

# Forward Calorimetry in ALICE at LHC

Tatsuya Chujo <sup>1)</sup>

for the ALICE Collaboration

M. Inaba <sup>2)</sup>, W. Sato <sup>1)</sup>, M. Hirano <sup>1)</sup>,  
H. Yokoyama <sup>1)</sup>, K. Ito <sup>1)</sup>

1) University of Tsukuba

2) Tsukuba University of Technology



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筑波大学  
University of Tsukuba

# CGS picture at LHC



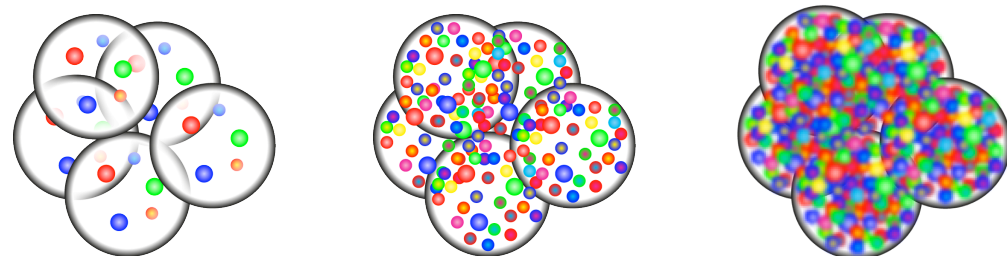
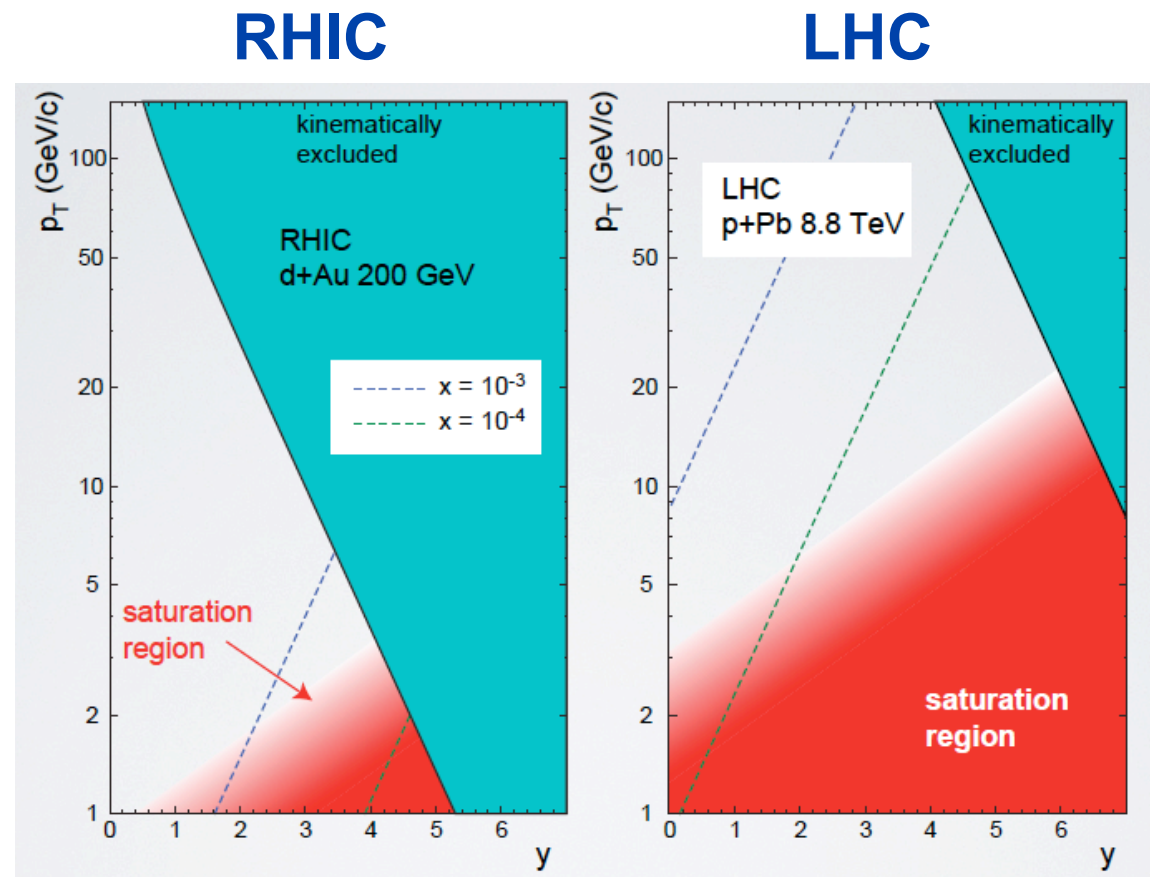
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- From the results in d-Au (RHIC) and p-Pb (LHC) collisions, there are indications of **Color Glass Condensate (CGC)**, but not conclusive yet.

- Many observables are used hadrons, which include final state interactions.

