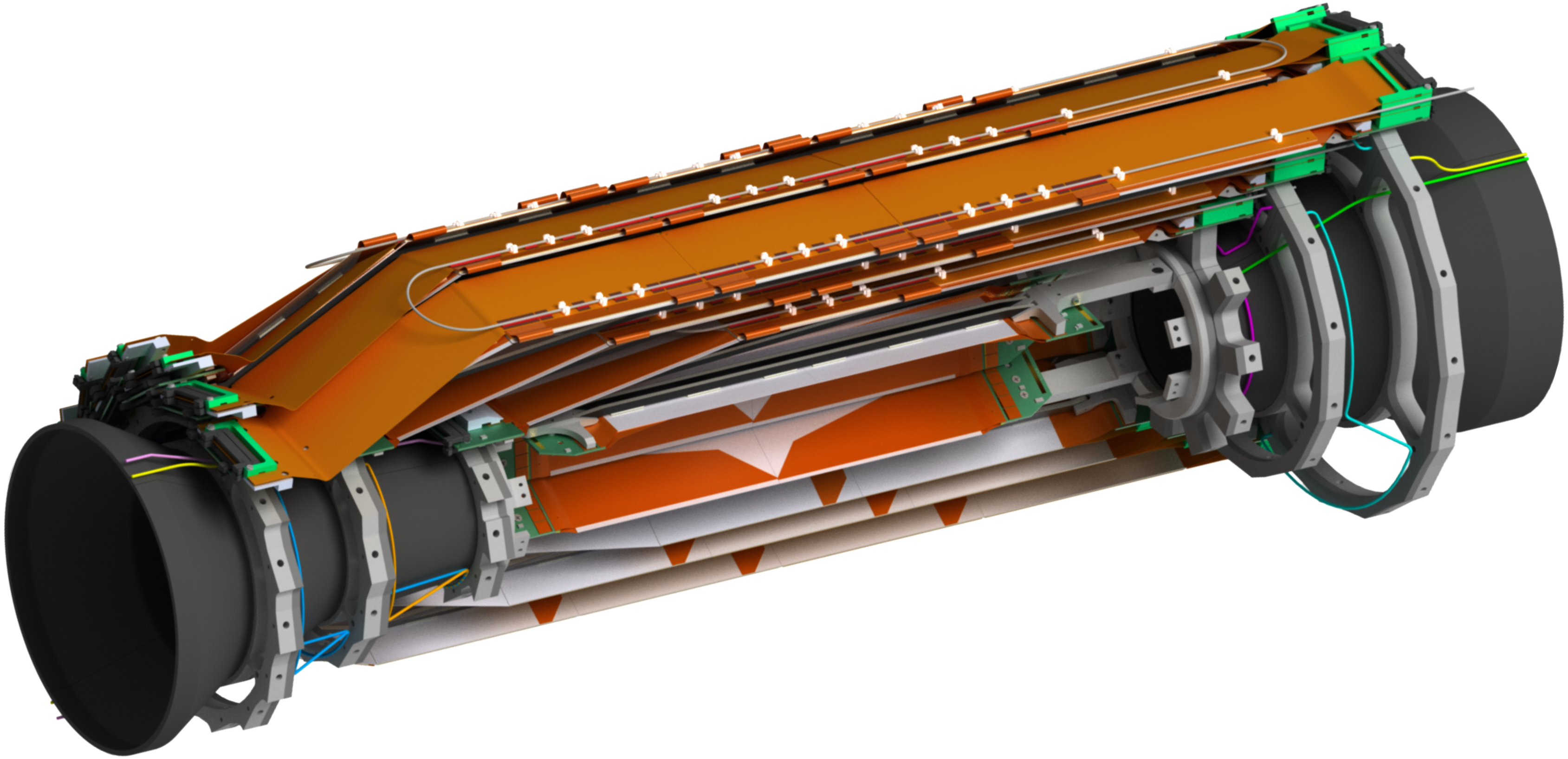
SVD Status Report



III Meeting Belle2-Italia
22 Maggio 2015

S.Bettarini per Belle2-SVD

OUTLINE

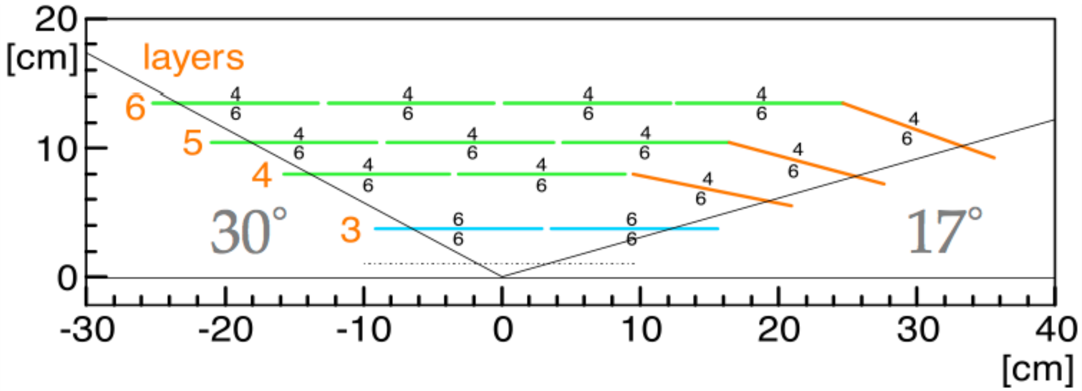
SVD general:
- Introduction
- SVD new organization
- Schedule
- Pitch Adapter Issues

Activity in Pisa:
- FW/BW sub-assembly construction
- Ladder Mech. Test & Mounting

Activity in Trieste:
- Sensor Test
- Radiation monitoring
- Monitoring/ILK temperature/humidity

Belle II SVD Overview

- Four DSSD layers
  - 2, 3, 4, 5 sensors (L3 to L6)
- Only three variants of sensor made from 6" wafers
  - Large rectangular DSSD (HPK)
  - Small rectangular DSSD (HPK)
  - Trapezoidal DSSD (Micron)
- Fast readout based on
  - APV25 chips 50ns shaping time
  - Origami chip-on-sensor concept
  - FPGA for pulse processing, zero-suppression, common-mode corr., hit time finding
- Low material budget 0.6%X_0 per layer
  - Very light mechanical structure
  - Thin cooling pipes (CO_2)

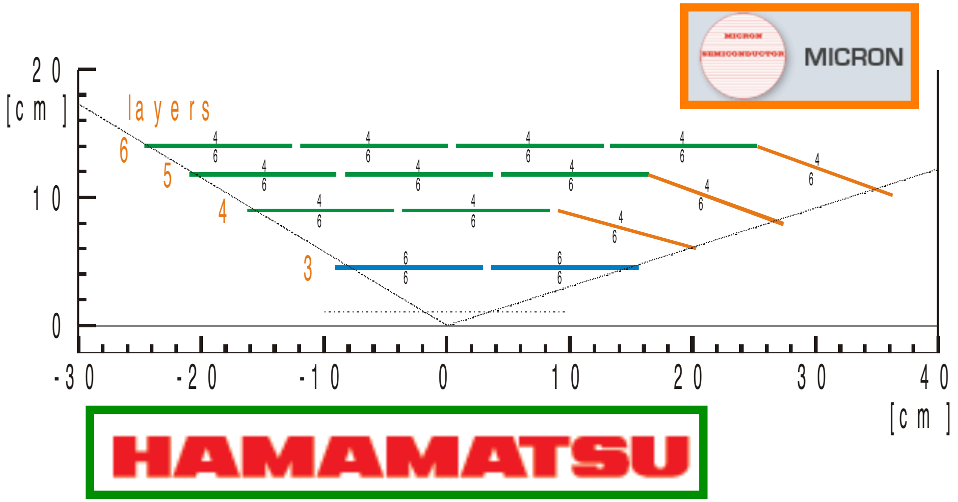


Layer	Ladders	Sensors / Ladder	APVs
6	16	5	800
5	12	4	480
4	10	3	300
3	7	2	168

Double-sided strip sensors from 6" wafers

Sensor Properties:

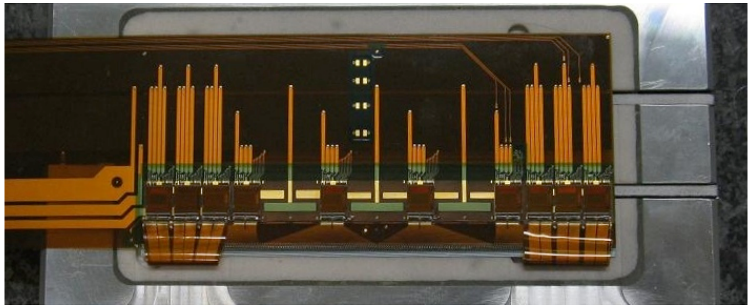
- Double-sided with perpendicular strips
- AC-coupled readout with polysilicon resistor
- N-bulk, 300/320 μm thickness
- Three layouts only:
  - Rectangular small for layer 3 (HPK)
  - Rectangular large for layers 4-6 (HPK)
  - Trapezoidal for forward layers 4-6 (Micron)

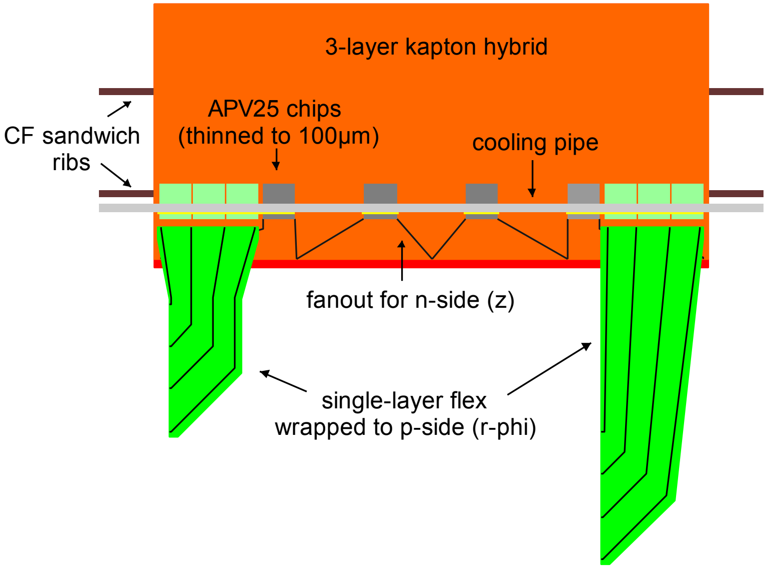


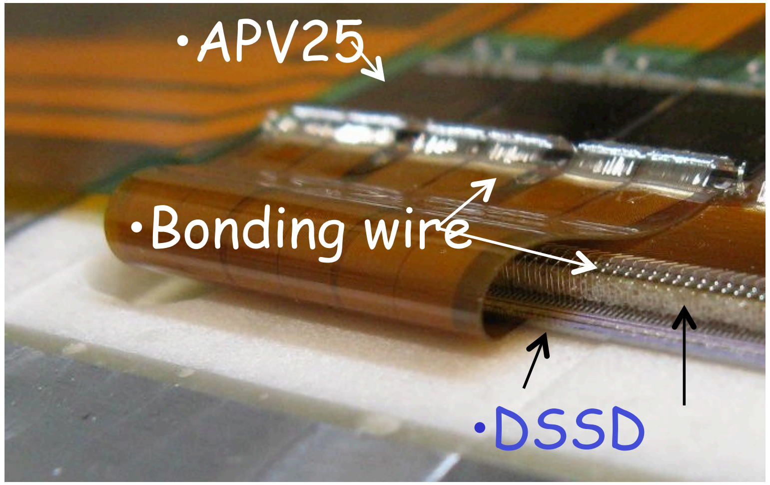
	Readout strips(p/ Rϕ)	Readout strips(n/z)	Readout pitch (p/ Rϕ)	Readout pitch(n/z)	Sensors # (+ spares)	Active area (mm^2)
Large	768	512	75 μm	240 μm	120+18	122.90x57.72 =7029.88
Trapezoidal	768	512	50-75 μm	240 μm	38+6	122.76x(57.59+38.42)/2=5893.09
Small	768	768	50 μm	160 μm	14+4	122.90x38.55 =4737.80

Origami Chip-on-Sensor Concept

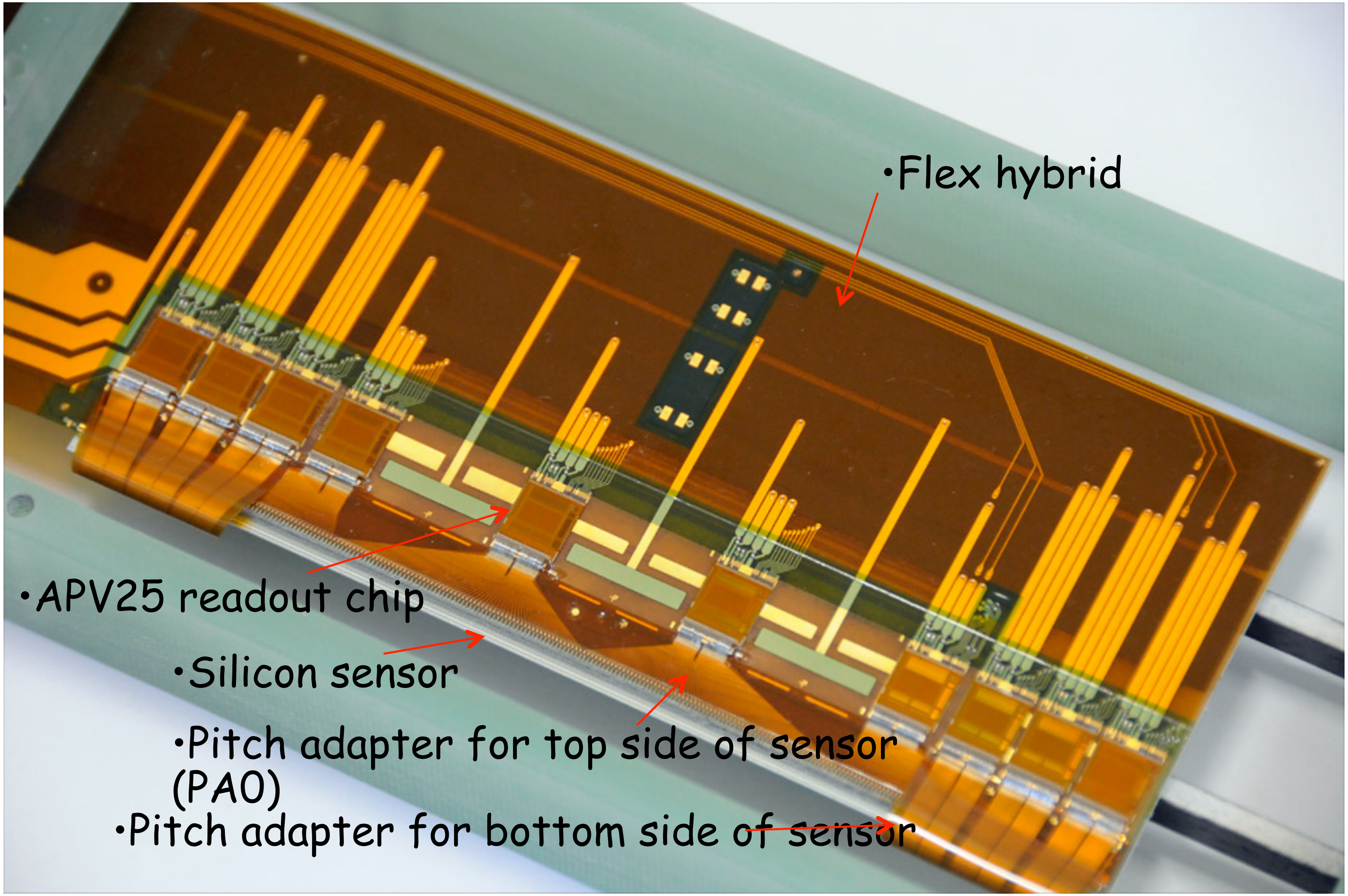
- **Chip-on-sensor** concept for **double-sided readout**
- **Flex fan-out** pieces **wrapped** to opposite side (hence "Origami")
- *All chips aligned on one side* → **single cooling pipe**







