PHOTON AND JET PHYSICS IN ALICE

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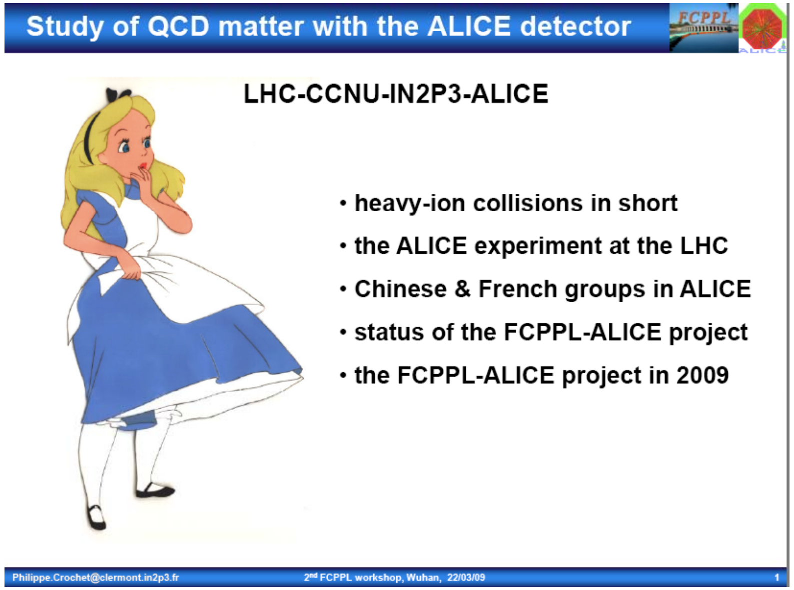
Introduction

- See the talk by P. Crochet



- I will focus on photons, high pt and jets as probes of the LHC QCD matter

What can be learnt by measuring 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

Photon source identification: the parameters

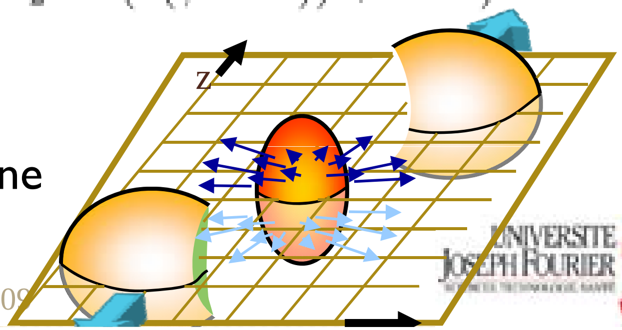
- Two variables:
  - Nuclear modification factor (R_{AA}):

$$R_{AA}(p_T) = \frac{d^2N^{AA}/dp_T d\eta}{T_{AA} d^2N^{pp}/dp_T d\eta}$$

  - Elliptic flow (v_2)- 2nd coefficient of Fourier expansion of angular distribution with respect to the reaction plane:

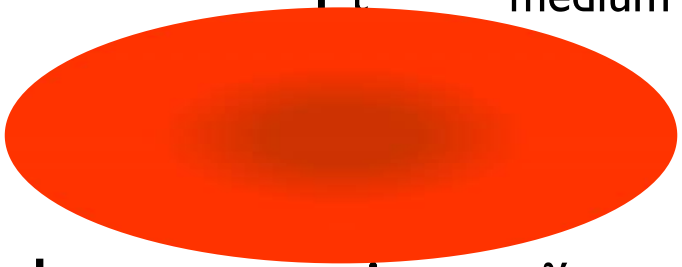
$$\frac{dN}{d(\phi - \Psi)} = N_0(1 + 2v_1\cos(\phi - \Psi) + 2v_2\cos(2(\phi - \Psi)) + ...)$$

    - ϕ : azimuthal angle of particles
    - Ψ : azimuthal angle of reaction plane



Photon source identification: medium generated

- Thermal: $p_t^{\gamma} \sim T_{medium} \sim 1$ GeV

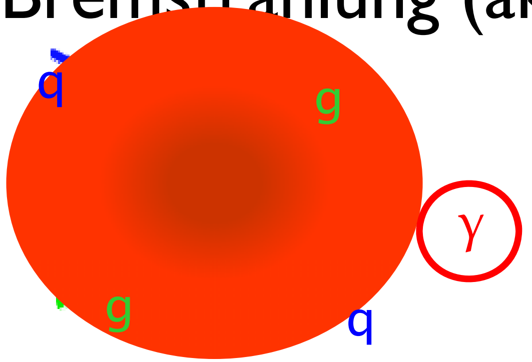


$R_{AA} > 1, v2 > 0$

- Jet conversion: $p_t^{\gamma} \sim p_t^{q}$

$R_{AA} > 1, v2 < 0$

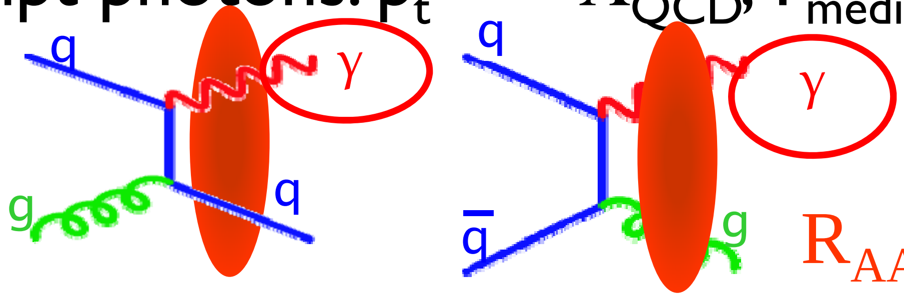
- Bremstrahlung (aka g radiation): $p_t^{\gamma} < p_t^{q}$



$R_{AA} > 1, v2 < 0$

Hard probe: prompt photons

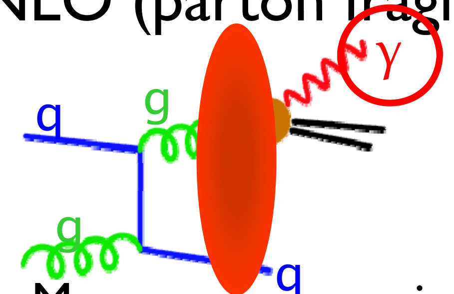
- Prompt photons: $p_t^\gamma >> \Lambda_{QCD}, T_{medium}$
  - LO



$R_{AA} = 1, v_2 = 0$

- Measured as isolated photons
- Reference study for medium effect

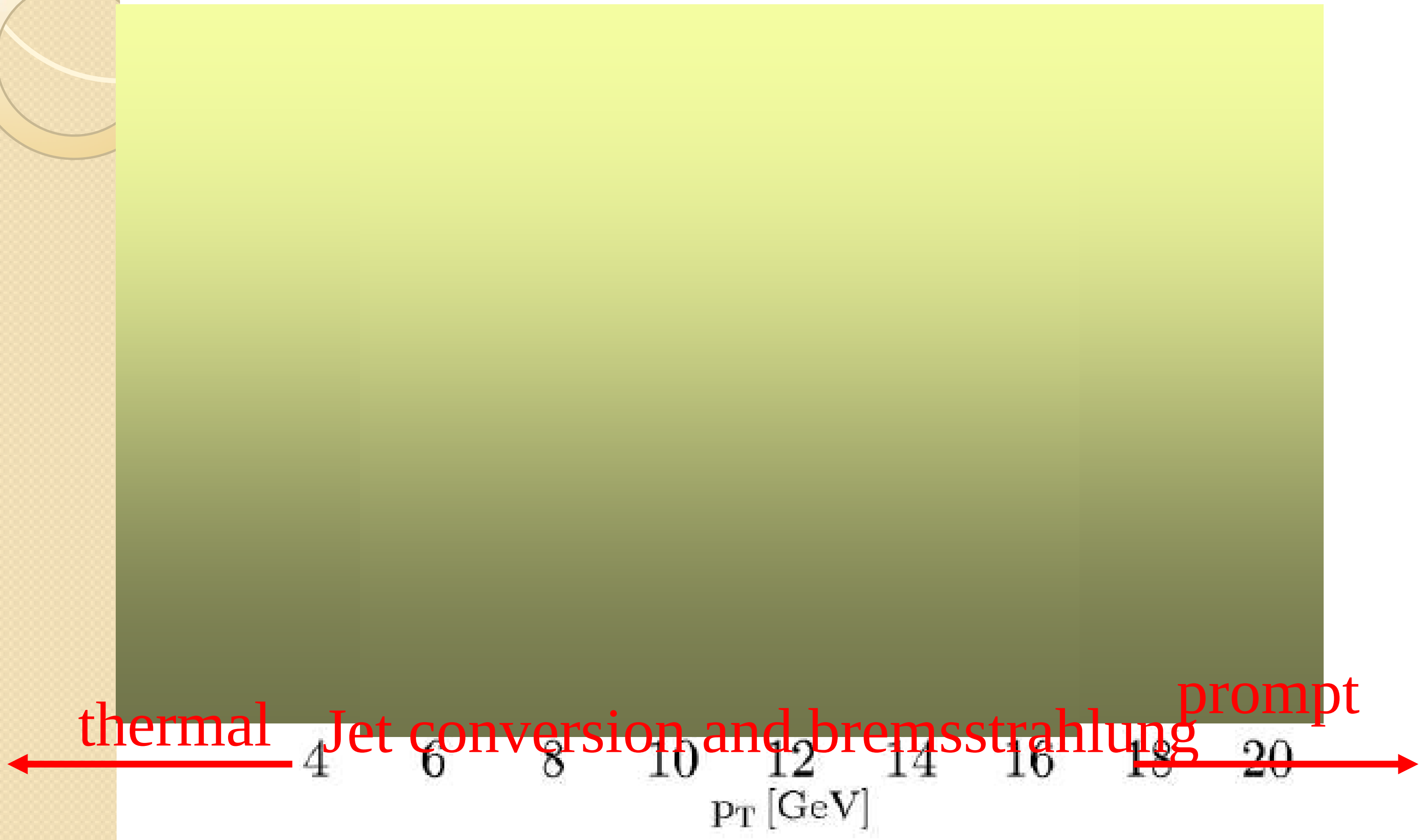
- Prompt photons: $p_t^\gamma >> \Lambda_{QCD}, T_{medium}$
  - NLO (parton fragmentation)



