# Technologies in ILC detectors

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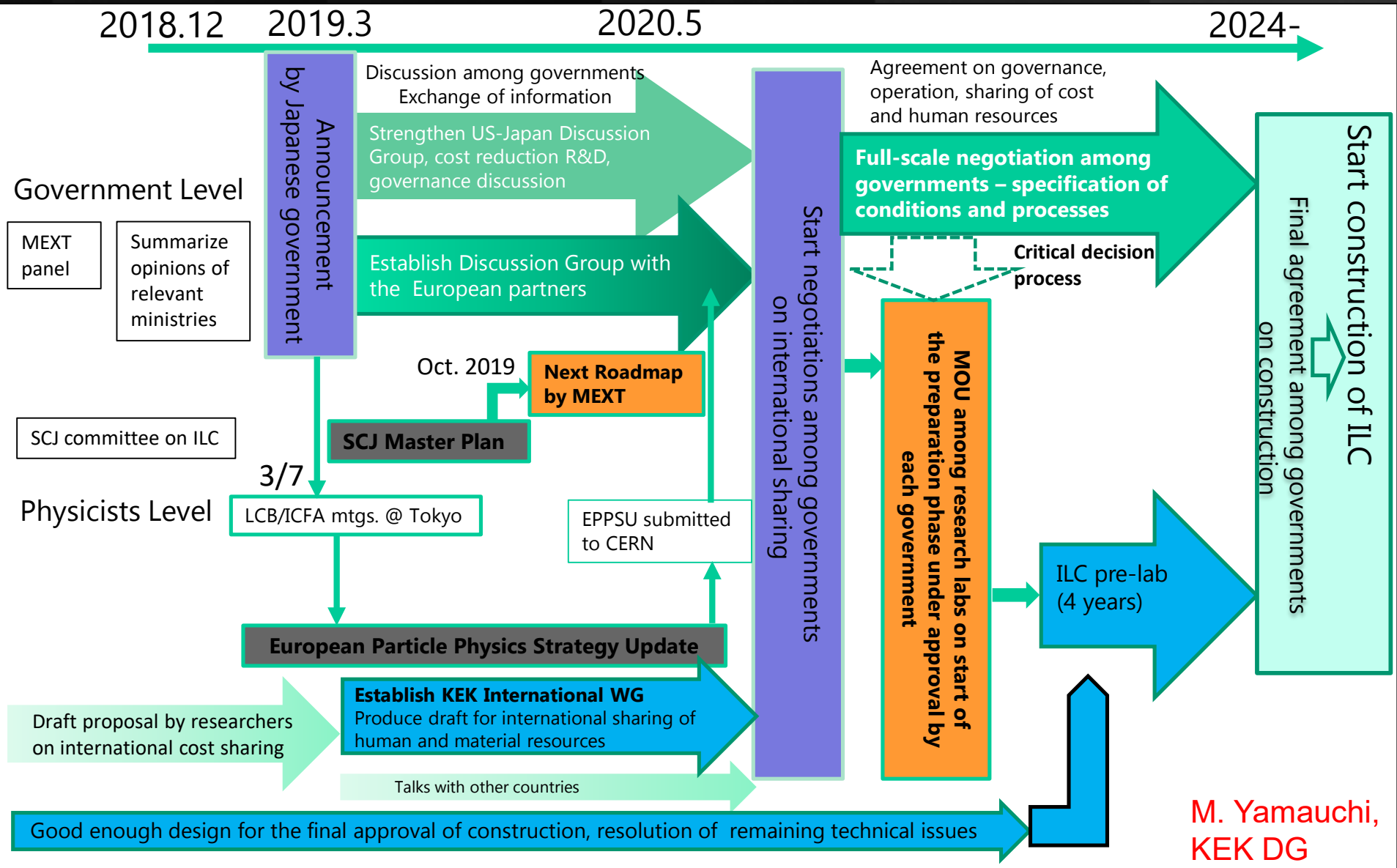
(Kyushu University)

# Timeline of ILC towards realization




M. Yamauchi, KEK DG

# Discussions at Granada etc.

All 1st gen Higgs factories have "competitive" performance

- A few times more lumi in circular
- Polarization in linear

$e^+e^-$ collider is the next way to go!

- Linear has energy upgrade
- Circular can be a step for pp

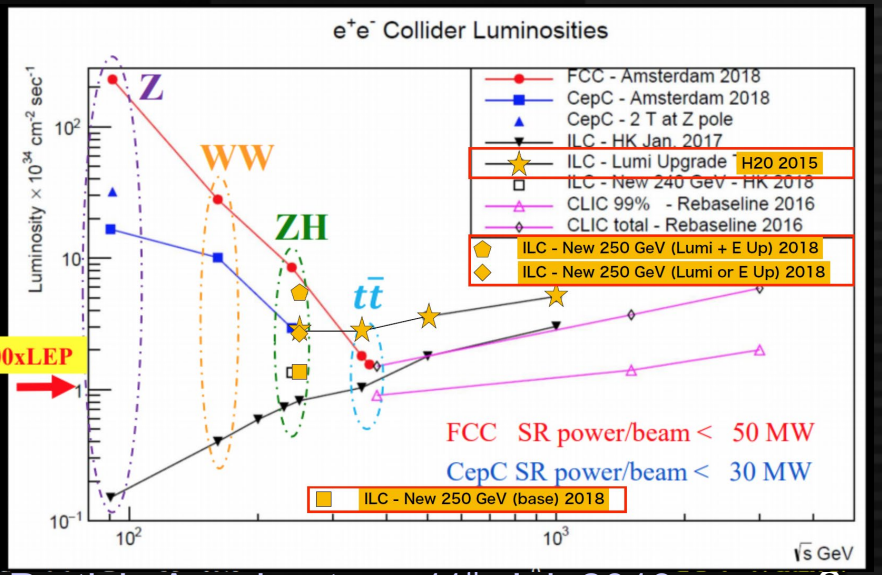
The ILC is the earliest machine if Japan will go timely…
we'll see, but strong worldwide support incl. Korea necessary.

