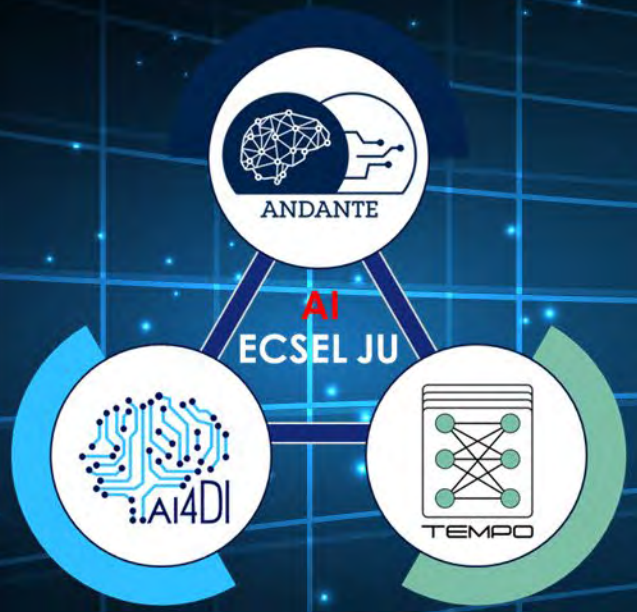
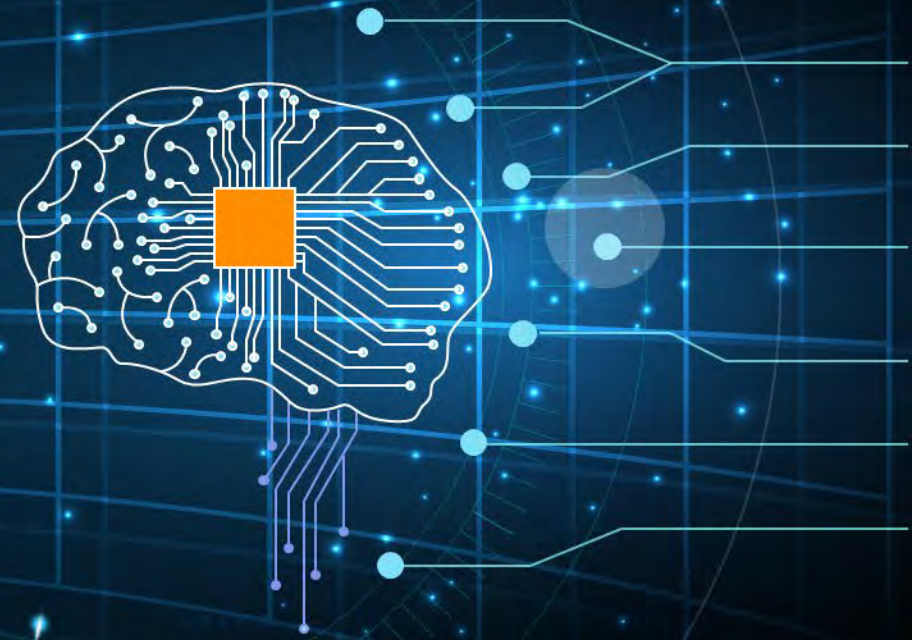
The International Workshop on Edge Artificial Intelligence for Industrial Applications (EAI4IA)

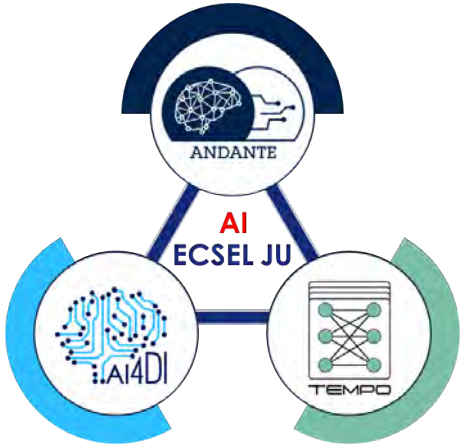




Vienna, Austria

25-26 July 2022

The International Workshop on Edge Artificial Intelligence for Industrial Applications (EAI4IA)



Feasibility of wafer exchange for European Edge AI pilot lines

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Vienna, Austria 25-26 July 2022

