Backward Calorimeter For SuperB

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Outline

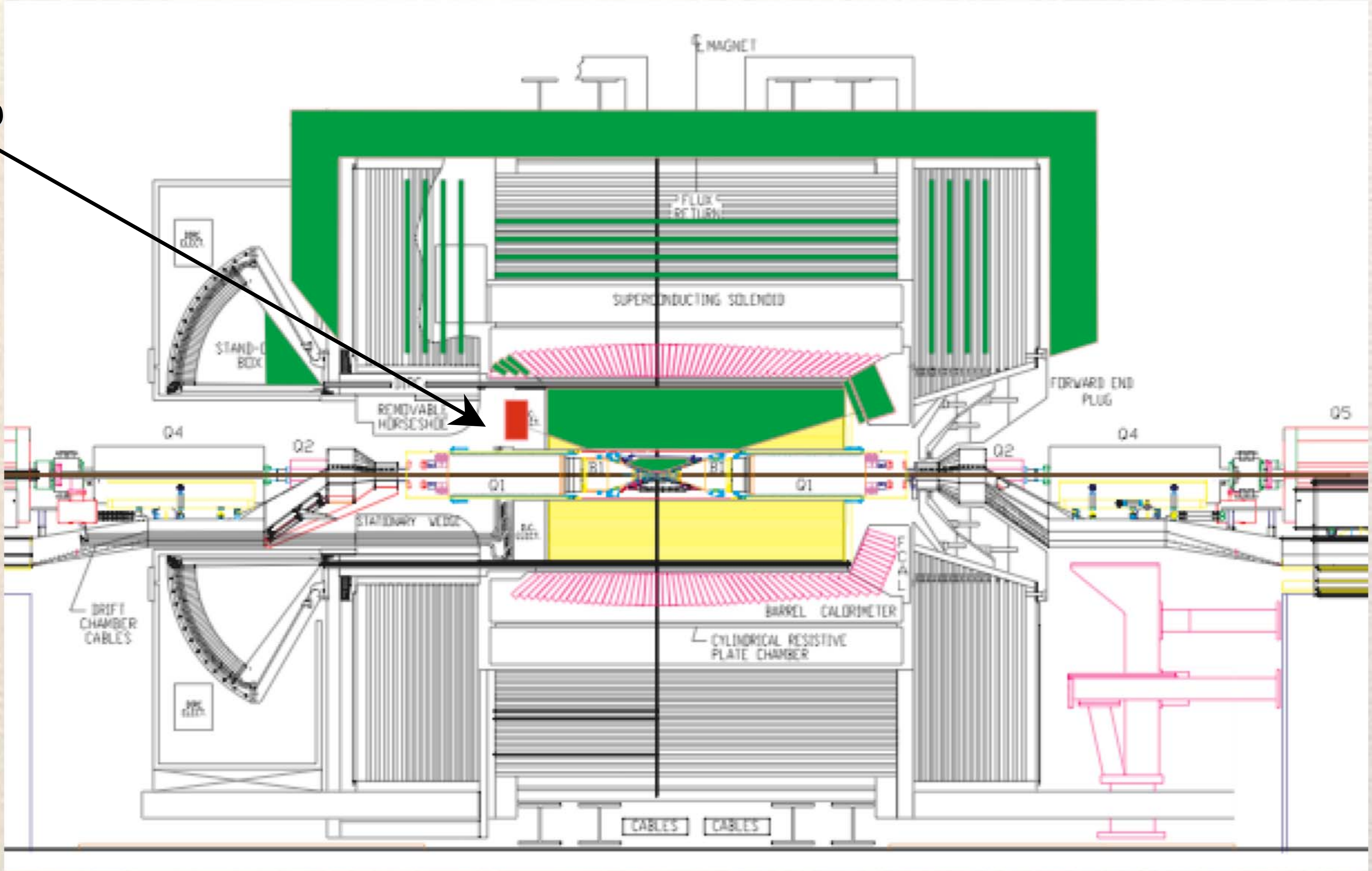
- New Design
- Estimates on precision of position measurements
- Cost estimate
- R&D in Bergen
- Conclusion and next steps

Introduction

- The backward endcap calorimeter is a 12 X_0 Pb-scintillator sampling calorimeter
- The original design for the backward endcap calorimeter consisted of tiles yielding 11520 readout channel
- Since on average only 1-2 particles are expected in the backward EC the segmentation can be substantially reduced
- Instead of using tiles we can use strips
- Dave Hitlin suggested to use spiral-shaped strips
- The new design is based on 3 different shapes of strips:
  - Right-handed spiral strips
  - Left-handed spiral strips
  - Sector strips
- The 3 layers will alternate 8 times

SuperB: Baseline Design

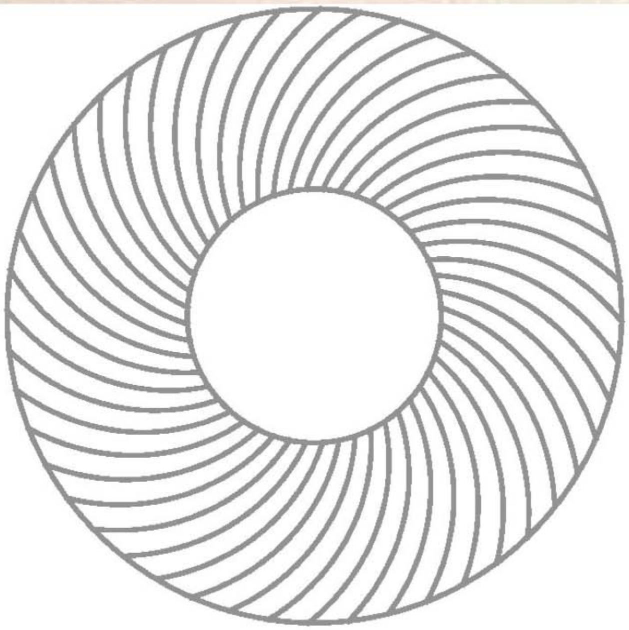
Rear endcap



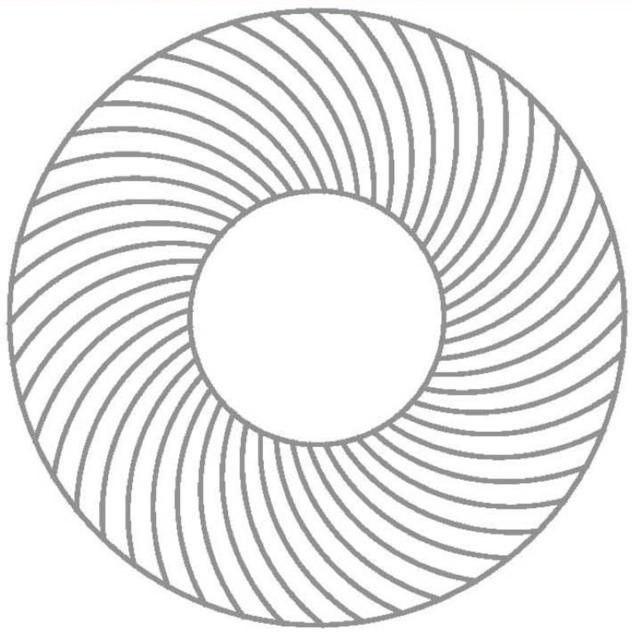
Scintillator Planes

- Alternate 3 different strip shapes 8 times ➔24 layers in total
- There are 48 strips per layer yielding 1152 strips
- Due to the different strip shapes each layer needs to be assembled completely ➔ no split into halves is possible
  ➔ need to remove beam pipe if calorimeter has to be taken out

