STCF fast simulation framework

Xiaoshuai Qin
Shandong University
On behalf of the fast simulation working group

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Outline

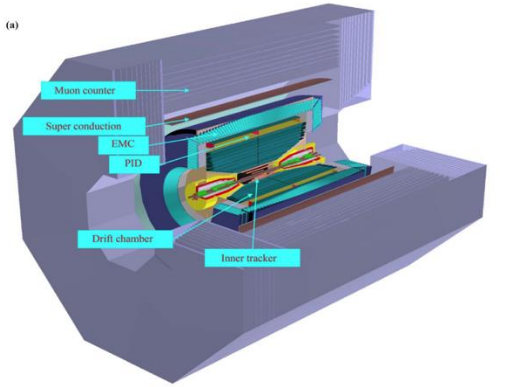
- Introduction to STCF project
- Fast simulation framework
- Performance compared with full simulation
- Porting to OSCAR and flexibility study
- Further prospects

Super Tau-Charm Facility

- Huge data statistic
  - The STCF will produce a data sample about a factor of 100 larger than that of the present τ-charm factory(BESIII)
- Variety of physics topics
  - XYZ physics, $e^+e^- \to \pi^+\pi^- J/\psi$
  - Hyperon CP symmetry, $J/\psi \to \Lambda\bar{\Lambda}$
  - Collins effect
  - Charmed hardon, K^0 system, τ physics
- Background
  - Expect to have $O(10^{11})$ level background events

  for $1ab^{-1}$ data.
- Huge CPU/storage consumption

Basic design:
Peak luminosity:
$0.5 \times 10^{35} cm^{-2} s^{-1}$ @ E_{cm}=4GeV
Luminosity per year: $1.4ab^{-1}$
Energy region: E_{cm} =2–7GeV



Fast simulation for STCF

- Goals of physics simulation
  - Feasibility studies for a dedicate physical topic (physical sensitivity, background etc.)
  - Optimize detectors (efficiency, resolution etc.)
  - Comparison to past/existing/future experiments

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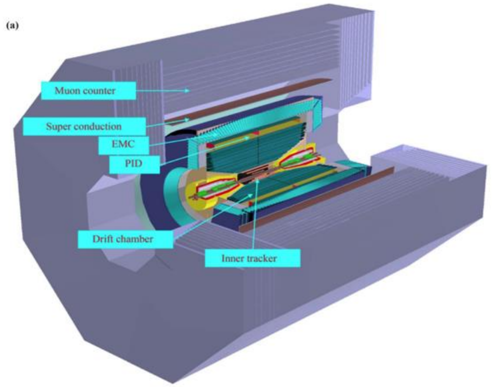

- Simulation Tools
  - Full Simulation (For signal and standard for fast simulation.)
  - **Fast Simulation (For the background study, sensitivity estimation, etc.)**

Fast simulation for STCF

- Basic ideas for Fast simulation:
  - Fast and small storage capacity (inclusive MC samples)
  - Flexible for detector responses/parameters
  - Convenient and friendly for users

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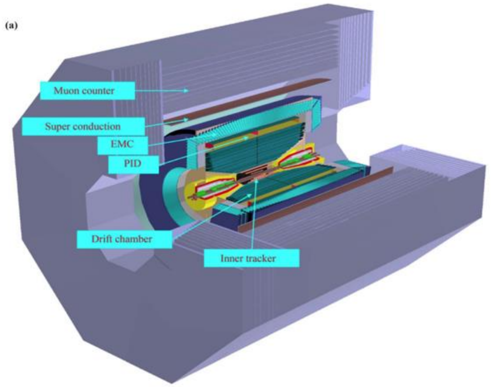


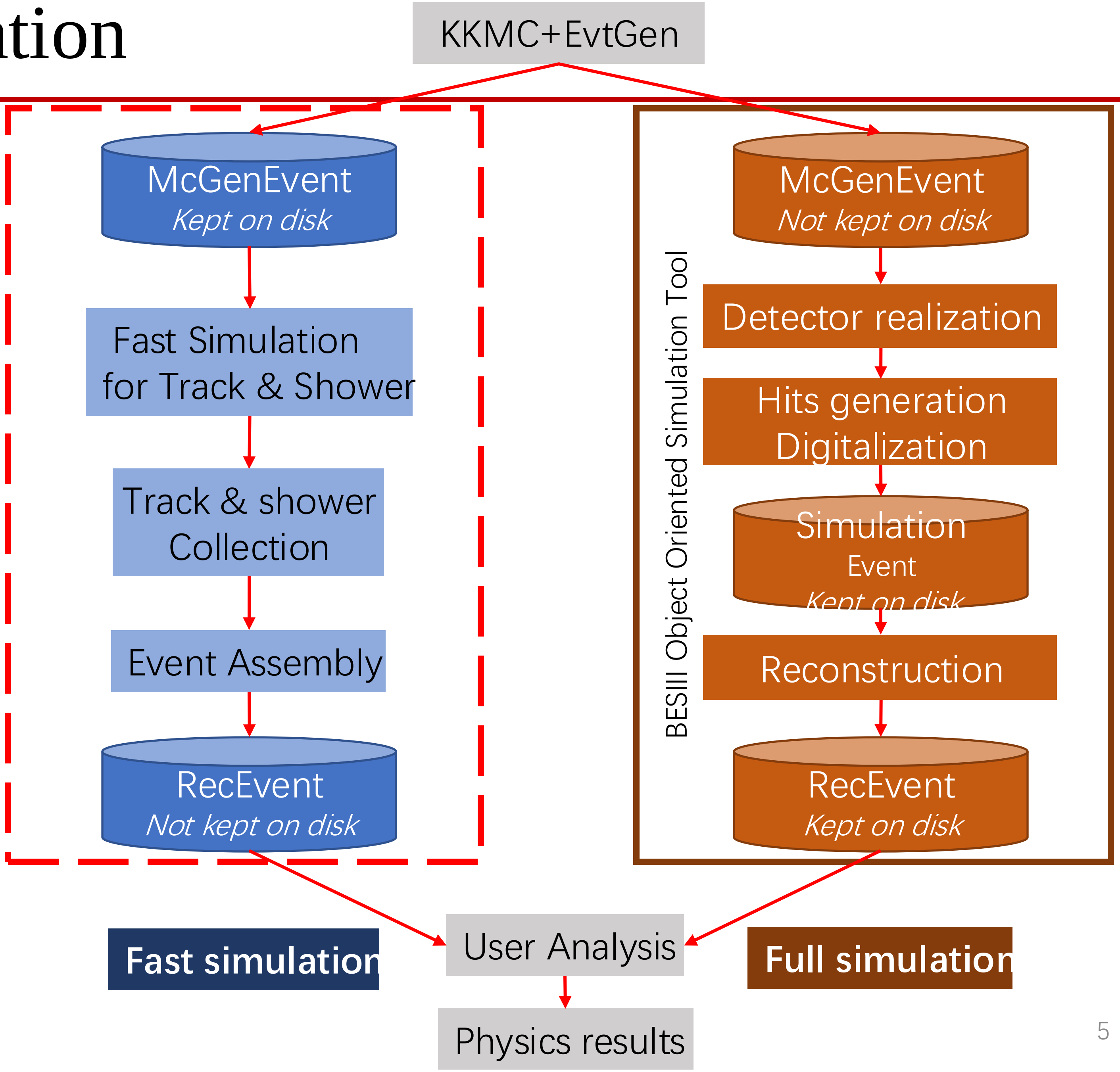
- Dedicated for pre-study of STCF project
  - Fast simulation framework developed long before the project
  - Originally make use of BESIII software system and event data management.

