STCF Offline Software

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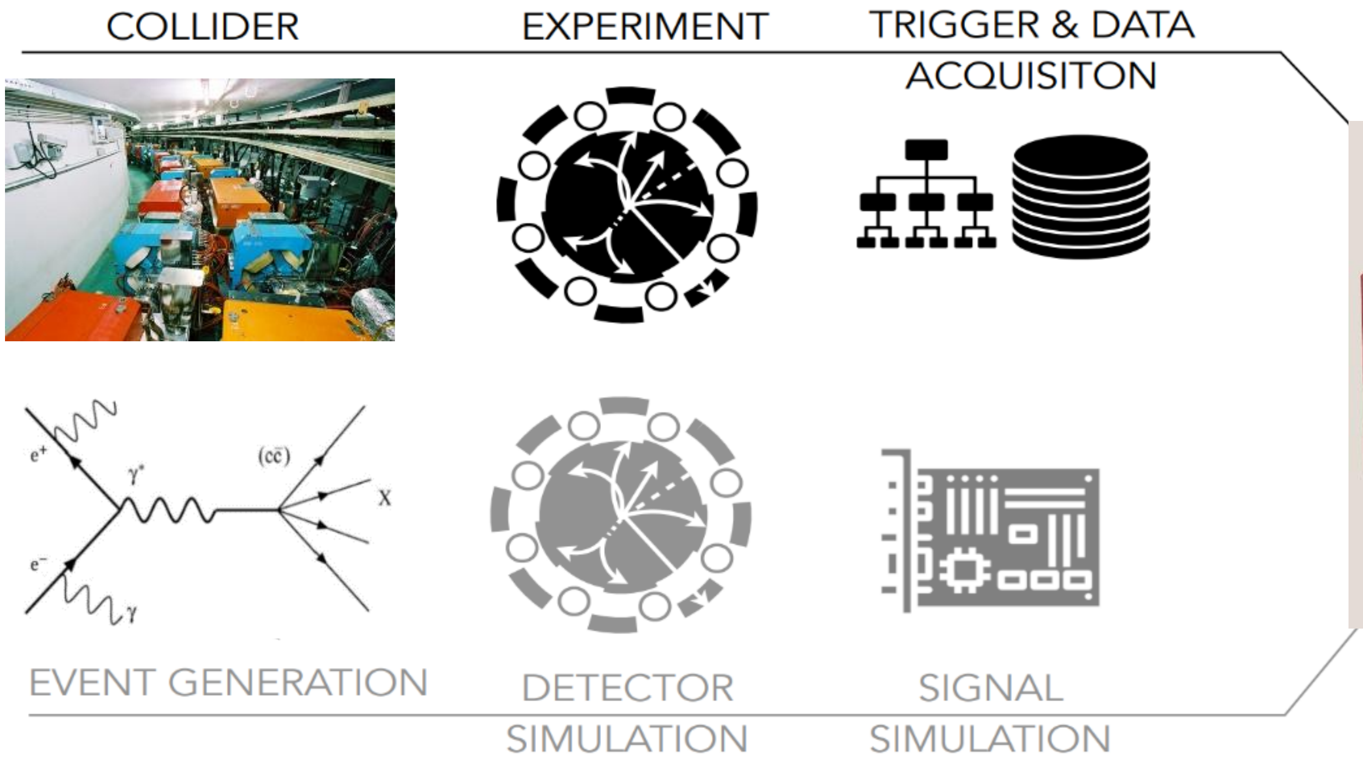
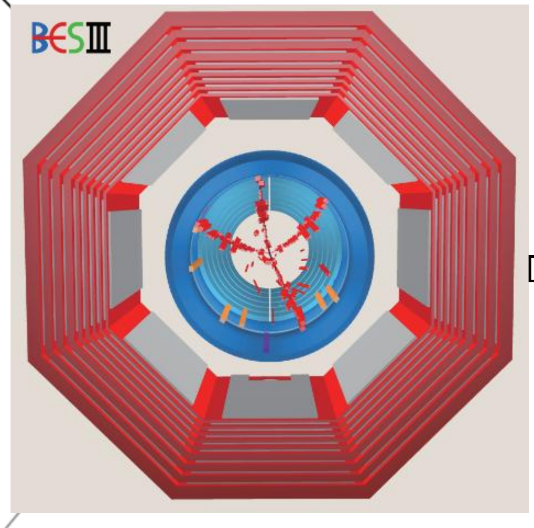
on behalf of the STCF software group

FTCF2025, Huangshan, Nov 24, 2025

The role of HEP offline software

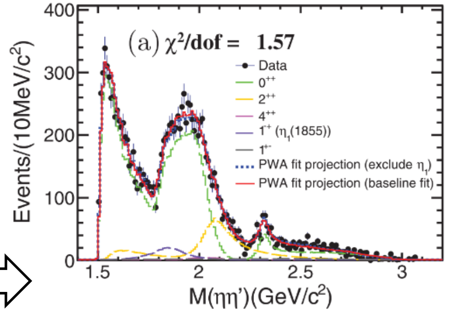


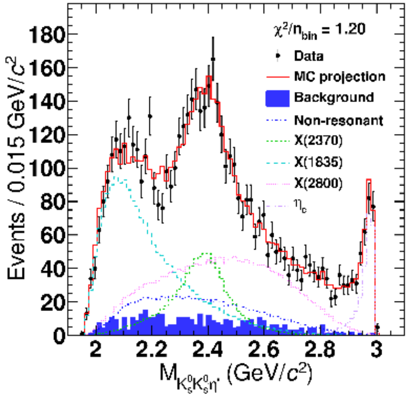
RECONSTRUCTION



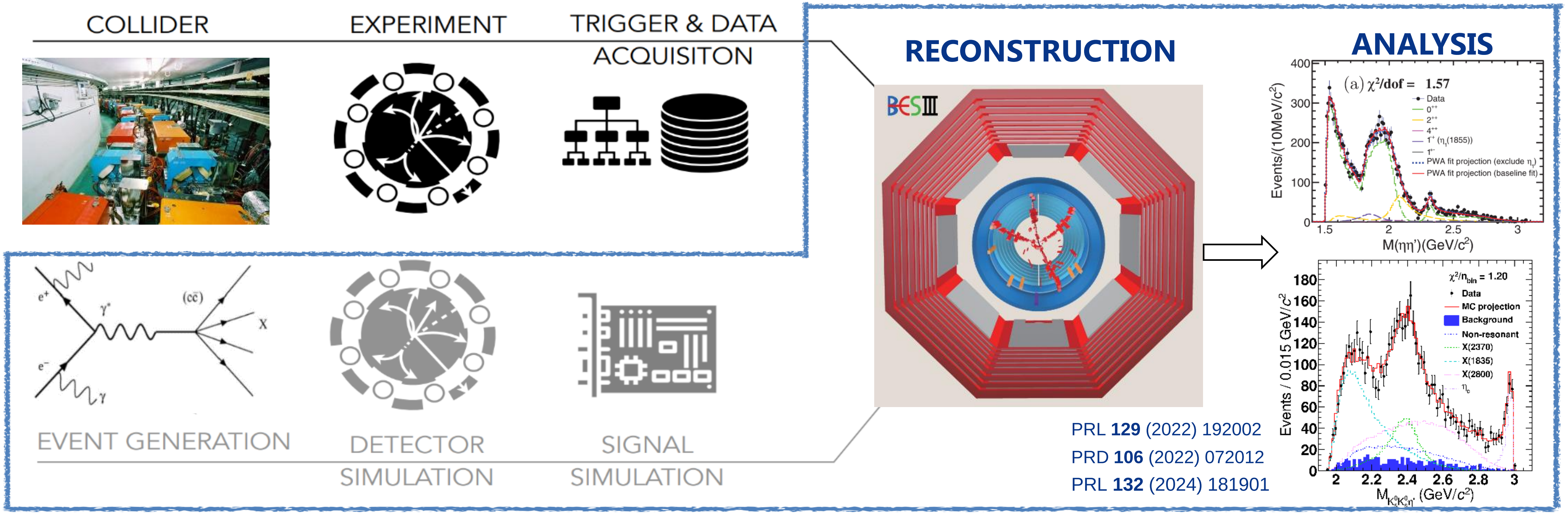
PRL **129** (2022) 192002
PRD **106** (2022) 072012
PRL **132** (2024) 181901

ANALYSIS



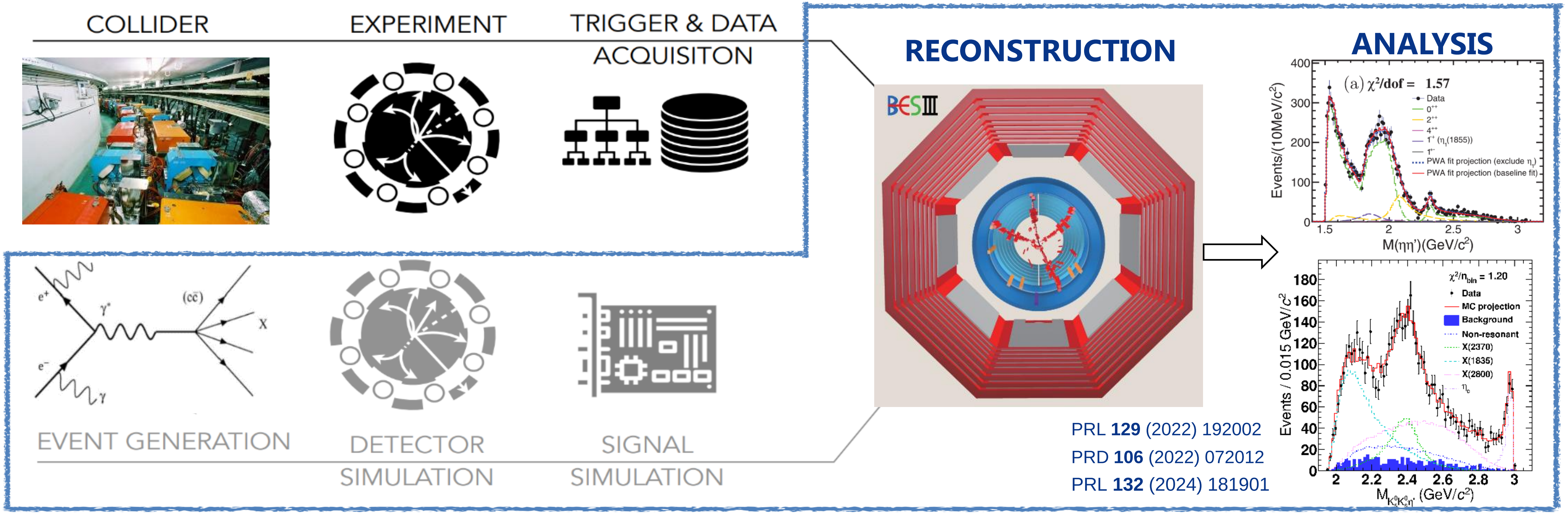


The role of HEP offline software



- The offline software is the “converter” from detector data to physics data to make physics discoveries (basically all physics analysis) possible!

The role of HEP offline software



- Besides, it's used to
  - Drive the design of often very sophisticated detectors
  - Exploit (i.e. not to spoil) the maximum performance of the detectors
  - Detect possible defects, malfunction, aging … of the detectors during production

STCF physics requirements

Requirements of offline software at STCF

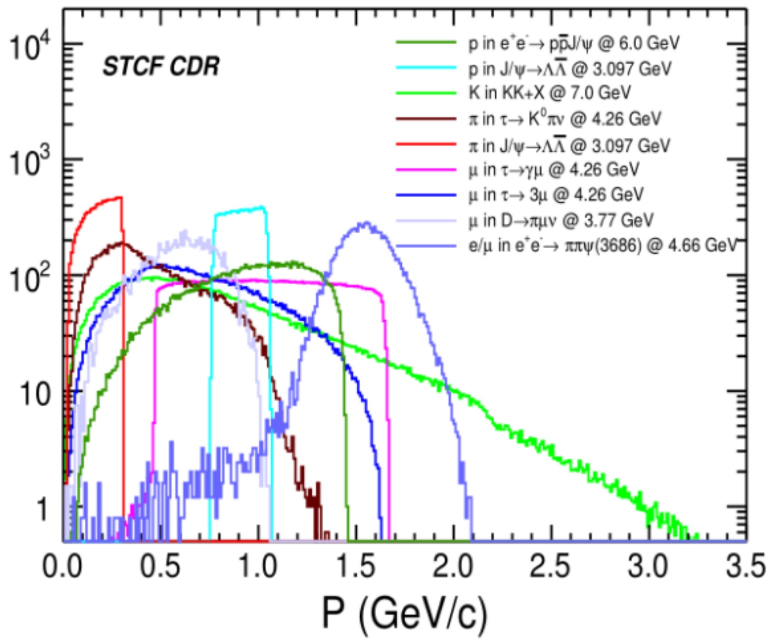
- Higher event rate, background hits ratio (~2/3 hits are from backgrounds), CPU consumption at STCF than BESIII. So we need to
  - develop **highly accurate and efficient** detector simulation and digitization algorithms to meet the demands of high luminosity, high background for **different detector options**
  - **reconstruct** the tracks and photon **with good efficiency and resolution,** and **identify** them **at high accuracy**, with **good speed**

Process	Physics Interest	Optimized Subdetector	Requirements
$\tau \to K_s \pi \nu_\tau$, $J/\psi \to \Lambda\bar{\Lambda}$, $D_{(s)}$ tag	CPV in the τ sector, CPV in the hyperon sector, Charm physics	ITK+MDC	acceptance: 93% of 4π; trk. effi.: $> 99\%$ at $p_T > 0.3$ GeV/c; $> 90\%$ at $p_T = 0.1$ GeV/c $\sigma_p/p = 0.5\%$, $\sigma_{\gamma\phi} = 130\ \mu$m at 1 GeV/c
$e^+e^- \to KK + X$, $D_{(s)}$ decays	Fragmentation function, CKM matrix, LQCD etc.	PID	π/K and K/π misidentification rate $< 2\%$ PID efficiency of hadrons $> 97\%$ at $p < 2$ GeV/c
$\tau \to \mu\mu\mu$, $\tau \to \gamma\mu$, $D_s \to \mu\nu$	cLFV decay of τ, CKM matrix, LQCD etc.	PID+MUD	μ/π suppression power over 30 at $p < 2$ GeV/c, μ efficiency over 95% at $p = 1$ GeV/c
$\tau \to \gamma\mu$, $\psi(3686) \to \gamma\eta(2S)$	cLFV decay of τ, Charmonium transition	EMC	$\sigma_E/E \approx 2.5\%$ at $E = 1$ GeV $\sigma_{\rm pos} \approx 5$ mm at $E = 1$ GeV
$e^+e^- \to n\bar{n}$, $D_0 \to K_L \pi^+ \pi^-$	Nucleon structure Unity of CKM triangle	EMC+MUD	$\sigma_T = \frac{300}{\sqrt{p^3({\rm GeV}^3)}}$ ps

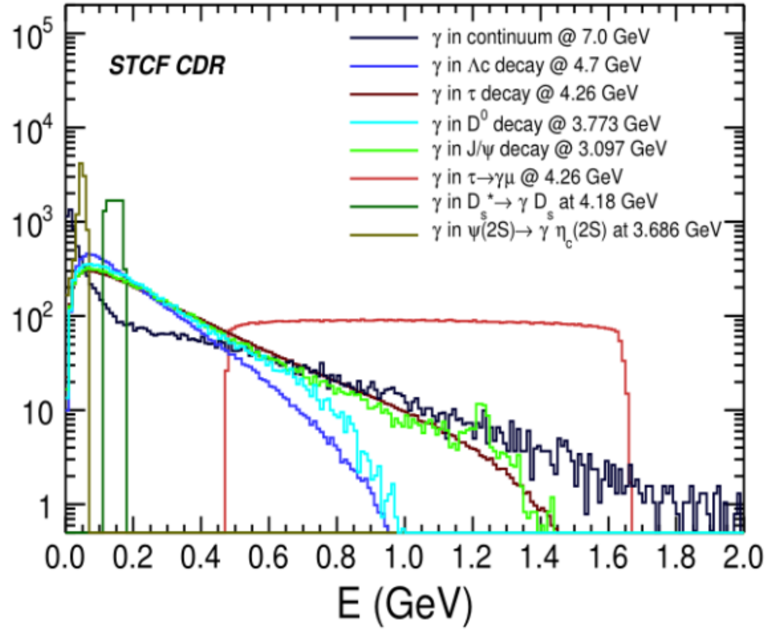
Particles at STCF

- Charged particles
  - **e, μ, K, π, proton** (most have p < 2 GeV, lots have p < 400 MeV)
- Neutral particles
  - **γ** (energy coverage: 25 MeV - 3.5 GeV) and **K_L, neutron** (up to 1.6 GeV)

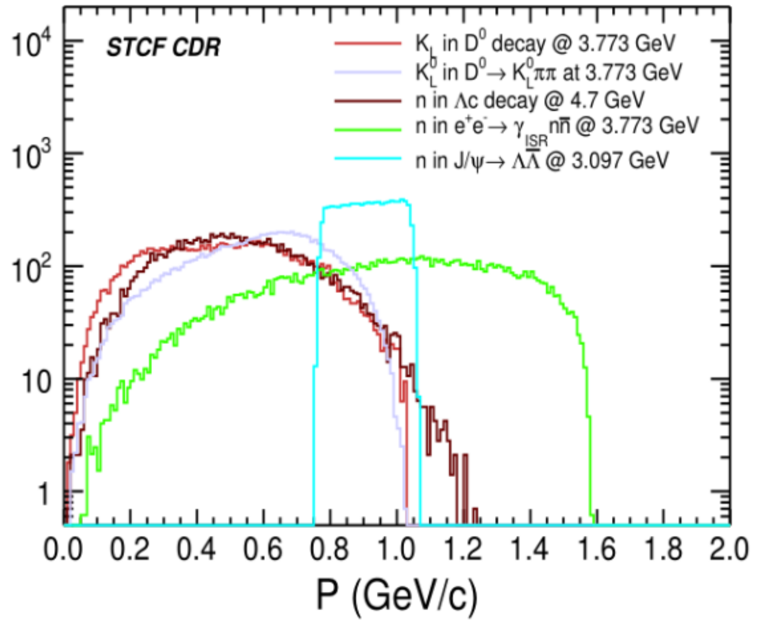
Charged particle momentum



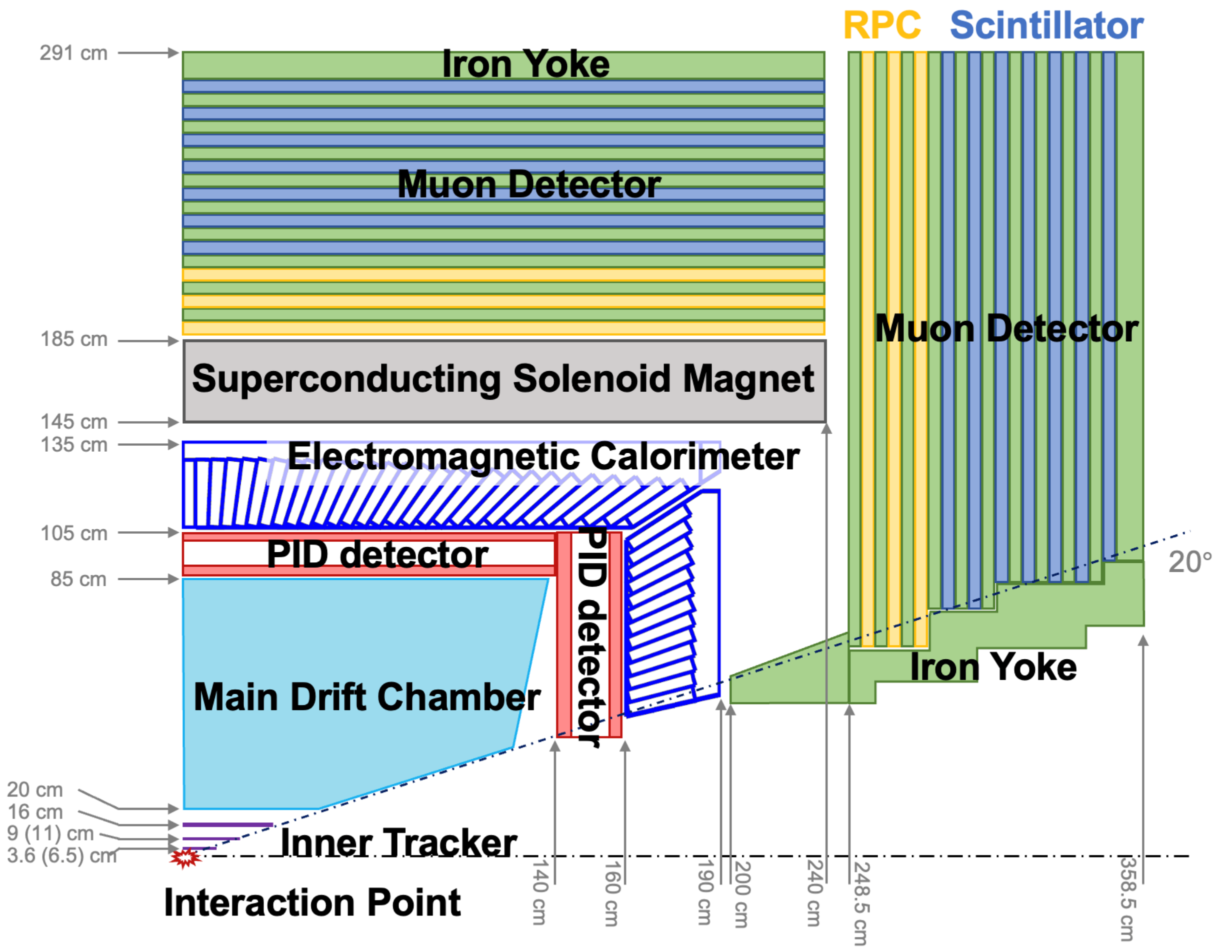
Photon energy



K_L, neutron momentum



Detector performance requirements



ITK

- Material < 0.01 $X0$, σ_{xy} < 100 um

MDC

- σ_{xy} < 130 um, σ_p/p < 0.5% at 1 GeV/c
- dE/dx resolution < 6%

RICH/BTOF & DTOF/RICH

- PID π/K PID efficiency > 97% up to 2 GeV/c @mis-ID rate 2%

EMC

- σ_E < 2.5%, σ_{pos} < 5 mm, σ_t < 300 ps @ 1 GeV

MUD

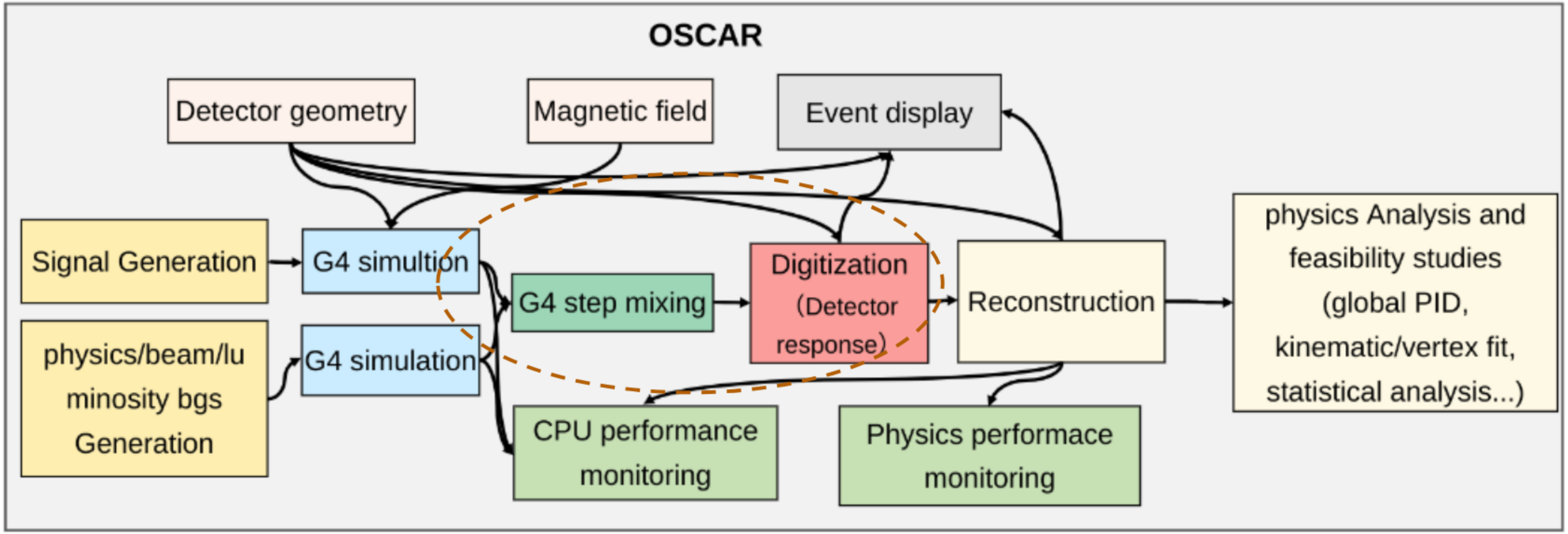
- μ PID efficiency > 95% with $\pi \rightarrow \mu$ mis-ID rate < 3.3% @ p = 1 GeV/c

