UNIVERSITÀ DEGLI STUDI DI TRIESTE
Dipartimento di Fisica
Department of Physics

VXD Environmental Monitors and Interlock

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On behalf of VXD monitoring crew

BPAC focused VXD review

KEK, October 17, 2017

Outline

- Radiation: sCVD Diamond sensors
- Temperature: NTC and FOS
- Humidity: Dew Point “sniffers”
- VXD Local Hardwired Interlock (VLHI): PLC

Prototypes have already been operated in Phase 1 or VXD Beam Tests

- here shortly mention phase 1
- more on installation status and schedule

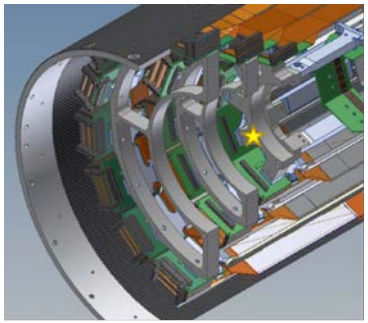
→ both Phase 2 and Phase 3 sometimes overlapping

Environmental monitoring summary

Subsystem	Phase 1/Beam Test Sensors	Phase 2 Sensors	Phase 3 Sensors
Time span	Feb-Jun 2016/Mar 2016 + Mar 2017	Feb-Jun 2018	Dec 2018 →
Diamonds	4	8	20
NTC	26	26	56+12
FOS	1 fiber 8 sensors	4+2 fibers 26 sensors	38+2 232 sensors
Dew Point	1	1+3	1+3

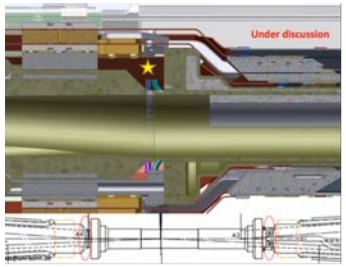
RADIATION: SCVD DIAMONDS

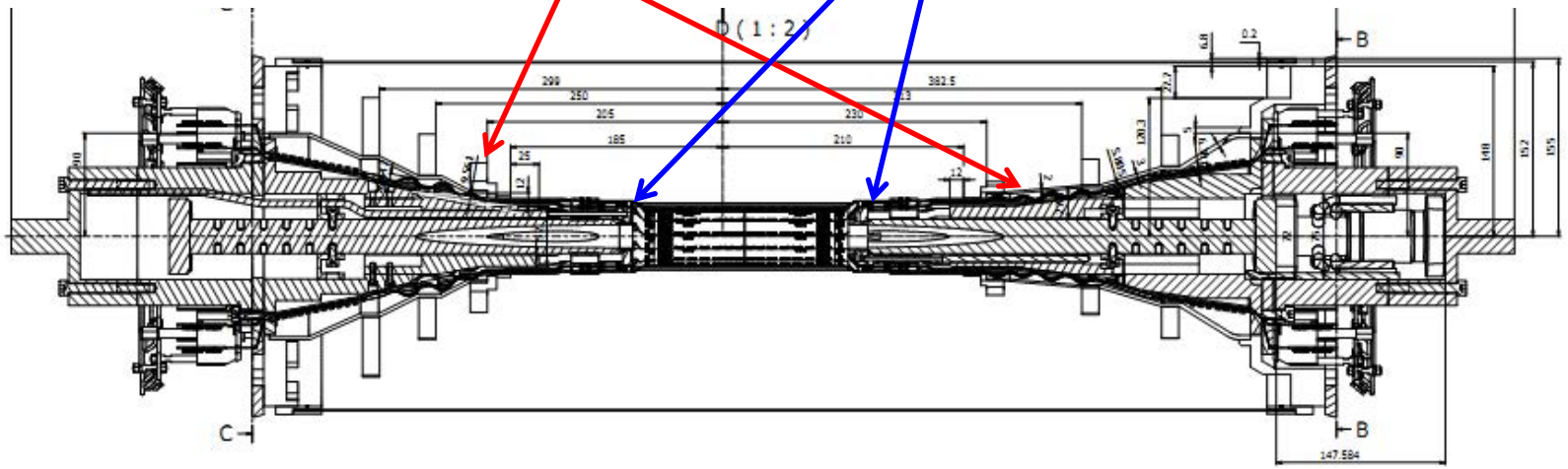
sCVD Radiation Sensors: Phases 2 and 3



6 + 6 sensors
close to SVD L3
support rings

4 + 4 sensors
PXD-beam pipe





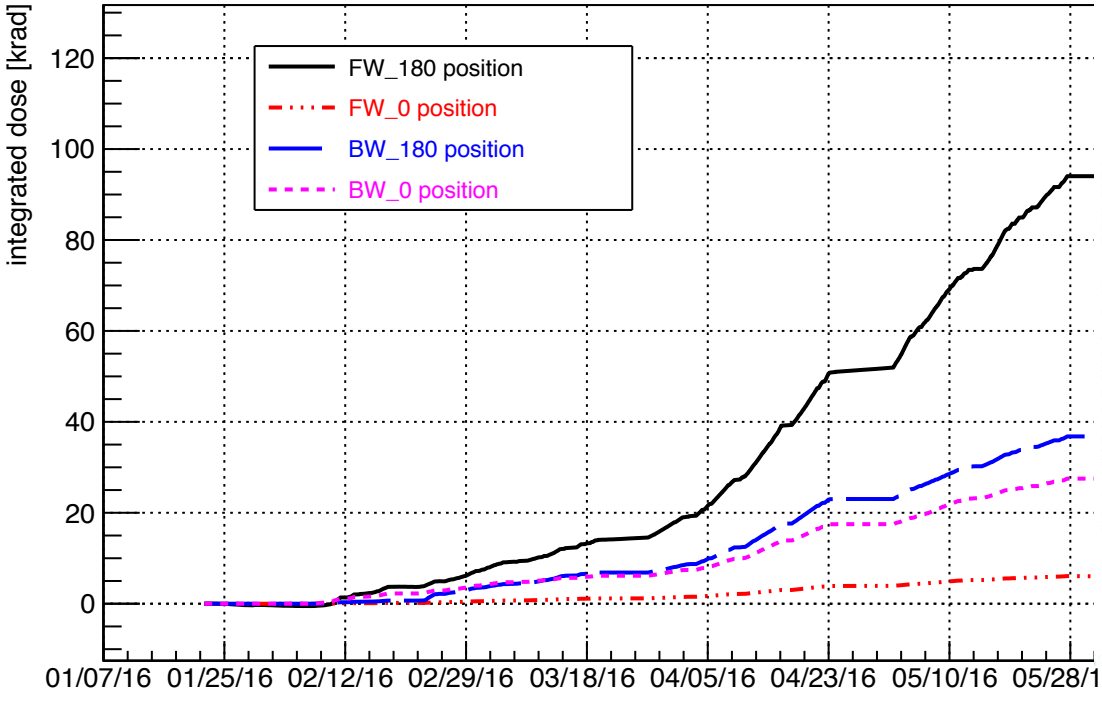
Now:
Installing
Assembling + test,
→ calibration 1-2 weeks/sensor

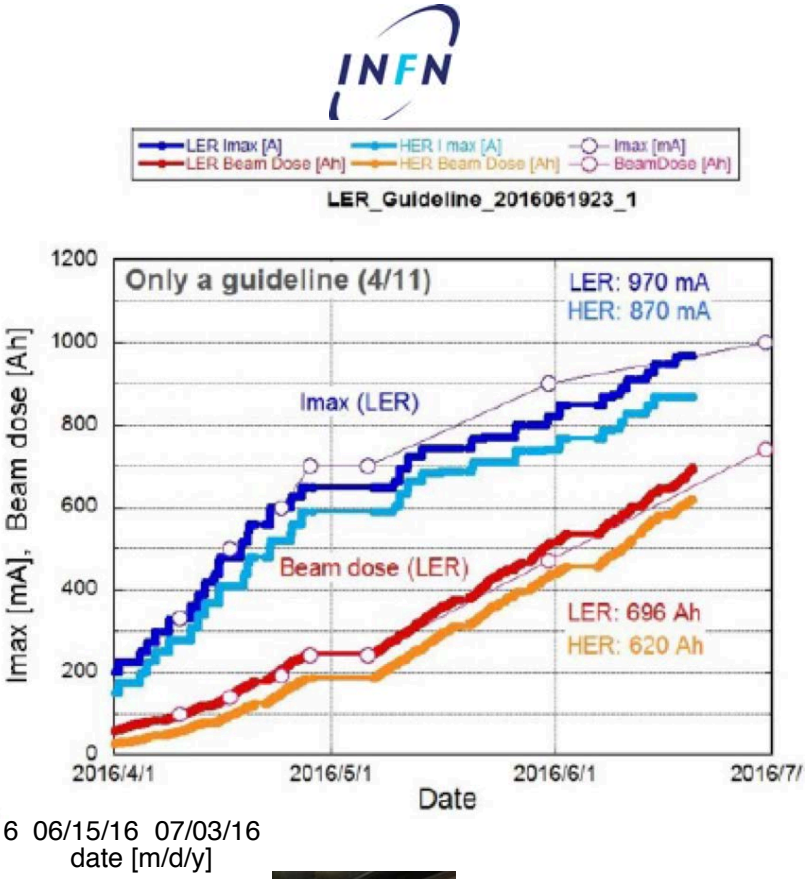
Phase 2: 8 “PXD” sCVD sensors
Phase 3: 8 “PXD”+ 12 “SVD”

In parallel !

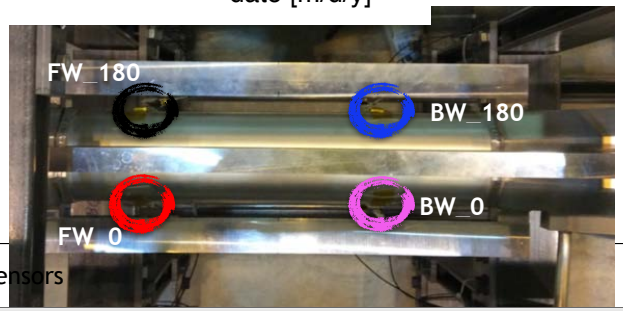
Phase 1 results

Integrated dose

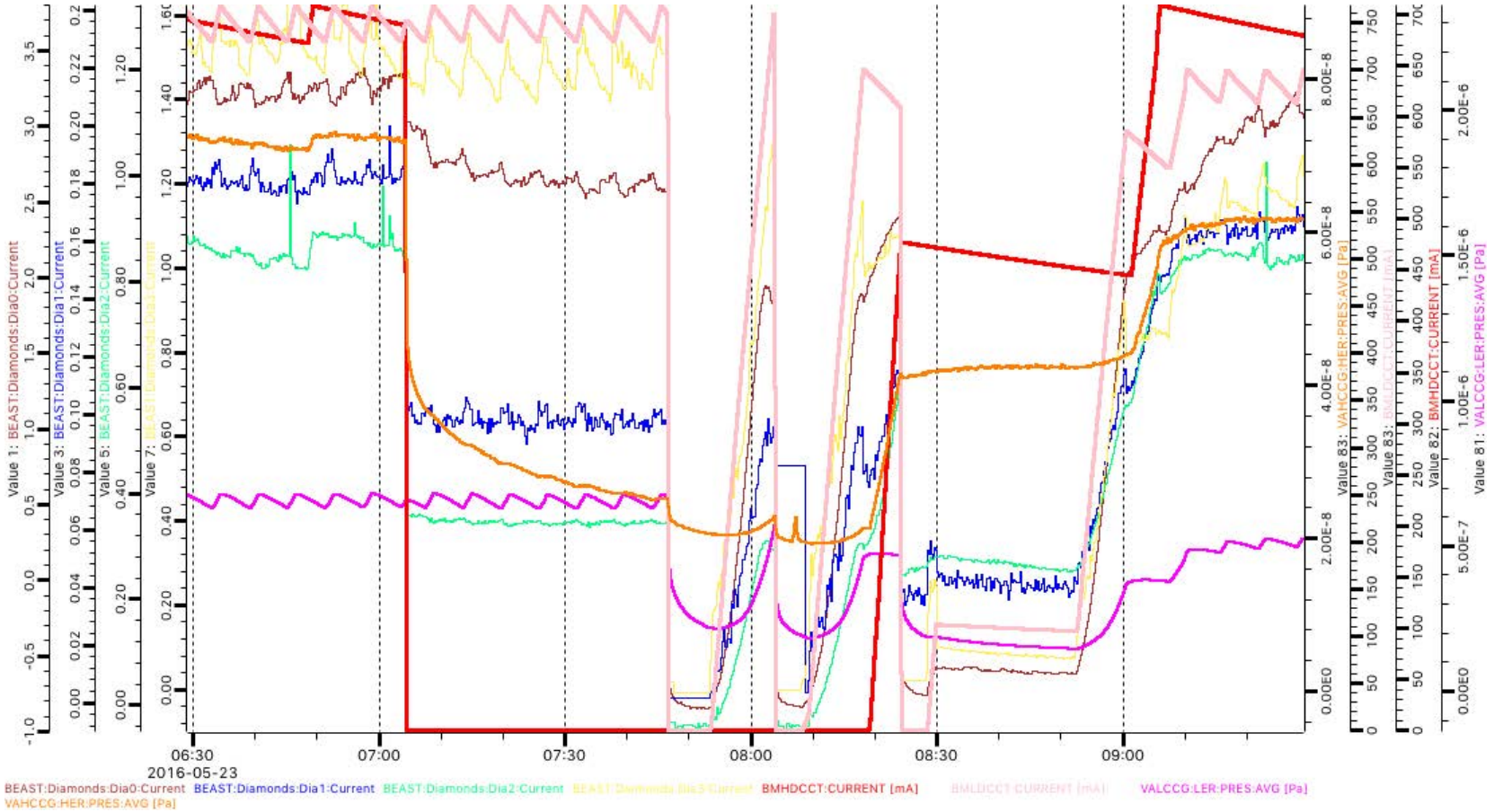




integrated dose measured in the four position on the beam pipe



Phase 1 diamonds– aborts, refilling



Dia0 Dia2

Dia1 Dia3

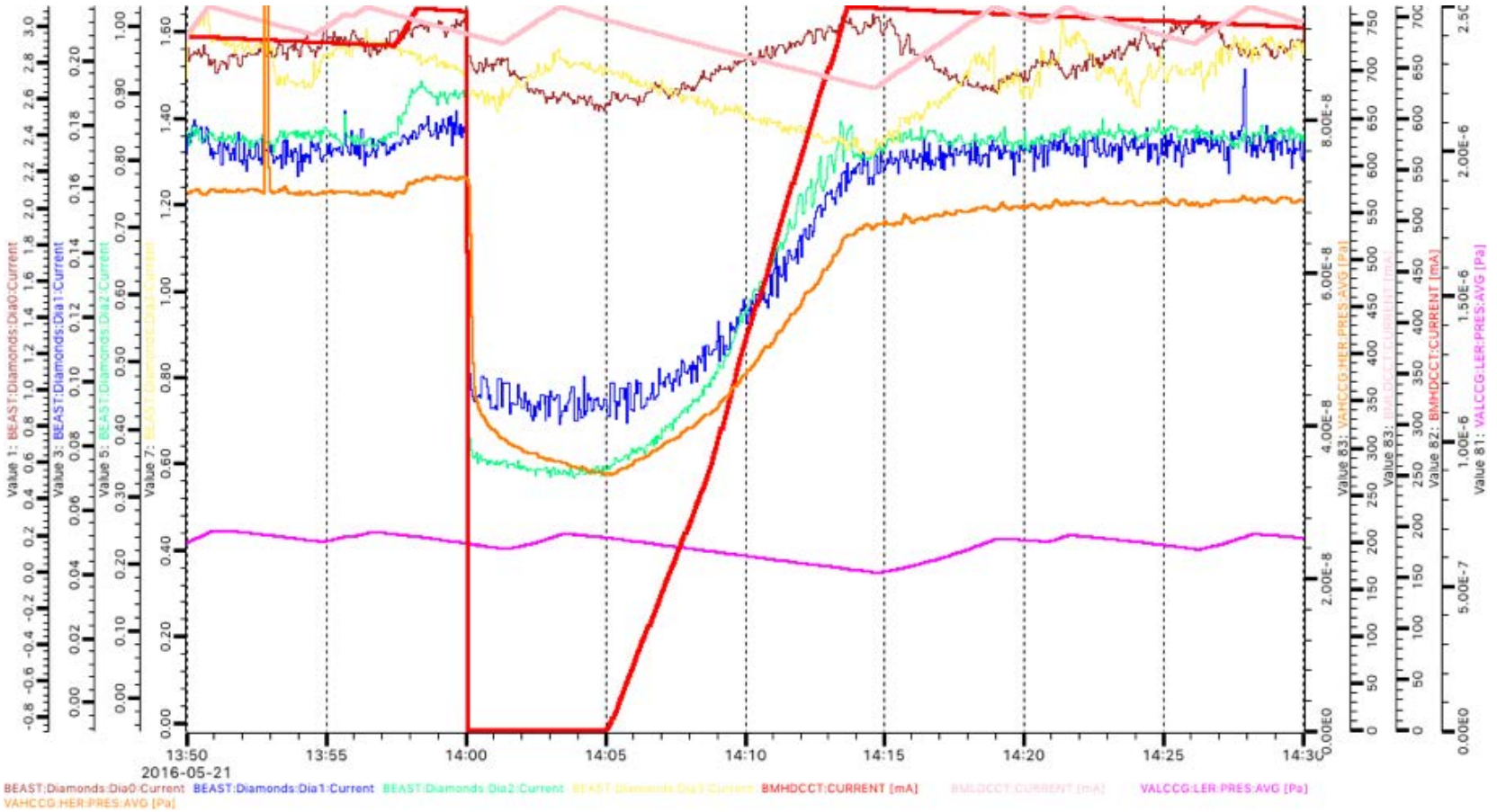
HER Abort

3 LER Aborts

HER current, pressure

LER current, pressure

Correlations with LER, HER



Dia0 Dia2
Dia1 Dia3

FW_180, BW_0: very sensitive to LER, not to HER

FW_0, BW_180: same sensitivity for both

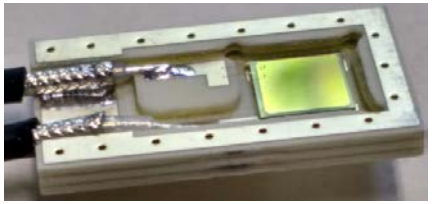
HER current, pressure
LER current, pressure

sCVD sensors: assembly, tests, calibration

- Package preparation:

