UNIVERSITÀ DEGLI STUDI DI TRIESTE
Dipartimento di Fisica
Department of Physics

INFN
Istituto Nazionale
di Fisica Nucleare
Sezione di Trieste

VXD Radiation and Environmental Monitoring

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INFN and Univ. Trieste
+ Electronics&Detectors group at Elettra, Trieste

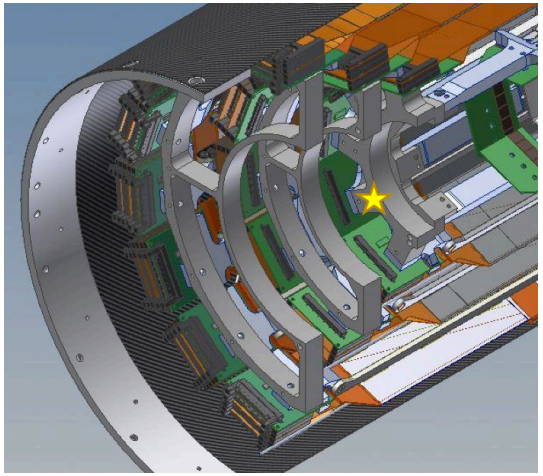
Outline

- Radiation monitor & beam abort
  - scCVD diamond sensors, electronics
  - Background simulations
  - Beast Plans
- Temperature monitoring
  - Optical Fibers Sensors (FOS)
  - NTC thermistors
- Humidity monitoring/interlock
- SVD+PXD interlocks: PLC

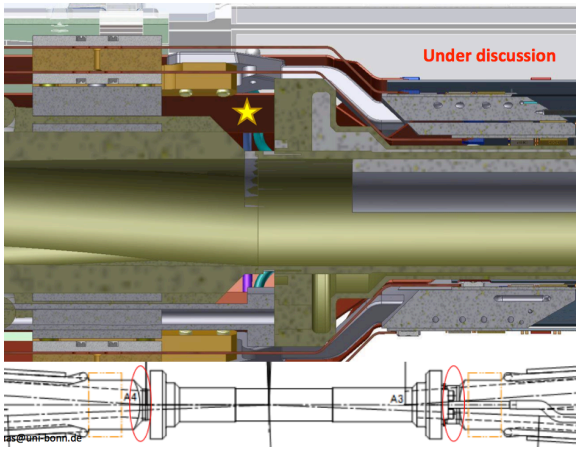
- Parallel session on Friday 10.30: discussion
- Still ongoing in Trieste: sensor testing - not covered in this talk

RADIATION MONITORING & BEAM ABORT

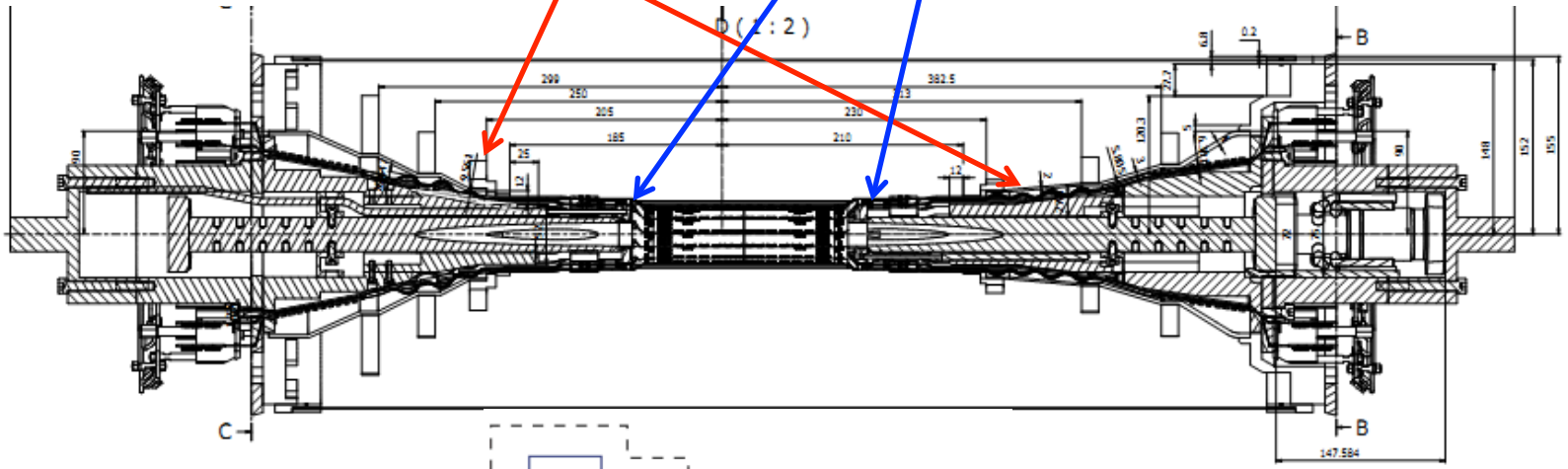
scCVD radiation sensors



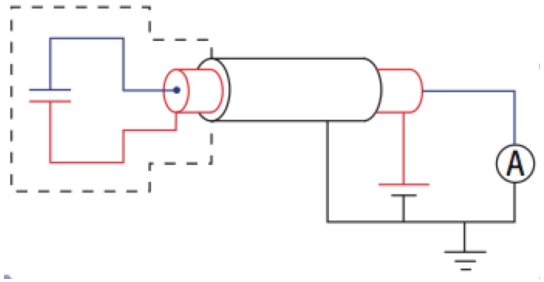
4 + 4 sensors
PXD-beam pipe



6 + 6 sensors
on SVD support cone
close to L3 rings



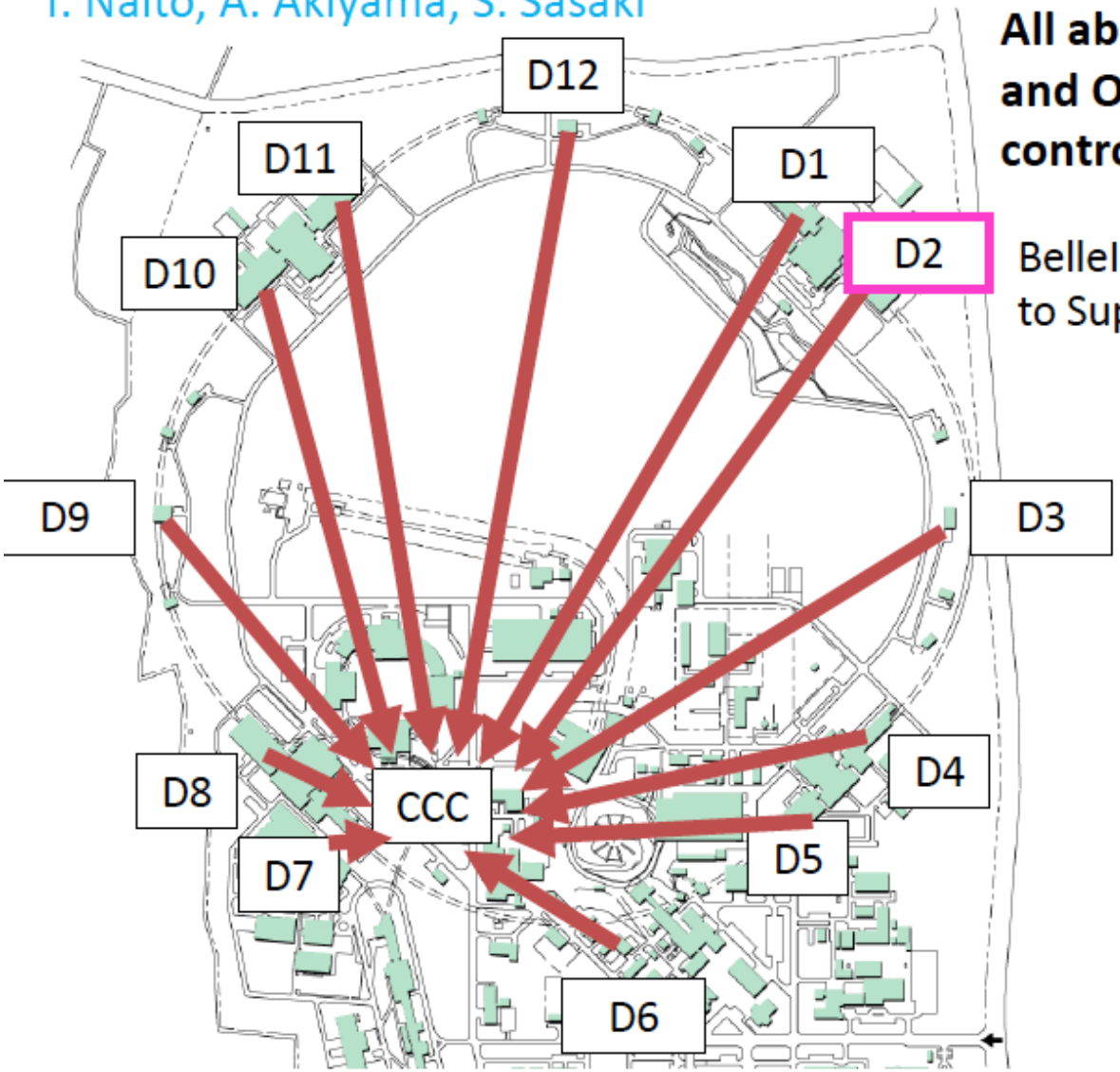
Shielded
diamond
sensors



3+15 m (3+40 m) cables
Voltage sources (150÷500 V)
picoAmmeters

Abort trigger system for SuperKEKB

T. Naito, A. Akiyama, S. Sasaki



All abort trigger signal is gathered and ORed together, at the SuperKEKB control building.

BelleII Abort signal is sent to SuperKEKB via D2.

Mechanics, cabling

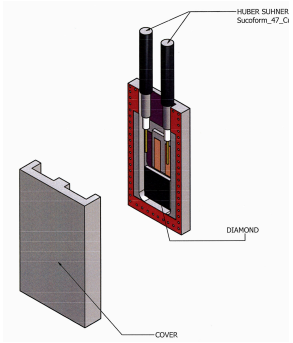
Compact packages:

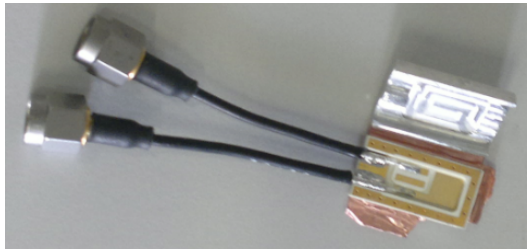
1) SVD 12 x 20 x 3.1 mm^3

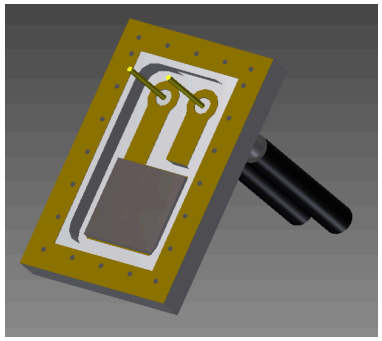
multi-layer package, Rogers laminate ok for SVD (we already have 28 pc)

2) PXD 12 x 10 x 3.3 mm^3

Same material, with perpendicular or parallel mounting (simulation)



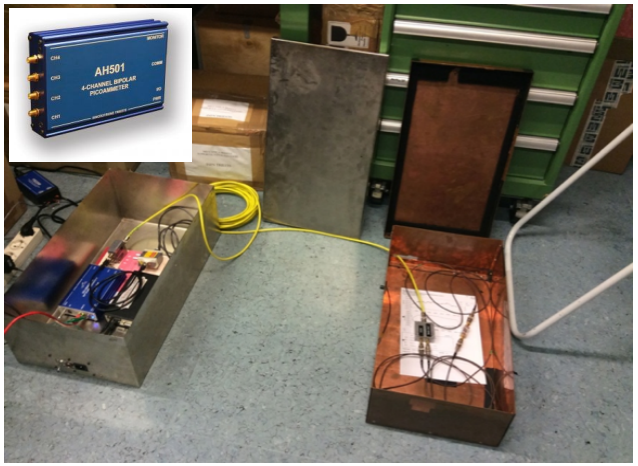




Cabling (~20 m)

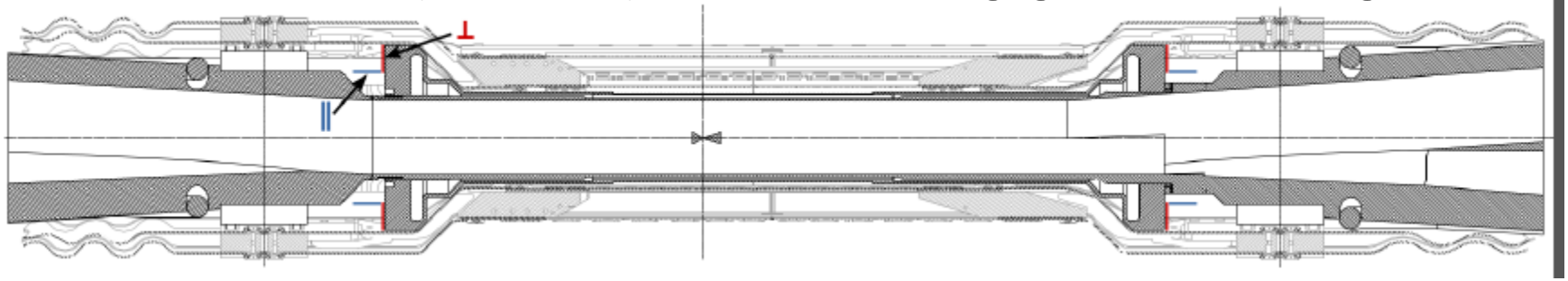
3 m coaxial thin (HS SM47LSFH) from sensors to DOCKs

+ 15 m (or more) HS S_04162-B60, double shield



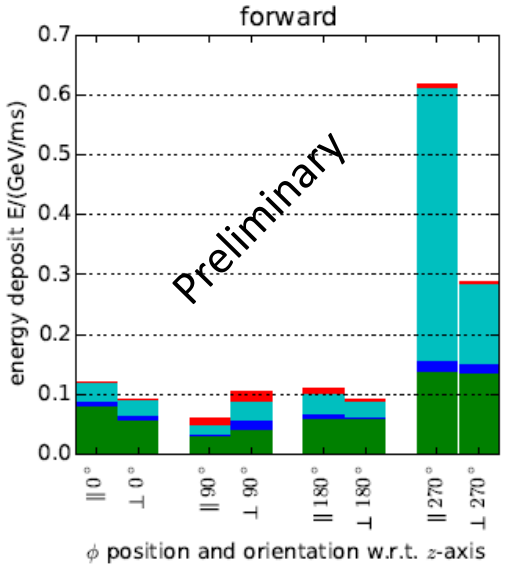
Expected radiation from simulations

VXD radiation/abort sensors included in simulation geometry, thanks to Martin Ritter MPI (Nov. 2014). Now Gianluca Inguglia DESY is taking over.