## # of "largely" improved H couplings (EFT)

| | | Factor ≥2 | Factor ≥5 | Factor ≥10 | Years from $T_0$ |
|---|---|---|---|---|---|
| Initial run | CLIC380 | 9 | 6 | 4 | 7 |
| | FCC-ee240 | 10 | 8 | 3 | 9 |
| | CEPC | 10 | 8 | 3 | 10 |
| | ILC250 | 10 | 7 | 3 | 11 |
| 2nd/3rd Run ee | FCC-ee365 | 10 | 8 | 6 | 15 |
| | CLIC1500 | 10 | 7 | 7 | 17 |
| | HE-LHC | 1 | 0 | 0 | 20 |
| | ILC500 | 10 | 8 | 6 | 22 |
| hh | CLIC3000 | 11 | 7 | 7 | 28 |
| ee,eh & hh | FCC-ee/eh/hh | 12 | 11 | 10 | >50 |

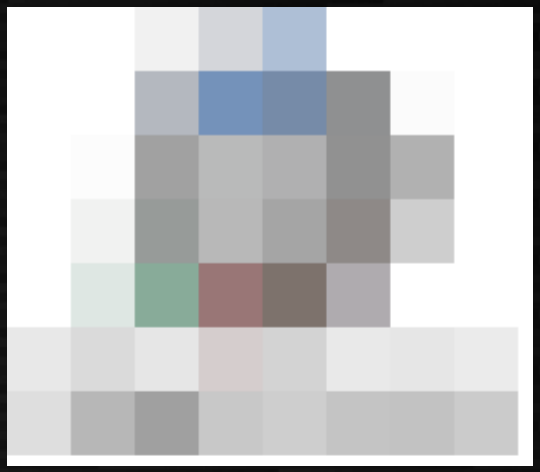
13 quantities in total

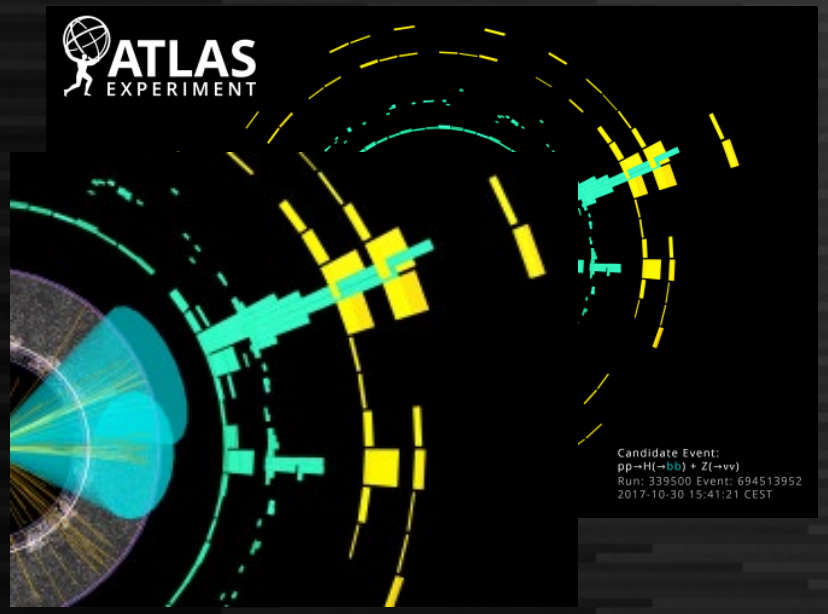
NB: number of seconds/year differs: ILC $1.6\times10^7$, FCC-ee & CLIC: $1.2\times10^7$, CEPC: $1.3\times10^7$