Scheme for Fast Simulation

- Generator: keep McGenEvent in storage

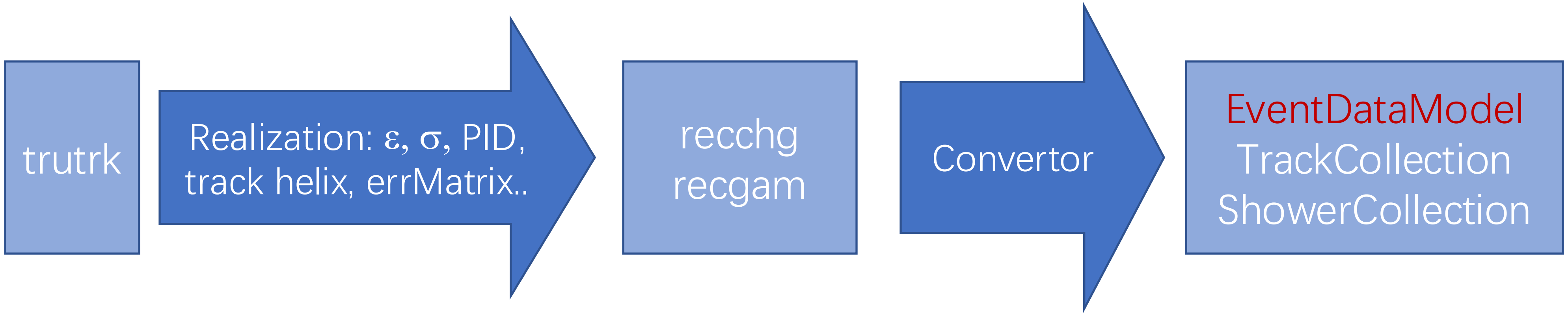
- Fast simulation for charge and neutral tracks (resolution, efficiency etc.)
- Fixed random seed for repeating analysis.
- Not kept RecEvent information on disk.
- Same analysis procedure as full reconstruction for users

- Expect to have O(10^{11}) level background events for 1ab^{-1} data.
- Apply this scheme to reduce CPU and storage consumption



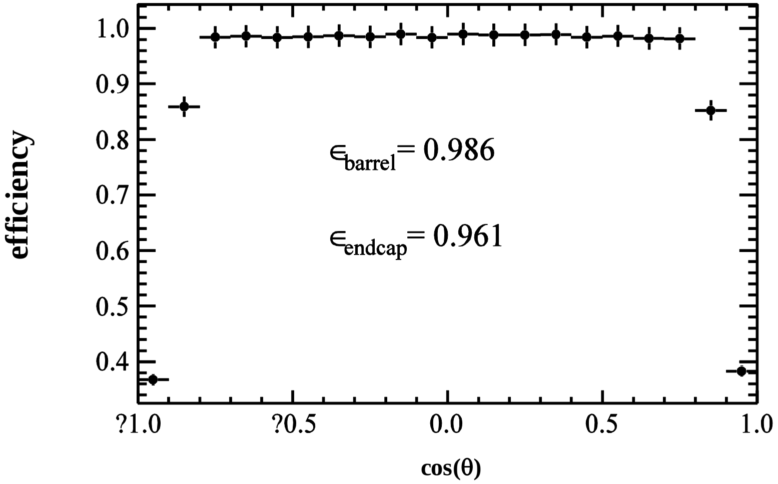
Data flow

- Truth information:
  - Particle type, momentum, vertex, decay chain
  - Data type: struct
- Information after reconstruction
  - Realization of tracking efficiency, sub-detector efficiency, momentum/energy and spatial resolution, decay vertex or generating point
  - Helix parameter and error matrix for tracks

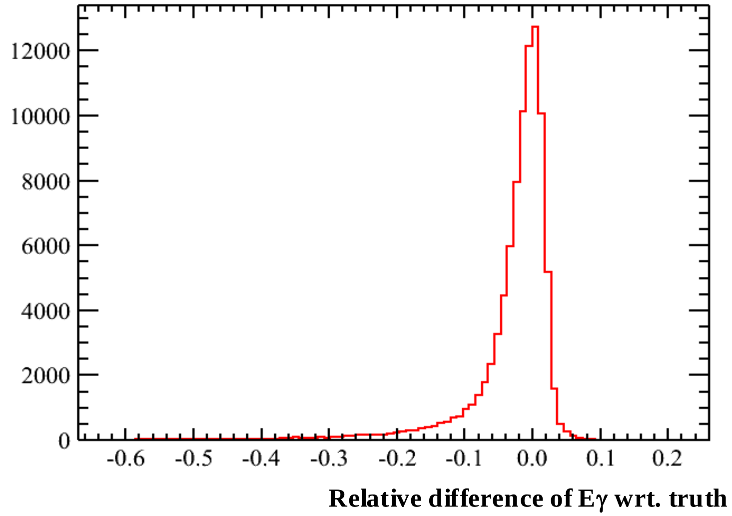


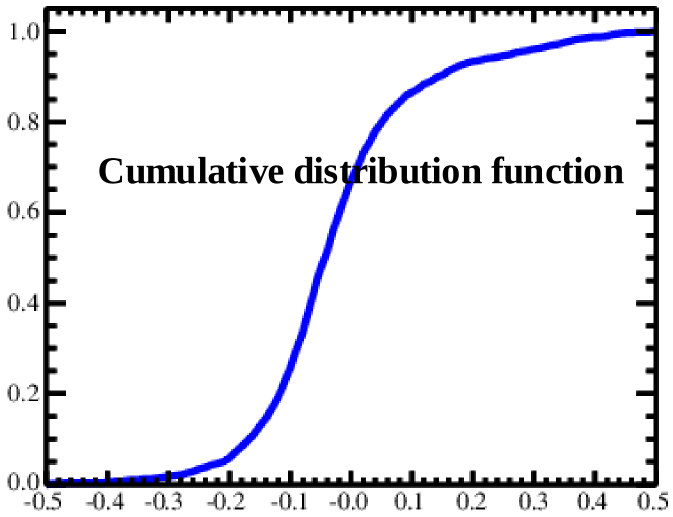
Realization for track and shower — efficiency and resolution

- Detector responses extracted from fully simulated single particle MC
- Efficiency via sampling, momentum/energy and spatial resolution via smearing



