Measurement of isolated photons in p–Pb collisions at 5.02 TeV with the EMCal detector in ALICE

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Introduction & Motivation

We present the isolated photon spectrum measurement performed by the ALICE experiment at the CERN LHC in p–Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV

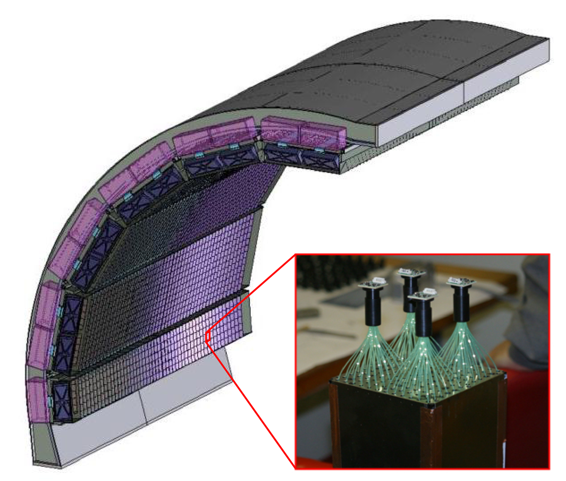
What do we measure?

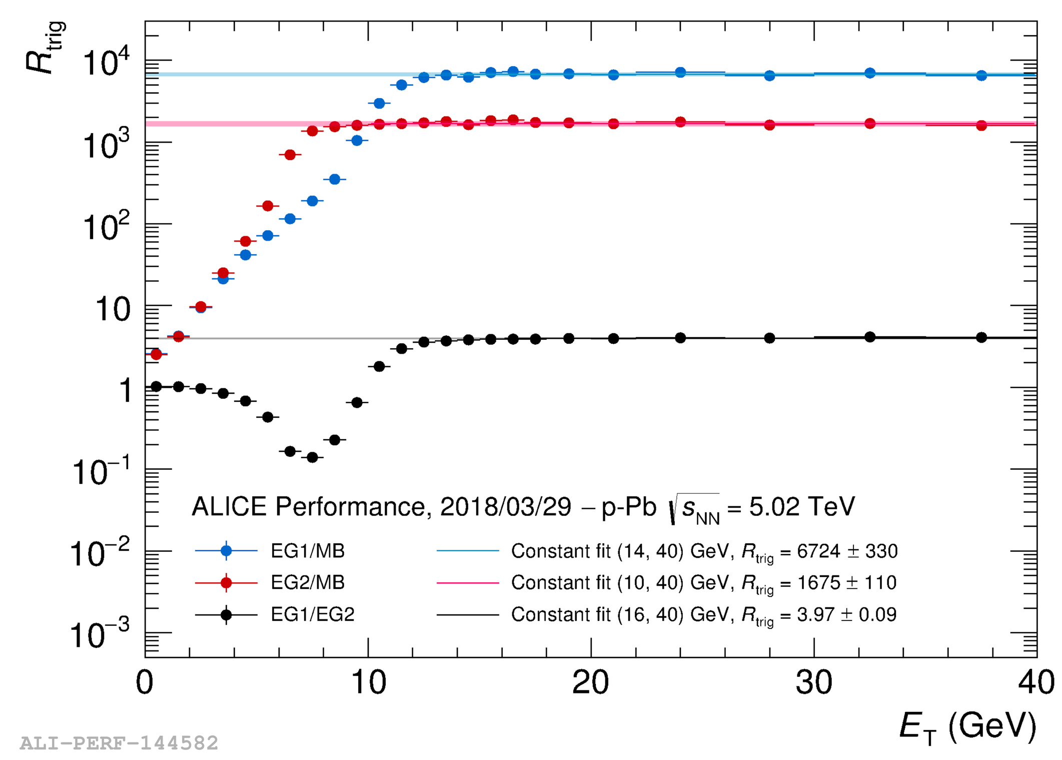
- Leading Order (LO) **direct photons γ_{LO}** emitted in **hard parton processes at the earliest stage** of hadron collisions (Compton scattering and quark annihilation) among many other photons $\rightarrow \gamma_{\text{inclusive}} = \underbrace{\gamma_{LO} + \gamma_{\text{fragmentation}}}_{\gamma_{\text{prompt}}} + \underbrace{\gamma_{\text{thermal}}}_{\text{in Pb–Pb}} + \underbrace{\gamma_{\text{decay}}}_{\pi^0,\ \eta\dots}$
- $\gamma_{\text{prompt}} \rightarrow$ dominant production at **high transverse energy** (> a few GeV) and well described by **Next-to-Leading Order (NLO) pQCD** theory predictions (NLO and higher $\rightarrow \gamma_{\text{fragmentation}}$)

Why do we want to access γ_{LO}?

