Annual Meeting 2021
WP7

Christian J. Schmidt, Otilia Culicov
25.03.2021, online via Zoom

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 871072.

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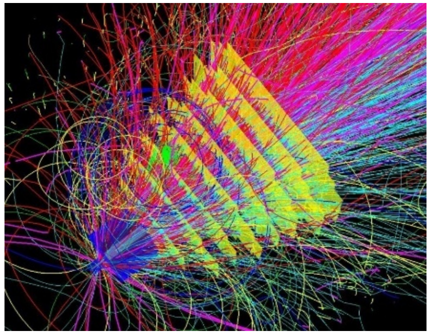
WP7- DETEC: horizontal activity on development of detector technologies



Charge: Develop beyond state of the art detector technologies

Aim to foster
- **cooperation, ideas and technologies-interchange**
- as well as **education of young scientists** in the field of particle detectors and related technologies

Joining two fields that typically have only few links:

- CMOS pixel sensors for nuclear- and high energy physics tracking applications
- Detector technologies for thermal neutrons

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Tasks within WP7

- Task 7.1: Development of CMOS technologies for high-rate Silicon trackers (**CNRS-IPHC**, FAIR, GUF, INR NASU)
  → task leader Michael Deveaux (FAIR/GSI)
- Task 7.2: Development of new methods for effective integration of MAPS sensors in large-area tracking-detector systems with extremely low material budget (**JINR**, FAIR, DESY, BINP)
  → task leader Michael Deveaux (FAIR/GSI)
- Task 7.3: Next generation Neutron Detectors (**ESS**, JINR, NRC KI PNPI, UNI MIB-ADSI) → task leader Evgenij Altinbaev (NRC-KI)
- Task 7.4: Training and school for young scientists on particle detection technologies (**BINP**, CERN) → task leader Sergej Kononov (BINP)

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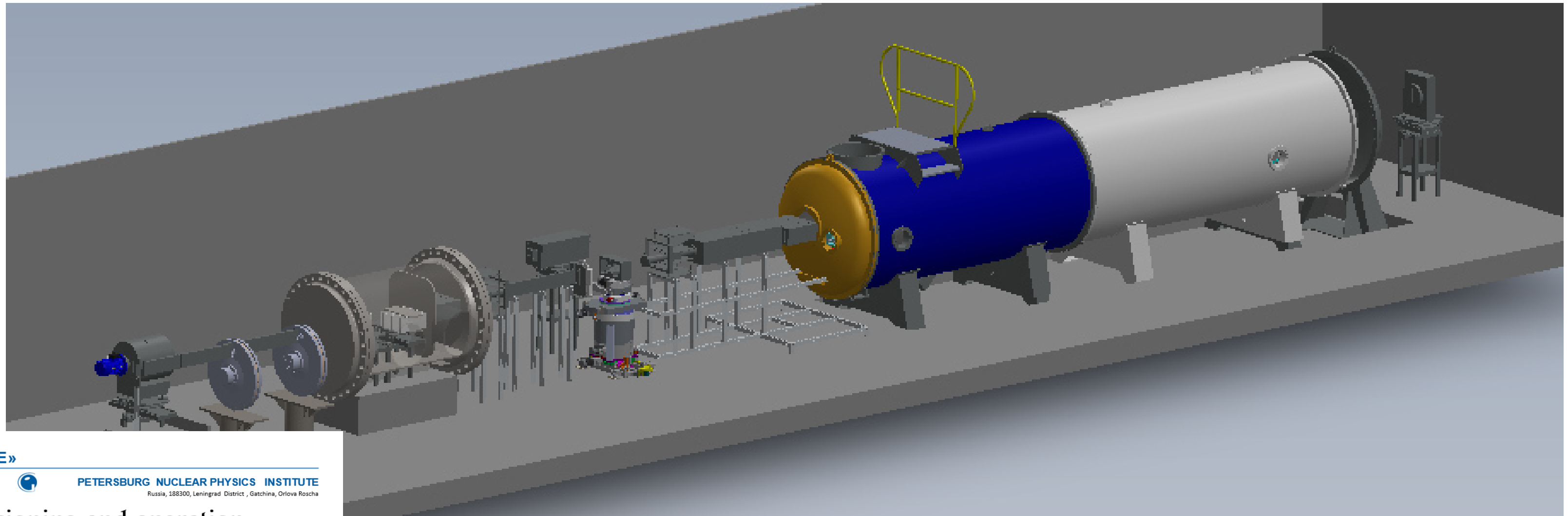
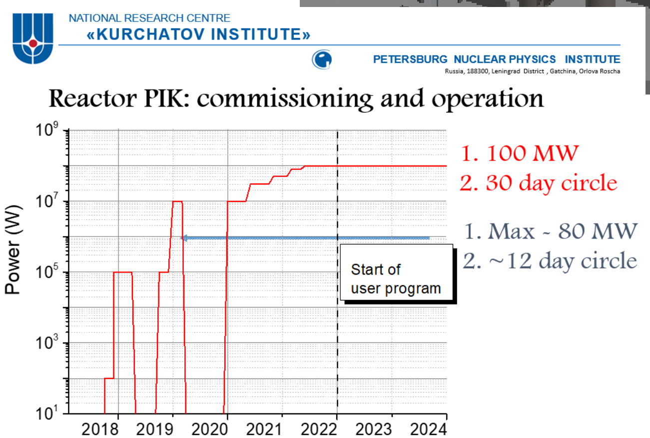
Multipurpose neutron reflectometer SONATA
(one out of 24 instruments scheduled at PIK until 2024)





Benefits:
- High flux
- Optional continuous or pulsed beam
- Implemented focusing and defocusing supermirror lenses
- 3-axis neutron polarization analysis
- Variable sample-detector distance

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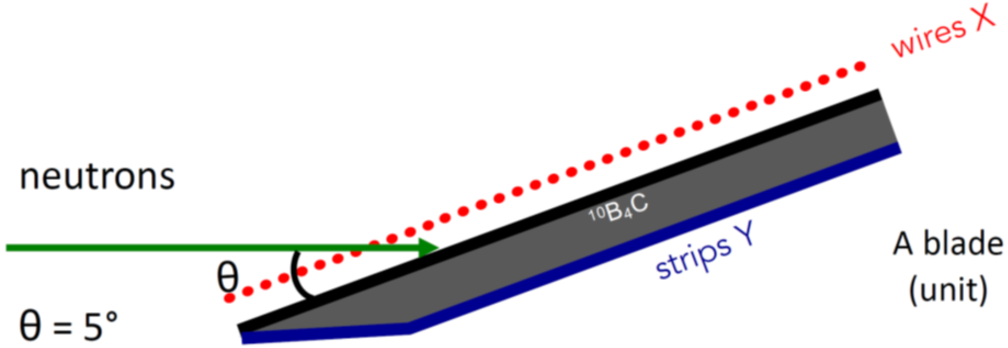
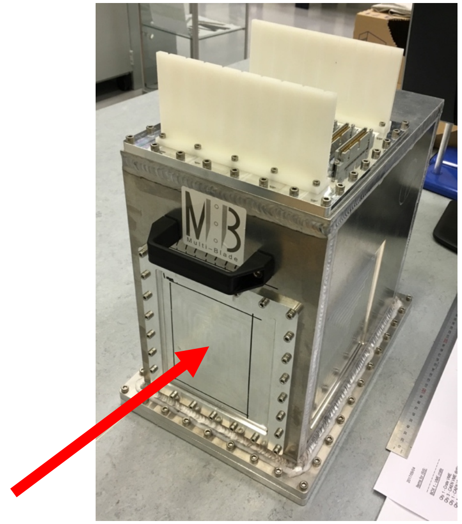
Multi Blade Neutron Detector

