Reconstruction methods in NC

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1. Impact of barrel neutron and K_L using Jacquet-Blondel method
- Argument of Hcal in barrel region

2. Comparison of reconstruction methods

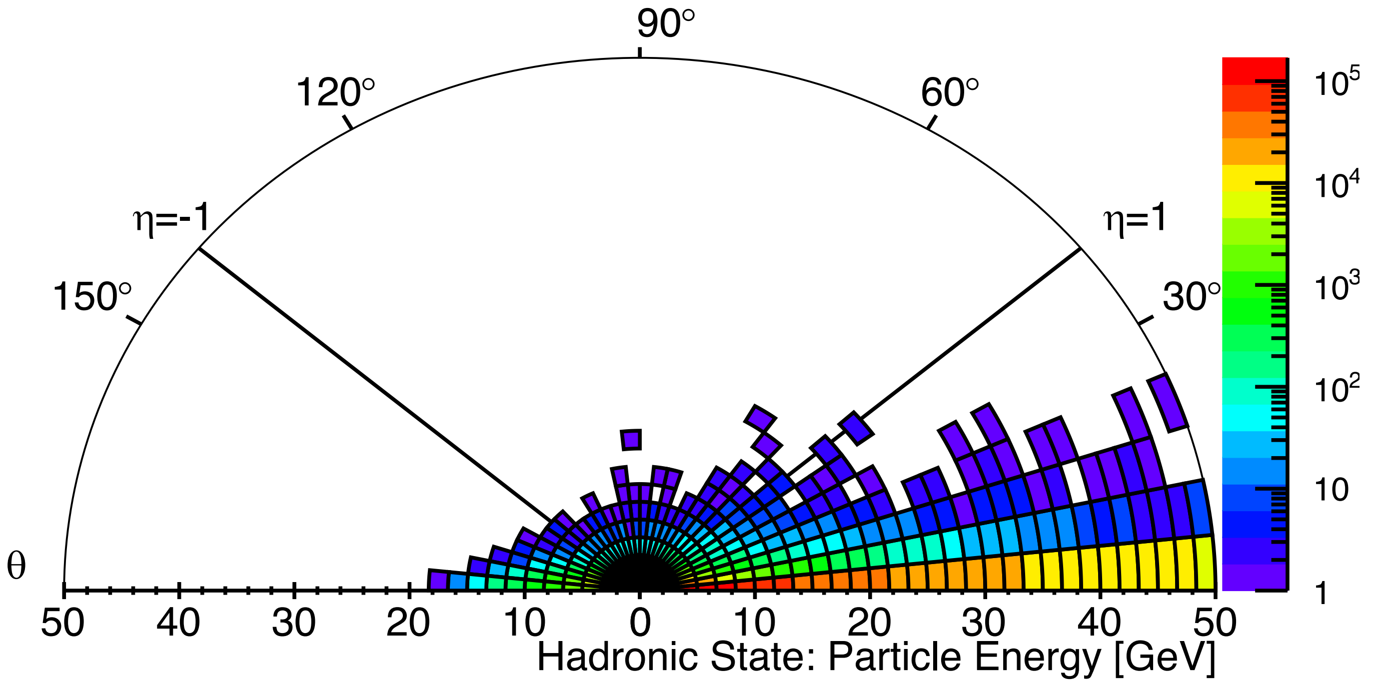
Calorimetry WG meeting

Final state particles hit map for JB

Data sample: NC from Pythia, ep 18×275 GeV, $Q^2 > 2$ GeV^2

Jacquet-Blondel method: $y^{rec} = \frac{\sum_h (E_h - p_{z,h})}{2E_e}$

final hadronic state: charged hadron + γ + n + K_L + e (except the scattered electron)



Neutrons and K_L relative cross section

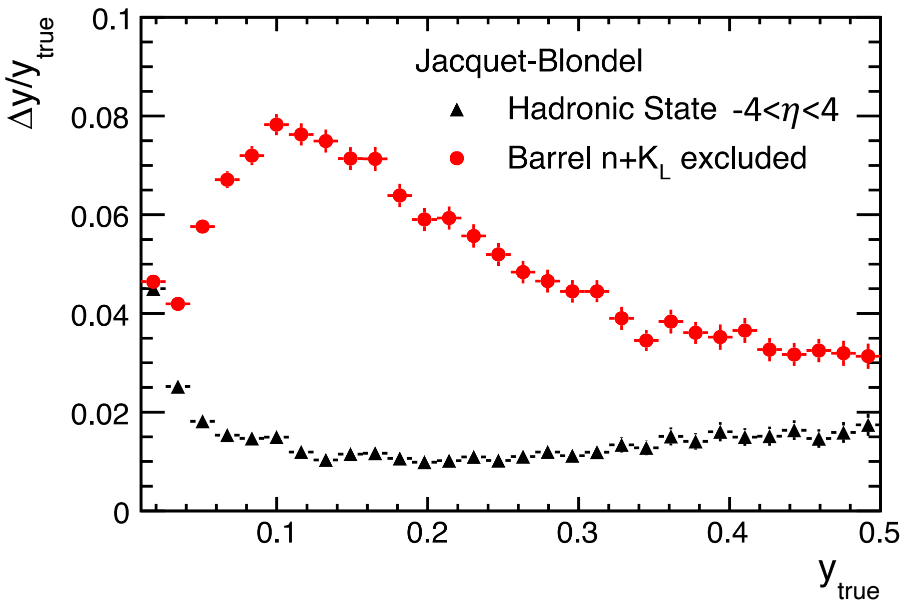
$$\frac{middle\ rapidity\ n + K_L}{tol} < 1\%$$

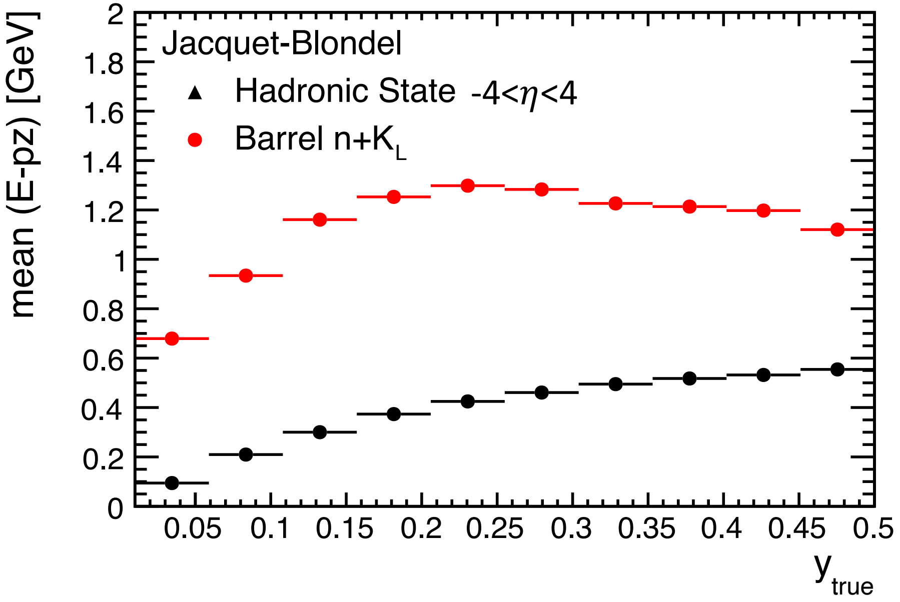
y resolution (unsmeared)

