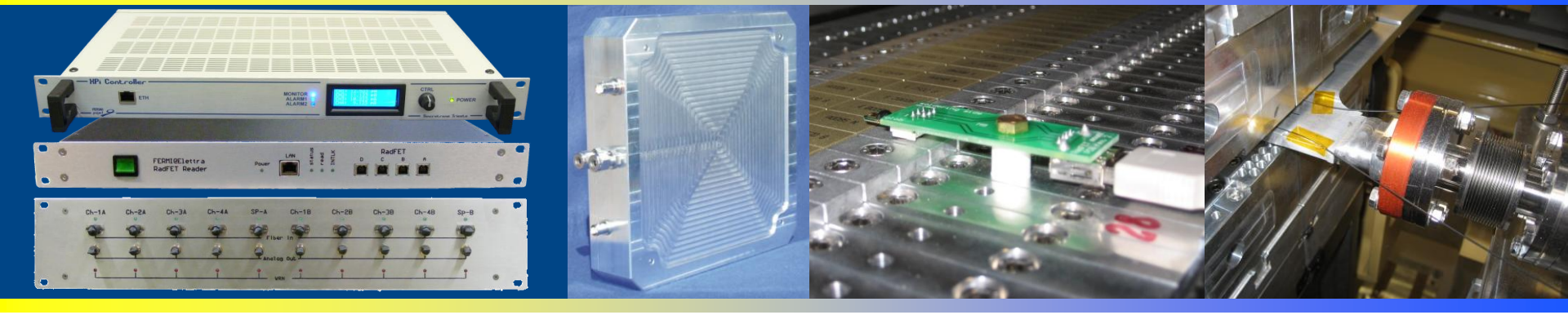
Diagnostics for Machine Protection at FERMI@Elettra



L. Fröhlich, A. I. Bogani, K. Casarin, G. Cautero, G. Gaio,
F. Giacuzzo, D. Giuressi, A. Gubertini, R. H. Menk, E. Quai,
G. Scalamera, A. Vascotto (Sincrotrone Trieste, Basovizza, Italy)
L. Catani (INFN, Rome, Italy), D. Di Giovenale

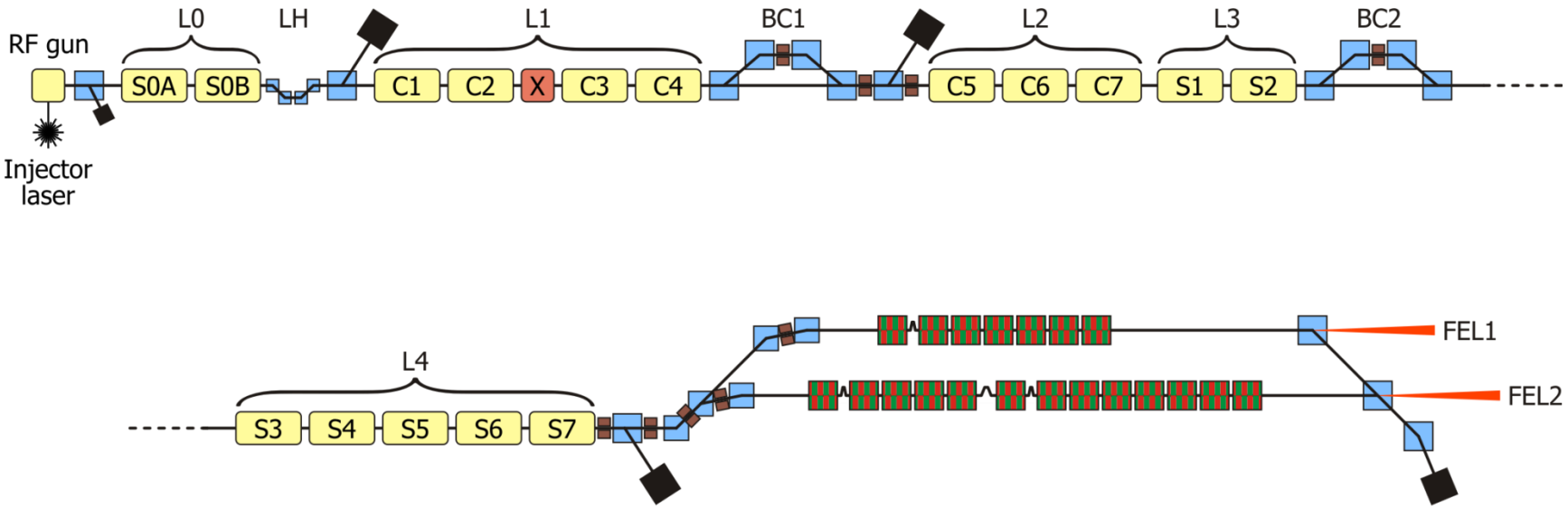
Overview

- FERMI@Elettra
- MPS architecture
- General features

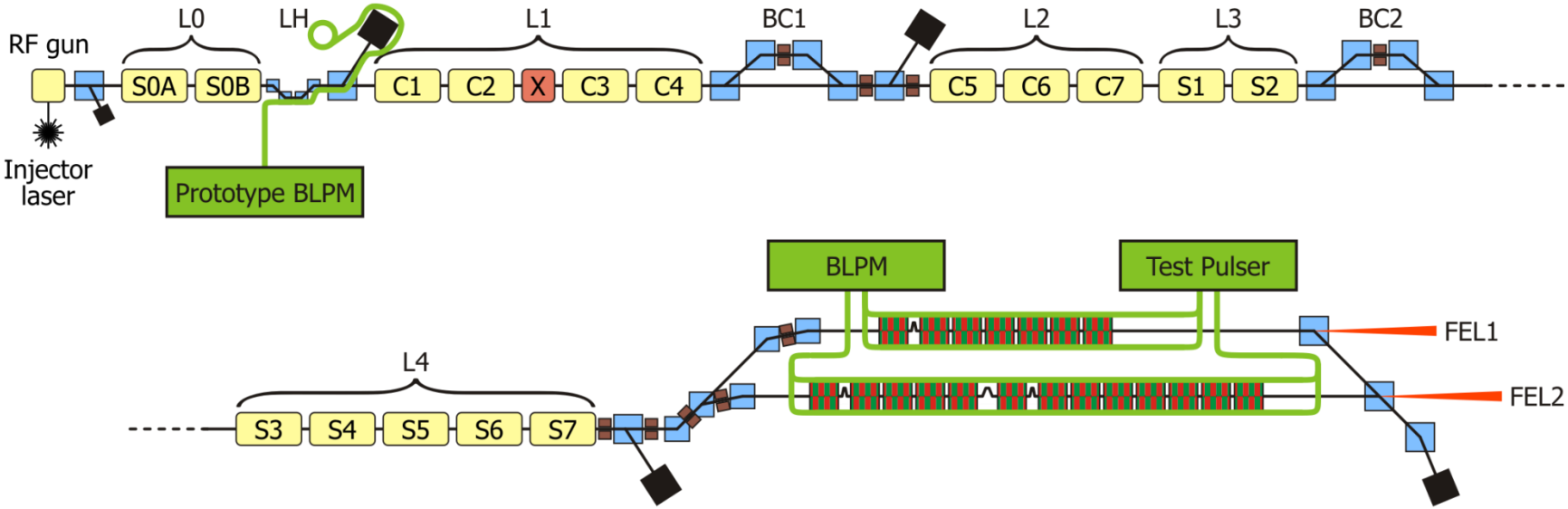
- Subsystems:
  - Fiber beam loss position monitors
  - Ionization chambers
  - RADFET online dosimetry

Elettra & FERMI

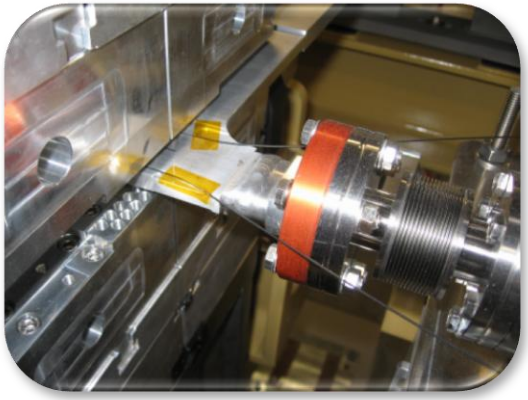
FERMI@Elettra

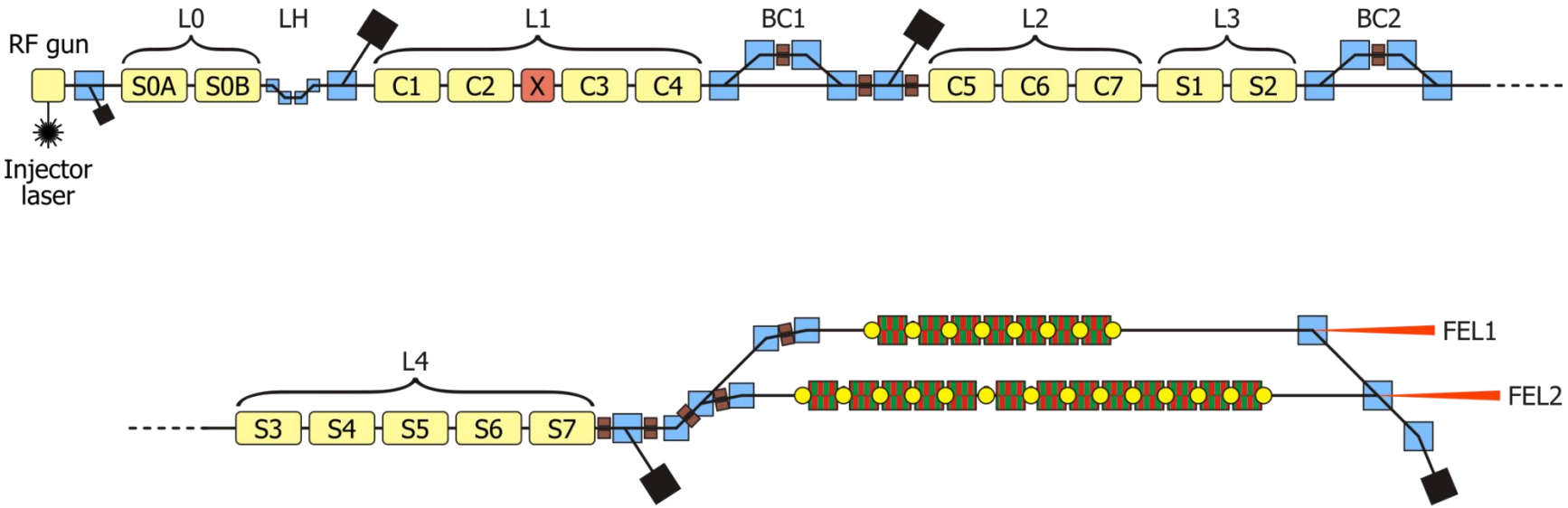


	Energy	Bunch Charge	Repetition Rate	Beam Power
Typical	1.2 GeV	350 pC	10 Hz	4.2 W
Design	1.5 GeV	1 nC	50 Hz	75 W