- Not affected by the QCD medium → **calibrated energy reference** for parton energy loss studies (e.g. with γ_{LO}-hadron correlations)
- Key observable to **test pQCD** and put new constraints on theory
- Measurement in p–Pb collisions → address **cold nuclear effects** by comparing with pp results and have a **reference for Pb–Pb** measurement and studying the QGP

EMCal: the ALICE ElectroMagnetic Calorimeter



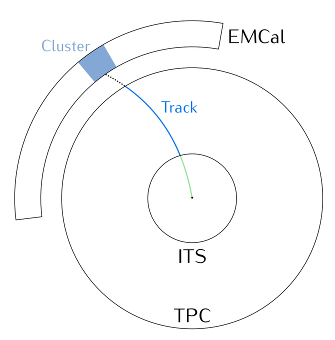


- EMCal → Pb-scintillator sampling calorimeter with **0.0143 × 0.0143 granularity** in (η, φ) [1]
- $|\eta| < 0.67$ and $\varphi \sim 107°$
- Photon reconstruction with deposited-energy cells grouped in **clusters**
- High level γ/jet triggers → E_T reach **from 10 GeV to 60 GeV** like the ALICE pp measurement [2]
- Other ALICE subsystems used → **ITS/TPC** (charged particle ID and tracking) and **V0** (minimum bias trigger and luminosity measurement)

Photon selection

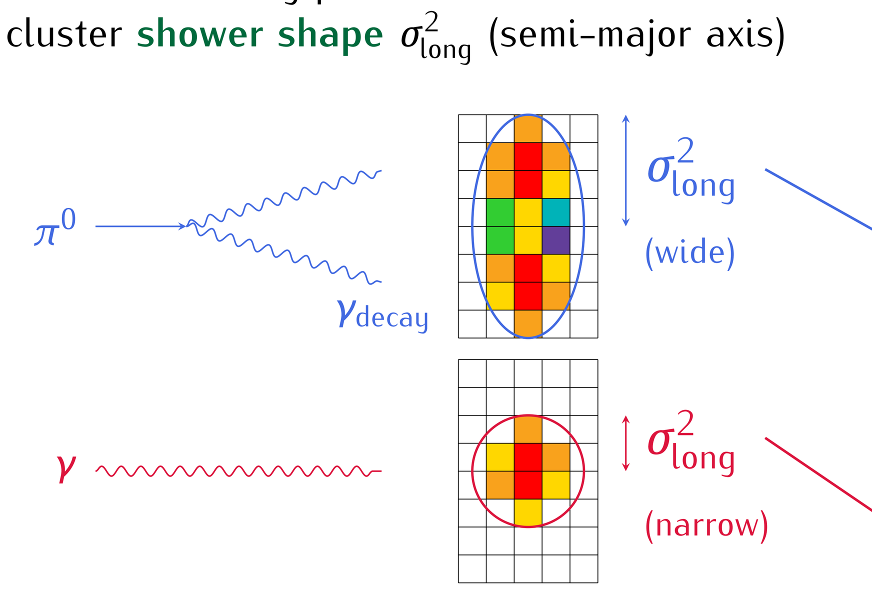
Neutral clusters (charged particle veto)

