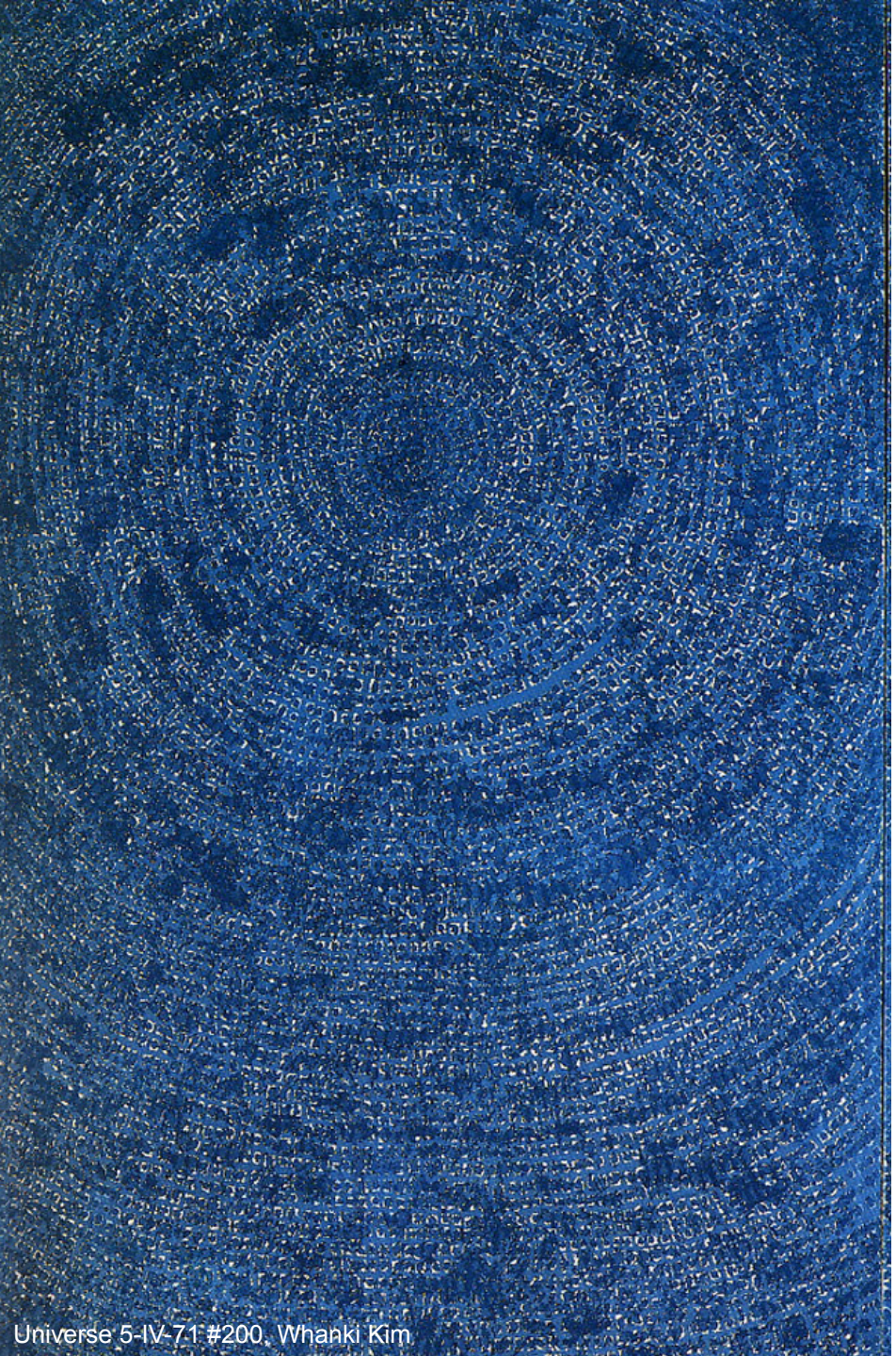


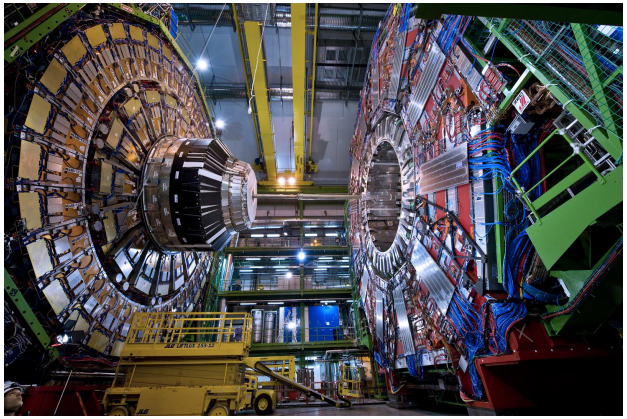
Prospective Activity for EIC experiment

Yongsun Kim (Sejong Univ.)

고에너지물리학회

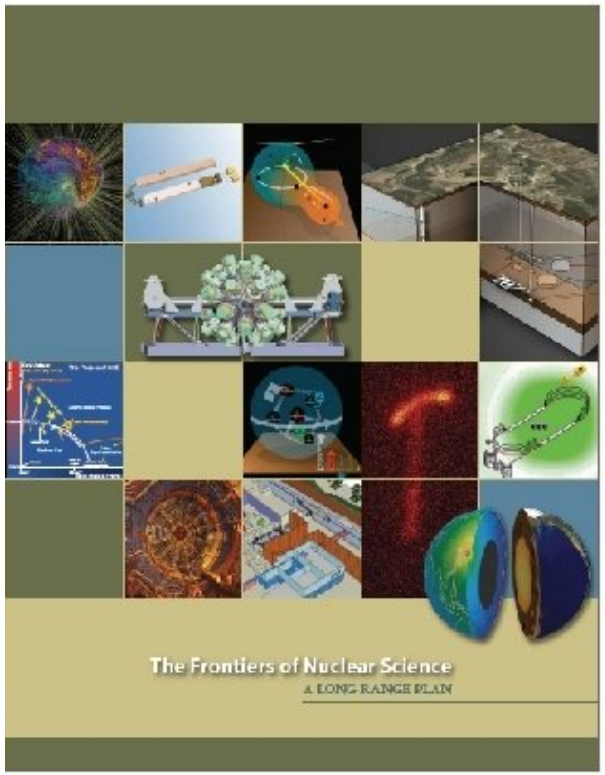
2022.11.19

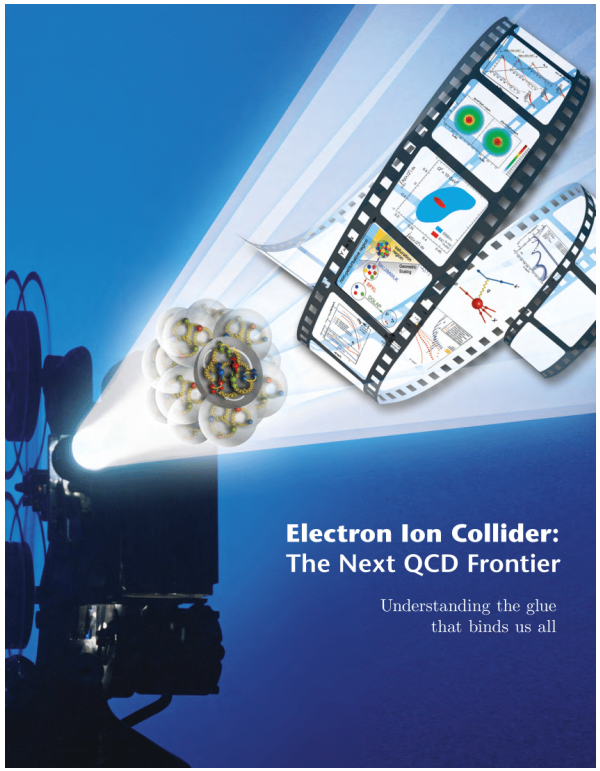
- CMS collaboration (2008 —)
  - heavy ion physics analysis
  - MIT, Korea University, Sejong Univ.
  - Forward group leader (Level 3) in 2020
  - HI PAG convener (Level 2) 2020 — 2022
- LAMPS collaboration (2018 —)
  - Low energy nuclear experiment using active target TPC
- SHINCHON collaboration
  - **S**imulation of **H**eavy Io**N** **C**ollision for **H**eavy **Q**uarks and **ON**ia

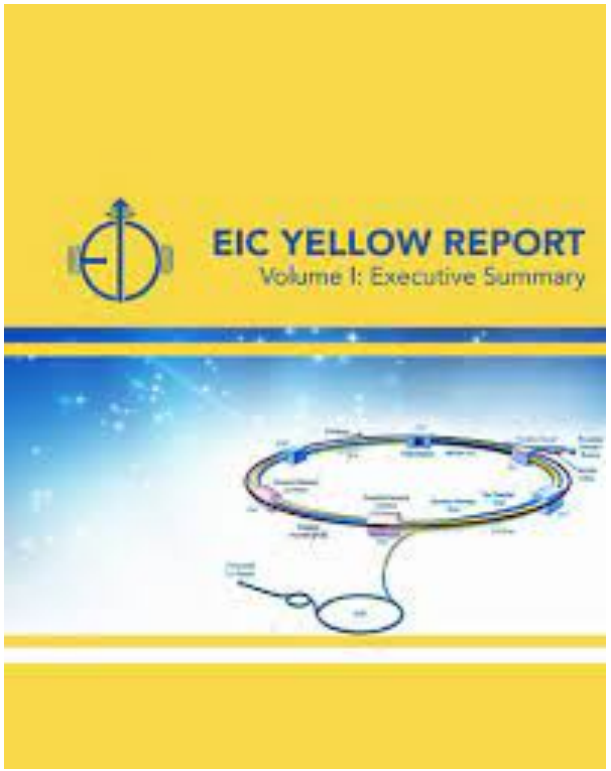


Brief history of EIC

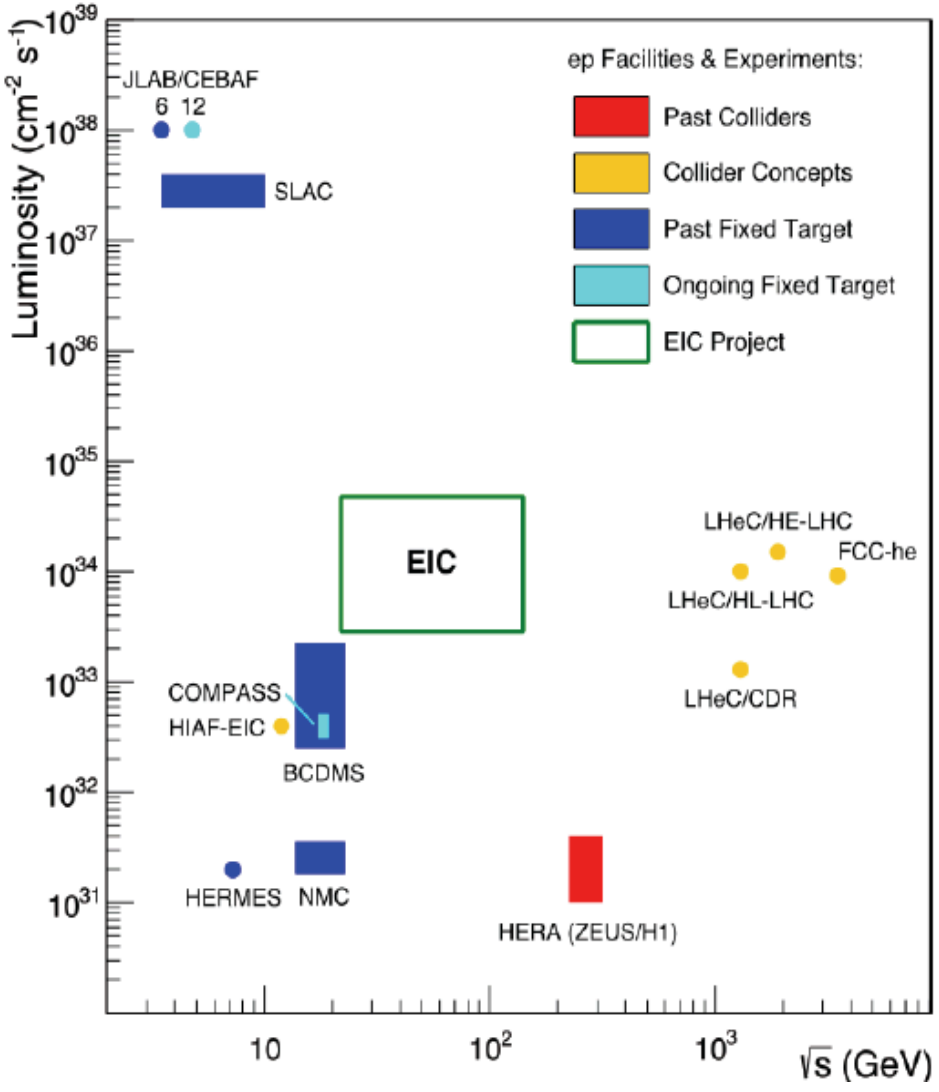
- 2002: eRHIC community formed and submitted a white paper to NSAC Long Range Plan(NRP) review
- 2007,2015: LRP endorsed the construction of electron-ion collider with polarized
- **2020: DOE selected BNL as the site for EIC construction**
- **2021: Yellow Report defines Science Requirements and Detector Concepts**

