ePIC SVT DSC meeting
October 3, 2023

Capabilities of RPE LTU (Kharkiv team) on aluminum flexible circuit manufacturing for international physics experiments

RPE LTU:
Prof., Dr. Vyacheslav (Slava) *Borshchov*
Dr. Ihor Tymchuk (speaker)
Dr. Maksym Protsenko

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Outline

- Brief information about RPE LTU and activities
- Some features of base approach and materials
- LTU’s contribution to particle physics experiments

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RPE LTU (Kharkiv team): introduction

- ***brief information about team:***
  - *staff of team: ~30 persons* ***(incl. 1 Professor, 3 PhDs, 2PhD students)***
  - *leader of team: Prof. Dr.* Vyacheslav (Slava) Borshchov
  - *leading experts: Dr. Ihor Tymchuk, Dr. Maksym Protsenko*
  - *departments/sites: microcables production site and assembly site*
  - *year 2013 – team is passed from SE SRTIIE to RPE LTU*

Note: *Prof. Dr. Borshchov, Dr.Tymchuk and Dr.Protsenko are affiliated with Bogolyubov Institute for Theoretical Physics (BITP) of the National Academy of Sciences of Ukraine*

- ***main activities:***
  - ***engineering for particle physics experiments***
  - *space engineering (solar arrays, flexible heaters, etc.)*
  - *terrestrial photovoltaics (concentrator photovoltaic)*

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Activities for particle physics experiments

- Designing ultra-light components of detector modules (single- and multilayered flexible cables and flexible-rigid boards etc.)
- Designing photomasks
- Manufacturing and assembling components of detector modules
- Developing assembly workflows for detector modules and their components
- Developing, designing and manufacturing precise assembly jig
- Implementing assembly processes at assembly sites (if necessary)
- Reliability tests of the components

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Some features & advantages of base ultra-light „aluminium" approach

Features:

- *Materials for the components:*
  - *- base materials -* *aluminium-polyimide adhesiveless foiled dielectrics*
  - *- conductive layer -* *aluminium*
  - *- dielectric spacer –* *Kapton/polyimide*
- *Manufacture techniques for flexible layers :* *photolithography &chemical wet etching*
- *Assembly techniques:* *SpTAB & gluing*

Advantages:

- *conductive layer* ***is aluminium***
- ***lower material budget*** *(compared to Cu)*
- ***absence of heavy metals*** *(Au, Sn) on the flex and on the chip (soldering is not needed)*
- *connection of aluminium leads of the flex to aluminium contact pads of the chip that ensure* ***high-reliable and mechanically stable connections****;*
- *possibility to realize* ***3-D (volumetric) design*** *of the module/component*
- *approach* ***is verified*** *in practice in detector modules and their prototypes for different particle physics experiments*
- *high-precise and high-throughput standard* ***automated equipment*** *can be used for assembly (Delvotec G4, G5 bonders etc.). Tunning the bonder is very simple and can be done in few hours!*

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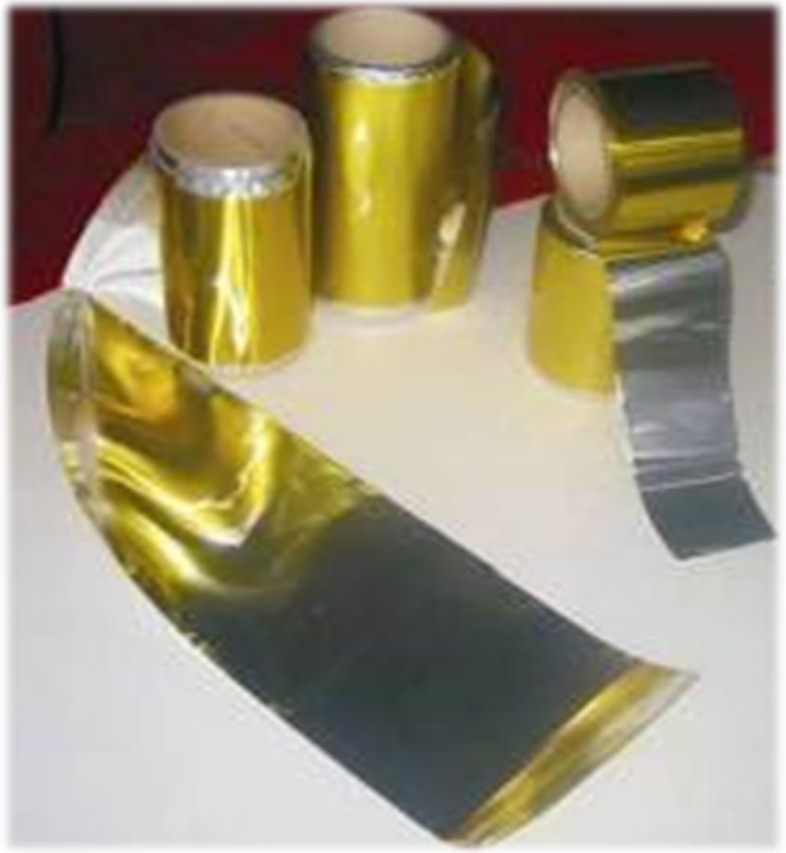
Materials for ultra-low mass flexible interconnection elements

Aluminium-polyimide adhesiveless foiled dielectrics



Materials developed by LTU

❖ **FDI-A-50**
polyimide – 20 um
aluminium foil – 30 um

❖ **LTU-2-100**
polyimide – 20 um
aluminium foil – 100 um

❖ **FDI-A-24**
polyimide – 10 um
aluminium foil – 14um

❖ **LTU-2-50**
polyimide – 20 um
aluminium foil – 50 um

❖ **FDI-A-20 (under development)**
polyimide – 10 um
aluminium foil – 10um

❖ **LTU-3-50**
polyimide – 10 um
aluminium foil – 50 um
polyimide – 10 um

Note: all abovementioned Al-Pi adhesiveless materials now producing by RPE LTU

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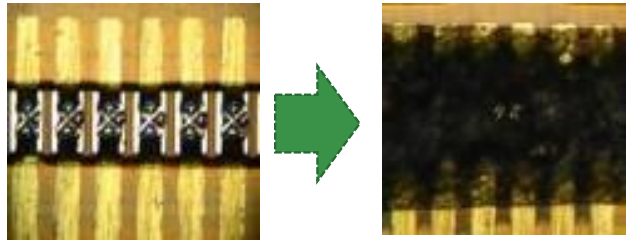
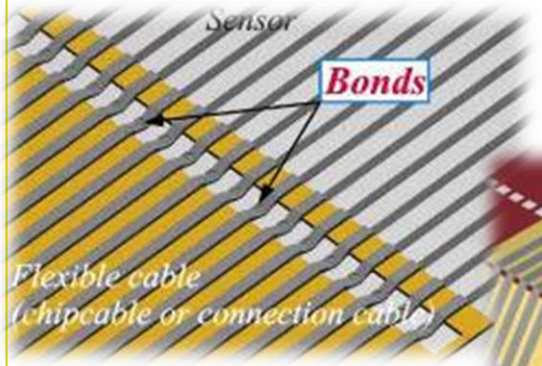
Some features of assembly process

Main process at assembling components of modules is an ultrasonic Single point TAB bonding (SpTAB, manual or automatic) of aluminium traces to aluminium contact pads on chip, sensor or flexible cable with further encapsulating by glue

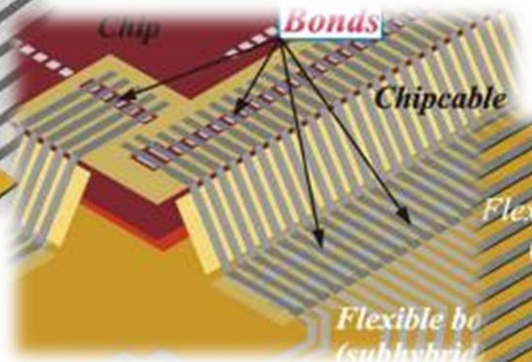


Schematic close-up views of some different SpTAB areas

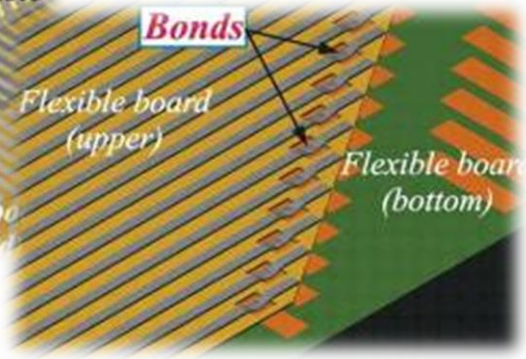
cable-to-sensor



chipcable-to-chip & chipcable-to-subhybrid



flexible board-to-flexible board (inside subhybrid)