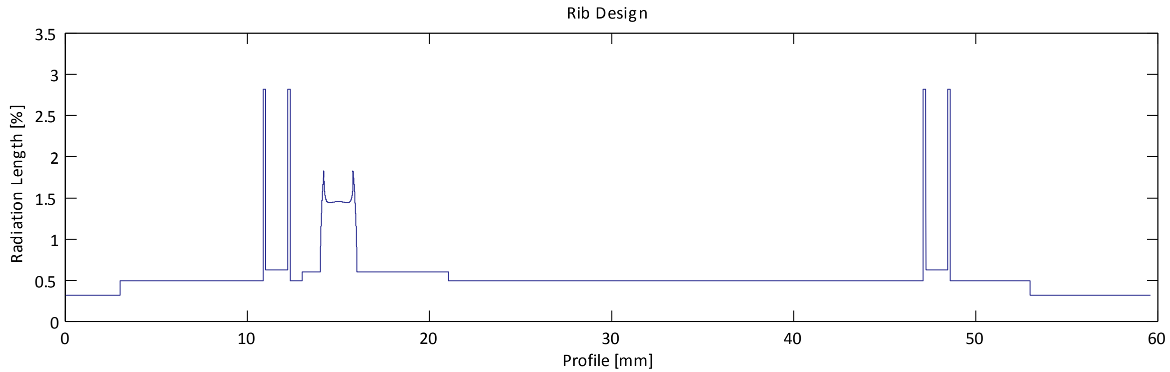
Origami Prototype Module with 6" HPK DSSD

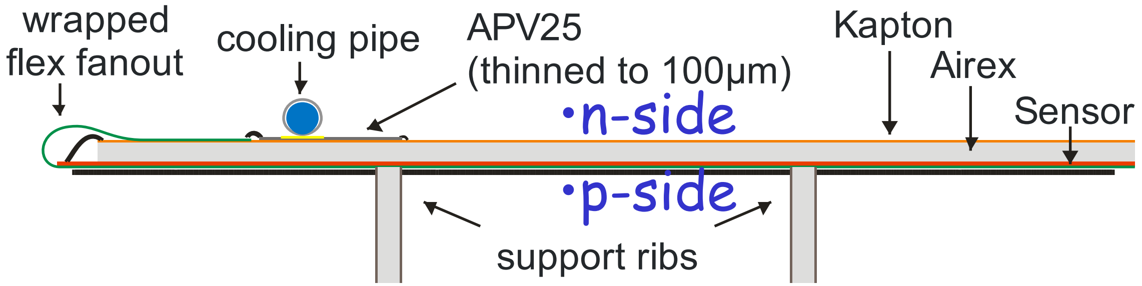


- Flex hybrid
- APV25 readout chip
- Silicon sensor
- Pitch adapter for top side of sensor (PA0)
- Pitch adapter for bottom side of sensor

Material Budget of a ladder

- Largest peak contribution by
  - Cooling pipe
  - Support ribs





- Average Material Budget:~ 0.6% X_0 /layer

Components:

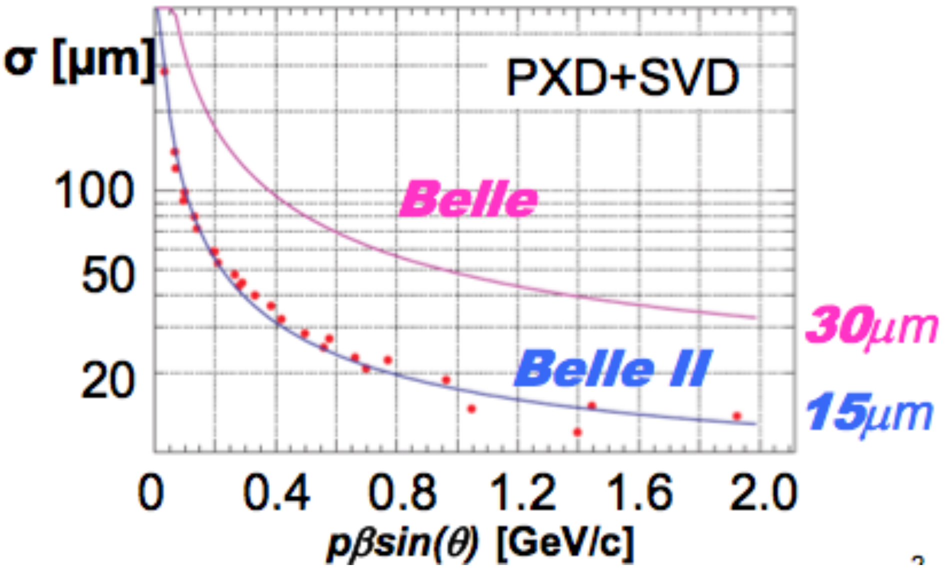
- Single cooling pipe
- Thinned APV25 (100μm)
- 3-layer flex circuit
- Connection to Strips:
  - PA on top side
  - wrapped PA for bottom
- 1mm Airex sheet
- 6" DSSD
- CF support ribs

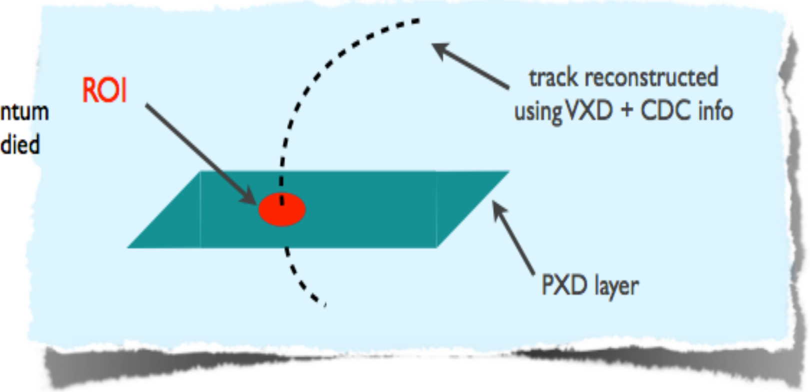
Performance

- The PXD + SVD resolution is adequate
  - ×2 improvement w.r.t Belle

- SVD+CDC fast tracking is essential to do Region-Of-Interest selection in PXD
  - Keep readout bandwidth under control
  - Tested in beam test at DESY Jan 2014

Significant improvement in z-vertex resolution



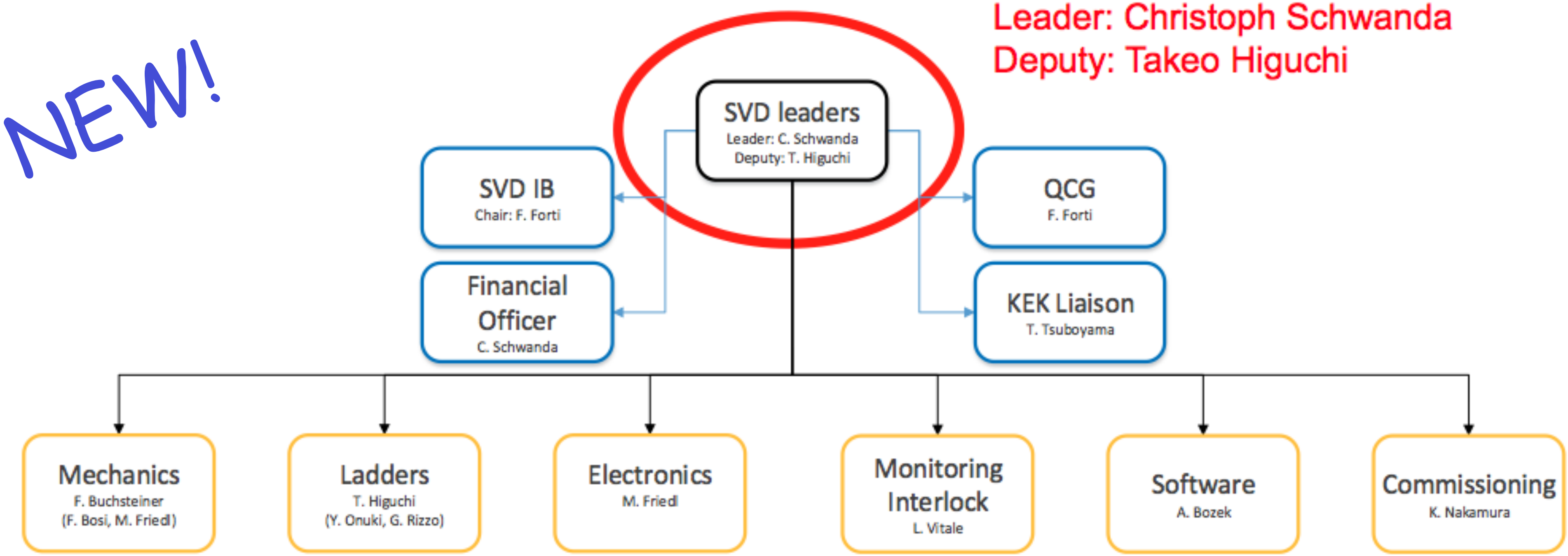


size, form, angle/momentum dependence to be studied and optimized

SVD Group Organization

NEW!

New leaders appointed Feb. 7th
Leader: Christoph Schwanda
Deputy: Takeo Higuchi



SVD leaders
Leader: C. Schwanda
Deputy: T. Higuchi

SVD IB
Chair: F. Forti

Financial Officer
C. Schwanda

QCG
F. Forti

KEK Liaison
T. Tsuboyama

Mechanics
F. Buchsteiner
(F. Bosi, M. Friedl)

Ladders
T. Higuchi
(Y. Onuki, G. Rizzo)

Electronics
M. Friedl

Monitoring Interlock
L. Vitale

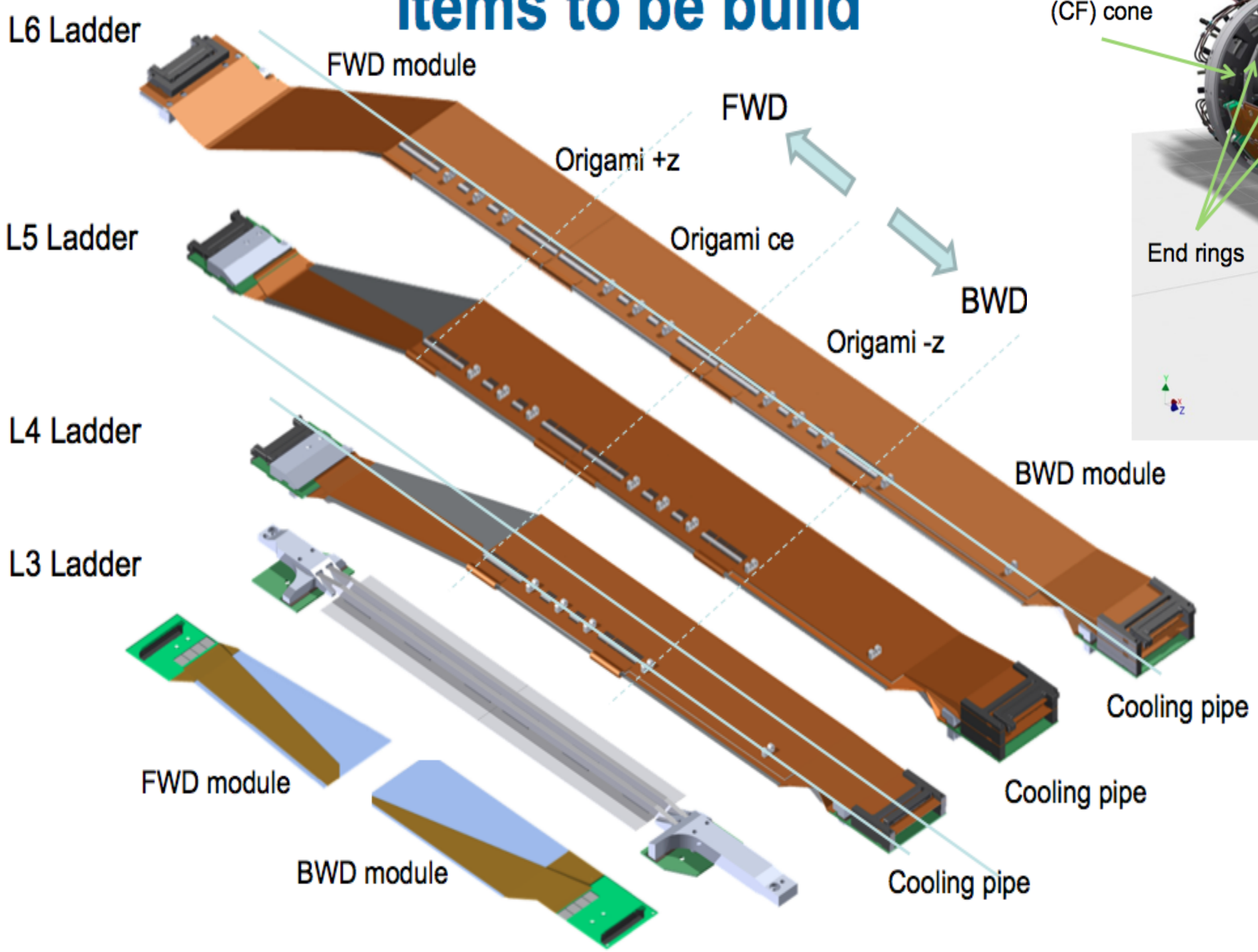
Software
A. Bozek

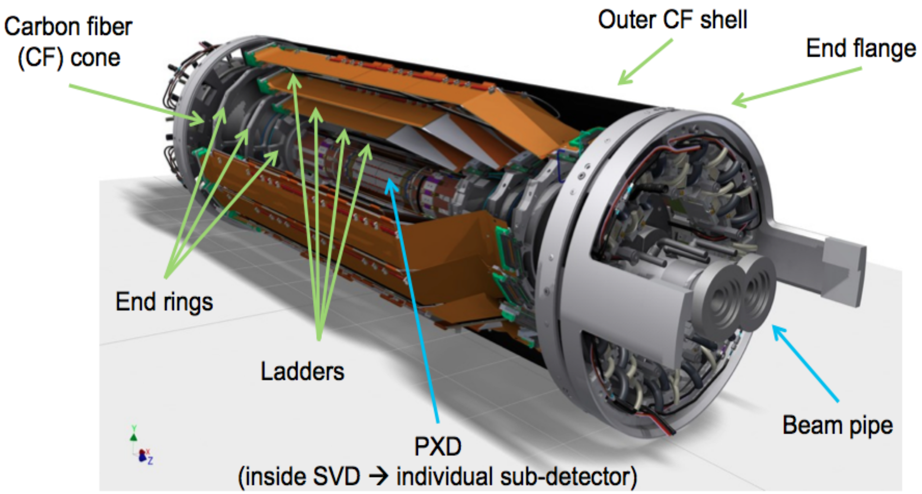
Commissioning
K. Nakamura

SVD Sub-Group Coordinators

Sub-group	Coordinator	Deputy	Advisor
Mechanics	Florian Buchsteiner	Markus Friedl	Filippo Bosi
Ladders	Takeo Higuchi	Yoshiyuki Onuki	Giuliana Rizzo
Electronics	Markus Friedl		
Monitoring & Interlocks	Lorenzo Vitale		
Software	Andrzej Bozek		
Commissioning	Katsuro Nakamura		

Items to be build



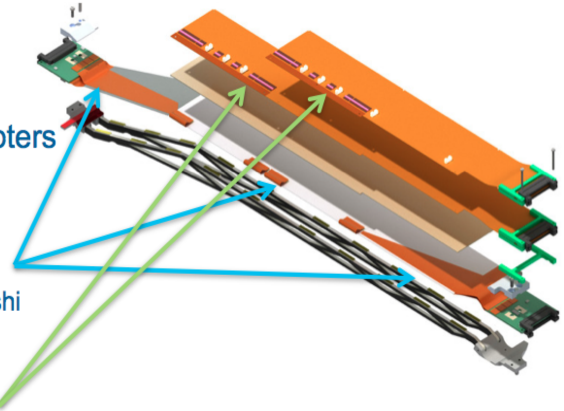


SVD Ladder Assembly Sites

L3 ladders:	Univ. of Melbourne
L4 ladders:	TIFR (@ IPMU)
L5 ladders:	HEPHY Vienna
L6 ladders:	Kavli IPMU
FWD/BWD sub-assemblies:	INFN Pisa

