Jets at Belle and LEP

Using PYTHIA-8

BELLE initialization at Upsilon mass.

```
pythia.readString("Beams:idA =  11");
pythia.settings.parm("Beams:eA", 7);
pythia.readString("Beams:idB = -11");
pythia.settings.parm("Beams:eB", 4);
double mZ = pythia.particleData.m0(553);
pythia.settings.parm("Beams:eCM", 10.52);
```

LEP initialization at Z0 mass.

```
pythia.readString("Beams:idA =  11");
pythia.settings.parm("Beams:eA", 45);
pythia.readString("Beams:idB = -11");
pythia.settings.parm("Beams:eB", 45);
double mZ = pythia.particleData.m0(23);
pythia.settings.parm("Beams:eCM", 91.0);
```

Particles : $-3 < \boldsymbol{\eta} < 3$ && $p_T > 0.2$GeV/c

R = 0.8

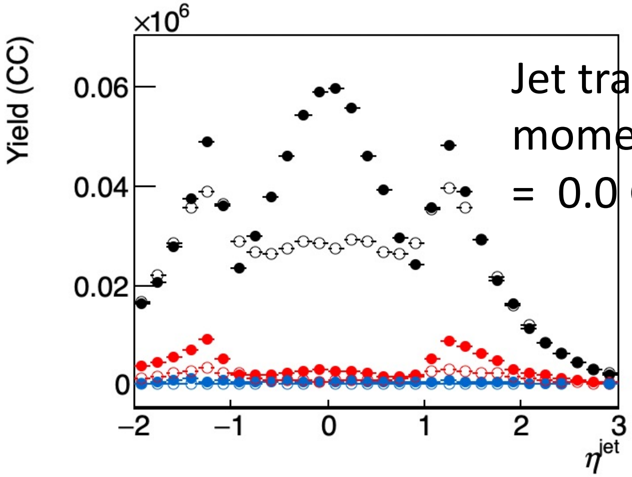
```
fastjet::JetDefinition
jet_def(fastjet::ee_genkt_algorithm, 0.8, -1);
```

Distance set with angle :

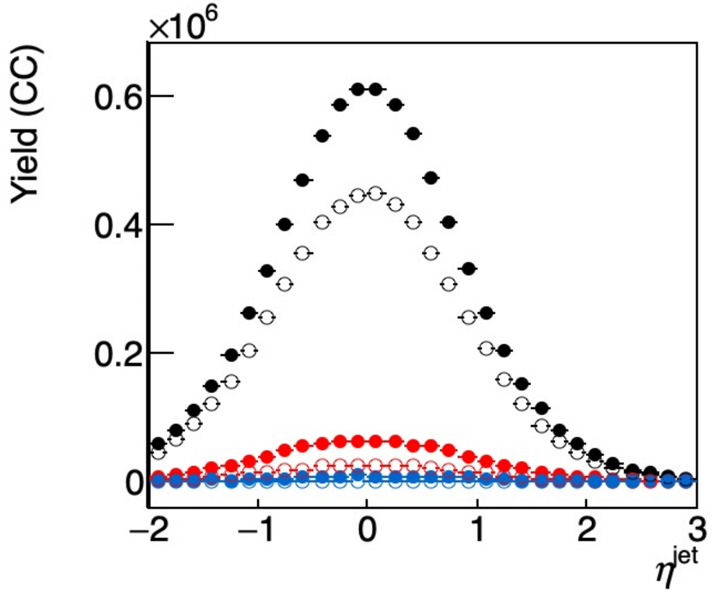
$$d_{ij} = \min\left(E_i^{-2}, E_j^{-2}\right) \frac{1-\cos\theta_{ij}}{1-\cos R_0}$$

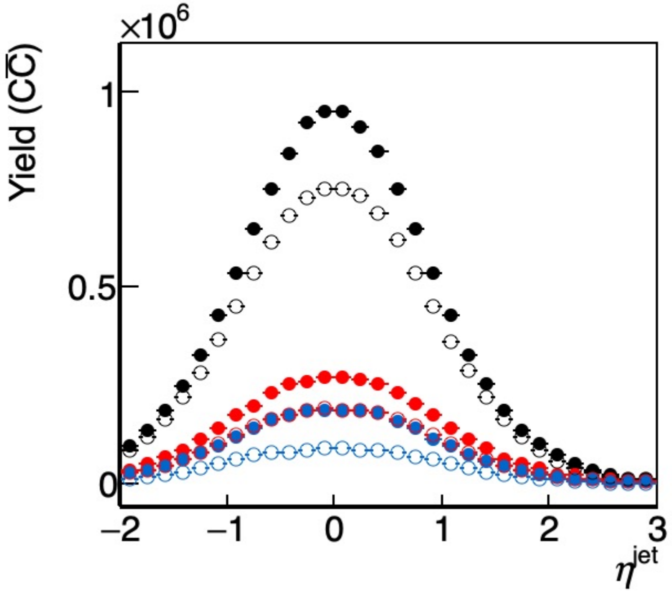
$$d_{iB} = E_i^{-2},$$

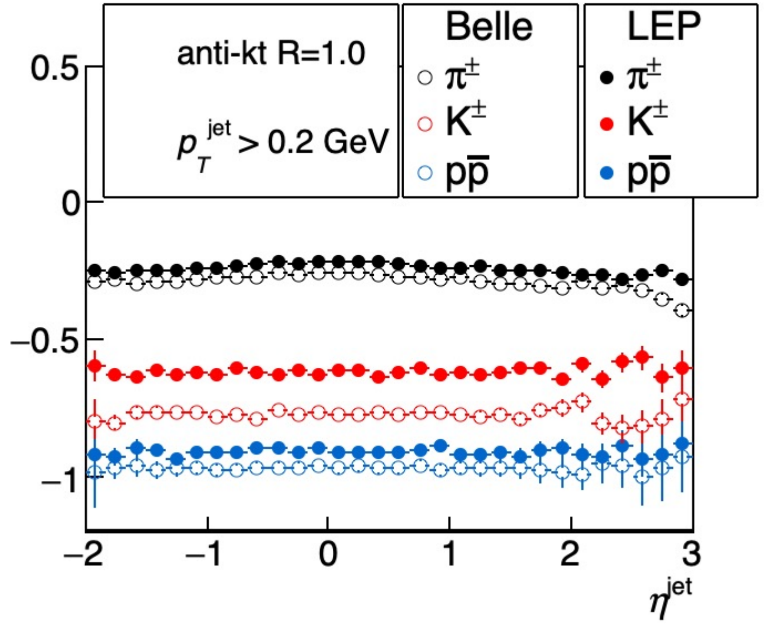
Jets with transverse momentum :
Jet transverse momentum threshold = 0.2GeV/c



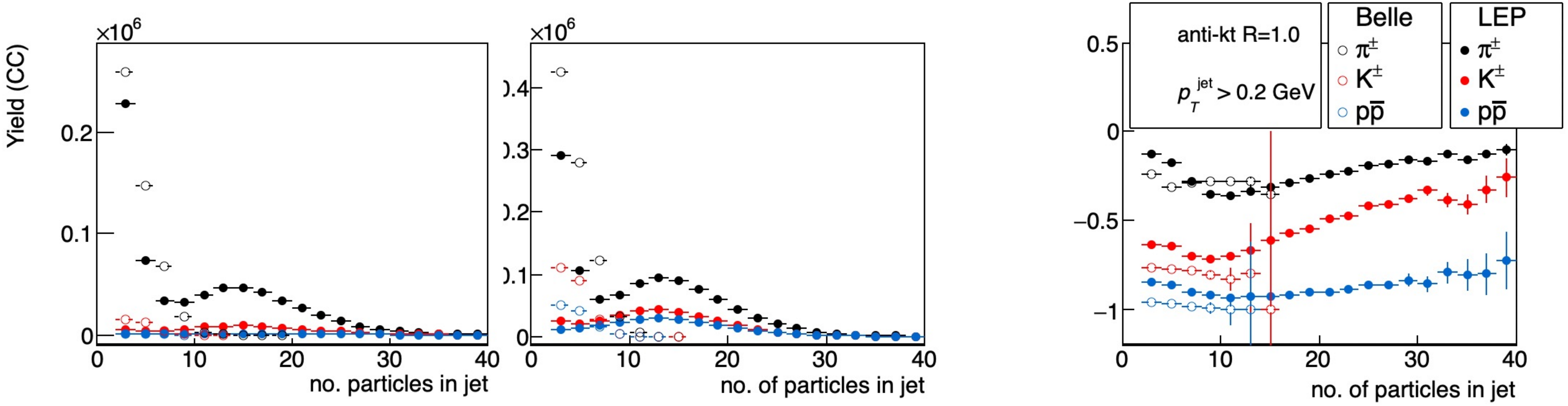
Jet transverse momentum threshold = 0.0 GeV/c



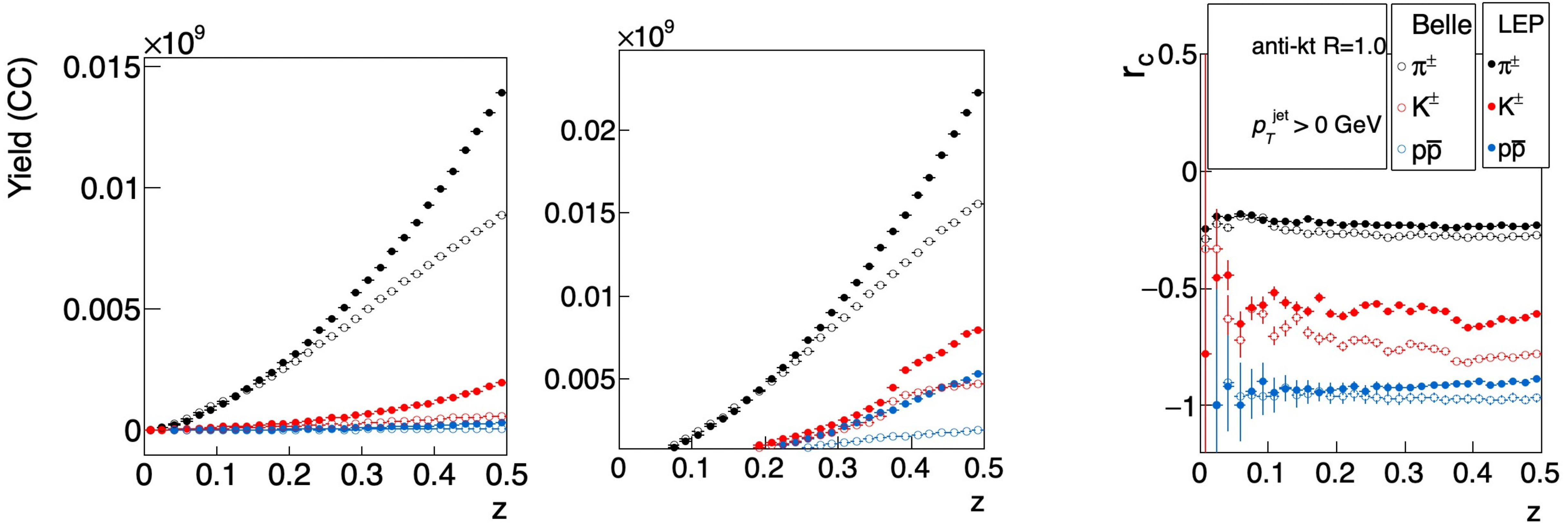




Number of particles in jet

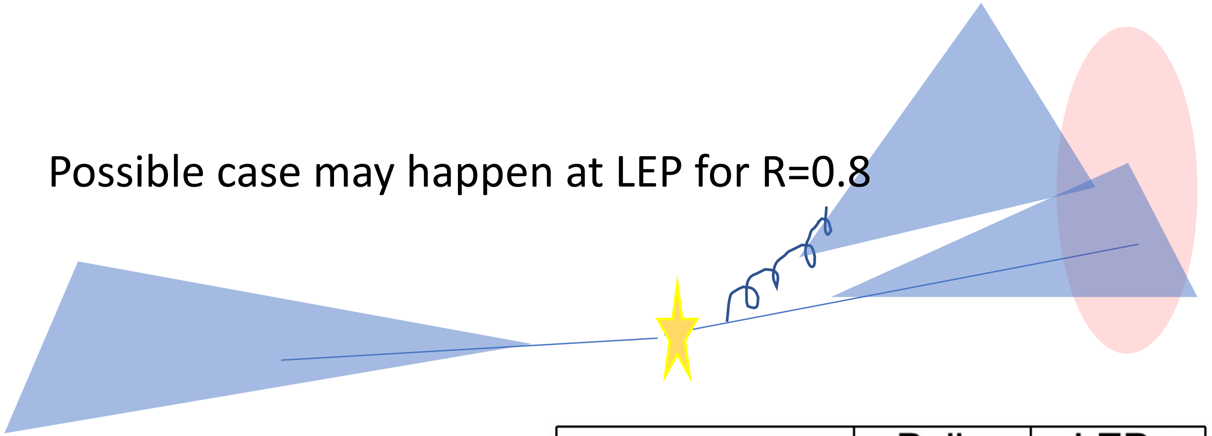


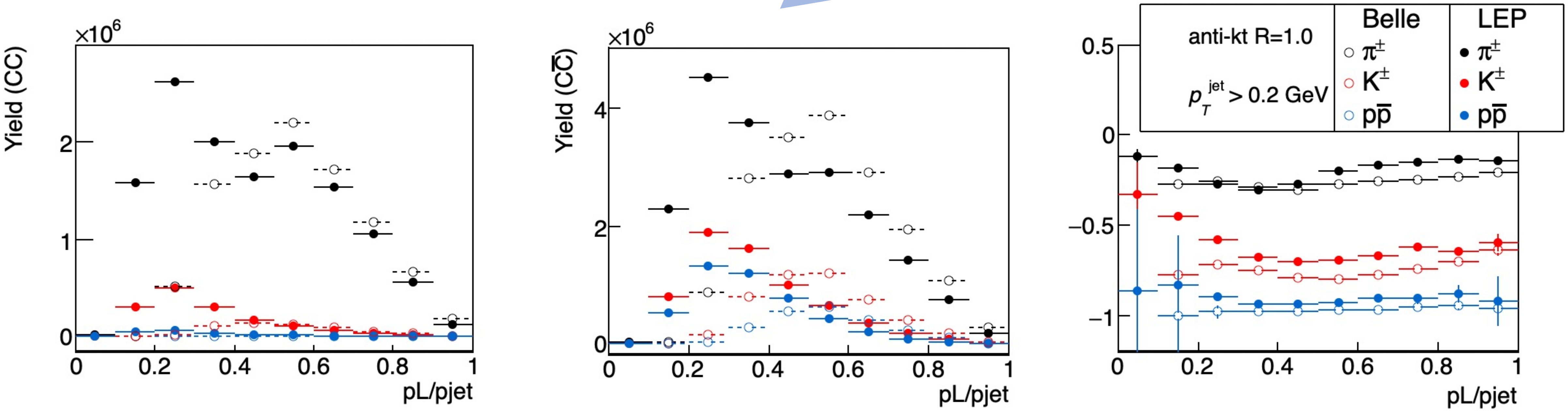
- Belle has relatively small number of particles in jet than LEP
- r_c is stronger



