PS-BGI: Status & Plans

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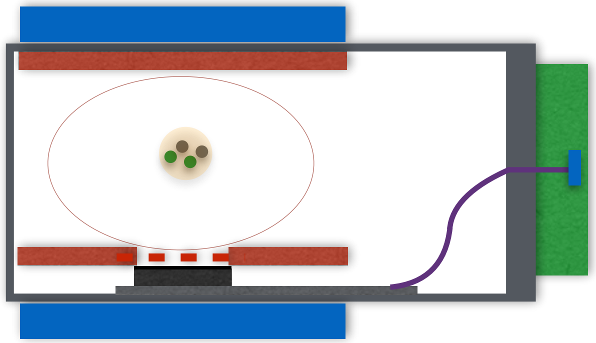
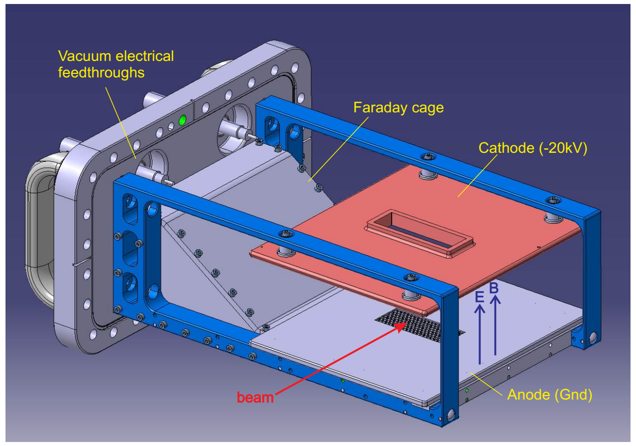
BI Technical Board, 19/11/2015

Outline.

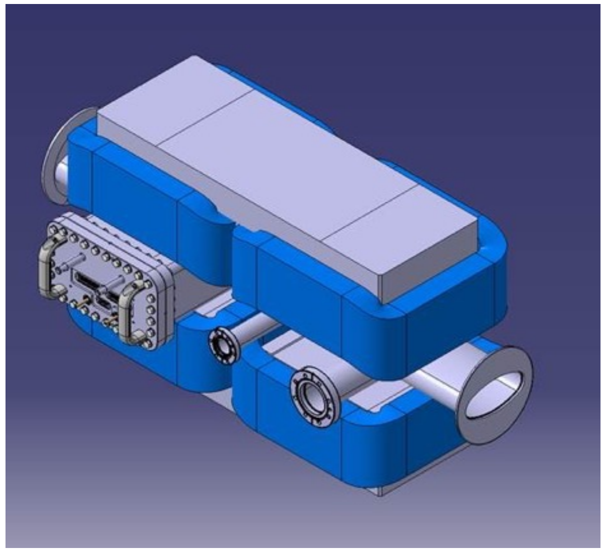
- Recap…



- In-vacuum components:
    - Field cage & pixel detector designs.
    - Current status & plans.



- Out-of-vacuum components:
    - Readout system.
    - Magnet.

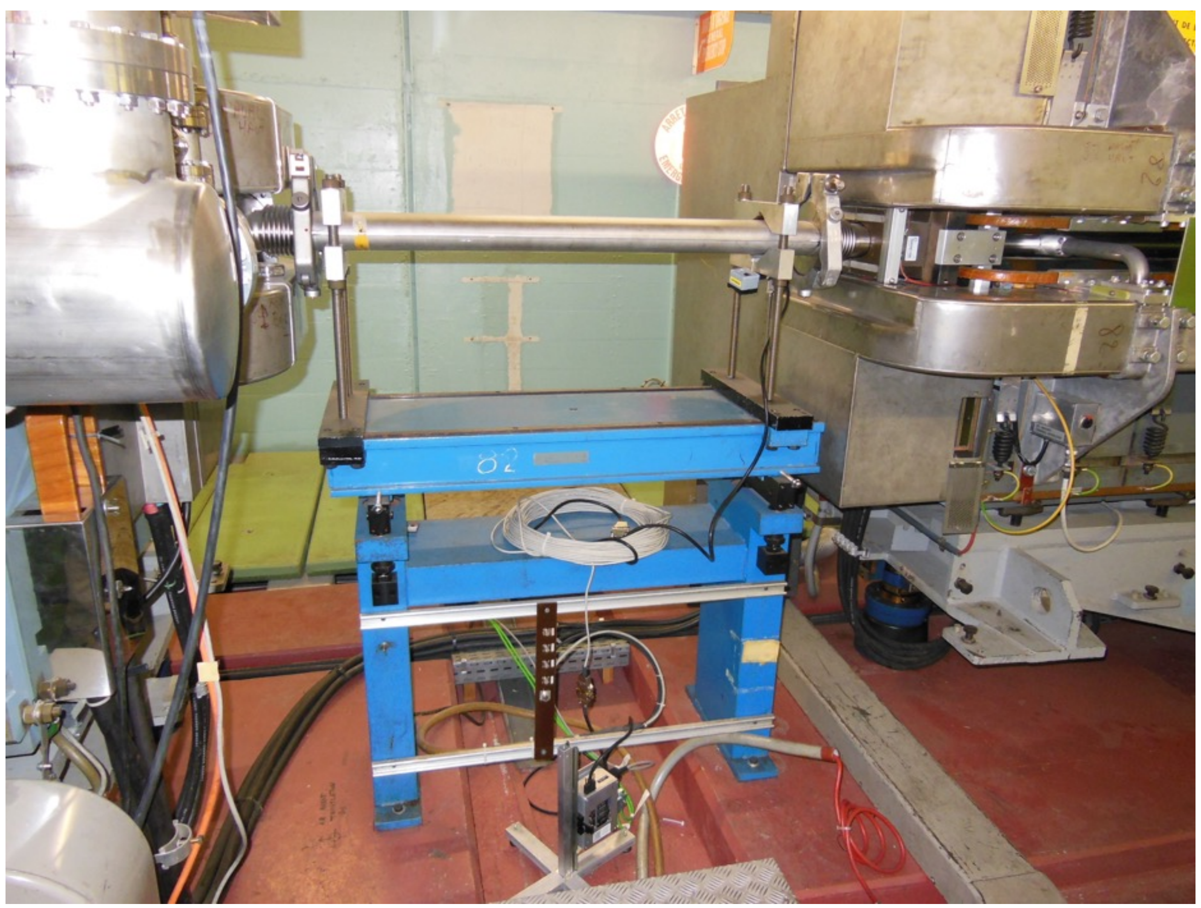


Recap: Operational specification.

- Measure horizontal (& vertical) **beam profile with $\Delta\sigma_x/\sigma_x$ =1%.**
- **Readout modes:**
    - **Basic mode:** Continuous measurement during the cycle averaged over all bunches @ 100-1000 acquisitions/s.
    - **Normal mode:** Continuous bunch-by-bunch measurement during the cycle @ 100-1000 acquisitions/s.
    - **Burst mode:** Bunch-by-bunch & turn-by-turn for 5000 turns at chosen moment of the cycle.

Recap: PS constraints.

- Gas injection not ~~possible~~ desirable (ion cross-section).
- Outgassing $\leq 1\cdot10^{-7}$ mbar·l·s^{-1}.
- Radiation: 10 kGy/yr at beam pipe, 1 kGy/yr at 40 cm.
- Mechanical:

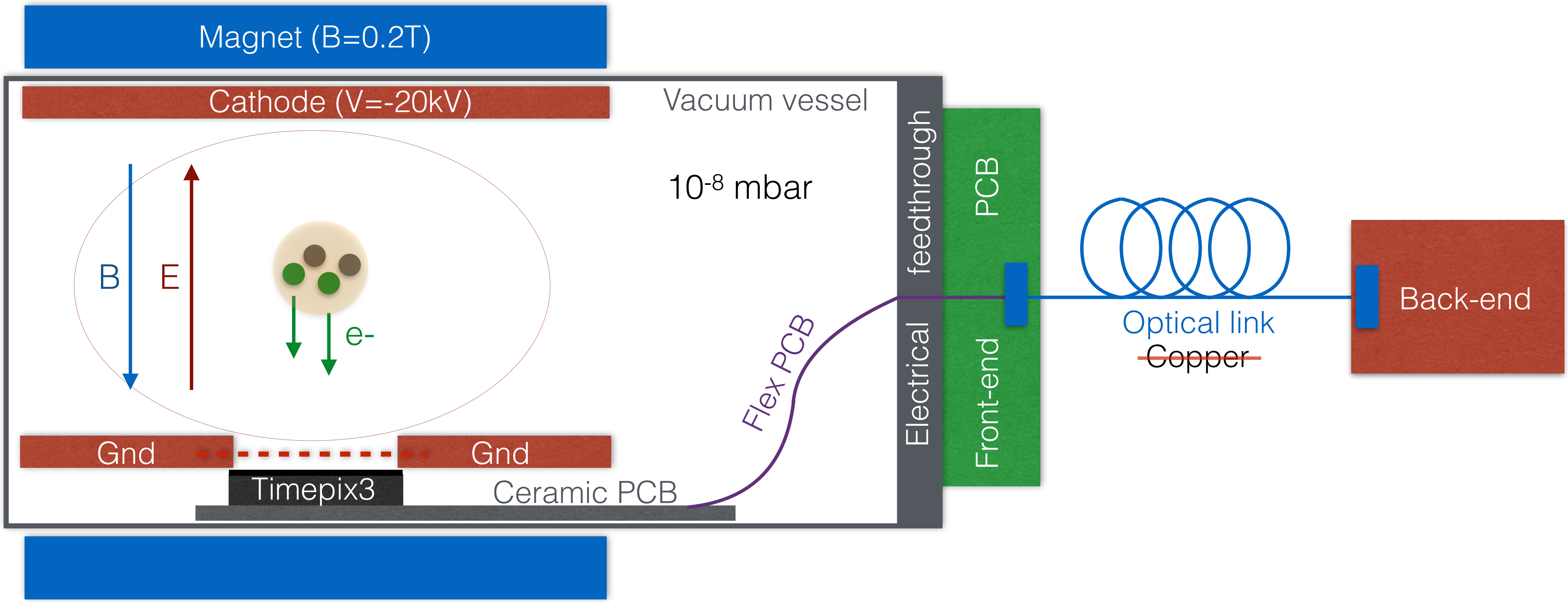


80 cm

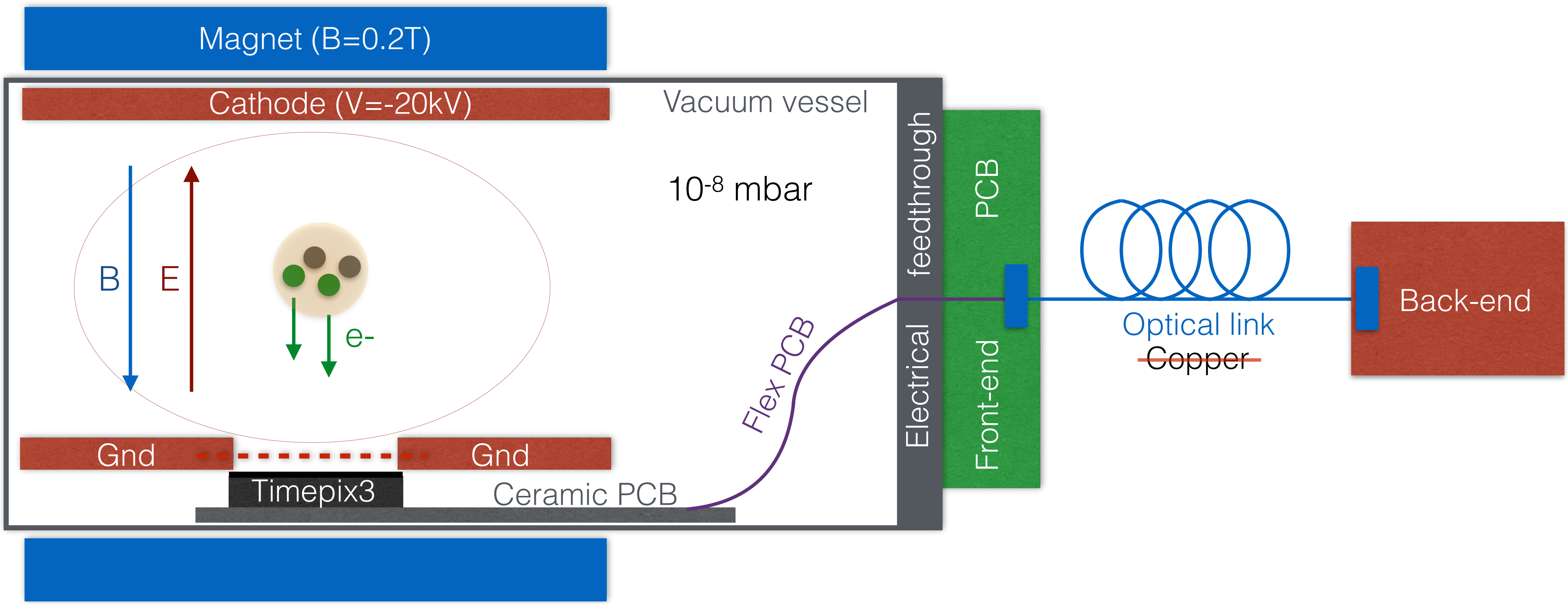
7.0 cm

14.6 cm

Recap: Conceptual design.



