Update on the Compact Pixel Readout

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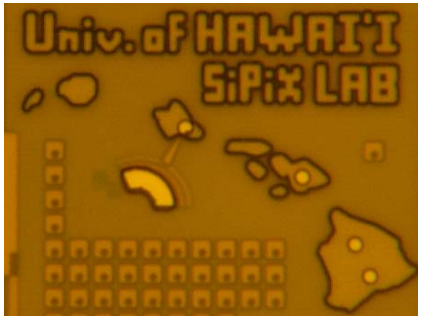
KEK, Krakow INP, Univ. of Hawaii, Tsukuba Univ.

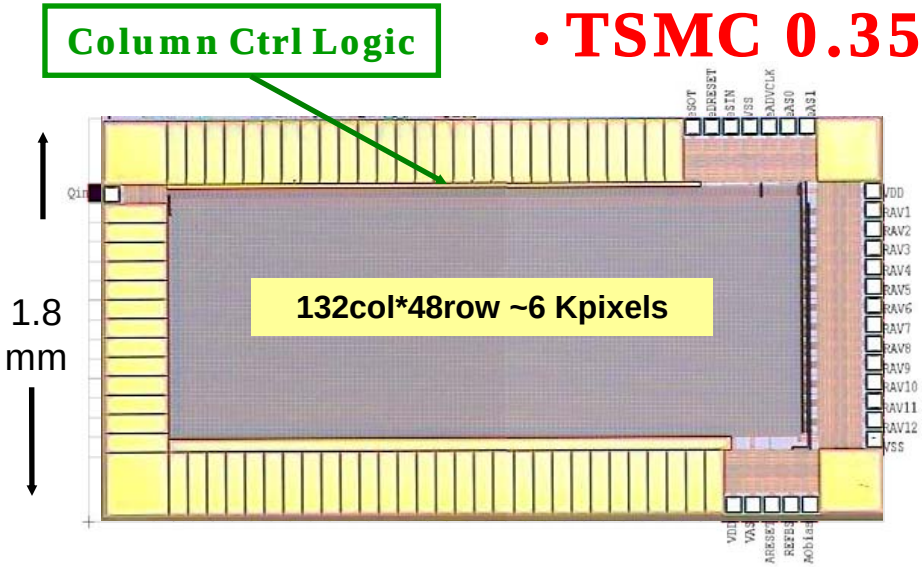
ID meeting – 16 August 2004



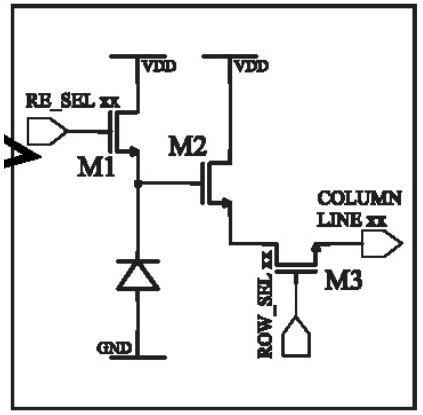
R&D for Belle SVD Upgrades

R=1cm / L>=3x10^{35}

Cont. Acq. Pixels (CAP) 1/2 Prototypes



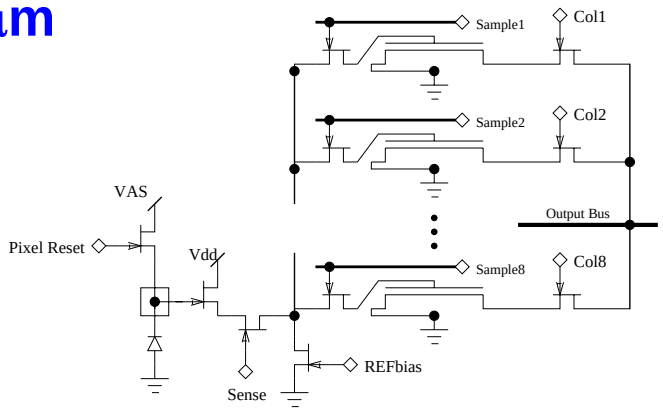
- **TSMC 0.35μm Process**
- **CAP1: simple 3-transistor cell**

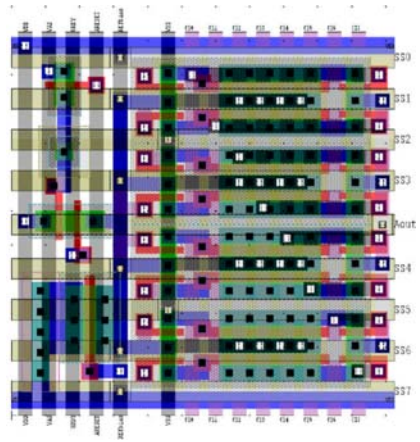


- **CAP2: 8x mini-pipeline in each cell**

Pixel size: **22.5 μm X 22.5 μm**
Pixel array**: 6 Kpixels**

Sample of CAP1/CAP2 tested:
all detectors (>15) function.

