NSC KIPT PARTICIPATION IN THE CMS (CERN) COLLABORATION

L.G. Levchuk, S.V. Marekhin, A.A. Nemashkalo, V.P. Popov, P.V. Sorokin, A.E. Zatserklianiy
National Science Center "Kharkov Institute of Physics and Technology", Kharkov, Ukraine

In conformity with the Agreement of 03.04.1993 between the Government of Ukraine and CERN, the National Science Center Kharkov Institute of Physics & Technology (NSC KIPT) takes part in the international CMS program. Its collaboration duties include: the manufacture of scintillation elements for the forward hadron calorimeter and investigation of their characteristics; the simulation of physical processes in the CMS detector; the preparation for processing experimental results.

PACS: 07.77.Ka.

CREATION OF SCINTILLATION MATERIALS

Kharkov scintillating plates for the tile/fiber system were produced by injection molding technology. The industrial granulated polystyrene PSM-115 was mixed with primary 1.5% pTP and secondary 0.02% POPOP scintillating dopants. The mixture was loaded into a standard injection molding machine including a peculiarly designed mold. Special studies were made to find optimum molding parameters for producing best-quality scintillating plates at given conditions. The plate dimensions were 240×210×4 mm^3.

To investigate the properties of scintillators and fibers, research setups with appropriate software were created. They were used to measure the absolute light yield in units pe/MIP, the attenuation length, the light yield uniformity, the response time of the tile/fiber system, the plastic scintillator light yield dependence on the magnetic field and the radiation hardness of the tile/fiber system, when irradiated by bremsstrahlung photons from 20 MeV electron linac.

Scintillation and optical characteristics of the Ukrainian Plastic Scintillator, Kharkov Injection-molded Scintillators, Kuraray SCSN-81 Scintillators and other scintillators and WLS fibers are presented.

a) Spectrum characteristics of the Kharkov UPS-923A scintillator are practically the same as those of Bicron and Kuraray scintillators. Scintillator emission spectra match quite well the absorption spectra of the INR (Moscow), Bicron and Kuraray WLS fibers [1]. In Kharkov, 400 scintillator tiles with the size of 22× 22 cm^2 , and 4mm thick and with the "sigma" key-shaped grooves were manufactured. The tile-to-tile light yield deviations is 3.8%. The tiles with the fiber (100 cm length) were wrapped with white paper. The light yield studies of the tile / the mirrored WLS fiber end / PMT systems are as follows:

- the lateral uniformity is ≈ 6%;
- the absolute light yield [2] in units pe/MIP is 4.7;
- time for 90% of signal collection is 22.2 nsec and decay time – 6.3nsec.

b) We have carried out comparative measurements for scintillating tile/fiber systems with Kharkov injection - molded scintillators [3,4] and Kuraray SCSN-81 scintillator, using Y11 fibers with length 70 cm and diameter 0.83 mm. The fiber end was non-mirrored. All the tiles were wrapped with Tyvek. The tile size was 131 mm × 122 mm × 4 mm.

The average uniformity of tile/fiber systems is 5.3% for the Kharkov scintillator and 3.6% for the SCSN-81 scintillator. This difference is due to the fact that the attenuation length of Kharkov scintillator is smaller.

- The light yield of tile/fiber systems made from scintillators of both types is nearly the same, about 5.5 pe/MIP.
- Sets with tile/fiber systems from Kharkov and Kuraray scintillators were irradiated up to 3.0, 4.0 and 5.3 Mrad by bremsstrahlung photons from 10 MeV electron linac. After two weeks of recovery, the light yield was practically the same for the two tile/fiber systems. The light yield uniformity (RMS) increases by a factor of 3.

c) The relative light yield change of polystyrene- and acrylic-based scintillators versus magnetic field have been investigated [5,6]. The magnetic field changes from 0 up to 2.2 T. Scintillators samples of different thickness from 1 up to 8 mm were exited by photons ($_{60}$Co, ^{137}Cs), electrons (^{90}Sr) and by α particles (^{239}Pu).

- In the case polystyrene the light yield increases up to 6%, for acrylic – up to 10% at a magnetic field of 2.2 T, reaching saturation.
- Under irradiation of polystyrene-based scintillators by α particles, the relative light yield change is close to zero.

