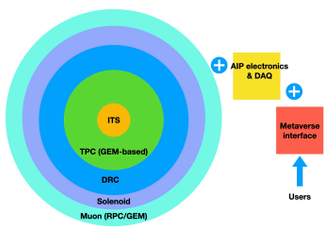
KFCC
Detector R&D Plan

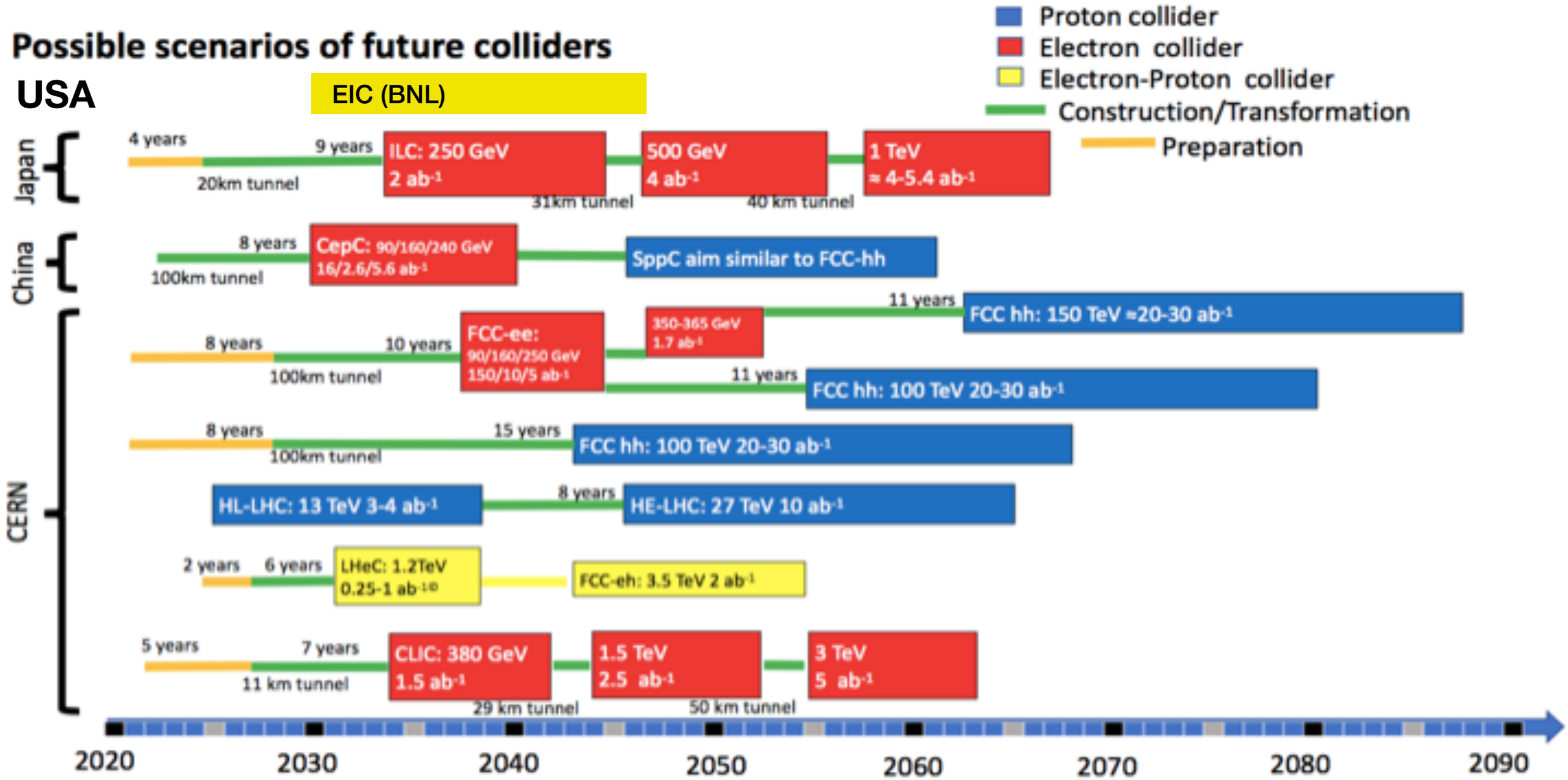
Hwidong Yoo (Yonsei Univ.)



DREAM FOR FUTURE

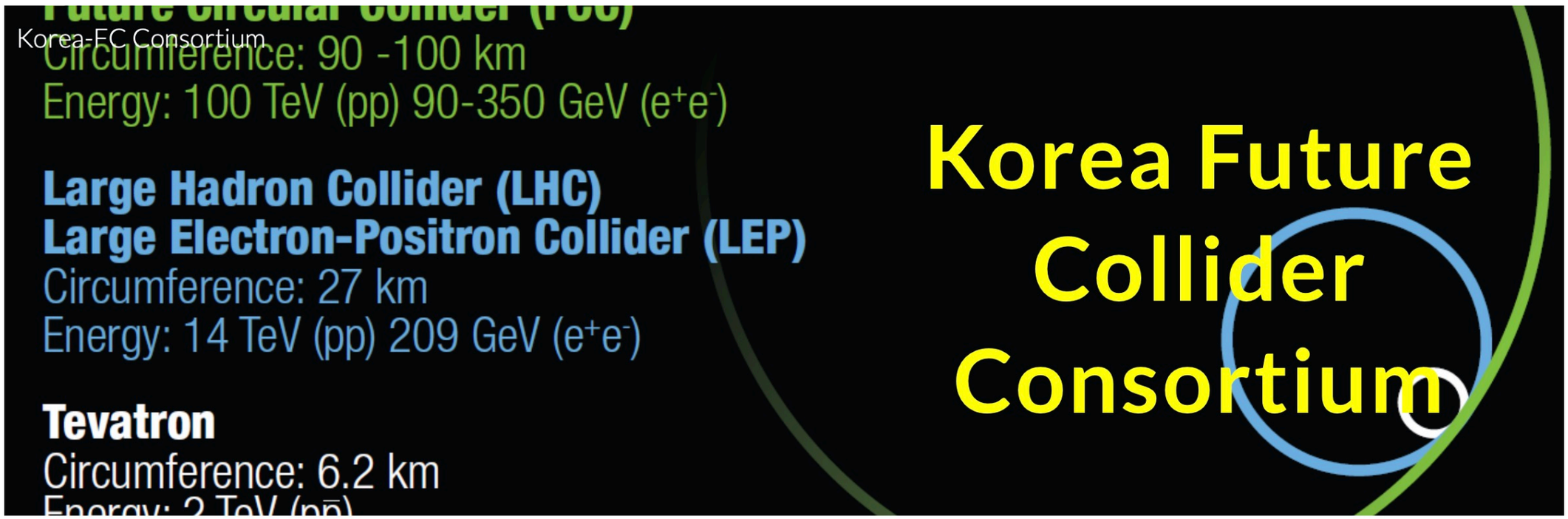
Roadmap of FC Projects

- Time flies very fast!



Korea Future Collider Consortium

- Participants from various fields: accelerator, computing science, experiment, phenomenology etc.



The Standard Model in particle physics has successfully explained all the experimental data up to now. Nevertheless, our minds do not rest in satisfaction because of the baffling questions such as the naturalness problem, the origin of CP violation, the baryogenesis, the non-zero neutrino masses, and the identity of dark matter. We should carry on our journey to the final theory. One essential measure for one step forward is studying future colliders, pushing the energy and intensity frontiers of particle colliders. In this regard, we put our minds together and launch the **Korea Future Collider Consortium**.

Goal: collaborate scientific activities for future collider projects in Korea such as theoretical approaches, detector R&D, accelerator R&D, communication etc.

