SESSION III SUMMARY
CAVITY DESIGN

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Talks

- Impedance and stability (Elena Shaposhnikova)
- KEK R&D for LHC (Kota Nakanishi)
- LARP R&D for LHC (Zenghai Li)
- UK R&D for LHC (Graeme Burt)
- Parallel-bar cavity (Jean Delayen)
- Compact Cavities (Erk Jensen)

Summary: longitudinal impedance budget

- Requirement for HOM damping in LHC given so far is 60 kOhm (defined by 200 MHz RF at 450 GeV)
- For nominal intensity
  - in 400 MHz RF system we have 80 kOhm for small emittance beam (1 eVs) at 7 TeV, 300 kOhm for 2.5 eVs
  - in 200 MHz RF system it is 70 kOhm , but the 400 MHz RF system can be used as Landau system
- Assumption: no loss of Landau damping due to broad-band impedance (ImZ/n > 0.1 Ohm, budget estimation in LHC DR - 0.07 Ohm), possible for small emittances (<0.7 eVs) at injection into 200 MHz RF system or at 7 TeV in the 400 MHz RF system (< 1 eVs)

➢ 10 kOhm for upgrade intensity and two identical cavities

Summary: transverse impedance budget

- Threshold for the nominal intensity and one cavity at 450 GeV determined by the damping time of 60 ms is 2.5 MOhm/m
- With margin for particle distribution:
  - $0.6/(1-f_r)$ MOhm/m f_r [GHz] < 0.8
  - $1.2(1+2f_r)$ MOhm/m f_r [GHz] > 0.8
  - 3 MOhm/m at 800 MHz $\rightarrow$ 0.4 MOhm/m for upgrade intensity and 2 cavities
- Additional factor proportional to local beta-function $\beta/\langle \beta \rangle$

KEK activities (800MHz)

- New EP system
  - Construction will be completed in January 2010.
  - We will test this EP system for 509 MHz cavities.
  - We can modify this system for LHC CC.
  - HPR system will be also available.
- Vertical cold test for LHC CC
  - Our cryostat is applicable for LHC CC cold test.
  - We are planning to make a new RF system for 800 MHz.
    - Many 509 MHz components are convertible.
- Aluminum model cavity
  - We will make a aluminum model cavity.
    - To check fittings for new EP system and vertical cold tests.
- Multipacting properties were calculated by Solyak-san and Liling-san (@LARP).
  - Simulation reproductions observed maltipacting well.
  - Cavity design modified to improve multipacting properties.
  - According to experience about KEKB crab cavity, it is expected that some of multipacting levels which are found by simulation can be overcome easily.

Compact crab cavity (400MHz) @ KEK

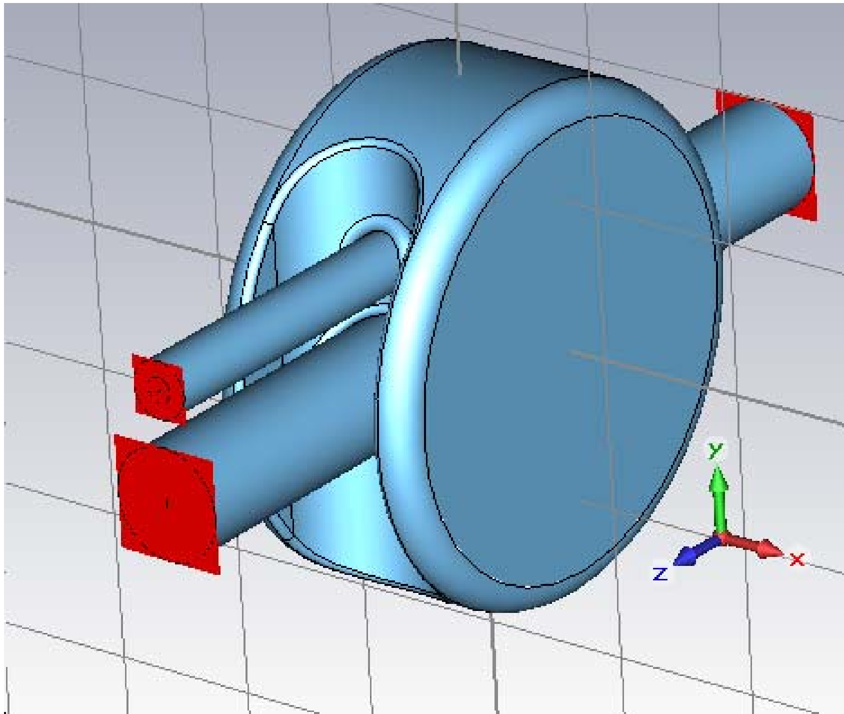
- RF properties of pillbox like crab cavity were calculated.

(1)Nose cone geometry is decided to make higher kick voltage and crab mode lowest.

(2)Some HOMs are not dumped well. It must be considered to meet required impedance.

(3)External Q-value of input coupler can adjust freely. It can be made from critical matching to less than 10^5.

(4)Available kick voltage is expected about 1MV @ 4.2K.

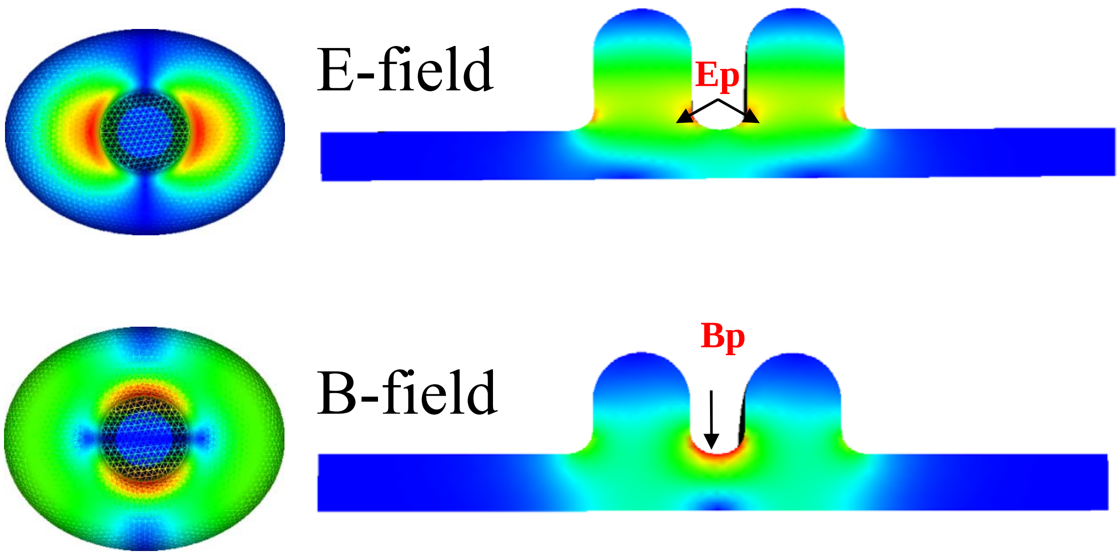


800-MHz Crab Cavity – LARP R&D

800-MHz, 2-cell elliptical shape was chosen as baseline design at LARP-CM11

Detailed cavity design and optimization performed, progresses are being made to integrate into the cryostat design

