# Detector Summary


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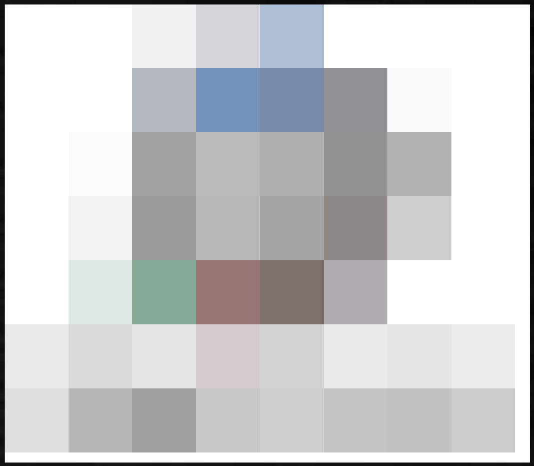
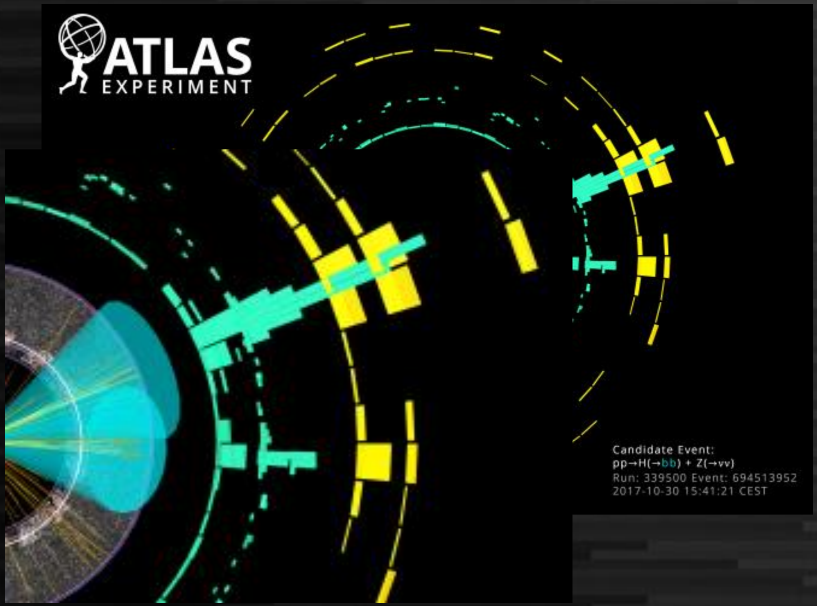
# Activities in Detector sessions

- Vertex
  - 3 talks (MIMOSA, DEPFET, HV-CMOS)
- Silicon tracking
  - 3 talks (SiD sensor, CMS, FTD)
- TPC and dE/dx
  - 3 talks (dE/dx, discharge, Timepix)
- Forward
  - 1 talk (LumiCAL/baemCAL)
- ECAL
  - 6 talks
- HCAL
  - 3 talks
- Muon
  - 3 talks
- MDI
  - 2 talks

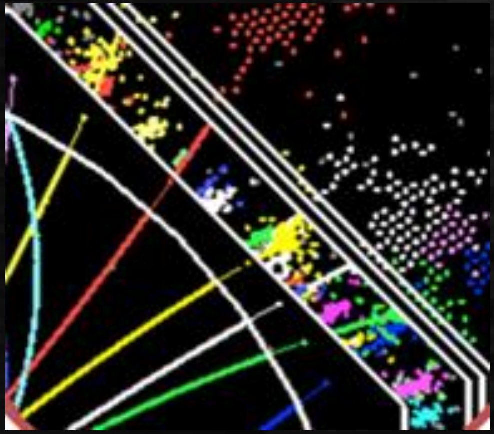
DISCLAMER
Impossible to cover all the topics.

