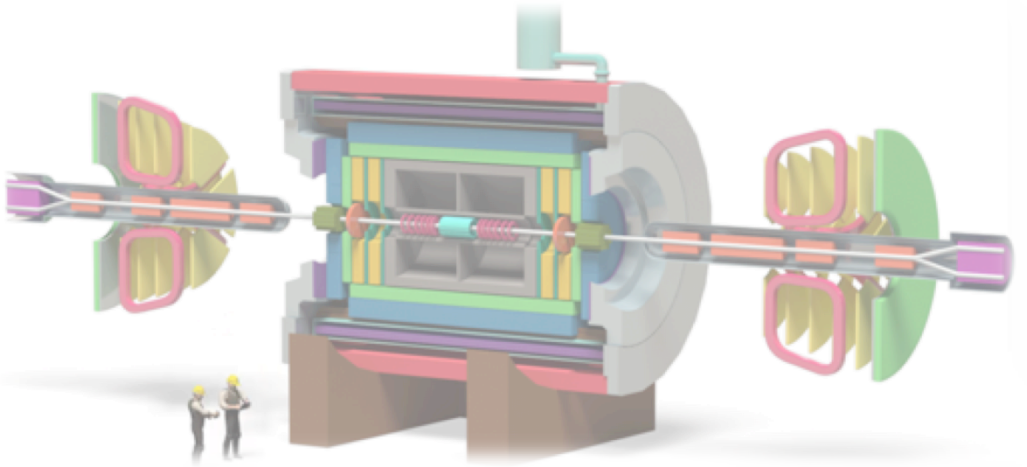
4th CBM-China Workshop
12-14 April 2019, CTGU, Yichang, China

Plan & Effort from China for the NICA/MPD Inner Tracker

Yaping Wang
Central China Normal University (CCNU)



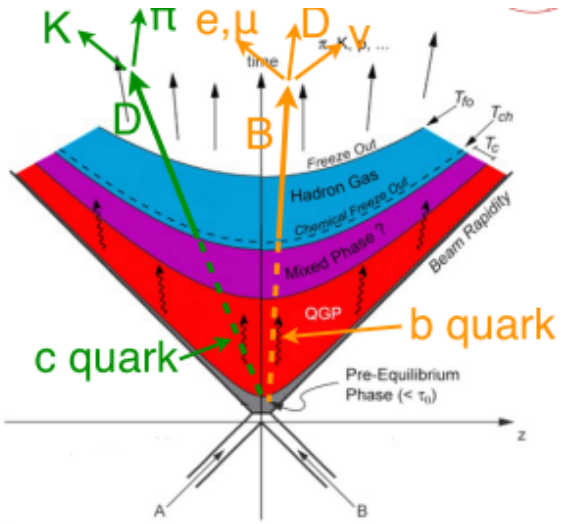
Outline

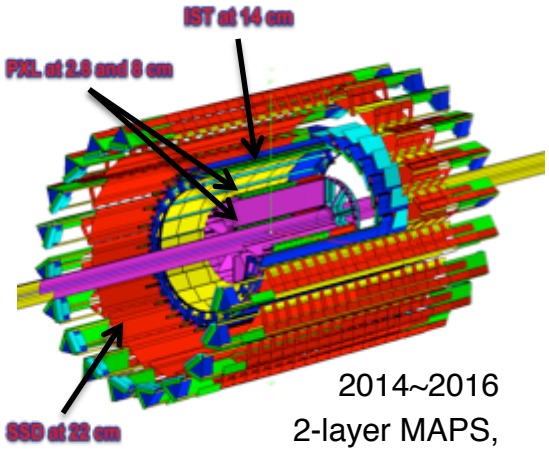
- Introduction
- MAPS-based Inner Tracker (IT) for the NICA/MPD
- Plan & Effort from China for the MPD/IT
  - Feasibility Plan and Effort from China Side
  - Organization and Timeline
- Summary and Outlook

Introduction – Pixel Detector in HIC Experiments

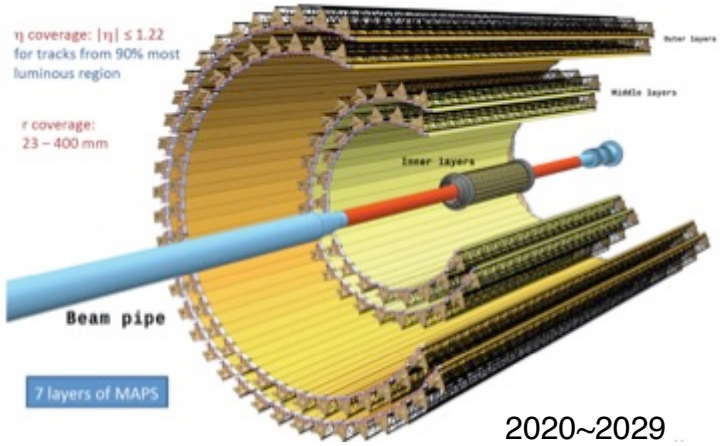
Vertex Detector for HF physics measurements in HIC experiments

- MAPS, hard radiation, low material budget, low power consumption, fast readout, high spatial resolution
- Produced mostly from initial hard partonic scatterings at RHIC energies; exposed to the whole evolution of the Quark-Gluon Plasma (QGP)
- Yield or mass not (significantly) altered within the QGP, sensitive to parton-medium interactions and medium properties

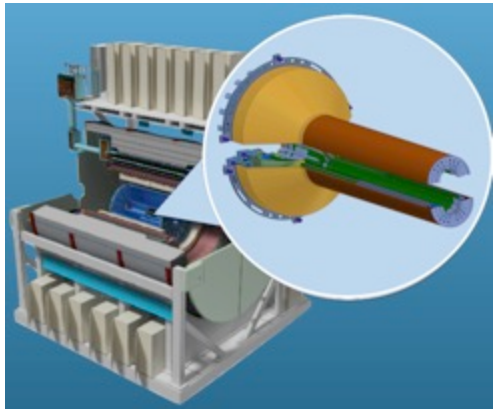




2014~2016
2-layer MAPS,
360M pixels, 20μmx20μm,
inner layer 0.4% X_0



2020~2029
7-layer MAPS, 12.5G pixels,
inner layer 0.3% X_0



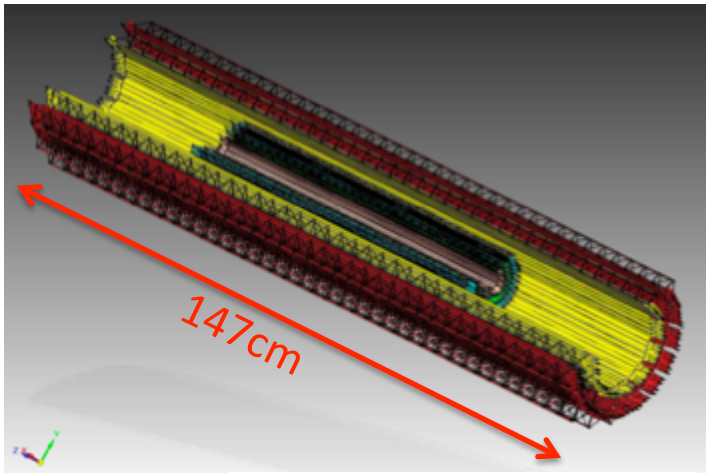
Proposed 2019~2023@sPHENIX
Replica of ALICE ITS Inner Barrel