- A cleaner probe at forward rapidity is necessary, such as **direct photons**

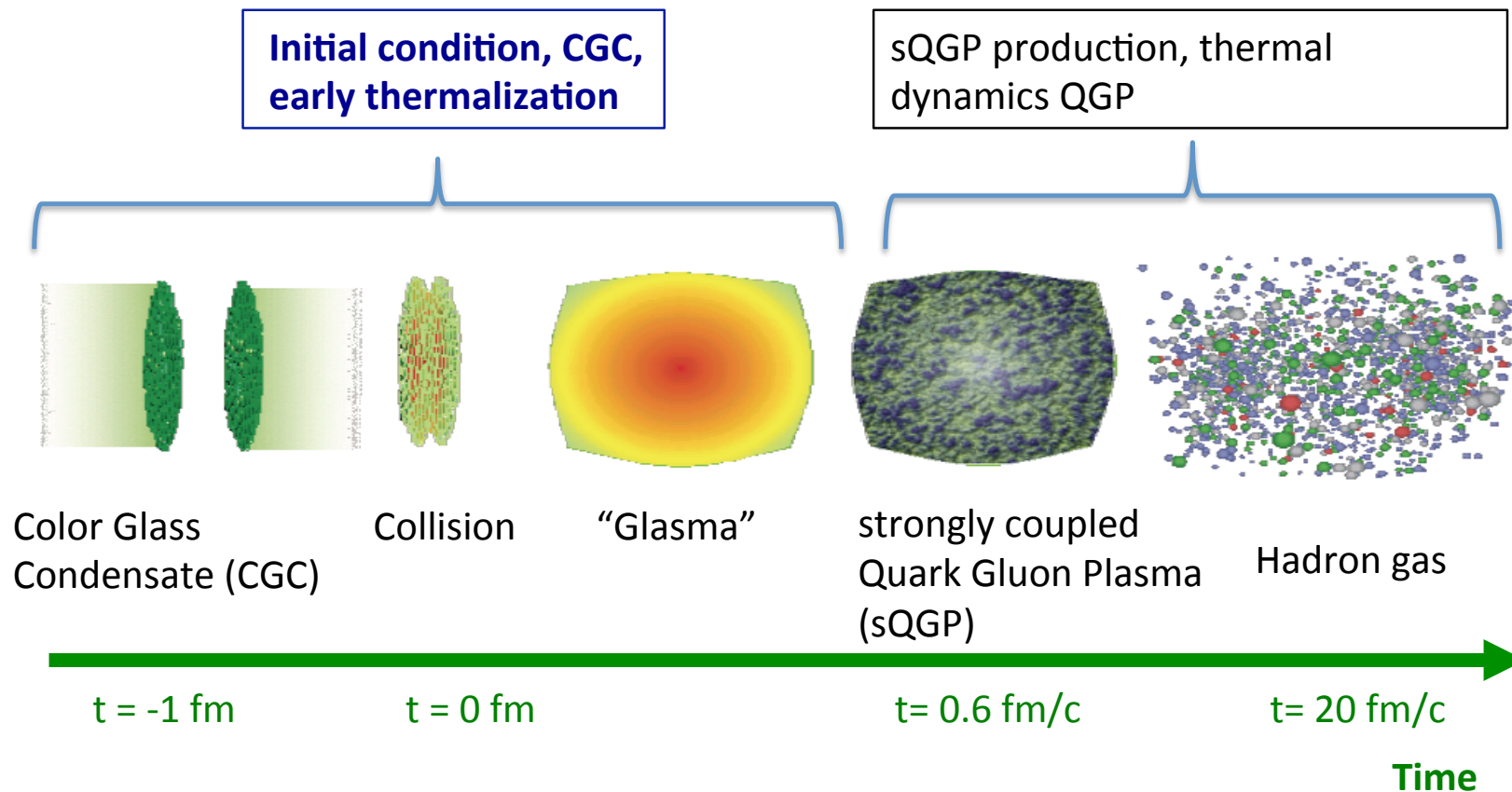
**Advantage at LHC** : Larger kinematic reach in saturation region at LHC, compared to RHIC.



# Initial condition and thermalization



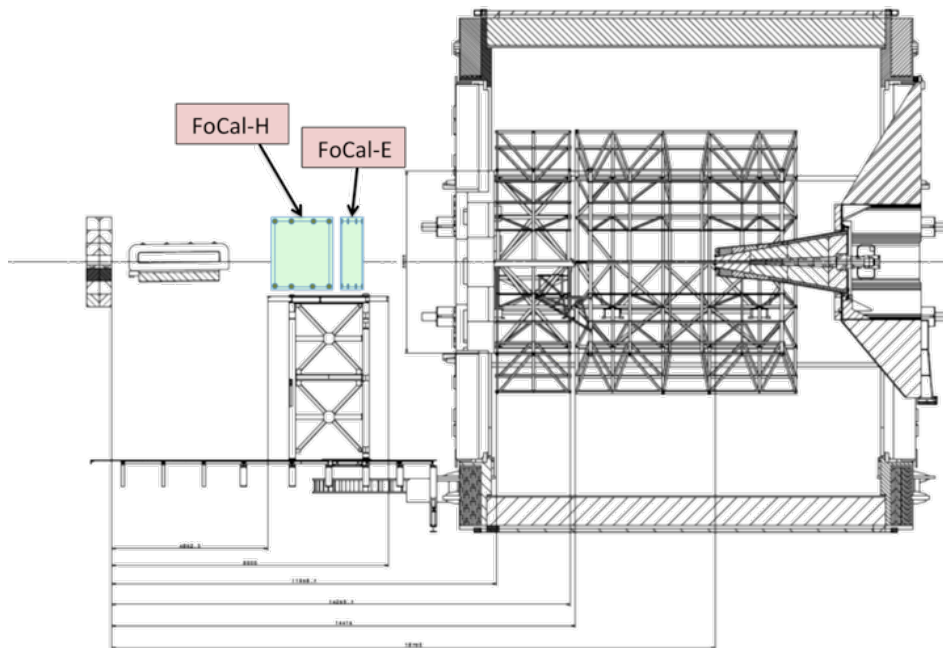
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RHIC/LHC data suggests an early thermalization of QGP ( $< 0.2$  fm), and it is still a big missing link between initial condition to QGP.

➡ Direct access to initial condition by direct photon

# Forward Calorimeter (FoCal) in ALICE



- Electromagnetic calorimeter for  $\gamma$  and  $\pi^0$  measurements, with Hadron Calorimeter.