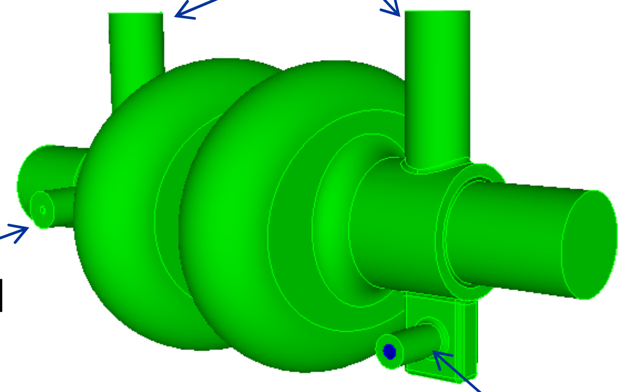
Cavity RF parameters



Frequency	800 Hz
$(R/Q)_T$	117 ohm/cavity
Deflecting Voltage V_T	2.5 MV
Deflecting Gradient E_{kick}	6.67 MV/m
E_{peak}	25 MV/m
B_{peak}	83 mT
Dip Mode separation	89 MHz

LOM,SOM,HOM, and Power Couplers

- High R/Q LOM/SOM, HOM well damped below, Qext < 250
- FM couplers re-designed to eliminate power coupling to LOM/SOM couplers



Damping Results

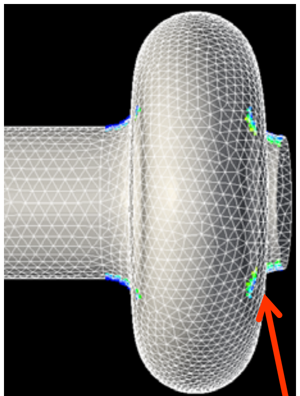
Monopole		
f	R/Q	Qext
5.91E+08	1.10	250
5.93E+08	191.20	202
6.11E+08	53.10	172
6.13E+08	42.40	206
1.35E+09	2.30	3464.16
1.36E+09	0.40	2491.76
1.46E+09	0.00	9705

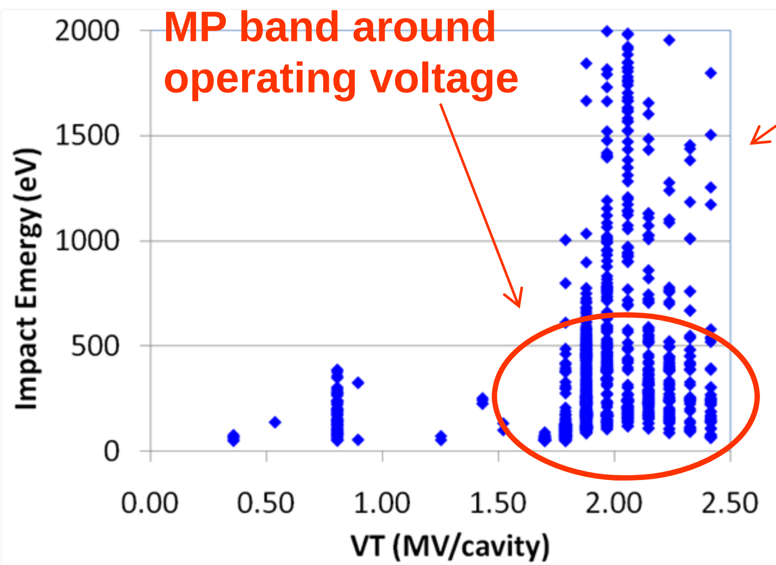
Horizontal DIpole		
f	R/Q_T	Qext
8.00E+08	**117.00**	**1.00E+06**
8.10E+08	0.03	1.00E+06
9.04E+08	1.30	1332.8
9.21E+08	12.40	5181.53
9.95E+08	10.70	2431.54
1.07E+09	8.50	2555.57

Vertical Dipole (SOM)		
f	R/Q_T	Qext
8.87E+08	83.40	185
8.90E+08	0.64	106
9.09E+08	9.10	79
9.36E+08	20.99	71
9.97E+08	7.10	119
1.07E+09	6.90	322