More about the latest detector design in Jianbei Liu's talk

STCF Core Software

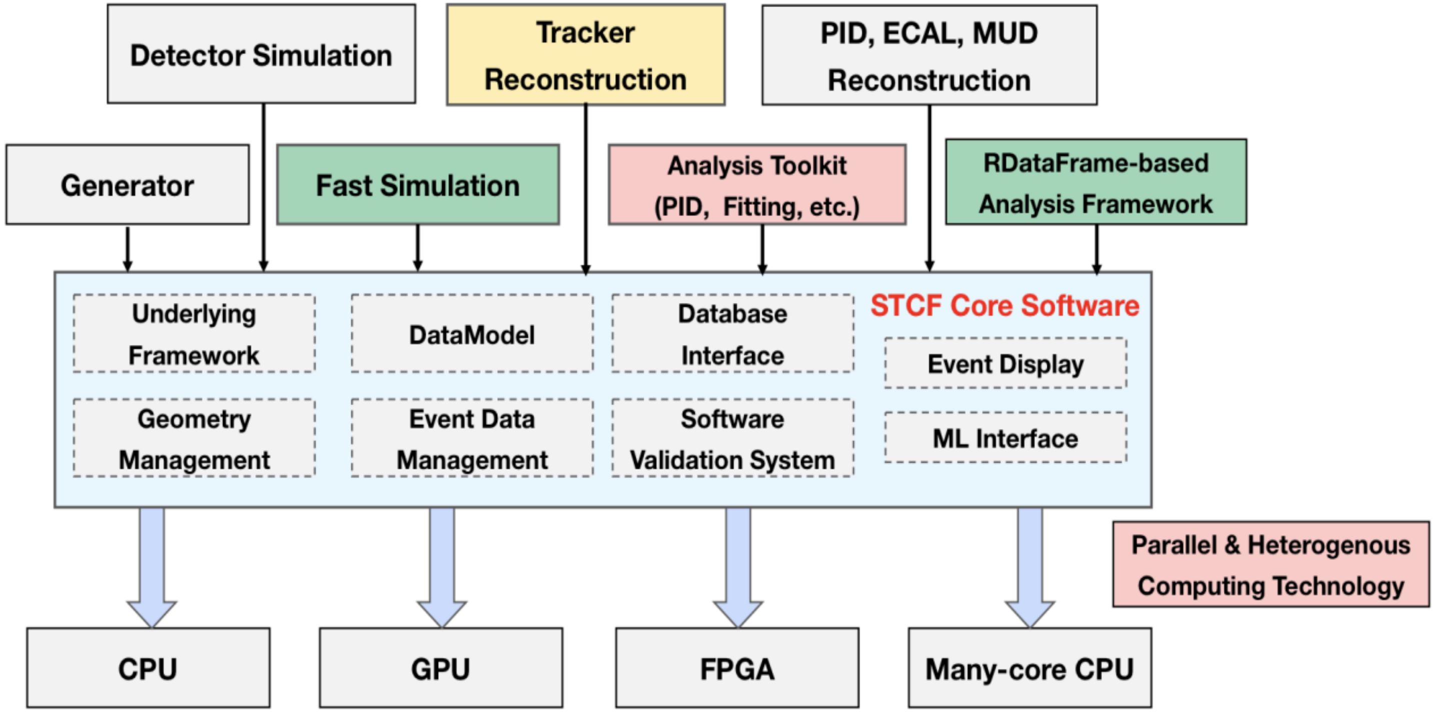
STCF offline software (OSCAR)

- OSCAR is developed to provide common functionalities for **detector simulation**, **reconstruction**, **calibration** and **physics analysis** at STCF
  - A full chain of simulation + digitization + reconstruction + analysis has been established
  - ML techniques exploited in simulation, reconstruction and analysis



OSCAR core software features

- The OSCAR core software is developed based on the SNiPER framework and the (partially) the **Key4hep** Stack, with lots of state-of-the-art techniques
  - Event Data Model based on **podio**
  - Geometry based on **DD4hep**
  - Tracking with **ACTS** (as an option)
  - Analysis framework with **RDataFrame**
  - ML inference with **ONNX**
  - Parellel computing with **TBB**
- Many new features are being develope
  - Fast simulation based on **GAN**
  - Software deployment with **Spack**
  - Support for **heterogenous** resources
  - Modern CI supported by **LLM**



Comput.Softw.Big Sci. 9 (2025) 1, 3
Mod.Phys.Lett.A 39 (2024) 40, 2440006
JINST 18 (2023) 03, P03004
J.Phys.Conf.Ser. 2438 (2023) 1, 012054

Major Updates in 2025

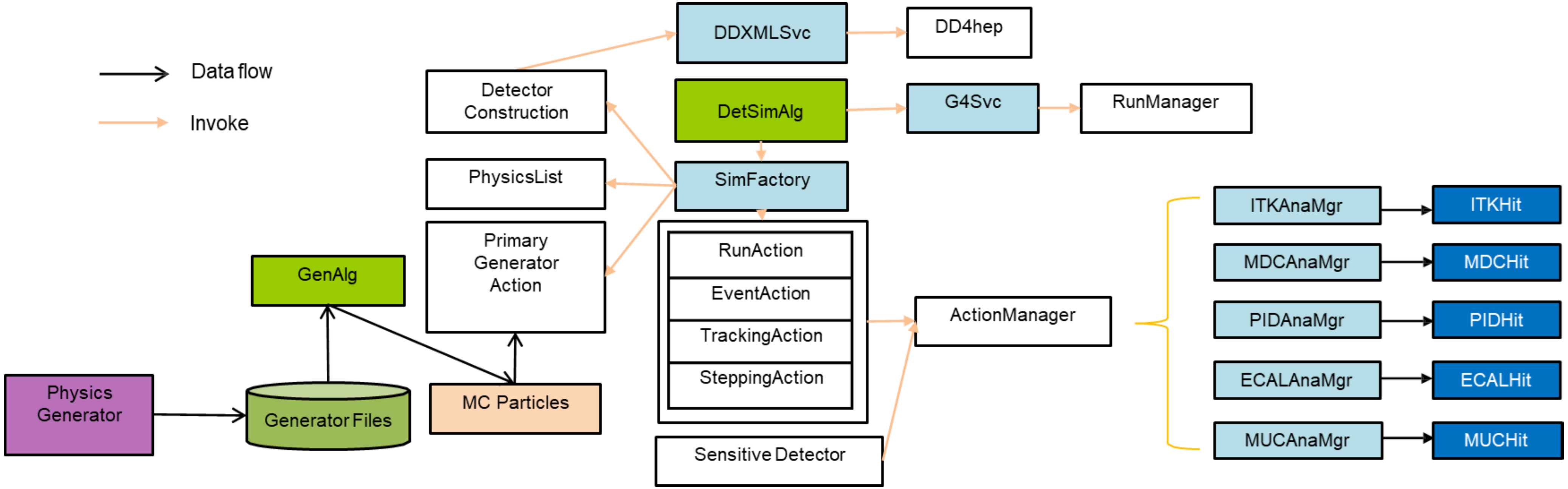
- OSCAR major updates on top of status reported at STCF workshop in Xiangtan
  - Major updates of **digitization, reconstruction** algorithms (see talks of each sub-detector)
  - **Vast geometry** optimization in progress (not yet merged)
  - Major optimization of the **fast simulation** software
  - Updates of the core software and analysis tools
  - Development of the **analysis data model** to simplify data analysis
    - Development of **modern CI** powered by LLM
    - Optimization of **RDFrame analysis framework** and **Global Vertex Fit**
    - Development of **software deployment toolkit** powered by Spack
    - ...

More details in Li Teng's talk

Simulation, digitization, background mixing

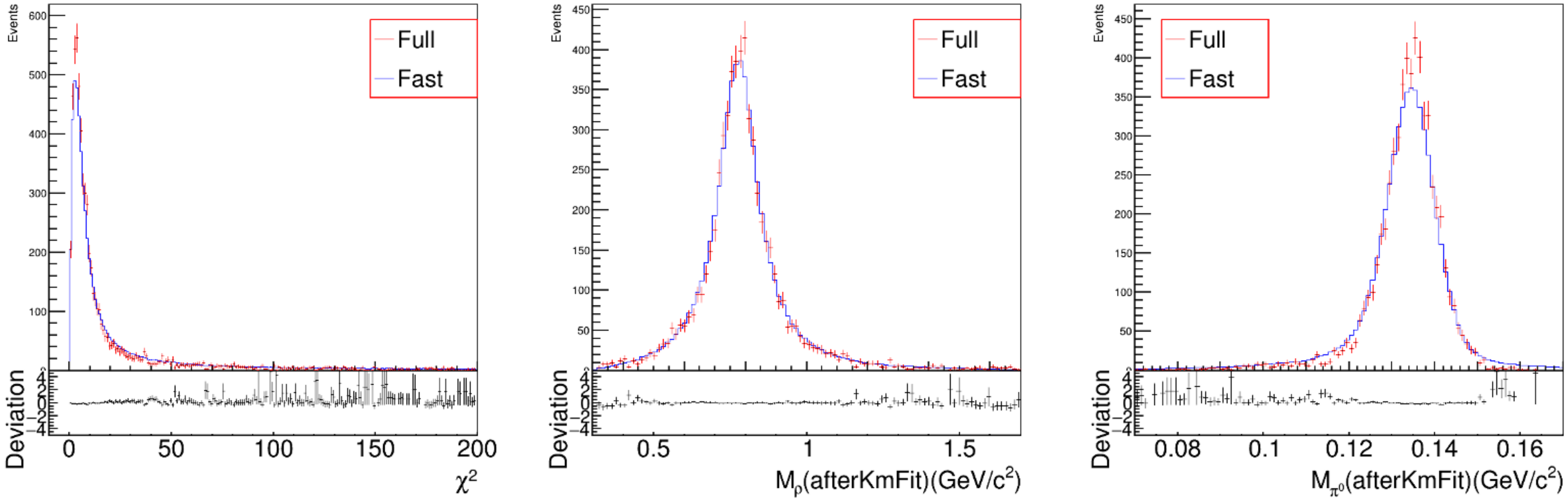
Full simulation

- Built **full simulation chain** from generated events to G4 hit information
- Providing **flexible configuration** in different steps
  - **Generator** for different physics topics i.e. Babayaga, KKMC, Phokhara, DIAG36, BBBrem …
  - **Geometry** for different detector design options
  - **User actions** for recording MC truth information, G4Step level



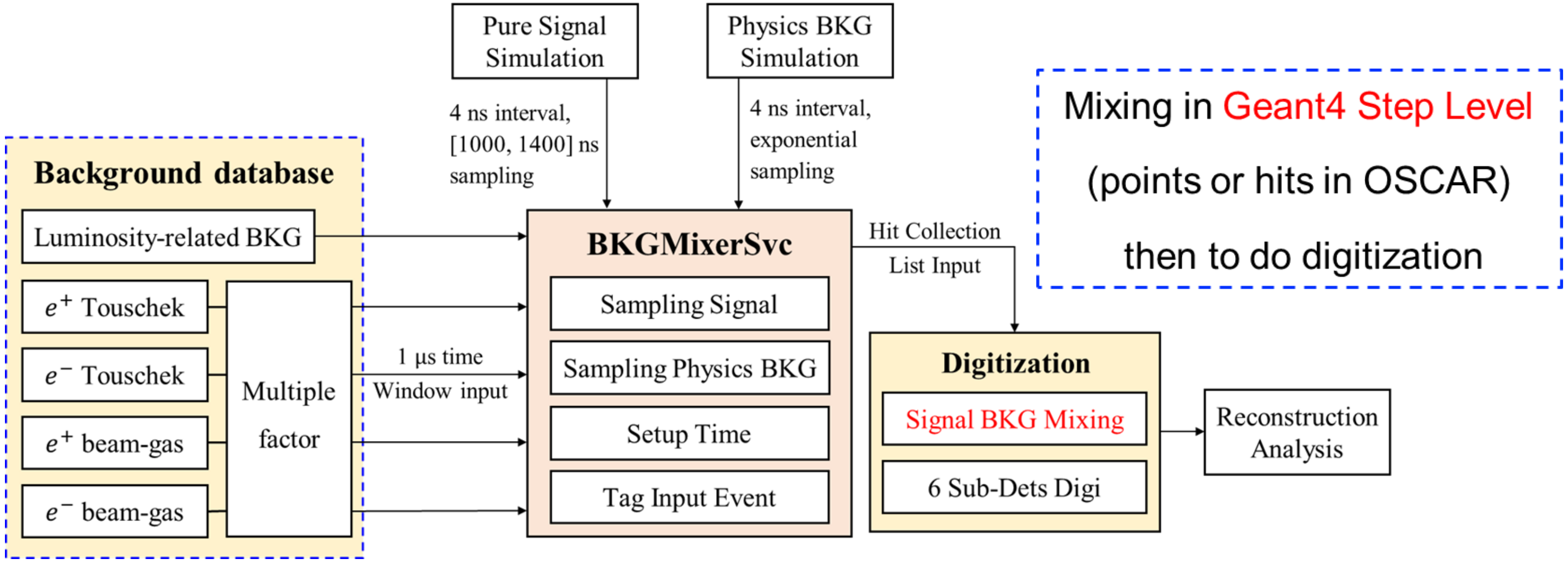
Fast simulation

- Parameterizations of STCF **detector responses (scalable efficiency, resolution…)** to “fake” responses from full simulation + digitization + reconstruction
- Performance validated against full simulation using multiple channels: $\rho\pi^0$, $\pi\pi J/\psi$, $\Lambda\bar{\Lambda}$ …
- Speed up and storage reduction:
    - ~**2 ms** per event, ~**1.8 kb** storage for a 4 prong J/ψ decay event
    - Storage being further reduced by optimizing track parameters covariance sampling



Background mixing and digitization

- Signal particles mixing with background particles at the **Geant4 step level**
  - To vastly improve the speed, optimization is ongoing to pre-digitize the background hit and do the **mixing partially at digi. hit level**
- Geant4 step info digitized to emulate the **detector measurement** (i.e. input for reconstruction)
  - Considering **electronic response, noise and other effects**
  - All sub-detector uses **sampling method,** including **MDC dE/dx** and **hit position**



More details in:

→ STCF EMC simulation, digitization and reconstruction (Bo Wang)

→ STCF BTOF simulation, digitization and reconstruction (Teng Ma)

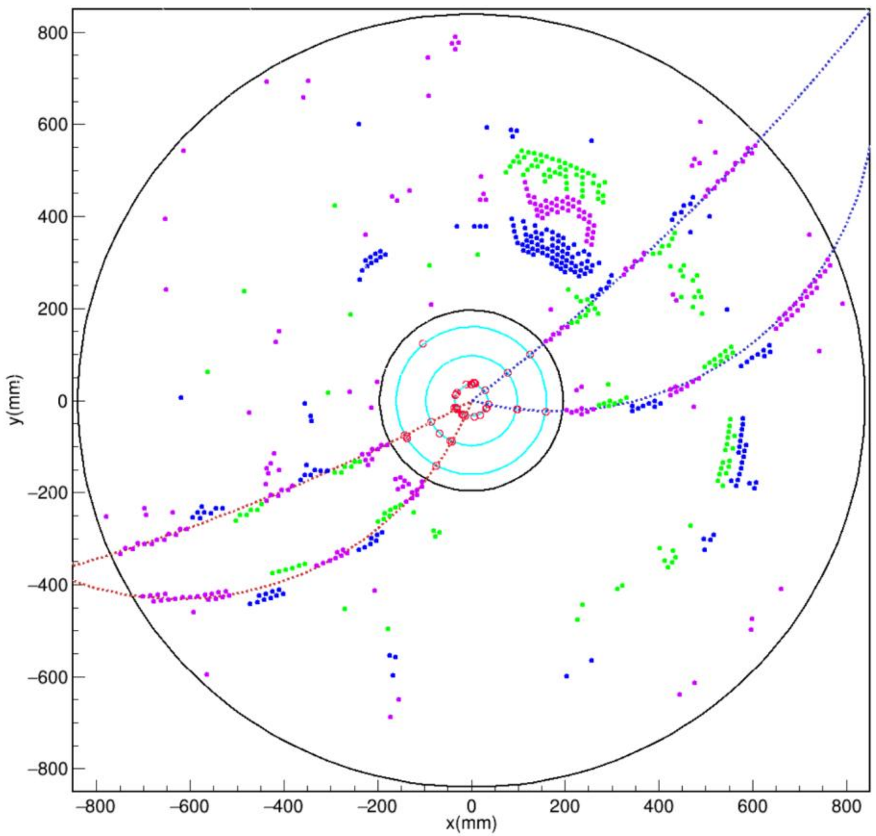
→ STCF MUD simulation, digitization and reconstruction (Yulin Liu)

Tracking performance

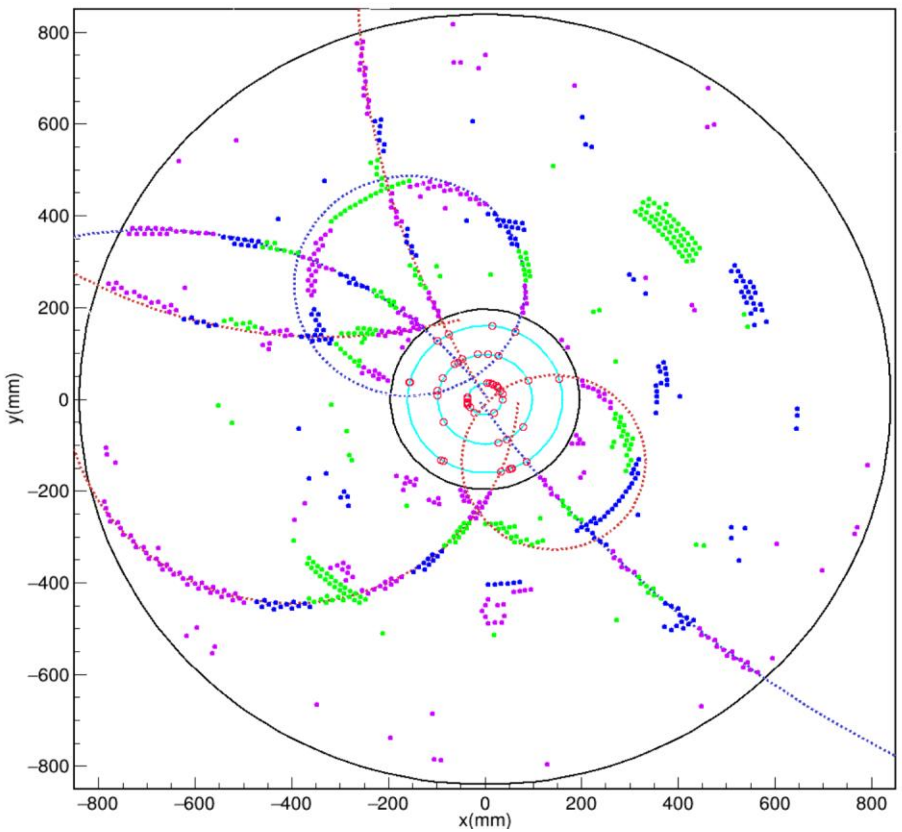
STCF tracking environment

- Both prompt and **displaced** tracks exist with presence of **noise hits** from beam backgrounds
- Most tracks have p_T below 500 MeV

$\psi' \to \pi^+\pi^- J/\psi \to \pi^+\pi^-\mu^+\mu^-$

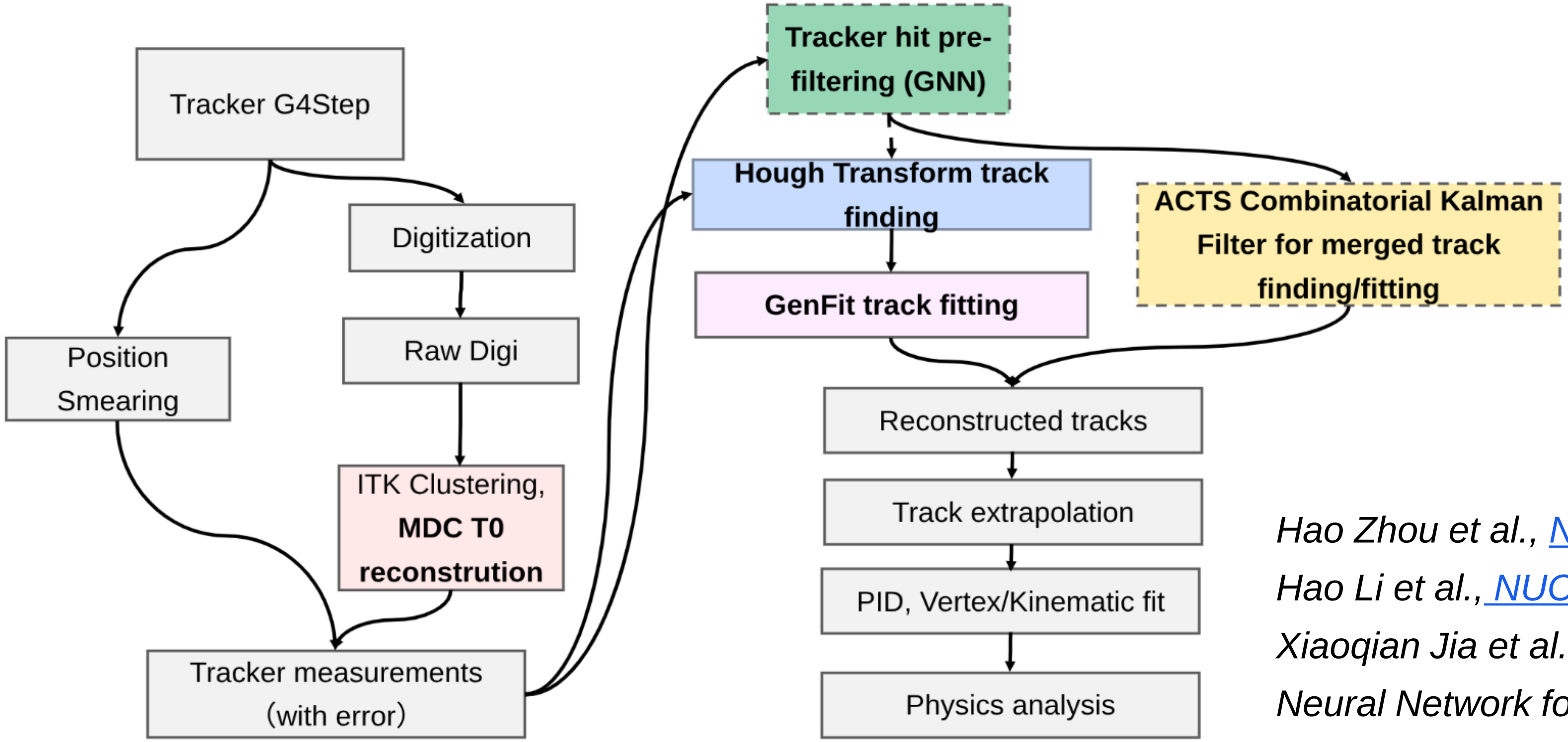


$J/\psi \to \Xi^-\bar{\Xi}^+ \to \Lambda\pi^-\bar{\Lambda}\pi^+ \to p\pi^-\pi^-\bar{p}\pi^+\pi^+$



Tracking strategies

- **Hough transform** + GenFit shows decent performance for both prompt and long-lived particles
- **ACTS** is promising to improve tracking efficiency of low p_T particles and reduce CPU overheads
- **GNN** shows promising performance in terms of noise removal



More details in talks:

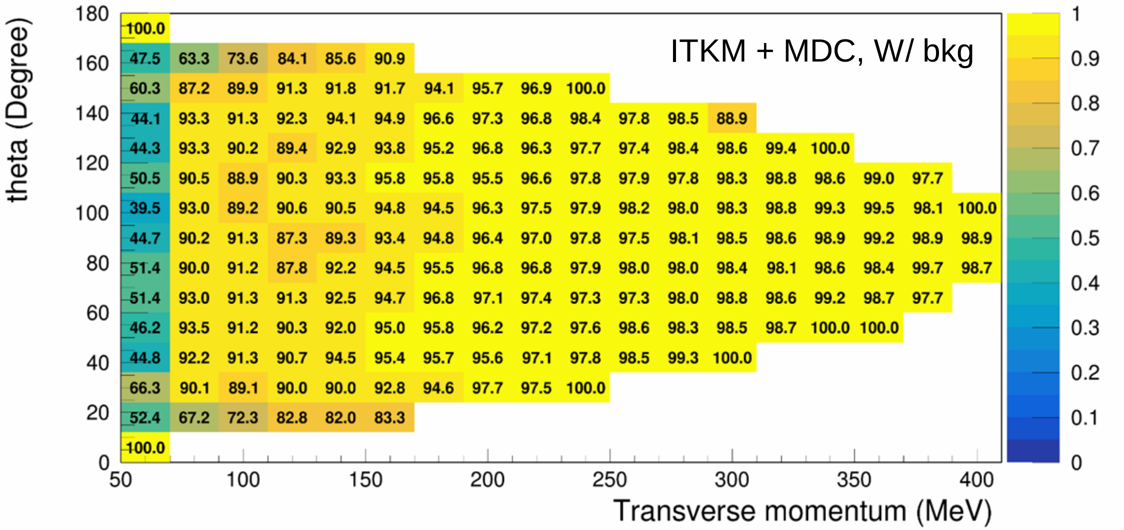
→ STCF MDC full reconstruction (Hongkun Mo)
→ BESIII/STCF MDC GNN tracking (Xiaoshuai Qin)
→ STCF Hough tracking and fitting (Jin Zhang)
→ ACTS tracking for STCF (Hao Li)

Hao Zhou et al., NIMA 1075, 170357 (2025)
Hao Li et al., NUCL SCI TECH 36, 171 (2025)
Xiaoqian Jia et al., Noise Filtering Algorithm Based on Graph Neural Network for STCF Drift Chamber (submitted to JINST)

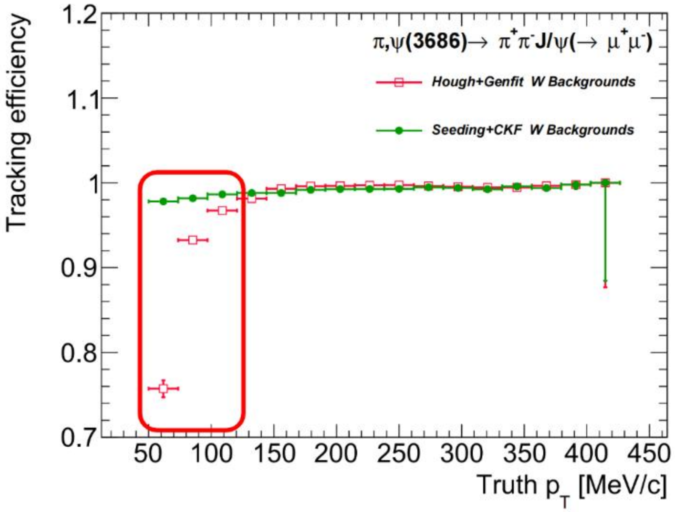
Tracking efficiency for prompt tracks

- Tracking performance with Hough + GenFit for **prompt** tracks has been well consolidated
  - **>90%** tracking efficiency for **p_T > 70 MeV** except detector edge region
- ACTS can improve the efficiency at low p_T, but more fake tracks need to be resolved

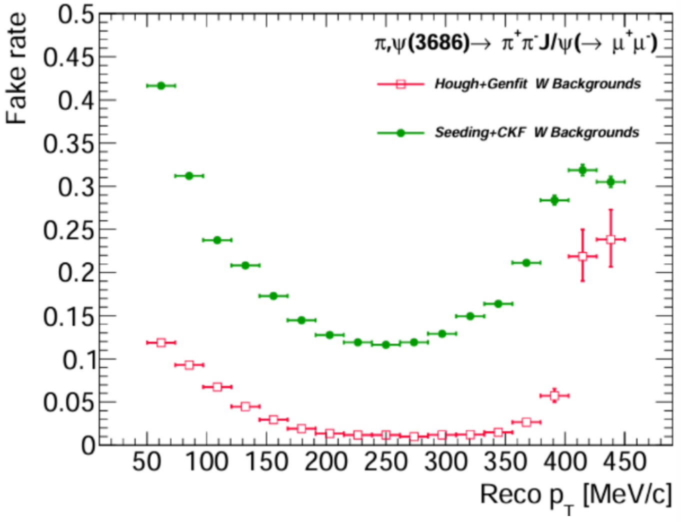
Hough + GenFit 2D tracking efficiency vs. theta and p_T
(π^- in $\psi' \to \pi^+\pi^- J/\psi \to \pi^+\pi^-\mu^+\mu^-$)



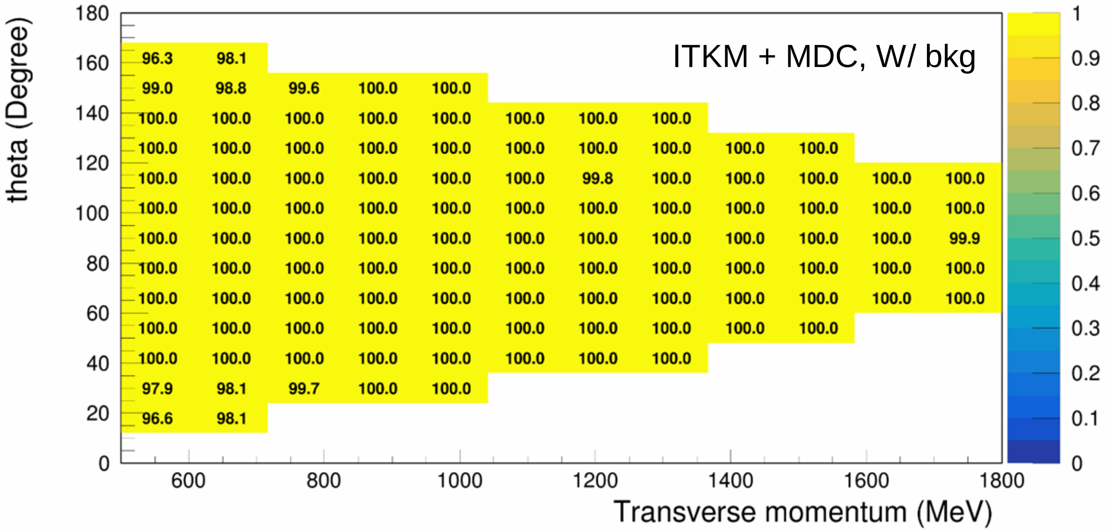
ACTS (seeding+CKF) tracking efficiency vs. pT
(π^- in $\psi' \to \pi^+\pi^- J/\psi \to \pi^+\pi^-\mu^+\mu^-$)



ACTS (seeding+CKF) fake rate vs. pT
(π^- in $\psi' \to \pi^+\pi^- J/\psi \to \pi^+\pi^-\mu^+\mu^-$)



Hough + GenFit 2D tracking efficiency vs. theta and p_T
(μ^- in $\psi' \to \pi^+\pi^- J/\psi \to \pi^+\pi^-\mu^+\mu^-$)

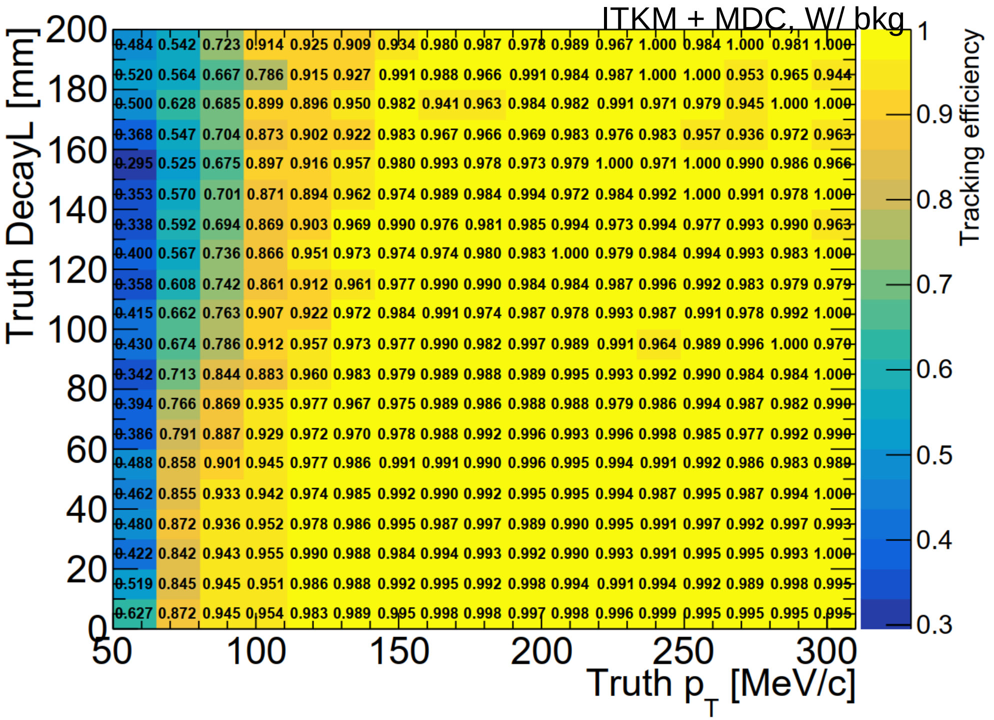


Tracking efficiency for displaced tracks

- Decent performance for **long-lived** particle (Λ, Ξ) products even in a complex scenario with low p_T and displaced tracks
  - Addressing the issue by using additional Hough transfrom with displaced segment position as reference point
  - **>80%** track efficiency with decay length up to **200 mm**

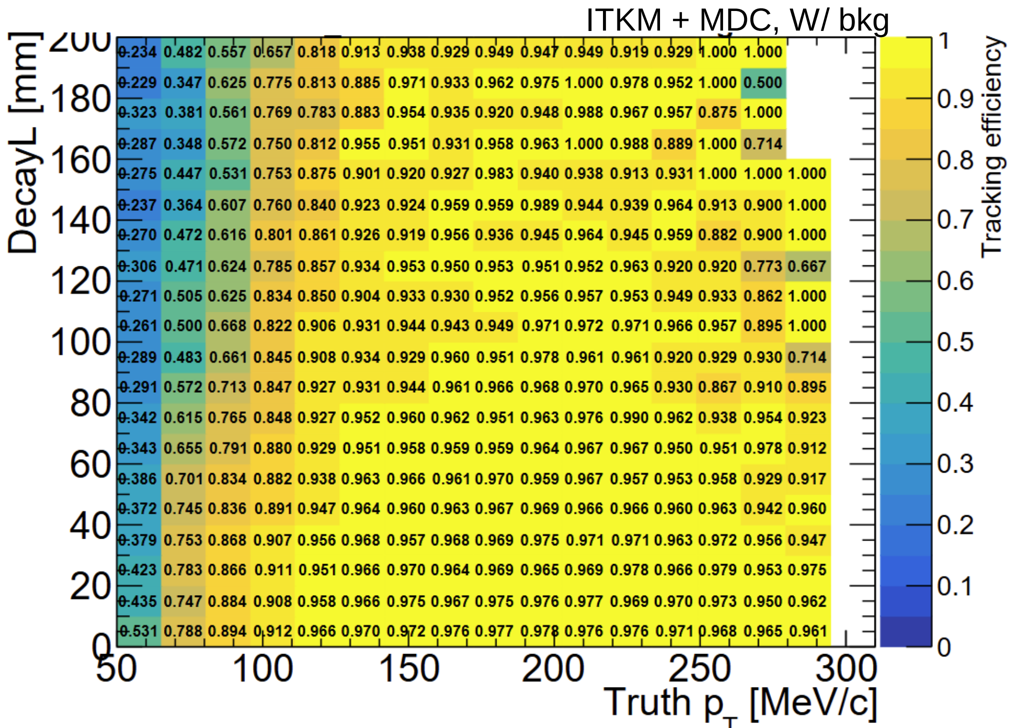
Tracking efficiency vs. decay length and p_T

π^- in $J/\psi \to \Lambda\bar{\Lambda} \to p\pi^-\bar{p}\pi^+$



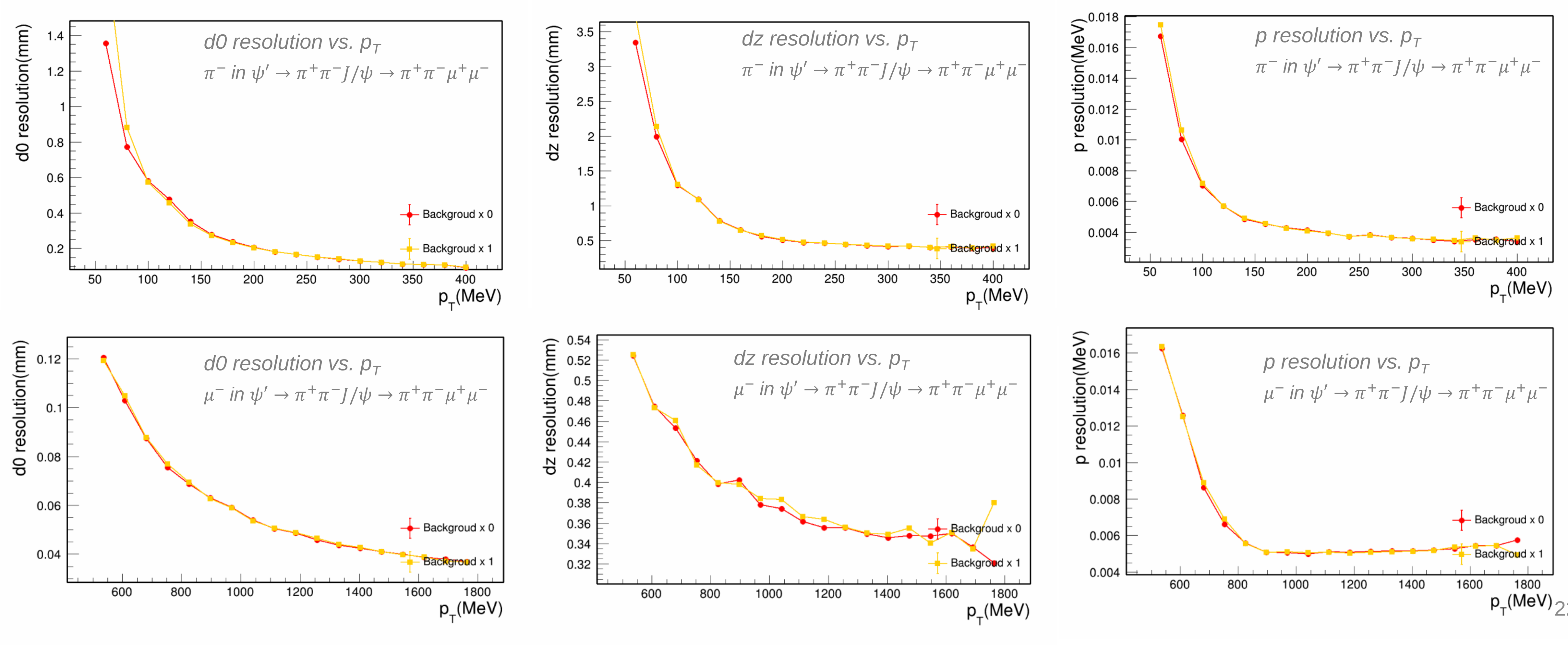
Tracking efficiency vs. decay length and p_T

π^- in $J/\psi \to \Xi^-\bar{\Xi}^+ \to \Lambda\pi^-\bar{\Lambda}\pi^+ \to p\pi^-\pi^-\bar{p}\pi^+\pi^+$



Tracking parameters resolution

- d0 (z0) has resolution down to **40 (350) um** with p_T > **1.5 GeV**
- p relative resolution is ~**0.5%** at p_T = **1 GeV**



Photon performance

EMC reconstruction

ECALRecAlg

Cluster search

↓

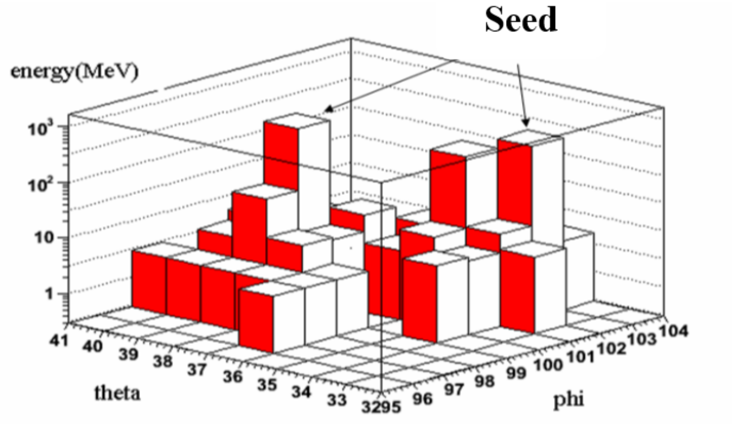
Seed search

↓

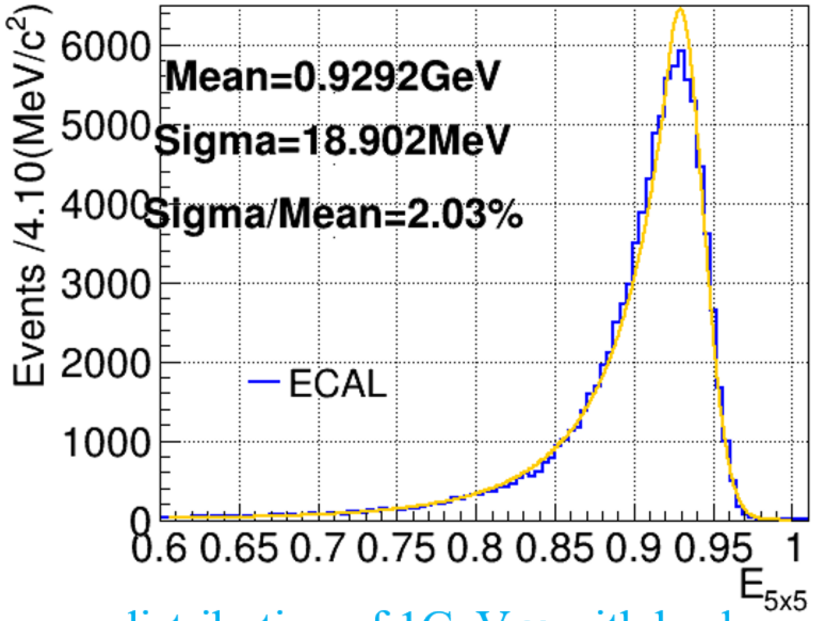
Clusters split into Showers

↓

Calculation and correction of shower energy and position



π^0 Cluster (two photons)



Energy distribution of 1GeV γ with background

- Fitted by Crystal Ball function
- Energy resolution defined by

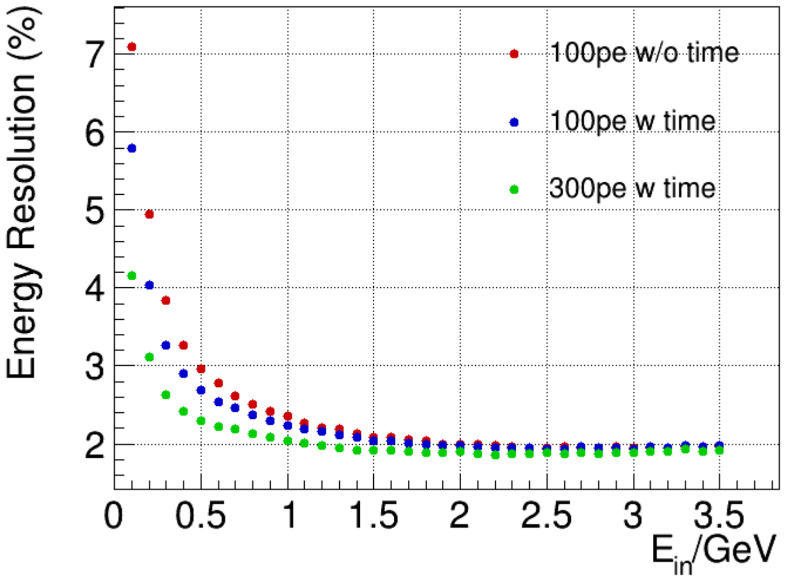
$$\sigma_E = \frac{FWHM}{2.355}$$

More details in Bo Wang's talk

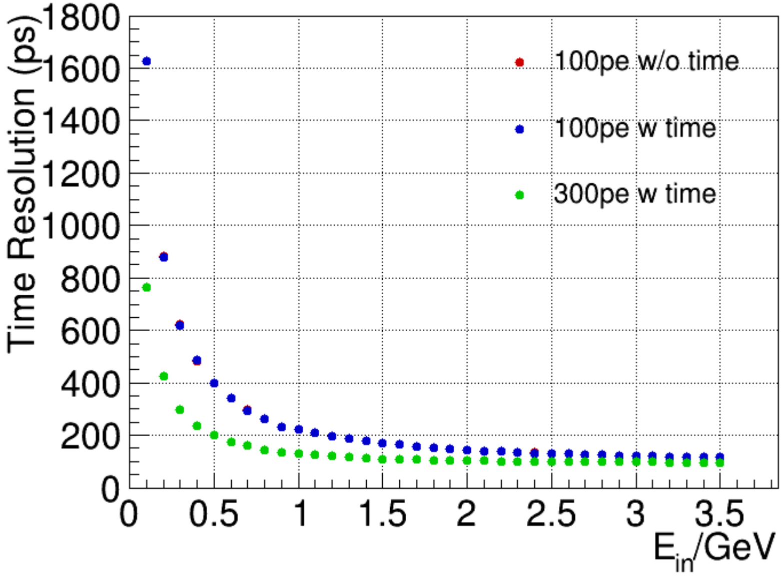
Photon reconstruciton performance

- Using realistic digitization parameters from beam test results
- Single **photon energy**, **time and position resoluton** with backgrounds can **meet physics requirements**

