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End–cap Electromagnetic Calorimeter for STAR Detector. Technical Design Review.

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Abstract

The End–cap Electromagnetic Calorimeter (**EEMC**) would significantly increase the physics capabilities of the STAR detector to study spin–dependent processes and to search for QGP signals. In this paper, the mechanical engineering design of the EEMC, proposed by the Particle Physics Laboratory, is presented.

The design of structural elements of the EEMC, its support frame and its optical system are described in details. The results of stresses and deformations analysis are also presented. The EEMC mounting scheme and assembling procedure are discussed.

The proposed engineering design of the EEMC is illustrated by the set of detailed drawings.

Contents

1 EEMC : physics motivation.

The existing measurements of polarized structure functions in DIS processes [1] revealed that quark contribution to the nucleon spin is small. About 2/3 of the proton spin might be attributed to orbital angular momentum and gluons.

The future RHIC collider gives unique possibility to study the contribution of the gluon and sea quark spin components to the total spin of the proton [2, 3]. These spin studies are part of the scientific program of the STAR experiment [4].

The most straightforward method of studying the gluon spin structure function is its extraction from the measured small spin asymmetries in reaction $\vec{p} + \vec{p} \longrightarrow \gamma^* + jet + X$. These studies require the installation of the electromagnetic calorimeters inside the STAR magnet. For the Barrel EMC, the effective acceptance for jets is only -0.3 $< \eta <$ +0.3. The End–cap Electromagnetic Calorimeter (EEMC) will extend the acceptance for jets up to -0.3 $< \eta <$ +1.3 (assuming the average jet radius equal to $\sqrt{(\Delta\phi)^2 + (\Delta\eta)^2} = 0.7$) [8].

Other important applications for the STAR Electromagnetic Calorimeters, such as Jet–Jet measurements, $W^{\pm}$ and Z^0 detection, transversity distributions measurements, are discussed in [5]. Also, EM Calorimeters are important for QGP studies [1]. Being the comparatively inexpensive device, the EEMC would significantly increase the experimental statistics for these processes.

Preliminary EEMC design has been considered by the ANL group. One of the possible option was recently presented by Penn State University [5]. In this paper, the design suggested by the Particle Physics Laboratory (JINR, Dubna), is discussed in details.

2 Mechanical Design of the EEMC.

2.1 Integration Group requirements.

The Integration Group drawings [6] give the exact dimensions of the EEMC envelope. According to the Integration Group drawing **SIM 140–A–1 (Fig.1a)**, the total thickness of the EEMC is limited by 389 mm. The End–cap EEMC of the STAR detector has to

[1] One of the promising methods of QGP search is the study of the process $\pi\pi \longrightarrow \gamma\gamma$. The cross–section of this process depends on the temperature and has a singularity at the critical temperature (Ref.: M.Volkov et al., to be published).

occupy in z–direction the region from 2711 mm to 3100 mm measured axially from the interaction point.

The maximal outside radius of the EEMC is limited by 2432 mm. Also, some space for TPC supports should be reserved in EEMC envelope, as shown in the Integration Group drawing **SIM 160–A–1 (Fig.1b)**. Also, there should be a gap between Barrel EMC and End-cap EMC (equal to 127 mm in the current design) for cable routing.

2.2 Overview.

The End–cap EMC is a lead–scintillator sampling calorimeter with the geometrical coverage $15^o < \Theta < 38^o$ and $0 < \phi < 2\pi$. The EEMC is mechanically divided into 12 *modules* of 30^o, each fixed to the magnet pole tip. The segmentation of each module is 5 intervals in ϕ (6^o) and 12 intervals in η. **Figs.2 and 3** shows the EEMC divisions in ϕ, η and θ. Each single elementary volume of the EEMC that covers $\Delta\eta\Delta\phi$ is called *tower*. The EEMC is composed of 714 towers [2].

The design of the EEMC is illustrated by the Figures 2–14, and presented in details in technical drawings OK-1261.0xx (see Section 4 for more details).

Mechanically, the EEMC is divided into twelve 30^o modules. Each module consists of 60 towers and mounted independently onto the magnet poletip. The 30^o–module is the basic mechanical unit of the EEMC.

The general view of all 12 assembled modules of the EEMC is shown in **Fig.2**. All EEMC modules have the same mechanical design, though for two EEMC modules the design is slightly different because of the Integration Group requirements (see, for example, Drawing **SIM 166–A–1**) showing the space needed for TPC supports.

[2] 10 modules have 60 towers each, and 2 modules have 57 towers each, due to the extra space reserved for the mechanical supports of the TPC.

The design parameters of the End–cap EMC are summarized in the Table below.

Segmentation	12 azimuthal modules 60 azimuthal sectors, $\Delta\phi = 0.105(6^o)$ 12 projective towers in $1 < \eta < 2$, $\Delta\eta \simeq 0.1$,
Total number of towers	714 projective towers
Inside radius	0.73 m (at front plate) 0.83 m (at back plate)
Outside radius	2.14 m (at front plate) 2.43 m (at back plate)
EEMC thickness	386 mm (including back plate - 59 mm)
Weight of the calorimeter	$\simeq$ 29.6 tons
Weight of one EEMC module	$\simeq$ 2.46 tons
Absorber	5 mm lead ($= 0.9\ \chi_o$) in 23 layers
Scintillator : pieces (tiles)	4 mm plastic in 26 layers, $\simeq$ 18600 pieces
Readout :	WLS fibers (2/tile) to PMT 714 PMT (1 PMT/tower)

2.2.1 Temperature requirements.

The End–cap EMC is located inside the STAR magnet, and the working temperatures lie inside the range 20–50^o C (68–122^o F). In this temperature range, any longitudinal stresses should not be developed in the scintillator tiles. In the EEMC support frame, the developed stresses should not exceed 100 MPa.

2.2.2 Tolerance requirements.

The design thickness of the EEMC scintillator tiles is 4 mm. The manufactured tile thickness should not deviate from this value more than 0.05 mm.
Other geometrical dimensions of the scintillator tiles should not deviate more than 0.05 mm from the reference values.
The manufacturing tolerance for the lead plates is 0.05 mm.

The geometrical tolerance for the assembled 30^o EEMC module is 0.2 mm. The tolerance for the EEMC mounting holes position in the magnet poletip is 0.15 mm. The assembling gap between the mounted EEMC modules is equal to 0.6 mm, that allows to fit the tolerance requirements.

2.3 Description of one EEMC tower.

The EEMC consists of 714 towers. The construction of one EEMC tower is shown in **Fig.4**. Each EEMC tower consists of 26 scintillator layers and 23 lead layers. The aluminium front plate and steel internal support plates – are also the absorber layers of the EEMC. After 6th scintillator layer ($\sim 5\chi_o$), the Shower Max Detector (SMD) is located. The total thickness of all absorbers and scintillator layers, including the material of internal support structures, is $\sim 22\chi_o$. The material of Shower Max Detector will increase this value up to $\sim 23\chi_o$.

2.3.1 Active layers.

The EEMC active layers are molded by pressure from the mixture of granulated polystyrene PSM–115, p–terphenile (1.5%) with maximum of radiation spectrum at 320 nm, and *PoPoP* (0.03%) with maximum of radiation spectrum at 420 nm.

Each scintillator tile is 4 mm thick and has a trapezoidal form. To form the projective EEMC towers, the tiles of 26×12 different basic dimensions should be used. Below, is an example of how the Table with the dimensions for scintillator tiles look like. [3]. The notations N_{cyl}, h_s, C and c are explained in **Fig.5** (see **OK–1261.Sci** for more details).

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OK-1261.Sci  - Size of scintillators (mm).

Number of layer - 1
hs = 114.51

N Cyl.        C           c
"1"           222.27      210.27
"2"           210.23      198.23
"3"           198.2       186.2
"4"           186.17      174.16
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[3] The complete Tables of dimensions for all gaskets, scintillator and lead plates, can be found at LBNL machine **me10.lbl.gov** in directory /star/DROPOFF/DUBNA : prokl_.dat, scin_.dat and pb_.dat.

"5"	174.13	162.13
"6"	162.1	150.09
"7"	150.06	138.06
"8"	138.03	126.03
"9"	125.99	113.99
"10"	113.96	101.96
"11"	101.93	89.92
"12"	89.89	77.89

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Each scintillator tile is wrapped with Tyvek 150 μk thick and aluminized mylar 20 μk thick. **Fig.6** shows schematically "one step" (lead–scintillator–lead) of the EEMC stacking sequence.

As shown in **Fig.6**, there is a resin–dipped fabric laminate gasket G10 between the lead and scintillator layers, 1.6 mm thick. Each gasket has cuts for fiber routing and covers 6^o sector (12 scintillators of one layer). The design of a gasket is shown in Drawing **OK–1261.Gas**, and the gaskets mounting scheme is shown in Drawing **OK–1261.000, 2nd part**.

In the assembled and mounted EEMC module, the scintillator layers are not influenced by compression forces.

2.3.2 Lead layers.

The passive layers of the EEMC are made of lead–antimony alloy [4] plates, 5 mm thick. Each 30^o EEMC module has 23 lead plates. Each of 23 lead plates covers 30^o segment (60 scintillators in one layer) as a single piece and has different dimensions. The design of a lead plate is shown in Drawing **OK–1261.Pb**. The weight of one plate is approximately 70 kg.

Each lead plate has the holes for *small pins* 3 mm in diameter. These pins are used for fixing of the scintillator tiles. Each lead plate has its own set of installation pins. The mounting scheme for scintillator tiles on a lead plate is shown in **Fig.5**.

[4] 90% Pb + 10% Sb .

2.3.3 Shower Max Detector.

The internal support walls 2 and 3 form the SMD box, 25 mm thick (see **Figs.4,7**). The proposal for Shower Max Detector design can be found in [9]. The elements of the Shower Max Detector are to be assembled during the assembly of EEMC module.

