

AGORA Detector and Physics Plenary

Meeting (30 September 2026)

Main purpose

- To assess the impact of FCC-ee requirements — in particular the $\sim 6\times$ higher data volume per bunch crossing and the $\sim 10\times$ stronger beam backgrounds of high-luminosity Z-pole running (the FCC-ee starting phase) — on the AGORA detector concept originally designed for CEPC, keeping the detector concept (the design is frozen) and adapting the specifications.
- To clarify open questions (event rates, luminosities, MDI parameters, occupancy definitions) and set up a plan towards a Letter of Intent / Expression of Interest for FCC-ee — preparation starting around mid-2027 (vertex EoI submission targeted for early 2028).
- To coordinate with FCC-ee MDI, the accelerator team and the other detector concepts (CLD, IDEA, ALPHA, ILD), and to prepare for the follow-up detailed meetings (~ 1 month) and the Shanghai workshop.

Project status

Event rates and DAQ (Fei Li)

- Current phase: Baseline comparison of the frozen CEPC Ref-TDR (AGORA) TDAQ against the FCC-ee Z pole, on the same 40 MHz bunch-crossing machine (39.4 MHz high-lumi Z vs 40 MHz / 25 ns).
- Progress highlights: Physics rate 75 kHz (CEPC) vs ~ 100 kHz (FCC-ee) — same order; the real gap is beam background: FCC-ee ~ 100 kHz, IPC-dominated (the CEPC TDR assumed $<1\%$ of the bunch-crossing rate); content per crossing ≈ 40 KB vs ≈ 250 KB ($\sim 6\times$); pre-trigger raw rate 1.6 TB/s (scaled by $\times 7$ luminosity, not independently simulated) vs ~ 10 TB/s (FCC-ee early estimates span 1.3–14 TB/s); TPC is the largest raw-data contributor ($\sim 91\%$); storage: HLT 150 kHz $\rightarrow$ 11.9 GB/s vs FCC-ee all-signal ≈ 260 GB/s (1.7 EB/yr; ~ 19 EB/yr with $10\times$ MC).

- Risks: FCC-ee's own background estimates span a factor ~ 10 (1.3 / 11 / 14 TB/s); occupancy definitions differ between the two communities (a factor of 6 with no traceable origin); luminosity numbers to be reconciled (FCC-ee Z-pole peak luminosity ~ 140 vs AGORA 192, in units of $10^{34} \text{ cm}^{-2}\text{s}^{-1}$ per IP).
- Decisions: With the detector design frozen, TDAQ's job is not to change the design but to compute what can be carried under FCC-ee conditions; all rate and luminosity numbers to be double-checked by everyone and re-discussed (target ~ 2 weeks); FCC-ee has left three trigger options (streaming readout, minimal hardware trigger, classic trigger scheme) open — “too early” to decide.
- Next steps: Run a genuine high-luminosity-Z TDAQ study on the FCC-ee background basis (pre-trigger rate, content per crossing, per-stage bandwidth, L1/HLT throughput, buffering depth) and replace the scaled table entry with a simulated one; fill in the FCC-ee TDAQ questionnaire as readings of the frozen design; obtain from FCC-ee the background bands with uncertainty, the source decomposition (incoherent pairs, synchrotron radiation, top-up) and the occupancy definition/threshold; share updated numbers as soon as available.

Vertex detector (Zhijun Liang)

