Study of jet fragmentation with ALICE at LHC through γ-hadron correlation measurement

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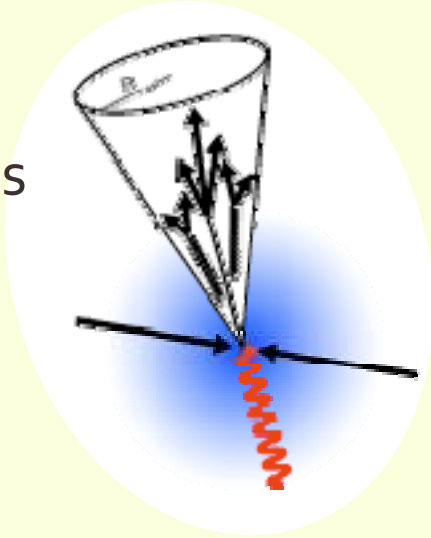
ALICE Physics Workgroup: High p_T and photons

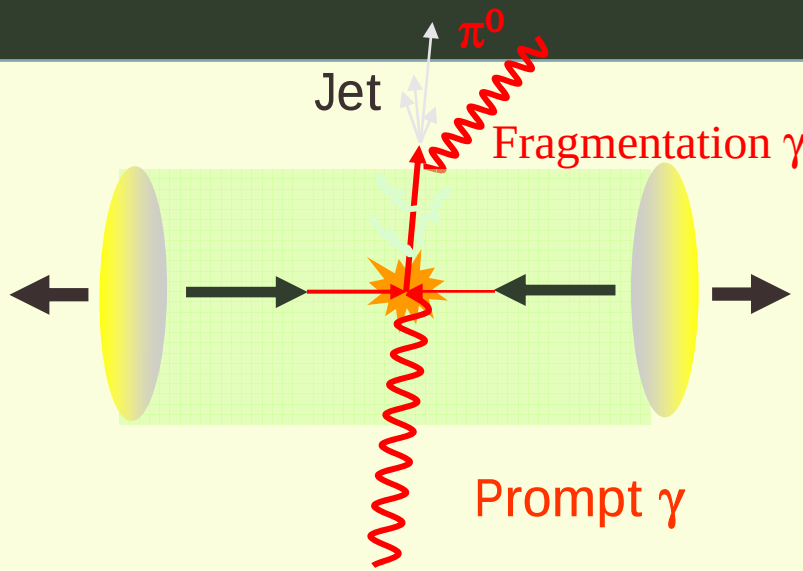
(for ALICE collaboration -- Wuhan)



Outline

- Motivation of γ-hadron correlation measurement:
  - Probe the medium created in HIC
  - Photons sources
- ALICE experiment: Detector performance
- Offline photon identification
- Prompt photon correlations
- Summary

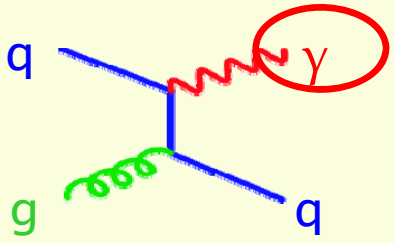
Why γ-jet correlations ?

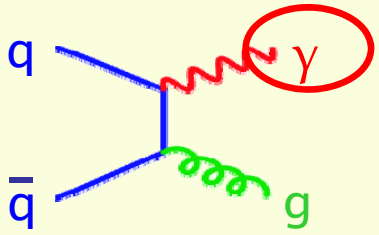


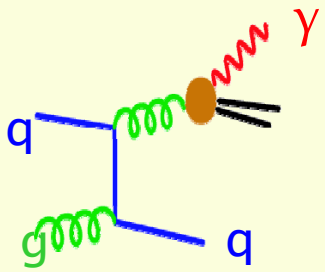
- The photon 4-momentum remains unchanged by the medium and sets the reference of the hard process
- Balancing the jet and the photon provides a measurement of the medium modification experienced by the jet
- Allows to measure jets in an energy domain (E_{jet} < 50 GeV) where
  - The jet looses a large fraction of its energy (ΔE_{jet} ≈ 20-50 GeV)
  - The jet cannot be reconstructed in the AA environment

Photon sources

- Direct photons (the signal)
  - Prompt pQCD photons ($E_\gamma > 20$ GeV)
    - g Compton scattering
    - $q\bar{q}$ annihilation
    - Fragmentation

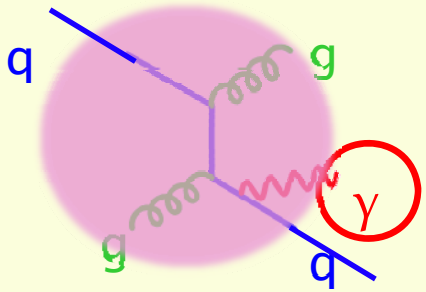


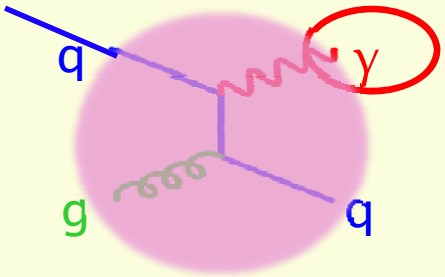


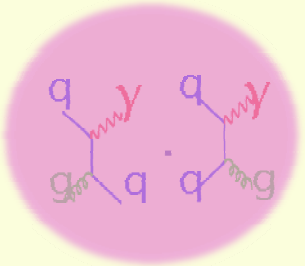


Photon sources

- Direct photons (the signal)
  - Photons produced by the medium (Eγ < 10 GeV)
    - Bremsstrahlung
    - Jet conversion
    - Thermal

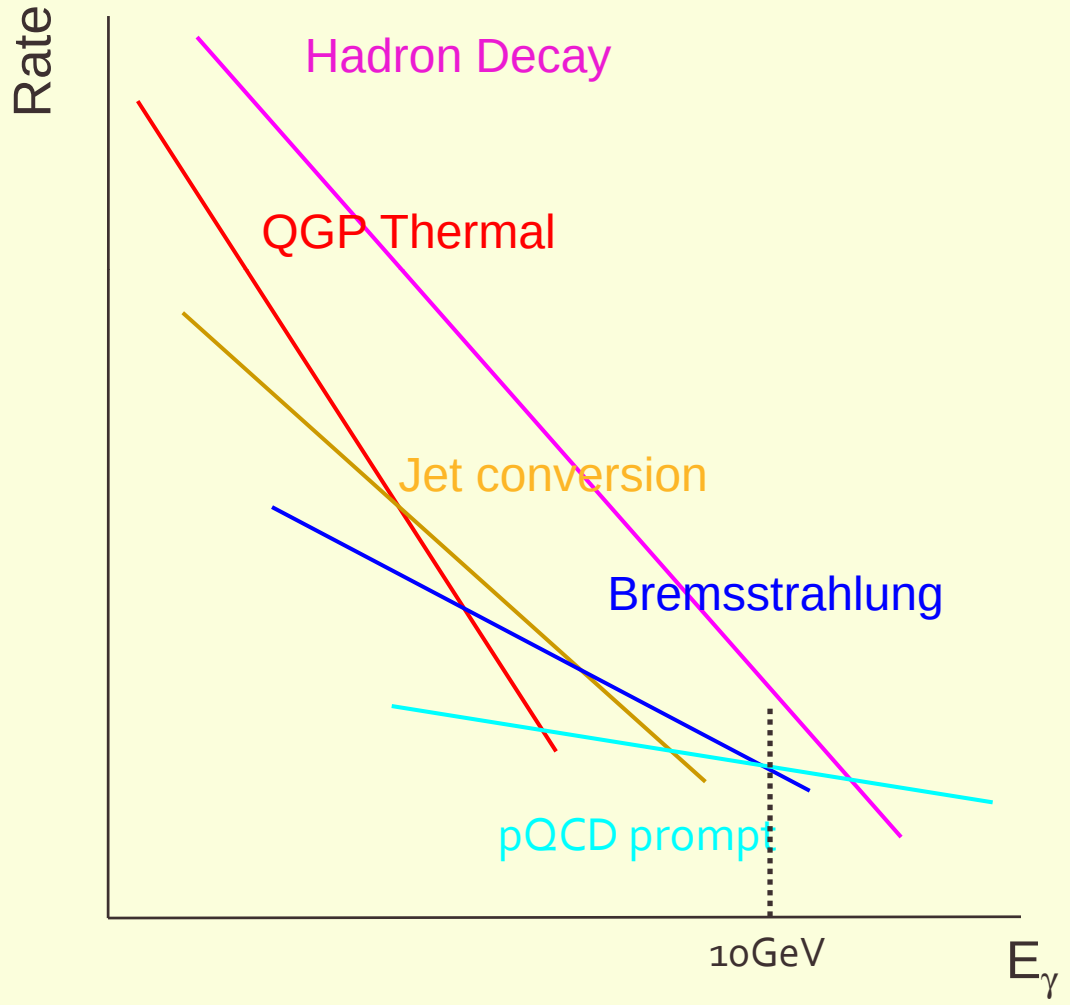




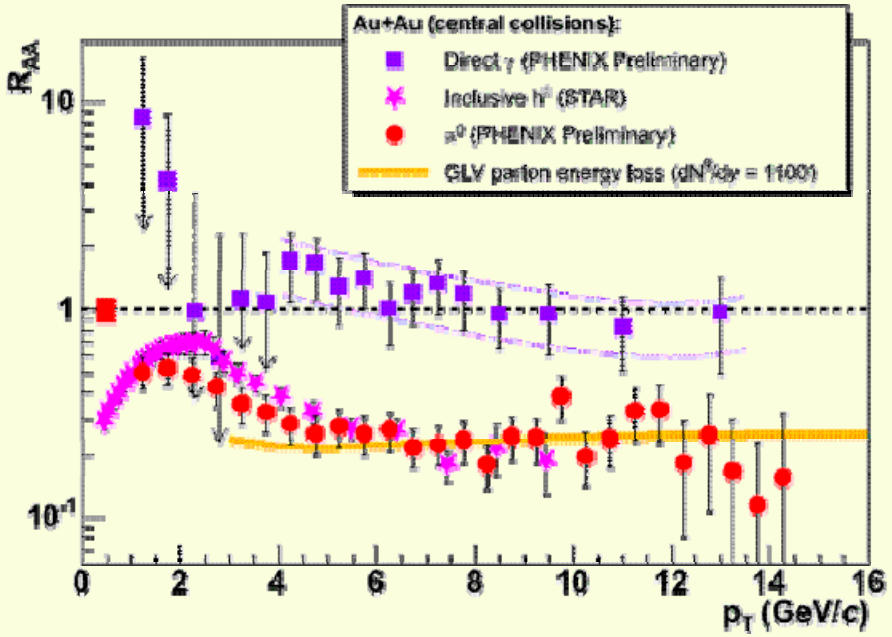


Photon sources

- Decay photons (the background)
  - Hadrons, mainly π^0
  - But suppressed by the medium