  HV test, sensor gluing, cables soldering/gluing,

  I-V in the dark



- Transient Current Test (TCT) with alpha source

  fast amplifier + fast oscilloscope

  sCVD crystal quality, electrons/holes transport parameters

- Beta source (3 MBq):

  Priming/pumping to fill-in traps

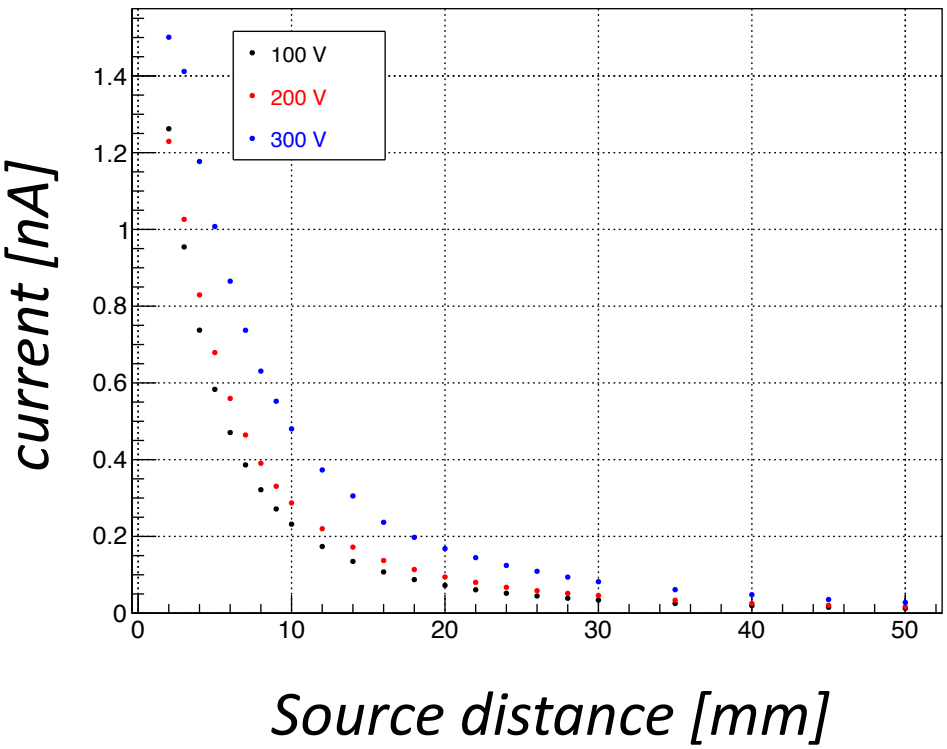
  Stability tests at “high” current (about 1 nA)

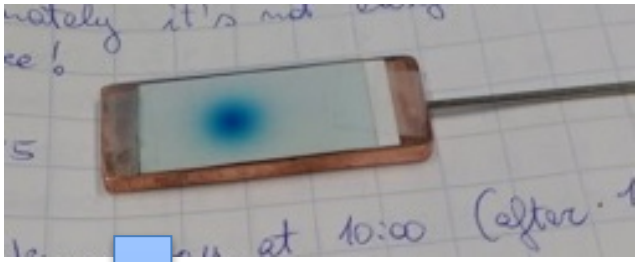
  Calibrations: current vs particle flux (realized by changing the source distance), comparison with Fluka simulation and film dosimeters

Example from 17 tested sensors

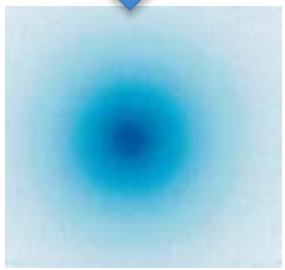
Calibrations: extracted from the sCVD current vs source distance, at different HV value and polarity, compared with FLUKA simulations

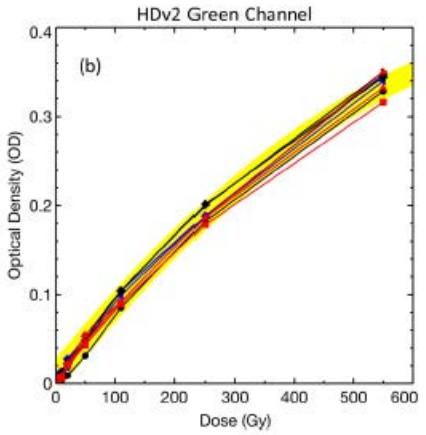
New: also radiochromic film dosimeters, collaboration with Naples



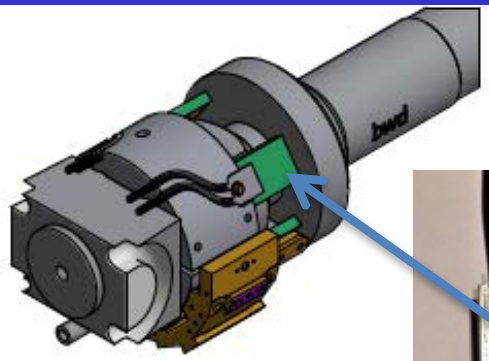


Dose range: 3 kGy- 100 kGy

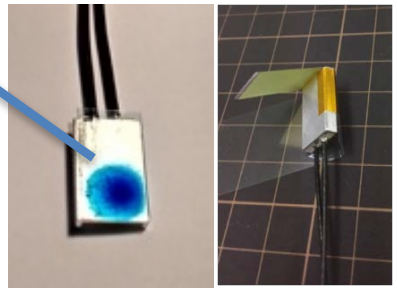


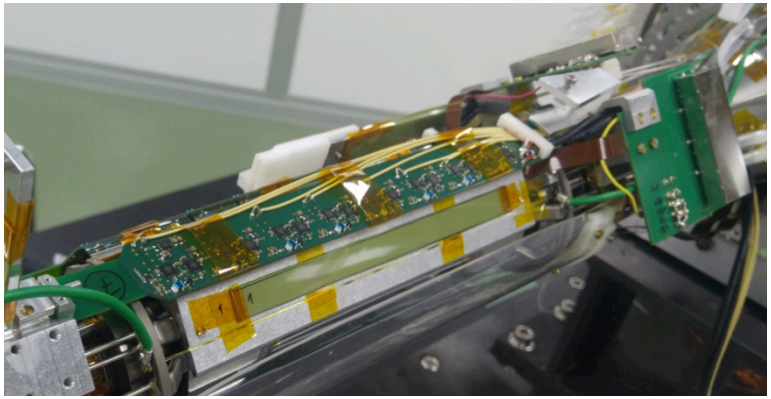


Film positioning in Phase 2

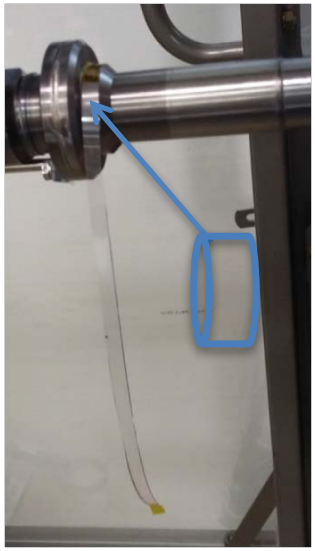


Diamonds



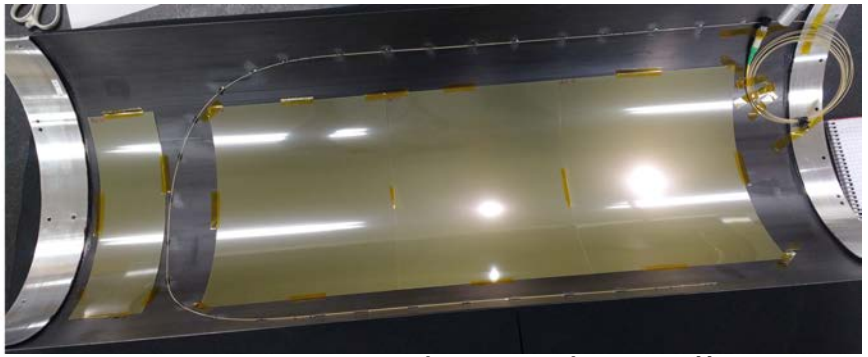


Several on FANGS, in particular 3 strips along z



Thin strips on Beam Pipe

SVD Layer 3 “fingers”



SVD Outer Cover and Cartridge walls

Moreover PLUME & ECL detectors, DOCKS

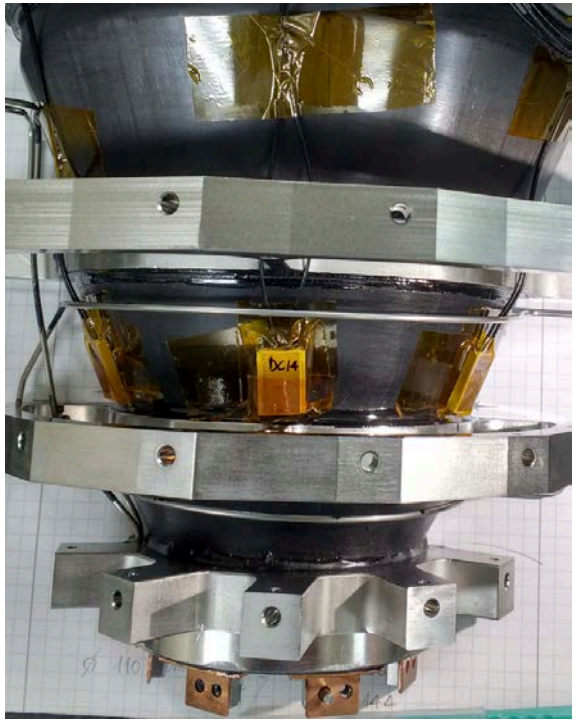
So far 4000 cm^2, aiming to reach 7000 cm^2

Phase 3: Diamond installation

6 final diamond sensors

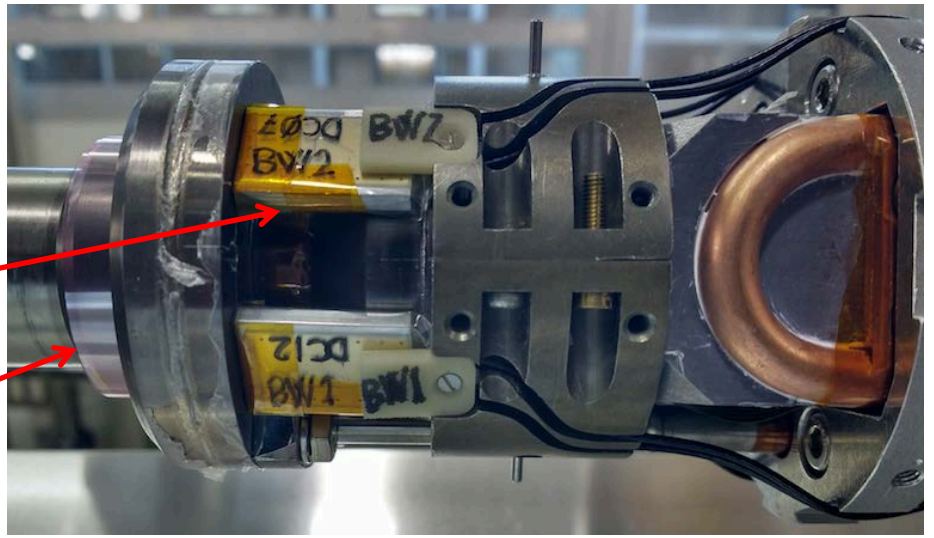
mounted in June 2017

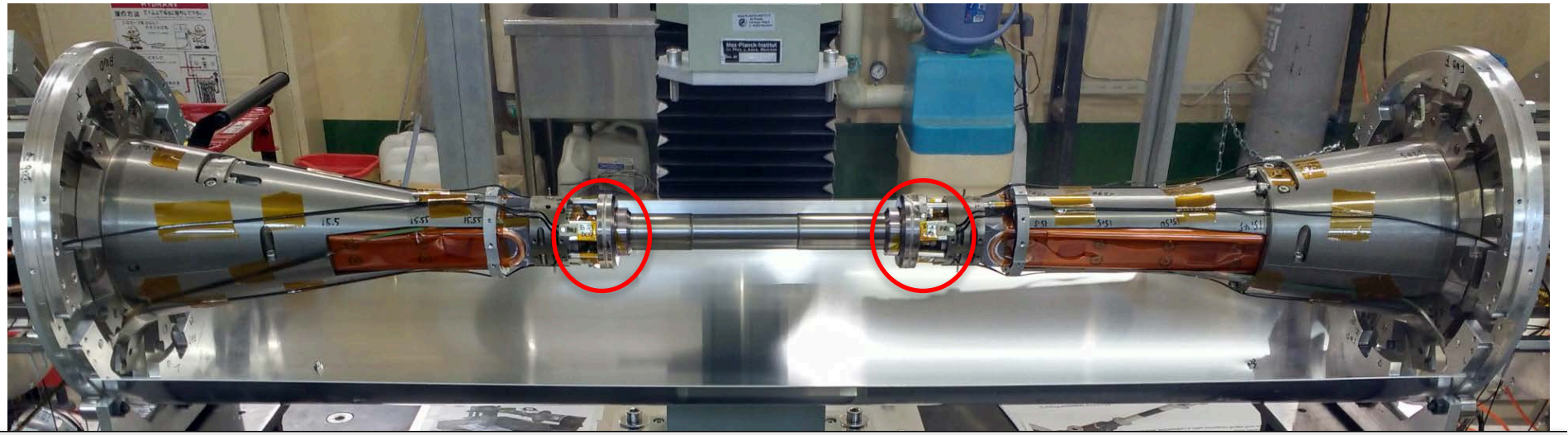
on the first 2 SVD half-cones (BW and FW)



Phase 2: Diamonds installation

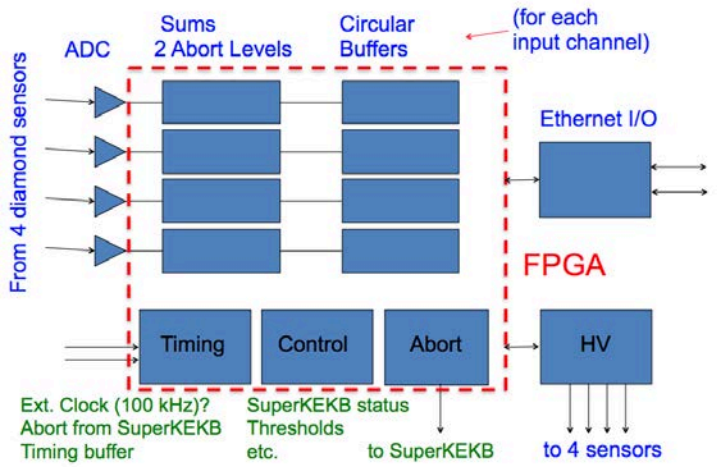
- All **8 diamonds** for phase 2 installed on the beam pipe on Sept 18-19
- Functionally tested with a ^{90}Sr beta source
- Two **radiochromic films** were attached on their inner surface
- Moreover two thin strips on BP





Diamonds readout electronics

- Prototype 4-channel module:
  - HV, currents digitization and averaging, beam abort logics
  - **successfully tested in Phase 1 (no abort)**
- Final engineered version in delivery now
  - the FINAL re-engineered hardware parts of the radiation monitoring electronics (FPGA board, analog front-end board, HV modules, Ethernet interfaces) are READY AND TESTED
  - The mechanical assembly of 2 modules for 8 diamonds are ongoing for Phase 2
  - 3 additional modules + 1 spare will be ready for Phase 3 (ordering now)
- Development in collaboration
  - Elettra Sincrotrone Trieste SCpa
  - (Electronics Division G.Cautero et al.)



TEMPERATURE: NTC AND FOS

SVD Temperature

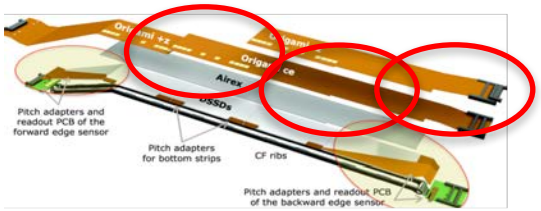
- **Requirements:**

  Temperature monitoring & interlocks:

  0.1°C precision, 1°C accuracy

  Monitoring points:

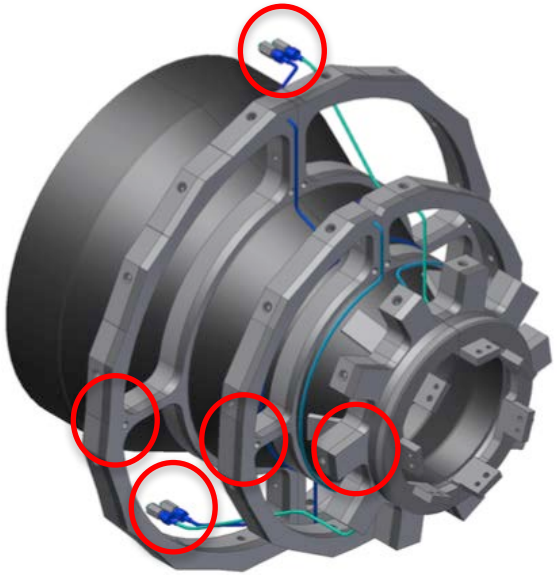
  - close to SVD FE chips (heat sources)
  - Inlets and outlets of CO_2 cooling pipes & half rings (possible indication of cooling failure)



