# Backward Calorimeter For SuperB

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SuperB meeting SLAC, October 6, 2009

# Outline

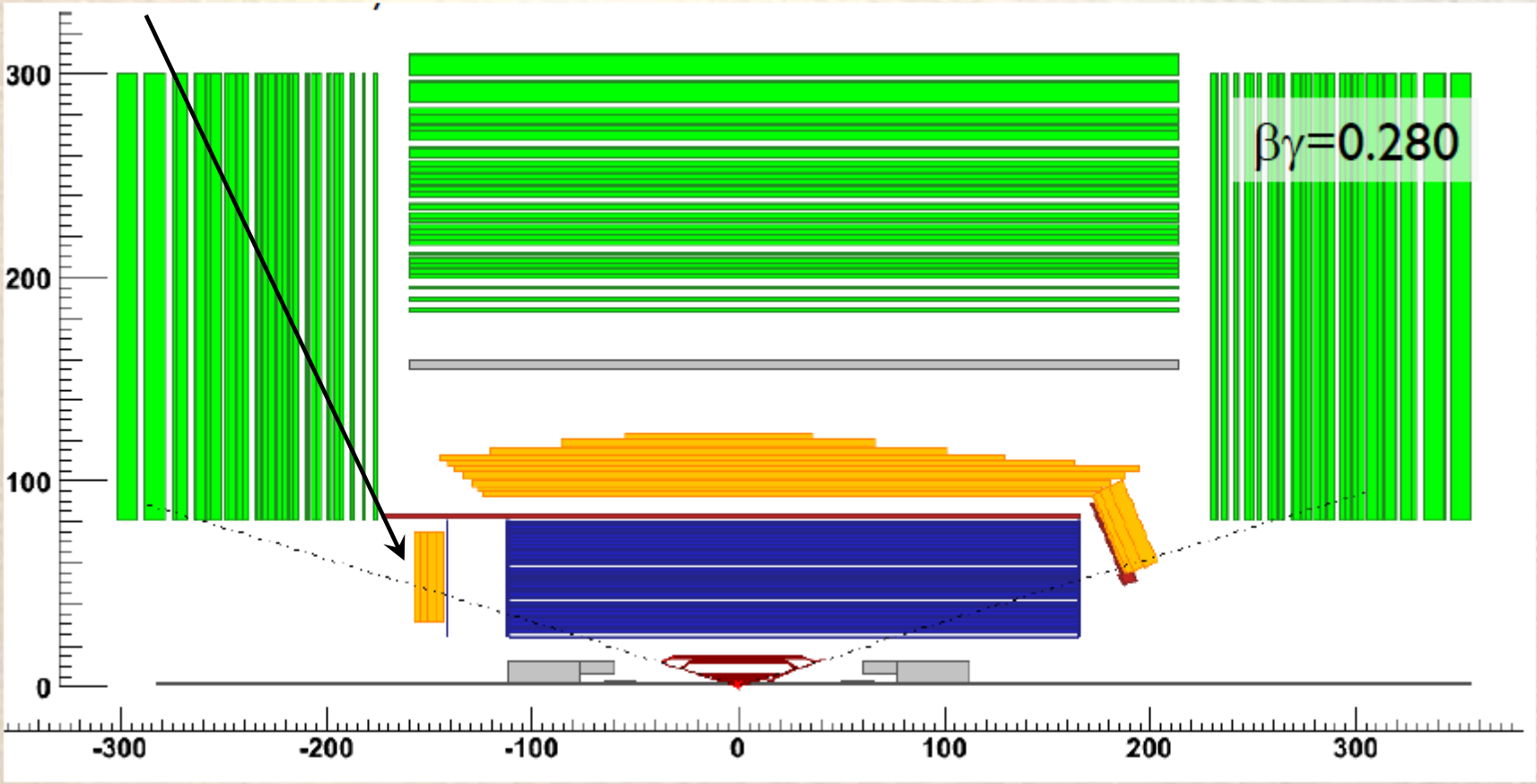
- Present Design
- Some thoughts about tile production
- Updated cost estimate
- Light yield studies of 3 mm thick scintillators
- Effects from n irradiation
- Conclusion and next steps

# Present Design

- The backward endcap calorimeter is a 12 $X_0$ Pb-scintillator sampling calorimeter, 24 layers of 0.3 mm thick scintillator strips 0.28 mm thick Pb
- It is located behind the DCH at z=-132 cm and is 14 cm deep
  It has been moved back by 22 cm to leave more space for DCH electronics
- Inner and outer radii are unchanged: $r_i$=31 cm, $r_o$=75 cm (increase $r_i$ ?)
- We use 3 different shapes of strips:
  - Right-handed spiral strips
  - Left-handed spiral strips
  - Sector strips
- The 3 layers will alternate 8 times

# SuperB Design

Rear endcap:

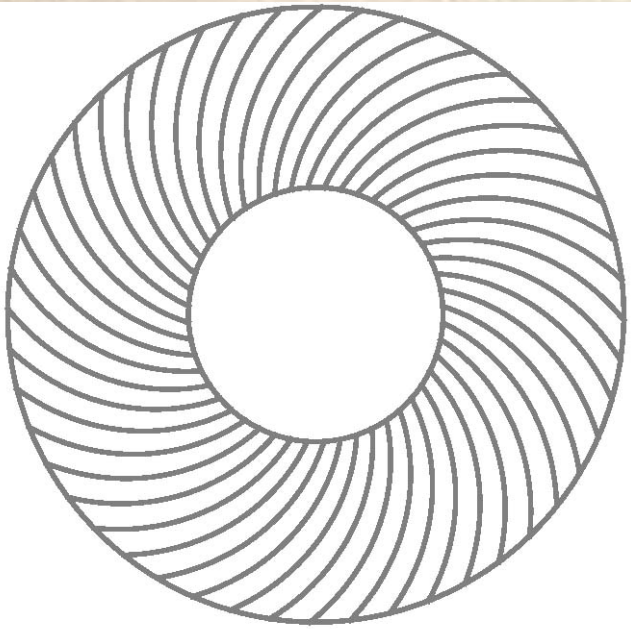



Position: $r_i$=31 cm, $r_o$=75 cm, $z_i$=132 cm, $z_o$=146 cm

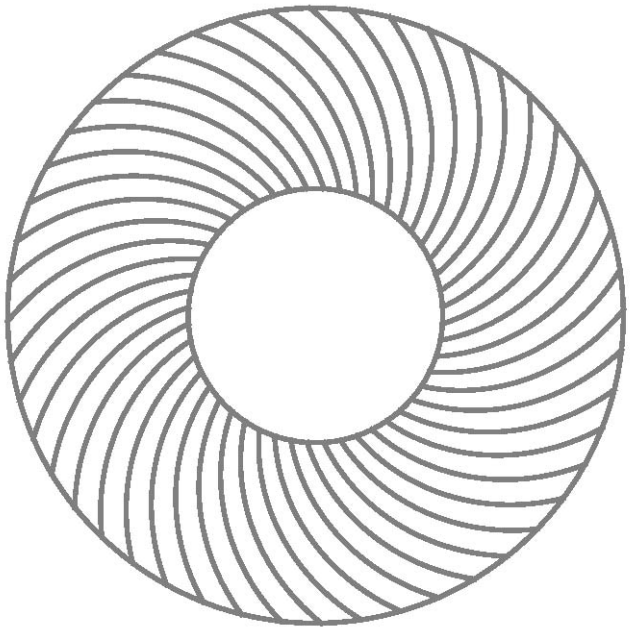
# Layout of Scintillator Planes

- 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

# Thoughts on Spiral Strip Production

- Production of spiral strip poses problems
  - For 75 cm x 75 cm plates,
    - need 4 plates/layer
    - get only 7 complete strips/plate
    - 10 strip segments/plate
  - For 50 cm x50 cm plates
    - need 8 plates/layer and larger inner radius
    - all strips are segmented into 2 pieces
  - Production of individual strips cut out of 50 cm x50 cm plates
    - Get around 4 strips with a lot of waste
- Segmented strips are connected by one WLS fiber
- Need to fix alignment of neighboring plates to relieve force on WLS fiber

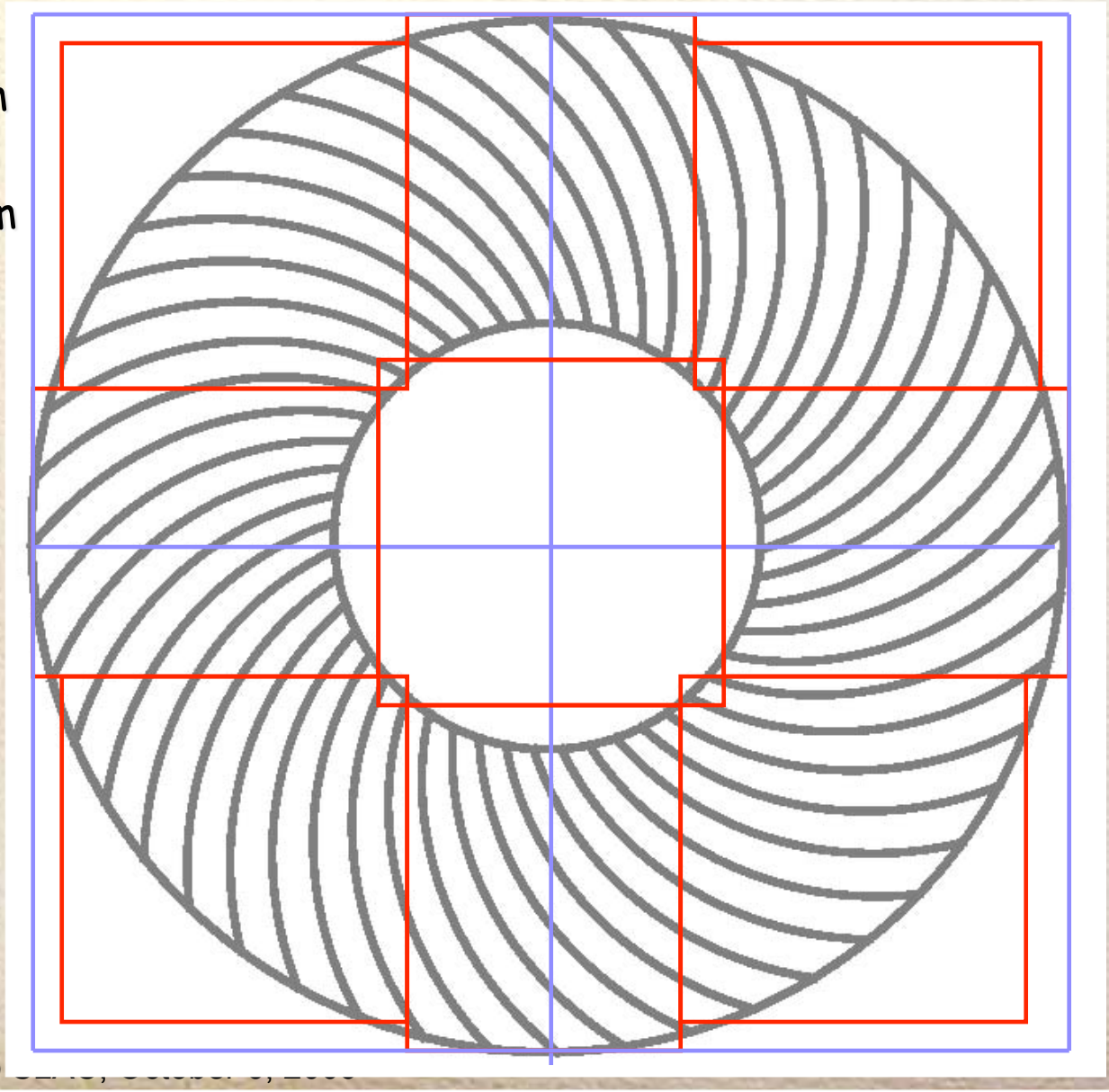
# Spiral Strip Production

Red: 50 cm x 50 cm

Blue: 75 cm x 75 cm

Need 8 small (red) or 4 large (blue) plates per plane

Old cost estimate is approximately correct for 8 small plates



# Updated Cost Estimate

- Scintillator material: $10^5$ cm$^3$ (89 Kg), St Gobain BC 408
  sheets: 50 cm x50 cm $515 ea, 75 cm x75 cm $876 ea ➔ 100k$
- Labor: 800 h for cutting sides and grooves (free) ↓ ➔ 80k$
- Pb sheet: $10^5$ cm$^3$, (1120 Kg), 20$/Kg
  ➔ 100 sheets, size 75x150 cm$^2$ ➔ 22k$
- Labor: 100 h for cutting rings ➔ 10k$
- MPPCs: 1152 detectors, 30 € (w/o tax) ↓ ➔ 52k$
- Fiber: 63 m, 1 mm Y11 fiber, 500 m ↑ ➔ 3k$
- Frontend electronics: LAL SPIROC chip? 1 LED/strip plus driver
  100$/channel ➔ 115k$
- Support structure, Al-carbon fiber ? ➔ 100k$
- Total ➔ ~402k$