# PFA detector: like HR camera

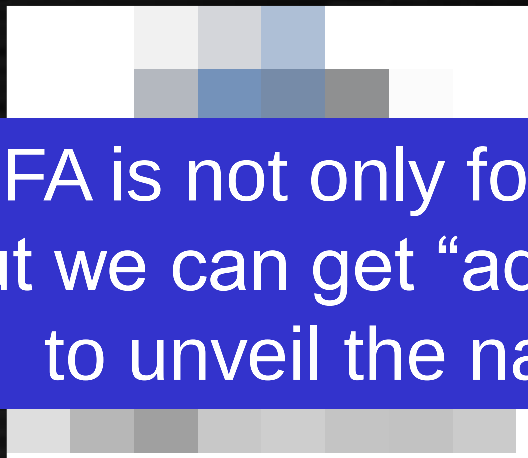


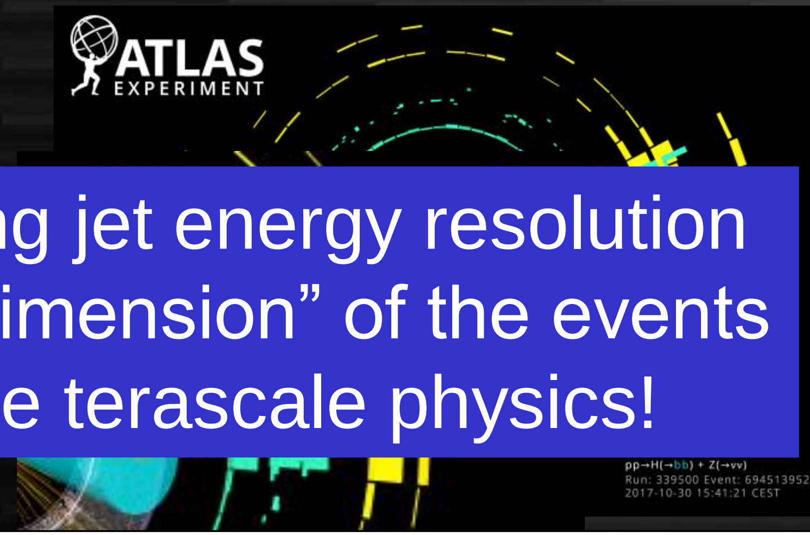






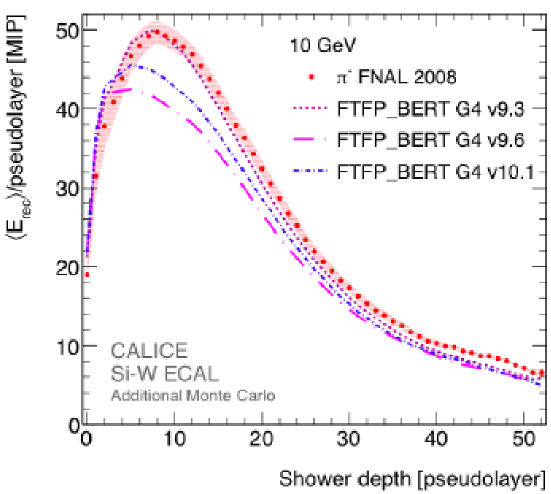
# PFA detector: like HR camera

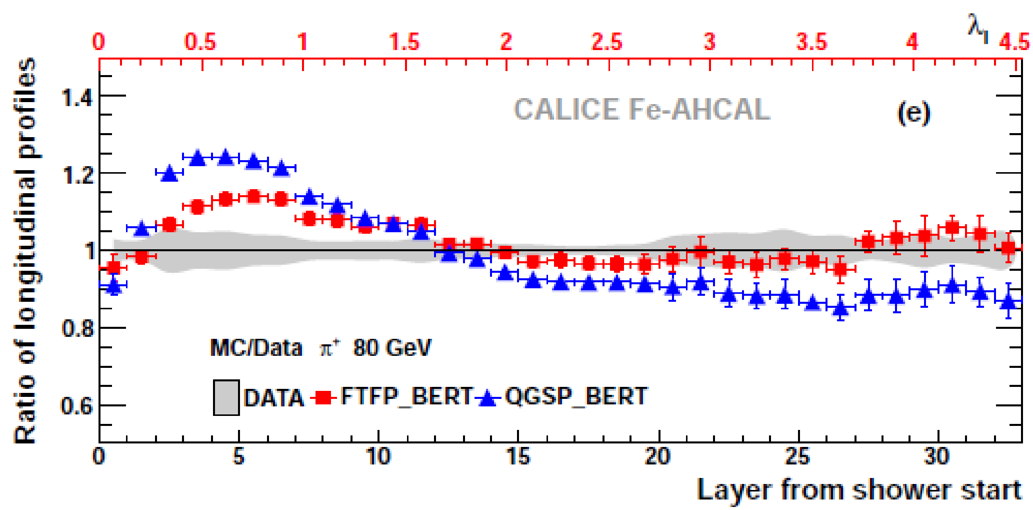





**PFA is not only for improving jet energy resolution but we can get "additional dimension" of the events to unveil the nature of the terascale physics!**

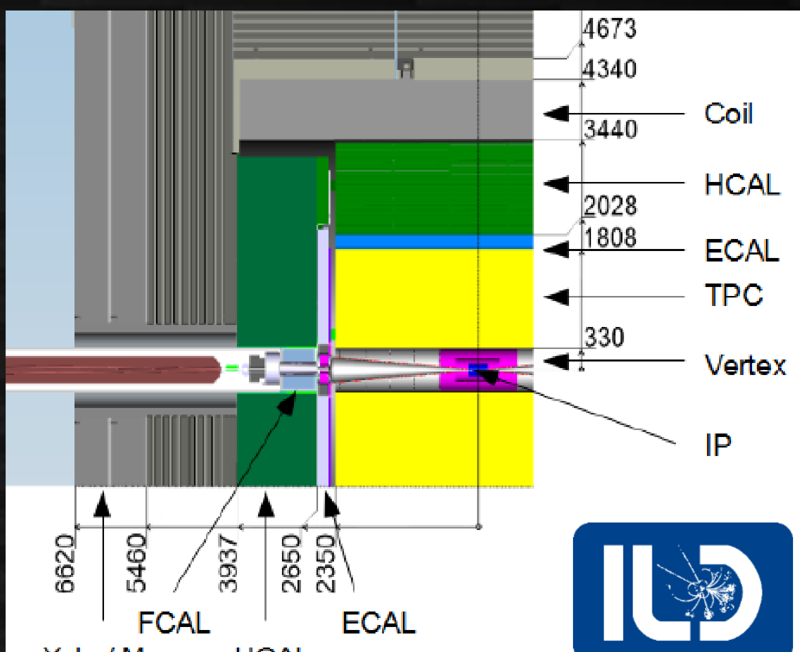
One example: CALICE sees deviation of shower profile from MC

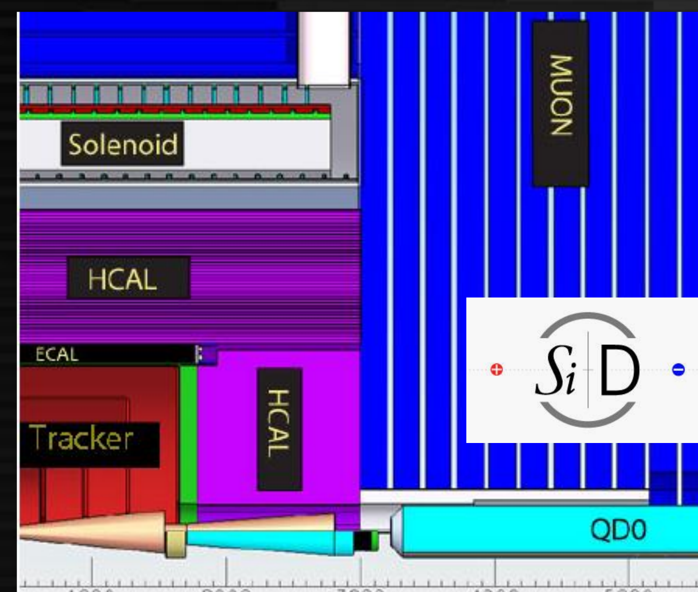


# Ingredients of PFA detectors

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

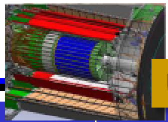


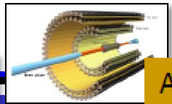



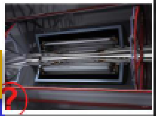
# Vertex detectors

$\sigma_x \sim 3\ \mu m$
Material ~ 0.2 % $X_0$ / layer

Evolving CPS





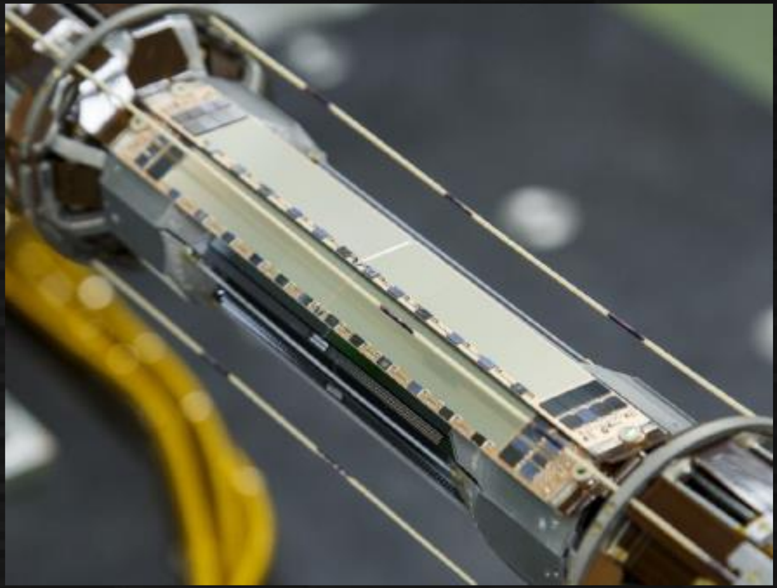


ULTIMATE — ALPIDE — MIMOSIS — PSIRA proposal

| | STAR-PXL | ALICE-ITS | CBM-MVD | ILD-VXD |
|---|---|---|---|---|
| Data taking | 2014-2016 | >2021-2022 | >2021 | >2030 |
| Technology | AMS-opto 0.35 μm | **0.18 μm** | 0.18 μm | 0.18 μm (conservative)<br>< 0.18 μm ? |
| | 4M | HR, $V_{bias}$ ~-6V<br>Deep P-well | HR, Deep P-well | ? |
| Architecture | Rolling shutter<br>+ sparsification<br>+ binary output | **Asynchronous r.o.<br>In pixel discri.** | Asynchronous r.o.<br>In pixel discri. | Asynchronous r.o. (conservative) |
| Pitch (μm²) / Sp. Res. | 20.7 x 20.7 / 3.7 | 27 x 29 / 5 | 22 x 33 / <5 | ~ 22 / ~ 4 |
| Time resolution (μs) | ~185 | **5-10** | 5 | **1 – 4** |