MP Analyses, Hard MP Barrier Removed

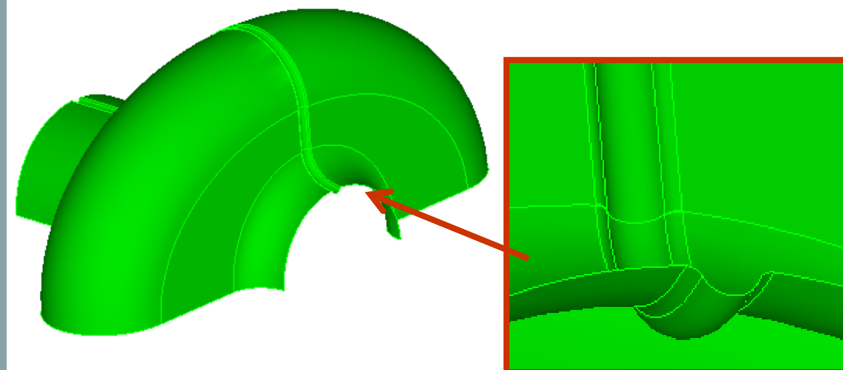
Identified potential hard MP barriers

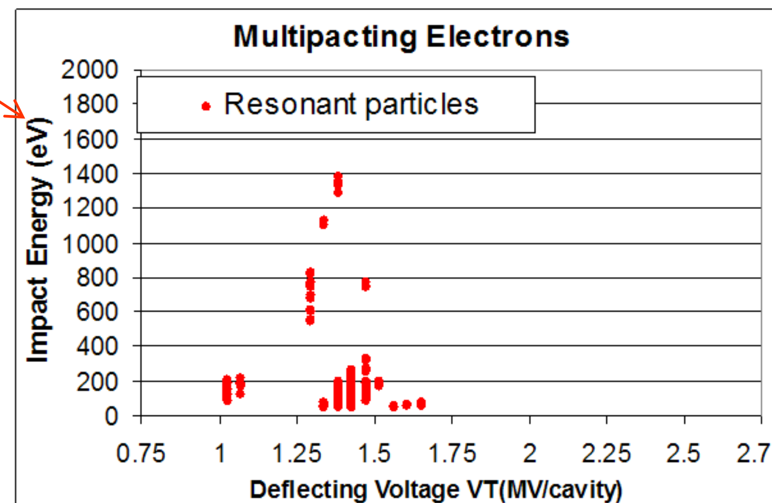




MP Map

Potential hard MP suppressed by modifying geometry

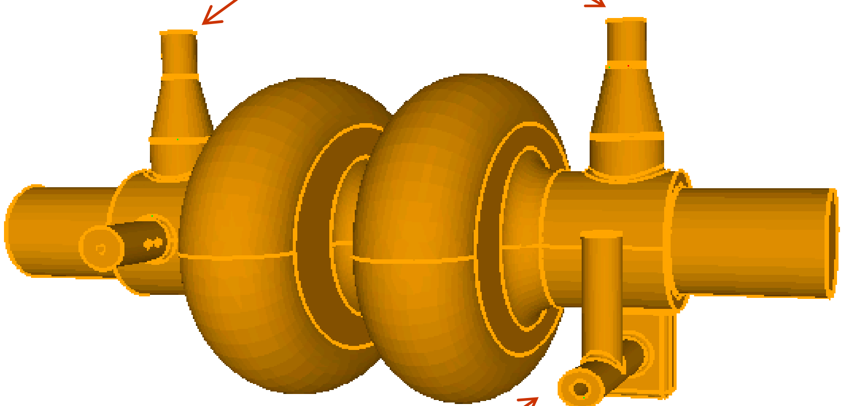




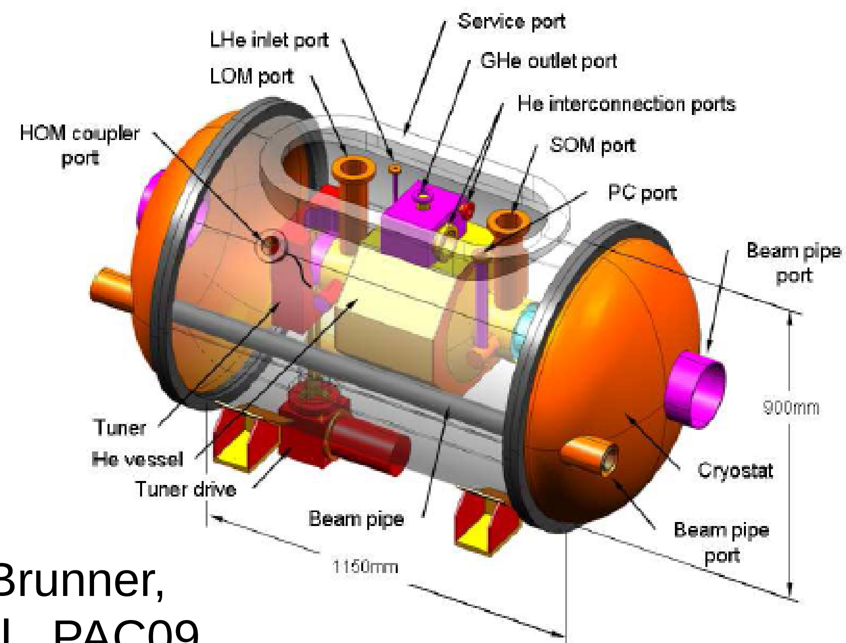
Towards Engineering Design

- Cavity dimension sensitivity and tolerances analyzed
- Progress being made towards an engineering design – the cryostat integration (FNAL)

Taper to smaller LOM/SOM size to minimize static heating



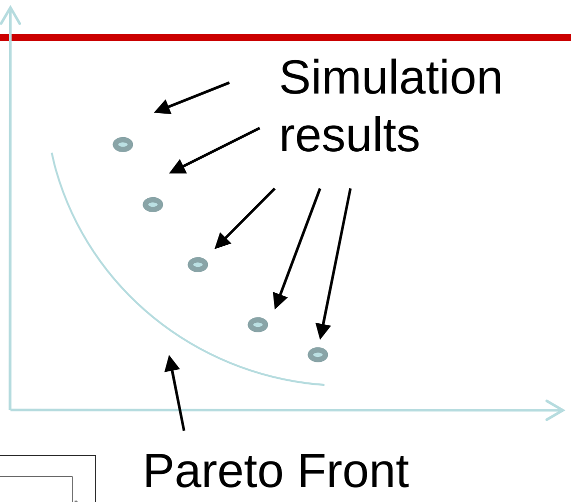
Elbow designed to turn FPC 90 deg upward to fit in cryostat

