pCT meeting,
Bergen, Norway, November 6-7, 2017

Possible approach for realization of detector modules for FoCal, pCT etc.

NIKHEF:

Thomas Peitzmann
Ton van den Brink

LTU:

Slava Borshchov
Ihor Tymchuk (speaker)
Maksym Protsenko

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Outline

- LTU /Kharkiv team and activities
- Activities for physics experiments
- Features of the approach
- Background
- Activities for FoCal
- 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 50 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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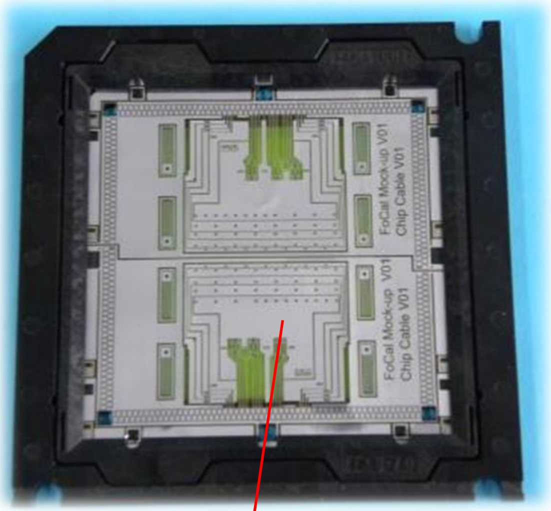
Feature of the approach: chipcable

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.

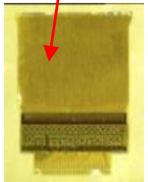
Framed cables

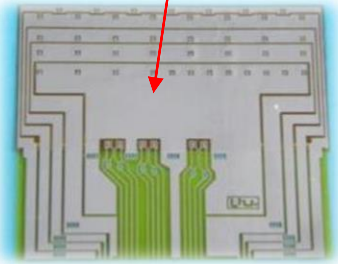
TAB-35 (1xALICE chipcable)

TAB-70 (2xFoCal chipcable)

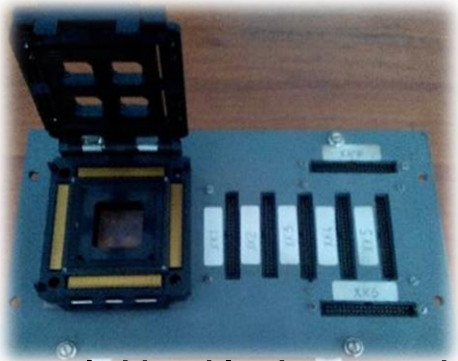


Cut-off work areas with chips





Test Socket (TAB-70)



FoCal chipcables in test Socket (TAB-70)

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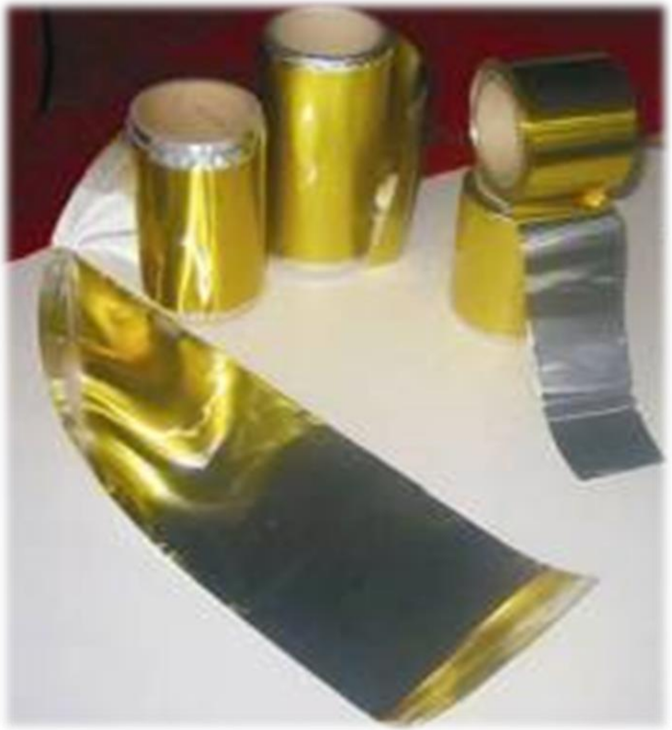
Materials and technological level

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



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

❖ **FDI-A-24**

polyimide – 10 um
aluminium foil – 14um

❖ **FDI-A-50**

polyimide – 20 um
aluminium foil – 30 um

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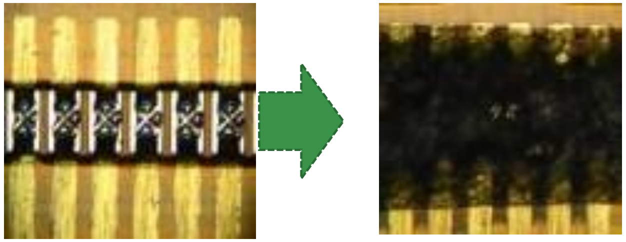
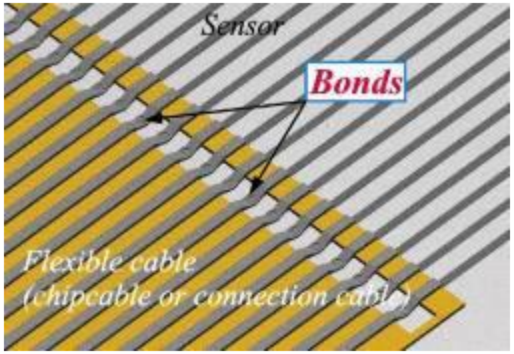
Some features of assembly process

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

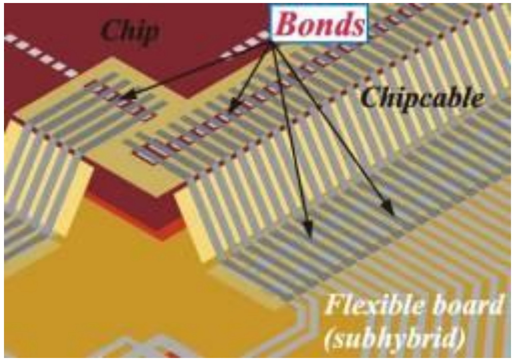


Schematic close-up view of some different connection areas

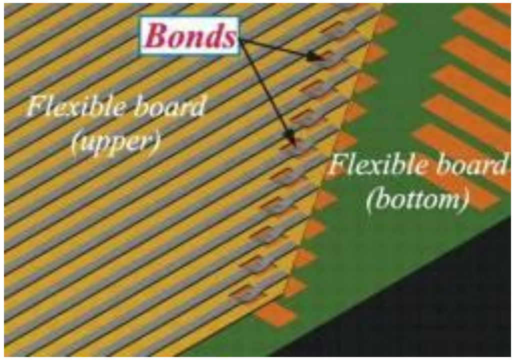
cable-to-sensor



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

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*

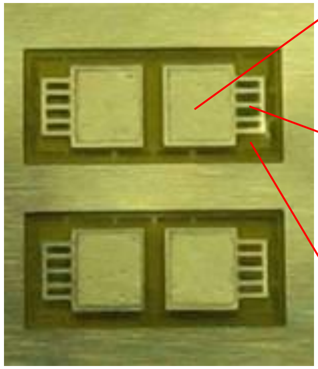
- *Bottom layer-to-chip*

- *Interlayer connection*

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

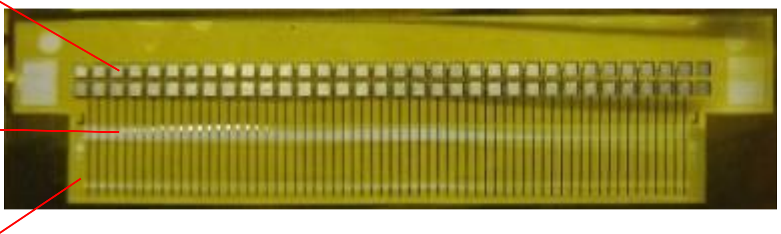


Ni + SnBi layer (pads for soldering)
Thickness ~ 3+8 um

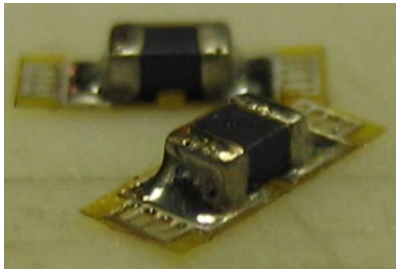
Aluminum layer (traces for bonding)
Thickness ~ 30 um

Polyimide layer
Thickness ~ 20 um

Flex-mount for SMT connectors



SMD resistor on flex-mount

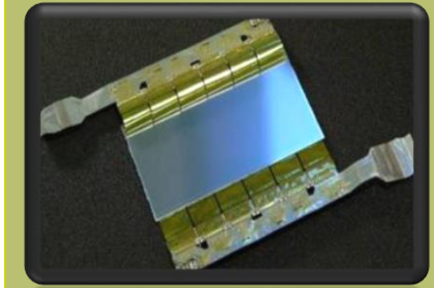


Dual row connector on flex mount

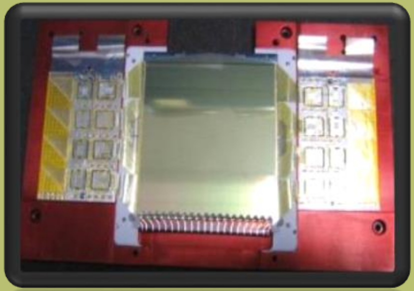
Background:
ALICE ITS SSD&SDD detector modules

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*)*



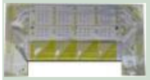
SDD
(*&*CERN, INFN*)*



For both module types were done :

