ALICE-STAR India Collaboration Meeting
Institute of Physics Bhubaneswar

Heavy Flavour Electron-Hadron Correlation in pp Collisions at $\sqrt{s} = 13.6$ TeV with ALICE

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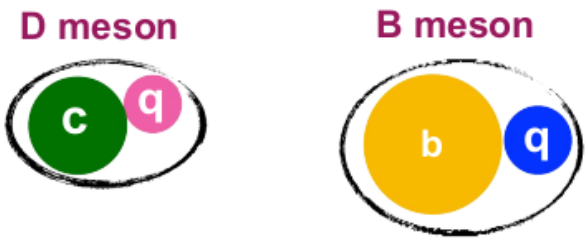
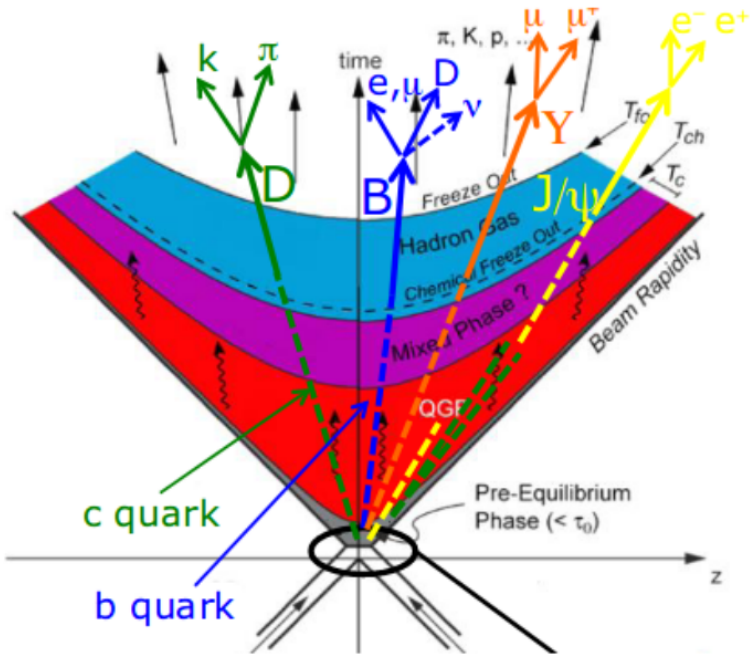
Outline

- Physics Motivation
- ALICE Detector
- Analysis Strategy
  - Heavy Flavour Electron-Hadron Correlation
  - Track and Cluster Matching
  - Electron Identification
- Results
- Summary and Outlook

Physics Motivation

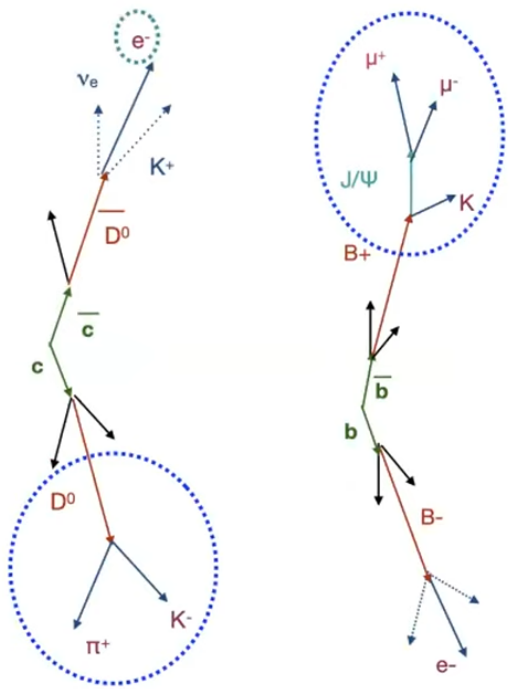
- Charm and beauty quarks (c,b) are produced in the initial hard scattering processes at the early stages of the collision
- $m_{c,b} >> \Lambda_{QCD}$
- Excellent probes of QGP due to their early production





Physics Motivation

- Heavy flavours can be reconstructed from ground state charm hadron decays or via semi-leptonic decays
  - $D^0(c\bar{u}) \rightarrow K^- + \pi^+$ (BR $\approx 3.88\%$)
  - $B, D \rightarrow e(\mu) + \bar{\nu} + X$ (BR $\approx 10\%$)
- HF production in different collision systems
  - pp collisions
    - Test for pQCD calculations
    - Baseline for heavy-ion collisions (p-Pb, Pb-Pb)
  - p–Pb collisions
    - Cold nuclear matter (CNM) effects
  - Pb–Pb collisions
    - Modification due to the interaction with the Quark Gluon Plasma (QGP).

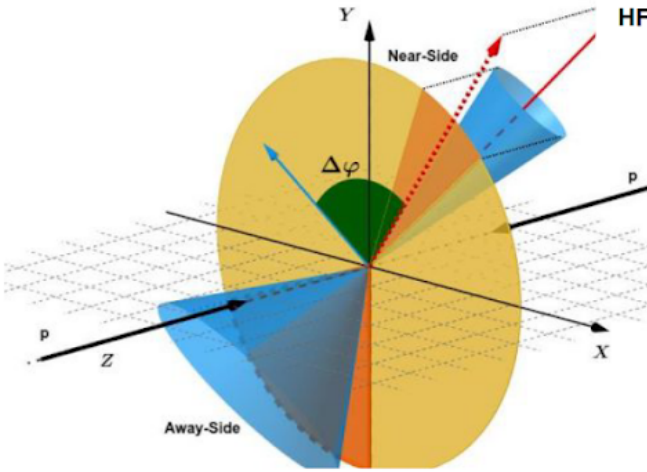


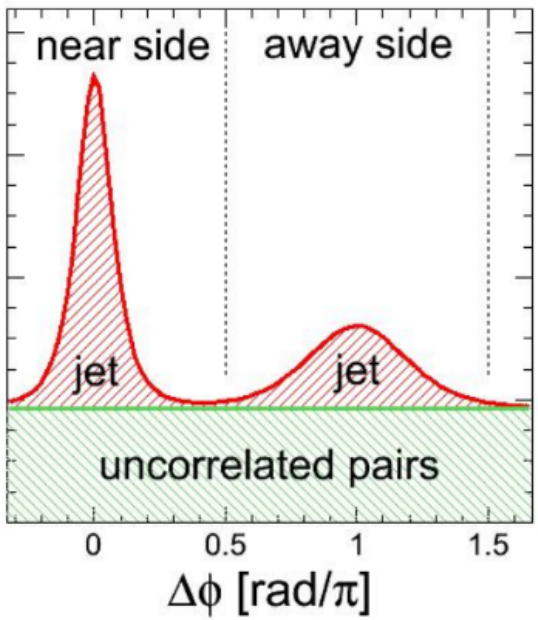
Physics Motivation

- High p_{T} heavy quarks produced in these collisions produce directed spray of particles called as jets
- $\Delta\phi$ distribution of charged particles

$$\Delta\phi = \phi_{\text{trigger}} - \phi_{\text{associated}}$$

- Azimuthal angular correlation of heavy flavour electrons (HFe) with charged-particles provide insight into:
  - Heavy quark production
  - Fragmentation and hadronization of heavy quarks

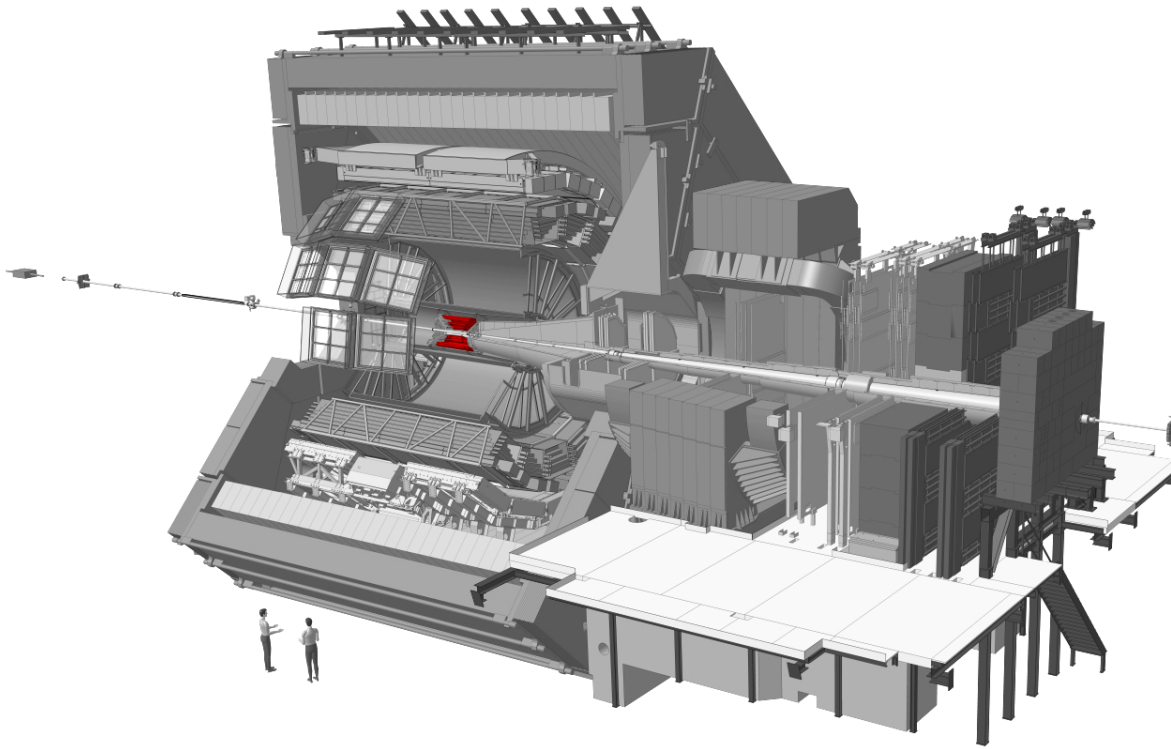




ALICE Detector

Inner Tracking System (ITS)