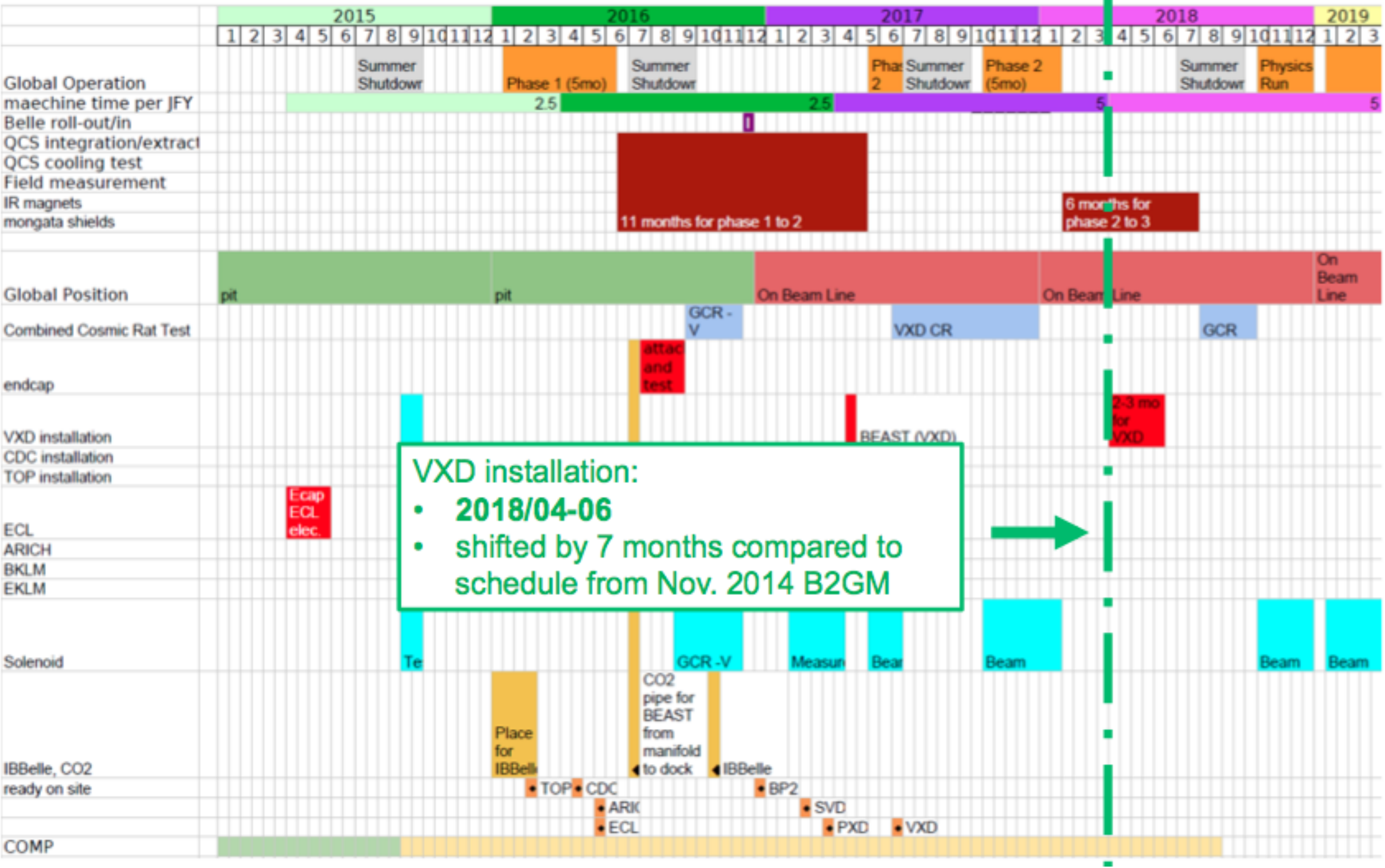
Pitch Adapters

connect sensor strips to APV25 chips



- Two types of pitch adapters
- **FlexPA**
  - Flexible, single-layer
  - PF,PB,P3F,P3B,PA
  - Produced by Tokai Denshi
- **PA0**
  - Flat, dual-layer
  - Glued onto Origami hybrids
  - Produced by Taiyo

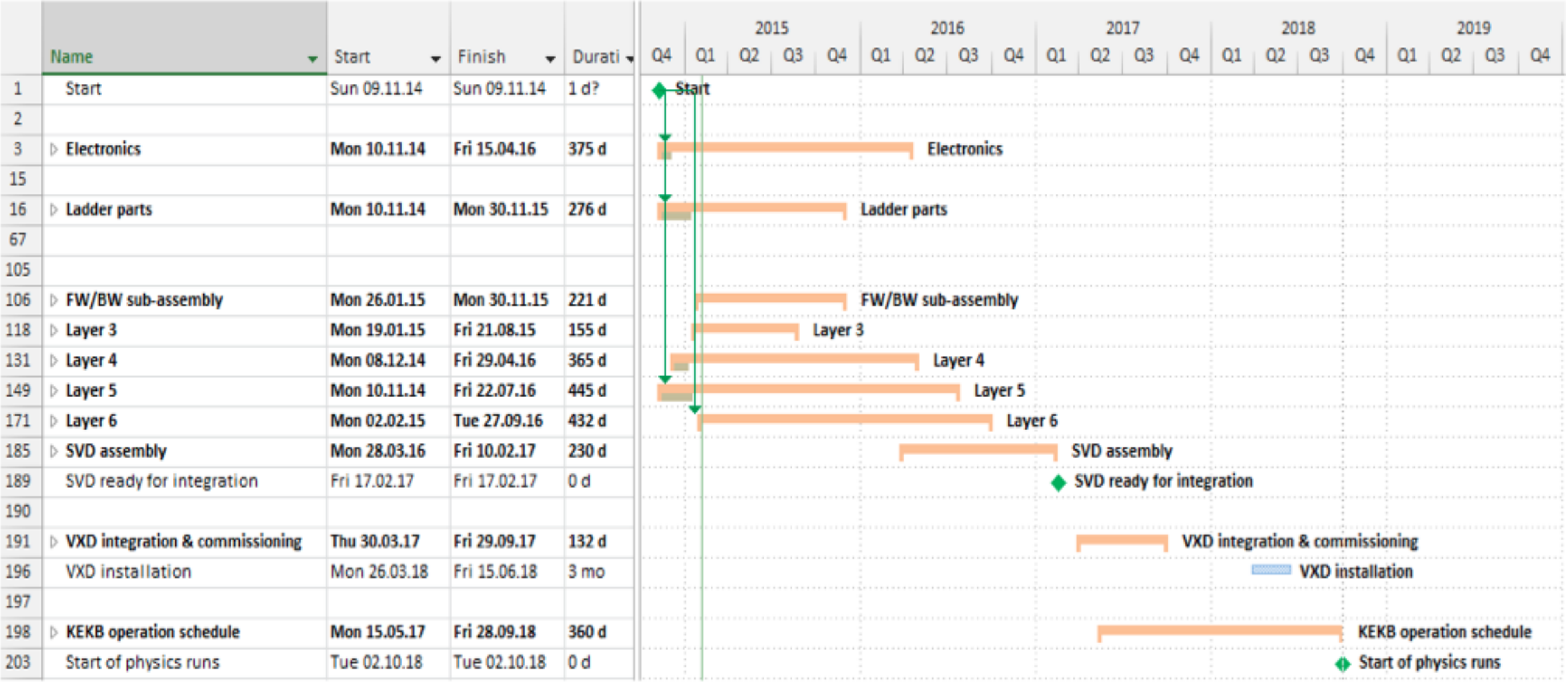
Belle II Schedule



VXD installation:

- **2018/04-06**
- shifted by 7 months compared to schedule from Nov. 2014 B2GM

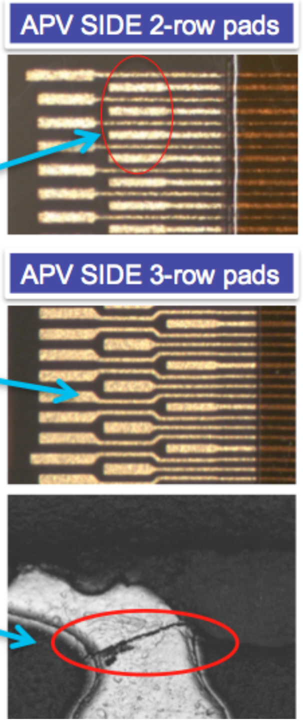
SVD Schedule Overview
(to match global Belle2 schedule)



	Name	Start	Finish	Durati
1	Start	Sun 09.11.14	Sun 09.11.14	1 d?
2				
3	**Electronics**	**Mon 10.11.14**	**Fri 15.04.16**	**375 d**
15				
16	**Ladder parts**	**Mon 10.11.14**	**Mon 30.11.15**	**276 d**
67				
105				
106	**FW/BW sub-assembly**	**Mon 26.01.15**	**Mon 30.11.15**	**221 d**
118	**Layer 3**	**Mon 19.01.15**	**Fri 21.08.15**	**155 d**
131	**Layer 4**	**Mon 08.12.14**	**Fri 29.04.16**	**365 d**
149	**Layer 5**	**Mon 10.11.14**	**Fri 22.07.16**	**445 d**
171	**Layer 6**	**Mon 02.02.15**	**Tue 27.09.16**	**432 d**
185	**SVD assembly**	**Mon 28.03.16**	**Fri 10.02.17**	**230 d**
189	SVD ready for integration	Fri 17.02.17	Fri 17.02.17	0 d
190				
191	**VXD integration & commissioning**	**Thu 30.03.17**	**Fri 29.09.17**	**132 d**
196	VXD installation	Mon 26.03.18	Fri 15.06.18	3 mo
197				
198	**KEKB operation schedule**	**Mon 15.05.17**	**Fri 28.09.18**	**360 d**
203	Start of physics runs	Tue 02.10.18	Tue 02.10.18	0 d

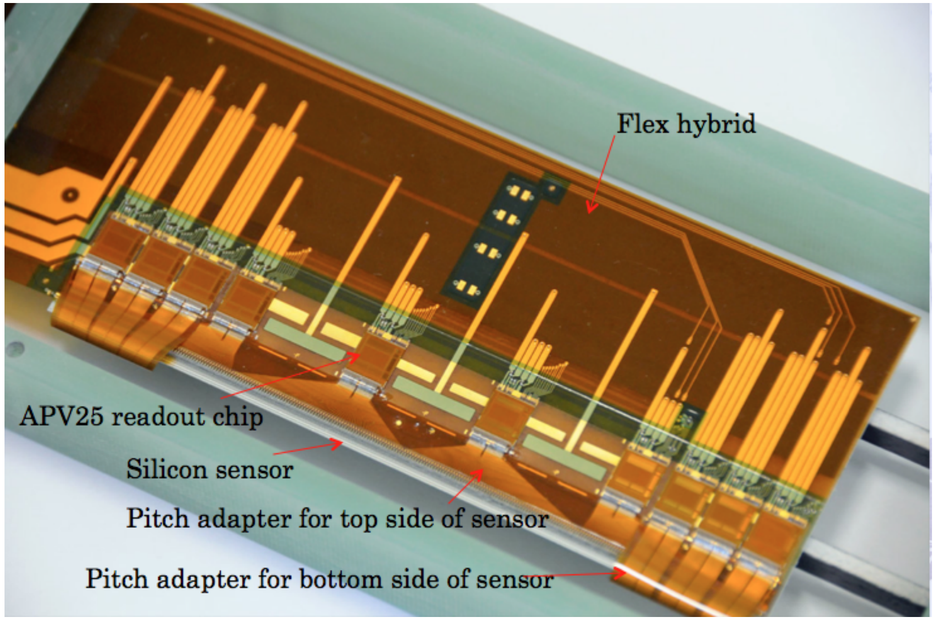
Pitch Adapters Issues

- **Problem #1**
  - Related to **FlexPA**
  - Arose end of 2013
  - Size of pads on APV side were too small for wire bonding
  - Could be solved by design change
- **Problem #2**
  - Related to **PA0** only
  - Disconnected lines due to cracks close to bond pads of PA0
- **PA task force formed to solve issues**



#1:

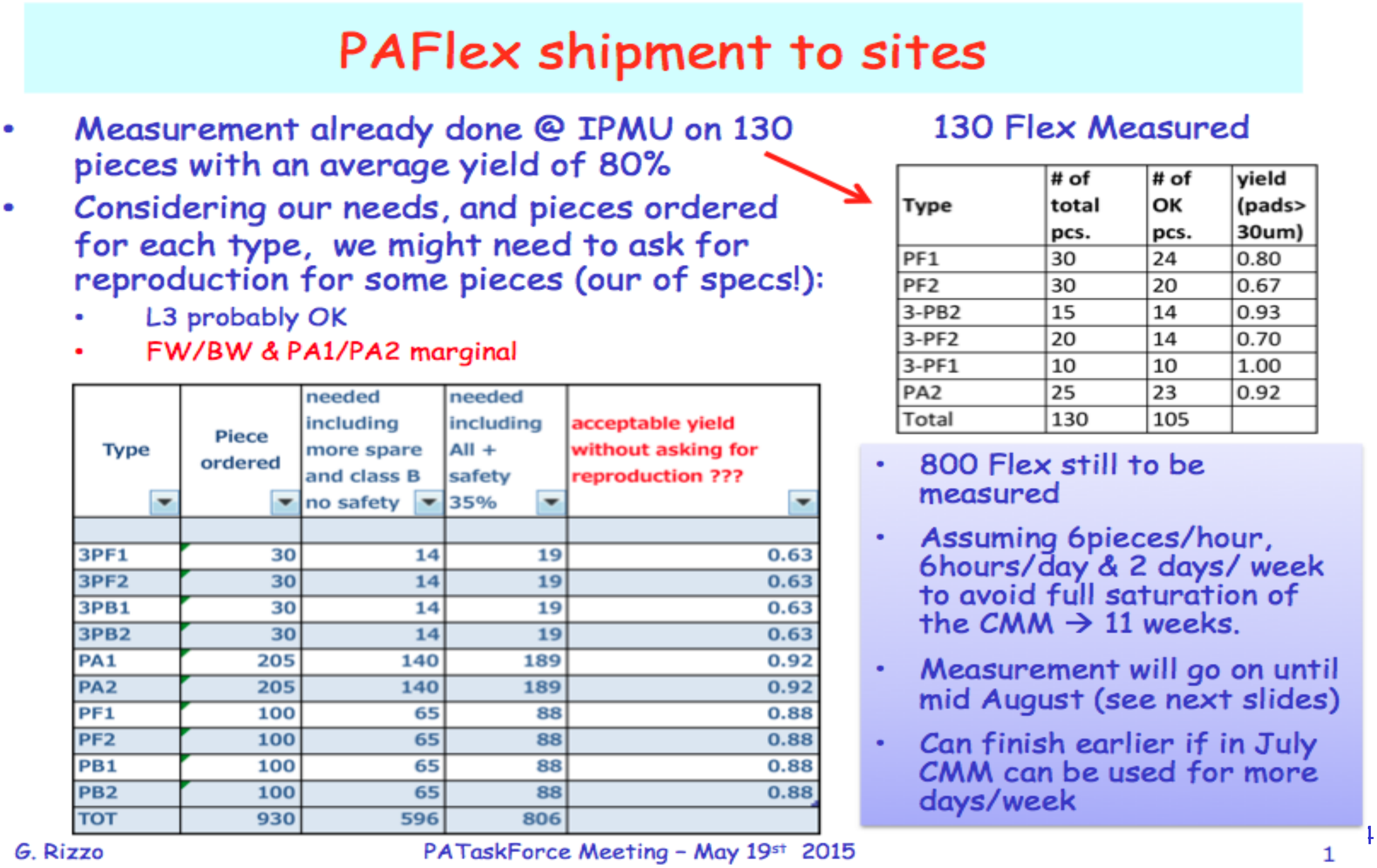
- Tested samples of the flex new production have been delivered in mid-March
- OK (~80% yield) after the pad survey@IPMU



#2:

- Required re-production of all Origami hybrids with thinned APV chips
- More robust design against cracks implemented

Thanks to the hard work of the PA-task force the flex issue seems to be solved…



PAFlex shipment to sites

- Measurement already done @ IPMU on 130 pieces with an average yield of 80%
- Considering our needs, and pieces ordered for each type, we might need to ask for reproduction for some pieces (our of specs!):
  - L3 probably OK
  - FW/BW & PA1/PA2 marginal

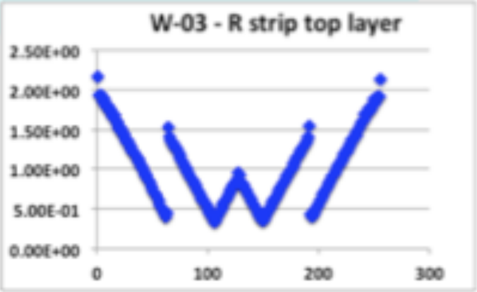
Type	Piece ordered	needed including more spare and class B no safety	needed including All + safety 35%	acceptable yield without asking for reproduction ???
3PF1	30	14	19	0.63
3PF2	30	14	19	0.63
3PB1	30	14	19	0.63
3PB2	30	14	19	0.63
PA1	205	140	189	0.92
PA2	205	140	189	0.92
PF1	100	65	88	0.88
PF2	100	65	88	0.88
PB1	100	65	88	0.88
PB2	100	65	88	0.88
TOT	930	596	806	

130 Flex Measured

Type	# of total pcs.	# of OK pcs.	yield (pads> 30um)
PF1	30	24	0.80
PF2	30	20	0.67
3-PB2	15	14	0.93
3-PF2	20	14	0.70
3-PF1	10	10	1.00
PA2	25	23	0.92
Total	130	105	

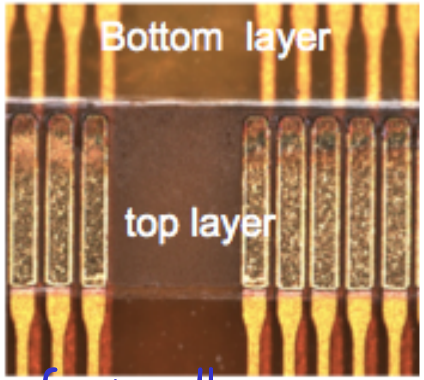
- 800 Flex still to be measured
- Assuming 6pieces/hour, 6hours/day & 2 days/ week to avoid full saturation of the CMM → 11 weeks.
- Measurement will go on until mid August (see next slides)
- Can finish earlier if in July CMM can be used for more days/week

Evaluation of new PA0 produced

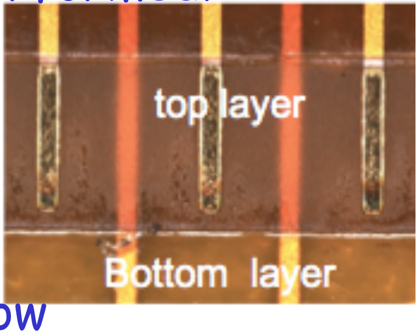


- **24 PA0 with new design**
  - No cracks found: no opens, from electrical test, no small cracks seen by visual inspection.
  - A few shorts found on 6/24 pieces
  - Yield 75%, acceptable

- **Unexpected new issues on PA0: "glue spread"**
  - PA0 are made of 2 layers: interlayer glue spreads onto edge of the top layer, covering part of the APV pads and with a lot of residuals on sensor side pads.



