DAQ/FEE/Trigger
for COMPASS beyond 2020 workshop,
CTU FNSPE Prague, November 9-11, 2017

Activities of LTU for high energy physics experiments

LED Technologies of Ukraine:
Slava Borshchov
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Outline

- LTU /Kharkiv team and activities
- Activities for physics experiments
- Features of the approach
- Background
- Activities for Compass
- Other activities
- Conclusions

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LTU/Kharkiv team and activities

- *brief information about team:*
  - *staff of team: ~25 persons (incl. 2 Professors, 3 Doctors)*
  - *leader of team: Prof. Dr. Vyacheslav (Slava) Borshchov*
  - *leading experts: Ihor Tymchuk, Maksym Protsenko*
  - *production area: ~ 500 sq.m.*
  - *departments/sites: microcables production site and assembly site*
  - *year 2013 – team is passed from SE SRTIIE to LTU*
- *main activities of team:*
  - *engineering for physics experiments*
  - *space engineering (solar arrays, flexible heaters, etc.)*
  - *terrestrial photovoltaics (concentrator photovoltaic)*
  - *indoor and outdoor LED lighting*

Activities for physics experiments

- Designing detector modules
- Designing components of the modules (single- and multilayered flexible cables and flexible-rigid boards etc.)
- Designing photomasks
- Manufacture of the components
- Developing assembly procedures 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

Notes:

- ✓ ***work „Development and implementation in industry of newest technologies of ultramodern detector modules creation on the basis of hi-tech base components with aluminium interconnection for particles detector systems in high energy physics experiments" submitted by Kharkiv team was awarded by the Ukrainian Government for the development and implementation of innovative technologies (April 6, 2016)***
- ✓ ***More then 80 papers on activities for physics experiments are published***

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Features & advantages of „full-aluminium” approach

Features:

- *Materials for the components:*
  - *- conductive layers - aluminium-polyimide adhesiveless foiled dielectrics*
  - *- dielectric spacer – Kapton or polyimide*
- *Layers manufacture techniques: photolithography &chemical wet etching*
- *Assembly techniques: SpTAB&gluing*

Advantages:

- *approach* ***is verified*** *in practice in existing ALICE ITS strip and drift detector modules*
- *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*
- *high-precise and high-throughput standard* ***automated equipment*** *can be used for assembly (Delvotec G4, G5 bonders etc.). Tune of the bonder is very simply and can be done in few hours!*

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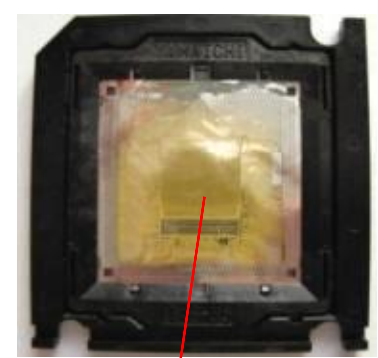
Feature of the approach: chipcable

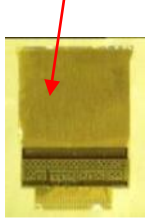
Chipcable- cable welded to chip/sensor for further connection to flex.
Cable allows to test chip/sensor after welding.
Plastic frame (TAB-35, TAB-70) for cable and chip+cable tests is using
Usage of chipcables allow to use for further assembly only good chips/sensors.

TAB-35 (1xALICE chipcable)

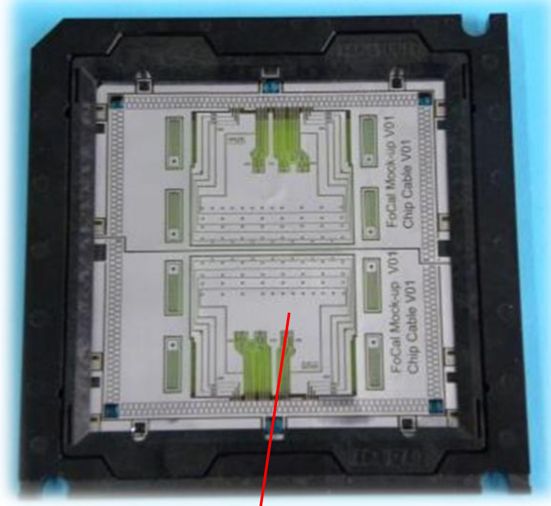
Framed cables

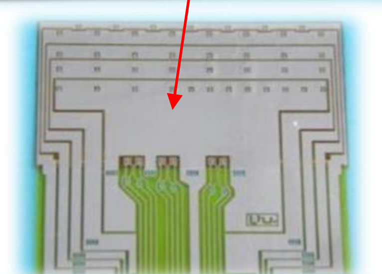


Cut-off work areas with chips

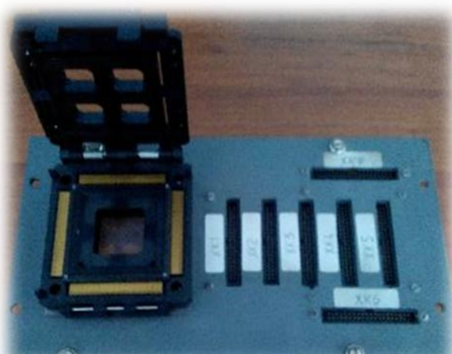


TAB-70 (2xFoCal chipcable)





Test Socket (TAB-70)



FoCal chipcables in test Socket (TAB-70)

