

Belle2 Silicon Vertex Detector

Riunione con i Referees
Pisa, 15 Maggio 2014



S.Bettarini
Per il gruppo SVD



SUNTO

Introduzione: SVD

•Attivita' PISA:

- Assemblaggio FW/BW
 - xyz- θ stage
 - MP jig
 - Gluing jig
- Construction Schedule
- Power Supply
- IBBELLE
- ROI software
- Spese 2014

•Attivita' Trieste:

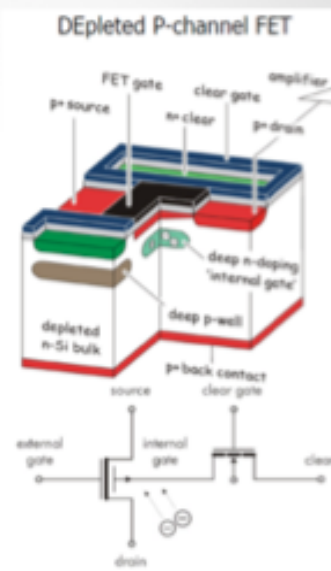
- Test sensori
- Monitoring Rad
- Monitoring T/Humy
- Schedule
- Spese 2014

Update piano complessivo

Vertex Detector

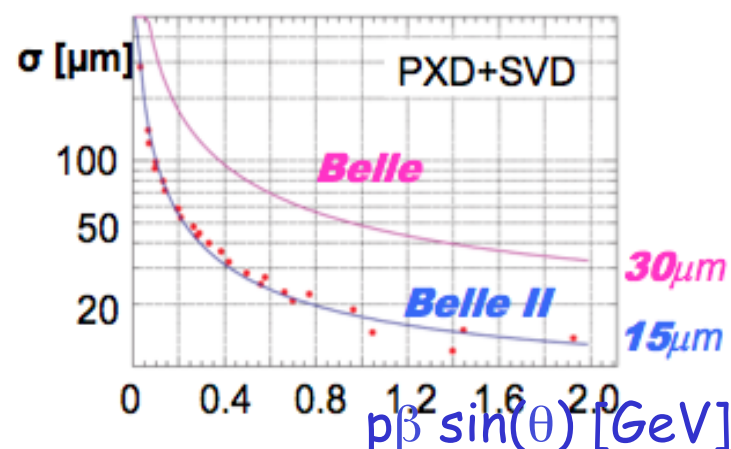
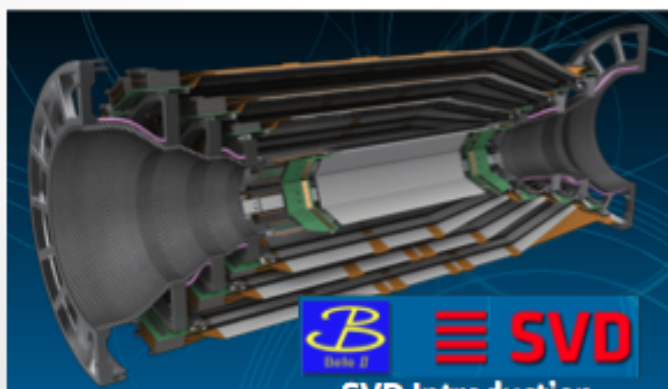
- **Pixel Detector (PXD)** – 8M pixels
 - 2 DEPFET layers at $r = 14, 22$ mm
 - Excellent and unambiguous spatial resolution ($\sim 15 \mu\text{m}$)
 - Coarse time resolution ($20 \mu\text{s}$)
- **Silicon Vertex Detector (SVD)** – 220k strips
 - 4 DSSD layers at $r = 38, 80, 104, 135$ mm
 - Good spatial resolution ($\sim 12/25 \mu\text{m}$) but ambiguities due to ghosting
 - Excellent time resolution (~ 3 ns)

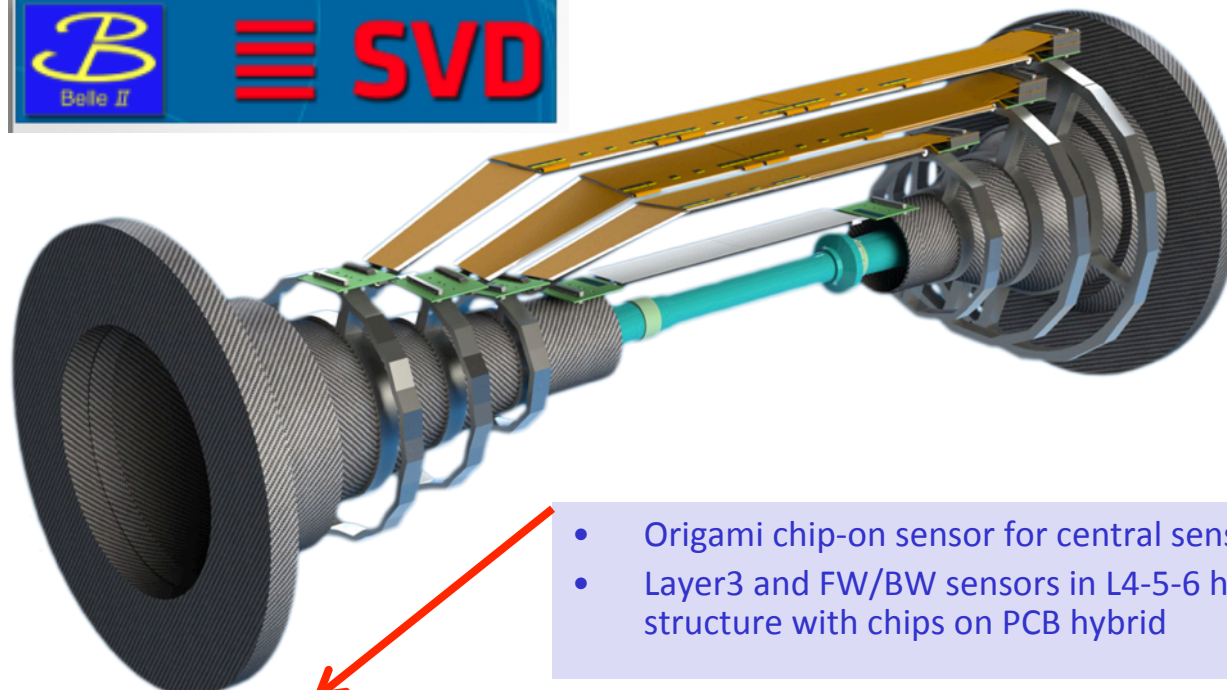
Mechanical mockup of pixel detector



Combining both parts yields a very powerful device!

Significant improvement in z-vertex resolution



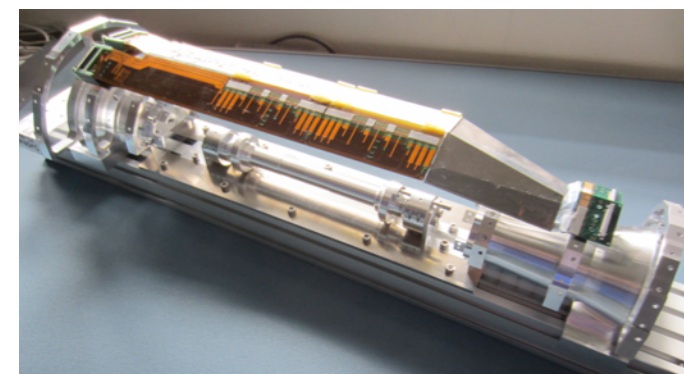
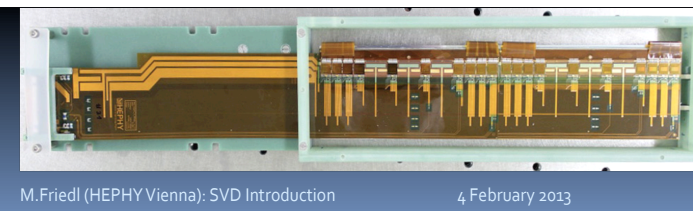
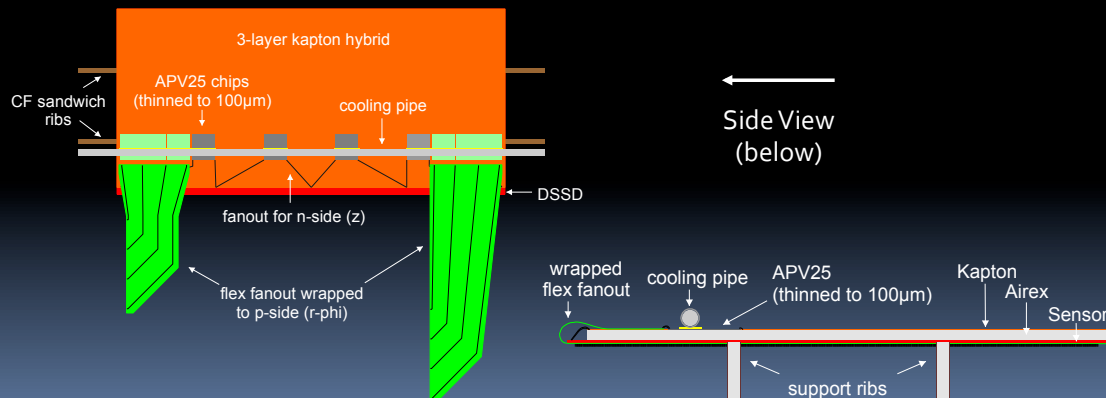


- 4 layers with silicon strips (DSSD) with APV25 read out
- Individual sensors connected to APV25 chips, to reduce capacitive load

- Origami chip-on sensor for central sensors in L4-5-6
- Layer3 and FW/BW sensors in L4-5-6 have more conventional structure with chips on PCB hybrid

Origami Chip-on-Sensor Concept

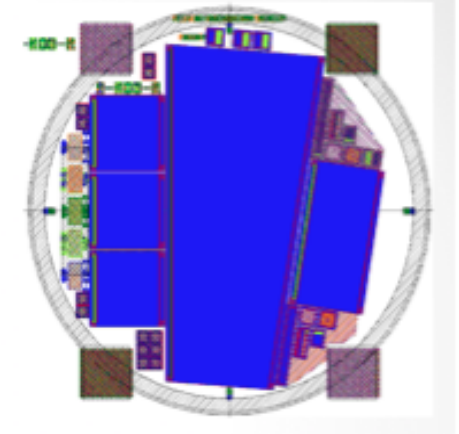
- Low-mass double-sided readout
- Flex fanout pieces wrapped to opposite side
- All chips aligned on one side → single cooling pipe (D = 1.6 mm)



Vertex Detector (PXD+SVD)

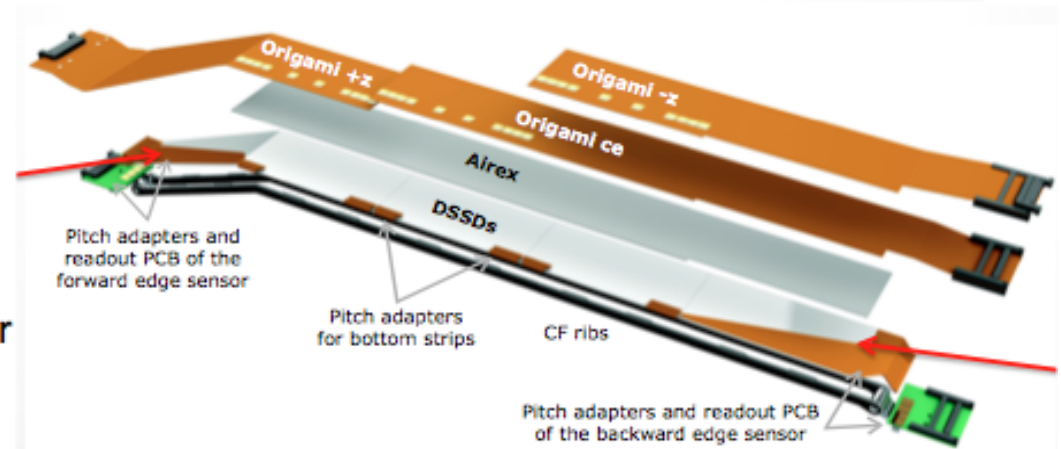
Trieste:

- Contribution to silicon detector testing (Micron)
- Environmental & Radiation Monitoring
 - Take advantage of development funded in SuperB for diamond detectors with fast remote readout



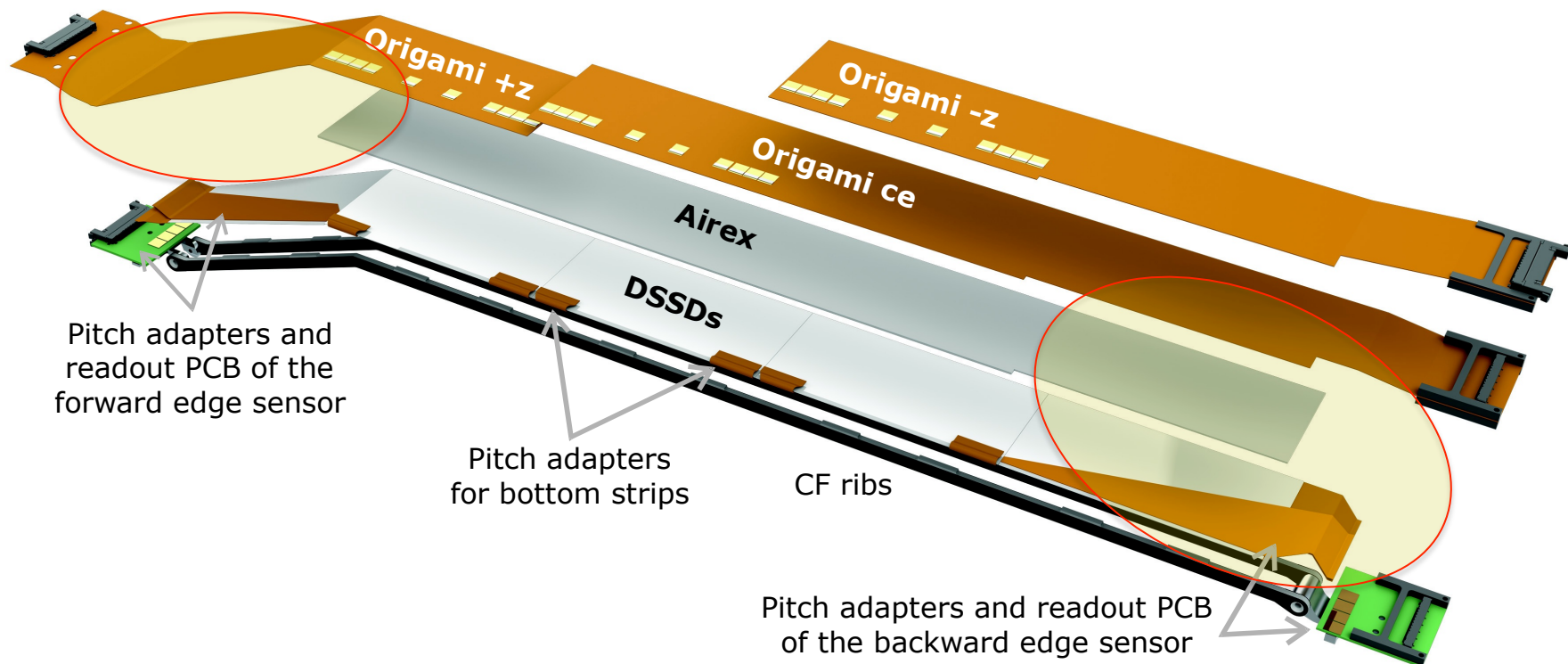
Pisa:

- Contribution to assembly of strip detector modules:
 - On critical path
 - Assemble FW and BW sensors of Layer 4-5-6 & ship to other assembly sites (Vienna, IPMU-Tokyo, TATA at IPMU lab)
- Participate in overall mechanical design & assembly
- SVD software development:
 - Si only tracking & PXD data reduction with ROI (region of interest) selection
 - Alignment
- Replacement of the old Power-Supply



Assembly procedures

- Produce single-sensor subassemblies of the forward and backward sensors.
- Connect sensor to pitch adapter, pitch adapter to hybrid
- Ship the tested sensor sub-assembly to the module assembly sites



Option "P" viability

- Build the L4-5-6 BW and FW assembly (i.e. glue the PA to det's and hybrids and u-bonding) and do their electrical characterization.

Review FW/BW Assembly Procedures & updates on jigs status, gluing & bonding tests, teststand.

- Safely shipment of the BW/FW assemblies to ladder production sites and sustain a proper production rate

Multi Purpose jig designed for shipment (bonding & testing during assembly in Pisa).