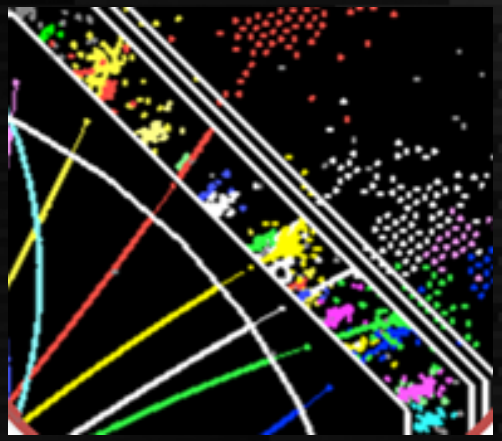

Technologies in
ILC detectors
ILD
SiD

# PFA detector: like HR camera

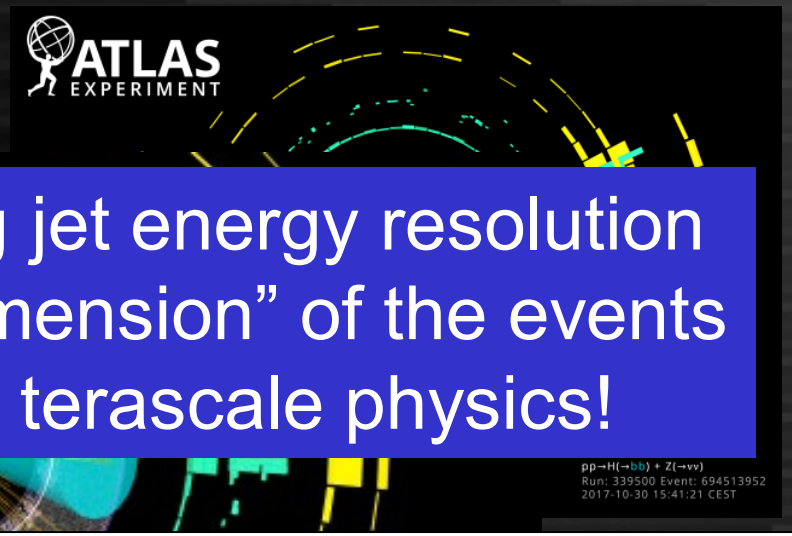






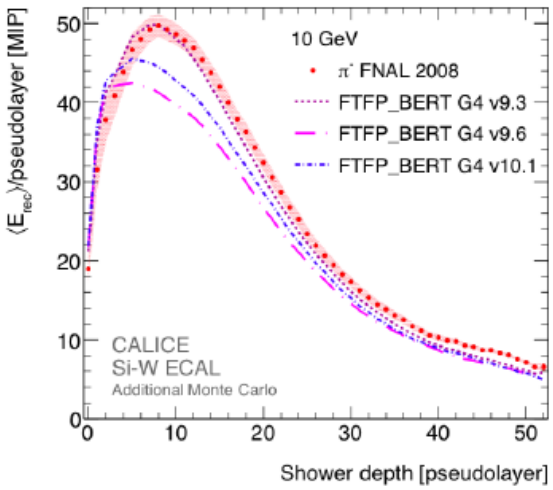


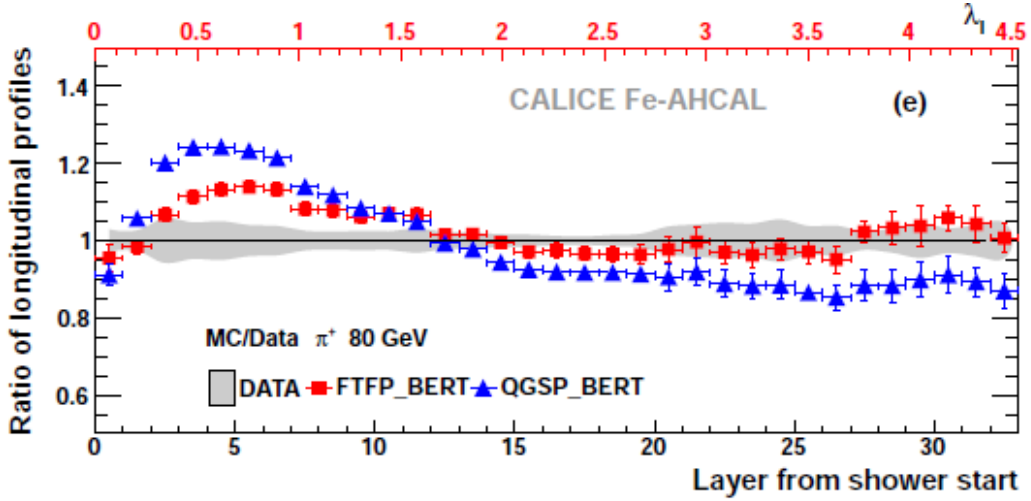
# PFA detector: like HR camera




PFA is not only for improving jet energy resolution but we can get "additional dimension" of the events to unveil the nature of the terascale physics!

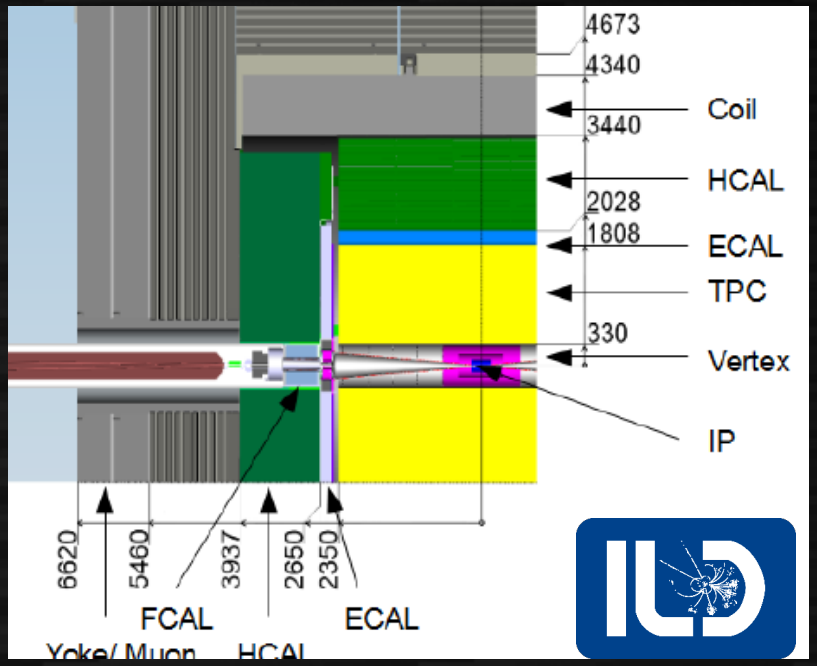
One example: CALICE sees deviation of shower profile from MC

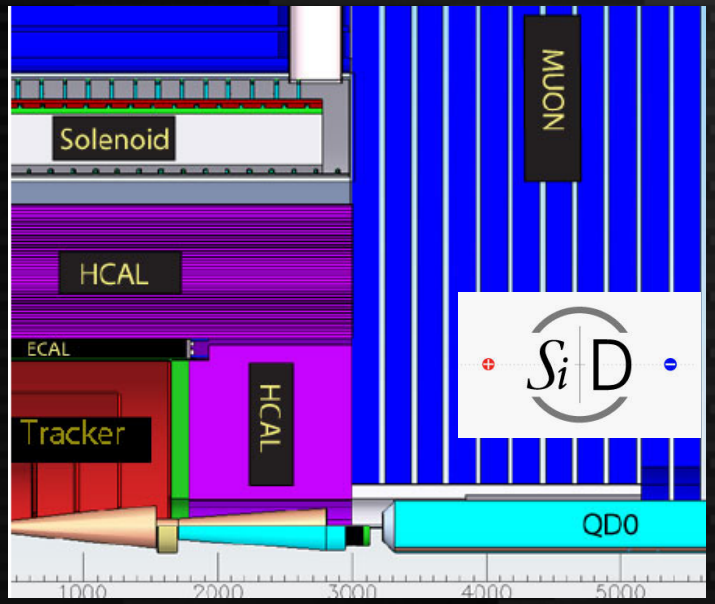


# Ingredients of PFA detectors

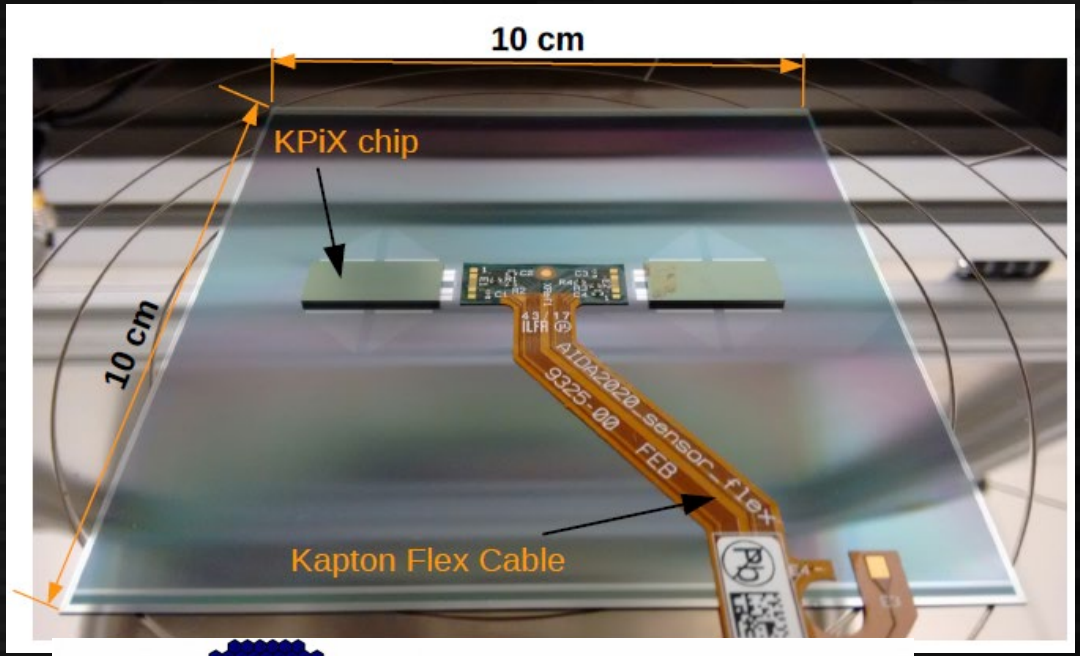
- Vertex detector
- Tracking (barrel / forward)
  - Silicon
  - TPC
- Very Forward
- ECAL
- HCAL
- Muon