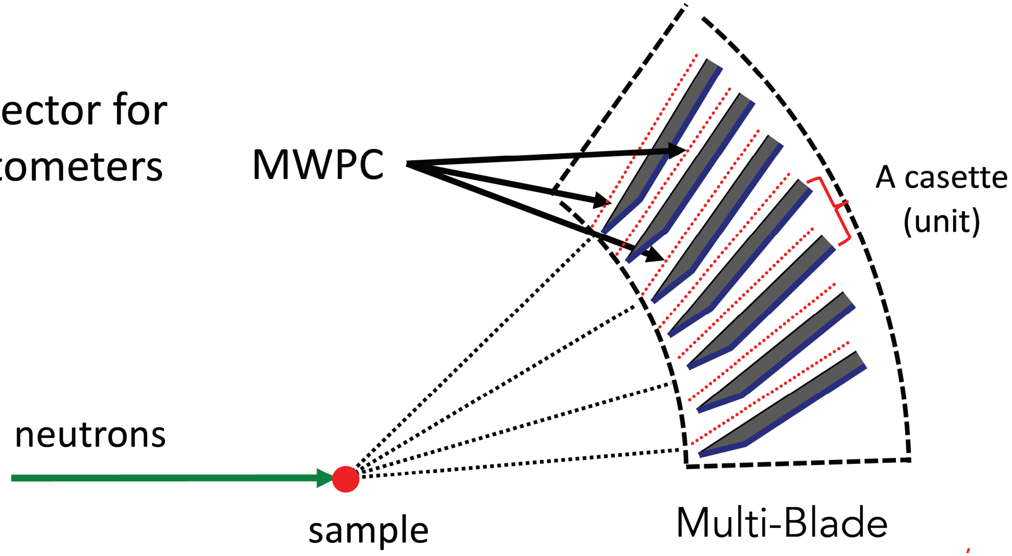
(originally developed at ILL and ESS)





- small angle gives high detection efficiency
- detection in volume with many wires give rate capability
- modular design

^{10}B-detector for reflectometers



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Milestone MS no. 7.1 & Deliverable no. D7.1 (Define neutron detector to be build)

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Connecting Russian and European Measures for Large-scale Research Infrastructures

Deliverable no. D7.1

Project information

Project full title	Connecting Russian and European Measures for Large-scale Research Infrastructures – plus
Project acronym	CREMLINplus
Grant agreement no.	871072
Instrument	Research and Innovation Action (RIA)
Duration	01/02/2020 – 31/01/2024
Website	www.cremlinplus.eu

Deliverable information

Deliverable no.	7.1
Deliverable title	Neutron Detector requirements
Deliverable responsible	Dr. Evgeniy Altinbaev
Related Work-Package/Task	Task 7.3: Next generation Neutron Detectors (ESS, JINR, NRC KI PNPI, UNIMIB)
Type (e.g. Report; other)	Report
Author(s)	Evgeniy Altinbaev NRC KI PNPI), Richard Hall Wilton (ESS)
Dissemination level	Public
Document Version	1
Date	14.10.2020
Download page	

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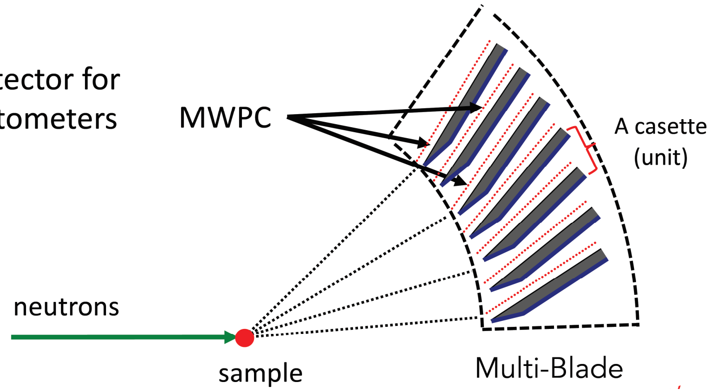
Specification for multiblade neutron detector:

- Sensitive area: 100x130 mm^2
- Spatial resolution: 0.5x3.5 mm^2
- Count rate: 100 MHz overall; 50 kHz per pixel
- Efficiency: 44% for neutrons with 2Å wavelength
- General purpose: Reflectometry
- Instrument: SONATA @ PIK

^{10}B-detector for reflectometers



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Reflectometry requirements@PIK - SONATA instrument

Multi-Blade

EUROPEAN SPALLATION SOURCE

	Required design*	MB version 1 (including readout system)	MB version 2 (detector only)
Sensitive area	400 × 400 mm^2	100 × 130 mm^2	400 × 260 mm^2
Spatial resolution	2 × 2 mm^2	0.5 × 3.5 mm^2	
Overall count rate		> 100 MHz (depending n scattering pattern)	
	50 kHz	13 kHz/mm^2 @10% deadtime 50 $kHz/px_{equivalent}$	
Efficiency (@ 2 Å)	40%	~ 44% (measured @ 2.5Å)	

x3-4 better than state-of-the-art

x20 better than state-of-the-art

* Communication with Evgeniy Altynbaev

- Will make us ready to set the new State-of-the-Art in reflectometry
- Will prepare to be ready in support of word leading science
- Collaboration between PIK, JINR and ESS