# Properties of BC Scintillators

- We ordered cast scintillator from St Gobain (Bicron) BC-408, due better match of scintillator light and Y11 fiber absorption spectrum
- But BC-404 may be even better, since it is faster

| | BC-400 | BC-404 | BC-408 | BC-412 | BC-416 |
|---|---|---|---|---|---|
| Light Output, % Anthracene | 65 | 68 | 64 | 60 | 38 |
| Rise Time, ns | 0.9 | 0.7 | 0.9 | 1 | - |
| Decay Time, ns | 2.4 | 1.8 | 2.1 | 3.3 | 4 |
| Pulse Width, FWHM, ns | 2.7 | 2.2 | ~2.5 | 4.2 | 5.3 |
| Light Attenuation Length, cm* | 160 | 140 | 210 | 210 | 210 |
| Wavelength of Max. Emission, nm | 423 | 408 | 425 | 434 | 434 |
| No. of H Atoms per $cm^3$, ($x10^{22}$) | 5.23 | 5.21 | 5.23 | 5.23 | 5.25 |
| No. of C Atoms per $cm^3$, ($x10^{22}$) | 4.74 | 4.74 | 4.74 | 4.74 | 4.73 |
| Ratio H:C Atoms | 1.103 | 1.1 | 1.104 | 1.104 | 1.11 |
| No. of Electrons per $cm^3$, ($x10^{23}$) | 3.37 | 3.37 | 3.37 | 3.37 | 3.37 |
| Principal uses/applications | General purpose | Fast counting | TOF counters, large area | Large area | Large area, economy |

# Preparations for R&D and Prototype

- Scintillator: Ordered BC-408 from St Gobain, 3 mm thick, cast,
  plates of 50 cm x 50 cm cost $515 each
  plates of 75 cm x 75 cm cost $876 each

- Y11 fiber: Get a few m free samples,
  500 m fiber (minimum) costs €2100

- 3M super reflector: ordered

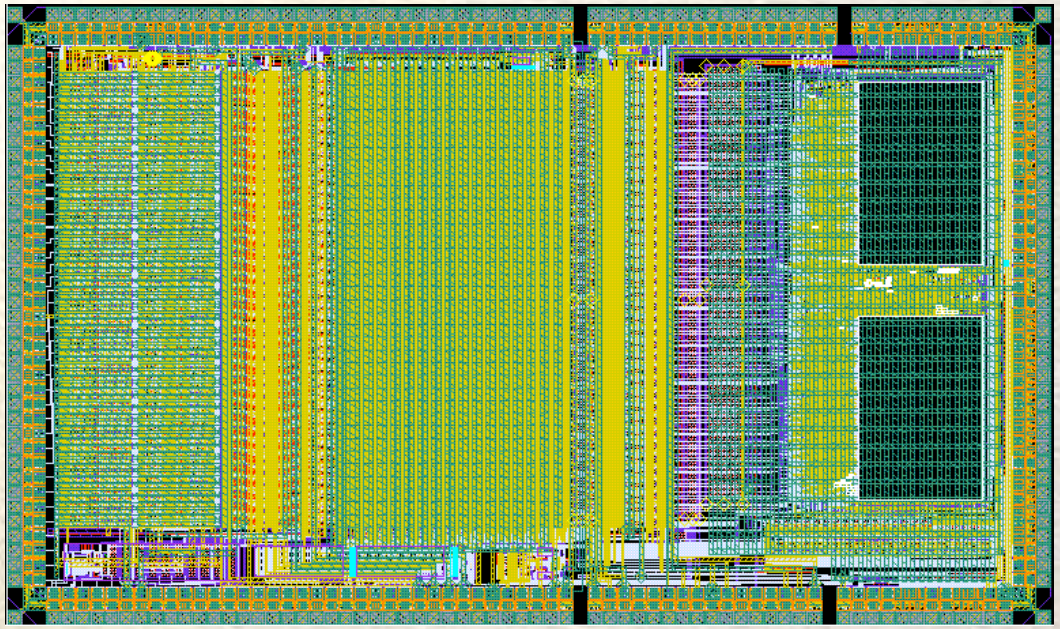
- Pb: still looking for vendor

- MPPC: We have 10 detectors 1 mm x 1mm (1600 pixels)
  for full detector we got a quote of ~€ 30/MPPC

- Readout electronics: Have 2 SPIROC chips from LAL (36 channels/ea)
  ➔ Looks like the right choice

