report by V L A D I M I R Z H E R E B C H E V S K Y

MODERN SILICON AND SCINTILLATION DETECTOR SYSTEMS FOR THE EXPERIMENTS AT THE NICA COLLIDER

16 09 25

Valeriy KONDRATIEV
Vladimir VECHERNIN
Nikolai MALTSEV
Grigory FEOFILOV
Sergey TORILOV
Vladimir KOVALENKO

Nikita PROKOFIEV
Vitaliy PETROV
Semen YURCHENKO
Egor ZEMLIN
Yulia TOLSTYH

Грант Российского научного фонда № 23-12-00042, https://rscf.ru/project/23-12-00042/

XXVI International Baldin Seminar on High Energy Physics Problems Relativistic Nuclear Physics and Quantum Chromodynamics.
Dubna, September 14-20, 2025

Outline

1. Today and the day after tomorrow of high-energy physics experiments
2. Silicon pixel detectors now and in the future + Civil Application.
3. Detector technologies for NICA: MPD, SPD
4. Detector technologies for NICA: ARIADNA
5. Conclusions, Next plans

Epigraph

A man ought to be able to be carried away by his feelings, he ought to be able to be mad, to make mistakes, to suffer!

Anton Pavlovich Chekhov

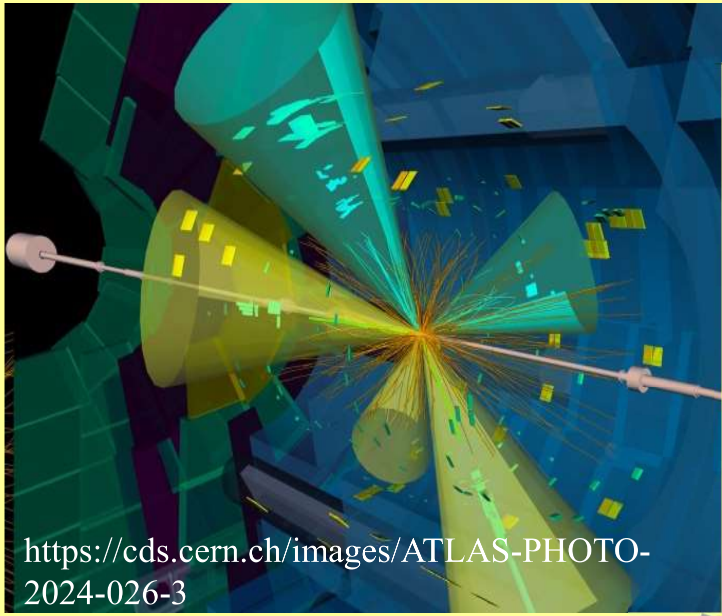
Today and the day after tomorrow of high-energy physics experiments

Leading high-energy physics experiments at the Large Hadron Collider:

ALICE

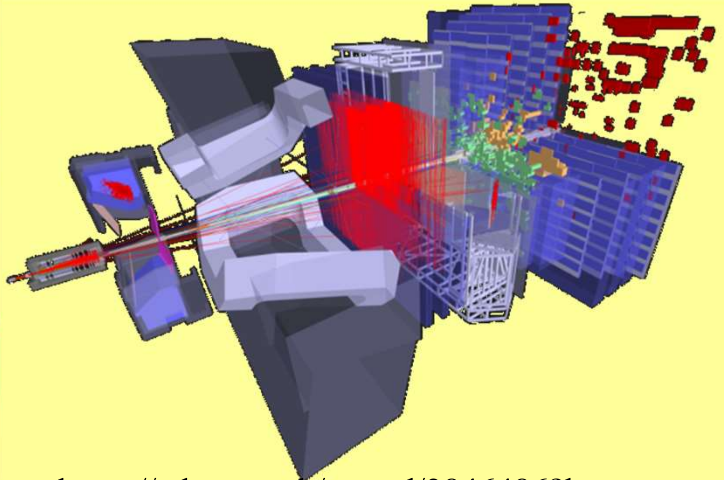
https://cds.cern.ch/collection/ALICE%20Photos?ln=es

ATLAS



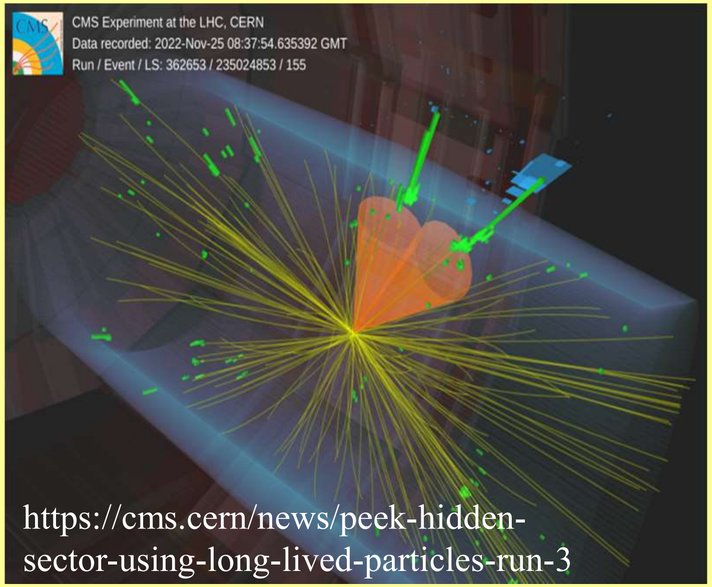
https://cds.cern.ch/images/ATLAS-PHOTO-2024-026-3

LHCb

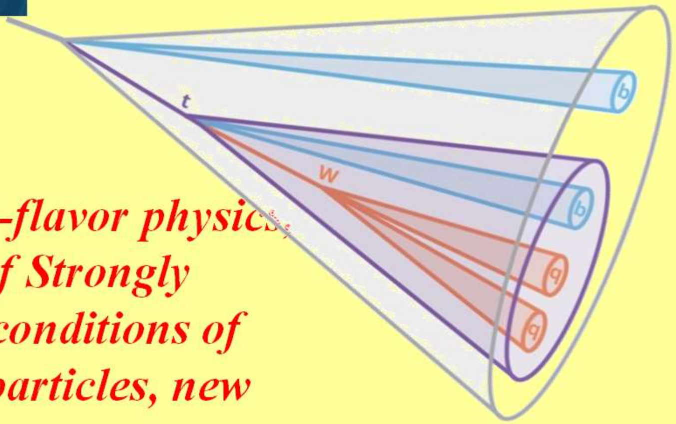


https://cds.cern.ch/record/2846486?ln=ru

CMS



https://cms.cern/news/peek-hidden-sector-using-long-lived-particles-run-3



Higgs, Standard Model, Heavy-flavor physics, Multi-Jet Physics, Properties of Strongly Interacting Matter at extreme conditions of temperature, Discover of new particles, new search for long-lived particles

Unprecedented tests of the CP-violation paradigm, New approaches to the hunt for dark matter particles

Today and the day after tomorrow of high-energy physics experiments

ALICE ITS-3
Run 4 -2030 y

MAPS
Monolithic Active
Pixel Sensors

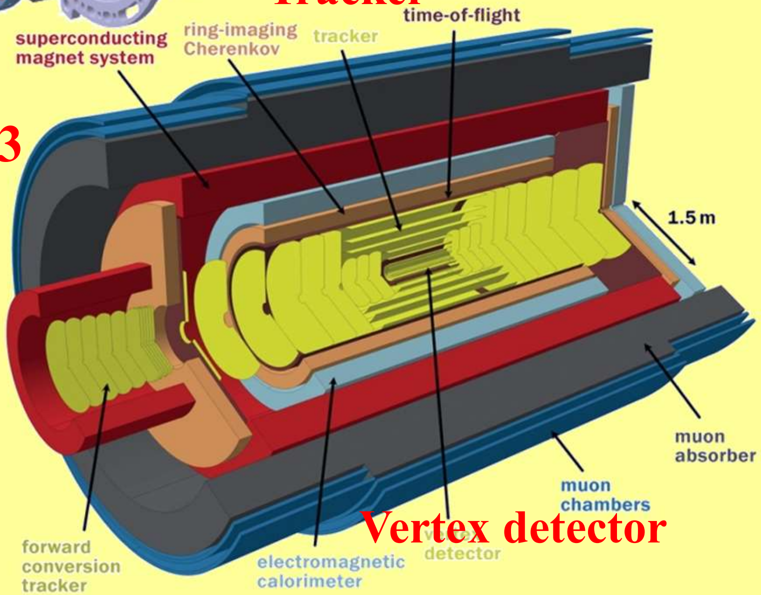
also

Hybrid pixel
detectors

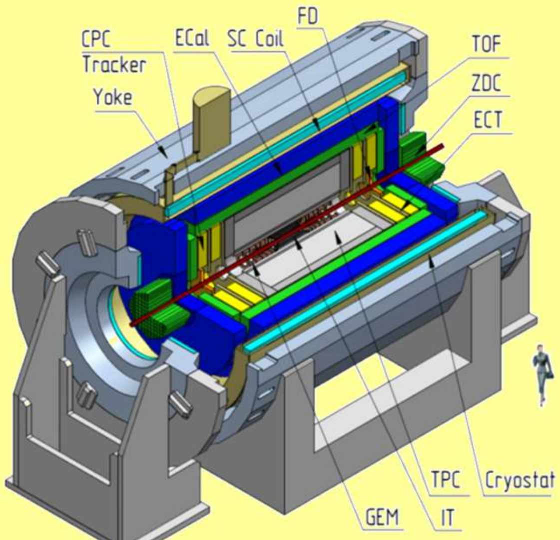
Tracker

ALICE 3

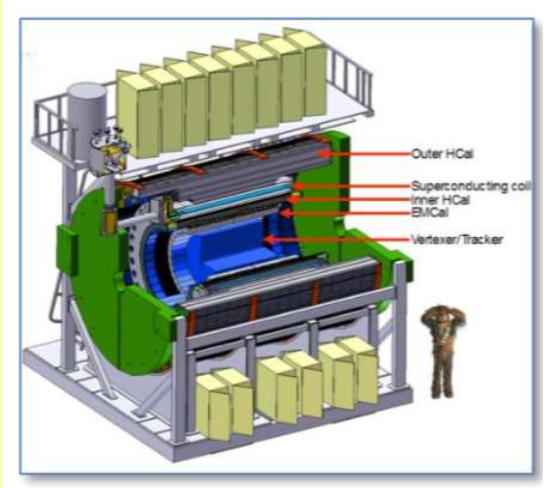
Run 5
2035 y



Vertex detector

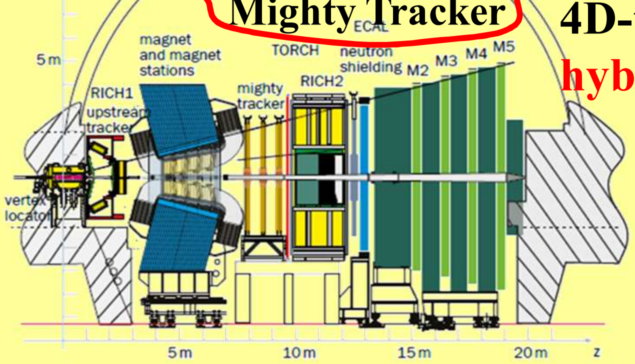


MPD at NICA



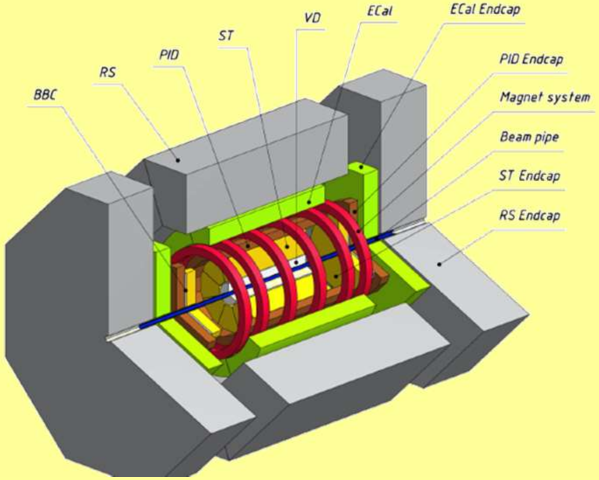
sPHENIX
0.2 m^2 251 M pixel

MAPS
Upstream Tracker
Mighty Tracker

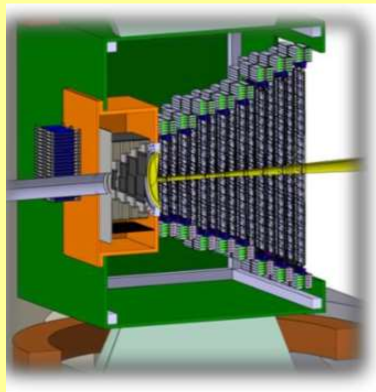


Vertex Locator
(VELO)
4D-tracking detector
hybrid pix.

LHCb
Run 5



SPD at NICA



CBM MVD
0.08 m^2 146 M pixel

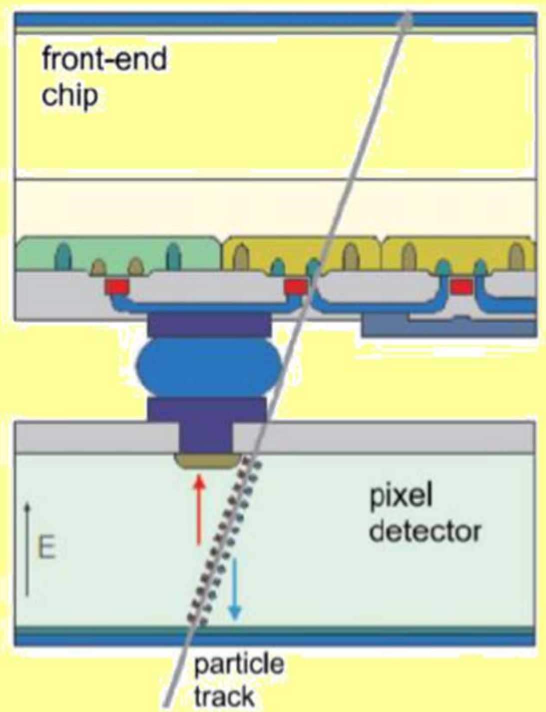
Silicon pixel detectors now and in the future + Civil Application.

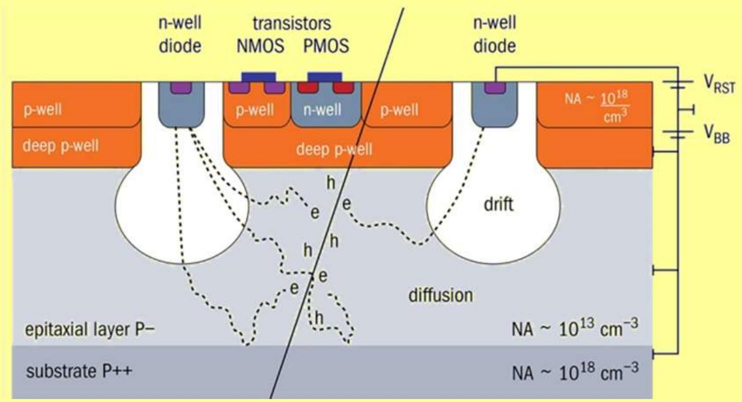
Silicon pixel detectors

Hybrid Pixel detectors

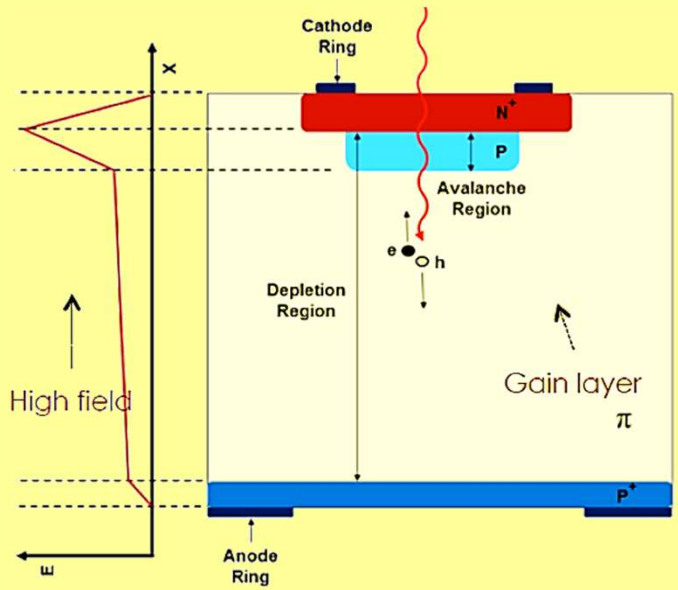
Monolithic Active Pixel Sensors - MAPS

Low Gain Avalanche Detectors (LGAD)





https://cerncourier.com/a/alice-tracks-new-territory/



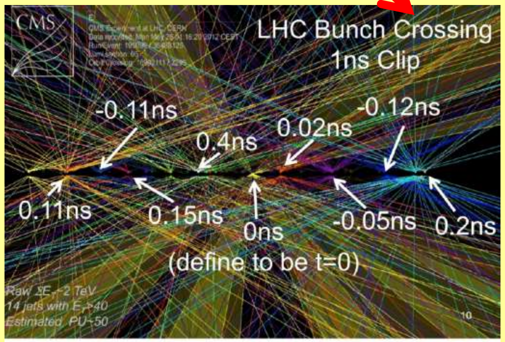
https://indico.global/event/3927/contributions/36135/attachments/18545/30331/Low_Gain_Avalanche_Detectors_-_Technology_Overview.pdf

Silicon pixel detectors now and in the future + Civil Application.

Motivation

High Luminosity (HL) LHC

The rate of events will increase by approximately a factor of 5 compared to the luminosity in the current LHC (Run-2)



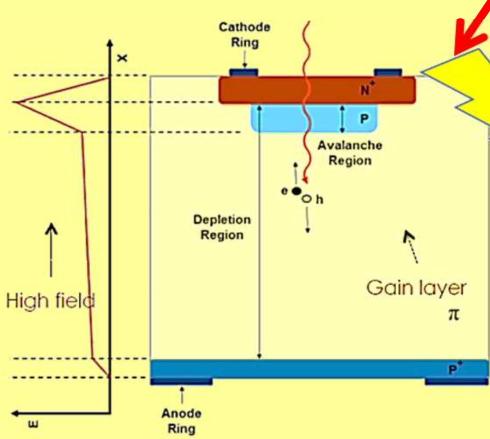
High event pile-up that will pose a challenge to separate individual tracks for reconstruction.

