Joint QUASAR and THz Group Workshop on Accelerator Science and Technology

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Beam Loss Monitoring with Optical Fibers for Particle Accelerators

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Overview

- Introduction to beam loss monitoring:

  - goals

  - requirements
- Beam loss monitoring by optical fibers
- Working principle of the composite sensor
- Parameters of Cerenkov effect in optical fibers
- SiPM structure
- SiPM response
- Outlook

How to select a beam loss monitor: goals and parameters

Goals

- Measure losses

  Regular losses

  Irregular losses

  ↓

  Radiation damages

- Localize losses

Parameters

- Sensitivity
- Ease of calibration
- Radiation hardness
- Reliability
- Costs (incl. Electronics)
- Physical size
- Localization of beam losses

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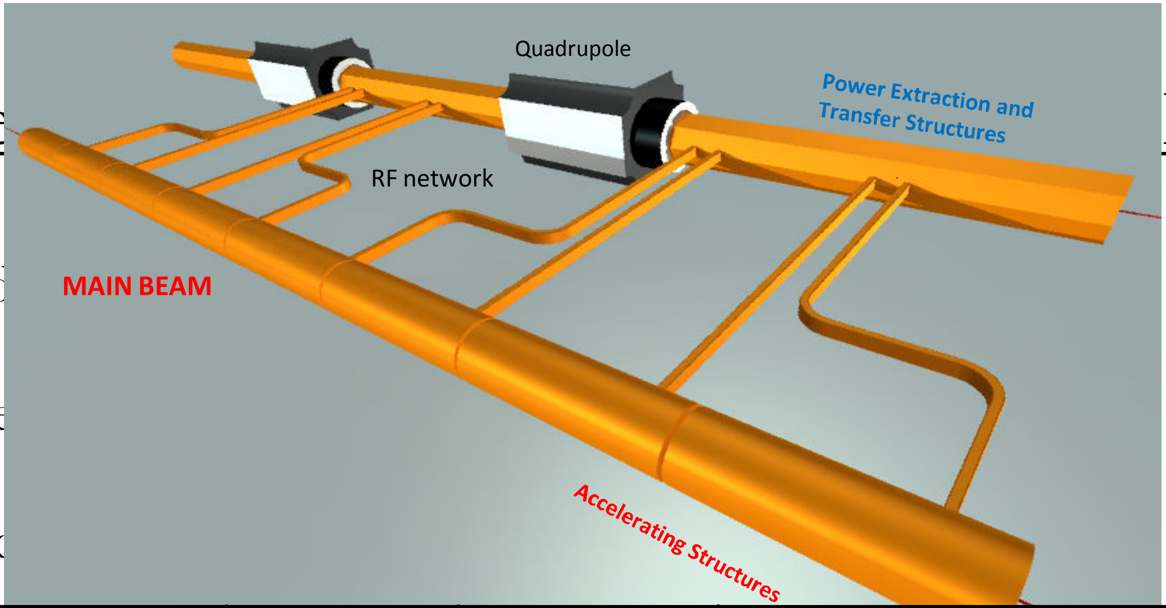
Optical Fiber Beam Loss Monitor

Advantage ... les



- Distributed ... (RIA)
- Small dime
- Smart struc
- Immun fields
- Radiati

	E (GeV)	e^-_{loss}/ year	Consequence for electronics
Main Beam	1500	1 E14	Unacceptably high failure rate
Main Beam	9	1 E15	More failures per year
Drive Beam	2.4	1 E16	Few failures per year
Drive Beam	0.24	1 E17	Few failures over lifetime

