CBM STS mainframe and enclosure

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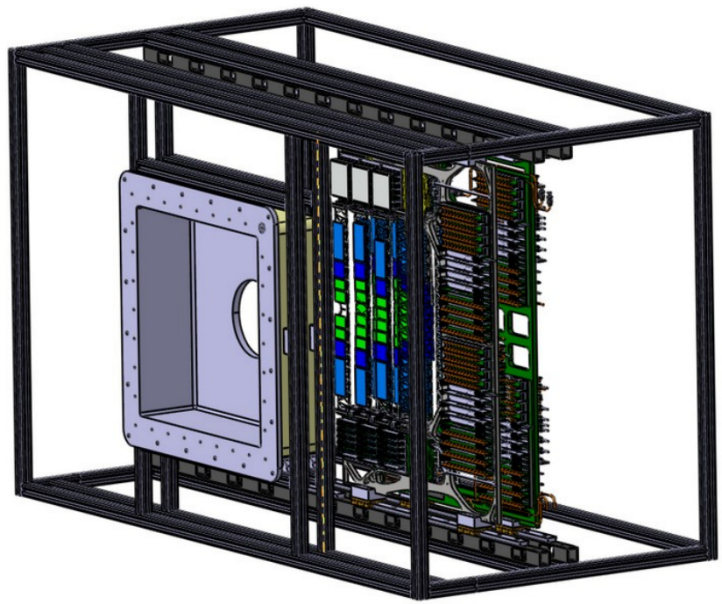
April 28, 2021



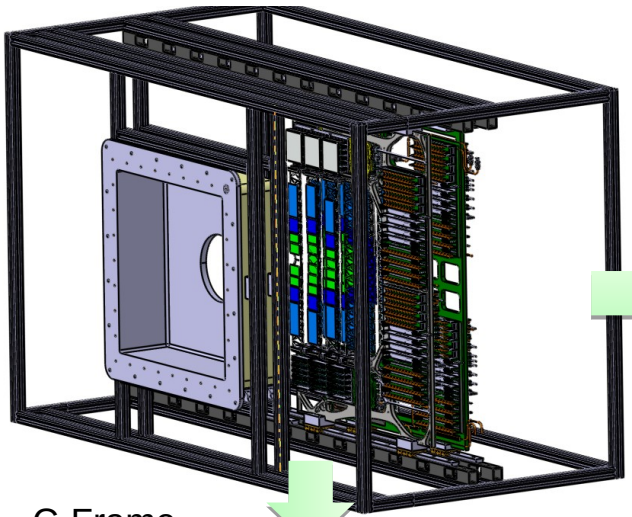
Constraints o the STS insulation box

- Gas tight, light tight
- Thermal insulation
  - temperature difference ($-40\,^{\circ}\mathrm{C} - 23\,^{\circ}\mathrm{C} = -63\,^{\circ}\mathrm{C}$)
  - temperature uniformity
    - to be specified
  - active cooling panels
  - heating panels if needed
- Mechanical support
  - $\sim$2000 kg weight of the setup
  - 0.1 mm unit position precision
- EMI shielding
  - bandwidth:

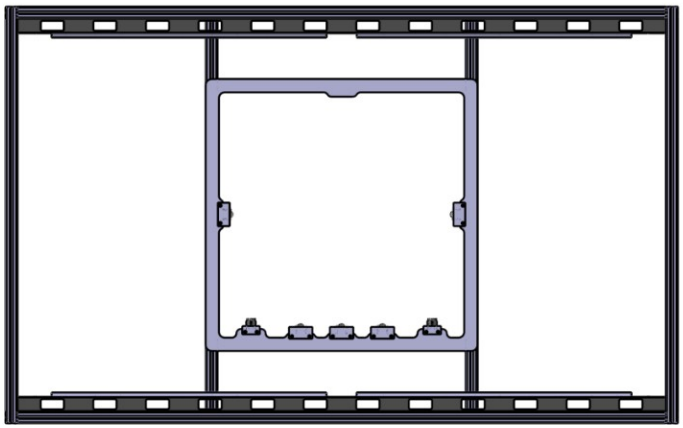
    slow shaper from 7 kHz to 2 MHz
    fast shaper to 20 MHz
  - front/back walls potentially more vulnerable
  - no electrical motors, switch mode power sources in proximity
- Grounding
  - gnd. terminal(s) to the magnet
  - gnd. c-frames to the box inside
  - multiple gnd. points of the beam pipe
- Radiation tolerance
  - side and front walls $10^{12}\,\mathrm{n_{eq}cm^{-2}}$
  - back wall $10^{14}\,\mathrm{n_{eq}cm^{-2}}$
- Material budget
  - back wall $\mathcal{O}(1\%\,X_0)$