$R_{AA} < 1, v_2 > 0$

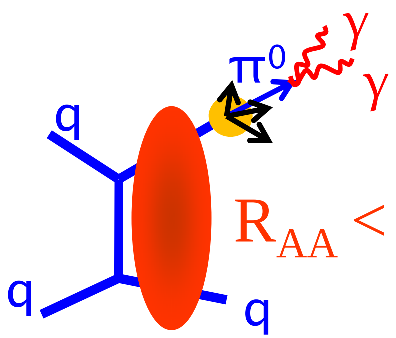
- Measured as non-isolated photons
- Quenched by the medium (aka parton)

LHC prediction



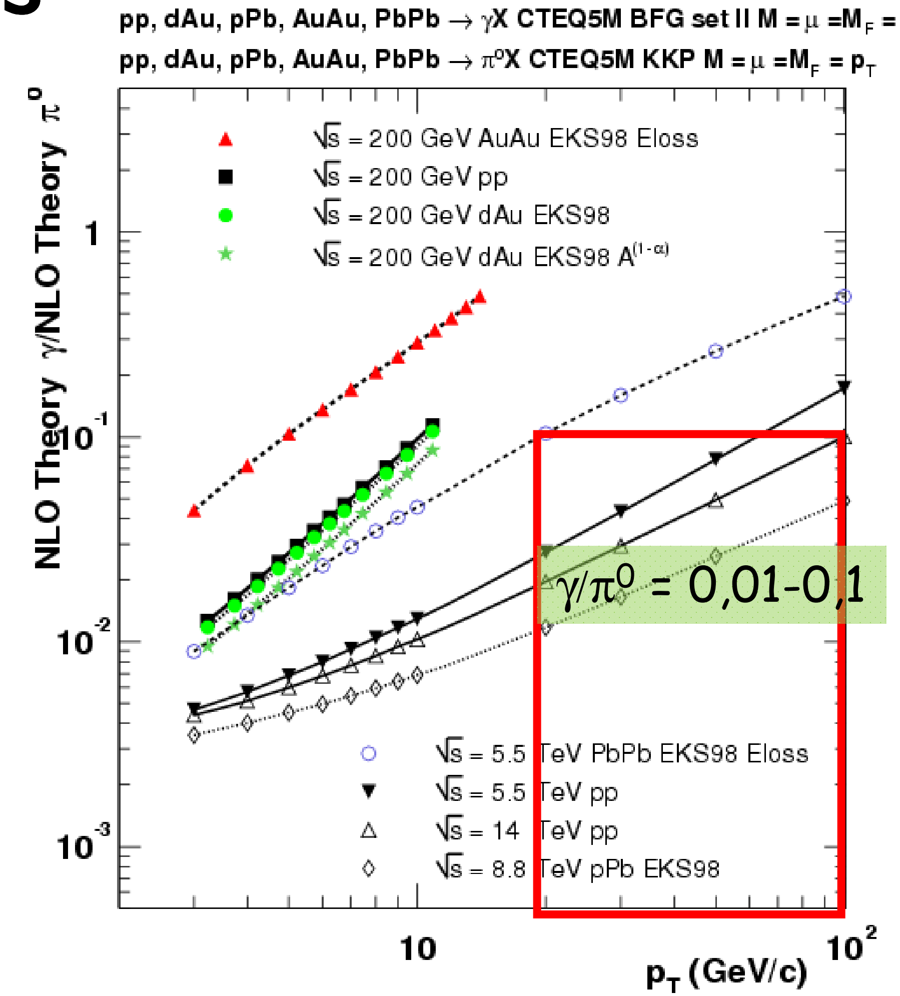
Decay photons

- Decay photons form the bulk: $p_t^{\gamma} = p_t^{\pi} / 2 < p_t^{q}$



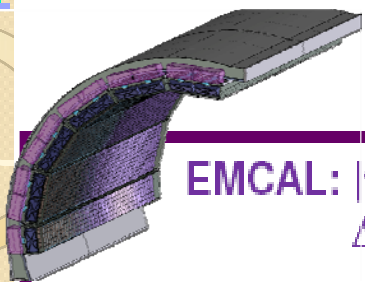
$R_{AA} < 1$, $v2 > 0$

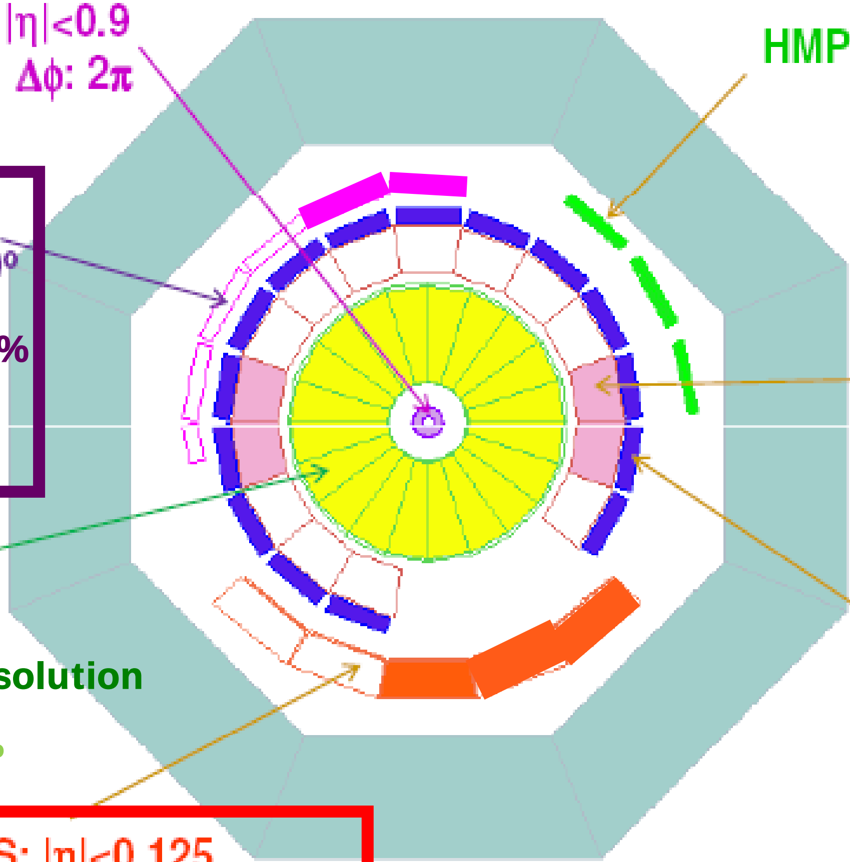
- p+p collisions:
  - mainly π^0
- A+A collisions:
  - Jet-Quenching
  - LHC:
    - $N_{\gamma} / N_{\pi} \approx 0.3$ for $p_T = 100$ GeV/c



Yellow Report **hep-ph/0311131**

How can we measure direct photons and jets in ALICE?