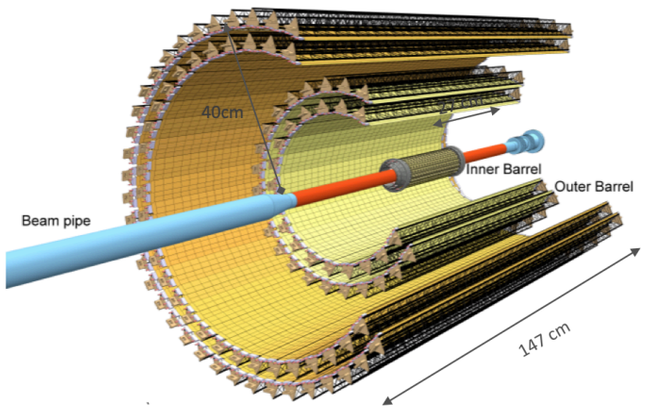
https://sites.google.com/yonsei.ac.kr/korea-fc-consortium

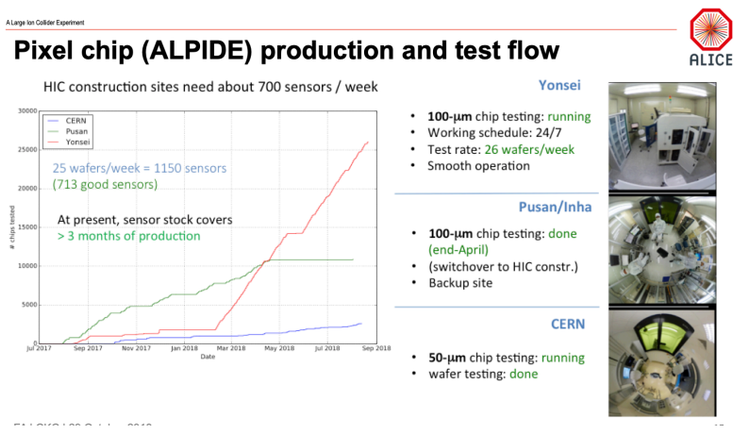
Major Experiments

- Major Korean groups for on-going collider experiments: ALICE, BELLE, CMS
  - We play a leading roles in various detector systems
- Many other detector R&Ds

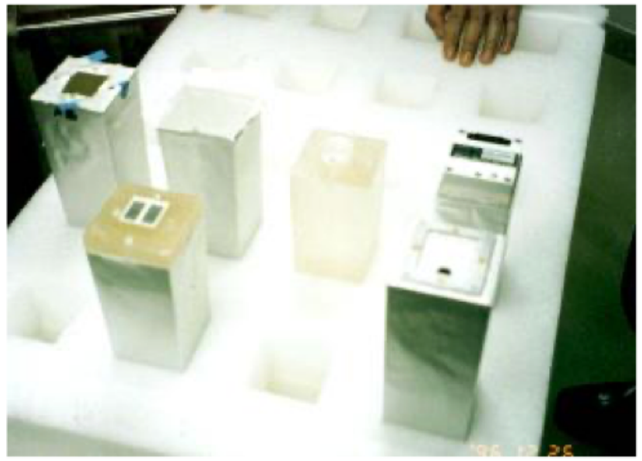
KoALICE group

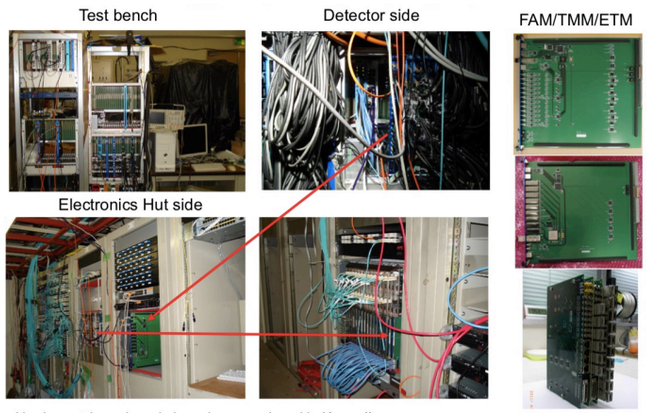
ITS Upgrade





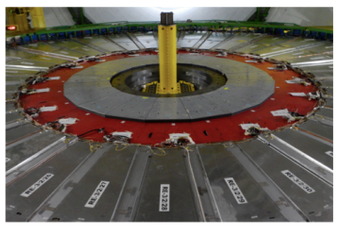
K-BELLE group





KCMS group

- LS1 : RPC (2013-2014)
  - RPC Gap & Chamber
  - Phase-1 RE4/2 installed
- LS2 : GE11, iRPC (2019-2022)
  - GE11 construction (complete)
  - iRPC gap production
- LS3 : GE21, ME0 (2024-2026)
  - GE21, ME0 foil production



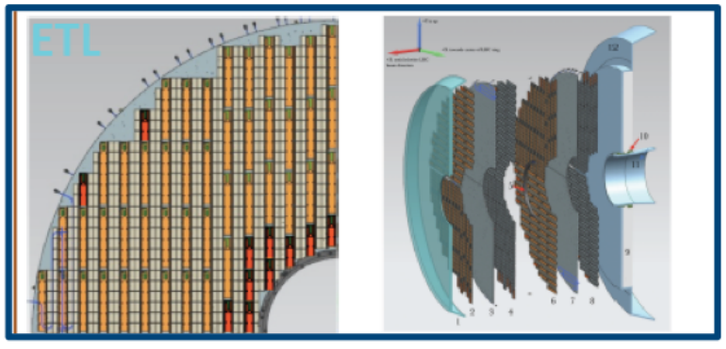
CERN-LHCC-XXXX-XXX
CMS-TDR-YYY
12 September 2020

The Phase-2 Upgrade of the
CMS Data Acquisition and High Level Trigger
Technical Design Report
CMS Collaboration

DRAFT

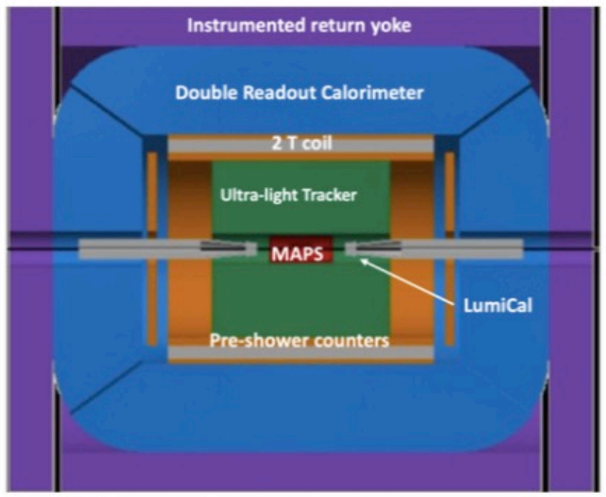
Triggers

ETL:LGAD+ASIC

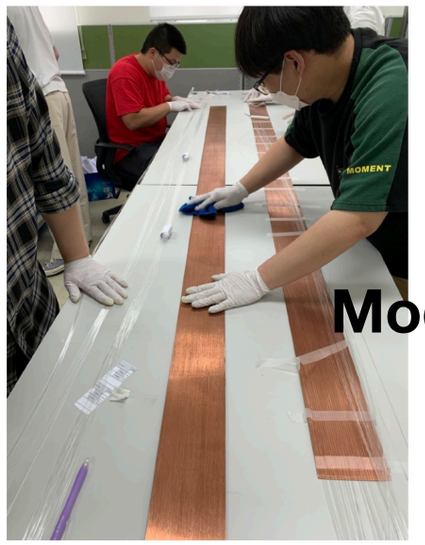


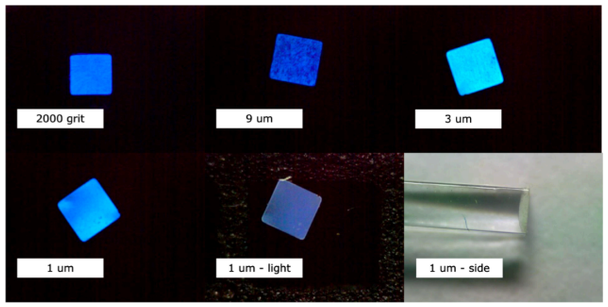
Dual-Readout Calorimeter

- $2M R&D funding (2020-2025): construction of a prototype detector
- Module production and many R&D are on-going, including simulation