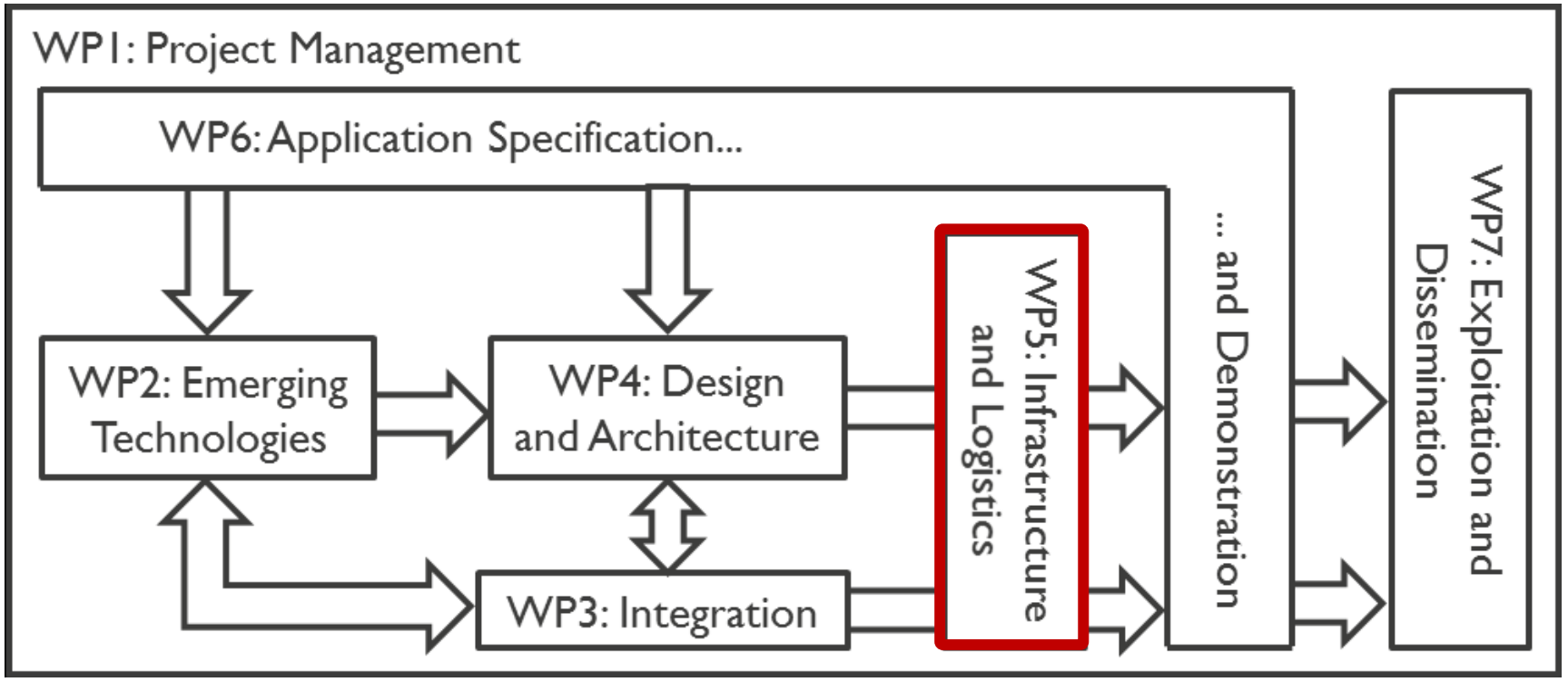
Presentation Outline

- Introduction
- Metallic contamination analysis
- Wafer exchange
- Experimental Results
- Conclusion and Outlook

Introduction

Technology alignment and roadmapping

→ Wafer exchange

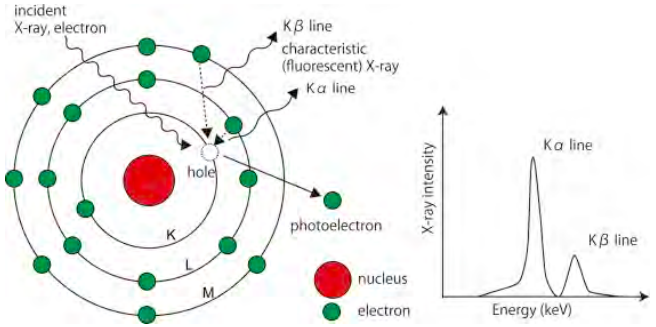


Metallic contamination analysis

TXRF (Total reflection X-ray fluorescence spectroscopy)