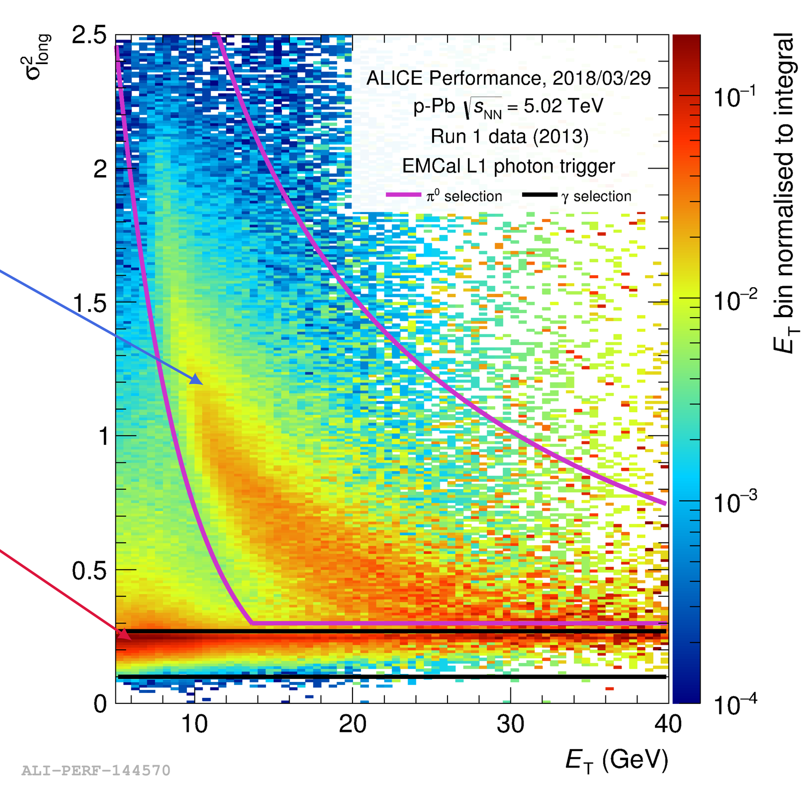
- Charged particle tracks **propagated** to EMCal surface
- Candidate clusters **must not match a track** spatially
- Selection with cluster-track matching residuals $(\Delta\eta, \Delta\varphi)$



Candidate photons (shower shape cut)

- Clusters induced by particle showers in EMCal → cluster **shower shape** σ^2_{long} (semi-major axis)

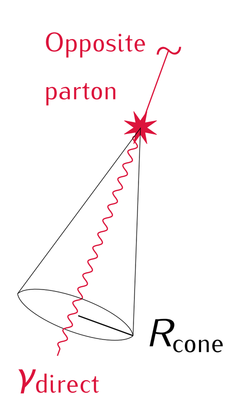




- $0.1 < \sigma^2_{\text{long}} < \left(\sigma^2_{\text{long}}\right)_{\max}$ → **candidate photons** with merged (single) π^0 γ_{decay} at high (low) E_T