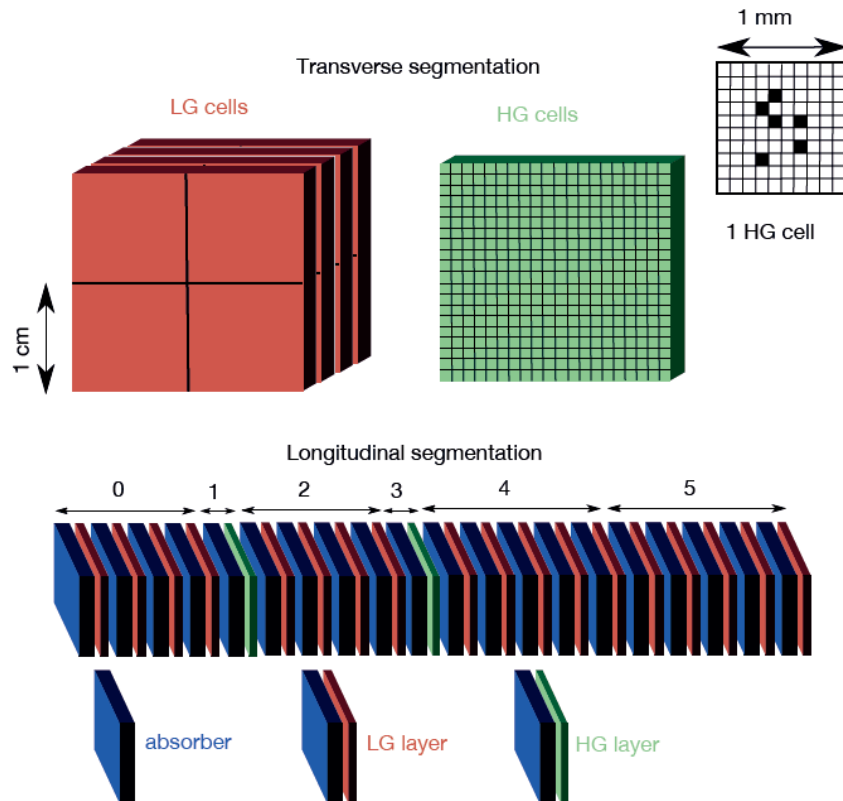
- At  $z \approx 8\text{m}$  (outside magnet)  
 $3.3 < \eta < 5.3$

Main challenge: **separate  $\gamma/\pi^0$**  at high energy

- Need small Molière radius, high-granularity read-out
- Si-W calorimeter, granularity  $\approx 1\text{mm}^2$



# FoCal-E Strawman Design



- **Si/W** sandwich calorimeter layer structure:
  - W absorbers (thickness  $1X_0$ ) + Si sensors
- Longitudinal segmentation:
  - 4 segments low granularity (LGL)
  - 2 segments high granularity (HGL)

- **LGL segments (PAD)**

- 4 (or 5) layers of Si/W
- Si-PAD with analog readout
- cell size  $1 \times 1 \text{ cm}^2$
- $8 \times 8 = 64$  PADs per layer
- signal are longitudinally summed

- **HGL segments (MAPS)**

- single layer with W.
- CMOS-pixel (MAPS\*).
- pixel size  $\approx 25 \times 25 \mu\text{m}^2$
- digitally summed in  $1 \text{ mm}^2$  cells