Typical SpTABed joints

- ***top layer-to-chip***

- ***bottom layer-to-chip***

- ***interlayer connection***

Note: SpTAB technique allows to have two times less bonds (comparing to wire bonding) - higher reliability

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Typical stages of cooperation

Pre-R&D

- analyzing initial data, developing base design and technological solutions, developing some technological mock-ups

R&D

- developing, designing, investigating and delivering prototypes (typically few iterations)

Pre-production

- designing, manufacturing and delivering prototypes for final verifying and approval

Production

- manufacturing and delivering final flexes/assemblies/components

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RPE LTU: contribution to international particle physics experiments

Bogolyubov Institute for Theoretical Physics

LHC

FAIR

HIMB

RIBF

CEBAF

Main partners of LTU:

CERN
Uni Bergen
NIKHEF/Uni Utrecht
INFN

GSI
FAIR
Uni Mainz

Uni Heidelberg
Uni Oxford

Tech Uni Darmstadt
LPC CAEN
GSI

Uni Manitoba

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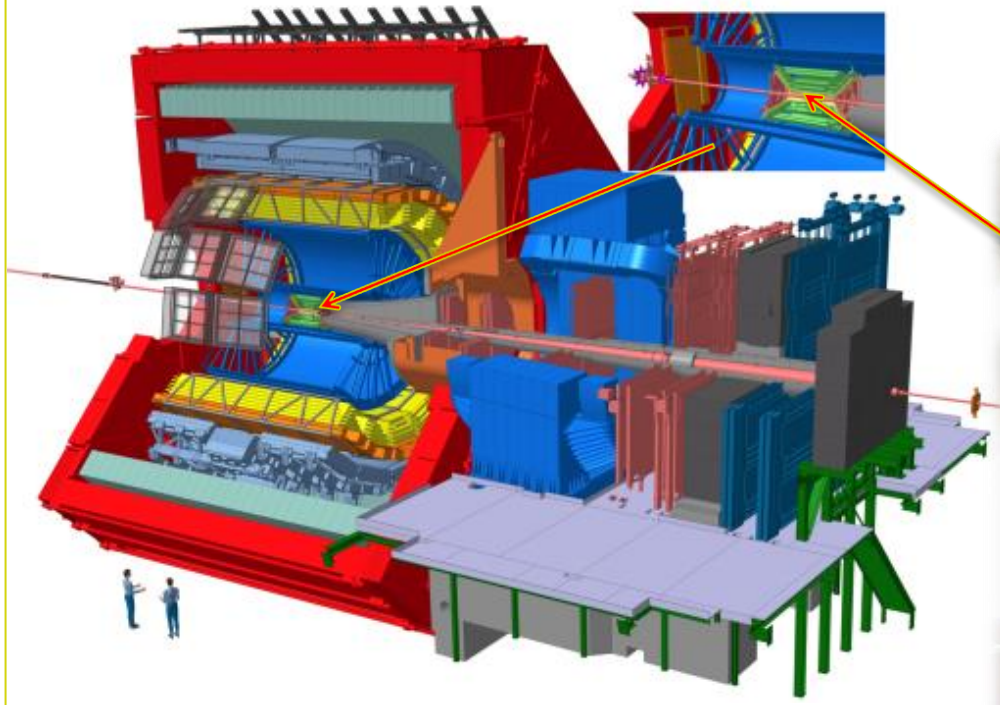
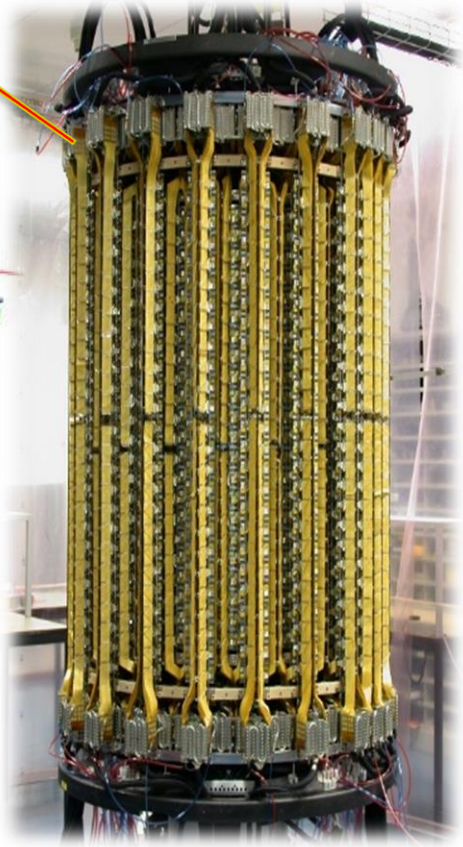
RPE LTU contribution to ALICE at CERN

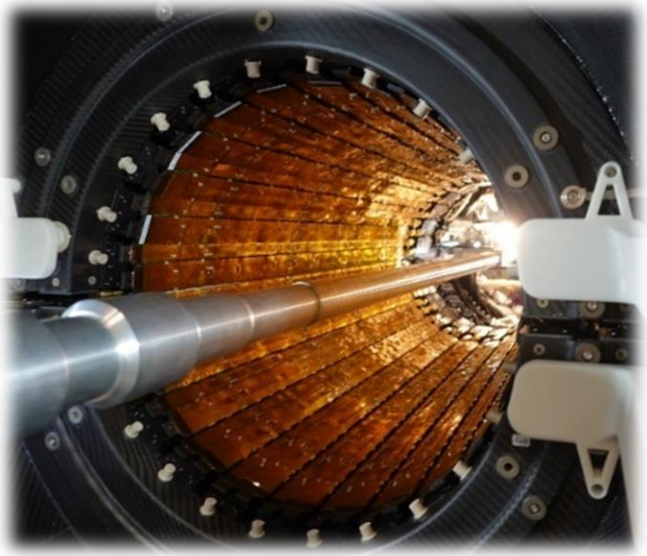


Projects: ***Inner Tracking System*** *(ITS1, ITS2, ITS3)*

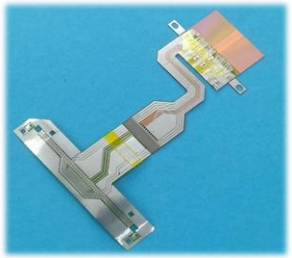
ITS 1
(1994-2007)



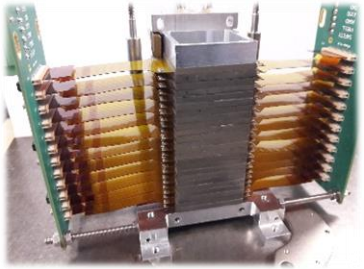
ITS 2
(2008-2018)



ITS 3
(2018-2025)



Project:
Forward Calorimeter
(FoCal)
(2017-2025)



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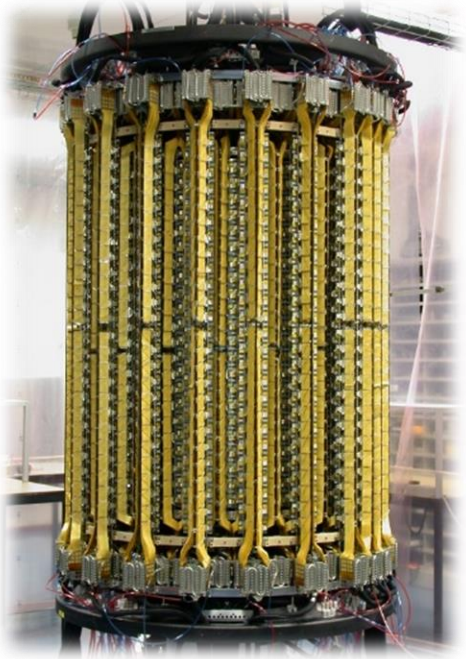
Kharkiv team for ALICE ITS1

ITS (1)