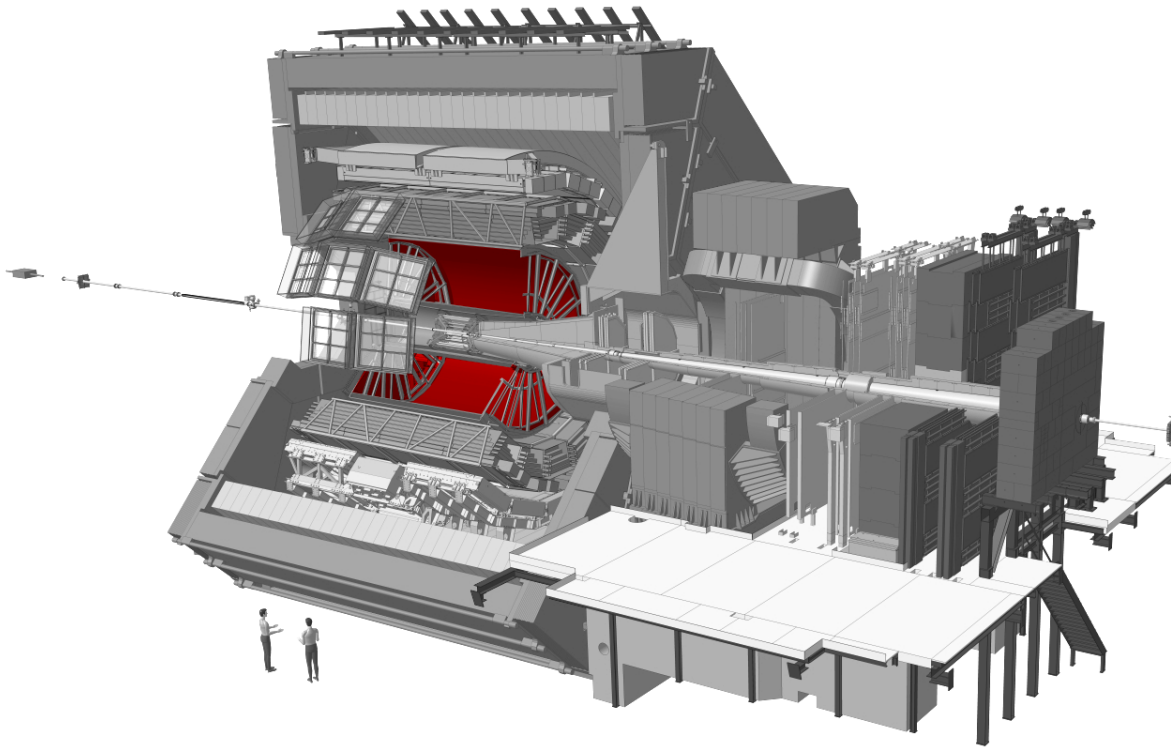
- $|\eta| < 0.9$
- $0° < \phi < 360°$
- Vertexing
- Tracking
- Particle Identification



ALICE Detector

Time Projection Chamber (TPC)

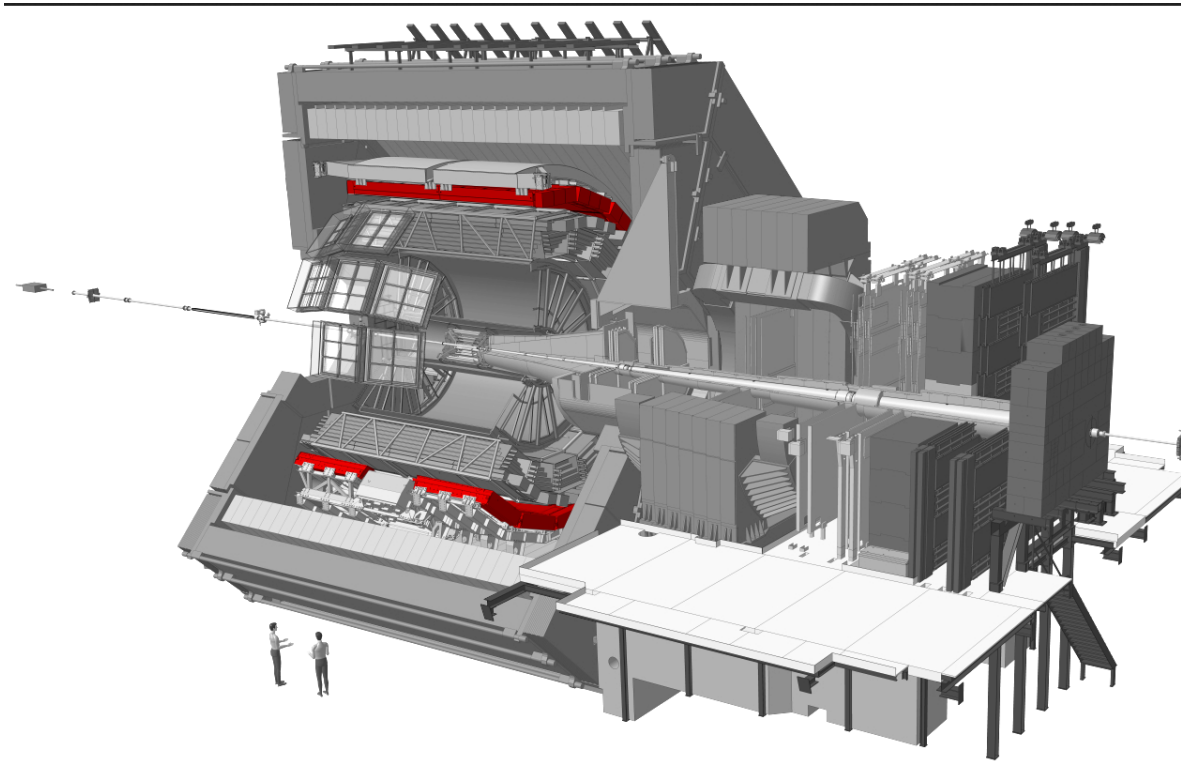
- $|\eta| < 0.9$
- $0° < \phi < 360°$
- Tracking
- Momentum information
- Particle identification



ALICE Detector

Electromagnetic Calorimeter (EMCal, DCal)

- $|\eta| < 0.7, 0.22 < |\eta| < 0.7$
- $80° < \phi < 187°, 260° < \phi < 320°$
- Energy measurement
- Particle identification



Heavy Flavour Elecrtron-Hadron Correlation

- Electron identification with TPC + EMCal (DCal) detectors
- $\Delta\phi$ distribution between HFe and charged particles is obtained as:

$$\Phi_{\text{HFe}} = \frac{dN}{d\Delta\phi}$$

$$\Phi_{\text{HFe}} = \Phi_{\text{Inclusive}} - \Phi_{\text{Non-HFe}}$$

- $\Delta\phi$ distribution for inclusive electrons is obtained as:

$$\Phi_{\text{Inclusive}} = \Phi^{\text{e-h}} - \Phi^{\text{h-h}}$$

  - $\Phi^{\text{e-h}}$ is the electron hadron correlation
  - $\Phi^{\text{h-h}}$ is the di hadron correlation

Datasets and Event/Track selection

Datasets used

- Run3
- pp $\sqrt{s} = 13.6$TeV (LHC22o)
- Total no. of events - 2.45B

- Event selection

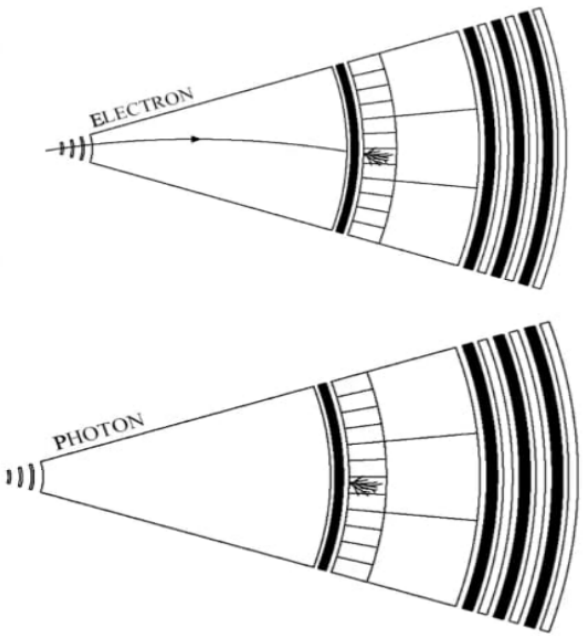
Trigger selection	Minimum bias (kINT7)
Contributors to primary vertex	≥ 2
Pileup rejection	sel8
Primary Z vertex range	$\pm$ 10 cm

