High p_T Physics with ALICE/EMCal

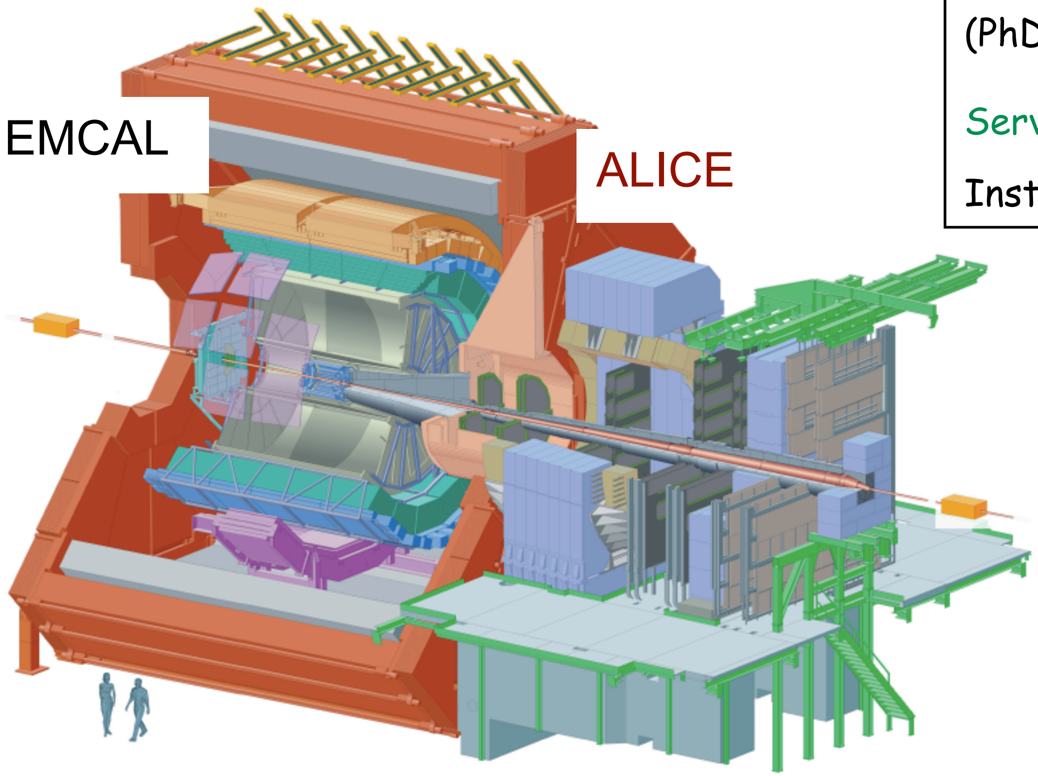
- Physics with ALICE/EMCal
- EMCal performance
- Physics performance (several topics)

Collaboration EMCal/FRANCE :

Subatech Nantes , LPSC Grenoble, IPHC Strasbourg

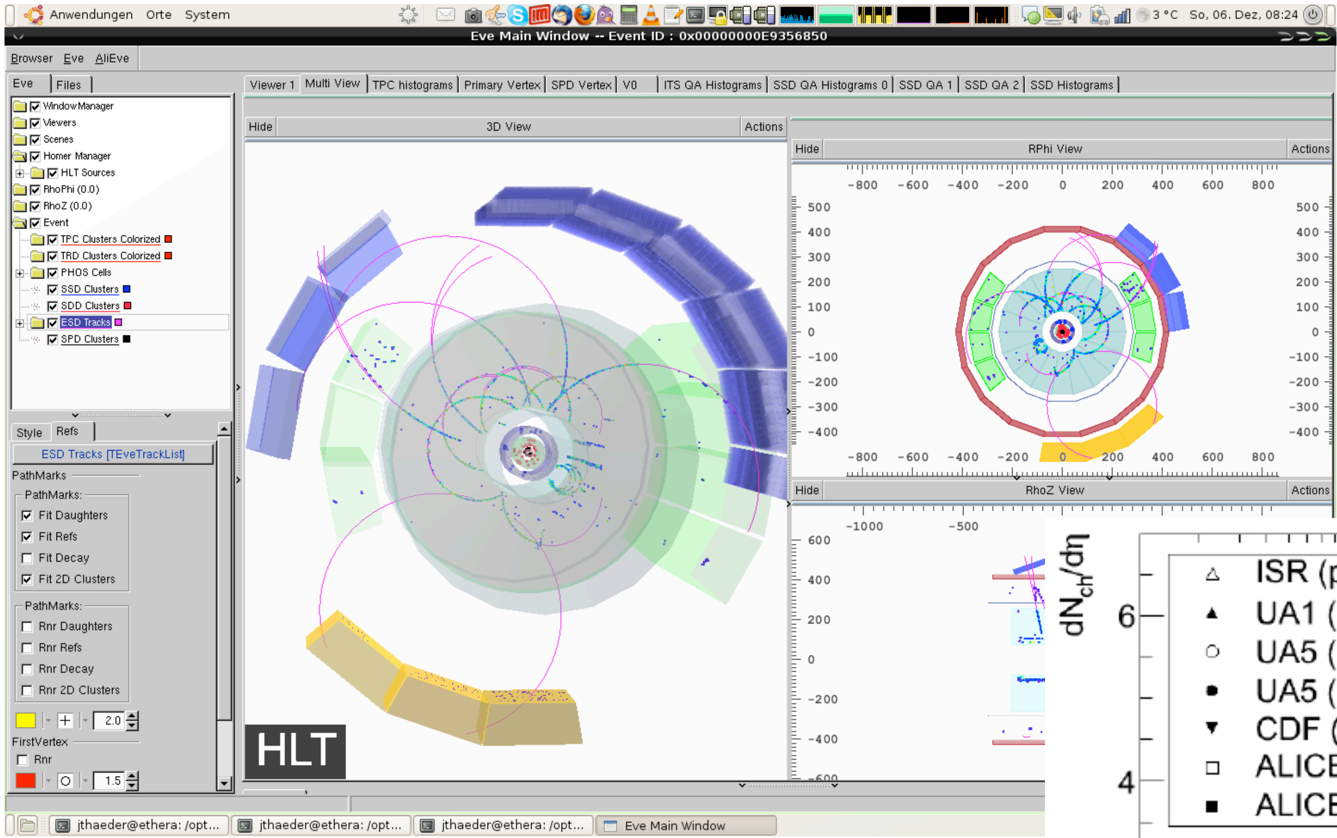
Groupe Physique ALICE/LPSC : G. Conesa-Balbastre (CDD-3ans), J. Faivre (UJF), C. Furget (UJF), S. Gadrat (CDD-3ans), R. Guernane (CNRS), S. Kox (CNRS), Y. Mao (PhD), J.S. Réal (CNRS)

Services techniques impliqués du LPSC (coord. J.M Muraz) : Instrumentation, Electronique, Mécanique, Informatique



C. Furget, 10 décembre 2009,
LHC colloquium, LPSC

First pp collisions with ALICE

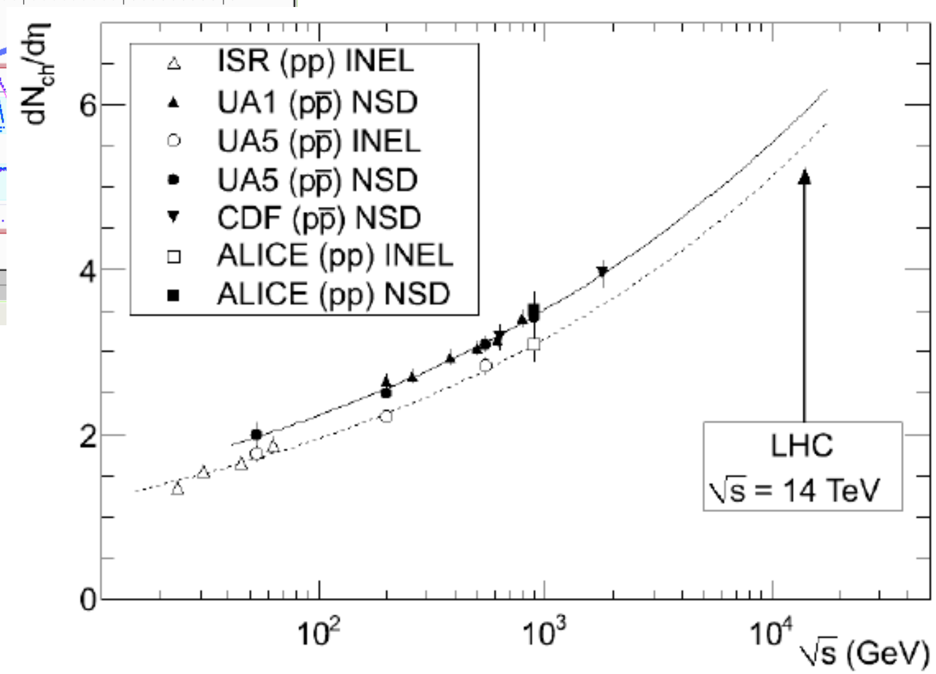


Sunday Dec. 6th 2009 :

First collisions with all working subsystems

First results :