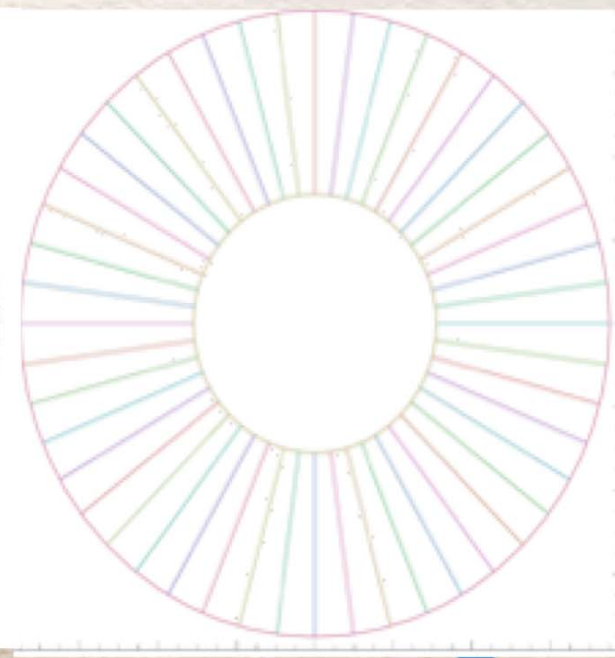
Left-handed spiral



Right-handed spiral

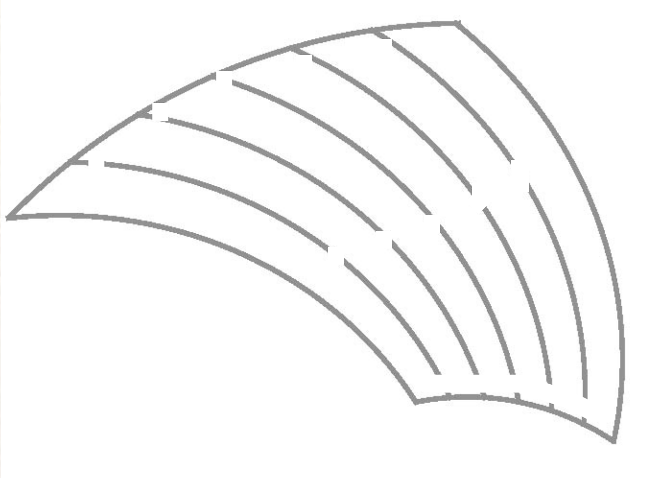


Sectors



Strip Fabrication

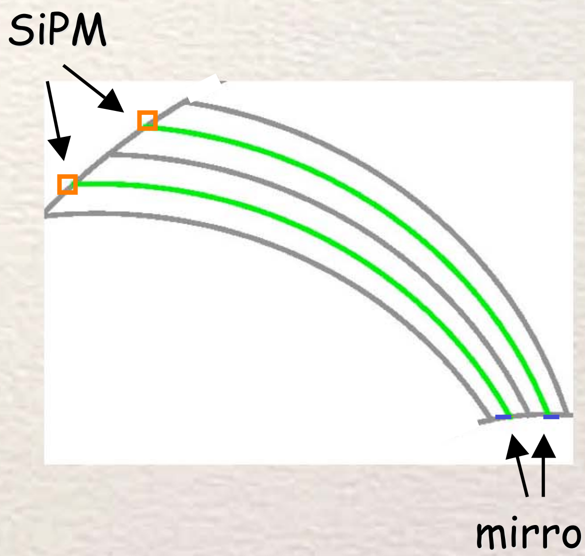
- For practical reasons it is best not to produce individual strips but to start out with a rectangular scintillator sheet
- First cut outer and inner spiral edges as well as inner and outer circular edges
- Next we mill 5 grooves along the spiral lines to produce 6 strips
- We leave small bridges uncut so that the 6 strips are connected in a few places
  ➔ we need to measure the cross talk to decide size of the bridges



- Gaps are filled with white diffuse reflector
- This procedure provides mechanical stability for each sheet
- 8 such sheets make one layer

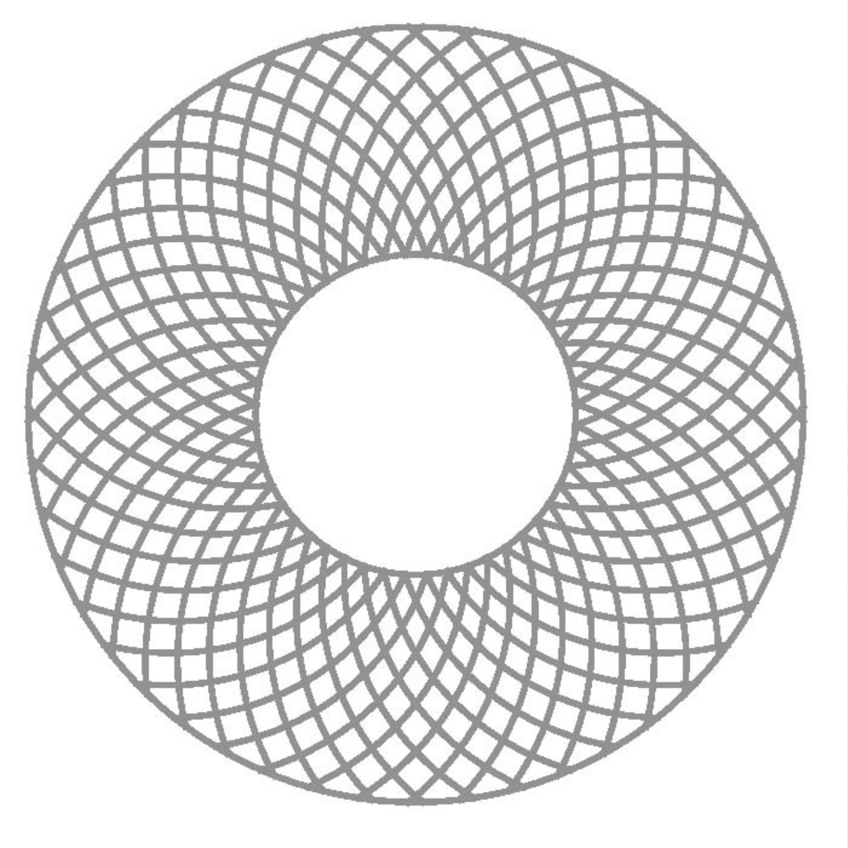
Strip Readout

- The scintillator strips are 3 mm thick
- At the outer edge the strips are 9.8 cm wide, at the inner edge 4.1 cm
- In the center a 1mm deep spiral-shaped groove is cut into which the WLS fiber is inserted
- A SiPM (MPPC) is mounted at the outer edge
- A mirror is positioned at the inner edge of the fiber
- Thin boards with traces are placed on the outer edge to which the SiPM pins are soldered to



