Status of crystal ECAL simulation and Plans

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CEPC Calorimeter Software Meeting

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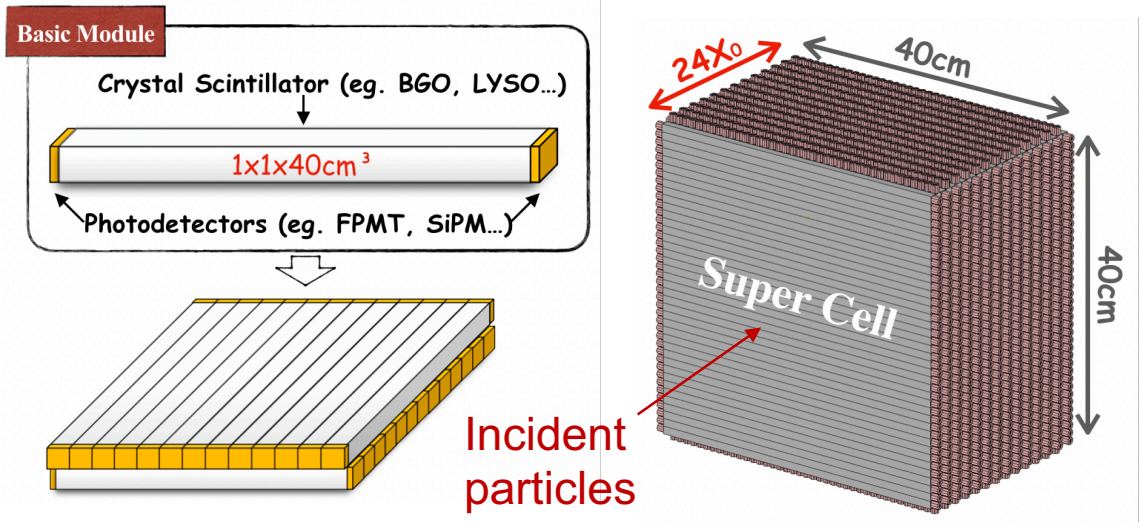
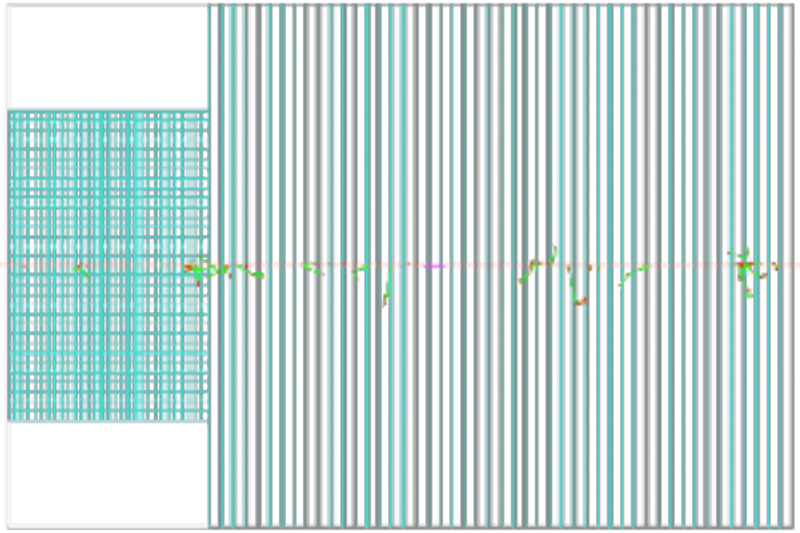
Crystal ECAL: detector layout



- Long bars: 1×40cm, double-sided readout
  - Super cell: 40×40cm
- Crossed arrangement in adjacent layers
  - Reduction of #channels
- Timing at two sides: positioning along bar
- Key issue
  - Multiplicity of incident particles (e.g. jets)
  - Separation power; confusion impact
- Tools
  - Digitisation of each long bar
    - Time stamps, #photons detected
  - Event display and reconstruction