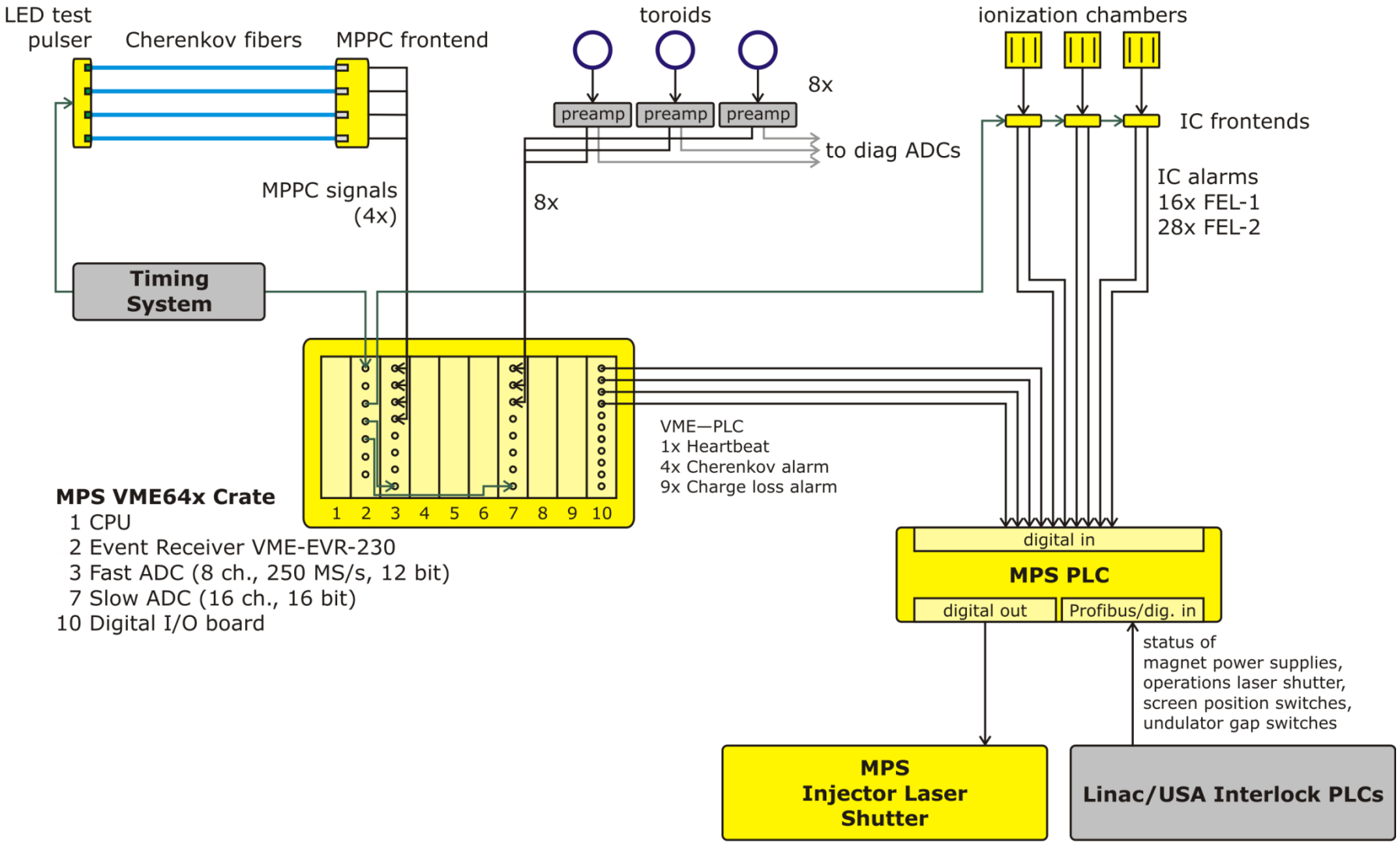
Cherenkov Fiber Beam Loss Position Monitors (BLPMs)



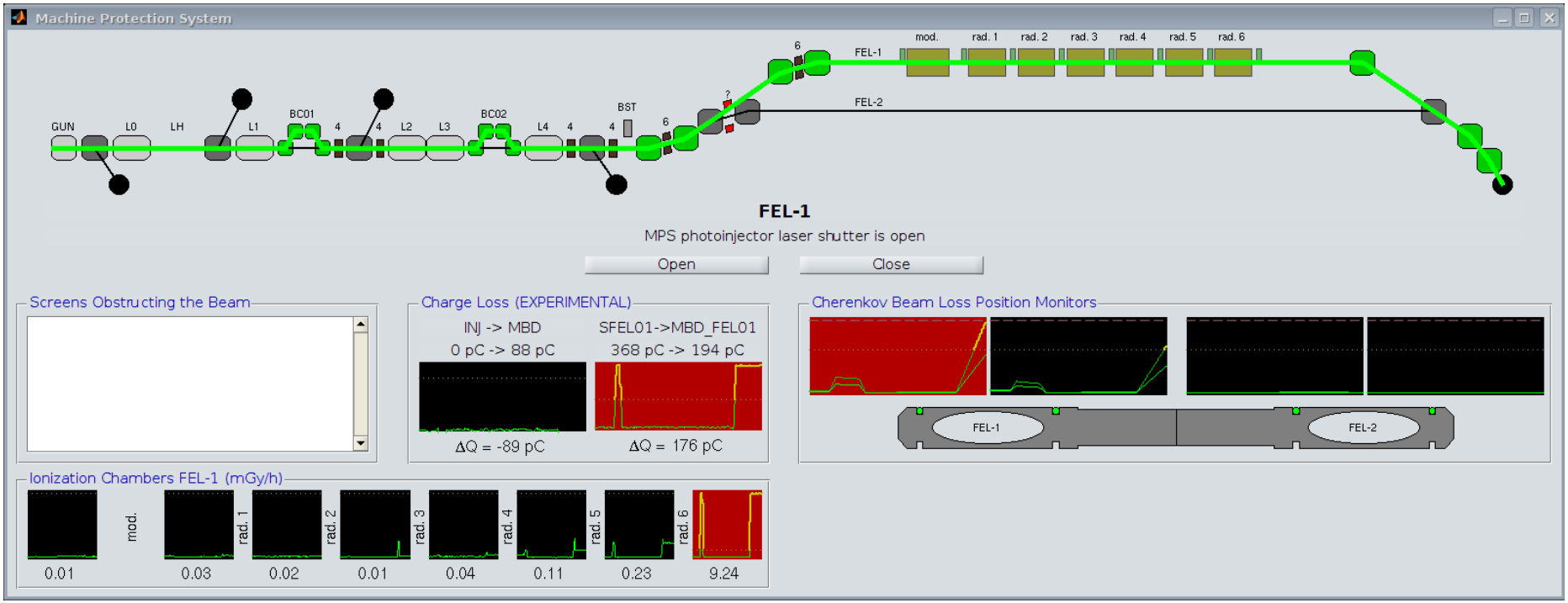


Ionization Chamber Beam Loss Monitors (BLMs)