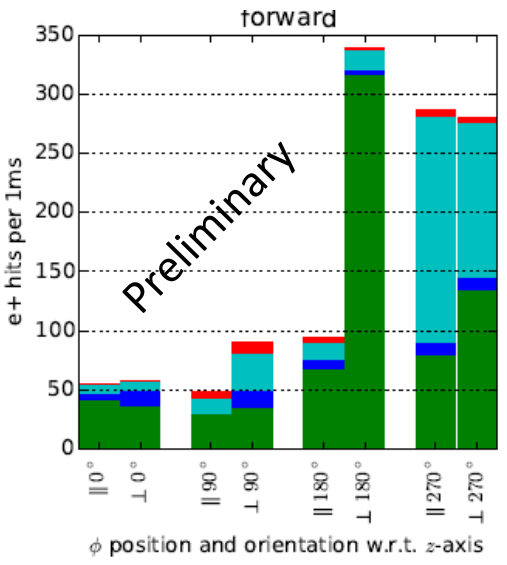


TwoPhoton Touschek RBB Coulomb

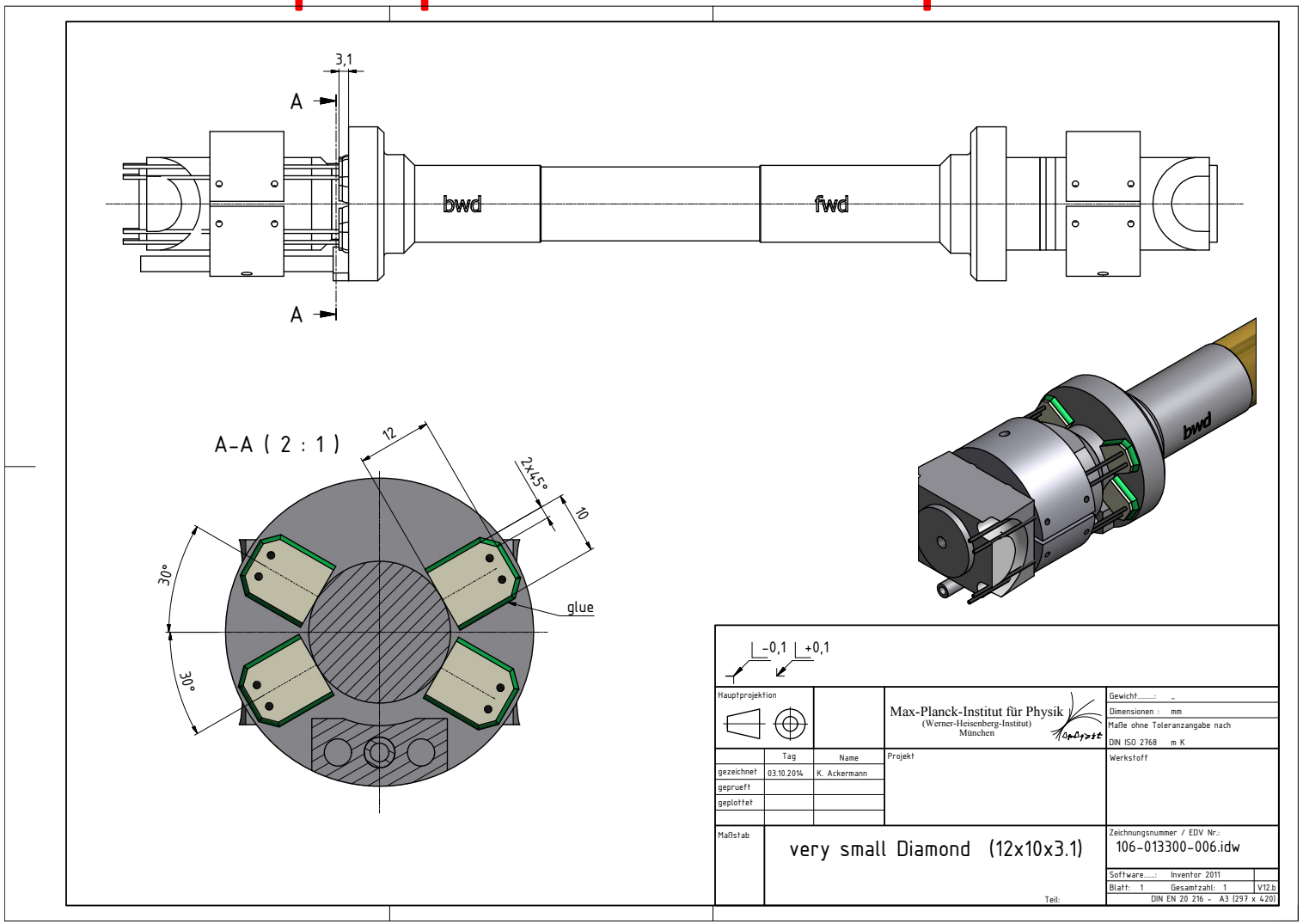
Energy deposit



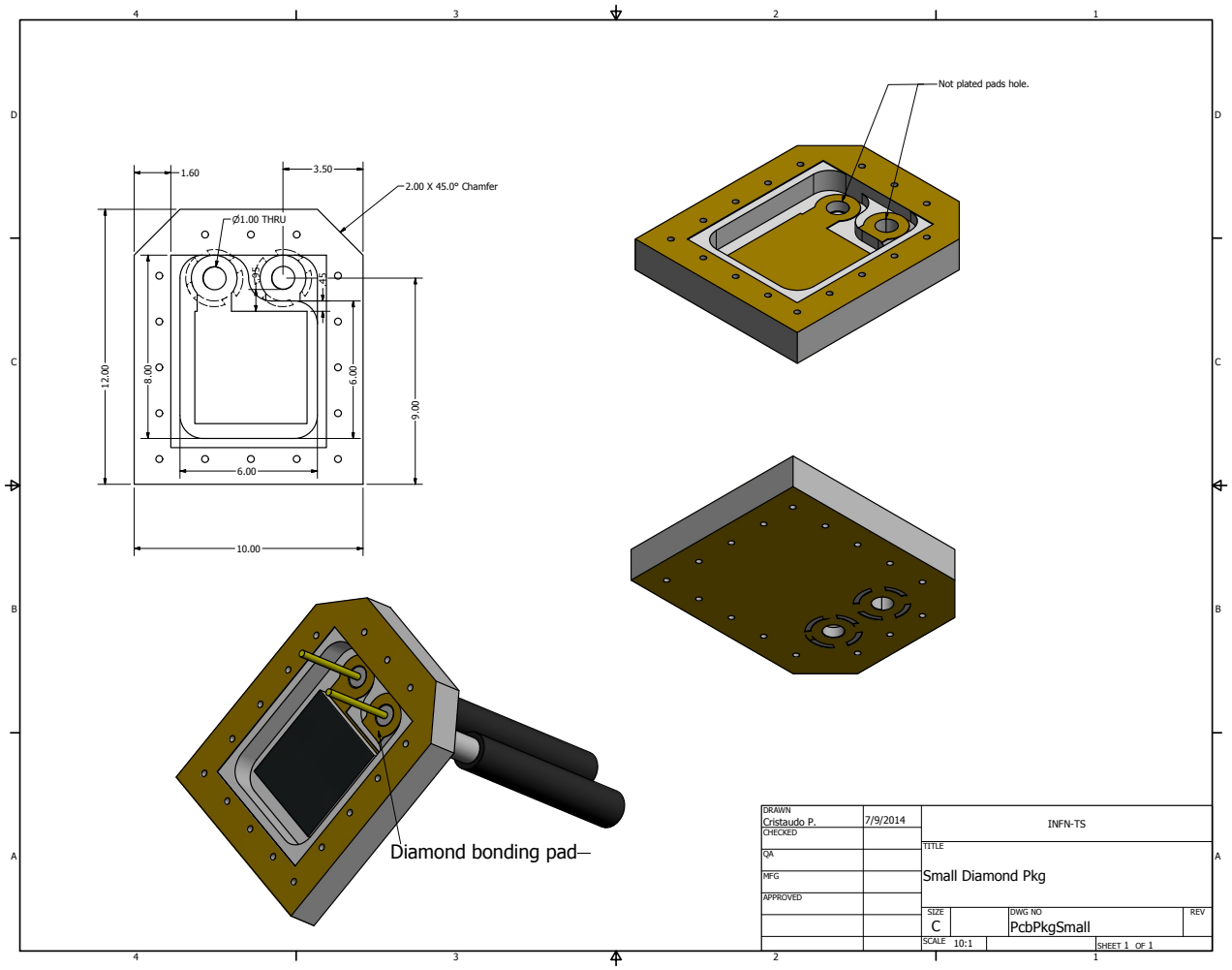
Particle fluence (e-)



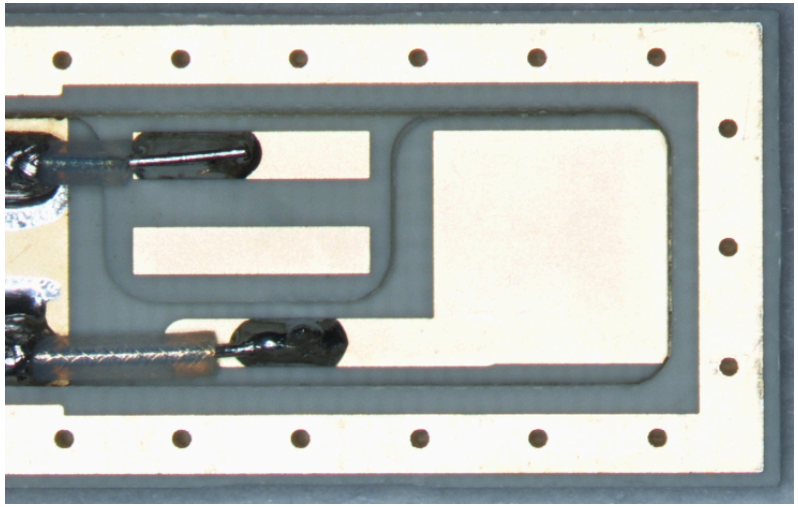
Location for “beam pipe” sensors: “perpendicular” option

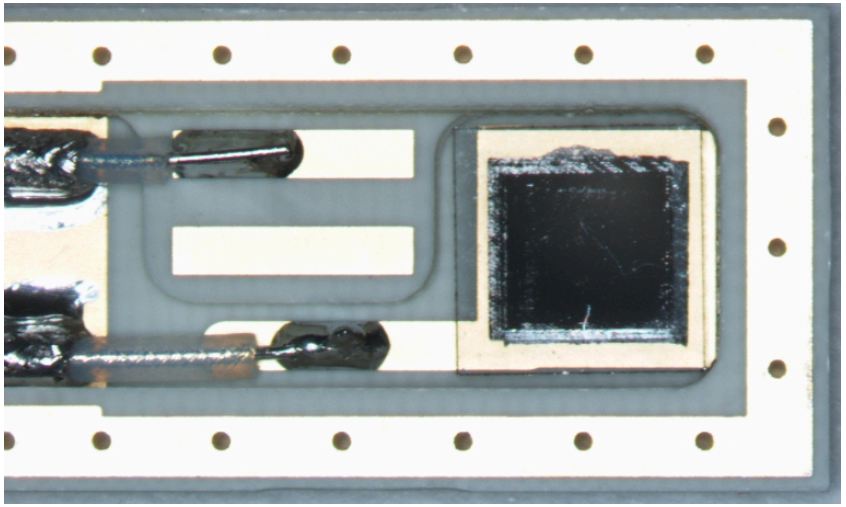


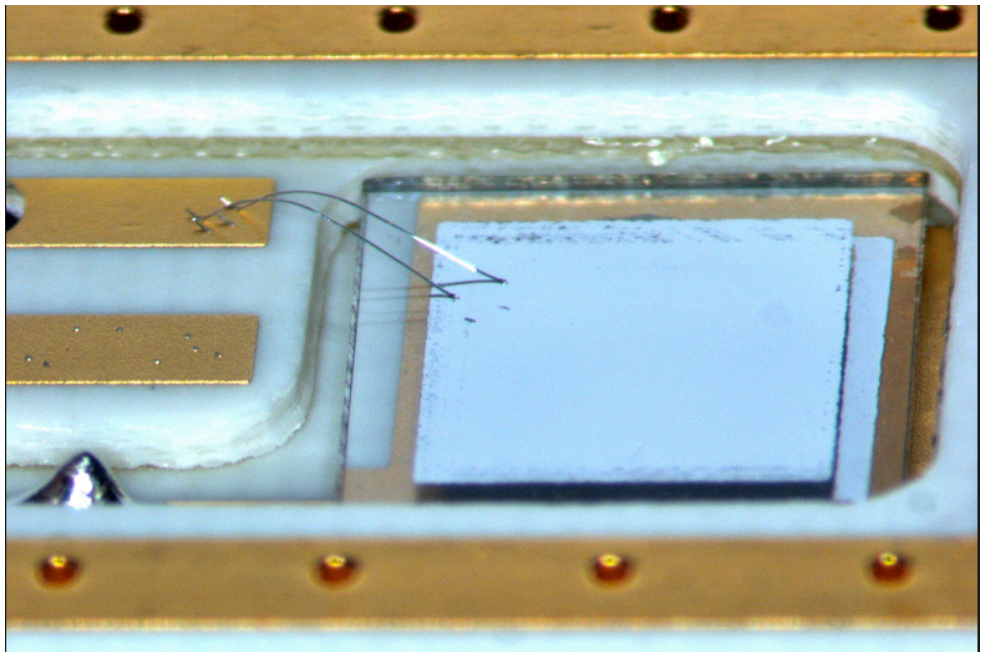
Modified package for “perpendicular”