$$y_{JB} = \frac{\sum(E - p_z)}{2E_e}$$

Using final hadronic state in -4<η<4

$$mean\ |(y_{rec} - y_{true})|/\ y_{true}$$

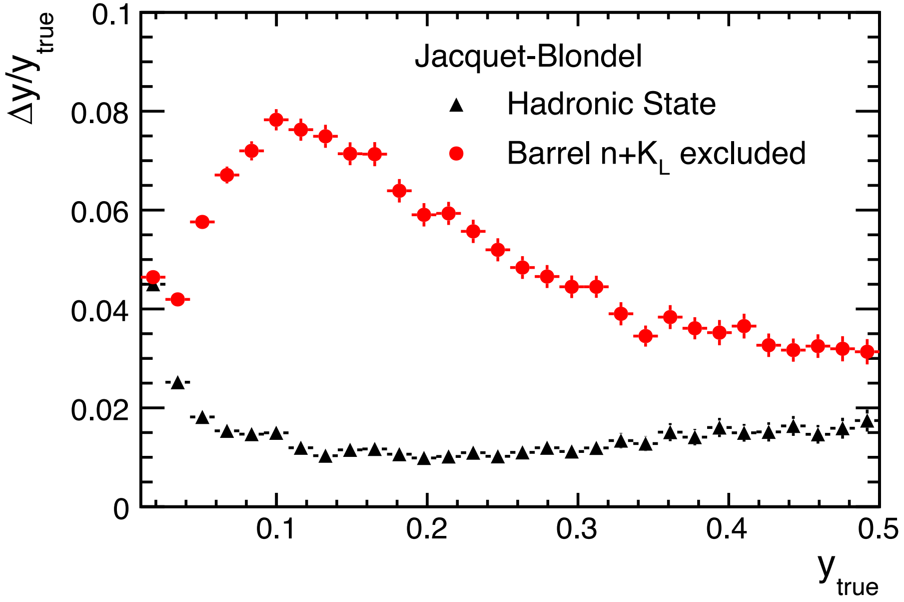




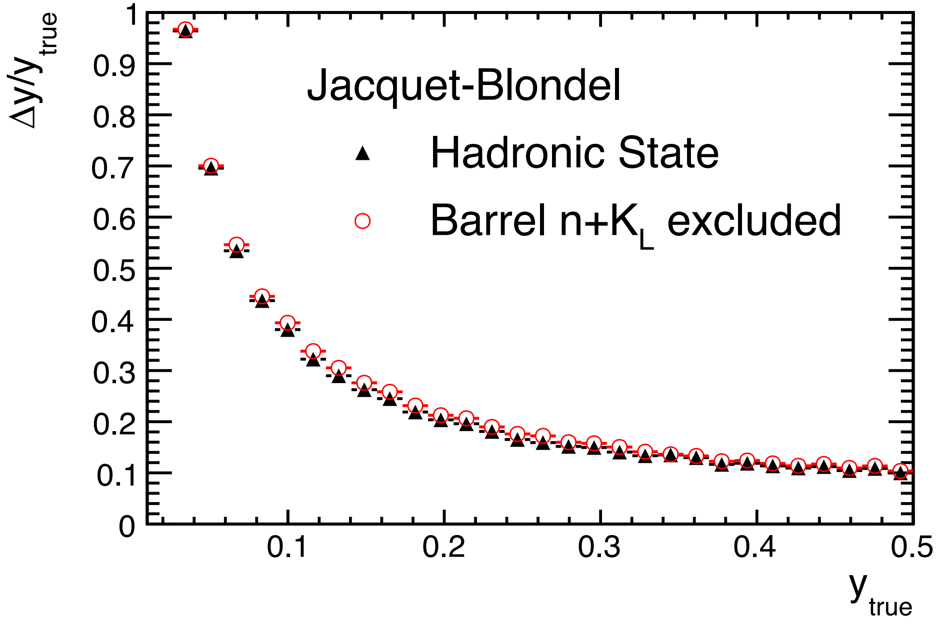
- Without detector smearing, the contribution of barrel neutron and K_L is not negligible: cross section of barrel n + K_L is < 1%, however the contribution to y resolution is up to 7%
- E-pz is large for barrel n + K_L , it makes significant difference when reconstructing y without smearing

y resolution (smeared, using HCal)

$$y_{JB} = \frac{\sum(E - p_z)}{2E_e}$$ Using final hadronic state in -4<η<4

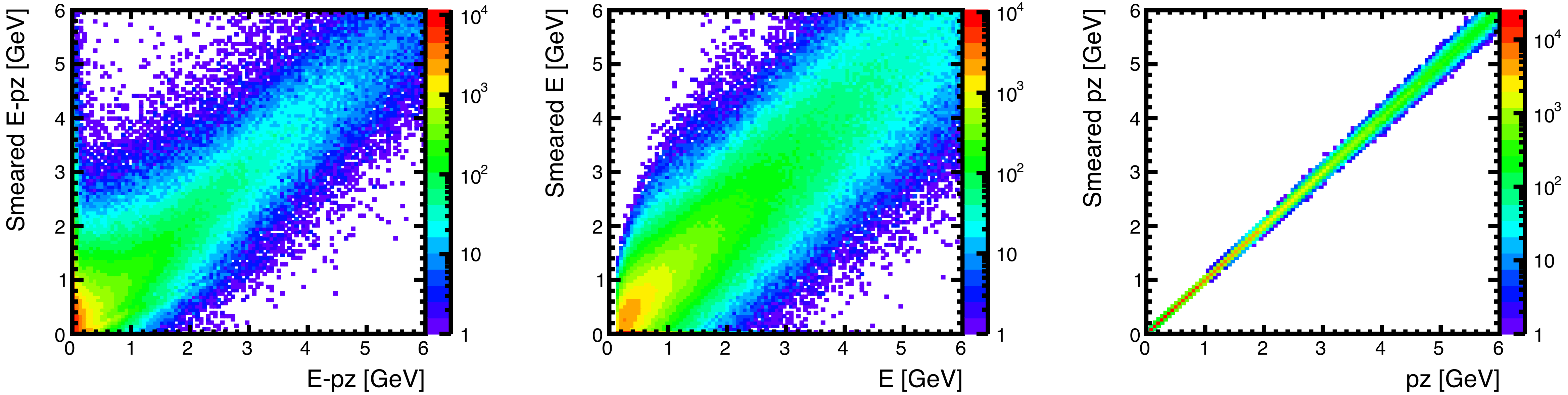


$$y_{JB} = \frac{\sum(E - p_z)}{2E_e}$$ Using final hadronic state after smearing