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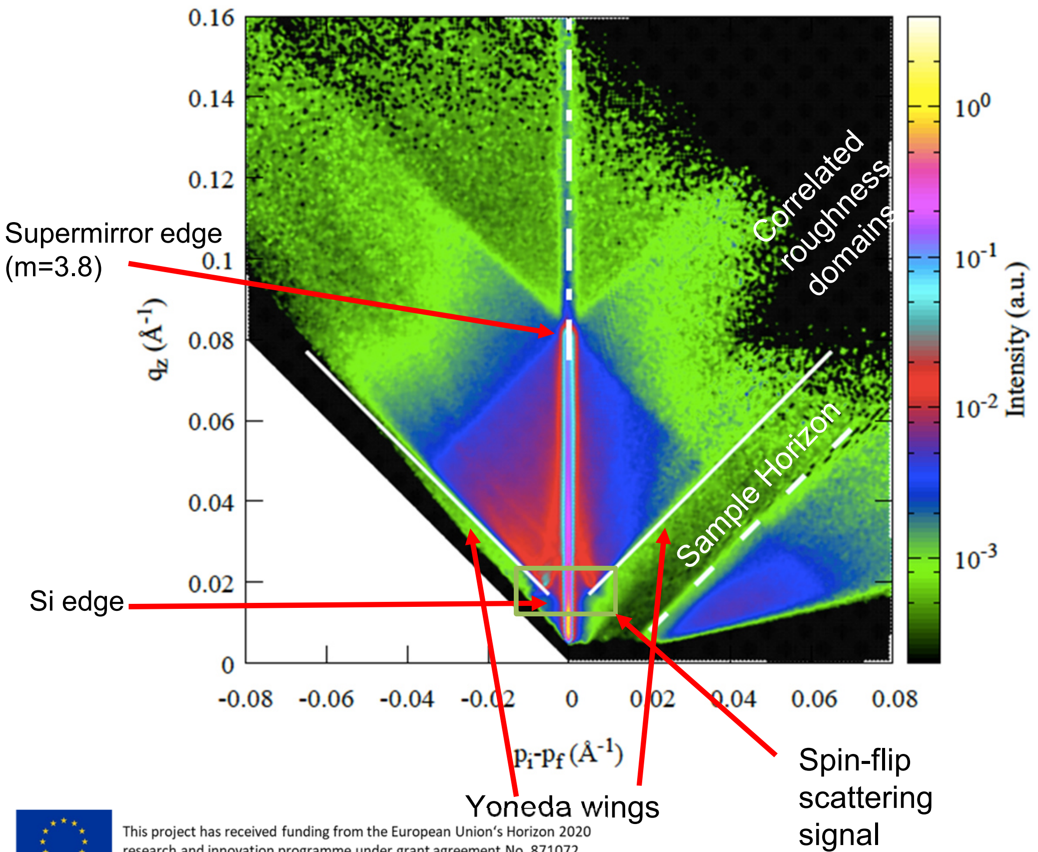
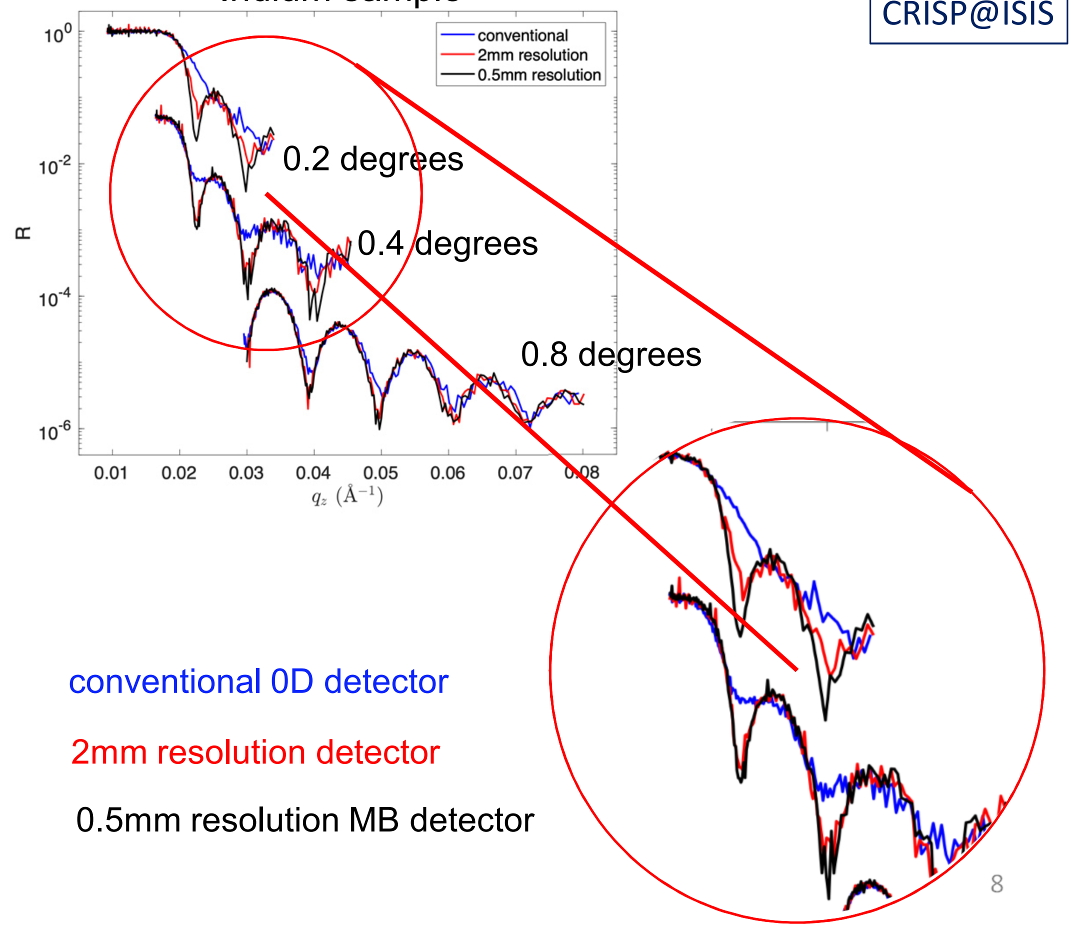
Some scientific results

Off-specular scattering from Fe/Si neutron supermirror
Measure with the MB detector



Iridium sample

CRISP@ISIS



conventional 0D detector

2mm resolution detector

0.5mm resolution MB detector

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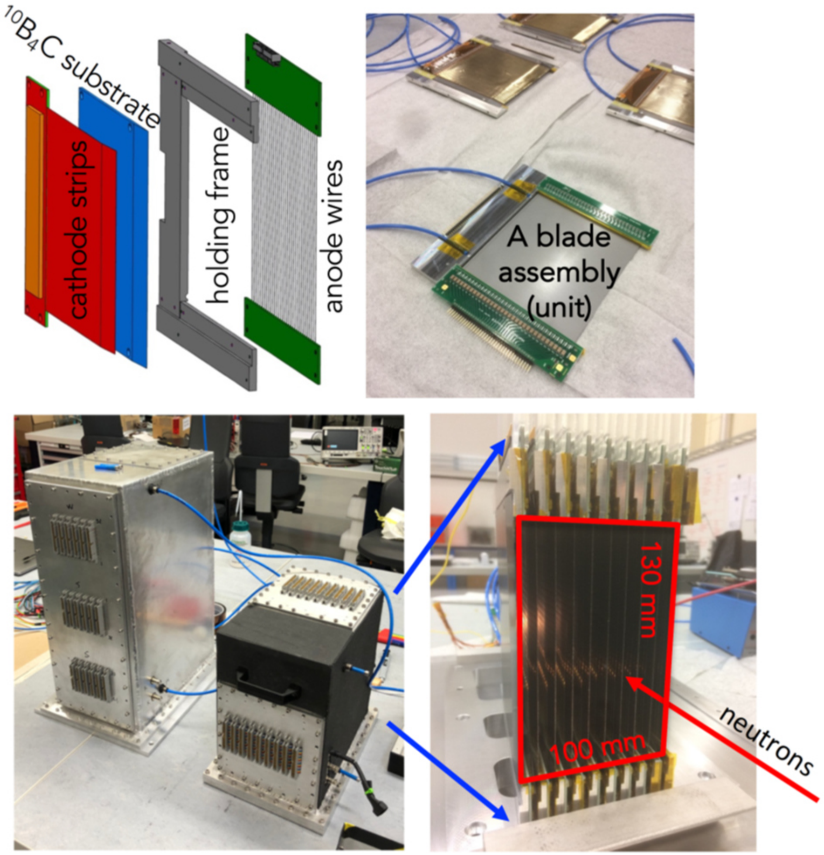
Neutron detector design is scheduled and participants defined → integrated collaboration among ESS, PIK and FLNP



Near and Mid Future Plans

April / May 2021: Come back to Evgeniy Altynbaev/PIK with a definitive proposal to address requirements as expressed in Deliverable 7.1 report

Jun. 2021: agreement on plan of action

Autumn or Winter (COVID and personnel dependent): Build detector in Lund with team from PIK, FLNP and ESS

Wish very much for personal exchange with PIK and JINR during the detector build: collaborate effort, skills transfer and networking

Spring/Summer 2022: Testing detector (at IBR2, JINR?)