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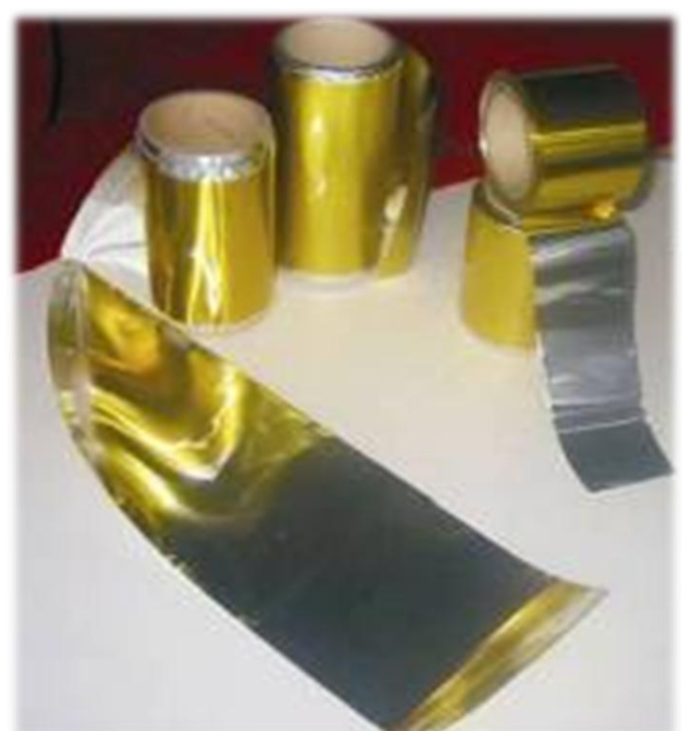
Materials and technological level

Main materials for flexible layers are aluminium-polyimide adhesiveless foiled dielectrics FDI-A type



❖ **FDI-A-24**

polyimide – 10 um
aluminium foil – 14um

❖ **FDI-A-50**

polyimide – 20 um
aluminium foil – 30 um

Fine-pitch cables FDI-A-24	pitch of traces	45÷60 um
	width of traces	20 ÷ 30 um
	length of cable	10 ÷ 20 mm
	quantity of traces	128÷1024
Connecting cables, flexes FDI-A-24 FDI-A-50	pitch of traces	100÷200 um
	width of traces	40 ÷ 100 um
	length of cable	up to 600 mm
	quantity of traces	up to 512

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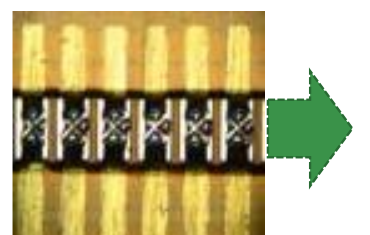
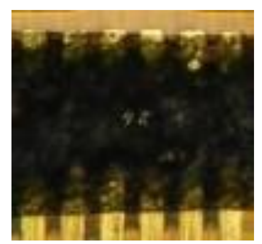
Some features of assembly process

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



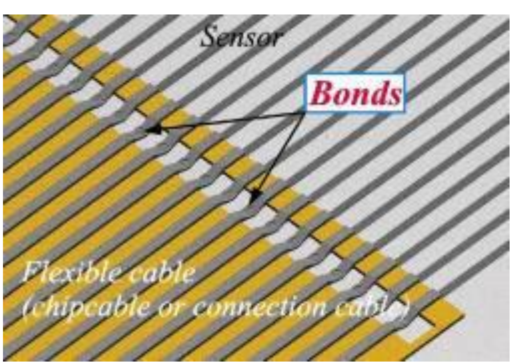


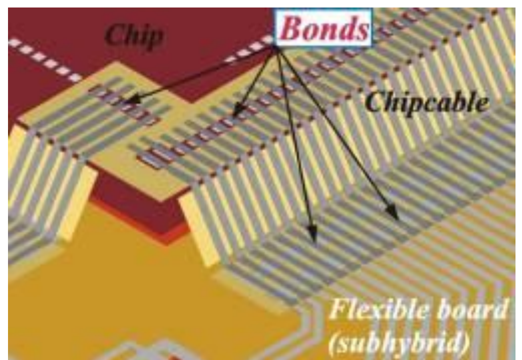
Schematic close-up view of some different connection areas

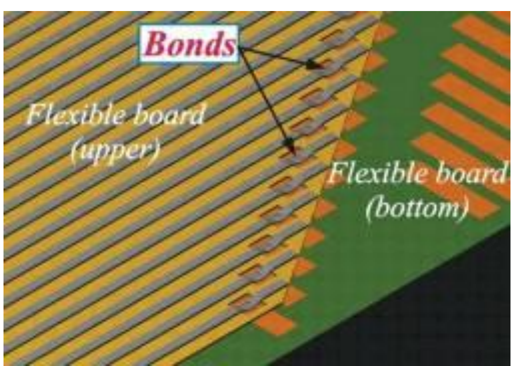
cable-to-sensor

chipcable-to-chip & chipcable-to-subhybrid

flexible board-to-flexible board (inside subhybrid)







Note: for SpTAB techniques two times less bonds are required- higher reliability

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Features of typical multilayered flex

- Flex consist of three layers: top, spacer, bottom
- Layers of the flex are manufactured based on photolitography and chemical wet etching technological processes
- Typical assembly sequence includes following main operations: multilayered flexible board gluing and bonding (TAB), board-to-chip bonding (TAB), bond joints protecting by glue
- Typical flex might includes following types of TABed joints:

- *Top layer-to-chip*

- *Bottom layer-to-chip*

- *Interlayer connection*

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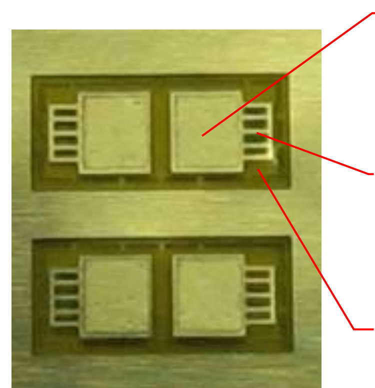
Some features of SMD components and SMT connectors mounting

For manufacturability increasing SMD components and SMT connectors are mounting on flexible carriers (flex-mounts) by soldering and after that connecting to board or cable by ultrasonic bonding