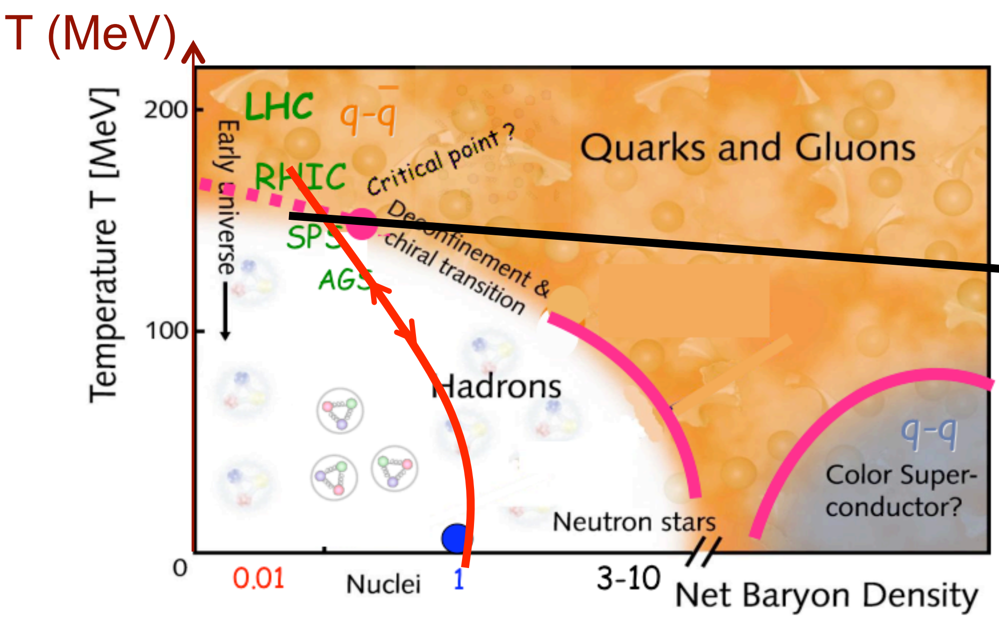
Charged particle density

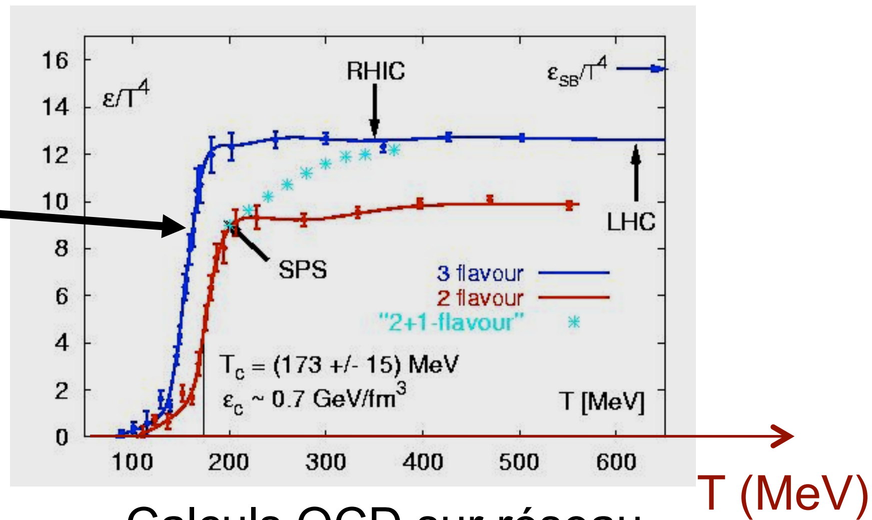


High energy A-A collision and quark-gluon plasma

Understanding QCD interaction using A-A collisions requires

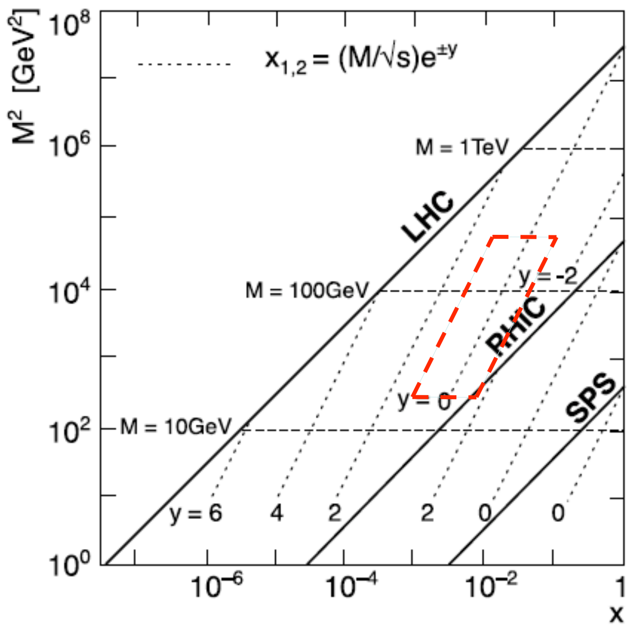
1. to create the quark-gluon plasma (QGP) (high temperature, large volume)
   - ⇒ Measure the energy density / temperature of the medium
2. to study the QGP properties through its interaction of high energy parton
   - ⇒ select a hard scattering process at the parton level (PDF, …)
   - ⇒ measure the particle production after hadronization (Fragmentation Function, …)





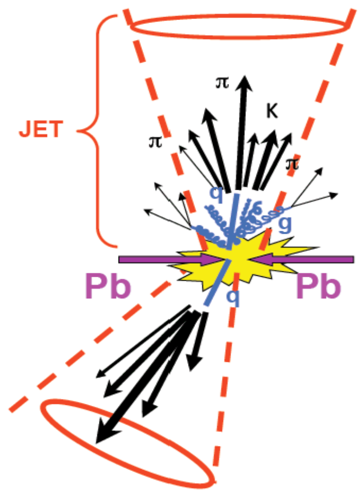
Calculs QCD sur réseau

High p_T Physics : π^0, photons, jets and correlations



Why high p_T ?

- ✓ High p_T (10-250 GeV) particles are produced directly from parton-parton hard scattering processes.
- ✓ Proton-proton collisions provide reference data for A-A collisions and a better understanding of the underlying QCD physics (PDF, hadronization).
- ✓ Different particles (photons, π^0, jets) produced in the collisions will not interact in the same way with the QGP.
- ✓ For jet studies, changes in jet profile is related to the parton energy loss in the QGP.



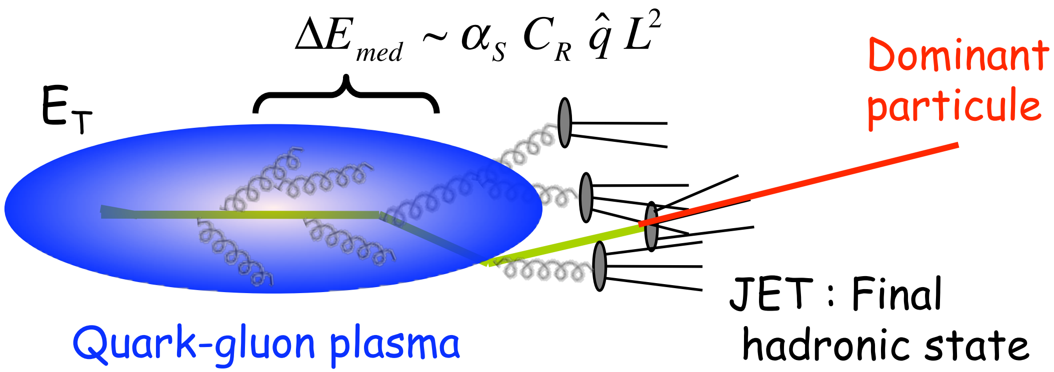
Physics case : jet quenching

Energy loss of high energy partons in quark-gluon plasma (QGP)

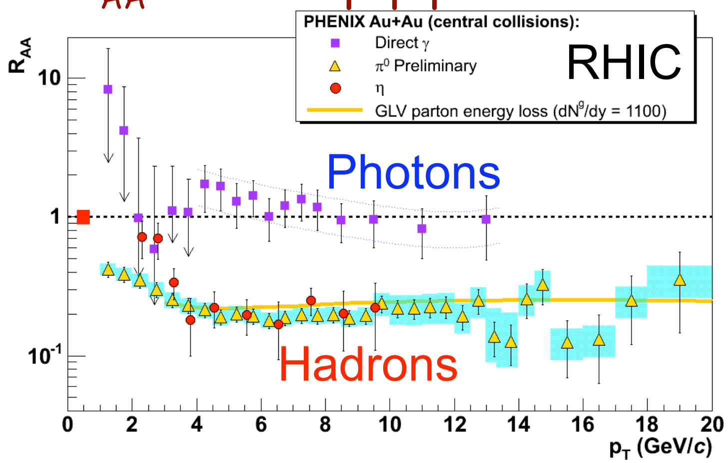
✓ A parton of high energy E_T is coming from the initial state (hard scattering).

✓ By passing through the QGP, the parton loss an energy ΔE_{med} by collision and/or bremstrahlung.