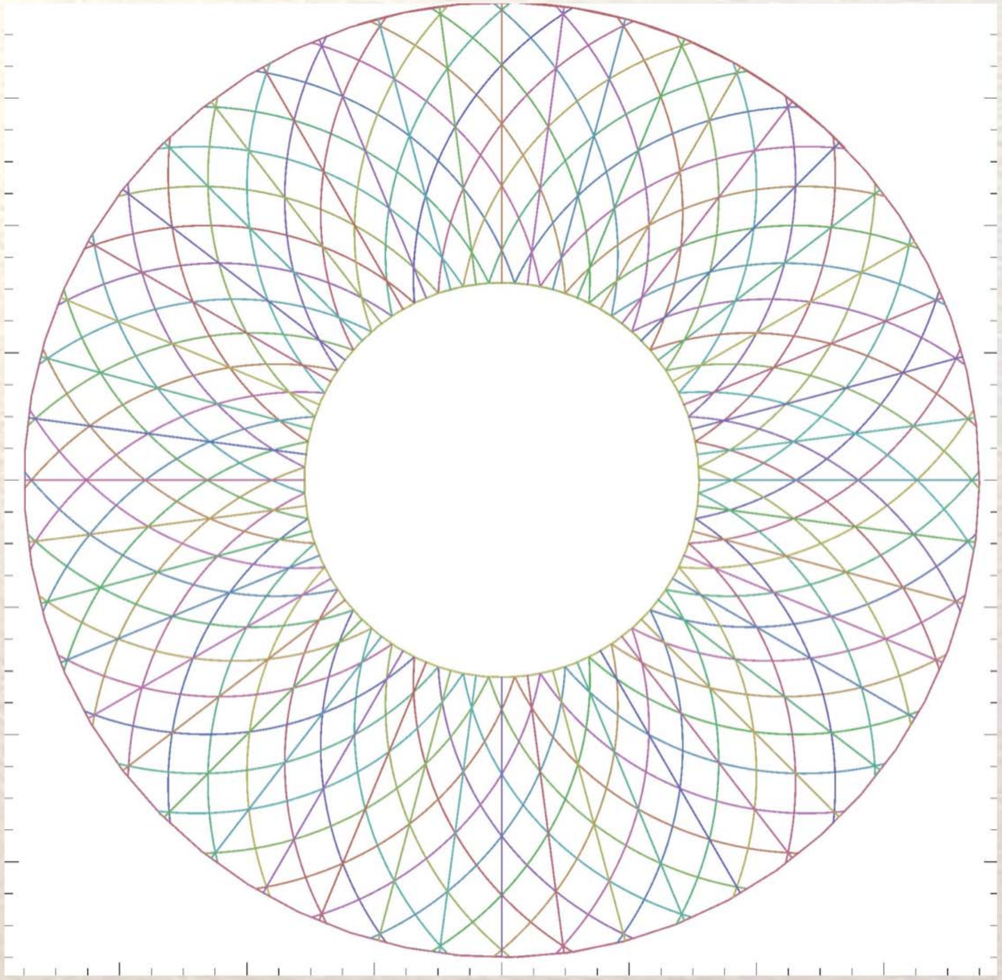
Position Determination from Spiral Planes

- The overlay of left-handed and right-handed spirals project out a tile structure, in radial direction we get 5 tiles
  ➔ $\Delta r \sim$ 10 cm for 4 tiles
  & $\Delta r \sim$ 4 cm for outermost tile
- In the worst case the resolution is $\sigma_r \sim \sigma_\varphi \sim 2.9$ cm (outer region)
- In the best case the resolution is $\sigma_\varphi \sim 1.2$cm (inner region)



Position Determination from all 3 Planes

- Adding sector strips improves σ_φ by factor of 2 around sector boundaries
- For separating two tracks only σ_φ is relevant
- Since sector strips can be cut out from a smaller rectangular sheet than spiral strips, save scintillator material

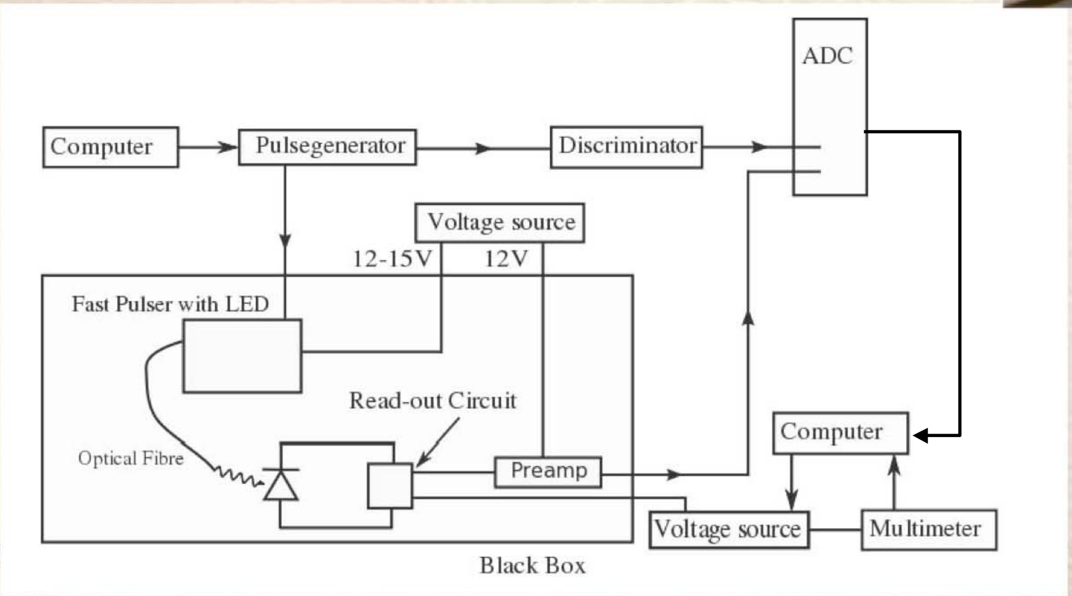


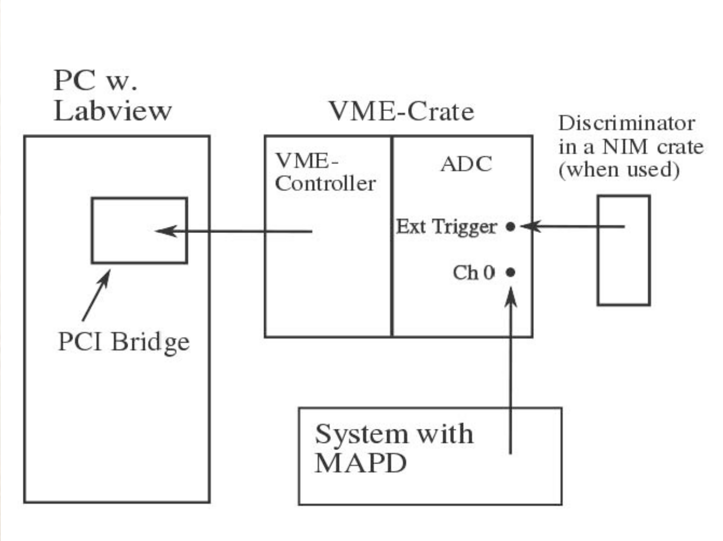
First Cost Estimate

- Scintillator material: 10^5 cm^3 → 89 Kg, eg Eljen EJ200 sheets: 12"x12"x3mm, $176.5/sheet, larger sheets 75x150 cm^2 968$/sheet for 5mm thickness ➔ 100k$
- Labor: 800 h for cutting sides and grooves ➔ 80k$
- Pb sheet: 10^5 cm^3, → 1120 Kg, 20$/Kg
  ➔ 100 sheets, size 75x150 cm^2 → 1720 Kg ➔ 22k$
- Labor: 100 h for cutting rings ➔ 10k$
- MPPCs: 1152 detectors, 100 €/MPPC → 50 €? ➔ 80k$
- Fiber: 63 m, 1 mm Y11 fiber, 1-2 spools ➔ 1k$
- Frontend electronics: LAL Spiroc chip? 1 LED/strip plus driver 100$/channel ➔ 115k$
- Support structure, Al-carbon fiber ? ➔ 100k$
- Total ➔ ~510k$

