Scintillator macrotiles

– possible mechanical concept for HGCAL

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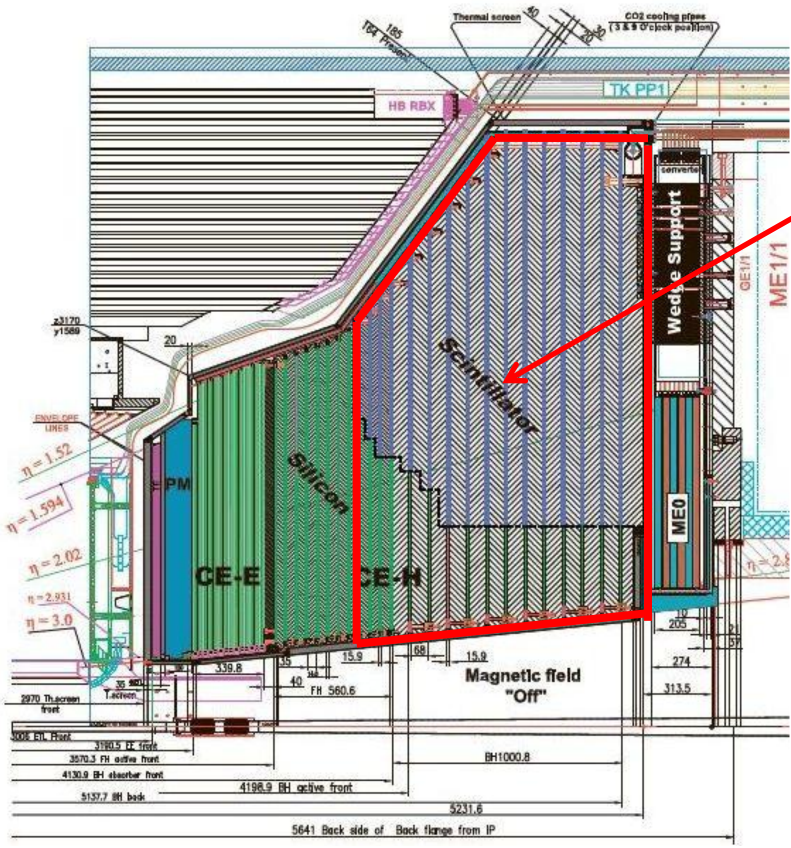
I.Golutvin

Mixed CE-H (Calorimetr Endcap–Hadron) cassettes for HGCAL



Mixed CE-H cassettes
(Layers 36…51)

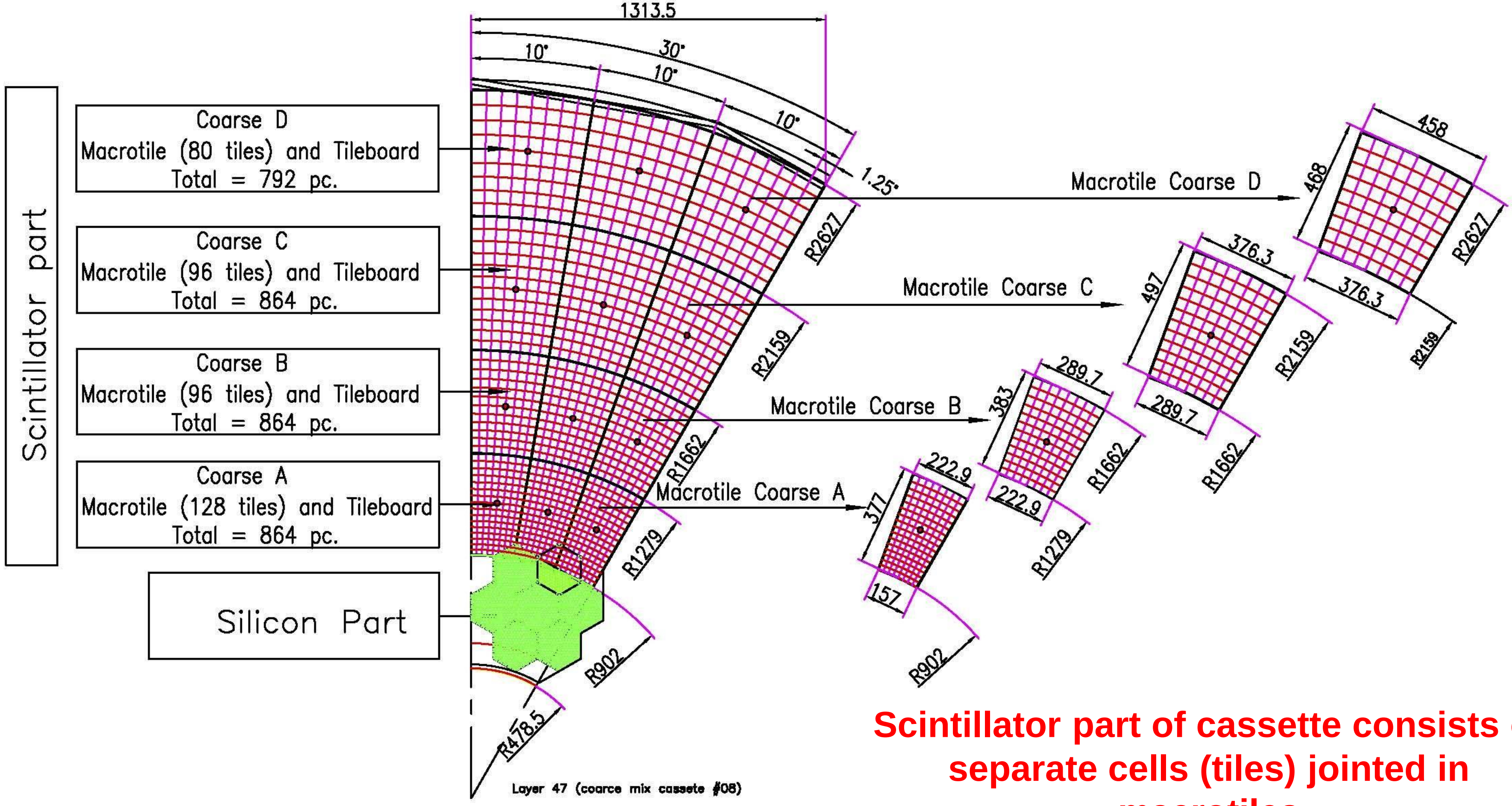
Mixed CE-H cassettes:

- 16 (4 fine and 12 coarse) detectors layers;
- 6 cassettes on 60° in each layer;
- Operation temperature – 30°C…-35°C;

Mixed CE-H cassette main parts:

-Scintillator detector part;
-Silicon detector part;
-Cooling plate;

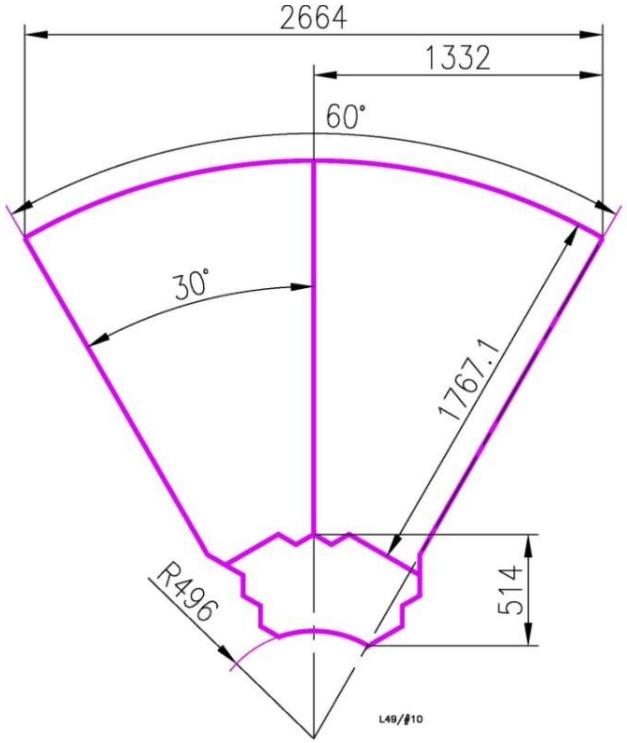
Mixed CE-H cassettes. Layers 40 - 51.
Coarse Scintillator macrotiles and SiPMs tileboards.
Types. Overall dimensions.