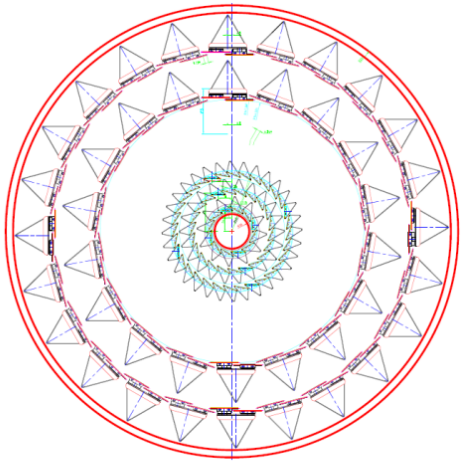
MAPS-based Inner Tracker (IT) for the NICA/MPD

The IT detector will enable charm-hadron measurement and isolate collision vertex at high luminosity environment for the MPD experiments

- Charm production in heavy ion collisions at these collision energies
- Clean measurement of multi-strange hadron spectra

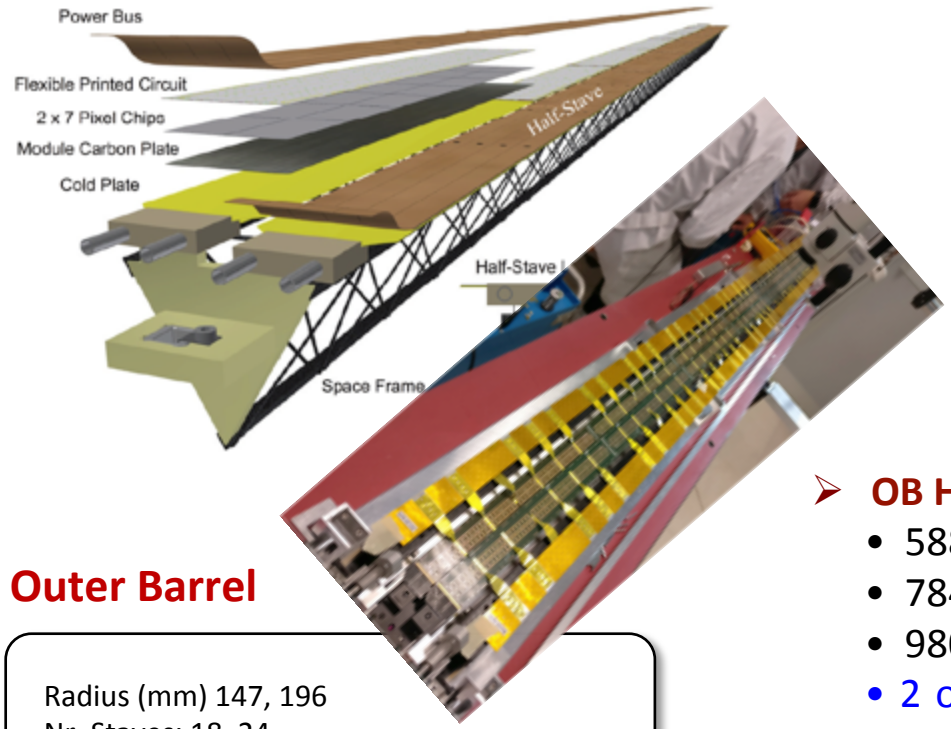
	Inner Barrel[a]			Outer Barrel	
	Layer0	Layer1	Layer2	Layer3	Layer4
R_{min} (mm)	22.4	40.7	59.8	145.8	194.4
R_{max} (mm)	26.7	45.9	65.1	147.9	197.6
Length (mm)	542[a]	542[a]	542[a]	1468	1468
Pseudo-rapidity	±3.1	±2.5	±2.2	±2.3	±2.0
Nr. Of pixel chips (chips per stave x stave)	18 x 12	18 x 22	18 x 32	196 x 18	196 x 24
Active area (cm^2) (2mm dead area in r-phi)	842	1546	2246	13758	18345



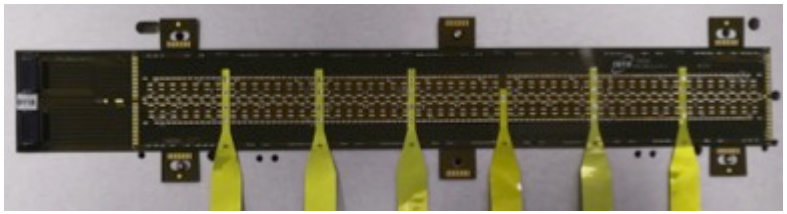


- 1st step: 2 Outer Barrel layers (0.8% X_0), ready in 2022
- 2nd step: 3 Inner Barrel layers, depend on beam-pipe upgrade (the new generation of MAPS chips – ALICE ITS3?), R&D can be started in parallel

MAPS-based Inner Tracker (IT) for the NICA/MPD



OB HIC module with 2 x 7 chips aligned on FPC



Outer Barrel

Radius (mm) 147, 196
Nr. Staves: 18, 24
Nr. Chips/ HIC module: 2x7

Length in z (mm): 1468
Nr. HIC module/ Stave: 7
Material thickness: ~0.8% X_0

Coolant Single-phase H_2O leak-less
Pixel operational temperature < 30°C
Pixel max temperature non-uniformity < 5°C
Chip Power dissipation < 40mW/cm^2

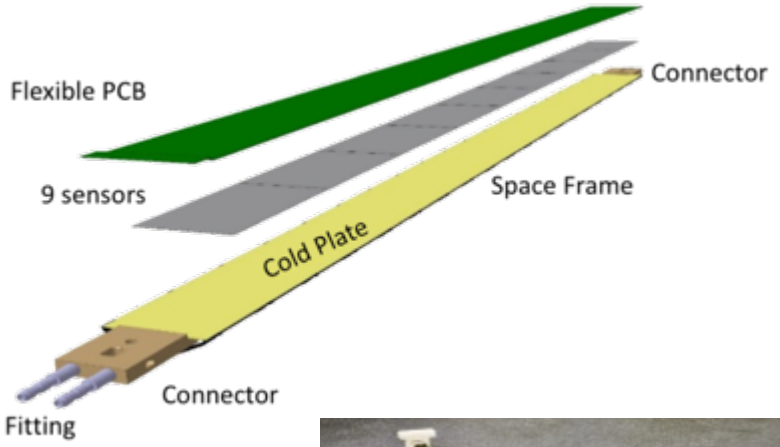
➢ OB HIC Production

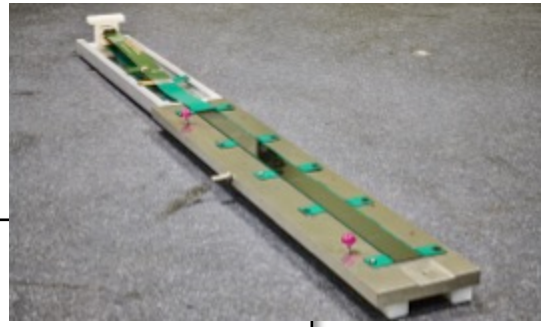
- 588 working HICs needed to assemble the OB barrel
- 784 assembled HICs assuming a total yield of 75%
- 980 assembled HICs with 20% spare
- 2 or 3 HIC production sites necessary: CCNU/Wuhan, JINR/Dubna, IMP?
- Target rate: 2 HICs per day per site in average, lasting for 1 year with 2 sites

