OSCAR框架下STCF L1触发算法的实现

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超级陶粲装置研讨会

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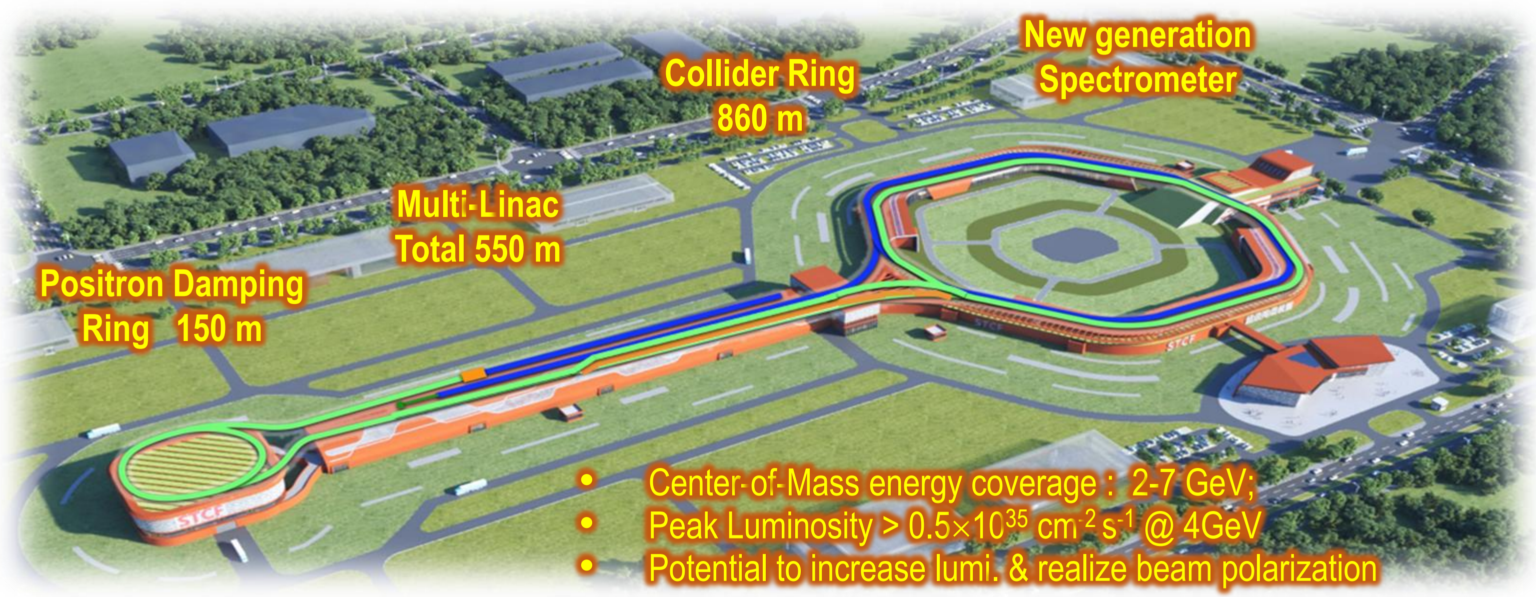
Outline

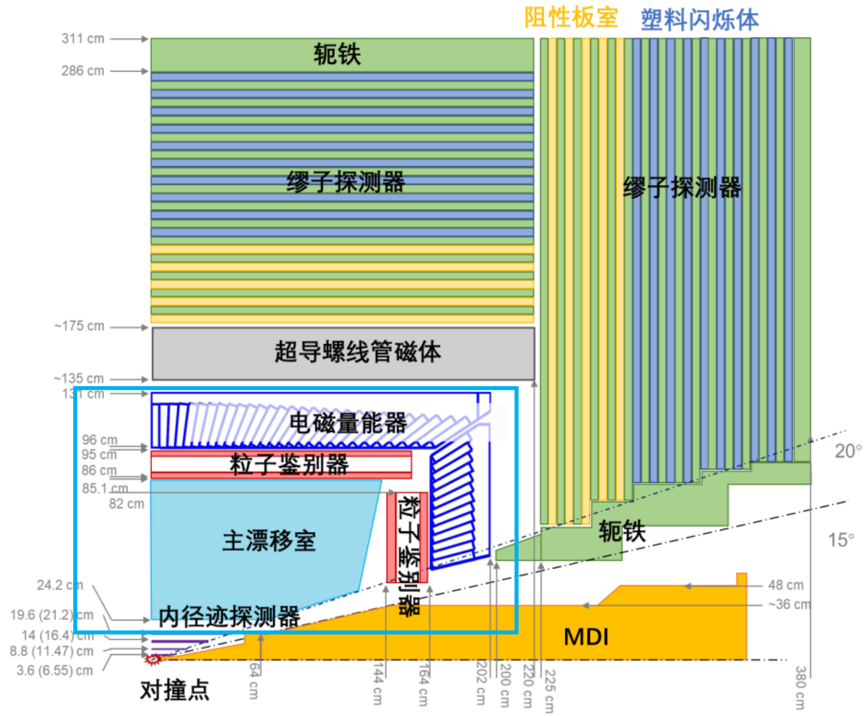
- Motivation
- Framework
- Implement in OSCAR
- Summary

Super Tau-Charm Facility

- STCF key design parameters
  - Peaking luminosity: > 0.5×10^{35} $cm^{-2} \cdot s^{-1}$ @ 4 GeV
  - Center-of-mass energy: 2~7 GeV
  - Highest physic event rate: 400 kHz



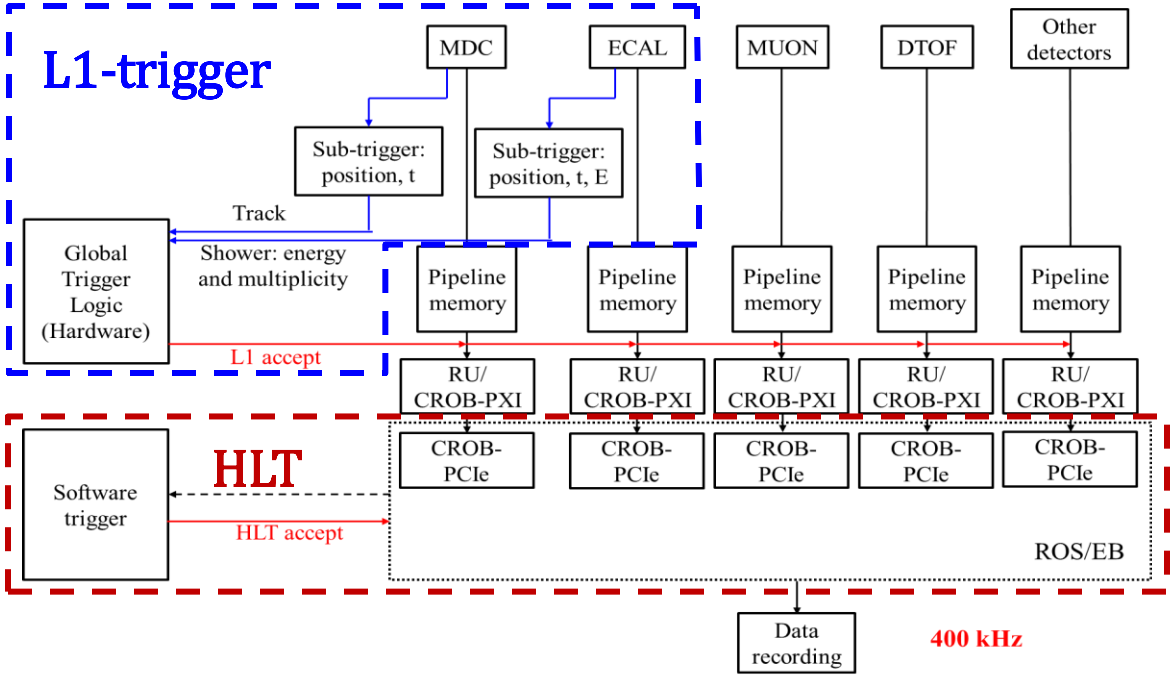
- STCF detector cross section



Motivation

- STCF trigger requirement
  - High trigger efficiency for physical process events (~99%)
  - Low trigger rate for background events (< 50 kHz)
  - Trigger rate (hundreds of kHz)
  - High throughput, low latency