  - PA0 have been wiped and then bonding tests successfully performed!



- **Continued with the assembly of 12 PA0/ORIGAMI with present PA0, to verify:**

– no cracks until the end of stress-full assembly steps

- verify all the ORIGAMI assembly procedure up to SMD and reflow (all the stress-full steps for PA0, but NO APV chips will be lost).
- Next visual inspection/measurements expected at the end of May.
- If OK go on with the chip loading/bonding and electrical tests (end-June)

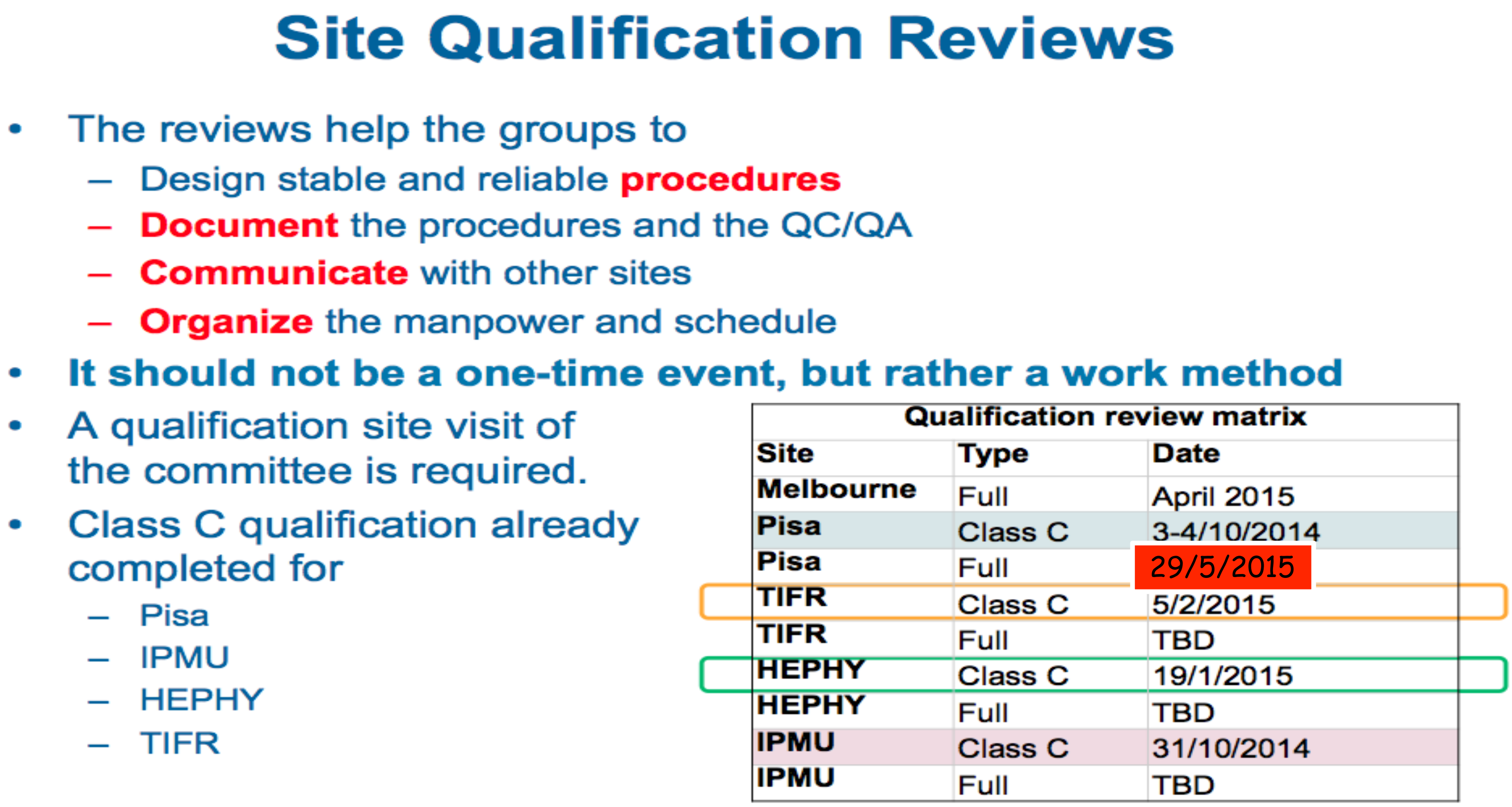
PA0 continued…& impact on ladder production schedule

- The (expected!) successful results of the test with a detector connected to the origami (mid-August) will give the OK to the mass production (i.e. assembly) of the origami with the new PA0.
- From mid-August, each site will start the production of its class B+ ladder (lasting ~1 month, test included)
- The construction of the 1st class A ladders will start in mid-September.
- The 1st batch of the new origami production is expected in mid-November, the last one 2 months later.

PA0 & Origami Spec's document ready for the final sign-off at the next B2GM.

Ladder Production

- Despite the issues causing a delay in the ladder production, each site is developing the assembly procedures.



Site Qualification Reviews

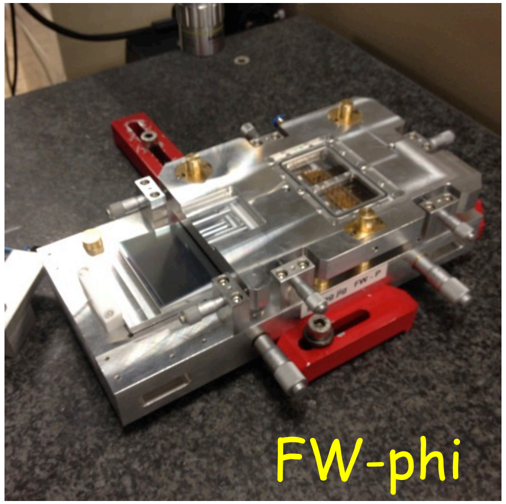
- The reviews help the groups to
  - Design stable and reliable **procedures**
  - **Document** the procedures and the QC/QA
  - **Communicate** with other sites
  - **Organize** the manpower and schedule
- **It should not be a one-time event, but rather a work method**
- A qualification site visit of the committee is required.
- Class C qualification already completed for
  - Pisa
  - IPMU
  - HEPHY
  - TIFR

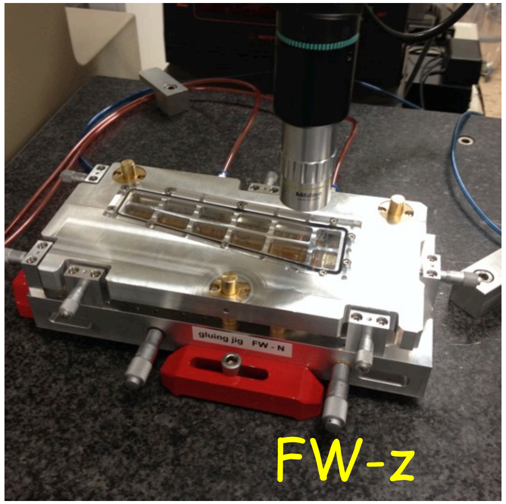
Qualification review matrix

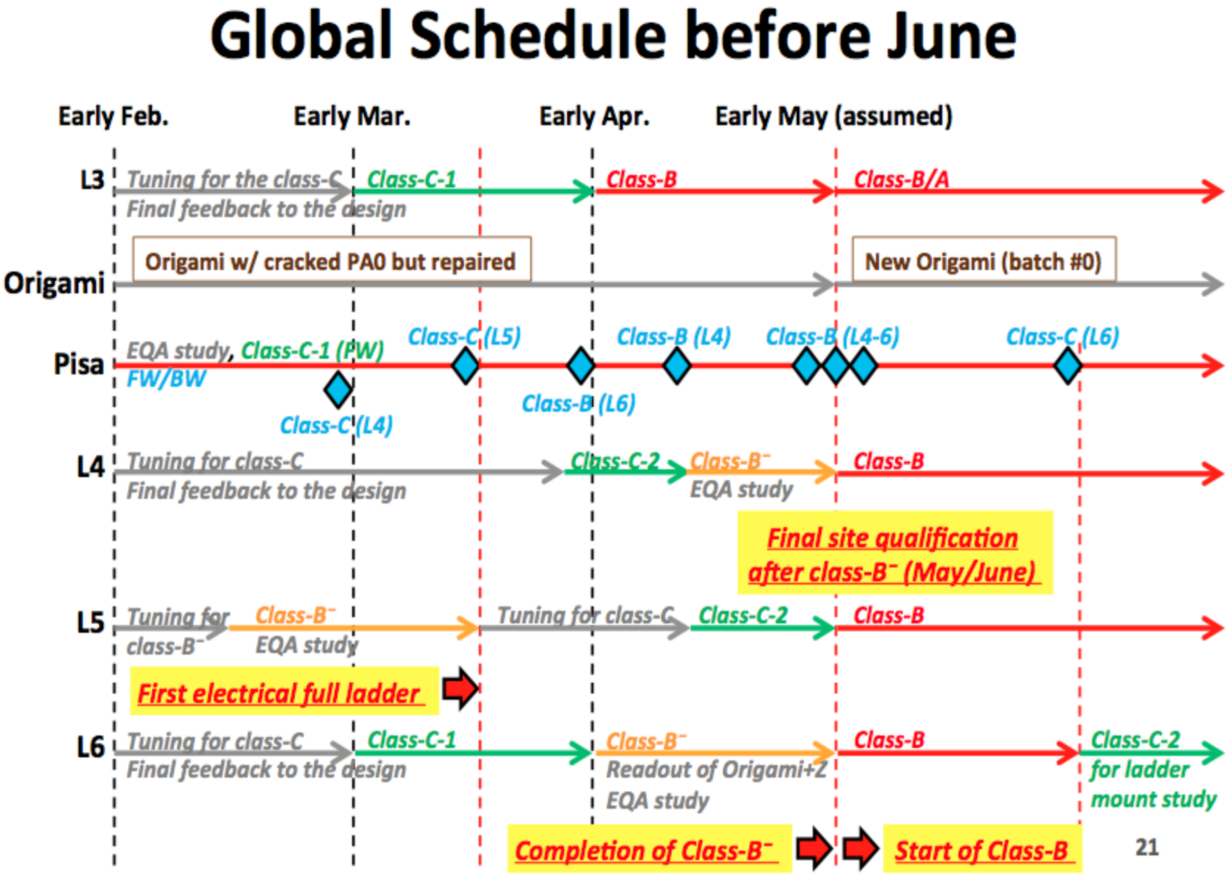
Site	Type	Date
Melbourne	Full	April 2015
Pisa	Class C	3-4/10/2014
Pisa	Full	29/5/2015
TIFR	Class C	5/2/2015
TIFR	Full	TBD
HEPHY	Class C	19/1/2015
HEPHY	Full	TBD
IPMU	Class C	31/10/2014
IPMU	Full	TBD

FW-BW subassembly production

The final gluing jigs and the procedures have been tuned to produce the Class C (mechanical) and Class B (electrically working, built with low quality parts) needed by the ladder assembly sites.


FW-phi


FW-z

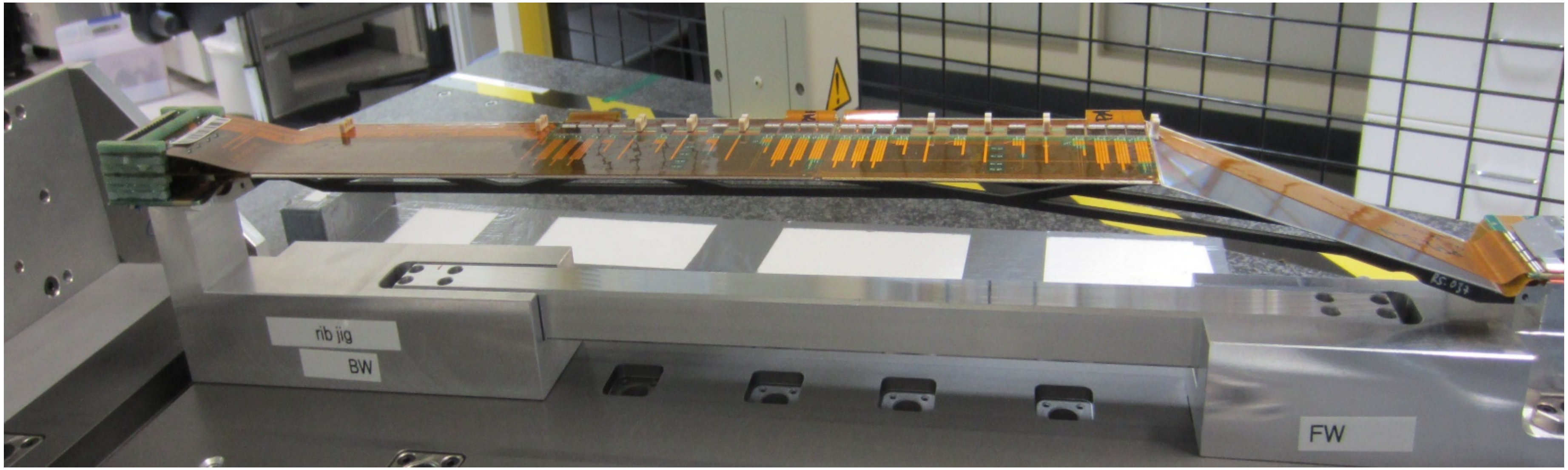

Global Schedule before June

FW/BW Subassemblies status/production

- Produzione dei subassemblies in Pisa
  - Mechanical (class C) prototypes: 6BW + 6FW
    - Ladder Costruiti: L4: 2 / L5: 1 / L6: 1
  - El. Funzionanti (class B): 3 BW+3 FW
    - 1 Ladder a Vienna
    - IPMU (L6) e TIFR(L4) li costruiranno dopo aver passato la relativa site Review
  - El. Funzionanti e di qualita' (classe B+): 3BW
    - In attesa dei sensori Micron (FW)
- Il 29/5 fissata la review di Pisa; una volta superata si potra' entrare in produzione dei classe A (da installare in esperimento)
- Start produzione: giugno. Durata effettiva: ~7.5 mesi:
  - 2FW+2BW subassemblies/working week → 2x[38+9(spares)]=2x47 ~24 settimane=6 mesi
  - Da aggiungere 1.5 mesi (chiusura estiva istituto + meetings vari)