Status: simulation software for crystal ECAL

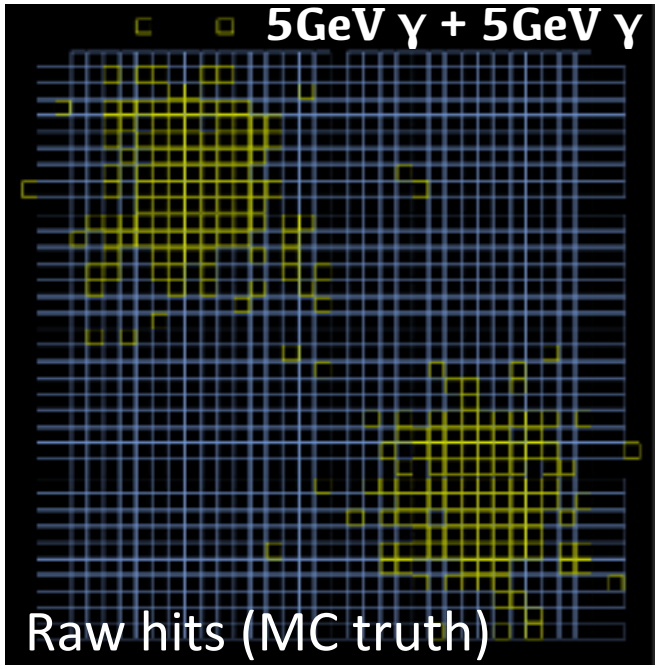
- Geant4 stand-alone simulation
  - Crystal ECAL + Scintillator-Steel HCAL
  - Simple geometry: like prototypes in beamtests
    - Basic ECAL unit: 1cm^3 crystal cubes
  - Tools developed
    - Digitizers for crystal/scintillator and SiPM readout: photo-statistics + ADC precision
    - Group every 40 crystal cubes (1cm^3) along each row as to read a long bar $(40 \times 1 \times 1\ \mathrm{cm}^3)$
  - Optimisation studies (done)
    - Longitudinal depth: energy leakage correction
    - Transverse size: separation of gamma/pion0