2.4 Description of one module.

2.4.1 Support structure.

The support frame of the EEMC module creates the EEMC volume, where active and passive elements of EEMC are placed. The EEMC support frame is a combined mechanical structure, consisting of (see **Fig.7**):
– strong back plate;
– 5 inner cover plates and 5 outer cover plates (not shown in Fig.7); they are jointed to strong back plate with M14 screws;
– duralumin front cover plate 8 mm thick (plate 1); it is bolted to inner and outer cover plates with $5\times2\times$M6 and $5\times3\times$M6 screws;
– three internal support plates (plates 2,3,4).
The *support plate 2* is made of duralumin 8 mm thick and is located after 6th scintillator layer. The *support plate 3* is made of stainless steel 8 mm thick and, together with the support plate 2, forms the box for Shower Max Detector.
The *support plate 4* is made of stainless steel 8 mm thick and is located after the 16th scintillator layer.
The internal support plates also play the role of EEMC absorbers (similar to lead layers).
The *support plates* 2,3 and 4 are connected to inner and outer cover plates with M8 screws;
– "left" and "right" radial walls of the module (shown in **Fig.8**). They are made of stainless steel 1.2 mm thick, and are connected to support plates, cover plates, front and back plate with 148 M4,M5 and M6 screws.

2.4.2 Properties of the EEMC materials.

The EEMC frame and back plate are made of stainless steel **03X18H11** (Russian industrial standard abbreviation). The properties of this steel correspond to those of **316L** (AISI Type). Their chemical compositions and mechanical properties are compared below:

		Stainless steel 03X18H11	Stainless steel 316 L
C	:	< 0.03 %	< 0.03 %
S	:	0.02 %	0.02 %
P	:	0.035 %	0.035 %
Si	:	< 0.8 %	< 1.0 %
Mn	:	0.7 - 2.0 %	2.0 %
Cr	:	17.0 - 19.0 %	16.0 - 18.0 %
Ni	:	10.5 - 12.5 %	10.0 - 14.0 %
Fe	:	Bal	Bal

Mechanical properties [5] of the steel 03X18H11 :
σ_B = 4400 kg/cm^2 = 63 psi×1000;
σ_T = 1600 kg/cm^2 = 23 psi×1000;
σ_S = 40 %;
$\alpha \times 10^{6o}\mathbf{C}^{-1} = 16.6$.
($\alpha \times 10^{6o}\mathbf{F}^{-1} = 9.2$).

Mechanical properties of the steel 316 L :
σ_B = 81 psi×1000;
σ_T = 34 psi×1000;
σ_S = 50 %;
$\alpha \times 10^{6o}F^{-1} = 8.9$.

2.4.3 The gaps and cracks.

The mechanical structure of the module should not introduce noticeable degradation to the EEMC performance. Nevertheless, the structural gaps between sensitive elements of the calorimeter cannot be avoided, though their size can be minimized.

The gaps between adjacent scintillator tiles do not exceed 0.3 mm (see **Fig.5**). In **Fig.8**, the assembled EEMC modules are shown. The tolerance gaps between EEMC modules are 0.6 mm wide. Together with the radial walls of the module they form the "dead areas" at the edges of the module, 1.2+0.6+1.2 = 3 mm wide.

[5] 1 psi = 0.0698 kg/cm^2.

2.4.4 Strong back plate.

The strong back plate of the EEMC module is shown in Drawing **OK–1261.060**. The maximal thickness of the strong back plate is 59 mm. At radius 826–1580 mm, the thickness of the plate is 40 mm, that helps to decrease the total weight of the module.

The material of the strong back plate is a stainless steel 03X18H11. Its thermal characteristics are similar to those of the poletip material, so the thermal deformations are minimized.

In the Integration Group drawings, the thickness of the EEMC envelope is not final, as this value (389 mm) [6] includes the tolerance gap for the poletip thickness. The total thickness of the EEMC can be changed by decreasing the thickness of the strong back plate from 59 mm to 47 mm. The bigger changes in back plate thickness would require the re–designing of the EEMC frame and the mounting scheme, especially the positions of mounting holes would be re–considered.

2.5 Finite elements analysis.

Deformations and distributions of stresses in 30^o modules of the EEMC were calculated using the method of finite elements (software package COSMOS).

The model of the EEMC module, used in calculations, consisted of :

– steel backplate (61 mm thick);

– outer and inner steel cover plates, 8 mm thick;

– four inner support walls (2 of 8 mm thick and 2 of 7 mm thick);

– two radial steel walls, 2 mm thick [7].

The frame of the module was filled with lead and scintillator plates. The total weight of one module was 2464 kg. The module was mounted to poletip with two M24 screws and one cone pin. This model is very close to the design described above. The calculations of stresses and deformations for the model were performed for modules positioned at : "12, 3 and 6 o'clock".

[6] In the Drawing SIM140–A–1 (**Fig.1a**), the thickness of EEMC envelope is 3100-2700-11≃389 mm. In the Drawing SIM160–A–1 (**Fig.1b**), the thickness of the EEMC envelope is 374.65 mm.

[7] This value is 1.2 mm in the current design. The thickness of the back plate was changed as well (from 61 mm to 59 mm), so we are planning to repeat these calculations.

The *maximum* stress and deformations developed are given in the Table below:

	"12 o'clock"	"3 o'clock" "9 o'clock"	"6 o'clock"
U_x, μk	3.2	6.3	3.1
U_y, μk	33.4	36.0	28.4
U_z, μk	100.0	23.3	89.4
$\sigma_{vonMizes}$ (kg/cm^2)	53.0	50.7	94.8

Here, U_x, U_y and U_z are the deformations of the module along the corresponding axes, $\sigma_{vonMizes}$ is the maximum developed stress.

These numbers indicate that :

– the maximal value of the deformation of the module does not exceed 100 μk (maximal allowed design value is 250 μk);

– the maximal stress value does not exceed 100 kg/cm^2 (maximal allowed design value is 1000 kg/cm^2 , i.e. 100 MPa).

The calculations are illustrated by the **Figs. 9a,b,c and 10**.

2.6 Optical system.

The EEMC scintillator tiles will be read out with waveshifting (WLS) optical fibers which go to photomultiplier tubes (PMT). The light from a tile is collected by a pair of green WLS fiber placed in a groove made in the scintillator. The general scheme of fiber routing is shown in Drawing **OK–1261.000, 2nd part.** The WLS fibers, belonging to the towers in the region $1.5 < \eta < 2.0$, go out of EEMC through the gaps between inner cover plates of the EEMC frame, another half of WLS fibers goes out of EEMC through the gaps between outer cover plates.

The more detailed view of a fiber to scintillator coupling is presented in **Fig.11**. The WLS fibers are coupled to both radial edges of each scintillator tile. The fibers are 1.0 mm in diameter, and aluminized on one end. At the distance of 300 mm after the exit from the groove, each WLS fiber is spliced with the clear fiber. Each fiber is about 3 meters long, all EEMC fibers have the same length. After exiting the scintillators, the fibers are combined into bundles that go between the EEMC layers [8]. All fibers from all tiles belonging to the same tower are coupled to one optical connector (in the present design, *all* scintillator layers of a tower are read out with one phototube).

Also, a special system is incorporated into the calorimeter for long–term monitoring of optical system. The UV laser light pulses can be transmitted through the thin (0.2–0.3 mm) quartz fibers to each scintillator tile. Drawing OK–1261.000(2) shows these quartz fibers routing through the gasket cutting to the center of each tile. The quartz fiber is coupled to the tile with the help of small round piece of scintillator.

2.7 EEMC mounting scheme.

Each of twelve End–cap EMC module is mounted *independently* to the poletip of the STAR magnet and positioned with the help of four mounting elements, shown in details in **Fig.12**.

The EEMC back plate (therefore, EEMC module) is positioned with the help of two alignment pins (Pos.3 and Pos.4,5 of Fig.12). The alignment accuracy is 0.3 mm. The mechanical clamping is done in three points with two screws M24 and the cone pin (Pos.3 of Fig.12).

The Drawing **OK–1255.510** (**Fig.13**) shows the the size and positions of EEMC mounting holes in the magnet poletip.

2.8 Shipping, assembly and installation.

To avoid possible damage of the EEMC elements (mostly scintillator tiles) during the transportation, the EEMC modules will be shipped from Dubna to BNL totally disassembled. Probably, only the scintillators would be wrapped with WLS fibers connected to tiles.

The EEMC modules will be assembled at the STAR experimental hall using the special

[8] In the present design, no optical connectors *inside* the EEMC volume are used. The usage of optical connectors will increase the cost of the project, though would make the assembling and mounting procedures more convenient and safe.

turn table (also made in JINR). The EEMC module will be assembled in a horizontal position at the turn table. The turn table has the same set of mounting holes as the magnet poletip. The assembling procedure starts from scintillator layer N 26 (see **Fig.4**) and finishes at scintillator layer N 1 and the front cover plate.

The assembling sequence is as follows :

• The strong back plate is installed onto the turn table and fixed with pins and screws.

• One central inner cover plate is mounted to the strong back plate.

• All *small pins* are installed into the strong back plate holes.

• All scintillator tiles of one EEMC layer are installed between the *small pins*; the WLS and quartz fibers are combined into bundles as shown in Drawing **OK–1261.000, 2nd part**. Then, the gasket is laid over the scintillator layer.

• The lead plate is laid over the gasket.

• Another set of *small pins* is installed into the lead plate.

• The next layer of scintillator tiles is mounted between the *small pins*.

• ....

• When the scintillator layer N 17 is finished, the support plate 4 (see **Fig.4**) is installed, and the distance between the strong back plate and support plate is checked. This basic distance should be 112 ± 0.1 mm. If necessary, the distance is corrected with the help of additional paper gaskets.

• The assembly continues, and the basic distances are checked each time after the installation of support plates 3, 2 and 1 (front plate).

• All inner and outer cover plates are installed and fixed to back plate and support plates.

• Both radial walls of the module are installed and fixed.

The assembling procedure wil be corrected, if necessary, during the construction of the full–scale prototype of the 30^o module.

To install the EEMC module onto the magnet poletip, the special mounting device is used (see **Fig.14**). The EEMC module is turned into vertical position on the turn table, the crane moves the mounting device close to the module, the module is fixed to mounting device, then disconnected from the turn table and equilibrated with counterweight.

Then, the module and mounting device are moved by crane inside the magnet, the module is fixed and aligned onto magnet poletip.

To install the EEMC modules, the magnet poletip should be moved out of magnet. The Integration Group drawing **SIM 222–A–1** gives the size of the clearance between the magnet and moved magnet poletip equal to $\sim$ 1 meter. To make the EEMC installation procedure more convenient and to avoid possible damage of optical fibers, the enlarging of the mounting clearance would be very desirable.