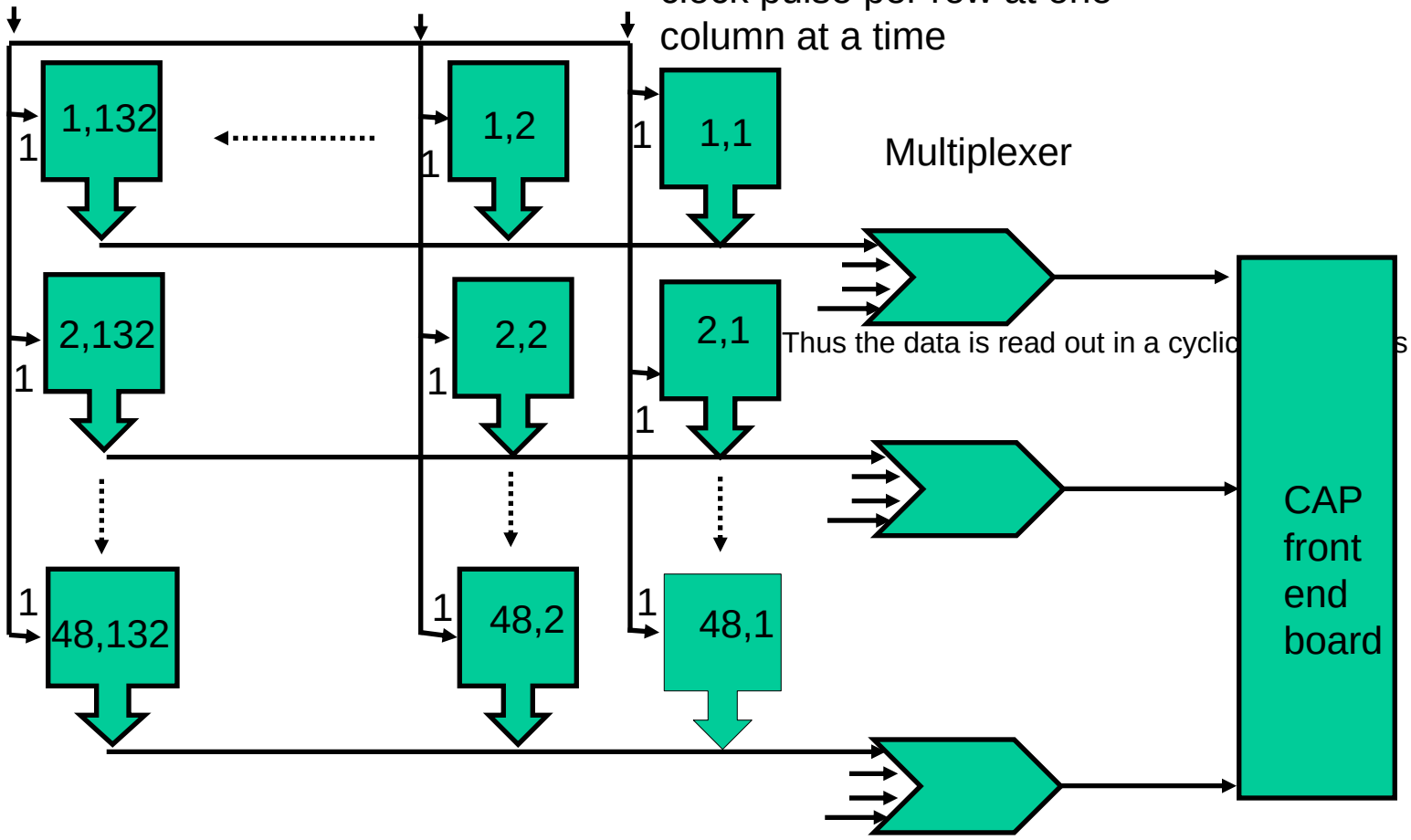




The CAP1 process

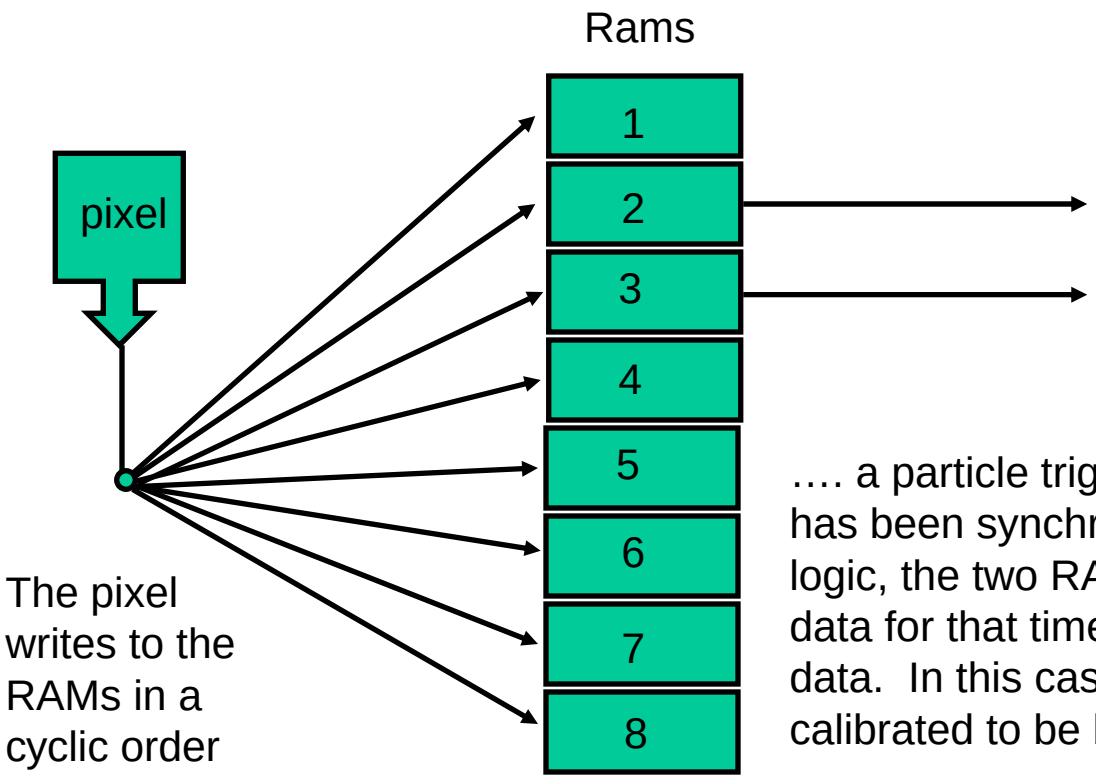
How the CAP1 works and reads the data.