Scintillator part of cassette consists of separate cells (tiles) jointed in macrotiles

Cooling plates are the main structural element of CE-H cassette :

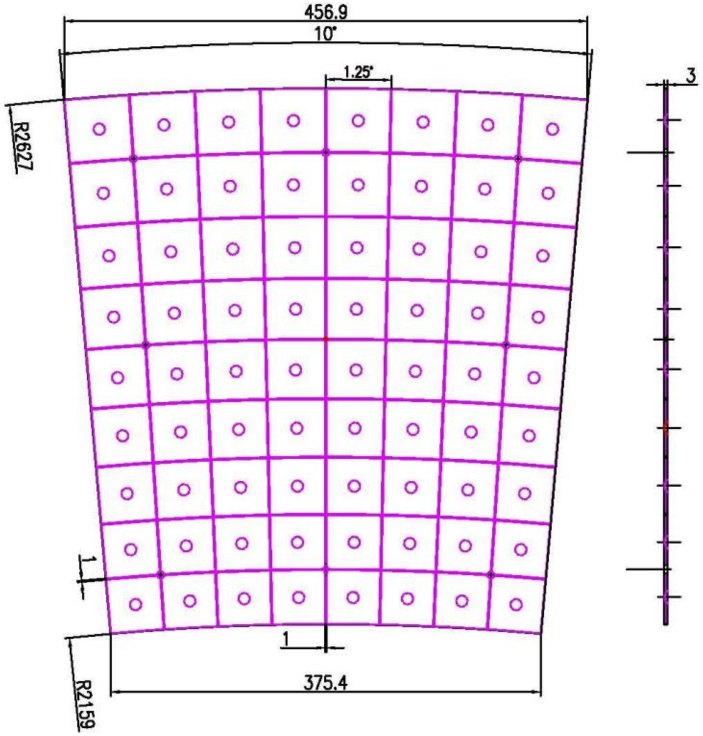
- - **provide operation temperature – 30°C…-35°C for silicon and scintillator detectors inside HGCAL;**
- **- used as a base for installation off all detector parts of the cassette;**
- **- provide the positioning of the assembled cassette in the absorber slot;**
- **- consist of 2 or 3 separate parts;**
- **made of 6 mm copper sheets and joined together.**

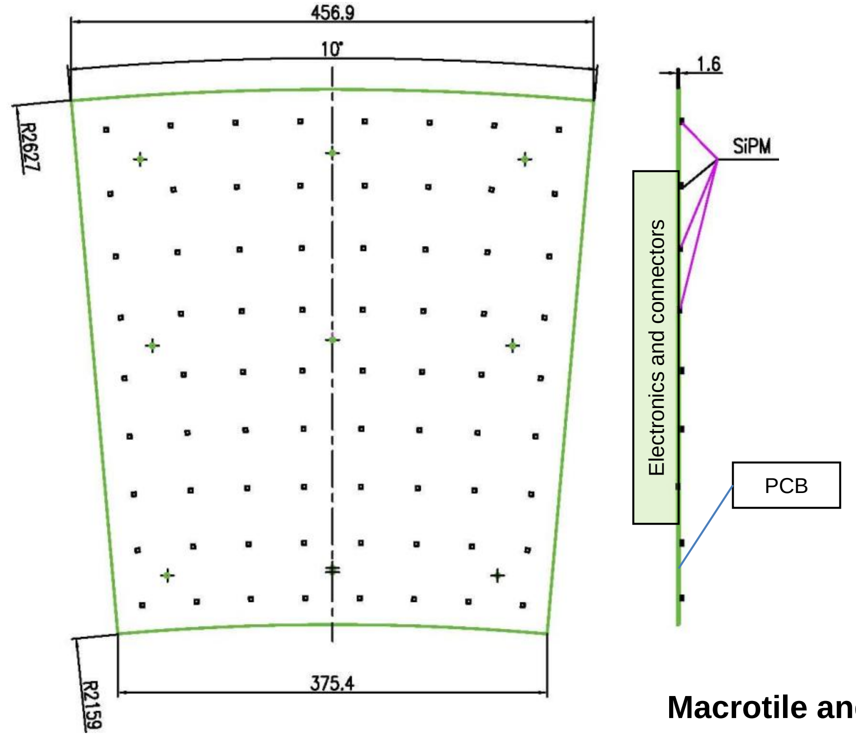


60° Cooling plate assembled
Overall dimension

Cooling plate design is not finalized and fixed yet.

Scintillator macrotile and SiPMs tileboard.





Scintillator macrotile:
- multi-cells (tiles) unit;
- R-φ tiles geometry;

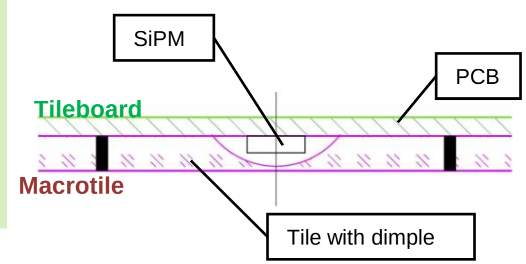
material - scintillator EJ 260

SiPMs tileboard:
- PCB with SiPMs on one side and electronics on the other side;

PCB material - G10

Macrotile and Tileboard

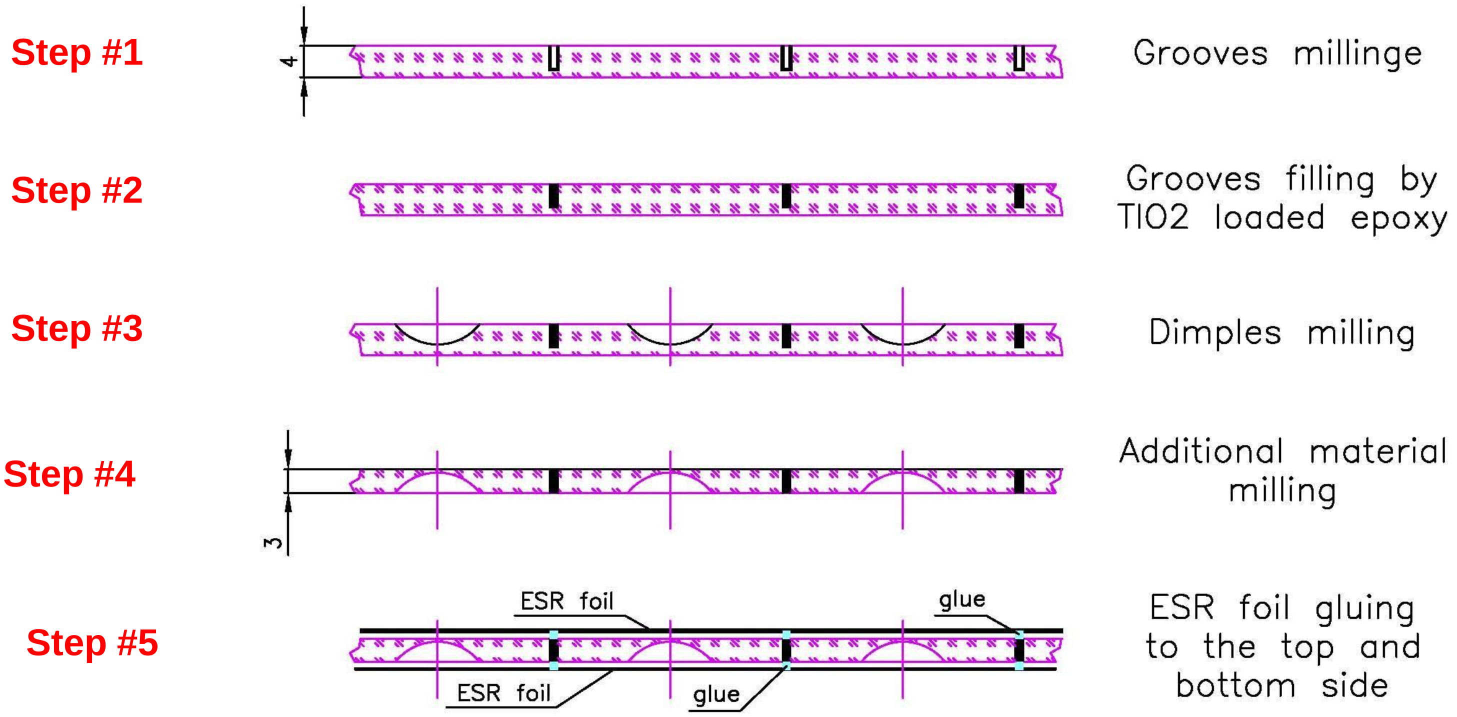
SiPM on tile position:



Scintillator macrotiles production.

Scintillator macrotiles construction is well-adapted to production by machining.

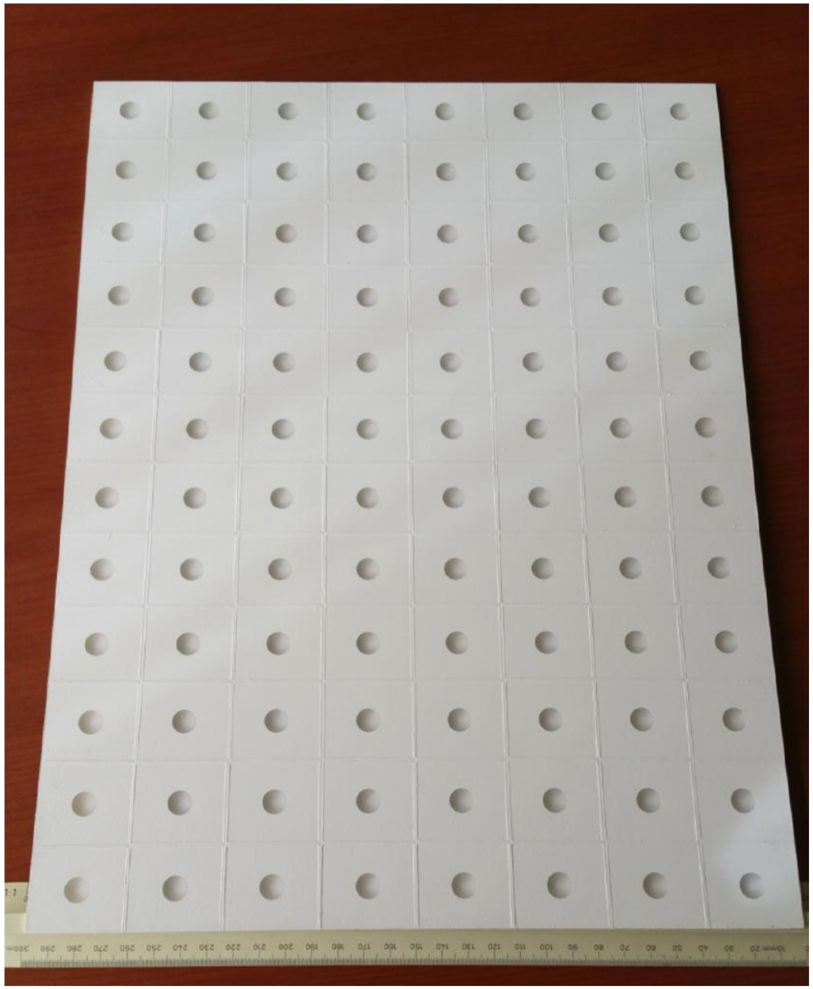
The process begins by milling scintillation material EJ-260.



After "Step #5" scintillator macrotile is ready for installation in the detector.

Additional procedure "tiles wrapping" is not required.

Scintillator macrotile prototypes.



3 full-size prototypes of scintillator macrotiles with orthogonal tiles of 30 mm x 30 mm were manufactured at ISMA Kharkov in June 2018 (by A.Boyarintsev).

The prototype size:
380mm x 290mm.

Number of tiles in macrotile:
8 x 12 = 96 pieces

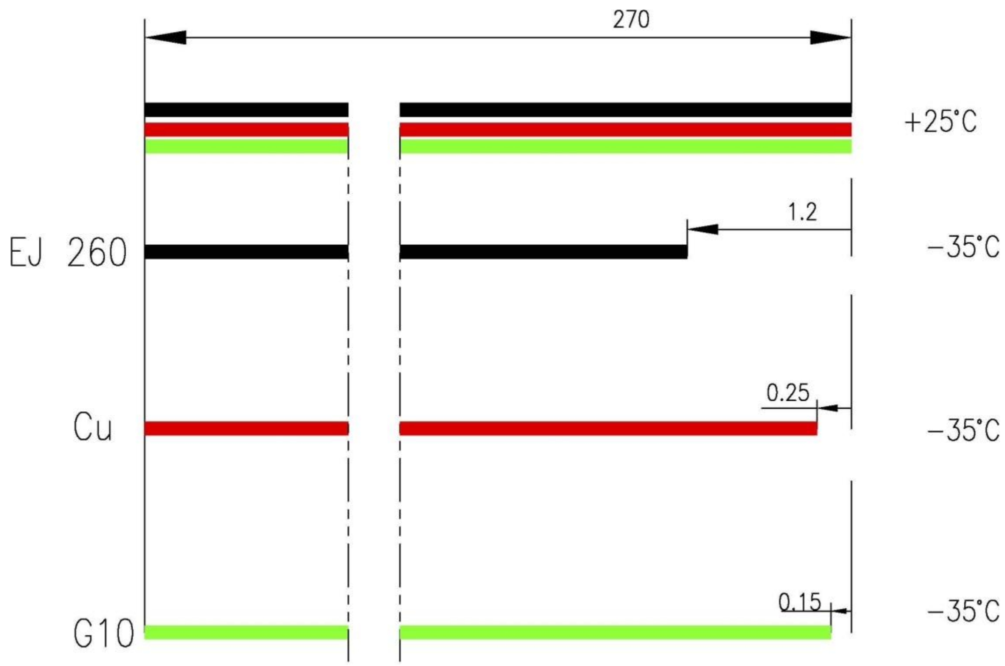
Final scintillator thickness = 3 mm

Mixed CE-H cassettes.
Features of the operation and thermal effects:

- **Assembly the detectors at room temperature (+20°…+25°C) ;**
- **Operation the detectors at -30°…-35°C;**
- **Parts of the detectors are made of materials with different coefficients of thermal expansion (CTE)**

Parts Material	CTE $x10^{-6}$ ^{o}C
Cu- Cooling plate	16.5
Stainless steel - Absorber	17.3
EJ-260 – Scintillator macrotile	78
G10 – SiPMs tileboard	10

Scintillator Macrotile, SiPMs Tileboard and Cooling plate.
Change in linear dimensions after cooling by 60 degrees (from +25°C to -35°C).