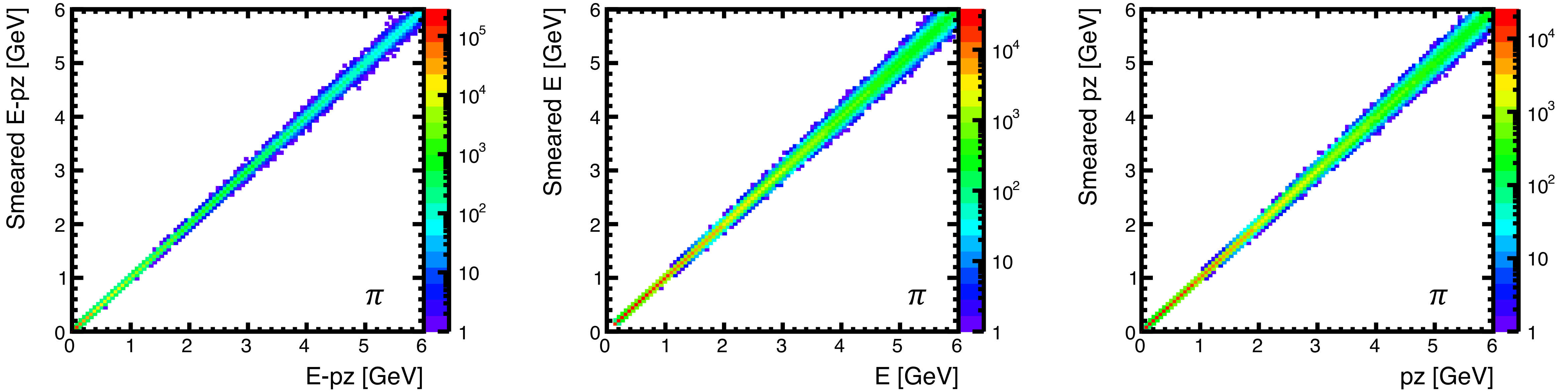
- Whether barrel neutron and K_L included or not, the resolution is not very good due to bad resolution of Hcal
- Energy of the n+K_L obtained from Hcal: smearing effect can be found in the backup
- Energy of charged hadrons: choose to obtain from Hcal or reconstruct by mass (PID) and momentum (tracking)

How does EICsmear work for π by HCal



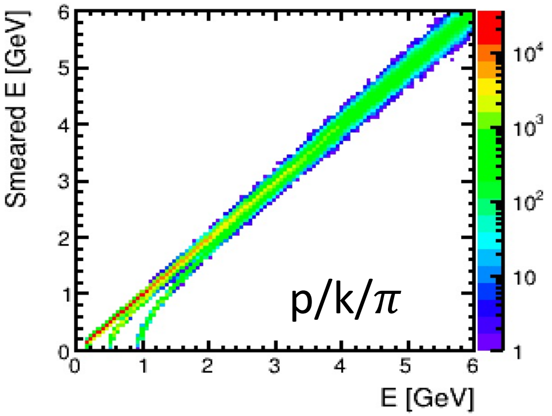
- The energy of charged hadron obtained from Hcal, momentum obtained from tracking
- Large smearing effect induced by Hcal in terms of the energy

How does EICsmear work for hadron by tracking



- Using mass and momentum of the charged hadrons to reconstruct the energy instead of obtaining energy from Hcal

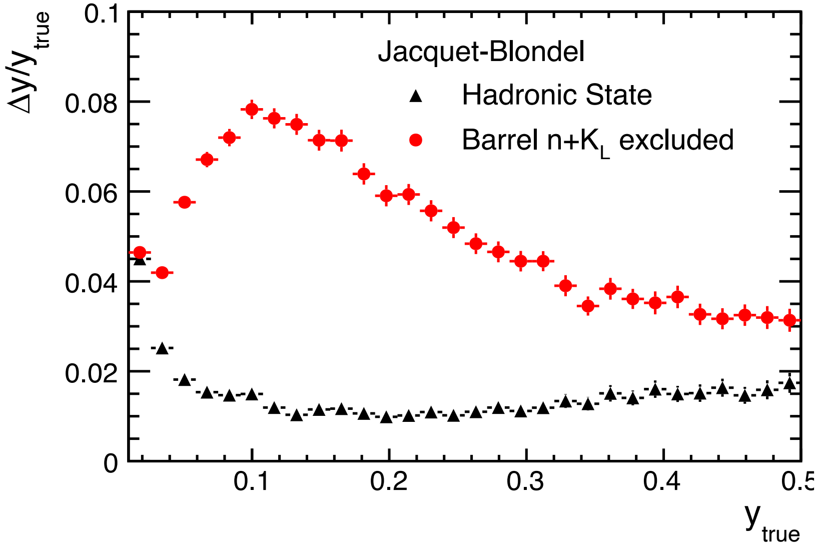
- Mass is used as charged particle's PDG mass:
  Condition (1) perfect PID applied: proton, kaon, pion identified (above 3 plots)
  Condition (2) using pion mass for proton, kaon and pion



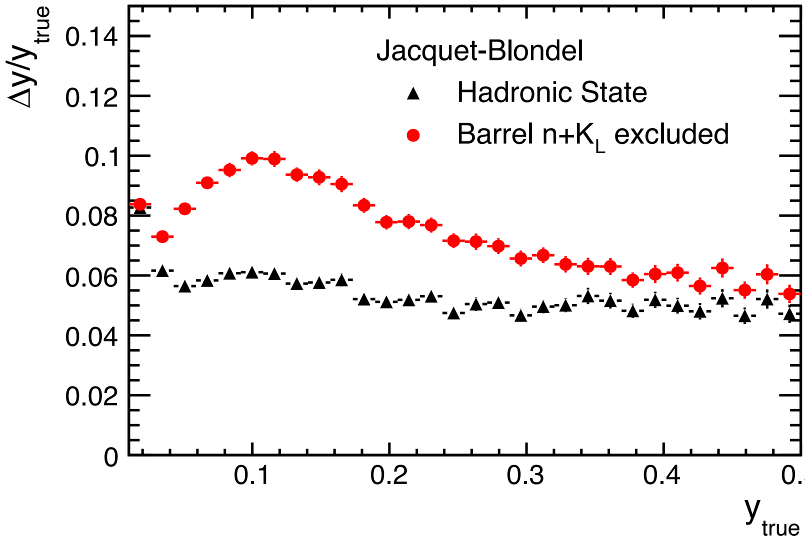
y resolution (smeared, by tracking)