Costruito il primo ladder elettricamente funzionanate (L5)

- Vienna ha finito (24/3) di costruire il primo ladder class B:

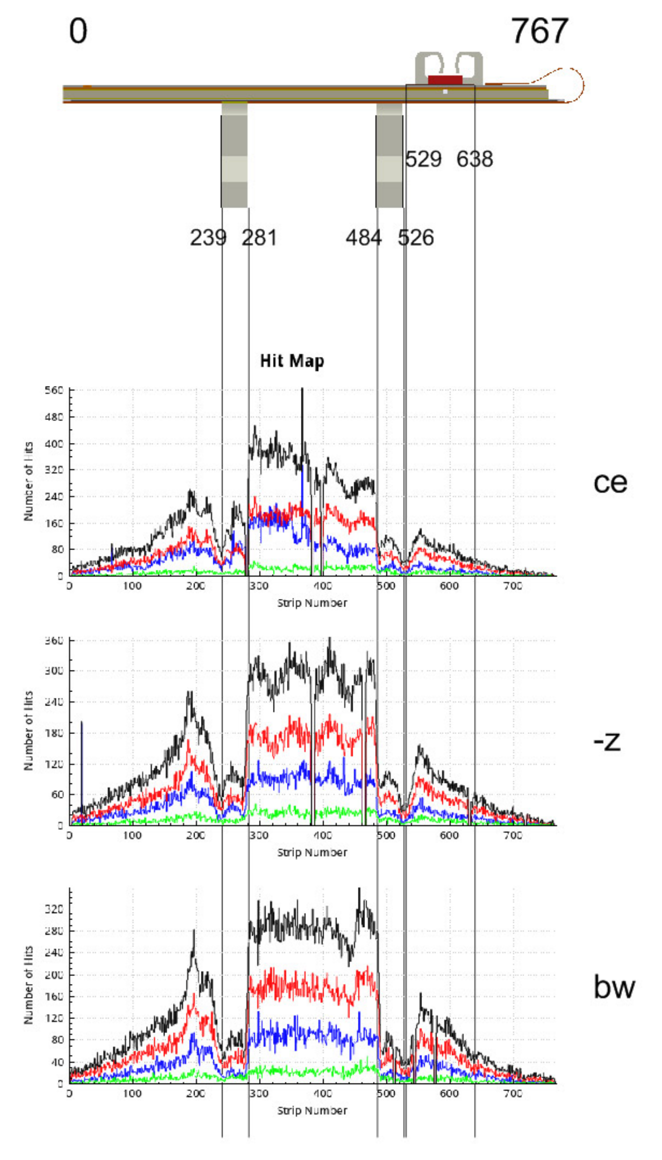


- Usati i tools meccanici e procedure finali
- Caratterizzazione elettrica → completamente funzionante
- Una milestone importante!

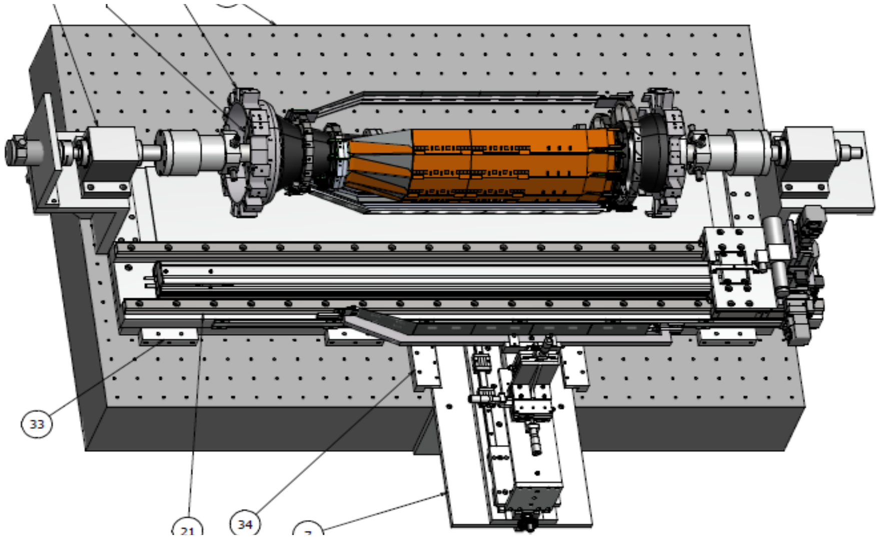
Hit Profiles

- FADC readout (full ladder)
- 4 measurements with source pointing ~at center of each sensor

- Profile is much wider than scintillator
    - multiple scattering
- Shadow of ribs clearly visible (blurred outer edges)
- APV25 chips not visible



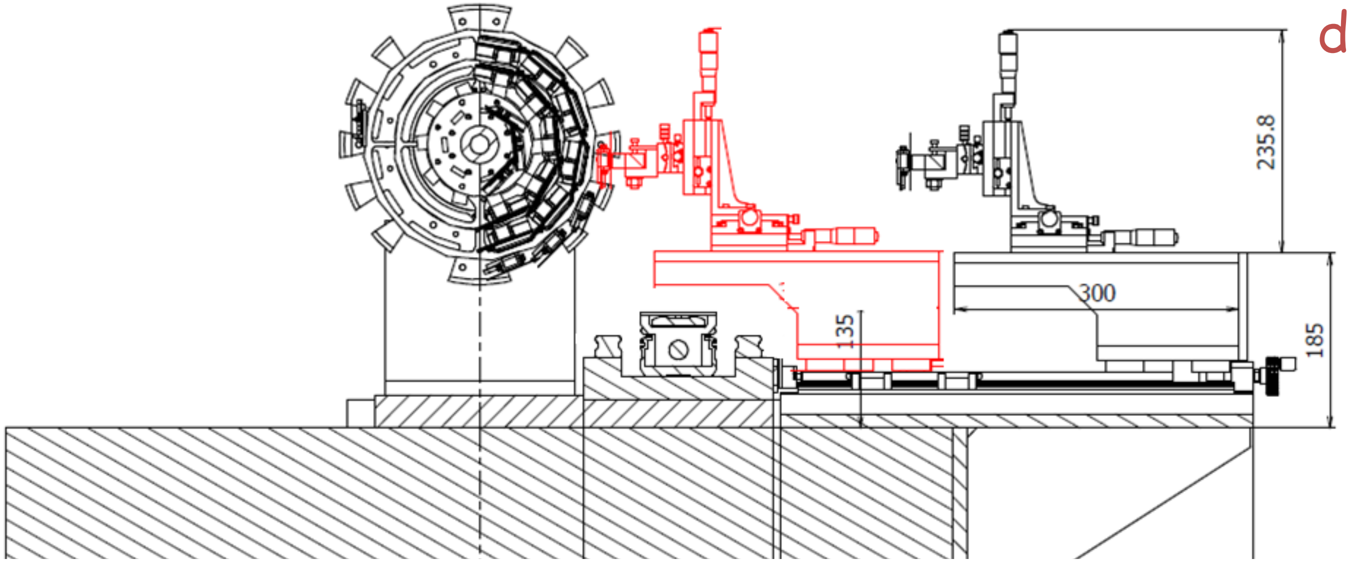
Ladder mount



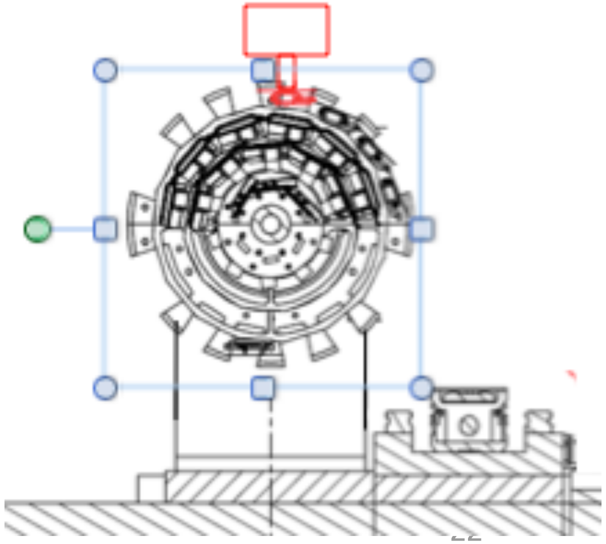
- Clearance between modules:

Less than 1 mm!

Option 1: hold ladders with arm and approach to the end rings by side, insert pins of ladders to the positioning holes.



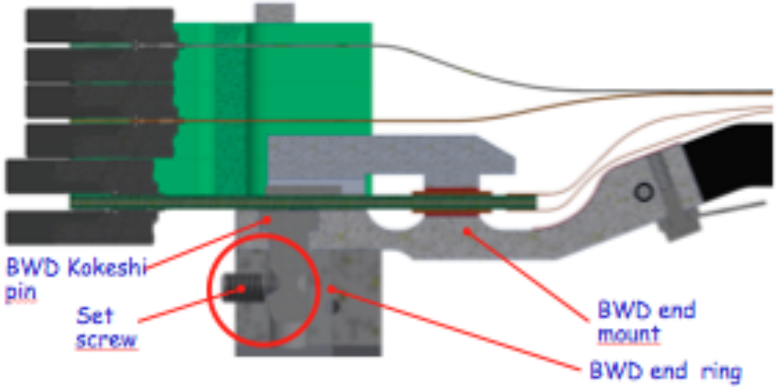
Option 2: support ladders from top using a sliding guide in vertical direction.



Conceptual Top mounting procedure

- According to our (BaBar-SVT) experience, the whole operation can be split into 3 main phases:

1. Ladder loading from the shipping box to the “Two Arm Support”, fixed to a sliding cart and equipped at each end with a thin flat pincer, hosting the K-pin.



2. Horizontal movement of the ladder on top of the end-rings
3. Guided lowering and locking of the ladder in its final position

- The system will be mechanically designed/realized/tested at home, reproducing the essential features on a mock-up and then shipped to KEK

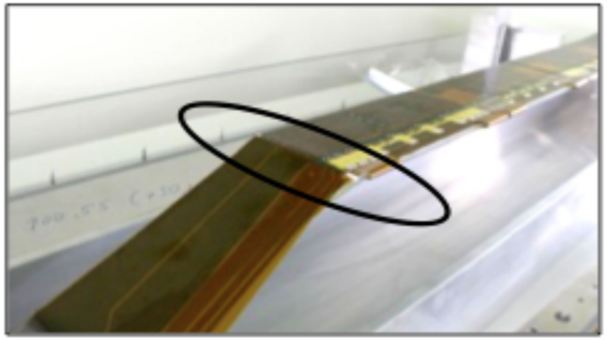
Now Pisa is working on the design of the prototype two arm support.

The Japanese side-mounting option is much more advanced, in terms of design and prototype realization.

In June @the B2GM the pros/contra of the 2 methods will be evaluated.

Issues in the Stress Tests

- **Thermal cycling test**
  - Study items (open issues):
    - Permanent deformation.
    - Permanent damage (e.g.: wire break).
    - Component aging (e.g.: glue at the PA1/2 bend).
    - Thermal fatigue (e.g.: sharply folded part in the Origami+Z).



The folded part in the Origami+Z

  - The thermal excursion program for the studies above needs defined.
    - Suggestion: x100 cycles of (–30 ↔ 60)°C at about ±2°C/min.

- **Mechanical stress test**
  - Study items (open issues):
    - Stress from the end-rings and CO_2 pipe.
    - Gravity sag.
    - Vibration in the transportation.

Pisa's vibration tester

Update on Trieste SVD activities

- Micron and HPK microstrip sensors tests

L.Bosisio, G.Orzan,
I.Rashevskaia

- Radiation monitor & beam abort

L.B., P.Cristaudo, L.Vitale,
L.L., M.Zuppichin, …

  - scCVD diamond sensors (Cividec): characterization & specs, tender
  - prototype electronics ready (digitizer, FPGA, beam abort)

F.Vulpone, G.Cautero,
D.Giuressi, L.L., …

- Temperature monitoring
  - NTC thermistors: mechanics, readout electronics, EPICS

P.Cristaudo,
L.L., L.V.

  - FBG fiber sensors: tests, calibrations (EPICS already done)

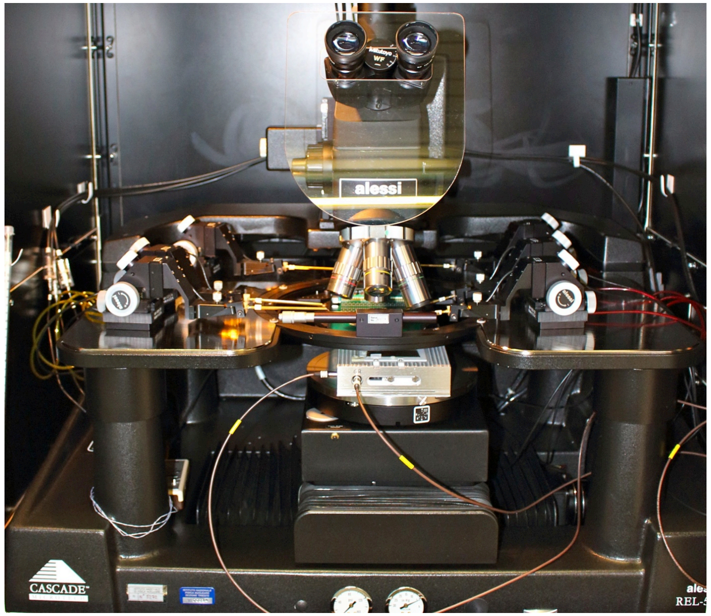
M.Bari,
L.Vitale

- Humidity monitoring, interlocks, PLC
  - Preparations for tests at the DESY VXD thermal mock-up

A.Zanetti,
L.L.

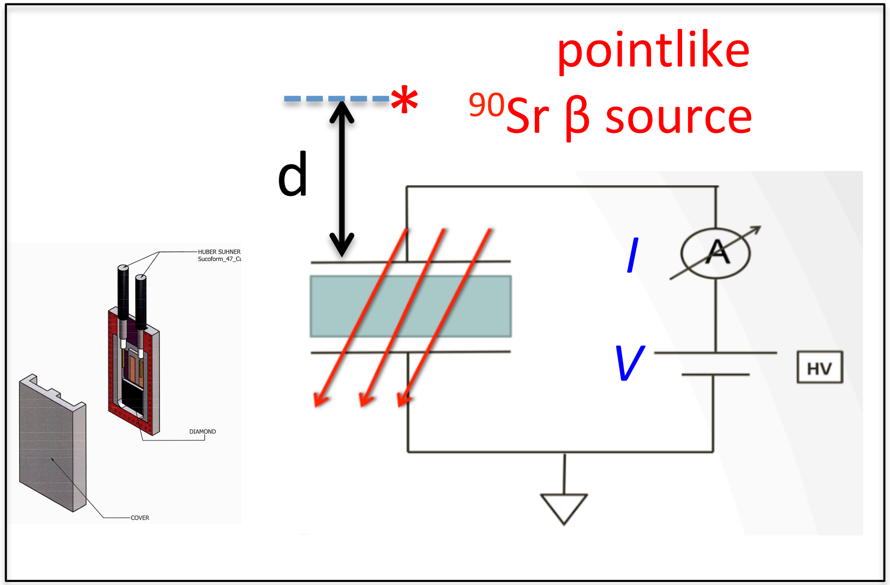
- + documentation and planning (Belle II Note etc.)

Test di sensori DSSD HPK e Micron

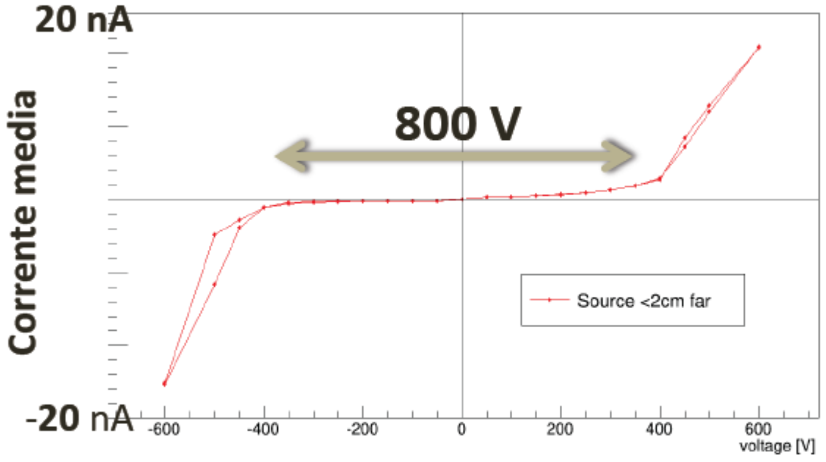


- Qualifica di sensori HPK 'meccanici' (parziale recupero?)
- studio dell'effetto di una tensione applicata alle strip metalliche (tramite l'elettronica di lettura) sulla capacità e sulla corrente delle strip.
- In programma test simili anche su un sensore Micron
- disponibilità a eseguire in futuro:
  - test di verifica sui sensori Micron graffiati durante il test a Vienna.
  - test di altri sensori HPK, se richiesto.

