WG4 – Progress report

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Outline

- Status of CDR - Chapter V
- Contents overview

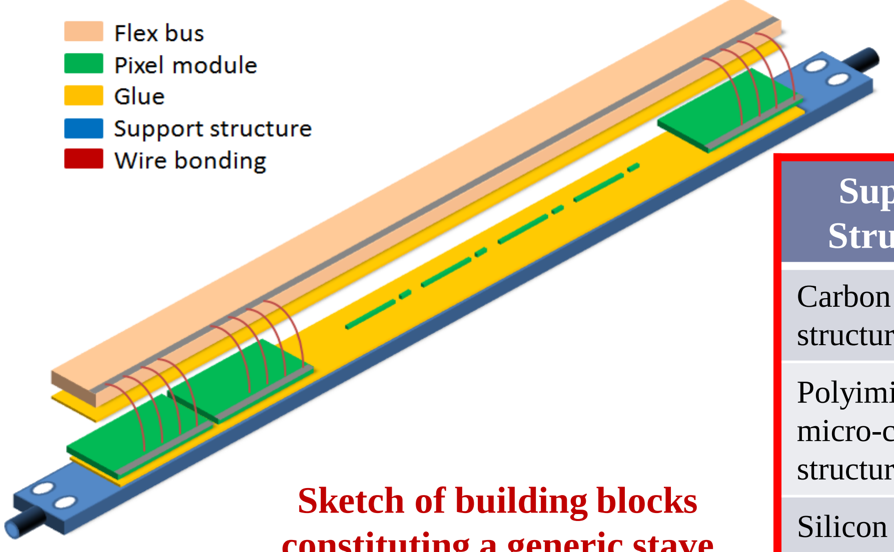
Upgrade requirements:

Parameters: Option 1		
Beam pipe radius	mm	20 (outer radius)
Number of pixel layers		3
Mean radial positions	mm	22, 47, 90
Stave length	mm	210, 270, 370
Power consumption	W/cm^2	0.3 – 0.5
Total material budget per layer	X/X_0 (%)	≤ 0.5
Working temperature	°C	≤ 35
Temperature gradient	°C	≤ 5
Maximum deformation	µm	Few microns

Parameters: Option 2		Pixel	Pixel – strip
Number of pixel layers		3	4
Mean radial positions	mm	22, 38, 68	124, 235, 396, 430
Stave length	mm	210, 250, 320	450, 670, 1070, 1140
Power consumption	W/cm^2	0.3 – 0.5	
Total material budget per layer	X/X_0 (%)	≤ 0.5	≤ 1
Working temperature	°C	≤ 35	
Temperature gradient	°C	≤ 5	
Maximum deformation	µm	Few microns	

Stave material budget

Component	Material budget X/X0 (%)	Notes
Support Structure	0.07 – 0.34	3 different structures are under discussion: carbon foam, polyimide and silicon
Glue	0.045	2 layers of glue 100 μm thick each
Pixel module	0.053 – 0.16	Monolythic (50 μm thick) – hybrid (150 μm thick)
Flex bus	1.5	Reasonable value if a singel layer flex bus is considered
Total	**0.32 – 0.7**	

