Direct photon measurements in ALICE

Alexis Mas for the ALICE collaboration

Outline

I - Physics motivations for direct photon measurements

II – Direct photon measurements in ALICE

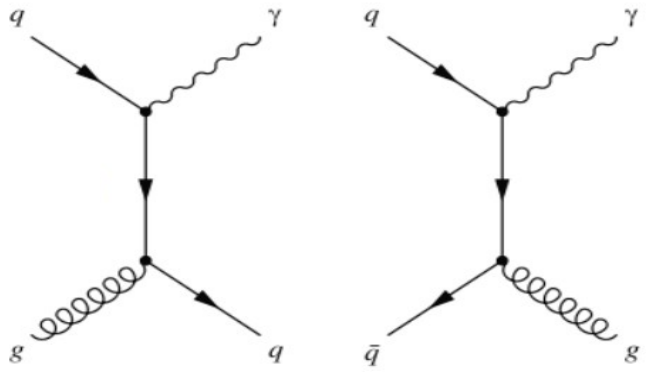
i - Conversion method with the TPC and the ITS (p_T 0.5-14 GeV/c)

ii - Isolation method with EMCal (p_T 10-50 GeV/c)

III - Conclusions

Direct photon production

In pp and Pb-Pb collisions



Compton scattering and **annihilation**

Independent of fragmentation functions (FF)

➡ **Their measurement constrains parton distribution functions (PDFs)**

Fragmentation photons: production can be affected by parton energy loss in Pb-Pb

Only in Pb-Pb collisions

Thermal photons: from QGP or hadron gas:

➡ **Direct information on the hot and dense medium**

Photons from interactions between hard partons and the medium:

- bremsstrahlung of partons
- $q_{hard} + g_{QGP} \rightarrow q + \gamma$

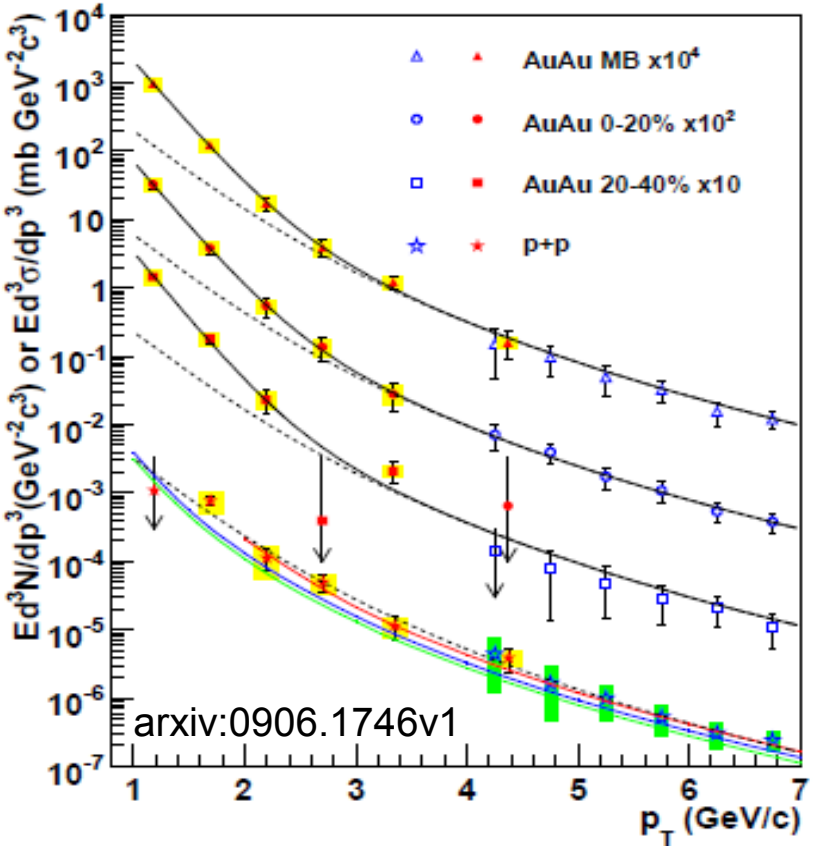
Electromagnetic probes do not interact with the color field

➡ Ideal to study HI collisions

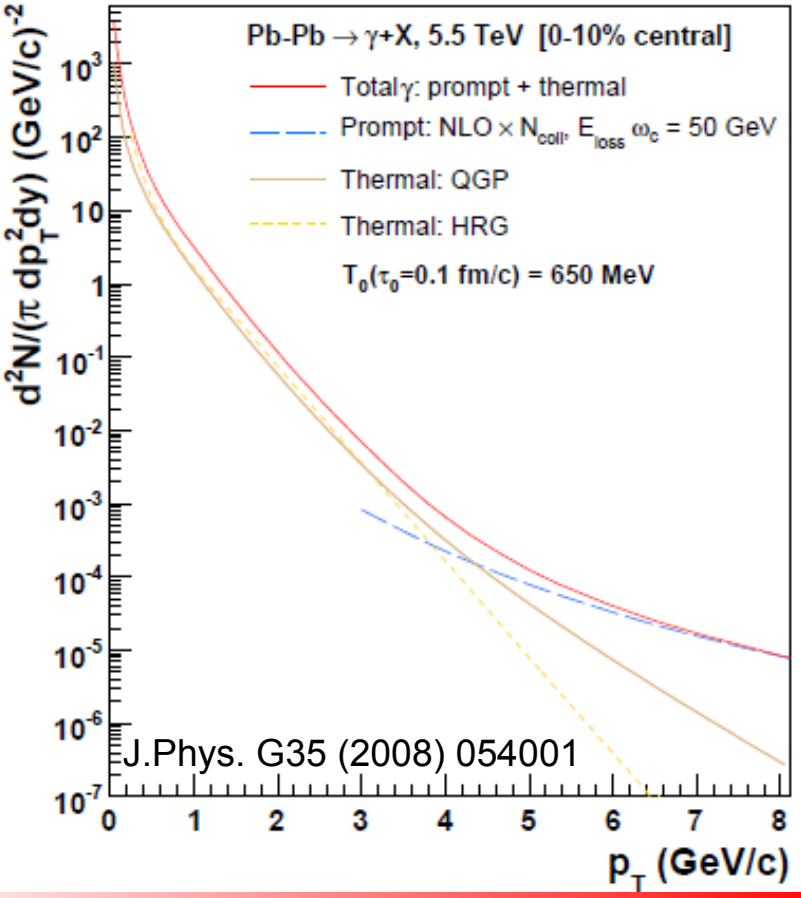
A medium thermometer: thermal photons

In heavy-ion collisions, low p_T direct photon production is dominated by QGP and hadron gas radiation => Access to medium properties

