Gamma-hadron correlation measurement in ALICE

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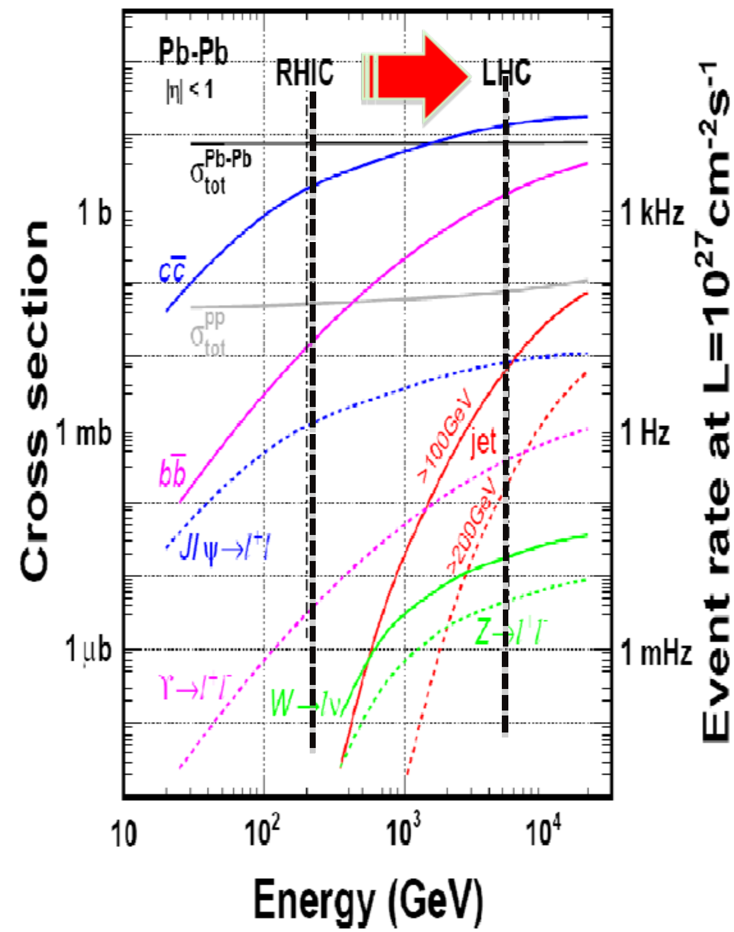
Heavy Ion Physics at LHC

Soft Probes ($p_T \le T_{medium}, \Lambda_{QCD}$)

- couple to the medium, in equilibrium with the medium
  - particle ratios, v_2, HBT, strange/charm particles, resonances
  - Medium generated photons and neutral mesons

Hard Probes ($p_T \gg T_{medium}, \Lambda_{QCD}$)

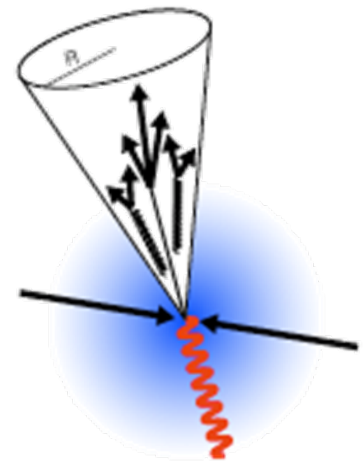
- Probe the matter formed in HIC
  - Originate from the initial state
  - decouple from the medium, non-equilibrate with the medium
- "Easy" to measure at LHC
  - significant fraction of the cross section
    - $\rightarrow \sigma_{hard} / \sigma_{total} \sim$ 98% (is only 50% at RHIC)
- Prompt photons, and jets …



Why we want to measure photons?

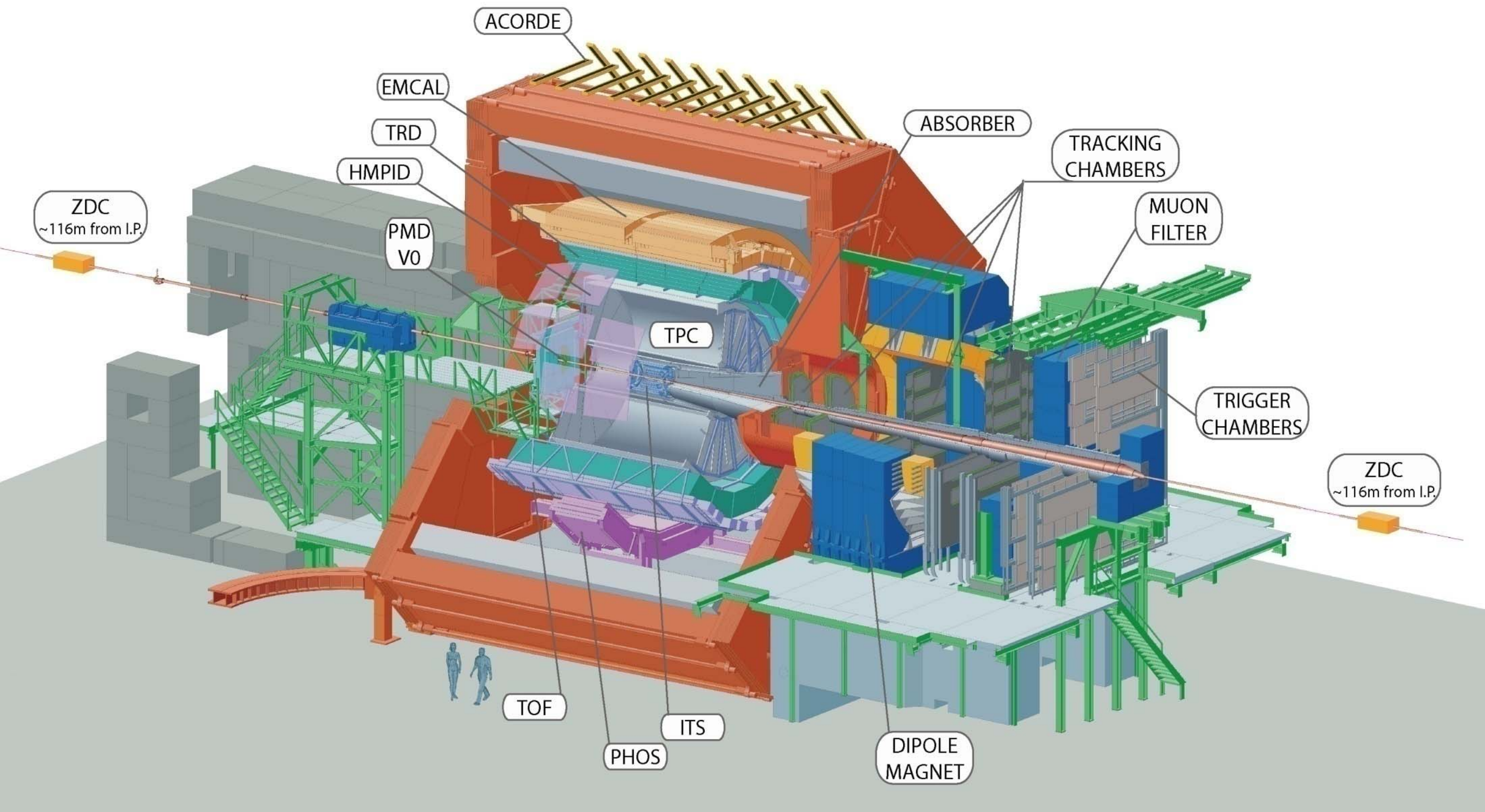
- Direct soft photons radiated from the medium
  - Temperature reached by the medium
- Direct semi hard photons produced by hard partons interacting with the hot medium
  - Chemical composition of the hot medium
- Direct hard photons
  - Non interacting probe provide a reference for the hard process
- Decay photons (neutral mesons)
  - Chemical and momentum modification of the fragmentation of jets traversing the medium

Why γ-jet/hadron correlations?

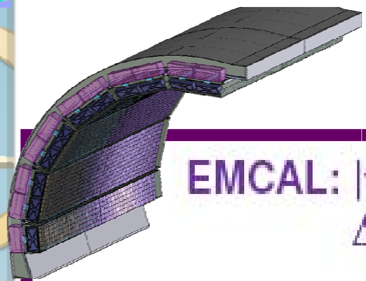


- The photon 4-momentum remains unchanged while traversing the medium and sets the reference of the hard process
- Balancing the hadron and the photon provides a measurement of the medium modification experienced by the jet
- Allows to measure jets in an energy domain (E_{jet} < 50 GeV) where
  - The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

ALICE: The dedicated HI Experiment



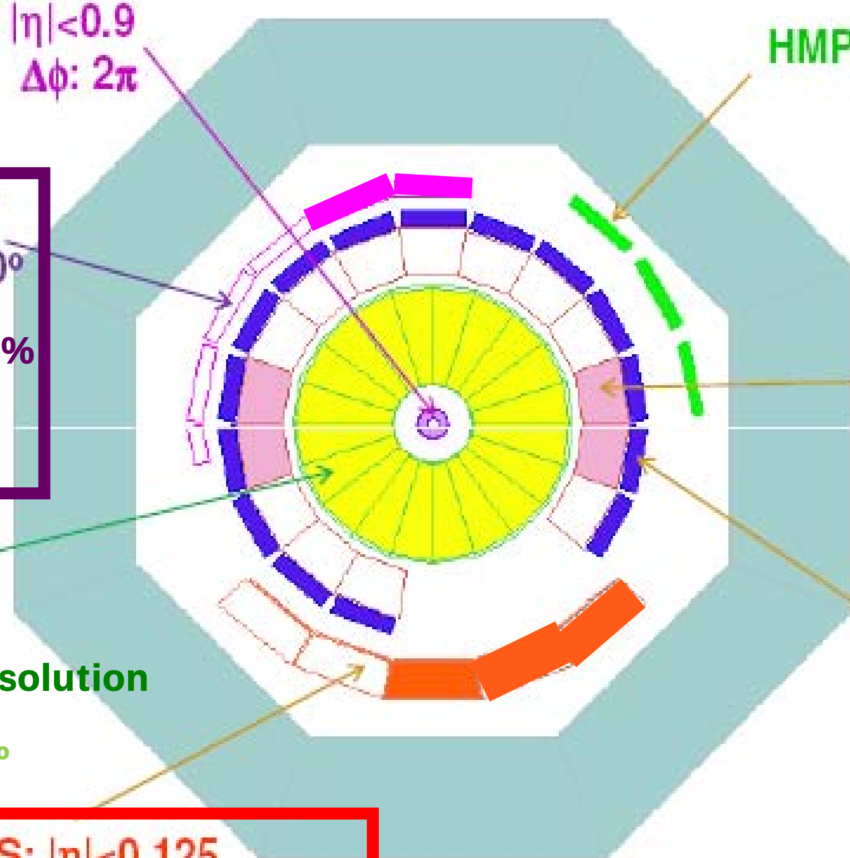
How can we measure direct photons and jets in ALICE?



EMCAL: $|\eta|<0.7$
$\Delta\phi$: 110°

E > 10 GeV $\rightarrow$ $\Delta E/E$ < 3 %

σx =[3,50] mm



Tracking System resolution

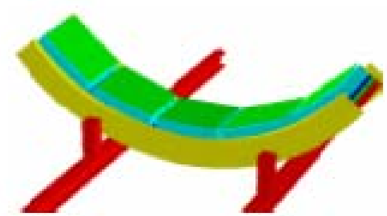
$\Delta p/p$ = 2%, α =1.1°

PHOS: $|\eta|<0.125$
$\Delta\phi$: 100°

E > 10 GeV $\rightarrow$ $\Delta E/E$ < 1.5%,

σ_x =[0.5,2.5] mm

*Holes are made in front of 3 PHOS modules



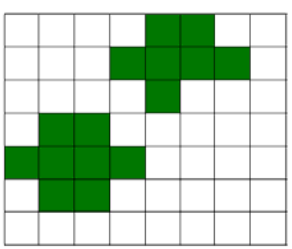
Photon identification in calorimeters

Three regions of analysis

increasing p_T

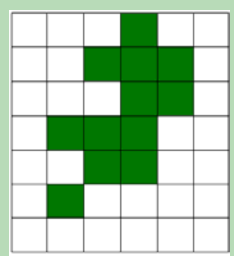
well separated clusters
➔ invariant mass analysis

< 10 GeV/c in EMCal
< 30 GeV/c in PHOS



merged clusters
not spherical
➔ shower shape analysis

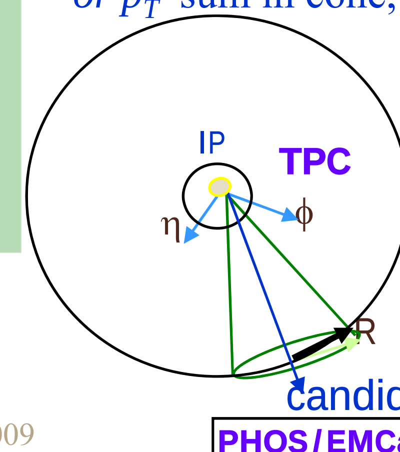
10 - 30 GeV/c in EMCal
30 - 100 GeV/c in PHOS