Sends a read “1” down at clock pulse per row at one column at a time



Thus the data is read out in a cyclic s a matrix.

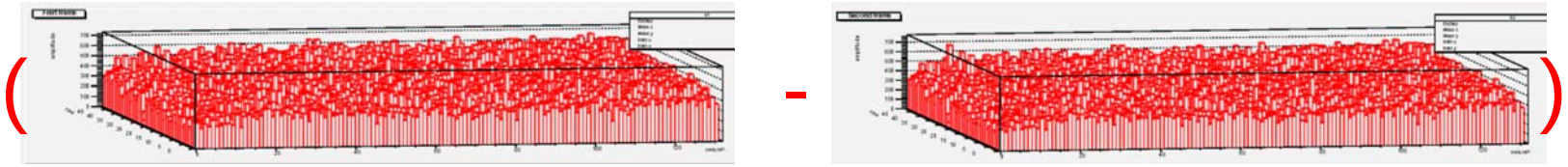
The CAP2 Process



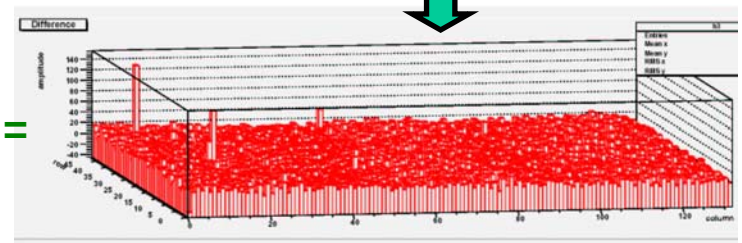
The pixel writes to the RAMs in a cyclic order until…

…. a particle triggers the PMT, which has been synchronized with the CAP logic, the two RAMs that have the data for that time period ship out their data. In this case, say at a time calibrated to be between RAMs 2 & 3.

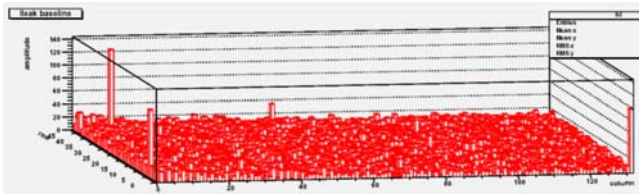
Correlated Double Sampling (CDS)



Frame 1 - Frame 2 =

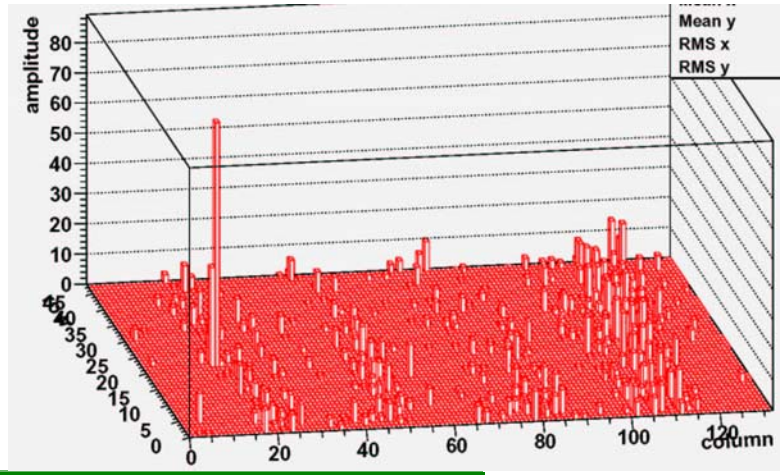


- Leakage current Correction



8ms integration

Can readout/process @ 20Hz ~ 16% live time (CAP1!)



~fA leakage current (typ)
~18fA for hottest pixel shown

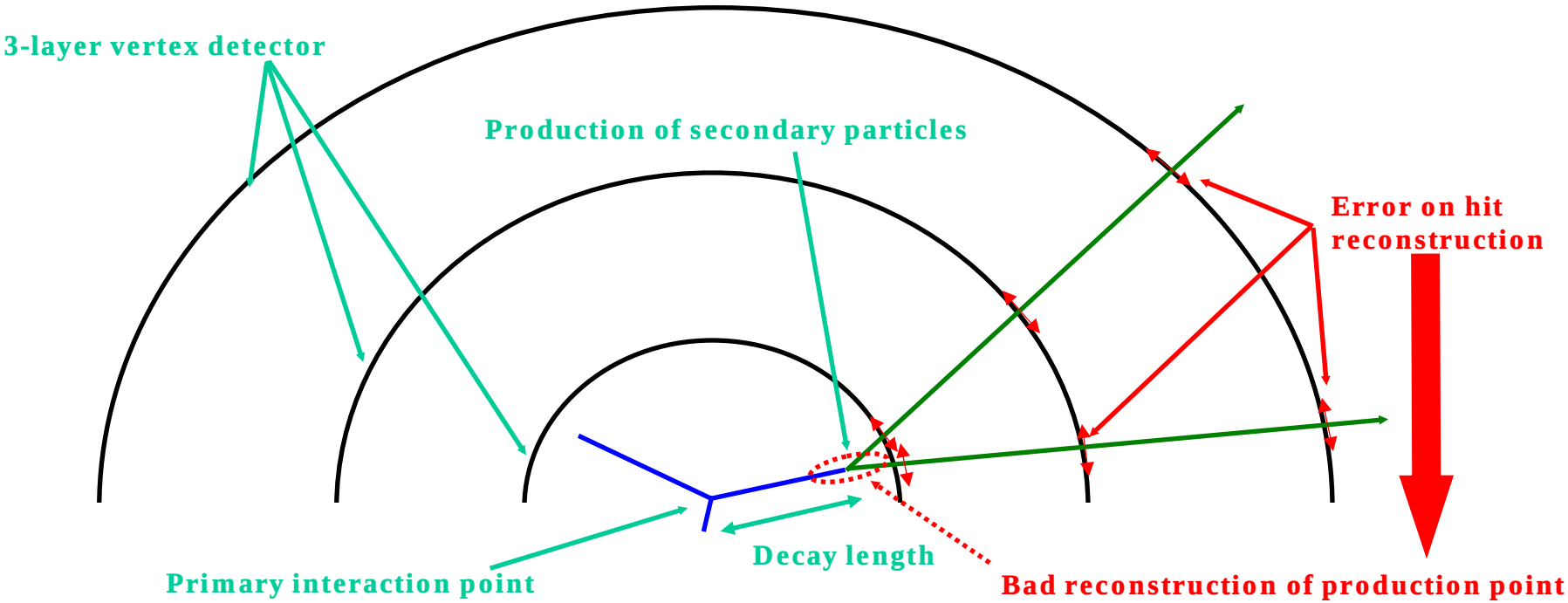
Hit candidate!