- Current phase: Translation of the Ref-TDR vertex (AGORA baseline) into FCC-ee specifications; concept unchanged — bent, wafer-scale stitched MAPS, long barrel covering $|\cos \theta| \leq 0.99$, air-cooled.
- Progress highlights: The FCC-ee central beam pipe (AlBeMet, rout 11.7 mm, 0.68% X0) exceeds the layer-1 radius of 11.06 mm $\rightarrow$ L1 must move out; proposed $r_{\min} \geq \sim 13$ mm (IDEA: 13.7 mm) with L2–L4 re-optimized; hit-rate capability to rise from ~ 40 to ≥ 150 – 200 MHz/cm^2 including margin (published FCC-ee L1 estimates span 70 – 370 MHz/cm^2) while staying ≤ 40 – 50 mW/cm^2 with air cooling; pixel $25 \times 25 \mu\text{m}^2 \rightarrow 16 \times 30 \mu\text{m}^2$ ($\sigma\phi < 3 \mu\text{m}$, already in the HC90L first-run plan); $\sigma_t = 100 \text{ ns}$ keeps occupancy $< 10^{-3}/\text{pixel}$; radiation $\sim 10 \text{ Mrad/yr}$ and $\sim 10^{14} \text{ neq/cm}^2$ over the Z run; triggerless inner layers reach O(Tbps) — to be coordinated with electronics/TDAQ.
- Risks: $\times 10$ hit rate at unchanged power under air cooling — no MAPS prototype yet meets all FCC-ee vertex specifications at once; background uncertainty (70 – 370 MHz/cm^2) requires AGORA-specific simulation with FCC-ee MDI (2 T) before freezing the specifications; the 2027 HC90L (90 nm) first

engineering run is the only sensor iteration before the EoI — FCC-ee targets must be built in now.

- Decisions: Change the specifications, not the concept; settle r_{min} with FCC-ee MDI proactively and now (do not wait until the end of next year); the $16 \times 30 \mu m^2$ pixel-size change and its efficiency justification to be presented in detail at a future meeting.
- Next steps: AGORA-FCC background simulation (FCC-ee MDI, 2 T, 20–25 ns bunch spacing) and agreement on r_{min} with FCC-ee MDI by Dec 2026; freeze the FCC-ee vertex specification table in Q4 2026; design review ~Mar 2027; HC90L first tape-out mid-2027; EoI vertex outline H2 2027; EoI submission early 2028.

Inner tracker (Yiming Li)

- Current phase: Assessment of the Ref-TDR design against FCC-ee tracking/vertexing requirements (M. Dam, arXiv:2505.06781).
- Progress highlights: FCC-ee requires $\delta(pT)/pT \approx 10^{-3}$ at ~ 50 GeV, few- μm hit resolution (more relaxed for the inner tracker), minimal material, 25 ns bunch spacing (CEPC designed for 23 ns) and a 200 kHz event rate at the Z pole; the Ref-TDR momentum resolution of $\sim 10^{-3}$ at high momentum is roughly OK; barrel material-budget goal 0.68% X_0 ; the CMOS sensors provide 3–5 ns timing and up to ~ 80 MHz/cm² rate capability — bunch spacing and hit rate are not an issue.
- Risks: The 0.68% X_0 budget has never been validated in real hardware (ALPHA, a very light all-silicon concept, is the benchmark); realizing the full rate capability has power-consumption and readout implications (data formats, on-chip processing, number of aggregation chips and optical links) that must be estimated; the geometry may shift if the TPC inner radius changes.
- Decisions: No showstopper and no substantial immediate change; keep the design and validate/optimize it through dedicated simulation (physics + FCC-ee beam backgrounds) and prototyping.
- Next steps: Module prototyping; input from common electronics (CERN-compatible components? FEDI/FEDA/OAT size/material); mechanics prototyping and cooling study (water cooling in Ref-TDR, bi-phase CO₂ as an option); explore serial powering and wireless transmission to reduce cabling; re-run the tracking performance with FCC-ee backgrounds.

Outer tracker hit rates (Qi Yan)

- Current phase: Check of the OTK readout-chain capability against FCC-ee hit rates.
- Progress highlights: Barrel — 16 FEDA chips on 8 FE boards per ladder aggregated to one FEDI chip via 346.7 Mbps e-links; ≤ 43.3 Mbps per LATRIC ASIC supports 8×10^4 Hz/cm², $\sim 24 \times$ the estimated peak background hit rate at the Z pole (3.32×10^3 Hz/cm²); endcap — 10–14 FEDA chips per FEDI at 693.3 Mbps, ≤ 86.7 Mbps per ASIC supports 2.1×10^5 Hz/cm², $\sim 11 \times$ the endcap background under high-luminosity Z (19.01×10^3 Hz/cm²).
- Risks: None identified at the concept level; the comparison still relies on estimated (not yet AGORA-specific) FCC-ee backgrounds.
- Decisions: No fundamental change needed for FCC-ee.
- Next steps: State the margin explicitly in terms of FCC-ee background numbers as soon as they become available.

