Belle2 - SVD

S. Bettarini
Riunione con i Referee di Belle-II - Pisa, 5 settembre 2013

- Introduzione
- Pisa:
  - BW/FW sensor assembly
  - Dettagli sulla meccanica(*):
    - shipping boxes
    - xyz-θ stage modification
    - Whole mech. design
  - Power Supply(*)
  - Tracking SW: ROI
- Richieste e manpower

- Trieste:
  - Test sensori
  - Radiation monitor(*)
  - T/humy monitor
    ILK system(*)

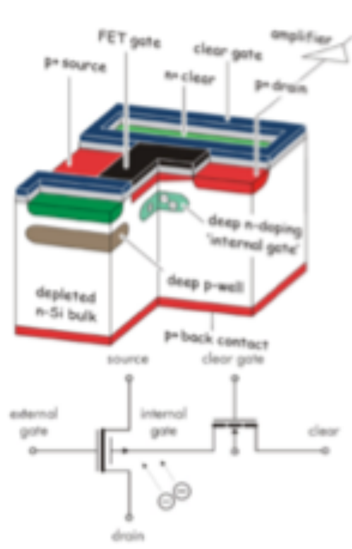
(*) esplicitamente richiesto maggior dettaglio rispetto alla presentazione dei preventivi

Vertex Detector

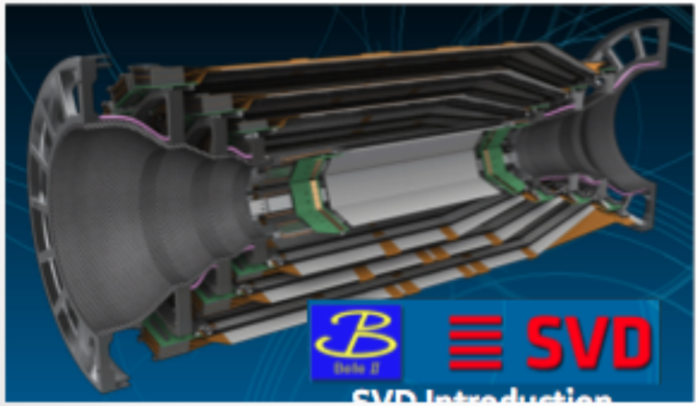
- **Pixel Detector (PXD)** – 8M pixels
  - 2 DEPFET layers at r = 14, 22 mm
  - Excellent and unambiguous spatial resolution (~15 μm)
  - Coarse time resolution (20 μs)

Mechanical mockup of pixel detector

DEpleted P-channel FET

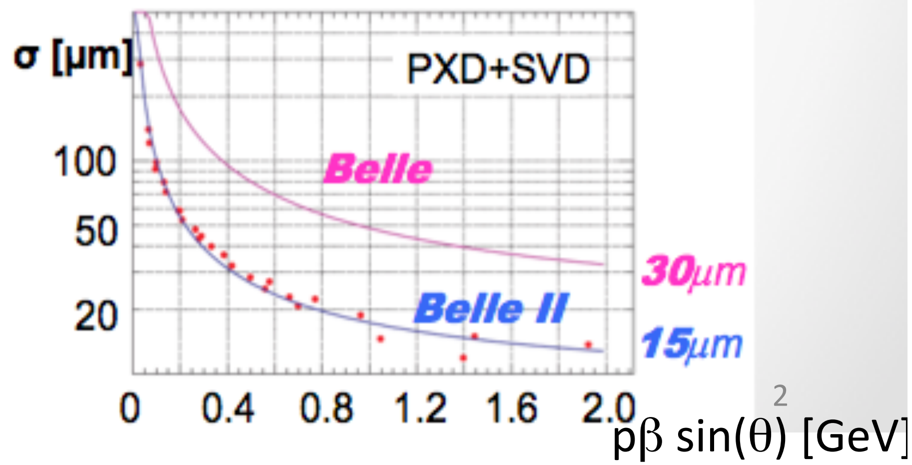


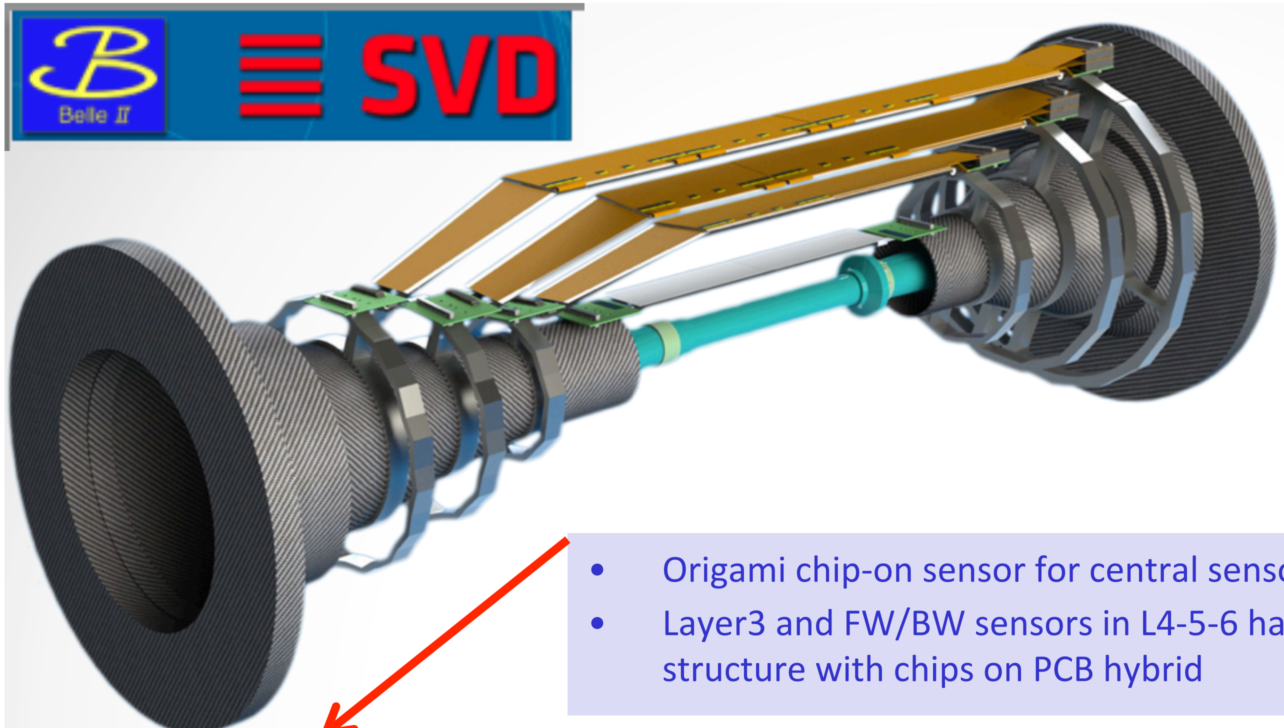
- **Silicon Vertex Detector (SVD)** – 220k strips
  - 4 DSSD layers at r = 38, 80, 104, 135 mm
  - Good spatial resolution (~12/25 μm) but ambiguities due to ghosting
  - Excellent time resolution (~3 ns)



Combining both parts yields a very powerful device!

Significant improvement in z-vertex resolution



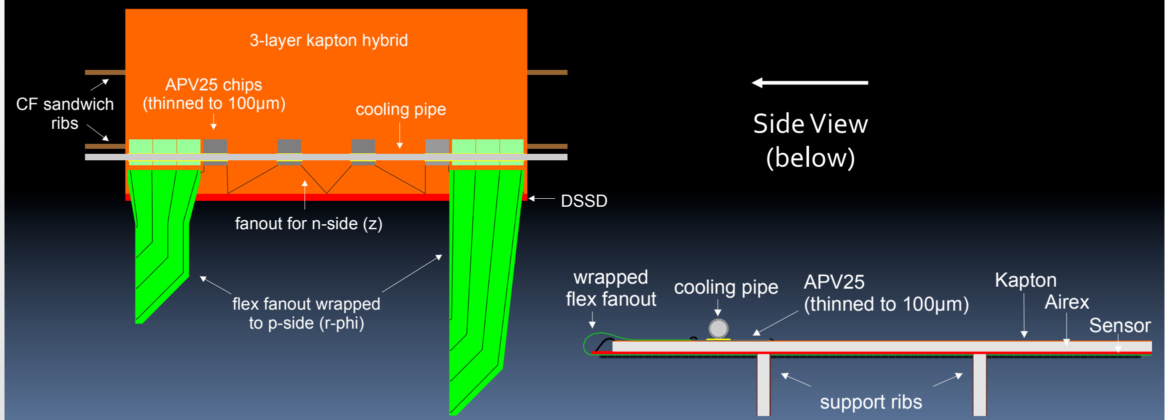


- 4 layers with silicon strips (DSSD) with APV25 read out
- Individual sensors connected to APV25 chips, to reduce capacitive load

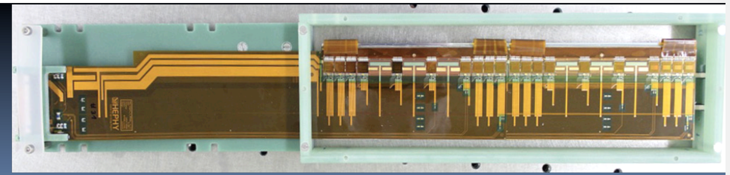
- Origami chip-on sensor for central sensors in L4-5-6
- Layer3 and FW/BW sensors in L4-5-6 have more conventional structure with chips on PCB hybrid

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)



M.Friedl (HEPHY Vienna): SVD Introduction 4 February 2013 15



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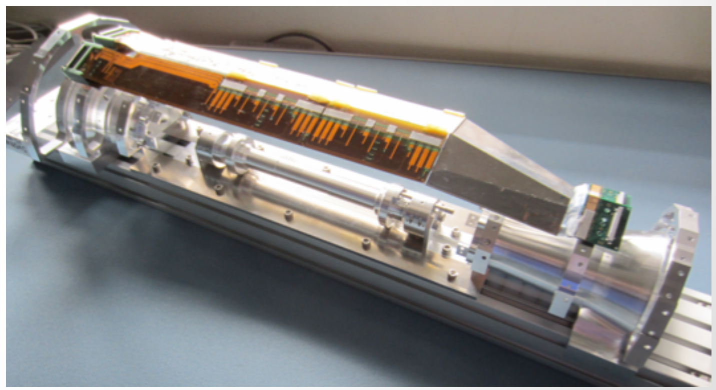
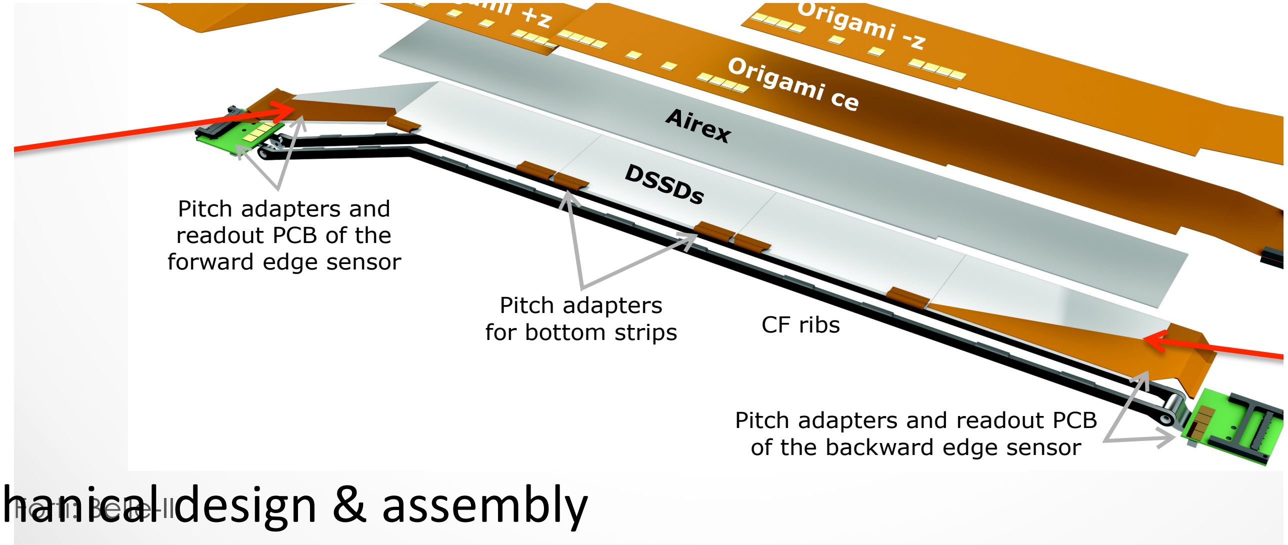