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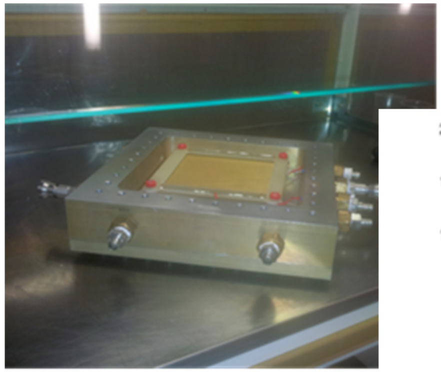
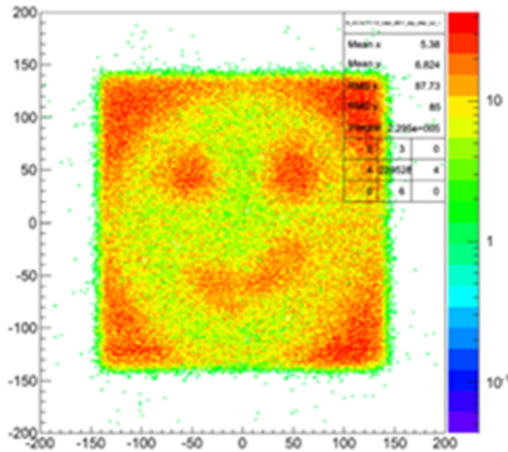
Achievements / highlights FLNP JINR



PSD prototype
with the top cover removed



Coordinate spectrum
from the prototype

Early - pre CREMLIN+ studies:

- FLNP JINR developed, designed and produced a working prototype of the position-sensitive thermal neutron detector based on a B_4C converter produced by ESS.
- Results:
- Spatial resolution (0,9 mm in the coordinate perpen-dicular to the anode, 1,3 mm parallel to the anode).
- Promising results in pulsed neutron flux at IBR-2 reactor
- Start development of local sputtering capacity in FLNP (in collaboration with Dubna State University)

proficiency in B_4C coating!

- Results:
- B_4C layer thickness of 100 nm-1 µm can be sputtered on aluminium substrate.
- The B_4C film: good adhesion to the surface, does not fly or flake.
- The uniform sputtering area 200mm*200mm, meets the first tasks demands. Now enlarge to meet 400mm detector needs

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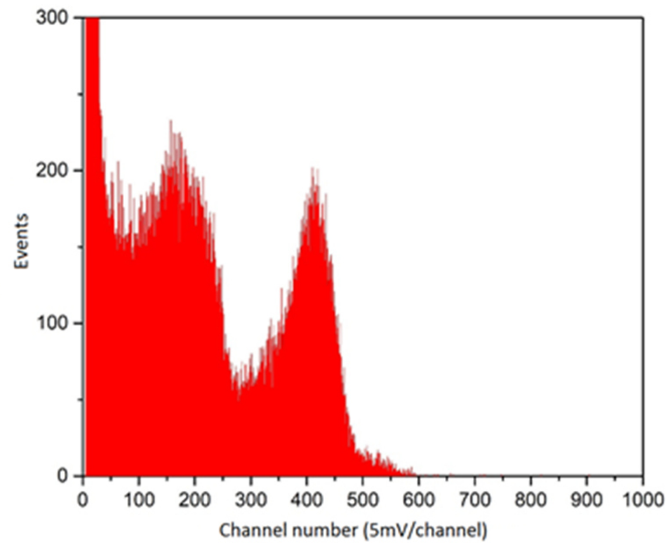
Achievements / highlights FLNP JINR

Studies within Cremlin+

- FLNP JINR developed, designed and produced a monitor counter for thermal neutrons based on B_4C converter produced in Dubna.
- The counter operates on the principle of a multi-wire proportional chamber and has a sensitive area of 40x60 mm^2.
- The sputtering thickness is 0.5 µm, since it was planned to use the counter in relatively low fluxes (~ $10^4 n/cm^2 sec$).
- A 2D PSD monitor for measuring the intensity and spatial distribution of neutron beams has been developed and it is in the process of manufacturing.



Amplitude spectrum of the thermal neutron monitor with the B_4C converter produced in FLNP JINR

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WP7 CREMAPS R&D status

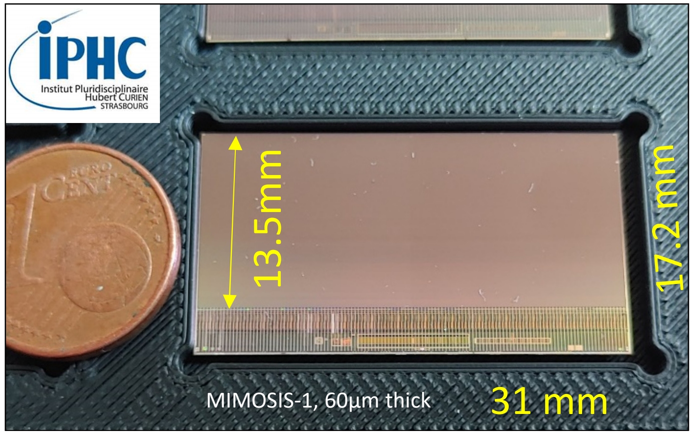
MIMOSIS-0 (2018)
- Demonstrate pixel-array readout. ✓
- Demonstrate zero suppression. ✓
- Demonstrate readout concept. ✓

MIMOSIS-1 (2020)
- Full dimension sensor ✓
- Add buffer structure. ✓
- SEE hardening 1/2 ✓

We are here

MIMOSIS-2 (Q4/2021e)
- On-chip sparce data scan.
- Restricted pixel variants.
- SEE hardening 2/2

CREMAPS
- Final sensor



MIMOSIS-1

All submissions:
Additional CE18 test structures to study specific design questions.


Commisioning during lock-down

In synergy with:

Supported by Bundesministerium für Bildung und Forschung

(05P19RFFC1)

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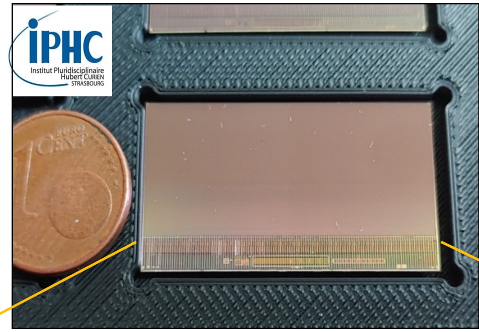
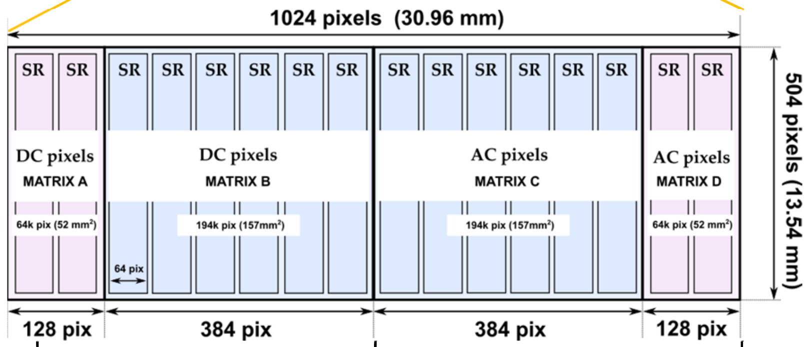
MIMOSIS-1: Highlights

CREMAPS goals (selected)	
Spatial resolution	~5 µm
Time resolution	< 5 µs
Sensor thickness	~60 µm
Power dissipation	< 100 - 200 mW/cm²
Rate (average/50 µs peak)	20/80 MHz/cm²

