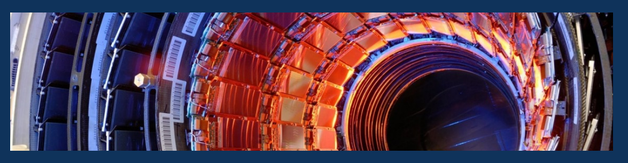
16TH PISA MEETING ON ADVANCED DETECTORS

La Biodola, Isola d'Elba, May 26-June 1, 2024



Planar silicon sensors for real-time monitoring of electron (and protons) FLASH beams

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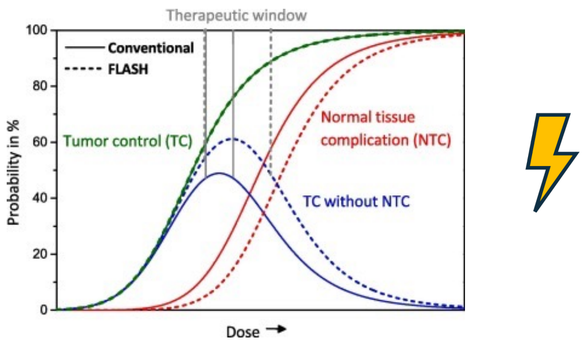
Dosimetry and beam monitoring for FLASH RT

- FLASH RT: emerging cancer treatment that delivers extremely high dose-rate of radiation (~10^7 Gy/s) over a short time period (< 200 ms)



State-of-the-art of **beam monitors** represented by **gas-filled ionization chambers:**

- ✓ Large area
- ✓ Good radiation hardness
- X Limited sensitivity
- X Slow charge collection times (~ 100 µs)

- Standard detectors for beam-monitoring and dosimetry saturate at ultra-high dose rates (UHDR)
- Alternative approaches: solid state detectors

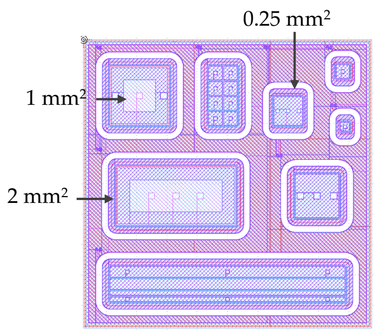
Sensors and readout system

Silicon devices in Turin: used so far for *single particle counting* → With **TERA08** signal can be integrated

Thin silicon sensors

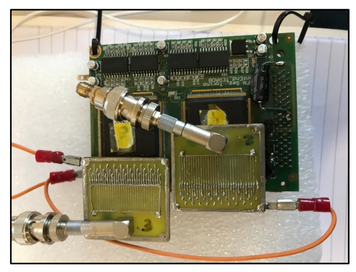
- 3 pad sensors (pin) [INFN ExFlu]
- Areas 2/1/0.25 mm^2, active thickness 45/30 μm, total thickness 615 μm)

FONDAZIONE BRUNO KESSLER



TERA08 readout chip

- TERA08 chip: 64 equal channels
- In each CHN current-to-frequency converter (each digital pulse = fixed input charge quantum)
- Converter based on recycling integrator architecture



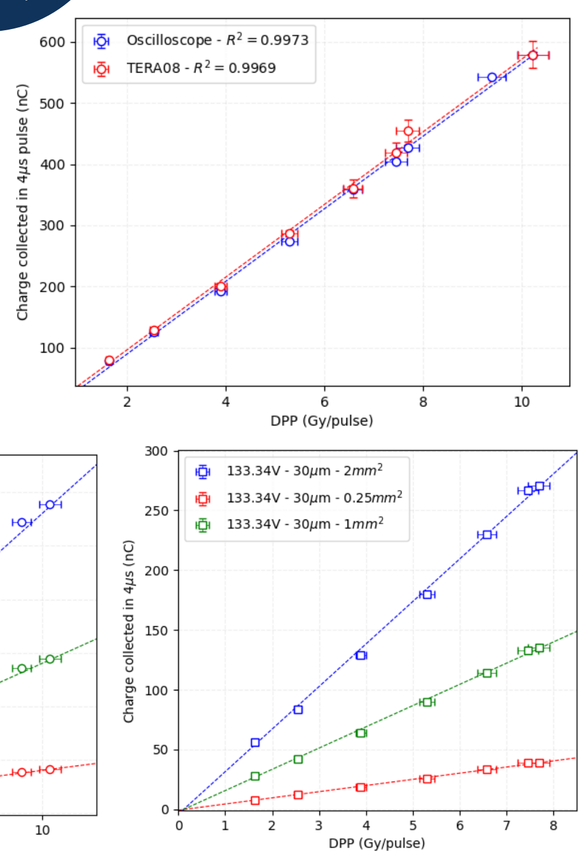
DAQ Period (µs)	Q_c(fC)	Max conversion freq per chn	Max conversion (total)	Max current (for 64 CHNs)
1e4 (0.01 s)	200 fC	20 MHz	1280 MHz	± 256 μA