CMOS detector of MIMOSA technology

Other technologies FPCCD, SOI, Chronopix, … exist as advanced options

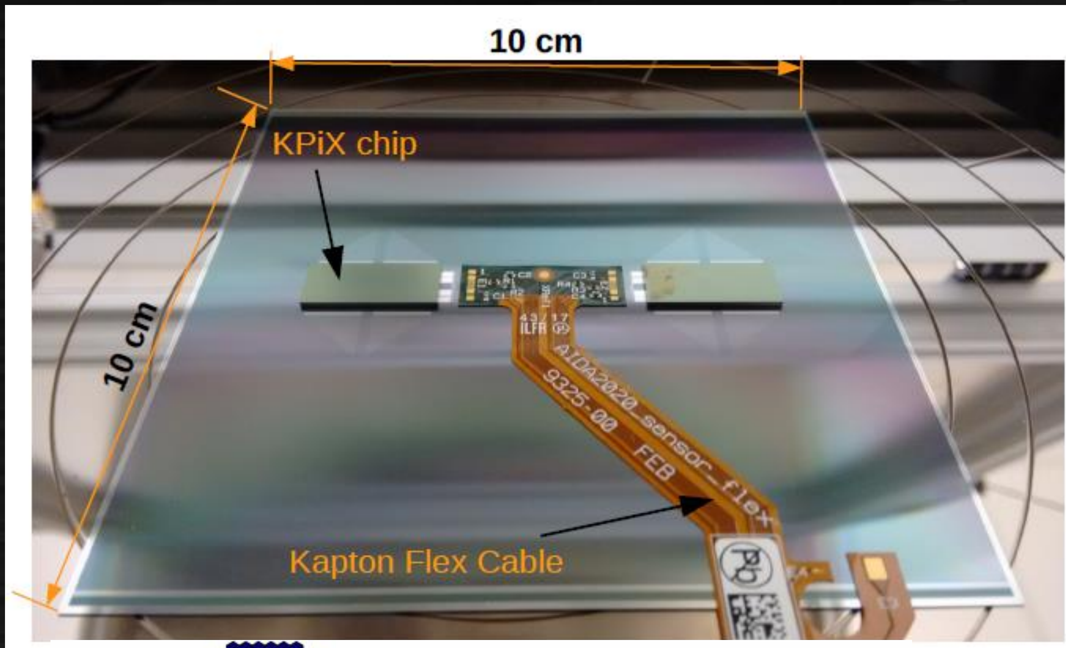


The monolithic sensors based on existing experiments are mature enough to extrapolate to ILC as “conservative baseline”

The first DEPFET layer installed at Belle2

# Silicon tracking

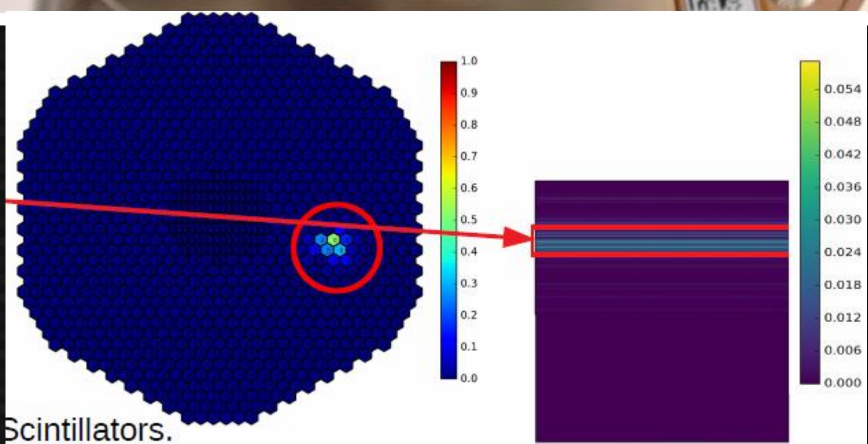
$\sigma_R \sim$ 7-10 μm
Material ~ 0.5 % $X_0$ / layer




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)

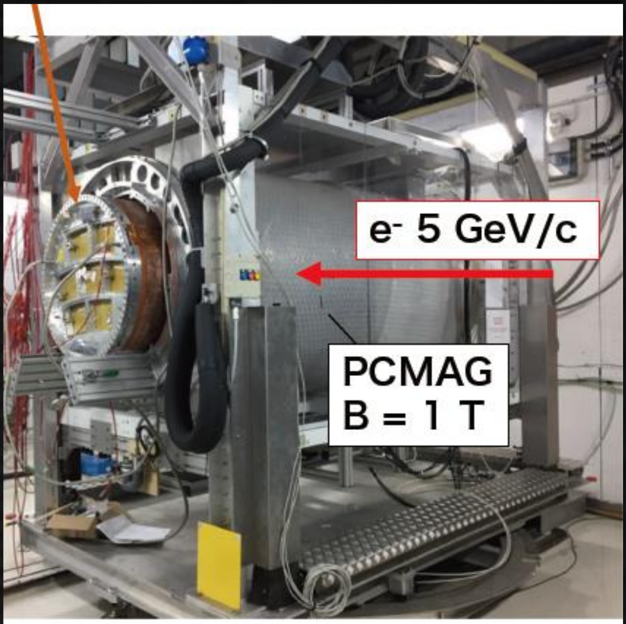
| | kPIXM-Trk | kPIXM-Cal |
|---|---|---|
| Pixel size | 50 x 200 μm² | 1000x1000 μm² |
| Array | 200 x 2400 | 100 x 94 |
| Full size | stitched 5 x 5 reticles | |
| Max. signal | 1 fC | 1pC |
| Effective ENC | < 200 e⁻ | < 1000 e⁻ |
| S / N | > 20 | > 4 |
| in-pixel memory | 1 bucket | 16 buckets |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

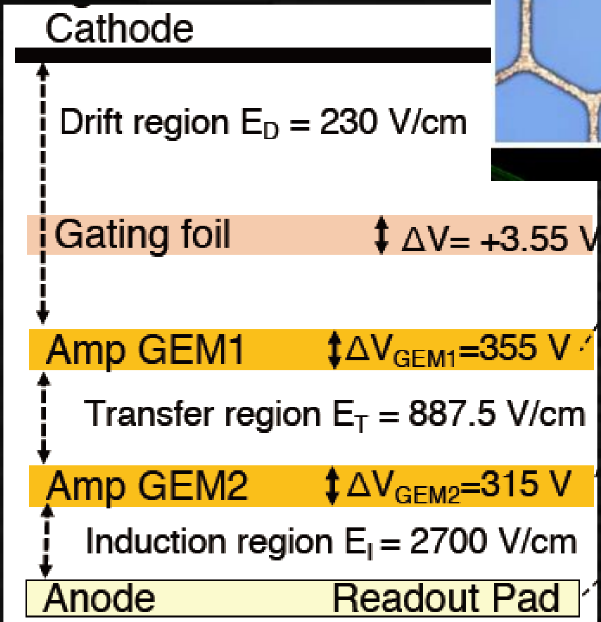
MAPS Pixel option being considered in both ILD & SiD

