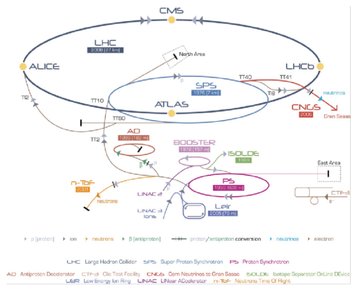
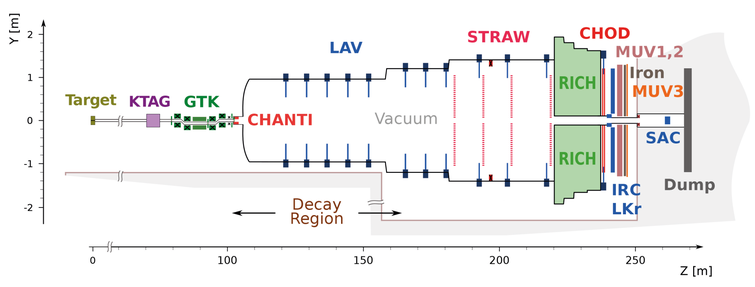
THE NA62 GIGATRACKER

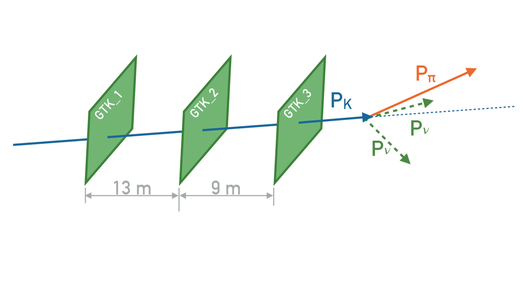
FROM SILICON MICROCHANNEL COOLING PLATES TO TRACKING DETECTORS

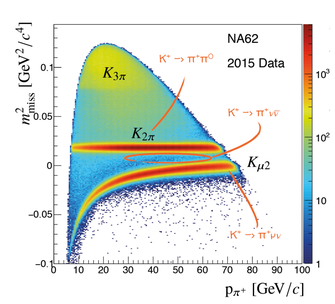
Alessandro MAPELLI, Diego ALVAREZ FEITO, Jordan DEGRANGE, François GARNIER, Pierre-Ange GIUDICI, Florentina MANOLESCU, Ian McGILL, Jerome NOEL, Paolo PETAGNA

alessandro.mapelli@cern.ch









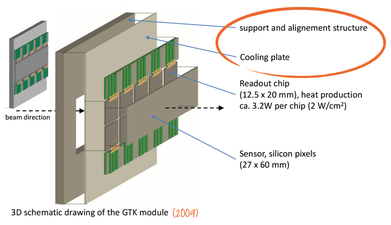
The GigaTracKer (GTK) is an essential element in the $K^+ \longrightarrow \pi^+ \nu\nu^-$ measurement. It determines **the momentum and the direction of the kaon** entering the NA62 experiment with a **time resolution of 100 ps**, better than the 200 ps expected from the design. About 5 x 10^{11} K^+ decays have been taken by the NA62 experiment to study the $K^+ \longrightarrow \pi^+ \nu\nu^-$ decay.

Since the beginning of the NA62 experiment, **9 silicon microchannel cooling plates** have been integrated into GTK modules. In 2014, the first module was installed in the NA62 beam line, **pioneering the use of microfluidic devices** for the thermal management of detectors in HEP experiments. In 2016, three fully functional GTK modules were installed in the and they were successfully operated without noise for the physics run.

SILICON MICROCHANNEL COOLING

The beam spectrometer GTK consists of **three silicon pixel stations** providing **momentum** and **direction** measurements of the **incoming kaons**. A **low-mass tracking system** is essential to minimize inelastic scattering of beam particles in the detector material that could mimic an isolated outgoing charged particle from a decay.

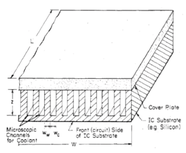
Gigatracker Module



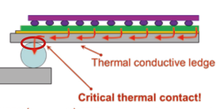
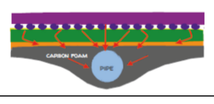
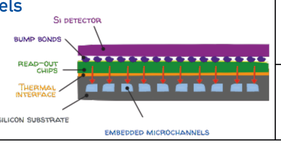
3D schematic drawing of the GTK module (2004)