Flex-mounts for SMD component

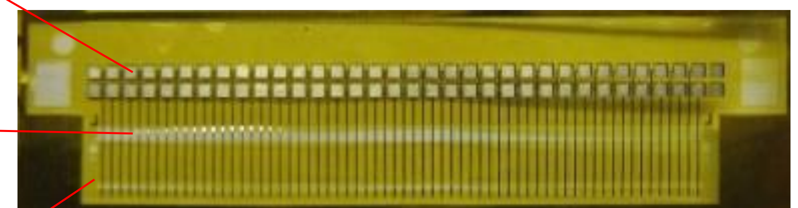


Ni + SnBi layer (pads for soldering)
Thickness ~ 3+8 um

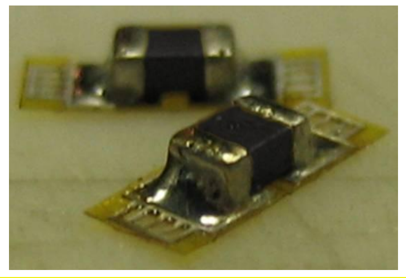
Aluminum layer (traces for bonding)
Thickness ~ 30 um

Polyimide layer
Thickness ~ 20 um

Flex-mount for SMT connectors



SMD resistor on flex-mount



Dual row connector on flex mount

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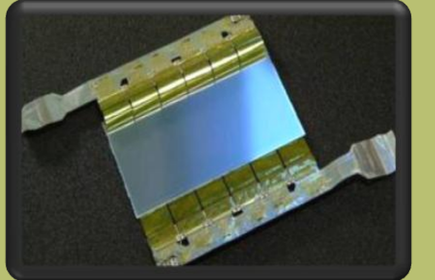
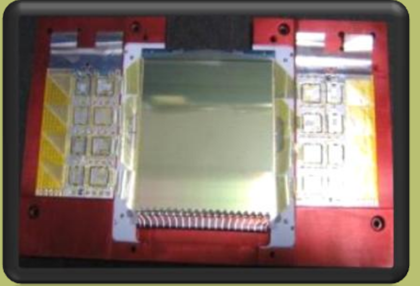
Background:
ALICE ITS SSD&SDD detector modules

For existing ALICE ITS by Kharkov team more than 200 types of module components developed and more than 50000 components manufactured and delivered for SSD and SDD modules creation

SSD
(&CERN, NIKHEF, IN2P3, HIP)



SDD
(&CERN, INFN)



For both module types were done :

- ***Modules and components design developed***
- ***Prototypes assembled and tested***
- ***Full-scale production organized***
- ***Assembly technologies developed and implemented at foreign assembly sites***
- ***Components for more than 2000 SSD and 400 SDD modules manufactured and delivered***
- ***Two foreign assembly sites organized for modules assembling***

Developed and manufactured components for the modules

Type	Brief description	Manufactured components quantity	
		SSD	SDD
Chipcables	*Single- and twochip single- and double layer ultralight flexible cables with min. pitch of traces 80-100um*	~35000pcs	~3000pcs
Subhybrids	*Flexible-rigid multilayered boards on the carbon fiber heat sink*	~4500pcs	~700pcs
Long connecting cables	*Connecting multilayered LV & HV cables (length up to 600mm, operating voltage up to 5kV)*	~4500pcs	LV~1500pcs HV~500pcs

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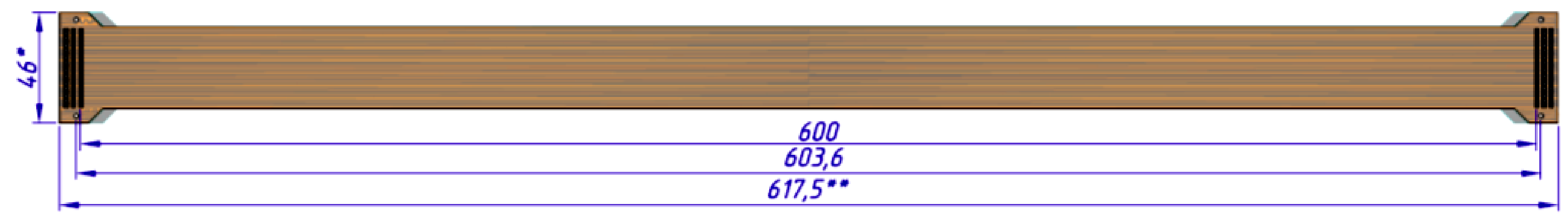
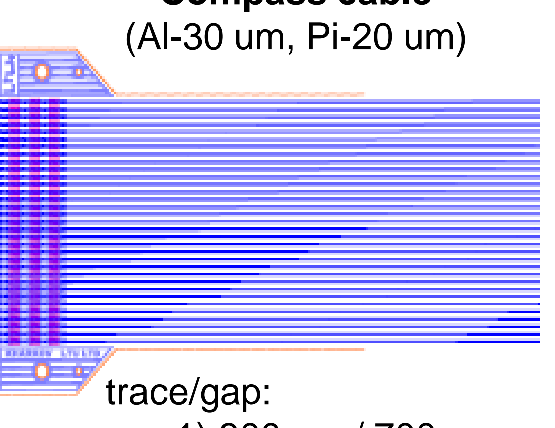
Activities for COMPASS

Single- and multilayered flexible connecting cables

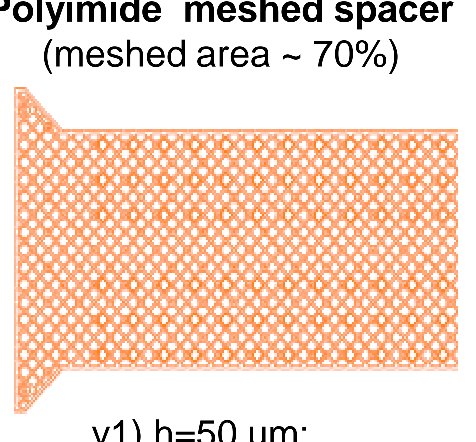


Compass cable
(Al-30 um, Pi-20 um)



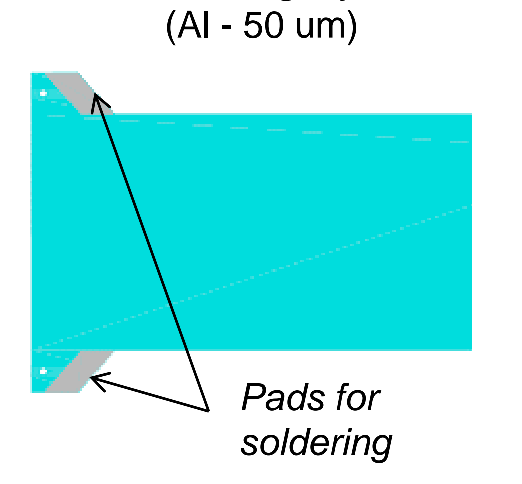
trace/gap:
v1) 300 um / 700 um;
v2) 400 um / 600 um;
v3) 500 um / 500 um.