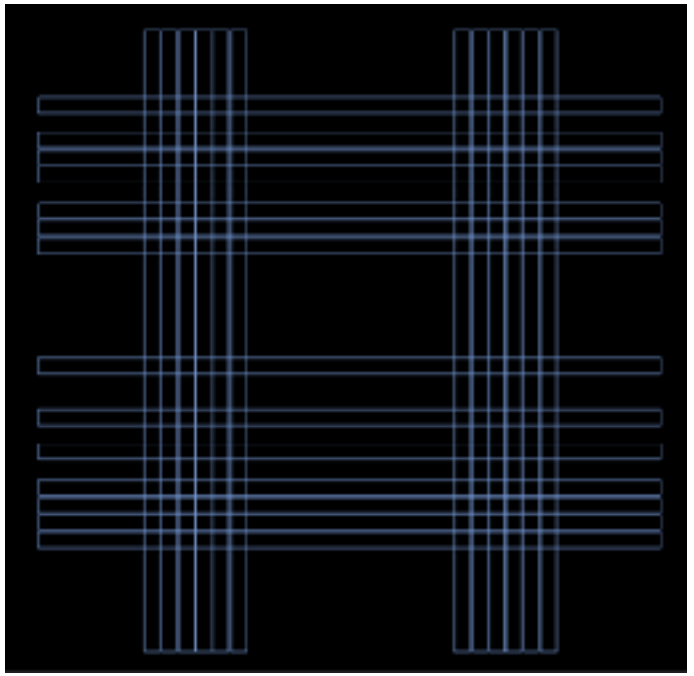


General status: simulation software for crystal ECAL

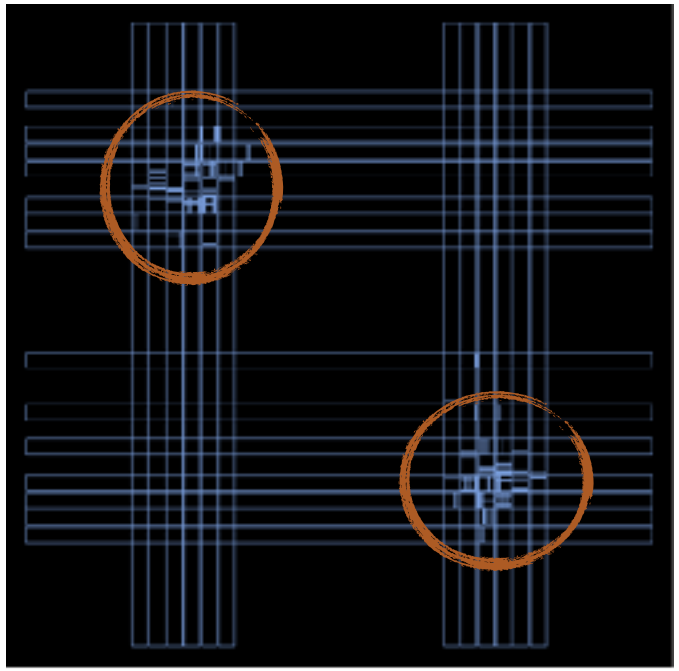
- CEPCsoft: working horse for the milestone CEPC CDR
  - Implementation of 2 designs for crystal ECAL
    - 40cm long bars
      - Reconstruction algorithm needs further development
    - 1cm^3 cubes: already implemented but with minor bugs (zero signal)?
      - Mostly compatible with PFA
  - Event display: “Druid”
    - Based on the tool which “groups” 40 cubes into a long bar
    - Visualise events with slcio files
      - First impression on shower profiles