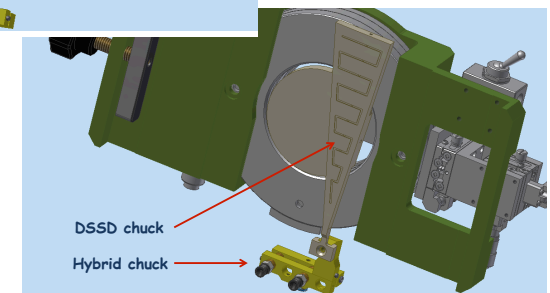
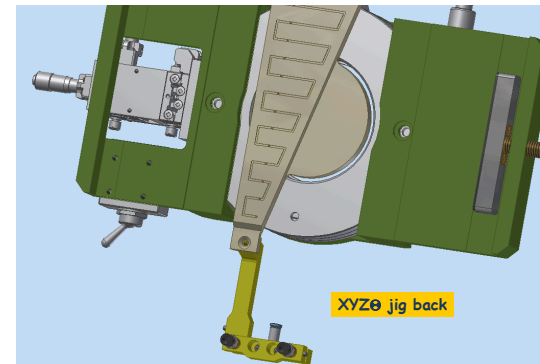
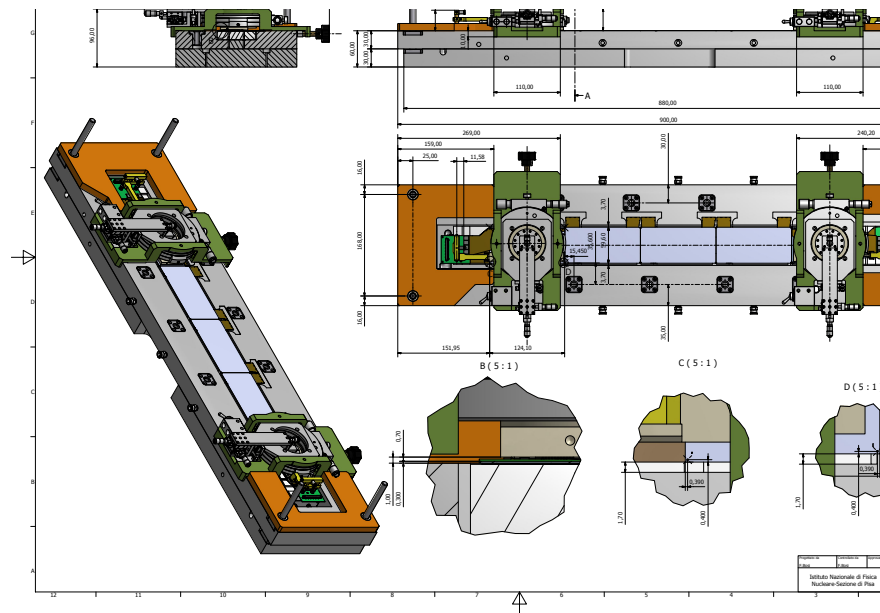
- Align the BW/FW on the assembly bench(es) and go back in stream with the original procedures

Modified xyz- θ stage built to safely align the BW/FW subassembly with the other detectors on the bench masks

At the last (Feb.) B2GM the SVD group decided that the option "P" becomes the baseline for the module production.

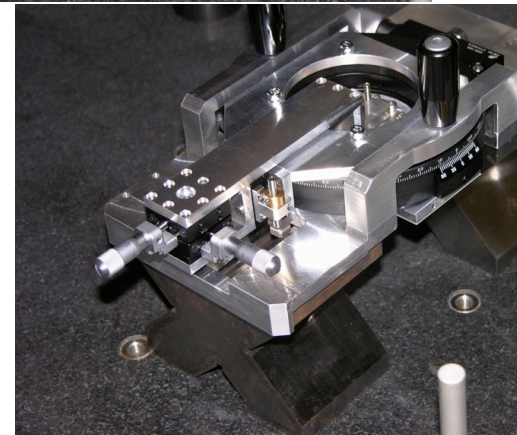
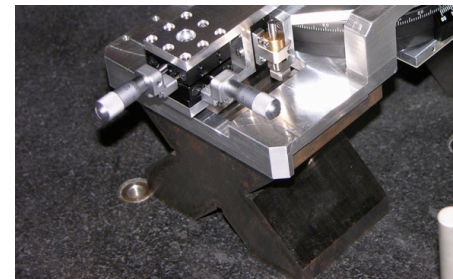
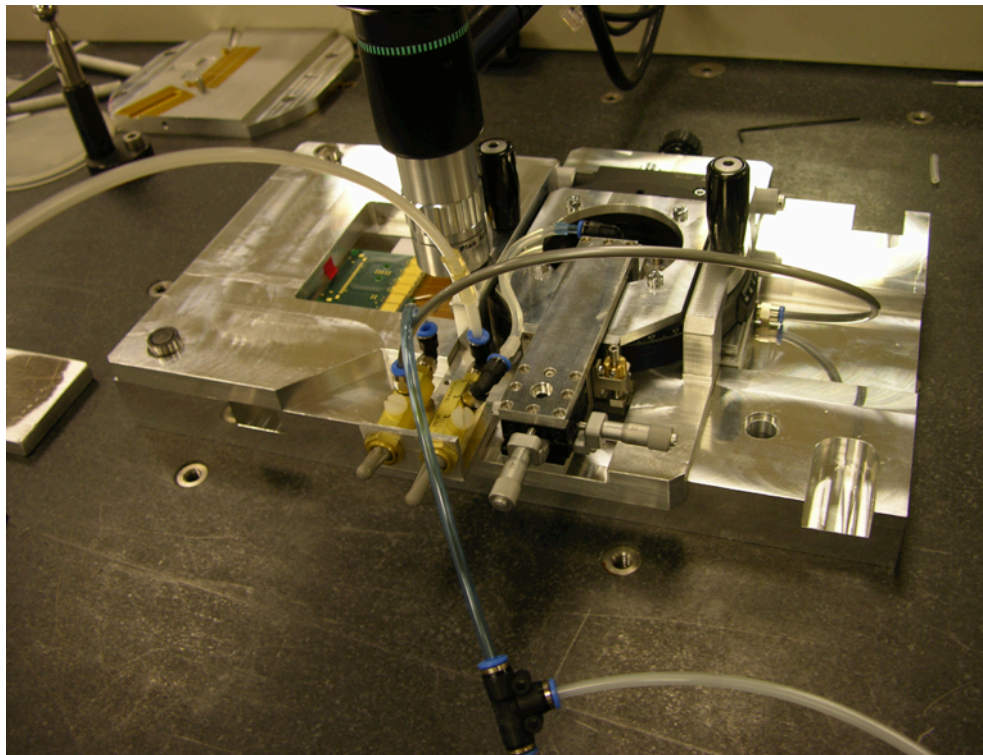
Modified xyzθ stage (2FW+2BW)

- Jig redesigned to allow a fine alignment of the FW/BW subassembly on the assembly mask
 - Picks up the sensor after it is glued to the PA and wirebonded.
- Requirements:
 - Need to be compatible with the assembly procedures
 - Need to guarantee good alignment/precision of the FW or BW assembly to the other sensors
- Added features:
 - safety mechanical stop to ensure jig cannot hit the wirebonds
 - A locking knob to make sure the jig cannot move



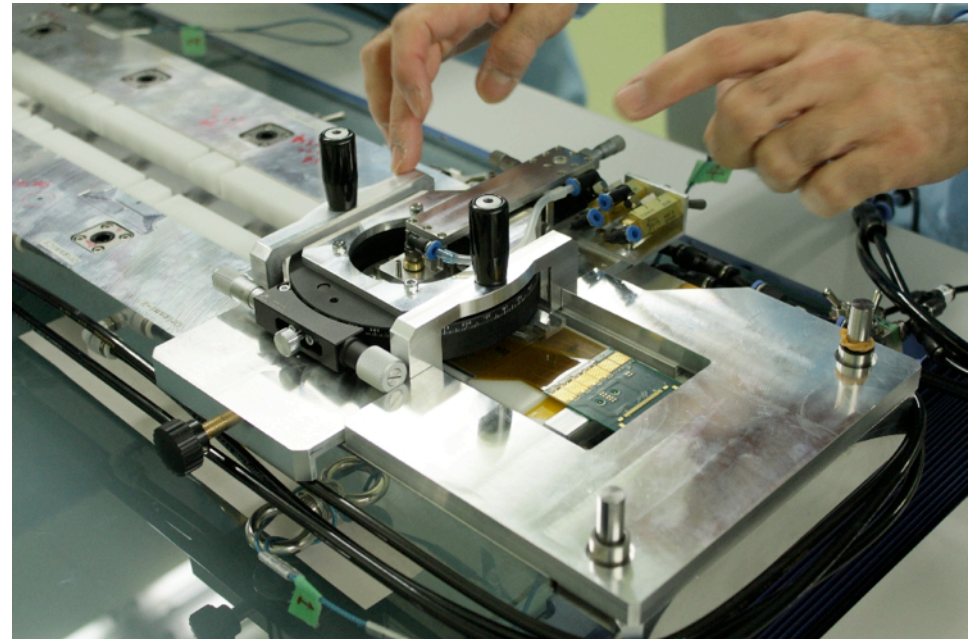
Modified xyz θ stage assembly & test in Pisa

- The 1st prototype (BW) produced and inspected under the CMM after mounting the stages. Within specs:
 - teflon chuck planarity ~ 20 μm
 - vacuum chuck set parallel to foothold plane with 3 screws + cup springs (30 μm)
- First test of the jig in Pisa using a BW subassembly prototype on a dummy bench-mask



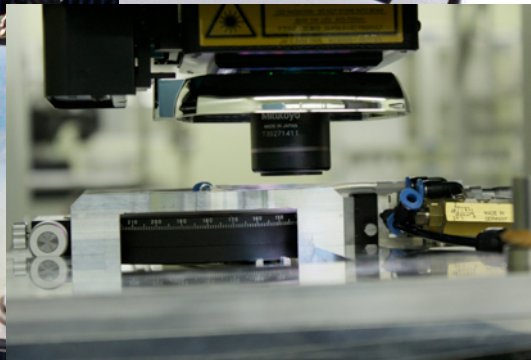
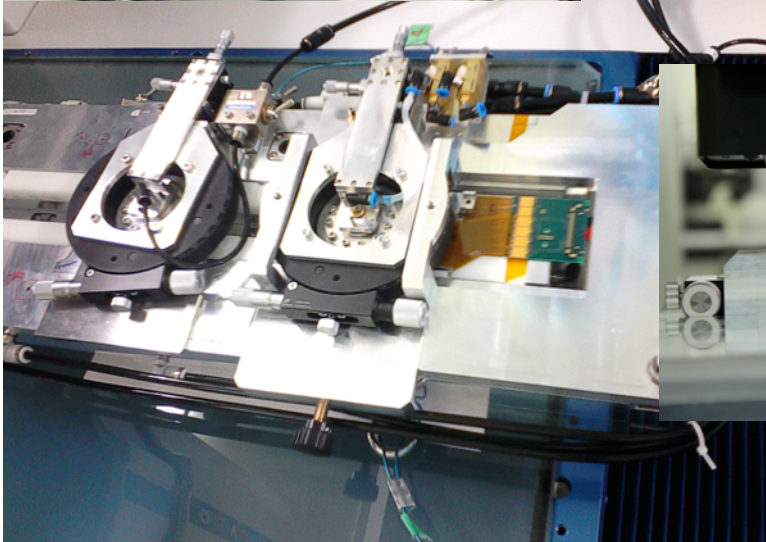
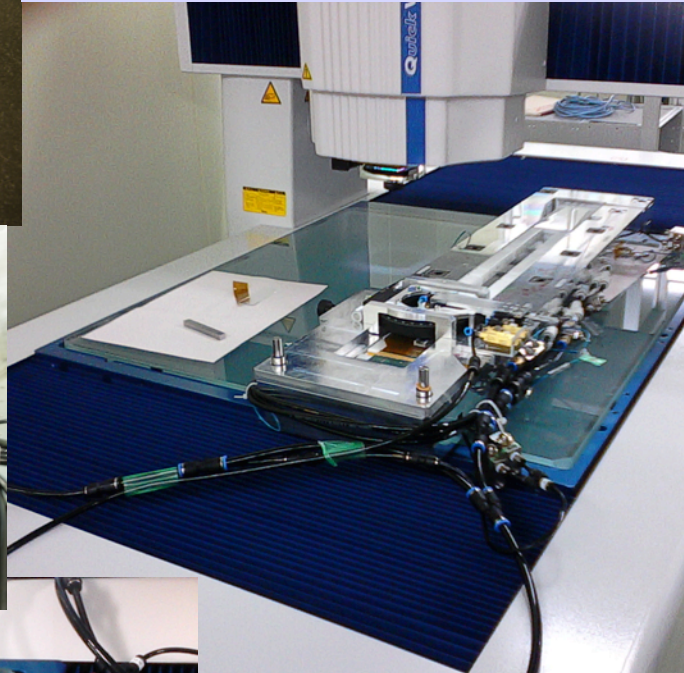
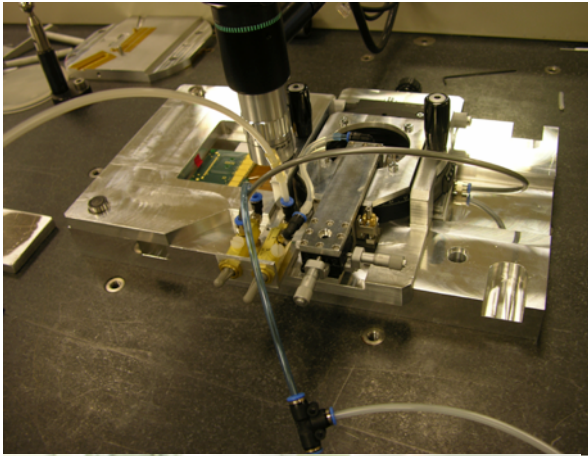
Modified xyz θ stage test @ IPMU

- Successful test done during the B2GM at IPMU to check the functionality of the jig on the real ladder bench mask and look for possible interference.
 1. Test angle alignment capability
 2. Test capability of positioning to nominal position
 3. Test position when assembly is dropped .



- The jig has demonstrated very good alignment capabilities, it is mechanically compatible with the real bench mask and adds some safety features
 - Minor modifications to improve usability
 - Small rotation in dropping from 250um but (displacement from nominal position ~ 5-15 um is acceptable) Some optimization may be required in dropping height/ procedure.
 - No need for bridge to hold the hybrid, since sensor chuck is strong enough.

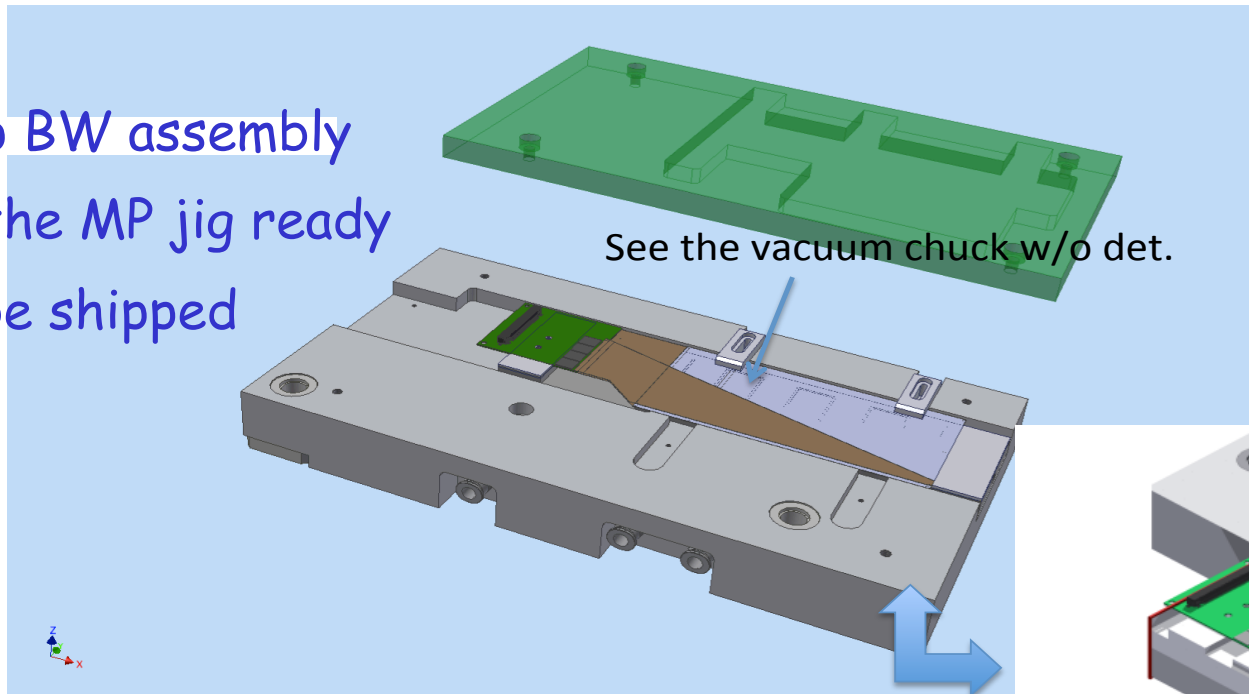
The xyz- θ stage
from Pisa to IPMU



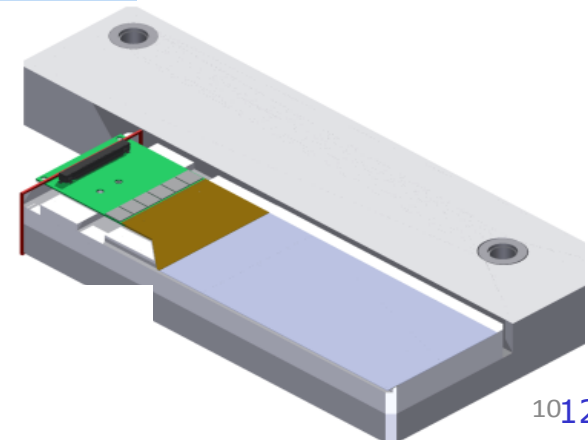
Multi Purpose jig

- The MP jigs are used for bonding/testing & rework operation on both sides.
- It has a holder in which to insert a teflon chuck that can be both phi or z up; the detector can be held with clamps and vacuum.
- The MP jig is also used for the final shipment of the BW/FW subassembly to the ladder construction sites with an appropriate cover.

