CEPC Silicon Tracker Progress Report (11)

Qi Yan *on behalf of the Silicon Tracker Group*

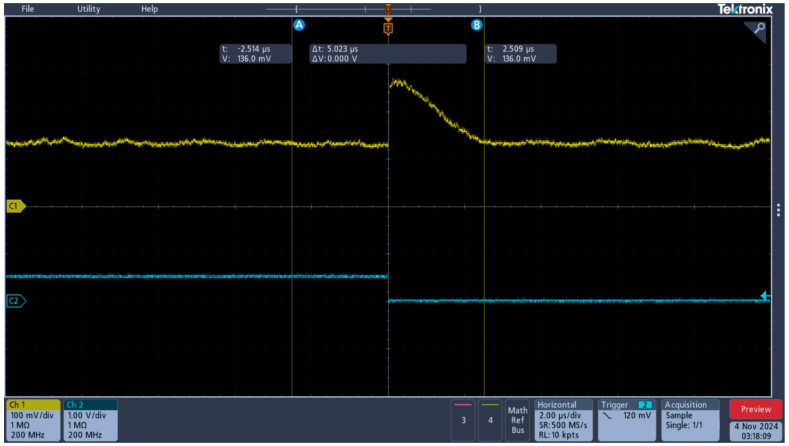
Nov 11, 2024, IHEP

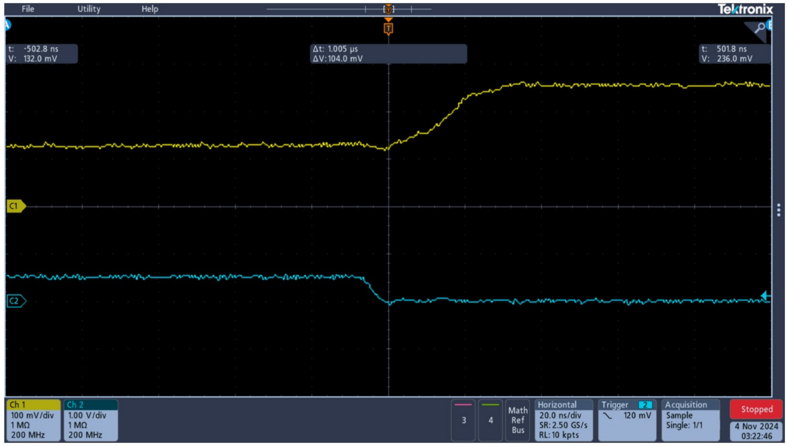
HVCMOS (COFFEE2) Chip Test Result (1)

Dexing Miao, Leyi Li, Yiming Li, Weiguo Lu, Jianchun Wang,
Zhiyu Xiang, Zijun Xu, Cheng Zeng, Mei Zhao, Yang Zhou, …

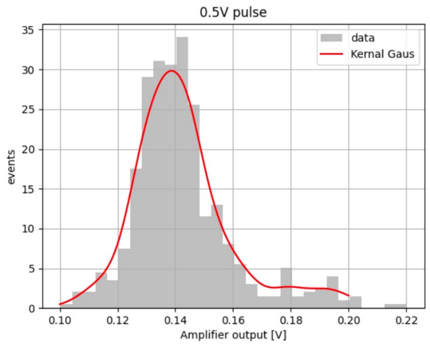
Active pixel test: Amplifier output

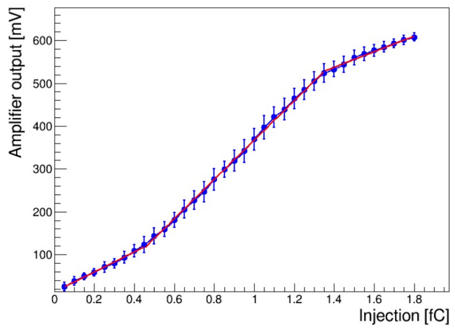
Inject a charge with a ~0.5 V pulse at 10 ns from the wave generator. A clear response appears. The amplifier (last 8 columns of pixels, Pin 62) has a rise time of ~25 ns. Define: Output = Max (Response) – Mean (Baseline).