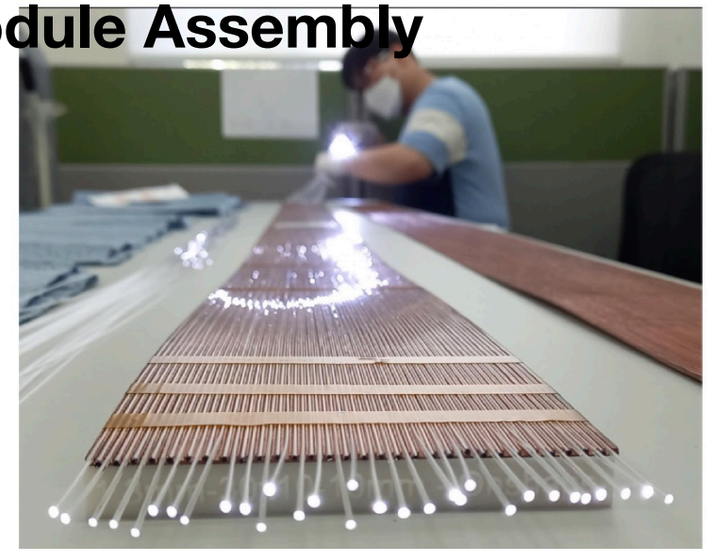


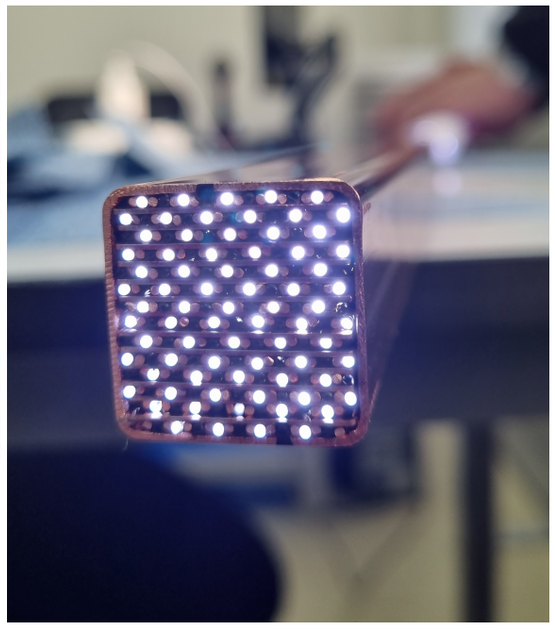
IDEA



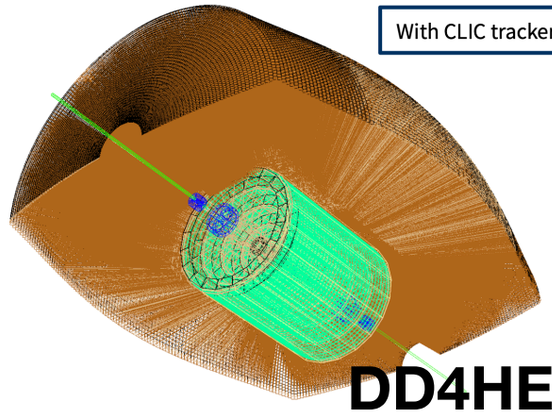


Module Assembly

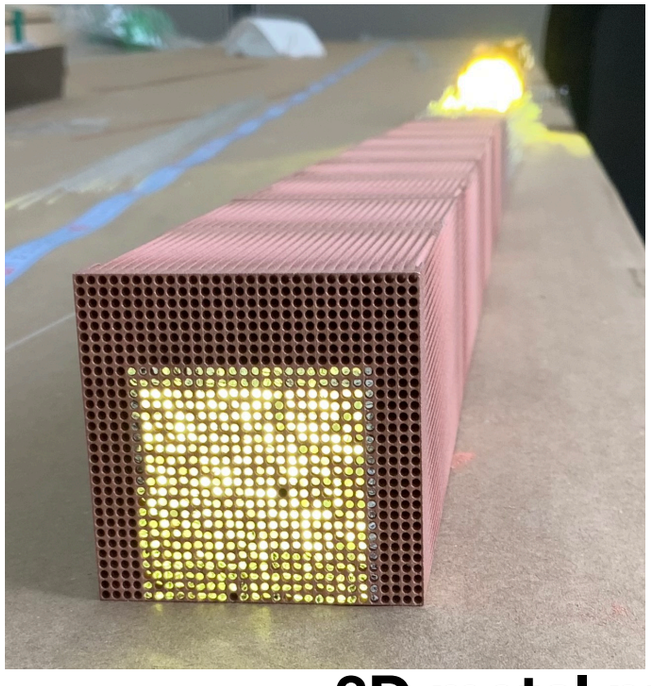




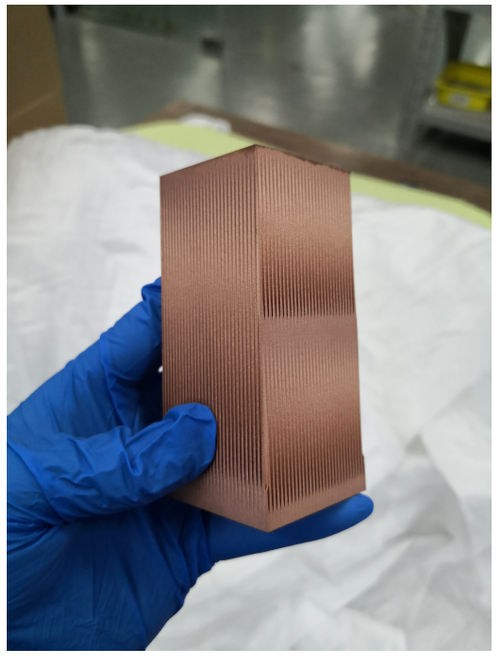
With CLIC tracker

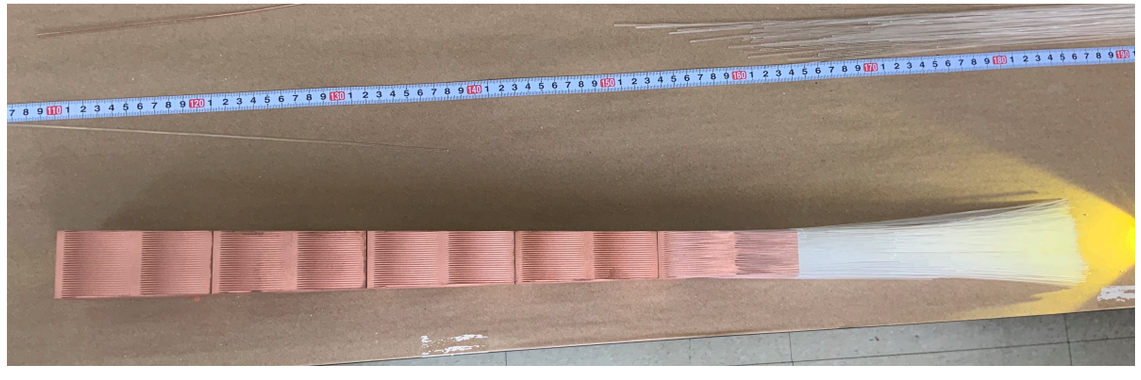


DD4HEP

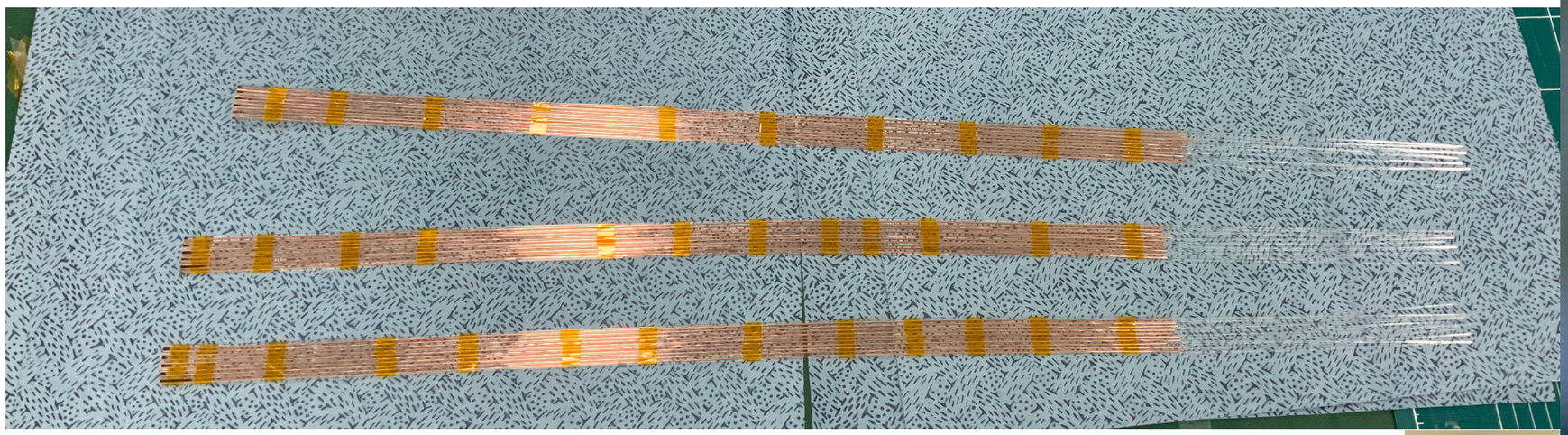


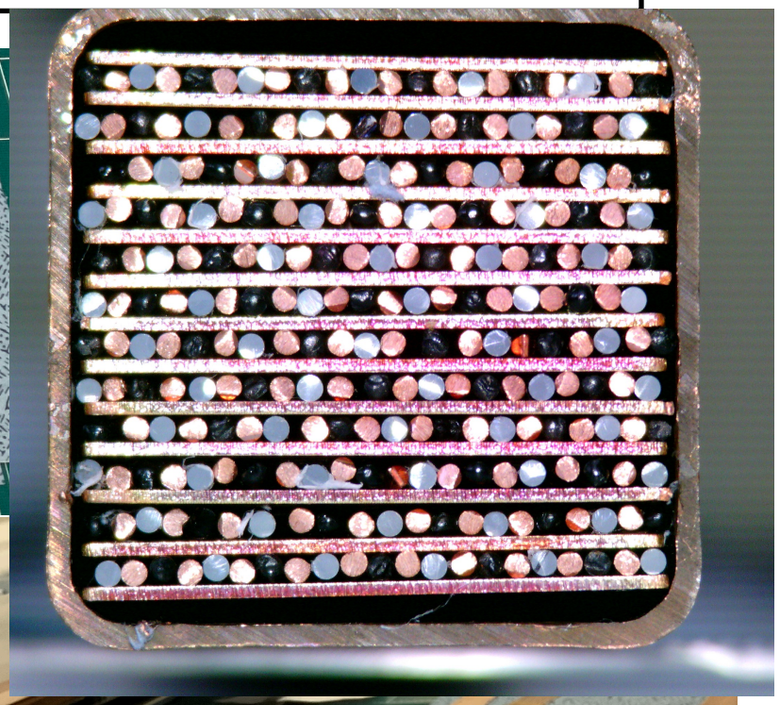