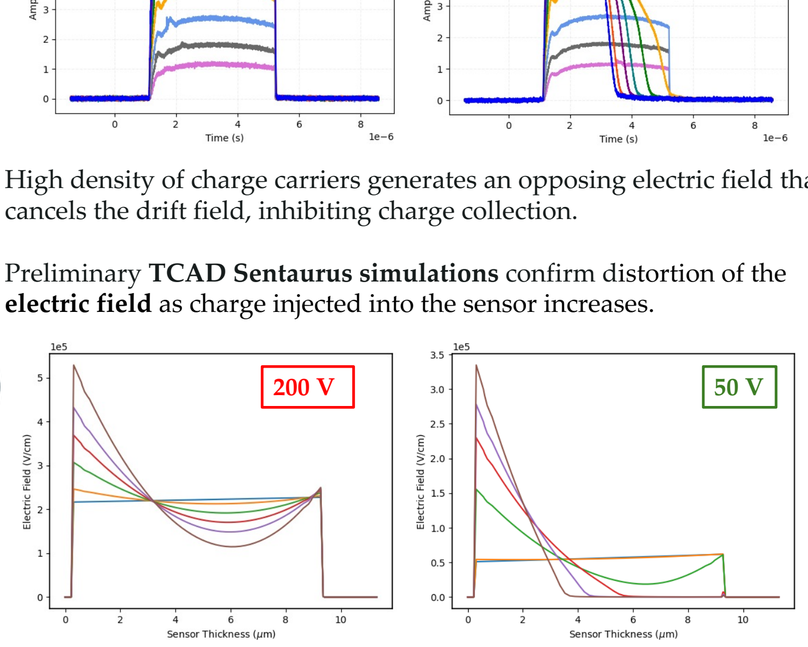
FRIDA project

Characterization on UHDR beams

ElectronFLASH acceleraror (CPFR, Pisa)

- CPFR in Pisa funded by Fondazione Pisa
- SIT-Sordina IORT Technologies S.p.A. (Aprilia, Italy)
- Electron pulsed beams of 7 and 9 MeV
- PMMA plastic applicators (different lengths and diameters) for dose uniformity
- Beam current 1-100 mA; pulse duration (0.5 - 4 µs); pulse frequency (1-249 Hz)





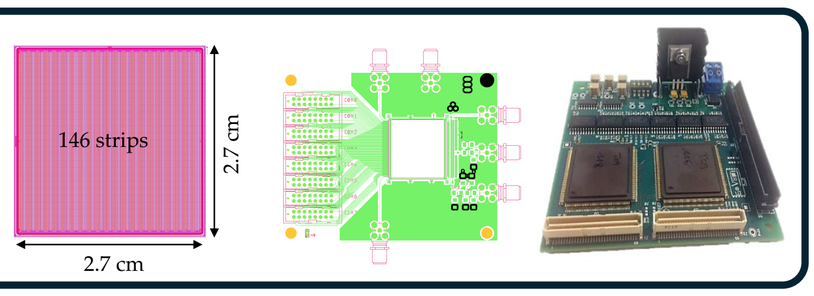
High density of charge carriers generates an opposing electric field that cancels the drift field, inhibiting charge collection.

Preliminary **TCAD Sentaurus simulations** confirm distortion of the **electric field** as charge injected into the sensor increases.