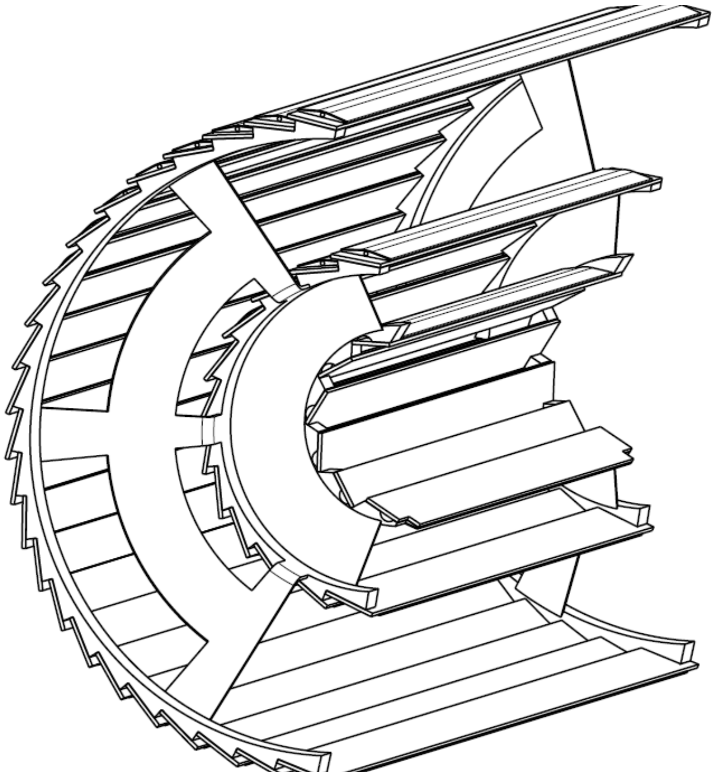


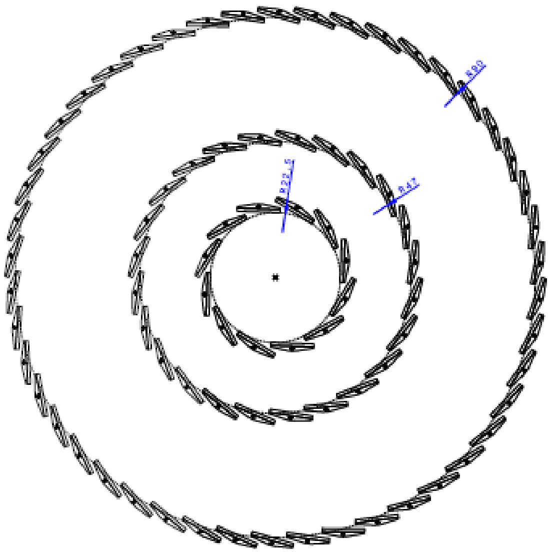
Sketch of building blocks constituting a generic stave

Support Structure	Material budget X/X0 (%)	Notes
Carbon foam structure	0.22 – 0.34	Different cooling tubes: PEEK or Metal (MP35N)
Polyimide micro-channel structure	0.085 – 0.13	Different coolant: H20 or C6F14
Silicon micro-channel structure	0.07 – 0.11	Different layout: sideline or distributed micro-channels

Conceptual Design: Option 1

- 3 layers of SI-pixel sensors: 1st layer at 23 mm from the IP
- Full structure divided in 2 half, to be mounted around the beam pipe and to be moved along the beam pipe towards the final position
- Modules fixed to the 2 carbon fiber wheels
- All the services on side A
- Number of staves per layer: 12, 24, 46



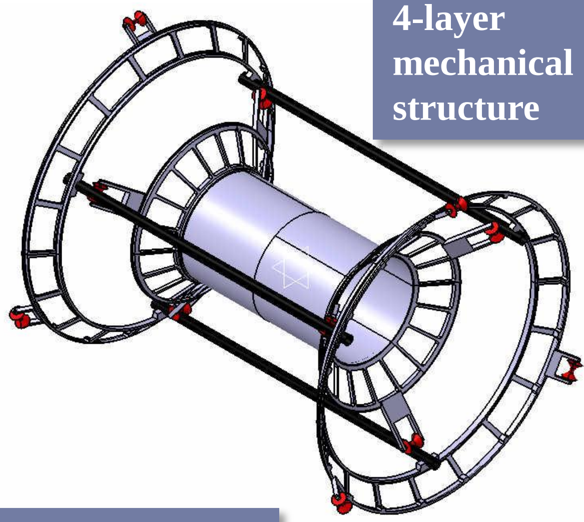


Constrains:

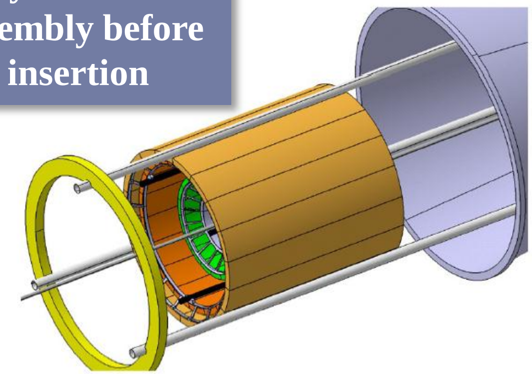
- Stave 15mm wide
- 2 mm dead area on one side
- Full azimuthally coverage
- Closest point to the beam pipe: 22.5mm (2 mm of clearance)
- 2 mm of clearance between neighboring staves