R&D in Bergen

- We have started to measure properties of SiPMs, MPPCs and MAPDs in our laboratory
- We have started to measure LED and source spectra from scintillator tiles

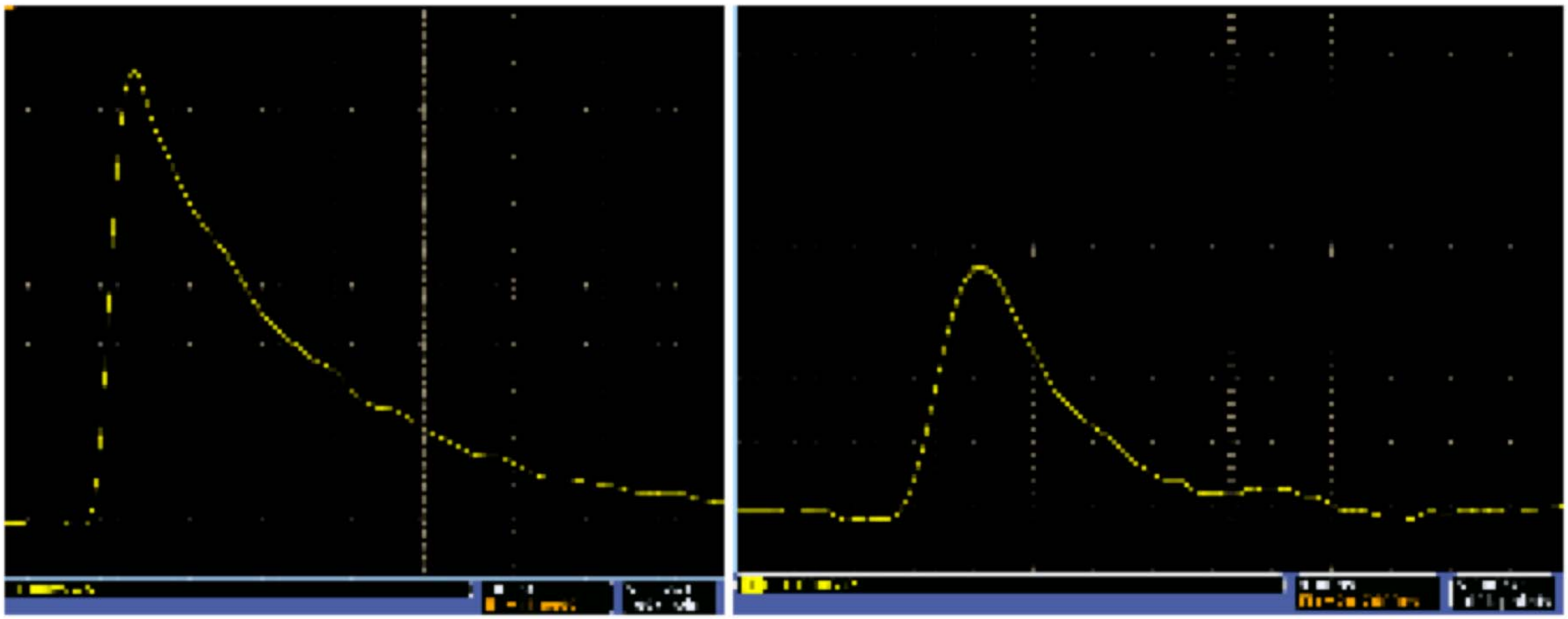




MPPC Signals

- We have detectors from 4 different manufacturers, tests were done on MPPCs (1x1 mm^2,3x3 mm^2), SiPMs , MAPDs,

- The 1x1 mm^2 MPPC has a faster response than the 3x3mm^2 MPPC (2 ns vs 2.7 ns)

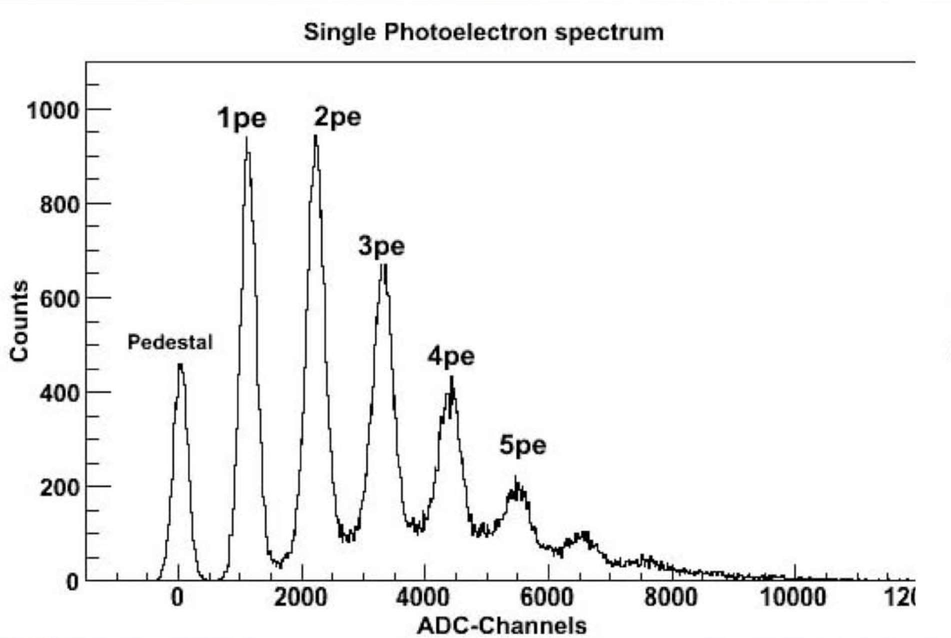


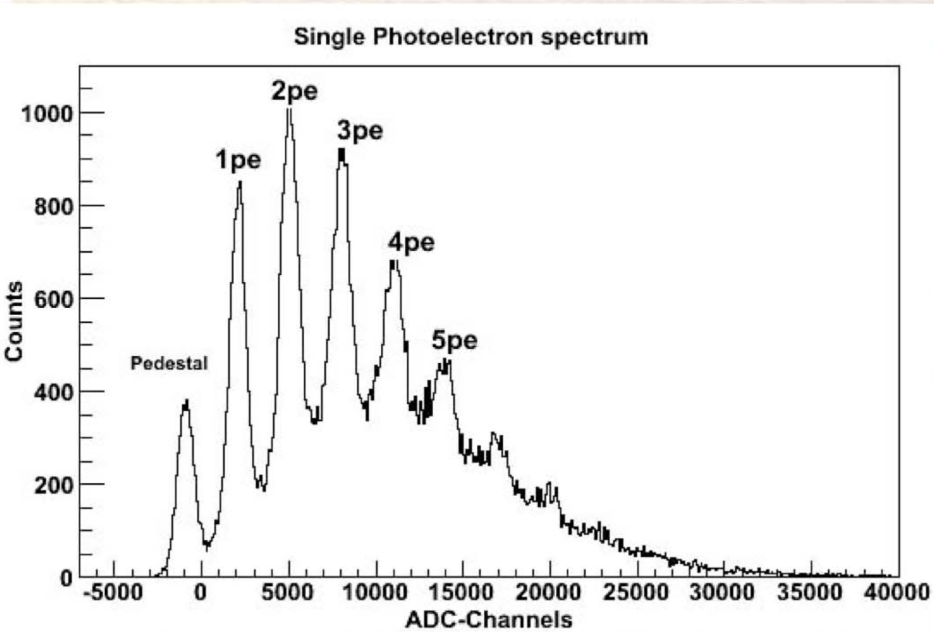
(a) MPPC 10362-33-050C, sample 341. X-axis: 10 ns, Y-axis: 1 mV

