EP-DT
Detector Technologies

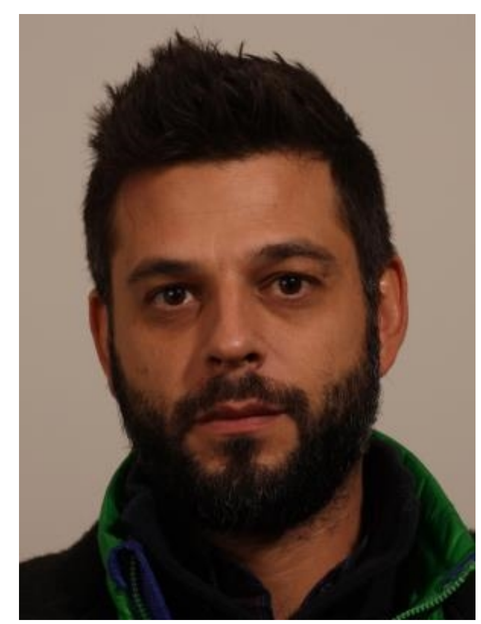
GROUP MEETING, 22 JUNE 2016

MICROFABRICATION

Jacopo
BRONUZZI
PhD, EPFL

Timothée
FREI
PhD, EPFL & CSEM

Clémentine
LIPP
MSc, EPFL



Alessandro
MAPELLI

Ranit
MONGA
TRAINEE, EPFL

MICROFABRICATION OF ON–DETECTOR COOLING SYSTEMS

Fabrication of structures with features below the mm.
Same techniques as used for microelectronics and silicon detectors.

Novel high performance compact systems based on microfluidics.

Scintillation Particle Detectors Based on Plastic Optical Fibres and Microfluidics

THÈSE N° 5033 (2011)

PRÉSENTÉE LE 2 SEPTEMBRE 2011
À LA FACULTÉ SCIENCES ET TECHNIQUES DE L'INGÉNIEUR
LABORATOIRE DE MICROSYSTÈMES 4
PROGRAMME DOCTORAL E

ÉCOLE POLYTECH

POUR L'OBTENTION

Ale

acceptée sur proposition du jury:

Prof. M. A. Ionescu, président du jury
Prof. Ph. Renaud, Dr P. L. G. Grafström, directeurs de thèse
Prof. A. Bay, rapporteur
Dr B. Gorini, rapporteur
Dr M. Haguenauer, rapporteur

ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

Suisse
2011

2. ***Detector cooling*** *(see detailed text of original propositions)*
   a. *CO2 cooling studies for trackers (Onnela, Catinaccio)*
   b. *CO2 cooling studies for other detectors, like crystal calorimeters (Petagna)*
   c. *Application of nano-technologies for local cooling (Petagna)*
   d. *Cooling pipework and joining techniques (Onnela, Catinaccio)*
   e. *Organisation of a workshop on detector coolin*

SILICON MICROCHANNEL COOLING

J. Buytaert, A. Catinaccio, J. Daguin, R. Dumps, K. Howell, A. Kluge, A. Mapelli, M. Morel, J. Noel, G. Nuessle, P. Petagna, Ph. Renaud (EPFL), G. Romagnoli, J. Thome (EPFL)

ELSEVIER

Nuclear Physics B (Proc. Suppl.) 215 (2011) 349–352

SICS B PROCEEDINGS SUPPLEMENTS

www.elsevier.com/locate/npbps

Low material budget microfabricated cooling devices for particle detectors and front-end electronics

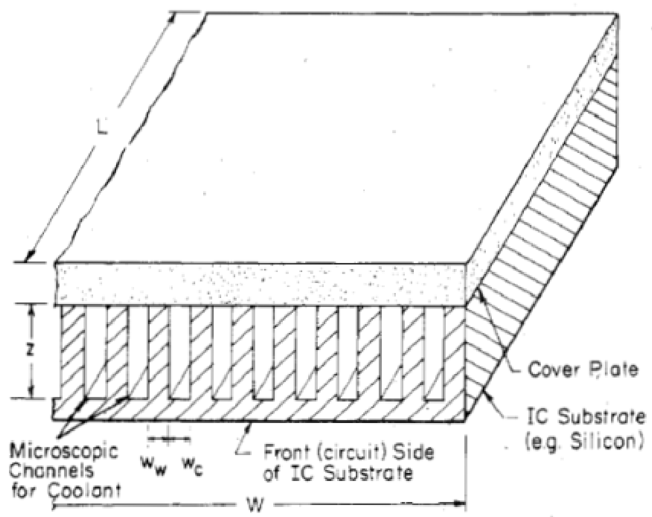
A. Mapelli[a b] *, A. Catinaccio[a], J. Daguin[a], H. van Lintel[b], G.Nuessle[c], P. Petagna[a], P. Renaud[b],

[a]Physics Department, CERN, Geneva, Switzerland

[b]Laboratoire de Microsystèmes, Ecole Polytechnique Fédérale de Lausanne, Switzerland