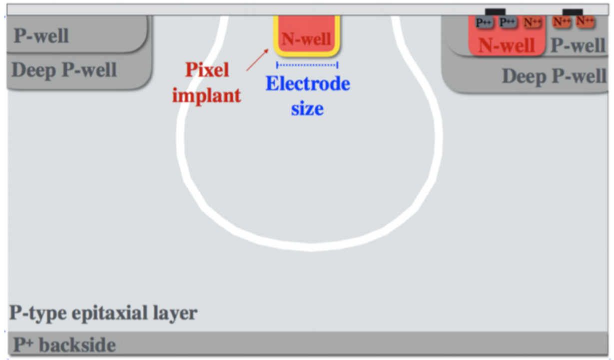




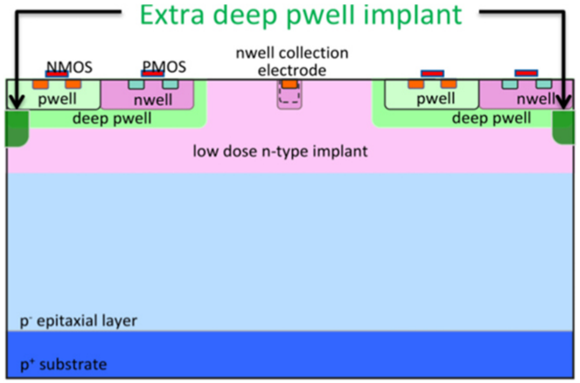
MIMOSIS -1 mission (selection):
Find best substrate and pixel

Established (ALPIDE)
⇒ Expect excellent performance

Should add radiation tolerance (full depletion)



Established substrate



Added value: Optimized drift fields

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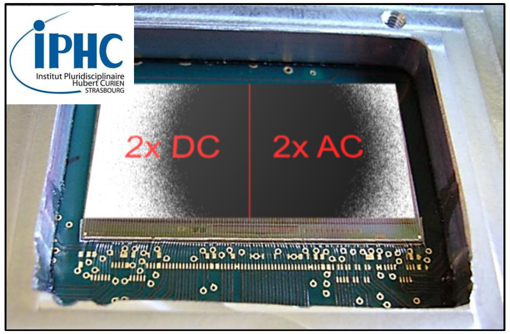
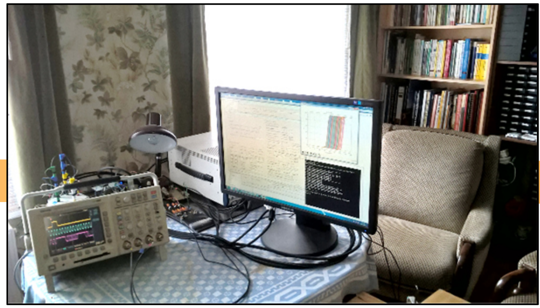
13

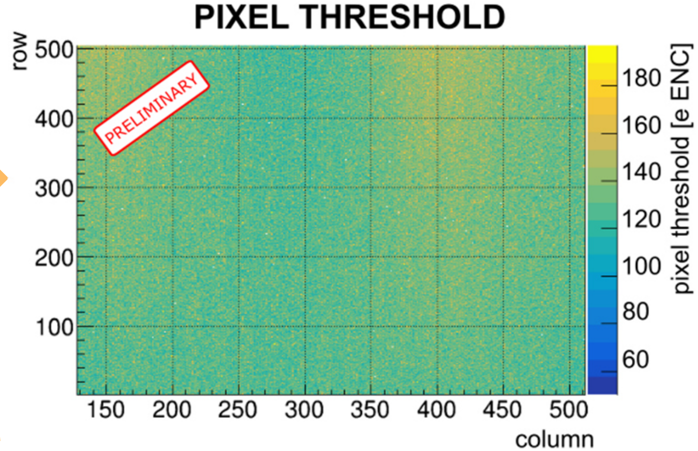
WP7 MIMOSIS-1: First test results (so far: standard epitaxial layer)

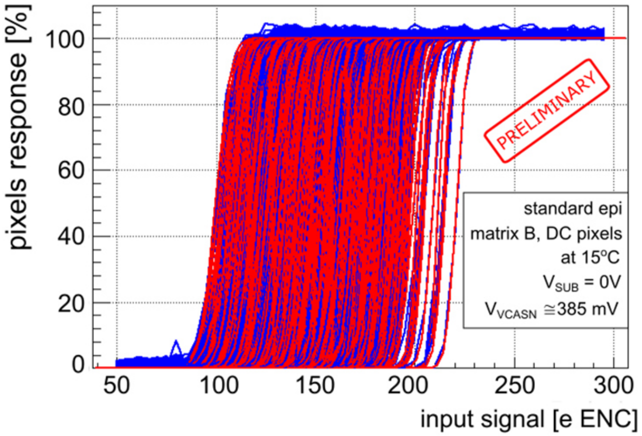


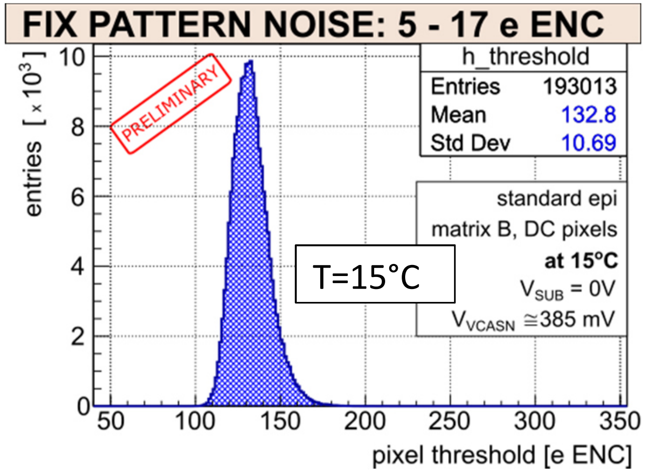
Sensor response to X-rays

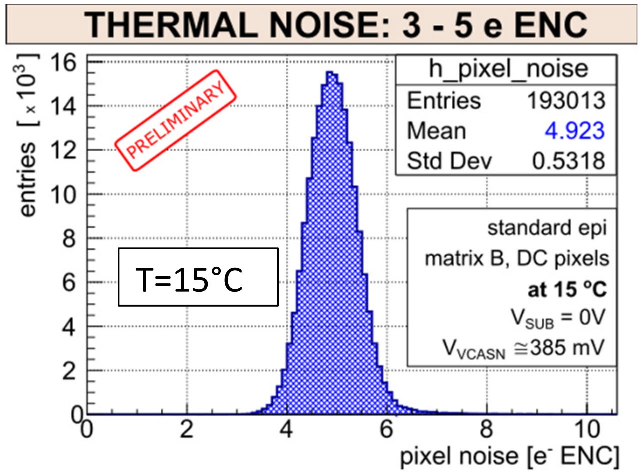


Test system, meanwhile transferred to lab









Plots: R. Bugiel, IPHC Strasbourg

Results match expectations, more to come.

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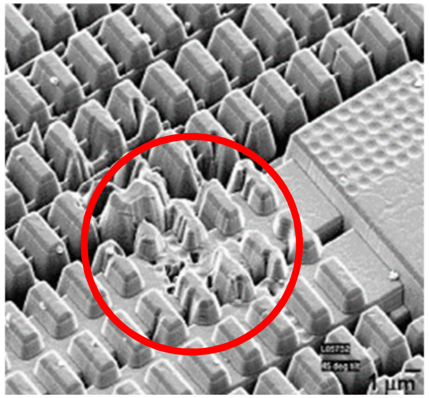
WP7 CREMAPS-1: Latch-up Test @ GSI, Heavy Ion Lead Beamtime

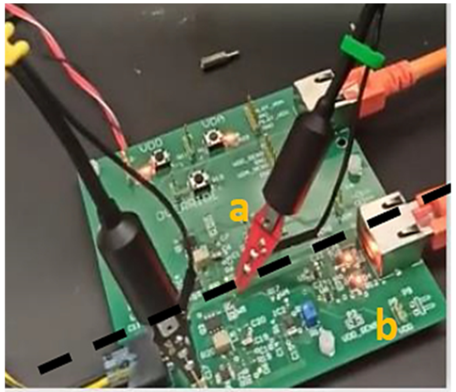
Latch-up:

- Reversible short circuit.
- Risk: Over heating destroyed sensors
- May be extinguised by power cycle.
- Detection: Over current.