MPS Overview



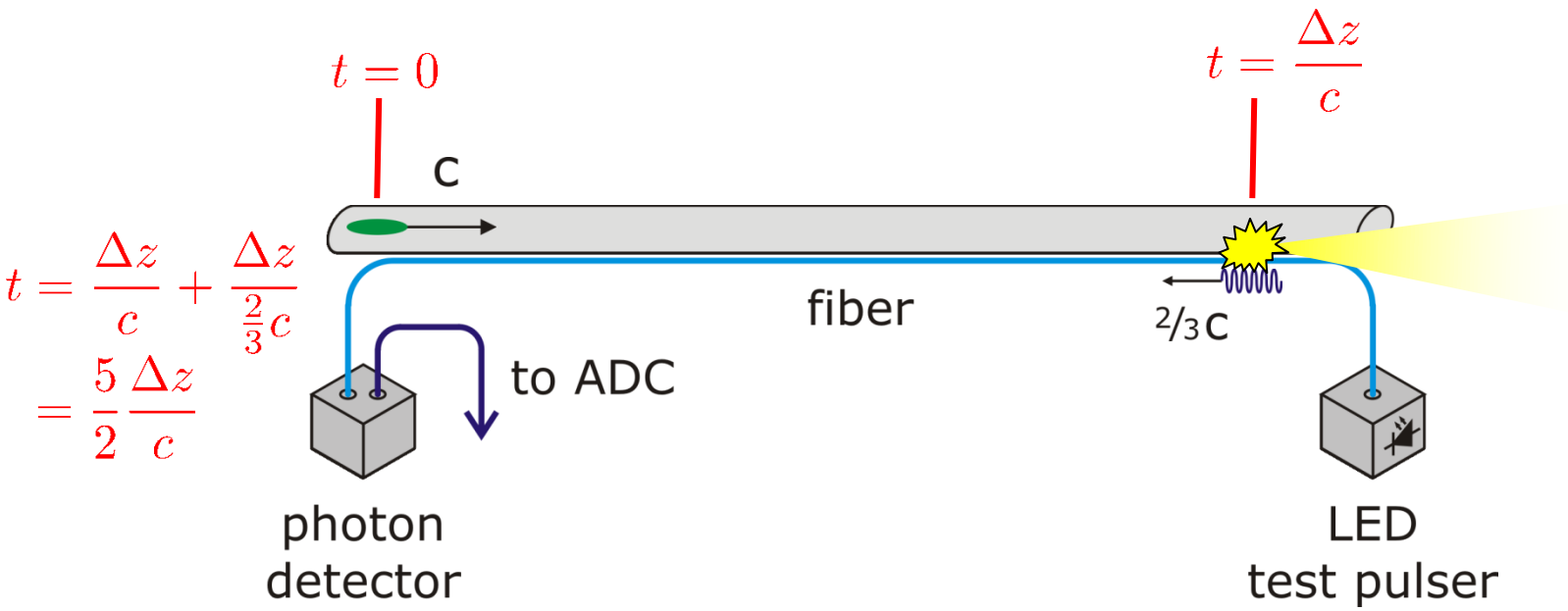
MPS Panel


Machine Protection System
GUN
L0
LH
L1
BC01
L2
L3
BC02
L4
BST
FEL-1
FEL-2
mod.
rad. 1
rad. 2
rad. 3
rad. 4
rad. 5
rad. 6
FEL-1
MPS photoinjector laser shutter is open
Open
Close
Screens Obstructing the Beam
Charge Loss (EXPERIMENTAL)
INJ -> MBD
0 pC -> 88 pC
SFEL01->MBD_FEL01
368 pC -> 194 pC
ΔQ = -89 pC
ΔQ = 176 pC
Cherenkov Beam Loss Position Monitors
FEL-1
FEL-2
Ionization Chambers FEL-1 (mGy/h)
mod.
rad. 1
rad. 2
rad. 3
rad. 4
rad. 5
rad. 6
0.01
0.03
0.02
0.01
0.04
0.11
0.23
9.24

Cherenkov Fiber Beam Loss Position Monitor

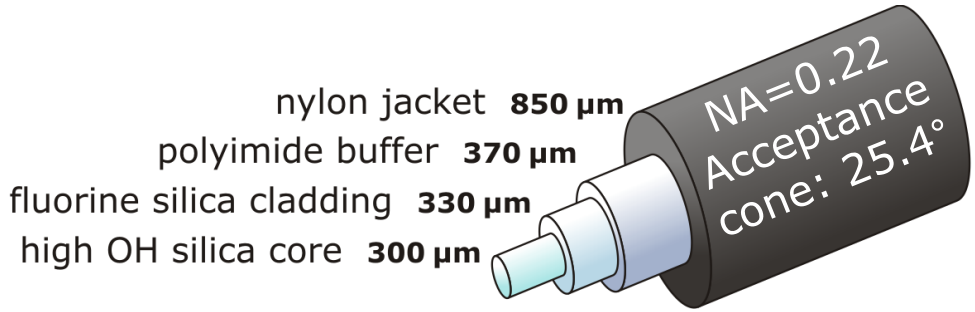
More information:
D. Di Giovenale, L. Catani, L. Fröhlich, "A read-out system for online monitoring of intensity and position of beam losses in electron linacs", Nucl. Instr. & Meth. A 665, pp. 33–39, 2011.

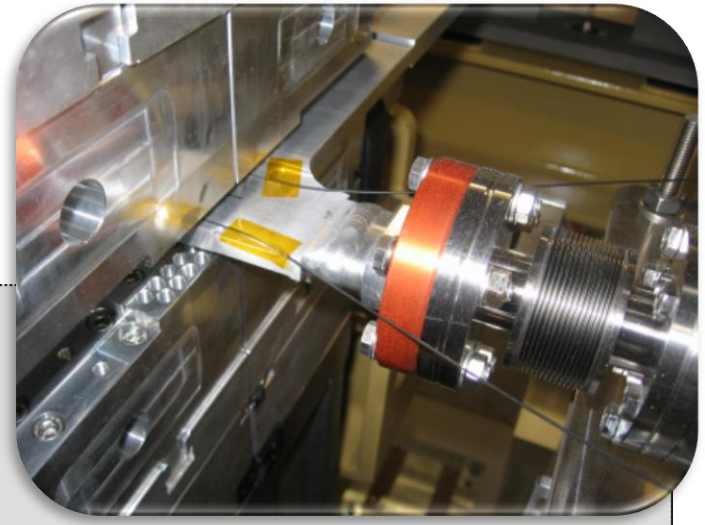
Cherenkov Fiber Beam Loss Position Monitor (BLPM)