Conceptual Design: Option 2

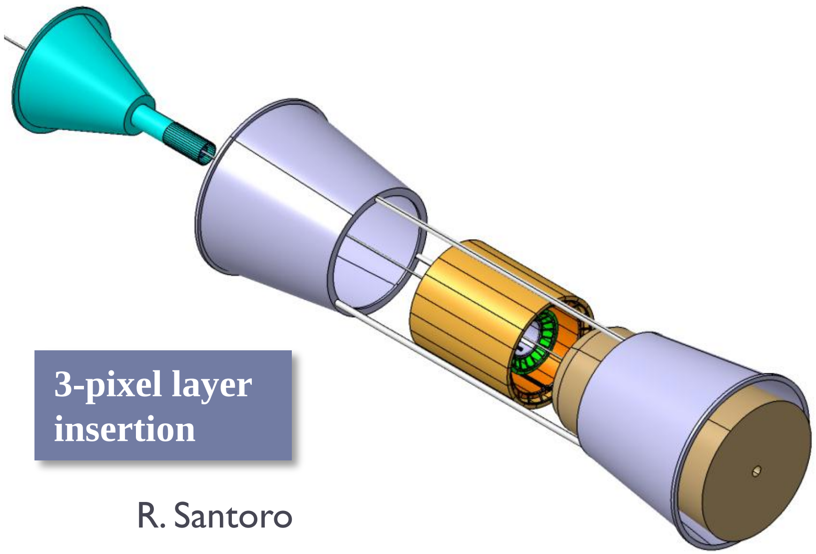
- 3-pixel layers are based on the same structure shown before
- 4 strip layers, based on 2 separate barrels, each one supporting two detector layers
- Three tubes in carbon composite or beryllium are permanently fixed between the 2 barrels both to rigidify the structure and to support - guide the inner barrel insertion
- Three tubes in carbon composite or beryllium are permanently fixed in the inner surface of the TPC to support - guide the 4layer barrel insertion
- 4-layer structure mounted outside the TPC before it is moved in the final position
- The 3-pixel layer insertion has to be studied