First tests of “final” package

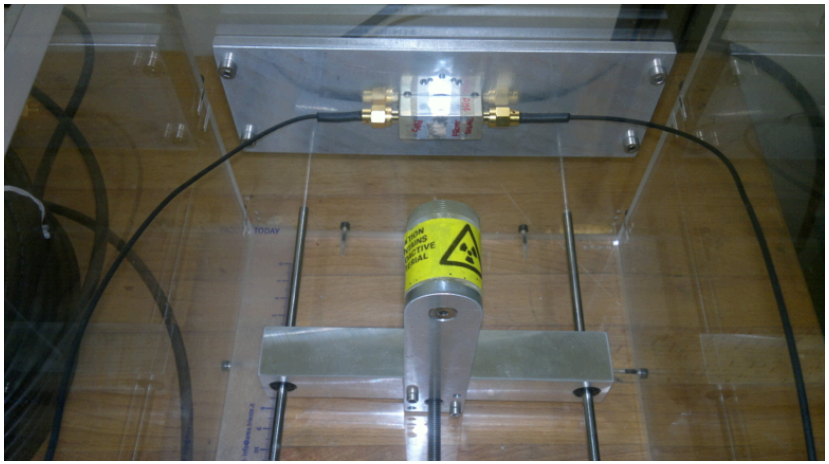


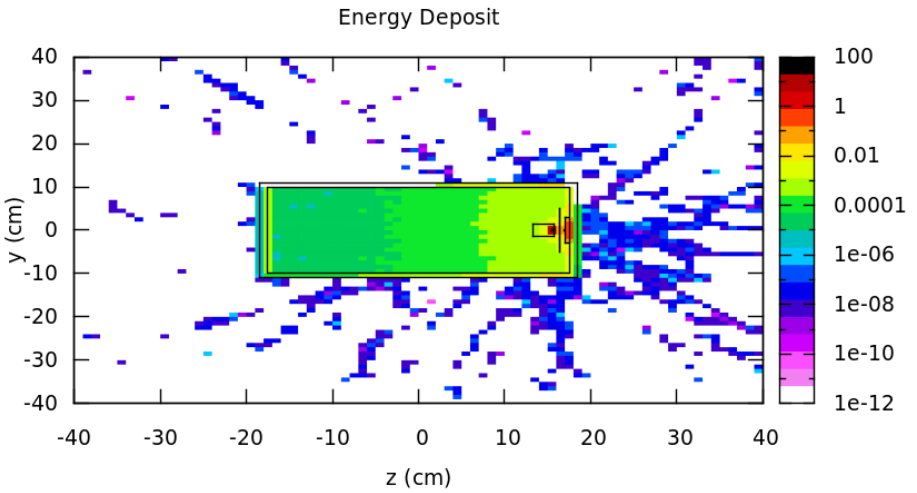


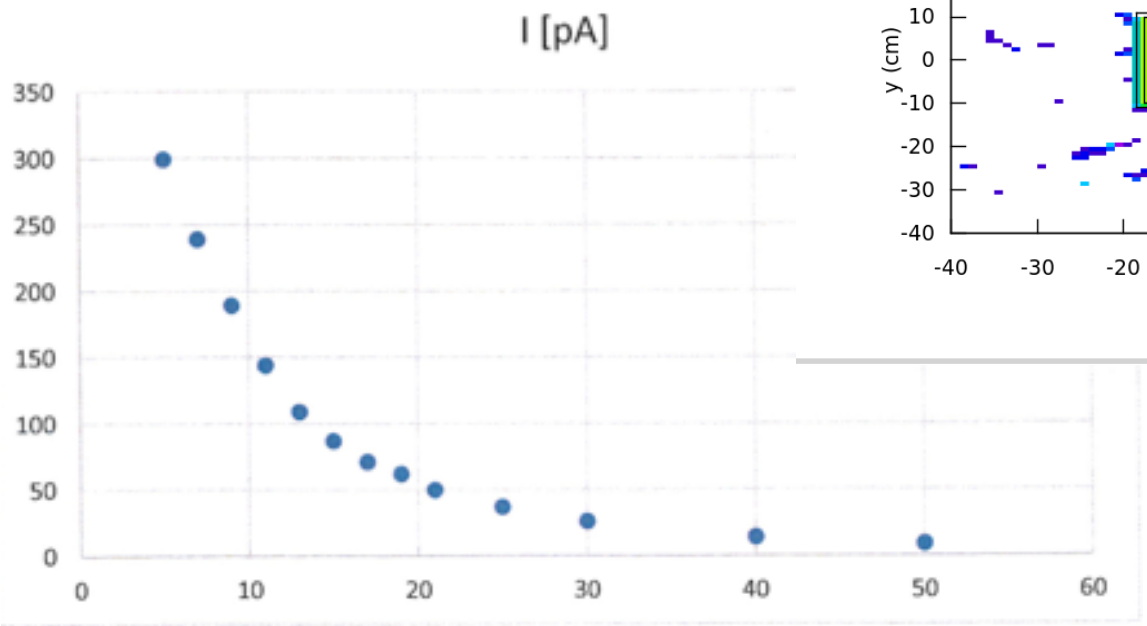


After MIPs tests: dosimetry

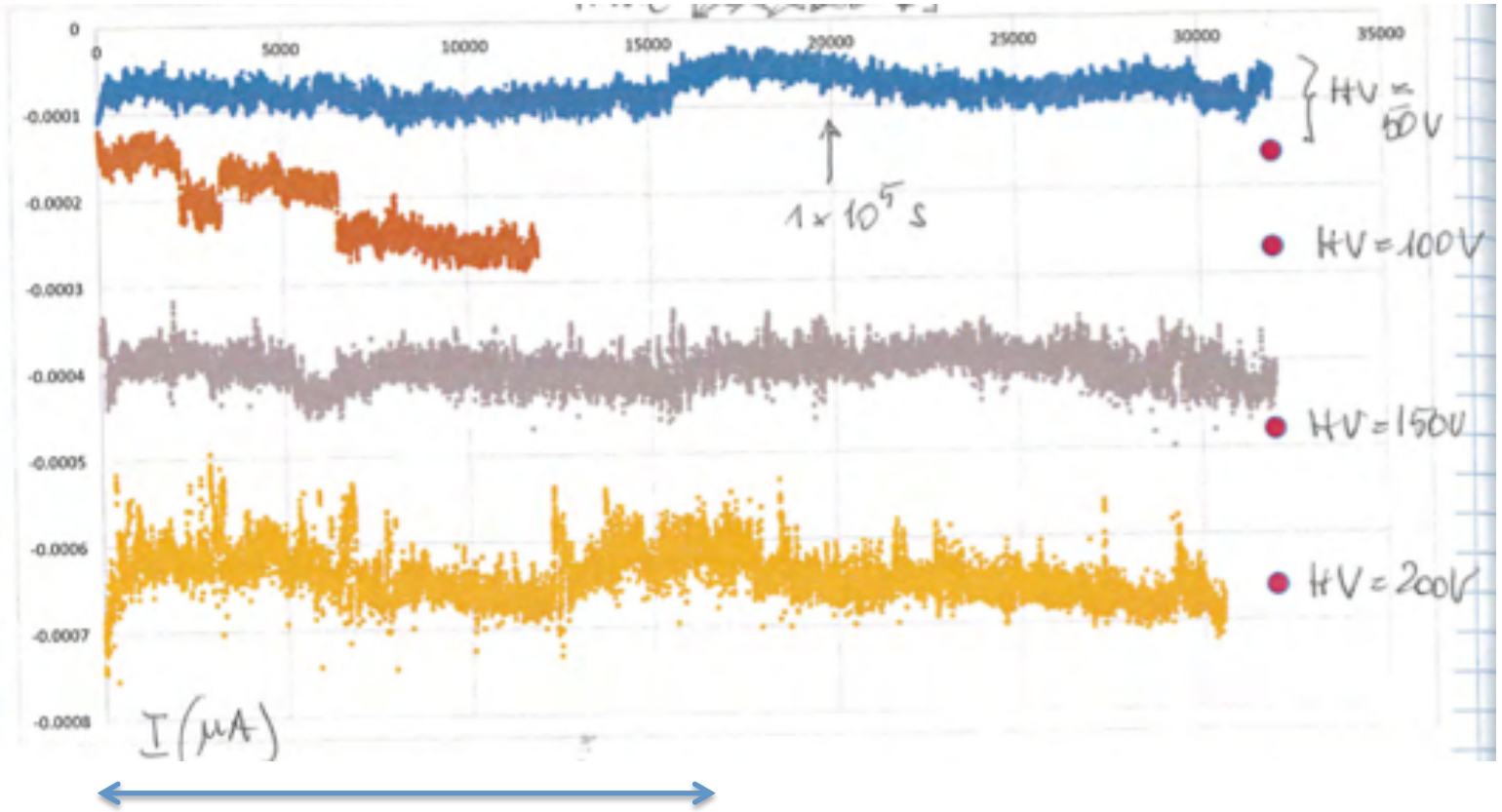
Sr90 point-like source, 3 MBq, at different distances, compared to FLUKA simulations







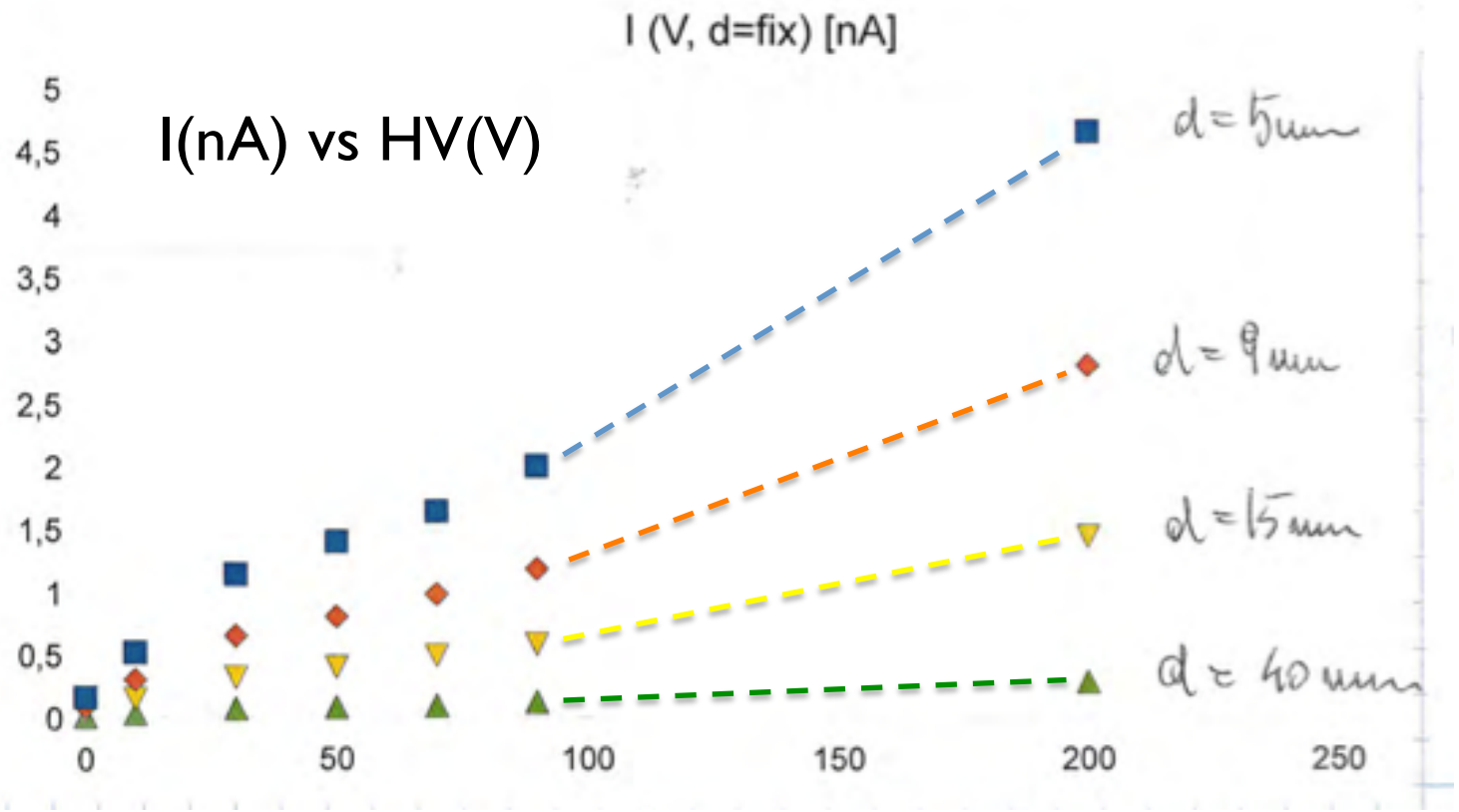
Long term stability studies



1 day

HV = 50-200 V

Current (dose rate) vs HV



unexpected voltage dependence (no saturation?)

- on both tested sensors (Micron)
- at all distances
- cross checked with different picoammeters

Diamond sensors are not that simple

- Simplest model: just “ionization chambers”, but…
- pCVD, known solid-state effects:
  - “pumping” or “priming” (filling of long-lived “deep” traps)
  - on/off transients (“shallow” traps, space charge and polarization)
  - electrodes: complicated metal-diamond interfaces
    - blocking vs. ohmic contacts, depending on materials & preparation
    - charge injection and “photoconductive gain >1” are possible
- scCVD: less defects, more stable behavior
  - However similar (smaller) effects are possible
  - Seen in our lab, to some extent (transients, gain?)

Sensors: plans

- One “final” Cividec prototype ordered recently
- Final acceptance tests will include:
  - I-V without irradiation, both polarities
  - Charge collection efficiency, MIPs (^{90}Sr β-source)
  - Currents/dose rates measurements (^{90}Sr β-source)
  - Measure electric field uniformity inside with TCT (Transient Current Technique) + ^{241}Am α-source
- At the moment Cividec
  - seems to be the most expert commercial provider of complete, metallized (and preliminarily tested) sensors
- Other solutions are still open (discussion Friday)

Cividec acceptance tests

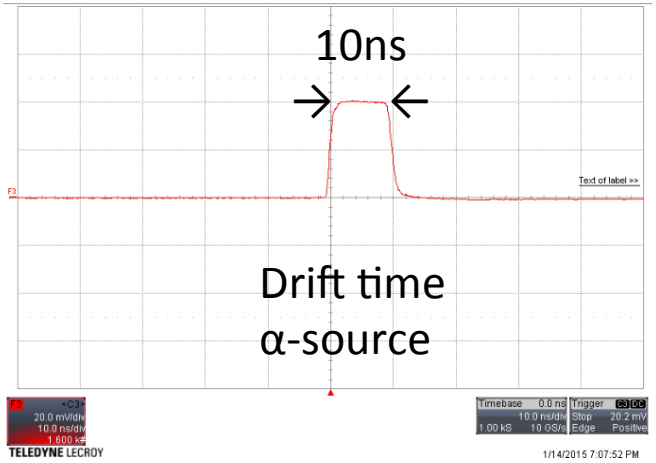
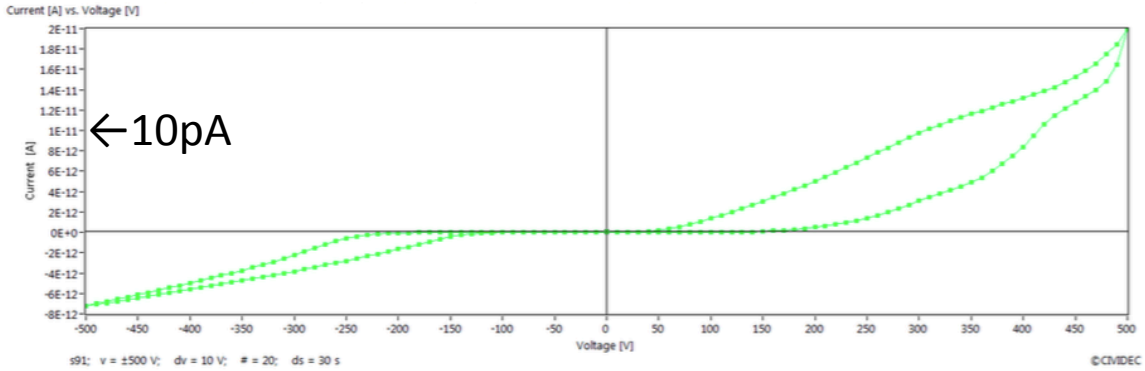
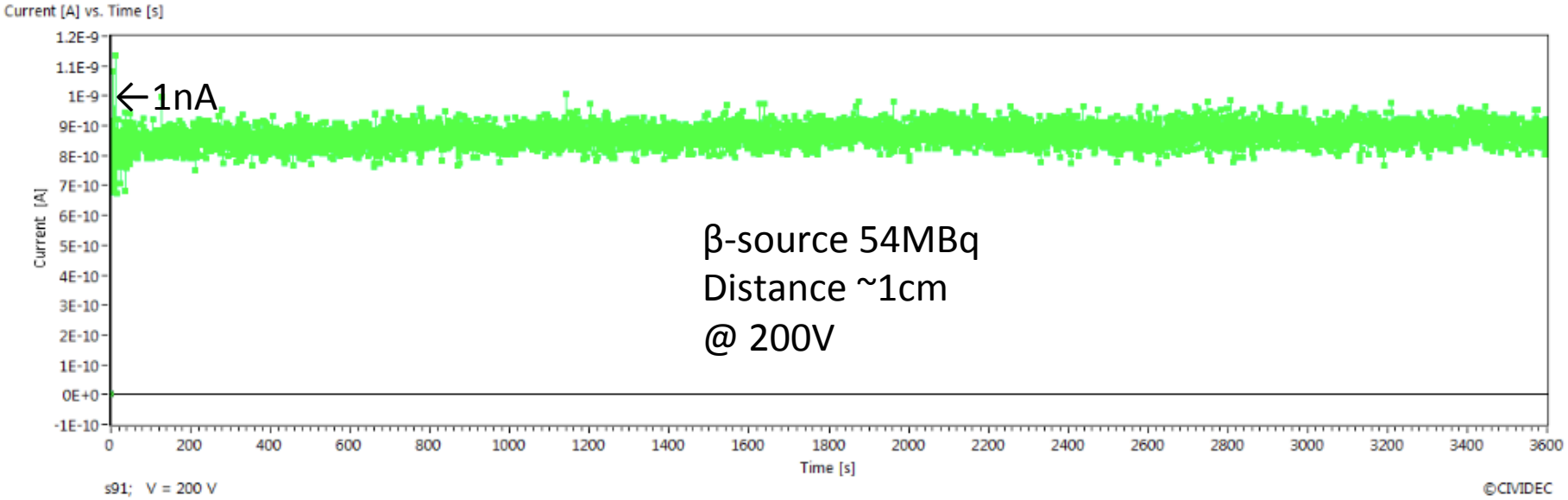


Figure 1: Response to α-particles.