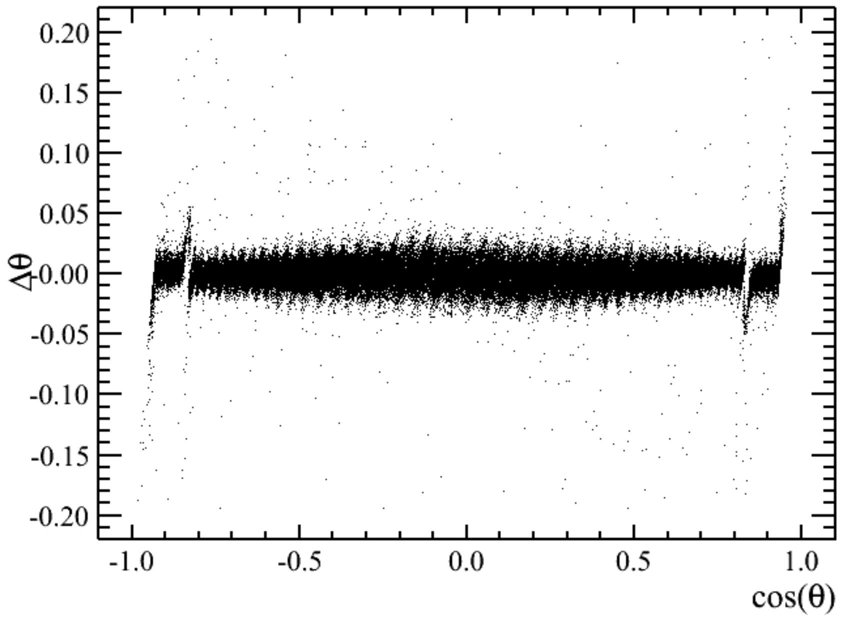
Efficiency sampling



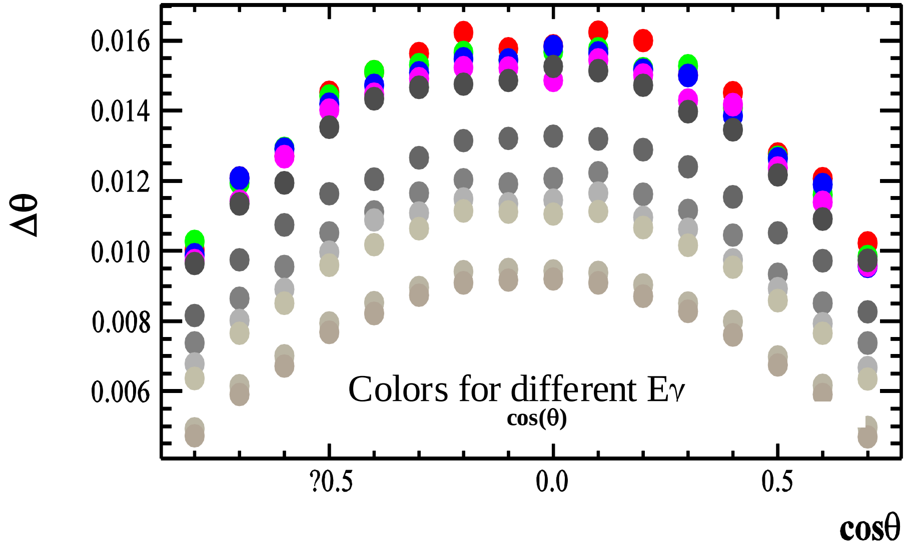


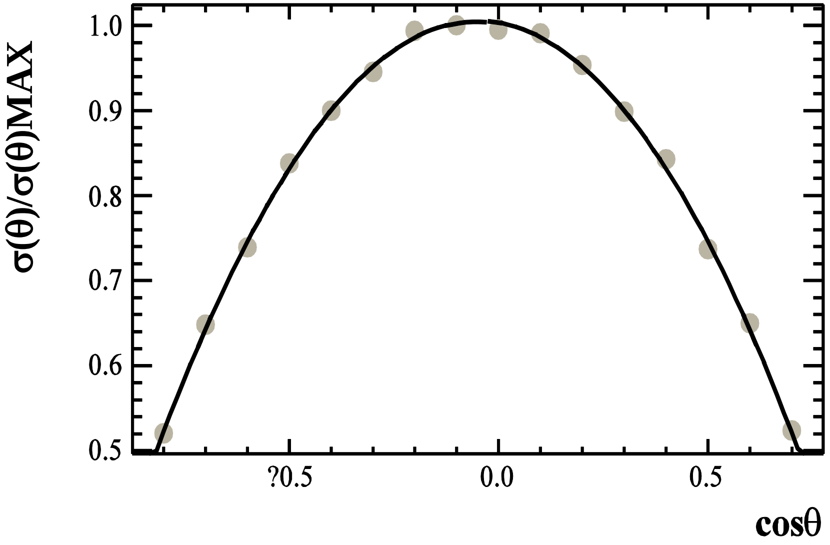
Resolution via smearing(CDF)

Realization for track and shower — spatial parameterization



- Parametrization
- Can also be realized via different CDF for momentum and polar angle bins