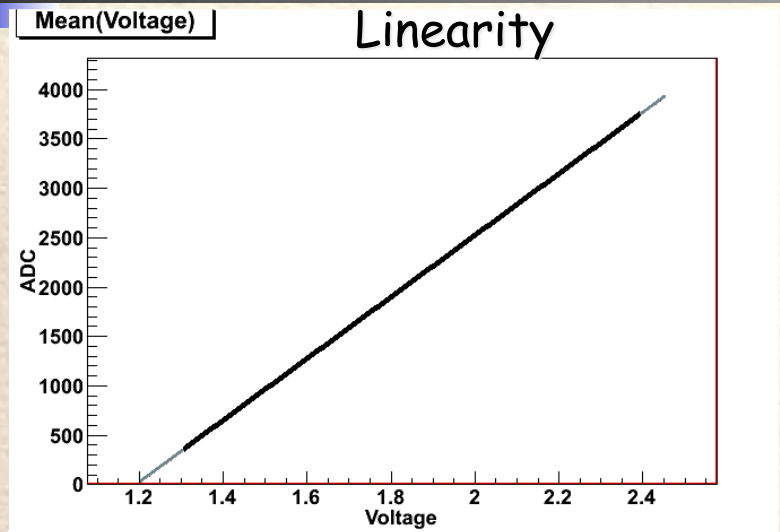
# SPIROC Chip

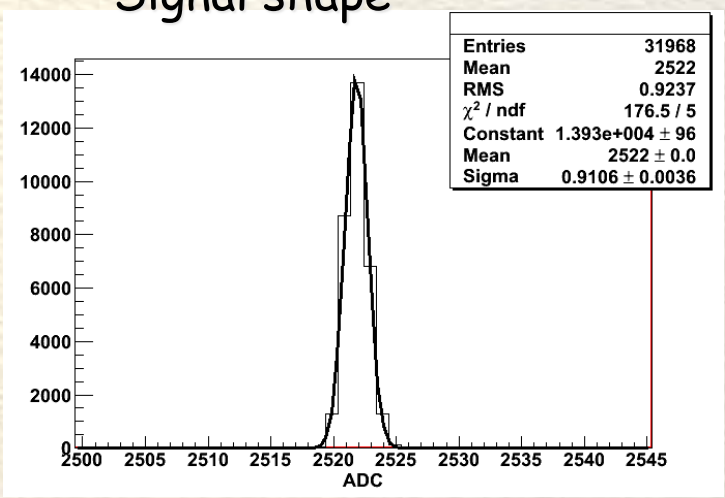
- SPIROC: dedicated very front-end electronics for an ILC prototype hadronic calorimeter w SiPM readout
- Designed to provide
  - large dynamic range
  - low noise
  - low consumption
  - high precision
  - large # RO channels

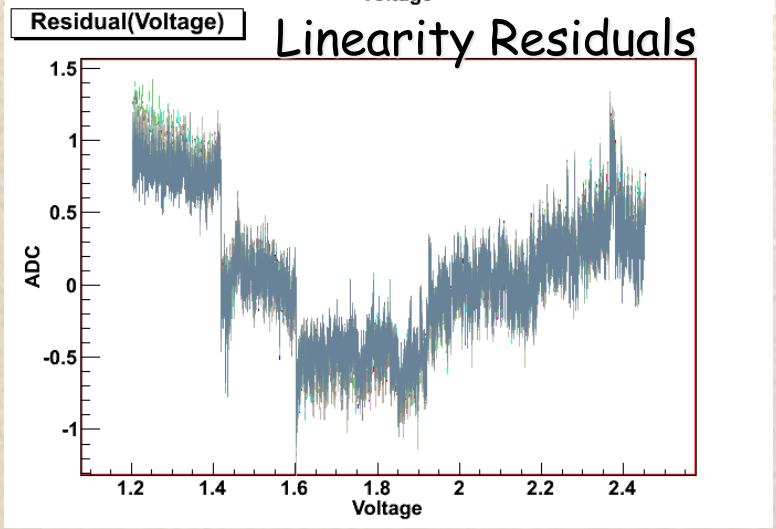


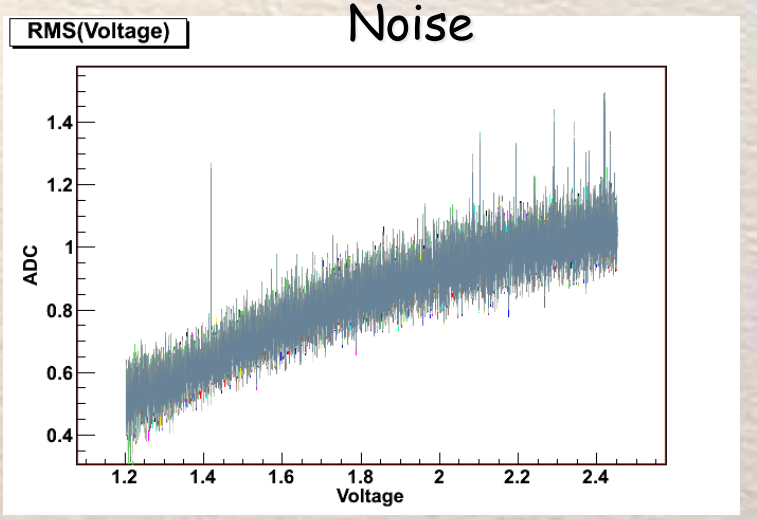
- SPIROC is an auto-triggered, bi-gain, 36-channel ASIC
  ➔ allows to measure the charge Q from one p.e to 2000 p.e. (on each channel)
  ➔ allows to measure the time t with a 100ps accurate TDC
- Analogue memory array (depth of 16 for each) stores t and Q measurements
- 12-bit Wilkinson ADC is embedded to digitize analogue memory contents (t & Q on 2 gains) ➔ data are stored in a 4kB RAM
- High-level state machine is integrated to manage all these tasks automatically and control the data transfer to the DAQ

# SPIROC Properties



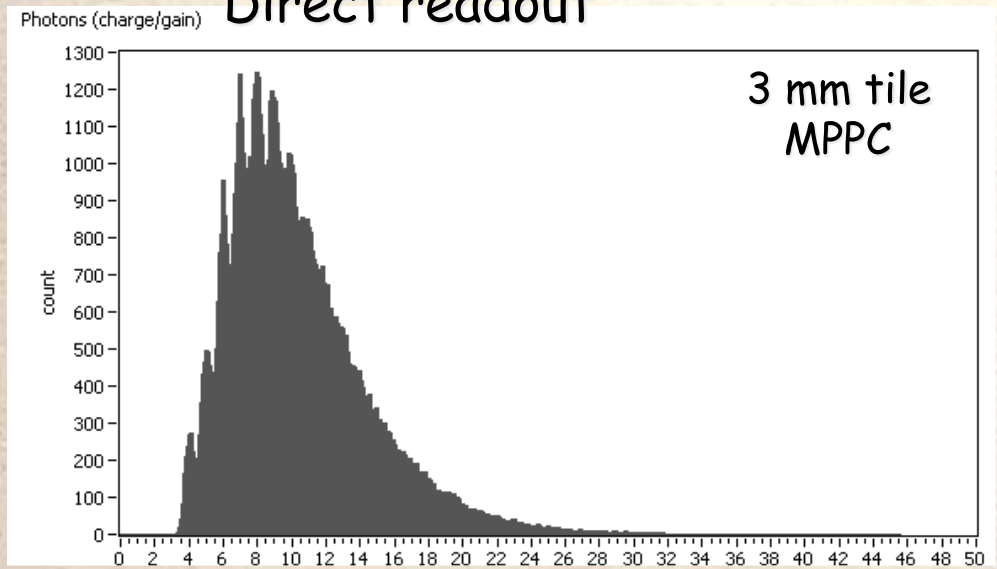

SPIROC gives Gaussian signals with no tails, shows excellent linearity and low noise