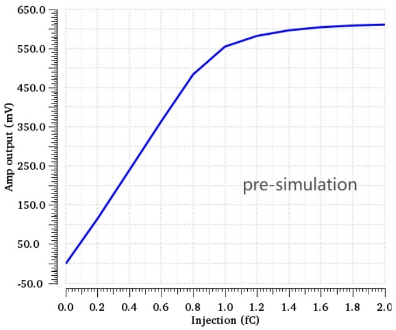




500 injections per voltage point are performed to determine the mean and standard deviation of the output. The response curve shows good linearity and then tends to saturate, similar to the simulation results.





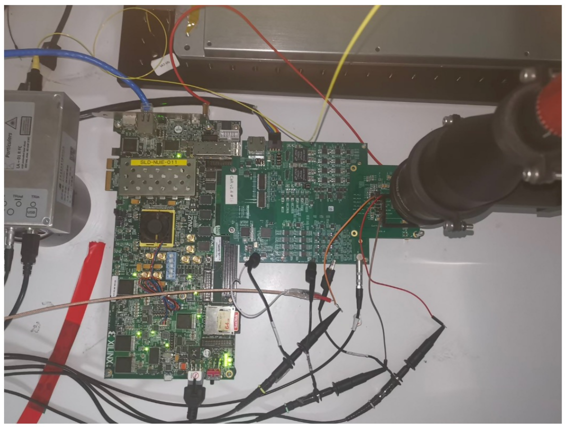


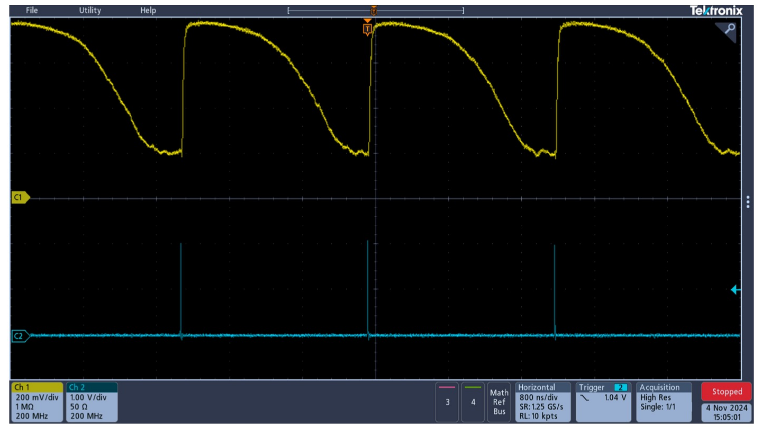
HVCMOS (COFFEE2) Chip Test Result (2)

Dexing Miao, Leyi Li, Yiming Li, Weiguo Lu, Jianchun Wang, Zhiyu Xiang, Zijun Xu, Cheng Zeng, Mei Zhao, Yang Zhou, …

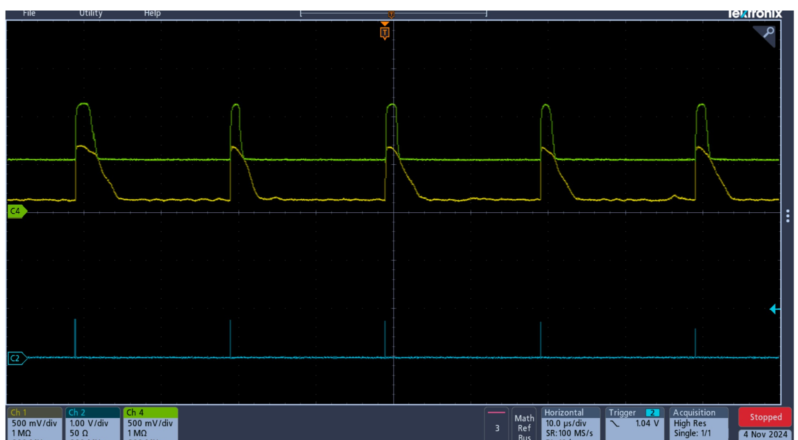
Active pixel test: laser

Only a single pixel can be read out, controlled by row-column gating. Testing with a laser is more efficient than using a radioactive source. Testing with a red laser (λ ~ 650 nm) shows a clear amplifier response following the laser trigger, even with a sensor bias of -1.2 V.





The discriminator also works well (green curve).

