SID muon detector R&D

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Outline

1. The SID muon detector/tailcatcher system
2. RPC –based detector R&D
3. Scintillator – based detector R&D
4. Plans for the future

SID Muon detector system/tailcatcher

SID is a compact detector with relatively thin (~5λ) calorimeters inside 5T solenoid, so in addition to conventional role of

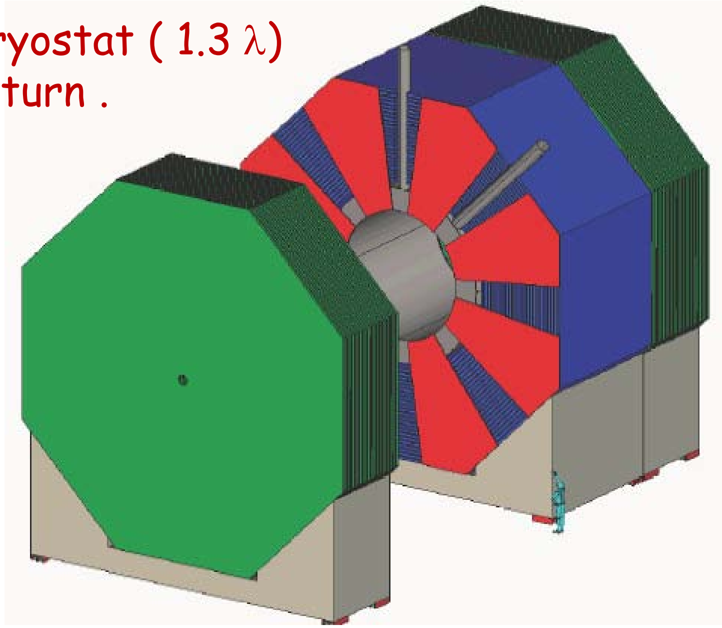
*identifying muons by ranging out charged particles

the muon detector system should

*measure leakage of highly energetic and late-developing showers

Central Muon System:

- after ~5λ Of calorimeters and the 5T solenoid coil and cryostat (1.3 λ)
- installed in the iron (2.3 m iron , 18 λ total) of the flux return .
- Central barrel 5.7 m long, R = 3.5 m.



Barrel and EndCaps muon System unit:
10 cm thick Fe plate with 4 cm gap

Total detector area ~6000 m2 for 14 layers.
Total no. of channels ~ 10^6

Candidate tecnologies:

a) RPC – based design (baseline)
b) Scintillator – based design (alternative)

Technology alternatives

Large area and channel counts imposes the following criteria on the choice of technology

- Low cost
- Easily made in a variety of shapes
- Adequate performance & reliability

The need to operate inside the return yoke adds the following criteria:

- insensitivity to magnetic field
- space economy for the readout system (cables, f/e etc)
- reliablity and slow aging

Base-line choice driven by past experience (BABAR, Belle), by synergy with the RPC alternative for the HCAL and by the possibilty of using the KPIX chip for RPC readout

However

- reliablity and aging are still concerns for RPCs
- wls fiber readout of cheap extruded scintillator and new, (potentially) low-cost Si-based photodetectors make the scintillator alternative progressively more competitive

The RPC alterative

Evidence that aging is current-dependent → avalanche mode

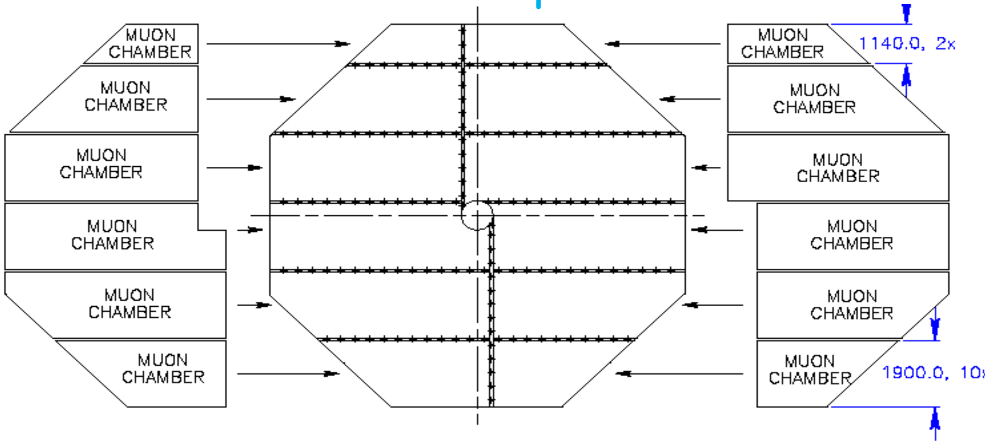
H. Band (ALCPG09):

- CMS ATLAS BESIII DAYABAY OPERA

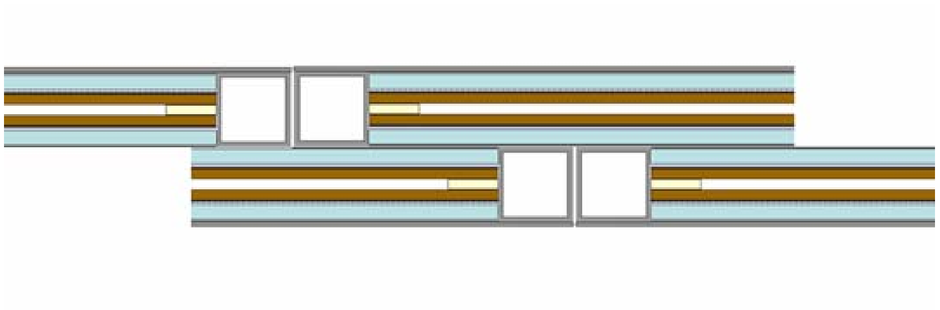
rate

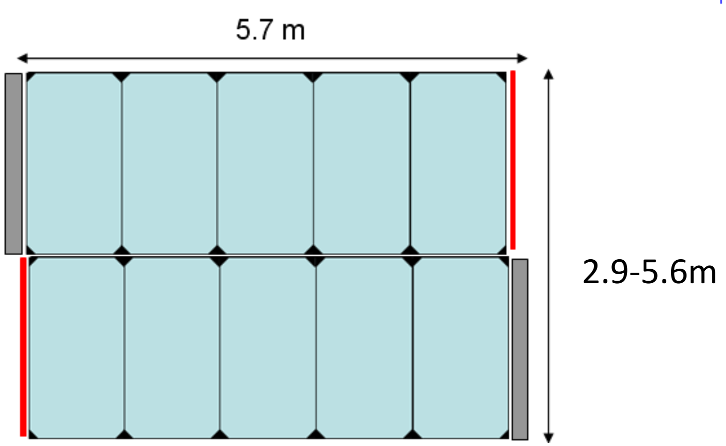
- Avalanche ----------- Streamer ------------

End-cap



- Proposed SiD RPCs
- IHEP Bakelite
- Double gap
- operated in Avalanche mode,
- KPIX readout
- > 93%/layer





Barrel

Band: ALCPG09

RPC Studies

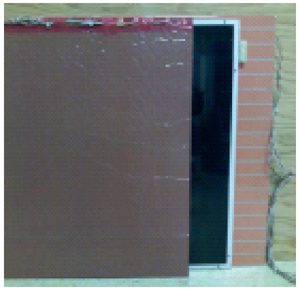
Ongoing programs at Princeton and Wisconsin to understand RPC aging (Bakelite/melamine)