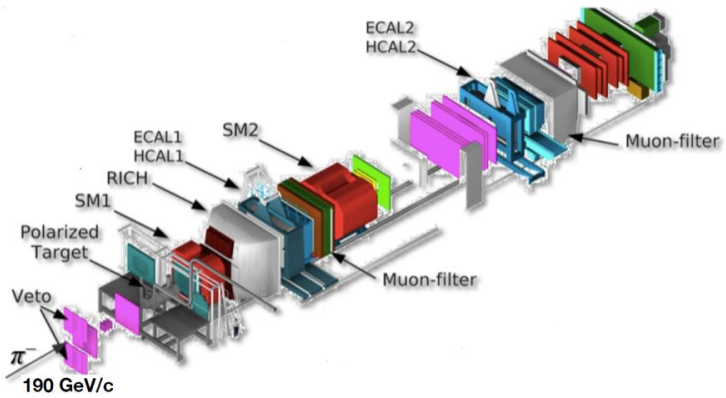




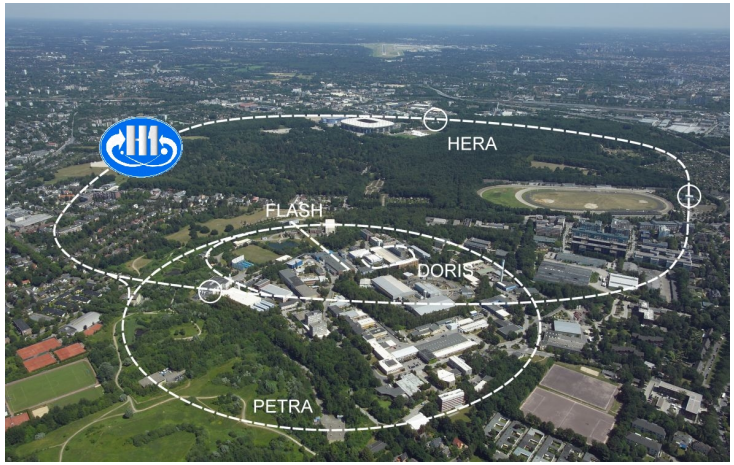


Powerful inelastic scattering





COMPASS (CERN)



HERA (DESY)

Brief history of EIC

BNL and TJNAF Jointly Leading Process to Select Project Detector		
2020	Call for Expressions of Interest (EOI) https://www.bnl.gov/eic/EOI.php	May 2020
	EOI Responses Submitted	November 2020
	Assessment of EOI Responses	On-going
2021	Call for Collaboration Proposals for Detectors https://www.bnl.gov/eic/CFC.php	March 2021
	BNL/TJNAF Proposal Evaluation Committee	Spring 2021
	Collaboration Proposals for Detectors Submitted	December 2021
✔	Decision on Project Detector – "ECCE"	March 2022
	Guide process to joint "Detector-1" Collaboration	Spring 2022
	EPIC Collaboration* Formed – 160 institutions	July 2022

R. Ent

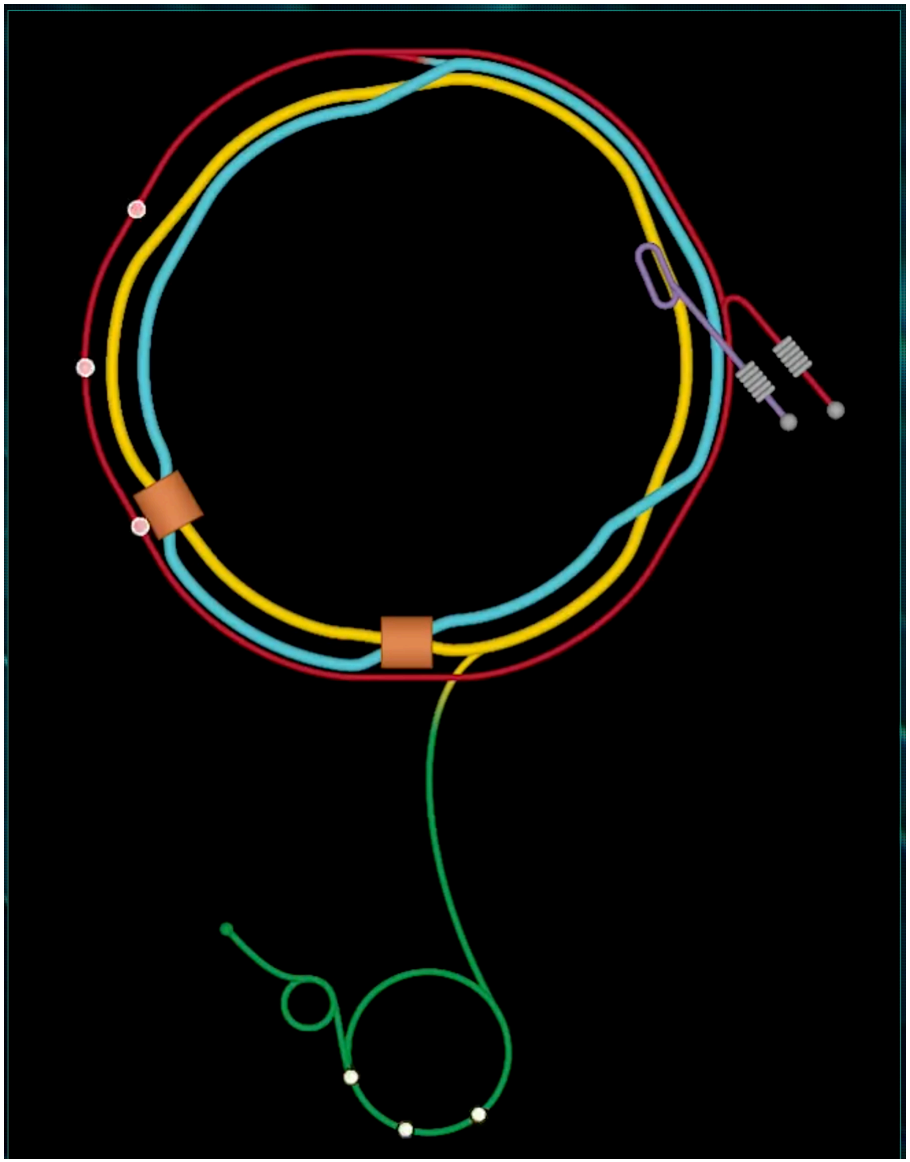
Science mission

World's first collider for polarized e+p and e+A collider

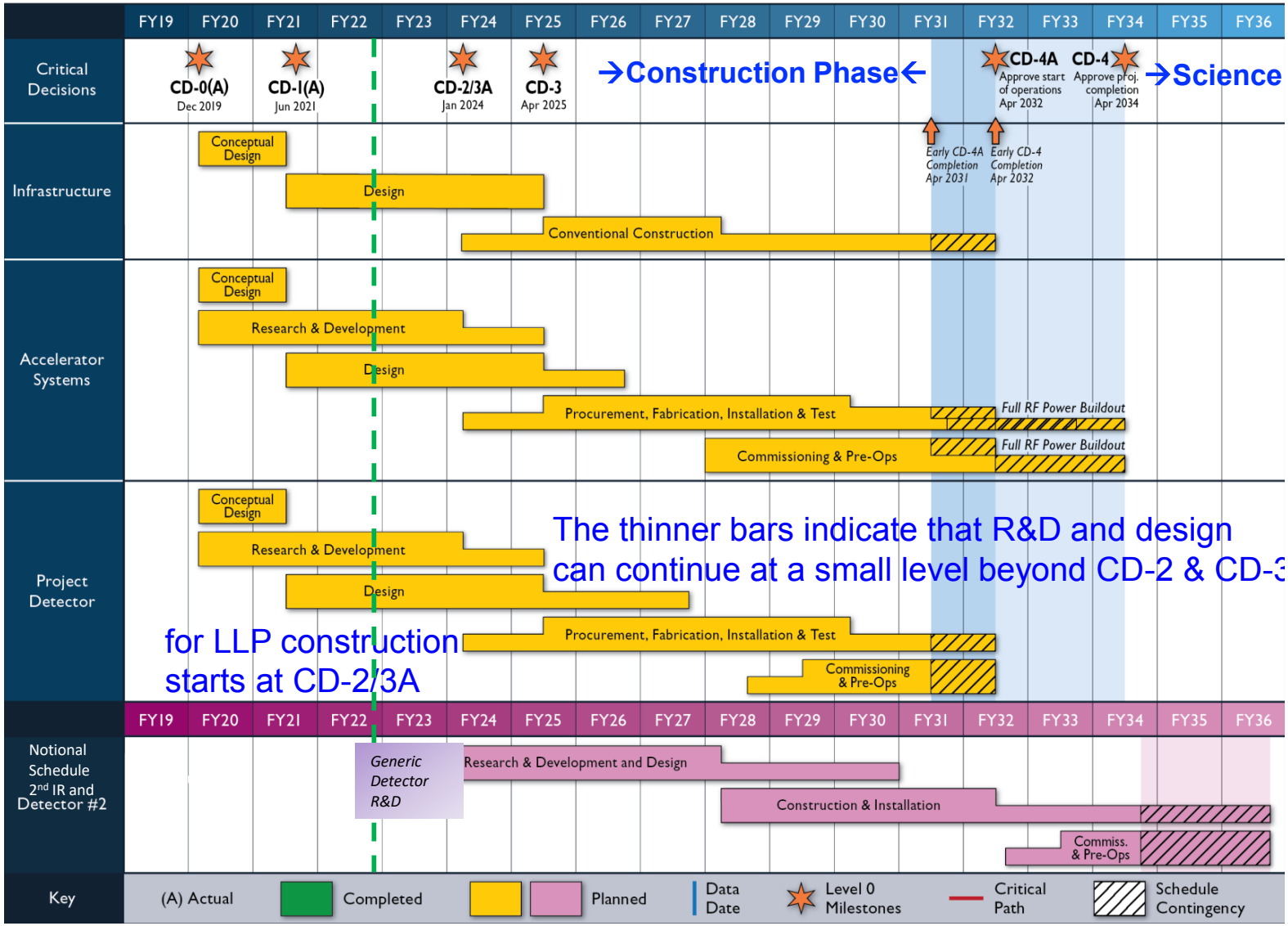
- High luminosity ~ 10^{34} $cm^{-2}s^{-1}$
- E_{cm} : 20 — 100 GeV
- Highly polarized electron (~70%) and proton (~70%) beams
- To be constructed at BNL in ~2030

Answer to Ultimate QCD questions

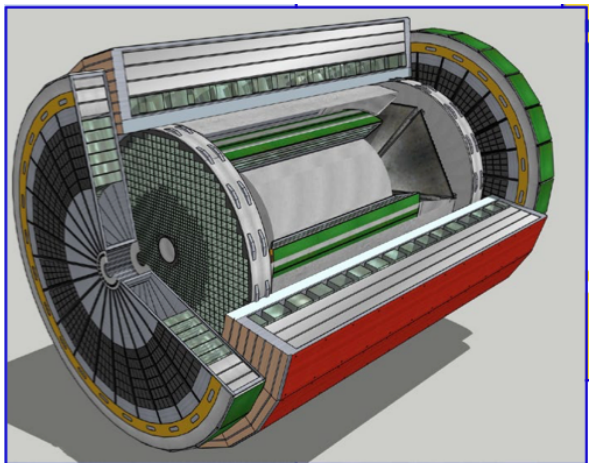
- How mass and spin of nucleons emerge from partons?
- How are partons distributed in momentum and position space?
- How do quarks and gluons interact with nuclear medium?
- Where does confinement come from?