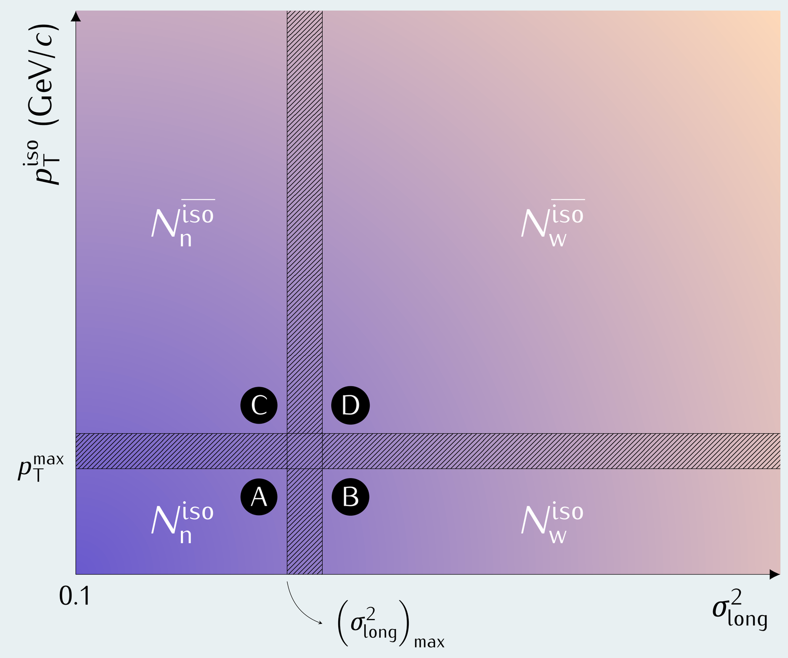
The isolation method

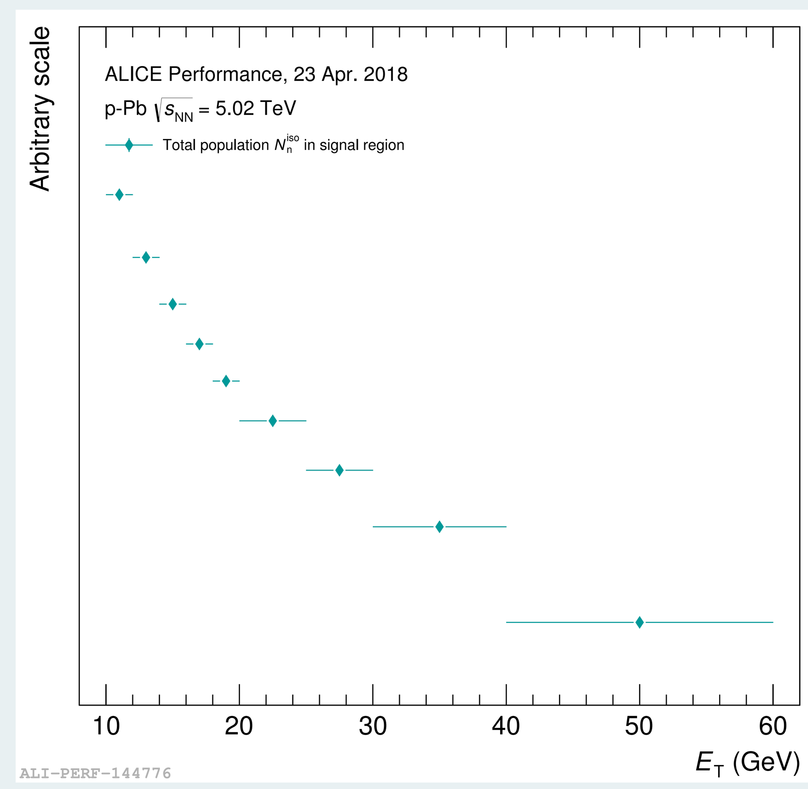
- γ_{LO} production process topology → possible to **isolate** them from other photon contributions
- Measure hadronic activity (p_T^{iso}) → sum of neutral and charged particle energy in an **isolation cone** around a candidate photon
- **Isolated photon** if $p_T^{\text{iso}} < 2$ GeV/c in $R_{\text{cone}} = \sqrt{(\eta - \eta_\gamma)^2 + (\varphi - \varphi_\gamma)^2} = 0.4$
- $\gamma_{\text{fragmentation}}$ and γ_{decay} contributions **strongly reduced** with isolation [3]



Signal extraction & Purity estimation

- Direct photons → **isolated** ($p_T^{\text{iso}} < 2$ GeV/c) and **narrow** (low σ^2_{long}) clusters
- **Underlying event** (UE) contribution subtracted beforehand → $p_T^{\text{iso}} \mapsto (p_T^{\text{iso}} - \text{UE}) < 2$ GeV/c
- Signal extracted from the $(p_T^{\text{iso}}, \sigma^2_{\text{long}})$ **phase space** → 4 regions, "ABCD method" [4]





- A = mainly signal
- B C D = mainly background (e.g. γ_{decay})
- $N_n^{\text{iso}} = S_n^{\text{iso}} + B_n^{\text{iso}}$ is measured in A → S_n^{iso} = **true γ_{LO} signal**, B_n^{iso} = background
- Need to estimate B_n^{iso} for obtaining S_n^{iso} → **isolated photon purity** $\mathbb{P}^{\text{ABCD}} = 1 - B_n^{\text{iso}}/N_n^{\text{iso}}$