3D metal printing

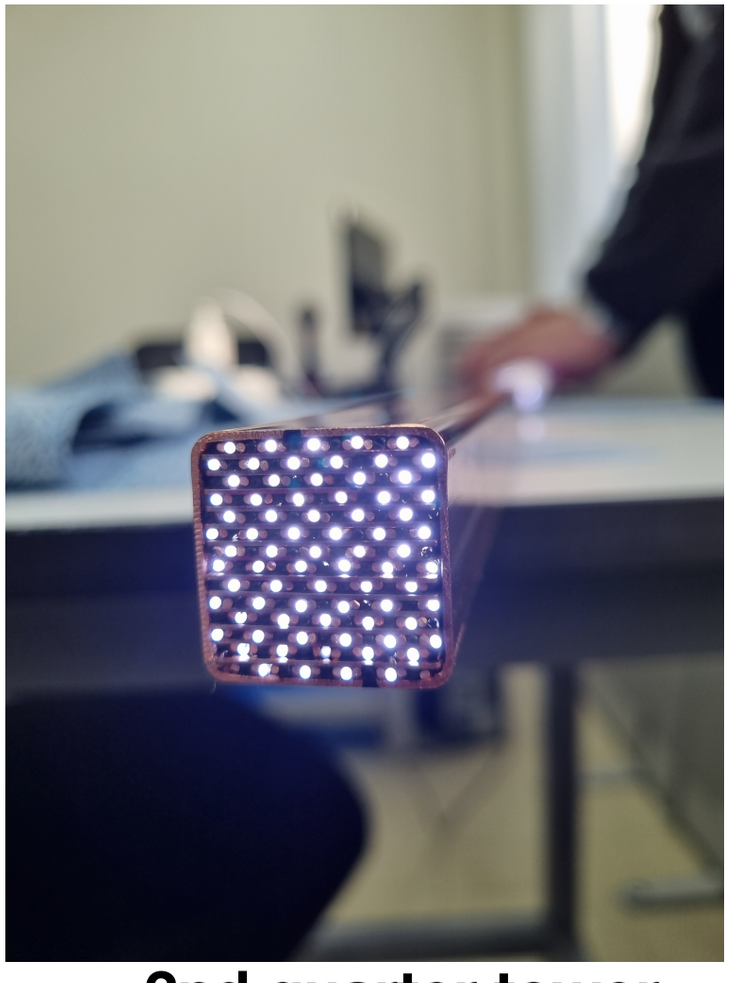




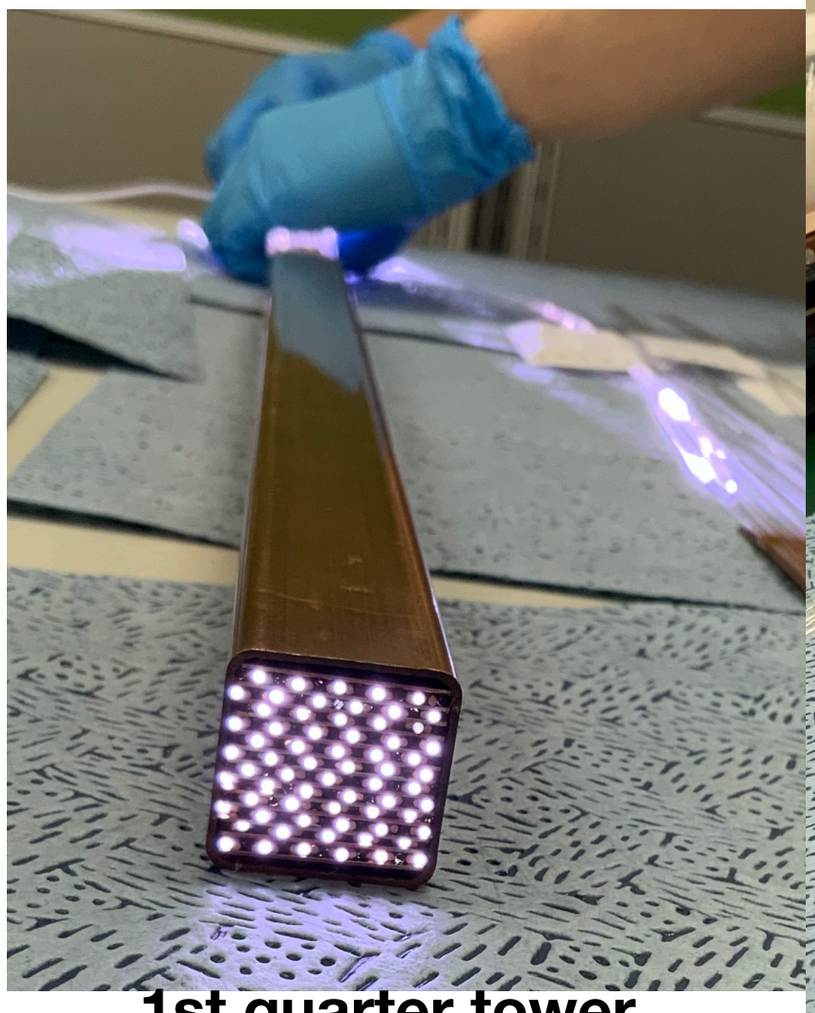
LEGO-like: Quarter Tower



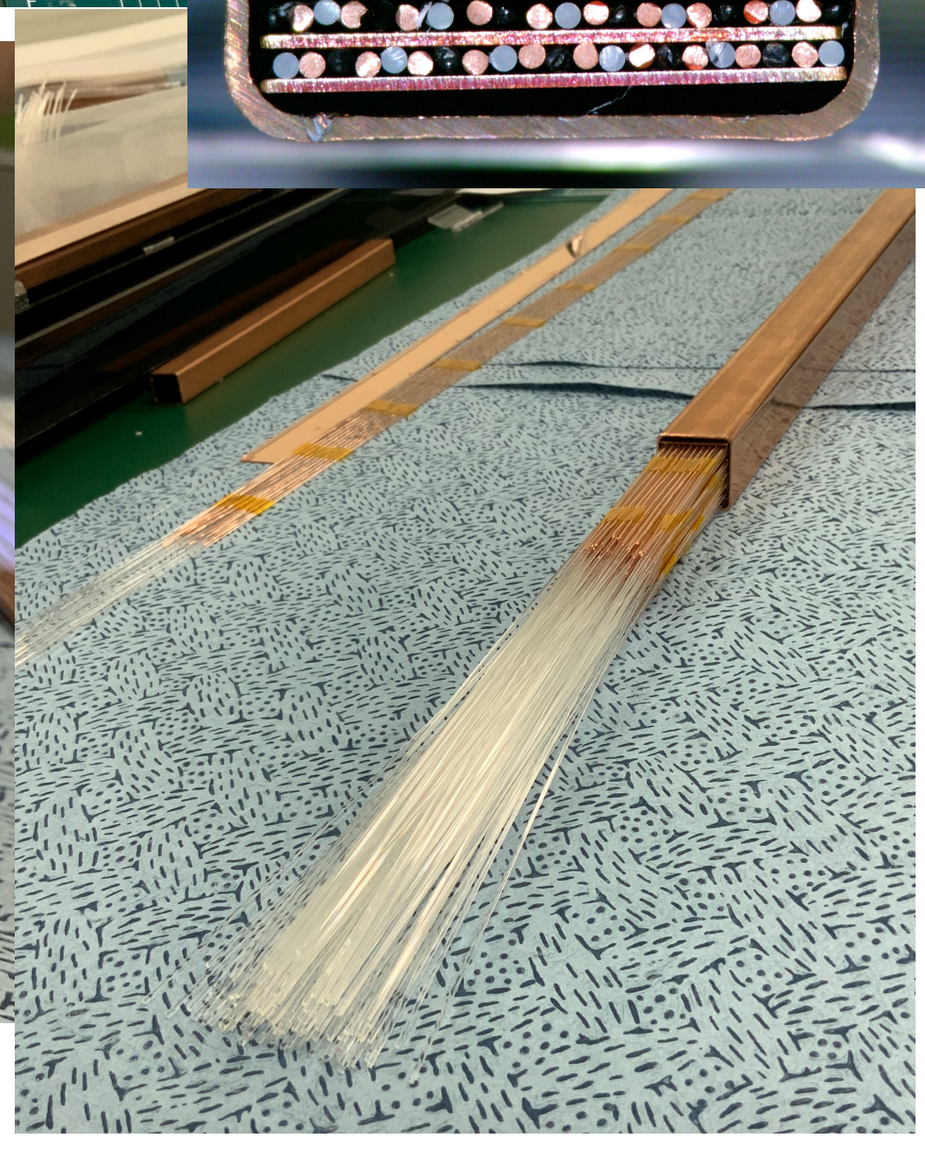




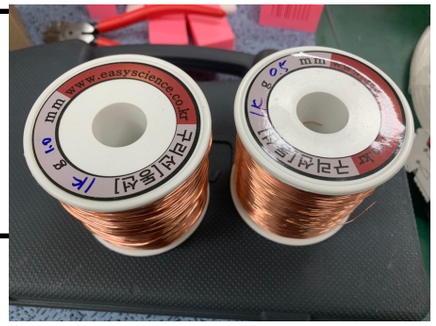
2nd quarter tower



1st quarter tower



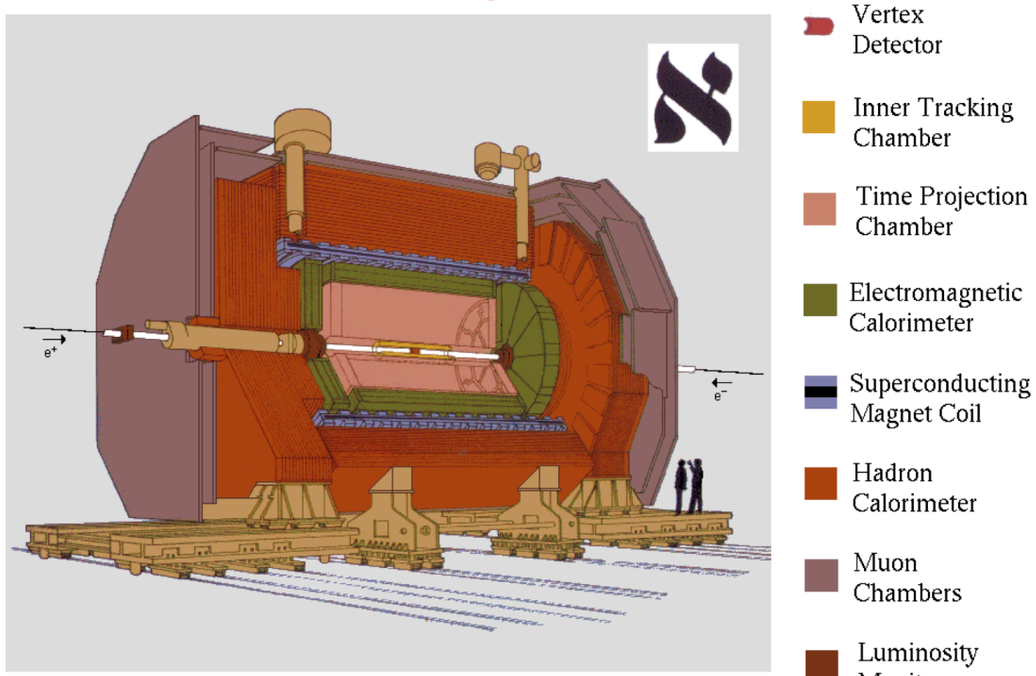
Straightening Wires

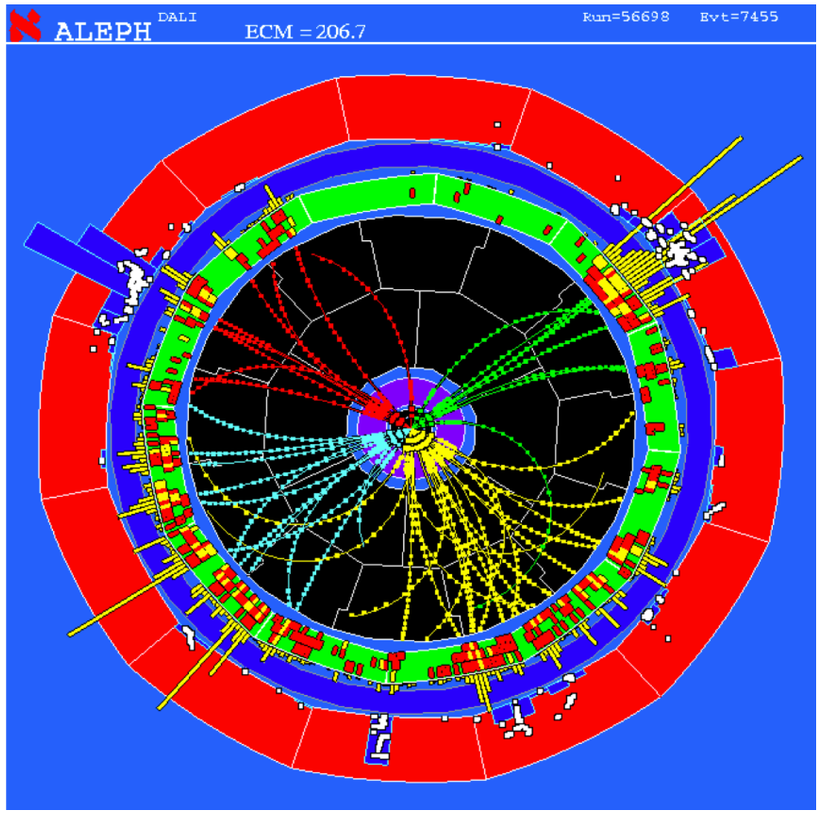


- Nowadays, what I am doing …

Particle Flow Detector

- For particle flow, design requirement:
  - Simplicity
  - 3D granularity for all sub-detectors
  - Large magnetic field (and large tracking volume)
  - Little material in front of the calorimeters
  - Redundancy of the measurements
- Full power (including future development) of computing should be considered for FCC
  - Including HPC and QC

