Photon and jet measurements with the ALICE detector at the LHC

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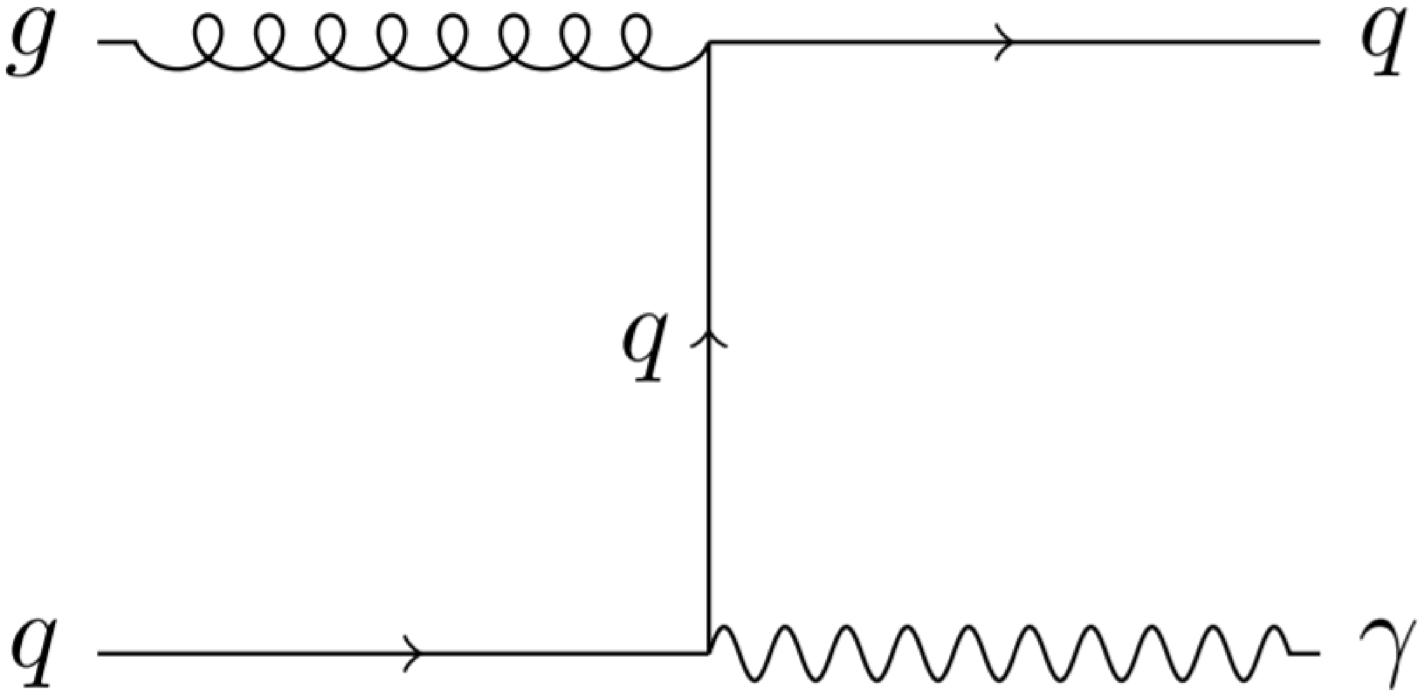
ALICE