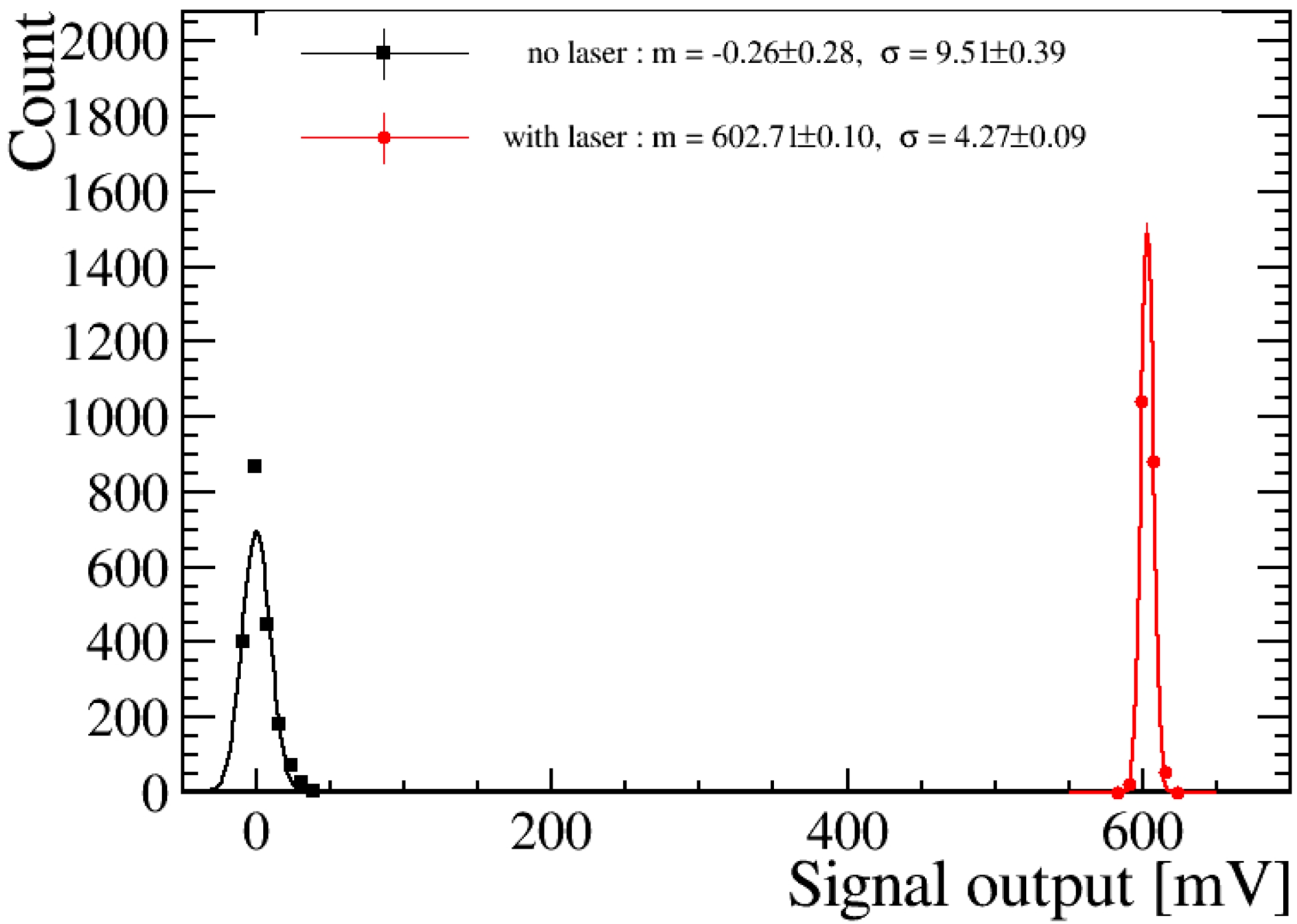


HVCMOS (COFFEE2) Chip Test Result (3)

Active pixel test: laser

Dexing Miao, Leyi Li, Yiming Li, Weiguo Lu, Jianchun Wang, Zhiyu Xiang, Zijun Xu, Cheng Zeng, Mei Zhao, Yang Zhou, …

Under a sensor bias of -70 V, 2000 injections with laser irradiation demonstrate the high charge resolution of the COFFEE2 pixel (sensor + amplifier).