Sentaurus TCAD
SYNOPSYS

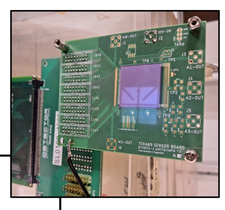
TERA09 and 146-strips sensor

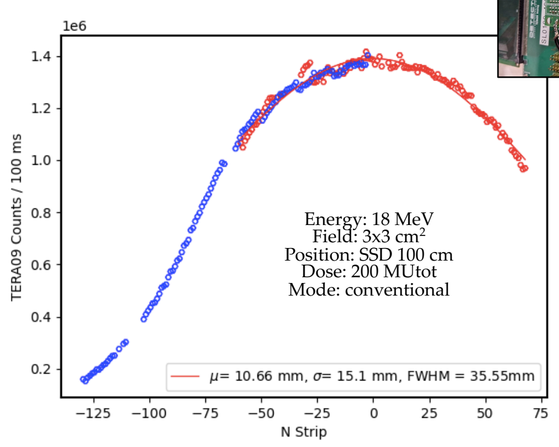
- TERA09 (upgrade TERA08) has an extended current range (12 µA / chn 200 fC)
- Silicon sensor of area 2.7 × 2.7 cm² (146 strips, Pitch of 180 µm, inter-strip of 66 µm, strip area of 114x26214 µm²)
- Strips read separately: online control of beam shape and dose after one single shot
- Preliminary tests in conventional regime for both electron and proton beams in 3 facilities



Linac ELEKTA (Turin department)

- Conventional electron beams
- Beam shape in different energy, dose-rate and position conditions

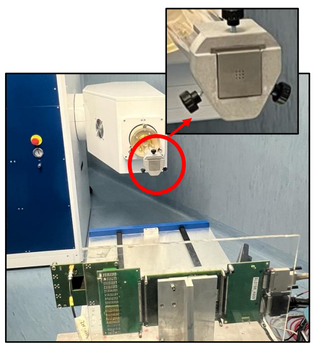


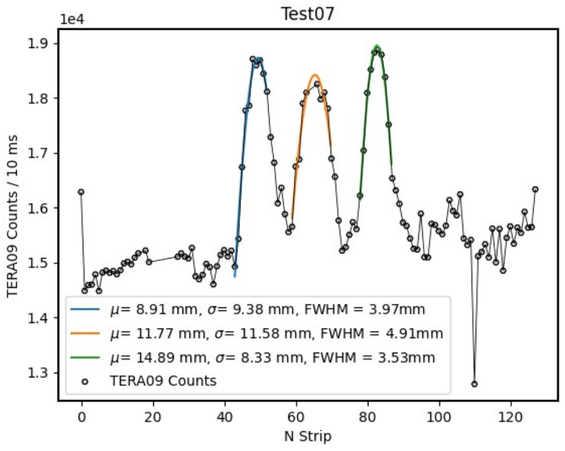


ElectronFLASH accelerator (Pisa, CPFR)

- INFN MIRO mini-beam project
- Template placed on applicator
- Tungsten template: 3x3 holes

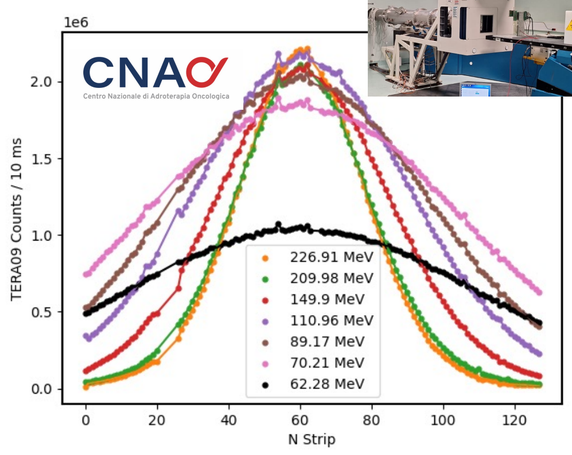
MIRO Minibeam Radiotherapy





National Center for Oncological Adrotherapy

- 5E9 protons/spill (20 spills)
- Different energy conditions (62.28 MeV - 226.91 MeV)



Conclusions and future steps

- Linearity of single sensor signals up to more than 10 Gy/pulse was verified on eletron FLASH beams
- Preliminary tests on conventional beams confirmed the use of TERA09 for beam spatial information
- New sensor production based on *trench* technology is in progress
- Further beam tests (soon to be FLASH proton beams)
- Ongoing study of a readout chip specifically for FLASH regimes

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