[c]CP3, Université catholique de Louvain, Louvain-la-Neuve, Belgique

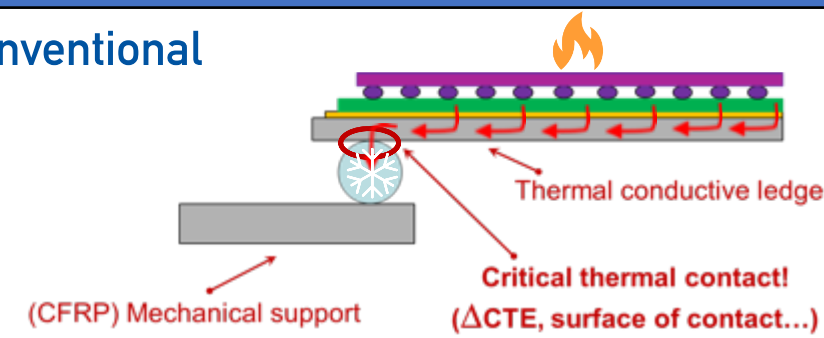
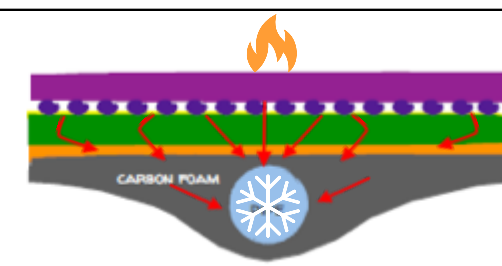
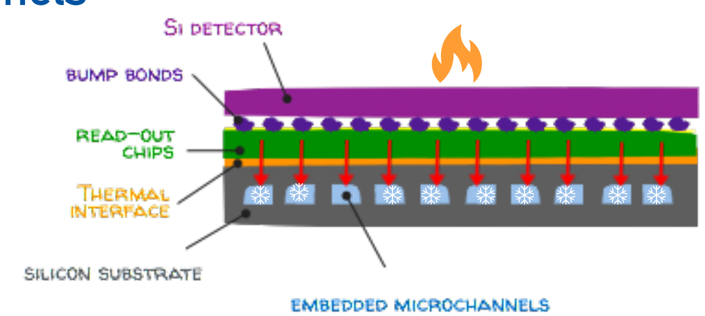
WHY MICROFLUIDIC ON–DETECTOR COOLING SYSTEMS ?



D.B. Tuckerman and R.F.W. Pease, IEEE Elec. Dev. Letters, Vol. 2, 5, 1981

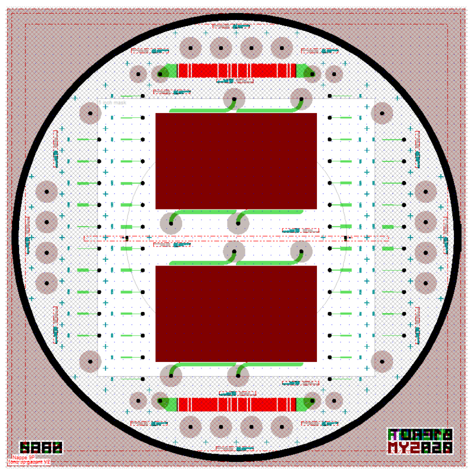
- No CTE mismatch
- Low material budget
- Active/distributed cooling
- Radiation resistance
- Great integration potential
- Thermal Figure of Merit

$$\text{TFM} = \frac{(\Delta T \text{ fluid-sensor})}{(\text{power density})}$$

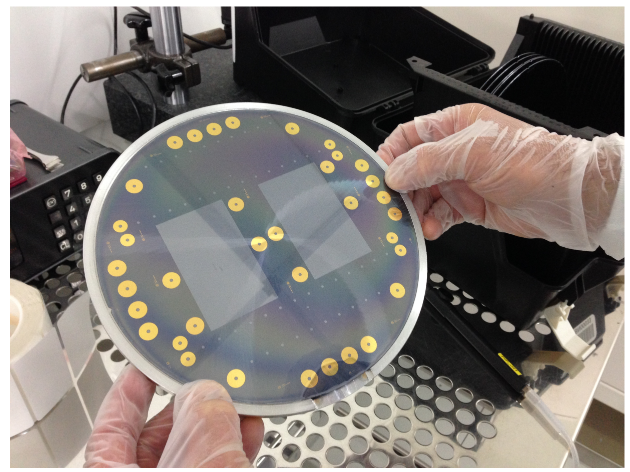
approach	TFM
conventional 	20
integrated 	12
microchannels 	5-8 liquid
	3 bi-phase

How do we manufacture silicon microchannels ?

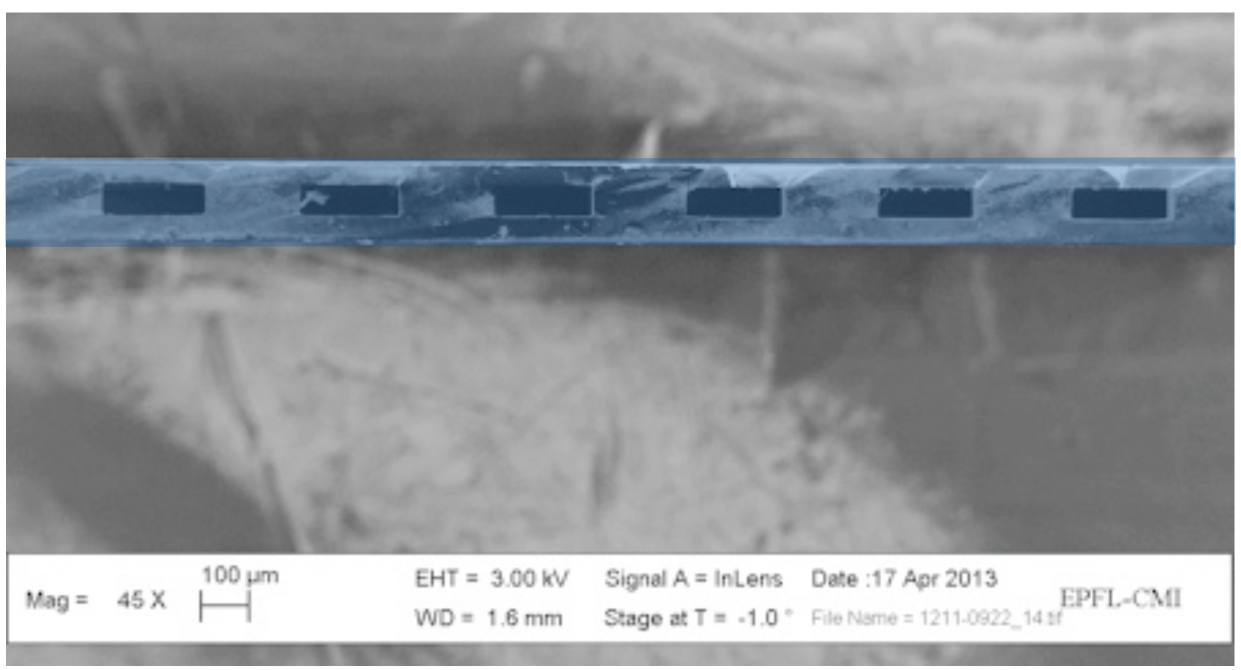
- Collaborative effort between experiments (**ALICE, LHCb and NA62**), support groups (**DT and ESE**), and external partners (**CSEM and EPFL**).