# First Tests of 3mm Thick Tiles

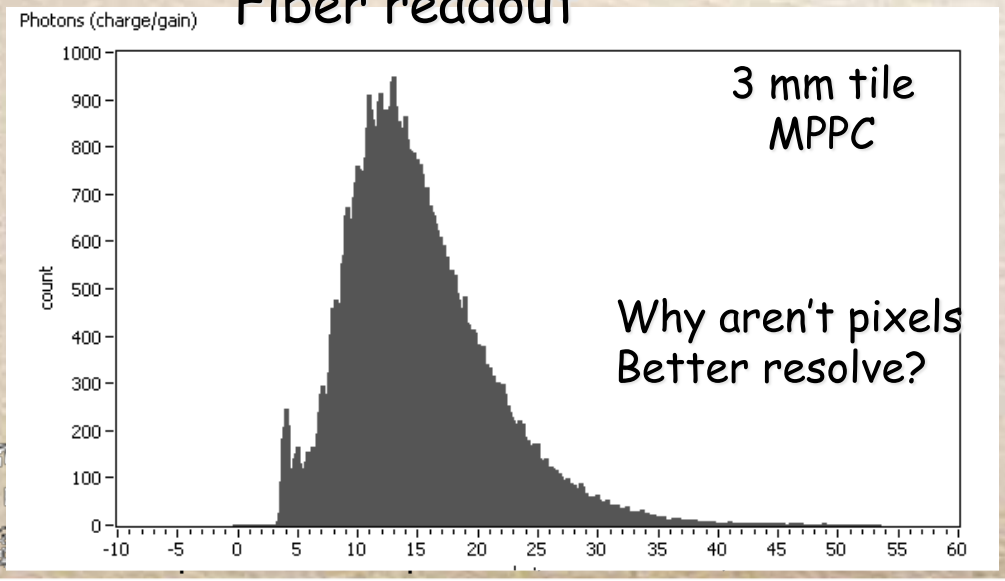
- Test 3mm thick 3 cm x 3 cm tiles using $^{106}$Ru source
- Tiles are wrapped with 2 layers of Teflon tape, (reflector not optimal) ➔ AHCAL uses 3M super reflector
- Attach MPPC on one side of tile on fiber or directly on tile
- Place source in the center of the tile
- For SuperB readout via WLS fiber has advantages

# Direct Readout of 3mm Thick Tiles

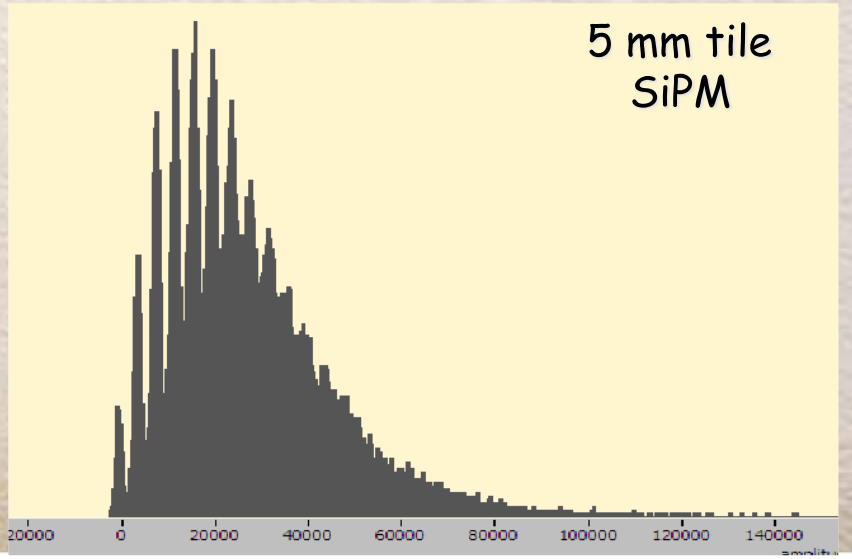
Direct readout




Fiber readout

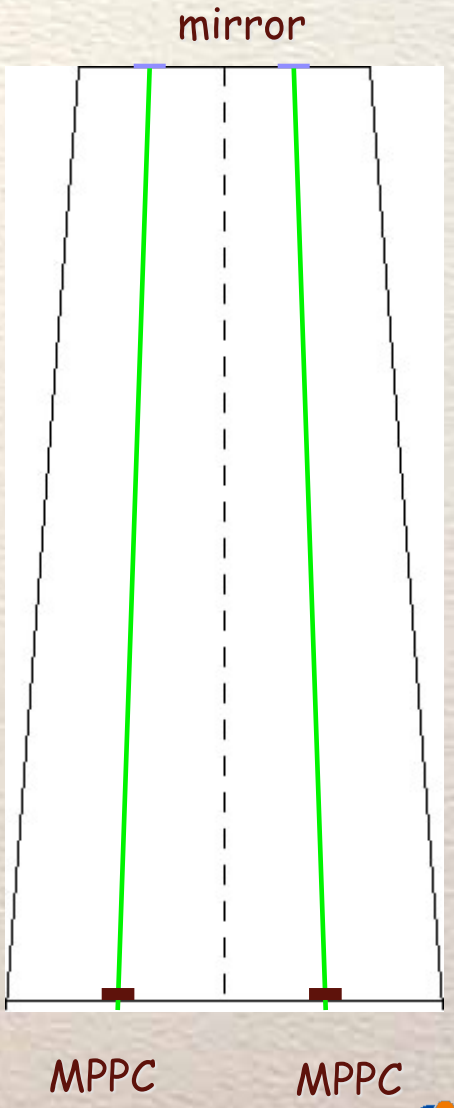



- Pedestal is suppressed
- Individual pixels are visible
- MIP peaks lie around 5 pixels for direct RO & ~8 pixels for fiber RO
- Expect peak ~7.8 pixels for fiber RO