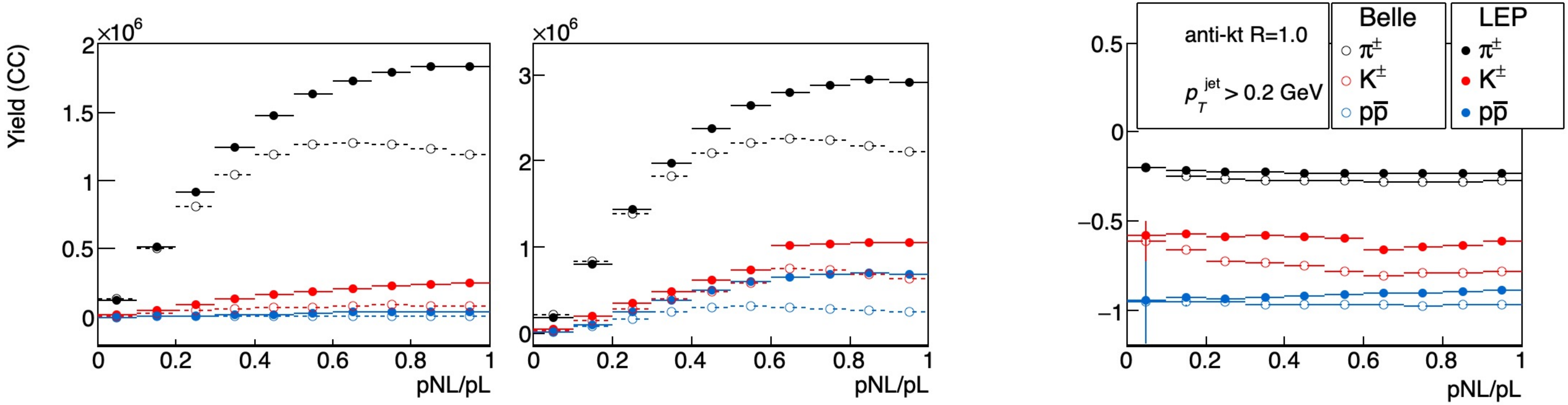
z distributions are different

Possible case may happen at LEP for R=0.8



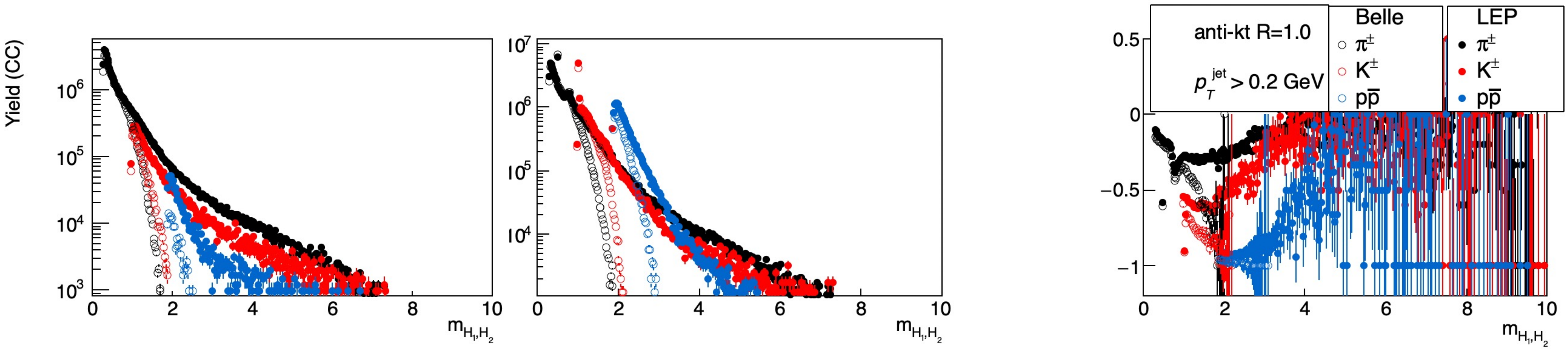


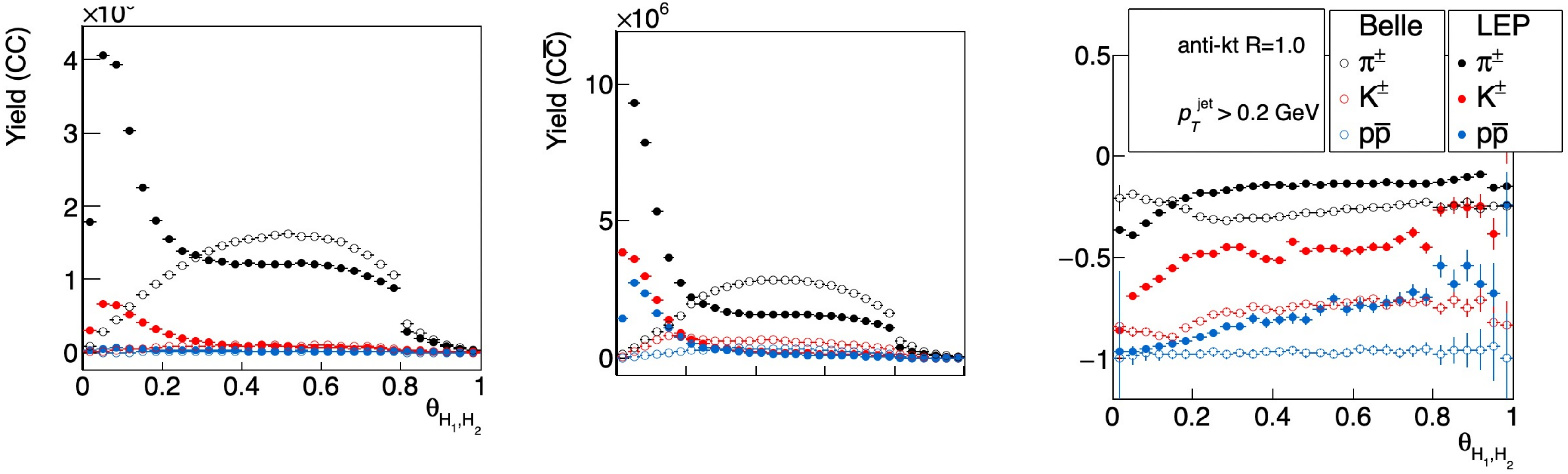
LEP shows a second hump at low pL/pjet.
does two jets with R=0.8 comes within?



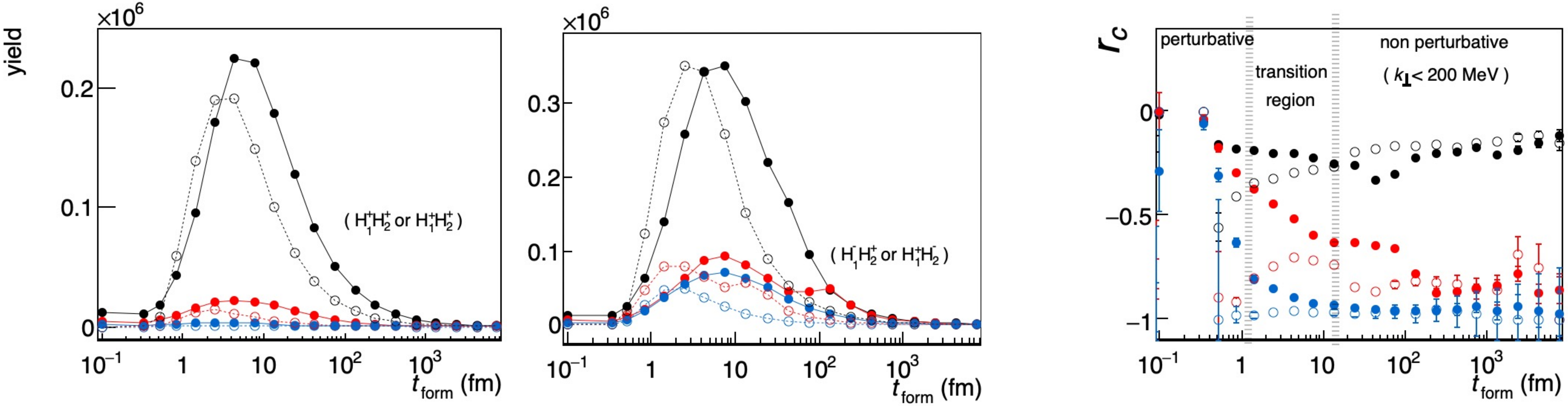
pNL/pL distributions are different

Invariant mass distributions

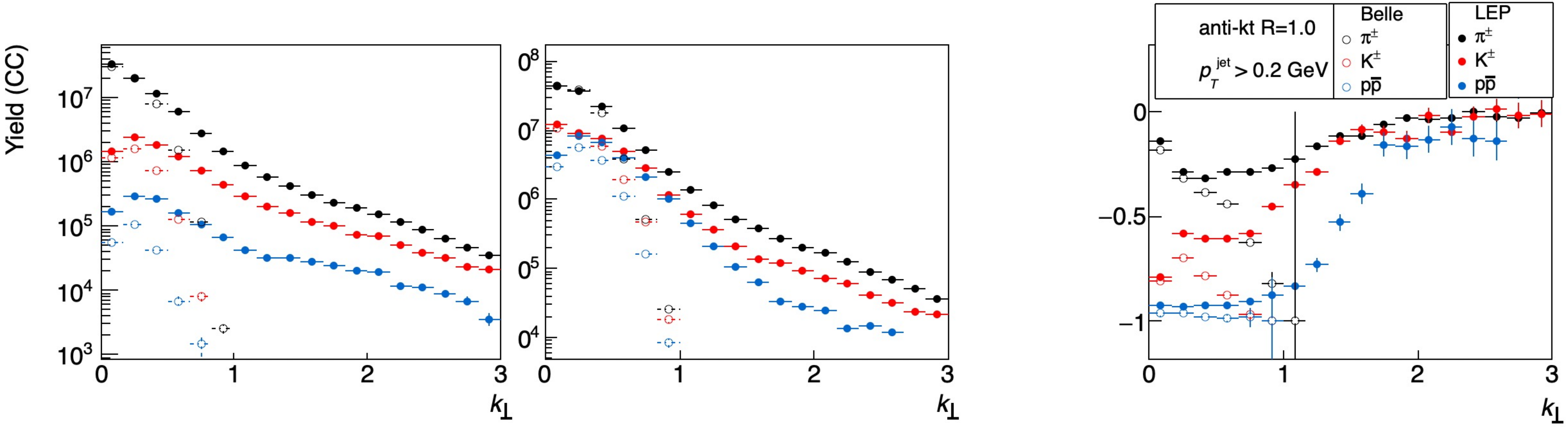




Narrow peak at LEP distributions are different

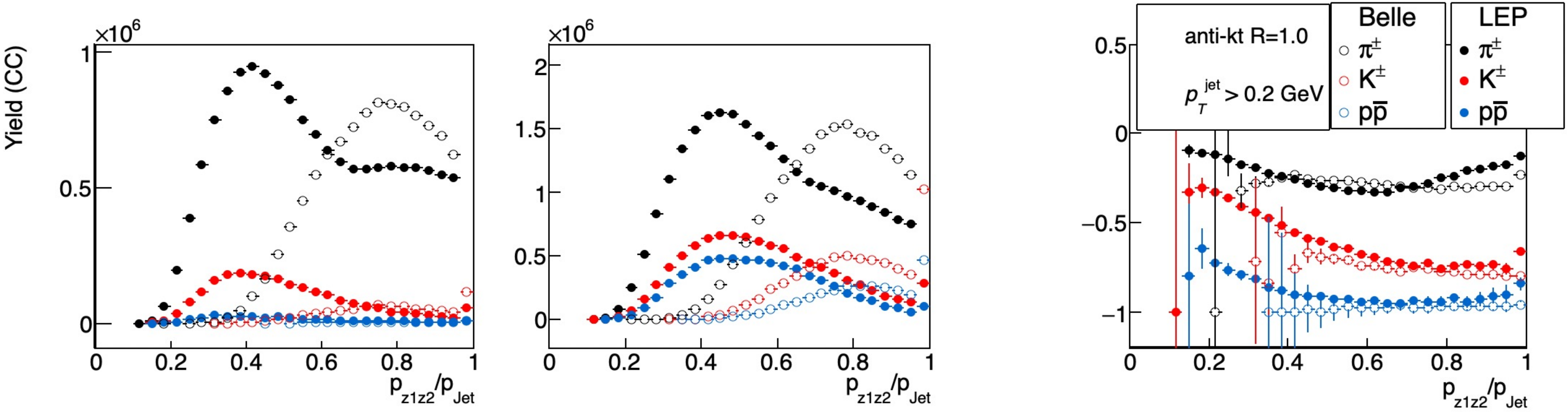


Formation time for opposite pair has distinct shift in peak position



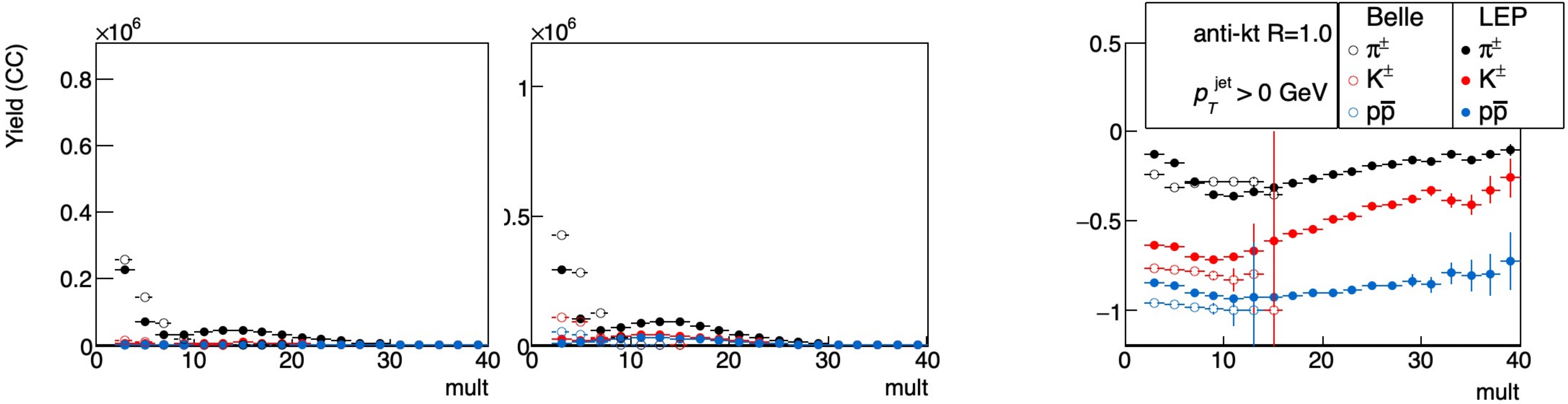
$K_\perp$ don't extend to large value for Belle – mostly nonperturbative