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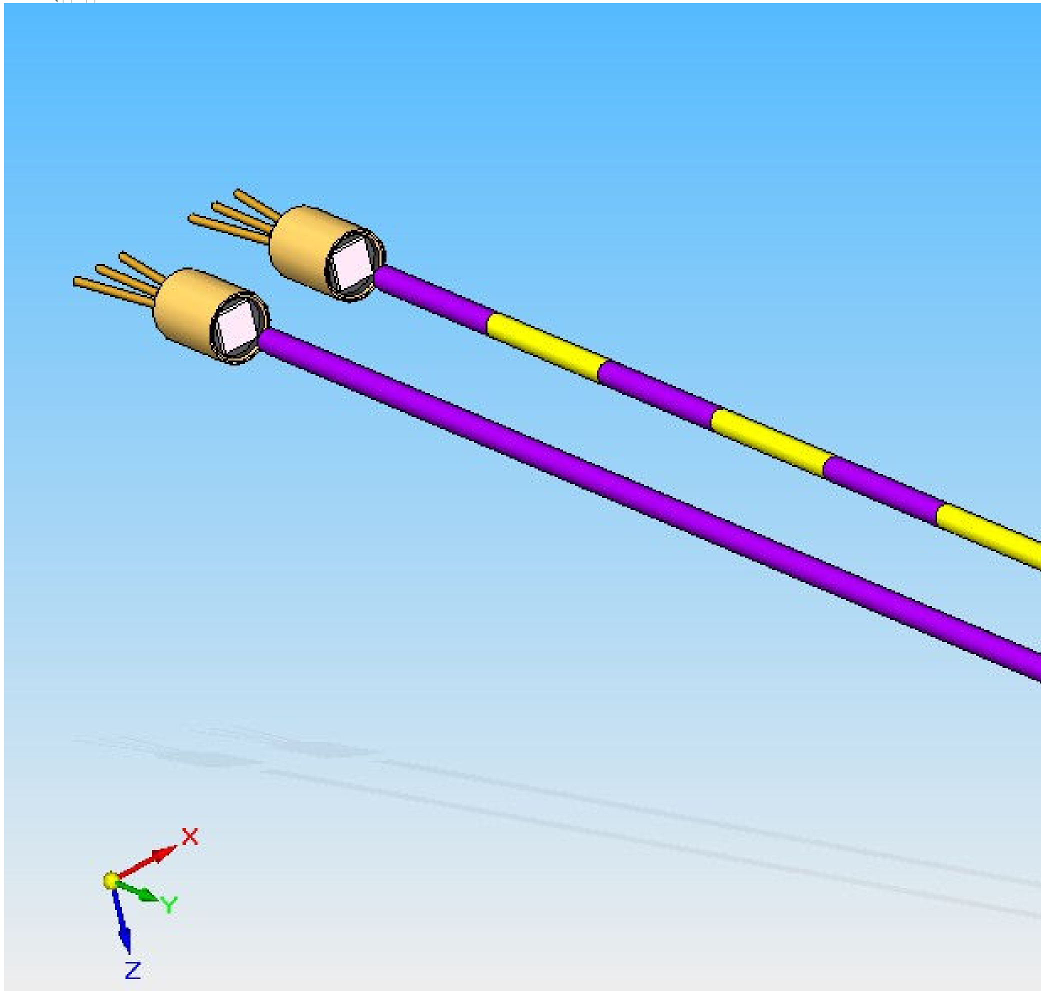
Working principles



- Composite sensor
- SiPM as detector

Cerenkov effect in optical fiber: parameters

- Silica multimode fibers with high NA (about 0,63)
- Refractive index 1,46
- Cerenkov semiangle 47° for electrons
- Average number of photon produced for each electron about 450 between [400-600]nm
- Electron energy threshold for Cerenkov production 0,192 MeV
- High fibers lifetime and radiation hardness
- Smart structure