Z-up BW assembly
On the MP jig ready
To be shipped

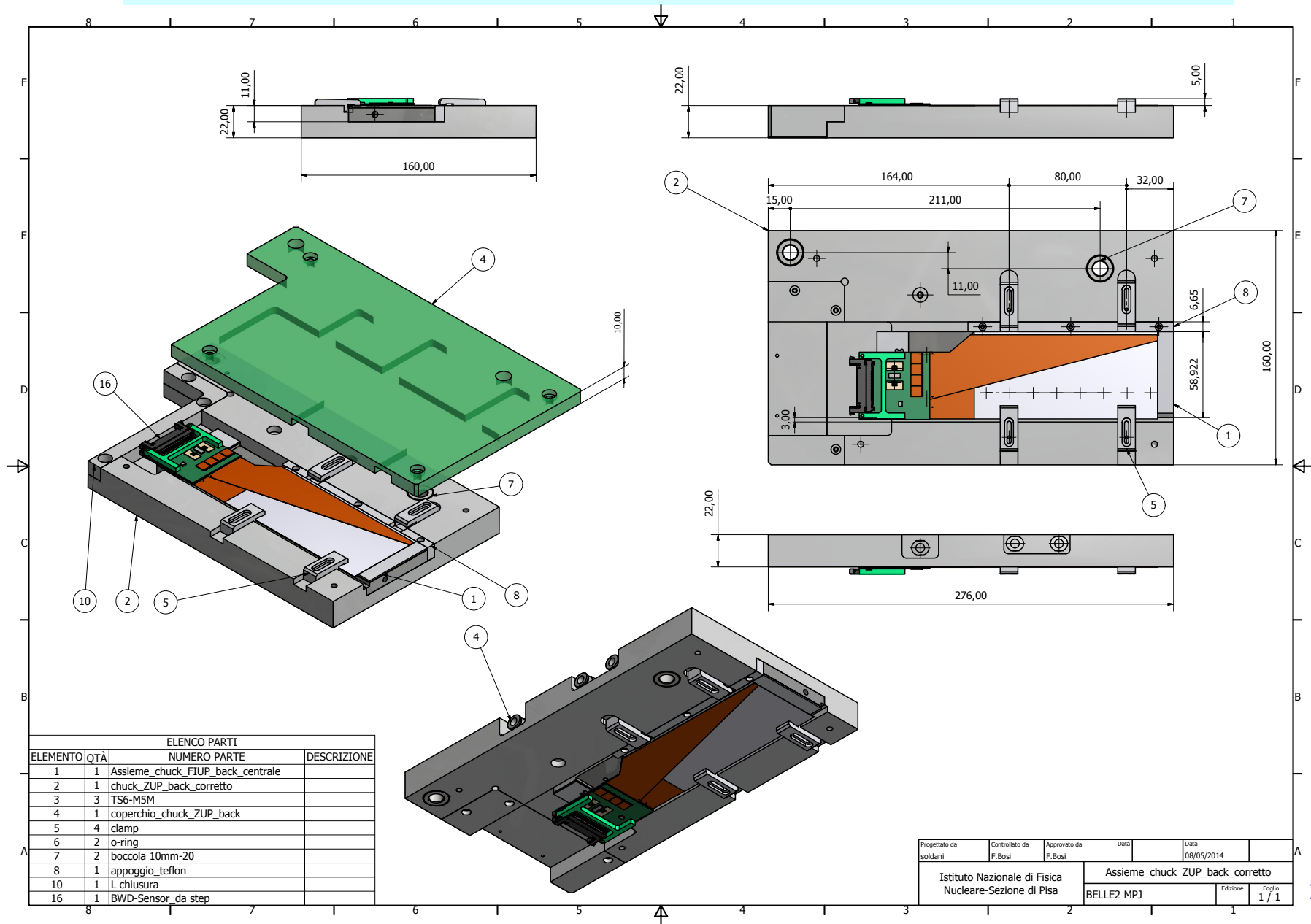


To be used with PB2
chuck to take the BW
assembly and place the
the assembly bench



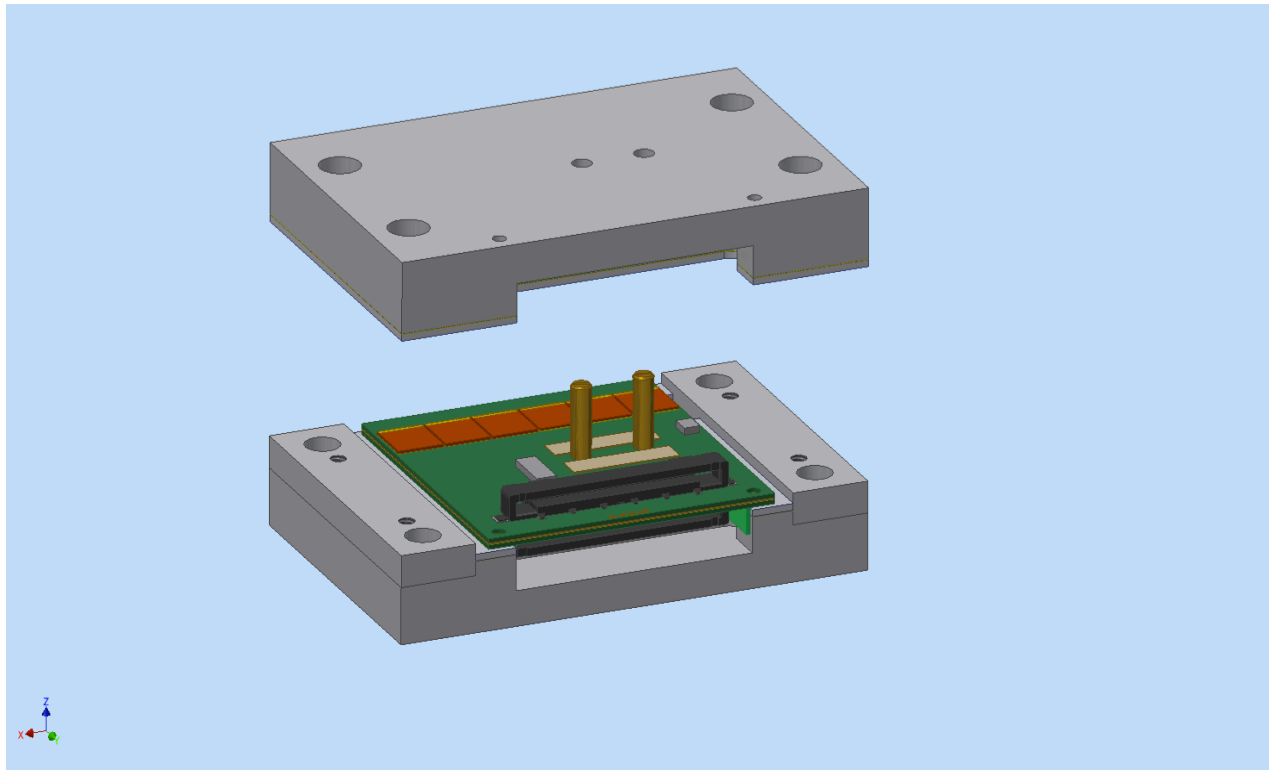
In production, delivery expected by mid-May.

... i MP jig non sono semplici scatole



HDI gluing chuck

- Single face L4-5-6 hybrids are equipped with chip, u-bonded by Vienna and sent to Pisa.
- After testing the halves, the double faced hybrid, with a SilPad (electrical insulator, thermal conductor) interposer, is assembled.



FW/BW Assembly: general strategy

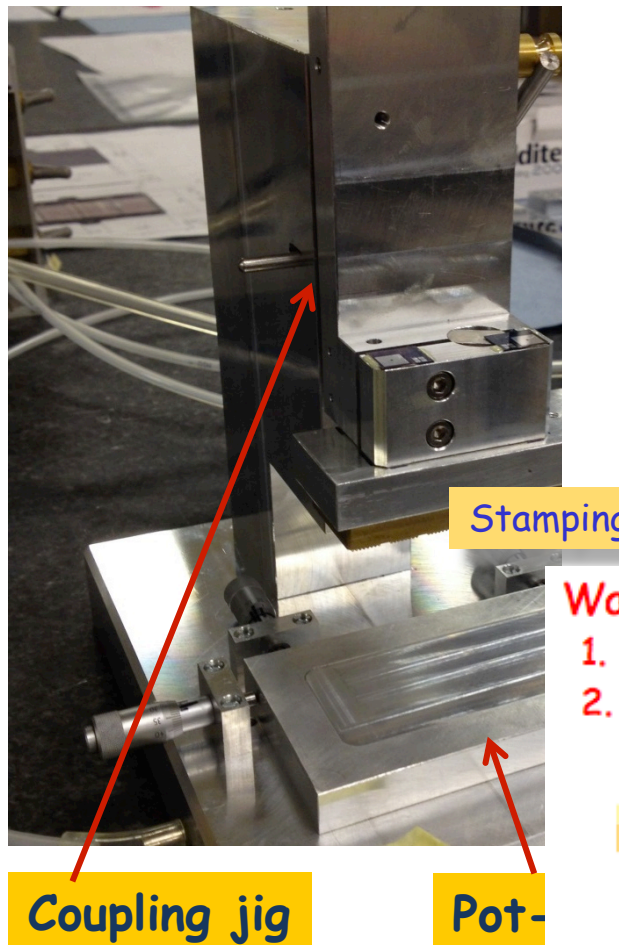
- The procedures are independent from the gluing technique, stamping or syringe dispensing: we will go under the stamping facility or the glue dispenser with the chuck hosting the PA.
- We will start with the phi side, put the hybrid on a base-chuck in the nominal position through pins and align the detector in order to reach the needed mechanical precision, in order to easily/safely allow the bonding.
- There are two independent towers, one for the detector and one for the hybrid, that can reach the right height.
- The PA is first aligned by the reference pins on a top-chuck, partly transparent (plexi-glass), and, after depositing the glue, the PA is "lowered" realizing the PA-to-detector and PA-to-hybrid gluing at a once, with all the surfaces lying on an unique plane.
- The quota of the PA chuck (w.r.t. det. & hybrid) is calibrated and can be adjusted, when lowering the chuck.
- First we realize all the gluing (phi side and then z side) then we make the micro-bonding
- The electrical tests must be foreseen after each bonding loop (low & high, on phi side), when reworking is still possible (i.e. detach/redo bondings).

The gluing jigs

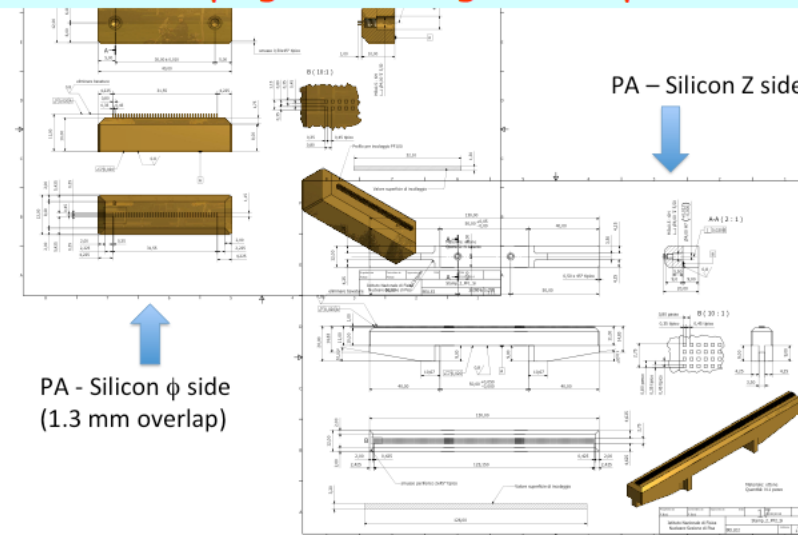
- Several gluing tests done with available chuck: we found that the definition of the quota is critical in such a gluing.
- The detector/PA design implied some difficulties:
 - Very small overlap between PA and det's on phy side (1.3 mm)
 - Also small overlap between PA and hybrid (3.2 mm)
 - PA pads very close to the boundary
- To cope with all these aspects, extensive gluing test performed and many critical aspects identified → a very complex gluing jig has been designed, submitted in production and delivery confirmed in mid-may.

Glue-stamping tests

- Dispensing the glue with the stamping technology allows to release a minimal and tunable quantity of glue/area
- Important to reach a better control of the position and the amount of glue in the most critical spots of the PA (i.e. below bonding pads)

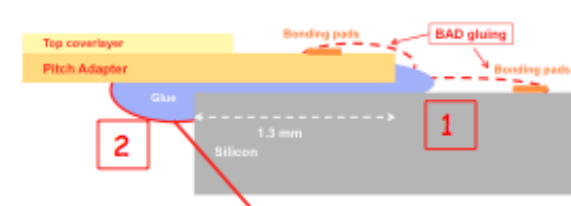
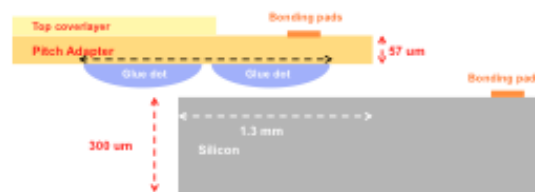


Several stamping tools designed and produced

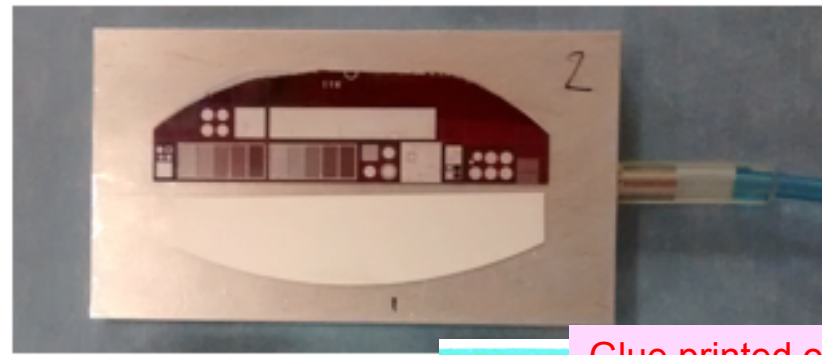
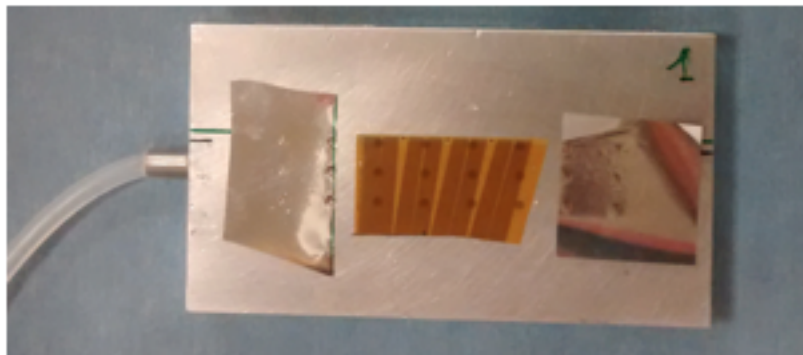


Want to study how the glue spreads on critical spots:

1. around PA edge $\rightarrow$ it can reach the PA or the Silicon bonding pads
2. around Silicon edge $\rightarrow$ want to have some glue there to make the gluing more robust



PA to Silicon phi side gluing: successfully realized



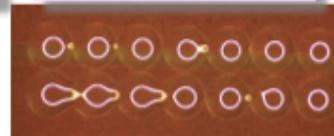
- Glue dispensed with a stamping tool with 2 rows of teeth (pitch=800 μm)

Stamping tool with 2 rows



Pitch=800 μm

Glue printed on PA



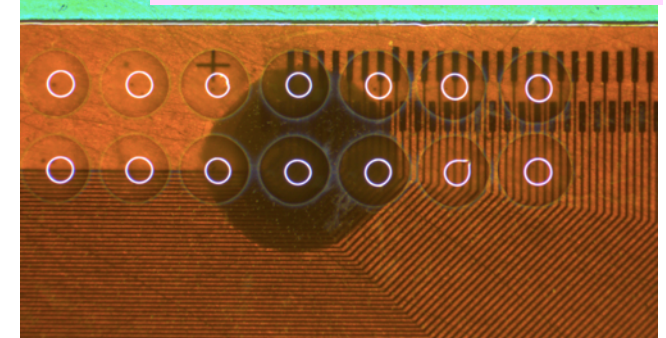
Typical dimensions of the glue spherical cap:

- Diameter=700-800 μm
- Height= 50-70 μm

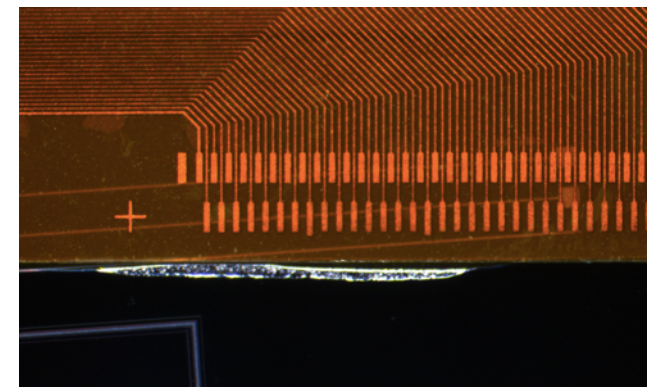
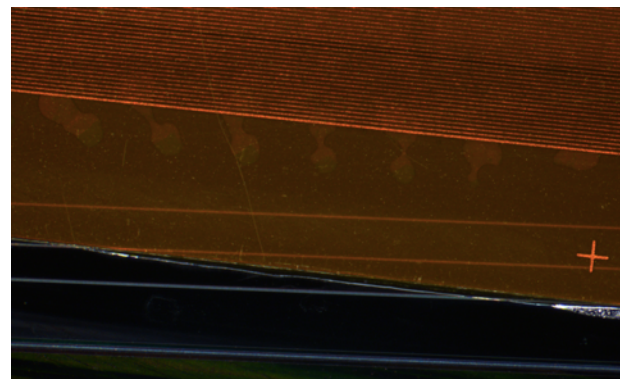
PA & Si chucks put in contact with no spacer for this test.