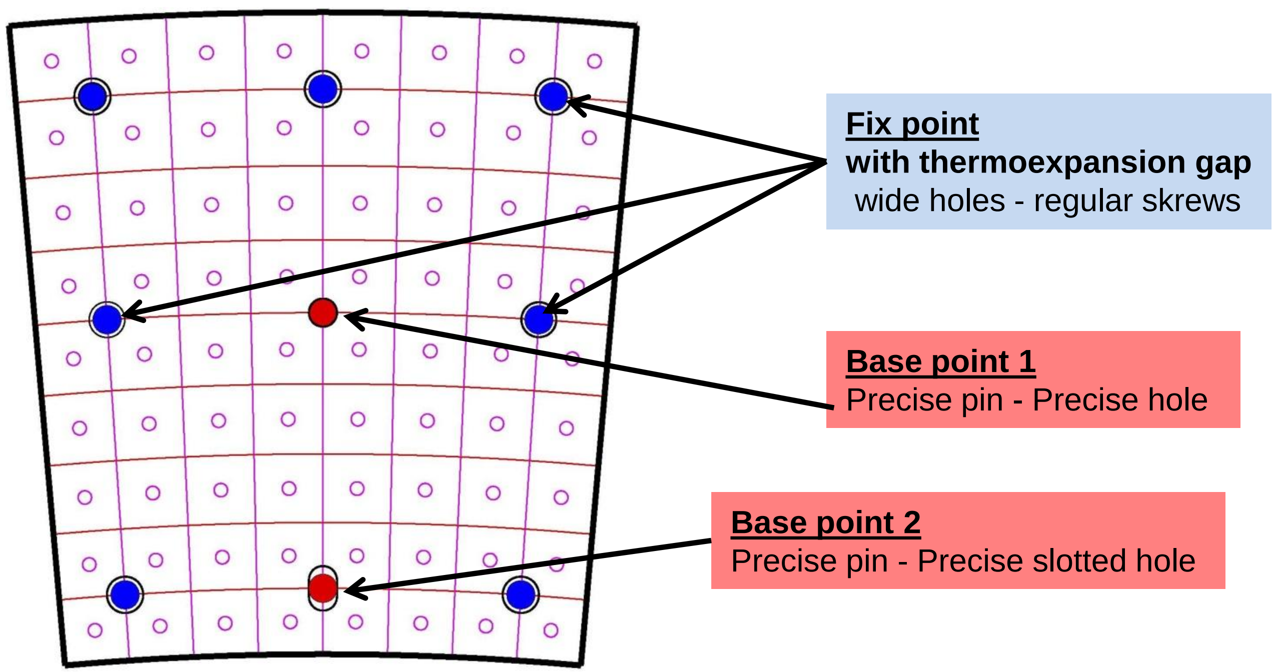


270 mm this is the maximum distance from the center of the macrotile to its edge.

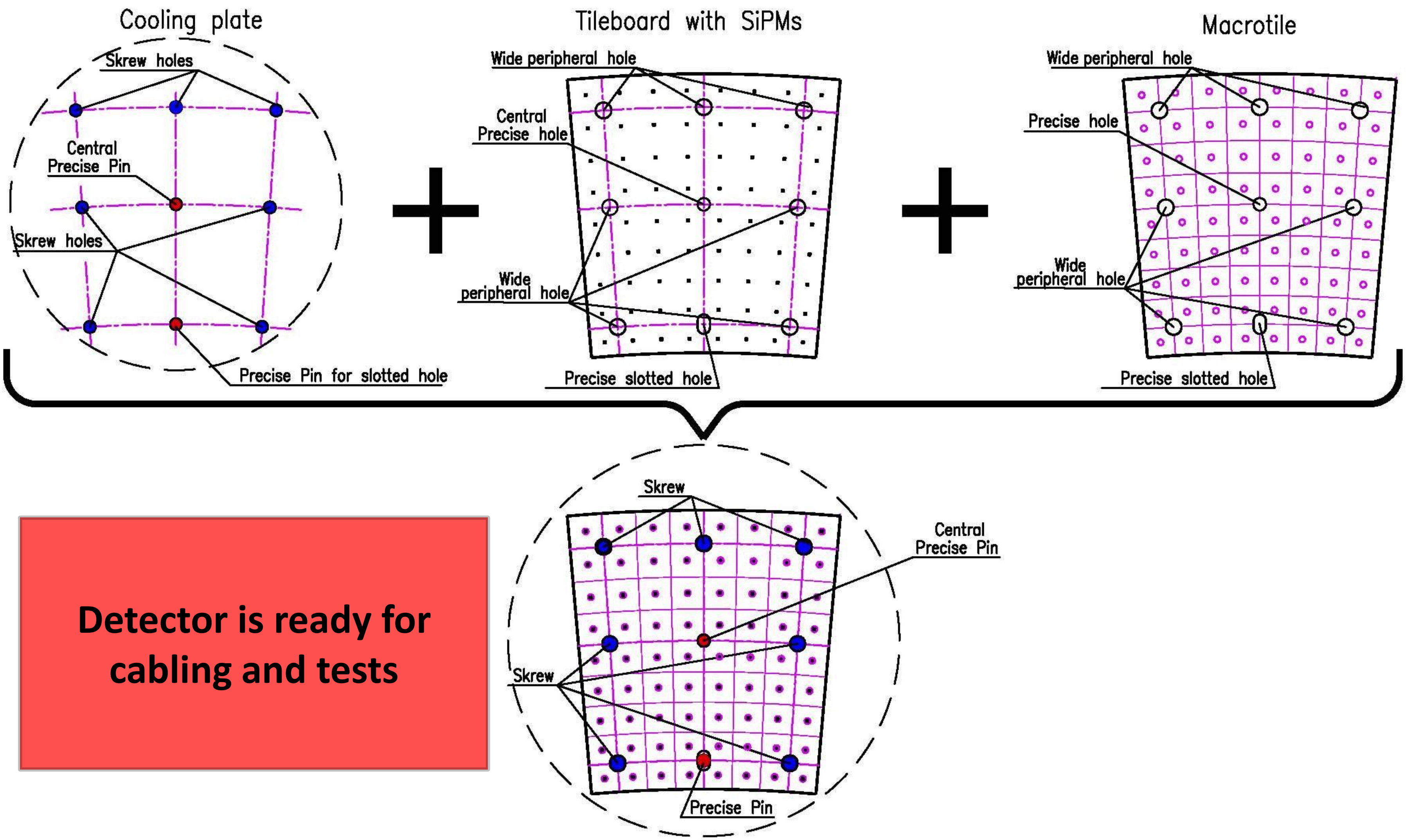
Scintillator macrotile, SiPMs tileboard. Fixation points.

To minimize thermal effects for parts made from different materials (macrotile, tileboard and cooling plate) the following alignment and fastening scheme is proposed:

- **Base point 1** - **precise pin and precise hole** – in the center of macrotile (to minimize distances);
- **Base point 2** - **precise pin and precise slotted hole** - on the central axis at the periphery of macrotile;
- **Fix points** - **holes with thermoexpansion gap -** wide holes and regular skrews.