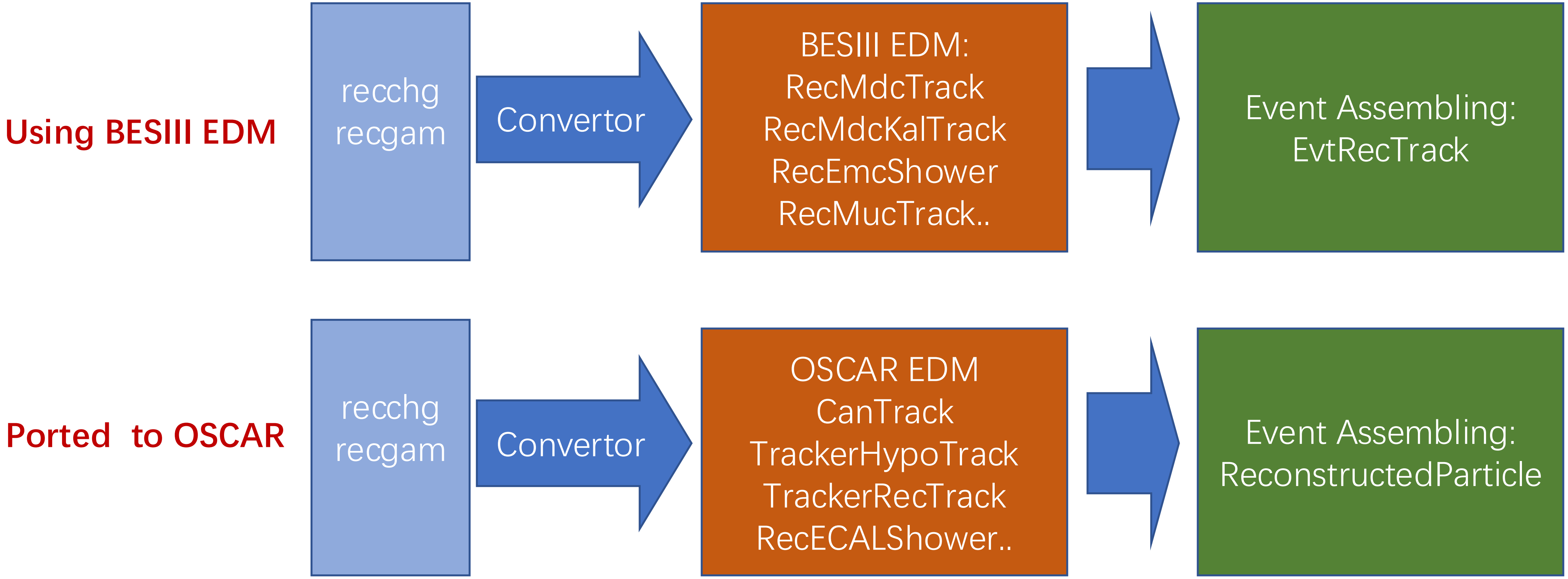




Parameterization
σ(pt, cos(θ))

Data management

- Track and shower assembling
- Event assembling



Performance: charged track

- Performance of low momentum charged tracks:
  - Check $e^+e^- \to Zc(3900)^{\pm}\pi$ with $Zc(3900)^{\pm} \to \pi^{\pm}\psi(3686)$
- Comparison with BESIII full simulation

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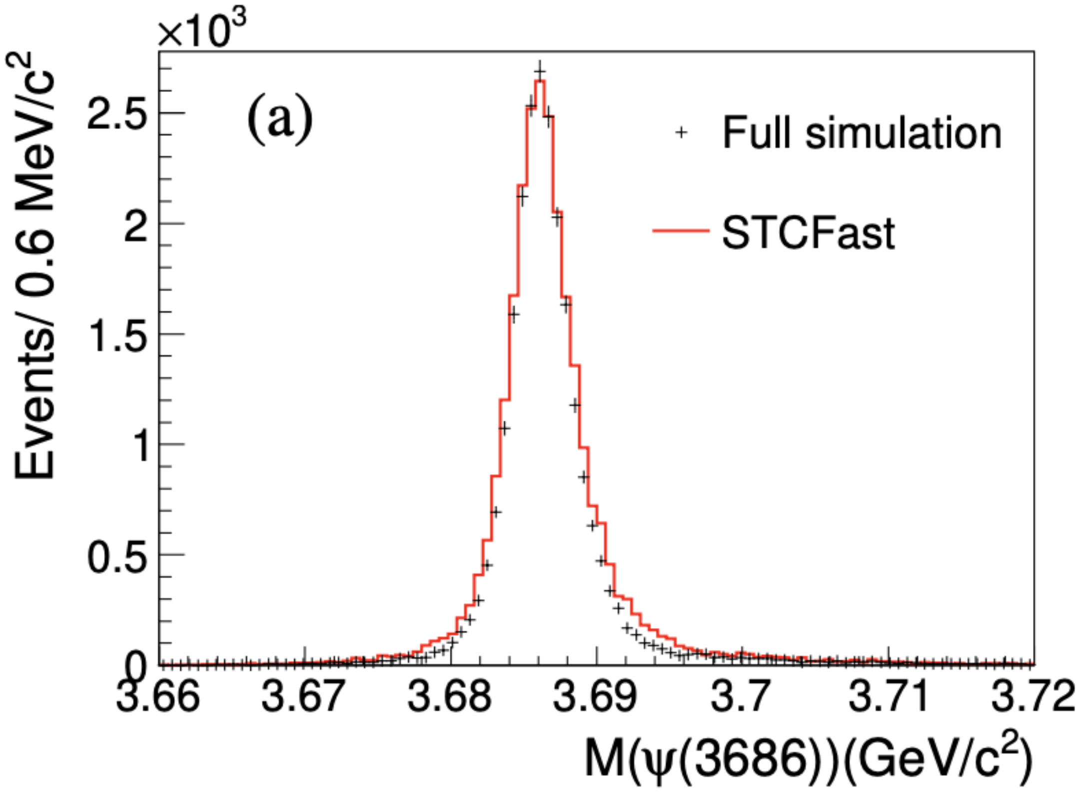
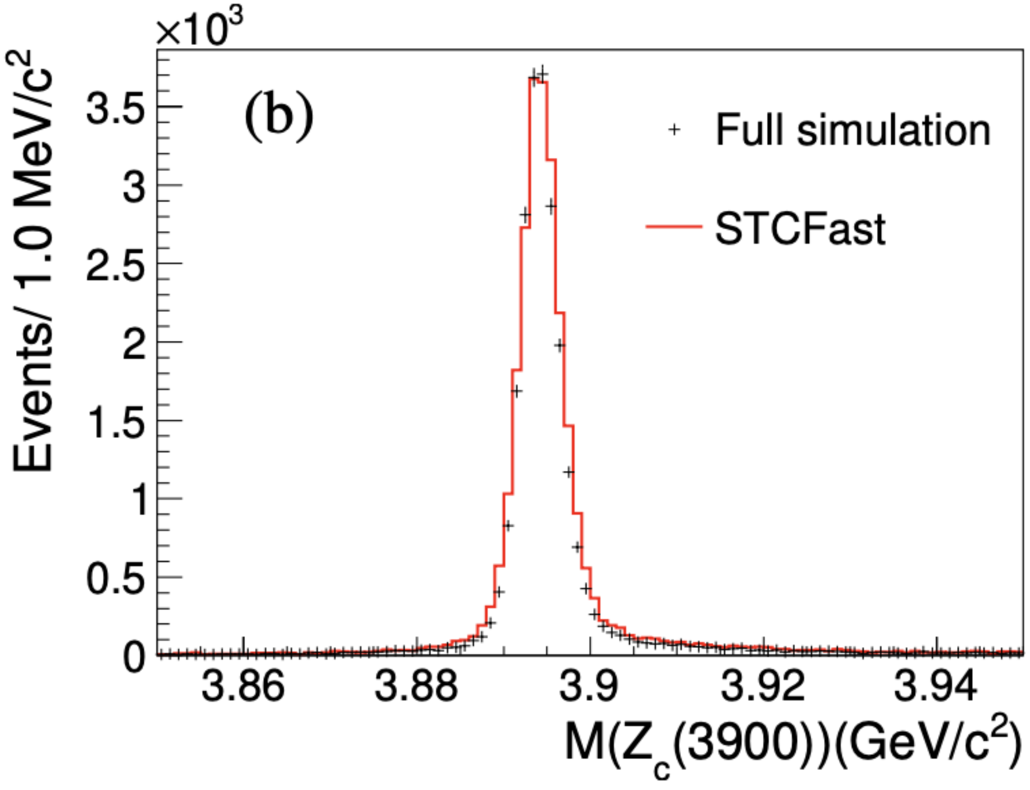
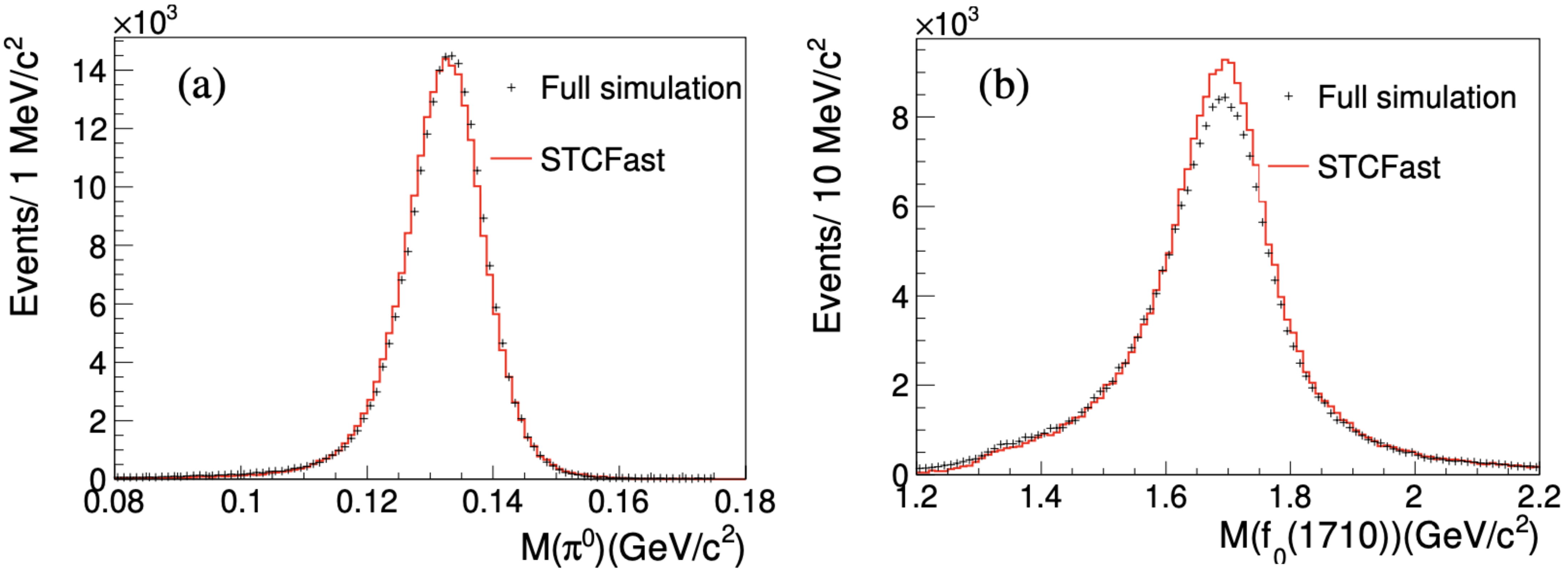