Belle2 Pisa activity

<u>The activity of Pisa will be mainly foused on:</u>

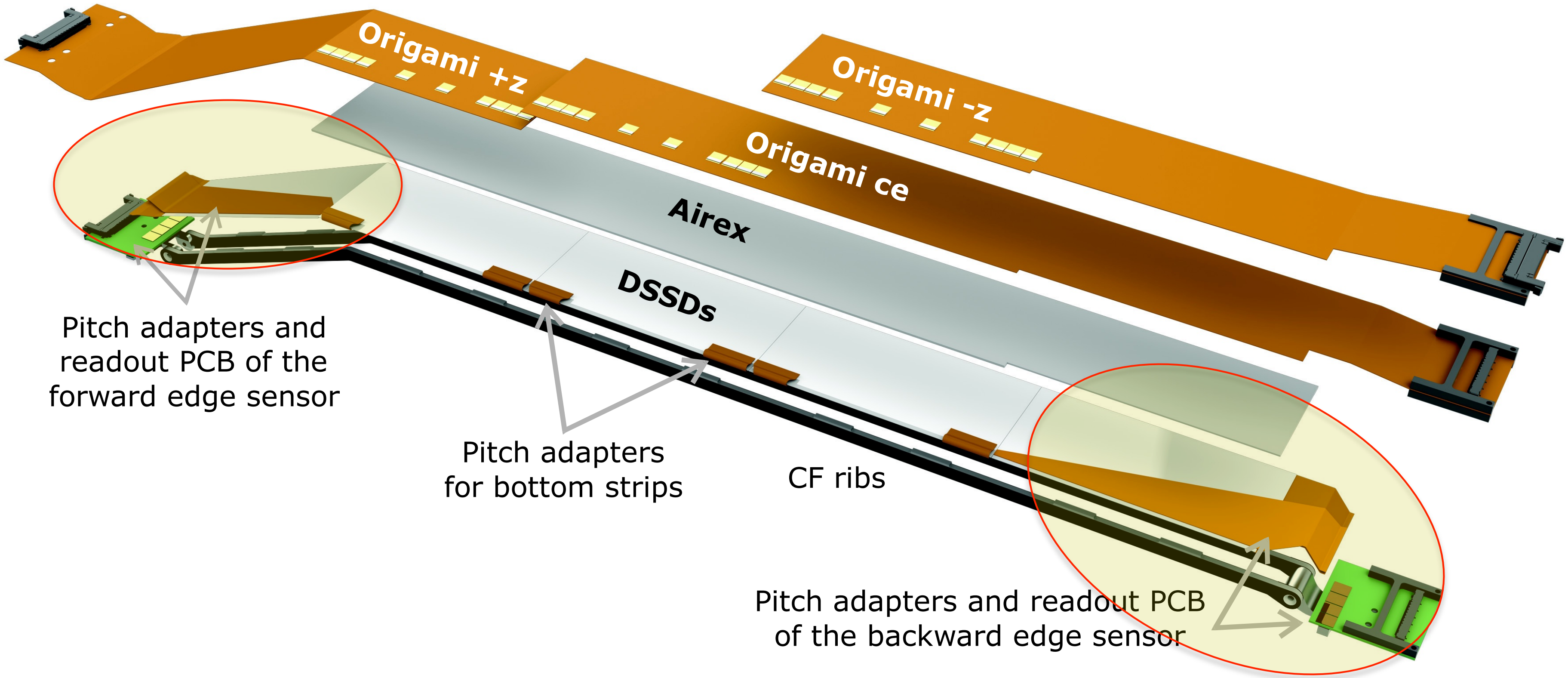
- Contribution to assembly of strip detector modules: Assemble FW and BW sensors of Layer 4-5-6 & ship to other assembly sites (Vienna, IPMU-Tokyo, TATA at IPMU lab)



- Participate in overall mechanical design & assembly
- Investigate possible replacement of the old Power-Supply
- SVD software development:
  - Si only tracking & PXD data reduction with ROI (region of interest) selection
  - Alignment
- Participation to the PXD-VXD joint test-beam in Desy

Assembly procedures

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



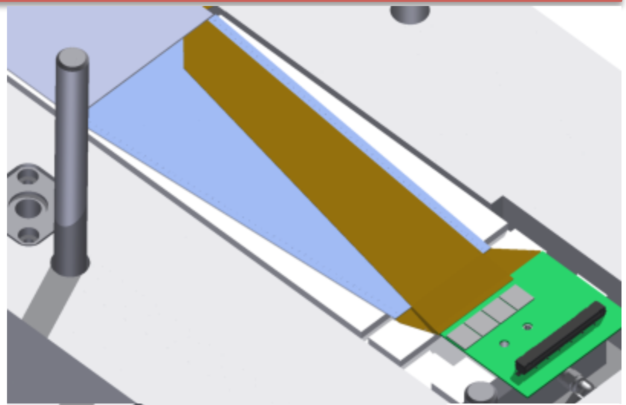
Motivation for separate FW/BW assembly

Advantages:

- Add manpower to the assembly lines, thus reducing total production time, with a gain of several months
- Parallelize some of the work and do better QC/QA
- Take full advantage of the experience in Pisa

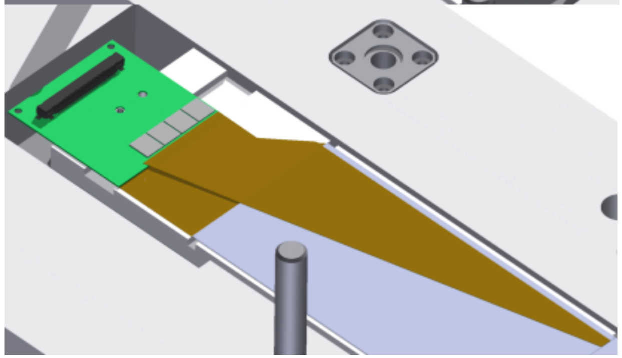
Disadvantages:

- Need some modifications of assembly procedures
- Logistics of shipment of FW/BW assemblies
- Assembly production in Pisa can only start in Feb 2014 (modified assembly procedures "Option P" can be phased in when ready)



General strategy

1. Sensors, PA and Hybrids are shipped to Pisa
2. Construction of FW/BW sub-assemblies
3. Final test
4. Shipment
5. Insertion into the rest of layer assembly flow



Technical Implementation

1. Sensors, PA and Hybrids are shipped to Pisa
   - Optical inspection for all. electrical test for hybrids
2. Construction of FW/BW subassemblies
   - Procedures similar to what foreseen for L6
   - Glue PA to sensor and hybrid; Optical inspection after gluing
   - Wirebonding on phi and zed; on each side bonding in two phases (low and high loop) with intermediate electrical test
3. Final test
   - Teststand, laser, 90Sr source
   - Burn-in option: long-term, elevated temperature
4. Shipment
   - Shipment box crucial for safety and successive assembly work; should also be usable for electrical test and burn-in
   - Possible to ship individual units or multiple units depending on schedule
5. Insertion into the rest of layer assembly flow
   - Minimize changes in procedures. Pickup and alignment as simple as possible.
   - Make test on arrival.
   - Modified xyz-Θ stage for alignment

2. Construction of FW/BW assemblies

- Issues
  - Procedures must be fully defined and optimized following the general scheme
  - Jigs must be designed and fabricated (multiplicity 2) in order to have 4 assembly in the production queue
  - Verification of goodness of PA/sensor/Hybrid alignment (must be good enough for bonding)
  - Glue deposition technique must be optimized
  - Production rate must match the rest of assembly on L6,L5,L4

- Relatively standard assembly, not worrisome (for our experience in Pisa).
- Intensive/short time production

List of jigs for Forw/Back assembly (2)

- Single-face HDI test (holder): 4ϕ and 4z = 8
- HDI face-to-face gluing jigs = 4

Assembly JIGS

- Det-PA-HDI aligning/Gluing: 2ϕ and 2z, x Forw/Back = 8
  - Aluminum support + Teflon surface precisely machined
  - Several u-metric screws needed for alignment
- For u-bonding (under bonding machine): 1ϕ and 1z, x Forw/Back = 4
- Rework: 1ϕ and 1z, x Forw/Back = 4

- Out of the 3 possible gluing technique under test, stamping is the most promising:
  - More accurate control (deposited 200 um thick layer of glue) against diffusion/capillarity
  - Possible to export to other phases of the module construction

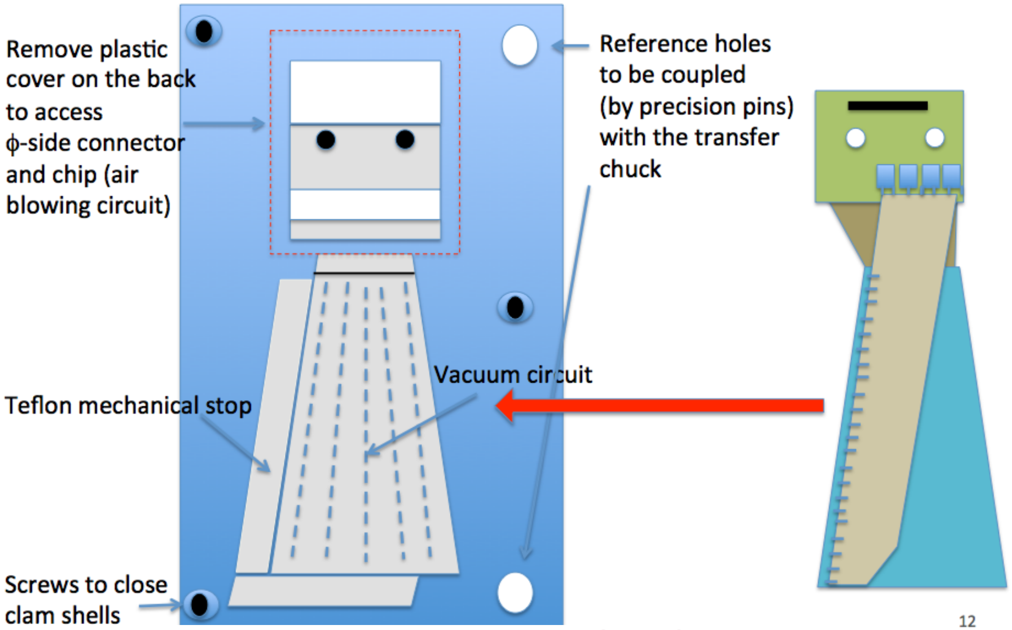
- A stamping tool (comb-like stamp + gluing pot) is to be realized for each side (ϕ/z) and Forw/Back = 4

4. Shipment strategy

- The central piece is a Multi-Purpose chuck (MP Chuck) which holds the subassembly.
- The MP chuck is composed of two clam-shell parts which hold the assembly in place
- Functions of the MP chuck:
  - Holds the subassembly safely for shipment with mechanical stop alignment
  - The upper part can be removed after applying vacuum. There are mechanical alignment bushings that mate to PF2-jig and PB2-jig that can be used to pick up the assembly and move it to the assembly bench at destination
  - Allows electrical tests before and after shipping
  - Can be inserted and fixed inside a bigger box, hosting several units, for shipping or burn-in
  - 50 BW+50 FW MP chuck needed (0.4 kEuro/each)

MP lower chuck: rest on ϕ side

a base during shipping and a (vacuum) holder at destination



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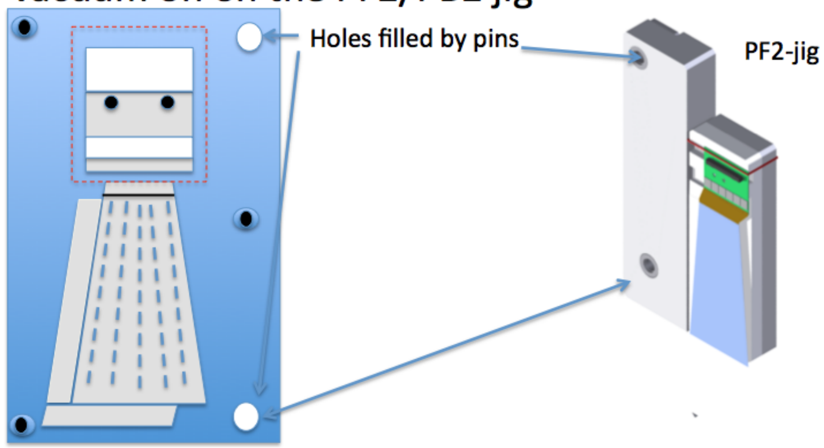
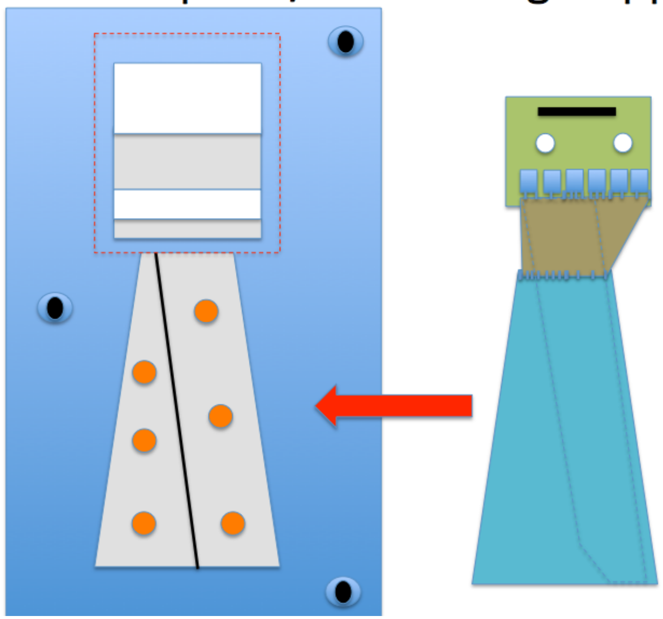
Insertion into the assembly flow: Transfer the sensor assembly