The response of the tile/fiber calorimeter light yield to incident muons (100 and 300GeV), electrons (100GeV), and pions (100, 200 and 300 GeV) was studied in transverse magnetic field up to 3 T. The light yield rises with magnetic field by about 20% [7].

MONTE-CARLO SIMULATIONS OF THE CMS ENDCAP CALORIMETER RESPONSE

The GEANT 3.21 program has been applied to simulate showers produced in the CMS ENDCAP calorimeter by single pions with energies ranging from 20 to 300 GeV [8]. Hadron calorimeter (HCAL) taken for our calculations consisted of two sampling scintillator/copper compartments with separate readouts (see Ref. [9]). This HCAL module was considered also in a conjunction with a crystal $PbWO_4$ electromagnetic calorimeter (ECAL). To optimize the shape of distributions of the showers over deposited energy, energy independent weights were assigned to signals coming from different calorimeter compartments. Within the energy range considered, for the calorimeter energy resolution, we obtained: $\sigma/E=105/\sqrt{E}\oplus5.7\%$ and $\sigma/E=87/\sqrt{E}\oplus6.5\%$ in case of HCAL only and the joint ECAL + HCAL system, respectively. These results are in agreement with the beam test data [7] (see Fig. 1).

A special version of the HCAL with a uniform sampling has been also considered. It has been shown that the energy resolution in this case is insensitive to the way of subdivision of the HCAL into two compartments [10].

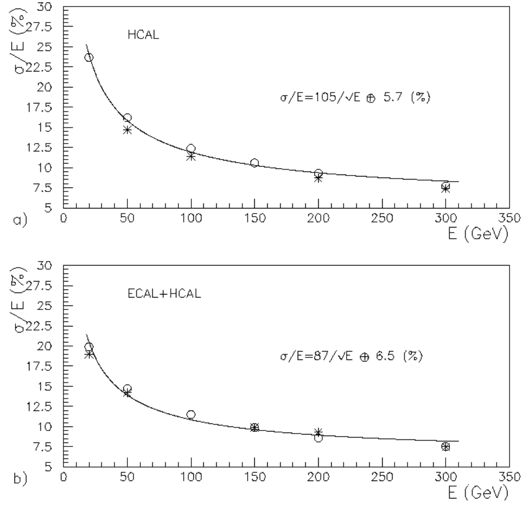


Fig. 1. *CMS calorimeter energy resolution: open circles refer to our calculations, and beam test data [7] are marked by asterisks*

We also simulated the influence of dead zones of the HCAL upon the calorimeter response (see ref. [11]). It has turned out that the dead zones with thickness of 2cm could substantially suppress (by 50%) the HCAL signal and deteriorate (by factor of 3) its energy resolution.

SIMULATIONS OF CMS PHYSICS

One of the main goals of the CMS collaboration is to find the Higgs boson in *pp* collisions at the LHC (see, e.g., ref. [9]). While existing theoretical and experimental restrictions upon Higgs mass values M_H are rather indefinite, it is still difficult to pick out one or another mode of Higgs decay as most preferable for its observation. A thorough search of "optimal" kinematical conditions for the decays providing the maximum signal/background ratio can be accomplished with the help of computer simulations.

We investigated observability of a very heavy Higgs (M_H=500 GeV/c^2) in the decays $HZ^0Z^0\rightarrow l^+l^-\nu\bar{\nu}$ using PYTHIA6.1 as an event generator and CMSJET4.7 to simulate the CMS detector response. The main background contributions to the $l^+l^-\nu\bar{\nu}$ signature come from channels Z^0+jets$\rightarrow l^+l^-+X$, $t\bar{t}\rightarrow l^+l^-+X$, $Z^0W^\pm\rightarrow l^+l^-+X$ and nonresonant production of Z^0 pairs ($Z^0Z^0\rightarrow l^+l^-+X$). The calculations were performed for the total energy of the colliding protons $\sqrt{s}$ =14 TeV. Cuts $p_T^l\geq20$ GeV/c for the transverse momenta of the detected leptons and $|\eta|\leq2.4$ for the pseudorapidity range were predetermined by the CMS detector performances. Only events with missing transverse energy E_T^{miss} and invariant mass of the lepton pair M_{ll} close enough to that of Z^0 boson ($|M_{ll}-M_Z|\leq6$ GeV) were selected for further analysis. To suppress more the background contributions, the requirement of the absence of jets with $E_T^{jet}\geq200$ GeV at $|\eta|\leq2.4$ was taken, and cuts $\theta^{ll}\leq90°$ and $\theta_T^{ll}\leq90°$ for the angle between total and transverse momenta of the detected leptons were imposed. Some of our results are shown in Fig. 2. It is seen that in spite of a fairly good *S/B* ratio, the shapes of she signal and the background are similar to each other making it difficult to observe Higgs via the signature under consideration. Further investigation is needed to get a definite conclusion about observability of Higgs in this case.