3 EEMC – expected properties.

The basic physical characteristics of the EEMC were obtained using GEANT simulation. The standard STAR GEANT software package was used [7]. Based on the current design, the EEMC geometry was described in details, including major mechanical structures and gaps. The GEANT simulations provided information on shower profiles in the EEMC, and on influence of the mechanical structures and cracks on the measured energy in the EEMC. The results of the software simulation of the EEMC are presented in [8]. The brief summary of the obtained results is given below.

Energy resolution. The EEMC energy resolution was calculated as $(16.5 \pm 2)\%/\sqrt{E}$. For the sampling structure of the current design, the energy collected in active layers is $\sim$7.3% of total deposited energy. The EEMC shows a good linearity for photons with energies $1 < E_\gamma < 20$ GeV.

Predicted distortions. Gaps between the EEMC modules, radial walls, between scintillator tiles, and (probably) WLS fiber couplings, create areas where the EEMC response is distorted. About 20% of all EEMC showers need some correction (during the data processing) in the sense that though the information is not completely lost here, the simple relation between the energy of the incident particle and the tower response, is not valid. These distortions are correctable with the help of SMD information about the shower position.

EEMC orientation. Each 30° EEMC module should be aligned with the TPC Wheel. It means that the spokes of the TPC Wheel will coincide with the radial walls of the EEMC modules. The spokes are thicker than the walls, so the EEMC radial walls will not create an additional dead space in the forward direction.

Dead material. The dead material in front of the EEMC ($\simeq 0.7\chi_o$ in average, see [8]) due to TPC elements, distorts the EEMC response. If γ or electron starts a shower in TPC Wheel, the EEMC energy resolution for such particle degrades to $\simeq 0.21/\sqrt{E}$.

The biggest distortions were observed in SMD profiles. To correct these distortions, the information from the first sensitive EEMC layer is very desirable. The additional design considerations for a possible separate read–out of the first layer should be done.

4 Drawings and CAD files.

The detailed engineering design of the EEMC was made in Particle Physics Laboratory. A complete set of technical drawings are available at LBNL computer **me10.lbl.gov** in directory **/star/DROPOFF/DUBNA** (use anonymous ftp !). The drawings exist both in .eps and .dxf formats. Below, is the short list of the available drawings.

OK–1261.000, 1st part – is the main assembly drawing. It shows the general view of one assembled 30^o EEMC module.

OK–1261.000, 2nd part – shows the lead plate mounting, scintillators assembly and fiber routing.

Other drawings show the detailed design of the EEMC parts.

OK–1261.060 – the strong back plate of the EEMC.

OK–1261.001 – the inner cover plate.

OK–1261.002 – the outer cover plate.

OK–1261.003 – the support plate 1 (front plate).

OK–1261.004 – the internal support plate 2.

OK–1261.005 – the internal support plate 3.

OK–1261.006 – the internal support plate 4.

OK–1261.007 – the "right" radial wall of the EEMC module.

OK–1261.007–01 – the "left" radial wall of the EEMC module.

OK–1261.009 – the joint element for mounting of front cover plate 1 and support plates 2,3,4, to outer and inner cover plates.

OK–1261.011 – the joint element for mounting the radial walls.

OK–1261.Sci – a scintillator tile and the Table of dimensions for complete set of tiles.

OK–1261.Pb – one lead plate and the Table of dimensions for complete set of lead plates.

OK–1261.Gas – one gasket and the Table of dimensions for complete set of gaskets.

OK–1255.510 (the same as **Fig.13**) – the holes in the magnet poletip for EEMC mounting.

Also, drawings OK–1261.015,016,017,018 show small mounting and alignment pins. Files gost.shp and gosts.shp are the font files. The *README* file gives the correspondence between the names of .eps files and OK–XXXX.xxx drawings.

5 Conclusion.

The current design of the EEMC is completed, and the technical drawings are ready. These drawings, after appropriate considerations and approval of the STAR Collaboration, will be used for manufacturing of the first EEMC module (1/12 part of EEMC), as the full–scale working prototype.

Any questions, comments and suggestions about the EEMC design are appreciated.
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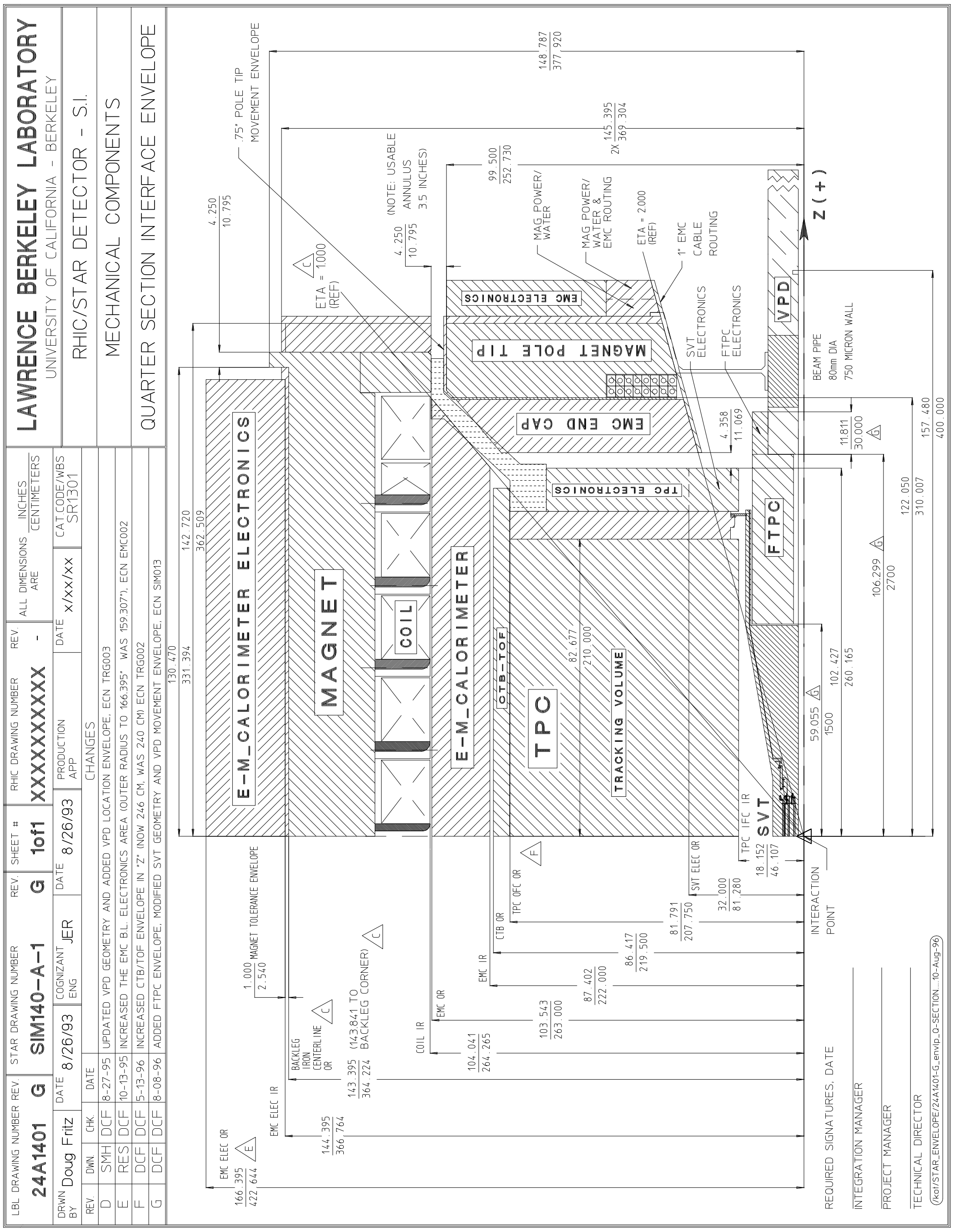

Figure 1a. *STAR Integration Group Drawing SIM140-A-1. The basic dimensions of EEMC envelope are shown.*

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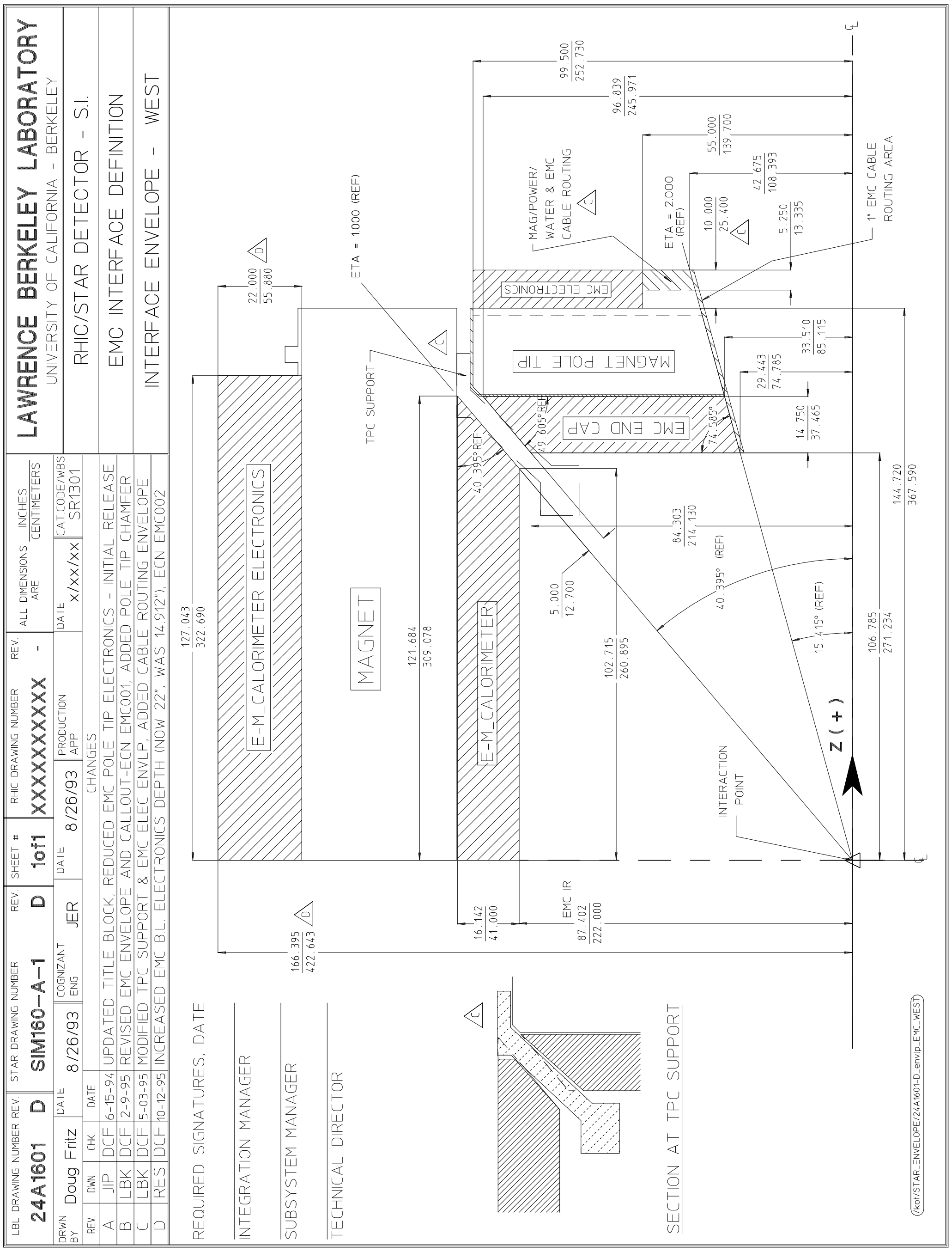