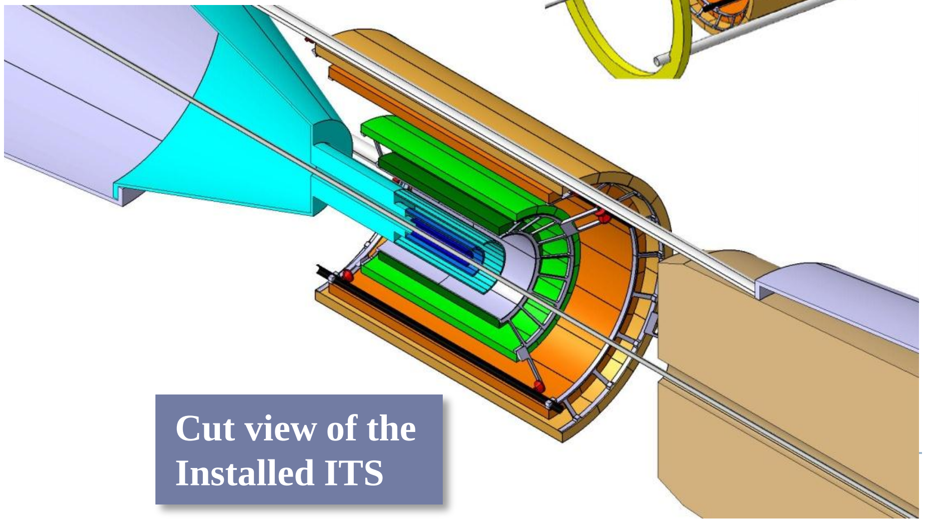
4-layer mechanical structure



4-layer assembly before the insertion



3-pixel layer insertion



Cut view of the Installed ITS

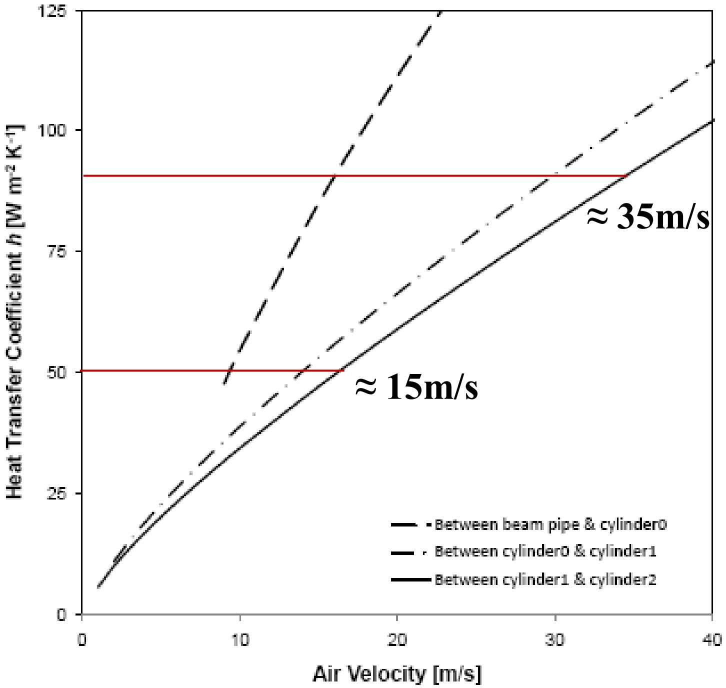
Air cooling

Preliminary considerations on air cooling, based on simplified calculation

- Assumptions
  - Air flowing along the tubes with no air leakage
  - 3 cylinders with the pixel structure dimension
  - Power uniformly distributed along the surfaces (0.3 or 0.5 W/cm^2)
  - Air inlet 7°C and sensor limit = 35°C

- Considerations
  - Those are only preliminary studies which show that we need very low power consumption to cool down the detector with reasonable air flow (less than 10 m/s)
    - Simulations could be started if power consumption lower than 0.3 W/cm^2 is feasible
    - STAR uses ≈10m/s with a power consumption of ≈0.17 W/cm^2
  - If air cooling will be considered, the mechanic design should be similar to the actual mechanics
  - The services needed to force the air could add material budget at forward rapidity on A side

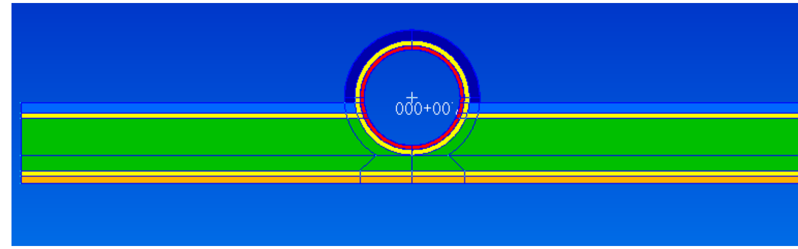
$$q/2 = h(T_s - T_a)$$
$$q = 0.3W/cm^2 \Rightarrow h \approx 50 W m^{-2} K^{-1}$$
$$q = 0.5W/cm^2 \Rightarrow h \approx 90 W m^{-2} K^{-1}$$