Estimating B_n^{iso}: two assumptions

1. Only background clusters in B C D → $N_w^{\text{iso}} = B_w^{\text{iso}}$, $N_n^{\overline{\text{iso}}} = B_n^{\overline{\text{iso}}}$, $N_w^{\overline{\text{iso}}} = B_w^{\overline{\text{iso}}}$
2. Same isolation probability for narrow and wide clusters → $B_n^{\text{iso}}/B_n^{\overline{\text{iso}}} = B_w^{\text{iso}}/B_w^{\overline{\text{iso}}}$

$$B_n^{\text{iso}} = \frac{N_w^{\text{iso}} \times N_n^{\overline{\text{iso}}}}{N_w^{\overline{\text{iso}}}} \Rightarrow \boxed{\mathbb{P}^{\text{ABCD}} = 1 - \left(\frac{N_w^{\text{iso}} \times N_n^{\overline{\text{iso}}}}{N_w^{\overline{\text{iso}}} \times N_n^{\text{iso}}}\right)_{\text{data}}}$$

Are these hypotheses valid?

1. Signal leakage in regions B C D
2. Non-factorisation between isolation probability and shower shape

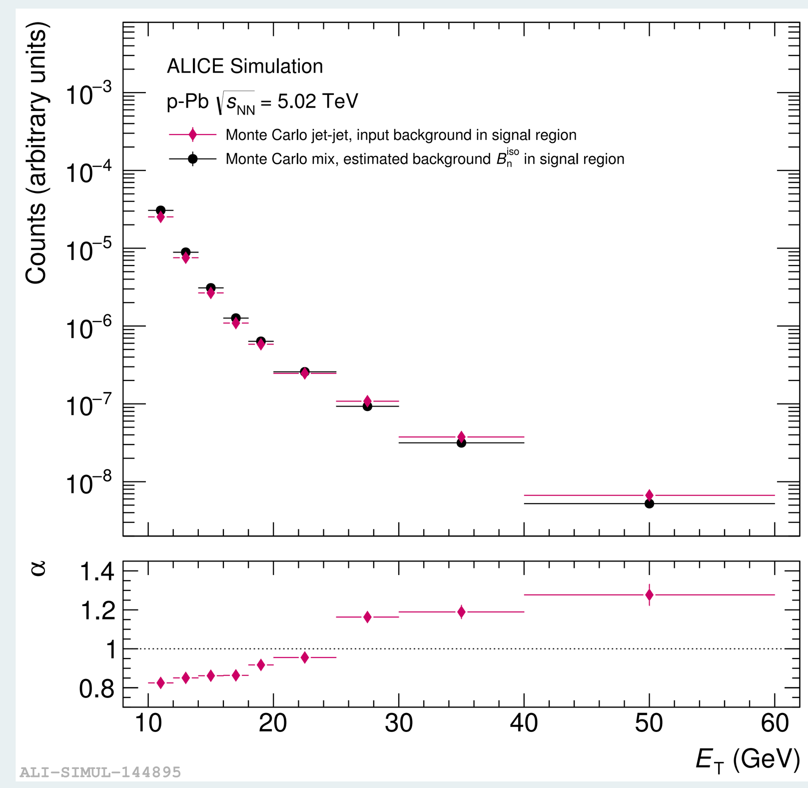
→ $\mathbb{P}^{\text{ABCD}}$ to be **corrected** using Monte Carlo

- **Jet-jet** input background compared to ABCD-estimated background in **γ-jet + jet-jet mix** → α correction factor

$$\alpha = \frac{\left(B_n^{\text{iso}}\right)_{\text{input}}}{\left(B_n^{\text{iso}}\right)_{\text{estimated}}}$$

- Corrected purity $\mathbb{P}^{\text{ABCD}}_{\text{corr}}$

$$\boxed{\mathbb{P}^{\text{ABCD}}_{\text{corr}} = 1 - \alpha \times \left(\frac{N_w^{\text{iso}} \times N_n^{\overline{\text{iso}}}}{N_w^{\overline{\text{iso}}} \times N_n^{\text{iso}}}\right)_{\text{data}}}$$