# Silicon strips

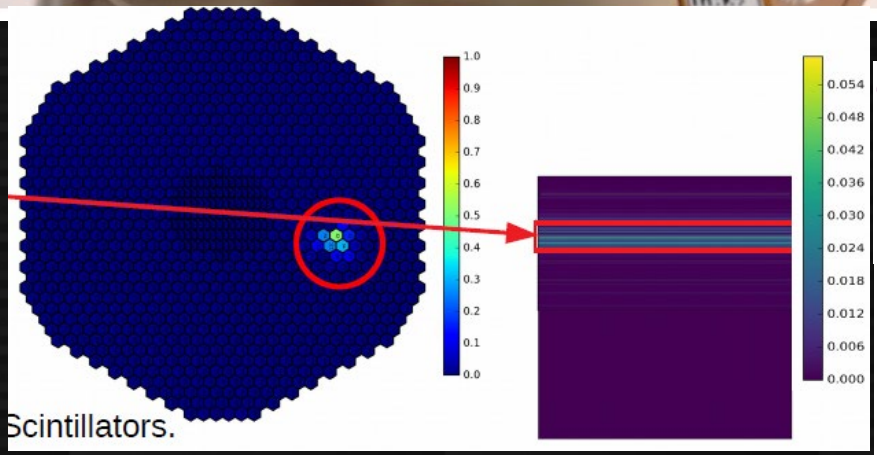
$\sigma_R$ ~ 7-10 μm, 50 μm pitch
Material ~ 0.5 % $X_0$ / layer




First SiD silicon tracker was fabricated with two KPiX ASICs (1024 ch each)

Preparing to be used for AIDA telescope in DESY

Technology of strip mature good for baseline, starting realistic prototyping




Concurrent event with tracker + ECAL seen

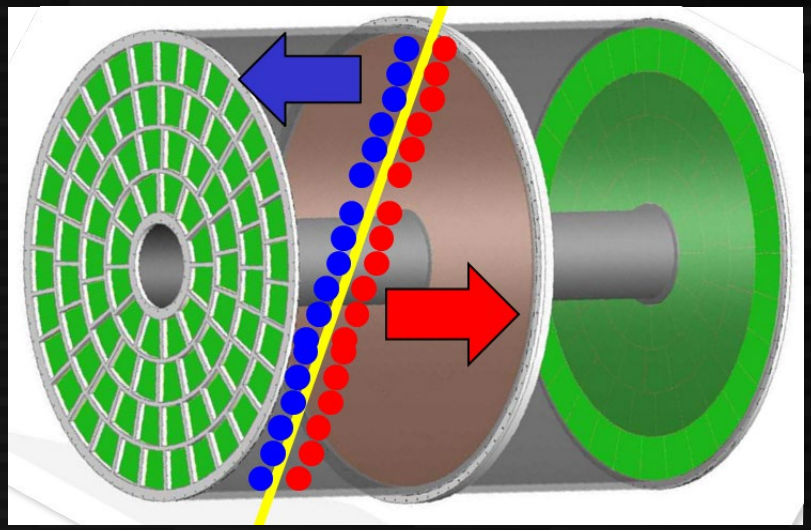
- Expected Performances
  - $\sigma_{sp}$ ~4 μm ⇨ Use double sided ⇨ $\sigma_{sp}$ ~2.8 μm
    - 22x22 μm² ~ 20% better spatial resolution % ALPIDE (
    - Faster = higher Power consumption
  - Read-out time: 2-4 μs (ILD-VXD) and 1 μs (ILD-SIT)

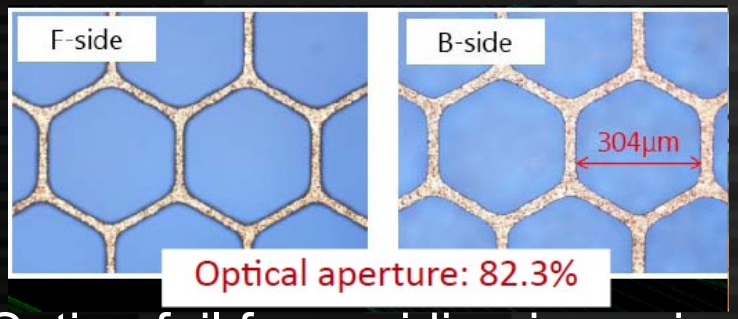
| | kPIXM-Trk | kPIXM-Cal |
|---|---|---|
| Pixel size | 50 x 200 μm² | 1000x1000 μm² |
| Array | 200 x 2400 | 100 x 94 |
| Full size | stitched 5 x 5 reticles | |
| Max. signal | 1 fC | 1pC |
| Effective ENC | < 200 e⁻ | < 1000 e⁻ |
| S / N | > 20 | > 4 |
| in-pixel memory | 1 bucket | 16 buckets |
| ADC resolution | 12 bits | |
| DC power consumption | ~20 μW / pixel | |
| power pulsing | yes | |