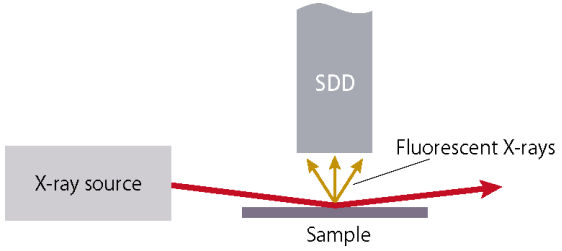
At Leti TXRFV310A

➢Electron-matter interaction



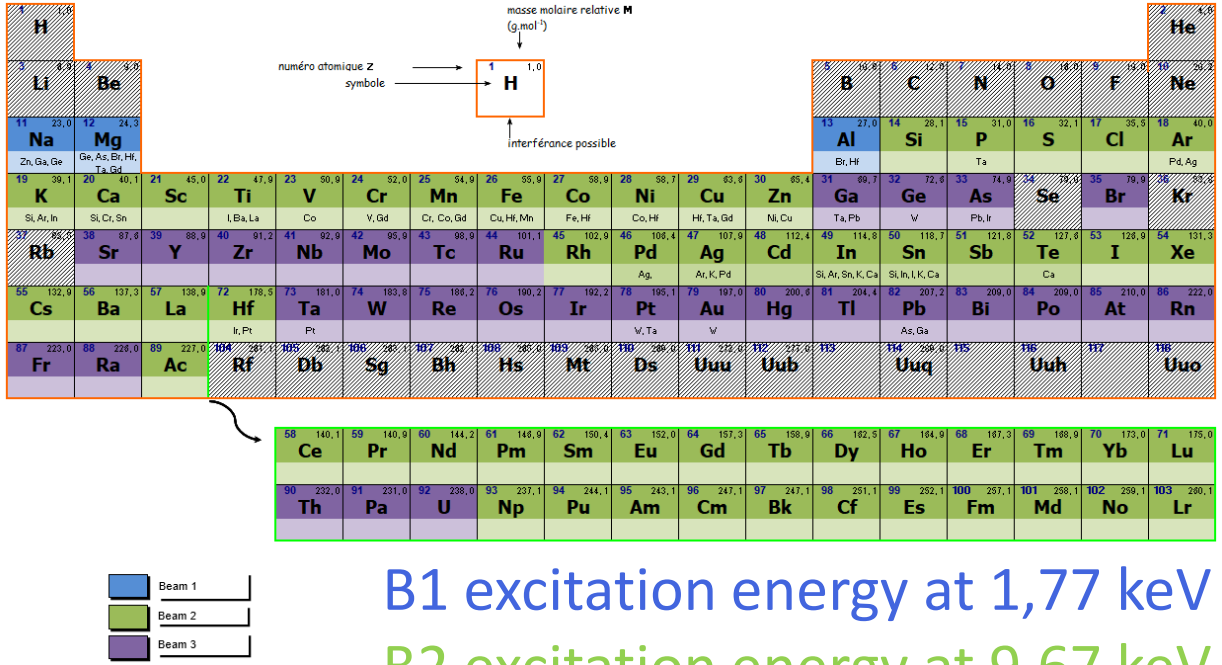
https://www.sciencedirect.com/science/article/pii/S1882761614000258

Total reflection:
Very low penetration <10nm



https://labsystematic.com/simple-overview-of-txrf-total-reflection-x-ray-fluorescence/