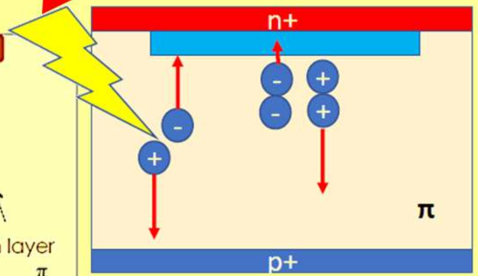
The inclusion of precise timing information (10 – 30 ps) could solve this problem by discriminating compatible hits based on timing information

4D - tracking

Low Gain Avalanche Detectors (LGAD)

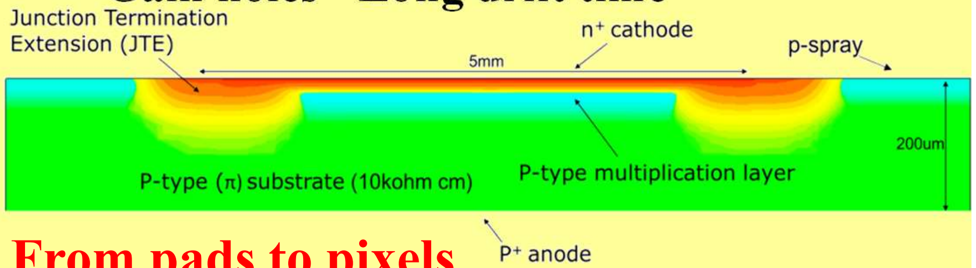
Solution



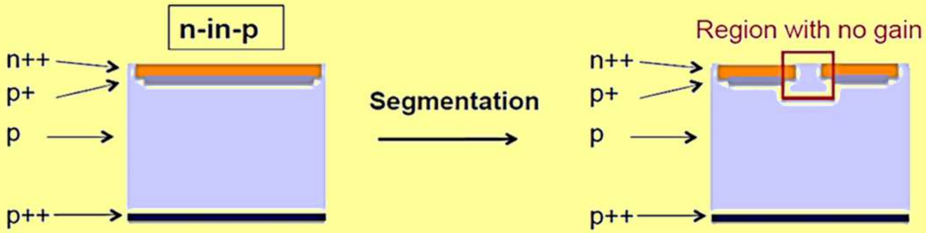


R. Bates, Fast Timing Silicon Pixel Detectors for New Applications

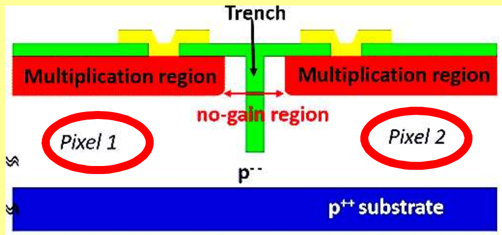
Gain electrons - Absorbed immediately
Gain holes - Long drift time



From pads to pixels



Trench isolation



Silicon pixel detectors now and in the future + Civil Application.

Example from High Energy Physics experiment

Low Gain Avalanche Detectors (LGAD)

High-Granularity Timing Detector based on LGAD technology, for the ATLAS Phase-II upgrade

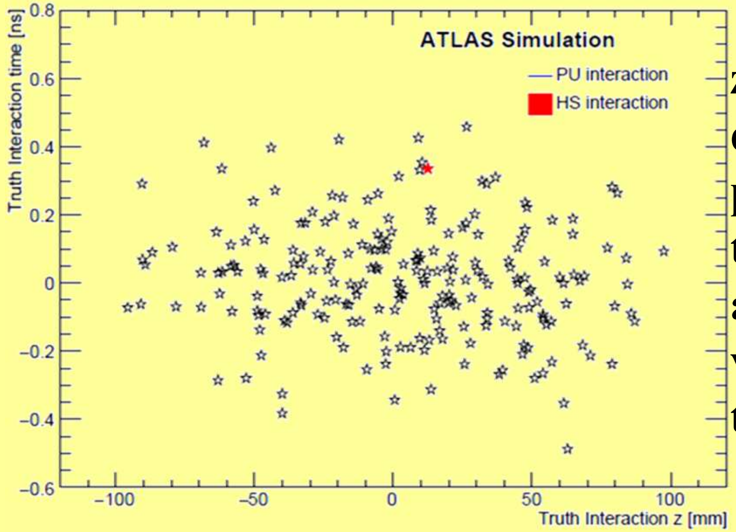
HGTD

ATLAS-TDR-031 · LHCC-2020-007

GOALS

Precise determination of the luminosity for measurements of the Higgs properties with ATLAS

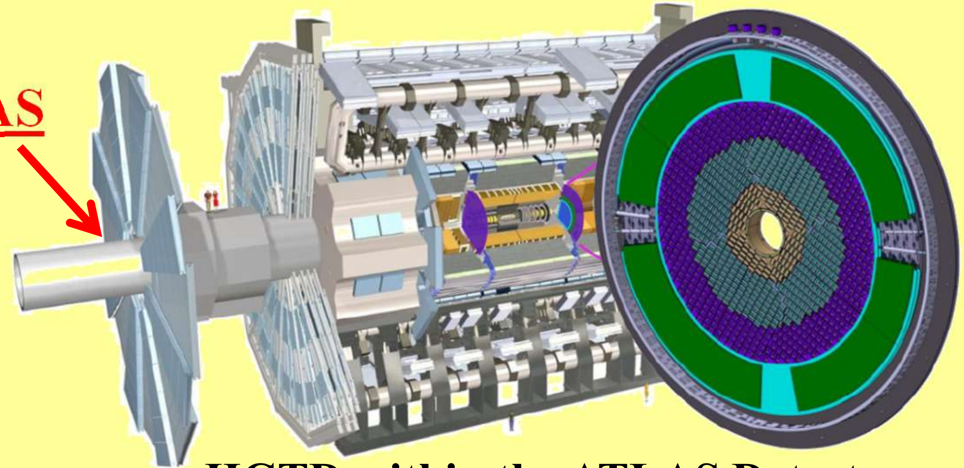
The HGTD is positioned to measure both the online luminosity on a bunch-by bunch basis during HL-LHC running, and the high-precision determination of the integrated luminosity offline



z_0 resolution degrades, precision timing allows these vertices to be separated

HGTD will measure the times of MIPs with an average time resolution of ~ 30 ps per track at the beginning of the HL-LHC operation

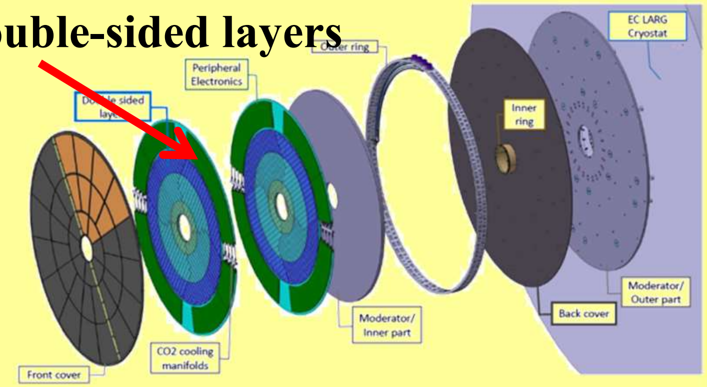
Realisation



HGTD within the ATLAS Detector

CERN-RD50 community + Hamamatsu Photonics

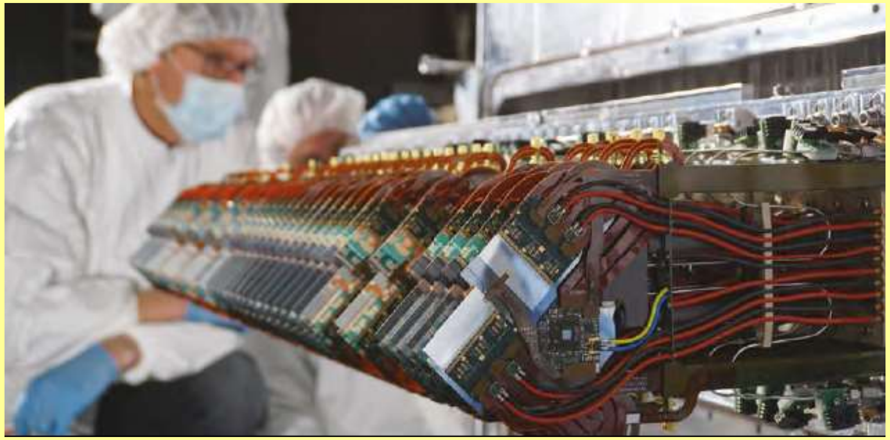
Two double-sided layers



The sensors will be operated at temperatures −30°C to mitigate the impact of irradiation

Silicon pixel detectors now and in the future + Civil Application.

LHCb new Vertex Locator



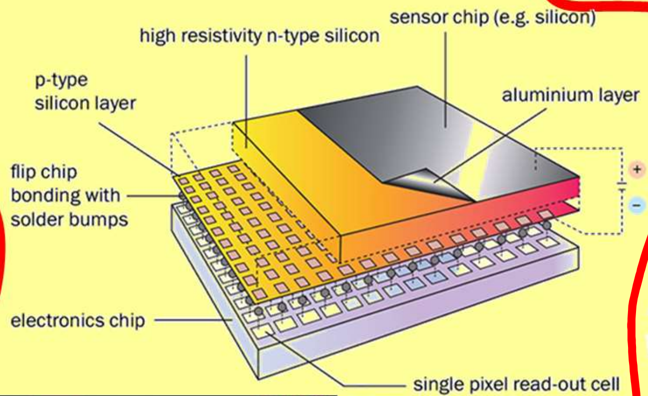
silicon-hybrid pixel detectors:
200 μm-thick "p-on-n" pixel sensor bump-bonded to a 200 μm-thick readout chip with binary pixel readout
CERN Courier May/June 2022 p38

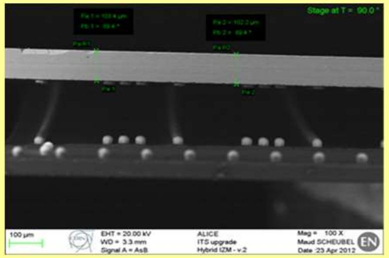
CMC Pixel Tracker

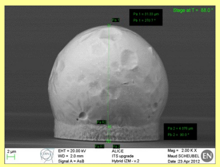
Concentric layers and rings of more than 1800 small silicon modules. Each of these modules has about 66000 individual pixels on it, for a total of 120Mpix

Each pixel is only 100x150 μm^2 in size
https://home.web.cern.ch/news/news/experiments/successful-installation-cms-pixel-tracker

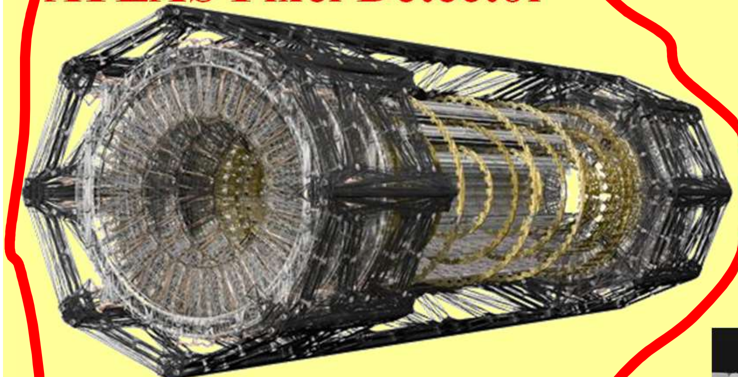
Hybrid Pixel Detectors





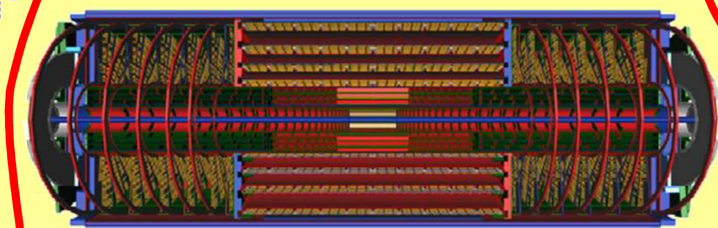


ATLAS Pixel Detector



80 million pixels,
Area 1.7m^2 , 15 kW power,
Pixel Size 50 x 400μm^2

ATLAS Inner Tracker for (HL)LHC



5 pixel layers

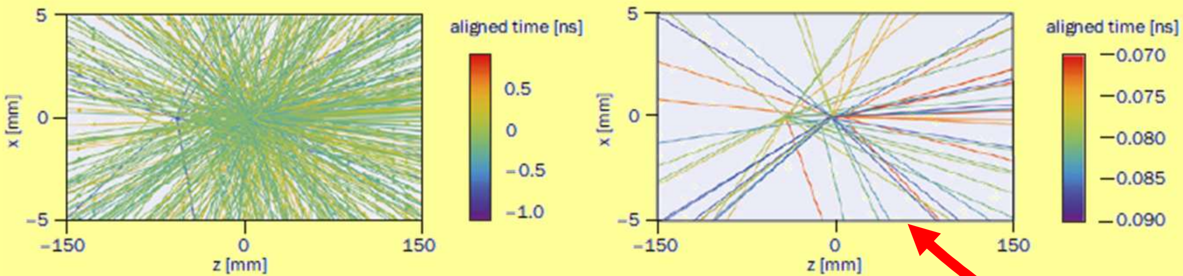
Inner layers: 1.7 $\cdot 10^{16}$ n_{eq}/cm^2
Outer layers: 5 $\cdot 10^{15}$ n_{eq}/cm^2

Silicon pixel detectors now and in the future + Civil Application.

LHCb new Vertex Locator

LHCb-DP-2022-002 May 23, 2024

Hybrid Pixel



CERN Courier March/April 2023 p22

VELO will be 4D-tracking detector 55 um pitch includes timing information with a precision of better than 50 ps per hit, leading to a track time-stamp resolution of about 20 ps

ASIC based on the Timepix 3

NIEL 6×10^{16} MeV n eq /cm^2

LHCb TDR 23

High-Luminosity LHC in Run 5

begin in 2035, will be operate at a peak luminosity of 1.5×10^{34} cm^{-2} s^{-1}.

Monolithic Active Pixel Sensors for **Upstream Tracker** and **Mighty Tracker**

large-scale implementation of MAPS in a high-radiation environment

Mighty pixels

Microscope image of the first LHCb-dedicated high-voltage CMOS sensor

large electrodes MAPS with high-voltage biasing (HV-CMOS) and small electrodes MAPS.

COST 8.1MCHF

Silicon pixel detectors now and in the future + Civil Application

Medipix

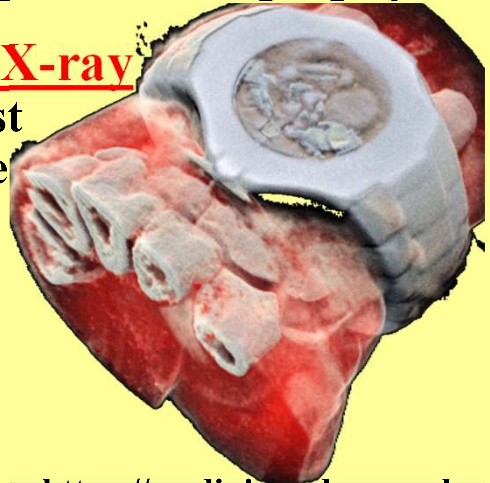
Hybrid pixel detector technology

The Timepix4 ASIC:
matrix of 448 x 512 pixels - 55µm

Radiography and computed tomography use X-ray

3D colour X-ray

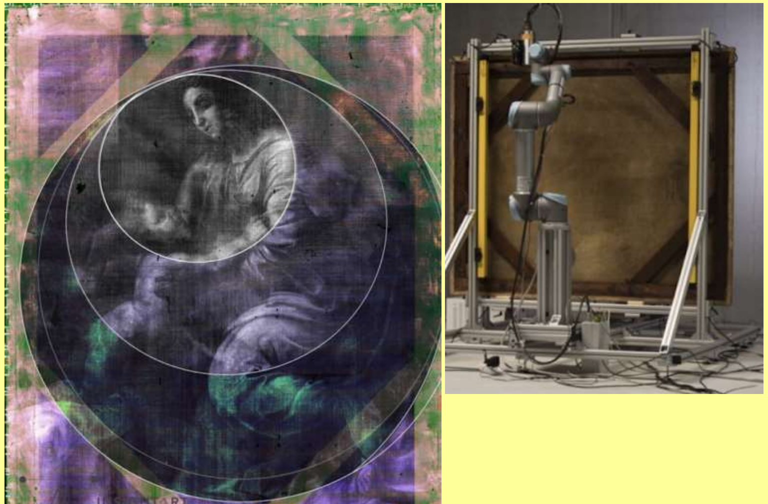
A 3D image of a wrist
finger bones - white
soft tissue - red



https://medipix.web.cern.ch

Dose-deposition monitoring in hadron therapy

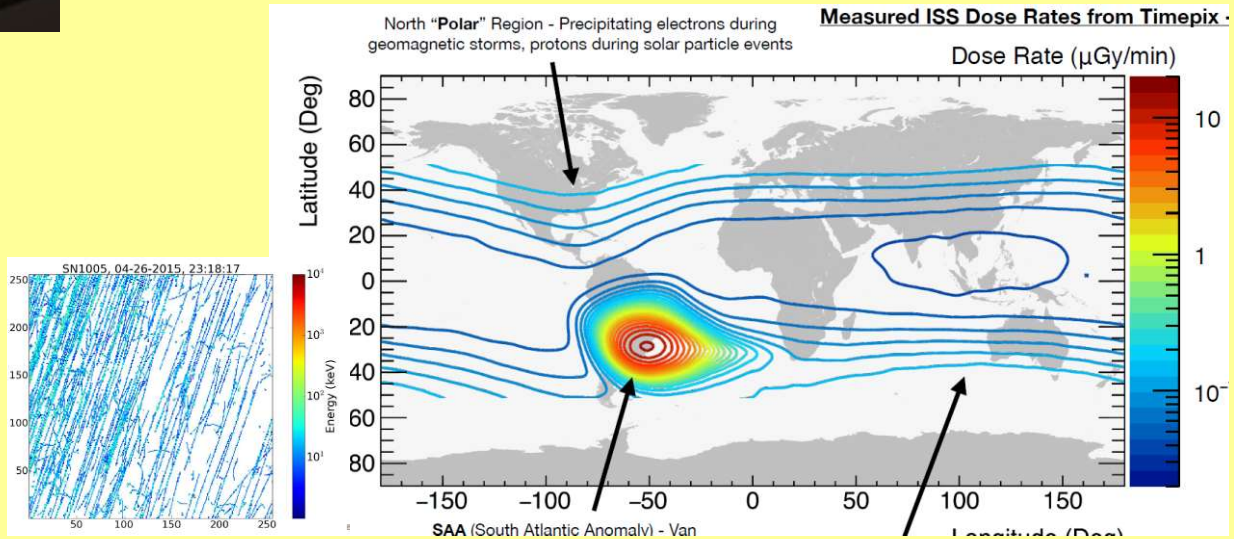
Raphael - The Madonna and Child



New high-resolution maps of the elemental composition of the paint

https://medipix.web.cern.ch/index.php/news/news/timepix/cern-technology-helps-rediscover-lost-painting-raphael