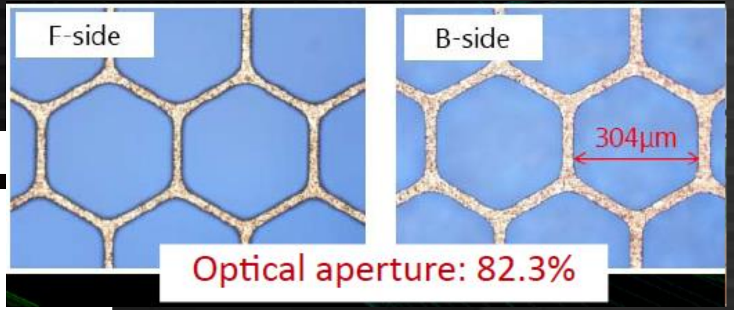
# Time Projection Chamber

σ ~ 60 μm, ~ 200 hits
Material ~ a few % $X_0$

Prototype TPC

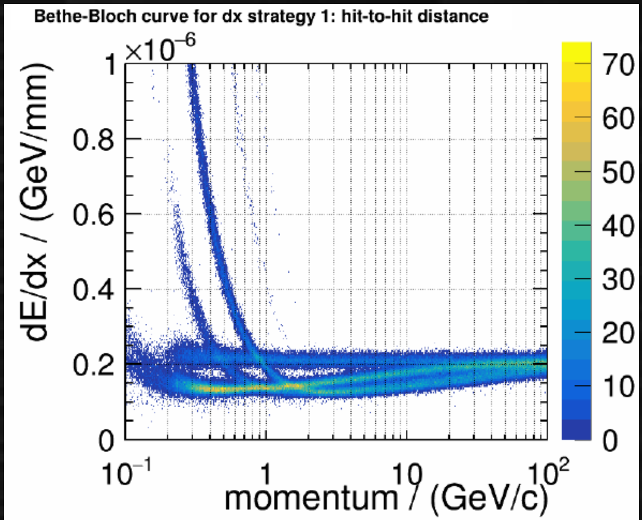



Gating foil for avoiding ion going back to TPC

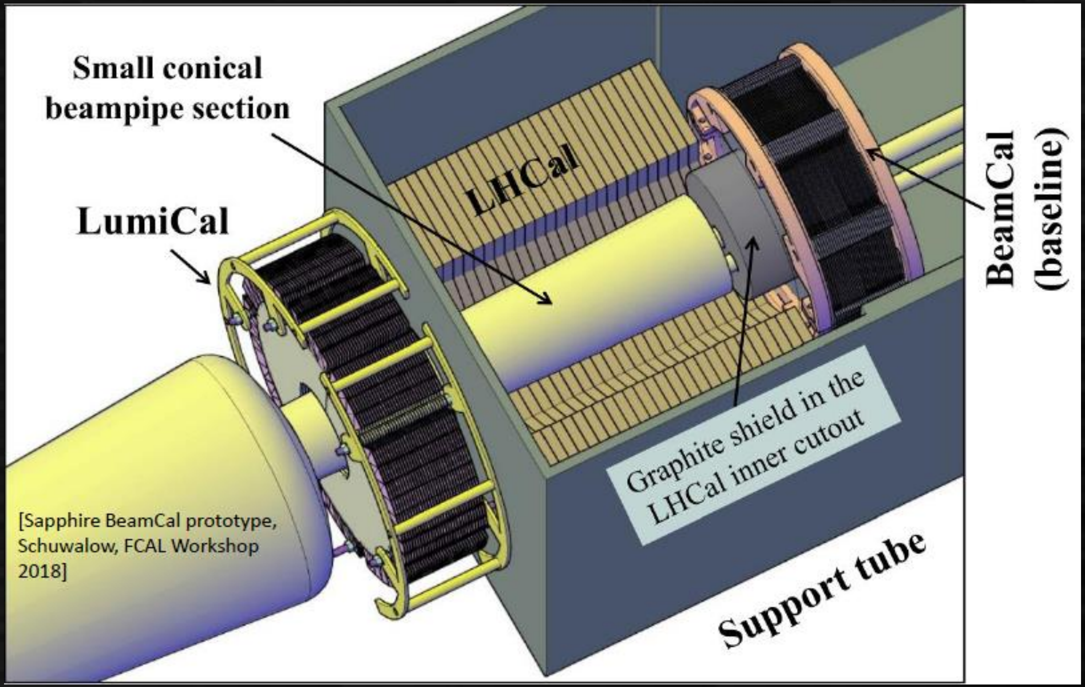
High optical aperture realized by cooperation with industry

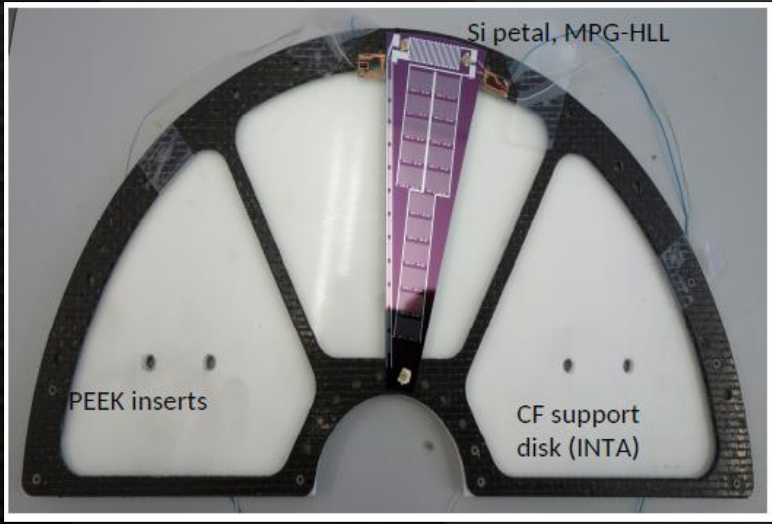



Frequent test beam at DESY with 70 cm TPC: hardware mature enough

TPC enables the unique dE/dx measurement for particle ID

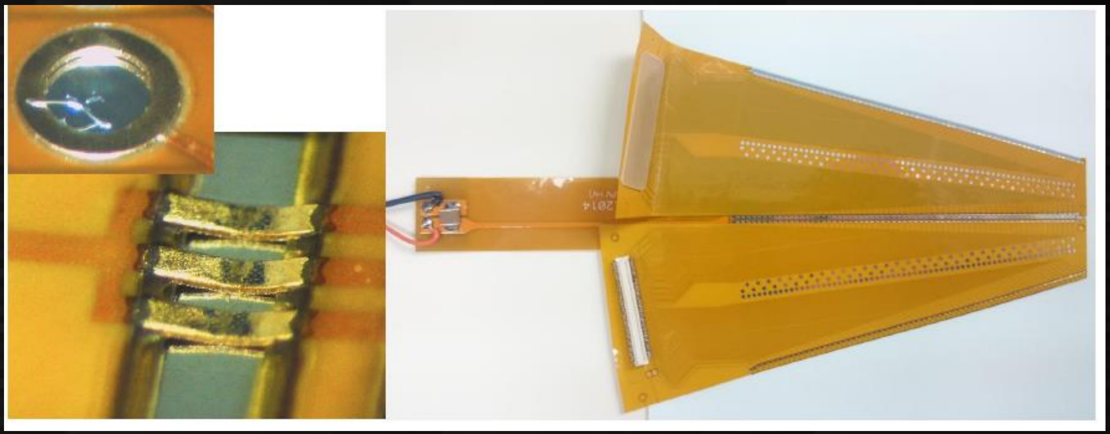
# Forward devices



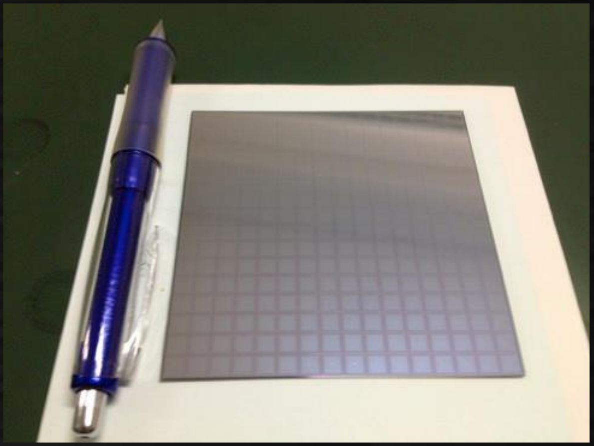

FTD mock-up

Detector technology common to tracker/calo
Mechanical design and prototyping ongoing