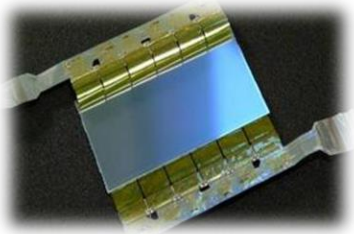


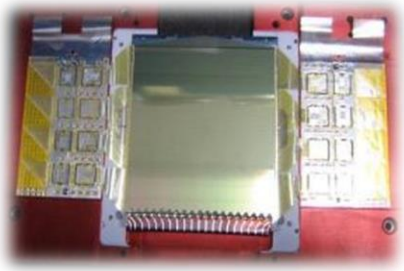
Ladders

Strip

Drift

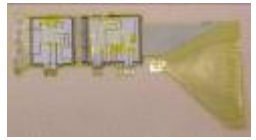
Detector modules





Components

Chipcables (fine-pitch microcables)



Subhybrids

Long connecting cables

ASICs: HAL25, PASCAL, AMBRA
Sensors: Strip, Drift

Main partners: CERN, NIKHEF/Uni Utrecht, INFN, HIP, IN2P3

Current status: *production complete* *(more than 50000 components (chipcables, subhybrids, long microcables) manufactured and delivered)*

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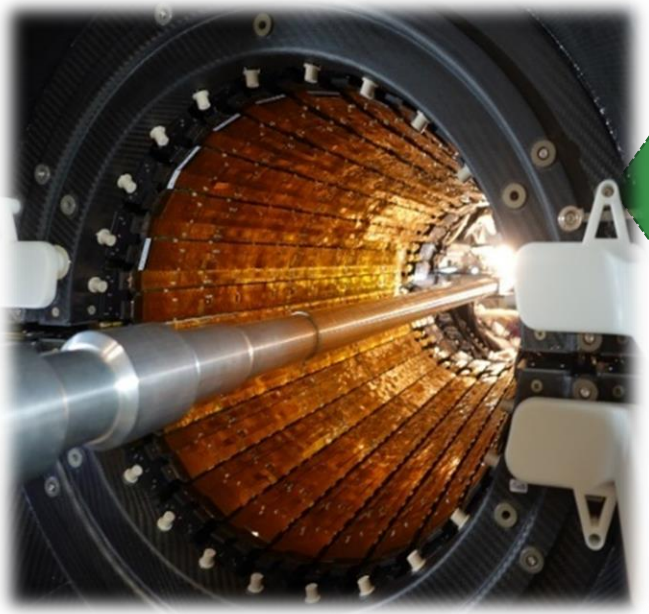
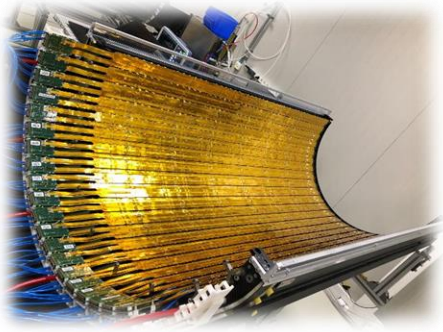
LTU for ALICE ITS2

ITS2



Sensors: ALPIDE MAPS

Semi-barrel



Components

Cross-cable (CC)

Multilayered (up to 10 layers), multicomponent (up to 80 components) flexible long (~up to ~1,6m) microcables and special single-layered flexible cable

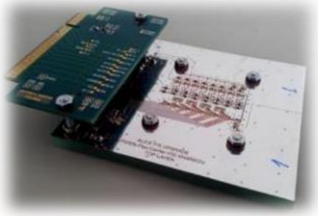
Power bus (PB)

Bias bus (PB)

SpTAB-prototypes

FPC prototype

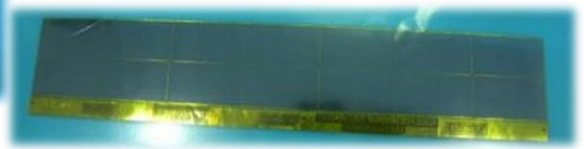
Single-MAPS prototype



IB FPC prototype (for 9 MAPS)

OB FPC prototype (for 14 MAPS)

SpTAB OB module mock-up



Main partners: CERN, LBNL, INFN, NIKHEF/UniUtrecht

Current status: *production complete (about 16000 components (PB, BB, CC) manufactured and delivered)*

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Some technological novelties and know-how developed and implemented in production for ALICE ITS2

New approaches

- to creating PBs, BBs and CCs
- to assembling PBs, BBs

New materials

- two-layered Al-Pi materials for 50 and 100um Al foil, Pi ~25um thick
- three-layered Al-Pi material for 50 um Al foil, Pi ~10um thick

New technologies

- for producing CCs based on new three-layered Al-Pi material with 50 um Al foil and Pi ~10um thick
- for producing components of PBs (thick Al foil)

Note: developed and implemented technological novelties and know-how are using for further activities and experiments

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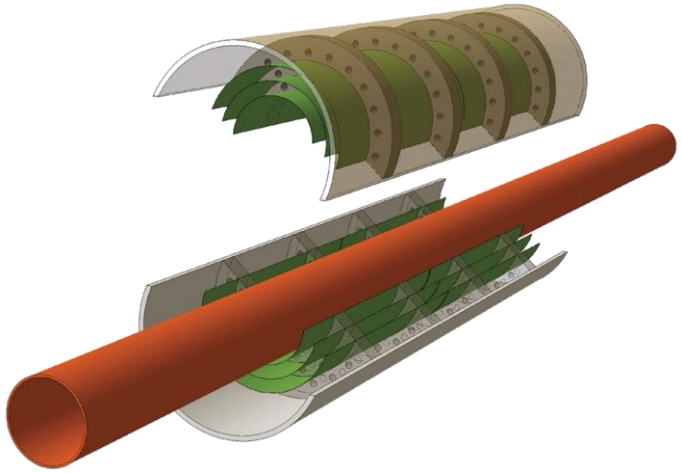
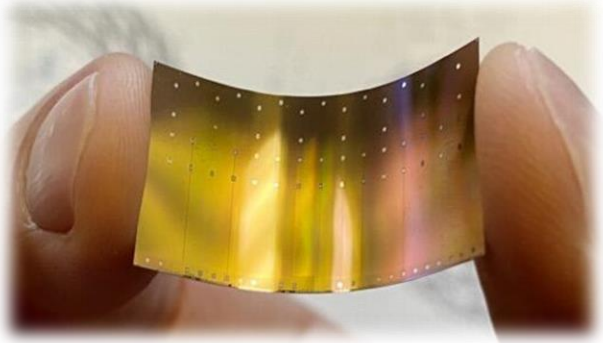
RPE LTU for ALICE ITS3

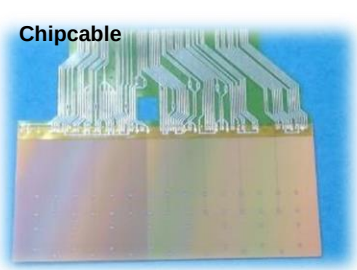
ITS3

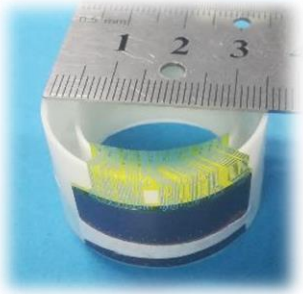


Key feature: bent MAPS



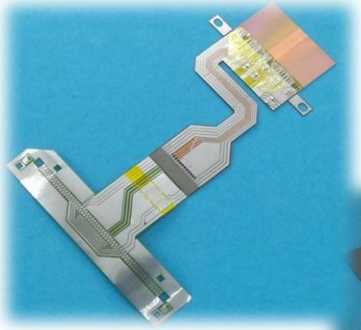
SpTAB-approach for interconnection of bent sensors