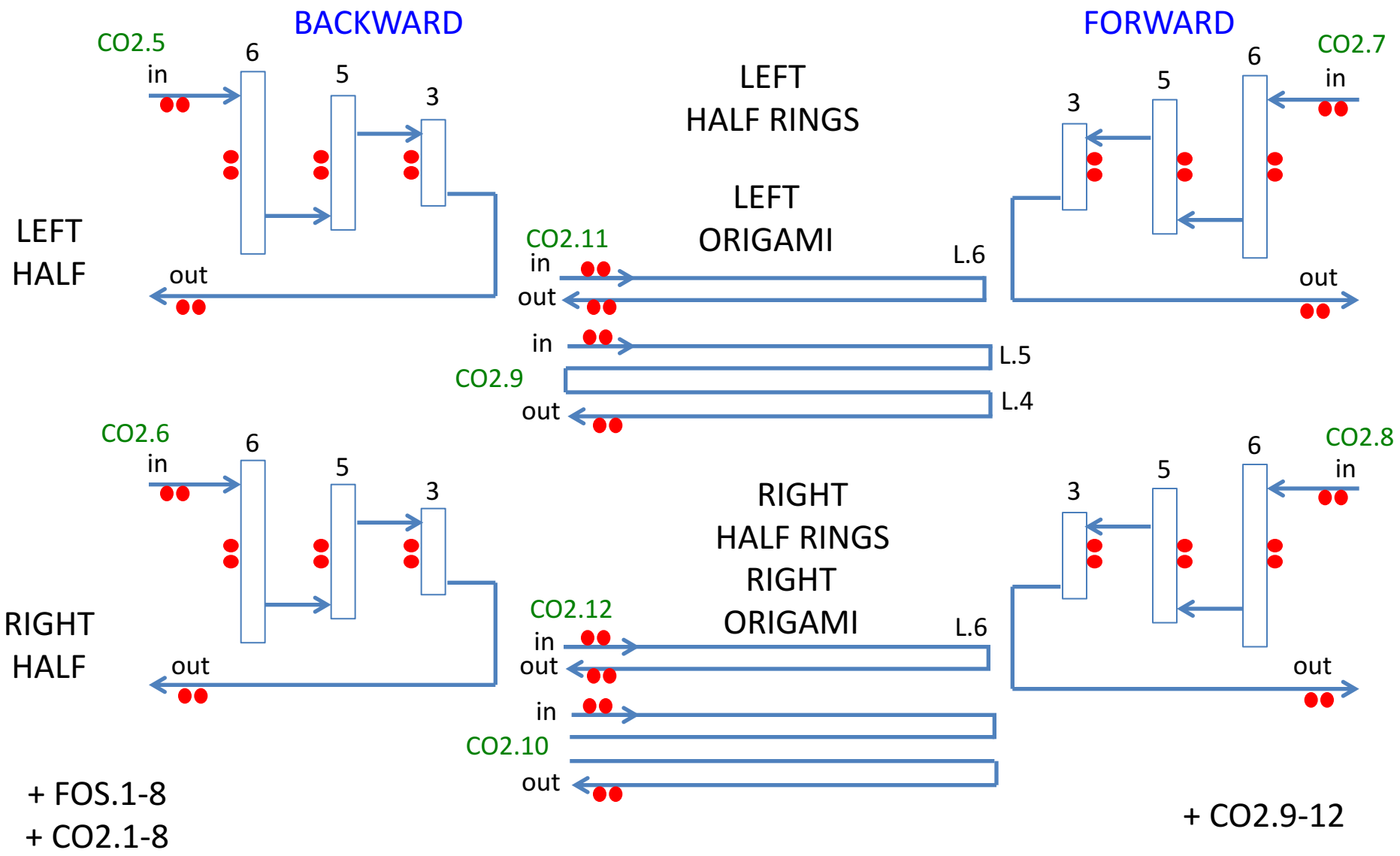
- **Design:**

  - FBG (Fiber Bragg Grating) sensors on optical fibers (FOS), embedded in SVD ladders (Airex)

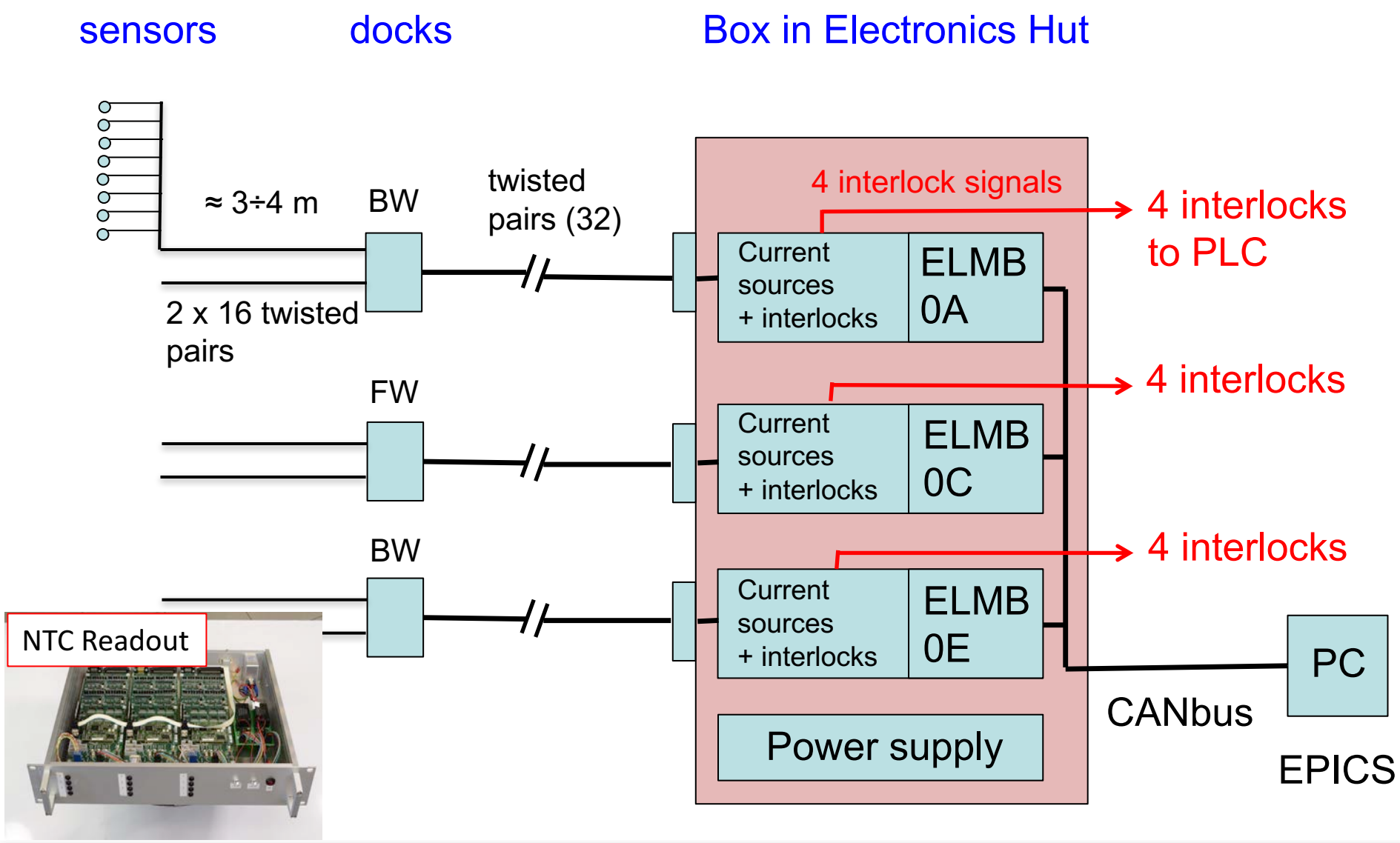
  - NTC thermistors, with hardware interlock capability, on cooling pipes and half-rings



NTC final configuration for Phase 3



NTC read out for Phase 3 (&2)



NTC temperature sensors: installation

- Phase 3

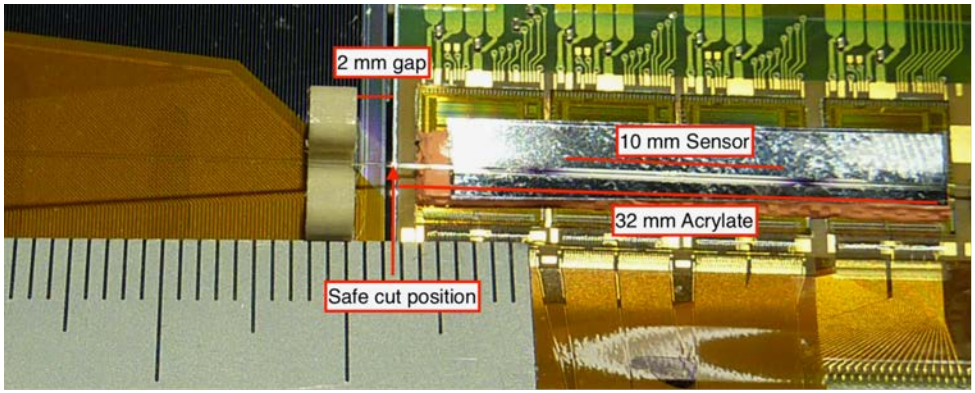
  In June the read out system and all the sensors were shipped to KEK, and re-tested: they have be mounted (1/2) at the end of **July** and (1/2) in **December** for the Ladder Mount of the two SVD halfs

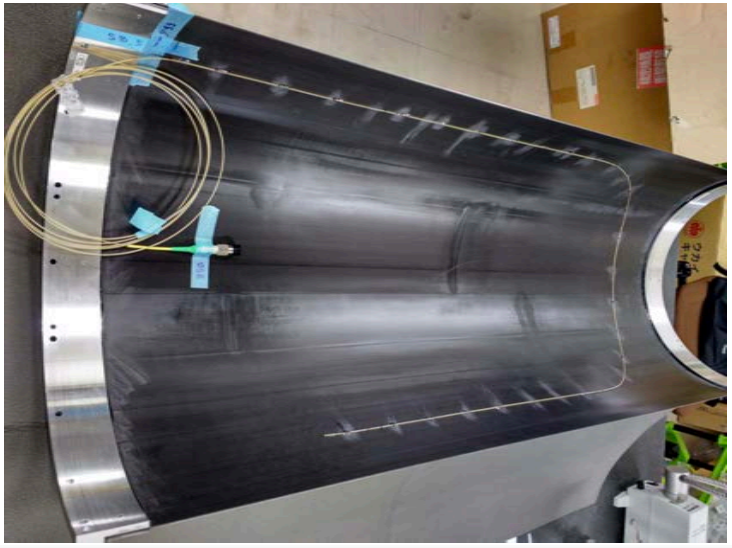
- Phase 2

  In July the back-up read out system and the sensors used for the DESY beam tests were dis-assembled and shipped from DESY to KEK. It has re-assembled in **September** with small modifications for Phase 2

Temperature FOS sensors: first half 2017

- Calibrations of 55 fibers completed
- Cutting fiber excess & glueing clamps
- System test with splitters and first prototype of EPICS software
- Mechanical tests in May at KEK:
  - insertions on all ladders
  - interference with Layer 6
  - logistics in B1
  - glueing on the SVD Outer Cover





FOS Schedule

Schedule:

- 2 Fibers for phase 2 outer cover installed on May
- 2 Fibers for phase 3 outer cover → installed in September
- 3 Fibers for phase 2 cartridge → installed in September
- 19 fibers SVD Ladder Mount +X half → first 2 installed on Layer 4 Sep-Oct
- 19 fibers SVD Ladder Mount -X half → to be installed starting from January 2018

Present status:

- 2 readout “interrogators” are available at KEK
- All fibers are available at KEK

HUMIDITY: DEW POINT SNIFFERS

Dew Point Sniffers: overview

- Based on Dew Point Sniffers
- Reduced system (1 line)

  Successfully operated in in two Beam Tests at DESY
- Full system: completely defined

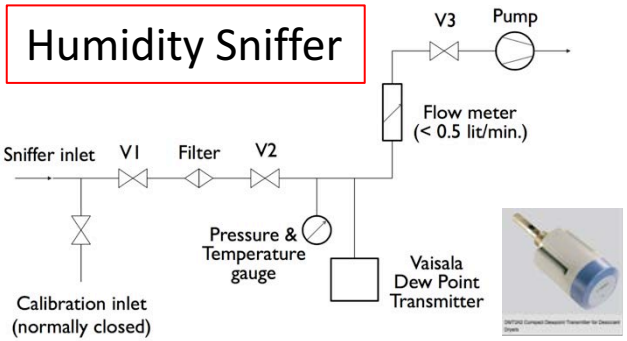
  4 Vaisala Dew Point Transmitters

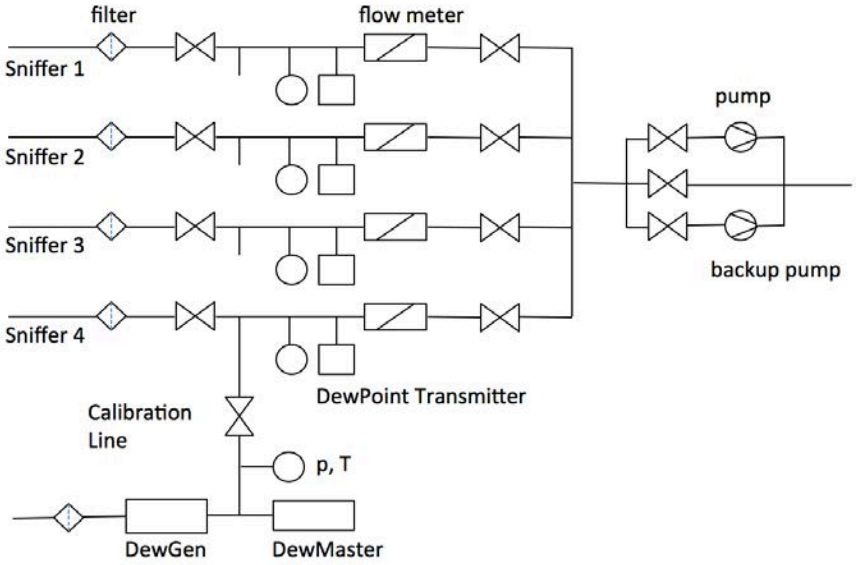
  Pressure sensors

  Bronkhorst flow meter

  Calibration system (DewGen, DewMaster)

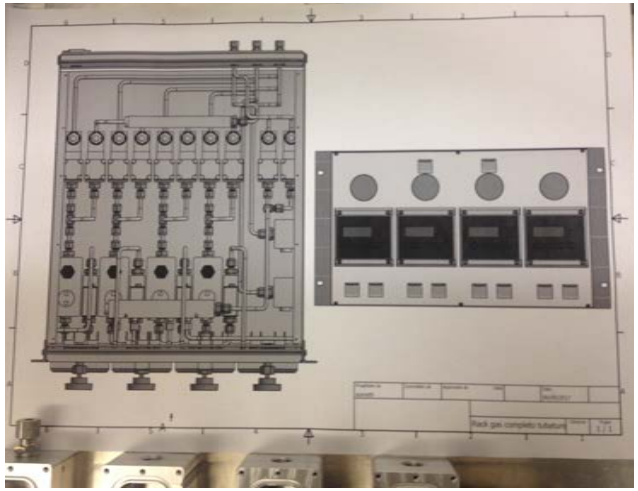
  2 pumps





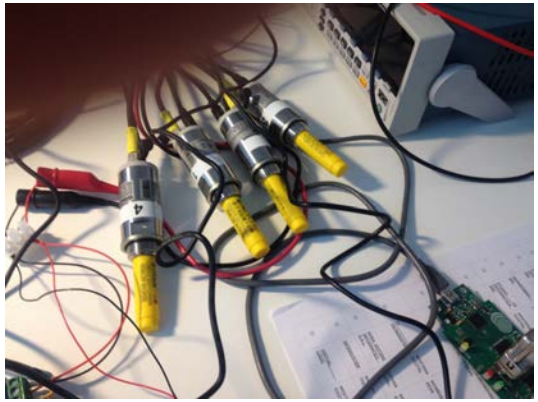
Dew Point Sniffers: status

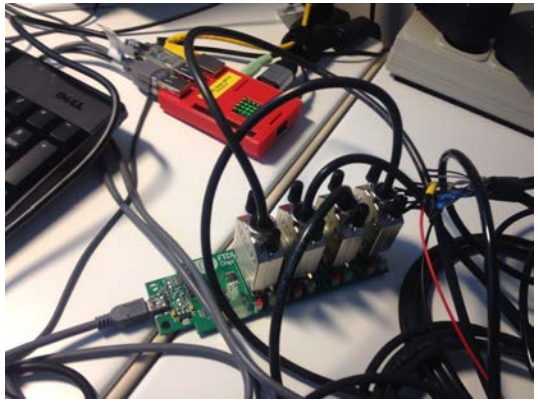
- Mechanics: Crate hosting Vaisala sensors, pressure sensors, flowmeters and electronics
  - CAD design completed
  - Mechanical components available
  - Mechanical assembly: started in October

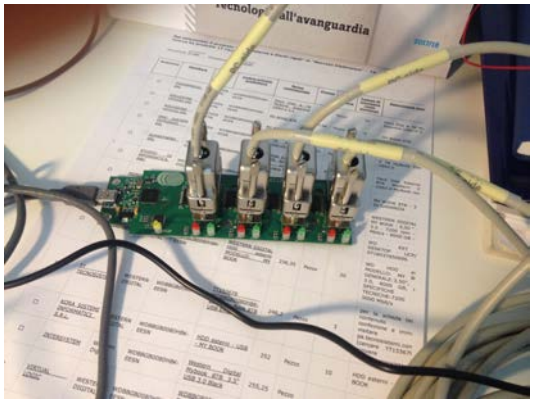


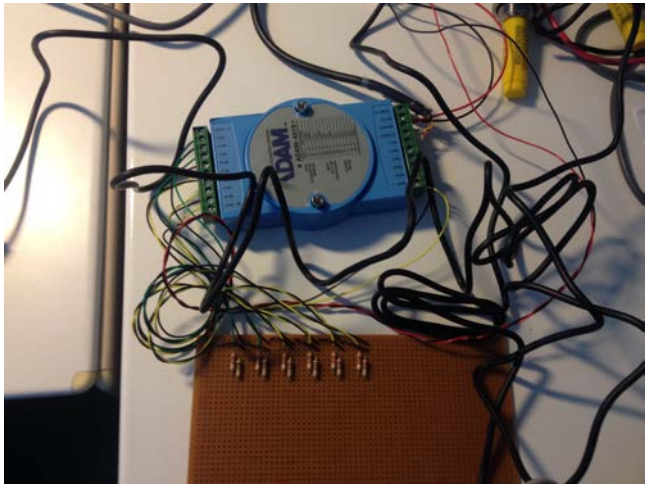
- Sensors, electronics:
  - All components available
  - Readout interfaces and drivers: ready
  - Linux software developed & tested for all sensors/actuators
- Next:
  - Completion of mechanical assembly and tests before shipping to KEK in November
  - EPICS interface in October
  - “DESY prototype” to be delivered at KEK as back-up