TPC and PID (Mingyi Dong)

- Current phase: Feasibility of the TPC at high-luminosity Z — the largest conceptual risk for AGORA at FCC-ee.
- Progress highlights: Key studies — distortion (beam background and ion back-flow); IBF suppression with double-mesh Micromegas (simulation done, prototype test planned) and graphene; reconstruction in CEPCSW (track finding/fitting, dN/dx , calibration) using ITK/OTK information and laser calibration; readout-module validation (ASIC–Micromegas coupling, layout, beam tests); pad-size optimization almost done. AGORA TPC: 0.5×0.5 mm² readout, ~ 100 μ m point resolution, $dN/dx \sim 3\%$ $\rightarrow 3\sigma$ K/ π up to ~ 20 GeV.
- Risks: A large part of the FCC-ee community doubts TPC feasibility at high rates — AGORA must demonstrate that TPC + silicon outperforms full-silicon concepts; the FCC-ee PID target is 3σ K/ π up to 30–40 GeV vs the CEPC 20 GeV; the Cherenkov detector (and the drift-chamber option) has no specific FCC-ee consideration yet; dimension changes (larger inner radius, shorter length) require updated simulations.
- Decisions: A plan with milestones and dates is required (next talk in ~ 1 month) showing how AGORA will decide what to propose by mid-2027; AGORA must be demonstrably among the top concepts to win the support of the FCC-ee community.
- Next steps: Move the TPC studies into the FCCSW framework; evaluate the beam-background impact on tracking efficiency, momentum resolution and

PID; prototype and test the IBF-suppression solutions; define the milestone schedule.

Calorimeters (Yuekun Heng)

- Current phase: Glass-scintillator (GS) ECAL + HCAL redesign; boundary dimensions temporarily retained.
- Progress highlights: ECAL thickness 30 → 44 cm but 24 → 20 X0 (GS X0 = 1.59 cm vs BGO 1.12 cm); HCAL 1315 → 1175 mm, 4.5–5.0 λ I (70–90% sampling); total $\approx 20 X0 + \sim 5 \lambda I \approx 6 \lambda I$; ECAL cells $2 \times 2 \times 2 \text{ cm}^3$ (16 layers), HCAL cells $4 \times 4 \times 4 \text{ cm}^3$; ECAL channel count $8.5 \times \text{Ref-TDR}$, so the occupancy stays similar when the beam-induced backgrounds rise $\times 10$ from low- to high-lumi Z; the Ref-TDR per-channel max rate of 230 kHz (ECAL) / 50 kHz (HCAL) is the pile-up limit; dynamic range defined (min $\sim 0.1 \text{ MIP}$, LSB $\sim 0.03 \text{ MIP}$, ENC $\sim 0.01 \text{ MIP}$).
- Risks: Reduced HCAL depth ($\sim 5 \lambda I$) — the FCC-ee baseline includes ttbar, so its adequacy (no leakage) must be demonstrated; the longer glass decay time vs BGO → pile-up to be re-evaluated together with the readout electronics; the calorimeter depth/interaction length is to be compared with the other FCC-ee concepts (ILD: 48 layers $\approx 6 \lambda I$, from the 500 GeV ILC era).
- Decisions: For the 2 T FCC-ee field the Z pole moves to the front seat — finer granularity is required and the granularity optimization must target the Z pole; produce a depth/ λI comparison table across concepts.
- Next steps: Integrated ECAL+HCAL design; update the requirements on glass, SiPM, front-end electronics, mechanics and cooling; finish the cell design and the granularity optimization this year; advance the software (simulation, digitization, reconstruction, compensation).

Common electronics (Wei Wei)

- Current phase: Compatibility check of the common-electronics concept (triggerless readout, FEDA–FEDI–OAT data interface, PAL power modules) with FCC-ee.
- Progress highlights: No conflict at the concept level — triggerless readout is the future trend; the FEDA–FEDI–OAT series originates from lpGBT/GBTx and is protocol-compatible; FEDI already supports both the 40 and 43.3 MHz clocks (only the current lpGBT does not support 43.3 MHz — updatable); $\sim 40/44 \text{ Gbps}$ per module transmission capability should suffice; mechanical room is reserved for the full 4TX capability of the data interface and optical modules; the PAL power module originates from bPol — its issue is technical and already solved.