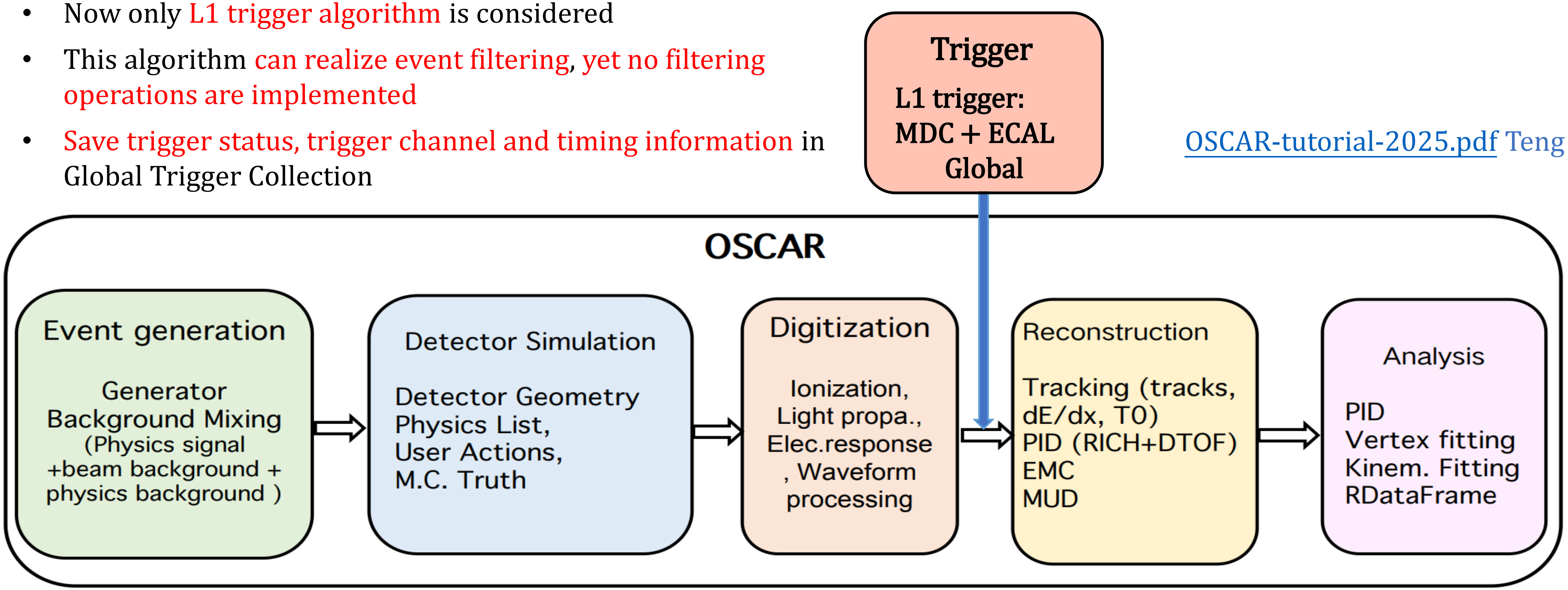
- It's better to consider trigger in OSCAR
  - More convenient to do trigger algorithm test using large data samples
  - Evaluate the trigger efficiency in physical analyses, especially in some physical channels with insufficient trigger efficiency, like $e^+e^- \to n\bar{n}$
  - Avoid difference between data and MC



Base on OSCAR

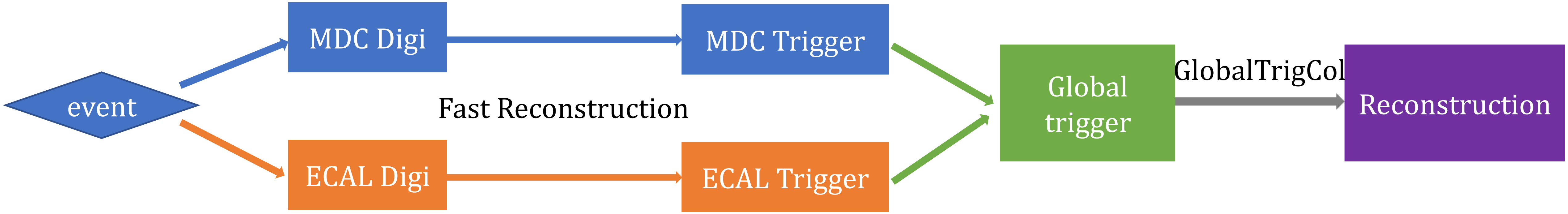
- OSCAR: Offline Software of Super Tau-Charm Facility
- Trigger algorithm is added between digitization and reconstruction
  - Now only L1 trigger algorithm is considered
  - This algorithm can realize event filtering, yet no filtering operations are implemented
  - Save trigger status, trigger channel and timing information in Global Trigger Collection

OSCAR-tutorial-2025.pdf Teng Li



Framework

- Detailed framework



- MDC: hit position and TDC → track segment finding and final tracking
- ECAL: hit position, energy and time → data slice and cluster finding

- MDC: p_T, ϕ, θ and time
- ECAL: number of clusters, total deposited energy, ϕ, θ and time

- Global: track-cluster matching, back-to-back track/cluster pair finding

→ GlobalTrigCol: Trigger status, trigger channel and timing

→ Users may decide whether to remove events failing the trigger according to their requirements

Implement in OSCAR

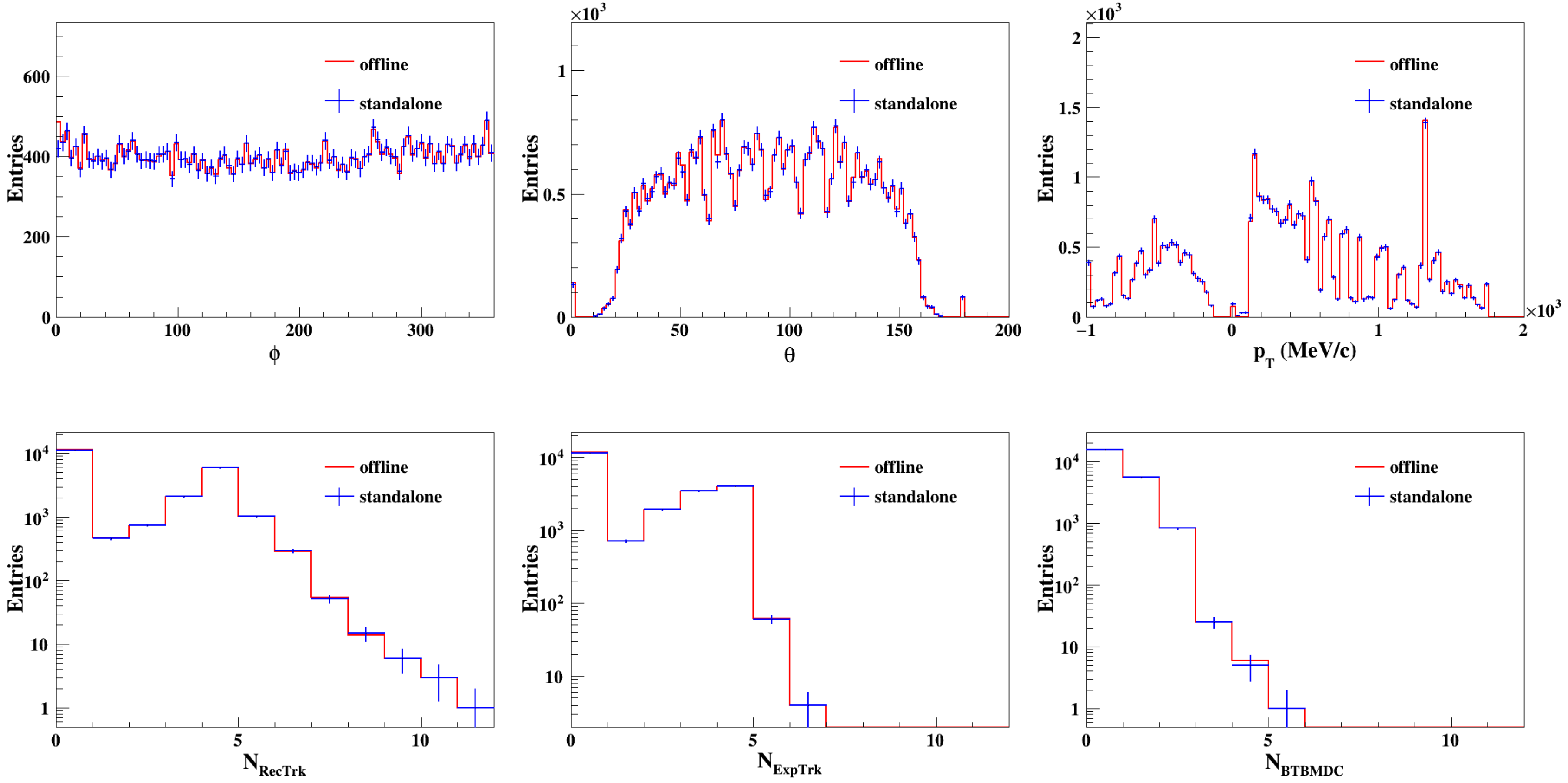
- Three physical processes are used to do test, comparing the performance of trigger algorithms running within OSCAR and in standalone

Process	$\sqrt{s}$ (GeV)	N_{events}	Background	Properties
$e^+e^- \to \pi^+\pi^- J/\psi$, $J/\psi \to e^+e^-$	4.260	10000	1 bkg	distinct final-state signature
$e^+e^- \to n\bar{n}$	3.097	10000	1 bkg	Pure neutral final states
$J/\psi \to$ inclusive	3.097	10000	1 bkg	Inclusive physical process

- Here the results from $e^+e^- \to \pi^+\pi^- J/\psi, J/\psi \to e^+e^-$ with 1bkg as an example

MDC object level comparison: track

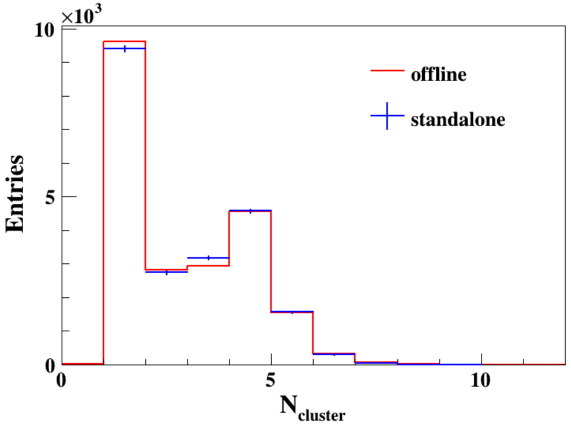
- MDC performance comparison between standalone and OSCAR