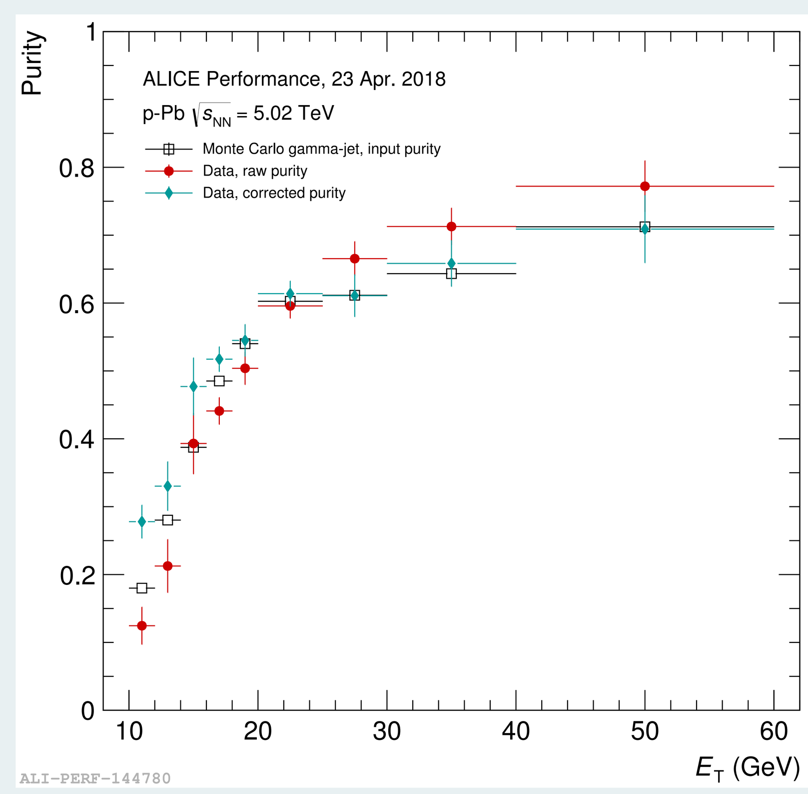
Results: isolated photon purity

- $\alpha < (>) 1$ at low (high) photon E_T → $\mathbb{P}^{\text{ABCD}}$ underestimated (overestimated) before correction
- $\mathbb{P}^{\text{ABCD}}$ and $\mathbb{P}^{\text{ABCD}}_{\text{corr}}$ compared to ideal purity $\mathbb{P}_{\text{input}}$ from Monte Carlo

$$\mathbb{P}_{\text{input}} = S_n^{\text{iso}}/N_n^{\text{iso}}$$

(S_n^{iso} = γ-jet signal, N_n^{iso} = γ-jet + jet-jet population in A)

- ABCD-method → $\mathbb{P}^{\text{ABCD}}_{\text{corr}}$ reaches 71 % at E_T = 60 GeV
- For E_T < 16 GeV, poorer comparison → need to study the **background shape** in signal region A



Conclusion & Outlook

- Statistic reach allowing to measure isolated photons with $E_T \in (10, 60)$ GeV → direct comparison to the ALICE **pp measurement** [2]
- High purity for high energy isolated photons → **good proxy** for measuring direct photons
- First isolated photon measurement in p–Pb collisions with ALICE → **cross section** and R_{pA} to be computed next
- Complementary to ALICE direct photon measurement **at low E_T** [5]

References

[1] ALICE EMCal Collaboration. "ALICE EMCal Physics Performance Report". 2010. arXiv: 1008.0413. [2] M. Germain for the ALICE Collaboration. "Direct photon measurements in pp and Pb–Pb collisions with the ALICE experiment". *Nucl. Phys.* A967 (2017), pp. 696–699. [3] R. Ichou and D. d'Enterria. "Sensitivity of isolated photon production at TeV hadron colliders to the gluon distribution in the proton". *Phys. Rev.* D82 (2010), p. 014015. arXiv: 1005.4529. [4] ATLAS Collaboration. "Measurement of the inclusive isolated prompt photon cross section in pp collisions at $\sqrt{s}$ = 7 TeV with the ATLAS detector". *Phys. Rev.* D83 (2011), p. 052005. arXiv: 1012.4389. [5] F. Bock for the ALICE Collaboration. *Direct photon production and flow at low transverse momenta in pp, p–Pb and Pb–Pb collisions.* Quark Matter 2018 Parallel Talk.

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