SILICON MICROCHANNELS

210 µm thick silicon plate
155 microchannels
70 x 200 µm
liquid C_6F_{14}



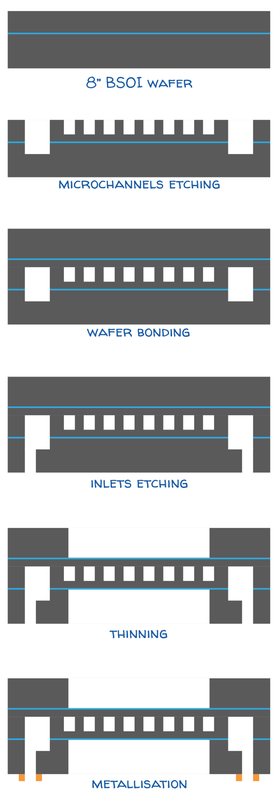
D.B. Tuckerman and R.F.W. Pease, IEEE Elec. Dev. Letters. Vol. 2, 5, 1981

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

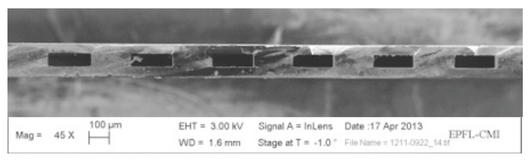
No CTE mismatch
Low material budget
Active/distributed cooling
Radiation resistance
Great integration potential
Thermal Figure of Merit

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

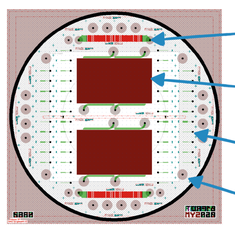
MICROFABRICATION OF COOLING PLATES



- Design by CERN EP-DT
- Prototypes fabricated by EP-DT at EPFL-CMi on 4" wafers
- Pre-production series by IceMOS on 6" wafers
- Two batches fabricated at CEA-Leti on 8" wafers

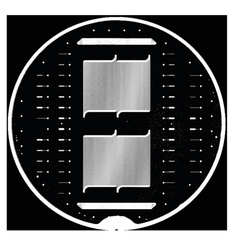


CROSS-SECTION OF THE COOLING PLATES WITH EMBEDDED MICROCHANNELS

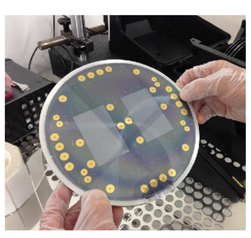


2x branches to fabricate cooling frames (alternative solution)
2x cooling plates
48 x pressure tests samples
Quality Control and structural studies
soldering tests samples
(common study with LHCb)

PHOTOLITHOGRAPHY LAYOUT



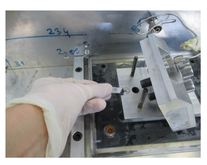
ACOUSTIC IMAGE OF BONDED WAFERS

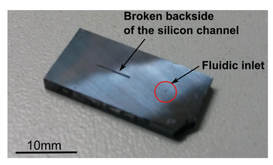


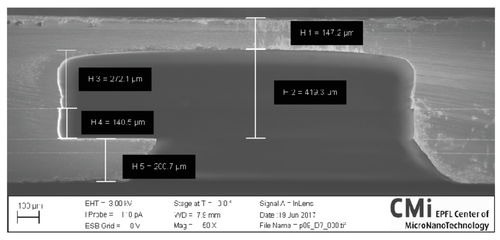
8" WAFER PROCESSED AT CEA-LETI

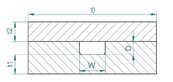
PRESSURE TESTS / QC

- Gaining a better understanding of the mechanical response of crystalline silicon
- Assess effect of channel geometry to optimise design of new devices
- Evaluate wafer-to-wafer bond strength
- Serve as quality control procedure