Cross section unknown, measure it…

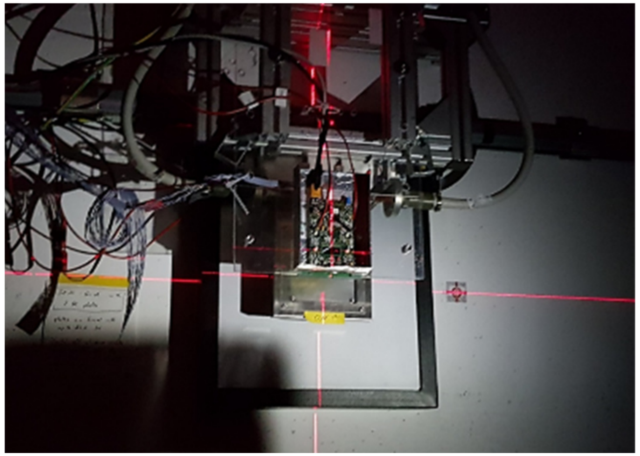


Sensor damaged by latch-up

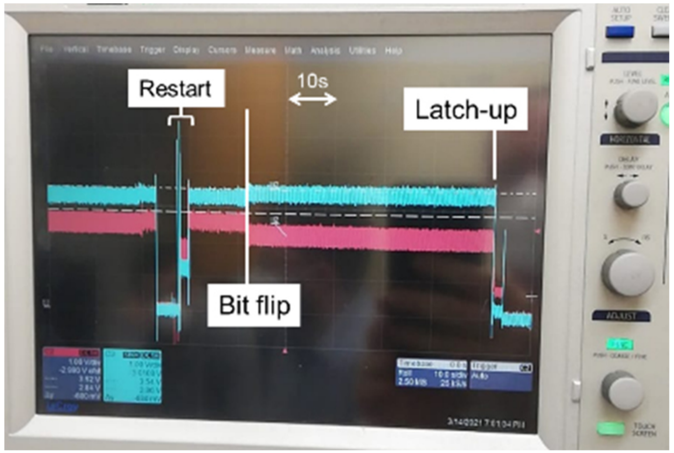


Latch-up detection board (GU Frankfurt)

System commisioning:
M. Koziel, GU-Frankfurt



Sensor installed in 1 AGeV Pb-beam @ GSI



Latch-ups as seen with online monitoring

Test successful – Results promising, stay tuned.

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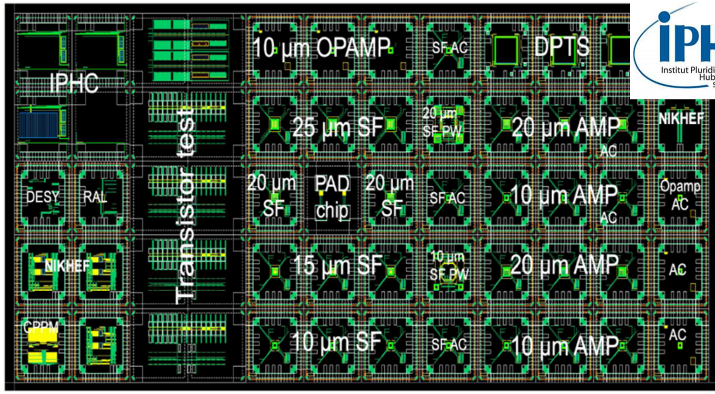
WP7 Exploration of 65 nm Imaging Technology

Motivation of the R&D:

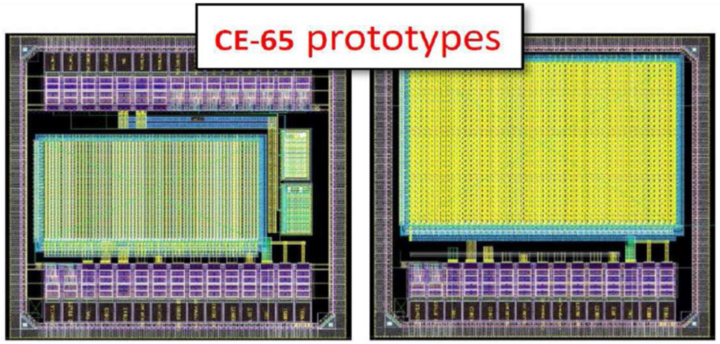
- Smaller feature size than 180 nm technology used for MIMOSIS
  ⇒ Smaller pixels, more in-pixel functionalities, less power consumption, faster readout, …
- Imaging technology available since ~Spring 2020, includes stitching
  ⇒ multireticle sensors.
- R&D coordinated at CERN (ALICE-ITS3 & EP-div)
- ITS3 goals: small pixels and very low material budget, exploiting stiching for "supportless" detector layers.

Prototyping at IPHC for MLR1 (2020):

- Design of "elementary" test structures with CERN
- Design of 2 chips featuring arrays of 15x15 µm² & 25x25 µm² pixels with rolling shutter readout & analog output.
- Grouped submssion sent to TowerJazz in Dec. '20
- Preparing for tests anticipated to start in Summer '21



Block diagram of 65 nm reticle



Variants A/B/C	Variant D
64 × 32 15 µm pitch	48 × 32 25 µm pitch

IPHC sensors in 65 nm technology

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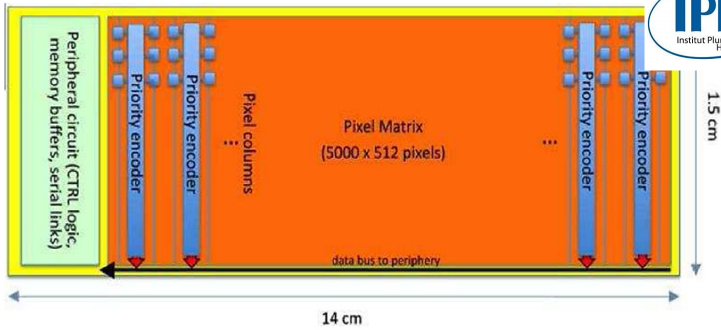
WP7 Sensor R&D, next steps

MIMOSIS-1 => Pixel and EPI selection

- Irradiations: Ionising & non-ionising, SEE
- Beam tests at DESY (June, t.b.c), CERN (July?)
  - ➢ determine ϵ_{det} and σ_{sp} vs. Discri. Threshold and V_{dep} for each Epi profile as a function of TID, NIEL, …

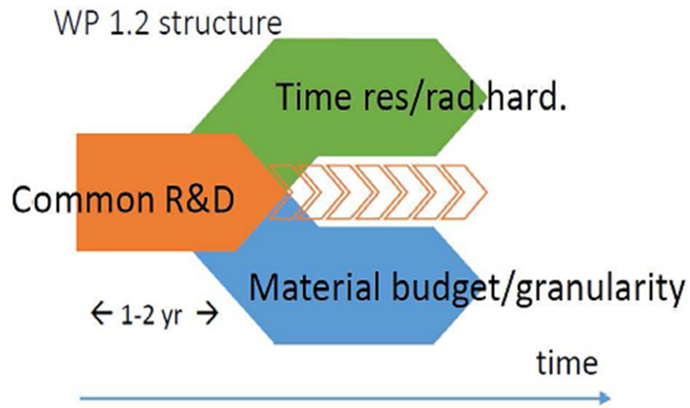
⇒ Find optimum combination, adapted to growing integ. dose.