➢ OB Stave Production

- 84 working half staves (HS) needed to assemble OB barrel
- 100 assembled HSs (take into account spare and stave yield)
- 2 OB stave production sites necessary: CCNU/Wuhan, JINR/ Dubna, ?
- Target rate: 1 HS per week per site in average

MAPS-based Inner Tracker (IT) for the NICA/MPD





Inner Barrel

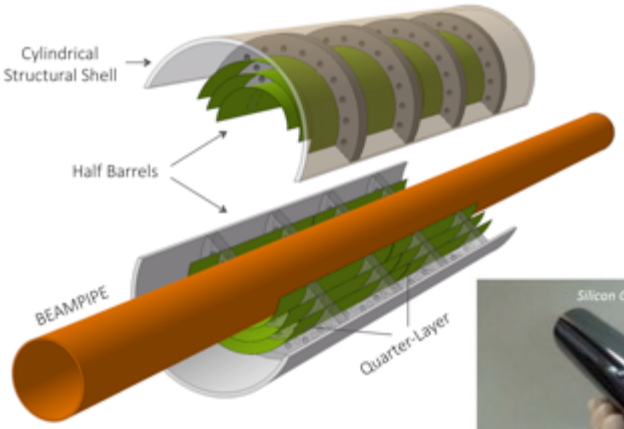
Radius (mm) 24, 43, 62
Nr. Staves: 12, 22, 32
Nr. Chips/ layer: 216, 396, 576

Length in z (mm): 542 mm
Nr. chips/ Stave: 18
Material thickness: ~0.3% X_0

Coolant Single-phase H_2O leak-less
Pixel operational temperature < 30°C
Pixel max temperature non-uniformity < 5°C
Chip Power dissipation < 50mW/cm^2

➢ IB HIC/Stave Option A (ALICE ITS2)

- 132 working HICs needed to assemble the IB barrel (double length of the IB staves of the ALICE ITS2)
- 218 assembled HICs assuming a total yield of 61%
- 240 assembled HICs with 10% spare
- 2 or 3 HIC production sites necessary: CCNU/Wuhan, JINR/Dubna, IMP?
- Target rate: 1 HIC per day per site in average, lasting for half year with 2 sites



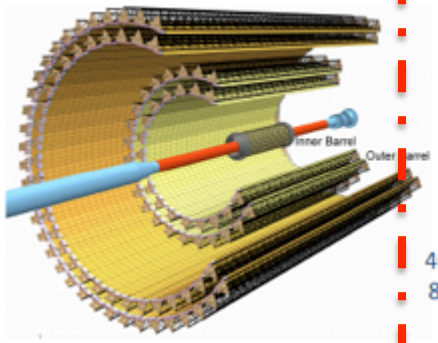
➢ IB HIC/Stave Option B (ITS3)

- Wafer-scale pixel sensor chip with spatial resolution better than 3 um and a time resolution of the order of 200 ns
- R&D will be started at CERN since 2019, which could benefit the IT of the NICA/MPD
- Production plan/strategy not defined yet

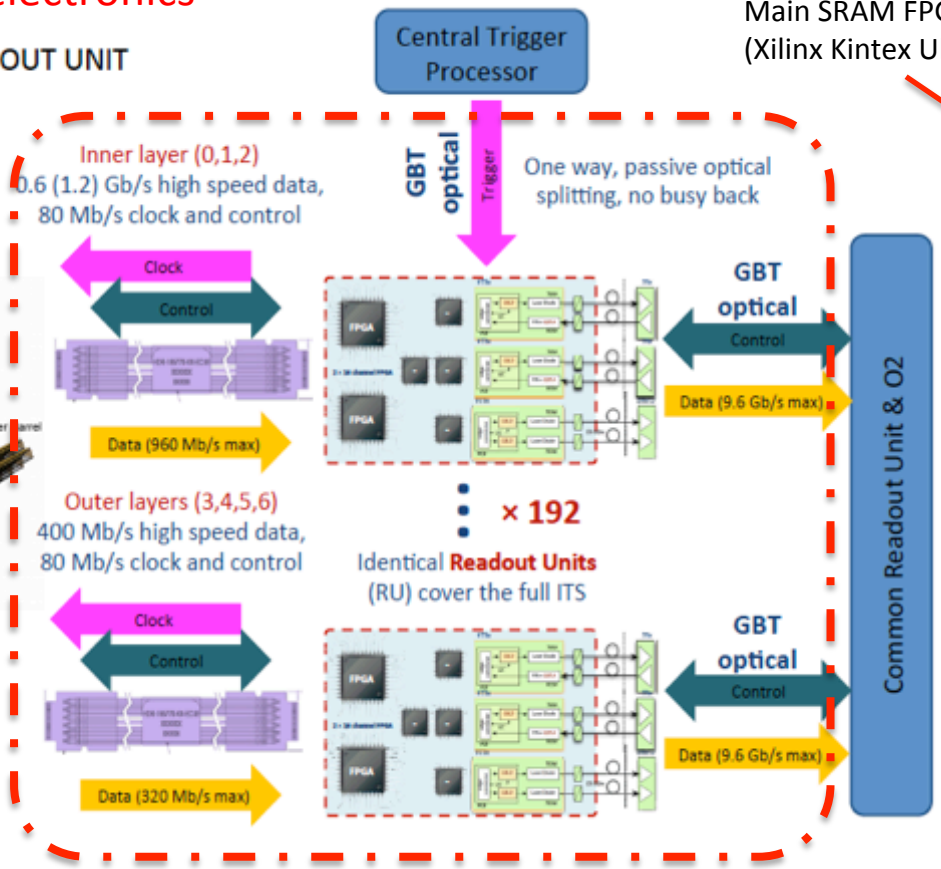
MAPS-based Inner Tracker (IT) for the NICA/MPD

ALICE ITS2 Readout electronics

Detector Readout ➔ 192 READOUT UNIT

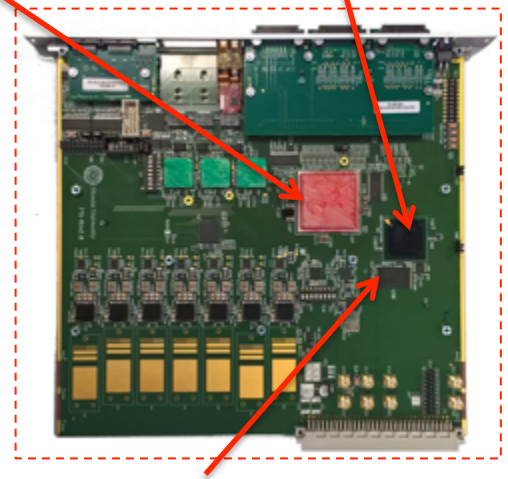


Each Readout Unit is connected to one stave both for Inner and Outer Barrels

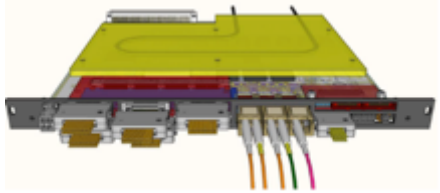


Main SRAM FPGA
(Xilinx Kintex Ultrascale)

Secondary FPGA
(Microsemi Proasic3)



FLASH memory (Samsung)



- ITS Frontend Electronics is subdivided into 192 Readout Unit (RU) modules, each connected to and control a stave and optically interfaced to the Common Readout Unit (CRU) and to the Central Trigger Processor (CTP)
- RU distributes trigger and control signals, interface data links to ALICE DAQ, control power supply of chips
- China side can contribute to the R&D of readout electronics and high speed data transition for the NICA/MPD IT