Polyimide meshed spacer
(meshed area ~ 70%)



v1) h=50 um;
v2) h=75 um.

Shielding layer
(Al - 50 um)



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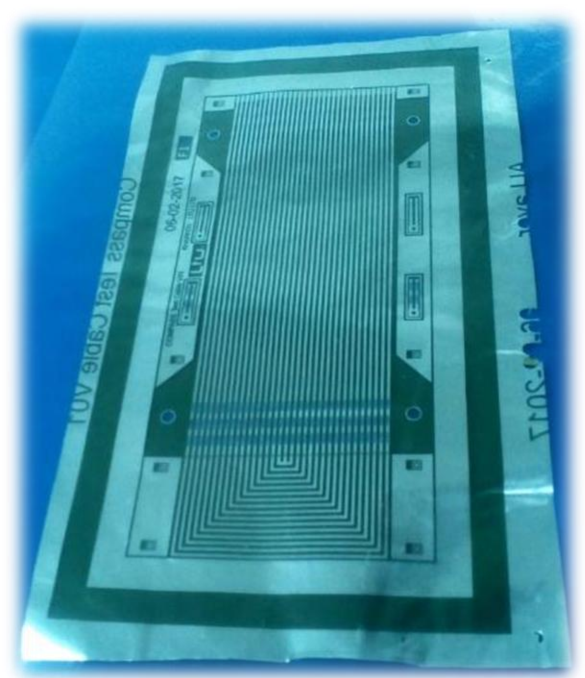
Activities for COMPASS: cable prototypes

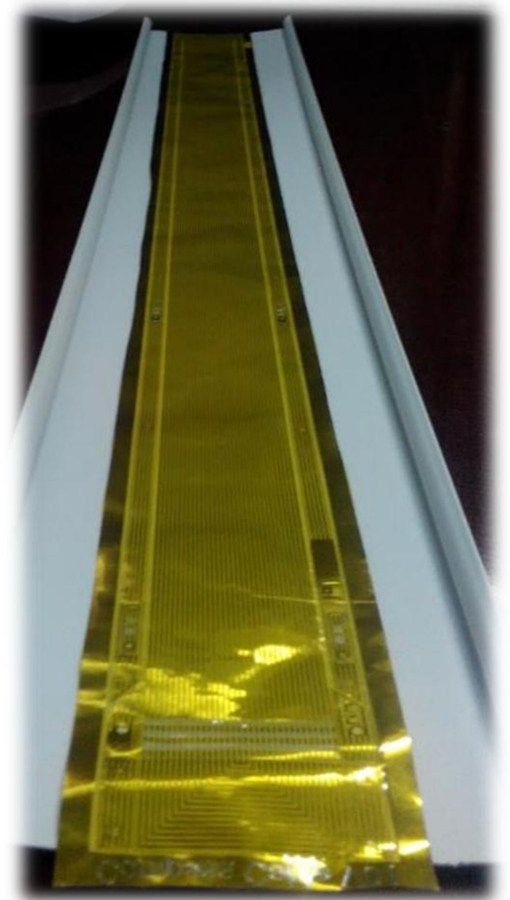
Technological test cable

(~ 15 cm long)



Cable prototype

(~ 65 cm long)



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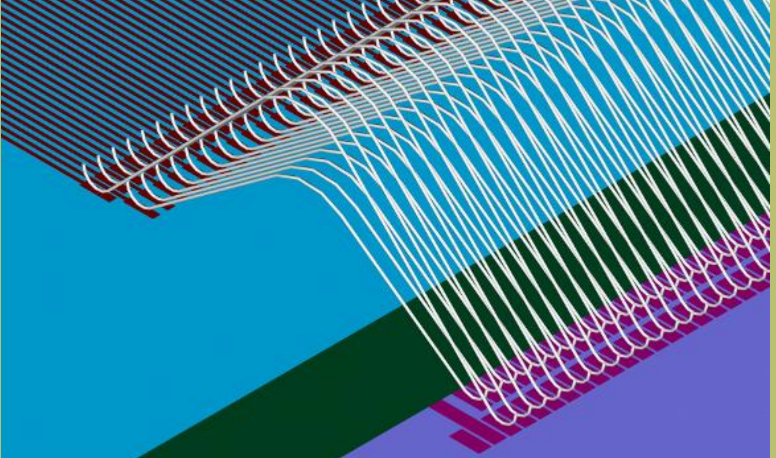
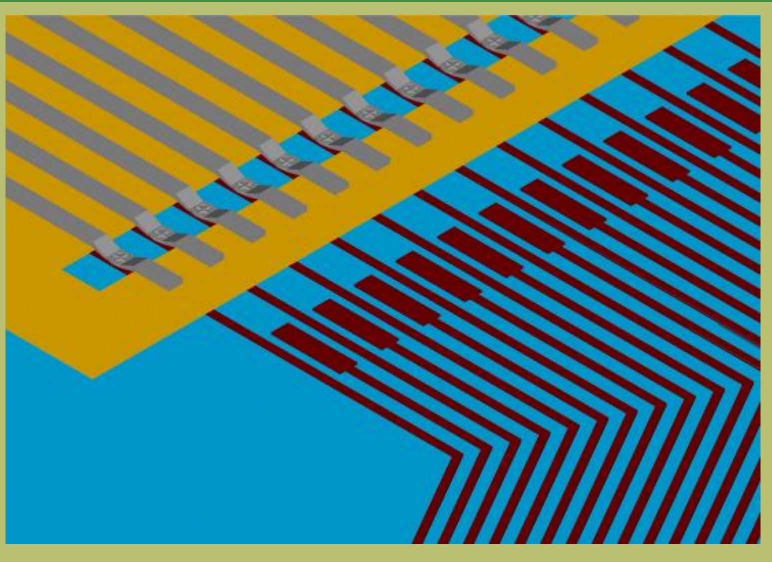
Type of connections