Glue squeezed to $\sim 15 \mu\text{m}$
→ only few spots without glue on one corner.

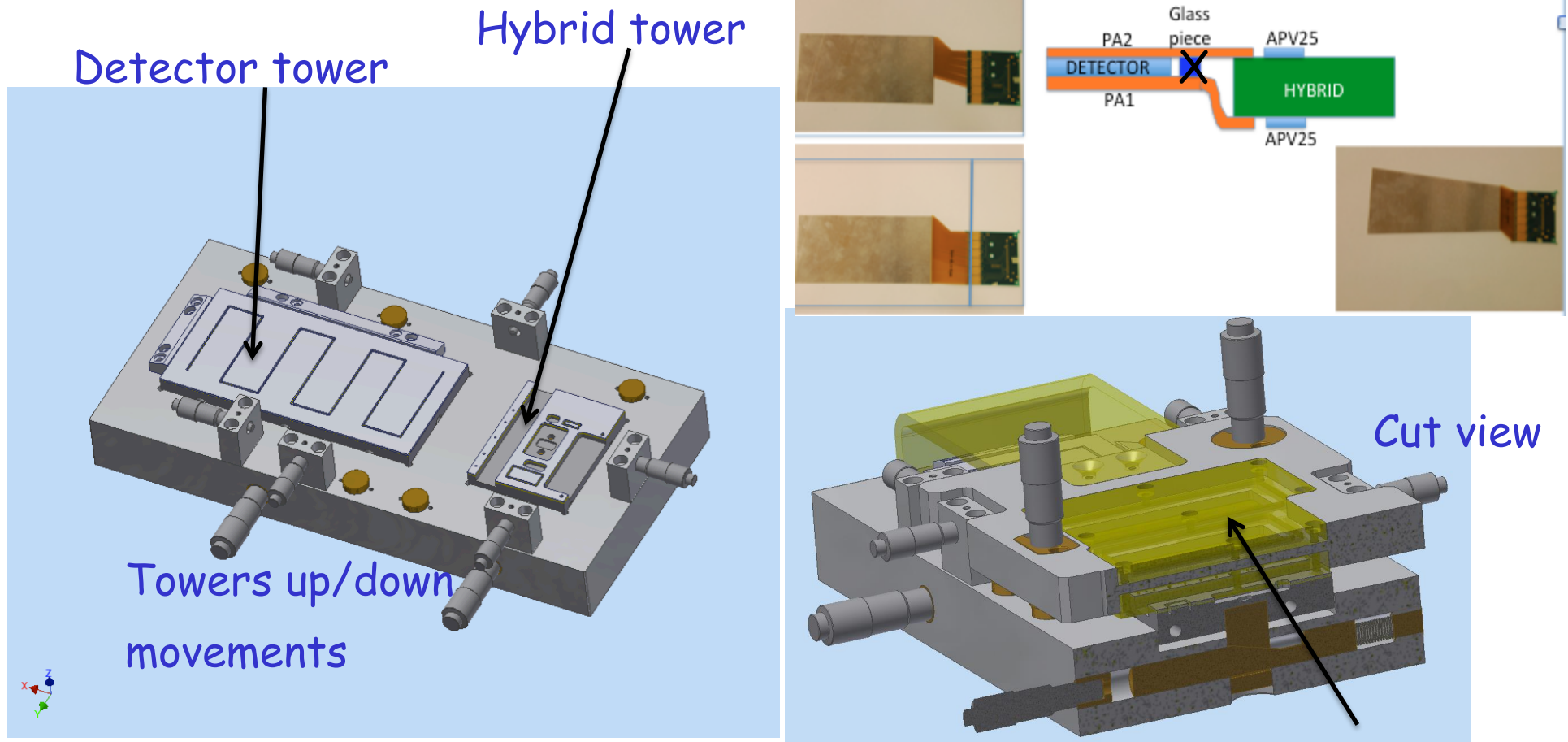
Glue printed on PA sample



Glue extends at the edge of the PA only by $\sim 300 \mu\text{m}$ & no glue above PA pads.



The final Gluing jig (BW-phi)

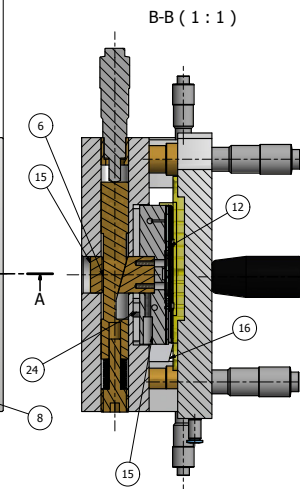
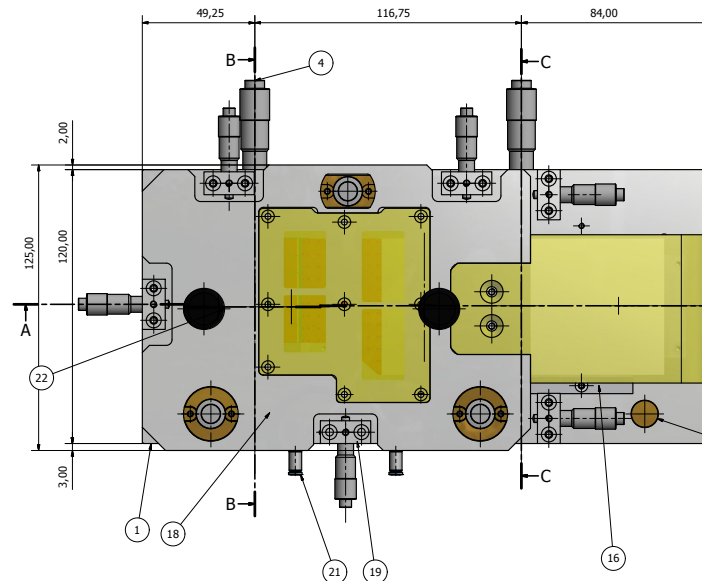
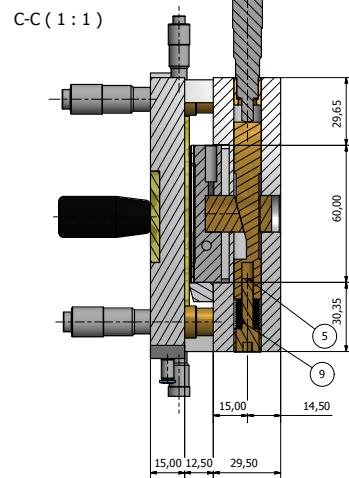
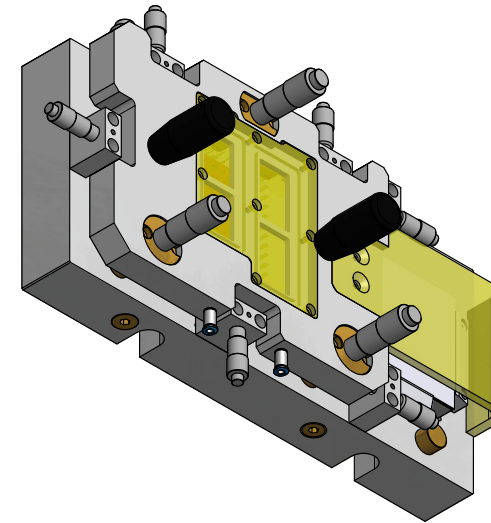
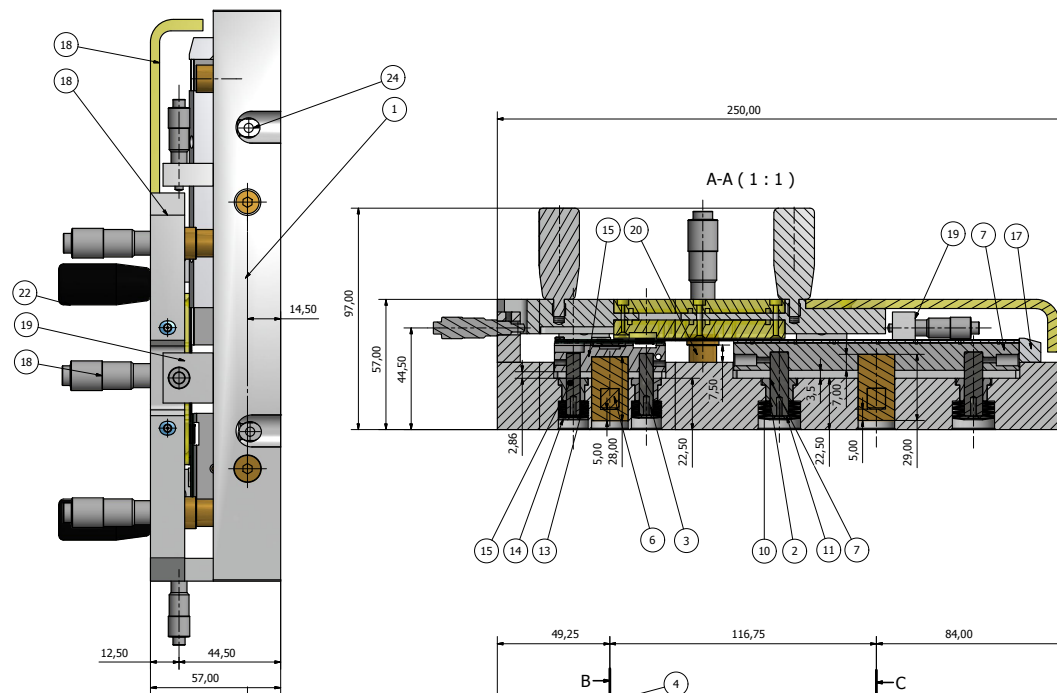


Other (similar) 3 jigs are required: BW-z, FW-phi and FW-z.

First version ready to be assembled on mid-May.

Possible home-made fine mech. adjustment/modifications.

The Gluing jig



ELENCO PARTI			
ELEMENTO	QTA	NUMERO PARTE	DESCRIZIONE
1	1	gluing bottom jig PB1	
2	2	boccola 8mm	
3	2	boccola 6 mm	
4	2	Assieme_micrometro_rinboccolato	
5	2	perno di regolazione	
6	2	albero orizzontale	
7	1	Assieme_gluing_torretta_si_PB2_UP	
8	3	boccola piena	
9	2	Assieme molle tazza albero orizzontale	
10	2	Assieme molle tazza albero verticale	
11	2	8,2x18x1,1	
12	1	rondella molle tazza 18	
13	2	BWD-Sensor da step	
14	2	Assieme molle tazza albero verticale	
15	2	6,35x12,7x0,43	
16	2	rondella molle tazza 13	
17	1	Assieme_gluing_torretta_Hy_PB1_UP	
18	1	bloccetto battuta lungo PB1_fori dritti	
19	6	Assieme_gluing_PA_jig_PB1_FIUP	
20	6	Assieme bloccetto micrometro piccolo	
21	2	boccola piena speciale	
22	2	raccordo festo dritto m3 lavorato	QSM-B-Push-in fitting
23	2	pomello dritto	
24	2	connettore angolo	
Progettato da F.Belli			
Controllato da F.Belli			
Approvato da F.Belli			
Data 22/04/2014			
Istituto Nazionale di Fisica Nucleare-Sezione di Pisa			
Assieme_gluing_jig_back_PB1_UP_generale			
BELLE2			
Edizione			

Spese SVD per i jigs

SVD (jig)				
Avuto	[kE]		[ke] SJ	
2013	30	x assemblaggio		
2014	30	(2a copia)		
	10	shipping boxes	30	shipping boxes
tot.	70		30	diventati 15 a Feb.
Spese				
	14	xyz-theta stages		
	22	Multi Purpose	(20BW+20FW)	
	20	gluing jigs		
Da Fare				
	24	Multi Purpose	(vedi sopra+6 phi-up x u-sald)	
	5	altri jigs		
tot.	85			

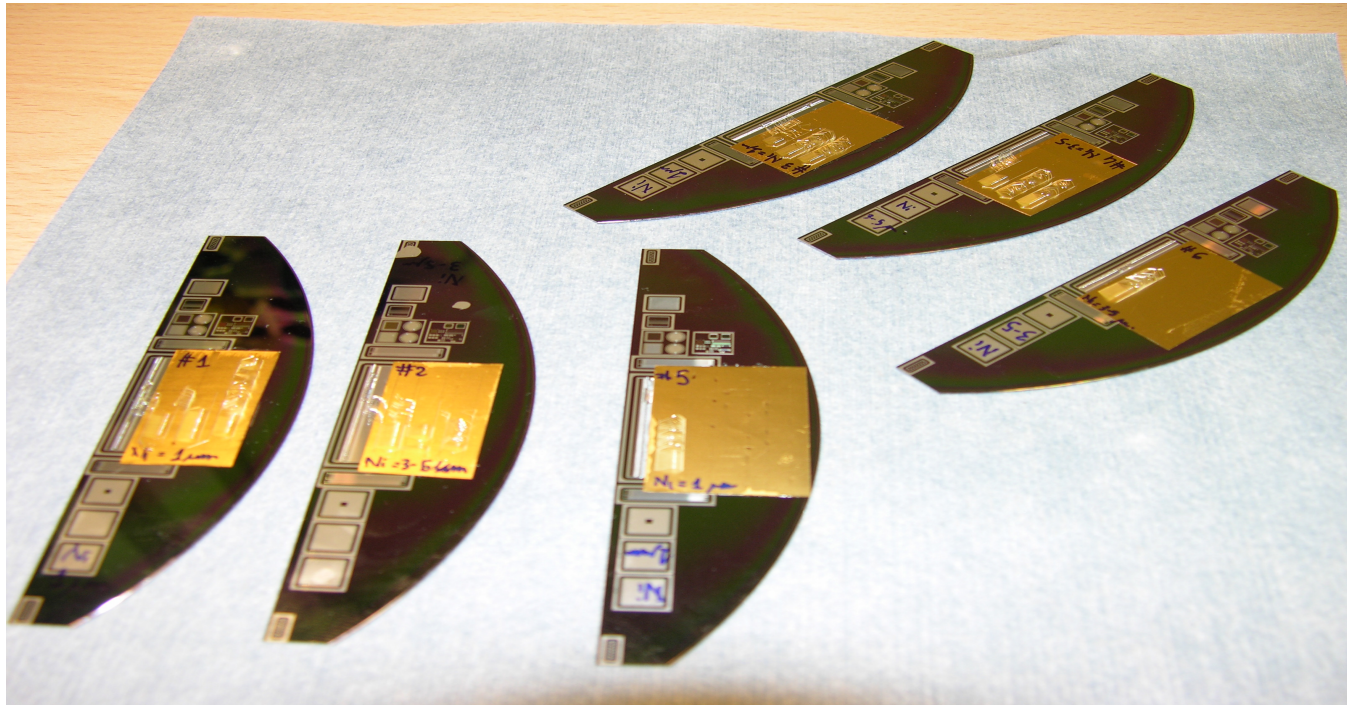
Chiediamo lo sblocco dei 15kE SJ

Bonding tests on PA samples with full metalized surface and different Ni plating

Bonding test on the PA with inside a layer of nickel at 1um and 3-5 um thickness

For the bonding test have been assembled six silicon "half-moon" with PA:

- 3 Half-Moon with glued 1um thickness Ni layer
- 3 Half-Moon with glued 3-5um thickness Ni layer