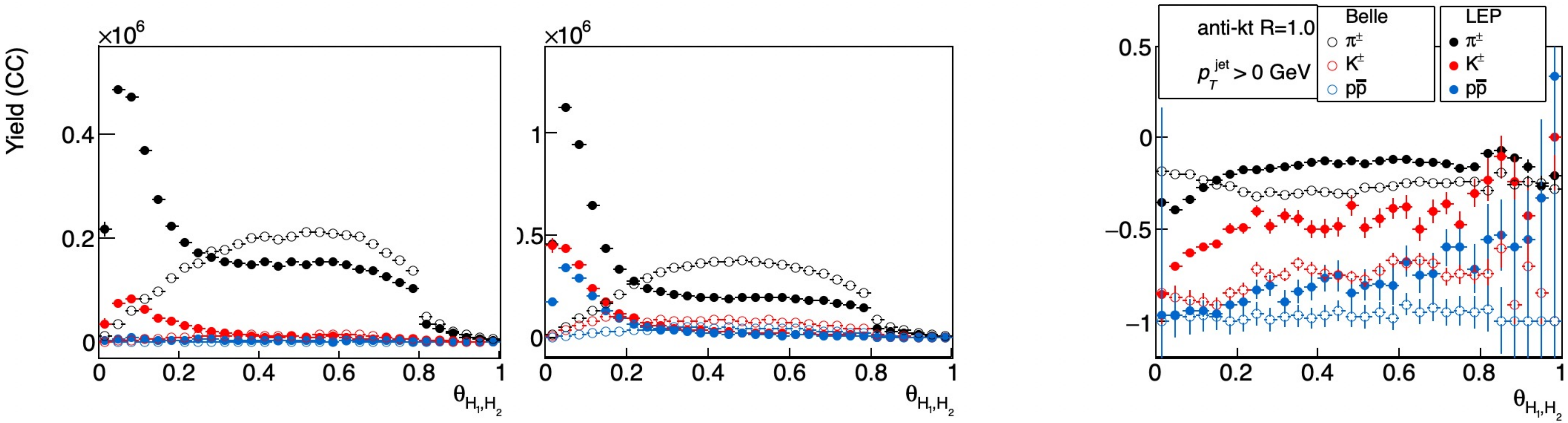
LEP can extend to large $K_\perp$ – significant perturbative contributions



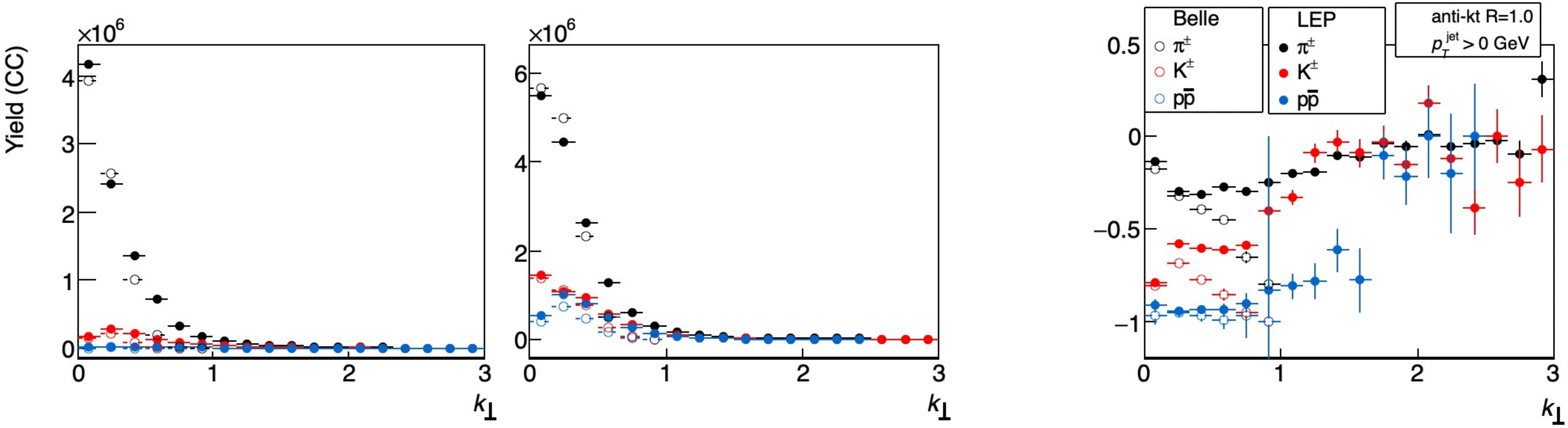
A single scale p_{z1z2}/p_{Jet} : BELLE and LEP 0.5-1.0 overlap region, while LEP exclusively can extend to vales < 0.5

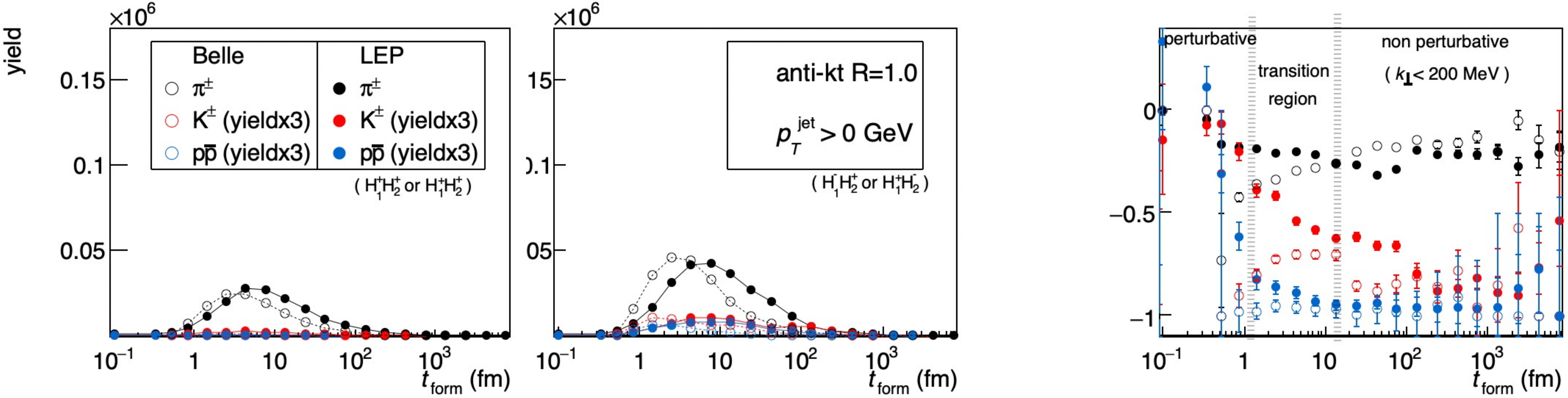
Backup


Yield (CC)
×10^6
0.8
0.6
0.4
0.2
0
0
10
20
30
40
mult
×10^6
1
0.5
0
0
10
20
30
40
mult
0.5
0
−0.5
−1
0
10
20
30
40
mult
anti-kt R=1.0
p_T^{jet} > 0 GeV
Belle
$\pi^\pm$
$K^\pm$
$p\bar{p}$
LEP
$\pi^\pm$
$K^\pm$
$p\bar{p}$

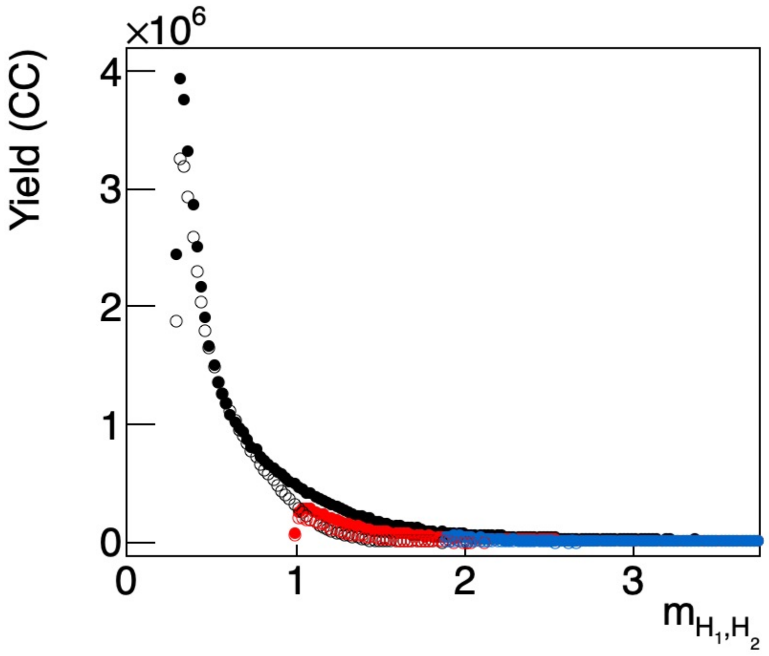


Yield (CC)
$\times10^6$
0.4
0.2
0
0
0.2
0.4
0.6
0.8
1
θ_{H_1,H_2}
$\times10^6$
1
0.5
0
0
0.2
0.4
0.6
0.8
1
θ_{H_1,H_2}
anti-kt R=1.0
$p_T^{jet} > 0$ GeV
Belle
$\pi^\pm$
$K^\pm$
$p\bar{p}$
LEP
$\pi^\pm$
$K^\pm$
$p\bar{p}$
0.5
0
−0.5
−1
0
0.2
0.4
0.6
0.8
1
θ_{H_1,H_2}

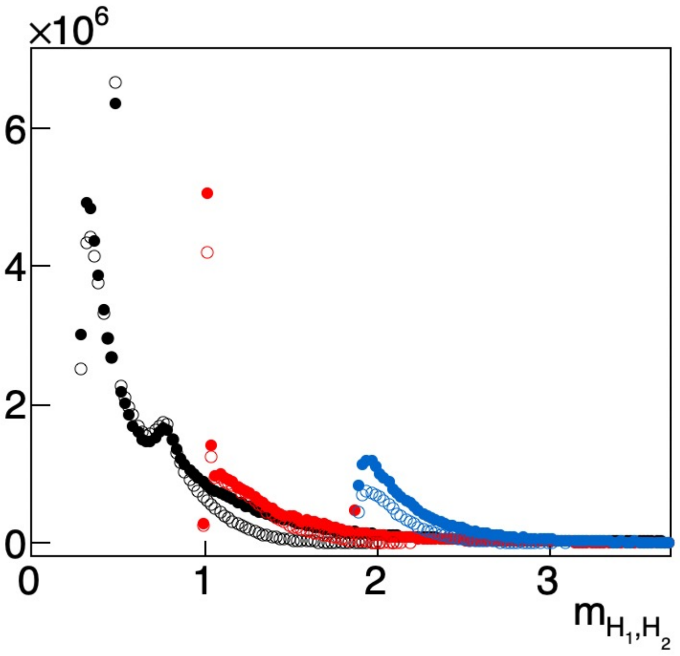

×10^6
Yield (CC)
4
3
2
1
0
0
1
2
3
k⊥
×10^6
6
4
2
0
0
1
2
3
k⊥
Belle
π±
K±
pp̄
LEP
π±
K±
pp̄
anti-kt R=1.0
p_T^jet > 0 GeV
0.5
0
−0.5
−1
0
1
2
3
k⊥



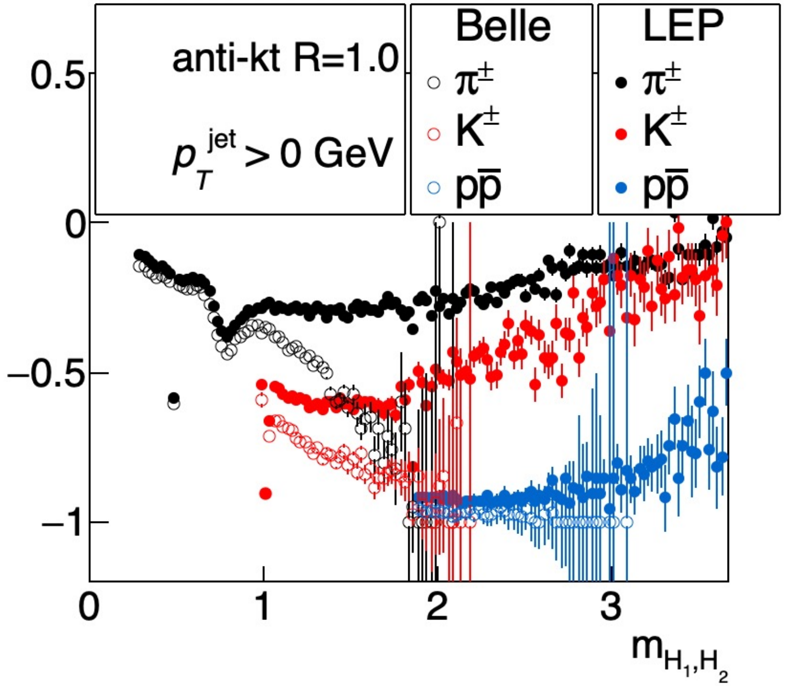
yield
×10^6
0.15
0.1
0.05
Belle
π±
K± (yieldx3)
pp̄ (yieldx3)
LEP
π±
K± (yieldx3)
pp̄ (yieldx3)
(H1+H2+ or H1+H2+)
anti-kt R=1.0
p_T^jet > 0 GeV
(H1-H2+ or H1+H2-)
t_form (fm)
perturbative
transition region
non perturbative
(k⊥< 200 MeV)
0
−0.5
−1



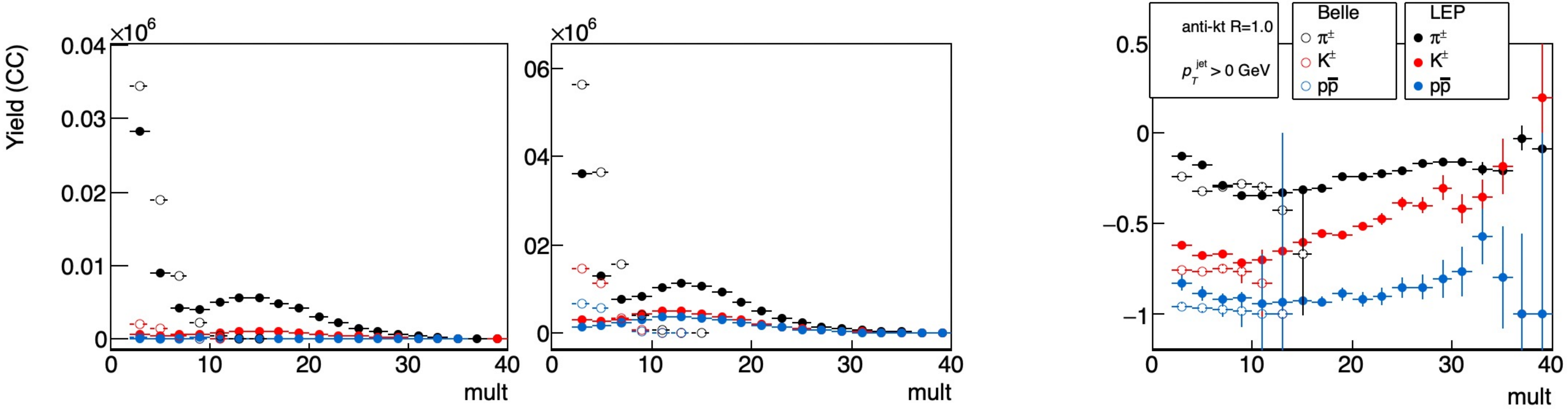
Yield (CC)
$\times10^6$
4
3
2
1
0
0
1
2
3
m_{H_1,H_2}