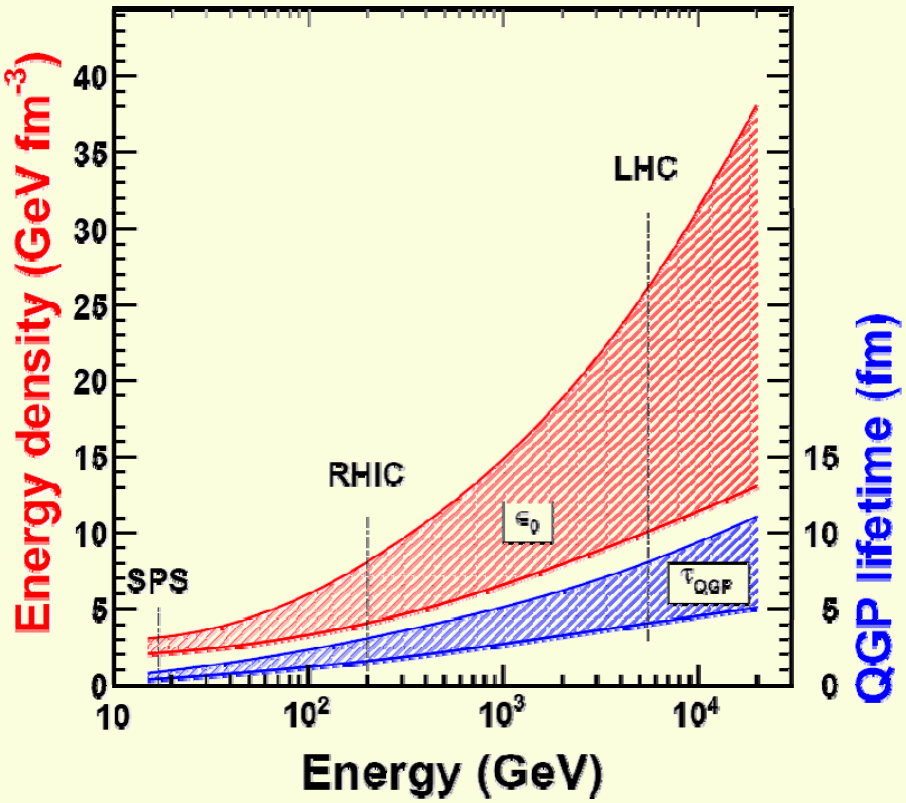
High p_T hadron suppression



$$R_{AA} = \frac{1}{N_{AA}} \frac{d^2\sigma_{AA}/dp_T dy}{d^2\sigma_{pp}/dp_T dy}$$

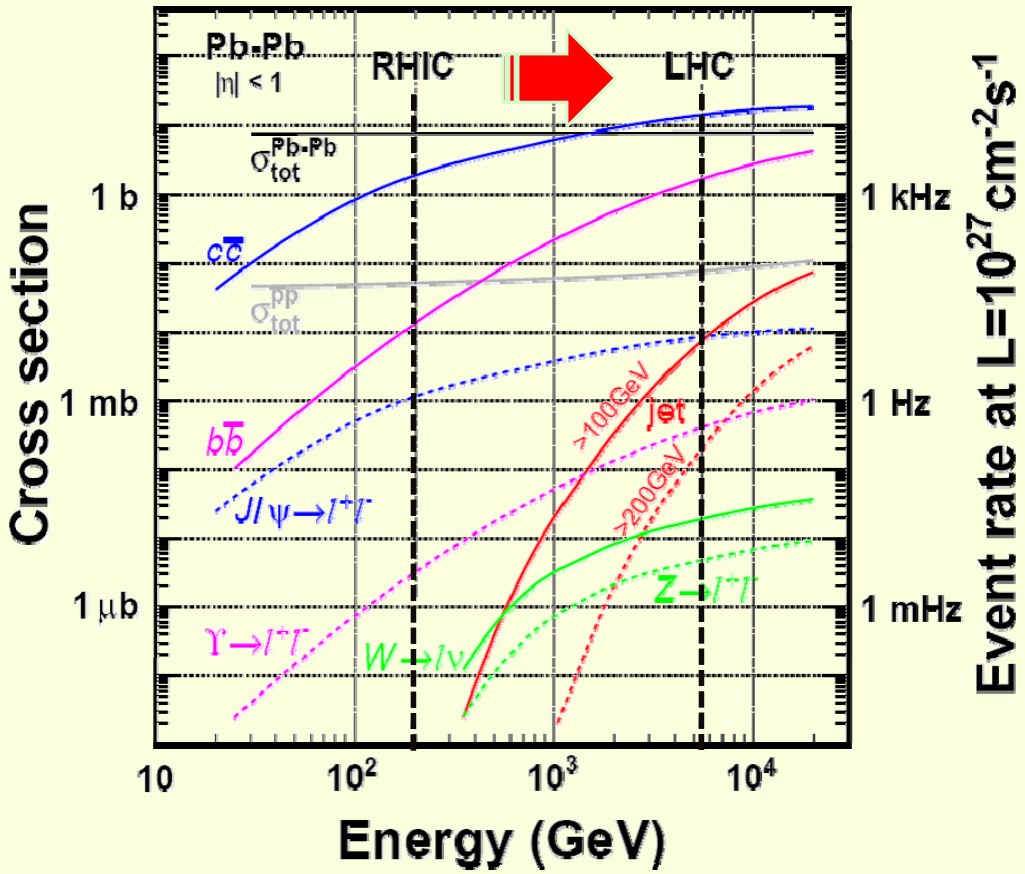
- Hard scattered partons interact with the color dense medium
- The energy loss is imprinted in the fragmentation hadrons
- The medium is transparent to photons

From RHIC to LHC (Fabjan, QM08)



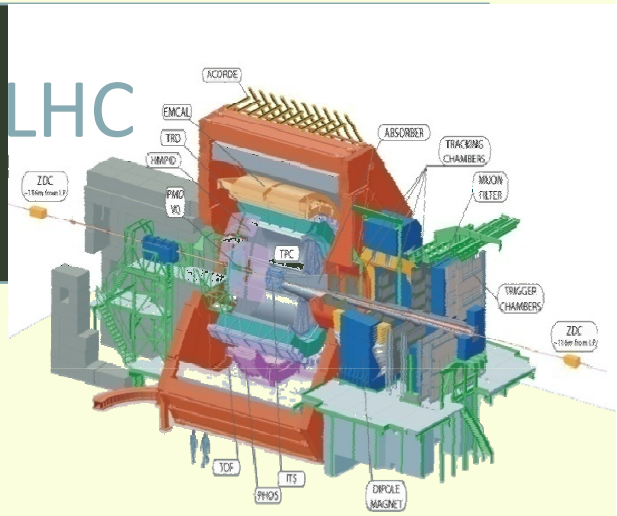
- The medium is formed with energy densities larger by a factor 2-3: a different QGP ?
- The lifetime of the QGP is increased by a factor 2-3: more favorable for observation