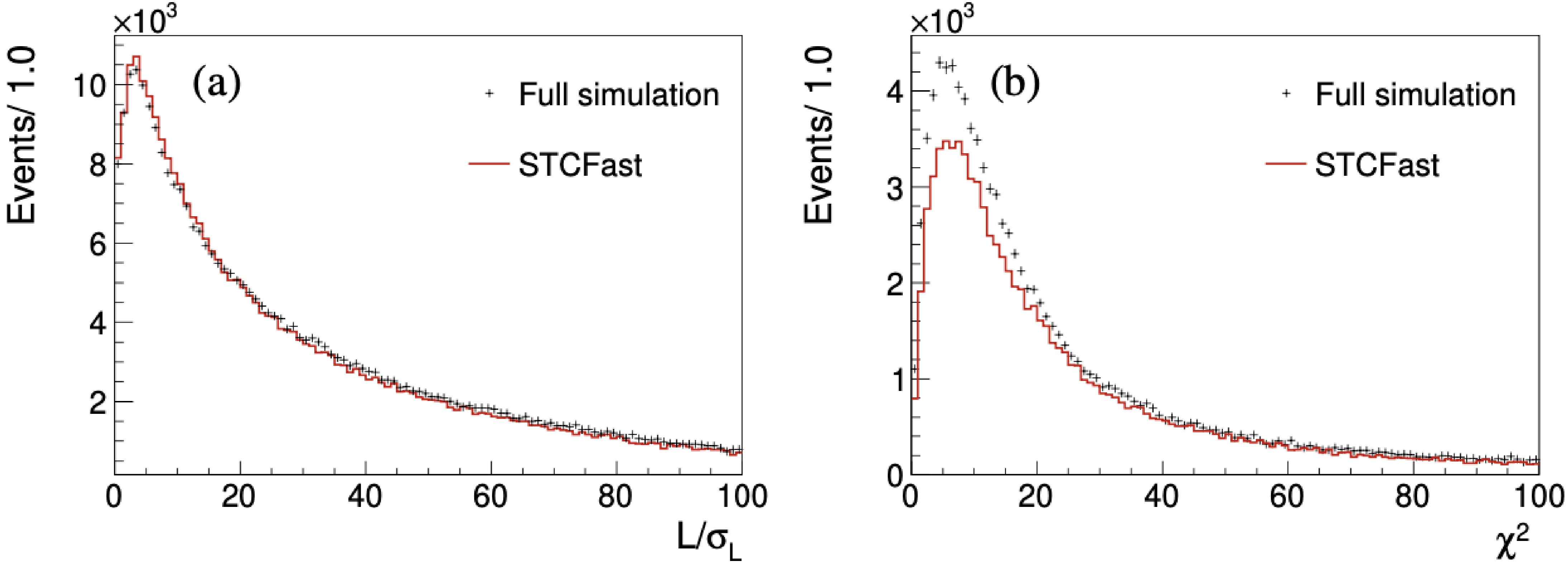
Performance: photon reconstruction

- For photons, refer to process $J/\psi \to \gamma f_0(1710)$, $f_0(1710) \to \pi^0\pi^0$
- Fast and full simulation consist well



Performance: vertex and kinematic fit

- Decay vertex position smeared around truth generating vertex.
- Validation of long-lived particles (K^0_S, Λ)
- Non-diagonal parameters in the helix error matrix not considered yet.