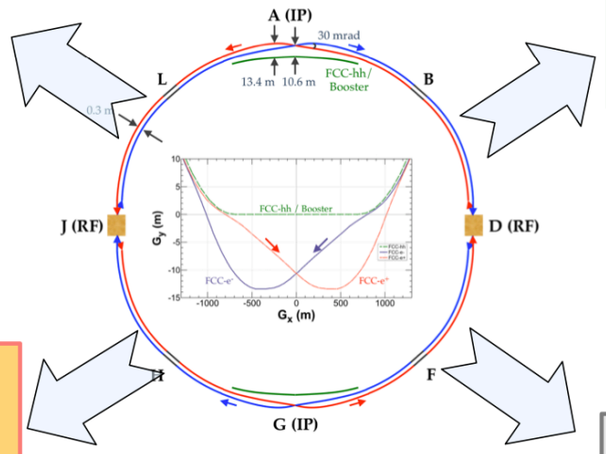




Detector Challenges

"Higgs Factory" Programme

- At two energies, 240 and 365 GeV, collect in total
  - 1.2 M HZ events and 75 k WW → H events
- Higgs couplings to fermions and bosons
- Higgs self-coupling (2-4 σ) via loop diagrams
- Unique possibility: measure electron coupling in s-channel production $e^+e^- \rightarrow H$ @ $\sqrt{s}$ = 125 GeV



Ultra Precise EW Programme

Measurement of EW parameters with factor ~300 improvement in *statistical* precision wrt. current WA

- 5×10^{12} Z and 10^8 WW
  - m_Z, Γ_Z, Γ_{inv}, $\sin^2\theta_W^{eff}$, R^Z_ℓ, R_b, α_s, m_W, Γ_W, …
- 10^6 tt
  - m_{top}, Γ_{top}, EW couplings

Indirect sensitivity to new phys. up to Λ=70 TeV scale

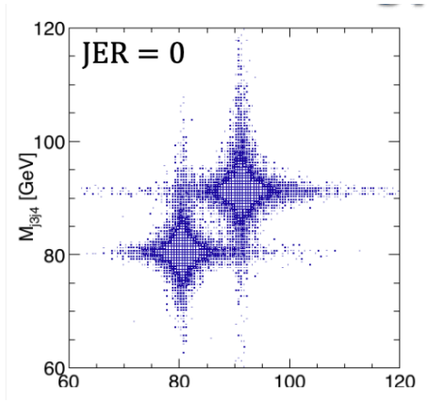
Heavy Flavour Programme

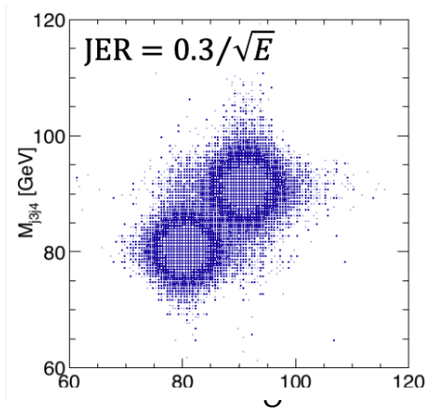
- Enormous statistics: 10^{12} bb, cc; 1.7×10^{11} ττ
- Extremely clean environment, favourable kinematic conditions (boost) from Z decays
- CKM matrix, CP measurements, "flavour anomaly" studies, e.g. b → sττ, rare decays, cLFV searches, lepton universality, PNMS matrix unitarity

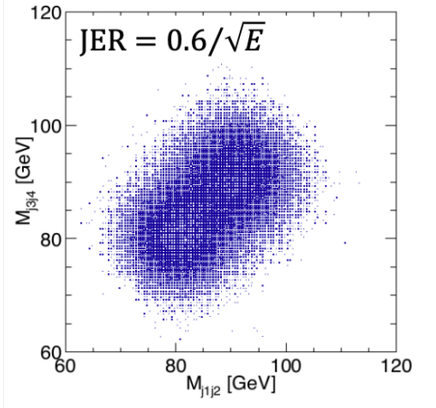
Feebly Coupled Particles - LLPs

Intensity frontier: Opportunity to directly observe new feebly interacting particles with masses below m_Z:

- Axion-like particles, dark photons, Heavy Neutral Leptons
- Signatures: long lifetimes - LLPs







Updated Roadmap for FCC

The PED Pillar Objectives in 2025

- **Mostly defined by the general (tight) timeline of the FCC project**

Infrastructure and accelerator **Physics, Experiments, and Detectors**

Milestone / activity	Target date	Possible timeline
First e^+e^- collisions in FCC-ee	Early 2040's	FCC-ee detector commissioning
Start machine installation	2037	Start FCC-ee detector installation
Tunnel completion	2035/36	
Start tunnel construction	2030	Start FCC-ee detector construction
Project approval	2028/29	FCC-ee Detector TDR's and approvals
Next European Strategy Update	2026/27	Next European Strategy Update (ESU)
Key prototypes (feasibility proof)	2026	FCC-ee Proto-collaborations and EoI's
FSR(*) (feasibility proof)	End 2025	PED FSR, includes enough common material and knowledge for FCC-ee proto-collaborations