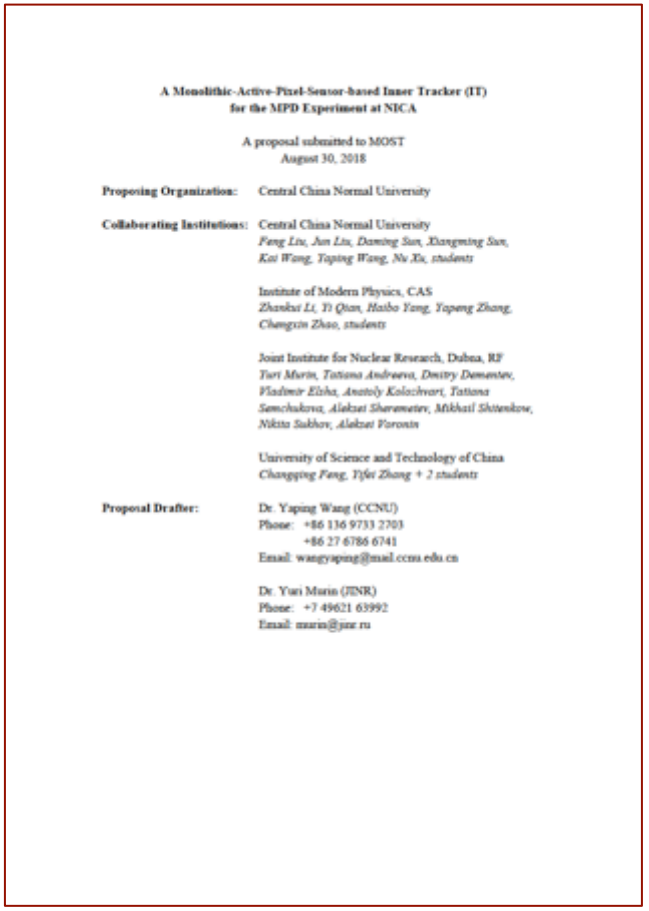
Plan & Effort from China for the NICA/MPD IT

Involved Institutions:

China side:
- Central China Normal University (CCNU)
- Institute of High Energy Physics (IHEP/CAS)
- Institute of Modern Physics (IMP/CAS)
- University of Science and Technology of China (USTC)

Russian side:
- Joint Institute of Nuclear Research (JINR)
- Moscow State University (MSU)
- Saint-Petersburg State University (SPBU)

CERN side:
- Luciano Musa (ALICE resources support)
- ……



A Monolithic-Active-Pixel-Sensor-based Inner Tracker (IT) for the MPD Experiment at NICA

A proposal submitted to MOST
August 30, 2018

Proposing Organization: Central China Normal University

Collaborating Institutions: Central China Normal University
Feng Liu, Jun Liu, Daming Sun, Xiangming Sun, Kai Wang, Yaping Wang, Nu Xu, students

Institute of Modern Physics, CAS
Zhanbai Li, Yi Qian, Haibo Yang, Yapeng Zhang, Chengxin Zhao, students

Joint Institute for Nuclear Research, Dubna, RF
Yuri Murin, Tatiana Andreeva, Dmitry Dementev, Vladimir Elsha, Anatoly Kolozhvari, Tatiana Samchukova, Aleksei Sheremetev, Mikhail Shitenkow, Nikita Sukhov, Aleksei Voronin

University of Science and Technology of China
Changqing Feng, Yifei Zhang + 2 students

Proposal Drafter: Dr. Yaping Wang (CCNU)
Phone: +86 136 9733 2703
+86 27 6786 6741
Email: wangyaping@mail.ccnu.edu.cn

Dr. Yuri Murin (JINR)
Phone: +7 49621 63992
Email: murin@jinr.ru

Technical goals:

1) master techniques for design & production of the state-of-the-art MAPS technology
2) master techniques for constructing the high-tech vertex detector within China
3) master the necessary techniques for operation of the vertex detector including calibration, daily running and maintenance

Plan & Effort from China for the NICA/MPD IT

NICA-China Consortium Pre-proposal to MOST

The Nuclotron-based Ion Collider fAcility (NICA) at the Joint Institute for Nuclear Research (JINR) in Dubna, Russia will provide high luminosity hadron-nucleus and nucleus-nucleus collisions over the center-of-mass energy range of 4-11 GeV per nucleon-nucleon pair in collider mode. The main physics goals of NICA are to create and study a new state of matter at high baryon density and to search for exotic particles. The physics to be addressed include hadron-QGP (quark-gluon plasma) phase transition, the critical point of the QCD (quantum chromodynamics) phase diagram, the interactions among quarks and gluons and their hadronization process, and the initial state and the evolution of the early universe. These physics goals represent human's next quest for the understanding of the inner working of nature, beyond the levels of atoms and nuclei, and are of fundamental importance.

The Multi-Purpose Detector (MPD) experiment at NICA is a collider experiment, composed of several detector subsystems, including Silicon-based Inner Tracking System (IT), the Time Projection Chamber (TPC), the Time-Of-Flight (TOF), the Electromagnetic Calorimeter (ECAL) and etc. Some of these detectors (e.g. ECAL) have not been built, and some others will need upgrade in readout electronics. In order to fully realize the physics goals, a complete suite of the detector subsystems is essential. Equally essential are the accelerator and energy storage technologies. We therefore propose and seek funding for the following projects (total ¥268 million):

1. Development and construction of ECAL (estimated cost ¥100 million RMB): Led by Tsinghua University (Coordinator: Yi Wang)
2. Development of endcap TOF and electronics (estimated cost ¥25 million RMB): Led by University of Science and Technology of China (Coordinator: Zebo Tang)
3. Development and construction of IT (estimated cost ¥50.75 million RMB): Led by Central China Normal University (Coordinator: Yaping Wang)
4. ECAL front-end readout chip design and production (estimated cost ¥13 million RMB): Led by Central China Normal University (Coordinator: Xiangming Sun)
5. Theory (estimated cost ¥5 million RMB): All participating theory groups (Contact person: Zuotang Liang)
6. Detector and physics simulations (estimated cost ¥4.25 million RMB): Led by Tsinghua University (Coordinator: Zhigang Xiao)
7. Design, manufacture and test of SMES (estimated cost ¥29.38 million RMB): Led by Institute of Plasma Physics CAS (Coordinator: Jinxing Zheng)

✓ Pre-proposal submitted to MOST in 2018

Cooperation Agreement between the JINR/NICA Megaproject and the Key Laboratory of Quark and Lepton Physics of Ministry of Education (MOE) of China at Central China Normal University (CCNU)

On the joint evaluation
technologies for developme
systems for the experiment
2019-2

September 21, 2018

Cooperation Agreement for the Silicon Pixel Detector in 2019-2025

The JINR/NICA Megaproject
And
The Key Laboratory of MOE (CCNU)

This is hereby to declare that the Parties agree to the all terms in the agreement for the cooperation on the JINR/NICA MPD project.