Recap: Conceptual design.



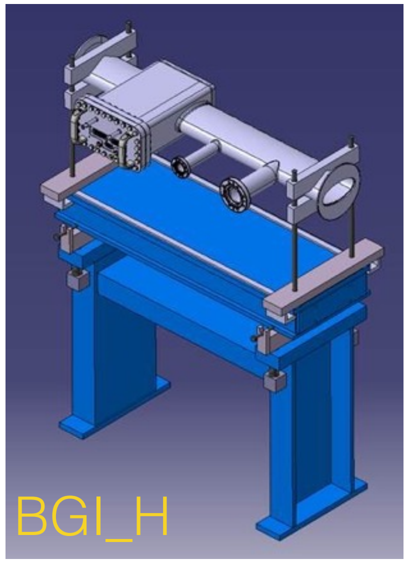
Main challenge/R&D:

High speed (20 Gbit/s) pixel detector readout; compatible with the PS vacuum, radiation & beam RF environment.

Timeframe.

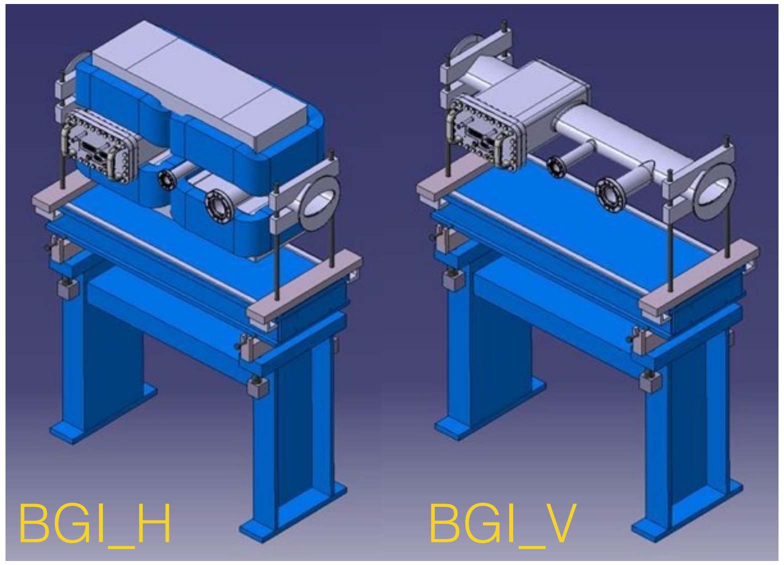
June 2016 technical stop:

- Installation of **horizontal BGI** vacuum vessel and prototype detector.

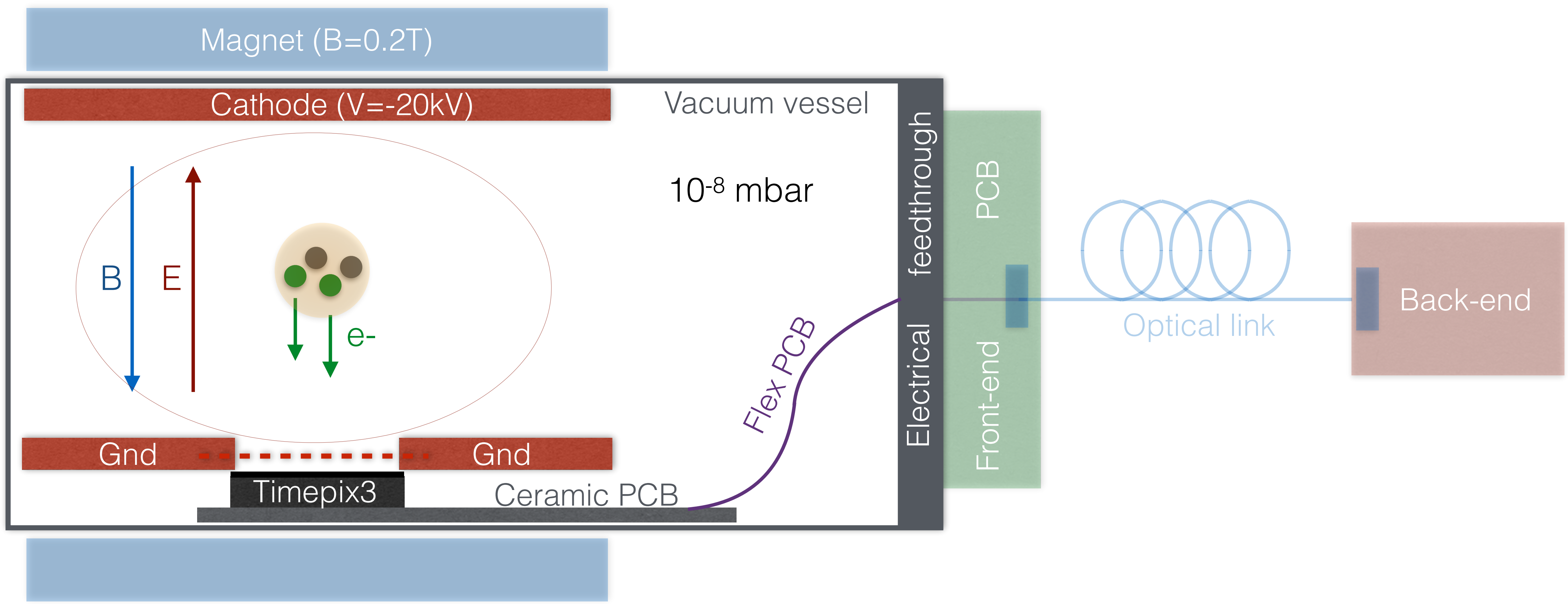


EYETS 16/17:

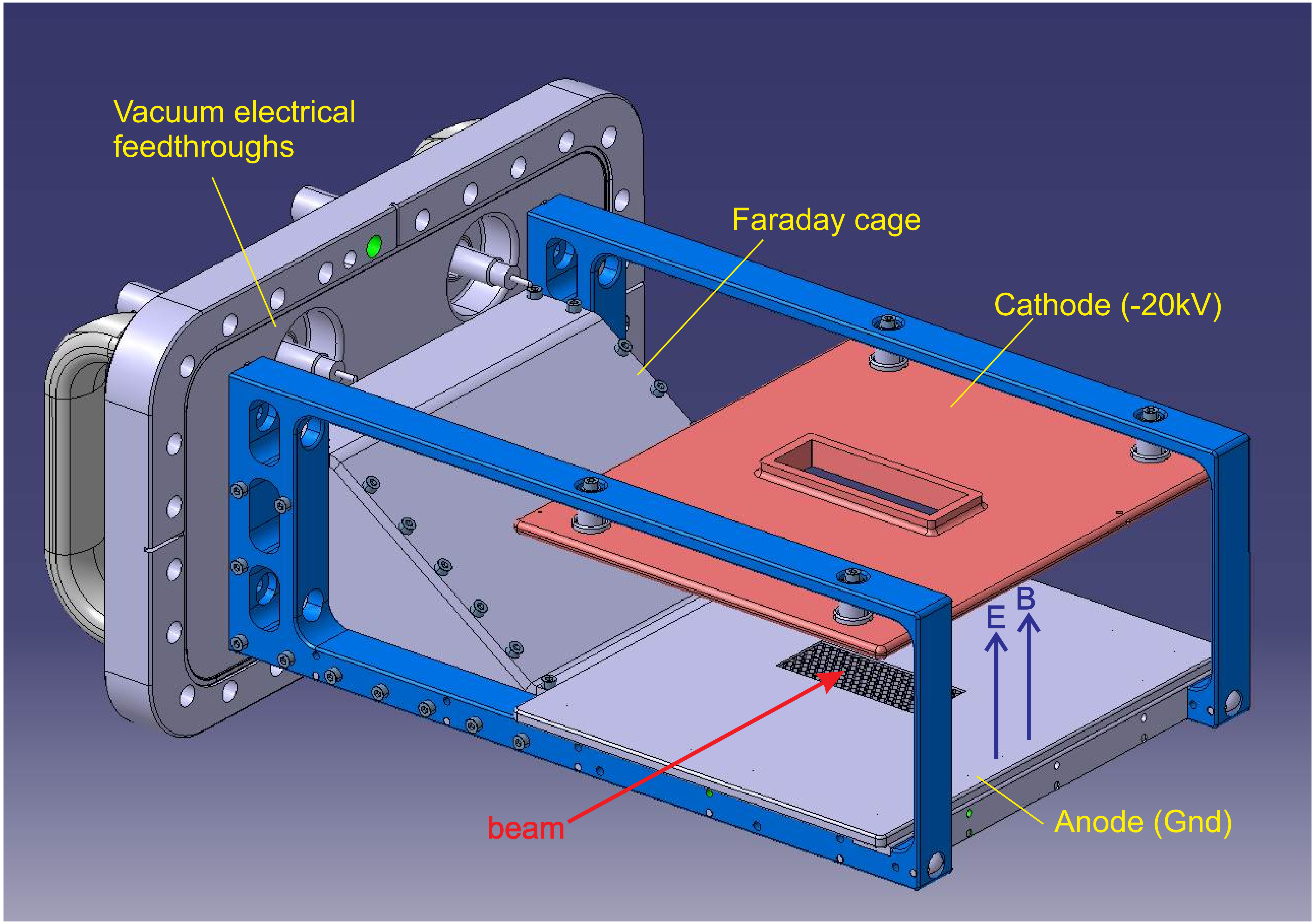
- Installation of magnet.
- Installation of **vertical BGI** vacuum vessel (+ detector(?)).
- Deployment of optical based readout system.



In-vacuum components:
Field cage & Pixel detector.

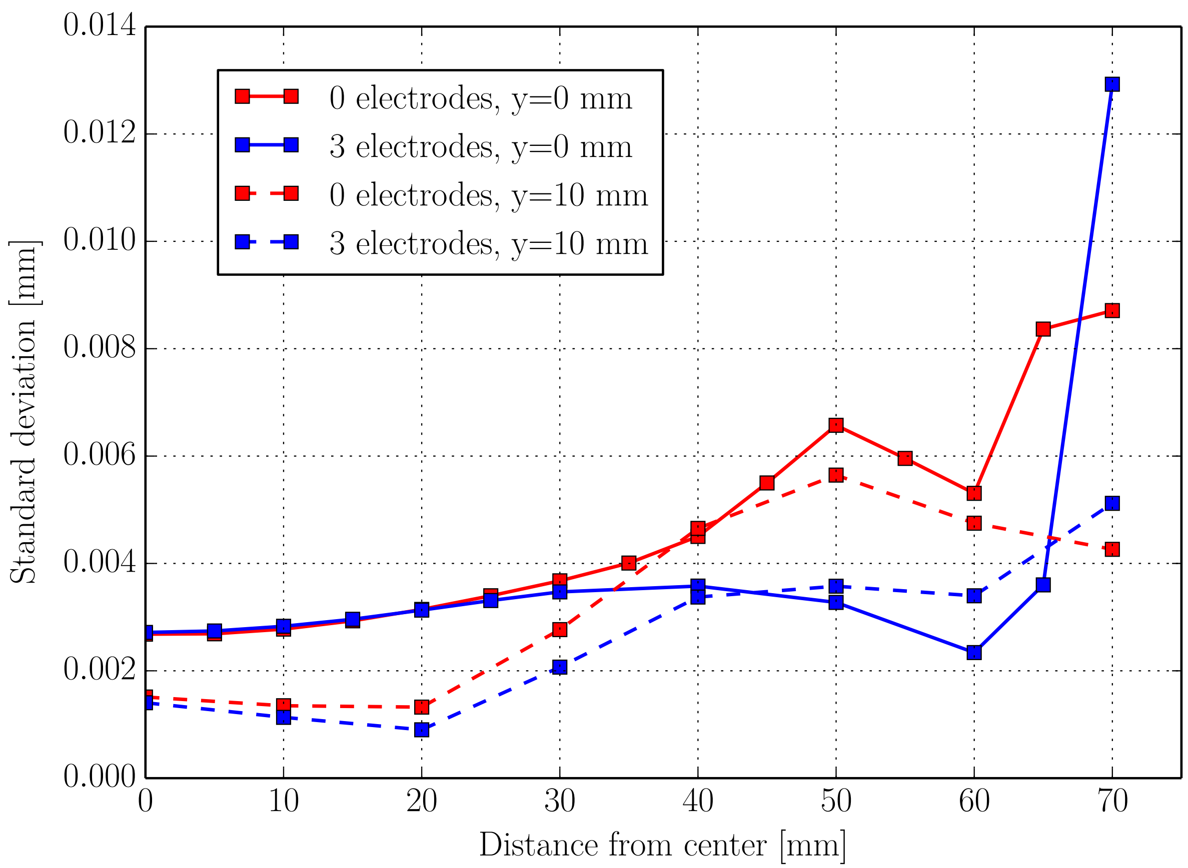


Field cage: Technical design.