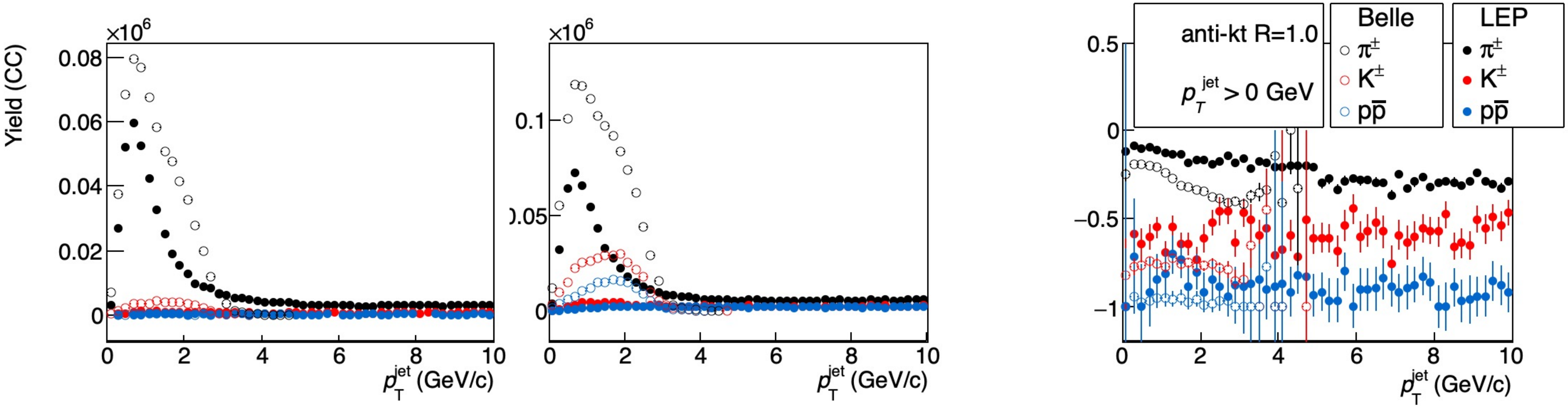


$\times10^6$
6
4
2
0
0
1
2
3
m_{H_1,H_2}

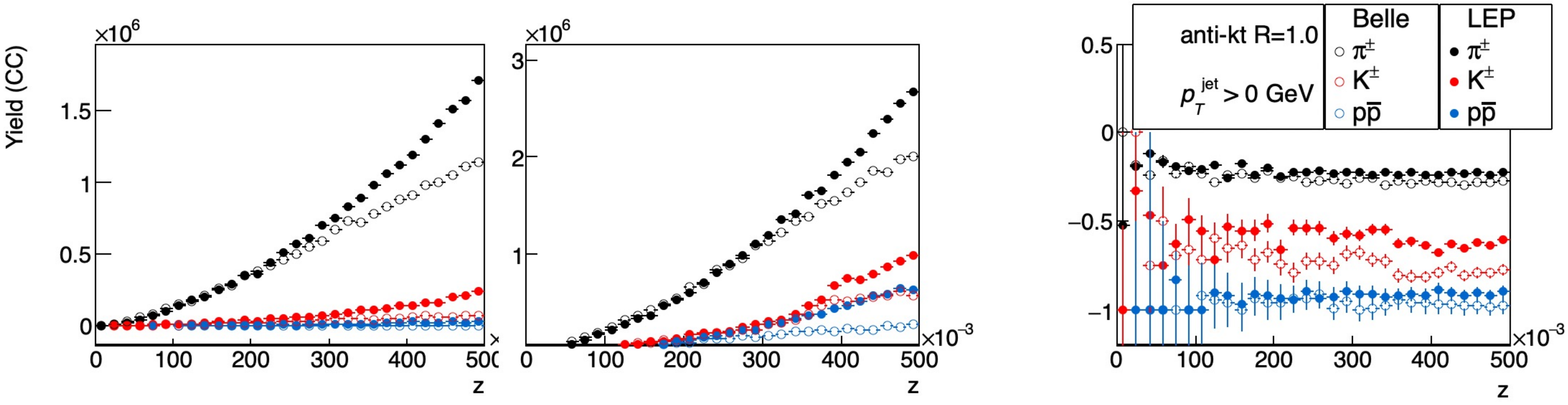


anti-kt R=1.0
$p_T^{jet} > 0$ GeV
Belle
$\pi^{\pm}$
$K^{\pm}$
$p\bar{p}$
LEP
$\pi^{\pm}$
$K^{\pm}$
$p\bar{p}$
0.5
0
−0.5
−1
0
1
2
3
m_{H_1,H_2}

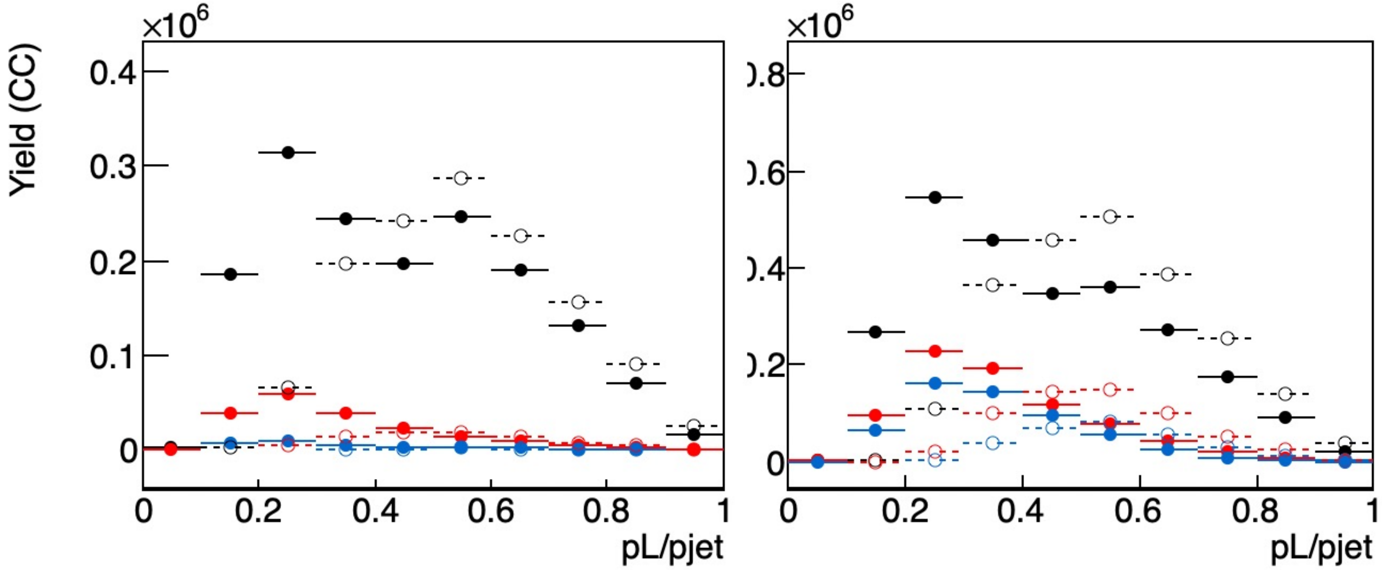

Yield (CC)
×10^6
0.04
0.03
0.02
0.01
0
0
10
20
30
40
mult
×10^6
06
04
02
0
0
10
20
30
40
mult
anti-kt R=1.0
p_T^{jet} > 0 GeV
Belle
π±
K±
pp̄
LEP
π±
K±
pp̄
0.5
0
−0.5
−1
0
10
20
30
40
mult

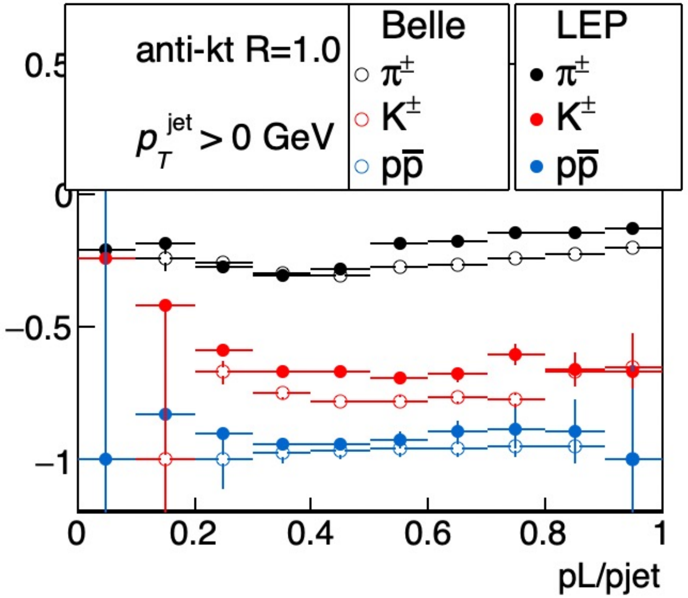


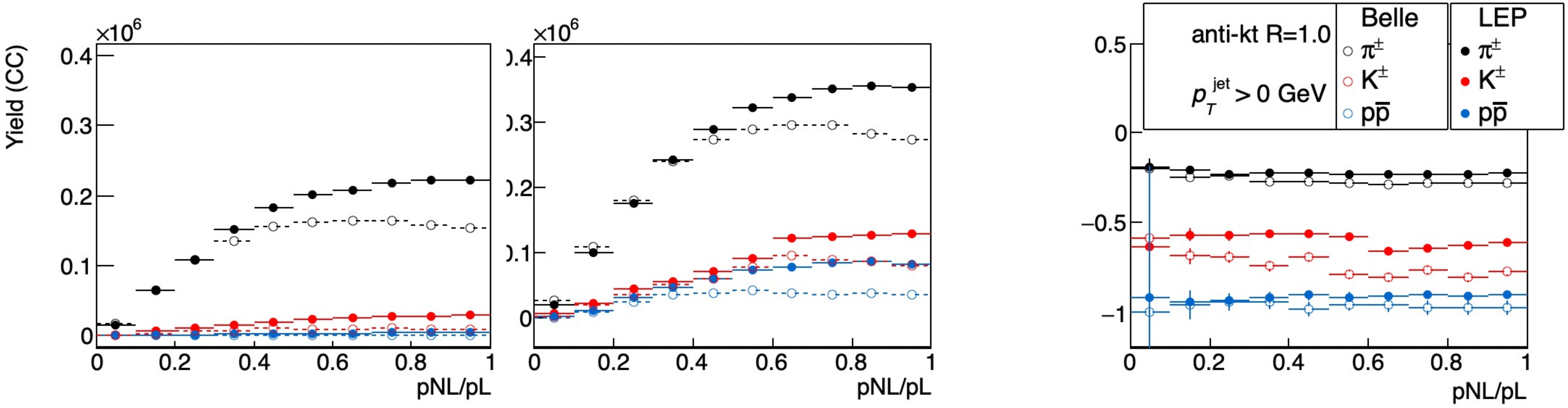
Yield (CC)
×10^6
0.08
0.06
0.04
0.02
0
0
2
4
6
8
10
p_T^jet (GeV/c)
×10^6
0.1
0.05
0
0
2
4
6
8
10
p_T^jet (GeV/c)
anti-kt R=1.0
p_T^jet > 0 GeV
Belle
π±
K±
pp̄
LEP
π±
K±
pp̄
0.5
0
−0.5
−1
0
2
4
6
8
10
p_T^jet (GeV/c)

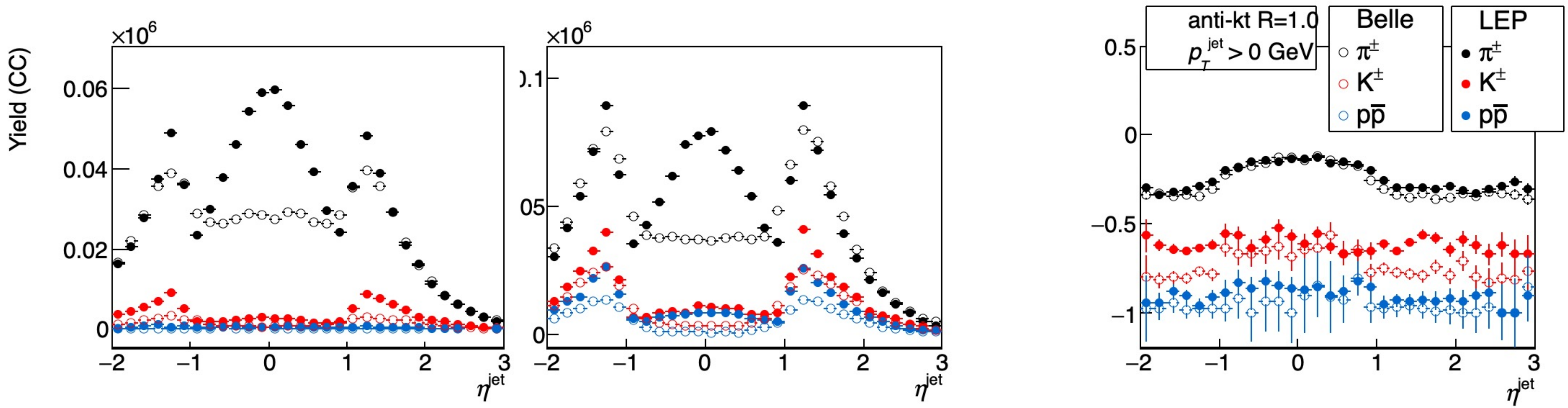


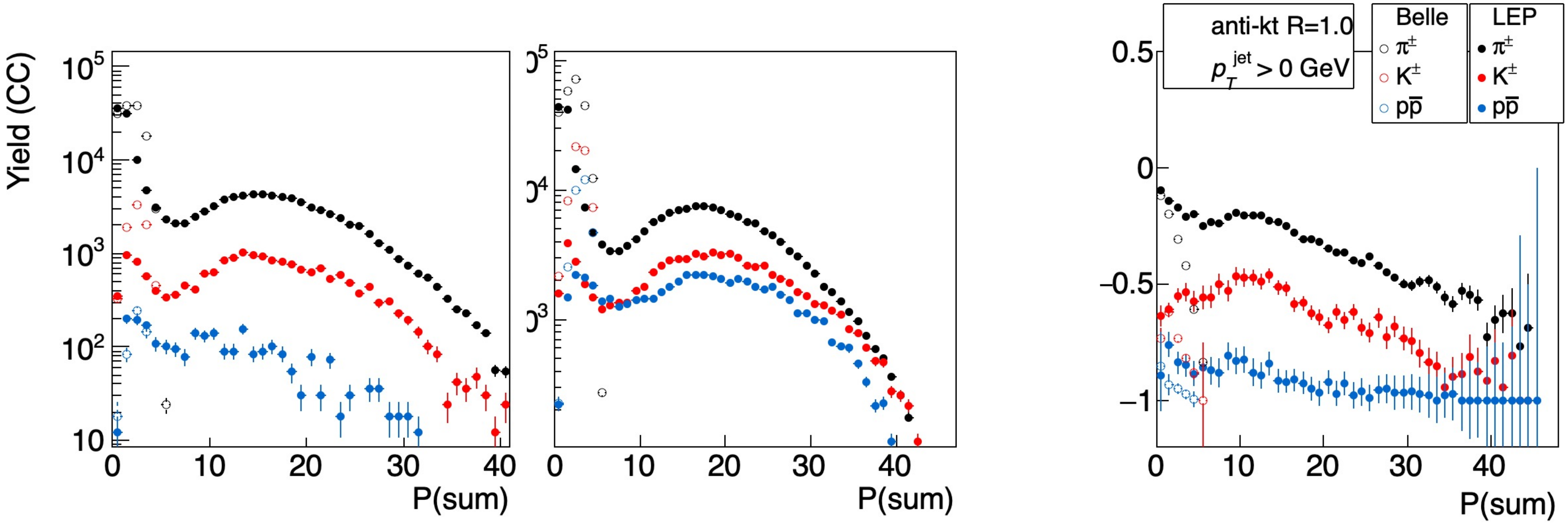
Yield (CC)
×10^6
1.5
1
0.5
0
0
100
200
300
400
500
z
×10^6
3
2
1
0
100
200
300
400
500
×10^-3
z
anti-kt R=1.0
$p_T^{jet} > 0$ GeV
Belle
$\pi^\pm$
$K^\pm$
$p\bar{p}$
LEP
$\pi^\pm$
$K^\pm$
$p\bar{p}$
0.5
0
−0.5
−1
0
100
200
300
400
500
×10^-3
z