500V

Figure 2: IV-curve.



3600 s

Figure 3: Long-term stability measurement.

Progress in electronics design

- Collaboration with electronics&detectors group at Elettra, Trieste
  - G. Cautero, D.Giuressi, R.H.Menk + F.Vulpone (student)

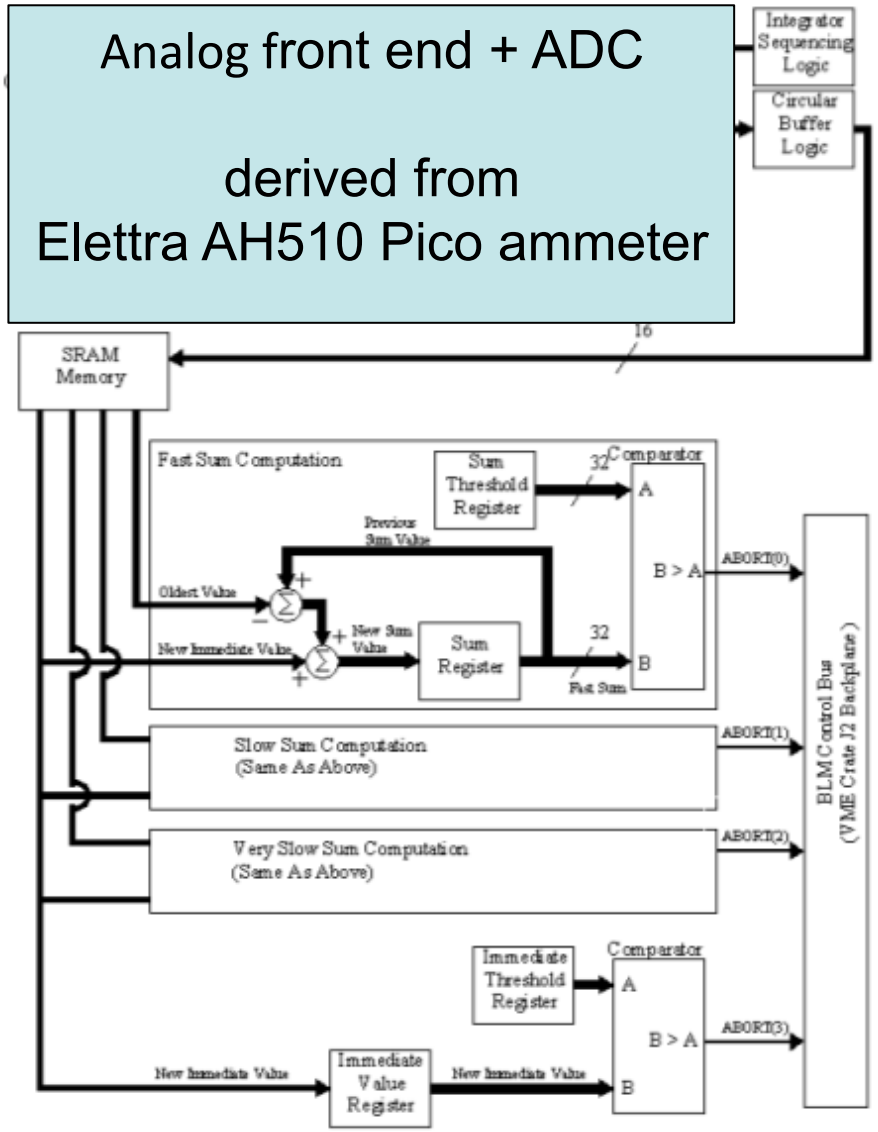
- Modular design, FPGA + Memory + ADCs + HV + Ethernet
  - project's kernel: ALTERA DE3 evaluation board, with a STRATIX III FPGA
  - External memory: Transcend 1GB DDR2 RAM
  - 3 peripheral boards will be connected with DE3
    - board with 4 ADCs, HSMC connector
    - board with 2 Ether-W-ease (Ethernet), 2 GPIO connectors
    - board with 4 DACs and 4 HV diamond bias outputs

- Schedule plans:
  - "Final" prototype available for test with 4 sensors at BEAST phase 1
  - "Production" modules ready for BEAST phase 2

BLM Digitizer Card ("logger"):
ADCs, circular buffers, running sums

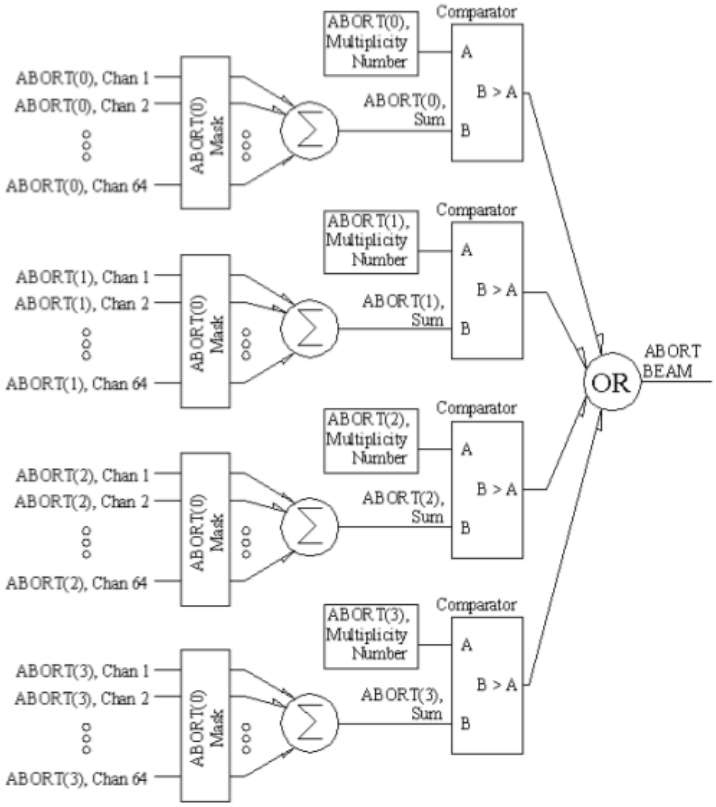
Analog front end + ADC

derived from
Elettra AH510 Pico ammeter

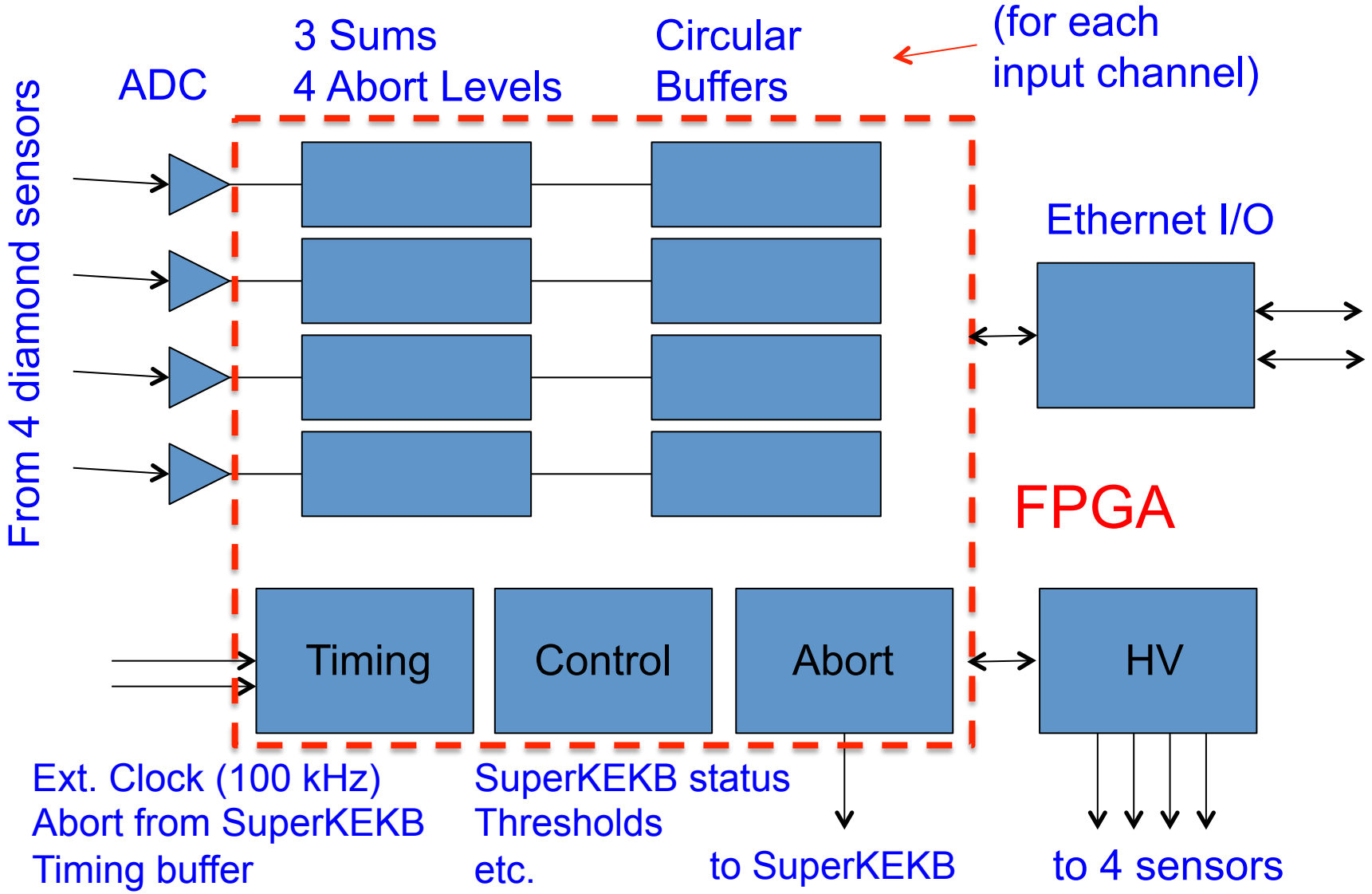


Desired functionality:
similar to Fermilab BLM

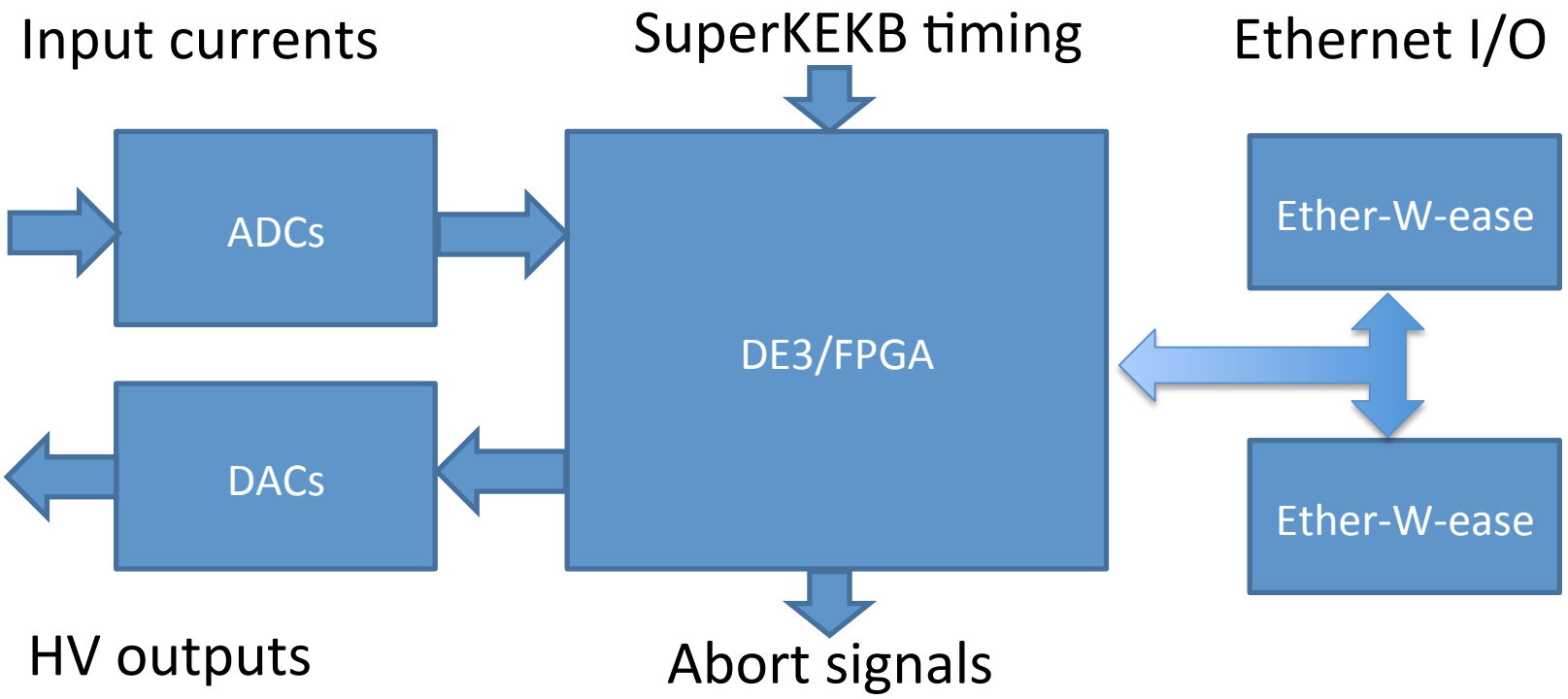
BLM Abort Card:
masks, majority logic,
thresholds (4 levels)