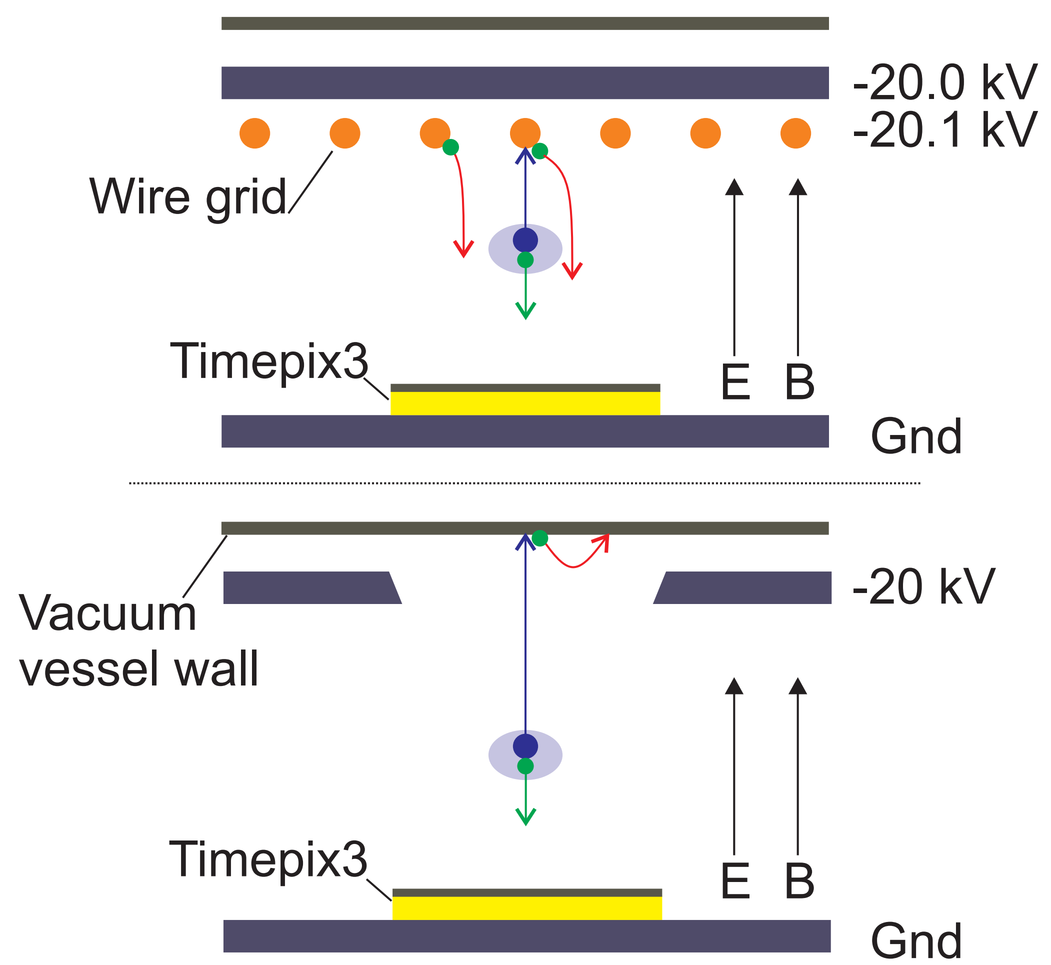


Field cage: Novel design elements.

Side-Electrodes



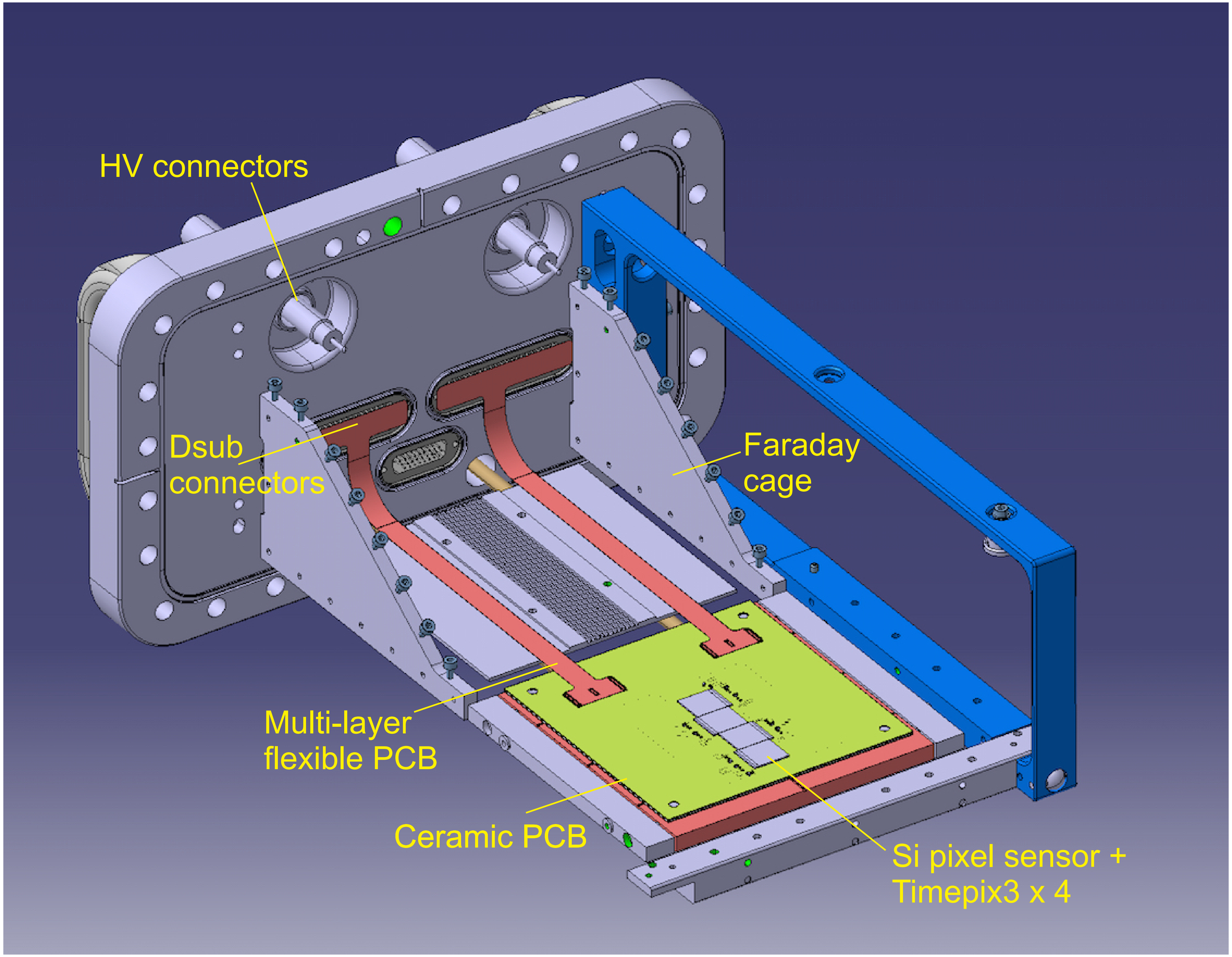
Ion Trap



BGI simulation.

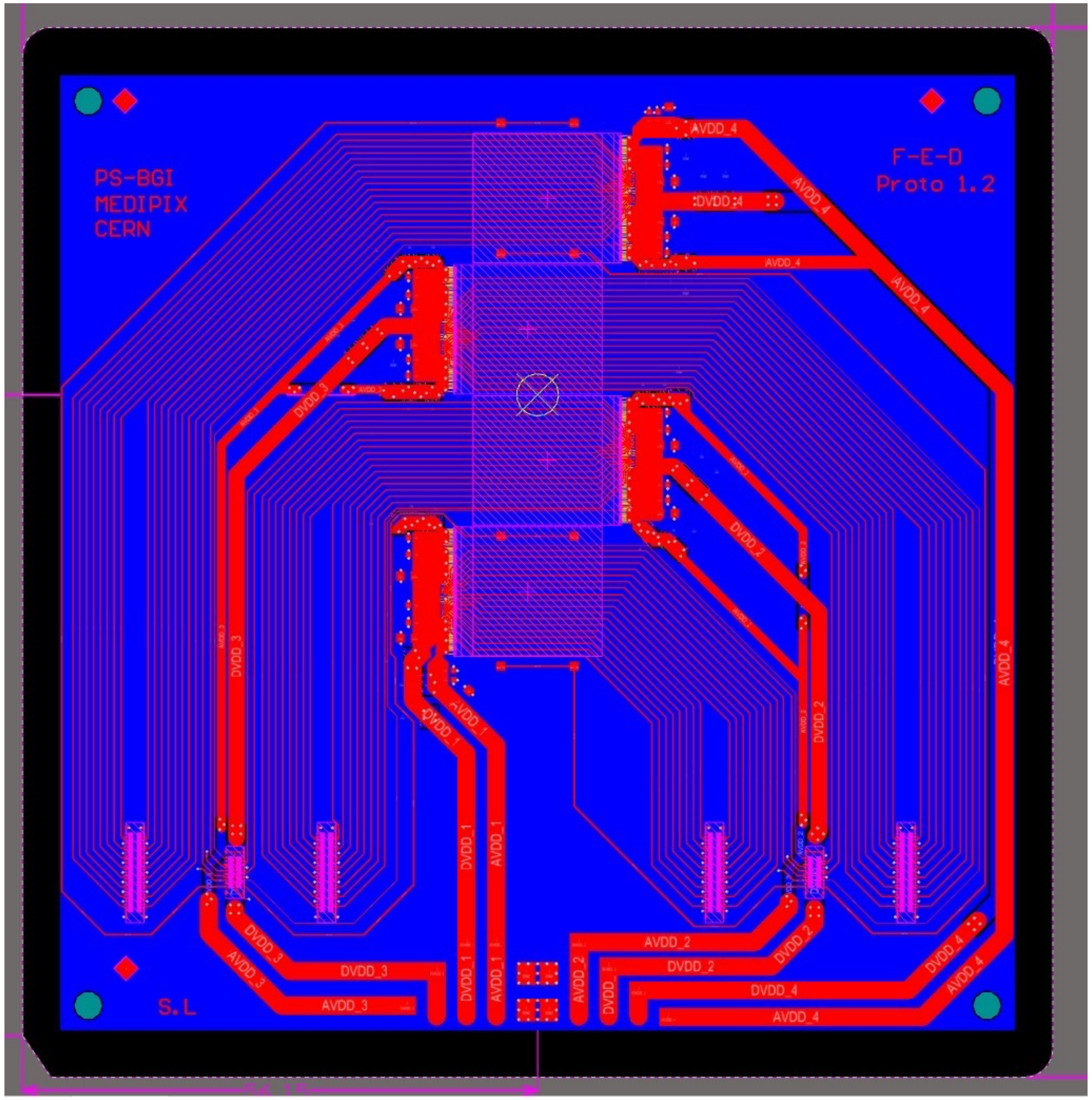
- Bottom up simulation of IPM performance.
- Includes effect of:
    - space charge,
    - initial momentum of ionisation electron,
    - magnetic field inhomogeneity,
    - electric field inhomogeneity.
- Validated on LHC BGI data.
- Distortion < 0.1%; even with factor 10 higher beam intensity.
- Extremely useful for:
    - ion trap & side electrode design,
    - specification of B-field strength & homogeneity.
- Tentative ideas for inter-lab collaborative project to produce & maintain a validated IPM simulation code.

Pixel detector: Technical design.