×10^6
Yield (CC)
pL/pjet
×10^6
pL/pjet


anti-kt R=1.0
$p_T^{jet} > 0$ GeV
Belle
$\pi^{\pm}$
$K^{\pm}$
$p\bar{p}$
LEP
$\pi^{\pm}$
$K^{\pm}$
$p\bar{p}$
pL/pjet

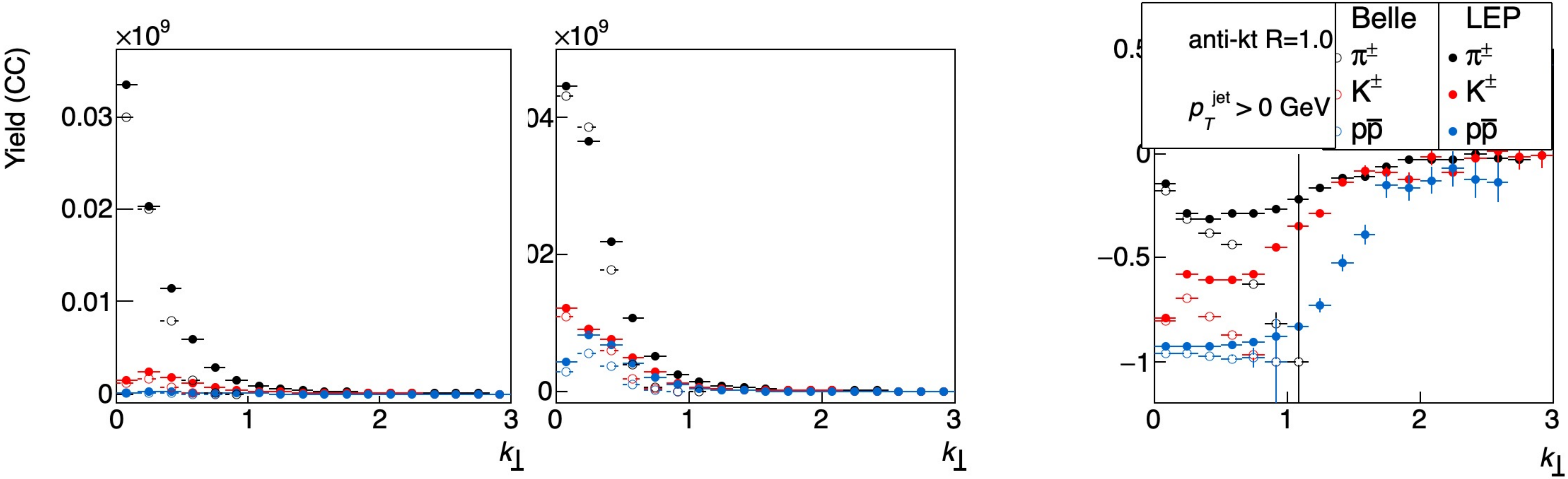

Yield (CC)
×10^6
pNL/pL
pNL/pL
pNL/pL
anti-kt R=1.0
$p_T^{jet} > 0$ GeV
Belle
$\pi^\pm$
$K^\pm$
$p\bar{p}$
LEP
$\pi^\pm$
$K^\pm$
$p\bar{p}$


Yield (CC)
×10^6
0.06
0.04
0.02
0
−2
−1
0
1
2
3
η^jet
×10^6
0.1
0.05
0
−2
−1
0
1
2
3
η^jet
anti-kt R=1.0
p_T^jet > 0 GeV
Belle
π±
K±
pp̄
LEP
π±
K±
pp̄
0.5
0
−0.5
−1
−2
−1
0
1
2
3
η^jet

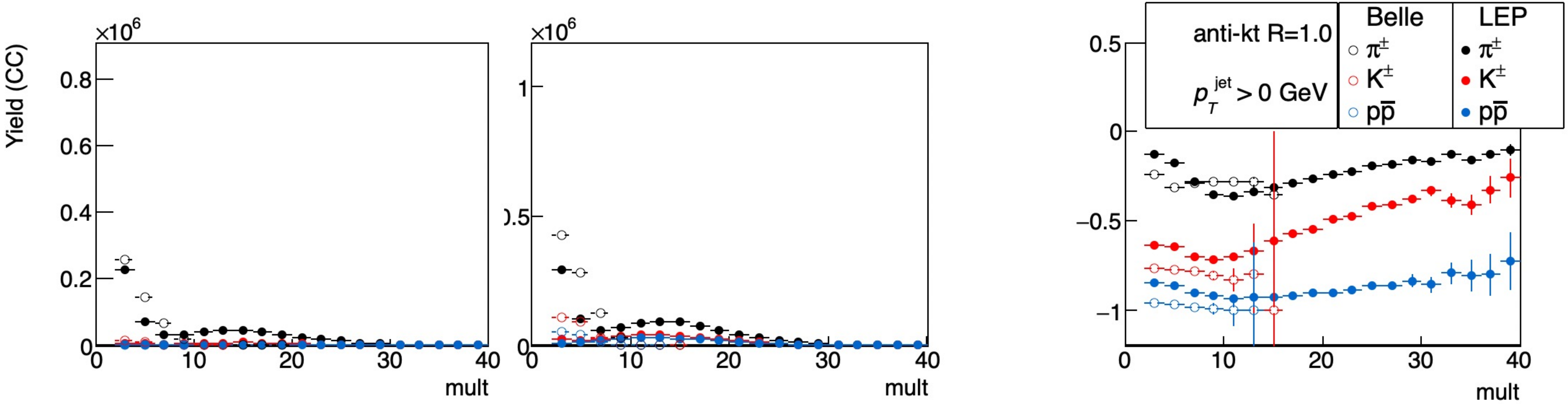


Yield (CC)
P(sum)
P(sum)
P(sum)
anti-kt R=1.0
$p_T^{jet} > 0$ GeV
Belle
$\pi^{\pm}$
$K^{\pm}$
$p\bar{p}$
LEP
$\pi^{\pm}$
$K^{\pm}$
$p\bar{p}$

With Jet pt > 0.2 GeV

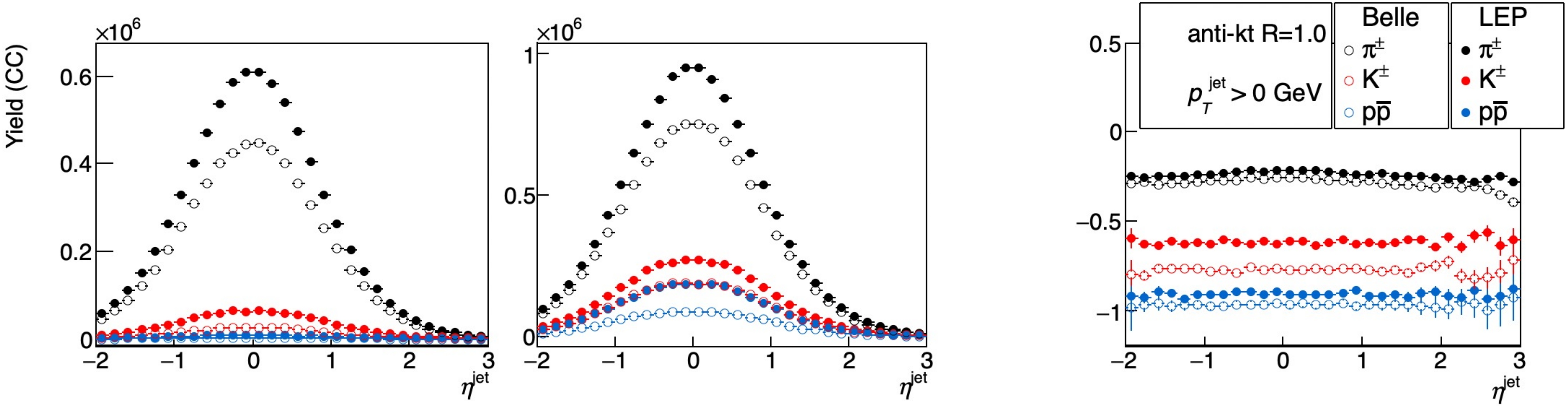


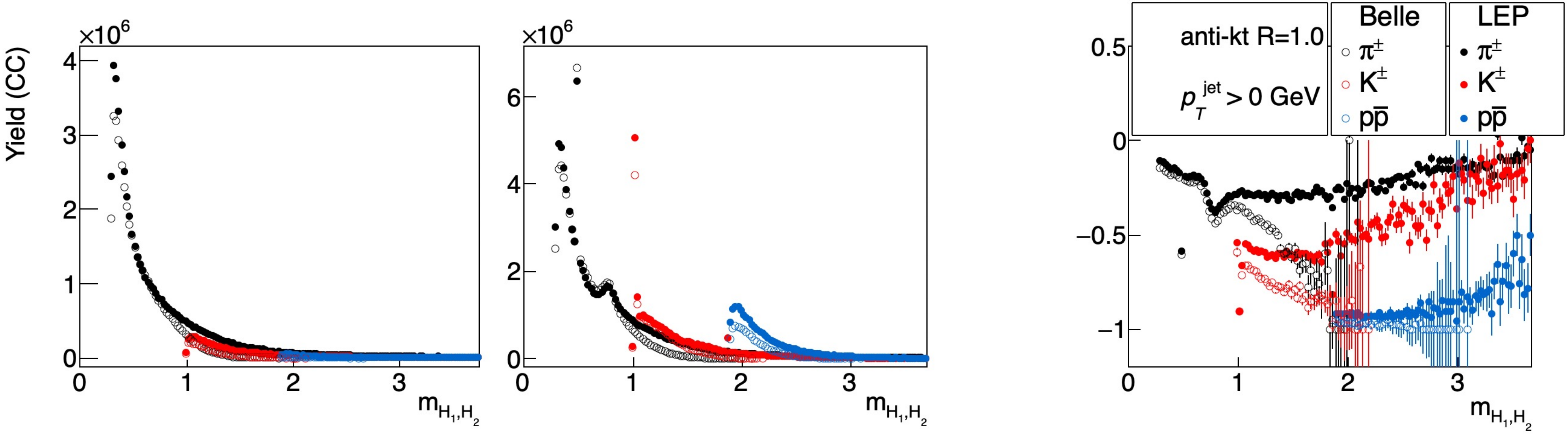
Yield (CC)
×10^9
0.03
0.02
0.01
0
0
1
2
3
k⊥
×10^9
04
02
0
0
1
2
3
k⊥
anti-kt R=1.0
p_T^jet > 0 GeV
Belle
π±
K±
pp̄
LEP
π±
K±
pp̄
0.5
0
−0.5
−1
0
1
2
3
k⊥



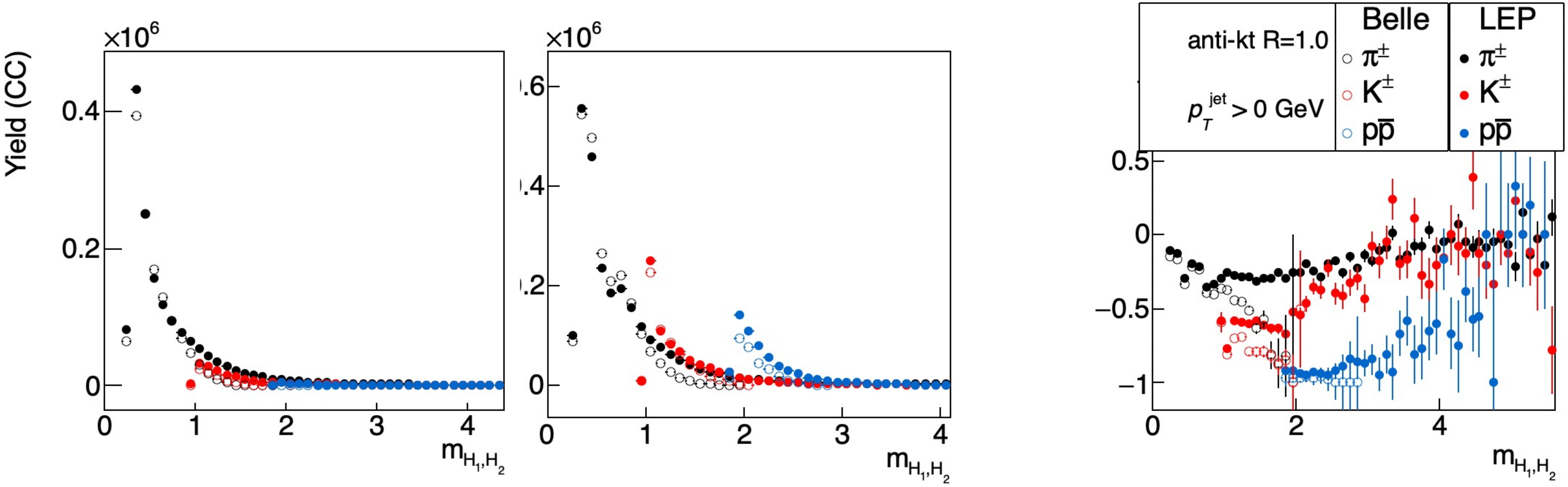
Yield (CC)
×10^6
0.8
0.6
0.4
0.2
0
0
10
20
30
40
mult
×10^6
1
0.5
0
0
10
20
30
40
mult
anti-kt R=1.0
$p_T^{jet} > 0$ GeV
Belle
$\pi^{\pm}$
$K^{\pm}$
$p\bar{p}$
LEP
$\pi^{\pm}$
$K^{\pm}$
$p\bar{p}$
0.5
0
−0.5
−1
0
10
20
30
40
mult

Jet pt > 0.2 GeV


Yield (CC)
×10^6
0.6
0.4
0.2
0
−2
−1
0
1
2
3
η^jet
×10^6
1
0.5
0
anti-kt R=1.0
p_T^jet > 0 GeV
Belle
π^±
K^±
pp̄
LEP
π^±
K^±
pp̄
0.5
0
−0.5
−1