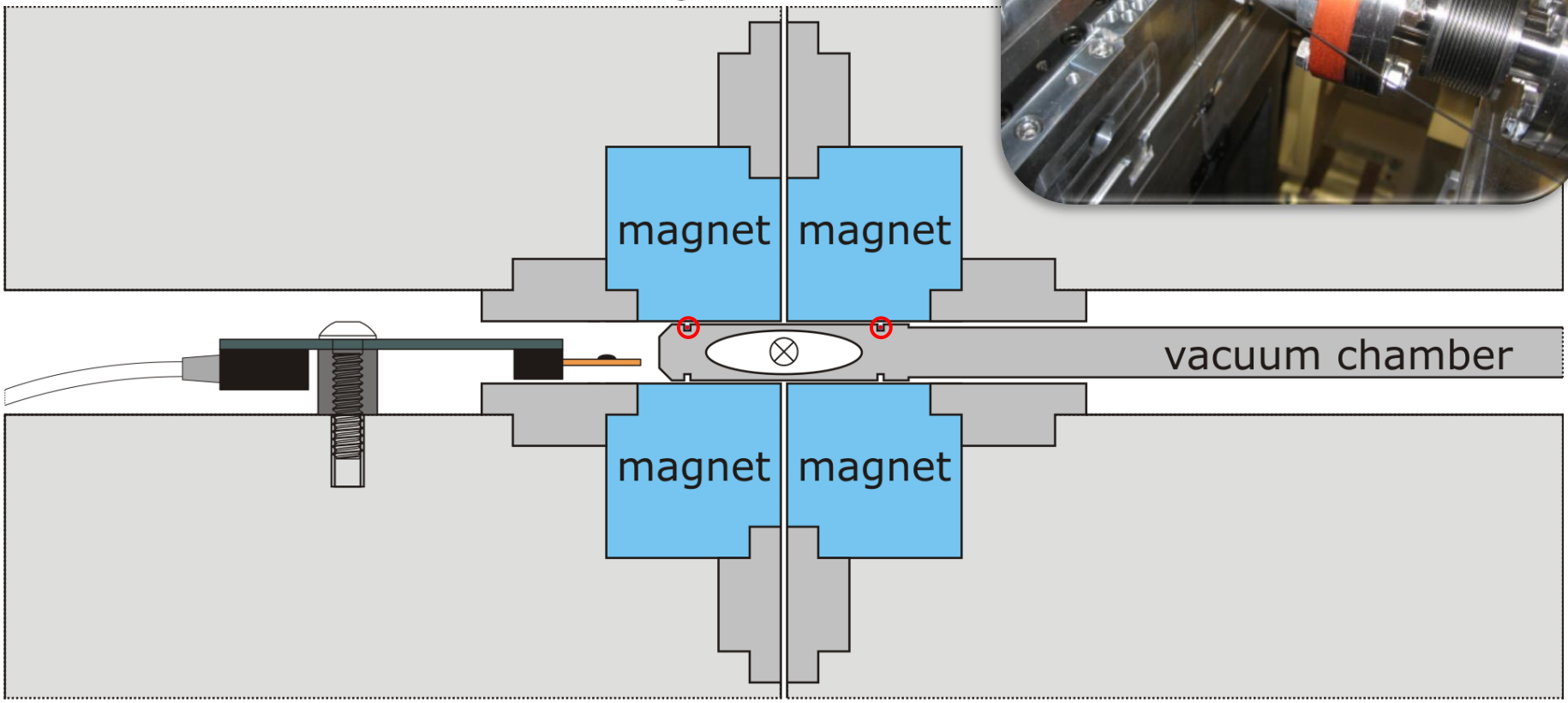


250 MS/s ADC → longitudinal resolution ~50 cm

Undulator Cross Section

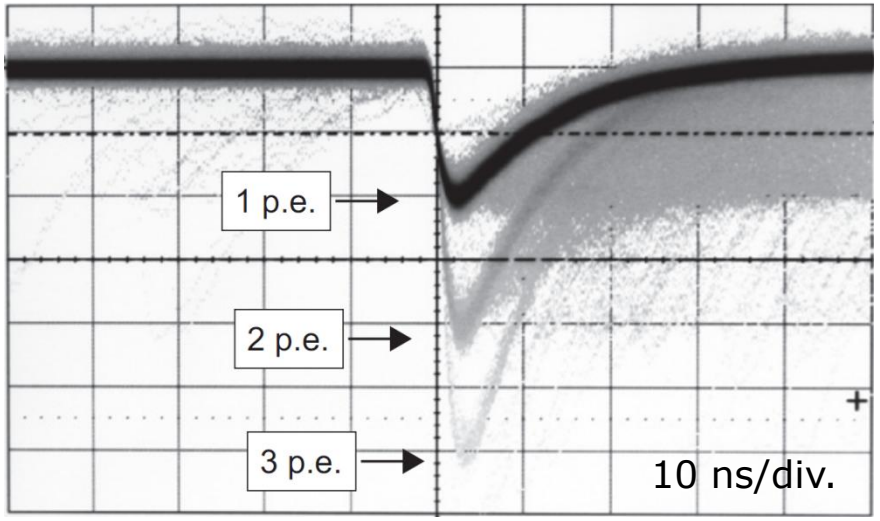


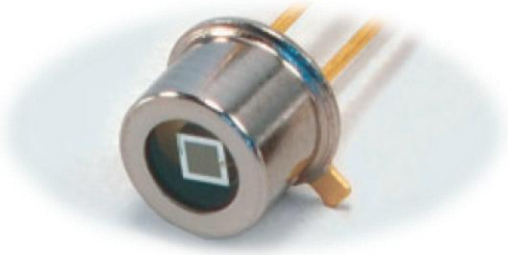


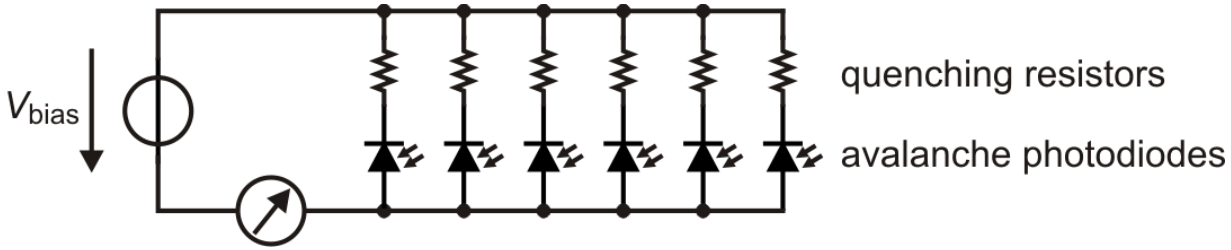


Multi-pixel Photon Counters (MPPCs)

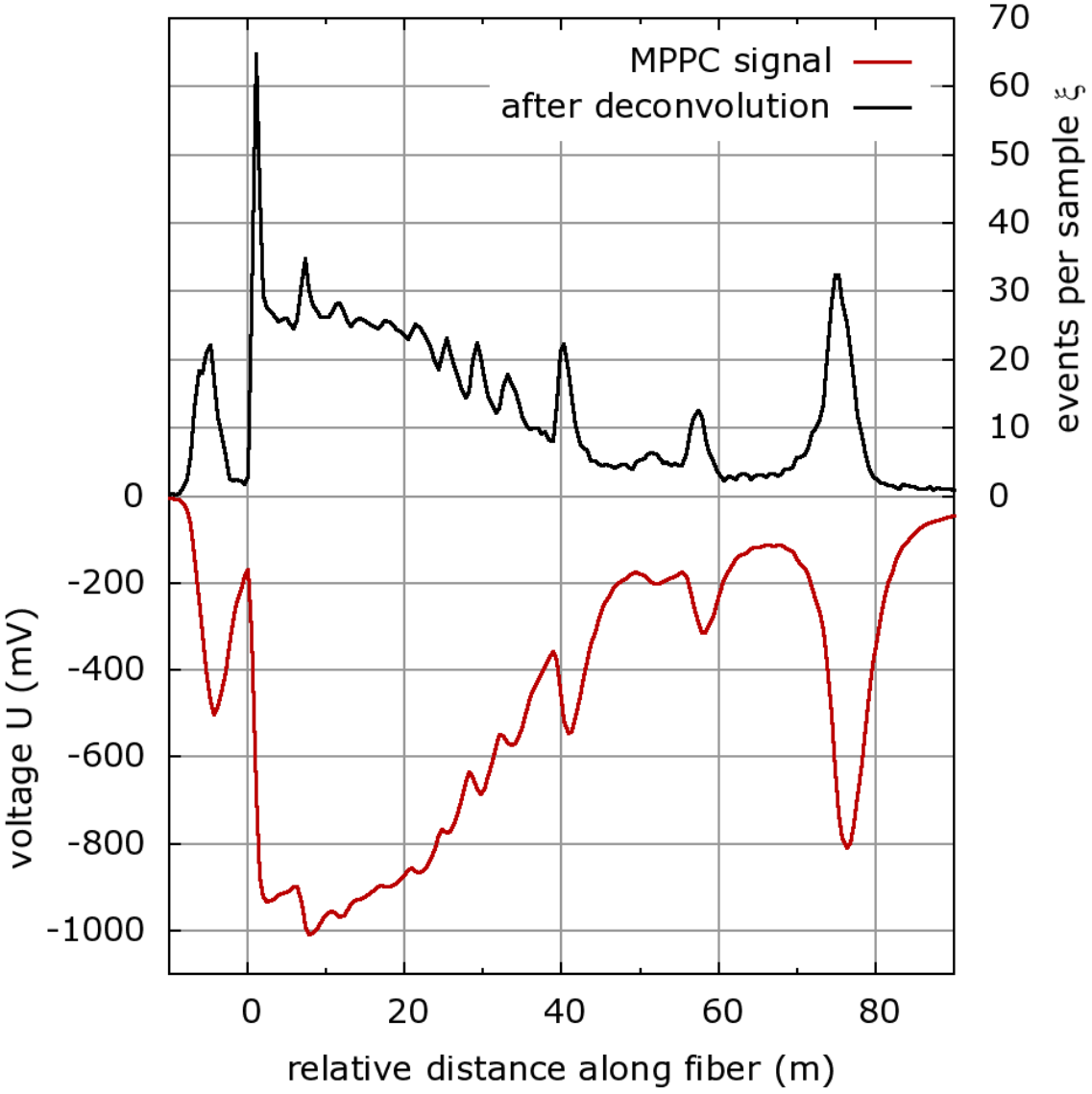
- Array of avalanche photodiodes (APDs) connected in parallel
- Reverse bias → photon causes APD breakdown
- Photomultiplier-like gain
- Dynamic range limited by number of APDs
- Rise time: some 100 ps
- Hamamatsu S10362-11-050U: 400 APDs at ~70 V reverse bias







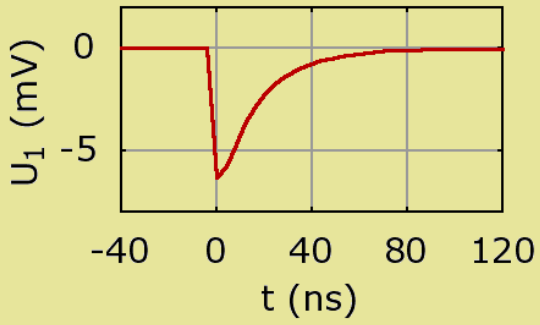
Signal Processing



number of photodiode breakdowns

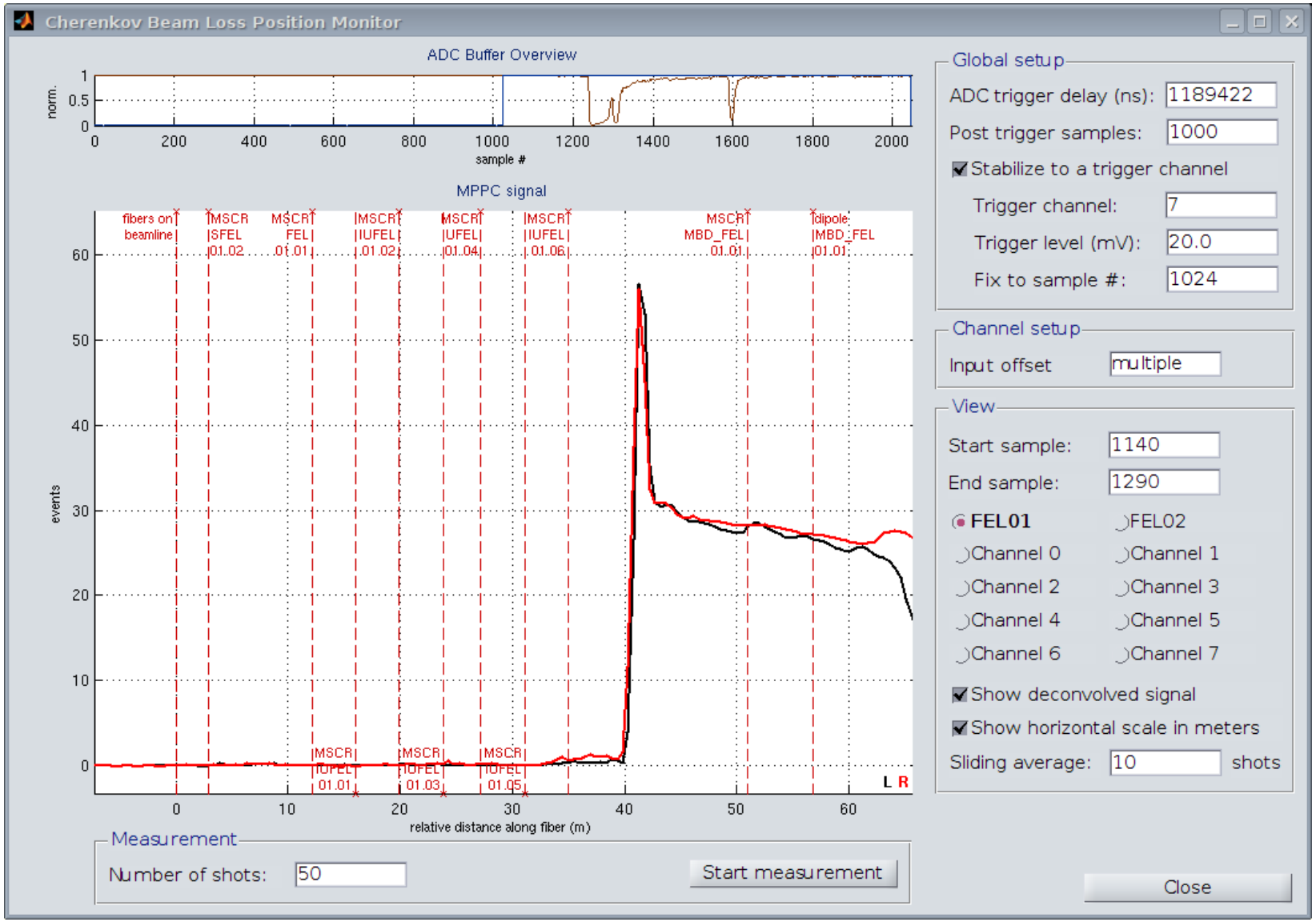
deconvolution

$$\xi(t) = \mathcal{F}_\nu^{-1}\left[\frac{\mathcal{F}_t[U(t)]}{\mathcal{F}_t[U_1(t)]}\right]$$