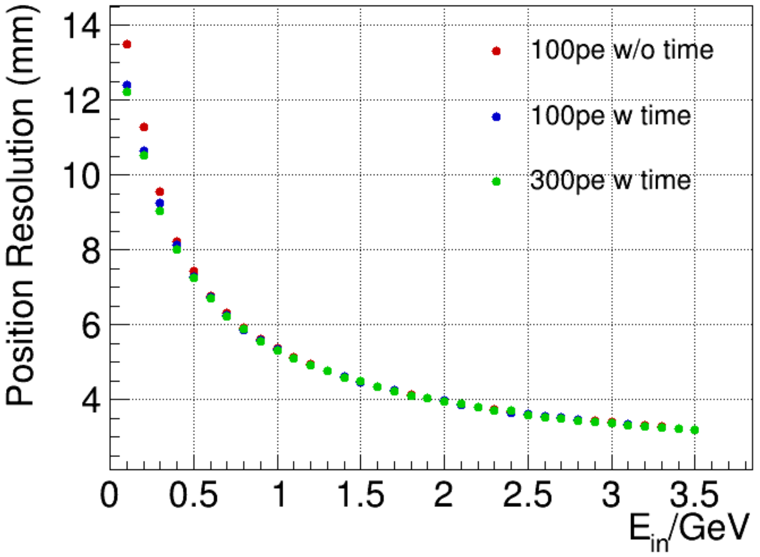
Energy resolution



Time resolution



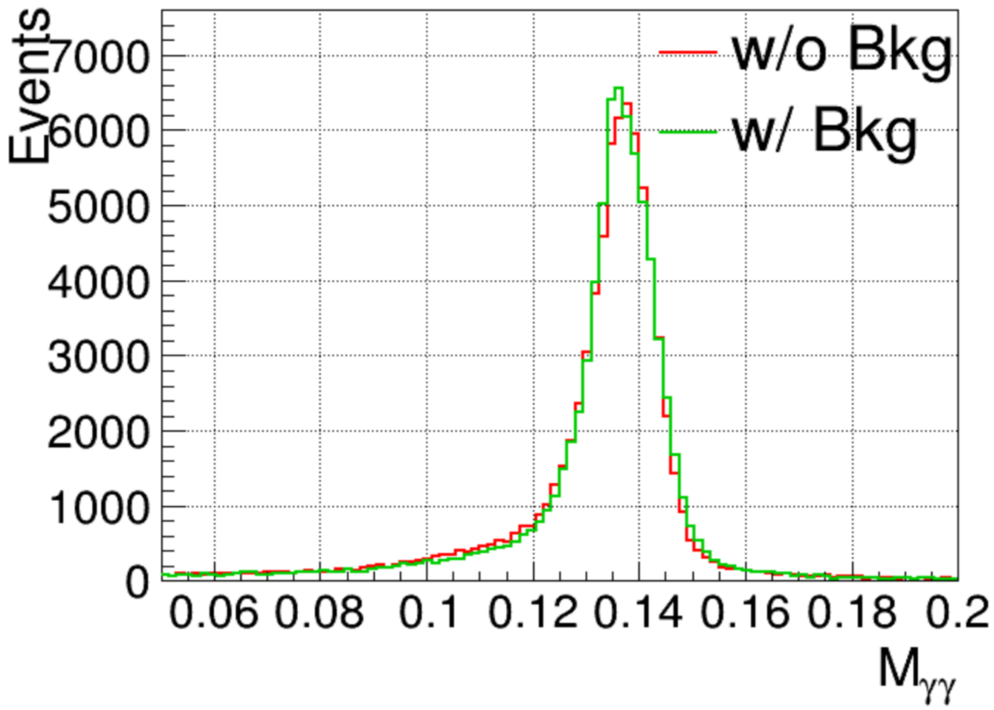
Position resolution



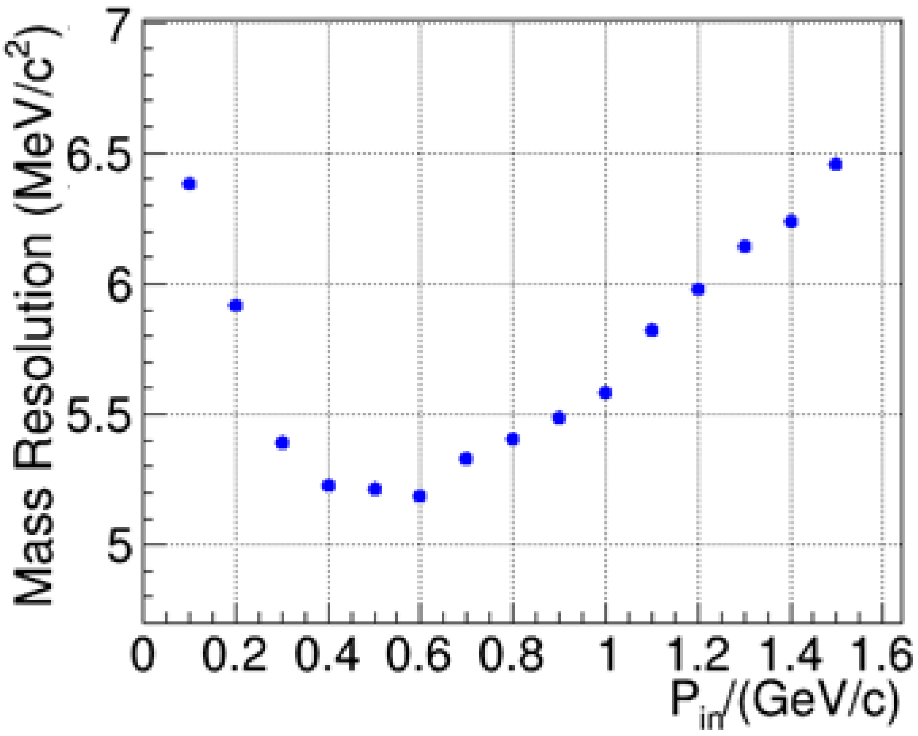
π^0 reconstruction performance

- Developed **4D EMC clustering algorithm** to improve photon resolution against beam backgrounds
  - No degradation of π^0 resolution with beam backgrounds

π^0 mass resolution in $J/\psi \to \rho\pi$



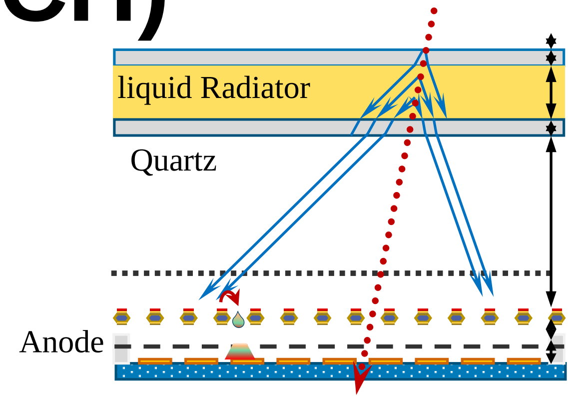
π^0 mass resolution vs π^0 momentum



PID performance

π/K PID performance (RICH)

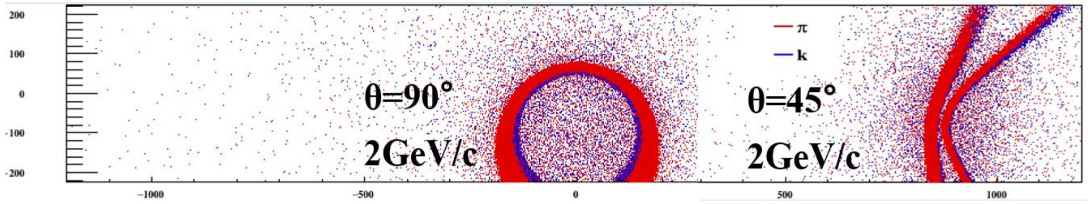
- Three **RICH** reconstruction algorithms (**PDF/thetaC/CNN method**), achieving >97% π eff @ K mis-ID=2%
  - Combining PDF (better performance, used for **high** p_T tracks) + θc reconstruction (low CPU cost, used for **low** p_T tracks)
  - CNN can further improve the performance at low p_T



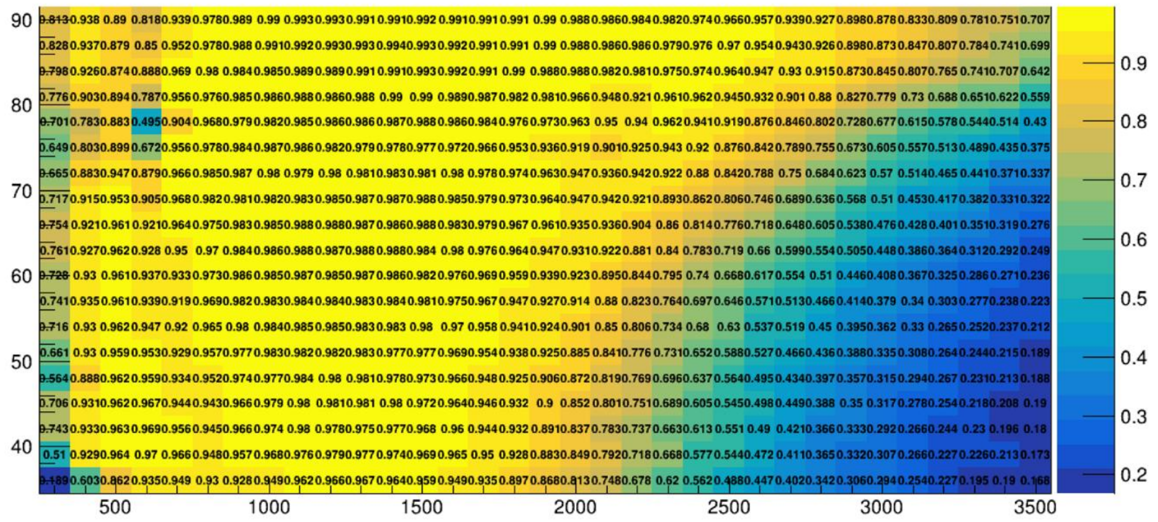
PDF: $\ln \mathcal{L}_h = \sum_{pixel} \ln[\, \text{Poisson}(N_i, pdf_{i,h}^{Chkv} + pdf_i^{bg})]$

θc: $\ln \mathcal{L}_h = \sum_{Hit} \ln[Npe * Gauss(\overline{\boldsymbol{\theta}_c}, \boldsymbol{\sigma}_{\boldsymbol{\theta}_c}) + Bkg]$

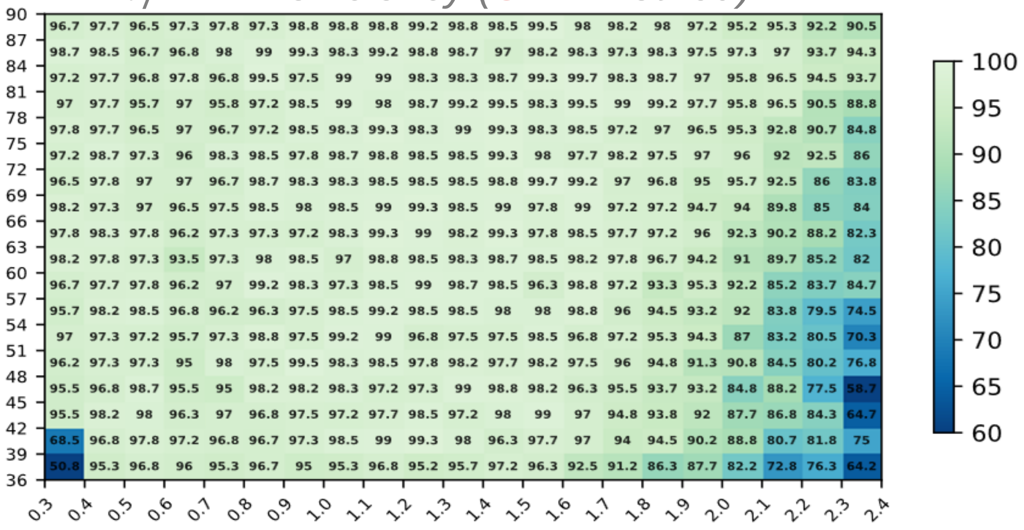
CNN: Take the Cherenkov photon distribution as an image



π/K PID efficiency (combined PDF + θc method)



π/K PID efficiency (CNN method)

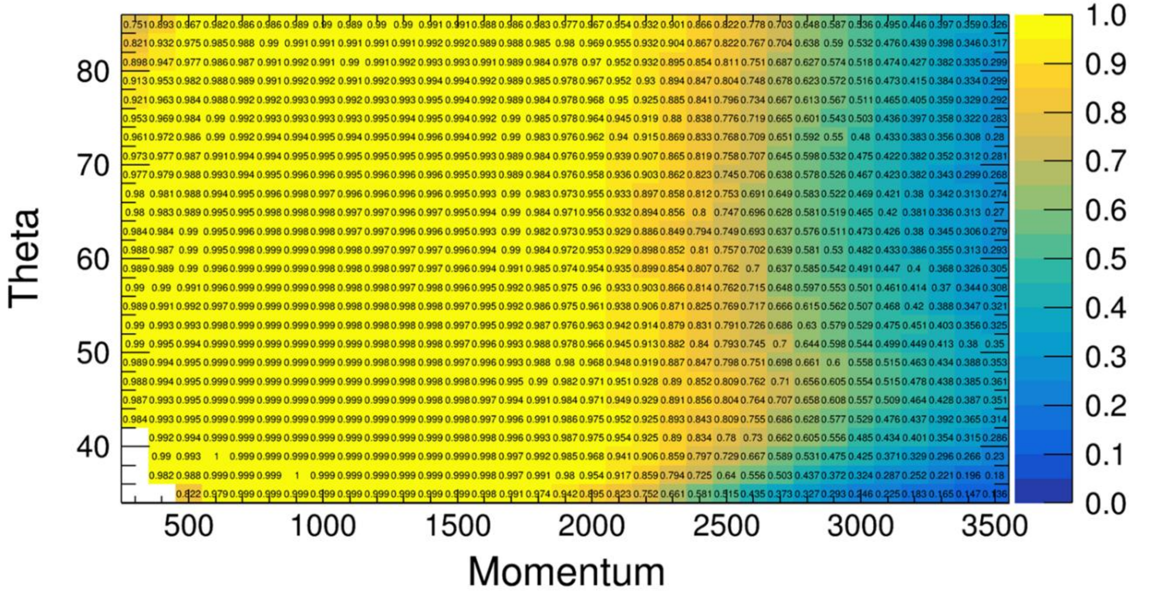


More about CNN method in [Wanlin Lin's talk]

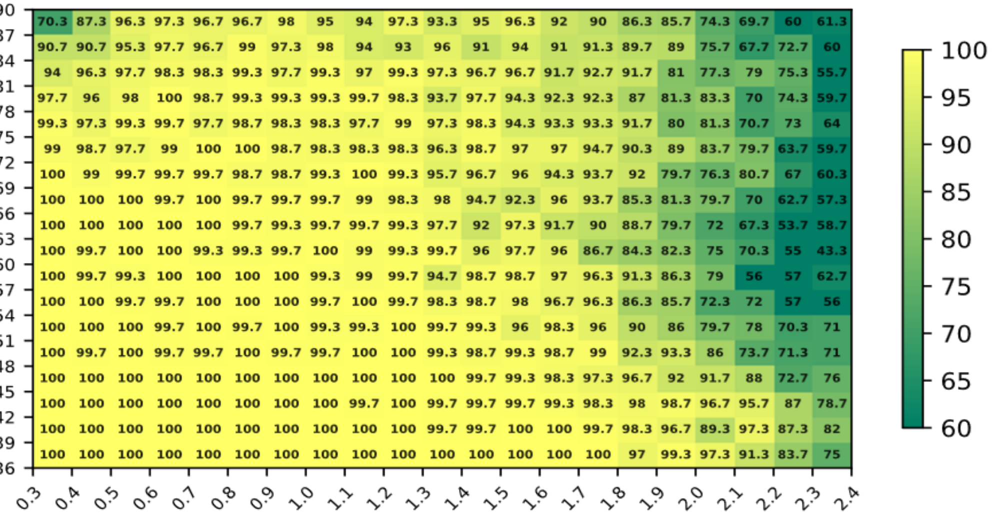
π/K PID performance (BTOF)

- Three **BTOF** reconstruction algorithms (**Timing/Imaging/CNN method**), achieving >97% π eff @ K mis-ID=2%

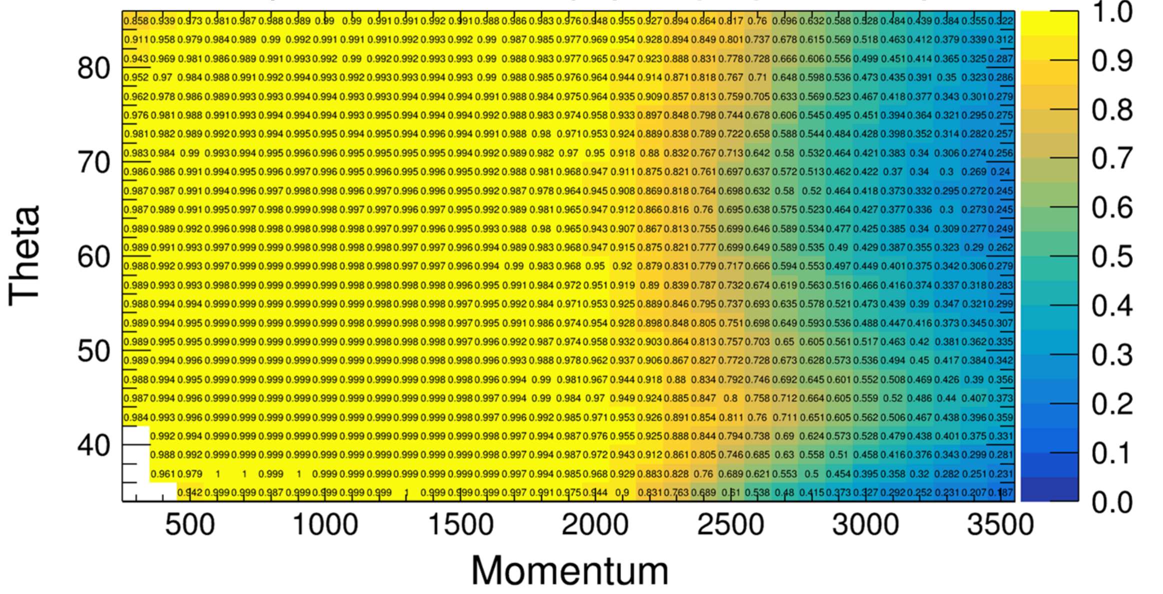
π/K PID efficiency (Timing method)



π/K PID efficiency (CNN method)



π/K PID efficiency (Imaging method)

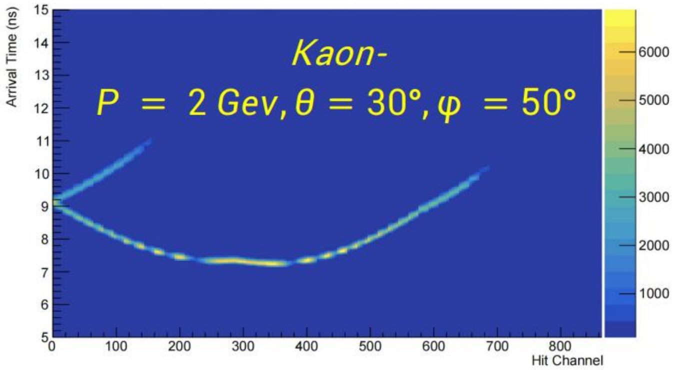


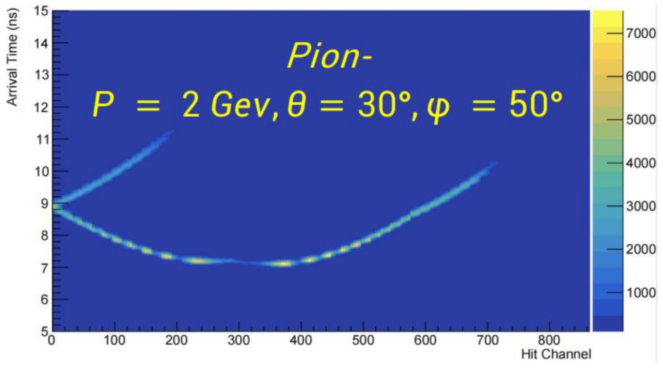
More about Timing and Imaging methods in [Teng Ma's talk]

More about CNN method in [Wanlin Lin's talk]

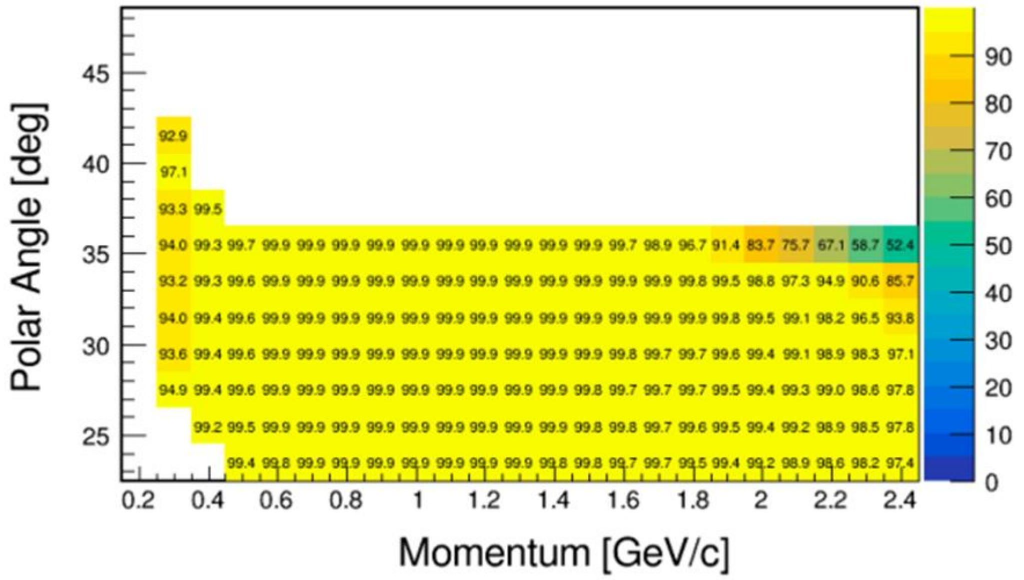
π/K PID performance (DTOF)

- Three DTOF reconstruction algorithms (**Timing/Imaging/CNN method**), achieving >97% π eff @ K mis-ID=2%
  - **CNN** is deployed to improve the performance in region with large polar angle and momentum

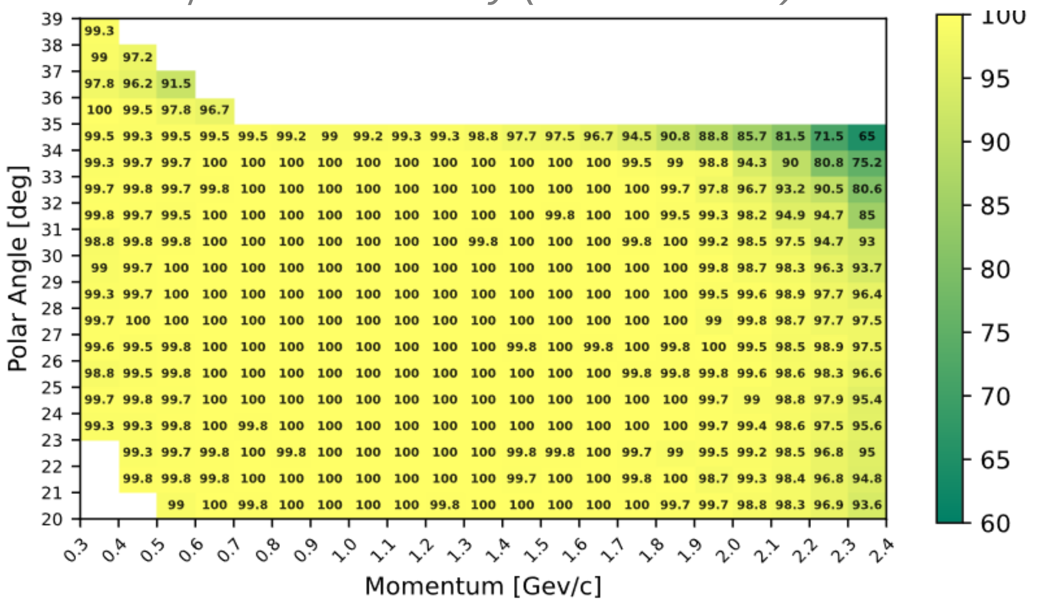




π/K PID efficiency (Imaging method, better performance than timing method, not updated with latest geometry)



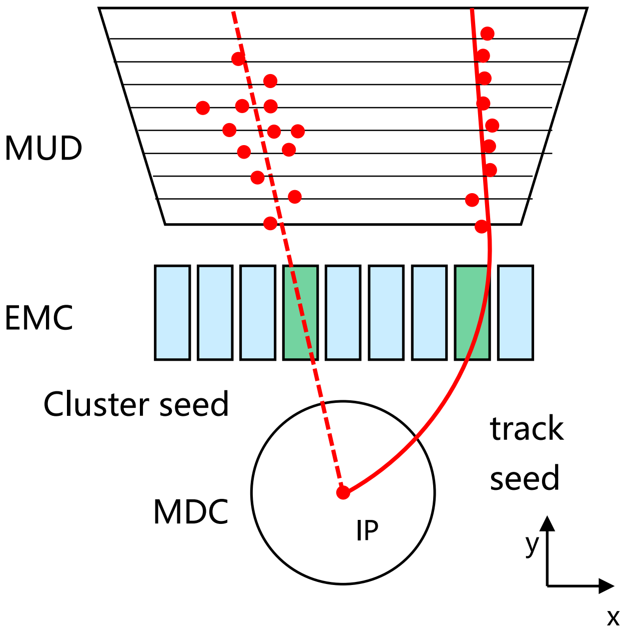
π/K PID efficiency (CNN method)



More about CNN method in [Wanlin Lin's talk]

μ/π PID performance (MUD)

