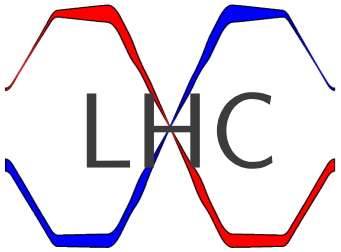
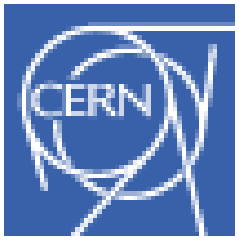


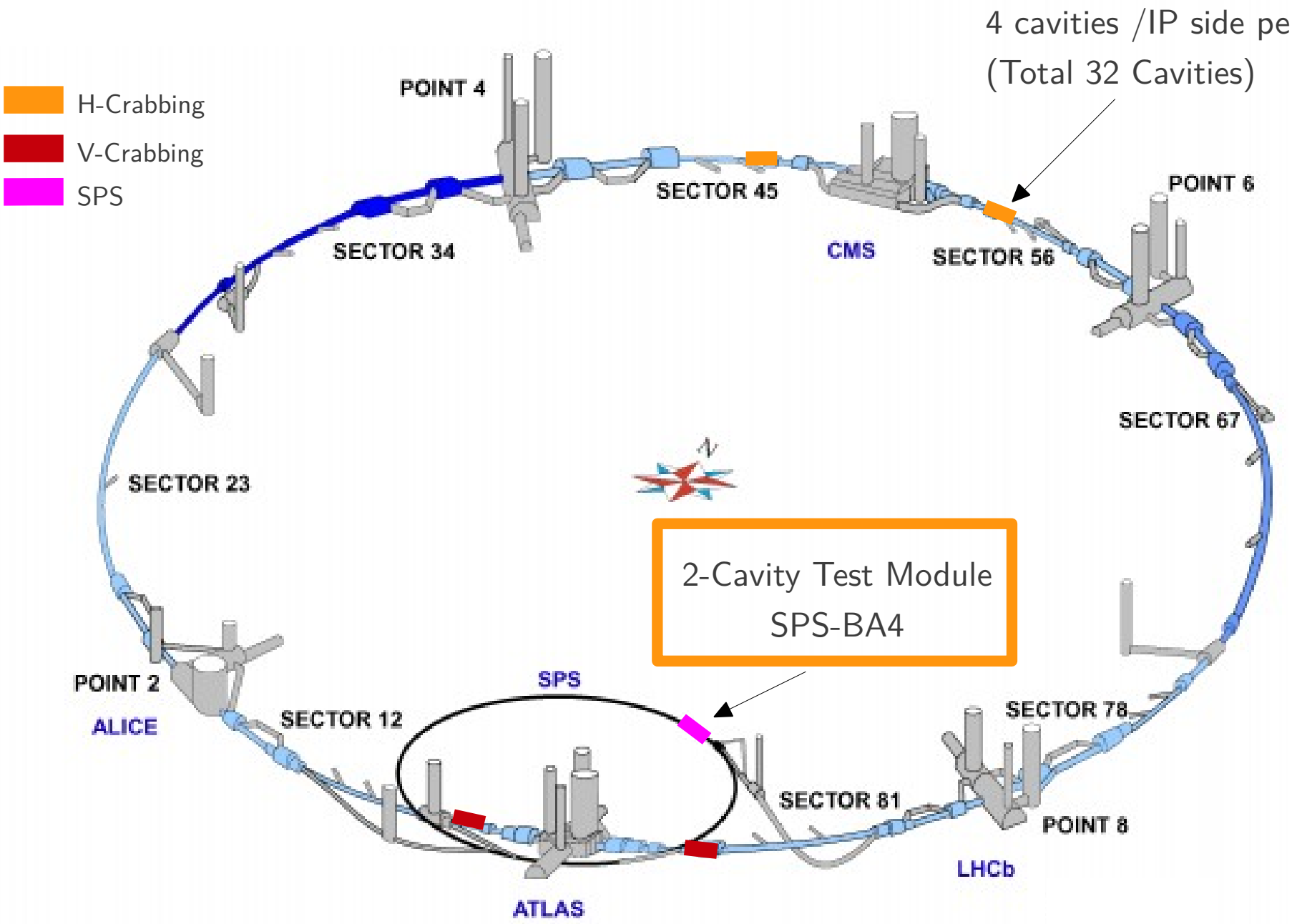

# Prototype Crab Cavities/CM for HL-LHC

Rama Calaga, CERN

TTC2014, December 4, 2014

Many thanks to
CERN: BE-RF, EN-MME
UK: STFC, DL, UL, CI
USLARP: BNL, FNAL, LBL, ODU, SLAC

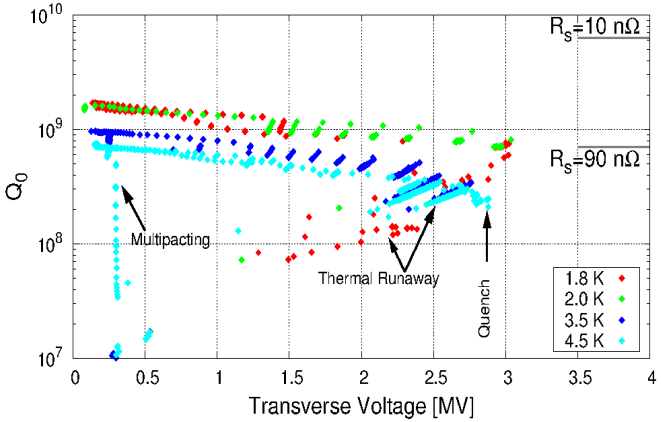
# LHC Crab Cavities



# First Compact Prototypes

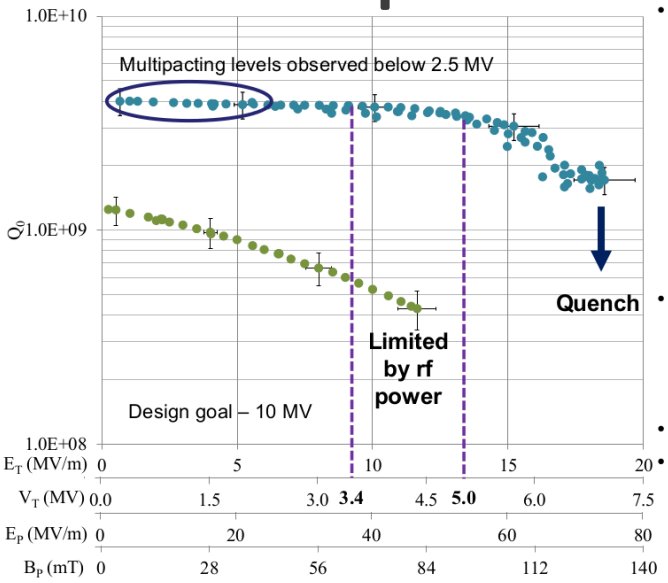
Three world record deflecting fields in superconducting LHC crab cavities

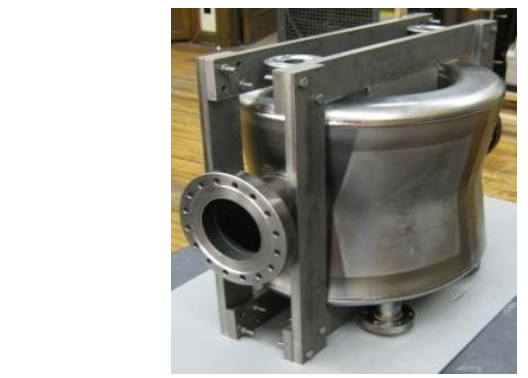
## 4rod



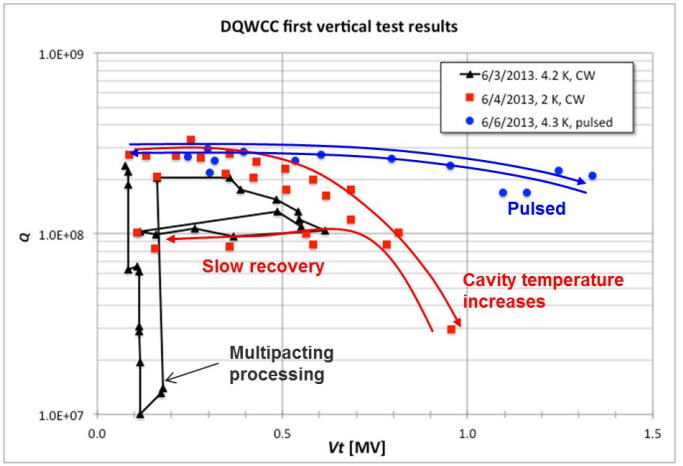

(4rod development stopped)

## RF Dipole



## Double Quarter Wave

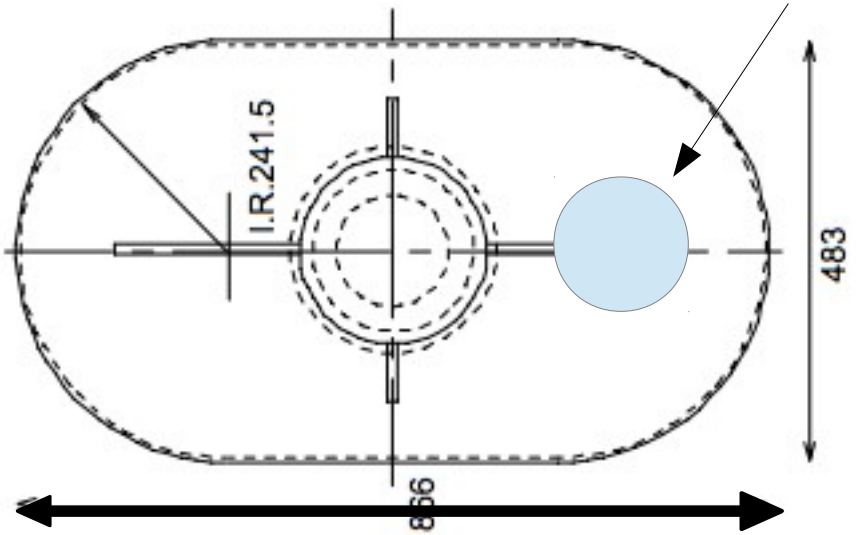


# Reminder, Compact Cavities

500 MHz, KEKB

$V_T = 2$ MV

(Ep/Bp = 28 MV/m, 82 mT)

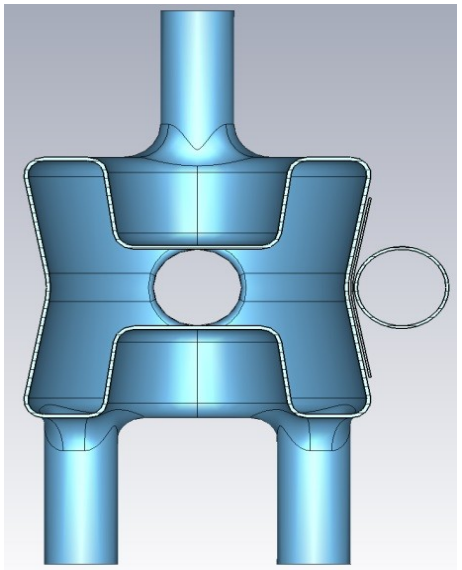



866 mm

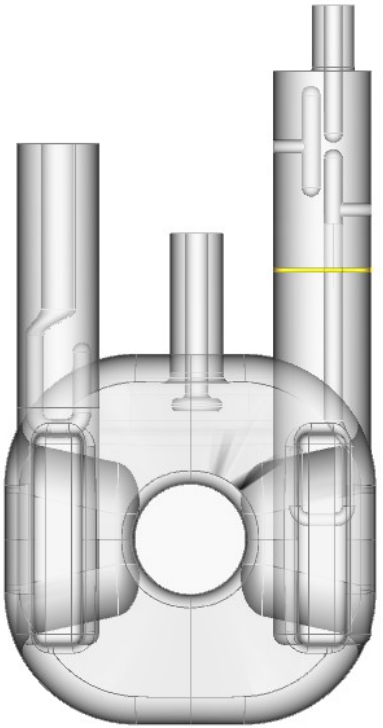
400 MHz, LHC

$V_T = 3.4$ MV

(Ep/Bp < 35 MV/m, 60 mT)

