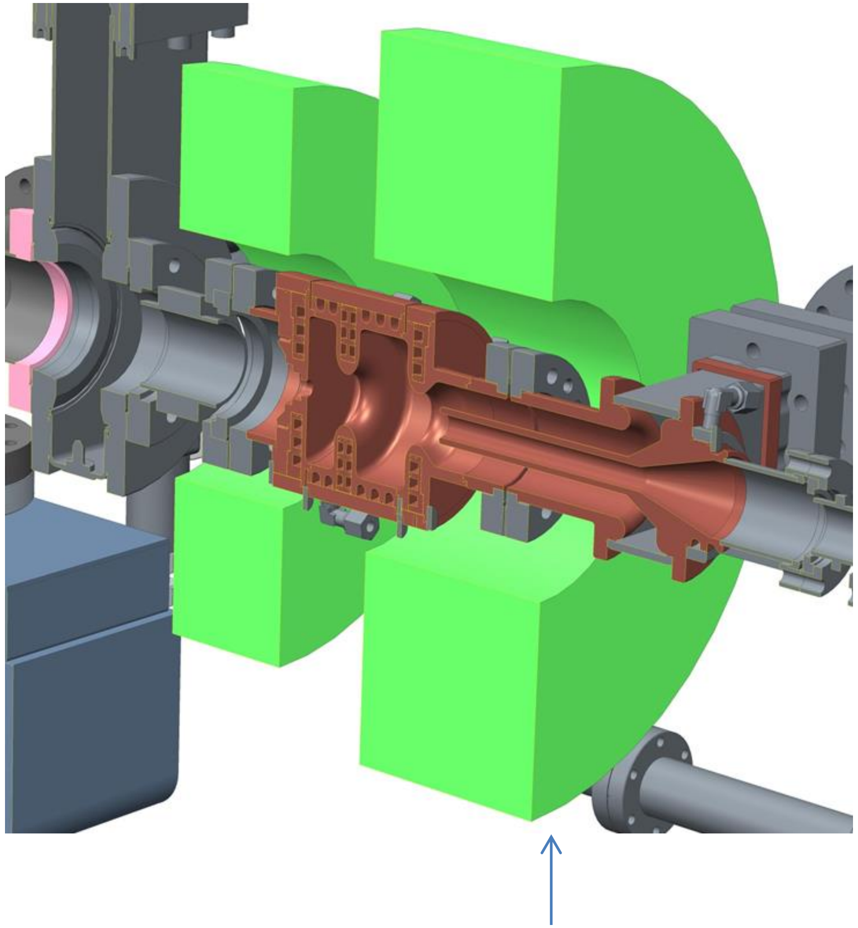
How multipactor is affected by the solenoid field: Example coax line





- Simple yes or no plot (1 means MP, 0 means no MP, 0.5 means maybe MP)
- Shows 500 mT is needed to completely get rid of MP in our operating band
- 100 mT has almost no effect on the MP