Rad.Mon+Abort, 4-channel Box

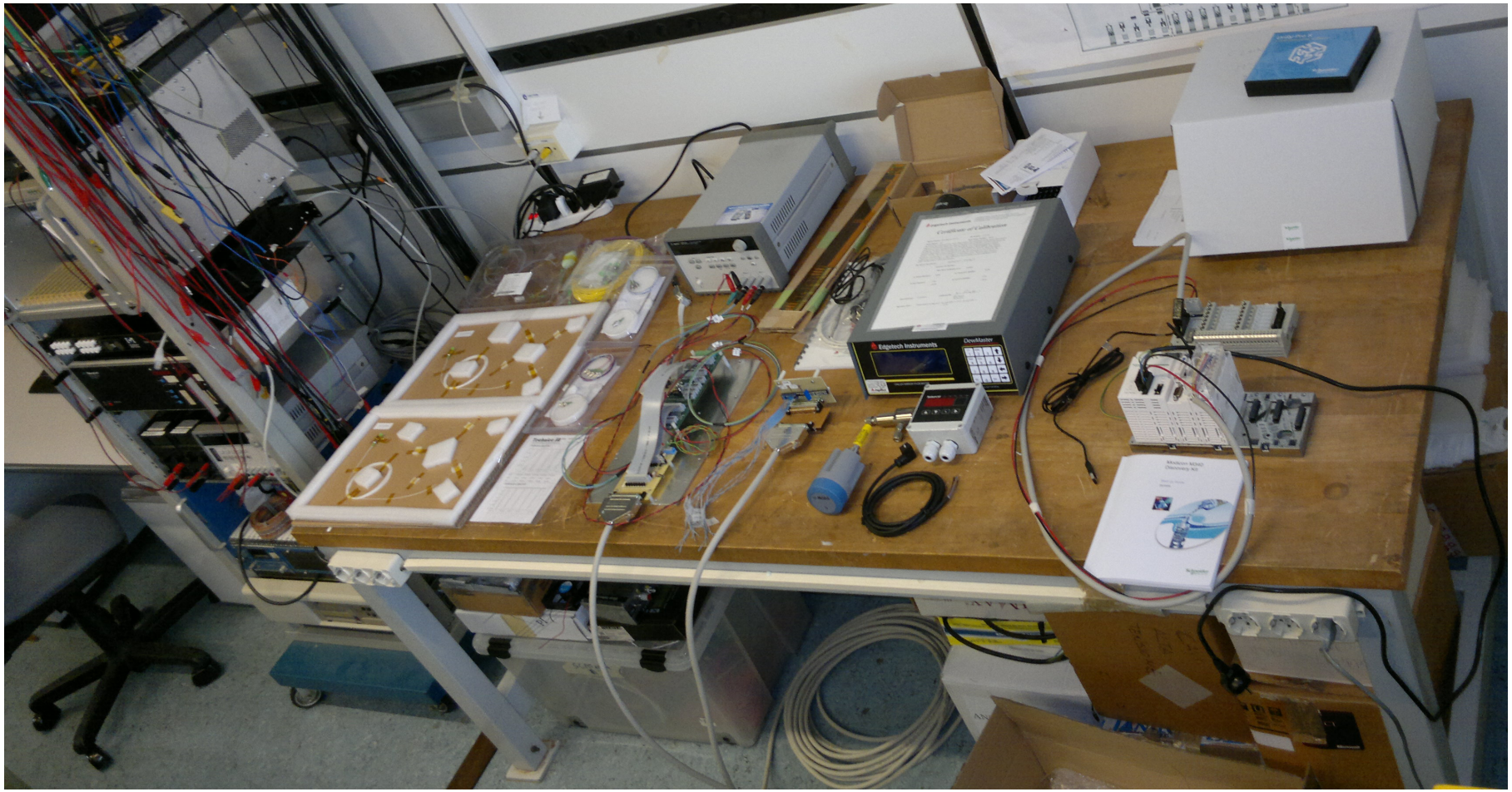


Design and implementation plans



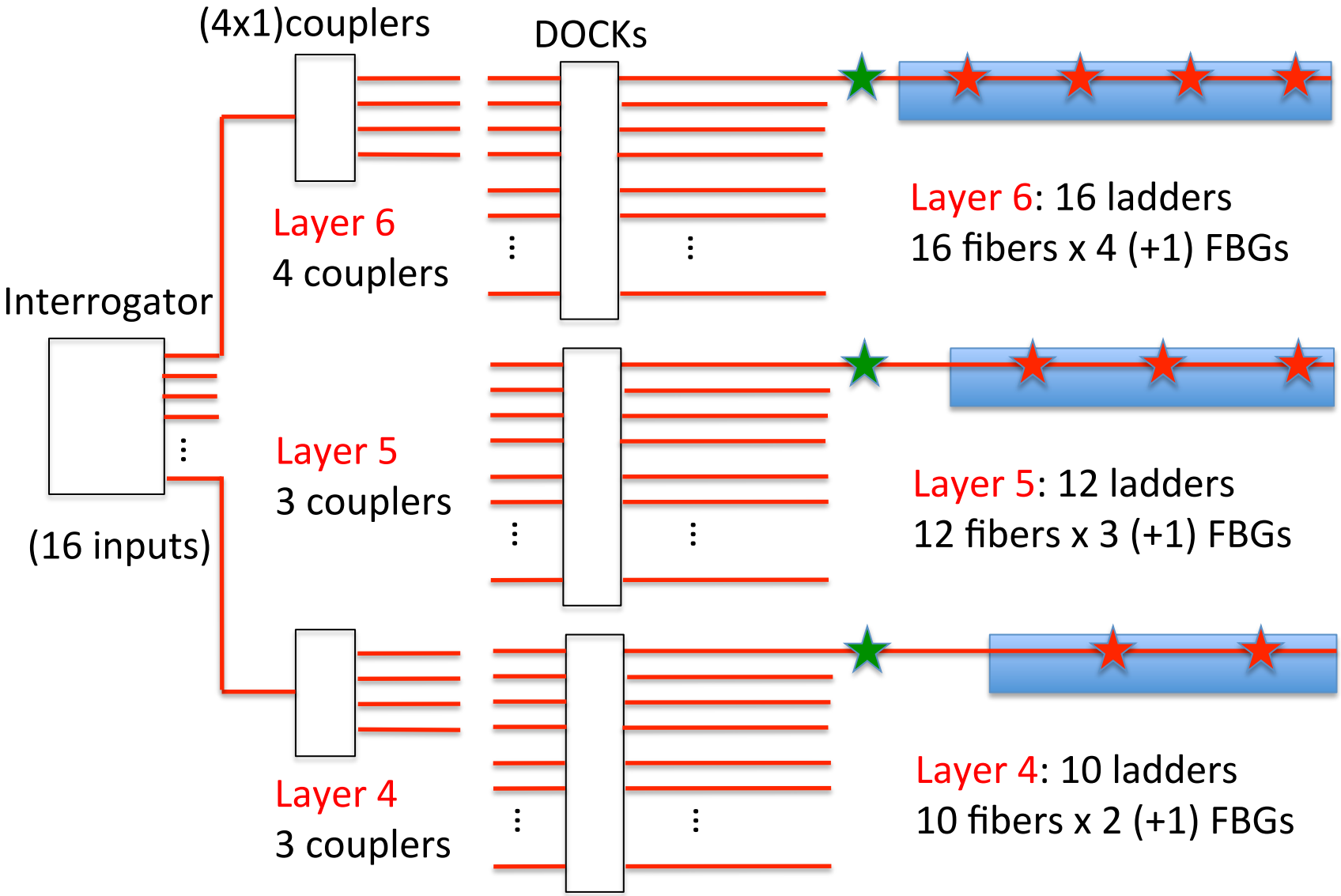
- Read and write the external RAM memory using the FPGA
- Design and prototypes of the ADC's and DAC's boards
- Design and prototype board with two Ether-W-ease
- VerilogHDL program for the FPGA

  Synchronization, buffers, running sums, thresholds, abort logics

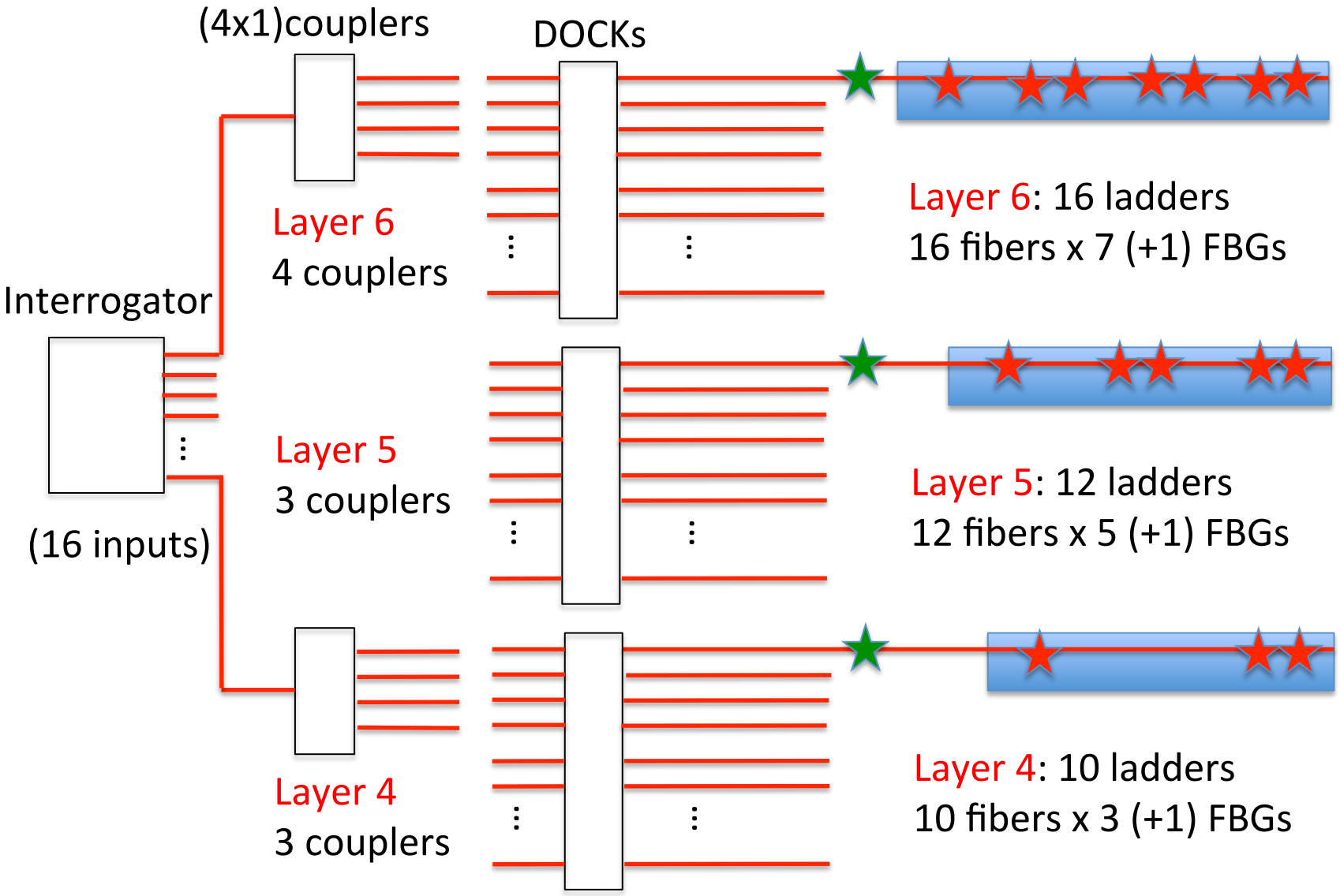


ENVIRONMENTAL MONITORING

SVD FOS fibers system (baseline)

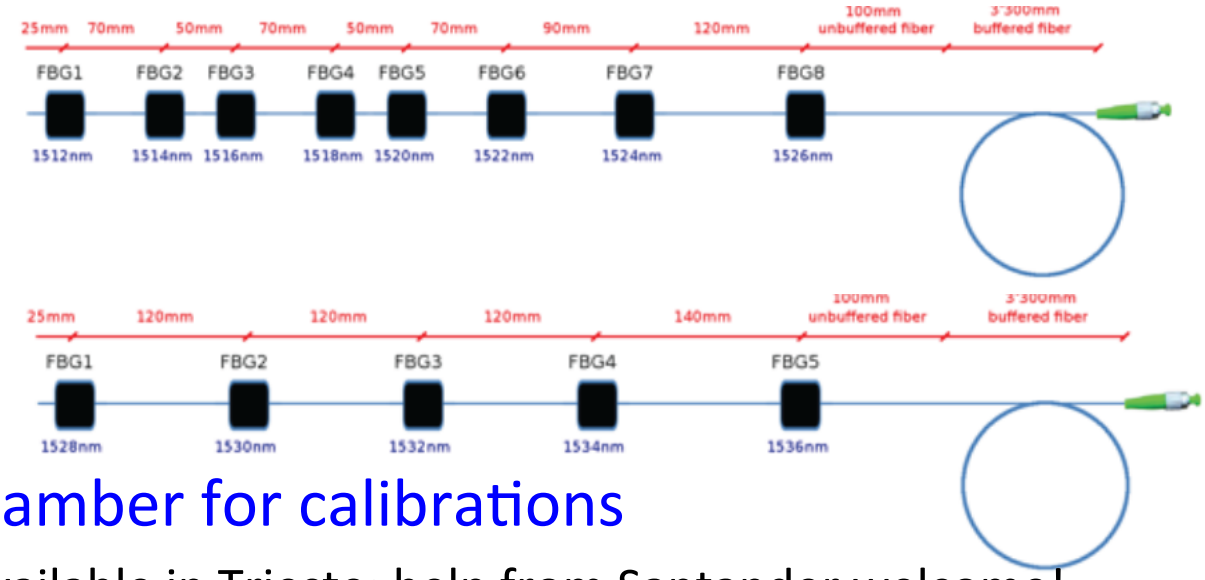


SVD FOS fibers system -2 FBGs/origami



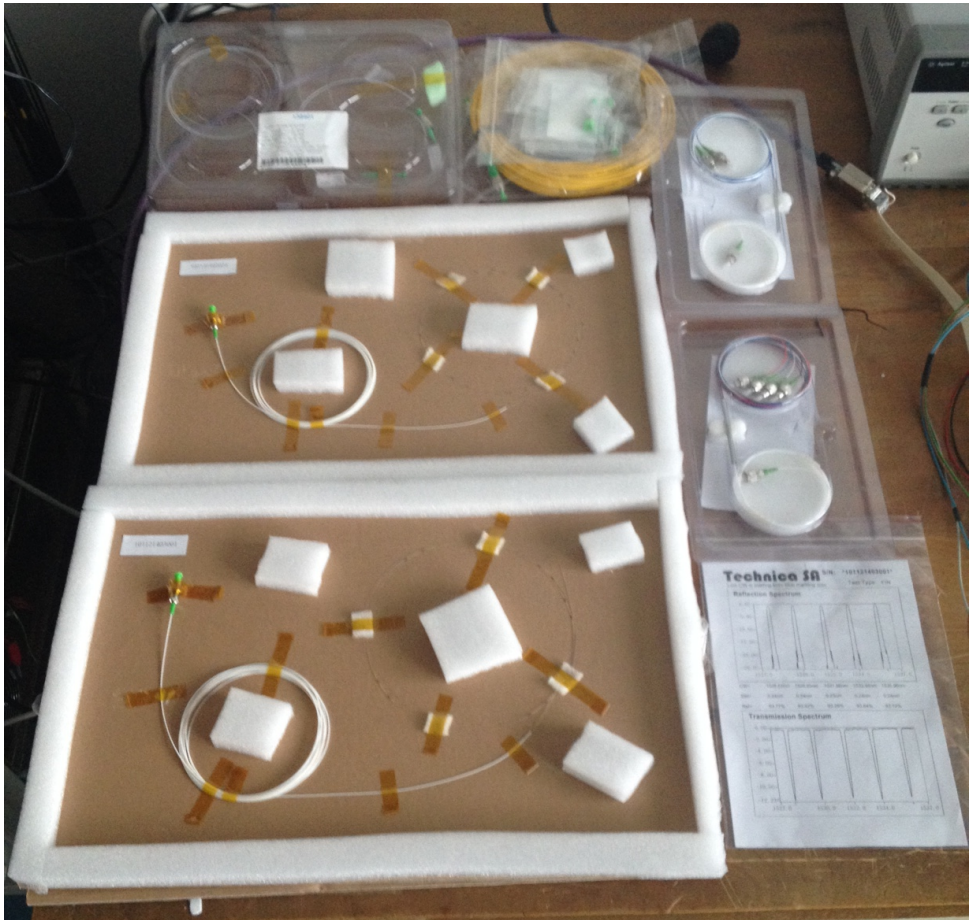
FOS temperature sensors: status

- Recent purchases (delivered last week and yesterday):
  - 16-channel interrogator, Micron Optics (Pisa)
  - Prototypes with different numbers of sensors per fiber, from 2 providers:
    - Micron Optics
    - Smart Fibres
  - Final purchases
    - 38 fibers
    - Early 2015



- Environmental chamber for calibrations
  - [−30°C ÷ +70°C], available in Trieste; help from Santander welcome!

