LHC-ALICE実験 $\sqrt{s}$ = 13 TeV 陽子-陽子衝突における ジェット内部中性中間子の測定

Measurement of neutral mesons inside jets in pp collisions at $\sqrt{s}$ = 13 TeV with ALICE at the LHC

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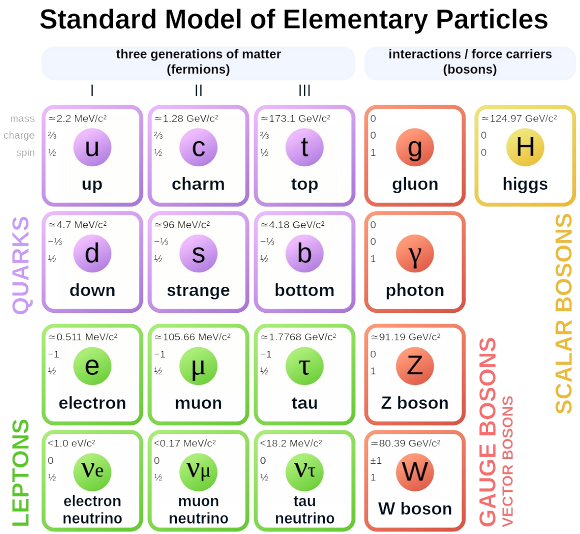
ALICE

2022/3/24

TCHoU

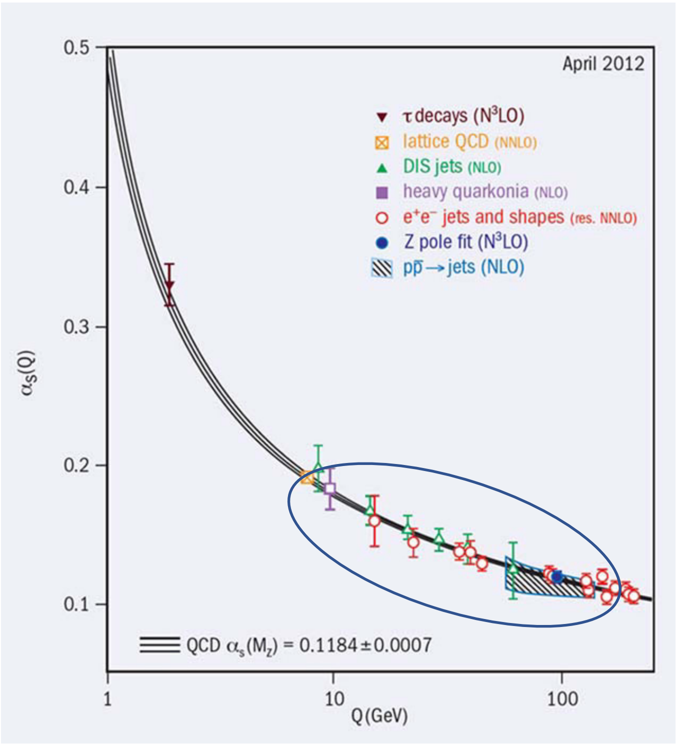
PARK HANSEO

Quantum Chromodynamics (QCD)

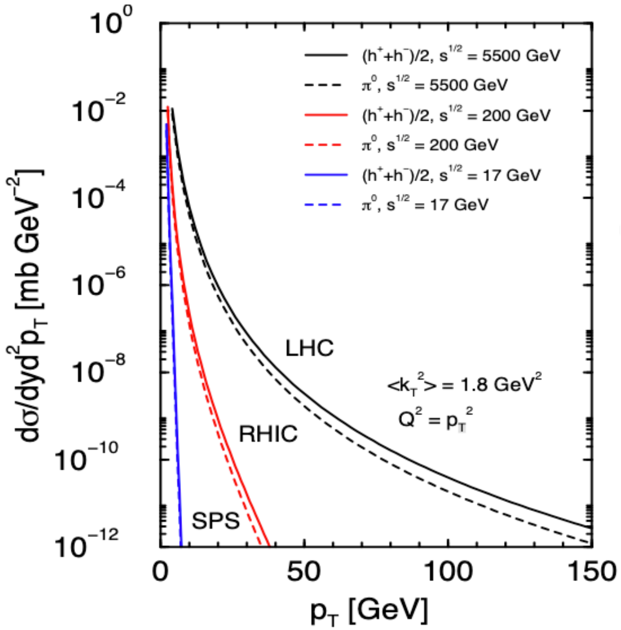


1. Asymptotic freedom

2. Color confinement



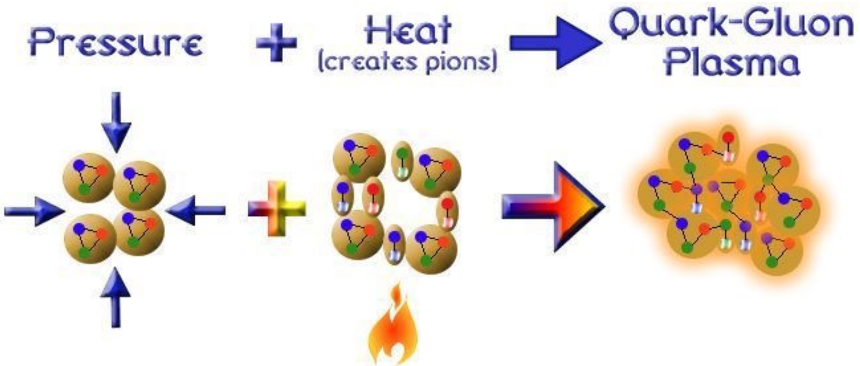
Hard process: Q >> Λ_{QCD}



[hep-ph/0212109]

Quark gluon plasma (QGP)

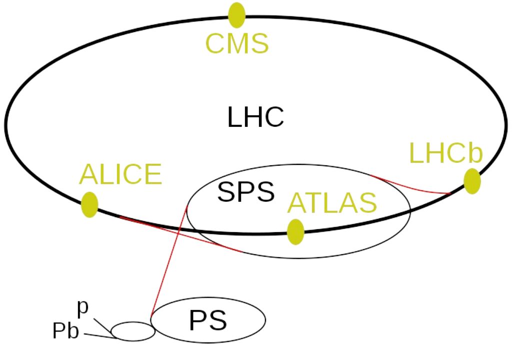
- **Quark, Gluon**
  - confinement by strong interaction
  - Free from confinement in high temperature and density conditions



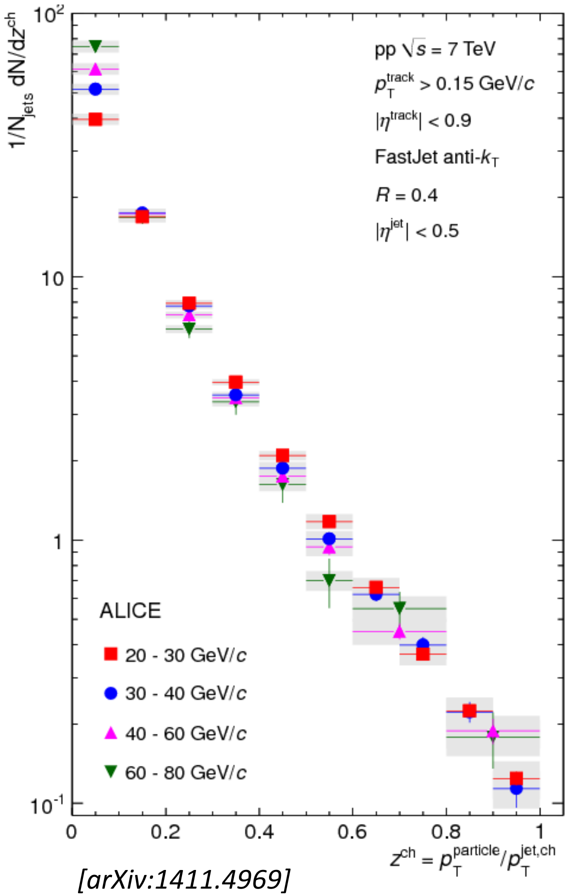
Quark gluon plasma (QGP)