Future stitched sensor layout

MIMOSIS-1 => MIMOSIS-2:

- MIMOSIS-2 = MIMOSIS-1 complemented with:
  - ➢ sparse data scan, full triple vote logic
  - ➢ optimized pixel & FE architecture accounting for MIMOSIS-1 results.
- Submission to foundry foreseen in October '21



65 nm Exploration:

- Lab. tests of 2020 prototypes starting in Summer '21
- Beam tests (with CERN coll.) toward end '21 – early '22
- Design of prototypes for MLR2 submission (end '21?)
  => prominent goal: stitching & spatial resolution (aligned with goals of ALICE-ITS3 rather than of EP R&D)

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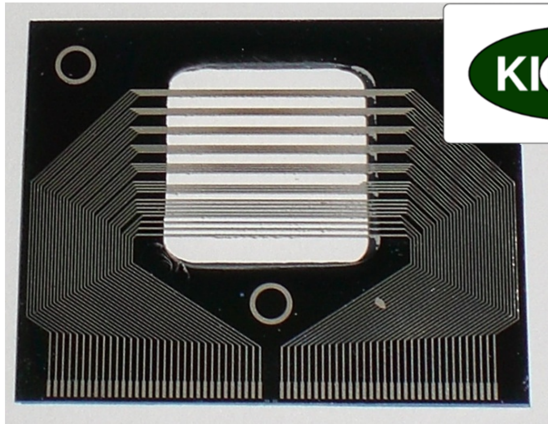
Status at DESY …

EUDET-Telescope

Integrate CREMAPS to EUDET telescope.

- Hosts beam test of MIMOSIS-1 (June '20).
  - ⇒ Obtain first running experience.
- Discussions on interfaces started.

…and INR NASU



Build spin-off sensor technologies.

- E.g. use CREMAPS for X-ray diffractometers.
  - ➢ Laser based test system designed.
  - ➢ Tools for measuring line separation designed.
- Will help to design DAQ-system for CREMAPS

Next step (Fall '21) - Design of a common, light and scalable DAQ system for CREMAPS.

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WP7 Sensor integration: Universal test system

Idea: Need to test sensors

- On PCB (reference).
- On light carrer (e.g. mCBM)
- On wafer (for mass production).

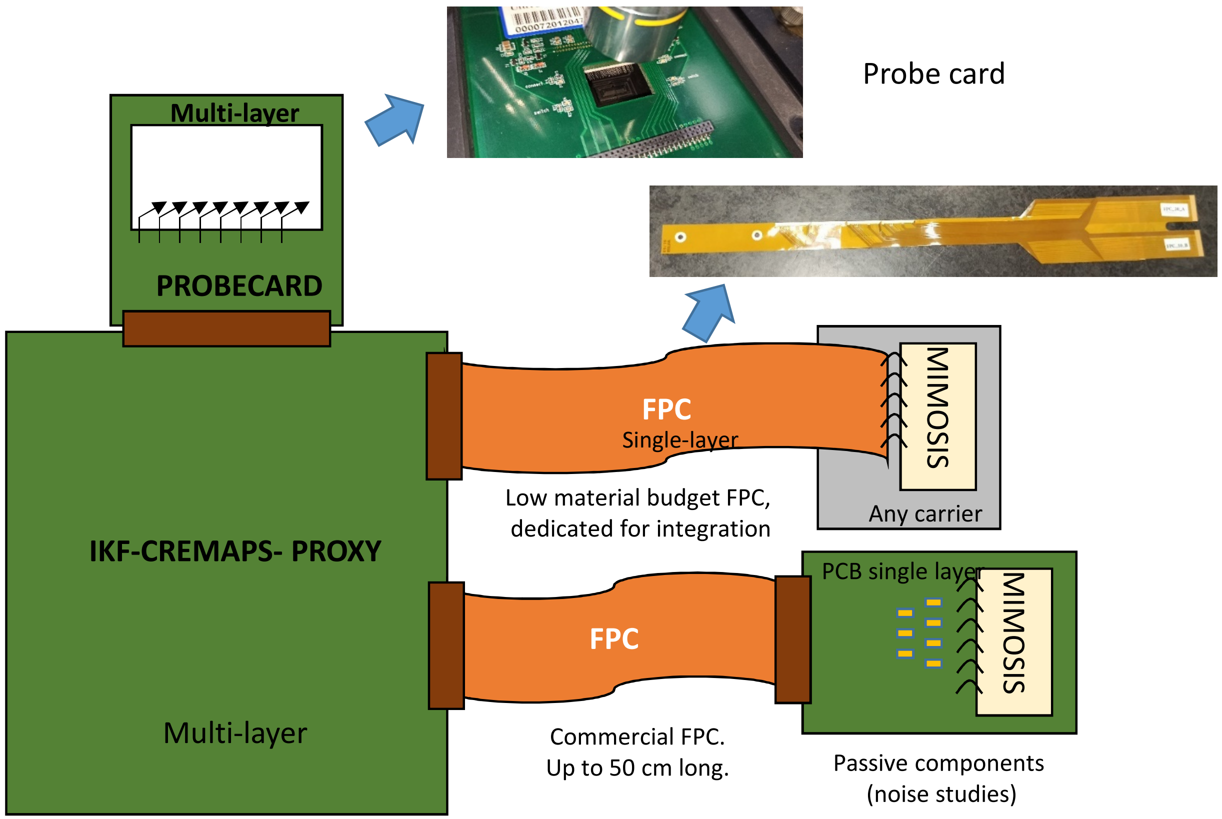
Approach: build board with adapters to.

- Commercial FPC
- Ultra-light FPC
- Probe card

⇒ Use identical electronic chain.
⇒ Direct comparison of measurements.

Status:

Board design started.



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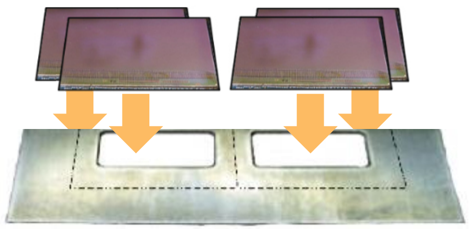
WP7 Sensor Integration in Fixed Target Geometry: envisaged work program