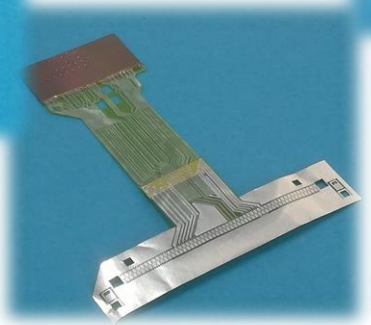


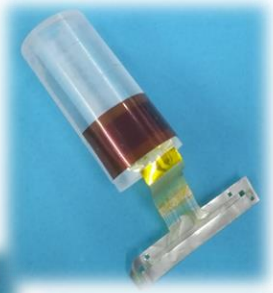
Investigated bent/unbent ALPIDE MAPS

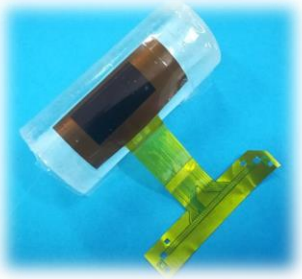
SpTAB single-ALPIDE prototype



SpTAB chipcable assembly







Sensors: ALPIDE MAPS, stitched MAPS

Main partners: CERN, Uni Bergen, INFN, NIKHEF/Uni Utrecht

Current status: *R&D (now is a bit postponed, will be resumed soon)*

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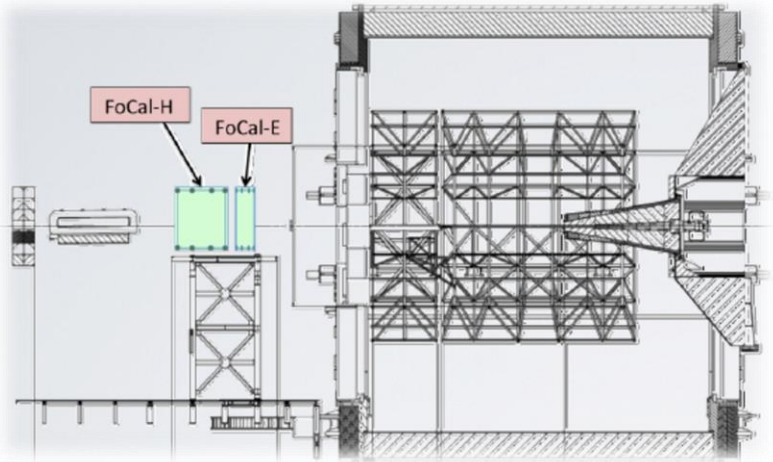
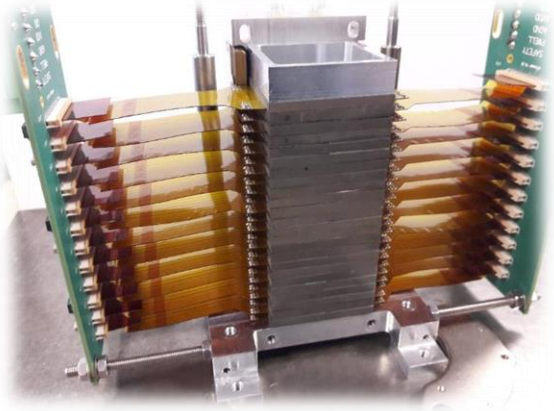
RPE LTU for ALICE FoCal

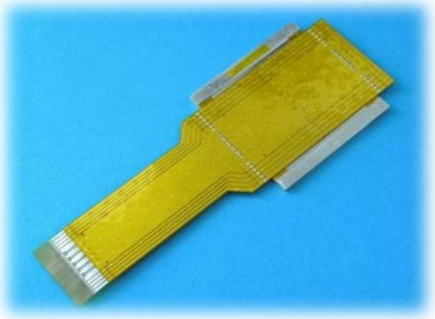
FoCal-E (ECAL Si-W)



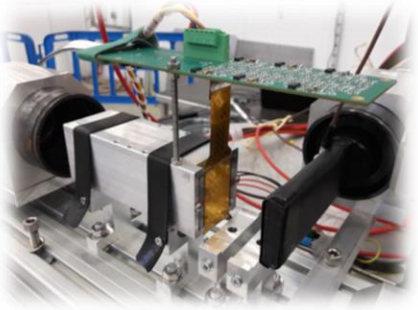
EPICAL-2 (24 layers)



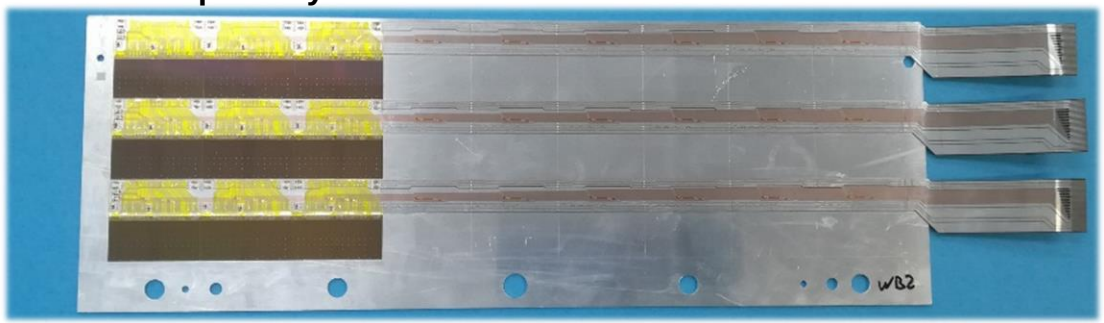
2-ALPIDE SpTAB module for EPICAL-2



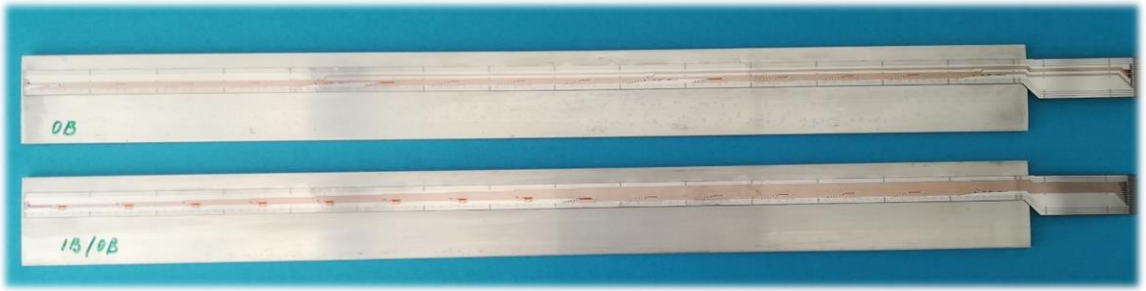
SpTAB-EPICAL module prototype under testing (CERN)



FoCal pixel layer for SPS beam test at CERN



Multilayered flexible boards on carriers for FoCal 15-chip OB and IB/OB strings



Sensors: ALPIDE MAPS

Main partners: CERN, Uni Bergen, NIKHEF/Uni Utrecht

Current status: *R&D*

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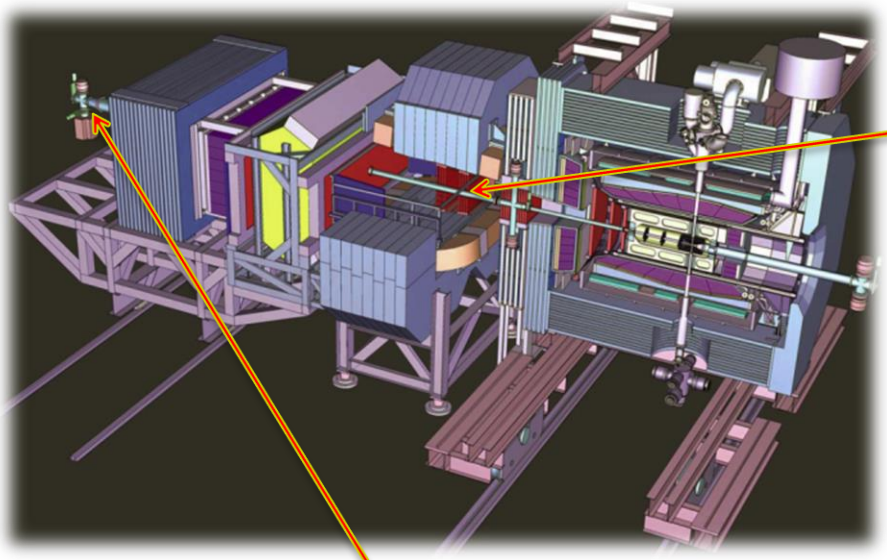
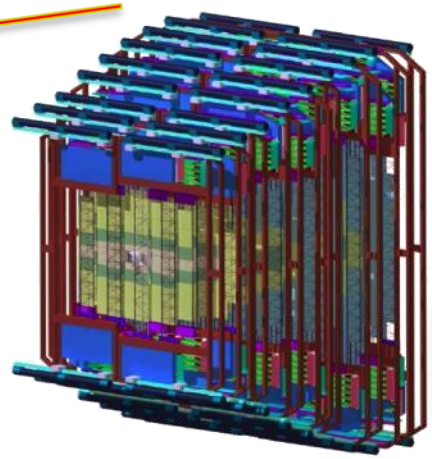
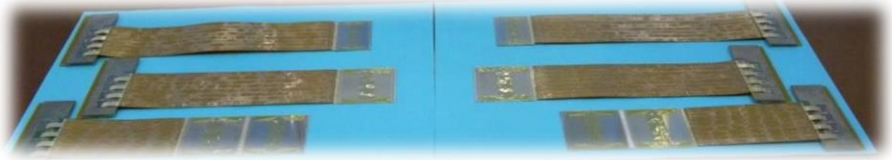
RPE LTU for CBM, PANDA, NUSTAR at GSI/FAIR