Construction Timeline



Detector Proposals for EIC

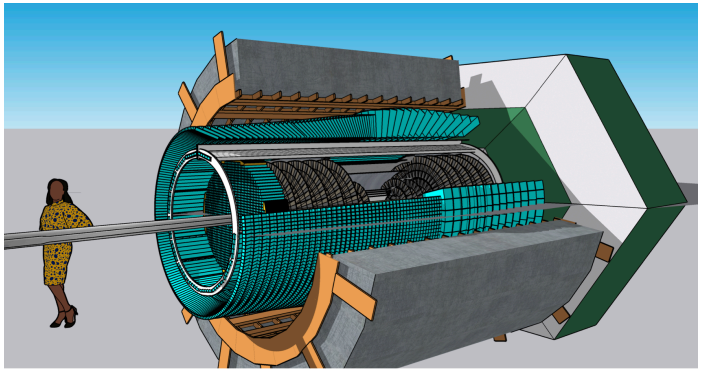


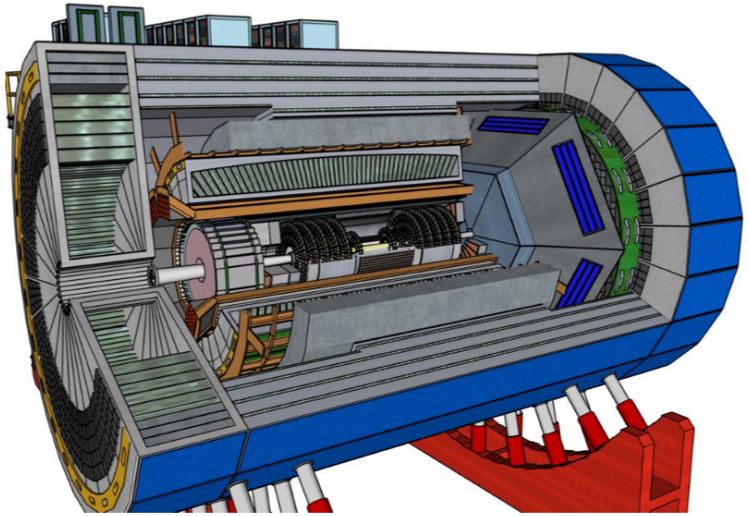
AHTENA

A Totally **H**ermetic **E**lectron-**N**ucleus **A**pparatus

CORE

a **CO**mpact detecto**R**
for the **E**IC

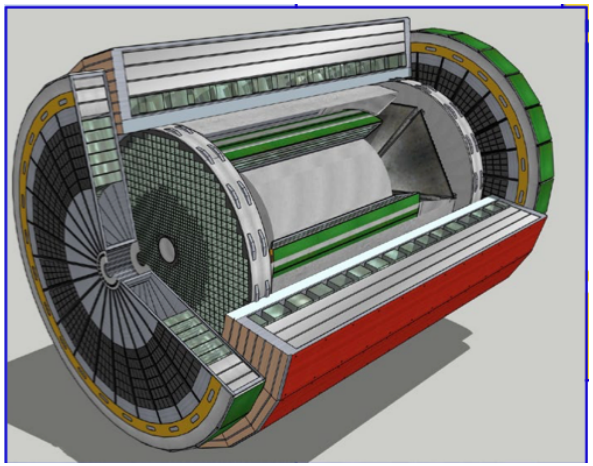




ECCE

EIC **C**ollider **E**xperiment

Detector Proposals for EIC



AHTENA

A Totally **H**ermetic **E**lectron-**N**ucleus **A**pparatus

CORE

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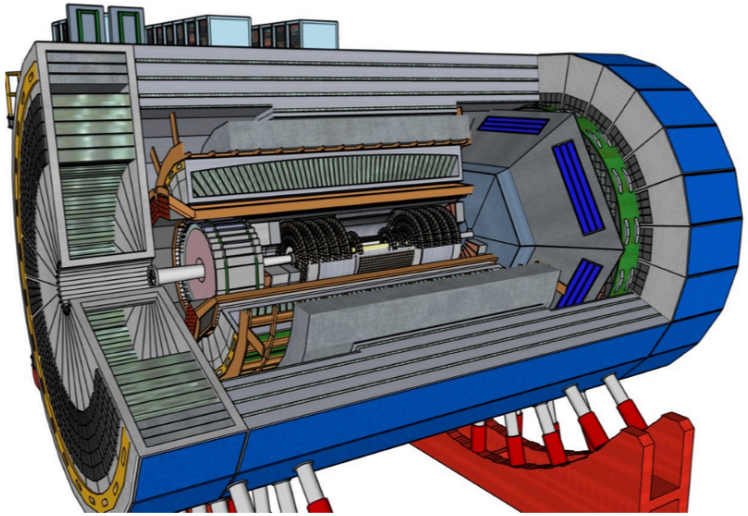
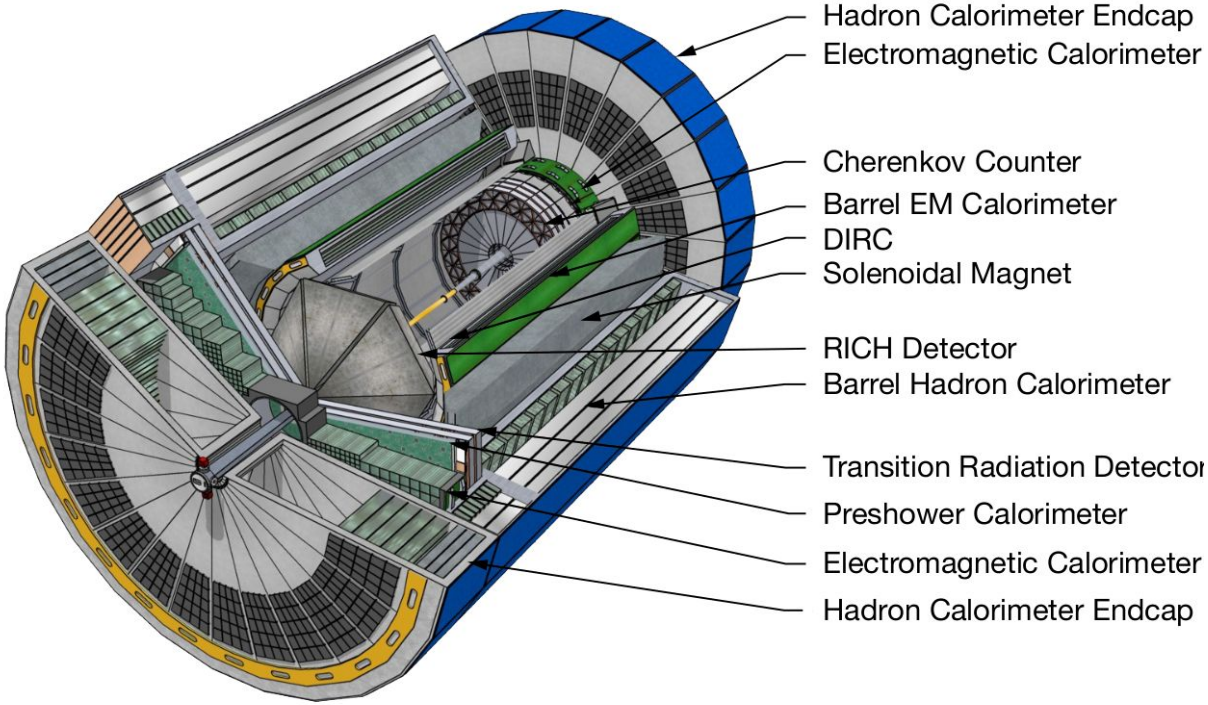
for the **E**IC



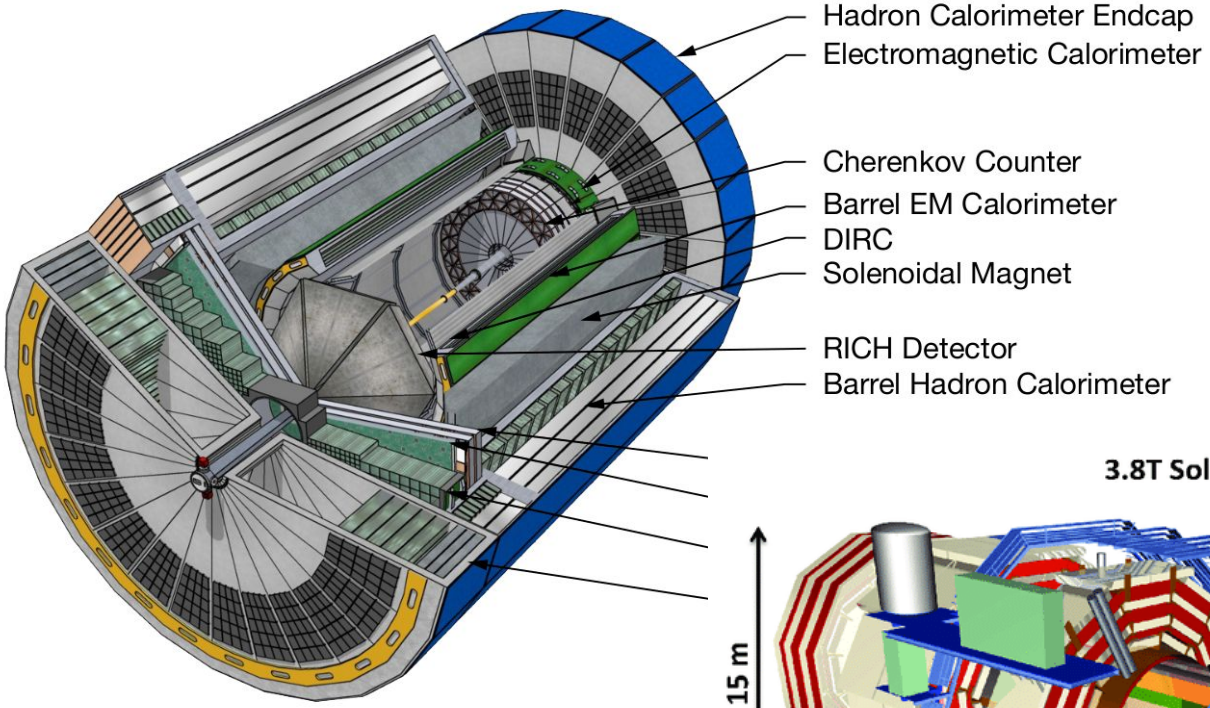
ECCE

EIC **C**ollider **E**xperiment

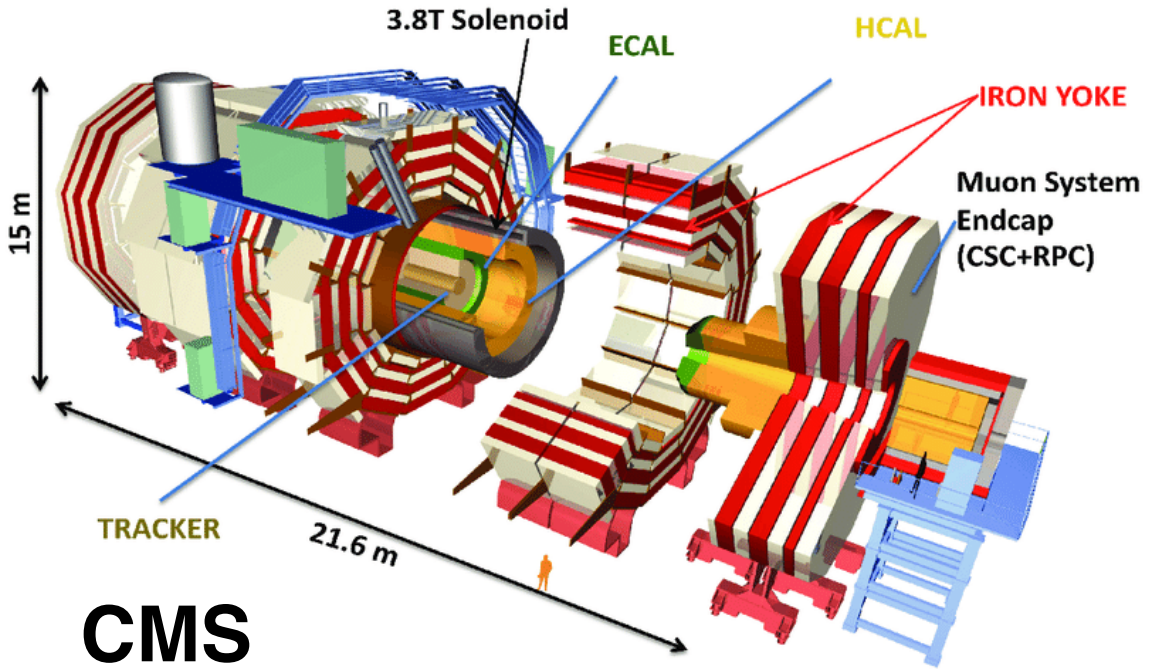

Hadron Calorimeter Endcap
Electromagnetic Calorimeter
Cherenkov Counter
Barrel EM Calorimeter
DIRC
Solenoidal Magnet
RICH Detector
Barrel Hadron Calorimeter
Transition Radiation Detector
Preshower Calorimeter
Electromagnetic Calorimeter
Hadron Calorimeter Endcap