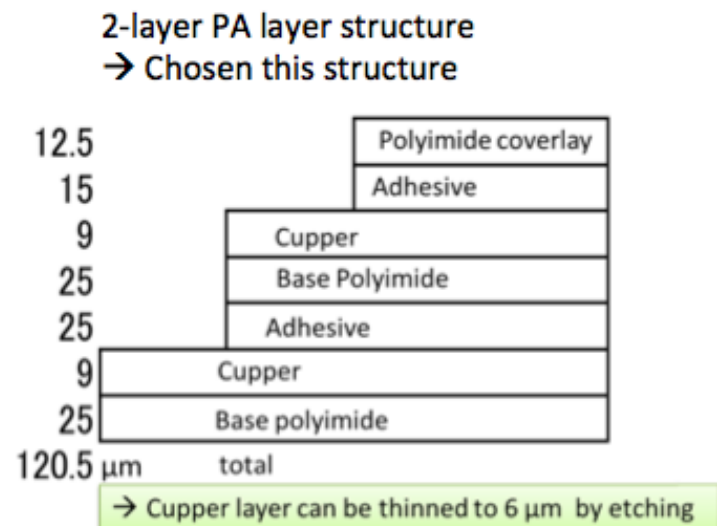


Un problema sui PA: soluzioni

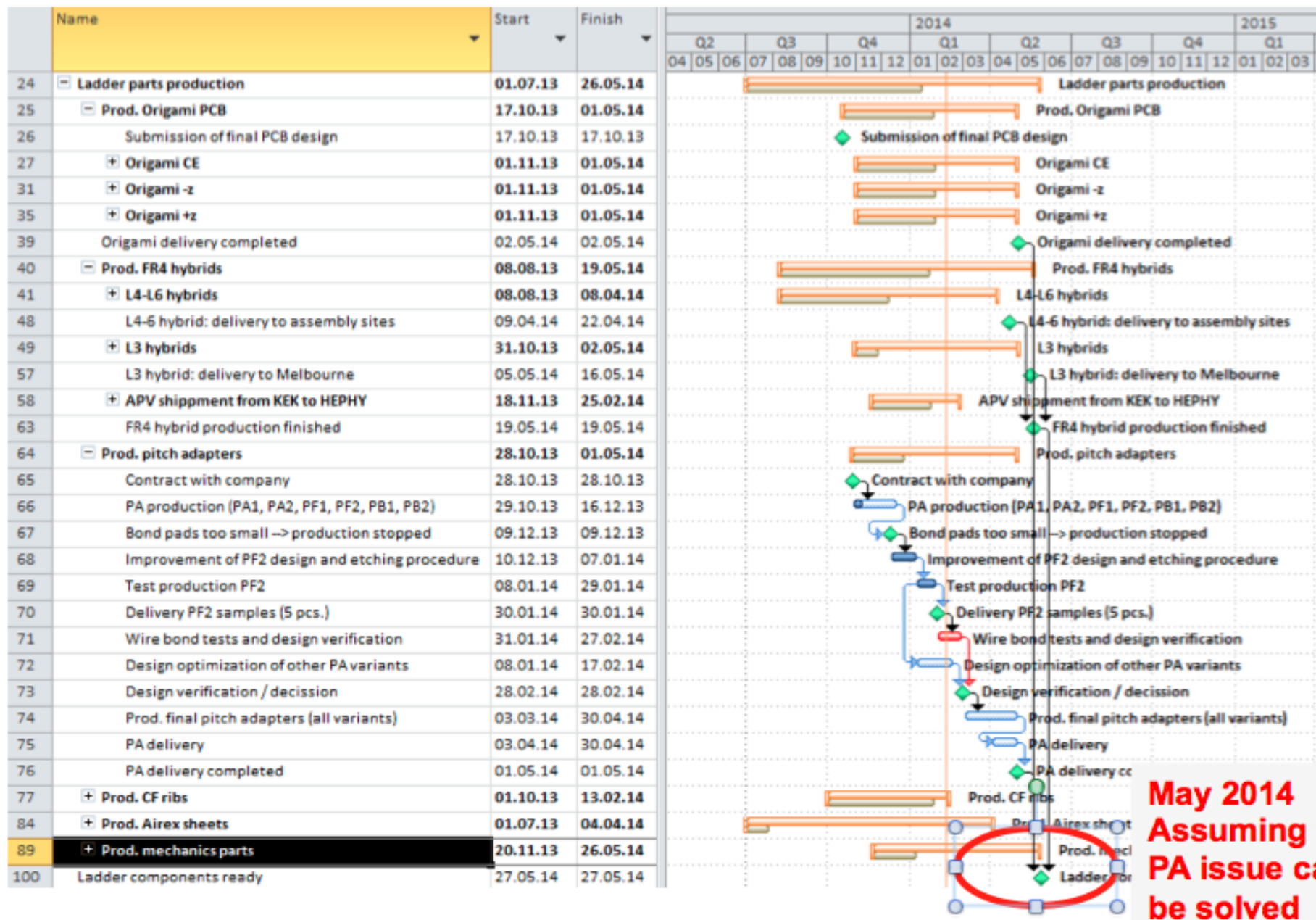
- Da Nov. scorso individuati (Pisa) problemi sulle larghezza (<30 μm) delle pads dei PAs (specialmente zona vs chip: 44 μm pitch).
- Sono state rivisti i requirements, fatte varie serie di prototipi sottoponendoli a test di bonding. Esito negativo: o cattiva bondabilita' oppure bassissimo yield ($\rightarrow$ no good for production!)
- Ad oggi le soluzioni messe in campo sono:
 - presso la stessa compagnia giapponese (Tokay Denshi) e' stato sottoposto un design a sempre 1 layer ma a 3 file di pads (invece di 2) per consentire la giusta larghezza delle pads (almeno 35 μm);
 - presso la compagnia che ha prodotto gli origami Taiyo (i lunghi circuiti stampati) e' stato sottoposto un design a 2 layers.
- Ad oggi i tempi per i PA nelle due soluzioni

Sono comparabili:

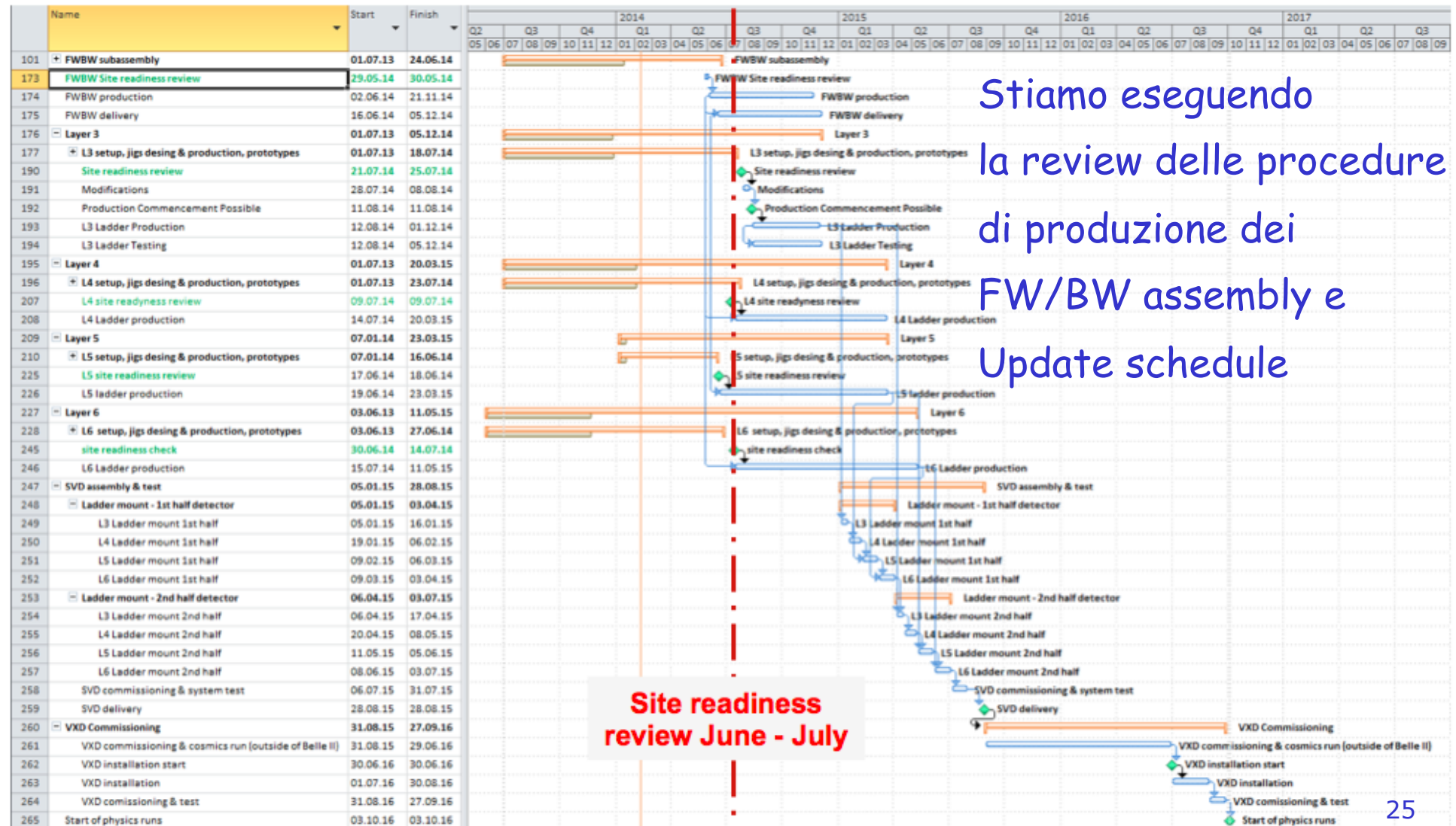
- Un mese per la pre-produzione dei prototipi, caratterizzazione e design di tutti i tipi
- Un altro mese e $\frac{1}{2}$ per la produzione finale
- KEK ci sta investendo risorse importanti.
- Impatto importante sulla schedule ...



Obsolete SVD construction Schedule



The schedule must be revisited: at least a 2 month delay



New Power Supplies Option

- Desire to replace the Kenwood Power Supplies
 - More than 10 years old and out of production and maintenance.
 - Little flexibility in granularity because designed for another system
 - Few HV channels:
 - can become a problem with large and/or non-uniform irradiation.
 - individual sensors going haywire may affect a large group of sensors
- Option to use the CAEN Power system
 - Keep the basic LV structure:
 - 8 boxes * (6 board/box) * (2 LV/board) = 96 LV with 5V/10A channels
 - For the HV voltage:
 - 48 HV Channels 100V/1mA, powering each a group of 4 sensors
 - Need fully floating channels that can be referenced to +HV, -HV or GND.
 - Finer granularity would require significant modifications of other electronic boards.

SVD power system requirements

- Voltage/Current requirements
 - APV chips require 2 positive voltages 1.25V / 60mA and 2.5V / 135mA
 - 2.5W/hybrid in L3 and L456 phi side; 1.65W/hybrid on L456 zed side
 - Sensor HV is below 100V, with single sensor leakage around 1uA initially, up to 100uA when irradiated (sensor area is between 50 and 75 cm²)
 - Low Voltage supplies must be floating so they can be referenced to the sensor HV
- Noise requirements
 - Power supply ripple should not add significantly to base detector noise
- Granularity requirements
 - (mainly coming from budget and cable plant considerations)
 - No requirement to power each hybrid individually
 - No requirement to power each sensor individually

CAEN System

A2518 : 8 Ch 8V/10A
(Power < 50W)

A1510: 12 Ch 100V/1mA



X 3



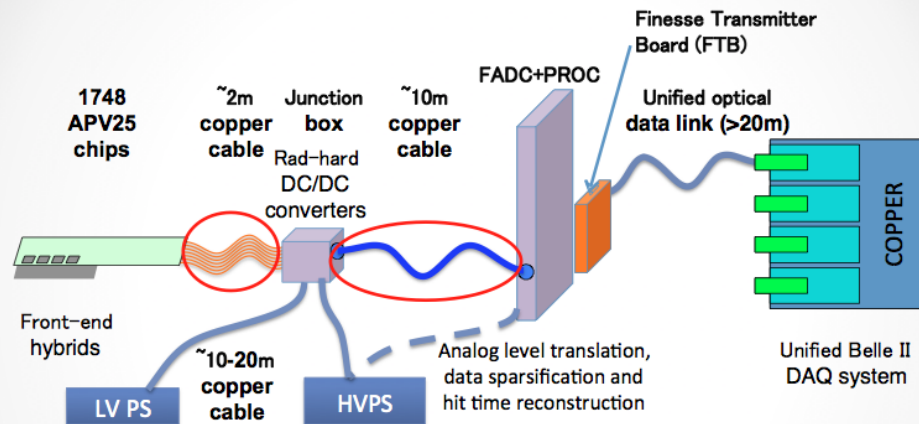
X 16



X 4

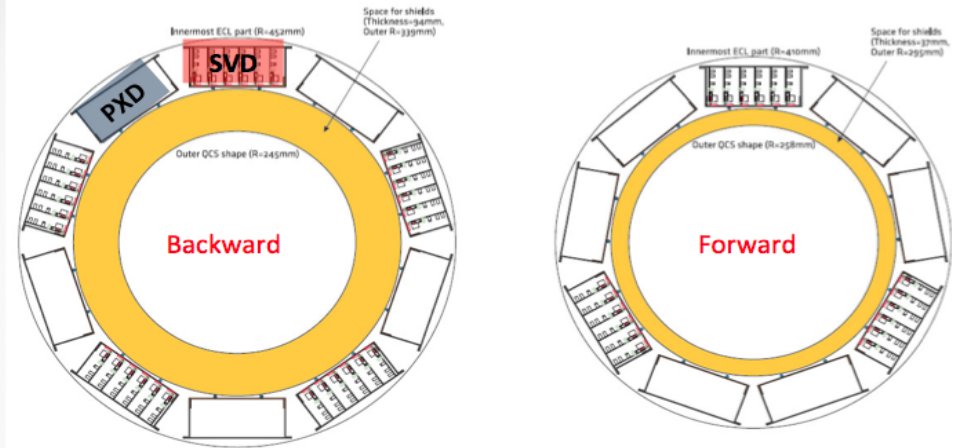
- **A2518**: use 2x A2518 for each dock (12 LV ch needed, 16 ch available)
- **A1510**: use 5x A1510: 3 BWD (30 HV Ch needed, 36 available), 2 FWD (18 HV ch needed, 24 available).
- **SY4527**: need 2 boosters for power requirements. Would like touchscreen.

Readout Chain Overview

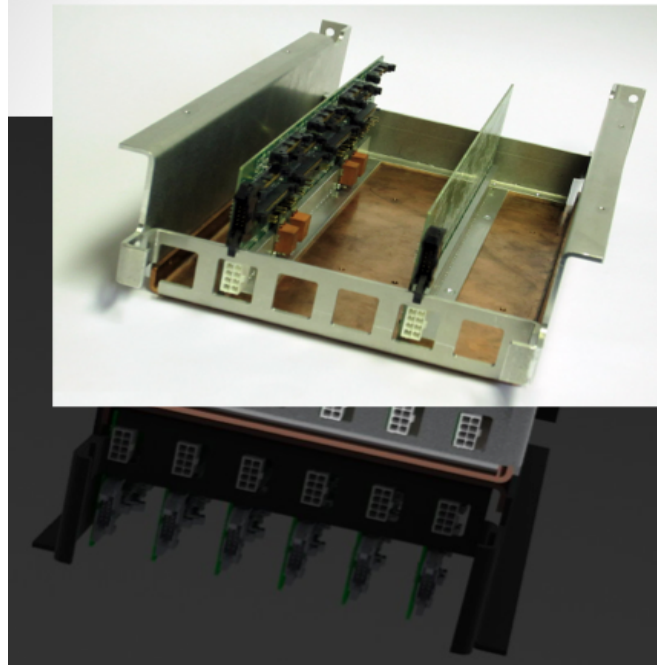


- Each sensor in the system is electrically independent
- LV (and signals) are level-shifted to HV on each side of detector
- Hybrids on the two sides of the detector are electrically independent
 - Connected only through the sensor HV bias

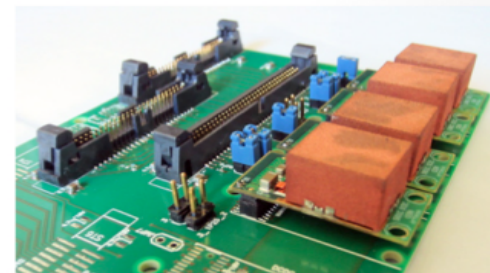
Junction boxes arrangement



Junction Box



- CERN-made DC/DC converters for front-end powering
- Comparative measurement: no noise penalty
- 6 PCB boards/box
- 8 hybrids/board (either p or n type)
- Max 48 hybrid (24 sensors) per junction box
- < 20W in each board
- Each group of 4 hybrids has:
 - 2(main) + 2(spares) DC/DC converters (1.25/2.5V)
 - = 8 DC/DC per board



Plan for procurement

- Cost: 95KE + VAT = $95 \times 1.22 = 115\text{KE}$

Modello	Tipo	V	I	N. Ch	N. Sch.	Prezzo Unit.	Prezzo Totale
A2518	LV	8V	10A	96	18	€ 1.950,00	€ 35.100,00
A1510	HV	100V	10 mA	48	5	€ 4.800,00	€ 24.000,00
SY4527 Basic					3	€ 5.700,00	€ 17.100,00
A4533 Booster					6	€ 1.450,00	€ 8.700,00
A4534 Touch.					3	€ 1.600,00	€ 4.800,00
						Totale	€ 89.700,00

+ 1 spare A1510 (4800kE)

- Including 2 spare A2518 and 1 spare A1510.
- Timing:
 - June 2014: start tender process
 - September 2014: assign contract
 - Around March 2015: delivery directly to KEK so to avoid VAT.
 - Need to understand how much tax we need to pay in Japan.
 - Need to understand how much the shipment costs
 - In time for SVD final commissioning.