Dew Point Sniffers: sensors & readout









Vaisala Dew Point
Transmitters
& readout board

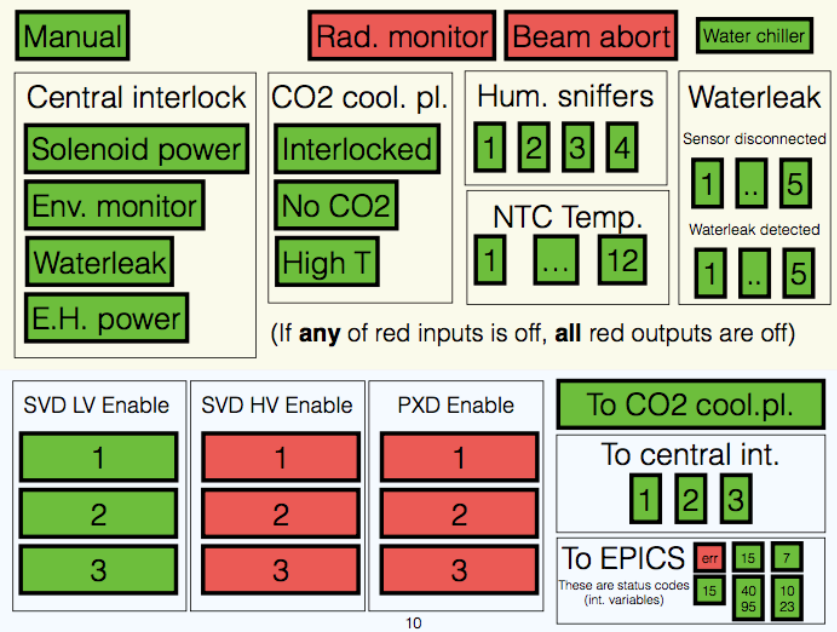
Bronkhorst
Flowmeters
& readout board

Pressure sensors
readout board

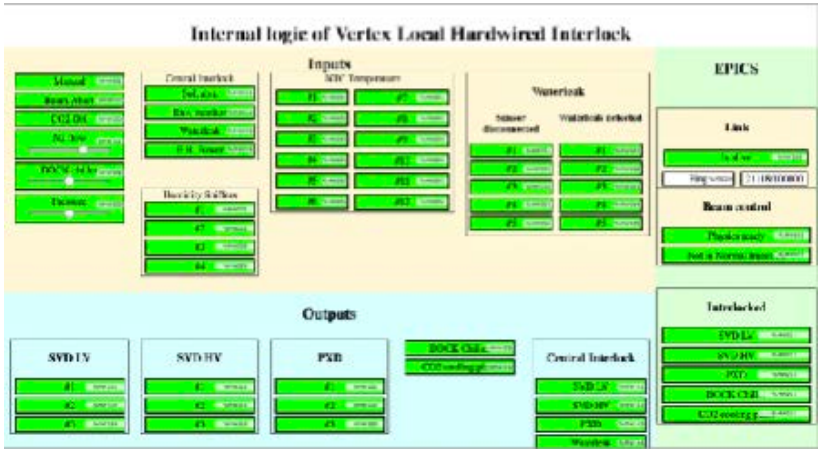
VXD LOCAL HARDWIRED INTERLOCK (VLHI): PLC

VLHI Overview

- Vertex Local Hardwired Interlock (VLHI) is hardwired PLC-based system aimed at prevention of damage to VXD
- It interlocks VXD PS basing on hardwired inputs and variables from EPICS, and also it is supervised by EPICS
- Presented in last BPAC



- Documentation:
  - confluence page
  - Belle II internal note
  - VLHI simulator describing its logics running online

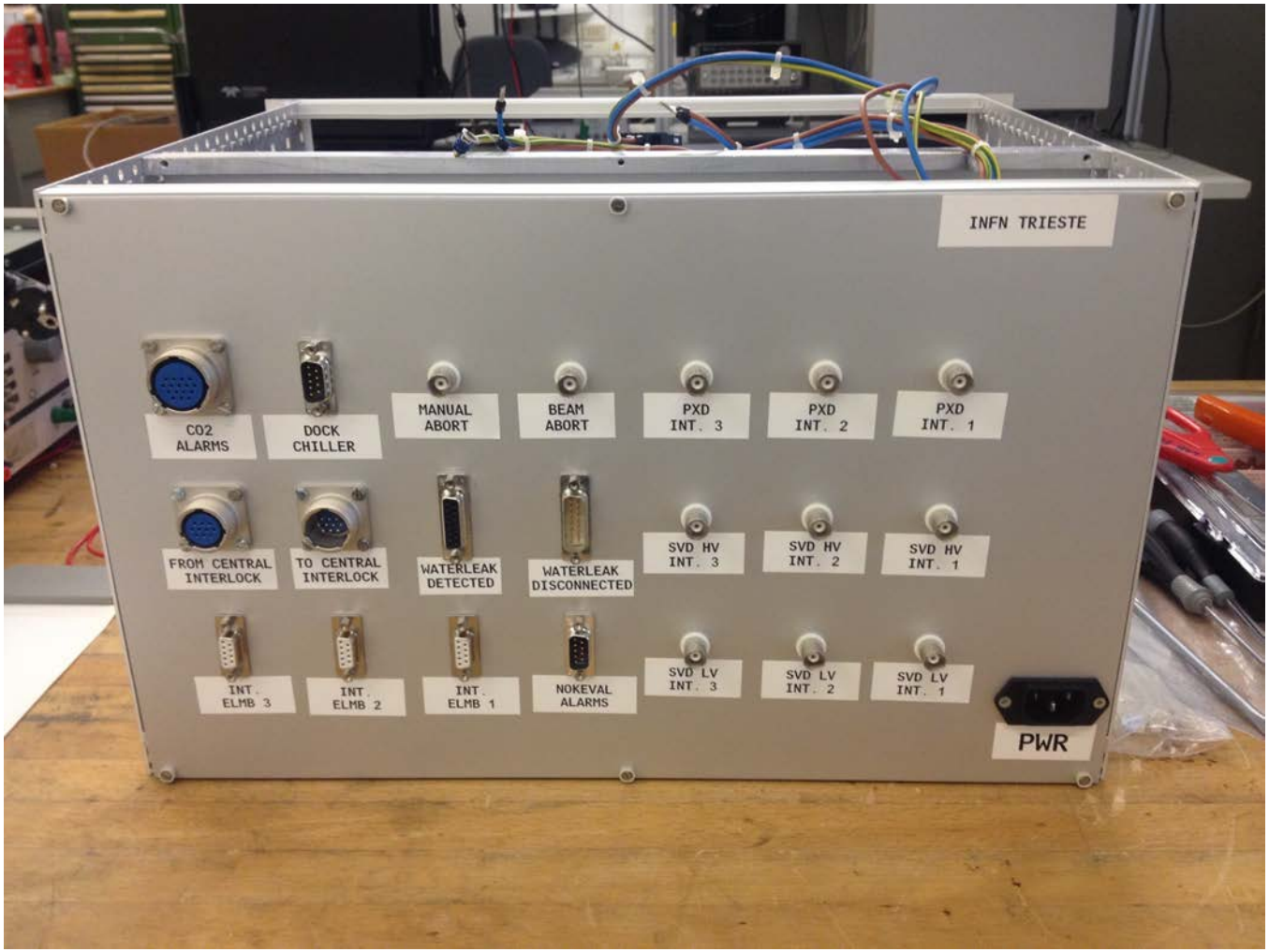


VLHI Interlocks Status

- PLC hardware:
  - I/O completely defined (modules, cables, connectors) (see spreadsheet and CAD schematics in backup)
  - PLC crate interconnections, power lines: CAD design completed
  - PLC crate mechanics, patch panel: ready (see photo)
  - PLC crate cabling: almost done
- Next:
  - PLC crate cabling, to be finalized in October
  - Functional tests in Trieste with simulated inputs, outputs programmed with the agreed interlock logics, before shipping to KEK for installation in E-hut in December

VLHI crate: back view

Back view of the PLC crate: patch panel, all I/O connections defined

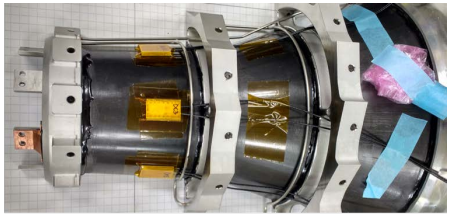


CONCLUSIONS AND SCHEDULE

In Summary

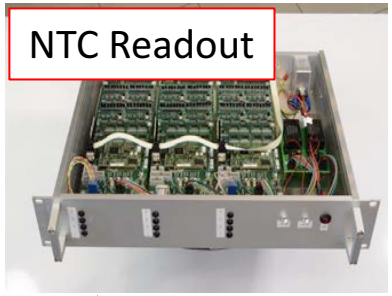
- Radiation: sCVD diamond sensors
  - BEAST Phase 1 analysis, NIM paper
  - Assembly & calibration of sensors in Trieste
    - *now 17 completed, 8 ongoing, out of 4+8+20*
  - Final electronics in preparation for Phase 2, Detector installations completed for Ph1 & Ph2
    - *4 Ph1, 6 SVD Jun17, 8 Ph2 Sep17, 6 SVD Dec17, 8 ph3 early 2018*
- Temperature: NTC and FOS sensors
  - All NTC+FOS sensors and electronics tested & calibrated in Trieste
  - Installation at KEK ongoing
    - From May 2017 to Apr 2018
- Humidity: Dew Point "sniffers"
  - Design and test of components completed, assembly in progress in Trieste
    - Shipping in Nov, inst/test Dec
- VXD Local Hardwired Interlock (VLHI)
  - Design and simulations completed
  - PLC & I/O assembled, cabling in progress
    - Shipping in Nov, inst/test DeC

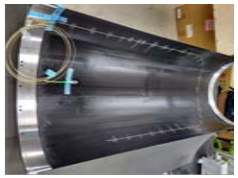
sCVD, Beam Pipe



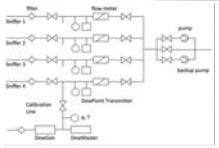
sCVD, FW cone

NTC Readout



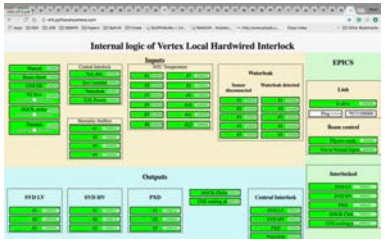


FOS, outer cover

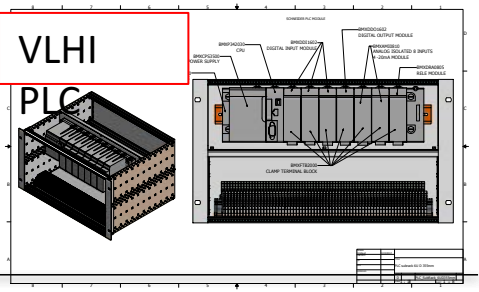


FOS, ladders

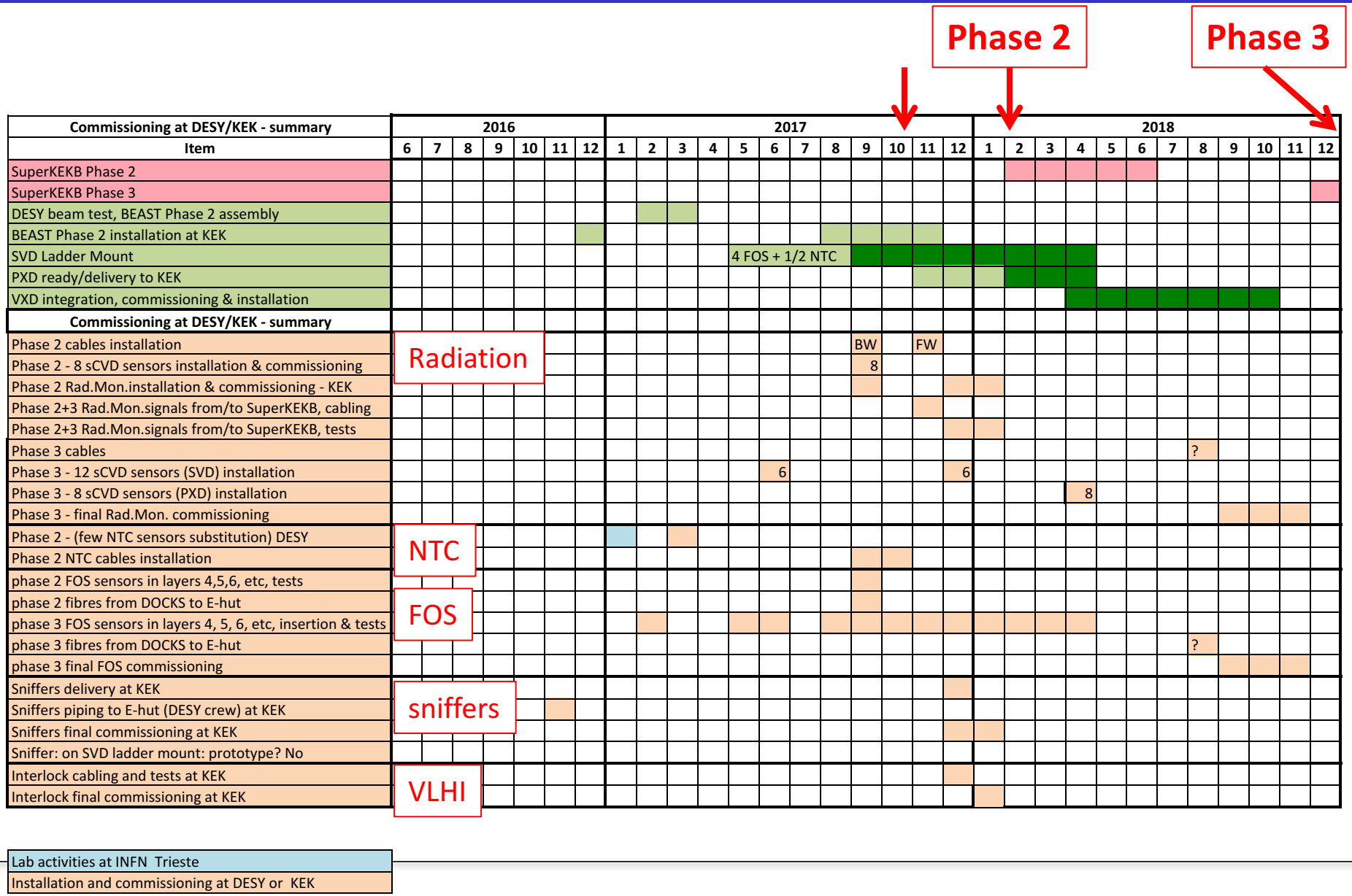
sniffers



VLHI PLC



VXD monitoring: schedules @ KEK



Backup

Documentation and Contributors

- More information on environmental monitors, electronics, etc:

  BELLE2-NOTE-TE-2015-026, SVD Radiation and Environmental Monitoring: general requirements
  BELLE2-NOTE-TE-2016-007, Environmental Monitors for the Beam Test at DESY
  BELLE2-NOTE-TE-2016-008, NTC Readout System for the Belle II VXD
  BELLE2-NOTE-TE-2016-xxx, The VXD Local Hardwired Interlock System (draft)
  Other documents in Confluence (internal Belle II repository)

- VXD Monitoring crew

  L. Bosisio, B. Gobbo, I. Komarov, C. La Licata, L. Lanceri, D. Tonelli, L. Vitale (Univ. & INFN Trieste) *+ students*

  Technicians: M. Bari, P. Cristaudo, A. Zanetti *+ electronics & mechanics workshops* (INFN Trieste)

  G. Cautero, D. Giuressi, H. Menk (Elettra Sincrotrone Trieste SCpA) *+ students*

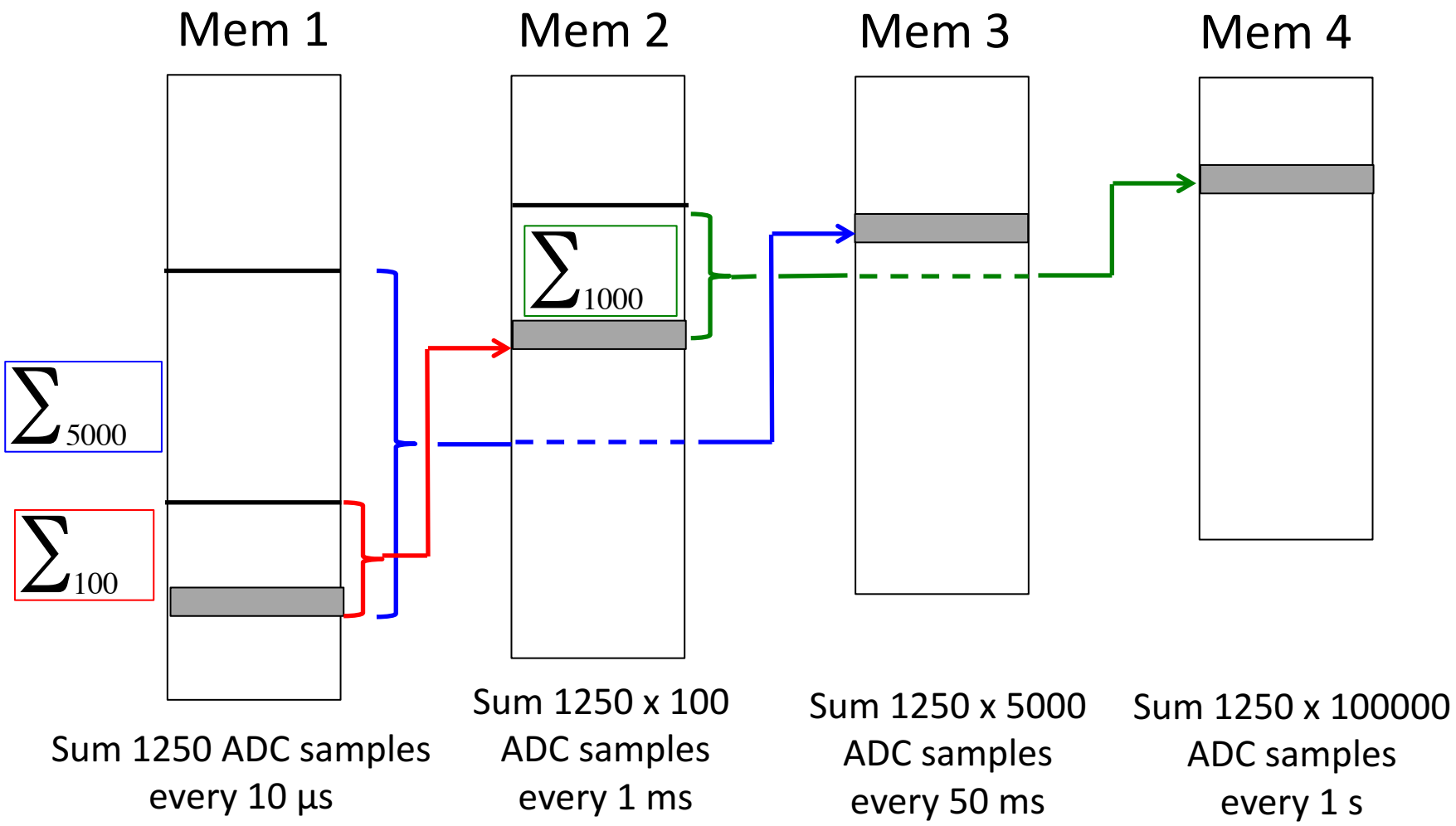
  S. Bacher (Krakóv)