The "excess" seen at RHIC

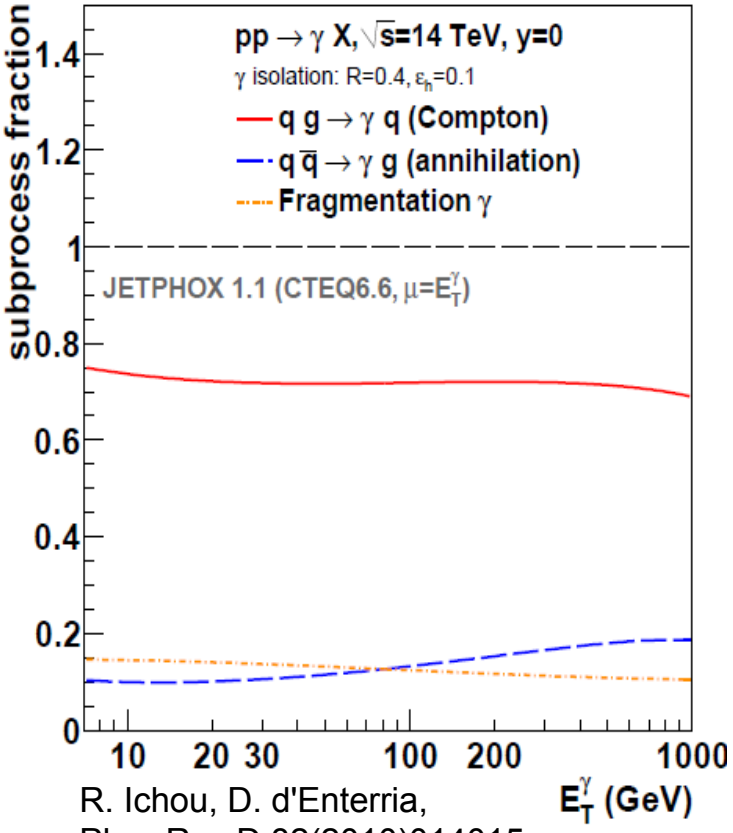


Prediction for the LHC



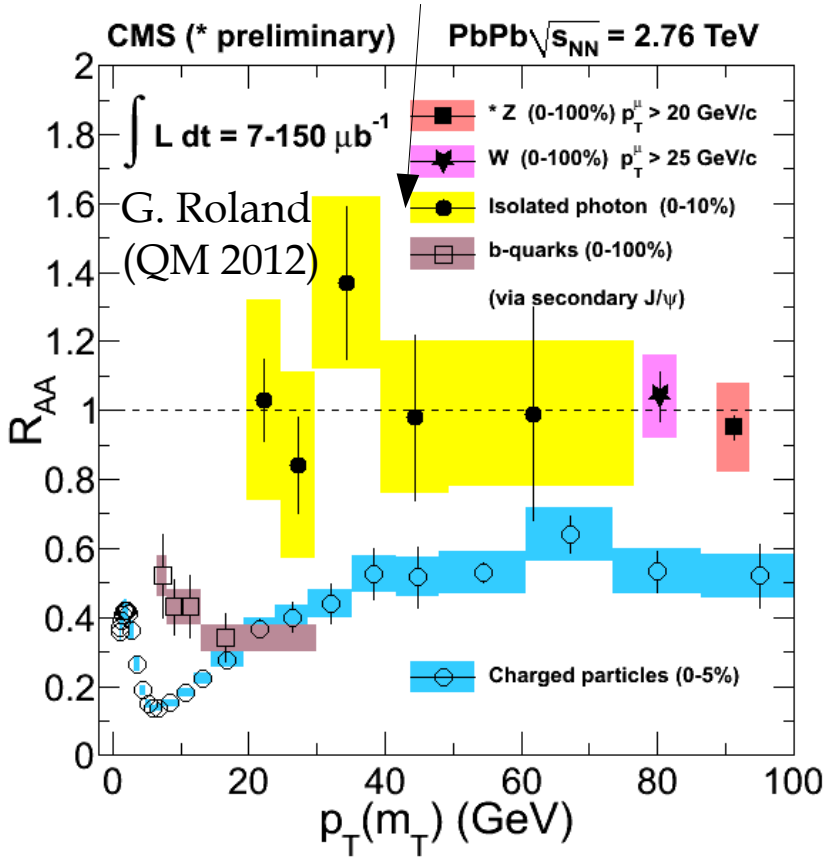
Isolated direct photons: an ideal probe

Compton scattering is the dominant channel of **high p_T** isolated direct photon at LHC
⇒ constraints on gluon PDF



R. Ichou, D. d'Enterria, Phys.Rev D 82(2010)014015

Unlike hadron production, **high p_T** isolated photon one is not affected by the medium created in HI collisions
⇒ ideal reference for PDF and FF modification studies



G. Roland (QM 2012)

Direct photon measurement: an experimental challenge

Photon production is completely dominated by hadron decays

The $\pi^0 \rightarrow \gamma\gamma$ channel contributes for more than 80% of those decay photons

➡ **Direct photon signal extraction is challenging**

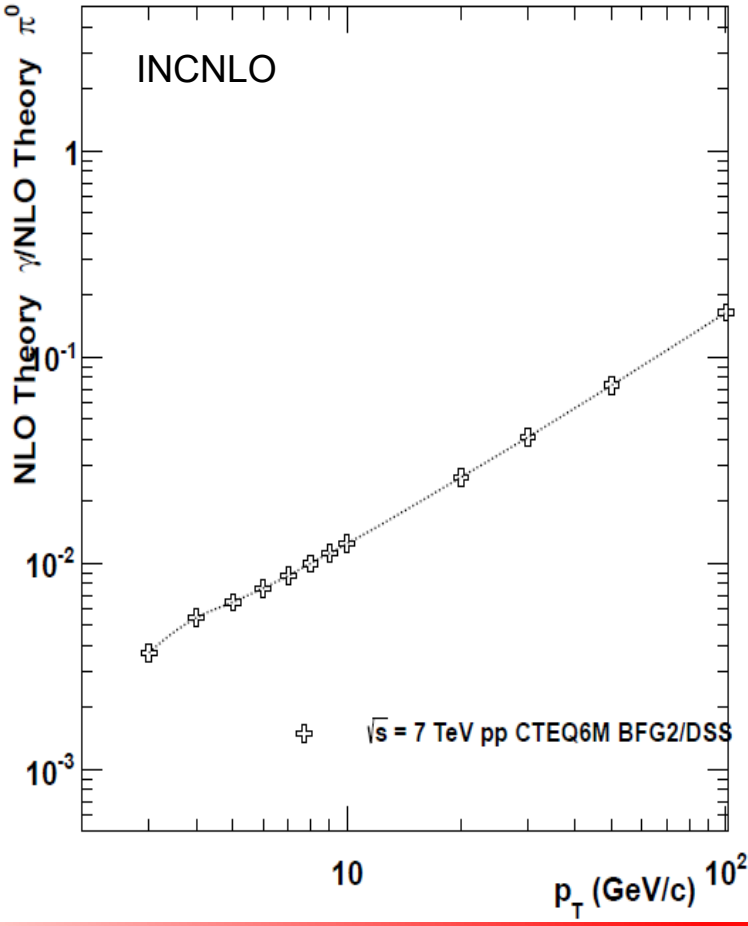
1st approach, **decay photon subtraction**:

$$\gamma_{dir} = \gamma_{inc} - \gamma_{decay}$$

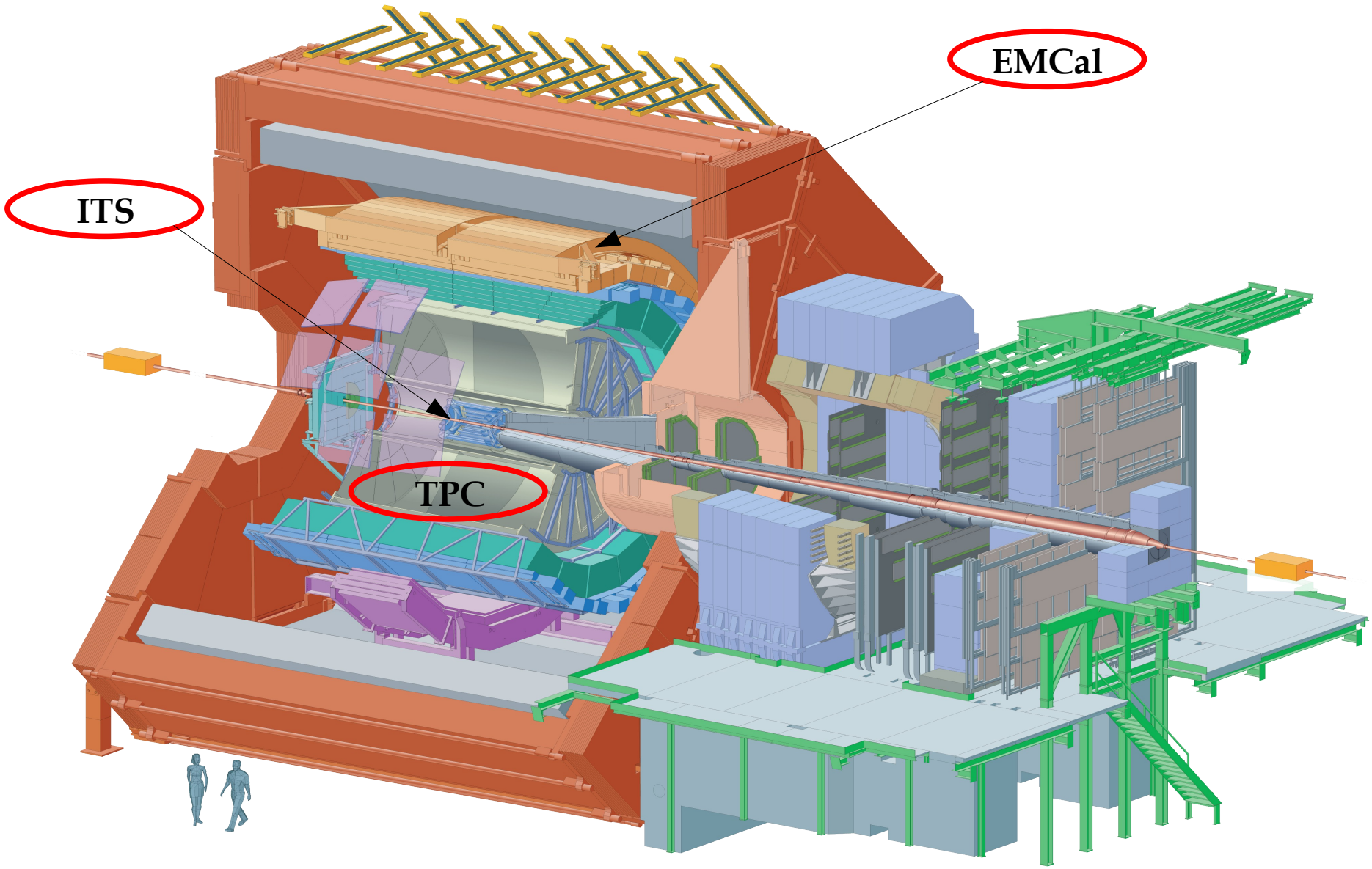
Used in the **conversion method**

2nd approach, **direct photon identification**:

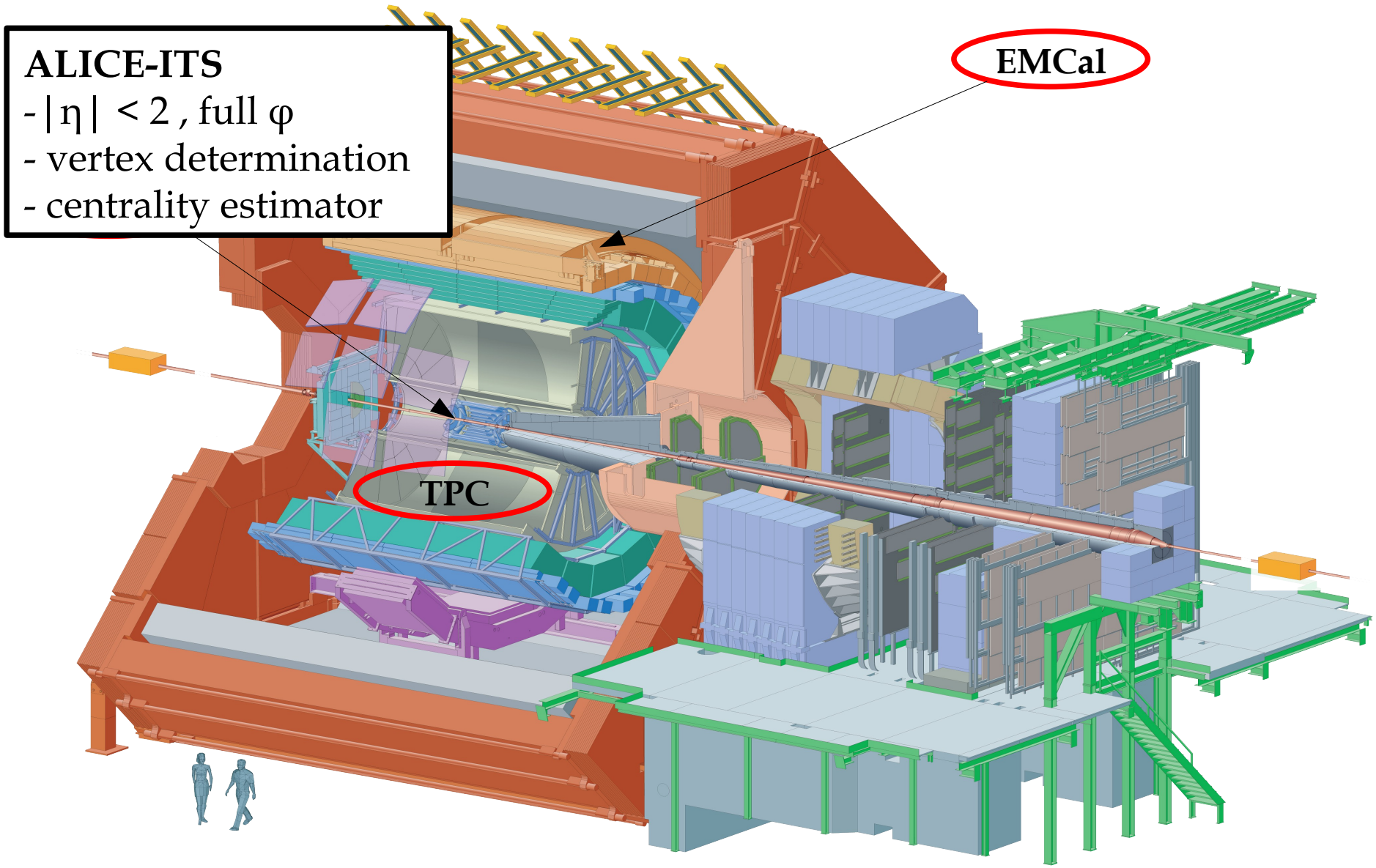
Used in the **isolation method**



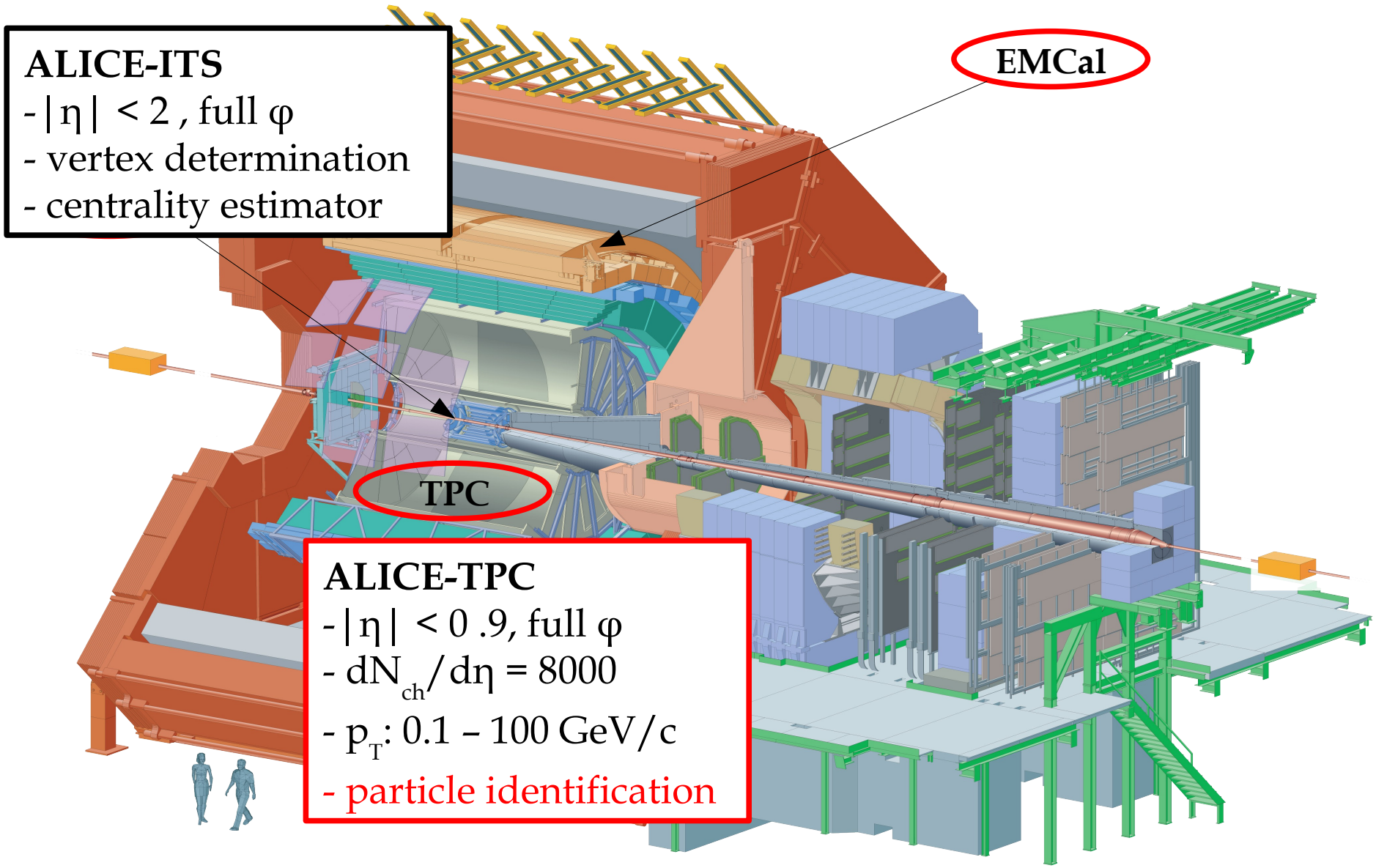
ALICE Detector Setup



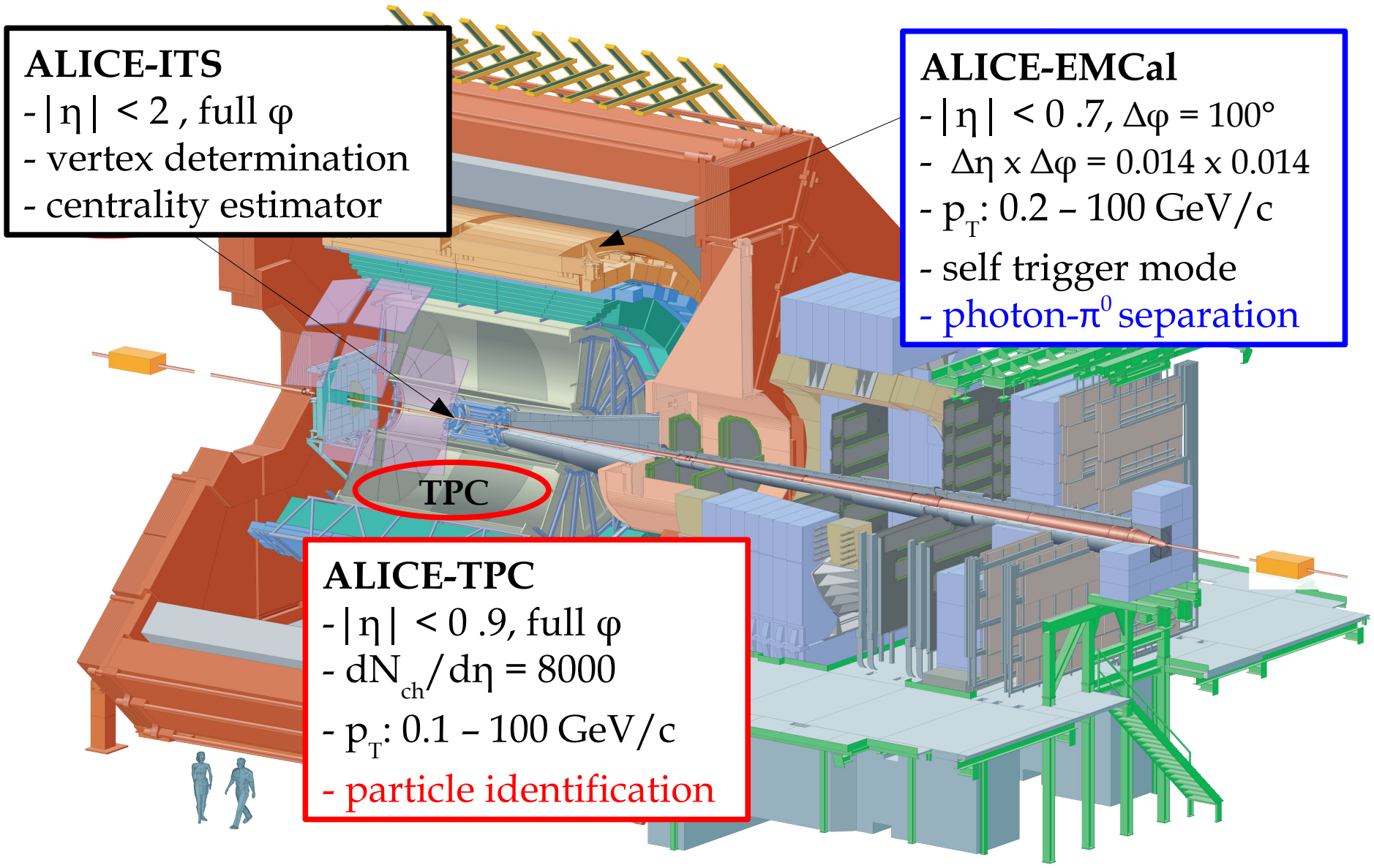
ALICE Detector Setup



ALICE Detector Setup



ALICE Detector Setup



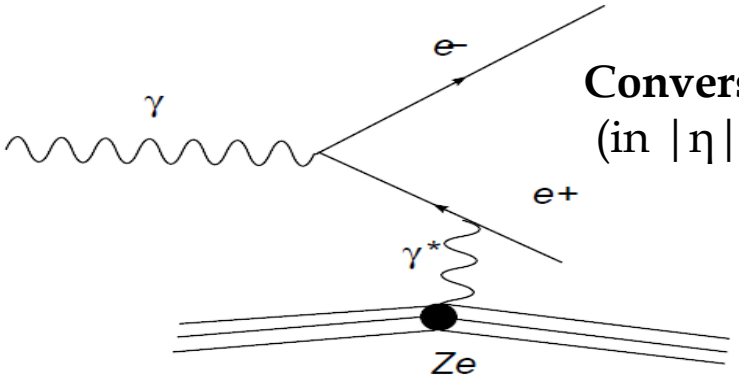
ALICE-ITS
- $|\eta| < 2$, full φ
- vertex determination
- centrality estimator

ALICE-EMCal
- $|\eta| < 0.7$, $\Delta\varphi = 100°$
- $\Delta\eta \times \Delta\varphi = 0.014 \times 0.014$
- p_T: 0.2 – 100 GeV/c
- self trigger mode
- photon-π^0 separation

ALICE-TPC
- $|\eta| < 0.9$, full φ
- $dN_{ch}/d\eta = 8000$
- p_T: 0.1 – 100 GeV/c
- particle identification