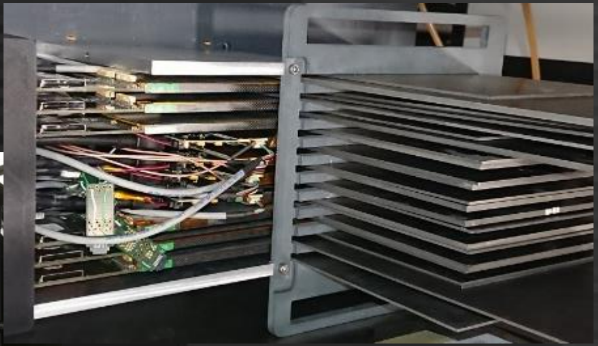
LumiCAL structure

# ECAL



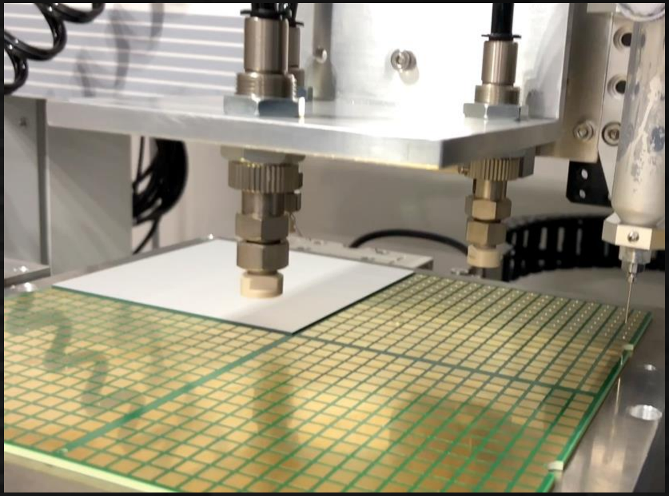
Silicon pad for ILD ECAL

"Long slab"



Testing new slabs in CERN SPS


Chip-on-board electronics



Assembly now possible both in France and Japan

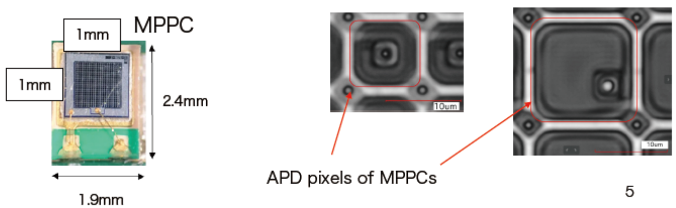
Intensive study ongoing mainly on electronics of large scale
Sensor and readout concept mature enough

**Long-life needed: reliability is crucial**

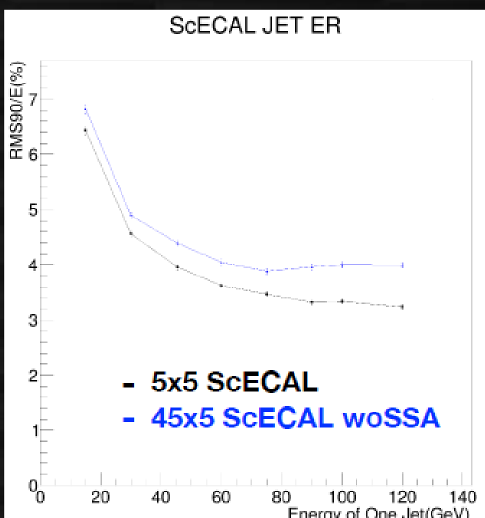
# ECAL (cont.)

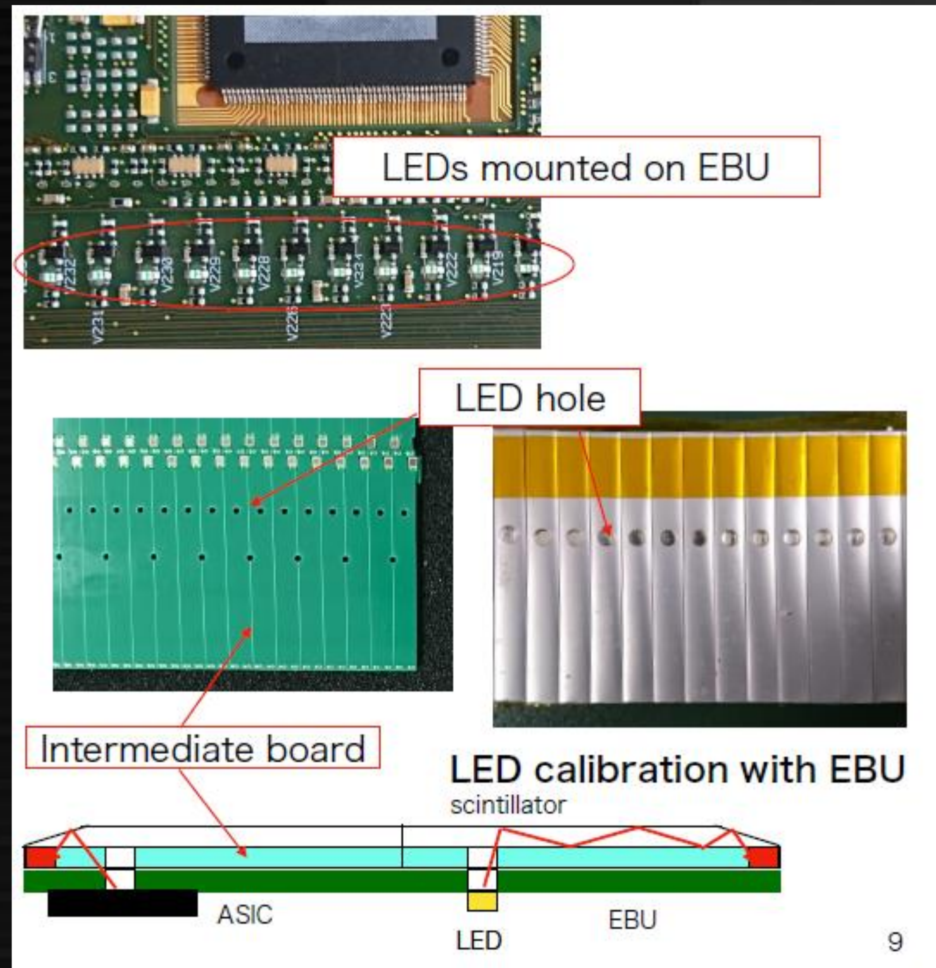
Hamamatsu catalog

| Model Number | S12571-010P | S12571-015P |
|---|---|---|
| Photosensitive area | 1$mm^2$ | 1$mm^2$ |
| Pixel size | 10$\mu$m | 15$\mu$m |
| Number of pixels | 10000 | 4489 |
| PDE | 10% | 25% |
| Gain | $1.35x10^5$ | $2.3x10^5$ |
| Geometrical fill factor | 33% | 53% |