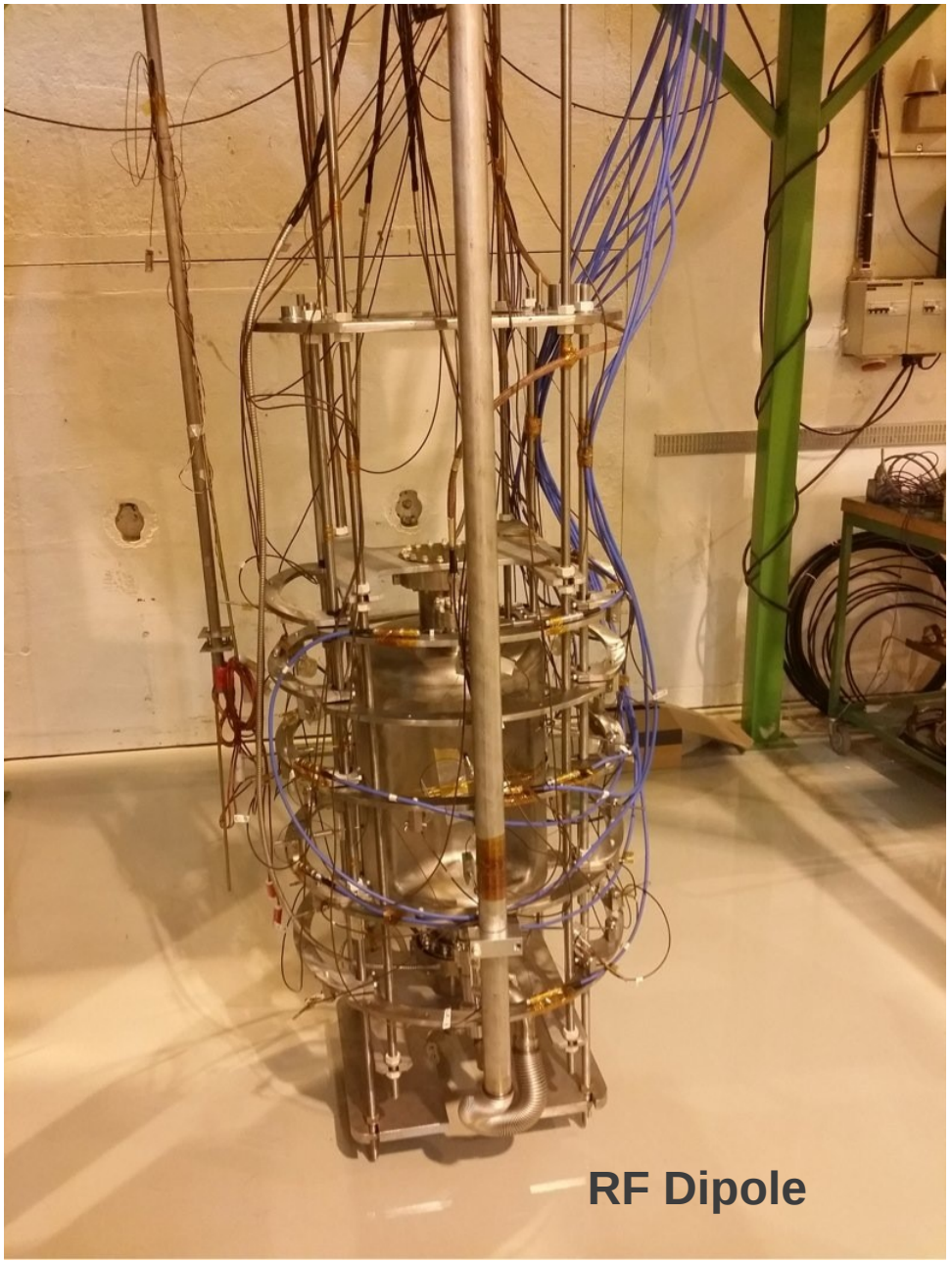


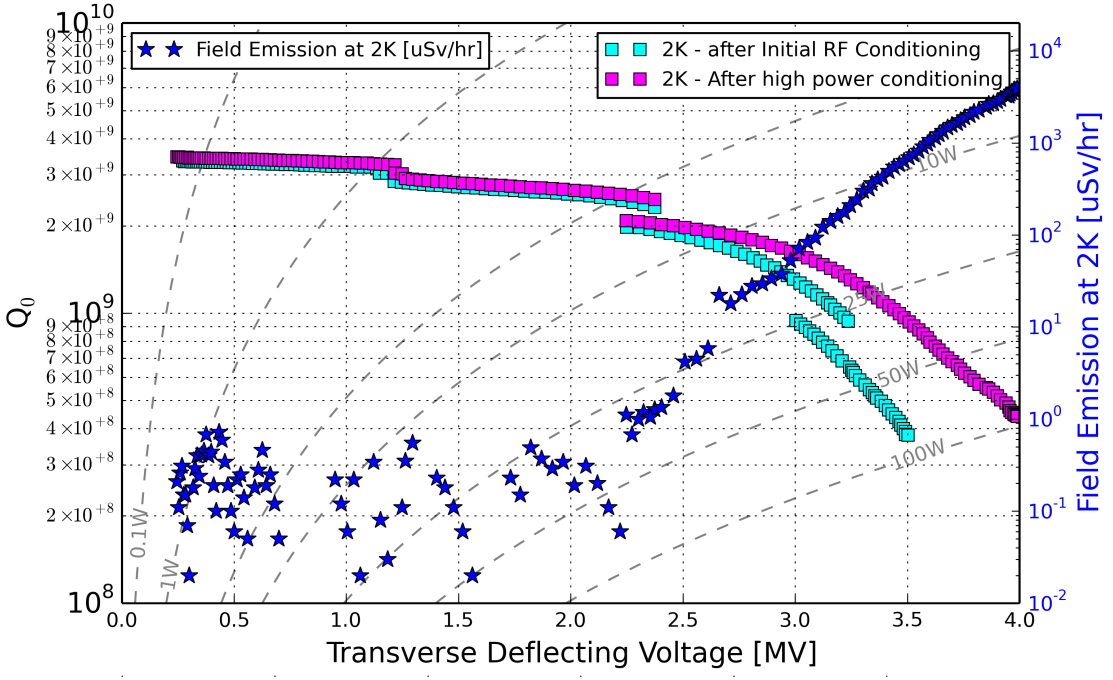
280 mm



281 mm

# Recent Tests at CERN

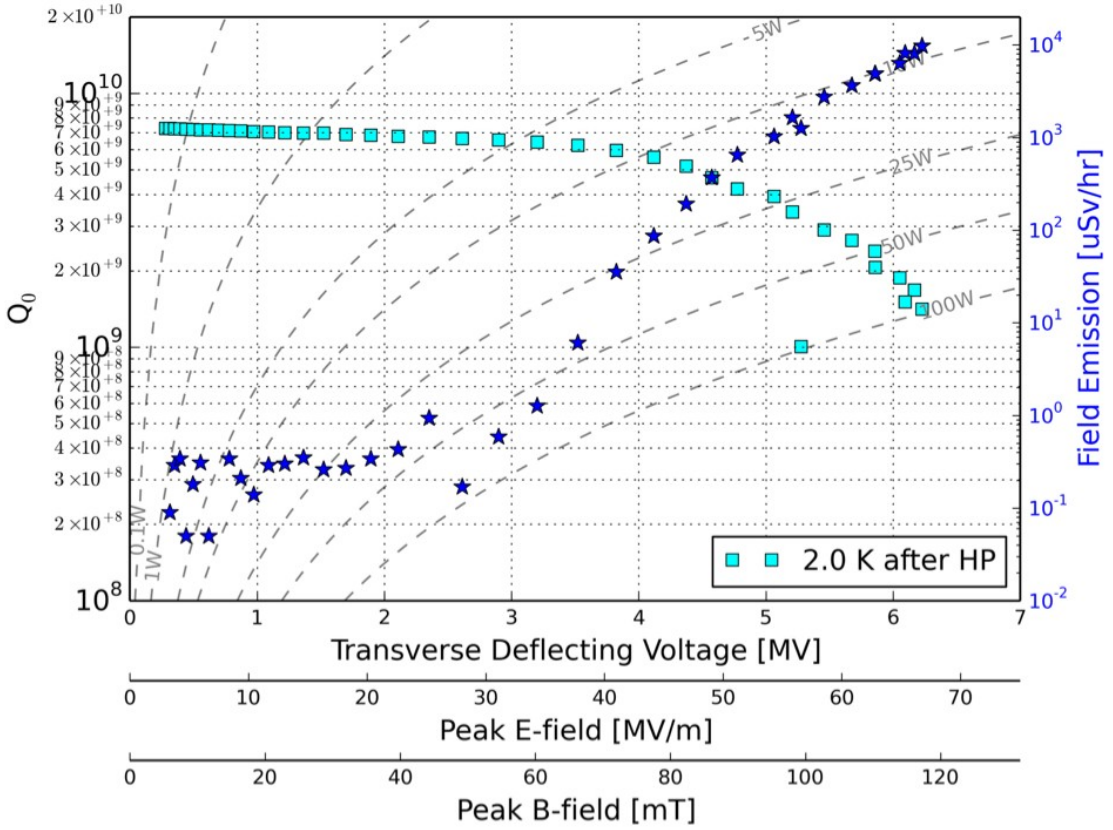



Similar results to BNL tests

3 Q-switches, voltage reach of 5 MV

(RGA showed quite high $CO/CO_2$)