Figure 1b. *STAR Integration Group Drawing SIM160-A-1. The basic dimensions of EEMC envelope are shown.*

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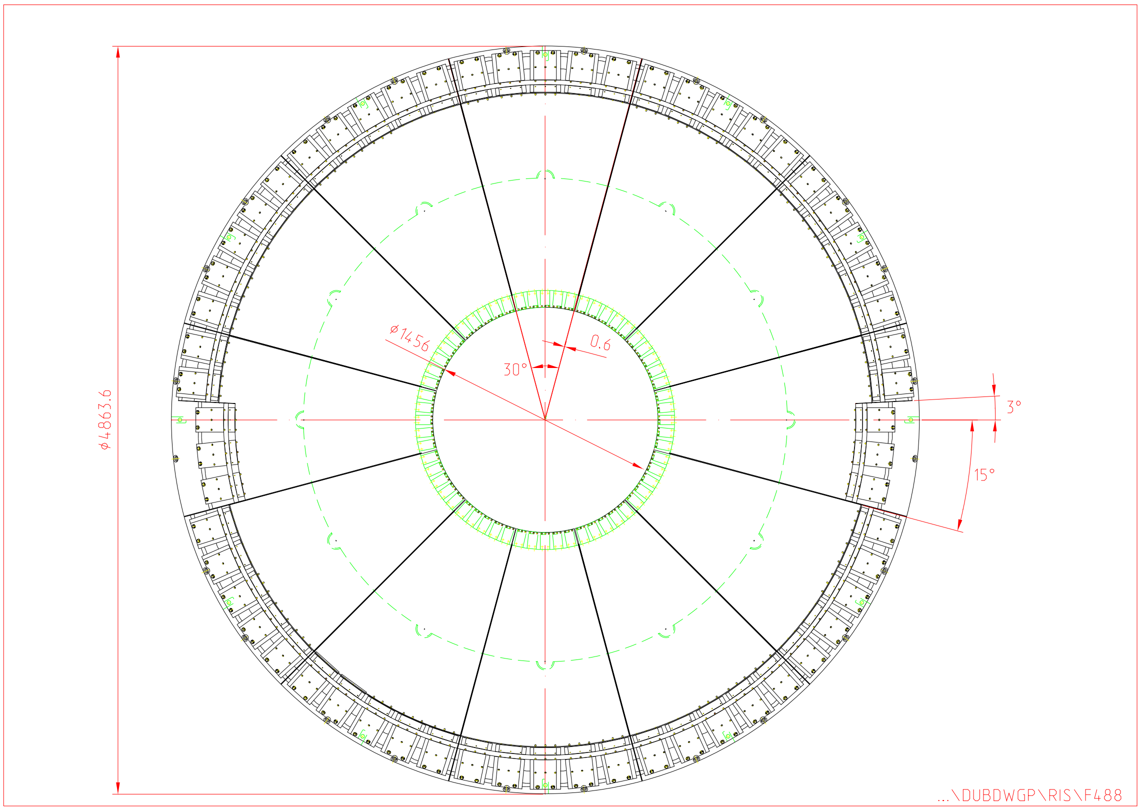

Figure 2. *The front view of all 12 assembled EEMC modules. Two EEMC modules have slightly different design, as they are affected by TPC supports.*

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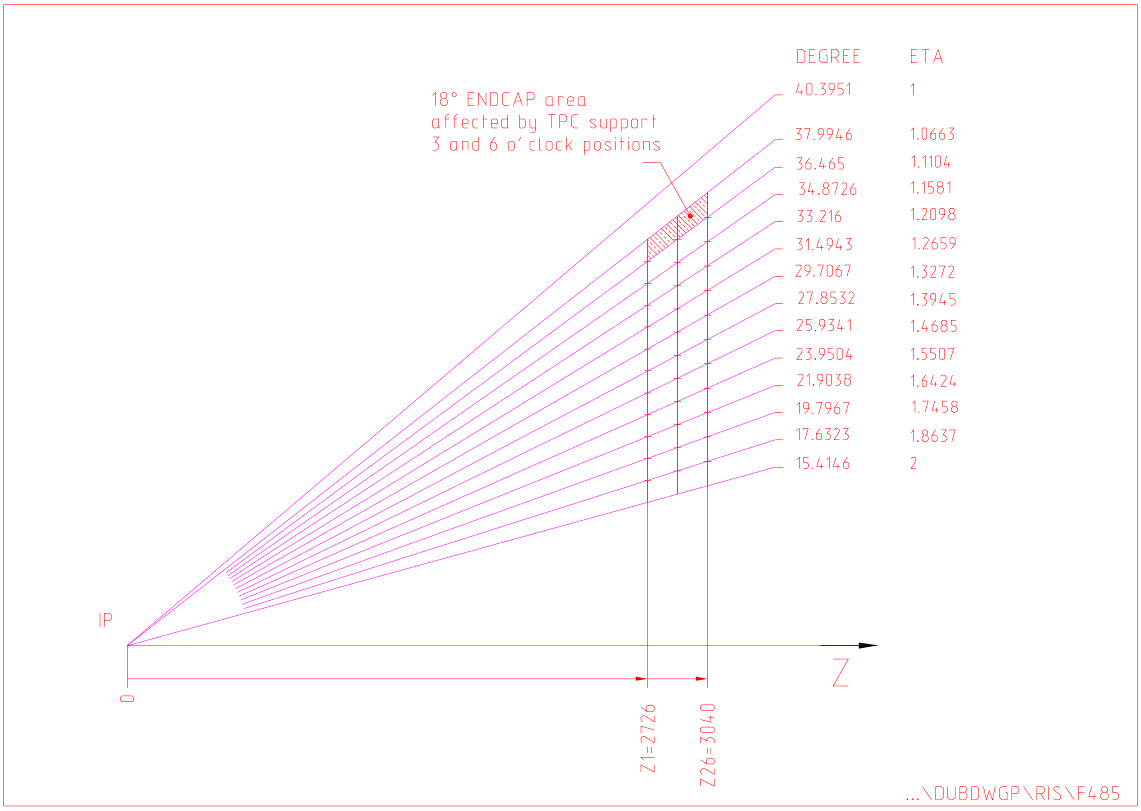

Figure 3. *End–cap EMC division in* Θ *(degrees) and* η *(units of pseudorapidity). All EEMC scintillator tiles are of equal height. The gap between BEMC and EEMC, and the area affected by TPC support, are shown.*

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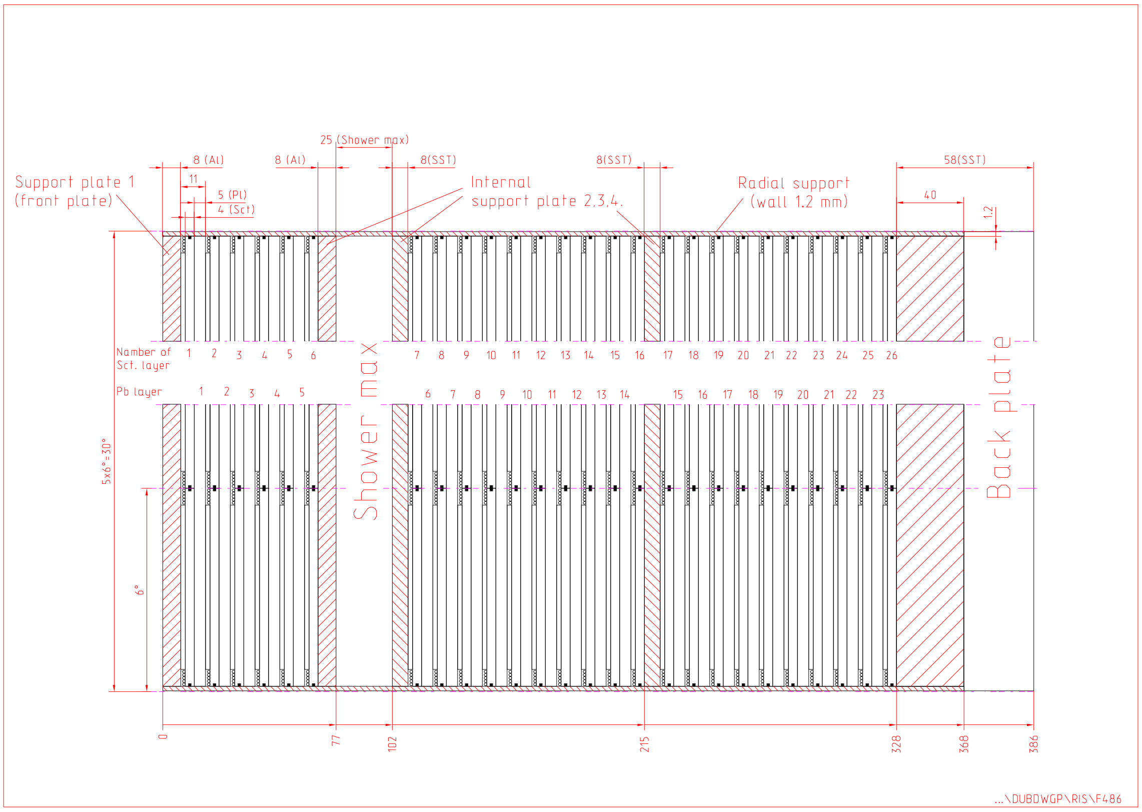