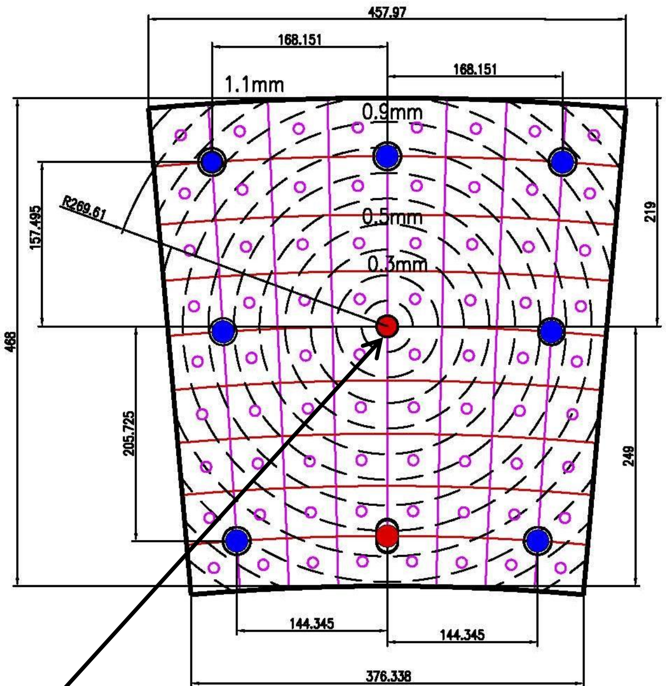
Scintillator part cassettes assembly



Detector is ready for cabling and tests

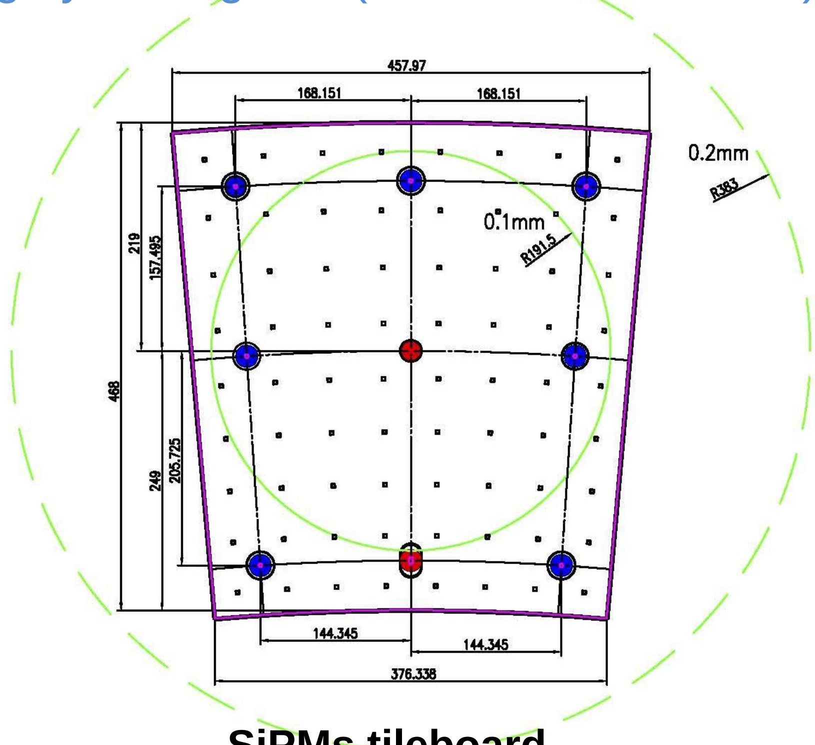
Scintillator macrotile and SiPMs tileboard.

Changing dimensions after cooling by 60 degrees (from +25°C to -35°C).



Base point

Scintillator macrotile



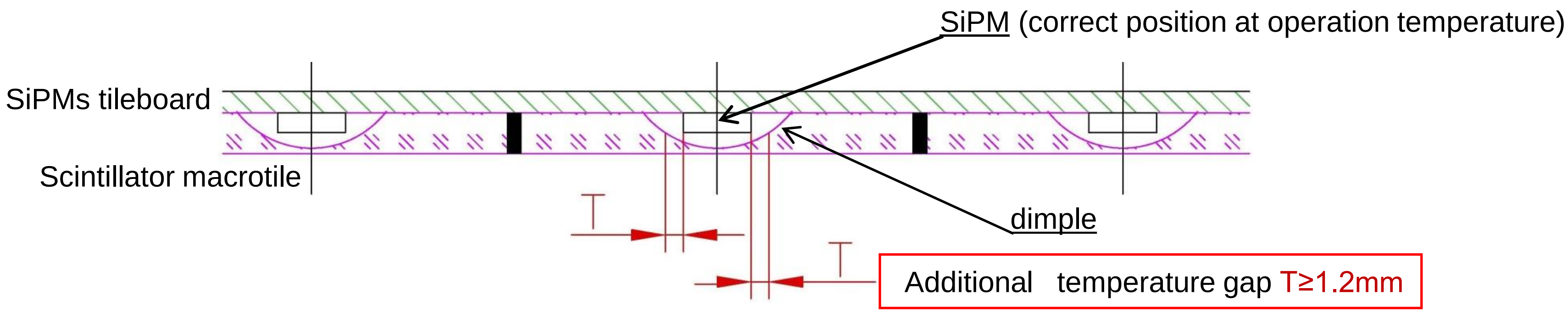
SiPMs tileboard

The concentric circles show (in increments of 0.1 mm) changing the dimensions after cooling down by 60º

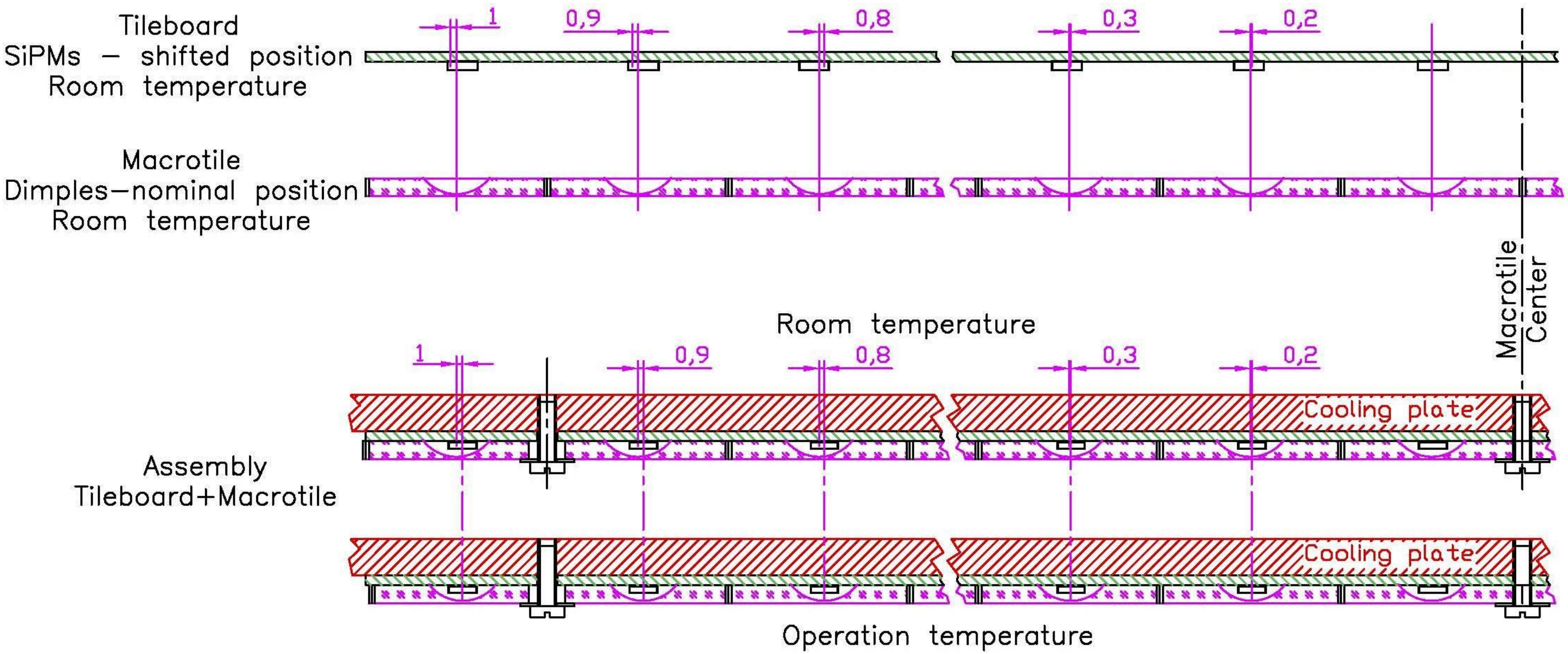
- **The selection of the base point in the center will be optimal for joint the macrotile and the tileboard**
- **The maximum discrepancy will be up to 1.1mm.**

For minimize of thermal effects for "SiPMs – dimples" position following design solutions are proposed :