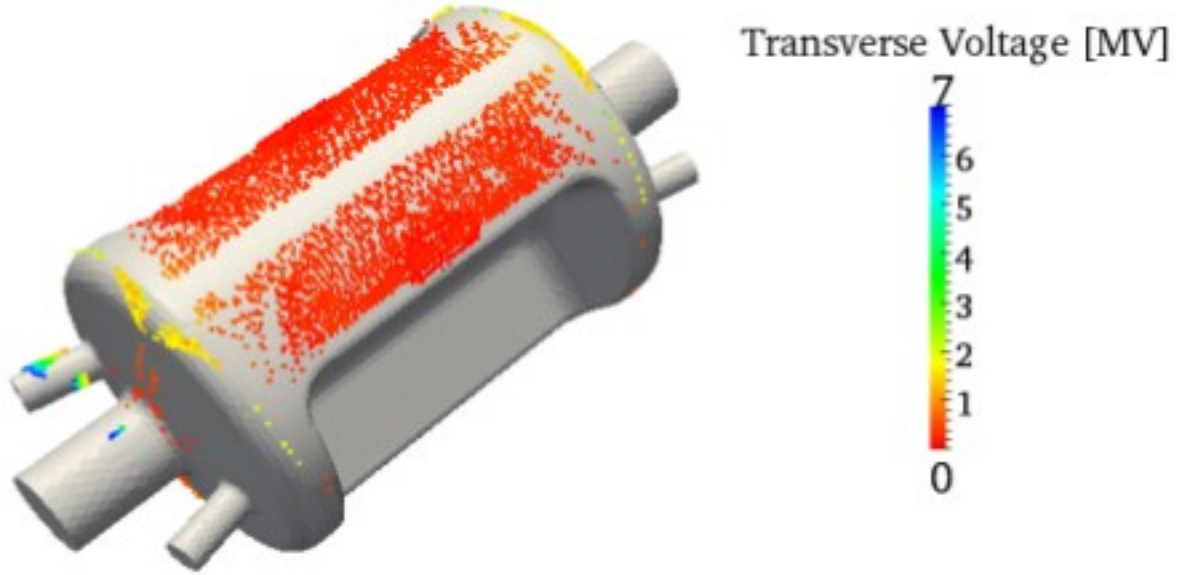

Results slightly worse than Jlab tests

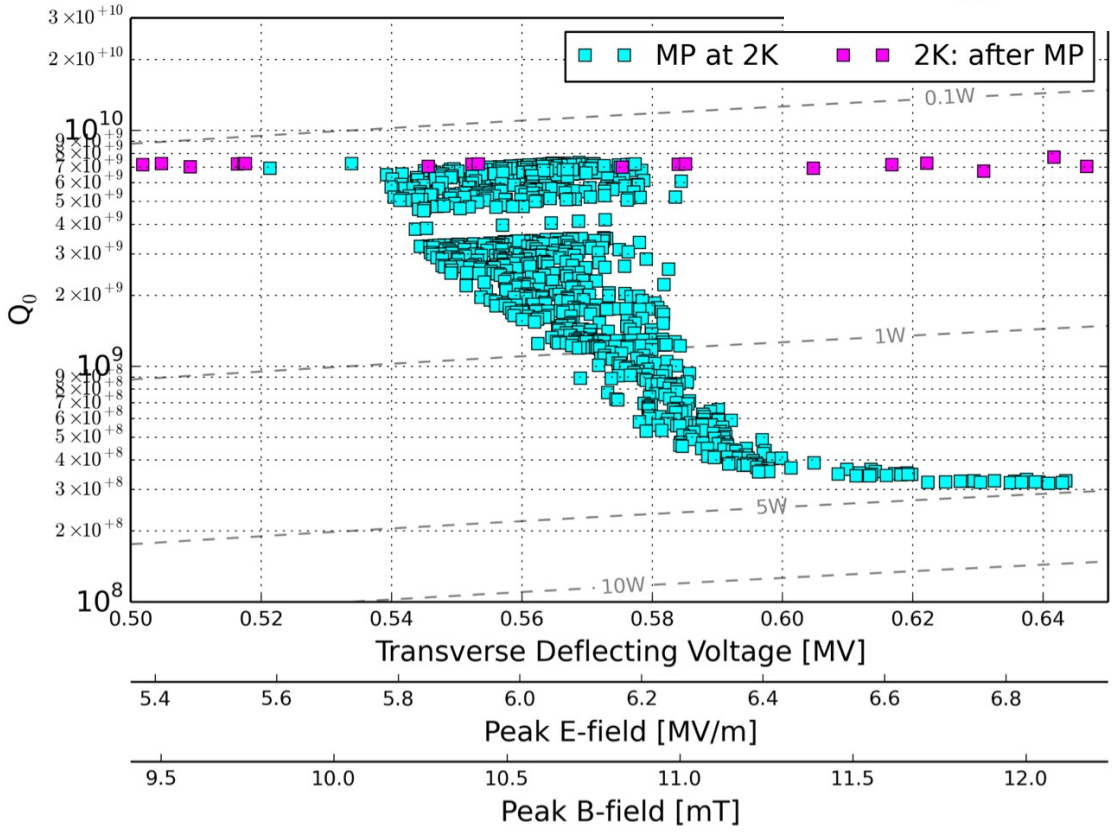
Very high FE (Temp rise at E-field region)

Courtesy: A. Macpherson et al.

# RF Dipole

Soft multipacting predicted at $V_T < 1$ MV, ACE3P (Z. Li et al.)



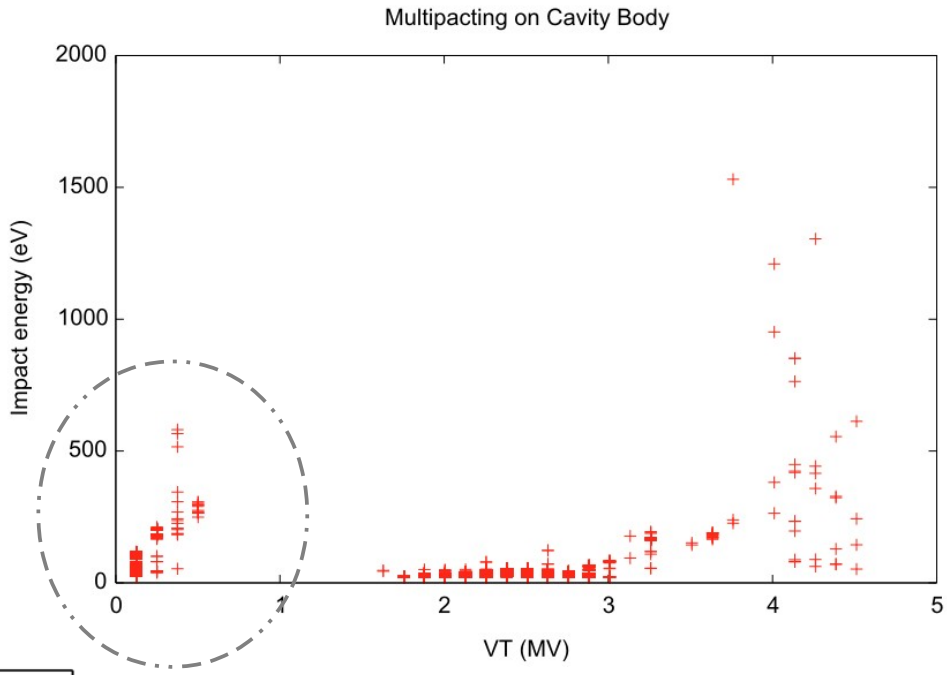

Measurements at CERN near the multipacting zone (A. Macpherson et al.)

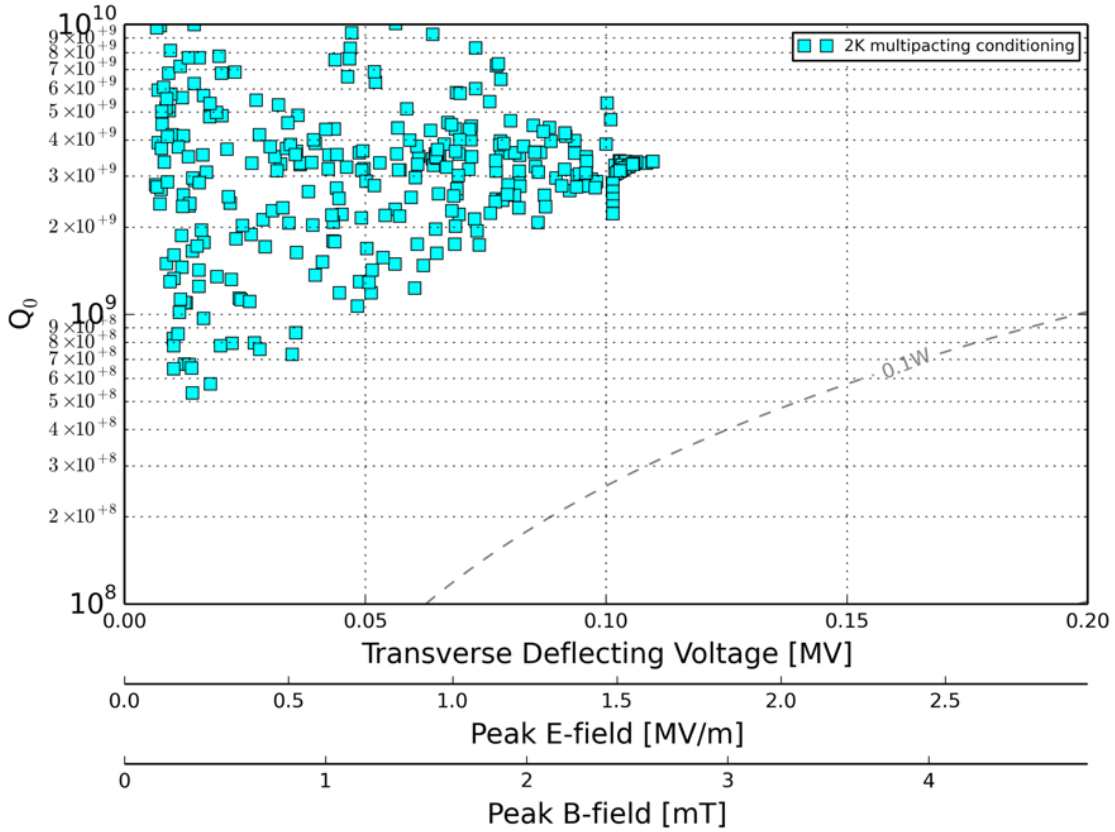
Processed away in ~20 min, doesn't come back

Courtesy: Z. Li, A. Macpherson et al.

# Double Quarter Wave

Multipacting predicted at VT <0.25 MV & 1.5-3 MV, ACE3P (Z. Li et al.)



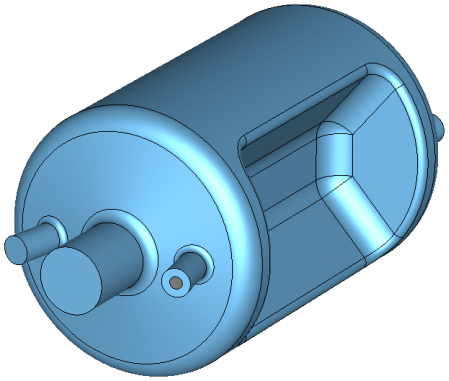



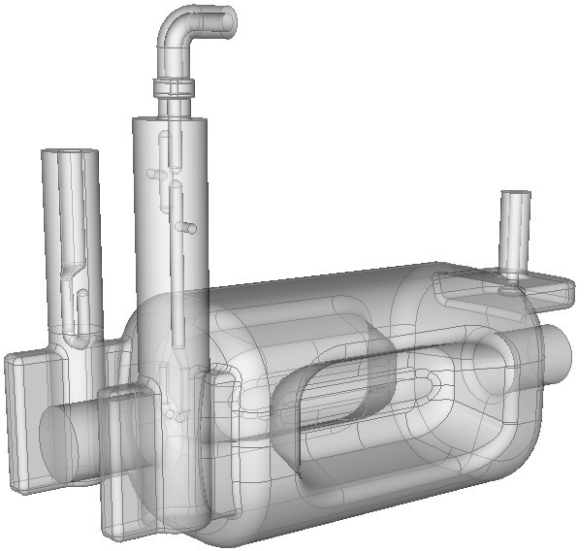

Measurements at CERN near very low field multipacting zone (A. Macpherson et al.)