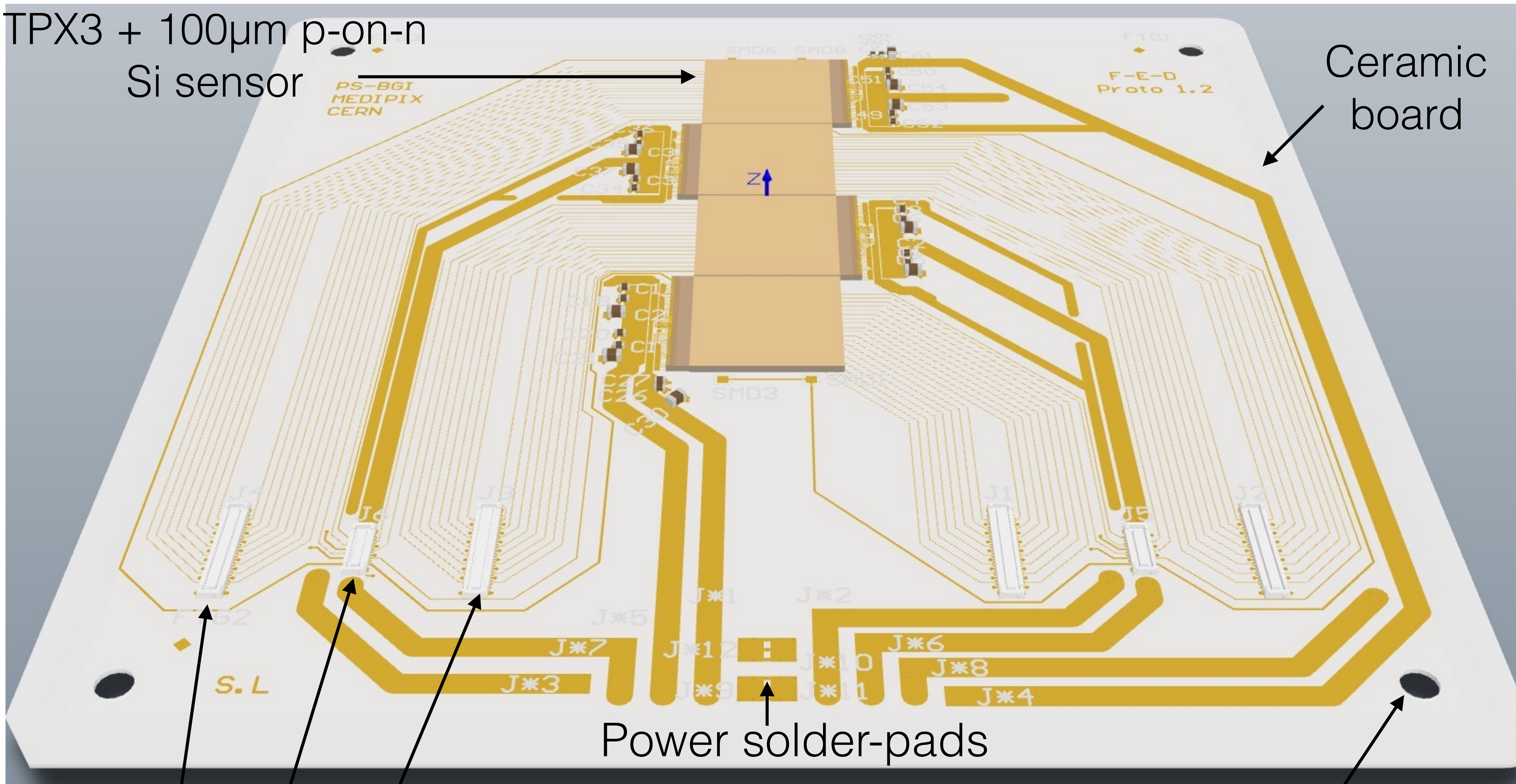


Pixel detector: Design challenges.

- Ultra High Vacuum (<10e-9 mbar).
- High Radiation levels (>10 KGy/yr).
- Minimal space available (<1.5mm).
- Long delay between accesses.
- High speed digital interface (5.12 Gb/s per TPX3).
- TPX3 requires ultra thin trace spacing (30µm) and complex wire-bonding.
- Low temp cooling is a necessity.
- First attempt to place TPX chips in an accelerator beam pipe.

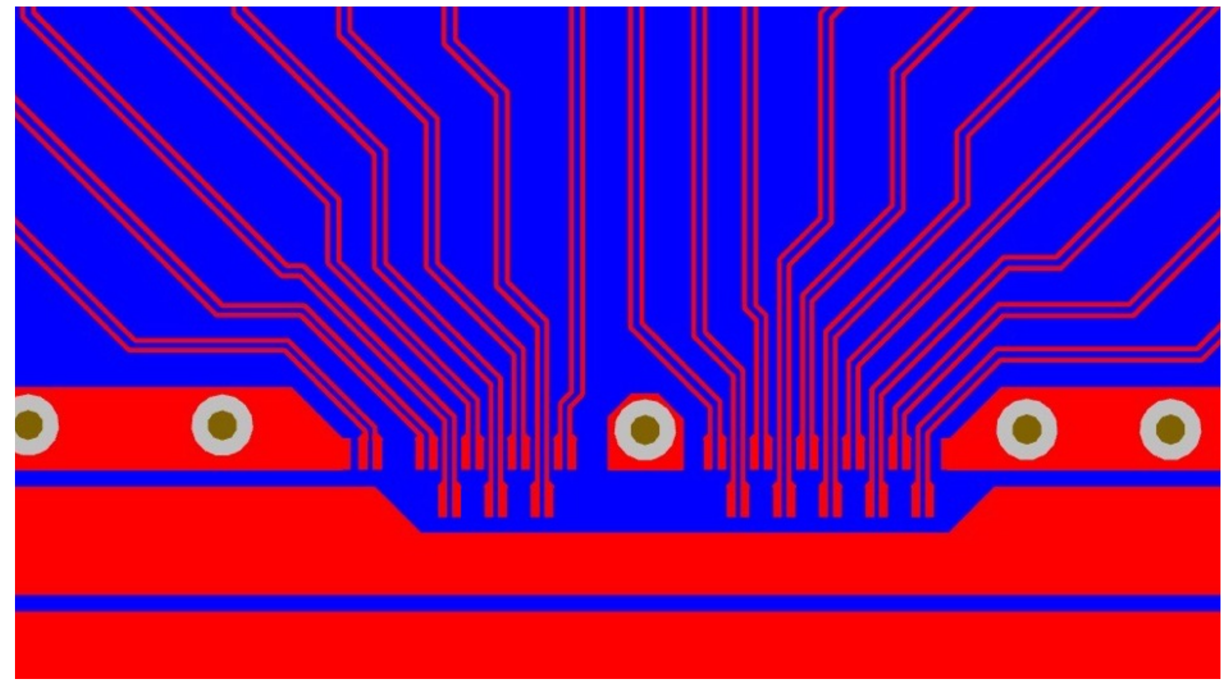


Pixel detector: Ceramic board.

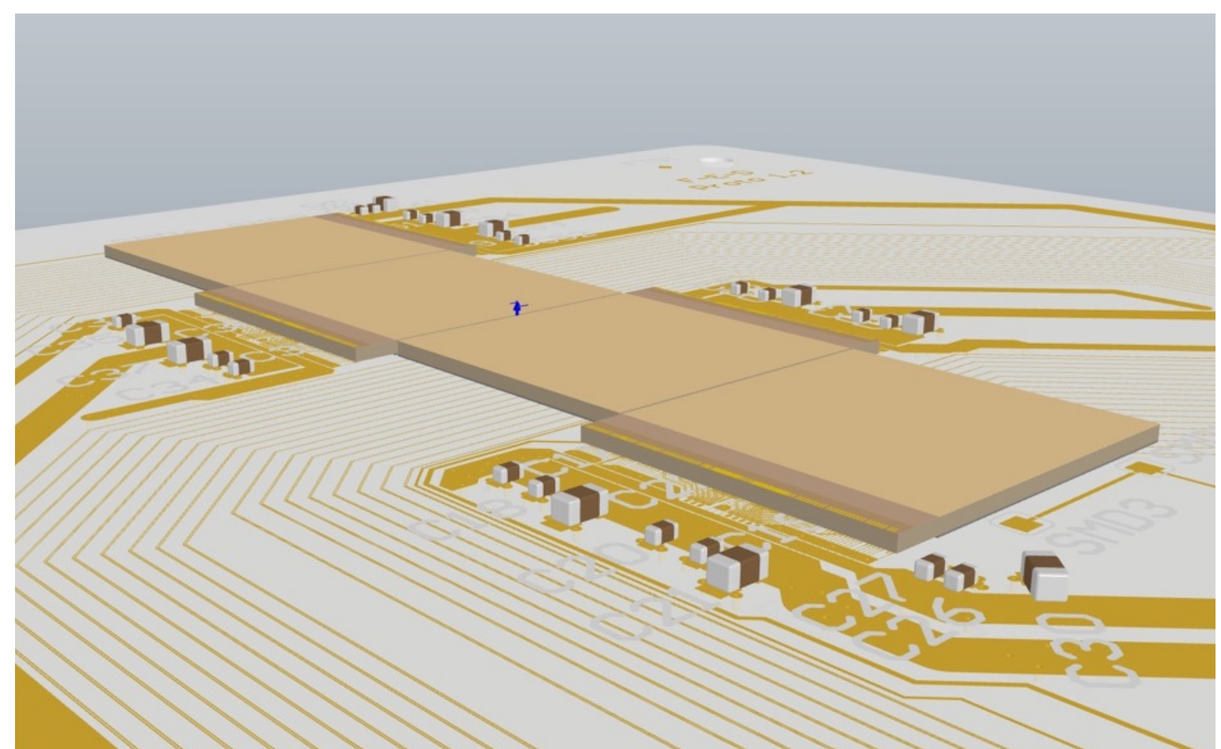


Pixel detector: Ceramic board.

- Careful selection of materials and processes.
- Careful control of track impedance and differential pair skew.

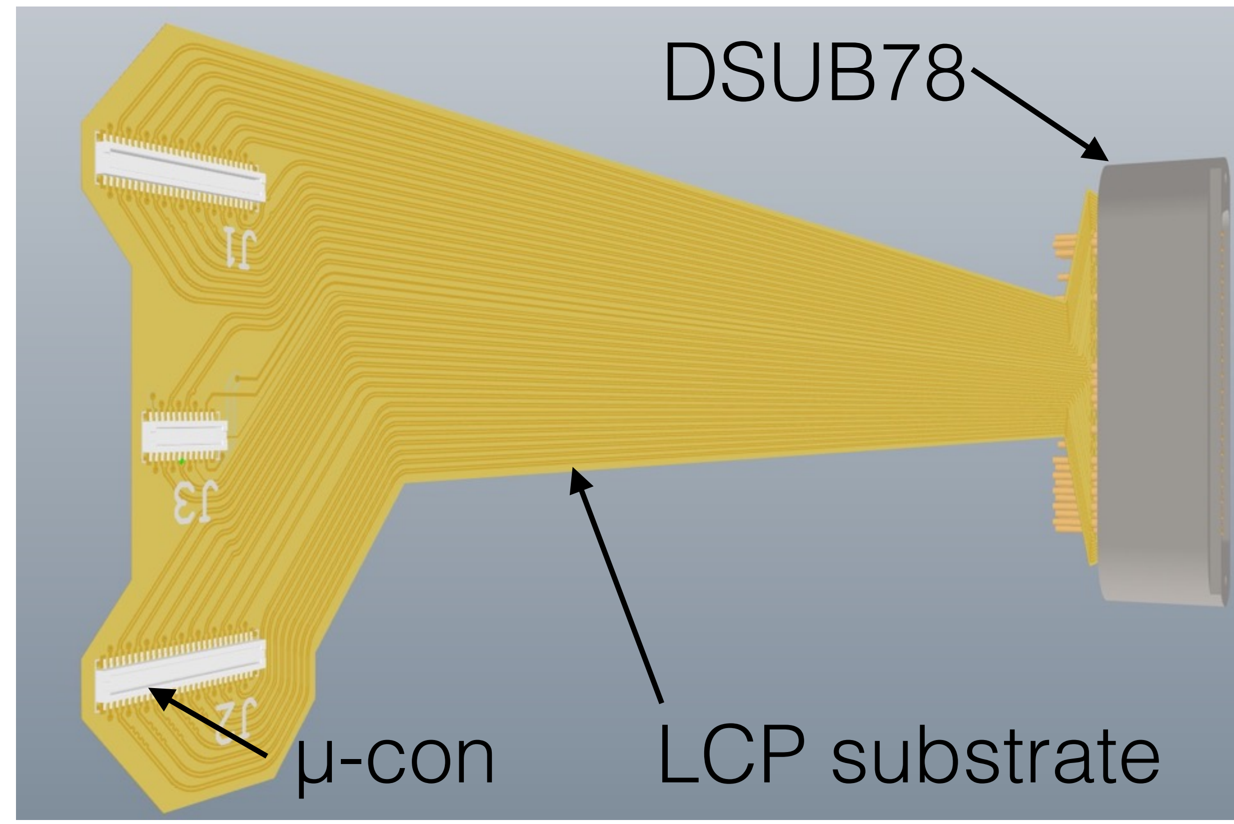


- 4 independent TPX3 (complete modularity for better reliability).