(b) MPPC 10362-11-025C, sample 741. X-axis: 4 ns, Y-axis: 1 mV

MPPC Single Photoelectron Spectra

- For 1x1 mm^2 MPPCs photoelectron peaks are narrower than those for 3x3 mm^2 MPPCs due to lower noise (smaller capacitance)





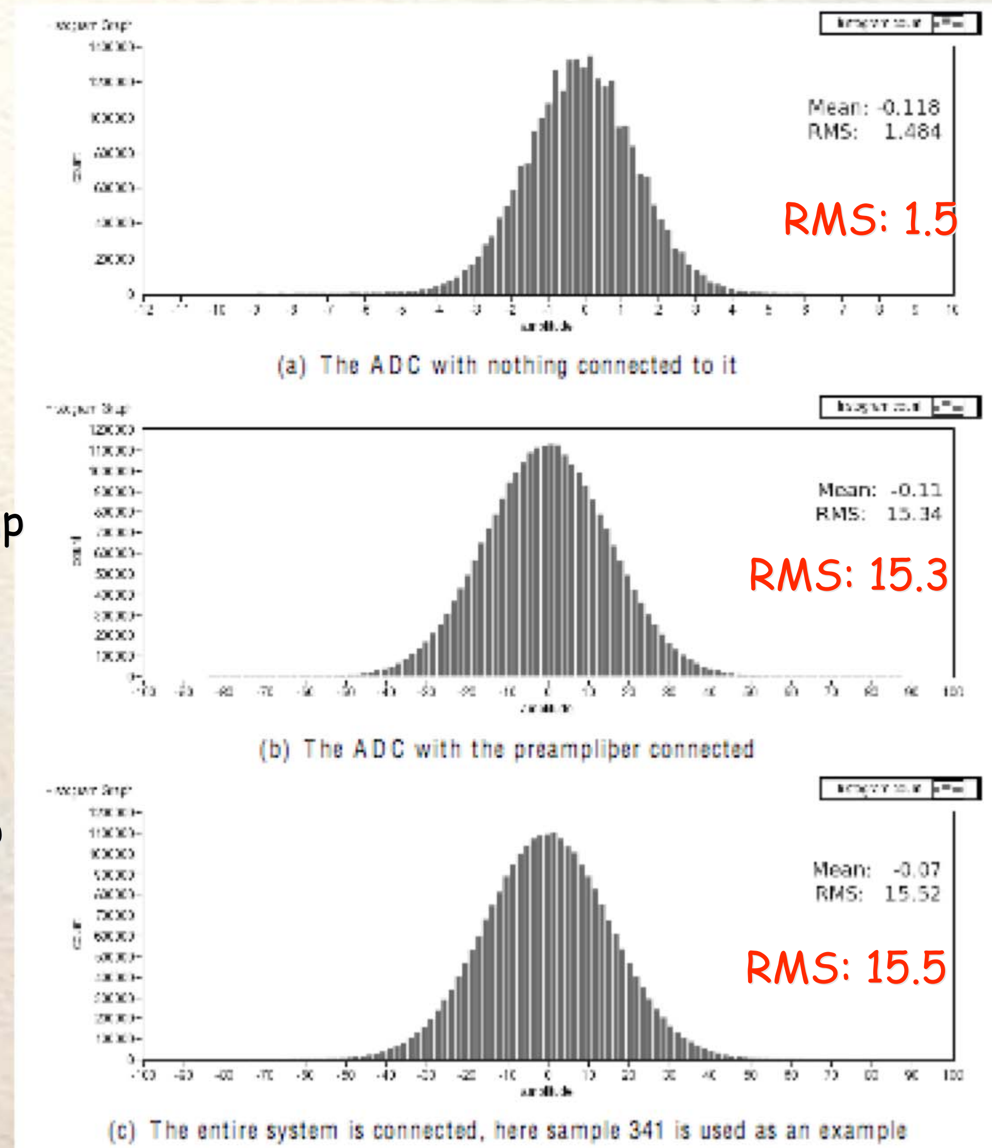
Noise Studies of Setup

- For recommended operating voltage noise of 1x1 mm^2 MPPC is 4 ADC bins

ADC

ADC +preamp

ADC +preamp +MPPC



(a) The ADC with nothing connected to it

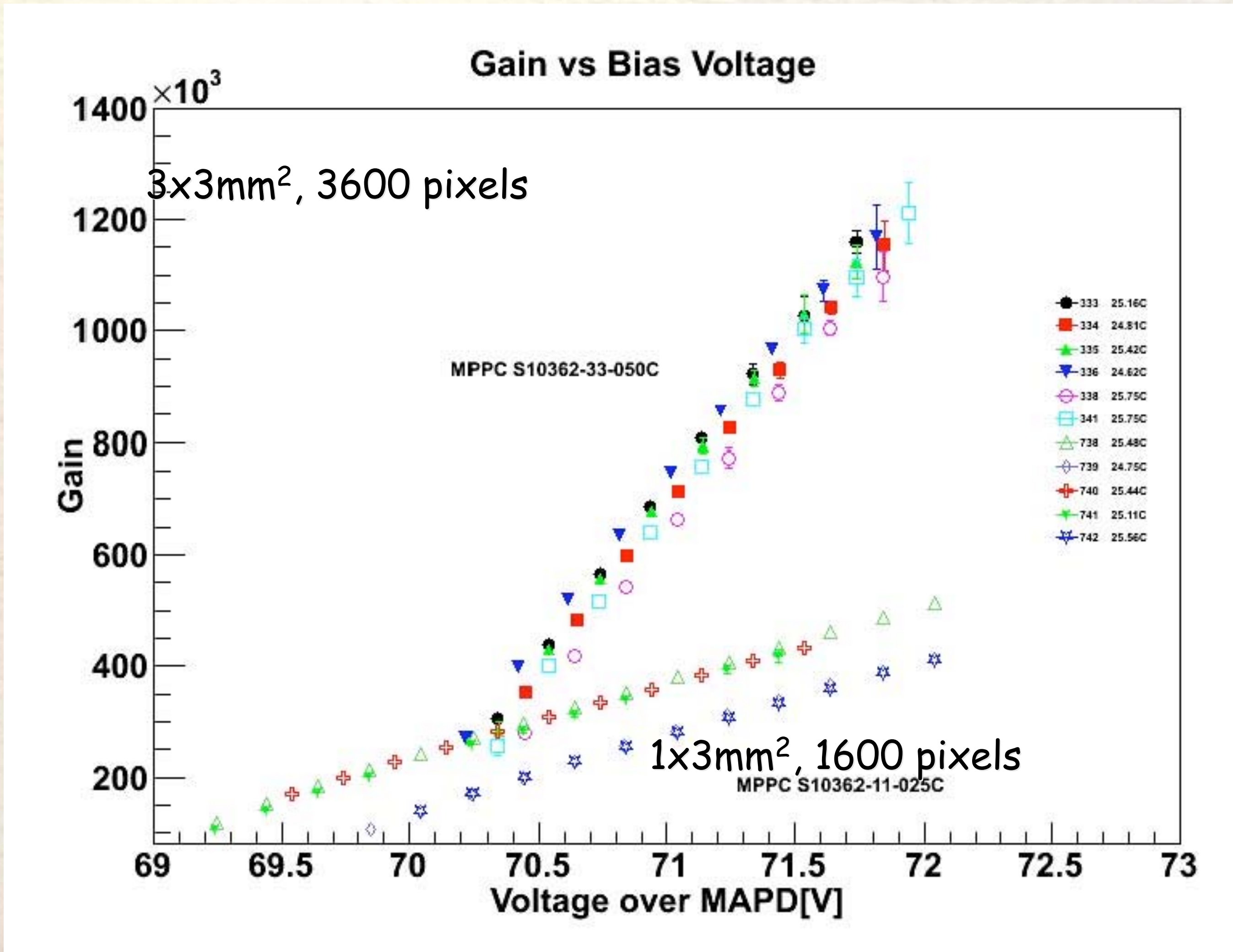
(b) The ADC with the preampliþer connected