$$y_{JB} = \frac{\sum(E - p_z)}{2E_e}$$

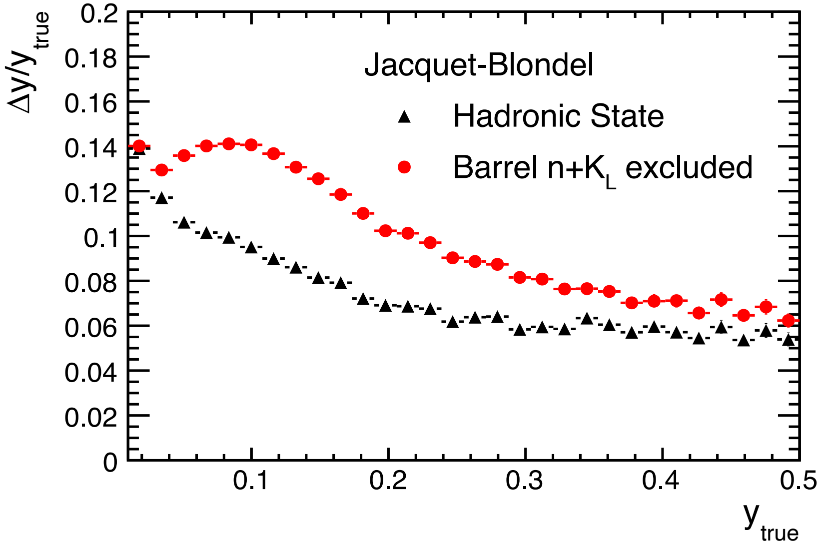
Using final hadronic state in -4<η<4



Using final hadronic state after smearing with condition (1)

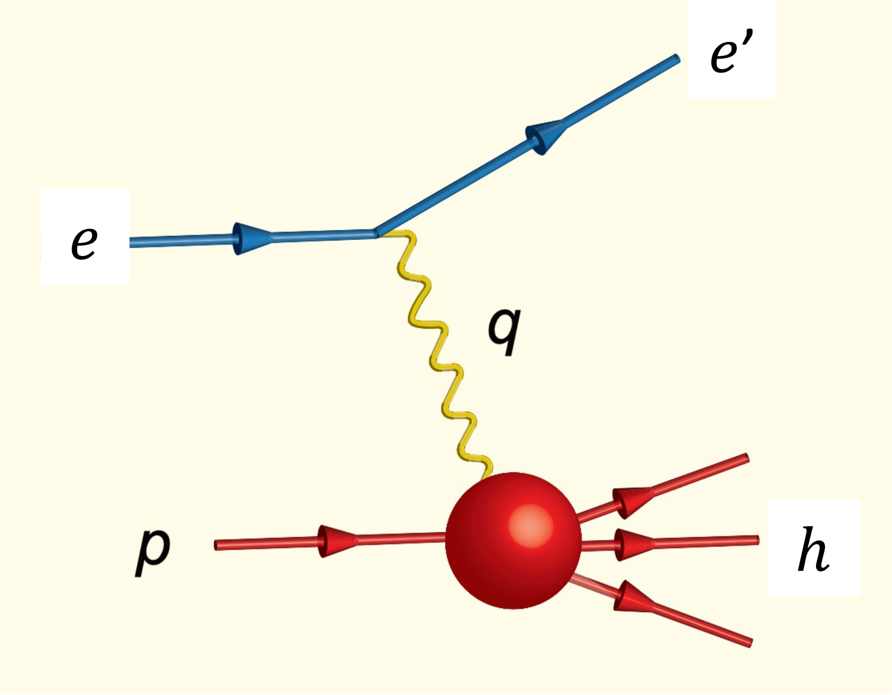


Using final hadronic state after smearing with condition (2)



- Difference between w/o barrel n+K$_L$ change from <= 0.07 → <=0.04 after smearing
  - energy of charged hadron is obtained from tracking
  - charged hadrons' PID affects the resolution at low y
- A barrel Hcal will improve y resolution of maximum at a level of 0.04 (if unfolding applied, there will be some corrections)

Method comparison



Electron method:

$$y^{rec} = 1 - \frac{E_e'}{E_e} cos^2\left(\frac{\theta'}{2}\right)$$

Jacquet-Blondel method:

$$y^{rec} = \frac{\sum_h (E_h - p_{z,h})}{2E_e}$$

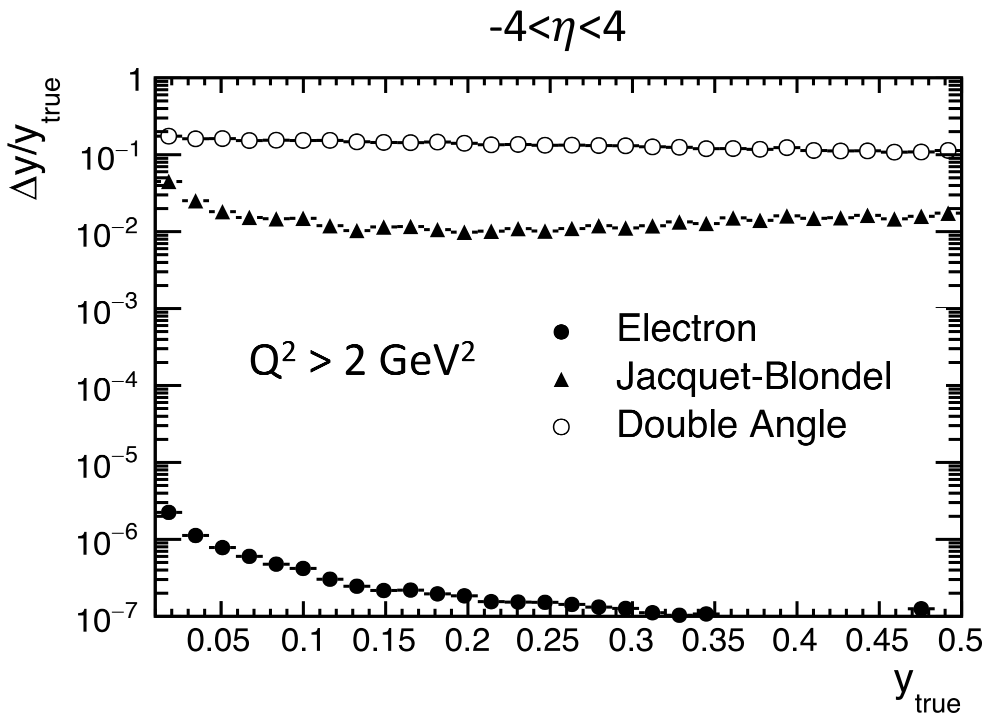
Double Angle method: (JHEP01 (2010) 109)

$$y^{rec} = \frac{\tan\left(\frac{\theta_h}{2}\right)}{\tan\left(\frac{\theta_{e'}}{2}\right)+\tan\left(\frac{\theta_h}{2}\right)}$$