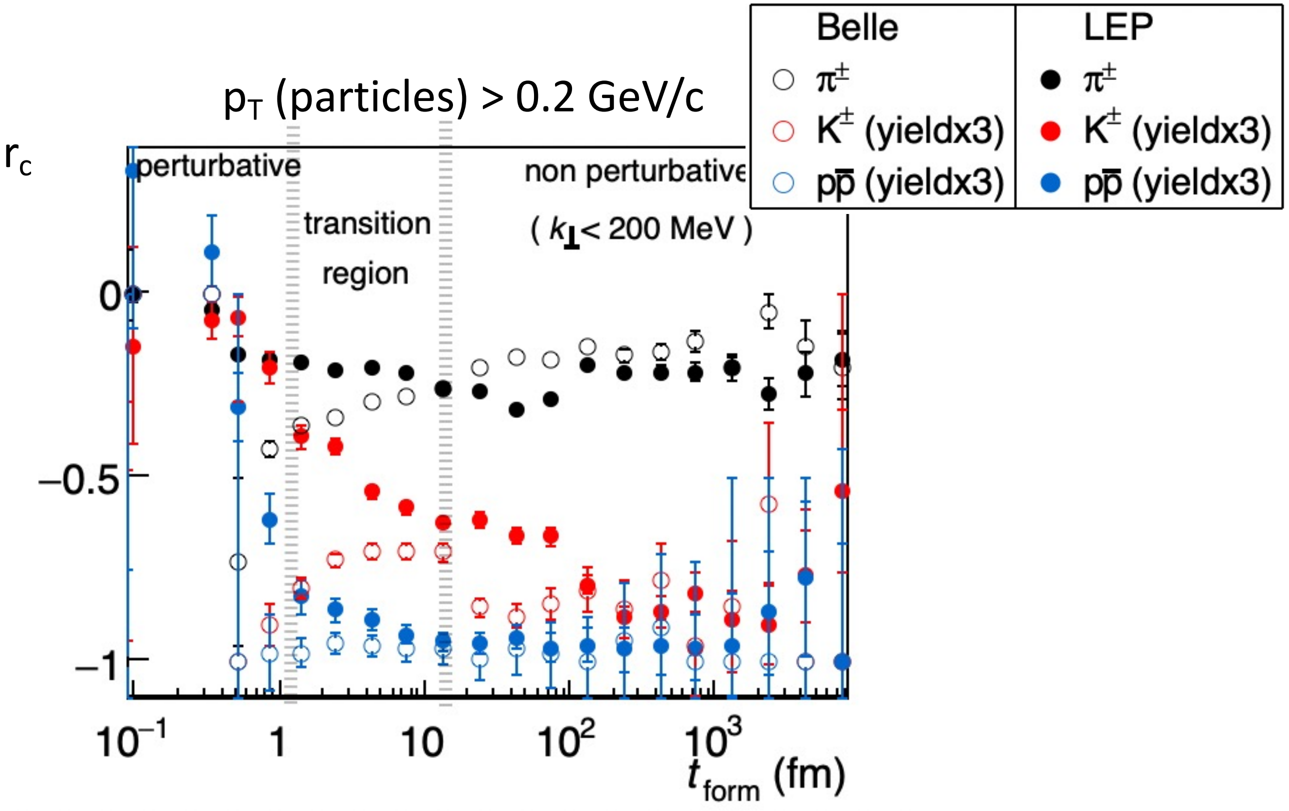
×10^6
Yield (CC)
4
3
2
1
0
0
1
2
3
m_{H1,H2}
×10^6
6
4
2
0
0
1
2
3
m_{H1,H2}
anti-kt R=1.0
p_T^jet > 0 GeV
Belle
π±
K±
pp̄
LEP
π±
K±
pp̄
0.5
0
−0.5
−1
0
1
2
3
m_{H1,H2}


Yield (CC)
×10^6
×10^6
anti-kt R=1.0
$p_T^{jet} > 0$ GeV
Belle
LEP
π±
K±
pp̄
m_{H_1,H_2}

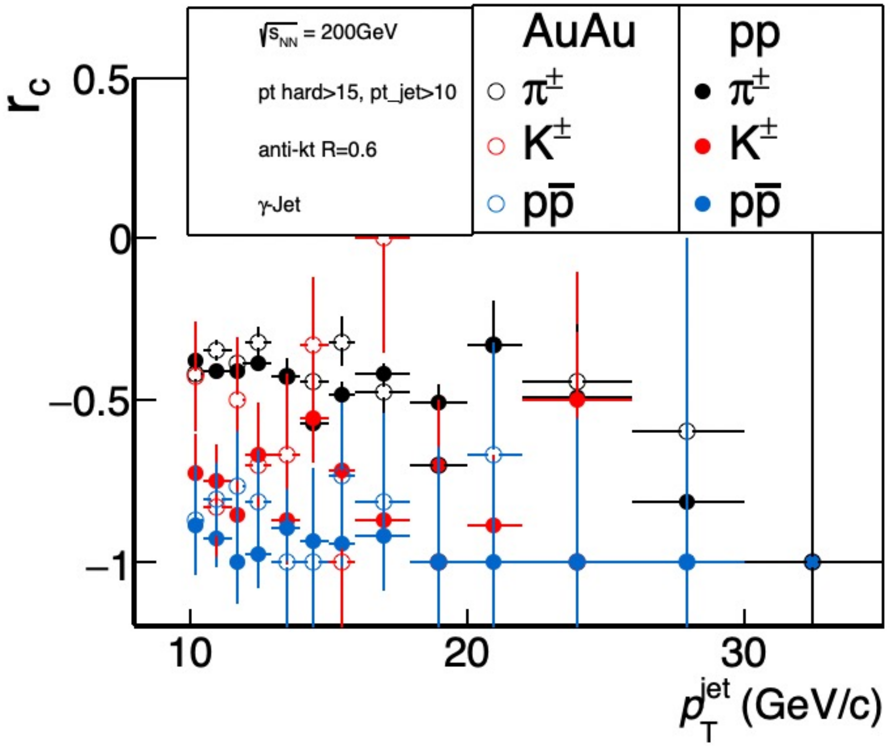
eA/AA/pA

r_c can be studied for fragmentations in other systems

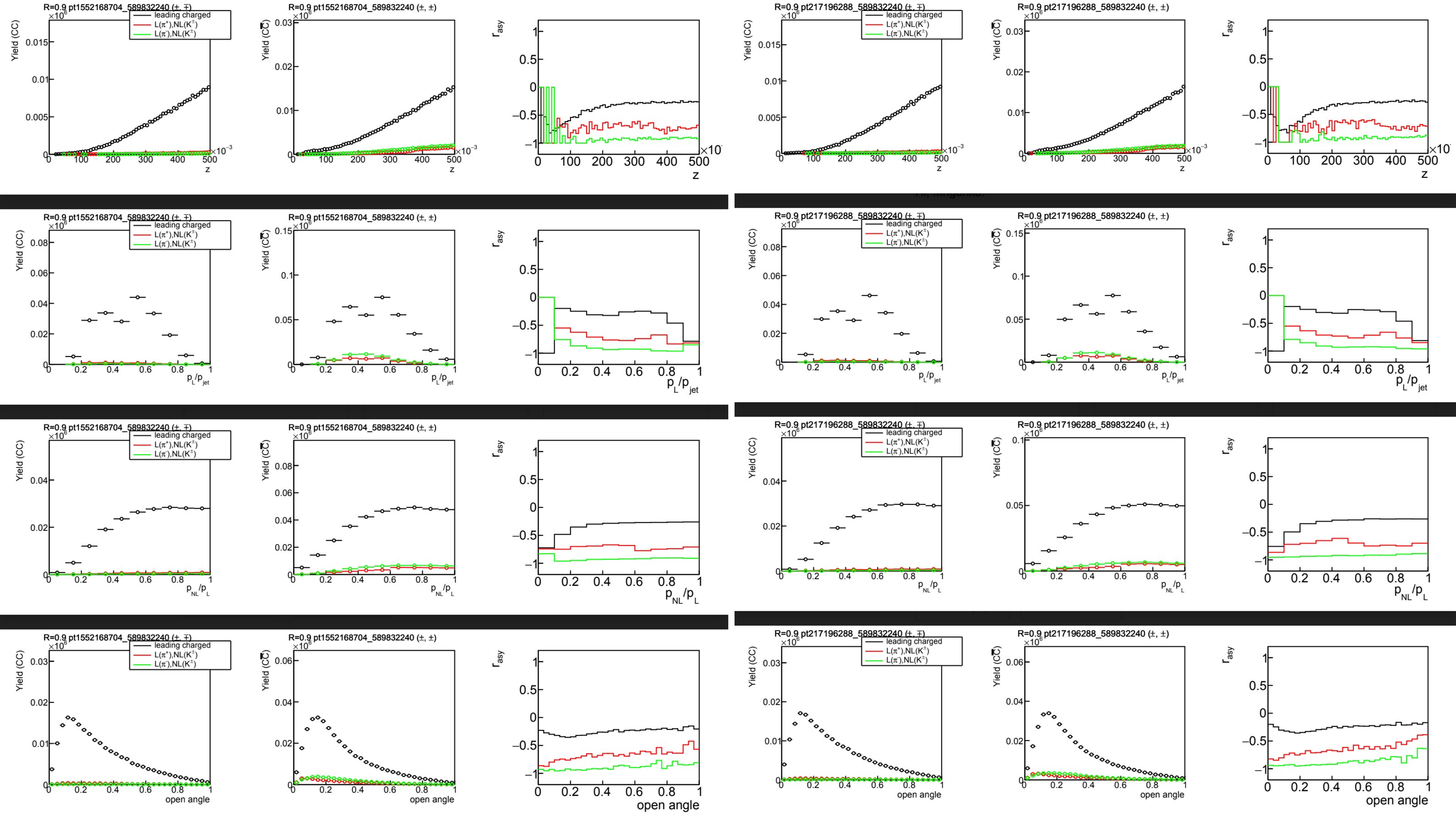
p_T (particles) > 0.2 GeV/c



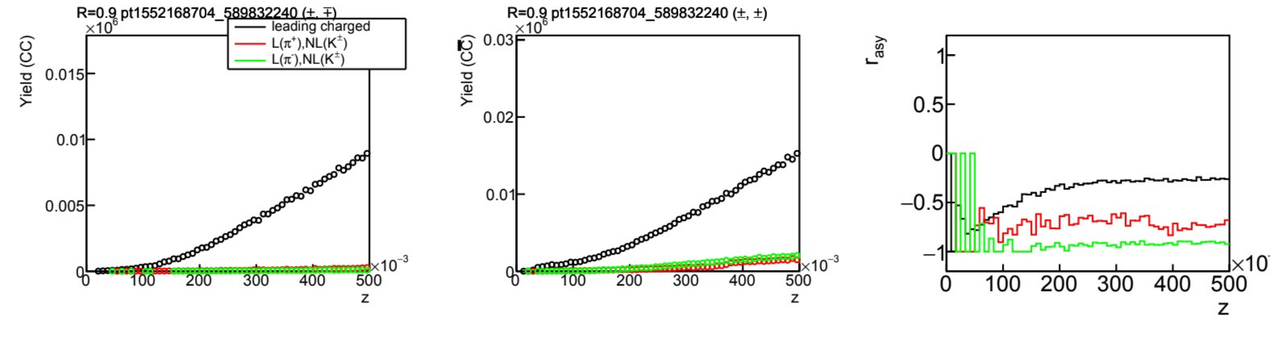
p_T (particles) > 1.2 GeV/c



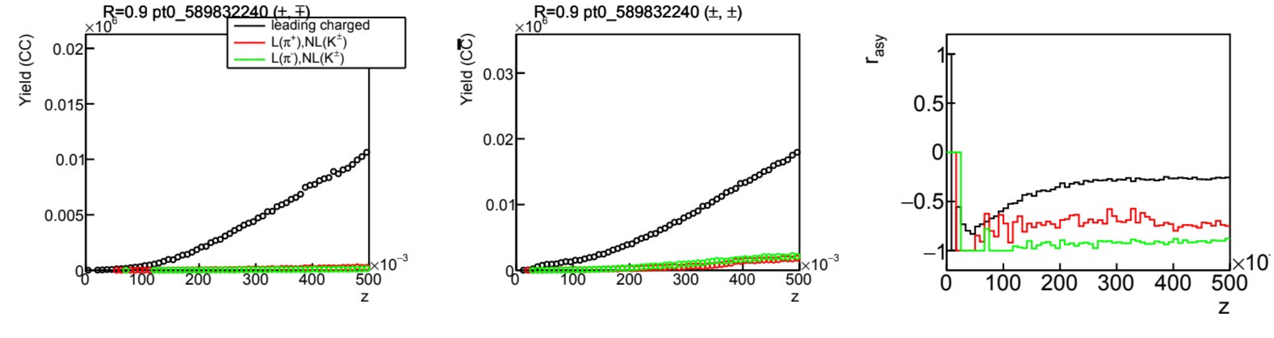
- Modification in cold nuclear matter(eA, pA) and hot nuclear matter (AA) – sPHENIX & STAR
- Measurement at BELLE and LEP



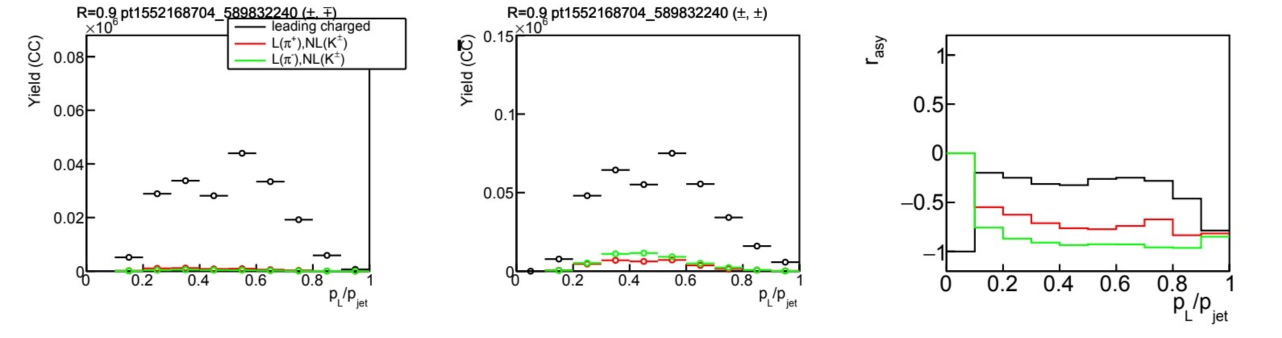
R=0.9 pt1552168704_589832240 (±, ∓)
R=0.9 pt1552168704_589832240 (±, ±)
R=0.9 pt217196288_589832240 (±, ∓)
R=0.9 pt217196288_589832240 (±, ±)
leading charged
L(π⁺),NL(K^±)
L(π⁻),NL(K^±)
Yield (CC)
r_asy
z
p_L/p_jet
p_NL/p_L
open angle



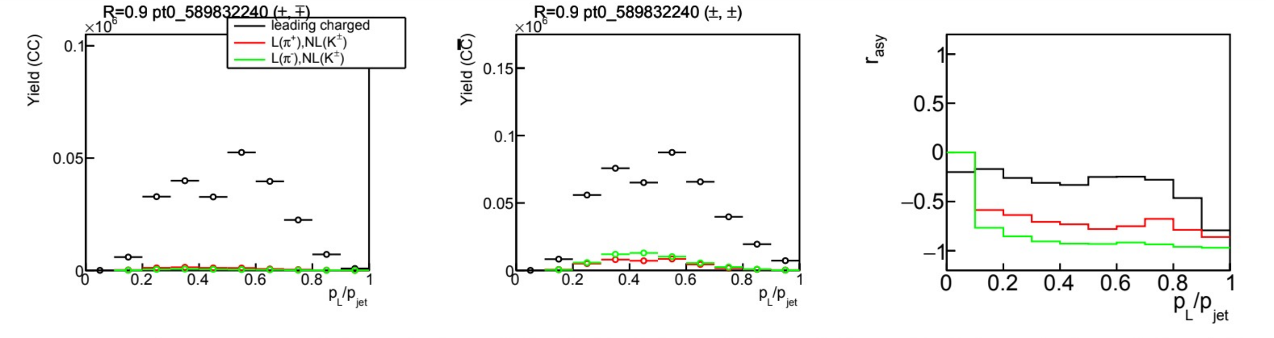
R=0.9 pt1552168704_589832240 (±, ∓)
R=0.9 pt1552168704_589832240 (±, ±)
leading charged
L(π⁺),NL(K±)
L(π⁻),NL(K±)
Yield (CC)
r_asy
z