  + Vienna, KEK, Bonn, DESY, MPI etc *precious contributions*

RADIATION: PHASE 1 STUDIES

Diamonds: Abort Buffer Memories

Present configuration of revolving Abort Buffer Memories
to be improved with really “running sums”



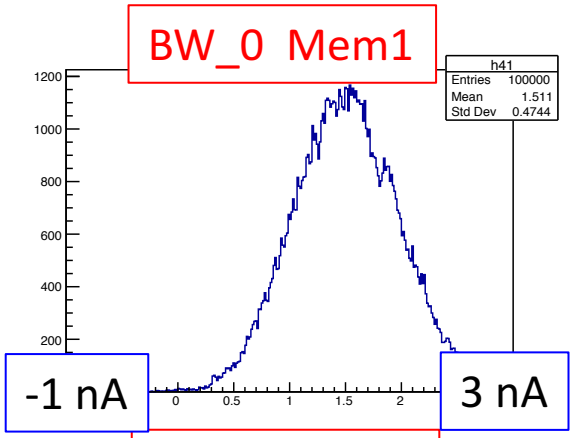
Buffer Memories: Snapshot Example

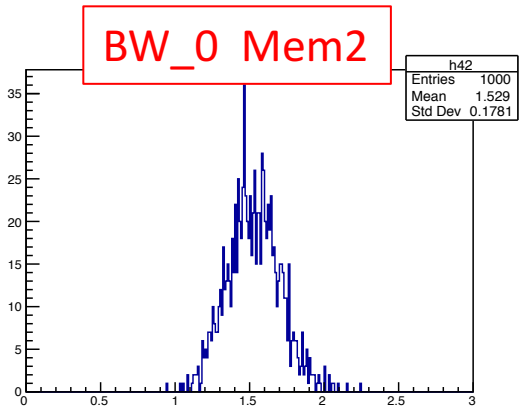
Example of snapshot of Buffer Memories (Mem1 to Mem4) for Dia3 = BW_0 in stable beam conditions, with average I(BW_0) = 1.5 nA

Noise decreases with increased averaging, from about 0.47 nA to < 0.04 nA

OK both for fast (10 µs) and slow (> 1 s) beam aborts with appropriate thresholds

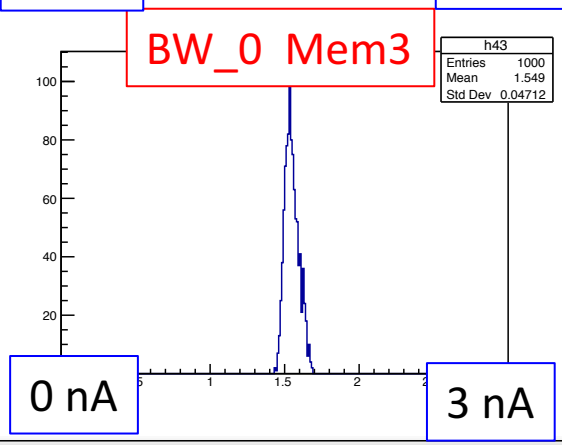
100000 entries
1 s history
σ = 0.47 nA

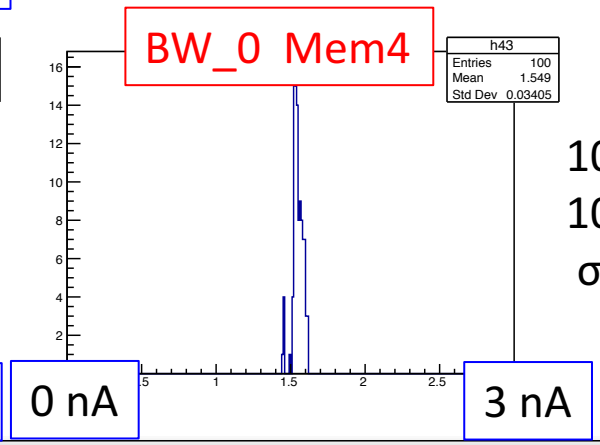




1000 entries
1 s history
σ = 0.18 nA

1000 entries
50 s history
σ = 0.047 nA





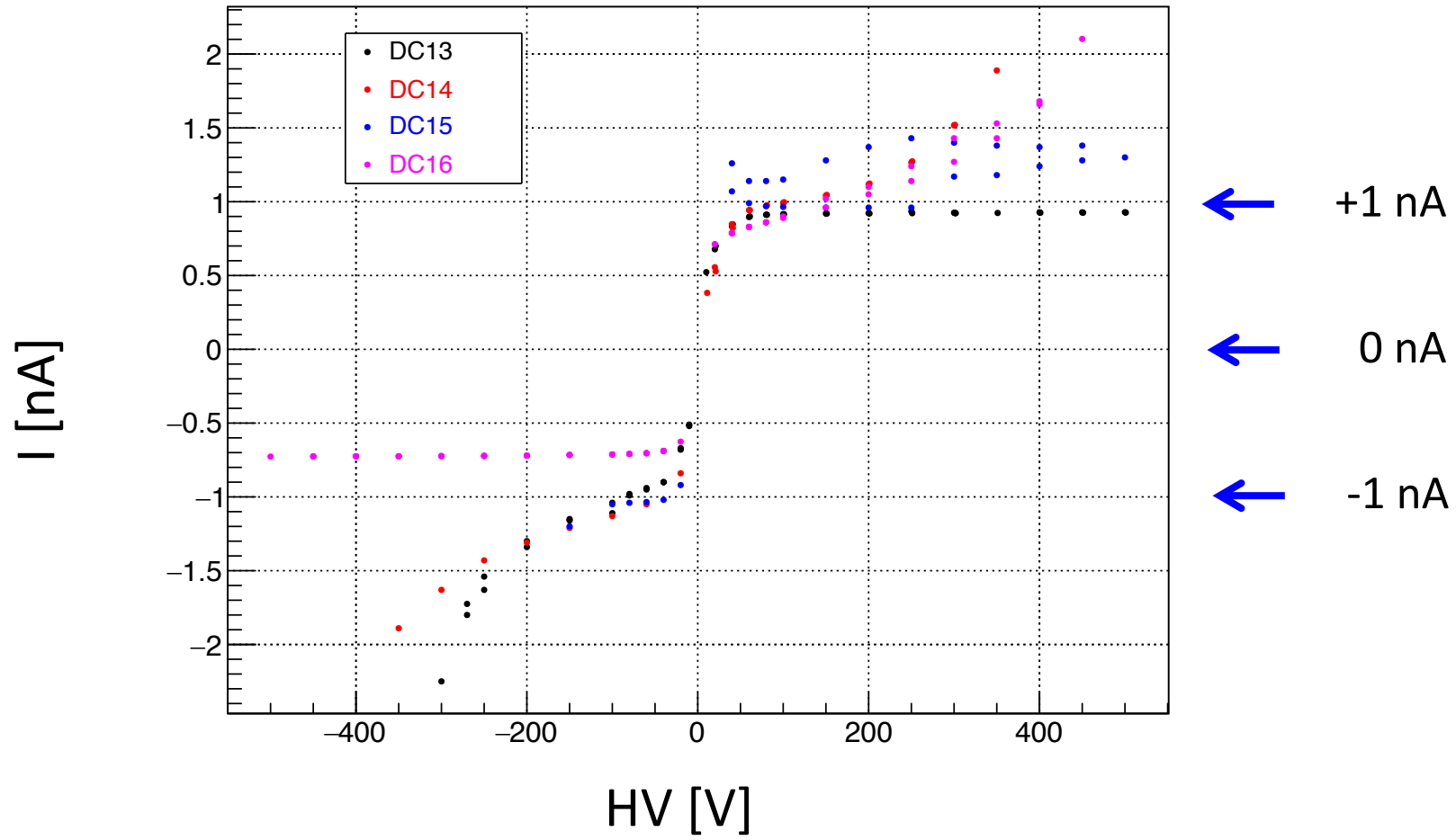
100 entries
100 s history
σ = 0.034 nA

Diamonds in BEAST 1: Summary

- Main goals for BEAST 1 and results
  - Validation of sCVD sensor choice, mechanics, cables **OK**
  - Characterization of prototype electronics **OK**
  - Stability and reliability of operation over several months **OK**
  - Correlations with accelerator conditions and backgrounds, contributions to BEAST studies **OK**
  - Initial studies of beam abort features **just started**
  - Integration in EPICS **marginal trick now: to be done!**
- Plans for the future (as May 2016)
  - Check absolute calibrations of the 4 BEAST-1 sensors
  - Mounting, test, calibrations of final diamond sensors in Trieste
  - Final electronics production (at least 2 boxes ready for BEAST – 2)
  - Prepare for BEAST – 2 and SVD installation

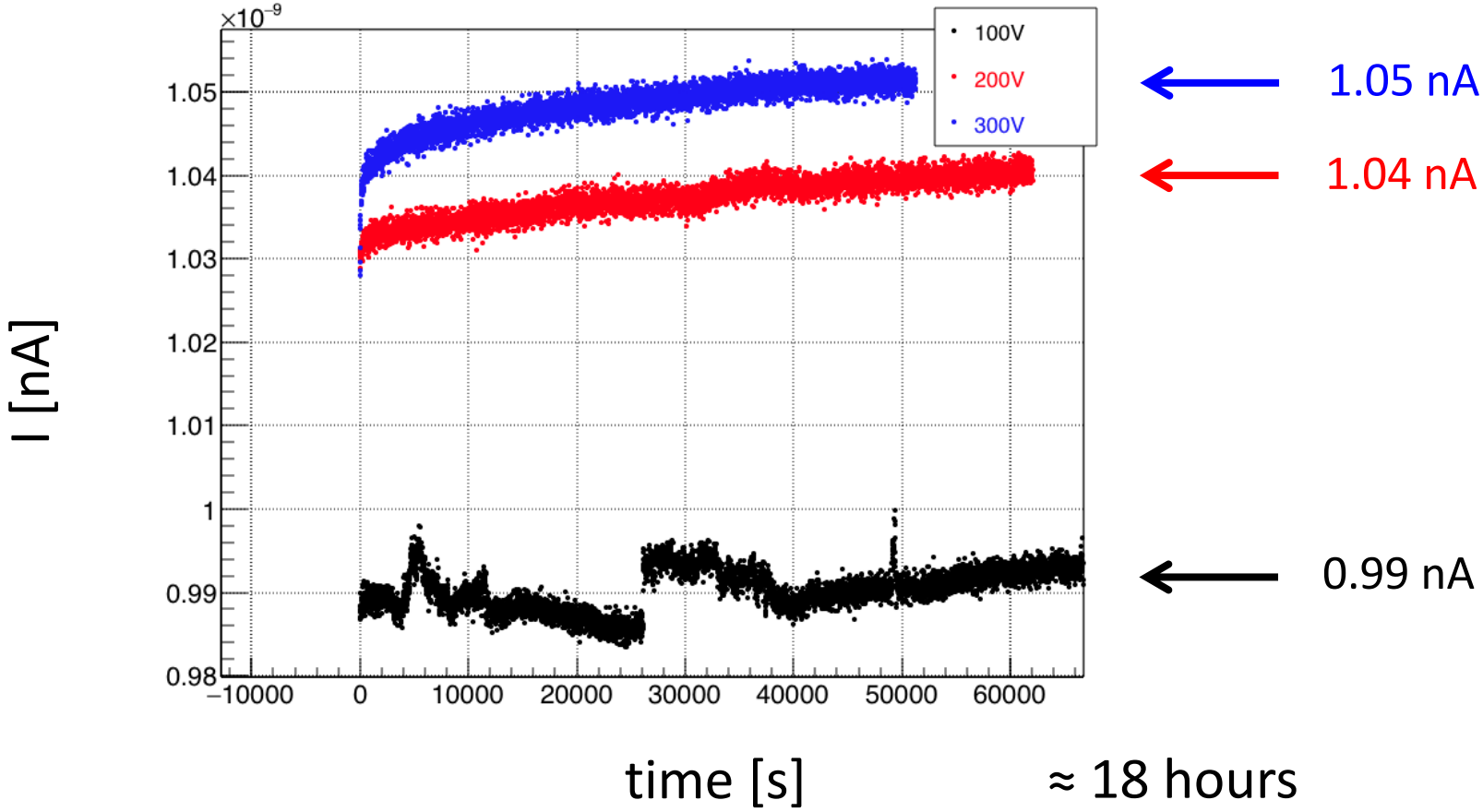
Examples from 17 tested sensors - 1

I-V measurements with β source of 4 sensors:
sCVD crystals are not all equal; asymmetric behaviour



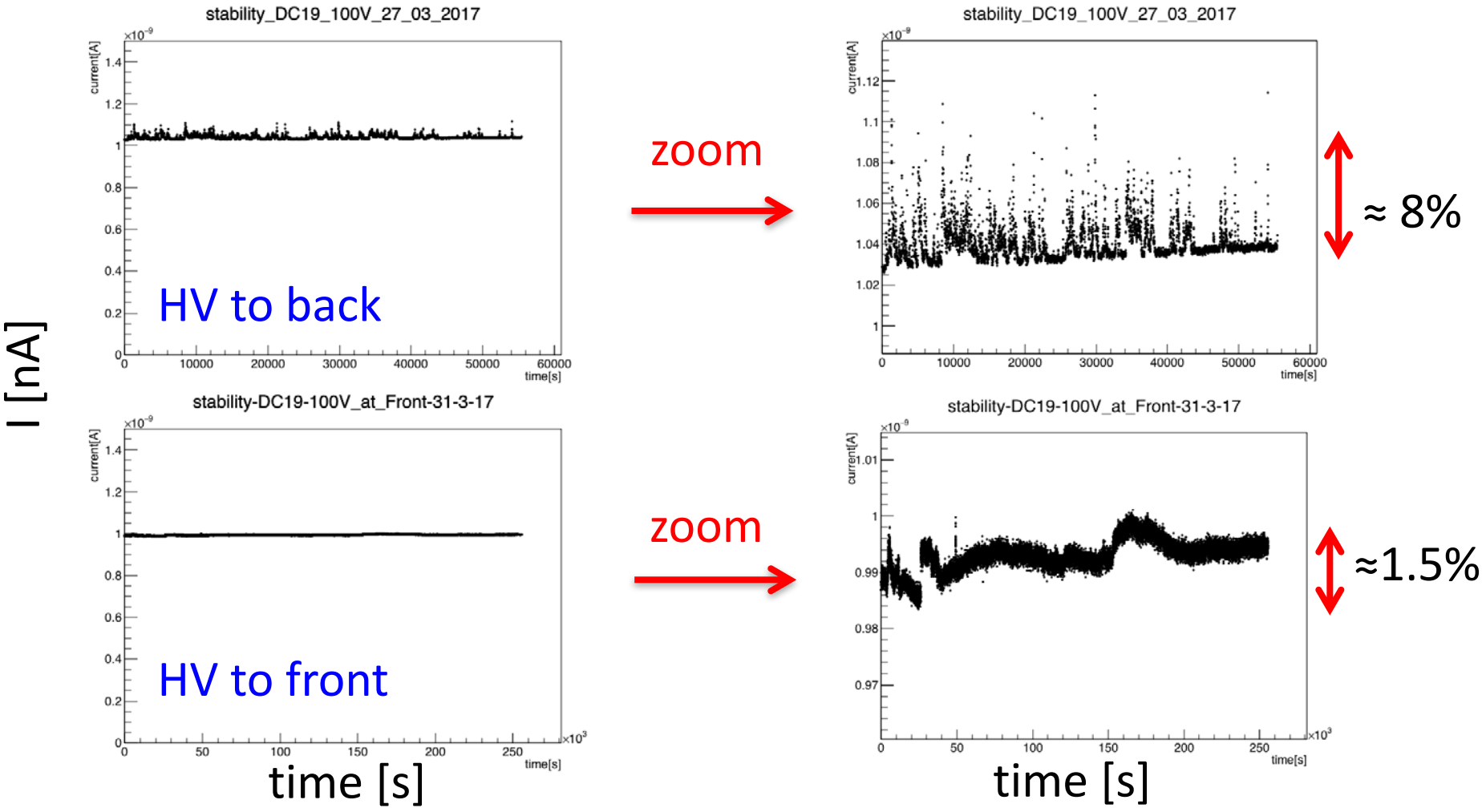
Examples from 17 tested sensors - 2

Priming/stability studies with β source at different HV values: example from one sensor



Examples from 17 tested sensors - 3

Stability at about 1 nA may depend (not always) on HV polarity



RADIOCHROMIC FILMS DOSIMETRY (WITH NAPLES)

Absolute dose measurement with radiochromic films in BEAST II phase 2 (Napoli group)

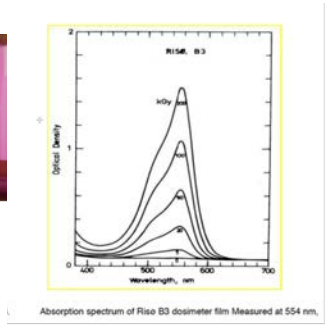
- Non-invasive radio-chromic films has been proposed for integrated measurements during phase 2, **collaboration with Trieste group**
- Proposal well accepted by Japanese colleagues
- Study of dose radial dependence
- Independent dose measurement cross-check for several sub-detectors
- Thin layer films and easy handling: negligible material budget
- High spatial resolution, no processing required to develop or fix the image, insensitive to visible light

Film types proposed for BEAST application

- B3 (3kGy-100 kGy), to be positioned very close to interaction point
- HDV2 (10 Gy – 1kGy) for intermediate range
- EBT3 (1-60 Gy) calorimeter region
- Wide range of doses could be covered with the 3 film types proposed