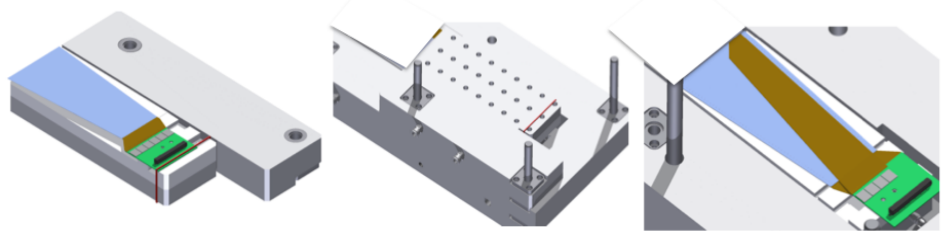
Un-screw the HDI (place rubber ribbon) and swap vacuum on on the PF2/PB2 jig



MP upper chuck: a cover and press/hold during shipping



Returning to assembly bench

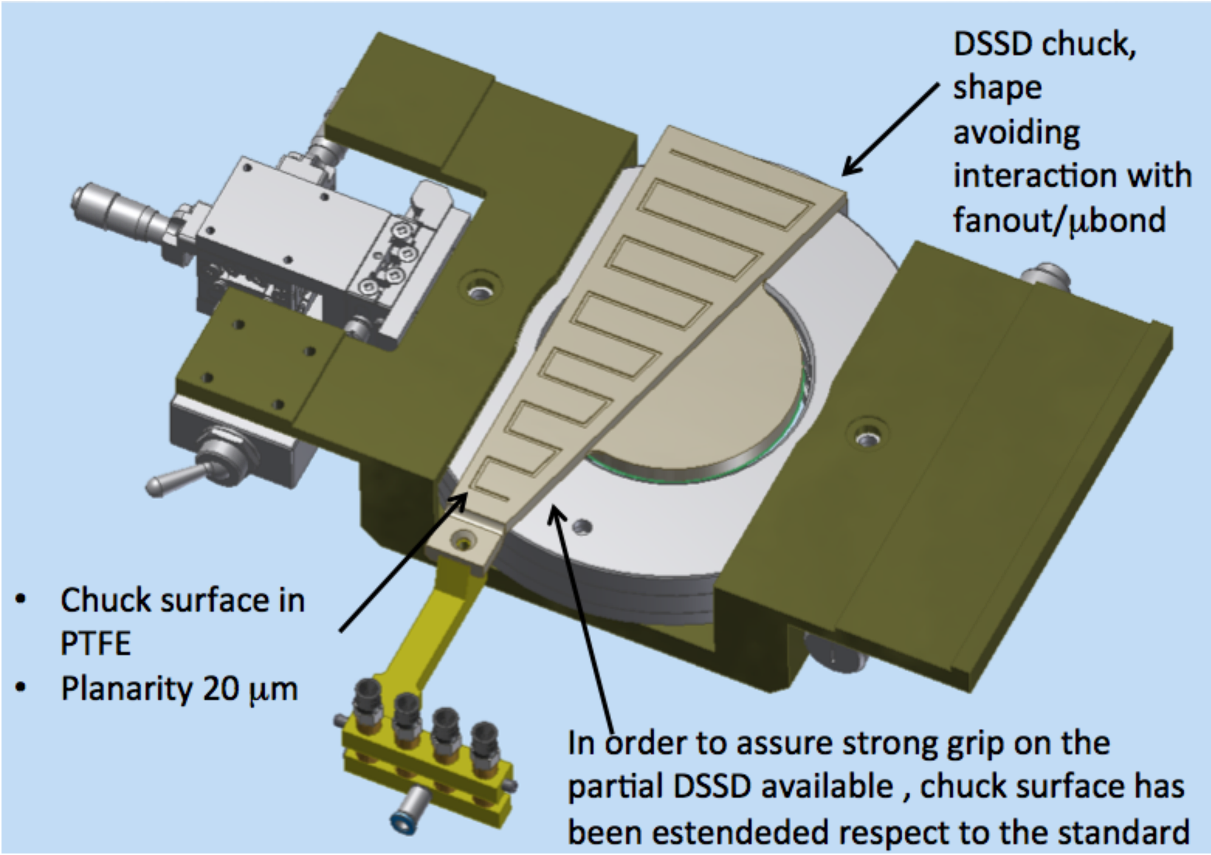


Precision is determined by mechanical stop on MP chuck, about a few hundred um.

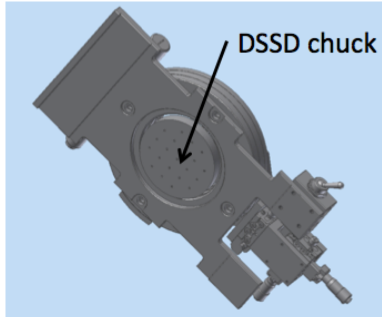
A similar procedure is used for returning the backward sensor assembly

The assemblies are only roughly aligned.
A precision **alignment** is to be performed on the assembly bench, before going on to the ribs

Modified xyzΘ stage (bottom view)



Redesign the xyzΘ stage:
the current one operates with naked sensors.



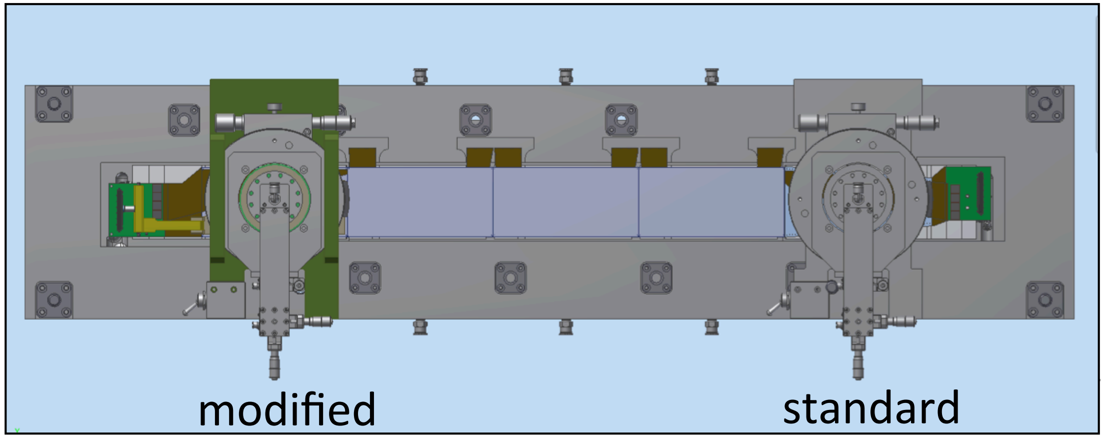
Modify as little as possible
to fit within the existing assembly procedures and jigs.

- Only pickup free silicon (not PA)
- Also pickup hybrid

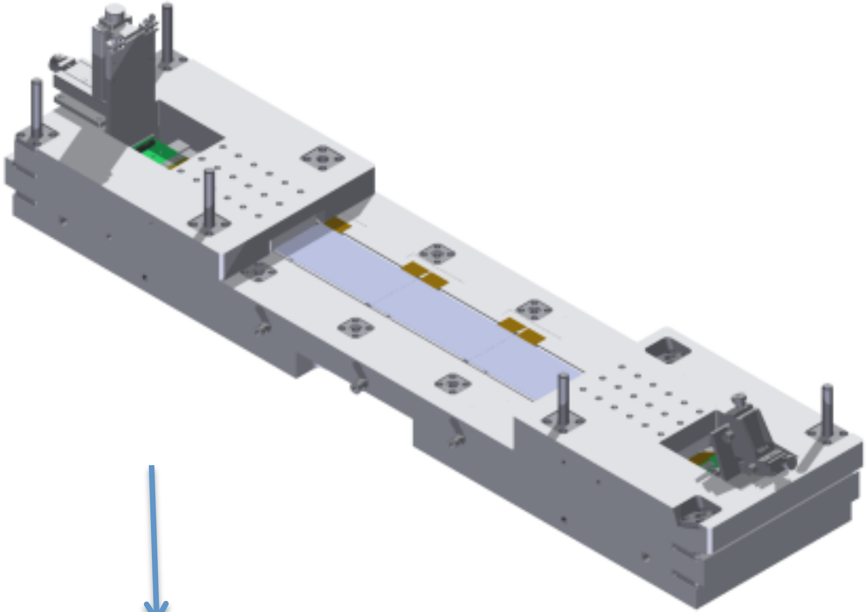
Costs:

- ~1 kE/movement →4 kE/stage
- x 2 BW/FW
- x 2 sites (L4-Wien, 5, 6 IPMU)

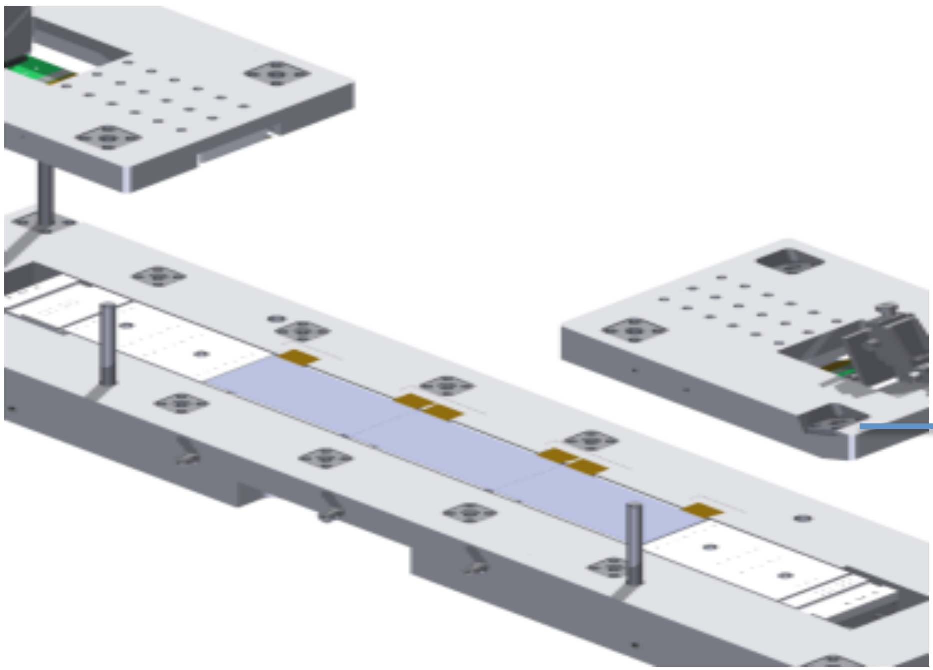
Alignment on the assembly bench (top view)

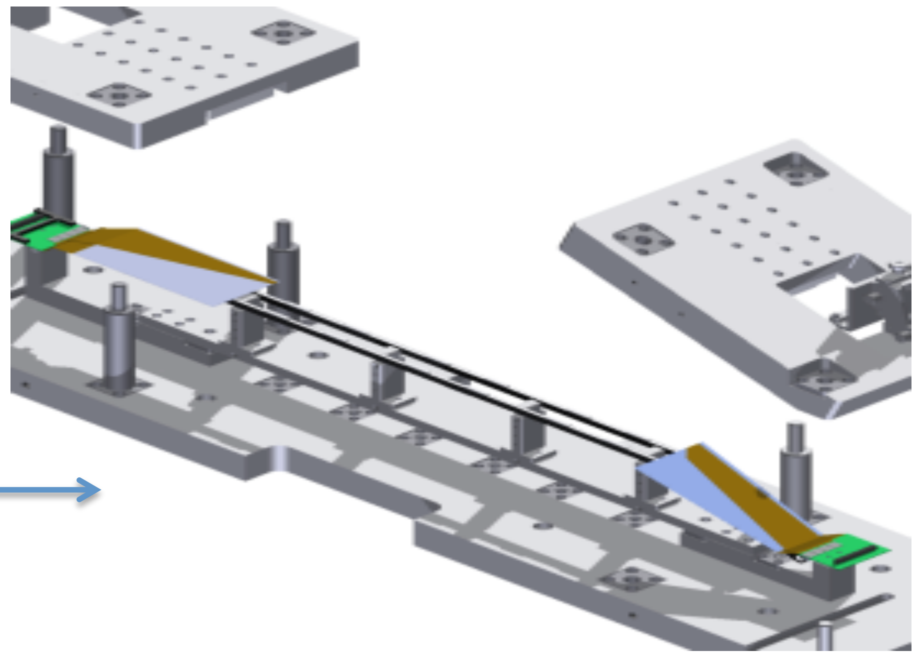


After receiving assembly in MP chuck→go ahead with normal procedures



FW&BWProc.18：
Placing Slant-jig and Backward-jig.