✓ Production of a jet of hadrons in the final state from parton hadronization



R_{AA} = A-A / p-p production ratio



So the QGP will modify the momentum distribution inside the jet

(Total jet energy is unchanged)

Fragmentation function (F.F.) measurement

Inclusive jet measurement :

✓ Extract the initial parton energy from the jet energy reconstruction

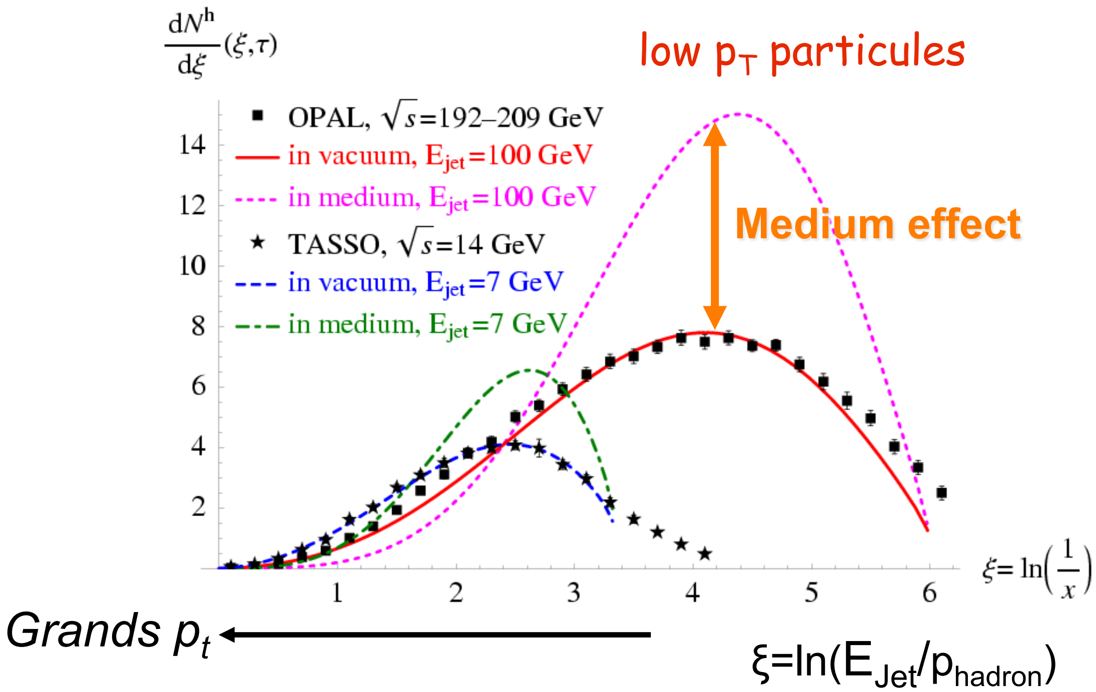
✓ Calculate the F.F. from the momentum distribution of charged particles

Coincidences γ-jet measurement :

✓ Deduce the initial parton energy from the photon energy measurement

✓ Calculate the F.F. from the momentum distribution of charged particles

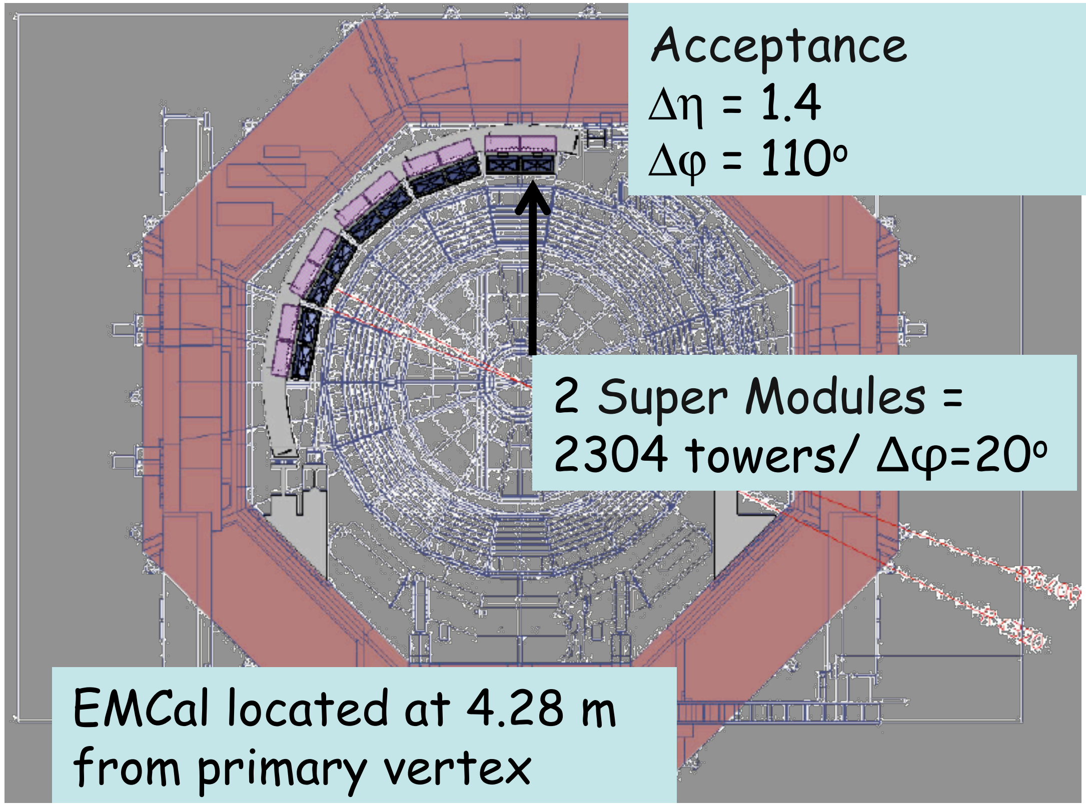
Increased rate of low p_T particules



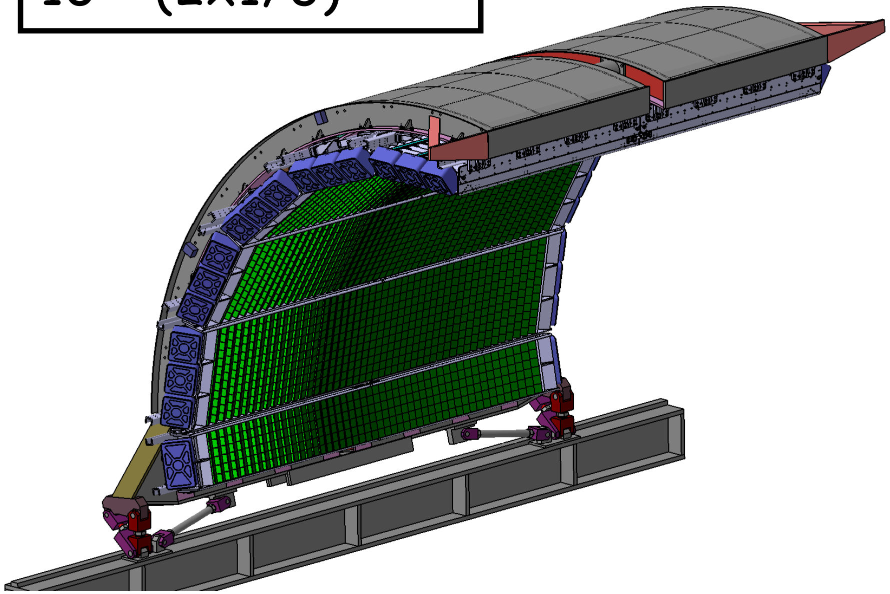
Need : - Tracking detectors (charged particles) : ITS+TPC

- calorimetry (neutral particles) : EMCal

EMCal calorimeter



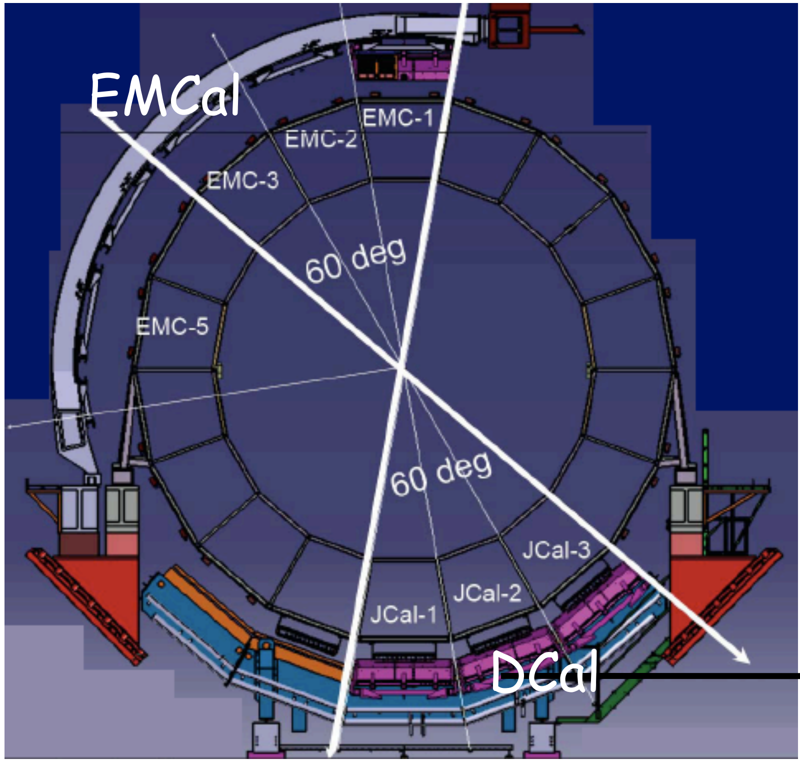
11 SuperModules
10 + (2x1/3)



Scintillator-Lead sampling calorimeter

- 1 module = 4 towers
- 1 towers = 77 layers
  1.76 mm scint./ 1.44 mm Lead
- Readout via optical fibers