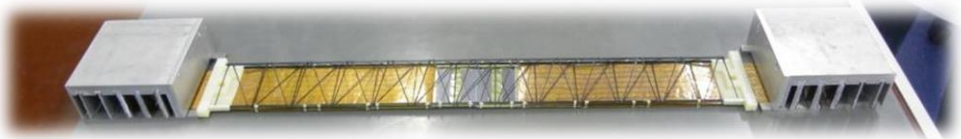


Project: ***CBM-STS***

Silicon Tracking System

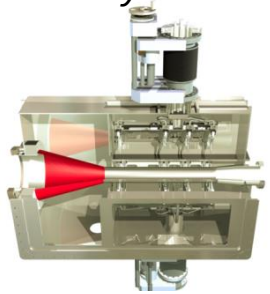


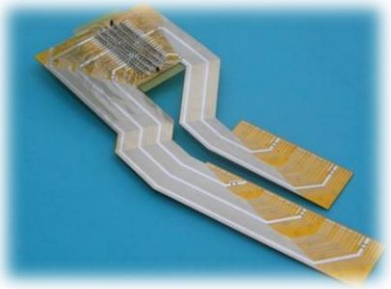




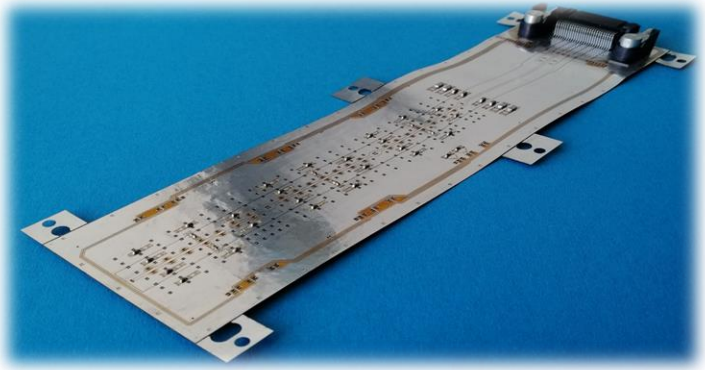
Project: ***PANDA***

Luminosity Detector





Project: ***NUSTAR***



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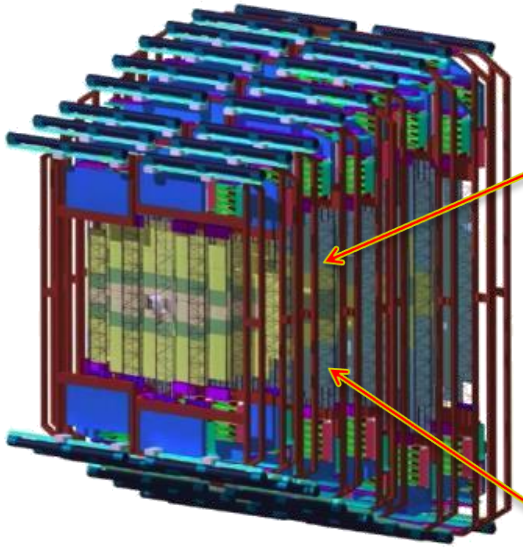
RPE LTU for CBM at GSI/FAIR

CBM STS (Silicon Tracking System)



Ladder

Detector modules

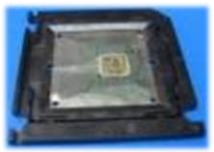
Main components (up to 50cm long)

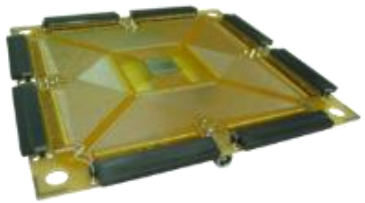
Two-layered ultra-light analog microcable

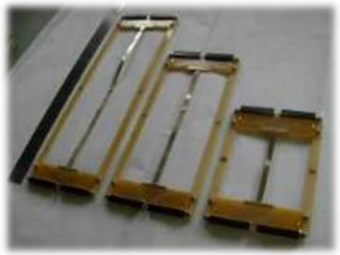
Multilayered ultra-light shielding layer

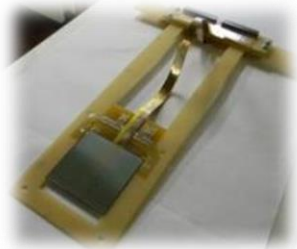
Prototype of CBM Multilayered DataCable

Mock-ups and prototypes









ASICs: STS xyter
Sensors: Strip

Main partners: GSI, FAIR

Current status: production *(more then 30000 components already manufactured and delivered)* ***& R&D*** *(for DataCables)*

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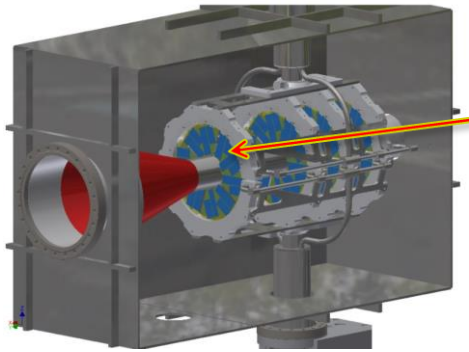
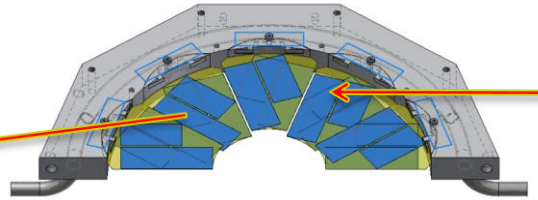
RPE LTU for PANDA at GSI/FAIR