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

E > 10 GeV → ΔE/E < 3 %

σx =[3,50] mm

Tracking System resolution

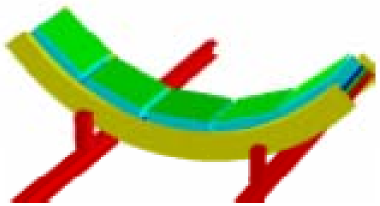
Δp/p = 2%, α =1.1°

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

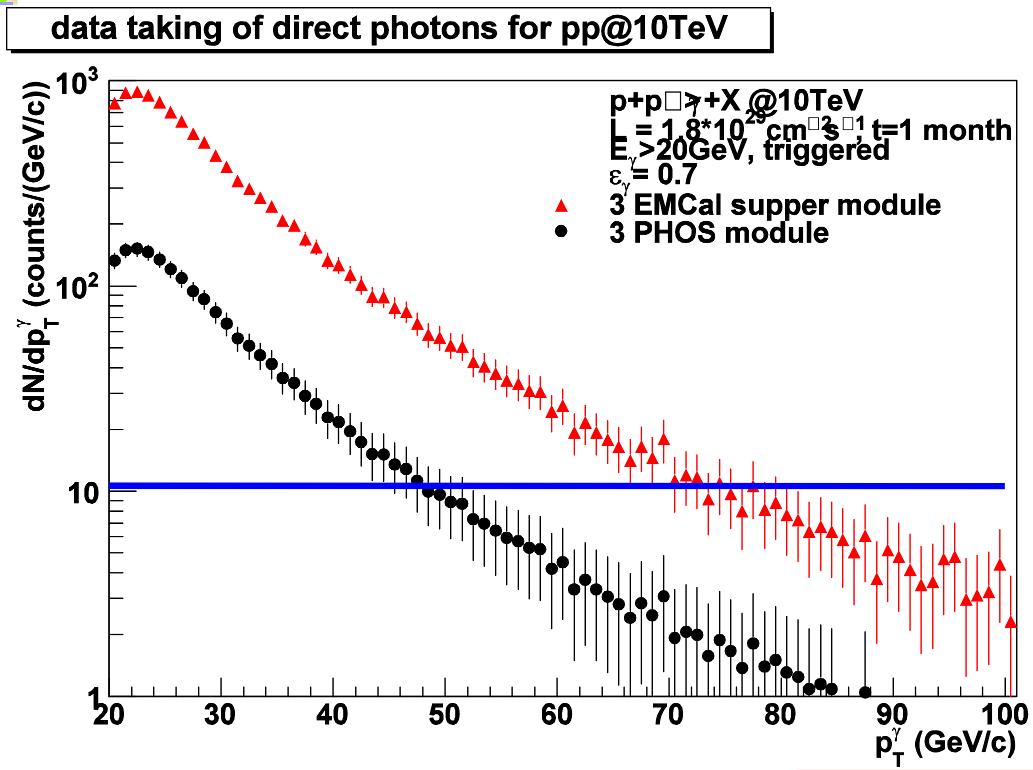
E > 10 GeV → ΔE/E < 1.5%,

σ_x =[0.5,2.5] mm

*Holes are made in front of 3 PHOS modules



Direct photon in ALICE



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

Triggered rare process

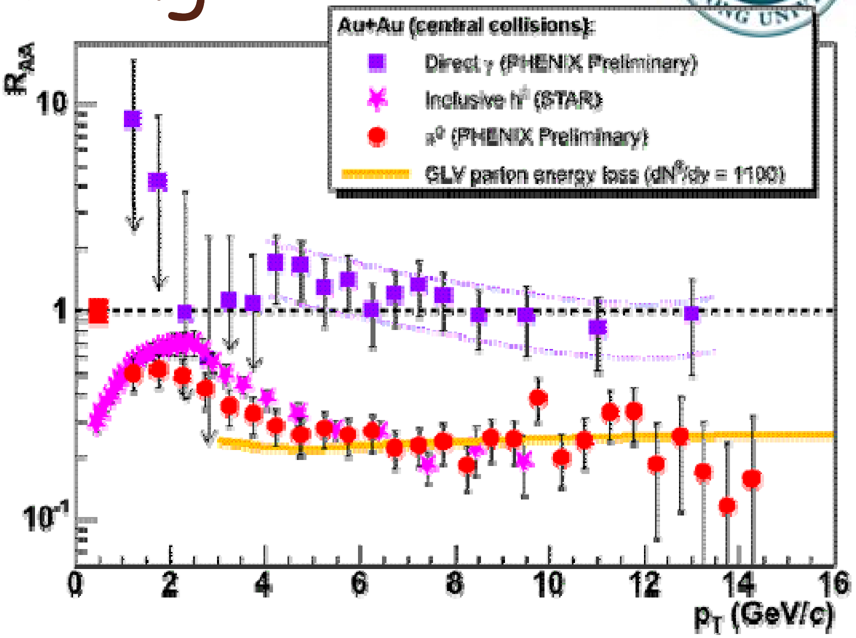
N events	$L = 2.e28 cm^{-2}s^{-1}$	$L = 1.8e29 cm^{-2}s^{-1}$	$L = 7.3e29 cm^{-2}s^{-1}$
MB	$2.69*10^9$	$2.4*10^{10}$	$9.83*10^{10}$
$\gamma^{E>20GeV}$	$2.17*10^3$	$1.95*10^4$	$7.9*10^4$
$\gamma^{3\ PHOS}$	50	546	2213
$\gamma^{3\ EMCAL}$	300	3183	12917

No trigger

Why jets? Jet-quenching

- Study of reconstructed jets increases sensitivity to medium parameters by reducing
  - Trigger bias
  - Surface bias

- Using reconstructed jets to study
  - Modification of the leading hadron
  - Additional hadrons from gluon radiation



- The measurement:
  - Particle species spectra
    1. $\sigma(p_T^h)$
    1. $R_{AA} = \sigma_{AA}/(\text{Norm} \times \sigma_{pp})$
  - Fragmentation function
    1. $FF(z = p_T^h/E_{jet})$
    1. $R_{FF} = FF_{AA}/(\text{Norm} \times FF_{pp})$

Medium coefficient transport $\hat{q}$

$$\Delta E \propto \hat{q} \cdot L^2$$

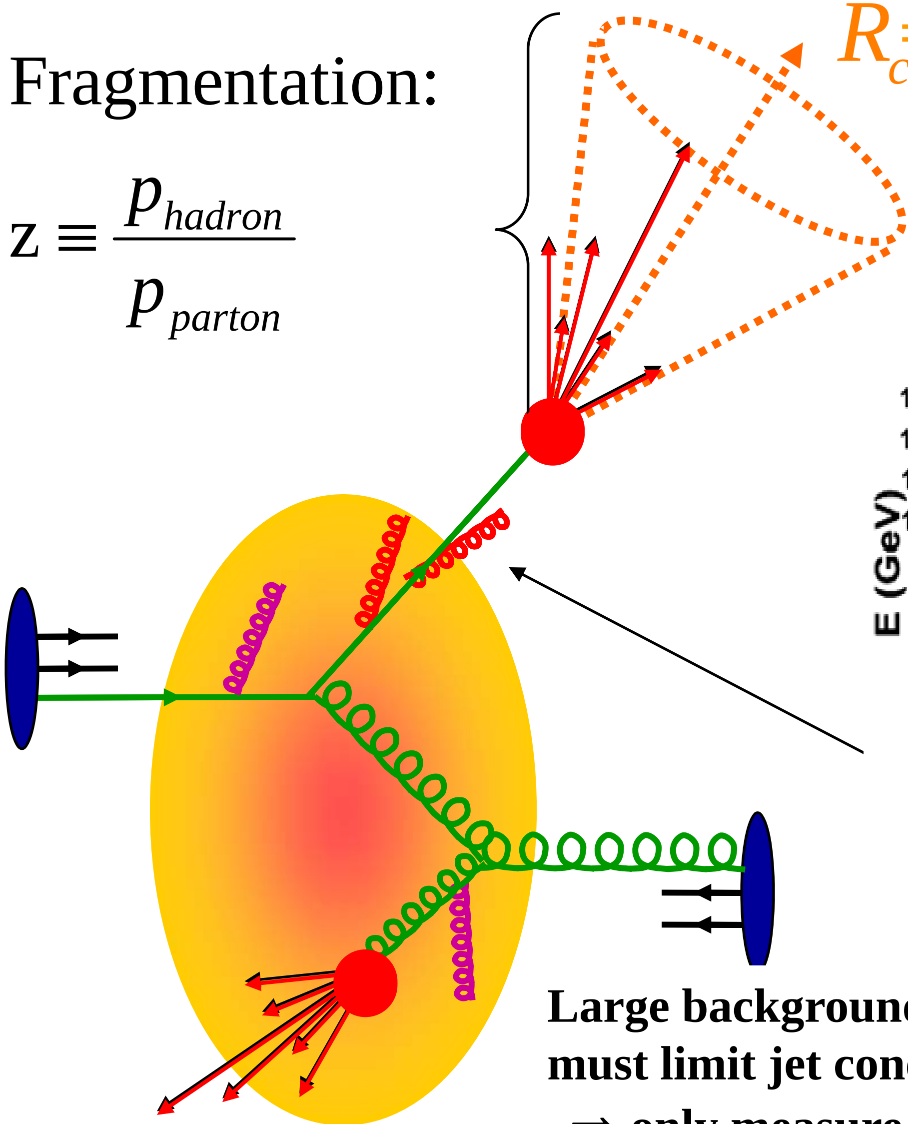
$$\frac{d\Delta E}{dz} \propto \hat{q} \cdot L$$

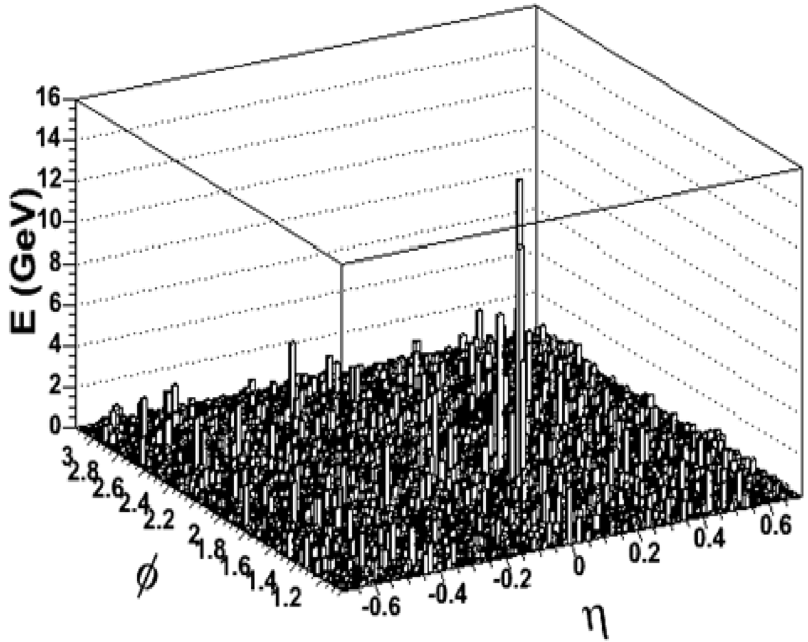
Jet Reconstruction

Fragmentation:

$$z \equiv \frac{p_{hadron}}{p_{parton}}$$

$$R_{cone} = \sqrt{(\Delta\phi^2 + \Delta\eta^2)}$$



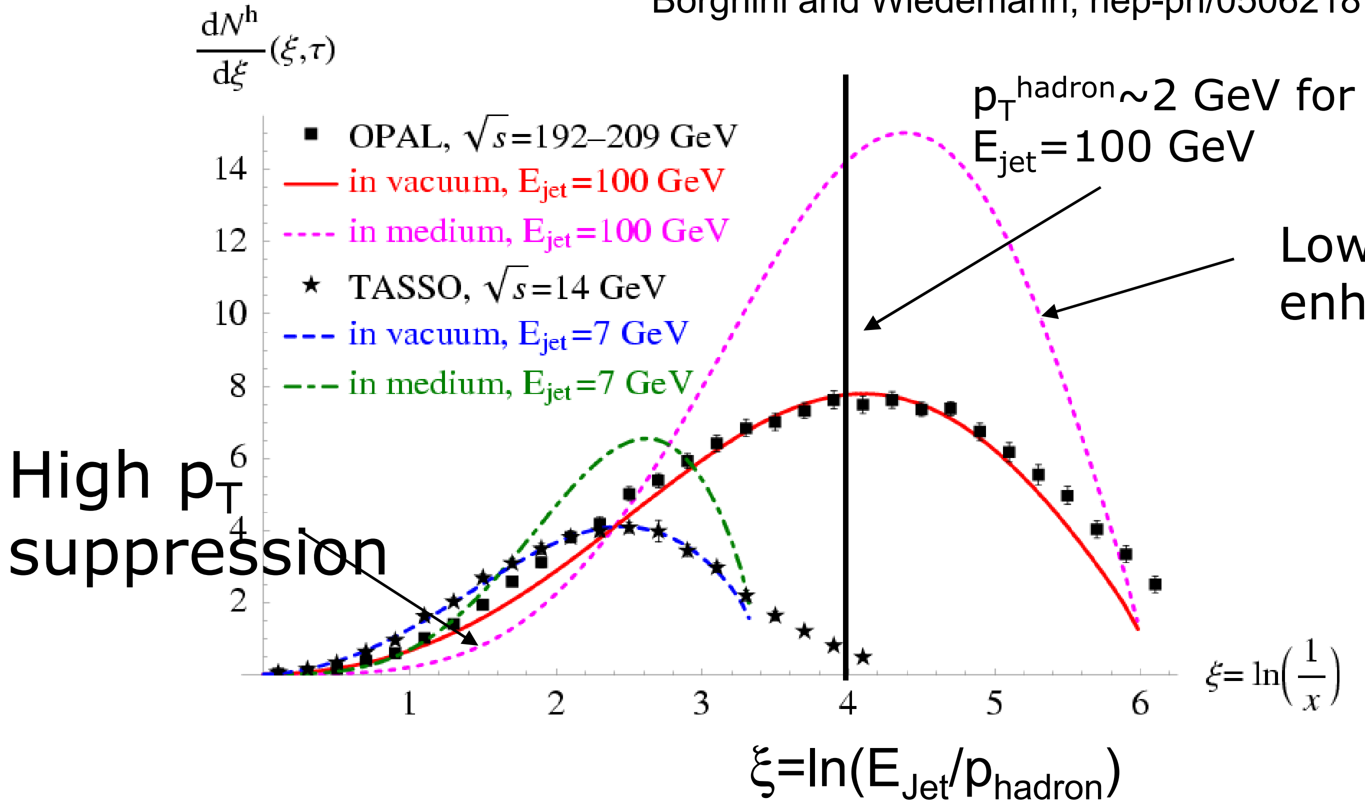


Large background in HI Collisions – must limit jet cone radius R, track p_T cut

$\Rightarrow$ only measure fraction of parton energy - calibrate

Medium effects on jets: FF

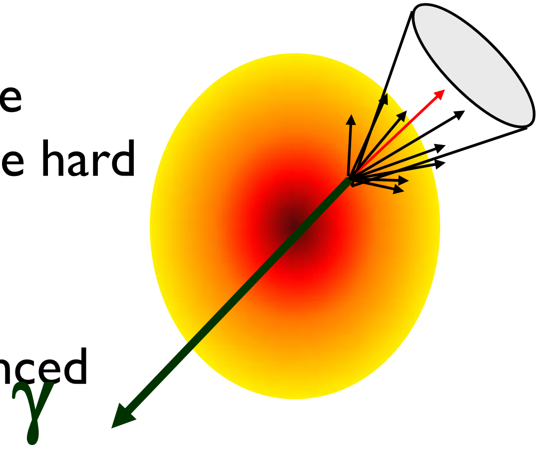
Borghini and Wiedemann, hep-ph/0506218



- Fragmentation strongly modified by medium

Why γ-jet/hadron correlations?

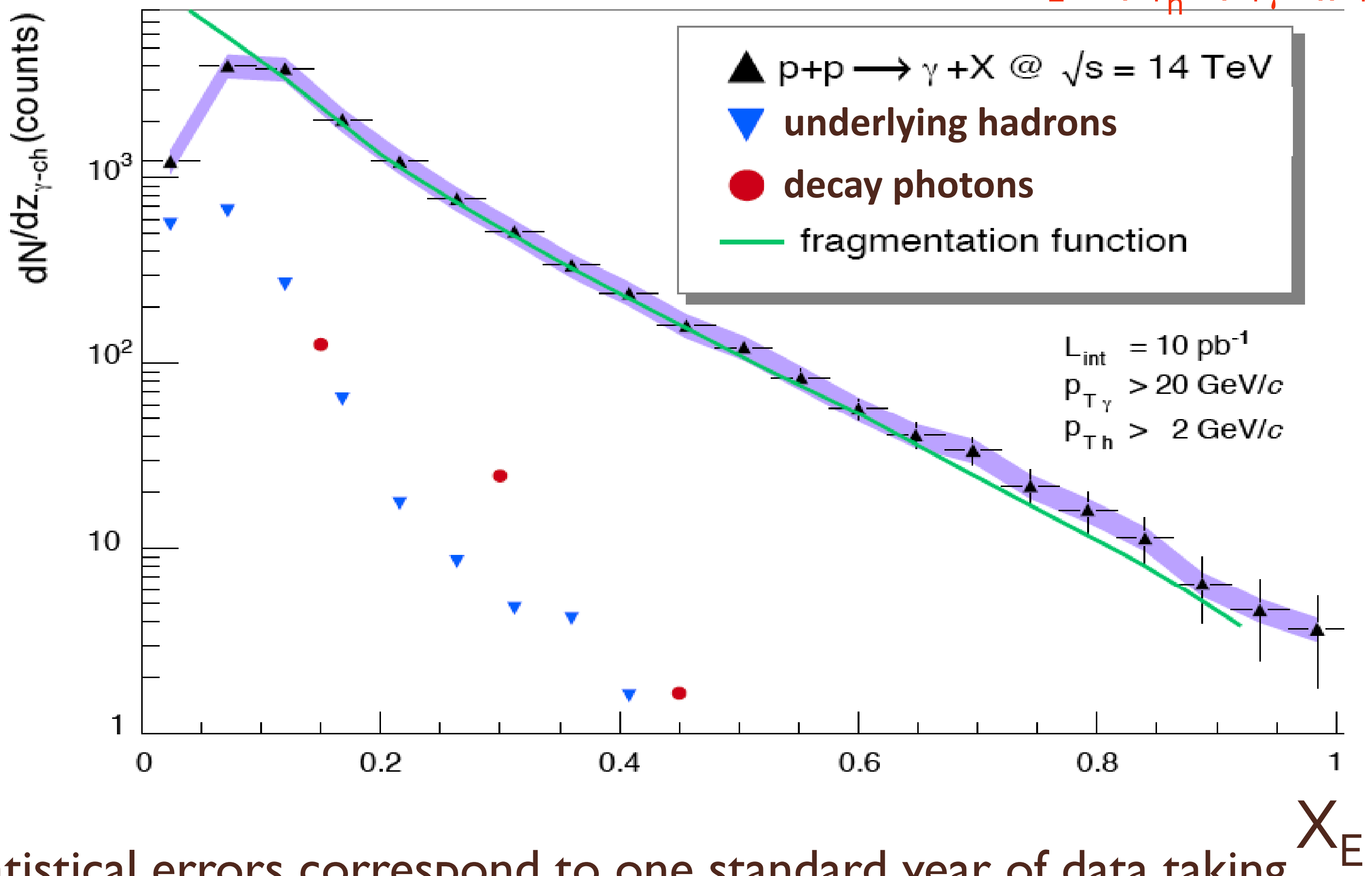
- The photon 4-momentum remains unchanged while traversing the medium and sets the reference of the hard process
- Balancing the hadron and the photon provides a measurement of the medium modification experienced by the jet
- Allows to measure jets in an energy domain (E_{jet} < 50 GeV) where
  - The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