1st measurement: Conversion method with TPC and ITS

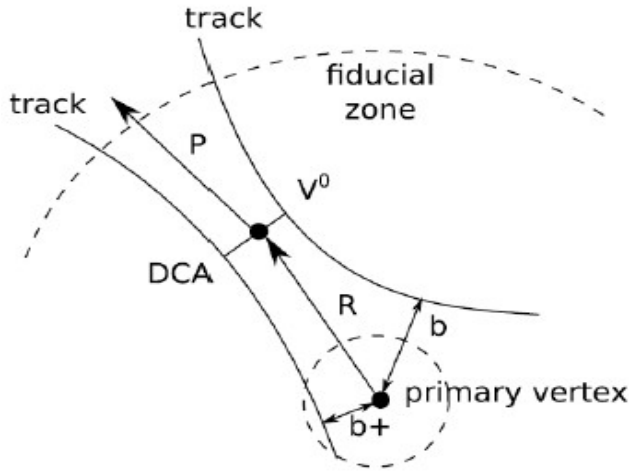
Photon Conversion Method

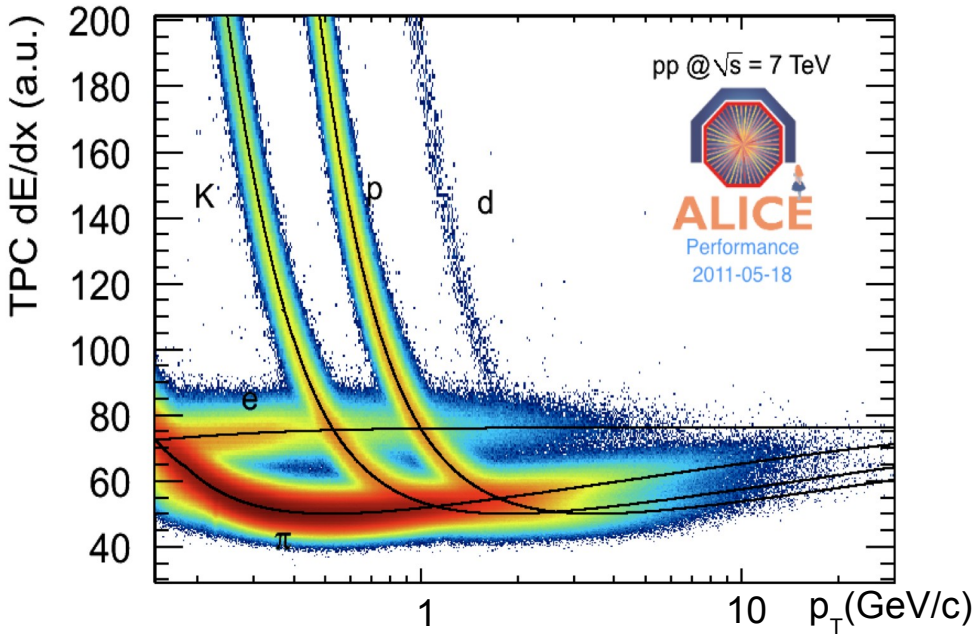


Conversion probability in ALICE inner material = 8.5 %
(in $|\eta| < 0.9$ to R=180 cm)

Remove other V0 sources (K^0_s, Λ, $\bar{\Lambda}$)
- cut on opening angle
- cut on dE/dx of the tracks

Track selection (V0 candidates)
- Large impact parameter (avoid primary particles)
- Small DCA





Contamination from combinatorial background estimated from MC simulation

Analysis strategy

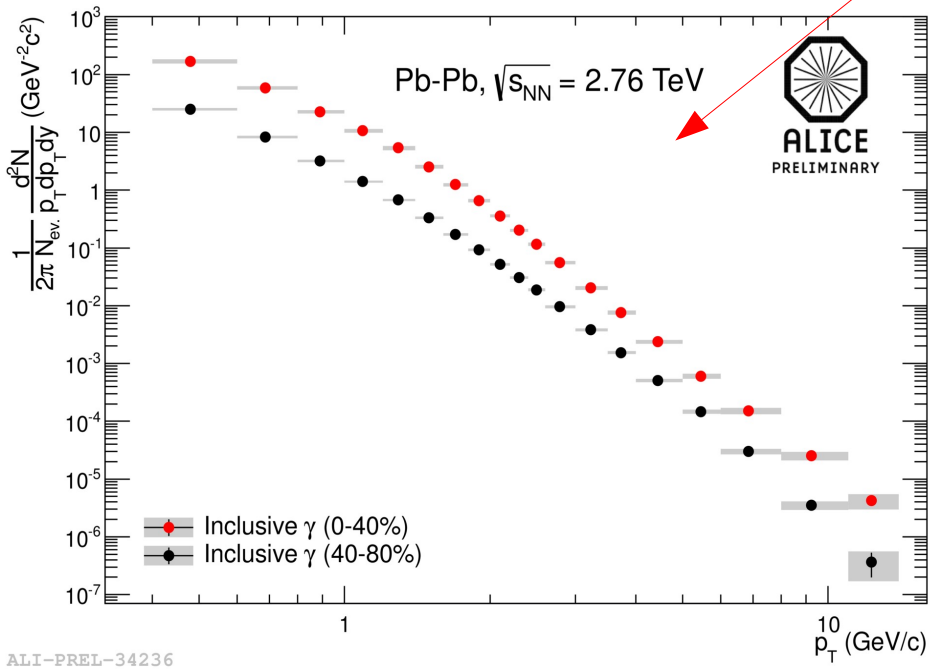
Direct photon contribution is obtained from inclusive spectrum by:

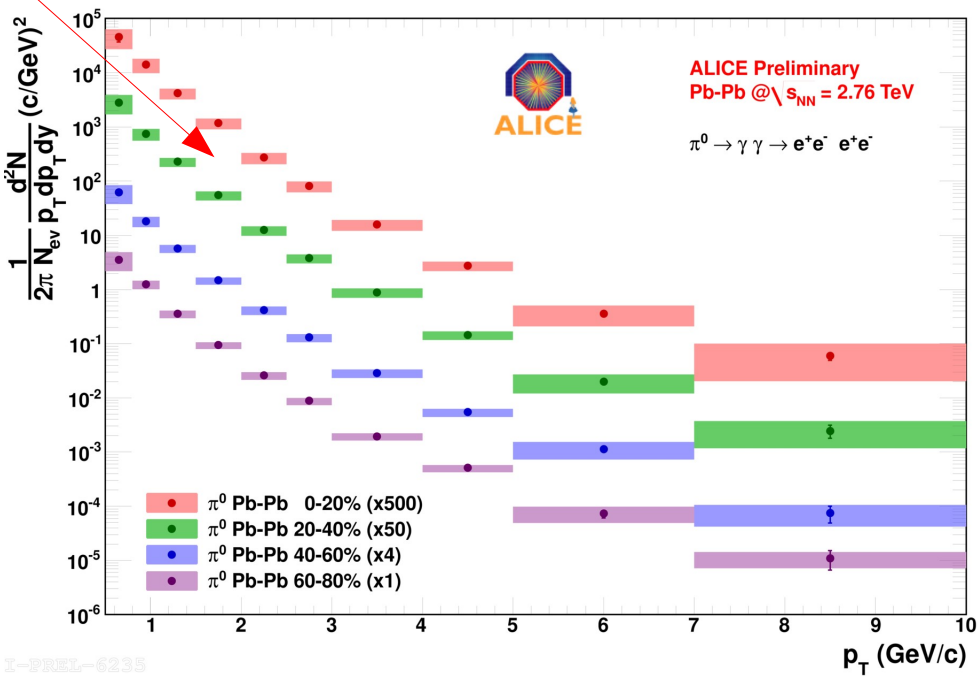
$$\gamma_{dir} = \gamma_{inc} - \gamma_{decay} = \gamma_{inc} \times \left(1 - \frac{\gamma_{decay}}{\gamma_{inc}}\right)$$

With **double ratio**: $\dfrac{\gamma_{inc}}{\gamma_{decay}} \simeq \dfrac{\gamma_{inc}}{\pi^0} \Big/ \dfrac{\gamma_{decay}}{\pi^0_{param}}$

From the cocktail generator (see next slide)

Measured from converted photons





Cocktail generator

A part from π^0 and η (in pp), **decay photon spectra are computed.**

Cocktail generator is based on the m_T- scaling of π^0 spectrum

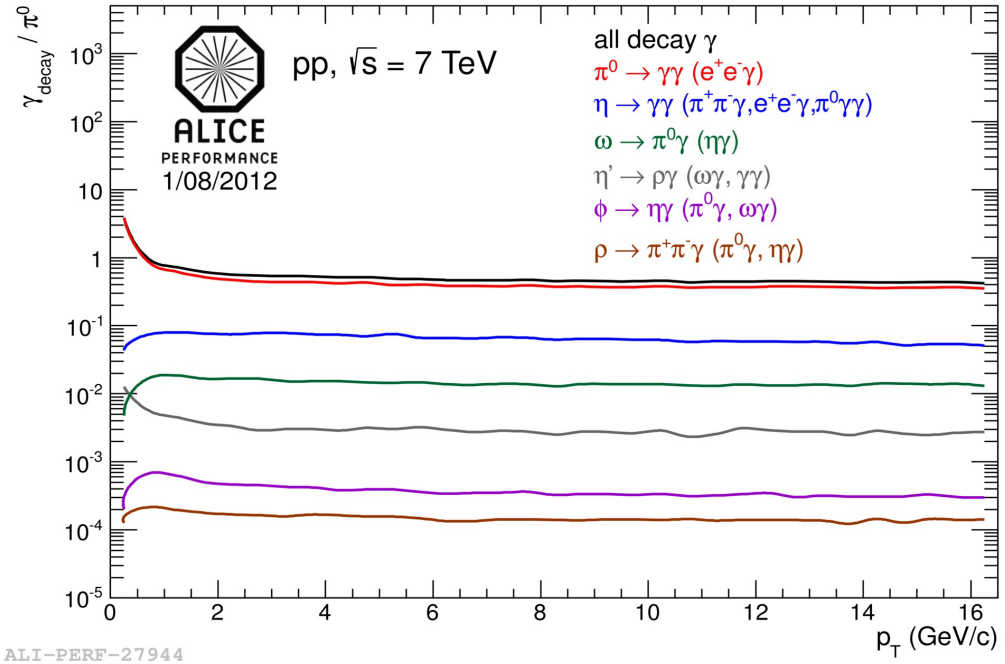
m_T- scaling ($m_T = \sqrt{m^2 + p_T^2}$)

Same shape of cross-section $f(m_T)$ of various mesons:

$$\frac{E d^3\sigma_m}{dp^3} = \boxed{C_m} \times f(m_T)$$

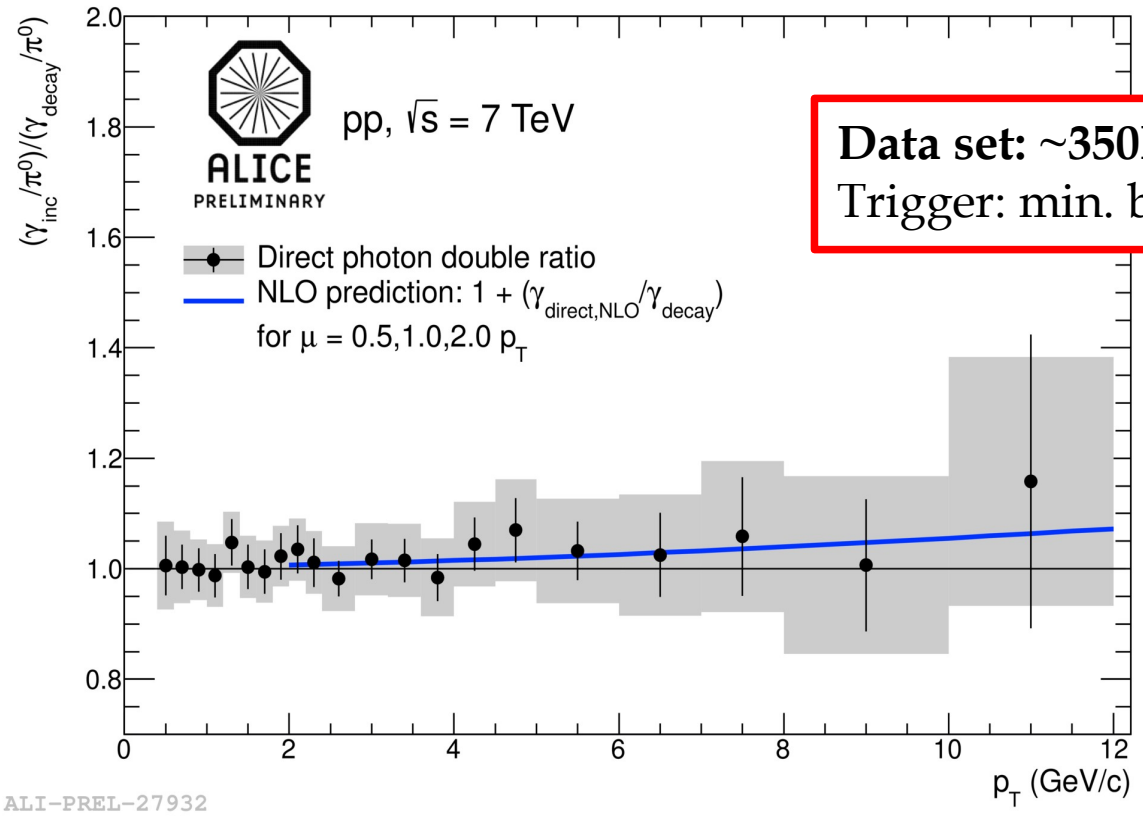
Normalization factors

Considered mesons: π^0, η, η', ω, ϕ and ρ_0



Meson (C_m)	Mass	Decay Branch	B. Ratio
π^0	134.98	$\gamma\gamma$	98.789%
		$e^+e^-\gamma$	1.198%
η	547.3	$\gamma\gamma$	39.21%
		$\pi^+\pi^-\gamma$	4.77%
(0.48)		$e^+e^-\gamma$	$4.9 \cdot 10^{-3}$
ρ^0	770.0	$\pi^+\pi^-\gamma$	$9.9 \cdot 10^{-3}$
(1.0)		$\pi^0\gamma$	$7.9 \cdot 10^{-4}$
ω	781.9	$\pi^0\gamma$	8.5%
(0.9)		$\eta\gamma$	$6.5 \cdot 10^{-4}$
η'	957.8	$\rho^0\gamma$	30.2%
		$\omega\gamma$	3.01%
(0.25)		$\gamma\gamma$	2.11%

Results for pp collisions at $\sqrt{s}$ = 7 TeV



Data set: ~350M events (2010 data)
Trigger: min. bias

$$\frac{\gamma_{inc}}{\gamma_{decay}} \simeq \frac{\gamma_{inc}}{\pi^0} \Big/ \frac{\gamma_{decay}}{\pi^0_{param}}$$

The double ratio leads to the **cancellation of some systematics errors** (efficiency, normalization, π^0 spectrum)