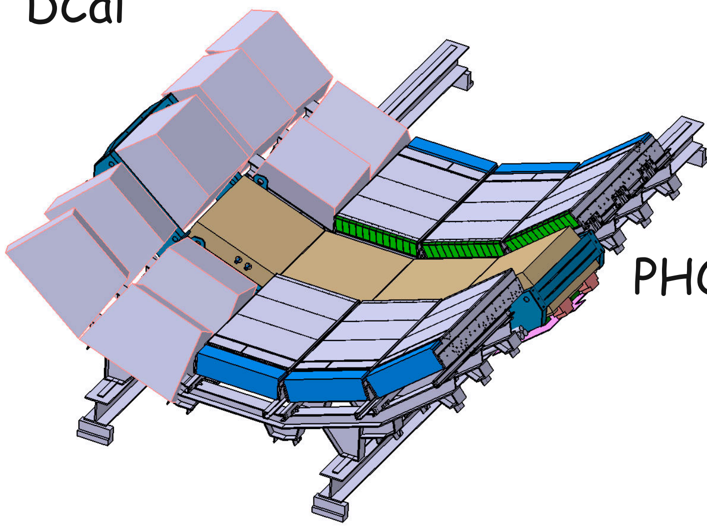
From EMCal to Dcal (for Di-jet calorimeter)



New proposal (approved by ALICE coll.) :

✓ Add a new calorimeter (Dcal) in addition to PHOS at $260 < \Delta\Phi < 320$

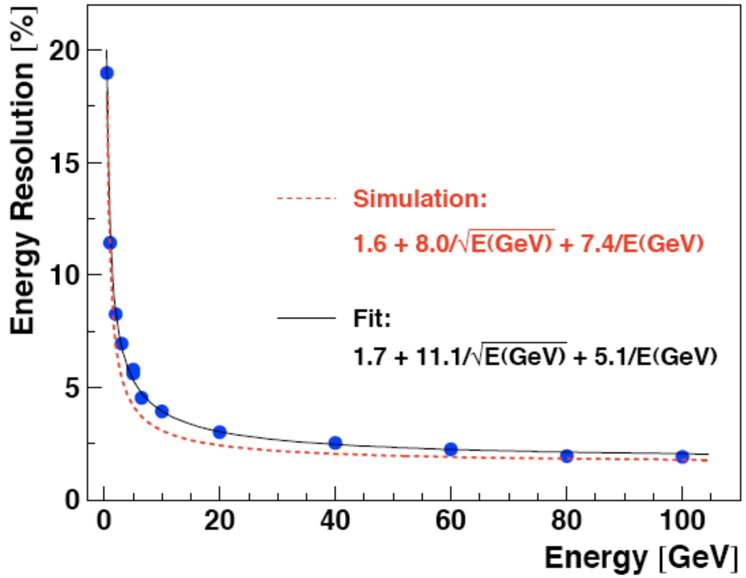
✓ Will provide additional observables on γ–jet, π^0–jet and jet–jet coincidences

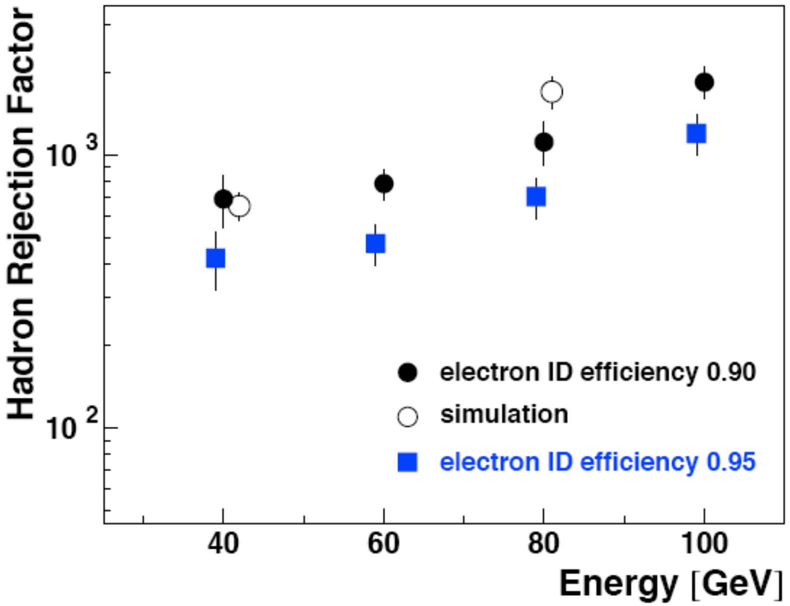


EMCal calorimeter performance

Beam tests performed at CERN (2007)

- ✓ Test of 4x4 modules (8x8 tours)
- ✓ Final electronics (FEE) + DAQ ALICE
- ✓ Electron and hadron beams at 0.5 à 100 GeV/c @ SPS and PS





EMCal performance :

- ✓ Energy resolution within specs

$$\frac{\sigma(E)}{E}(\%) = \frac{11.1}{\sqrt{E}} \oplus \frac{5.1}{E} \oplus 1.7$$

- ✓ ~1 % linearity measured between 10 to 100 GeV
- ✓ Hadron rejection > 600 for electron PID = 90%
- ✓ Cosmics calibration performed at ~3%

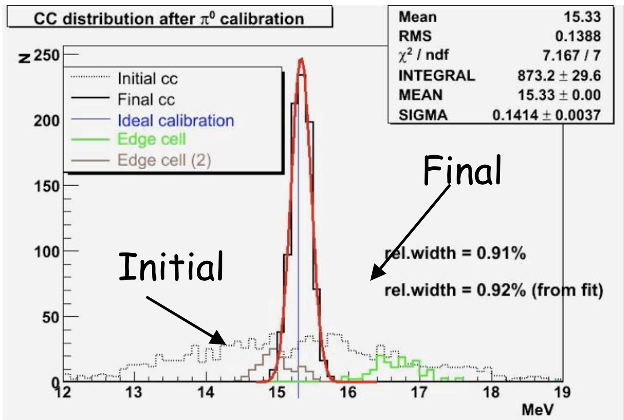
EMCal Monitoring and calibration

(Services SDI, Electronique + groupe ALICE)

Goal : achieve 1 % accurracy on the energy scale

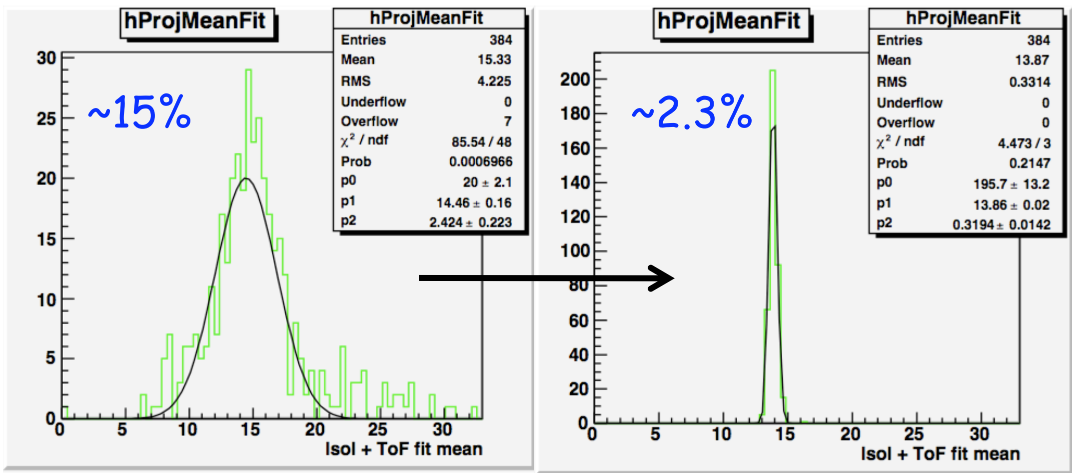
- ✓ Monitoring using LED system (temperature dependence)
- ✓ Cosmics calibration performed at LPSC (<3% tower by tower dispersion achieved)
- ✓ 1% final calibration using π^0 invariant mass reconstruction

π^0 invariant mass reconstruction



Coefficients de calibration

Cosmics calibration



EMCal contribution to ALICE experiment

Extend ALICE capabilities to high p_T photon and jet measurements:

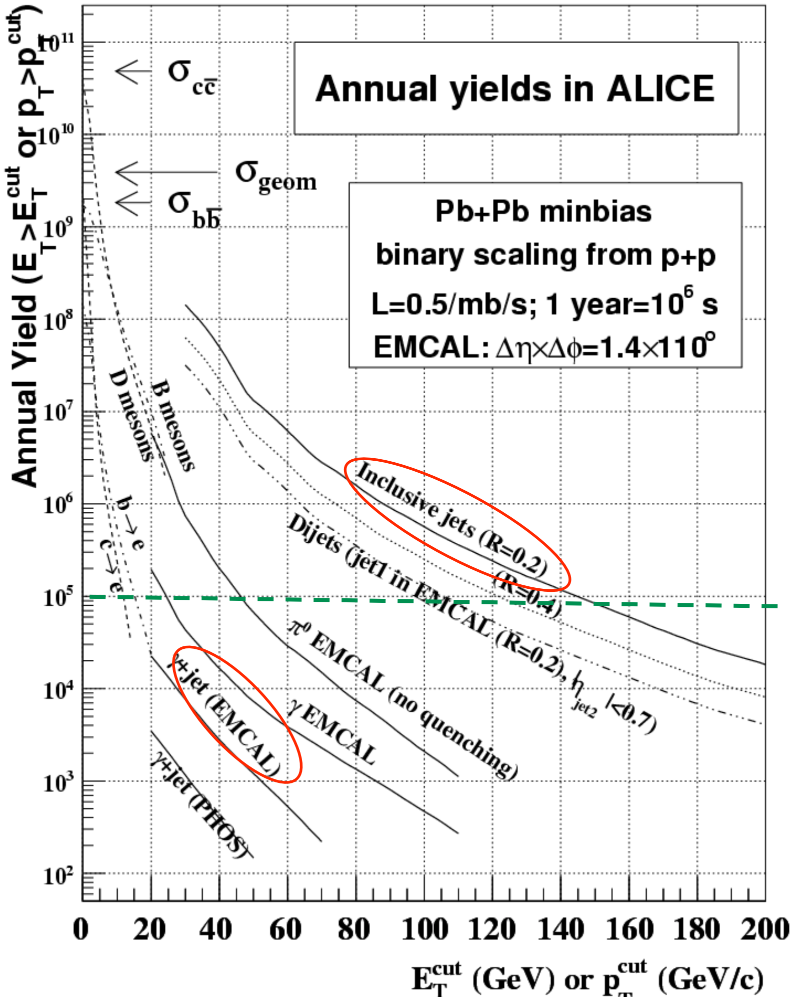
✓ Increase (x7) the detection acceptance (compared to PHOS)