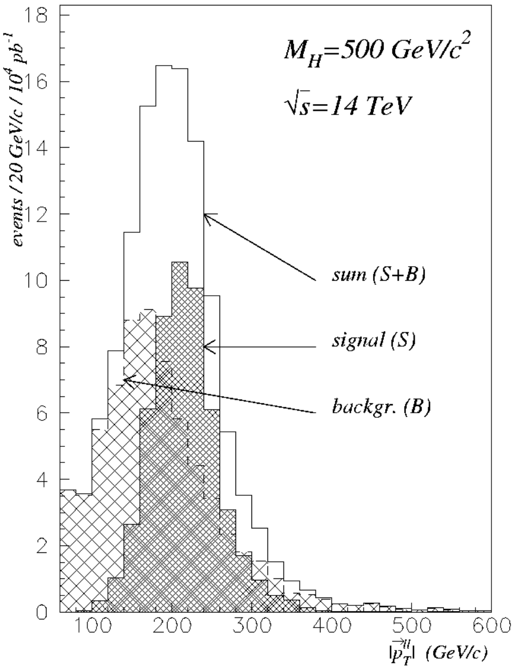


Fig. 2. *Distribution of signal ($H\rightarrow Z^0Z^0\rightarrow l^+l^-\nu\bar{\nu}$) and background events over the total momentum of the detected lepton pair*

PRODUCTION OF TILES

The National Science Center "Kharkov Institute of Physics & Tehcnology" (NSC KIPT) and the Institute for Single Crystalls (ISC) as one team are responsible for Quantity production of the tiles for Hadron Calorimetetry at CMS (LHC).

The NSC KIPT and ISC scientists have developed the process for quantity production of Kuraray SCSN–scintillator tiles with using the CNC machines. As a result, now nearly 120 tiles of required quality can be produced per day.

The manufacture of tiles is produced at Scientific Research Department of Alkaly Halide Crystals of ISC.

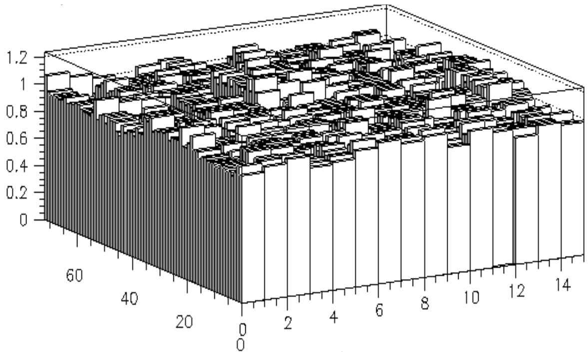
NSC KIPT is involved during many years in the HE CMS scintillator tile R&D and organized the Quality program and final Quality tests of tiles.

The first package of scintillator tiles was delivered to NSC KIPT from Institute ISC October 15, 2000.

So far the quality control was done for 1100 tiles. The outer dimension, quality of the grooves, light yield, transverse light yield were measured for two tiles from each megatiles: for small one (about 0.4 cm × 11 cm × 18 cm) and large one (about 0.4 cm × 23 cm × 31 cm).

The tiles were non-wrapped with Tyvek, using Y11 fibers, ∅ 0.94 mm, 90 cm in length for small tiles and 120 cm in length for large tiles without clear fiber. The fiber end was non-mirrored. Relatively light yield of fiber/control tile assemblies were measured before insertion into tiles. The RMS of this distribution is 2.5%. Results are:

- the outer tiles dimensions correspond to the drawings;
- the thickness of the tiles (RMS<3%) corresponds to the TDR requirement;
- the light yield is the same for the small and large tiles about 2.2 p.e. with the RMS = 6.2% (Fig. 3);
- the transverse uniformity is better than 4.2% for all the tiles measured.



