Silicon detector activities in Korea

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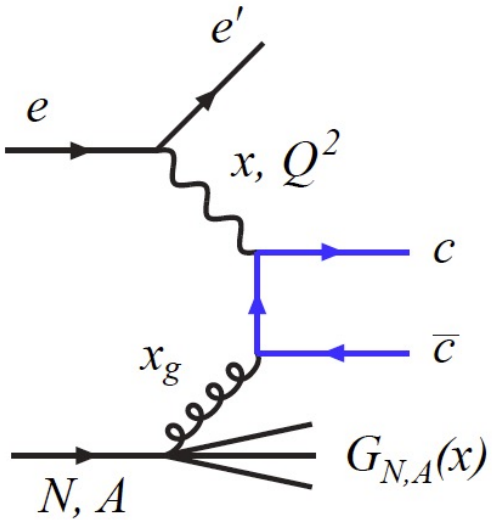
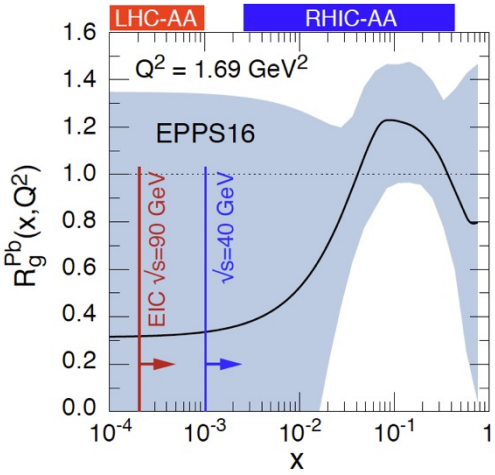
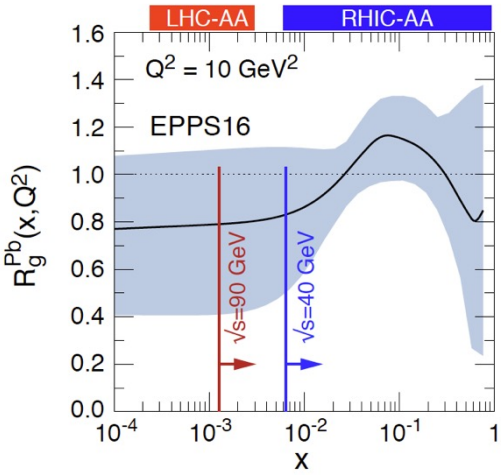
Pusan National University

PSQ@EIC 2021

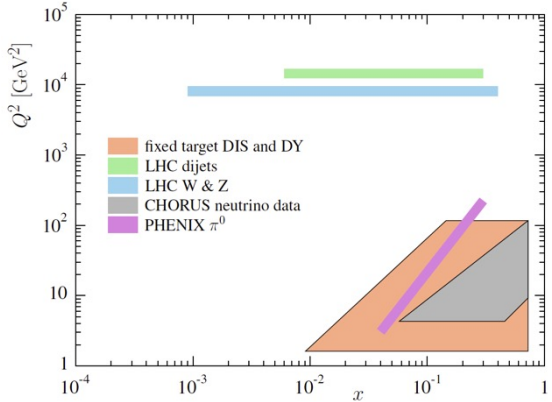
Gluon PDF in necleus
at the Electron-Ion collider