Outline

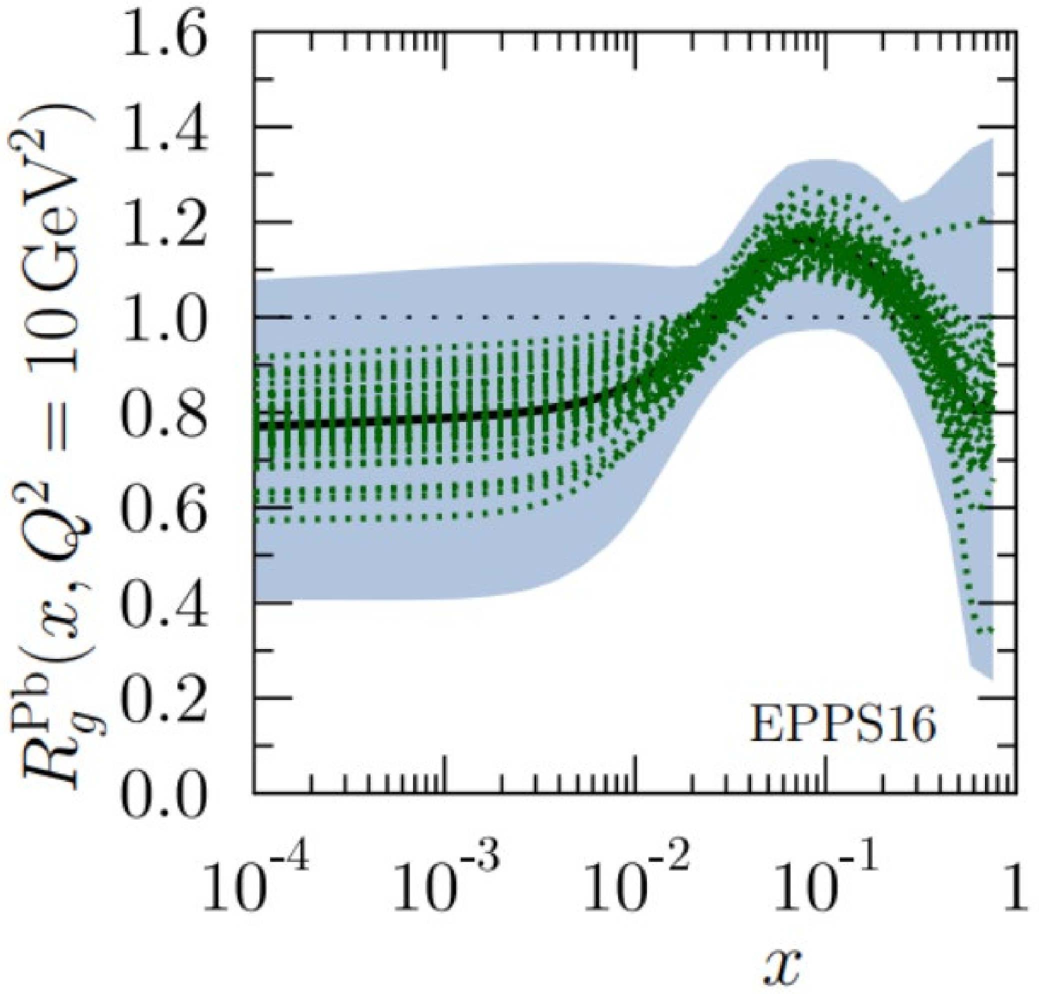
- Why measure photons?
- How to measure photons?
- Preliminary results
- Prospects

Photons emerge from process like:



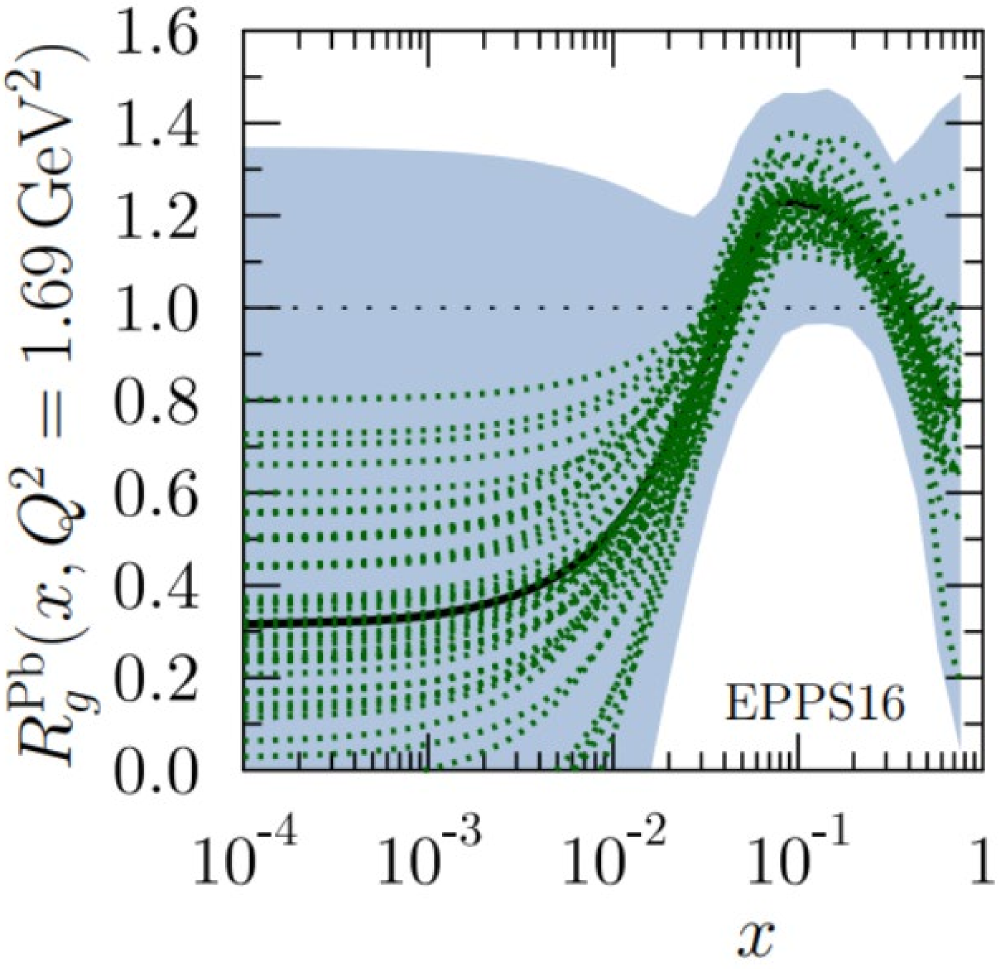
Sensitive to gluon density in proton (nuclei)