- Risks: At high-lumi Z, some detectors' background rates may exceed the triggerless capability — the vertex needs a partial/fast-trigger scheme (fast trigger to the vertex only, other sub-detectors unchanged); worst case for ECAL: pile-up so serious that single-hit discrimination fails and waveform processing is needed; if the TPC proves unworkable, drift-chamber readout must be considered; everything depends on real MDI background input.
- Decisions: The electronics run at 40 MHz (FCC-ee baseline) without redesign — confirmed compatible; the 43.3 MHz clock issue is a technical problem only.
- Next steps: Obtain the high-lumi-Z MDI background rates together with DAQ, vertex and TPC; propose the vertex partial-trigger/compression scheme; present a plan for running at high-lumi Z within ~1 month.

Magnet (Feipeng Ning)

- Current phase: Status check (no slides presented).
- Progress highlights: The solenoid baseline moved from 2 T (previous CEPC design) to 3 T (present AGORA designs); no change required from the FCC-ee integration itself (the FCC-ee MDI operates at 2 T).
- Risks: The FCC-ee MDI anti-solenoid design is still pending; the combined solenoid + anti-solenoid field map is needed.
- Next steps: Follow the FCC-ee MDI (anti-)solenoid design and provide combined-field input.

Mechanics, cooling and services (Xiaoyan Ma)

- Current phase: Initial re-assessment of the overall mechanical design for FCC-ee; no detailed data or adjustment plan yet.
- Progress highlights: The MDI interface, geometric constraints, beam parameters and field scheme differ from CEPC → re-define the global mechanical envelope, re-allocate dimensions among sub-detectors, re-design connections and support; the central beam pipe and VTX require joint design across background, cooling and support (not a simple rescale); civil-engineering constraints differ (cavern layout, hall crane capacity, maintenance access) — installation/assembly steps (e.g. pre-installation point → collision point) may be infeasible; cooling: local heat loads and electronics adaptations change the requirements, and some sub-detector cooling is already being re-simulated/re-designed; the FCC-ee opening scenario drives the yoke design and the cable/cooling-pipe routing and must

be fixed jointly with FCC MDI, the cavern and the accelerator maintenance scheme; the CEPC auxiliary-hall layout is not compatible with FCC.

- Risks: The current installation strategy may not fit the FCC-ee cavern and civil engineering.
- Decisions: Engage proactively with FCC-ee MDI and civil engineering — the FCC-ee detector leadership encourages AGORA participation in the MDI meetings (Indico page available); FCC-ee will have two big and two small caverns, and AGORA likely fits in a small cavern — this input should be provided proactively.
- Next steps: Attend the FCC-ee MDI and civil-engineering meetings and gather the constraints; replan the overall dimensions, support, cooling and cabling; present an adjusted mechanical/cooling plan before the Shanghai workshop (~1 month).

Physics and performance (Mingshui Chen)