MAPS Pixel option being considered in both ILD & SiD

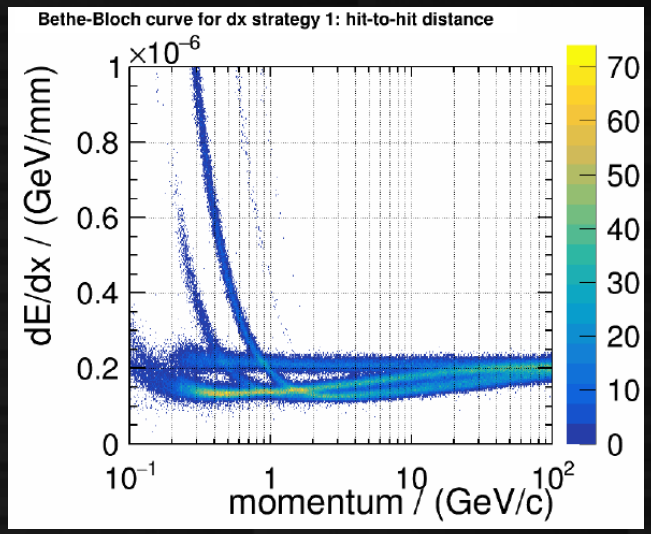
# Time Projection Chamber

$\sigma$ ~ 60 $\mu$m, ~ 200 hits
Material ~ a few % $X_0$

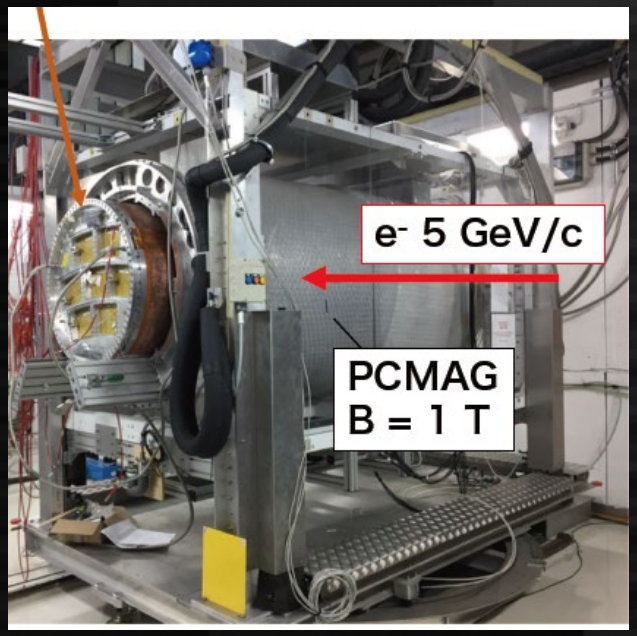





Gating foil for avoiding ion going back to TPC High optical aperture realized by cooperation with industry