CAP1 vs. CAP2

- CAP1 is simple in operation, and less connections and operations, thus simple in the programming of the firmware. Readiness in less time.
- No triggering needed from the PMTs.
- Active searching of particles needs large integration times ~8ms (hence more leakage current), and ratio of searching vs. processing times is not optimal.

- CAP2 is more complex in operation, has more signals and connections leading to more complicated firmware and increased realization time.
- External trigger from PMTs needed, with synchronization of timing to readout proper RAMs.
- Since it passively searches, the CAP2 spends more time looking than the CAP1. With RAMs to store data, the integration time can be reduced ~15us (thus lessening signal errors due to leakage current).

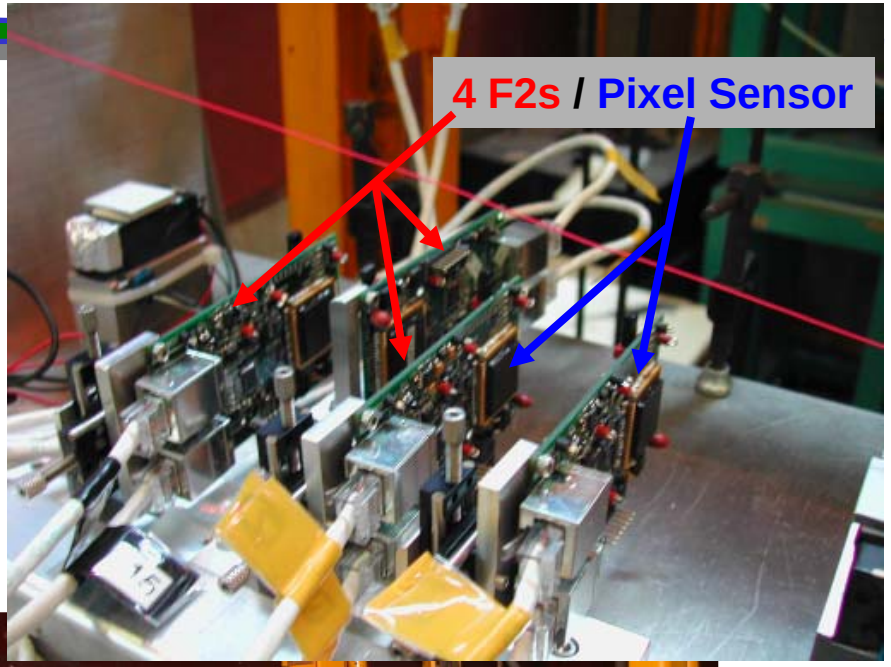
Hit resolution in Vertex detector

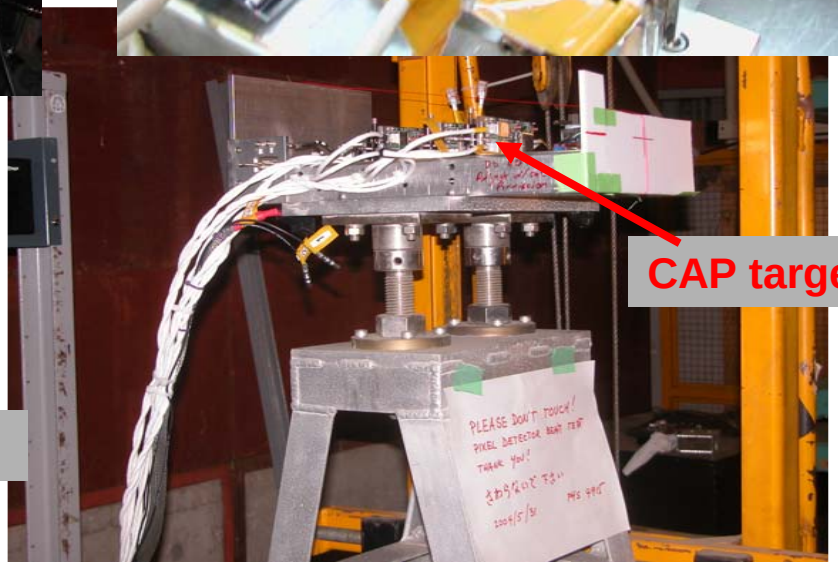


The determination of a as precise as possible decay length gives a hint at which particle was produced. BUT, to do this measurement, we need to be accurate in our extrapolation from recorded hit: hence we need to have a good hit resolution in outer layers of detector.