Overall schedule plan

- B2GM November: final review of jigs, procedures and prototypes
- Before end of 2013: first production of mechanical-grade sensor assemblies
- January 2014: produce final jigs
- February : Start production
- Production plan:
  - Each sub-assembly will take about one week from beginning to end: Gluing: 2 days; u-bonding:2 days; final test: 1 day
  - We can have four (2FW+2BW) assemblies in parallel: 4 alignment "stations" under the CMM

- FW/BW Sensor Assembly production rate :
  - Minimum needed is 6 forward + 6 backward /month
  - We think we can do up to: 8+8/ month=2+2/week
- Total production time for 50 FW +50BW (including spares) = 6-8 months
  - Production completed by October 2014
- Extended time burn-in test should be performed (tbd):
  - In Pisa prior to shipping or at destination just before mounting on ribs.

Estimated overall production time saving: 3 months for L4-L5-L6
(We think that) the schedule may become more robust with the Pisa expertise/ production capability dedicated to the production of the FORW/BACK assemblies.

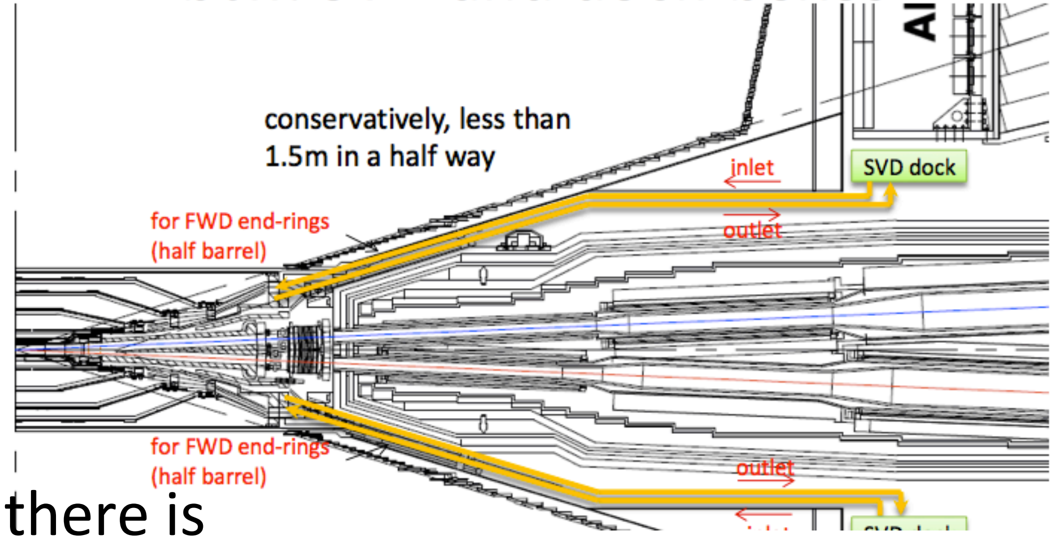
Whole SVX mechanics & cooling

The temperature requirements:

- -20 °C inside the SVX volume
- +20 °C outside (for the CDC)

The CF support cilinder delimits the two zones.

CO_2 cooling pipes in FWD btw. SVD and dock-boxes



This is a critical issue and so far there is no design able to fulfill these requirements.

Pisa has been asked to contribute to the design solution, profiting by our cooling expertise (CMS, SuperB) and the experimental facility (TFD lab.@INFN-Pisa) already set-up for prototype (10 kE) characterization and comparison w.r.t. thermal simulations: after JIGS design and production start (spring '14).

Numeri di elementi

Layer	Radius	ladders	Sens/ladder	Sensors	RO/sensor	RO chips
6	135	16	5	80	10	800
5	104	12	4	48	10	480
4	80	10	3	30	10	300
3	38	7	2	14	12	168
				172		**1748**

- I FWD/BWD sensor subassemblies da installare sono:
  (16+12+10) = 38 FWD e 38 BWD
- Ogni sensore è elettricamente indipendente dagli altri, con flex ed un cavo individuale
  - Alimentazioni: HV, LV lato HV+, LV lato HV-
  - Le alimentazioni per l'elettronica sono flottanti alla tensione del rivelatore

SVD Power supplies

Reference Table 3/p. 95 NEW

Power Supply

- Procure new low voltage power supply system and replace the 20-year old power supply system that was built for the Belle SVD
- Improvements in granularity and monitoring features
- Totals: LV = nsensor*2 = 344; HV = nsensor = 172

Started interaction with CAEN to understand possible solutions.

For LV: 96 LVunit 10V / 5A. Floating and with sense

each unit powers 4 sensors on one side

For HV:

option 0: 8 HV 100V/5mA – marginal, same as Kenwood

option 1: 96 HV 100V/ 1mA – one per pair of sensors (half ladder)

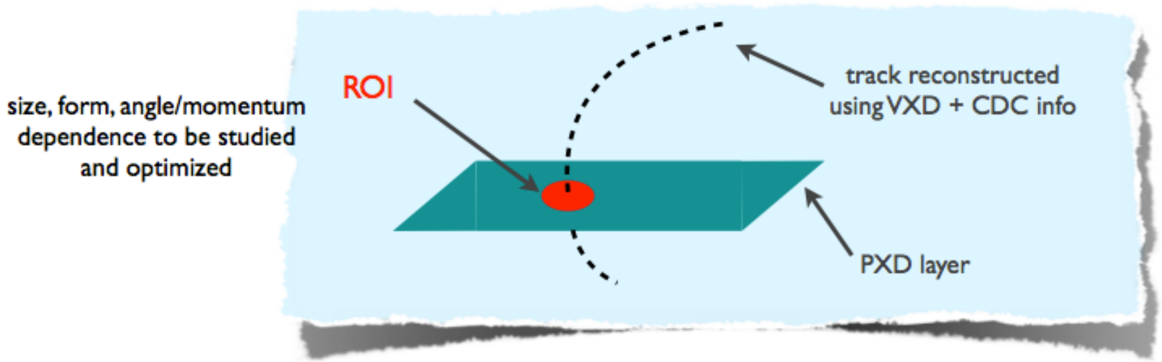
option 2: 192 HV 100V/ 1mA (maybe 0.5mA) – one per sensor

People involved: F.Forti, C.Avanzini

Acquisto anticipabile a fine 2013

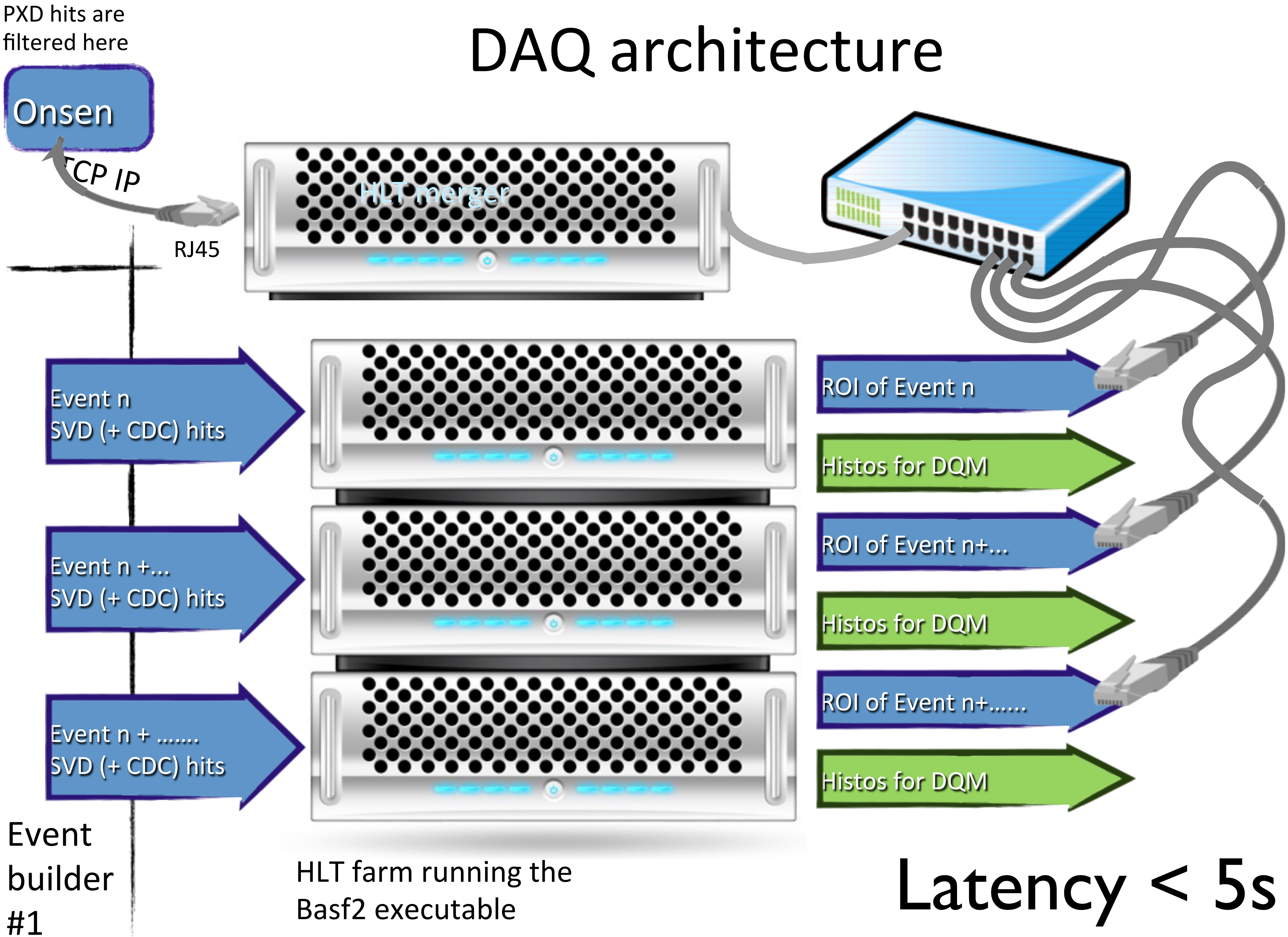
(Silicon) Tracking software

PXD data reduction strategy

- The rolling shutter read-out of the PXD can provide a time stamp granularity of order 20 μs
- The expected number of fired pixel per event due machine and physics background is way too large to be entirely written on tape (~1 Mbyte / event x 20 kHz = 20 Gbyte/s)
- Data reduction idea: save only the interesting hits and discard the background ones.
- 

  - tracks are reconstructed using SVD (and CDC) informations
  - each track is extrapolated on the PXD
  - for each track a set of Regions Of Interest containing the hits belonging to the track is defined
  - pixels belonging to the ROI are saved, the others are discarded

DAQ architecture



Latency < 5s

ROI: Status and Plan

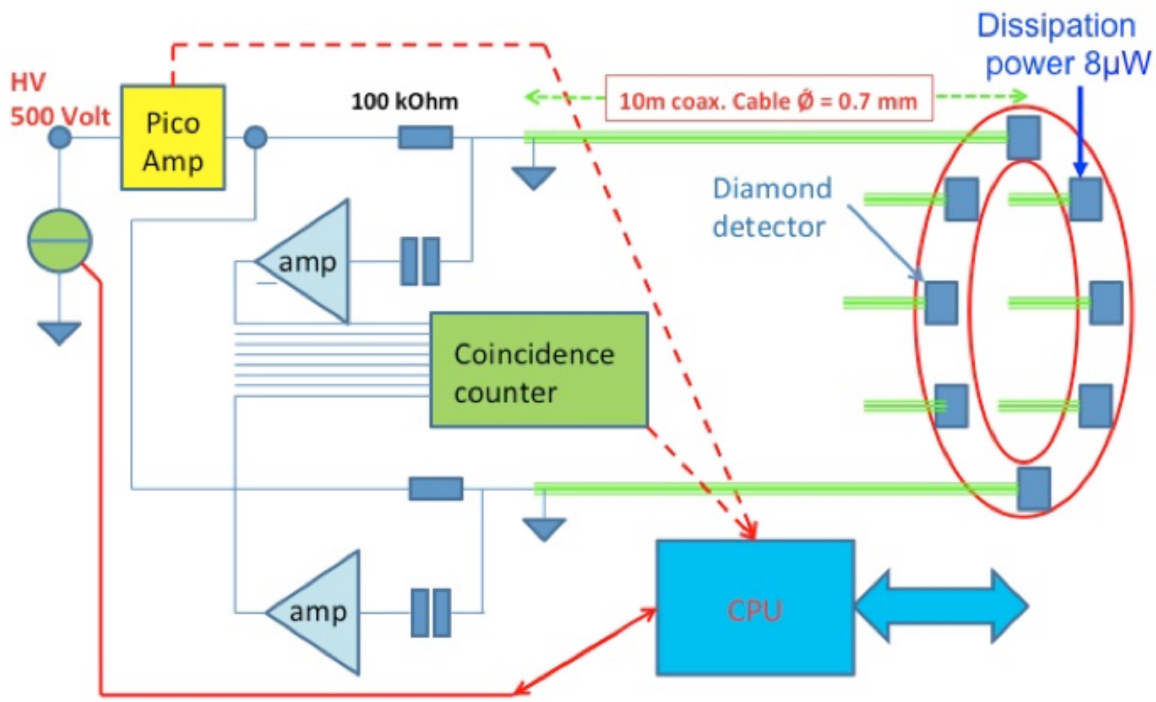
- Pisa will take care of:
  - deploying the PXD data reduction software together with its Data Quality Management system
- The software had been designed and written and is under test and optimization right now
- The test-beam will be the bench test of the whole system (PXD+SVD) with the pixel data-reduction alghoritms based on ROI
- The code will be tested on real data at Desy in January 2014