EPIC

EPIC

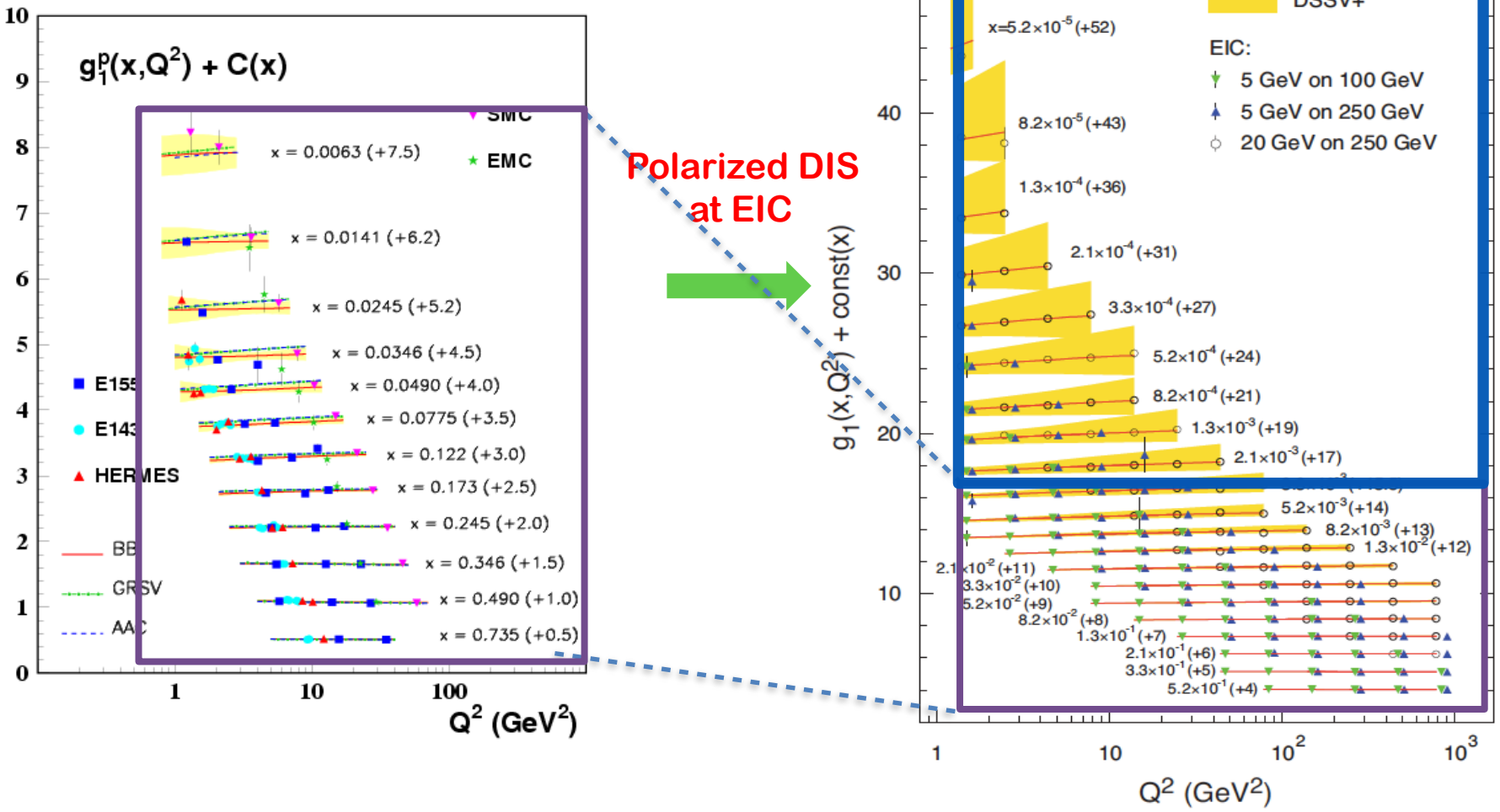


EPIC

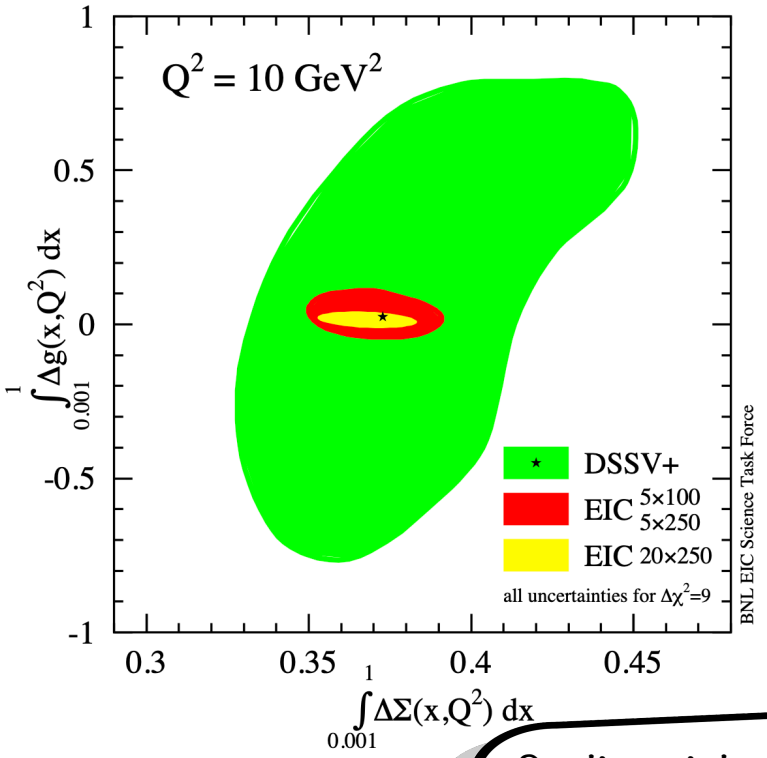


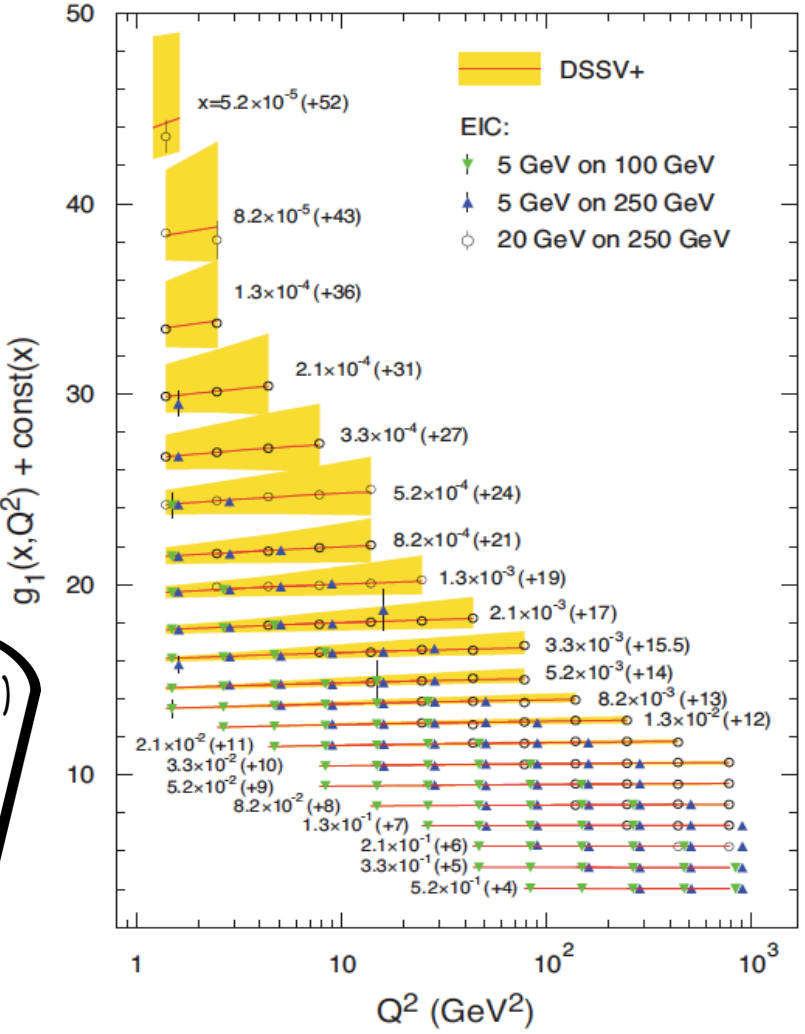
CMS

Unprecedented precision for proton spin structure



Gluon spin and 3-d tomography

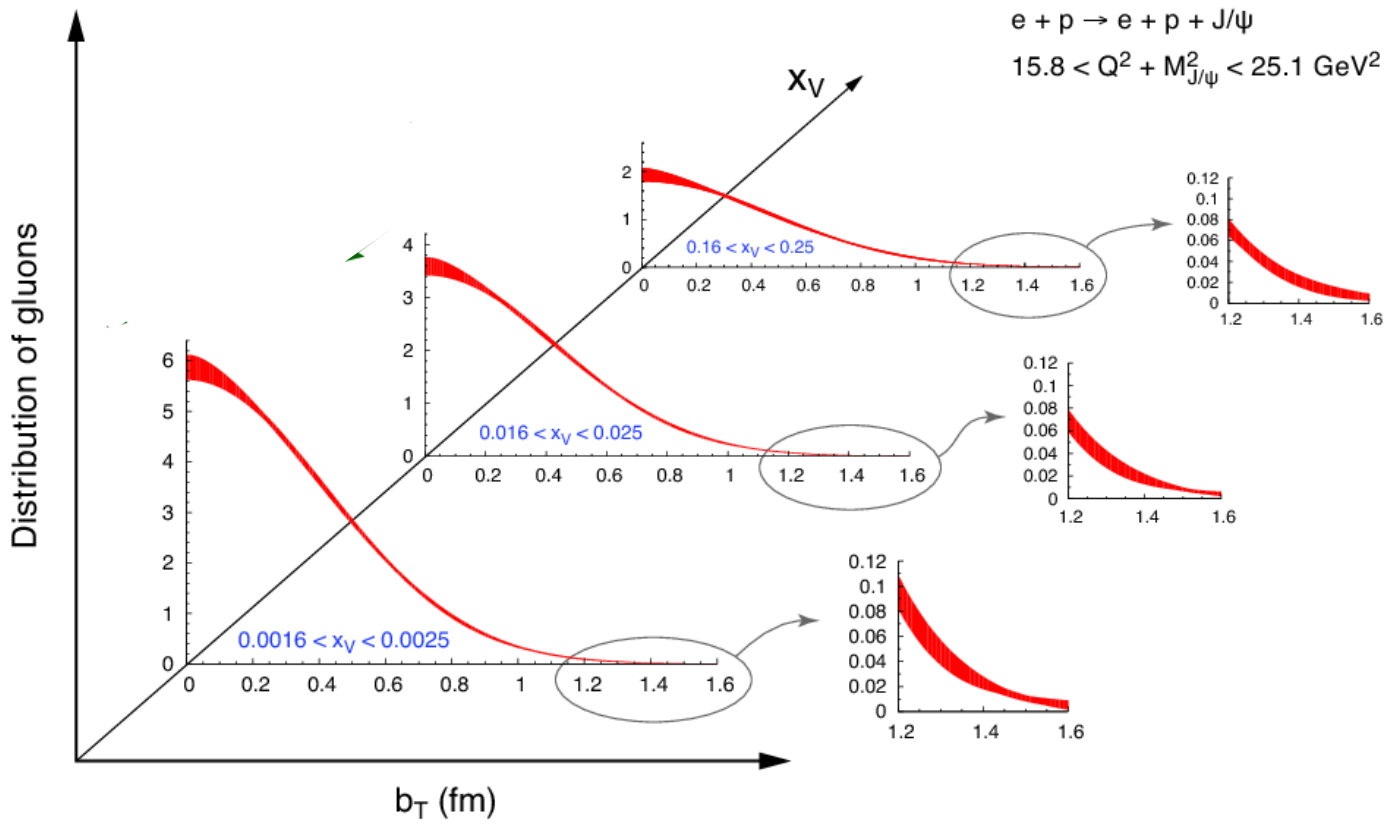




Scaling violation in $g_1(x,Q2)$ is sensitive to the gluon polarizaiton

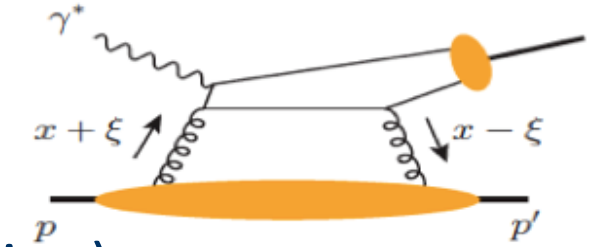
$$\frac{dg_1(x,Q^2)}{d\ln Q^2} \approx -\Delta g(x,Q^2)$$

Tomography of nuclei



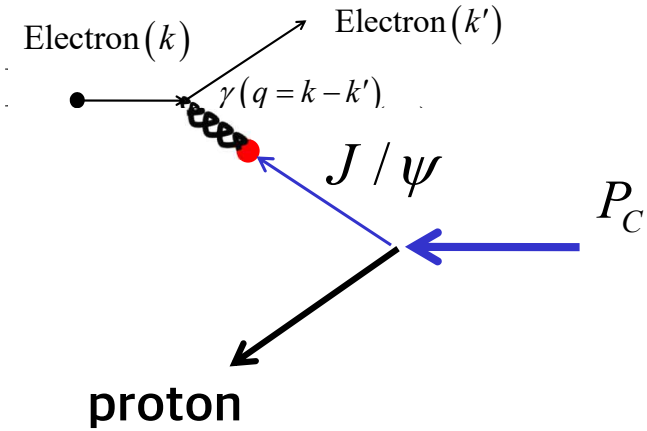
- GPD : generalized parton distribution
- Imaging gluons and (sea)quarks with 3 degrees-of-freedom

Meson Production



J/ψ, ϕ, ρ, etc.

Factory for exotic hadrons



High Energy Physics - Phenomenology

[Submitted on 23 Feb 2022]

Production of $P_c(4312)$ state in electron-proton collisions

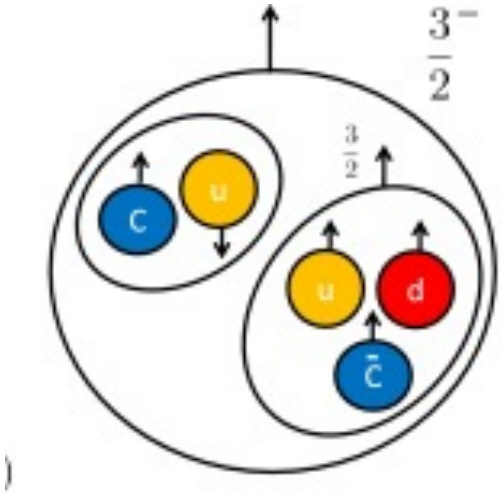
In Woo Park, Su Houng Lee, Sungtae Cho, Yongsun Kim

We study the cross sections for the electro-production of $P_c(4312)$ particle, a recently discovered pentaquark state, in electron-proton collisions assuming possible quantum numbers to be $J^P = \frac{1}{2}^{\pm}, \frac{3}{2}^{\pm}$. $\sqrt{s}$ is set to the energy of the future Electron Ion Collider at Brookhaven National Laboratory, in order to asses the possibility of the measurement in this facility. One can discriminate the spin of $P_c(4312)$ by comparing the pseudorapidity distribution in two different polarization configurations for proton and electron beams. Furthermore, the parity of $P_c(4312)$ can be discerned by analyzing the decay angle in the $P_c \to p + J/\psi$ channel. As the multiplicity of P_c production in our calculation is large, the EIC can be considered as a future facility for precision measurement of heavy pentaquarks.