✓ Increase statistics on jet measurement for p_T up to 250 GeV/c by implementing a specific trigger

✓ Improve jet energy reconstruction (x2 for 100 GeV jet energy) + jet energy resolution (x1.4 at 100 GeV)

✓ Discrimination between γ and π^0 for p_T > 10 GeV/c

✓ Electron identification for 10 < p_T < 50 GeV/c for b-jets

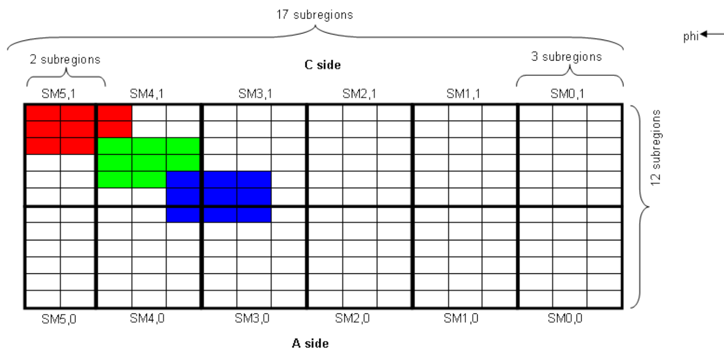


Jet trigger performance

L1 jet trigger is needed to optimize the jet detection for p-p and A-A collisions :

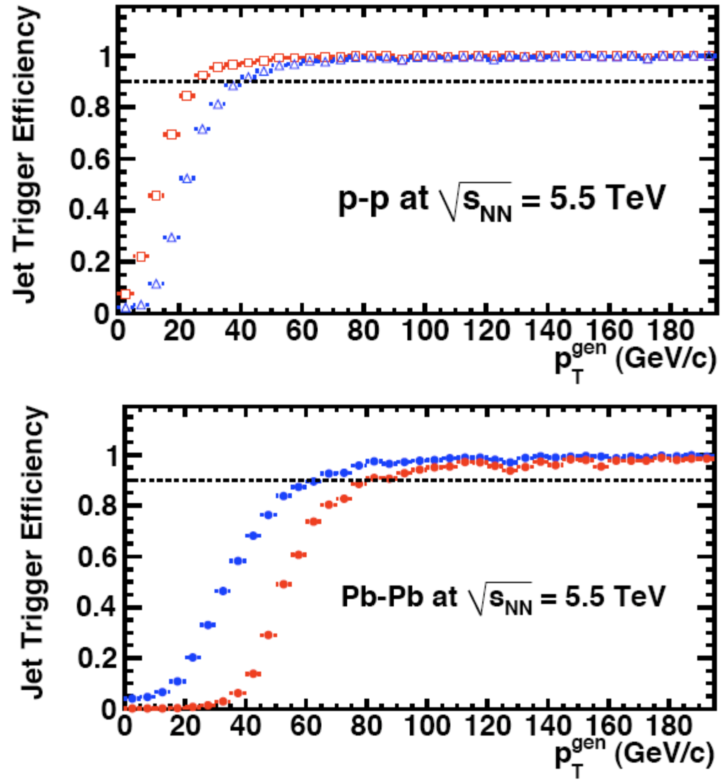
- ✓ Energy sum over a large acceptance (R=0.4 ~ 400 towers)
- ✓ Apply a centrality dependent threshold (V0 detector)

(service électronique + groupe ALICE)



System	$\sqrt{s}$(TeV)	$L_{mean}(cm^{-2}s^{-1})$	Time (s)	DAQ rate (Hz)	Gain at L1
p–p	5.5	5×10^{30}	10^5	500	110
p–p	14	5×10^{30}	10^7	500	500
Pb–Pb Centrality					
min. bias	5.5	5×10^{26}	10^6	20	21
min. bias	5.5	5×10^{26}	10^6	50	9
min. bias	5.5	5×10^{26}	10^6	100	4
0–10%	5.5	5×10^{26}	10^6	50	5
0–10%	5.5	5×10^{26}	10^6	100	2
60–80%	5.5	5×10^{26}	10^6	50	12
60–80%	5.5	5×10^{26}	10^6	100	6

Jet trigger efficiency

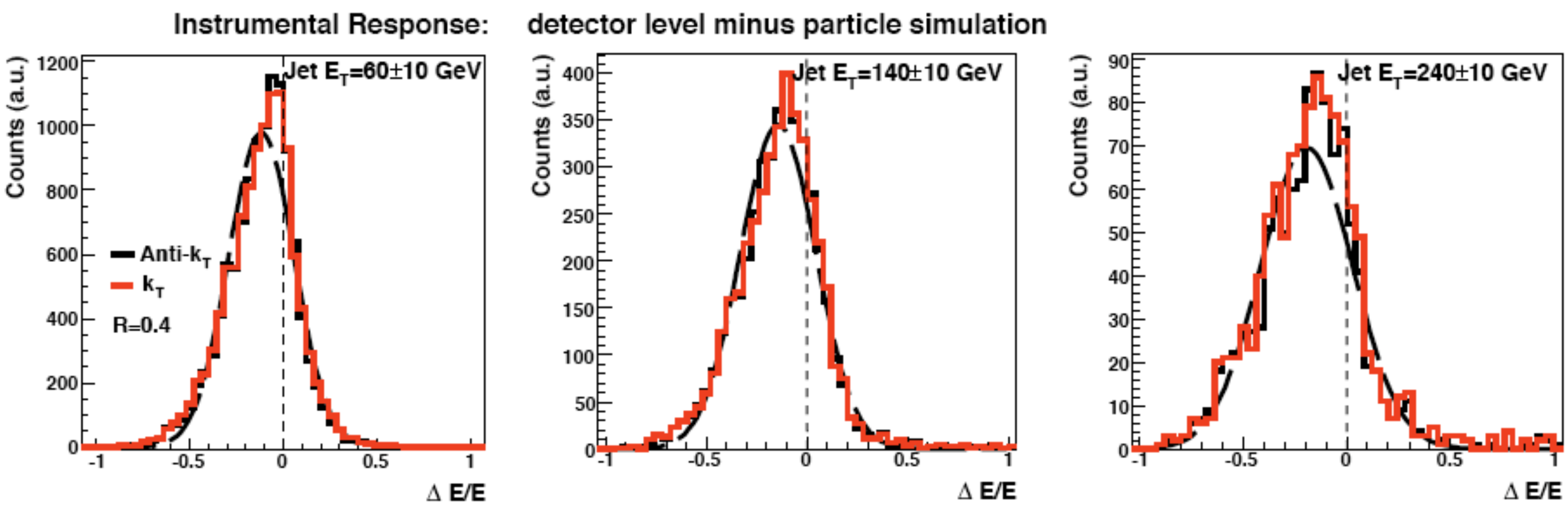


Jet energy resolution

Instrumental effects on jet energy measurement

✓ Shift (~ 11-20%) : experimental cuts (jet cone, low p_T), undetected neutral particle, tracking efficiency

✓ Resolution (~ 18-22%) : charged particle tracking and calorimeter resolution



Inclusive jet cross-sections measurement

Methodology

- ✓ Fast level 0/1 trigger provided by EMCal
- ✓ Combine Precise charged particle tracking in 0.5 T B-field with the deposit energy in EMCal
- ✓ Correction for double counting (electrons and hadrons) and for unmeasured neutral hadrons

Systematic effect	Incl. cross section sys. uncert.
Common in p–p and A–A	
Tracking distortions (space charge etc.)	unknown
Tracking efficiency	1%
Hadronic and electron energy double counting	3-4%
EMCal energy scale	8-10%
Unobserved neutral energy	13-15%
Underlying event (central Pb–Pb)	
Fluctuations	20% (75 GeV/c), 3% (150 GeV/c)
False Jets	small (>50 GeV/c)