Three different beams to be able to measure as many elements as possible



B1 excitation energy at 1,77 keV

B2 excitation energy at 9,67 keV

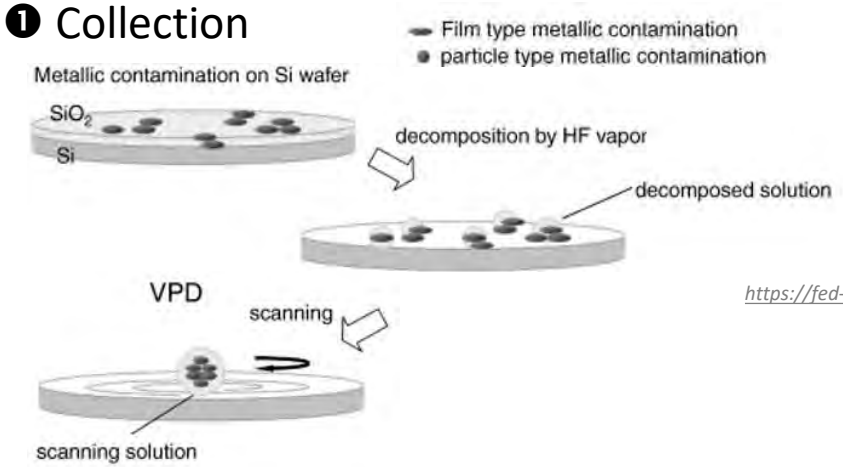
B3 excitation energy at 24 keV

Metallic contamination analysis

VPD (vapour phase decomposition) - ICPMS

➢Chemical analysis

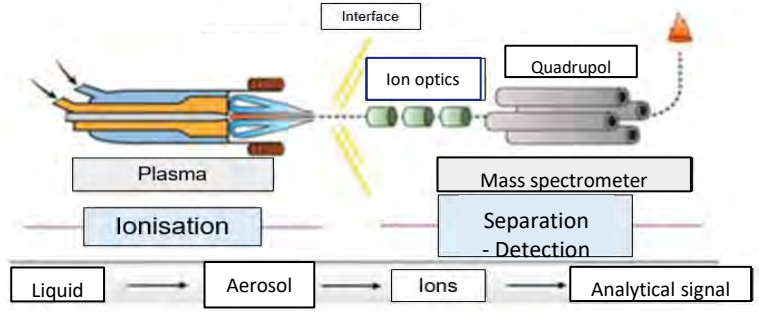
❶ Collection

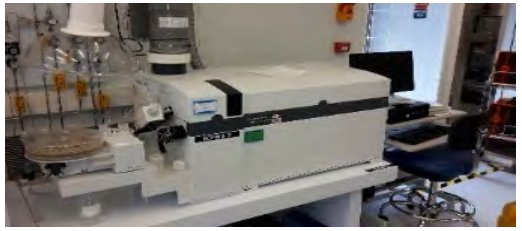


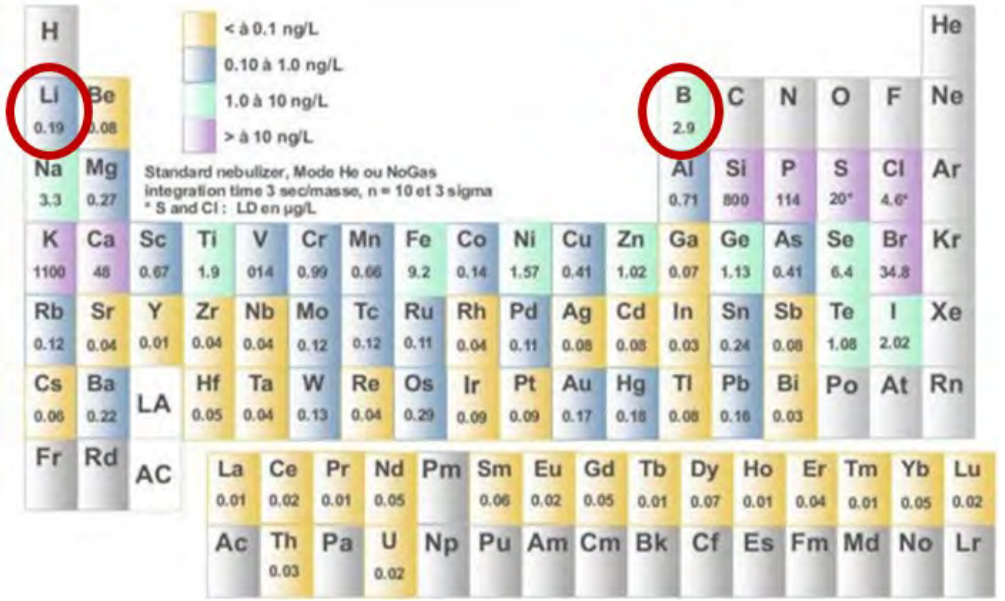
https://fed-chimiebalard.cnrs.fr/IMG/pdf/M_Tillard.pdf

https://www.vpdintegrationservice.com/vpd-in-brief

❷ Quantification







➢Lithium and Boron detected.

➢For noble metals, a different scanning solution is used

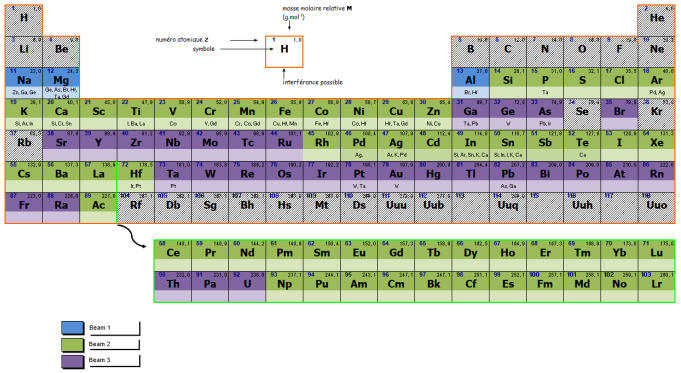
Standard Method: HF / H_2O_2

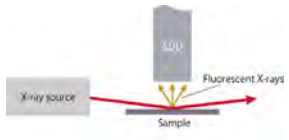
Noble Elements: HF / Aqua regia

Metallic contamination analysis

TXRF

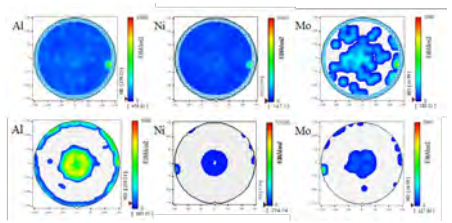
➢ Electron-wafer interaction





Very sensitive to roughness

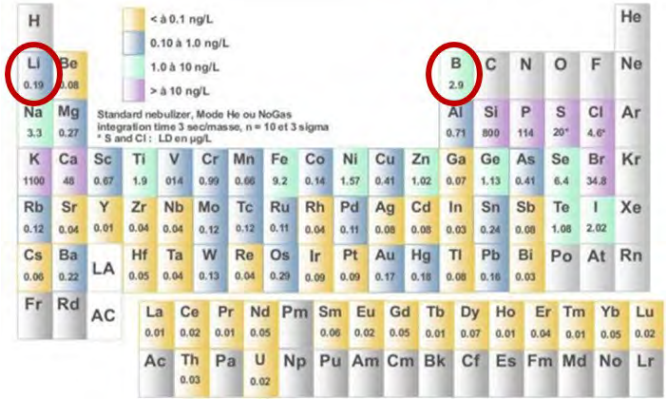
- Analysis of standards and nobles elements easily
- LLDs between E+9 et E+11 at/cm^2
- Possibility to localize the metallic contamination