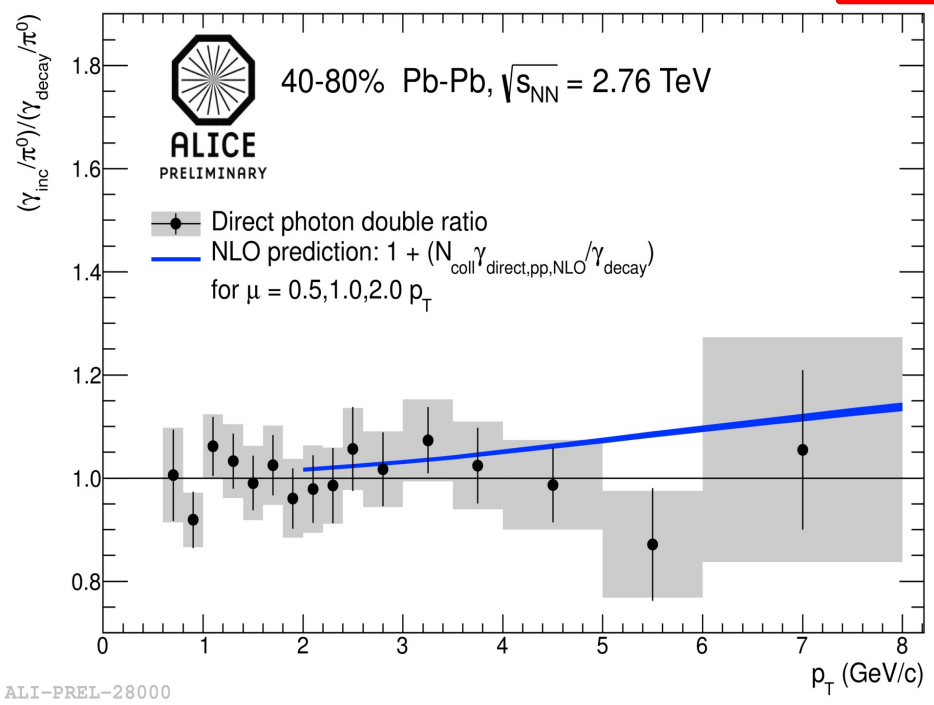
- No significative direct photon signal

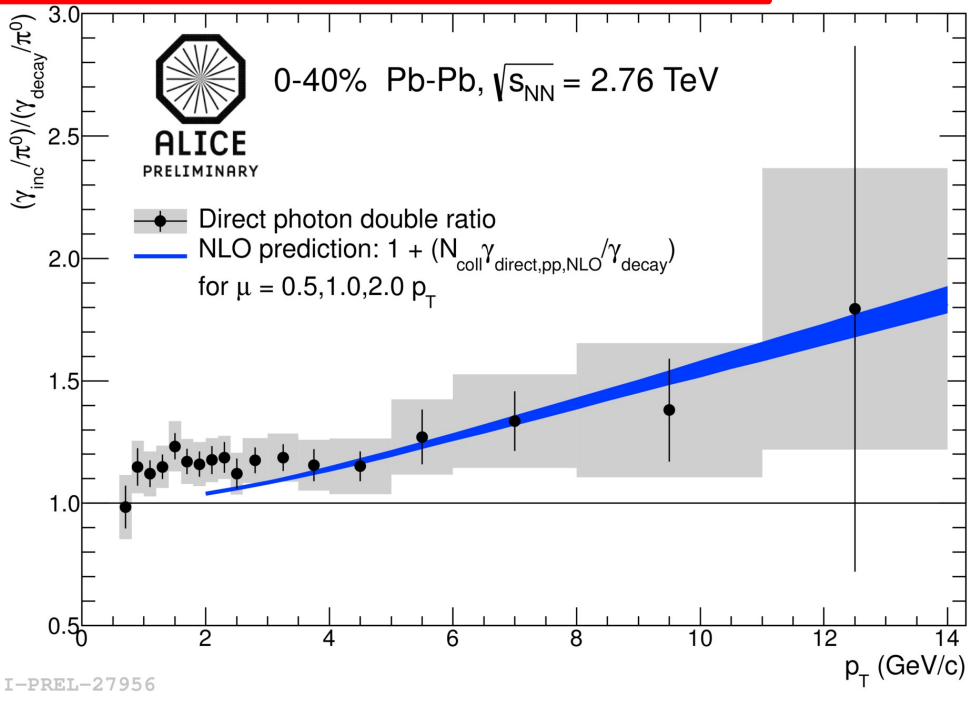
- The result is compatible with NLO predictions

Results for Pb-Pb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV

$$\frac{\gamma_{inc}}{\gamma_{decay}} \simeq \frac{\gamma_{inc}}{\pi^0} \Big/ \frac{\gamma_{decay}}{\pi^0_{param}}$$

Data set: ~17M events (2010 data)
Trigger: min. bias

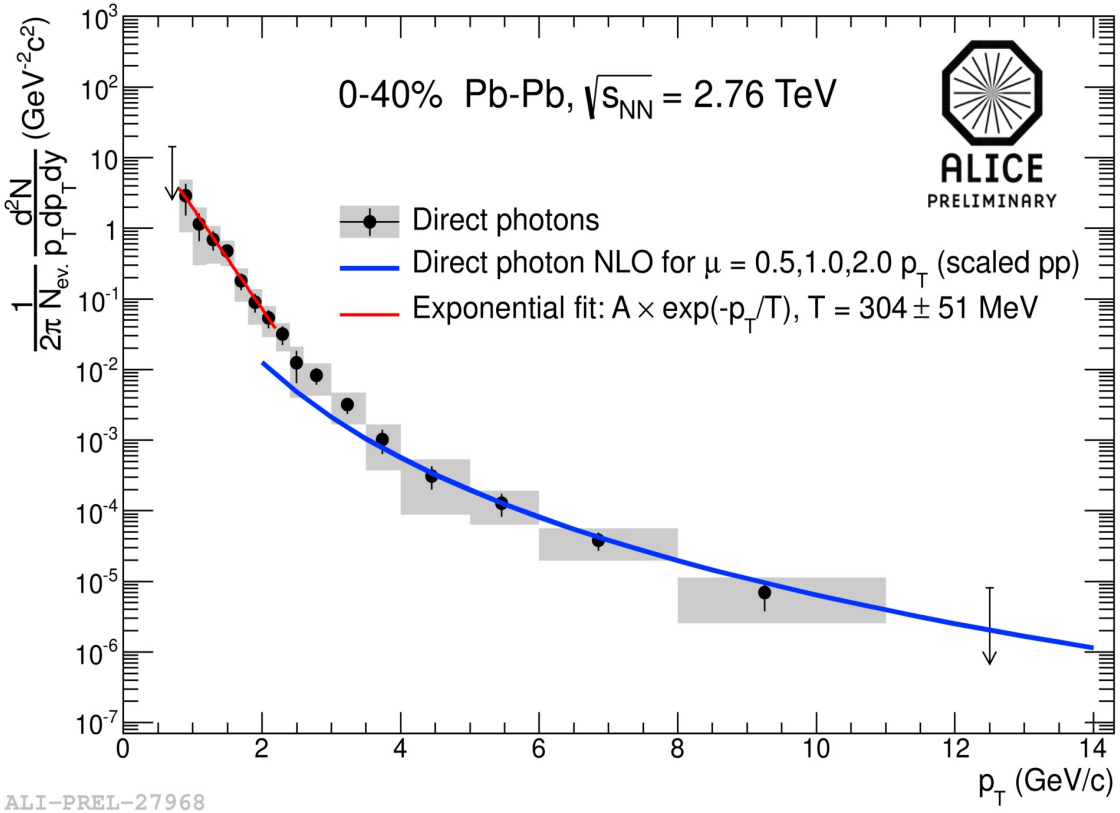




- Above 4 GeV/c, in both peripheral and central collisions, results are consistent with NLO predictions

- We see a **direct photon signal at low p_T in central collisions**

Direct photons in central Pb-Pb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV



The direct photon yield is extracted from:

$$\gamma_{dir} = \gamma_{inc} \times (1 - \frac{\gamma_{decay}}{\gamma_{inc}})$$

Using the double ratio:

$$\frac{\gamma_{inc}}{\gamma_{decay}} \simeq \frac{\gamma_{inc}}{\pi^0} / \frac{\gamma_{decay}}{\pi^0_{param}}$$

- At p_T < 2.2 GeV/c, the spectrum is fitted with an exponential with a slope parameter: $T = 304 \pm 51^{stat+syst}$ MeV

- The excess is similar to the one measured at RHIC:

$$T = 221 \pm 19^{stat} \pm 19^{syst} \text{ MeV}$$

(Au-Au centrality 0-20%)