Event display with long bars

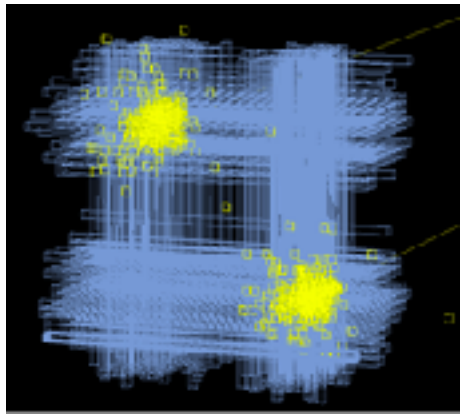




After digitisation and require Edep > 1 MIP



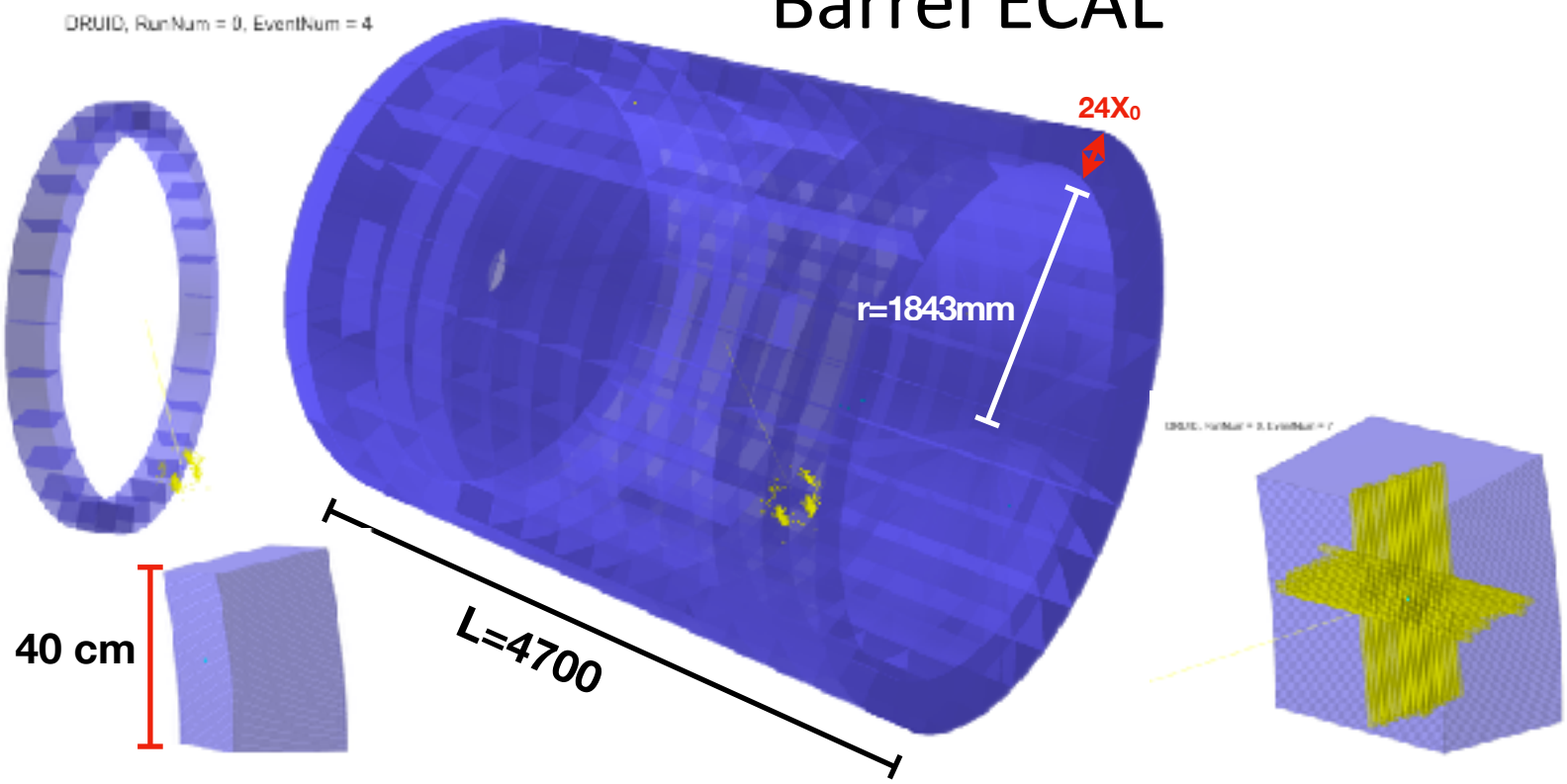
Reconstruction of hit positions using time stamps at two ends



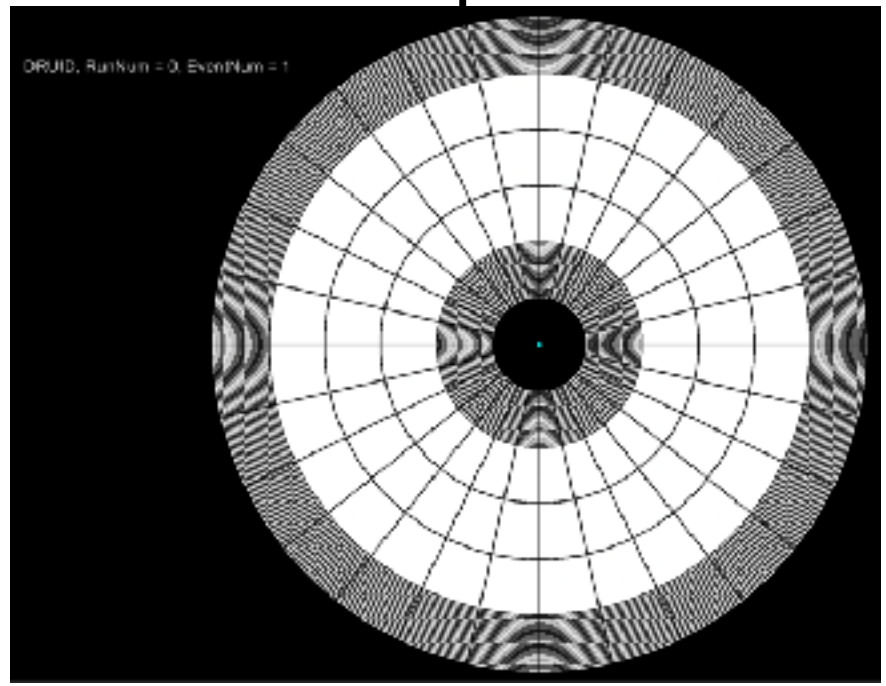
- Implementation of 1cm^3 cubes as basic detector units
- Group 40 cubes into a 40cm long bar for readout/reconstruction