- **High energy heavy ion collision experiment**
  - Accelerate particle to near the speed of light and collide → create high temperature and density state

Large Hadron Collider (CERN)
Pb-Pb collision ($\sqrt{s_{NN}} = 5$ TeV)



Perturbative QCD and Jets

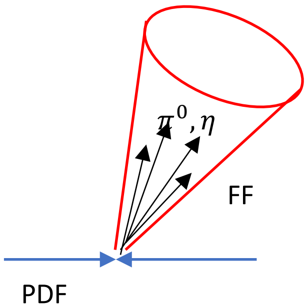


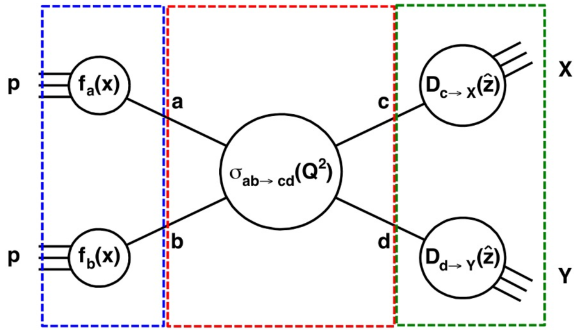
[arXiv:1411.4969]

Parton Distribution function (**PDF**) which is from deep inelastic scattering describe the momentum fraction of the partons inside the incoming proton.

Fragmentation Function (**FF**) which is from collisions describe the probability that an outgoing parton fragments into the observed hadron as a function of the momentum fraction.

Jets are collimated spray of particles produced by a high momentum quark or gluon





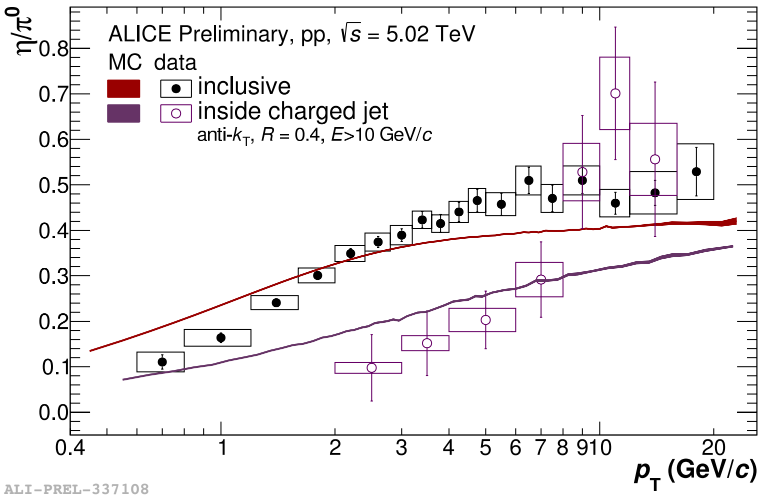
$$Z(FF) = \frac{p_{T,hadron}}{p_{T,parton}} \approx \frac{p_{T,hadron}}{p_{T,jets}}$$

- **Jets fragmentation function can be measured directly**

Motivation and Goal

- The difference of measurement between inside jets with inclusive jets
  - ➢ The measurement of η/π^0 ratio in low p_T
  - ➢ **The dependency of the minimum jet transverse momentum**

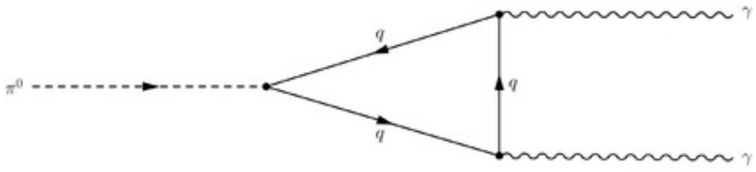
- The measurement of neutral meson in **high and low p_T** inside jets
  - ➢ The measurement of neutral meson using trigger data and hybrid method



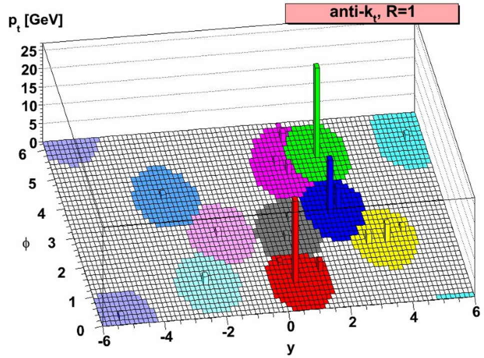
1. The suppression effect of η/π^0 ratio inside jets
2. The measurement of neutral mesons and jet fragmentation function in high statistics

Analysis outline

1. Neutral meson reconstruction
   - Photon reconstruction
     - ✓ Calorimetric method
     - ✓ Photon Conversion Method
   - Signal (Invariant mass method), Background (Event Mixing Method)
   - (1) Detector acceptance (2) Reconstruction efficiency

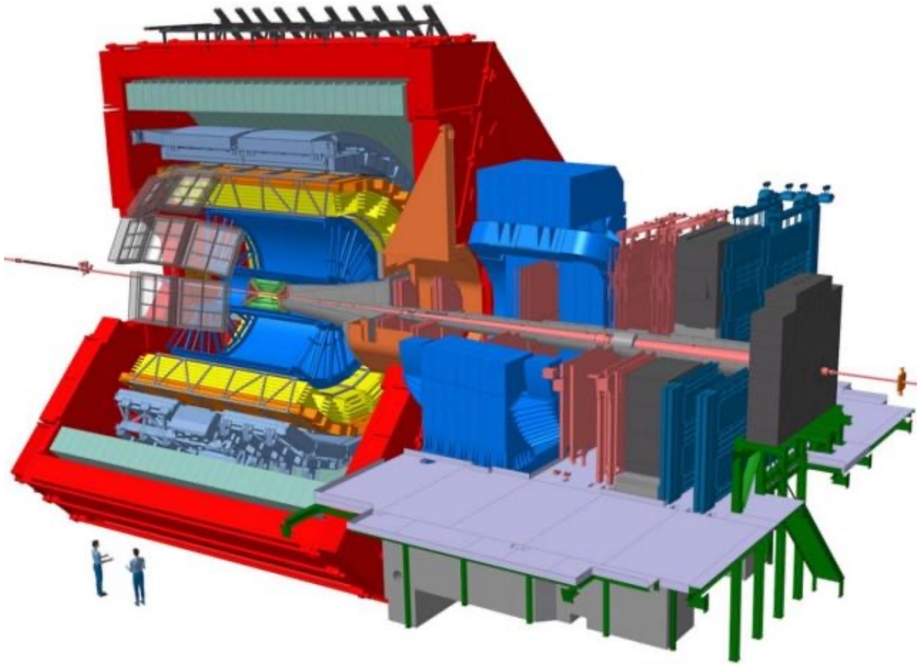


2. Jets measurement
   - Jets reconstruction
   - (3) Neutral meson correction function inside jets



ALICE Detector

- $\sqrt{s}$ = 13 TeV, pp collision, (LHC2016-2018)
- Event number ：MB:1.32×10^{9} , EG1:8.32×10^{7} (E > 10 GeV), EG2: 1.13×10^{8} (E > 4 GeV)



- V0 detector
  - ➢ MB trigger

✓ Photon Conversion Method
- Inner Tracking System (ITS)
- Time Projection Chamber (TPC)
  - ➢ Tracking and particle identification
  - ➢ Jets reconstruction

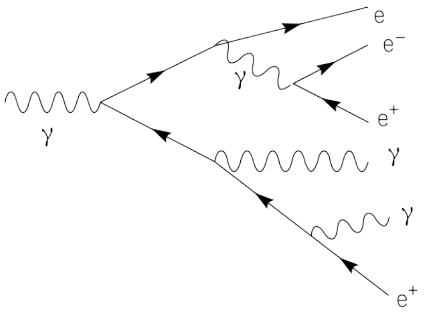
✓ Calorimetric method
- Electromagnetic Calorimeter (EMCal)
  - ➢ EG1, EG2 trigger
- Photon Spectrometer(PHOS)