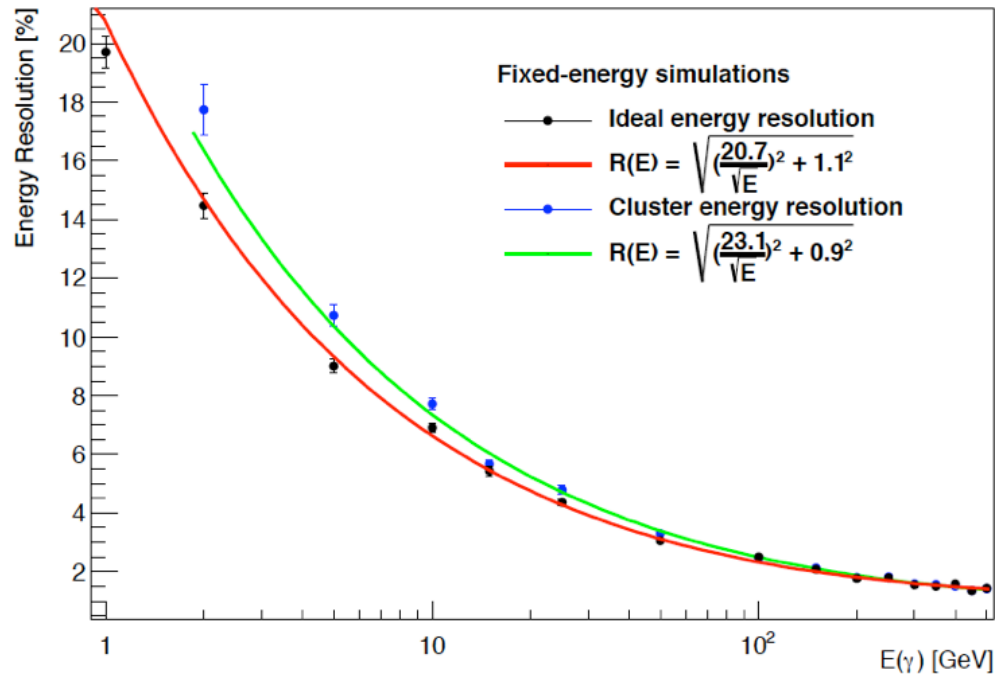
\*MAPS = Monolithic Active Pixel Sensor

# Detector Performance (simulation)

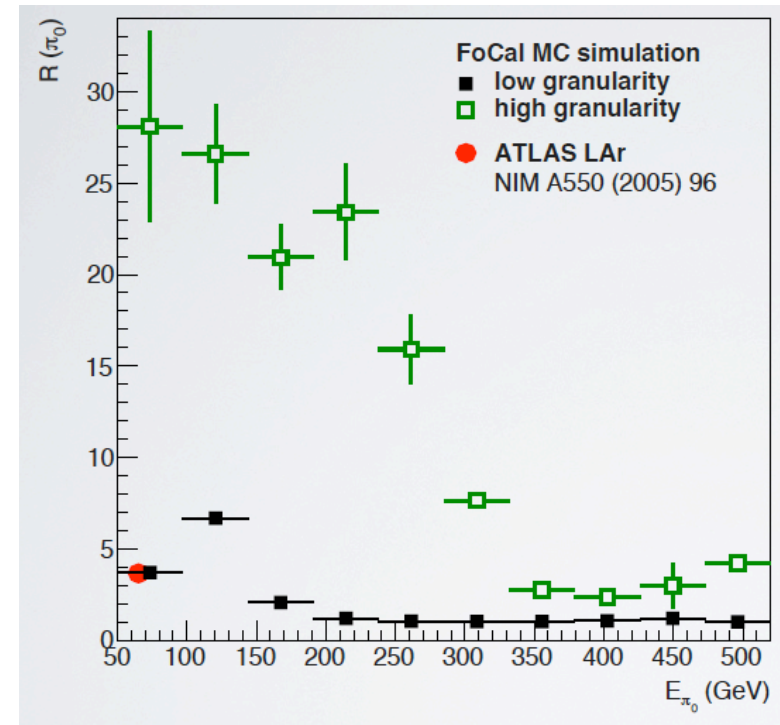


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## Energy resolution (FoCal-E)



## Pion rejection factor



- Reasonable energy resolution, extremely good two-shower separation with HG segments ( $\sim 0.2$  mm position resolution at  $E_\gamma > 100$  GeV)
- Efficient for pion rejection (via shower shape analysis)