- **Pre-shift SiPMs position on SiPMs tileboard at room temperature to correct dimensions changes after cooling down.**
- **Dimple dimension should provide the assembly of scintillator macrotile and SiPMs tileboard with pre-shifted SiPMs at room temperature.**
- **Additional temperature gap T≥1.2mm for SiPMs required.**
- **After cooling down the detector to (– 30°C…-35°C) shifted SiPMs will take the correct position in dimples.**



Pre-shift of SiPMs from the nominal position to obtain their correct position in the dimples after cooling down by 60°



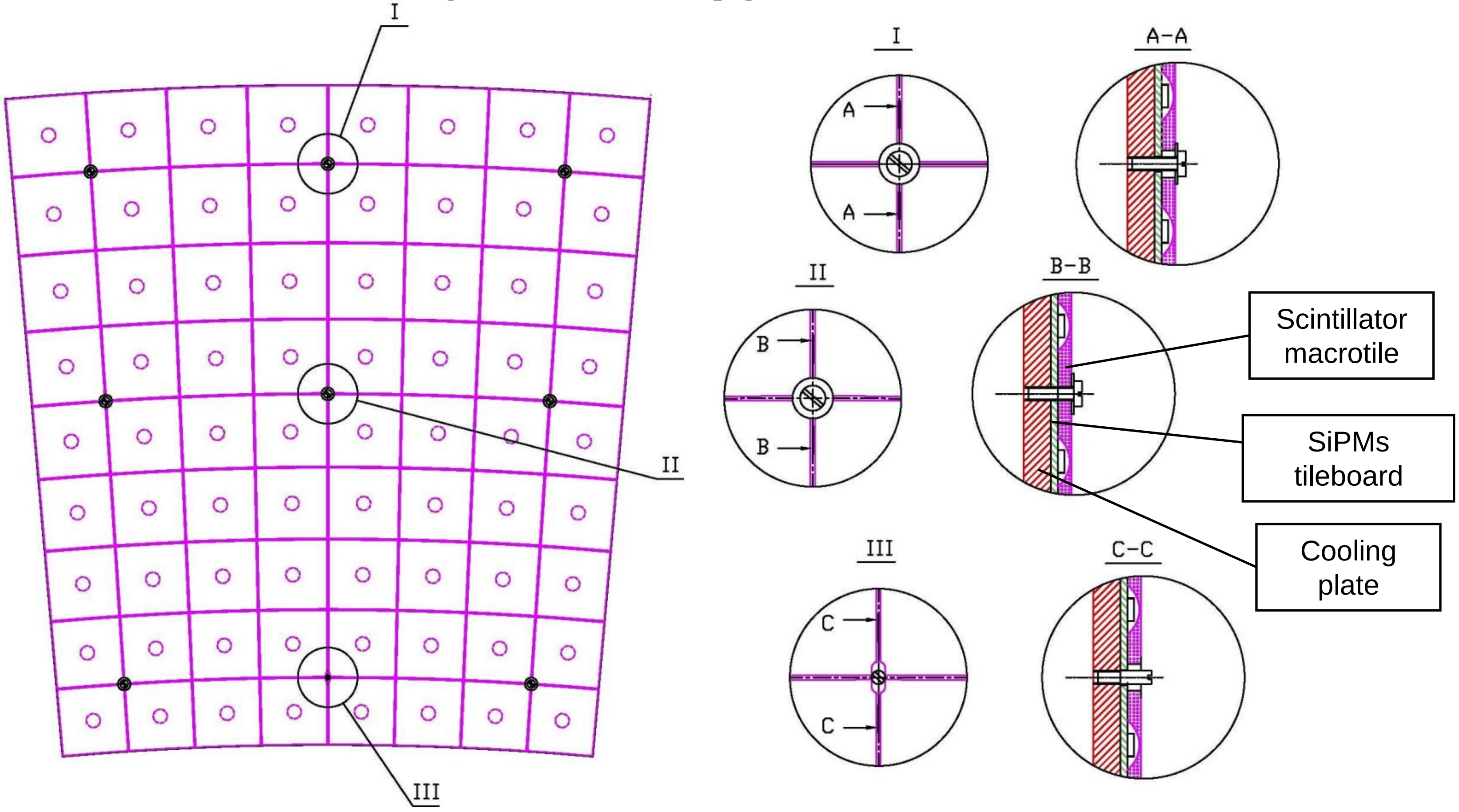
Conclusions

Scintillator macrotiles – possible mechanical concept for HGCAL:

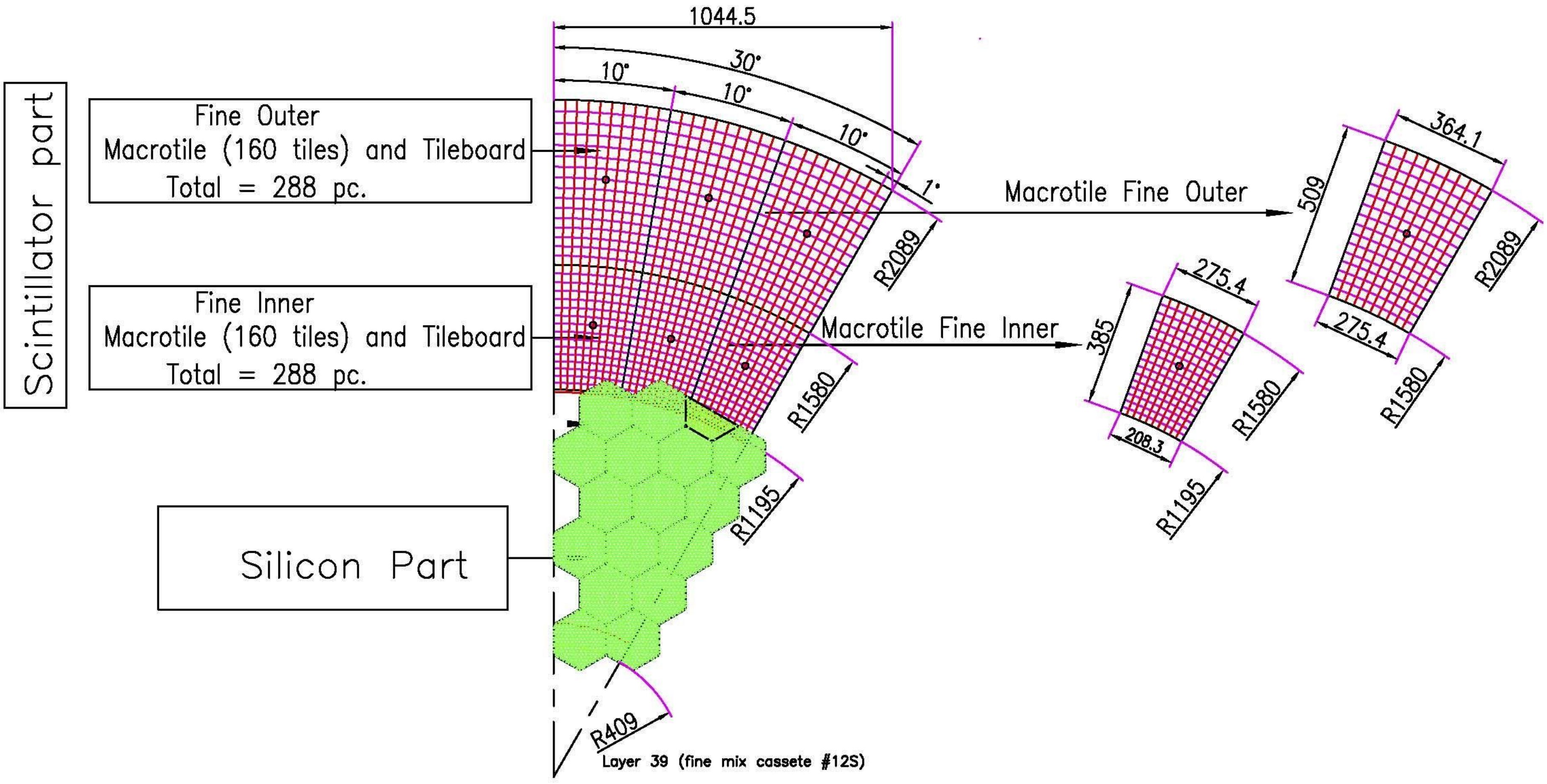
- **Scintillator macrotiles are easy to manufacture and do not require special equipment;**
- **Scintillator macrotiles do not require extra tiles wrapping operation;**
- **proposed design provides the detector assembly at room temperature and operation after cooling down to (– 30°C…-35°C);**
- **detector assembly procedure is very simple and fast.**