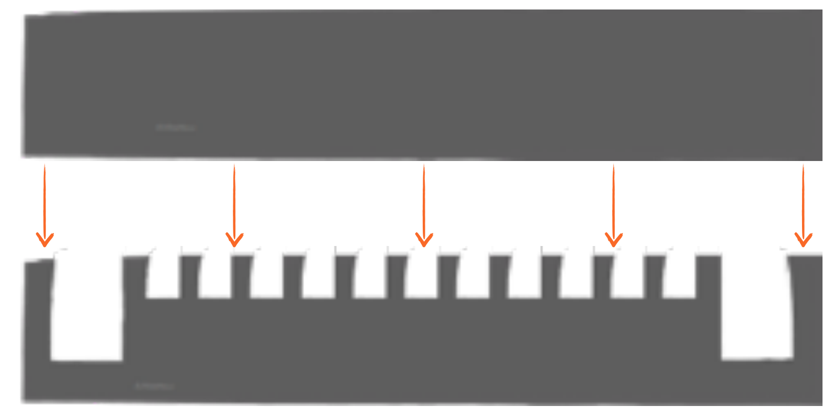
photolithography layout



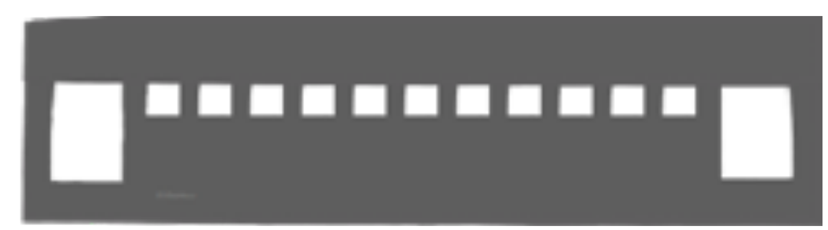
8" wafer processed at CEA-LETI



cross-section of the cooling plates with embedded microchannels



µchannels etching & Wafer Bonding

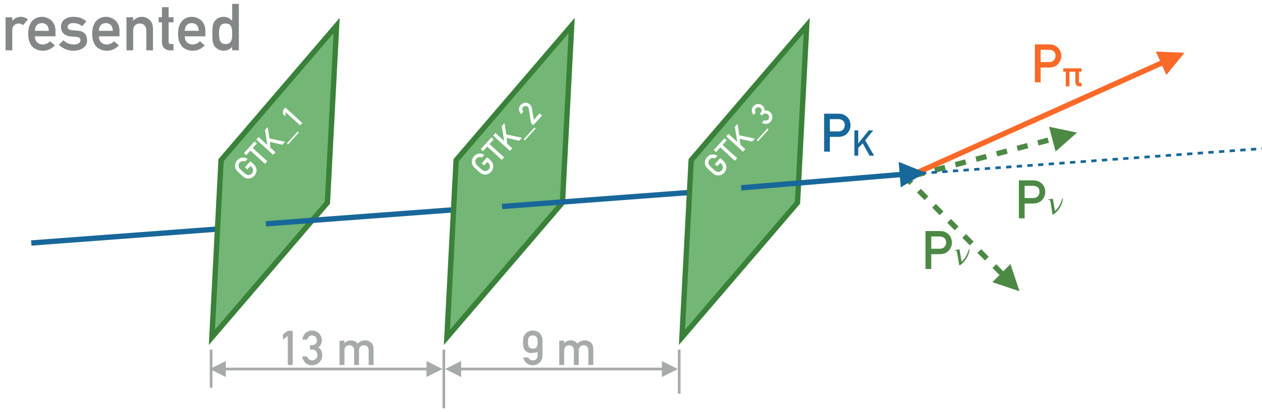


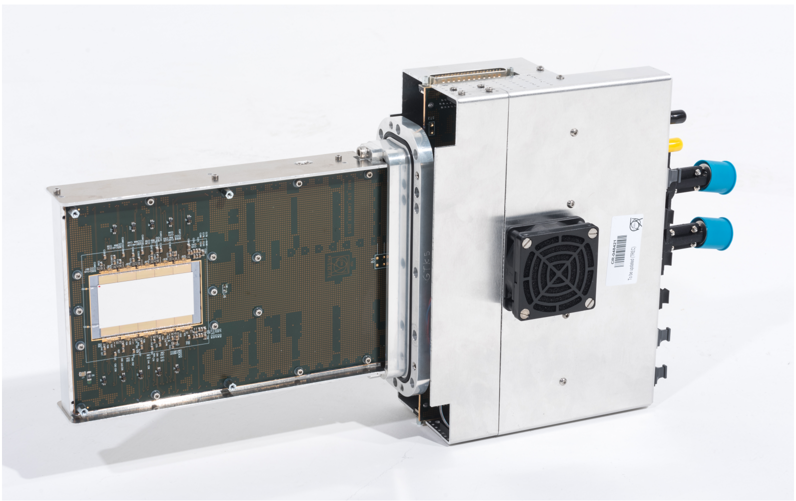
Wafer Thinning

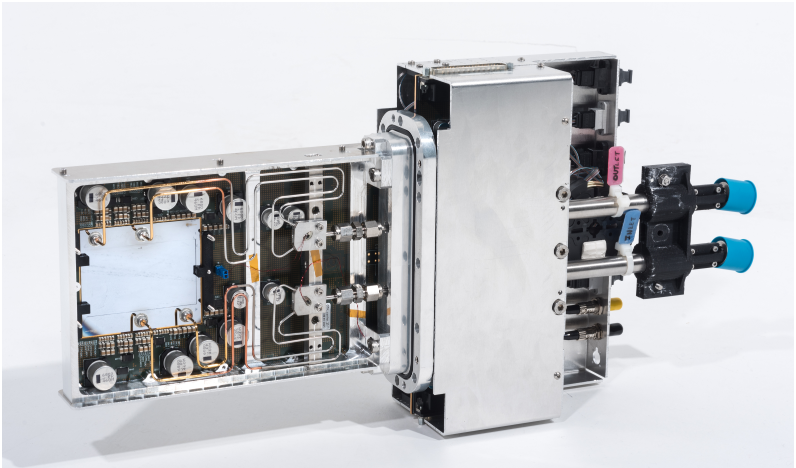
Silicon Etching

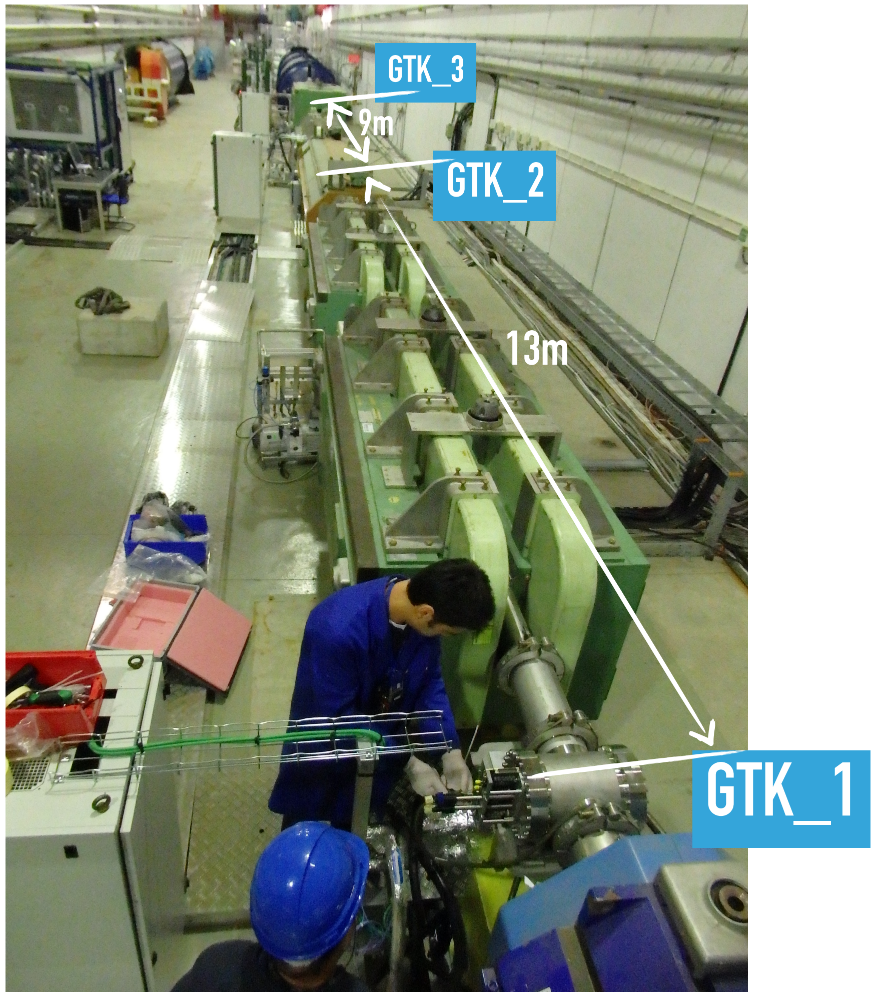