- Princeton - C. Lu
  - IHEP RPCs
    - Bakelite/melamine from Chinese industry
    - No linseed oil design
    - Used in BESIII, DayaBay,
    - Proposed for SiD
  - Surface quality
  - Source studies

- Wisconsin - H. Band
  - BaBaR forward RPCs
    - Construction similar to ATLAS/CMS RPCs
    - 6 years of data
    - Huge range of background & signal rates
  - Analysis of trends & correlations
  - Autopsy of aged RPCs

10/02/09 H. Band –LCWA 09 10

RPC/KPiX R&D Plans



- 2009 Milestones
  - Relocate test-stand
  - Optimize RPC/KPiX interface board design to maximize efficiency and minimize strip multiplicity.
  - Make current, rate, and efficiency measurements of IHEP test RPCs operating in avalanche mode.
  - Test KPiX (v. 7 & v. 8) trigger and reset operating modes.
- 2010-11 Milestones:
  - Readout multiple KPiX chips
  - Use position and charge information from multiple RPC/KPiX devices to make fitted cosmic ray tracks
  - Study position resolution of RPC/KPiX tracks,
  - Test HCAL prototypes in teststand

On-going work

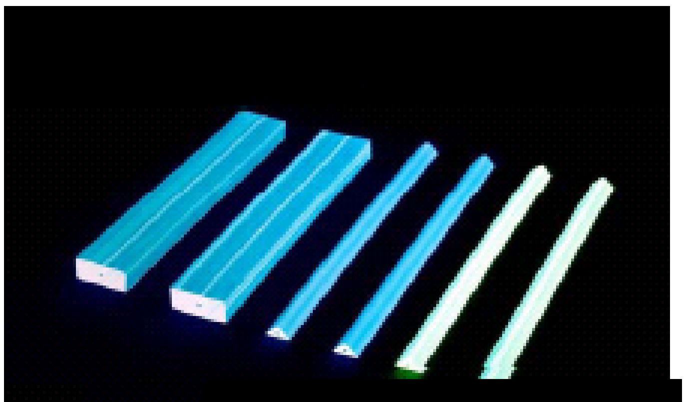
RPC R&D focussing on

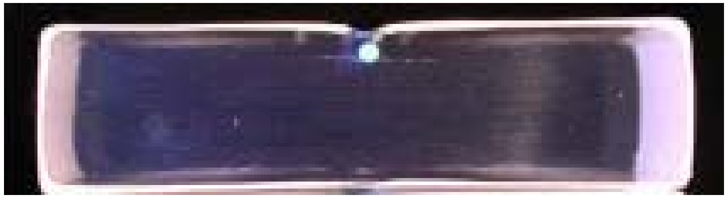
-Understanding aging
-Optimizing surfaces
-Optimizing readout (KPIX interface)
-Understanding inefficiencies and multiplicities

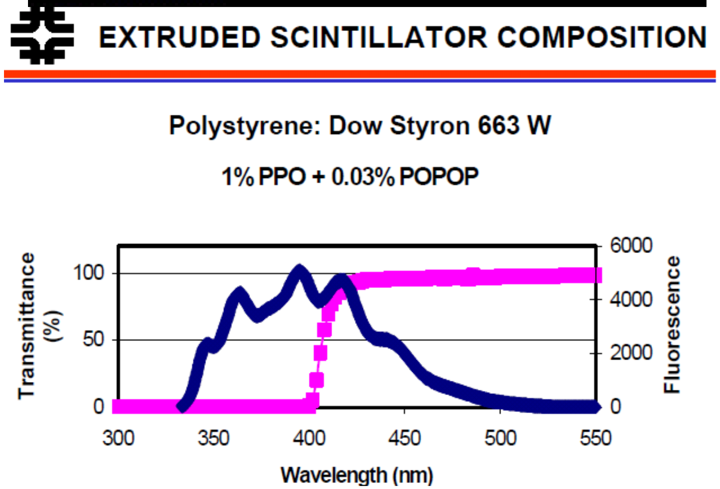
So far they have been relying on cosmic ray test stands, on the use of radiation source for accelerated aging and on analysis of a large store ammount of data from past experiments

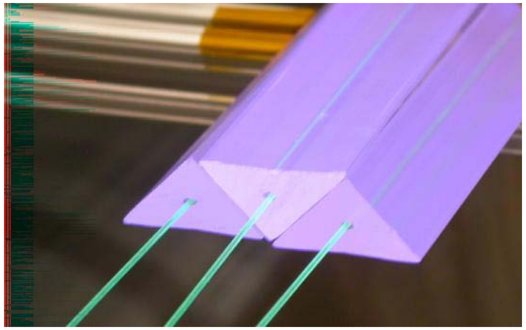
Scintillator – based muon detector R&D

In 2000 it was noted that the ILC muon system requirements could be met with a MINOS type scintillator detector design that would give both muon identification and be used to measure the tails of late developing or highly energetic hadron showers.



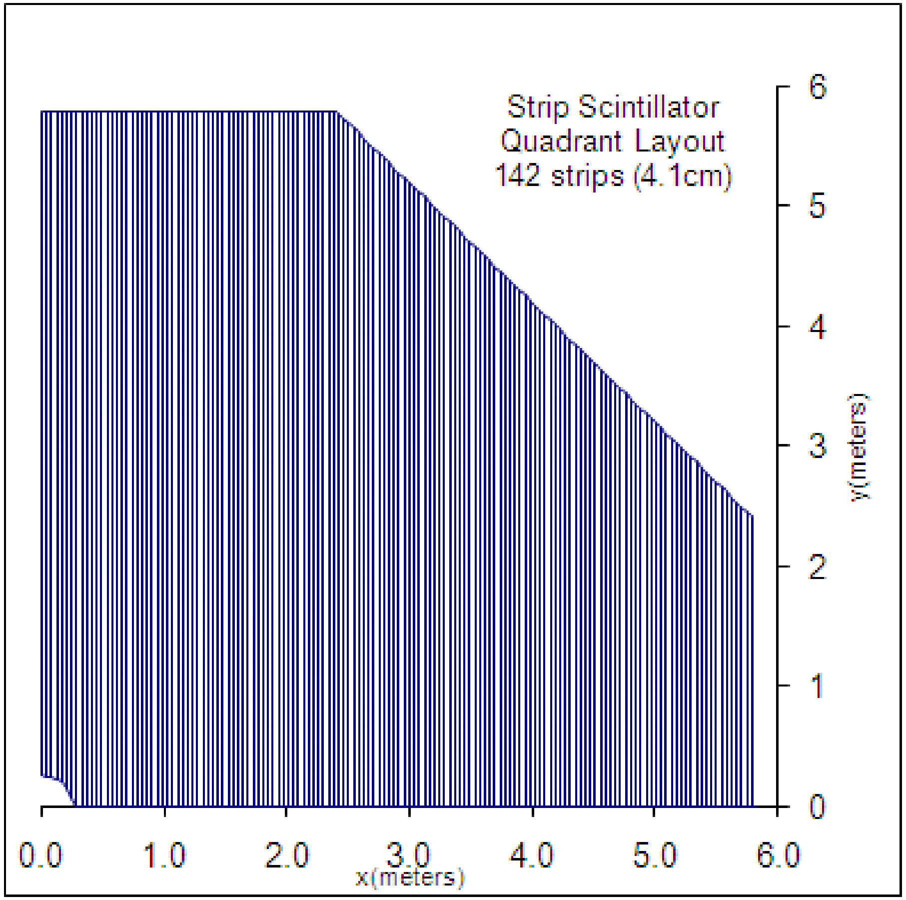






Fisk: ALCPG09

Forward Muon Strip Layout



The maximum strip length is 6m. From MINOS measurements the attenuation over 6m is ~ 0.3.