SM 225-800 16-channel interrogator, Micron Optics



Test fiber received from Santander

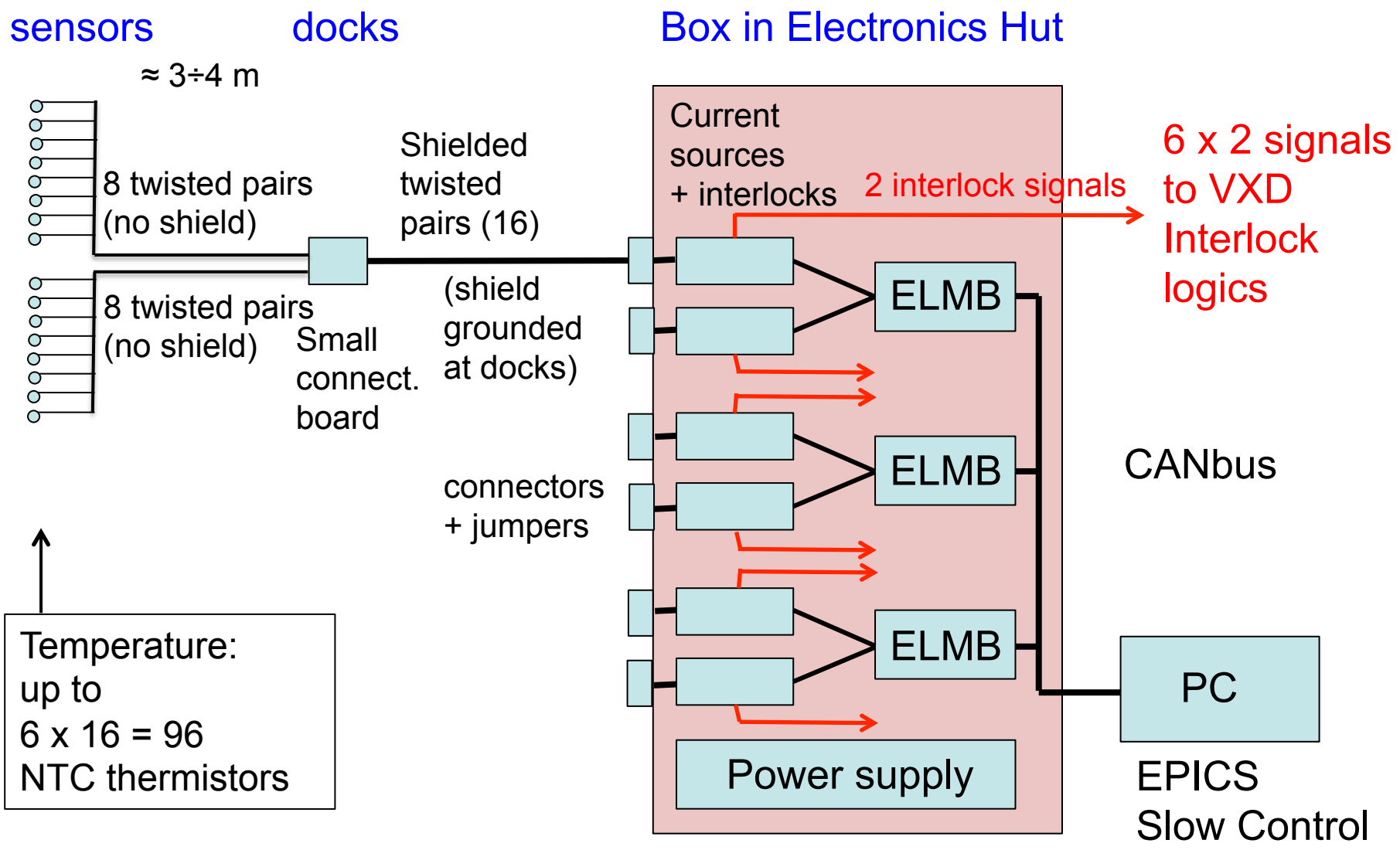
(2x1)coupler

Fiber with 8 sensors

(4x1)coupler

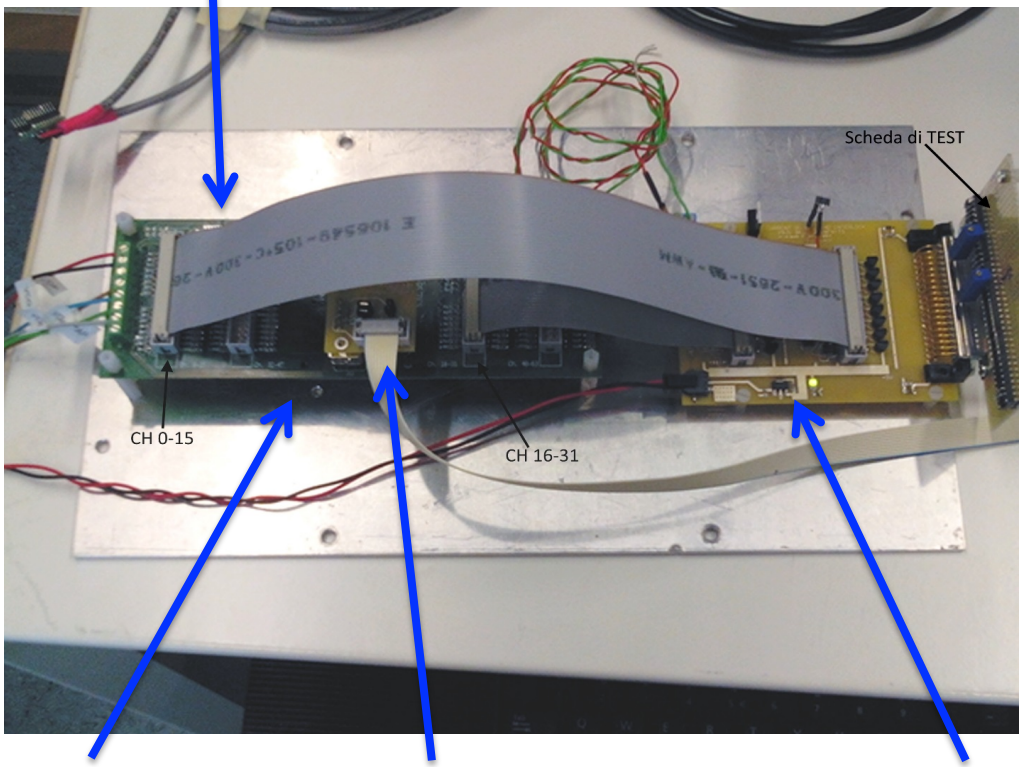
Fiber with 5 sensors

NTC ELMB readout, preliminary design

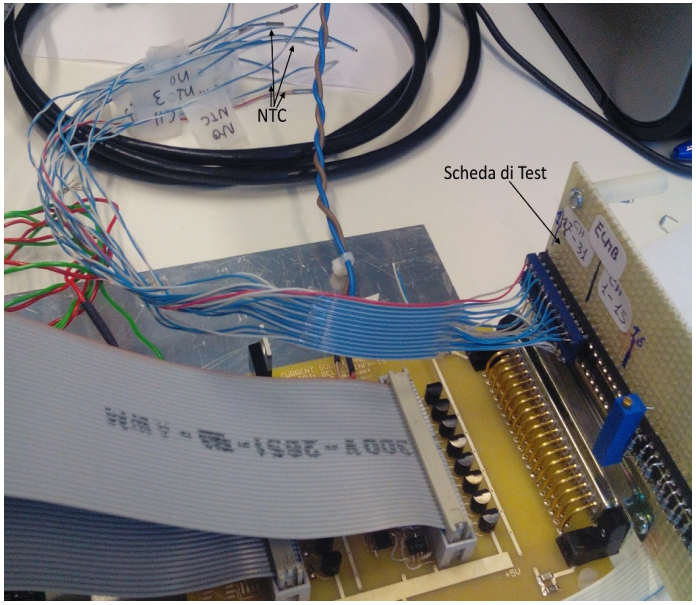


NTC: full prototype chain tested

Motherboard



100k NTC thermistors
- Betatherm (TS)
- Murata (Vienna)



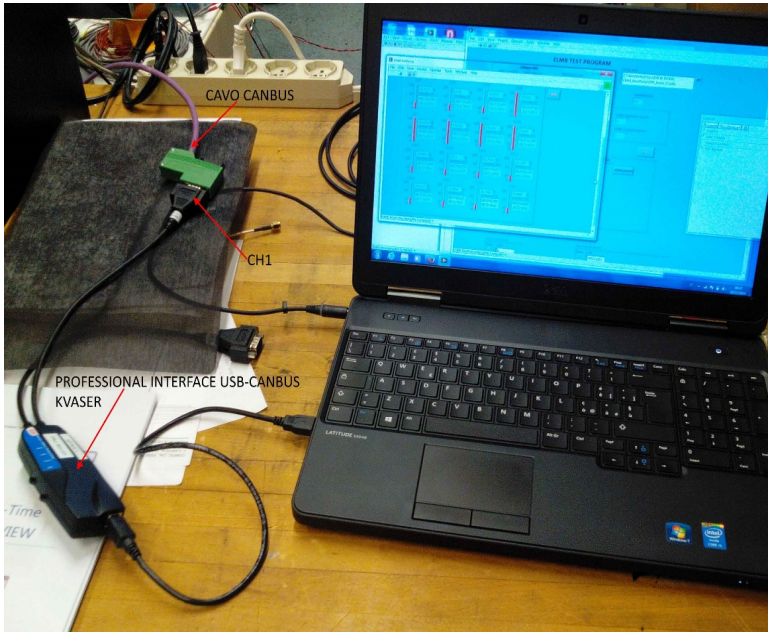
ELMB board

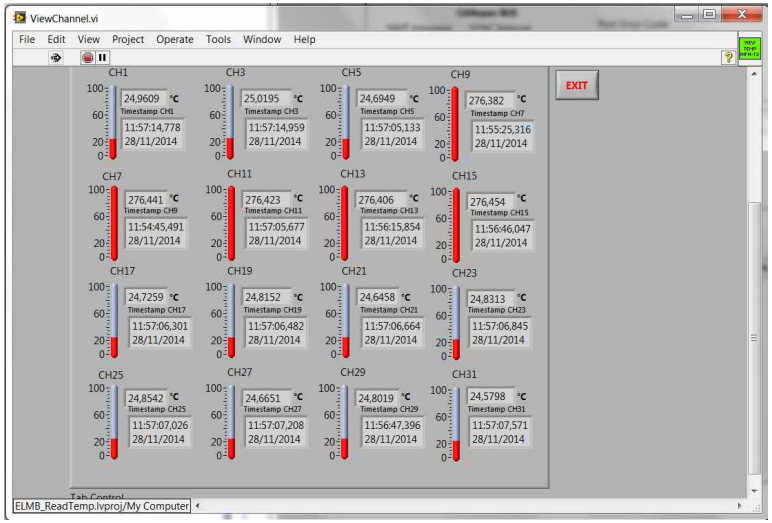
CANbus adapter

Current sources
Interlock comparators

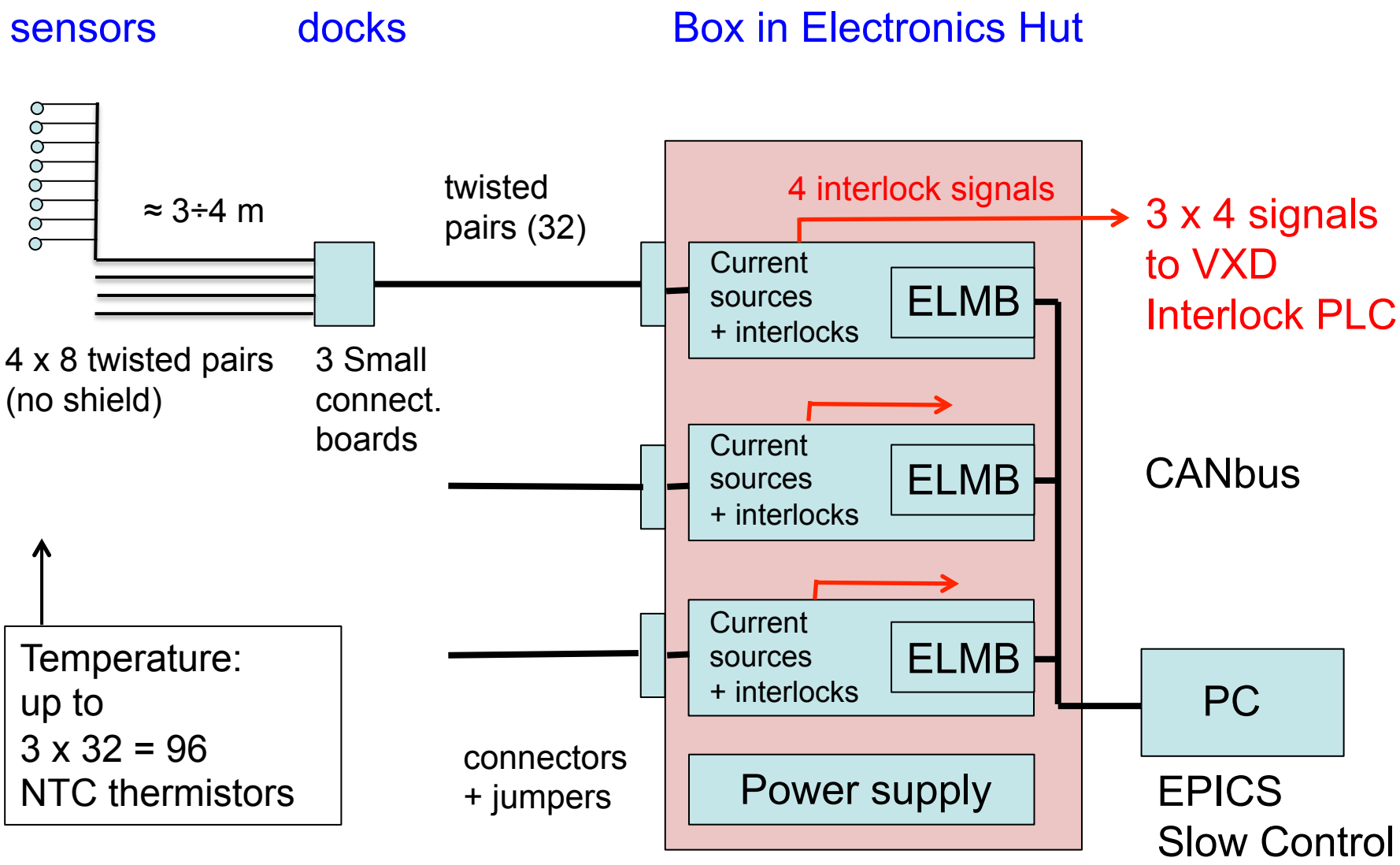
Interface, software and stability

- New Kvaser CANbus-USB interface installed
- Software
  - Stand-alone debugging program
  - LabView + CANopenOPCServer 2.9.7.4
  - EPICS: expert visit welcome
- Uniformity and stability tests on 11 thermistors
  - OK !