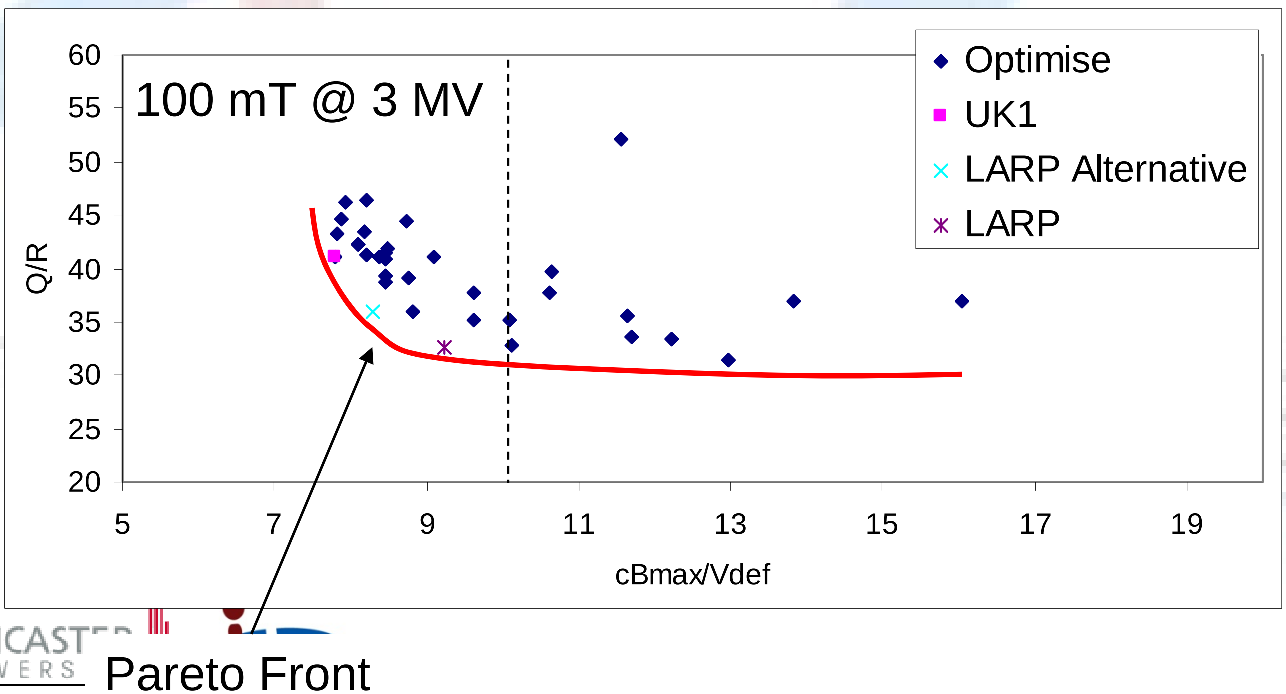


O. Brunner, et al., PAC09

Non-dominated optimisation

- Optimisation is based on a non-dominated technique where optimal solutions lie on the Pareto front and sub-optimal solutions lie in front of it.

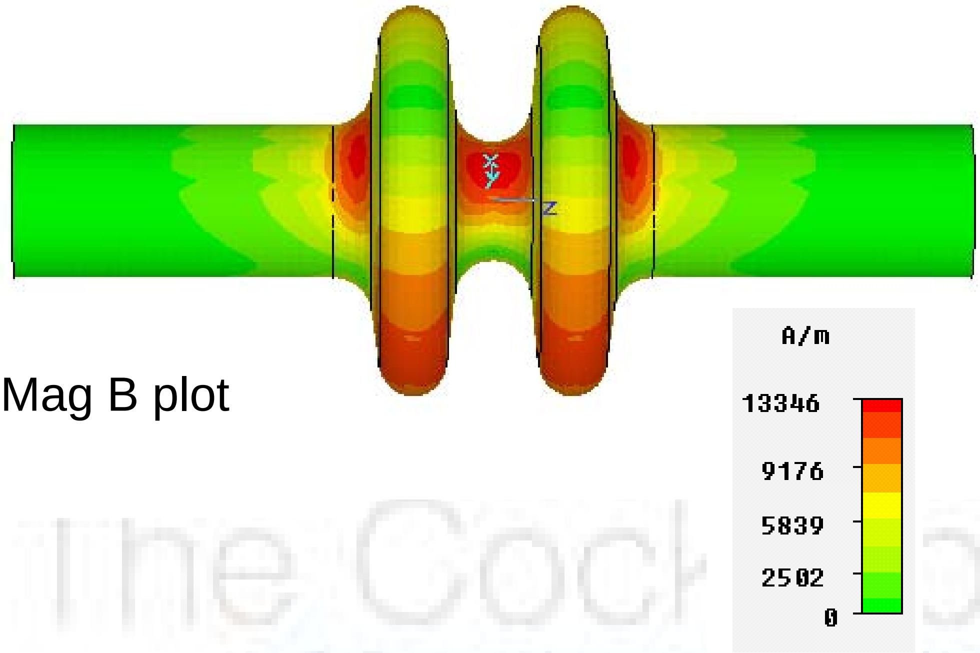




Multipactor studies may change the optimal solutions.

Cavity Shape

Cavity was given a small angle on the wall to simplify acid removal. The angle can be doubled decreasing the equator rounding with little effect on B_{max}



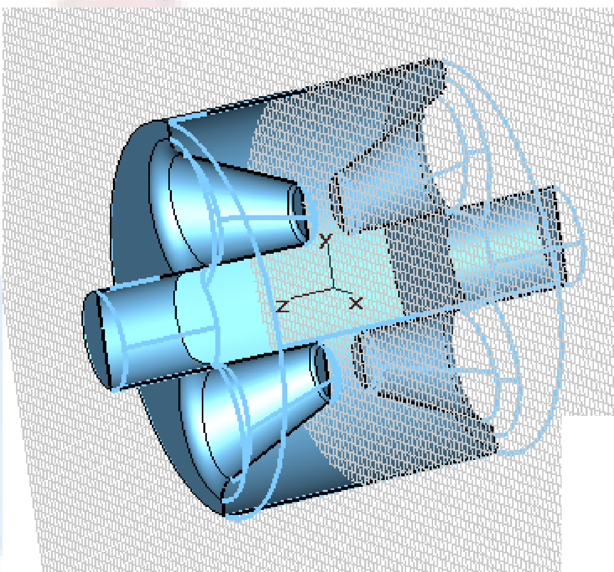
Mag B plot

Cavity Dimensions	mm
Cavity Length	187.50
Beampipe Radii	90.00
Iris Curvature	45.00
Iris Radii	70.00
Equator Radii	~230.00
Equator Curvature	40.00

V_T/cB_{max}	0.128	m
V_T/E_{max}	0.102	m
R_T/Q	86.5	Ohms

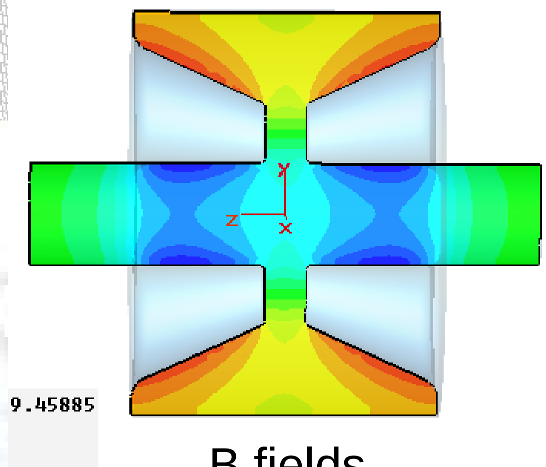
The cavity is not squashed and relies on the waveguide dampers to polarise the cavity.