Taking 20 p.e.s as the mean yield for no attenuation, you expect ~ 6 p.e.s from the far end.

With Poisson statistics, the probability of 0 or 1 p.e.s at the far-end is 1.7%

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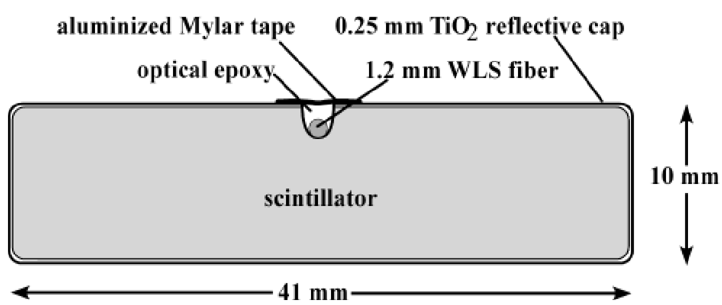
Sintillator – based muon detector R&D: a brief history

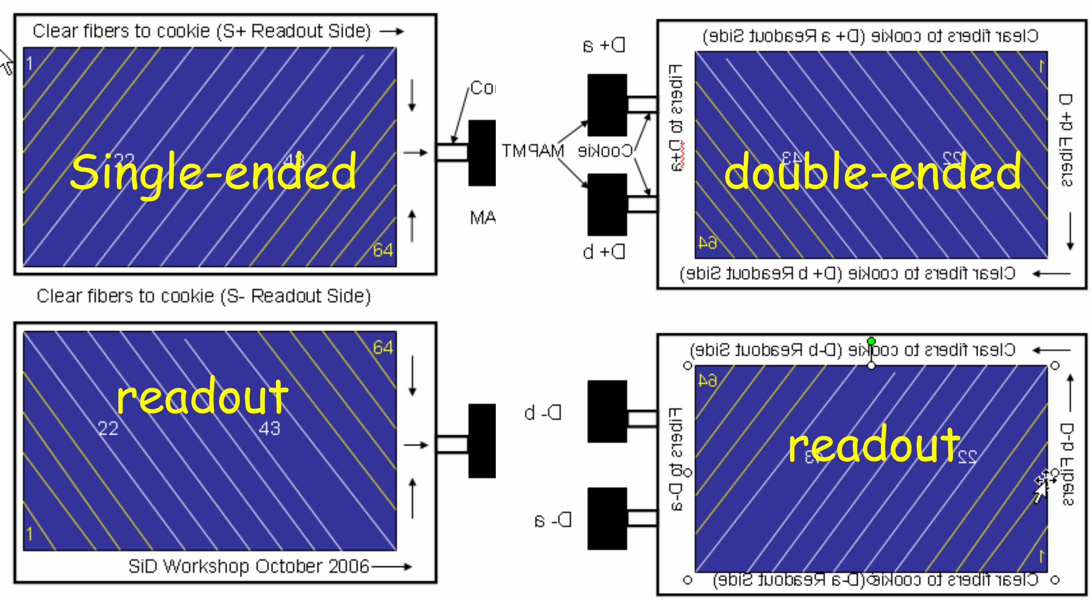
Begin with

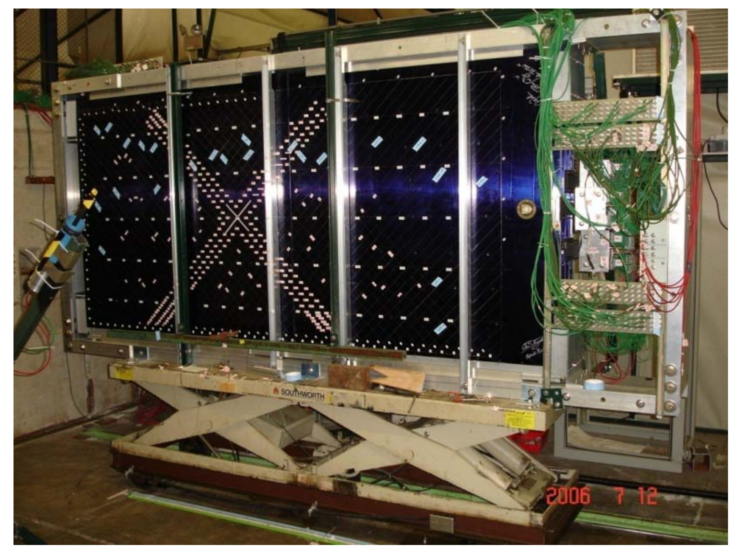


+

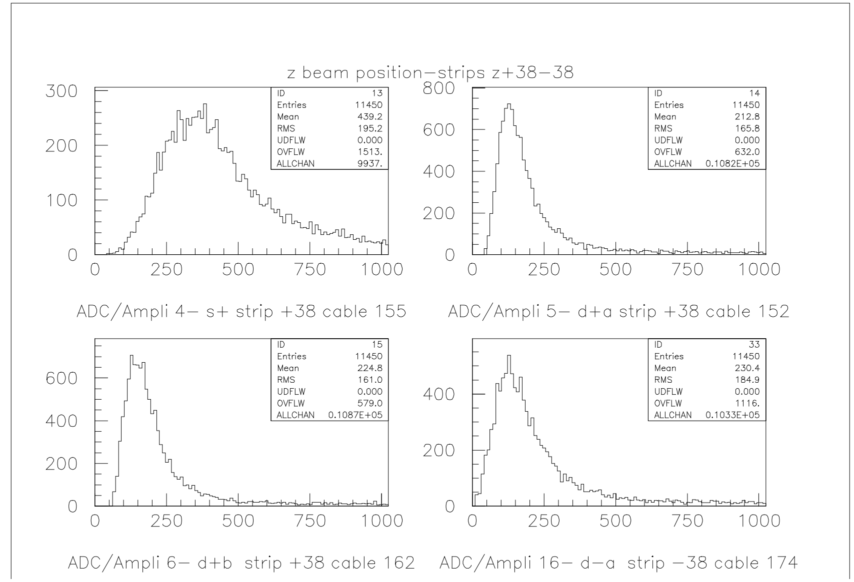
Hamamatsu H7546B : 64 \ channel MAPMTs calibrated using a 5mCi Sr^{90} in contact w/plastic scintillator and WLS fiber to ea ch MAPMT pixel.

Prototypes inst alled in Fermilab Beam Test Facility
256 scint illat or st rips 384 PMT channels





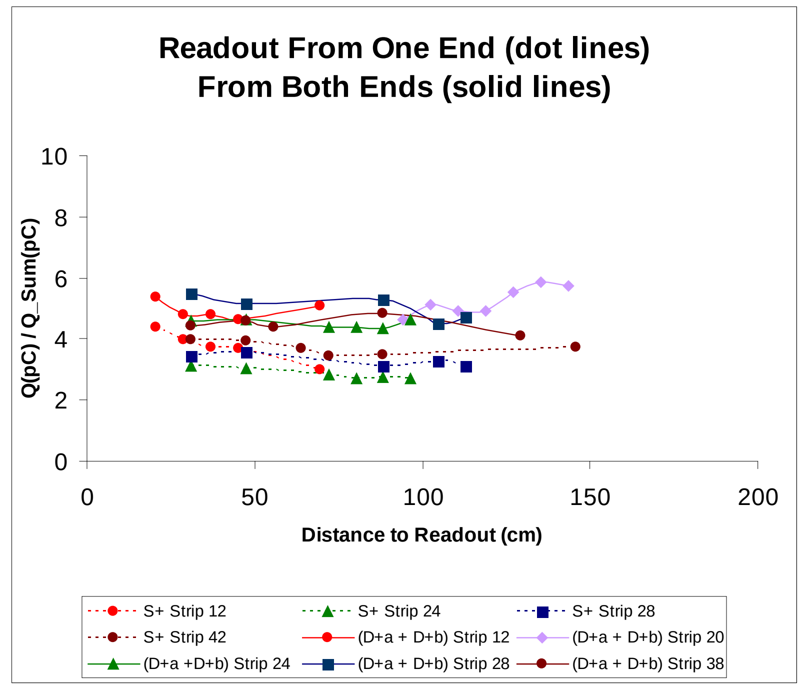
No. of photo-electrons is > 9.3 (**Sept 2006**) --- fully efficient



Measured both single ended (S) and dual (D) readout.