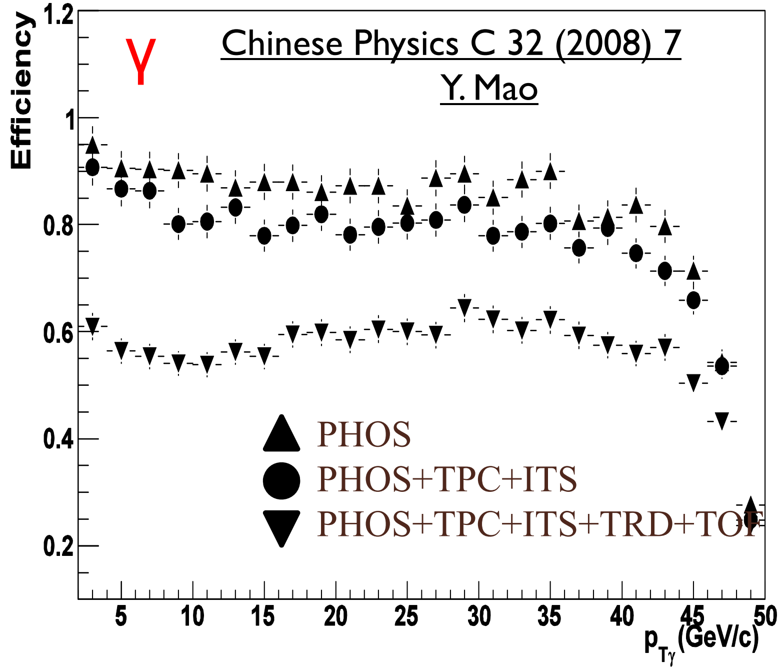
Opening angle << 1 cell
all π^0's at this energy are in jets
➔ isolation cut

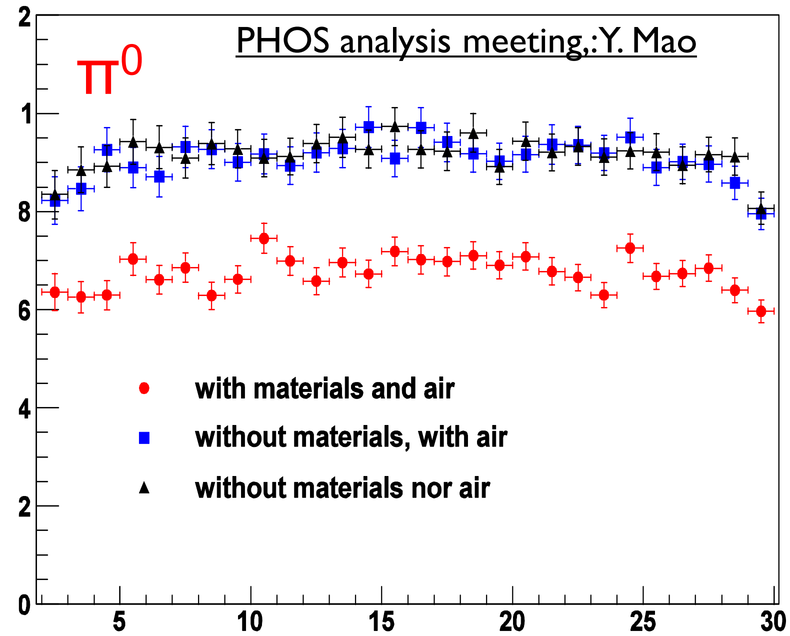
> 30 GeV/c only method in EMCal

Isolated if:
- no particle in cone with $p_T > p_T^{thres}$
- *or* p_T sum in cone, $\Sigma p_T < \Sigma p_T^{thres}$



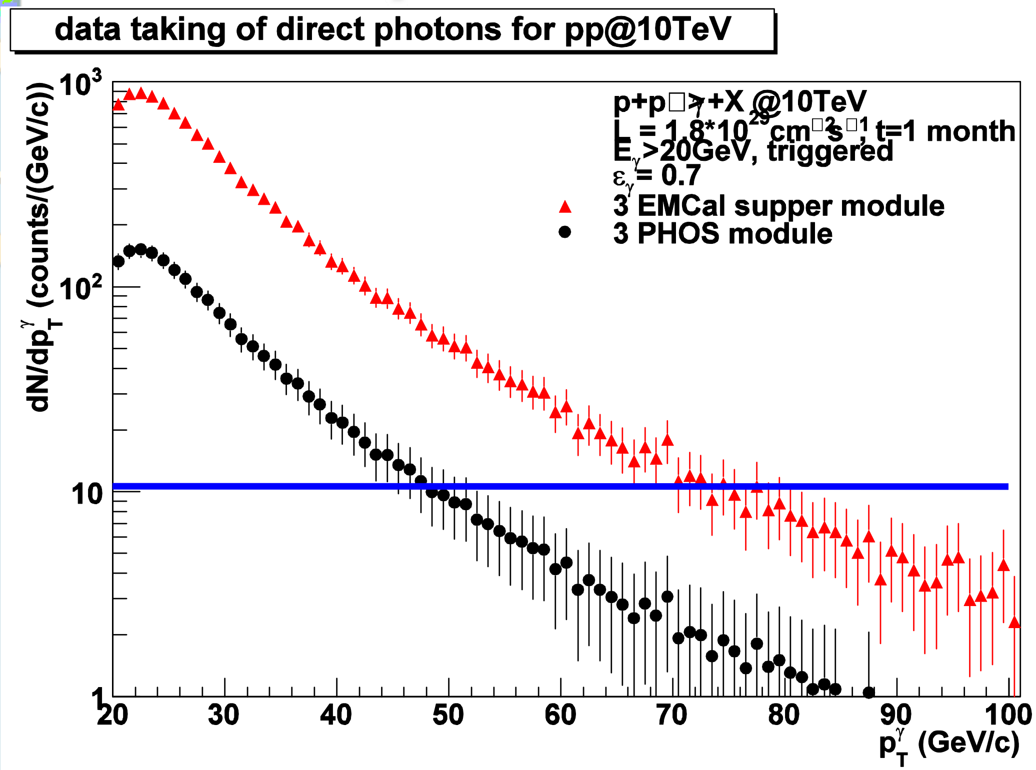
Measurement efficiency





- γ and π^0 identification efficiency is lowered due to the material of the tracking detectors in front of PHOS

Direct photon in ALICE



- •3 EMCal super modules or 3 PHOS modules
- Triggered γ-jet energy: E_γ >20 GeV
- Identification efficiency: $\varepsilon_\gamma = 0.7$
- 1 month data taking
- Assuming $\sigma^{tot}_{pp} = 52$ mb

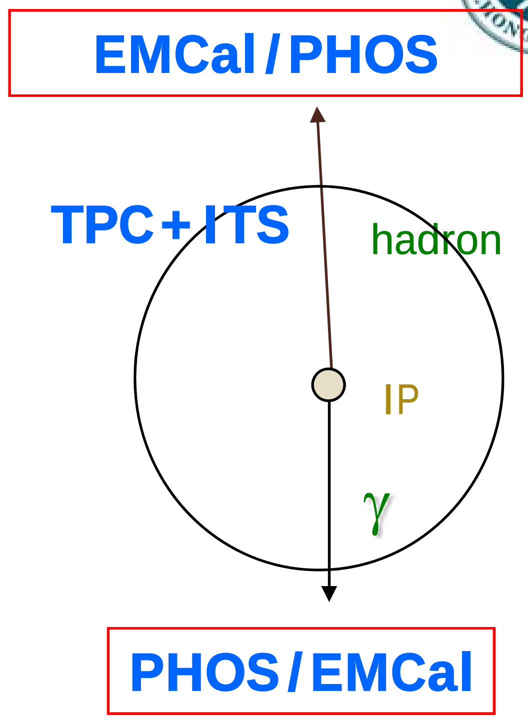
Triggered rare process

N events	L =2.e28cm^{-2}s^{-1}	L =1.8e29cm^{-2}s^{-1}	L =7.3e29cm^{-2}s^{-1}
MB	2.69*10^9	2.4*10^{10}	9.83*10^{10}
$\gamma^{E>20GeV}$	2.17*10^3	1.95*10^4	7.9*10^4
$\gamma^{3\ PHOS}$	50	546	2213
$\gamma^{3\ EMCAL}$	300	3183	12917

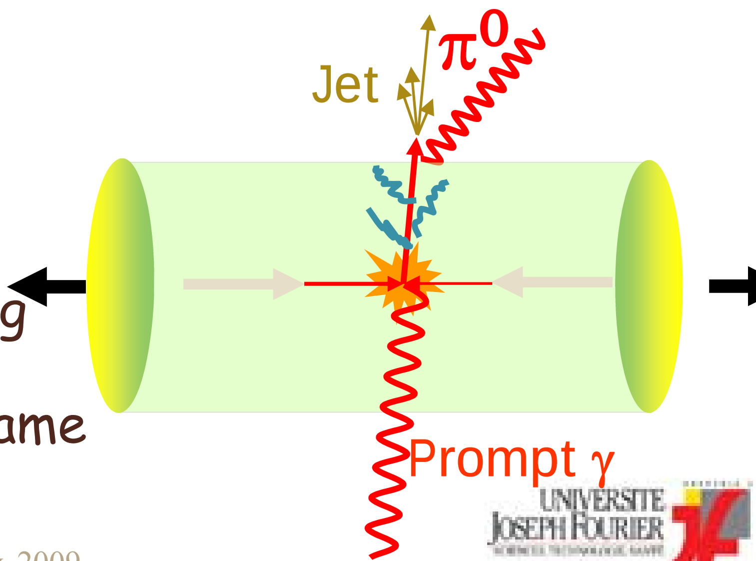
No trigger

γ-hadron correlations in ALICE

- Strategy (event by event):
  - Search identified prompt photon (PHOS or EMCal) with $E_\gamma > 20$ GeV
  - Search for all charged hadrons (central tracking) or neutral π^0 (EMCal or PHOS):
    - $90^o < \phi_\gamma - \phi_{hadron} < 270^o$
    - $p_{T\ hadron} > 2$ GeV/c



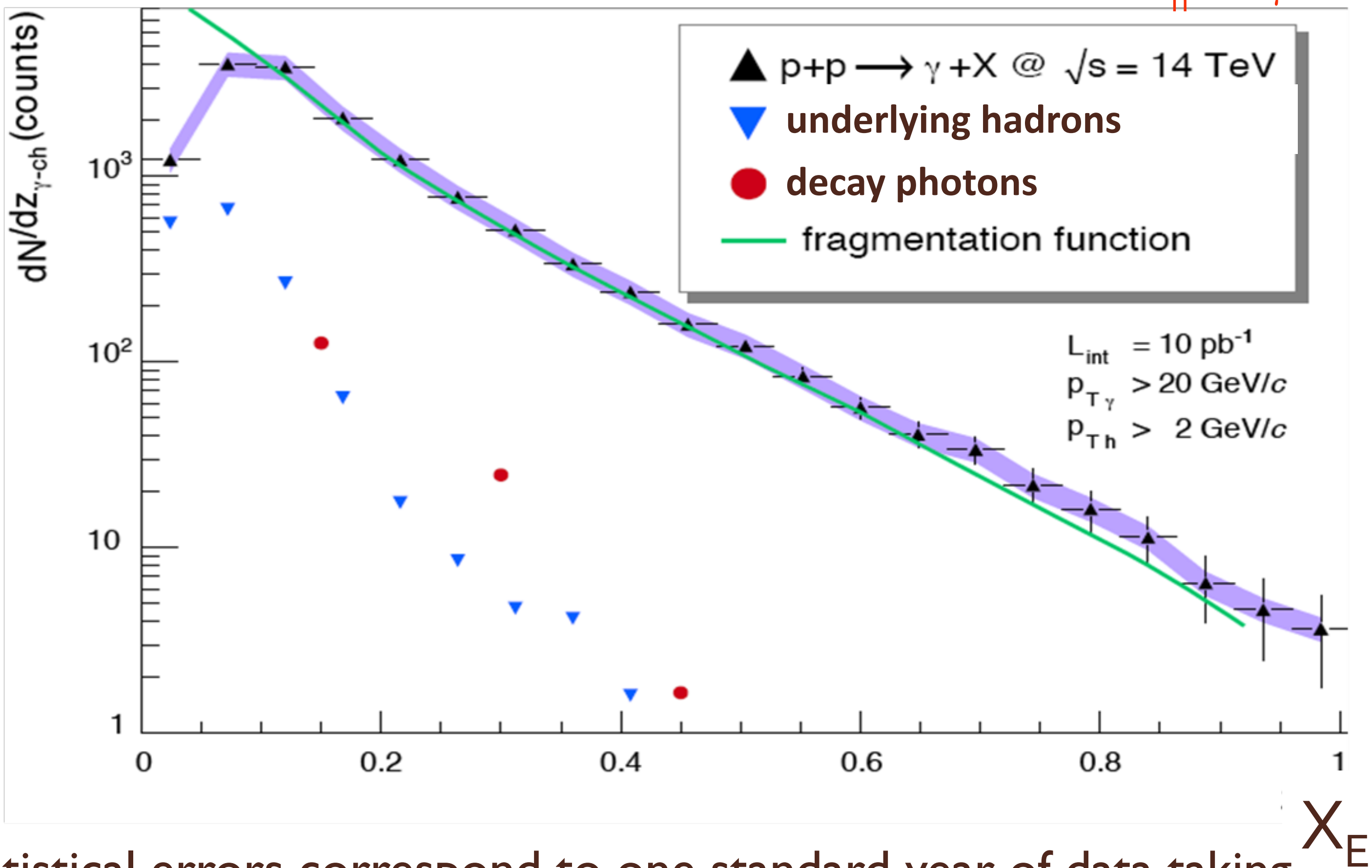
- Background:
  - Decay photons misidentified as isolated photon
  - Soft hadrons from the underlying event (UE):
    - take the hadrons from the same side of direct photons as UE