High Repetition Rate RF Gun

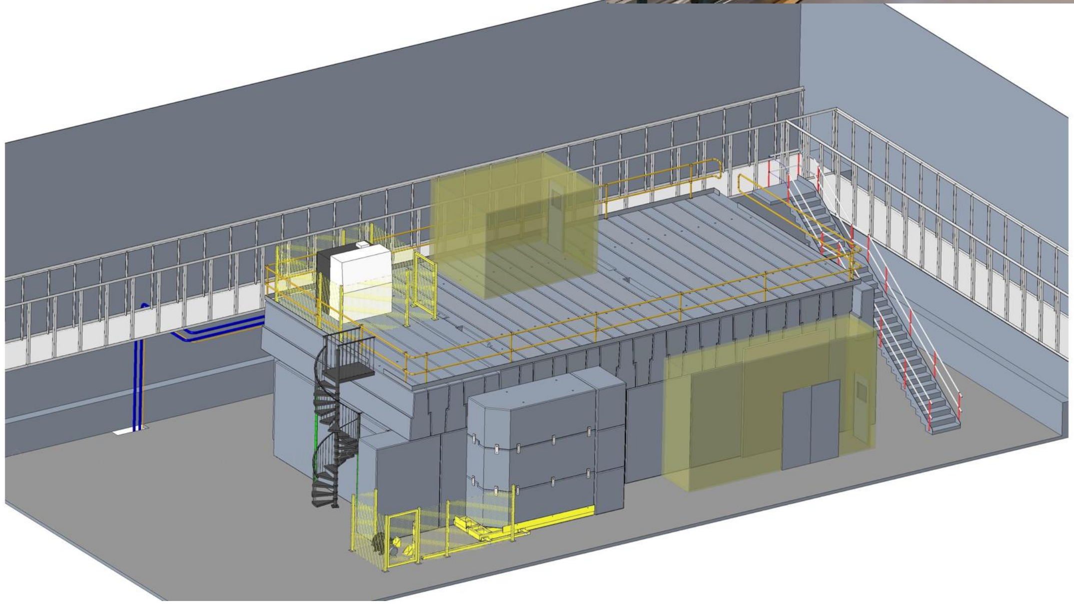


- ASTeC in collaboration with Lancaster University has developed a High Repetition Rate Gun for CLARA.
- The gun has a solenoid on it allowing some testing with lower magnetic fields (0.2 - 0.3 T)
- May be partially relevant for muons in the short term to validate models.
- Testing gradients of 80/100/120 MV/m
- Is being conditioned now and we ae very interested in the effect of B field on conditioning

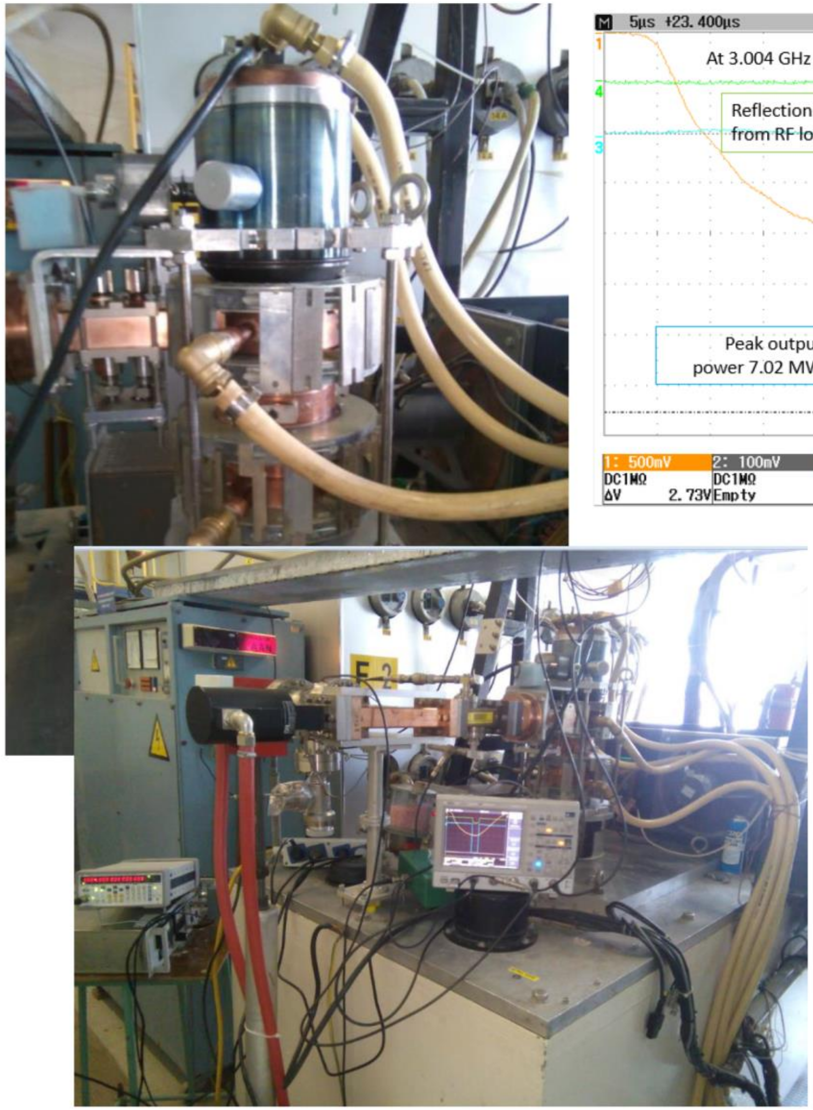
UKRI Science and Technology Facilities Council