Implementation in CEPC detector geometry

Barrel ECAL



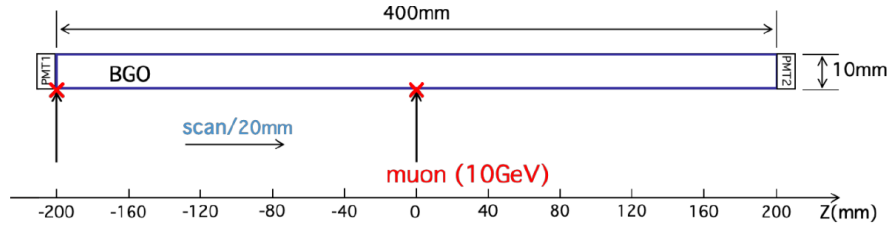
Endcap ECAL



- Super cells with 40cm long bars: implemented in the CEPCsoft
- Crossed layout in alternating layers

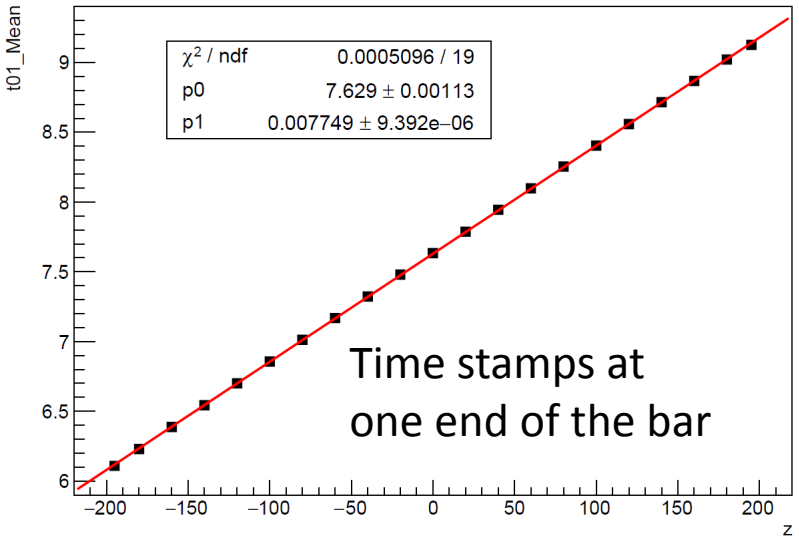
Digitisation of long crystal bars

- Focus on the time digitisation
  - 2 time stamps at each end of a crystal bar: dependent on the hit positions
  - Based on the stand-alone simulation of a single bar with complete optical processes (Yuexin)