Correlation Function (CF) in pp

EPJC (2008) 57: Y. Mao

$X_E = -p_{T_h} \cdot p_{T\gamma} / |p_{T\gamma}|^2$



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

Effects modifying the correlation

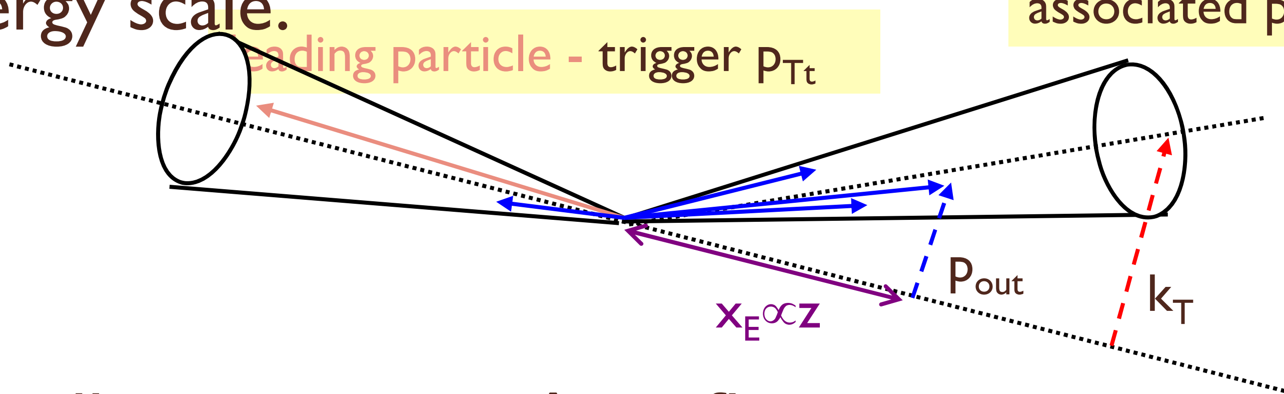
- In pp
  - Intrinsic k_T
  - Initial state radiation (ISR) and final state radiation (FSR)
- In AA
  - In addition, interaction with the medium

D(z) from gamma tagged correlation

PRD74(2006) 072002

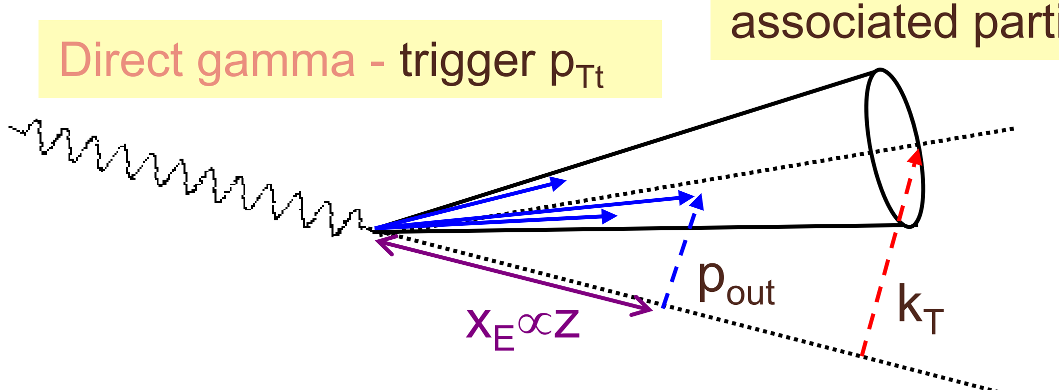
h-h: Leading particle **does not** fix Energy scale.

away-side fragments - associated particles p_{Ta}



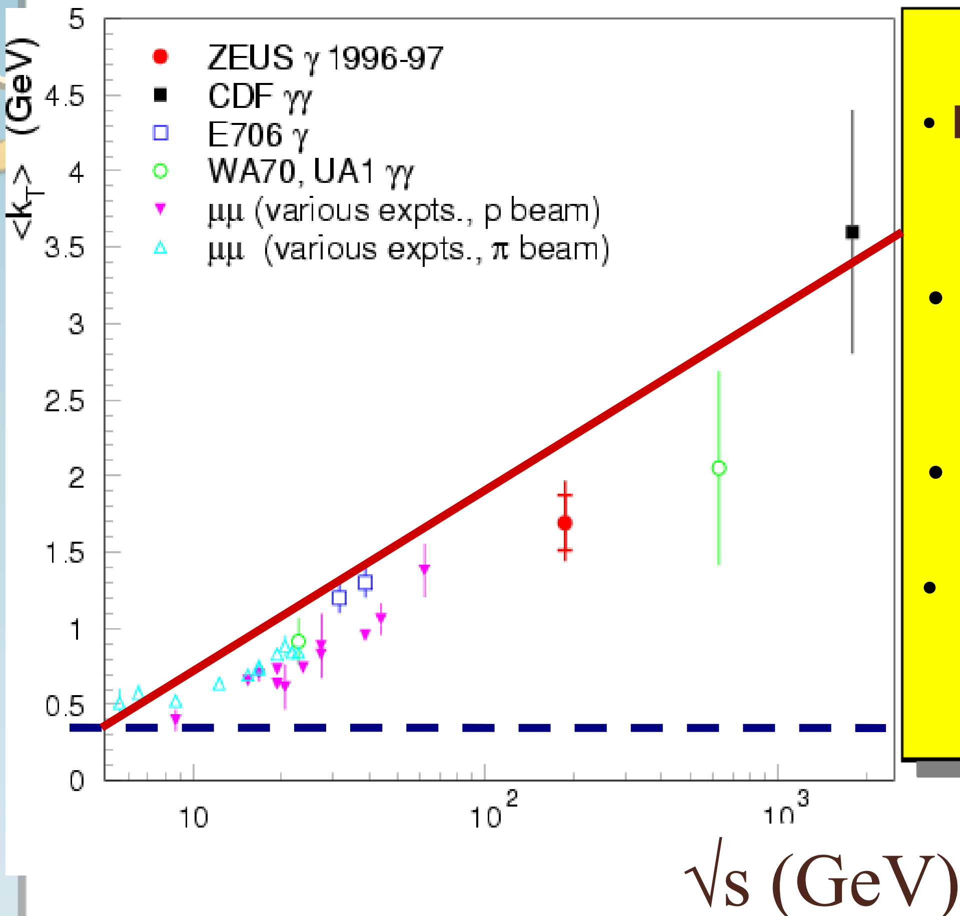
γ-h: direct gamma **does** fix Energy scale if no k_T

away-side fragments - associated particles p_{Ta}



Experimental measurement of k_T

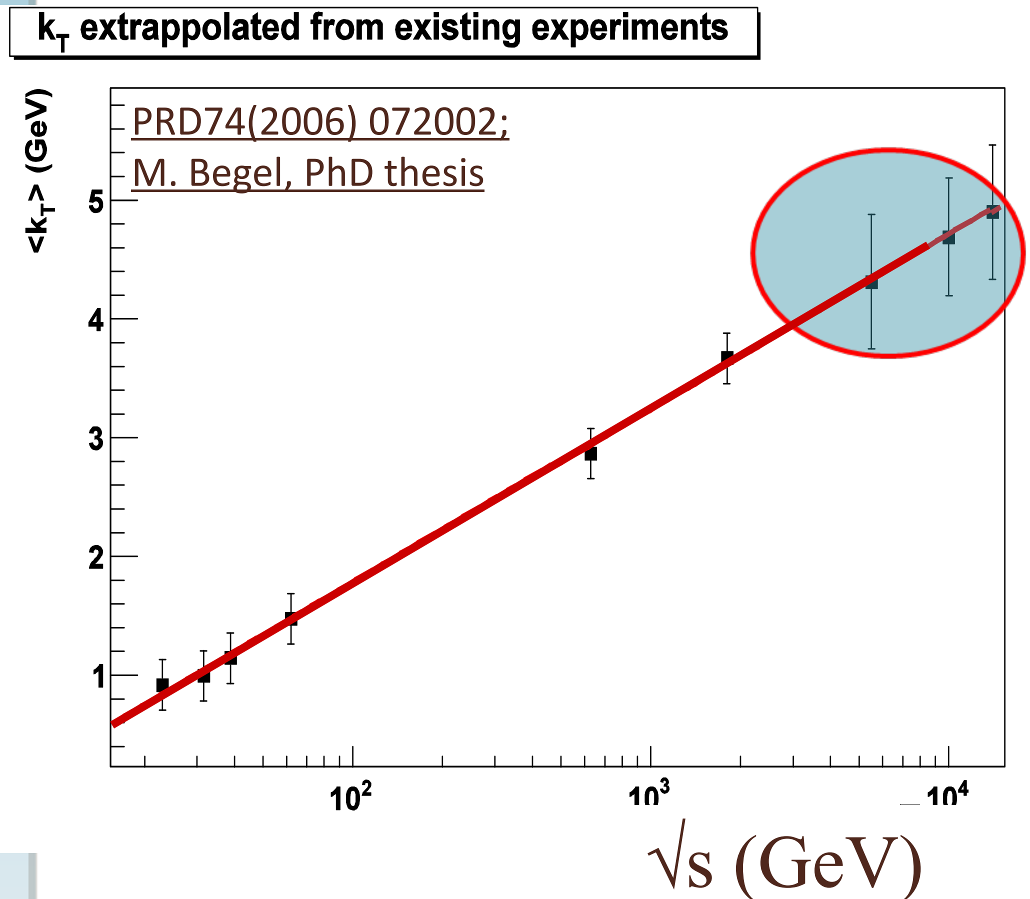
PRD74(2006) 072002; M. Begel, PhD thesis



- Many experiments have made measurement of the effective parton k_T in the proton
- Lower energies: expect a value ~ 0.5 GeV corresponding to size of the proton
- Higher energies: higher values obtained
- Different exp. use different methods, but the trend is evident

PYTHIA $\langle k_T \rangle$ in γ-jet events at LHC

- Extrapolated from existing measurements:



- Use PYTHIA generator (with ISR/FSR on) and tune k_T (PARP(91)) to reproduce measured

$\langle p_T \rangle_{pair} = \langle p_T \rangle_{\gamma\text{-jet}}$

$\langle k_T \rangle = \langle p_T \rangle_{pair} / \sqrt{2}$

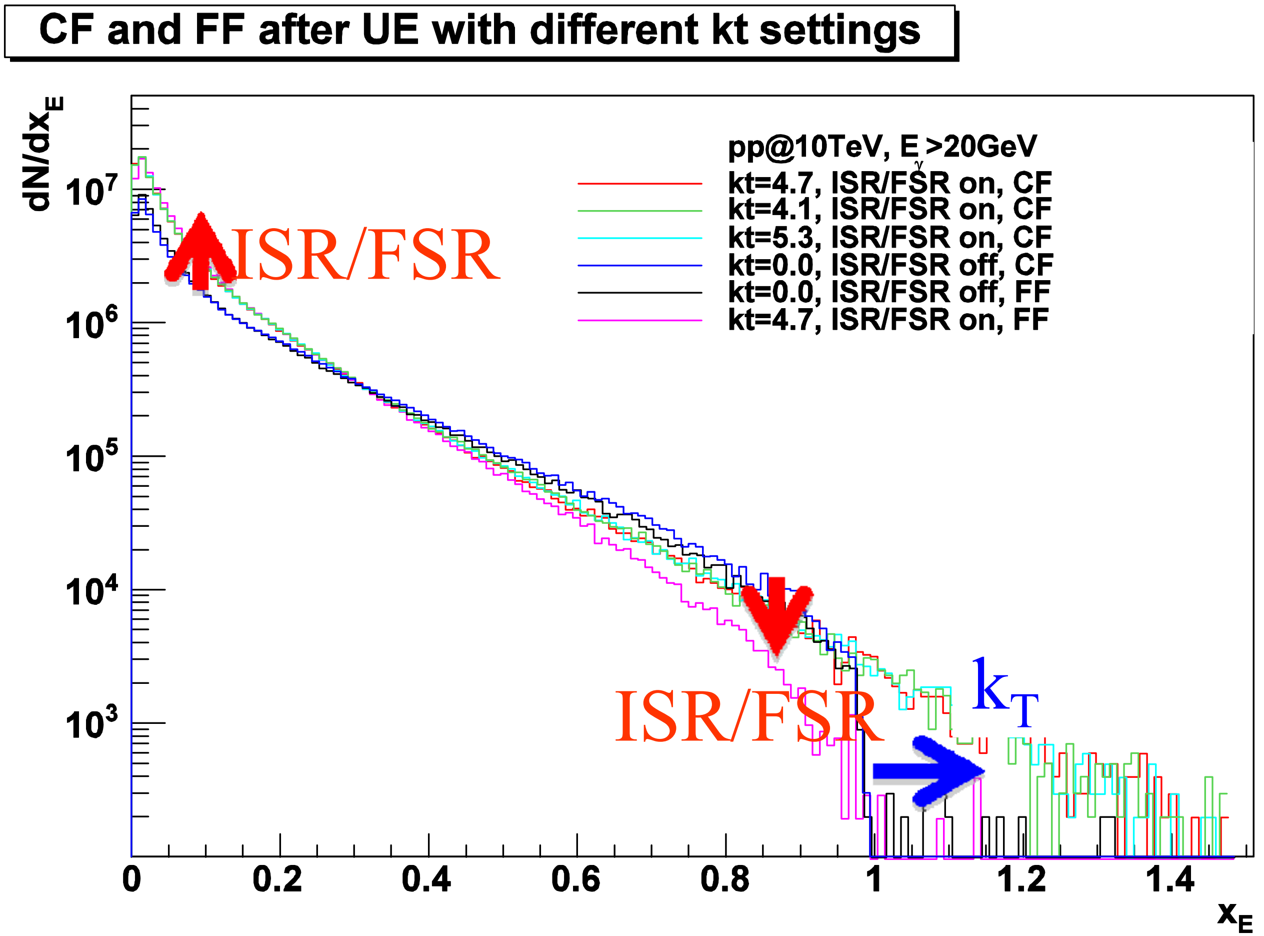
- fitting function:

$\langle p_T \rangle_{pair} = A * \log_{10}(B * \sqrt{s})$

$A = 2.06 \pm 0.171$

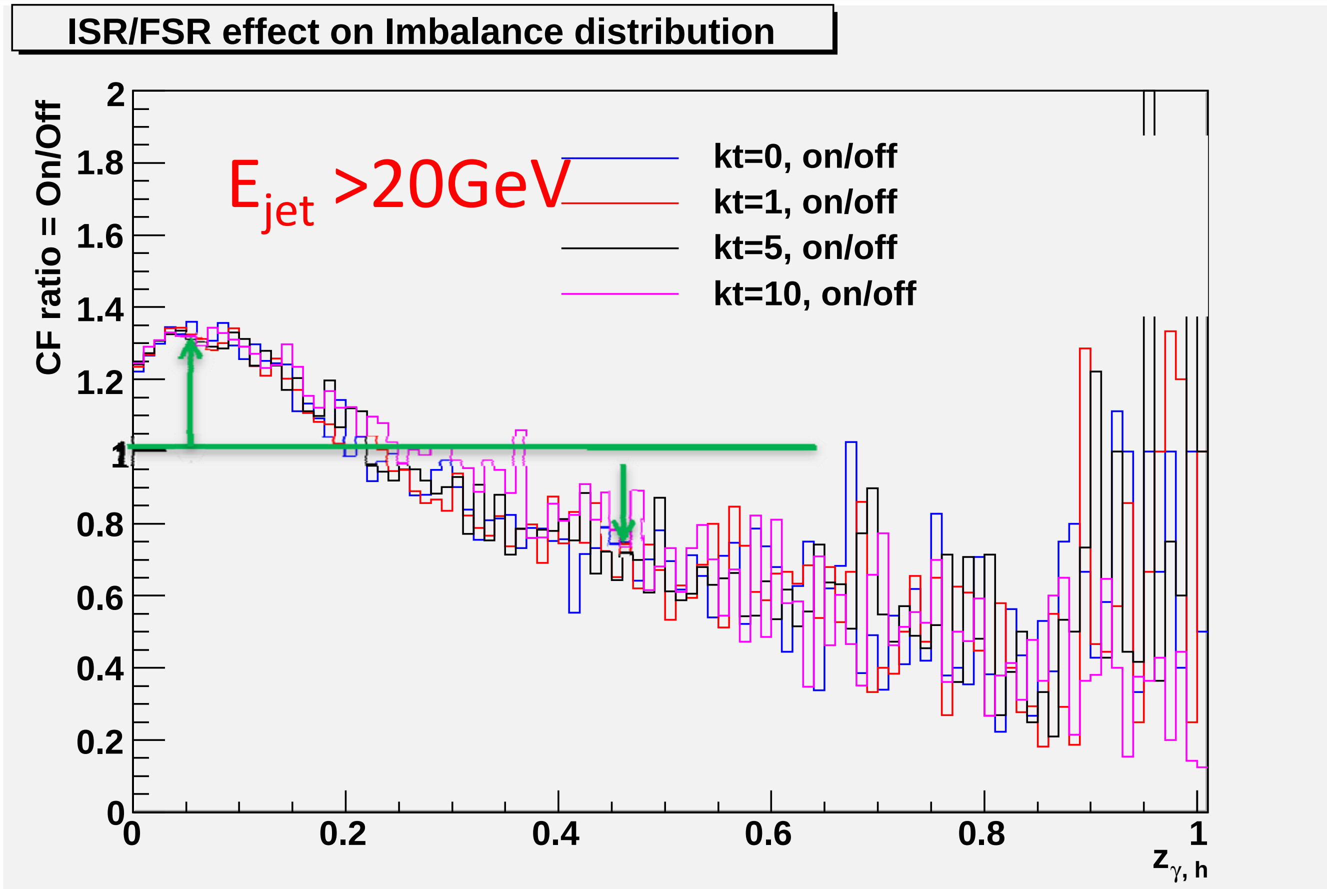
$B = 0.16 \pm 0.045$

Pythia k_T and ISR/FSR in CF and FF



- k_T generates a tail at $X_E > 1$ ($X_E = -p_{t_h} \cdot p_{t\gamma} / |p_{t\gamma}|^2$)

Ratio ISR/FSR ON over OFF in CF

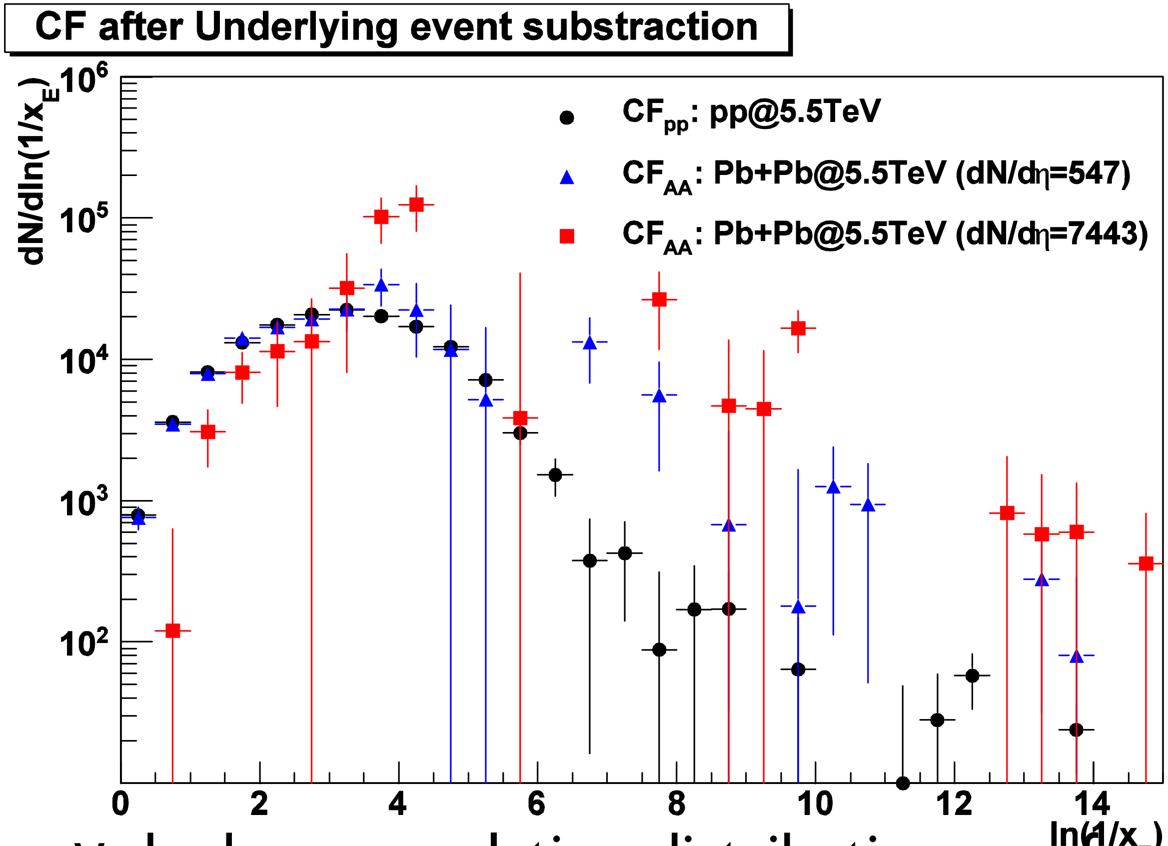


- ISR/FSR depletes the CF at high X_E values and increases the CF at low X_E values.

HI environment simulation

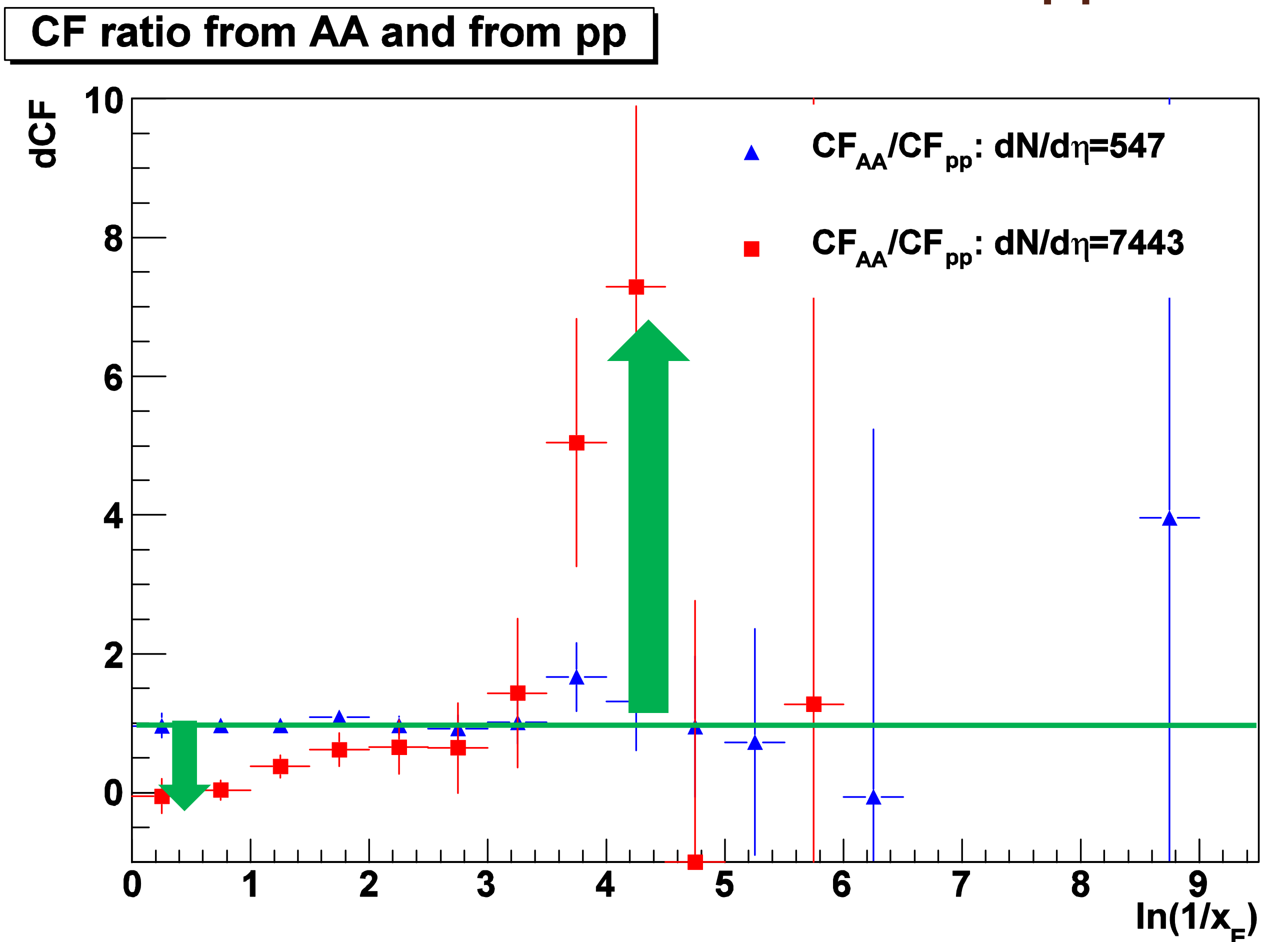
- PYTHIA: ($E_{\gamma\text{-jet}}$>20GeV) without quenching (10 month of pp data)
- HIJING: merged into γ-jet PYTHIA events (1month of PbPb data) :
  - b = 10-15 fm($dN/d\eta \sim 550$), no quenching
  - b = 0-5 fm($dN/d\eta \sim 7500$), quenched
- Quenching model: PYQUEN
  - event generator for simulation of rescattering, radiative and collisional energy loss of hard partons in expanding quark-gluon plasma created in ultrarelativistic heavy ion AA collisions (implemented as modification of standard pythia6.4xx jet event)

CF in pp and HI…



- γ- hadron correlation distribution as a function of $\ln(1/x_E)$, where $x_E = -p_{T_h} \cdot p_{T\gamma} / |p_{T\gamma}|^2$;
- Correlation distribution after the underlying events subtraction.