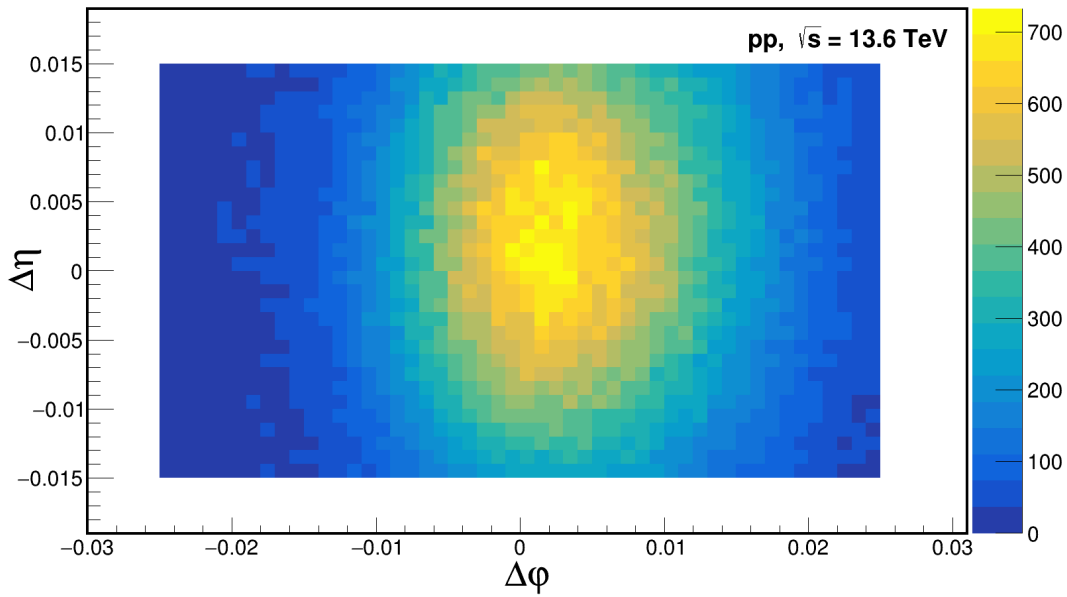
- Track selection

Pseudo-rapidity	TPC (-0.8, 0.8), EMCAL (-0.6, 0.6)
Transverse momentum	> 3.0 GeV/c
ITS refit, TPC refit	Yes
TPC crossed rows	> 70
Ratio crossed rows over findable clusters	> 0.8
Number of ITS clusters	> 2
χ^2 / clusters of the momentum fit in the TPC	< 4
Hits on SPD layers	kAny
DCA_{xy}	< 1 cm
DCA_z	< 0.5 cm

Track and Cluster Matching

- Tracks reconstructed from TPC and clusters from EMCal are matched by their track topology
- $|\Delta\phi| < 0.025$ and $|\Delta\eta| < 0.015$

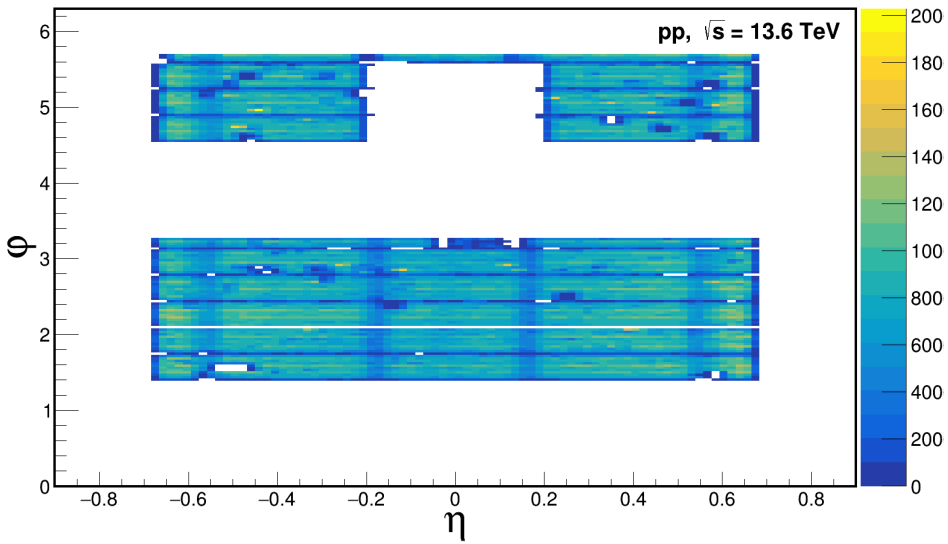




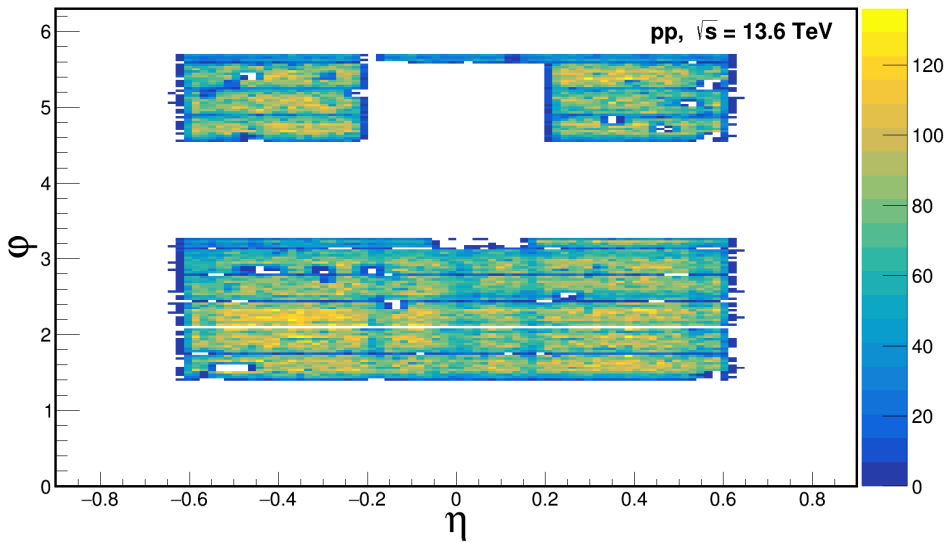
$$\Delta\phi = \phi_{\text{track}} - \phi_{\text{cluster}}$$
$$\Delta\eta = \eta_{\text{track}} - \eta_{\text{cluster}}$$

Cluster η and φ Distributions

- Before track-cluster matching

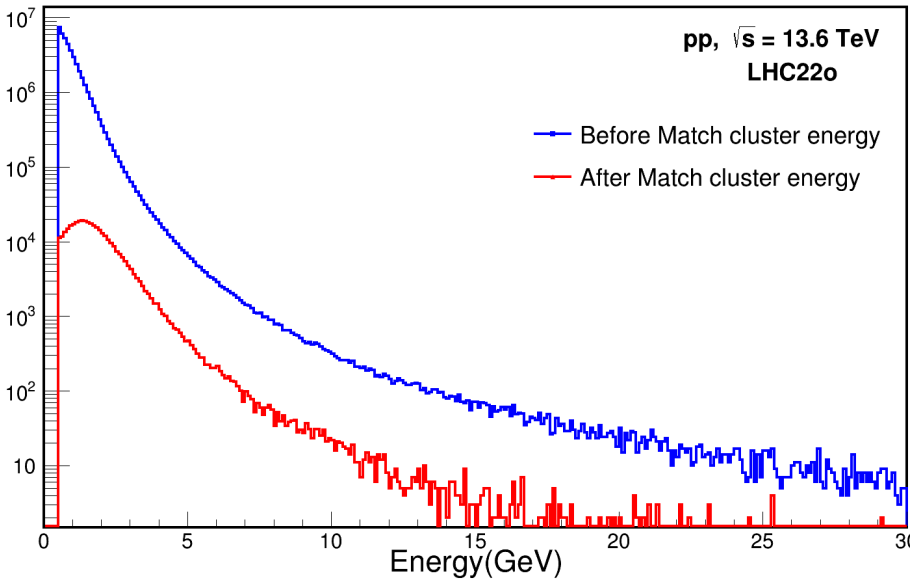


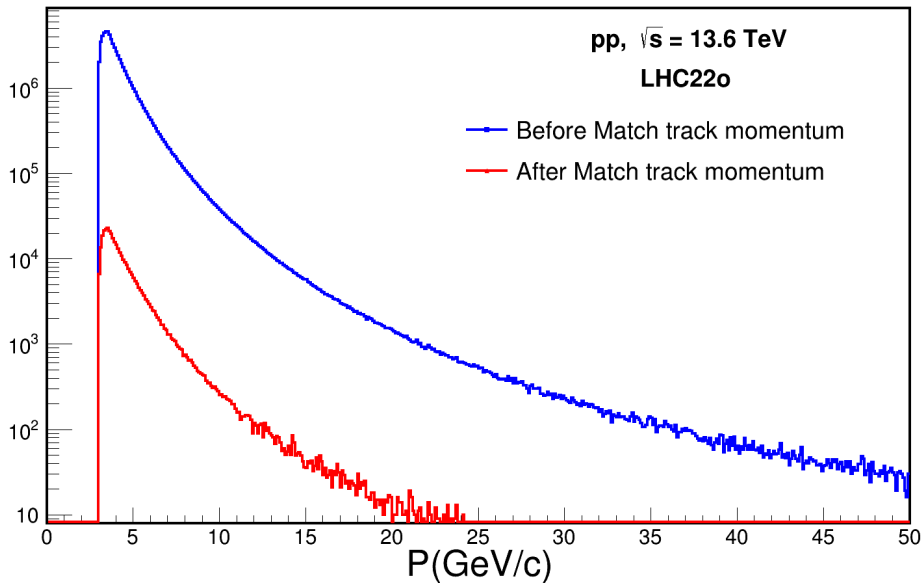
- After track-cluster matching



- Cluster η range
  - EMCal $|\eta| < 0.6$
  - DCal $0.22 < |\eta| < 0.6$
- Cluster ϕ range
  - EMCal $80° < \phi < 180°$
  - DCal $260° < \phi < 320°$