Initial Modified 2-Rod Design

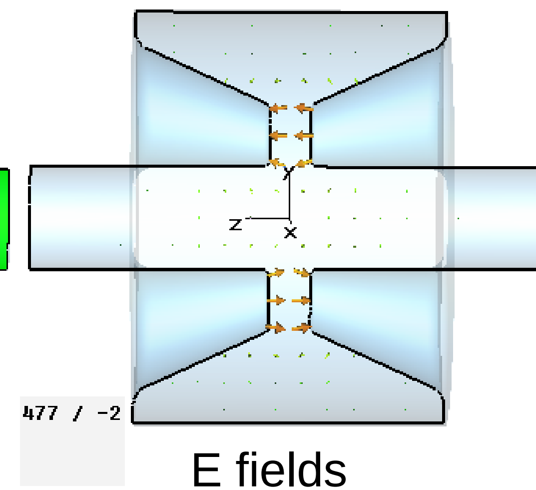


- Modification of existing CEBAF 2-rod separator cavity (collaboration with H Wang at JLab):
  - Has a 10 cm diameter beam-pipe,
  - Has 40 cm diameter for both frequencies.

- At 400 MHz, and V = 3 MV:
  - single cell (length = 30 cm)
  - R/Q = 700 Ohms
  - Emax = 90 MV/m
  - Bmax = 120 mT



B fields



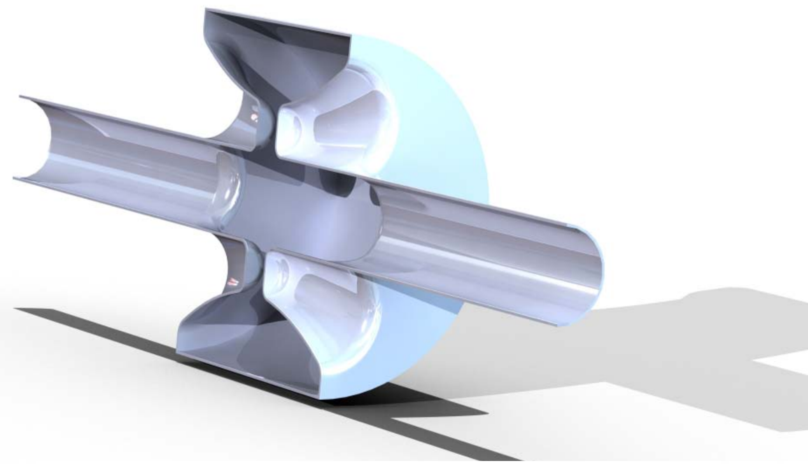
E fields

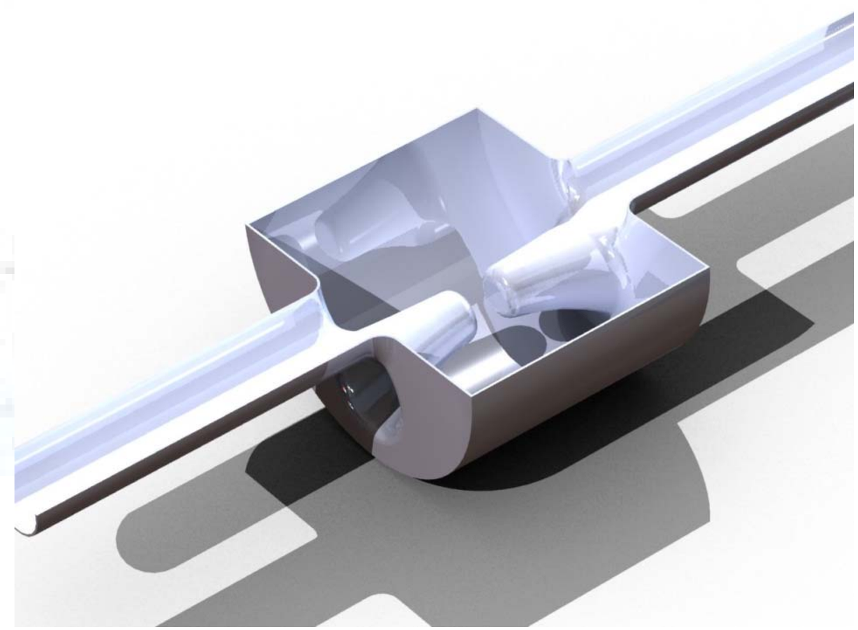
Improved 2-rod design

- Improved conical rod shape and removing sharp edges on the beampipe has achieved much lower surface fields.
- We still have a lot of parameter space to cover for optimisation (may possibly use an evolutionary algorithm).
- At 3 MV we now achieve