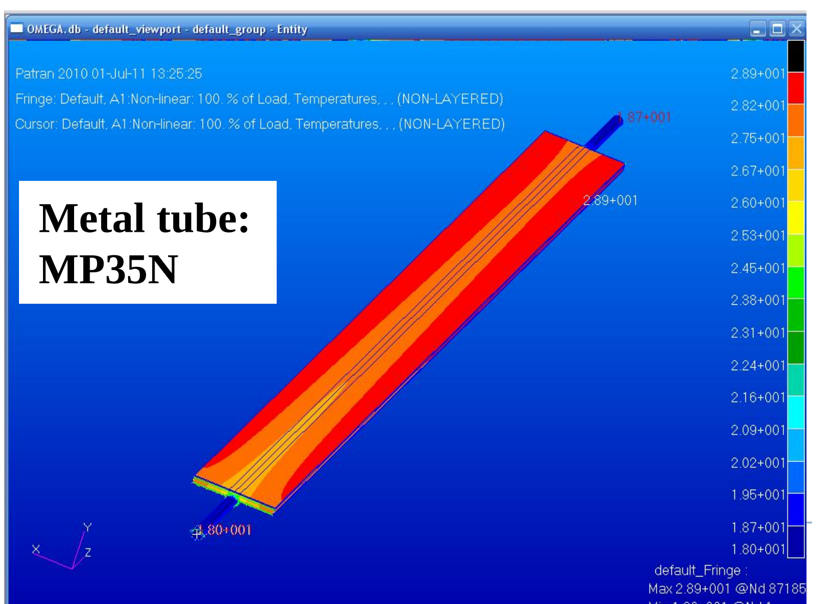
Carbon foam structure

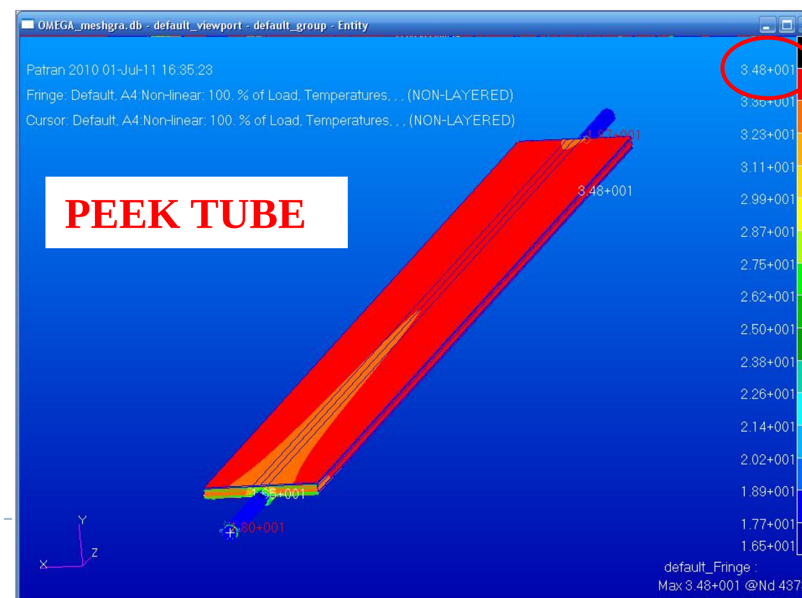
Preliminary simulations with resonable velues of material conductivity and thickness.
In these studies we assume surfaces with ideal contact

- Power consumption 0.5 W/cm2
- Cooling with water in leakless
- Inlet temperature = 18°C and flow rate 0.3 lit/min
- Glue conductivity 1 W/mK (100μm thick)
- Carbon foam conductivity 50 W/mK (1mm thick)



- **Glue**
- **Tube 2mm diameter ext and wall 80μm thick**
- **Omega in carbon fiber**
- **Carbon foam**
- **Silicon detector**

