Back-side Illuminated SiPM for VUV/NUV light detection at FBK: first results

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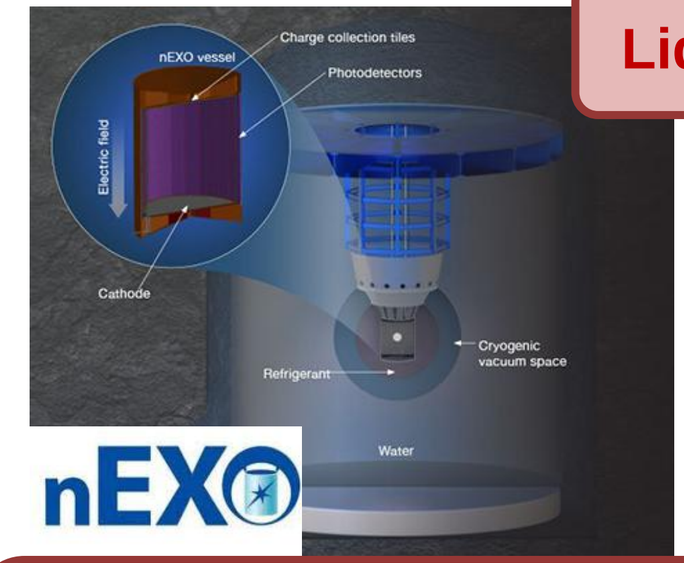
Motivation: nEXO and DUNE experiments

Detecting scintillating light from cryogenic liquid noble gases (LXe and LAr)

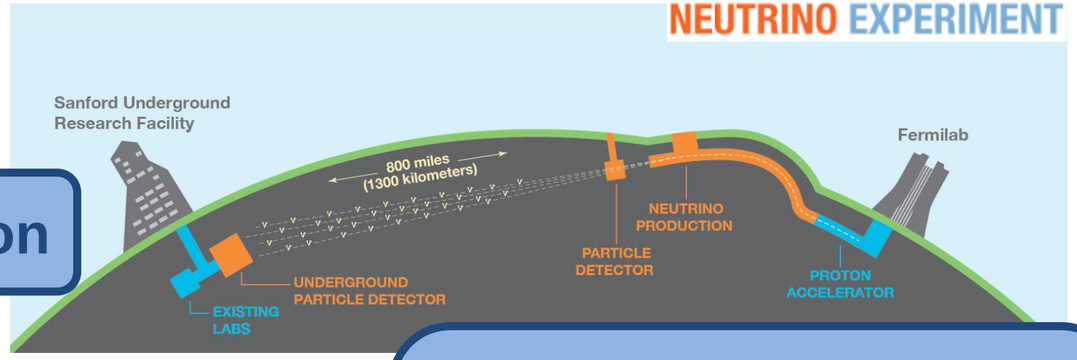
Liquid Xenon



nEXO

Liquid Argon

DUNE
DEEP UNDERGROUND NEUTRINO EXPERIMENT



SiPM tech. requirements

- Radioactive background < 0.5%
- PDE > 15% at 178 nm (glass-free)

BSI SiPM for VUV/NUV light detection

SiPM tech. requirements

- PDE > 35% at 127 nm (or 435 nm with down shifter)