# Cross Talk Measurement

- Machine two tapered strips that are separated by cuts (in preparation)
- 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



# Neutron Irradiation of MPPCs

- **Prospective damage**

  Increasing lattice defect in silicon bulk

**Flux**

$3.1\times10^{8}$ neutron/cm$^2$
$3.1\times10^{9}$ neutron/cm$^2$
$3.1\times10^{10}$ neutron/cm$^2$
$3.1\times10^{11}$ neutron/cm$^2$

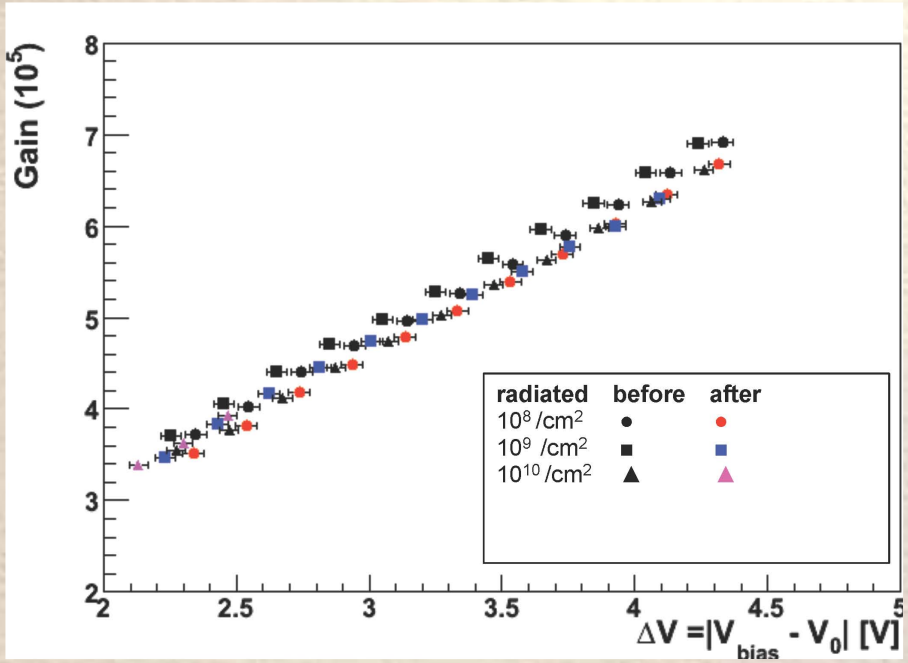
From talk by T. Takeshita
CALICE meeting Sep 17, 2009

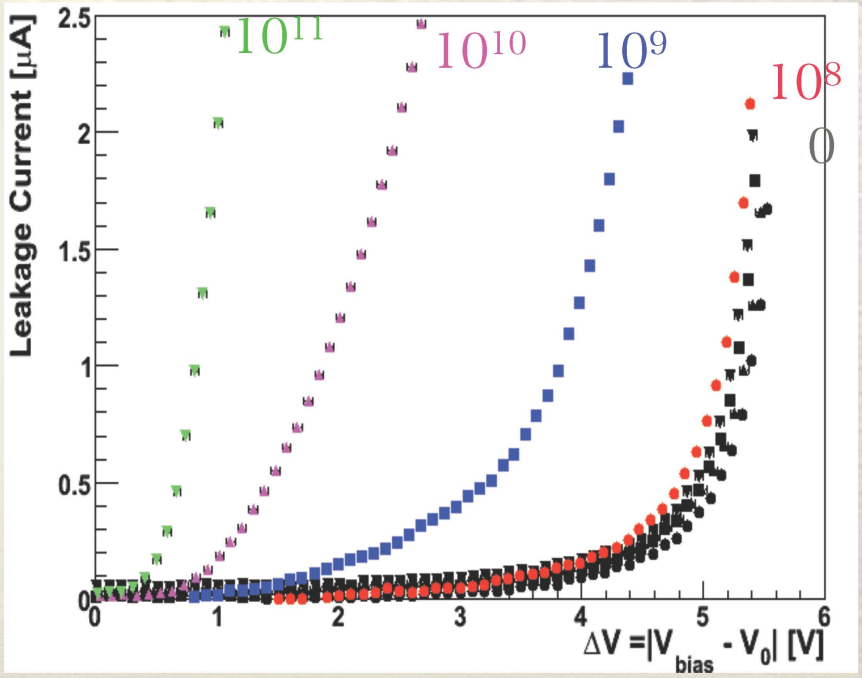
**Radiation test location**

The reactor YAYOI
(Fast neutron source reactor of the University of Tokyo)

# Gain and Leakage Current

- No significant changes on the gain due to neutron irradiation
- Huge increase in leakage current for neutron flux > $3 \times 10^9/cm^2$