Performance and outcome

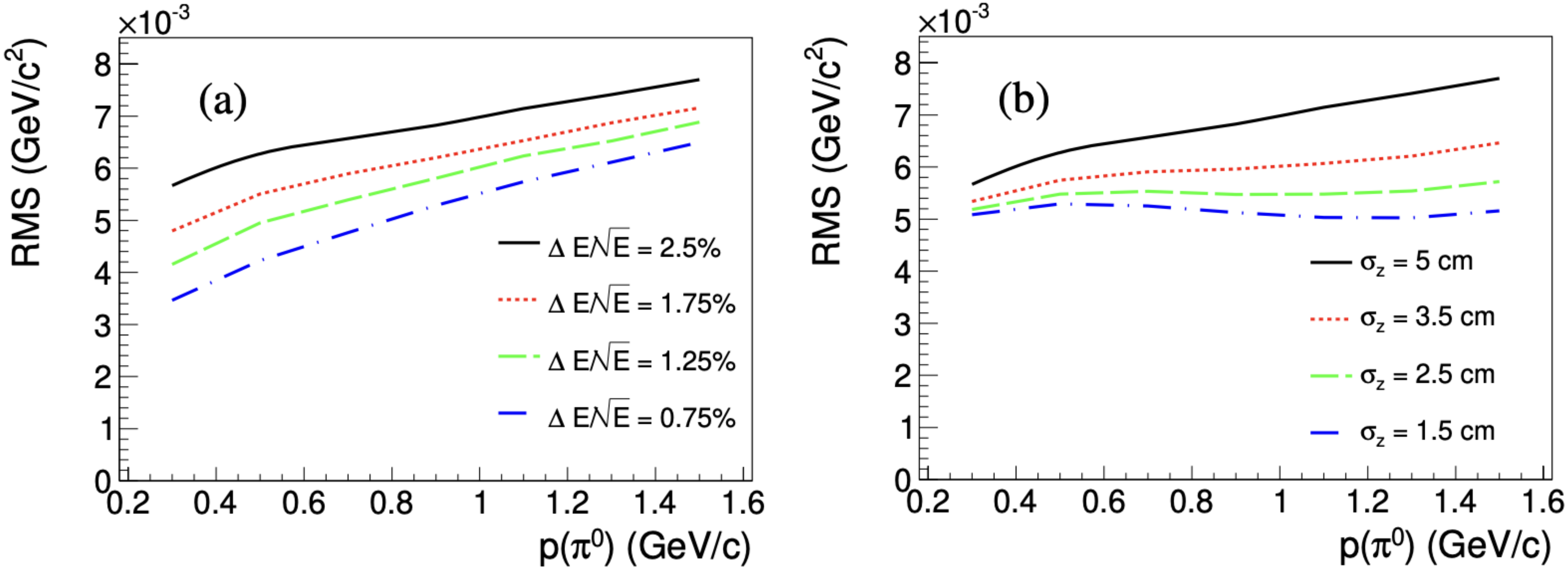
- **$O(10^2)$ improvement on time and storage consumption via fast simulation**

	Full sim（BESIII）	Fast sim
CPU time	~5300s/k	~50s/k
Event size	~160Mb/k	~0.8Mb/k

- **Contributions to sensitivity studies of physics topics**
  - Feasibility study of $D_s^+ \to \tau^+ \nu_\tau$ decay and test of lepton flavor universality with leptonic D_s^+ decays at STCF
  - Sensitivity of CP violation of Λ decay in $J/\psi \to \Lambda\bar{\Lambda}$ at STCF,
  - Sensitivity study of the charged lepton flavor violating process $\tau \to \gamma\mu$ at STCF
  - Feasibility study of measuring $b \to s\gamma$ photon polarisation in $D^0 \to K_1(1270)^- e^+ \nu_e$ at STCF
  - Feasibility study of CP violation in $\tau \to K_S \pi \nu_\tau$ decays at the Super Tau Charm Facility
  - ...

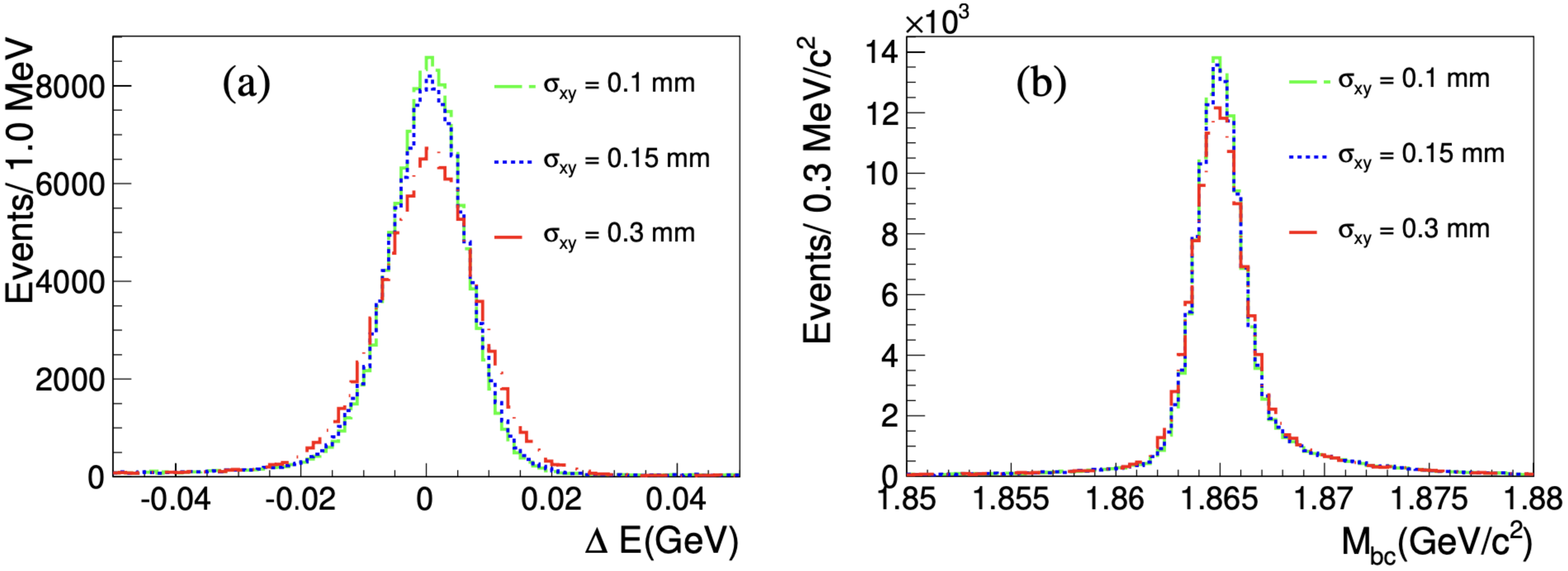
Flexibility: performance of π^0 reconstruction

- Provide scaling factor according to the expected performance
- For low momentum π^0, mass resolution improved with energy resolution of photon
- For high momentum π^0, mass resolution improved with better spatial resolution of photon