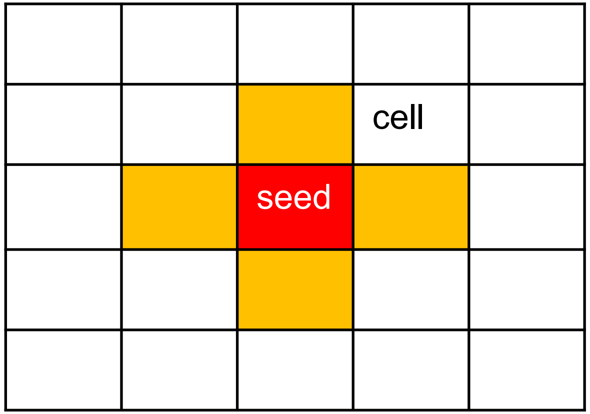
Photon reconstruction

Calorimetric method	Photon Conversion Method

Calorimetric method

- Neutral mesons which are π^0 and η are made by hadronization.
- Decay photon enters electromagnetic calorimeter, they create the electromagnetic shower.
- Electromagnetic showers are reconstruction into clusters in EMCal, PHOS.

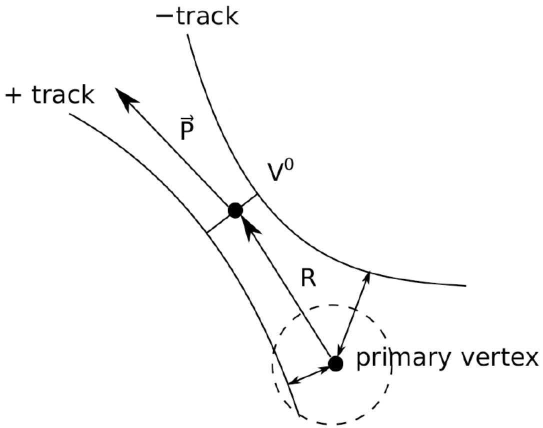




Photon Conversion Method

- The decay photons split e^+e^- pair by electro pair production
- The reconstruction of V^0(neutral particles) by electron

- Neutral meson reconstruction using energy loss



Invariant mass distribution of π^0 meson

- Invariant mass method

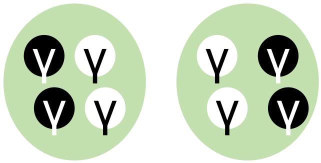
$$M_{\gamma\gamma} = \sqrt{2E_{\gamma 1}E_{\gamma 2}(1-\cos\theta_{12})}$$

$$y = Gaussian + exponetial + linear$$

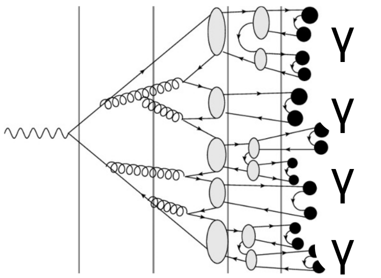
- Event mixing method (background)

BG

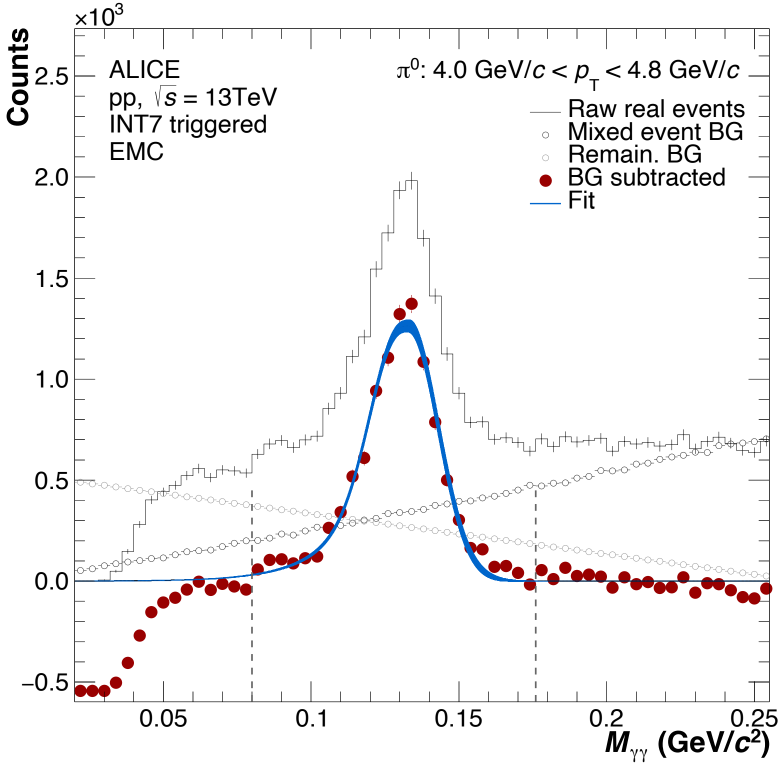
BG



Signal



BG

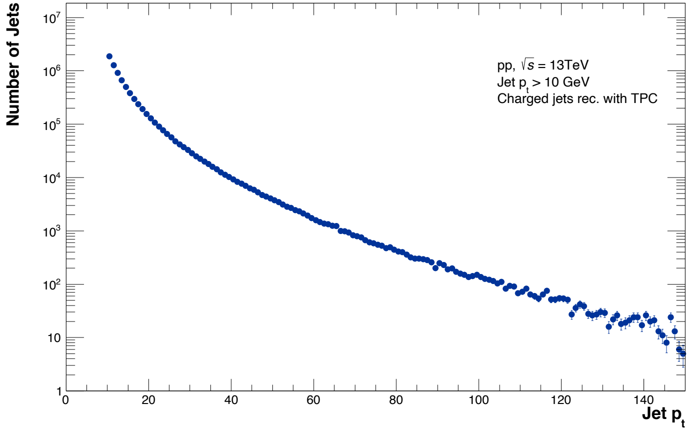


Jets reconstruction

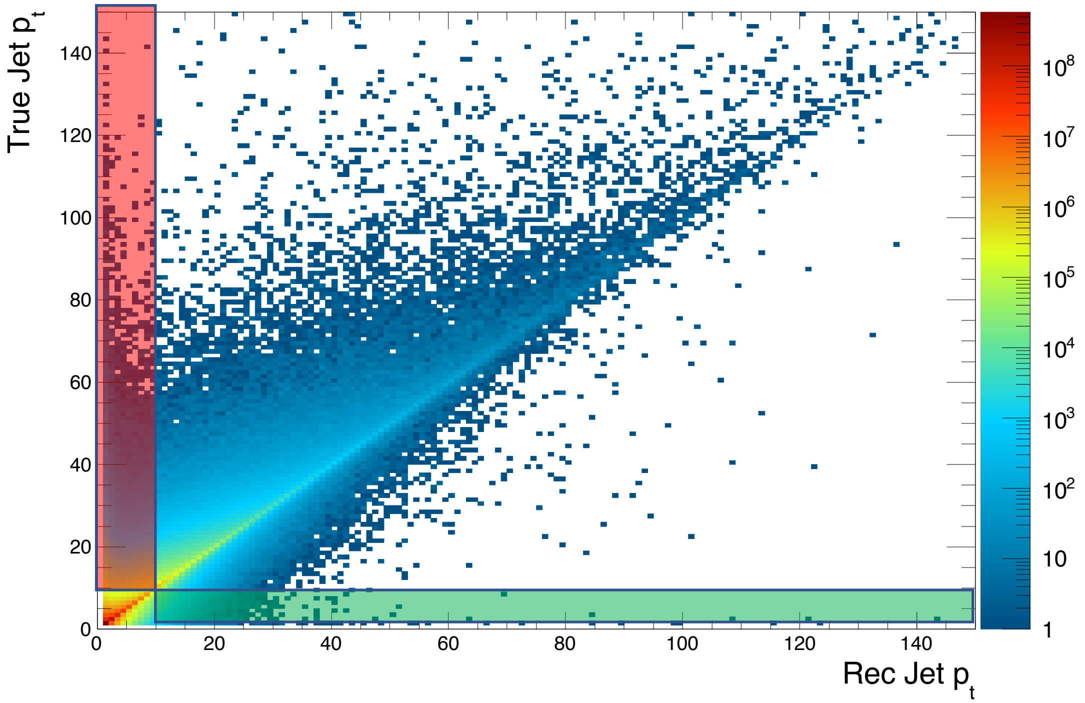
Jets algorithm	anti-k_t algorithm
Jet radius	0.4
Minimum track p_T	0.15 GeV/c
Type of jets	Charged jets
Minimum jet p_T	10 GeV/c
Jet axis range	$\|\eta_{axis}\| < 0.5$