NA62 GTK – PIONEERING MICROCHANNELS !

- 2009 - concept of micro-cooling for the GTK presented to NA62: https://indico.cern.ch/event/58370/
- 2014 - First GTK in the experiment
- 2016 - Data taking with 3 GTK detectors
- 2017 - Assembly of 6 GTK modules for 2018





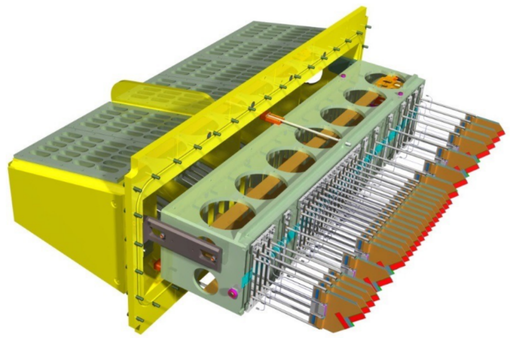


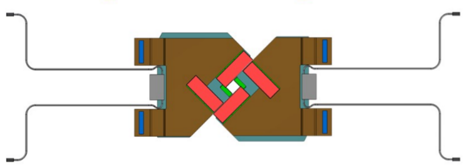


The beam and detector of the NA62 experiment at CERN, Journal of Instrumentation, Volume 12, May 2017, https://goo.gl/P391U3