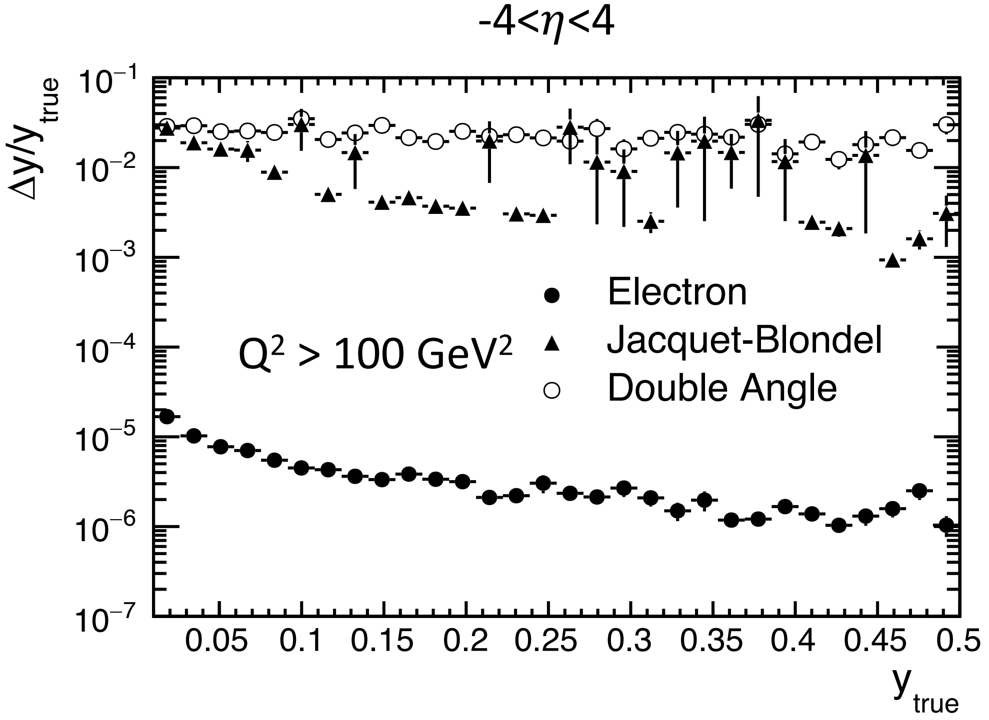
$$\cos(\theta_h) = \frac{\sum_h p_{x,h} + \sum_h p_{y,h} - \sum_h (E_h - p_{z,h})}{\sum_h p_{x,h} + \sum_h p_{y,h} + \sum_h (E_h - p_{z,h})}$$

θ_h is the hadronic scattering angles

Method comparison at true level



True level, without smearing, low Q^2

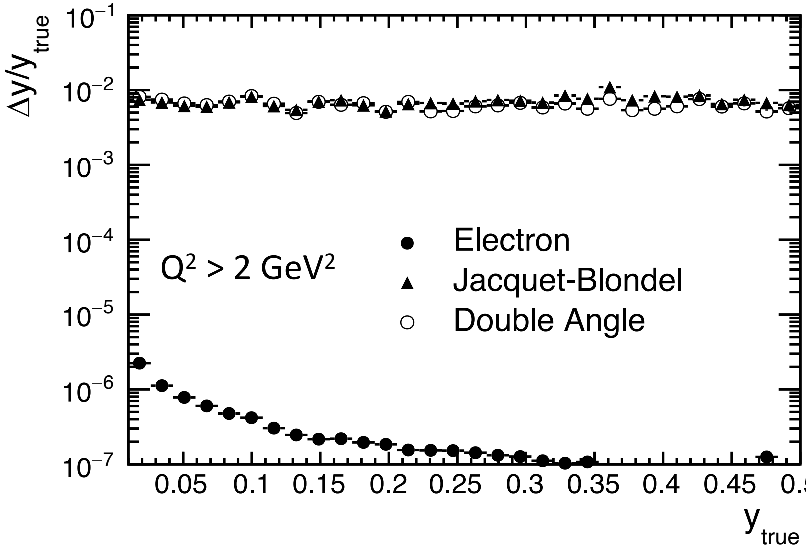


True level, without smearing, high Q^2

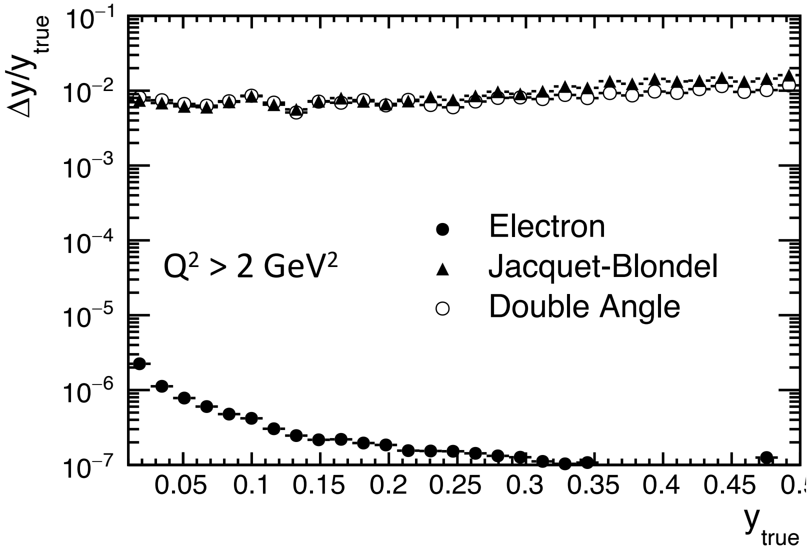
- Double Angle method: off at low Q^2; requires high precision tracking at very forward when Q^2 is low