  Emax=40 MV/m

  Bmax=53 mT





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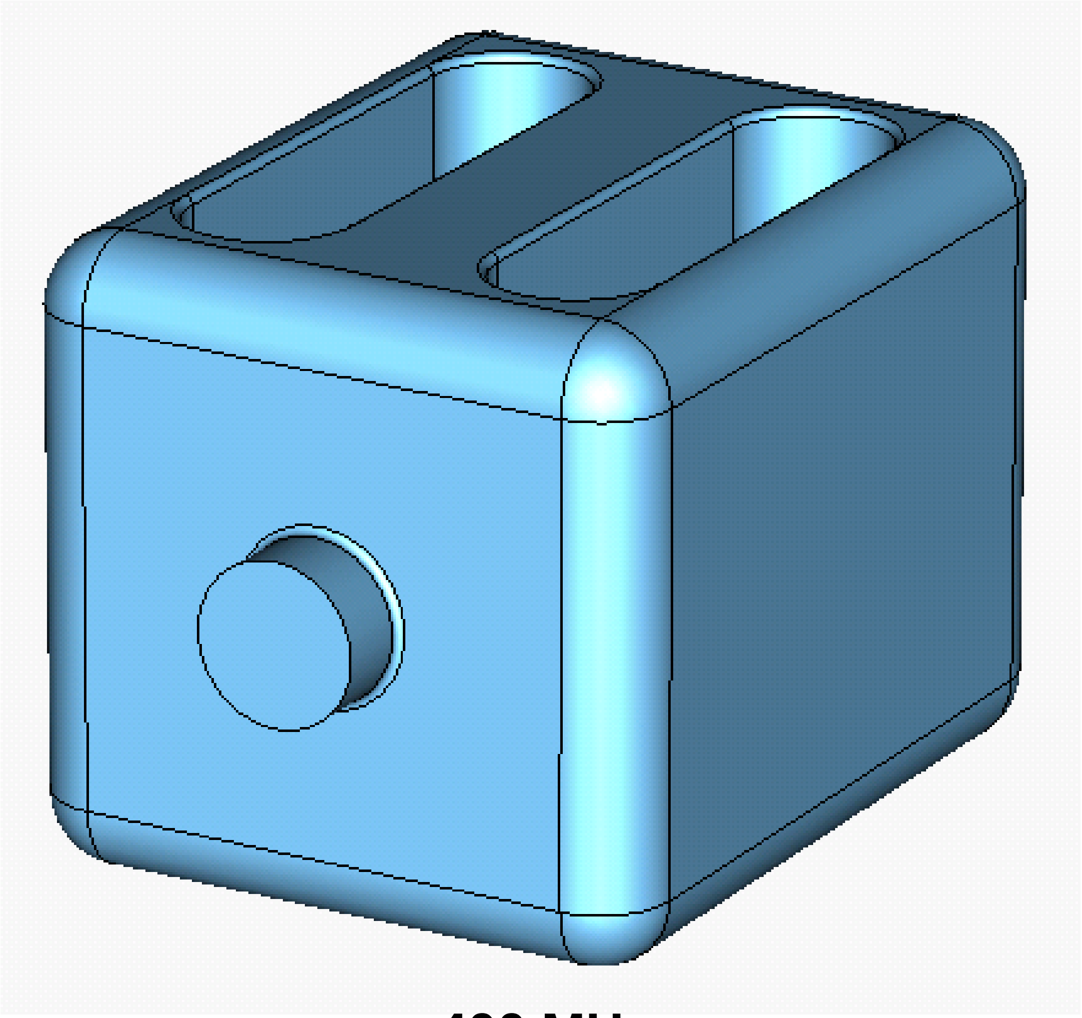
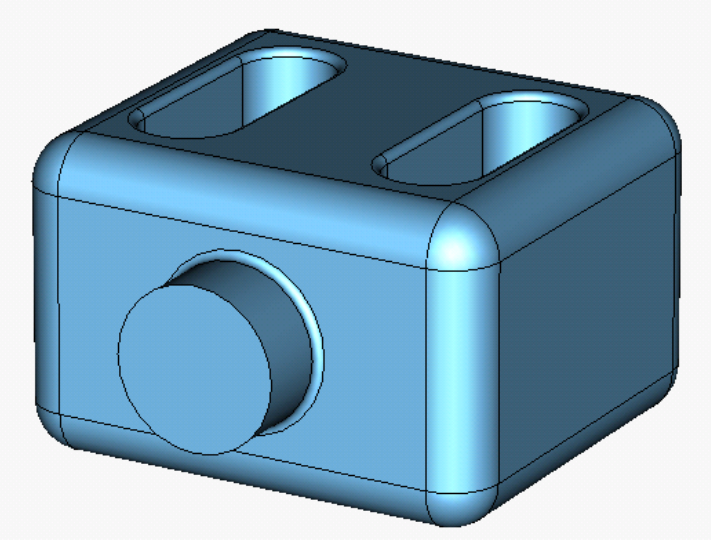
Conclusion

- On-cell waveguide damping development is underway at Jlab for ANL.
- On-cell damping is also a suitable solution for LHC and meets all requirements.
- It is probably the easiest of the designs to manufacture and process.
- The non-squashed cavity also has much looser tolerances on the couplers.
- Multipactor simulations have some question marks for all cavities.
- 4-rod compact cavities could also meet the LHC requirement for a 400 MHz cavity. A full design is expected within 12 months.