- Current phase: Re-baselining the physics programme and detector performance for FCC-ee.
- Progress highlights: Programme — FCC-ee (4 IP): 205 ab^{-1} at the Z pole (6×10^{12} Z), 10.8 ab^{-1} ZH, 19.2 ab^{-1} WW, 3.1 ab^{-1} ttbar, vs CEPC upgraded (2 IP): $100 / 21.6 / 6.9 / 1.0 \text{ ab}^{-1}$; peak Z luminosity per IP (140 vs 192) and bunch spacing (~25 vs 23.1 ns) are comparable — the difference is statistics, not physics reach; timing and rate requirements largely transfer. Precision — comparable across the board in full simulation (mH ± 4 MeV, mW ~ 0.5 MeV, mtop 14/32 MeV vs FCC-ee 4.2 MeV); already at the FCC-ee target: vertex resolution/material, ECAL resolution, HCAL BMR (3.87% demonstrated), luminosity precision. Requirements — FCC-ee is stricter on: tracking $\sigma/p < 0.1\%$ (aggressive) / $< 0.2\%$ (conservative) vs AGORA $< 0.3\%$ (barrel; the FCC-ee number is Delphes-based/idealized and barrel-only — 0.1% is unattainable in the endcap); PID 3σ K/ π up to 30–40 GeV vs 20 GeV; low-pT muons ($p < 1$ GeV, $\sim 400 \mu\text{m}$, calorimeter-based muon ID) vs AGORA ~ 1 cm for $p > 4.5$ GeV/c; acceptance 100 mrad vs $|\cos \theta| \leq 0.99$ ($\sim 8^\circ$) — the FCC-ee forward acceptance serves $\gamma\gamma$ physics (though the small angle complicates the MDI and costs luminosity — the reason should be understood).
- Risks: Rates, occupancy and radiation must be recomputed with FCC-ee backgrounds (vertex IPC $\sim 70 \text{ MHz/cm}^2$ in the innermost layer; muon system $\sim 14 \text{ Hz/cm}^2$ endcap for CEPC vs $\sim 100 \text{ Hz/cm}^2$ barrel for FCC-ee; TID $\sim$ tens of

kGy/yr, fluence $\sim \text{few} \times 10^{13}$ neq/cm²/yr; ~ 2 mm tungsten shielding at the final focus); the software is not yet integrated with FCC-ee.

- Decisions: Repeat the benchmark and object-performance studies under FCC-ee conditions; AGORA does not need to be best on everything but must have no weak point and aim to be among the top concepts; there should be one AGORA inside the FCC-ee software stack, not a second version.
- Next steps: Bring the glass calorimeter and the endcap RICH into the full simulation; adopt Key4HEP/EDM4HEP (AGORASW $\rightarrow$ FCCSW); obtain FCC-ee MDI/background samples (Key4HEP) and overlay them on AGORA; re-derive rates, occupancies and radiation; re-run the key benchmarks plus additional ones per the PED recommendations; targeted R&D on tracking σ_p/p , PID reach and calorimeter-based low-pT muon ID.

Other topics

- FCC-ee machine parameters: 40 MHz bunch crossing, ~ 25 ns bunch spacing, 4 IPs (lower per-IP peak luminosity, lattice design), smaller ring $\rightarrow$ more synchrotron radiation $\rightarrow$ lower Z-pole luminosity (140 vs 192, in units of 10^{34} cm⁻²s⁻¹ per IP) — all luminosity/rate numbers to be double-checked by everyone and re-discussed in ~ 2 weeks.
- Comparison with the other FCC-ee concepts (CLD, IDEA, ALPHA, ILD): CLD and ALPHA claim 3σ K/ π PID up to 40 GeV (to be verified — the GridPix result is chip-only, without diffusion); ALPHA is a very light all-silicon concept and sets the material-budget benchmark; ILD remains TPC-based like AGORA. AGORA must be competitive and demonstrate clear advantages to convince the FCC-ee community (e.g. TPC + silicon vs full silicon).
- The FCC-ee baseline includes $t\bar{t}$ — AGORA must also demonstrate its performance for $t\bar{t}$ (calorimeter leakage is the main concern).
- The muon-detector talk (Xiaolong Wang) was postponed (speaker absent); the muon requirements (low-pT muon ID) were discussed under the physics report and are followed up at the muon meeting.
- Follow-up meetings: one or two detailed meetings within about a month, before the Shanghai workshop; a re-discussion of the rate/luminosity numbers is targeted in ~ 2 weeks.

Action items

Fei Li (TDAQ)

- Run a genuine high-luminosity-Z TDAQ study on the FCC-ee background basis (~ 100 kHz, IPC-dominated): pre-trigger raw rate, content per crossing, per-stage bandwidth, L1/HLT throughput and buffering depth; replace the scaled table entry with a simulated one.
- Fill in the FCC-ee TDAQ questionnaire as readings of the frozen design (processable rates per sub-detector, acceptable external triggers, readout granularity, occupancy definitions, TDAQ share of the material budget).
- Request from FCC-ee the background bands with uncertainty, the source decomposition (incoherent pairs, synchrotron radiation, top-up) and the occupancy definition/threshold; share the updated numbers as soon as available (re-discussion in ~ 2 weeks).