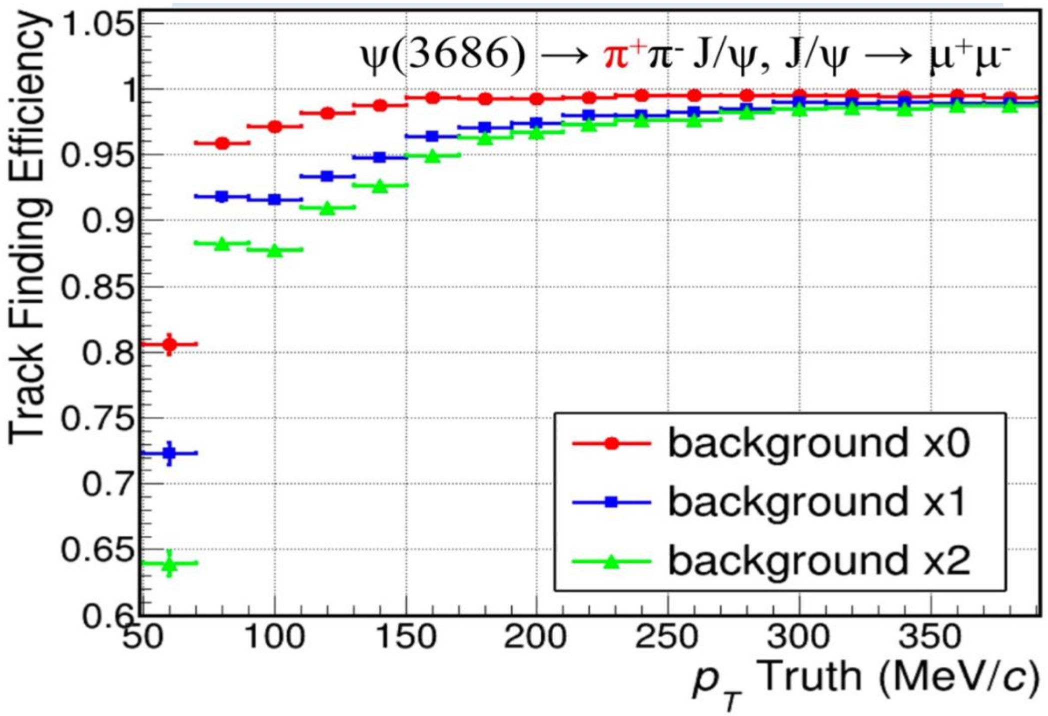
Flexibility: charged track reconstruction

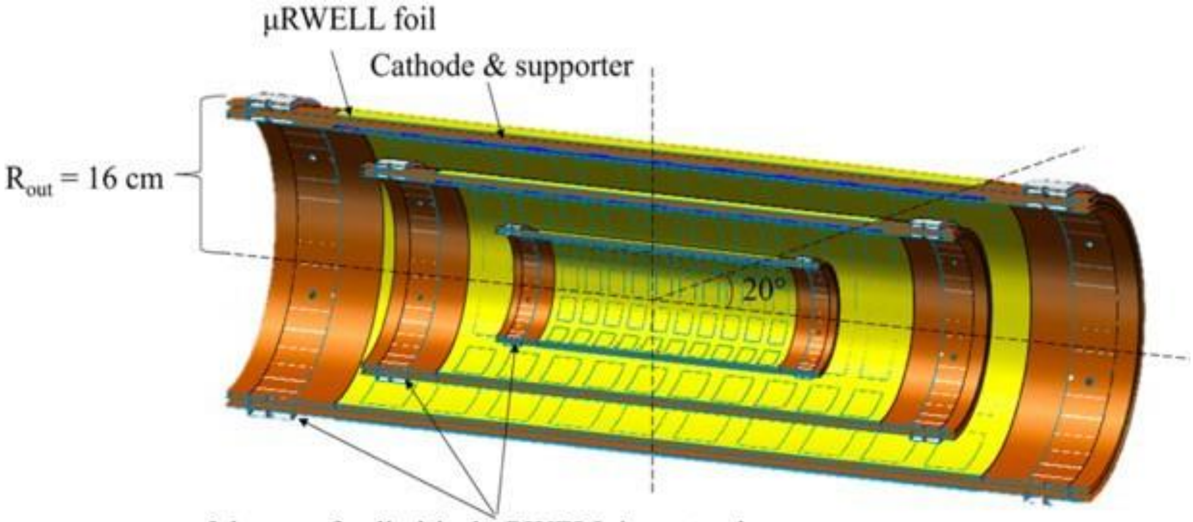
- $e^+e^- \rightarrow D^0\overline{D}^0$ at $\sqrt{s}$ = 3.77GeV with $D^0 \rightarrow K^-\pi^+$
- Study of improvement we can gain with better spatial resolution



Flexibility with different detecting response or detector design

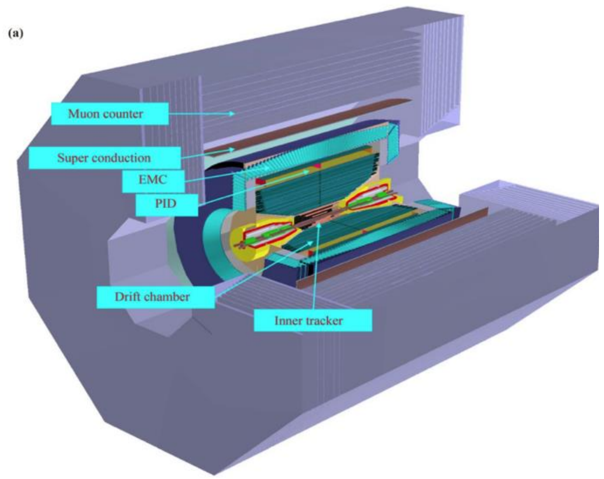
- Tracking efficiency varies according to different background level.
- Different detector design leads to different detecting resolution.