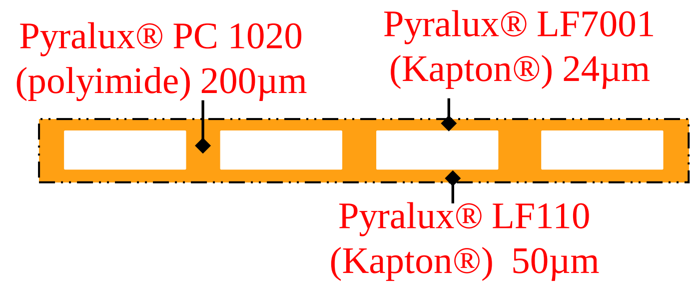




Polyimide micro-channel

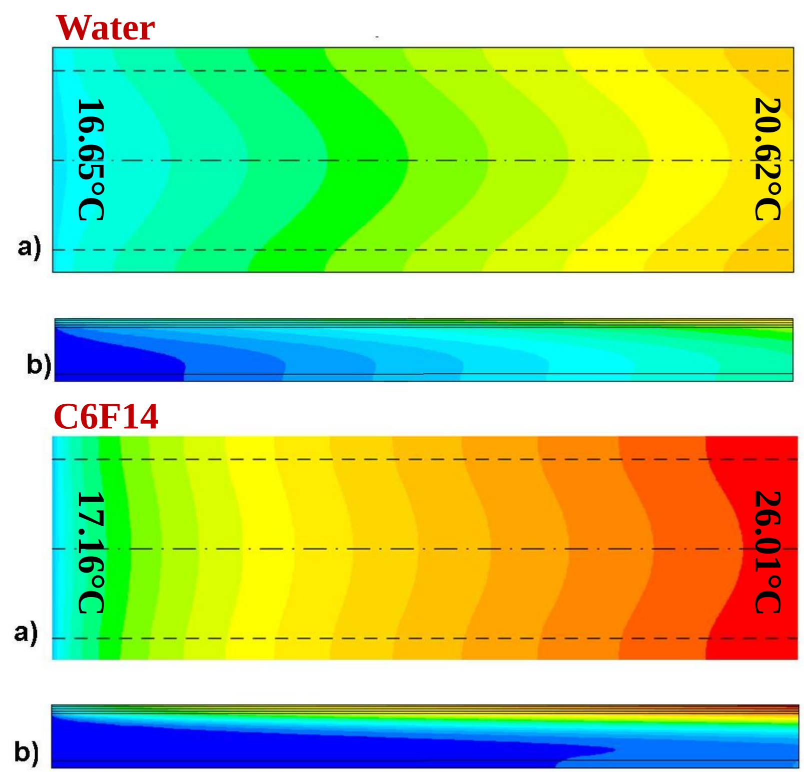
Fabrication process

- Starting point: 1 layer of LF110 (50 μm thick) and 1 layer of PC1020 (50 μm thick)
- Grooves obtained with photolithography
- Cover lay hot pressed on the top and final cure @ 180°C for 10 Hours



Simulation and tests on prototype based on micro-channels 200 x 800 μm²

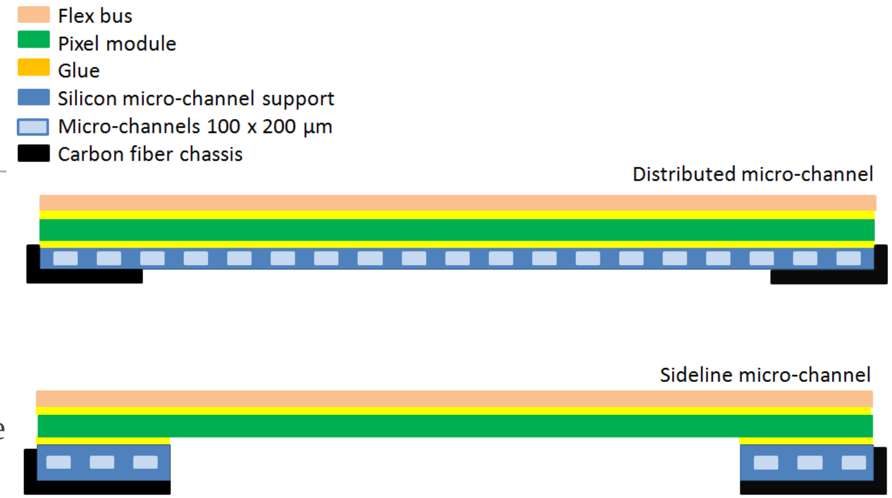
- Tests on prototypes:
  - Leak test and water compatibility (ok)
  - Thermo fluid dynamic test (soon)
  - Mechanical test (soon)



Simulated temperature distribution: polyimide surface and side view with 0.5 W/cm2

