

**Project name**

A Fast Gas Cerenkov Calorimeter for Bunch-by-Bunch Luminosity Measurement at the Next Linear Collider

**Classification (accelerator/detector: subsystem)**

Accelerator: Luminosity Monitor

**Institution(s) and personnel**

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**Project Overview****Introduction**

We will design and construct a gas Cerenkov calorimeter for beam luminosity measurement that is emptied of Cerenkov light between bunch crossings, thus becoming quiescent before the next bunch arrives 1.4 ns later. This calorimeter is explicitly radiation hard, completely insensitive to radioactivation of the calorimeter mass, and blind to  $e^\pm$  and  $\gamma$  IR backgrounds below 10 MeV. This proposal addresses item ID #56 of the “long list”. This detector is also potentially useful for tagging low angle electrons from two photon events which are the dominant background to most SUSY channels.

**Basic Design**

A fast nanosecond calorimeter must carry its energy and spatial information in photons, and these photons must be able to exit the calorimeter volume unimpeded. A gas has an index of refraction,  $n$ , which differs from one by a small amount  $\delta \approx 10^{-3}$  where  $\delta = n - 1$  and since  $\cos \theta_c \approx 1/n \approx 1 - \delta$ , the generated Cerenkov light is channeled forward at an angle  $\theta_c \approx \sqrt{2\delta} \approx 0.05$ , which is easier to collect geometrically.

The collection and transport of the Cerenkov light down highly reflective optical conduits can be accomplished in several ways, two of which are described in more detail

in <http://www.public.iastate.edu/~oleksiy/calor2002.pdf>. The “lasagna” geometry consists of metal plates with half-round rods evenly spaced on one surface of the plate, and another array of rods on the other side, but shifted with respect to the first by half of a period. These “washboard” surfaces are covered with 2 mil stainless steel shims polished to optical quality. The detector consists of a stack of these plates.

The Cerenkov light is generated by shower particles as they cross the gas gaps between the reflecting stainless shims, and since the Cerenkov angle is small, a large fraction of the light is channeled down the optical conduits. The light makes typically 10-12 small angle reflections before exiting the 30-cm deep calorimeter. This Cerenkov light co-moves with the shower particles as they traverse the metal medium in depth, forming a thin 50 ps wide pancake of light which exits the conduits at the rear of the calorimeter. We will use aluminized metallic mirrors to redirect the Cerenkov light to PMTs out of the path of the beam. To the extent that wide-angle light is attenuated by multiple reflections and that negligible luminescent light is generated in the gas, the calorimeter is emptied of light in 1ns, and this device becomes completely quiescent between bunches.

The velocity threshold for Cerenkov light emission is  $(p/E)_{th} = 1/n \approx 1 - \delta$ , and  $p/E \approx 1 - \frac{1}{2}(m/p)^2 \approx 1 - \delta$ , so that  $p_{th}/m = 1/\sqrt{2\delta}$ , and the momentum threshold for electrons is

$$p_{th}^e \approx m_e / \sqrt{2\delta} \approx m_e / \theta_c \approx 11 \text{ MeV}/c$$

comfortably above the  $\beta$  and  $\gamma$  energies of all decay nuclei. The critical energy of a dense metal is typically 10-20 MeV, and therefore most shower electrons will participate in Cerenkov light generation.

Therefore, this luminosity calorimeter has three unique features: (i) it is constructed wholly of metal and gas, and therefore cannot be damaged by any conceivable dose of radiation; (ii) the generation of Cerenkov light is instantaneous, its transport from within the calorimeter volume is at nearly the speed of light, bunched in a 50-ps pancake, and the calorimeter volume is emptied of light well before the next bunch; and, (iii) the Cerenkov threshold is about 11 MeV, and therefore no  $\beta$  ray from any degree of radioactivation will result in Cerenkov light, and all IR  $e^\pm$  backgrounds below this threshold are invisible.

Remaining problems are the choice of a nearly completely non-luminescent gas (to avoid the generation of ‘resident’ light), the manufacture of highly reflective metallic surfaces for aluminization, and the design of a fast phototube readout. We have experience with reflecting metallic surfaces and will search for non-luminescent gases.

### Expected Performance

A detailed Geant3 simulation of 100 GeV electrons in an Fe mass has been performed with exact optics for the Cerenkov light in reflective ss tubes. The tubes are 2-mm inner diameter, centered every 5-mm. The calculated energy resolution in this geometry is about 10% for 100 GeV electrons. We are now developing a Geant4 code to simulate the lasagna and hex rod geometries, and to optimize the metal-gas volumes and the light channeling and collection efficiencies. Cerenkov light is generated with a  $1/\lambda^2$  distribution, and therefore we prefer to aluminize all metallic surfaces and use PMTs as far into the UV as possible.

### Calibration

Both energy and time can be calibrated by pulsing a fast light source into several fibers differing successively by 1.4 ns, and injecting the light into the front end of the conduits.

### Description of first year project activities

In the first year we will establish design of the luminosity monitor. Geometry and mechanical support will be finalized. Performance will be understood based on improved existing GEANT4 simulation; optimal geometry of the absorber, as well as optimal materials will be chosen. Readout electronics chain will be designed and performance-to-cost ratio will be maximized by the proper choice of high performance pmt, similar to existing Hamamatsu R3809U-57 (200ps, UV), very fast (GHz) digitizers, similar to now available MAXIM104, and design of very fast bunch-by-bunch storage memory, based on XyLinks FPGA. In addition delamination of aluminum coating under high doses will be investigated (although this is not considered a problem at NLC).

First year research will enable our research team to start production of beam ready prototype of Luminosity Monitor. The first year activities will consume only a fraction of three year budget.

### Budget (3 year)

This is an estimate of costs (in K\$) for building a beam-ready prototype that can be tested in an electron beam at SLAC. We will involve undergraduate and graduate students, and work in close association with SLAC on reflecting surfaces.

Institution	Item	Cost
ISU	Salary for graduate students	\$18,000
ISU	Salary for undergraduates	\$12,000
ISU	Equipment & materials	\$30,000
ISU	Travel	\$10,400
ISU	Indirect costs (26% of non-equipment)	\$13,000
	Direct	\$40,000
	Grand total (beam ready module)	\$83,000