Parallel Bar Cavity Geometry

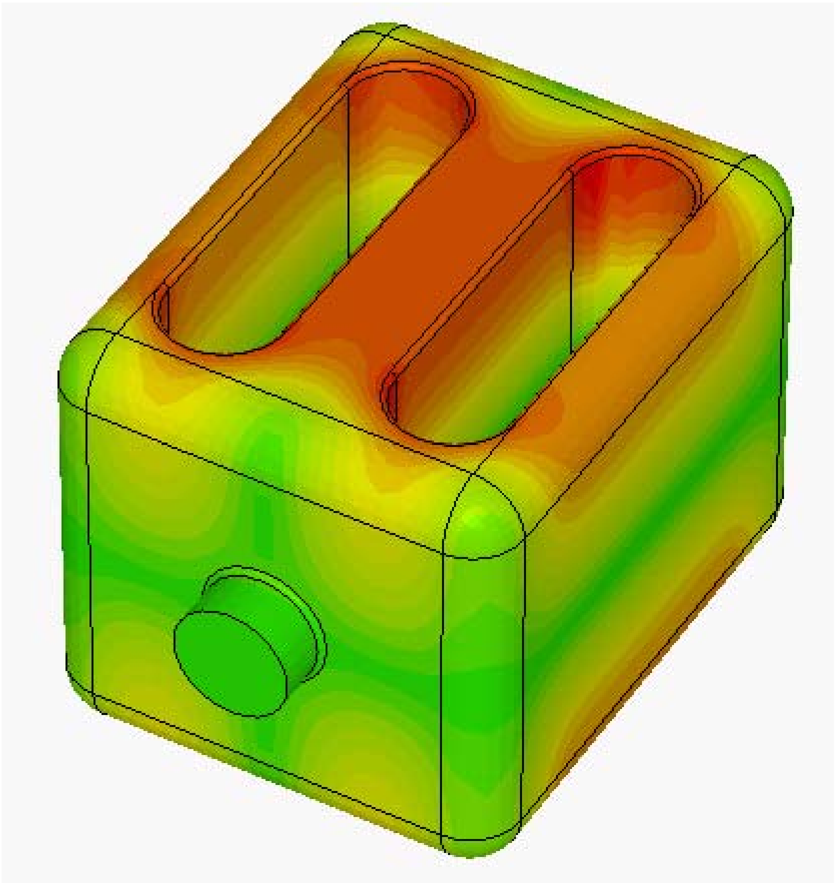


400 MHz

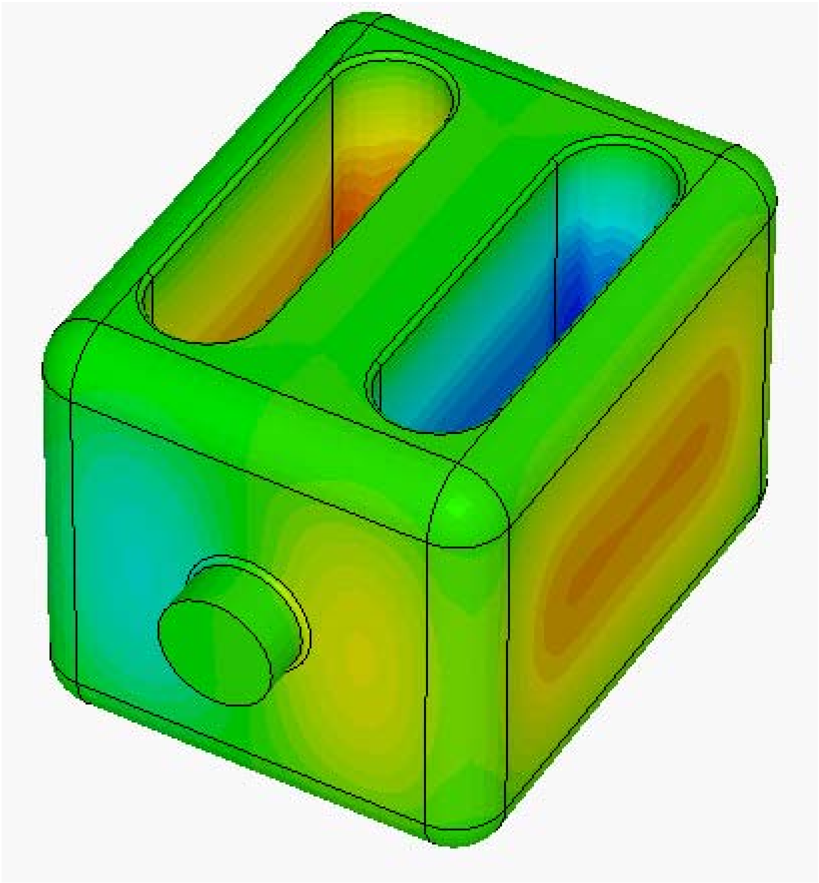


800 MHz

E and H Fields in 400 MHz Cavity

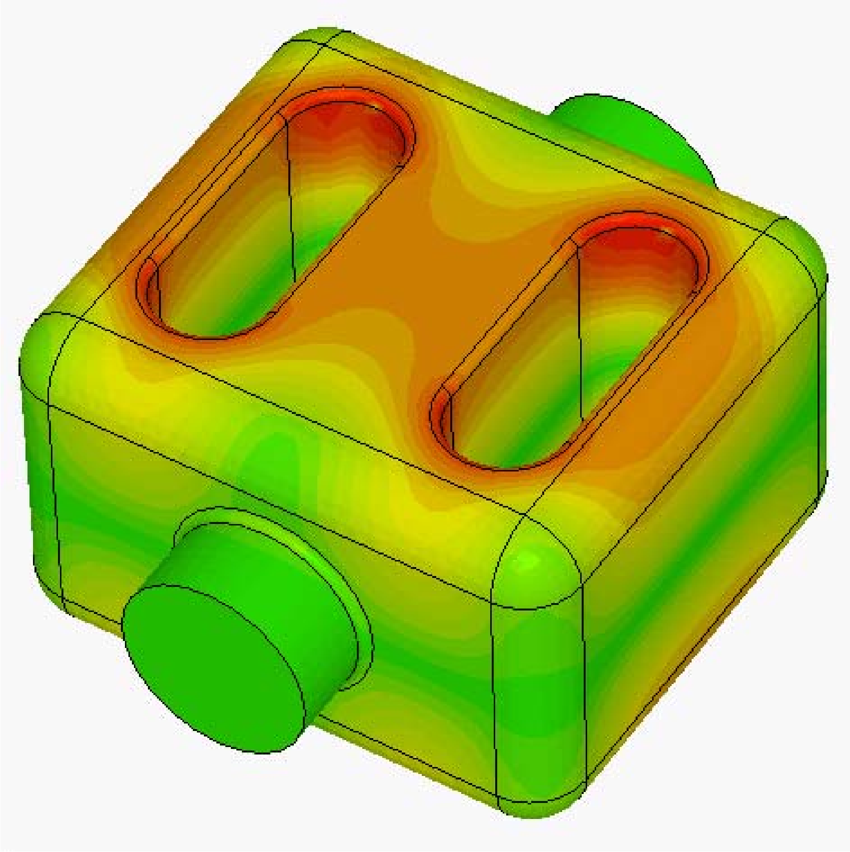


Surface H field

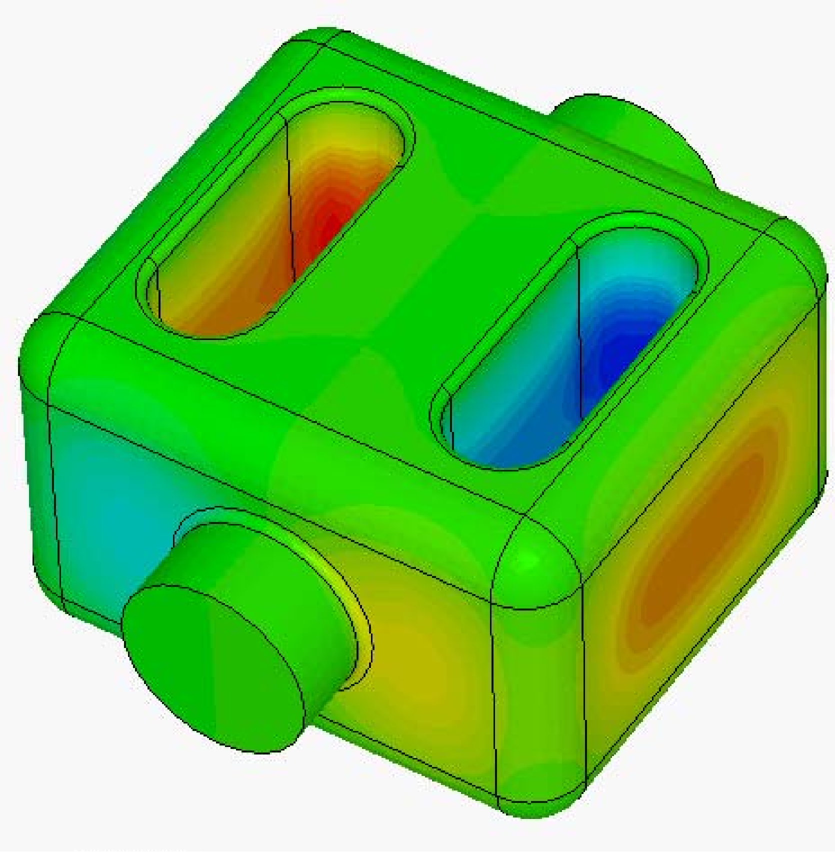


Surface E field

E and H Fields in 800 MHz Cavity

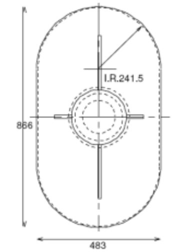


Surface H field



Surface E field

Cavity Properties



Parameter	Fig. 7	Fig. 8	Units	
Freq. of π mode	400	800	MHz	**400**
λ/2 of π mode	374.7	187.4	mm	
Freq. of 0 mode	407.1	815.3	MHz	
Cavity length	494.7	267.4	mm	
Cavity width	400	300	mm	**615**
Bars height	382.2	191.8	mm	**1101**
Bars width	100	60	mm	
Bars length	370	170	mm	
Aperture diameter	100	100	mm	**305**
Deflecting voltage (V_T*)	0.375	0.187	MV	**0.375**
Peak electric field (E_P*)	2.16	2.79	MV/m	**4.25**
Peak magnetic field (B_P*)	7.05	9.78	mT	**12.24**
Energy content (U*)	0.175	0.062	J	
Geometrical factor	81.37	112.3	Ω	**220**
$[R/Q]_T$	319.13	113.55	Ω	**46.7**
$R_T R_S$	2.6×10^4	1.3×10^4	Ω^2	**10274**