Many features entangled in the same objects

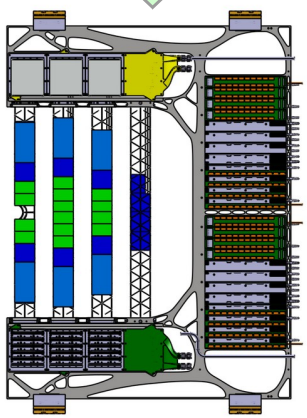
Mechanical stucture of the CBM STS



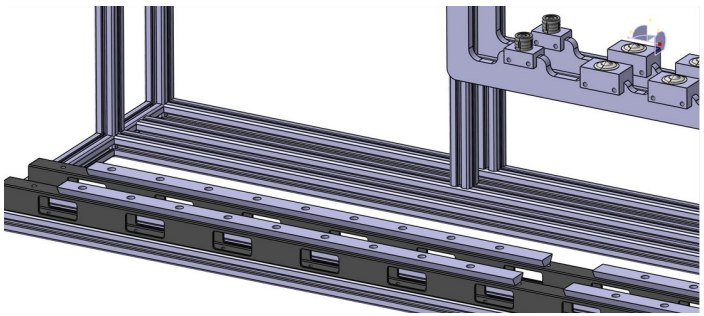
Main frame



C-Frame



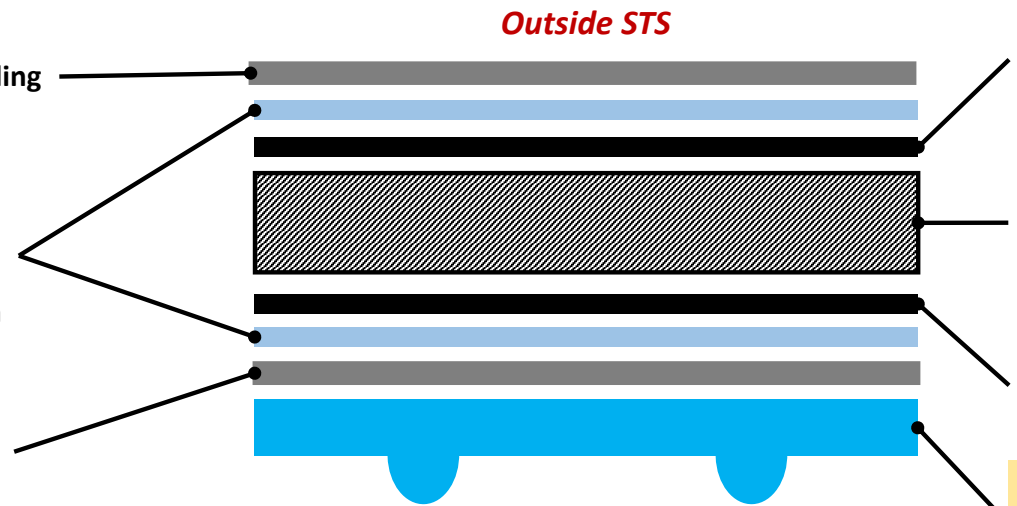
Rail supports



- **Rigid frame** (alu. or CF) for mechanical support, **sandwich side panels** attached
- **Stiff bottom plate** with the rails for c-frames (+ reinforcement bars)

Structure of the side walls

- CF sandwiches with AIREX foam
- Aluminium foils for thermal radiation and EMI protection



- Aluminium Sheet
- Grounding & Shielding
- Thickness (50 µm?)

- Araldite 2011
- Good adhesion
- Radiation Hard
- Thickness ≈ 100 µm

- Aluminium Sheet
- Radiative Shielding
- Thickness (50 µm?)