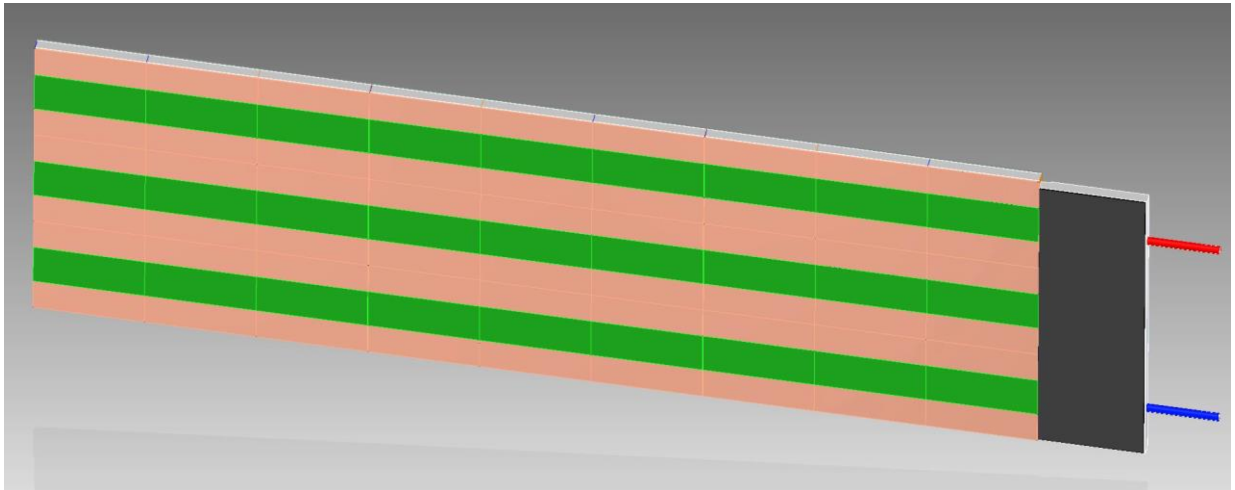
- ***Modules and components design developed***
- ***Prototypes assembled and tested***
- ***Full-scale production organized***
- ***Assembly technologies developed and implemented at foreign assembly sites***
- ***Components for more than 2000 SSD and 400 SDD modules manufactured and delivered***
-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

Activities for FoCal: FoCal slab

***FoCal slab** (3x9 ALPIDE chips per side)*



- Approach for realization is developed
- Assembly procedure is developed
- Technological mock-up is developed, designed and manufactured
- Proposed approach is verified
- Further activity is ongoing (test procedure and equipment)

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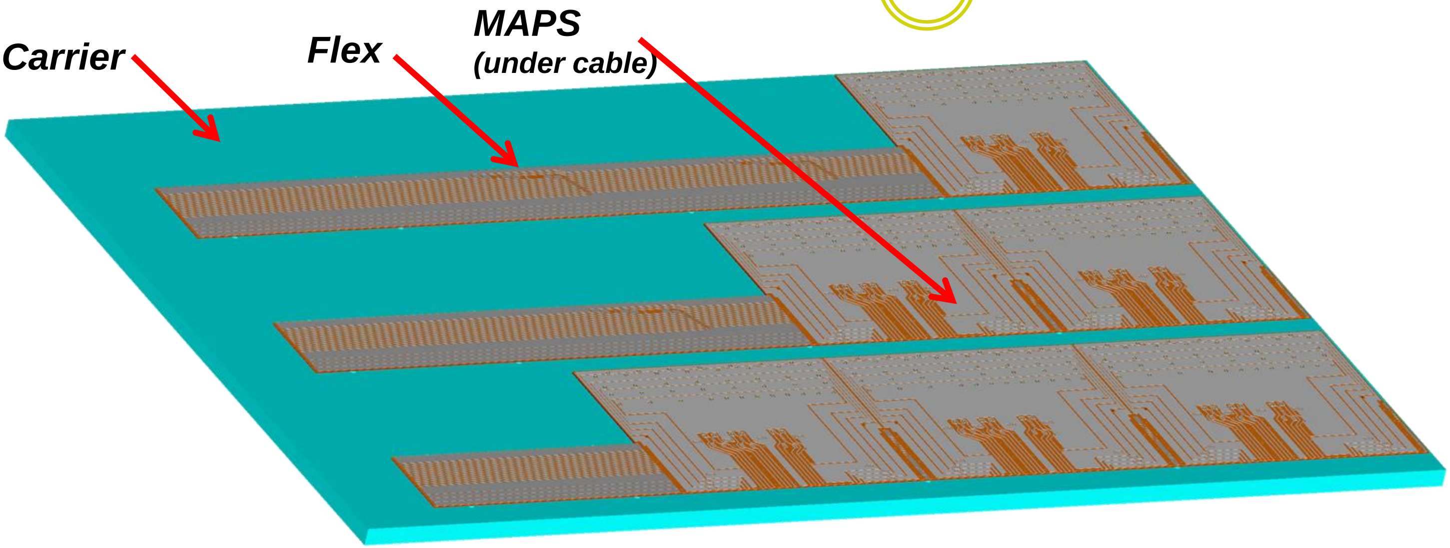
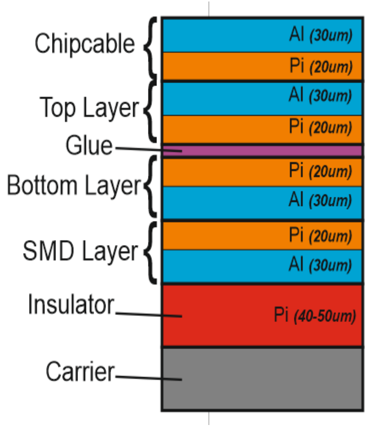
FoCal slab: mock-up



Cross-section
(schematically)



Composition of the mock-up:

- ***Carrier – 1 pc***
- ***Multilayered flex – 3 pcs***
- ***MAPS (bad ALPIDE) – 6 pcs***
- ***SMDs –54 pcs***

Estimated total thickness of real slab will be ~2,2mm, including:

- carrier ~1,67mm
- assemblies 2x~0,27mm

Notes:

- ***Design of the mock-up is based on 9 sensor row and the mock-up flex contains all the necessary traces but is only shorter***
- ***Flex can be easy extended up to 15 chips (additional width ~ 3 mm is required, but required space for this is reserved between the rows of chips).***

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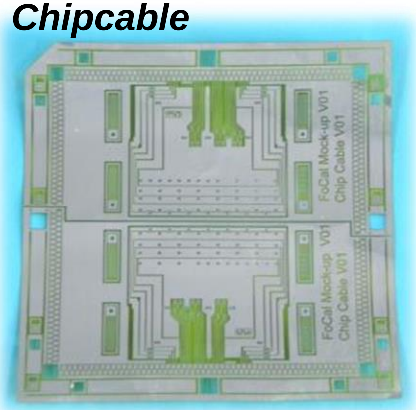
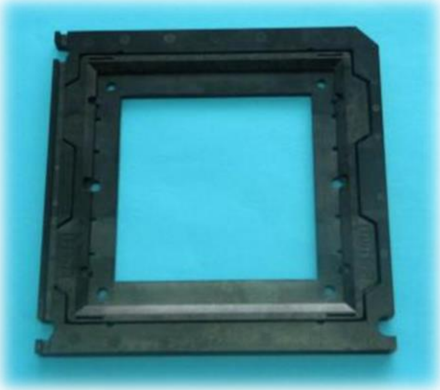
FoCal chipcable:
assembling MAPS with chipcable

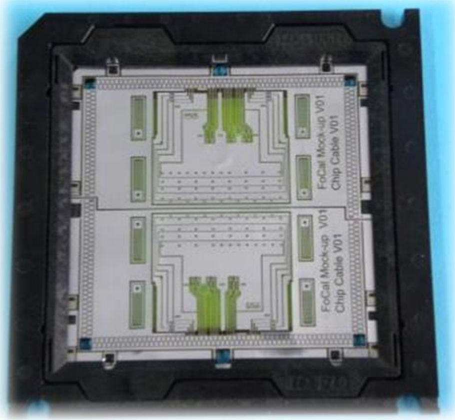
Chipcable



Test frame

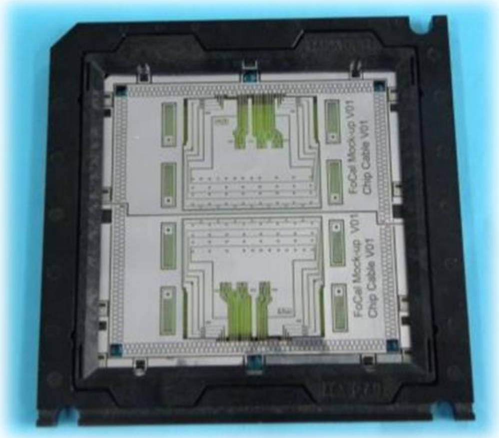


Framed cable

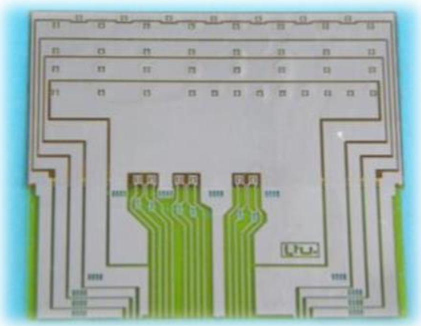


MAPS

Aligning,
SpTAB,
Testing,
Protecting bonds



Cutting-off
work area



Cutout cable
(with MAPS)

Notes:

- ***each chipcable is developed for 2 sensors***
- ***testing MAPS on cable allows to exclude mounting defective MAPSs in slab***

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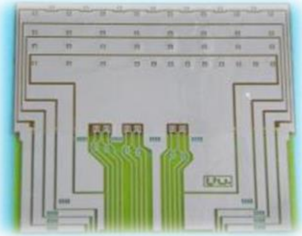
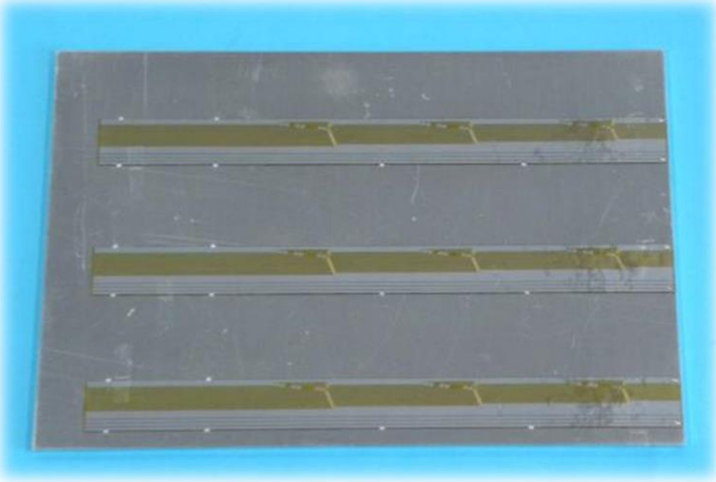
FoCal slab mock-up