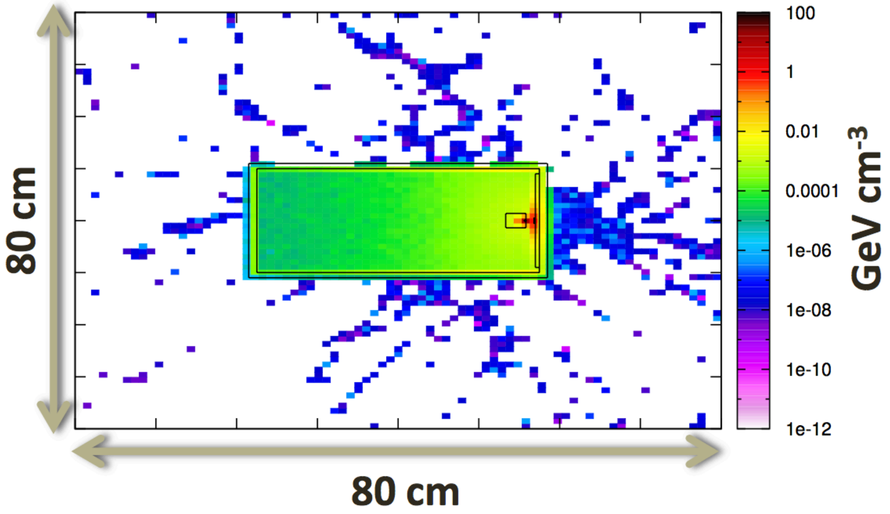
Characterisation of scCVD sensors - 1



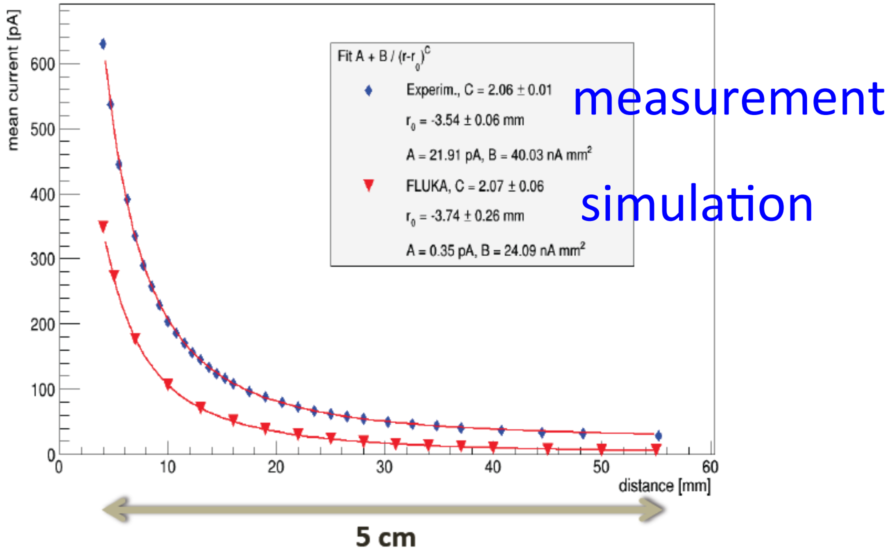
I-V with ^{90}Sr β source at fixed *d*



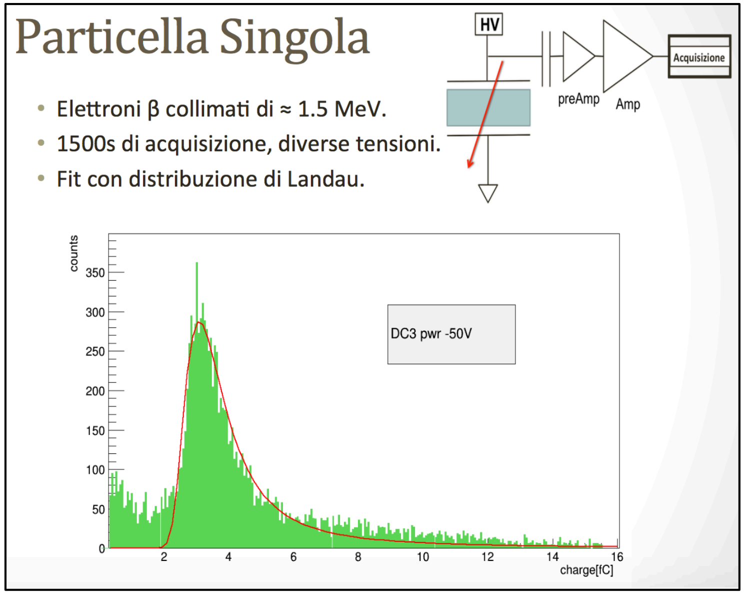
FLUKA simulation, ^{90}Sr β source



Current *I* vs distance *d* of ^{90}Sr β source



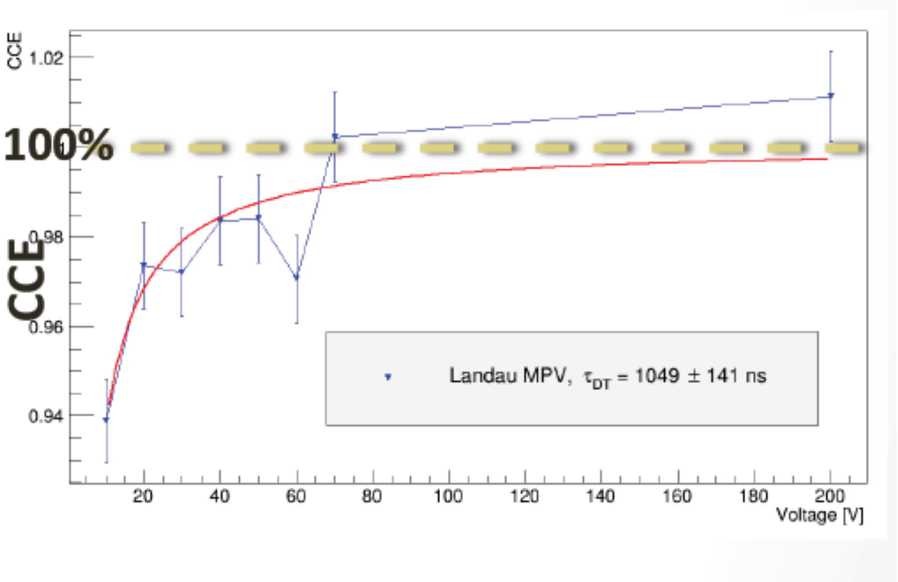
Characterisation of scCVD sensors - 2

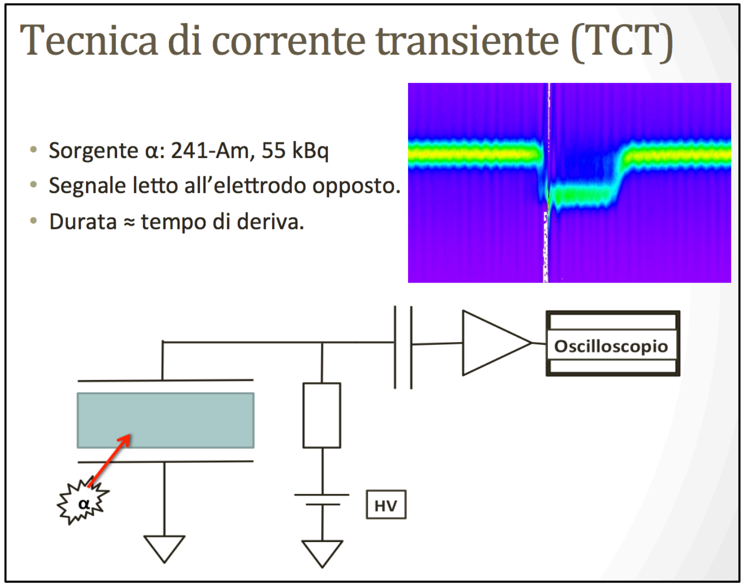


Particella Singola

- Elettroni β collimati di ≈ 1.5 MeV.
- 1500s di acquisizione, diverse tensioni.
- Fit con distribuzione di Landau.

Charge Collection Efficiency from MIPs

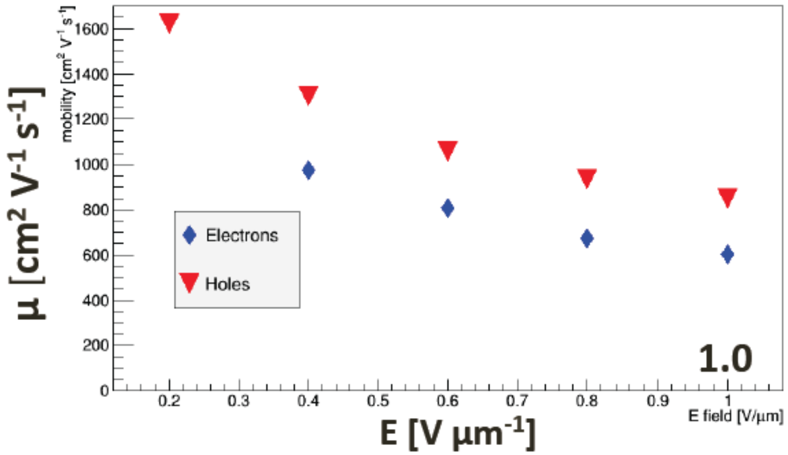




Tecnica di corrente transiente (TCT)

- Sorgente α: 241-Am, 55 kBq
- Segnale letto all'elettrodo opposto.
- Durata ≈ tempo di deriva.

Carrier mobility, α source (TCT)



Readout & Beam Abort: electronics prototype

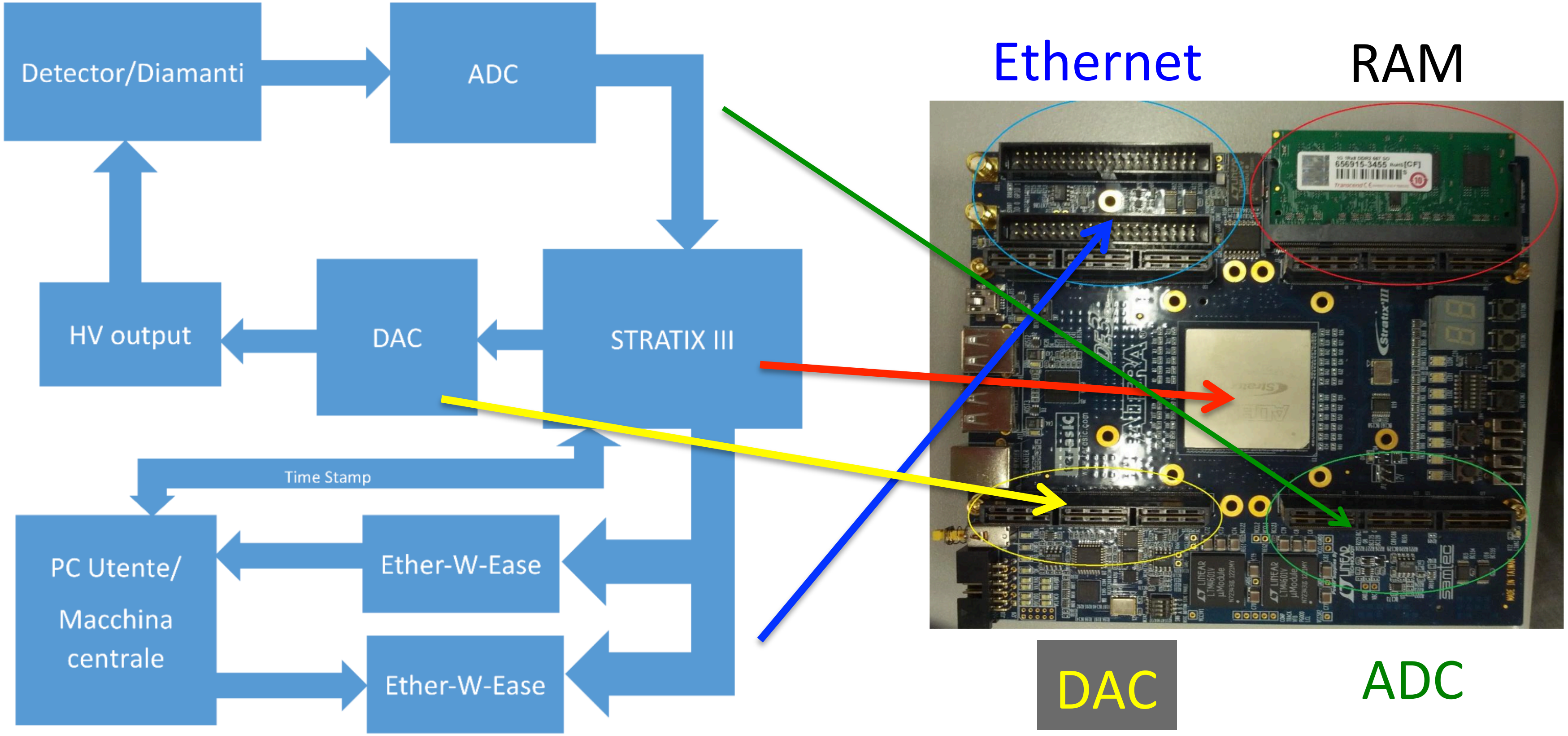
F.Vulpone, thesis with G.Cautero et al. (Elettra): prototype ready of:

Analog front end: picoammeter (transimpedence amplifier, ADC 16 bit 130 MHz)

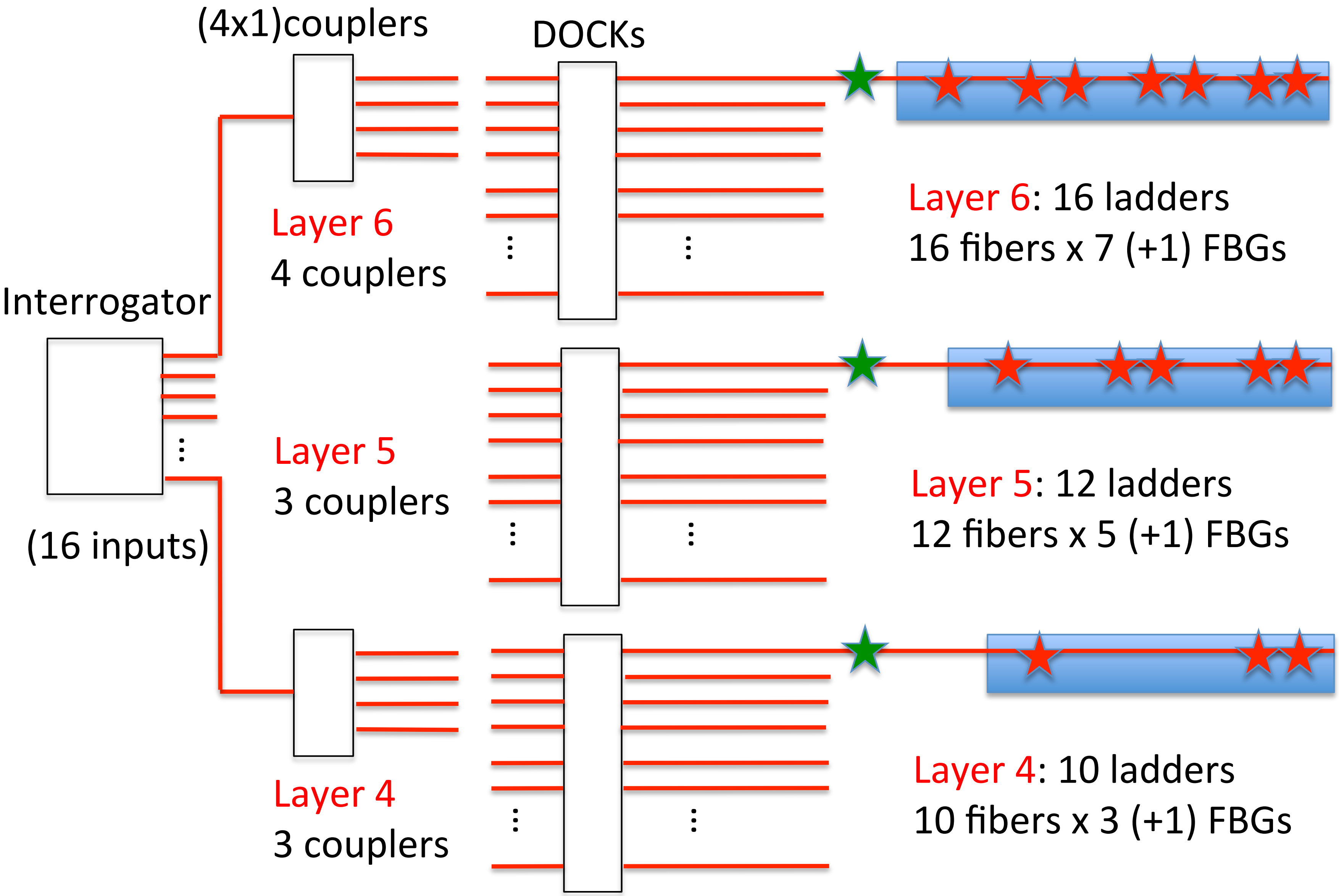
Digital section: FPGA (running averages, abort thresholds, timing&control)

External RAM and Ethernet interfaces; Labview control & readout test program

Ready for first field tests at KEK in October!