Figure 4. *The schematic view of one EEMC tower. Front cover plate, three internal support plates, SMD box and strong back plate, are shown.*

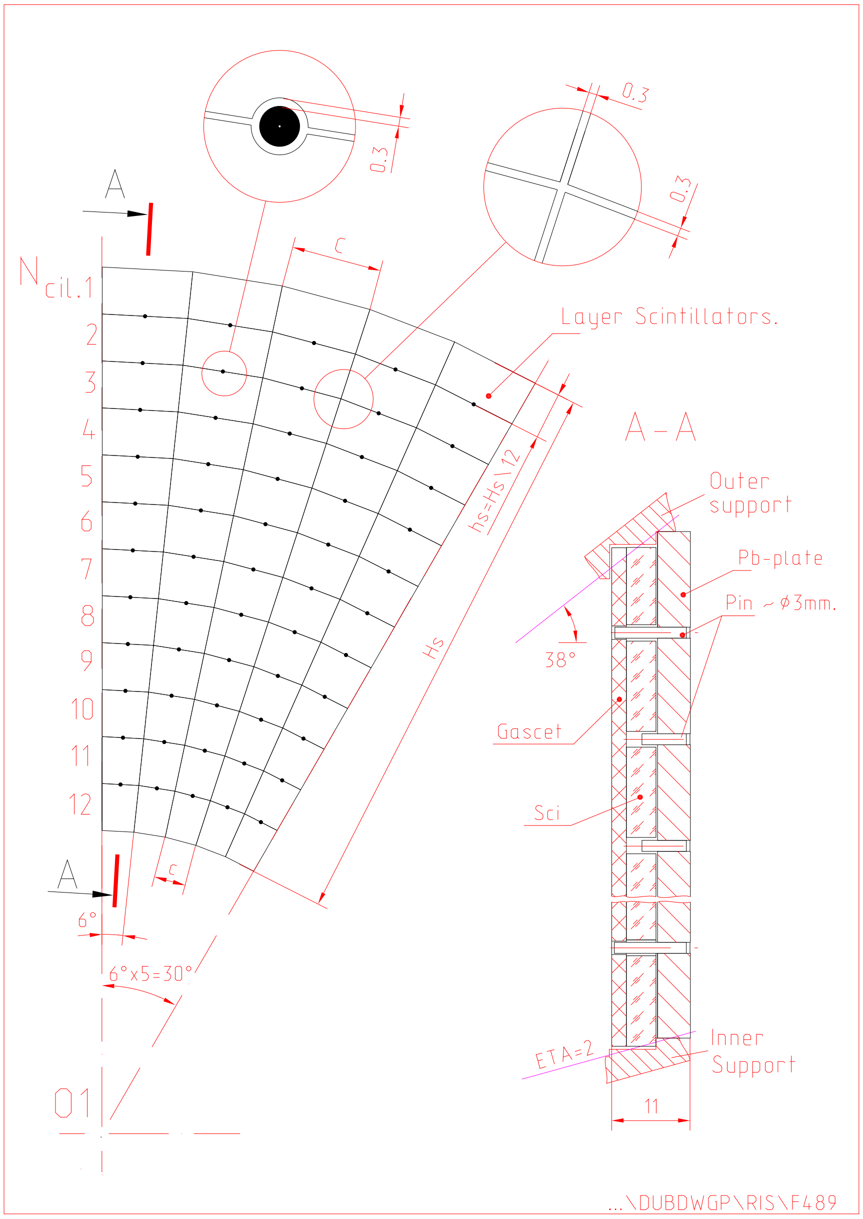

Figure 5. *The mounting scheme for scintillator tiles of one EEMC module. The areas around the small mounting pins and between edges of the tiles are shown more closely. Two mounting pins are used also for gasket installation and alignment, and have the larger height.*

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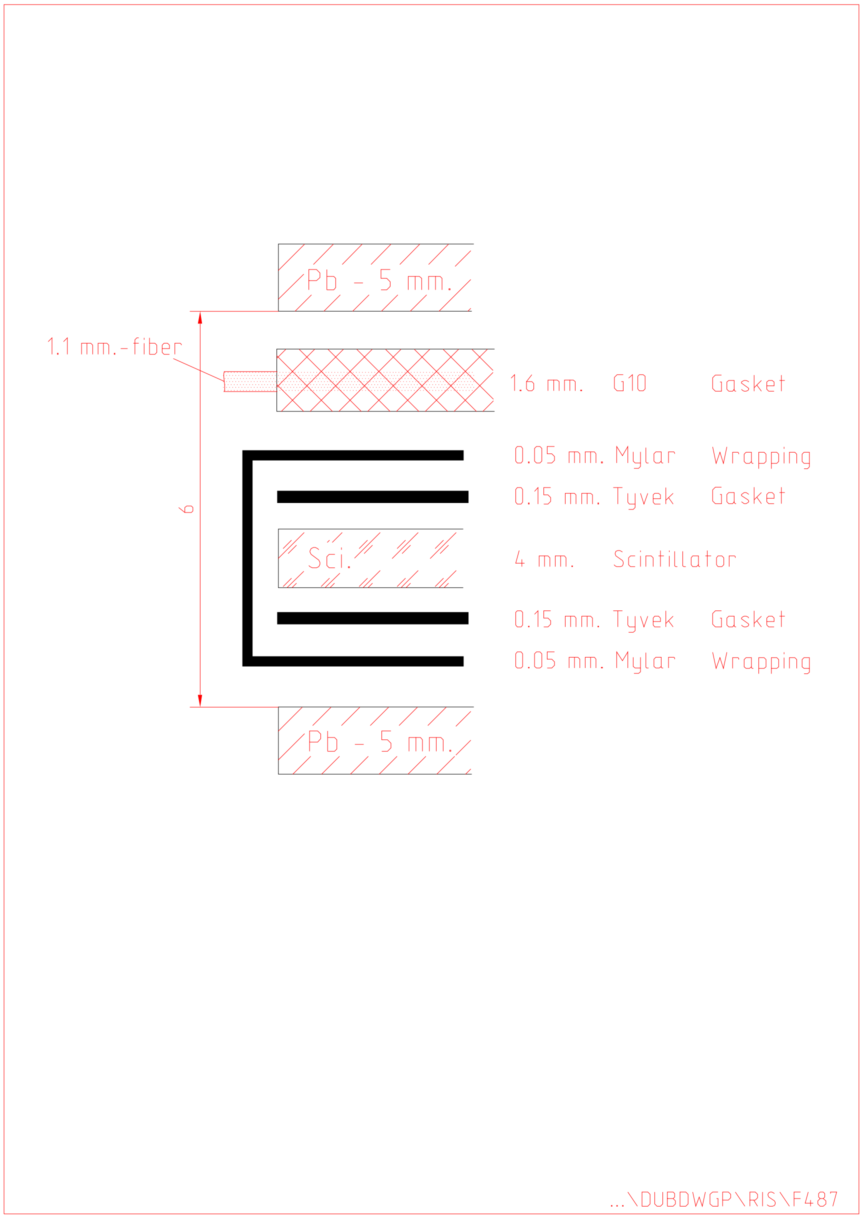

Figure 6. *The schematic view of "one step" of EEMC stacking sequence.*

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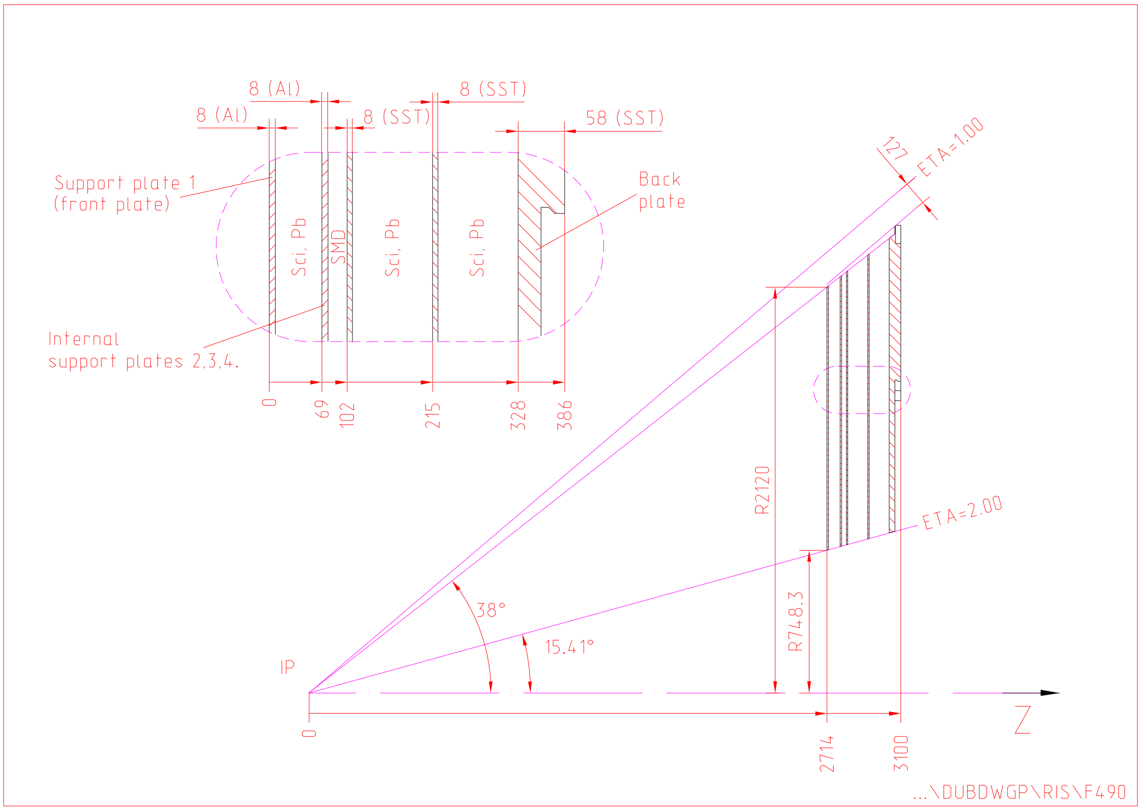