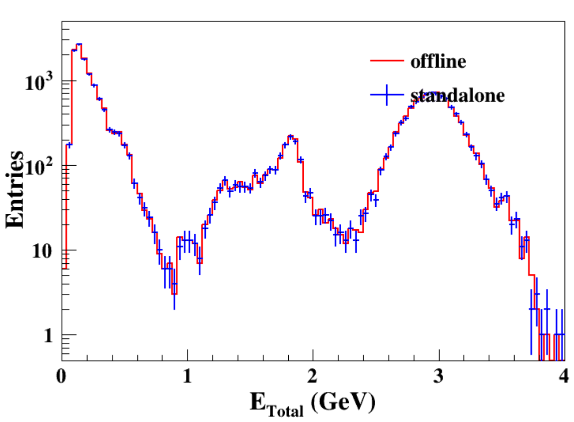


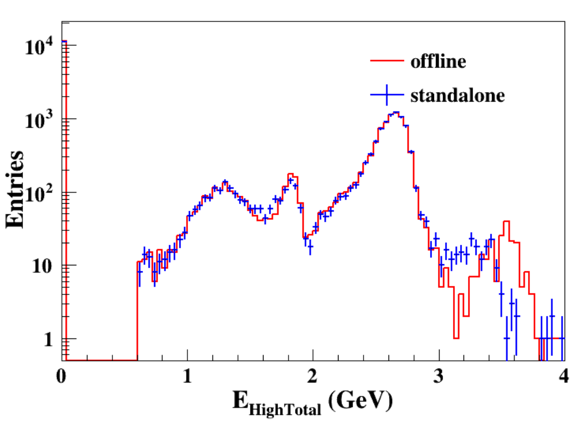
- There is a good agreement of MDC track information between standalone and OSCAR

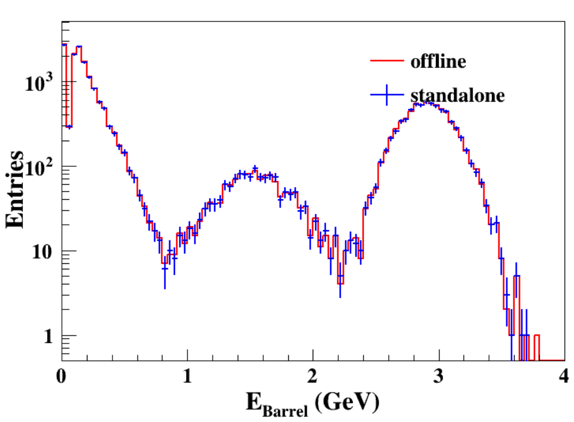
ECAL object level comparison: cluster

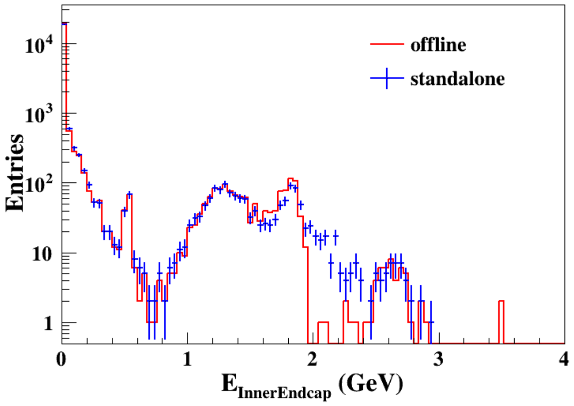
- ECAL performance comparison between standalone and OSCAR

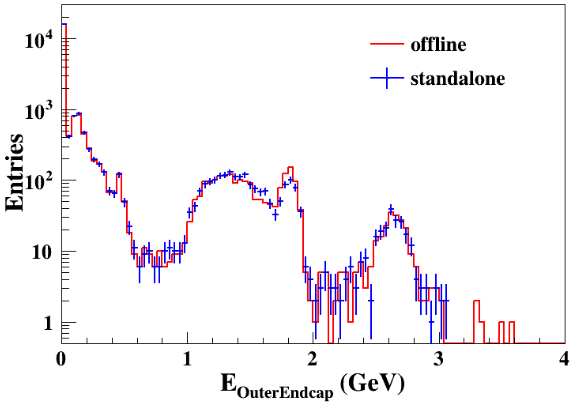


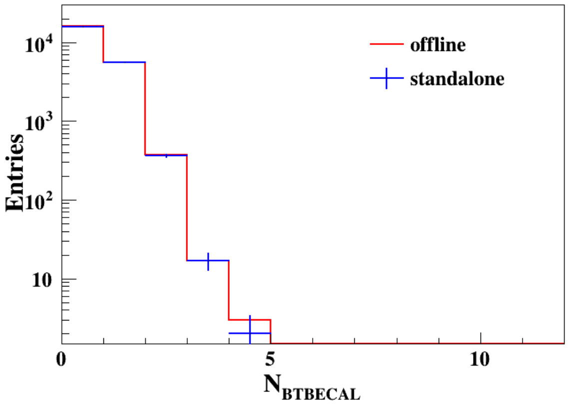








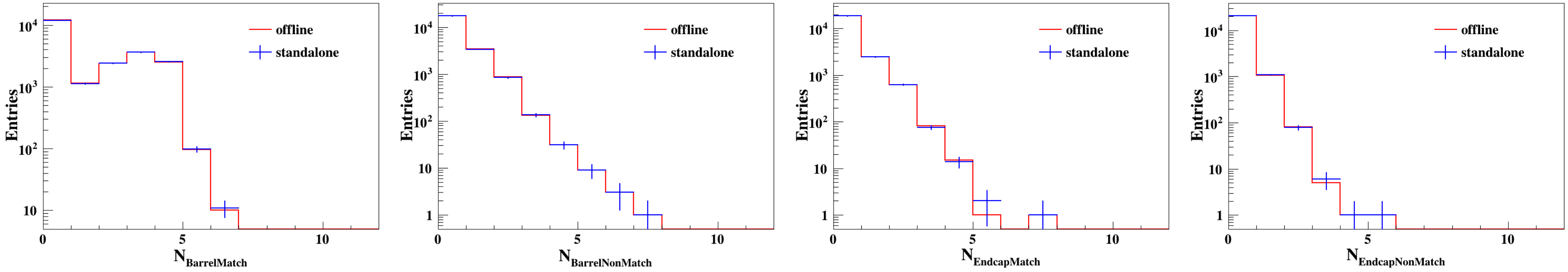




- Distributions of total deposited energy show consistent behavior
- A slight discrepancy exists in the cluster multiplicity distributions

Global object level comparison

- Global performance comparison between standalone and OSCAR

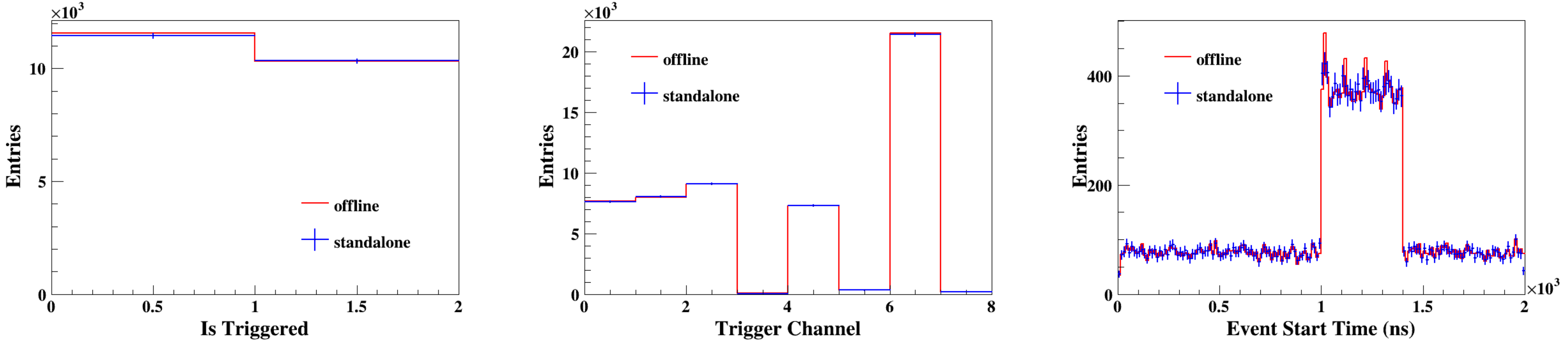


- Time, theta and phi are exploited for track-cluster matching
- The number of successfully matched track-cluster pairs
- An MDC track cannot find a matching cluster within the time limit in the barrel and end-cap

A good agreement in two version

Global event level comparison

- Global performance comparison between standalone and OSCAR



Process	$\epsilon_{\text{trigger}}$ in OSCAR		$\epsilon_{\text{trigger}}$ in standalone	
	Signal (%)	Background (kHz)	Signal (%)	Background (kHz)
$e^+e^- \to \pi^+\pi^- J/\psi$, $J/\psi \to e^+e^-$	99.2	20.7	99.1	21.1
$e^+e^- \to n\bar{n}$	58.2	20.0	58.4	20.4
$J/\psi \to$ inclusive	95.7	22.1	95.8	23.2