MPPC output signal

Viewer Application

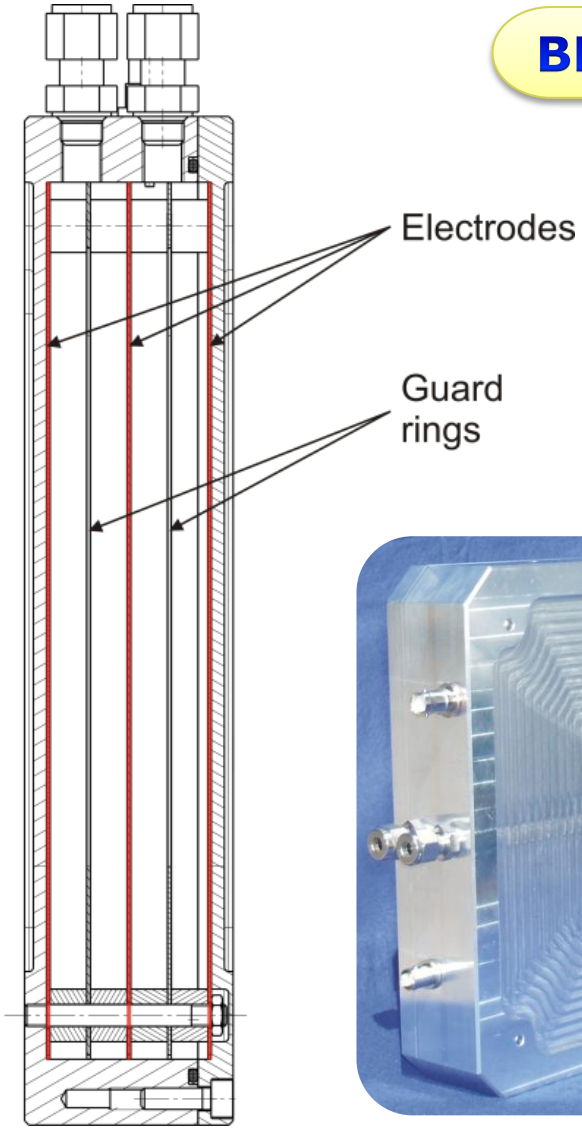


Ionization Chambers

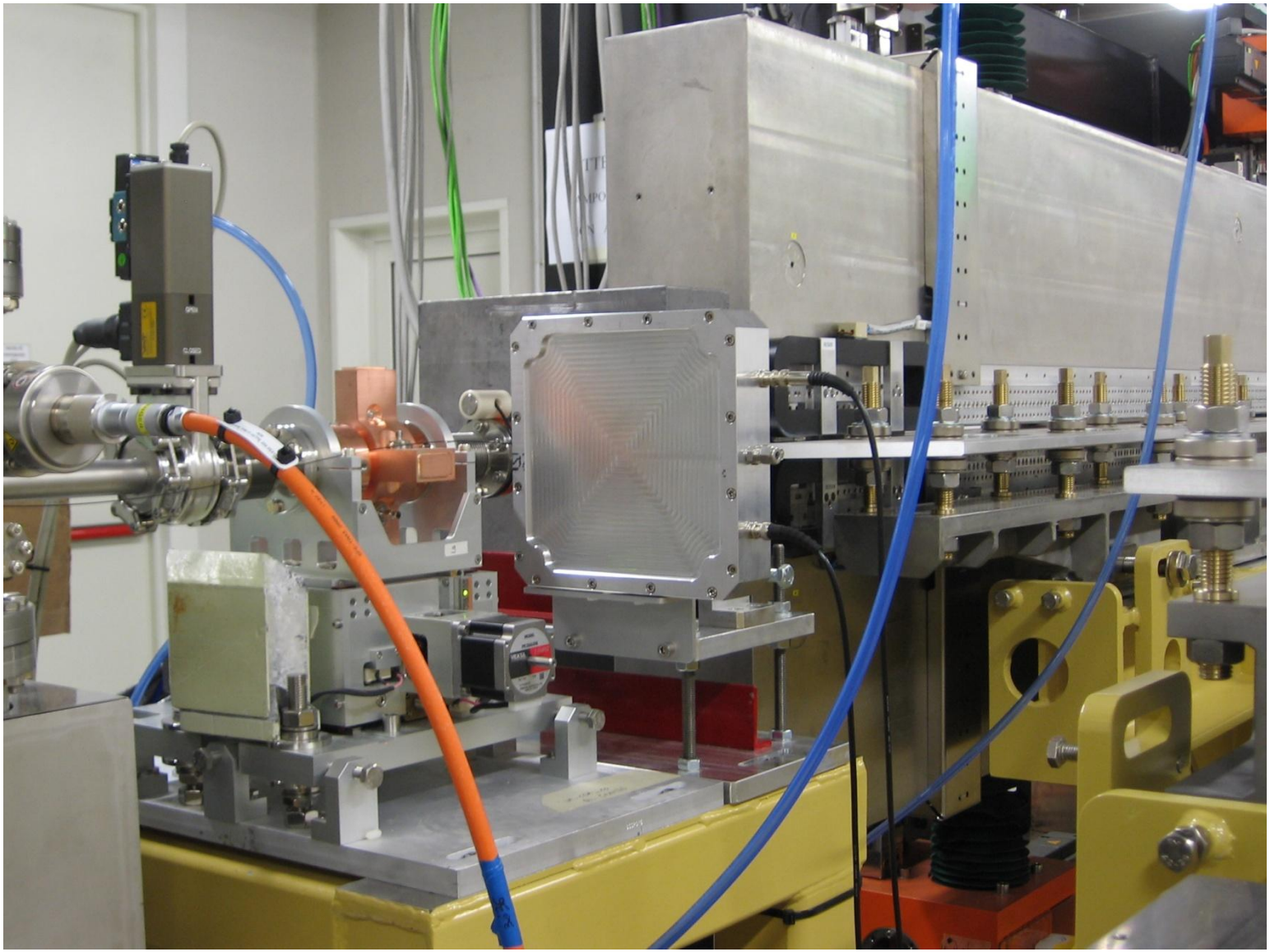
Ionization Chambers

BLM–IC02

- Milled aluminum enclosure
- Electrodes: printed circuit boards
- Use in air or with gas flux
- Volume:
  1.3 l
- Voltage:
  up to 1000 V
- Sensitivity (air):
  ~46 µC/Gy
- Leakage current:
  ≪ 200 fA (at 1000 V)
- Fermi:
  1 ionization chamber in air
  per undulator segment (19 total)