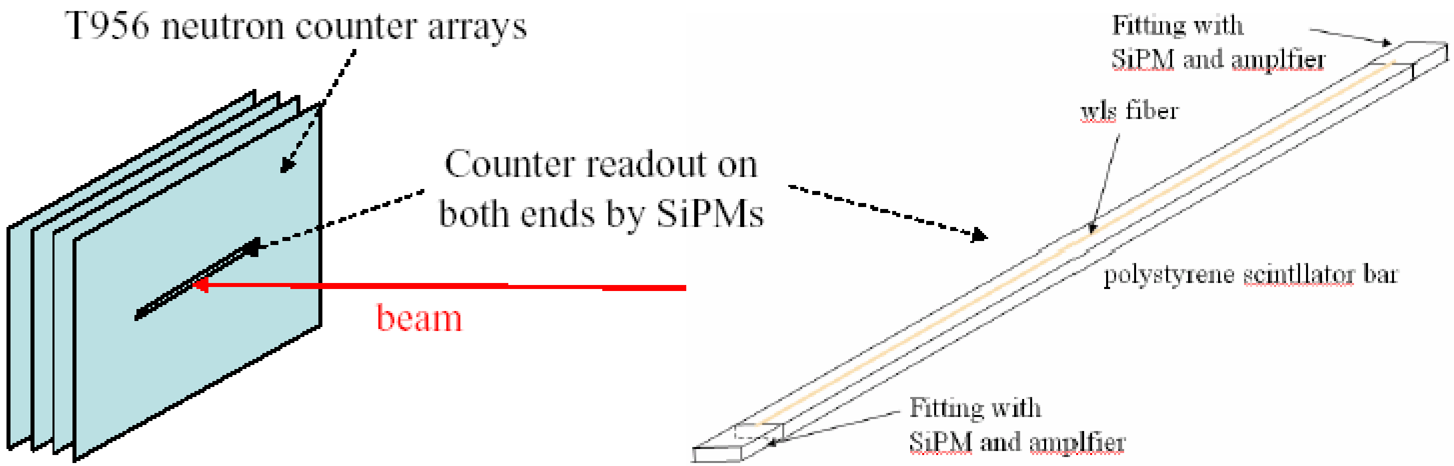
3 pC for (S), 5 pC for (D)
~50% more light with (D)

Nominal gain ~ $2X10^6$ @ 960 V

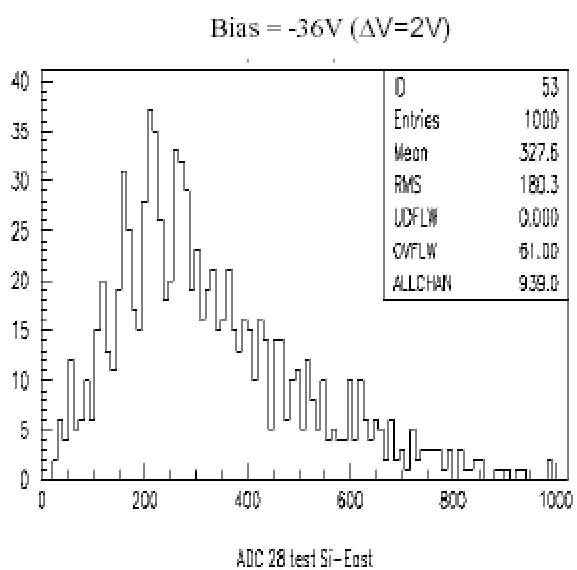


2006:Introduce SiPMs (first IRST prototypes)

Preliminary study : Scint. Strip viewed by IRST SiPM



w/X10 Amp



Data with 120 Gev p - beam

$$N_{p.e.} \approx 6.5\,p.e.$$

$$\varepsilon = 99\%$$

$$N_{d.c.} \approx 1.5MHz$$

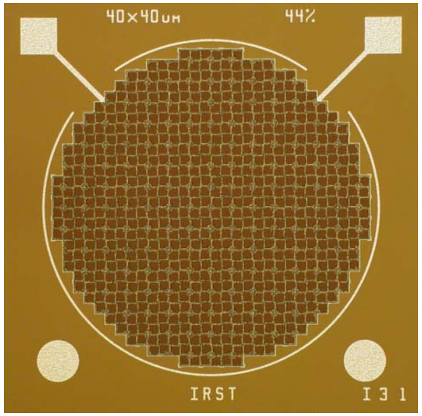
$$G \approx 1.6 \times 10^6$$

Giovanni Pauletta INFN Udine

Develop SiPMs with improved geometry/fill-factor

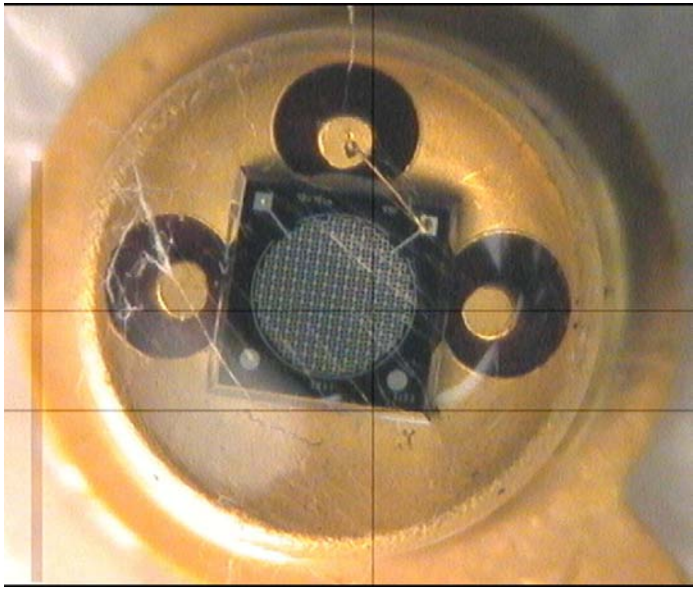
FBK/IRST SiPMs for muon-counter/tailcatcher study at FNAL

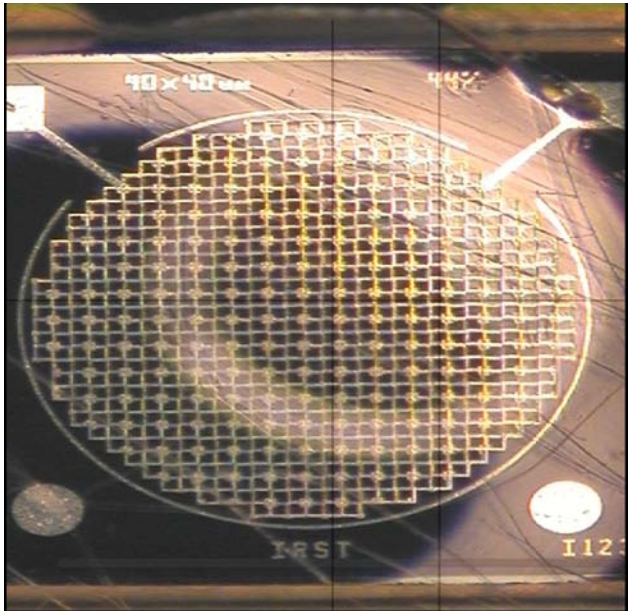
On commission from INFN Udine/Trieste, SiPMs have been produced by FBK-IRST (Trento, Italy) for this application.