$I_{AA} = CF_{AA}/CF_{pp}$



- Medium modification factor I_{AA} calculated from the γ-hadrons correlation (CF) distribution.
- Enhancement at low x_E and suppression at large x_E.

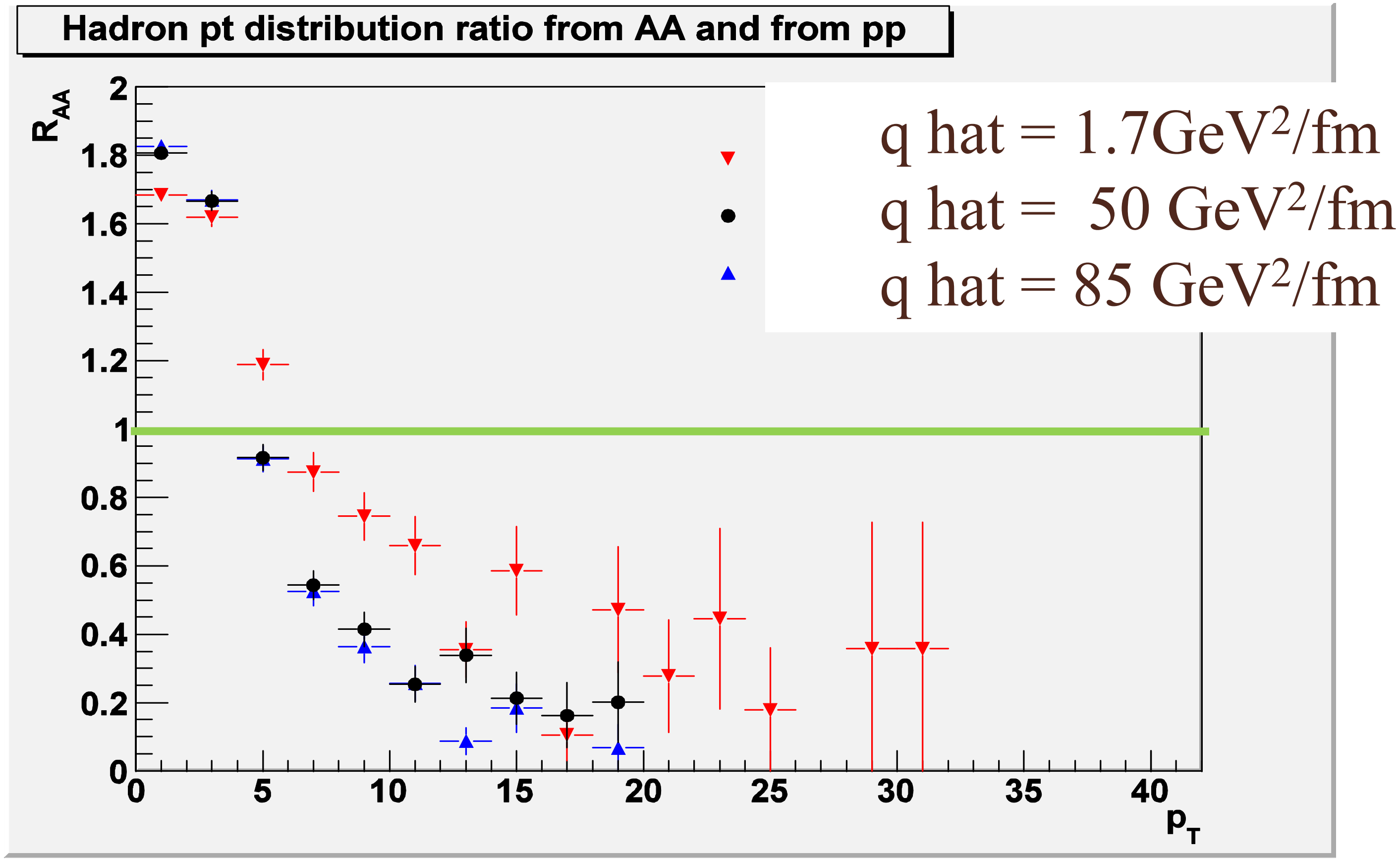
A different model: QPYTHIA (ask Leticia…)

- N. Armesto, L. Cunqueiro and C. A. Salgado change of the splittings
- Quenching comes through medium-modified splitting functions
- Quenching weights in the multiple soft scattering approximation are used based on "BDMPS" formalism

Configuration of the production

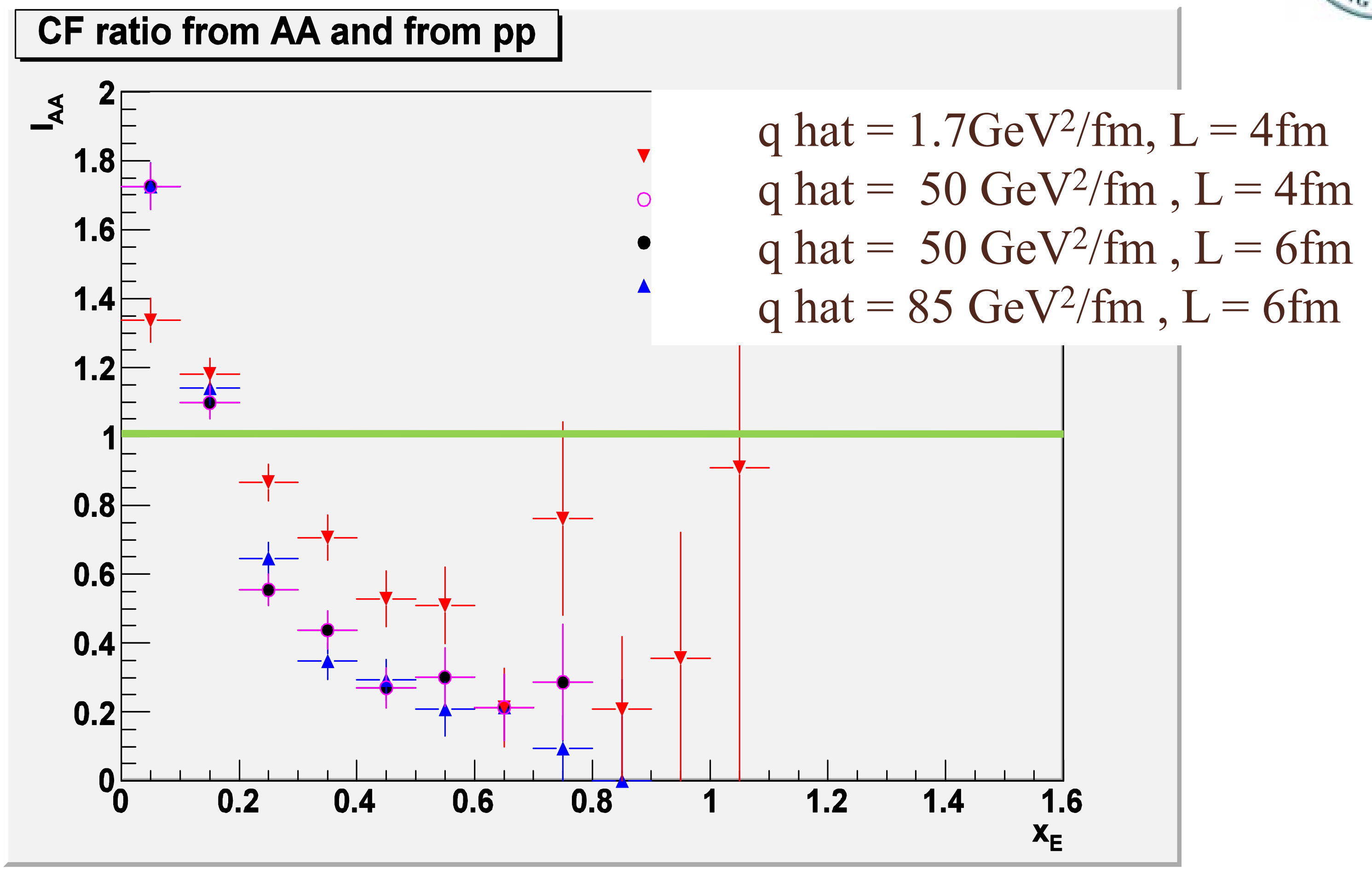
- γ-jet events at pp@5.5TeV without quench from PYTHIA;
- γ-jet events at pp@5.5TeV with quench from PYTHIA merged into PbPb@5.5TeV from HIJING;
- Quenching model (QPYTHIA) implemented in PYTHIA, 3 different settings:
  - q hat = 1.7GeV^2/fm
  - q hat = 50 GeV^2/fm
  - q hat = 85 GeV^2/fm

R_{AA} in γ-jet events



- q hat is the average medium-induced transverse momentum squared transferred to the parton per unit path length
- Modification will be stronger if q hat is large

I_{AA} in γ-jet events



- I_{AA} behaves the same as R_{AA} to reflect the medium effect
- Medium length setting in QPYTHIA is not working

What's more…

- According to the idea of X. N. Wang, γ-hadron correlation could probe volume (surface) emission of HI collisions by selecting x_E at different range (arXiv: 0902.4000v1):
  - large x_E, contributions to CF come mostly from the surface;
  - small x_E, contributions to CF are mostly from the whole volume.
- Is it possible to illustrate this picture in ALICE?

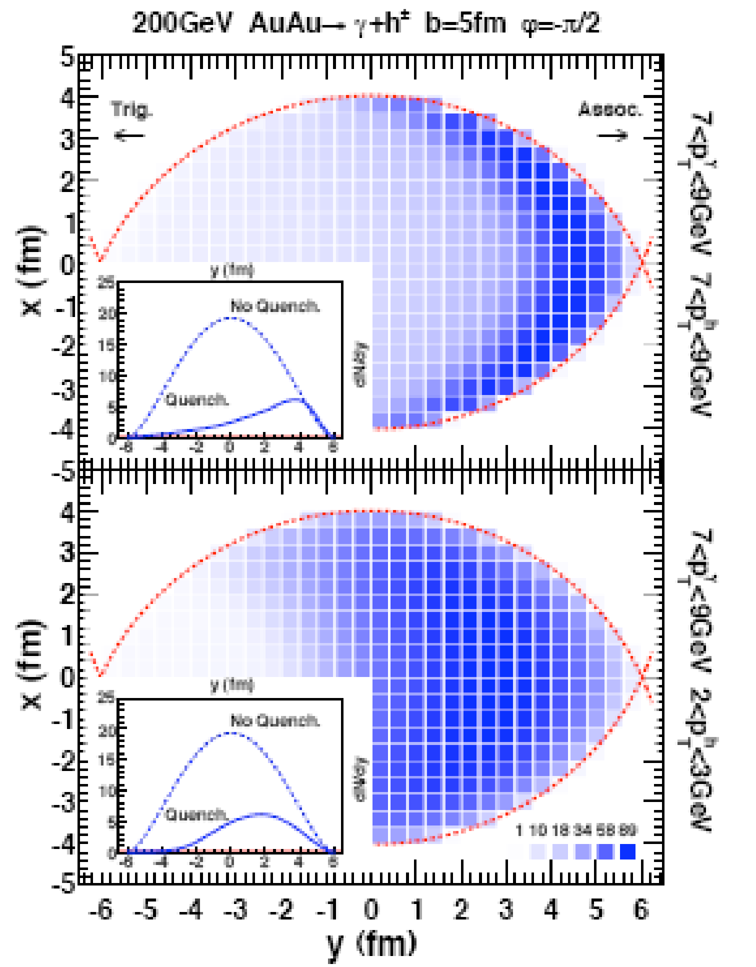
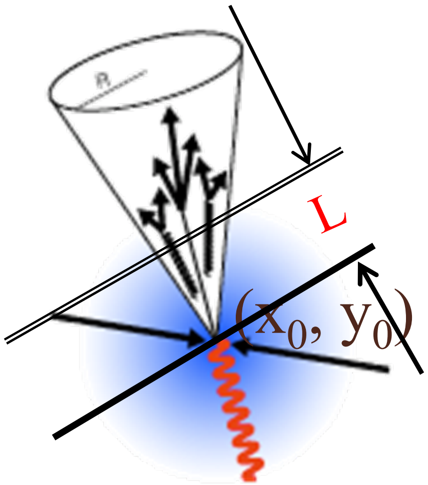