Ionization Chambers



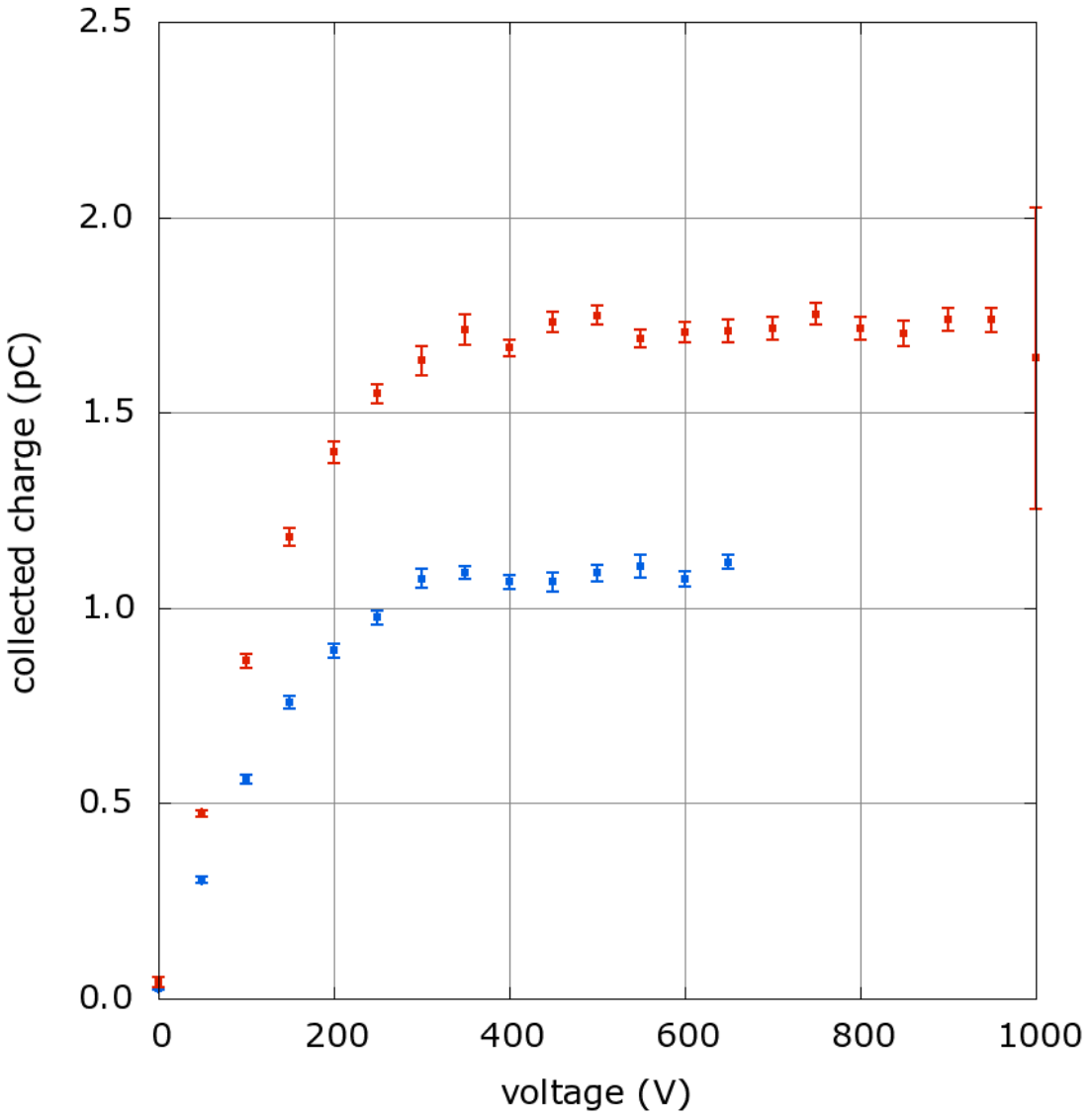
Ionization Chamber Frontend

XPi DAS

- Modular data acquisition system
- Ethernet interface
- 1× HV up to 2000 V, ≤ 1 W
- 4× Charge-integrating amplifier
  Ranges: 0…50 pC – 0…1.8 nC
  Integration time: 1 ms – 1 s
- 20-bit ADC
- Noise w/ Fermi chamber: <0.4 µGy/h

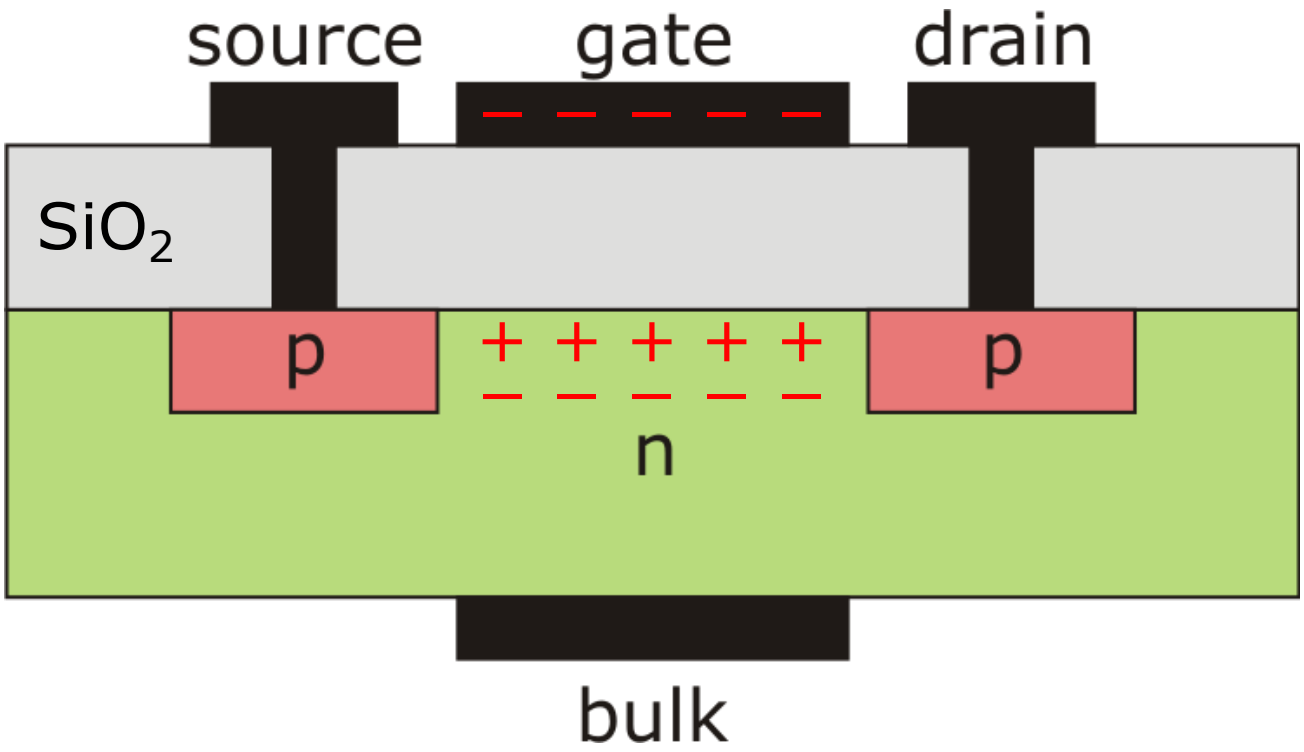
Collection Efficiency

- Air filled chamber
- Charges collected:
  - Electrons
  - Oxygen ions (O_2^-)
  - Positive ions (N_2^+ etc.)
- Integration time: 3 ms (2 ms sufficient to collect all charges)



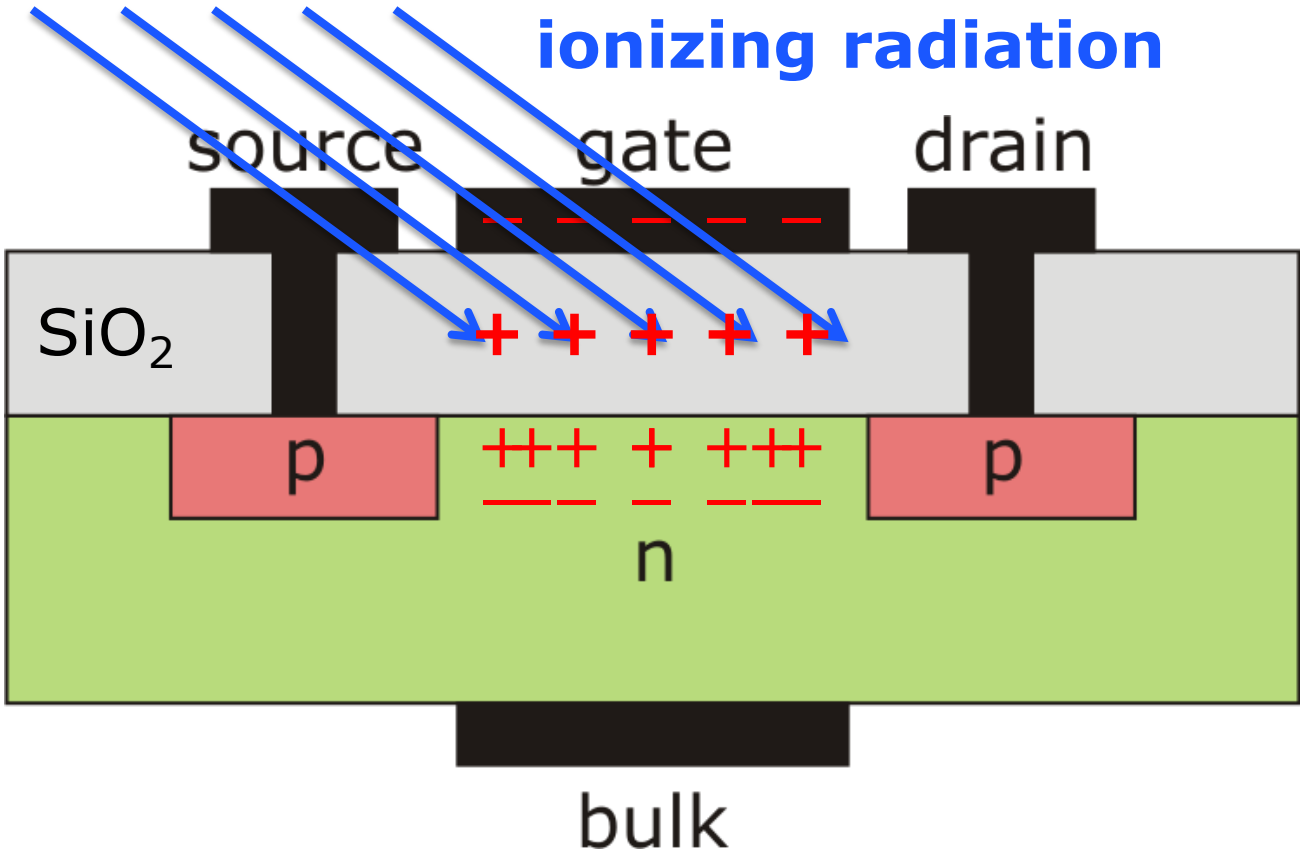
Online Solid-State Dosimetry

P-channel MOSFET



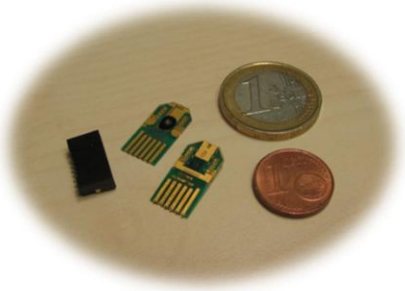
negative gate potential → conductive inversion layer