Geometry: circular
diameter: 1.2 mm
Microcell: 40 x 40 μm
Improved fill-factor (44%)
Breakdown voltage ~30.5V

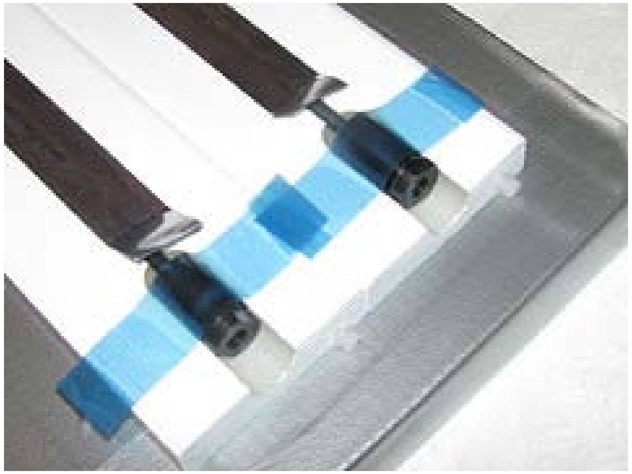
They are presently packaged (T018) with photocathode protected by epoxy(glob-top)

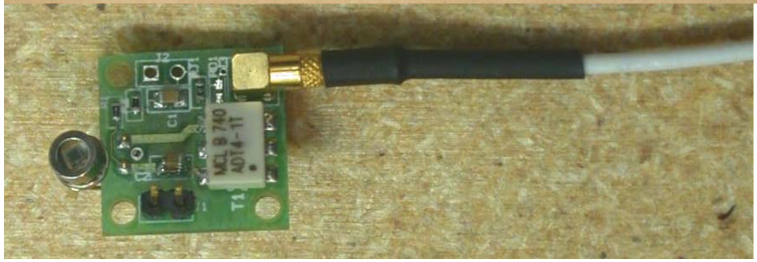




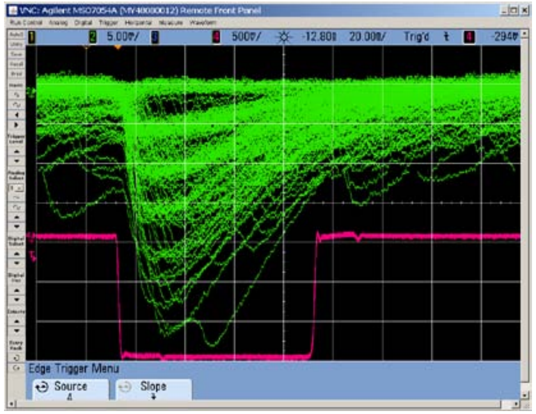
FNAL MTEST Oct-Nov 2008

- Using NIM based 6ch amp built at Fermilab for this work
- Using optical coupling designed at Notre Dame
- Using 120 GeV proton beam (1in x 1in spot)





FNAL MTEST Oct-Nov 2008



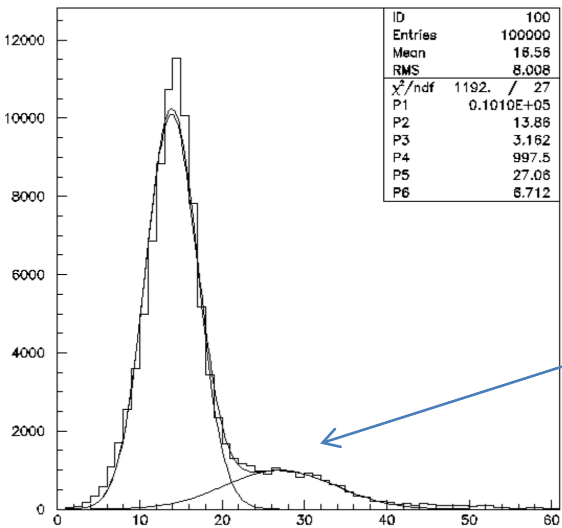
Our strategy :

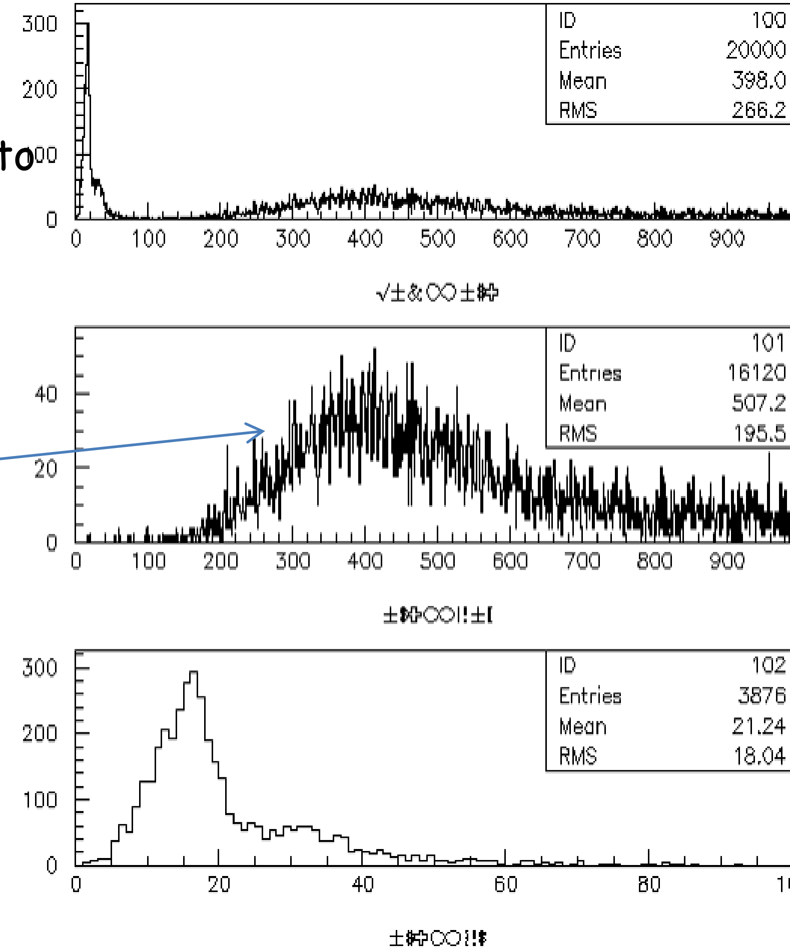
Take data with loose trigger to enable us to see pedestal.

Use other counters to select MIPs.