space dosimetry 10 Years of Timepix in Space

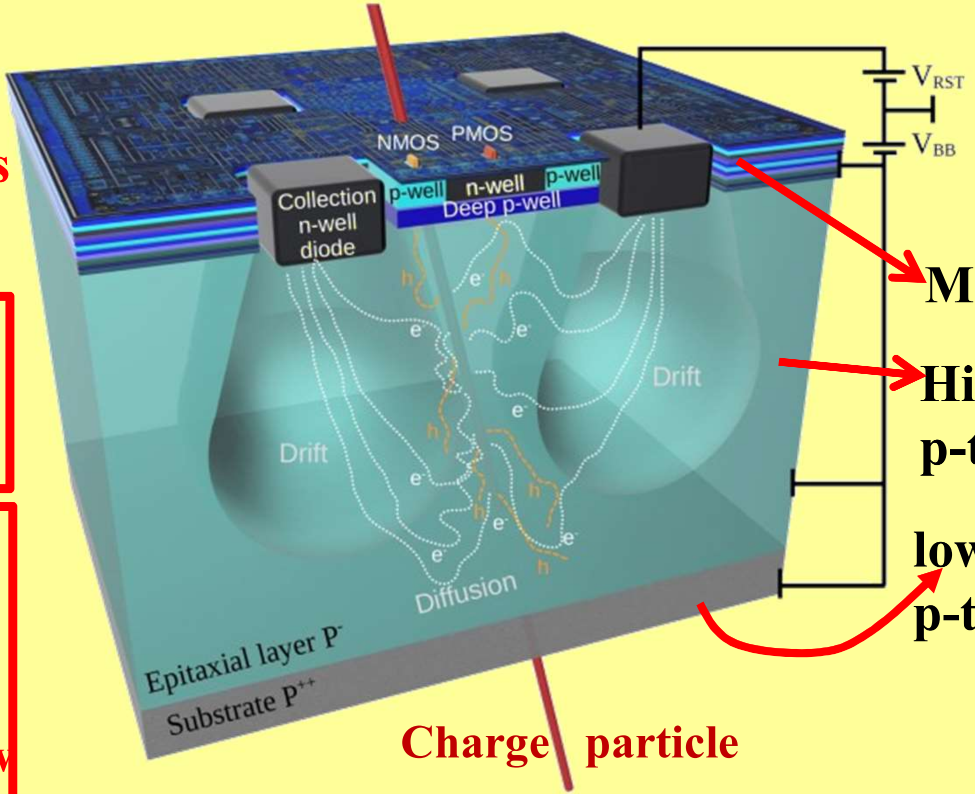


Dr Stuart P. George (NASA) CERN Detector Seminar
https://indico.cern.ch/event/1218130/

Silicon pixel detectors now and in the future + Civil Application.

MAPS:
180nm CMOS
Imaging Process

Monolithic Active Pixel Sensors - MAPS



Shield NWELL of PMOS transistors

Small n-well diode (2μm diameter), ~ 100 times smaller than pixel → low capacitance

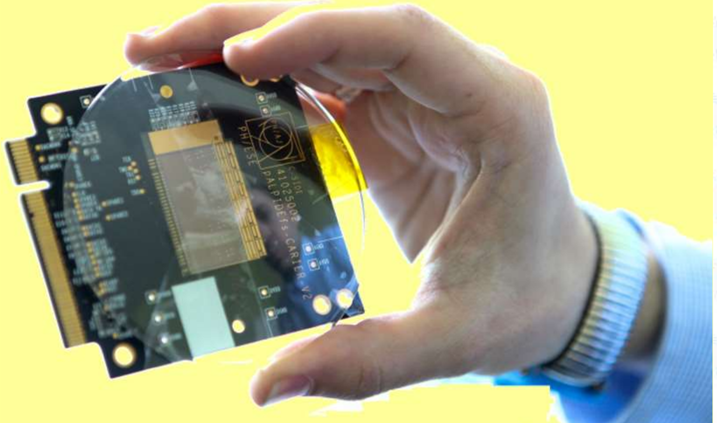
Metal layers (11 μm)

High resistivity(> 1kΩ ·cm) p-type epitaxial layer (25μm)

low-resistivity p-type substrate (14 μm)

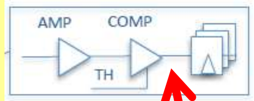
Charge particle

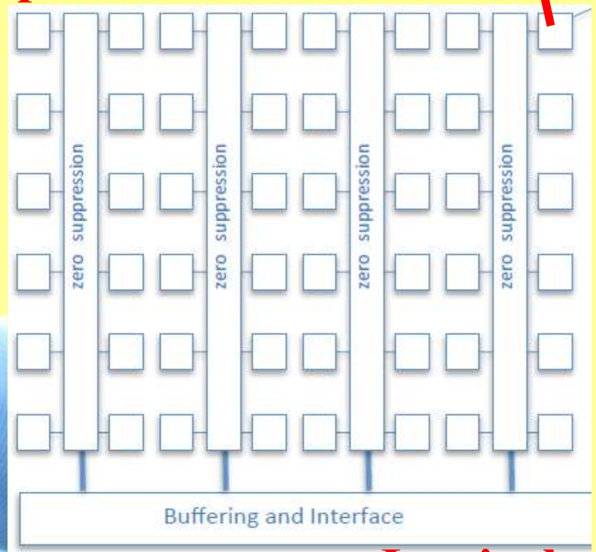
Back bias
S/N ratio increases, higher efficiency



512 × 1024 sensitive pixels

Chip architecture





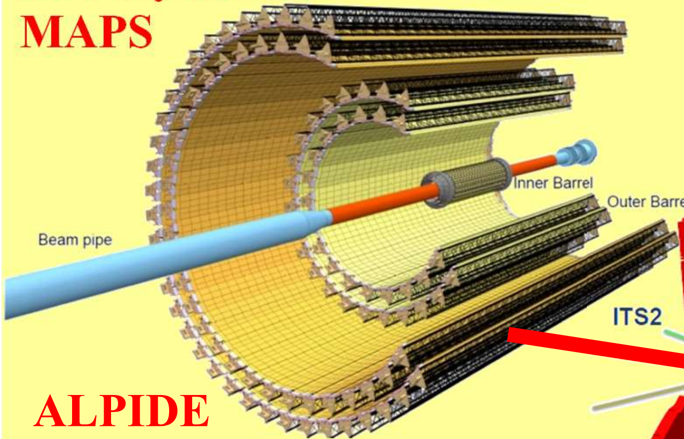
In-pixel: amplification, discrimination, hit buffer

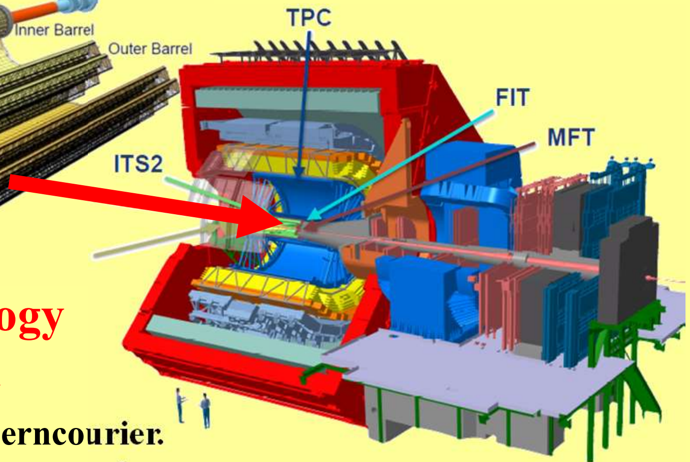
Silicon pixel detectors now and in the future + Civil Application.

MAPS trackers

ALICE: ITS-2

all 7 layers with MAPS

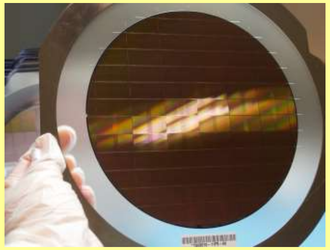




ALPIDE

180 nm CMOS technology

10 m^2 12 G pixel

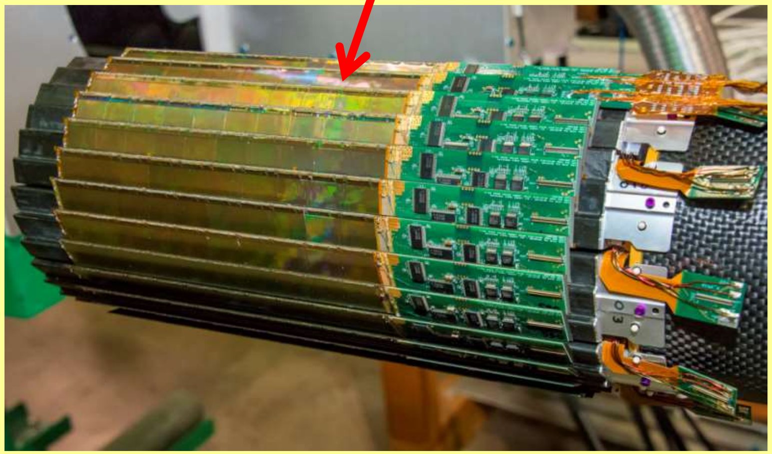


https://cerncourier.com/a/alice-tracks-new-territory/

STAR Heavy Flavour Tracker

1. Silicon Strip Detector (SSD)
2. Intermediate Silicon Tracker (IST)
3. Pixel Detector (PXL)

} Strip (1, 2)



Petra Riedler CERN Detector Seminar, April 28, 2017

PXL is the first operational vertex detector based on MAPS 350 nm CMOS technology

NA61/SHINE
Small Acceptance Vertex Detector (SAVD)

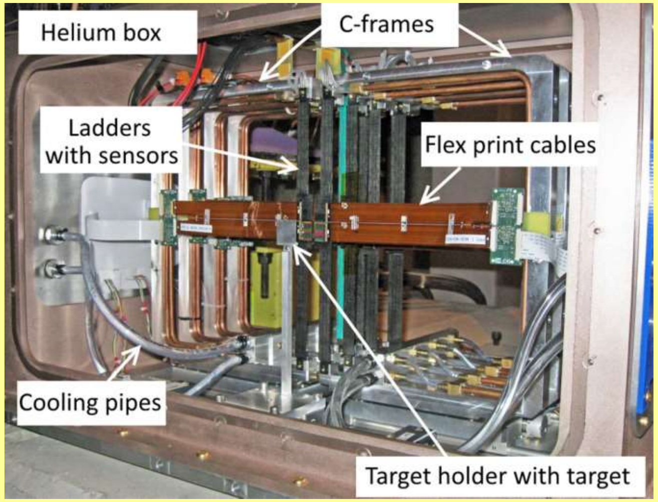
2018-2022

MIMOSA-26AHR

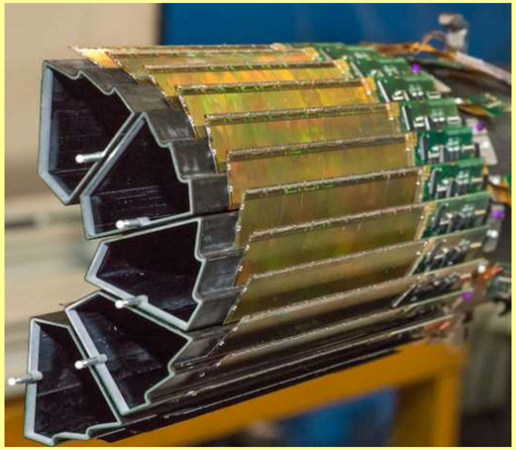
350 nm CMOS technology

NOW

ALPIDE 180 nm CMOS technology



Eur. Phys. J. C (2023) 83:471



0.16 m^2 356 M pixel

https://nsww.org/projects/bnl/star/sub-systems.php

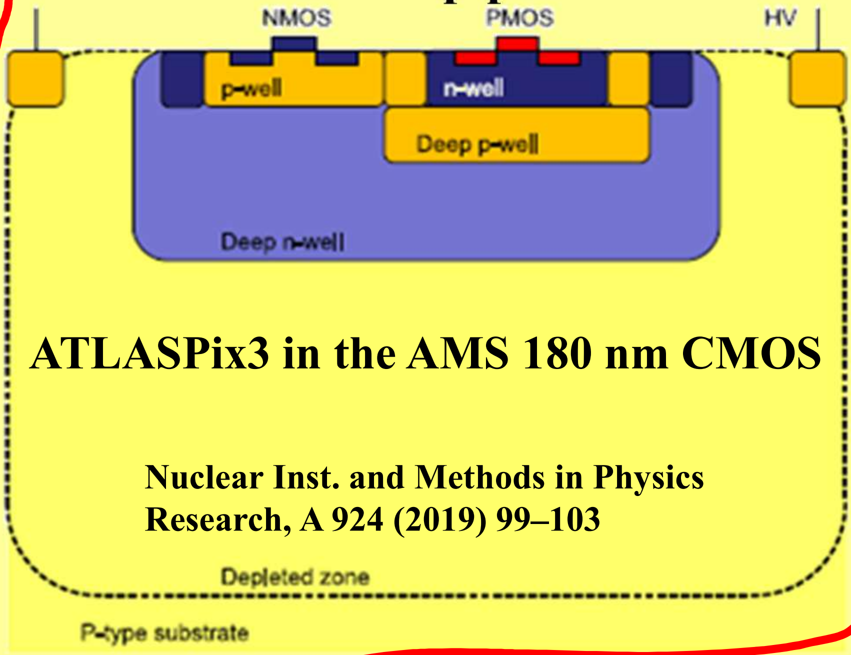
Silicon pixel detectors now and in the future + Civil Application.

EXAMPLES

Monolithic Active Pixel Sensors - MAPS

Large area monolithic HV-CMOS sensors fabricated in 180 nm high voltage CMOS process technology.

The standard process has been extended for high resistive substrates and deep p-well isolation



ATLASPix3 in the AMS 180 nm CMOS

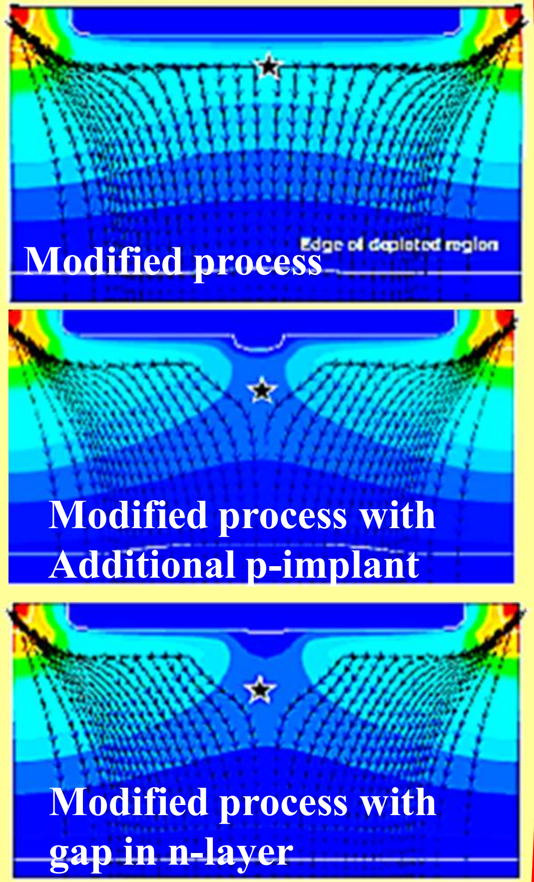
Nuclear Inst. and Methods in Physics Research, A 924 (2019) 99–103

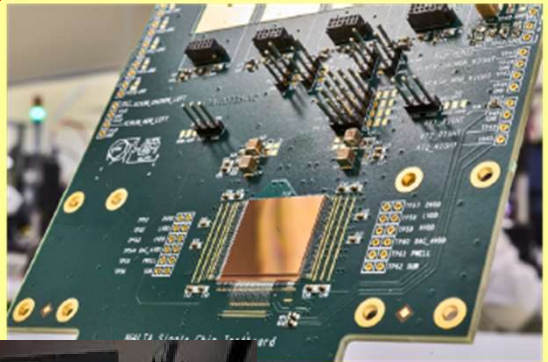
MALTA is a full scale MAPS TowerJazz 180 nm CMOS technology **MALTA 2,3**

radiation hardness:
2.0×10^{15} MeV n_{eq}/cm^2
>100 Mrad

high-granularity:
pixel 36.4 × 36.4 µm,
area 2 × 2 cm^2

small charge collection electrode design





4-chip telescope

NIM, A 958 (2020) 162404
NIM, A 1047 (2023) 167809

Silicon pixel detectors now and in the future + Civil Application

Monolithic Active Pixel Sensors - MAPS

All-sky Medium Energy Gamma-ray Observatory eXplorer (AMEGO-X) is

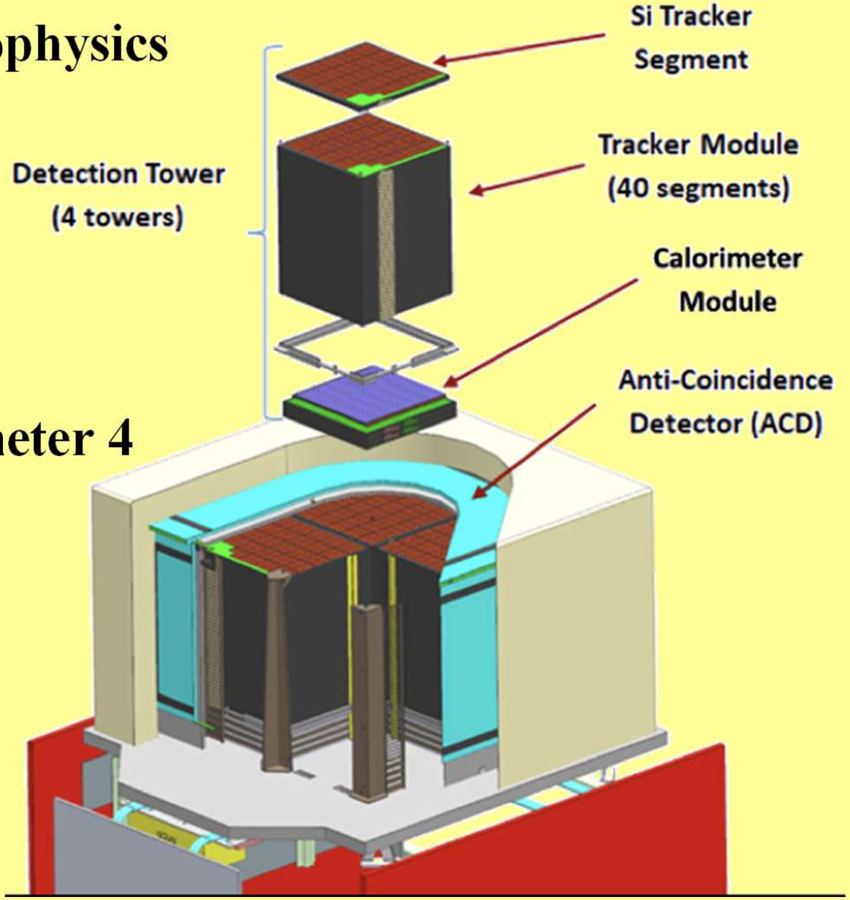
gamma-ray observations in the multimessenger astrophysics

AMEGO-X
two detector subsystems:
the Anti-Coincidence Detector (ACD)
the Gamma-Ray Detector (GRD)

The GRD - 40 layers of MAPS detectors + a calorimeter 4 layers of CsI scintillator bars.