Wires



Wire-welding to the aluminum-polyimide flexible board (FDI-A-50 - aluminum thickness is 30 um) is possible

SpTAB



SpTAB of the aluminum-polyimide flexible board (FDI-A-50 - aluminum thickness is 30 um, width of trace is 100 um) to PCB contact pads is possible

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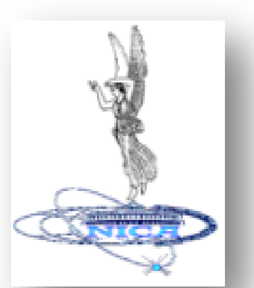
Activities for other experiments

- ALICE ITS upgrade
- LHCb IT upgrade
- CBM
- NICA/MPD
- PANDA
- Mu3e



Activities for CERN: ALICE ITS upgrade

Upgraded ITS

Outer layers
Middle layers
Inner layers
Beam pipe

Stave composition

Power Bus
Flex Printed Circuit
2 x 7 Pixel Chips
Module Carbon Plate
Cold Plate
Half-Stave
Spaceframe

- ✓ *Power Bus*
- ✓ *Flexible printed circuit (FPC)*

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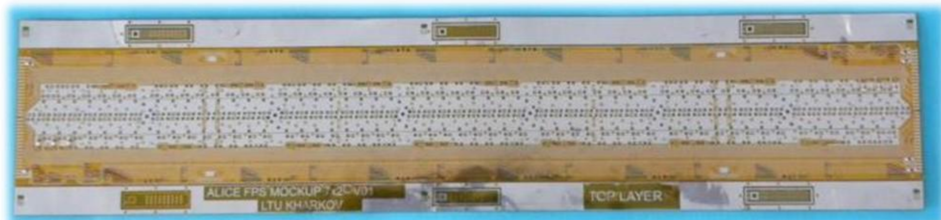
Mock-ups and prototypes for ALICE ITS Upgrade

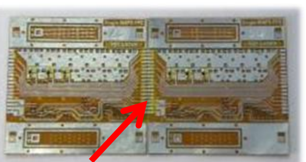
OB FPC prototype (for 14 MAPS, ~21 cm long)



PB cross-cable prototype

IB FPC prototype (for 9 MAPS, ~45 cm long)

Inter-module connection (prototype)



Inter-module cable

OB PB prototype (for 6 HIC, ~1,5 m long)

Notes:

- *All components are made of aluminium-polyimide adhesiveless materials*
- *Some own adhesiveless aluminium-polyimide materials are developed (Al 50um, 100um)*

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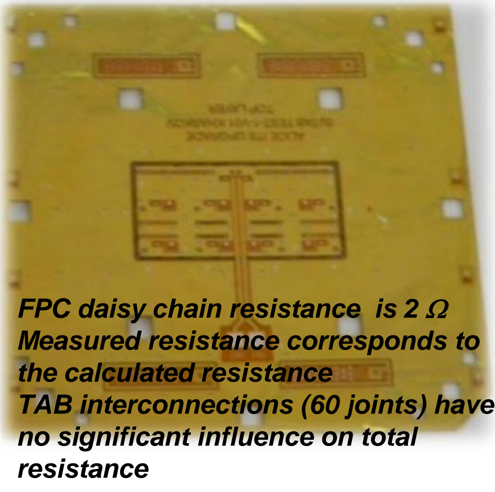
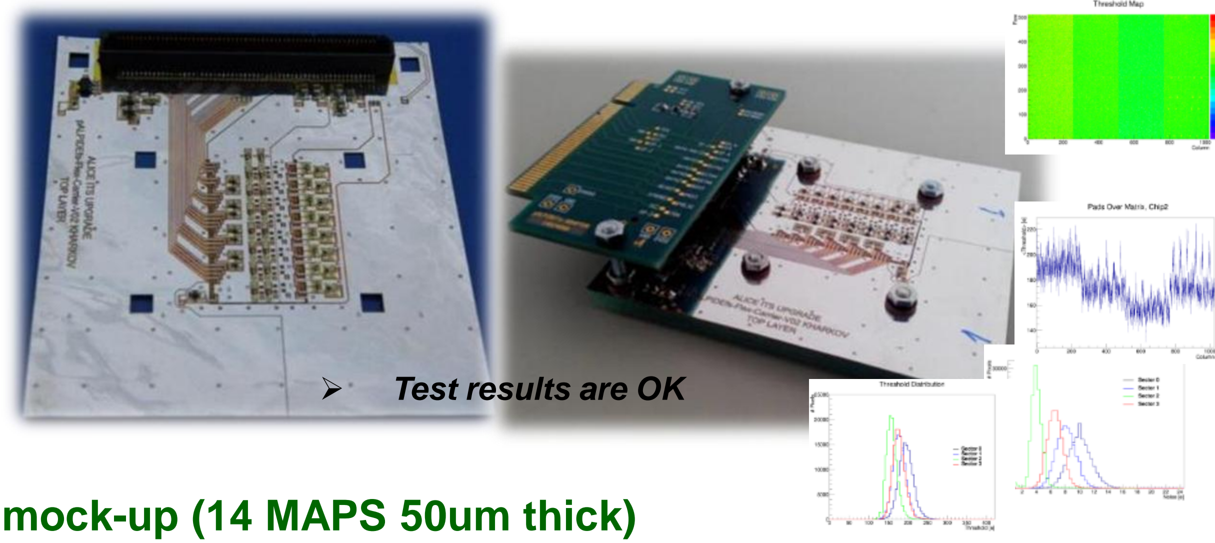
Prototypes for ALICE ITS upgrade: test results