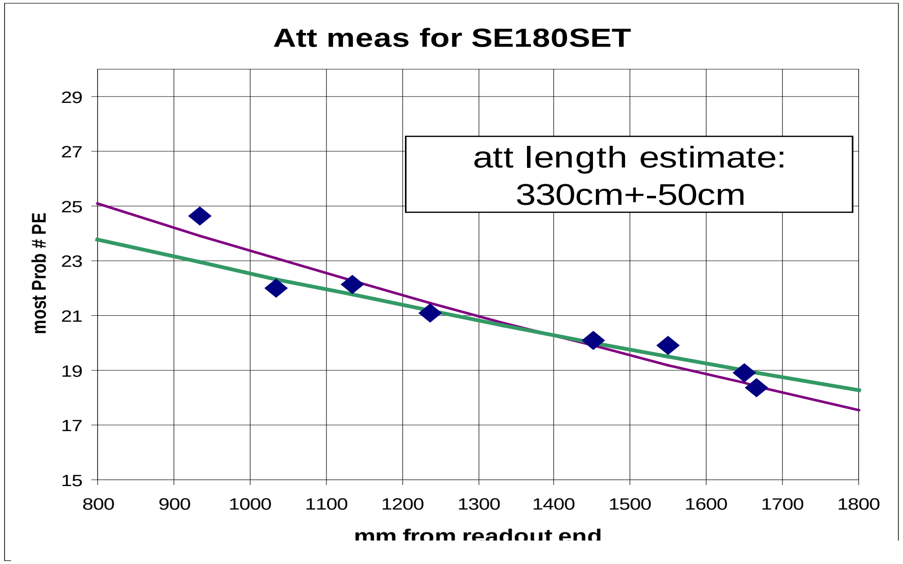
Peak at 400 counts is ~ 25 photo-electrons.

Extract 1pe peak from pedestal.

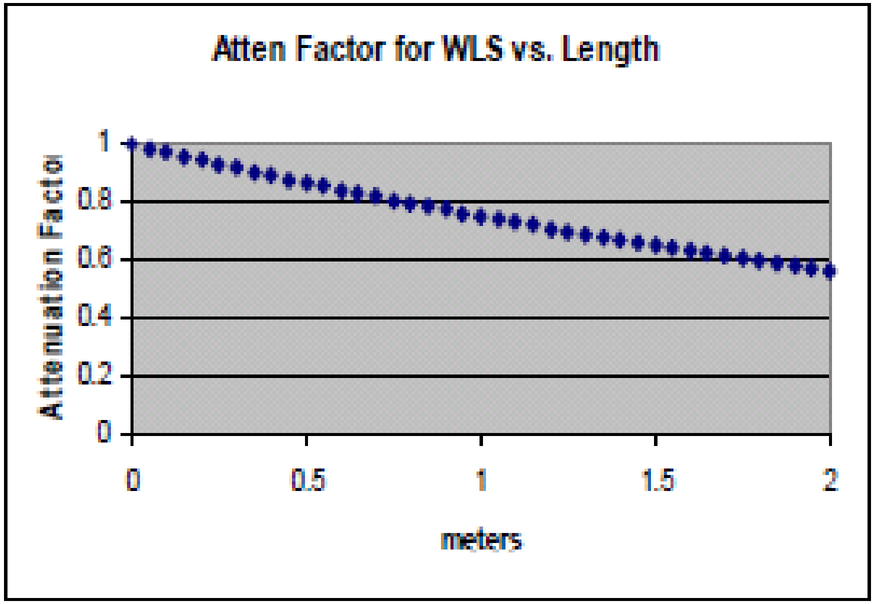




- A scan of the 1.8m bar across the beam gives an estimate of the attenuation length



- *good agreement with previous (2006) measurment*



$\lambda = 3.5$ m

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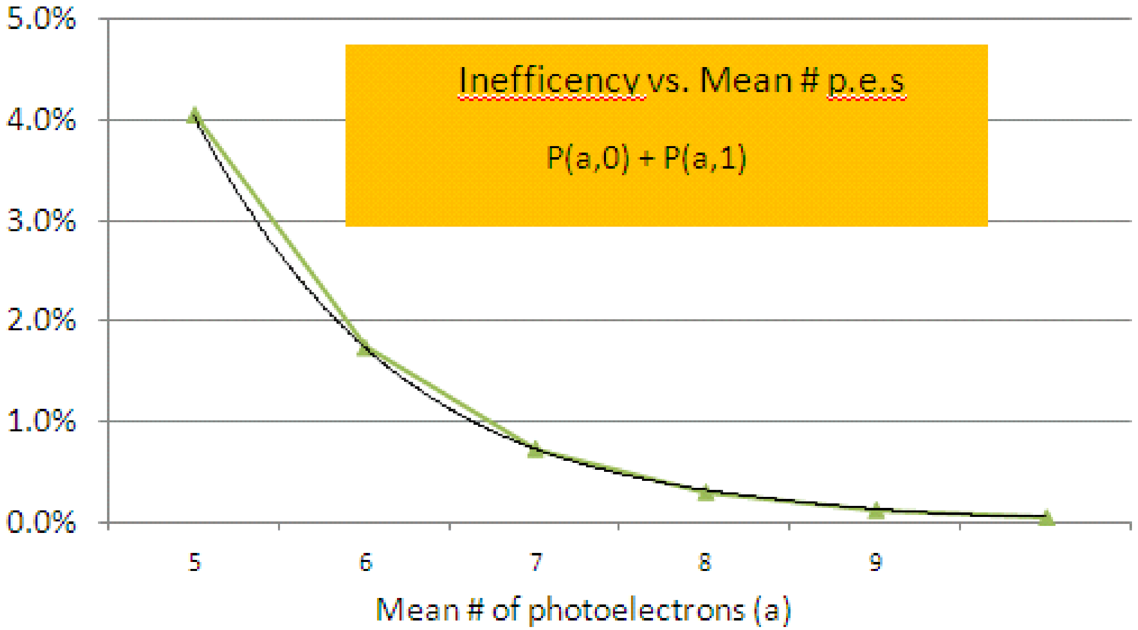
Inefficiency (far end) vs. <p.e.s>

Poisson statistics only; threshold @ 1.5 p.e.



This is fun, but very naïve. The noise rate can be as high as 1 MHz/mm^2.
So we need to understand rates at various thresholds and that will depend on pulse shape, temperature, after pulsing, etc. All of this points to the test beam and the instrumentation that Rubinov and Fitzpatrick have been developing, and the measurements that many of you have been doing. WE NEED YOU!

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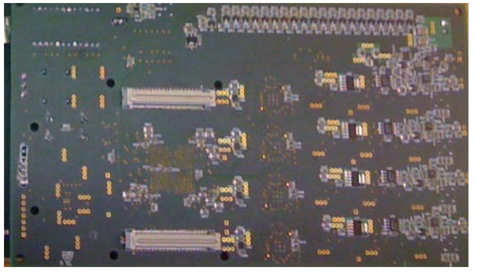
New since LCW08

- Our plan for readout was (and is)
  - Fall 08: just an amplifier in a NIM bin using 50ohm cables
  - Spring 09: Integrate amp, ADC, bias on one board
  - Fall 10?: SiPM readout ASIC