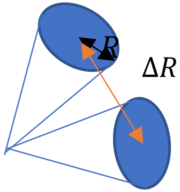
- Reconstructing charged jets only, to avoid auto-correlation from the neutral meson decays.
- To avoid jet from underlying event, minimum momentum of jet set 10 GeV/c.
- TPC acceptance is 0.9, therefore we restrict the reconstructed jet axis within < 0.5. This can be further restricted to minimize the edge effect of the acceptance

- anti-k_t algorithm is selecting highly energetic particles first in the recombination.



Neutral meson correction function inside jets - 1





$\Delta R = \sqrt{\Delta\eta^2 + \Delta\phi^2} < 0.3$

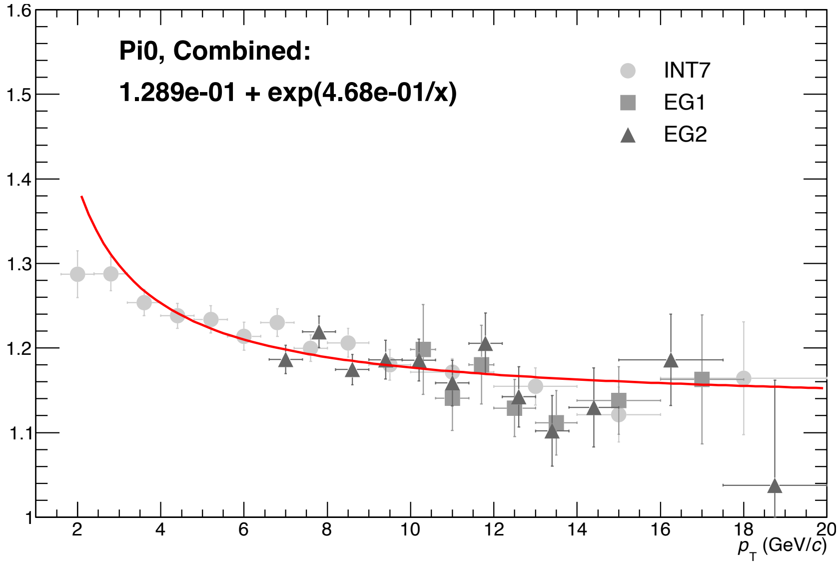
(1)	Reconstructed jet p_T < 10 GeV/c & true jet p_T > 10 GeV/c	positive
(2)	Reconstructed jet p_T > 10 GeV/c & true jet p_T < 10 GeV/c	negative

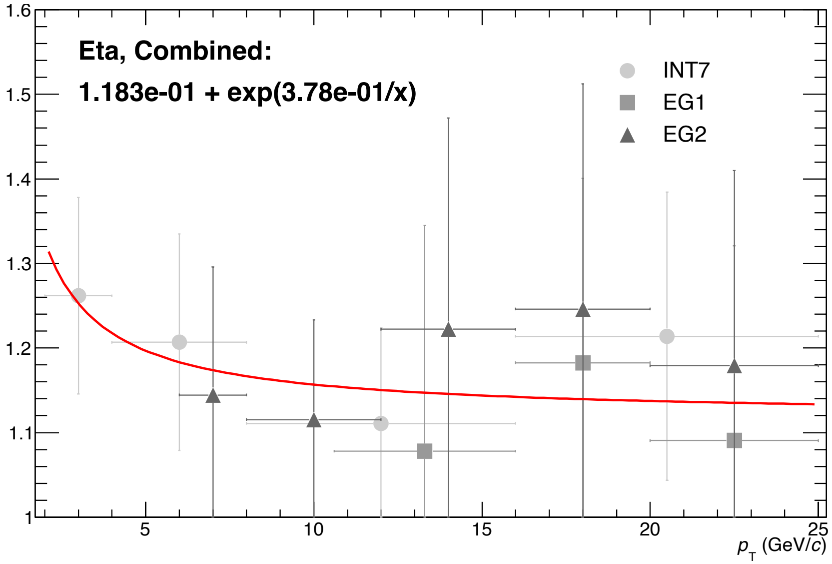
1. Missed data: jets **should be reconstructed**, but jets was not reconstructed
2. Rejected data: jets **should not be reconstructed**

$$\text{Neutral meson correction function inside jets} = 1 + \frac{(1)-(2)}{matching\ data}$$

Neutral meson correction function inside jets - 2

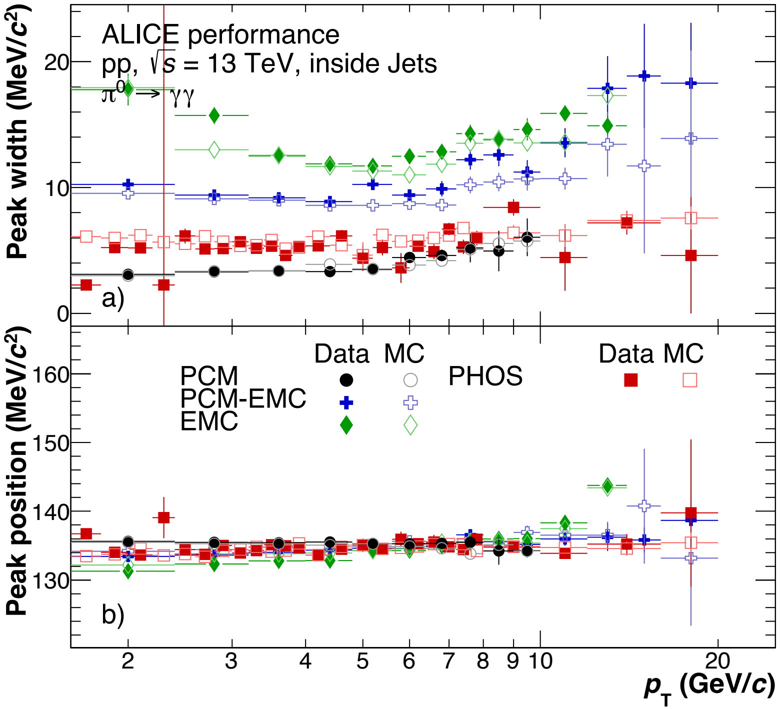
$$\text{Neutral meson correction function inside jets} = 1 + \frac{(1) - (2)}{matching\ data}$$