Also processed away quickly

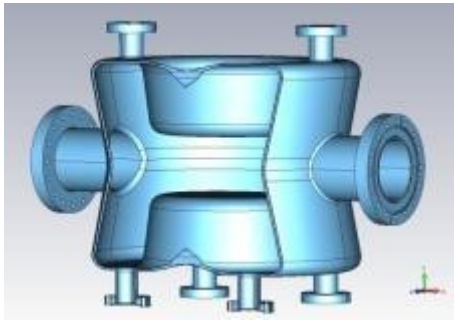
# Cavities for SPS Beam tests

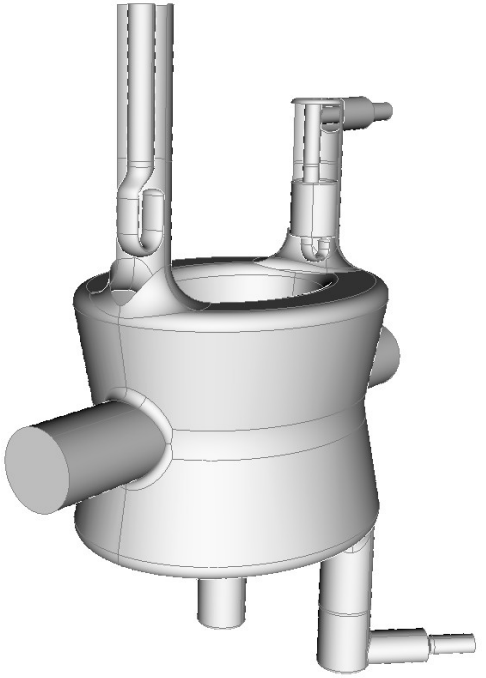
RF Dipole





Double Quarter Wave

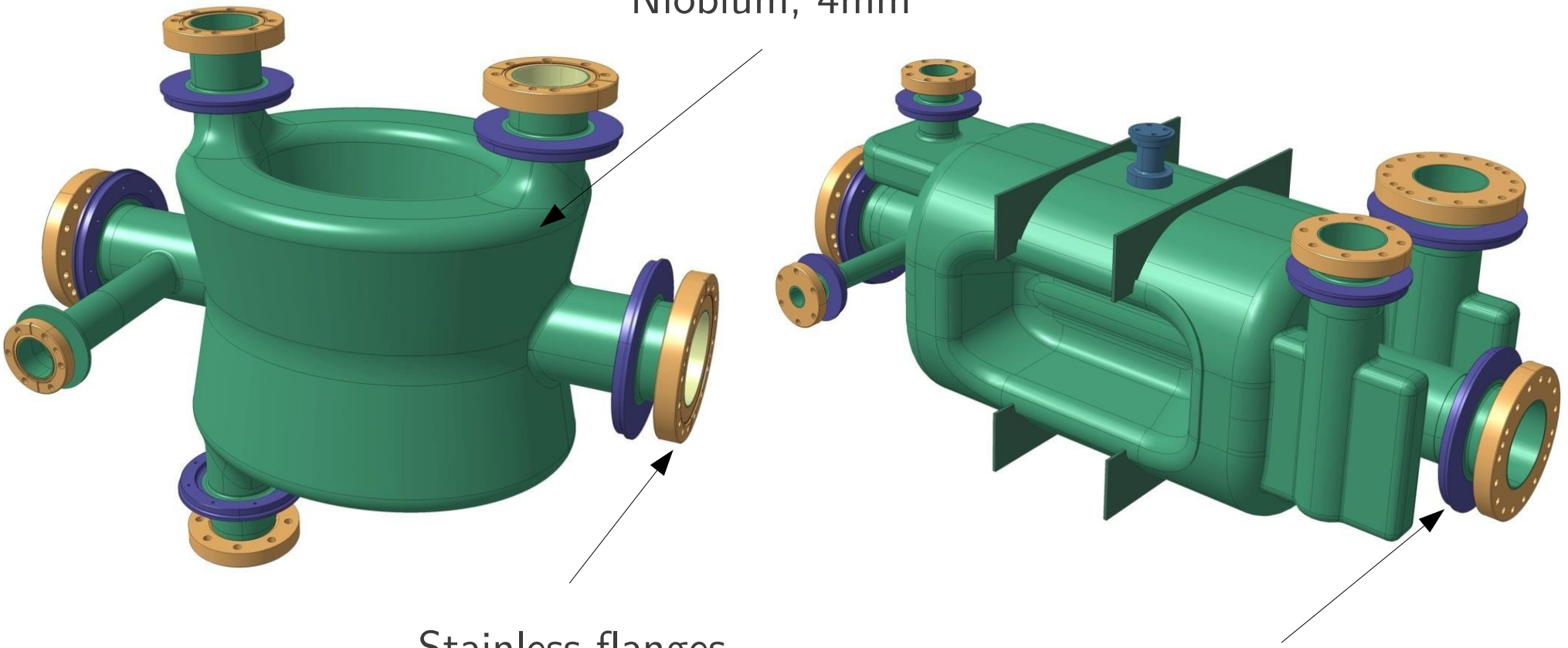




# Cavity & Interfaces

Courtesy: CERN EN-MME

Standardized interfaces for all ports



# He-Vessel, Ti

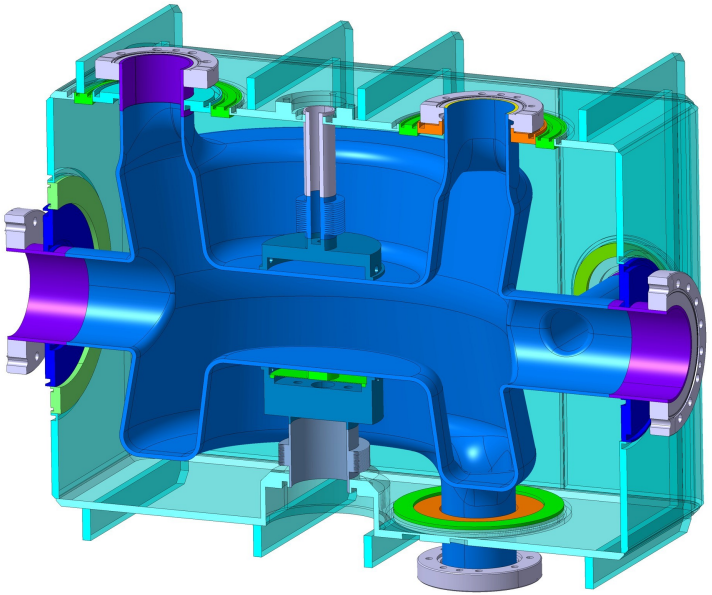
Courtesy: CERN EN-MME

Several ports, not completely symmetric

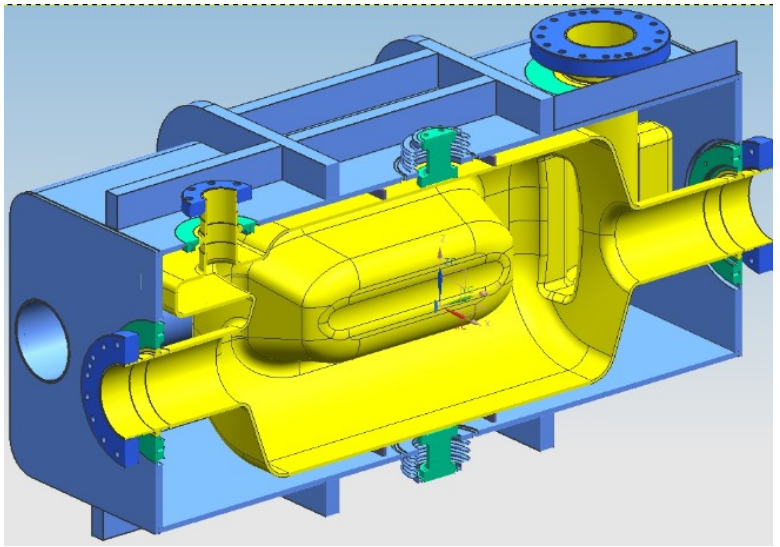
Ti vessel to minimize differential contraction (avoid bellows)

(For DQW, the vessel is also acts as stiffner)

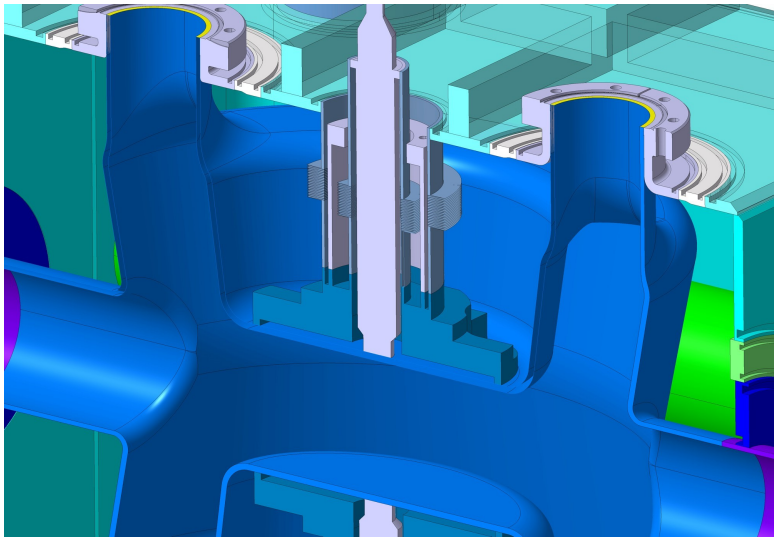
Double Quarter Wave

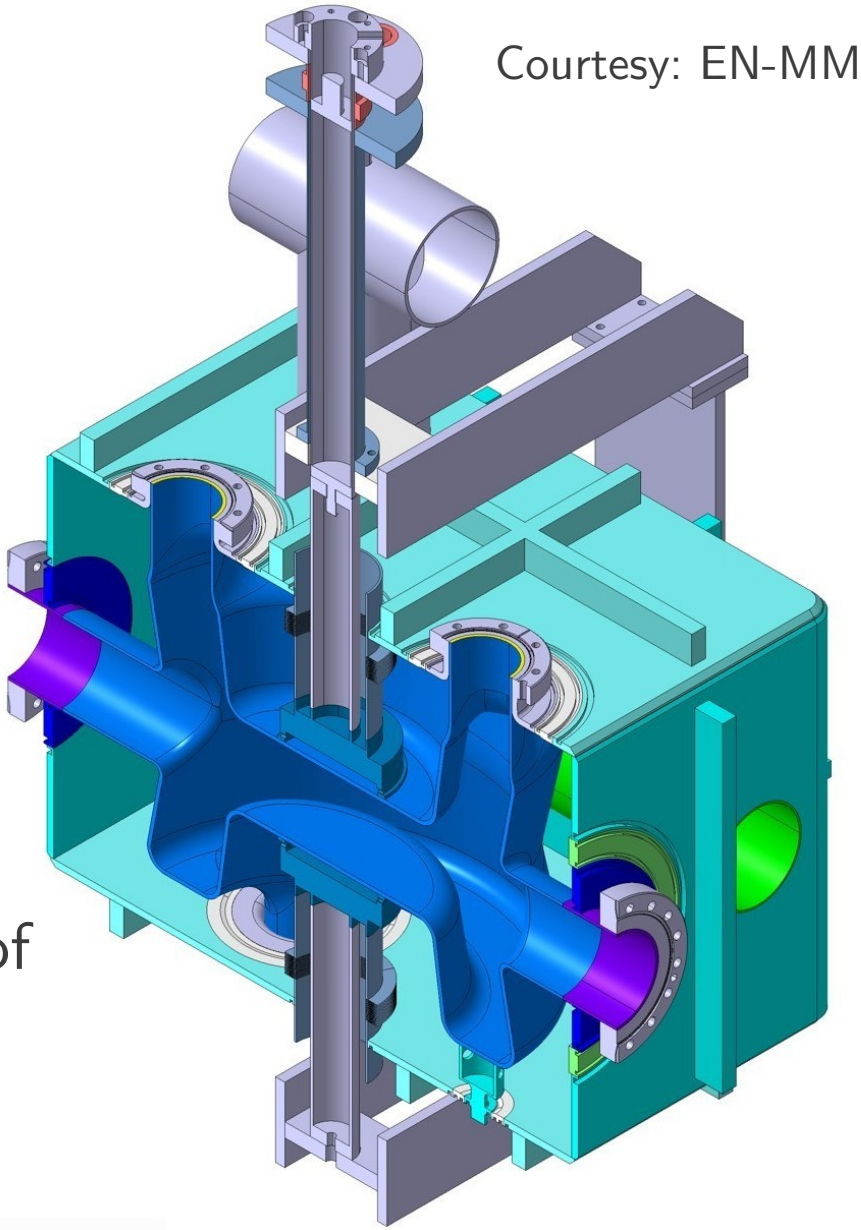


RF Dipole



# Cavity Tuning (DQW Example)





Courtesy: EN-MME

Push-pull from differential movement of concentric Ti-cylinders
(adapted from Jlab scissor-jack)