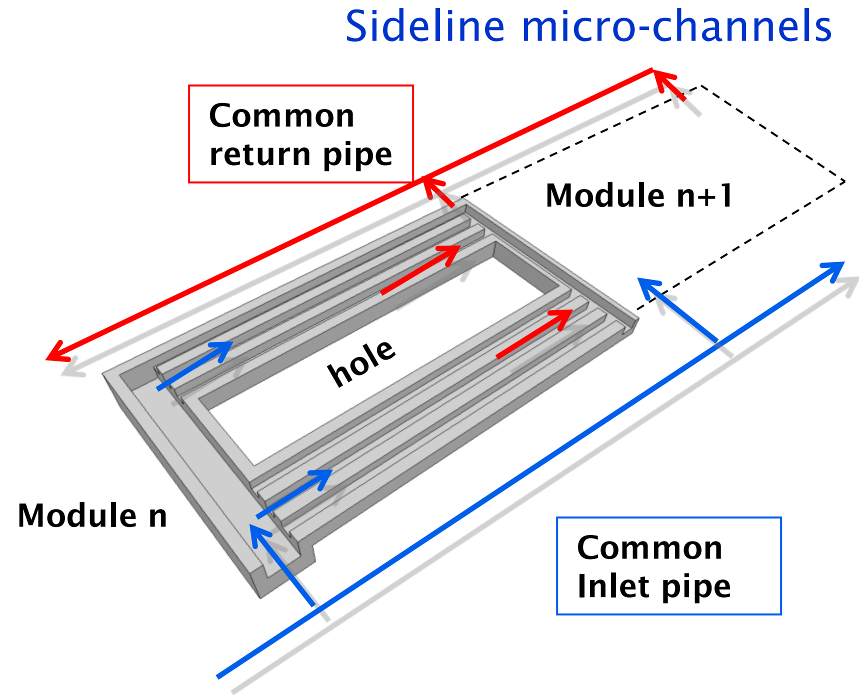
Si-Micro-channel

- Micro-channels made on etched silicon plates covered with Si-plate by fusion bonding
- Two layouts are under discussion
  - Distributed micro-channels: material budget equally distributed below the sensitive area
  - Sideline micro-channels: micro-channels confined at the chip's border

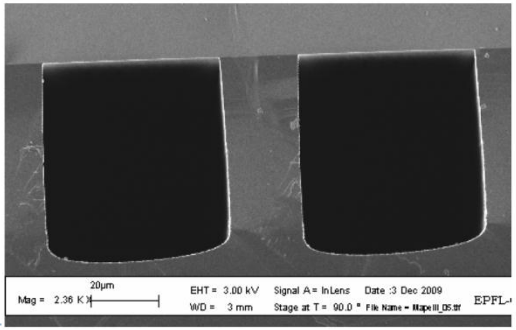


Further considerations

- This is actually an option considered for the NA62 Experiment at CERN
- Suitable with double-phases cooling (C02 or fluorocarbons)
  - Simulation and R&D are needed
- Limitation: the standard process is actually 4" wafer although CEA-LETI is trying to manufacture 8" silicon wafer

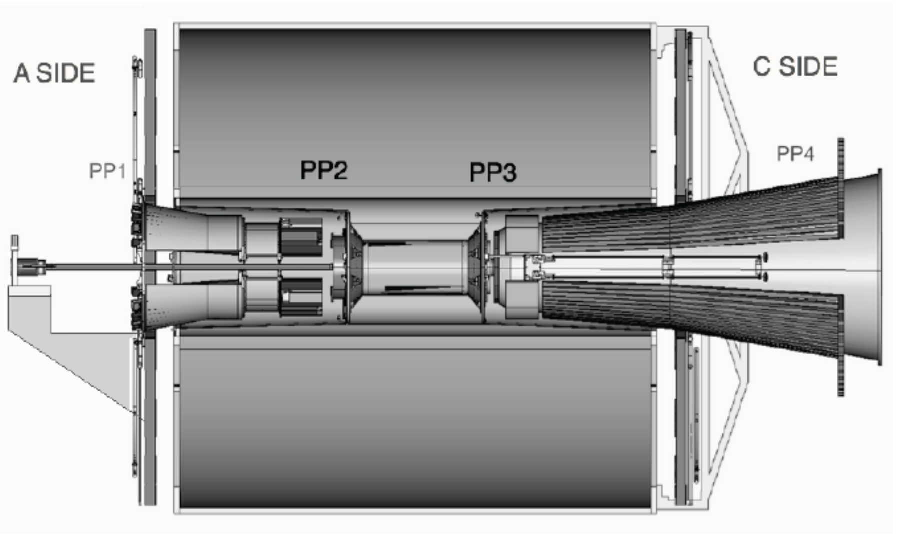


Cross section image of silicon microchannels 200 x 200 µm²



Beam pipe considerations

- The beampipe is actually hold in 3 points (FMD2, FMD3 and service support wheels)
- To permit the insertion of the ITS from the A side, the central support has to be removed
- The sagitta of a beampipe 5m long with the wall 800µm thick has been studied
  - The sagitta can be reduced applying a moment along the beam axis on one end (8Nm)
  - Almost the same result has been calculated with a thinner wall (500µm)
- Discussions to have a beam pipe with the inner radius of about 19mm are on-going
- Beam pipe with 500µm wall seems to be feasible although R&D is needed
  - The worry is the "porosity" and the vacuum tightness
  - Prototypes are needed



Spare