(c) The entire system is connected, here sample 341 is used as an example

Gain vs Voltage in MPPCs

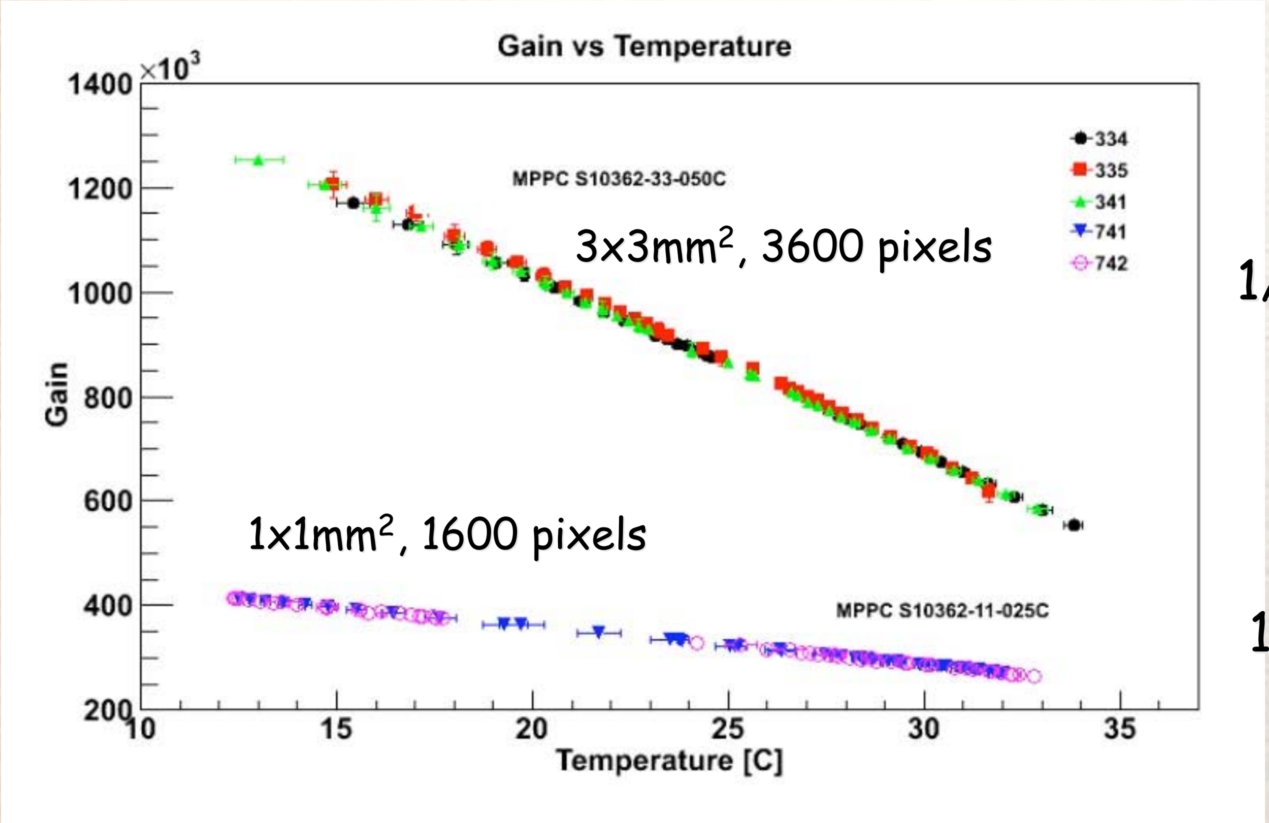
- Gain of MPPCs depends linearly on voltage, it is lower than that of SiPMs