Symmetric deformation with frame around & warm actuation system

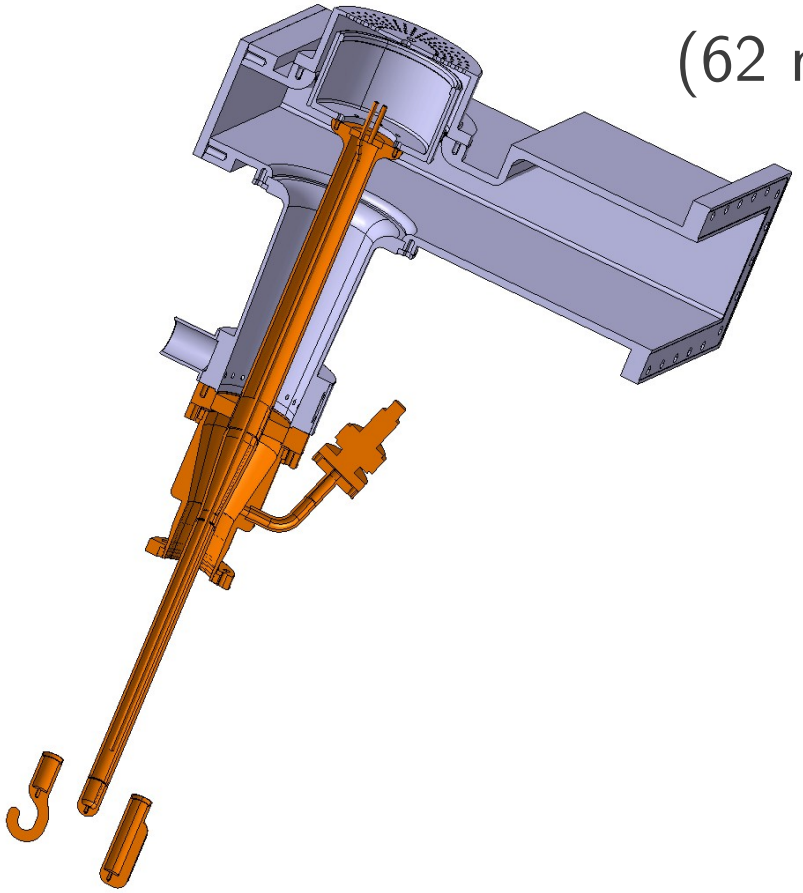
Similar on RFD

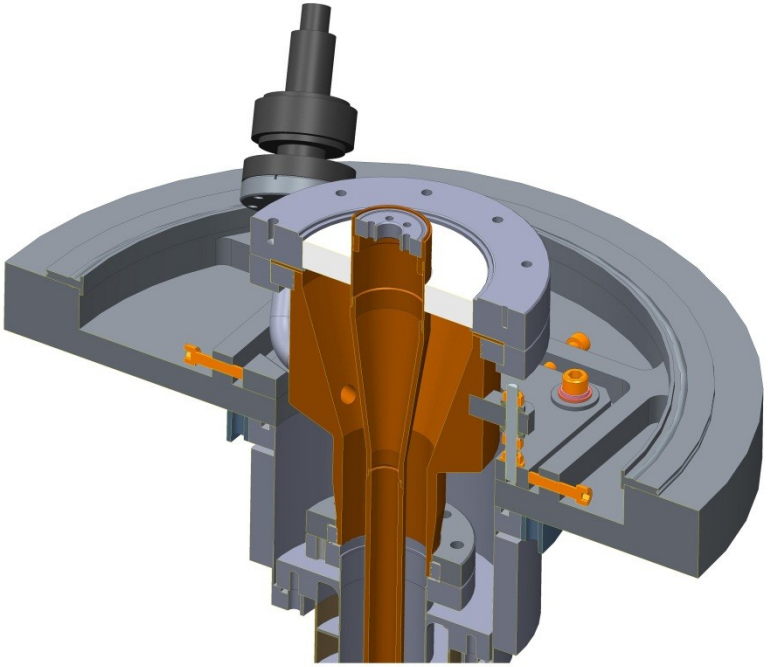
# Input Coupler

Courtesy: E. Montesinos

Custom made coupler, 50kW CW

(62 mm ID, 50Ω, SPS like disk ceramic)



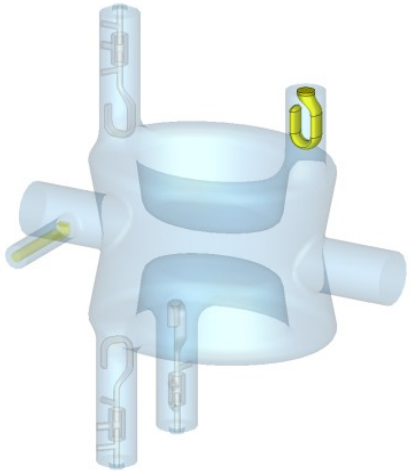


Conical transition to go to bigger ID

for ceramic with air flow

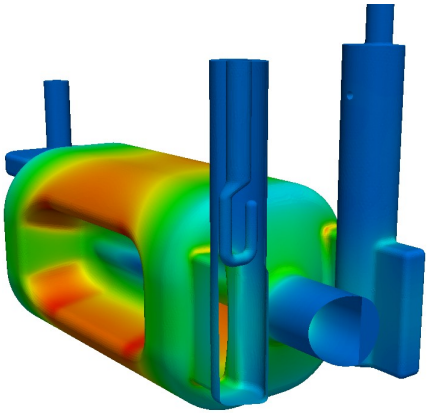
# FPC Heating

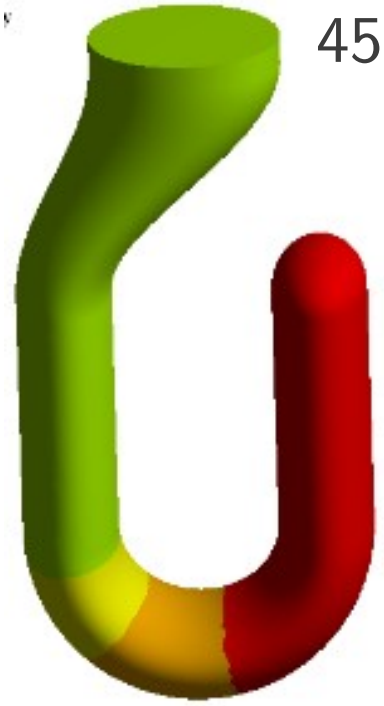
Courtesy: S. Verdu, Z. Li et al.



Qe = 5 x $10^5$

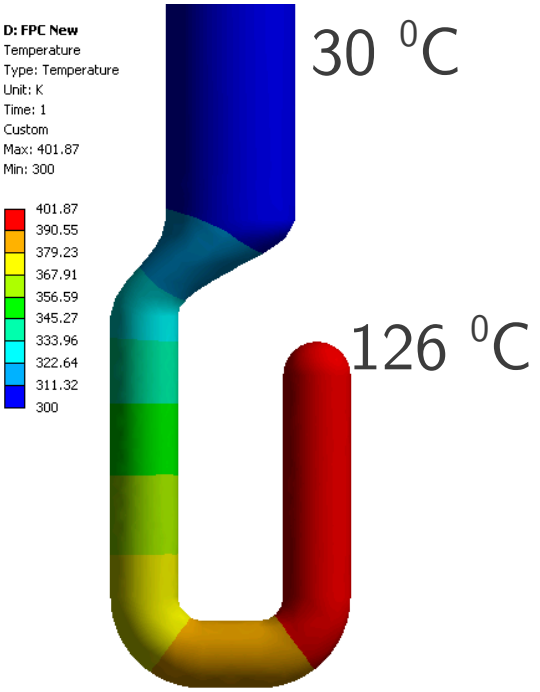
P ~ 60 W (T~100 deg)





45 $^0$C

90 $^0$C




30 $^0$C

126 $^0$C

Radiation losses to 2K

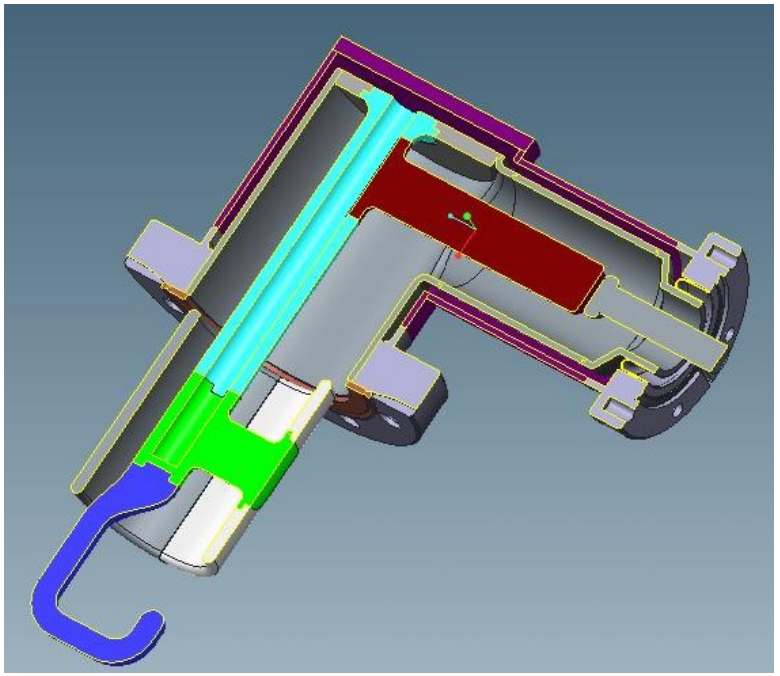
< 1 W (F. Carra)

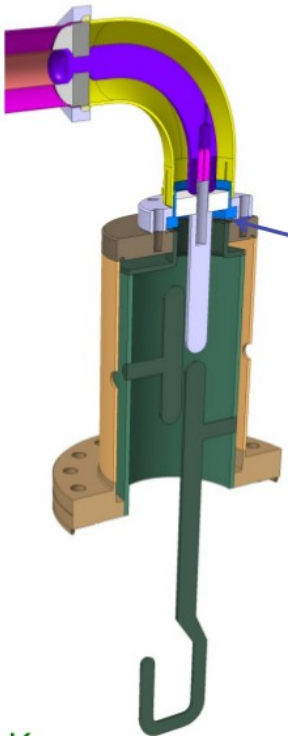
# HOM Couplers

CW LHC beam (1.1 A), very strong damping + HOM power

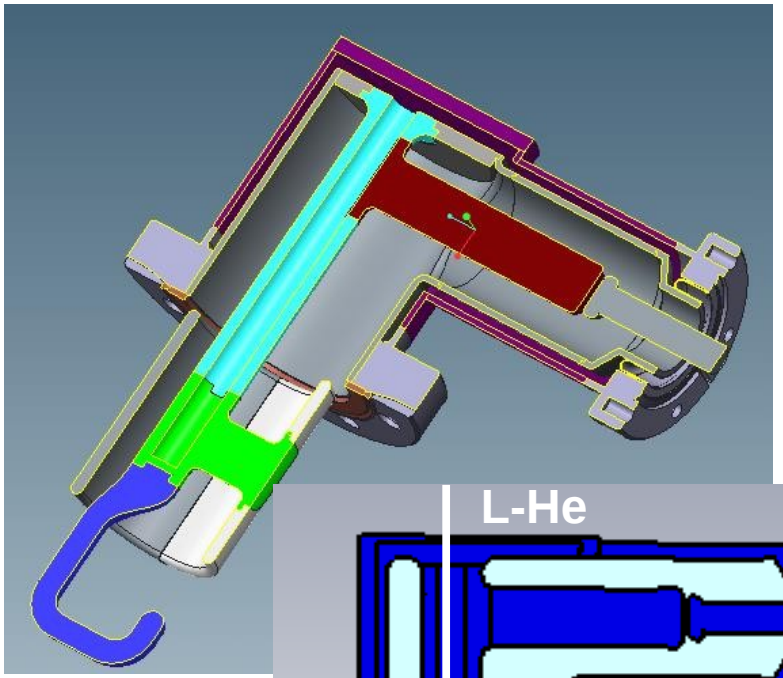
Two different "high-pass" like concepts

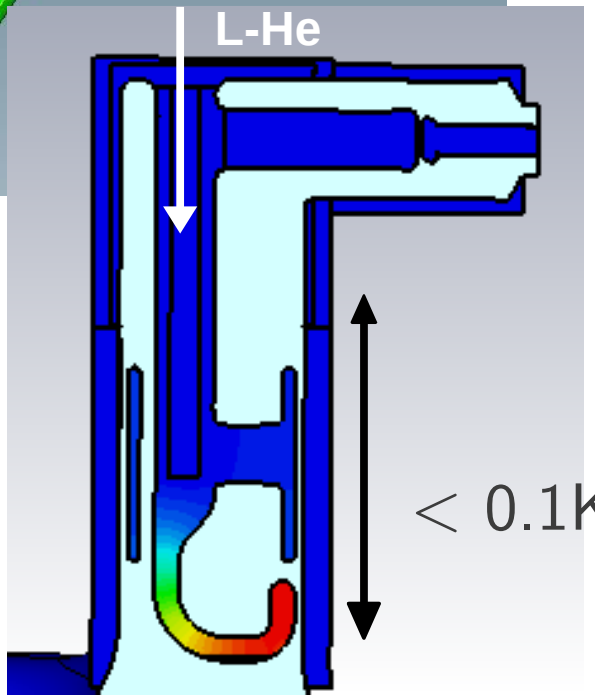
Challenge: Very tight tolerances (sub-mm) !