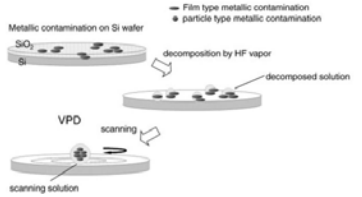
☝ Problems of interferences between elements

VPD-ICPMS

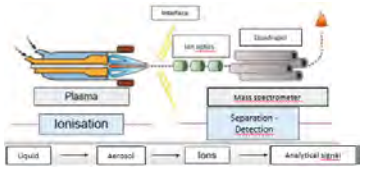
➢ Chemical analysis



❶ HF decomposition + collection : VPD



❷ Quantification : ICPMS



- Campains for noble elements due to the use of different chemical solutions
- LLDs lower, between E+6 and E+11 at/cm^2
  - ➢ Used when lower LLDs are needed and when interferences with TXRF
- No localization of the metallic contaminants
- Possibility to analyse the entire bevel (FS, bevel, BS)

Metallic contamination analysis

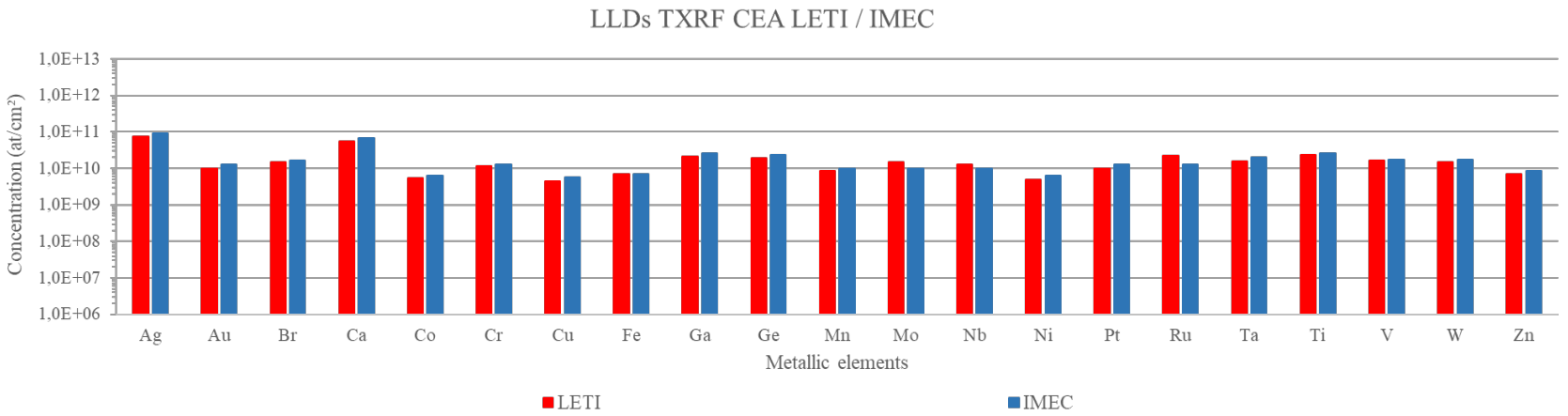
Technical analysis for metallic contamination available at Leti-imec-FhG

Technics	LETI	IMEC	FhG
VPD-ICPMS	Wafer surface analysis • Back side • Front side • Bevel	Wafer surface analysis • Back side • Front side • Bevel	Wafer surface analysis • Back side • Front side • *Bevel under development*
TXRF	Wafer surface analysis • Back side • Front side • Bevel/Edge	Wafer surface analysis • Back side • Front side • Edge	*For wafer fragments and not yet available, under development*

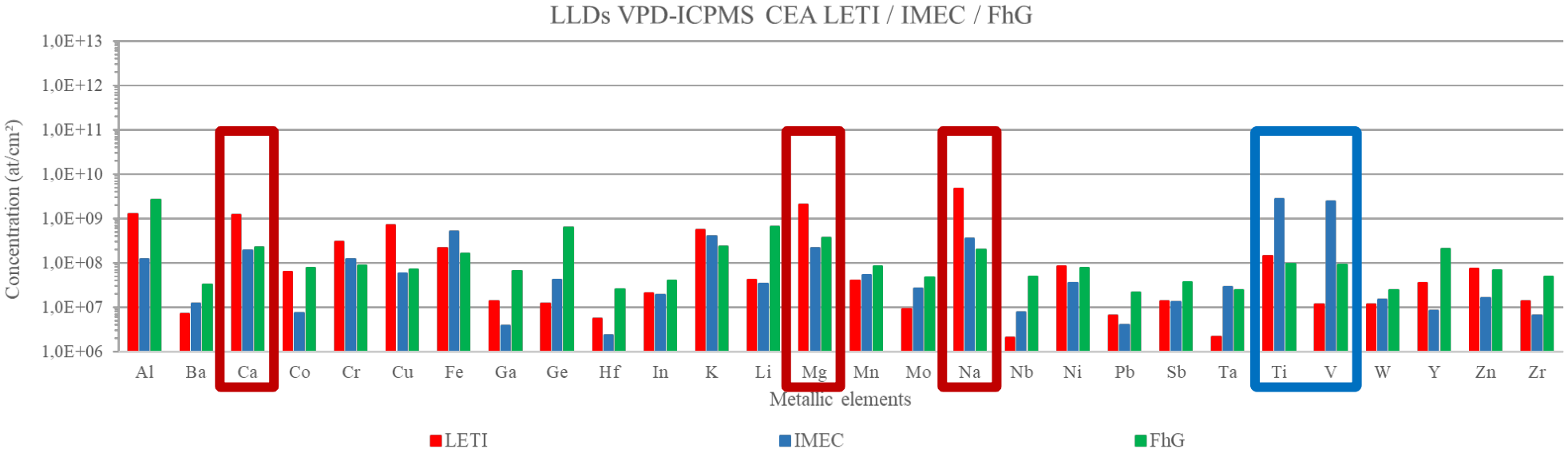
For regular contamination checks :