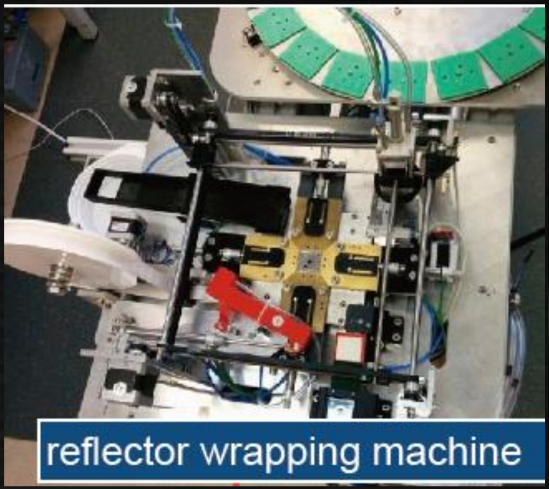



New 15 $\mu$m MPPC

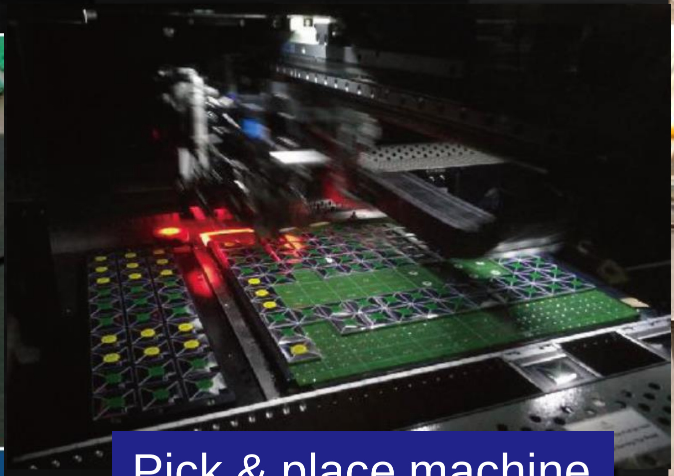


# HCAL



reflector wrapping machine



Pick & place machine

Automatic assembly system developed

Big stack in test beams

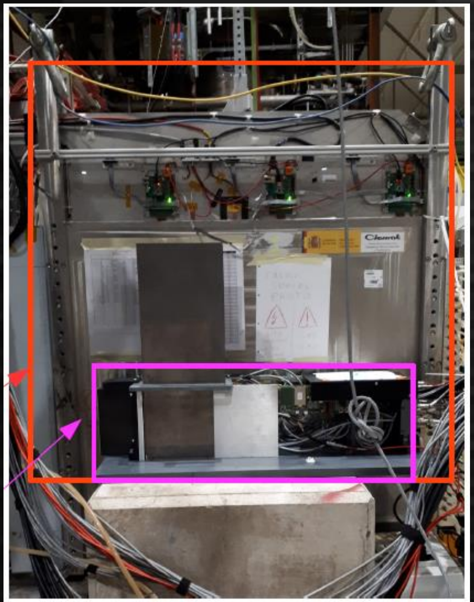
6 x 6 cm “Tokyo” module

Large technological prototype made and tested by beam
Technical feasibility well demonstrated

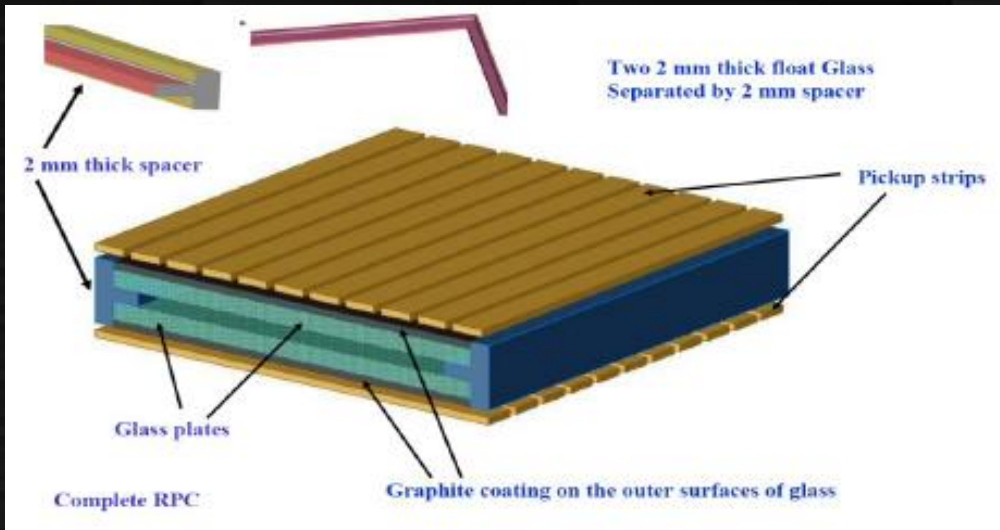
Combined testbeam

SDHCAL

SiW-ECAL



# Muon




CEPC design of RPC muon

Though hardware activity of muon detectors is not high, Detector technology is common to calorimeter → no technical show-stoppers

ILC muon options

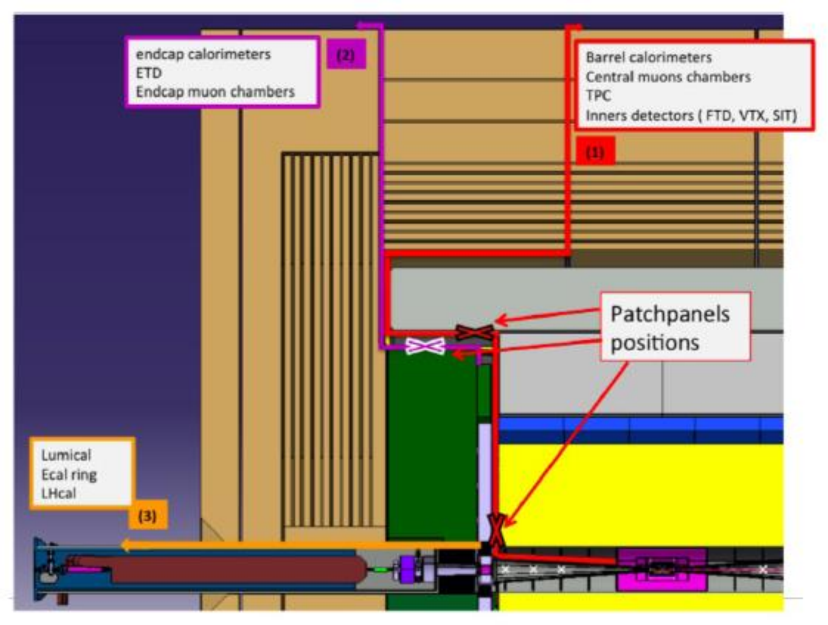
- Scintillator
- RPC
  → HCAL technology

- **Drift Tubes** (DT) in the Muon Barrel (MB)
- **Cathode Strip Chambers** (CSC) in the Muon Endcap (ME)
- **Resistive Plate Chambers** (RPC) throughout
- **Muon Alignment** derived for DT and CSC