Cutout cable

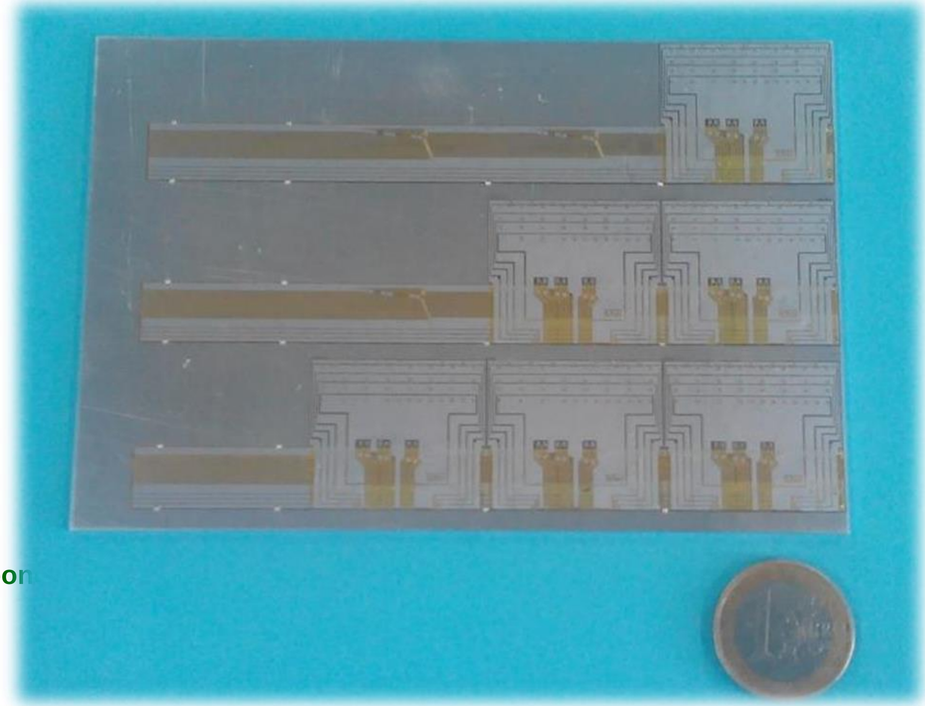


Carrier with multilayered flexes



Aligning,
Gluing,
SpTAB,
Testing,
Protecting bon

Assembled mock-up



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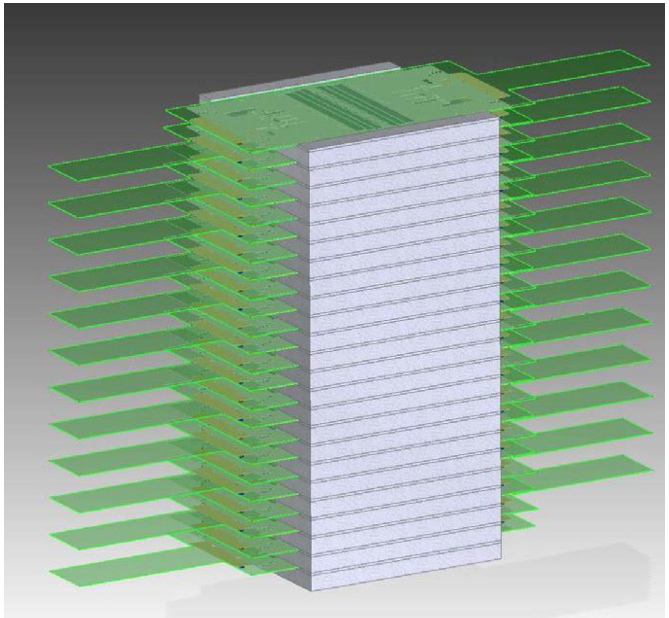
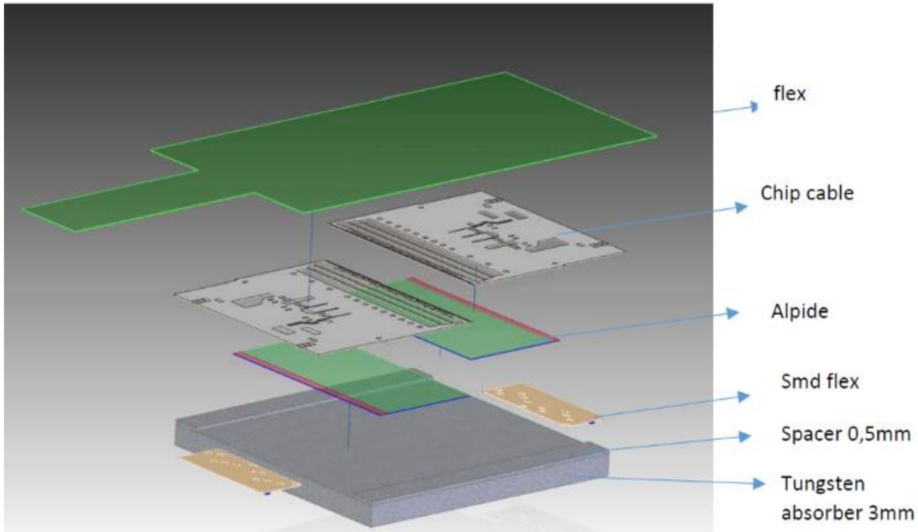
Activities for FoCal: mTower

***FoCal mTower** (24 layers, 24x2 ALPIDE chips)*



Composition of mTower layer



- Approach for realization is developed
- Assembly procedure is developed
- Technological mock-up is developed and designed
- Components are under production
- Mock-up will be delivered at CERN during ALICE week in November (next week)
- Activity is ongoing

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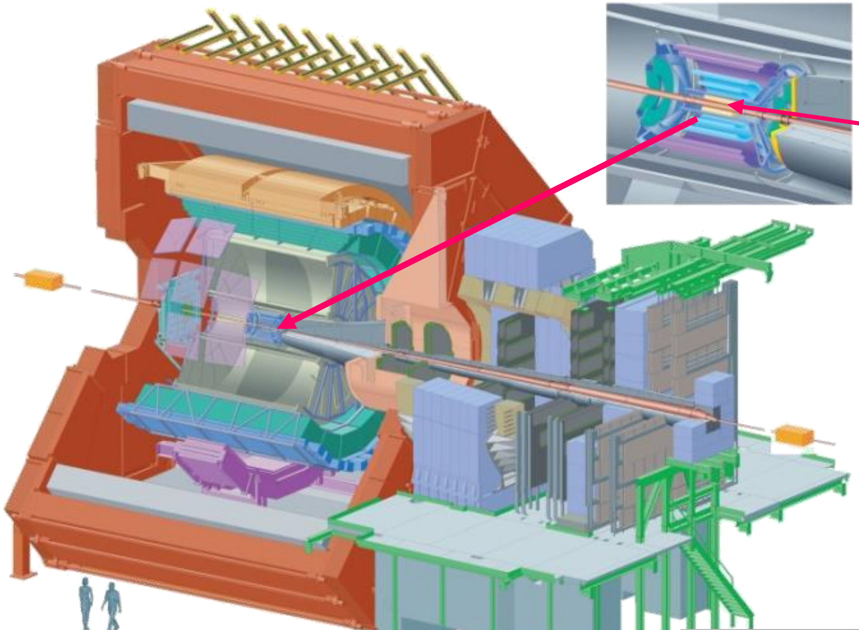
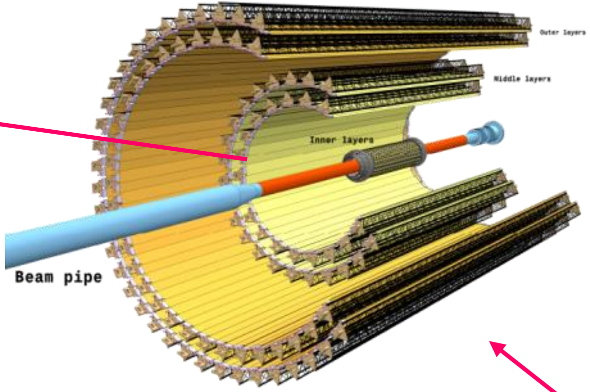
Activities for other experiments

- ALICE ITS upgrade
- LHCb IT upgrade
- CBM
- PANDA
- Mu3e

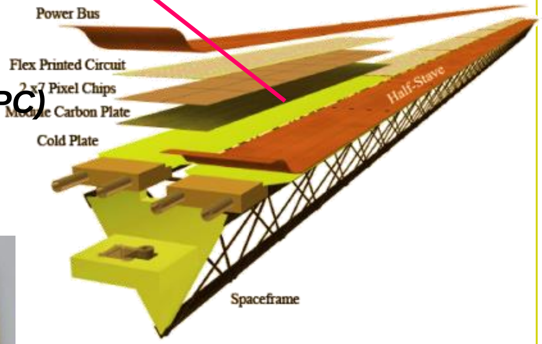
Activities for CERN: ALICE ITS upgrade



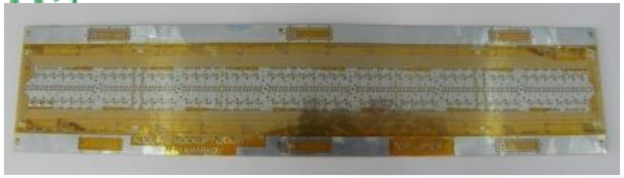
Upgraded ITS

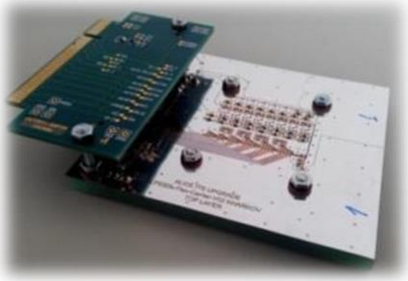


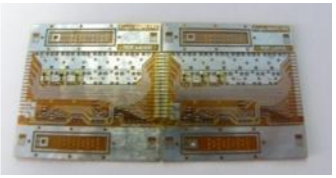
Stave composition

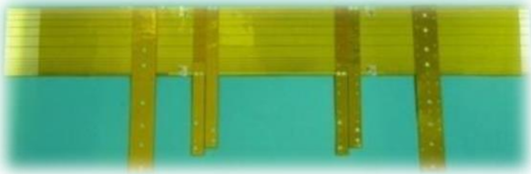


- ✓ *Power Bus*
- ✓ *Flexible printed circuit (FPC)*









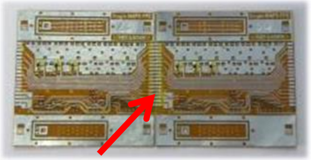
Mock-ups and prototypes for ALICE ITS Upgrade