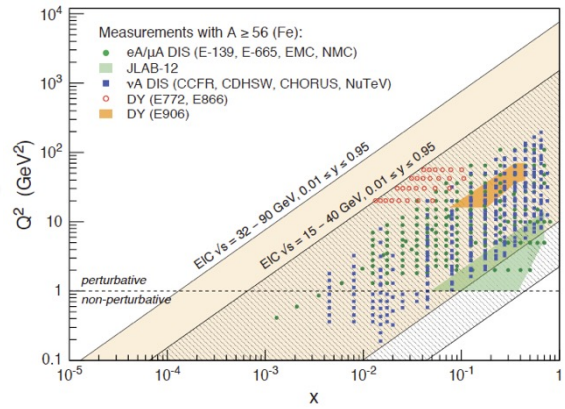






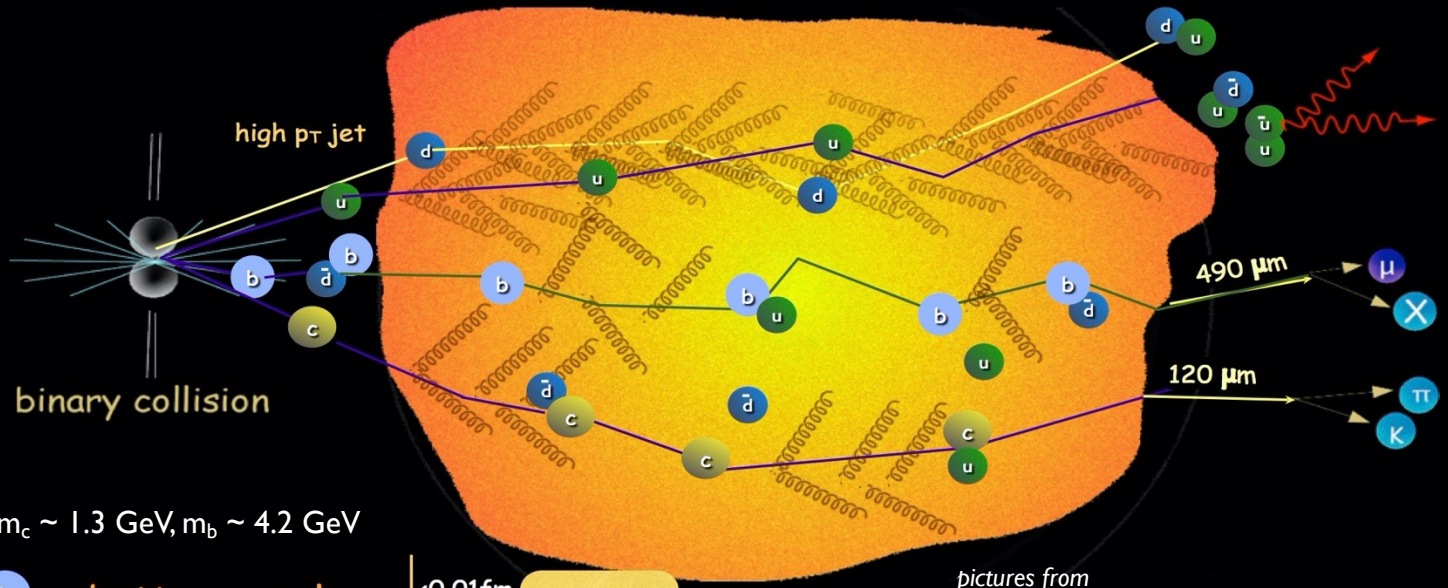
Kinematic range for nuclear PDF





EPPS16 nPDF **EIC**

Study of heavy-flavor in heavy-ion experiments



m_c ~ 1.3 GeV, m_b ~ 4.2 GeV

b bottom quark

c charm quark

quark or gluon jet

thermalized QGP

D meson

B meson

<0.01fm 0.4 fm

<0.07fm 1.5 fm

~20 fm decay

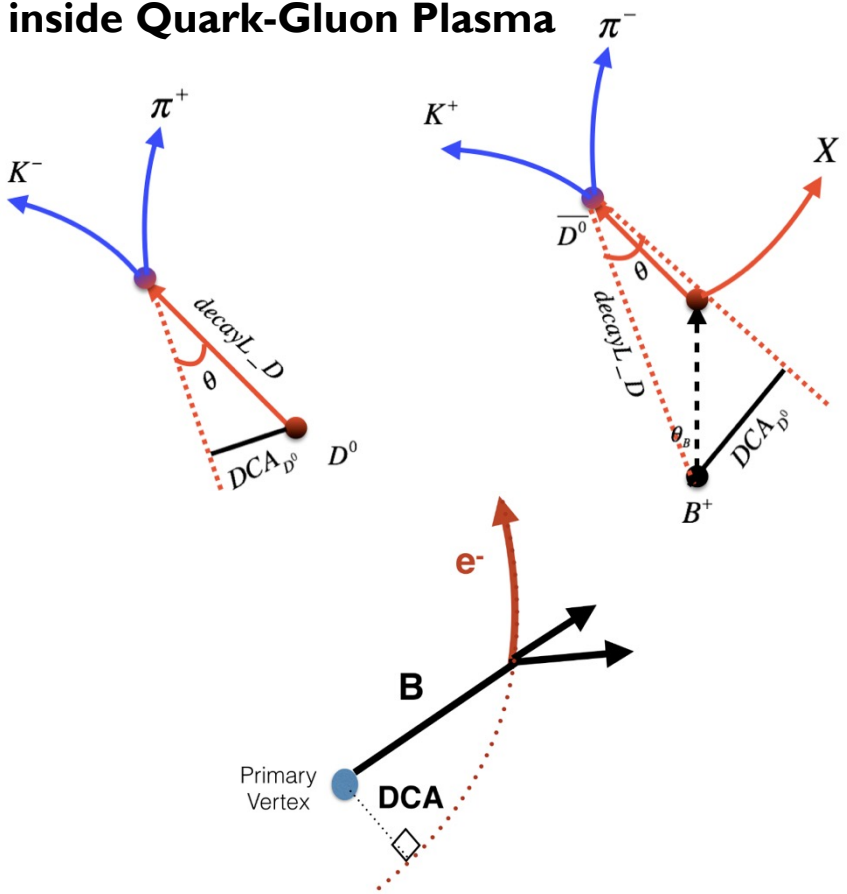
~0.6fm ~5 fm

dissociation, coalescence,drag decay

dissociation, coalescence,drag decay

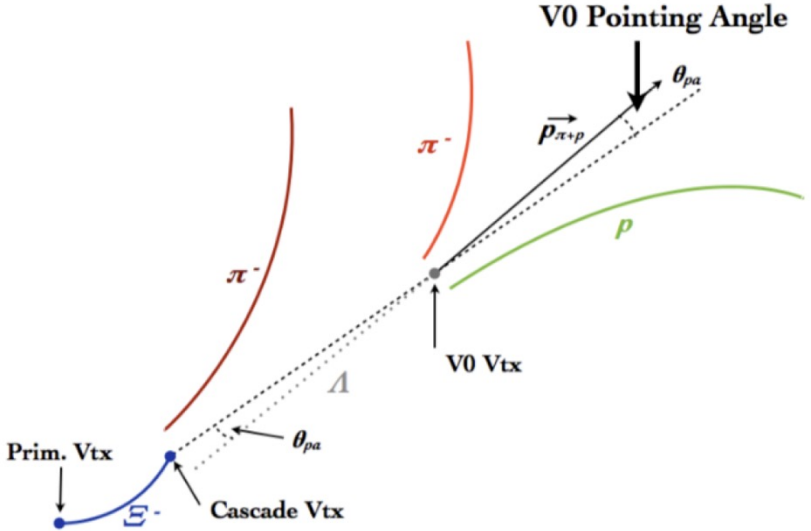
pictures from
Cesar Silva's slides
numbers from
A. Adil, I. Vitev, PLB649 (2007) 139

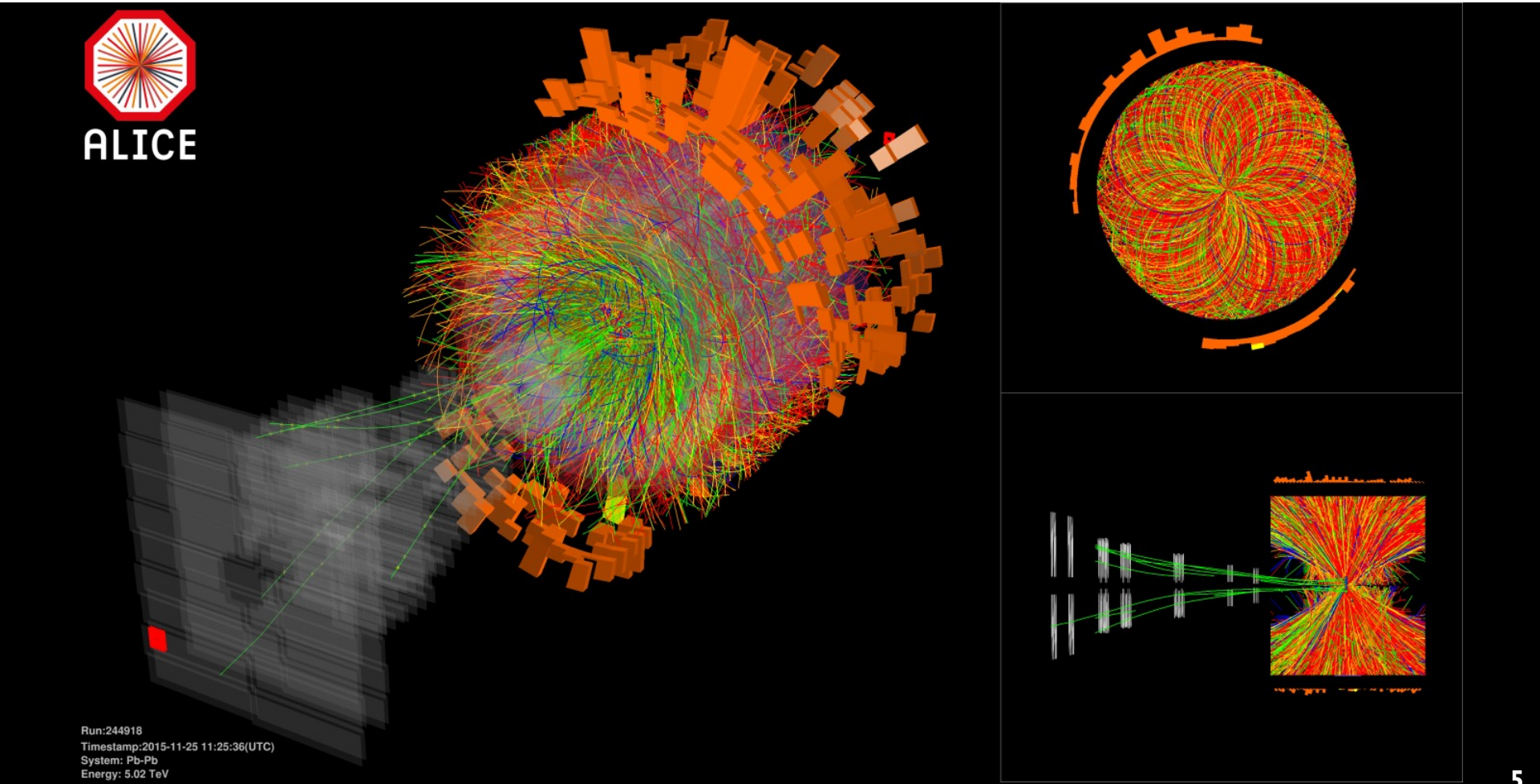
Response of heavy quarks inside Quark-Gluon Plasma



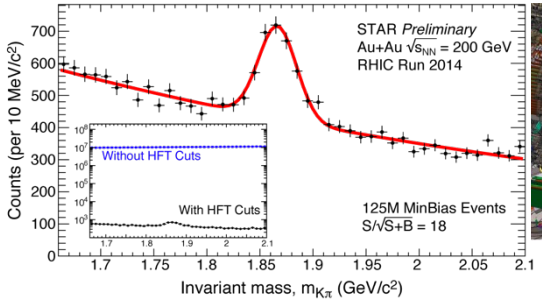
Hadronization of heavy quarks

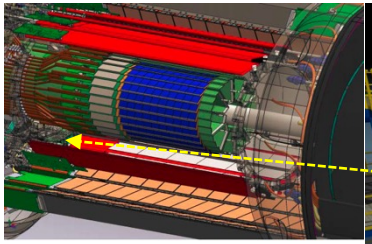
$$\Xi_c^0 \to e^+\Xi^-\nu \to e^+(\pi^-\Lambda)\nu \to e(\pi p\pi)\nu + c.c.$$



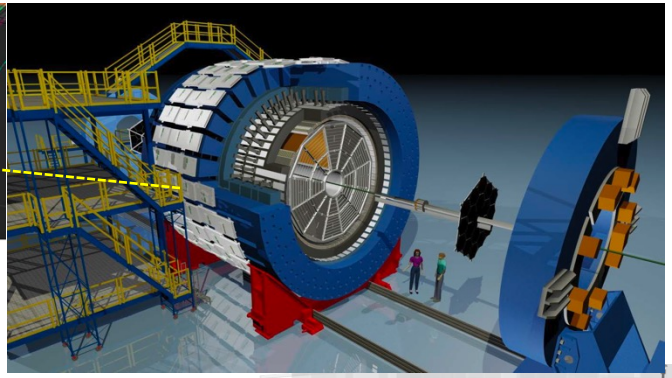

ALICE
Run:244918
Timestamp:2015-11-25 11:25:36(UTC)
System: Pb-Pb
Energy: 5.02 TeV