1062 tiles, MEAN = 9 2.29, RMS/MEAN = 6.2%. CUT =0.82

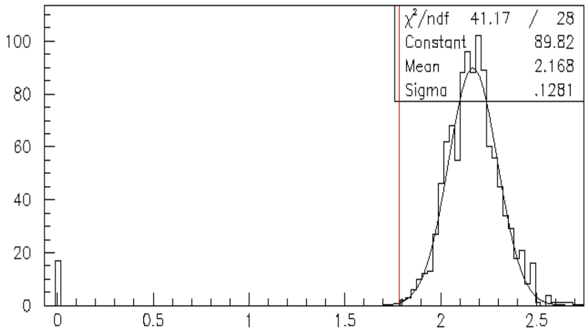


Fig. 3. *Light yield distribution of 1062 tiles or 15 layers × 72 (36 small size + 36 large size) tiles and its graphical cut (lower figure). The RMS of this distributions is 6.2%, MEAN= 2.2 p.e.*

So, the mass quality control of the tiles produced by "Monocrystall" is going well. The main characteristics of the tiles satisfy to the CMS TDR2 (1997).

At present, the main prerequisite for efficient participation of Ukraine and, in particular, NSC KIPT in the CMS collaboration is to provide necessary conditions for active work on the CMS physics program. First of all, it is the creation of a computer Linux cluster powerful enough to perform simulations of CMS physics, partial processing of data provided by the CMS detector with installation of the software developed for this purpose, and training of young scientists.

REFERENCES

1. A. Nemashkalo, V. Popov, P. Sorokin, A. Zatserklyany et al. Sigma Tile/Fiber Production and Investigation for the CMS Hadron Calorimeter Prototype. *TN/94-168,* April 20, 1994, 17 p.
2. A. Zatserklyany, A. Nemashkalo, V. Popov, The measurements of the light yield in number of the photoelectrons. VANT, 1999. №1 (33), p. 44-44.
3. A. Nemashkalo, V. Popov, A. Rubashkin, P. Sorokin, A. Zatserklyany A. Borisenko, V. Senchishin, O. Skrebtsov, V. Bolotov. Comparisen Studies of Tile/Fiber Systems Manufactured from Kharkov Injection-molded and Kuraray SCSN-81 Scintillators. *CMS TN/97,* 1997, 14 p.
4. A. Nemashkalo, V. Popov, A. Rubashkin, P. Sorokin, A. Zatserklyany. Study of Tile/Fiber Systems manufacted from Kharkov injection molded and Kuraray CSN-81 Scintillators. *Nuclear Instuments & Methods*, 1998, A419, p. 609-611.
5. A. Nemashkalo, V. Popov, A. Rubashkin, P. Sorokin, A. Zatserklyany. Plastic Scintillator Light Yield Dependence on the Magnetic Field. *CMS. TN/95-81*. November 29, 1995, 16 p.
6. A. Nemashkalo, V. Popov, A. Rubashkin, P. Sorokin, A. Zatserklyany. Study of the Light Yield of Plastic Scintillators in a Magnetic Field. Pribory i Tekhnika Eksperimenta, №6. 1977, p. 57-61 (in Russian).
7. V. Abramov, B. Acharya, N. Akchurin, et al. Studies of the Response of the Prototype CMS Hadron Calorimeter, Including Magnetic Field Effects, to Pion, Electron, and Muon Beams, *Nuclear Instuments & Methods*, 2001, A457, p. 75-100; *Status Report on Endcap Calorimeter R&D*, Pisa CMS Week, 1995.
8. L.G. Levchuk, S.V. Marekhin, P.V. Sorokin. Monte-Carlo simulation of the CMS endcap calorimeter, *CMS TN/95-078*, 1995, 8 p.
9. *The Compact Muon Solenoid* Technical Proposal, *CERN/LHCC 94-38, LHCC/P1*, 1994, p. 76.
10. L.G. Levchuk, S.V. Marekhin, P.V. Sorokin. Simulations of the CMS endcap calorimeter resolution, *CMS TN/95-090* , 1995, 6 p.
11. L.G. Levchuk, S.V. Marekhin, P.V. Sorokin. Influence of inert material on parameters of the CMS endcap hadron calorimeter *CMS TN/95-113*, 1995, 8 p.