Summary

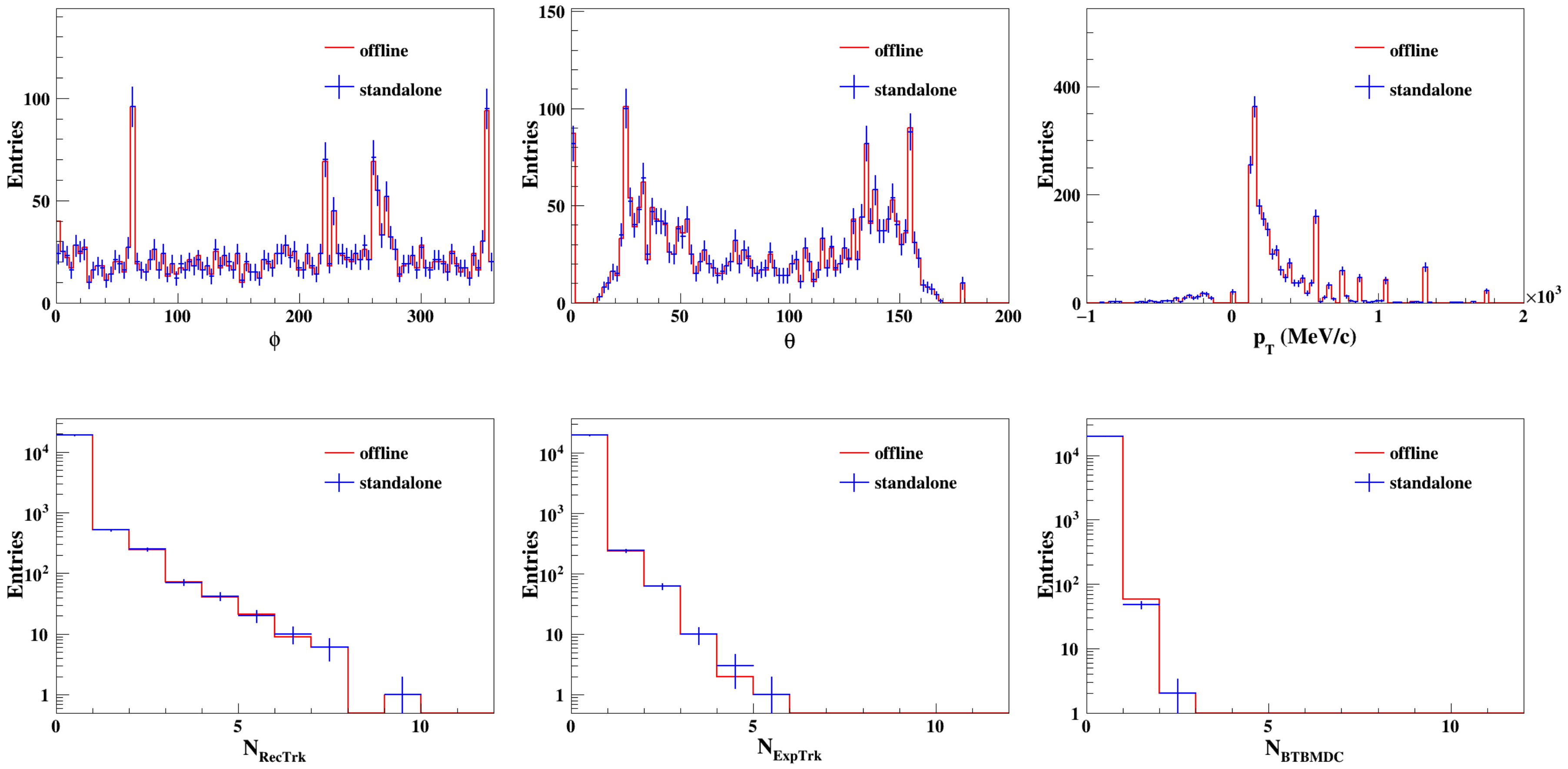
- Summary
  - For convenient test of L1 trigger algorithm, evaluation of trigger efficiency and elimination data/MC difference, it's better to consider trigger in OSCAR
  - L1 trigger algorithm has been implemented in OSCAR between digitization and reconstruction
  - Users can retrieve trigger status, trigger channel and timing information for each event, so far no event filtering operations are implemented in this algorithm
  - The performances of the algorithm running within OSCAR and in standalone mode are compared via three physical processes, and the observed discrepancies are acceptable
- Next to do
  - Update the geometry to the latest version
  - Study influence of the algorithm's output parameters on physical processes

Thank you!

Back up

MDC object level comparison: track, $e^+e^- \to n\bar{n}$

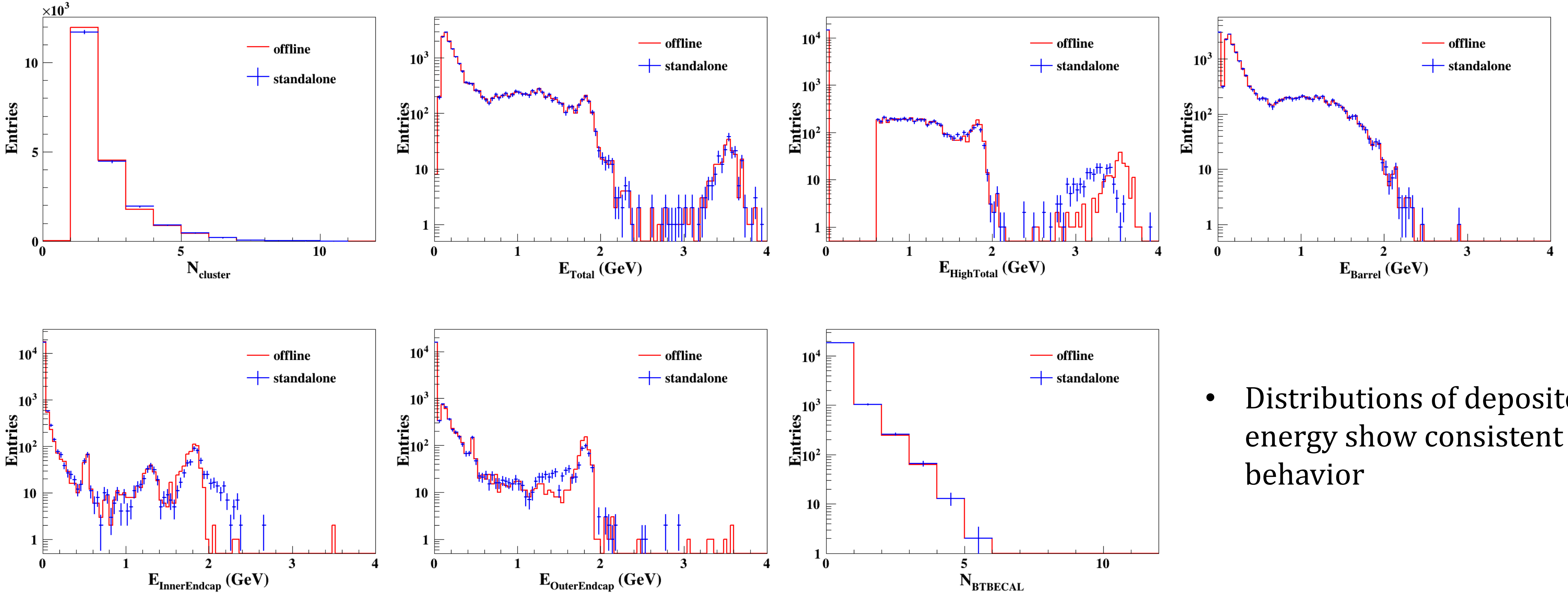
- MDC performance comparison between standalone and OSCAR



- There is a good agreement of MDC track between standalone and OSCAR

ECAL object level comparison: cluster, $e^+e^- \to n\bar{n}$

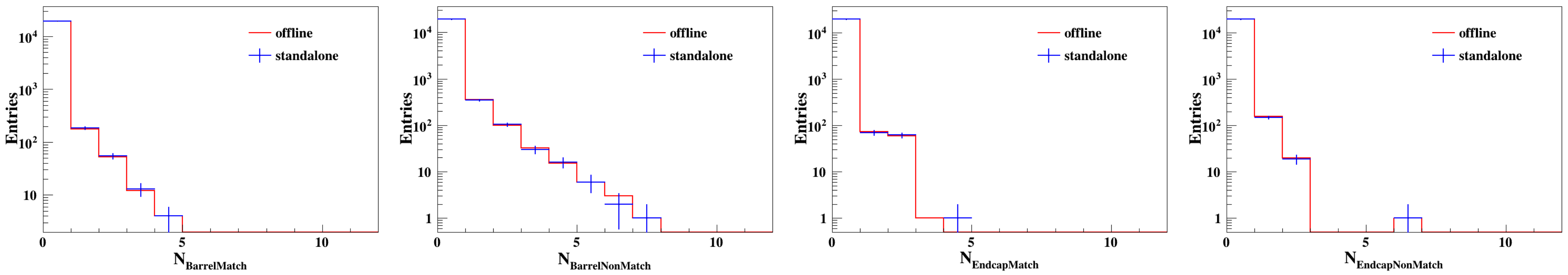
- ECAL performance comparison between standalone and OSCAR