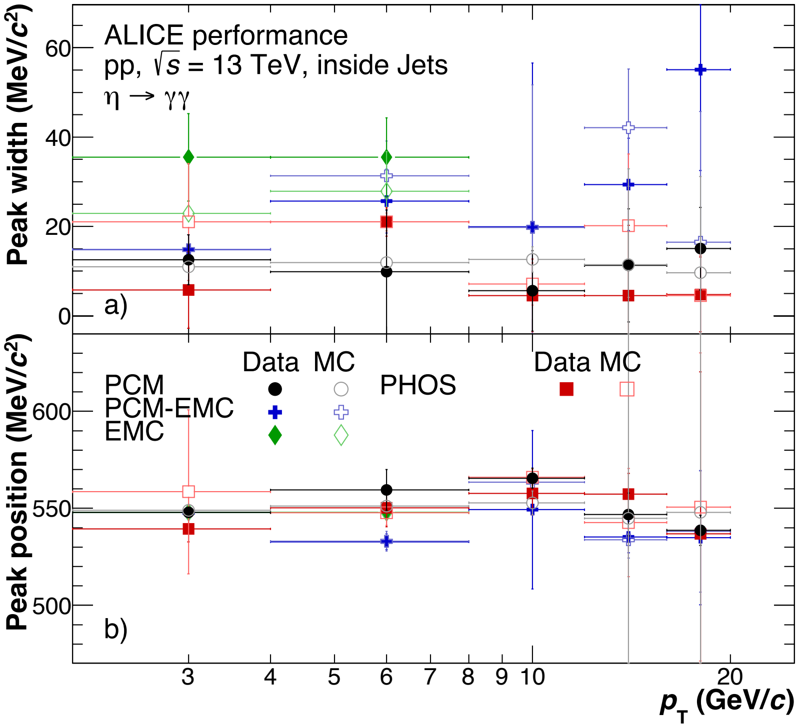




- The correction function is used for neutral meson yield

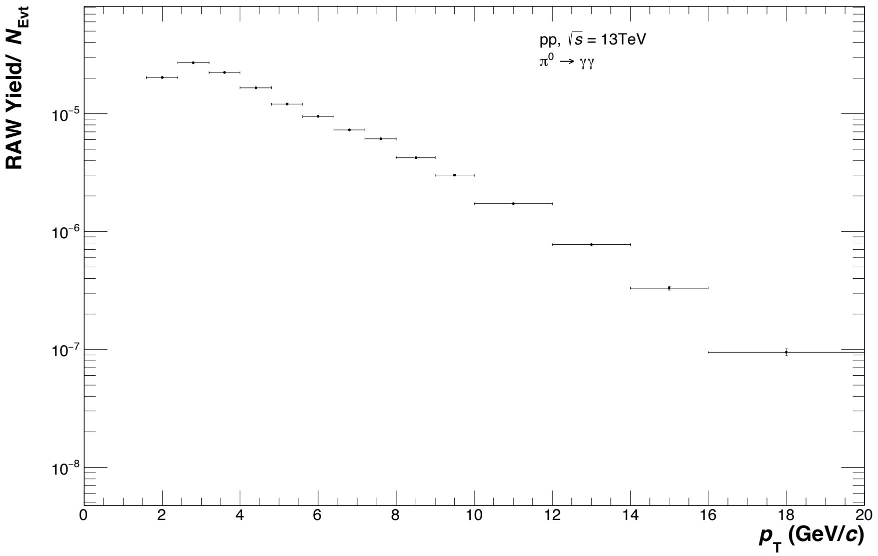
π^0, η measurement

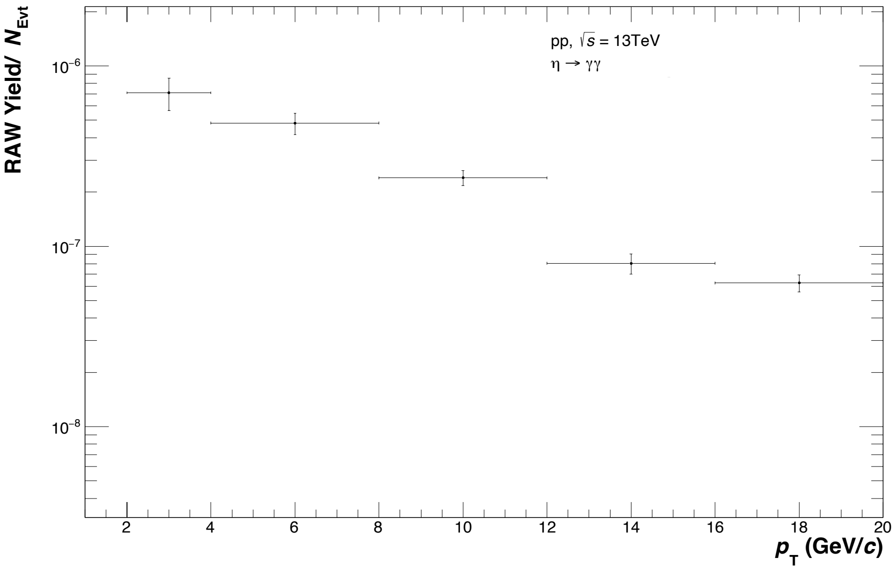




- The neutral mesons are measured for the hybrid method of Electromagnetic calorimeter (EMCal, PHOS) , PCM and PCM-EMC
- PCM and PHOS can be measured in low p_T

η/π^0 ratio



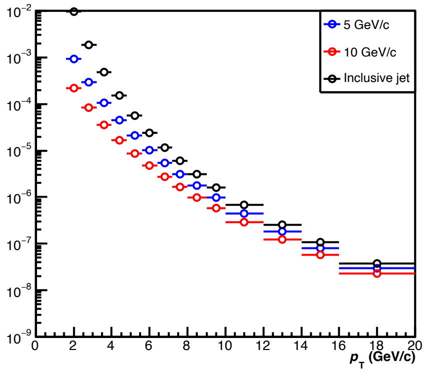


- η/π^0 ratio inside jets is suppressed when compared to inclusive jets.
- The suppression effect inside jets is presented definitely at low p_T.
- This difference shows modification of neutral meson production inside jets

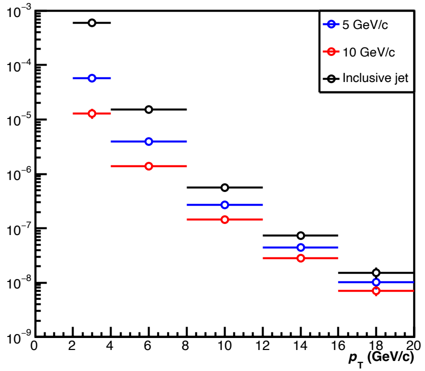
Comparison of neutral meson measurement for minimum jet p_T - 1

MC (Pythia)

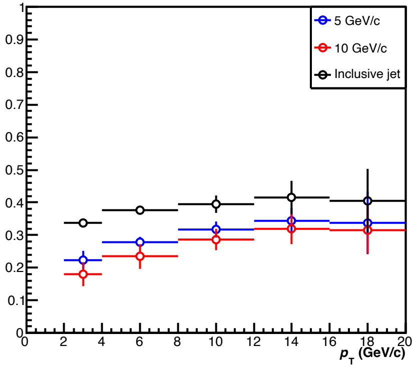
π^0



η



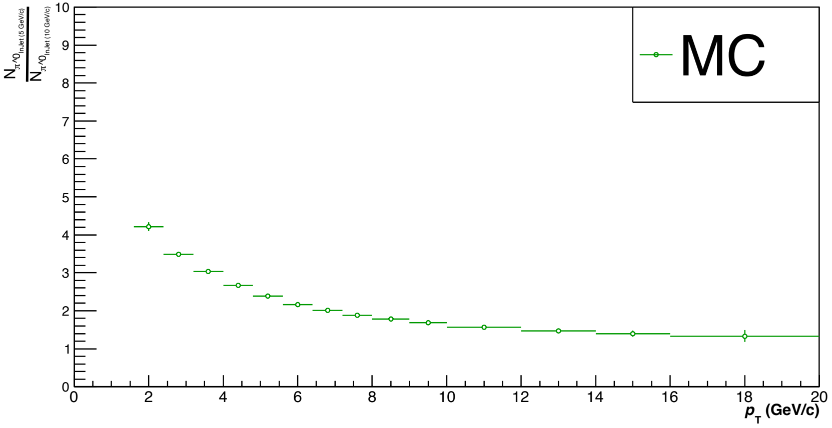
η/π^0



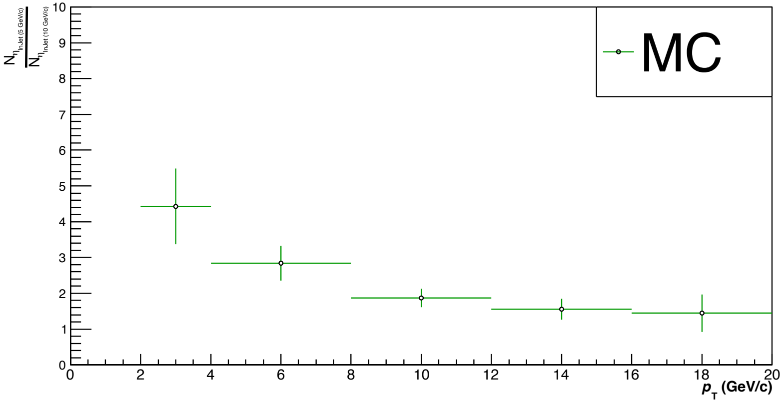
- The measurement of neutral mesons inside jets when compared inclusive jets
- The measurement for minimum jet p_T is small when compared inclusive jets