⇒ EMCal calibration

⇒ Unmeasured neutral hadrons

⇒ Large background fluctuations at small jet energy

Deconvolution of Background fluctuation

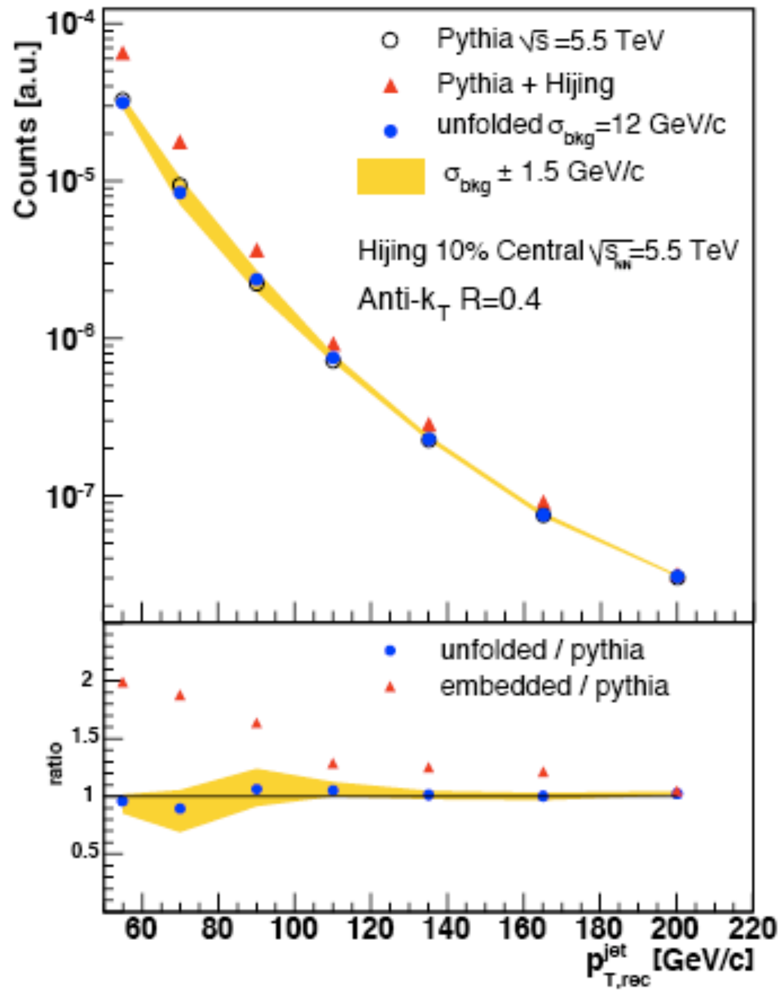
Background correction applied on the inclusive jet spectrum

$$E_{jet} = E_{jet}^{rec} - \rho \times A \pm \sigma \times \sqrt{A}$$

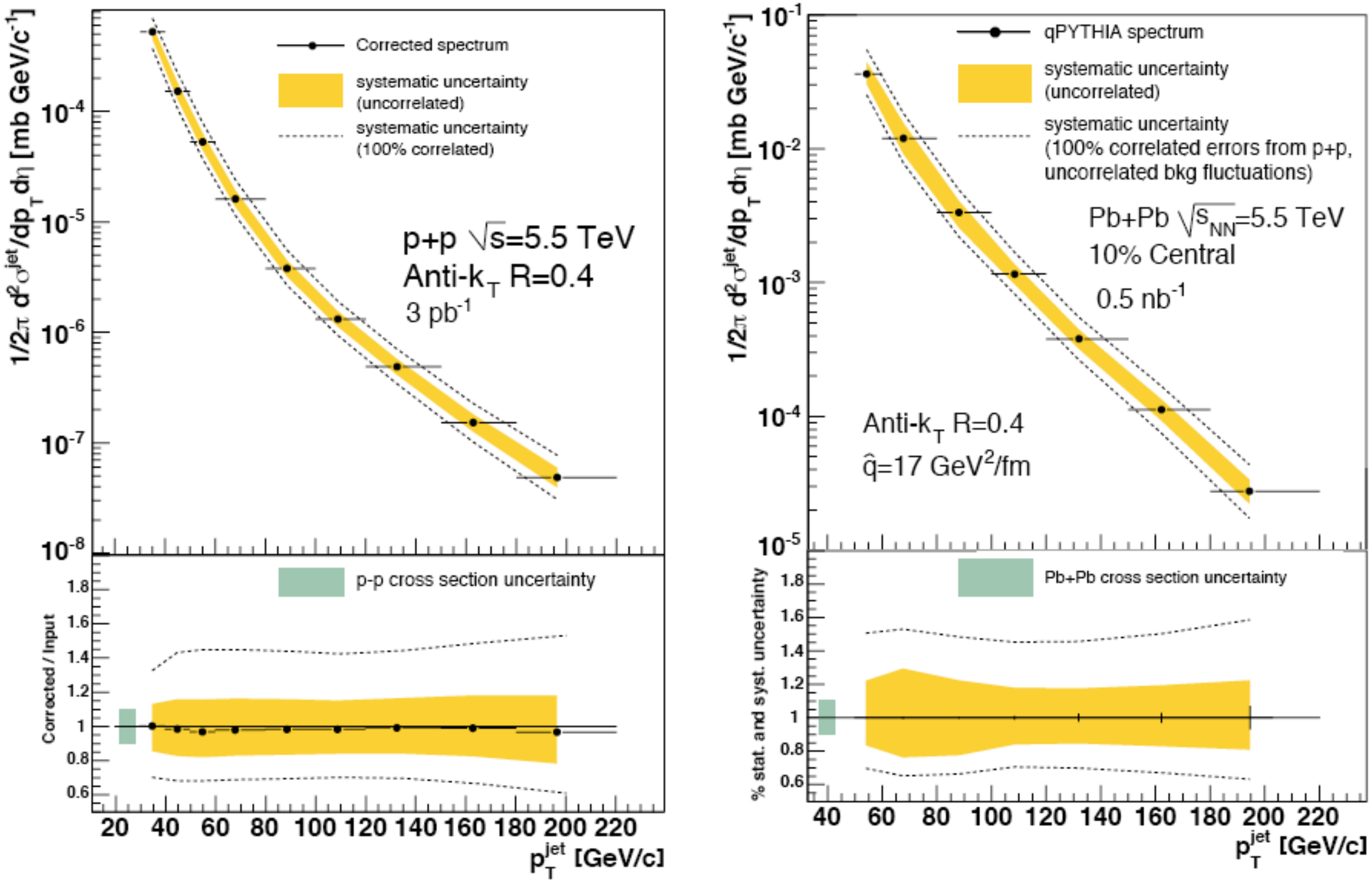
where A is the jet area.

✓ Underlying background ρ ~ 200 GeV/unit area for cone radius R =0.2 to 0.4 corrected for each event.

✓ Background fluctuations σ ~ 12.5 GeV/c corrected on the inclusive spectrum via unfolding.



Inclusive jet production



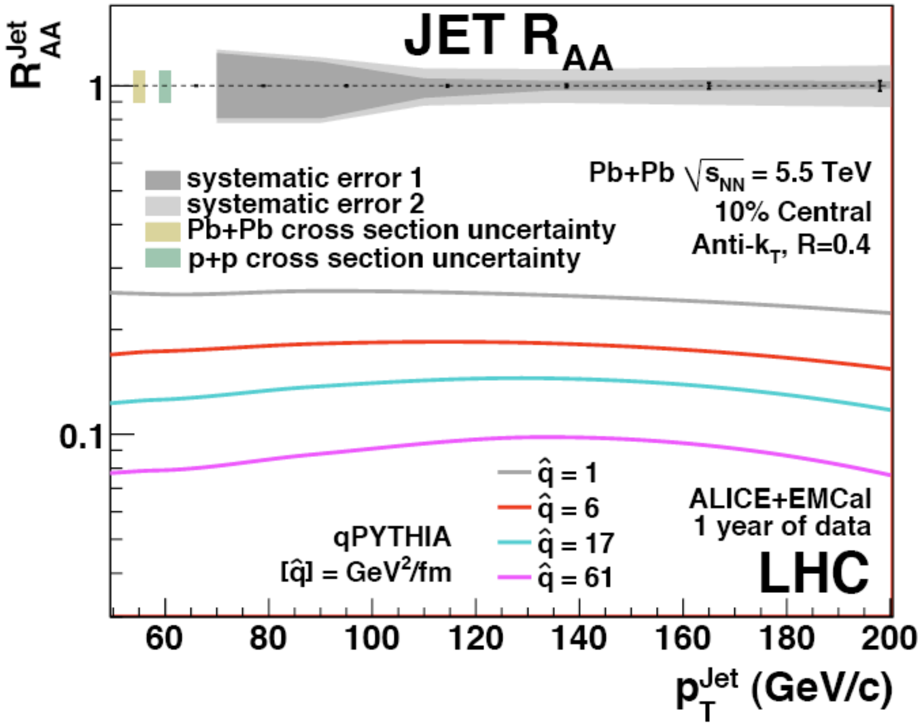
Inclusive jet production

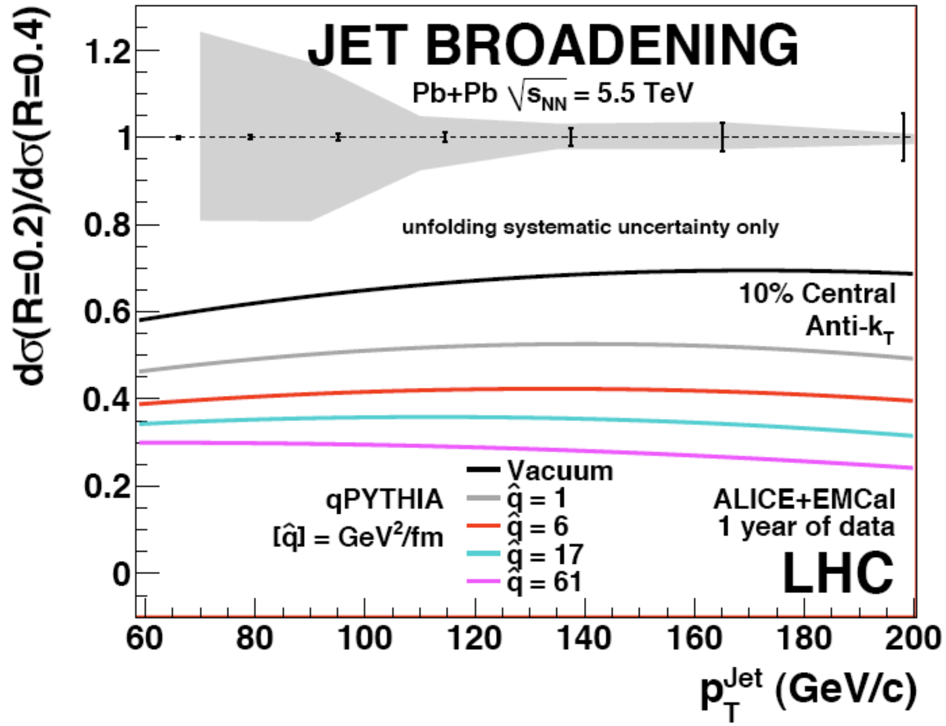
Theoretical predictions and systematic uncertainties jet quenching observables