At $E_T^* = 1$ MV/m

Erk Jensen/CERN: Compact Cavities (1/3)

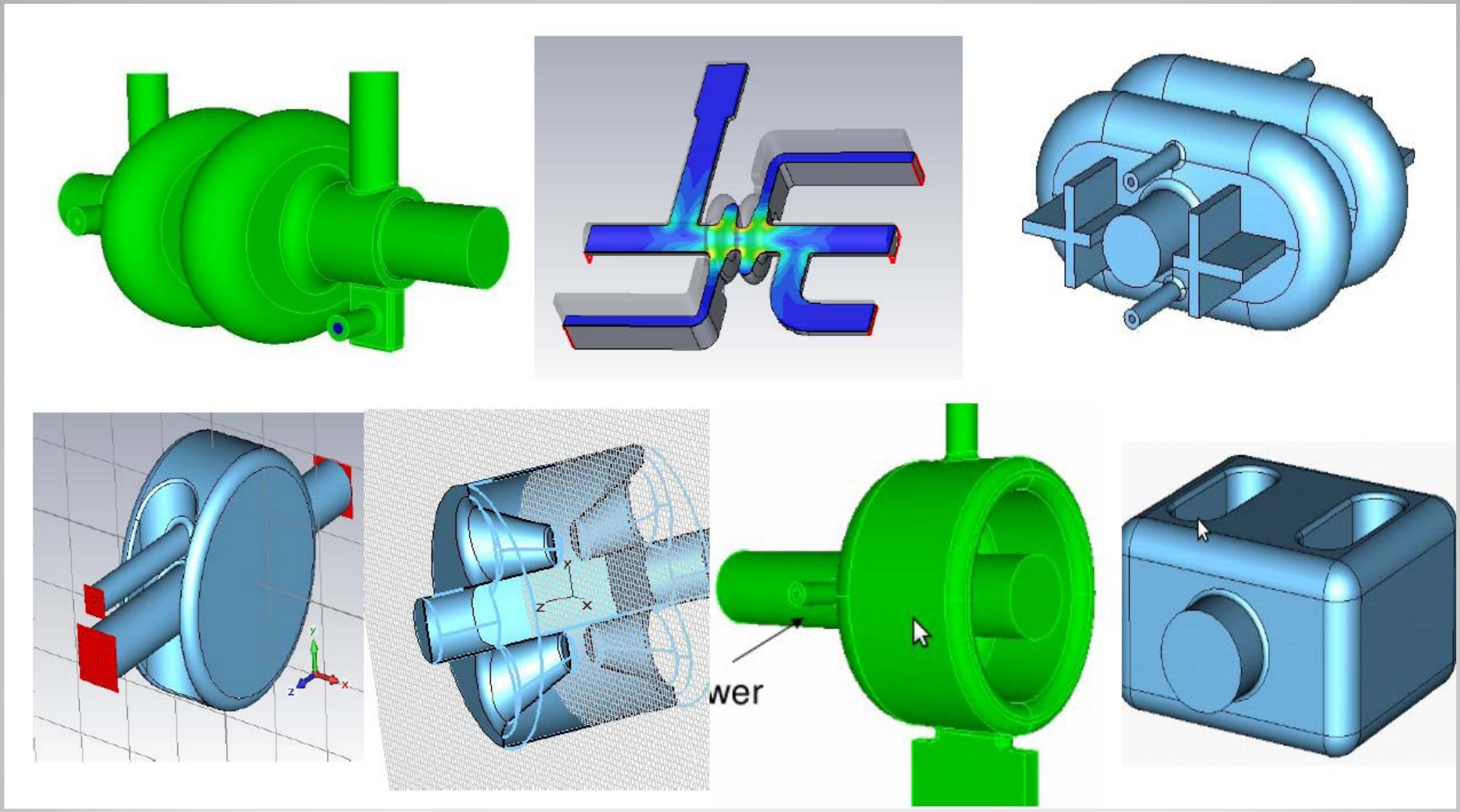
- Speculations:
  - After successful (re-)start-up of the LHC later this year, it will take some time to ramp it up in both energy and luminosity.
  - Highest priority then will then be given to
  - Unless the case is very strong, how likely is the OK for a test-cavity in the LHC by say 2011?
- What is a strong case?
  - **Test must not perturb HEP run**!
  - **Test must demonstrate significant gain (in $\mathcal{L}$)**.
  - The result should be **relevant** for a later upgrade! (correct beam separation, frequency, …)
- Danger:
  - If the outcome is negative, marginal or non-conclusive, it may be interpreted as a general "CC's do not work"!

Erk Jensen/CERN: Compact Cavities (2/3)

- Why compact cavity?
  - For a significant luminosity gain in more than one IP, **local** crab cavities would be desired.
  - The global scheme uses enlarged beam separation near point 4 (420 mm) – local crab cavities can't rely on this luxury!
  - The areas around point 4 may eventually be used by other RF systems and will not remain available (ACN200 capture system/ADT upgrade ?)!
- Considering all of the above, Erk recommends to **concentrate R&D effort** on
  - a **local scheme**,
  - **compact crab cavities** that fit LHC constraints,
  - the technological & beam dynamics issues which result from this choice.
  - R&D must be significant and requires good coordination!

Erk Jensen/CERN: Compact Cavities (3/3)

- *f* is not limited to 400 or 800 MHz; any *h* of 40 MHz is OK.
- Multiple harmonics can make *kick(z)* linear.
- There are many interesting new ideas; good candidates for really compact cavities:



"Conclusions" for Session III

- Significant progress in optimization, simulation, enginnering of TM_{110} cavities
  - 400 MHz does not appear feasible
  - Local option may not be feasible
- Several concepts for "compact" cavities have emerged
  - Attractive in terms of size, HOM properties, surface fields, and shunt impedance
  - May enable 400 MHz and local option
  - Some support is available for development for deflecting and crabbing applications
- Is 800 MHz compatible with 4.6K?