Back-side illuminated SiPM for VUV/NUV light detection

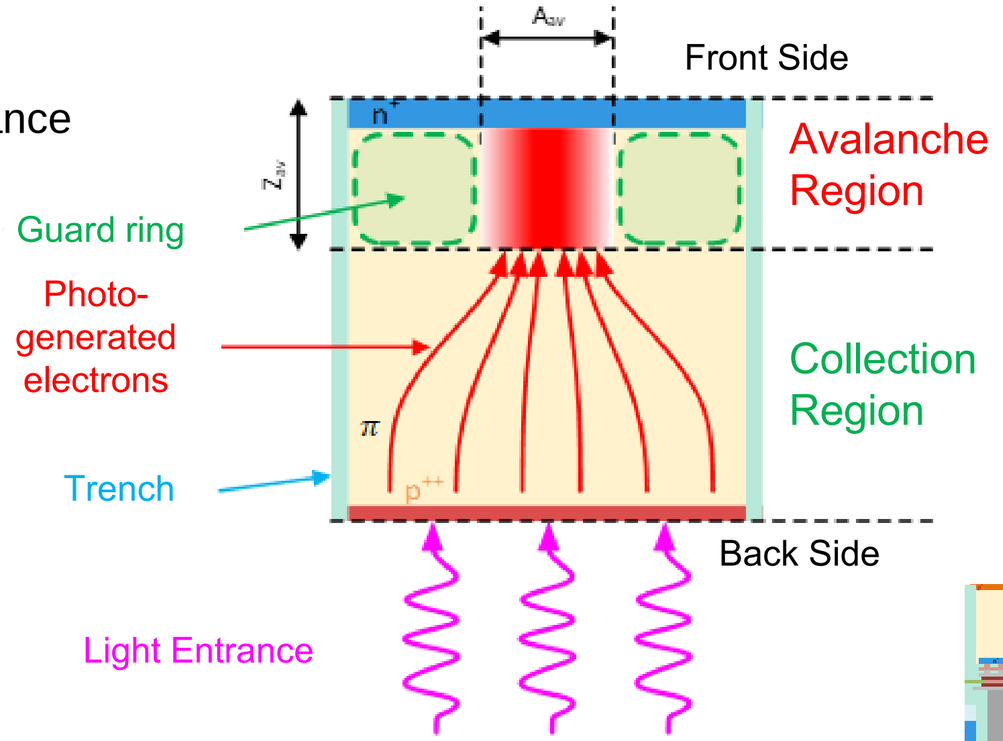
Innovative internal structure where the absorption and multiplication regions are decoupled

Challenge R&D:

- Creation of the new entrance window

Radiation hardness:

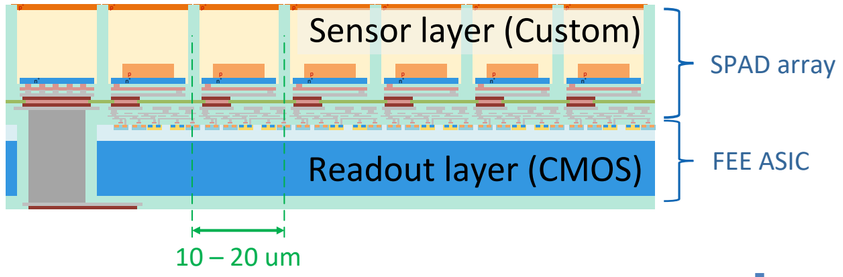
- The SiPM area sensitive to radiation damage, is much smaller than the light sensitive area
- **Assumption**: the main source of radiation damage is on the avalanche region.



Concept proposed by A. Gola in 2019. More details in PD24 talk.

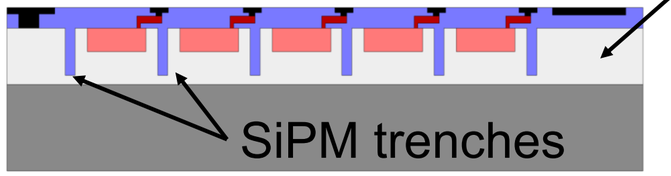
Potential Advantages:

- Up to 100% FF even with small cell pitch
- Device ready for direct 3D integration from the front