$$G = \frac{Peak_{1pe} - Pedestal}{G_{preamp}\,\varepsilon}$$



Gain vs Temperature

- MPPC gain drops linearly with temperature



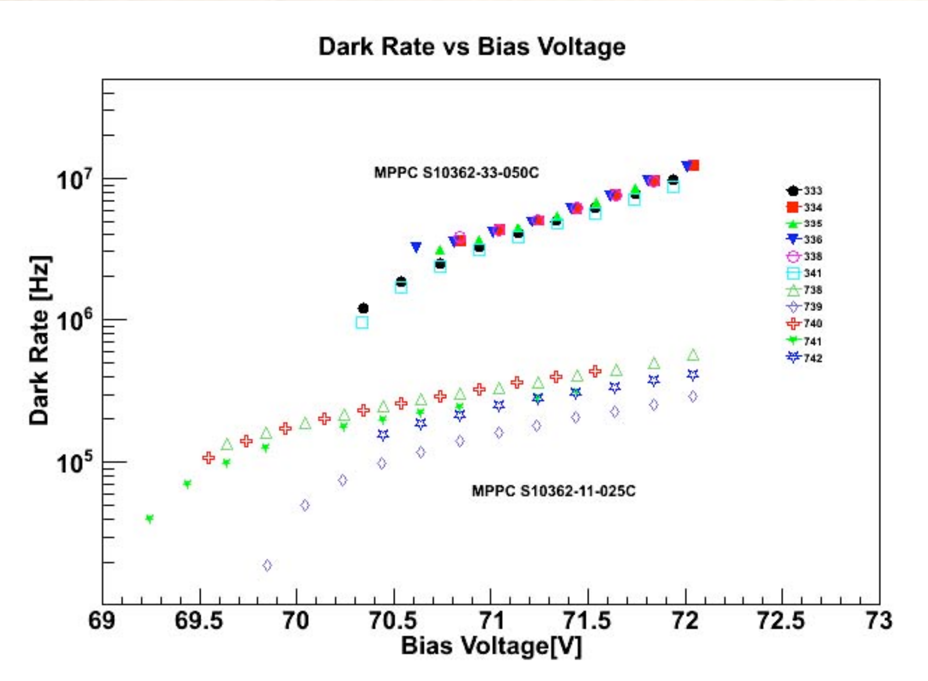
$1/G*dG/dT=-3.81\%/1^{o}C$

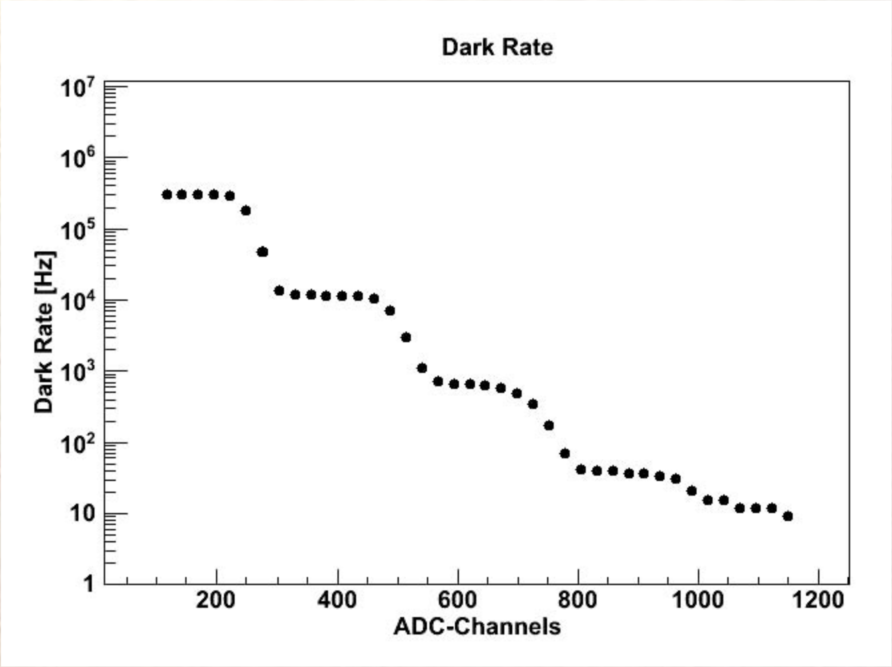
$1/G*dG/dT=-2.2\%/1^{o}C$

Dark Rate

- Dark rate increases with bias voltage, for 1x1 mm^2 detectors the slope is much flatter than that for 3x3 mm^2 detectors

- Dark rate drops with increasing threshold, typically cut at 0.5 MIPs for data taking, no cut for gain calibration





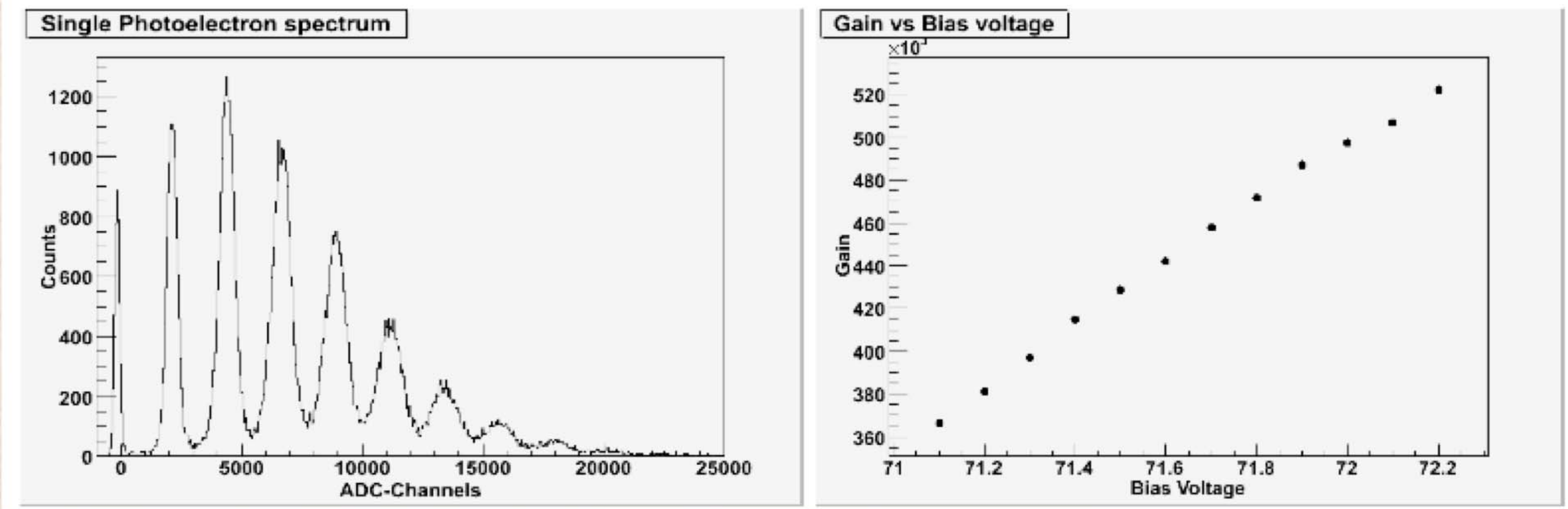
Some Properties of MPPCs

- Breakdown voltage is similar for 1x1 mm^2 and 3x3 mm^2 MPPCs ~70V
- Capacitance of 1x1 mm^2 MPPCs is 4 times lower than that of 3x3 mm^2
- Temperature and voltage dependence is lower for 1x1 mm^2 MPPCs

Photodetector	C_{pixel}[fF]	$V_{breakdown}$	%G/0.1V	%G/1^{o}C
MPPC S10362-33-050C				
Sample333	98.5±1.7	69.83±1.70	7.07	
Sample334	92.4±1.2	69.82±1.29	6.79	-3.77
Sample335	97.4±1.9	69.83±1.91	7.06	-3.87
Sample336	96.3±0.5	69.76±0.48	6.86	
Sample338	97.1±1.4	69.96±1.48	7.14	
Sample341	96.3±1.4	69.88±1.47	7.17	-3.81
MPPC S10362-11-025C				
Sample738	22.29±0.15	68.31±0.65	4.35	
Sample739	23.97±0.15	69.13±0.60	4.47	
Sample740	21.73±0.30	68.28±1.34	4.24	
Sample741	26.09±0.19	68.58±0.71	4.68	-2.19
Sample742	21.63±0.19	69.00±0.86	4.27	-2.21