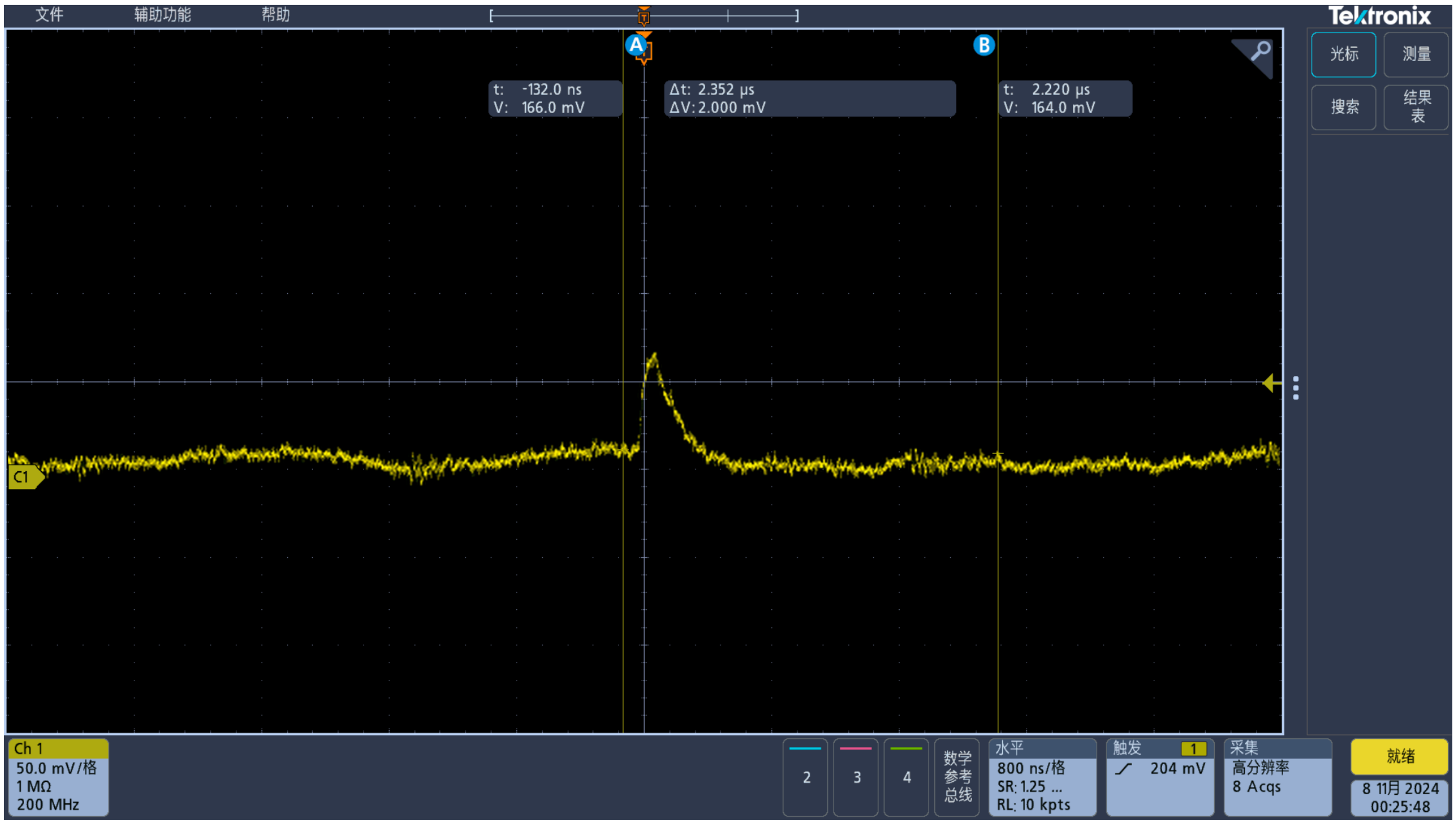


HVCMOS (COFFEE2) Chip Test Result (4)

Active pixel test: Fe55 X-ray

Dexing Miao, Leyi Li, Yiming Li, Weiguo Lu, Jianchun Wang, Zhiyu Xiang, Zijun Xu, Cheng Zeng, Mei Zhao, Yang Zhou, …

A clear response to the Fe-55 source was observed. The charge deposit is estimated to be between 1000 and 2000 e-, which is consistent with the expected value of 1640 e-.