AstroPix is a Monolithic Silicon Pixel detector derived from ATLASPix

ATLAS Pix3 - 180 nm CMOS, pixel size of 150 × 50 μm^2, timing resolution ~10 ns



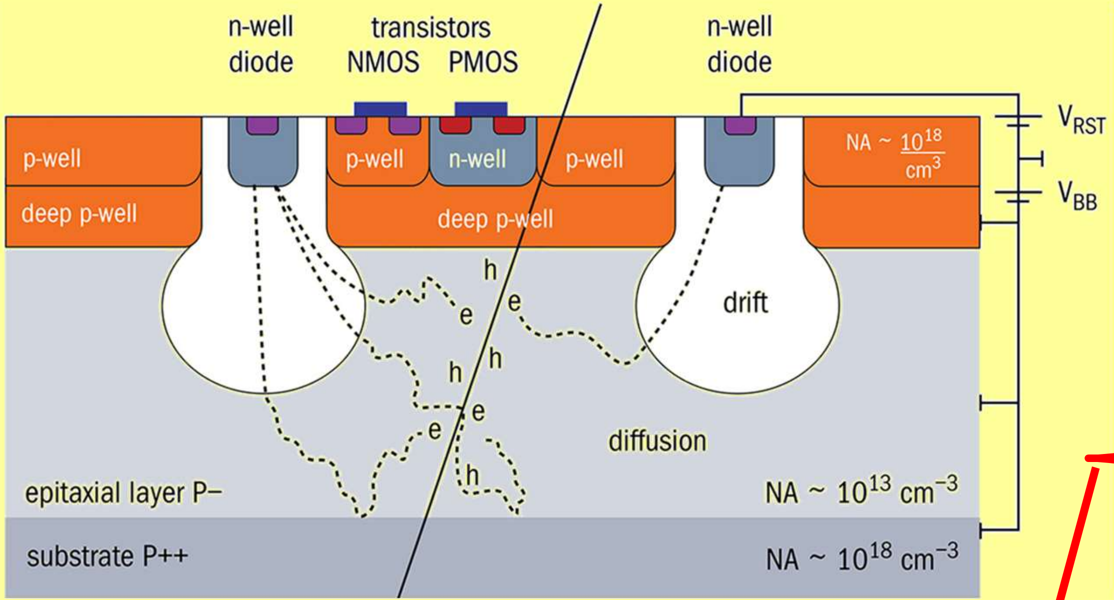
Compton and pair-production telescope sensitivity from 100 keV to 1 GeV

arXiv:2203.07626v2 [physics.ins-det] 29 Mar 2022

Silicon pixel detectors now and in the future + Civil Application

Monolithic Active Pixel Sensors - MAPS

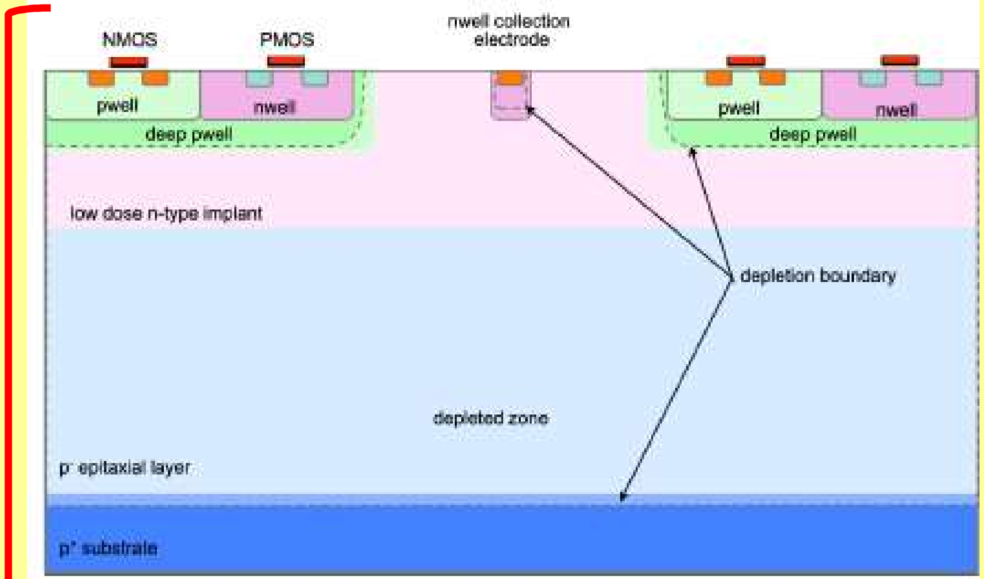
Standard: no additional low-dose implant (used in ALPIDE in 180 nm technology)



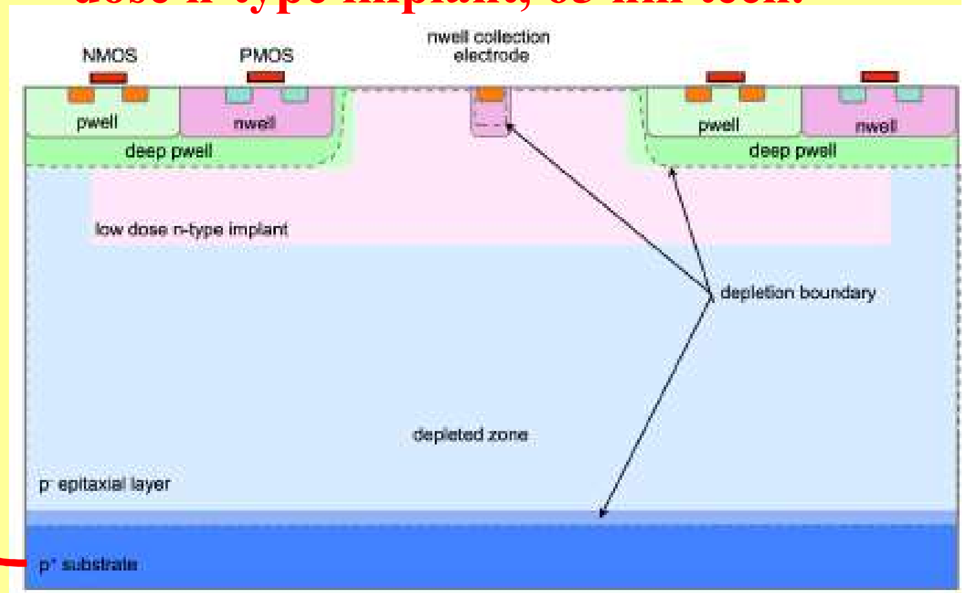
https://cerncourier.com/a/alice-tracks-new-territory/

depletion layer (balloon-shaped) does not reach the pixel edges

NEW: with deep blanket low dose n-type implant



NEW: with gap in the deep low dose n-type implant, 65 nm tech.



full depletion of the epitaxial layer

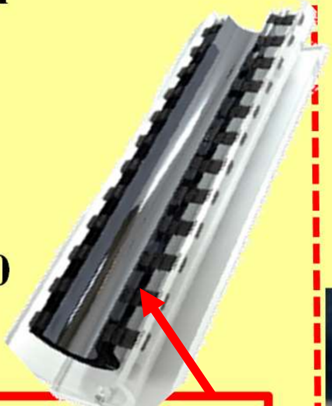
TDR for ITS-3: CERN-LHCC-2024-003; ALICE-TDR-021

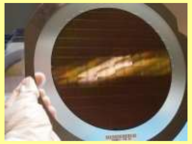
Silicon pixel detectors now and in the future + Civil Application

ALICE-3

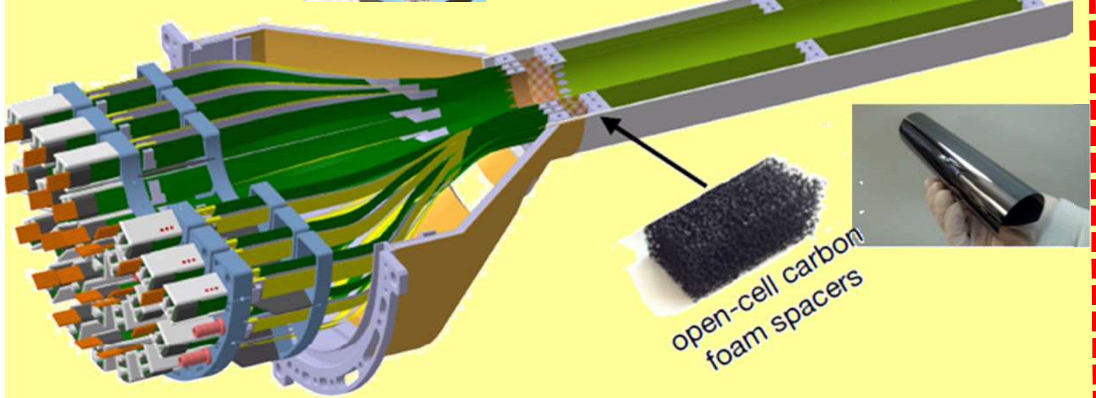
PHYSICS **ITS-3**

Low momentum particle reconstruction
Low-mass di-electrons
Heavy flavor with small decay length
(Λc ≈ 60 μm, Ds ≈ 150 μm)
and also: Bs0, Ds+, Λb, Ξc,
"c-deuteron", dΛc
"strangeness tracking"
- Anti-3He production from anti-Λb0



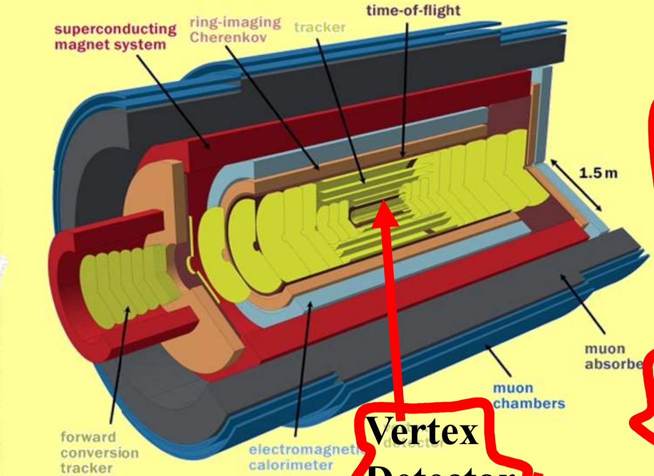


cylindrical detection layers



σ_{pos} – 5 μm, X/X0 ≈ 0,1%

300 mm wafer-scale sensors, (using stitching) thinned to 20 - 40 μm are flexible bent to the target radii - mechanically held in place by carbon foam support structures. Max power density is 20 mW/cm²

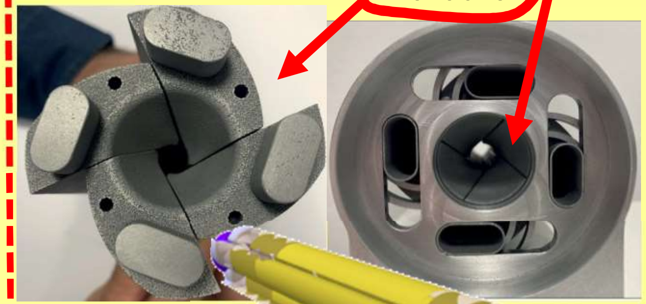


Vertex Detector

PHYSICS

Determination of the average temperature of the QGP before the formation of hadrons

precision measurements of di-electrons and multi-charm barions and heavy-flavor hadrons $p_t \rightarrow 0$



Si-pixel tracker:
The four segments can be rotated to bring the tracker sensors closer to the beam pipe. In vacuum!!

IRIS tracker

σ – 2,5 μm, X/X0<0,1%

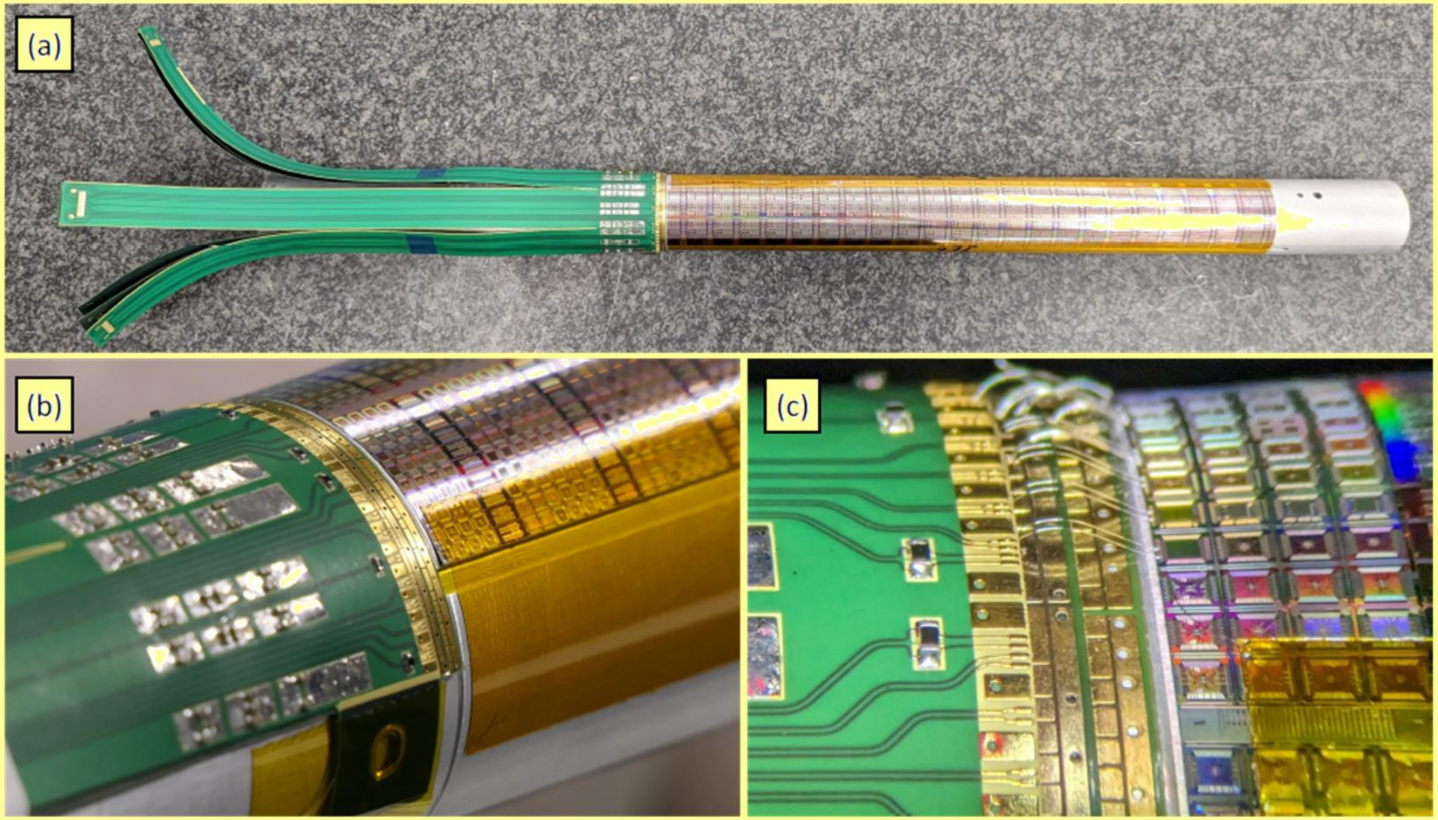
https://cerncourier.com/a/alice-3-a-heavy-ion-detector-for-the-2030s/

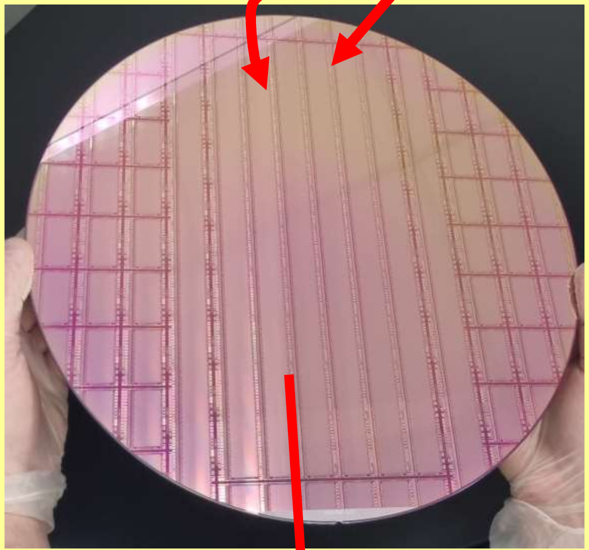
Silicon pixel detectors now and in the future + Civil Application

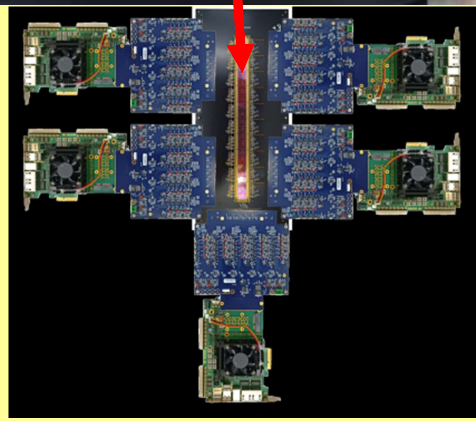
ALICE Inner tracking system - ITS-3

Technical Design Report for the ITS-3:
A bent wafer-scale monolithic pixel detector