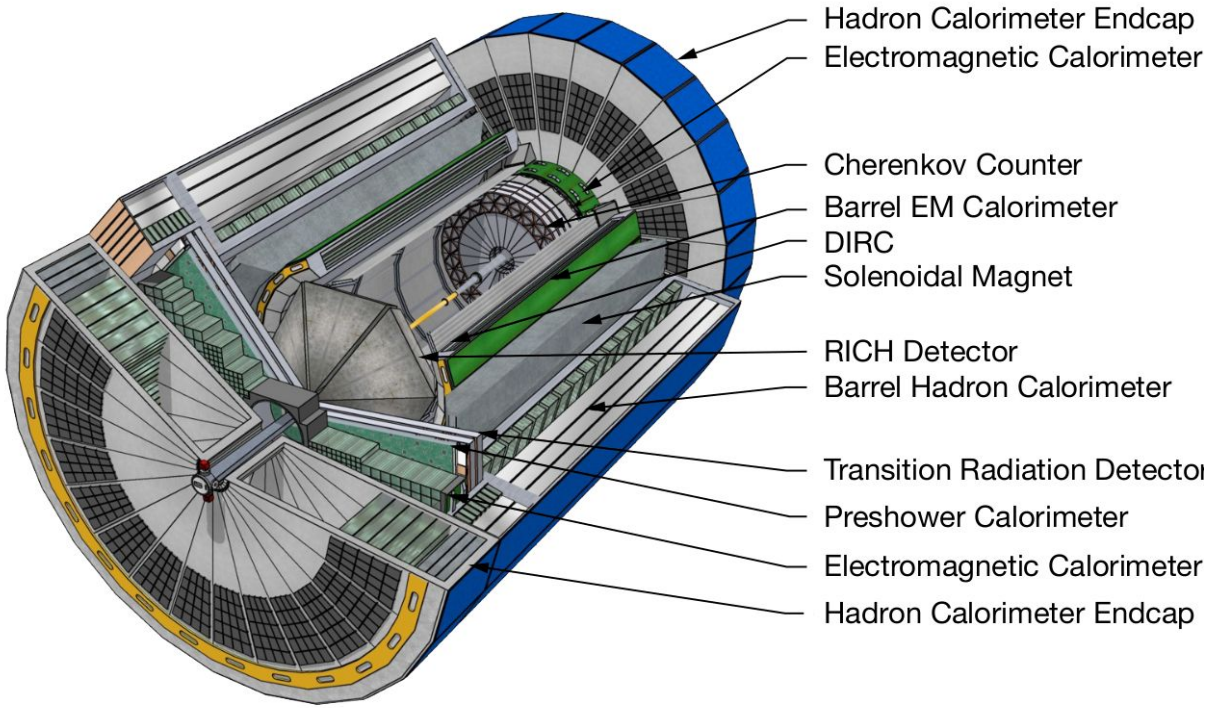
Comments: 7 pages, 6 figures
Subjects: **High Energy Physics - Phenomenology (hep-ph)**; Nuclear Experiment (nucl-ex); Nuclear Theory (nucl-th)
Cite as: arXiv:2202.11631 **[hep-ph]**
(or arXiv:2202.11631v1 **[hep-ph]** for this version)
https://doi.org/10.48550/arXiv.2202.11631

Submission history

From: Yongsun Kim [view email]
[v1] Wed, 23 Feb 2022 17:07:42 UTC (557 KB)



Detector requirement



- electron tagging
- particle ID
- jet energy and substructure
- secondary vertex

Potential Korean involvement for EIC

Maximization of productivity

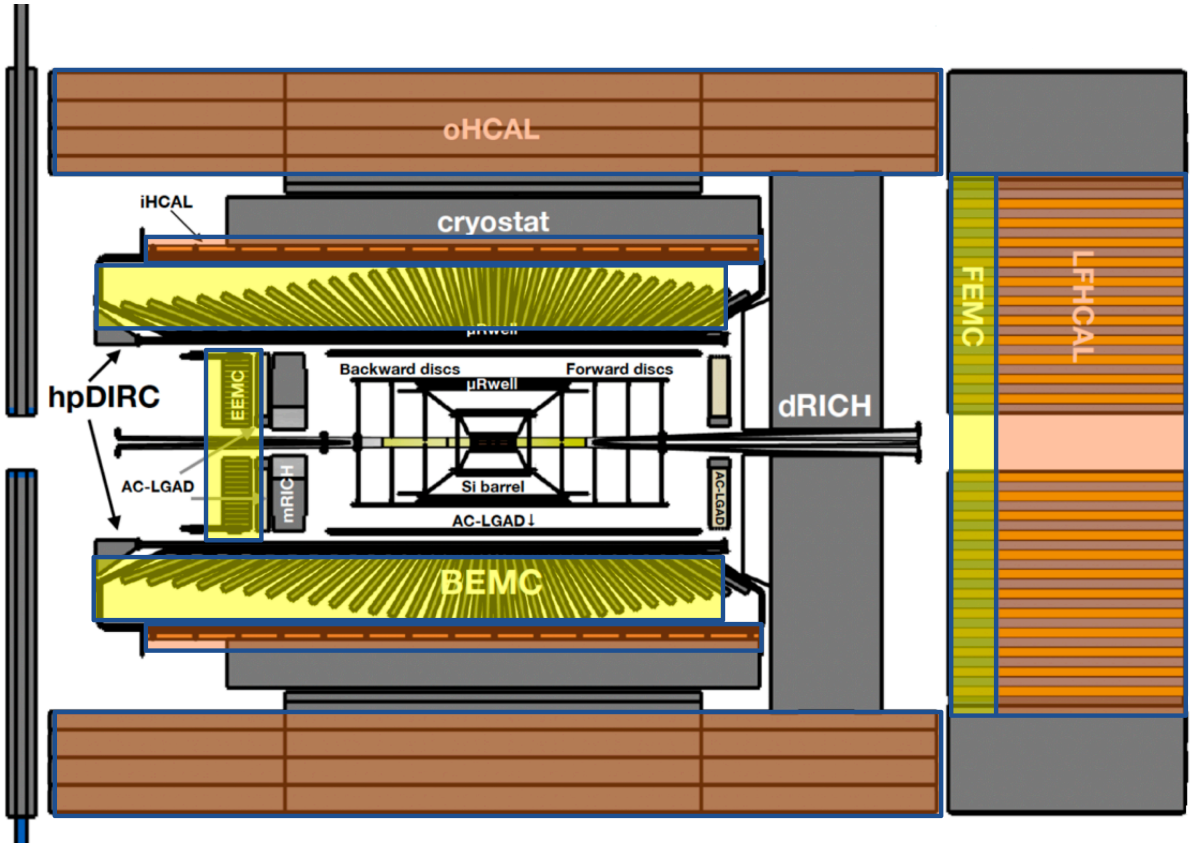
Extension of ongoing hardware developments for EIC detectors

- ALICE ALPIDE, Focal -> EIC vertex tracker and calorimeter
- CMS MTD, GEM -> EIC LGAD, μRWELL
- FCC DRC -> EIC calorimeter

Active collaboration with foreign groups

- BNL, ORNL, LANL, RIKEN, and more…
- Allows concentrating on well defined tasks and minimizes risks

EIC Detector-1 reference design



Tracking:

- Si MAPS (65nm)
- AC-LGAD
- µRWELL

PID:

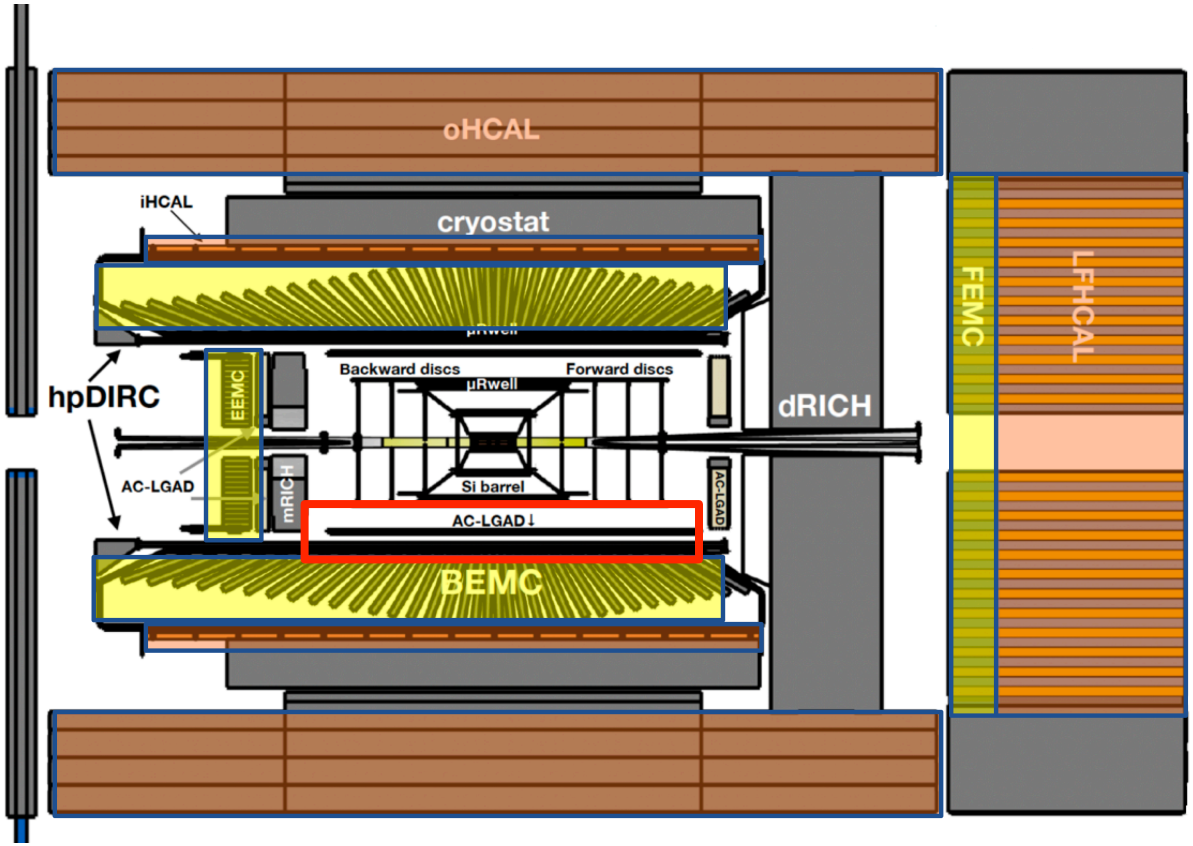
- hp-DIRC
- mRICH
- dRICH
- AC-LGAD (~30ps TOF)

Calorimetry:

- SciGlass Barrel EMCal
- PbWO EEEMCal
- Longitudinally separated EM+Hcal
- Inner HCal (instrumented frame)
- Outer HCal (sPHENIX re-use)

J. Lajoie, ORNL seminar

EIC Detector-1 reference design



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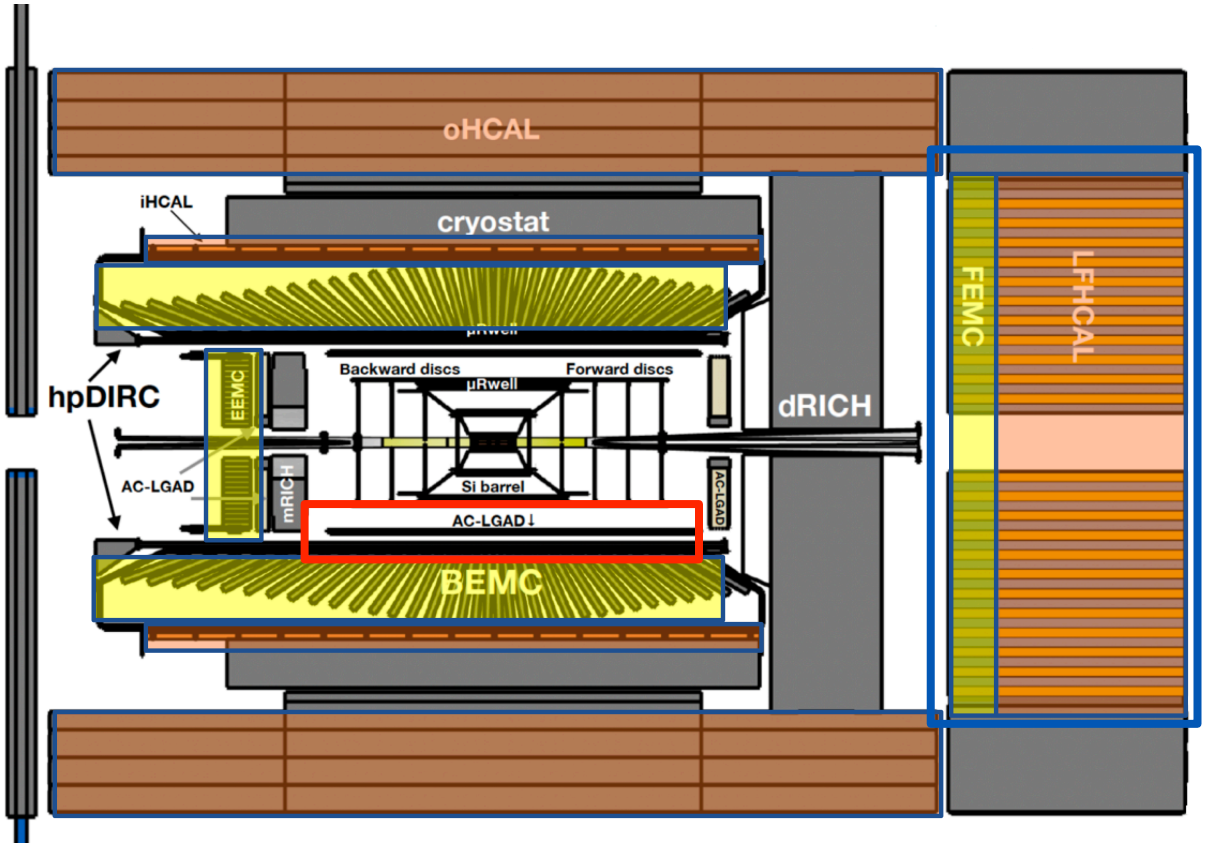