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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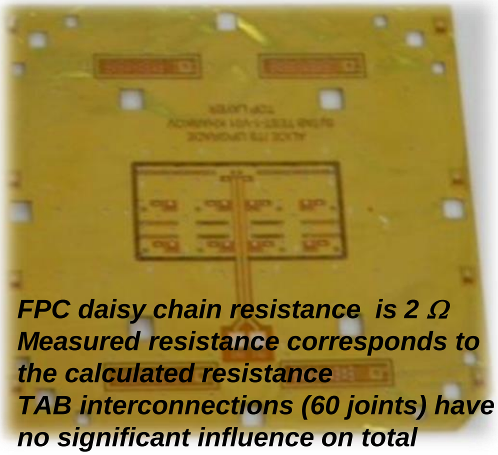
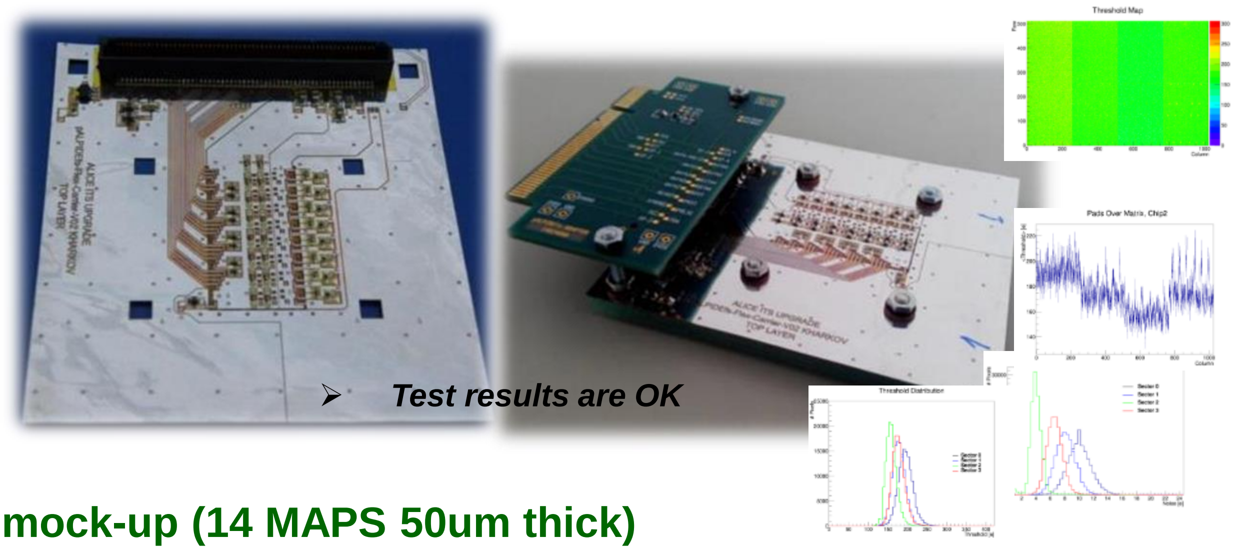
Prototypes for ALICE ITS upgrade: test results

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

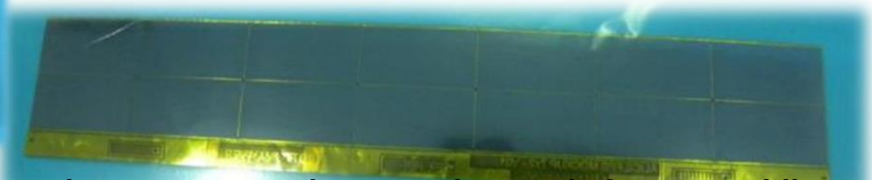


- Test results are OK

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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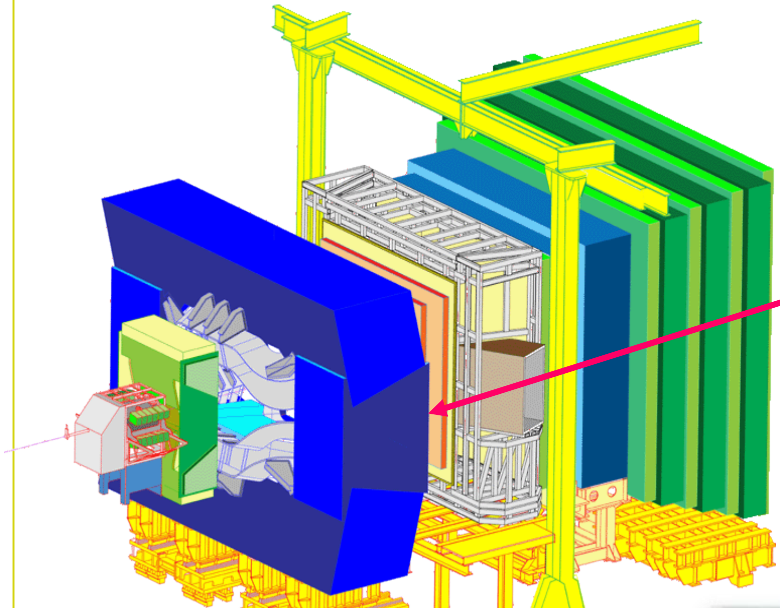
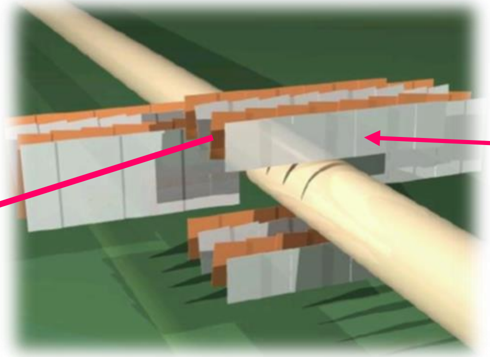
Activities for CERN:

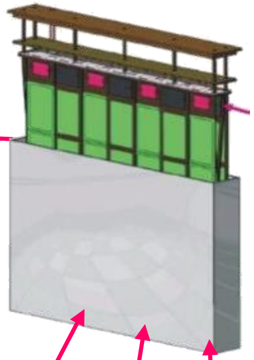
LHCb IT upgrade



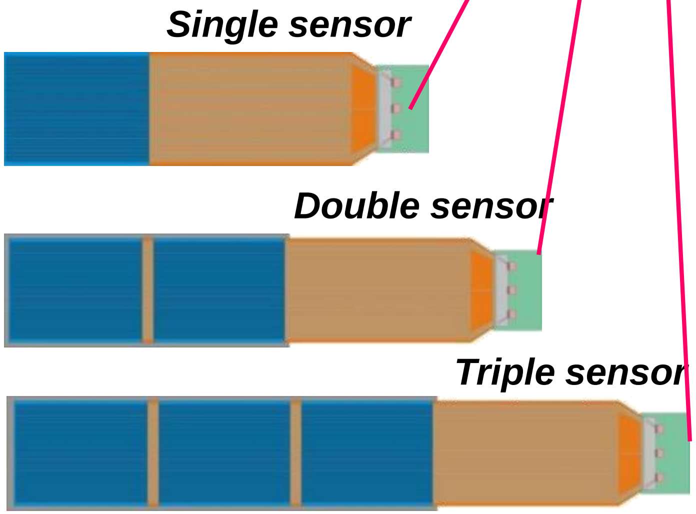
Inner Tracker



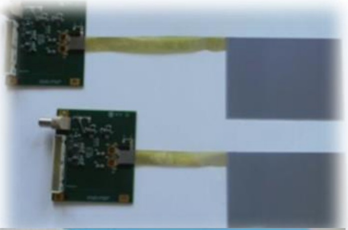
Detector box

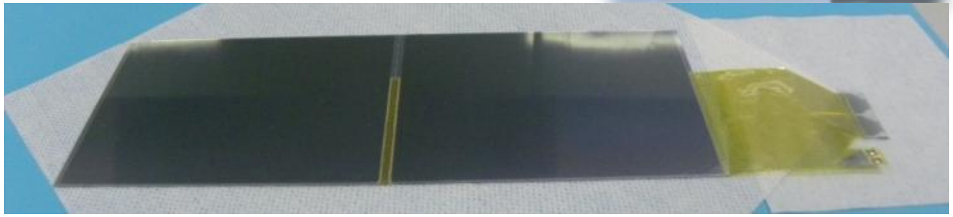


Detector modules



- ✓*Connecting cable*
- ✓*Inter-sensor cable*

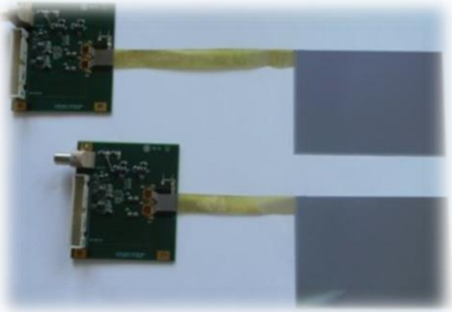


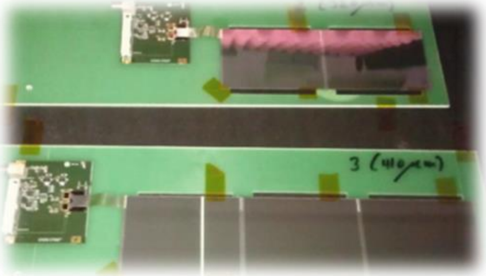


LHCb IT upgrade: prototypes

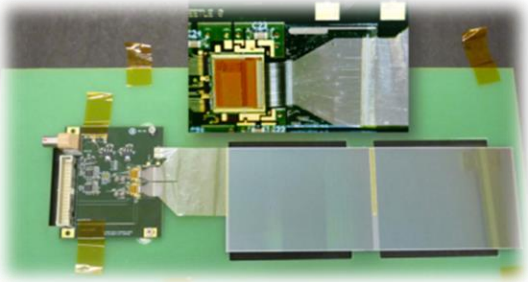
module prototypes

64 ch





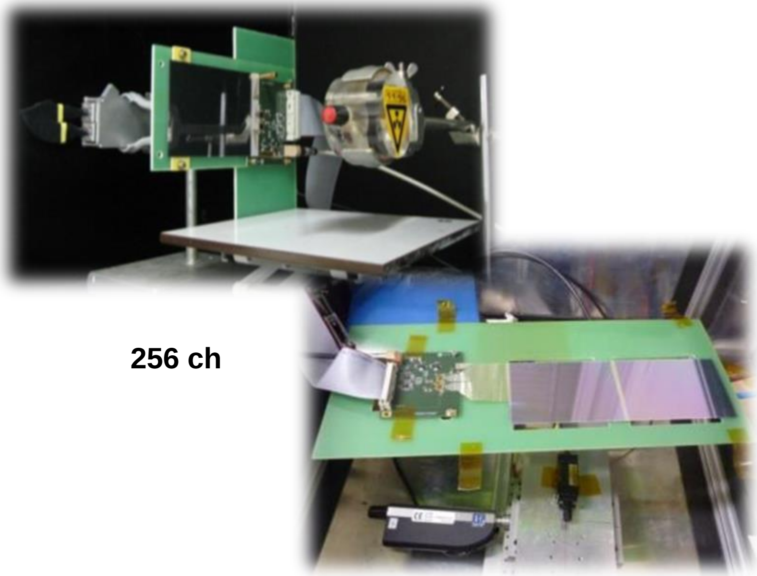
256 ch



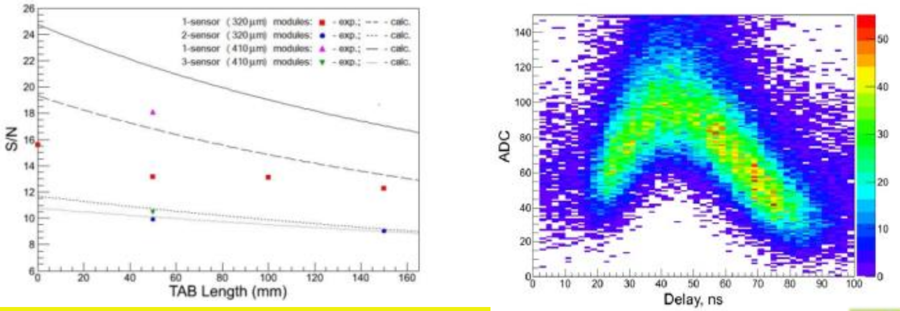
module prototypes under testing (CERN)

64 ch

256 ch

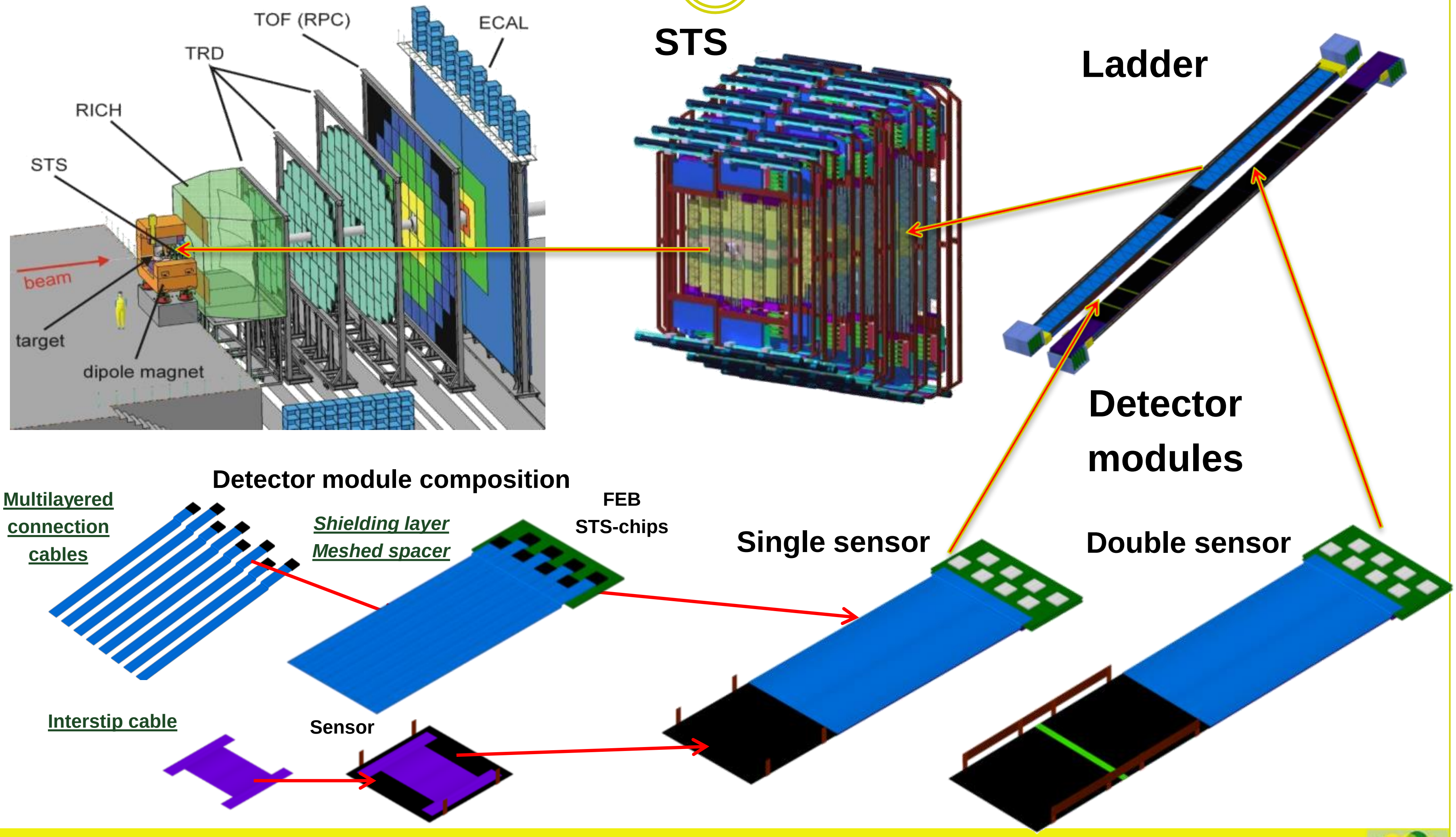


Module prototypes: test results



Activities for GSI:

CBM experiment



STS

Ladder

Detector modules

Detector module composition

Multilayered connection cables

Shielding layer

Meshed spacer

FEB

STS-chips

Single sensor

Double sensor

Interstip cable

Sensor

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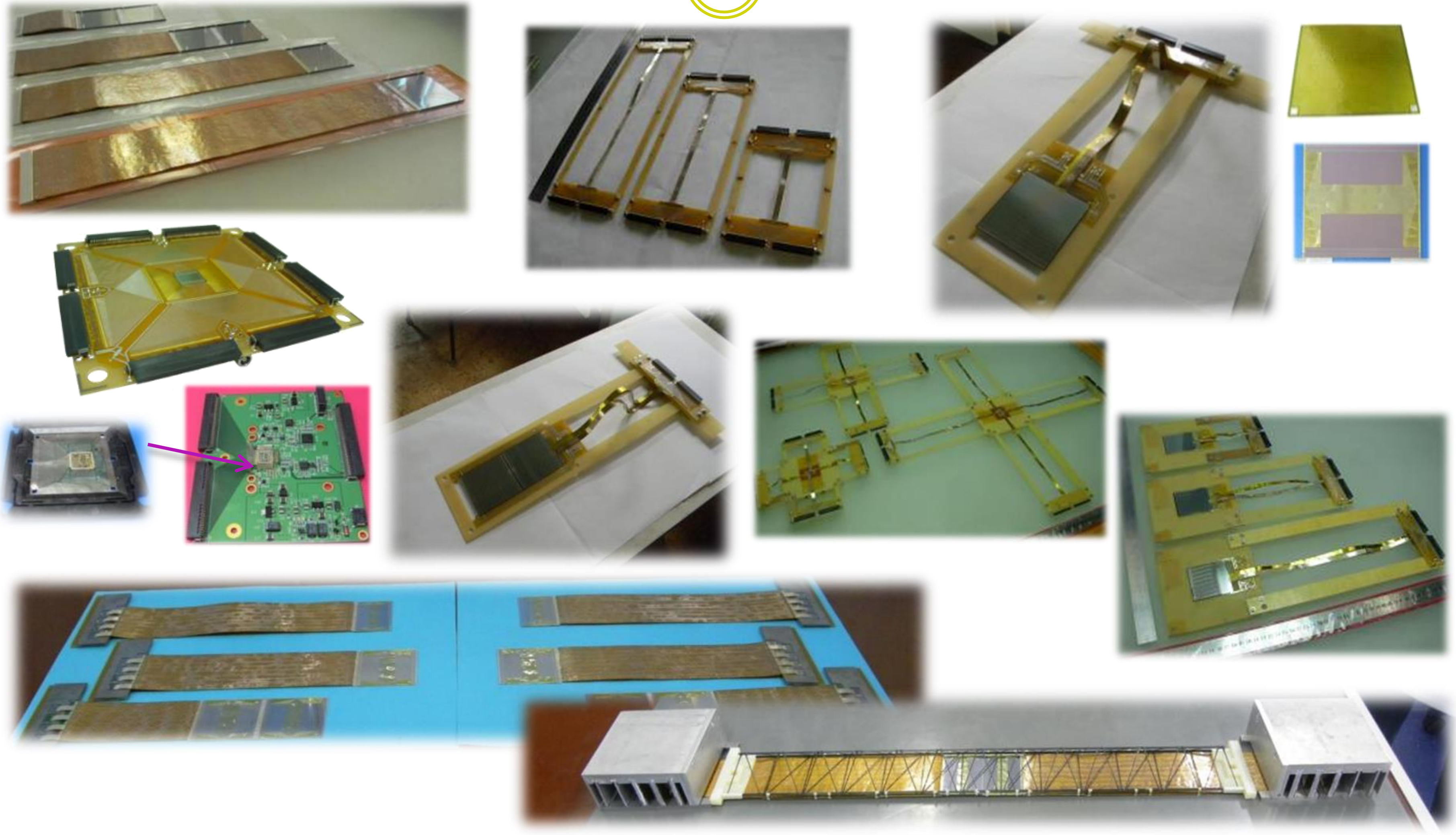
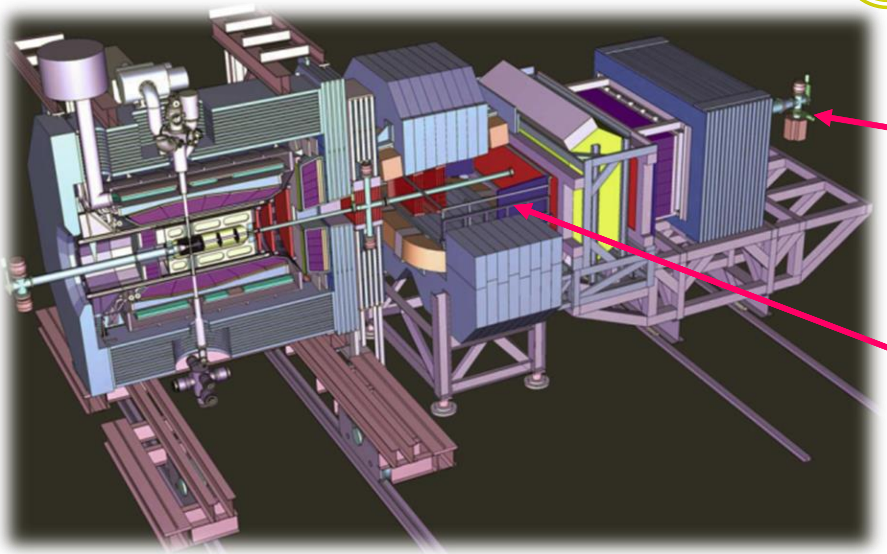
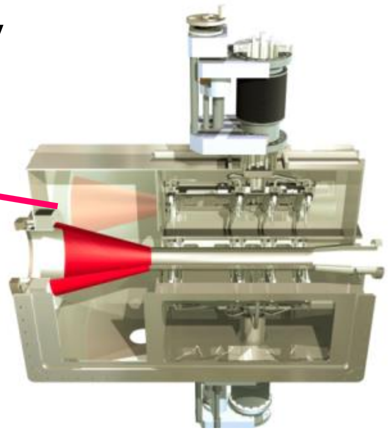
Mock-ups and demonstrators (CBM)