Backup

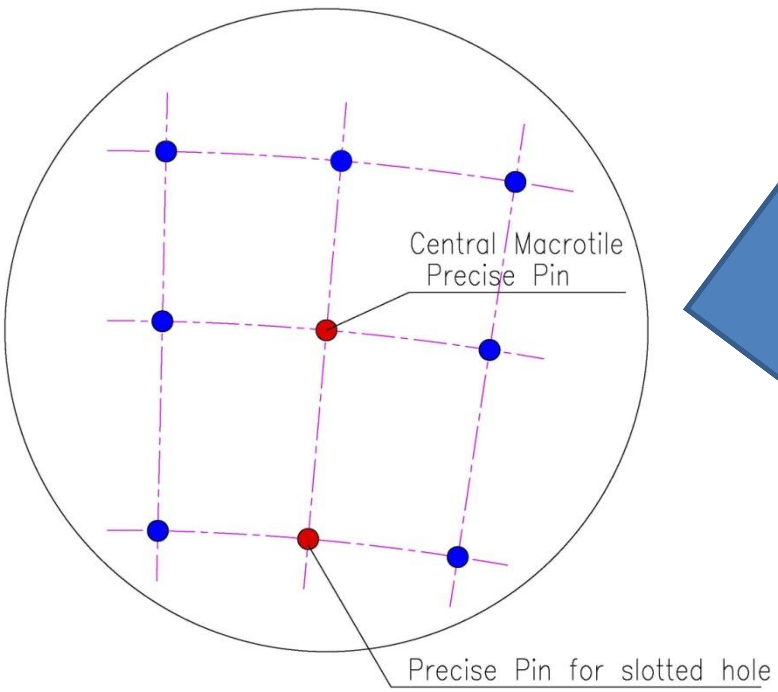
Scintillator macrotile and SiPMs tileboard. Assembly with cooling plate.

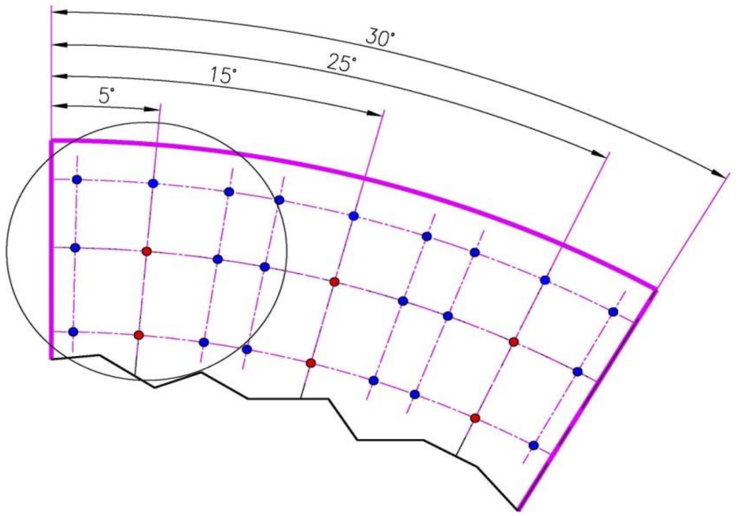


CE-H Layers 36 - 39. Fine Scintillator macrotiles and tileboards. Types. Overall dimensions.



Holes for scintillator macrotiles and SiPMs tileboard on Cooling plate.





Holes
for macrotiles positioning and fixing

The holes for mounting and fixing the detector elements must be made with an accuracy of 0.1 mm.

Table 17-1. Linear thermal expansison coefficients of metals and alloys (Cont.)

Alloys	Coefficient of Expansion ppm/°C	Coefficient of Expansion ppm/°F
ALUMINUM AND ALUMINUM ALLOYS (Continued)		
Casting Alloys		
A13	20.4	11.4
43 and 108	22.0	12.3
A108	21.5	12.0
A132	19.0	10.6
D132	20.5	11.4
F132	20.7	11.5
138	21.4	11.9
142	22.5	12.5
195	23.0	12.8
B195	22.0	12.3
214	24.0	13.4
220	25.0	13.9
319	21.5	12.0
355	22.0	12.3
356	21.5	12.0
360	21.0	11.7
750	23.1	12.9
40E	24.7	13.8
COPPER AND COPPER ALLOYS		
Wrought Coppers		
Pure Copper	16.5	9.2
Electrolytic Tough Pitch Copper (ETP)	16.8	9.4
Deoxidized Copper, High Residual Phosphorous (DHP)	17.7	9.9
Oxygen-Free Copper	17.7	9.9
Free-Machining Copper 0.5% Te or 1% Pb	17.7	9.9

Table 17-1. Linear thermal expansison coefficients of metals and alloys (Cont.)

Alloys	Coefficient of Expansion ppm/°C	Coefficient of Expansion ppm/°F
NICKEL AND NICKEL ALLOYS		
Nickel (99.95% Ni-+Co)	13.3	7.4
Duranickel	13.0	7.2
Monel	14.0	7.8
Monel (cast)	12.9	7.2
Inconel	11.5	6.4
Ni-o-nel	12.9	7.2
Hastelloy B	10.0	5.6
Hastelloy C	11.3	6.3
Hastelloy D	11.0	6.1
Hastelloy F	14.2	7.9
Hastelloy N	10.4	5.8
Hastelloy W	11.3	6.3
Hastelloy X	13.8	7.7
Illium G	12.19	6.8
Illium R	12.0	26.7
80 Ni-20 Cr	17.3	9.6
60 Ni-24 Fe-16Cr	17.0	9.5
35 Ni-45 Fe-20 Cr	15.8	8.8
Constantan	18.8	10.5
STAINLESS STEELS		
301	16.9	9.4
302	17.3	9.6
302B	16.2	9.0
303	17.3	9.6
304	17.3	9.6
305	17.3	9.6
308	17.3	9.6

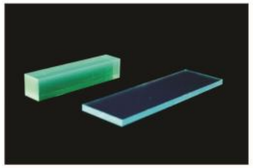
GREEN EMITTING PLASTIC SCINTILLATOR
EJ-260, EJ-262

These plastic scintillators have been formulated for use where longer wavelengths are needed for efficient optical coupling to solid-state photosensors. Because of their longer emission wavelengths, they will exhibit somewhat greater radiation hardness than conventional blue plastic scintillators. Both scintillators can be used to detect the same kinds of radiation commonly measured with blue scintillators.

EJ-260 is a green emitting plastic scintillator that has been formulated for use where longer wavelengths are advantageous for purposes of light piping. The green fluorescence is of short enough wavelength and the scintillation efficiency is high enough for successful use with conventional blue sensitive photomultiplier tubes. The light output data presented in the table were determined with a flat response photodetector and would be approximately one half that level for a typical bialkali photomultiplier tube.

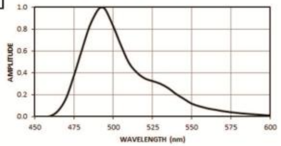
EJ-262 is also a green emitting scintillator, but has a faster decay time and a shorter maximum emission wavelength than those of EJ-260. The shorter emission wavelength makes EJ-262 suitable for use with blue sensitive photomultiplier tubes.