P-channel MOSFET



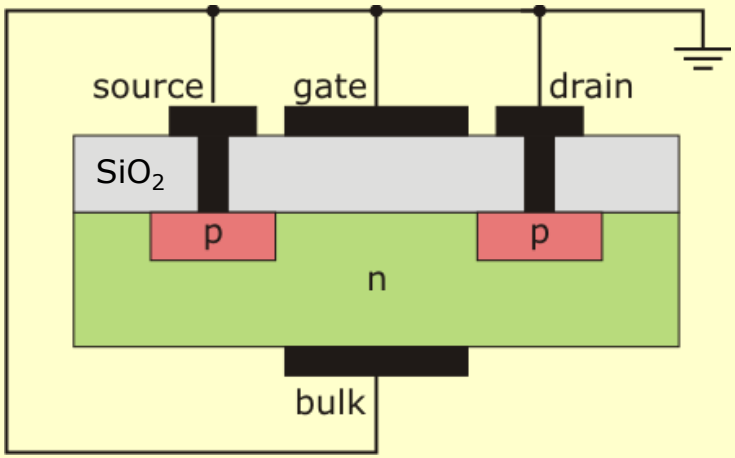
ionizing radiation → stationary charges in insulation layer

RADFET Dosimeters

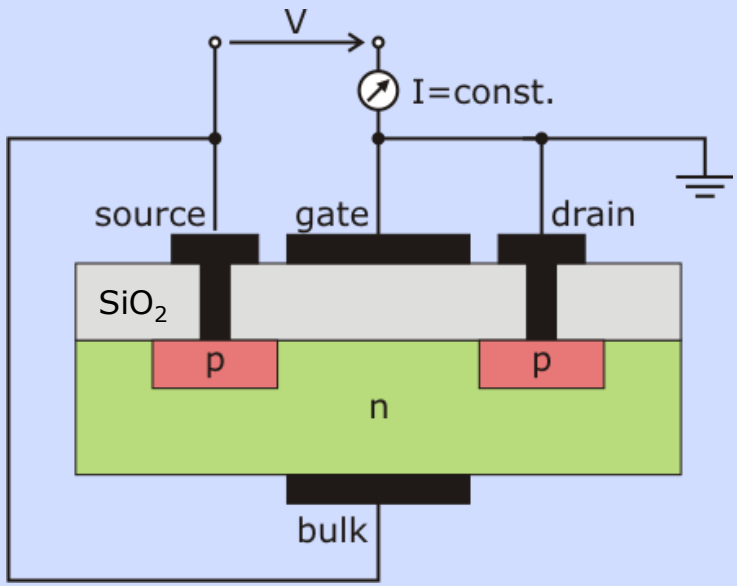


- REM Oxford Ltd. RADFET RFT-300-CC10G1
- Chip contains 2 p-channel MOSFETs with 300 nm insulator layer

exposure "zero bias"



read-out



Track voltage for constant current (490 µA) between source and drain

Dosimeter Reader

L01-DOSFET

- Ethernet interface
- 4 RADFET channels
- Fixed read-out current: 490 µA
- Voltage read-out: 24 bit ADC, up to 25 V
- Programmable interlock output
- Uses standard USB cables

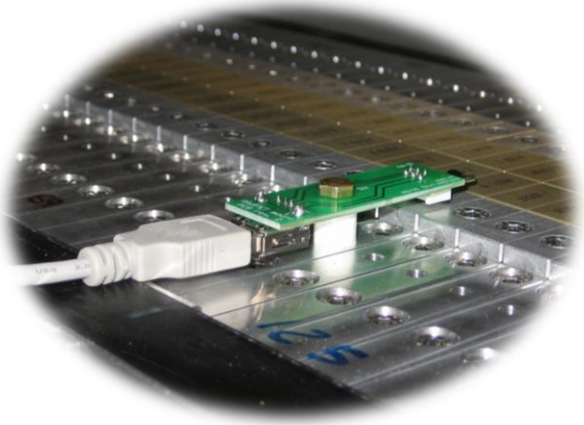
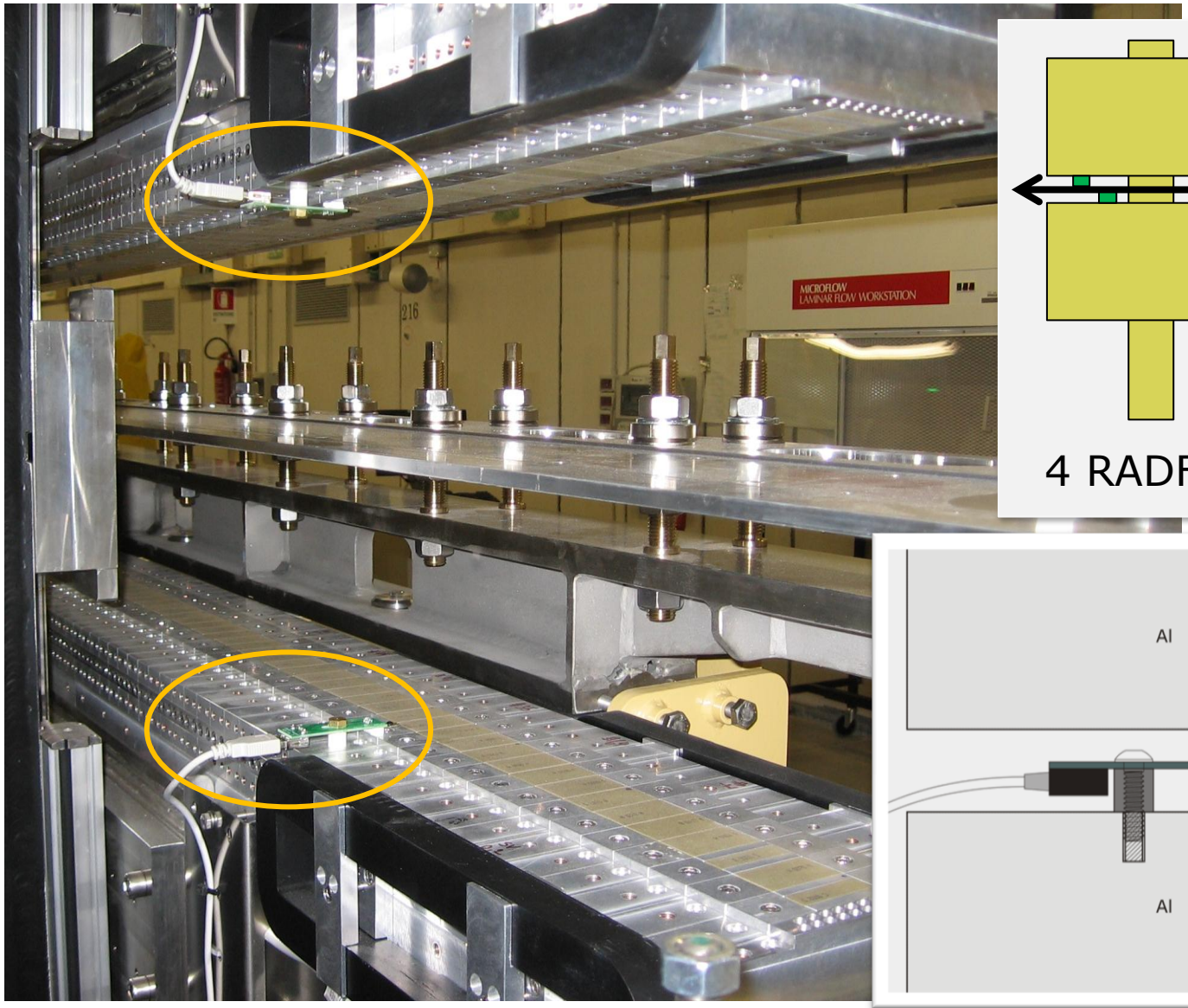
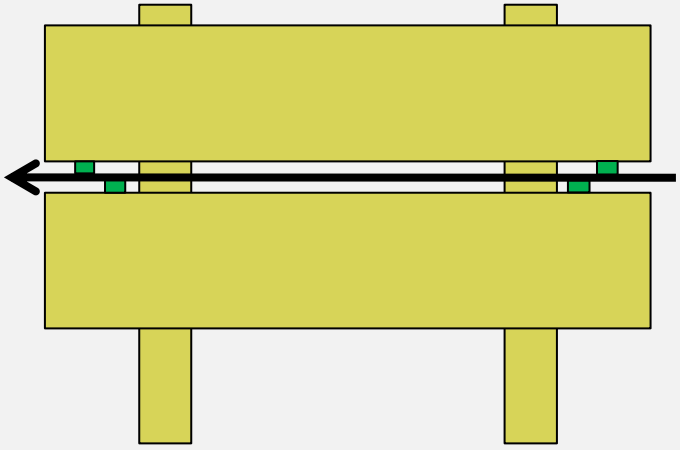