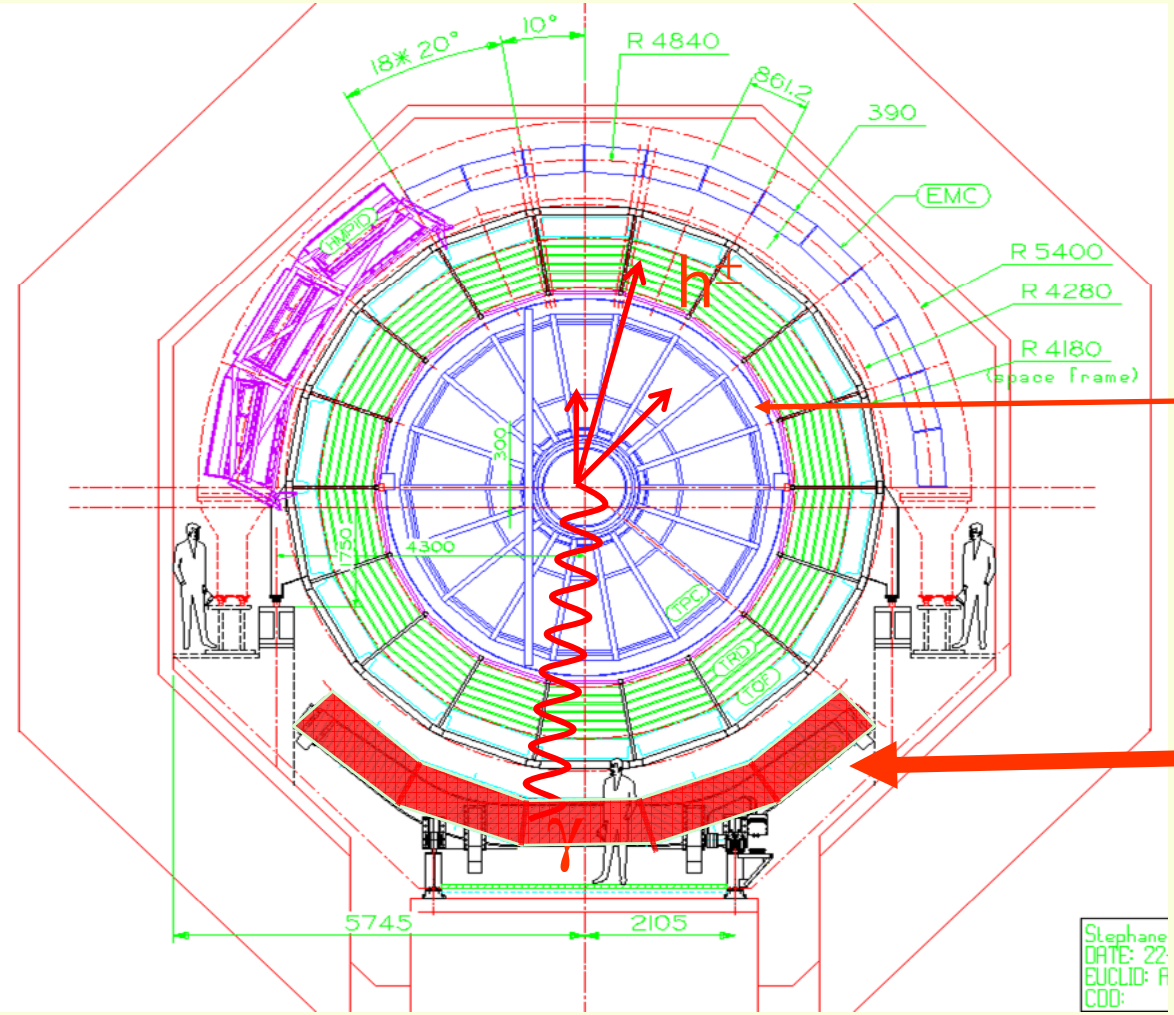
From RHIC to LHC (Fabjan, QM08)



- Cross section of hard probes increased by large factors
  - 10^5 for very high p_T jets
- Differential measurements become possible
  - Jet fragmentation function
  - Photon tagging

Measurement with ALICE@LHC





Charged hadrons:

CB

$\Delta\phi = 360^{o}$ $|\eta| < 0.9$

$\Delta p/p < 5\%$ at $p_T < 100$GeV

Photons:

PHOS

$\Delta\phi = 100^{o}$ $|\eta| < 0.12$

$\Delta E/E = 3\%/\sqrt{E}$

Strategy for a feasibility study

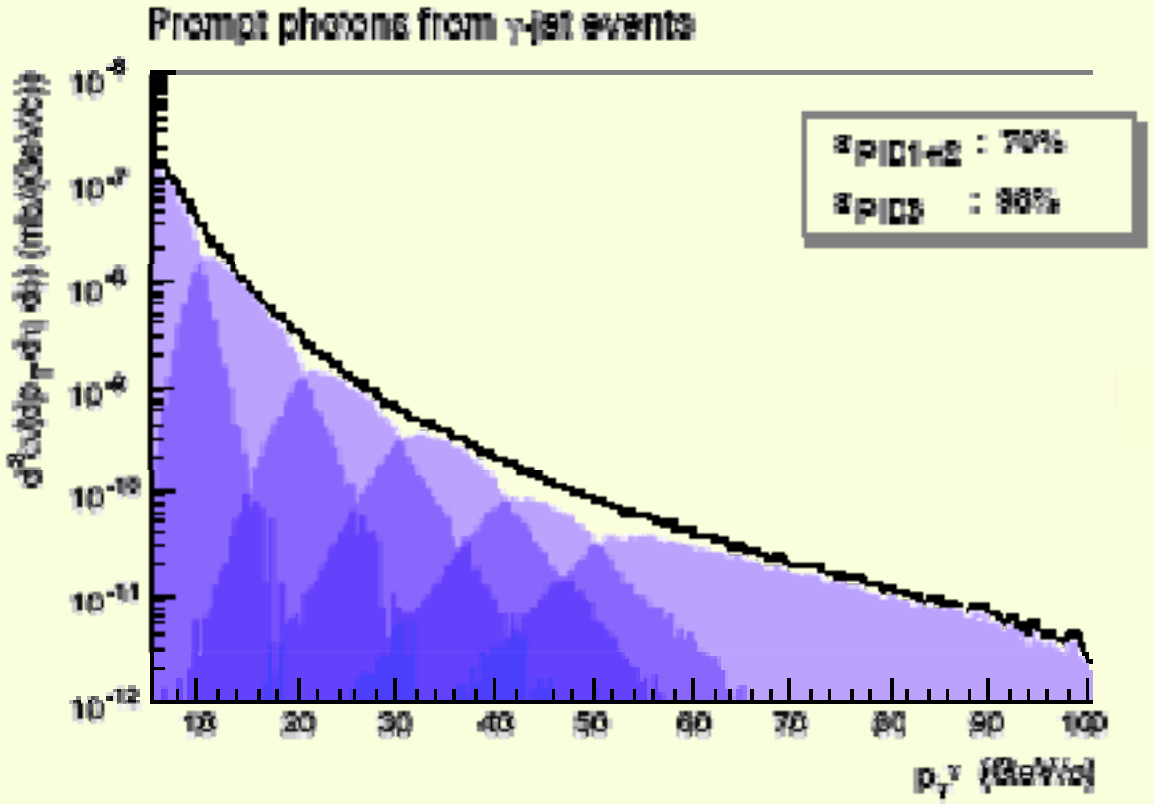
1. Identify prompt photons with ALICE PHOS detector (PID + Isolation Cut)
2. Construct γ-charged hadrons correlation from detected events (detector response)
3. Compare the imbalance distribution (CF) to the fragmentation function (FF)
4. Do the same study in γ-jet events (signal) and jet-jet events (background).
5. Estimate the contribution of hadrons from underlying events
6. Start with pp, base line measurement in AA

Monte-Carlo data production

- γ+jet in final state $\equiv \gamma -$ jet @ $\sqrt{s} = 14$ TeV
  - Prompt γ is the signal under study: 6×10^5 events ($5\ \text{GeV} < E_{\gamma} < 100$ GeV)
- 2 jets in final state $\equiv$ jet – jet @ $\sqrt{s} = 14$TeV
  - These events constitute the background: high-p_T π^0 [$O(\alpha_S)$] and fragmentation: 24×10^5 events ($5\ \text{GeV} < E_{jet} < 200$ GeV)
- ALICE offline framework AliRoot
  - Generator: PYTHIA 6.214; PDF: CTEQ4L
  - Luminosity: $L_{int} = 10\ pb^{-1}$
  - Acceptance: two PHOS modules

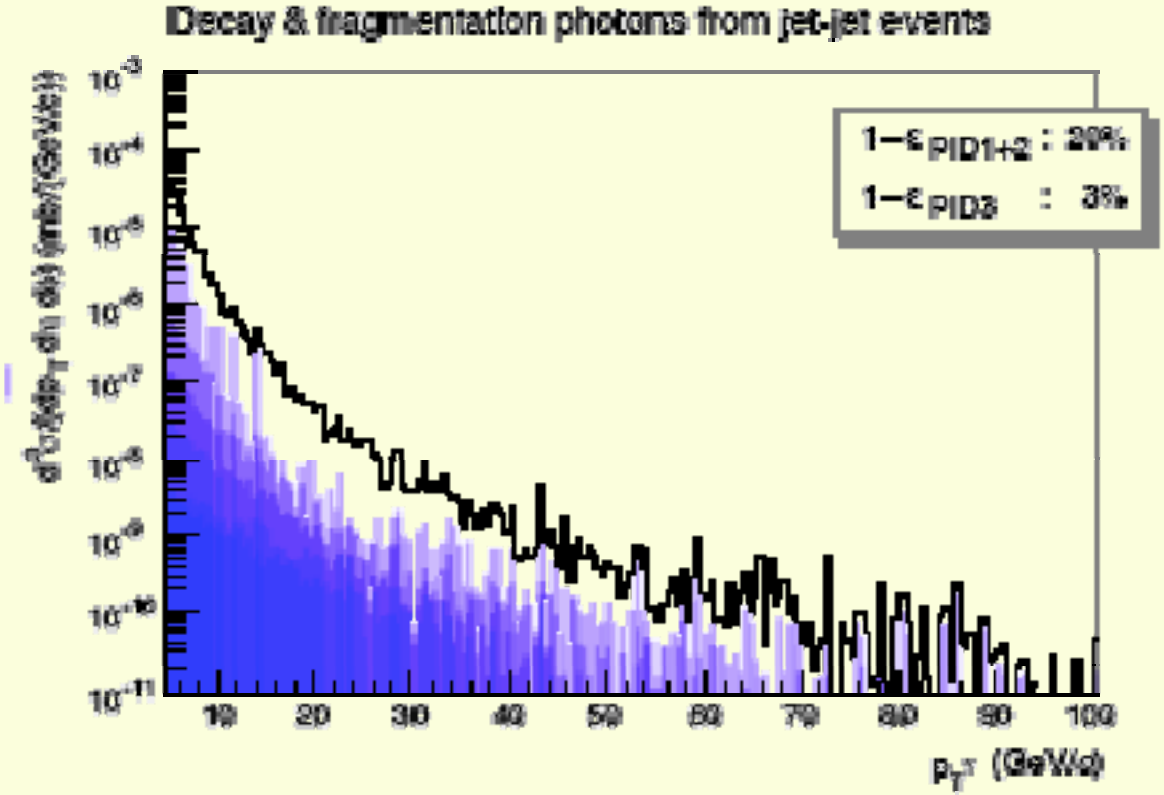
    $\eta = [-0.13, 0.13]$; $\phi = [259, 301]$