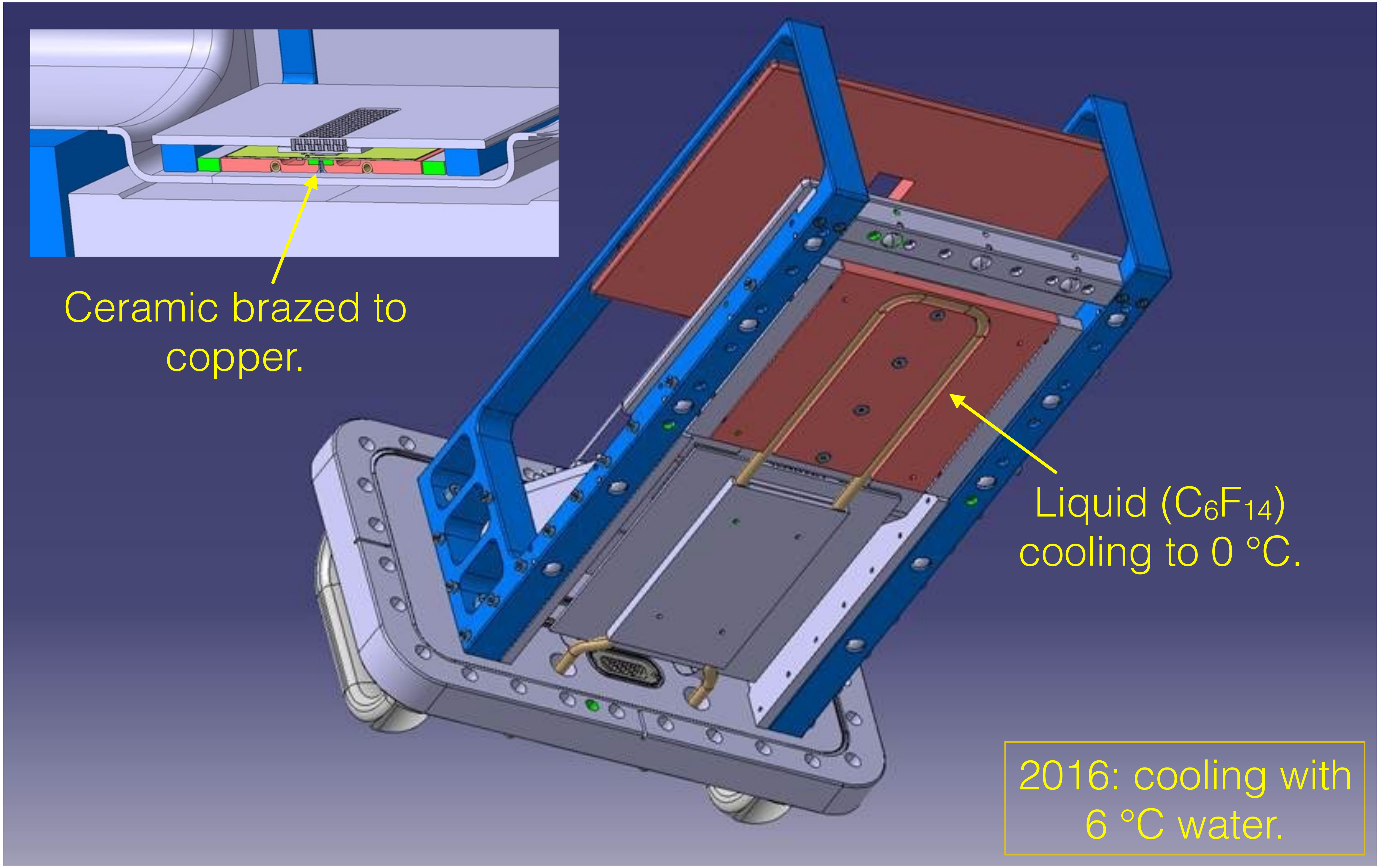


Pixel detector: Flexible cables.

- Link between the ceramic board and the flange.
- Custom design to fit with the ceramic board (ping-pong with the mechanical designer).
- Impedance and differential pair skew control.
- Vacuum qualified polyamide substrate.



Cooling.


Ceramic brazed to copper.
Liquid (C_6F_{14}) cooling to 0 °C.
2016: cooling with 6 °C water.

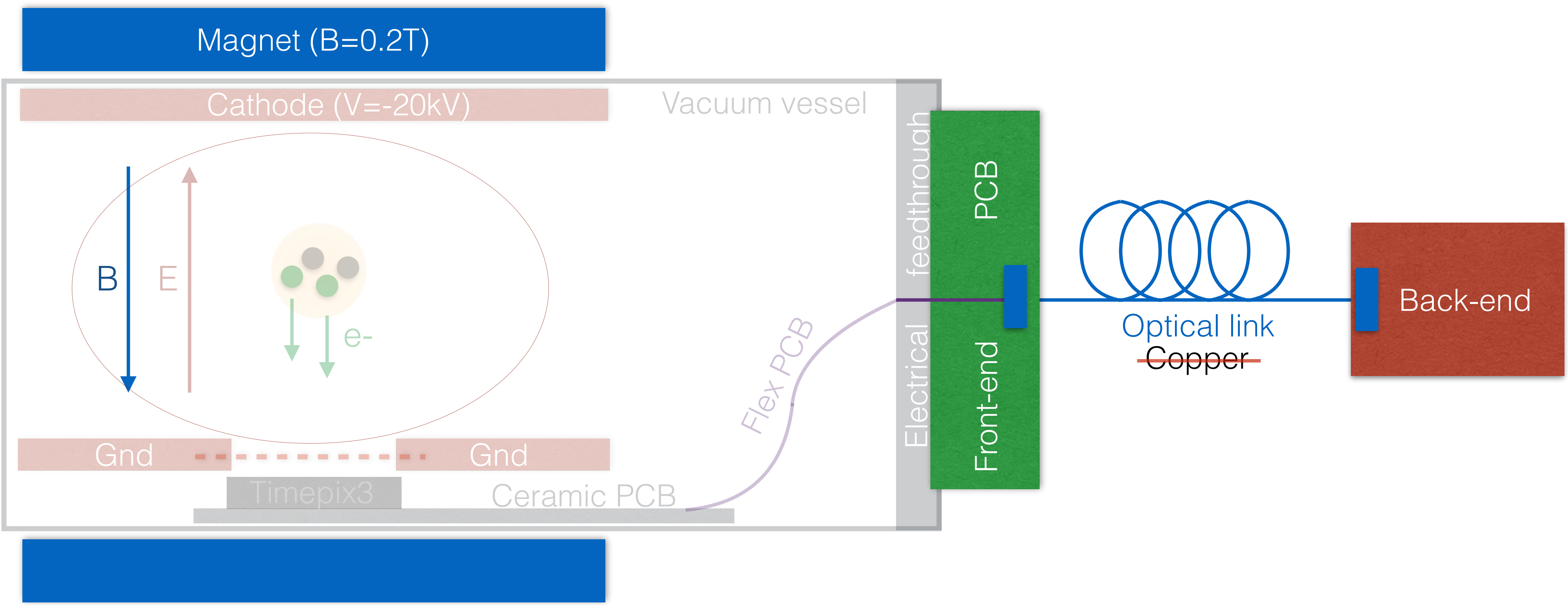
Status of significant components.

Component	Status
Vacuum vessel & electrical feedthrough	Manufacture at CERN central workshop. Delivery Feb. 2016.
Field cage	Manufacture at CERN central workshop. Delivery TBC.
Pixel detectors	Order placed with Advacam (Finland). Delivery Dec. 2015.
Ceramic PCBs	Order placed with Hightec (Switzerland). Delivery Dec. 2015.
Flex PCBs	Submitted to QPI (Netherlands). Expected within 1 month from order.

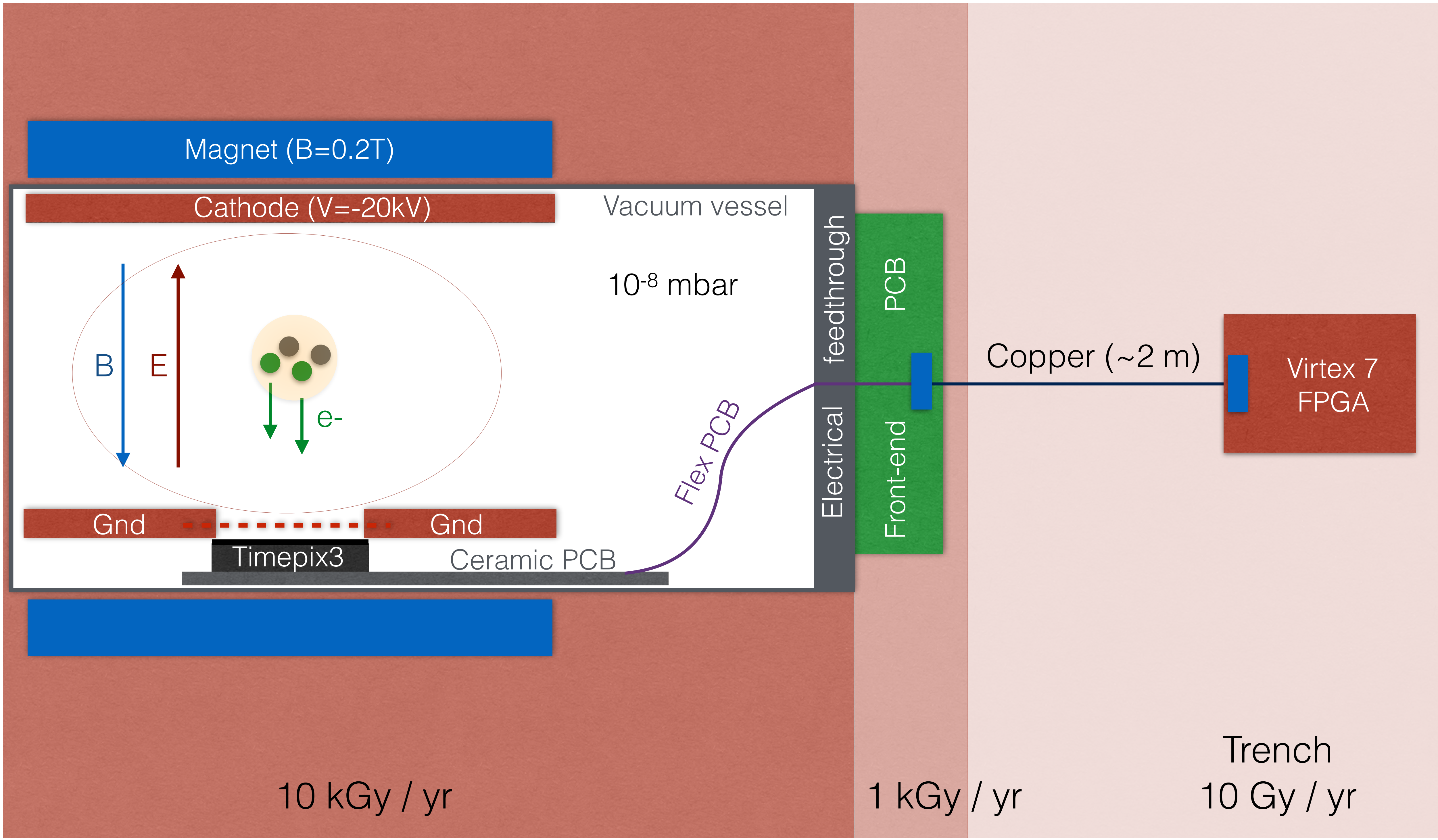
Plan for 2016.

Milestone	~ Date
ECR	Dec. 2015.
Test of in-vacuum readout electronic chain in the lab	Jan.-Feb. 2016.
Detection of keV electrons with lab setup	Feb.-Mar. 2016.
Assembly of in-vacuum components	Mar.-Apr. 2016.
Vacuum & impedance qualification tests	Apr. 2016.
Installation during PS technical stop	June 2016.
Operation of readout chain in the PS	> June 2016.
Reconstruction of beam profile in basic mode	> June 2016.

Out-of-vacuum components: Readout system & Magnet



Original readout architecture.



Readout architecture: Considerations.