FPC prototype



- FPC daisy chain resistance is 2 Ω
- Measured resistance corresponds to the calculated resistance
- TAB interconnections (60 joints) have no significant influence on total resistance

Single-chip SpTAB FPC with pALPIDE chip

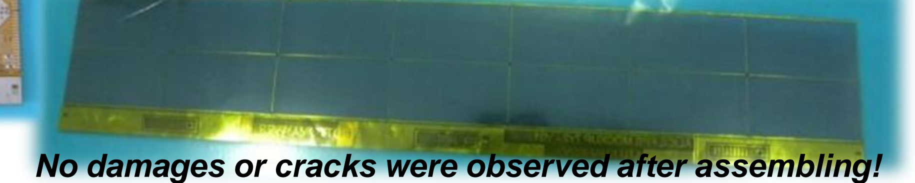


- *Test results are OK*

Module mock-up (14 MAPS 50um thick)

Side of the FPC

Side of chips



No damages or cracks were observed after assembling!

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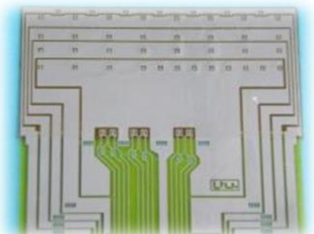
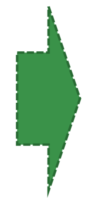
Activities for CERN FoCal experiment

Cutout cable

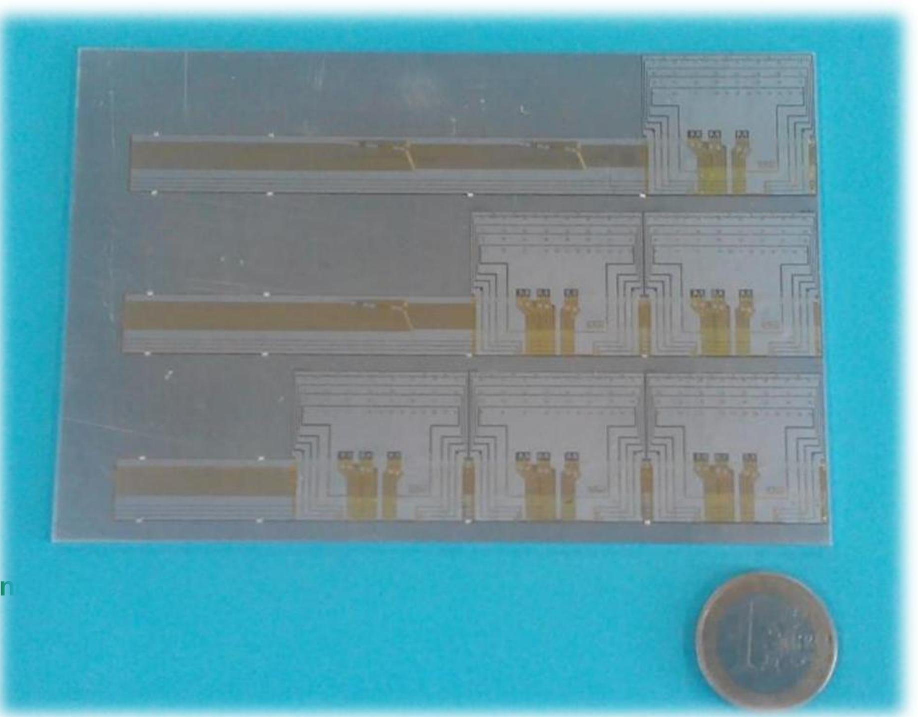


Carrier with multilayered flexes



Aligning,
Gluing,
SpTAB,
Testing,
Protecting bon

Assembled slab mock-up



Joint activity with NIKHEF

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Activities for CERN:

LHCb IT upgrade

Inner Tracker

Detector box

Detector modules

Single sensor

Double sensor

Triple sensor

✓Connecting cable
✓Inter-sensor cable

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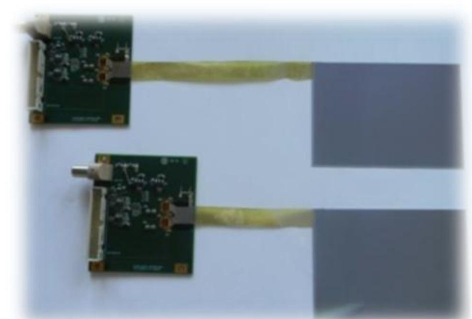
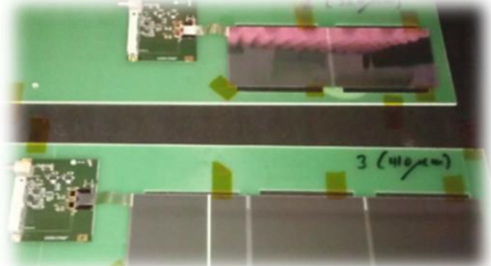
LHCb IT upgrade: prototypes