Gruppo Belle2-Trieste
Impegni costruttivi in Belle II

- Contributo alla caratterizzazione dei rivelatori “wedge” prodotti da Micron per SVD
  - Stazione di test: esistente (vedi slide back-up)
  - Sono state progettate e acquistate 2 probe cards dedicate
- Progettazione e costruzione del sistema di monitor della radiazione (e interlock) e ambientale del rivelatore di vertice
  - Definizione delle specifiche
  - Definizione dell’interfacciamento con il sistema di acquisizione dati di Belle II
  - Selezione dei sensori (rivelatori a diamante per la radiazione, sensori per temperatura, umidità, posizione …)
  - Progettazione dell’elettronica di lettura e di interfacciamento
  - Meccanica, cablaggi; produzione, test

What about SuperB radmon

- detailed estimates of expected backgrounds
- radiation monitor and beam abort based on 2 rings with 8 diamond sensors each



Contatti per monitoring di radiazione e ambientale a Belle2

Belle2 aveva previsto nel TDR un sistema decisamente meno elaborato.

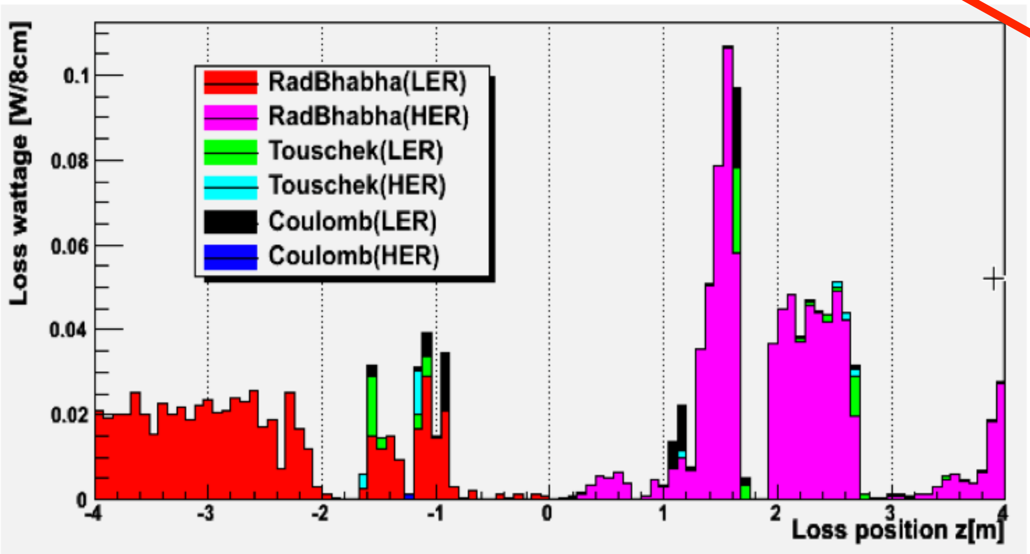
- Trieste ha preso contatti con gruppo di Vienna (responsabilità generale per SVD)
  - ha accolto favorevolmente la proposta di potenziare il sistema di monitoring di radiazione e ambientale
  - Sono in atto contatti per verificare le necessità vincoli meccanici (non ancora tutto definito)

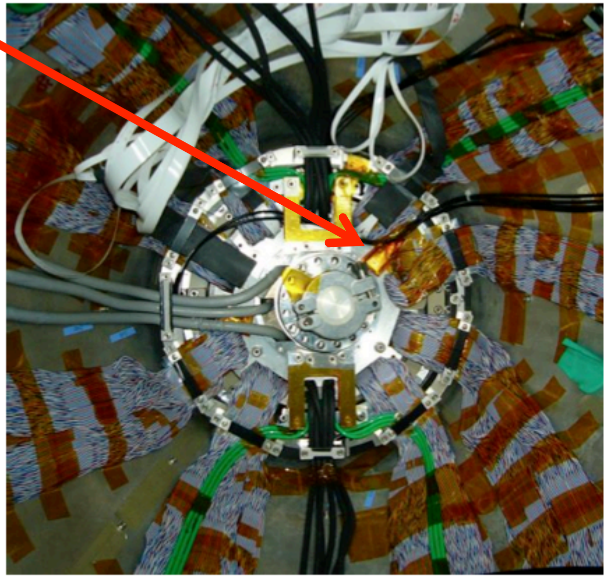
- Collaborazione con gruppo di Bonn che ha iniziato ad lavorare sul sistema di monitoring della radiazione per PXD e beam loss abort

Belle1: Background e diamond beam monitor

Beam loss abort

- Radiation monitor focused on radiative Bhabha events
- Beam abort on large current spikes or prolonged radiation doses.
- Readout of DC current of a diamond detector produced by the particle flux





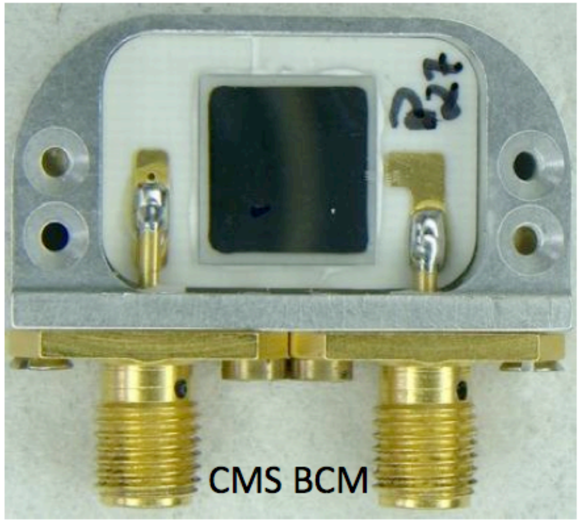
Belle2: Sensori di radiazione

Sensor type

Diamond detector offers many advantages
→ Fast, radiation hard, small leakage

- To be defined:

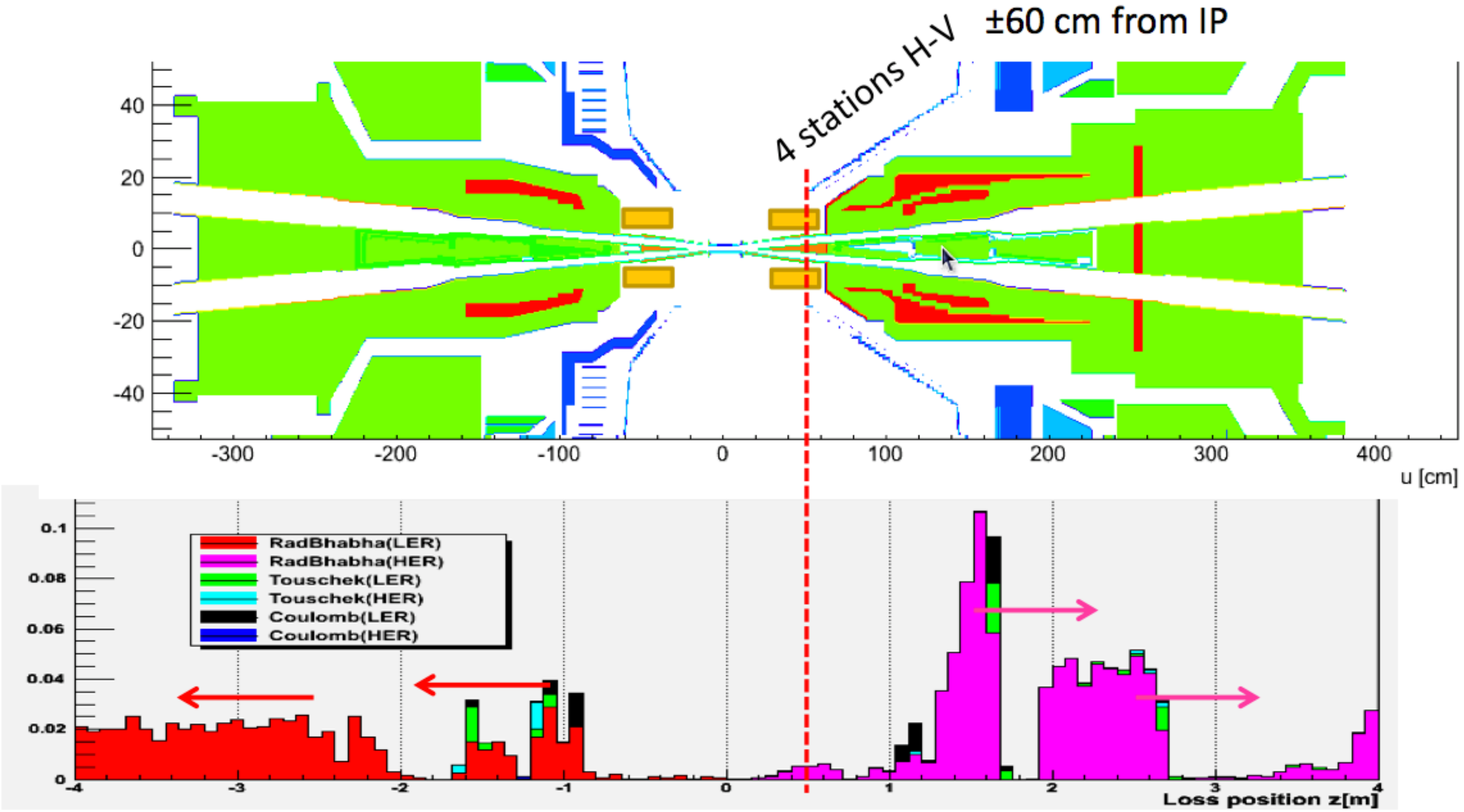
  pCVD or sCVD
  Detector size
  Detector readout and response time
  Dynamic range
  Type of output (current, pulse, counting)
  Machine interface
  Services



In addition, pin diodes closer to the IP, most likely hidden behind the PXD cooling blocks