Cluster Energy and Track Momentum Distributions

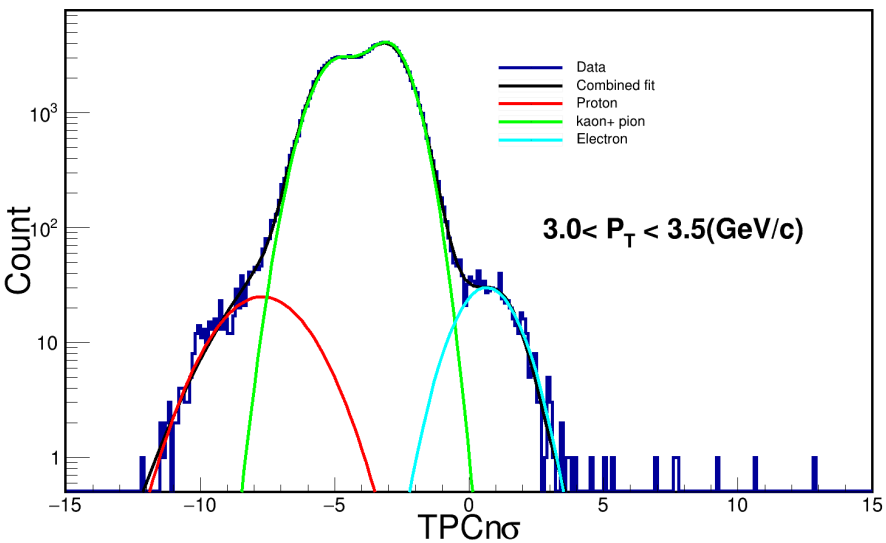


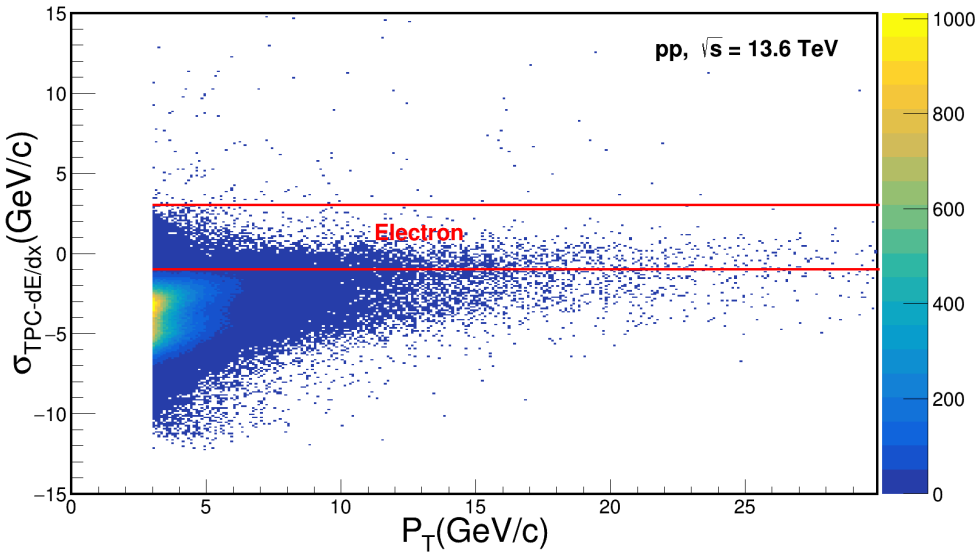


- Cluster energy is suppressed 99.15 % after track-cluster matching
- Track momentum is suppressed 99.46 % after track-cluster matching

Electron Identification

- Electrons are identified via their specific energy loss ($\mathrm{d}E/\mathrm{d}x$) in the TPC detector
- Due to large background at high momentum, combined identification of electrons from TPC and EMCal is performed

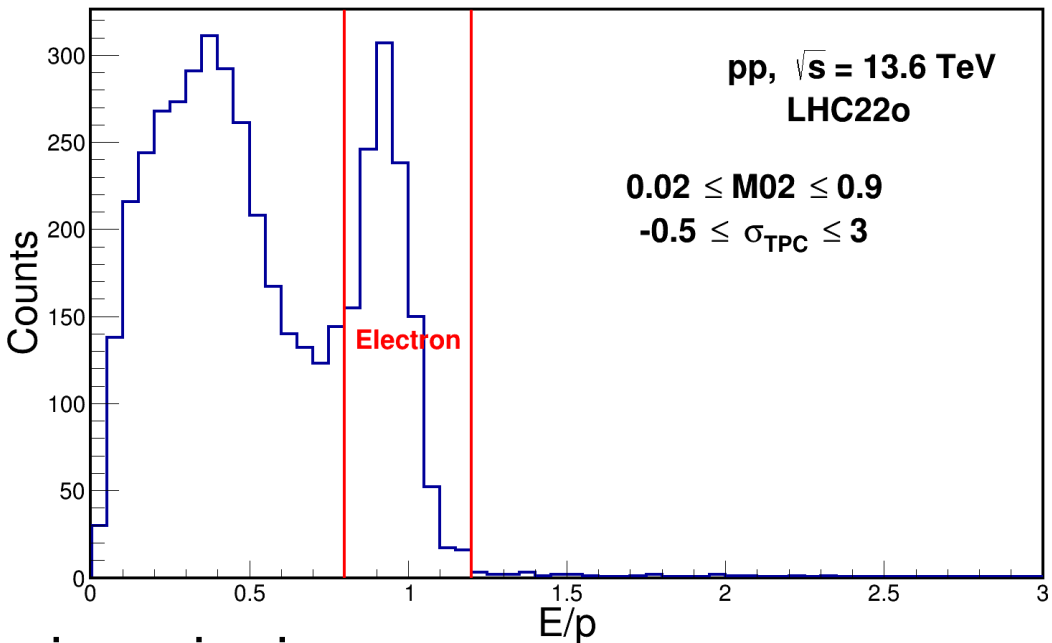




$$n(\sigma) = \frac{\mathrm{d}E/\mathrm{d}x_{\mathrm{obs}} - \mathrm{d}E/\mathrm{d}x_{\mathrm{th}}}{\sigma(\mathrm{Resolution})}$$

Electron Identification

- Electrons and hadrons deposit energy in EMCal
- Particles can be characterised based on the shower created in the EMCal
- E(energy) = Energy deposited to EMCal cluster
- p(Momentum) = Momentum of corresponding particle