Check η cut at true level

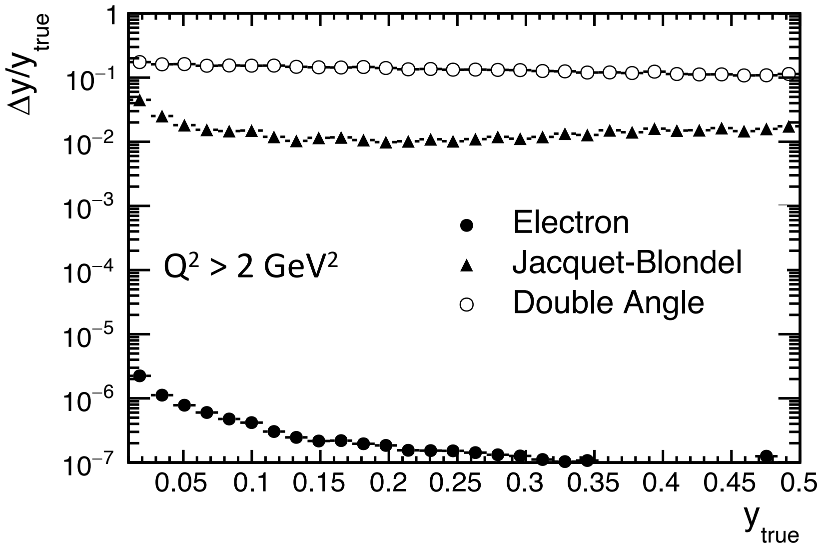
No cut



-4<η



-4<η<4

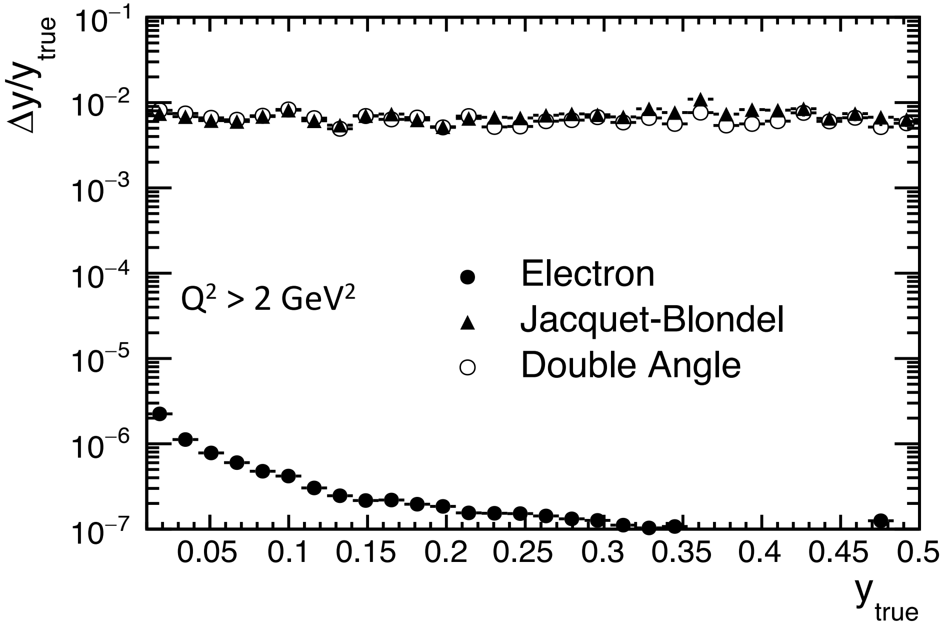


No cut:
Electron method: the scattered electron without any cut
Jacquet Blondel and Double Angle method: charged hadron + γ+ n + K_L + e (except the scattered electron) without any cut

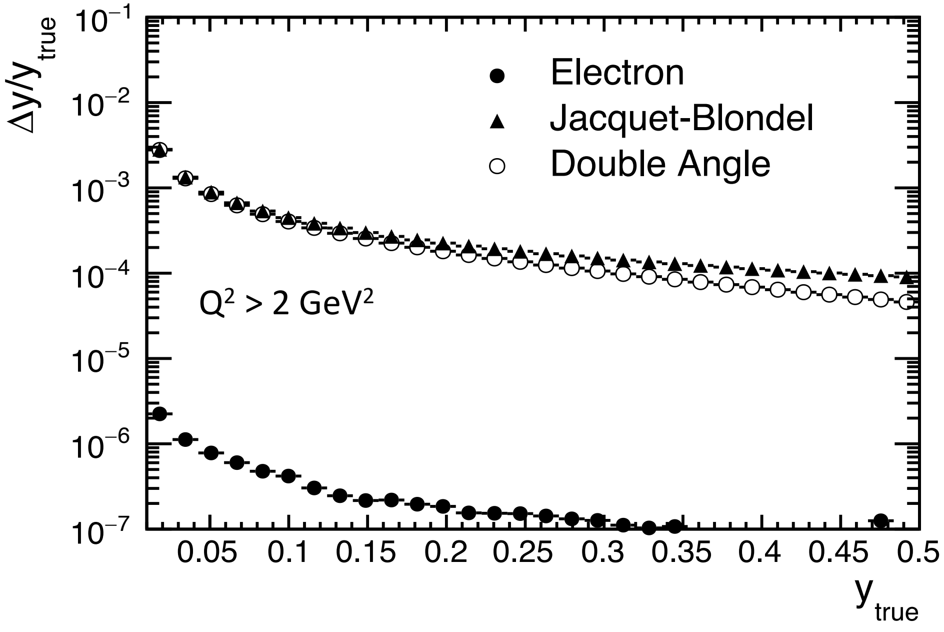
Double Angle method is very sensitive to hadronic state which belongs to very forward region:
Difference is around a factor of 20 w/o forward particle with η>4

Check PID at true level

No cut



Perfect detector

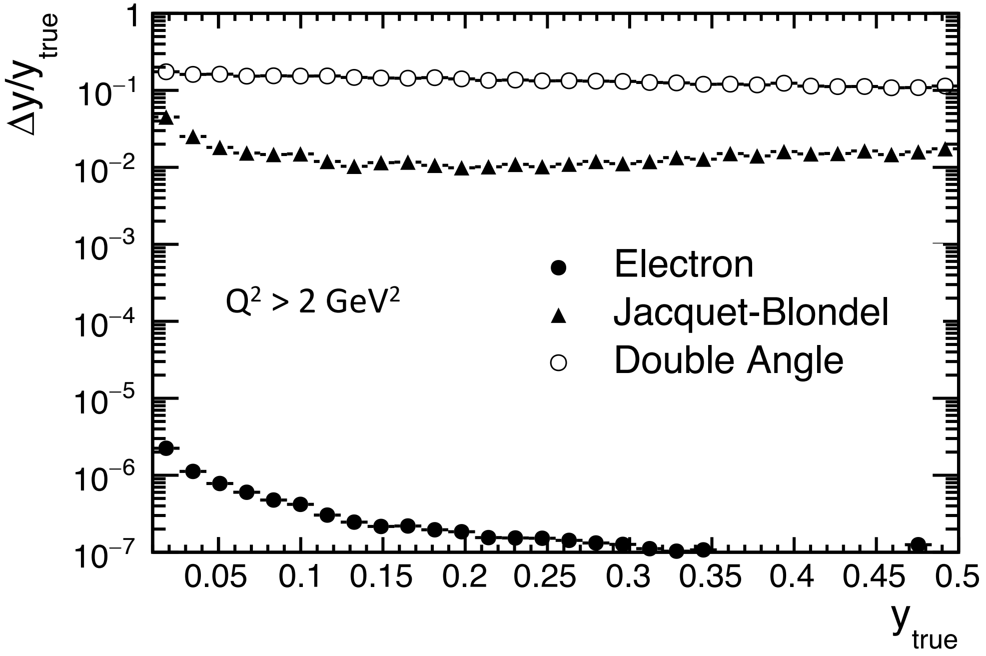


No cut:
Electron method: the scattered electron without any cut
Jacquet Blondel and Double Angle method: charged hadron + γ + n + K_L + e (except the scattered electron) without any cut