PXD+SVD: Background dominante: Bhabha radiativo

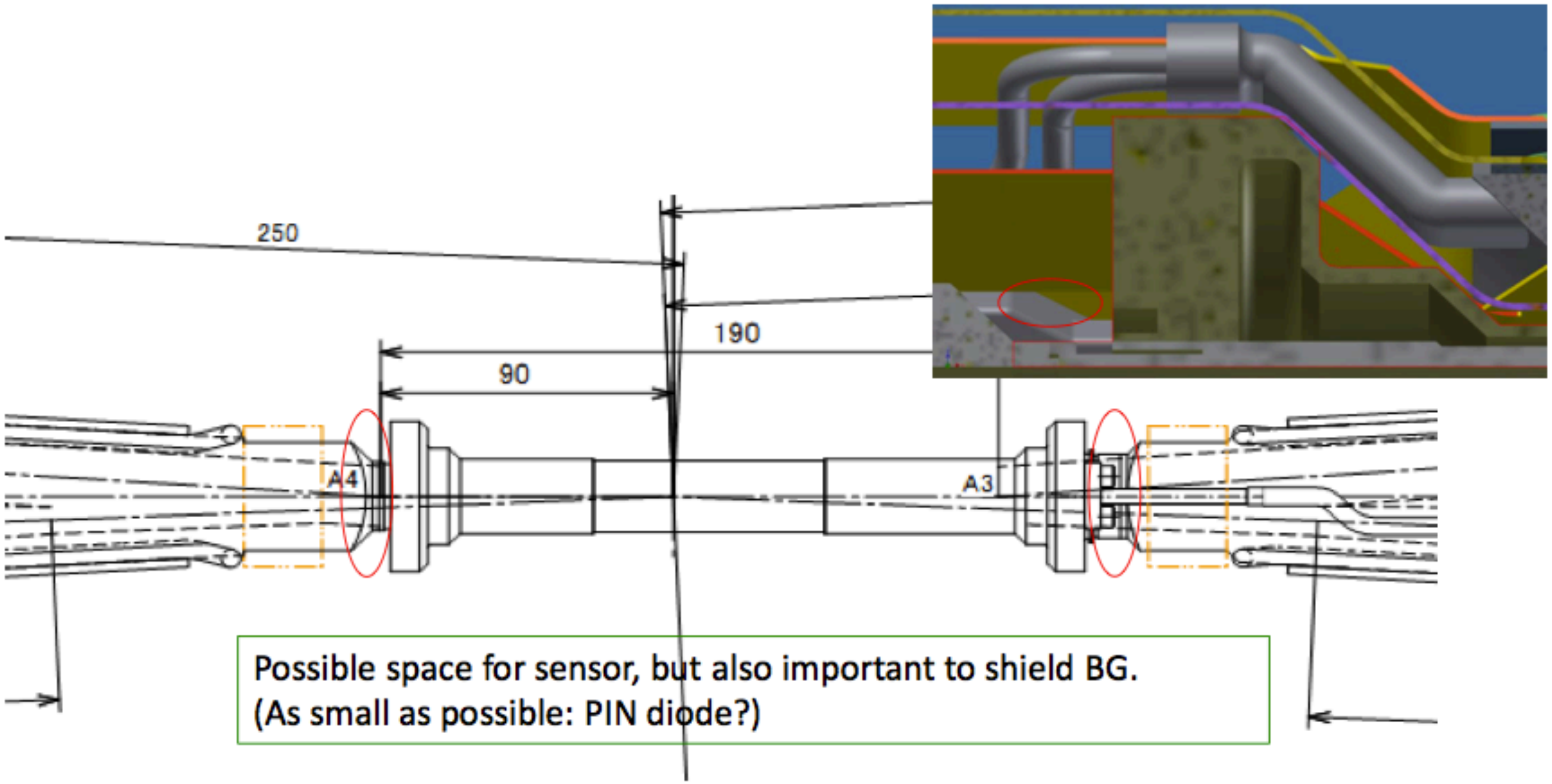
Loss position



- Radiative Bhabha: QED process, Luminosity dependent
- Represents the major background source via particle loss after IP
- Detection of beam losses by measuring ionizing radiation (e^- and e^+)

Opzioni di posizionamento

BG monitor position (option)



- Monitoring BG is quite important to decide ramp-up detector and send beam abort signal to machine

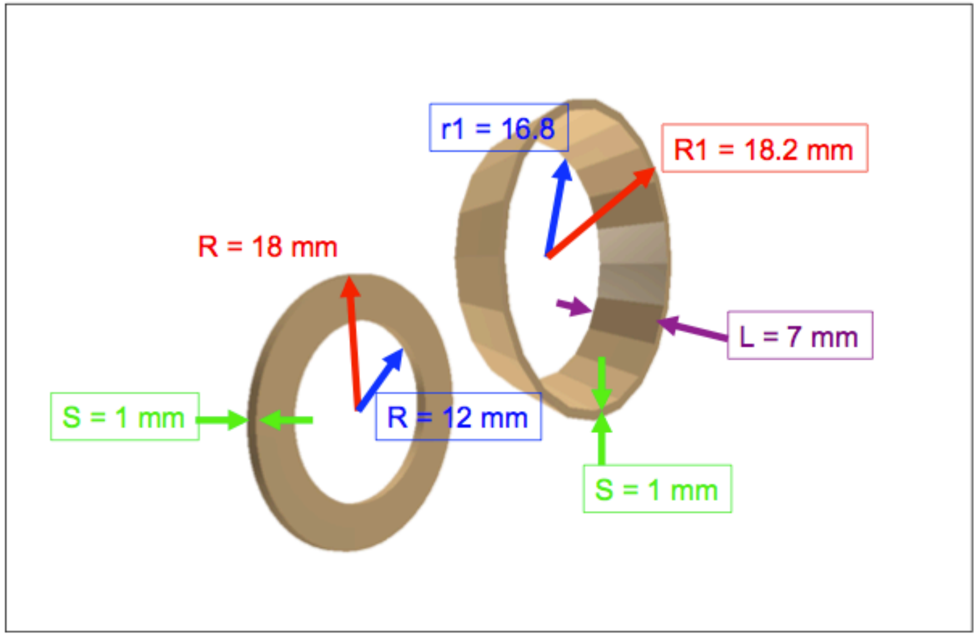
Proposta di Trieste

- La nostra proposta è quella di adattare il sistema previsto nel TDR di SuperB a Belle2 e quindi posizionare due anelli con 8 sensori al diamante ciascuno.

- Uso sistemi di readout veloci già sviluppati e testati in SuperB (e confronto con quelli di Elettra a TS).

- Posizionare monitor (temperatura e umidità)

Tentative detector shape



Work in progress a Trieste

- Contatti coi (pochi) fornitori di sensori (E6 element six, II-VI) e metallizzazione (IZM) or entrambi (Cividec, Micron, …) i costi dei soli sensori sono di:
  - 700-800 euro per pCVD 5 x 5 x 0.5 mm^3
  - 2800-3000 euro per sCVD 4.7 x 4.7 x 0.5 mm^3
  - Per le metallizzazioni i costi sono molto elevati (~6000 euro per design specifici custom). Per più pezzi i costi unitari scendono molto.
  - Abbiamo ricevuto una prima quotazione per il lotto completo di 16 sCVD con singolo elettrodi per 50keuro. Attendiamo altre quotazioni.

- Setup degli strumenti di test (readout, sorgente beta ^{90}Sr in campo magnetico, etc).
- Caratterizzazione dei campioni con sensore a diamante che abbiamo a disposizione

– Caratterizzazione statica, come single-particle detectors e come radiation monitors (vedi backup slides)

Working plan (TS)

- Comprensione approfondita di requirements/constraints.

- Scrittura di un documento completo delle specifiche (per ora è disponibile solo uno schematico) includendo anche monitor ambientale

- Continuare caratterizzazione dei campioni con sensore a diamante che abbiamo a disposizione
  - Sistemi di lettura veloce per radiation monitors
  - Essere in grado di confrontare i risultati dei questi sensori con altri dosimetri in ambienti di acceleratori come Elettra (synchrotron light source a Trieste)

Richieste SVD

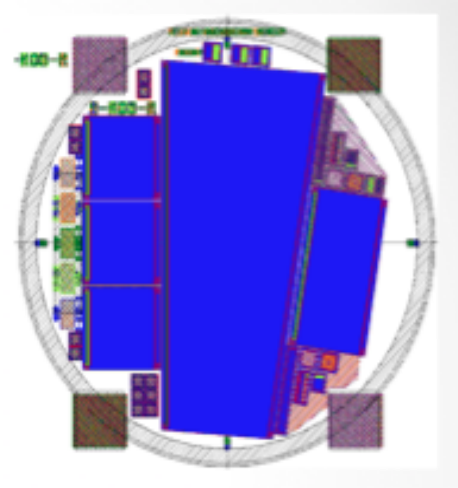
Sys	Sede	Capitolo	Categoria	Descrizione	Richiesta
SVD	TS	missioni	A	3 (contatti SVD per misure sensori e progettazione monitor) x 2 pers. (tecn inclusi) + 2 (SVD workshop) x 2 pers. + 1 (test beam DESY) x 1 pers., valutati in totale 2.75 mu x 6 kE/FTE = 16.5 kE	16.5
SVD	TS	consumo	A	prototipi monitor radiazione e ambientale	27
SVD	TS	consumo	A	consumi laboratorio e servizi sezione	3
SVD	TS	trasporti	A	spedizioni varie sensori	2
SVD	TS	licenze-SW	A	Mentor Graphics + quote Europractice e Synopsys	2.5
SVD	PI	missioni	A	2 SVD workshop 2kE x 3 pers	12
SVD	PI	missioni	A	(3 contatti x3 pers+ prep.installazione 1 contatto x 3 pers inclusi tecnici) x 2kE	24
SVD	PI	missioni	A	Test-beam Desy 3kE x 2 pers	6
SVD	PI	consumo	A	jigs per assemblaggio (seconda copia)	30
SVD	PI	consumo	A	costruzione shipping boxes	40
SVD	PI	trasporti	A	spedizioni	10
SVD	PI	consumo	A	consumi costruzione (colle, cleaning-tools, isopropilico,...)	10
SVD	PI	apparati	A	Power Supply SVD	150
SVD	PI	apparati	A	Schermo termico e meccanica	10

Spese su fondi ass. 2013

- TS (ass. consumi 10.5 kE):
  - probe cards per testare wedge det ~2keuro
  - ordinato (stanno per arrivare) circuiti stampati per montare sensori diamante ~ 1100 euro
  - connettori sma, cavi, adattatori vari: 1200euro
- PI: ordini dopo ½ settembre per
  - CMM Mitutoyo, CPU VME (test-stand) e PCs lab.
  - Xyzθ stage mod. da fornire (x3) non preventivato (pensavamo di poter modificare solo il chuck di teflon, "plug&play")
  - MP chuck piu' complicato del previsto e non possibile riuso per "shipping back".

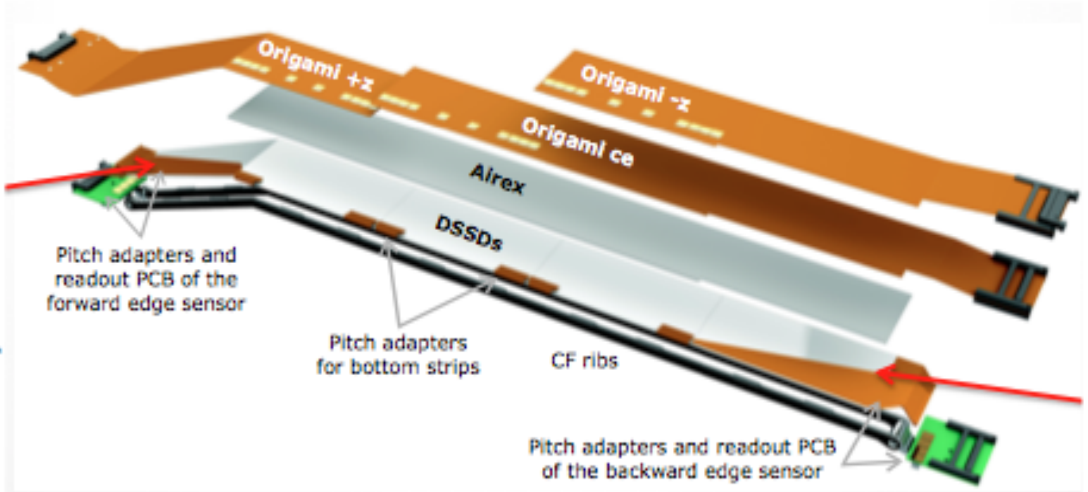
Backup slides

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:

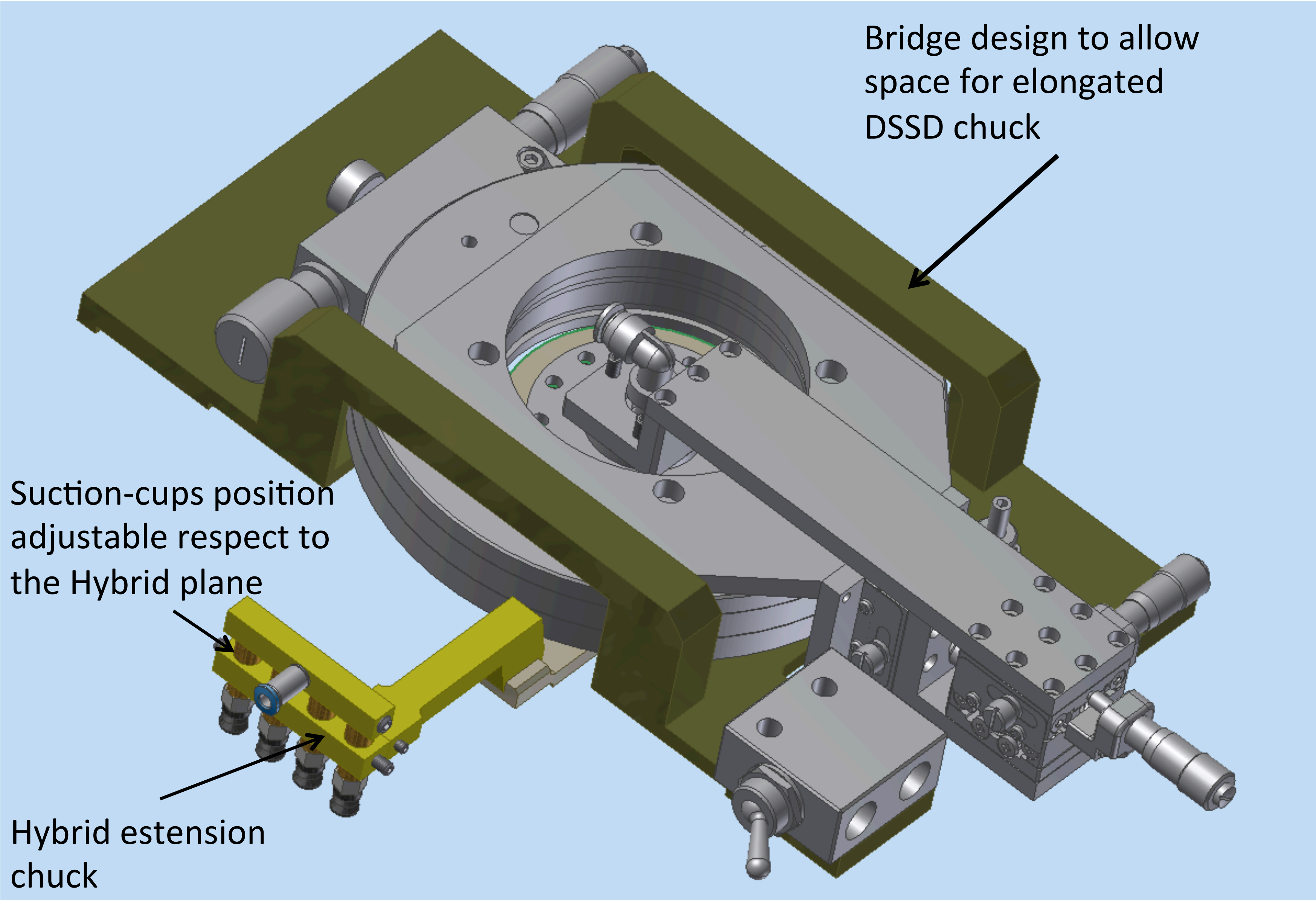
- Contribution to assembly of strip detector modules:
  - On critical path
  - Assemble FW and BW sensors of Layer 4-5-6 & ship to other assembly sites (Vienna, IPMU-Tokyo, TATA at IPMU lab)
- Participate in overall mechanical design & assembly
- SVD software development:
  - Si only tracking & PXD data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