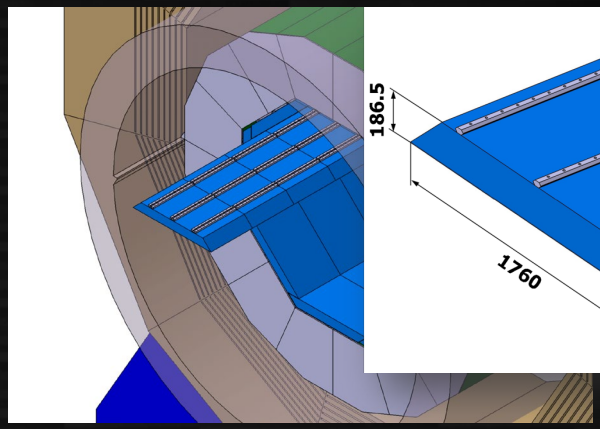


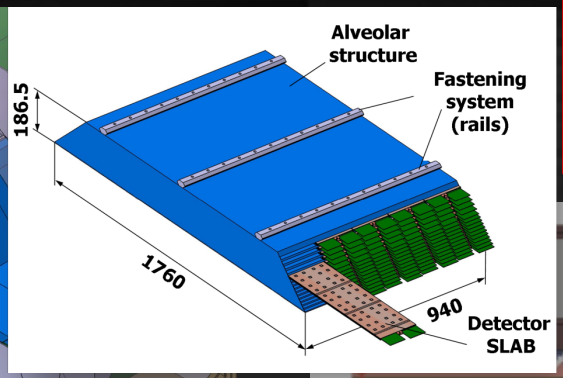

Prototype TPC



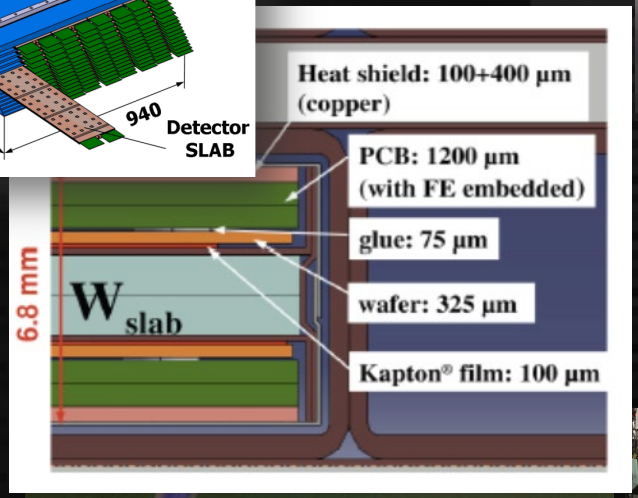

TPC enables the unique dE/dx measurement for particle ID

# Silicon-tungsten ECAL

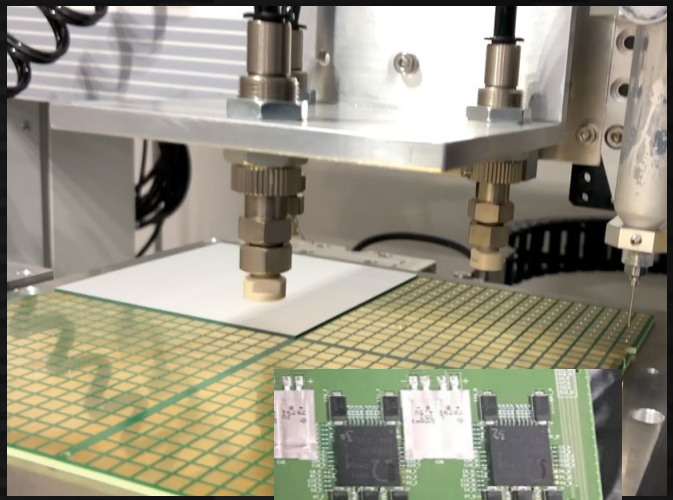


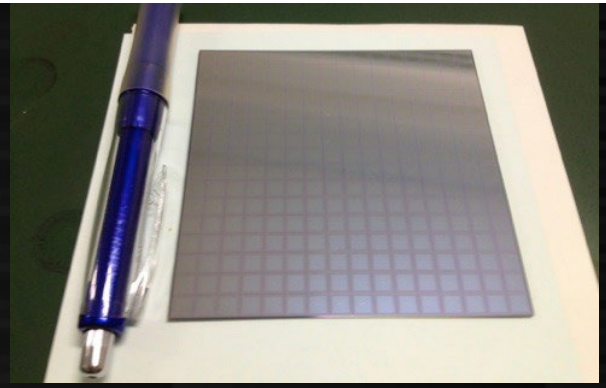



~$10^8$ channel in total: Challenge on electronics




Testing new slabs in CERN SPS 2018 and DESY 2019



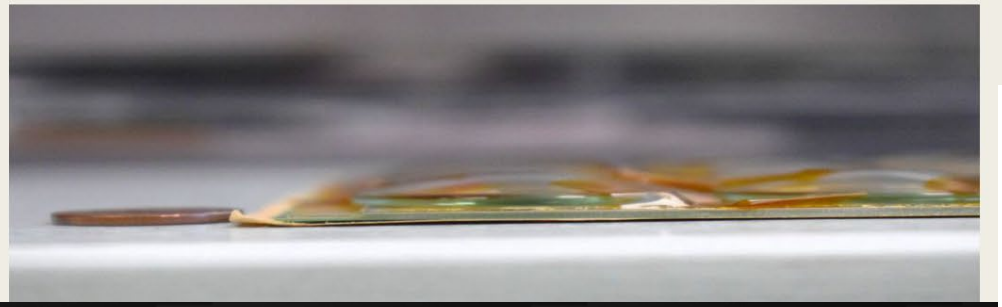


Silicon pad for ILD ECAL

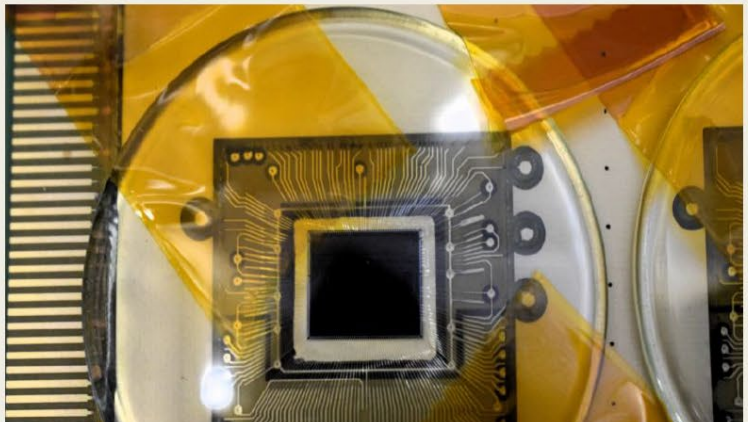
"Long slab"

# Korea-France cooperation for SiW-ECAL electronics

- **LAL & OMEGA** collaboration with **ITAEC/SKKU** (Sungkyunkwan University, Suwon – Korea) and **EOS company** for the PCB production.
- 10 FEV11_COB produced.
  - 1.2mm thickness ⟶ 9 layers PCB !
  - Good Planarity (metrology made in LAL) and electrical response.
- **4 boards wirebonded** at **CERN** bonding lab. Also In contact with CAPTINNOV Platform.