# HOM Damping

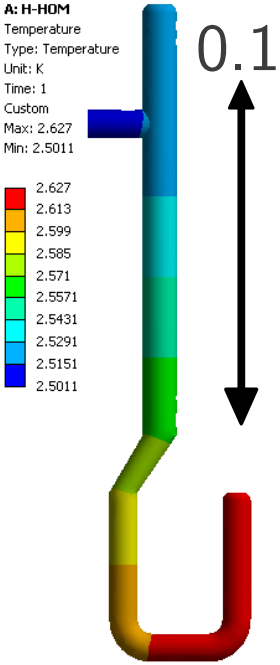


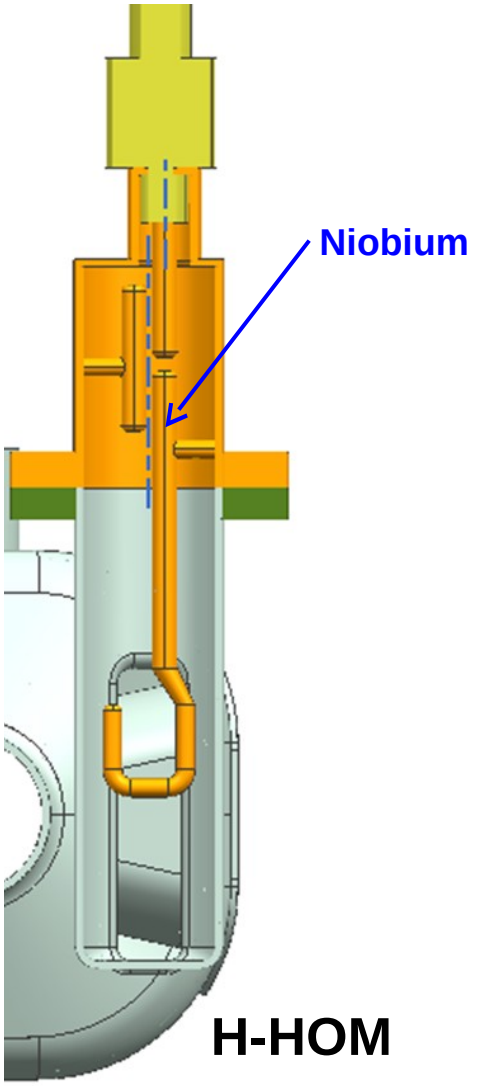



$<$ 0.1K thermal gradient

Conduction cooled

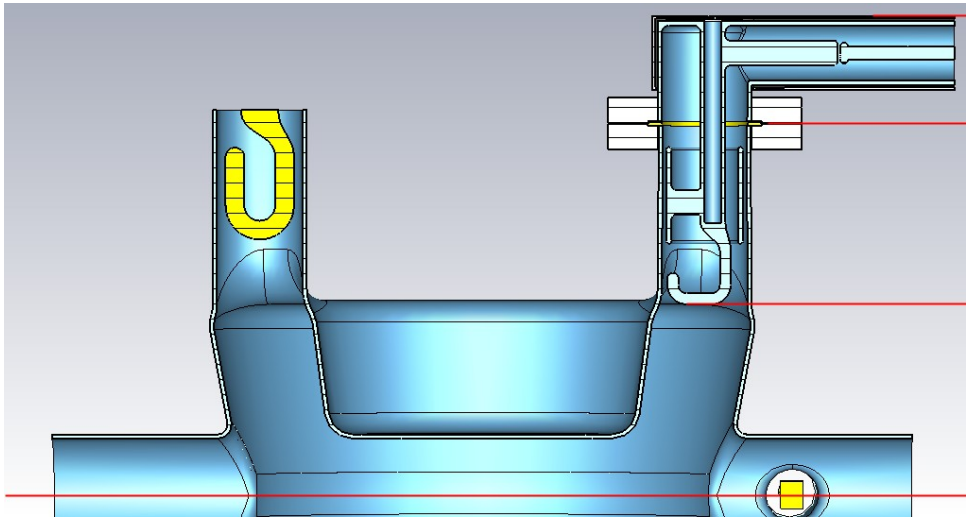
0.1K thermal gradient



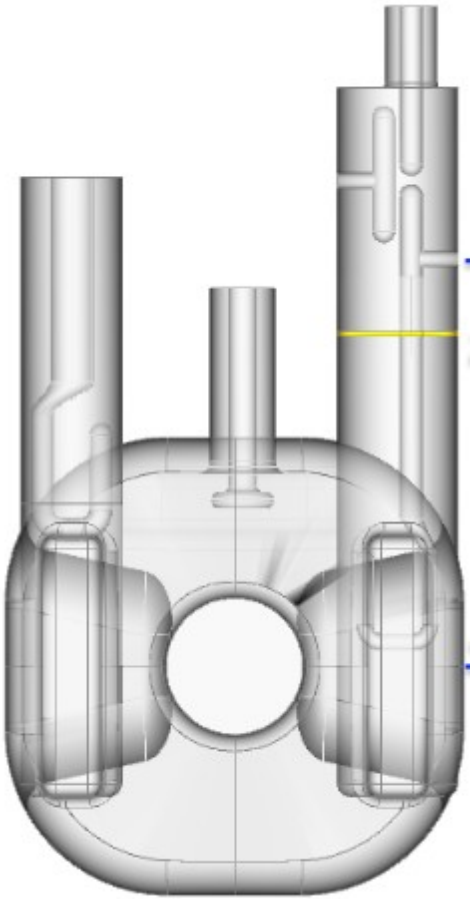



# Heat Load Optimization

Courtesy: S. Verdu, Z. Li et al.



SPS tests pose strict 15W per cavity constraint @2K



Cavity RF losses 3W

FPC radiation $< 2$ W

Cu gaskets: $< 0.3$ W

HOM couplers: $< 2$ W

Static losses: 7 W

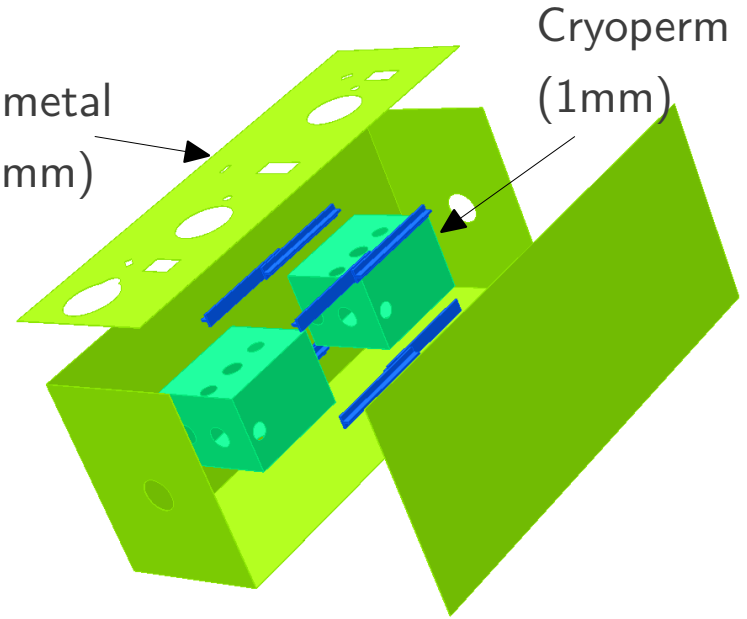
(No 4.5K Shield)

# Magnetic Shielding

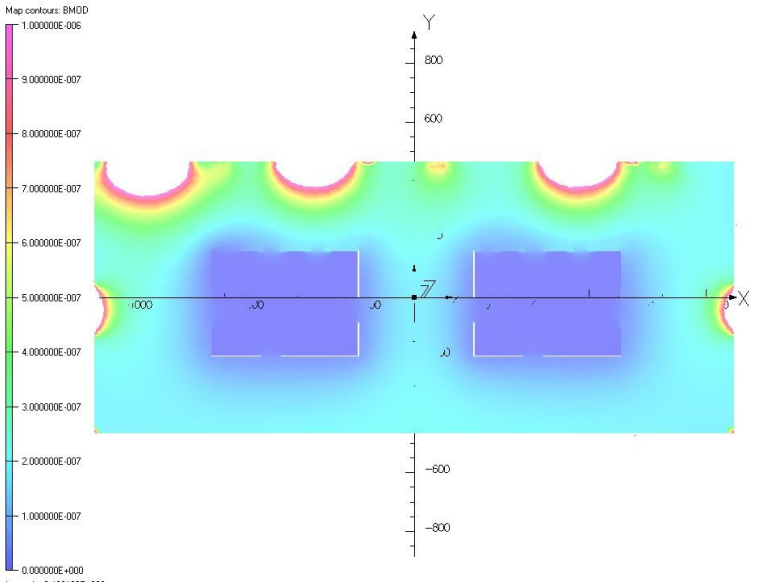
Courtesy: T. Jones et al.

Specification: ~1μT (≤ 1nΩ)

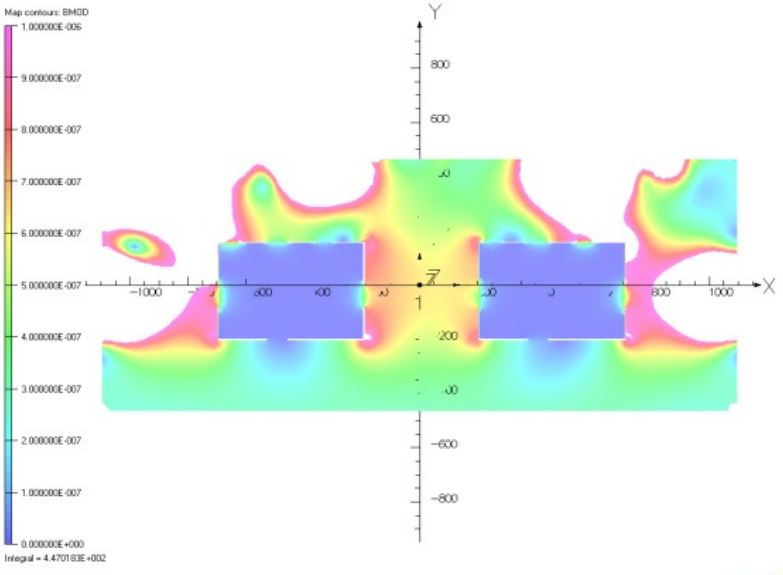
Double layer shielding for additional safety




Transverse B-Field (60 μT)