- Distributions of deposited energy show consistent behavior

Global object level comparison, $e^+e^- \rightarrow n\bar{n}$

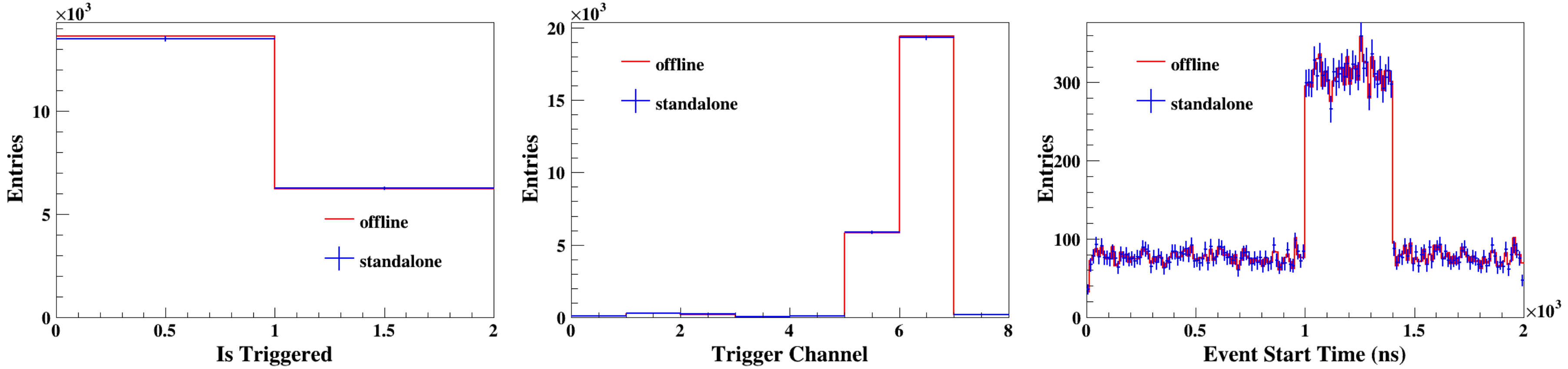
- Global performance comparison between standalone and OSCAR



- Time, theta and phi are exploited for track-cluster matching
- The number of successfully matched track-cluster pairs and an MDC track cannot find a matching cluster within the time limit in the barrel and end-cap show a good agreement in two version

Global event level comparison, $e^+e^- \to n\bar{n}$

- Global performance comparison between standalone and OSCAR



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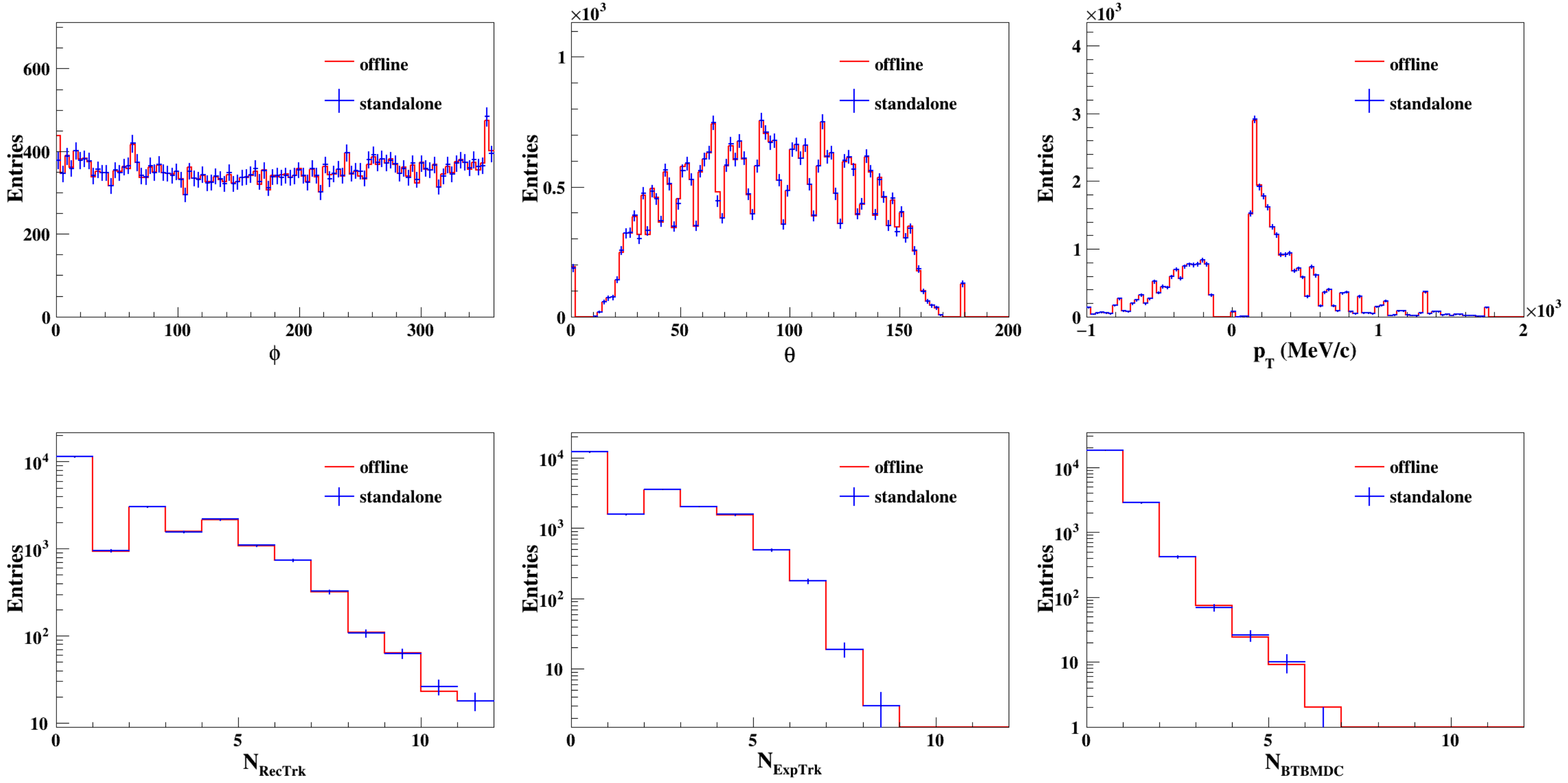
MDC object level comparison: track, $J/\psi \rightarrow$ inclusive

- MDC performance comparison between standalone and OSCAR



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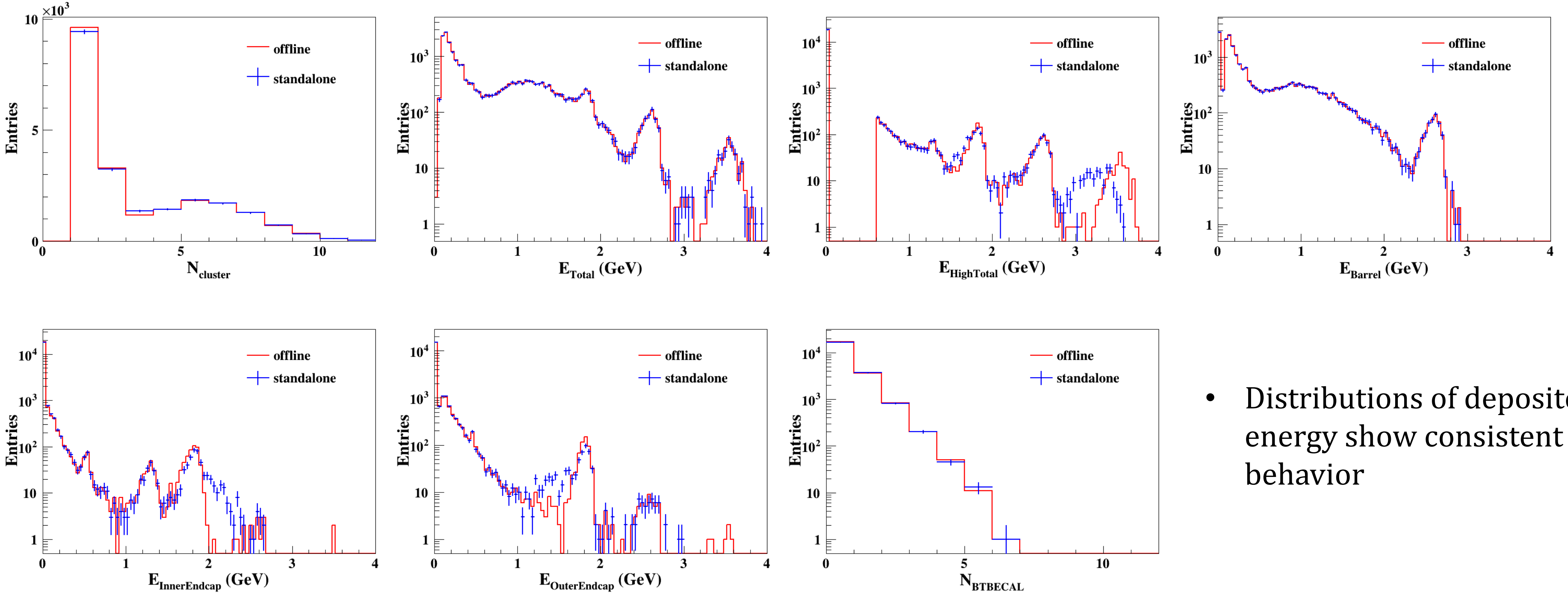
ECAL object level comparison: cluster, $J/\psi \rightarrow$ inclusive