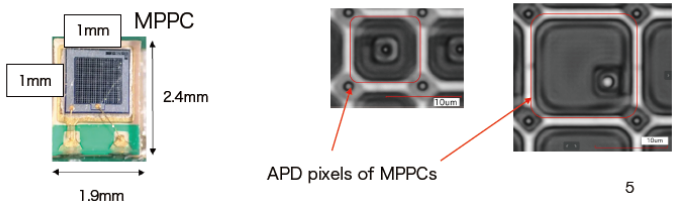
**SK2a**



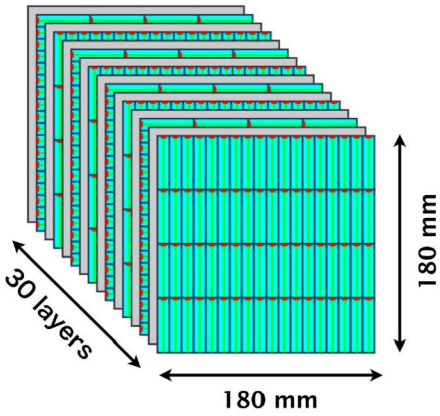
# ECAL with strip scintillators

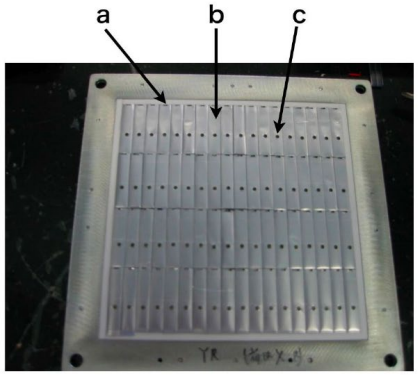
Hamamatsu catalog

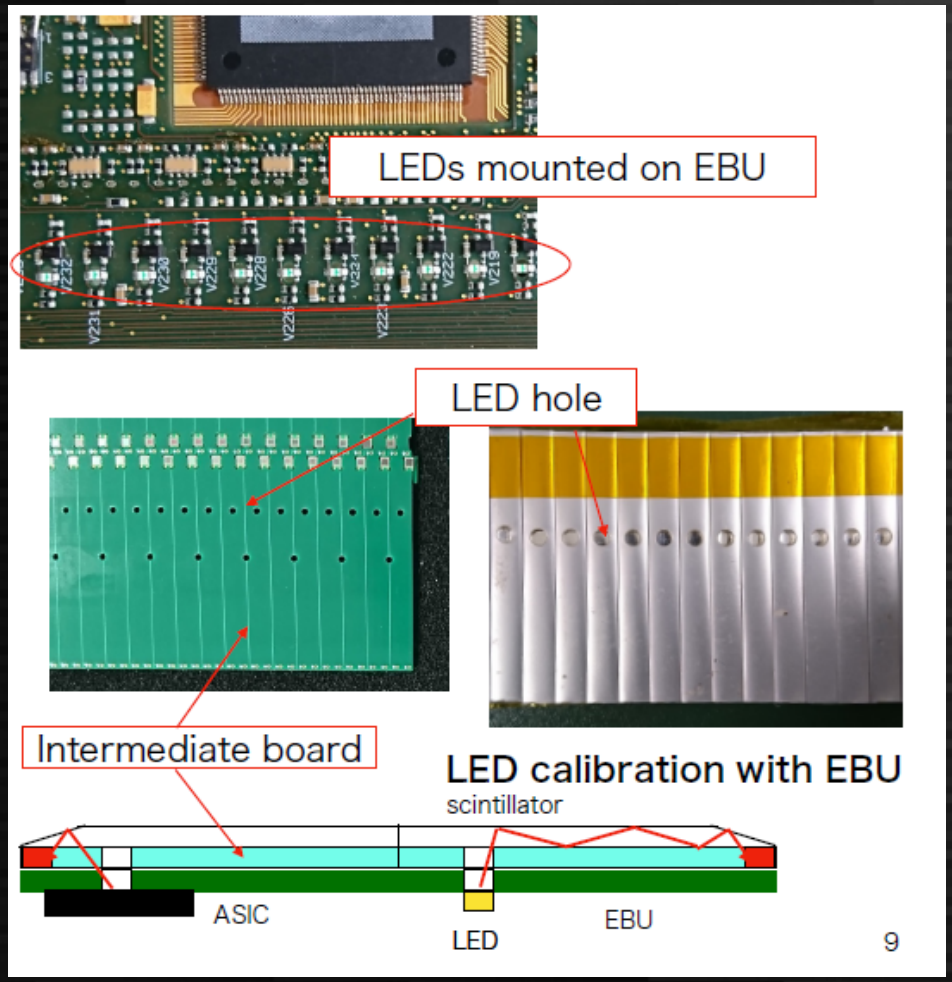
| Model Number | S12571-010P | S12571-015P |
|---|---|---|
| Photosensitive area | 1mm² | 1mm² |
| Pixel size | 10μm | 15μm |
| Number of pixels | 10000 | 4489 |
| PDE | 10% | 25% |
| Gain | 1.35x10⁵ | 2.3x10⁵ |
| Geometrical fill factor | 33% | 53% |