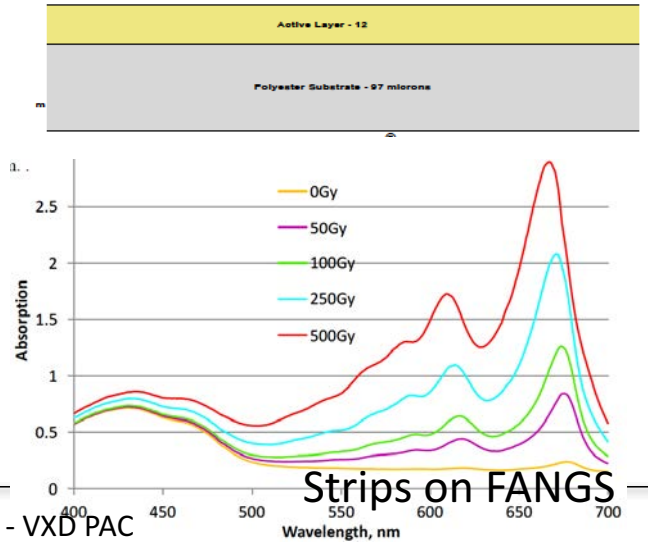
B3 films

- Plastic polyvinyl butyral by Riso laboratory Denmark
- Thickness: 20 µm
- Dose range (3kGy-100 kGy)
- Readout peak at 554 nm



HD-V2

- Active layer (12 µm) coated on a 97 µm polyester substrate
- Dose range (10Gy-1kGy)
- Readout peak maximum at 670 nm

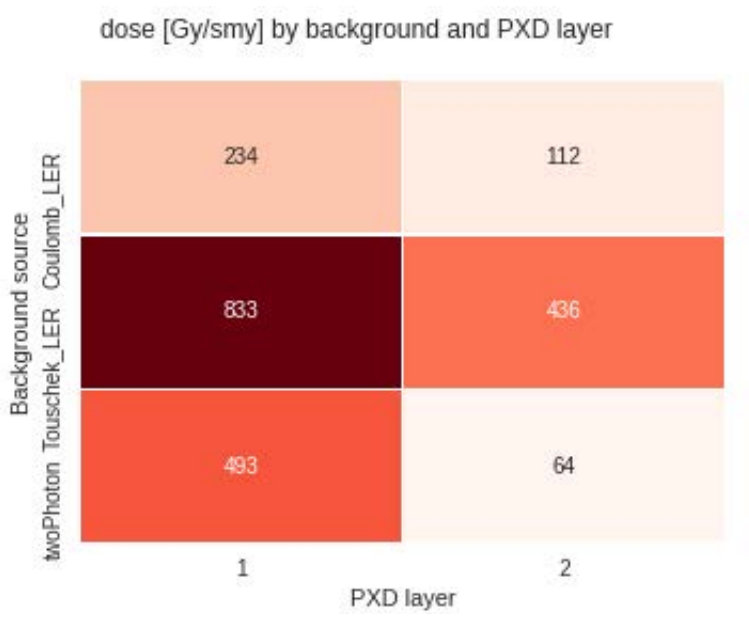


Strips on FANGS

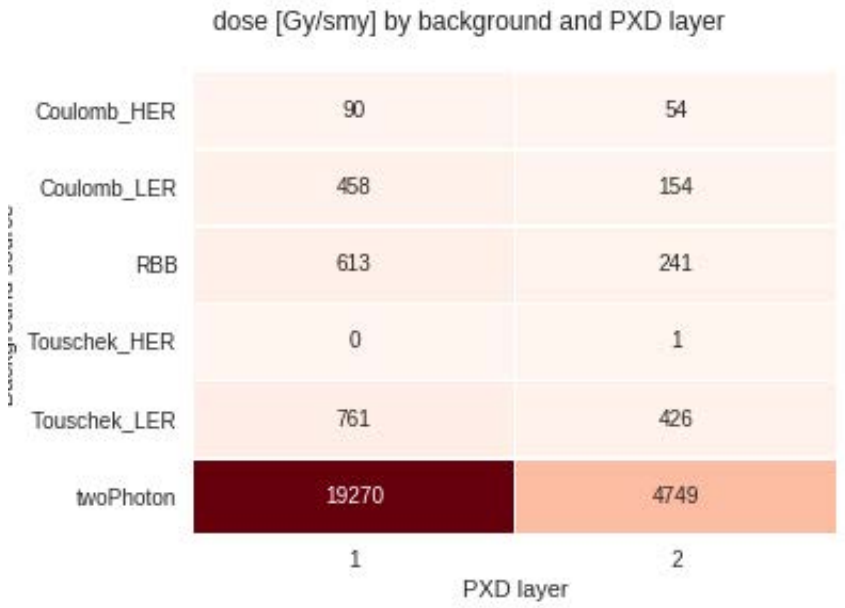
RADIATION: SIMULATION RESULTS

PXD: Ph2 vs Ph3 dose rate

Phase 2



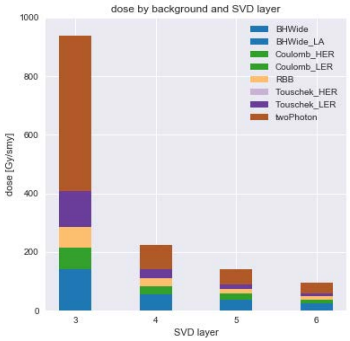
Phase 3



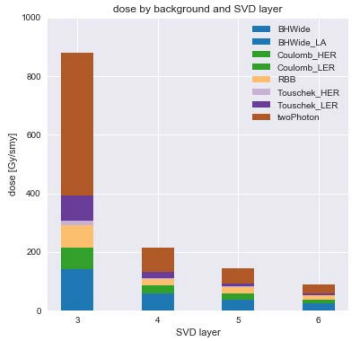
SVD: Ph3 dose rate

Dose

(a) Campaign 16



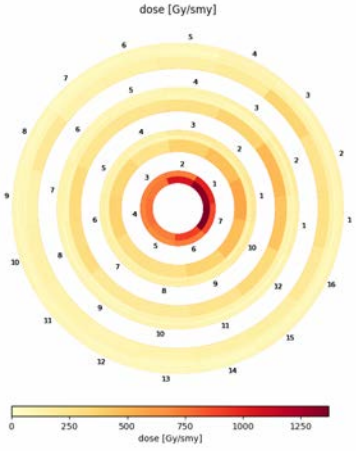
(b) Campaign 15



dose [Gy/smy] by background and SVD layer

	3	4	5	6
BHWide	123	50	32	21
BHWide_LA	18	5	4	2
Coulomb_HER	9	2	1	1
Coulomb_LER	63	24	21	12
RBB	73	28	16	12
Touschek_HER	0	0	1	0
Touschek_LER	122	31	15	11
twoPhoton	531	82	51	34

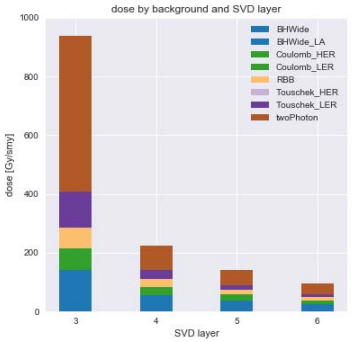
SVD layer



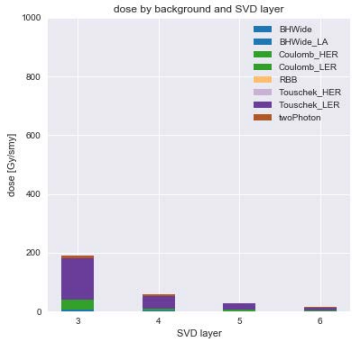
SVD: Ph3 vs Ph2 dose rate

Dose

(a) Phase3



(b) Phase2



dose [Gy/smy] by background and SVD layer

	3	4	5	6
BHWide	123	50	32	21
BHWide_LA	18	5	4	2
Coulomb_HER	9	2	1	1
Coulomb_LER	63	24	21	12
RBB	73	28	16	12
Touschek_HER	0	0	1	0
Touschek_LER	122	31	15	11
twoPhoton	531	82	51	34

SVD layer

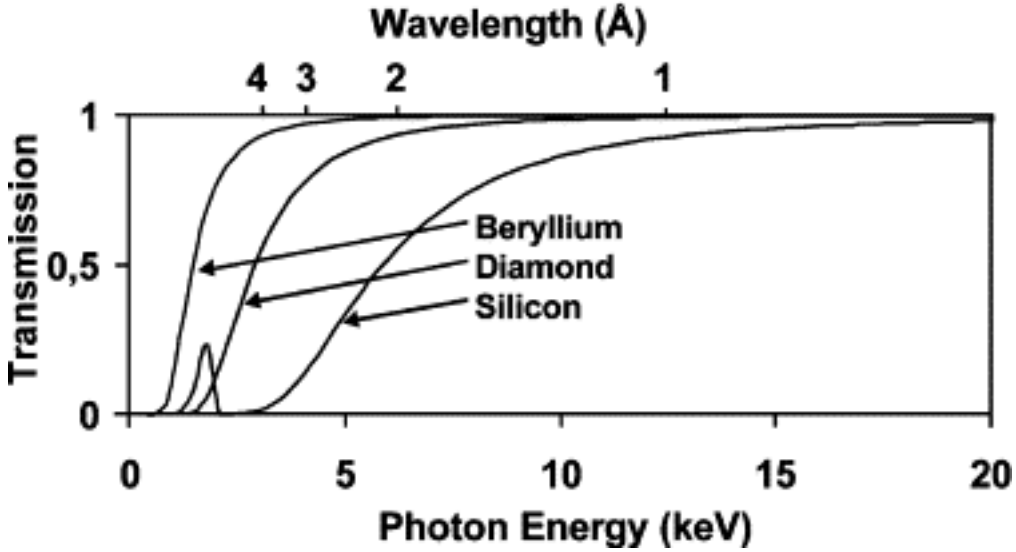
dose [Gy/smy] by background and SVD layer

	3	4	5	6
BHWide	6	2	1	1
BHWide_LA	1	0	0	0
Coulomb_HER	0	0	0	0
Coulomb_LER	34	6	4	3
RBB	0	0	0	0
Touschek_HER	0	0	0	0
Touschek_LER	140	45	22	9
twoPhoton	10	4	2	2

SVD layer

Diamond low sensitivity to x-rays

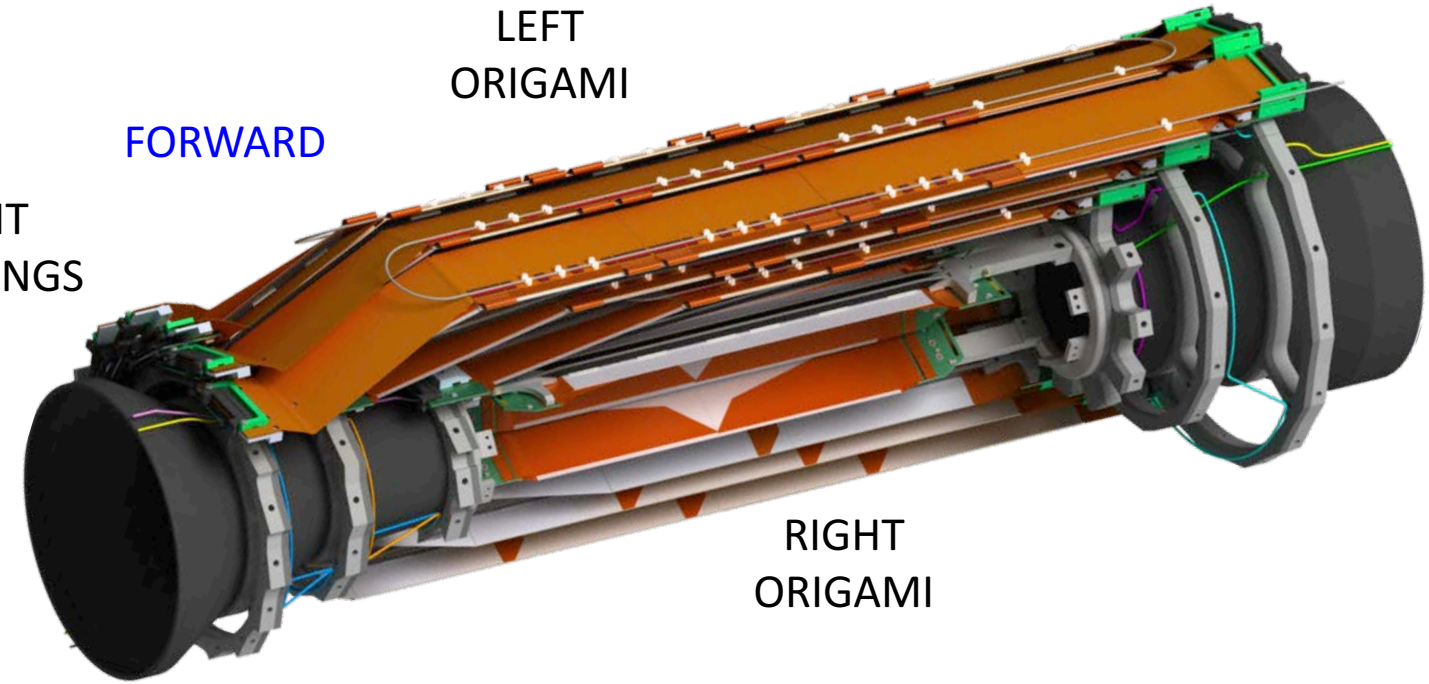
- Comparison Diamond vs. Silicon 20 um thick



Property	Beryllium	Silicon	CVD diamond
Atomic number	4	14	6
Density (g cm^{-3})	1.85	2.33	3.52
Thermal conductivity (W m^{-1} K^{-1})	230	170	500–2600
Thermal expansion @ 300 K (10^{-6} K^{-1})	11.5	2.5	1.1
Young's modulus (GPa)=Elastic modulus	300	100	1220
Poisson's ratio	0.18	0.28	0.2
Bond strength (kJ/mole) Si–Si, C–C sp^3		220	330–380
Refractive index δ at 10 keV ($\times 10^{-6}$)	3.4	5.0	7.4
Refractive index δ at 20 keV ($\times 10^{-6}$)	0.9	1.2	1.8
Attenuation length at 10 keV (mm)	9.4	0.13	1.3
Attenuation length at 20 keV (mm)	28	1.0	7.7

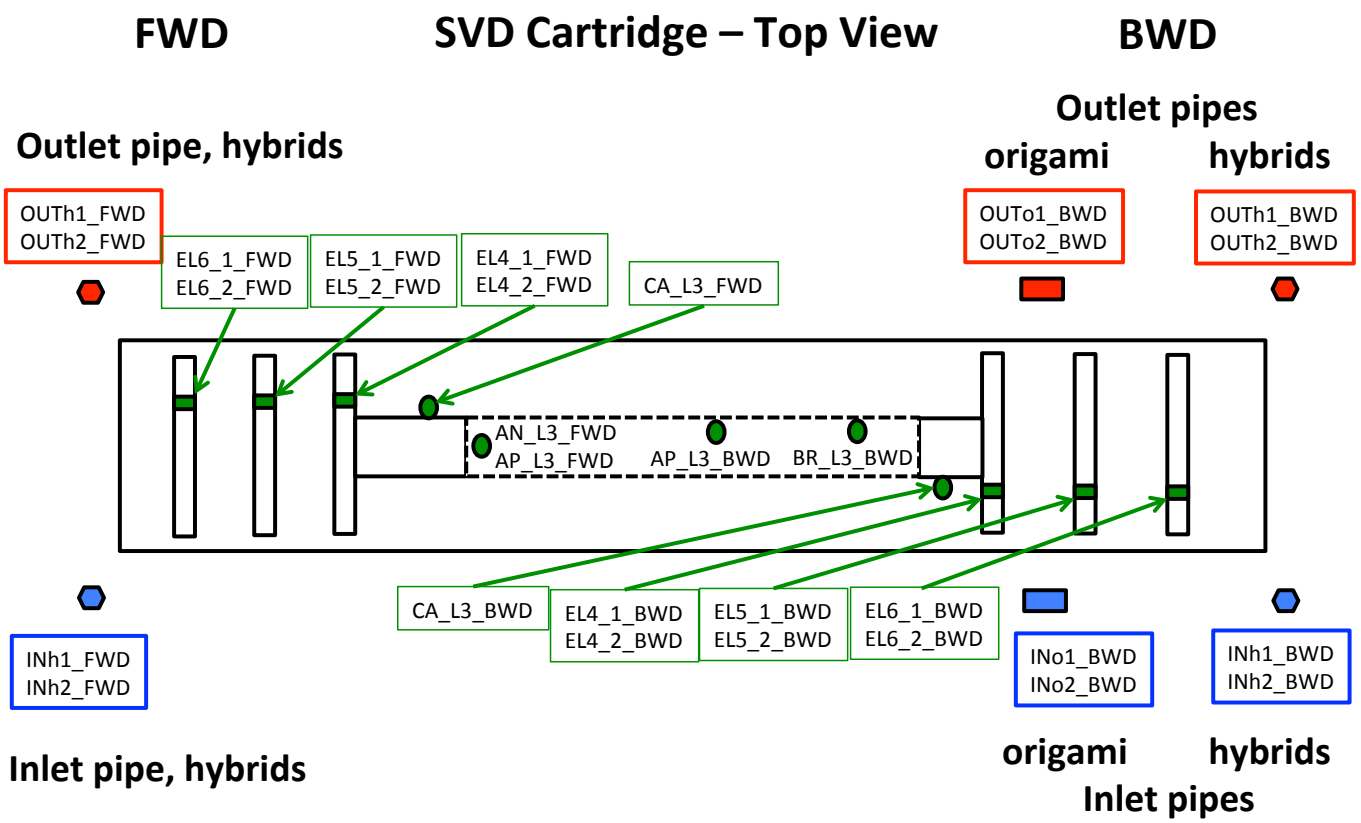
CO_2 cooling system: NTC sensors

Temperatures of the half rings
and at the inlets and outlets
of each CO_2 circuit



+ 8 sensors to cross-check
a sample of FOS sensors
+ 12 for CO_2 in the external circuits,
requested by the CO_2 group