Disadvantanges

- Loss of particles with angles non included in the acceptance angle

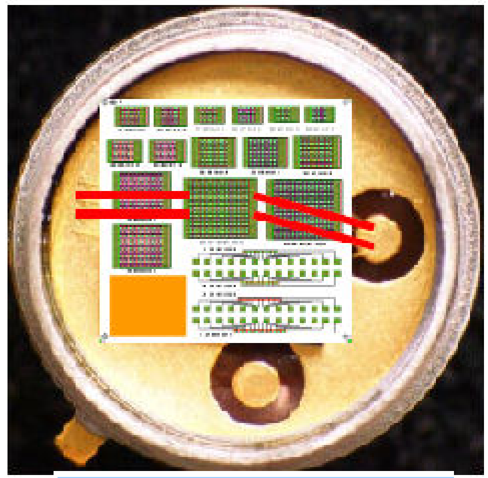
Improvements

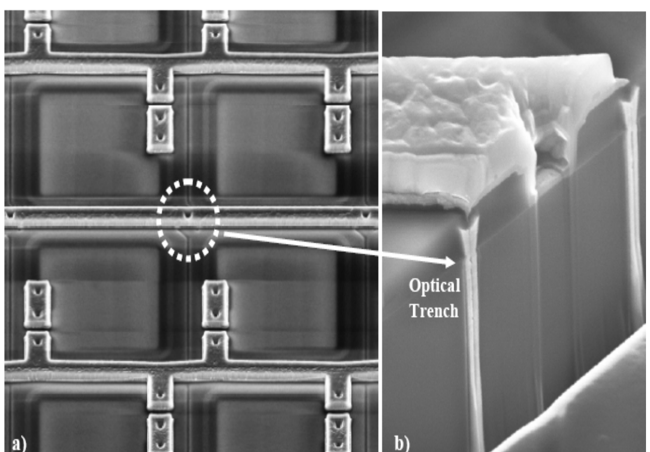
- Increase NA: Photonic bandgab fiber

Photon detector: SiPM

In collaboration with STMicrolectronics-Catania

Mod F





Mod F

Chip size: 4.37 x 4.37 mm

Array size: 1 x 1 mm

Cells array: 20 x 20

Cells Pitch: 50 µm

Cells fill factor: 36 %

-Matrix of n pixels (SPAD) in parallel

- Every pixel gives the same signal when it is hit by a photon but the output charge is proportional to the number of triggered cells, i.e the number of injected photons:
$\mathbf{Q_{out}=C(V_R - V_{BR})\ N_{fired}}$