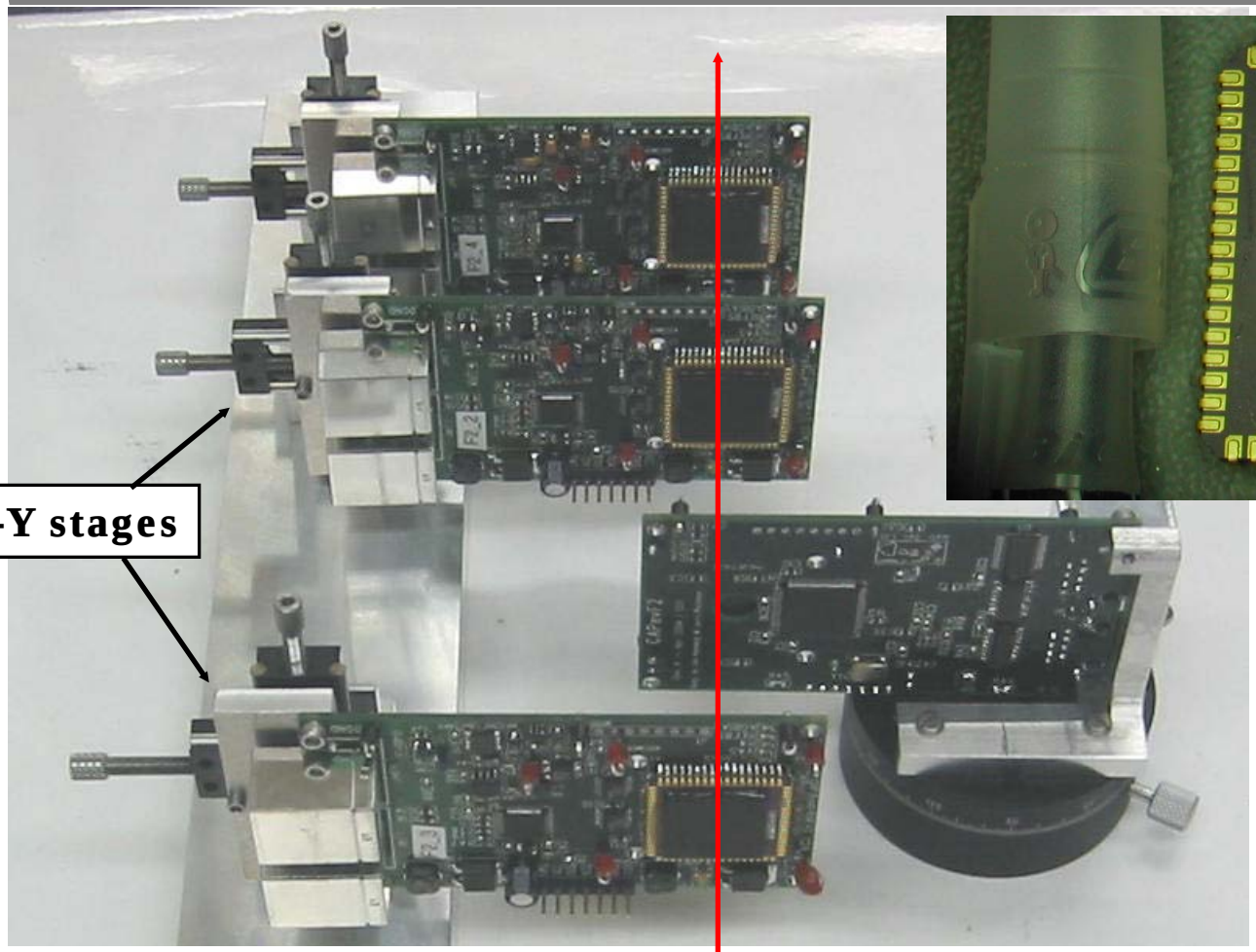
(Note: and not too much material!)