Figure 7. *The structure of the support frame of EEMC module.*

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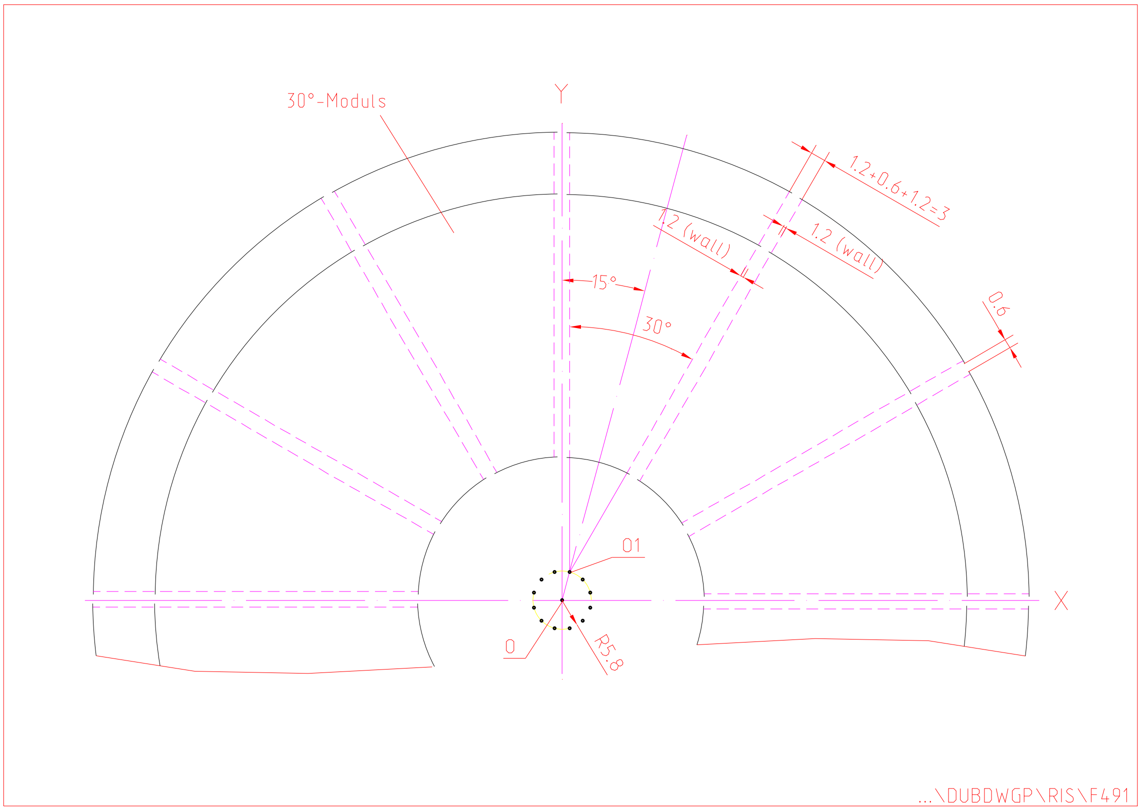

Figure 8. *The schematic view of the assembled EEMC modules. The walls and tolerance gaps between modules create the dead areas along the edges of the EEMC module.*

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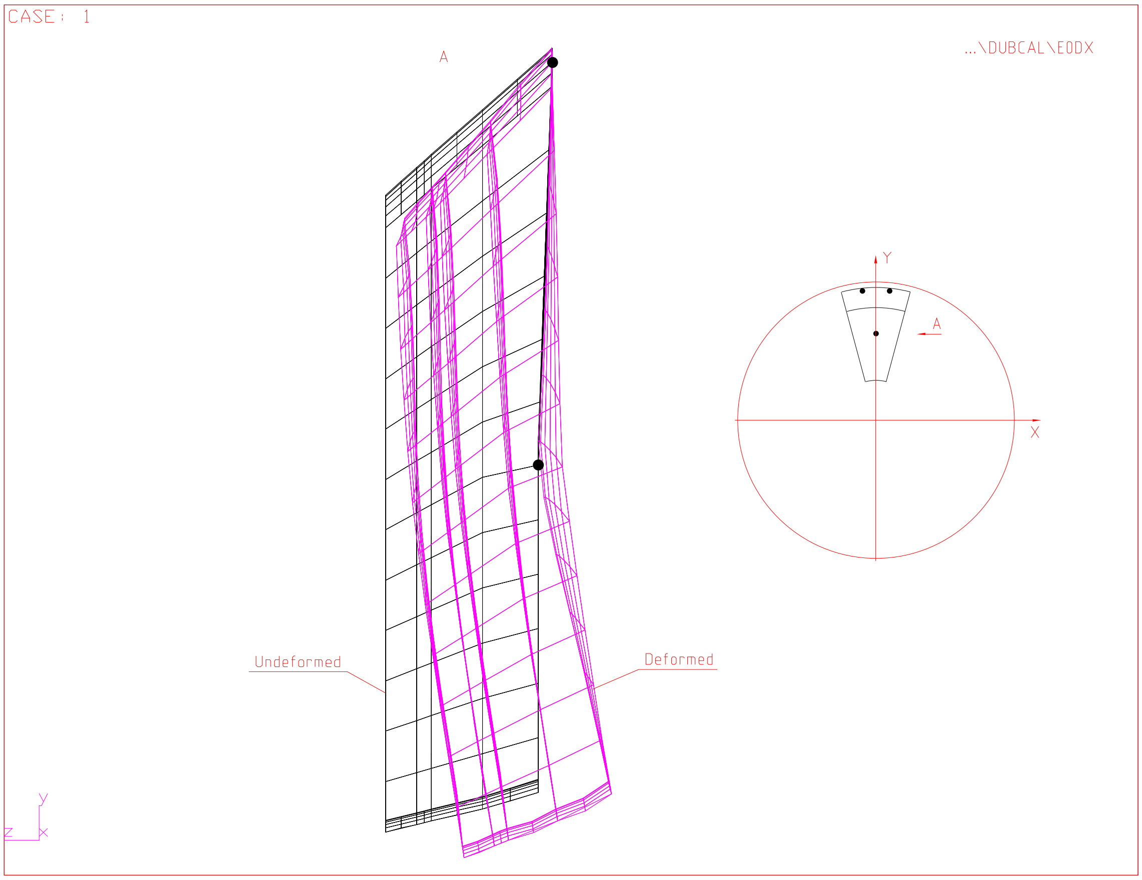

Figure 9a. *The deformation of EEMC module is shown for the module installed at "12 o'clock". The black dots at the right side of the module frame indicate the positions of mounting screws and pin.*

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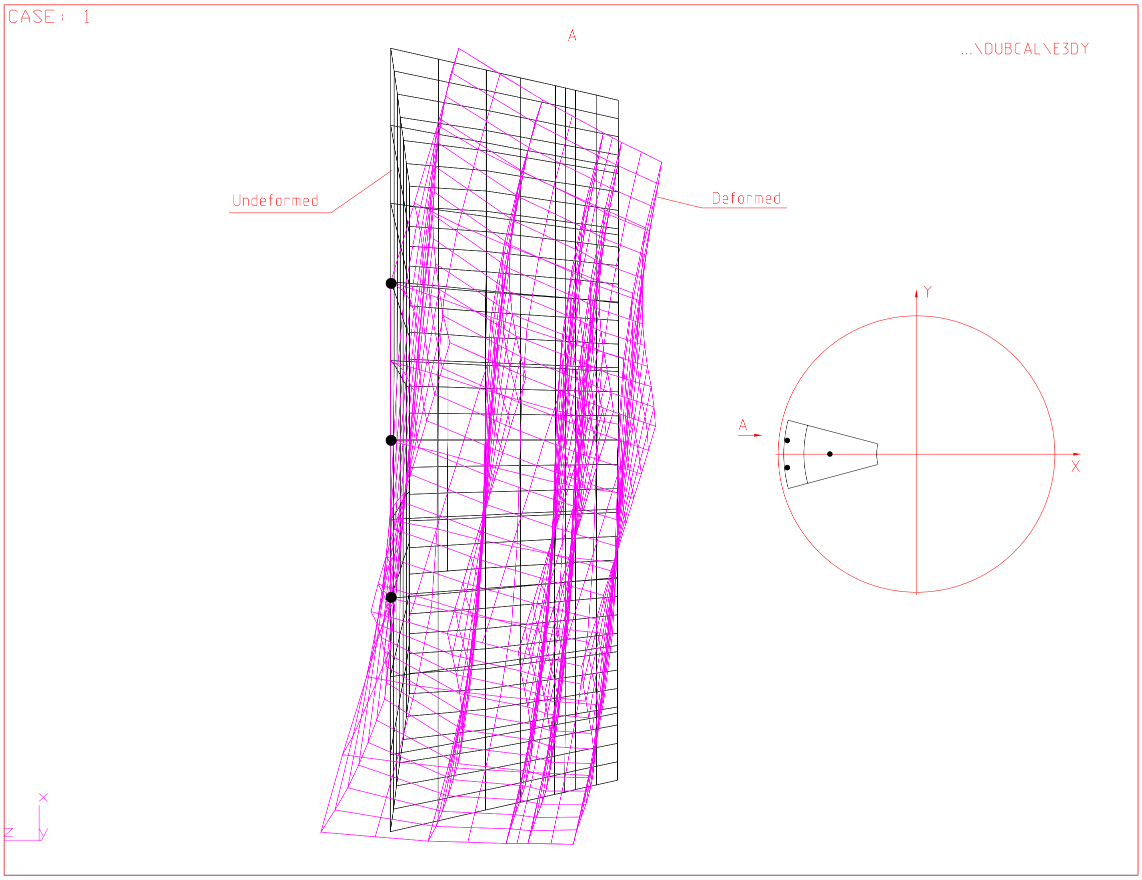

Figure 9b. *The deformation of EEMC module is shown for the module installed at "9 o'clock" (the similar picture is for "3 o'clock"). Three black dots at the left side of the picture indicate the positions of mounting screws and pin.*

