QUANTUM DIARIES
Thoughts on work and life from particle physicists from around the world.

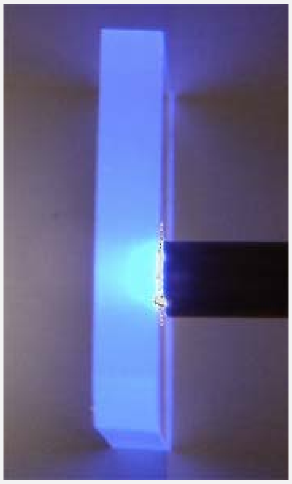
« Neutrinos: A question and an answer
Party in the salt mine! »

FRANK SIMON | MPI FOR PHYSICS | GERMANY

Light from Plastic

After a shamefully long absence from the blogosphere, I'm finally back with a post about my work on calorimeters for the Linear Collider. I've already written about this a bit, for example here and here, and more details about the CALICE analog hadron calorimeter I'm mostly focusing on here and on my webpage. The key theme is always granularity, to get a detailed 3D picture of the particle showers to be able to use Particle Flow to get the best possible resolution.

So far, so good, but how do we measure the particle showers? We use so-called sampling calorimeters, which consist of layers of passive and active material. The passive material is usually dense stuff, in our case steel plates, where the incoming particles interact and form particle showers. After a passive layer follows an active layer that essentially measures how many particles have been created in the passive layer in front. By doing this layer after layer until the complete shower is absorbed, you get the total number of created particles, which then tells you the energy of the incoming particle if you know how the showering works in the absorber. Of course it is not quite that simple once you look deeper into this, but to understand the principle its certainly good enough…

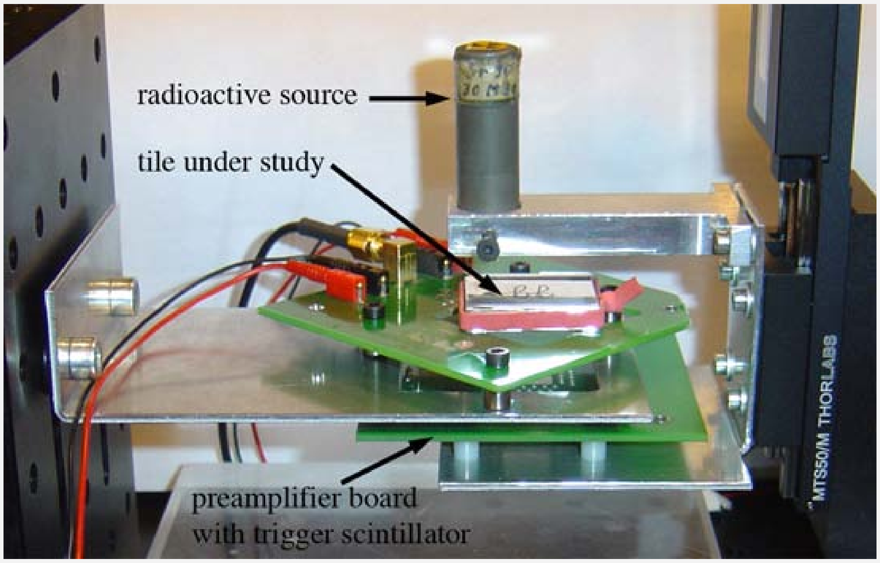


Blue light emitted by a piece of plastic scintillator.

But: how do we get a signal out of the active layers? After all, in the end we want some information that can be processed by a computer… In the hadron calorimeter, we use plastic scintillators, which emits light if a charged particle flies through it. The granularity of the detector then comes from building the active layers out of small scintillator tiles, in our case typically 3 cm by 3 cm, 5 mm thick. The light created in the tiles is detected with tiny silicon-based light detectors, so-called silicon photomultipliers, SiPMs, which we put on each little piece of scintillator. Those guys are capable of detecting individual photons in the visible spectral range, and transforming the light into an electrical signal… exactly what we need! But again, it is not quite that simple: The scintillator emits blue light (as you can see nicely illustrated in the picture on the right), but the first generation of SiPM that we use in our calorimeter that went into various test beams, most recently last May at Fermilab, are best at detecting green light. That is why a wavelength-shifiting fiber, a plastic fiber that absorbs blue light and then emits green light, is embedded in each scintillator tile. This fiber collects the light, changes it to green and leads it to the SiPM. That works quite well, with the added benefit that the response of the scintillator tile is quite uniform over the full surface, meaning that the signal you get out in the end for a particle that goes through the scintillator is the same no matter where it went through the tile. The downside is that it is mechanically quite complicated to put the fiber into each tile, in particular once we think about a full-scale experiment, which would use about 8 million of such tiles!