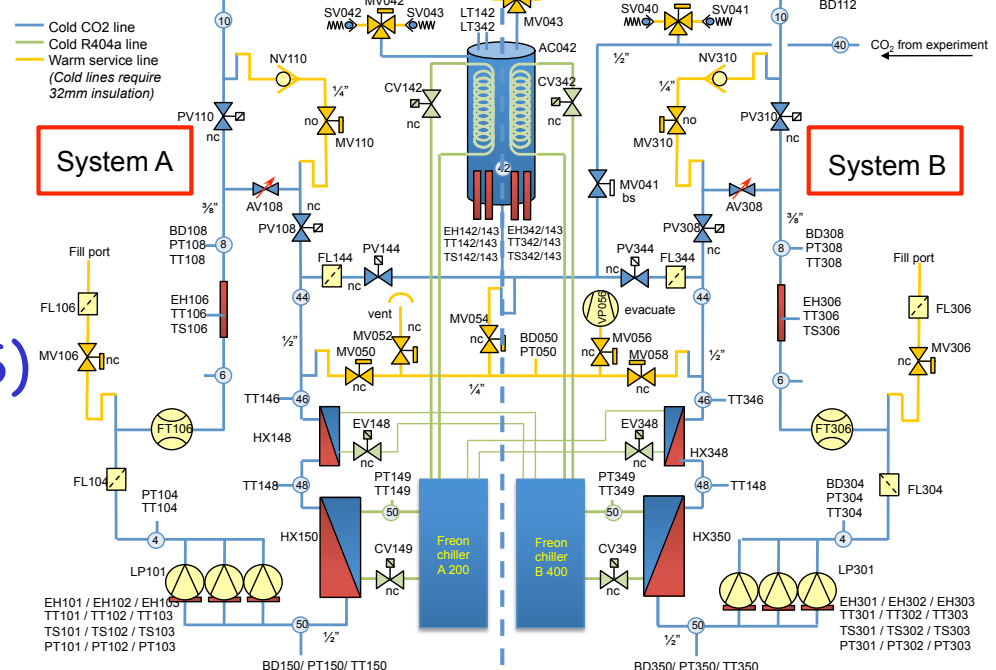
Funding for VXD CO₂ Cooling

- Total dissipated power of SVD
 - 1748 APV25 chips
 - ~ 0.4W / chip
 - ~ 700W in total
- Cooling of APV25 chips required
- Common CO₂ system with PXD
 - Operated at -20°C
 - IBelle developed by CERN & Nikhef (ATLAS)
 - MPI Munich builds an exact copy for VXD
 - Complex system

MARCO used @ DESY



IBelle



Costs and Funding

- Original plan was that the whole cost would be covered by MPI
- Significantly more expensive than planned (about factor 2).
- Additional budget mostly secured, but about 50K requested from SVD groups.
- We are going around the SVD institutions to divide the load

Additional costs:

MPI:	180
BMBF:	185
DESY:	50
Prague:	10
HLL:	5
SVD:	
50	

Sum. 480

=====

Contributo INFN

- Il sistema e' necessario al funzionamento di SVD.
- Spiacevole coprire gli extra costi di altre istituzioni ma:
 - Il sistema e' sviluppato per Atlas, e non ci sono le forze per svilupparne uno in casa
 - E' stato comunque fatto uno sforzo enorme per reperire i fondi in PXD dai contributori originali
- Proposta:
 - Usare i 10KE assegnati per schermo termico a Pisa (attivita' di fatto non iniziata per mancanza di forze)
 - Usare altri 5-10 KE della tasca, se possibile.

Schermo termico e meccanica generale: attività non svolta (10 kE finanziati su apparati)

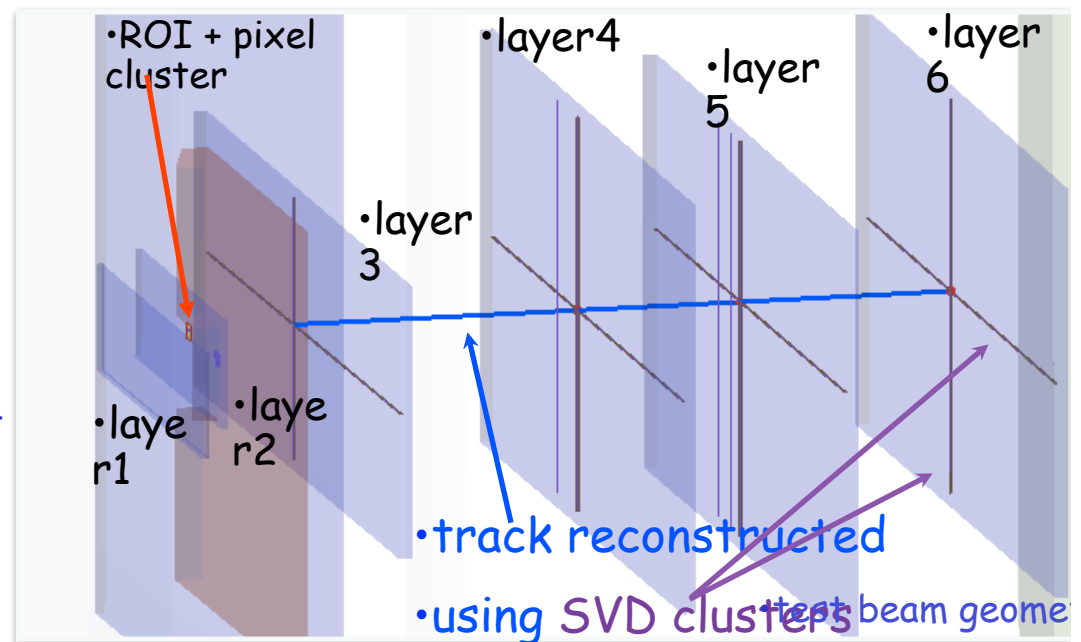
- Il design dei tools necessari per la costruzione degli assembly ha saturato le risorse di progettazione
- Il cooling a CO_2 e' in comune tra PXD ed SVD: evidenziata la necessita' di una mock-up realistico su cui confrontare le simulazioni. E' stato realizzato a DESY, dove vengono condotti i test sperimentali sui prototipi. Manpower individuato all'interno dei gruppi tedeschi di PXD.

Regions Of Interest Finding

➔ The online software for the Region Of Interest (ROI) finding runs on the HLT

➔ ROI finding algorithm:

- pattern recognition using SVD data only
- track fit and extrapolation on the PXD layers
- definition of the a rectangular ROI, widths takes into account the statistical error of the extrapolation

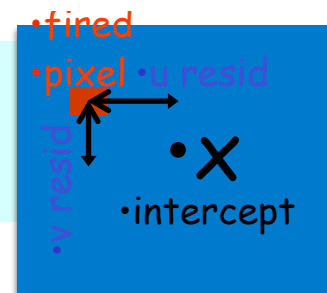


➔ estimated efficiency on the test-beam geometry is $(97.5 \pm 0.7)\%$

- inefficiencies due to failed track fit (true also with Belle II geometry, generic events)

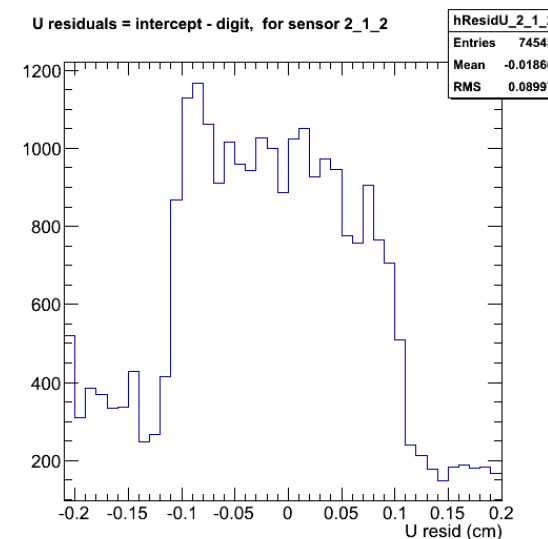
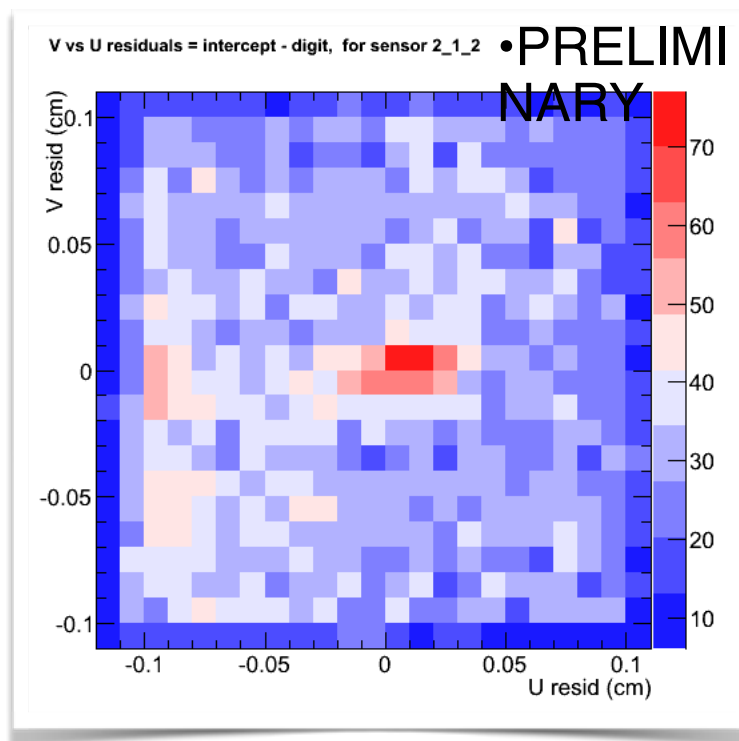
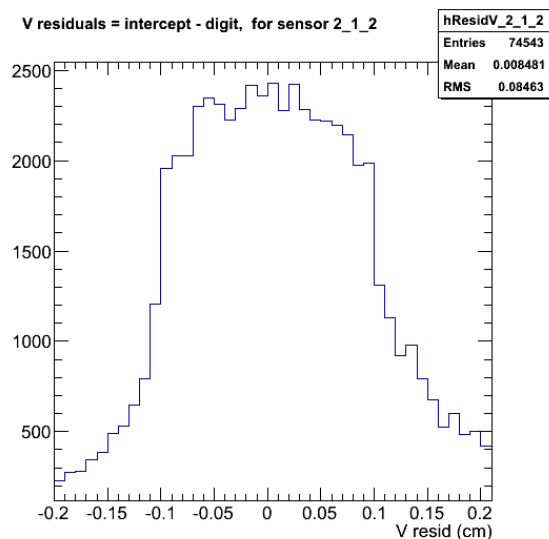
➔ The overall efficiency will depend also on the SVD pattern recognition efficiency

ROIs at work in the Test Beam



- DESY test beam proved the functioning of the software-based ROI finding
- a clear peak of signal pixels is shown in the residuals plots:

•ROI



Belle2 Trieste

Activities and plans for 2014

- Test on DSSD sensors:
 - Micron wedges
 - Hamamatsu L3 sensors
- Radiation monitoring and beam abort:
 - Requirements and conceptual design
 - Tests on diamond sensors
 - Noise measurements, cabling, initial electronics design
- Temperature & humidity monitoring and interlocks:
 - Requirements and conceptual design
 - New item: Fiber Bragg Grating (FBG) sensors and read-out
 - Other T&H sensors, interlocks
- Schedule, BEAST activities, update on spending profile

Test on Micron sensors

Bottleneck for the production was testing at Micron
Trieste/Vienna decided to take over these tests

- 3 pre-series and 11 final tested
- 14 are under test now

Overall quality good

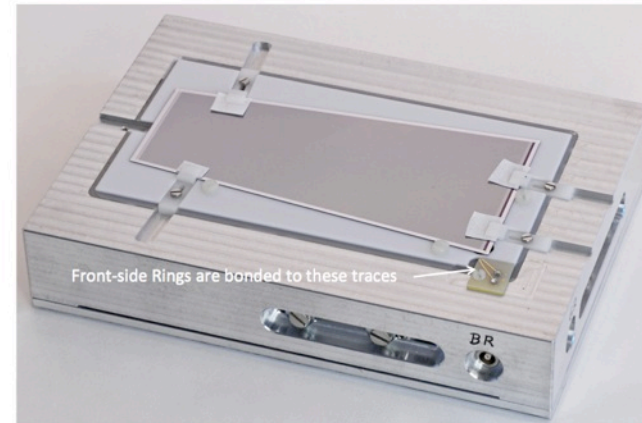
Summary of Test Results: Parameter Values

Sensor ID Date test started	Side	I _{BR} at 100V (uA)	I _{GR} at 100V (nA)	N-side Insulation Voltage (V)	Strip Scan Voltage (V)	max I _{total} at V _{scan} (uA)	Average I _{strip} (nA)	Average R _{strip} (Mohm)	Average C _{AC} (pF)	Sensor Location
BL3048-01 08/11/13	P	14.80	181	20-22	100	16.10	3.1	22.3	210	Vienna
	N				30	7.49	4.7	11.7	137	
BL3048-24 12/11/13	P	7.05	273	22-24	100	7.03	3.4	15.7	213	Trieste
	N				30	5.78	5.4	11.5	134	
BL3066-11 15/11/13	P	3.05	157	36-38	100	3.47	1.7	18.1	202	Trieste
	N				100	3.33	3.0	11.7	140	
BL3066-12 18/11/13	P	2.73	102	36-40	100	3.44	1.4	28.5	213	Trieste
	N				100	3.32	3.0	11.3	136	
BL3067-10 19/11/13	P	2.99	106	38-40	100	3.23	1.5	29.6	208	Trieste
	N				100	3.56	3.2	11.3	136	
BL3067-20 20/11/13	P	2.94	86	30-32	100	3.08	1.7	17.6	203	Trieste
	N				100	3.06	2.8	11.5	136	
BL3067-23 21/11/13	P	2.85	60	38-40	100	3.09	1.7	25.0	208	Trieste
	N				100	3.05	2.6	11.4	133	
BL3048-12 16/12/13	P	7.45	234	22	100	7.91	3.4	18.6	216	Trieste
	N				100	7.91	7.3	10.6	132	
BL3048-23 19/12/13	P	6.49	185	22-24	100	6.77	3.5	32.9	206	Trieste
	N				100	6.76	6.3	11.8	135	
BL3066-19 20/12/13	P	2.79	53	36-40	100	3.98	1.35	27.4	208	Trieste
	N				100	3.57	3.06	10.3	140	
BL3067-08 03/01/14	P	3.99	85	32-34	100	3.49	1.14	35.4	202	Trieste
	N				40	1.95	1.67	10.2	136	

Summary of Test Results: Defect Statistics

Sensor ID Date test started	Side	I _{DC} >20nA	Implant Short	Implant or Poly open	Nr. of DC Defective Strips	DC Defect %	Broken AC Capacitor	Metal Short	Metal Open	Nr. of AC Defective Strips	AC Defect %	Total Defective Strips	Total Defect %
BL3048-01 08/11/13	P	7	0	0	7	0.5%	0	0	0	0	0.0%	7	0.5%
	N	3	0	0	3	0.3%	0	0	0	0	0.0%	3	0.3%
BL3048-24 12/11/13	P	1	0	1	2	0.1%	1	2	0	3	0.4%	5	0.3%
	N	0	0	0	0	0.0%	0	0	0	0	0.0%	0	0.0%
BL3066-11 15/11/13	P	3	2	0	5	0.3%	3	0	0	3	0.4%	8	0.5%
	N	0	0	0	0	0.0%	1	0	0	1	0.2%	0	0.0%
BL3066-12 18/11/13	P	3	0	3	6	0.4%	2	0	0	2	0.3%	8	0.5%
	N	0	0	0	0	0.0%	0	0	0	0	0.0%	0	0.0%
BL3067-10 19/11/13	P	3	2	0	5	0.3%	3	2	0	5	0.7%	10	0.7%
	N	0	0	0	0	0.0%	1	0	0	1	0.2%	1	0.1%
BL3067-20 20/11/13	P	1	0	1	2	0.1%	1	0	0	1	0.1%	3	0.2%
	N	0	0	0	0	0.0%	0	0	0	0	0.0%	0	0.0%
BL3067-23 21/11/13	P	2	0	3	5	0.3%	3	4	0	7	0.9%	12	0.8%
	N	3	0	0	3	0.3%	0	0	0	0	0.0%	3	0.3%
BL3048-12 16/12/13	P	3	4	0	7	0.5%	0	2	0	2	0.3%	9	0.6%
	N	0	0	0	0	0.0%	0	0	0	0	0.0%	0	0.0%
BL3048-23 19/12/13	P	5	0	4	9	0.6%	3	0	0	3	0.4%	12	0.8%
	N	0	0	0	0	0.0%	0	0	0	0	0.0%	0	0.0%
BL3066-19 20/12/13	P	4	0	1	5	0.3%	2	0	0	2	0.3%	7	0.5%
	N	0	0	0	0	0.0%	1	0	0	1	0.2%	1	0.1%
BL3067-08 03/01/14	P	5	0	0	5	0.3%	6	0	0	6	0.8%	9	0.6%
	N	1	0	0	1	0.1%	0	0	0	0	0.0%	1	0.1%