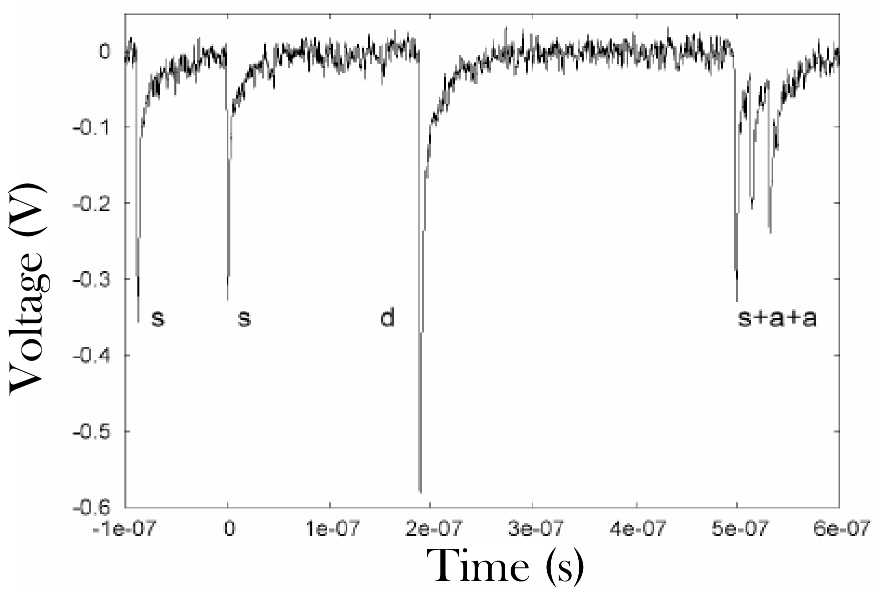
- Analog device

- Photon detection efficiency: ca 20% at 450 nm

SiPM Response - part 1

Rise time: 1-2 ns

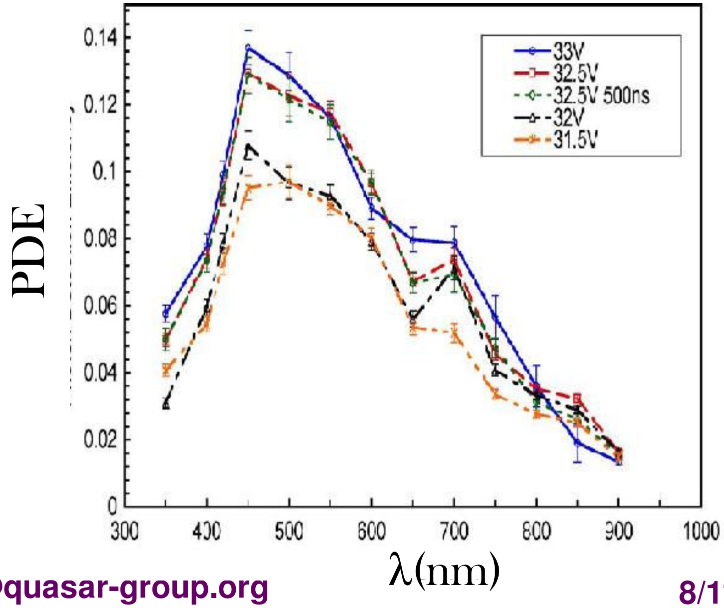
Recovery time:
ca 20 ns
(depending on the quenching circuitry)



Photon Detection Efficiency

\# Detected photons / # Incident photons

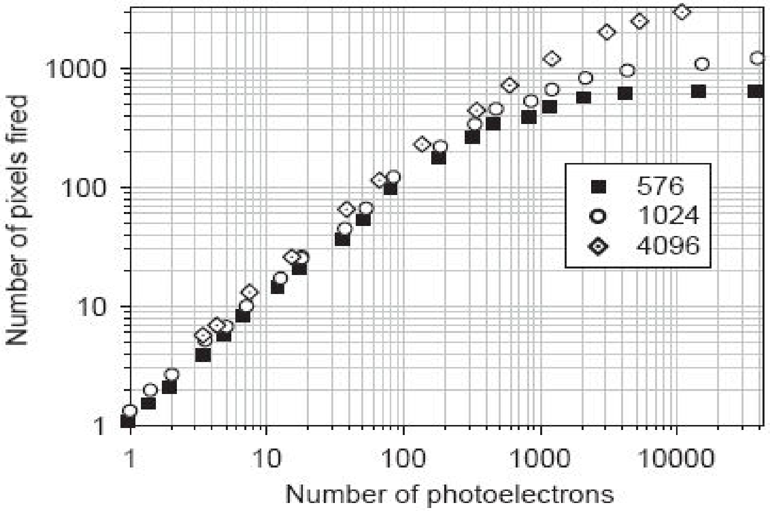
$$\eta_{SiPM} = \varepsilon_{geom} \times QE \times \varepsilon_{avalanche}$$