Gruppo Belle2-Pisa

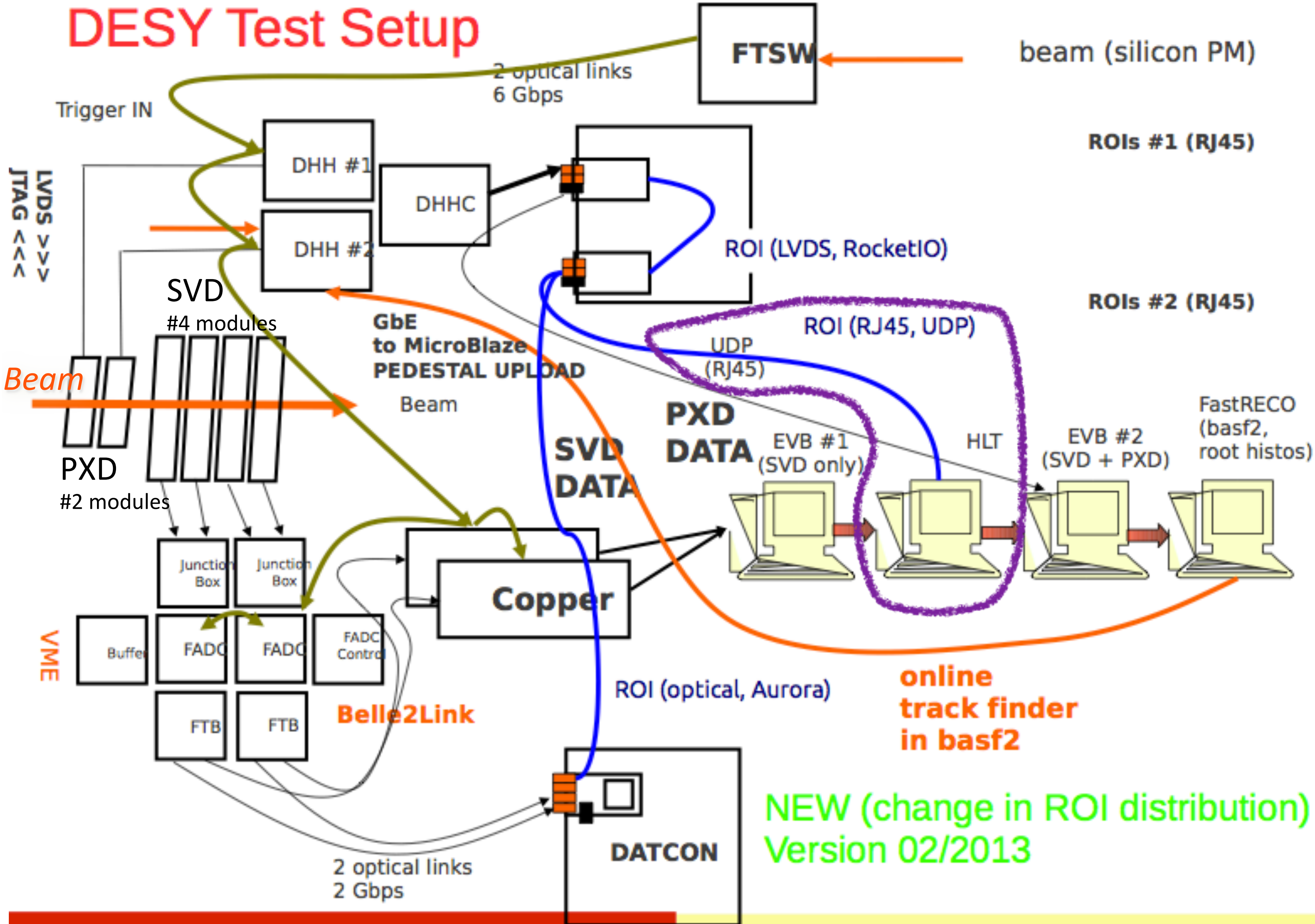
- Totale 5.7 FTE, 10 persone

Last	First	Role	FTE
Angelini	Carlo	Full Professo	50
Batignani	Giovanni	Full Professo	70
Bettarini	Stefano	Staff researcl	70
Casarosa	Giulia	Postdoc	40
Fella	Armando	Engineer	100
Forti	Francesco	Associate Pr(	70
Giorgi	Marcello	Full Professo	0
Paoloni	Eugenio	Staff researcl	70
Perez	Luis.Alejandr	Postdoc	50
Rizzo	Giuliana	Staff researcl	50

Modified xyz-Θ stage



DESY Test Setup



NEW (change in ROI distribution)
Version 02/2013

INFN Trieste: gruppo e supporto

- Docenti/Ricercatori UniTS
  - Luciano Bosisio 60%
  - Livio Lanceri 80%
  - Lorenzo Vitale 80%

- Supporto tecnico di Sezione
  - Laboratorio Elettronica (Pietro Cristaudo)
  - Officina Meccanica

Sensor testing in Trieste

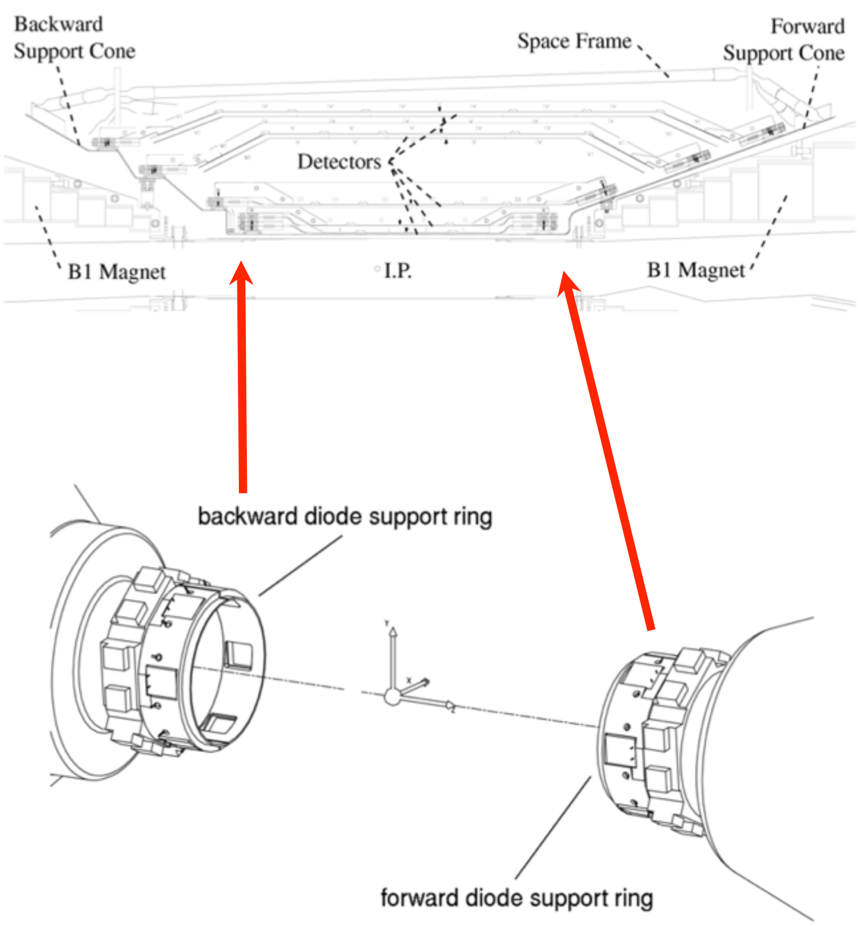
Hardware:

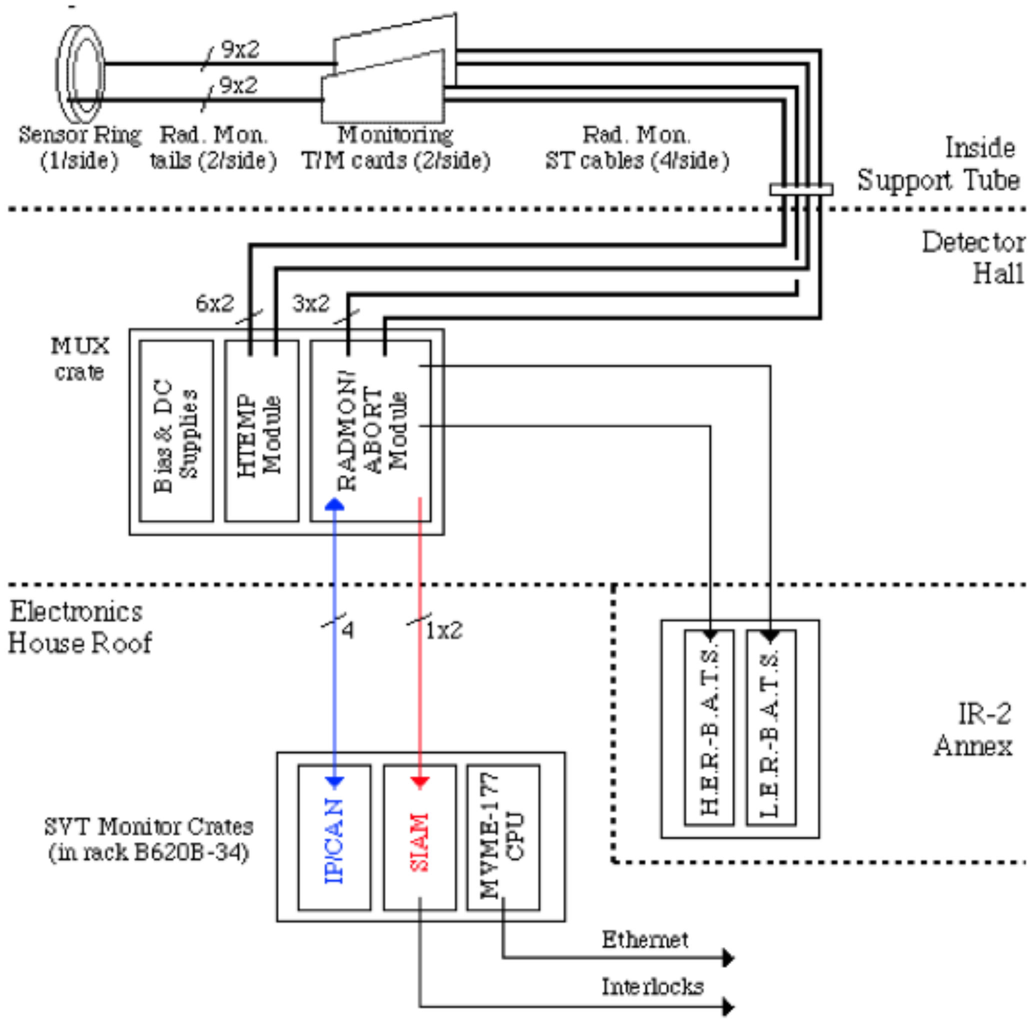
- Alessi REL55 semi-automatic prober
- *I-V* and *C-V* testing instruments (HP 4156A, Keithley 237, HP4287A) + scanner (Keithley)

Software:

- "M-Shell" set of LabView programs for control, data acquisition and analysis (developed by R.Wheadon, INFN Torino)