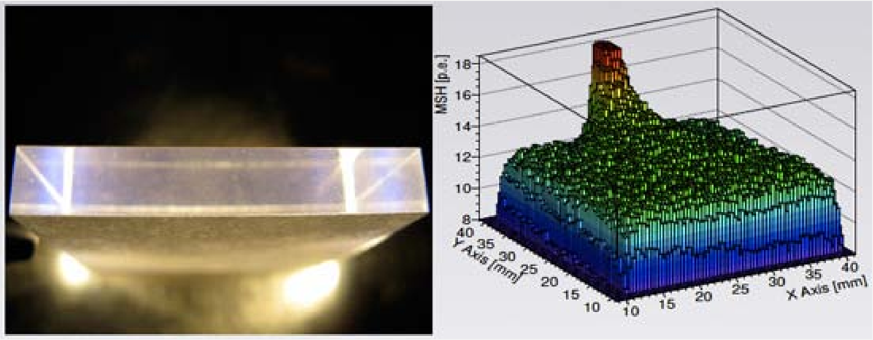
Luckily, silicon technology is advancing at incredible speed, so by now you can buy SiPMs that are optimized to detect blue light off the shelf. The fiber is no longer necessary, which has a number of advantages: Most notably an easy (and thus cheap) manufacturing of the scintillator tiles and a faster signal, since we get rid of the detour of absorption and reemission of the light in the fiber (this will be important for some beam tests I'm planning at CERN in the fall, more about this at some later time…). But one question immediately comes up: What about the uniformity? After all, the fiber is collecting the light, leading it to the SiPM. What happens if we throw it out, and stick a SiPM directly to a piece of plastic?

My grad student Christian and I studied this, with a small experimental setup developed exactly for this purpose. It scans a small radioactive source over a scintillator tile, and measures the response (meaning the number of photons we detect with the SiPM), depending on the position of the source. The figure below shows a picture:



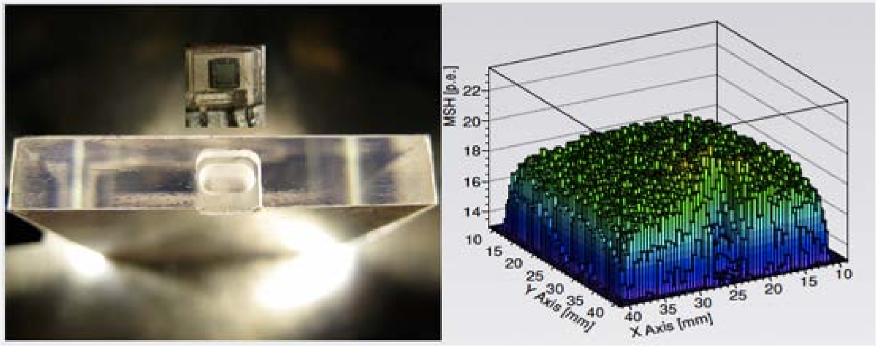
Test setup to study scintillator tiles with SiPM readout in detail: Scanning a radioactive source across the surface.

A first try was to just stick a SiPM directly to a piece of plastic, which gave rather disheartening results: A large signal close to where the photon sensor sits, and a much lower signal elsewhere. Not exactly what we want to use in our calorimeters:



Naive fiberless coupling of a SiPM: Just stick it to the side of a scintillator tile. The result: Not at all uniform...

However, just by looking at the figure of the response, you can already come up with a possible solution: Reduce the amount of plastic close to the SiPM, and you'll reduce the huge spike. After quite a few iterations, we came up with a shape for the plastic tile that works extremely well. It also now includes a SiPM that is embedded into the tile, which is important or a realistic calorimeter since then the individual cells can be placed edge on edge, without any gaps between them. We get a large signal, and beautiful uniformity, at least as good as with the fiber, with something that is quite a bit easier to produce:



Making it work: A special "dimple" at the spot where the SiPM is attached solves the uniformity problem. A zoomed photograph of the SiPM we use is also shown in the left part of the picture.

A few weeks ago, we submitted a paper on the results which you can already find on the ArXiv. Meanwhile, we have also found uses for our studies outside the Linear Collider project, which I'll post about soon, hopefully… But for today I've written more than enough!

> This entry was posted on Saturday, March 6th, 2010 at 9:49 am and is filed under Latest Posts. You can follow any responses to this entry through the RSS 2.0 feed.