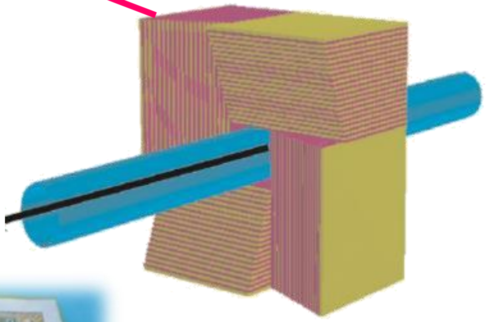
Activities for GSI: PANDA experiment



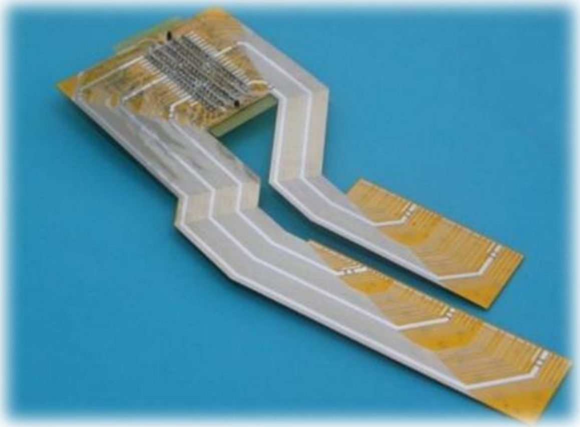
Luminosity detector



Secondary target

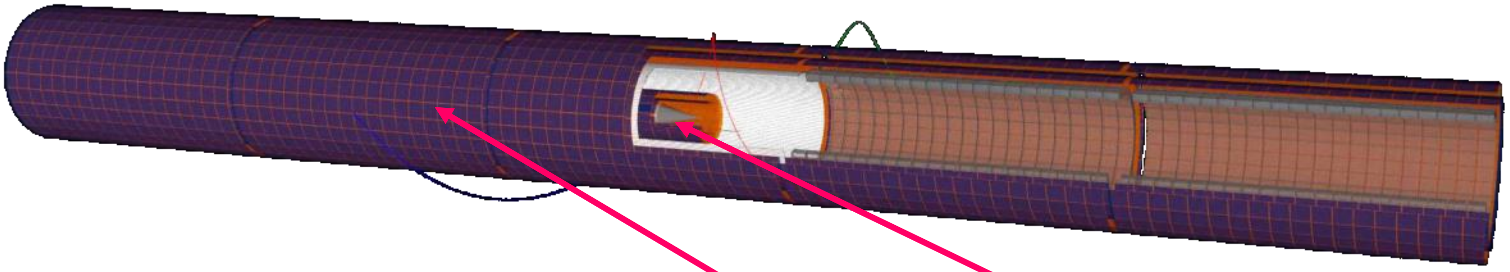


Joint activity with University of Mainz



Activities for PSI: Mu3e experiment

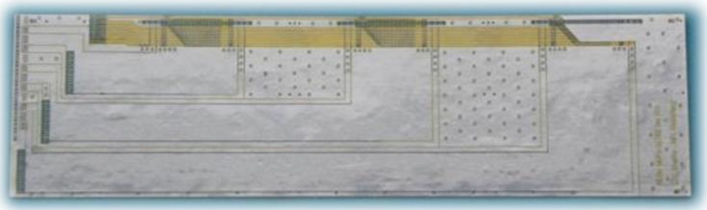
The Mu3e detector



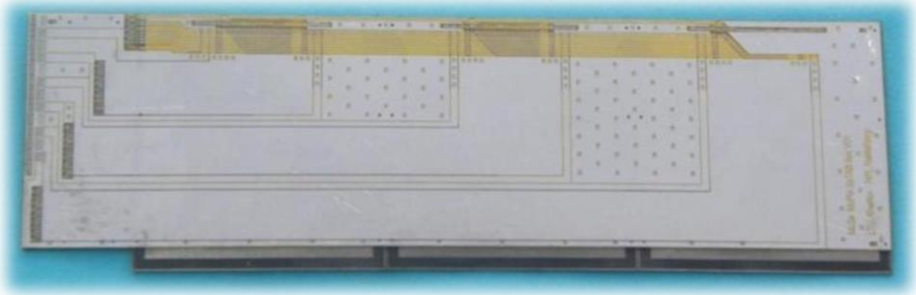
Inner detector layer

Outer detector layer

Mu3e FPC



Mechanical mock-up of Mu3e pixel detector module



Joint activity with Heidelberg Physics Institute
University of Heidelberg

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 FoCal are ongoing
- Obtained experience within activities for FoCal and other experiments can be used for pCT