MAPS based vertex detector

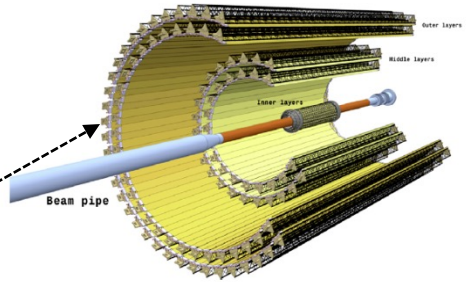


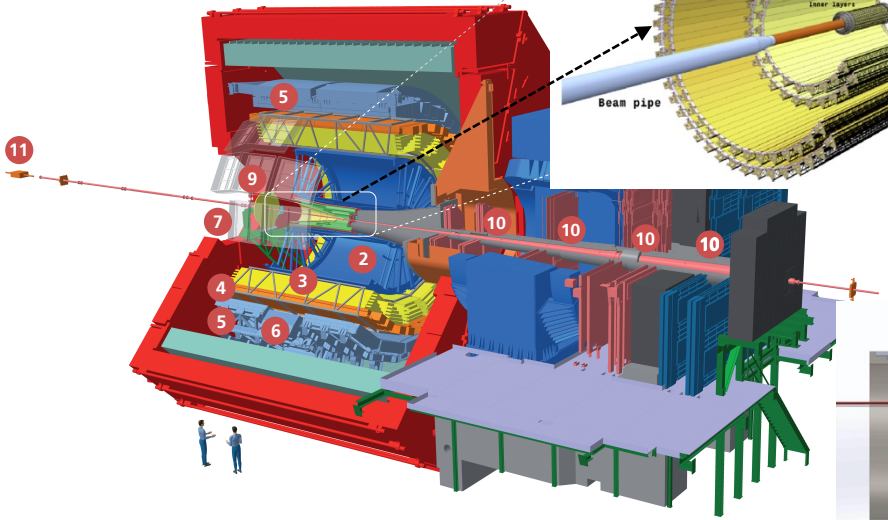


STAR HFT

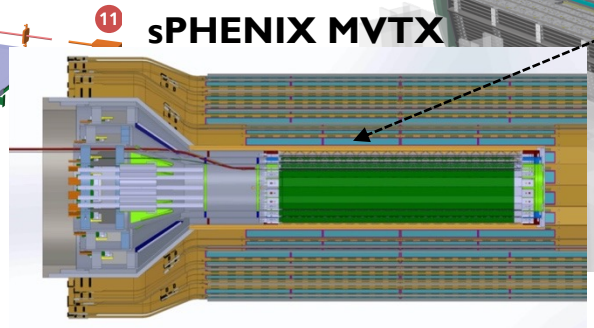


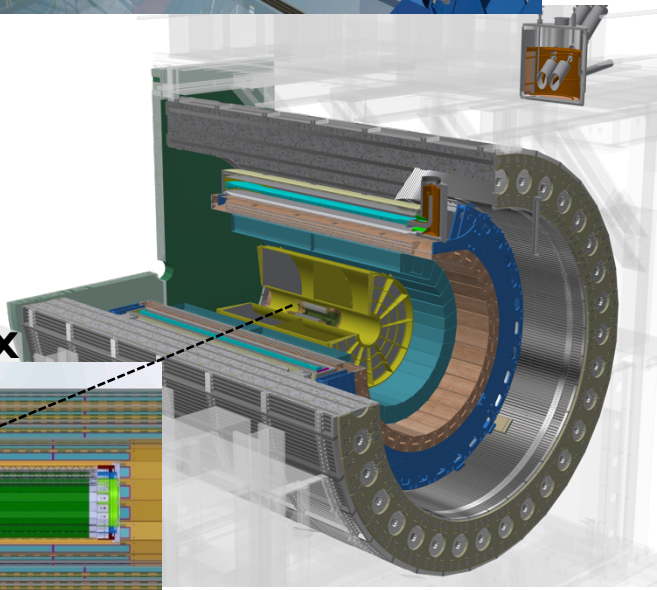
ALICE ITS2





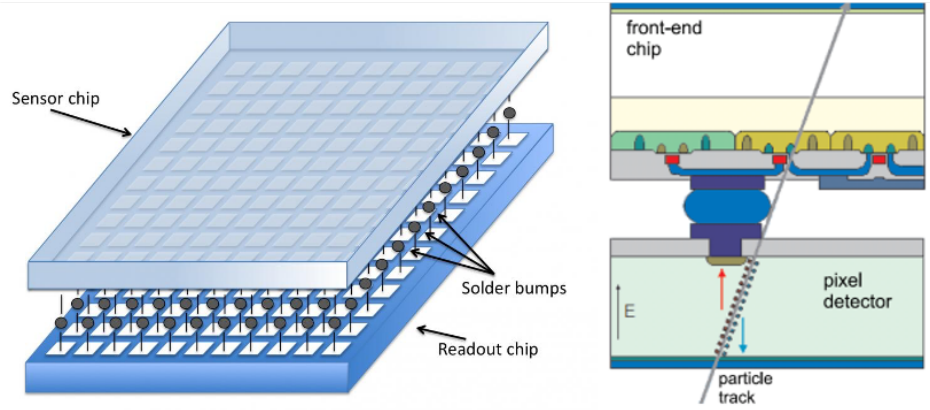
sPHENIX MVTX





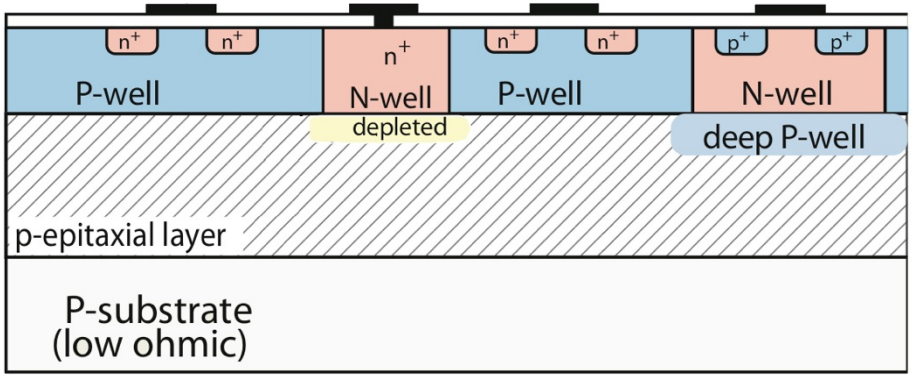
Monolithic Active Pixel Sensor (MAPS)

Hybrid
:Sensor and readout electronics separated

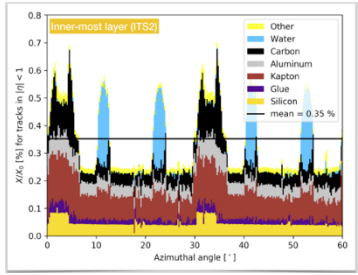


- **Majority of currently used silicon detectors**
- **Can be optimized sensor and readout electronics separately**
- **Large power consuption and material budget**

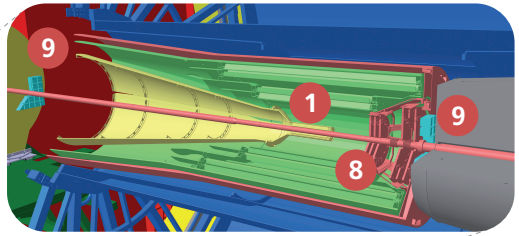
Monolithic
:Sensor and readout electronics integrated

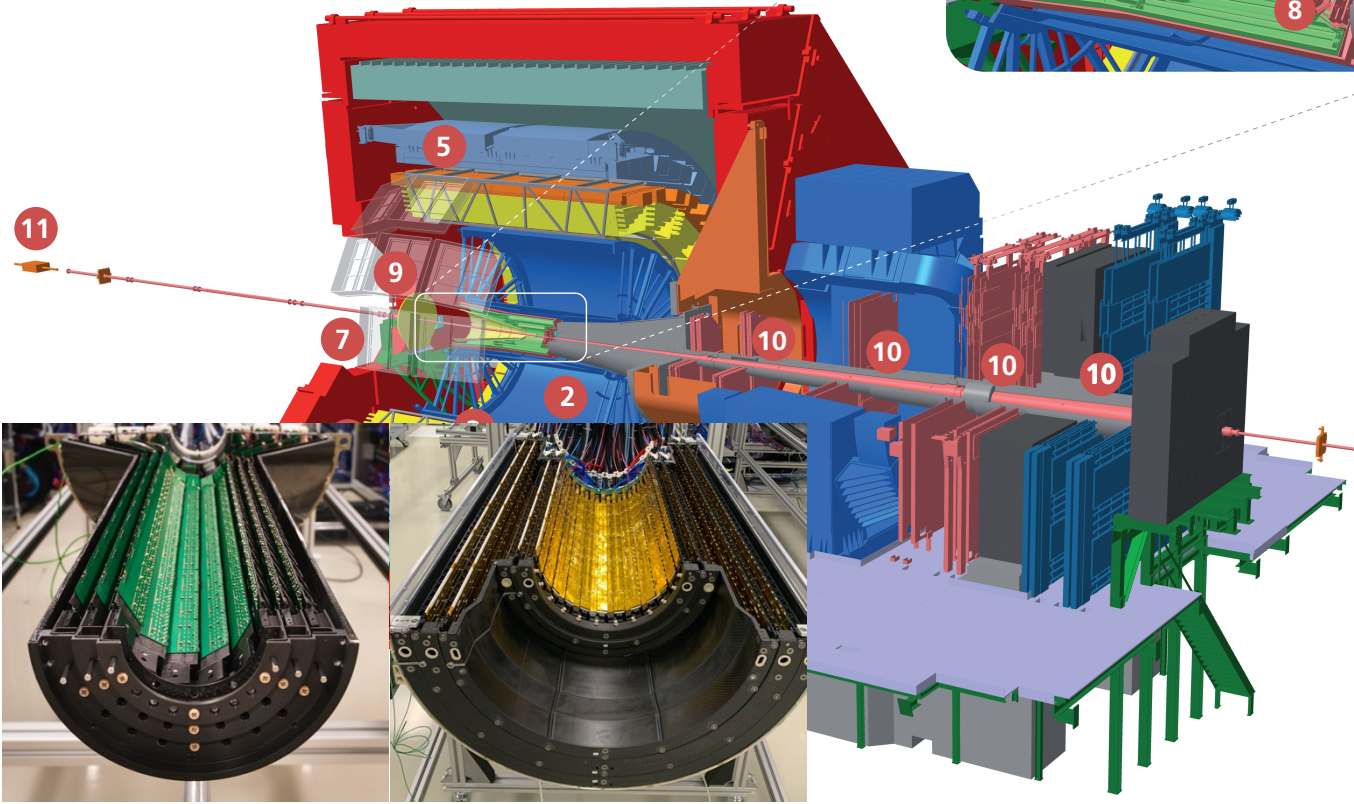


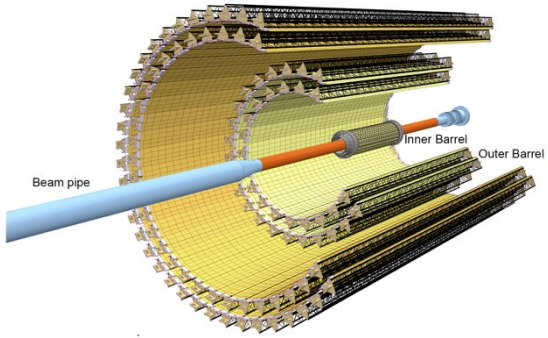
- **Recently developed and used (first generation for STAR HFT)**
- **Easier integration**
- **Lower power consumption and material budget**
  1.14% X_0 → 0.3% X_0