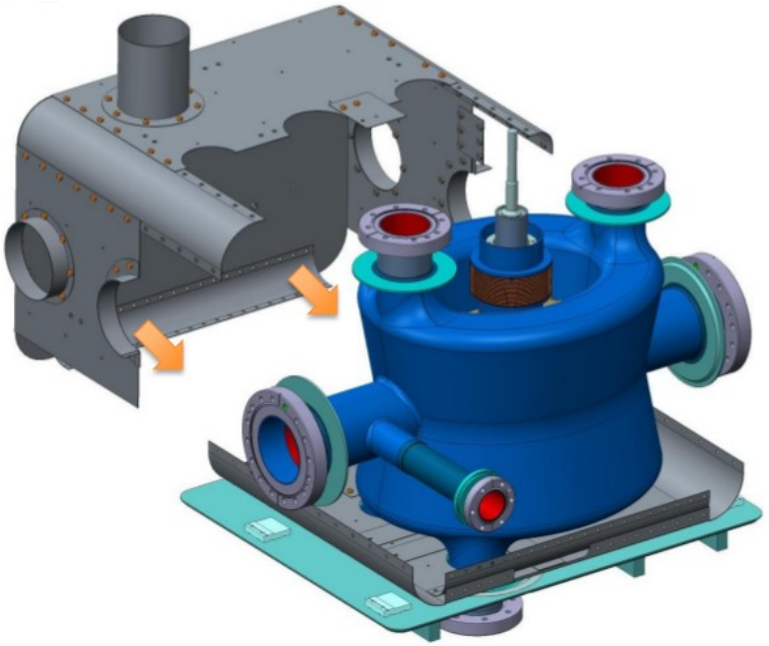


Longitudinal B-Field (60 μT)

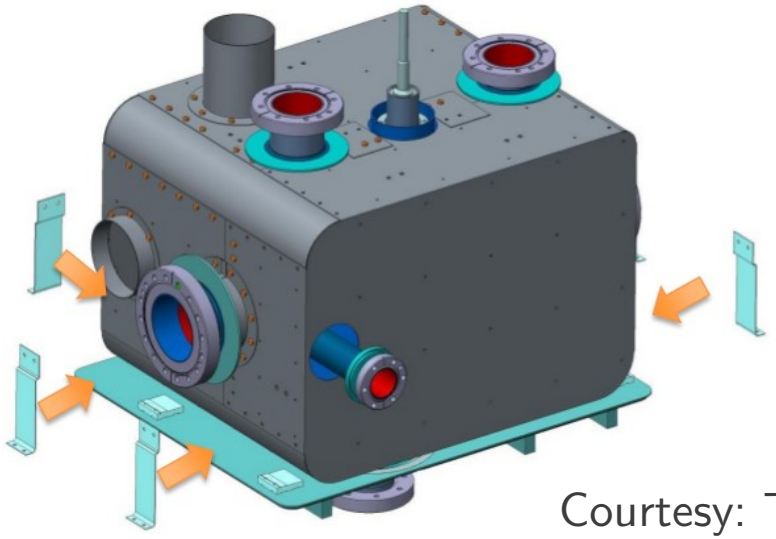


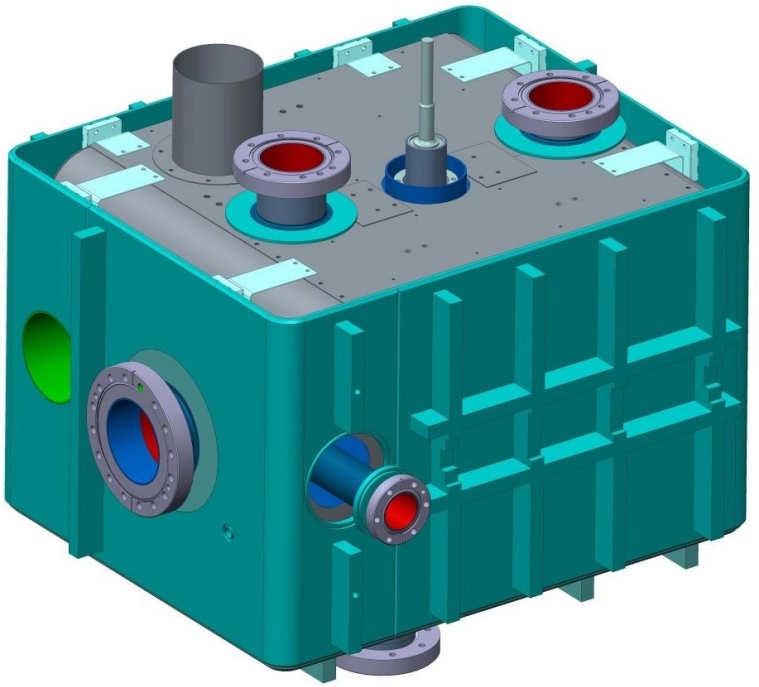
With single shield, red: 1 μT & blue: $< 0.01$ μT

# Internal Cold Magnetic Shielding



Better shielding due to many port openings & less constraints on the inter-cavity support



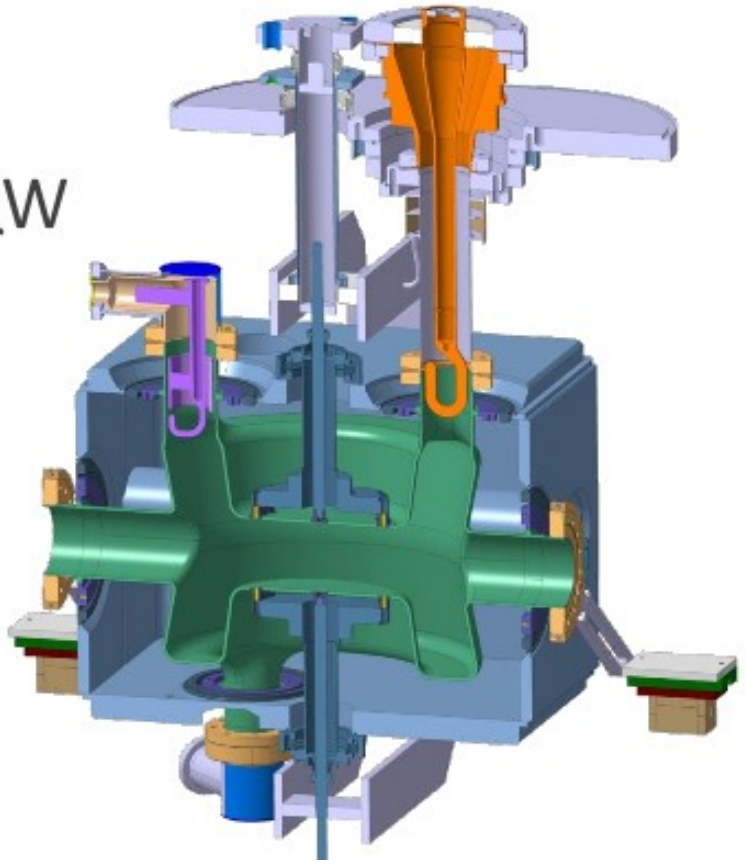


Courtesy: T. Jones et al.

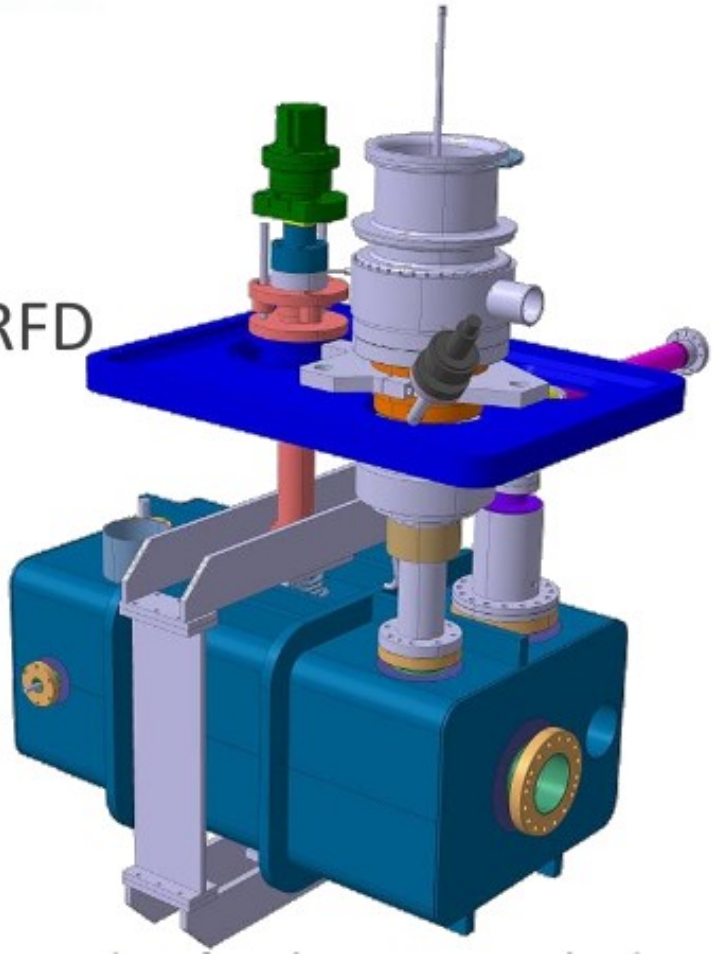
# Cavity Cold Mass

Courtesy: CERN EN-MME

DQW



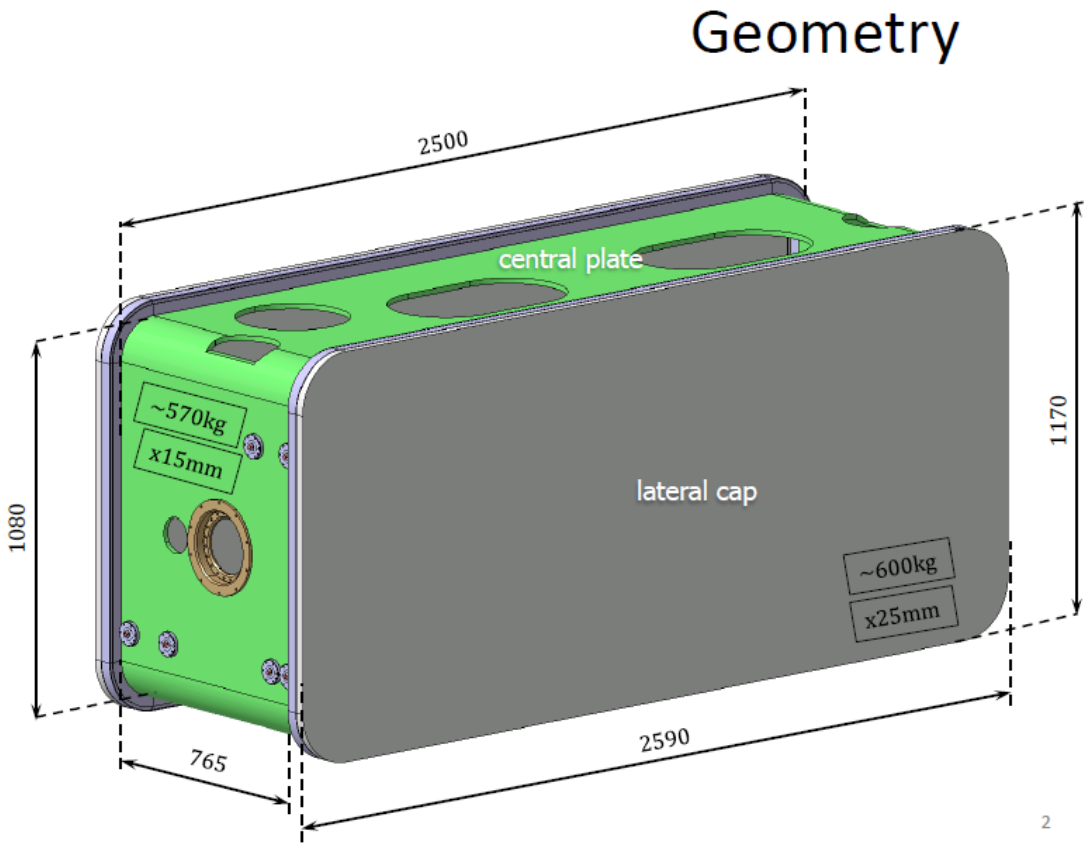
RFD



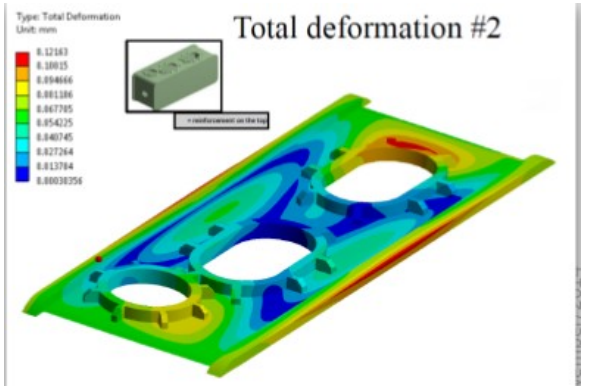
Pressure loading and alignment requirements defined the choice of interfaces and connections to He-vessel.