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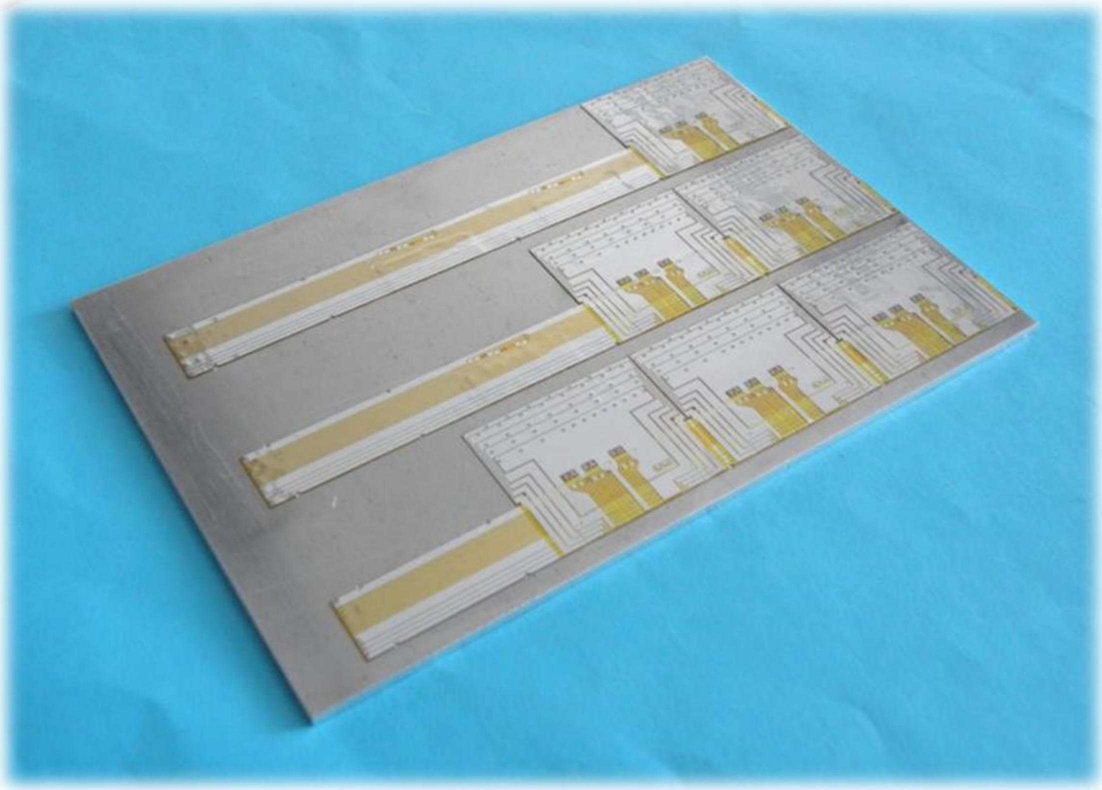
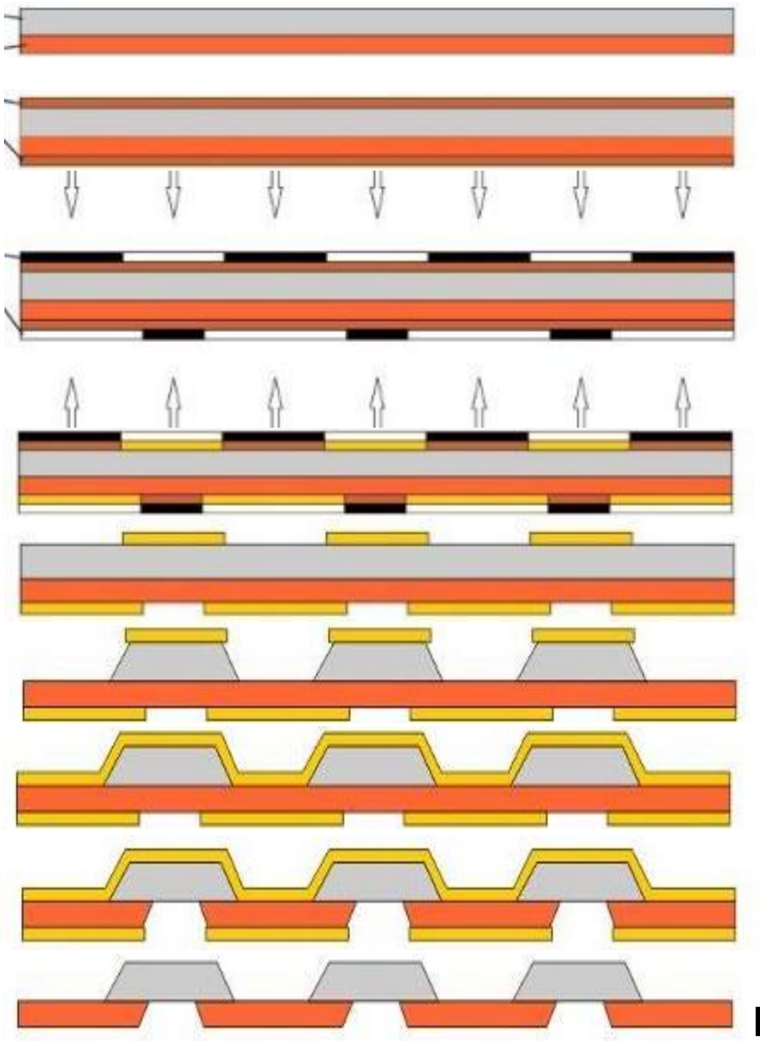
Thanks a lot



for your attention!

Backup slides

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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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.

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Microcable production site


substrates preparing


(clean room)


photoresist coating, exposing, developing


Wet chemical etching


Visual inspection

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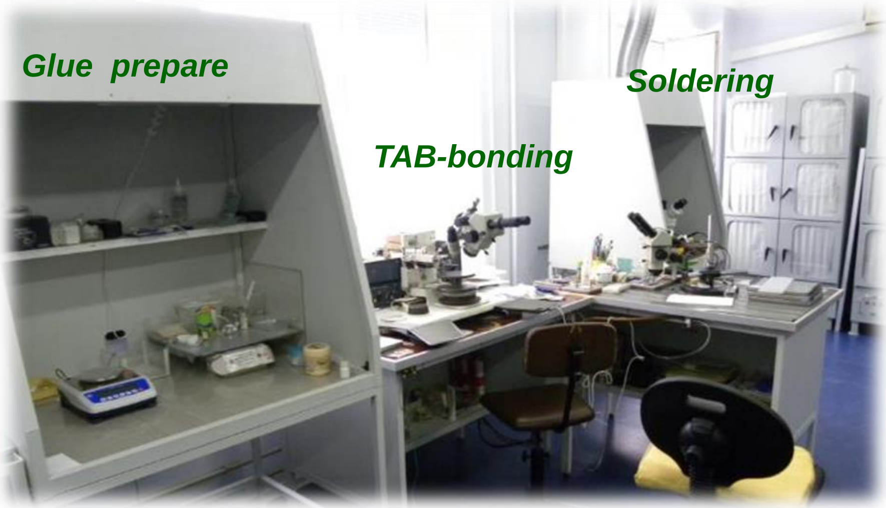
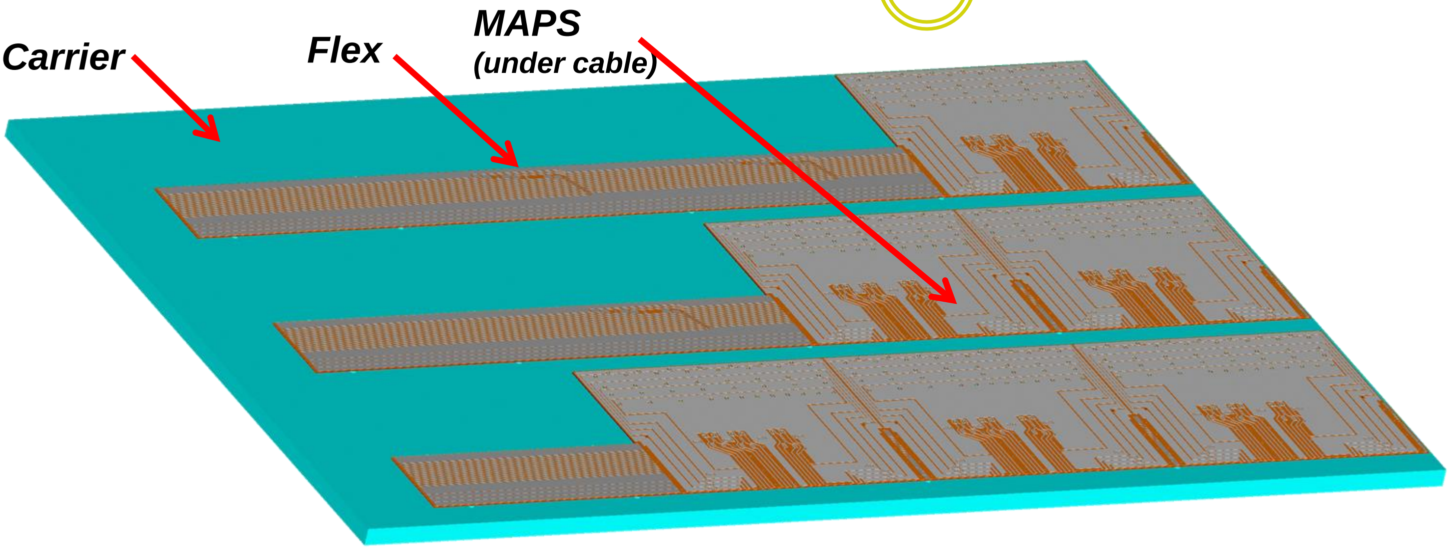
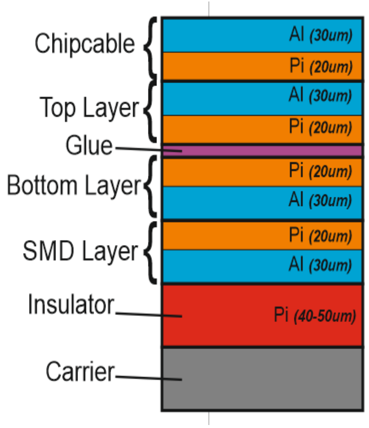
Microelectronics devices assembly site



Mock-up of FoCal slab



Cross-section
(schematically)



Composition of the mock-up:

➢ *Carrier*	*– 1 pc*
➢ *Multilayered flex*	*– 3 pcs*
➢ *MAPS (bad ALPIDE)*	*– 6 pcs*
➢ *SMDs*	*–54 pcs*

Estimated total thickness of real slab will be ~2,2mm, including:

- ***carrier ~1,67mm***
- ***assemblies 2x~0,27mm***

Notes:

- ***Design of the mock-up is based on 9 sensor row and the mock-up flex contains all the necessary traces but is only shorter***
- ***Flex can be easy extended up to 15 chips (additional width ~ 3 mm is required, but required space for this is reserved between the rows of chips).***

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Key features

- before mounting sensors on carrier full functional test might be performed (special chipcables are using). Such approach allows to exclude mounting defective MAPSs in slab

- flexible layers are made of aluminium-polyimide adhesiveless foiled dielectric (Al-30um, Pi -20um)

- connecting method for chip-to-flex connection is direct ultrasonic welding (Single-point TAB) traces of flex to the chip (wires are not needed)

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Main assembly steps

- Assembling MAPSs with chipcables
- Assembling multilayered flexes
- Mounting flexes on carrier
- Mounting MAPS with chipcables on carrier

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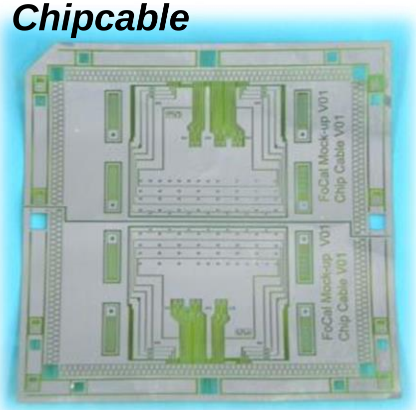
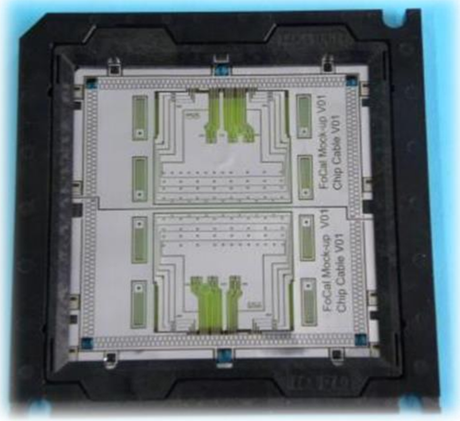
Step 1:
assembling MAPS with chipcable