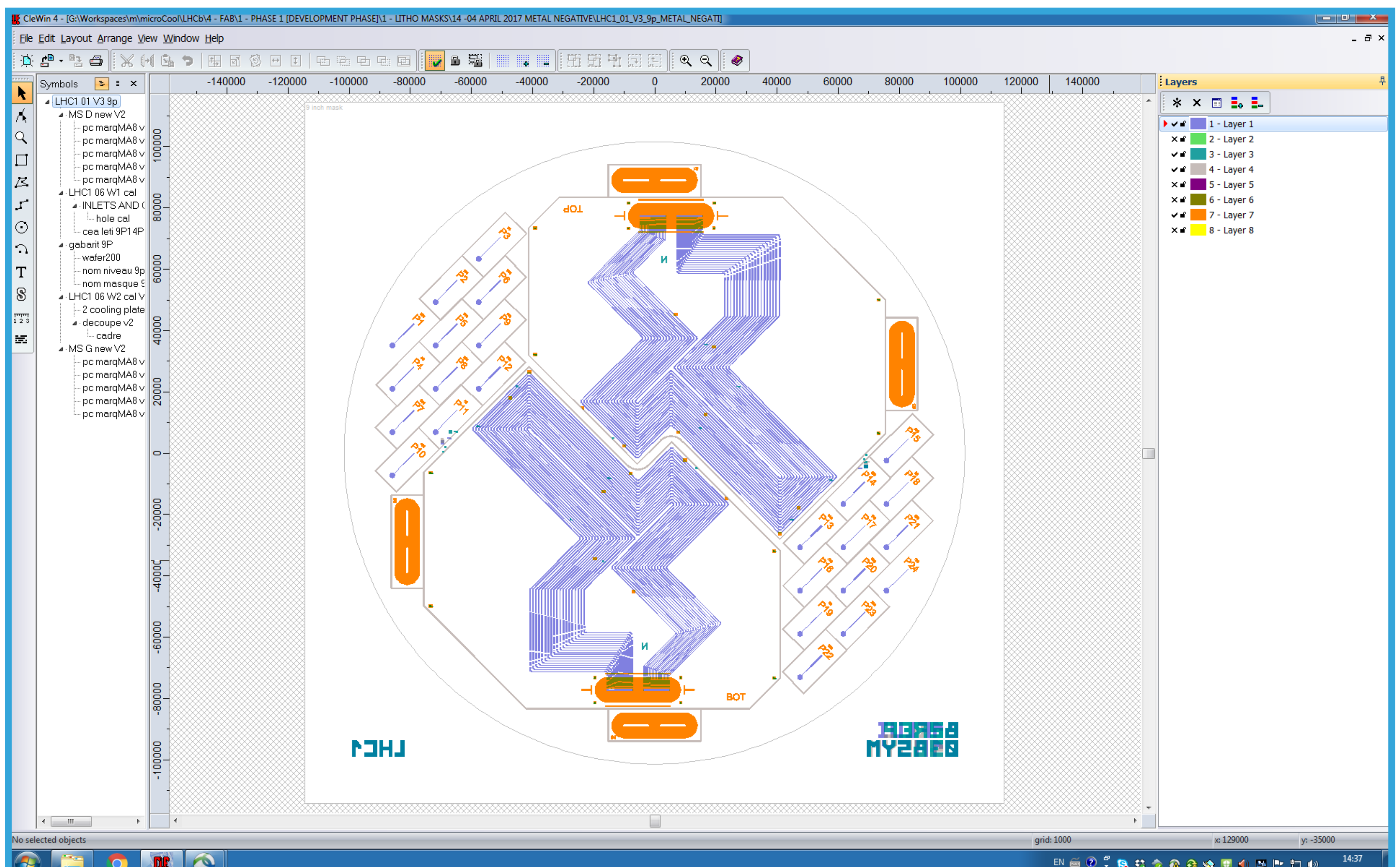
See Hans DANIELSSON's talk.

LHCb VELO UPGRADE – EVAPORATIVE CO_2 IN MICROCHANNELS



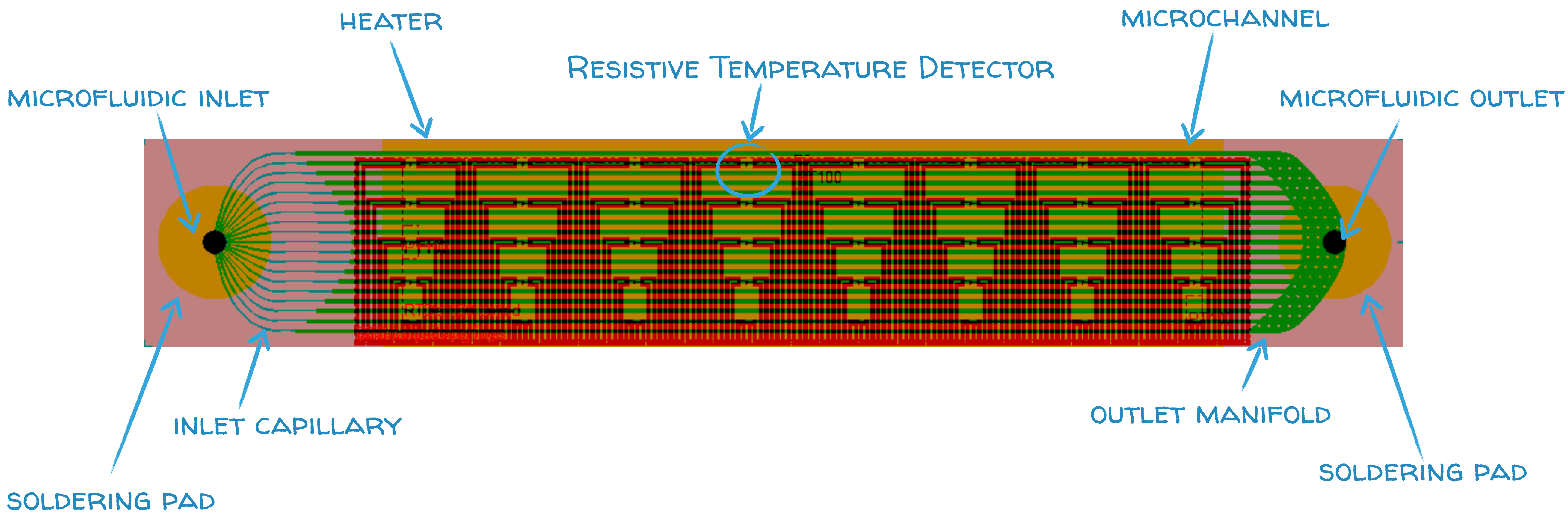


- Primary heat source due to the VeloPix chips (~1 W/cm2)
- Sensors must be kept at -20°C
- Evaporative CO_2 circulates in microchannels routed directly under the VeloPix chips.
- Total power consumption > 2kW.
- 52 modules in secondary vacuum separated by primary beam vacuum by a 0.25 mm thick Al foil.
- 12 cooling plates delivered by CEA-Leti. 14 more will be delivered soon.
- Void-less soldering of connector to cooling plates procedure under development.