Silicon Tracker TDR Drafting

5.1 Requirements . . . .
5.2 Overview of ITK and OTK . . . .
5.2.1 Tracker system layout optimization . . . .
5.3 Inner silicon tracker (ITK) . . . .
5.3.1 CMOS chip R&D . . . .
5.3.1.1 HV-CMOS pixel R&D . . . .
5.3.1.2 CMOS strip R&D . . . .
5.3.2 ITK design . . . .
5.3.3 Readout electronics . . . .
5.3.4 Mechanical and cooling design . . . .
5.3.5 Prospects and plan . . . .
5.4 Outer silicon tracker (OTK) with TOF . . . .
5.4.1 AC-LGAD sensor and ASIC R&D . . . .
5.4.1.1 AC-LGAD Sensor R&D . . . .
5.4.1.2 AC-LGAD ASIC R&D . . . .
5.4.2 OTK design . . . .
5.4.3 Readout electronics . . . .
5.4.4 Mechanical and cooling design . . . .
5.4.5 Prospects and plan . . . .
5.5 Performance . . . .

Participants: Qi YAN (Main Responsible), Gang LI (Deputy), Yiming LI (Deputy), Yang ZHOU, Xin SHI, Yunyun FAN, Mei ZHAO, Xiongbo YAN

Chapter 5 Silicon Trackers

The CEPC Silicon Tracker, positioned outside the Vertex detector, consists of the Inner Silicon Tracker (ITK) and the Outer Silicon Tracker (OTK). The ITK and OTK are separated by the Time Projection Chamber (TPC). The ITK utilizes advanced CMOS sensor technology to achieve precise position measurements for accurate particle trajectory determination. In addition to position measurement, the OTK integrates AC-LGAD semiconductor detectors for precise time measurement of charged particles, significantly enhancing particle identification capabilities ...

Responsible person: Qi YAN, ...

5.1 Requirements

The CEPC Silicon Tracker is designed to operate in both Higgs and Z-pole modes. In Z-pole mode, the luminosity reaches $\mathcal{L} = 115 \times 10^{34}\text{cm}^{-2}\text{s}^{-1}$ with 23 ns between bunch crossings.

The basline design of the CEPC Inner Silicon Tracker (ITK) includes 3 barrel layers and 4 endcap layers, while the basline design of the Outer Silicon Tracker (OTK) consists of 1 barrel layer and 1 endcap layer. Among all the tracker system in CEPC (Vertex, Silicon Tracker, and TPC), the Silicon Tracker spans the largest lever arm with high intrinsic spatial resolution for accurate trajecotry determination of charge particles.

The primary goal of the Silicon Tracker is to precisely meausre momentum of the particles. Along with the Vertex detector, the Silicon Tracker also helps to identify primary and secondary vertices for tagging long-lived objects like b or c quarks and τ-leptons. To enable precise measurements of Higgs properties and other key physics objectives, CEPC requires an overall track momentum resolution of better than 0.5% for momenta below 100 GeV/c. This places high demands on the tracking detector. Each detector layer should achieve a spatial resolution of 10 microns or better in the particle bending direction, while the material thickness needs to be minimized to reduce multiple scattering, which is essential for low momentum resolution. The material budget should be below $1\%\text{X}_0$ per tracker layer.

In Z-pole mode, the high luminosity with a 23-nanosecond gap between successive bunch crossings necessitates that the detector can distinguish between adjacent bunch crossings, requiring a timing resolution better than a few nanoseconds. Additionally, effective particle identification (PID) is crucial for distinguishing between various particle types, supporting the CEPC's flavor physics studies and the measurement of jet substructure. This can be achieved through time-of-flight (TOF) measurements with a time precision of $\sim$50 ps in the OTK, enabling robust PID for K/π/p seperation below a few GeV/c momentum range.

Responsible person: Qi YAN, Gang LI, ...

Plan and Timeline

- Every Friday, we have a regular progress discussion, followed by the assignment of tasks for the next week. This cycle will repeat for about three weeks.

- Afterwards, we will conduct a comprehensive review, including reading, discussion, and revision.