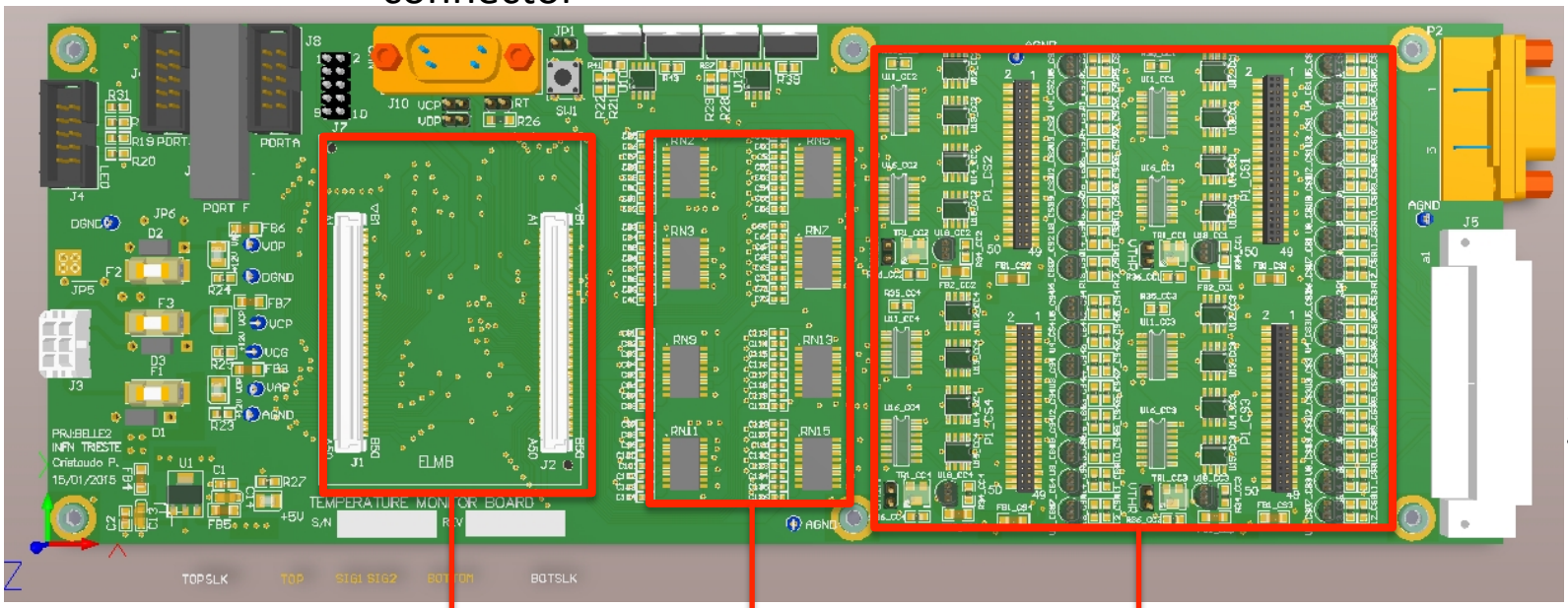


Final motherboards design, completed



“Final” NTC ELMB design readout and interlock board

CANbus connector



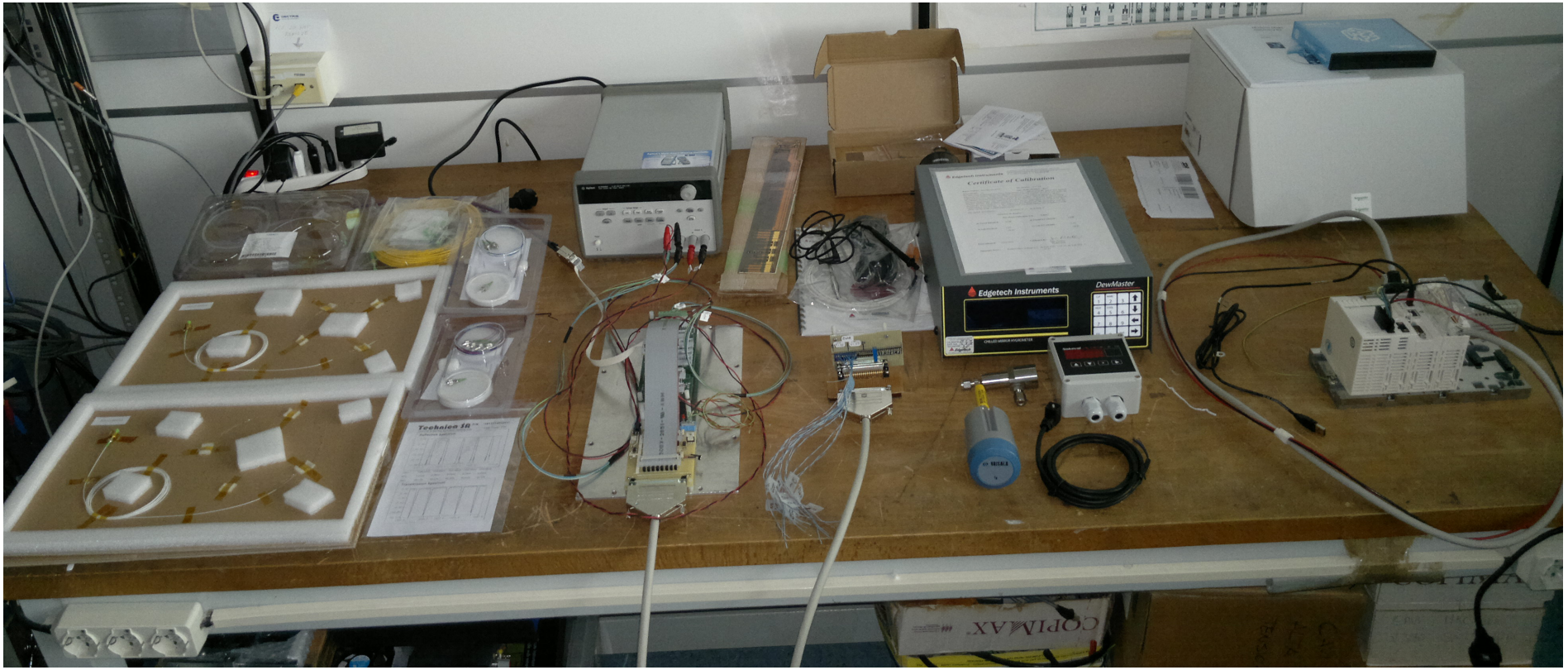
interlock to PLC

Input 32 NTC

ELMB

Reference resistors

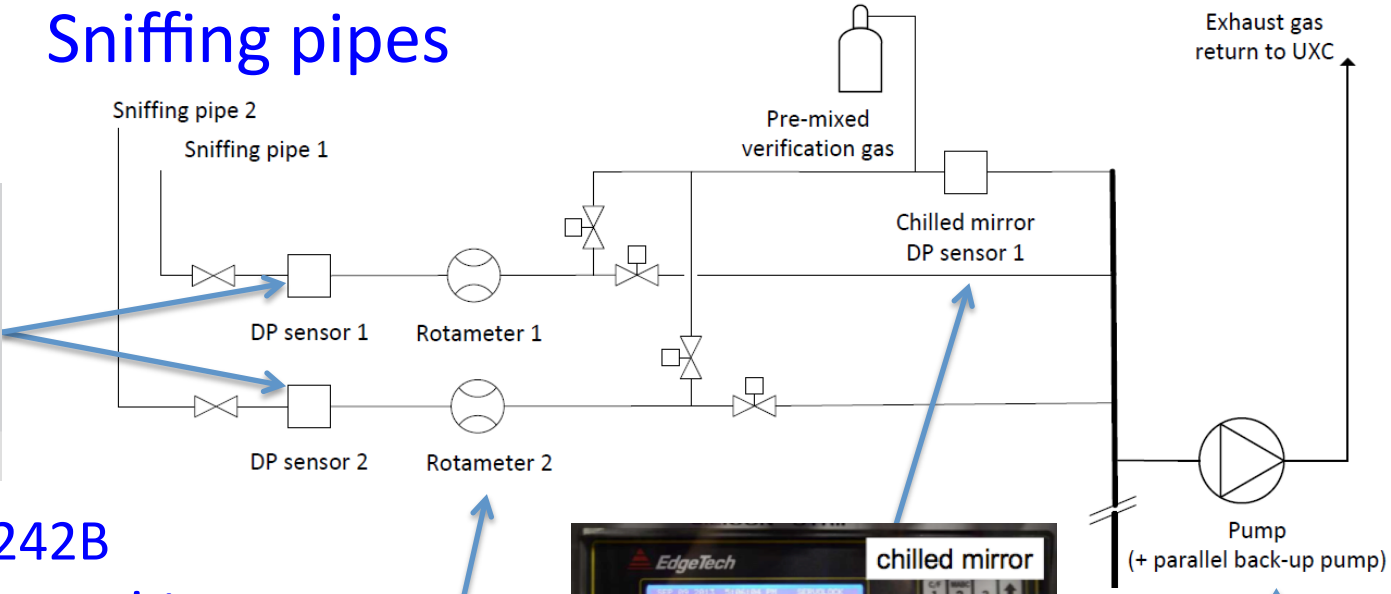
Current sources and interlock comparators



HUMIDITY MONITORING & INTERLOCK

Dew Point Sensors (interlock @ -30°C)

Sniffing pipes



Vaisala DMT242B
Dew Point Transmitters
[-60, +60]°C dew point range

Edgetech Dewmaster
Chilled Mirror Hygrometer
(for calibrations)

Rotameter
flux meters

Pump

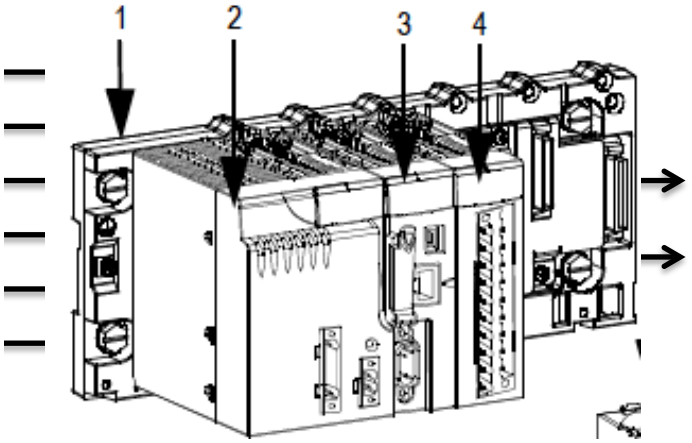
Main components received
Prototype planned (1st quarter 2015)

INPUTS

INTERLOCK LOGICS

OUTPUTS

Temperature (NTCs)
Dew point (Vaisala)
Sniffer Pump(s)
Cooling plant failure
Beam Abort
Fire alarm?
…etc



PXD power supplies
VXD power supplies
(not segmented)
…etc

Programmable Logic Controller (PLC)
Schneider M340 – cpu BMX P34 2030
Modbus/EPICS drivers exist! expandable
kit (p.s. + cpu + I/O + software) purchased
Local expertise: INFN technician

SVD + PXD INTERLOCKS

Summary

- Good progress on:
  - Radiation monitor & beam abort
  - Temperature monitoring
  - Humidity monitoring/interlock
  - SVD+PXD interlocks: PLC
- Documentation to be prepared!!!
- Parallel session on Friday 10.30: discussion
- A very busy period also for us …

Approximate schedule

Radiation	2014				2015				2016	
What	1	2	3	4	1	2	3	4	1	2
Specifications, sign up										
Simulations										
Dosimetry, characterization										
Diamond sensors choice										
Mechanics & cabling design										
Electronics specifications										
Electronics design & proto.										
Overall design, sign up										
Components, procurement										
"final" prototypes (4 ch.)										
BEAST, 1 preliminary tests										
BEAST, 2 complete test (4 ch)										
electronics production & test										
sensors installation & cabling										
electronics installation										

Temperature & humidity	2014				2015				2016	
What	1	2	3	4	1	2	3	4	1	2
T&H Specifications, sign up										
Fibers, mechanical layout										
Fibers, assembly tests (SVD)										
Fibers, multiplexing scheme										
Fibers design sign up										
Procurement, assembly										
installation (PXD & SVD)										
Thermistors, lab tests										
Mechanics & cabling design										
Procurement										
assembly, installation										

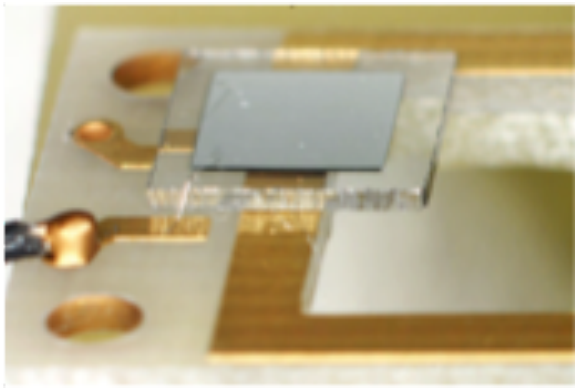
Back-up slides

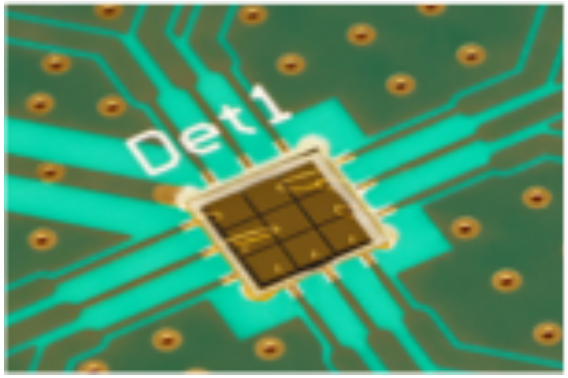
Diamond sensor characterization

Label	Provider	sc/p CVD	Geometry mm^3	pads	Validation ^{90}Sr beta
PD	DDL	sc	4.7x4.7x0.15	2x2	OK
DC1	Cividec	sc	4.7x4.7x0.50	3x3	OK
DC2	Cividec	p	5.0x5.0x0.50	3x3	TBD
DM1*	Micron	p	5.0x5.0x0.50	1	OK
DM2*	Micron	sc	4.7x4.7x0.50	1 round	OK
DM3	Micron	p	5.0x5.0x0.50	1	Rejected
DM4	Micron	sc	4.7x4.7x0.50	1	OK
DM5	Micron	sc	4.7x4.7x0.50	1	OK
DM6	Micron	p	5.0x5.0x0.50	1	TBD