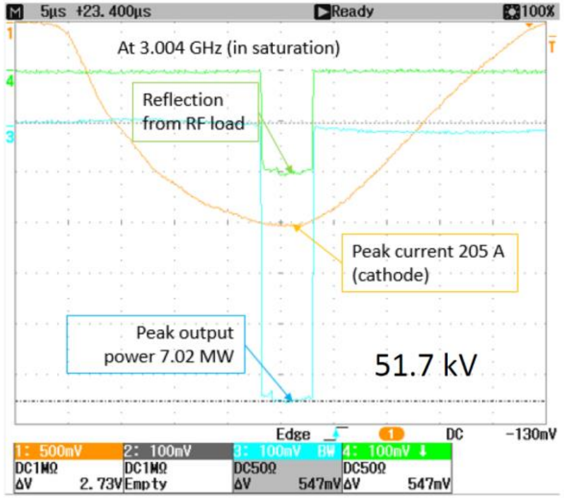
CI RF Bunker

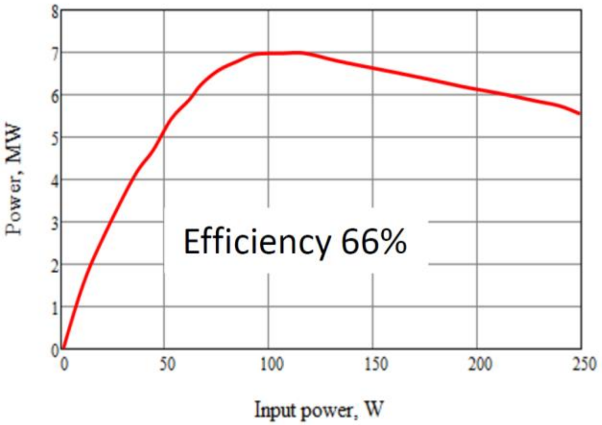
- Have started putting the concrete in place with handover expected mid 2022
- S-band 7 MW klystron and LLRF control being shipped/procured



BAC MBK factory test results





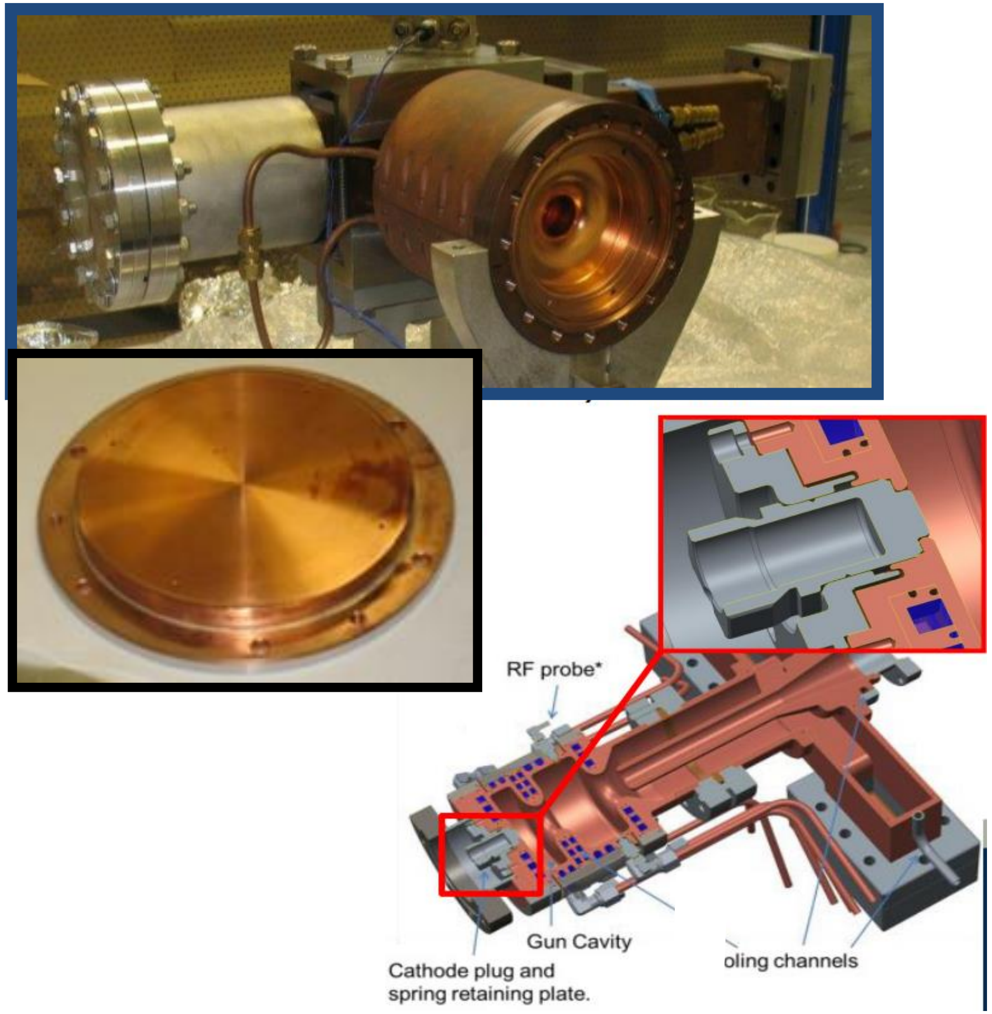


The achieved S-band BAC MBK klystron performance confirmed the excellent potential of the new bunching technology. In this case by ‘simply’ replacing the klystron RF circuit (retrofit), the peak output RF power was boosted by almost 50%!