- TXRF at **Leti and imec**, and VPD for increased sensibility on certain elements
- VPD-ICPMS at **FhG**

Metallic contamination analysis



TXRF LLDs of CEA Leti and imec are nearly the same → good agreement between both institutes



Ca, Na and Mg
→ Environment

Ti and V
→ Specific detector settings

VPD-ICPMS LLDs differs → due to different equipment and different environment

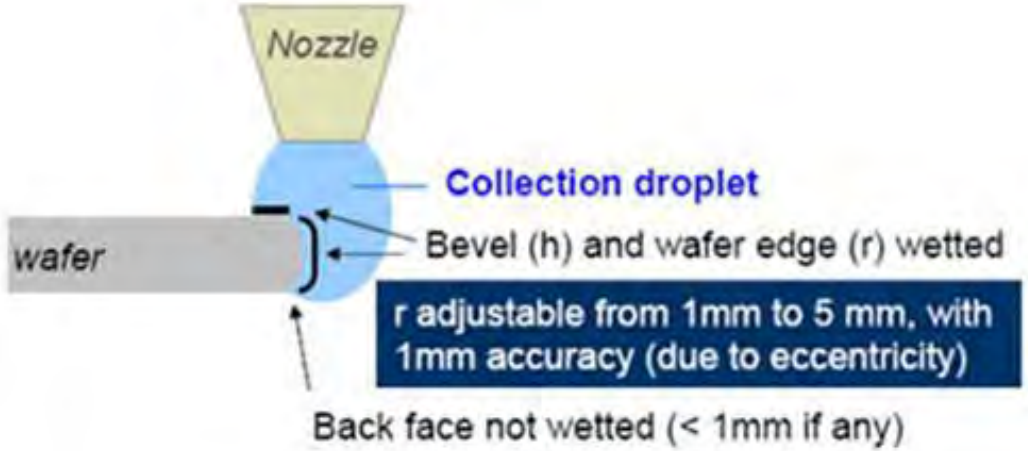
Metallic contamination analysis

Aligned Data	LETI	IMEC	FhG IPMS CNT
Determination of LLD (VPD-ICPMS)	LLD VPD-ICPMS = 3xSigma for each elements	Calculated from 3xstandard deviation of calibration blank and slope of calibration curve.	For complete process VPD-ICPMS permanent blank method.
VPD Brand and type	Rigaku VPD300A, stand alone	IAS ExpertTM VPD system	**External source:** no data **CNT:** TePla System stand alone
ICP-MS brand and type	Agilent 8800, three quadrupoles	Perkin-Elmer Nexion™ ICP-MS	**External source:** no data **CNT:** Thermo Fischer RQ, single quadrupole
Exclusion size VPD	7 mm	1 mm	**External source:** no data **CNT:** 5 mm (planned)