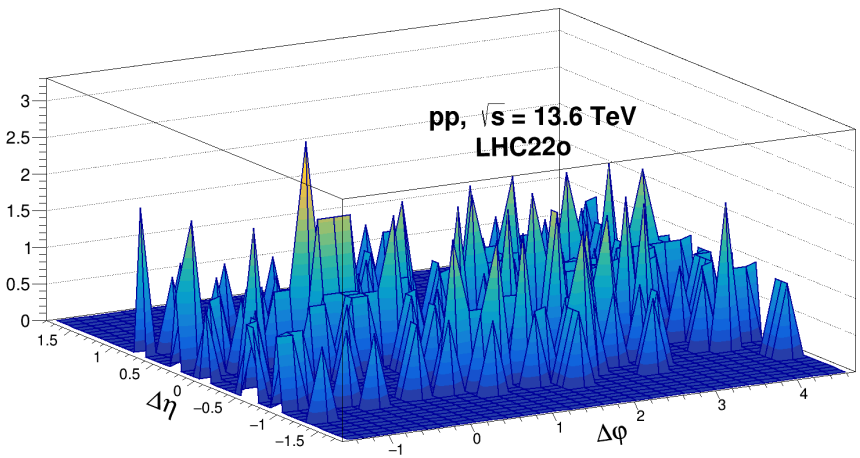


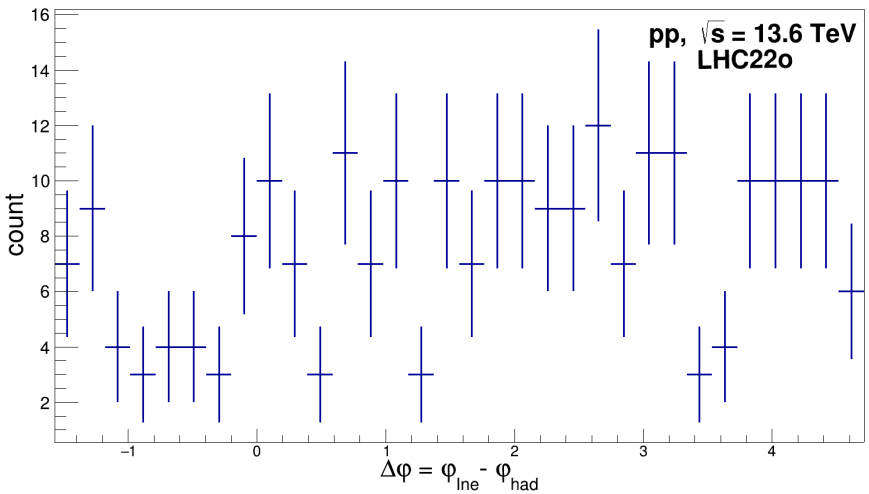
Electron Identification criteria

$\sigma_{\mathrm{TPC-d}E/\mathrm{d}x}$	(-0.5, 3)
Shower shape long axis(M02)	(0.02, 0.9)
E/p	(0.8, 1.2)

Inclusive Electron Hadron Correlation

- Total number of events = 80M
- p_{T} trigger $> p_{\mathrm{T}}$ associated
- p_{T} associated > 0.1 GeV/c

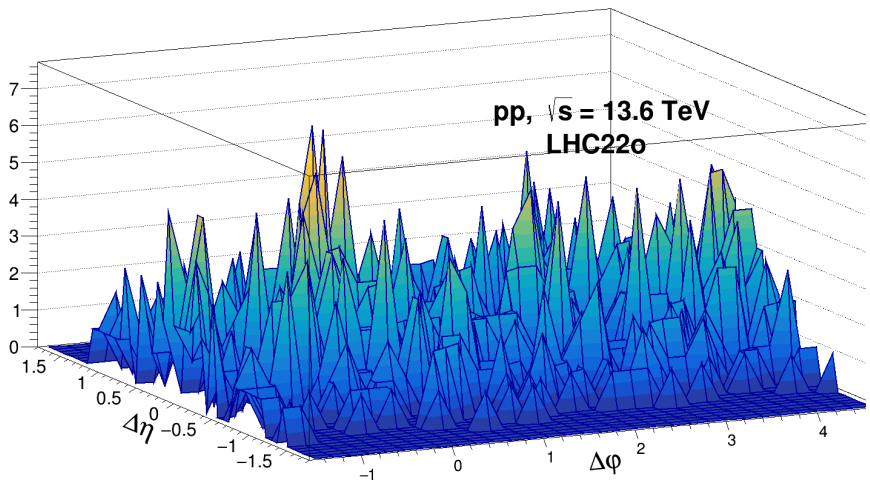


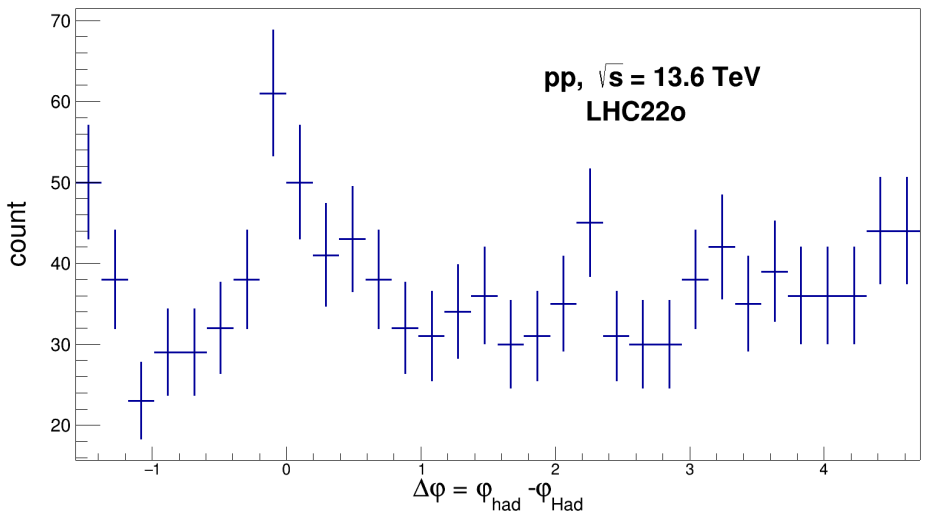


- Trigger particle → inclusive electron
- Associated particle → charged hadron
- Near side peak at $\Delta\phi = 0$
- Away side peak at $\Delta\phi = \pi$

Hadron-Hadron Correlation

- p_{T} trigger $> p_{\mathrm{T}}$ assosiated
- p_{T} assosiated > 0.1 GeV/c

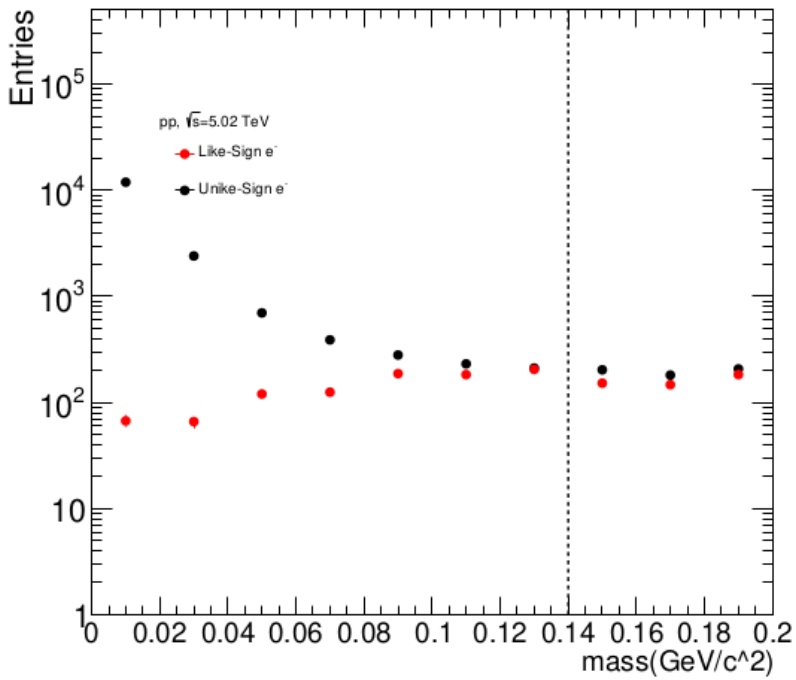




- Trigger particle → Charge hadron
- Associated particle → Charge hadron
- Near side peak at $\Delta\phi = 0$
- Away side peak at $\Delta\phi = \pi$

Non-HFe Hadron Correlation

- Dalitz decay and photon conversion process contribute to non HFe
  - $\pi^0 \rightarrow \gamma + e^- + e^+$
  - $\eta \rightarrow \gamma + e^- + e^+$
  - $\gamma \rightarrow e^- + e^+$
- Non-HFe are reconstructed via their using invariant mass calculation
  - $\Phi_{\text{Non HFe}} = (\Phi_{\text{ULSE}} - \Phi_{\text{LSE}})_{M_{e^+e^-} < 0.14\ GeV/c^2}$
- For finding the electron pair a loose $\sigma_{\text{TPC-dE/dx}}$ (-3, 3) cut is applied to increase the efficiency of electron identification



Mixed Event HFe-Hadron Correlation

- To remove pair acceptance and uncorrelated pairs due to detector inhomogeneity
- These effects can be evaluated and corrected for by using the $\Delta\phi, \Delta\eta$ distributions from mixed events
- In mixed event distribution electron and hadron coming from different event
- The same event distributions are corrected as:

$$\frac{d^2N^{\text{pair}}}{d\Delta\eta d\Delta\phi} = \beta \times \frac{S_{SE}(\Delta\eta, \Delta\phi)}{B_{ME}(\Delta\eta, \Delta\phi)}$$

$$S_{SE}(\Delta\eta, \Delta\phi) = \frac{d^2N^{\text{same}}}{d\Delta\eta d\Delta\phi}$$

$$B_{ME}(\Delta\eta, \Delta\phi) = \frac{d^2N^{\text{mix}}}{d\Delta\eta d\Delta\phi}$$

- β is the normalization yield for mixed events

Summary and Outlook

- Summary
  - Inclusive electron-hadron correlation
  - Mc reconstruction electron-hadron correlation
  - Mixed event inclusive electron-hadron correlation
  - Like and Unlike sign electron-hadron correlation
  - Electron selection task is committed to O2Physics repository
  - Results are presented in ALICE collaboration physics analysis group for heavy flavor correlations (PAG-HFL and HFC) meeting
    - https://indico.cern.ch/event/1380066/
    - https://indico.cern.ch/event/1303169/
- Outlook
  - Implement identification of HF electrons.
  - HFe - hadron correlation task implementation and offline task