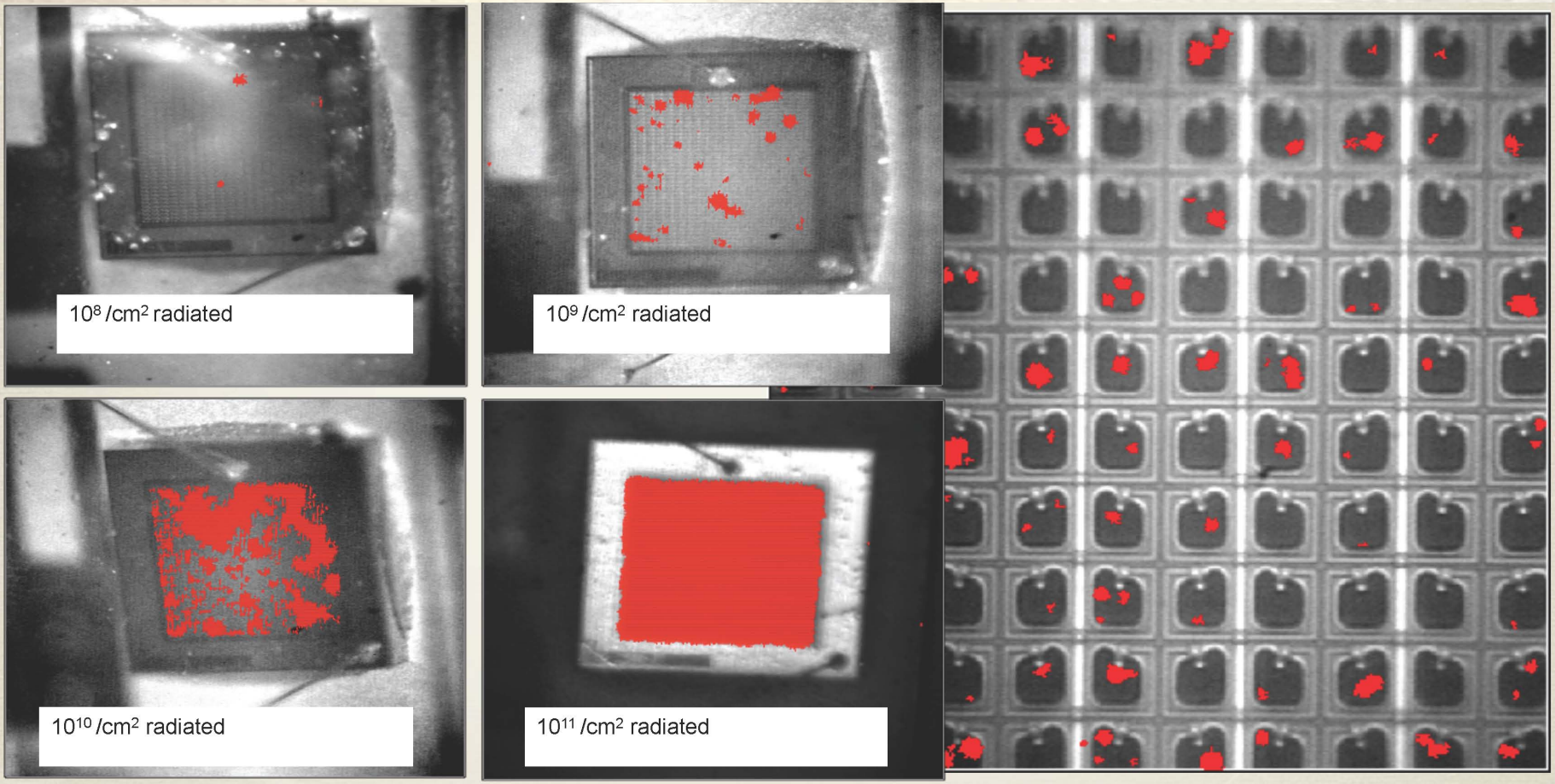



| radiated | before | after |
|---|---|---|
| $10^8$/cm$^2$ | ● | ● |
| $10^9$ /cm$^2$ | ■ | ■ |
| $10^{10}$ /cm$^2$ | ▲ | ▲ |
| $10^{11}$ /cm$^2$ | ▼ | ▼ |

# Hot Spot Pictures

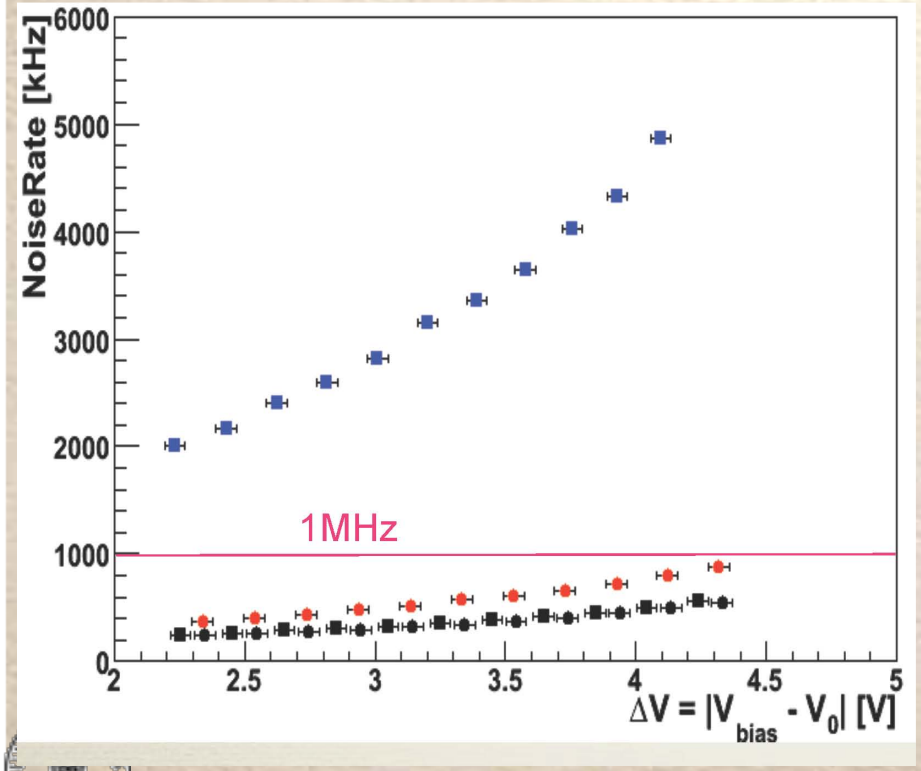
- Observe increased number of hot spots after irradiation of $3 \times 10^9$ n/cm$^2$