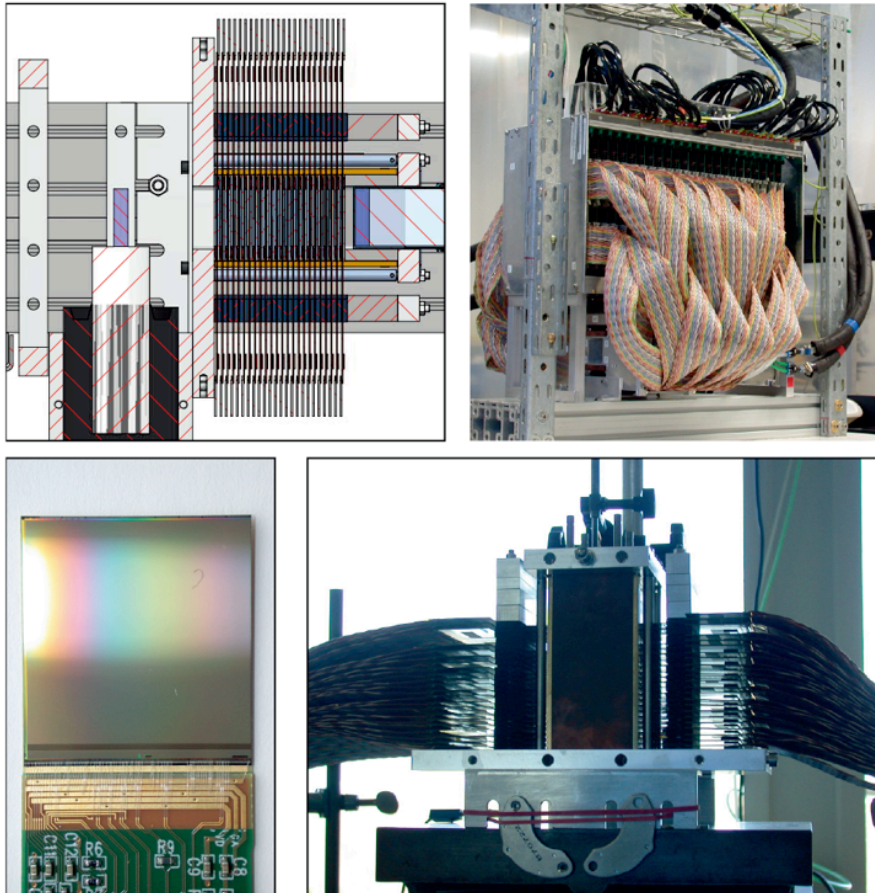


# High Granularity Layer (HGL) Prototype, MAPS

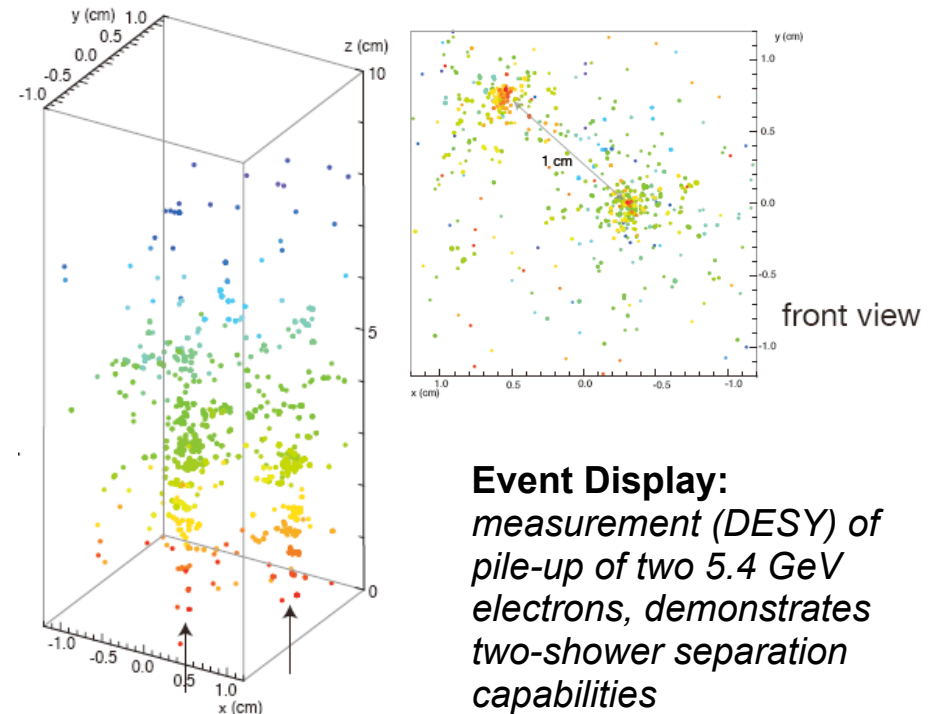


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MAPS prototype

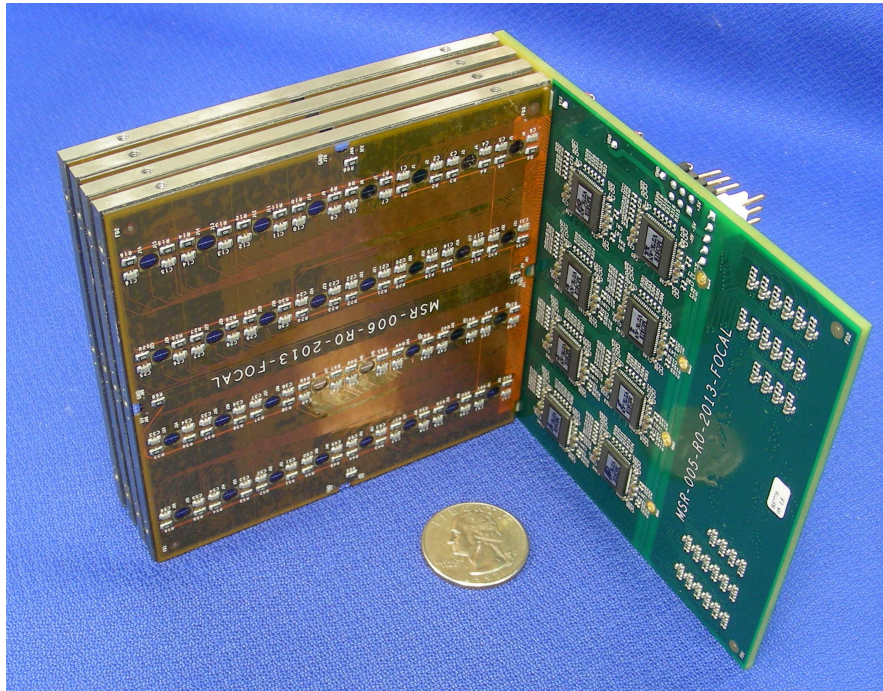


- 4x4 cm<sup>2</sup> cross section, 28 X<sub>0</sub> depth
- 24 layers: W absorber + 4 MAPS each
- MIMOSA PHASE 2 chip (IPHC Strasbourg)
  - 30 μm pixels
  - 640 μs integration time (needs upgrade – too slow for experiment)
- 39 M pixels total
- Test with beams at DESY, CERN PS, SPS

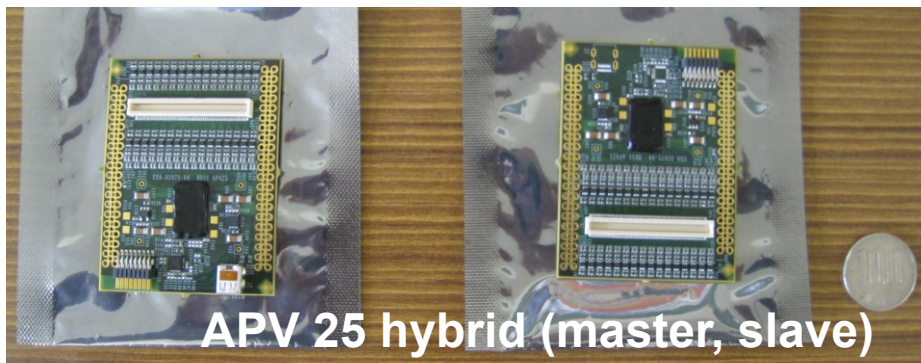


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# Low Granularity Layer (LGL) Prototype, PAD