Prompt photons spectrum



- Cross section of generated photons from γ-jet events in pp@14TeV
- Colored lines are the simulation bins

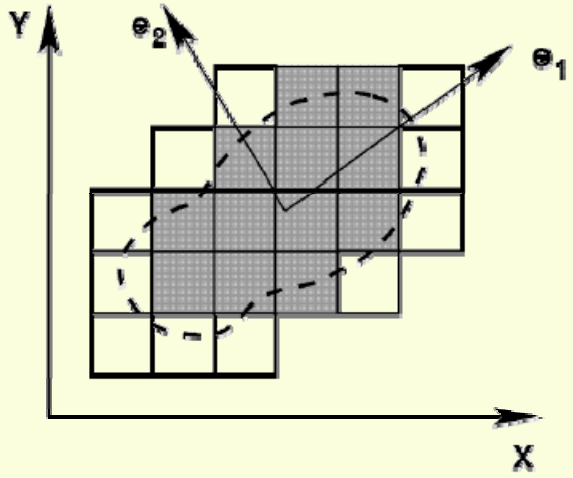
Decay photons spectrum



- Cross section of generated photons from jet-jet events in pp@14TeV
- Colored lines are the simulation bins

Photon identification (PID)

- We can discriminate γ, $e^{\pm}$ and π^{o} from anything else, based on:
  - CPV : Charged particle identification
  - TOF : Identification of massive low p_T particles
  - EMCA : Hadron rejection via shower topology (SSA)

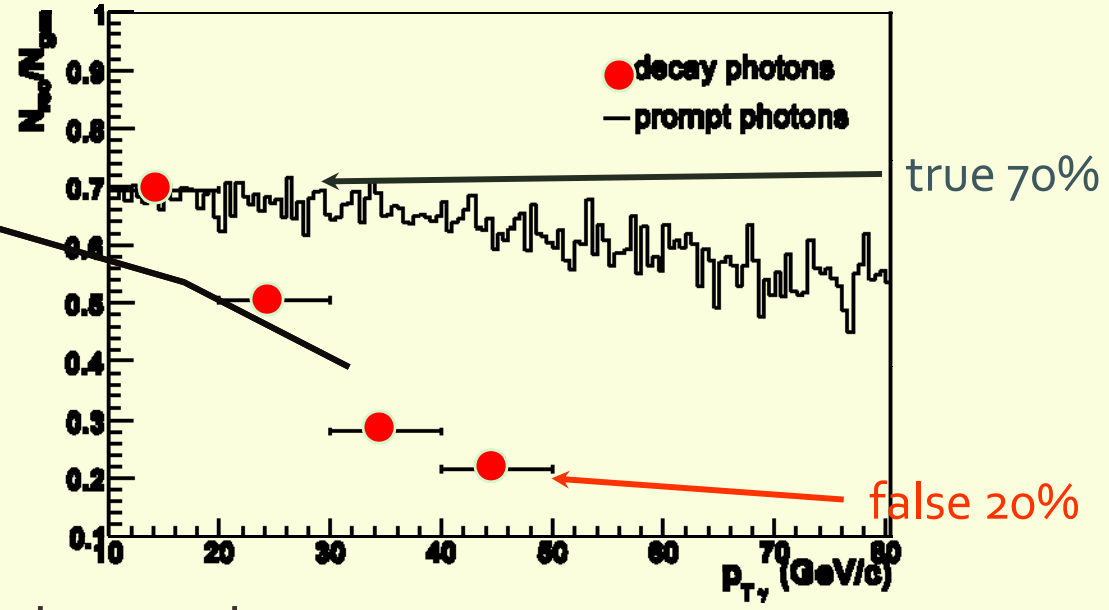


Shower from:
- single photon/*e* : $e_1/e_2 = 1$
- π^0 ($p_{\pi 0} > 30$ GeV/c) : $e_1/e_2 > 1$

Photon PID efficiency

- discriminate γ and π^0 (SSA) 30 GeV < E < 100 GeV
  - High γ identification efficiency, ~ 70%,
  - Misidentification efficiency decreasing from 70% to 20%

Decay photons merge into a single cluster in the calorimeter

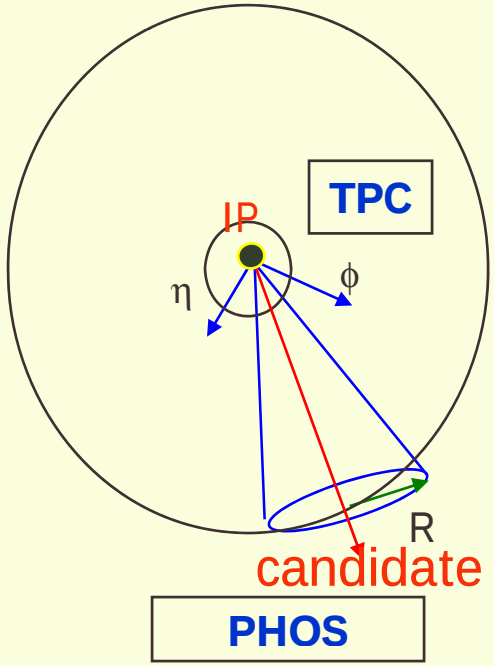


- Not good enough

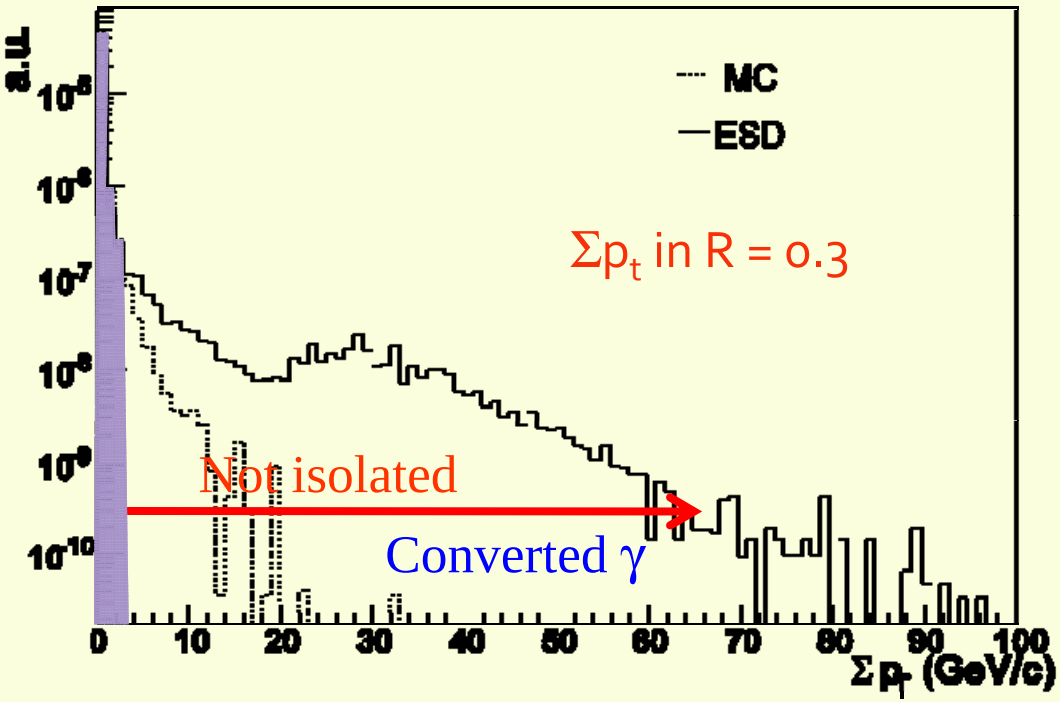
Isolation Cut (IC)

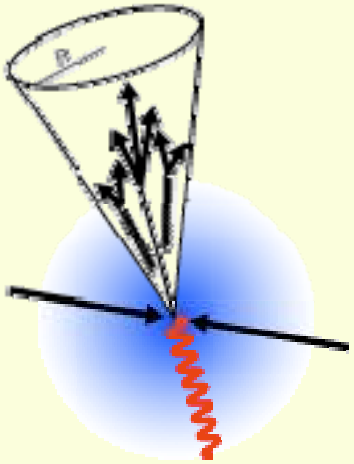
- Prompt γ are likely to be produced isolated
  - Cone size
  - p_T threshold cardinal if:
    - no particle in cone with $p_T > p_T^{thres}$
    - p_T sum in cone, $\Sigma p_T < \Sigma p_T^{thres}$
  - pp collisions: R = 0.3, Σp_T^{thres} = 2.0 GeV/*c*
  - Identification probability 98 %
  - Misidentification 3 %