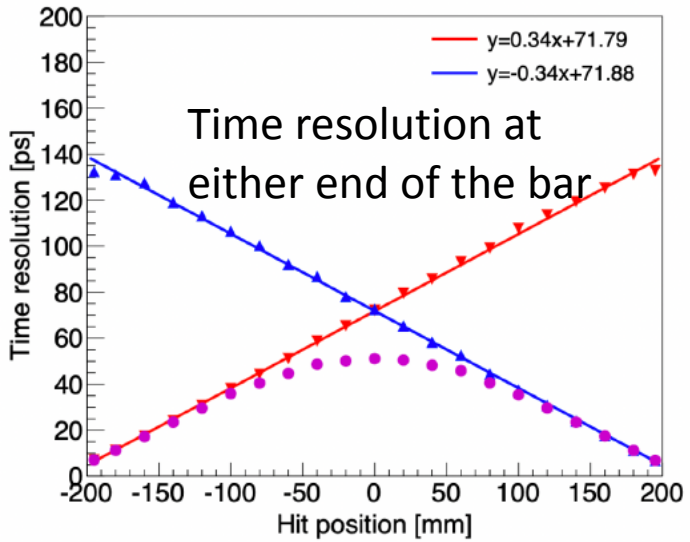


Including scintillation, light propagation, attenuation → realistic modelling of time stamps and #photons detected at both ends

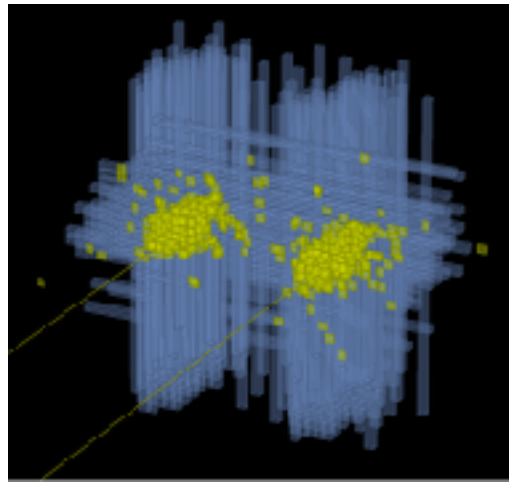
Time stamp (mean) vs hit positions



Time resolution vs hit positions



Event display of two 5GeV gammas (20cm away) hitting at the very same bar



Key issues for discussions

- Validation of the long crystal bar simulation: key for digitisation
  - Build Geant4 full simulation with optical photon process (Yong, Baohua)
    - A long bar with 2 SiPMs at both ends
    - Realistic properties of BGO (scintillation, transmission) and SiPMs
    - #Photons (detected) in time domain
    - Signal pulse from two ends of the long bar
  - Design and perform a dedicated experiment (Yong, Baohua)
    - To check the typical SiPM pulses at both two ends
      - Position dependence -> Overlap? Possibility to separate?
    - BGO bars: to be discussed with SIC, e.g. length, price (transverse 1x1cm^2)
    - Test stands with light sources and XYZ stage
    - Use cosmic muons, laser/LED, radiative sources

Key issues for discussions

- CEPCSW
  - Implementation of ECAL and HCAL
    - Geometry, digitisation tools, event display (?), …
  - Road map: for discussions
    - Option 1
      - 1st stage: implement crystal cubes (1cm^3) for ECAL (highest priority)
        - Go through the whole reconstruction chain and compare PFA performance; potentials of compensation (e/h~1) for better resolution
      - 2nd stage: use the same designs as for CEPC CDR baseline?
        - To reproduce the merit figures in CDR as the validation process
    - Option 2: go first with CDR for validation and later crystal (steady progress)

Key issues for discussions

- CEPCSW: performance studies
  - Neutral pion reconstruction
    - In single hadron showers, and in jets
  - Software compensation in PFA: energy deposition density with high granularity
    - Implemented in PandoraPFA, by CALICE teams
    - Follow-up studies? (Arbor, Pandora, APRIL)
  - Dual readout scheme of crystals
    - Similar idea as for software compensation: e/h~1
    - Detect Cherenkov light for EM cores, scintillation of EM+hadronic, determine the e/h factor for each event -> improve hadronic energy resolution
  - …

Discussions on the plans

- Implementation of ECAL and HCAL
  - Geometry, digitisation tools, event display (?), …
  - Task force: discussions for detailed arrangements
  - Time needed: estimate?
- Performance studies
  - Pion0 reconstruction, esp. within hadron shower and jets
  - PFA performance with crystals
    - With software compensation, or dual readout of crystals
  - Estimate of time and person power needed
- …