Correlation Function (CF) in pp

EPJC (2008) 57: Y. Mao

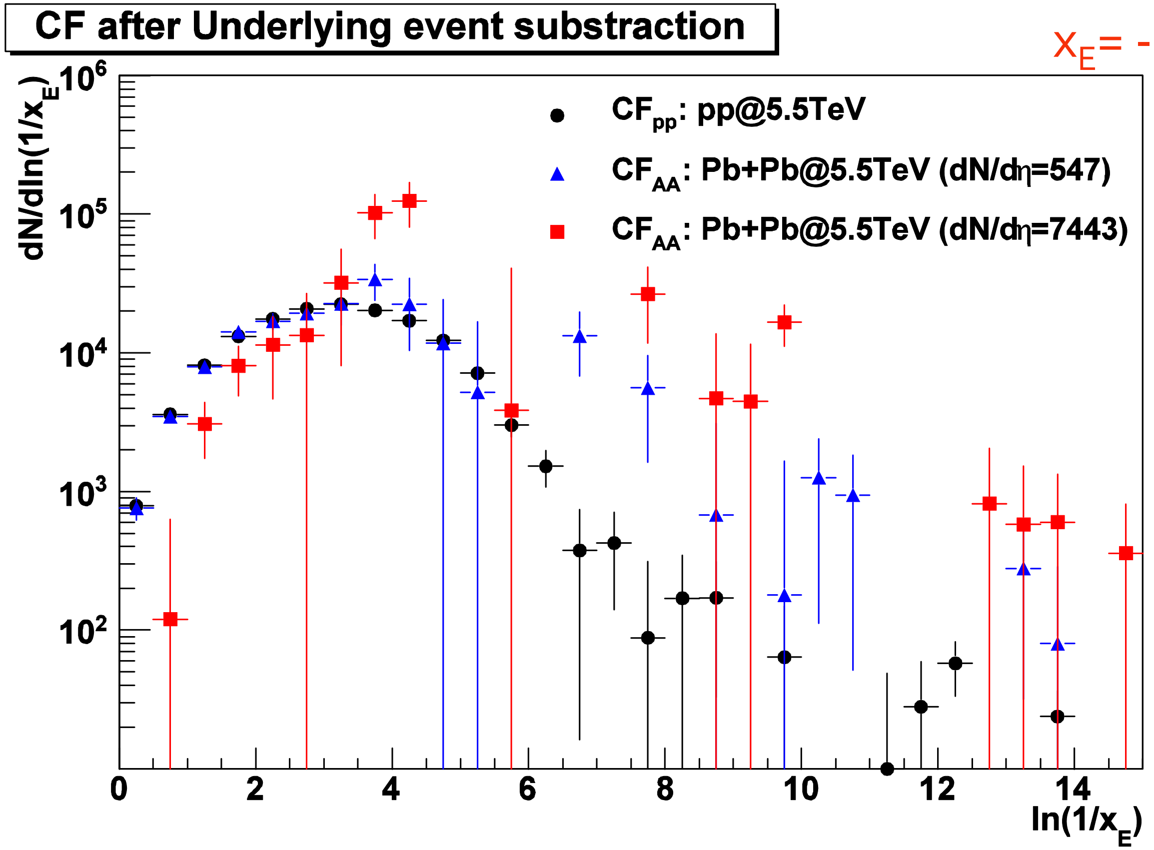
$X_E = -p_{T_h} \cdot p_{T\gamma} / |p_{T\gamma}|^2$



- 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.

and in HI …

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

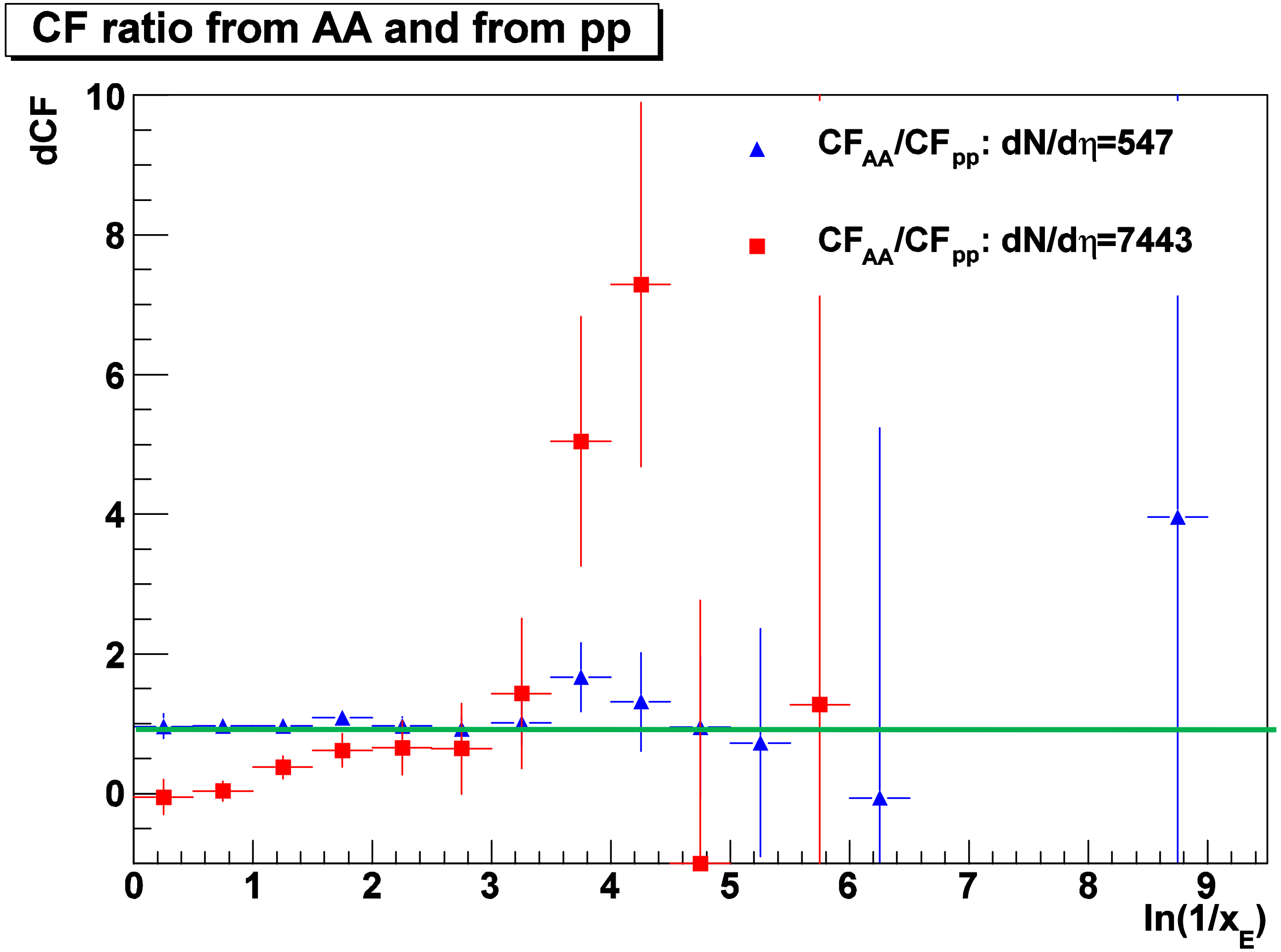


PYTHIA: 10k γ- jet (E_{jet}>20GeV) events ⟶ 10 month of pp data taking

HIJING: 1k MB events ⟶ 1month of PbPb data taking

Quenching model: PYQUEN

Just a preview…



Conclusion…

- There is enough material for very exciting studies …

- But now let us …

- Wait patiently until LHC delivers collisions to make all what I said become eventually true…

Back up

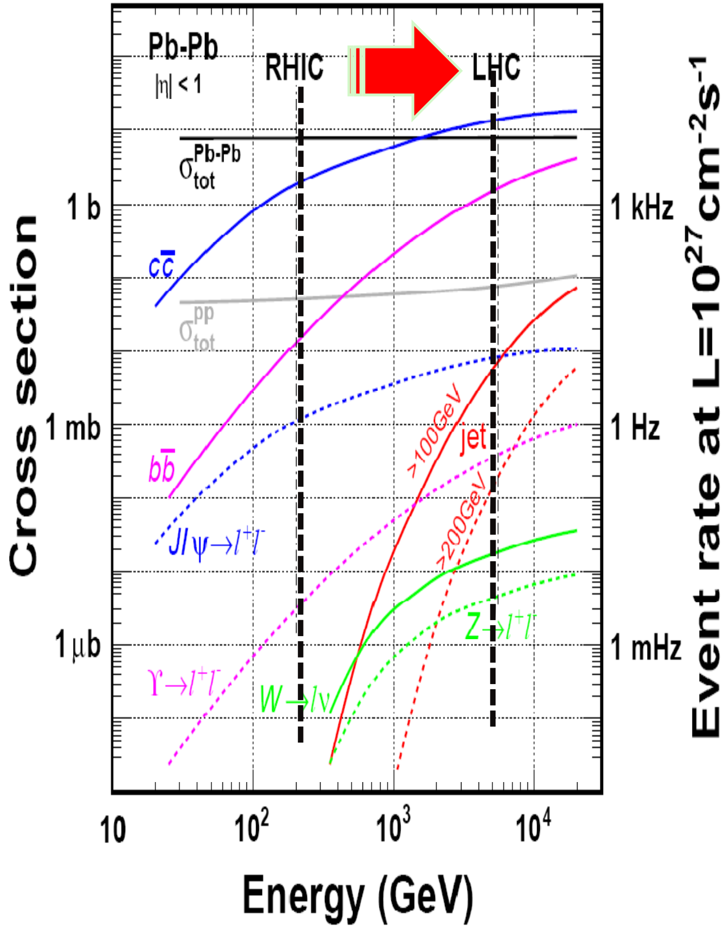
Heavy Ion Physics at LHC

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

- 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 …



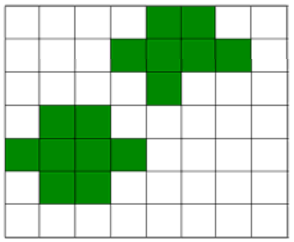
Photon identification in calorimeters

Three regions of analysis

increasing p_T

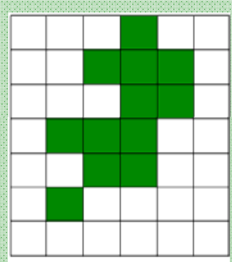
well separated clusters
➔ invariant mass analysis