- CFRP sheet
- Fibre? Resin?
- Thickness ≈ 1 mm

- AIREX R82.60 (closed cell)
- k = 0.04 W/m.K
- ρ = 40…60 kg/m³
- Thickness ≈ 35 mm

- CFRP sheet
- Fibre? Resin?
- Thickness ≈ 1 mm

- Cold Plate
- Novec 649@-40°C
- Cryo-Trap

Requirements on the cooling plate –

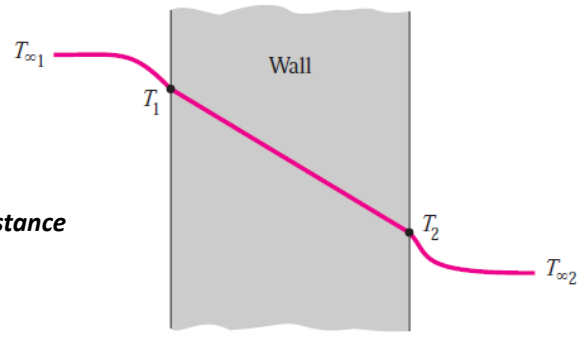
- Working Temp.: -40°C
- Working Pressure: up to 5 bars
- Coolant: 3M NOVEC 649
- Surface temp. uniformity: +/- 1°C
- Area: 1000 mm x 400 mm

- Thickness: 2…3 mm
- End Connections: ½ in. pipe for Swagelok connections
- Inlet Flow Velocity: 1 m/s
- Pressure Drop: < bar
- Cooling Capacity: up to 300W

K. Agarwal Mar 26, 2021

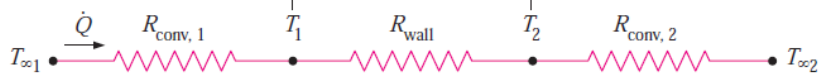
- Alternative filler: Nomex honeycomb + Rohacell 32 (24 kg/m^3) light and stiff

Thickness of the walls



Temperature ≡ Potential or Voltage
Heat Transfer Rate ≡ Current
Thermal Resistance ≡ Electrical Resistance

$$\dot{Q} = \frac{T_{\infty 1} - T_{\infty 2}}{R_{\text{conv, 1}} + R_{\text{wall}} + R_{\text{conv, 2}}}$$



Thermal network

For CBM-STS,

- $T_{\infty 1}$: Cave Temp. = 20°C
- T_1 : Outer Wall Temp. > Dew Point (9°C for 20°C ambient @ 50% RH)
- T_2 : Inner Wall Temp.
- $T_{\infty 2}$: Enclosure Temp.

Ideally, none of the walls need heaters on their outer surface (T_1)

	T_inf_1 [°C]	T_inf_2 [°C]	h_1 [W/m².K]	h_2 [W/m².K]	d [mm]	k [W/m.K]	q_cc [W/m²]	T_1 [°C]	T_2 [°C]
Front Wall	20	-10	10	10	35	0.036	25.59	17.44	-7.44
Back Wall	20	-10	10	10	15	0.036	48.65	15.14	-5.14
Top Wall	20	-10	10	10	35	0.036	25.59	17.44	-7.44
Bottom Wall	20	-10	10	10	35	0.036	25.59	17.44	-7.44
Side Walls	20	-40	10	10	35	0.036	51.18	14.88	-34.88

- Foam thickness not greater than 4 cm (may be smaller for back wall)
- Radiative heat transfer: $\sim 2.6\,\mathrm{W/m^2}$, $\sim 4.6\,\mathrm{W/m^2}$ for side walls

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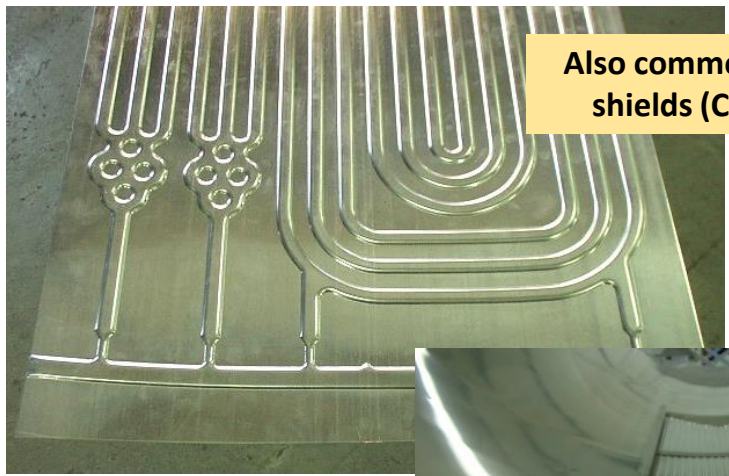
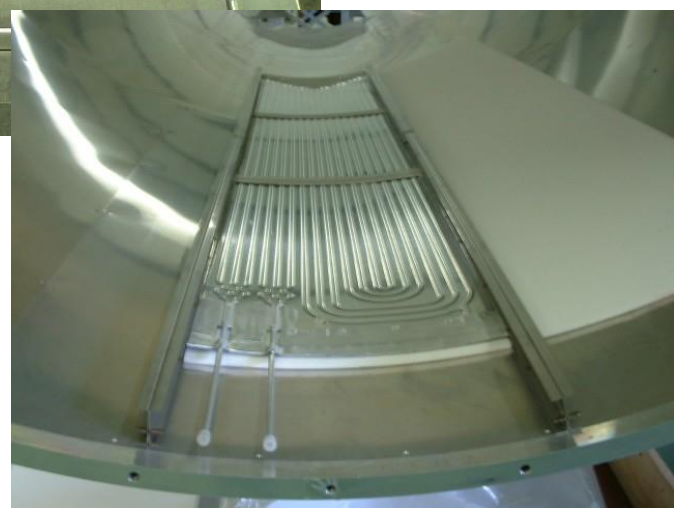
Active cooling of the side walls