# Vacuum Vessel

Courtesy: CERN EN-MME

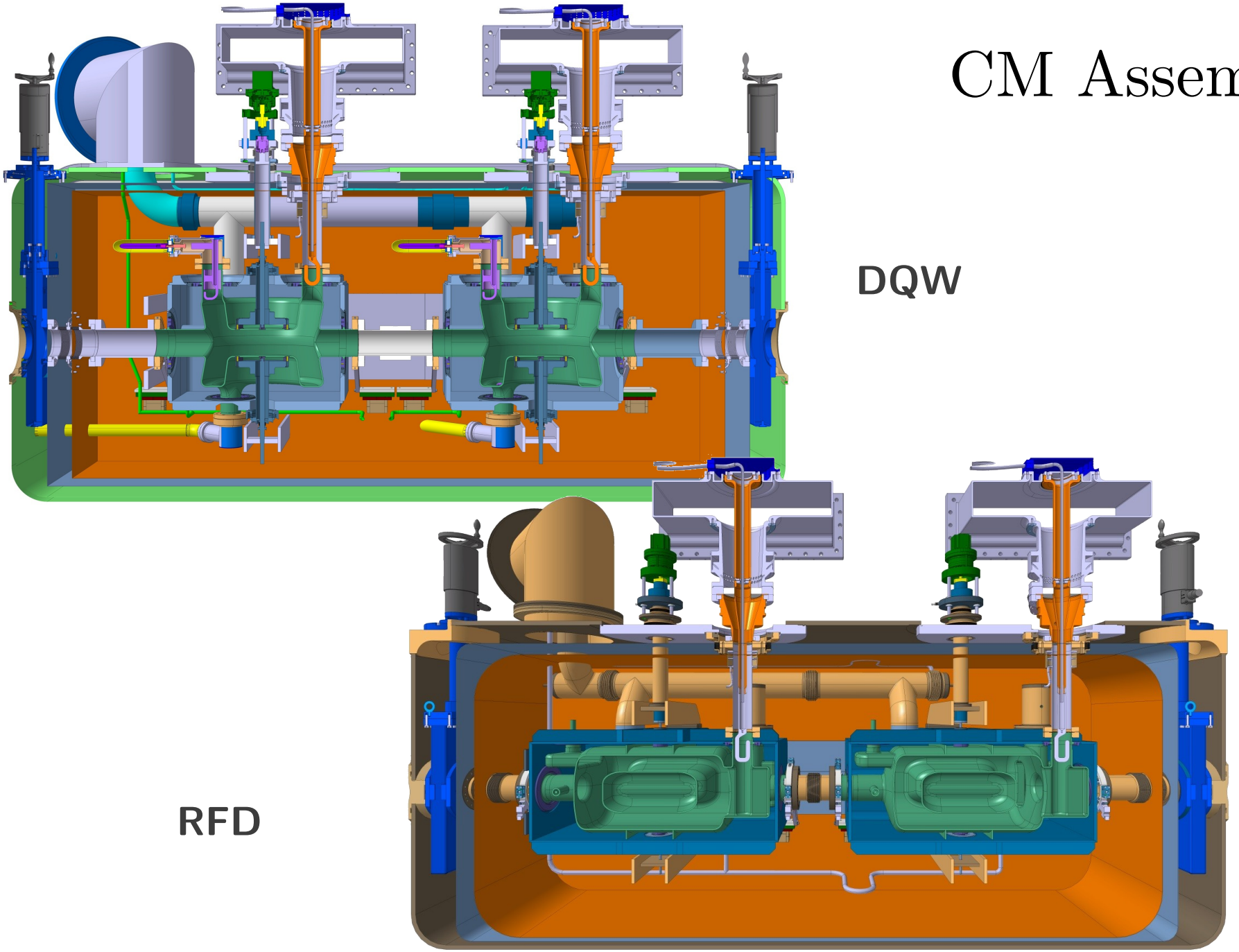



Side-loading concept with Lateral removable plates for R&D module (S. Pattalwar et al.)




Limit deformation to $< 0.1$mm and ensure cavity alignment

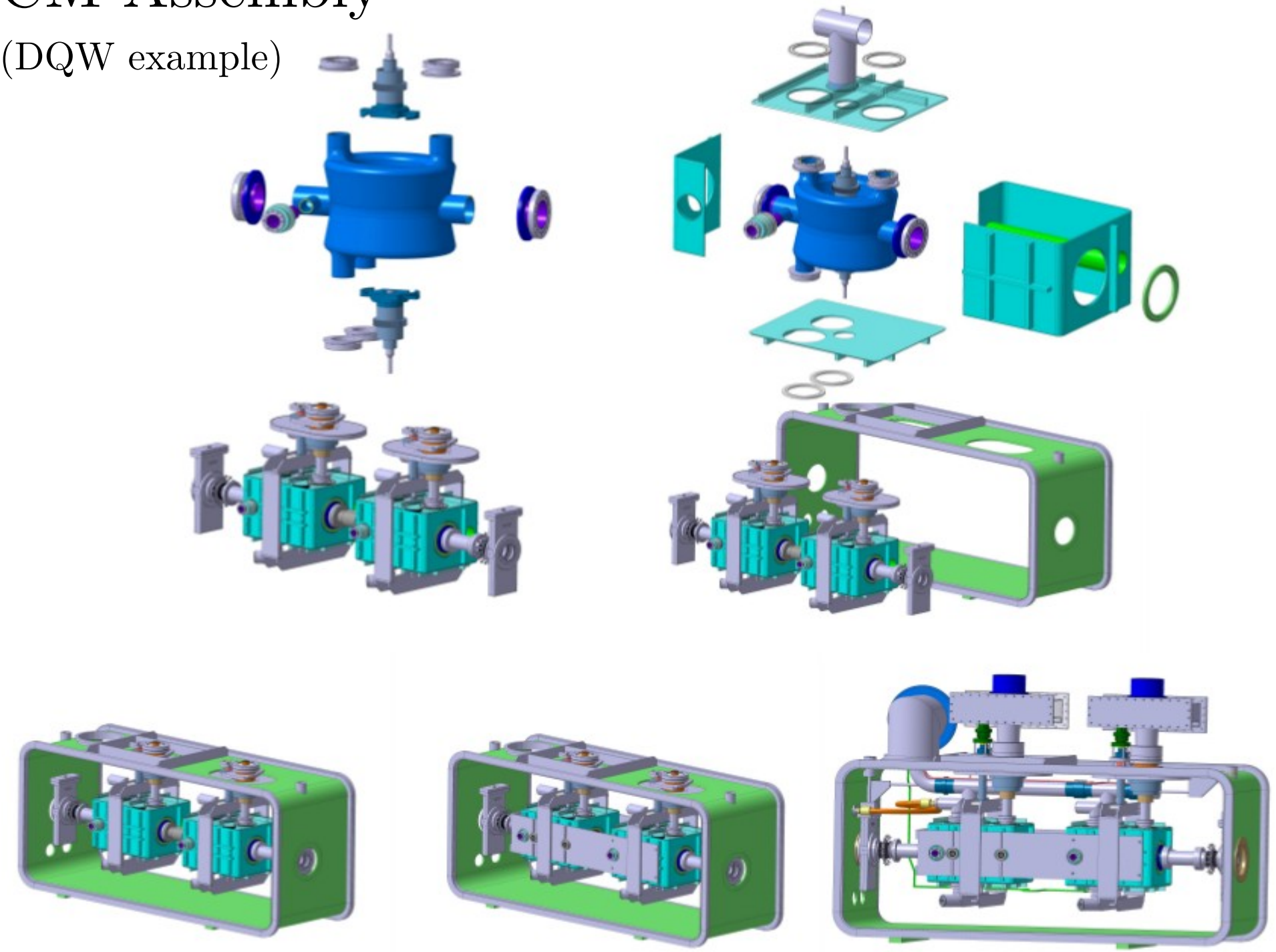
# CM Assembly



# CM Assembly

(DQW example)

Courtesy: CERN EN-MME



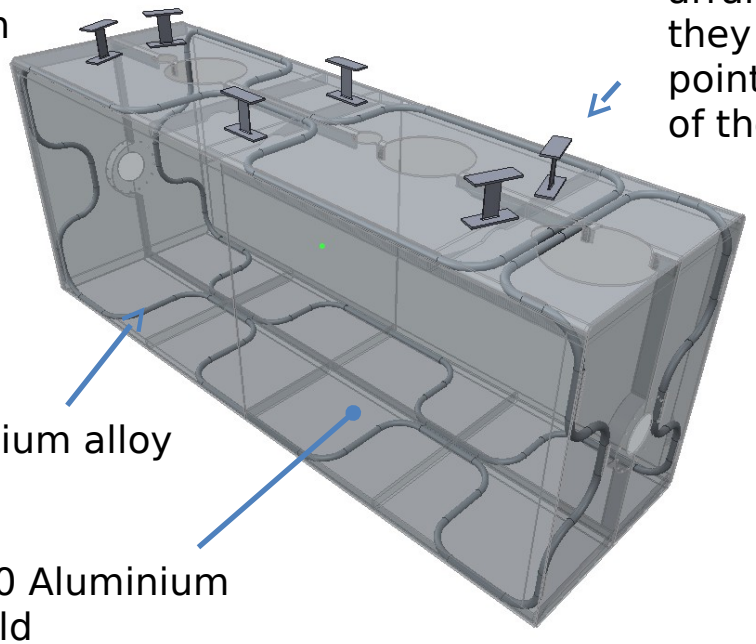
# What did he pick ?

# Thermal Shield

T. Jones, A. May et al.

Flexures optimised for maximum stiffness at 1W heat leak – 2mm thick x 40mm chosen

Flexure mounts arranged such that they create a fixed point at the centre of the shield.

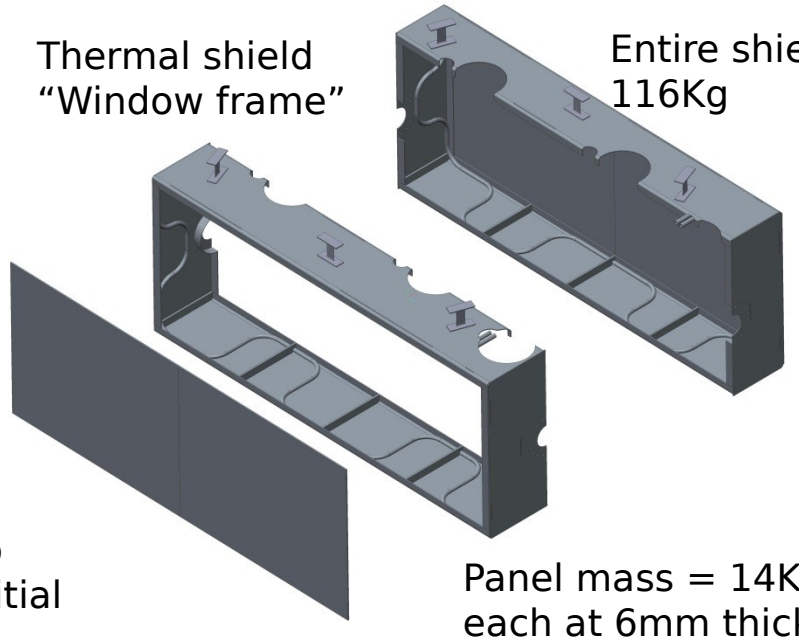


Aluminium alloy tubing

1050 Aluminium shield

Thermal shield "Window frame"

Entire shield = 116Kg



Removable side panels (fitted to frame during initial assembly)

Panel mass = 14Kg each at 6mm thick

# CM String Support
## (RF Dipole Example)

Tom Nicol/Fermilab