Back-side Illuminated process flow 1/2

1. Front-side fabrication



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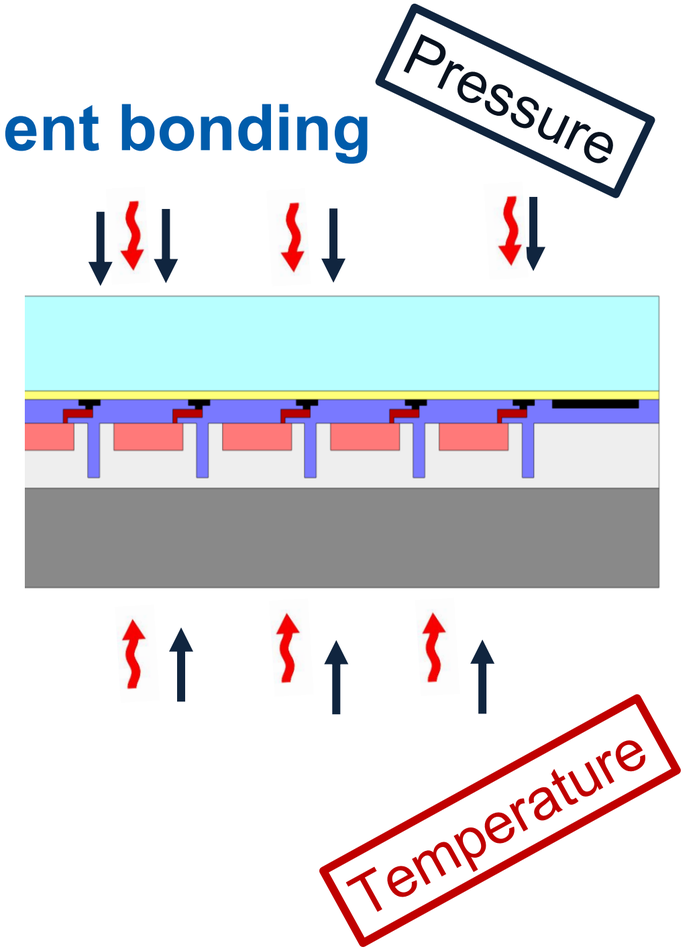
2. Permanent bonding



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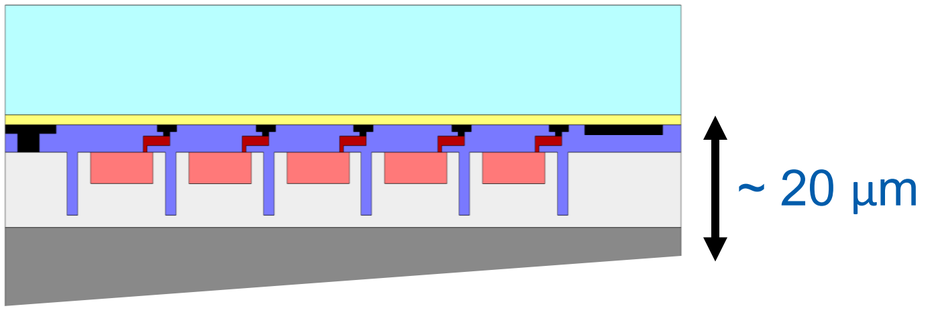
3. Fine grinding



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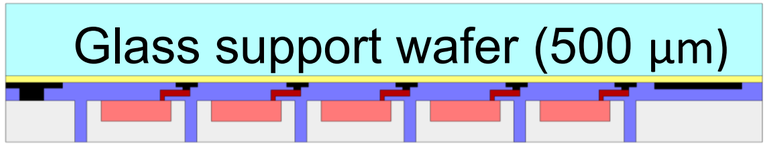
Remaining Substrate buffer after grinding: ~ 20 µm
with expected thickness total variation (TTV) ~ 5 µm