- This (3 mm) aluminium roll bonded plates with Novec 649 circulation at $-40\,^{\circ}\mathrm{C}$
- Attached to side walls from inside: temperature stabilisation, cryo trap

Commonly used in home-refrigerators and battery cooling



Also commonly used as thermal shields (CMS-TK, ALICE-TPC)



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Thermal deformation of the structural elements

Upper wagons y-axis constrained (left) and free (right), T=−20 °C

- Thermal effects are important, particularly for non-homogeneous objects
  - twist (stress), structural displacement (affect module positions)
- Adequate mech. constraints for c-frames, rigid non-deformed support

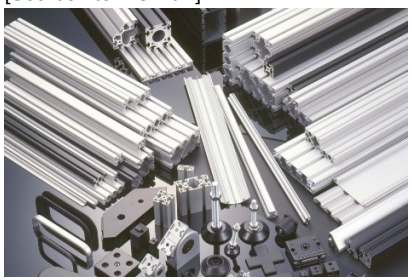
M. Teklishyn Jan 18, 2021

Choice of material for the mainframe

What we can get in real life:

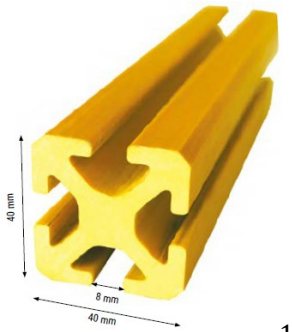
Main frame:

[Source: Item GmbH]



$\alpha_{th,Al} = 23.5 * 10^{-6} \frac{1}{°C}$

[Source: Fibrolux GmbH]



$\alpha_{th,GF} = 10 - 30 * 10^{-6} \frac{1}{°C}$

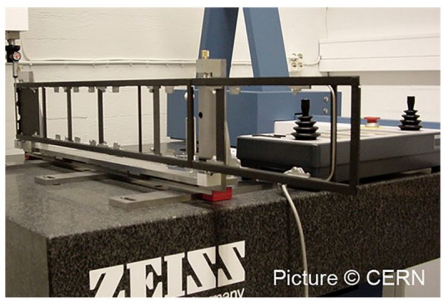
- moderate quality
- heavy

[Source: Carbosix]

$\alpha_{th,CF} = ?? \frac{1}{°C}$ **no data available**

Custom carbon solution

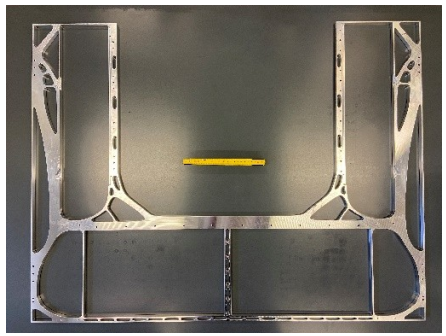
Exel Composites carbon fibre profiles deliver precision, performance and longevity at CERN



- requires intense R&D process

C-Frame:

[Source: J. Weinert, S. Schwab]