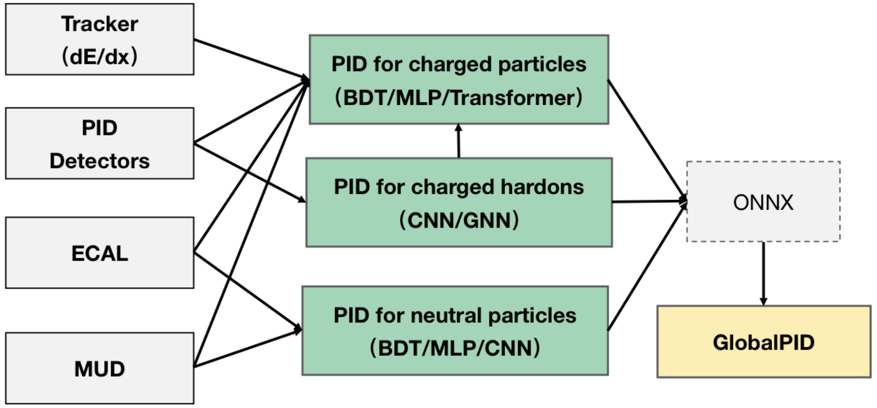




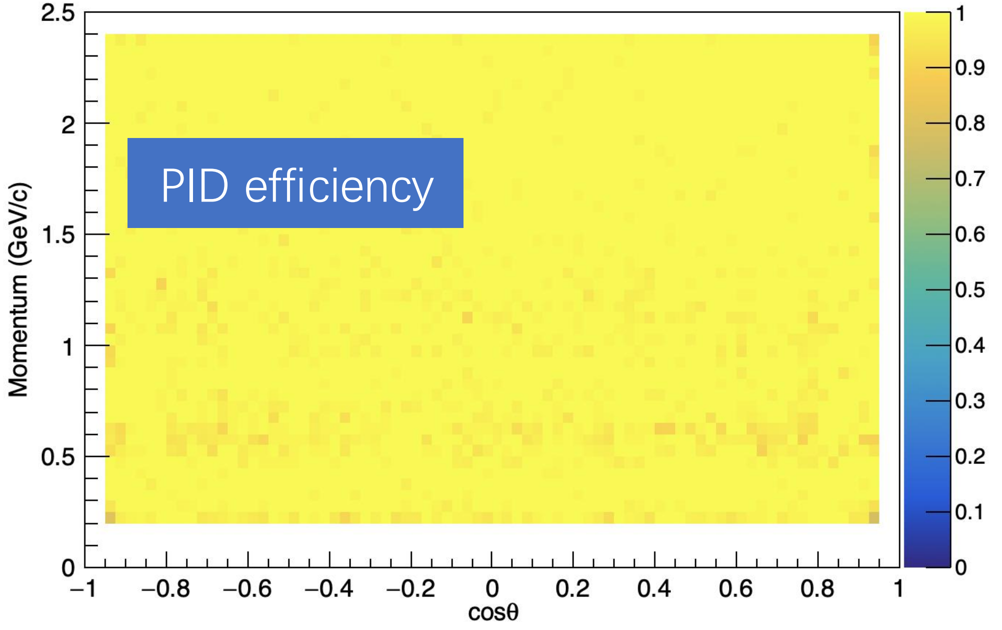
Particle identification

- Sub-detectors designed for different identification purpose
- PID algorithm works quite well combining information from sub-detectors
- For fast simulation, implement the overall identification efficiency and fake rates.



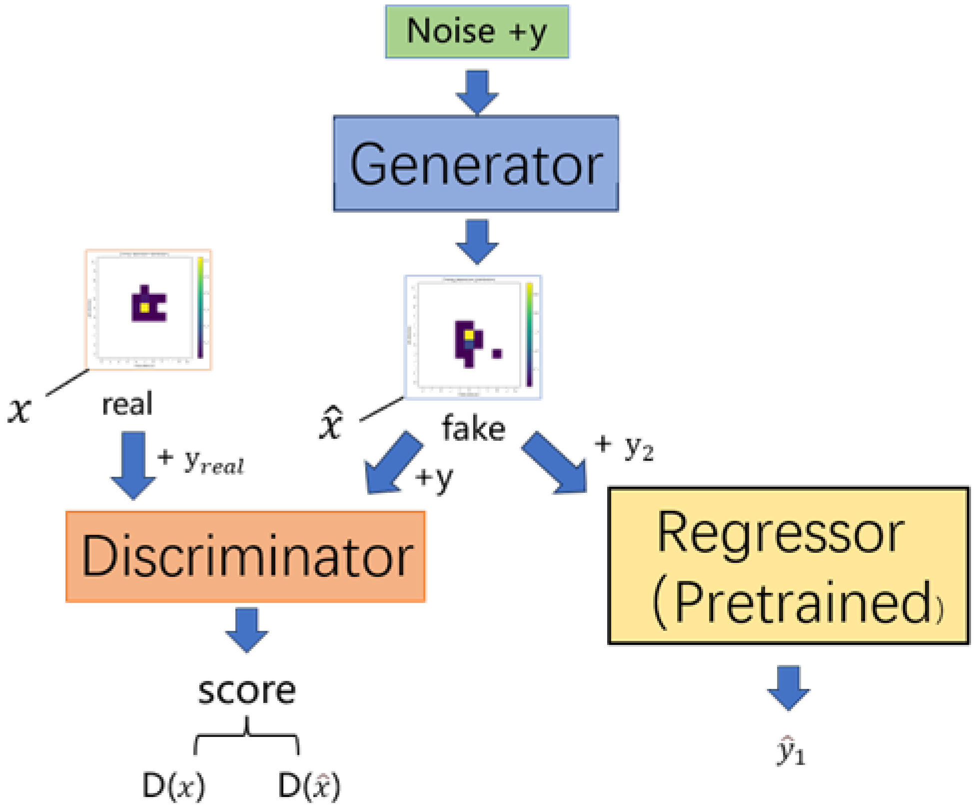


More details in Yuncong Zhai's talk

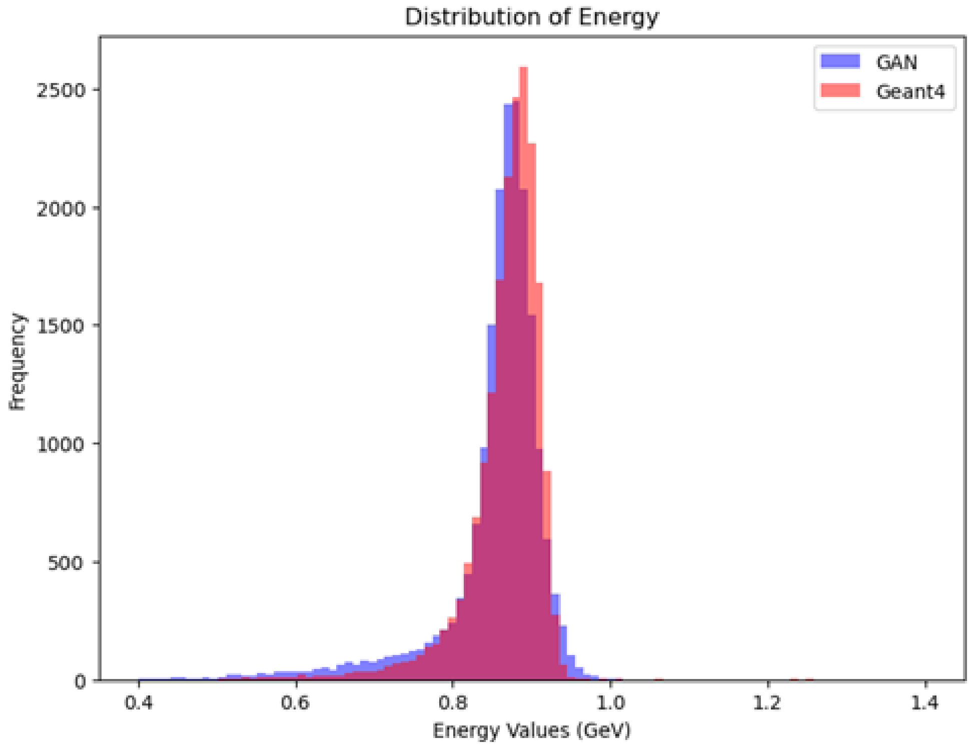


Fast simulation based on GAN

- Researching on hybrid technology of full and fast simulation
- ECAL simulation is the most time consuming part, novel methods like GAN are investigated



More details in Yujie Chai's talk



Summary

- The fast simulation framework works well
- Flexible for different detecting response and friendly for physics sensitivity study.
- The basic framework porting to OSCAR is done.
- More features under improvement

Thank you!

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