BaBar SVTRAD





SuperB SVT radiation monitor

A radiation monitor near the interaction point has been designed:

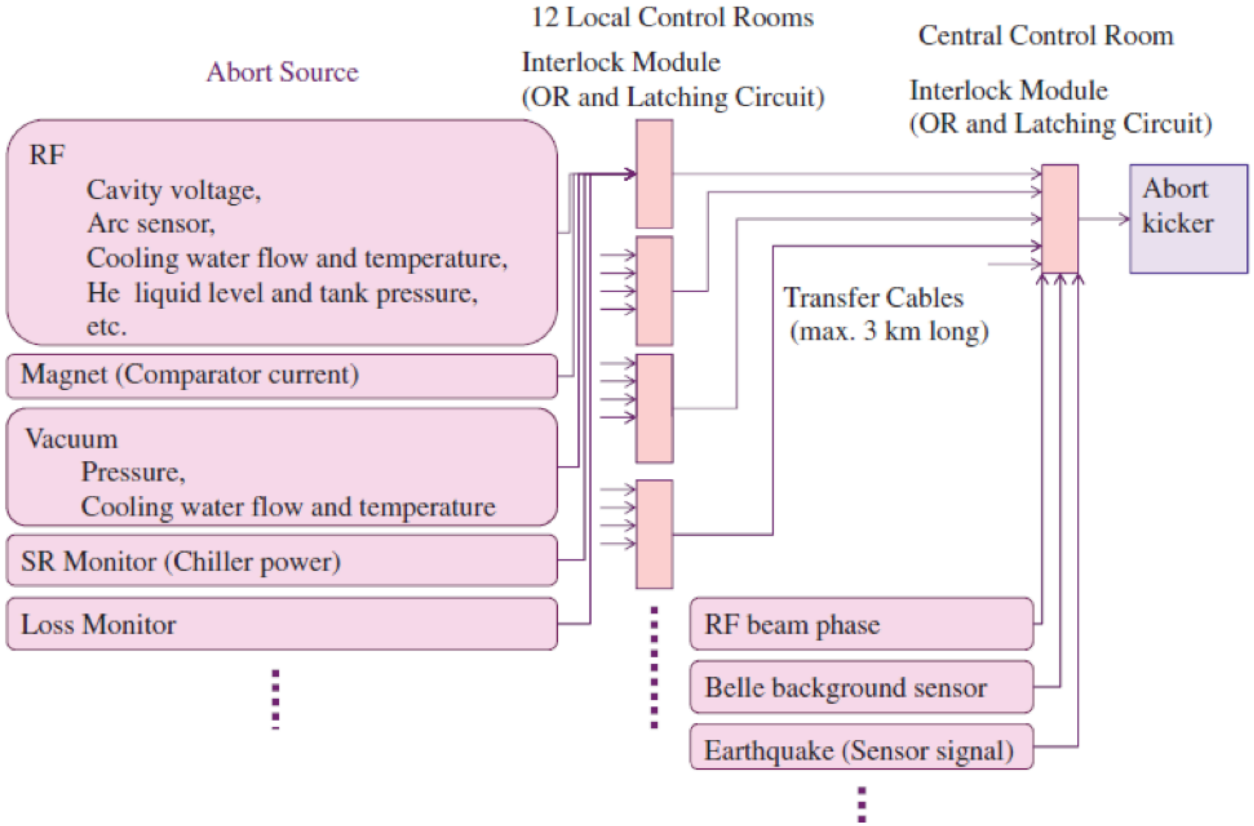
- to protect the SVT from a high radiation dose and
- to abort the beam in the presence of a current spike or a prolonged radiation dose.

Detailed estimates of expected backgrounds:

- for the SVT, the SuperB TDR gave total integrated doses (TID) ranging from 3.3 to 0.01 Mrad/year, depending on the detector layer, and 1MeV neutron equivalent fluence, according to NIEL (non-ionizing energy loss), of 5.2 x 10^12 to 1.8x10^11 n/cm^2/year.

Situazione precedente a KEK (Belle 1)

KEKB beam abort system

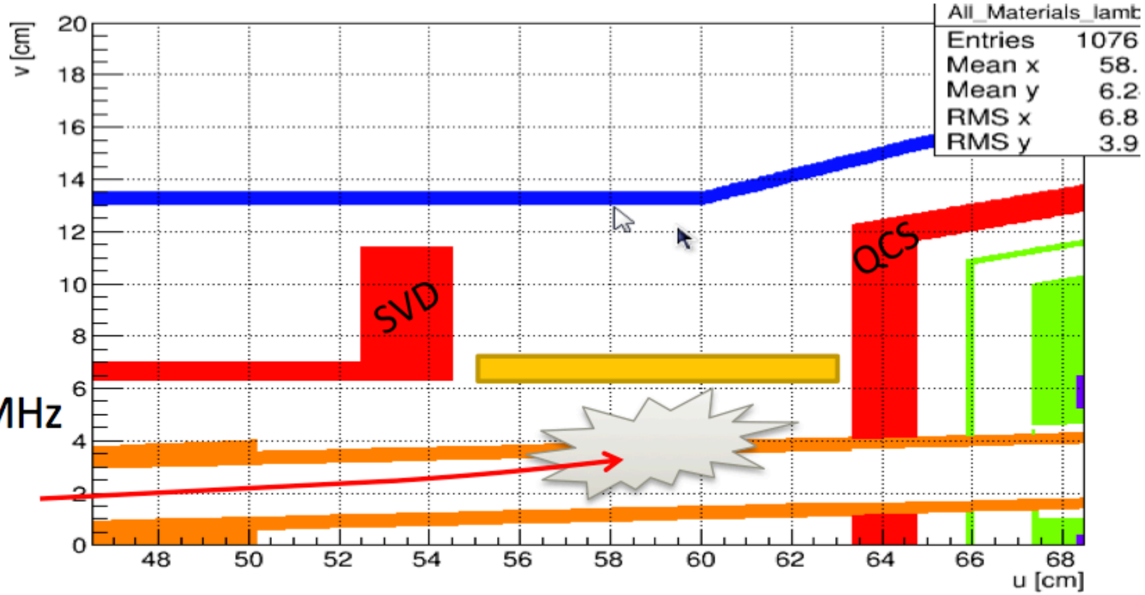


- Readout and pulse delivery to the control room in less than 100 μs
- Optical fibre to the control room

SuperKEKB and Belle Ii should have a similar configuration

Radiative Bhabha HER

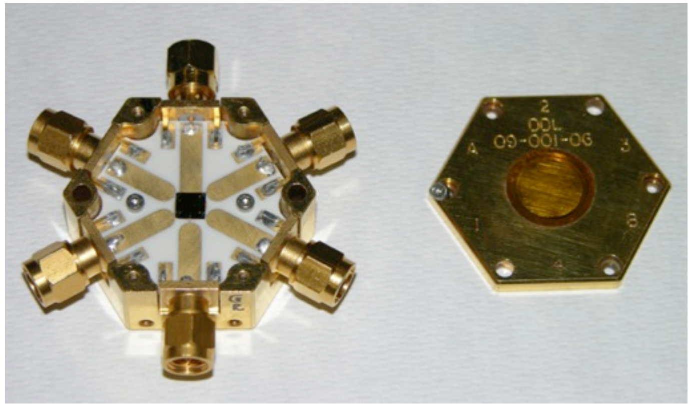
Loss at z ~ 50-60 cm
(x,y) = (~2cm, ~1cm)
Energy ~ 0.1-0.3 GeV
Px , Py << 0.01 GeV
Rate: 110 e^-/10μs → 10MHz



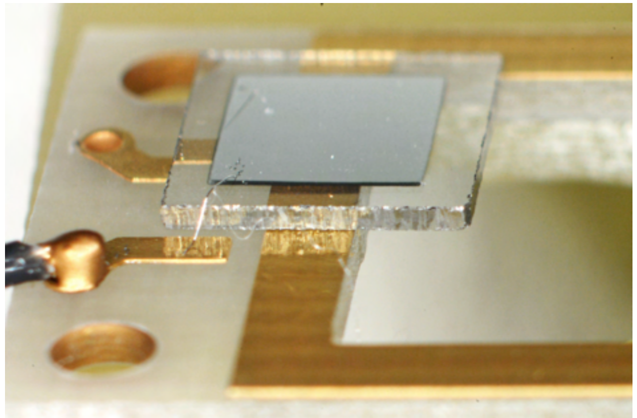
QCS: final focus quadrupole magnet

Available sensors

- A preassembled single crystal 4.7 x 4.7 x 0.15 mm^3 with 4 quadrants from DDL Diamond Detector Ltd (no longer available).



- Micron seems interested to take over the DDL know-how. We have received a poly-crystal test sensor 5 x 5 x 0.5 mm^3 in July; waiting for more soon.

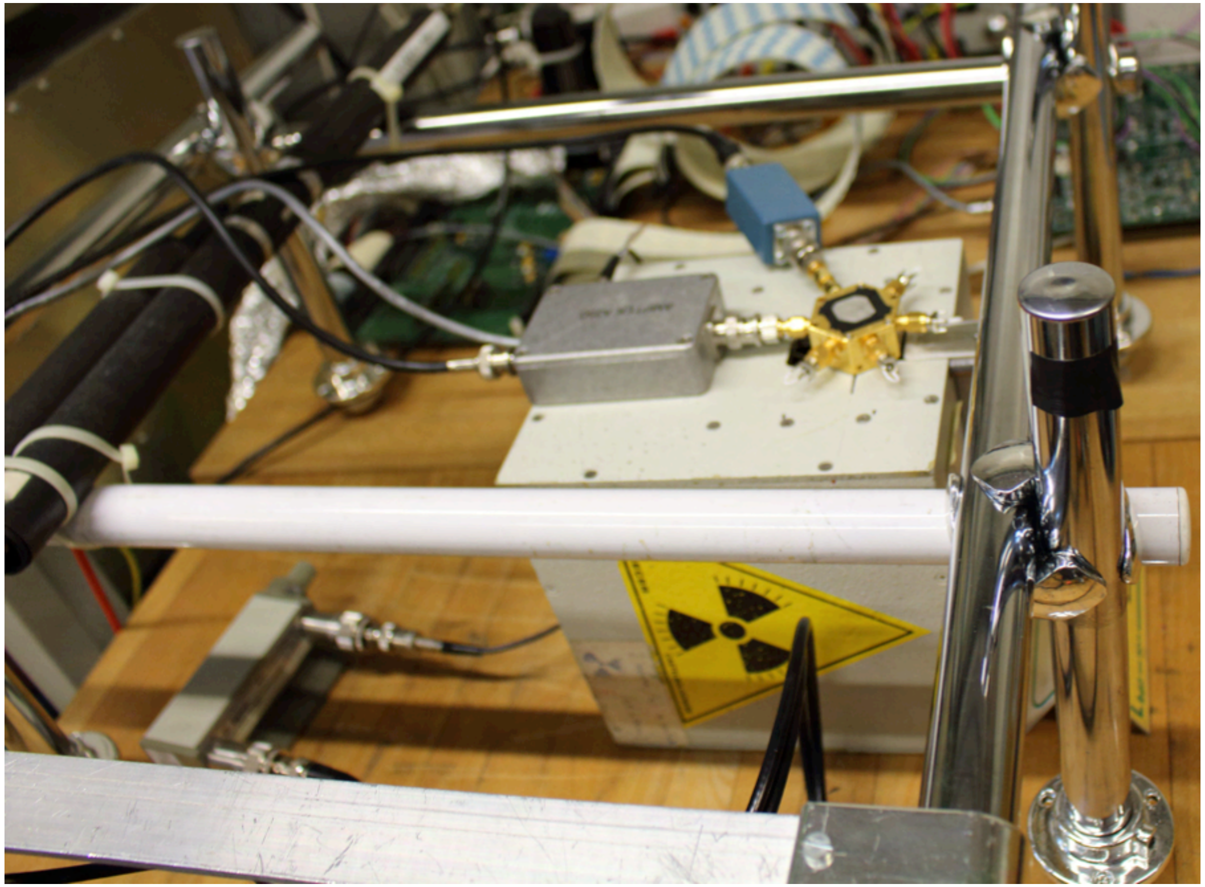


- Moreover, we just received two sensors from Cividec (Austria), single & poly –crystal 5 x 5 x 0.5 mm^3, with 3x3 pads and a fast charge amplifier (3.5 ns rise time).

Setting up test tools

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

- Single channel Amptek chain: A250 preamp. (2.5 ns risetime) + PX5 digital shaper (semi-gaussian equivalent time 40 ns – 40 μs).
- A pointlike ^{90}Sr source ~2 MBq in magnetic field to harden its spectrum
- Two scintillators for triggering purpose



Results with DDL sample
single crystal 4.7 x 4.7 x 0.15 mm^3

- Extremely low currents @10 fA level.
- Collected charge from MIP (beta source) close to the expected (first estimate @~10%).
- No significant variation with bias voltage (10-150 V).
- Good signal even from ^{241}Am X ray source.