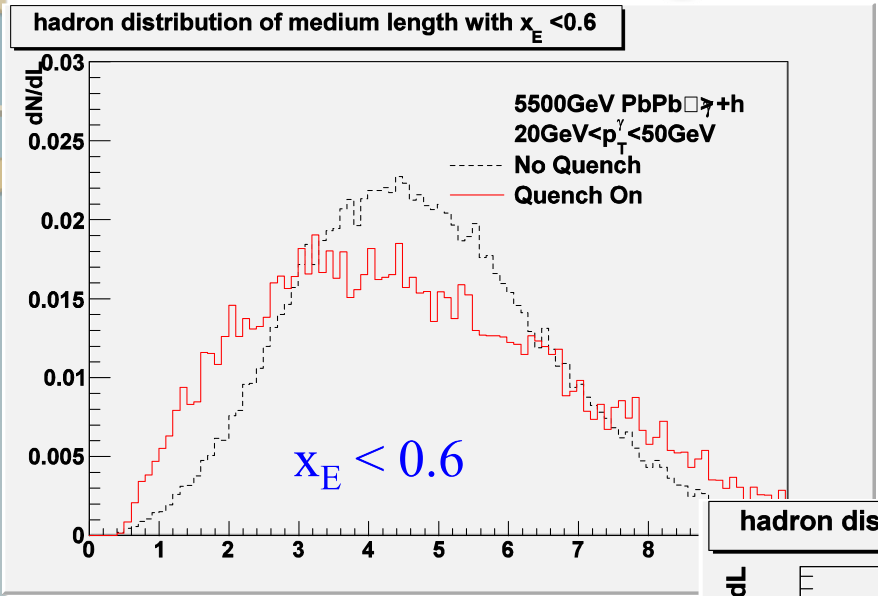
FIG. 3: (color online). Transverse spatial distributions of the initial γ-jet production vertexes that contribute to the final observed γ-hadron pairs along a given direction (arrows) with $z_T \approx 0.9$ (upper panel) and $z_T \approx 0.3$ (lower panel).

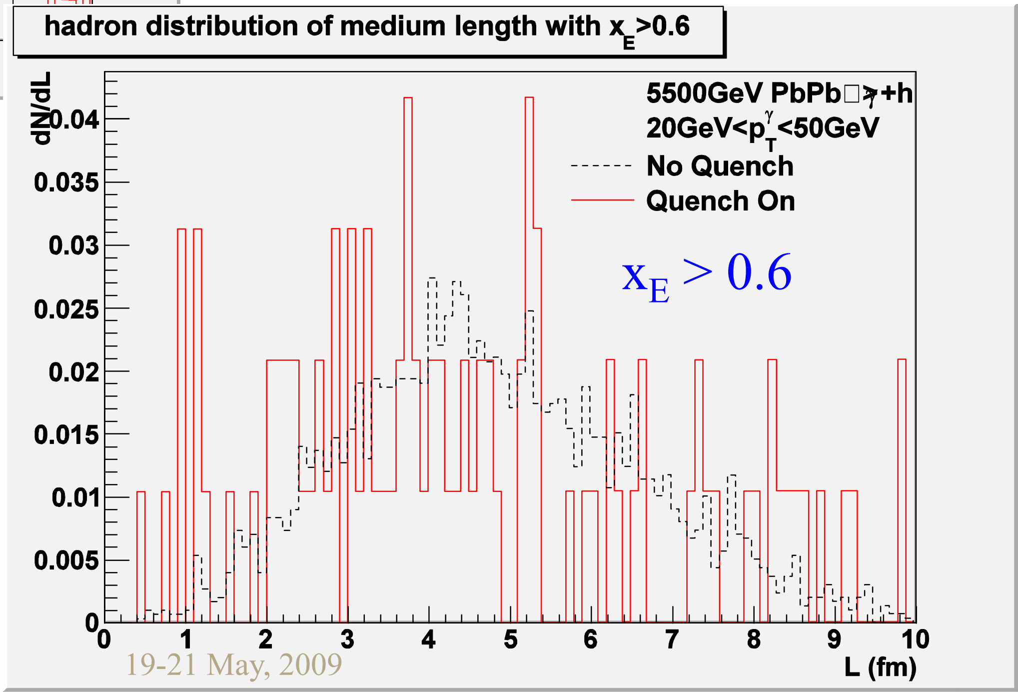
On going testing…

- Generate γ-jet events with PYTHIA;
- Quenching the jet with QPYTHIA;
- Get the jet production point (x_0, y_0) inside AA geometry by fast glauber model;
- Calculate medium length based on jet direction.

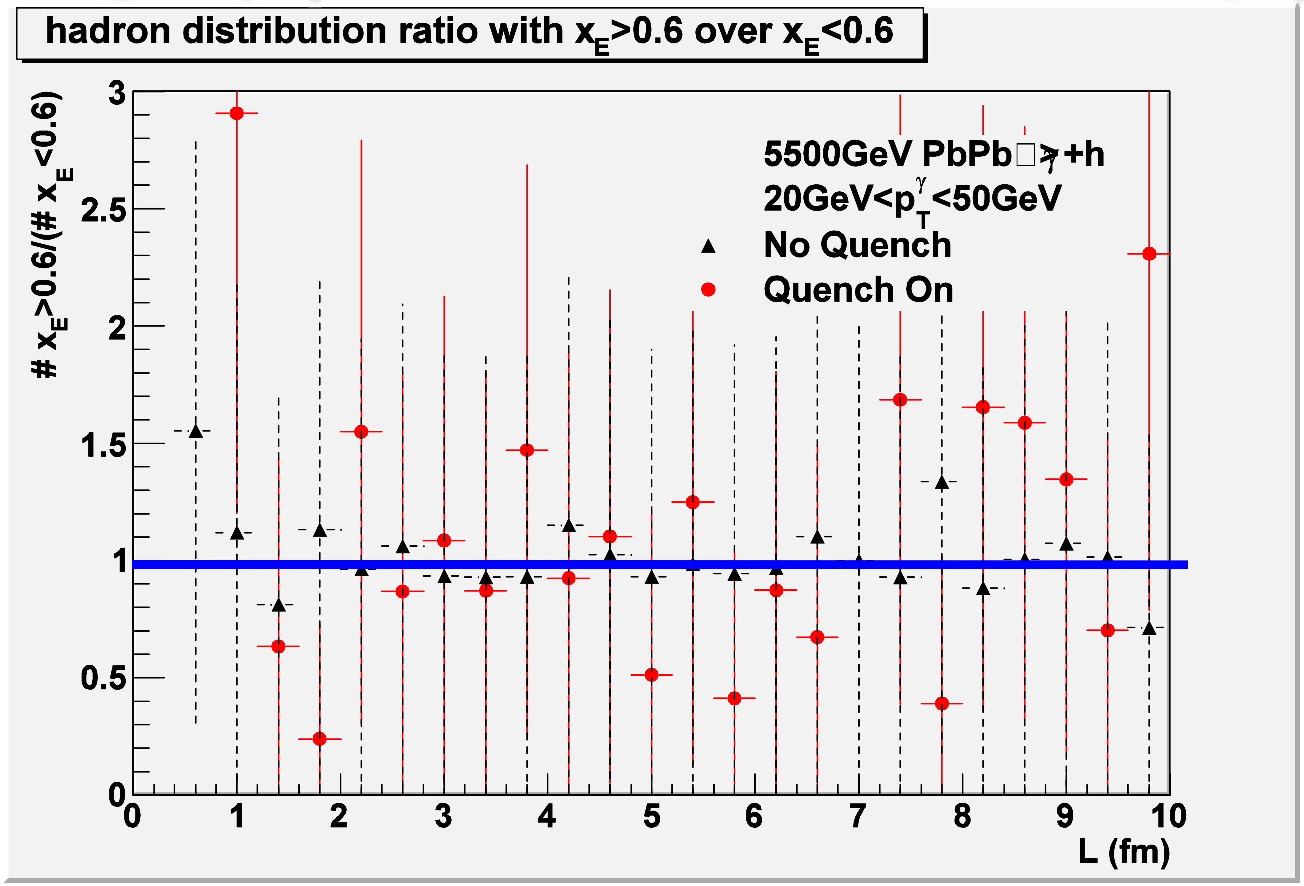


Medium length of jet hadrons





High p_T hadrons over low p_T's



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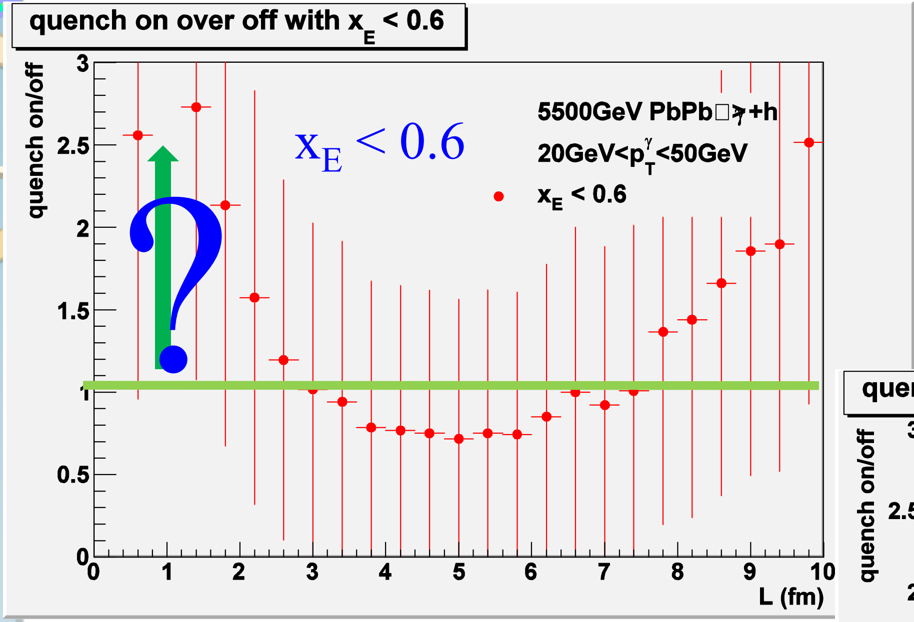
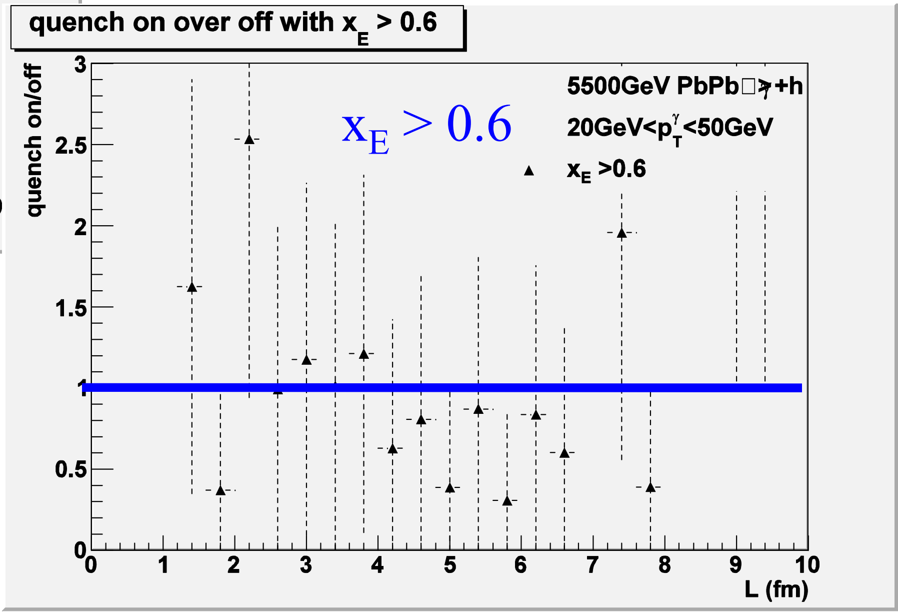
- Did NOT see enhancement at small L and suppression at large L as expected, something is wrong?

Quenching effect on L





- Why enhancement for low p_T hadrons (small x_E) at small L?
- Is there suppression for high p_T hadrons (large x_E) at large L as expected?