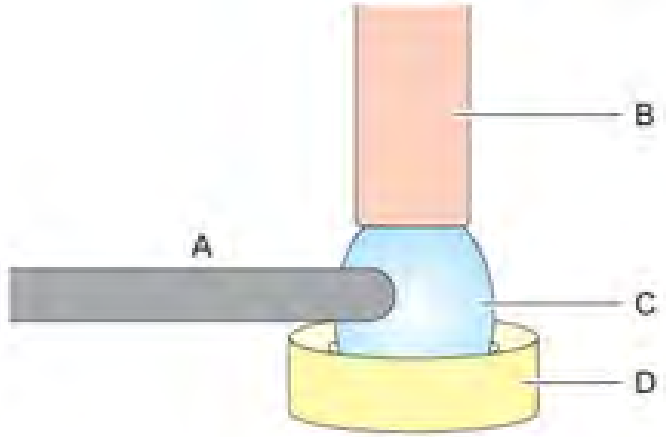
Metallic contamination analysis

VPD Bevel analysis

Leti



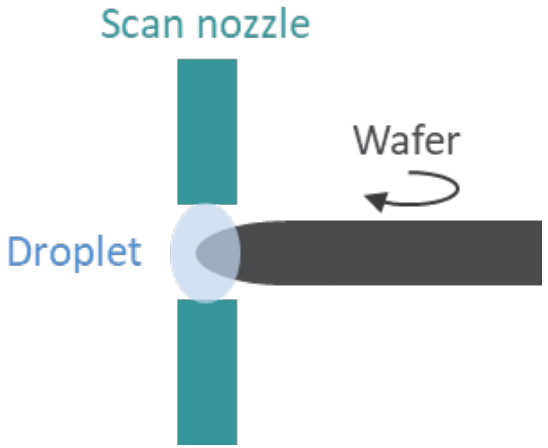
FhG



Bevel scanning principle

A Rotating wafer
B Scan tube
C Droplet
D Droplet holder

IMEC



Wafer exchange

Wafer exchanges protocols or ‘’line of defense’’ to secure exchanges

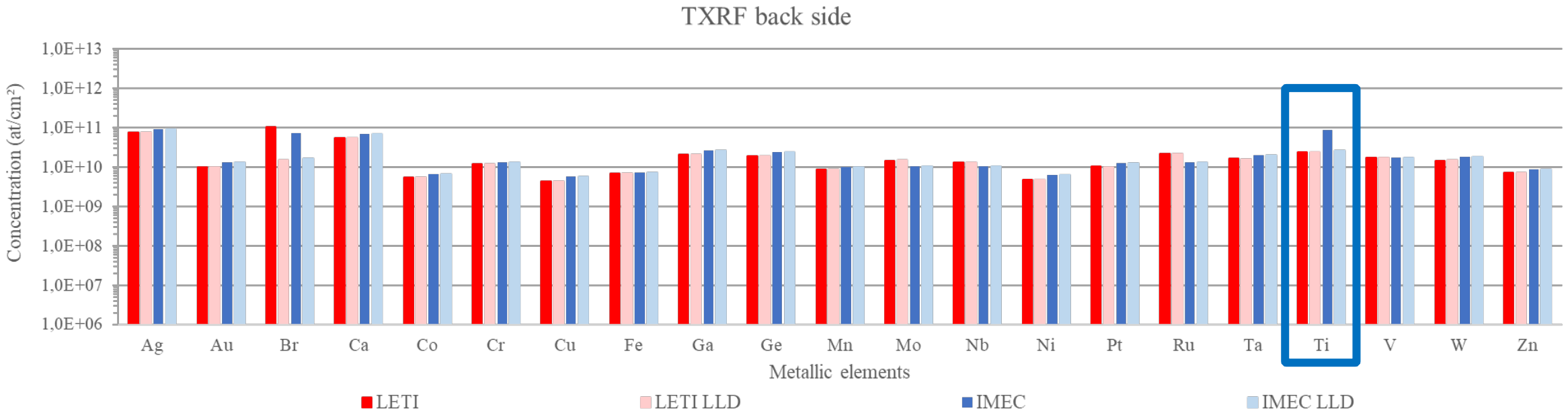
at CEA-Leti, imec, FhG:

- Contamination analysis on witness wafers to check contamination levels of tools
- Comparison with specs

Tool owner	Type of tool	Date of Wafer	Wafer analysis
CEA-Leti	Ellipsometer	19.04.2020 to FhG 19.04.2020 to imec	31.07.2021 at imec 19.04.2021 at Leti 14.06.2021 at FhG
IMEC	Inspection	17.03.2021 to Leti 17.03.2021 to FhG	29.04.2021 at imec 13.04.2021 at Leti 14.06.2021 at FhG
FhG CNT	Deposition	15.09.2020 to Leti 21.09.2020 to imec	17.09.2020 at FhG 01.02.2021 at imec 25.02.2021 at LETI