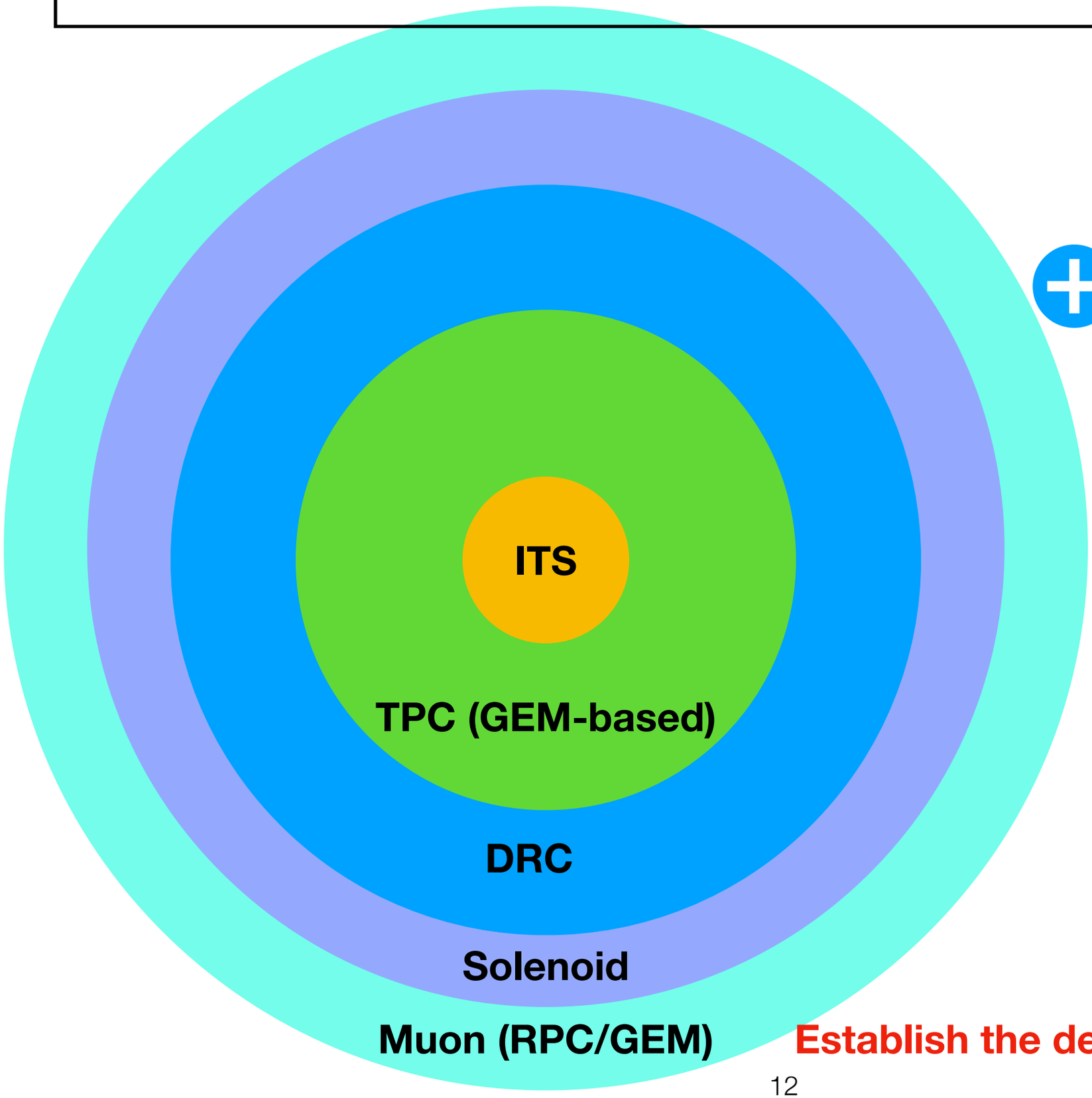
(*) FSR = Feasibility Study Report

Adapted from schedule in M. Benedikt's presentation

Our Vision

- For future e+e- collider projects, we should obtain the knowledge how to design the collider detector
- Beyond particle-flow detector, ML friendly detector should be essential
  - AI Physicist: all detector subsystems should have sufficient granularity, resolution, functionality with ML process
  - Image-based process (+ end-to-end) should be strongly considered
  - For advantage: compactness, low cost, fast timing resolution
- Metaverse should be able to plug in the design
  - Do you have a vision for young generation to attract them to HEP?
- Essential collaboration with: database expert, game expert, metaverse expert, AI (computing science) expert, etc.

0th Idea of AIP Detector Concept



AIP electronics & DAQ

Metaverse interface

Users

Establish the detector design requirement

Initial Idea of Requirement

- Need to have
  - High performance on flavor tagging (b, c, s quarks), particle identification, timing resolution
- Compactness
  - Electronics: chip on board? Collaborate with silicon detector expert
  - Wireless data transmission
- Ultra fast timing resolution
  - Real-time occupancy of subsystem is much lower than LHC
- AI-friendly design
  - high granularity (3D)
  - Support end-to-end process
- Metaverse: doing physics like metaverse game?
- Higher energy
  - Muon collider (Fermilab proposed) is initiated and needs a detector concept

KFCC Letter of Intent: v0

Letter of Intent from the Korea Future Collider Consortium

송정현 (건국대학교)

김홍주, 문창성, 박환배, 이세욱 (경북대학교)

이강영 (경상대학교)

고정환 (경희대학교)

원은일, 유재혁, 이승준, 최수용, 최준곤 (고려대학교)

임상훈 (부산대학교)

강신규, 박명훈 (서울과학기술대학교)

양운기, 정성훈 (서울대학교)

이상훈 (서울시립대학교)

김범규 (성균관대학교)

김용선 (세종대학교)

권영준, 박성찬, 유희동 (연세대학교)

문동호, 이재식 (전남대학교)

최성렬 (전북대학교)

이현민 (중앙대학교)

김정한 (충북대학교)

손민호 (한국과학기술원)

김태정 (한양대학교)

요약문

CERN 연구소의 Future Circular Collider (FCC) 프로젝트

- LHC 실험의 후속 프로그램으로 2030년대 후반 가동 시작을 목표로 함
- 건설비용만 수십 조 원으로 예측되는 금세기 최대 국제 공동연구 프로젝트
- 주요 연구 주제로 힉스 입자의 정밀 관측 및 새로운 물리현상 탐사
- 2020년부터 HL-LHC 업그레이드와 함께 CERN 연구소의 최우선 순위 연구주제로 선정됨
- CERN 연구소의 FCC 가속기 및 검출기 R&D 프로그램이 시작되어 관련 연구가 본격적으로 진행되고 있음 (2021 - 2025)
- 예상 일정: 가속기, 검출기 디자인 제출 (2025), 국제 공동연구단 구성 (2026), 프로젝트 승인 (2028), 건설 시작 (2030), 가동 시작 (2040)

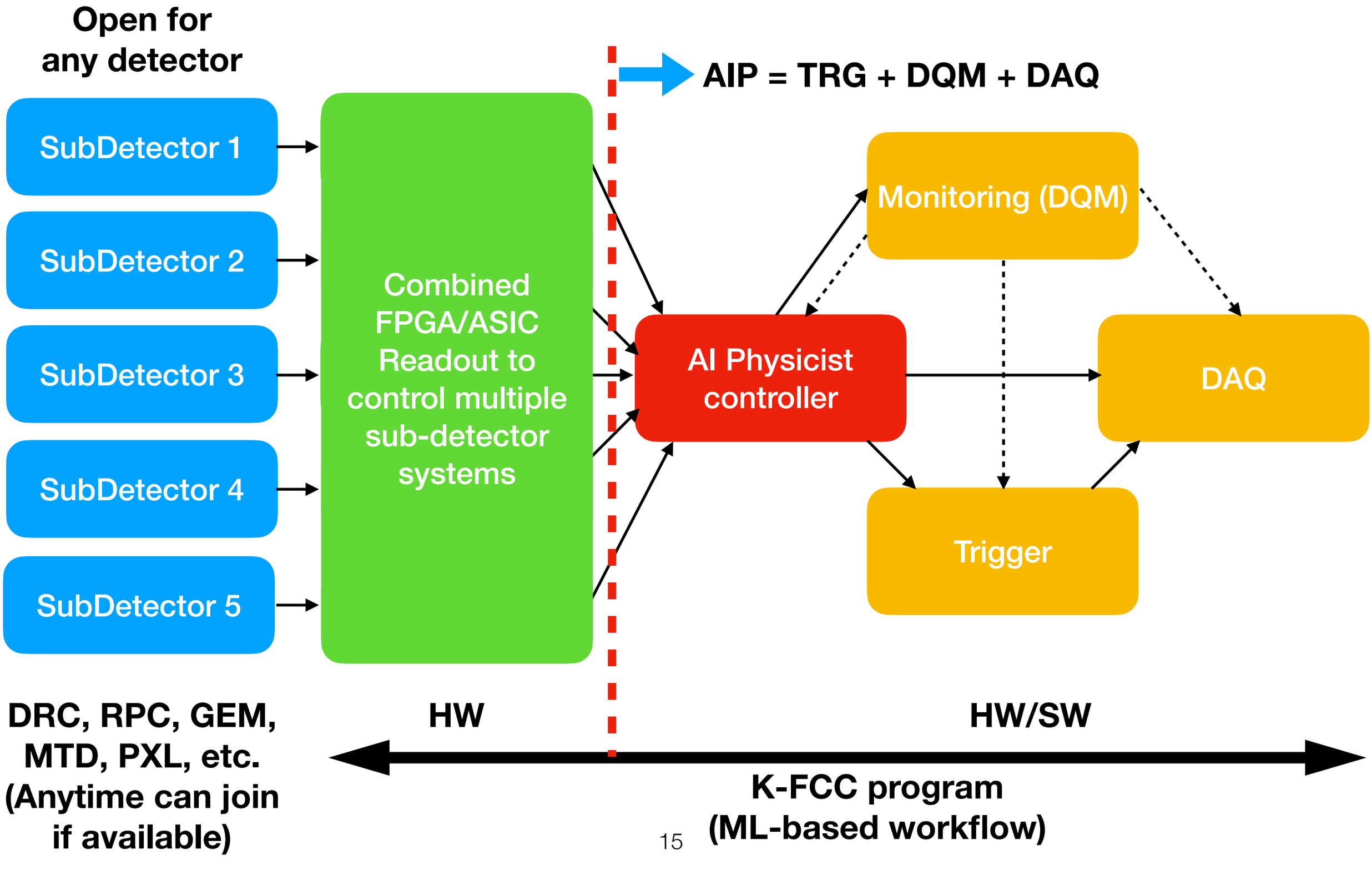
한국 차세대 가속기 컨소시움 (Korea Future Collider Consortium)

- 차세대 가속기 관련 연구에 대하여 한국 물리학자들이 전 세계 입자물리 커뮤니티에서 **선도적 역할**을 위하여 구성
- FCC 실험에 사용될 주요 검출기에 대한 디자인, 프로토타입 R&D, 제작을 통한 **검출기 오너십**을 한국 연구진이 획득하는 것을 주요 목표로 함
- 이론, 실험, 빅데이터, 인공지능 등 다양한 분야의 전문가들이 모여 차세대 기초과학 연구의 방향성 설립 및 새로운 아이디어로 확장
- 차세대 가속기 관련 국내외 전문가 커뮤니티와의 협업체계 구축