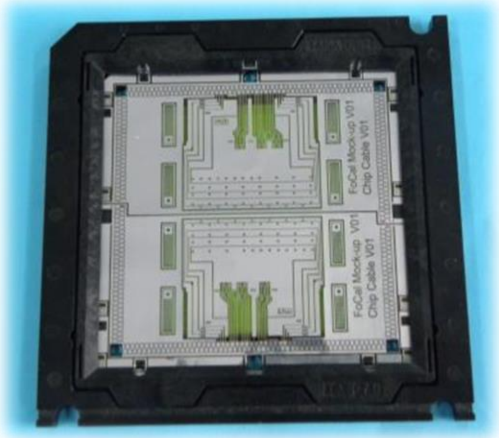
Chipcable



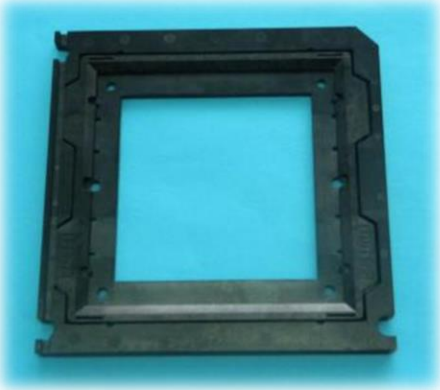
Framed cable



Aligning,
SpTAB,
Testing,
Protecting bonds

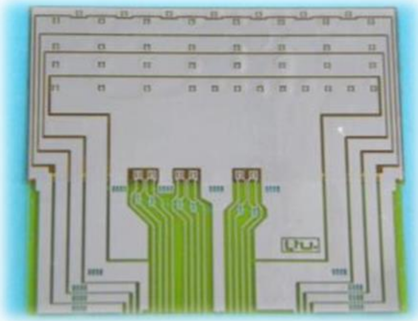


Test frame



MAPS

Cutting-off
work area



Cutout cable
(with MAPS)

Notes:

- ***each chipcable is developed for 2 sensors***
- ***testing MAPS on cable allows to exclude mounting defective MAPSs in slab***

Step 2: assembling multilayered flex

Top Layer

Bottom Layer

<u>Note:</u>
- layout of top layer is developed for 100 Ohm impedance

SMDs (0402,
dimensions 1,1mmx0,6mmx0,6mm)

Flex Mount

Soldering

Flex Mount with SMDs

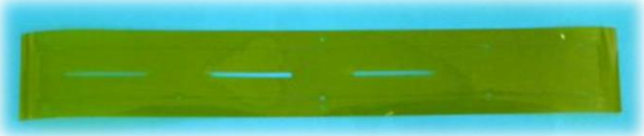
Two-layered flex

Aligning, SpTAB,
Testing, protecting bonds

Three-layered flex

Aligning, SpTAB,
Testing, protecting bonds

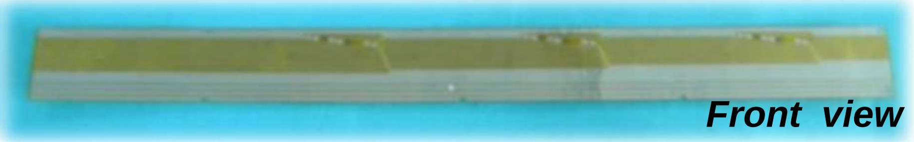
Cover layer (insulator)



<u>Multilayered flex</u>

Aligning, laminating

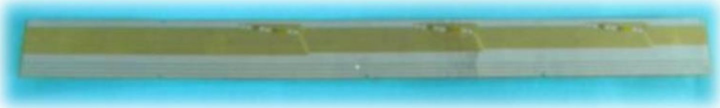
Rear view



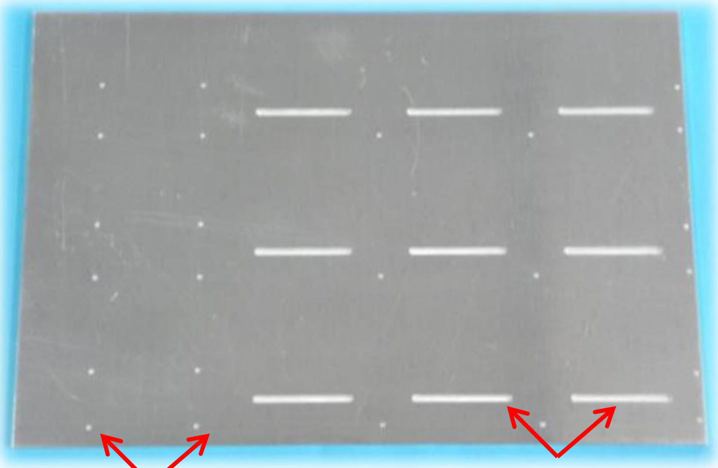
Front view

Step 3:
mounting flexes on the carrier

Multilayered flex



Carrier

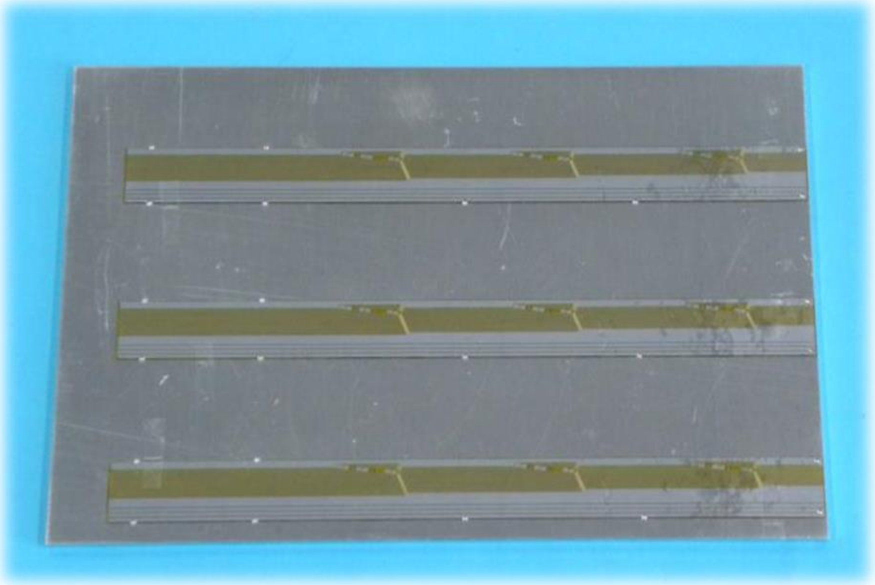


Grooves for aligning

Grooves for SMDs

Aligning, laminating

Carrier with flexes



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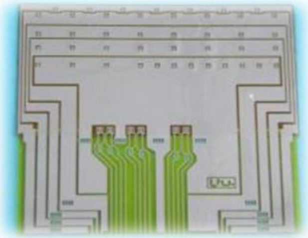
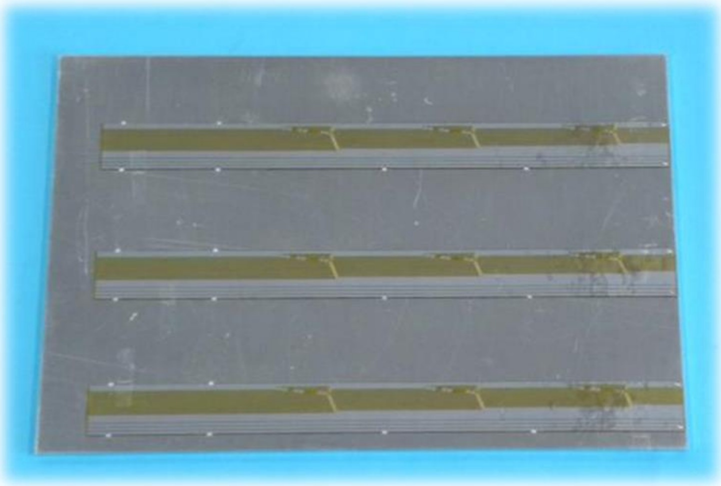
Step 4:
mounting MAPS on carrier

Cutout cable

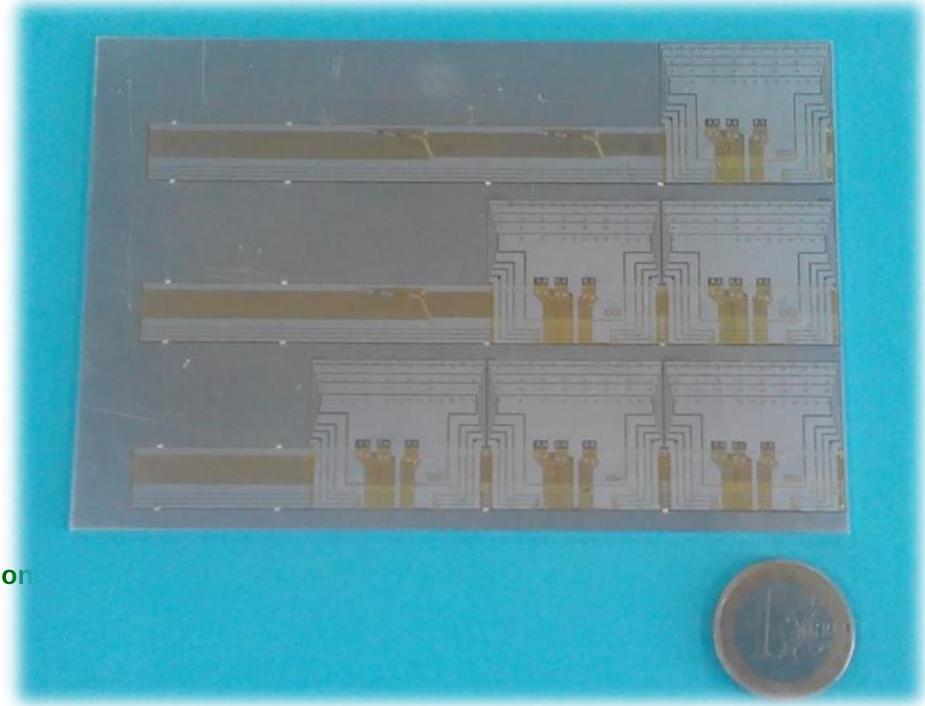


Carrier with flexes



Aligning,
Gluing,
SpTAB,
Testing,
Protecting bon

Mock-up



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