CMS muon detectors:
important for momentum
of TeV muons → strip detectors

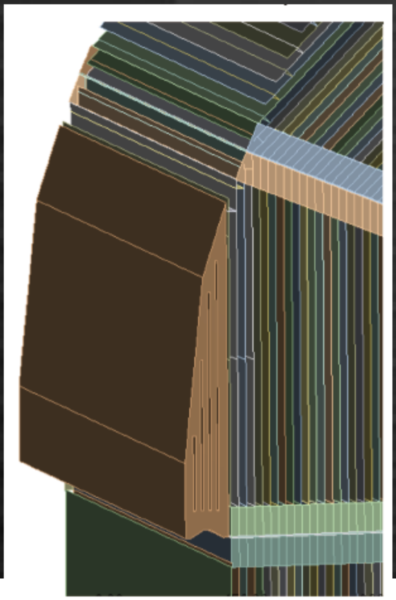
for ILC little advantage of strips

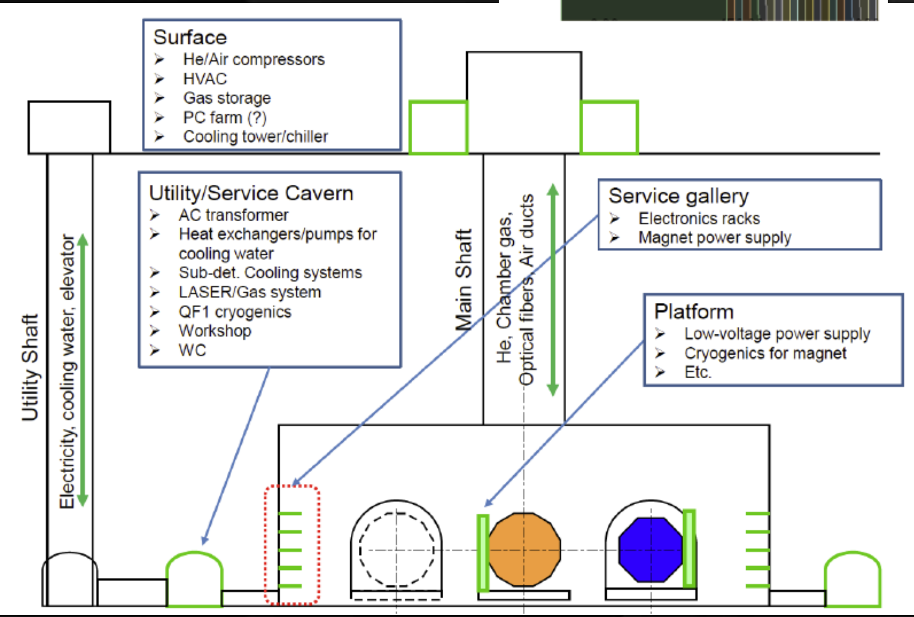
# Integration




ILD cabling plan

Support structure of HCAL





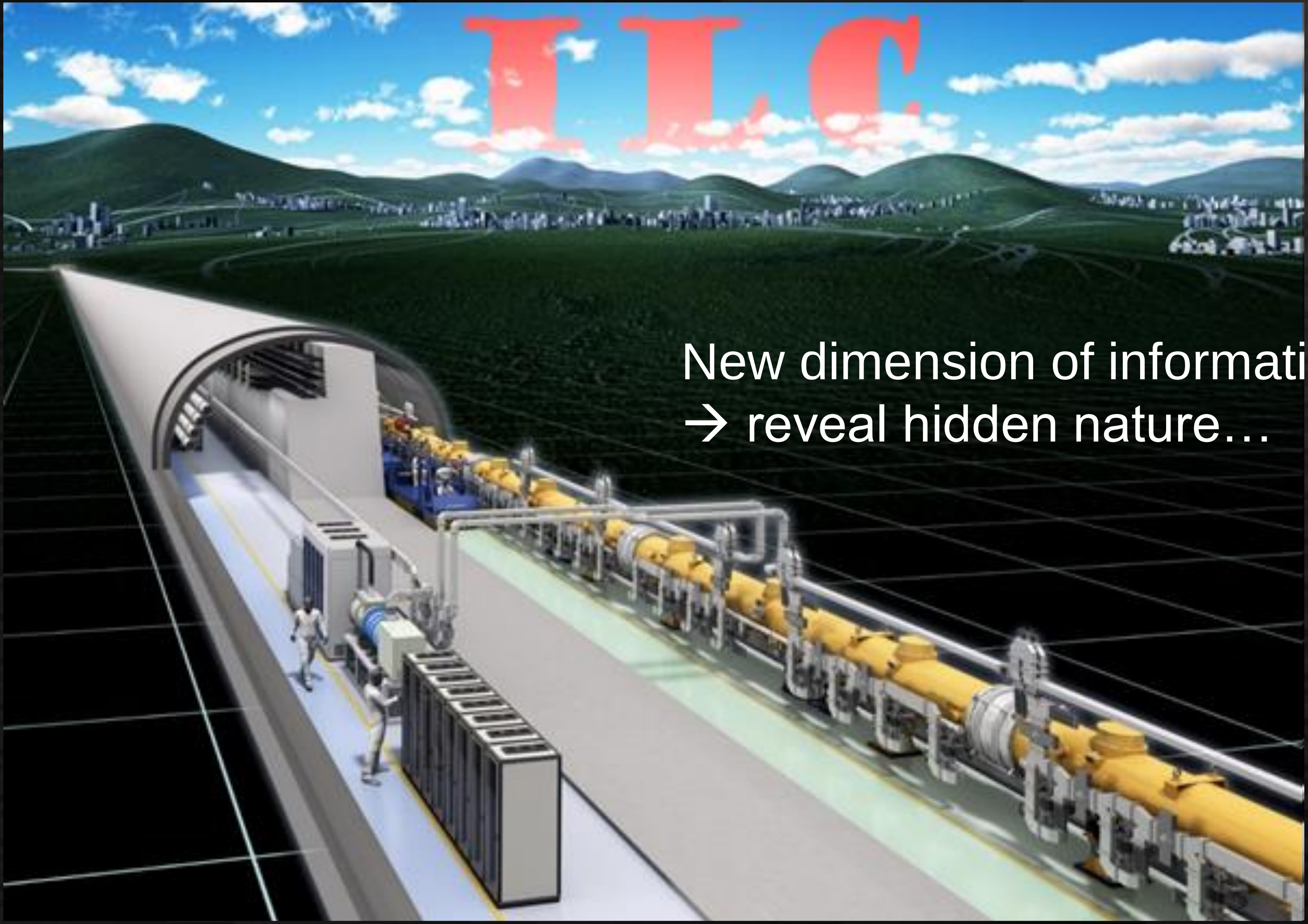

Consideration on space/power

Discussion on power, cabling, etc. has started towards realistic detector

# Our PFA detector is ready!

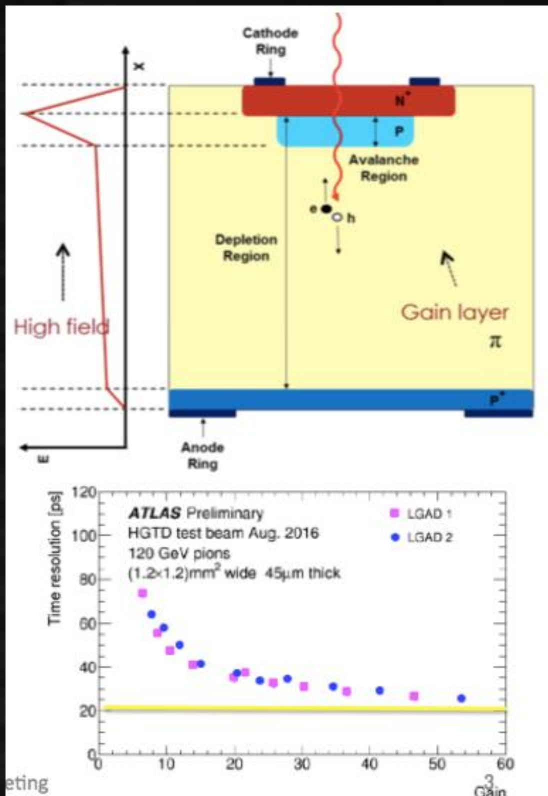
- Active developments on core detectors
  - Vertex, Silicon tracker, TPC, ECAL, HCAL
- Baseline technologies are mature enough
  - Technological prototype already built
    or extrapolation from existing experiments expected
  - Powerful alternatives exist on some components
- No technical show-stoppers appeared
- Ready to start construction-ready design
  just after the "green light"

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




New dimension of information
→ reveal hidden nature…

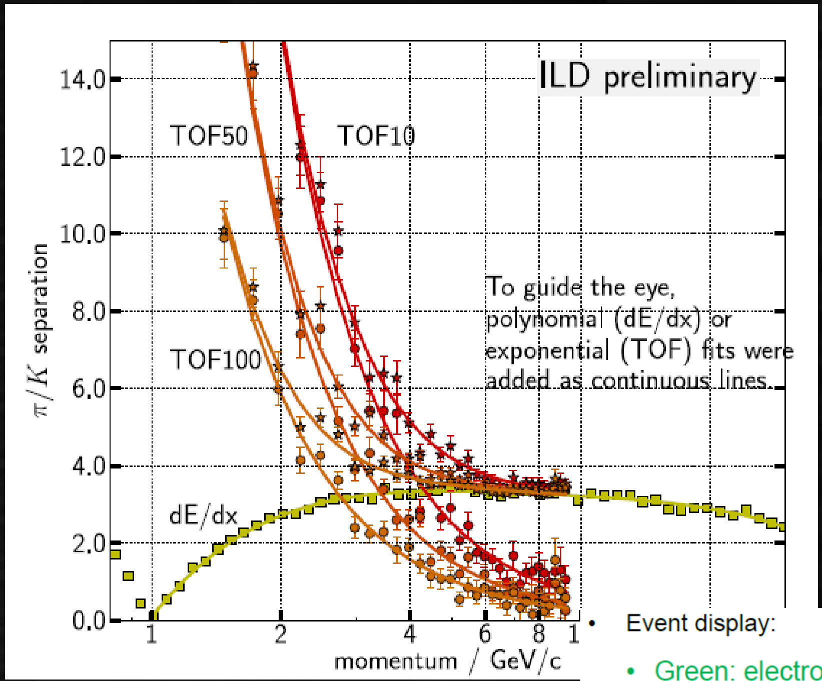
# Timing resolution




Low Gain Avalanche Detector (LGAD) for ultra-fast silicon detector
~20 psec obtained with small sensor
Thin sensor is also possible

- Vertex: slow (10s of BX)
  - Except chronopix
- Silicon tracker (inner/outer)
  - Strip, CMOS, HV-CMOS, LGAD
  - < 1 ns possible with strips
  - Slow for pixels
    - 1 BX tagging possible with intensive effort (if needed)
  - ~20 psec with LGAD
- TPC (slow)
  - Slow if no topological calib.
- Calorimeter (fast)
  - ~100 psec possible with pads
  - ~20 psec with LGAD

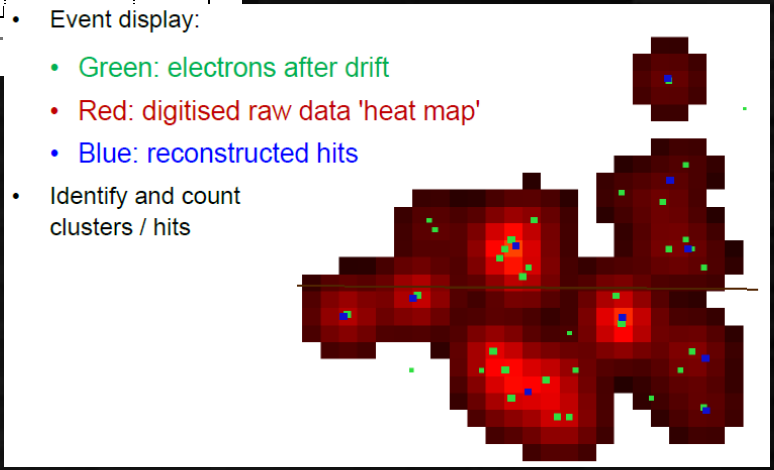
# Particle ID

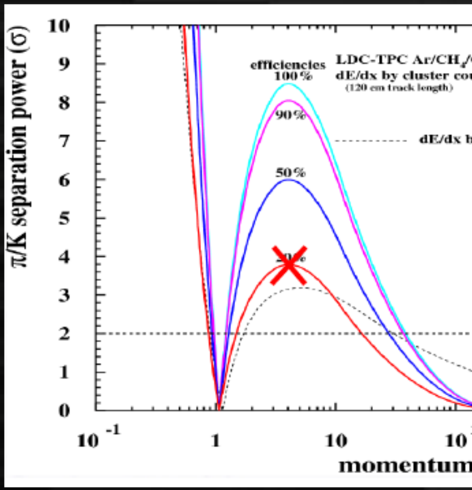



K/π separation by dE/dx and ToF

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