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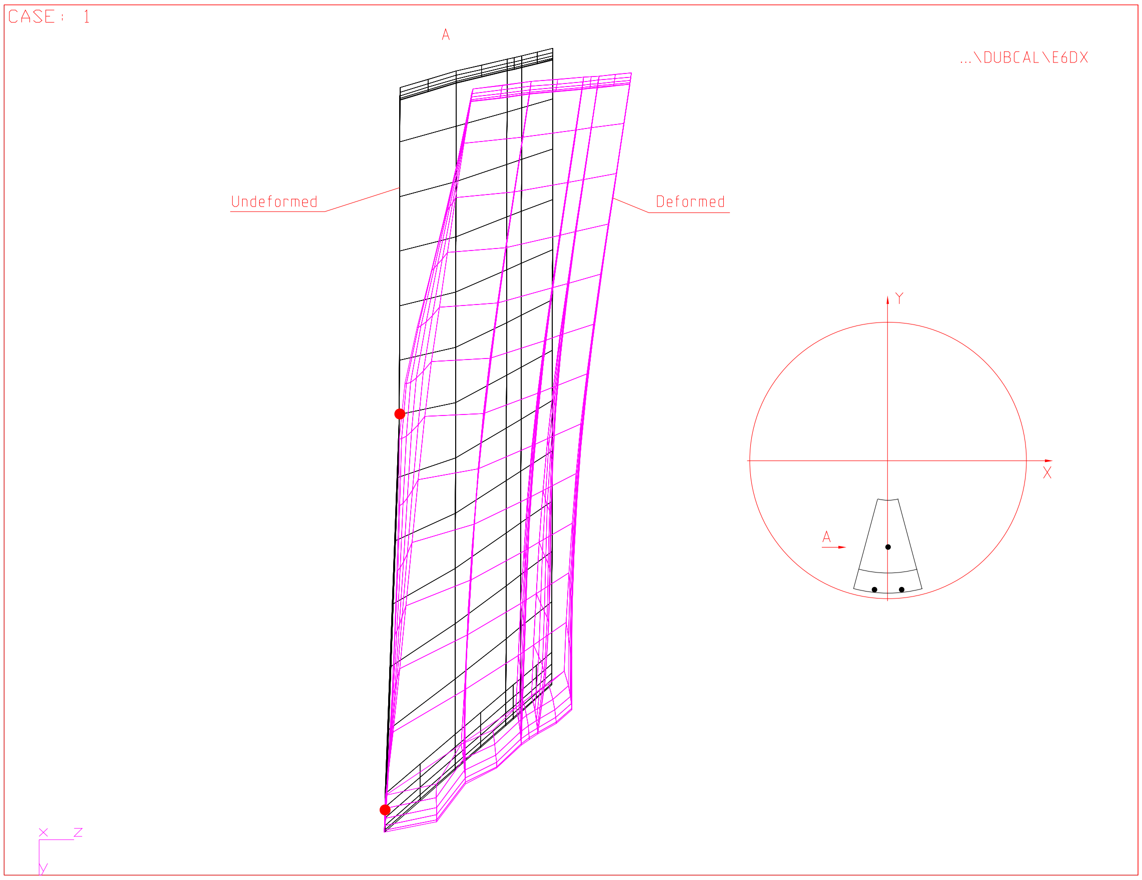

Figure 9c. *The deformation of EEMC module is shown for the module installed at "6 o'clock". The big dots at the left side of the module indicate the positions of mounting screws and pin.*

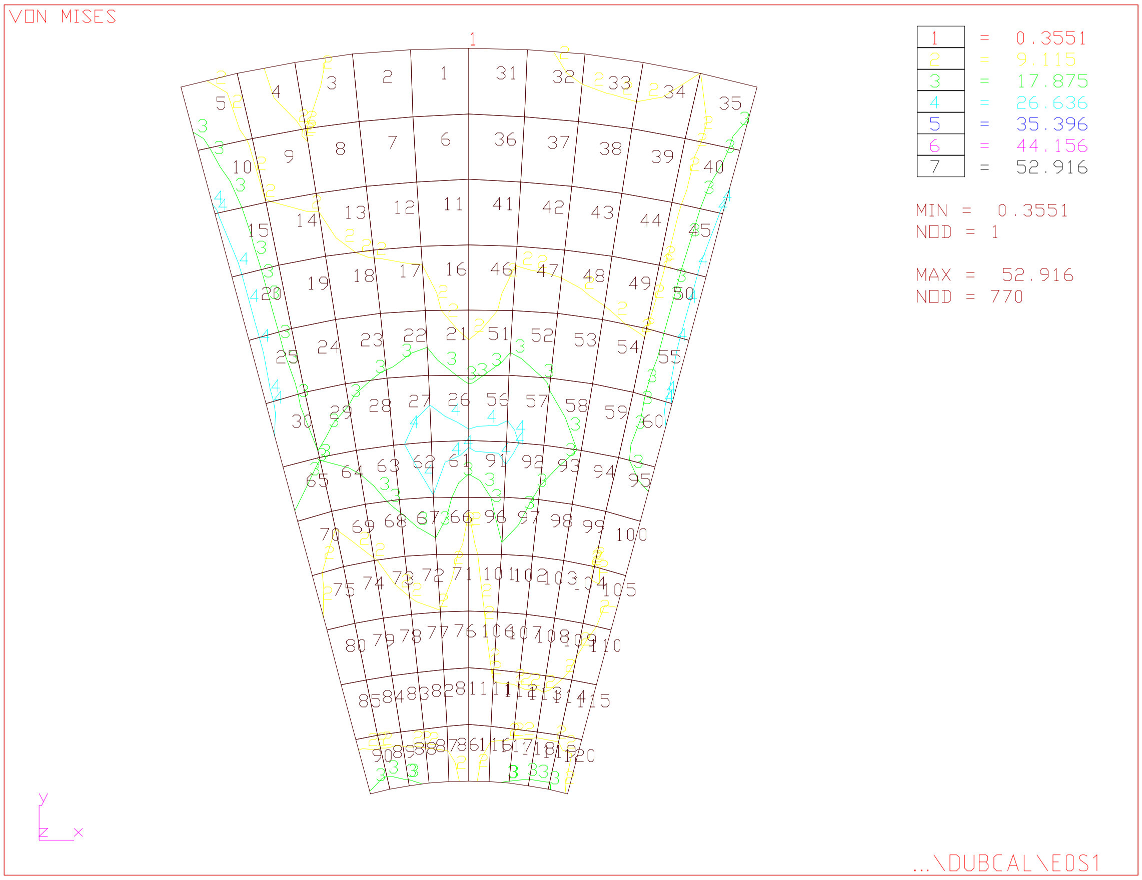

Figure 10. *The distribution of calculated stresses in the strong back plate of "12 o'clock" EEMC module. Must be seen in color. The contour lines represent the areas of equal stresses. The calculated stresses (in kg/cm^2) corresponding to each color contour, are given in the upper right corner of the figure.*

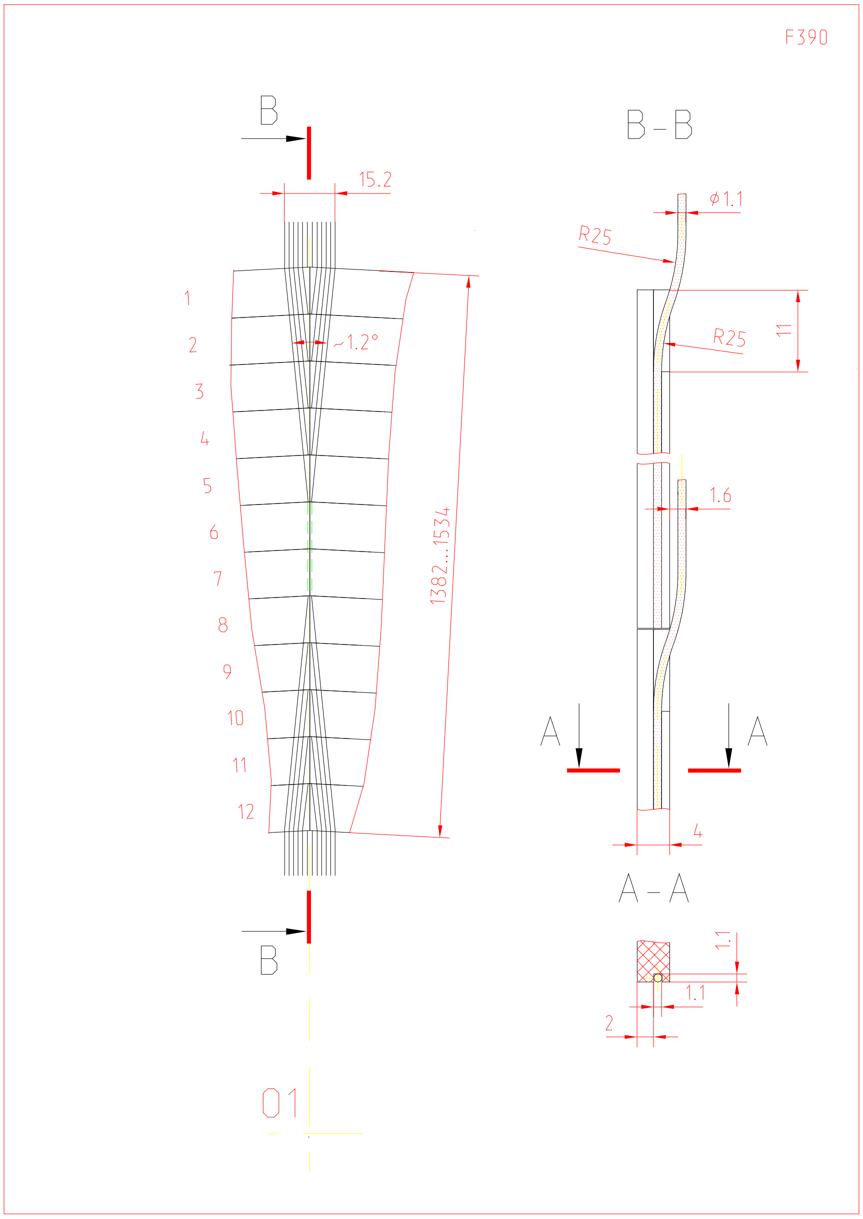

Figure 11. *Fiber–to–scintillator coupling and general fiber routing are shown for two adjacent 6° scintillator sectors.*

