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Fabrication of and testing the Si/W ECAL prototype for TESLA detector

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Abstract

An R&D proposal is presented for the design and construction of a barrel wedge of the Si/W electromagnetic calorimeter for the TESLA detector. The wedge (supertower) is constructed of 49 (7×7) sandwich-type towers of size $1\,\mathrm{cm} \times 1\,\mathrm{cm} \times (12 \div 15)\,\mathrm{cm}$. The tower is a stack of 56 layers, and each layer is made of a tungsten pad and a silicon sampling wafer glued on a ceramic plate thus making radiation length of $24X_0$. Due to the small Molliere radius and fine granularity of the prototype, one expects a good $\gamma - \gamma$ separation and coordinate resolution $\sigma_x \leq 400\mu m$. The material supply and fabrication will be made at reasonable prices. The front-end and read-out electronics will be produced in cooperation with co-partners. The financial support is planned to be shared between ISTC and DESY.

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1 Introduction

Following the recommendations cosidered at the ECFA/DESY ECAL meeting in June, 2000[1] we propose to make a Si/W prototype version of the electromagnetic calorimeter (ECAL) for the TESLA detector. The relevant GEANT simulations were performed in the frame of the ECFA/DESY studies [1], and they showed that the silicon-tungsten sandwich could satisfy basic CDR requirements for ECAL [2].

The Si/W calorimeters were experienced in $e^{\pm}$ colliding beams at LEP (OPAL, ALEPH) where they were used as luminosity monitors [3] [4].

The fine granularity is obtained due to the small Molliere radius, $r_M = 0.89\,\mathrm{cm}$, and structural properties lead to a good position resolution.

The expected GEANT-based energy resolution is $\Delta E/E = 10\%/\sqrt(E)$ and the coordinate resolution is estimated as $\sigma_x \leq 400 \mu m$.

Although the size of the Si/W cell is $1\,\mathrm{cm}\times 1\,\mathrm{cm}$, mechanical design is made so that the tungsten plate in a supertower has size $7\,\mathrm{cm}\times 7\,\mathrm{cm}$. This is made to simplify much the mechanical assembly.

After all, we would like to recall that Si/W **pre-shower** combined with the lead tungsten ($PbWO_4$) **crystals** is used in the CMS end-cap ECAL. And this version exhibits the following fine features:

- good energy resolution $5\,\%/\sqrt{E} + 0.5\%$;
- coordinate resolution $\sigma_x \leq 450\,\mu\mathrm{m}$;
- gamma-gamma separation of $5 \div 6\,\mathrm{mm}$;
- good time resolution;
- the radial space prescribed for ECAL is not enlarged;
- threshold of 10 MeV with PMT and 50 MeV with VPT or APD.

The crystal version with Si/W preshower can be manufactured at a reasonable price. Say, for the crystals of size $25*25*220\,\mathrm{mm}^3$, $1\,\mathrm{m}^2$ of ECAL costs about 0.95 M and $1\,\mathrm{m}^2$ of the pre-shower costs $\sim$0.56 M (in USD).

We express also our interest in a possible R&D study, if needed, of the ECAL prototype by the formula Si/W pre-shower + $PbWO_4$ crystals.

2 Brief description of the Si/W ECAL prototype

Below we describe the main features of the prototype construction. Primarily the prototype is thought to be a wedge of the **barrel** electromagnetic calorimeter. The projective geometry of the wedge is determined by the cell size and the ECAL radius R. Currently the ECAL radius is defined as $R = 172\,\mathrm{cm}$.

[1]after preparation of this short version of R&D proposal, we have been aware of the ECAL chapter with the detailed description prepared for CDR at http://www.desy.de/flc/LC/LCdetector.html .

Mechanical design. In the radial direction, the wedge is viewed as a matrix of towers. Each tower is a stack of silicon-tungsten layers of the size 1 cm×1 cm thus making the angular tower size equal to 0.333^o.

The layer is assembled of a 0.3 mm thick silicon diode and 1.5 mm thick tungsten pad. The chosen thickness of the tungsten ($< X_0/2$) garantees a reasonable level of the energy sampling fluctuations. Choosing the length of a tower equal to $24X_0$ one gets the number of layers in a tower equal to 56.

To investigate properly the energy, coordinate and space resolutions, the size of the matrix is chosen as 7 towers×7 towers. 49 towers form a supertower.