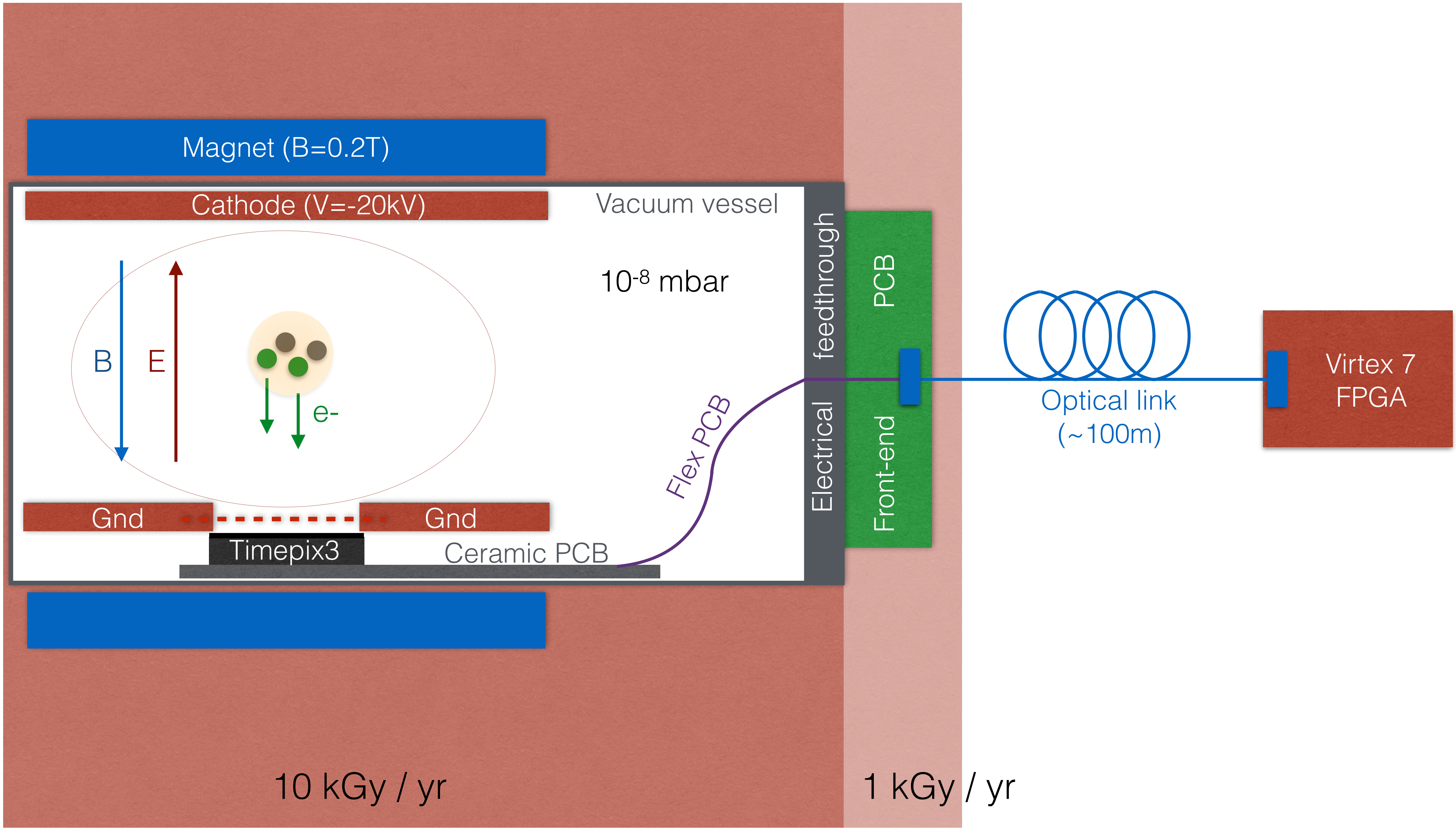
- First attempt to readout TPX3 through an UHV flange and one of the few applications to attempt full readout rate.
- TPX3 can be readout at 640, 320, 160 or 80 Mbps

  ➥ Run at lower rate in case of transmission problems.

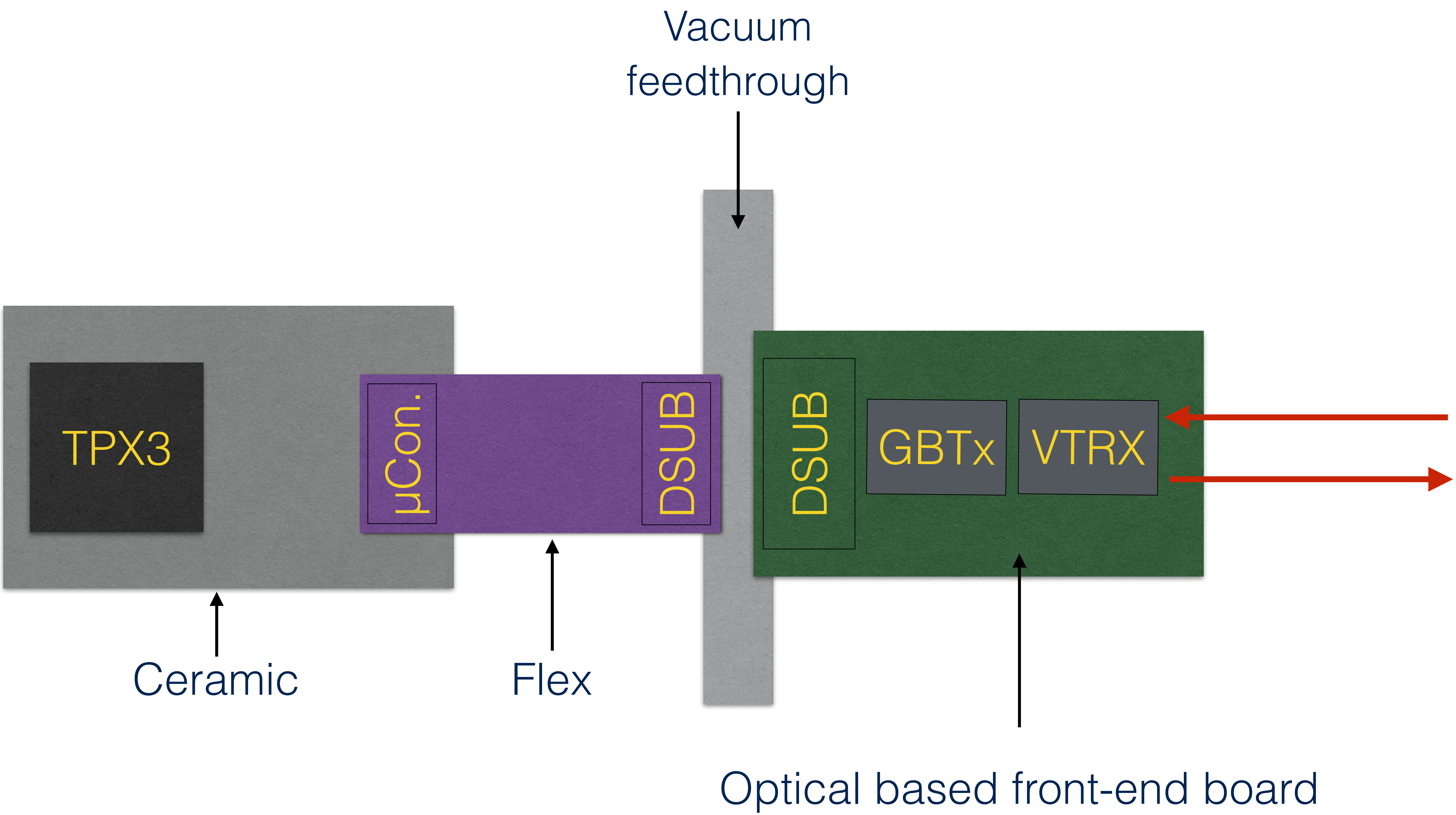
- To run at full data-rate (4 x 8 x SLVDS @ 640 Mbps) need to minimise track lengths and number of connectors.
- Reliability improved by moving Virtex7 FPGAs outside of the PS ring.

  ➥ Solution: transform SLVDS onto optical link.

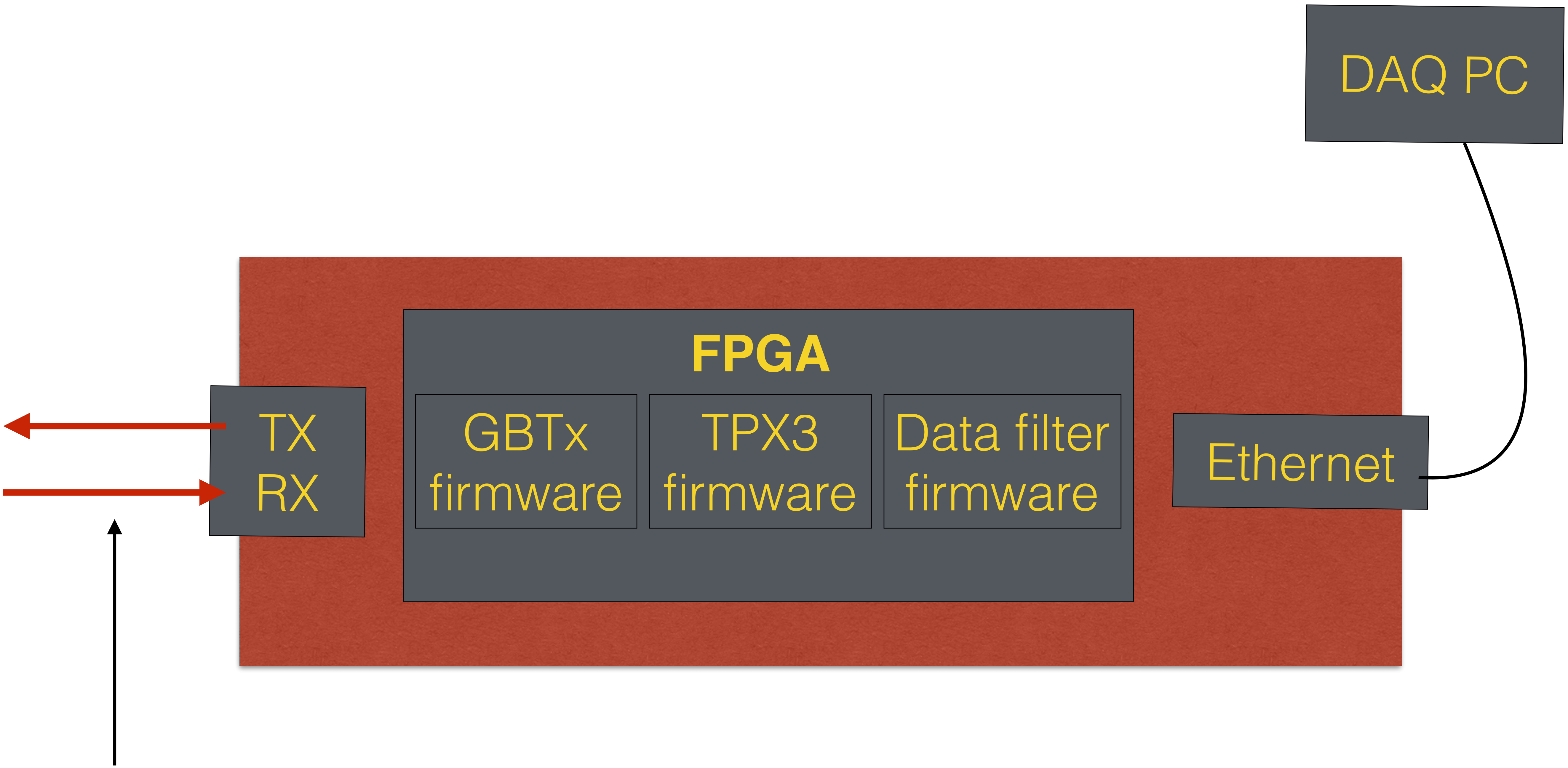
Optical based readout.



Optical readout: Front-end example.



Optical readout: Back-end example.