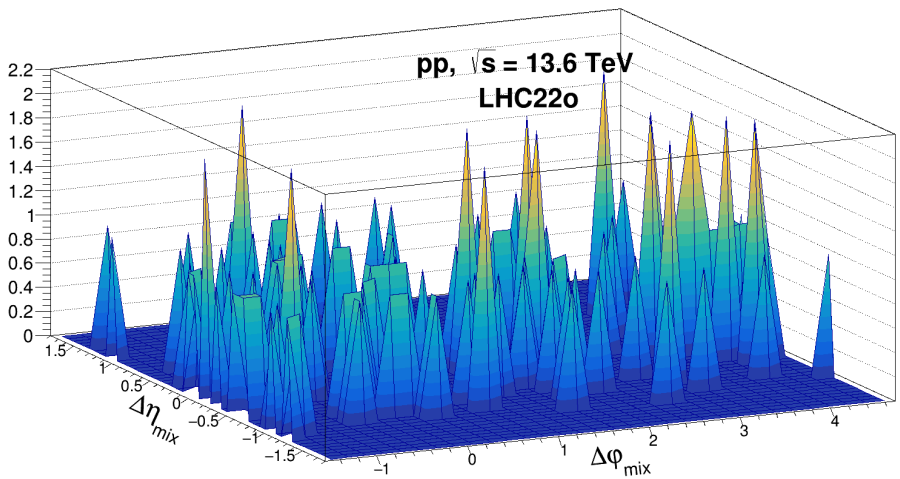
Thank you for your attention

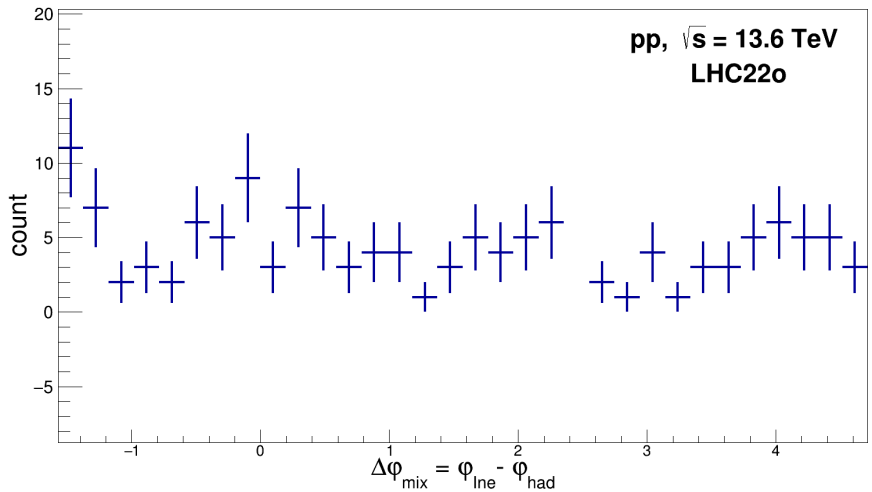
Backup

Backup Slide

Mixed event Inclusive Electron Hadron Correlation

- p_{T} trigger $> p_{\mathrm{T}}$ associated
- p_{T} associated > 0.1 GeV/c

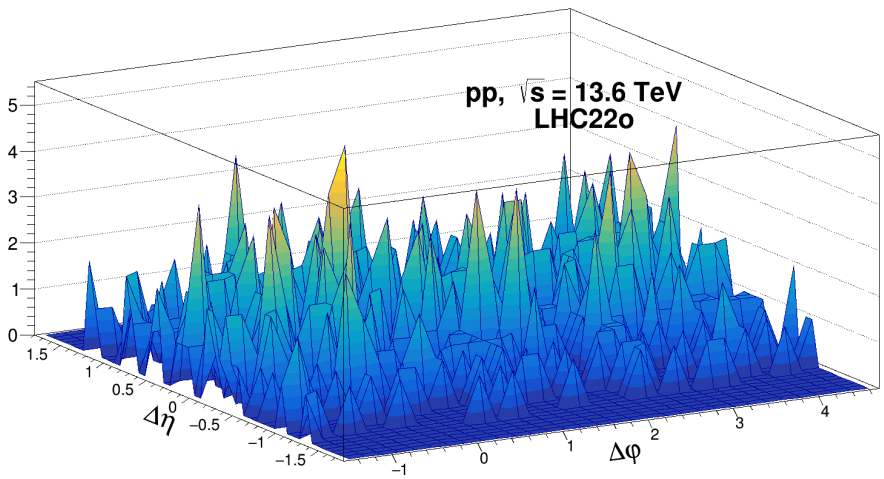


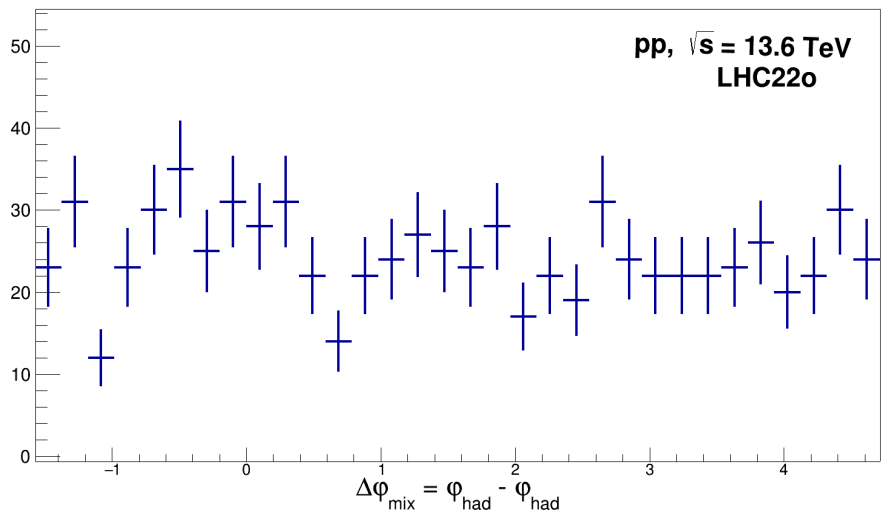


- Trigger particle →Inclusive electron
- Associated particle →Charge hadron

Mixed Event Hadron-Hadron Correlation

- p_{T} trigger $>$ p_{T} associated
- p_{T} associated > 0.1 GeV/c

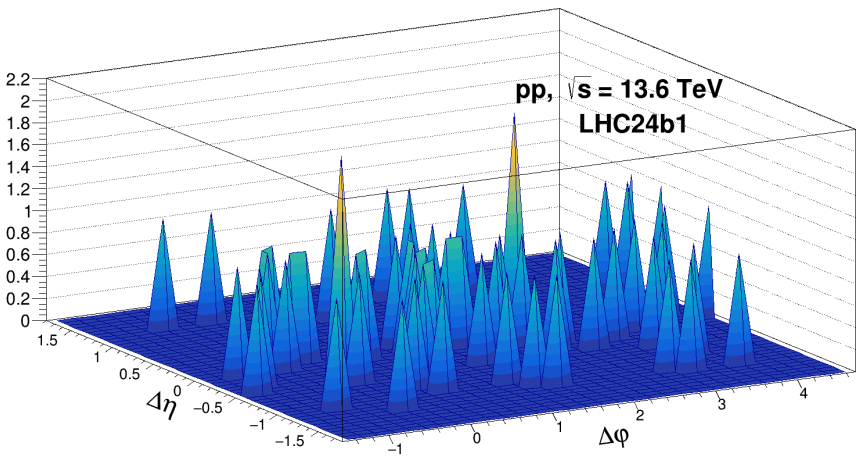


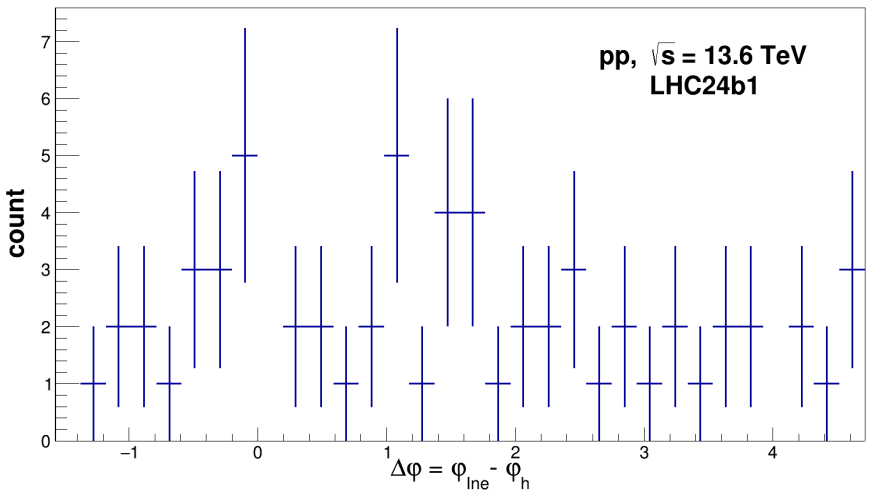


- Trigger particle $\rightarrow$ Charge hadron
- Associated particle $\rightarrow$ Charge hadron