Diamond sensors

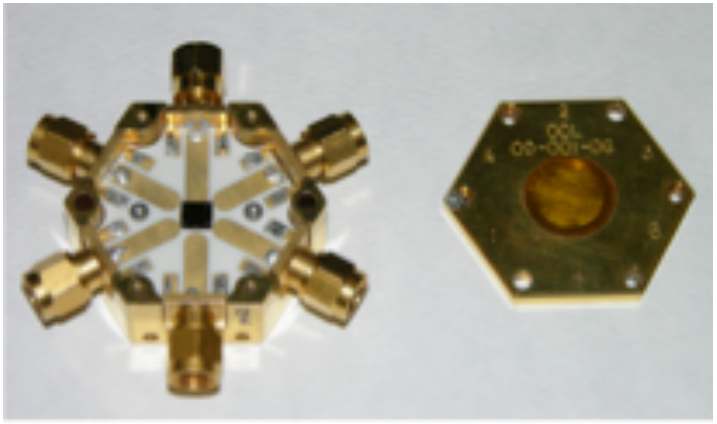
DM1





DC1

PD

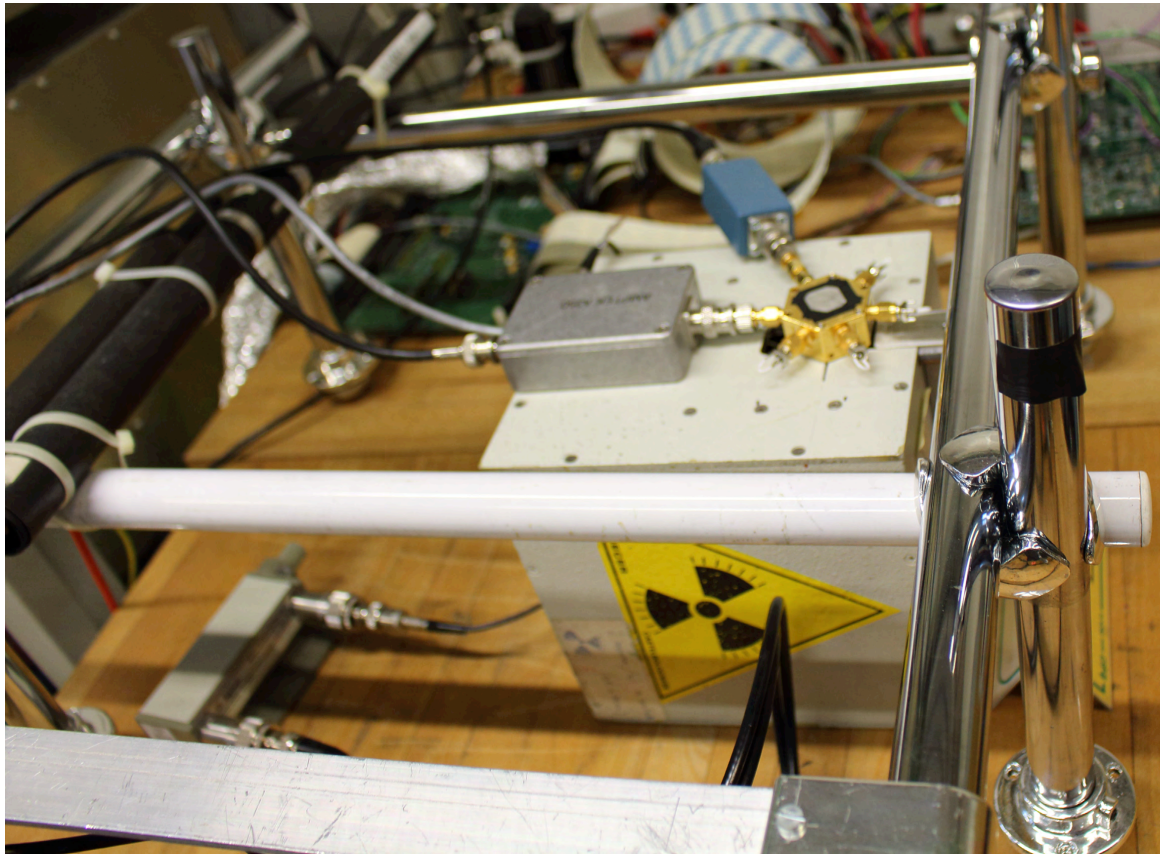


DM4

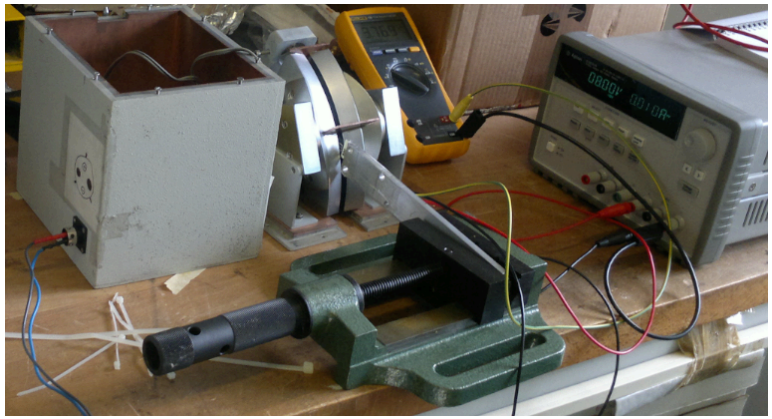
Test tools

- Static characterization of the samples (I-V and C-V)

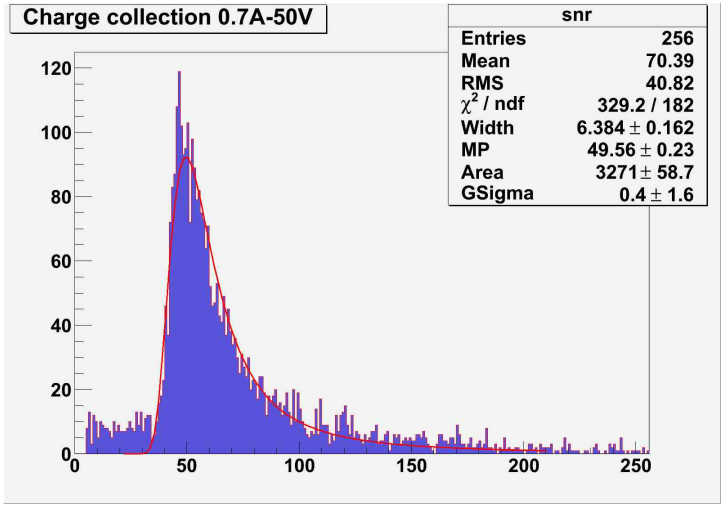
- Single channel Amptek chain: A250 preamp. (2.5 ns risetime) + PX5 digital shaper (semi-gaussian equivalent time 40 ns – 40 µs).
- A pointlike ^{90}Sr source (~2 MBq), beta spectrum hardened by magnetic field and collimators
- Tests repeated at DESY 2-6 GeV electron beam

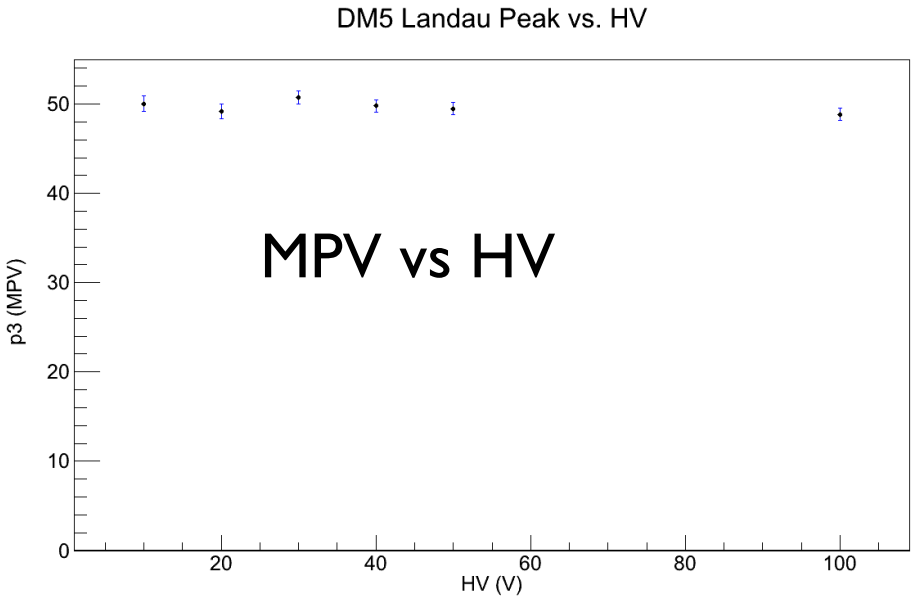


MIP Characterization of scCVD sensors



Single electrons, 1-2 MeV (MIP): Landau peak vs HV





Belle II-VXD Radiation Monitoring and Beam Abort

- Main requirements
  - Measurement of instantaneous dose rates & integrated doses
    - Sensitivity ≈ 1 mrad/s = 10 µGy/s, sampling rate ≈ 100 KHz
  - Beam Abort for excessive beam losses affecting PXD, SVD
    - Programmable thresholds, depending on accelerator conditions (filling injection, stable beams, machine development, …)
    - "Fast" (10 µs = 1 accelerator revolution) Beam Abort trigger
    - "slower" Beam Abort triggers, based on digitally filtered signals (averages over programmable numbers of samplings)
- Conceptual design
  - Based on experience from Belle, BaBar, CDF, LHC
  - scCVD diamond sensors, measurement of currents:
    - Reference: typical pCVD sensor (10 × 10 × 0.5) mm^3 @ 500V: 1 nA = 7 mrad/s = 70 µGy/s
    - Noise should be limited to a few pA, in current measurements
  - 4 + 4 sensors located near PXD (very limited space)
  - 6 + 6 sensors located near SVD
  - Background dominated by electrons

VXD Monitoring & Beam Abort electronics

5 modular Boxes, dealing with 4 scCVD sensors each:

- 4 individual HV bias supplies
- Currents digitization with 4 (16-bit) ADCs at 160 MHz, with oversampling
- Data averaging and buffering for
  - Continuous Monitoring (averaged data, 1-10 Hz read-out)
  - Post-mortem (abort) analysis (full data, frozen circular buffers)
- Running Sums, Programmable Thresholds, Majority logics for Abort signals
- Ethernet interfaces (2) for programming and data read-out

Compatibility with the SuperKEKB Abort System requires:

- Sampling synchronized to SuperKEKB revolution period (10 μs)
- "SuperKEKB status" register, set via EPICS (for the selection of thresholds)
- 2 final output "fast abort" signals, correlated with LER and HER
- 600 ms deep data buffers, read out upon an abort, internal or external
- Synchronization with SuperKEKB aborts: digitization of 2 beam currents, and "abort confirmation" digital signal from SuperKEKB

Similar approach: BLM at LHC

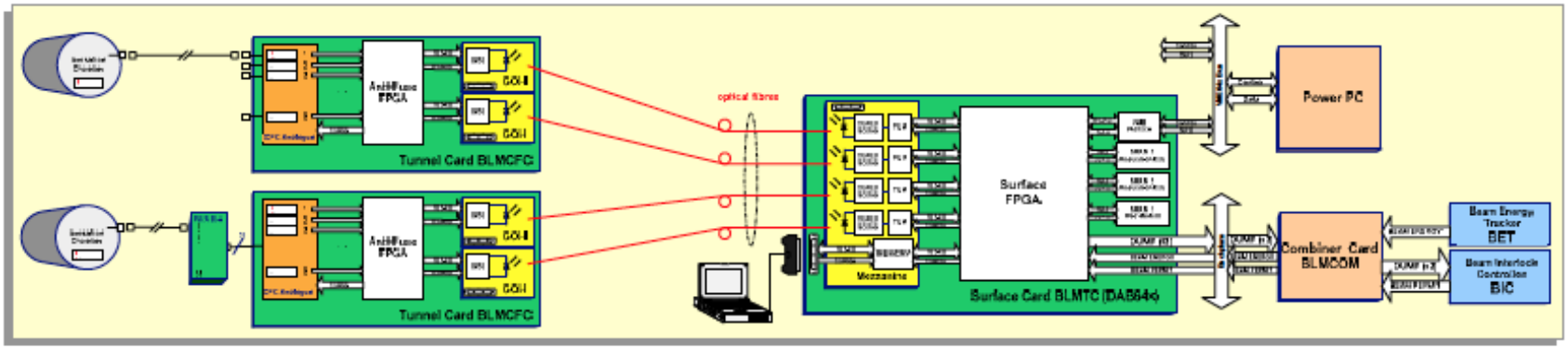


Figure 1: Overview of the complete BLM System for the LHC.

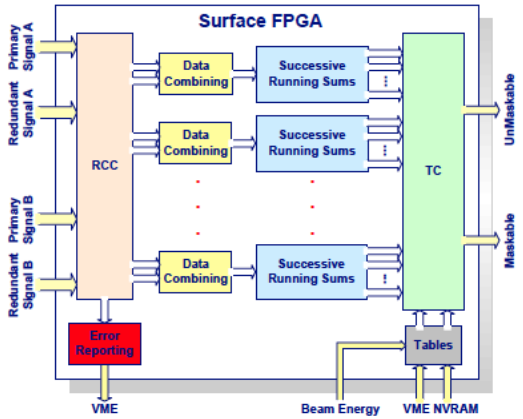


Figure 2: Block diagram of processes related to data analysis running in the surface FPGA.

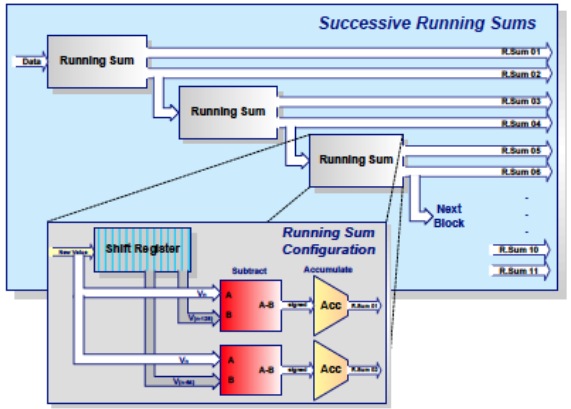


Figure 5: Production of Successive Running Sums.

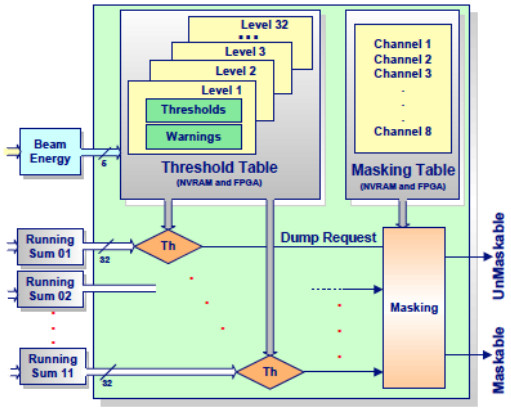
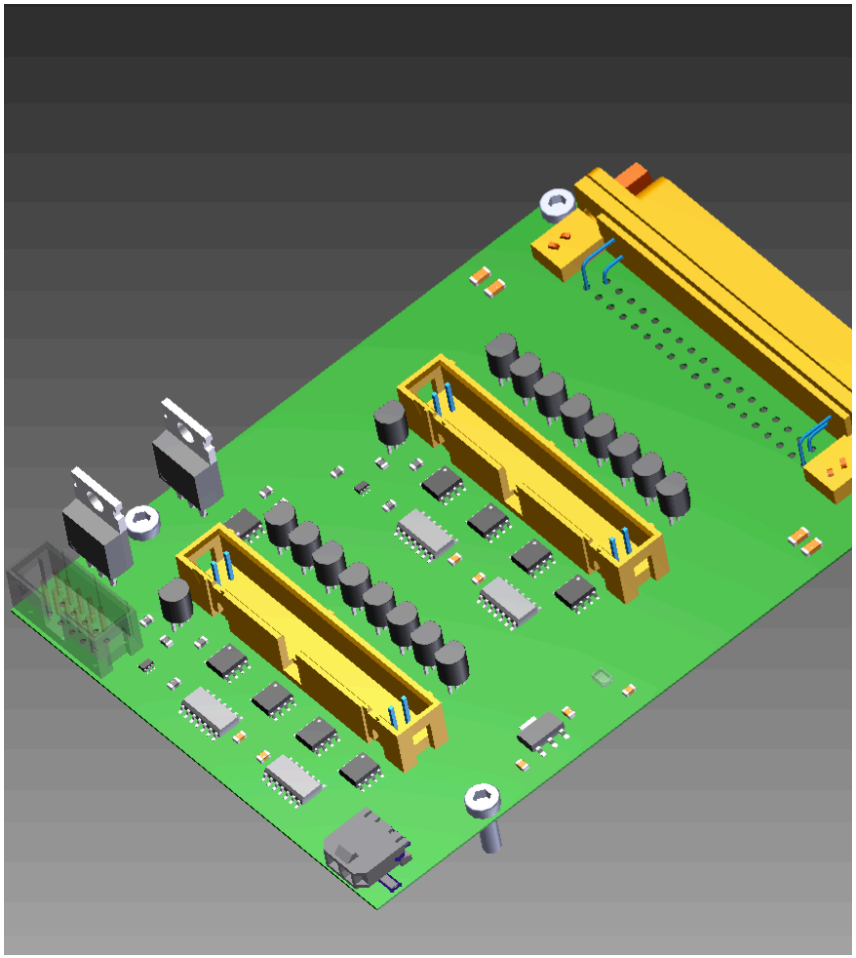


Figure 6: Threshold Comparator (TC) Block Diagram.

FPGAs Running Sums Thresholds

NTC current sources and interlock signals



- 6 small boards, each:
  - Current sources for 16 NTCs
  - 16 comparators with hardwired thresholds
  - 2 interlock signal outputs (each: OR of 8 channels)
- Built-in redundancy
  - 2 NTCs per measurement point
  - Each contributes to a separate interlock OR
- Design completed, prototype channel tested

ELMB-based NTC readout

In one box, with 3 x 32 NTC channels modularity:

1 power supply board, 3 motherboards with ELMB and CANbus adapter, 3 x 2 current source (16-channel) boards, 3 x 2 x 16-channel connectors