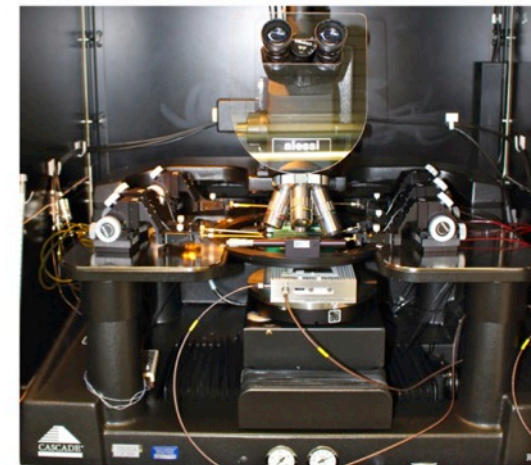
Sensor testing Jig (top)



Sth Belle II PXD/SVD Workshop 23-01-2014 -- L. Bosio - Test of Micron Trapezoidal Sensors

3

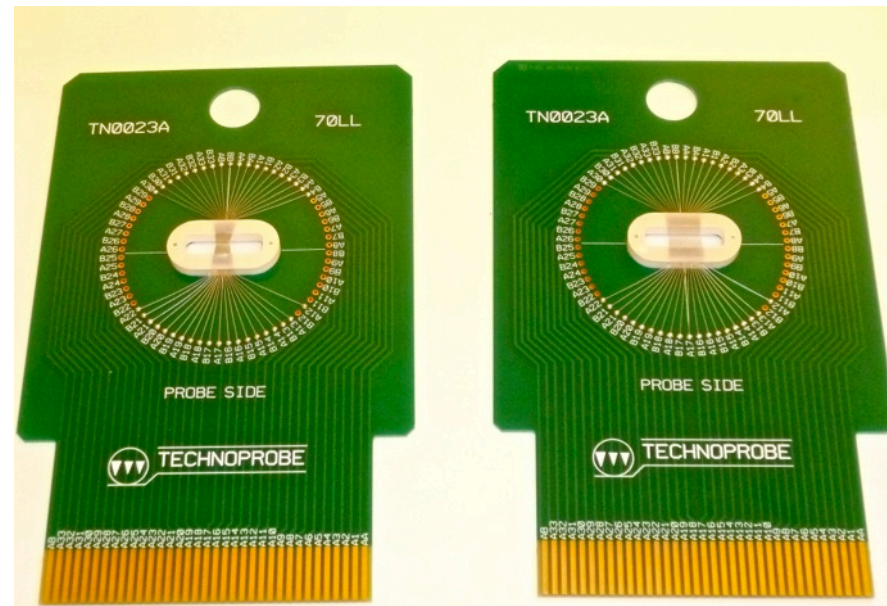
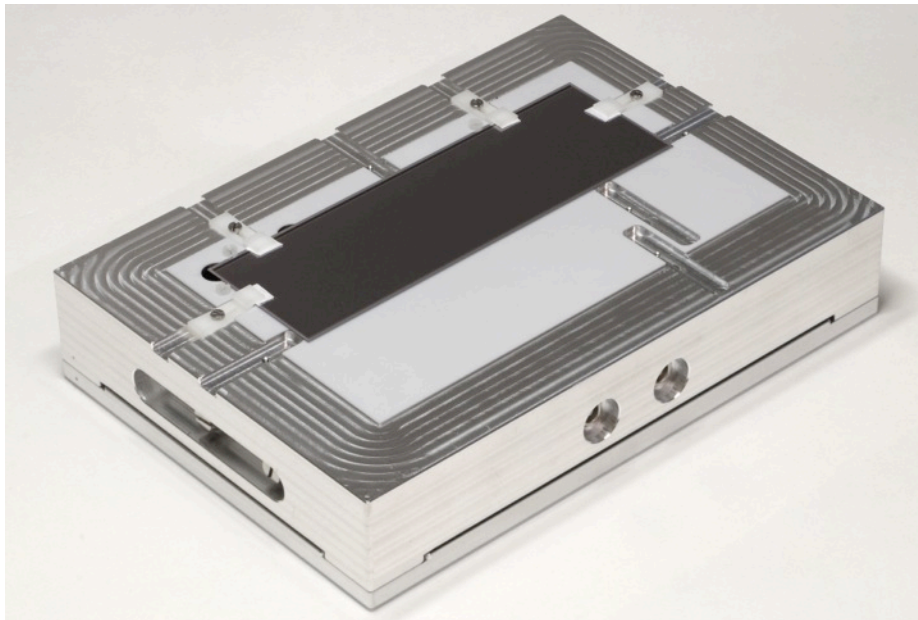
Sensor testing set-up



- Front and Back-side Rings are connected through cables
- Strips are contacted by a 40-needle Probe Card

Test on Hamamatsu sensors

- Detailed tests performed on 2 sensors (more carefully than HPK, eg they didn't test n-side)
- Some problem showed up (low inter-strip resistance)
- Detailed evaluation of the HPK test procedure by LB
- HPK acknowledged our results



Summary of Test Results

(Updated to February 28th)

Parameter Values

Sensor ID – Date test started	Side	N-side Insulation Voltage (V)	Strip Scan Voltage (V)	max I _{total} at V _{scan} (uA)	Average I _{strip} (nA)	Average R _{strip} (MΩ)	Average C _{AC} (pF)	Implanted strip R (kΩ)	Metal strip R (Ω)	Interstrip C (pF)
HPK_L3-15	P		150	6.14	1.1	11.3	222	1.07E+03	117	16
28/01/14	N	58 - 62	100	2.48	0.7	10.5	116	42	18	
HPK_L3-16	P		150	0.83	0.49	11.1	221			
30/01/14	N	60 - 62	100	0.90	0.48	11.4	119			

Defect Statistics

Sensor ID – Date test started	Side	I _{DC} >20nA	Bad Strip Insulation	Implant or Poly open	Nr. of DC Defective Strips	DC Defect %	Broken AC Capacitor	Metal Short	Metal Open	Nr. of AC Defective Strips	AC Defect %	Total Defective Strips	Total Defect %
HPK_L3-15	P	6	5	0	11	1.4%	0	5	0	5	0.7%	16	2.1%
28/01/14	N	6	0	1	7	0.9%	3	0	0	3	0.4%	10	1.3%
	Both				18	1.2%				8	0.5%	26	1.7%
HPK_L3-16	P	0	9	6	14	1.8%	0	0	0	0	0.0%	14	1.8%
30/01/14	N	0	0	0	0	0.0%	0	0	0	0	0.0%	0	0.0%
	Both				14	0.9%				0	0.0%	14	0.9%

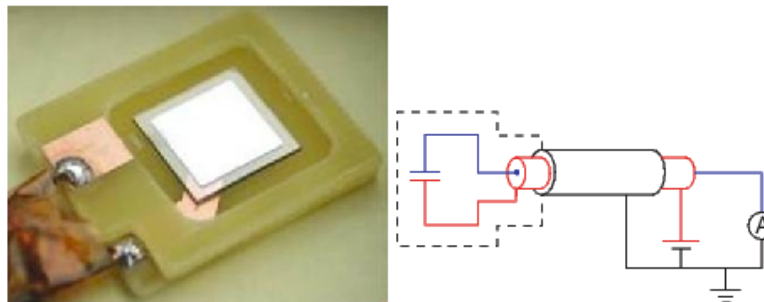
Radiation Monitoring and Beam Abort

- Requirements

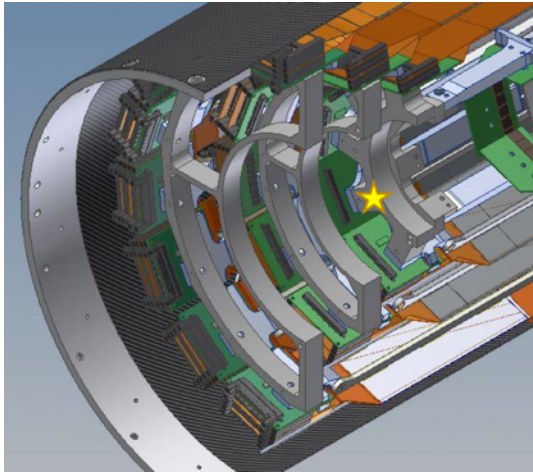
- Measurement of instantaneous dose rates & integrated doses
 - sensitivity $O(1 \text{ mrad/s} = 10 \text{ } \mu\text{Gy/s})$, sampling rate $O(100 \text{ KHz})$
- Beam Abort for excessive beam losses affecting PXD, SVD
 - “Fast” (10-100 μs) “slow” (ms), “very slow” ($> 1\text{s}$) Beam Abort triggers
 - Programmable “intelligent” thresholds, depending on accelerator conditions

- Conceptual design

- Based on experience from Belle, BaBar, CDF...
- Diamond sensors, measurement of currents
 - Typical pCVD sensor ($10 \times 10 \times 0.5$) mm^3 : $1 \text{ nA} = 7 \text{ mrad/s} = 70 \text{ } \mu\text{Gy/s}$
 - Noise should be limited to a few pA, in current measurements
- up to 4 + 4 sensors near PXD
- up to 8 + 8 sensors near SVD

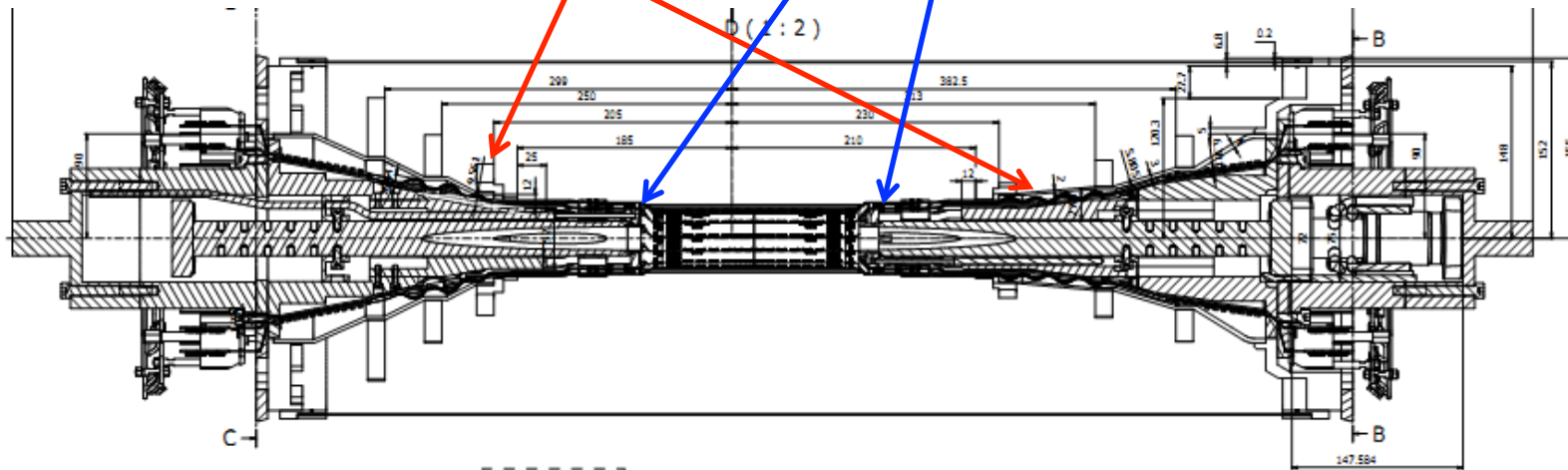
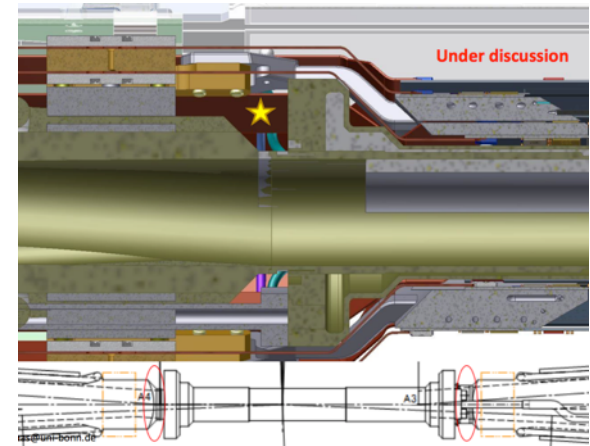


Conceptual Design

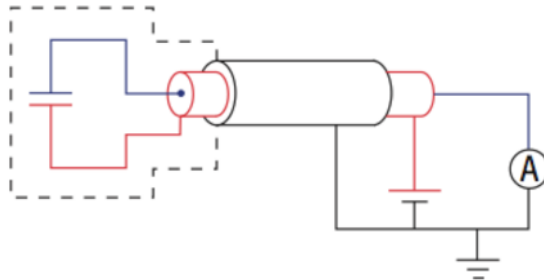


4 + 4 sensors
PXD-beam pipe

8 + 8 sensors
on SVD L3
support rings



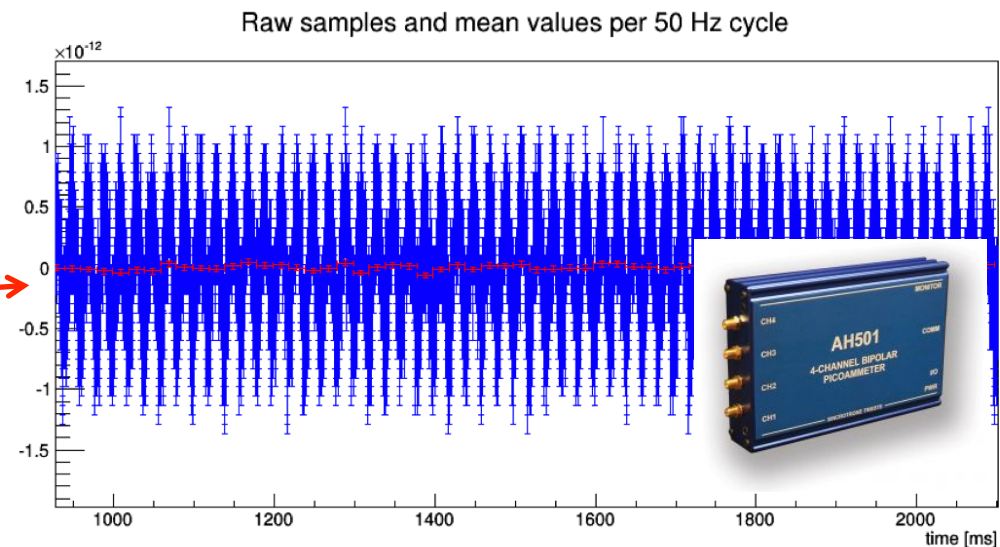
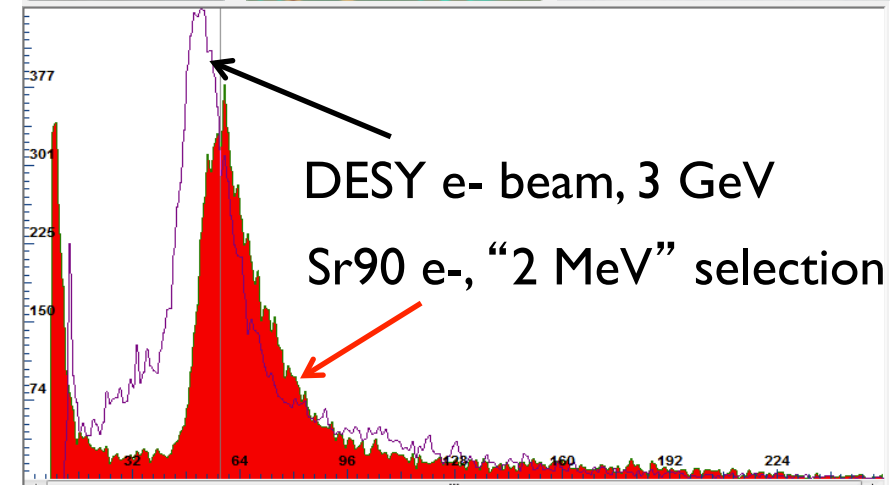
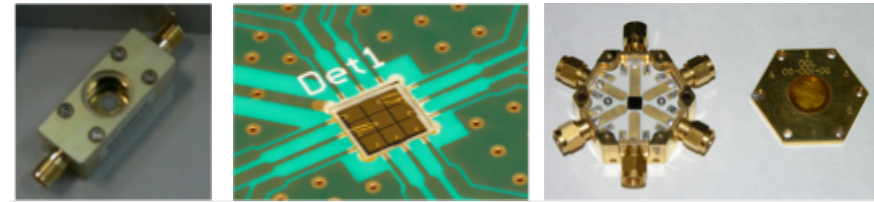
Shielded
diamond
sensors



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

Measurements

- 9 p/scCVD sensors
 - different types, vendors
 - charge collection efficiency with single particles
 - Beta source + beam test: MIPs
- Currents measurements for dosimetry and beam abort
 - collaboration with Elettra, Electronics Division
 - AH501 fast picoammeter
 - Noise measurements and optimization, different cables and grounding (a few pA level now)
 - Digital filtering studies
 - Agreement with Elettra: customization to increase sampling frequency, include Beam Abort and HV supply