AL 7075

- GF BMC
- CF BMC
- CF Prepreg
  - thickness usually <5mm
  - cutouts will influence TEC
- CF Sandwich
  - many unclear details
  - manufacturing doesn‘t seem possible

no visible advantage

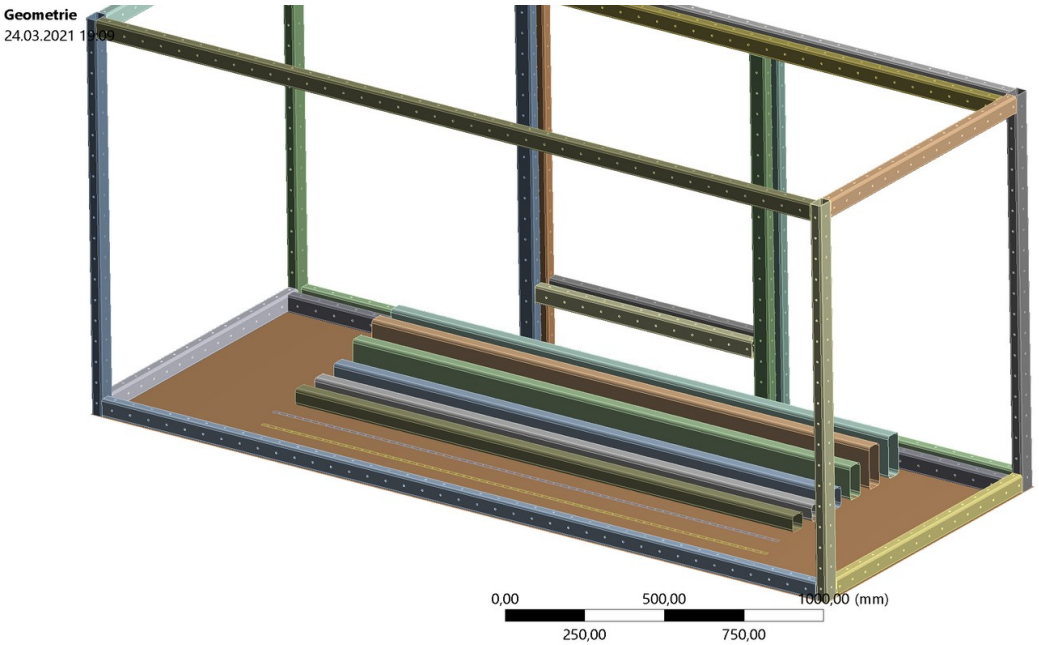
O. Vasylyev Sep 11, 2020

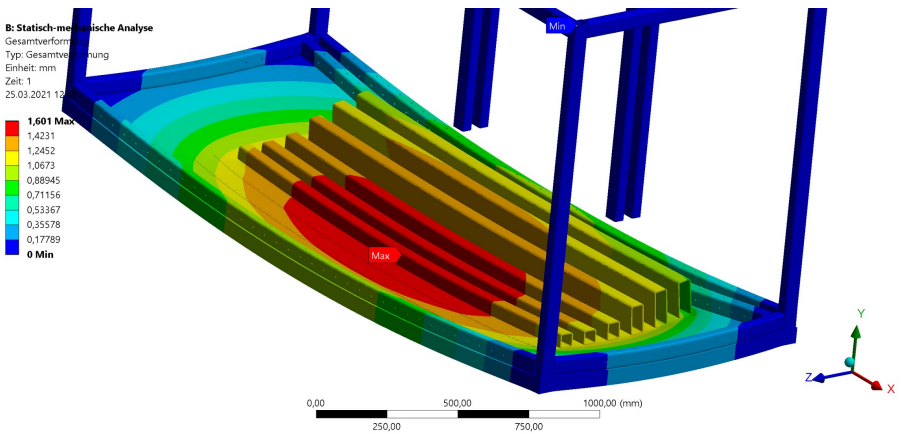
- Current approach: CF for the frame and base plate, AL 7075 for c-frames

CF sandwich base plate stiffness

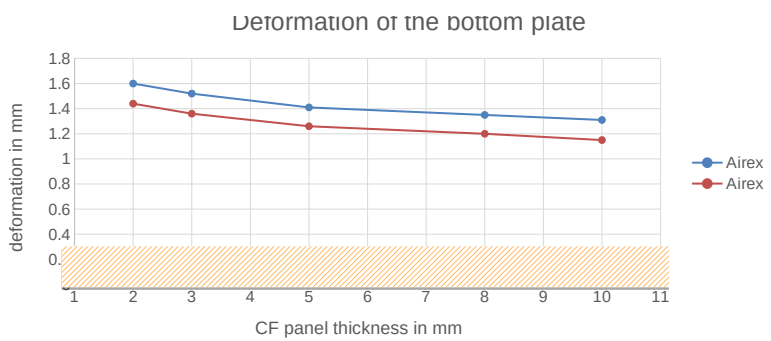
- CF plate sandwich filled with foam:
  - thermal insulation
  - mechanical stiffness
- Simplistic simulations to estimate feasibility
- Detailed studies needed