Back-side Illuminated process flow 2/2



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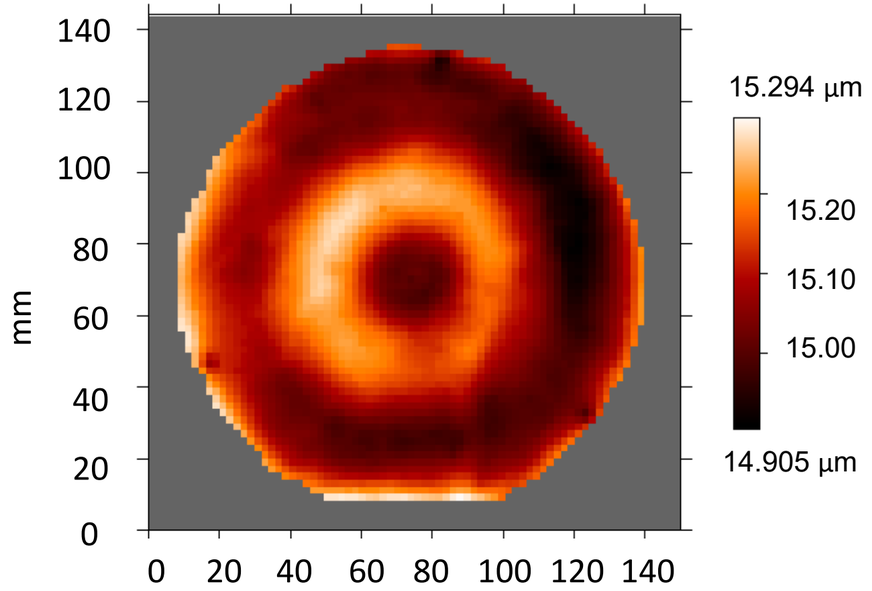
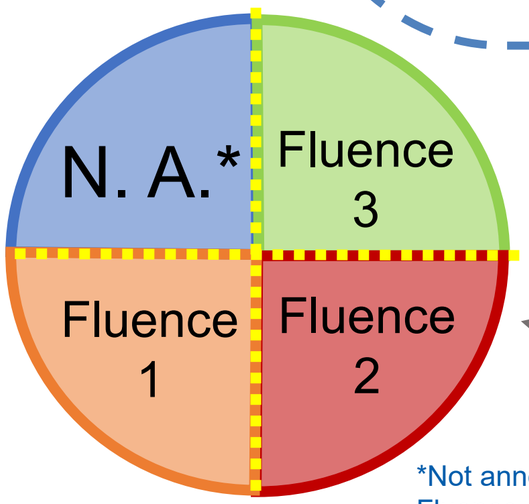
4. Precise ultra-thinnig

- Doping selective wet etch to reach the epitaxial thickness with very low TTV of about 1 µm
- Chemical mechanical polishing to obtain a mirror-like surface



Final TTV ~ 0.4 µm



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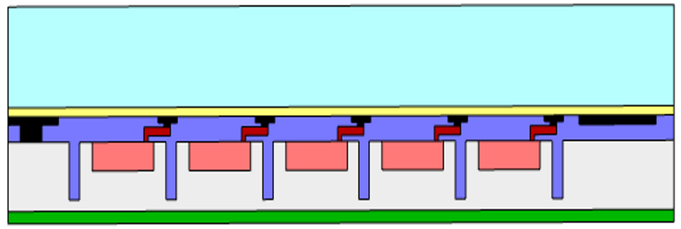
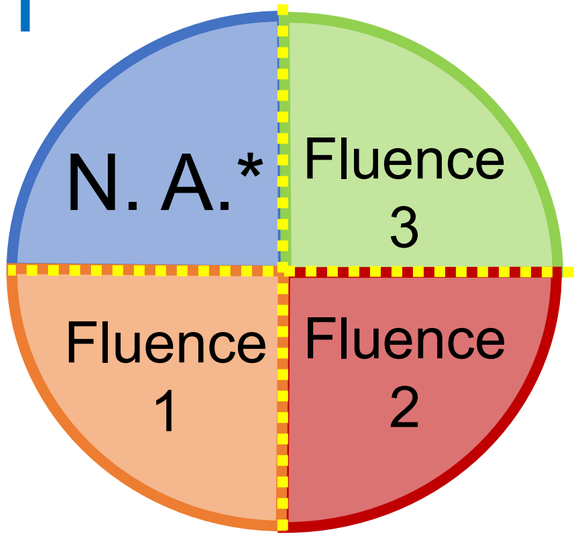
5. Back surface passivation