Each tower has a **longitudinal segmentation** with the number of segments 3 to 4. Such segmentation improves largely the $\gamma - \gamma$ separation using information from the first 3-5 radiation lengths where the shower is narrow. The segmentation will help out also to separate a hadron and an electron.

The supertower assembled with the front-end electronics is placed in a aluminium (?) box with thermostabilization.

Else, mechanically 49 tungsten pads in a supertower layer are made as a one-piece tungsten plate of size 7 cm×7 cm.

Construction parameters. The basic construction parameters are summarized in Table 1.

Table 1. Basic parameters of the Si/W prototype.

Number of towers	49 plus one spare
Silicon pad size	10 mm×10 mm
Azimuthal size of a tower	0.333^o
Number of silicon pads	2800
Number of front-end chips	2800
Thickness of W pad	1.5 mm
Number of layers in a tower	56 ($24X_0$)
Number of ADC's	245
Transverse size of the prototype	7 cm×7 cm
Length of the prototype	12 – 15 cm

Electronics. For the proposed R&D, we are going to use preamplifiers designed and manufactured for CMS ECAL preshower by the National Centre for Particle and High Energy Physics, Minsk (Belarus). The price is expected to be reasonable (see Table 2).

Performance. The required physical characteristics (shower separation, ΔE, coordinate resolutions) and the prototype componnents and features will be tested: amplifiers, signal collection, wire length and signal degrading along wire, noise, design studies etc.

Cost of the components. The prices in the following table are taken as of the August, 2000. They are applicable for manufacturing the small prototype sample. Some prices can be subject to sizeable discount when booking large volumes of materials.

Table 2. Cost estimates in USD.

	cost per unit	cost per prototype, $K
Silicon pads	10/pad*	28.0
Preampli	10/piece	28.0
Tungsten	150/kg*	1.2
Cables and connectors		2.8
DAQ interface		5.0
Box and thermo-stabilization		10.0
Work place		3.0
Total		78.0

∗ - The price accounts for booking a small amount of the material.

3 Man power

The proposed R&D project will be performed by a team of highly experienced physicists from IHEP, Protvino. Currently it includes four experts in electronics (A.D., S.E., V.M.

and V.T.), two experts in the readout coding (B.C. and E.V.), one world-level expert in calorimetry (V.K.) and project menager/expert in MC simulations (Yu.A.).

4 Co-partners

The fabrication of the prototype will be made in cooperation with two known organizations in the Moscow region which have high-tech production of tungsten ('Lutch', Podolsk) and silicon wafers ('Elma', Zelenograd). Both organizations are well experienced in the scientific cooperation within military conversion programs, including the cooperation with IHEP, Protvino.

The production of and testing amplifiers and readout electronics will be shared with the National Centre for Particle and High Energy Physics, Minsk, Belarus.

5 R&D cost estimate

The total R&D estimate includes the cost of the prototype components (Table 2), man power, visits to the co-partners and expenses when beam testing.

6 Beam tests

It is preferable to perform the beam tests at the DESY electron test beams aiming to use the high-quality DESY apparatus.

7 GEANT simulations

The program support and necessary MC simulations and GEANT studies will be done by the IHEP team. So far a lot of MC simulations for the Si/W version of ECAL have been made by the groups from LPNHE and DESY in the frame of the ECFA/DESY studies. So the program support can be made by the IHEP team in cooperation with the LPNHE and DESY people.

8 Request to DESY

After the assembly of the prototype is over, we would like to start beam testing at DESY. So we want to make a request for the run time at the DESY test beam. Initially we request 4 weeks during two months in the following regime: 1 week of measures on beam, then 1 week of analysing and fitting the components and so on.

9 Financing scheme and milestones

To provide the financial support for this R&D project we intend to apply to **ISTC, International Science and Technology Center**. ISTC suppotrs the non-proliferation and conversion research projects in Russia. Else we want to have **DESY** as a partner in this R&D work to apply for the ISTC 'partnership' grant. So the funding this R&D project is thought to be shared between **ISTC and DESY**.

10 Further development

In case of successful completion, a new round of R&D can be performed for, for example, prototyping the Si/W wedges for the **end-cap** calorimeter and for the **luminosity monitor**.

References

[1] http://www.desy.de/flc/LC/LCdetector.html .

[2] see http://www.desy.de/ behnke/tdr/detector_toc.html .

[3] G. Abbiendi *et al*, Eur.Phys.J. C14 (2000) 373-425; see also hep-ex/9910066.

[4] http://alephwww.cern.ch/SUBDET/lumi.html .