In progress…

- Verify the tomography of the medium on γ- hadron correlation measurement.
- γ- hadron correlation measurement with EMCal and central tracking system (ITS+TPC) in pp and in AA.
- Prepare well for the first year data analysis…

Back up

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 wher there is no jet contribution

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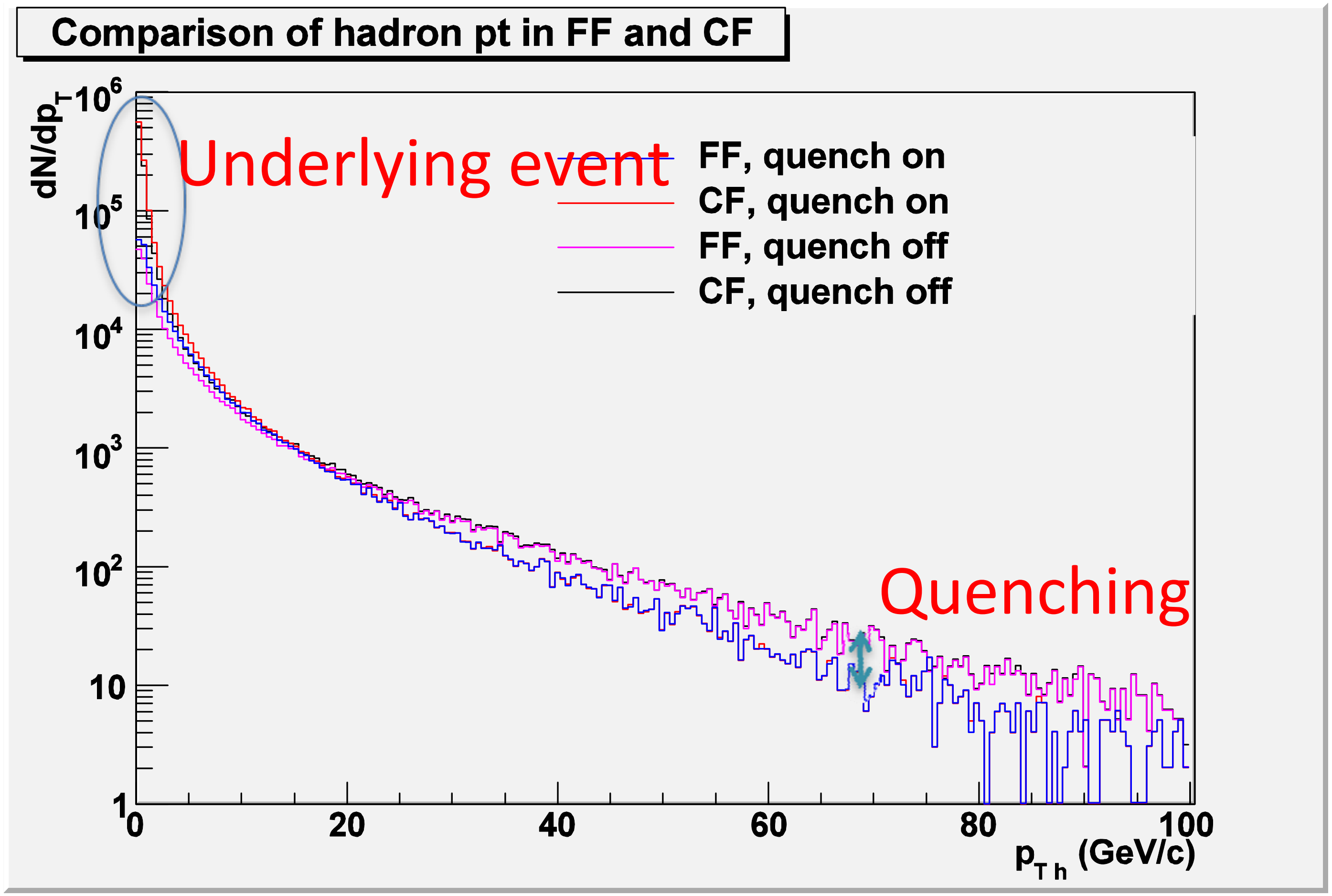
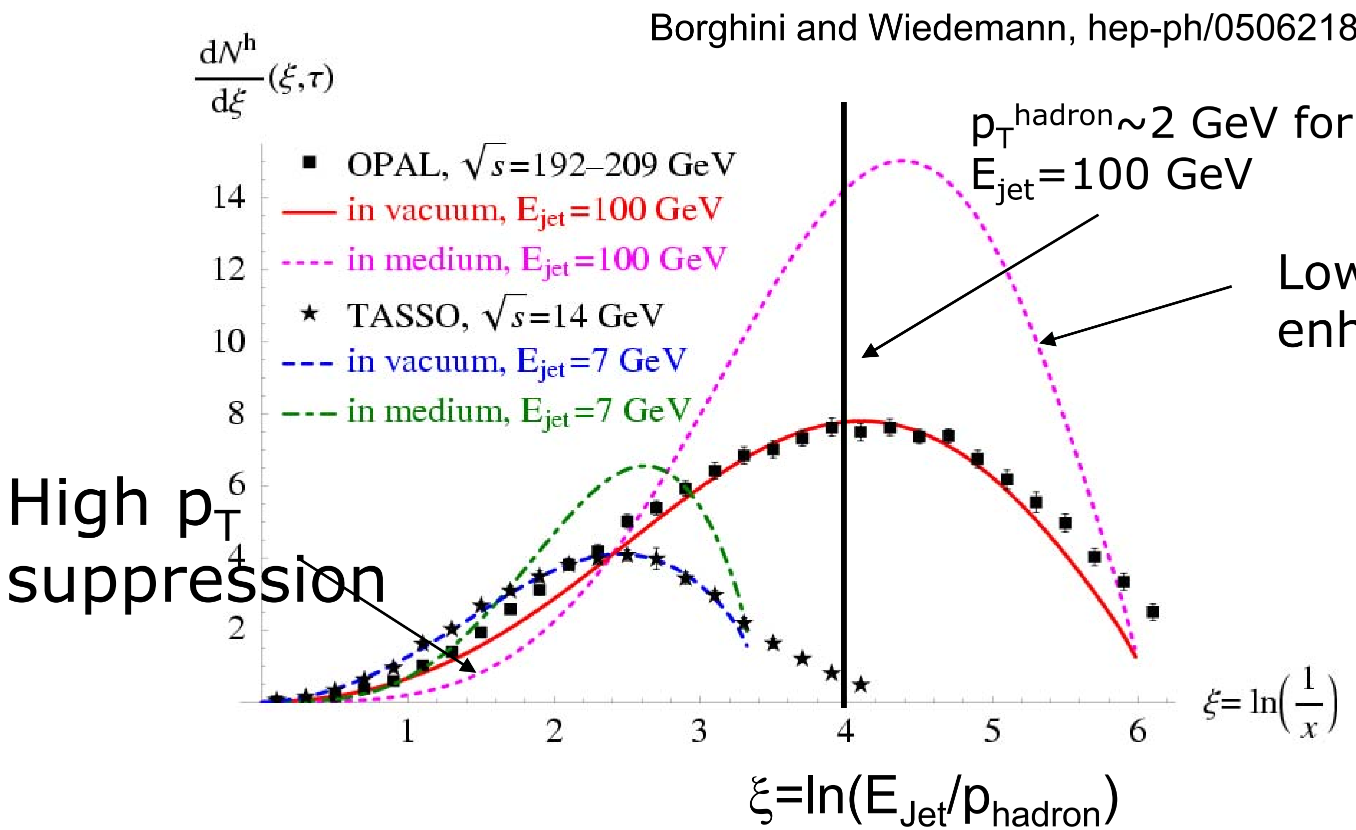
p_t spectrum of hadrons entering in the construction of FF (R=1) and CF (opposite to photon)



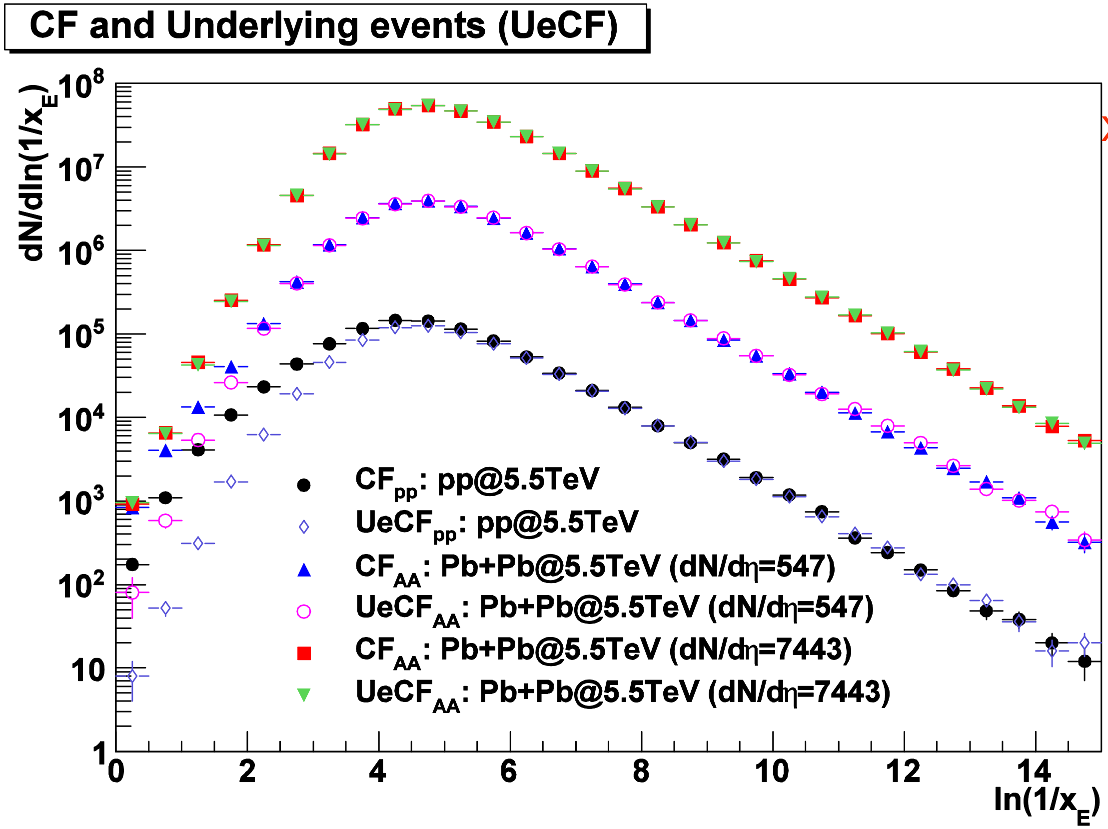
Quenching effect will make hadrons' distribution shift from high momentum to low momentum