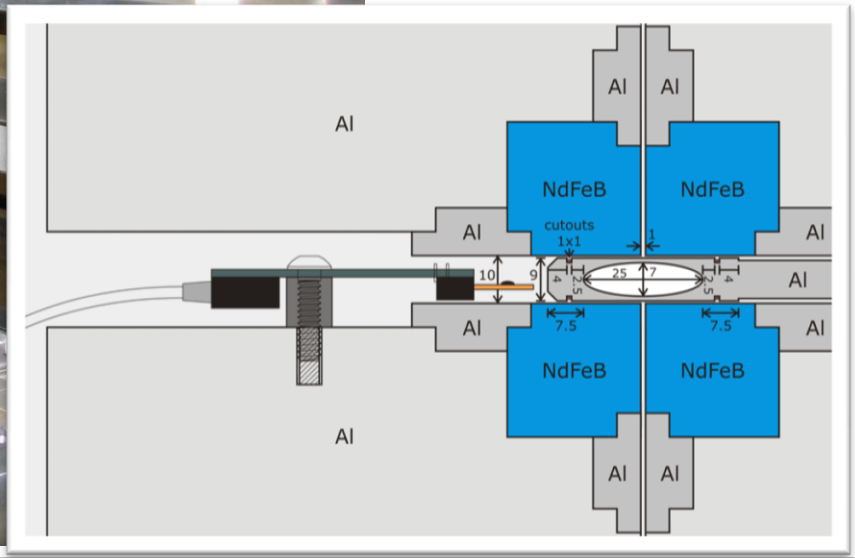
Photo: M. Peloi

Undulator with Open Gap

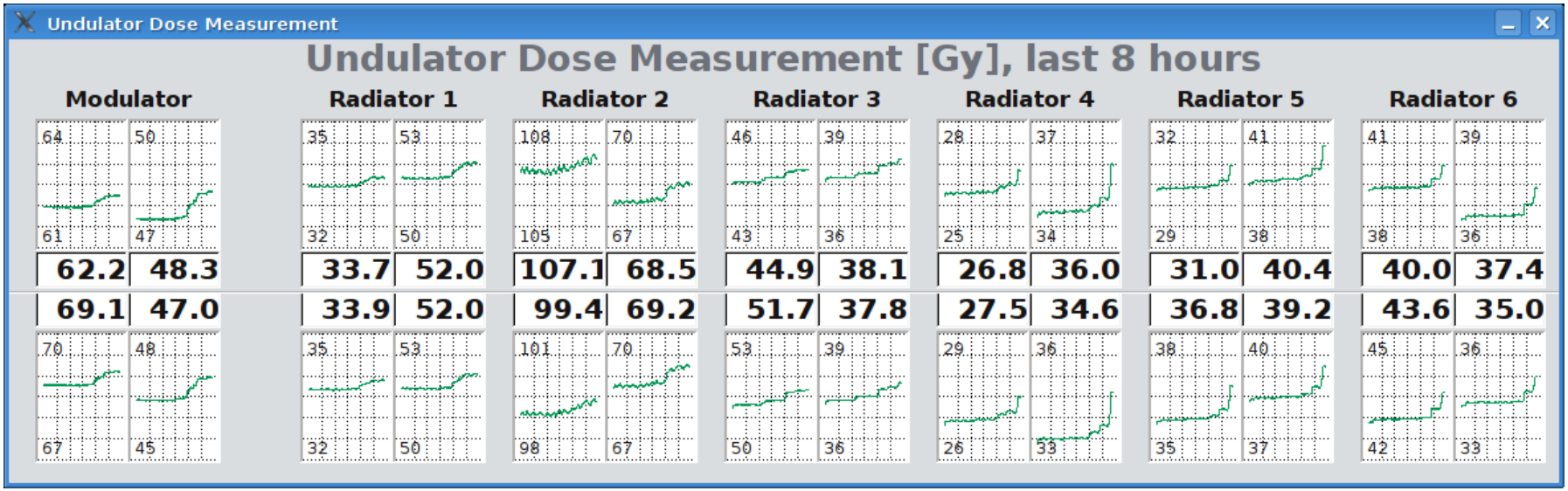




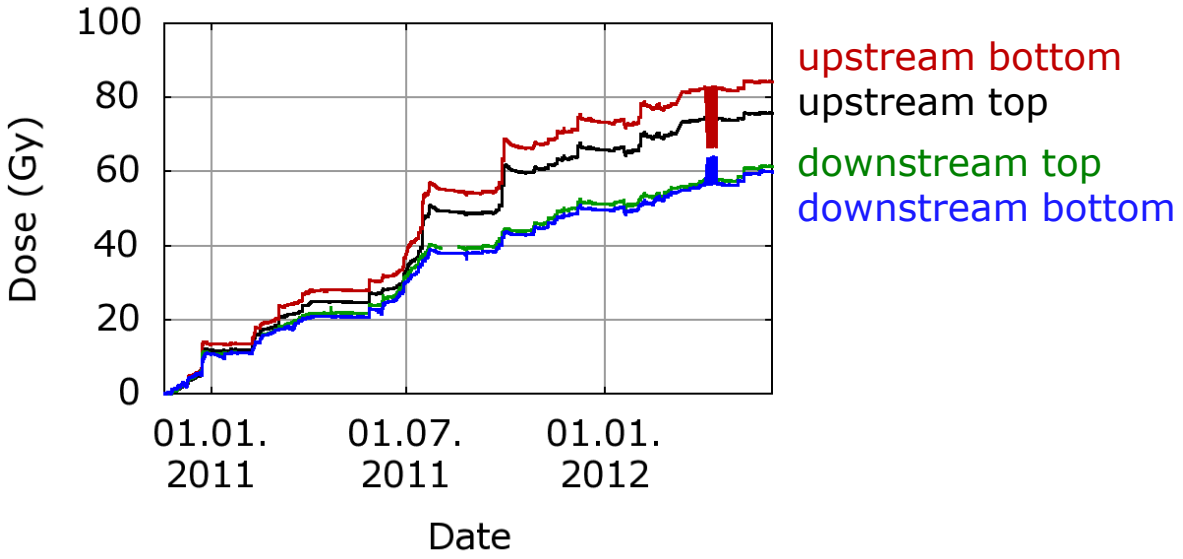
4 RADFETs per undulator



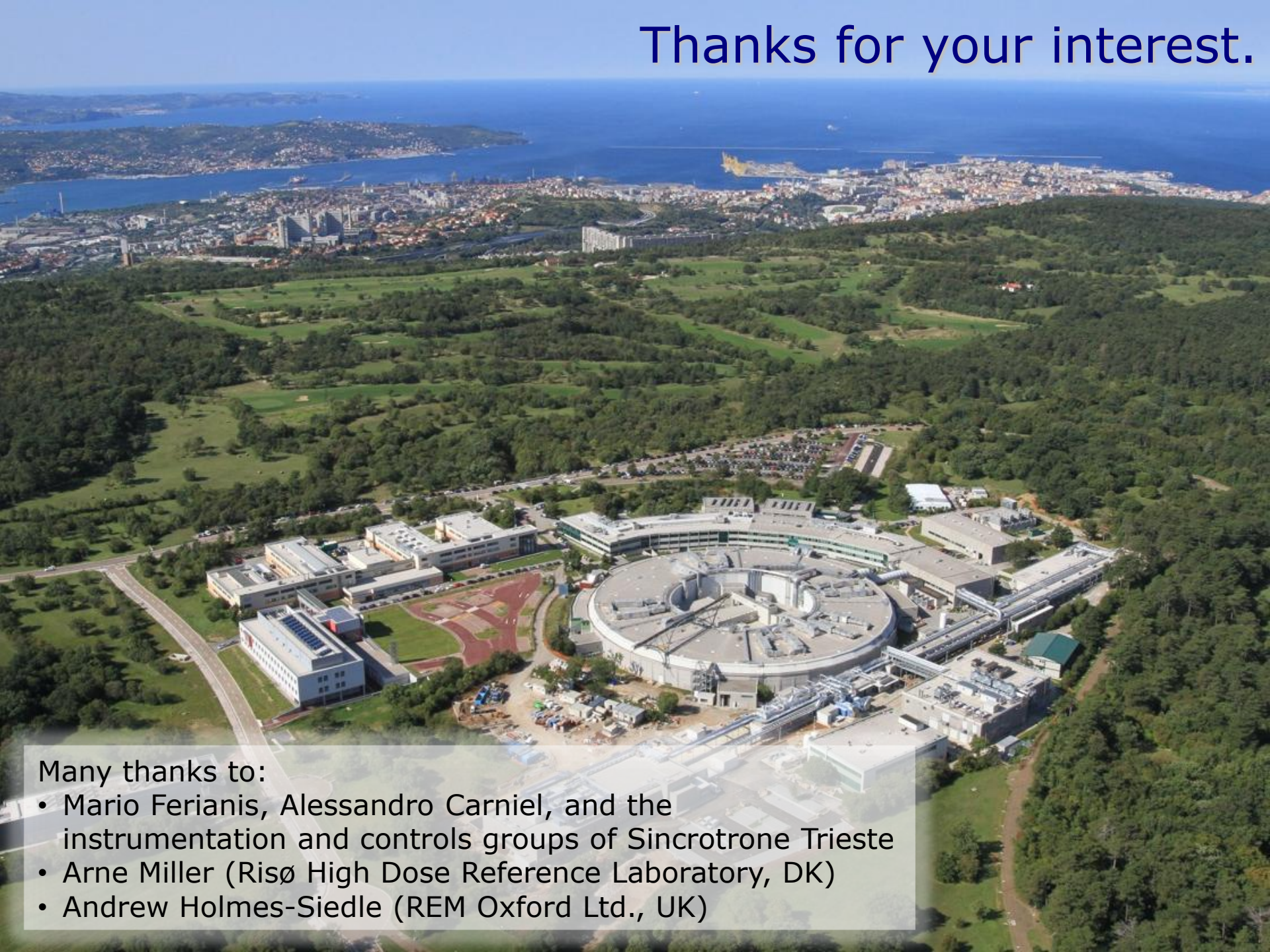
Dose Histories



First undulator of FEL-1:



Thanks for your interest.



Many thanks to:
- Mario Ferianis, Alessandro Carniel, and the instrumentation and controls groups of Sincrotrone Trieste
- Arne Miller (Risø High Dose Reference Laboratory, DK)
- Andrew Holmes-Siedle (REM Oxford Ltd., UK)