Gluon density nuclei/proton



Eur.Phys.J. C77 (2017) no.3, 16

At low Q^2



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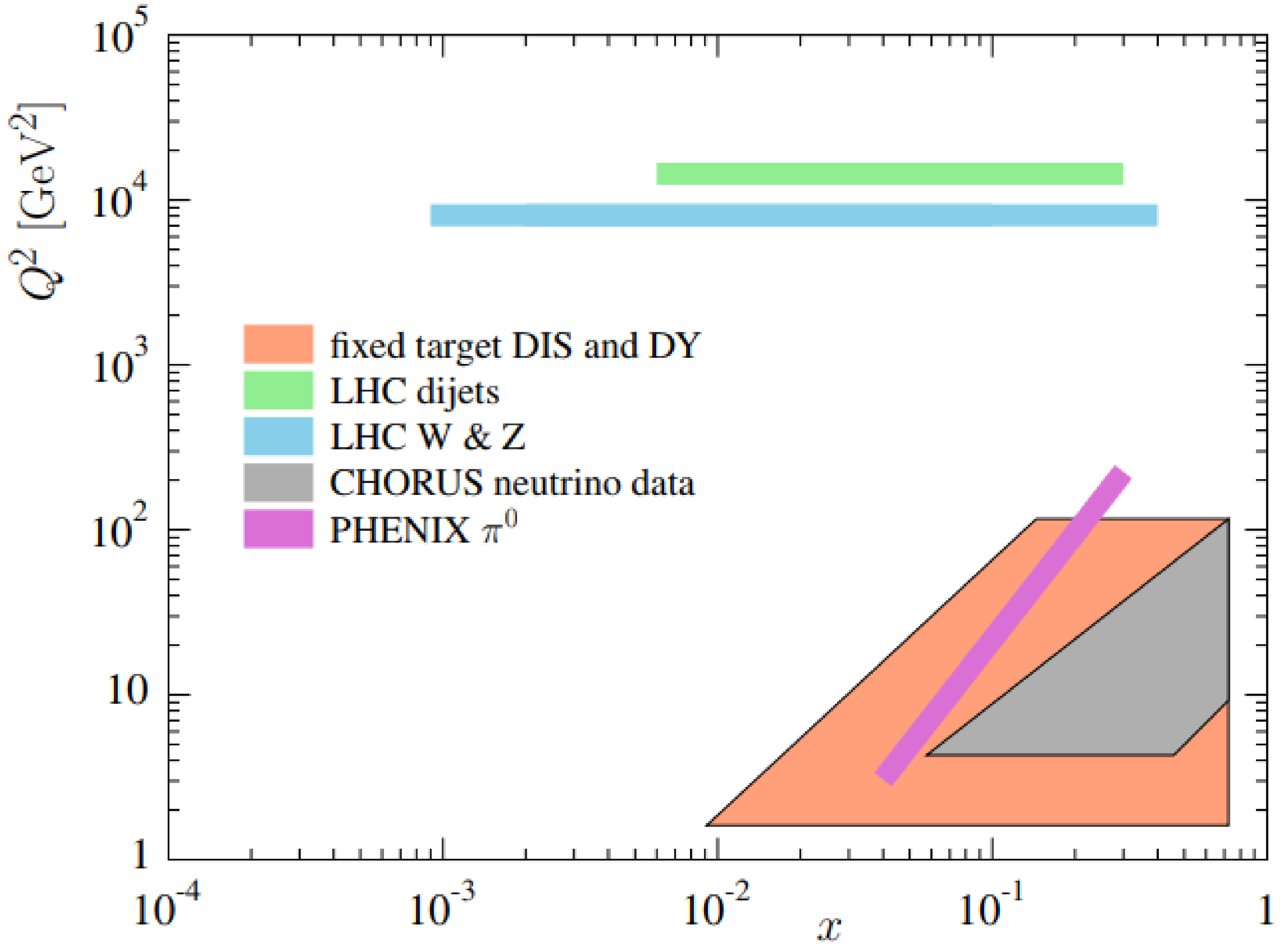
Existing data constraining gluon density in nuclei