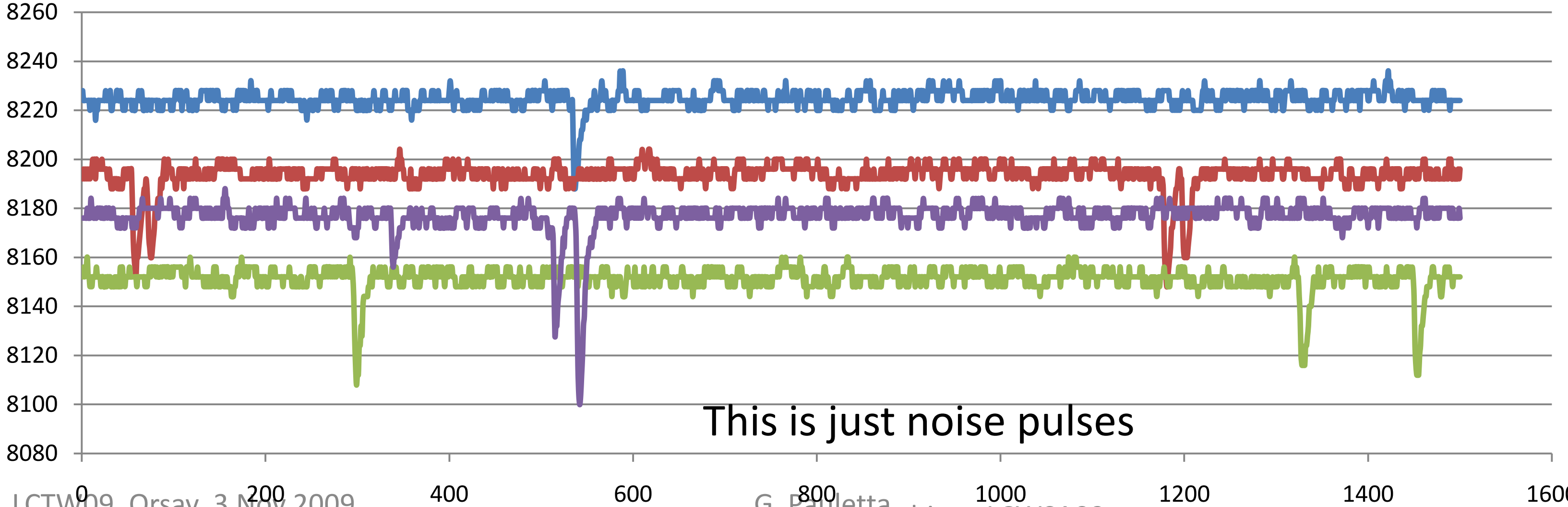
- New electronics ready to go for TB
  - A board that strikes a good balance of high performance and reasonable cost to support SiPM studies
  - self sufficient, simple to use and flexible
  - reuse known working designs whenever possible.

TB4



TB4 key features

- 4ch of HS ADC (10 or 12 bit, 210 or 250 MSPS)
- Largish FPGA (with 4kpts memory/ch)
- USB interface, High Speed io
- On board bias generation for SiPMs (and current meas)



Scintillator elements (extruded strips) are separable and it makes sense to instrument a small number of channels and use test beams to accelerate the testing process. In the process, w can also develop and evaluate/test photodetectors and F/E under operating conditions, so:

our plans for the immediate future are:

* test new F/E (TB04) under operating conditions (in test beam) with same 4-cm x 1 cm extruded strips as used previously, read out by SiPMs (IRST), MPPCs, etc

- Verify wls attenuation measurements
- establish possibilty of single – ended readout for strips of up to 6 m – length
- understand effects of threshold , rates, dark count, afterpulsing,
- etc.

For this work, we are very undemanding:
* need limited test beam space and
* mips.

So far, we have been operating under the following typical conditions :
* 120 GeV protons @ 10e2 -10e4 p/sec
* 1cm beam spot

- So long an we can work in a well-defined beam spot there is no need for tracking
- It seems convenient (man-power, beam-time,..) to share beam and set-up with other, compatible, R&D, e.g. testing of individual crystals for calorimetry

Plans for the less immediate future:

Develop, detailed proposal for a scintillator-based "muon detector/tail catcher" for SID (simulations, costing etc.)

as we:

- Continue development of F/E → VLSI
- Continue optimiztion of SiPMs (lay-out, efficiency, cost)
- Continue development/optimization of optical coupling)
- optimization of light collections from scintillator extrusions
  - location of extruded hole,
  - glue/no glue (or other) optical coupling
  - coextrusion wls fiber
  - etc.

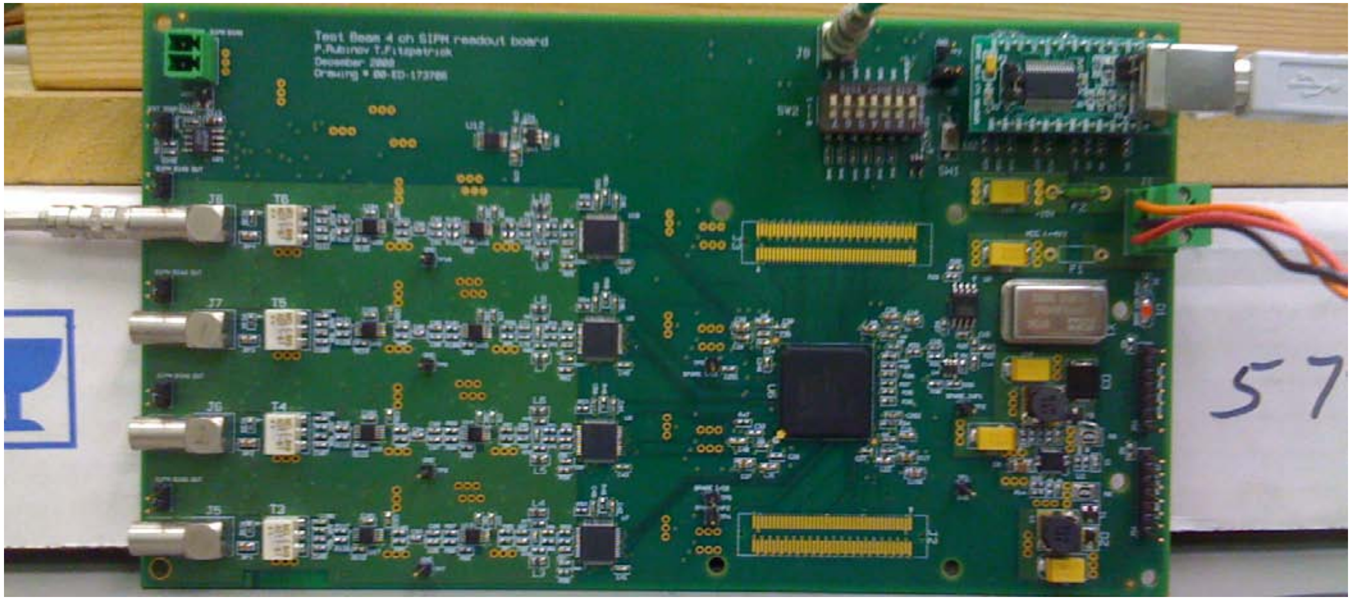
construction and testing of a complete "muon/detector tail catcher" module --- preferably in conjunction with a calorimeter module .