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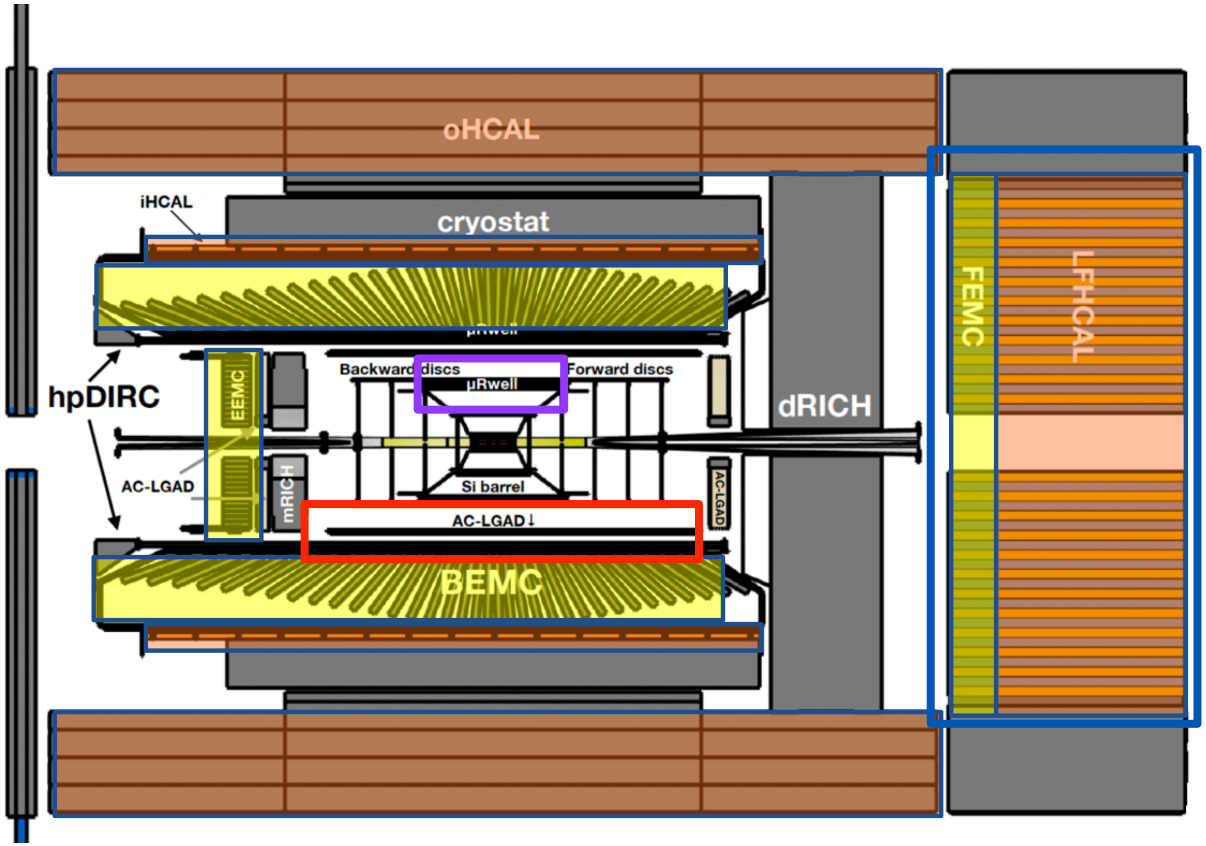

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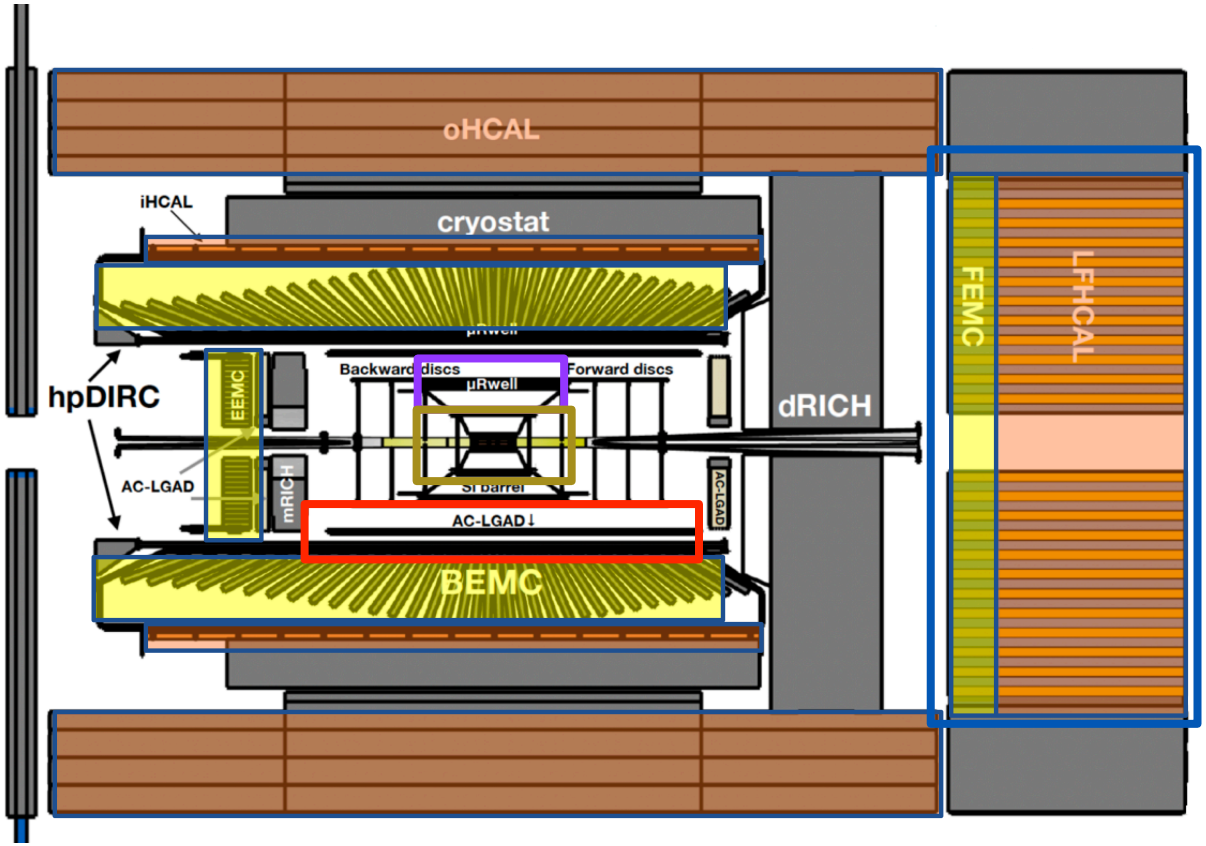

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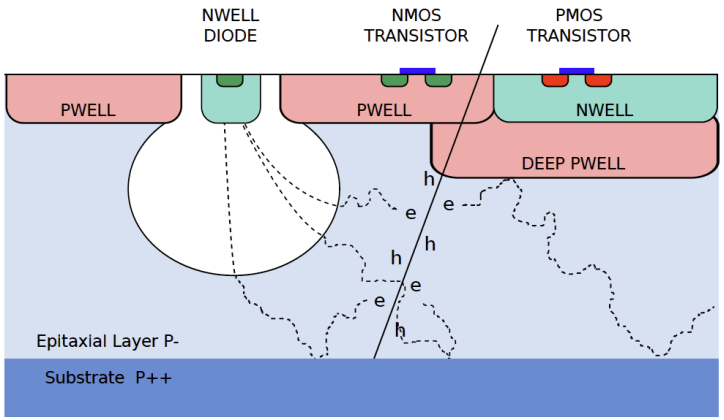
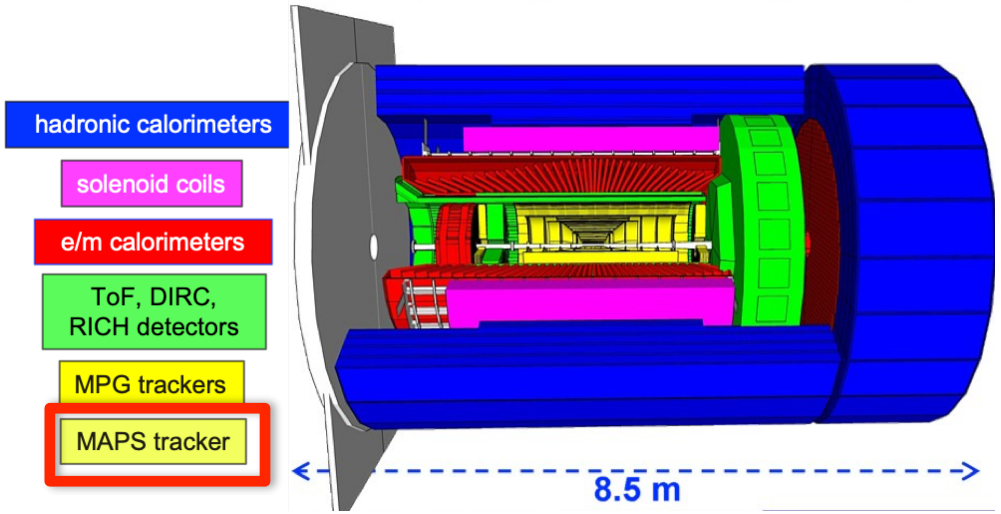
1. Silicon vertex tracker

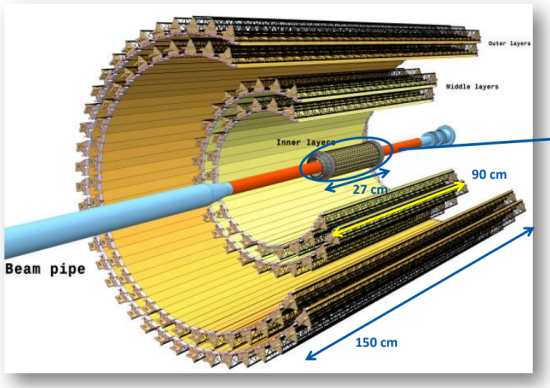




- Precise tracking and vertexing
- MAPS based silicon (STAR HFT, ALICE ITS2, sPHENIX MVTX)
- R&D for the EIC detector is in parallel with R&D for ALICE ITS3
  - ~ 10 μm pitch and improved rate capability
- KoALICE group – PNU, Yonsei U., JNU

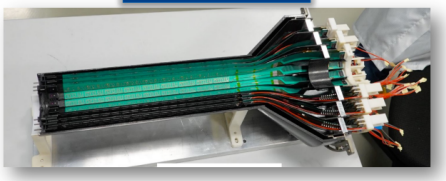
1. Silicon vertex tracker

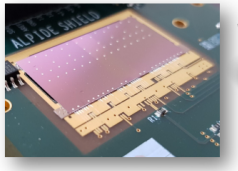
Involvement in post-processing for ALICE ITS2, ITS3

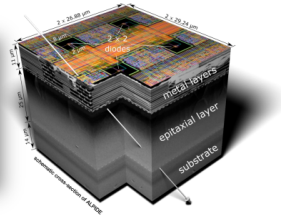


~12.5 Gpixels, 10 m² sensitive area
24120 **ALPIDE** Pixel Sensors (CMOS 180 nm)

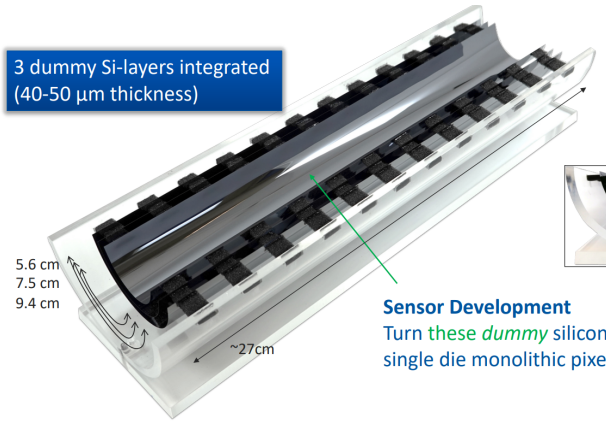
ITS2 Half Inner Barrel

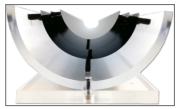






3 dummy Si-layers integrated
(40-50 µm thickness)