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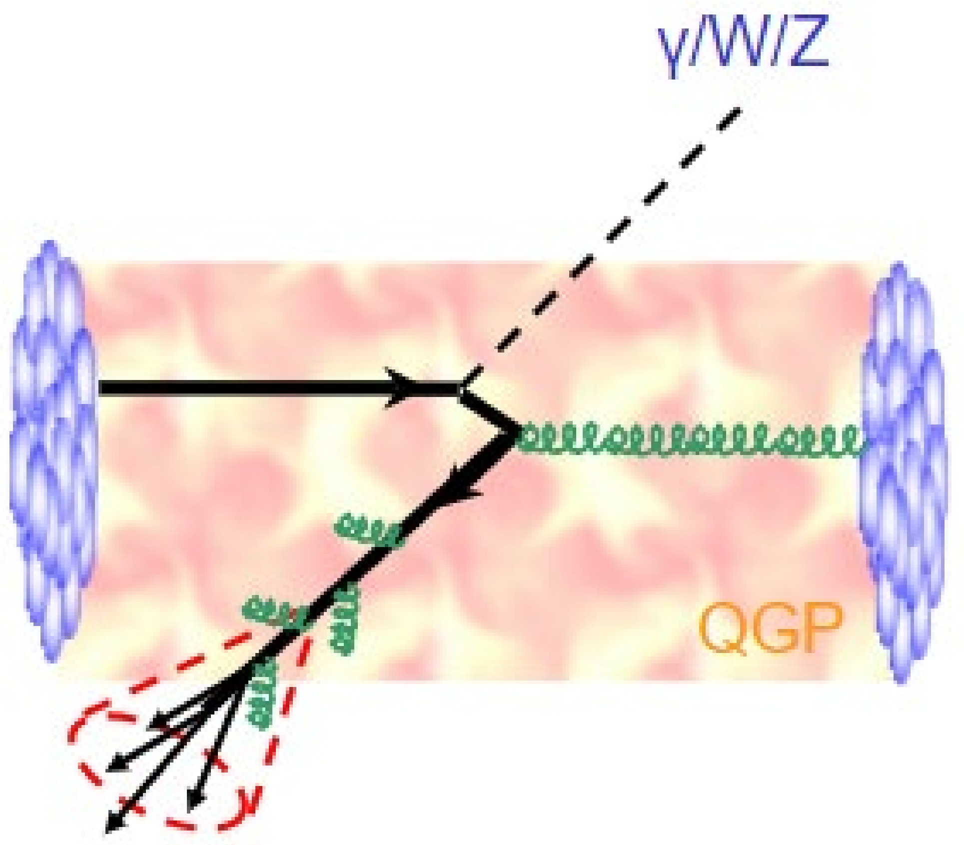
"Standard candle" for jet-quenching studies in quark-gluon plasma