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



merged clusters
not spherical
➔ shower shape analysis

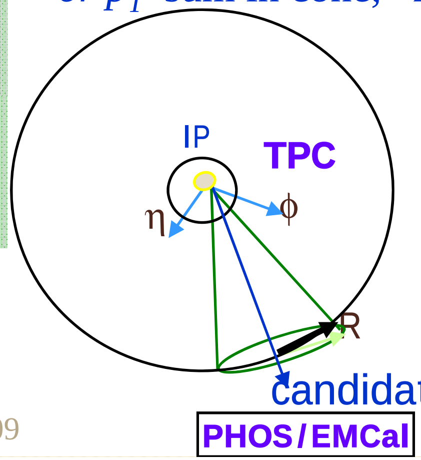
10 - 30 GeV/c in EMCal
30 - 100 GeV/c in PHOS



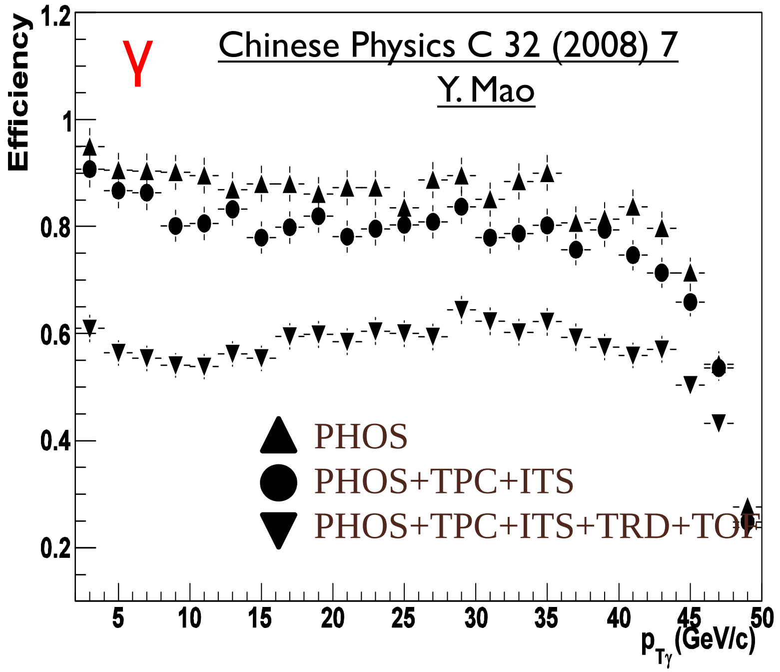
Opening angle << 1 cell
all π^0's at this energy are in jets
➔ isolation cut

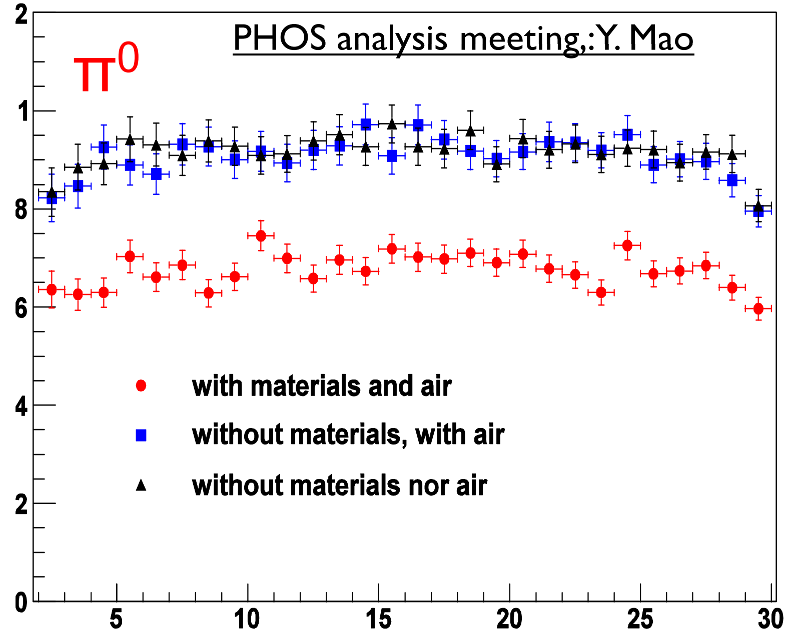
> 30 GeV/c only method in EMCal

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 in PHOS

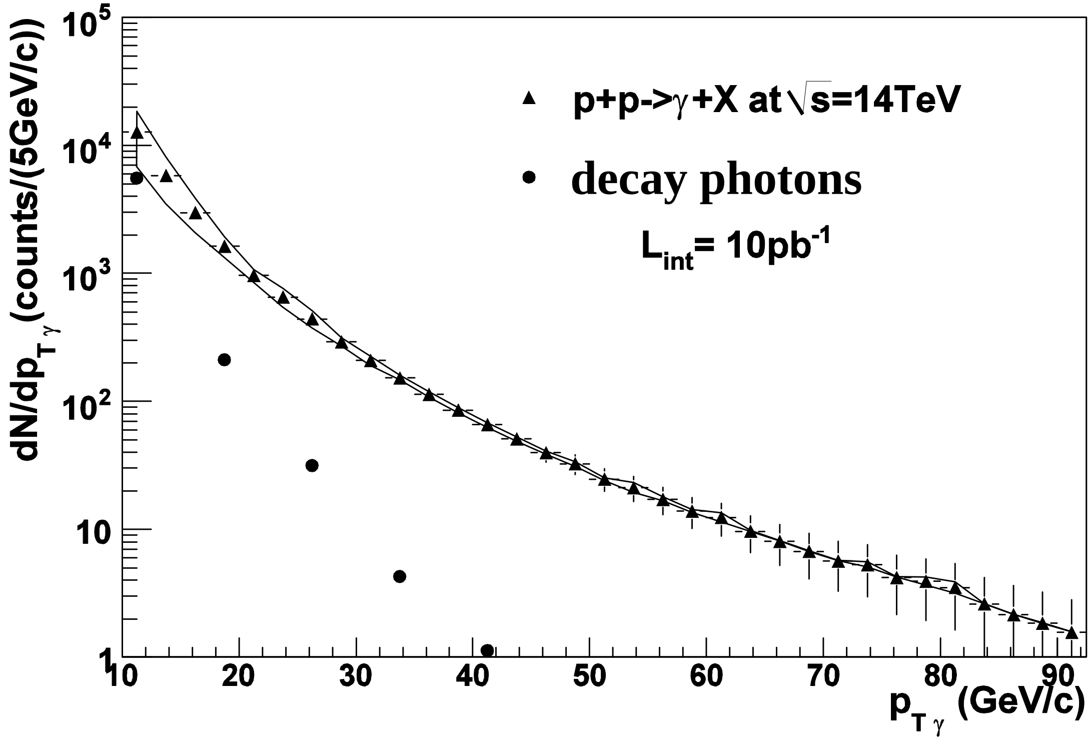




- γ and π^0 identification efficiency is lowered due to the material of the tracking detectors in front of PHOS