See Burkhard SCHMIDT's talk.

SILICON THERMAL MOCKUPS



- Test complex silicon microchannel layouts in the new CO_2 test setup at CERN.

See Paolo PETAGNA's talk.

AIDA 2020

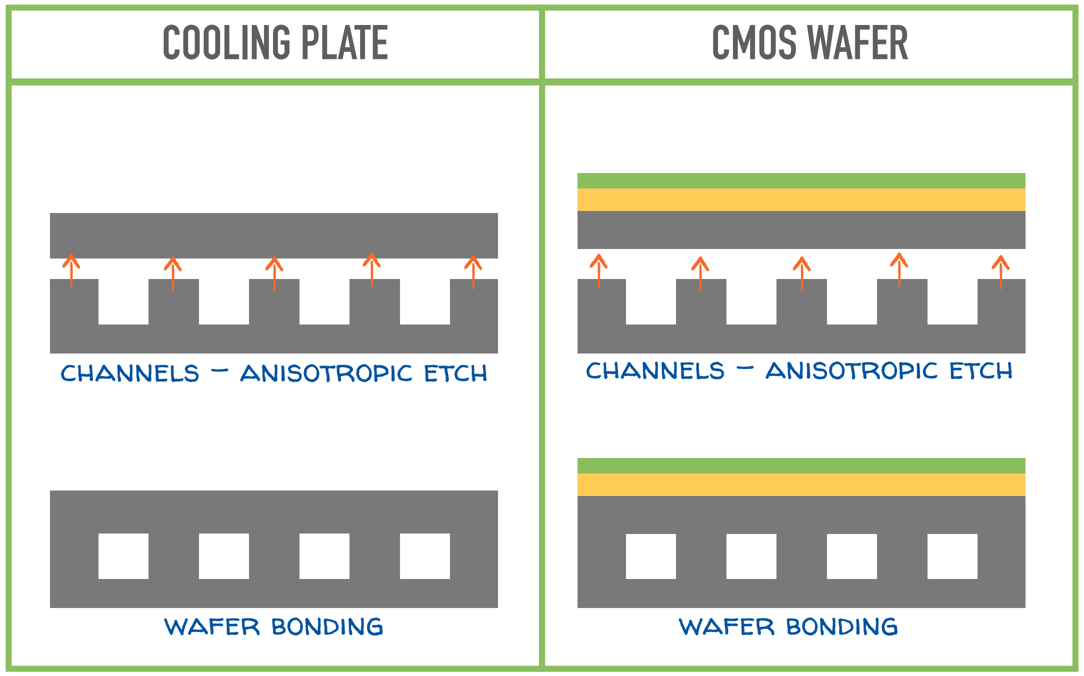
CLEMENTINE LIPP

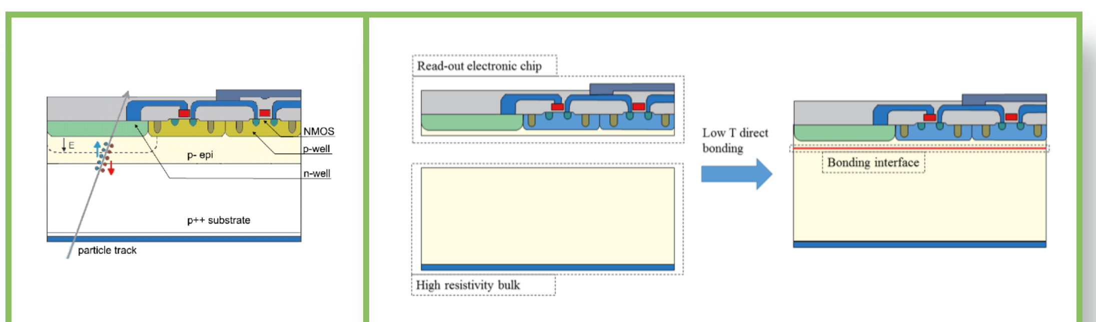
INTEGRATING MICROCHANNELS ON PIXEL DETECTORS

STREAM

"LOW TEMPERATURE" WAFER BONDING
CEA-Leti, EPFL, G-Ray

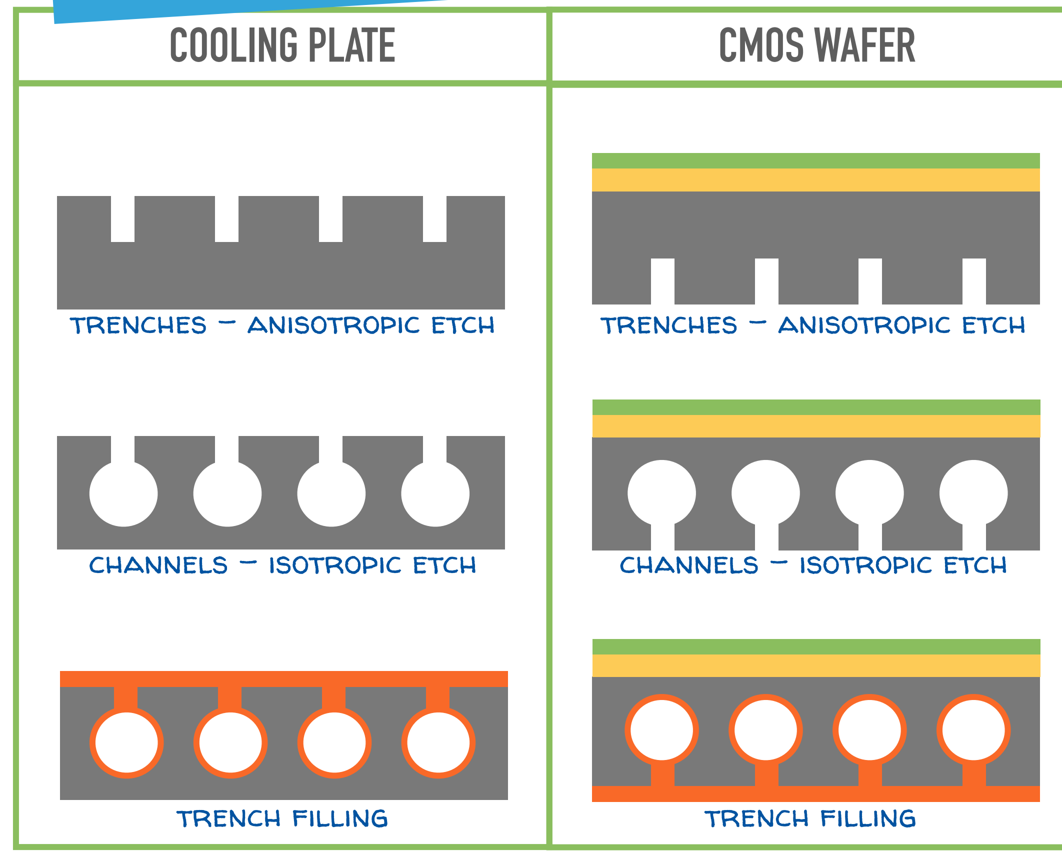
Jacopo BRONUZZI, PhD EPFL, 2018

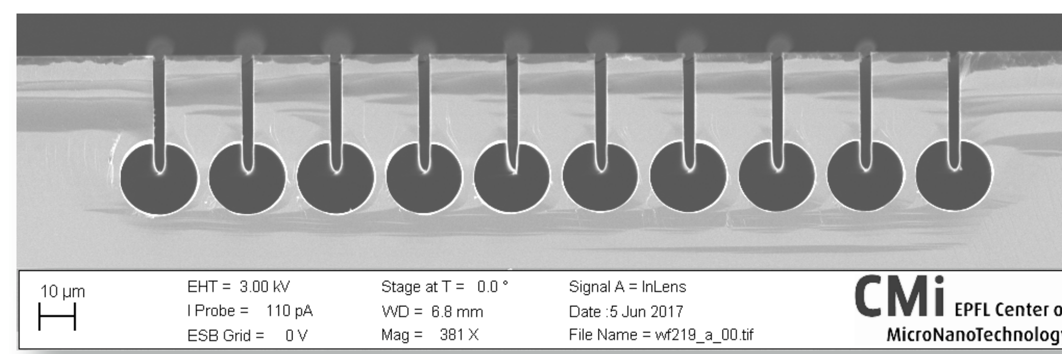




BURIED CHANNELS
EPFL, FBK