Signed in Dubna on

Prof. Vladimir Kekelidze
Vice Director, JINR

Signed in Wuhan on

Dr. Nu Xu
Dean of the Key Laboratory of MOE (CCNU), Wuhan

✓ CCNU-JINR cooperation agreement on MPD/IT signed in 2018

Plan & Effort from China for the NICA/MPD IT

Cost estimate (2019~2023):

This is a joint project between China and Russia, with roughly equal contributions (China $8.12M USD, Russian $8.2M USD)

Timeline:

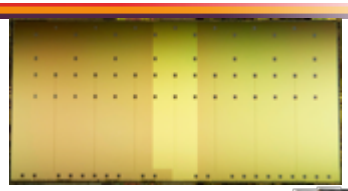
Timeline	Tasks
2019	• infrastructure and tooling/jigs preparation • Simulation, CDR, TDR
2020	• R&D of MAPS chips and FPCs • Readout electronics R&D (e.g. high speed, radiation hard Data Transmission Channel) • Chip / FPC mass production (ALPIDE)
2021	• Stave development & mechanics • Global mechanics development • OB HIC/stave mass production
2022	• Readout production • OB HIC & stave mass production • IB HIC / Stave R&D
2023	• Installation, Integration, commissioning, etc. • IB HIC/Stave R&D, prototyping

Plan & Effort from China for the NICA/MPD IT

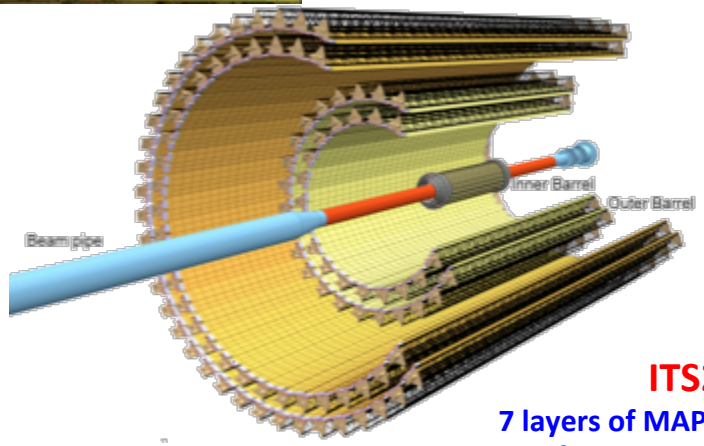
- Consortium within China need to be constructed
- Consortium between China and Russia also need to be constructed
- Regular workshop/meeting with all involved institutions (every half year or shorter) to be organized
- Infrastructure/jigs preparations (including HIC and stave assembly and testing) for detector construction sites
- Technician training on detector (HIC/stave) assembly & testing
- Readout electronics, data transition, …
- Databases preparation, construction and running for the materials, assembly, testing
- Testing software, online/offline software …
- All the above items need to be clear and detailed discussions

Effort on the ALICE ITS Upgrade from CCNU

- Contribute to the ALICE/ITS upgrade at LS2
  - ➢ ALPIDE chip design: (1) Matrix readout architecture; (2) Pixel analog front-end revision and optimization.
  - ➢ ITS OB HIC assembly R&D, construction, and testing
    - ✓ Clean room commissioning in Nov. 2016
    - ✓ Assembly R&D and technician training in 2017
    - ✓ Pre-series production started in Dec. 2017
    - ✓ Series production started in April 2018, to be ended in May 2019 (2~3 HICs/day, ~450 HICs in total)
    - ✓ Commissioning, calibration and alignment since 2019



ALICE PIxel Detector (ALPIDE)



ITS2

7 layers of MAPS

12.5G pixels, ~10 m^2 active area

ISO6 Clean room @ CCNU
(Temperature/humidity controllable，~100 m^2)

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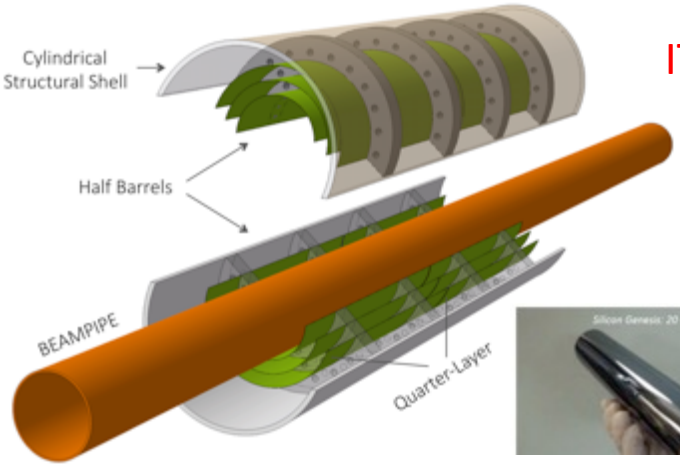
- R&D on wafer-scale MAPS chip design with CERN team for ITS3 (ALICE Upgrade beyond 2020, LS3)

ITS3



- Wafer-scale pixel sensor chip with spatial resolution better than 3 um and a time resolution of the order of 200 ns

ISO6 Clean room @ CCNU
(Temperature/humidity controllable, ~100 m²)

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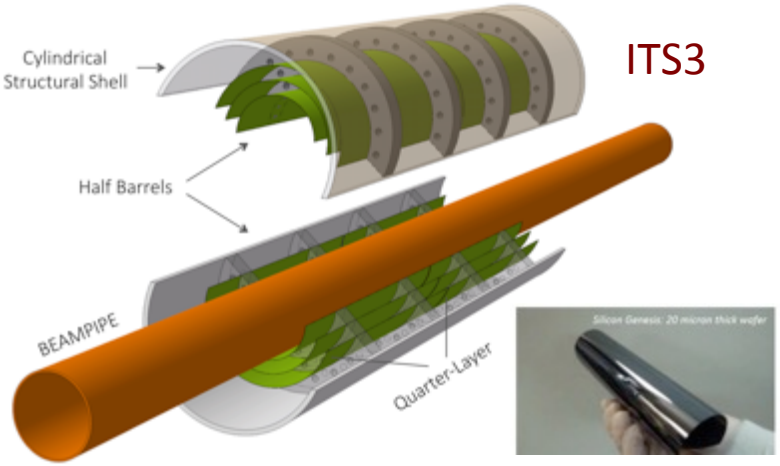

ITS3

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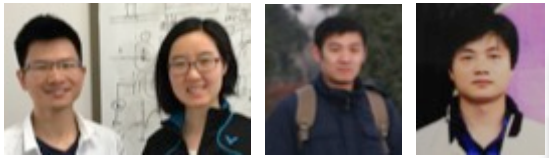
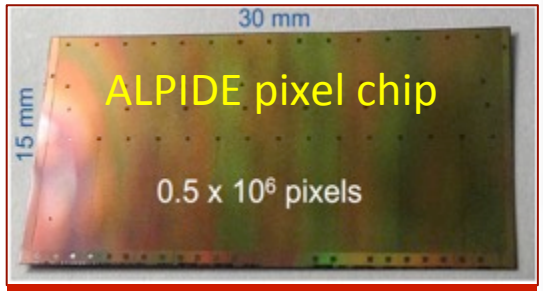




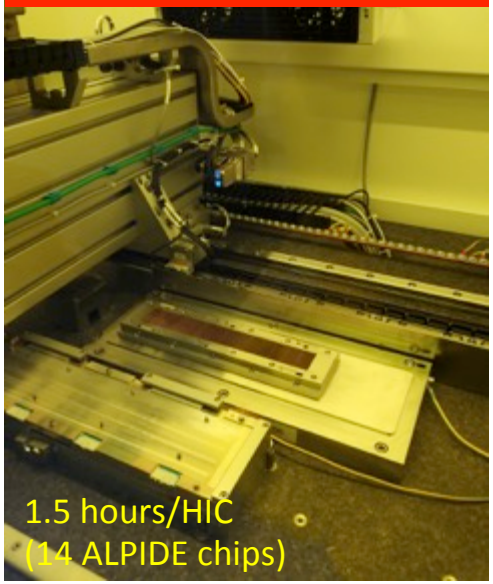
ALICE/ITS Chip Design / HIC Assembly R&D（CCNU）:
Chaosong, Ping, Mangmang, Shuguang