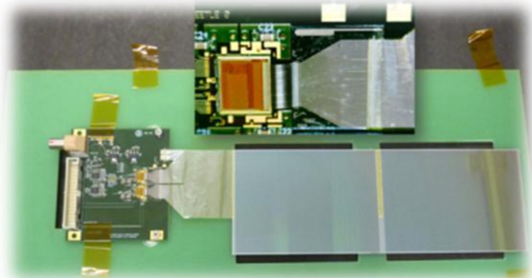
module prototypes

64 ch





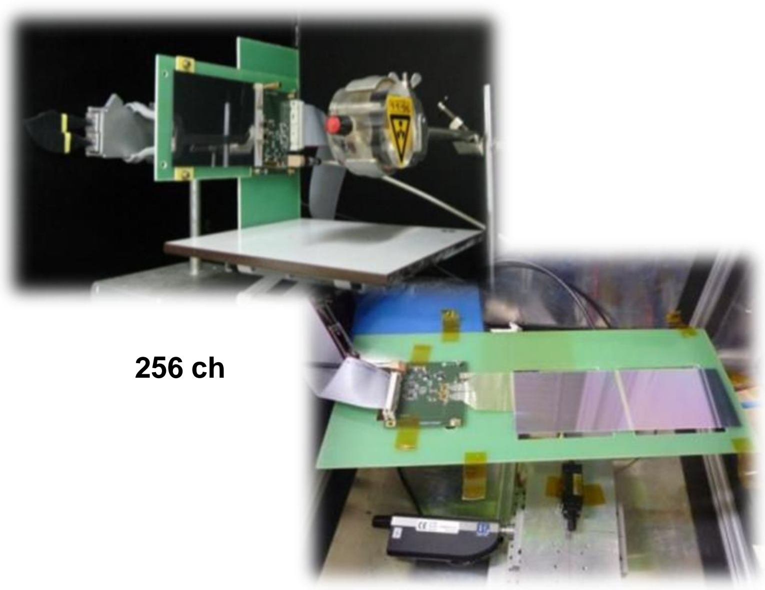
256 ch



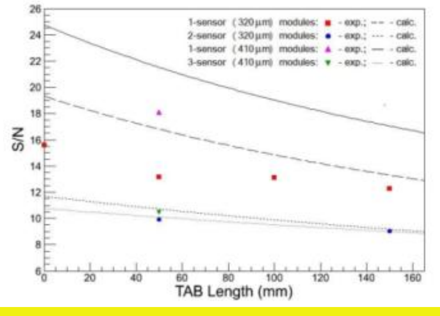
module prototypes under testing (CERN)

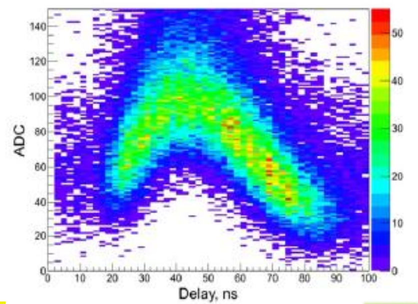
64 ch

256 ch



Module prototypes: test results





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Activities for GSI:

CBM experiment

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Mock-ups and demonstrators (CBM)

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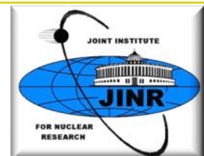
Activities for JINR: NICA experiment



SC Coil
Cryostat
ExtRPC
Yoke
ECT
IntRPC
BT
ZDC
BBC
IT

Barrel silicon tracking system

Multisensor detector module

Disk silicon tracking system

Multisensor detector module

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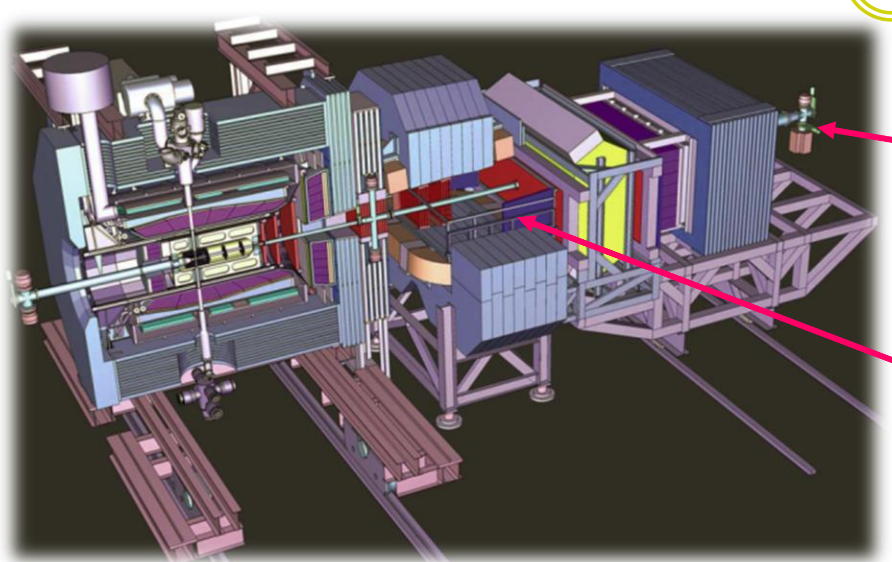
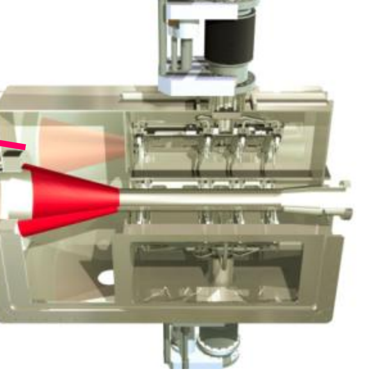
Activities for GSI: PANDA experiment