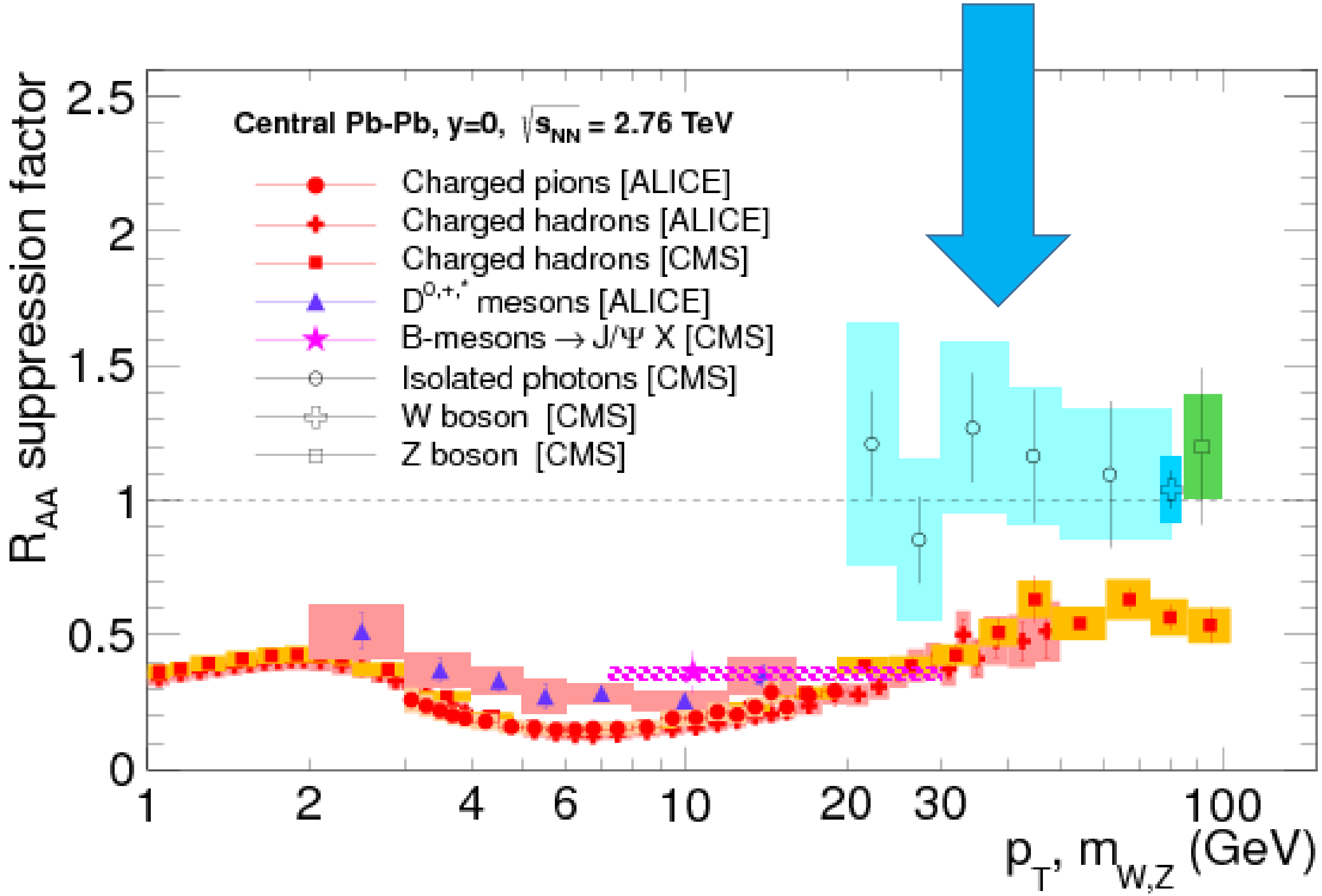


Mean-free-path of photons in quark-gluon plasma is relatively large.

Photon momentum constrains momentum of recoiling quark.