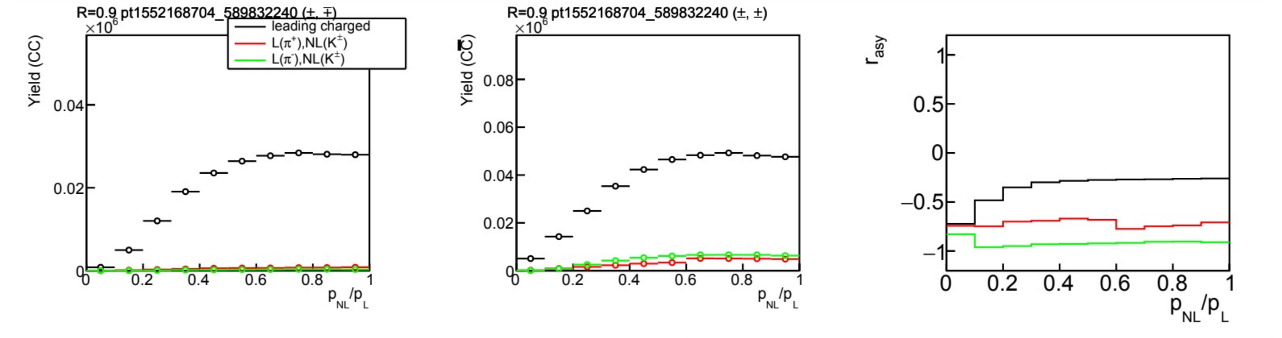
R=0.9 pt0_589832240 (±, ∓)
R=0.9 pt0_589832240 (±, ±)
leading charged
L(π⁺),NL(K±)
L(π⁻),NL(K±)
Yield (CC)
r_asy
z



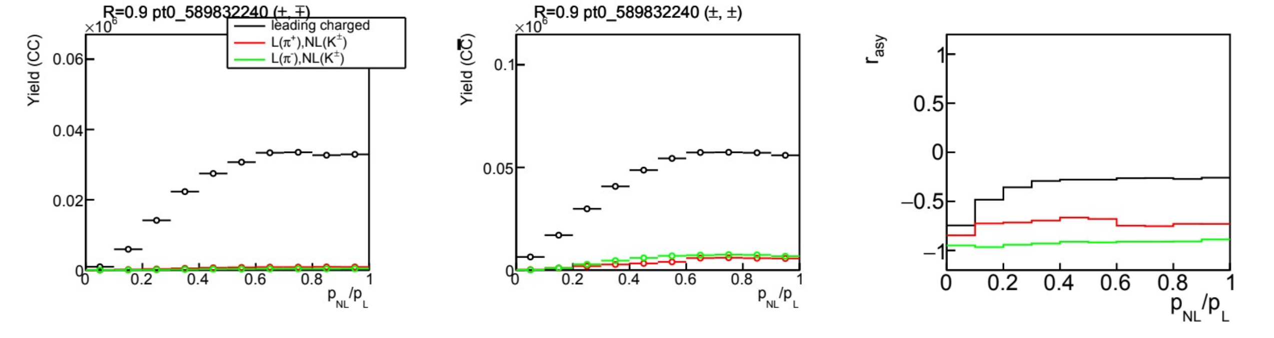
R=0.9 pt1552168704_589832240 (±, ∓)
R=0.9 pt1552168704_589832240 (±, ±)
leading charged
L(π⁺),NL(K±)
L(π⁻),NL(K±)
Yield (CC)
r_asy
p_L/p_jet



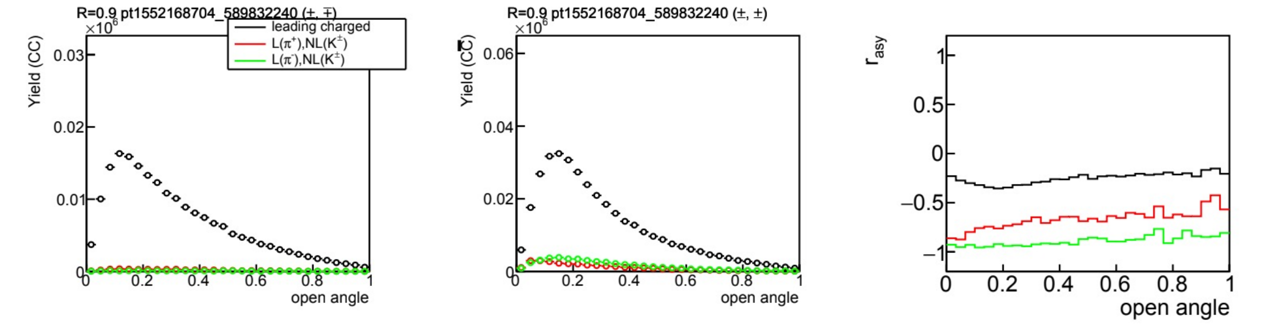
R=0.9 pt0_589832240 (±, ∓)
R=0.9 pt0_589832240 (±, ±)
leading charged
L(π⁺),NL(K±)
L(π⁻),NL(K±)
Yield (CC)
r_asy
p_L/p_jet



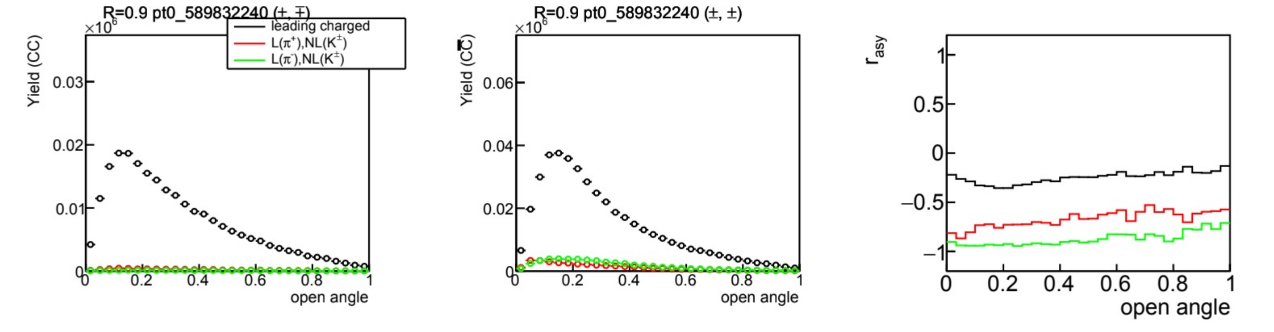
R=0.9 pt1552168704_589832240 (±, ∓)
R=0.9 pt1552168704_589832240 (±, ±)
leading charged
L(π⁺),NL(K±)
L(π⁻),NL(K±)
Yield (CC)
r_asy
p_NL/p_L



R=0.9 pt0_589832240 (±, ∓)
R=0.9 pt0_589832240 (±, ±)
leading charged
L(π⁺),NL(K±)
L(π⁻),NL(K±)
Yield (CC)
r_asy
p_NL/p_L



R=0.9 pt1552168704_589832240 (±, ∓)
R=0.9 pt1552168704_589832240 (±, ±)
leading charged
L(π⁺),NL(K±)
L(π⁻),NL(K±)
Yield (CC)
r_asy
open angle



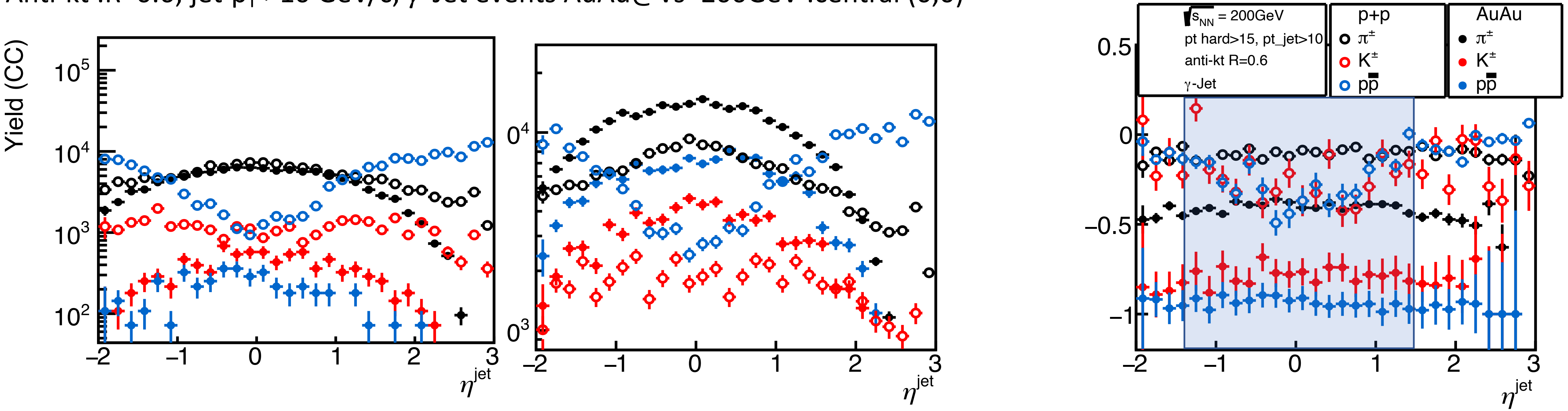
R=0.9 pt0_589832240 (±, ∓)
R=0.9 pt0_589832240 (±, ±)
leading charged
L(π⁺),NL(K±)
L(π⁻),NL(K±)
Yield (CC)
r_asy
open angle

Au Au r_c

Testing r_c for HIJING : gammajet-jet, Jet pt> 10GeV and head on AuAu events for c.m. energy of 200 GeV

C....initialize HIJING for Au+Au collisions at c.m. energy of 200 GeV:	
C WRITE(*,*) 'random number seed'	
READ(*,*) dum,NSEED	32,32331
C WRITE(*,*) 'frame(LAB,CMS), enegy-frame'	
READ(*,*) dum,FRAME,EFRM	32,CMS,200
C WRITE(*,*) 'Proj, Targ(A,P,PBAR)'	
READ(*,*) dum,PROJ,TARG	32,A,A
C WRITE(*,*) 'A,Z of proj; A,Z of targ'	
READ(*,*) dum,IAP,IZP,IAT,IZT	32,197,79,197,79
C WRITE(*,*) 'number of events'	
READ(*,*) dum,N_EVENT	32,50000
C WRITE(*,*) 'Print warning messages (0,1)'	
READ(*,*) dum,IHPR2(10)	32,0
C WRITE(*,*) 'Keep information of decayed particles (0,1)'	
READ(*,*) dum,IHPR2(21)	32,0
C WRITE(*,*) minumim pt transfer in hard scatterings	
READ(*,*) dum,HIPR1(8)	32,15 (pt hard scattering)
C WRITE(*,*) pt of each triggered hard jet	
READ(*,*) dum,HIPR1(10)	32,10 (triggered hard jet)
C impact parametre A	
READ(*,*) dum,HIPR1(34)	32,0 (central)
C impact parametre B	
READ(*,*) dum,HIPR1(35)	32,0 (central)
C intial and final stae radiations 0, 1, 2, 3	
READ(*,*) dum,IHPR2(2)	32,3 (ISR, FST ON)
C trigger 0 ho jet, 1 ordinary hard scattering, 2 direct photon	
READ(*,*) dum,IHPR2(3)	32,2 (direct photon)
C jet quenching ON=1	
READ(*,*) dum,IHPR2(4)	32,0 (on QUENCHING)
C maximum number of hard scatterings	
READ(*,*) dum,IHPR2(8)	32,1 (One hard scattering in each event)

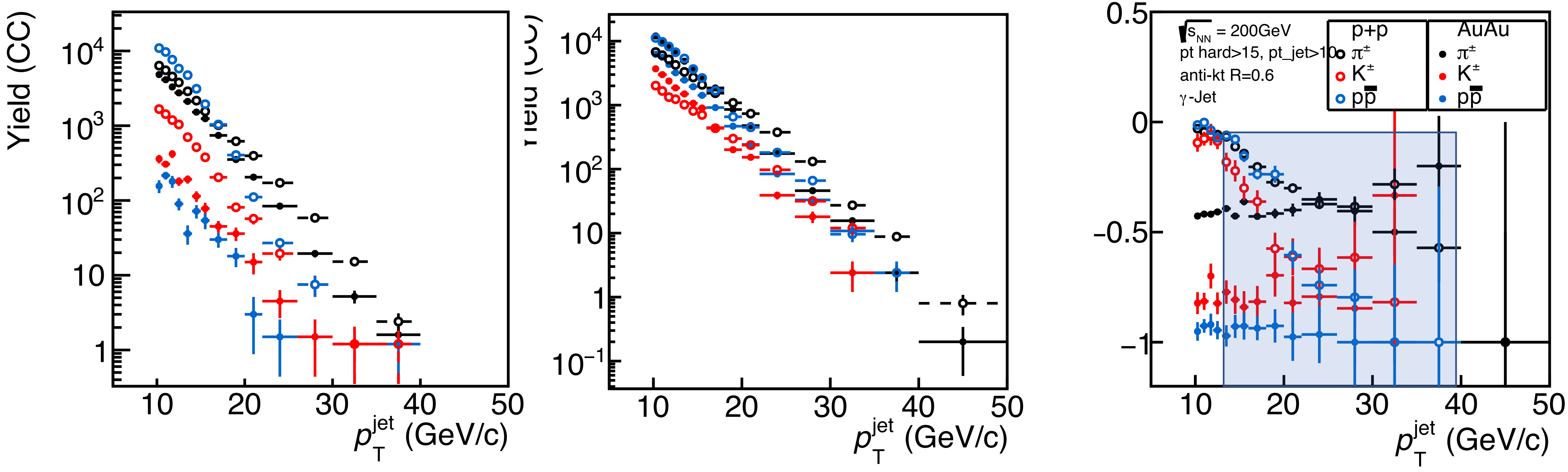
Anti-kt :R=0.6; jet-p_T >10 GeV/c; γ-Jet events AuAu@√s=200GeV :central (0,0)



K,p = baryon and flavor transport in AuAu significantly different : May be coming from participants and strongly beyond |η|>1

Detector in reality may be confined |η| < 1.5

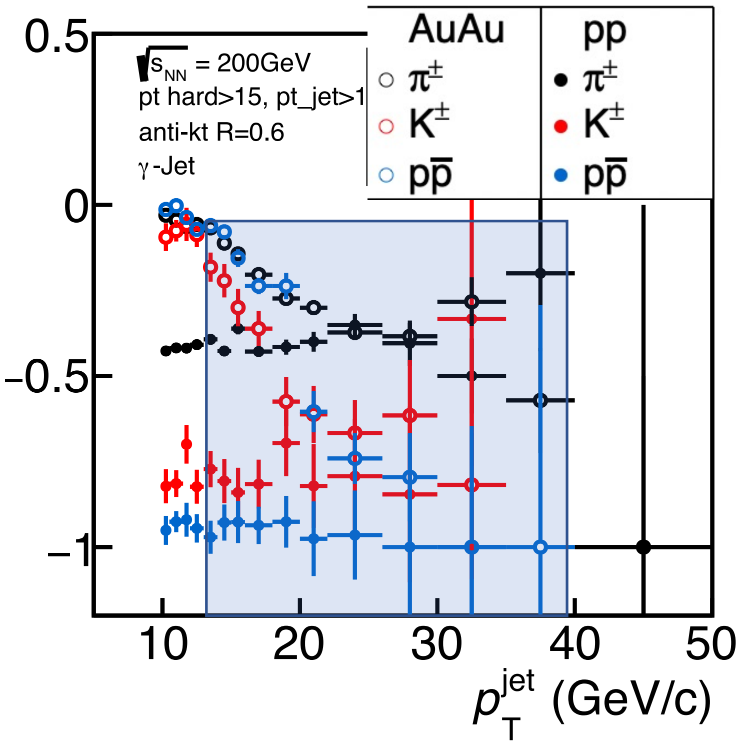
Anti-kt :R=0.6; jet-p_T >10 GeV/c; γ-Jet events AuAu@$\sqrt{s}$=200GeV :central (0,0)