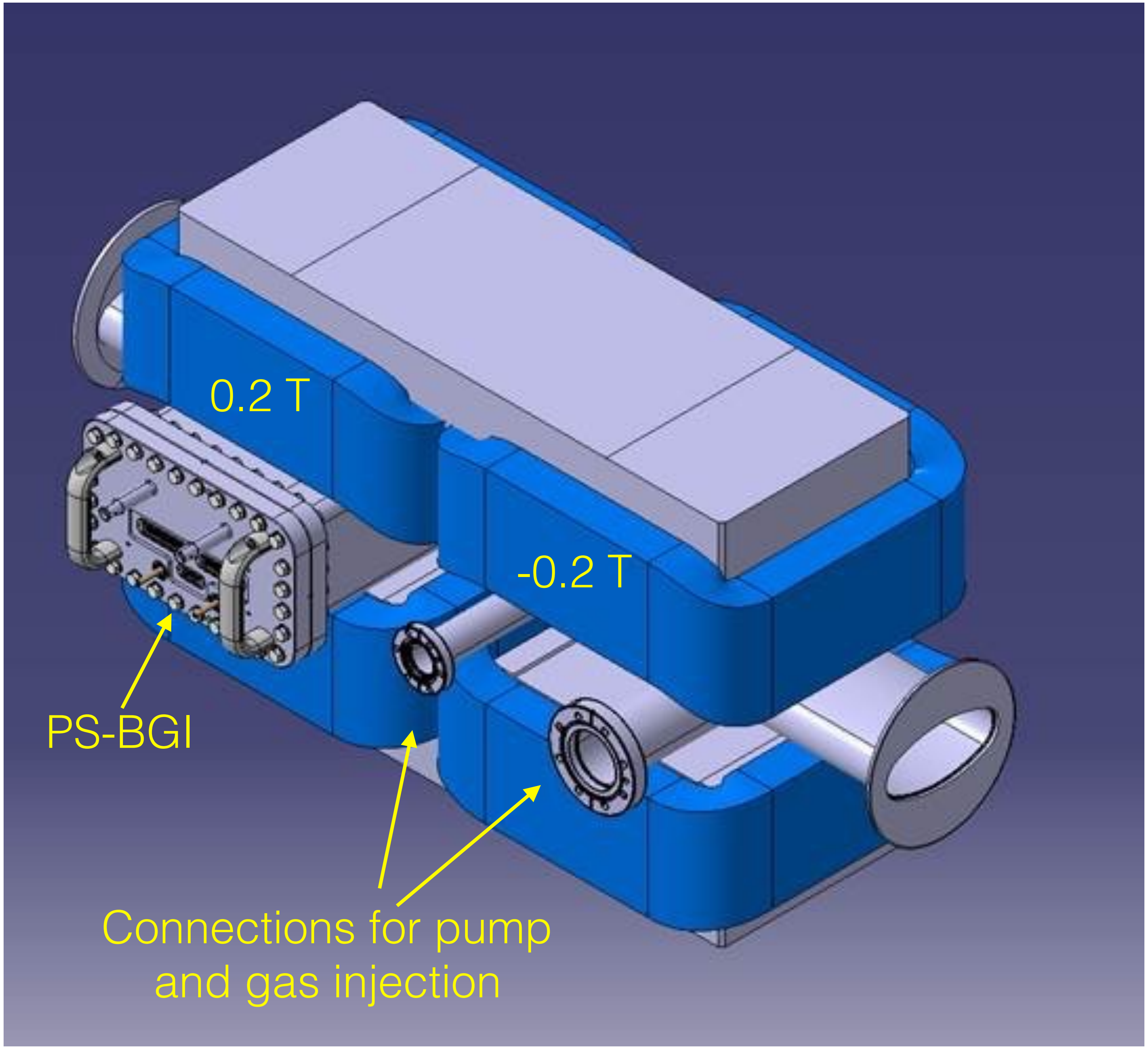


@ 640MHz -> 4 x 5.12 Gbit/s = 20.48 Gbits/s

Readout system: Plans.

- For June 2016 prototype plan to use original readout scheme:
  - TPX3 to FMC interface boards are available (PH-ESE-ME).
  - TPX3 FPGA firmware is available (NIKEF).
  - But need to develop software for our application.
- Begin development of optical based readout scheme in 2016:
  - Investigating what we could do with GEFE and GBTxFMC (from Marcel Rossewij, Uni. of Utrecht.)
  - Installing optical fibers during the YETS. Could exchange readout during a TS.
  - Exact strategy to be defined…

Magnet: Technical design.



Magnet: Status.

- Technical design complete; now producing production drawings.
- Solid yoke (non-laminated) design.
- Delivery for magnetic field measurements ~ June 2016.
- Installation during EYETS 16/17.

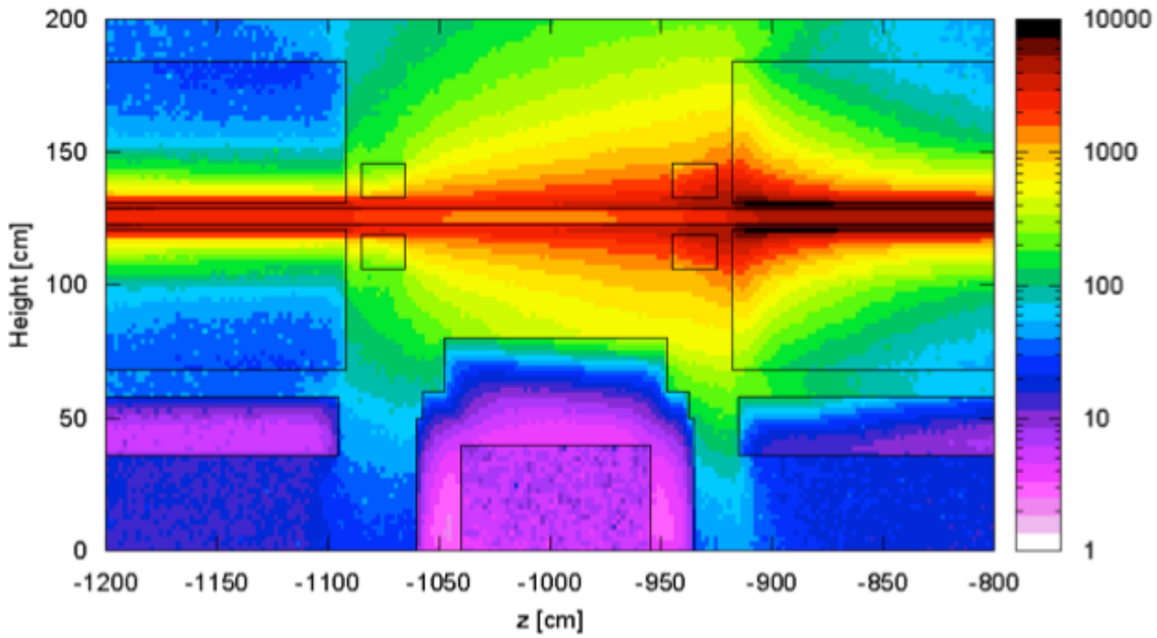
Summary.

- BGI design complete & performance verified by simulation.
- Vacuum vessels & electrical feedthroughs submitted for production to the central workshop.
- Pixel detectors and ceramic boards ordered.
- Lab tests of the readout chain in Jan.-Mar. 2016.
- Prototype will be installed during June 2016 technical stop.
- Work towards optical readout in 2016.

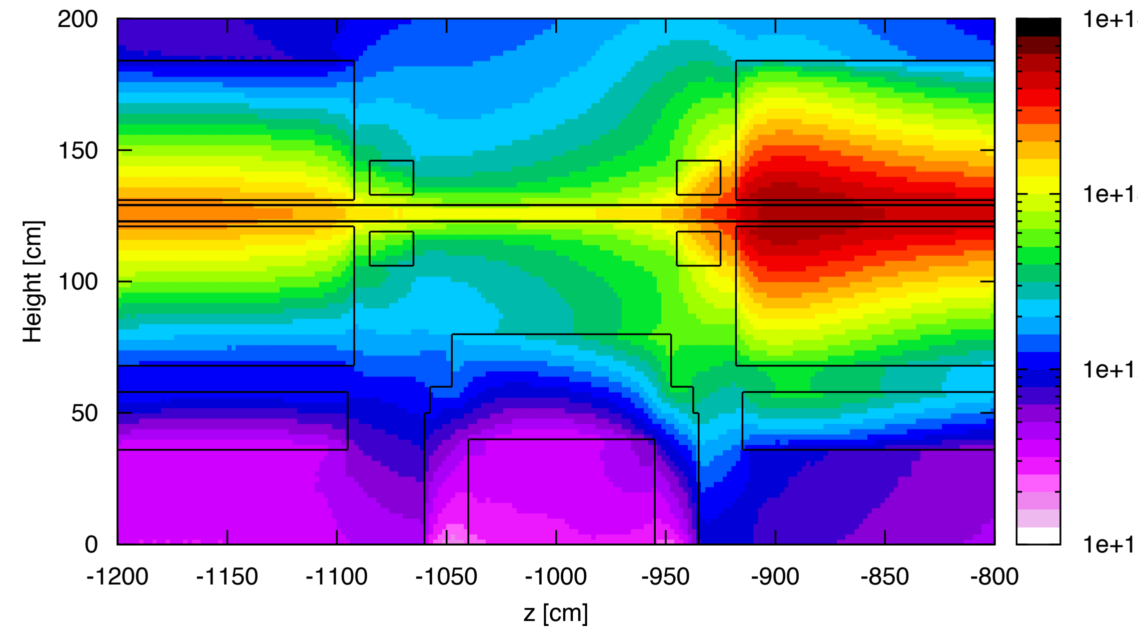
Backup Slides.

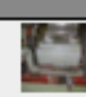
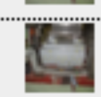
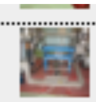
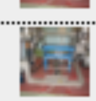
Radiation levels.

SS02 TID (Gy/yr)



SS02 1MeV Eq Fluence



#	PS	S [m]	location[1] 05/2014	Picture	TID[2] [Gy/y] (2011-2012)	TID[3] [Gy/y] (2011-2012)	TID[4] [Gy] (20-11-2014)	TID[4] [Gy] (04-01-2015)
01	PR.SIMA1	8	SS02_Sh		1400	**7**	0.0	**0.1**
	PR.SIMAD1	8	SS02		1400	**70**	16.2	**23.6**
13	PR.SIMA13	510.5	SS82		500	**25**	1.6	**4.0**
	PR.SIMAD13	510.5	SS82		500	**500**	103.6	**201.4**

Electron production rates.

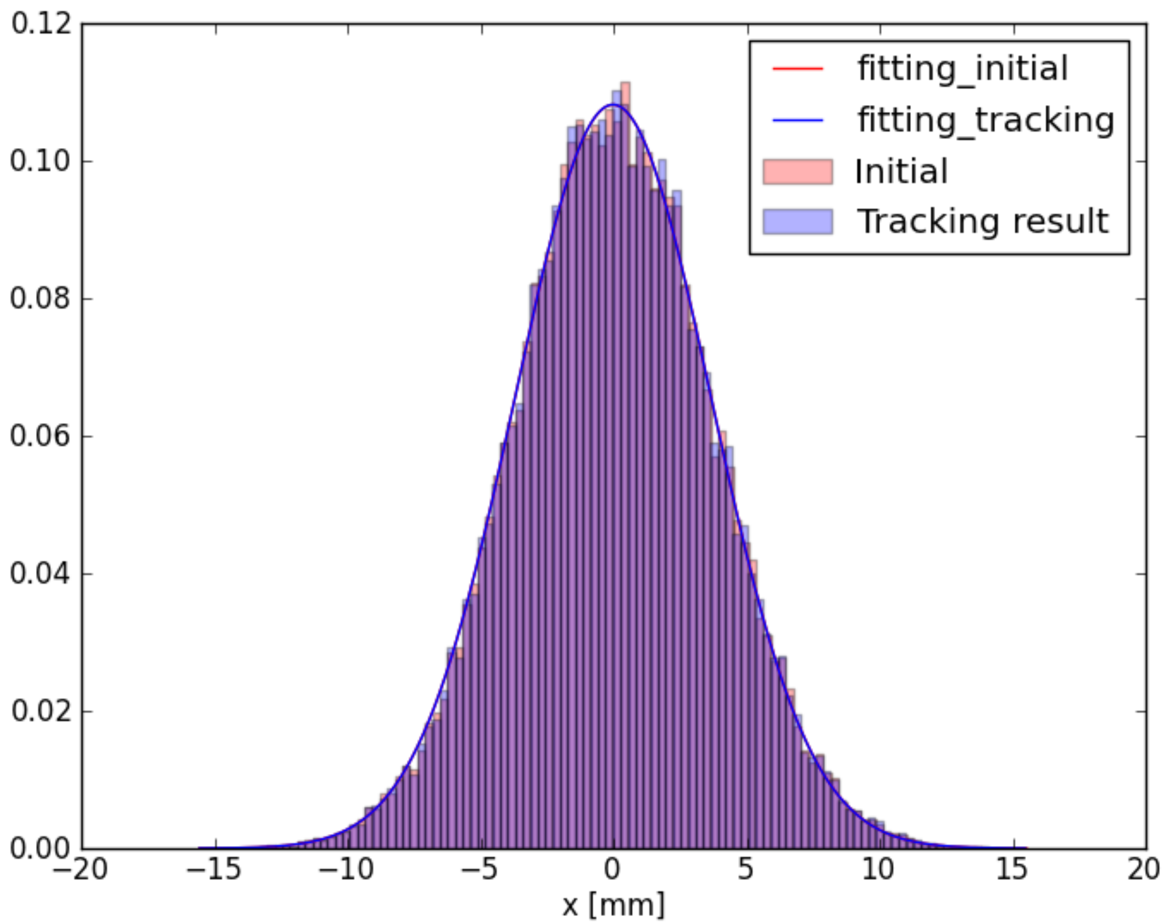
Table 2: Electron Production Rate for Various Beams

name	achieved 25 ns		LIU 50 ns		HL-LHC 25 ns		LHC ion	
particles	**p**	**p**	**p**	**p**	**p**	**p**	Pb^{54+}	Pb^{54+}
E_k [GeV]	1.4	25	2	25	2	25	15.02	1227
emittance [μm]	2.25	2.36	1.7	1.8	1.8	1.9	0.7	1.0
N_b [$\cdot 10^{10}$]	168	13	189	30	325	25.7	0.03	0.025
bunch length ($4\sigma_l$) [ns]	180	3	205	3	205	3	200	4
$\Delta p/p$ [10^{-3}]	0.9	1.5	1.0	1.5	1.5	1.5	1.2	1.1
σ_{beam} [mm]	3.9	3.7	3.5	3.7	4.4	3.7	4.0	2.9
number of bunches (n_b)	6	72	6	36	6	72	2	2
n_e (H_2)	13	1	14	2	24	2	30	5
R^{av}_{chip}[MHz] $= \frac{n_e \cdot n_b}{\tau_{rev}[s]}$	37	34	40	34	69	69	11	4.8
R^{max}_{chip}[GHz] $= \frac{0.68 \cdot n_e}{2 \cdot \sigma_l[s]}$	0.1	0.5	0.1	0.9	0.2	0.9	0.2	1.7
R^{av}_{pixel}[kHz] $= \frac{n_e \cdot n_b \cdot 55[\mu m]}{255 \cdot \sigma_{beam}[\mu m] \cdot \tau_{rev}[s]}$	2.0	2.0	2.5	2.0	3.4	4.0	0.2	1.7

Performance with & without magnetic field.