Comparison of neutral meson measurement for minimum jet p_T - 2

π^0



η



- The ratio of the measurement of neutral mesons produced inside jets for minimum jet p_T > GeV/c when compared 10GeV.
- The ratio is higher in low p_T

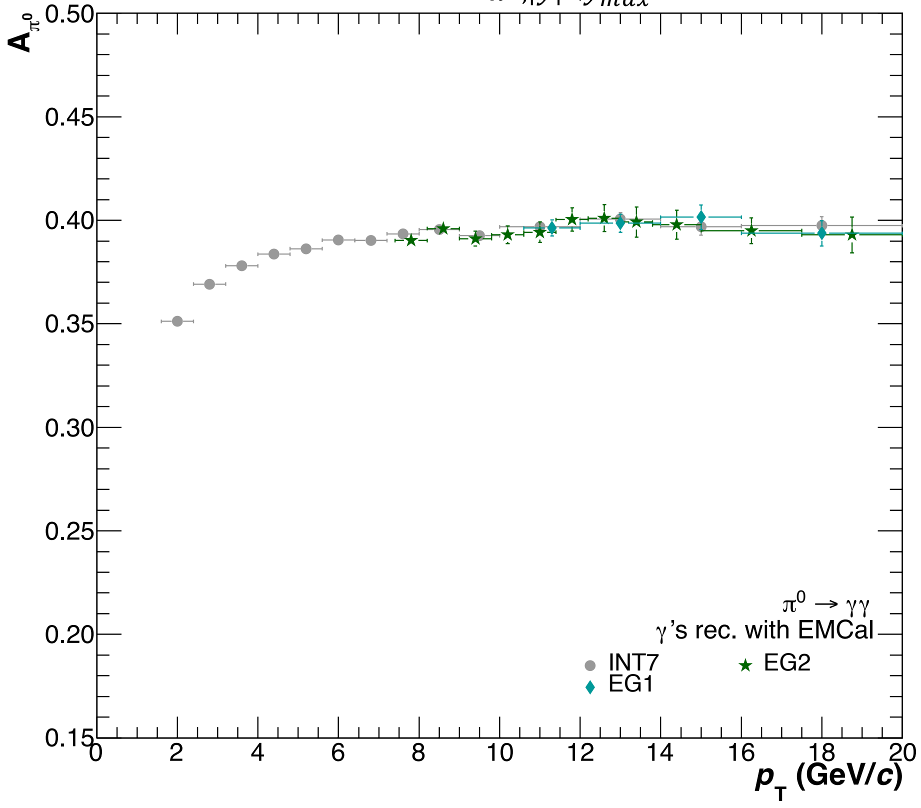
Conclusion

- Summary
  - Neutral mesons (π^0, η) measurement inside jets is performed at $\sqrt{s}$ = 13 TeV in pp collision
  - The suppression effect inside jets for η/π^0 ratio is presented in MC
  - The comparison of η/π^0 ratio for minimum jet p_T in MC
- Outlook
  - The measurement of cross section with correction factor and function
  - The dependency of jets radius
  - Jets fragmentation function in pp and heavy ion collision