ALICE/ITS OB HIC Assembly Team（CCNU）:
Biao、Jun、Daming、Kai、Peipei、Wenjing

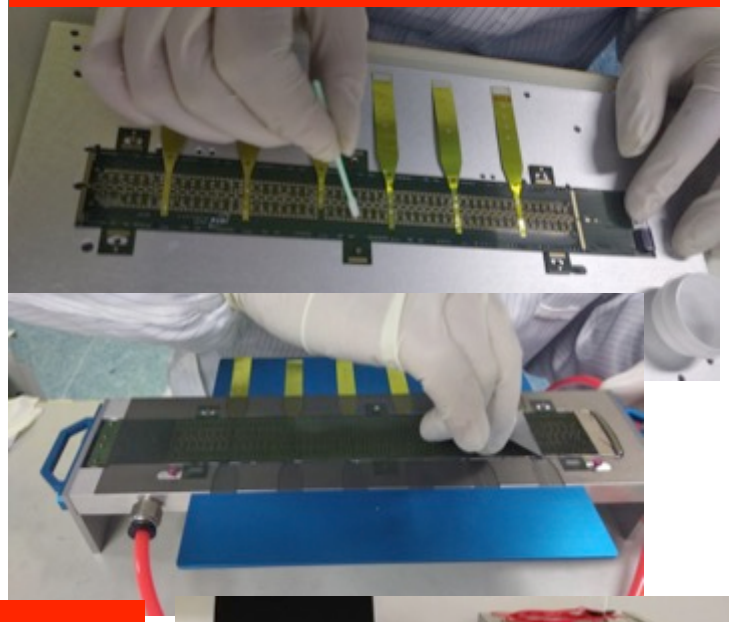
Yuri Murin, YPW, Johann Heuser @ CCNU, Sept., 2017