Monolithic stitched sensor (MOSS)
Monolithic stitched sensor timing (MOST)







Wire-bonding step:
(a) A-side FPC wrapped on the mandrel with the wafer-size MLR1 sensor, (b) and after (c) wire-bonding

MOSS large stitched ASIC
259mm × 14mm 6.72 million pix

MOST large stitched ASIC 259mm × 2.5mm
0.9 million pixels

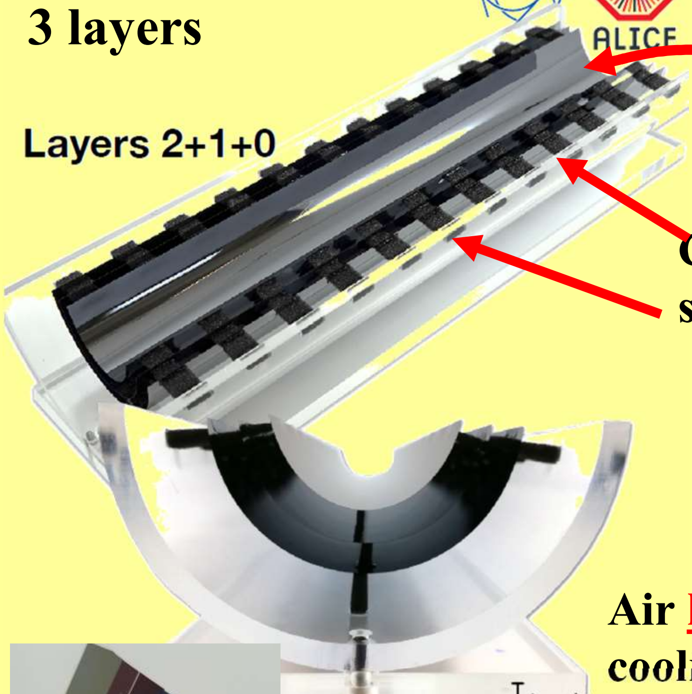
CERN-LHCC-2024-003/ALICE-TDR-021 February 26, 2024, version: V4

Silicon pixel detectors now and in the future + Civil Application

ITS-3

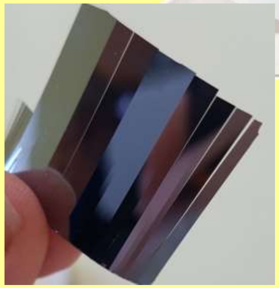
Conception from CERN

3 layers

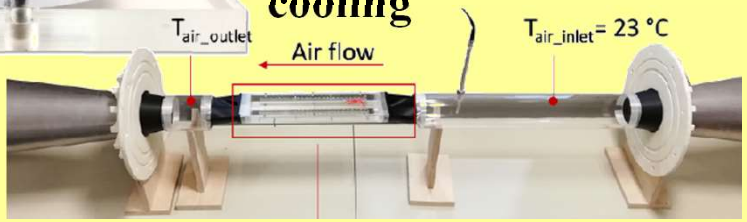


Bended MAPS

Carbon foam ribs as support structures



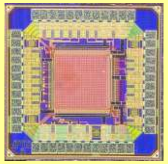
Air high speed (6-7 m/s) cooling



R&D: sensor development

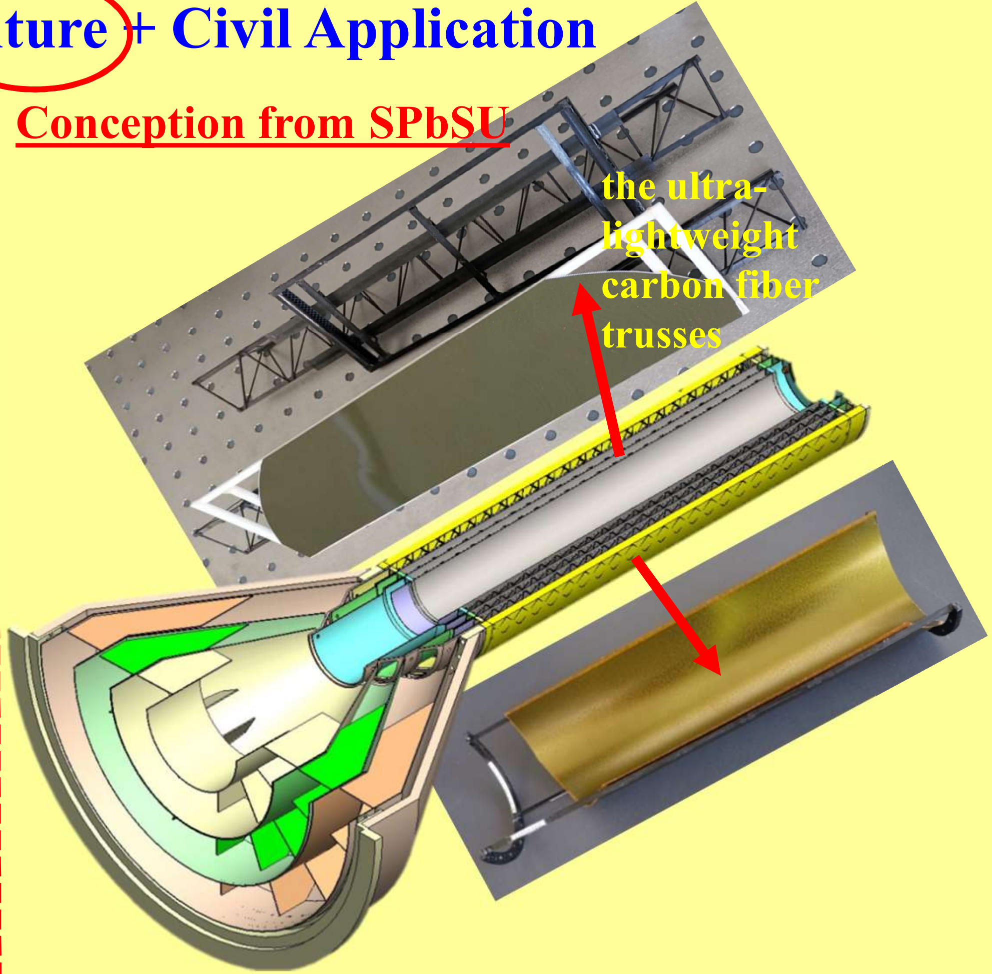
65 nm prototypes, MLR1

Digital Pixel Test Structure (DPTS) 32 × 32 pixels, 15 μm pitch



65nm wafers

Conception from SPbSU



Barrel configuration: 3 layers with carbon fiber trusses + thin curved silicon MAPS inside. Barrel covered by space blanket.

For this construction an effective low speed (< 0.1 m/c) gas cooling system (nitrogen at temperature < 15 ^{o}C) could be used

without condensation and without frost gathering

TDR for ITS-3: CERN-LHCC-2024-003; ALICE-TDR-021

Silicon pixel detectors now and in the future + Civil Application

ALICE-3 (LS4 upgrade)

outer tracking layers

in-vacuum tracker
the vertex detector

Letter of intent for ALICE 3:

arXiv:2211.02491v1

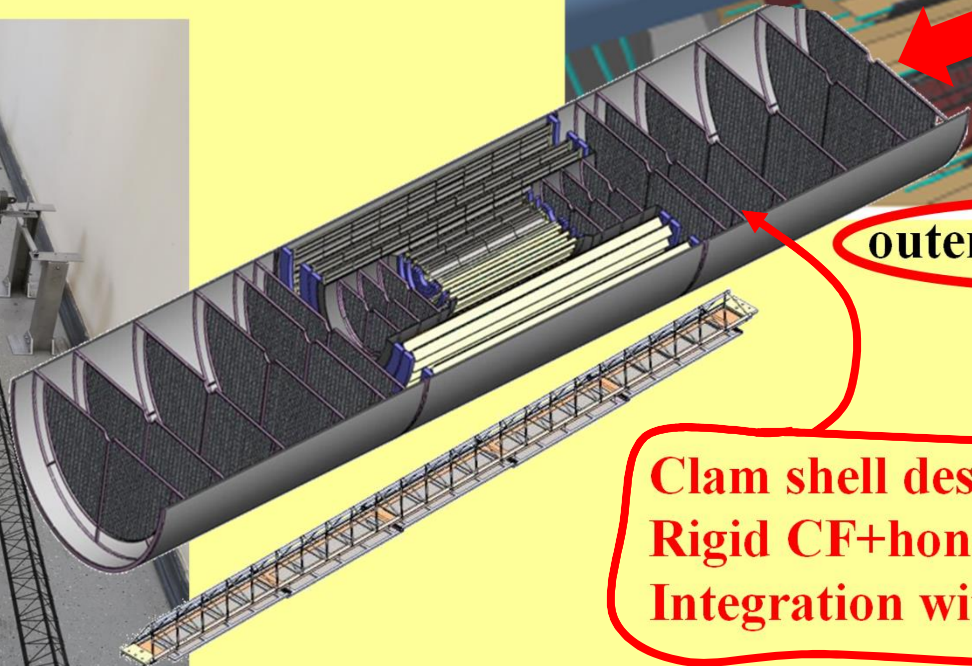
Conception from SPbSU

For outer tracker:

long ladders 3000 mm

+ heat bridges

+ low speed gas cooling



Clam shell design
Rigid CF+honecomb outer shell
Integration with the beam-pipe and the IRIS

Transfer technologies ALICE-3 - JINR

G. Feofilov, S. Igolkin, V. Zherebchevsky et.al

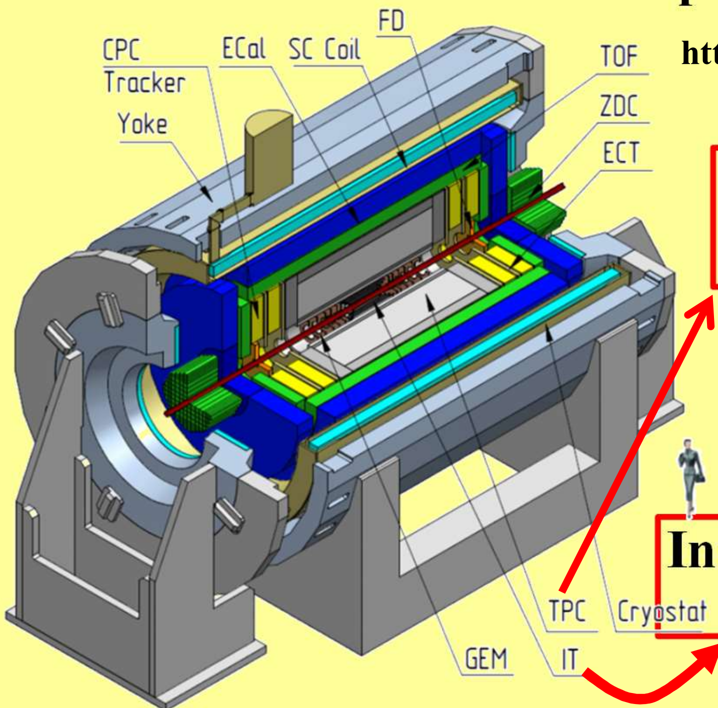
https://indico.cern.ch/event/1405488

Detector technologies for NICA

Experiments:

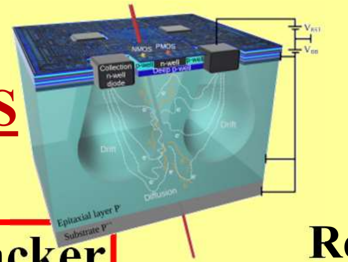
1. MPD at NICA – Multi-Purpose Detector

https://nica.jinr.ru/projects/mpd.php



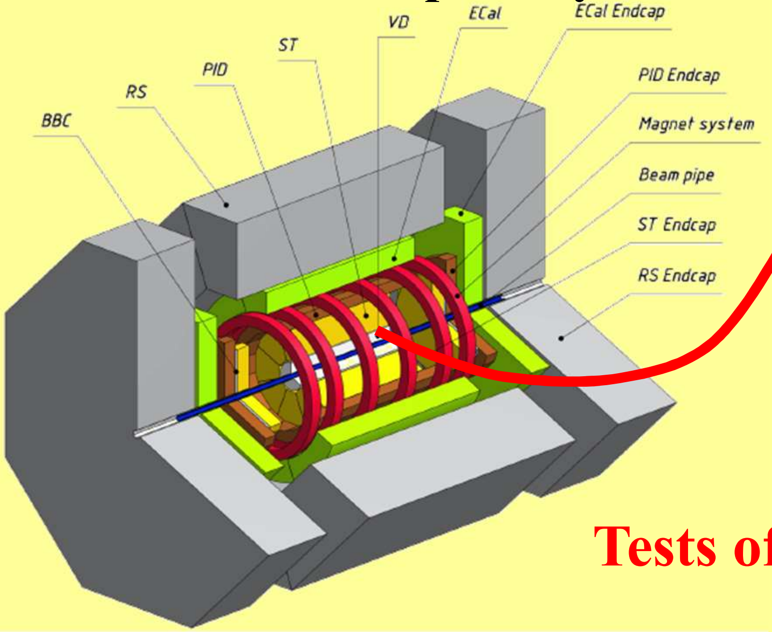
Time Projection Chamber

MAPS



Inner Tracker IT

2. SPD at NICA – Spin Physics Detector



Vertex detector VD

3. ARIADNA

ARIADNA collaboration

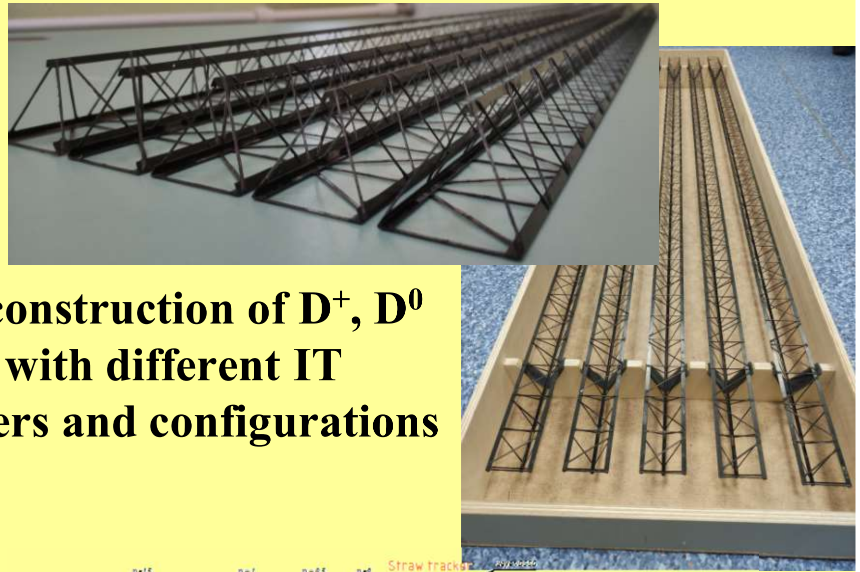
Tests of detector systems

II stage of the MPD experiment: TPC + IT

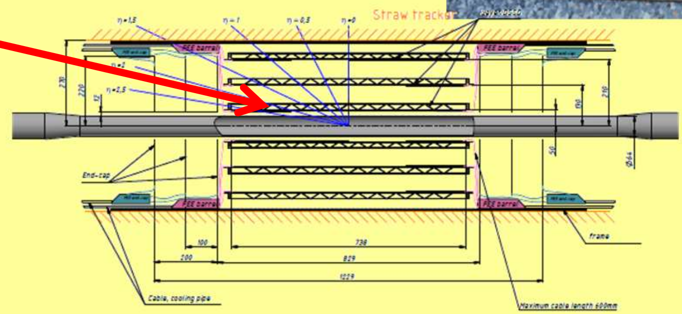
Geometrical model of MPD vertex detector

Carbon fiber structures production

60 Wound-truss structures were produced at SPbSU and shipped to JINR



Reconstruction of D^+, D^0 D^+_s with different IT layers and configurations



http://spd.jinr.ru/spd-cdr/

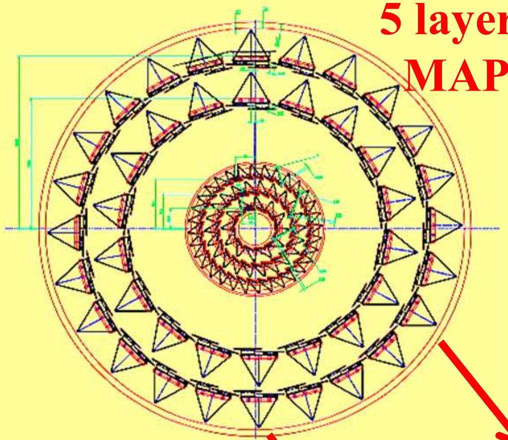
Proton tomography

Beam monitoring

Detector technologies for NICA: MPD, SPD

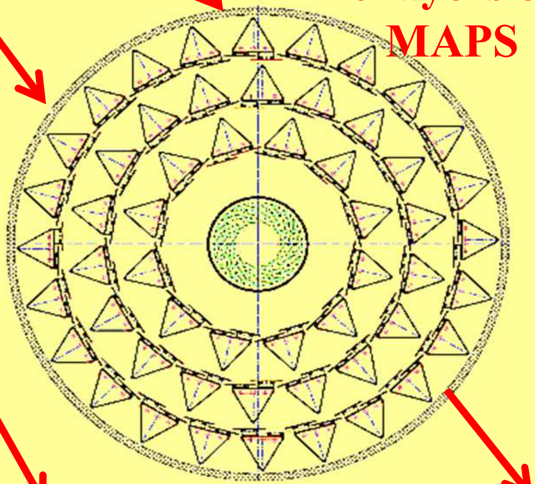
Evolution of NICA MPD IT concepts

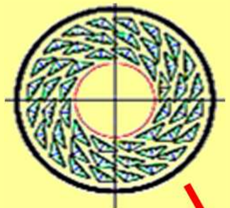
5 layers of MAPSd



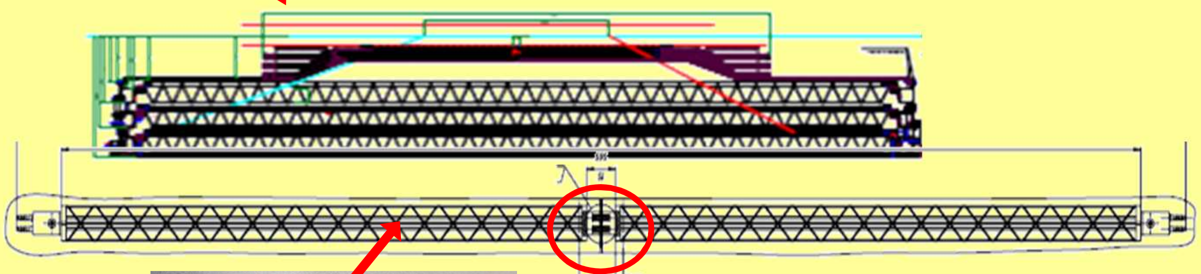
V.I. Zherebchevsky, V.P. Kondratiev, V.V. Vechernin, S.N. Igolkin NIM, A 985 (2021)

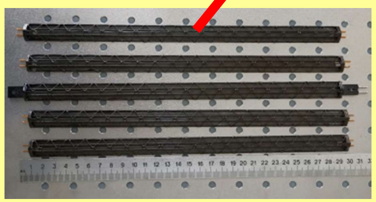
6 layers of MAPS





Snap back to reality





Hole!!