At this point (2011?) , we will be more demanding

Backup

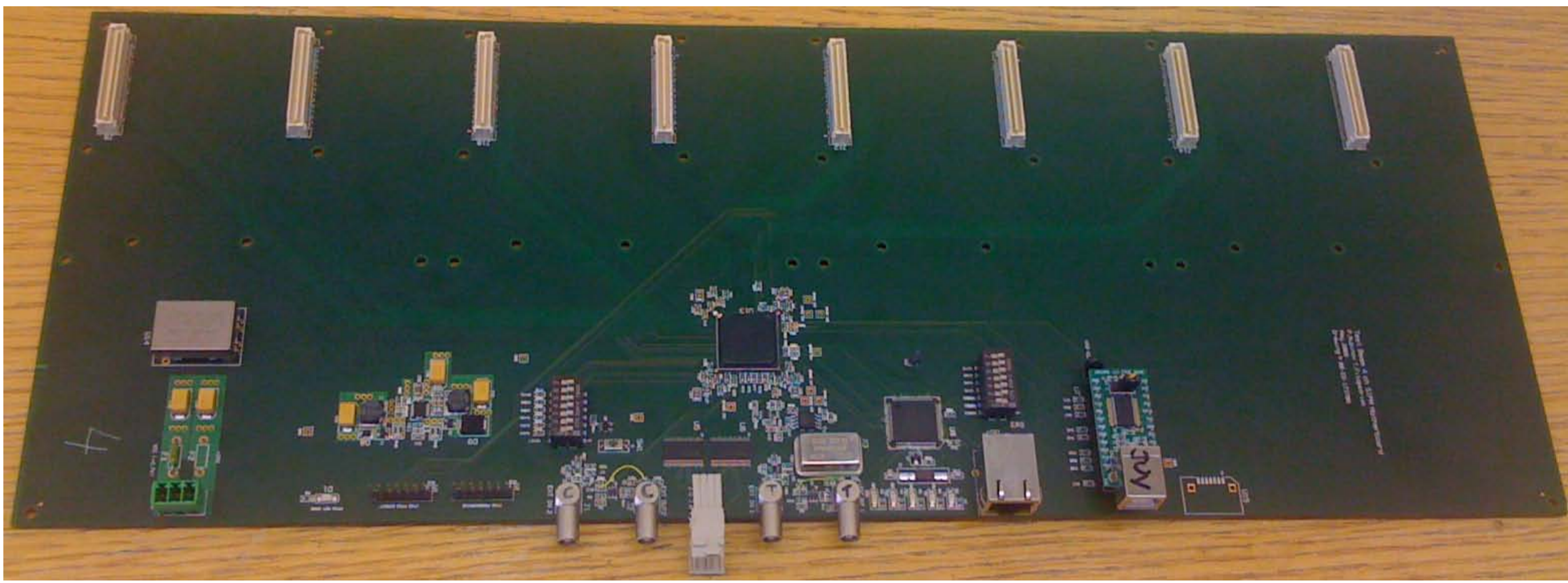
Emphasis on simple

- Plug in 5V power
- Plug in SiPM into an end of a 50 ohm cable
- Plug the other end of the cable into the TB4 board
- Plug in the USB connector into your computer
- Start the software, and press the RUN button



TB4 continued

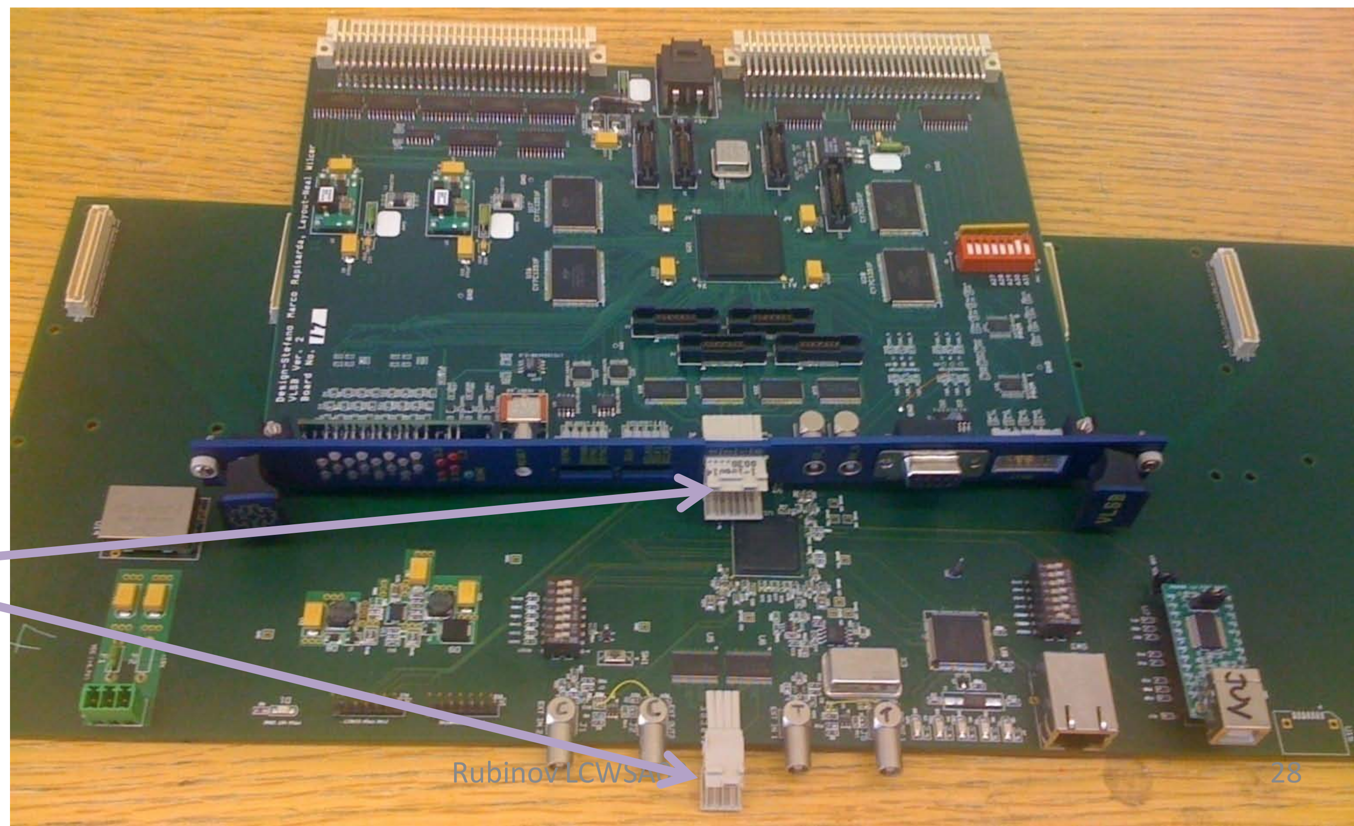
- For slightly larger applications, like test beam
  - 4x TB4 combined on 1 motherboard
  - Mother board provides:
    - Ethernet interface, USB interface, triggering, clocking



TB4 continued

- For fast readout: LVDS links (2 x 1 Gbps) go to a VME module (1 module has 4 links) with sufficient memory (512KB) to act as a buffer for better throughput

LVDS links run from MB to VLSB (old Dzero module left over from AFE2 project)



Original invitation to Fisk

Among the calorimeters TB program we keep a place for the SiD Muon, for which ~15' could be given
The aim of the talk is to summarize the experience gained from the previous TB (what went well or wrong, what can be improved) and to give an idea of the future needs for the next 4 years:
beam time, very rough schedule, beam specifications
and put requests on the TB facilities:
what would be a the perfect beam line from your point of view ?

Subsequent invitation to me

I think I have tried to send you this mail at least 10 times, so I am glad it made it through.

That would be for a 15' presentation, basically listing the needs for the Muons detectors in term of TB facility :
- time needed,
- beam quality (intensity, beam spatio-temporal structure, mix of particle, energy range),
- improvements from previous experience [HW and SW interfaces to the DAQ: tracking, Cherenkov, trigger]

Given that representatives from all the TB facility will be present, it is also a way to softly to ask for more services even from one's own "home" facilities (in front of their "competitors").