GOETHE UNIVERSITÄT FRANKFURT AM MAIN

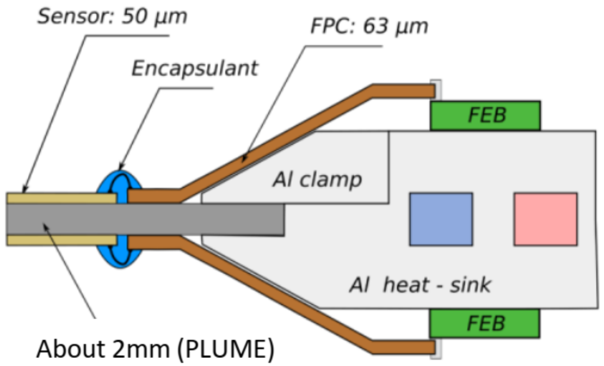
CRETEL-1

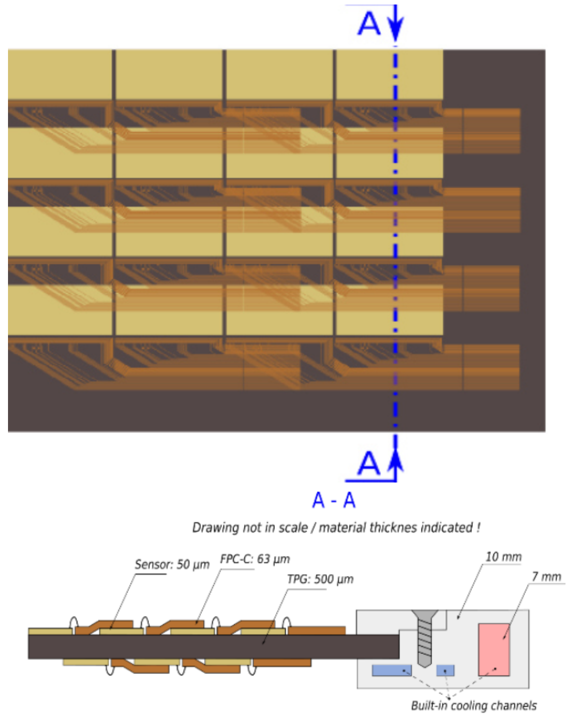
- ~9 cm² telescope plane.
- Double sided integration.
- Simple materials.
- ~0.1 % X_0 in active area.
- Possible application: EUDET



CRETEL-2 = CRETEL-1 plus:

- Carbon based support.
- Vacuum compatibe.
- ~0.3% X_0
- Possible application: mCBM





CRESTAT = CRETEL-2 plus:

- Large acceptance.
- < 0.5% X_0 (additional cables).
- Base for fixed target tracking station.
- Synergies: CBM – MVD.

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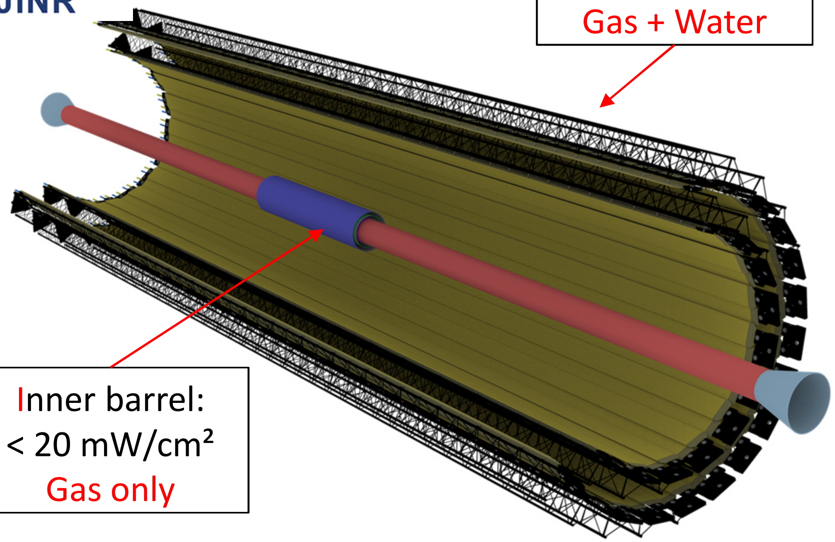
WP7 Sensor integration for collider geometries

The MPD-ITS

Outern barrel:
> 20 mW/cm²
Gas + Water



Inner barrel:
< 20 mW/cm²
Gas only

Ongoing activity (inner barrel):

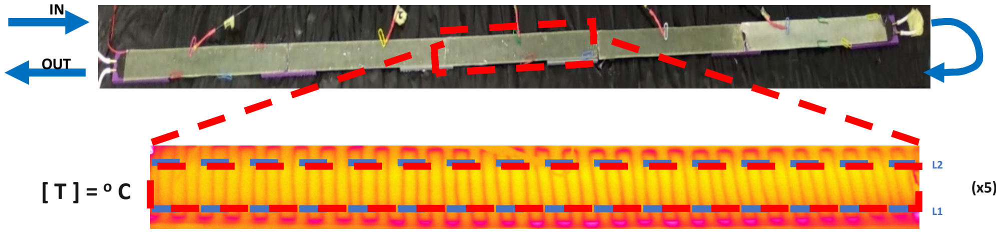
- Confirm tolerance of materials to neu
- Research carried out together with C
- Irradiations done with JINR IBR-2 rea

Analysis of irradiated materials ongoing.

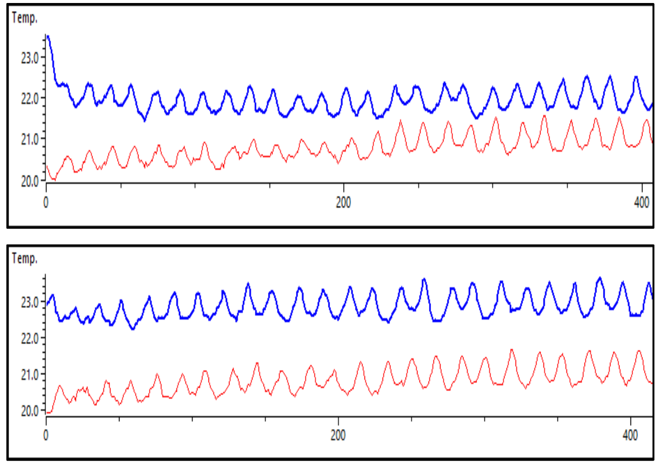
Very healthy cooperation started within JINR (neutron irradiation at IBR-II)

Ongoing activity (outer barrel):

- Substitute dual use carbon fibre by civilian fibres and graphene paper
- Confirm reaching same performances.
- Test with water, 4-6 l/h @ 18°C



CERN – version:
21.0 – 22.2 °C



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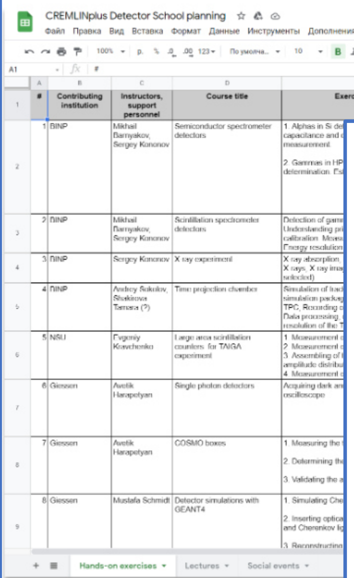
Detector School at Budker Institut BINP being organized and planned for July 4 – 15, 2022

List of Hands-on exercises



Lectures

1. BINP HEP facilities – 1h
2. Tracking – 4h
3. Calorimetry – 4h
4. Silicon detectors – 4h
5. Neutron detection – 2h OR
6. Particle identification – 4h
7. Photodetectors – 2h
8. Gaseous detectors – 4h
9. Trigger and Data Acquisition – 4
10. ASIC design – 2h
11. FPGA programming – 2h
12. Test beam analysis – 2h
13. Historical evolution of tracking
Grancagnolo

- 37 hours in total

Social events

1. Welcome party (Reception) - July 4, 2-3 hours
2. Conference dinner - July 6, 3 hours
3. Trip along the Ob river - 1 weekend day
4. …

…. this is all under construction and none final! additonal suggestions may be expressed to Sergej Kononov <S.A.Kononov@inp.nsk.su>

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WP7 Workprogram on Detectors

- Neutron- and CMOS-Pixel communities are individually progressing well
- So far very limited interchange due to COVID-19 → hope this to improve
- Summer School on Detectors will be important for networking and for fostering young scientists into the field, but needed to be postponed to July 4 – 15, 2022 (12 days) due to COVID-19. (Task 7.4)
- Teams will appreciate program extension by 6 months to make up for limitations

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