MC Reco Inclusive Electron Hadron correlation

- Total number of events = 10M
- p_{T} trigger $> p_{\mathrm{T}}$ associated
- p_{T} associated > 0.1 GeV/c

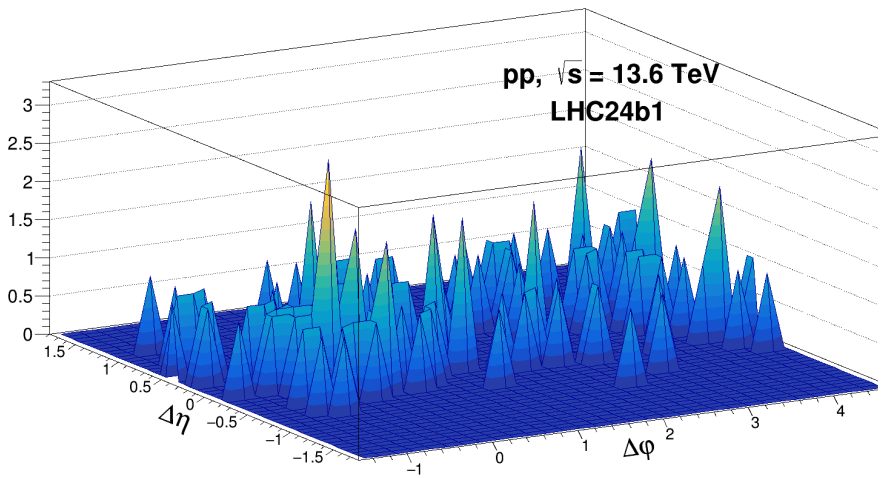


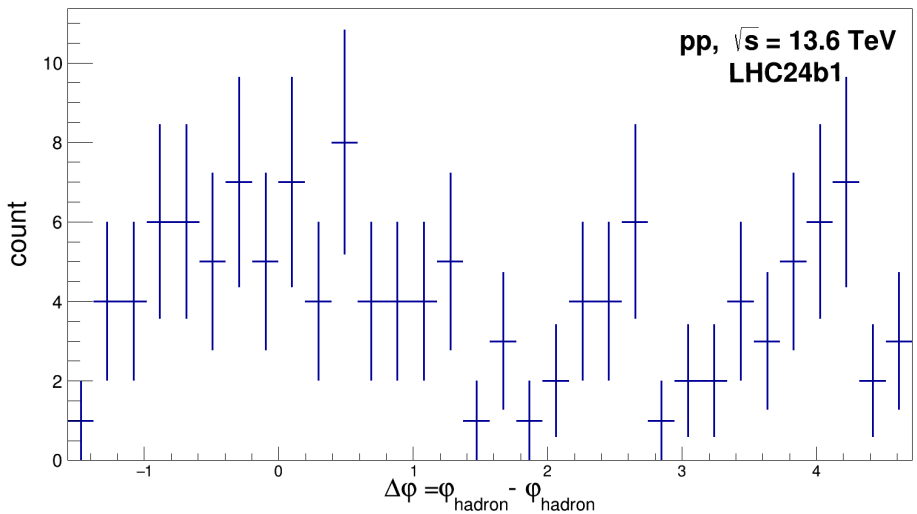


- Trigger particle → Inclusive electron
- Associated particle → Charge hadron
- Near side peak at $\Delta\phi = 0$
- Away side peak at $\Delta\phi = \pi$

MC Reco Hadron Hadron Correlation

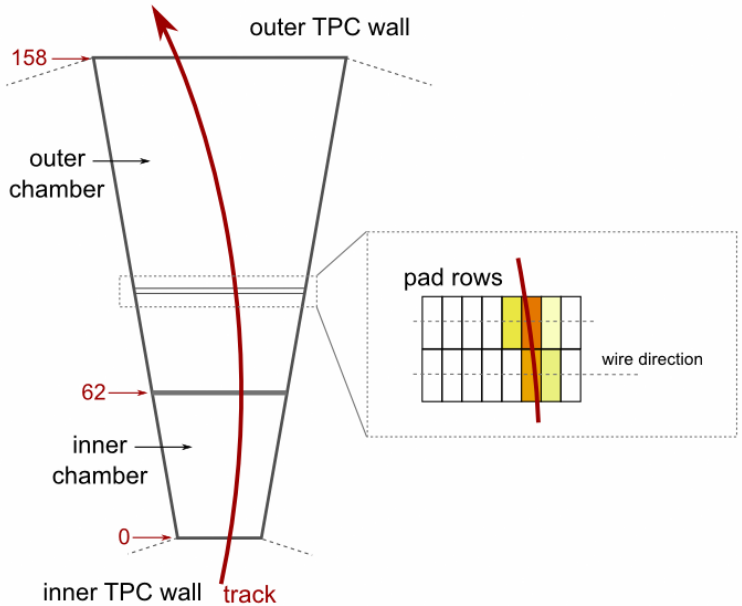
- p_{T} trigger $>$ p_{T} associated
- p_{T} associated > 0.1 GeV/c





- Trigger particle $\rightarrow$ Charge hadron
- Associated particle $\rightarrow$ Charge hadron

TPC



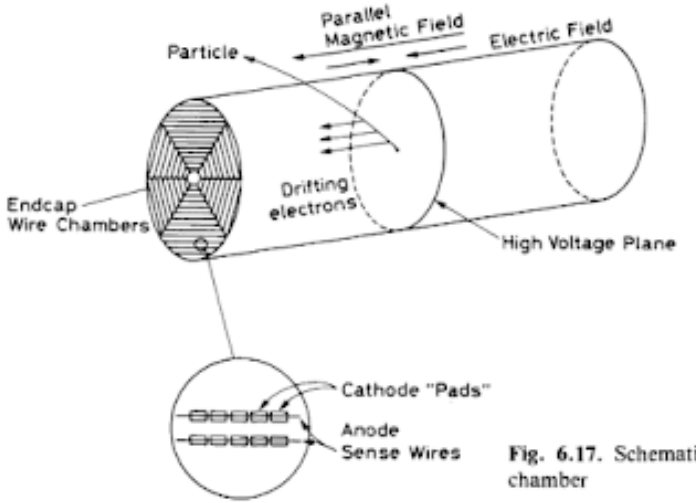
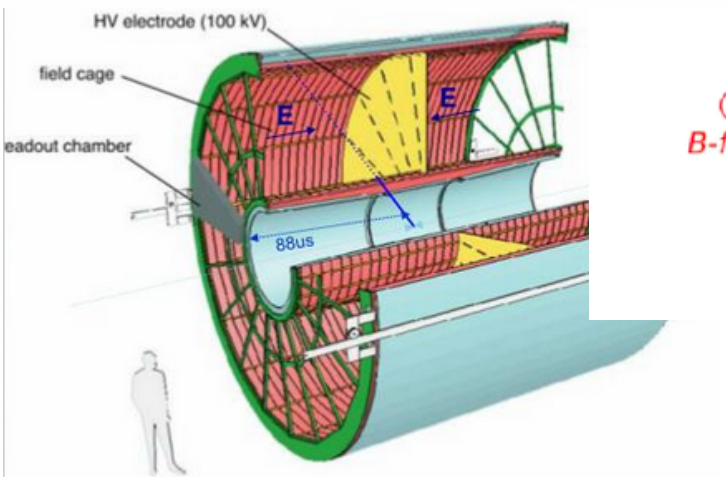
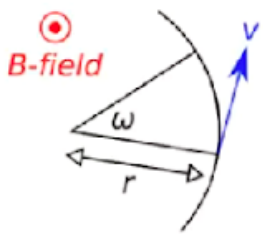