SiPM Response - part 2

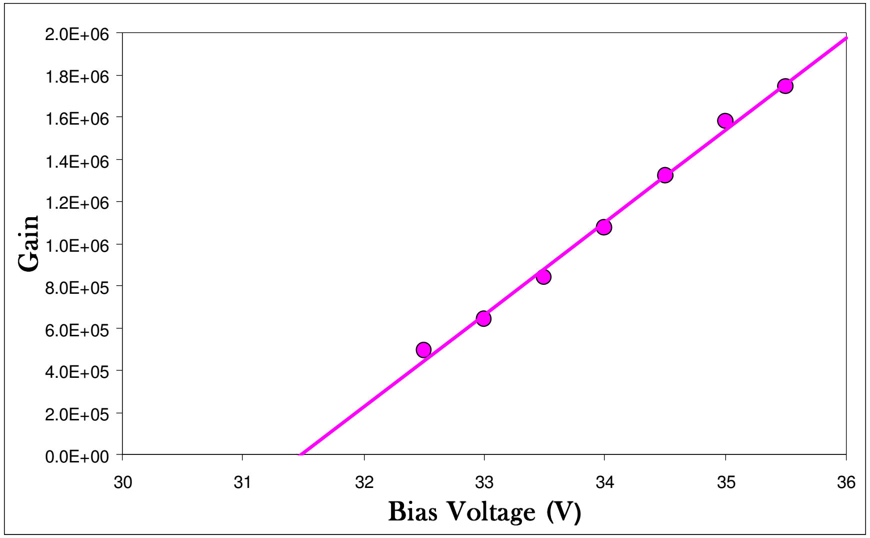
Dynamic range

Best working condition => $N_{photons} < N_{cells}$



Gain linearity

• linear variable with Vbias

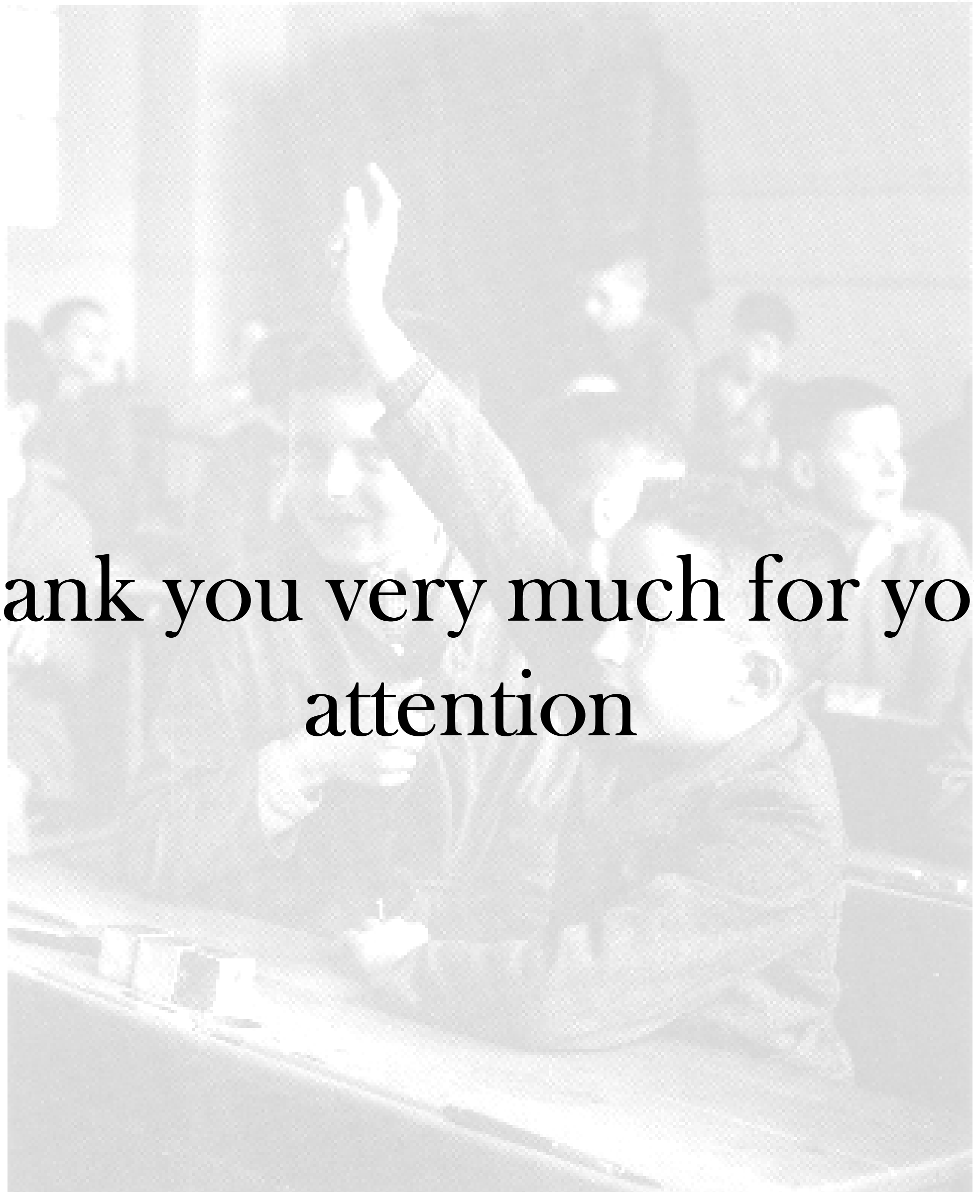


Conclusions

- It seems possible to realize a sensor:
  - low cost
  - extremely compact
  - with a robust mechanical design
  - immune to external magnetic field
  - radiation hardness

- After the experimental test the ST SiPMS seems to be the best solution for this particular application

- Next steps:
  - sensor performances analysis
  - installation at Cern for measuring beam losses at Two Beam Test Area.



Thank you very much for your attention

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