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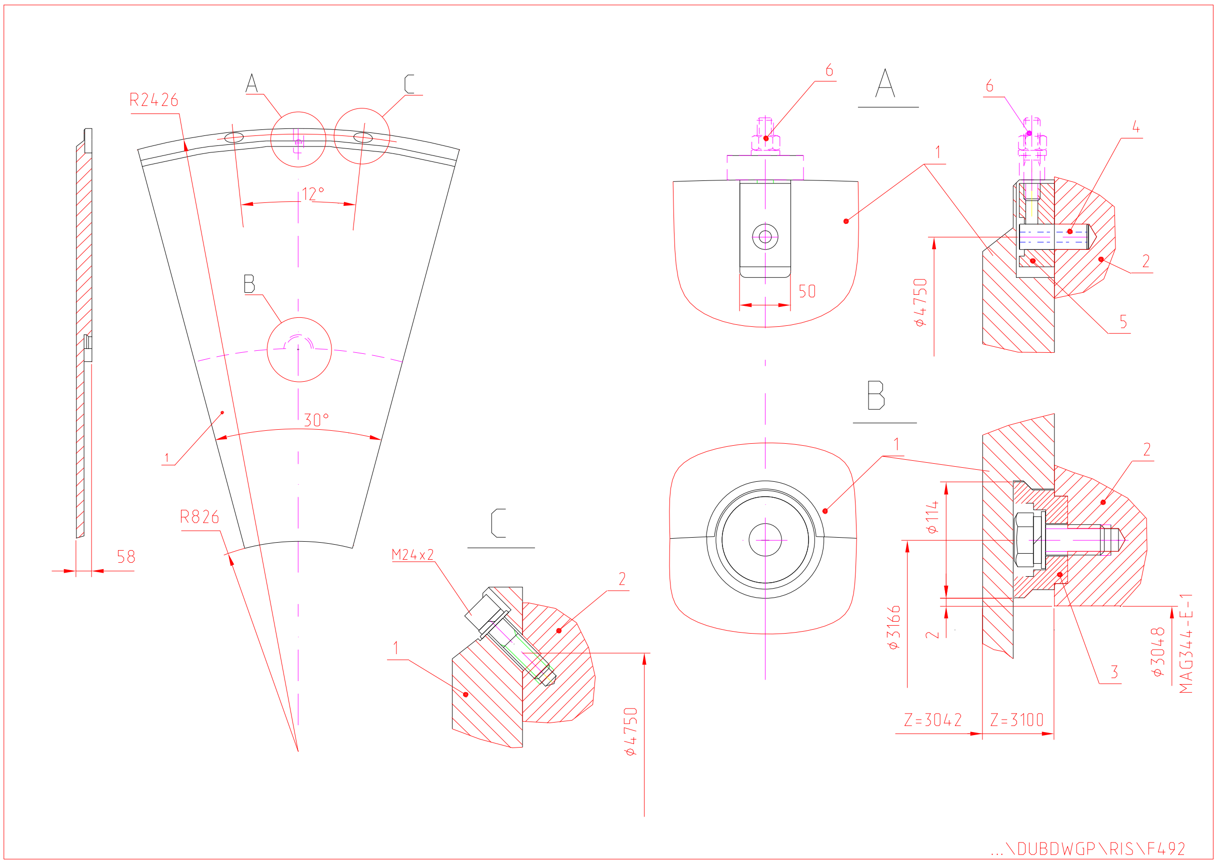

Figure 12. *The mounting elements of the EEMC module : cone pin, alignment pin, and two M24 screws.*

(1) – back plate;

(2) – magnet poletip;

(3) – cone pin;

(4) – alignment pin;

(5) – adjusting element;

(6) – mounting device.

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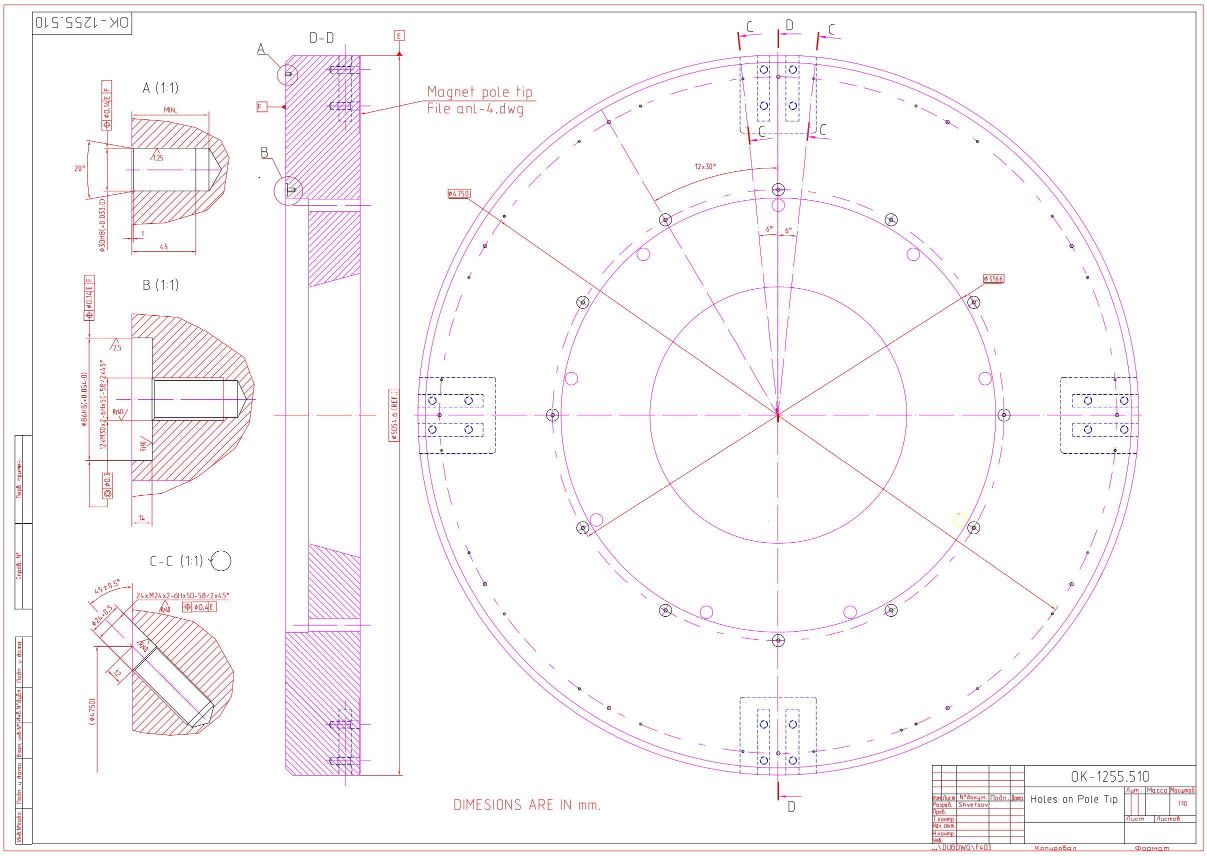

Figure 13. *The EEMC mounting holes in the STAR magnet poletip.*

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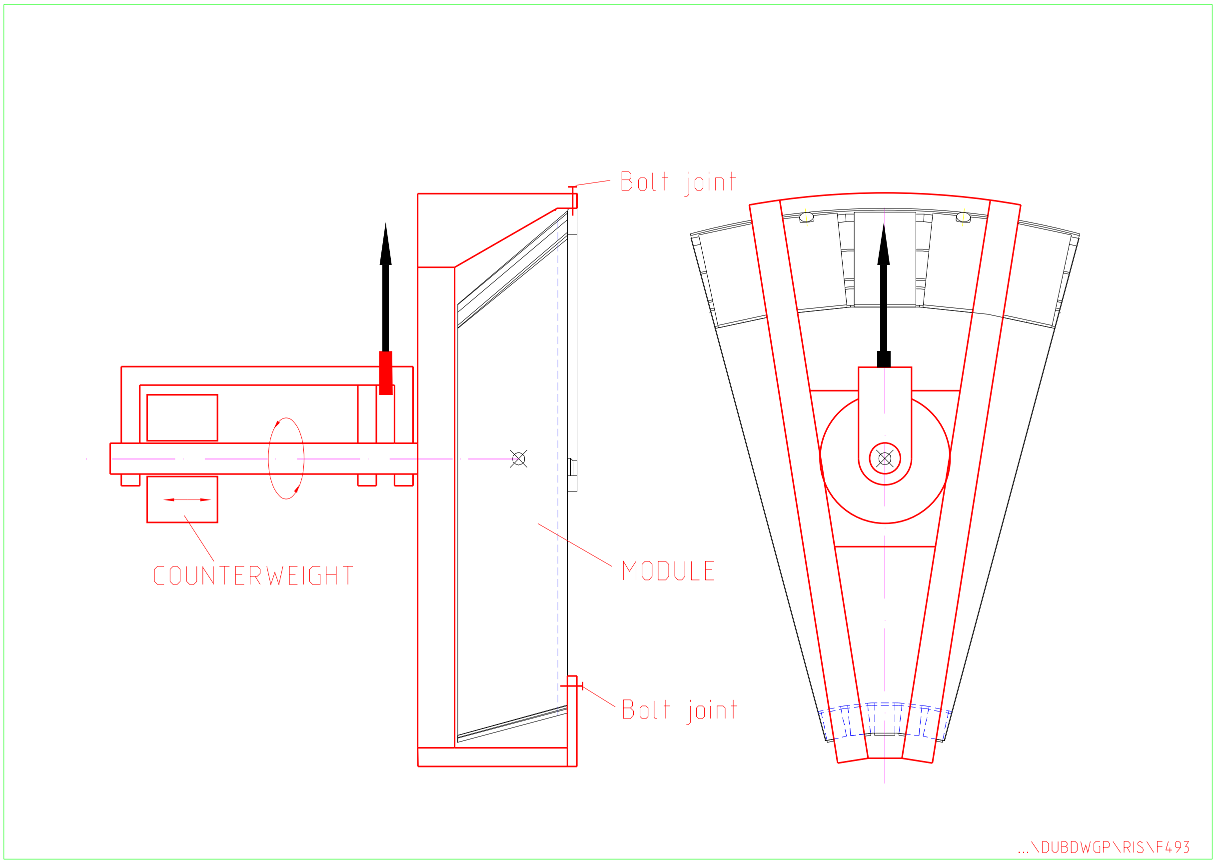

Figure 14. *The mounting device for installation of EEMC modules to the magnet poletip.*