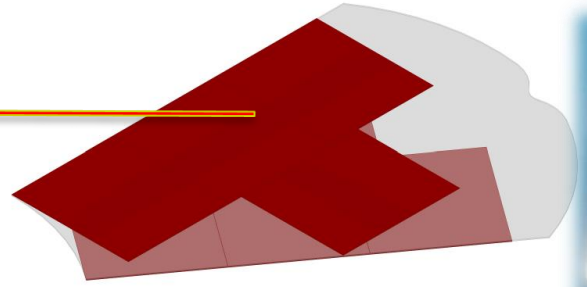
Luminosity Detector



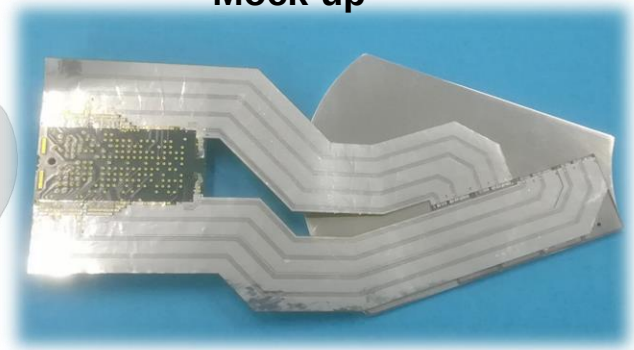
Half-disc



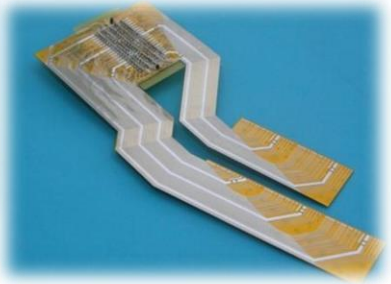
Detector module

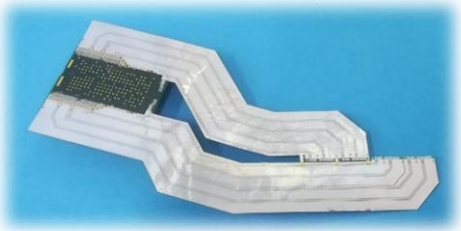


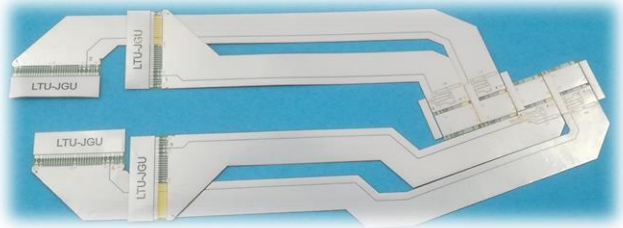
Mock-up



Mock-ups and prototypes







Sensors: MuPix MAPS

Main partners: UniMainz, GSI, FAIR,

Current status: *R&D*

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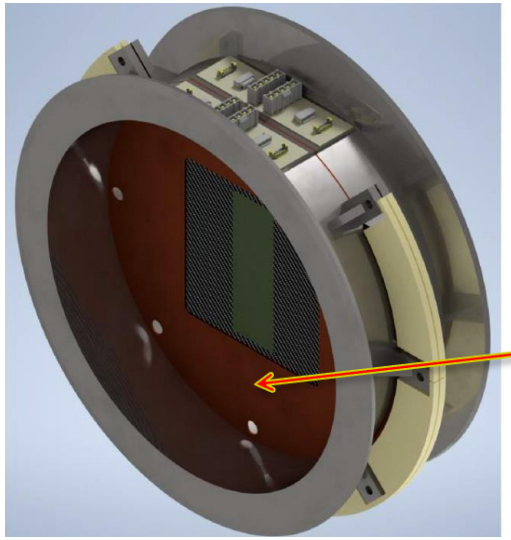
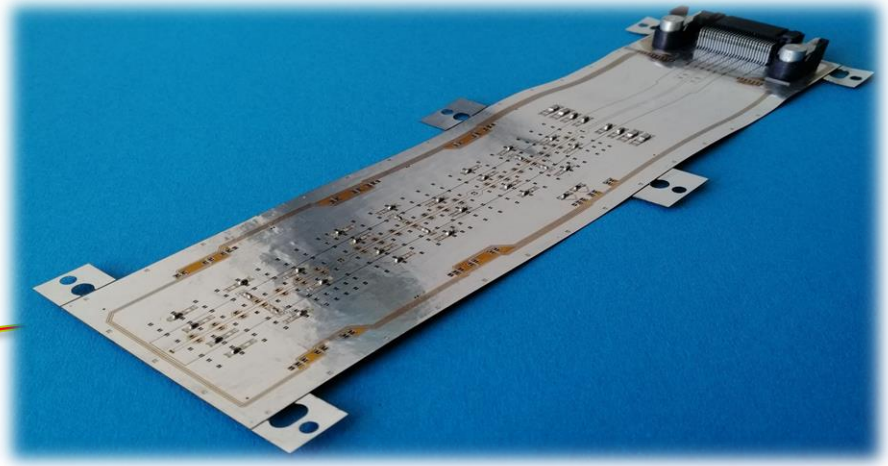
RPE LTU for NUSTAR at GSI/FAIR

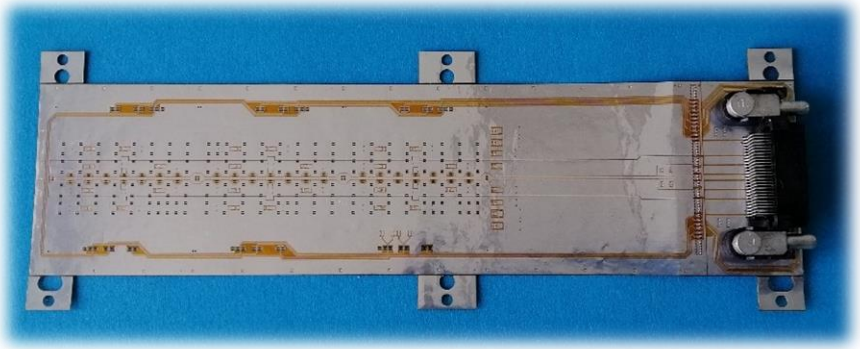
Pixel tracker



Prototype of ultra-light multilayered flex



Mock-up of multilayered flex



Sensors: ALPIDE MAPS

Main partners: GSI, FAIR, INFN

Current status: *R&D*

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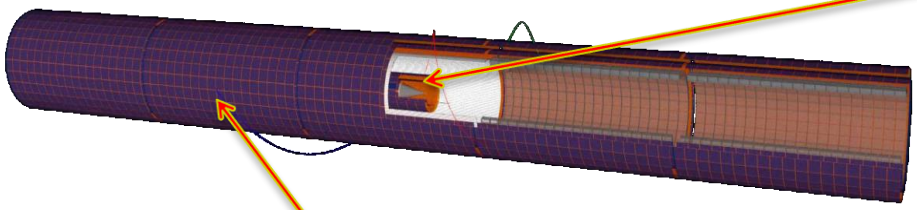
RPE LTU contribution to Mu3e at PSI

Mu3e pixel tracker

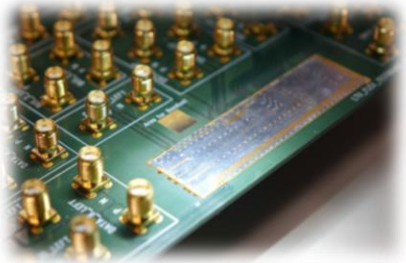


Outer detector layers (17/18 chips/module)

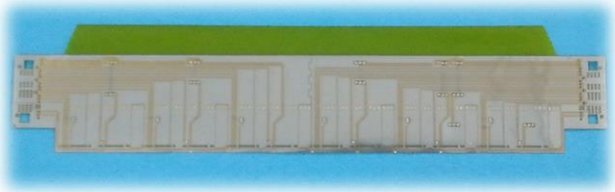
18-chip multilayered flex prototype (~40cm long)

Inner detector layers (6-chips/module)

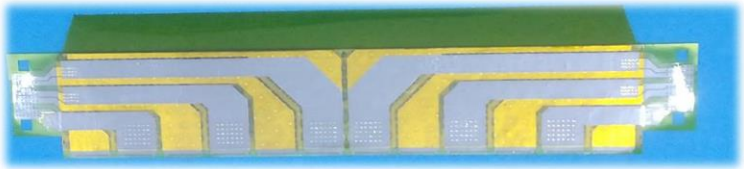
Flex under testing



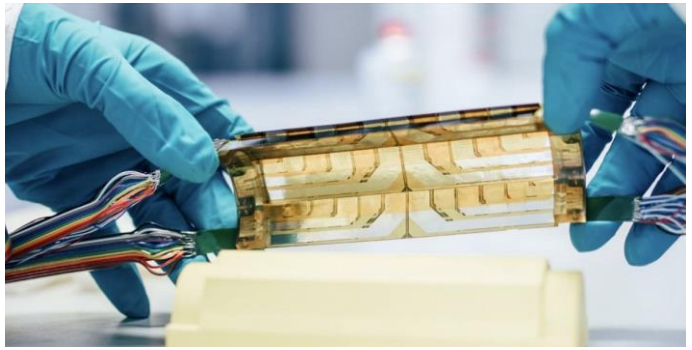
6-chip multilayered flex



6-chip multilayered flex for thermal-mechanical mock-up



Thermal-mechanical mock-up of inner layer



Sensors: MuPix MAPS

Main partners: Uni Heidelberg, Uni Oxford

Current status:

Inner layers - production complete (about 100 flexes manufactured and delivered)