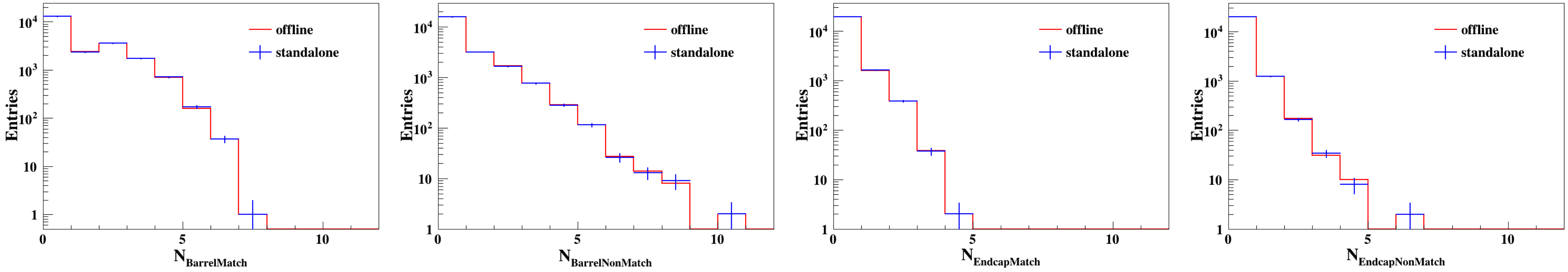
➢ ECAL performance comparison between standalone and OSCAR



- Distributions of deposited energy show consistent behavior

Global object level comparison, $J/\psi \rightarrow$ inclusive

➢ Global performance comparison between standalone and OSCAR



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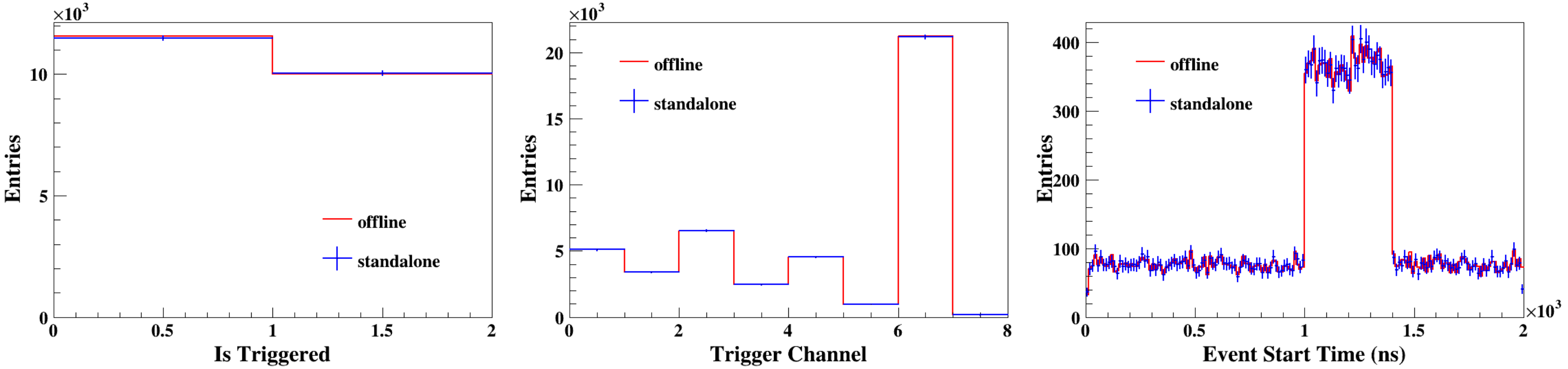
Global event level comparison, $J/\psi \to$ inclusive

- Global performance comparison between standalone and OSCAR



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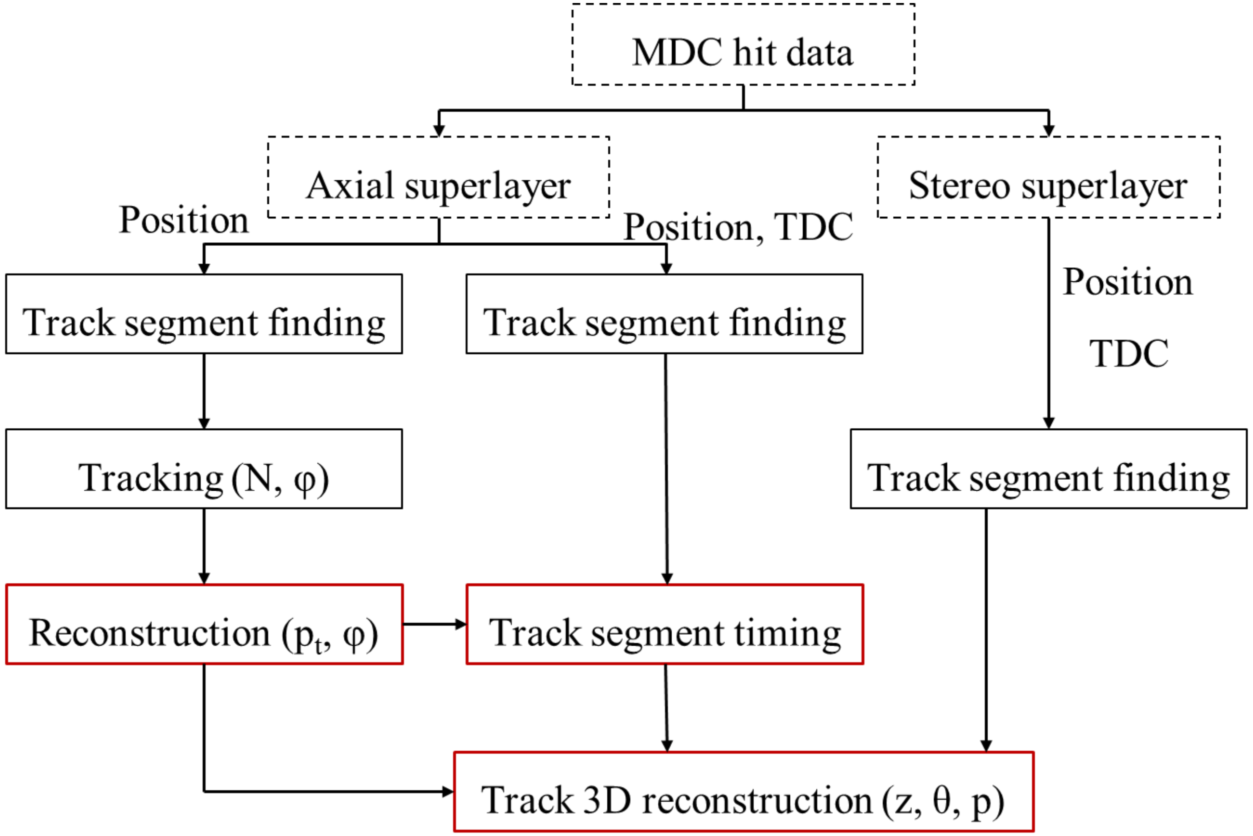
MDC Sub-trigger R&D

- MDC algorithm

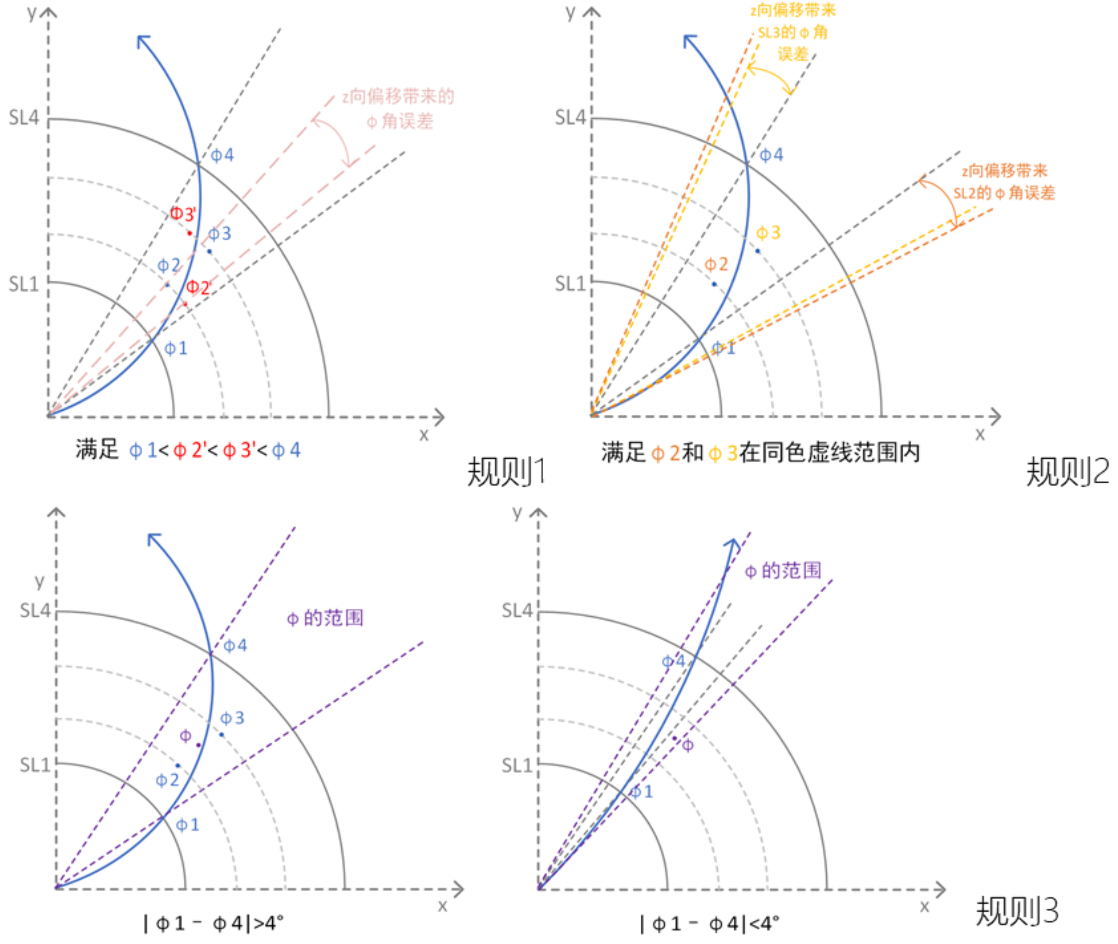


- Sub-algorithms
  - **2D tracking and reconstruction:** transverse momentum(p_t), azimuthal angle(φ)
  - **Time reconstruction:** track segment time, track time(t)
  - **3D reconstruction:** z-vertex, polar angle(θ), momentum(p)