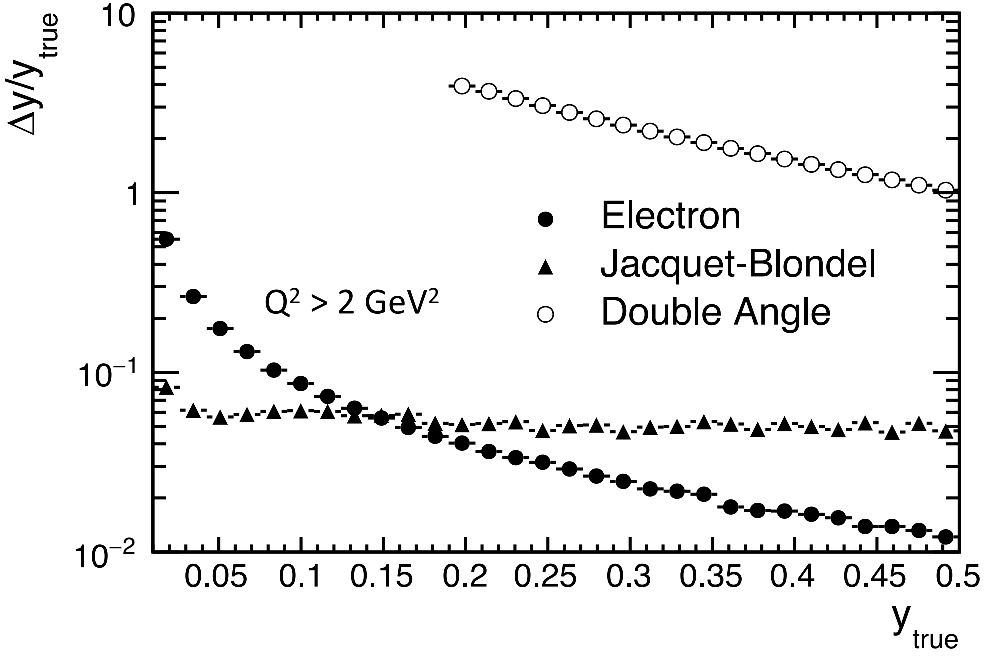
Perfect detector:
Jacquet Blondel and Double Angle method: everything except scattered electron

Method comparison after smearing

$-4<\eta<4$



True level, without smearing



With smearing, Perfect PID for p/K/π

Charged particles energy is obtained from tracking

- Electron method: divergence at small y after including smearing
- Jacquet-Blondel method: good resolution when y<0.15 after smearing
- Double Angle method at low Q^2: totally off after smearing

Summary

Whether barrel Hcal is necessary: after smearing,

- if changed hadron's energy is obtained from Hcal, resolution is bad for w/o barrel n+K_L
- If changed hadron's energy is obtained from tracking, by including barrel Hcal, maximum resolution improvement is ~ 4% (unfolding will have an impact)

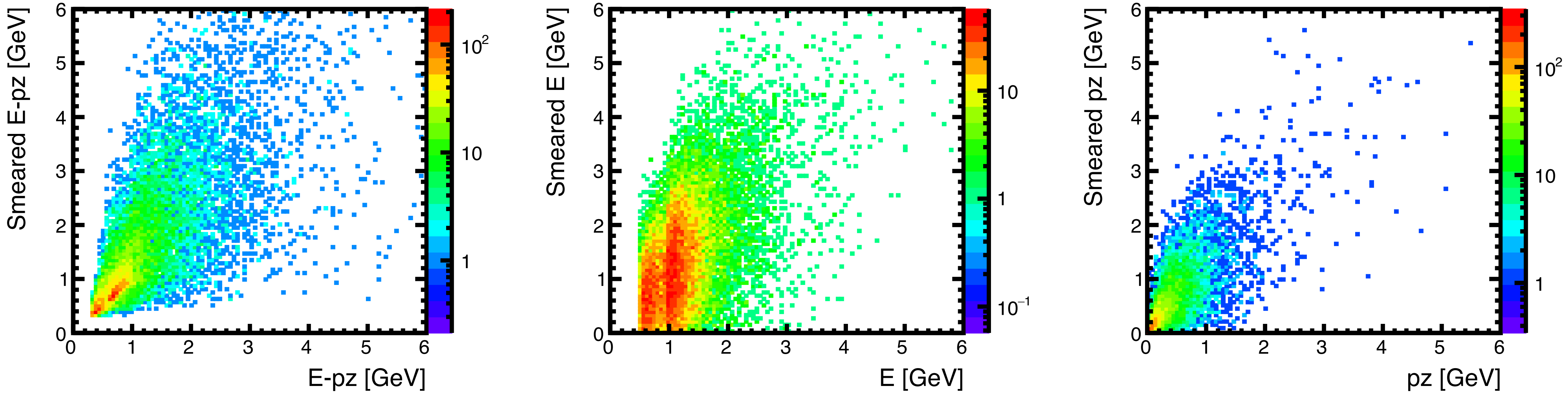
Comparison of electron, JB and DA method:

- With EIC smearing included: electron method works at y>0.15; JB is better at y<0.15
- DA works at high Q^2: the hadronic angle is less well-determined than the electron angle due to particle loss in the beampipe; requires high precision forward tracking and PID when Q^2 is low

Next step: sigma method, e-sigma method

backup

How does EICsmear work for barrel $n+K_L$

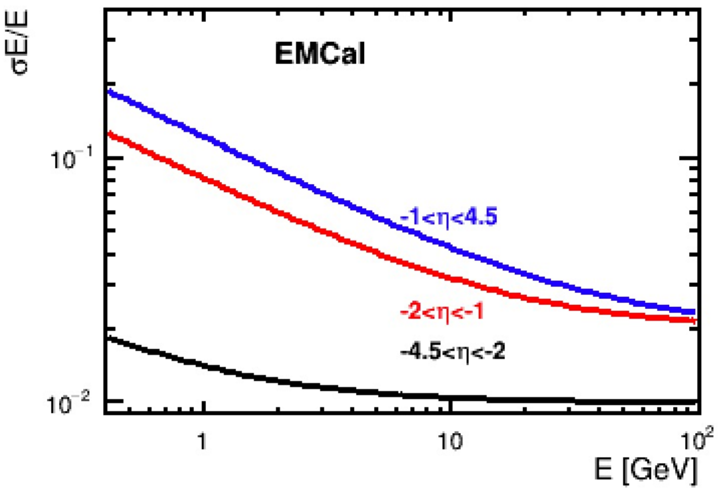


HCal resolution is bad at barrel region for $n+K_L$: energy obtained from Hcal smearing, momentum obtained from calculation of smeared energy, phi and theta

Be careful using EIC smearing for neutral particles: mass was set to be the energy; momentum was set to be 0. Here I used the energy and mass to calculate the momentum