Fig. 6.17. Schematic diagram of chamber



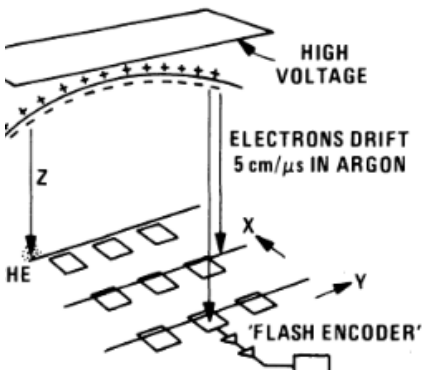


$$F = qvB$$

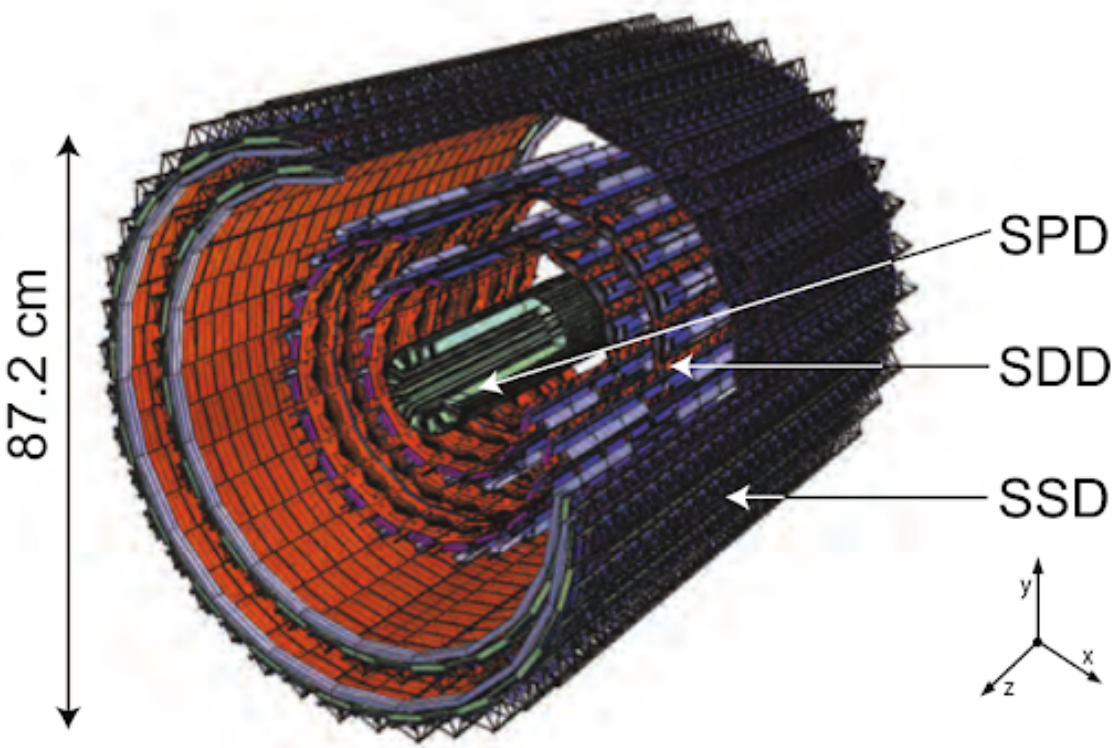
$$ma = qvB$$

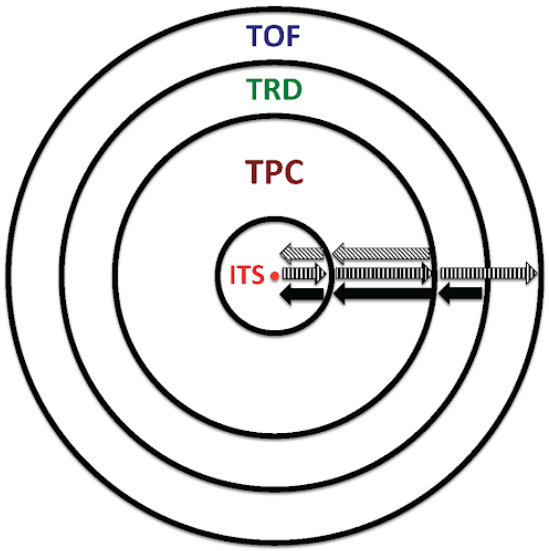
$$m\left(\frac{v^2}{r}\right) = qvB$$

$$\frac{mv}{r} = qB$$



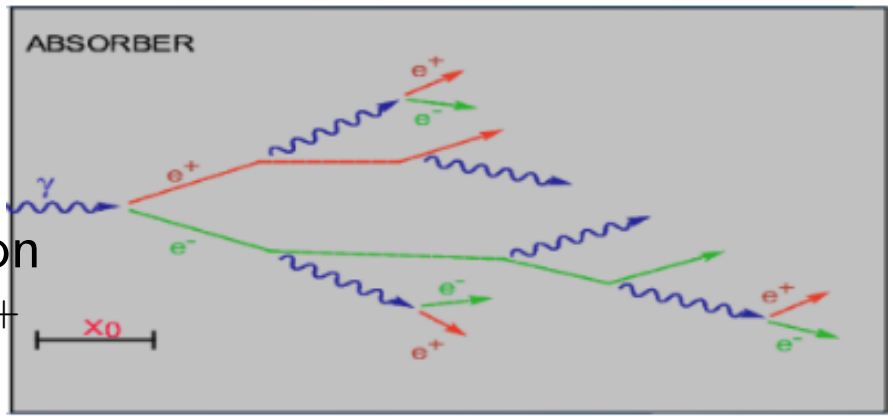
ITS

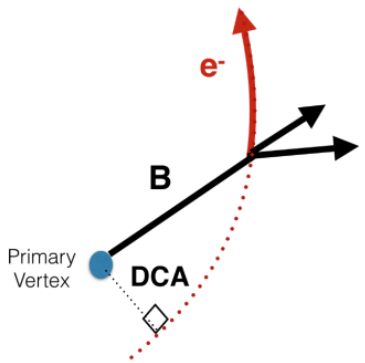




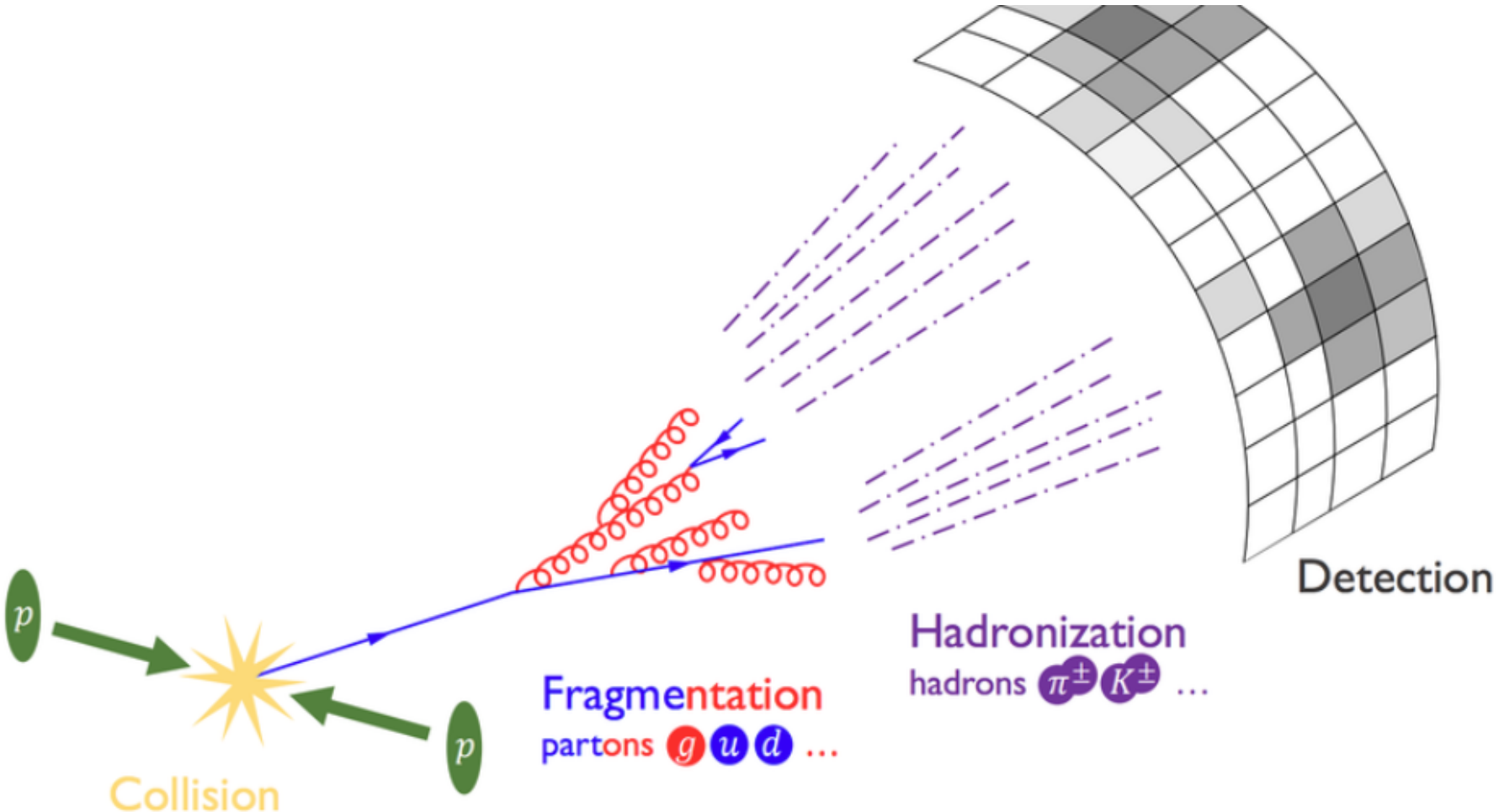
EMCAL

- Electron loses energy by Bremsstrahlung
  - $e^- + nucleus \rightarrow e^- + nucleus + \gamma$
- Photon is absorbed by pair production
  - $\gamma + nucleus \rightarrow e^- + nucleus + e^+$





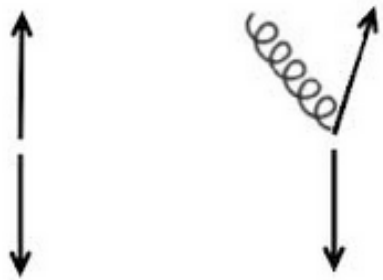
Fragmentation



Heavy Quark Production

Hard scattering

We would desire nature to be LO, giving us only back-to back HQ pairs



... not the case