Figure by Yen-Jie Lee

Photons are a control probe to the quark-gluon plasma



Electroweak bosons are NOT suppressed in the quark-gluon plasma

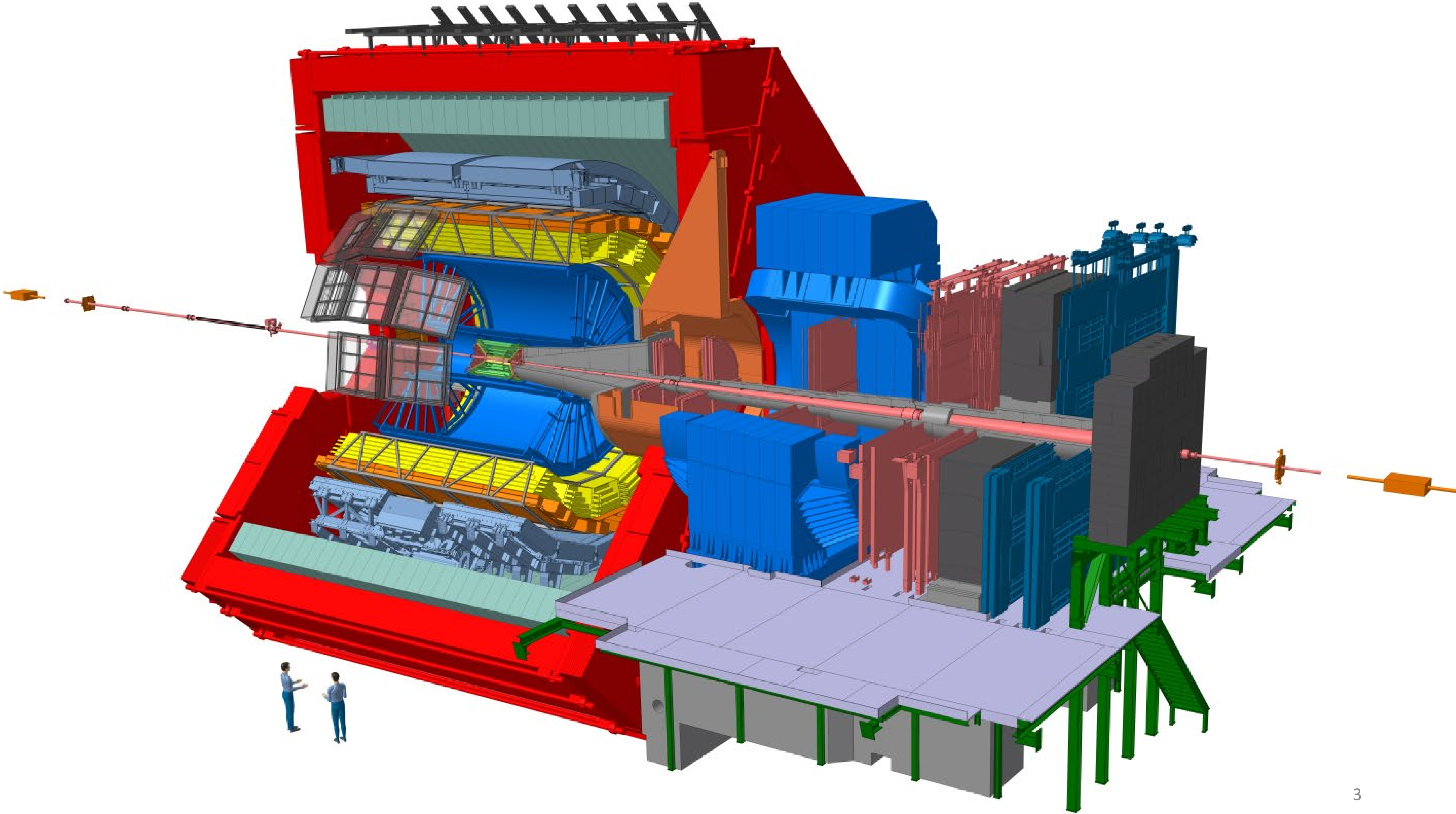
Challenges

- The γ/π^0 cross-section ratio **is about 1%** in the pT at 10 GeV.
- High-energy photons measurements require large data samples.