- ToF: outer tracker with 20 psec may improve the potential (LGAD tracker)




Timepix3 for monolithic TPC readout

# Issues on Electronics/Mechanics

- Development of electronics
  - Need silicon circuits (MAPS or ASICs) everywhere
  - Development of MAPS/ASICs needs
    - Time (1-2 year per production needed)
    - Cost (> 200 k$ initial cost, depending on process & area)

    → Practical large-scall R&D extremely difficult before the project will go

  → Slow progress, more money necessary…
- Replacement/repair
  - ATLAS/CMS needs major upgrade/fix on each LS
  - Is this possible in ILC? How to open calorimeter?

# Summary / Way forward

- Considering that the project is not approved yet, we have tremendous progress on detector study
- Base technologies are mature enough for conservative baseline options.
- No fundamental show-stoppers to prevent detectors to make
- Some advanced techniques with timing and PID functions proposed
  - Can consider to use if they become mature enough

# Timing resolution

Technology for silicon tracking

| Technology | Strip | MAPS | LGAD |
|---|---|---|---|
| Maturity | *** | ** | * |
| Position reso | ** | ** | *** |
| Ghost hits | * | *** | * |
| Speed | ** | * | *** |
| Material | * | *** | ** |
| Initial cost | **** | * | *** |
| Unit cost | ** | ***? | * |

- Compared with the state-of-the-art the proposed solutions can lower the time walk and increase time resolution:
  - Design simple
  - More power consumption
- Other solutions, with higher pixel areas and higher power consumption claim to arrive to 100 ps. In our case we are working with pixels from 50x50 $um^2$ to 80x80 $um^2$

Tracker: LGAD possible
ECAL: LGAD is too expensive
Update electronics with ~100 psec possible without novel sensor technology