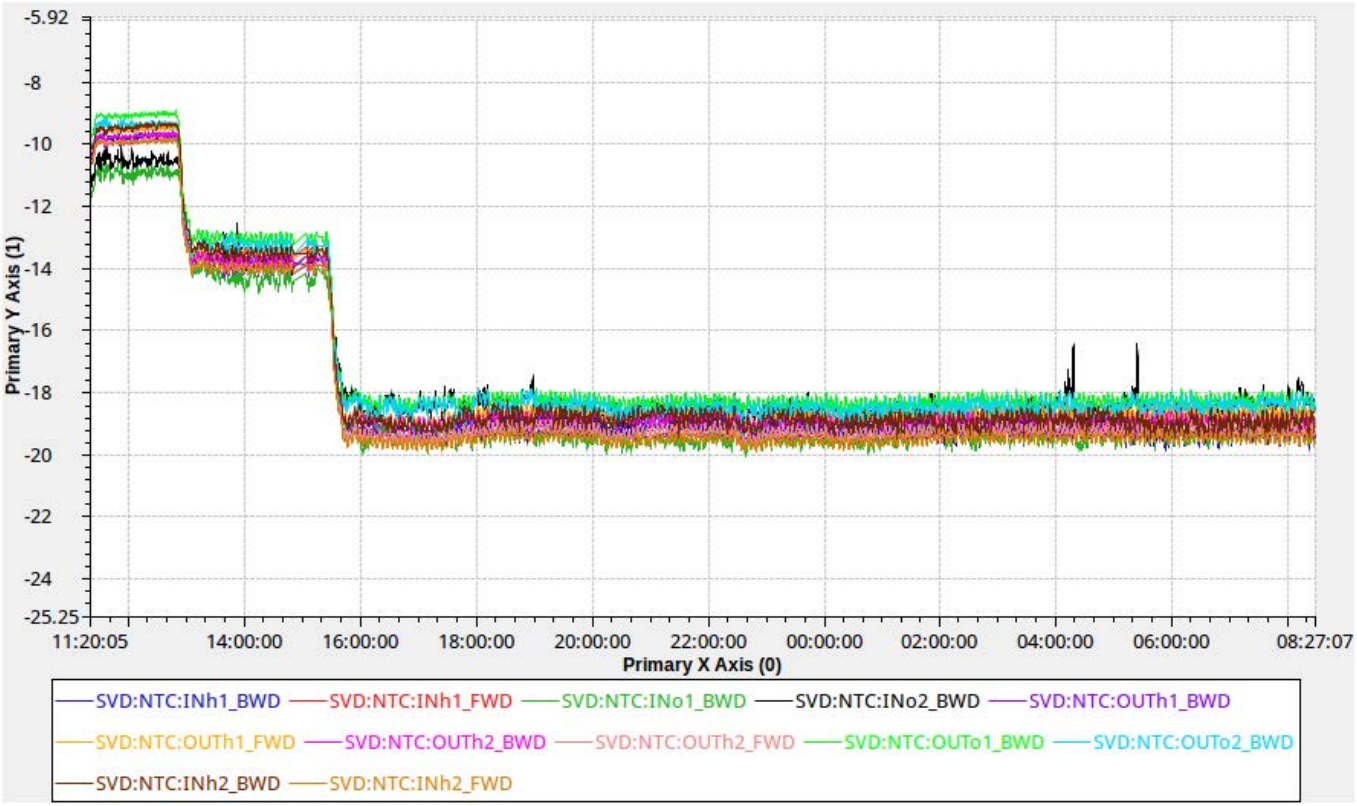
NTC Sensors in SVD Cartridge @BT



Similar to the final SVD configuration, where pairs of NTCs will monitor inlets and outlets of the CO_2 cooling lines, and each of the supporting "half rings", with their cooling channels

NTC Temperature @BT

The temperature of the CO_2 cooling system (MARCO) decreased gradually in steps. With MARCO running at -27°C, NTC readings of SVD CO_2 in/out lines were at -20°C



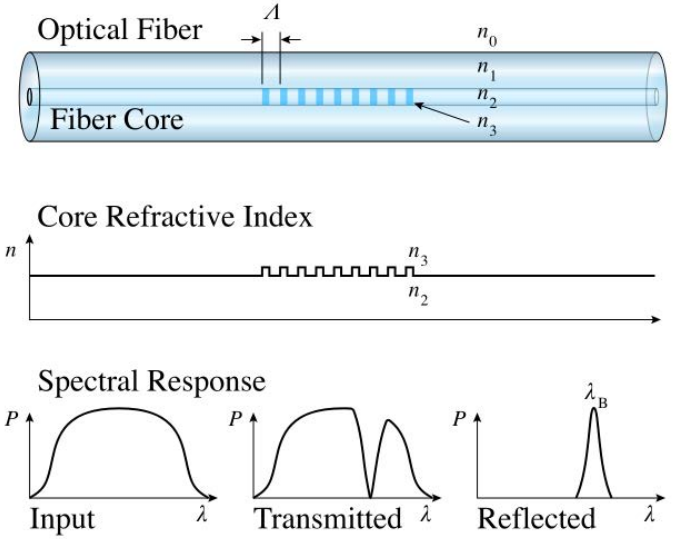
FBG Sensors Calibrations

- Fiber Bragg Grating (FBG)

  Maximum reflectivity at $\lambda_B = 2n_{eff}\Lambda$

  Wavelength λ_B depends on strain ε, temperature T

$$\Delta\lambda_B = \lambda_B(1-\rho_\alpha)\Delta\epsilon + \lambda_B(\alpha+\xi)\Delta T$$



- Calibrations

  Environmental chamber

  Reference PT100

  Polynomial fit (3rd order)

  Stable and reproducible results, within specs.

Phase3: FOS on SVD outer covers

FOS fibers with 4 sensors were glued and tested on the SVD outer covers in Sept (Phase 2 were done on May)

Phase 3 activities: ladder-mount

First 2 FOS on L4+x, locations 4.09, 4.10; unfortunately L4.006 in 4.10 was dismounted on Sept 26, the other later

- In location 4.09 with a modified “dedicated” clamp and “after” H shape
- In location 4.10 with a “normal” clamp and “before” H shape

TEMPERATURE IN PXD: IN DCP

Temperature in PXD-1

Module Temperatures

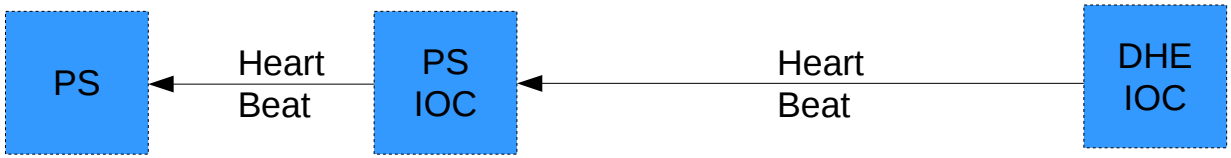
- measured via DHP temperature diode
- all covers, with clamp, chiller @ 18°C
  - only DHPs powered
    - 25-30
  - DHPs and DCD powered, but DCD analog OFF
    - 30-35

  --> for both W37_OF1 and EMCM
  - DHPs and DCDs powered and DCD analog ON
    - 50-58
  - all powered (DCDs analog ON and matrix)
    - 55-60
- calibration?
  - even with only DHPs powered: 5-10 spread between DHP temperatures

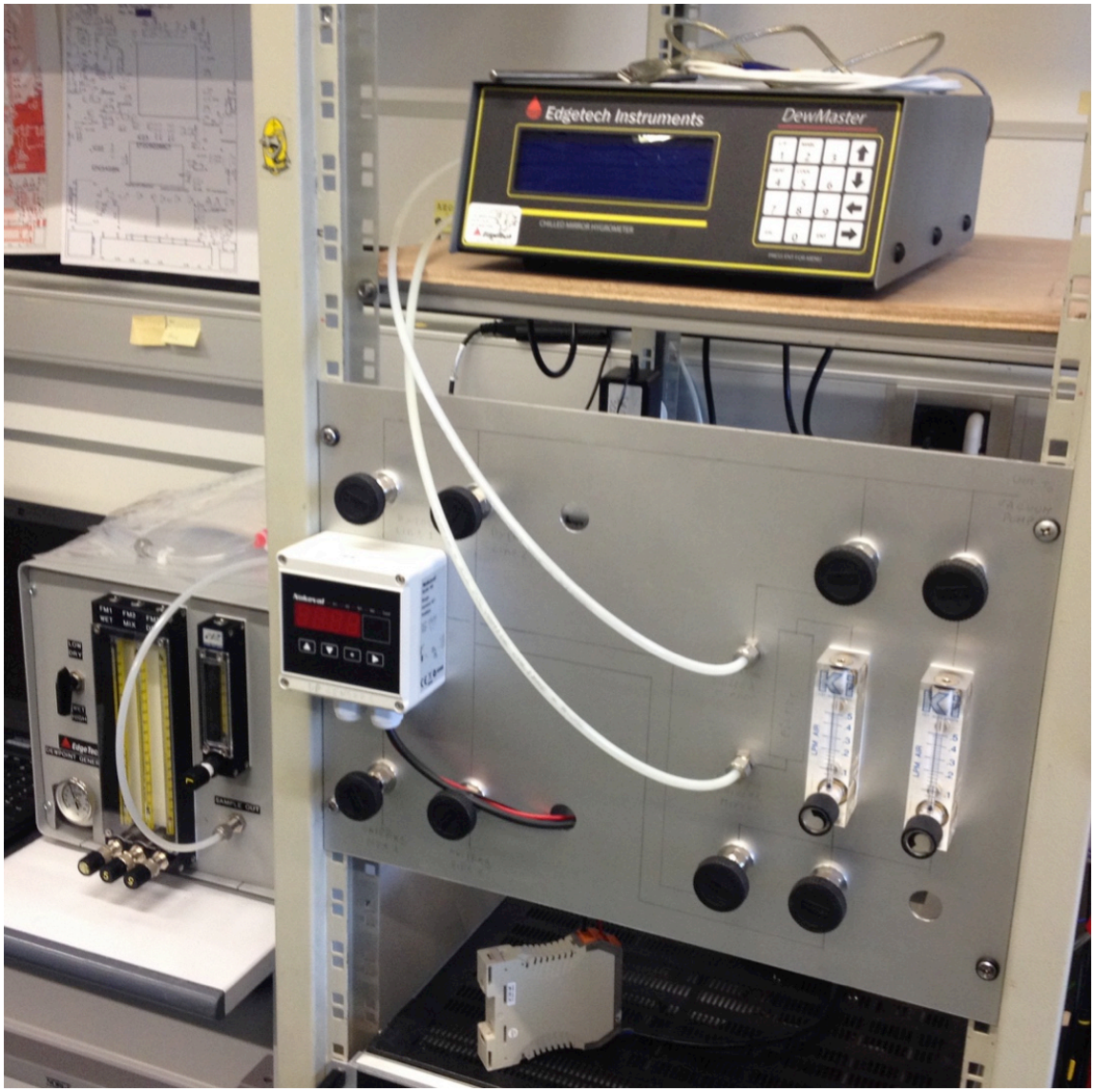
Temperature in PXD-2

Temperature Interlock

- Utility IOC can monitor the DHP temperatures and trigger an emergency shutdown
- Utility IOC is a temporary solution for lab setups and will not be used in the final experiment
- Heartbeat between PS Seq IOC and DHH IOC required for a stable and save solution
  - This requires some work on both IOCs, to produce/receive the heartbeat and perform the temperature measurement



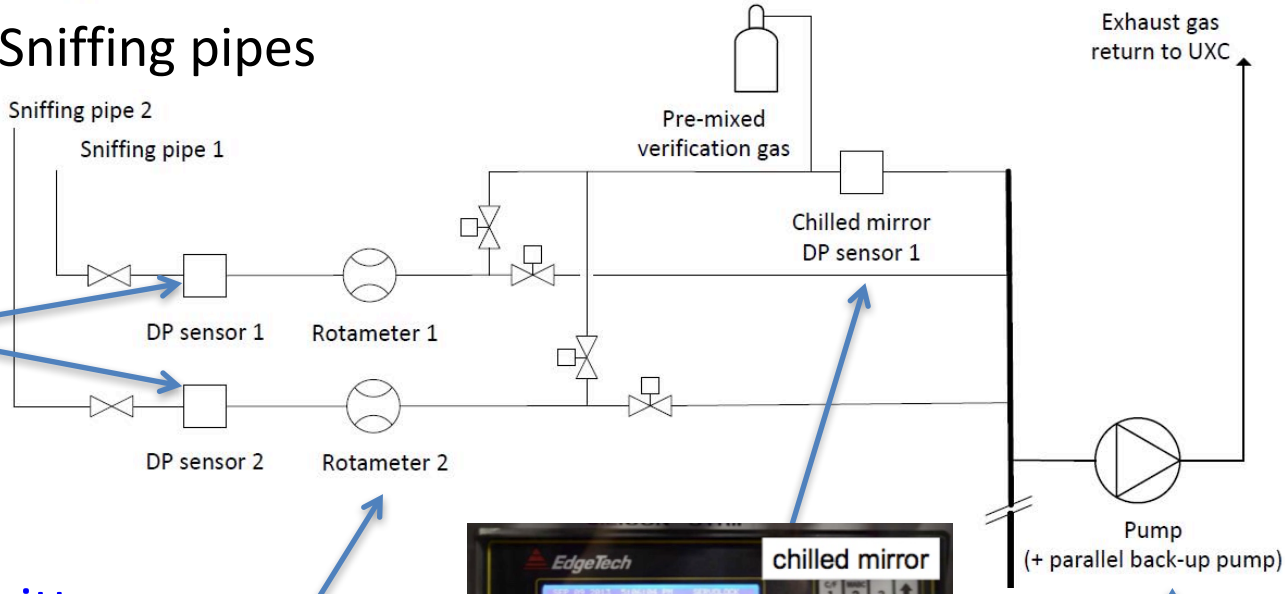
Humidity calibration system



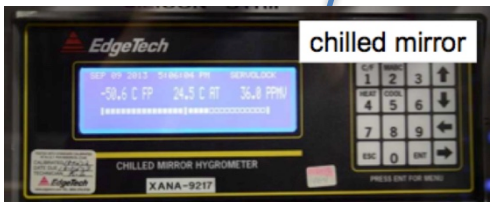
Dew point generator (DewGen) for calibrations

Humidity: inputs from Dew Point Sensors

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



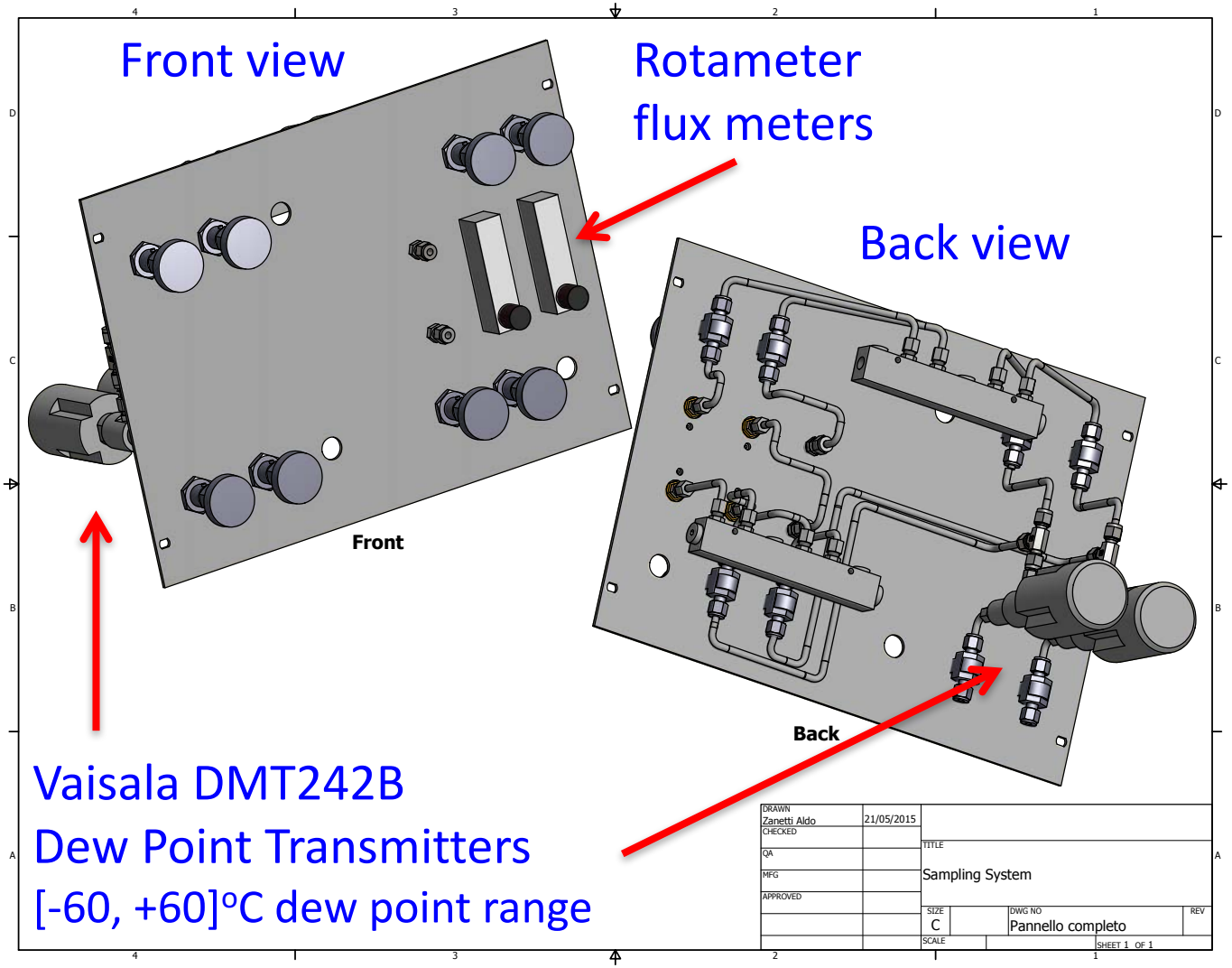
Rotameter
flux meters



Edgetech Dewmaster
Chilled Mirror Hygrometer
(for calibrations)