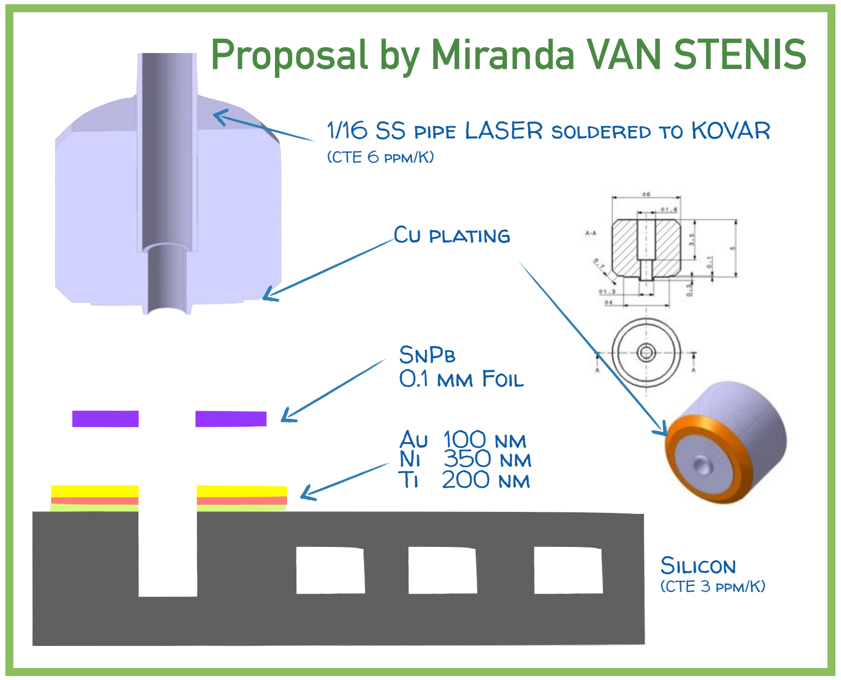
Clémentine LIPP, MSc EPFL, 2017

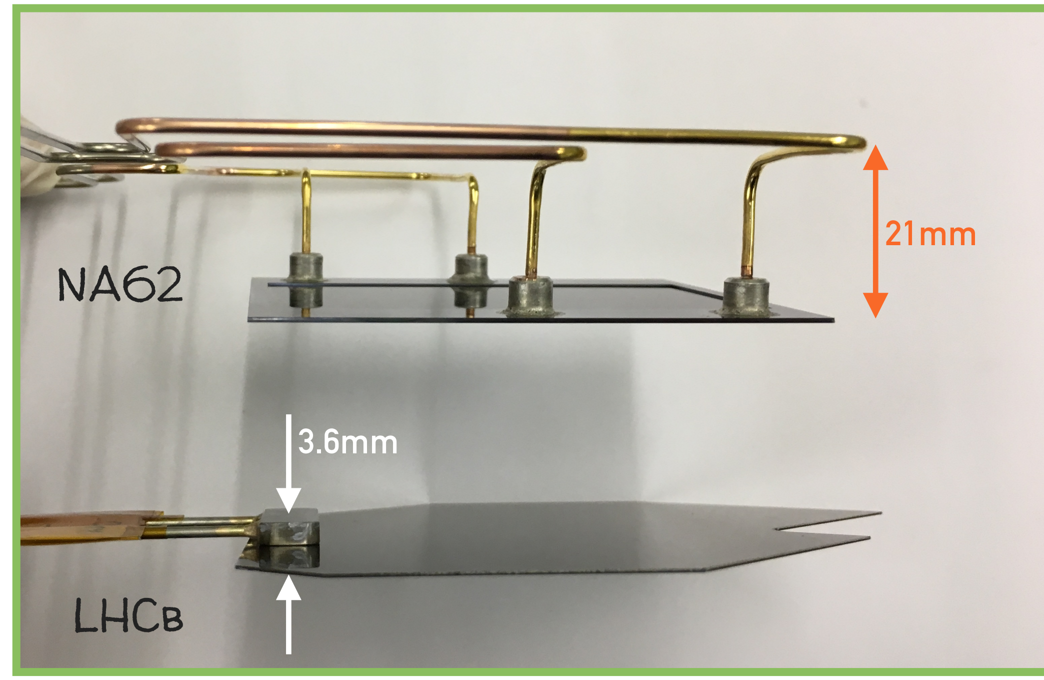


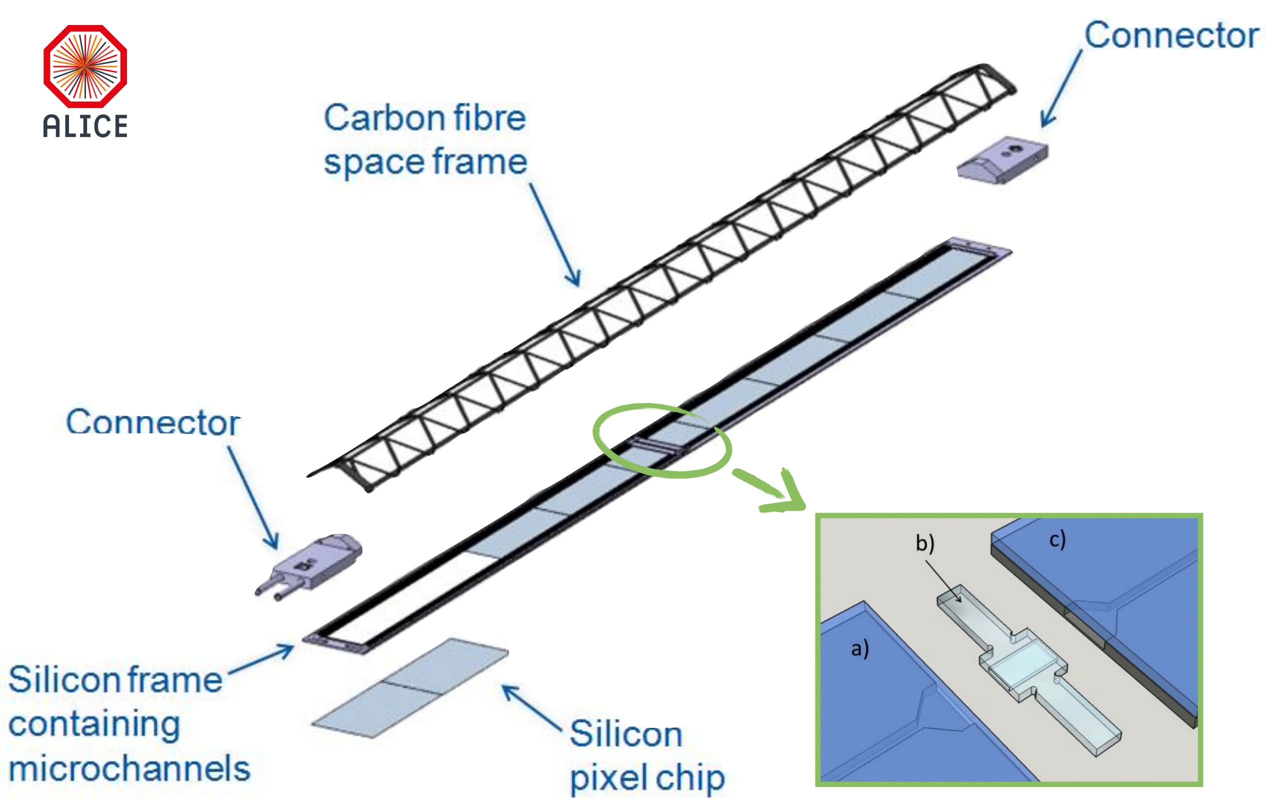


- Tests ongoing with blank wafers
- Embed microchannels on the backside of CMOS wafers, tests later this year.

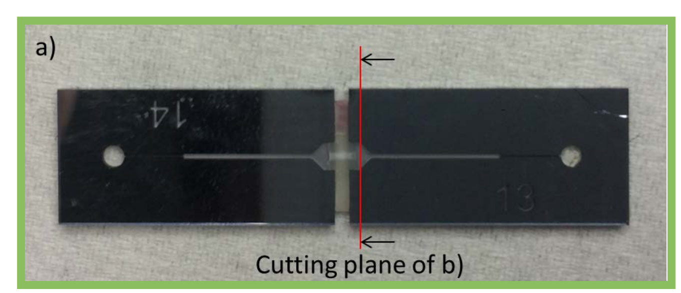
INTERCONNECTIVITY – DAISY CHAINING MICROFLUIDICS







- NA62 and LHCb cooling plates
  - limited surfaces
  - access from the side
- For **larger systems** we need in-plane **interconnections**.



See Corrado GARGIULO's talk.

SUMMARY & OUTLOOK

- Inter-disciplinary activity to develop, fabricate and operate microsystems and microfluidic devices, involving several other sections.
- DT provides the perfect environment for such a development.
- First application in a running experiment: NA62 GTK.
- Followed up by LHCb Velo Upgrade: fabrication of the cooling plates and development of the soldering procedure for the connector ongoing as part of the baseline development.
- Study of buried channels ongoing. Plans to test this on CMOS wafers later in the year.