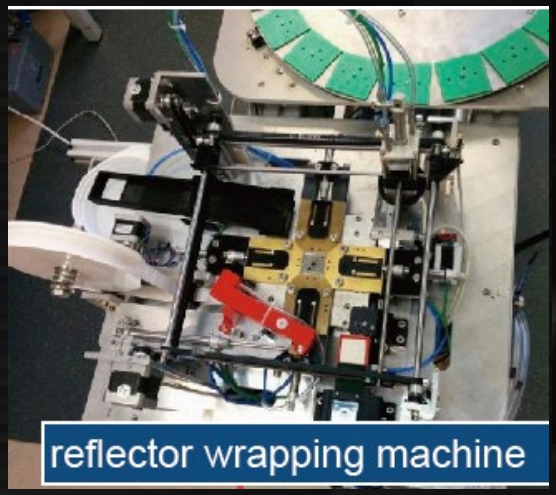

New 15 μm MPPC



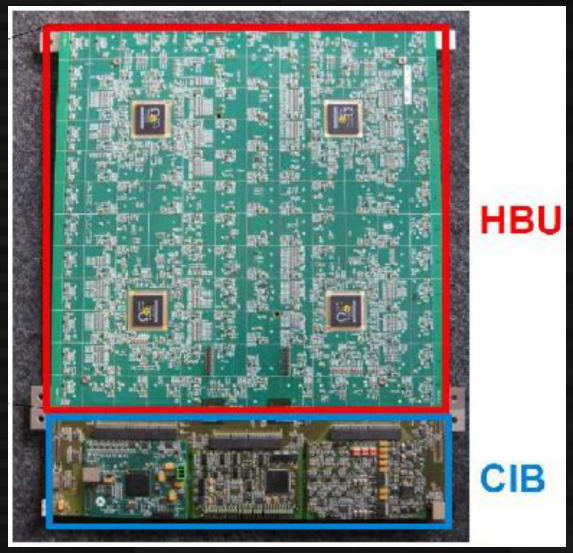
# HCAL





Automatic assembly system developed

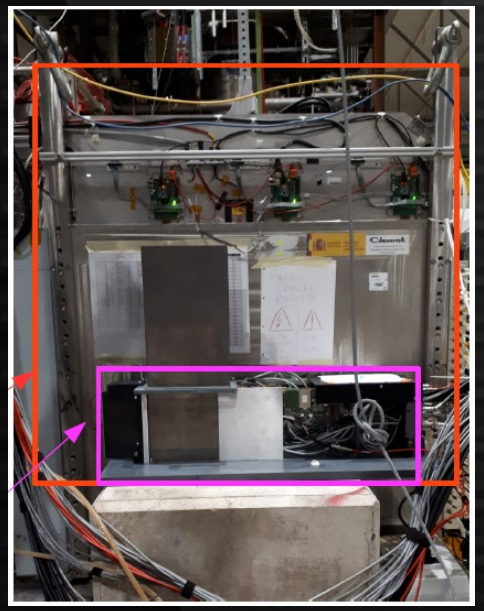
Big stack in test beams



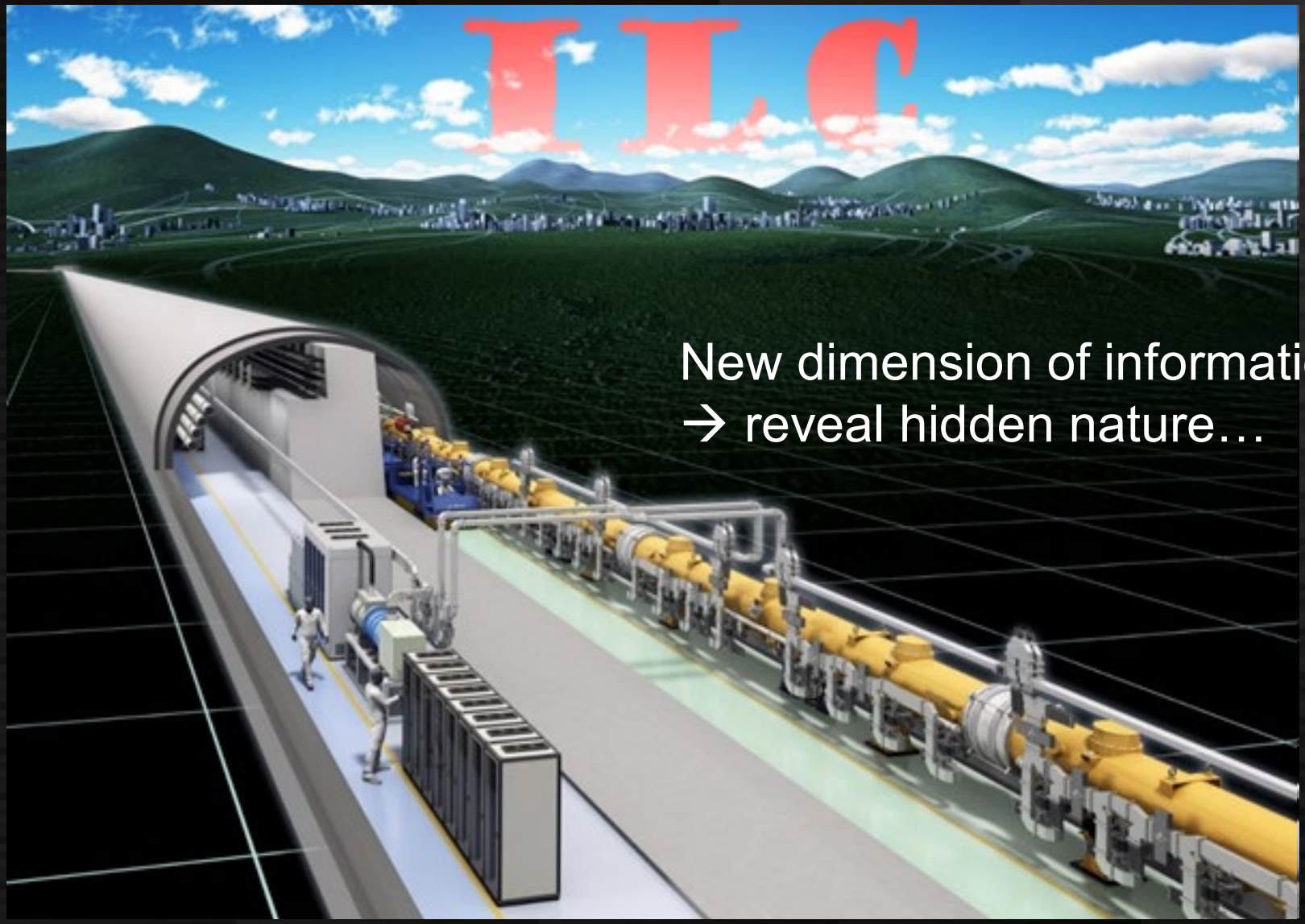

Combined testbeam

SDHCAL

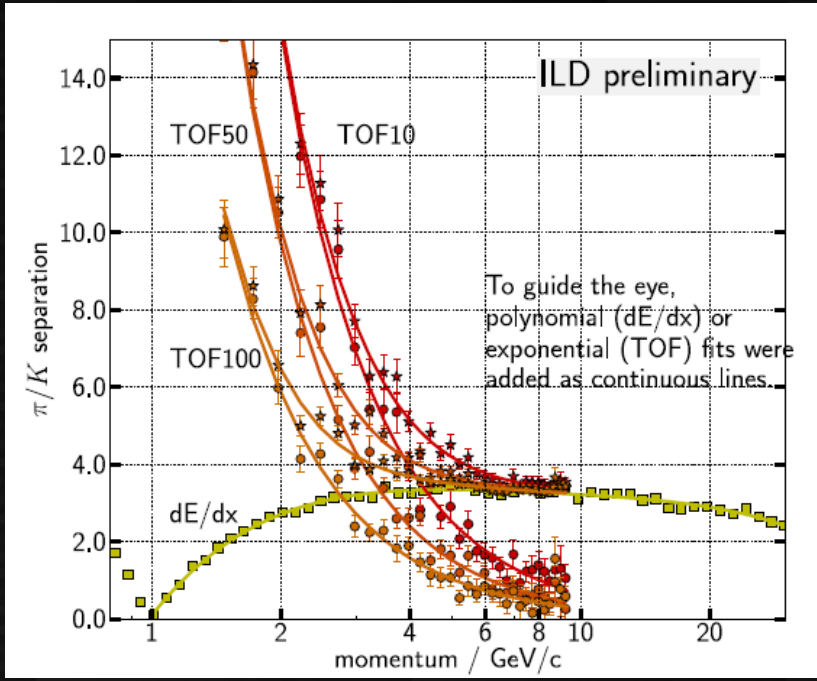
SiW-ECAL



# More advanced: 3D to 4D/5D

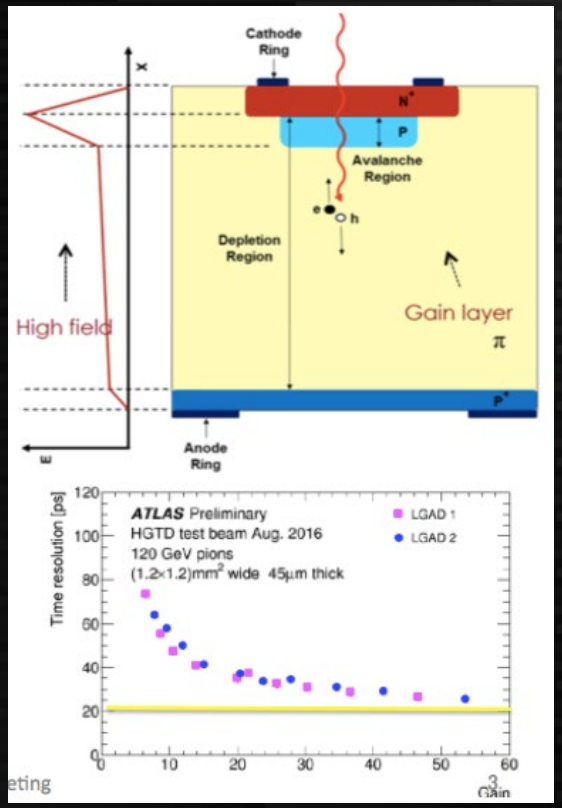


# Particle ID by dE/dx and ToF




K/π separation by dE/dx and ToF

- dE/dx: a few – a few tens GeV
- ToF: < 5-10 GeV




Silicon with avalanche gain (LGAD) can be a fast timing detector ~ 20 psec

Studies ongoing

Timepix3 for monolithic TPC readout

# Final comments

- We are working hard for the realization of ILC
- Physics case is competitive for all Higgs factories
- Detector technologies are being finalized
  - Need studies on mass production/quality control
  - New ideas are coming and further welcomed
- PFA detector is a “big data” detector
  - Scientists of artificial intelligence are curious
    we are trying to get close collaboration with them
- Worldwide support is essential
  - Japan needs clear view for prospects of the project