- Plasma ion implantation + laser annealing
- Antireflective coating deposition



*Not annealed
Fluence 1 < Fluence 2 < Fluence 3

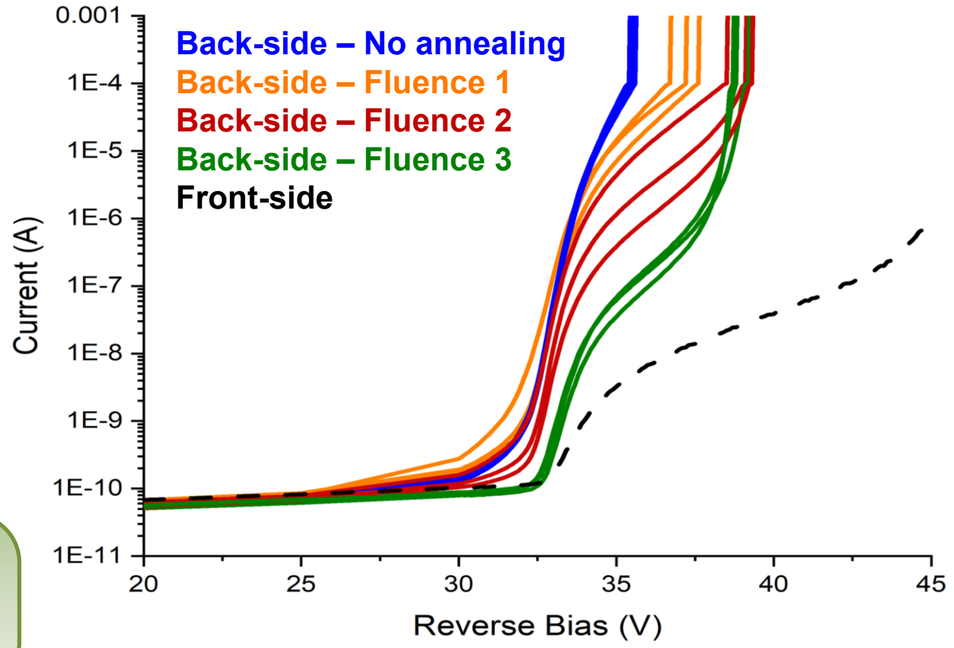
Preliminary results 1x1 mm² SiPM



*Not annealed
Fluence 1 < Fluence 2 < Fluence 3

WE OBTAINED FUNCTIONAL DEVICES

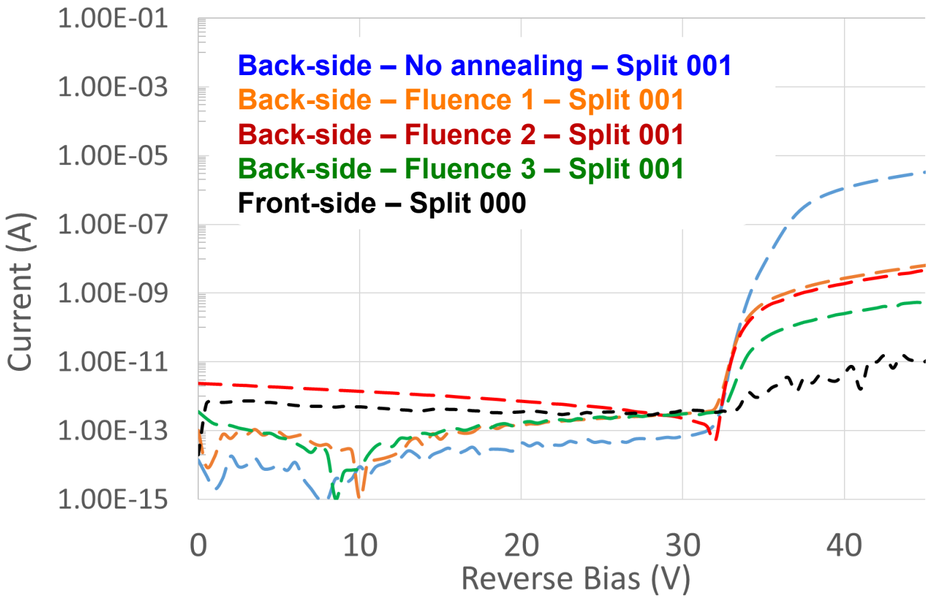
12.5 µm cell size (split 000) – Guard ring grounded



PRELIMINARY

SPAD

15 µm cell size – Guard ring grounded



- Similar breakdown voltage and leakage current when compared to the front-side illuminated (not-thinned)
- Trend in the process split, indicating an improvement with higher fluence ➔ better performance can be achieved
- From SiPM: shorter operating range for the thinned devices due to earlier second divergence compared to front-side due to crosstalk
- From SPAD: Dark current is higher, but further optimization can also be tested

SAVE THE DATE

5 MAY

FBK-Center for Sensors and Devices

ROADMAP FOR MICRO-NANOTECHNOLOGIES

2019-2029

- **IPCEI ME**
  3D integration with EU industry big players
- **IPCEI ME/CT**
  Chips JU Pilot Lines
  Partner in strategic EU actions
- **FESR**
  New infrastructures for research and innovation