MDC Sub-trigger R&D

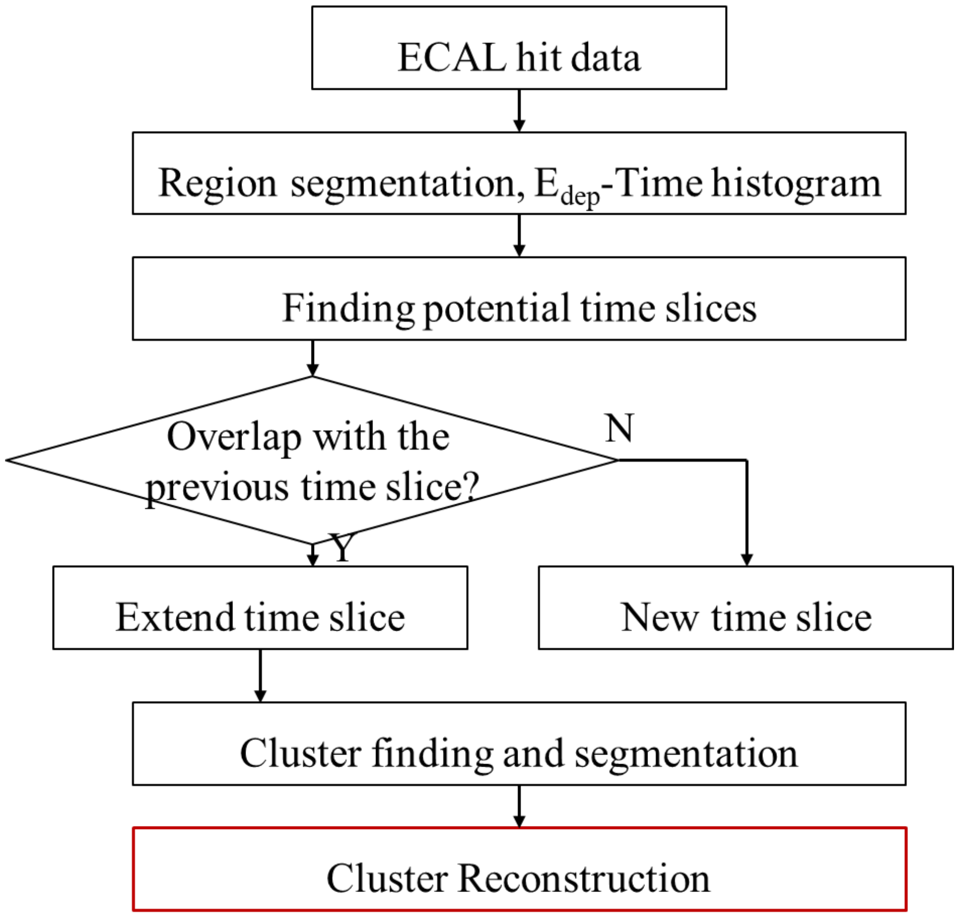
□ 斜丝超层引入短径迹2D寻迹

- 通过三个φ向约束实现2D寻迹
- 降低带电触发道50%的本底触发

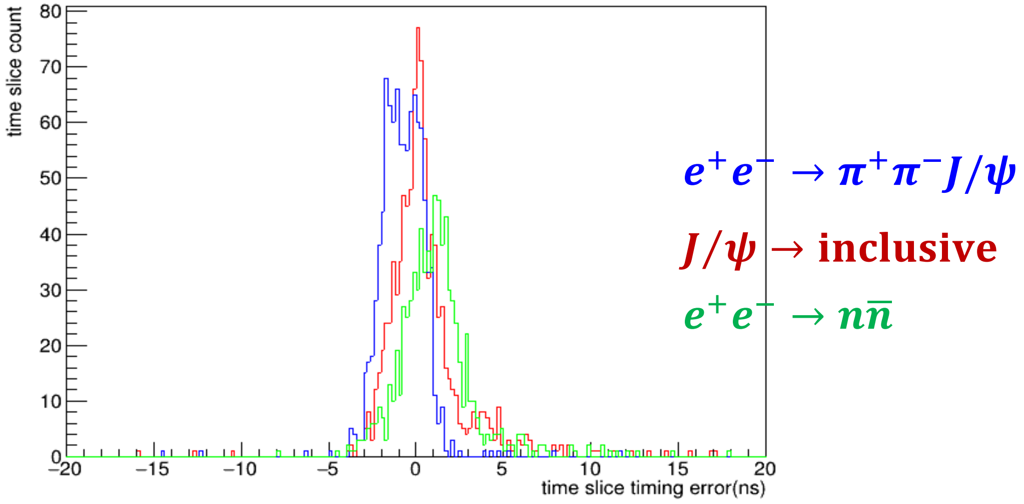


ECAL Sub-trigger R&D

- ECAL algorithm

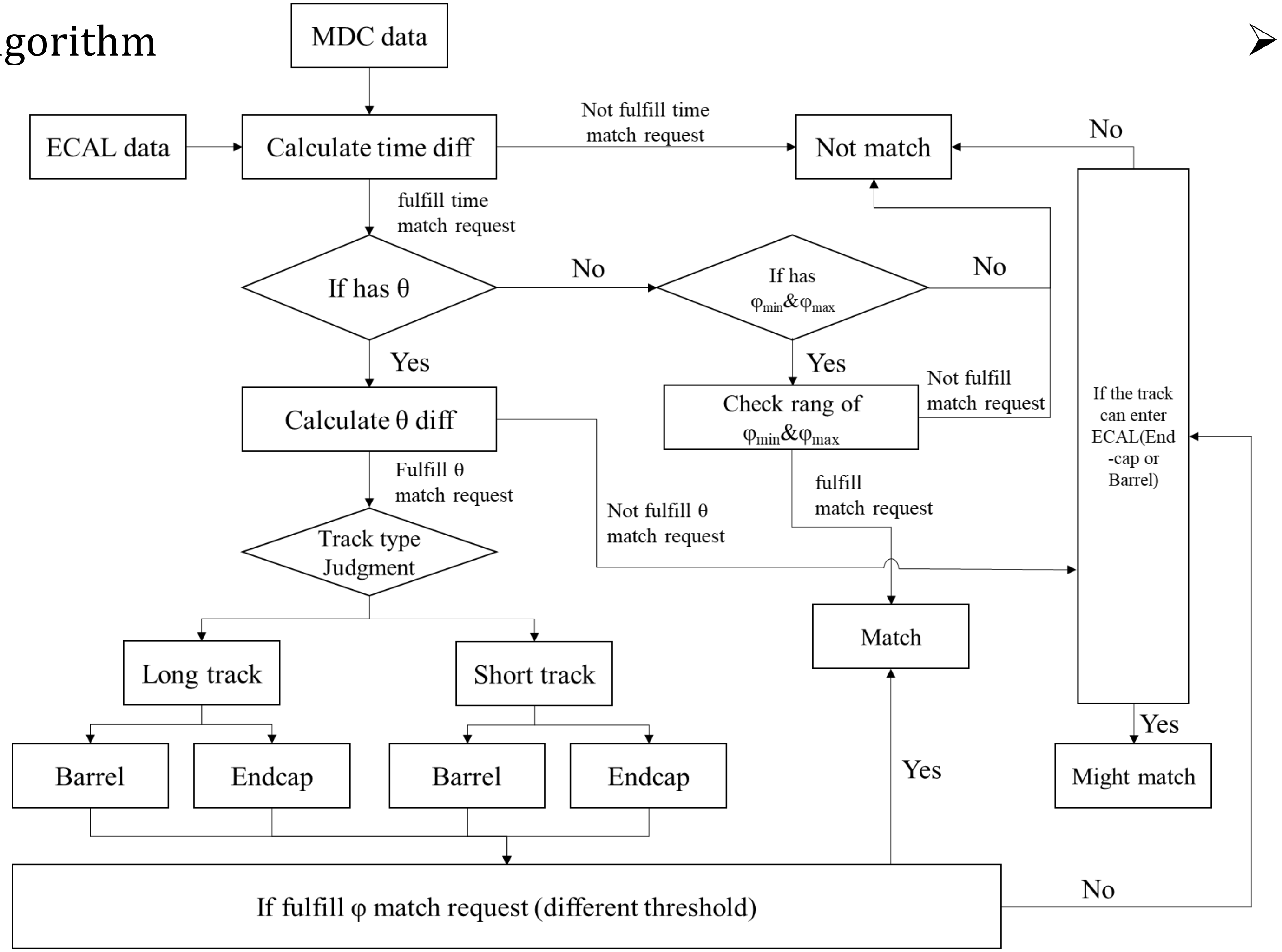


- Event T_0 residual



L1 Trigger GTL R&D

- GTL algorithm



- Match logic optimization
  - Un-matched track and cluster
  - Using θ in match
  - Various criteria in different ECAL regions