Igor Syratchev, CERN

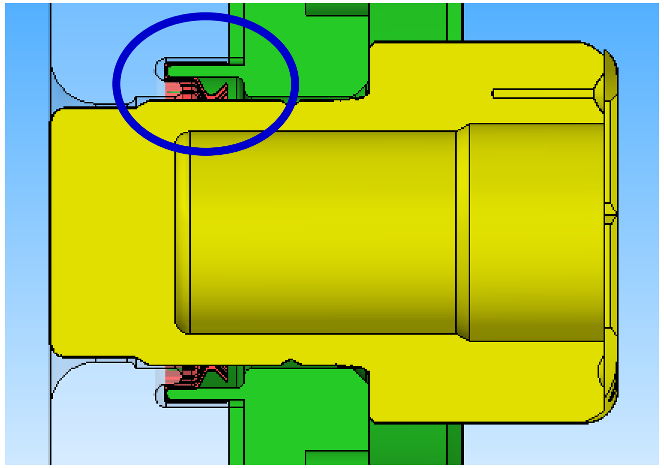
RF sample testing

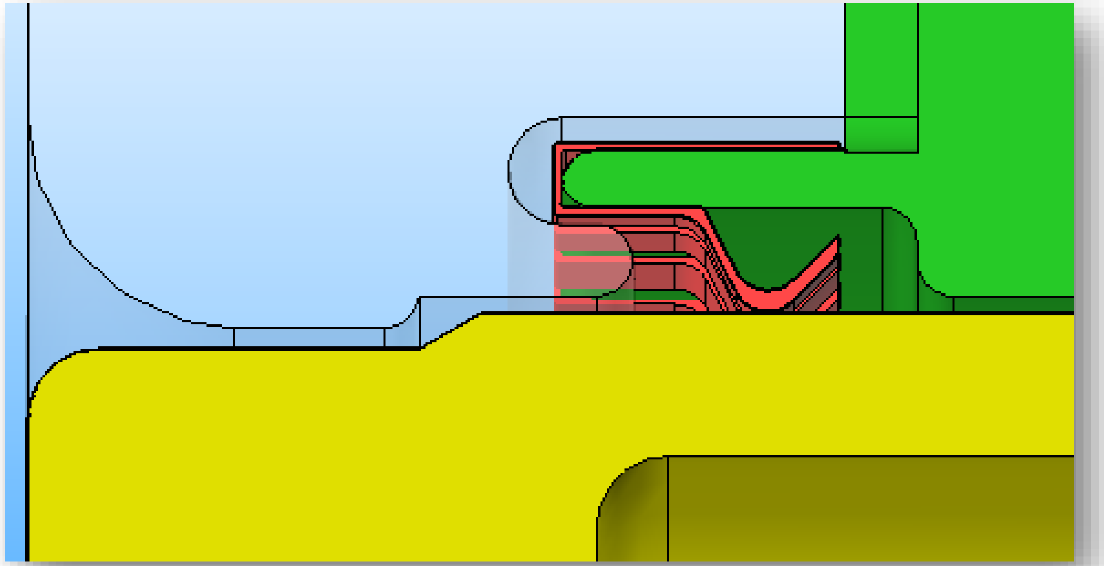
- Plan to replicate something like our RF guns where we have removable back plates or plugs
- Can design to maximise peak fields on the removable part while keeping most of the cavity the same
- Can test different materials
- Possibility to test same sample with DC
- Southampton could design a solenoid to go around this cavity
- As its only 3 GHz we can use a smaller bore (~10-15 cm)
- Can couple via an axial coax line similar to our RF gun to avoid having large waveguide feed go through the coil



Photocathode plug design

Courtesy S. Schreiber, DESY





New design allows for:

Avoid direct view of RF fingers to RF cavity

Robust, good contact, avoid fragile copper parts (like the thin rim)

- New design with RF fingers
- compatible with existing LASA/DESY photocathode design

Science and Technology Facilities Council

Solenoid

- Southampton will design a solenoid to go around this cavity
- As its only 3 GHz we can use a smaller bore (~10-15 cm) with the peak field maximized over one of the cells.
- Can couple via an axial coax line similar to our RF gun to avoid having large waveguide feed go through the coil

University of Southampton

Plans

- Without further funding:
  - CLARA HRRG commissioning will happen but more emphasis on getting it operating and less on physics
- With future infrastructure funds
  - Can do testing in CI RF bunker at higher B fields with a dedicated solenoid, still at 3 GHz