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



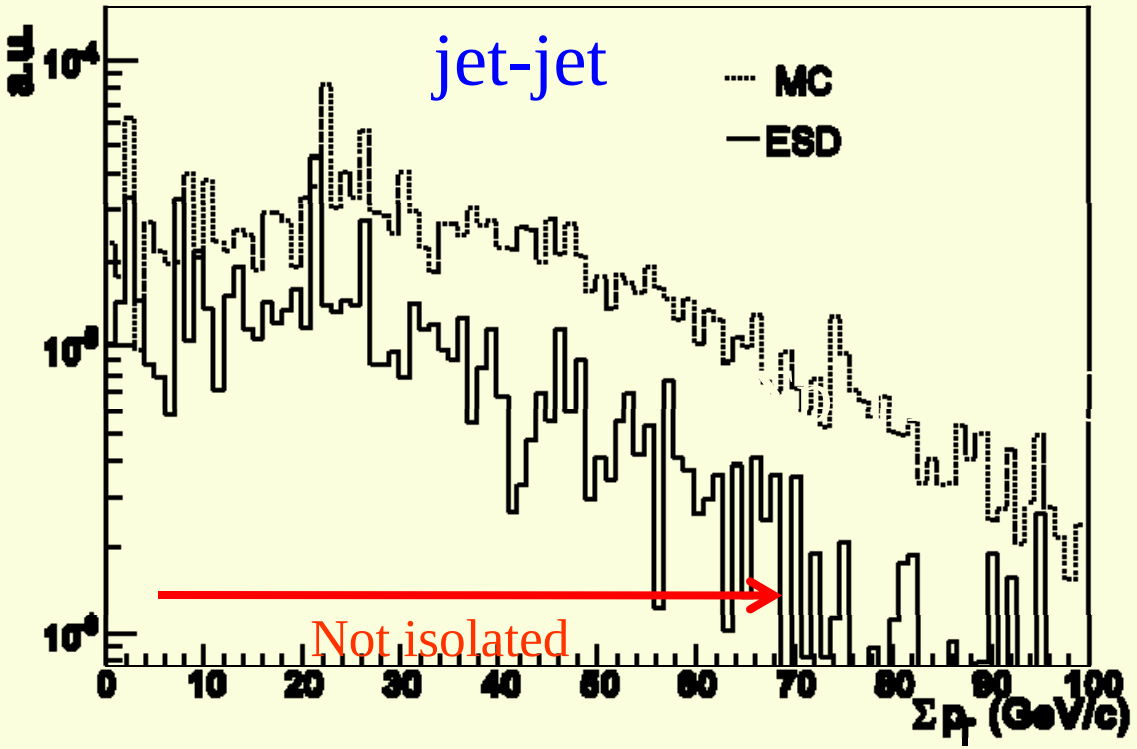
Hadronic activity around photon

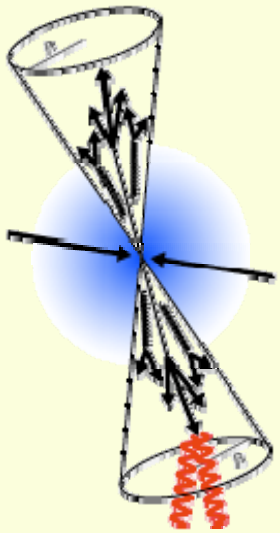




Most photons are isolated in γ-jet events, few hadrons around them are from underlying events.

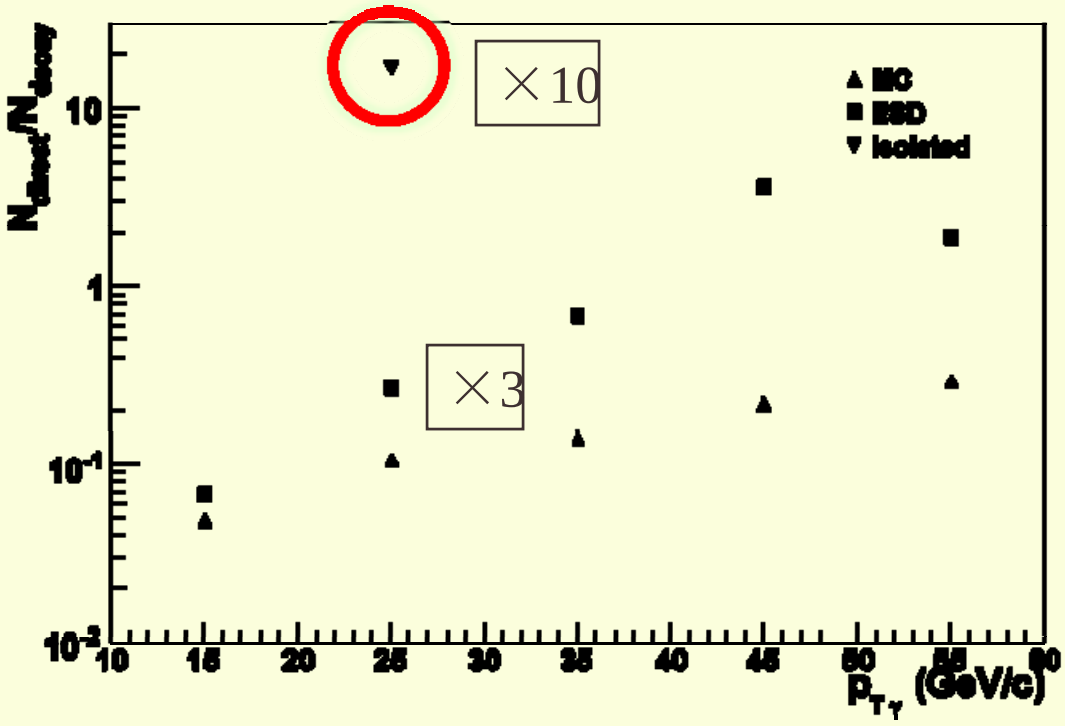
Hadronic activity around photon





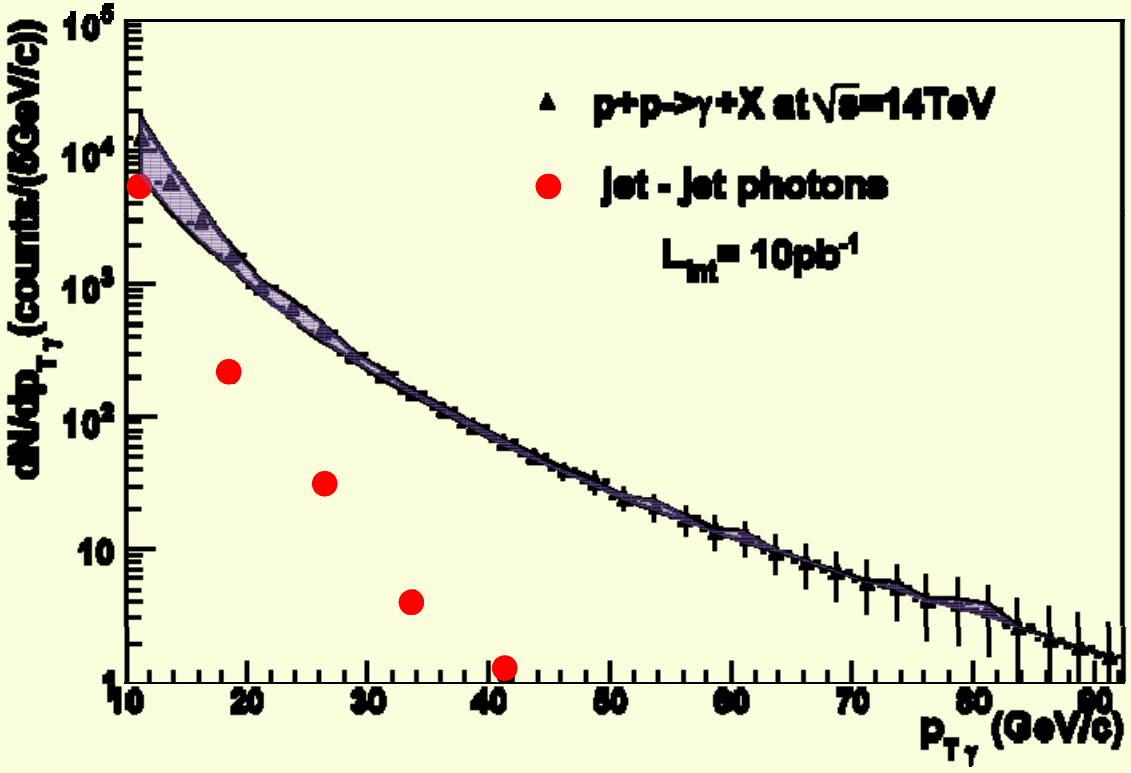
Most decay/fragmentation photons are not isolated, hadrons around them are from jet fragmentation

Isolation Cut (IC)



- S/B:
  - ~ 0.1 at p_T =25 GeV/c (generated events)
  - ~ 0.3 at p_T =25 GeV/c (reconstructed events + SSA)
  - > 10 at p_T = 25 GeV/c (after IC selection)

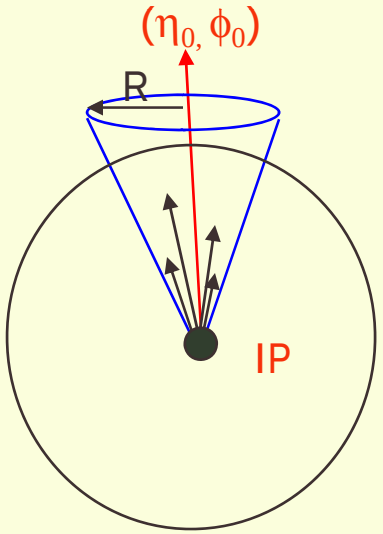
Photon spectrum after one year of data taking