Reconstruction of D^+, D^0, D^+_S with 6 layer IT, beam pipe 40 um, 10^8 central Bi+Bi collisions

$D^+ \rightarrow K^- + \pi^+ + \pi^+$ $D^0 \rightarrow K^- + \pi^+$ $D^+_s \rightarrow K^- + K^+ + \pi^+$

Particle	D^+	D^0	D^+s
Efficiency, %	1.0	0.4	0.1

Reconstruction of D^+, D^0, D^+_s with 6 layer IT, beam pipe 40 um, 10^8 central Au+Au collisions

Done by V.P. Kondratiev

Physical tasks

Proposed by V.N. Kovalenko

Particle	D^+	D^0	D^+s
Efficiency (hole), %	0.18	0.05	

Detector technologies for NICA: MPD, SPD

Evolution of NICA MPD IT concepts

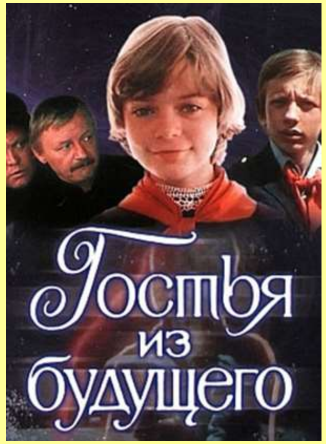
3 layers of MAPS

+

3 layers of large area Uth MAPS

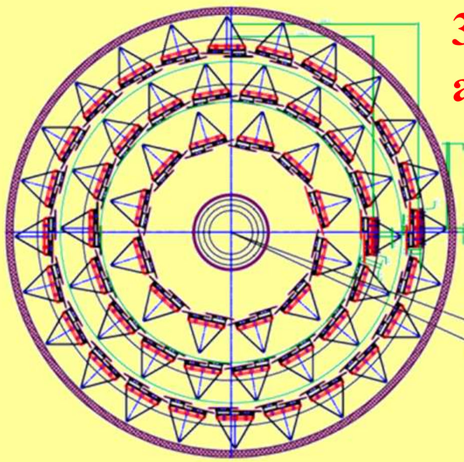
IV stage MPD: TPC + ITS

A bright future ahead.

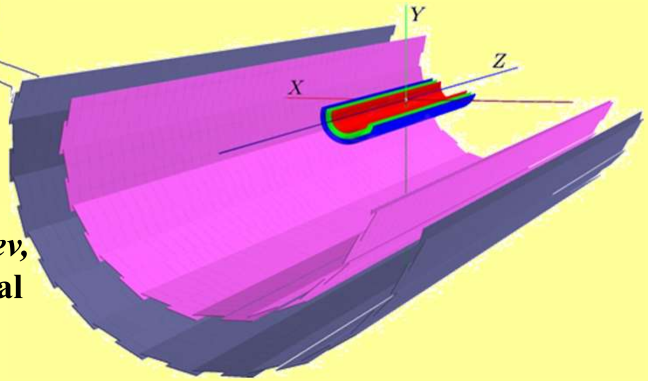


From ALICE to Alice

"The Distant Beautiful Future"

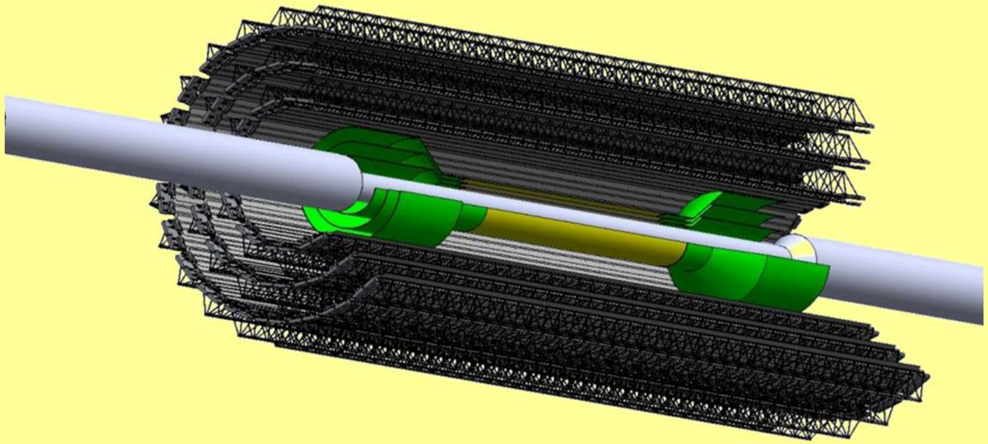


V.I. Zherebchevsky, V.P. Kondratiev, N.Maltsev, V.Petrov, IJMP E, Vol. 33, No. 12 (2024)



V.I. Zherebchevsky, V.Kondratiev, Y. Murin et al. Eurasian Journal of Physics and Functional Materials, 2023, 7(3), 139-147

JINR-SPbSU

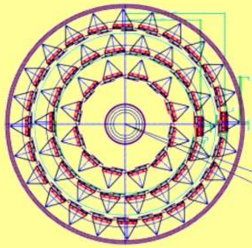


Inner Barrel - 3 layers of bended MAPS with large area and thickness of 40 µm

Outer Barrel - 3 layers of standard MAPS, Thickness of 50 µm

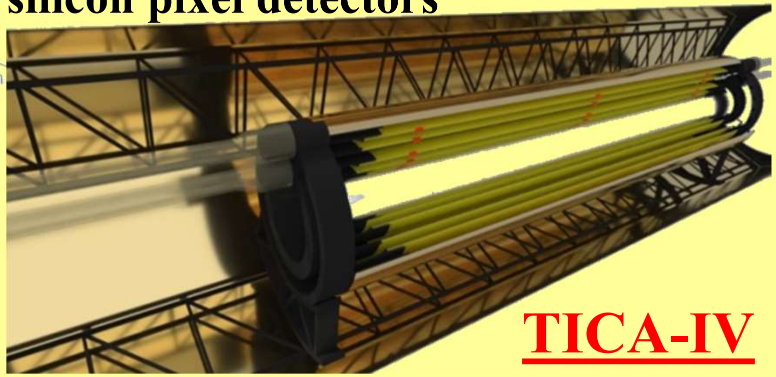
Detector technologies for NICA: MPD, SPD

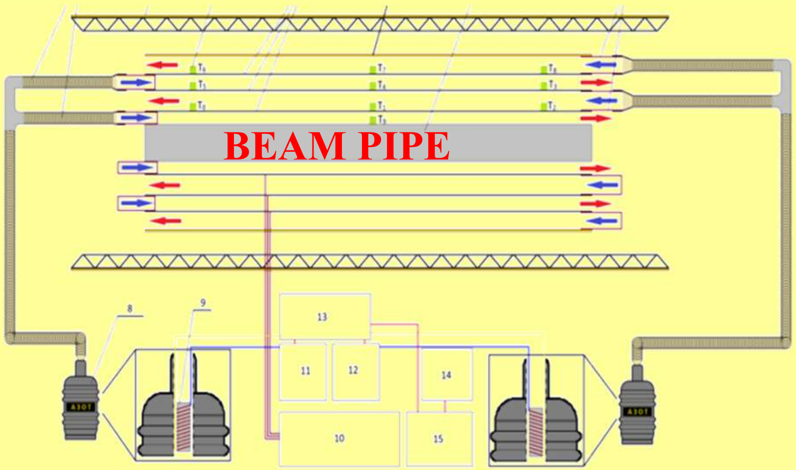
Cooling for Tomorrow



3+3 layers MAPS conception

New experimental set-up for studying the cooling processes of new generation thin silicon pixel detectors





TICA-IV

Cooling of 3 layers Uth large area MAPS

Optimization of gas-cooling processes

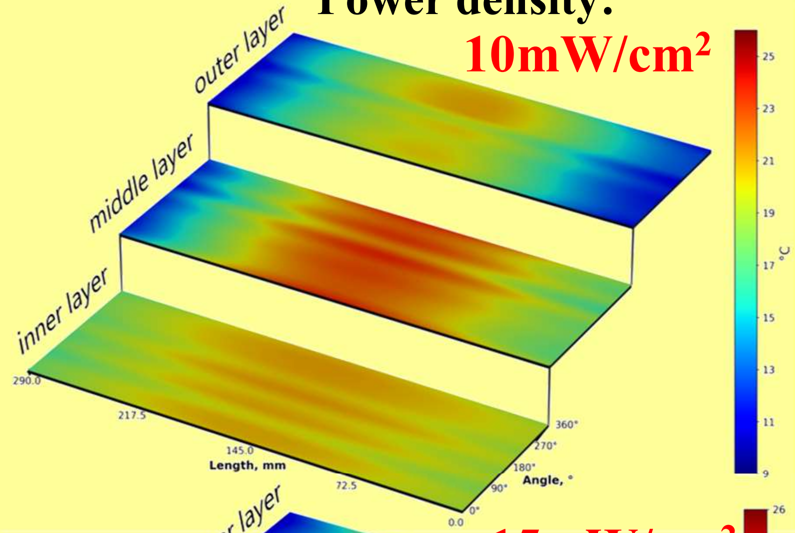
V. Zherebchevsky, et al. Instruments and Experimental Techniques, 2025, Vol. 68, No. 2

Mechanics and cooling crash tests
New set-up

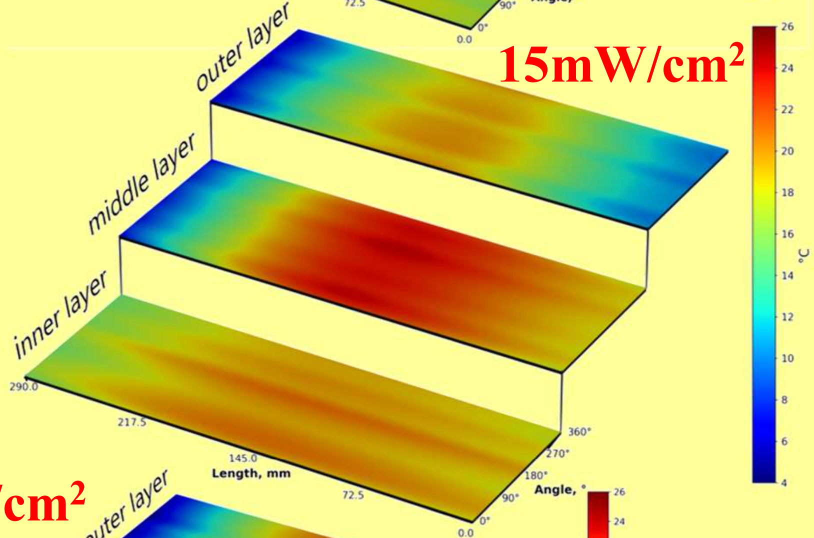
Temperature map of the detector layers

Power density:

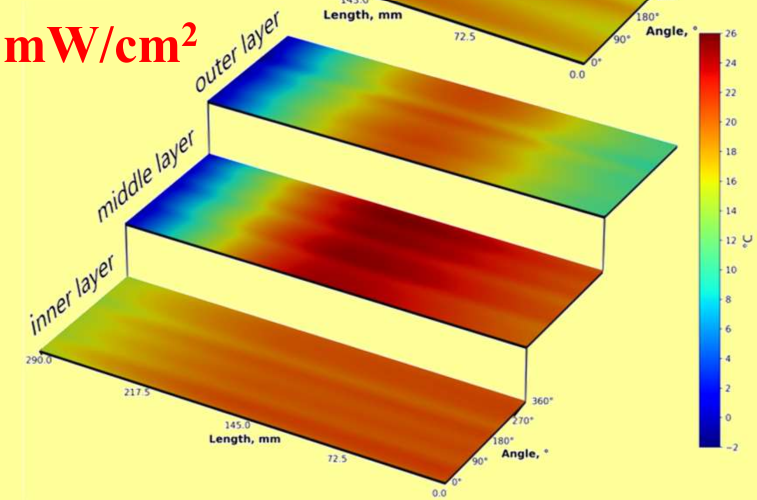
10mW/cm^2

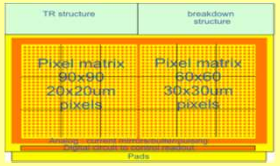


15mW/cm^2



25mW/cm^2



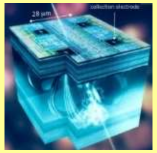


R&D MAPS technologies: CERN+SPbSU+JINR

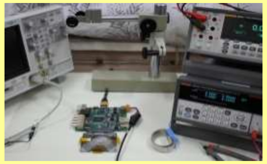
Detector technologies for NICA: MPD, SPD

Explorer-1,2 — 2012

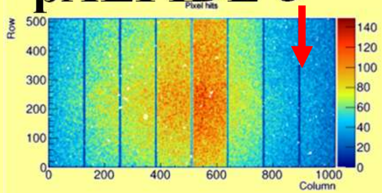
2013 — pALPIDEss



pALPIDE-1 — 2014

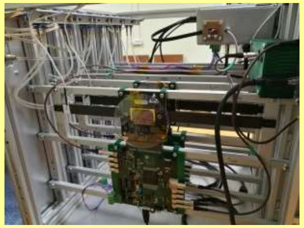


2015 — pALPIDE-2 pALPIDE-3



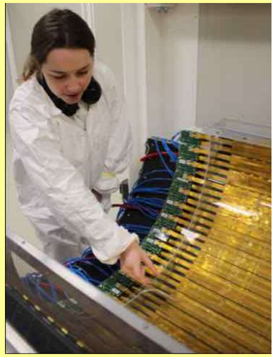
pALPIDE-4 Final — 2016

2017-2018 — ALPIDE investigations

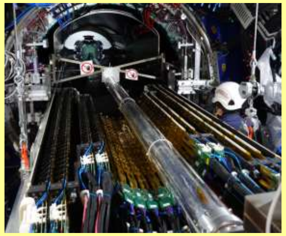


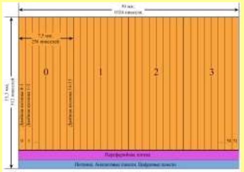
CERN+SPbSU+ JINR Linac-200

ITS-2 ALICE — 2018-2020



CERN + 35 Institutions

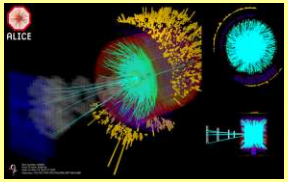




2020-2022 — ITS-2 ALICE commissioning

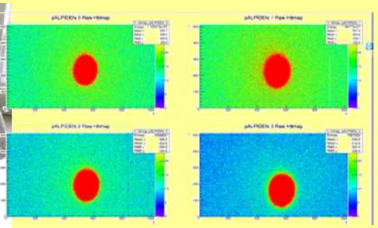
Pixel tests at 1GeV PNPI Start — 2021

2022 — ITS-2 ALICE In operating



Experiments PNPI+new scint. trigger — 2022

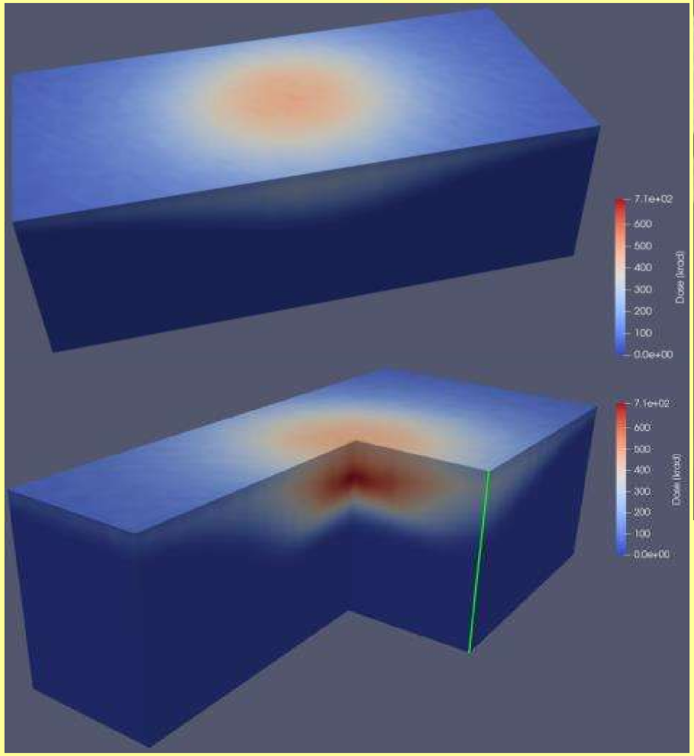
2023-2025 — Proton Tomography R&D Experiments Modeling



For MPD IT

Detector technologies for NICA: MPD, SPD

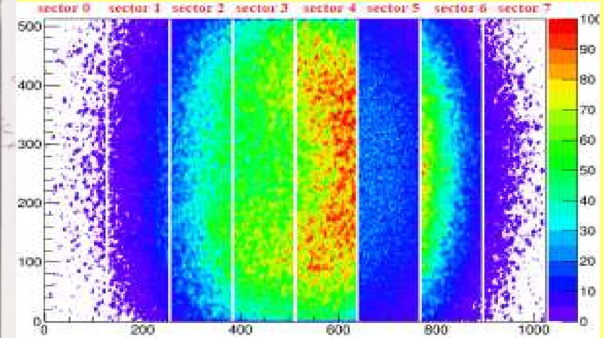
Irradiated MAPS:
Central area,
max dose depth - 15 um



Studies of radiation effects in irradiated detector structures

During the 6 month experimental period, the irradiation zone accumulated TID dose of 7.4 kGy (740 krad)

Alpha source 4-5 MeV

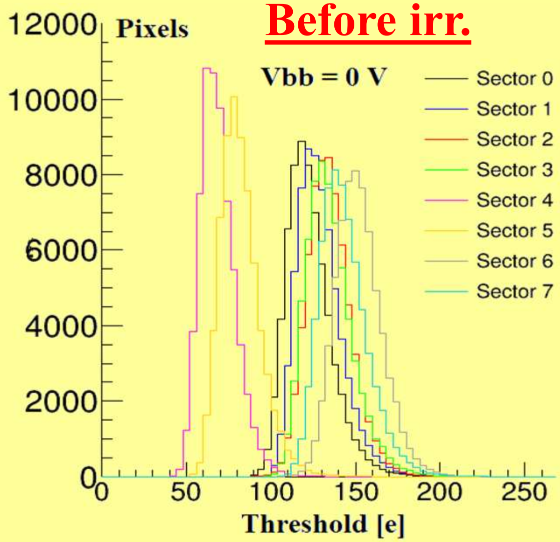


Example
Pixel thresholds

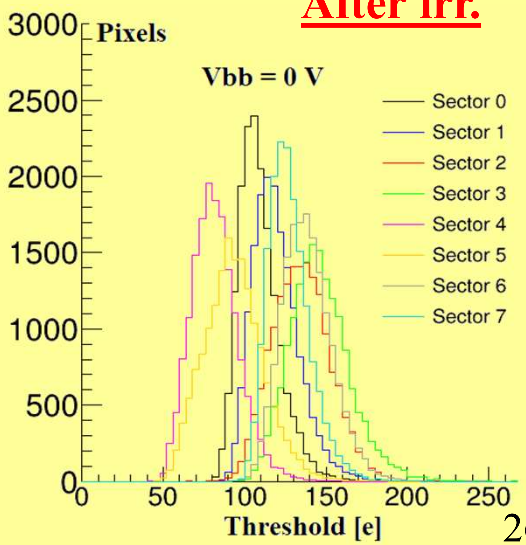
RESULTS

Threshold and temporal noise were changed: 30-40% MAPS still worked!!