Effort on the ALICE ITS Upgrade from CCNU

1. Chip Alignment

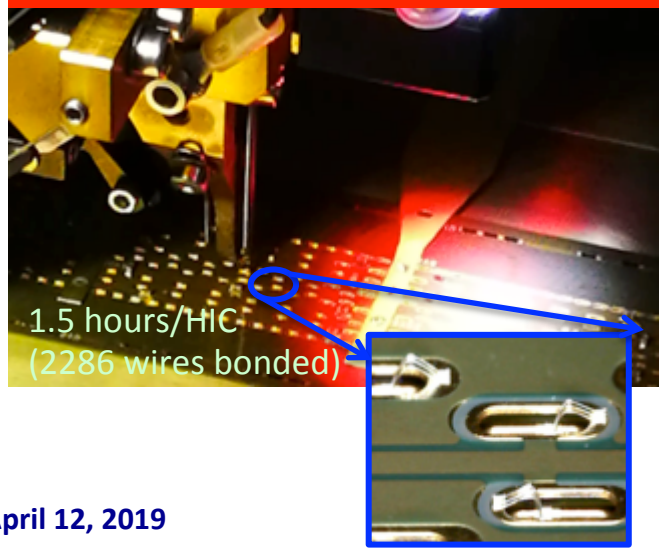


2. FPC preparation & glue spreading



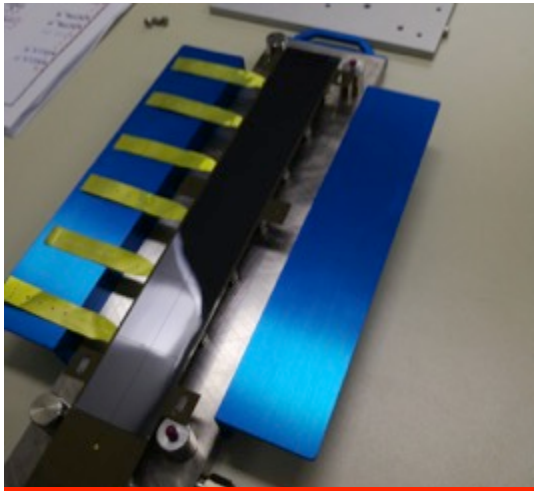
3. Pre-curing & fully curing

4. Wire-bonding



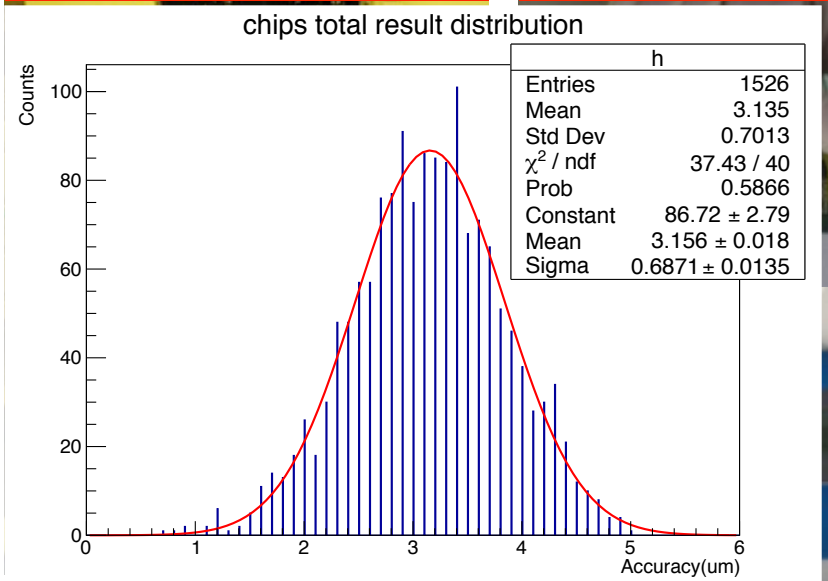
5. Qualification & endurance testing

6. Assembled ITS OB HIC



Effort on the ALICE ITS Upgrade from CCNU

1. Chip Alignment



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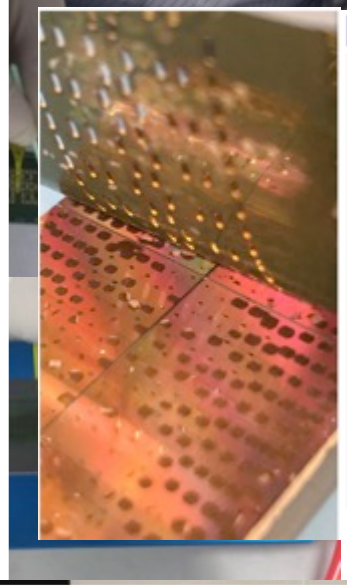
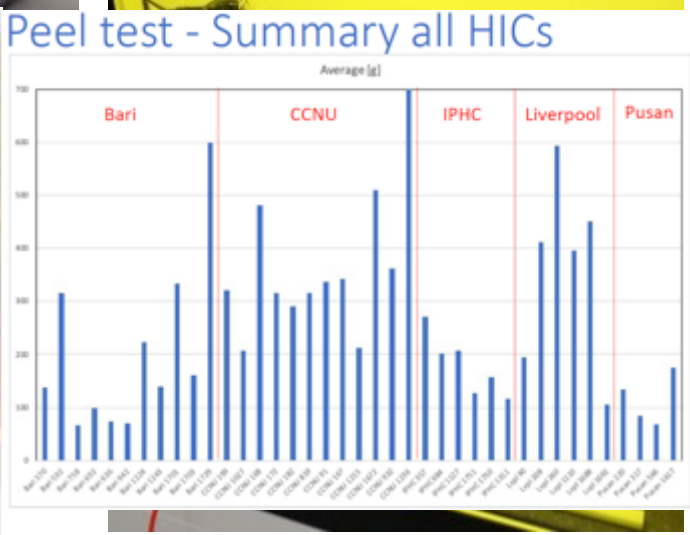
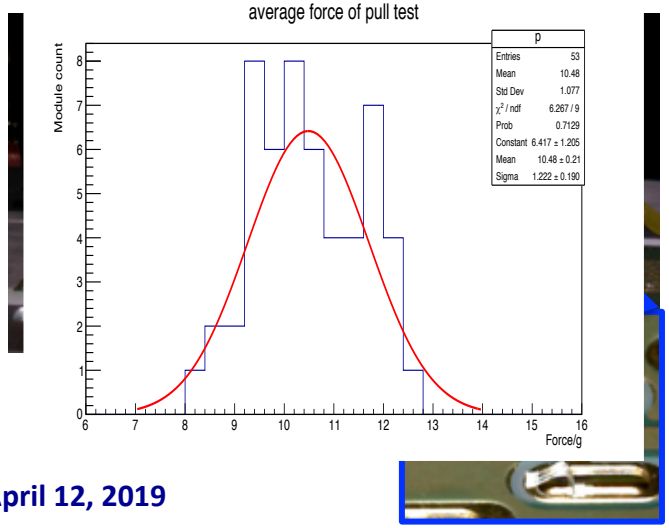
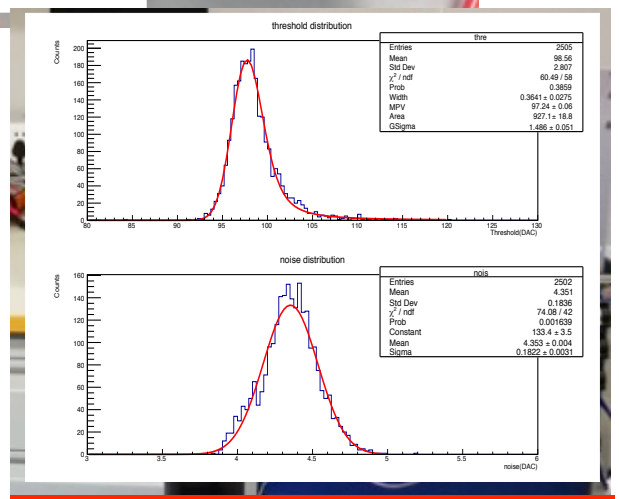


3. Pre-curing & fully curing

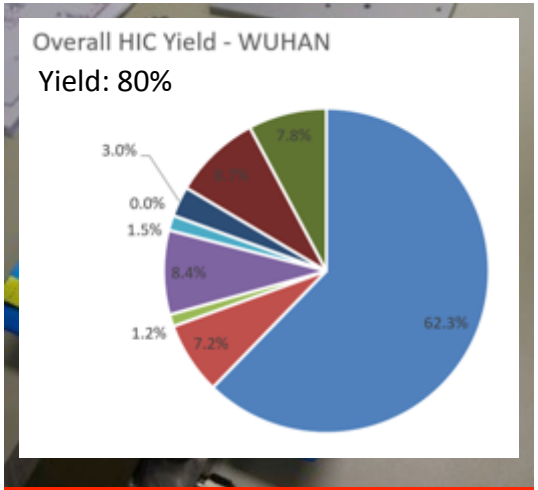


4. Wire-bonding





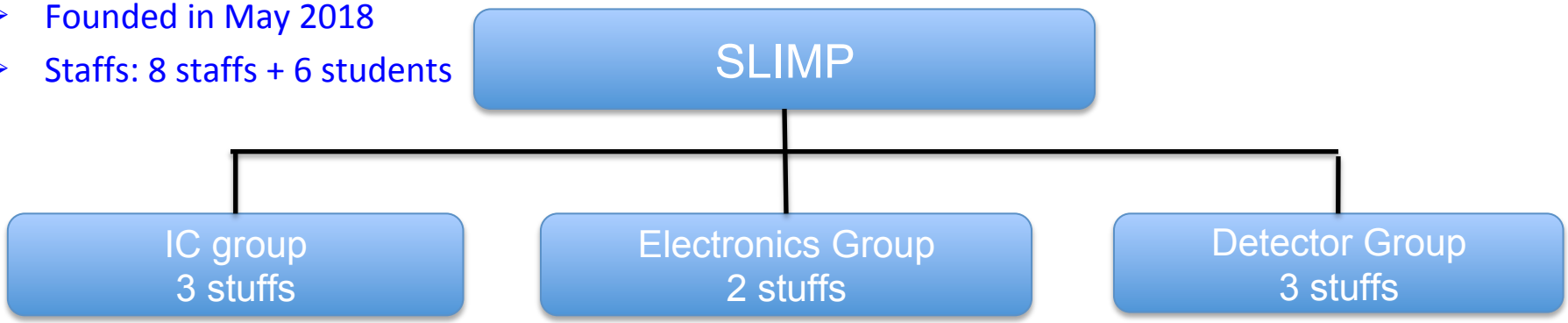
5. Qualification & endurance testing



6. Qualified ITS OB HIC

Feasibility Effort on the MPD/IT from IMP

- SLIMP (Silicon Lab at IMP)
- **Interests in MPD: Pixel Chip design, readout electronics, detector packaging and test**
- Founded in May 2018
- Staffs: 8 staffs + 6 students

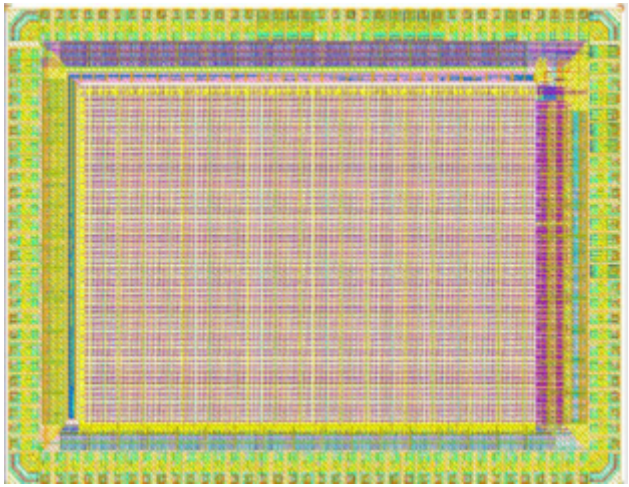


- ~4 million has been invested to build the lab (Phase 1)
- ISO6 (~25㎡), ISO7 (~35㎡) and System lab (~70㎡)
- Manufacture line for pixel detector: bonding machine, pull tester, dicing saw, probe station …



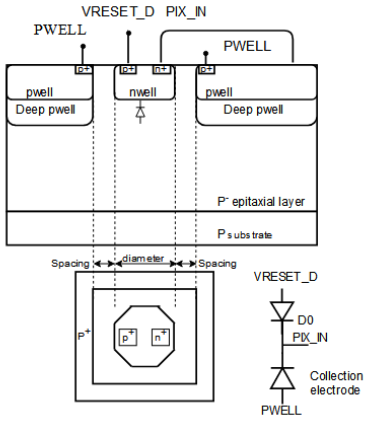
Feasibility Effort on the MPD/IT from IMP