Vertex detector (Zhijun Liang)

- Run the AGORA-FCC background simulation (FCC-ee MDI, 2 T, 20–25 ns bunch spacing) and agree on $r_{\min}$ ($\geq \sim 13$ mm) with FCC-ee MDI by Dec 2026; freeze the FCC-ee vertex specification table in Q4 2026.
- Put the FCC-ee rate/bandwidth/power targets into the HC90L first engineering-run design now (design review $\sim$ Mar 2027, tape-out mid-2027).
- Present a detailed justification of the $16 \times 30 \mu\text{m}^2$ pixel-size choice and its efficiency at a future meeting.
- Coordinate with electronics/TDAQ on the O(Tbps) triggerless data volume of the inner layers.

Inner tracker (Yiming Li)

- Build detailed mechanical/electronics models to validate the 0.68% X0 barrel material budget.
- Study bi-phase CO_2 cooling (vs water) and the options from common electronics (CERN-compatible components, FEDI/FEDA/OAT size/material); explore serial powering and wireless transmission.
- Re-run the tracking performance with FCC-ee backgrounds; estimate the power/readout implications of the ~ 80 MHz/cm² sensor rate capability.

Outer tracker (Qi Yan)

- Document the readout margins explicitly (barrel $\sim 24\times$, endcap $\sim 11\times$) in terms of FCC-ee background numbers once available.
- **TPC and PID (Mingyi Dong)**

- Prepare a plan with milestones and dates (next talk in ~1 month) demonstrating TPC feasibility at high-lumi Z and what AGORA will propose by mid-2027.
- Move the distortion/IBF/reconstruction studies into the FCCSW framework; evaluate the beam-background impact on efficiency, momentum resolution and PID; update the simulations for the dimension scenarios (larger inner radius, shorter length).
- Prototype and test the double-mesh Micromegas and graphene IBF-suppression solutions.
- Study the PID reach (TPC and Cherenkov) against the FCC-ee 30–40 GeV target and the other concepts.

Calorimeter (Yuekun Heng)

- Finish the ECAL/HCAL cell design and the granularity optimization this year (targeting the 2 T / Z-pole operation).
- Re-evaluate the pile-up (longer glass decay time) together with the readout electronics; verify the per-channel rates against the FCC-ee backgrounds.
- Prepare a comparison table of the calorimeter depth/interaction lengths vs the other FCC-ee concepts; address the $t\bar{t}$ leakage.

Common electronics (Wei Wei)

- Quantify the high-lumi-Z background/event rates together with DAQ, vertex and TPC (MDI input is critical).
- Propose the vertex partial-trigger/compression scheme; present the plan for running at high-lumi Z within ~1 month.
- Confirm the 40 MHz operation (done: compatible without redesign); track the lpGBT 43.3 MHz update as a technical item.

Magnet (Feipeng Ning)

- Follow the FCC-ee MDI anti-solenoid design; prepare the combined solenoid + anti-solenoid field simulations.

Mechanics/cooling/services (Xiaoyan Ma)

- Attend the FCC-ee MDI and civil-engineering meetings; gather the constraints on the caverns (two big + two small), crane capacity and maintenance access.
- Replan the overall dimensions, support structures, cooling and cabling; re-evaluate the installation/assembly steps against the FCC-ee hall.
- Present the adjusted mechanical/cooling plan before the Shanghai workshop.

Physics/software (Mingshui Chen)

- Integrate the glass calorimeter and the endcap RICH into the full simulation; adopt Key4HEP/EDM4HEP (AGORASW/FCCSW).
- Obtain the FCC-ee MDI/background samples (Key4HEP) and overlay them on AGORA; re-derive the rates, occupancies and radiation loads.
- Re-run the physics benchmarks and object-performance studies under FCC-ee conditions; add benchmarks per the PED recommendations; targeted R&D: tracking σ/p , PID reach, low- p_T muon ID.

All subsystems

- Prepare focused updates for the follow-up meeting (~1 month, before the Shanghai workshop) addressing the FCC-ee-specific challenges and the proposed solutions.
- Be ready for detailed discussions with the FCC-ee colleagues at the Shanghai workshop.