J. Thaufelder Mar 26, 2021





Sandwich Panel with 2 mm CF plates and 56mm Airex R82.60 core

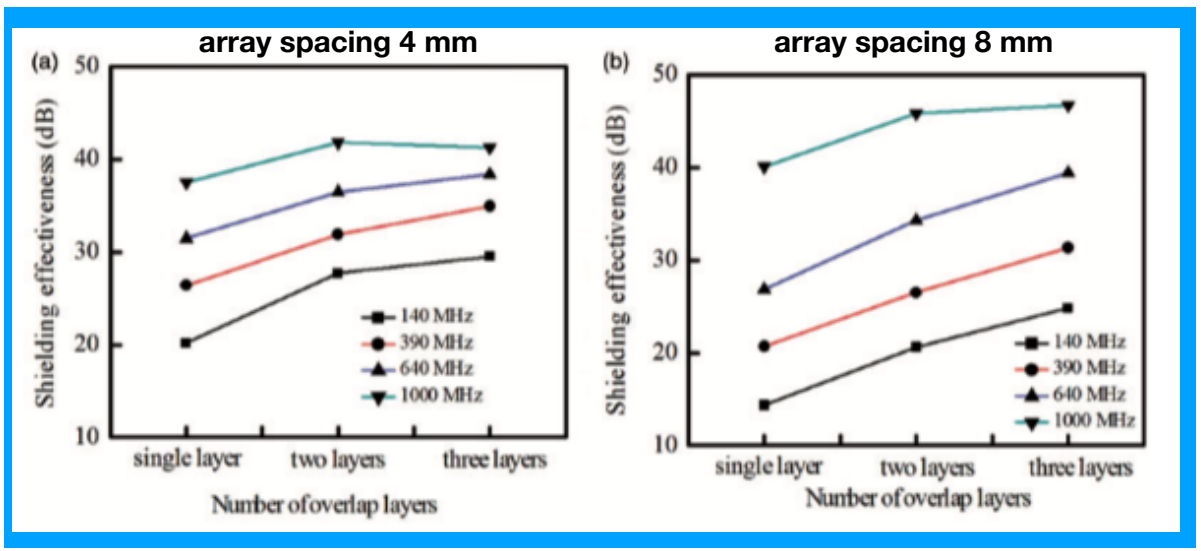


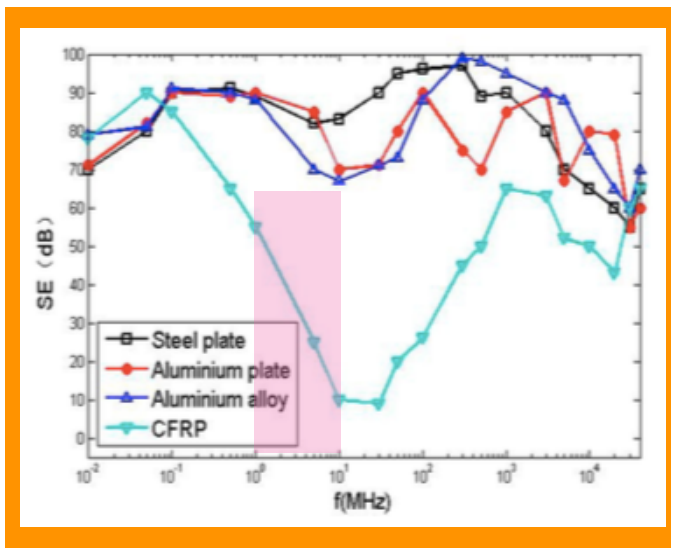
Sandwich panel shielding efficiency

- Shield function is to reflect, absorb or offset the energy from external electromagnetic interference: A. Lymanets Mar 19, 2021
  - good conductor (Ag, Cu, Al) reflection
  - moderate conductor (Fe, magn. steel, e.g 304) absorption
- skin depth for Al: 80 µm 80 (1 MHz), 26 µm (10 MHz)

$$SE = 20\log_{10}\left(\frac{E_i}{E_t}\right) = 20\log_{10}\left(\frac{H_i}{H_t}\right) = 10\log_{10}\left(\frac{P_i}{P_t}\right)$$

CF is conductive material at f=0 Hz, but may display various SE depending on given frequency, specific CF material and weave spacing.





Zhao et al. DOI: 10.1177/1528083715573278 *Munalli et al.* 10.1016/j.compositesb.2019.106906