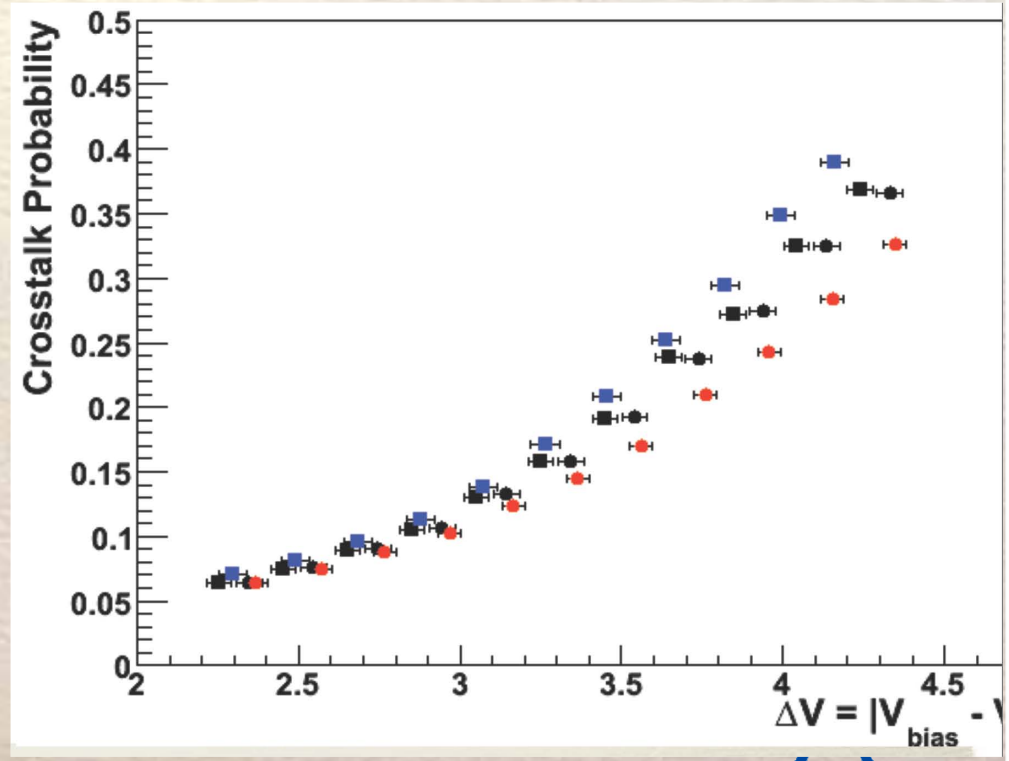


# Noise Rate and Cross Talk

- Significant changes on noise rate already for $3 \times 10^9/cm^2$
- No significant changes on the cross talk probability

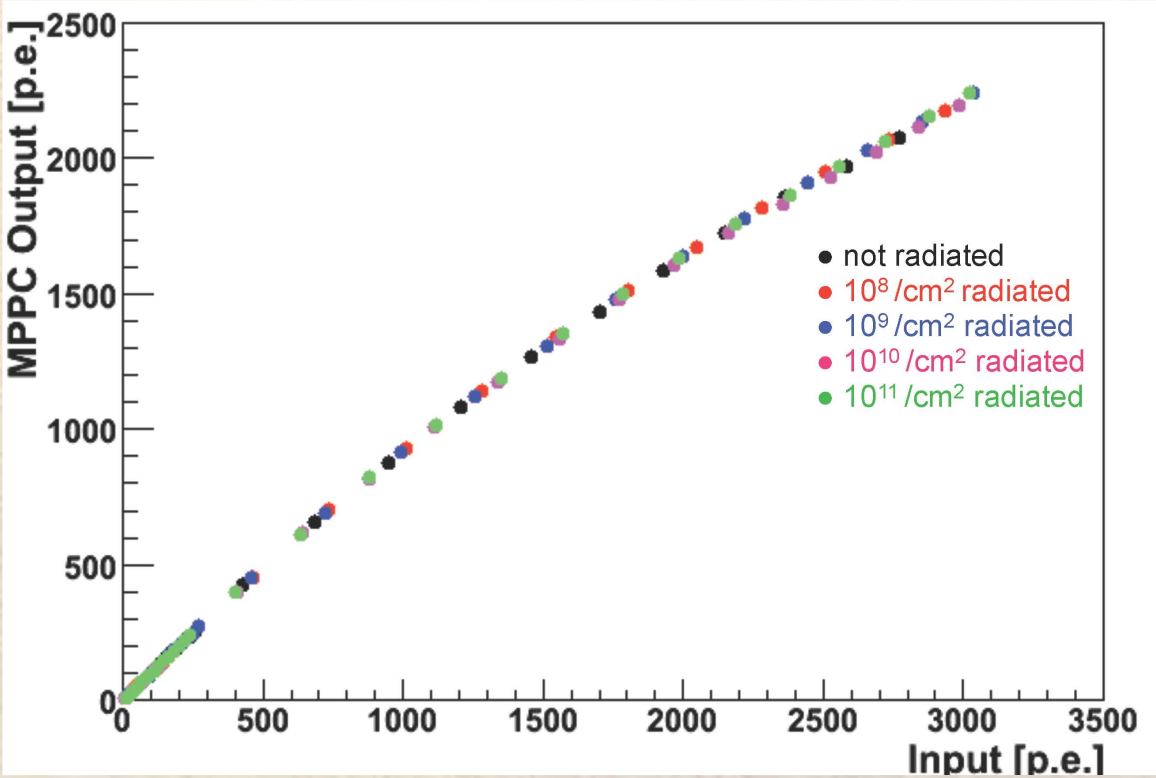
| radiated | before | after |
|---|---|---|
| $10^8/cm^2$ | ● | ● |
| $10^9/cm^2$ | ■ | ■ |



# Saturation Curve

- Observe no significant change on the saturation curve




- Results look consistent with ITEP measurements

# Conclusion

- We started to order components needed for R&D
- We are working on getting quotes from companies for the prototype and the full detector
- We need to decide on optimum plate geometry for strip production
- We started with light yield measurements
- SPIROC is promising readout chip
- Neutron radiation is a concern, for fluxes above $3 \times 10^9/cm^2$ MPPCs clearly show damage effects consistent with ITEP measurements
  ➔ may need shielding

# Next Steps

- Measure cross talk of two neighboring tiles, tapered shape
  Look at uniformity
- Measure cross talk of full spiral-shape strips
- Study light yield of two segmented strips connected by fiber
- Test readout with SPIROC, interface to DAQ used in beam test
- Think about calibration and monitoring
- Study effects of recovery from n radiation, need realistic estimates
- Design support structure, will talk to engineer in Bergen next week
- Perform MC simulations
- Design prototype