Monolithic Active Pixel Sensor Technology
~13x10⁹ pixels (pixel size: 29 μm x 27 μm)

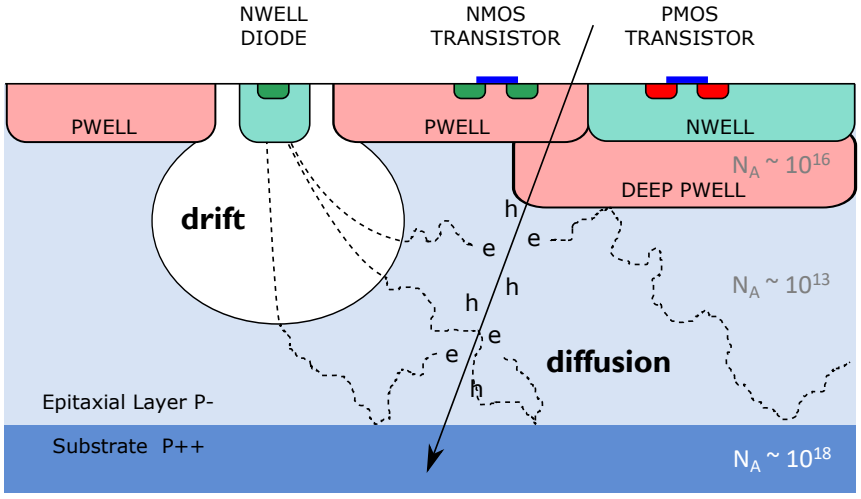


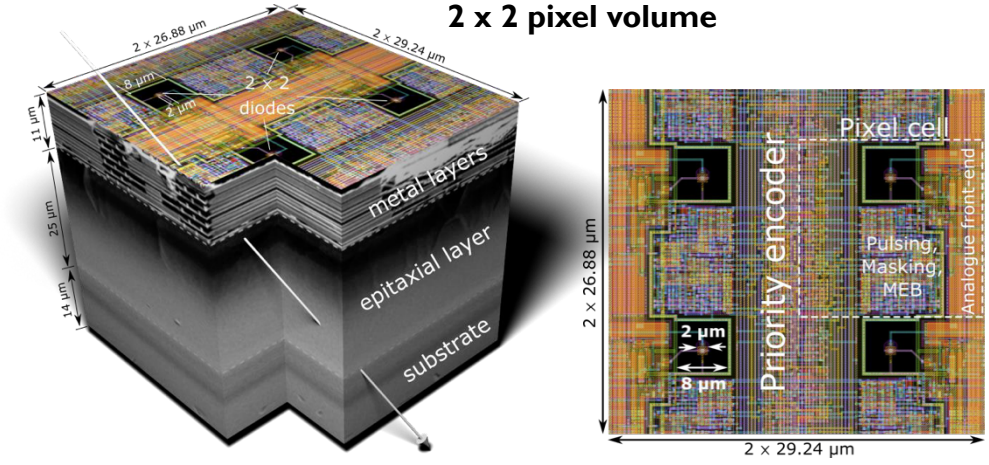




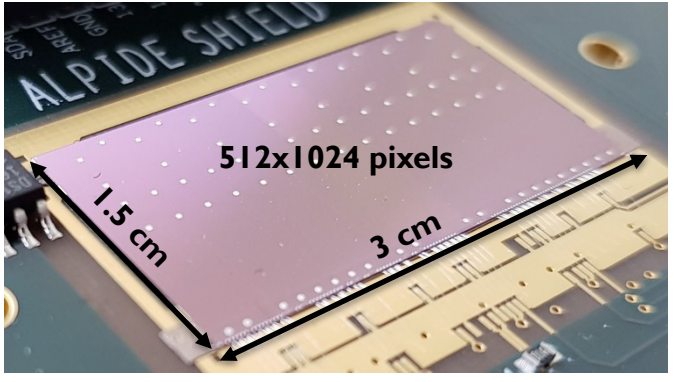
- 7 layers
- All silicon pixels
- Chip tickness
  Inner 3 layers: 50 um
  Outer 4 layers: 100 um
- Rate capability
  ~100 kHz Pb+Pb

CMOS pixel sensor using 180 nm CMOS Imaging Process

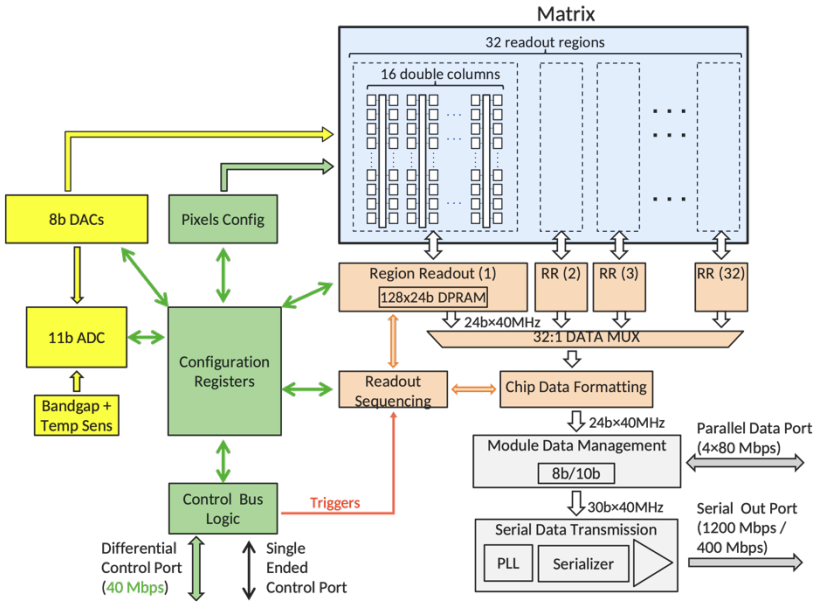


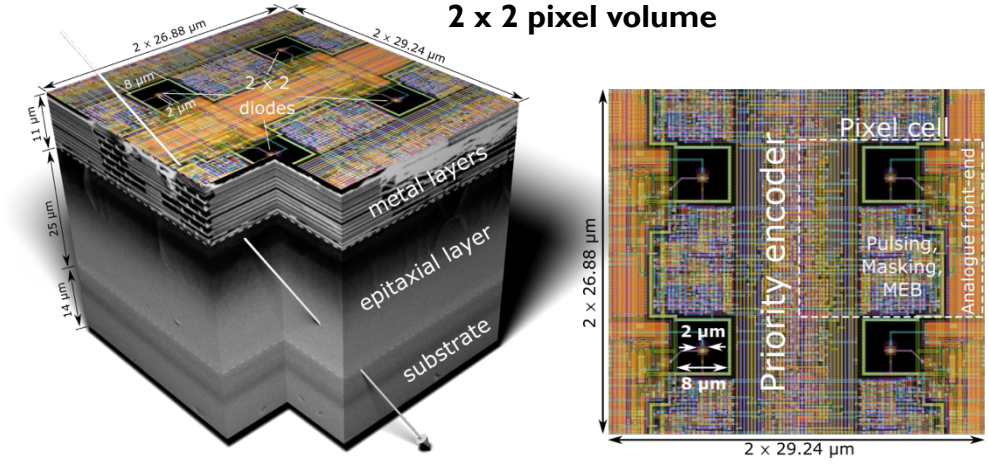


- High-resitivity (>1 kΩ cm) p-type epitaxial layer (25 µm) on p-type substrate
- Small n-well diode (2 µm diameter) ➔ low capacitance (~5 fF)
- Reverse bias voltage (-6V < V_{BB} < 0V) to substrate to increase depletion region (<30 ns charge collection time with V_{BB} =-3V)
- Deep p-well shields n-well of PMOS