Experimental Results

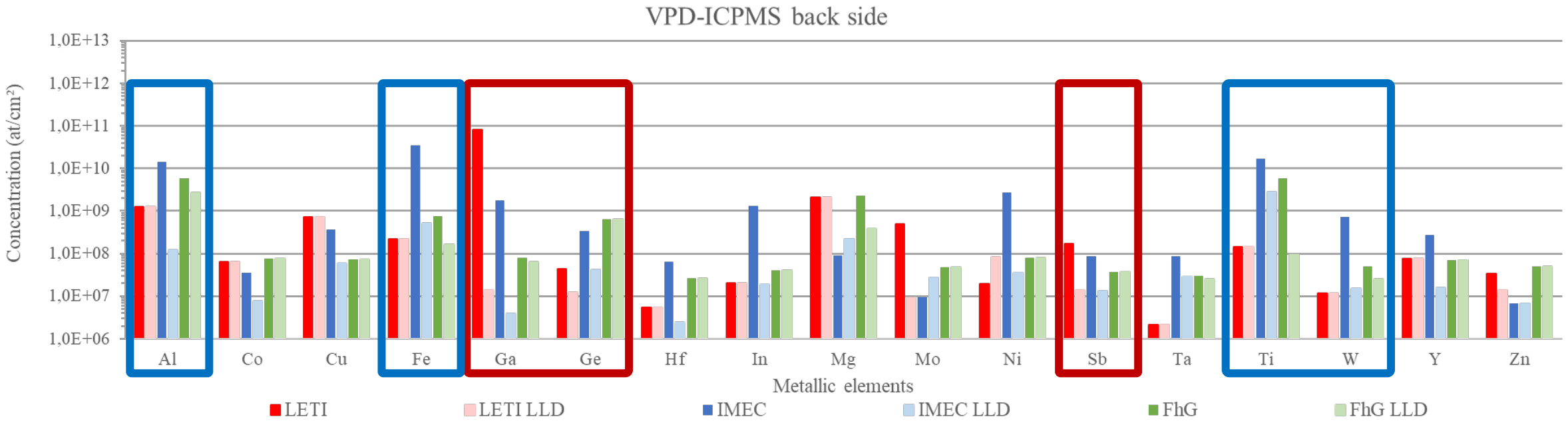
Results for imec tool



- High agreement between the values
- Ti (imec) is assumed to be a handling contamination

Experimental Results

Results for imec tool

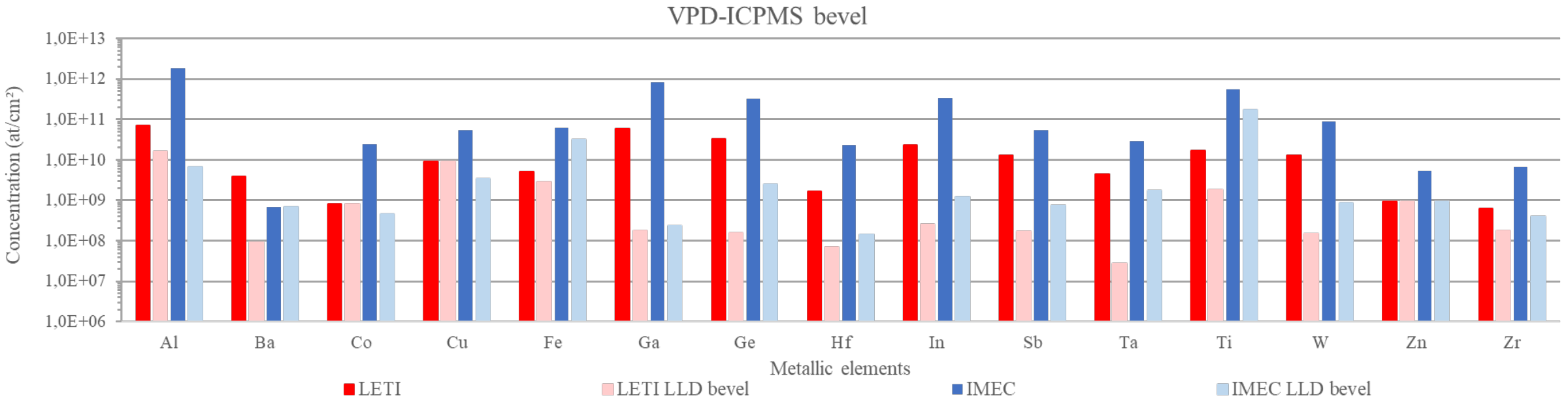


- More elements are detected due to the lower LLDs
- The three analysed wafers have not the same contamination

→ The process do not allow to contaminate each wafer at the same concentration

Experimental Results

Results for imec tool



Contamination levels on the bevel are higher than those measured on the surface

Conclusion and Outlook

Conclusion

- Analysis of metal contamination with comparable LLDs
- The handling in one tool can not produce identically contaminated wafers
- First step for easier wafer exchange accomplished (first experiences and strengthening of cooperation)
- Important milestone in the alignment of the three research institutes has been reached

Outlook

- Next step an interlaboratory test with intentionally standardised contaminated wafers
- Develop techniques to analyse the metallic contamination on real wafers during the flow

Event Organisers

The Key Digital Technologies Joint Undertaking - the Public-Private Partnership for research, development and innovation – funds projects for assuring world-class expertise in these key enabling technologies, essential for Europe's competitive leadership in the era of the digital economy. KDT JU is the successor to the ECSEL JU programme. www.kdt-ju.europa.eu

The AI4DI project has received funding from the ECSEL Joint Undertaking (JU) under grant agreement No 826060. The JU receives support from the European Union's Horizon 2020 research and innovation programme and the national authorities. www.ai4di.eu

The TEMPO project has received funding from the ECSEL Joint Undertaking (JU) under grant agreement No 826655. The JU receives support from the European Union's Horizon 2020 research and innovation programme and Belgium, France, Germany, The Netherlands, Switzerland. www.tempo-ecsel.eu

The ANDANTE project has received funding from the ECSEL Joint Undertaking (JU) under grant agreement No 876925. The JU receives support from the European Union's Horizon 2020 research and innovation programme and Belgium, France, Germany, The Netherlands, Portugal, Spain, Switzerland. www.andante-ai.eu

Thank You

For your attention

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