Trigger Table Design

- GTL algorithm

		1	2-1	2-2	2-3	2-4	3-3	4-1	4-2	4-3	5-1	5-2	5-3	6	7	8	9-1	9-2	10-2	10-3	10-4	10-5	11	12-1	12-2	12-3	13	14	15
Charged	1-1	N		Y					Y					Y						Y			N					Y	
	1-2	N		Y					Y						Y	Y				Y			N					Y	
	1-3	N		Y					Y											Y			N				Y	Y	
	1-4	N		Y					Y					Y						Y			N						Y
	1-5	N		Y					Y						Y	Y				Y			N						Y
	1-6	N		Y					Y											Y			N				Y		Y
	2-1	N	Y		N		N	Y				Y					Y		Y			N							
	2-2	N	Y		N		N	Y				Y							Y			N					Y		
	3-1	N			Y	N				Y			Y	Y					Y										
	3-2	N			Y	N				Y			Y		Y	Y			Y										
	3-3	N			Y	N				Y			Y						Y								Y		
	3-4	N			Y	N		Y				Y					Y			Y							Y		
	3-5	N			Y	N			Y								N				Y								
	4-1	N				Y								Y					Y										
	4-2	N				Y									Y	Y			Y										
	4-3	N				Y													Y								Y		
	4-4	N											N	Y					Y										
	4-5	N											N		Y	Y			Y										
	4-6	N											N						Y								Y		
Neutral	5-1	N	Y	N				N																Y					
	5-2	N	Y	N				N																	Y				
	5-3	N		Y	N			N																Y					
	5-4	N		Y	N			N																	Y				
	5-5	N			Y			Y	N															Y					
	5-6	N			Y			Y	N												Y								
	6	N	Y																Y										
L.M.	7-1							Y			Y							Y					Y					Y	
	7-2							Y			Y							Y								Y		Y	
	7-3							Y			Y							Y						N	Y	Y		Y	
	7-4							Y			Y							Y					Y						Y
	7-5							Y			Y							Y								Y			Y
	7-6							Y			Y							Y						N	Y	Y			Y
Random																													

Trigger Table Design

<table>
<tr><th></th><th>No</th><th>触发道类型</th><th>触发道设置</th></tr>
<tr><td rowspan="4">Charged trigger channel</td><td>01</td><td>Charged final state with back-to-back characteristic</td><td>IfRBB == 0 && (tempEMCpair[x]>=1 || tempMDCpair>=1) && (((EMC_totalclusternumber[x]>=2 && MDC_TWtracknum[x]>=2) && (Barrelmatch_num[x]>=1 || Barrelmightmatch_num[x]>=1 || (Endcapmatch_num[x]>=1 && Endcapmatch_num[x]<=2 && Inner_Endcap_match_num[x]<2)))) && GTL_EMC_TotalEDep[x]>=EMC_totalEDepmidthreshold&&GTL_total_highcluster_EDep[x]<3</td></tr>
<tr><td>02</td><td>Charged final state with few final states (signal track number≤2)</td><td>IfRBB == 0 && EMC_totalclusternumber[x]>=1 && EMC_totalclusternumber[x]<=4 && MDC_TWtracknum[x]>=1 && MDC_TWRetracknum[x]<=4 && (((Barrelmatch_num[x]+Endcapmatch_num[x]>=1||Barrelmightmatch_num[x]+Endcapmightmatch_num[x]>=2) && Inner_Endcap_match_num[x]<=1 && GTL_EMC_TotalEDep[x]>=0.15)) &&GTL_EMC_TotalEDep[x]<EMC_totalEDephighthreshold&&EMC_overhighEDepthreshold[x]<=1</td></tr>
<tr><td>03</td><td>Charged final state with middle final states (3≤signal track number≤6)</td><td>IfRBB == 0 && (EMC_totalclusternumber[x]>=3 && EMC_totalclusternumber[x]<=7) && ((MDC_TWtracknum[x]>=3 && MDC_TWRetracknum[x]<=7 && (Barrelmatch_num[x]>=1 || Barrelmightmatch_num[x]>=1 || (Endcapmatch_num[x]>=1&&Endcapmatch_num[x]<=2 && Inner_Endcap_match_num[x]<=1)) && GTL_EMC_TotalEDep[x]>=EMC_totalEDeplowthreshold) || (MDC_TWtracknum[x]>=1&&(Barrelmatch_num[x]+Endcapmatch_num[x]+Barrelmightmatch_num[x]) >=1 && (GTL_EMC_TotalEDep[x]>=EMC_totalEDepmidthreshold) && MDC_TWRetracknum[x]<=3) || (Barrelmatch_num[x]+Endcapmatch_num[x]==0 && MDC_TWtracknum[x]>=2 && GTL_EMC_TotalEDep[x]>=0.6))</td></tr>
<tr><td>04</td><td>Charged final state with massive final states (signal track number≥7)</td><td>IfRBB == 0 && (EMC_totalclusternumber[x]>=7 || MDC_TWRetracknum[x]>=7) && (Barrelmatch_num[x]>=1 || Barrelmightmatch_num[x]>=1 || (Endcapmatch_num[x]>=1 && Endcapmatch_num[x]<=2 && Inner_Endcap_match_num[x]<1)) && GTL_EMC_TotalEDep[x]>=EMC_totalEDeplowthreshold</td></tr>
<tr><td rowspan="2">Neutral trigger channel</td><td>05</td><td>Neutral final states</td><td>IfRBB == 0 && ((EMC_totalclusternumber[x]>2 && MDC_TWtracknum[x]<=1 && (EMC_BarrelEDep[x]>=0.4 || GTL_EMC_TotalEDep[x]>=0.6)) || (EMC_totalclusternumber[x]==2 && MDC_TWtracknum[x]<1 && (EMC_BarrelEDep[x]>=0.4 || (EMC_OuterEndcapEDep[x]>=0.5 && EMC_OuterEndcapEDep[x]<=1.4))) || (EMC_totalclusternumber[x]==1 && (EMC_BarrelEDep[x]>=0.5 || (EMC_OuterEndcapEDep[x]>=0.5 && EMC_OuterEndcapEDep[x]<=1.4))&&MDC_TWtracknum[x]<=1))&&GTL_total_highcluster_EDep[x]<3</td></tr>
<tr><td>06</td><td>High Neutral Trigger</td><td>IfRBB == 0 && EMC_totalclusternumber[x]>=1 && GTL_EMC_TotalEDep[x]>=0.1</td></tr>
<tr><td>Luminosity monitoring trigger channel</td><td>07</td><td>Radiative Bhabha</td><td>((tempEMCRBBpair[x]>=1 || MDC_RBBcount==1) && MDC_TWtracknum[x]>=0 && MDC_TWRetracknum[x]<4 && (GTL_total_highcluster_EDep[x]>=3 || ((EMC_InnerEndcapEDep[x]>=1.5 || (EMC_InnerEndcapEDep[x]+EMC_OuterEndcapEDep[x])>=2.8) && EMC_BarrelEDep[x]<=0.2)) && (Barrelmatch_num[x]+Endcapmatch_num[x])<=3)</td></tr>
<tr><td>Random trigger channel</td><td></td><td></td><td></td></tr>
</table>

Trigger Table Design

No	Trigger criteria	Definition
		ECAL(簇团能量，簇团位置和数据片段定时信息)
02	ECAL_totalclusternumber	ECAL中的簇团数量>=1, >=2, >=3, >=7
03	ECAL_overEDepthreshold_clusternum	ECAL 中单个簇团能量沉积超过一定阈值的簇团数量
10	ECAL_TotalClusterEDep	ECAL 中的总能量沉积低(除少径迹道和高通过中性道为0.1外其他均为0.28)，中1(0.4)，中2(0.6)，高(3.5)四个阈值
12	ECAL_RegionEDep	ECAL桶部，外端盖，内端盖各自的总能量沉积
14	ECAL_btb	ECAL是否有背靠背簇团
11	ECAL_Total_high_EDep	ECAL中高能簇团(>0.6GeV)沉积的能量之和
		MDC(径迹数量，径迹位置和径迹定时信息)
04	MDC_totaltracknumber	MDC中的识别径迹总数>=1,>=2, >=3
05	MDC_totalretracknumber	MDC中的能够到达ECAL的径迹总数<=3,<=4,<=7
15	MDC_btb	MDC中是否有背靠背径迹
		Global(匹配信息)
06	Barrelmatch_num	桶部的匹配数量
07	OuterEndcapmatch_num	外端盖的匹配数量
08	InnerEndcapmatch_num	内端盖的匹配数量
09	Match_num	总的匹配数量
13	Non-match_num (Might_matchnum)	在空间维度(方位角，极角)没能完成匹配，但是在时间维度上能够与ECAL时间片段匹配的径迹数量
01	IfRBB	是否满足RBB道的触发条件