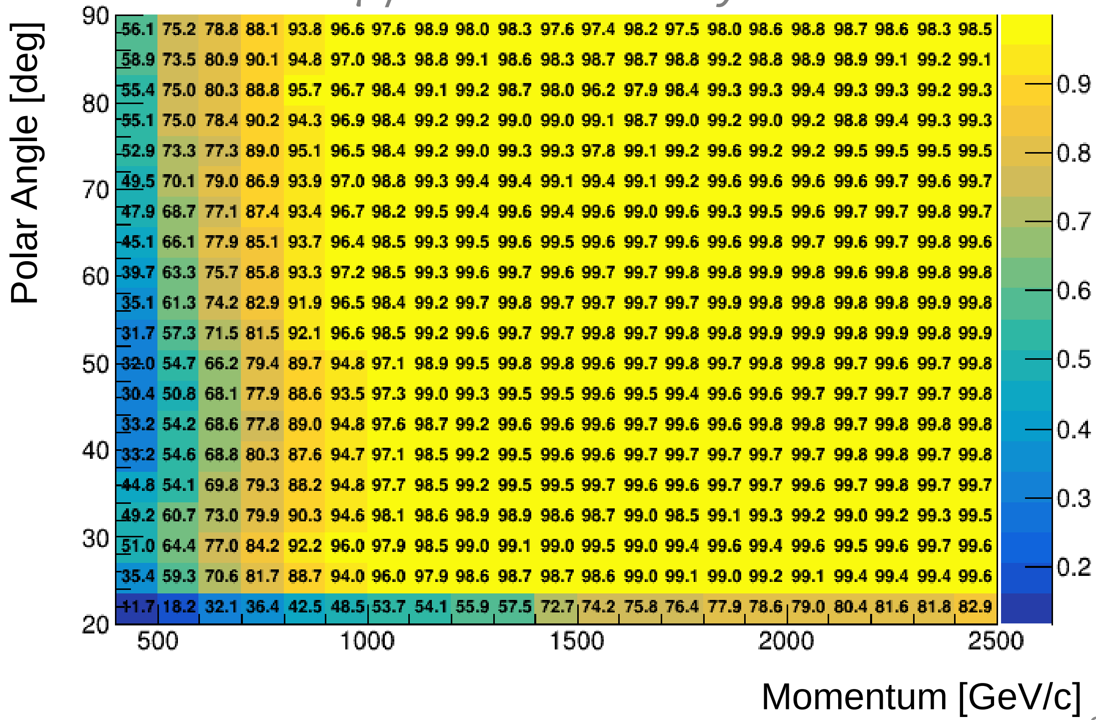
- Obtained μ/π identfication efficiency using **BDT** with variables about MDC, EMC and MUD reco
  - μ efficiency is above **95%** @suppression = 30 with momentum above **1 GeV**
  - A new detector design has been proposed and improves the performance in low energy region
- Identification between neutral hadron (n, KL) and photon is being optimized



BDT variables

TrackInfo	ClusterInfo
MomentumMag	SeedTheta
SeedTheta	SeedPhi
SeedPhi	DeltaTheta
DeltaTheta	DeltaPhi
DeltaPhi	LargestDistance
LargestDistance	MaxHitLayer
MaxHitLayer	MaxHit
MaxHit	LastLayerInBarrel
LastLayerInBarrel	LastLayerInEndcap
LastLayerInEndcap	PSHitCenter
HitAverageDistance	LowHitCenter
HitEntries	HitEntries
HitInRPC	HitInRPC
HitInPS	HitInPS
TrackType	PSHitNorm1
TrackQuality	PSHitNorm2
EcalEnergy	TrackType
EcalSeedEnergy	EcalEnergy
Eseed/E3x3	EcalSeedEnergy
Eseed/E5x5	Eseed/E3x3
E3x3/E5x5	Eseed/E5x5
EcalDev	E3x3/E5x5
	EcalDev
	EcalTime

μ/π PID efficiency

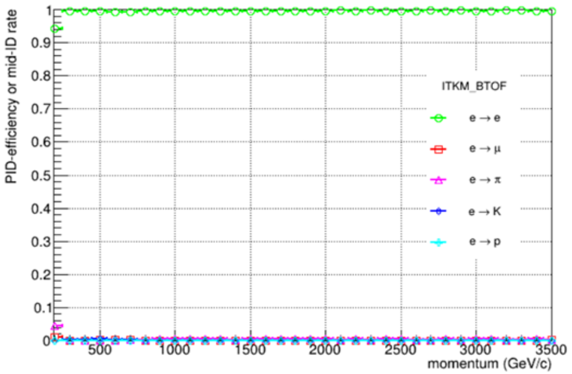


More details in [Yulin Liu’s talk]

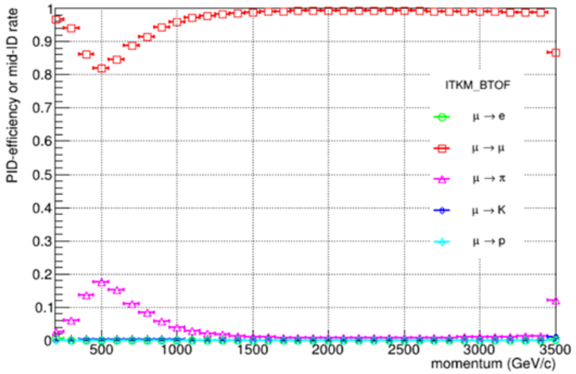
Traditional global PID performance

- A **combined likelihood with weight** was applied to integrate all PID information.
- Different PID information is assigned **different weights** in **different pairwise particle comparisons**.
  - $\mathcal{L}_h = \prod_{det} \mathcal{L}_{det,h}^{w_{det}}$
  - $w \propto \frac{\overline{\mu}_{\Delta logL}}{\overline{\sigma}^2_{\Delta logL}} \propto \frac{N_\sigma}{\overline{\sigma}_{\Delta logL}}$

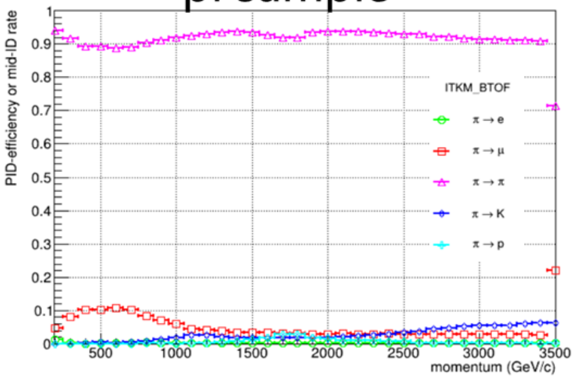
e sample



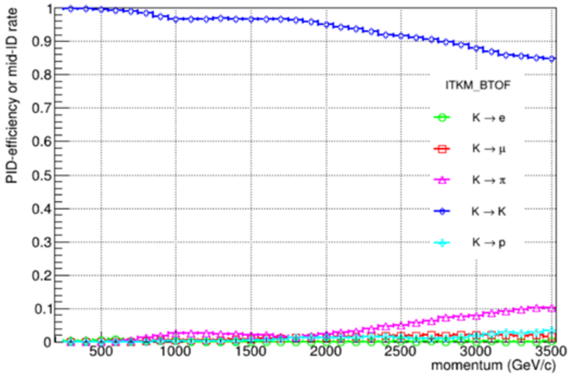
mu sample



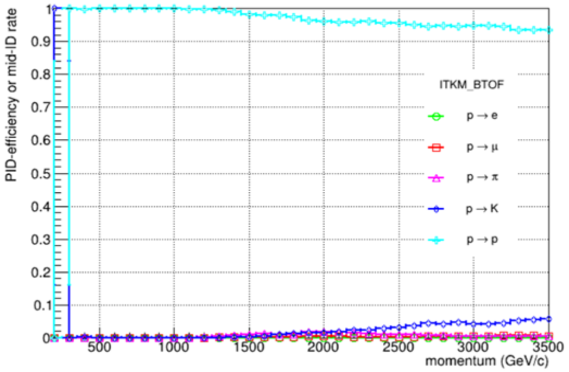
pi sample



K sample



p sample

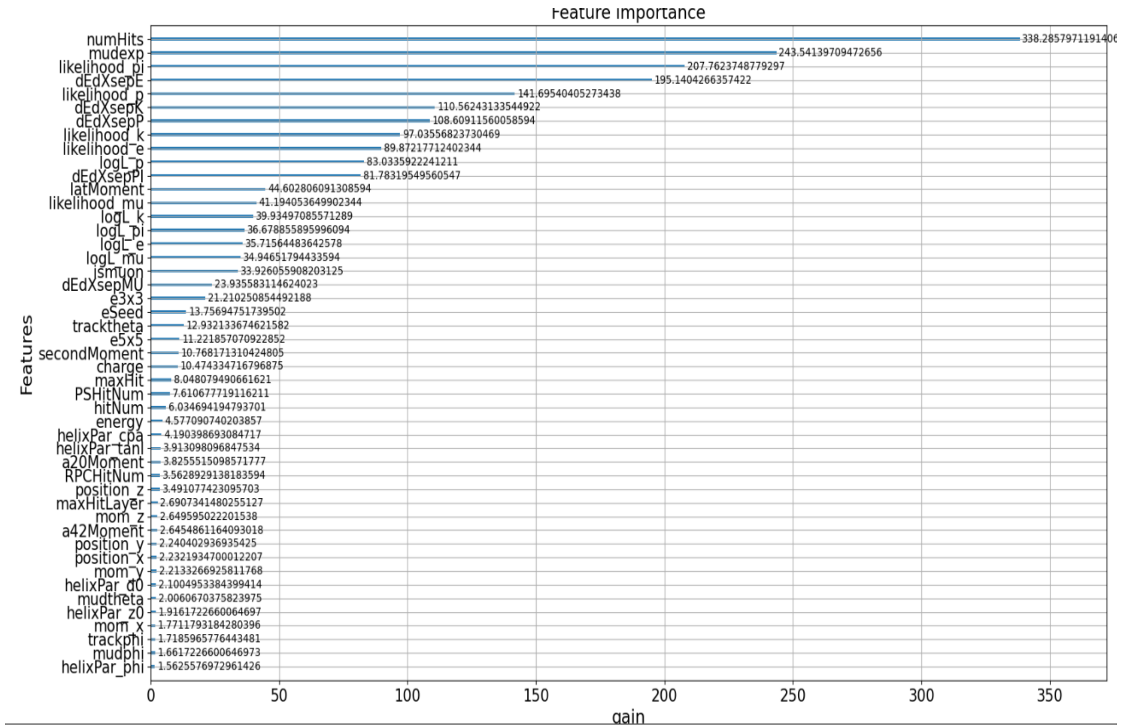


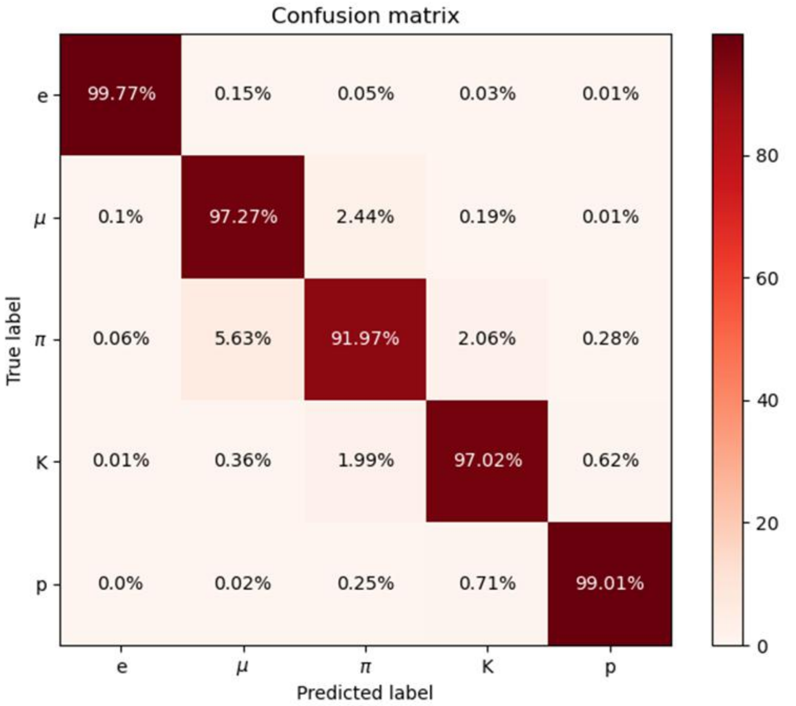
More details in [Binbin Qi's talk]

BDT-based global PID performance

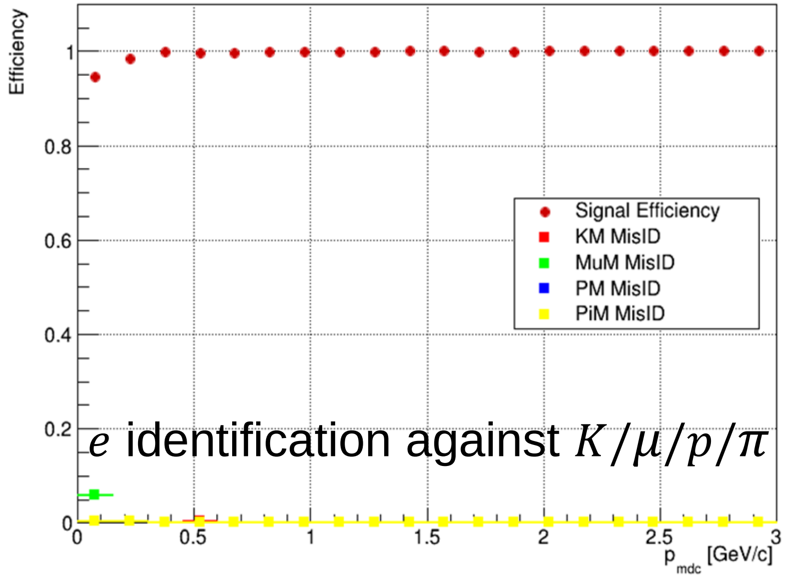
- Combining Tracker/dEdx/BTOF/DTOF/ECAL/MUD reco info (49 features) using BDT
  - **~ 100%** identification efficiency for e and proton
  - **>95%** efficiency for K
  - **> 90%** efficiency for μ (>95% with momentum above 1.5 GeV)
  - **>90%** efficiency for π in most regions

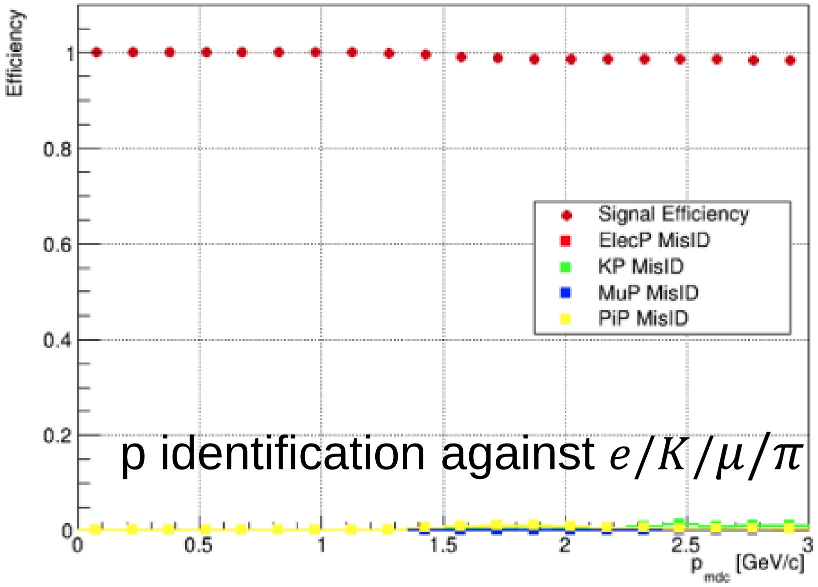
More details in [Yuncong Zhai's slides]

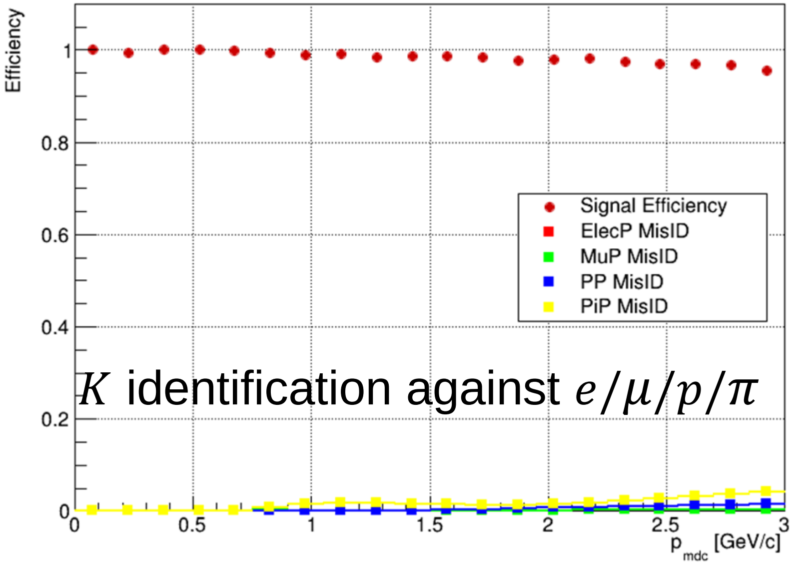


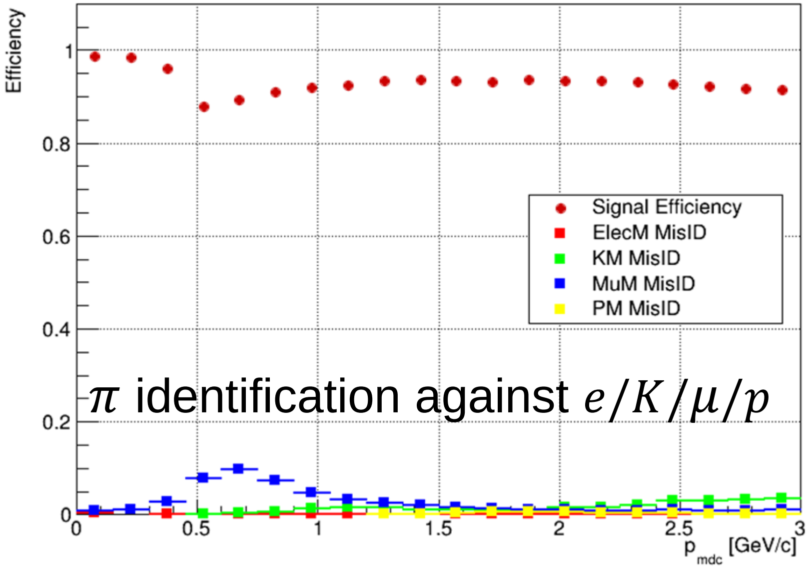


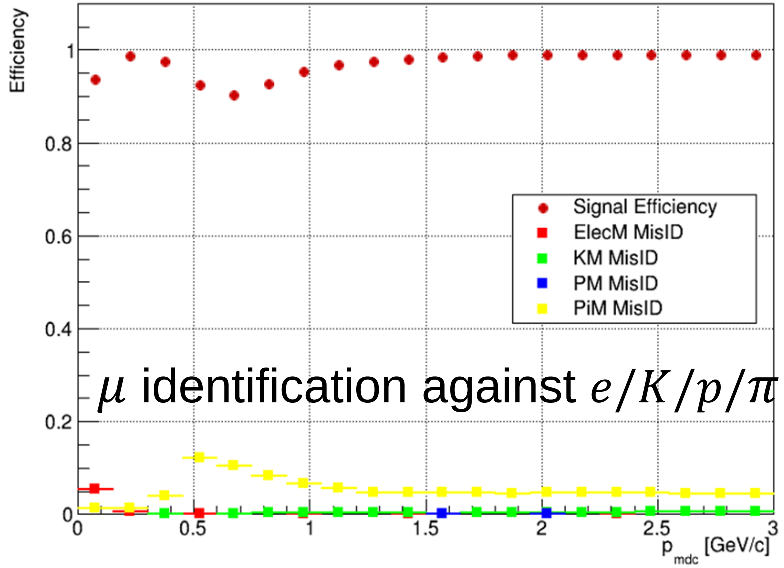
BDT-based global PID performance



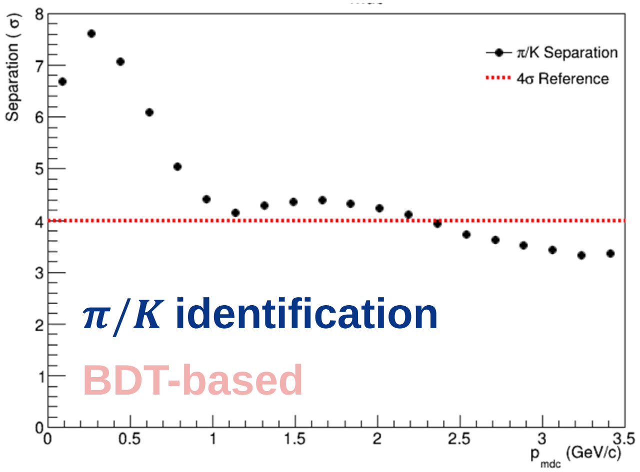




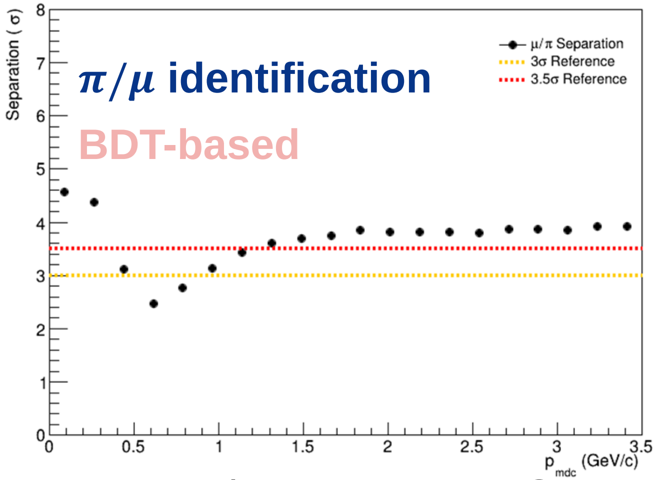




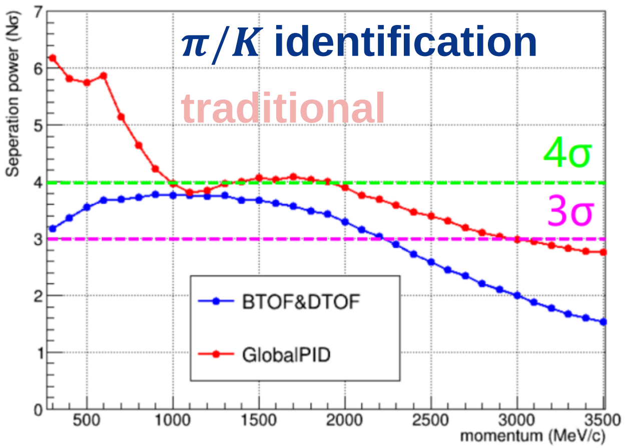
Global PID performance



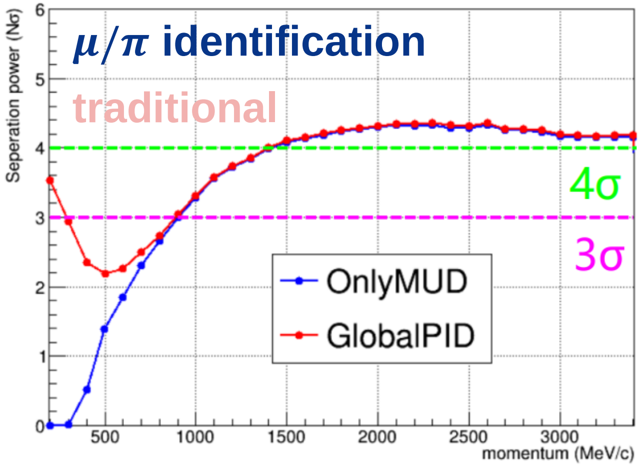
- Separation power >**4σ** @ p < 2 GeV/c
- Separation power > **3σ** in all range



- Separation power >**3σ** @ p > 1 GeV/c
- Separation power > **3.5σ @** p > 1.5 GeV/c