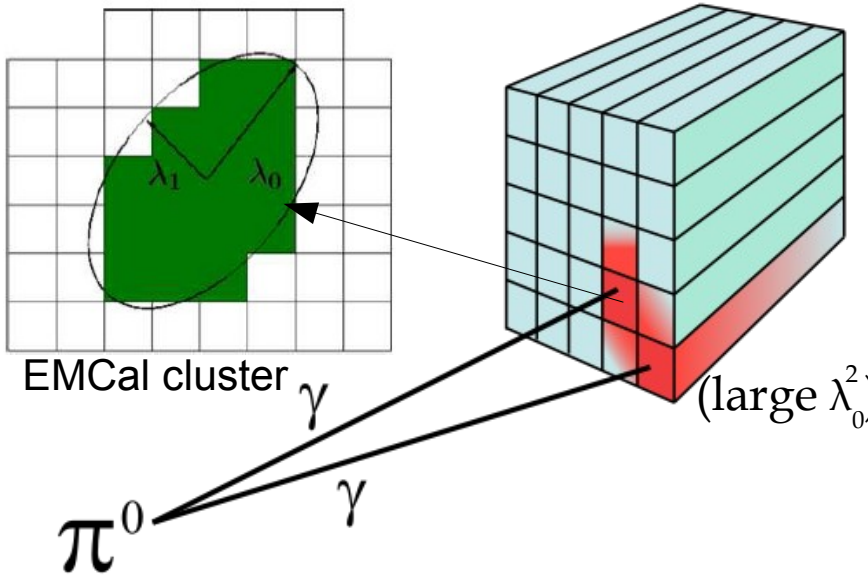
2^{nd} measurement: Isolation method with EMCal

Photon identification with EMCal

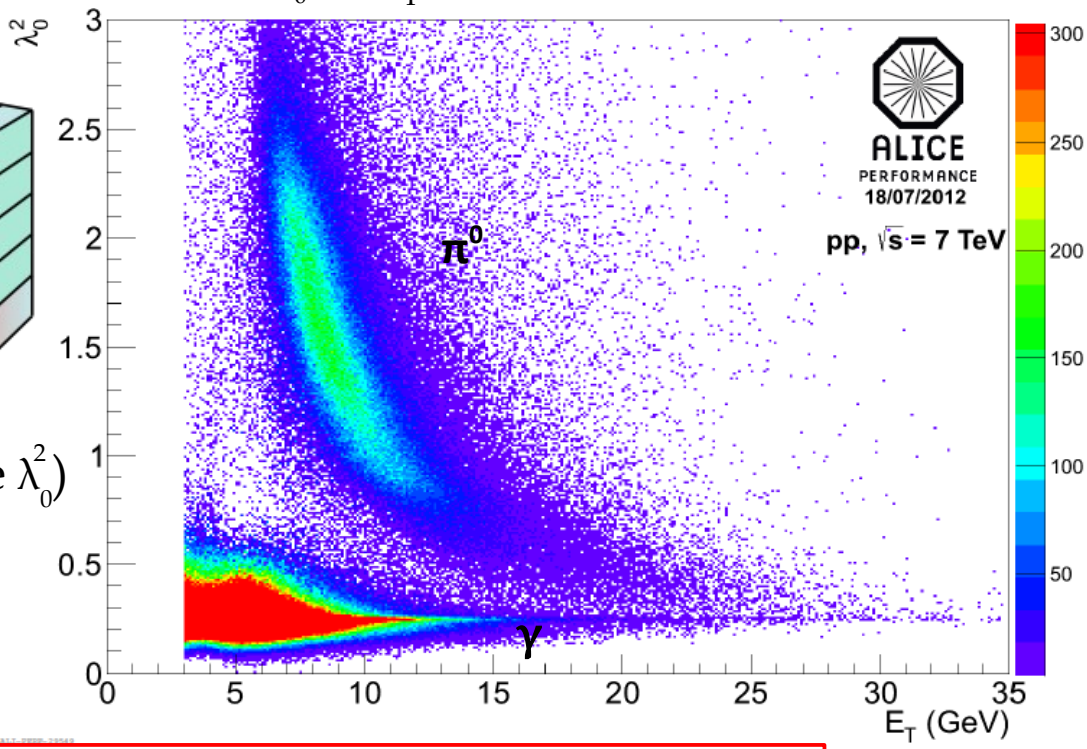
I – Charged particle veto (CPV)

Selection of clusters that are not matching a track (matched if $\Delta\eta < 0.02$ & $\Delta\varphi < 0.03$)

II – Shower shape discrimination ($\lambda_0^2 < 0.27$)

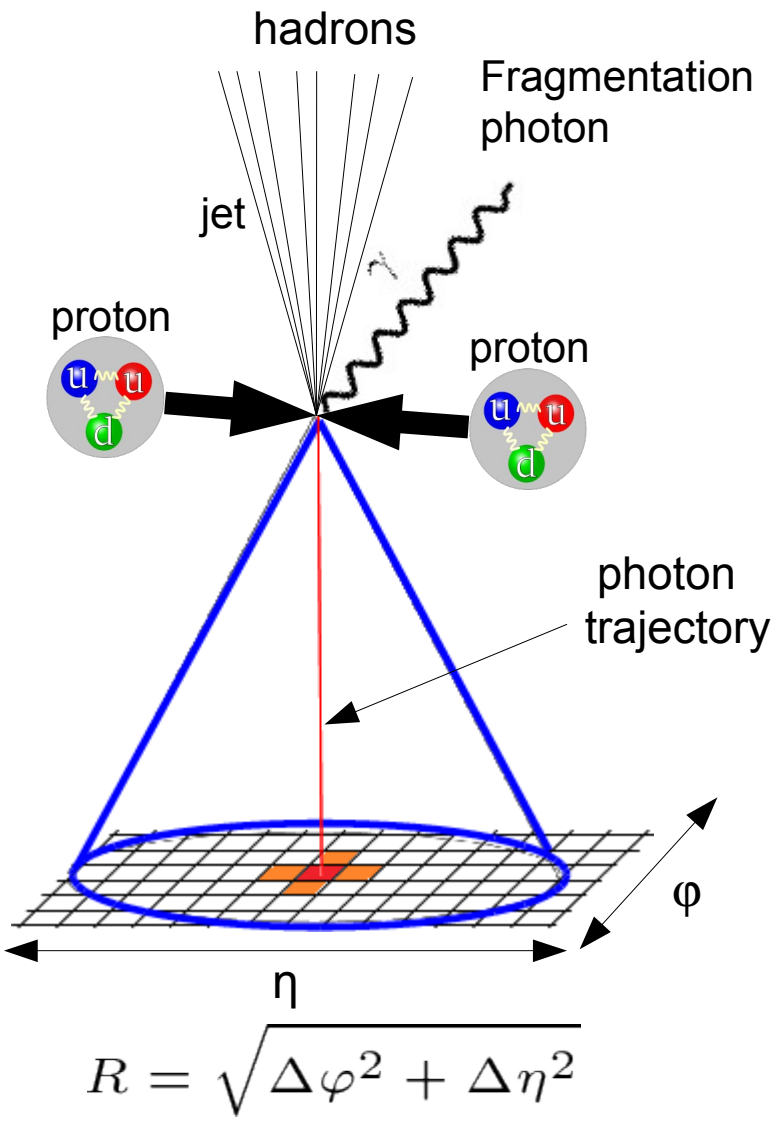


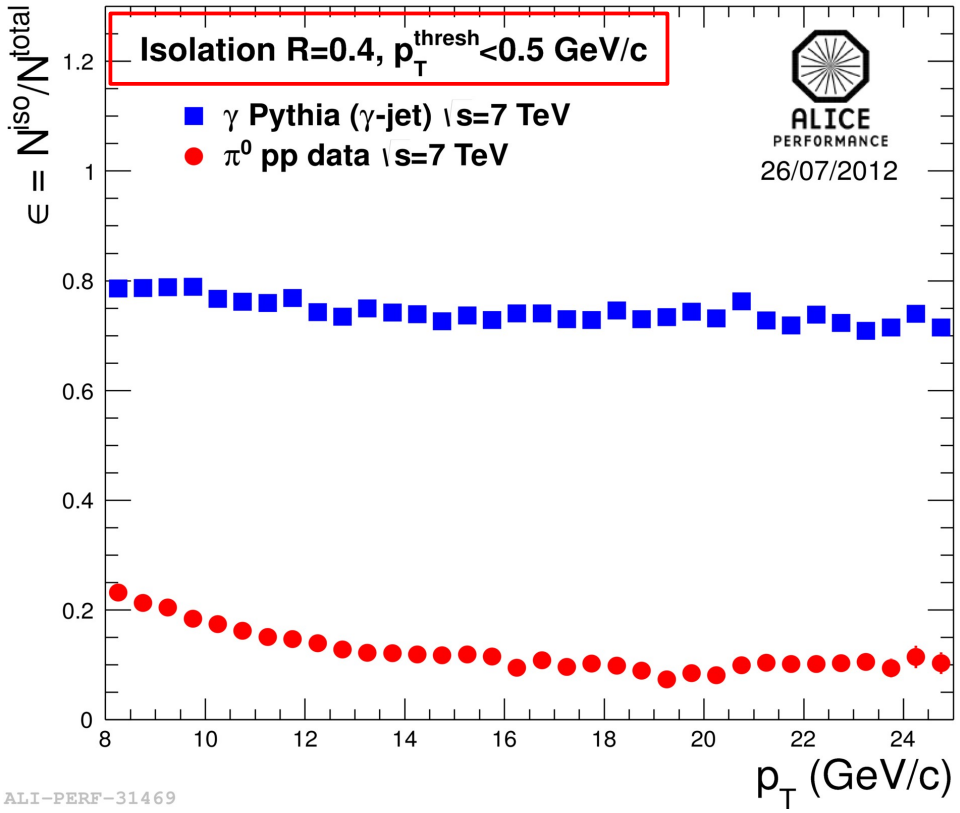
λ_0^2 vs E_T of clusters (after CPV)