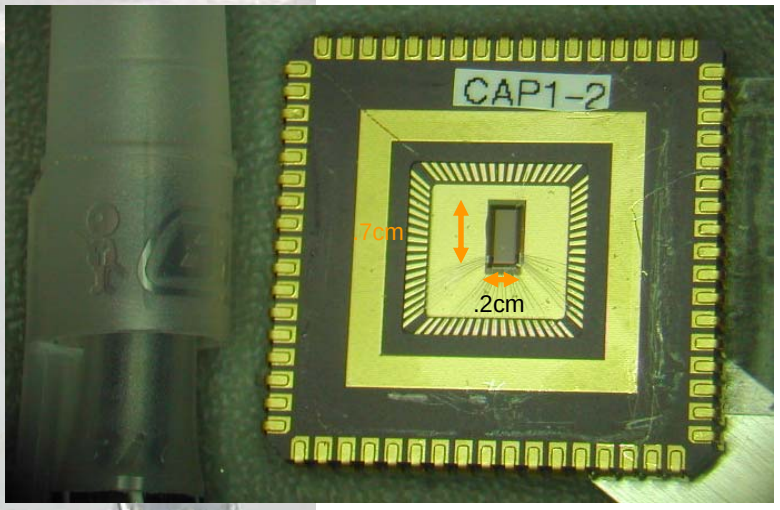
June 2004 Test Beam/π2-area





Beam test bench

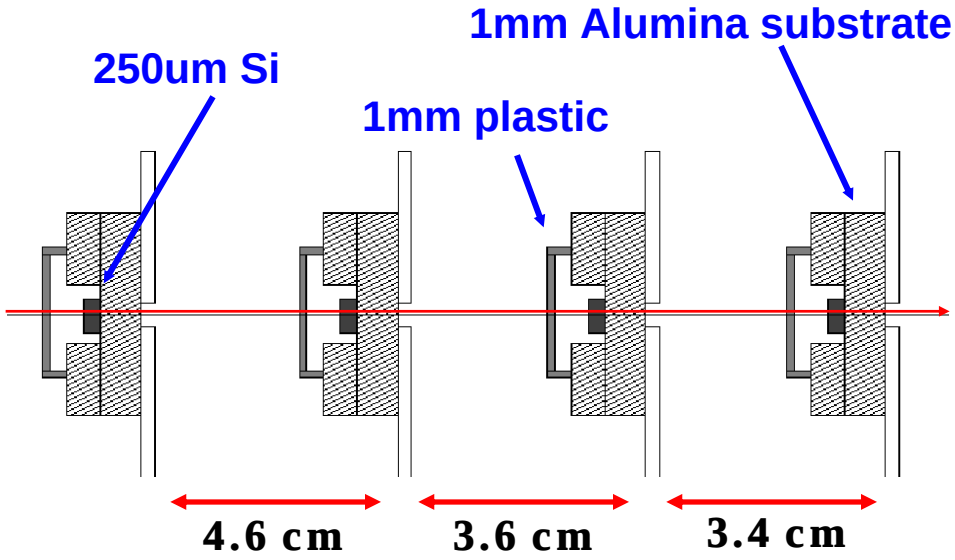


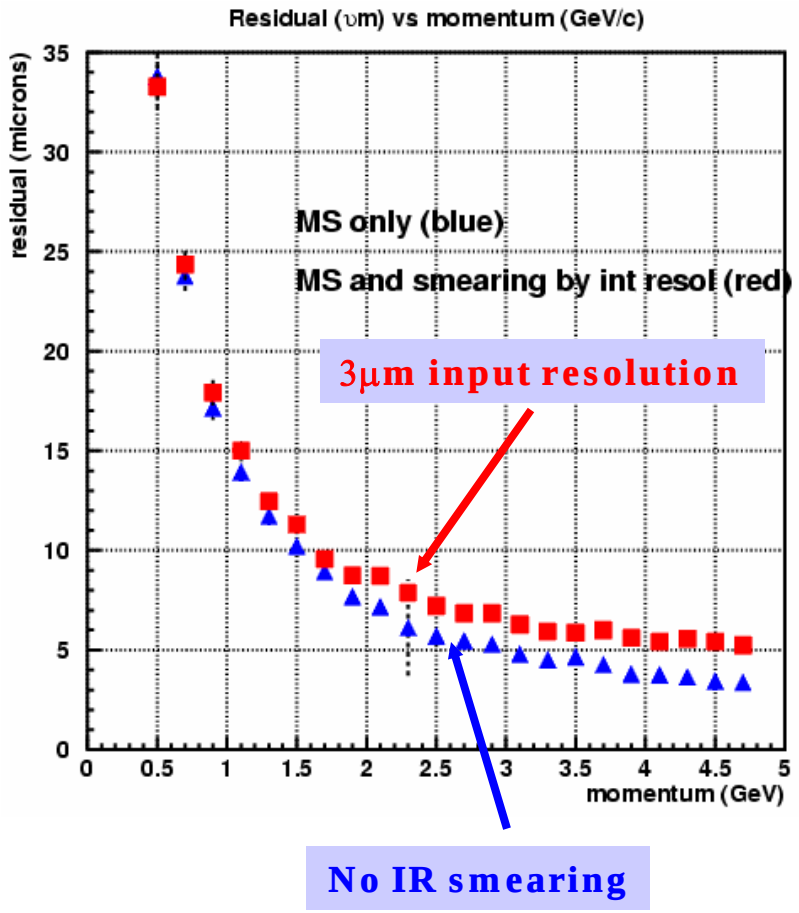


Assembled:

- **Base plate**
- **Trigger counters (small PMTs and tiny scintillators)**
- **Cables (6m)**

Resolution: Simulation





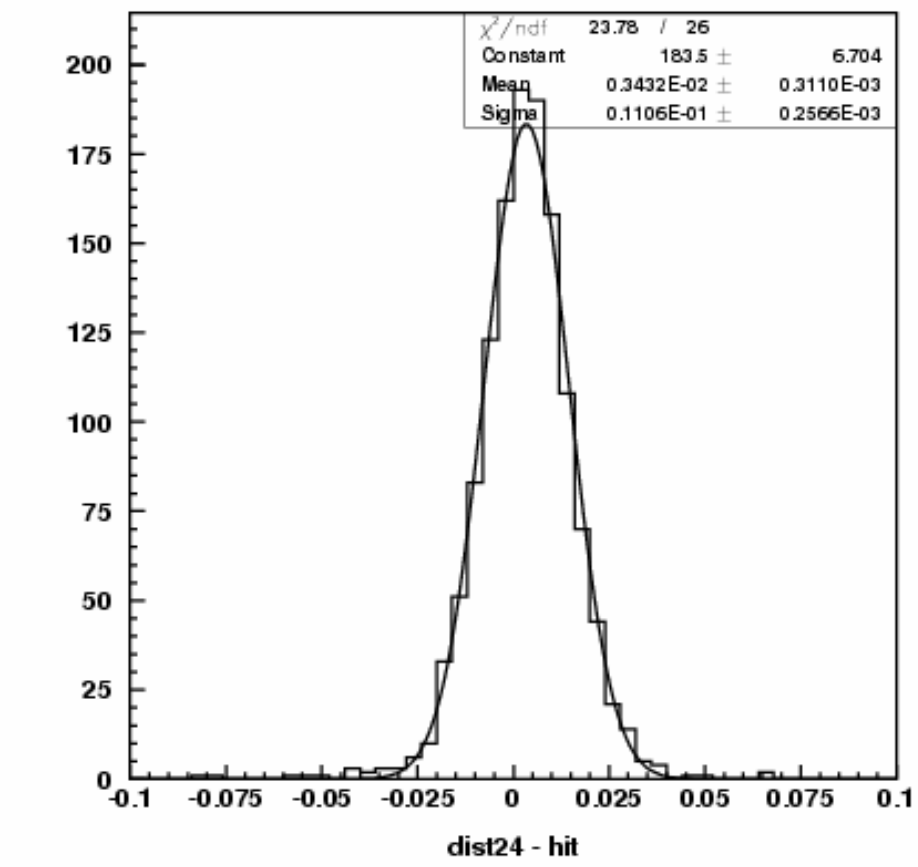
What degrades the resolution (setup related):