✓ pp cross-section uncertainties : Luminosity, trigger efficiency, Glauber scaling

✓ Pb-Pb cross-section uncertainties : Luminosity, trigger efficiency

✓ Background fluctuation dominates the uncertainty at low jet energy (< 120 GeV)



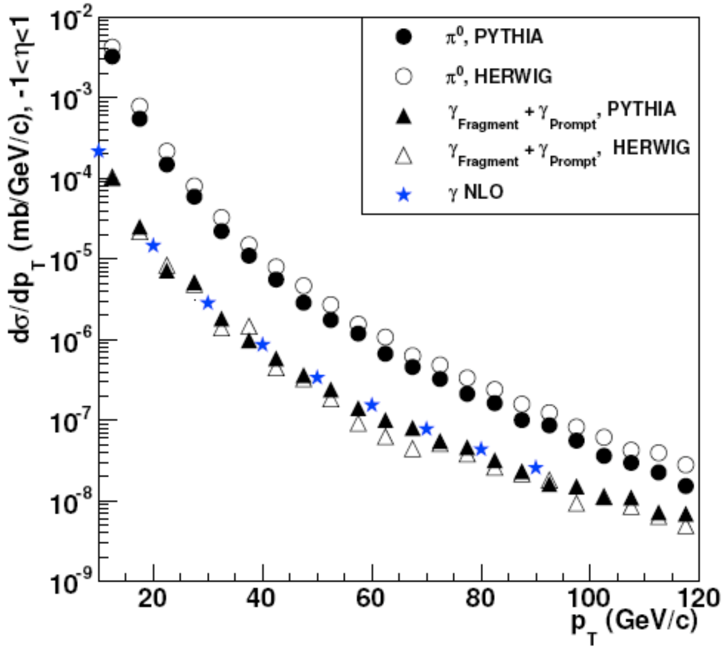


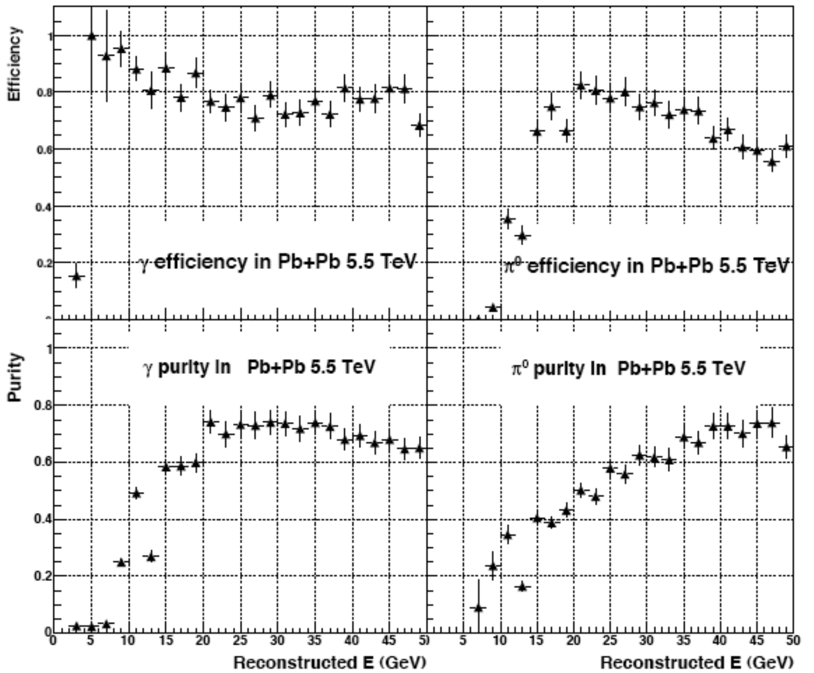
Direct photon et neutral pion measurements

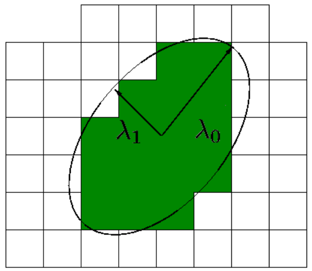
Physics goal and γ/π^0 discrimination

✓ Direct photons can be used alone (reference) or to tag γ-jet coincidences

✓ Method to discriminate prompt photons from π^0 : invariant mass analysis (p_T < 10 GeV), Shower shape analysis (10 GeV< p_T < 50 GeV), Isolation cuts (to remove fragmentation photons)







Isolation cuts results :

✓ p-p : p_T^{th} = 0.5 GeV/c, R = 0.4

➔ efficiency ~ 70%, S/B ~ 1

✓ Pb-Pb : p_T^{th} = 2 GeV/c, R = 0.3

✓ ➔ efficiency ~ 60%, S/B ~ 1 (for quenched jets)

Photon tagged-jets/hadrons correlation

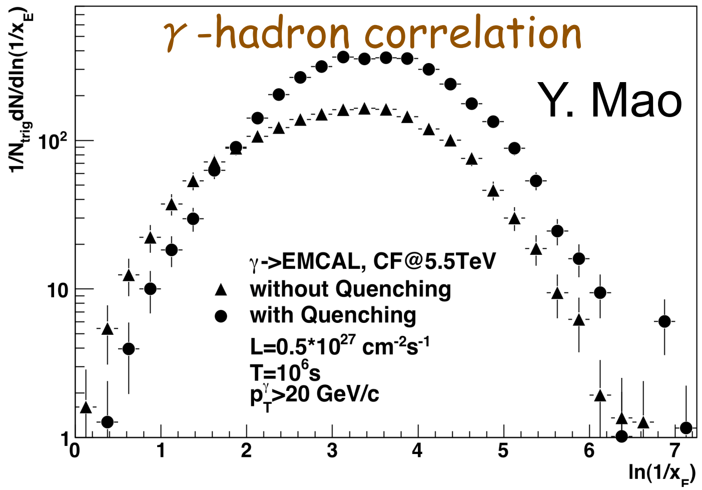
Hard process → photon + jet

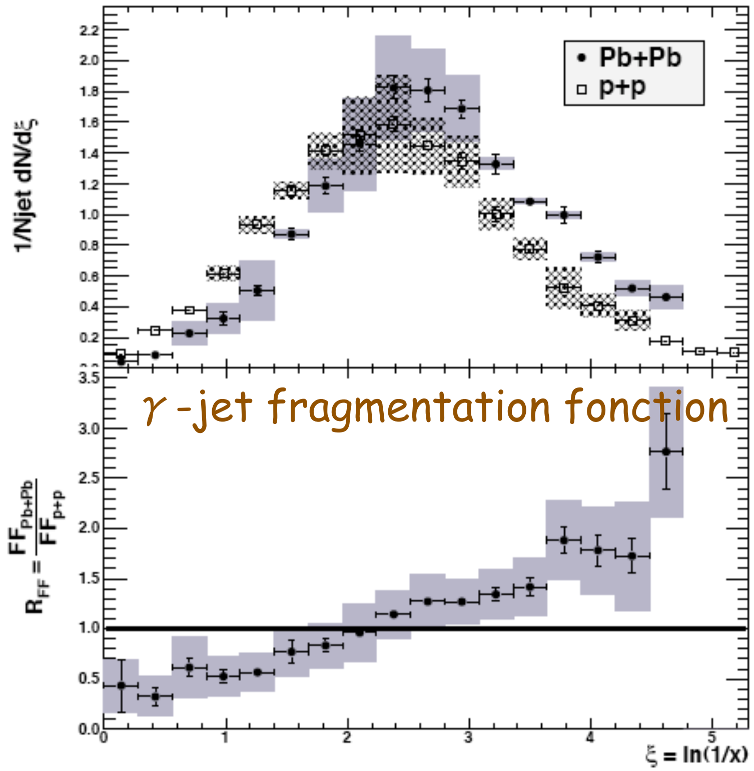
- ✓ γ-jet mainly from gluon + quark → gamma + quark
- ✓ Measured γ energy = Parton energy (reference)
- ✓ Scattered parton is sensitive to QGP medium.