Before irr.

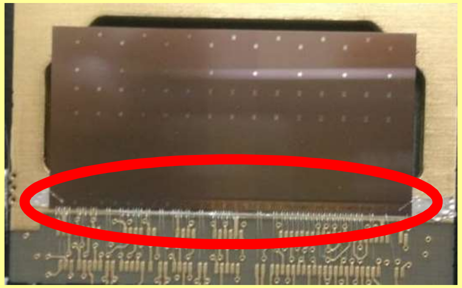


After irr.



New experiment:

Dose 900 krad on the MAPS edge, where pixel electronics are located



Detector technologies for NICA: MPD, SPD

Study of flucton-flucton interaction in D-D collisions

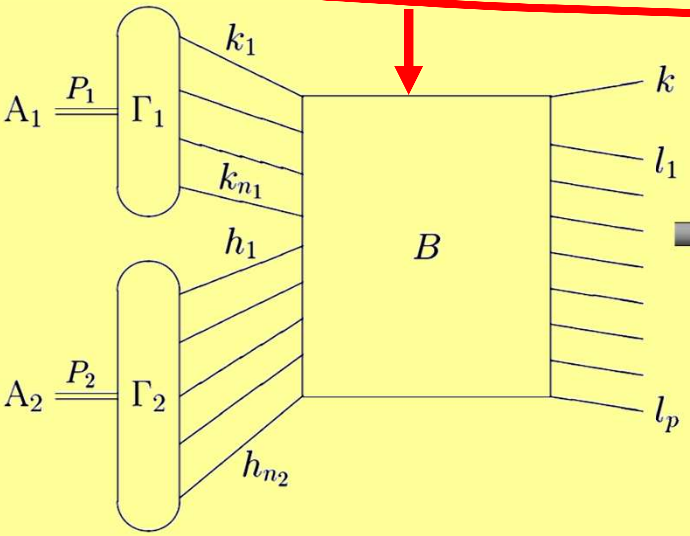
1) It can be studied **only in new cumulative region of large transverse momenta in mid-rapidity region at NICA** (not in the traditional cumulative region of fragmentation of one of the nuclei).

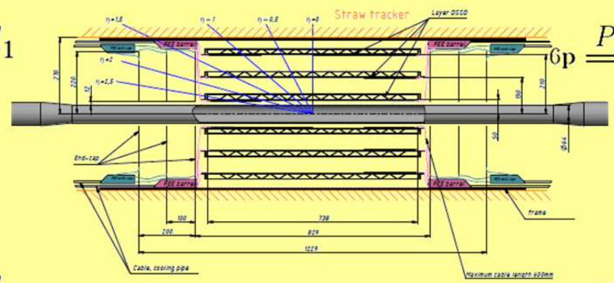
2) There are **no additional interactions in dd collision**, compared with collisions of heavier nuclei, if both deuterons are in flucton configuration at the moment of collision.

3) **Higher frequency of dd collisions** that can be recorded by the SPD

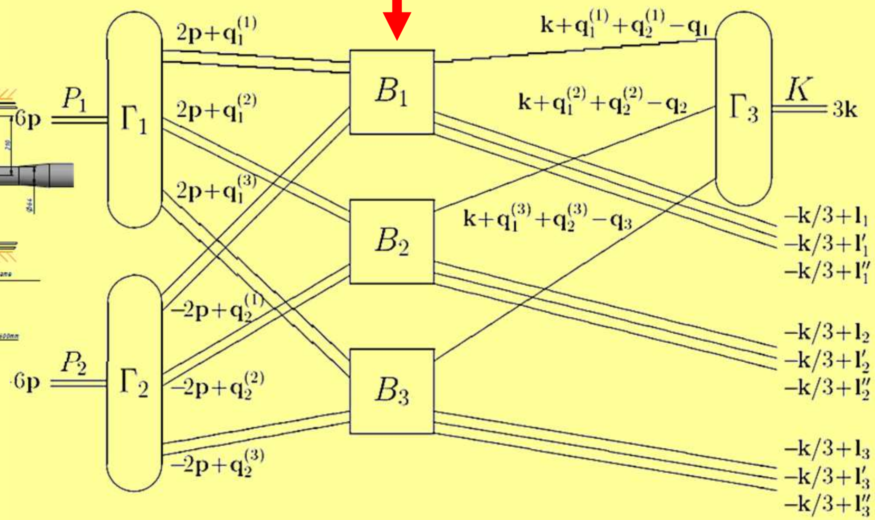
The formation of **pions** goes through the production of one cumulative quark (*k*)

The formation of protons goes through the Coherent Coalescence of three cumulative quarks (k1, k2, k3):





http://spd.jinr.ru/spd-cdr/



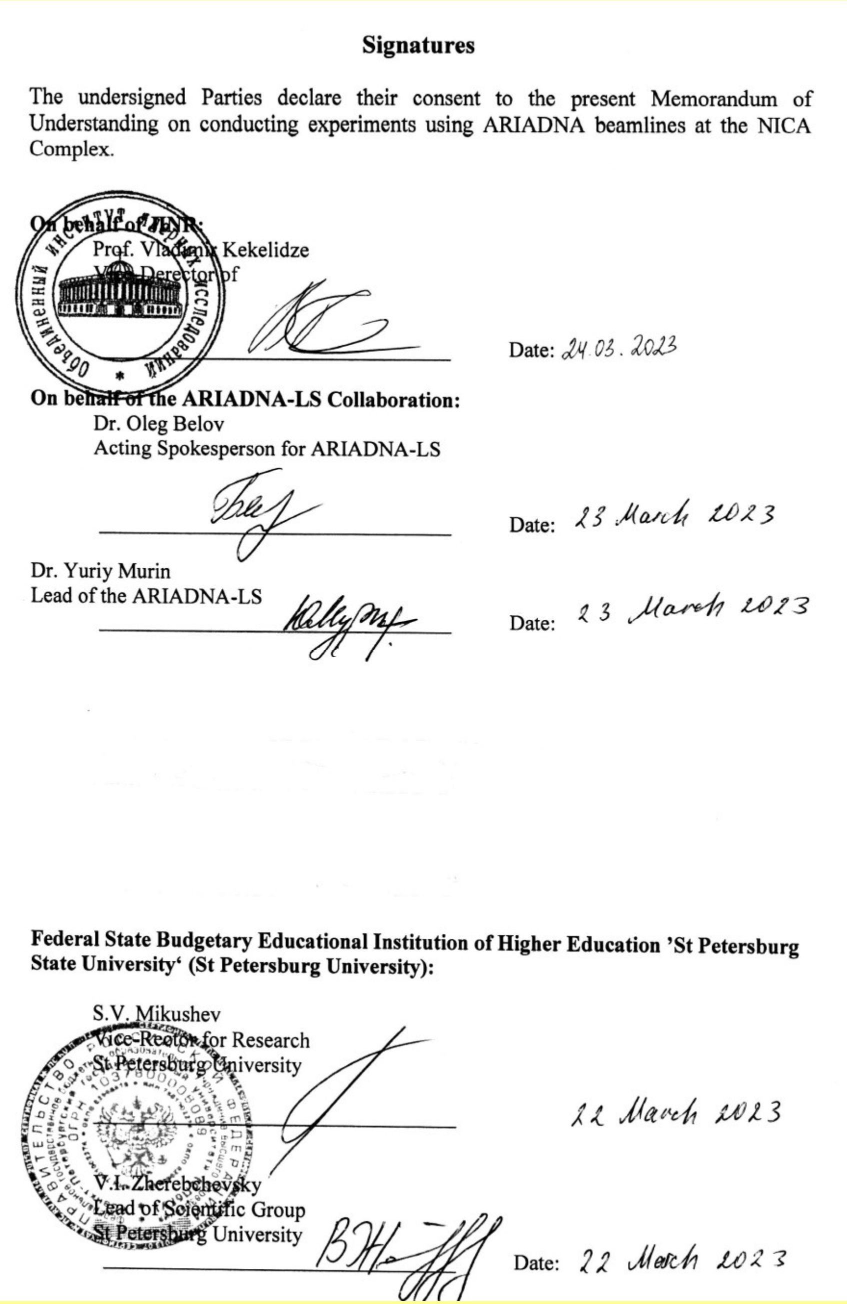
MAPS detector system will give possibility to confirm the tracks of a cumulative particle from the primary interaction vertex, and thus isolate this rare event from the noise background.

For the **amplitude of inclusive proton** production (**D+D**) the new cumulative region could be reached

For details see reports at the present conference: Vechernin V.V., and Yurchenko S.V

Detector technologies for NICA: ARIADNA

2023 Memorandum of Understanding: SPbSU + JINR + ARIADNA-LS



Signatures

The undersigned Parties declare their consent to the present Memorandum of Understanding on conducting experiments using ARIADNA beamlines at the NICA Complex.

On behalf of JINR:
Prof. Vladimir Kekelidze
Vice-Director of

Date: 24.03.2023

On behalf of the ARIADNA-LS Collaboration:
Dr. Oleg Belov
Acting Spokesperson for ARIADNA-LS

Date: 23 March 2023

Dr. Yuriy Murin
Lead of the ARIADNA-LS

Date: 23 March 2023

Federal State Budgetary Educational Institution of Higher Education 'St Petersburg State University' (St Petersburg University):

S.V. Mikushev
Vice-Rector for Research
St Petersburg University

22 March 2023

V.I. Zherebchevsky
Lead of Scientific Group
St Petersburg University

Date: 22 March 2023

Special Purpose Funding Programme within the NICA Megascience Project in 2023 – 2024

Our projects:

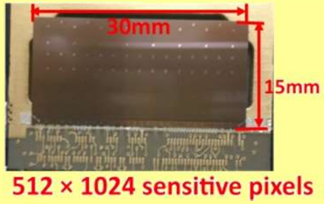
1) Concept creation and model development of a proton tomography based on silicon pixel detectors

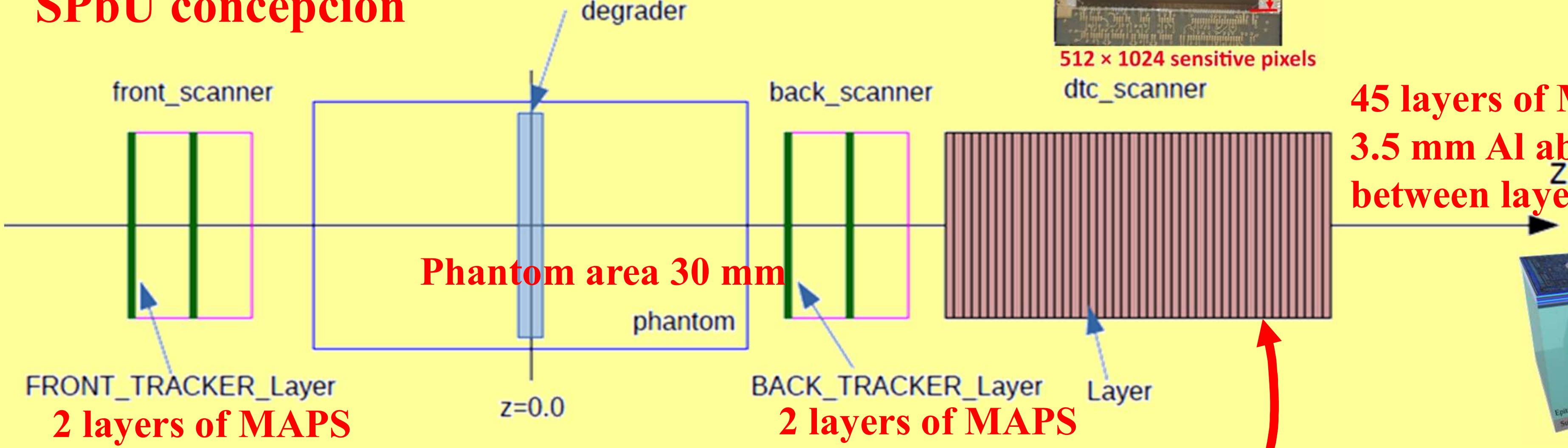
2) Creation of a new high energy heavy ion beams monitoring system (based on plastic scintillators)

https://indico.jinr.ru/event/3364/

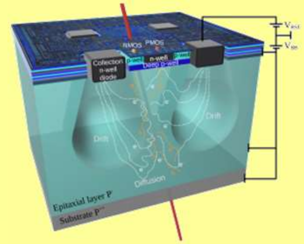
Detector technologies for NICA: ARIADNA

SPbU concepcion

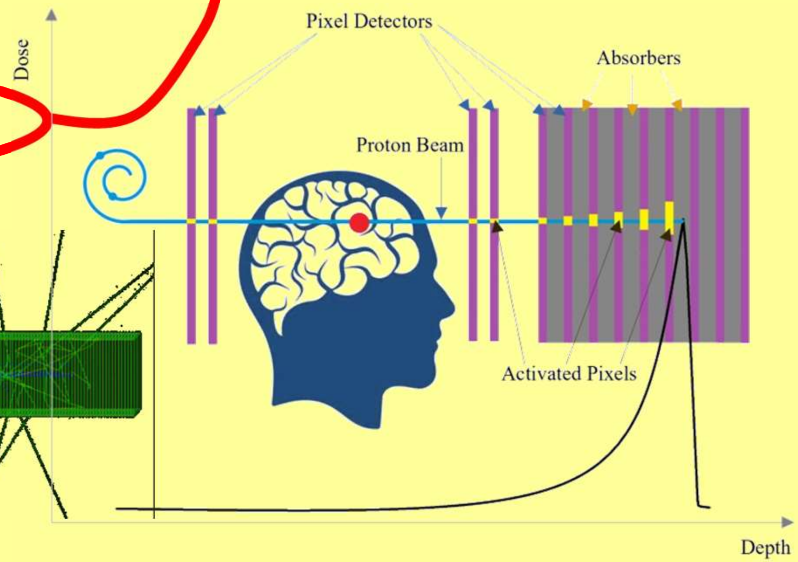




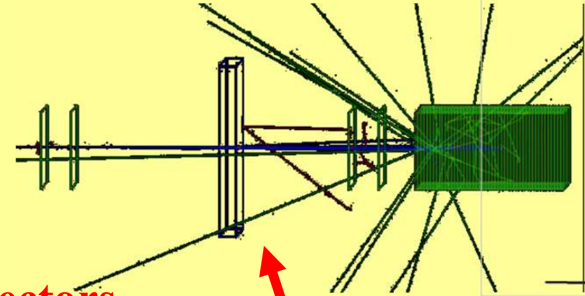
45 layers of MAPS + 3.5 mm Al absorber between layers

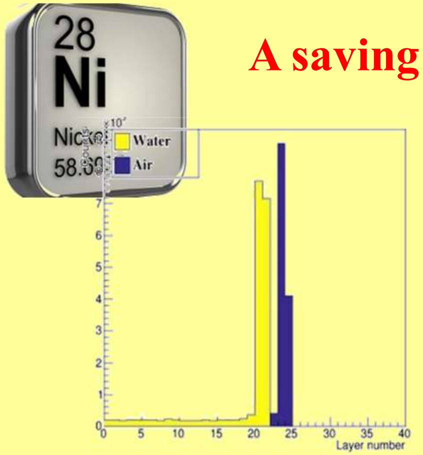


Modelling of Digital Tracking Calorimeter (dtc)



Nickel as absorber material gives minimum number of detector layers with good enough energy resolution + good tracking





A saving of 2268 MAPS detectors

GATE - Geant4 Application for Emission Tomography GATE – adopted to tomography tasks
Using GATE one can construct different type of detectors

Detector technologies for NICA: ARIADNA

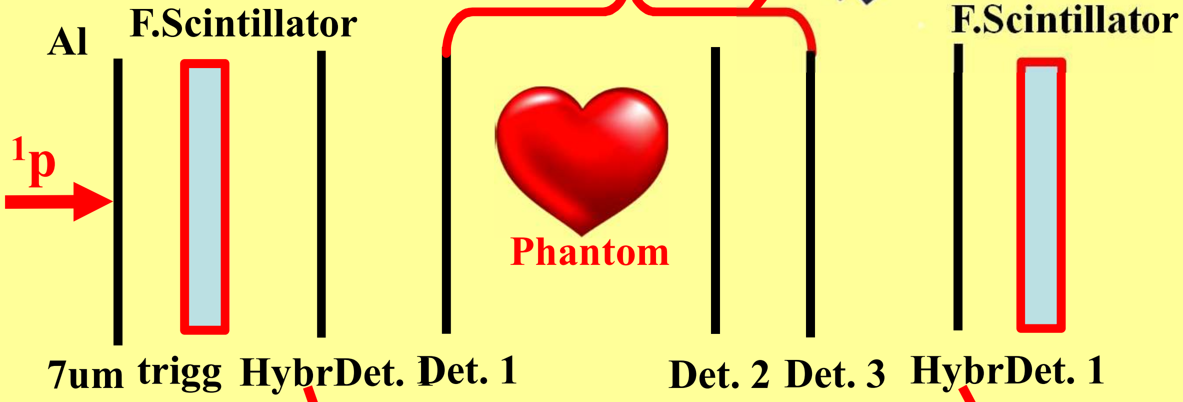
Experiments with MAPS

PNPI Synchrocyclotron- 1000
Beam: protons - 200 MeV

Experimental investigations

Geometry

MAPS: 50 um

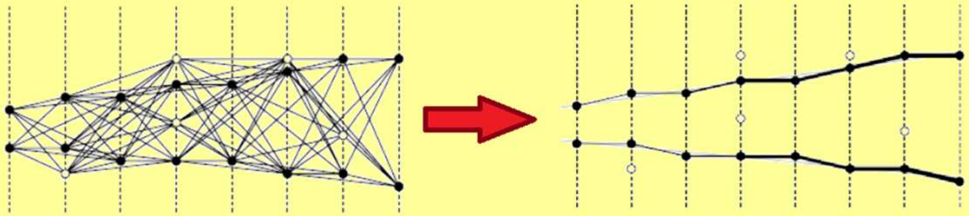


Hybrid pixel detector TimePiX

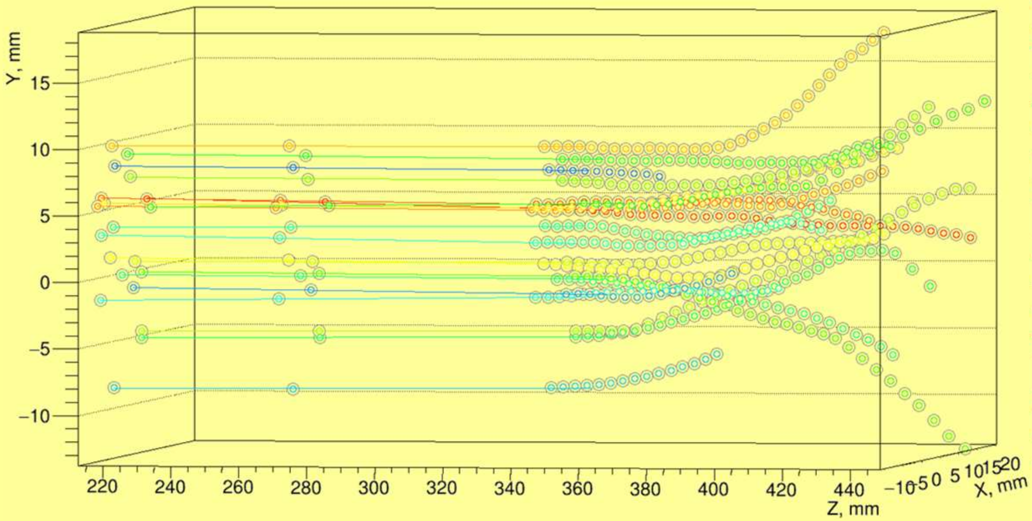
Detector technologies for NICA: ARIADNA

Modelling

Track-finding algorithm based on cellular automaton was developed for tomograph prototype.