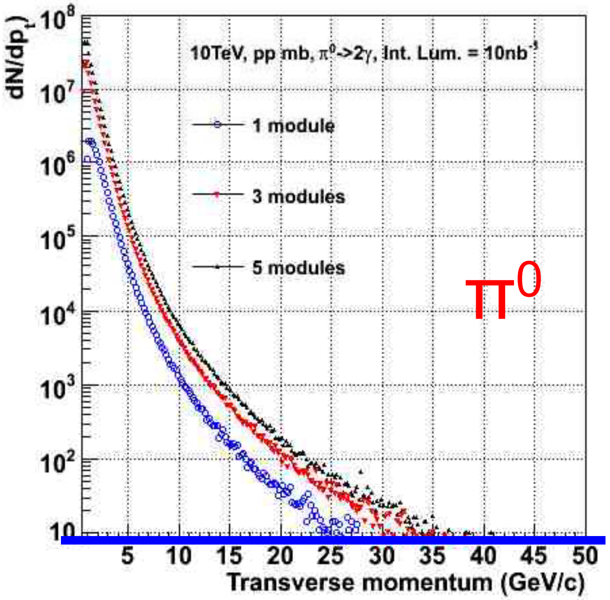
Photon spectrum with PHOS

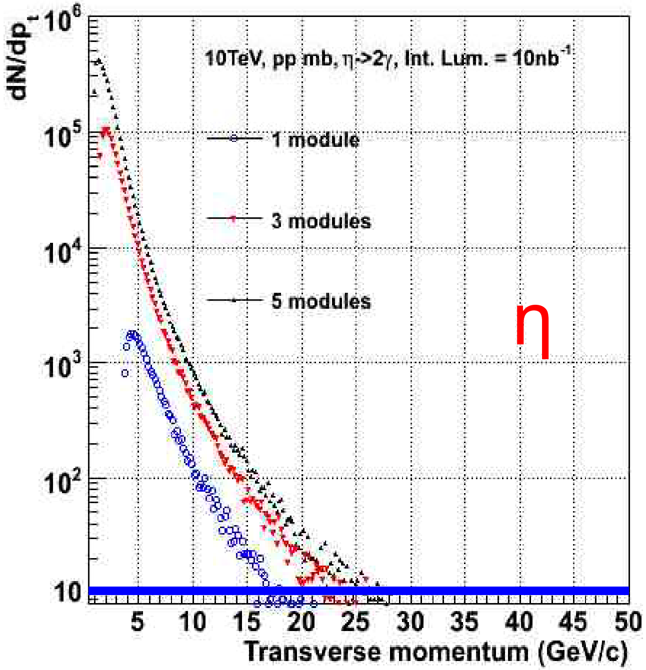
EPJC (2008) 57:Y. Mao

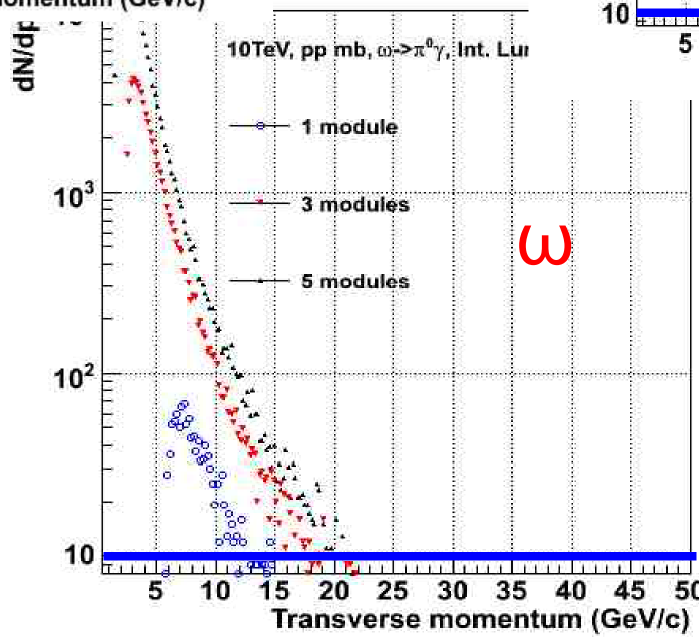


- Estimated counting statistics in one pp run for 2 PHOS modules
- Systematic errors from misidentified π^o

Neutral mesons spectrum with PHOS





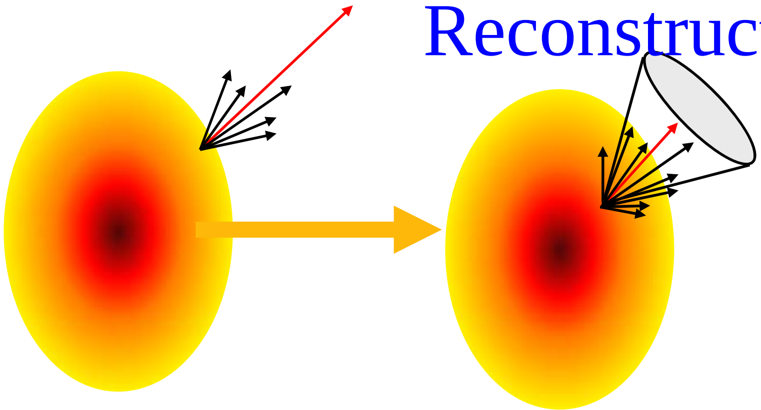


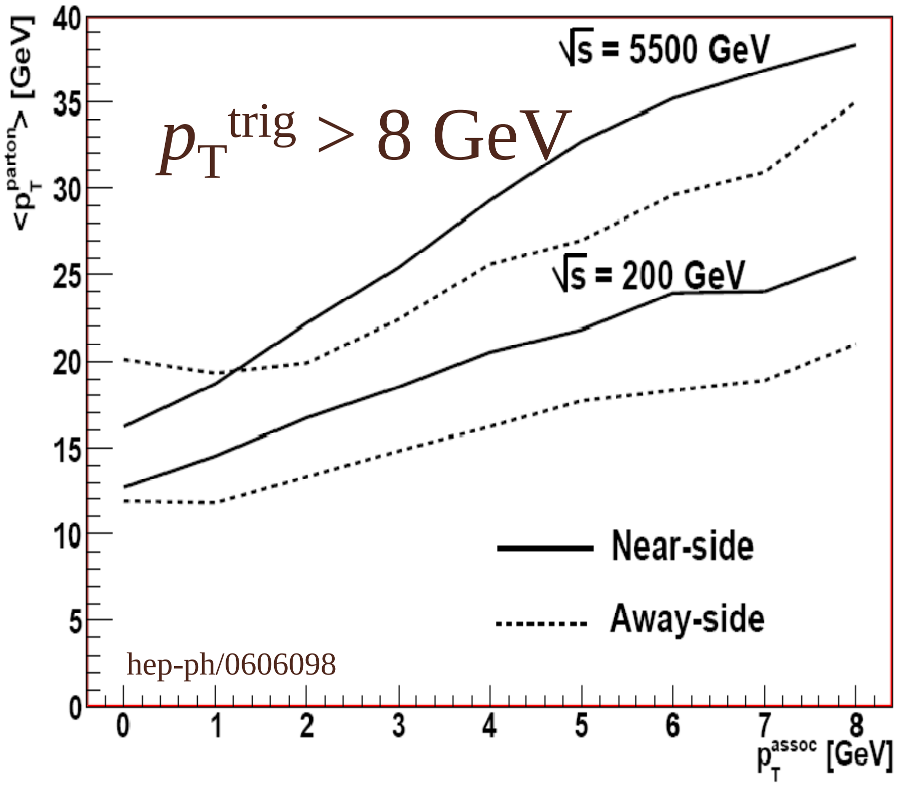
- For the first pp run at LHC

  --by R. Wan

Jet reconstruction

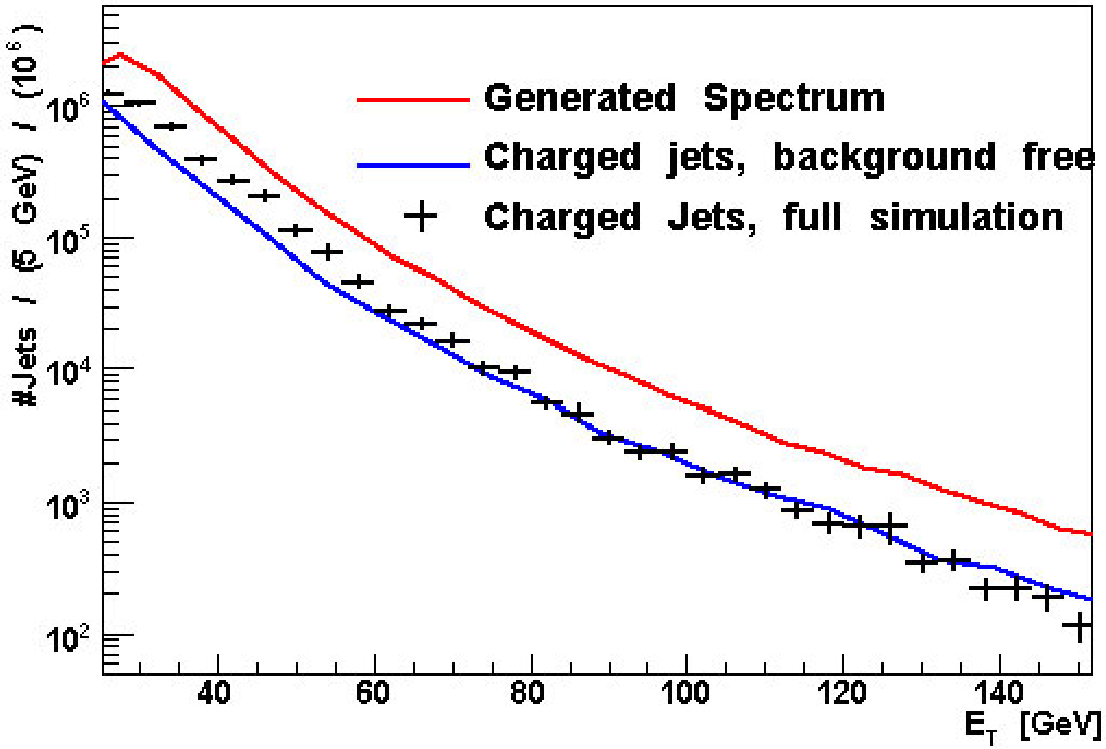
- Trigger bias
- Surface bias





$<p_T^{part}>$ is a function of p_T^{trig} but also p_T^{assoc}, $\sqrt{s}$, near-side/away-side, ΔE

Reconstructed jets



Cone-Algorithm:
$R = 0.4$, $p_T > 2$ GeV

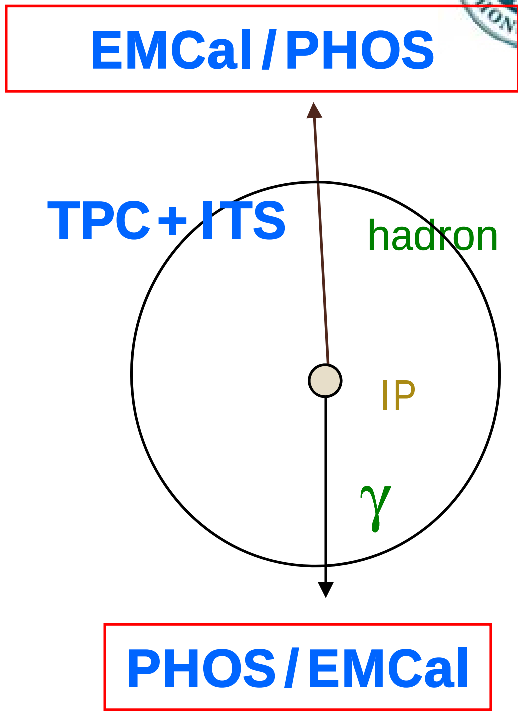
Selection efficiency ~30% as compared to 6% with leading particle !