→ **FBK**
Partner for innovate in the next 10 years

FONDAZIONE BRUNO KESSLER · IPCEI · Chips JU · IPCEI Microelectronics and Communication Technologies

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FUTURE BUILT ON KNOWLEDGE

Thank you

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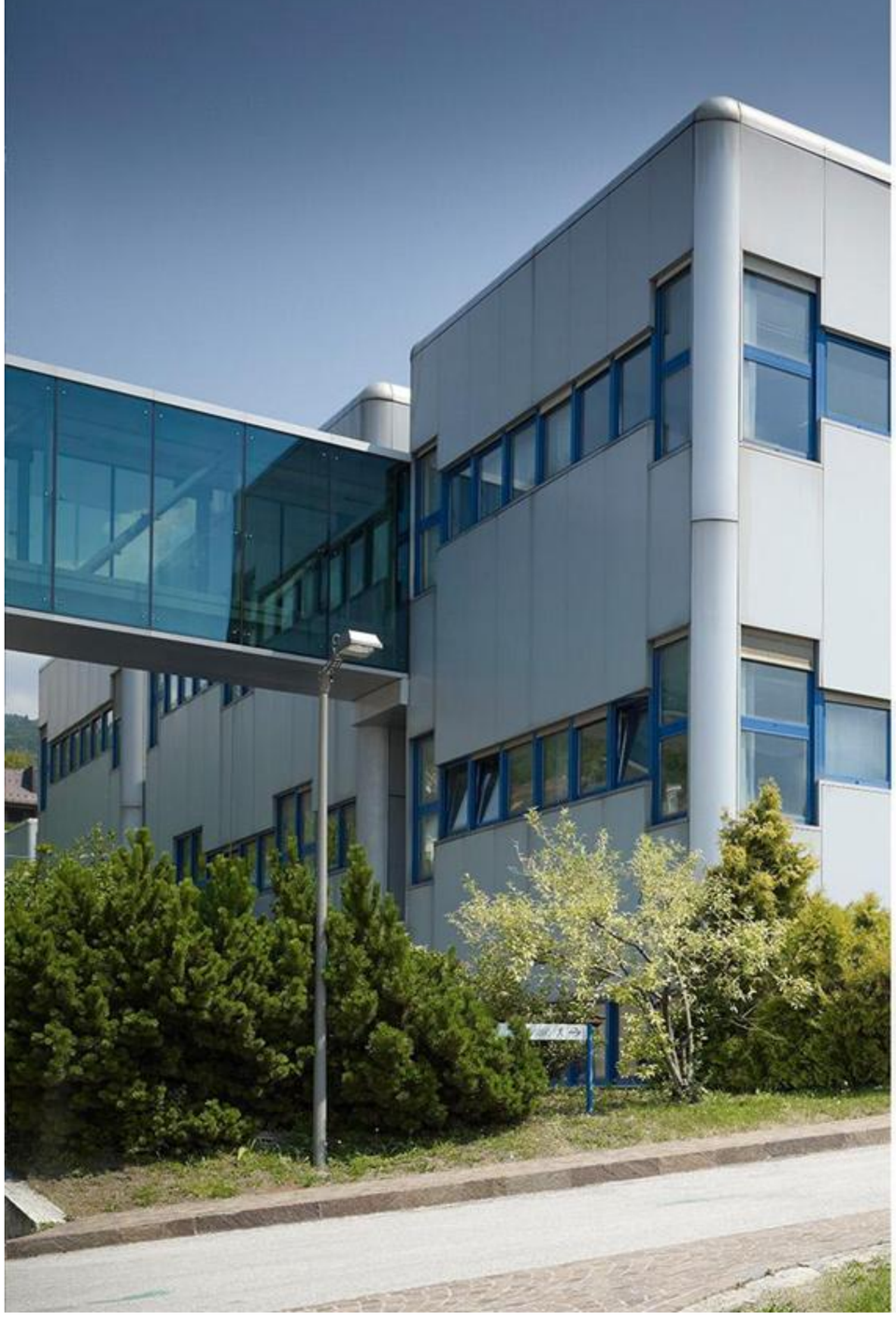

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