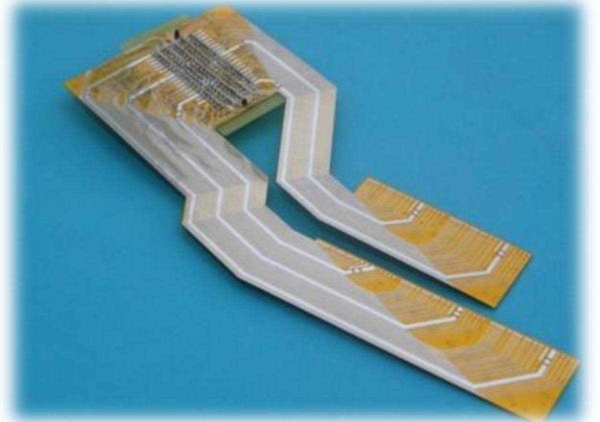


Luminosity detector



Secondary target

Joint activity with University of Mainz



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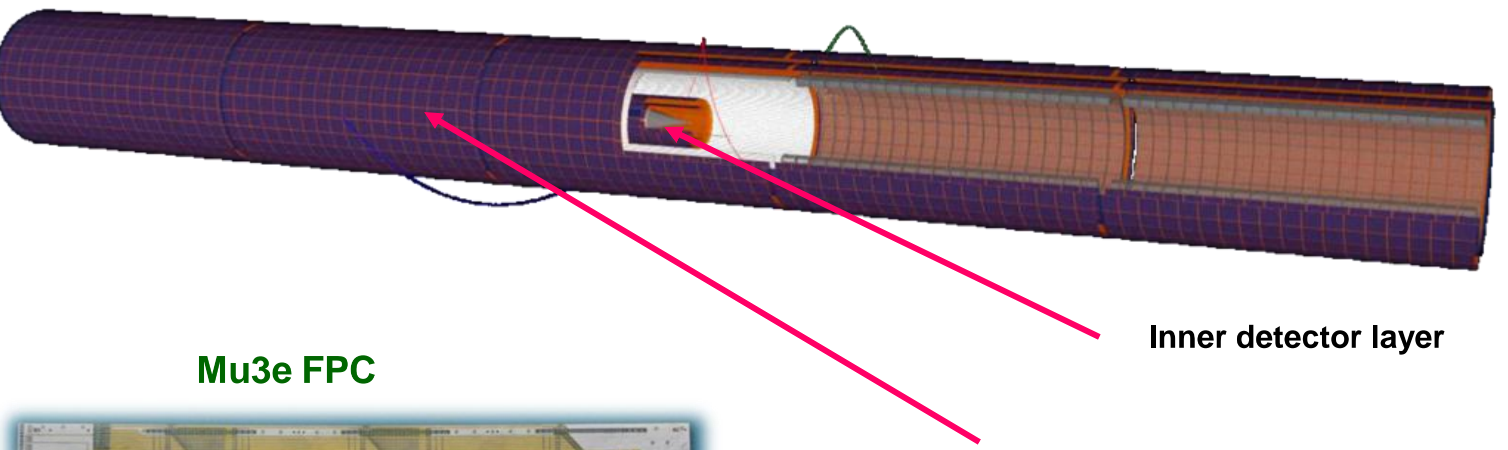
Activities for PSI: Mu3e experiment

The Mu3e detector

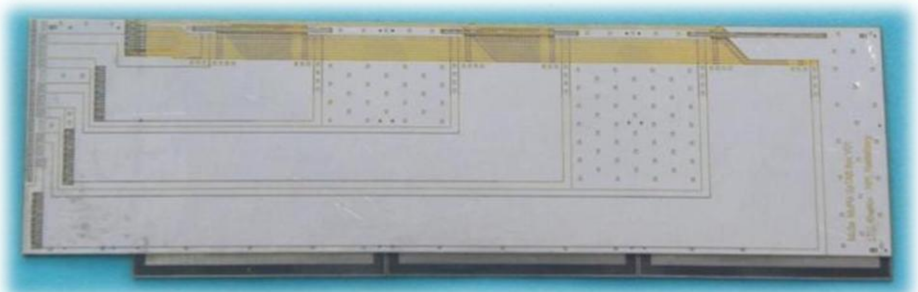


Inner detector layer

Outer detector layer

Mu3e FPC

Mechanical mock-up of Mu3e pixel detector module



Joint activity with Heidelberg Physics Institute
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Conclusions

- Kharkiv team is experienced team in development and creation of detector modules and their components for physics experiments
- Main part of activities of Kharkiv team are single- and multilayered flexible boards and cables and also assembly procedures
- Activities for Compass are ongoing

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Thanks a lot for your attention!

Backup slides

Kharkiv team capabilities

For works on detector modules and components creation at LTU Ltd two well equipped sites are available

- ***Cable production site** (~110sq.m, incl. 20 sq.m clean room)*

for development and production components of detector modules (flexible cables and boards, dielectric spacers etc.). Manufacture technology based on photolithography and wet chemical etching.

- **Microelectronics devices *assembly site*** *(~110sq.m)*

for detector modules and components assembling (multilayered flexible and flexible-rigid boards etc.). Assembly technology based on SpTAB.

Microcable production site

(clean room)

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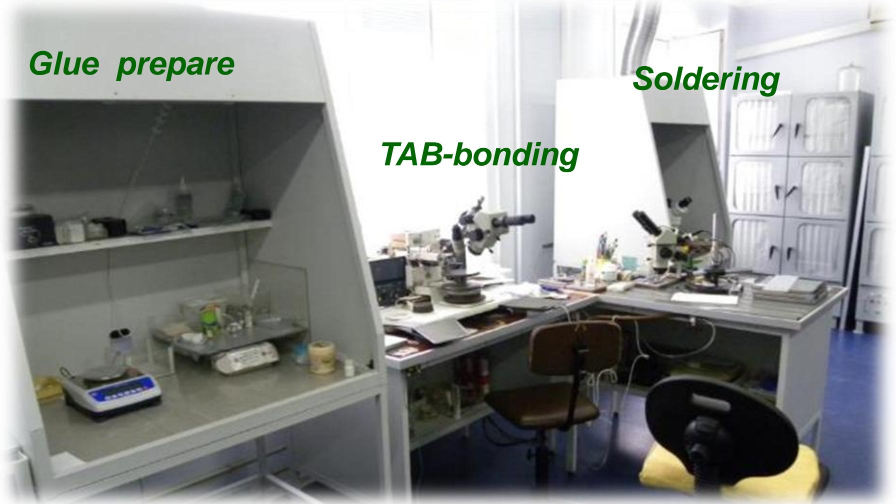
Microelectronics devices assembly site



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Cable production- technological steps

Flexible substrate preparing

Double side photoresist coating

Double side exposing

Photoresist development

Aluminium etching

Photoresist coating for aluminium protection

Polyimide etching

Photoresist removing, inspection

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