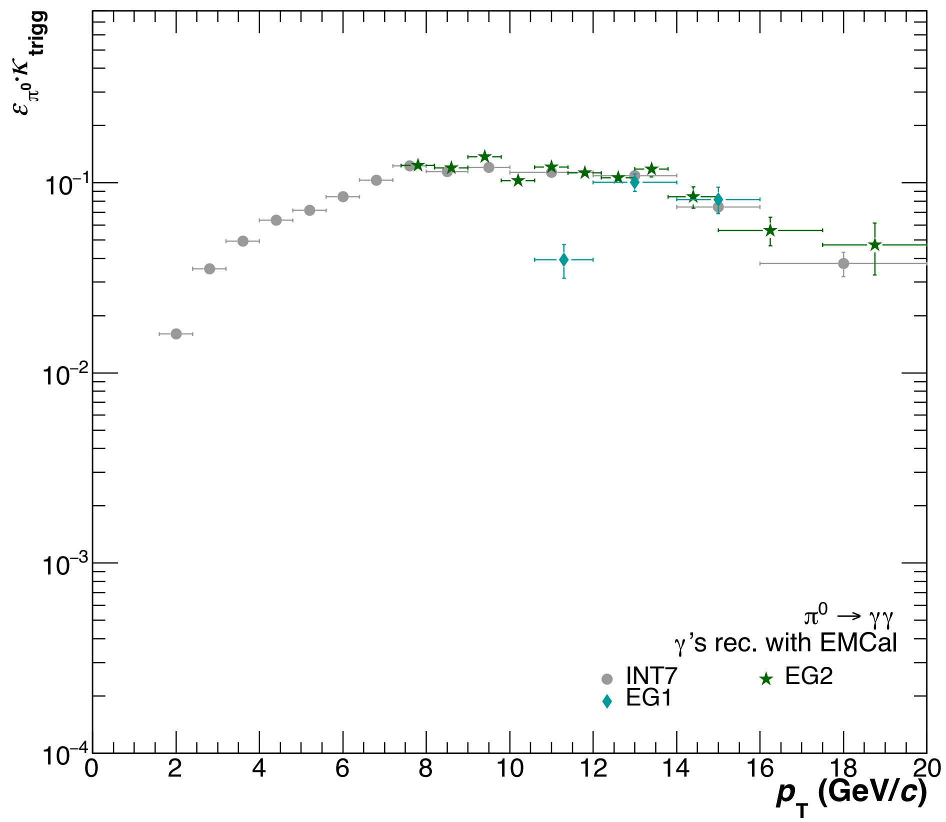
Backup

Detector acceptance and Reconstruction efficiency

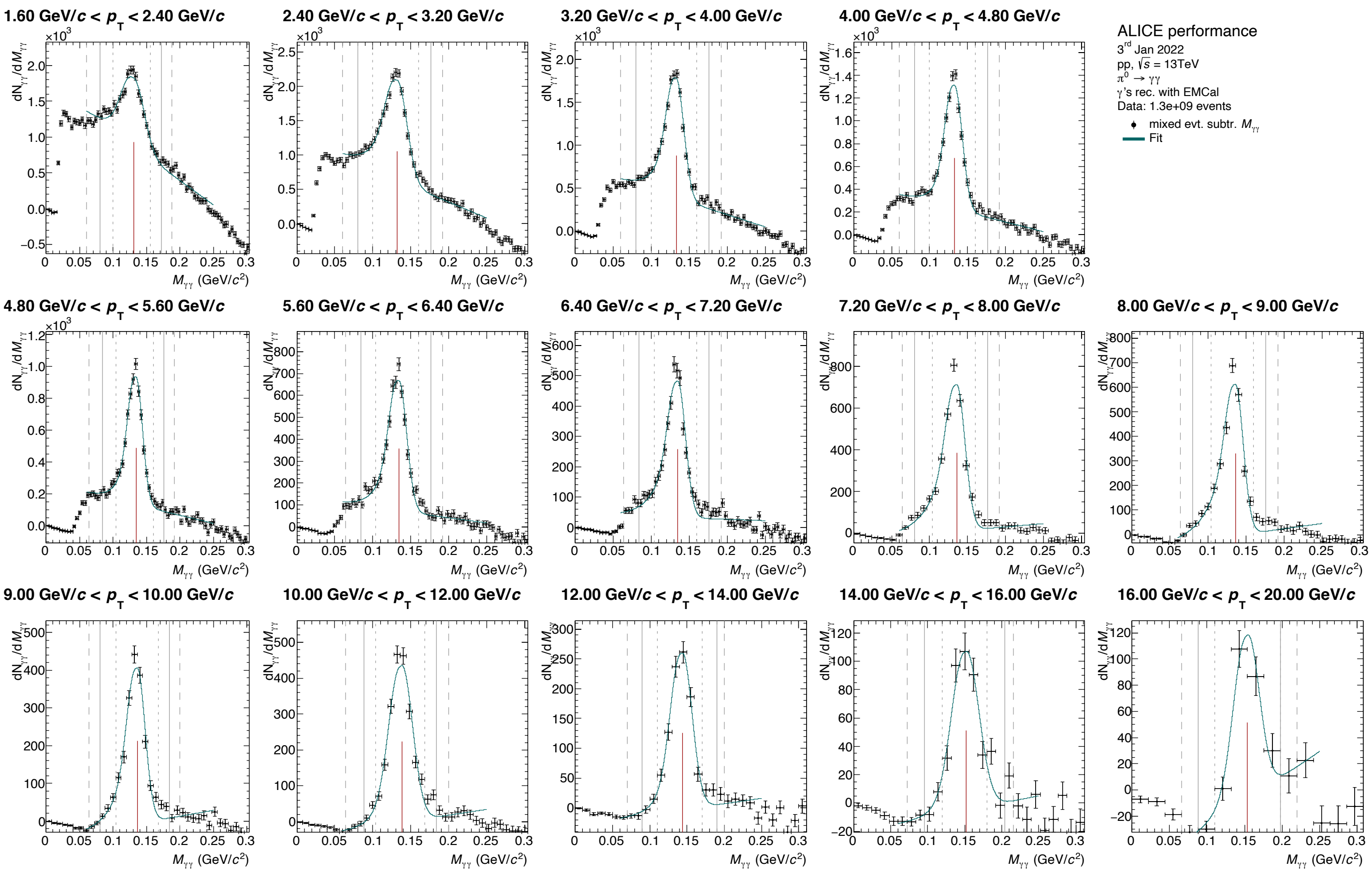
$$A_{\pi^0(\eta)} = \frac{N_{\pi^0(\eta),|y|<y_{max},\eta_\gamma}}{N_{\pi^0,|y|<y_{max}}}$$



$$\epsilon_{\pi^0(\eta)} = \frac{N_{\pi^0(\eta),|y|<y_{max},MC\ rec}}{N_{\pi^0,|y|<y_{max}}}$$

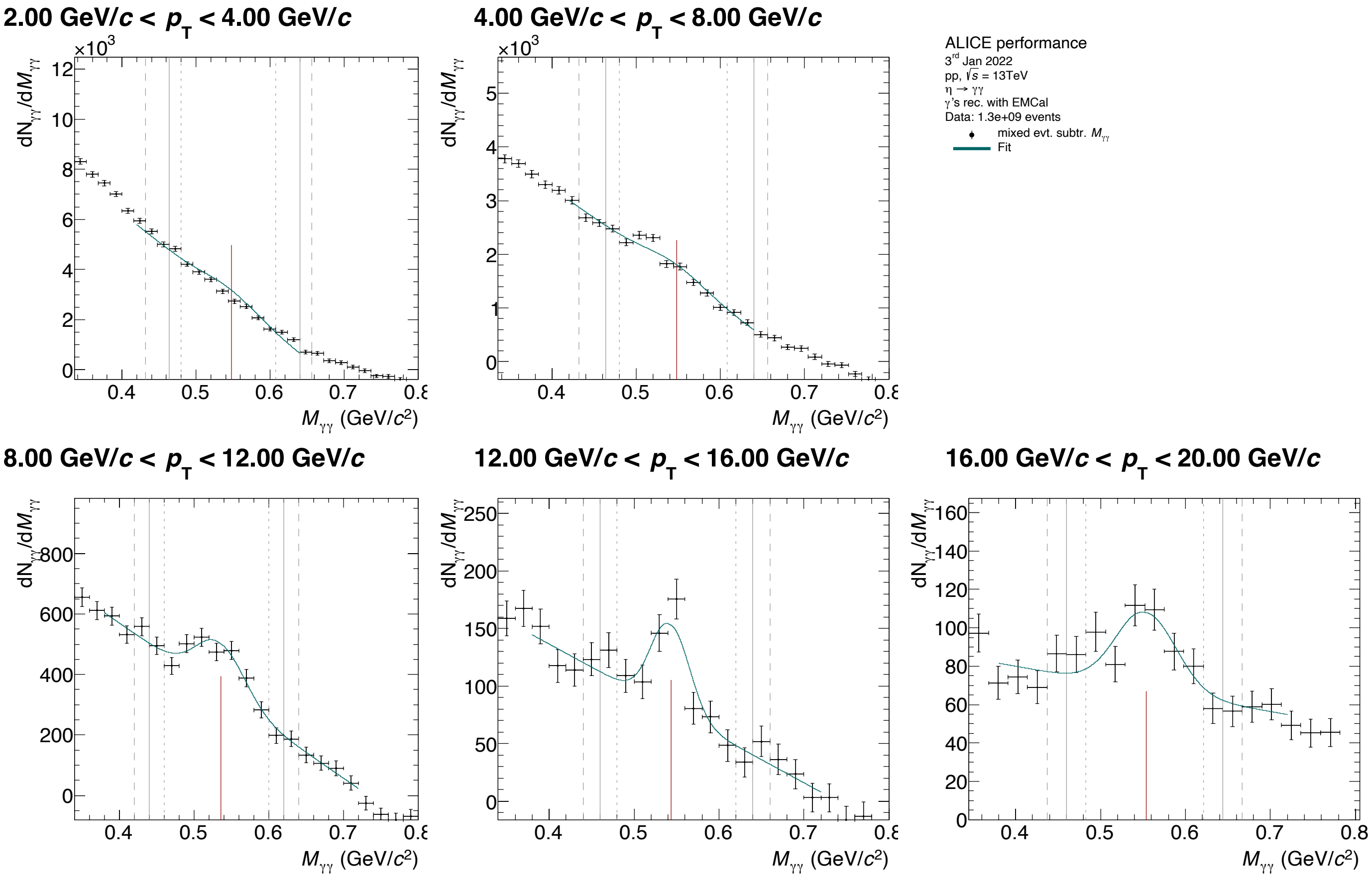


不変質量分布



1.60 GeV/c < p_T < 2.40 GeV/c
2.40 GeV/c < p_T < 3.20 GeV/c
3.20 GeV/c < p_T < 4.00 GeV/c
4.00 GeV/c < p_T < 4.80 GeV/c
4.80 GeV/c < p_T < 5.60 GeV/c
5.60 GeV/c < p_T < 6.40 GeV/c
6.40 GeV/c < p_T < 7.20 GeV/c
7.20 GeV/c < p_T < 8.00 GeV/c
8.00 GeV/c < p_T < 9.00 GeV/c
9.00 GeV/c < p_T < 10.00 GeV/c
10.00 GeV/c < p_T < 12.00 GeV/c
12.00 GeV/c < p_T < 14.00 GeV/c
14.00 GeV/c < p_T < 16.00 GeV/c
16.00 GeV/c < p_T < 20.00 GeV/c
dN_γγ/dM_γγ
M_γγ (GeV/c²)
ALICE performance
3rd Jan 2022
pp, √s = 13TeV
π⁰ → γγ
γ's rec. with EMCal
Data: 1.3e+09 events
mixed evt. subtr. M_γγ
Fit