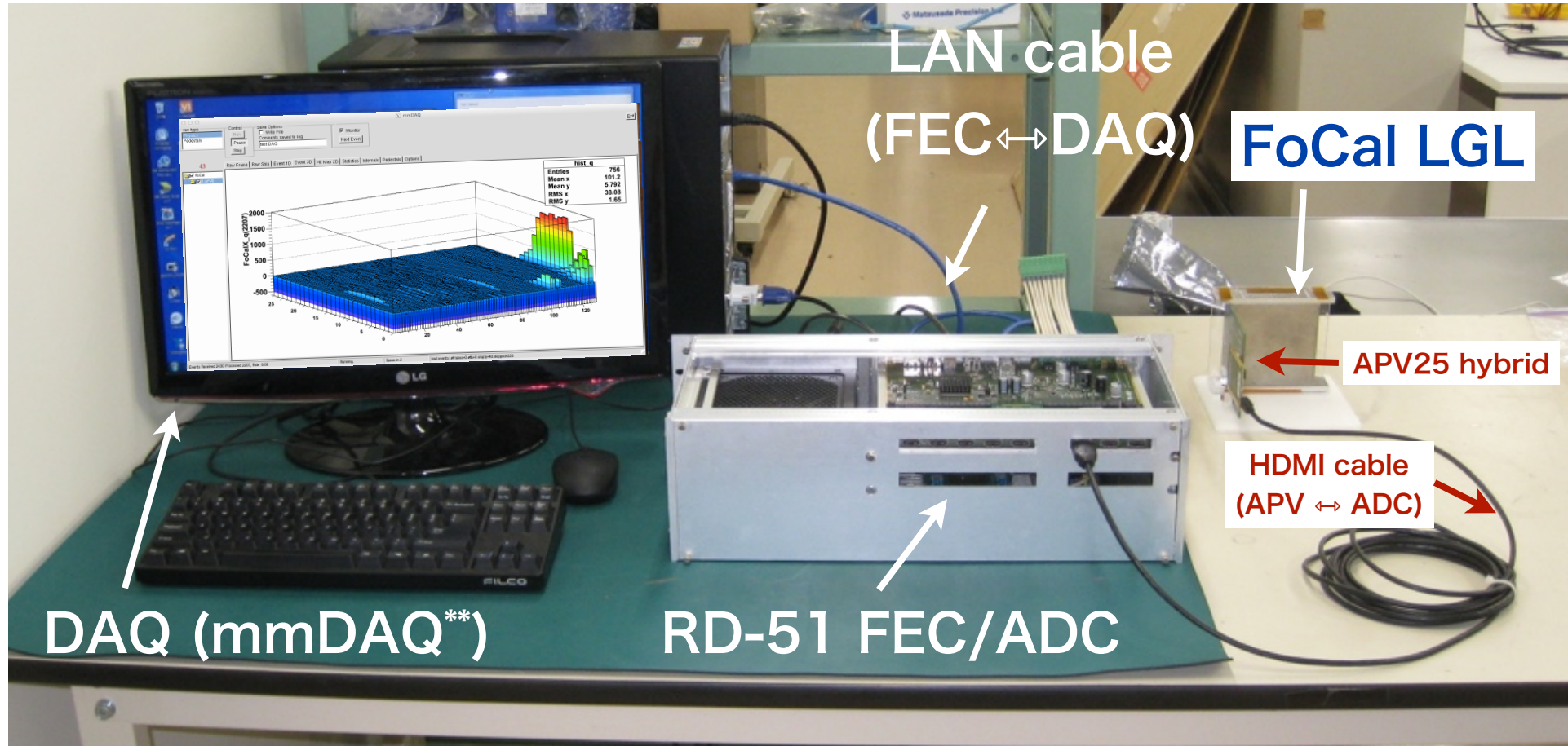


- **LGL (PAD) prototype (ORNL):**
  - Si-PAD (Hamamatsu S10938)
  - cell size 1x1 cm<sup>2</sup>
  - longitudinally summed (4 segments), analog readout.
  - W layer per Si-PAD
- **Readout system:**
  - ORNL ASICs, on a summing board.
  - RD-51 SRS readout system:
    - APV25 hybrid (128 ch, pre-amp, shaper)
    - SRS Front End Card (FEC) and ADC.
  - SRS: Scalable Readout System (point-to-point readout)
  - **Responsibility: Tsukuba, ORNL**





# RD51 SRS FEC/ADC for LGL(PAD)



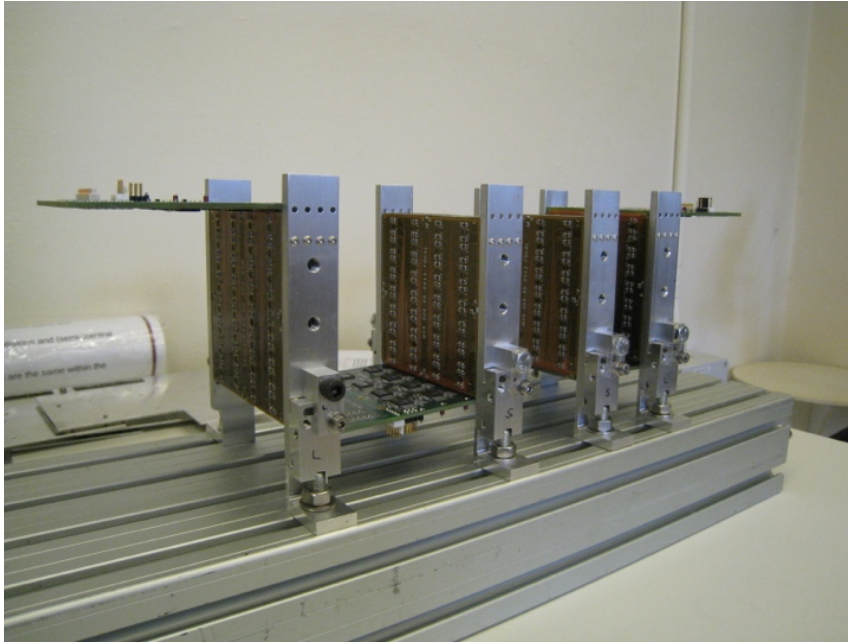
\* SRS-ADC: 12 bit 128 ch. ADC 40MS/s , 8x HDMI ports)

\* mmDAQ: Micromegas DAQ system for SRS.