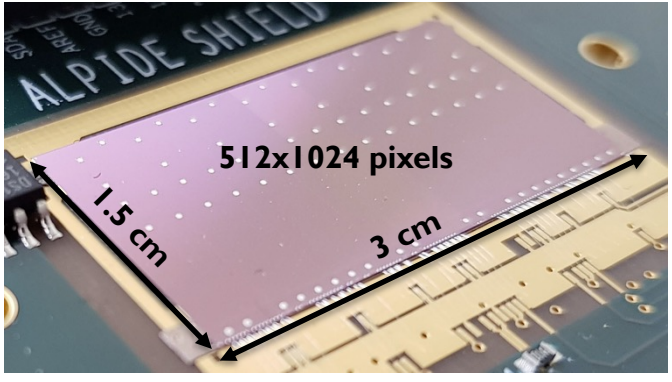


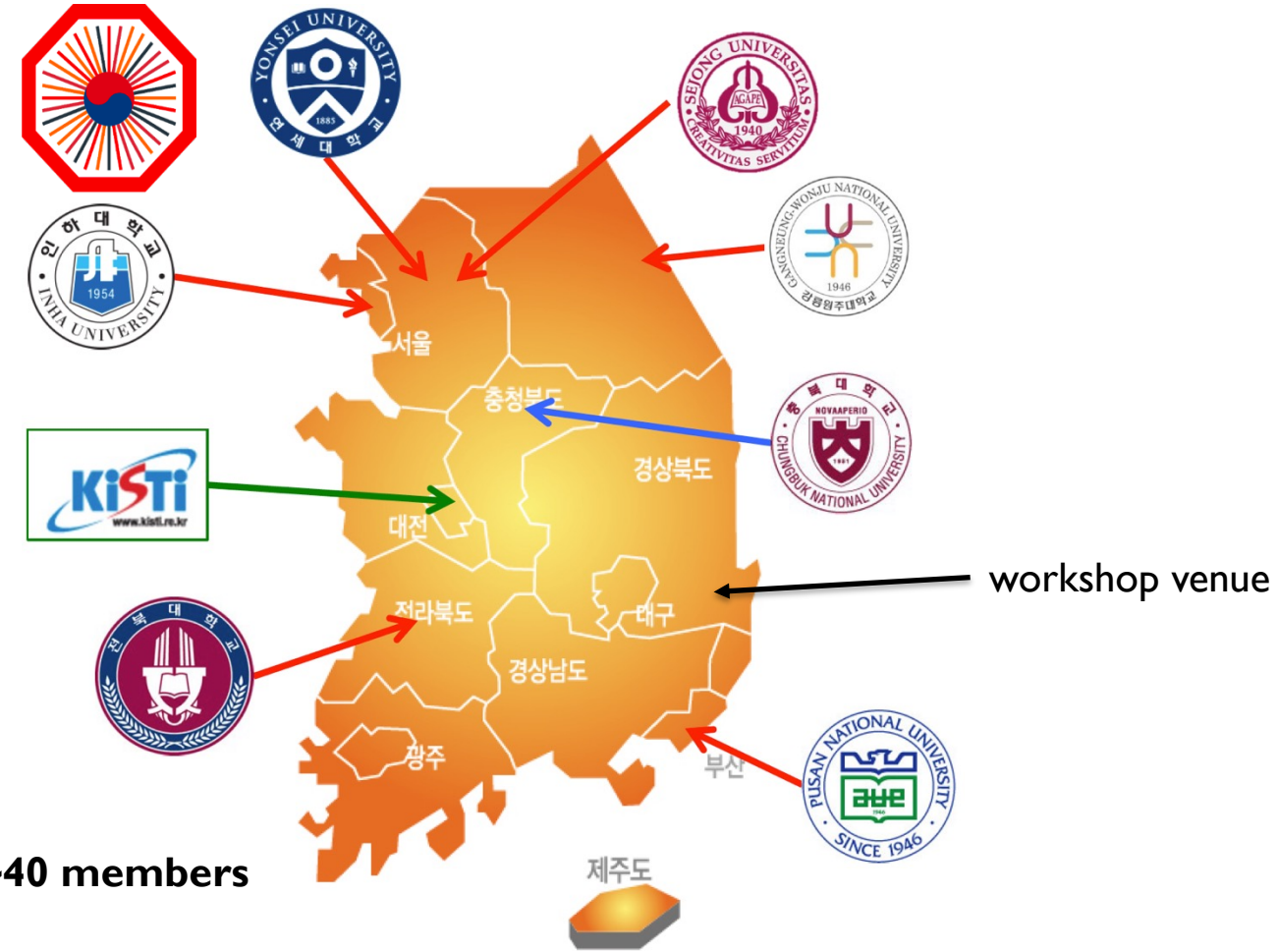
Fully integrated signal processing





- **Front-end**
  shaping time: <10 µs
  power consumption: ~300 nW/pixel (<40 mW/cm^2)
- **Multi-event memory: 3 stages**
- **Fake-hit rate: <1 Hz/cm^2**
- **Triggered or consinuous readout mode**

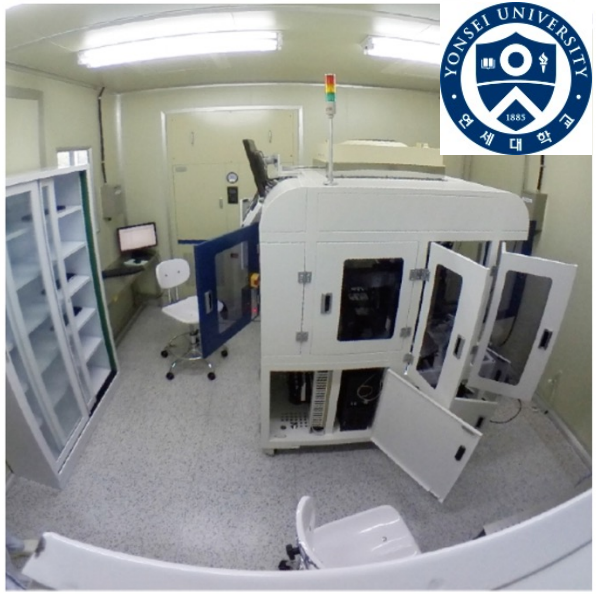




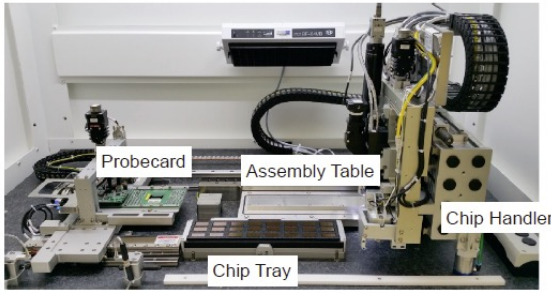
- **8 institutions and ~40 members**

KoALICE contribution to the ALICE ITS2

PNU/Inha University

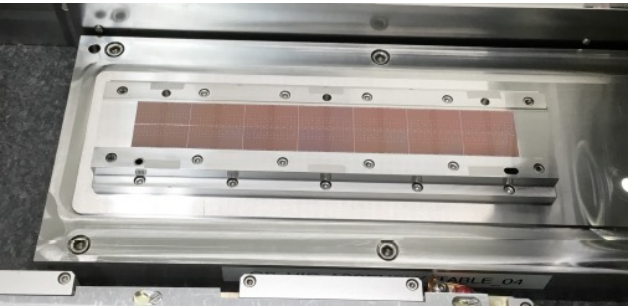


Yonsei University



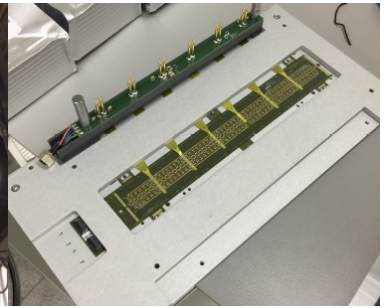
- Caracterization of Pixel Sensor Chip
- Chip production (thinning & dicing)
- Chip test
- Detector module production and test

Hybrid Integrated Circuit production

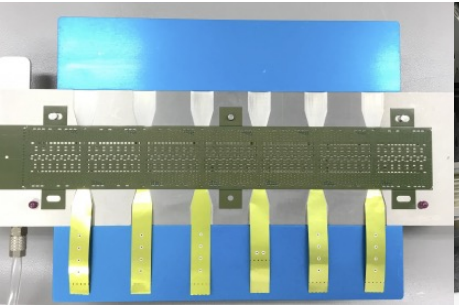


chip alignment

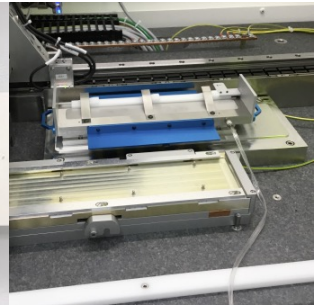
Visual inspection



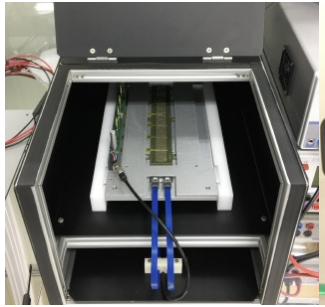
Electrical test



Glue FPC



Curing



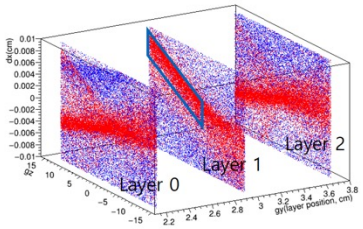
Qualification and endurance test

Development of detector alignment procedure

Motivation : Detector Alignment by Artificial Intelligence

Offset Identification and Correction (First shot)

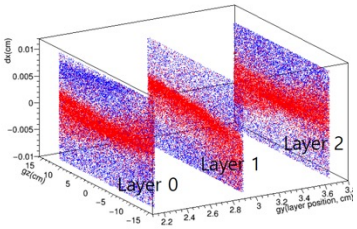
Line fitting offset in x direction(dx) plot, cosmic muon



Apply Simple Correction

$$F_C : gx \rightarrow gx' = gx + C_x$$

$$C_x = \left(\frac{0.01}{15}\right) \cdot gz + 0.001$$



Global hit position $\{ gx, gy, gz \}$ → **Correction Function** F_C →

$$gx' = gx + C_x$$

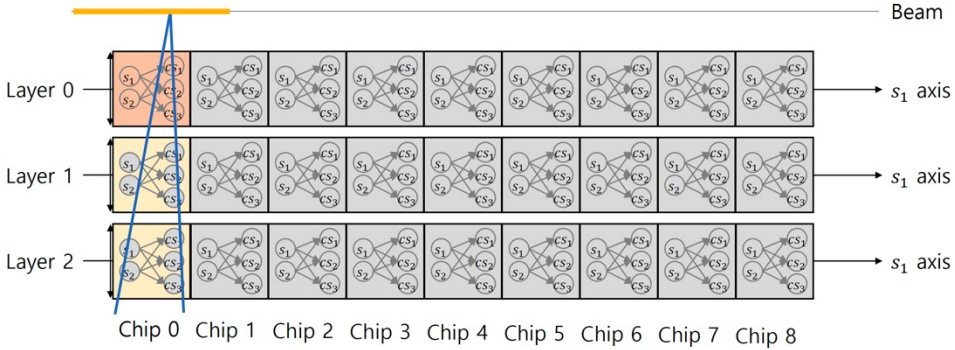
$$gy' = gy + C_y$$

$$gz' = gz + C_z$$

We can see the deformation structure from cosmic muon events but there is no way to verify the right answer.