Temperature: optical Fiber Bragg Grating sensors



(4x1)couplers

DOCKs

Interrogator

(16 inputs)

Layer 6
4 couplers

Layer 5
3 couplers

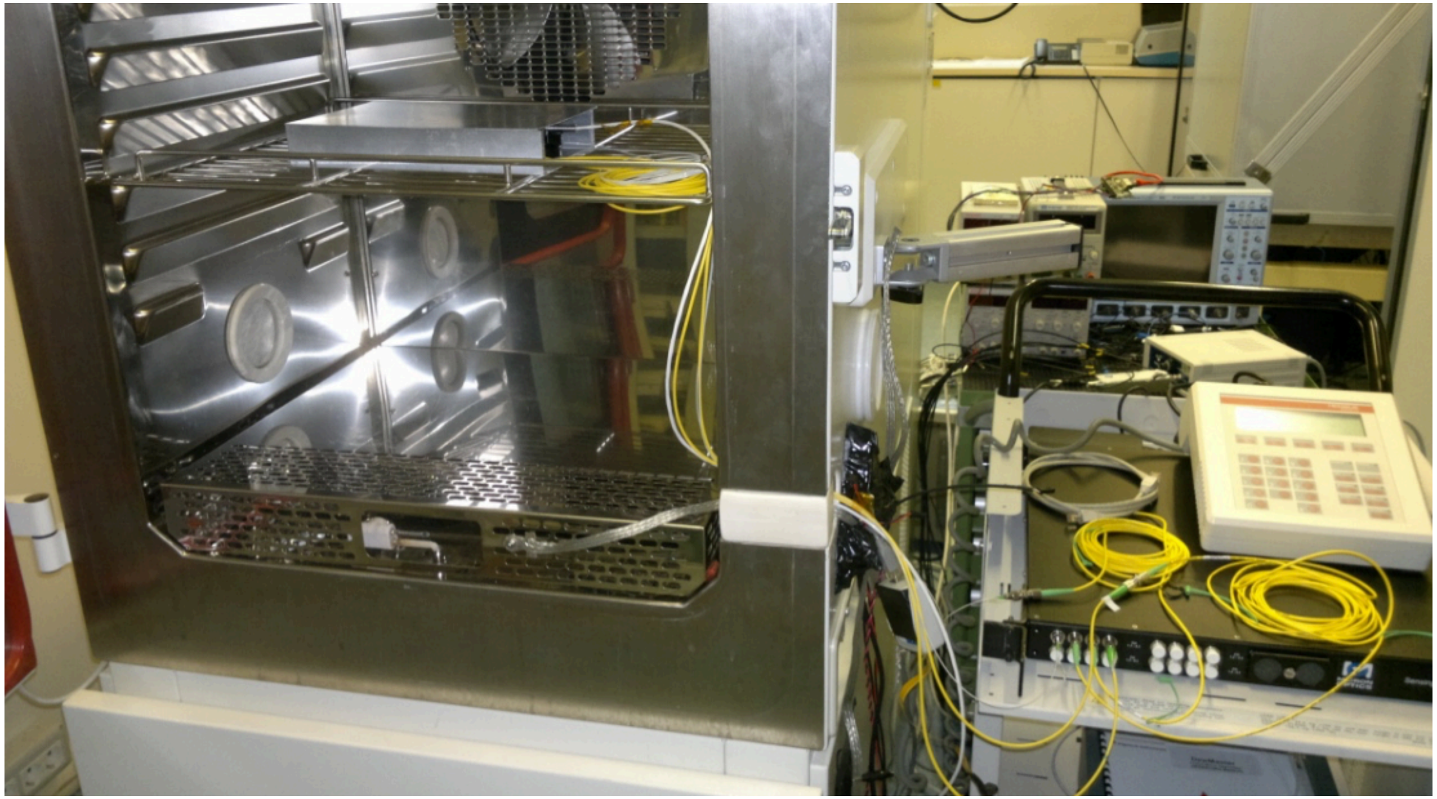
Layer 4
3 couplers

Layer 6: 16 ladders
16 fibers x 7 (+1) FBGs

Layer 5: 12 ladders
12 fibers x 5 (+1) FBGs

Layer 4: 10 ladders
10 fibers x 3 (+1) FBGs

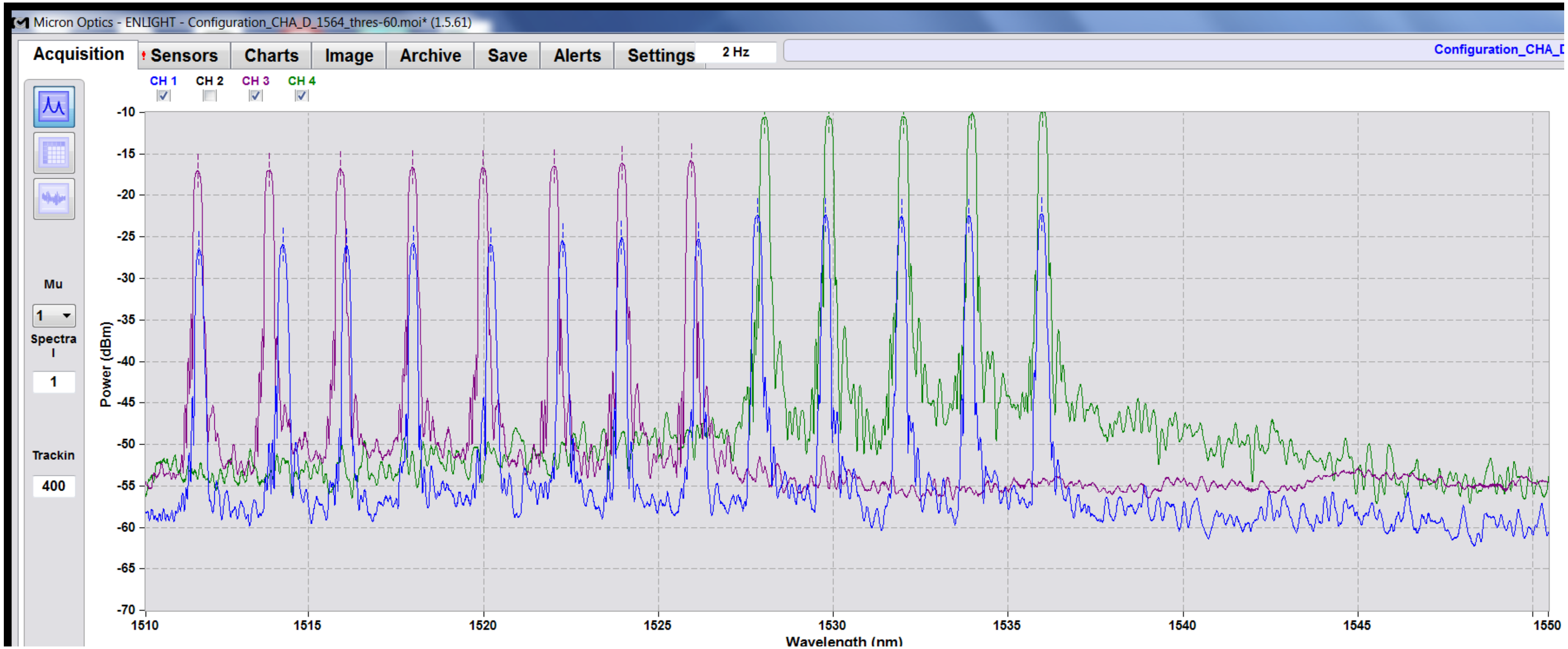
FBG (FOS): tests and calibrations



- Multiplexed fibers with 5 or 8 FBG sensors
  attenuations OK, well separated peaks
- Calibrations in environmental chamber,
  -20 to +40 °C: polynomial fits OK

8/5 FBGs with/without splitters

- 5 sensors fiber direct to interrogator
- 8 sensors fiber with 1x2 splitter
- 2 fibers (8 sensors +5 sensors), 1x4 splitter, 30m fiber and all PC/APC connectors is OK, the attenuation is ~ as expected: OK!



Micron Optics - ENLIGHT - Configuration_CHA_D_1564_thres-60.moi* (1.5.61)

2 Hz

Configuration_CHA_D

CH 1 ☑ CH 2 ☐ CH 3 ☑ CH 4 ☑

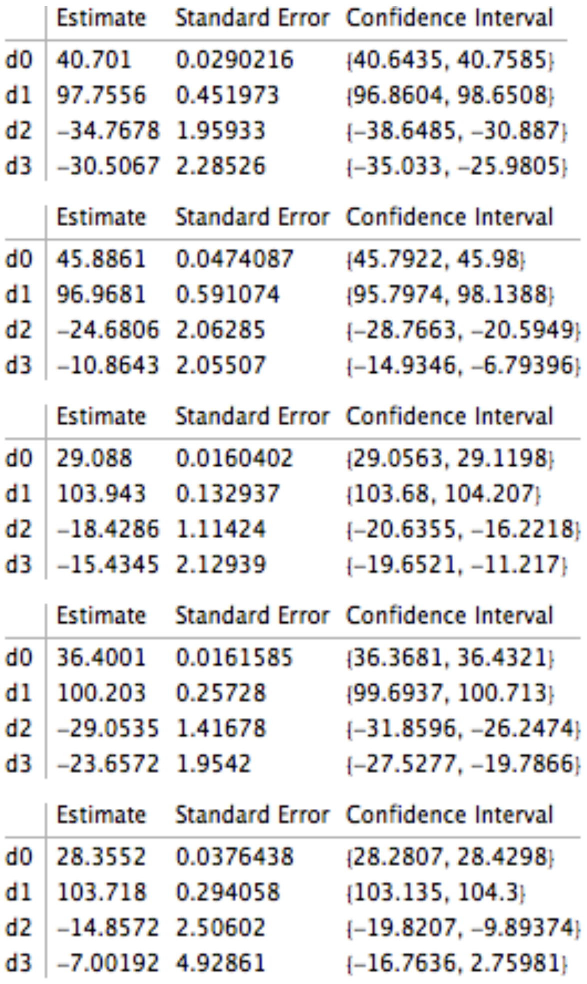
Mu 1

Spectra l 1

Trackin 400

FBG calibrations (-20 to +40°C)

4-parameter polynomial fits: stable and reproducible results, residuals and stability within about ± 0.15°C (less than ± 0.5°C)



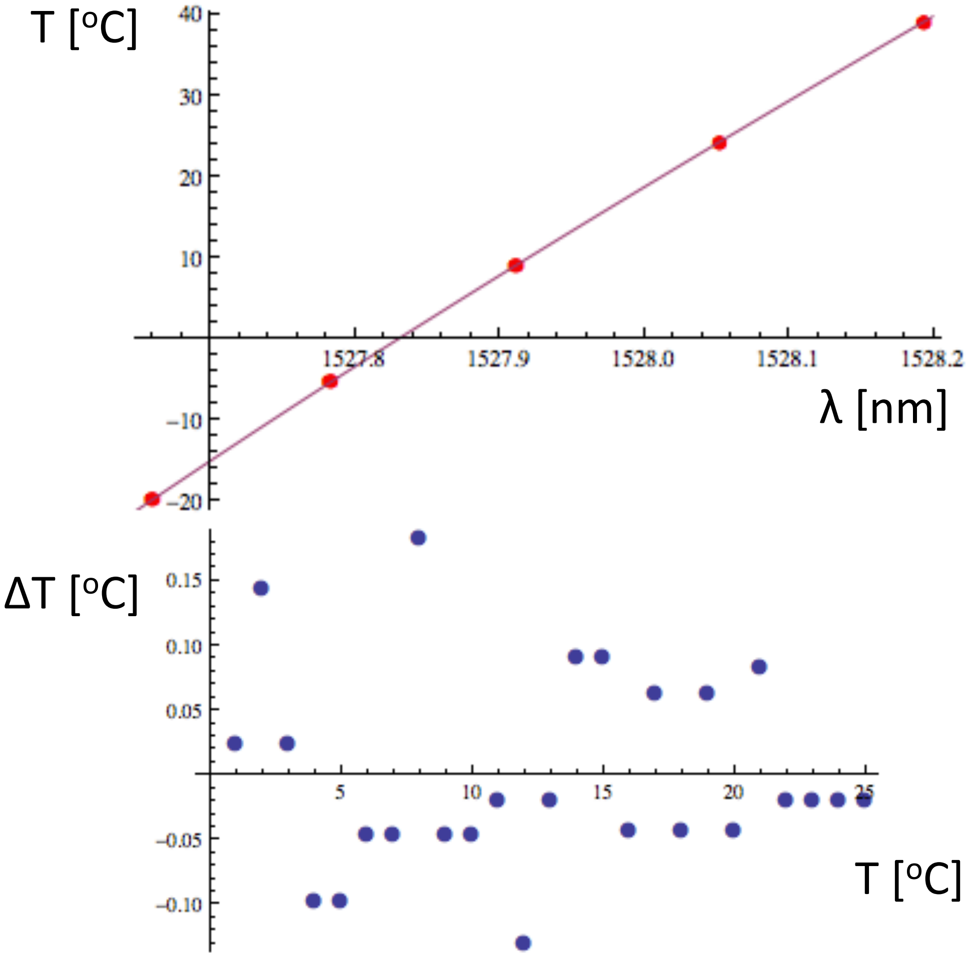
	Estimate	Standard Error	Confidence Interval
d0	40.701	0.0290216	{40.6435, 40.7585}
d1	97.7556	0.451973	{96.8604, 98.6508}
d2	−34.7678	1.95933	{−38.6485, −30.887}
d3	−30.5067	2.28526	{−35.033, −25.9805}

	Estimate	Standard Error	Confidence Interval
d0	45.8861	0.0474087	{45.7922, 45.98}
d1	96.9681	0.591074	{95.7974, 98.1388}
d2	−24.6806	2.06285	{−28.7663, −20.5949}
d3	−10.8643	2.05507	{−14.9346, −6.79396}