Pixel Chip design

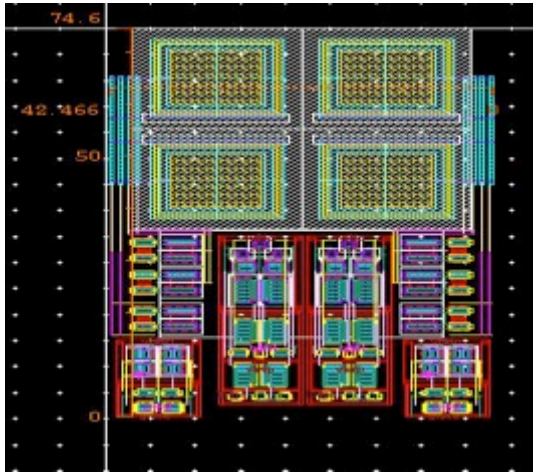


- Topmetal-M (With CCNU)
- Size: 3cm x 1.5cm
- Spatial Resolution: ~10um
- Pixel Array： 500 x 210
- Based on 0.13um Process from Huahong Corporation
- Design will be finished at the end of April, 2019

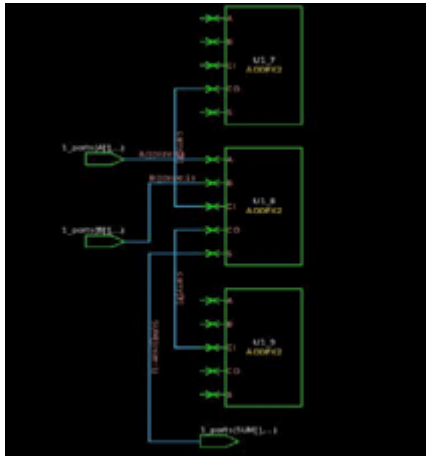
Key Logic R&D for future Pixel Chip



- High Performance Sensing Node



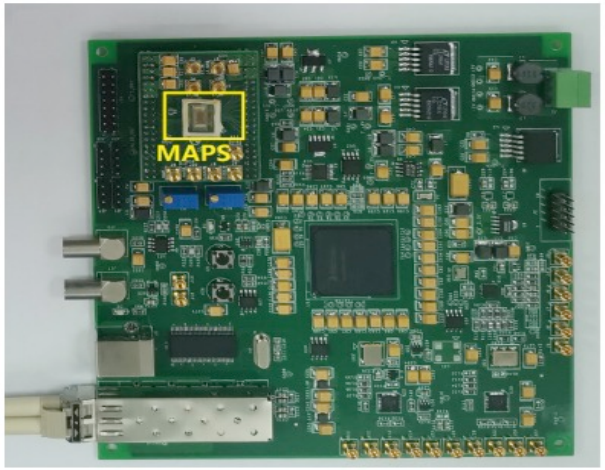
- Low power Collum ADC

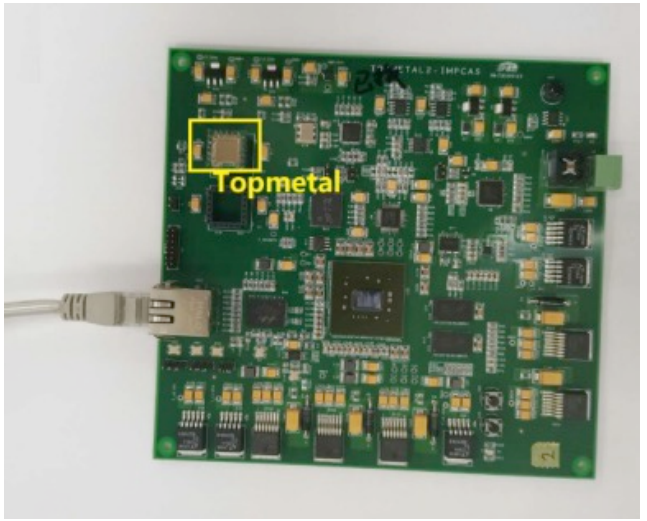


- Fast Centroid Finder

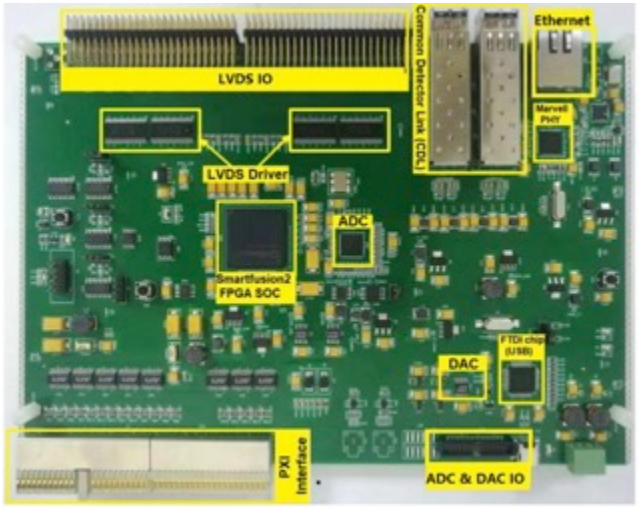
Feasibility Effort on the MPD/IT from IMP

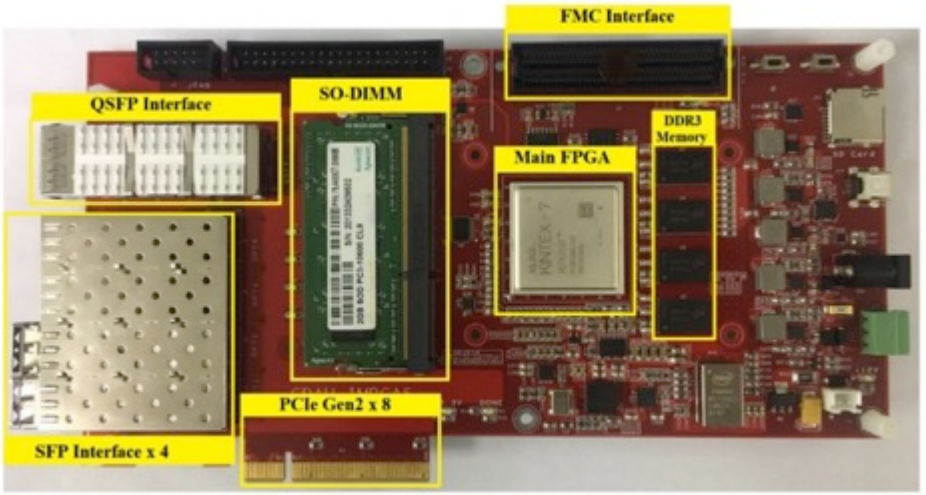
- Front-end Electronics for pixel detector (MAPS and Topmetal)





- Common Readout Electronics for particle experiments (HCRU and CDAU)





Summary and Outlook

- MAPS-based Inner Tracker has been proposed to be constructed for the NICA/MPD, and it's scheduled to install the 2-layers outer barrel in its 1st phase (before 2023)

- Pre-proposal from China side has been submitted to the MOST for funding support, seems very positive!

- Infrastructure preparation and technician training with the support of ALICE ITS upgrade project will be discussed

- Facilities are under construction from China institutions, and CCNU team can transferred to MPD/IT project after the ALICE ITS upgrade.

Thanks for your attention!