Strategy

- ✓ Identify a prompt photon (E_γ > 20 GeV)
- ✓ Find all charged hadrons (tracking) or neutral pions (EMCal or PHOS)
- ✓ Observables to be measured :
  - ✓ the photon-hadron correlation ($x_E = \dfrac{\vec{p}_\gamma \cdot \vec{p}_{had}}{p_\gamma^2}$)

    ($p_T(\gamma)$ > 30 GeV/c and p_T(hadron) > 0.2 GeV/c)
  - ✓ the jet fragmentation fonction ($x = \dfrac{E_{had}}{E_\gamma}$)





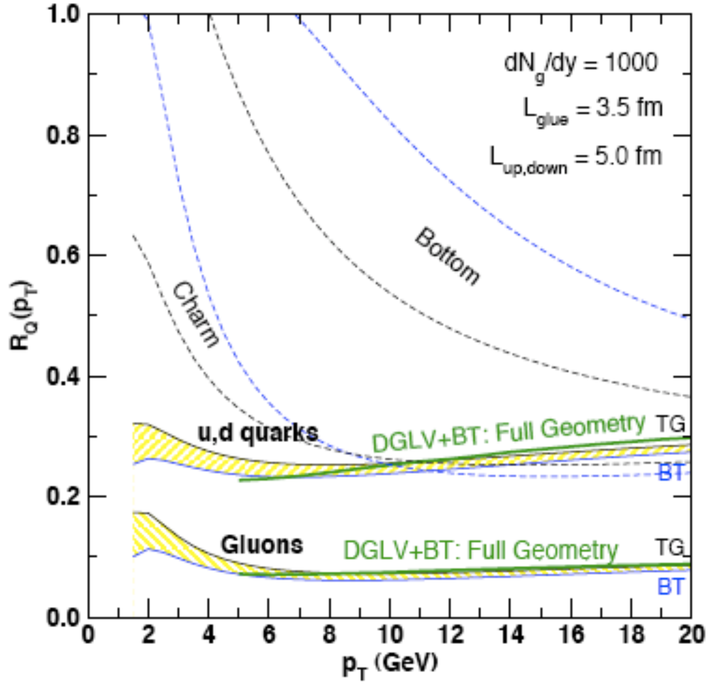
Heavy flavour study

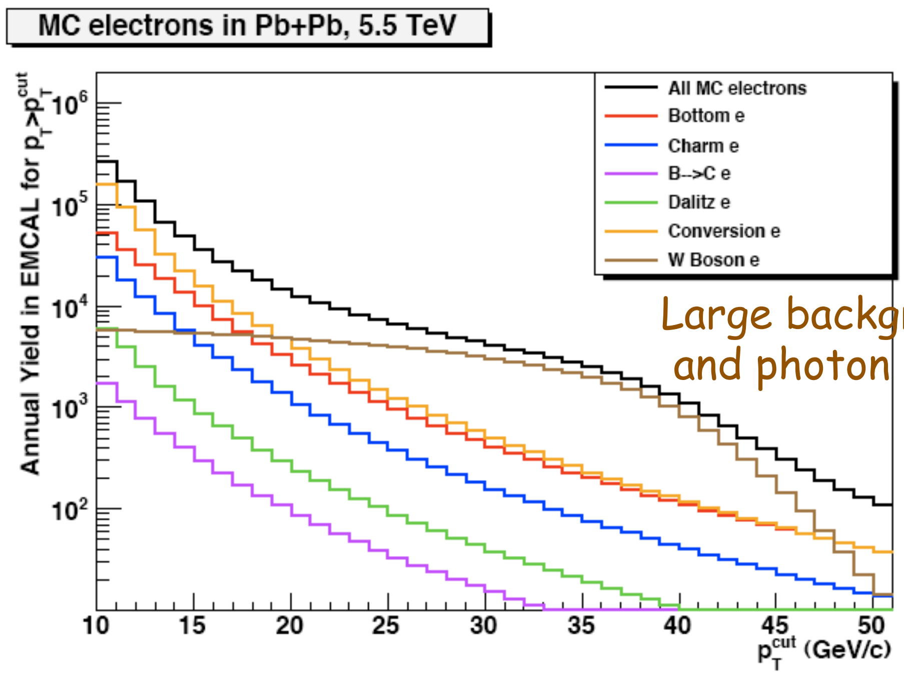
Physics predictions :

- ✓ Flavour dependence of energy loss in the medium
- ✓ Color charge effect between gluons and quark-jets.

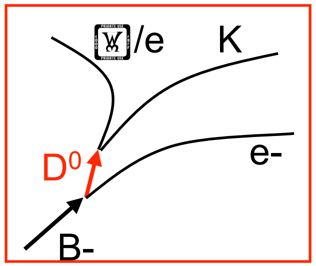
➔ b-jet identification via electron detection in semi-leptonic decay

Flavour dependence of nuclear modification factor





Large background from W decay
and photon conversion

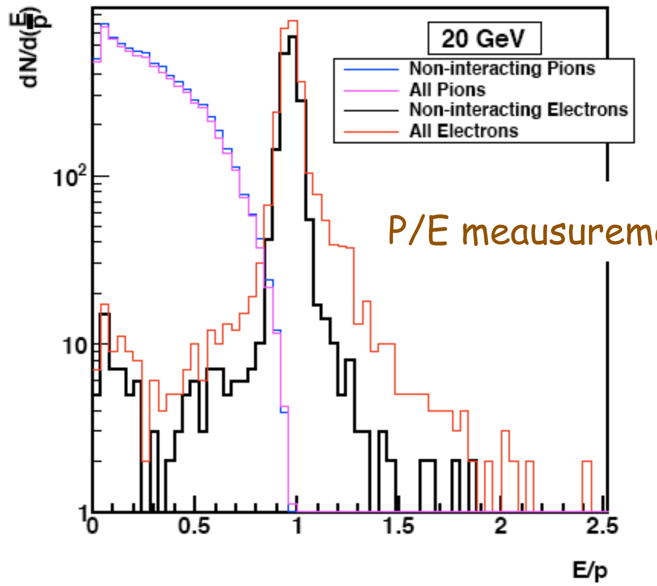


High p_T b-jets identification

High p_T electron measurement:

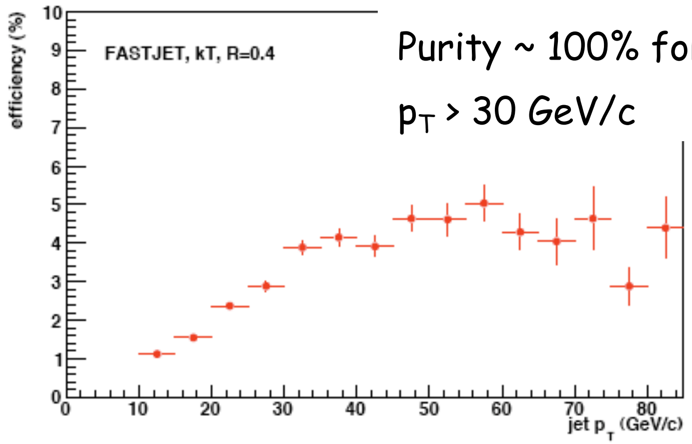
✓ Track-matching + p/E mesurement (E with EMCal for $p_T > 10$ GeV/c (ITS can be used at lower p_T)

✓ Vertex reconstruction (DVM) using 1 electron and 2 hadrons (to reduce W background and photon conversion)

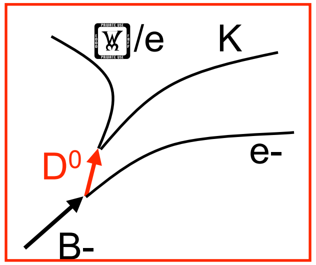


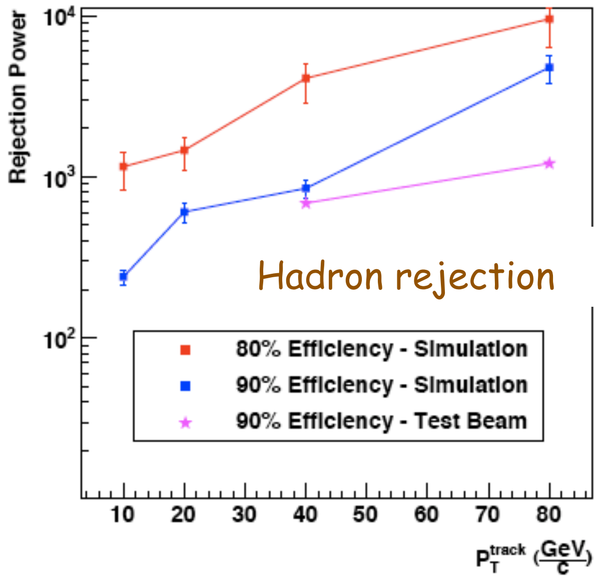
P/E meausurement

DVM method



Purity ~ 100% for $p_T > 30$ GeV/c





Hadron rejection

Conclusions

A lot of observables to be measured

- ✓ Inclusive jet production (cross-section, RAA, broadening, Fragmentation Function)
- ✓ Photon and neutral pion measurements (reference)
- ✓ Coincidences (γ -jet, π^0-jet, jet-jet,)
- ✓ Flavor dependence (b-jets …)

Activities of ALICE group in LPSC

- ✓ Strong involvement in EMCal calibration (until spring 2011)
- ✓ Level 1 trigger jets study (hardware, commisionning, simulation …)
- ✓ Software tasks (calibration, trigger …)
- ✓ Physics analyses in preparation (photons, jets , photon-hadron correlation, PDF ?, …)