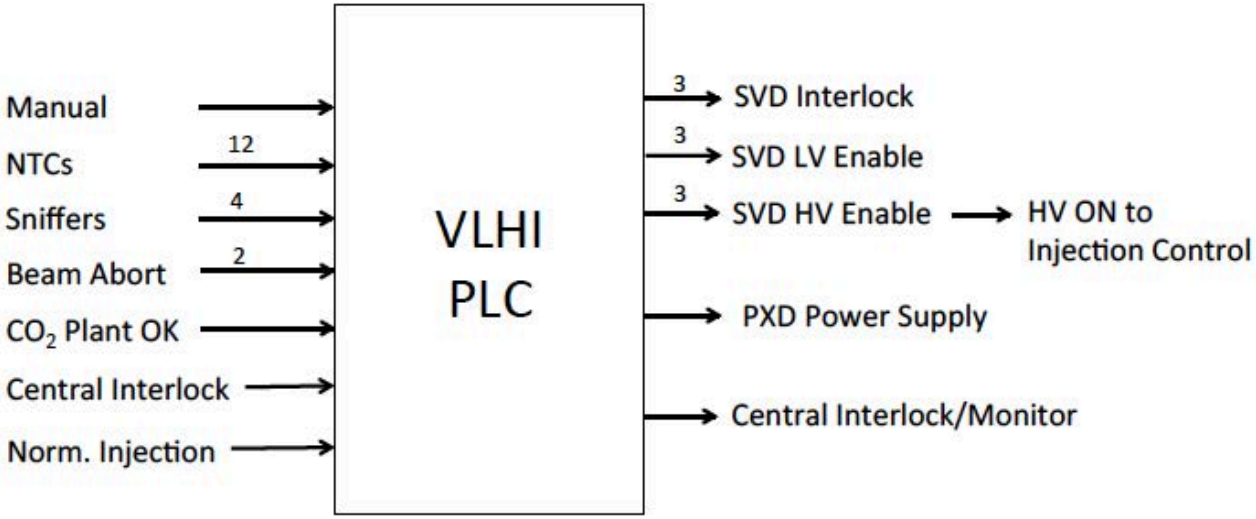
Pump

Prototype system under construction

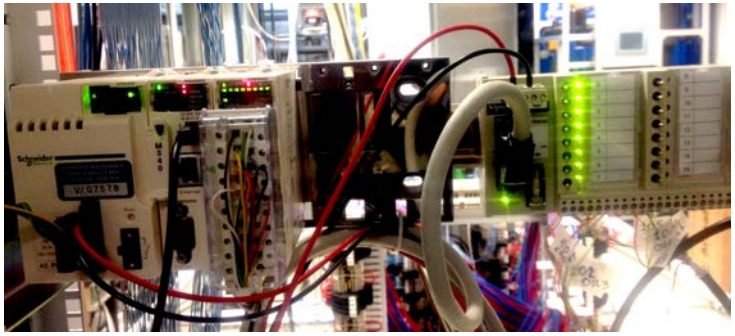


Simplified Block Diagram, PLC

VXD Local Hardwired Interlock = VLHI



Schneider Electric Modicon M340
+ BMX DDM 16022 Discrete I/O
+ BMX AMI 0410 Analog Input



VLHI I/O spreadsheet

VLHI PLC crate configuration: inputs, outputs, connectors (preliminary, August 24, 2017)

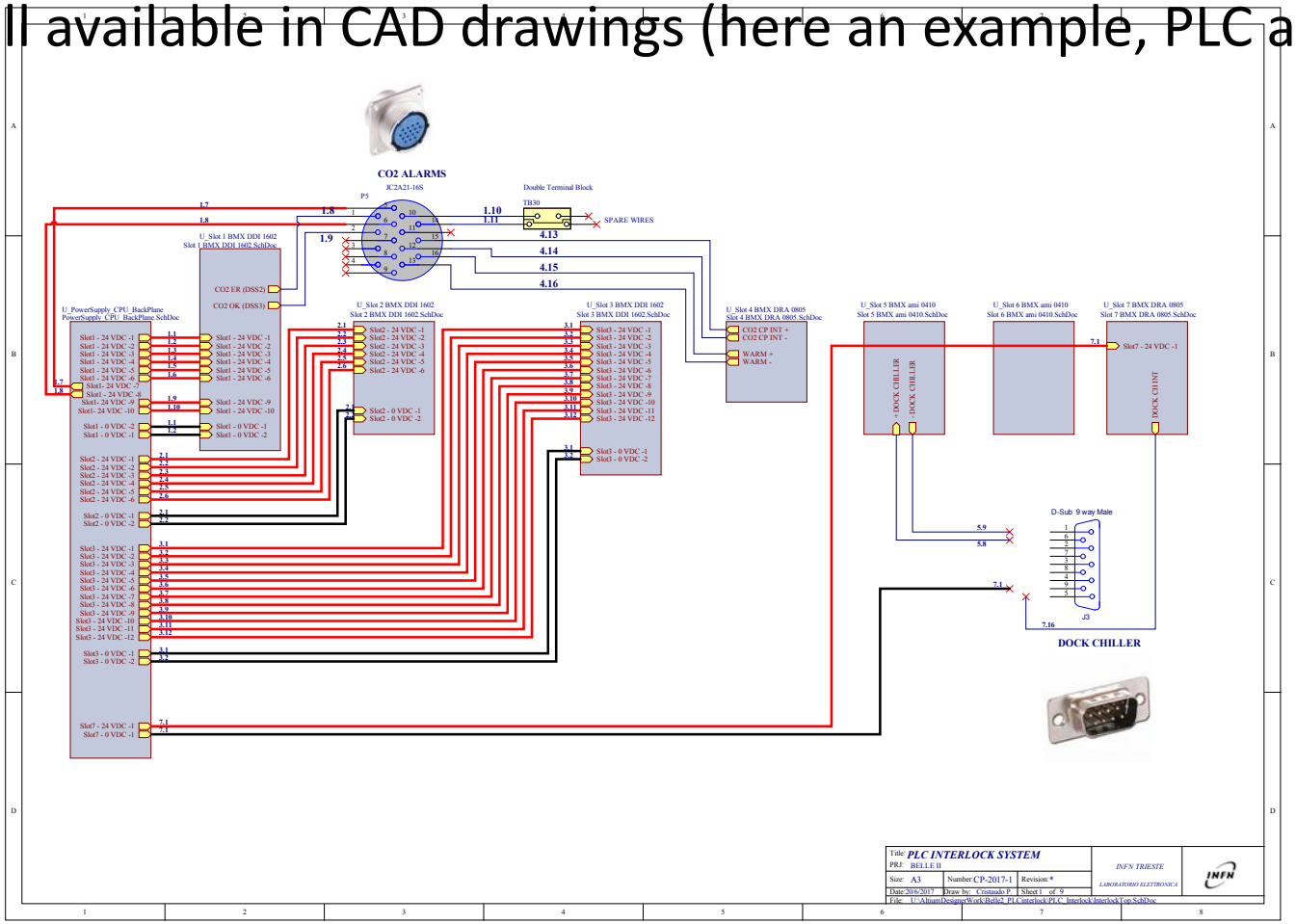
						cable				PLC Pannel Connector			
Unit	**purpose**	**I/O channels**	**type**	**assignment**	**PLC memory**	**type**	**length**	**from**	**to**	**type**	**pins**	**Reference person**	**Institution**
CPS3500	power unit												
BMX P34 20302	M340 CPU	USB											
		Ethernet											
		CANopen											
BMX DDI 1602	16-ch digital input	%I0.1.0	EBOOL	Manual	%MW001	?						?	
slot 1		%I0.1.1	EBOOL	Beam Abort	%MW002	?						?	
		%I0.1.2	EBOOL		%MW003								
		%I0.1.3	EBOOL	from_Central_Interlock_Sol_Abn	%MW011							Sadaharo Uehara	KEK
		%I0.1.4	EBOOL	from_Central_Interlock_Env_Mon	%MW012	Multiconductor 8 wires				JC series 10 pin Female		Sadaharo Uehara	KEK
		%I0.1.5	EBOOL	from_Central_Interlock_WaterLeak	%MW013							Sadaharo Uehara	KEK
		%I0.1.6	EBOOL	from_Central_Interlock_EH_Power	%MW014							Sadaharo Uehara	KEK
		%I0.1.7	EBOOL	CO2 ER COND. (DSS2)		Multiconductor 10 wires				JC series 16 pin Female (4pin of 16)		Hans-Gunther Moser	MPI Munich
		%I0.1.8	EBOOL	CO2 OK (DSS3)								Hans-Gunther Moser	MPI Munich
		%I0.1.9	EBOOL										
		%I0.1.10	EBOOL										
		%I0.1.11	EBOOL										
		%I0.1.12	EBOOL										
		%I0.1.13	EBOOL										
		%I0.1.14	EBOOL										
		%I0.1.15	EBOOL										
BMX DDI 1602	16-ch digital input	%I0.2.0	EBOOL	HumiditySniffer_1	%MW021							Benigno Gobbo	INFN Trieste
slot 2		%I0.2.1	EBOOL	HumiditySniffer_2	%MW022					D-SUB 9 pin Male		Benigno Gobbo	INFN Trieste
		%I0.2.2	EBOOL	HumiditySniffer_3	%MW023							Benigno Gobbo	INFN Trieste
		%I0.2.3	EBOOL	HumiditySniffer_4	%MW024							Benigno Gobbo	INFN Trieste
		%I0.2.4	EBOOL	NTC_Temperature_1	%MW031							Pietro Cristaudo	INFN Trieste
		%I0.2.5	EBOOL	NTC_Temperature_2	%MW032	twisted round cable 5 couple				D-SUB 9 pin Female		Pietro Cristaudo	INFN Trieste
		%I0.2.6	EBOOL	NTC_Temperature_3	%MW033							Pietro Cristaudo	INFN Trieste
		%I0.2.7	EBOOL	NTC_Temperature_4	%MW034							Pietro Cristaudo	INFN Trieste
		%I0.2.8	EBOOL	NTC_Temperature_5	%MW035							Pietro Cristaudo	INFN Trieste
		%I0.2.9	EBOOL	NTC_Temperature_6	%MW036	twisted round cable 5 couple				D-SUB 9 pin Female		Pietro Cristaudo	INFN Trieste
		%I0.2.10	EBOOL	NTC_Temperature_7	%MW041							Pietro Cristaudo	INFN Trieste
		%I0.2.11	EBOOL	NTC_Temperature_8	%MW042							Pietro Cristaudo	INFN Trieste
		%I0.2.12	EBOOL	NTC_Temperature_9	%MW043							Pietro Cristaudo	INFN Trieste
		%I0.2.13	EBOOL	NTC_Temperature_10	%MW044	twisted round cable 5 couple				D-SUB 9 pin Female		Pietro Cristaudo	INFN Trieste
		%I0.2.14	EBOOL	NTC_Temperature_11	%MW045							Pietro Cristaudo	INFN Trieste
		%I0.2.15	EBOOL	NTC_Temperature_12	%MW046							Pietro Cristaudo	INFN Trieste
BMX DDI 1602	16-ch digital input	%I0.3.0	EBOOL	WaterLeak_Disconnected_1	%MW051	flat?						Markus Friedl	Vienna
slot 3		%I0.3.1	EBOOL	WaterLeak_Disconnected_2	%MW052	flat?				D-SUB 15 pin Male		Markus Friedl	Vienna
		%I0.3.2	EBOOL	WaterLeak_Disconnected_3	%MW053	flat?						Markus Friedl	Vienna
		%I0.3.3	EBOOL	WaterLeak_Disconnected_4	%MW054	flat?						Markus Friedl	Vienna
		%I0.3.4	EBOOL	WaterLeak_Disconnected_5	%MW055	flat?						Markus Friedl	Vienna
		%I0.3.5	EBOOL	WaterLeak_Detected_1	%MW061	twisted pair						Markus Friedl	Vienna
		%I0.3.6	EBOOL	WaterLeak_Detected_2	%MW062	twisted pair				D-SUB 15 pin Female		Markus Friedl	Vienna
		%I0.3.7	EBOOL	WaterLeak_Detected_3	%MW063	twisted pair						Markus Friedl	Vienna
		%I0.3.8	EBOOL	WaterLeak_Detected_4	%MW064	twisted pair						Markus Friedl	Vienna
		%I0.3.9	EBOOL	WaterLeak_Detected_5	%MW065	twisted pair						Markus Friedl	Vienna
		%I0.3.10	EBOOL										
		%I0.3.11	EBOOL										
		%I0.3.12	EBOOL										
		%I0.3.13	EBOOL										
		%I0.3.14	EBOOL										
		%I0.3.15	EBOOL										
BMX DRA 0805	8-ch rele	%Q0.4.0	EBOOL	SVD_LV_Interlock_1	%MV101	coax BNC				BNC		Francesco Forti	INFN Pisa
slot 4		%Q0.4.1	EBOOL	SVD_LV_Interlock_2	%MV102	coax BNC				BNC		Francesco Forti	INFN Pisa
		%Q0.4.2	EBOOL	SVD_LV_Interlock_3	%MV103	coax BNC				BNC		Francesco Forti	INFN Pisa
		%Q0.4.3	EBOOL	SVD_HV_Interlock_1	%MV111	coax BNC				BNC		Francesco Forti	INFN Pisa
		%Q0.4.4	EBOOL	SVD_HV_Interlock_2	%MV112	coax BNC				BNC		Francesco Forti	INFN Pisa
		%Q0.4.5	EBOOL	SVD_HV_Interlock_3	%MV113	coax BNC				BNC		Francesco Forti	INFN Pisa
		%Q0.4.6	EBOOL	CO2_CoolingPlant_Interlock	%MV132	Multiconductor 10 wires				JC series 16 pin Female (4pin of 16)		Hans-Gunther Moser	MPI Munich
		%Q0.4.7	EBOOL	WARM								Hans-Gunther Moser	MPI Munich
BMX AMI 0410	4-ch analog inputs	%I0.5.0	INT	N2 Flow	%MW301	?						?	DESY ?
slot 5		%I0.5.1	INT	DOCK_Chiller_flow	%MW302	?				D-SUB 9 pin male (2pin of 9)		Markus Friedler	Vienna
		%I0.5.2	INT	Pressure	%MW303	?						?	?
		%I0.5.3	INT										
BMX AMI 0410	4-ch analog inputs	%I0.6.0	INT										
slot 6		%I0.6.1	INT										
		%I0.6.2	INT										
		%I0.6.3	INT										
BMX DRA 0805	8-ch rele	%Q0.7.0	EBOOL	to_Central_Interlock_SVD_LV_Int	%MV141							Sadaharo Uehara	KEK
slot 7		%Q0.7.1	EBOOL	to_Central_Interlock_SVD_HV_Int	%MV142	Multiconductor 8 wires				JC series 10 pin Male		Sadaharo Uehara	KEK
		%Q0.7.2	EBOOL	to_Central_Interlock_PXD_Int	%MV143							Sadaharo Uehara	KEK
		%Q0.7.3	EBOOL	to_Central_Interlock_Waterleak_Int	%MV144							Sadaharo Uehara	KEK
		%Q0.7.4	EBOOL	PXD_Interlock_1	%MV121	coax BNC				BNC		?	?
		%Q0.7.5	EBOOL	PXD_Interlock_2	%MV122	coax BNC				BNC		?	?
		%Q0.7.6	EBOOL	PXD_Interlock_3	%MV123	coax BNC				BNC		?	?
		%Q0.7.7	EBOOL	DOCK_Chiller_Interlock	%MV131	?				D-SUB 9 pin male (2pin of 9)		Markus Friedler	Vienna

PLC I/O hardware completely defined:

- module types
- cables
- connectors

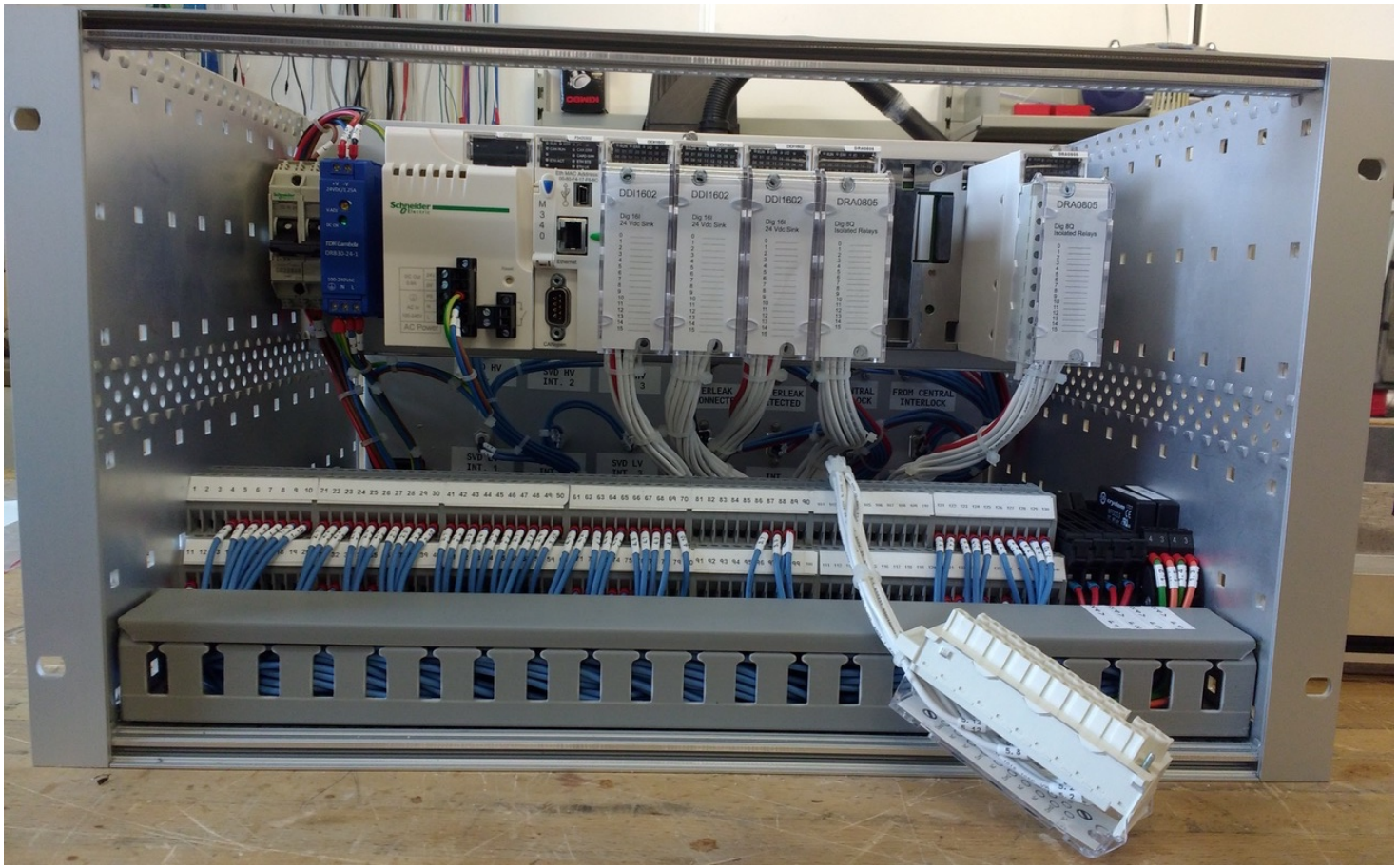
VLHI crate: CAD design

PLC crate internal cabling, I/O signal definitions and connection types: all available in CAD drawings (here an example, PLC at top level)



VLHI crate: front view

Front view of the cabled PLC crate;
Two empty slots: analog modules (available) to be inserted



VLHI crate: top view

Top view of the PLC crate: interconnections cabled