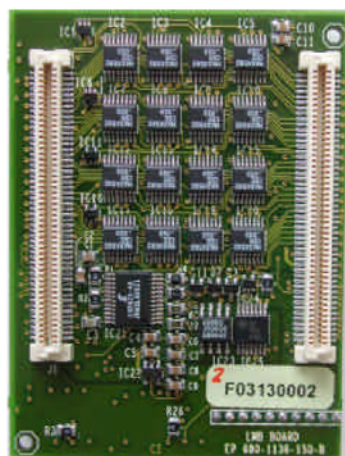
Temperature and humidity

- System characteristics
 - PXD+SVD Front End power dissipation: 360+700 W
 - CO₂ cooling pipes (-20°C); dry air / nitrogen flow (20°C)
- Requirements
 - Temperature monitoring:
 - near heat sources and at the inlets/outlets of cooling pipes
 - about 1°C (0.1°C) absolute (relative) accuracy
 - Interlocks on temperature and humidity (stand-alone, VXD)
 - Temperature above threshold, or dew point approaching -30°C
- Current activities and preliminary design
 - Conventional NTC thermistors for cross-calibration and *interlocks*
 - Fiber Optical Sensors (FOS) and laser interrogators
 - Based on Bragg grating reflection of specific wavelengths
 - Can monitor stress, temperature, humidity (with humidity-sensitive coating) at several points
 - Humidity *interlock*: “sniffers” plus chilled mirror hygrometer outside

New

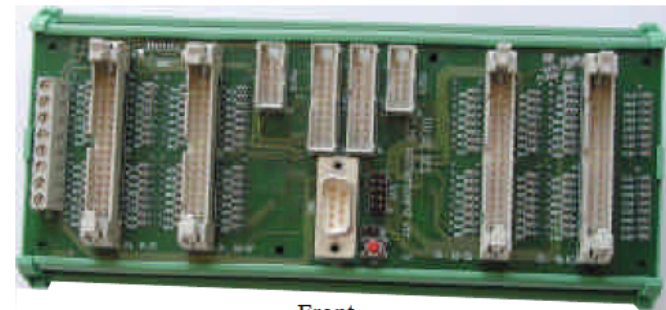
NTC temperature sensors

- At least $28 \times 2 = 56$ NTC thermistors
 - 12 sensor pairs attached to the 12 half-rings supporting the SVD ladders
 - 16 sensor pairs on the inlets and outlets of the CO₂ cooling pipes
 - A few positioned near fibers for cross-calibration
- Adopt rad-hard proven sensors and readout
 - Borrowed from CMS experts: ELMB board and Betatherm NTC thermistors
 - Under construction: 2 motherboards and 10 adapter mini-cards
 - Procurement of more Betatherm thermistors
 - Read-out via CANbus interface

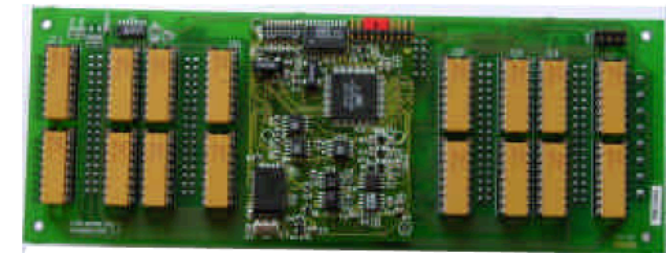


67 mm

50 mm

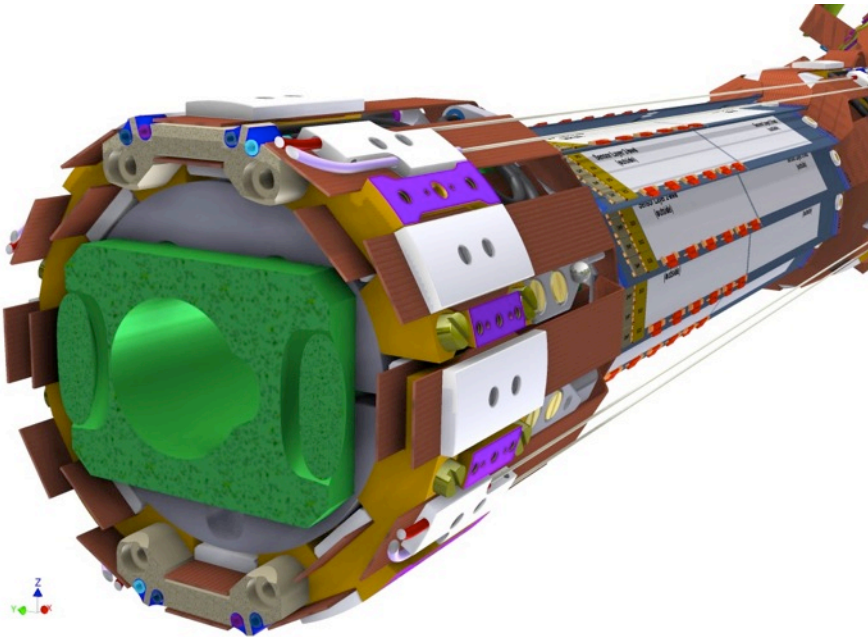


Front



Back

Reminder: FOS Monitor proposal



PXD FOS R&D completed,
successfully tested at the DESY
beam test

Recent SVD proposal: 1 fiber per
ladder, inserted in the Airex foam,
to measure silicon temperature

	Nº of sensors per fiber	Nº of fibers
layer 4	2 FBG sensors	10
layer 5	3 FBG sensor	12
layer 6	4 FBG sensors	16

One FBG temperature sensor for each of the SVD strip
sensors in layers 4,5,6; 38 fibers and 120 sensors are needed.

Initial plan for humidity

- Humidity *interlock*: “sniffing pipes” plus Chilled Mirror Hygrometer outside the detector
 - See CMS developments for their tracker upgrade: 3-fold approach
 - “sacrificial” expendable radiation-soft sensors for initial calibrations
 - Combination of FOS fibers measuring temperature and humidity
 - 26 sniffer lines and Vaisala hygrometers in accessible positions
 - To start: lab tests using an hygrometer purchased with committed dot.1 funds
 - Mechanics, pipes, valves, etc: to be understood !
- Some FOS fibers sharing the same interrogator with temperature FOS fibers

BEAST phase 1 & 2

BEAST: Beam Exorcisms for A Stable Experiment
(*a.k.a. Commissioning Detector*)

- **Jan-May 2015 Phase 1** (no QCS
no solenoid no Belle detector)
 - First diamond prototypes (to be installed already in Nov 2014!!!)
- **Jan-Apr 2016 Phase 2** (QCS, solenoid,
most of Belle, No PXD)
 - Tests of final prototypes (reduced system)

Timeline

Radiation What	2014				2015				2016	
	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 What	2014				2015				2016	
	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										

Trieste Spending profile update

no additional requests for 2014

Item	2013	2014	2015	2016	TOT
Initial CORE	5	75	70	0	150
DSSD tests	2.5	0	0	0	2.5
Rad.Mon.+Abort (diamonds, cables, etc)	2	7	96	10	115
Rad.Mon.+Abort (electronics)	0	4	4	19	27
Temperature Mon. (FOS fibers, offers)	0	17.5	1	30	48.5
Temperature Mon. (NTC thermistors)	0	3	2	4	9
Humidity Mon. (very preliminary)	0	0	10	0	10
TOTAL	4,5	31.5	113	63	212

Notes (details available on separate spreadsheet):

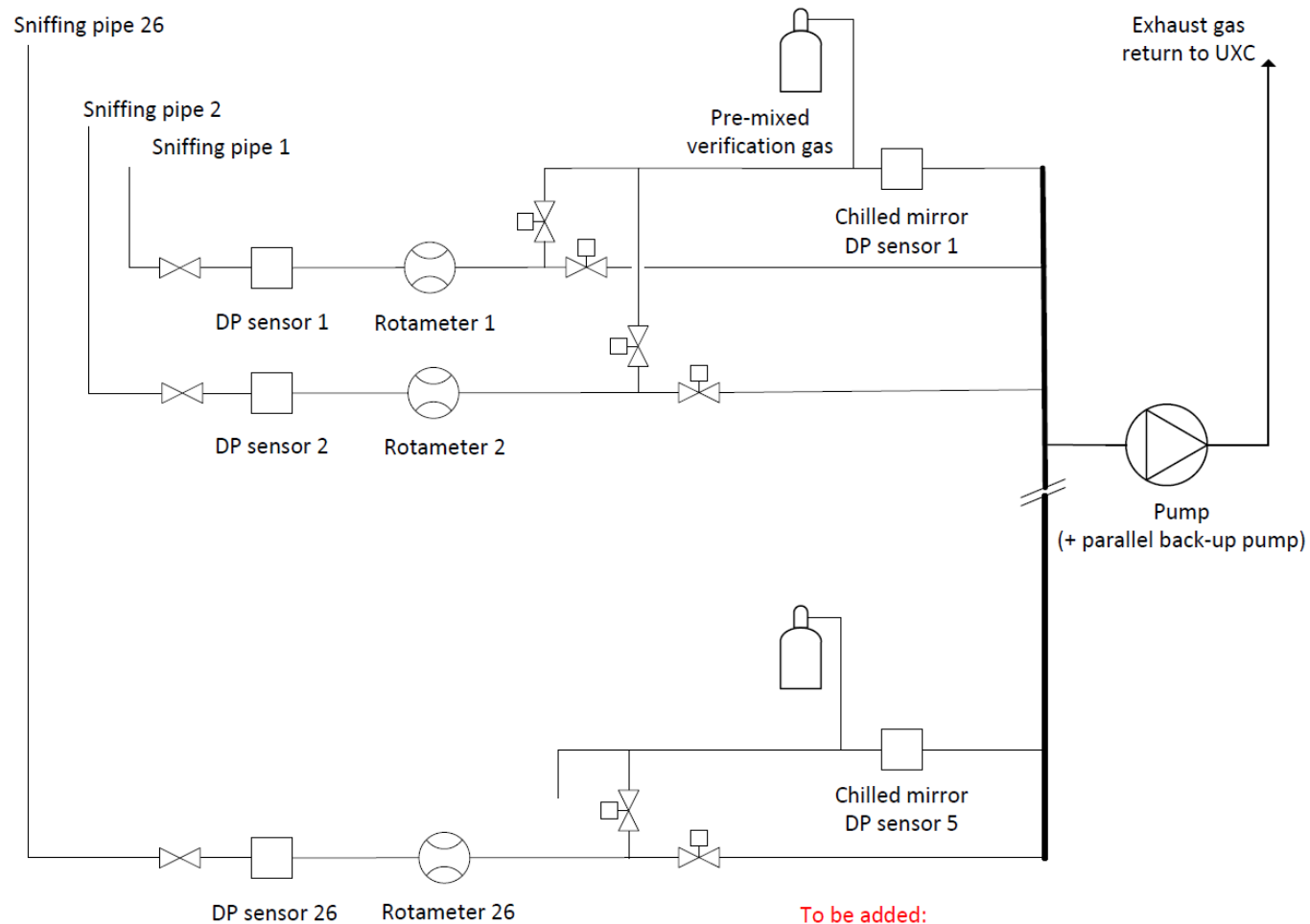
- 1) not included: some prototypes and inv. on other funds (univ., dot.I)
- 2) 24 diamonds
- 3) TOT.: 212 (update) – 150 (prev.) = 62 keuro, mostly due to FOS (48.5)

Info per l'update del piano complessivo

- Monitoring: ~48.5 kE per l'acquisto del sistema FOS. Rispetto al piano iniziale (150kE) sono stati valutati 62 kE extra costo.
- Per quanto riguarda la costruzione degli assembly:
 - da prevedere costi di spedizione e consumi lab. anche per il 2015
- Finalized Power Supply: 115 kE
- Cooling IBELLE: addebitato a SVD un 10% dell'extra costo. Proposta: utilizzo dei 10 kE già finanziati su costruzione apparati (+5/10 kE?)
- Non sono emersi elementi nuovi tali da dover/potere aggiornare le missioni.

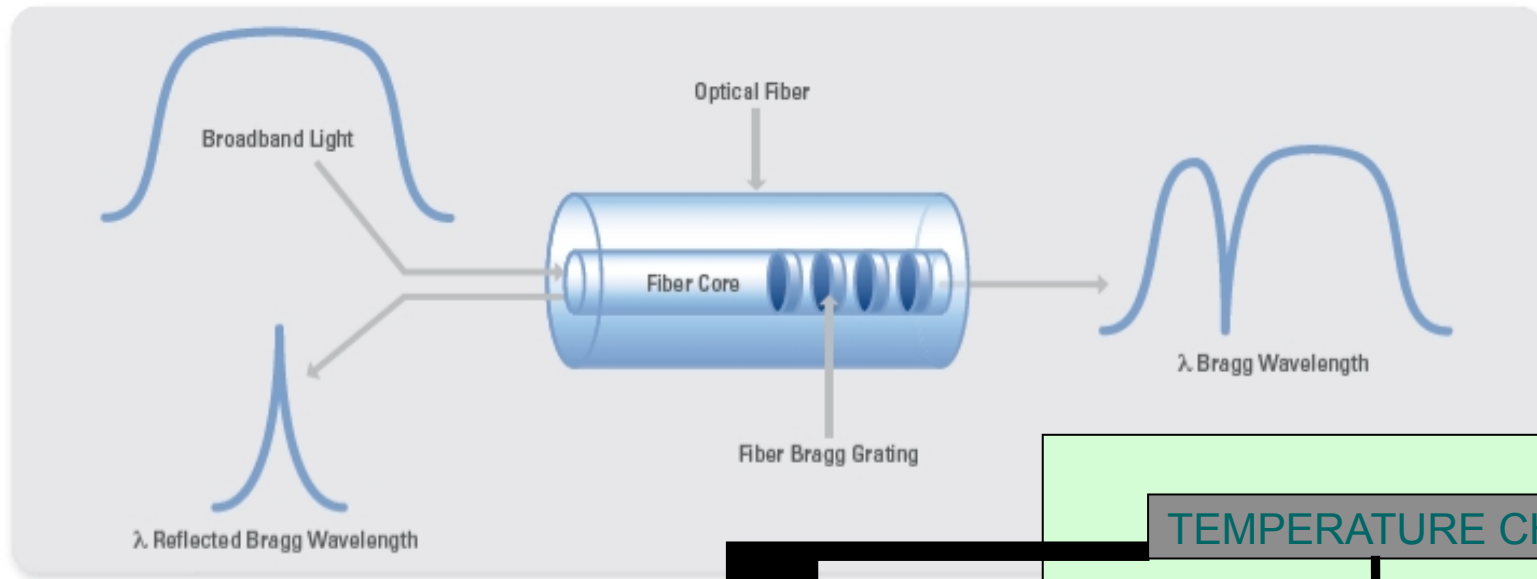
BACKUP SLIDES

Humidity: CMS “sniffer” approach



To be added:
Pressure sensors (at least in the manifold)
Rotameters for Chilled mirrors?
Buffer volume in front of the pump?

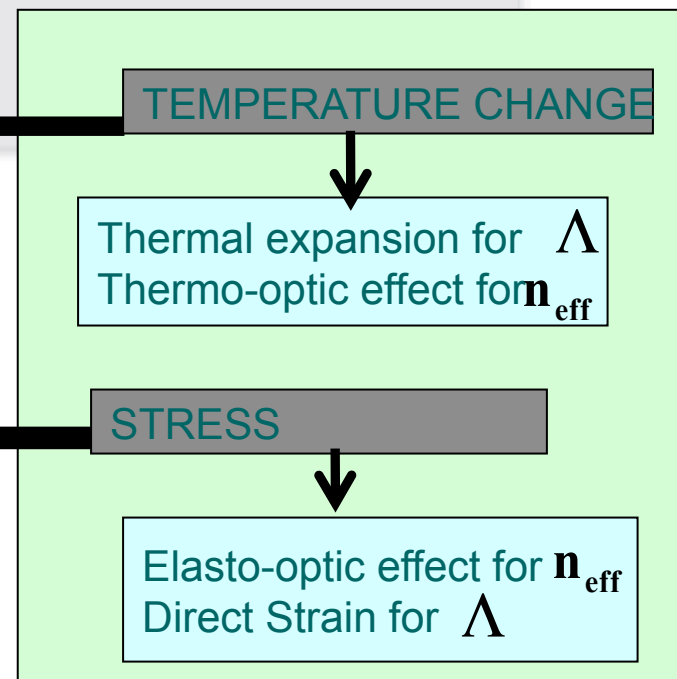
FOS Technique



$$\lambda_B = 2 \cdot n_{eff} \cdot \Lambda$$

Where:

n_{eff} is the effective refractive index of the fiber,
 Λ is the grating pitch and
 λ_B is the reflected Bragg wavelength.



Radiation monitoring and beam abort (backup information)

- Enquiry for suppliers sensors/metallization (list)
- Cabling tests and prototypes (list)
- Noise characterization and filtering
- Electronics sketch

List of Diamond sensors characterized in Trieste

Label	Provider	sc/p CVD	Geometry mm ³	pads	Validation
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

Cabling tests for currents measurements:

Measure the noise in different configurations with AH501

- Optimize:
 - grounding scheme
 - cables layout
- Compare coaxial and tri-axial cables
- Noise characterization and filtering
 - Noise dominated by 50Hz and mult.
 - Good quality cables better
 - A few pA level now
 - Digital filtering studies can further reduce