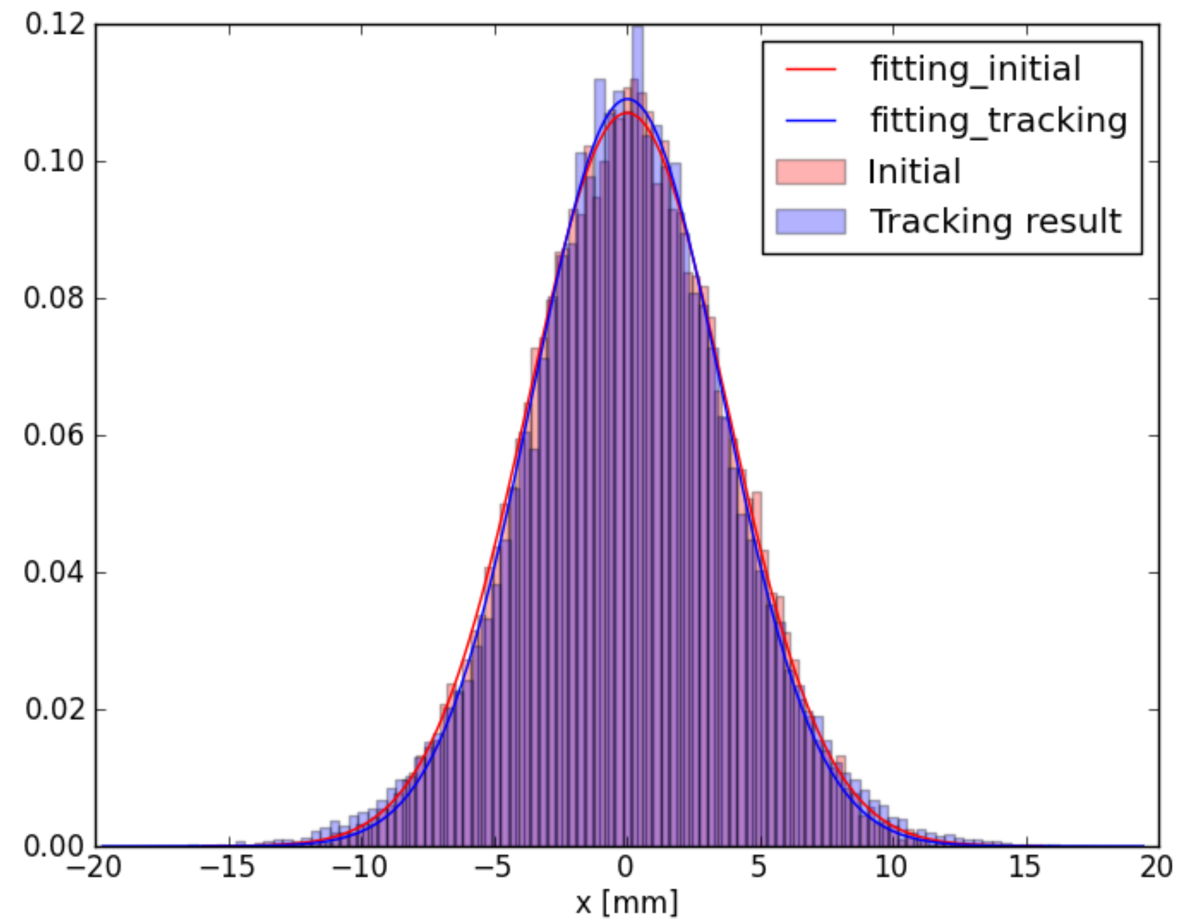
Input: LIU/STD 25ns, extraction: σx=3.7mm

B=0.2 T



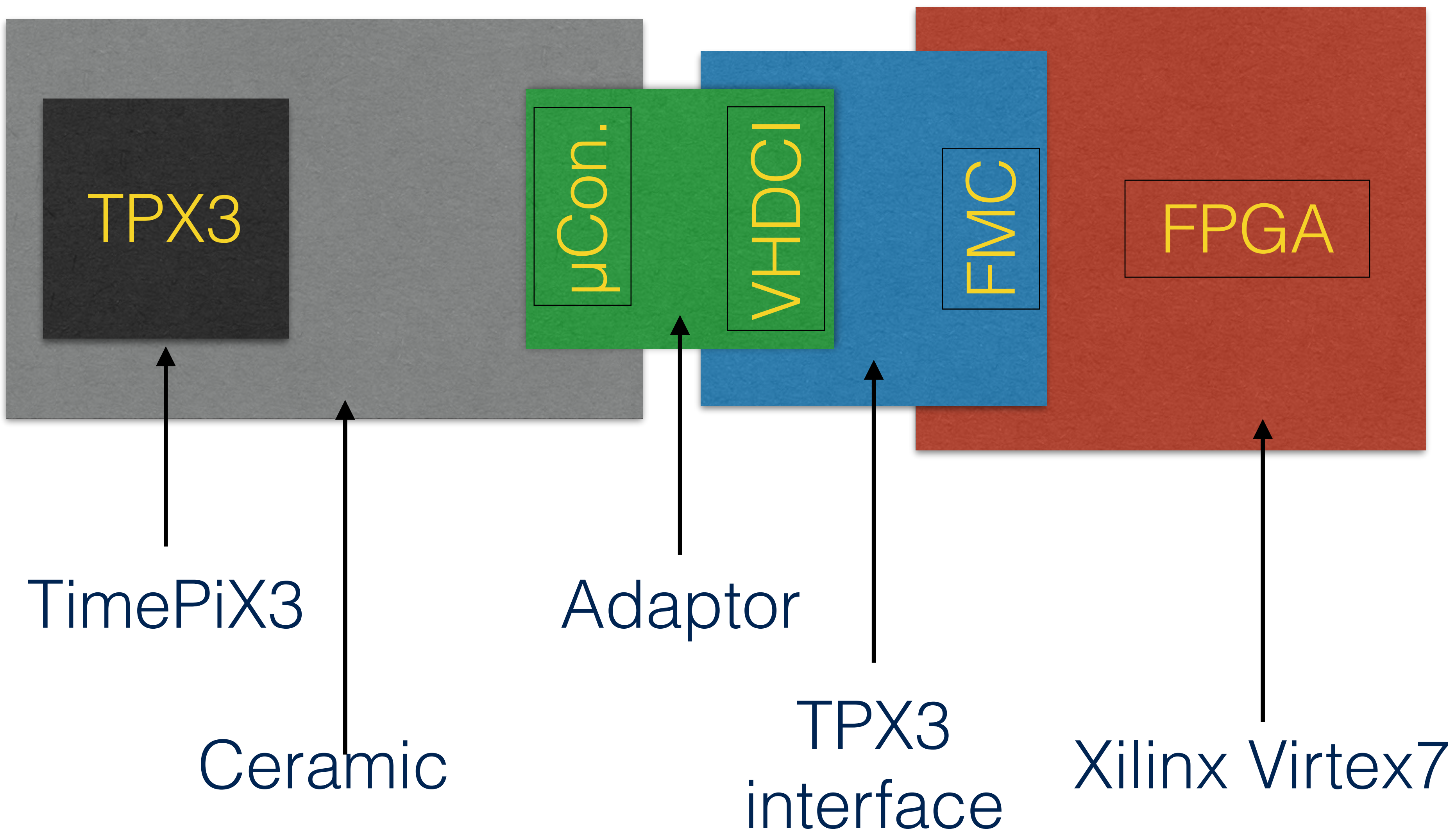
Gauss fit:3.6845->3.6834mm(-0.03%)

B=0 T

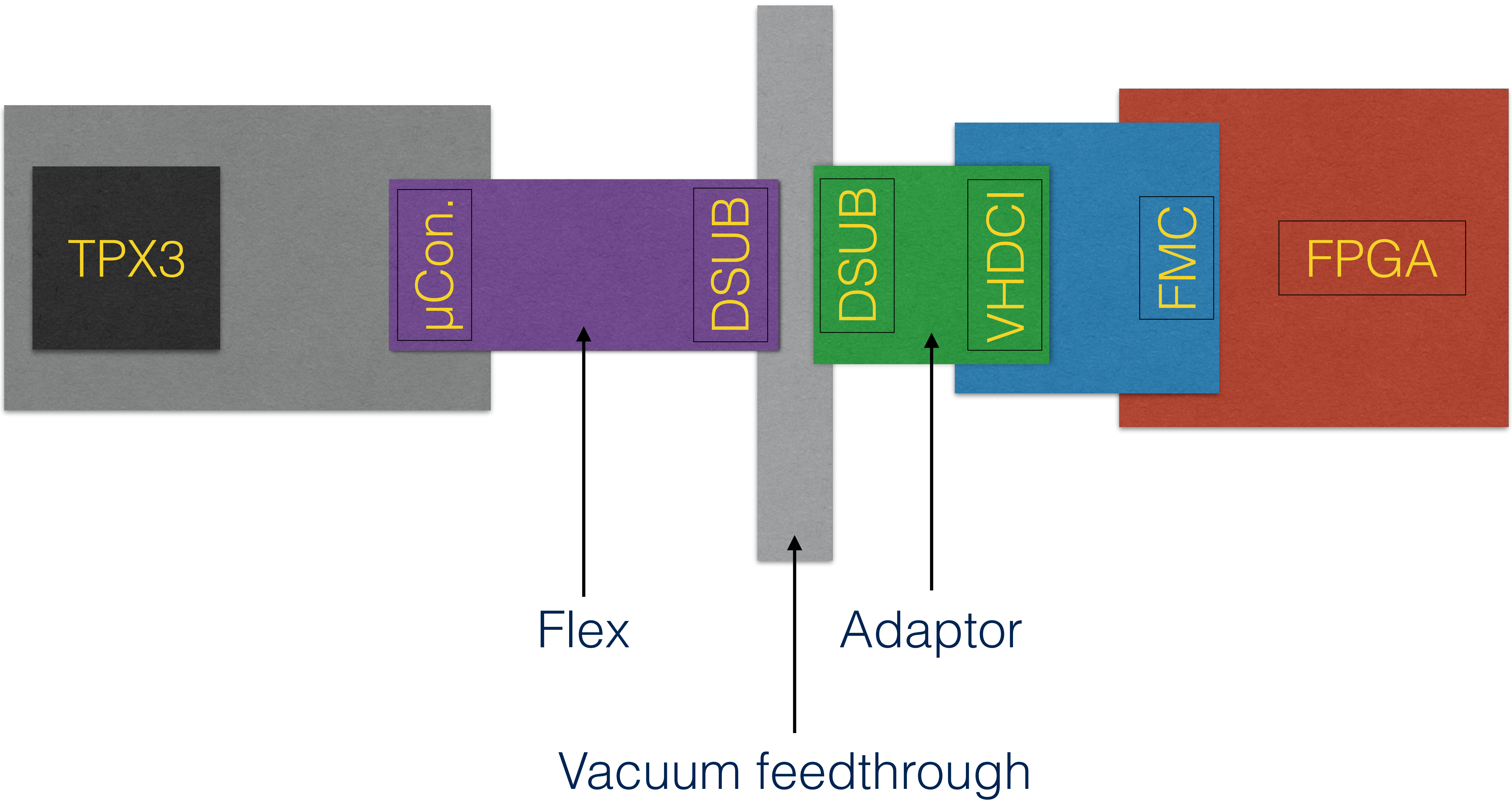


Gauss fit:3.57mm(+2.6%)

Lab test of ceramic PCB.



Lab test of flex & vacuum feedthrough.



Readout architecture for 2016 prototype.