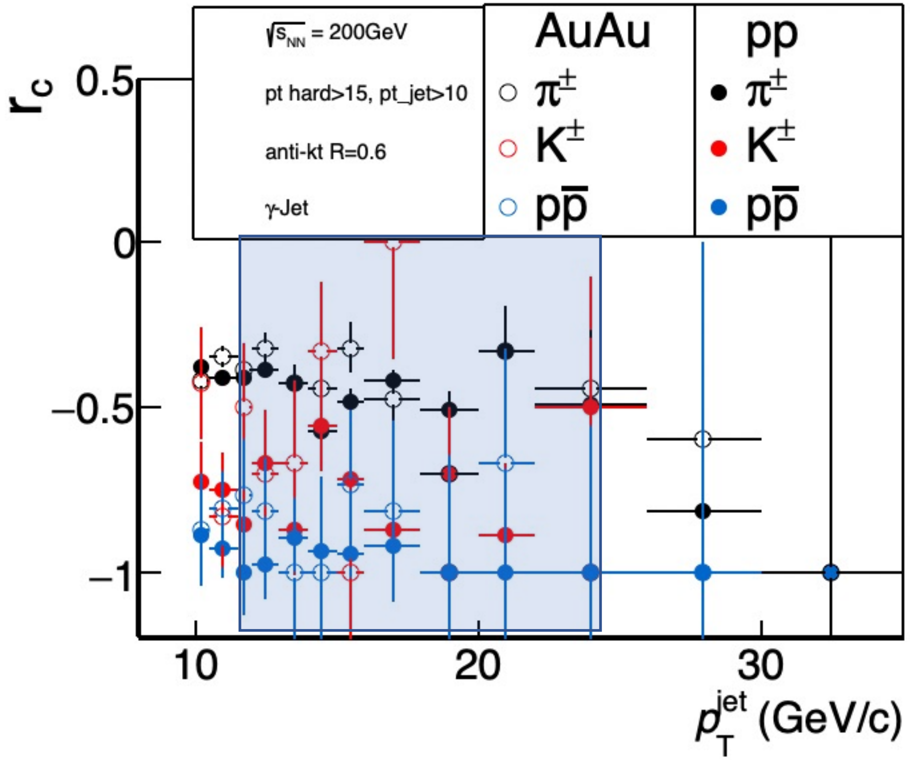
Low pt might be dominated by background

High pt region would be interesting for Au-Au systems

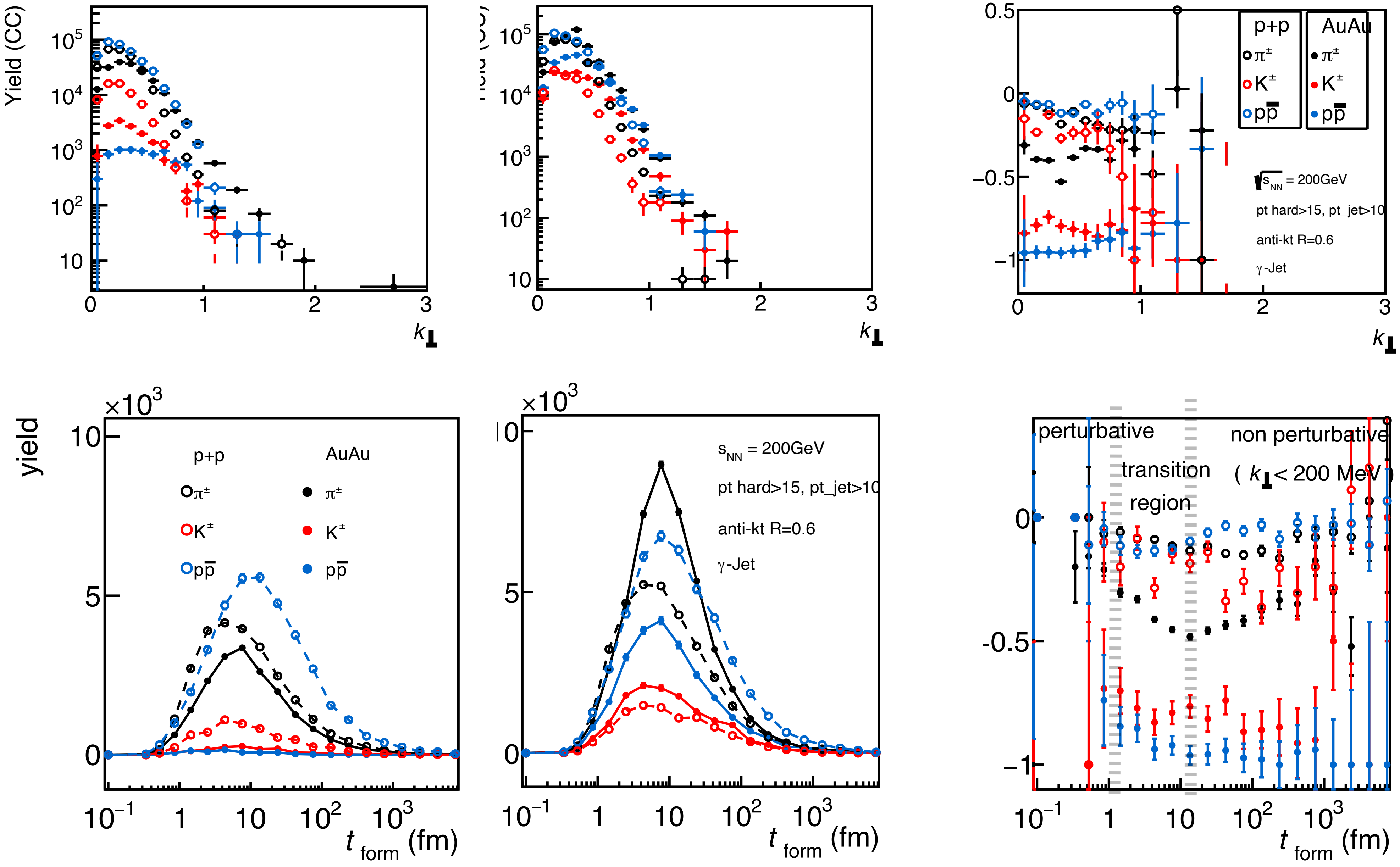
Pt > 0.2



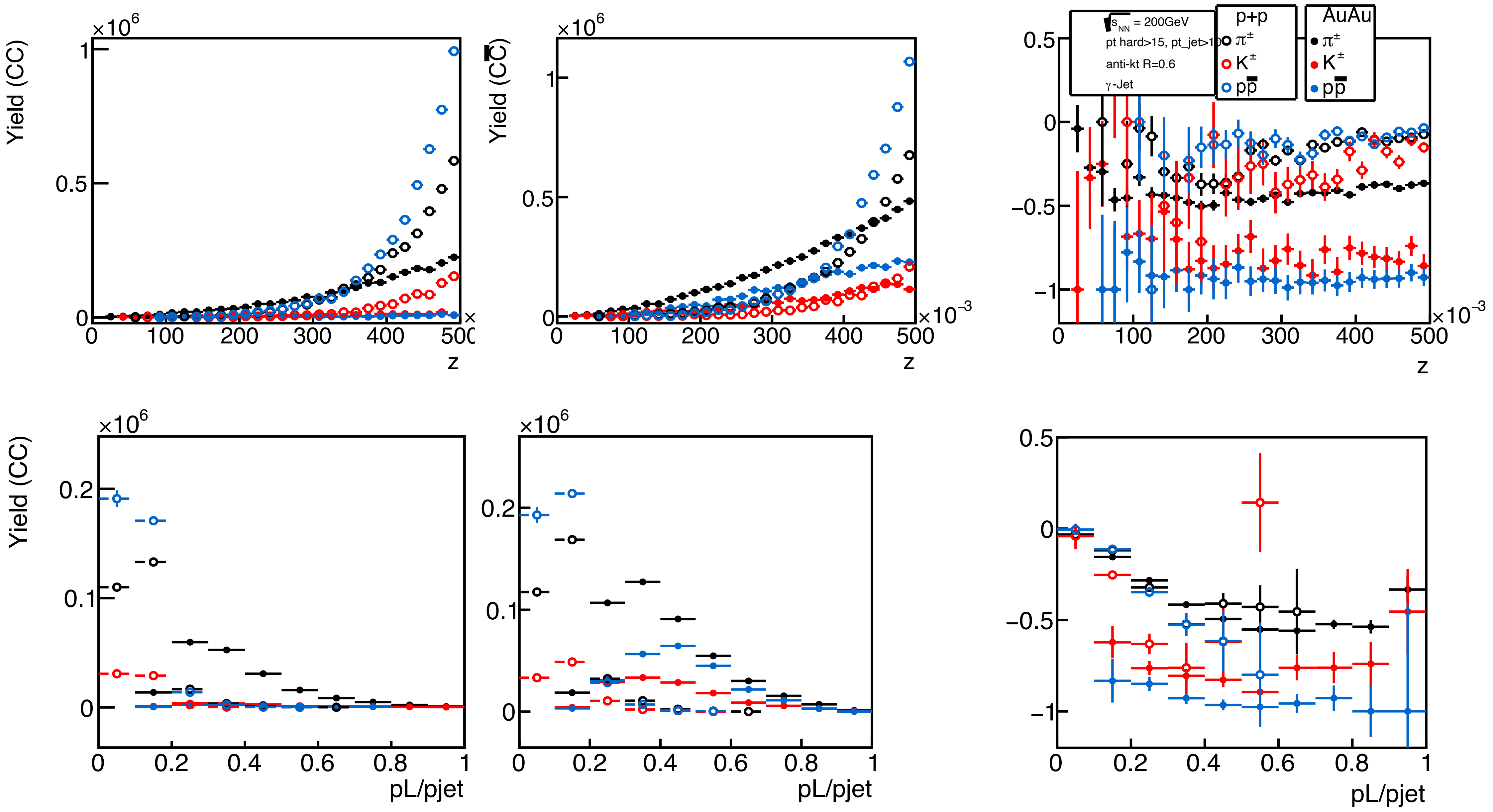
Pt > 1.2



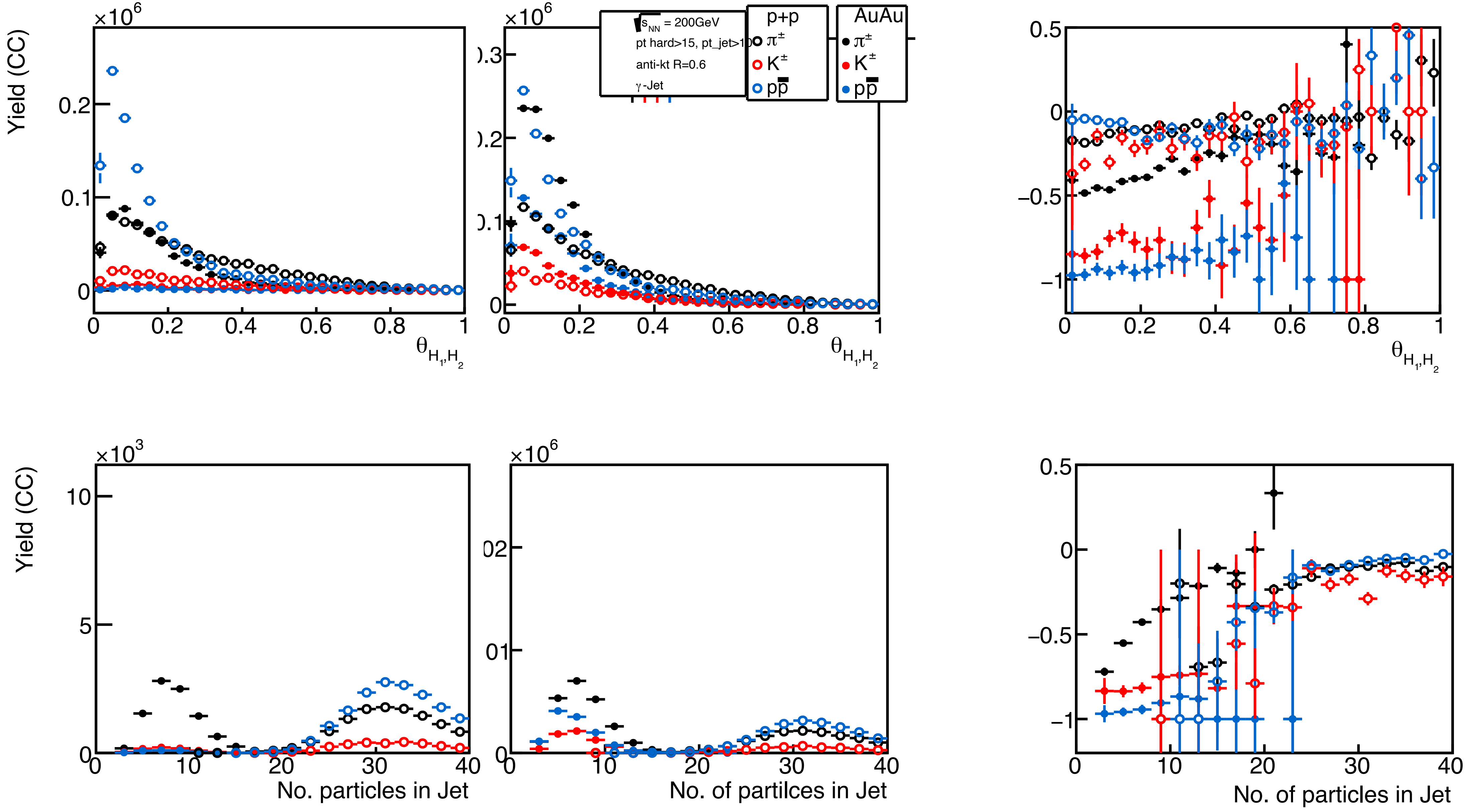
Use some simulated data – with real quenching effect


Yield (CC)
k⊥
p+p
AuAu
π±
K±
pp̄
√sNN = 200GeV
pt hard>15, pt_jet>10
anti-kt R=0.6
γ-Jet
×10³
yield
sNN = 200GeV
t form (fm)
perturbative
transition
region
non perturbative
(k⊥< 200 MeV)

L, NL particle kinematics



$\sqrt{s_{NN}}$ = 200GeV
pt hard>15, pt_jet>10
anti-kt R=0.6
γ-Jet
p+p
$\pi^{\pm}$
$K^{\pm}$
$p\bar{p}$
AuAu
$\pi^{\pm}$
$K^{\pm}$
$p\bar{p}$
Yield (CC)
z
pL/pjet
$\times 10^{6}$
$\times 10^{-3}$



×10^6
Yield (CC)
0.2
0.1
0
θ_{H_1,H_2}
√s_NN = 200GeV
pt hard>15, pt_jet>10
anti-kt R=0.6
γ-Jet
p+p
π±
K±
pp̄
AuAu
π±
K±
pp̄
×10^3
10
5
No. particles in Jet
No. of partilces in Jet
No. of particles in Jet
0.5
−0.5
−1