Medium effects on jets: FF



- Fragmentation strongly modified by medium

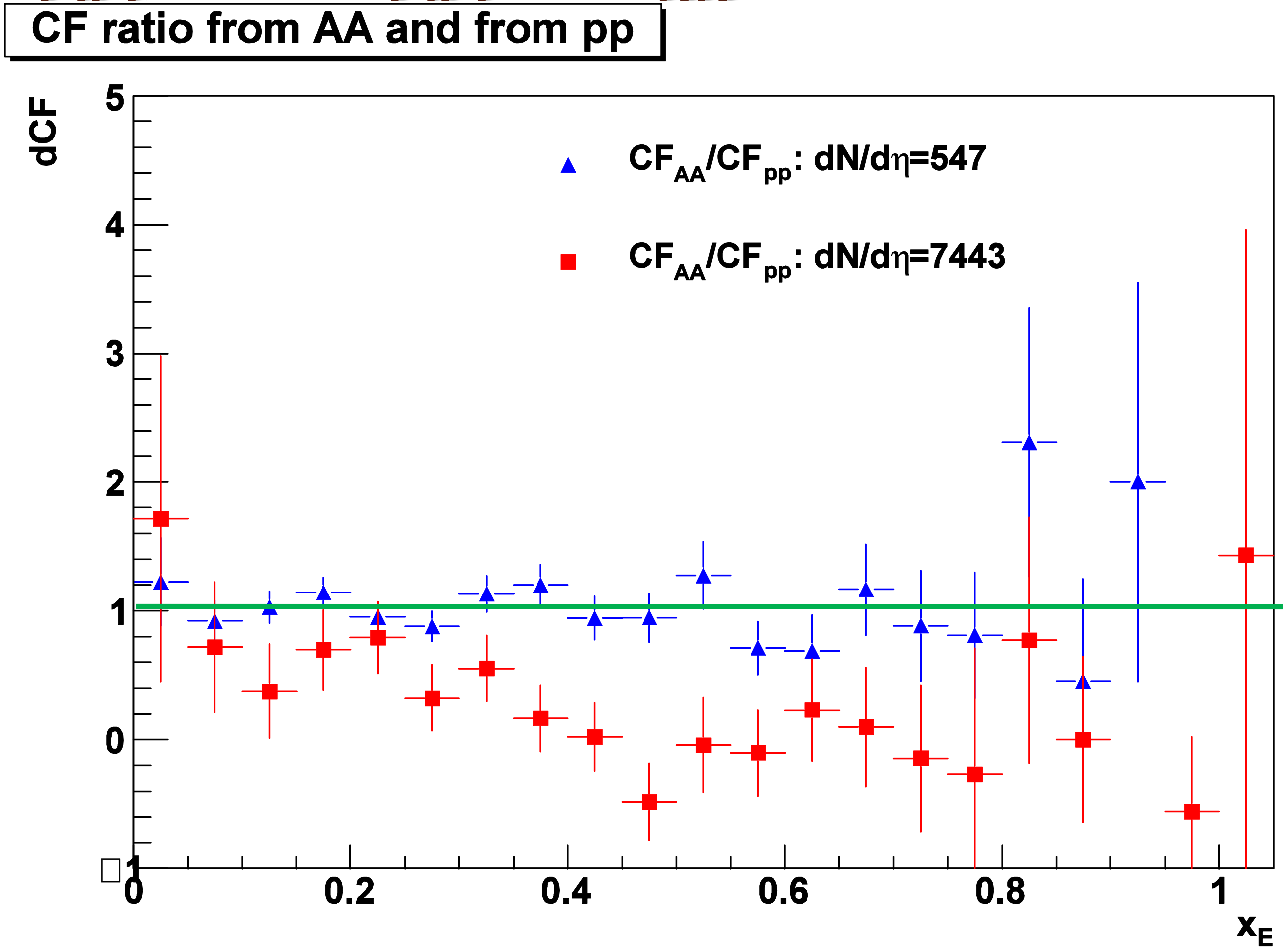
In HI …



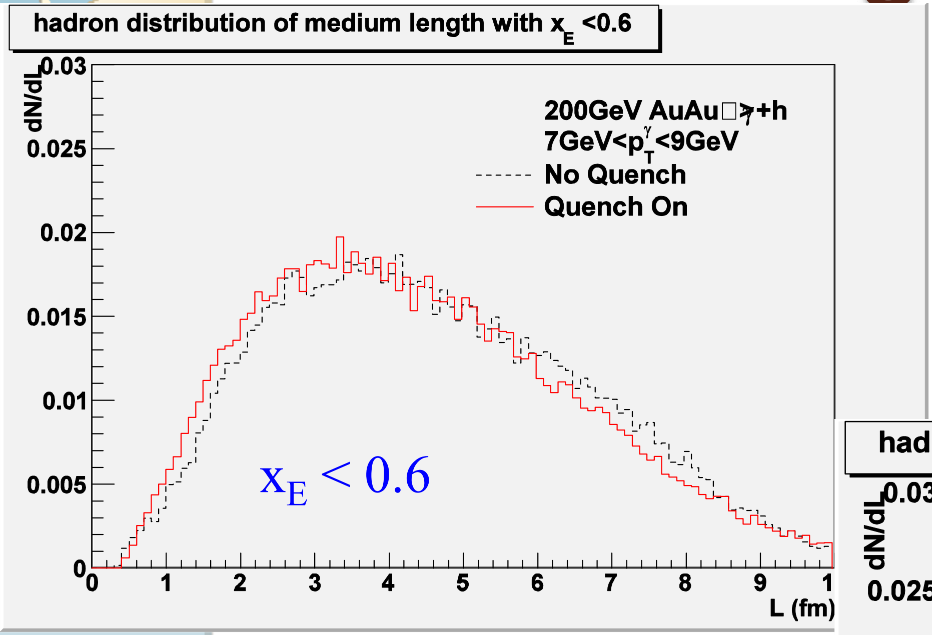
$x_E = -p_{T_h} \cdot p_{T\gamma} / |p_{T\gamma}|^2$

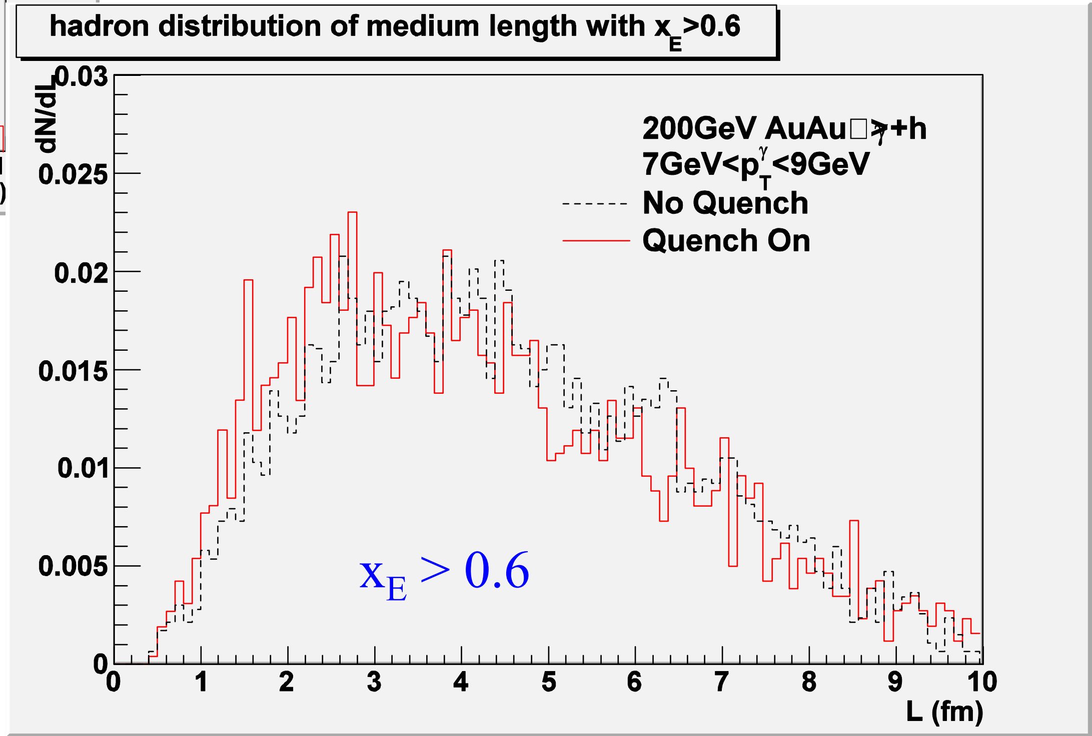
PYTHIA: 10k events → 10 month of pp data taking
HIJING: 1k events → 1month of PbPb data taking
Quenching model: PYQUEN

$I_{AA} = CF_{AA}/CF_{pp}$ …



Medium length of jet hadrons





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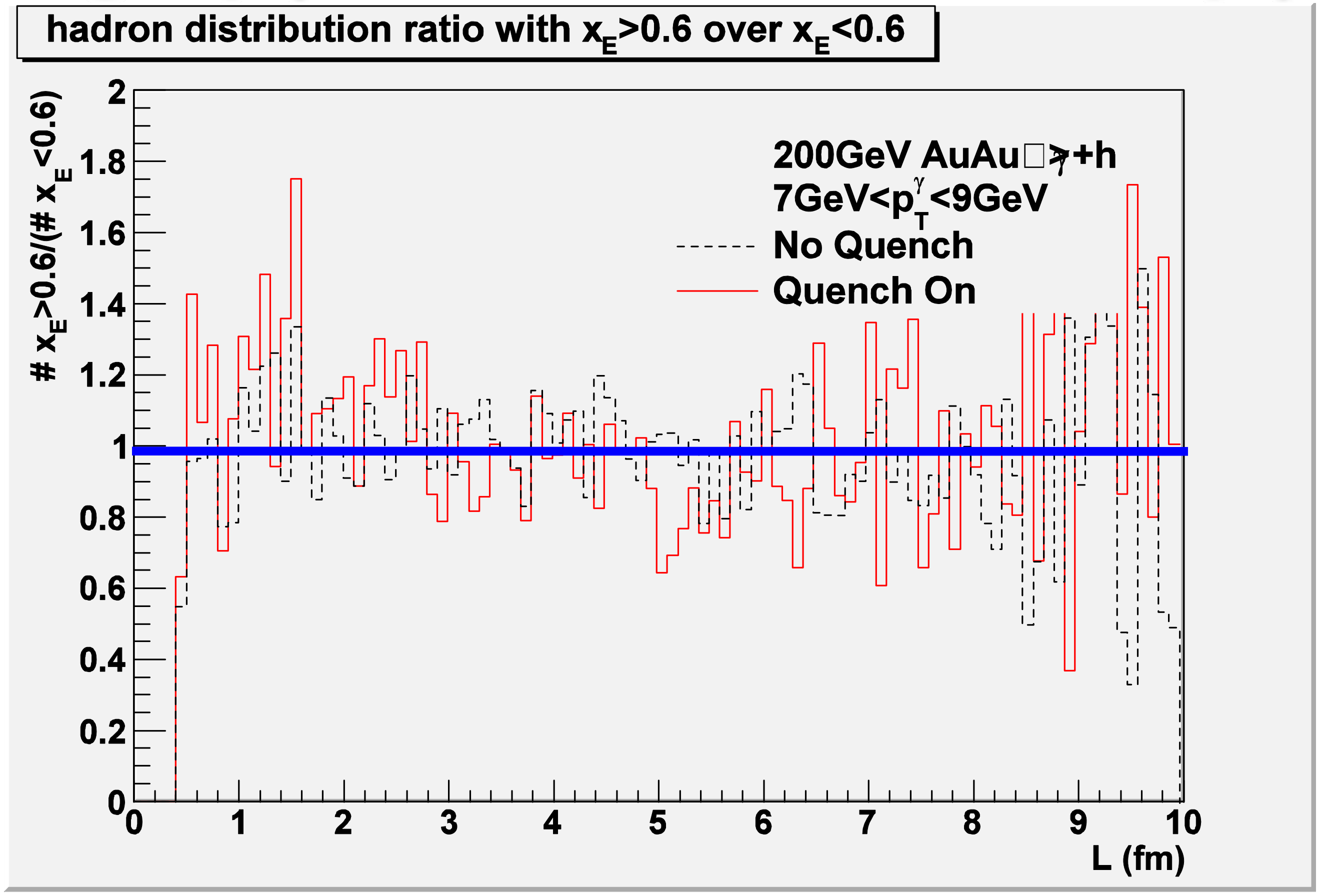

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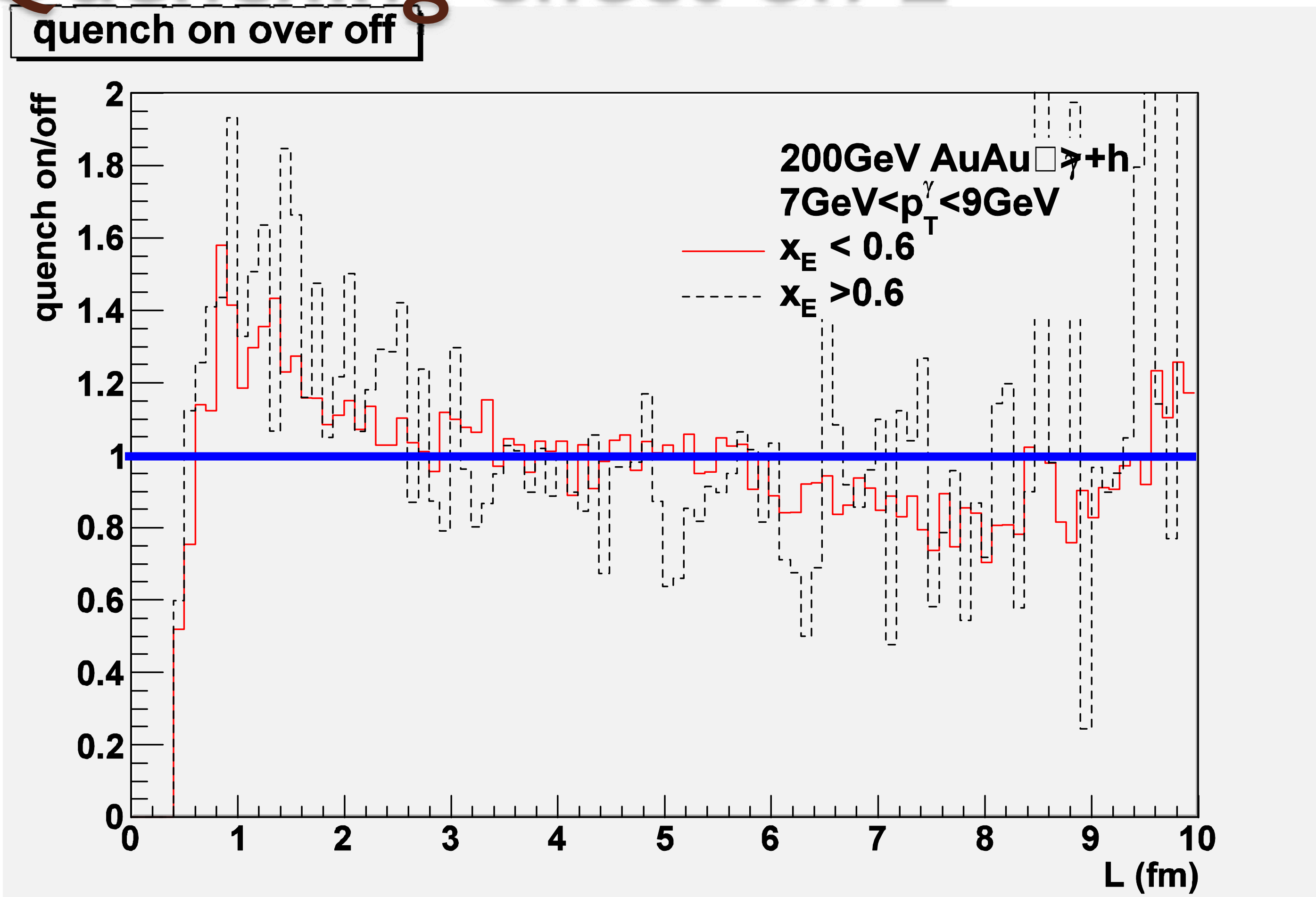
Quenching effect on L



- Quenching effect generates enhancement of the small L but suppress at large L???