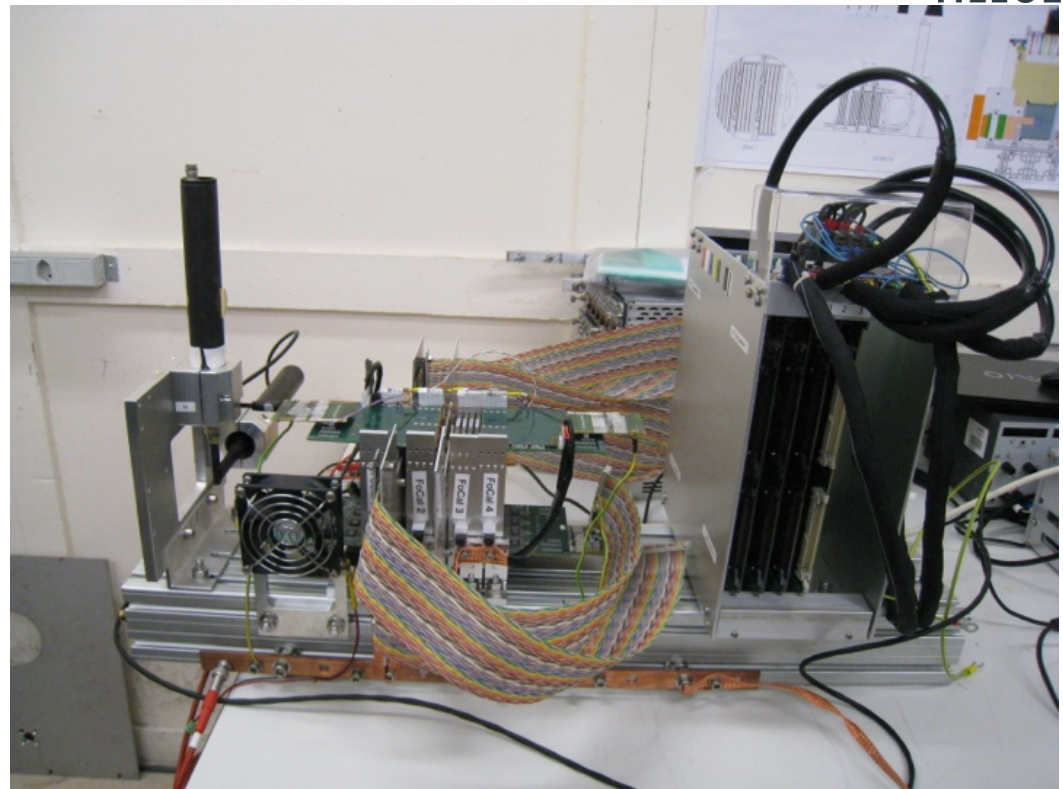
# Prototype of “a strawman design”



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LGL (PAD), 4 segments  
w/ summing board

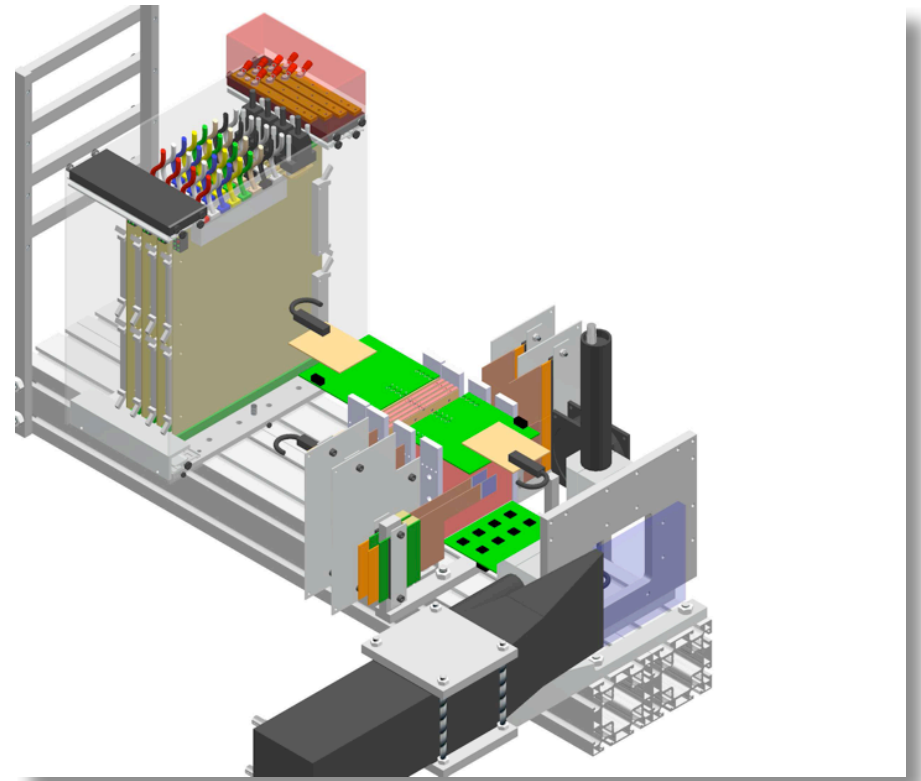


LGL (PAD) + HGL (MAPS x2)  
“strawman detector”

- **LGL PAD:**
  - Importance of proper grounding and shielding on (i) detectors, (ii) APV, (iii) LV power supply to summing board.

# CERN PS beam test (2014)

- ✓ **Beam time:**
  - Sep. 17 - Oct. 1, 2014
- ✓ **Beam line:** PS T9 beam line
- **Beam energy:**
  - 2 - 10 GeV/c (negative)
- ✓ **Trigger:** 10x10 cm<sup>2</sup> & 1x1 cm<sup>2</sup> Scinti. + Cherenkov (ON/OFF)
- ✓ **Responsibility:**
  - LGL (PAD) :Tsukuba, ORNL
  - HGL (MAPS) Utrecht, NIKHEF, Bergen
- ✓ **LGL:**
  - PAD Silicon pad bias voltage: -100V
  - Operated in the black box.
  - First time exposed by beam.



Drawing by Brink, A. van den (Utrecht Univ.)