- Estimated counting statistics in one pp run for 2 PHOS modules
- Systematic errors from misidentified π^0

Fragmentation Function

- Construct jets within jet finder in PYTHIA;
- Calculate fragmentation function of these jets: the distribution of charged hadrons as a function of the fraction of jet momentum $z = p_T / E_T^{jet}$

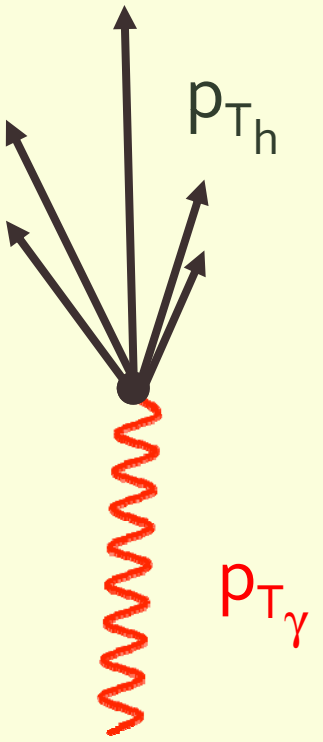


$$R = \sqrt{(\eta-\eta_0)^2 + (\phi-\phi_0)^2} = 1$$

- Requirement: reconstruction of jet energies
  - Possible in pp
  - Difficult in AA

γ-hadron correlation

- Momentum imbalance variable
  - $z_{\gamma\text{-}h} = -p_{T_h} \cdot p_{T\gamma} / |p_{T\gamma}|^2$
- In leading-order kinematics (α_s)
  - $z_{\gamma\text{-}h} \cong p_{T_h} / p_{T\gamma}$
- According momentum conservation,
  - $p_{T\gamma} = k_\perp = E_{parton}$
- Therefore,
  - (exp.) $z_{\gamma\text{-}h} \Leftrightarrow z$ (th.)



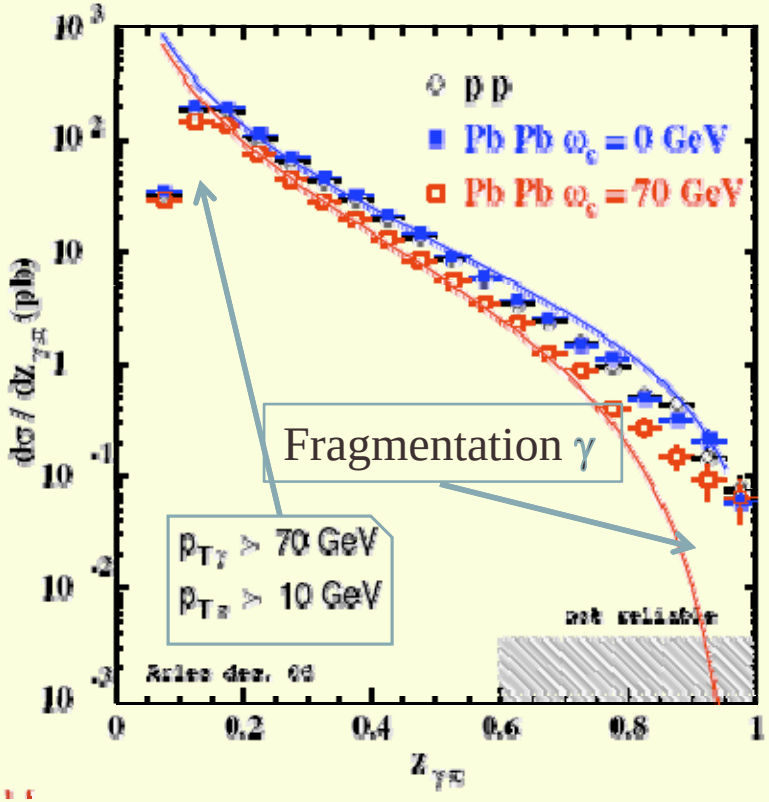
Imbalance distribution from NLO (See F. Arleo)

○ pp CF

■ AA CF no medium

□ AA CF with medium

AA FF



Within appropriate kinematics condition, the fragmentation function (FF) can be measured by imbalance distribution (CF) without the need to reconstruct the jet.

Kinematics condition

- Photon and hadron momenta cuts must be very asymmetric:

$$p_{T_\gamma}{}^{cut} >> p_{T_h}{}^{cut}$$

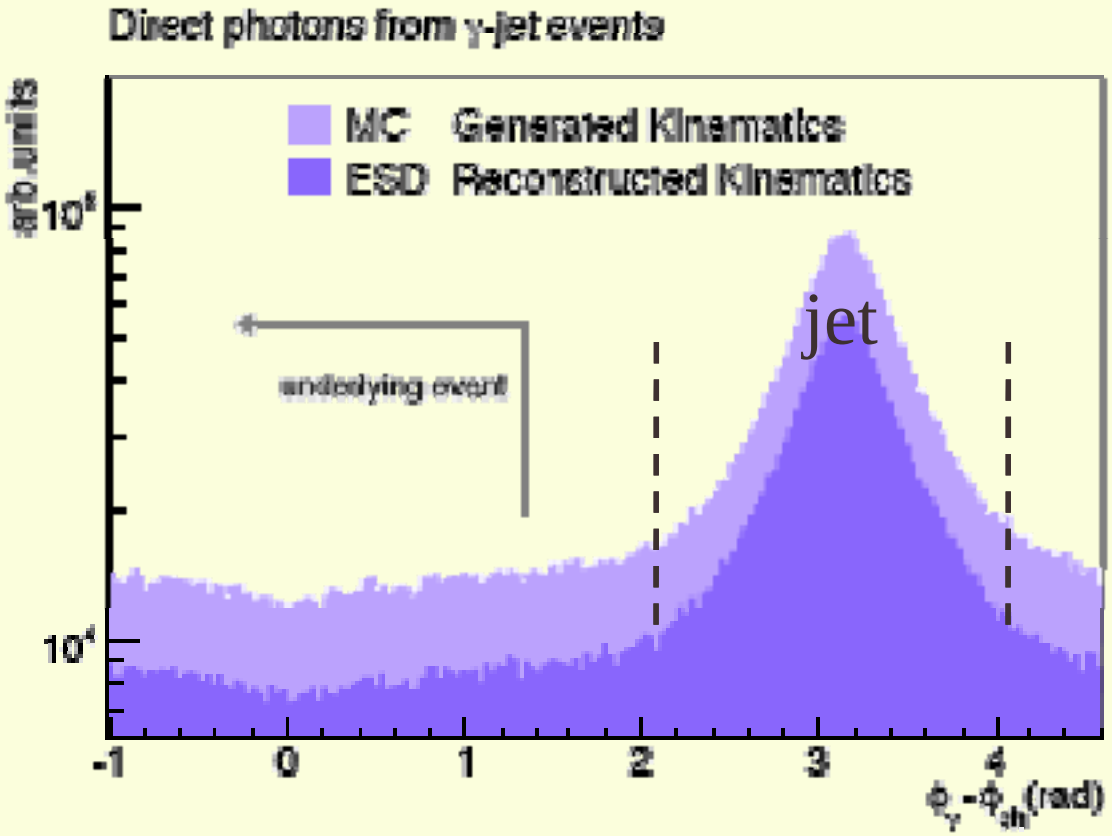
- Photon must be produced directly from the partonic process and not from a jet fragmentation:

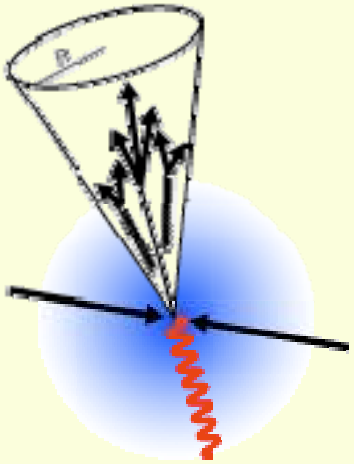
isolated and $p_T{}^{\gamma} > 20 GeV/c$

- Photon – hadrons are back to back:

$$\pi/2 < \Delta\Phi < 3\pi/2$$

Azimuthal correlation

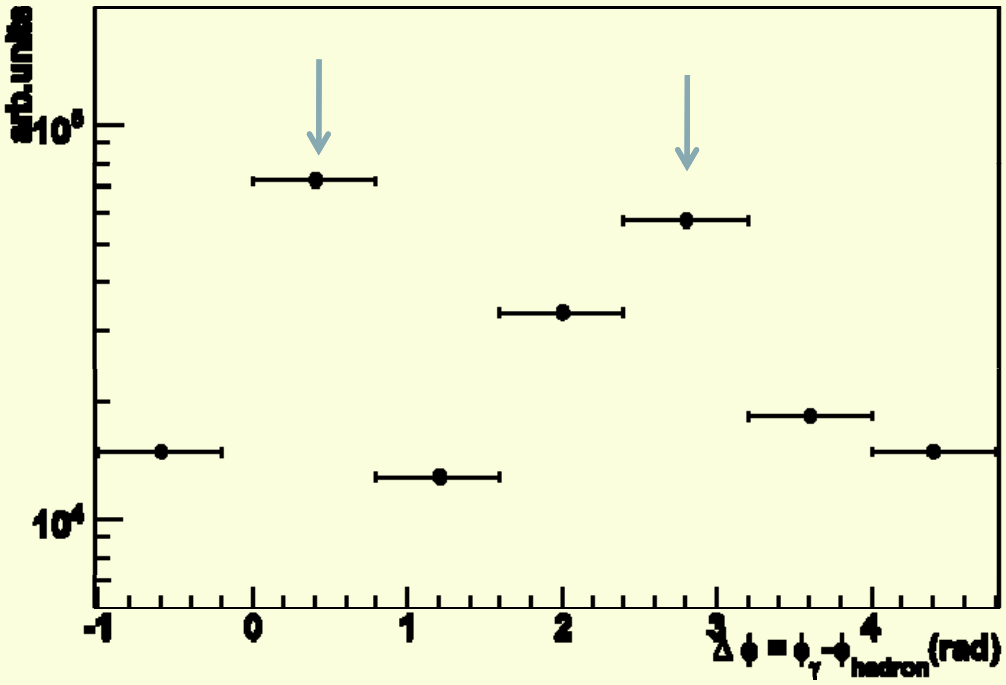


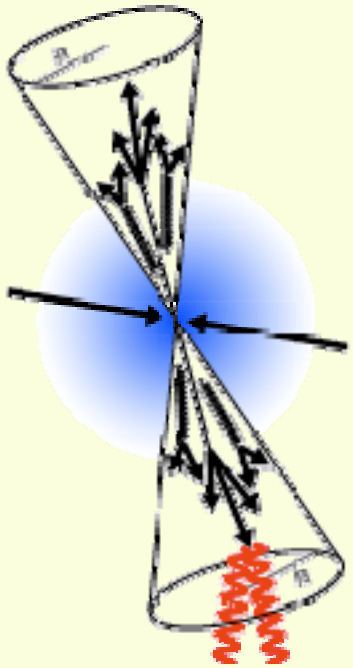


Clear jet signal opposite to the photon in γ-jet events

Azimuthal correlation

Decay photon





A near side and a far side peak found, the later being shifted and broader compared to γ-jet events.

Underlying Event (UE)

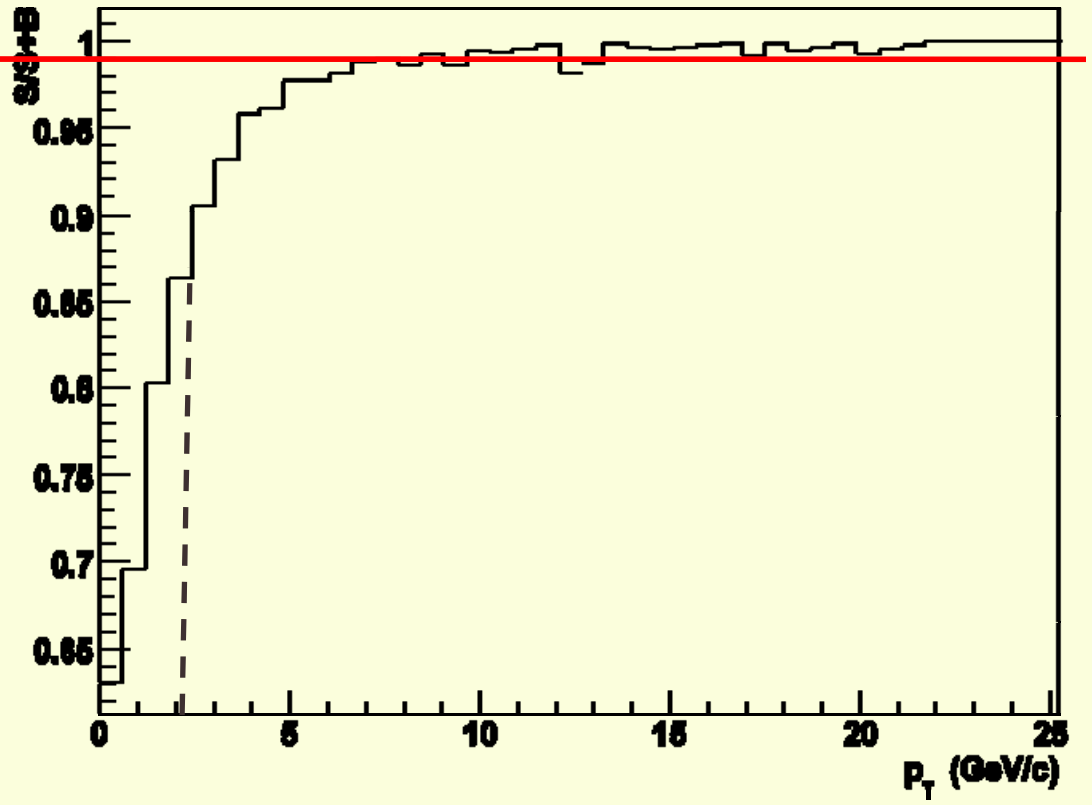
- Based on:
  - Hadrons spatial distribution from underlying events (UE) is isotropic:

$$UE\ (|\phi_\gamma - \phi_{hadron}| < 0.5\,\pi) \cong UE\ (0.5\pi < |\phi_\gamma - \phi_{hadron}| < 1.5\,\pi)$$

- Strategy:
  - Calculate UE contribution on the same side as photon where there is no jet contribution

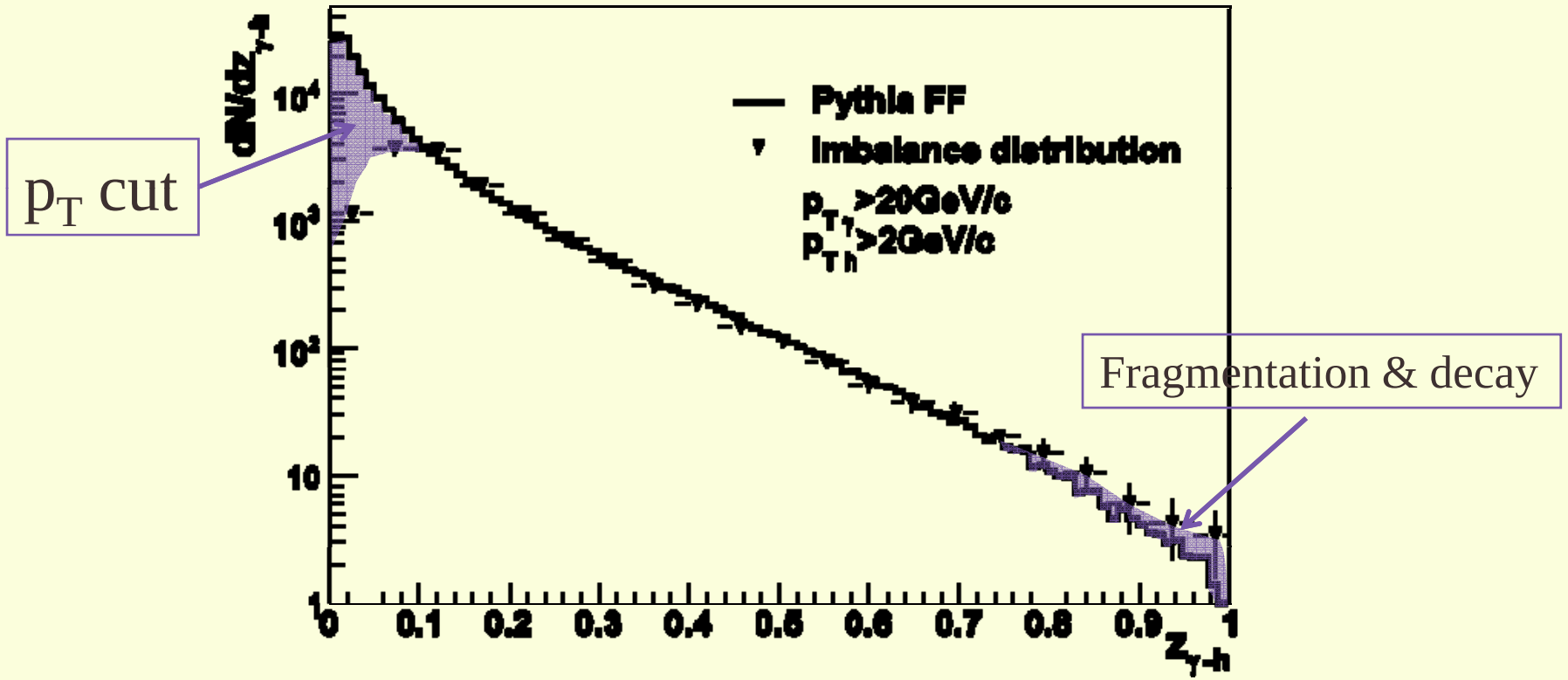
jet/(jet+UE)