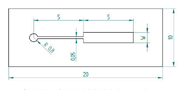




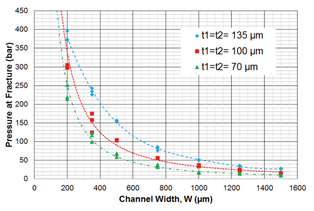




CROSS-SECTION OF PRESSURE SAMPLE



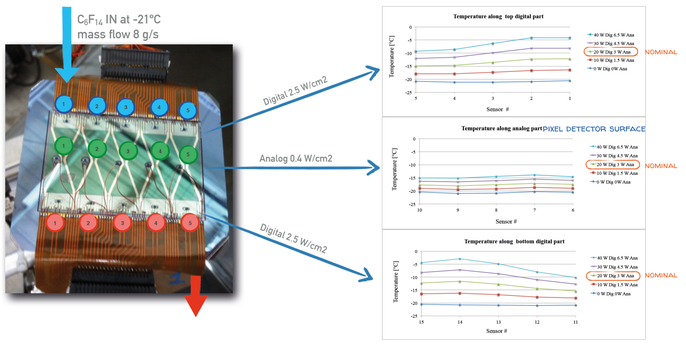
TOP VIEW OF PRESSURE SAMPLE



COOLING PERFORMANCE

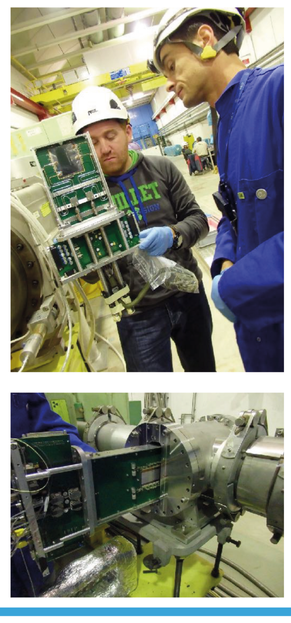
The silicon microchannel cooling plates designed for the GTK meet the specifications of NA62 at nominal operating conditions:

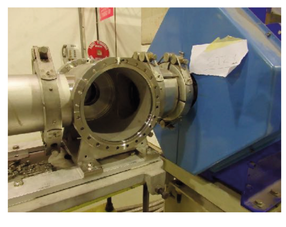
- ΔT_{sensor} 1 °C
- ΔT_{chip} 3 °C
- ΔT_{module} < 5 °C



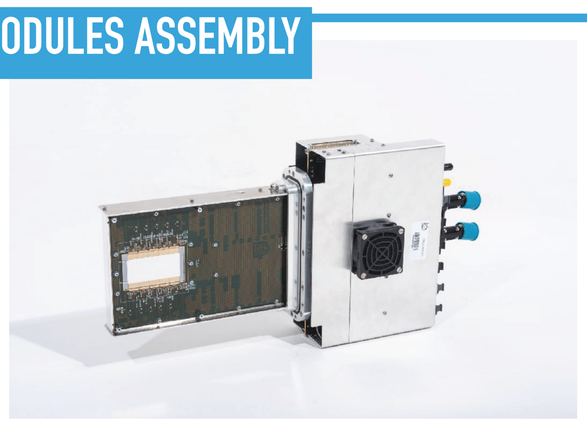
INSTALLATION IN THE BEAM LINE

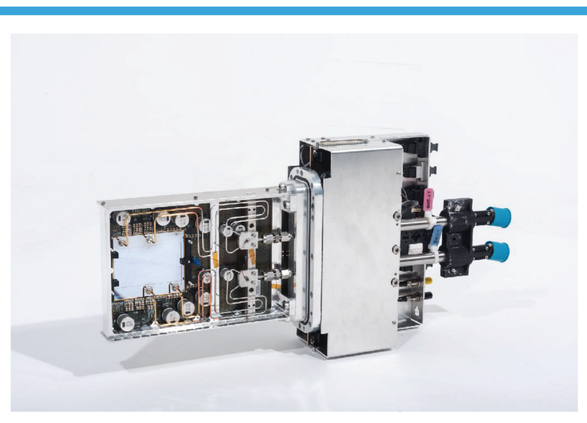
The detectors are located in a harsh radiation environment. At nominal beam intensity the detectors are exposed to a fluence corresponding to 4x10^{14} one-MeV neutron equivalent cm^2 in one year (200 days) of data taking. In order to minimize ageing effects due to radiation damage, the detectors are operated at approximately -15°C. It is expected that they can be operated continuously for more than 100 days without any significant performance degradation under these conditions. The detector mechanics has been designed such that **detectors can be replaced rapidly**, for example, during one of the regular short accelerator stops.





MODULES ASSEMBLY





REFERENCES

The NA62 Collaboration, **The beam and detector of the NA62 experiment at CERN**, 2017 JINST 12 P05025, goo.gl/LP4umG
G. Romagnoli et al., **Silicon micro-fluidic cooling for NA62 GTK pixel detectors**, Microelec. Eng. 145 (2015) 133-137, goo.gl/VwuawR
P. Petagna et al., **Application of micro-channel cooling to the local thermal management of detectors electronics for particle physics**, Microelec. Journal 44 (2013) 612–618, goo.gl/VRijT4
A. Mapelli et al., **Low mass integrated cooling**, PoS(Vertex 2013)046, https://goo.gl/SUqkwJ
A. Mapelli et al., **Low material budget microfabricated cooling devices for particle detectors and front-end electronics**, Nuclear Physics B (Proc. Suppl.) 215 (2011) 349–352, goo.gl/Kx3v4v