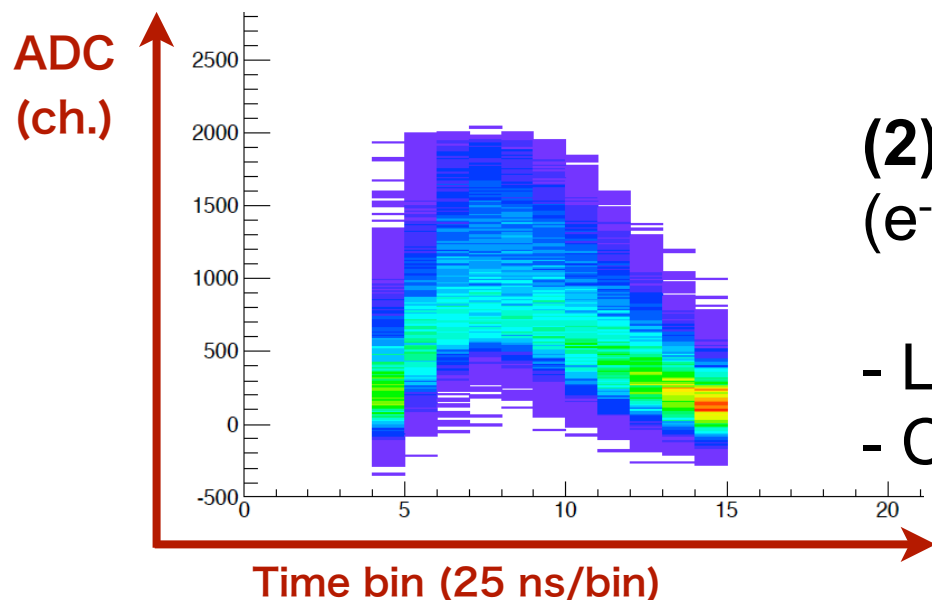
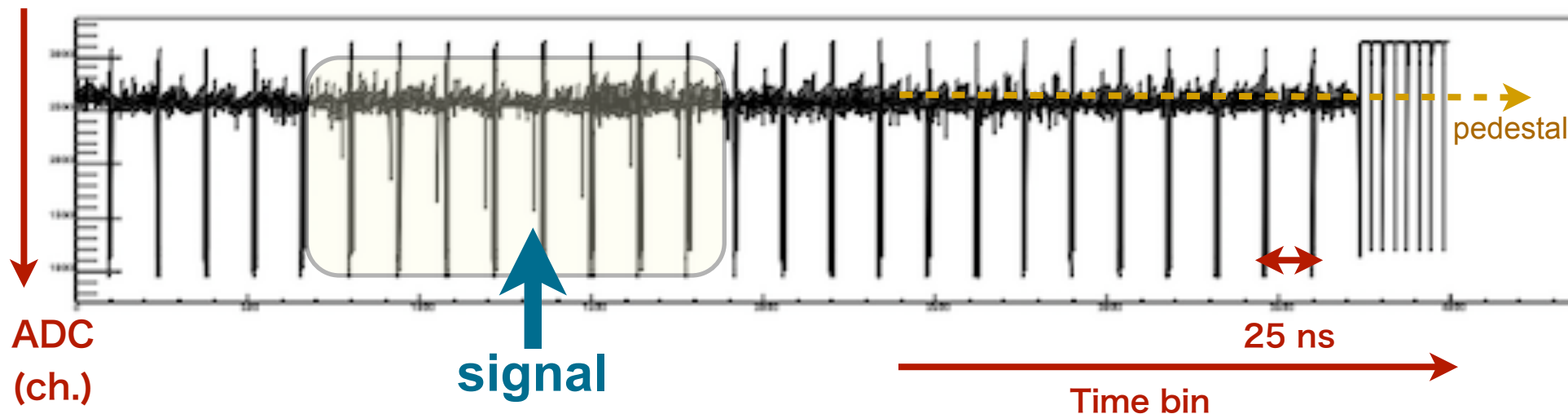


# Some plots from PS test; LGL (PAD)



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## (1) Online display (e<sup>-</sup> enhanced, 2 GeV/c beams)



## (2) Offline analysis

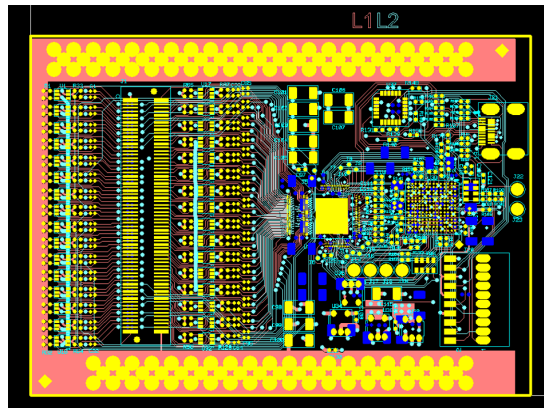
(e<sup>-</sup> enhanced, 2 GeV/c beams)

- Looked at a hit candidate PAD only.
- Clear electron like shower is seen.



# 4. Summary

- Proposing a Forward Calorimeter in ALICE for direct photon measurement at  $\eta = 3.3 - 5.3$ .
- A prototype has been build, and it consists of LGL (PAD) and HGL (MAPS) as the EMCal part.
- The integrated system of FOCAL-E (HG+LG) has been tested for the first time at PS (Sep. 2014).
- First look at the data, analysis is ongoing.



↑ Beetle hybrid chip

## Outlook

- Results from PS test beam.
- SPS beam test in Nov. 2014, integrated readout for LGL and HGL.
- Upgrade readout chip from APV to Beetle (trigger and high rate capability) w/ RD51.
- Lol is under preparation.

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