λ_0^2 cut provides a strong π^0 rejection between 5 and 60 GeV

Photon isolation





- The isolation technique strongly reduces the residual π^0 contamination

- Fragmentation photons are also strongly suppressed since they are surrounded by hadronic activity

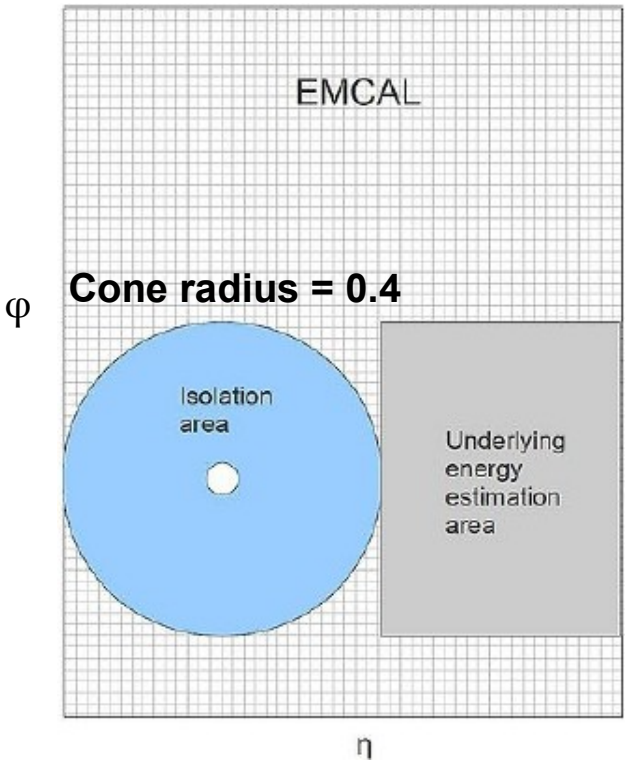
Isolation method: signal extraction

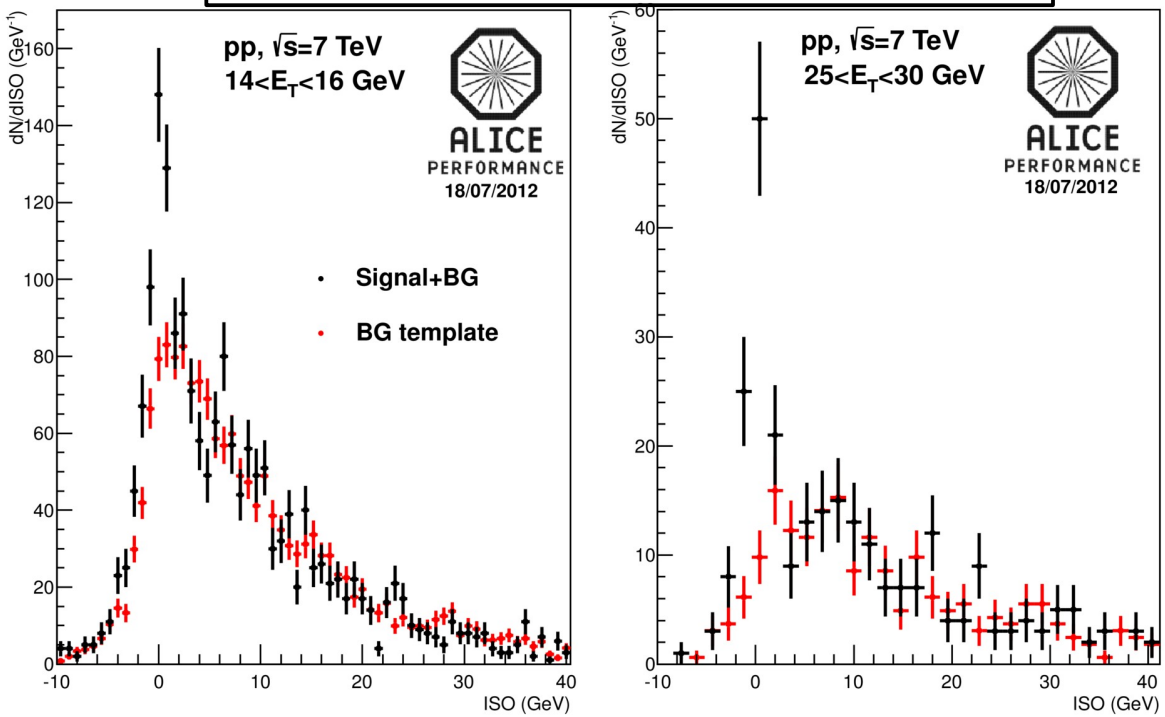
Computation of $ISO = E_T^{Cone} - E_T^{UE}$ for:

- BG template: clusters with $0.5 < \lambda_0^2 < 2$ (normalized using distribution tails: ISO>15 GeV)

- Signal+BG: clusters with $0.1 < \lambda_0^2 < 0.3$

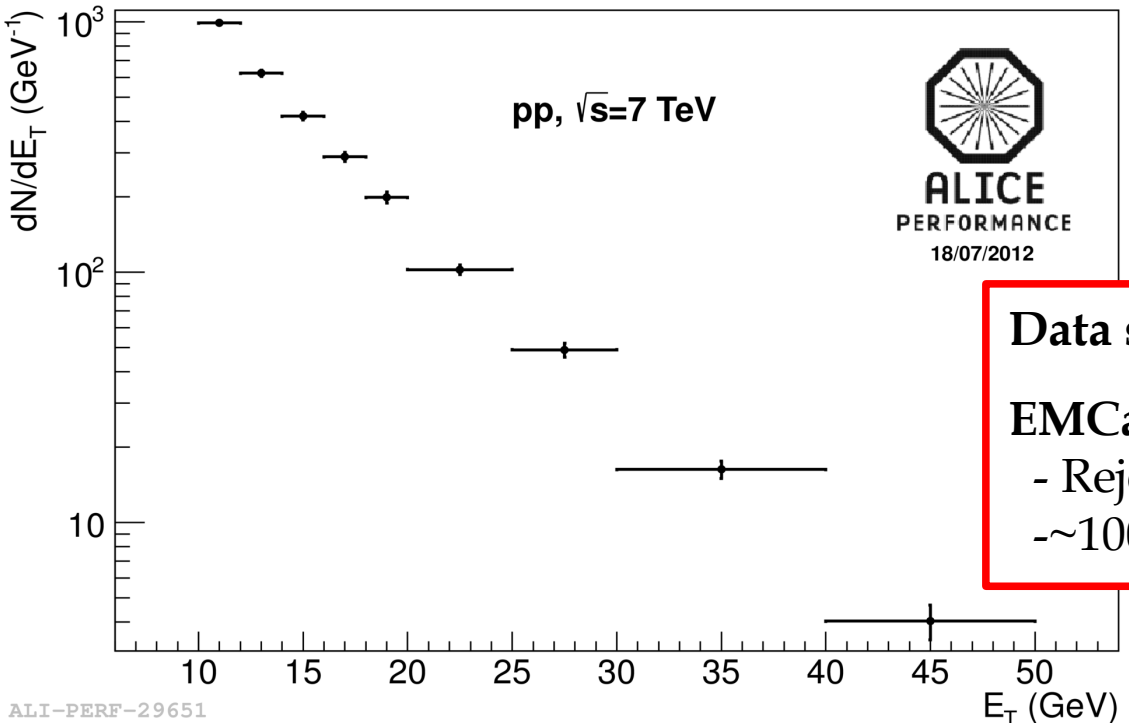
Yield is extracted substracting the BG ISO distribution from Signal + BG one





ISO distributions for 2 E_T bins

Isolated photons in pp collisions at $\sqrt{s}$ = 7 TeV



Data set: ~10M events (2011 data)

EMCal Trigger (threshold ≈ 5 GeV)
- Rejection factor ~3000
-~100 x more luminosity

- E_T range covered is complementary with ATLAS and CMS measurements

	p_T range (GeV/c)	η range	reference
CMS	21-300 / 25–400	|η| < 1.45 / < 2.5	Phys.Rev.Lett.106 082001 /Phys.RevD84 052011
ATLAS	15-100 / 45-400 100-1000	|η| < 1.81 / < 2.37 |η| < 1.37	Phys.Rev.D83 052005/ Phys.Lett. B706 150-167 Moriond 2013
ALICE (in EMCal)	10 - 50	|η| < 0.3	ALICE

Conclusions

ALICE can measure direct photons using two complementary methods:

Conversion method (0.5 – 14 GeV)

- No significative direct photon signal in pp and Pb-Pb peripheral (consistent with NLO)
- Low p_T excess in central Pb-Pb is interpreted as thermal photon production with: $T = 304 \pm 51^{stat+syst}$ MeV

Isolation method (10 – 50 GeV)

- Measurement of raw isolated photons spectrum in pp at 7 TeV
- Outlook: extraction of direct photon cross-section (work ongoing)

GENERAL PERSPECTIVES

- Measurement in Pb-Pb and p-Pb with both approaches
- Measurement of the nuclear modification factor of direct photons