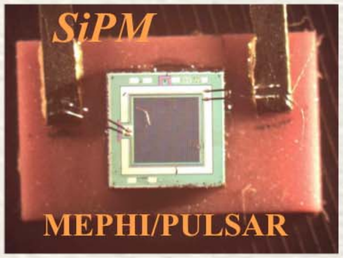
R&D in Bergen

- We have started gain and MIP measurements of scintillators using SiPMs

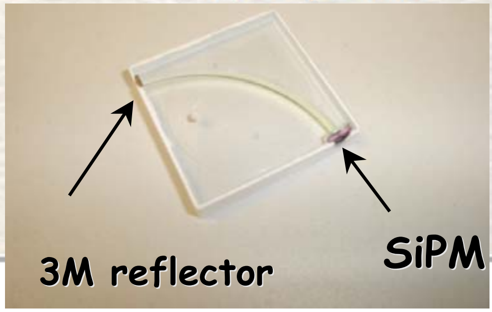


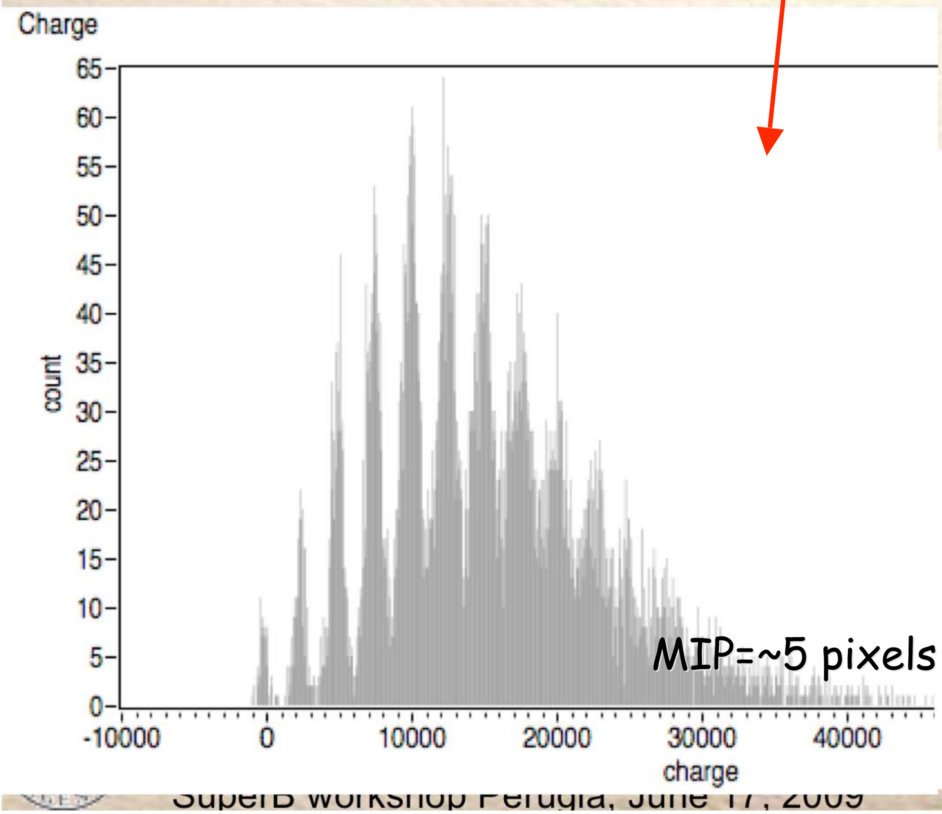
Scintillator Spectra

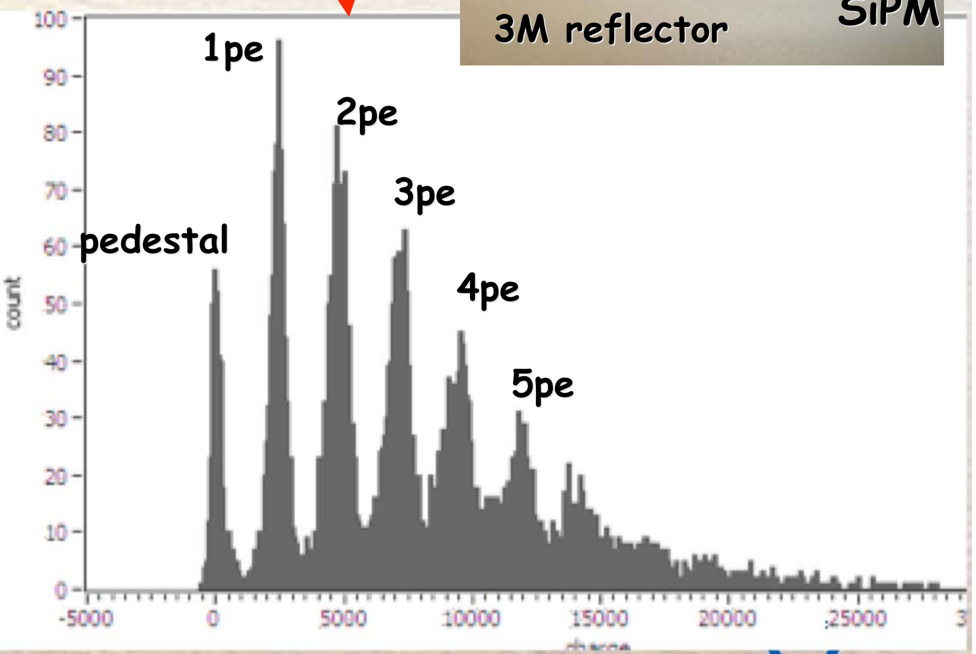
- Operate SiPM with $gain_{SiPM} \sim 4\times10^5$
- Measure spectrum with ^{90}Sr source and light pulser



1156 pixels

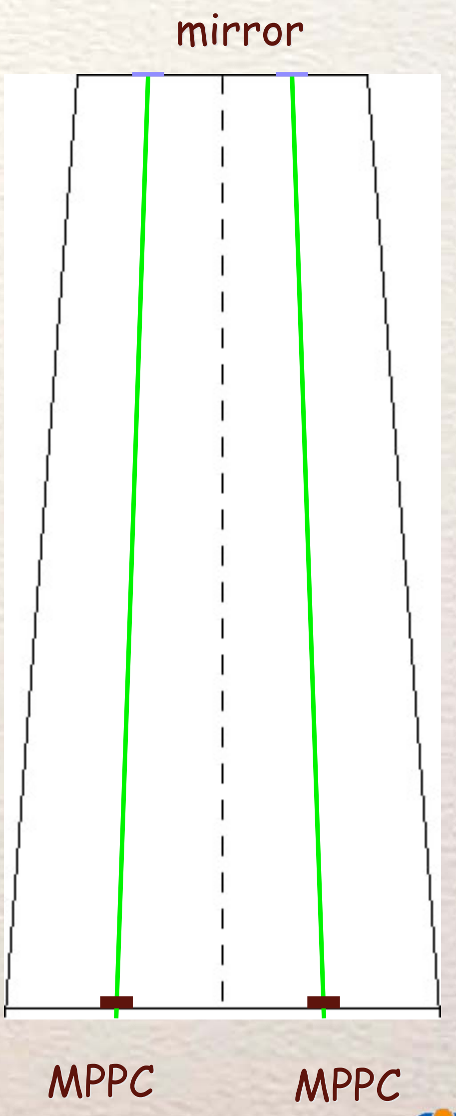






Cross Talk Measurement

- Machine two tapered strips that are separated by cuts
- Start with ~50% bridges and measure cross talk
- Remove bridges down to 1-2% in steps to establish a relation of cross talk vs size of bridges
- Redo study for full size
- Repeat measurement for spiral strips for chosen bridge size



Conclusion

- The new design reduces the number of channels to 1152
- With the spiral design (sectors overlap 7 left-handed and 7 right-handed spirals) the position of the shower is determined rather precisely, effectively get 5 tiles in radial direction
  ➔ effectively get more tiles, since tracks are curved
- Resolution in φ should be better than that in r, φ resolution is relevant for separating nearby tracks
- In this design the entire calorimeter is built in one piece
  ➔ it cannot be removed without removing the beam pipe
- In Bergen, we have the equipment to perform R&D

Next Steps

- Measure cross talk of two neighboring tiles, tapered shape
  Look at uniformity
- Measure cross talk of two neighboring tiles, spiral shape
- Study calibration and monitoring with LED
- Design support structure
- Perform MC simulations
- Compare Pb vs W, (mechanical stability)
- Design prototype