Separation power ≈4 (3) @ p=2 (3) GeV/c



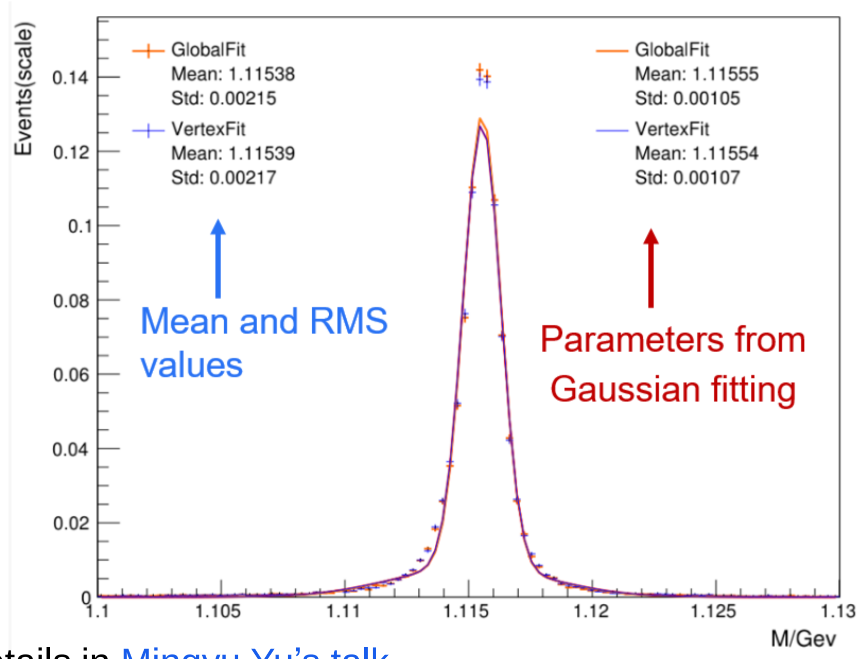
Separation power >3 @ p>0.8 GeV/c

Analysis tools

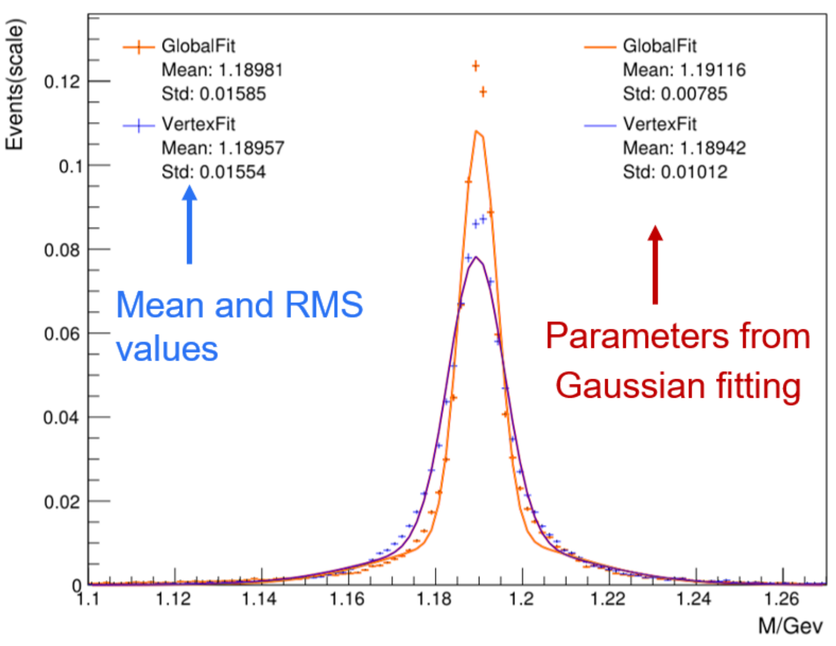
Vertex fit performance

- Designed and developed the **GlobalFit** package for STCF based on the global vertex fitting algorithm of **Belle II**, showing better performance than previous **vertex fit** package (i.e. **VertexFit**) imported from **BESIII**
  - Slightly better mass resolution $\Lambda/\bar{\Lambda}$ for and 1% higher efficiency
  - Improved $\Sigma/\bar{\Sigma}$ resolution by including constraint for decayed photon vertex in the fit

$J/\psi \to \Lambda\bar{\Lambda} \to (p\pi^-)(\bar{p}\pi^+)$



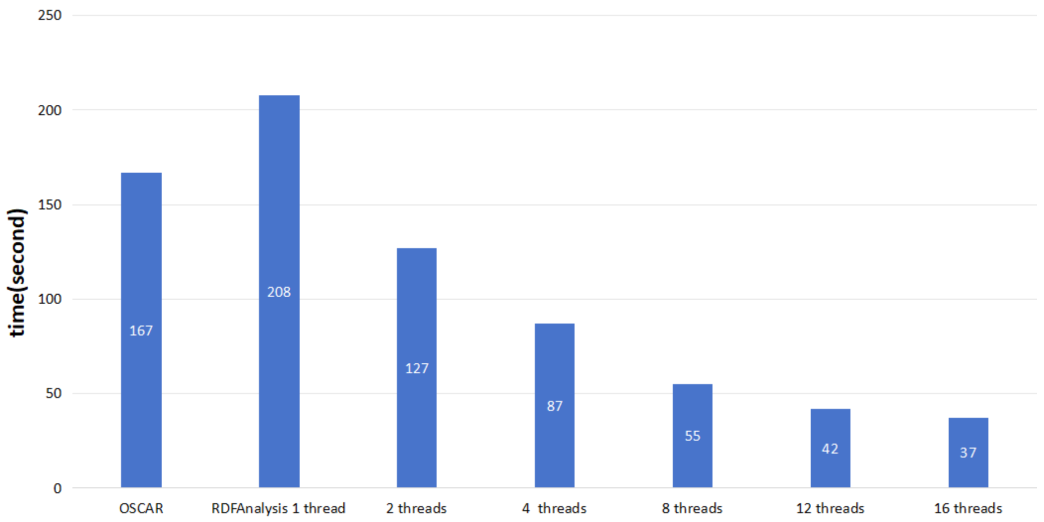
$J/\psi \to \Sigma^+(Pr)\bar{\Sigma}(\pi_0(rr)\bar{P})$

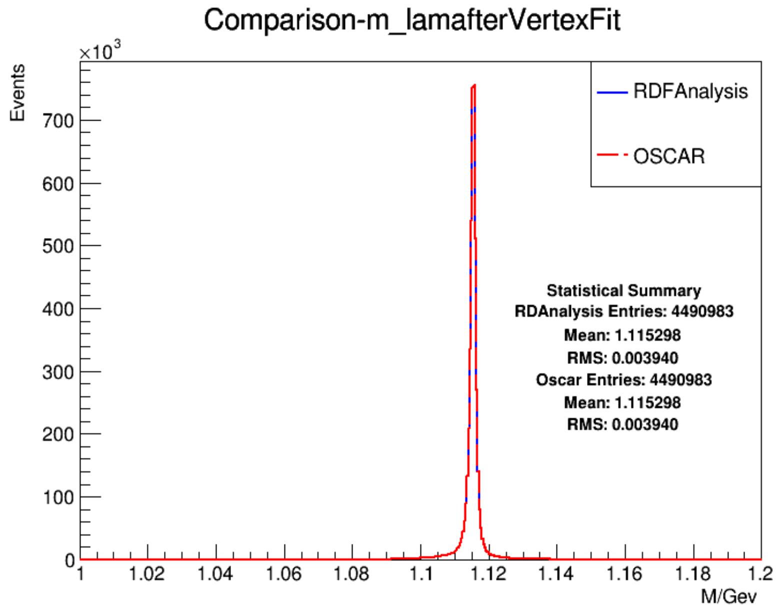


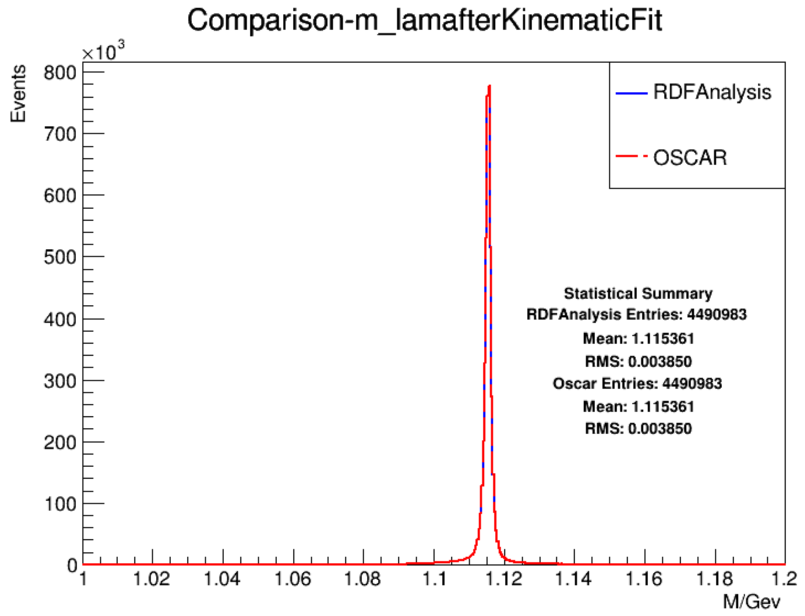
More details in Mingyu Yu's talk

RDataFrame analysis

- RDataFrame-based analysis interface is developed to ease and speed up analysis in OSCAR
- The physics analysis outputs are validated using 10 million $J/\psi \rightarrow \Lambda\bar{\Lambda}$ events
- CPU performance analysis for 200 thousand events
  - RDataFrame-based anlaysis shows better performance utilizing multicores







More details in [Ying Yang's talk]

Analysis examples

$J/\psi \to \Lambda\bar{\Lambda} \to p\pi^-\bar{p}\pi^+$

Courtesy of Mingyu Yu

BESIII Signal MC	Events	Eff. (%)	Re. Eff.(%)
	100000	100.0	
Charged tracks	55912	55.91	
Λ Rec.	45772	45.77	81.86
$\bar{\Lambda}$ Rec.	38341	38.34	83.77
$L_{\Lambda/\bar{\Lambda}}$ cuts	35982	35.98	93.84
4C fit	35293	35.29	98.09

OSCAR Signal MC	Events	Eff. (%)	Re. Eff.(%)
	1000000	100.0	
Charged tracks	640948	64.10	
Λ Rec.	506784	50.68	79.07
$\bar{\Lambda}$ Rec.	400592	40.06	79.05
$L_{\Lambda/\bar{\Lambda}}$ cuts	384515	38.45	95.98
4C fit	376990	37.70	98.04

- Better tracking efficiency than BESIII
- Final event selection at STCF is **2.4% higher** than BESIII

$J/\psi \rightarrow \Xi^-\bar{\Xi}^+ \rightarrow \Lambda\pi^-\bar{\Lambda}\pi^+ \rightarrow p\pi^-\pi^-\bar{p}\pi^+\pi^+$

Courtesy of Yue Xu

BESIII	Events	Eff. (%)	Re. Eff.(%)
	9,000,000	100.0	
Charged tracks	3057857	34.0	
Λ、Ξ^- Rec.	2545353	28.3	83.2
$\bar{\Lambda}$、$\bar{\Xi}^+$ Rec.	2092432	23.2	82.2
4C fit	1724213	19.2	82.4
χ^2_{4C} cut	1526267	17.0	88.5
$L_{\Xi^-/\bar{\Xi}^+}$ cuts	1359450	15.1	89.1
$M_{\Xi^-/\bar{\Xi}^+}$ cuts	1281108	14.2	94.2
$M_{\Lambda/\bar{\Lambda}}$ cuts	1126527	12.5	87.9

- Better tracking efficiency than BESIII
- Final event selection efficiency suffers from more background hits at STCF
  - Room for improvement after background hits and fake/duplicate tracks resolving

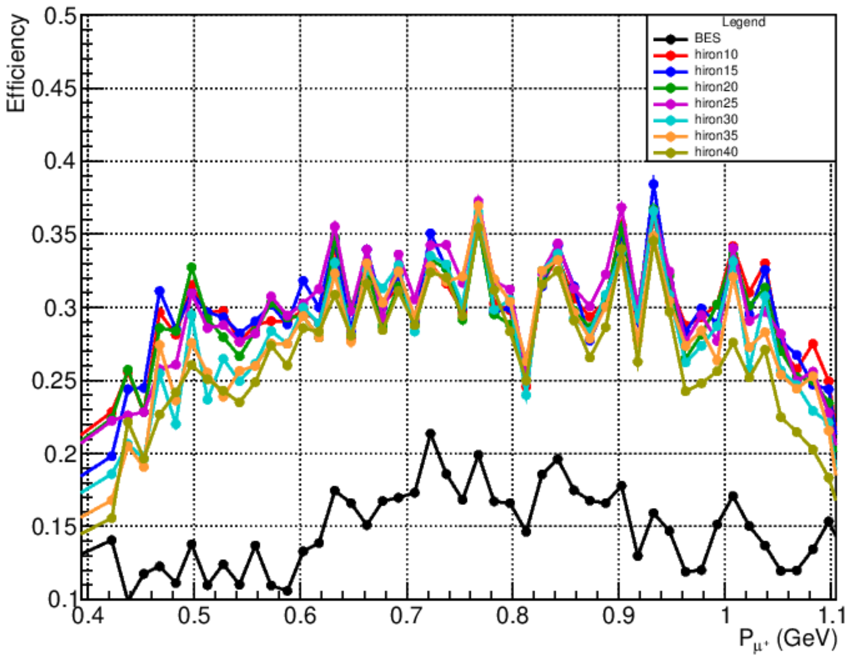
OSCAR (no bkg mix)	Events	Eff. (%)	Re. Eff.(%)
	200,000	100.0	
Charged tracks	106291	53.1	
Λ、Ξ^- Rec.	85268	42.6	80.2
$\bar{\Lambda}$、$\bar{\Xi}^+$ Rec.	68674	34.3	80.5
4C fit	44665	22.3	65.0
χ^2_{4C} cut	40014	20.0	89.6
$L_{\Xi^-/\bar{\Xi}^+}$ cuts	36764	18.4	91.9
$M_{\Xi^-/\bar{\Xi}^+}$ cuts	35385	17.7	96.3
$M_{\Lambda/\bar{\Lambda}}$ cuts	31196	15.6	88.2

OSCAR (phy + beam bkg mix)	Events	Eff. (%)	Re. Eff.(%)
	200,000		
Charged tracks	108823	54.4	
Λ、Ξ^- Rec.	85303	42.7	78.4
$\bar{\Lambda}$、$\bar{\Xi}^+$ Rec.	66600	33.3	78.1
4C fit	37102	18.6	55.7
χ^2_{4C} cut	31479	15.7	84.8
$L_{\Xi^-/\bar{\Xi}^+}$ cuts	27899	13.9	88.6
$M_{\Xi^-/\bar{\Xi}^+}$ cuts	26471	13.2	94.9
$M_{\Lambda/\bar{\Lambda}}$ cuts	22698	11.3	85.7

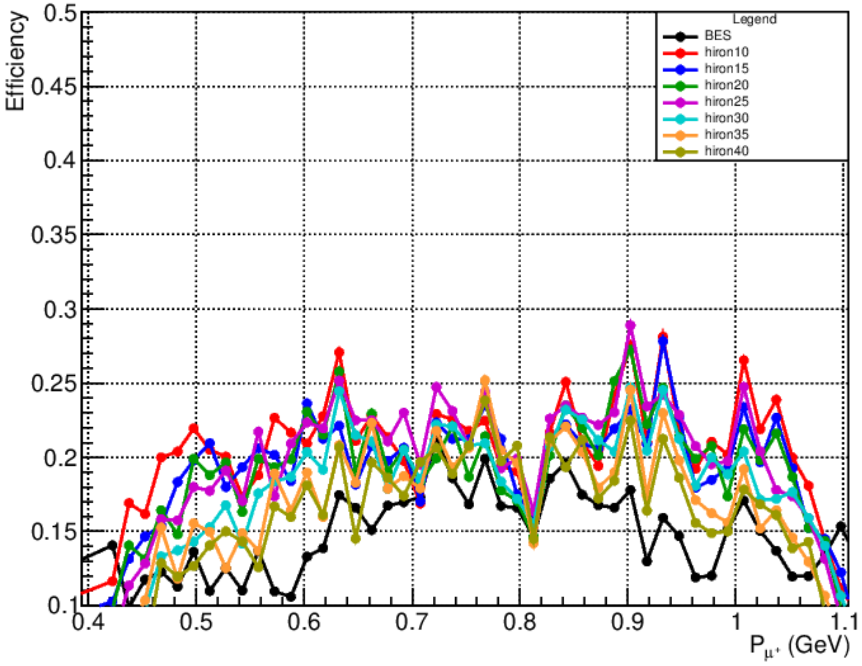
$J/\psi \to \mu^+\mu^-\eta$

Courtesy of Yi Li

efficiency @ mis-ID efficiency = 3.33%



efficiency @ mis-ID efficiency = 1%



- Better μ/π identification efficiency than BESIII

Summary

STCF offline software status

Tasks				ITKW	ITKM	MDC	BTOF	RICH	DTOF	EMC	MUD
Simulation				good state	good state	good state	good state	good state	good state	good state	good state
Bkg mixing				under optimization	under optimization	under optimization	under optimization	under optimization	under optimization	under optimization	under optimization
Digitization				good state	good state	under optimization	good state	good state	good state	under optimization	good state
Reconstruction	Charged tracks			good state	good state	good state	Irrelevant	Irrelevant	Irrelevant	good state	good state
	dE/dx			Irrelevant		under optimization	Irrelevant				
	Photon			Irrelevant						good state	Irrelevant
	T0			Irrelevant	Irrelevant	under optimization	under optimization	Irrelevant	under optimization	Under development	Irrelevant
PID	sub-detector PID			Irrelevant	Irrelevant	under optimization	under optimization	good state	good state	under optimization	under optimization
	global PID	ML-based	Charged	good state							
			Neutral	Irrelevant						Under development	Under development
		Likelihood-based	Charged	under optimization							
			Neutral	Irrelevant						Under development	Under development
Analysis	Vertex fit, Kinematic fit			good state			Irrelevant			good state	Irrelevant
Detector optimization				under optimization	under optimization	under optimization	under optimization	under optimization	under optimization	under optimization	under optimization
Event display				under optimization							
Calibration&Alignment				Under development							
CPU&disk optimization				under optimization							

- good state
- under optimization
- Under development
- Irrelevant

Summary

- STCF offline software has much matured in the past two years providing **full functionalities of simulation + digitization + reconstruction + analysis**
  - Supporting tens of **physics feasibility studies** and **detector optimization** towards STCF TDR
- Both traditional and **ML-based algorithms** are deployed for tracking and PID (and fast EMC simulation)
  - Tracking, photon and PID performance can fulfill CDR requirements
  - Still room for improvement in difficult phase space (e.g. low p_T/displaced tracks), and in CPU consumption
- Developed STCF-dedicated global vertex fit package with better performance
- Developed RDataFrame-based analysis to facilitate fast physics analysis
- The performance with optimized detector geometry is being consolidated

Thanks for your attentions!

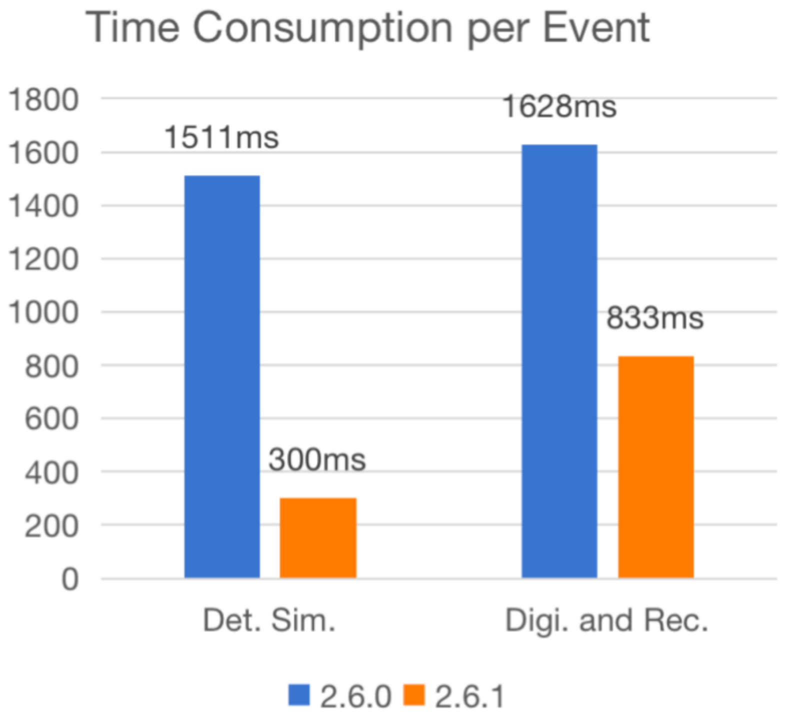
Many thanks to all people of the software group!

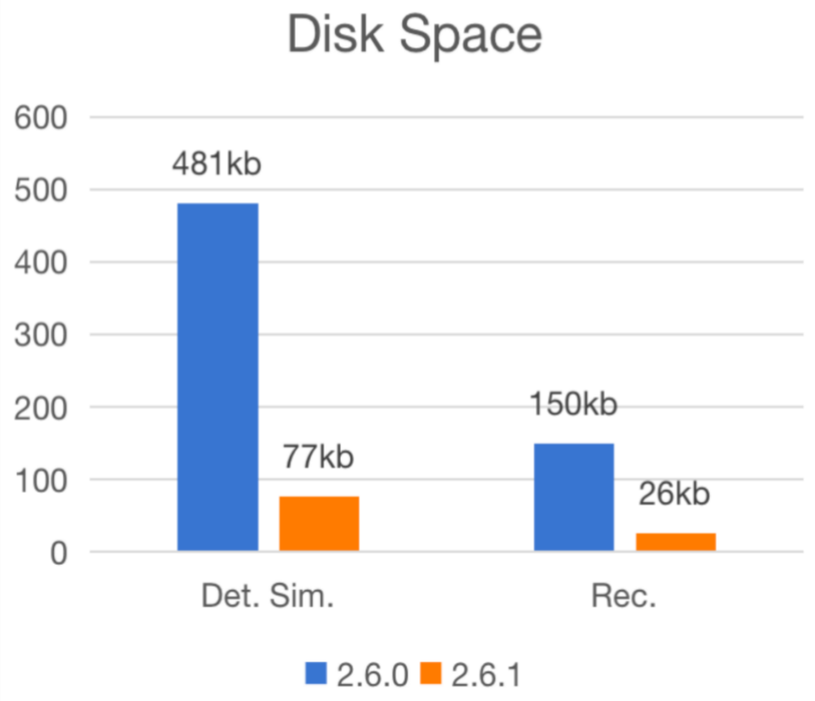
And many thanks to the physics simulation group for the inputs and feedbacks!