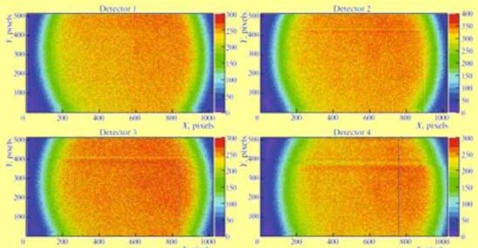


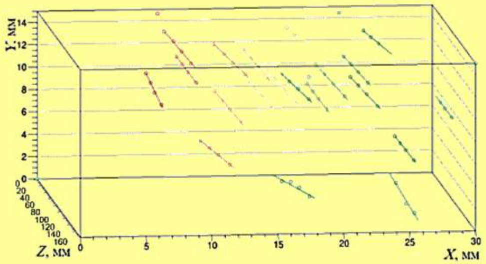
Tracks are identified with 80-90% efficiency for the proton beam with diameter of 20 mm and 10^6 p/s intensity.

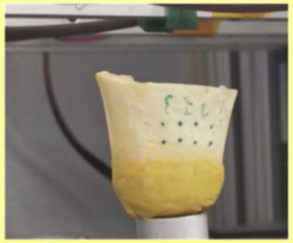


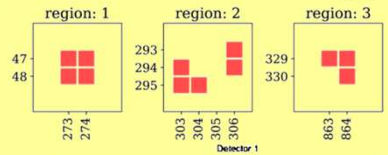
Experiments with MAPS

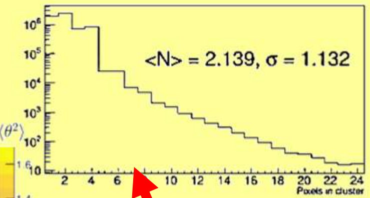
PNPI Synchrocyclotron- 1000
Beam: protons - 200 MeV



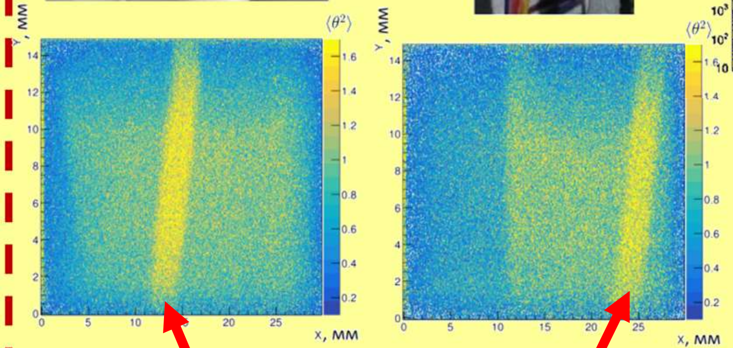








Cluster analysis



Phantom image reconstruction based on ^{1}p tracks

Detector technologies for NICA: ARIADNA

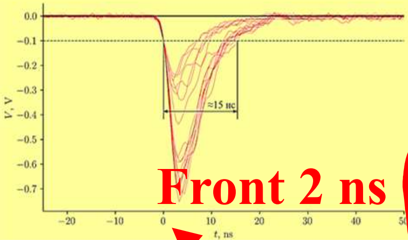
High energy heavy ion beams monitoring system based on modern plastic scintillator + PM or SiPM

Developments are designed to operate under extreme conditions: high beam intensity - 10^7 particles/cm²·s and high energy.

World: Radiation hard scintillators: SCSN81T (Kuraray, Japan), BC408 (Bicron,United States), UPS09RH

Example: $^{124}Xe^{54+}$
Energy: 3.8 GeV/A

→ **Calculations for 10 mm plastic scint.(energy losses 6.38 GeV) light output 6·10^7 photons**



Front 2 ns

Technology from TOF NA61

The plastic has been changed

Now:
Polystyrene plastic scintillator- EPS100
Thickness – 10 and 6 mm

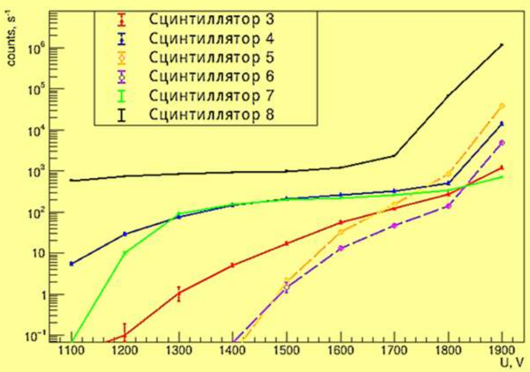
fast PM: Philips XP2972

ARIADNA long-term irradiation station

GOALS:
1) Intensity and dose detector
2) Beam components identification
(in the place of irradiated samples)

Under development

Sc3 - censor thickness 6 mm
Sc4 - censor thickness 10 mm
Sc5 - censor thickness 6 mm + light filter
Sc6 - censor thickness 10 mm + light filter
Sc4 - censor thickness 6 mm + dark paper
Sc8 - censor thickness 23 mm



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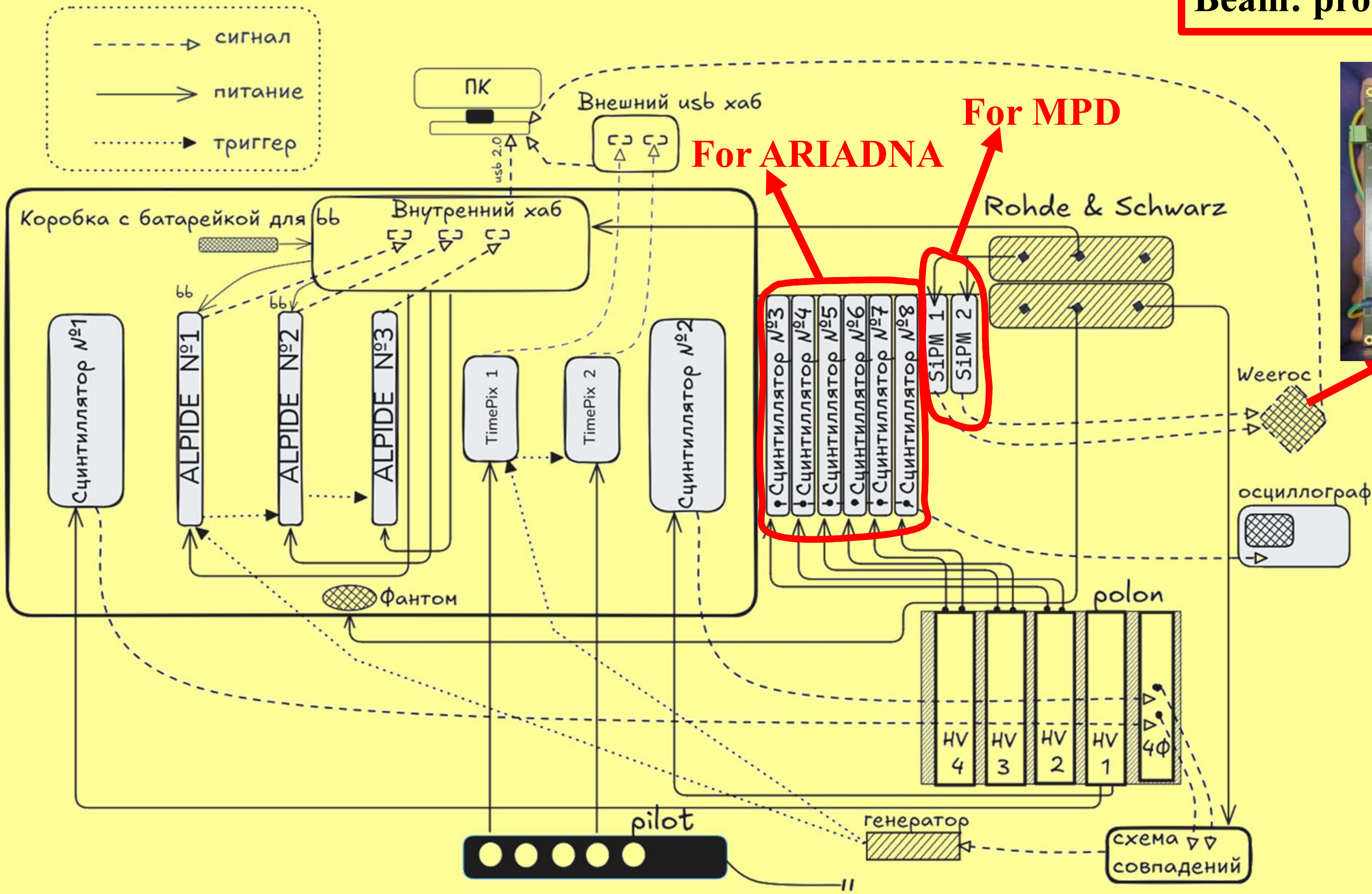
CAEN N1081

Four-Fold Programmable Logic Unit

Detector technologies for NICA: ARIADNA

High energy heavy ion beams monitoring system based on <u>modern plastic scintillator + PM or SiPM</u>

PNPI Synchrocyclotron- 1000
Beam: protons - 1000 MeV



Fast electronics

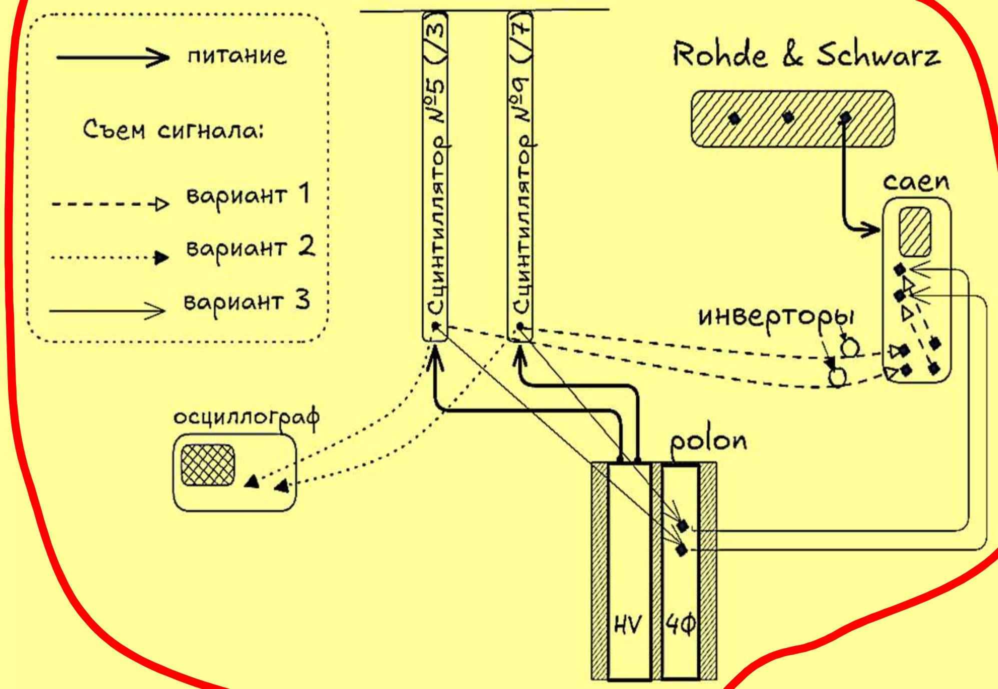
ASIC PETIROC2A
32 channels, ~ 100 ps

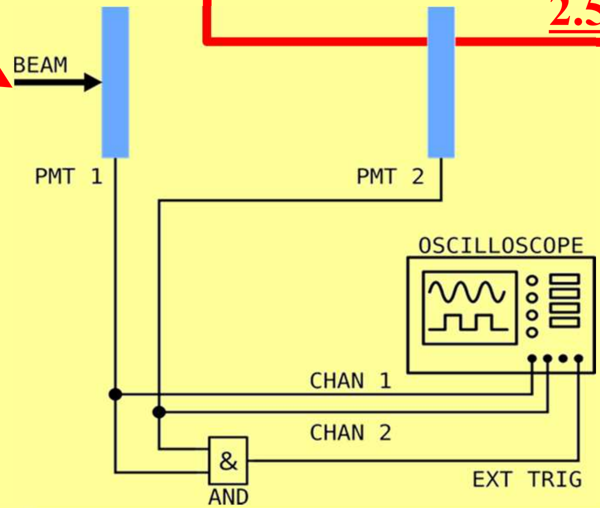
Detector technologies for NICA: ARIADNA

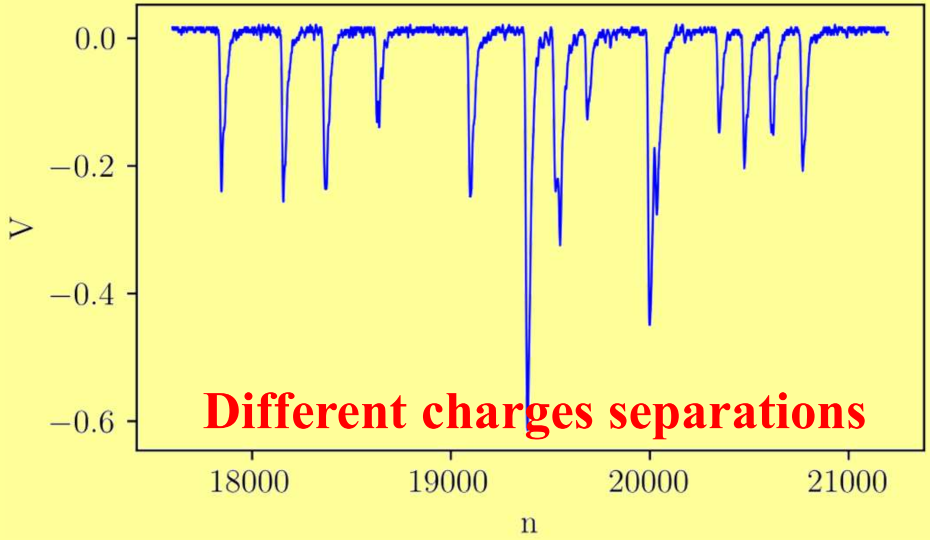
High energy heavy ion beams monitoring system based on modern plastic scintillator + PM or SiPM

PNPI Synchrocyclotron- 1000
Beam: protons - 1000 MeV
$2.5 \cdot 10^6$ prot/s

Proposal for Nuclotron → **Beam tests**

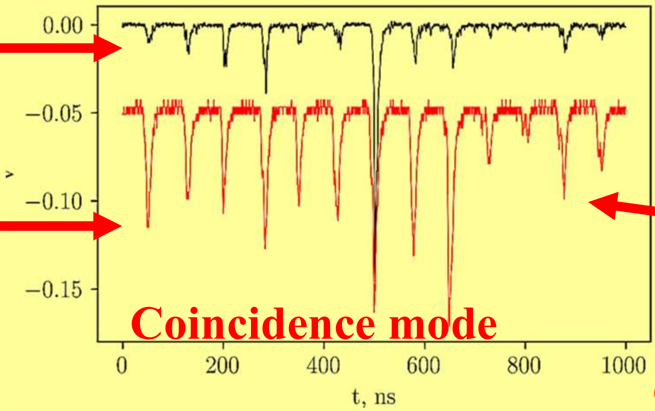






Sc5 - censor thickness 6 mm + light filter

Sc3 - censor thickness 6 mm



It indicates the registration of individual beam particles. Counting pulses in this mode provides information on the beam intensity

Conclusions

Novel detector technologies based on silicon monolithic active pixel sensors and plastic scintillators could be used for NICA: MPD, SPD, ARIADNA experiments

Real Tracking for conception of MPD ITS (identification D_0, D^+, D^+_S) has been done

The advanced cooling system was proposed for new large area, thin silicon pixel detectors

In-beam tests: tracking, pixel energy scan, Cluster analysis, digital calorimetry

Next plans

Continue of pixel detectors radiation effects investigations

For MAPS proton tomography:
Tracking + visualization

Medical beams tests


Thank you