1) **The material in the beam: more material = more deflection of incoming particles ('multiple scattering').**

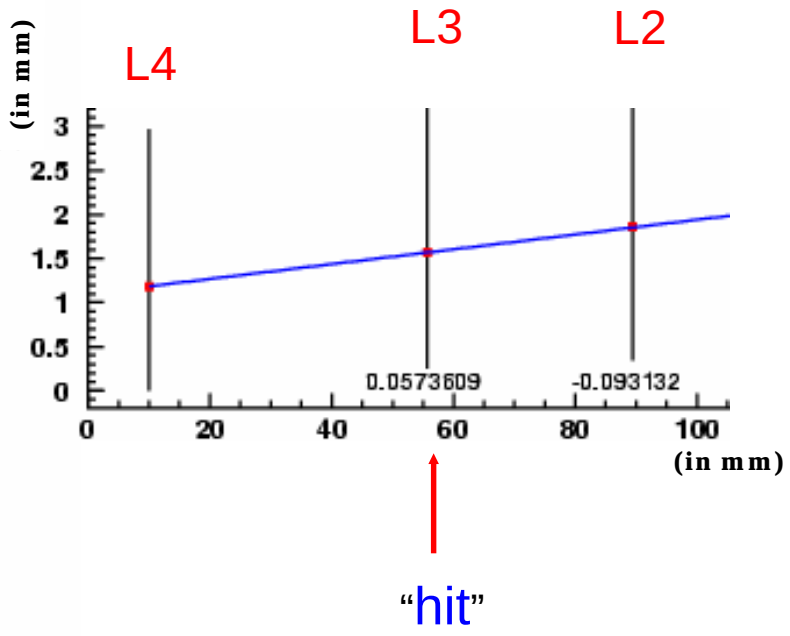
2) **The distances between sensors: larger distances to drift away.**

In our case: measurement of intrinsic resolution degrades mainly because of distances between pixel detectors (constraints from Front-End board design)

Resolution from data



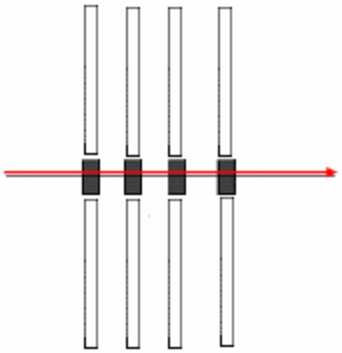
x-plane



Current Residuals, @ 4GeV:

- **11μm in x plane**
- **14μm in y plane**

What to do?



First, remove the cover.

That means attaching the die to the board.

Next, remove the die package.

Finally, move the boards closer.

Clashes of lessening the distance

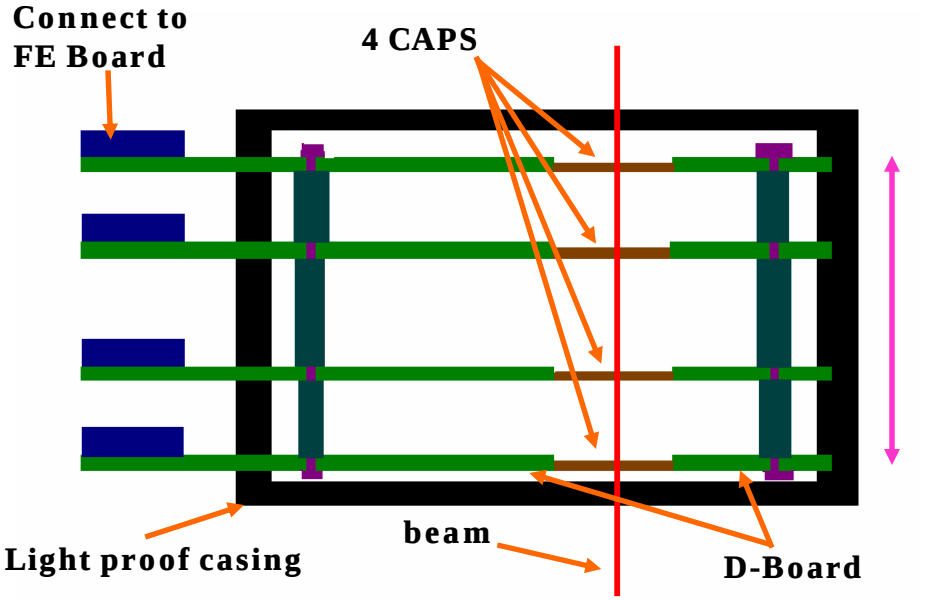
OR separate the front end board from the CAP dies board.