EIC Smear: detectors smear input

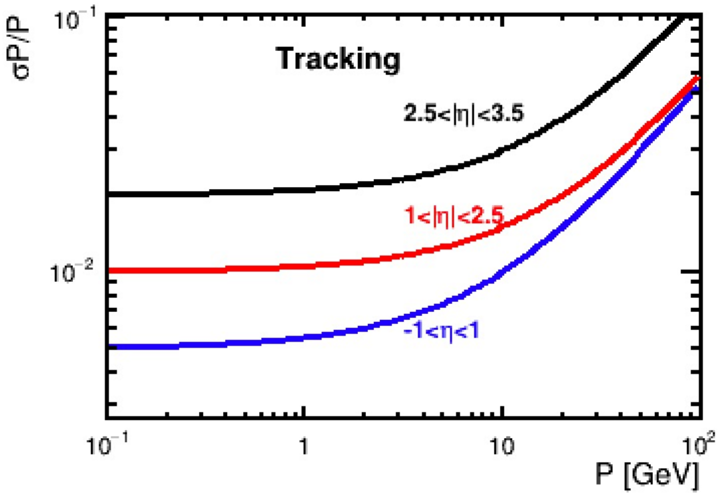
Photons



EMcal: -4.5 < eta < 4.5

eta = -4.5 – -2: sigma_E~sqrt(pow (0.01*E,2) + pow(0.01,2)*E)
eta = -2 – -1: sigma_E~ sqrt(pow (0.02*E,2) + pow(0.08,2)*E)
eta = -1 – 4.5: sigma_E~ sqrt(pow (0.02*E,2) + pow(0.12,2)*E)

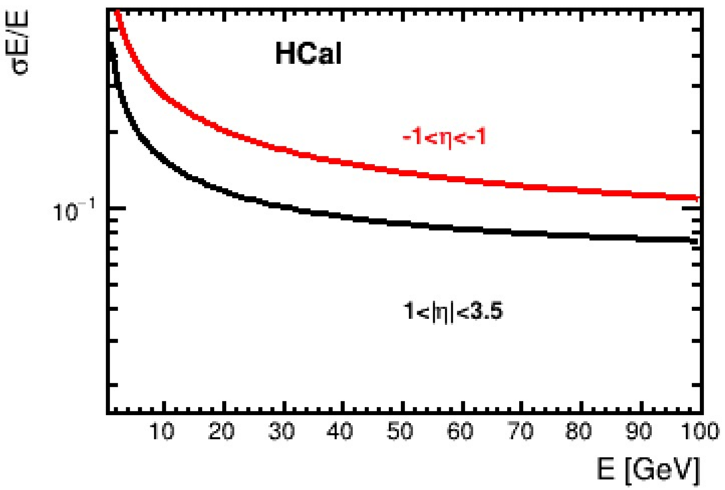
Charged hadrons



Tracking: -3.5 < eta < 3.5

eta = -3.5 – -2.5: sigma_p/p ~ 0.1% p+2.0%
eta = -2.5 – -1: sigma_p/p ~ 0.05% p+1.0%
eta = -1 – +1: sigma_p/p ~ 0.05% p+0.5

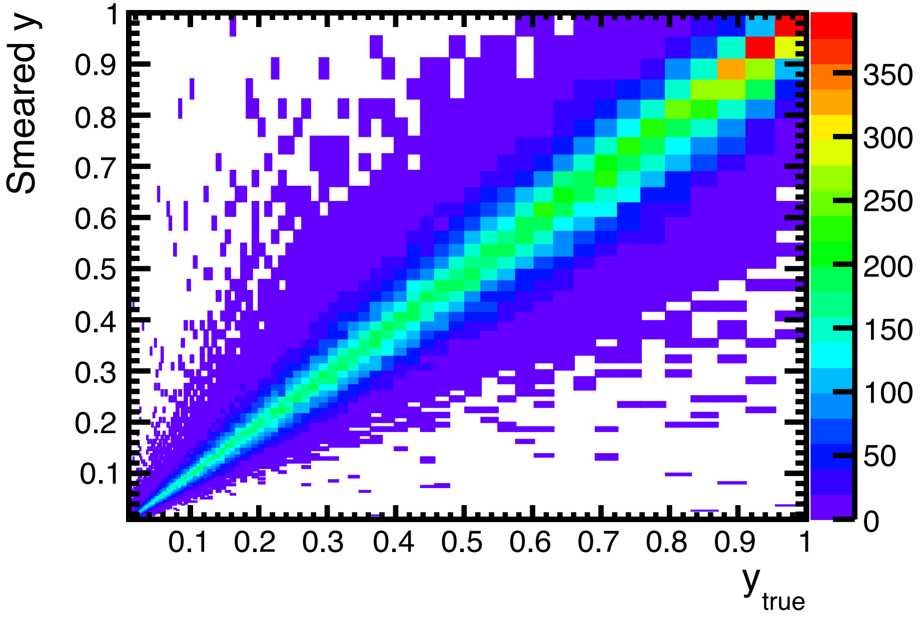
Charged hadrons+neutrons

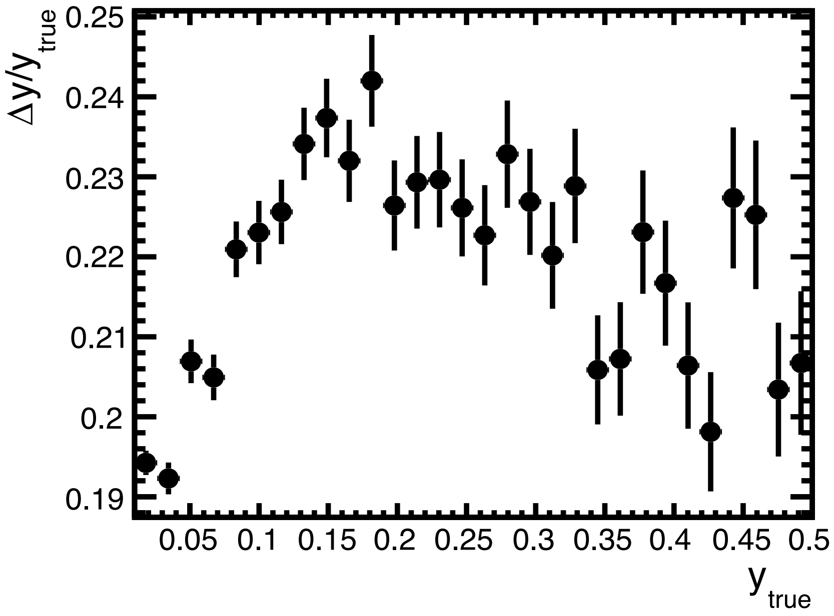


Hcal is -3.5 < eta < 3.5

eta = -3.5 – -1: sigma_E ~sqrt(pow(0.06*E, 2) + pow (0.45,2) *E
eta = -1 – 1: sigma_E ~ sqrt(pow(0.07*E, 2) + pow(0.85, 2)*E)

Double Angle method





Jacquet-Blondel method