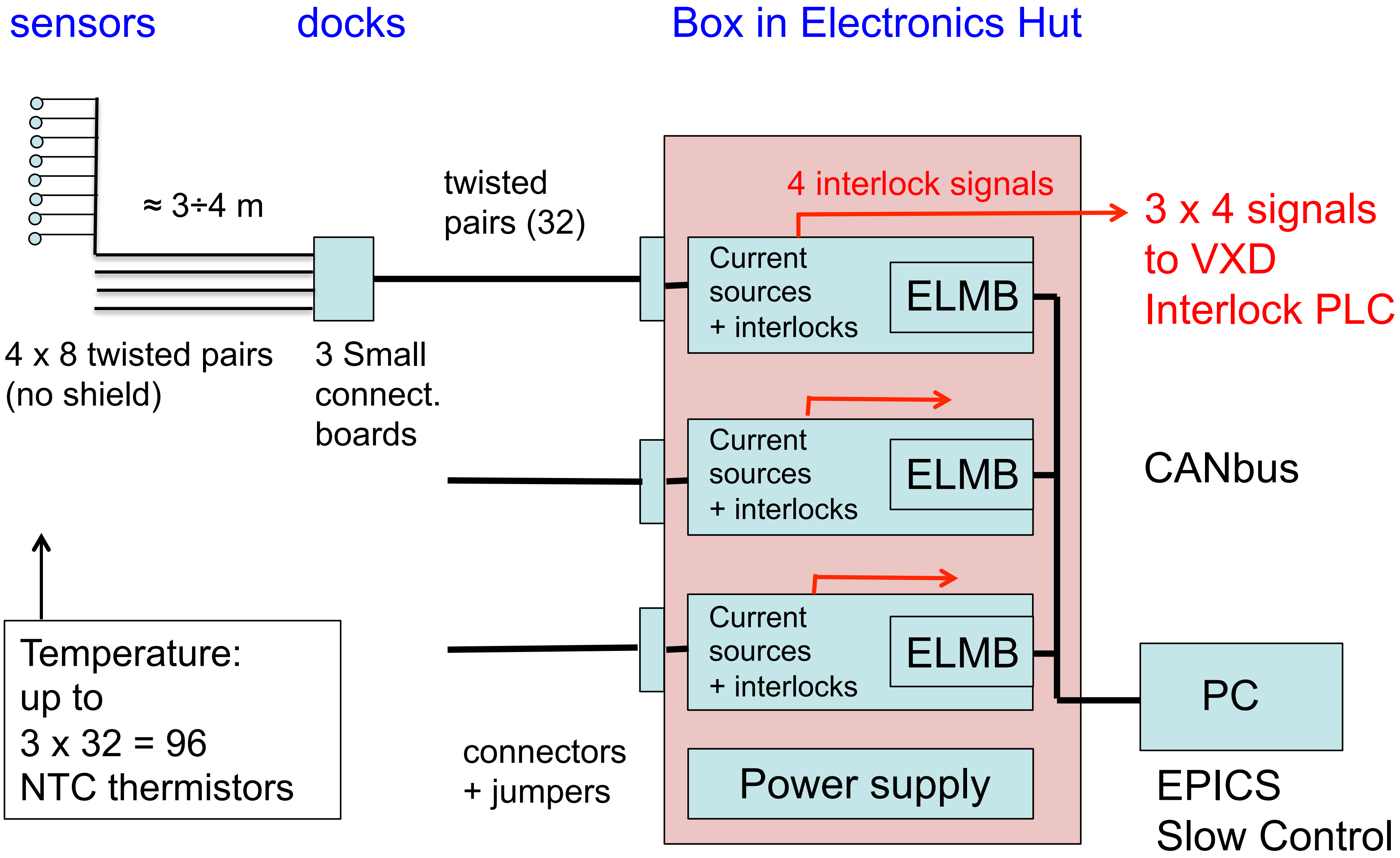
	Estimate	Standard Error	Confidence Interval
d0	29.088	0.0160402	{29.0563, 29.1198}
d1	103.943	0.132937	{103.68, 104.207}
d2	−18.4286	1.11424	{−20.6355, −16.2218}
d3	−15.4345	2.12939	{−19.6521, −11.217}

	Estimate	Standard Error	Confidence Interval
d0	36.4001	0.0161585	{36.3681, 36.4321}
d1	100.203	0.25728	{99.6937, 100.713}
d2	−29.0535	1.41678	{−31.8596, −26.2474}
d3	−23.6572	1.9542	{−27.5277, −19.7866}

	Estimate	Standard Error	Confidence Interval
d0	28.3552	0.0376438	{28.2807, 28.4298}
d1	103.718	0.294058	{103.135, 104.3}
d2	−14.8572	2.50602	{−19.8207, −9.89374}
d3	−7.00192	4.92861	{−16.7636, 2.75981}



NTC final readout (ELMB) system ready!



sensors

docks

Box in Electronics Hut

≈ 3÷4 m

twisted
pairs (32)

4 interlock signals

3 x 4 signals
to VXD
Interlock PLC

Current
sources
+ interlocks

ELMB

4 x 8 twisted pairs
(no shield)

3 Small
connect.
boards

Current
sources
+ interlocks

ELMB

CANbus

Current
sources
+ interlocks

ELMB

Temperature:
up to
3 x 32 = 96
NTC thermistors

connectors
+ jumpers

Power supply

PC

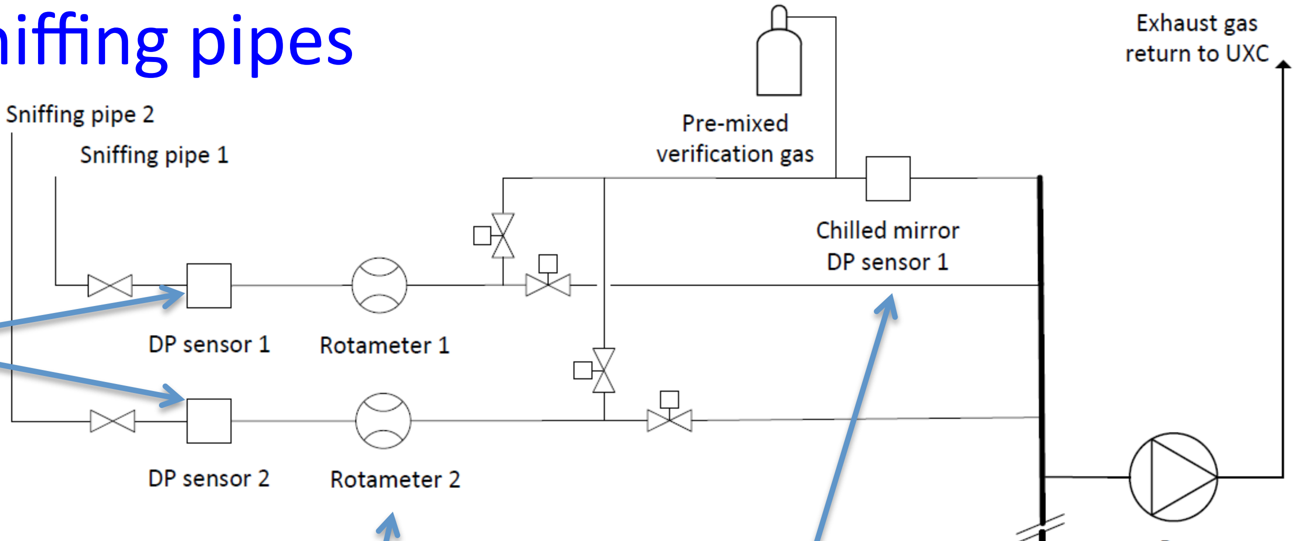
EPICS
Slow Control

NTC final readout (ELMB) system ready!

- ELMB-based readout for 96 NTC thermistors: ready
- Recently brought to DESY for tests on the thermal VXD mock-up
- VXD mechanics meeting in DESY: progress in fine details of mechanics, cabling and interconnections
- Labview software (P.Cristaudo) OK; Szymon Bacher in Trieste now to translate it into EPICS

Dew Point Sensors (interlock @ -30°C)

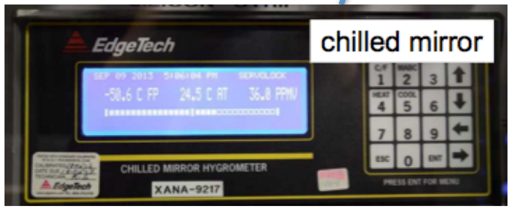
Sniffing pipes



Vaisala DMT242B

Dew Point Transmitters

[-60, +60]°C dew point range



Rotameter

flux meters

Edgetech Dewmaster

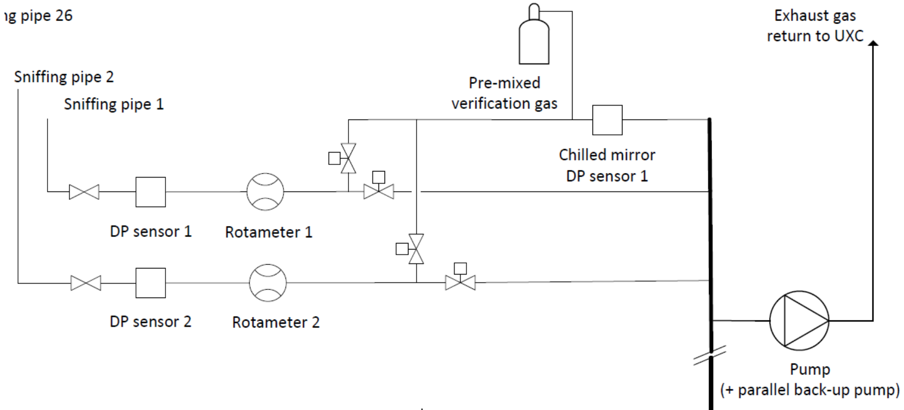
Chilled Mirror Hygrometer

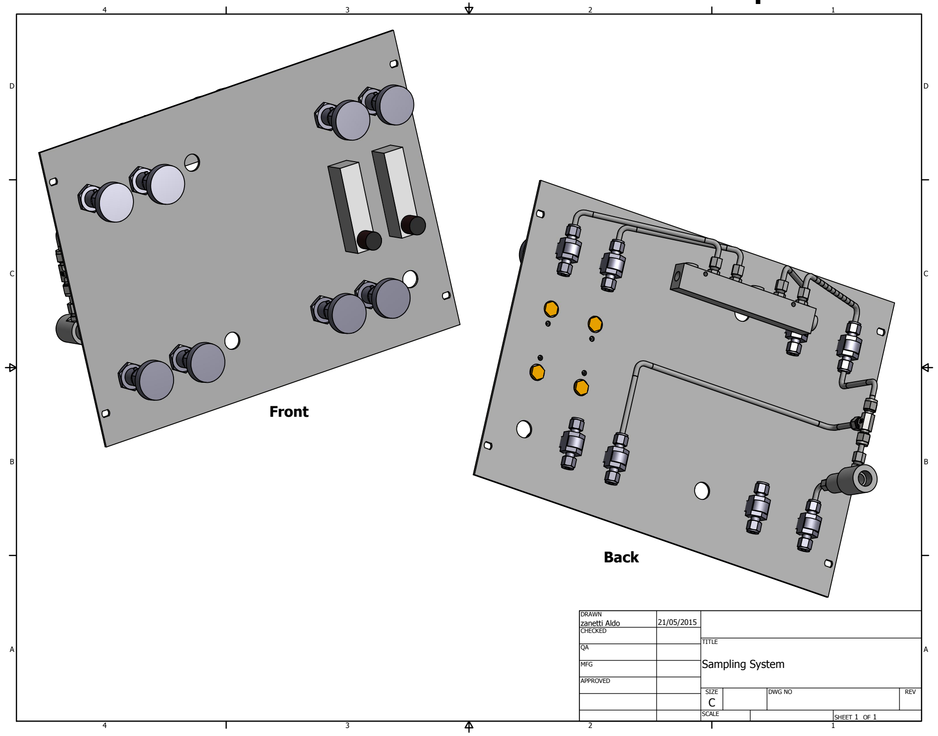
(for calibrations)

Pump

Dew Point Sensors (interlock @ -30°C)

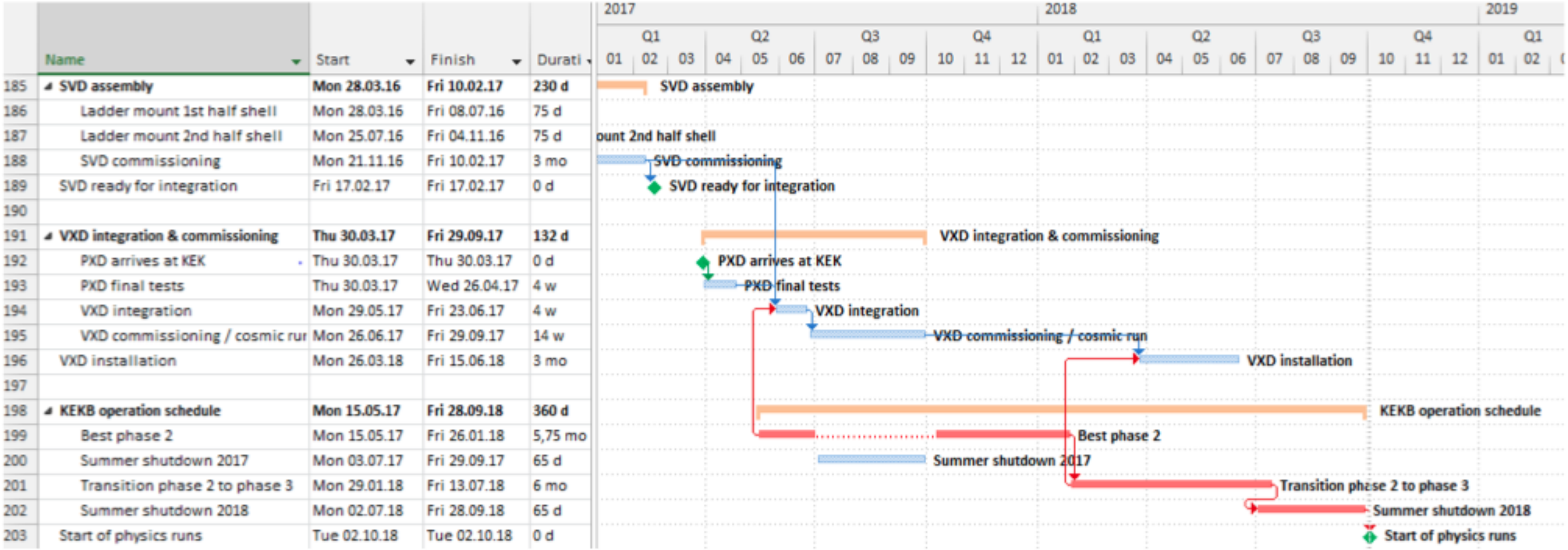
- Main components received
- Detailed mechanical design almost completed.
- Prototype system in preparation for tests on the VXD thermal mock-up (DESY)





BACKUP SLIDES

Commissioning Schedule



	Name	Start	Finish	Durati
185	**SVD assembly**	**Mon 28.03.16**	**Fri 10.02.17**	**230 d**
186	Ladder mount 1st half shell	Mon 28.03.16	Fri 08.07.16	75 d
187	Ladder mount 2nd half shell	Mon 25.07.16	Fri 04.11.16	75 d
188	SVD commissioning	Mon 21.11.16	Fri 10.02.17	3 mo
189	SVD ready for integration	Fri 17.02.17	Fri 17.02.17	0 d
190				
191	**VXD integration & commissioning**	**Thu 30.03.17**	**Fri 29.09.17**	**132 d**
192	PXD arrives at KEK	Thu 30.03.17	Thu 30.03.17	0 d
193	PXD final tests	Thu 30.03.17	Wed 26.04.17	4 w
194	VXD integration	Mon 29.05.17	Fri 23.06.17	4 w
195	VXD commissioning / cosmic rur	Mon 26.06.17	Fri 29.09.17	14 w
196	VXD installation	Mon 26.03.18	Fri 15.06.18	3 mo
197				
198	**KEKB operation schedule**	**Mon 15.05.17**	**Fri 28.09.18**	**360 d**
199	Best phase 2	Mon 15.05.17	Fri 26.01.18	5,75 mo
200	Summer shutdown 2017	Mon 03.07.17	Fri 29.09.17	65 d
201	Transition phase 2 to phase 3	Mon 29.01.18	Fri 13.07.18	6 mo
202	Summer shutdown 2018	Mon 02.07.18	Fri 28.09.18	65 d
203	Start of physics runs	Tue 02.10.18	Tue 02.10.18	0 d

Ordine fatto per 3 Boards LV Power Supply

- Il Vsep e’ la differenza di tensione che si stabilisce tra la faccia del rivelatore (N o P) e l’ingresso dell’amplificatore

- Sul P-side e’ obbligatoria perche’ in caso di qualche pinholes (C rotto) l’alta corrente in ingresso puo’ non far funzionare l’intero chip

- Dai tests recenti sui moduli veri abbiamo capito che sull’N-side la Vsep puo’ recuperare (far tornare a funzionare efficientemente):
  - i canali dovuti ai pinholes
  - i canali rumorosi (field-plate effect)

Rivelatori HPK (Large DSSD)

- Le indicazioni del BPAC:
  - Ladder complessi da costruire (necessario aumentare le parti spares durante la costruzione)
  - Finire la produzione con un congruo numero finale di ladder spares
  - Si tratta di aumentare di un 10% le parti per arrivare ad un 20% di spares
- Istituzioni di SVD si stanno impegnando sul procurement degli small DSSD, chips, PAs, hybrids, ribs, parti meccaniche.
- Il fattore limitante e' costituito dai rivelatori large DSSD:

(Financial shortfall for SVD)

Type	**Number**	**Unit cost kYen**	**TOTAL (kYen)**	**With tax**	**TOTAL (Euro)**
Large DSSD	25	702	17550	18954	146.25
Small DSSD	10	988	9880	10670.4	77.1875