연구계획

- 인공지능을 기반으로 하는 차세대 검출기에 대한 개념 설계, 디자인, 프로토타입 R&D 수행을 목표로 함
- 인공지능 성능 가속화를 위하여 하드웨어와 소프트웨어를 결합한 하이브리드형 인공지능 플랫폼 개발
- 하위 검출기 시스템을 유기적으로 작동시켜 최적화하는 **인공지능 물리학자** 개발
- FCC 실험에서 수행 가능한 표준모형 및 새로운 물리이론에 대한 현상론적 연구
- 슈퍼컴퓨터, 양자컴퓨터를 이용한 양자머신러닝 등 첨단 미래 기술 활용

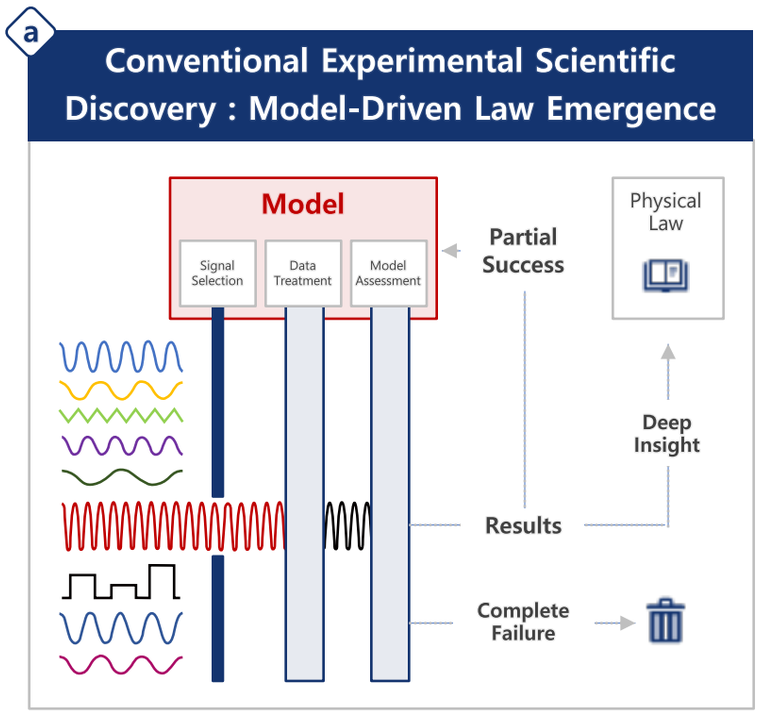
AI Physicist

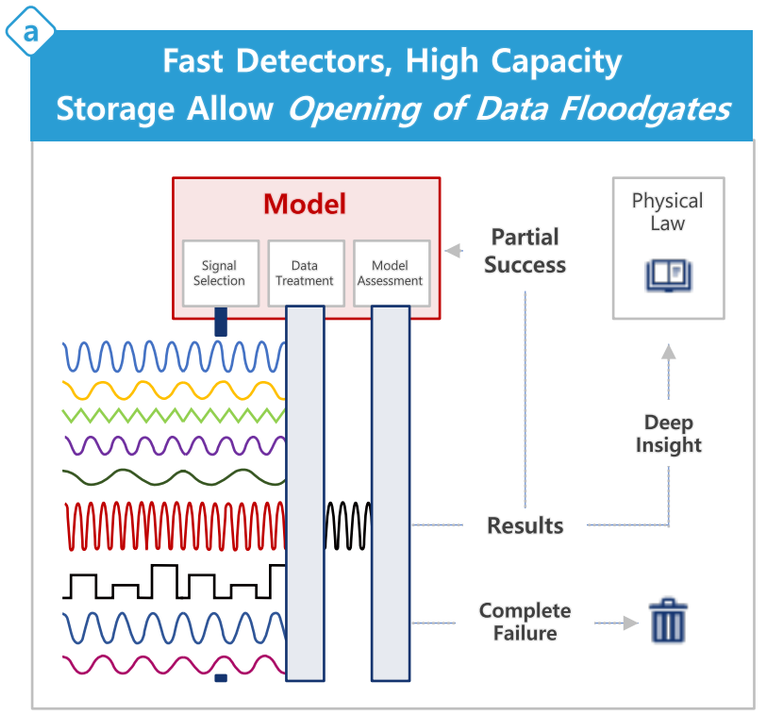


AI Physicist Idea

인공지능 물리학자

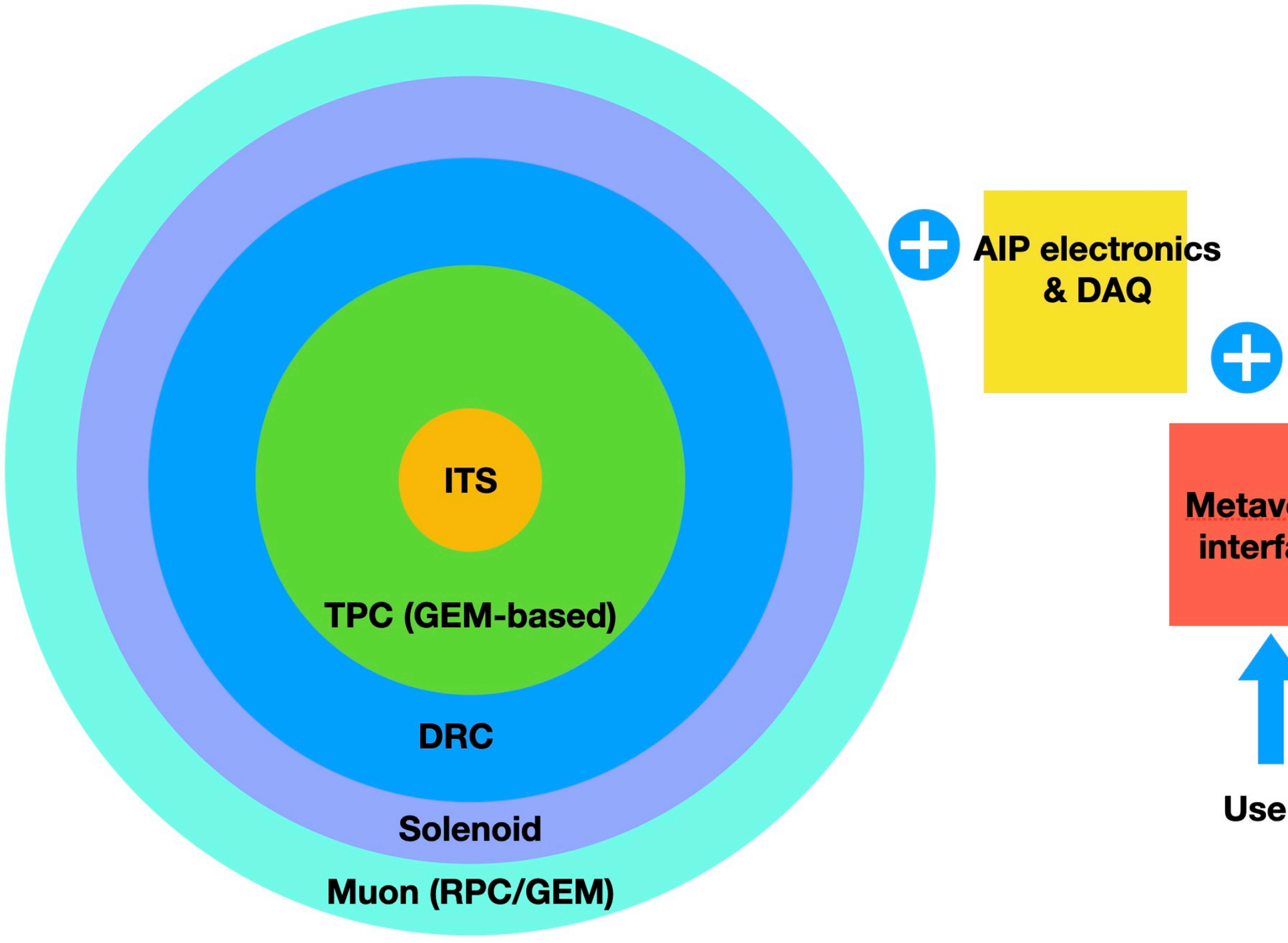
시스템 작동 과정	시스템 필수요소
데이터 획득	자동화
데이터 처리	시각화
데이터 분석	두뇌화





Summary

- We will move forward!



Backup