Outer layers – pre-production

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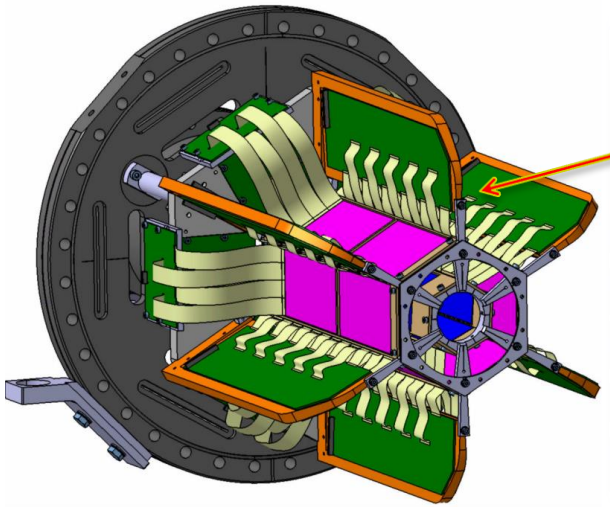
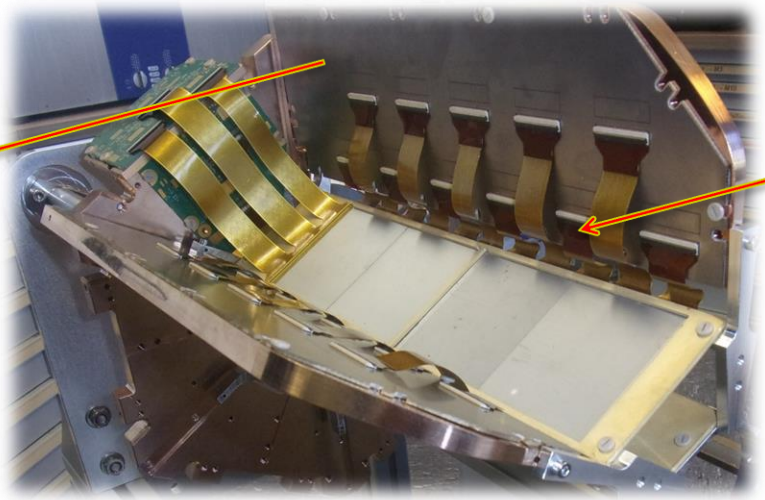
RPE LTU contribution to STRASSE at RIKEN

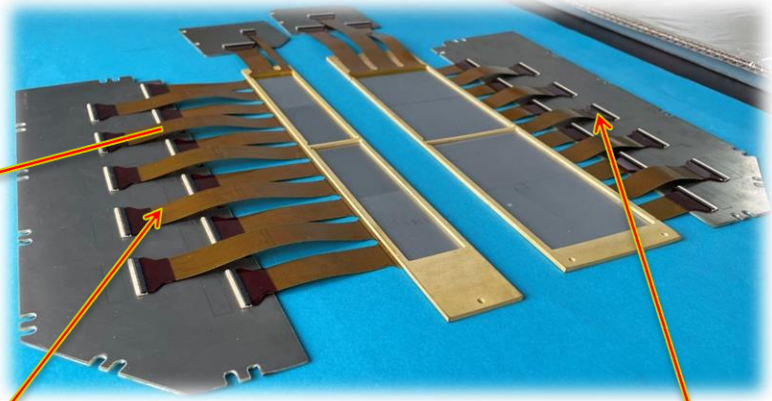
STRASSE detector



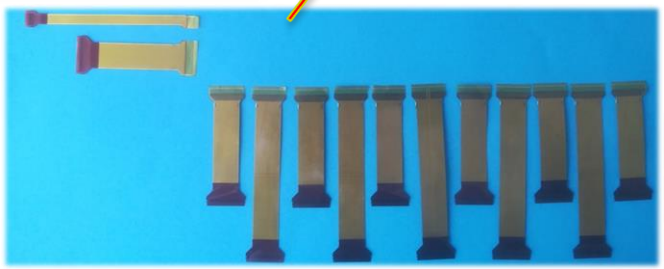
STRASSE detector with folded dummy modules

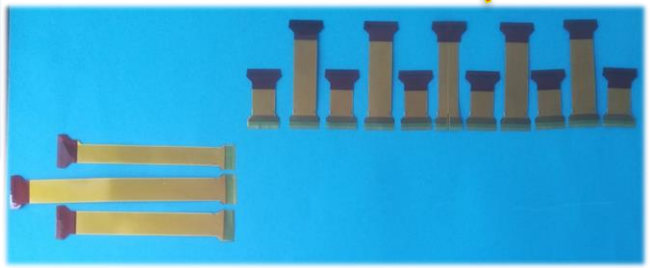


Flat (unfolded) dummy modules



Microcable sets
(27 types of microcables)





ASICs: STS xyter
Sensors: Strip

Main partners: Tech Uni Darmstadt, LPC CAEN, GSI

Current status: *Pre-production*

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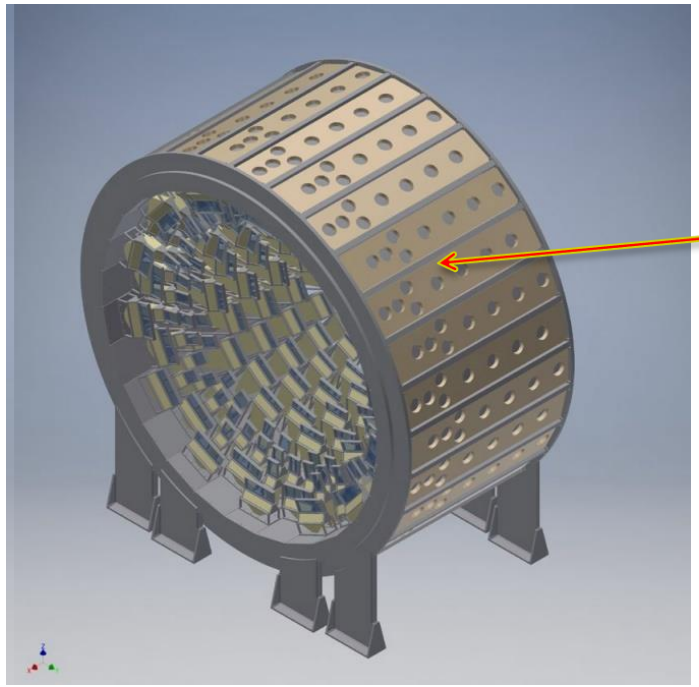
RPE LTU contribution to MOLLER at JLab

MOLLER main detector

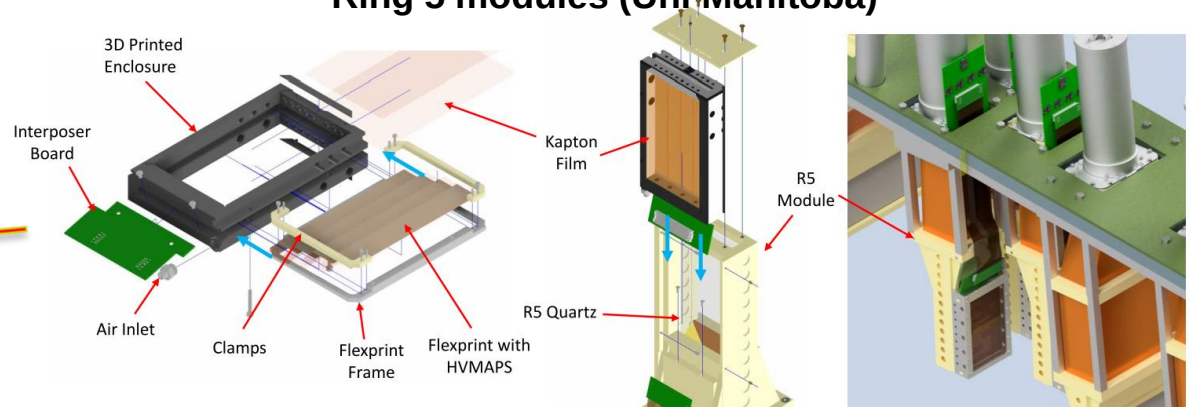


Sensors: MuPix MAPS

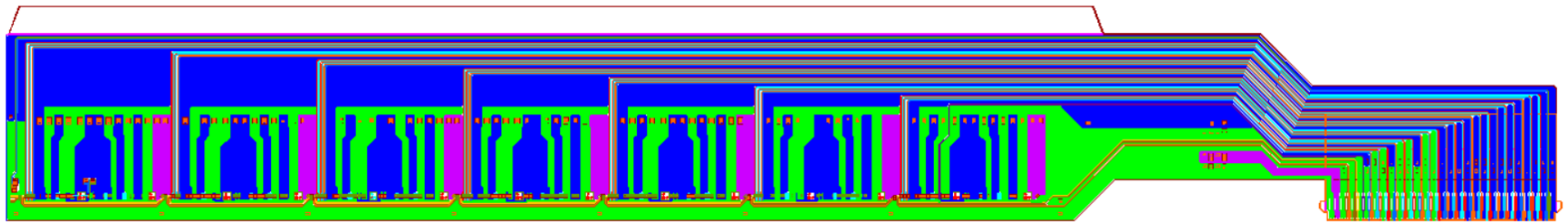
Main partner: Uni Manitoba

Current status: *Pre-R&D*

Ring 5 modules (Uni Manitoba)