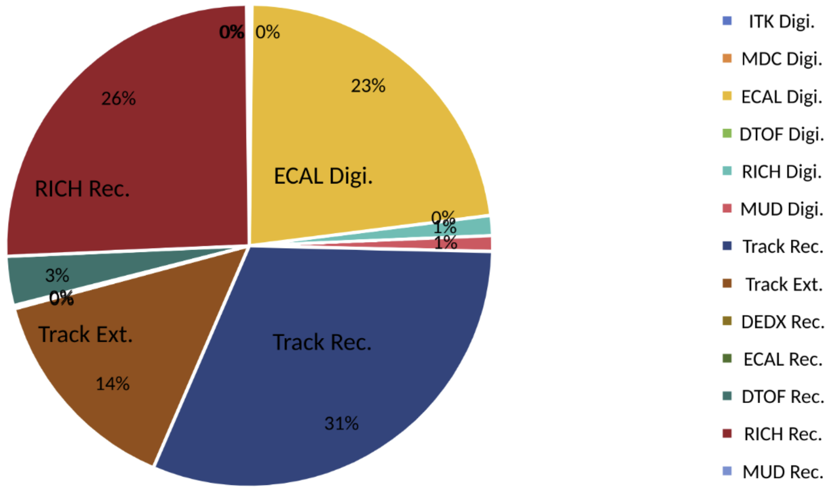
backup

CPU performance status

- Much improved CPU consumption and disk space (comparable to BESIII now)

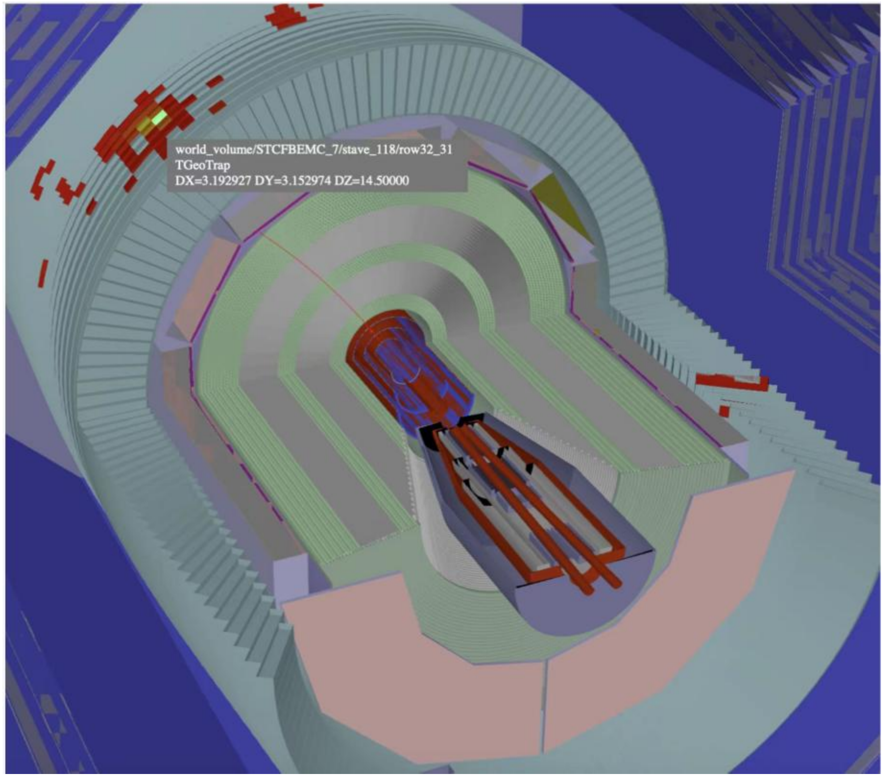


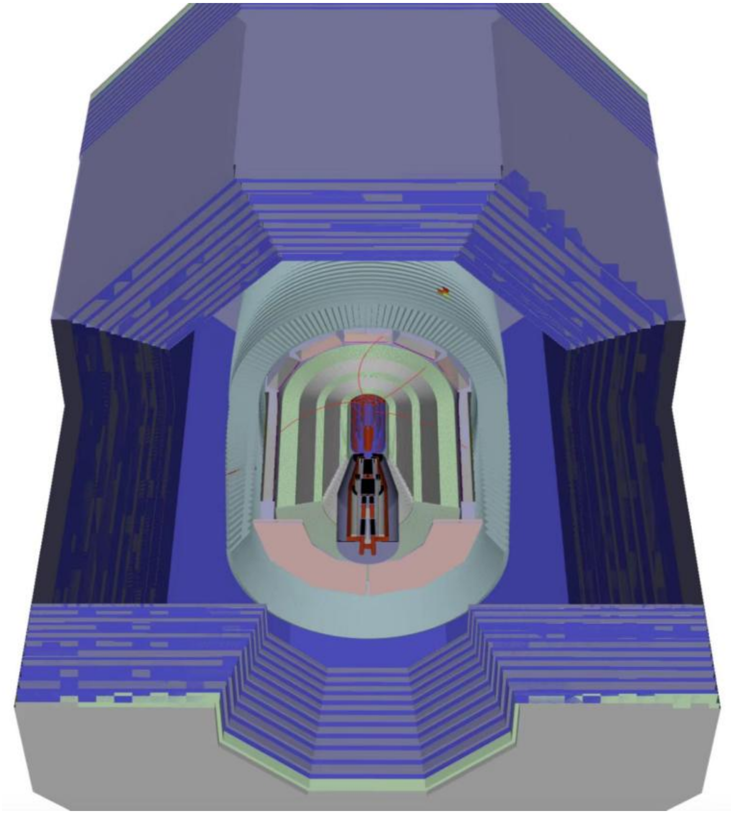




Event display

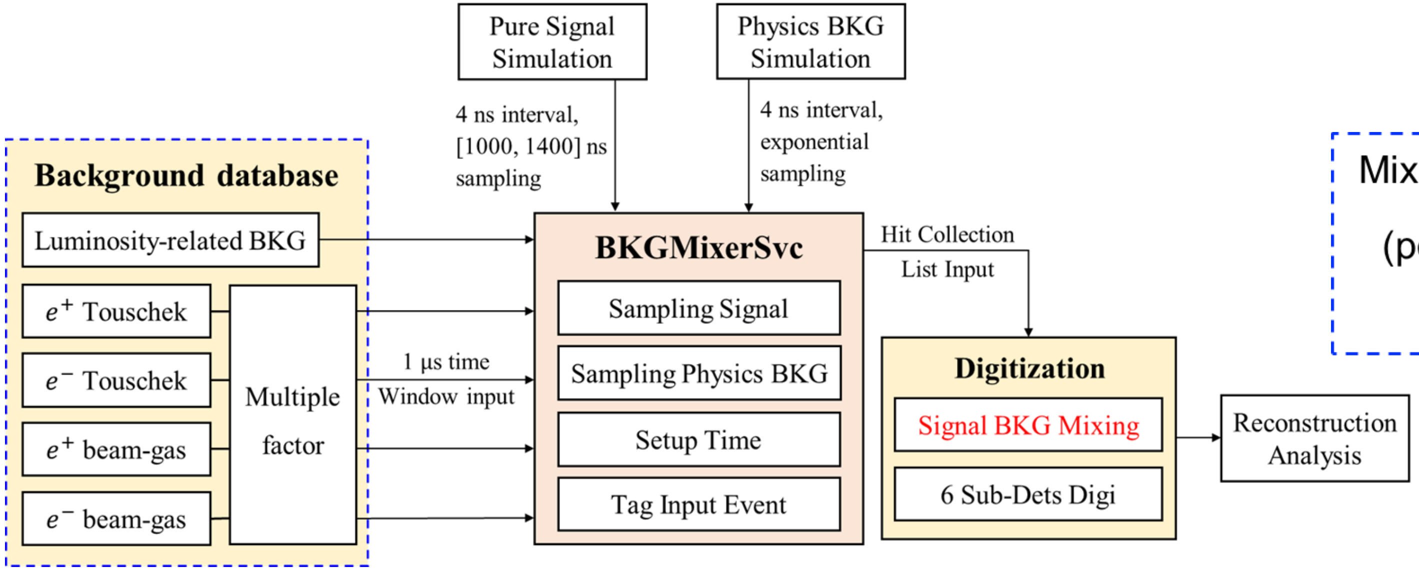
- A common geometry and event display system is being developed
  - Based on **Web3D** technology and the open-source **JSROOT**
  - 3D engine and graphic library based on **Three.JS**
  - Using the Vue.js HTML5 development framework toimplement the **Web interface**





Background mixing

- Event mixing with background at the **Geant4 step level**
  - Simulated background particles as input, a unified algorithm applied to each sub-detector.
- Raw hit data digitized to emulate the **detector measurement**
  - Considering **electronic response, noise and other effects,** as input for reconstruction and analysis



Mixing in Geant4 Step Level

(points or hits in OSCAR)

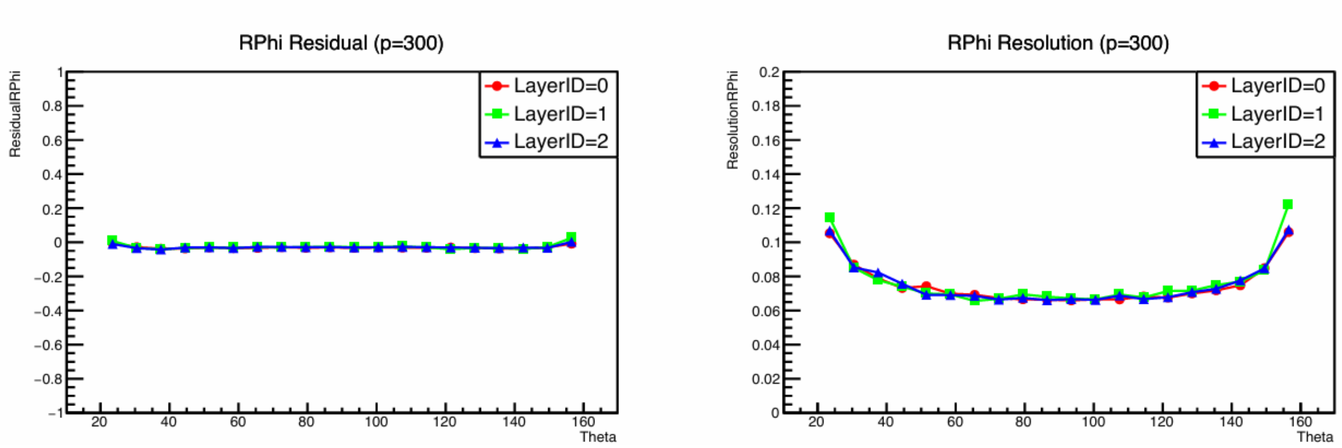
then to do digitization

- Another Mixing Framework
  - Some or all hits **mixing in digi. hit level**, pre-digitize the Bkg raw hit to produce **a Bkg digi. Database**
  - **One order of magnitude time savings**, but the digi merge methods **is developing**

Digitization

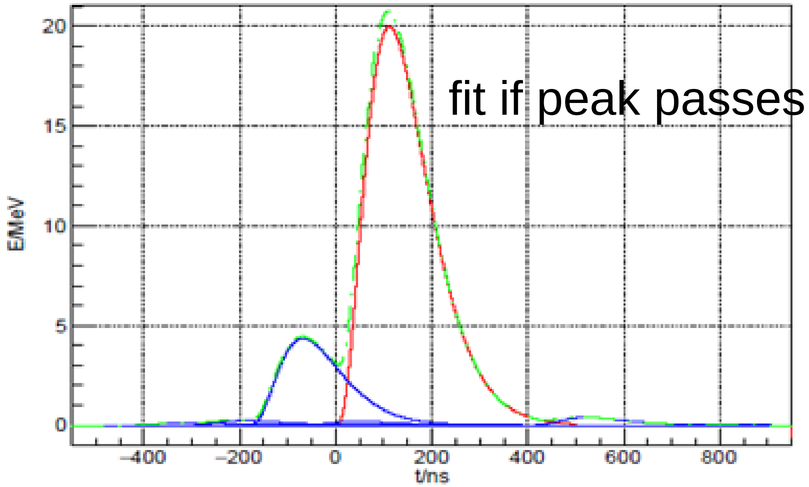
- Developed a **unified digitization framework** for all sub-detectors within OSCAR
- All sub-detector moved to **sampling method,** including **MDC dE/dx** and **hit position**
- Got **breakthrough** in the **correction of offset** for **ITKW**'s reconstruction position
- New **waveform fitting strategy** for **ECAL**, time with BKG mixing improved from **~20s to 10s**
- A more **precise** digital model of **MUD**, including aspects such as **efficiency and time accuracy**

offset and resolution of ITKW in rφ direction

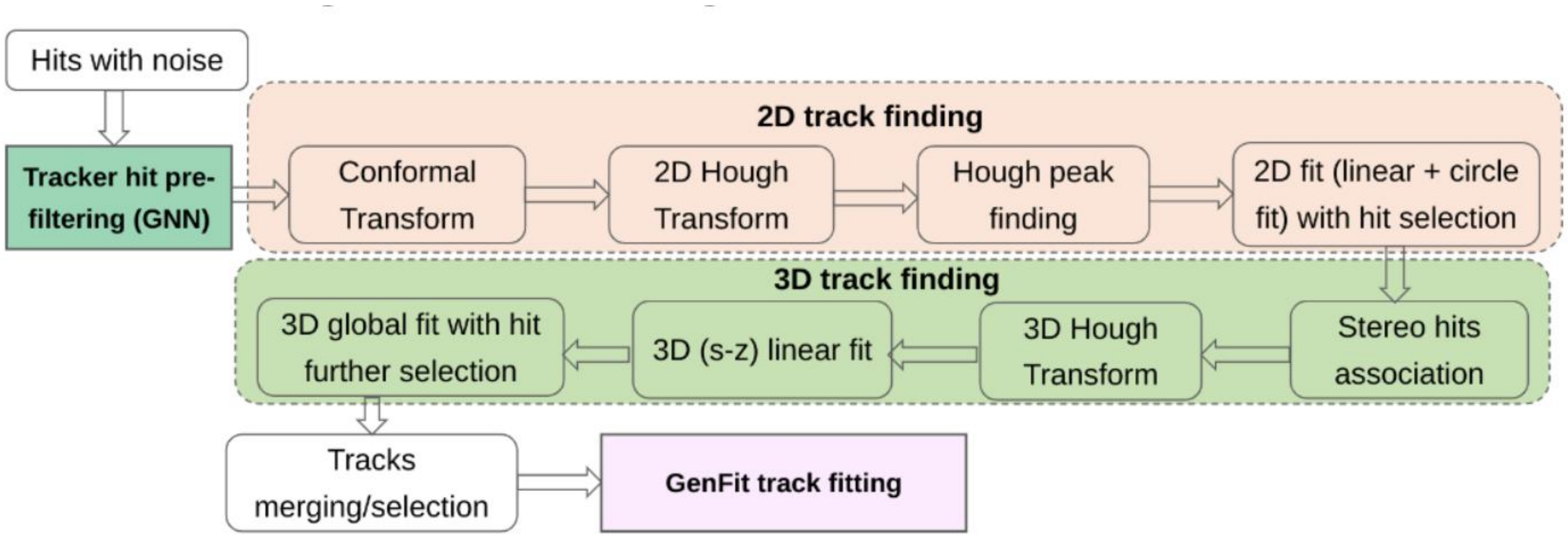


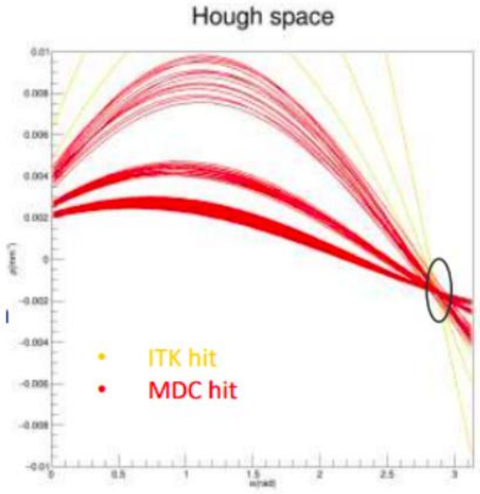
300 MeV/c kaon

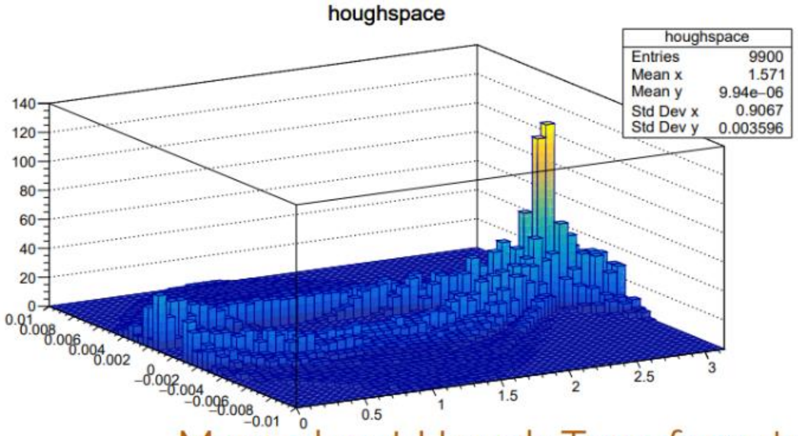
ECAL pipeline fitting

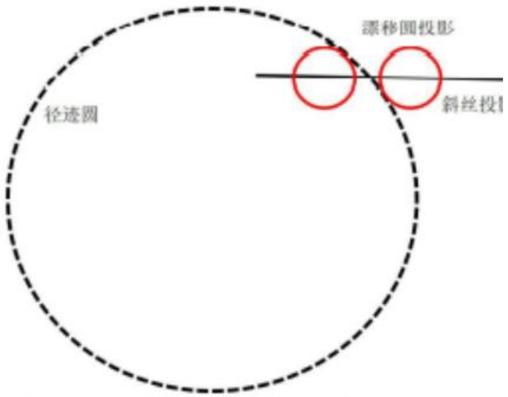


Hough tracking workflow





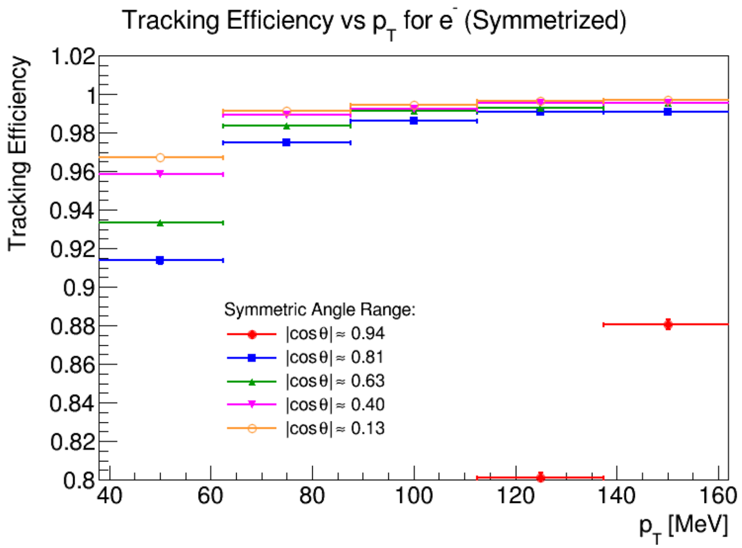


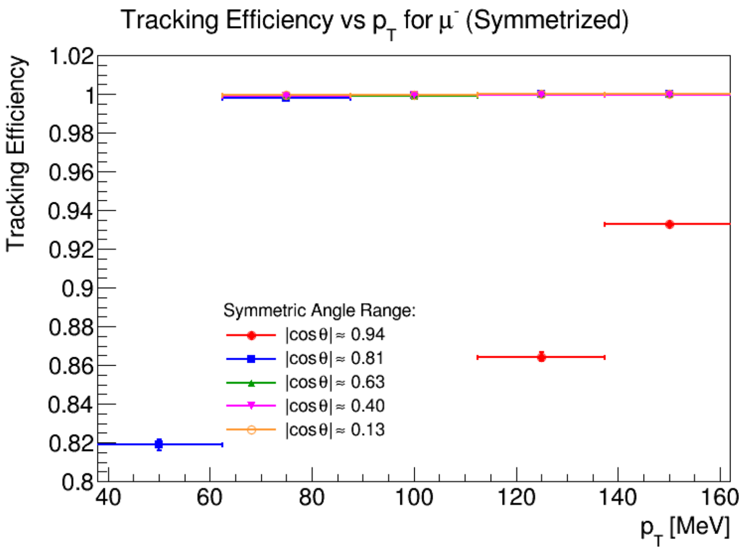


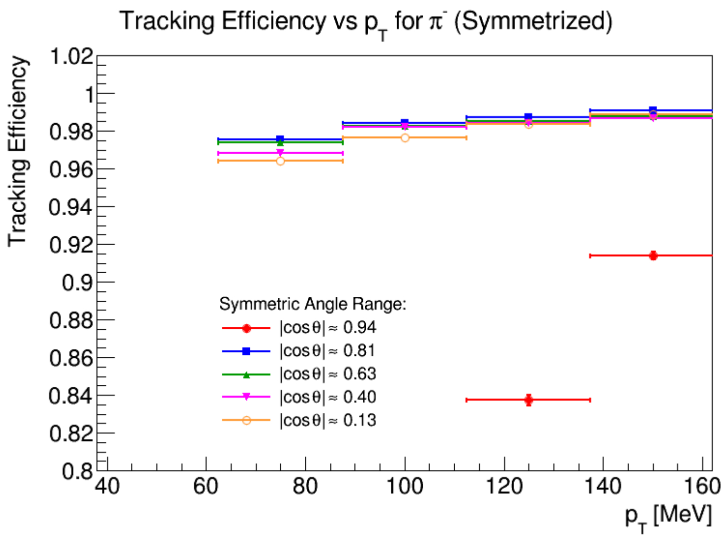
More about Hough Transform tracking in H. Zhou's talk

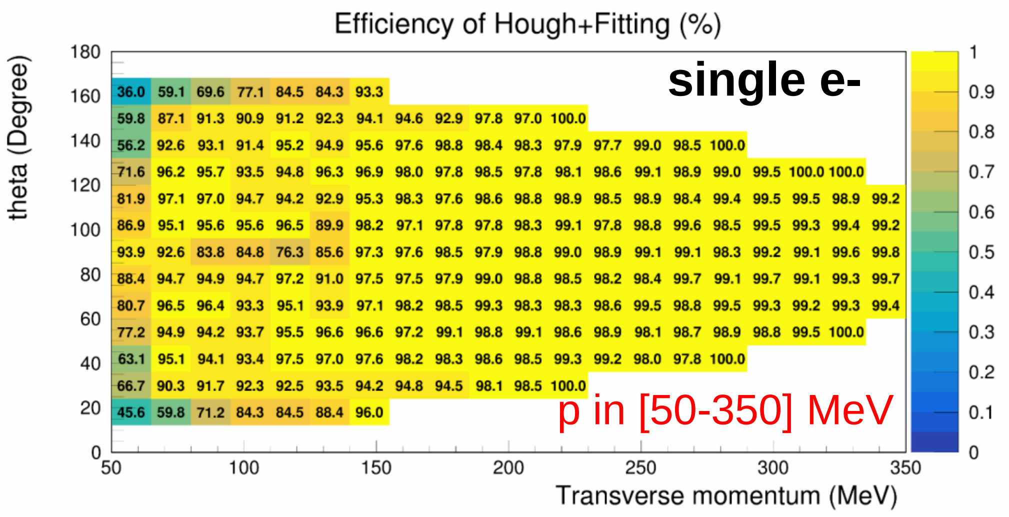
Single particle tracking efficiency

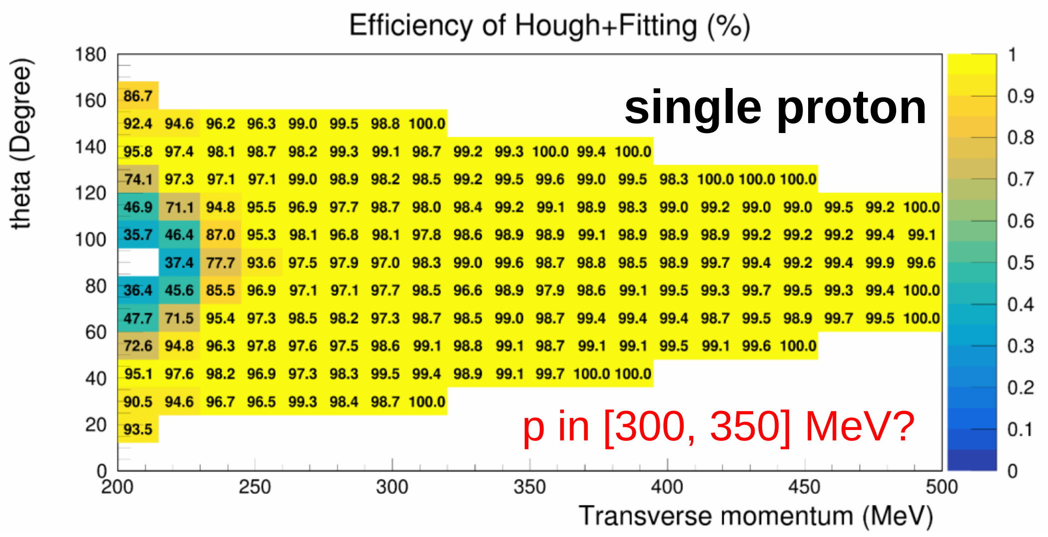
ITKM + MDC, W/ bkg





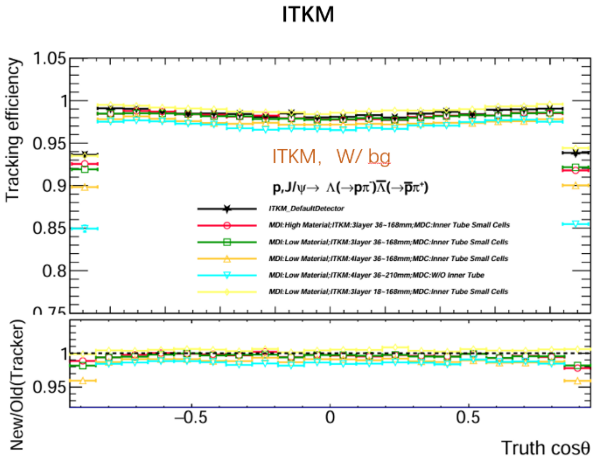


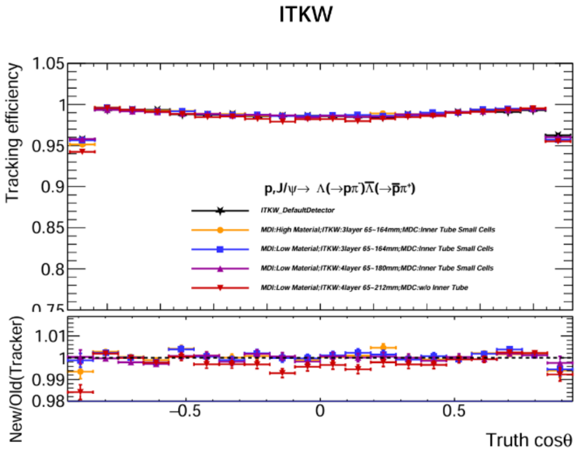


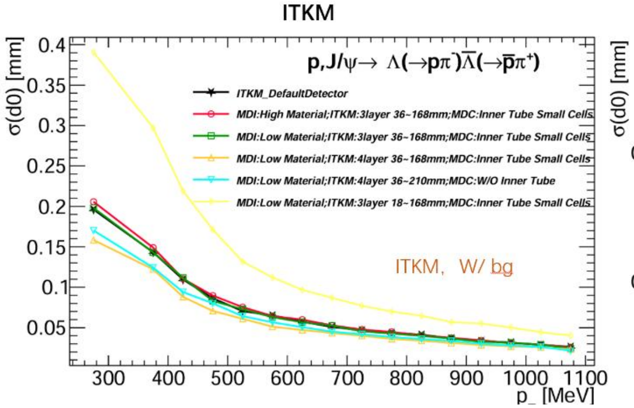


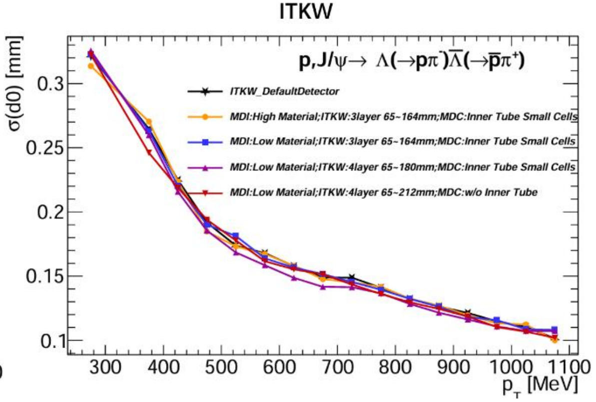
ITKW vs ITKM

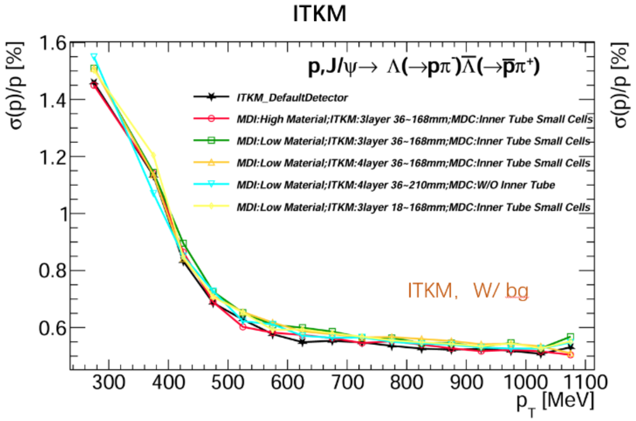
Please note the ITKW digitization is based on smearing instead of realistic digitization