不変質量分布



2.00 GeV/c < p_T < 4.00 GeV/c
4.00 GeV/c < p_T < 8.00 GeV/c
8.00 GeV/c < p_T < 12.00 GeV/c
12.00 GeV/c < p_T < 16.00 GeV/c
16.00 GeV/c < p_T < 20.00 GeV/c
dN_γγ/dM_γγ
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Data: 1.3e+09 events
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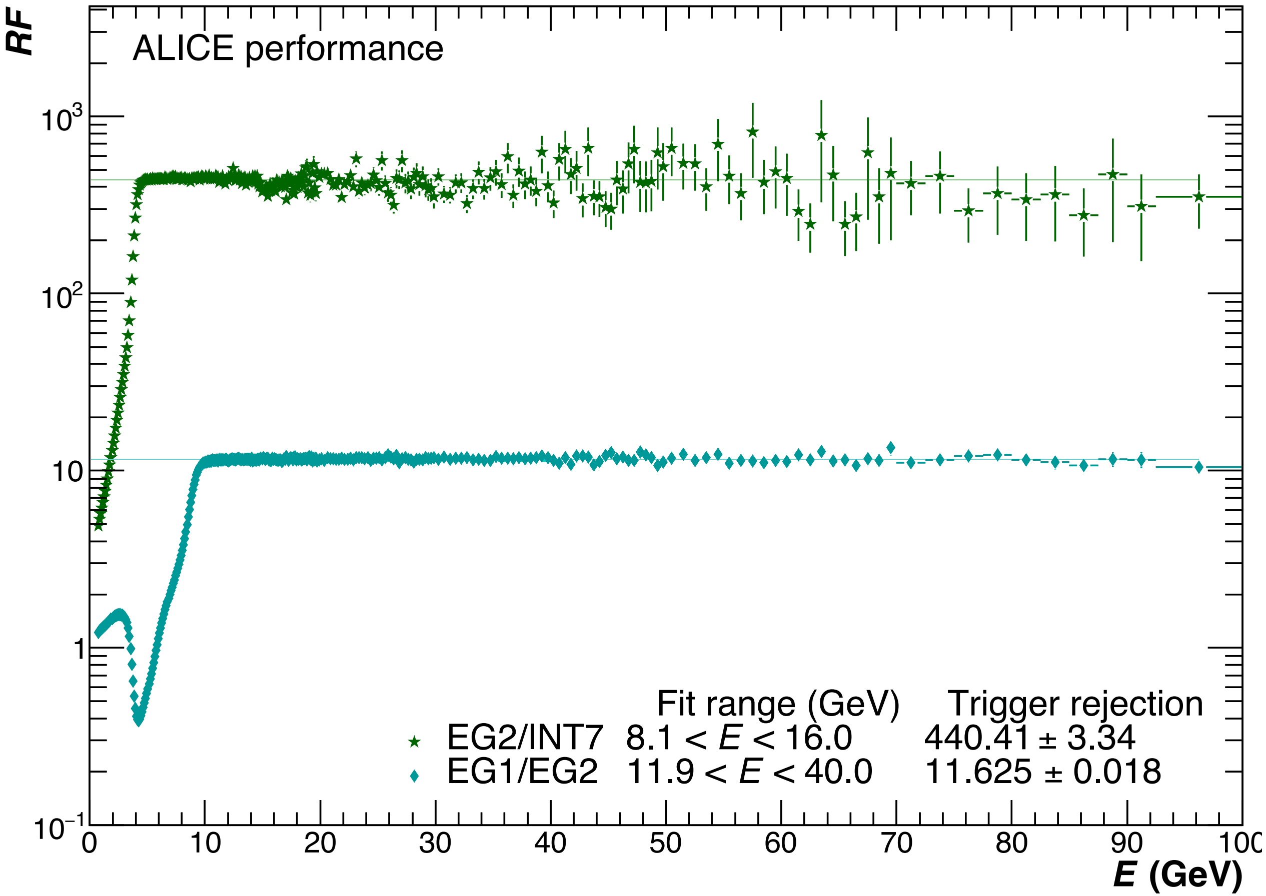
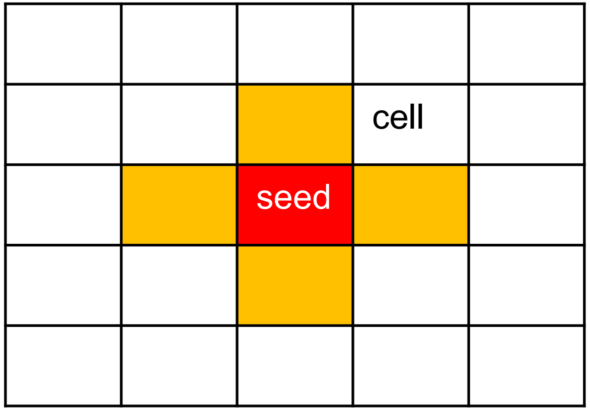
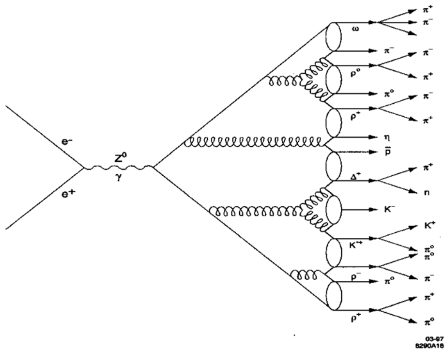
Rejection Factor

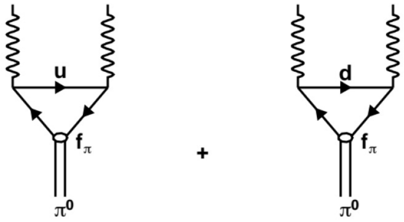


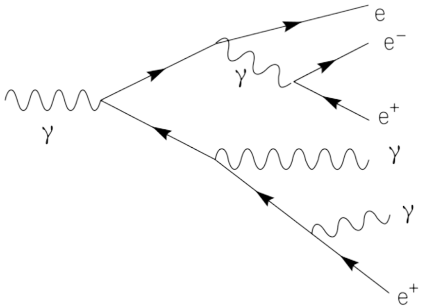
電磁シャワーによるクラスター

- ハドロン化に生成される中性中間子は二つの光子に崩壊
- 崩壊光子は電磁カロリメータ中で電磁シャワーが生じる
- 電磁カロリメータを通常複数のセルにまたがって生成された電磁シャワーをクラスタリングする



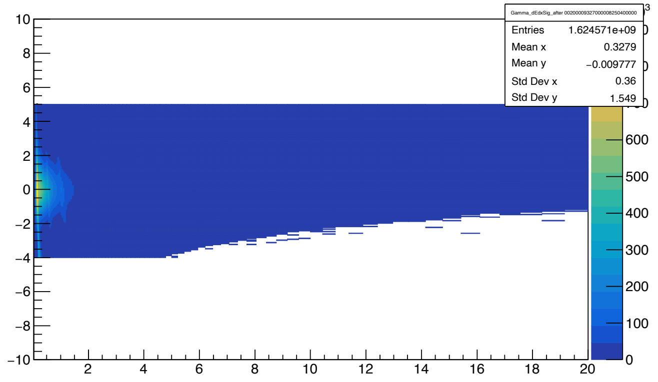




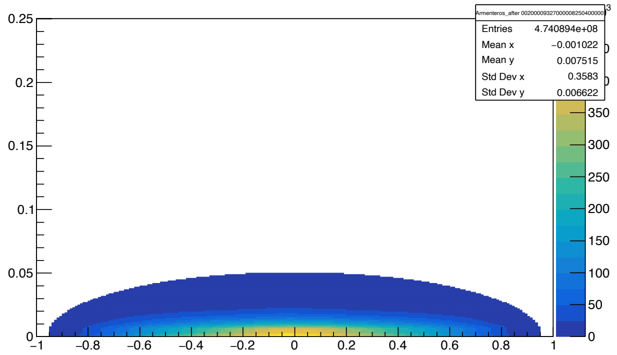


Photon Convertsion Method

- V0 選択
  - ➢ Kalman filter
  - ➢ DCA(Distance of Closest Approach)



- バックグラウンド除去
  - ➢ $-4 < n_\sigma < 5$
  - ➢ Armenteros-Podolanski



ジェット内中性中間子の補正－Backup