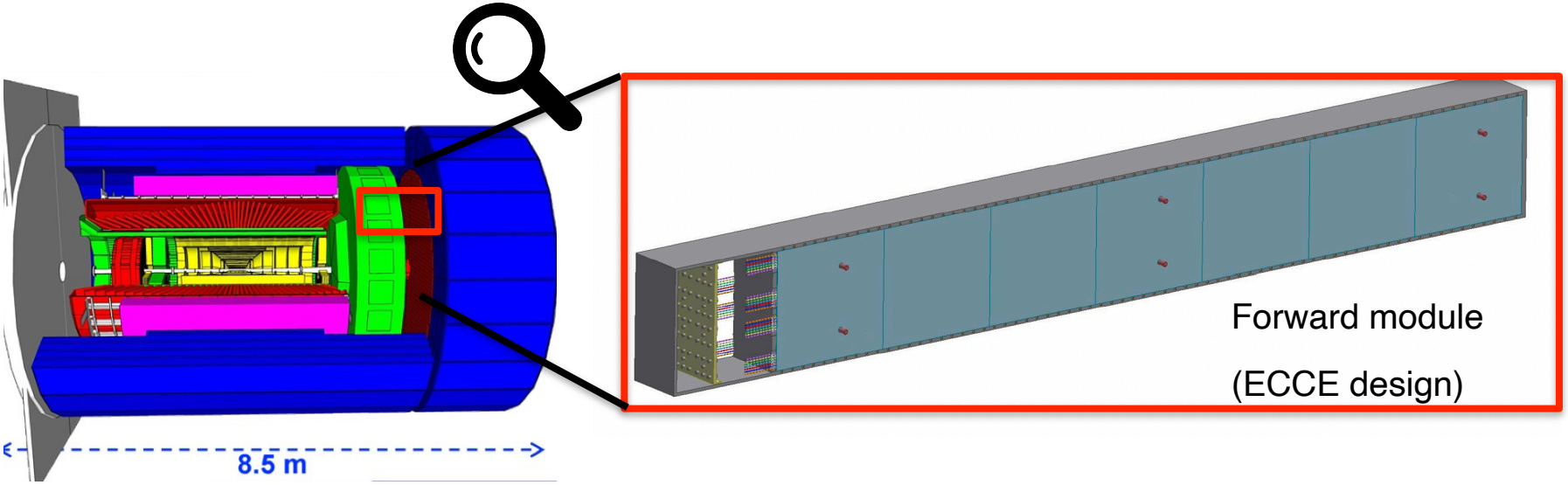


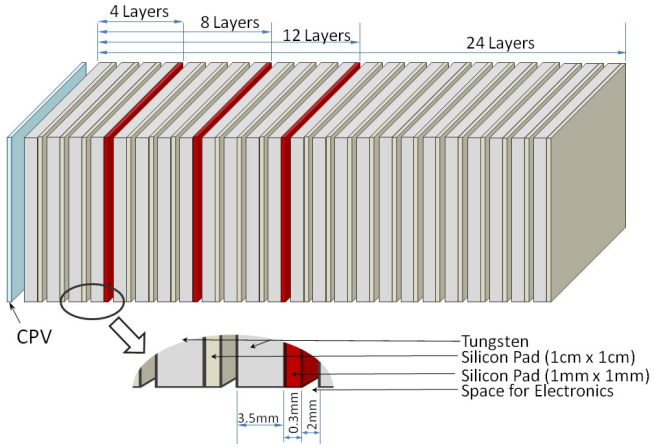


Sensor Development
Turn these *dummy* silicon chips into *true* single die monolithic pixel sensors

- Thinning & Dicing by a Korean company FUREX
- Mass production test
  - probe-card, NOTICE/EQENG
  - Automatic test equipment, C-On
- Module assembly
  - Wire-bonding by a Korean company Sejung
- Also participating in ITS3 design team

2. Readout for EMcal



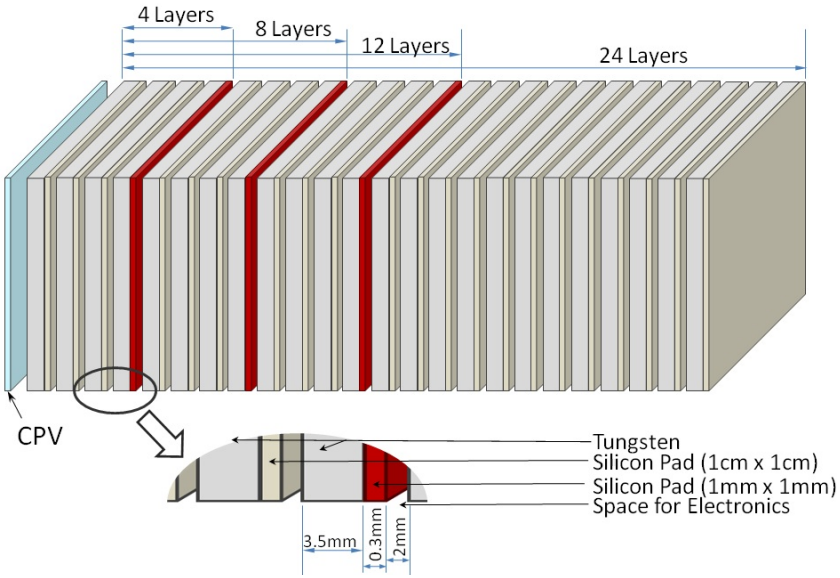


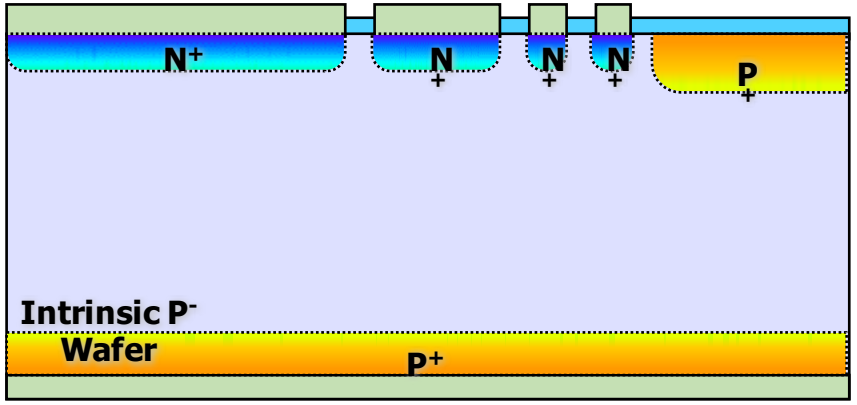
(Ref.) ALICE FoCal

- Measure longitudinal profile of EM shower to enhance e/γ/π^0 separation
- Similar technique with ALICE FoCal
- Kinematics range
  - Δz = 37 cm, 20 < r < 183 cm
  - $1.24 < |\eta| < 3.5$
- Korea Univ., Sejong Univ.

2. Readout for EMcal

Involvement of ALICE FoCal



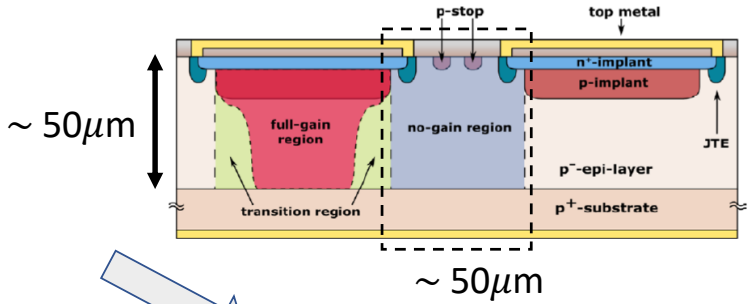


- Medium scale production record ~400 units of 6x6 cm^2
- Design and fabrication process are well understood
- Readout ASIC has to match the ever-developed back-end
- Yonsei U and SJU are involved in R&D to adapt HGCROC (High granularity calorimeter readout chip) for general purpose

3. LGAD (low gain avalanche detector)

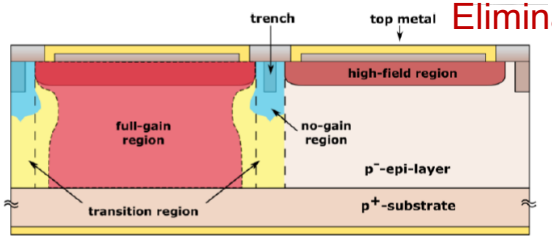
Standard LGADs at HL-LHC

- **Pixel: 1.3x1.3 mm²**
- ~ 50 μm intrapad dead zone

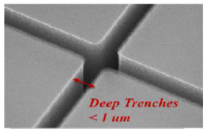


W. Lie

(1) Trench-Isolated (TI) LGADs

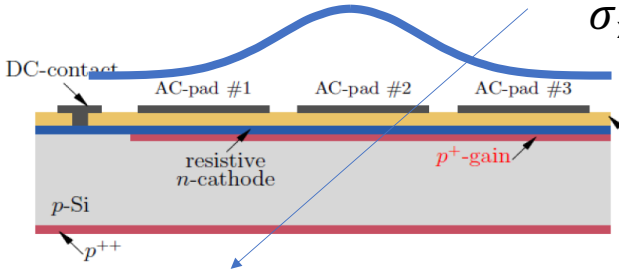


Eliminate dead zone

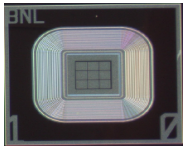


(2) AC-coupled LGADs

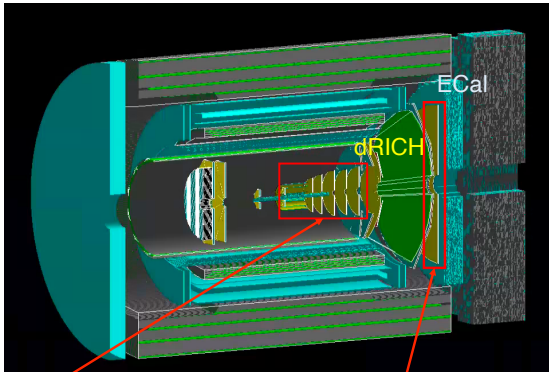
$$\sigma_x < \frac{\text{Pitch}}{\sqrt{12}}$$



BNL



Fine pixelization (~ 100-200 µm) achievable for tracker

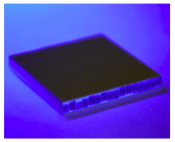


- Fast timing silicon detectors for EIC tracking system
- Key element for particle PID

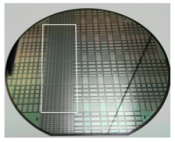
KCMS contribution for LGAD in CMS

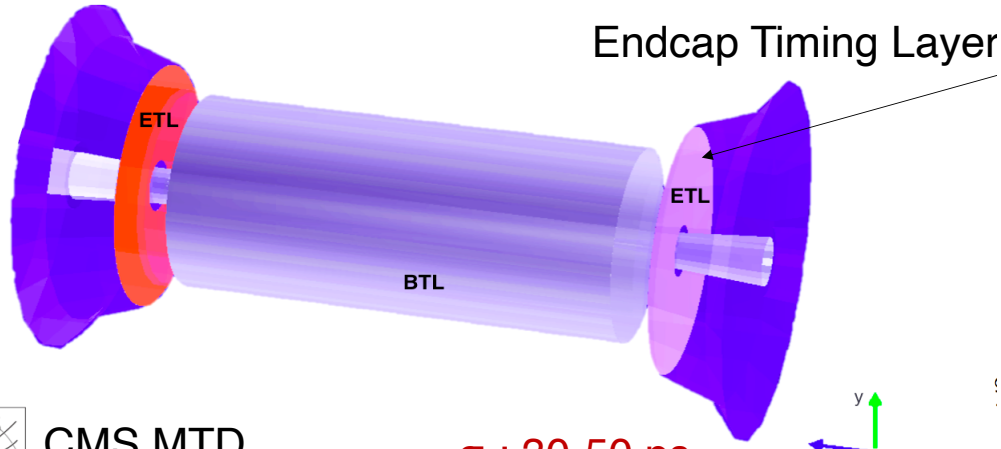
LGADs at the HL-LHC (2028)

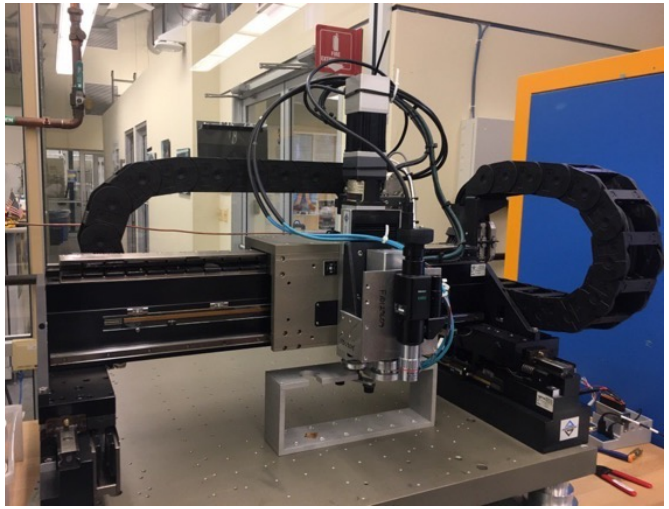
BTL: LYSO bars + SiPM readout:
- TK / ECAL interface: $|\eta| < 1.45$
- Inner radius: 1148 mm (40 mm thick)
- Length: ±2.6 m along z
- Surface ~38 m^2; 332k channels
- Fluence at 4 ab^{-1}: $2x10^{14}$ n_{eq}/cm^2



ETL: Si with internal gain (LGAD):
- On the CE nose: $1.6 < |\eta| < 3.0$
- Radius: 315 < R < 1200 mm
- Position in z: ±3.0 m (45 mm thick)
- Surface ~14 m^2; ~8.5M channels
- Fluence at 4 ab^{-1}: up to $2x10^{15}$ n_{eq}/cm^2