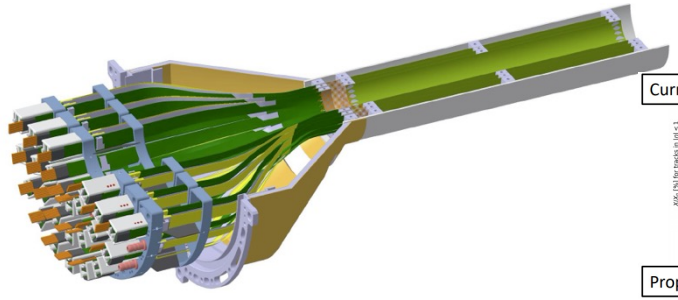
Current Status

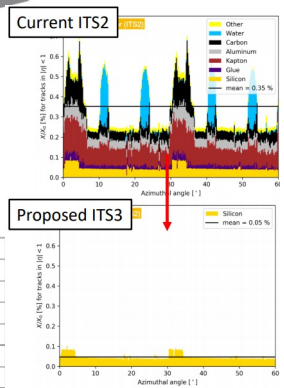
Correction function : Construction



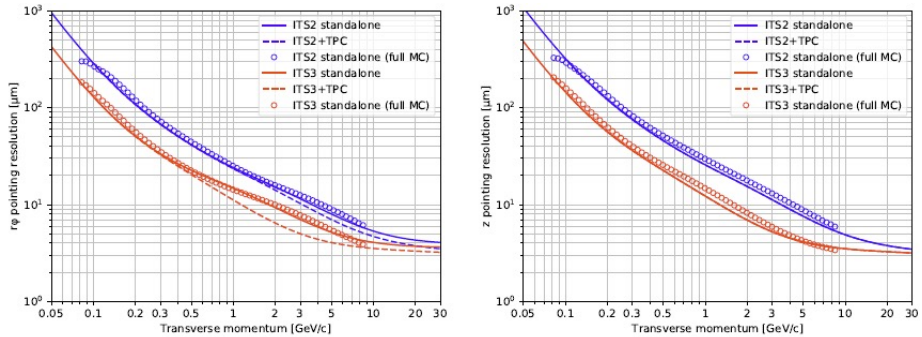
➡ A Correction Function is constructed by track group whose reconstructed hits are on the three specific sensors.

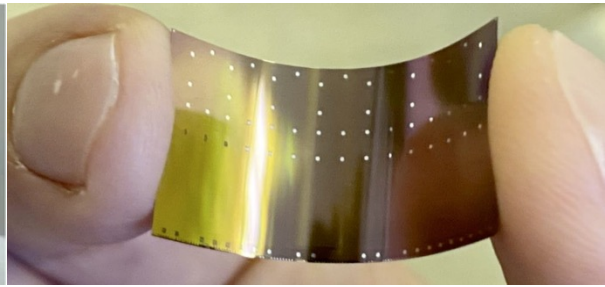
ALICE ITS3 upgrade





Beam pipe Inner/Outer Radius (mm)	16.0/16.5		
IB Layer Parameters	Layer 0	Layer 1	Layer 2
Radial position (mm)	18.0	24.0	30.0
Length (sensitive area) (mm)	300		
Pseudo-rapidity coverage	±2.5	±2.3	±2.0
Active area (cm²)	610	816	1016
Pixel sensor dimensions (mm²)	280 x 56.5	280 x 75.5	280 x 94
Number of sensors per layer	2		
Pixel size (μm²)	O (10 x 10)		





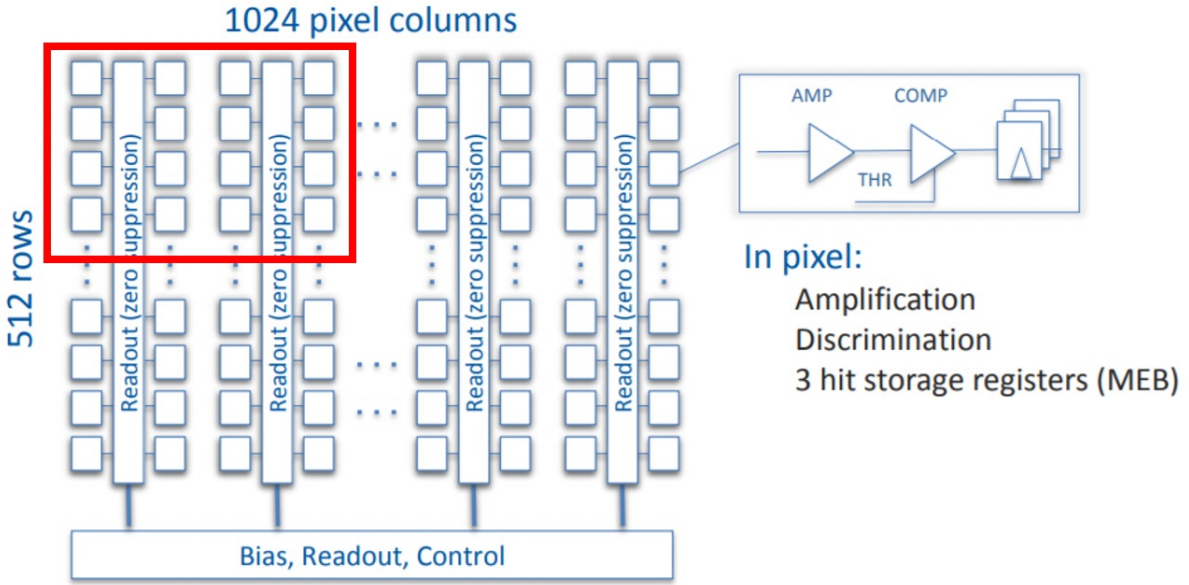
Bent chip

- Sensor R&D
- Beam test data analysis
- Sensor characterization

~10 um impact parameter resolution at p_T~1 GeV/c

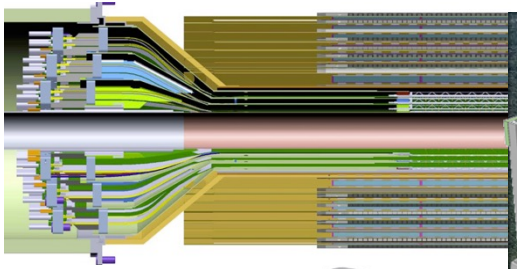
ALPIDE Rebin

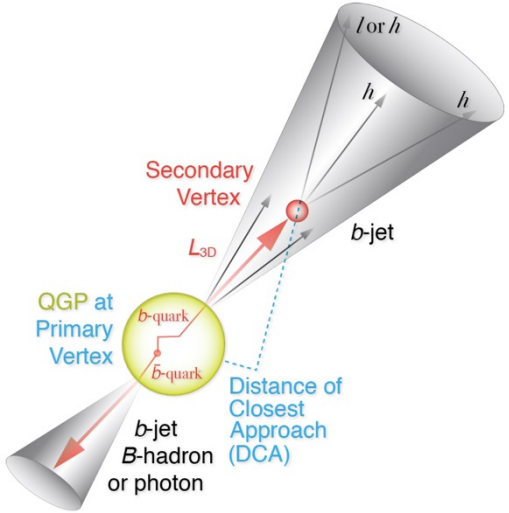
n x n
super cell
n=8,16,32?

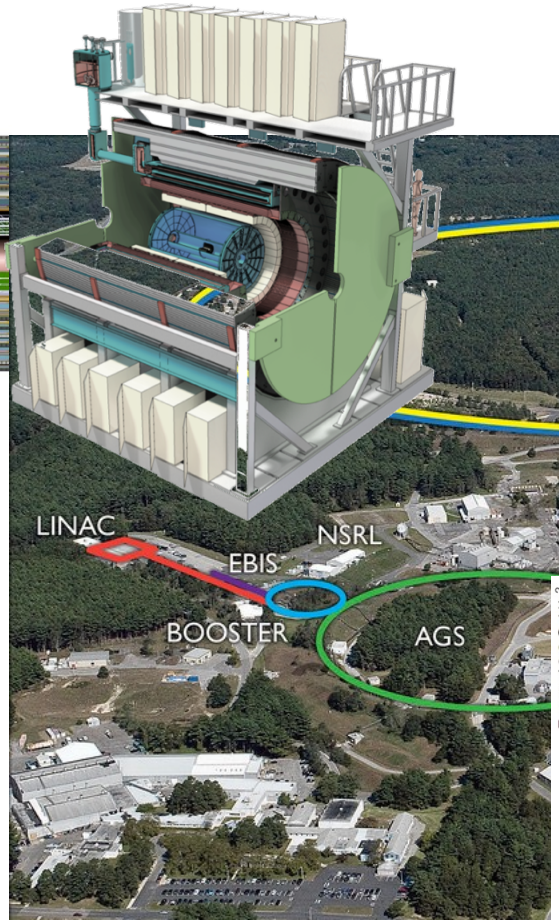


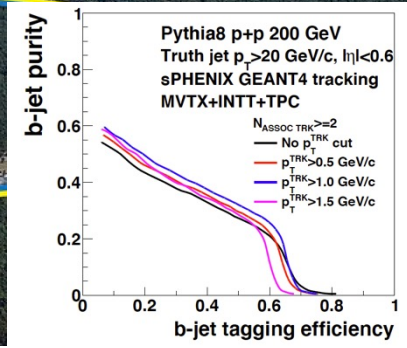
What we deal with is the digital storage,
and all modification is in periphery.