99%



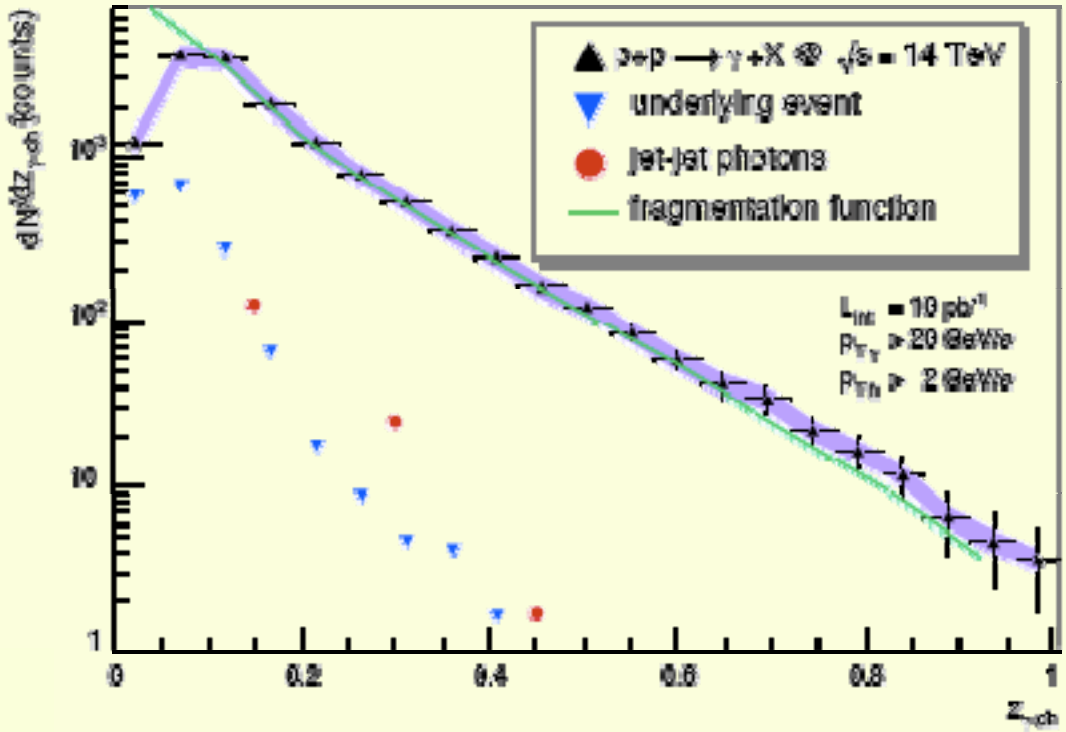
For $p_{t\,h}$ > 2GeV/c, contribution from UE represents less than 15%

Comparison CF with FF



Imbalance distribution is equivalent to fragmentation function for z = 0.12 – 0.8

My final result



- Statistical errors correspond to one standard year of data taking with 2 PHOS modules.
- Systematic errors is contributed by decay photon contamination and hadrons from underlying events.

Summary

- Measuring the modification experienced by jets traversing the color dense medium formed in heavy-ion collisions is a valuable approach to access the medium properties
- Tagging jets with direct prompt photons is the only approach to identify low energy jets (E_{jet} < 50 GeV) in AA
- The modification is best measured in the jet fragmentation function
- The fragmentation function can be measured in photon – charged hadrons correlations

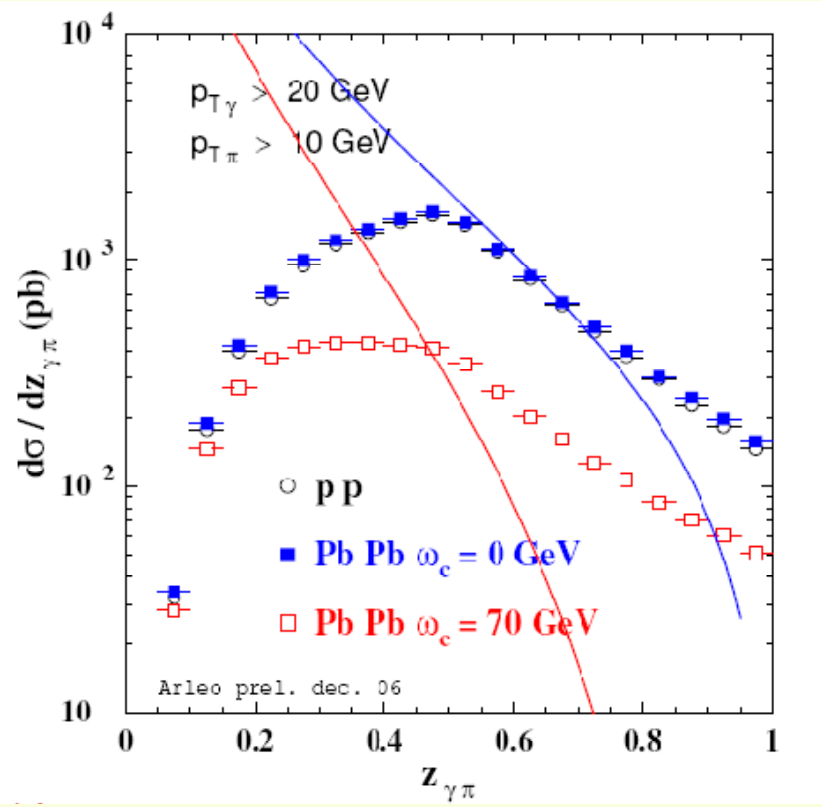
Summary

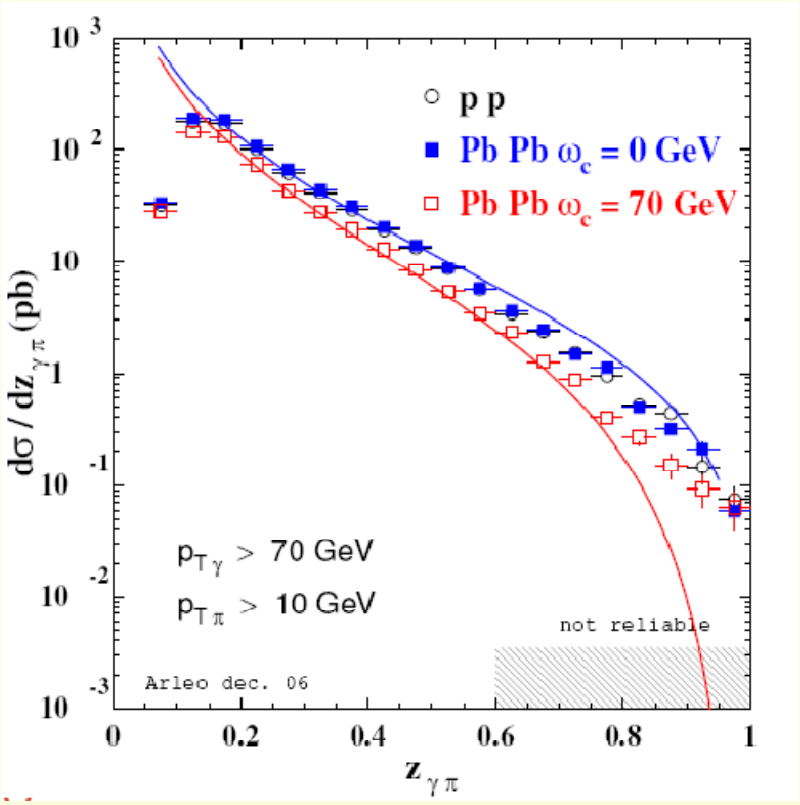
- The feasibility of such a measurement with the ALICE experiment has been evaluated in pp at 14 TeV
  - identification of direct photon and rejection of decay photons (PID and isolation cut)
  - counting statistics estimated and systematic errors due to decay photons
- The measurement in pp will be dominated by systematic errors not by statistics
- Near future , different kinematics cuts and AA …

Thanks for your attention!

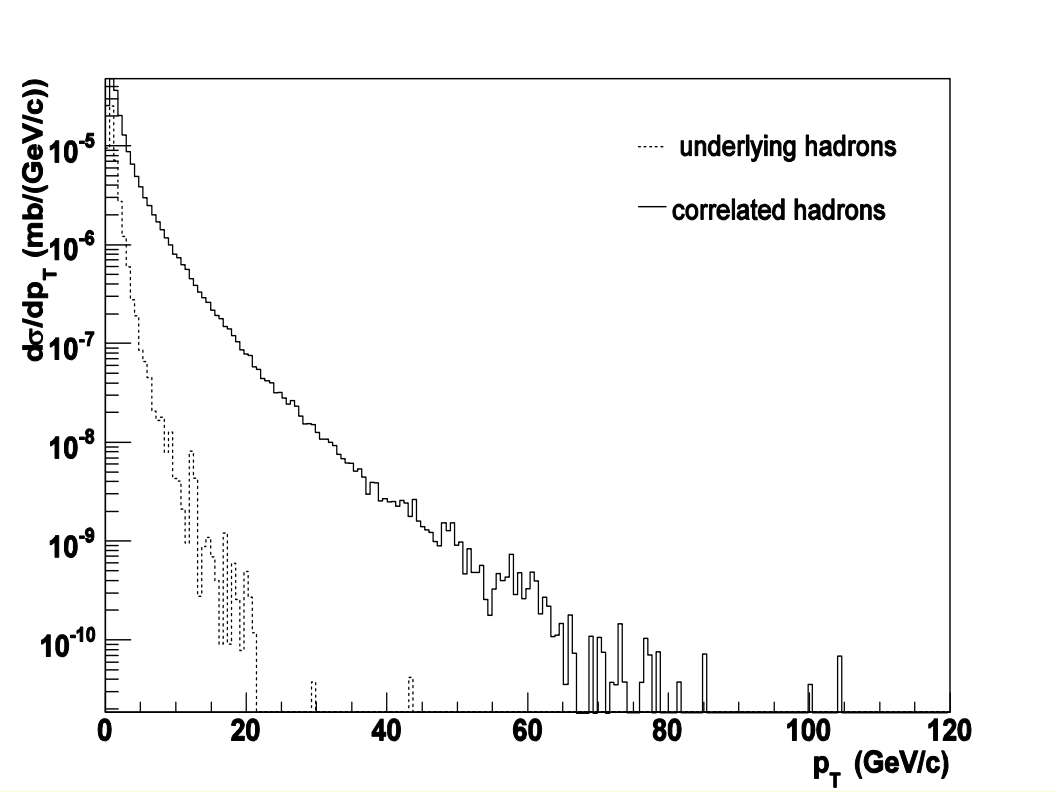
Back up slides

Different cuts





Hadrons distributions



Difference between CF and FF