PROPERTIES	EJ-260	EJ-262
Light Output (% Anthracene)	60	57
Scintillation Efficiency (photons/1 MeV e^-)	9,200	8,700
Wavelength of Maximum Emission (nm)	490	481
Light Attenuation Length (cm)	350	250
Decay Time (ns)	9.2	2.1
H Atoms per cm^3 ($\times 10^{22}$)	5.21	5.20
C Atoms per cm^3 ($\times 10^{22}$)	4.70	4.69
Electrons per cm^3 ($\times 10^{23}$)	3.35	3.33
Density (g/cm^3)	1.023	1.023

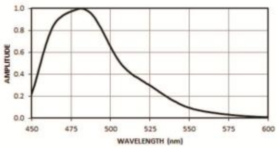


Polymer Base	Polyvinyltoluene
Refractive Index	1.58
Softening Point	75°C
Vapor Pressure	Vacuum-compatible
Coefficient of Linear Expansion	7.8×10^{-5} below 67°C
Temperature Range	-20°C to 60°C
Light Output (L.O.) vs. Temperature	At 60°C, L.O. = 95% of that at 20°C No change from -60°C to 20°C

EJ-260 EMISSION SPECTRUM



EJ-262 EMISSION SPECTRUM



CHEMICAL COMPATIBILITY

Attacked By: Aromatic solvents, Chlorinated solvents, Ketones, Solvent bonding cements, etc.
Stable In: Water, Dilute acids and alkalis, Lower alcohols, Silicone greases.
It is safe to use most epoxies with these scintillators.

Revision Date: 2/2/2016

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McMaster-Carr Item Number 8667K43

Product Description

Acculam® Epoxyglas G10/ FR4, is a laminate sheet comprised of a flame retardant epoxy resin and a woven fiberglass substrate. This grade qualifies to NEMA FR4 and MIL-I-24768/27.

Typical Applications

This material has high mechanical strength and excellent electrical insulating qualities in both dry and humid conditions. These attributes along with good fabricating characteristics allow this grade to be used in a wide variety of electrical and mechanical applications.

Typical Properties	Typical Value	Units
Physical Data		
Specific Gravity/Density	1.85	g/cm³
Water Absorption -.125"	< .10	%
Temperature Index	140 \ 284	°C \ °F
Rockwell Hardness	110	M scale
Bond Strength	> 2,200 \ 1,000	lbs \ kgs
Flexural Strength-LW-A-.125"	> 65,000 \ 448	PSI \ MPa
Flexural Strength-CW-A-.125"	> 50,000 \ 345	PSI \ MPa
Izod Impact Strength-LW	> 10	ft-lbs/in
Izod Impact Strength-CW	> 8	ft-lbs/in
Compressive Strength-Flatwise	> 60,000 \ 415	PSI \ MPa
Electrical Data		
Dielectric Breakdown-A	> 50	kV
Dielectric Breakdown-D48/50	> 50	kV
Permittivity-A	4.8	
Permativity-D24/23	4.8	
Dissipation Factor-A	0.017	
Dissipation Factor-D24/23	0.018	

November 1, 2016

Accurate Plastics, Inc. ~ Sheet Comparative Data Chart

THERMOSET INDUSTRIAL LAMINATE PROPERTIES
Engineering Values (MIN unless noted)

Properties	G 10, FR4	G10	G11, FR5	G11	G3	G5, G9	G7	GPO 1	GPO 3	X	XX	XXX	C, CE	L, LE
Nema Grades reinforcement	glass cloth	glass cloth non FR	glass cloth	glass cloth non FR	glass cloth	glass cloth	glass cloth	glass mat	glass mat	paper	paper	paper	canvas	linen
resin binder	epoxy	epoxy	epoxy HT	epoxy HT	phenolic	melamine	silicone	polyester	polyester	phenolic	phenolic	phenolic	phenolic	phenolic
Tensile Strength lengthwise, PSI	40,000	40,000	40,000	40,000	23,000	37,000	23,000	8,000	8,000	20,000	16,000	15,000	9,000	12,500
crosswise, PSI	35,000	35,000	35,000	35,000	20,000	30,000	18,000	----	----	16,000	13,000	12,000	7,000	8,750
Compressive Strength flatwise, PSI	60,000	68,000	60,000	60,000	50,000	70,000	45,000	30,000	30,000	36,000	34,000	32,000	39,000	37,000
edgewise, PSI	35,000	35,000	35,000	35,000	17,500	25,000	14,000	----	----	19,000	23,000	25,500	24,500	25,000
Flexural Strength - .125" lengthwise, PSI	55,000	55,000	55,000	55,000	20,000	55,000	20,000	18,000	18,000	25,000	15,000	13,500	17,000	16,500
crosswise, PSI	45,000	45,000	45,000	45,000	18,000	35,000	18,000	----	----	22,000	14,000	11,800	16,000	14,000
Modulus of Elasticity - Flexural lengthwise, kPSI	2,700	2,700	2,800	2,800	1,500	2,500	1,400	1,200	1,200	1,800	1,400	1,300	1,000	1,000
crosswise, kPSI	2,200	2,200	2,300	2,300	1,200	2,200	1,200	1,000	1,000	1,300	1,100	1,100	900	850
IZOD Impact lengthwise, ft-lb/in of notch	7.0	7.0	7.0	7.0	6.5	7.0	6.5	8	8	0.55	0.40	0.40	2.1 / 1.6	1.35 /1.25
crosswise, ft-lb/in of notch	5.5	5.5	5.5	5.5	5.5	5.5	5.5	----	----	0.50	0.35	0.35	1.9 / 1.4	1.1/1.0
Rockwell Hardness M scale	110	111	114	112	100	120	100	100	100	110	105	110	104	105
Specific Gravity	1.85	1.80	1.85	1.80	1.65	1.90	1.68	1.80	1.85	1.36	1.34	1.32	1.36	1.34
Bond Strength, in lbs.	2,000	2,000	1,600	1,600	850	1,700	650	850	850	700	800	950	1,800	1,600
Coefficient of Thermal Expansion cm/cm-°C X 10^{-5}	1.0	0.9	1.0	0.9	1.8	1.0	1.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Water Absorption .062" thick, % per 24 hrs	0.25	0.25	0.25	0.25	2.70	0.80	0.55	1.00	0.60	6.00	2.00	1.40	4.4 / 2.2	2.5 / 1.95
.125" thick, % per 24 hrs	0.15	0.15	0.15	0.15	2.00	0.70	0.35	0.70	0.50	3.30	1.30	0.95	2.5 / 1.6	1.6 / 1.3
.500" thick, % per 24 hrs	0.10	0.10	0.10	0.10	1.50	0.40	0.20	0.35	0.25	1.10	0.55	0.45	1.2 / .75	0.9 / 0.7
Dielectric Strength, volt/mil perpendicular to laminations; Step by Step .062" thick	450	450	450	450	500	350	350	370	400	500	500	450	300	300
.125" thick	350	350	350	350	450	275	250	----	----	360	360	320	220	220
Dissipation Factor condition A, 1 megacycle-max	0.025	0.025	0.025	0.025	--	0.017	0.003	0.03	0.03	----	0.045	0.038	----	0.055
Dielectric Constant condition A, 1 megacycle-max	5.2	5.2	5.2	5.2	----	7.80/7.20	4.2	4.3	4.3	----	----	----	----	----
Insulation Resistance Megaohms at Condition C	200,000	200,000	200,000	200,000	----	10,000	100,000	----	----	----	60	1000	----	----
Arc Resistance - Sec.	----	----	----	----	----	180	180	100	150	----	----	----	----	----
Temp Index .062" and over Electrical - °C	130	130	170	170	140	—	170		120	130	140	140	115	115
Mechanical - °C	140	140	180	180	170	140	220		140	130	140	140	125	125
Mil-I-24768	27	2	28	3	18	8 / 1	17	4	6	12	11	10	16, 14	15, 13
MIL - Type	GEE-F	GEE	GEB-F	GEB	GPG	GMG/GME	GSG	GPO N-1	GPO N-2	PBM	PBG	PBE	FBM/FBG	FBI/FBE