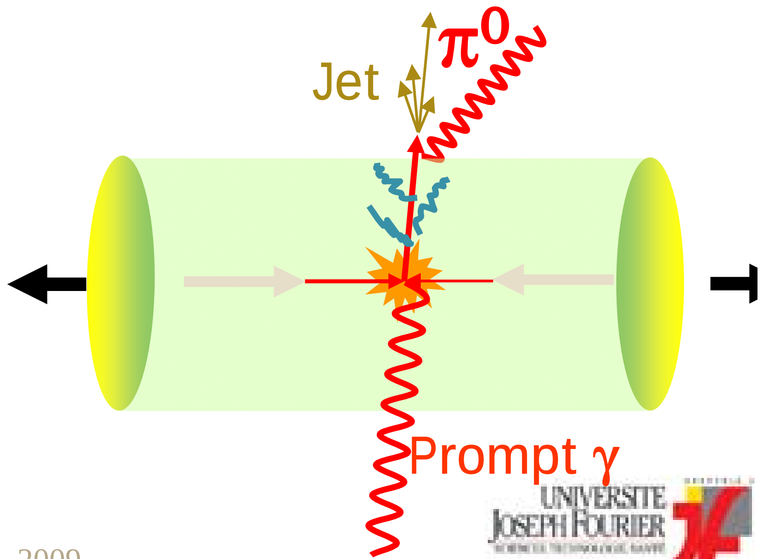
γ-hadron correlations

- Do we really need to reconstruct the jet?
- We could do the same study in a simpler way: tagging hadrons opposite to the isolated γ.
- Suggested by X. Wang, F. Arleo *et al.* in :
  - Phys. Rev. Lett. 77 (1996) 231
  - JHEP 0609:015,2006, hep-ph/0601075
  - JHEP 0411:009,2004, hep-ph/0410088
  - hep-ph/0701207

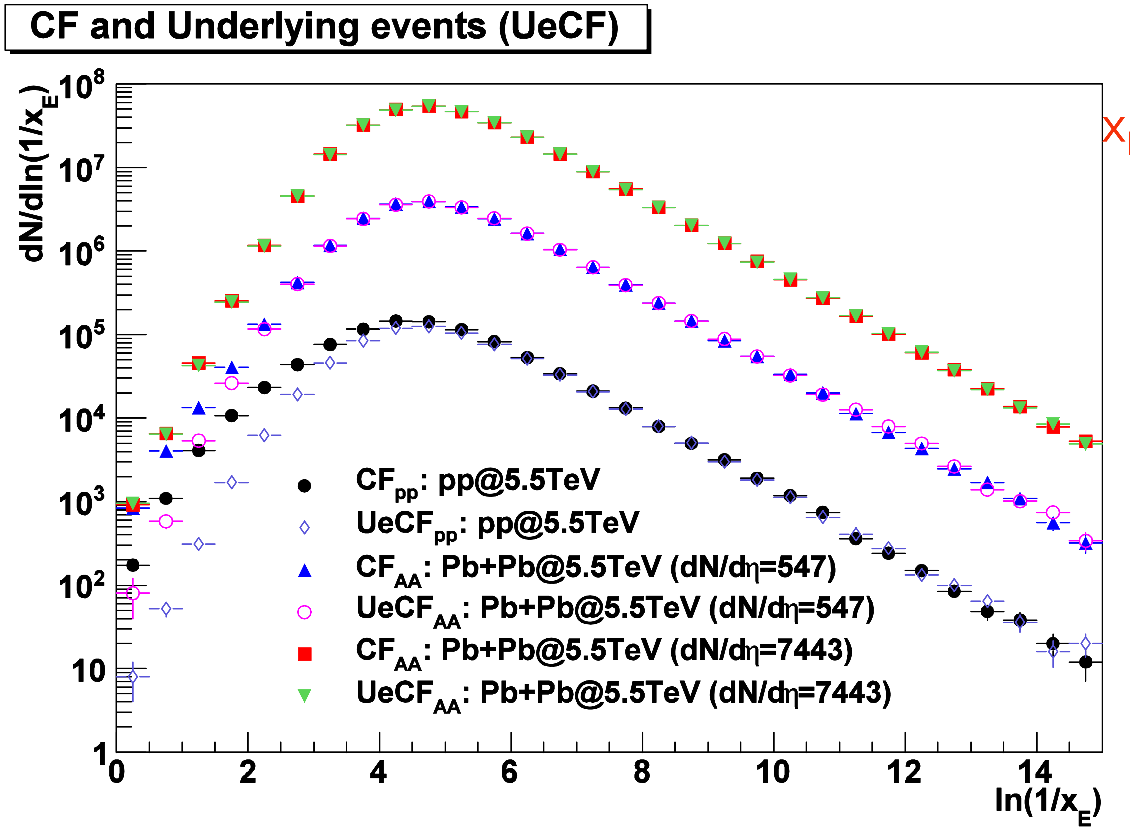
γ-hadron correlations in ALICE

- 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):
    - $90^o < \phi_\gamma - \phi_{hadron} < 280^o$
    - $p_{T\ hadron} > 2$ GeV/c
- Background:
  - Decay photons misidentified as isolated photon
  - Soft hadrons from the underlying event





In HI …

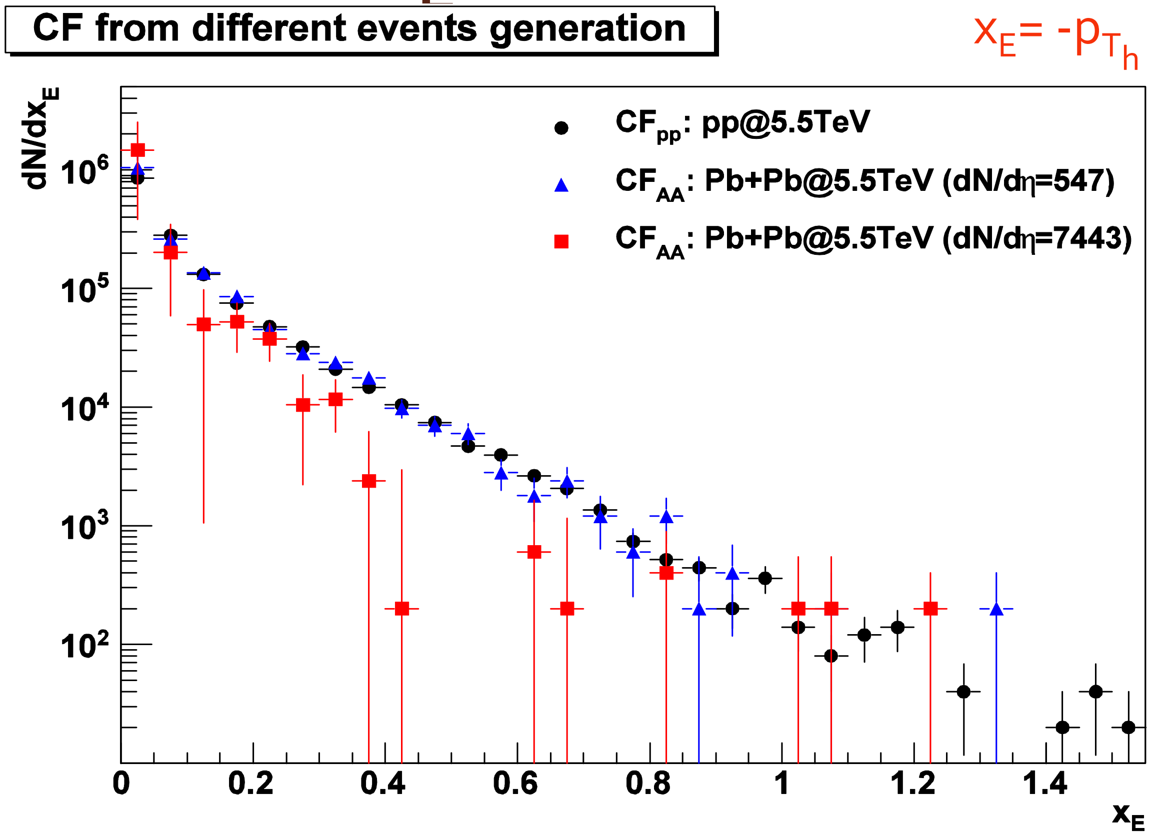


$x_E = -p_{T_h} \cdot p_{T\gamma} / |p_{T\gamma}|^2$

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

CF with X_E…

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



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HIJING: 1k MB events → 1month of PbPb data taking

Quenching model: PYQUEN

$I_{AA} = CF_{AA}/CF_{pp}$ …