Layout of SpTAB multilayered flex



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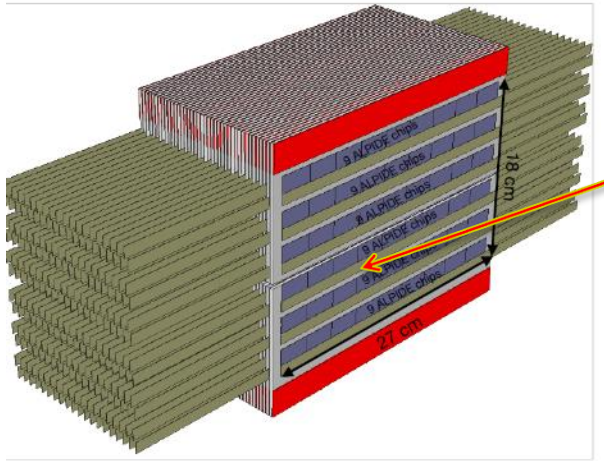
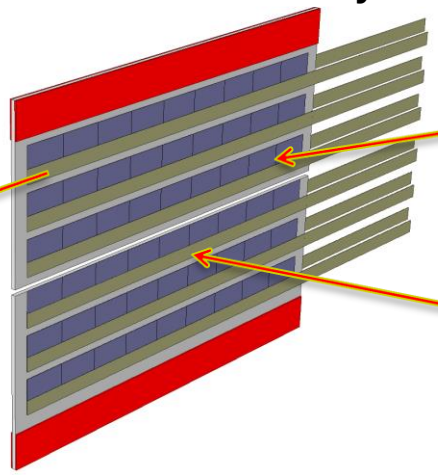
RPE LTU contribution to pCT (proton CT)

Digital Tracking Calorimeter

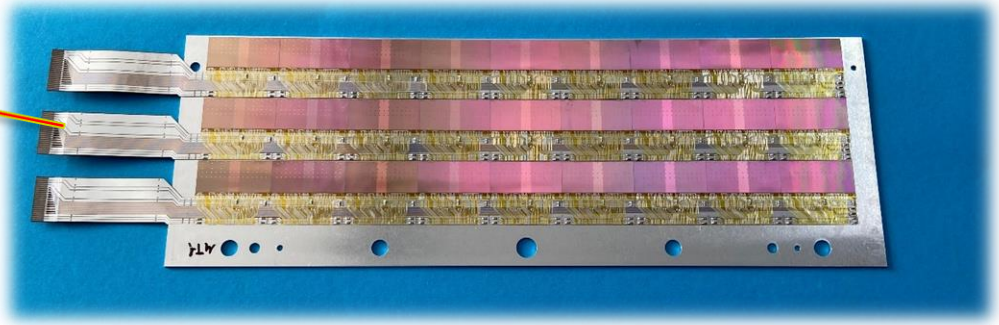


Pixel detector layer



pCT 9-chip string prototype

Mock-up of pCT slat

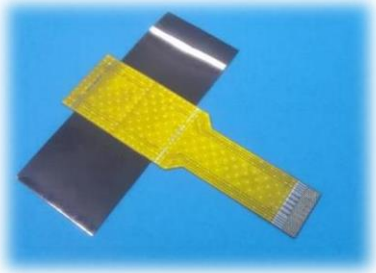


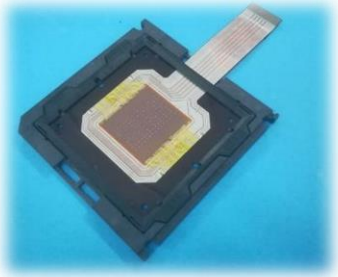
pCT SpTAB ultralight test modules

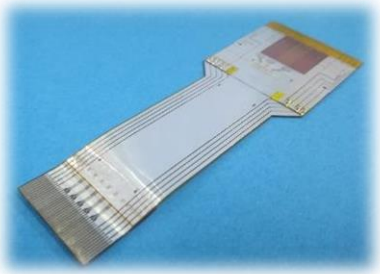
Sensors: ALPIDE MAPS

Main partners: Uni Bergen, CERN, NIKHEF/Uni Utrecht

Current status: *R&D/Pre-production*







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Conclusion

Available knowledge, background, approaches, materials and technologies allow to create low mass (low budget) tracking detector modules and might be useful for ePIC collaboration

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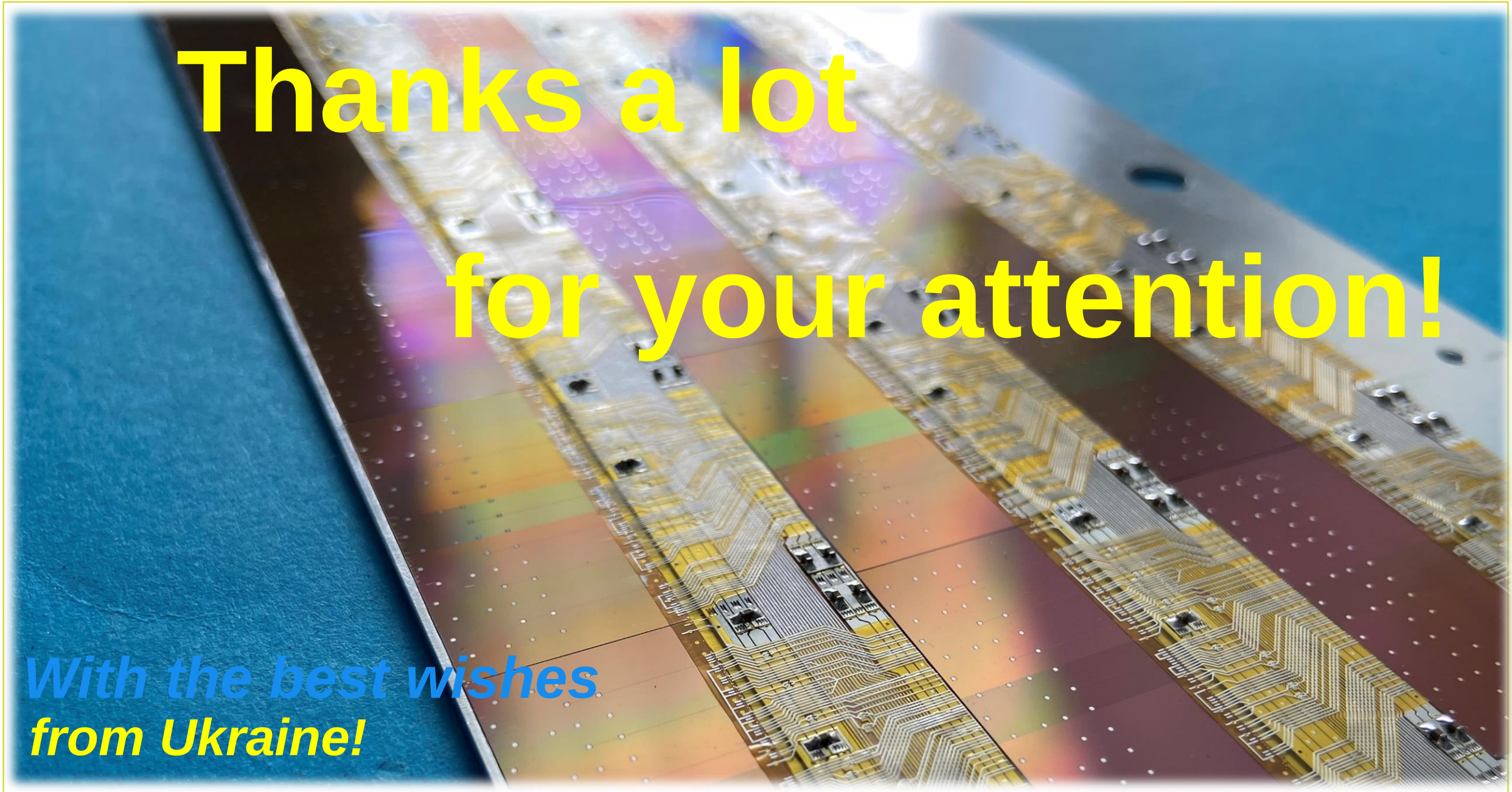

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