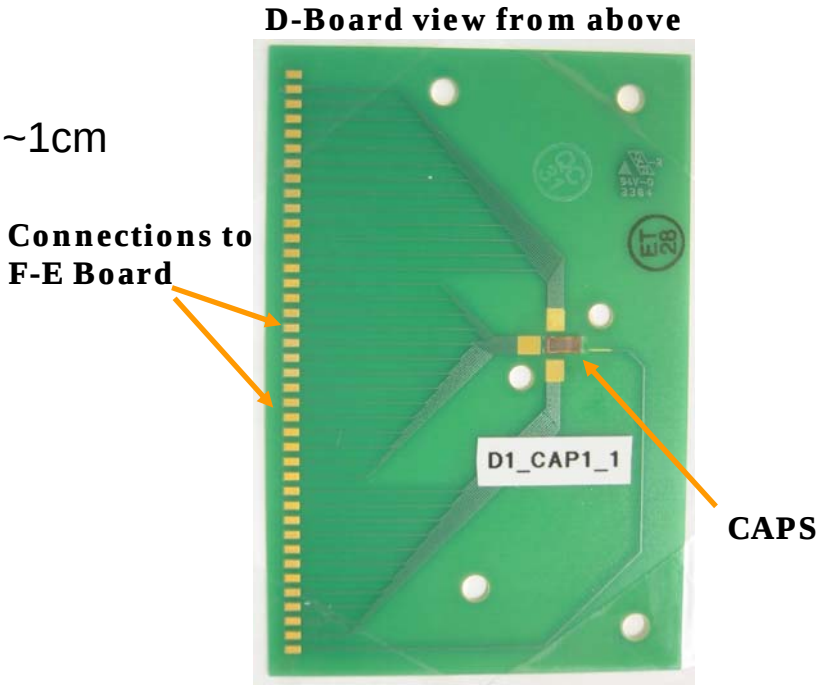
But we are limited by other components located on the front end board in the effort to tighten the gap between the CAP dies.

So we must eliminate the other components on the board but we need all components.

Compact Packaging

- **Compact packaging for next beam test:**
  - **Expect a better upper limit on intrinsic resolution**

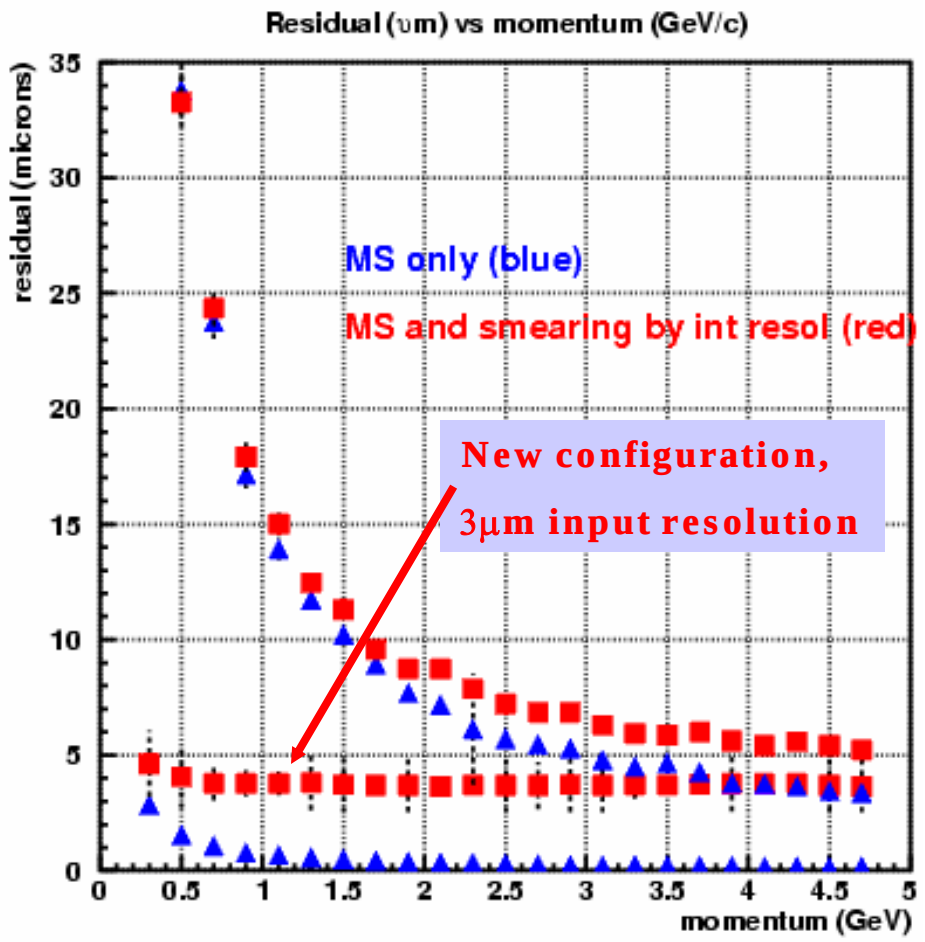




Highlights: - <0.3cm between CAPS.
- eases alignment.

Status: PCBs from vendor are in and die are being installed.

Resolution with Compact Packaging



0.3cm spacing between detectors, 300 μm Si.

@ 4GeV, 5-7μm (as in June beam test configuration) → 4μm

Effects of multiple scattering and of distances become negligible!

When could the next beam test be scheduled?

Summary & Conclusion

- **Quite successful beam test in June:**
  - **We built a setup bench with four front-end boards that allowed us to adjust the distances between the boards.**
  - **Experience gained / Demonstrate beam test operation.**
  - **We measured a resolution of 11μm.**

    We think that we could still do better.

Summary and Conclusion

- **A new compact packaging was designed:**
  - **The distances between the detectors will be greatly reduced: from ~4cm to ~0.3cm for an overall distance of ~1cm for all four. This reduced distance along with the removal of materials greatly decreases errors due to particle deflection.**

  - **The alignment of the detectors should be eased.**

  - **Our measurement of the resolution of our pixel detectors should be greatly improved.**

  - **We look forward to the next beam test opportunity.**