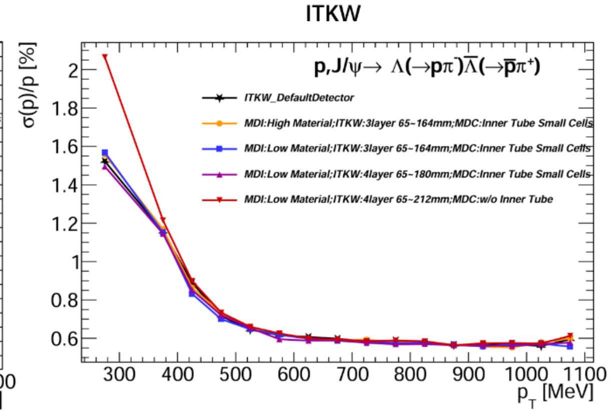






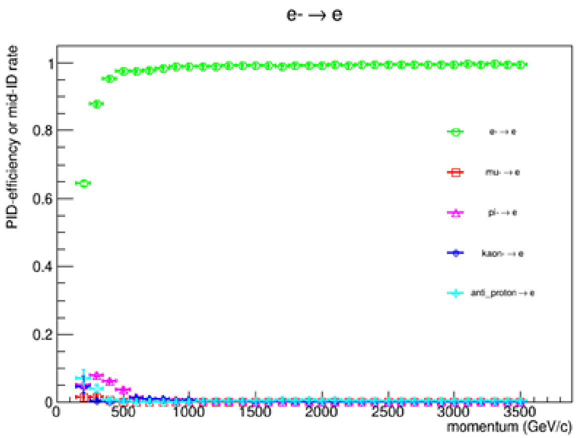


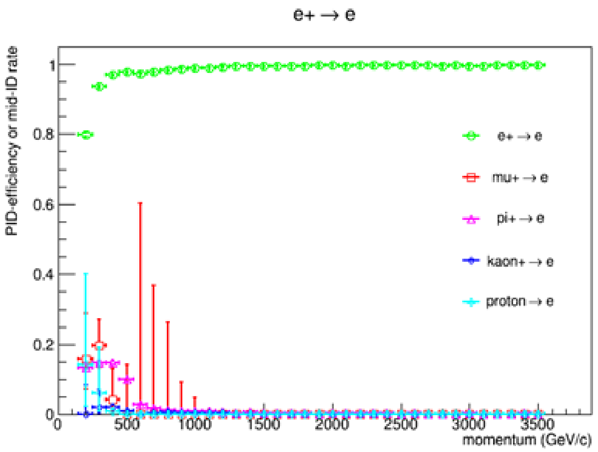




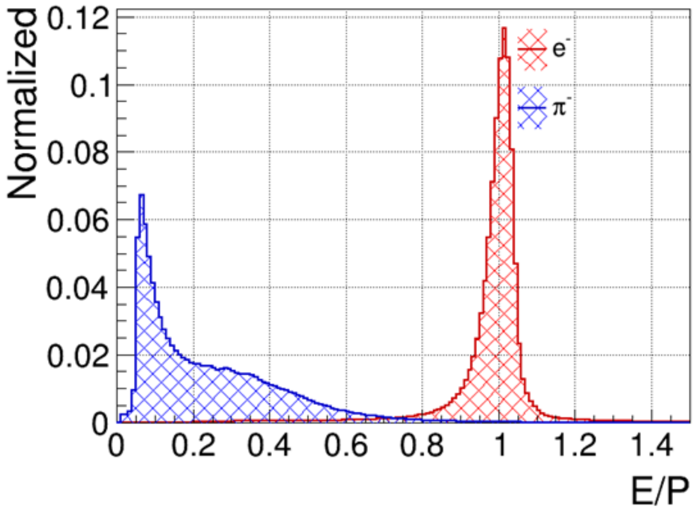
Electron PID (EMC)

- **E/p Ratio**
  - E: Energy of ECAL Shower
  - p: Momentum from Track
  - L(e)=ln(e)+0.001; L(other)=ln(other)+0.001
  - Poor performance in low-momentum

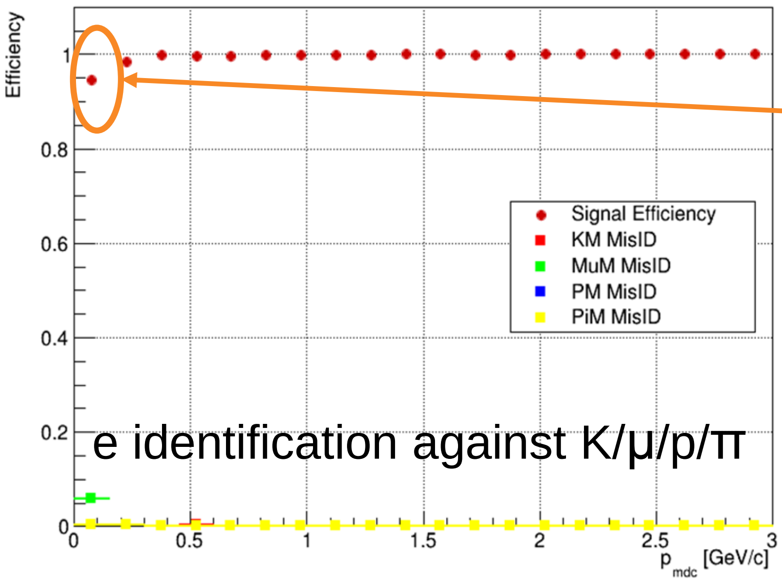


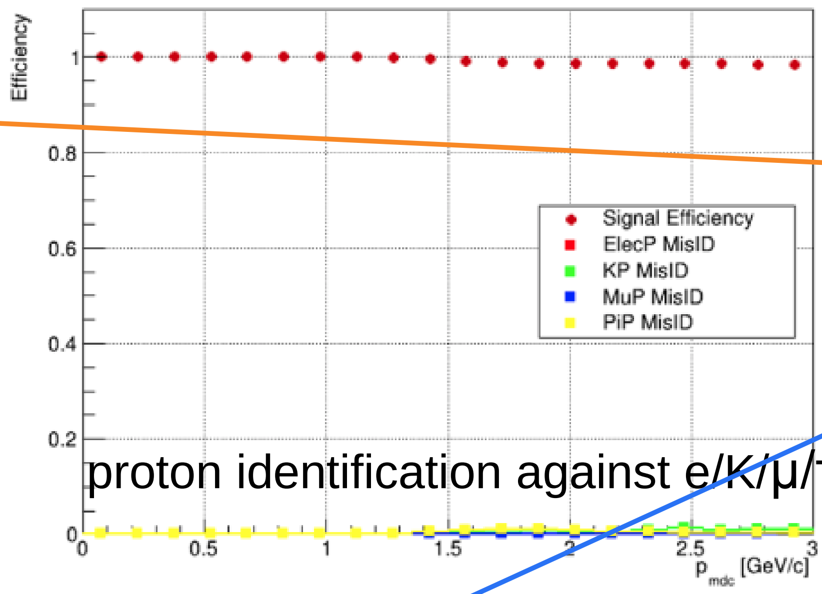


- **BDT Methd**
  - Input variables: charge, p, E, E/p, T, |R_ext-R_shower|, N_hits, E_seed/E_shower, (E_3x3-E_seed)/E_shower, (E_5x5-E_3x3)/E_shower, second moment, kateral moment, A20 moment, A42 moment
  - Distinguishing electrons from other charged particles
  - Finally BDT Method used

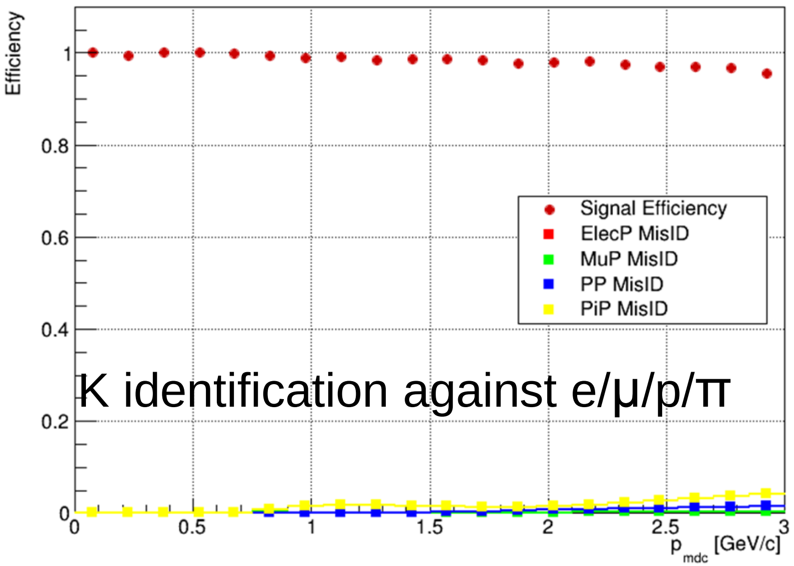


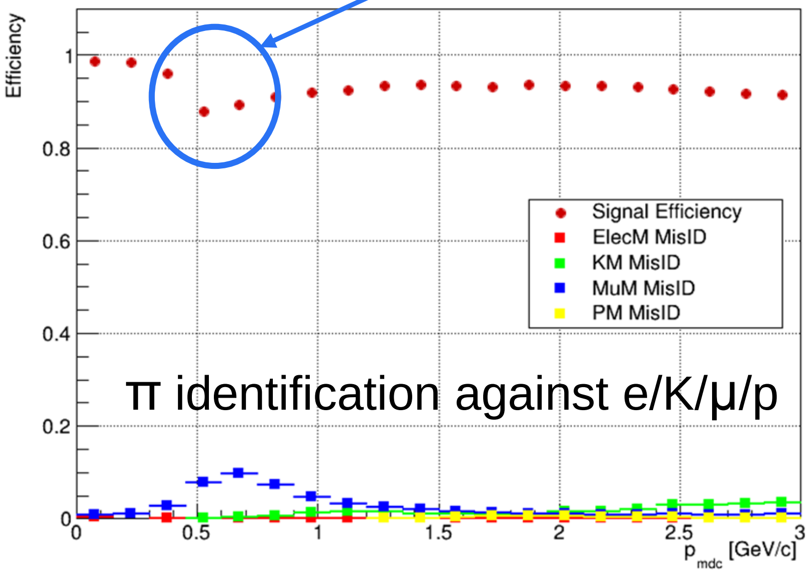
BDT-based global PID performance

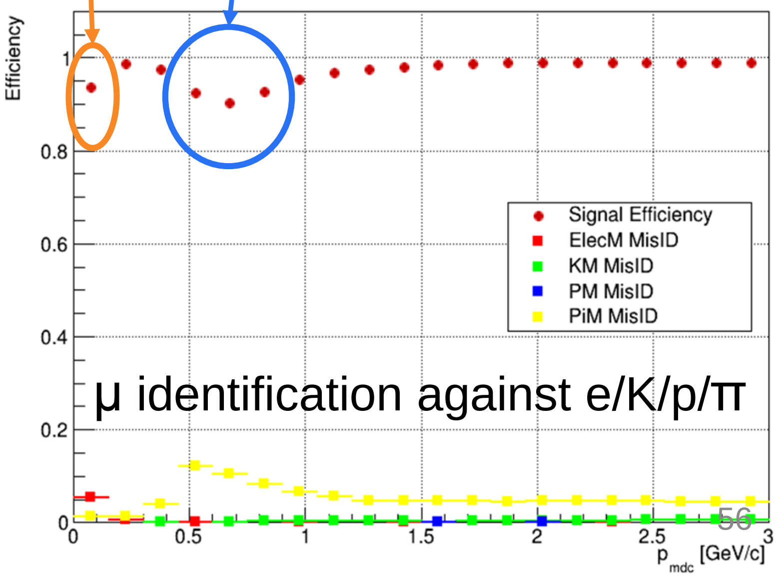




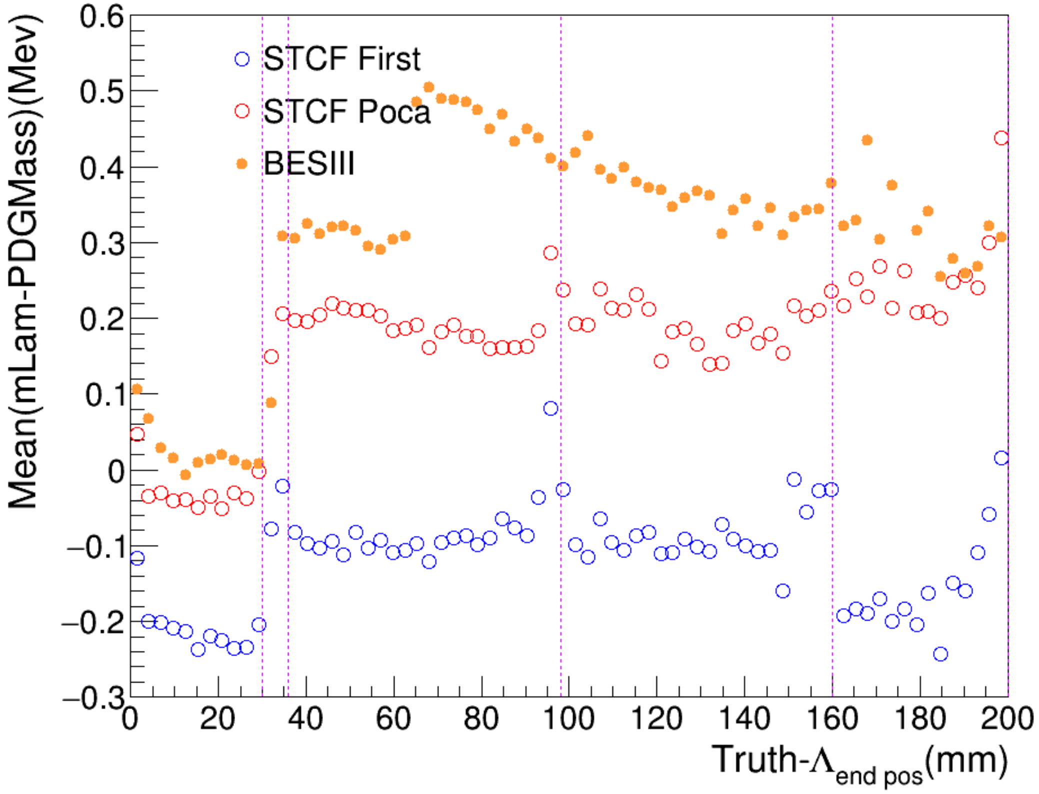
- Only dE/dx works at momentu below 100 MeV, and has poor performance for distinguishing between e and μ
- Both dE/dx and MUD have relatively worse performance for distinguishing between π and μ in this region

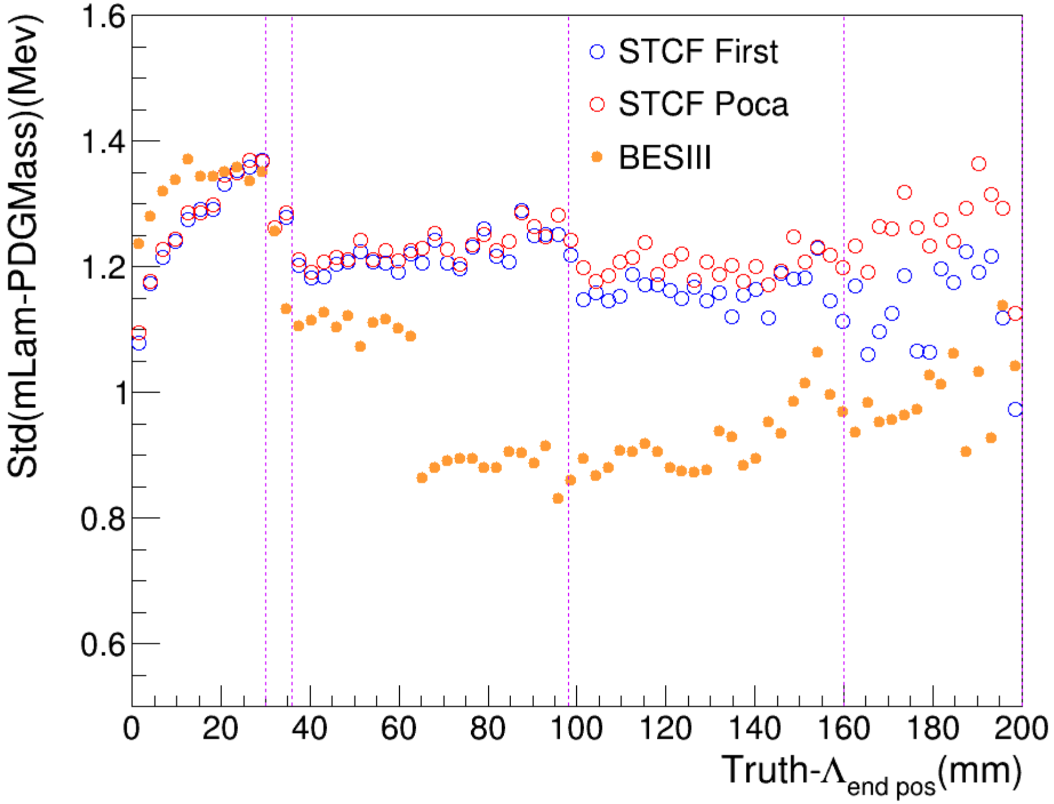






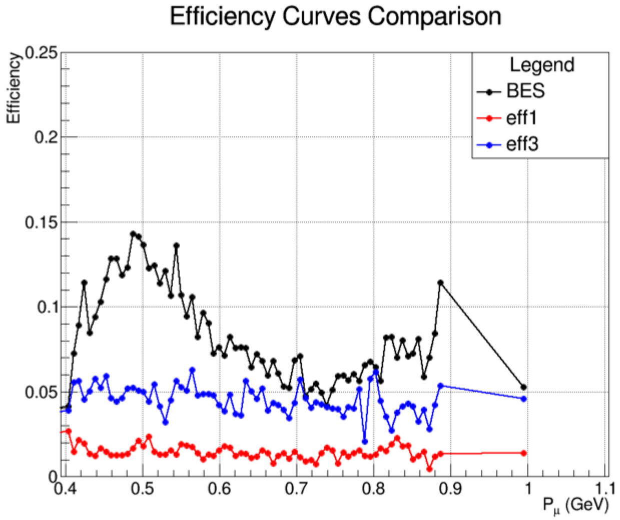
VertexFit at STCF vs BESIII





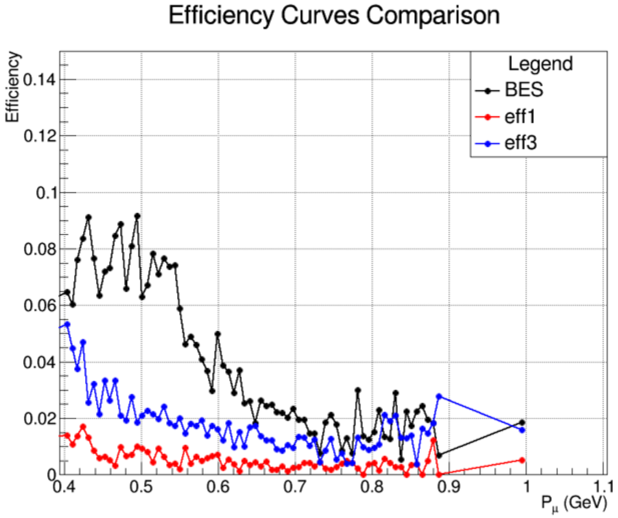
$D^+ \to K^-\pi^+\pi^+$

BESIII noise hit level： 25.36%



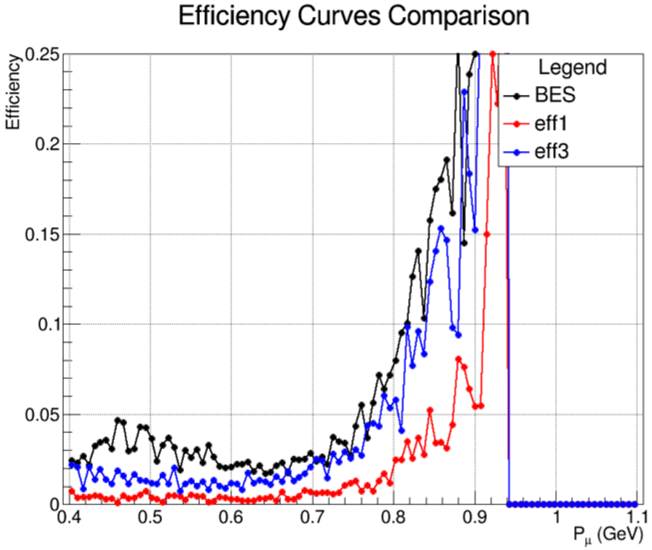
$D^+ \to \pi^+ \pi^-\pi^+\pi^0$

BESIII noise hit leval： 4.5%



$D^+ \to \pi^+ \pi^-\pi^+$

BESIII noise hit leval： 0.1%



- Better π/μ (as well as μ/π) identification efficiency than BESIII

eff1: mis-ID efficiency = 1%

eff3： mis-ID efficiency = 3.333%