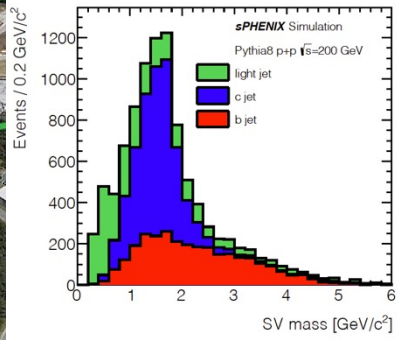
b-jet tagging and detector alignment in sPHENIX

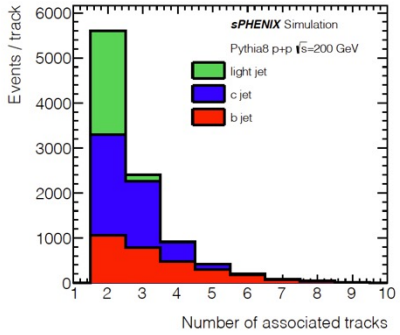






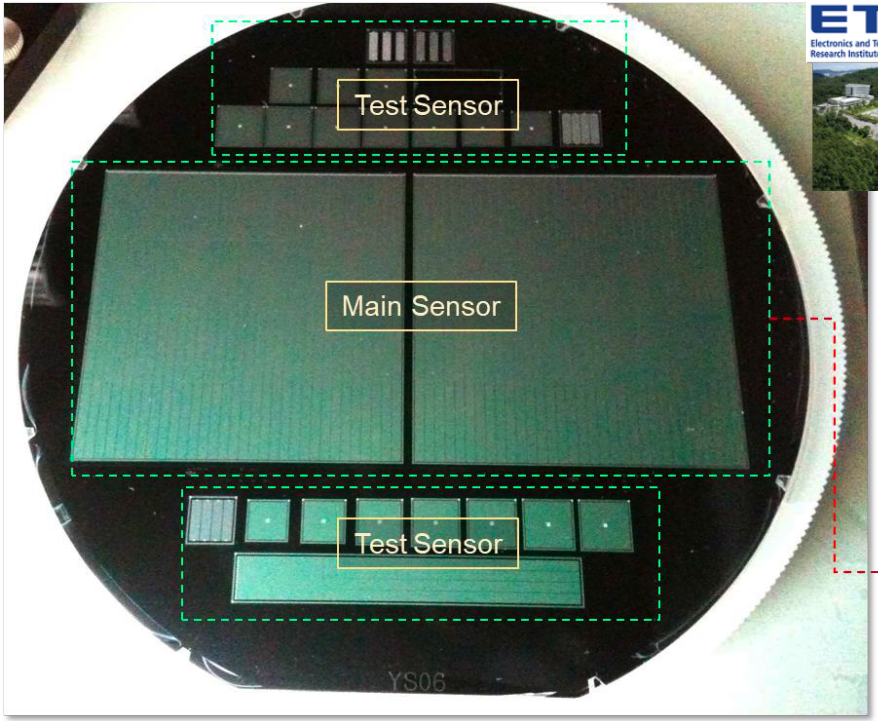




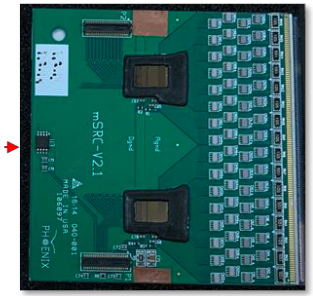


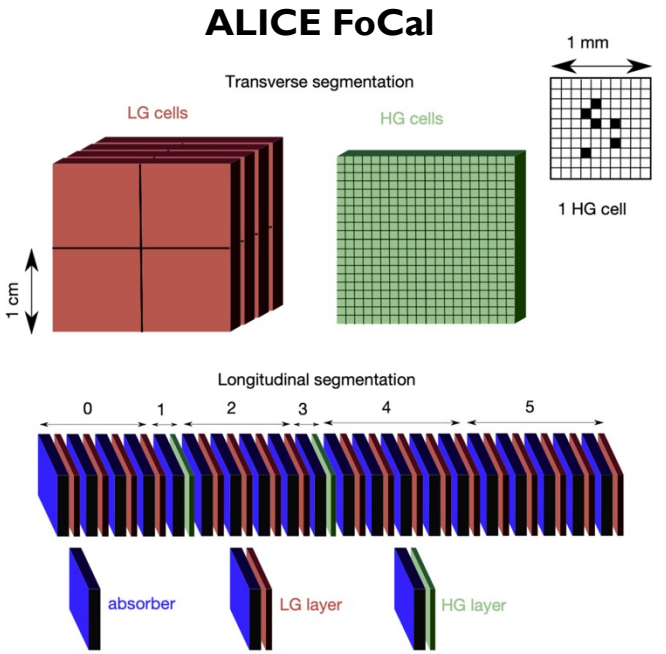
Silicon pad sensor

- Production of silicon mini-pad sensor for PHENIX MPC-EX
- Interest in ALICE FoCal



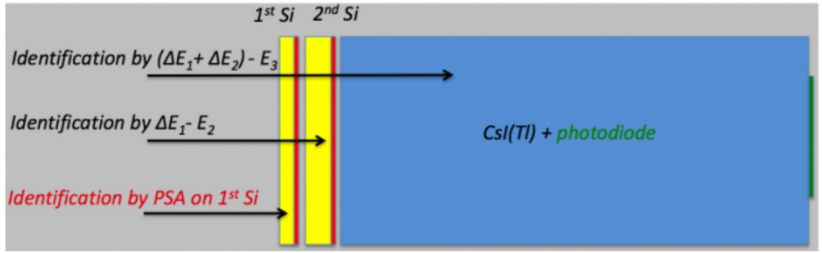
Sensor Packaging





FAZIA experiment upgrade at GANIL

- FZAIZ is a three-layer telescope [Si+Si+CsI(Tl)] array which aims at detecting and identifying particles and fragments produced in heavy-ion reactions around Fermi energy.



Silicon chip: 2 cm x 2 cm x 300 μm or 500 μm

- FAZIA plans detector upgrade to extend their acceptance and also change the silicon chip depth to explore different particle momentum range.
- Korean groups participate in
  - Wafer production in Korea. At the moment, fabrication is done in Europe but it is also being locally investigated (Nano FAB in Pohang, ETRI)
  - FEE board design & production by the company NOTICE
  - Prototype assembly and test (guided by FAZIA experts)

- Similar telescope will be developed for RAON low energy LAMPS experiments, and the R&D is ongoing.

Table 11.2: Requirements for the tracking system from the physics groups.

Tracking requirements from PWGs						
			Momentum res.	Material budget	Minimum pT	Transverse pointing res.
η						
-3.5 to -3.0	Central Detector	Backward Detector	σp/p ~ 0.1%×p ⊕ 0.5%	~5% X0 or less	100-150 MeV/c	
-3.0 to -2.5					100-150 MeV/c	dca(xy) ~ 30/pT μm ⊕ 40 μm
-2.5 to -2.0			σp/p ~ 0.05%×p ⊕ 0.5%		100-150 MeV/c	
-2.0 to -1.5					100-150 MeV/c	dca(xy) ~ 30/pT μm ⊕ 20 μm
-1.5 to -1.0					100-150 MeV/c	
-1.0 to -0.5		Barrel	σp/p ~ 0.05%×p ⊕ 0.5%		100-150 MeV/c	dca(xy) ~ 20/pT μm ⊕ 5 μm
-0.5 to 0						
0 to 0.5						
0.5 to 1.0						
1.0 to 1.5		Forward Detector	σp/p ~ 0.05%×p ⊕ 1%		100-150 MeV/c	dca(xy) ~ 30/pT μm ⊕ 20 μm
1.5 to 2.0					100-150 MeV/c	
2.0 to 2.5					100-150 MeV/c	
2.5 to 3.0			σp/p ~ 0.1%×p ⊕ 2%		100-150 MeV/c	dca(xy) ~ 30/pT μm ⊕ 40 μm
3.0 to 3.5					100-150 MeV/c	dca(xy) ~ 30/pT μm ⊕ 60 μm