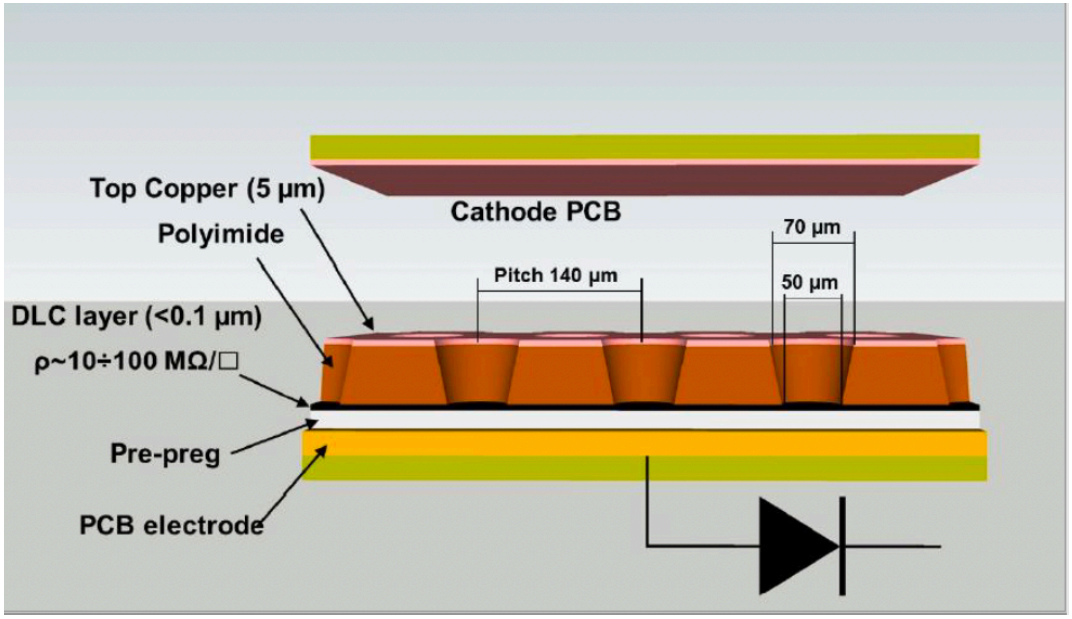


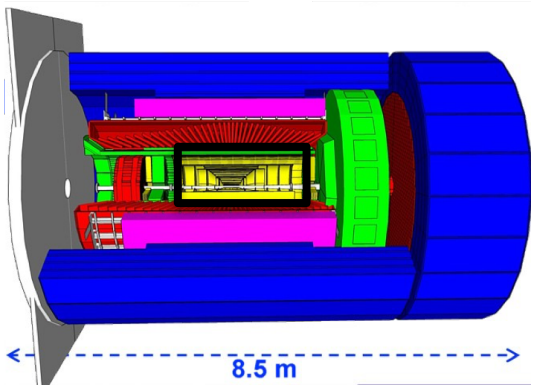




- Endcap layers for CMS MIP Timing Detector (MTD) to be made of LGAD
- KCMS groups – KNU, CNU, KU – are actively involved
  - Prototype assembly, sensor tests with beams and lasers
- A huge synergy can be expected by collaboration with EIC-Japan

4. μRWELL (MPGD)

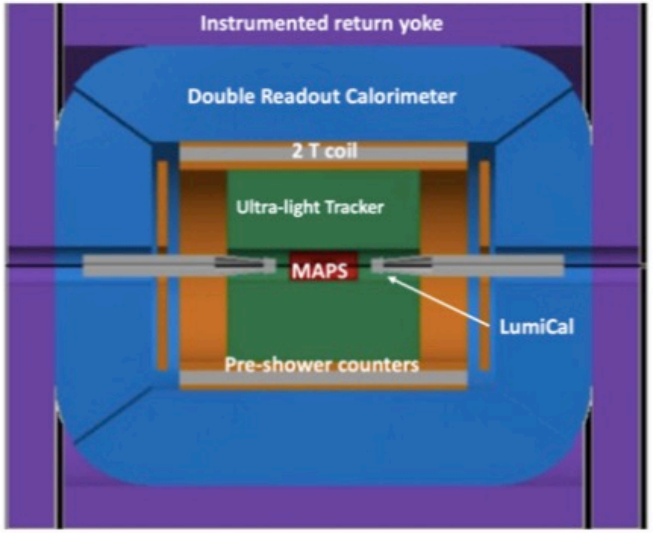




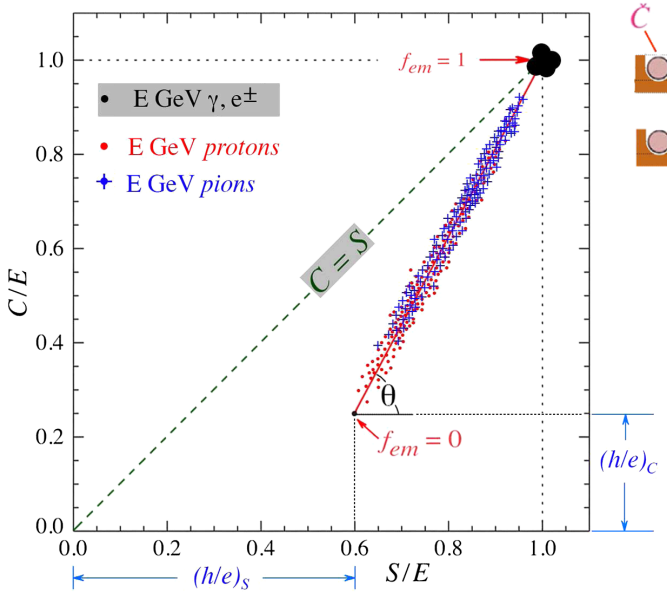
- Used for charged particle tracking
- Operating principle is combination of GEM and RPC, both of which are the world best expertise of Korean groups
- The infrastructure of KCMS is the great opportunity for mass production of MGPD
- Seoul Nat'l Univ., Hanyang Univ.

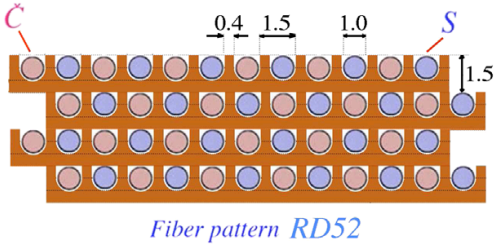
5. Daul Readout Calorimeter

- Cherenkov and scintillation fibers combined in **dual**
  - offers high-quality energy measurement for both EM particles and hadrons
  - The main culprit of poor hadronic energy resolution is fluctuations of the EM shower components of hadron showers (f_{em})
- Proposed for FCC and CEPC
- KNU, Yonsei U. PNU
- Candidate for both barrel and forward calorimeters

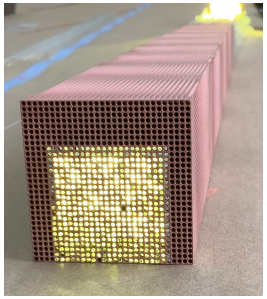


IDEA

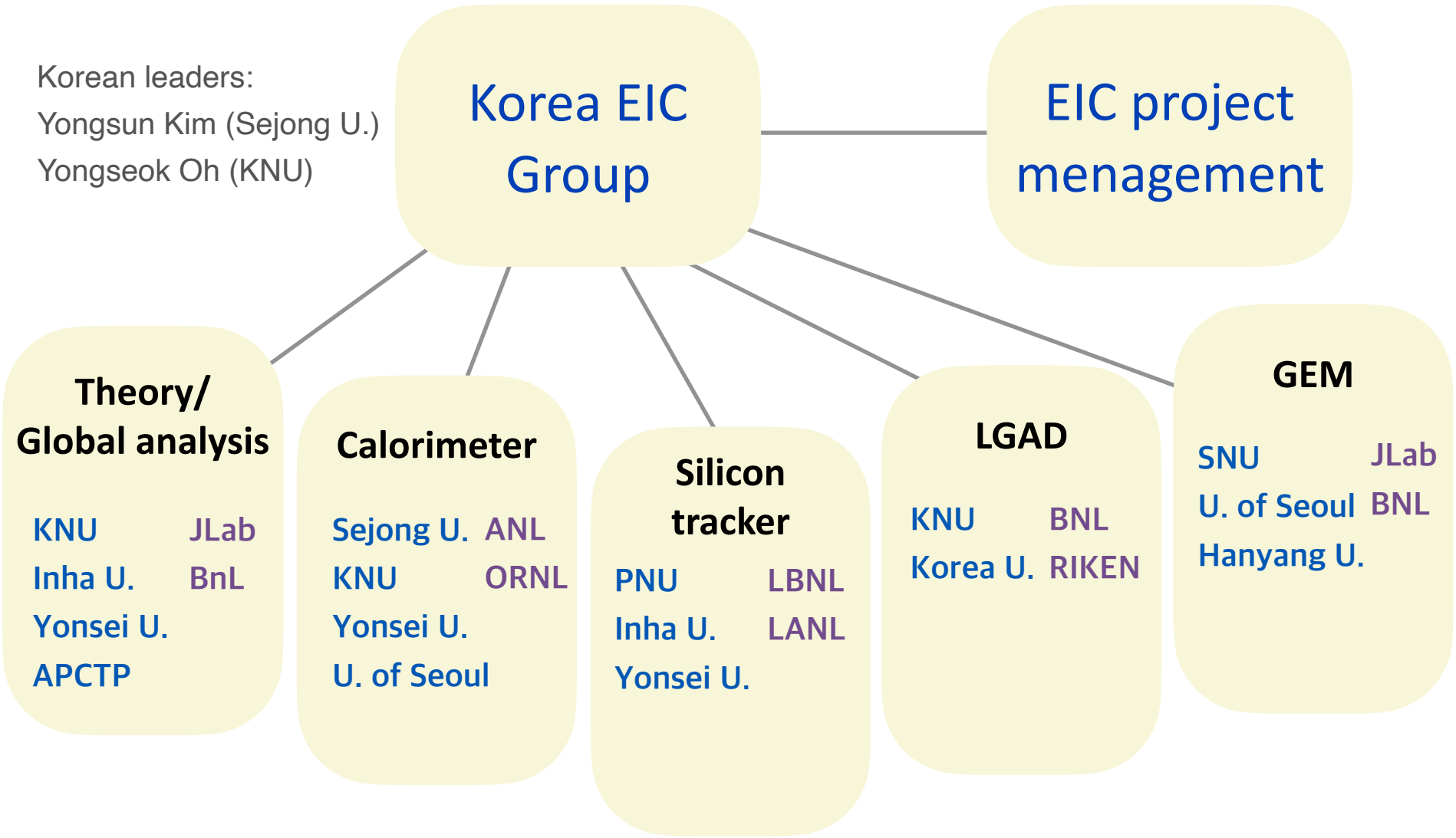




Fiber pattern RD52



International Partnership Proposal



Summary

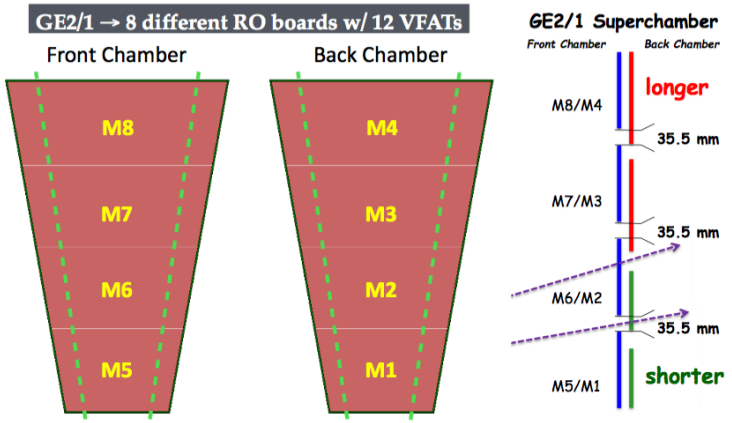
- **For EPIC, we are interested in contribution of following projects**
  - Electronics for calorimeters (HGCROC)
  - μRWELL detector
  - Silicon pixel tracker
  - LGAD sensor
  - Dual readout calorimeter
- **To realize the involvement, we are …**
  - Hard gymnastics to establish concrete plan to be achieve best output with limited manpower and funding
  - Discussion is ongoing with national labs in the US and Japan for practical collaboration
  - seeking for substantial long-term support for R&D and detector construction

backup

Precedent contribution for international collaboration

RPC gap production for CMS

- A longstanding hardware activity from 1990s by Korean high energy & nuclear physics groups

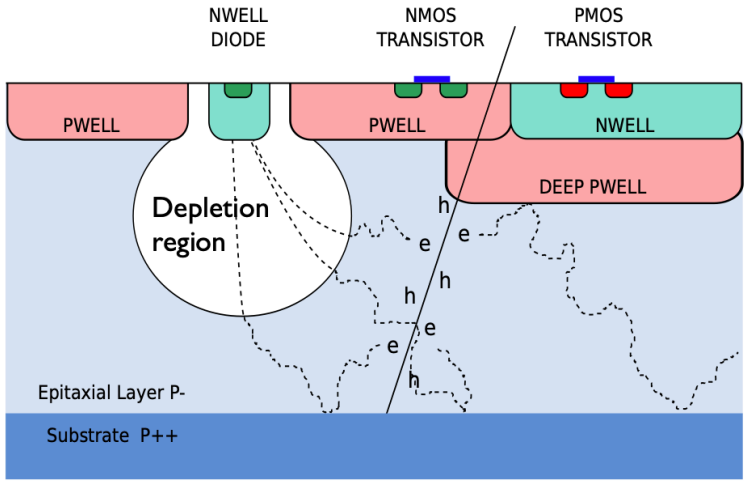


Mass production of GEM foils

- CMS upgrade
- R&D from 2014 by K-CMS group
- GE1/1, ME0

MAPS upgrade for ALICE ITS

- R&D for Pixel chip design and beam test
- Ko-ALICE groups
  - Inha U., Yonsei U., PNU



Experimental nuclear physics groups in Korea

CNU
KNU
Korea U.
IBS
Inha U.
JBNU
PNU
Sejong U.
SKKU
SNU
U. of Seoul
Yonsei U.