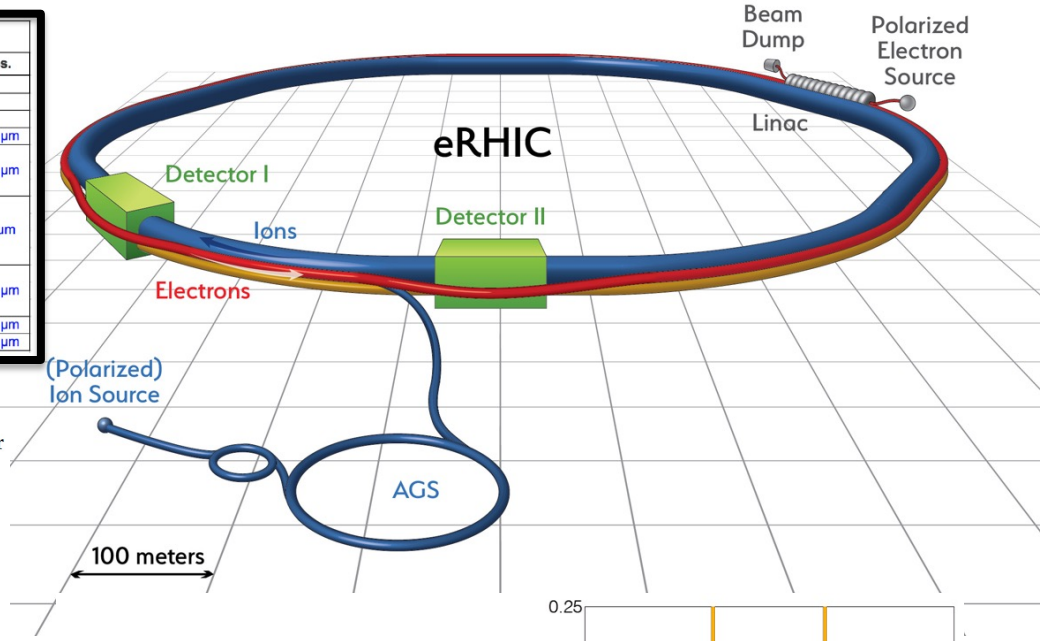
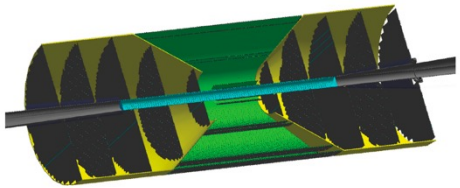
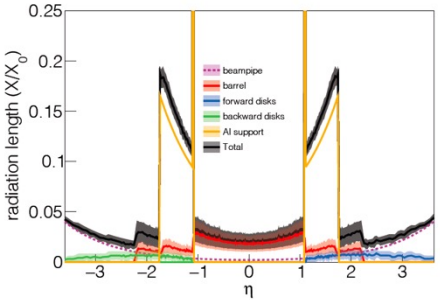


Table 11.3: Specifications for the ALICE ITS2 ALPIDE sensor and the proposed sensor for the ITS3 upgrade.

Parameter	ALPIDE (existing)	Wafer-scale sensor (this proposal)
Technology node	180 nm	65 nm
Silicon thickness	50 μm	20-40 μm
Pixel size	27 x 29 μm	O(10 x 10 μm)
Chip dimensions	1.5 x 3.0 cm	scalable up to 28 x 10 cm
Front-end pulse duration	~ 5 μs	~ 200 ns
Time resolution	~ 1 μs	< 100 ns (option: <10ns)
Max particle fluence	100 MHz/cm^2	100 MHz/cm^2
Max particle readout rate	10 MHz/cm^2	100 MHz/cm^2
Power Consumption	40 mW/cm^2	< 20 mW/cm^2 (pixel matrix)
Detection efficiency	> 99%	> 99%
Fake hit rate	< 10^{-7} event/pixel	< 10^{-7} event/pixel
NIEL radiation tolerance	~3 x 10^{13} 1 MeV n_{eq}/cm^2	10^{14} 1 MeV n_{eq}/cm^2
TID radiation tolerance	3 MRad	10 MRad

All-silicon tracker geometry





[1]Expression of Interest (EOI)
Questionnaire

(Use this template for your document. The document can be at most 10 pages long, in this style, font and font size, but you can have appendices and do not have to include the tables in the page count. There is no prescribed format of the document, but you are asked to address the questions below. This document will be viewable by password to all who submit. You can also submit a separate document with certain information you would only like to be viewable by the EIC Project. DEADLINE FOR SUBMISSION: NOVEMBER 1.)

Please indicate the name of the contact person for this submission:
we ask for one main contact person per submission. You can as needed provide further contacts, but there should be one primary contact)

Primary contact: Oh, Yongseok (Kyungpook National University), yohphy@knu.ac.kr

Deputy contacts:
- Kim, Yongsun (Sejong University), yongsun@sejong.ac.kr
- Lim, Sanghoon (Pusan National University), shlim@pusan.ac.kr
- Jo, Hyon-Suk (Kyungpook National University), hyonsuk@knu.ac.kr

All institutions are located in South Korea.

Please indicate all institutions collectively involved in this submission of interest:
(even if institutions can submit on their own, it is highly encouraged to form groups to work together within their country, their geographical region, or as a general consortium)

Group	Devoted to	Institutions	Faculties
A	Forward Calorimeter	Korea University	Byungsik Hong Jung Keun Ahn
		Sejong University	Yongsun Kim
		Chonnam National University	Dongho Moon
B	Pixel Tracker	Jeonbuk National University	Eun-Joo Kim
		Pusan National University	Sanghoon Lim
		Yonsei University	Youngil Kwon
		Inha University	Minjung Kweon
C	Dual-Readout Calorimeter	Kyungpook National University	Hyon-Suk Jo Sehwook Lee
		University of Seoul	Jason Lee
		Yonsei University	Hwidong Yoo

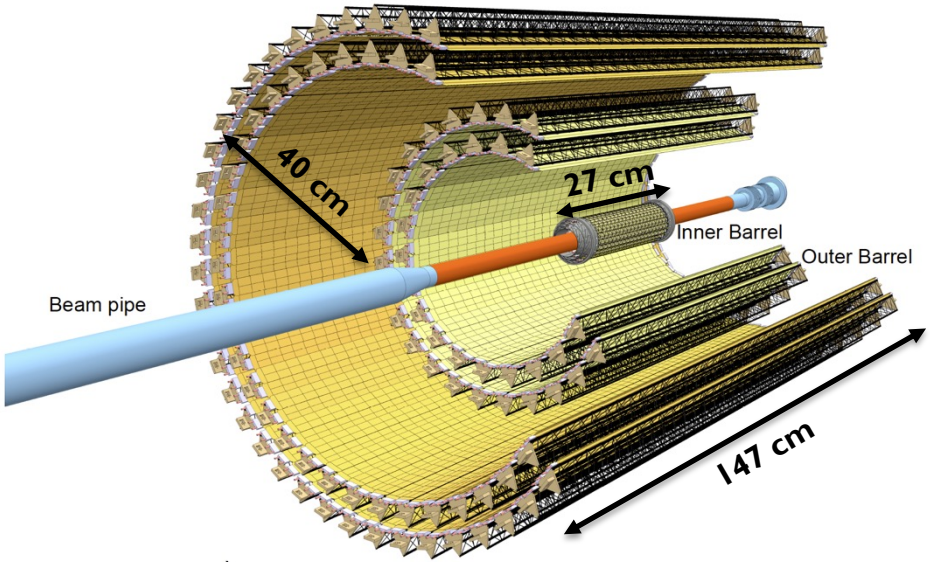
Please indicate the items of interest for potential equipment cooperation:

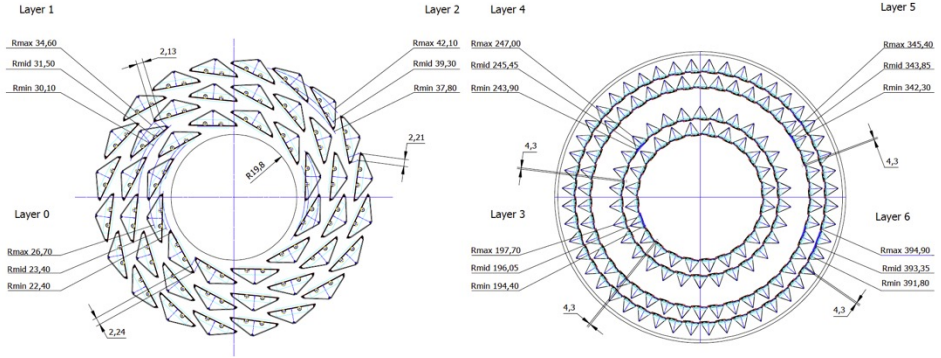
[1]

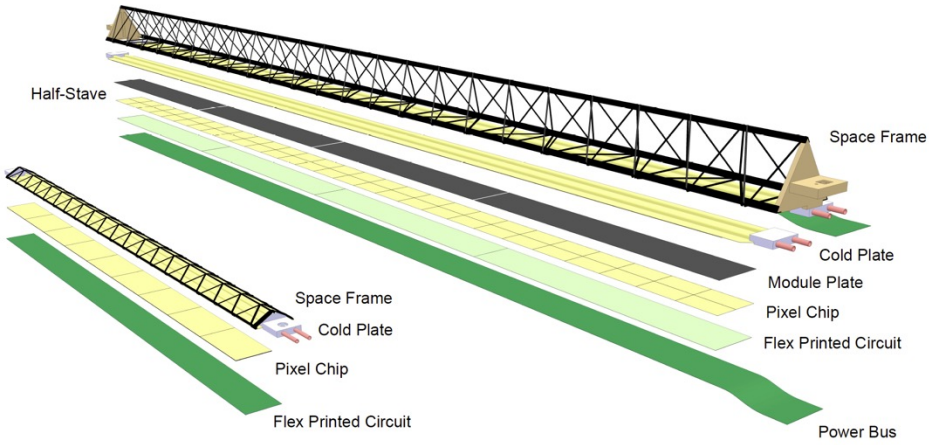
- **Discussion with the EIC Silicon Consortium on May/31 ➔Current R&D activity for the EIC is along with the ALICE ITS3 project**
- **We will keep searching for specific contributions for the EIC**

Thank you!

Monolithic Active Pixel Sensor Technology
~13x10^9 pixels (pixel size: 29 μm x 27 μm)







- **Inner Barrel**
  3 layers: 12+16+20 staves
  9 sensors per stave
- **Outer Barrel**
  2 middle layers: 30+24 staves (2x4 modules/stave)
  2 outer layers: 42+48 staves (2x7 modules/stave)
  2x7 sensors/module