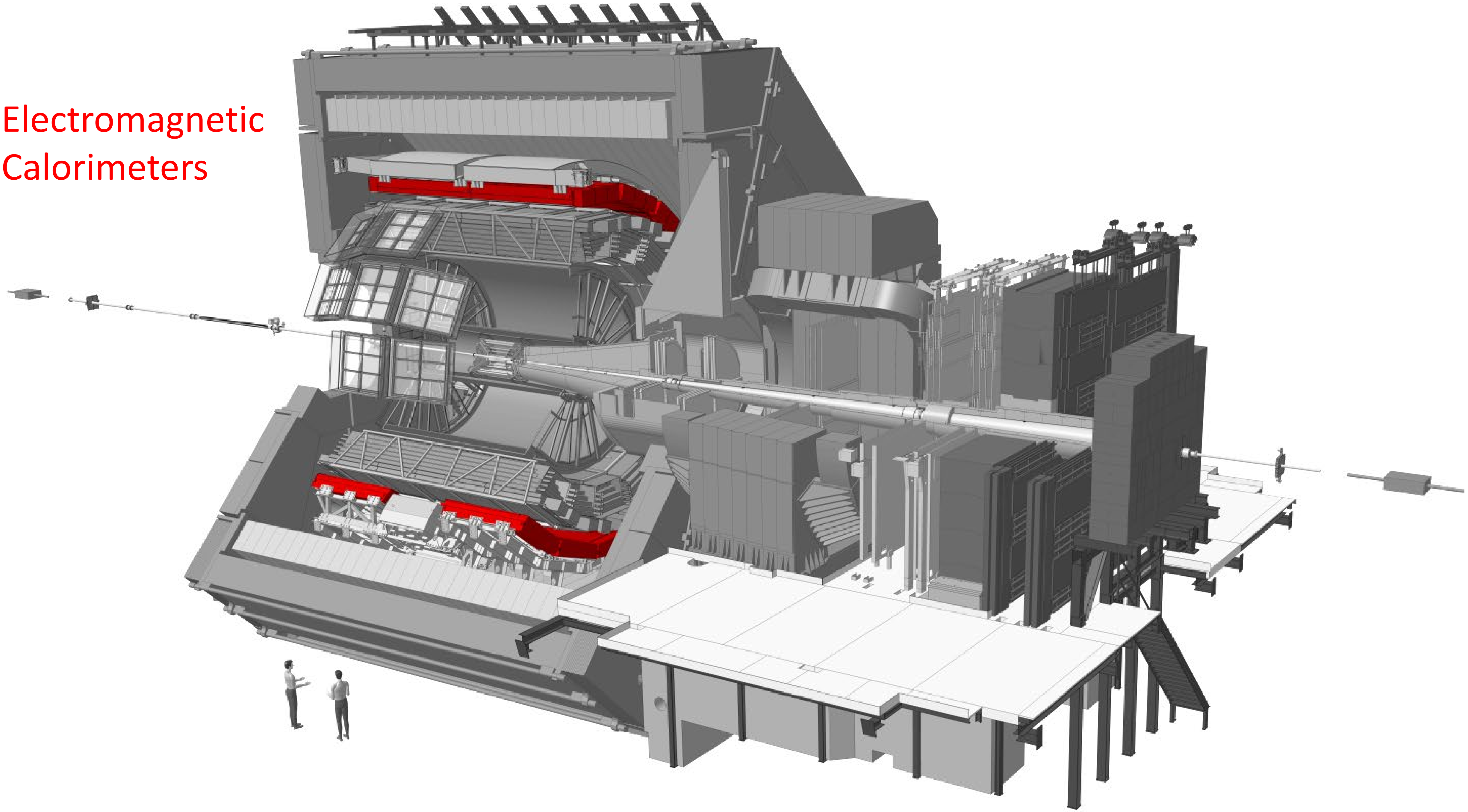
LHC data

- **pp collisions at 5 TeV**
- **p-Pb collisions at 5 TeV**
- **Pb-Pb collisions at 5 TeV**

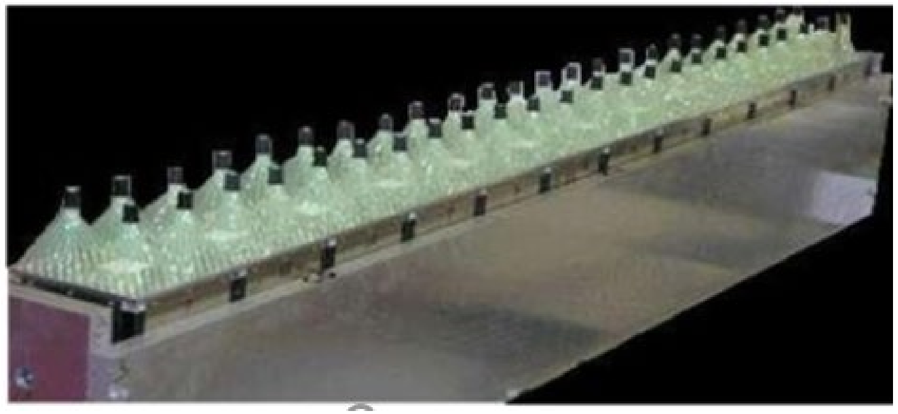
} I will show results on these today



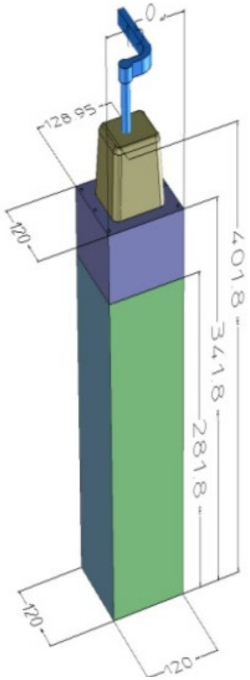
Electromagnetic Calorimeters



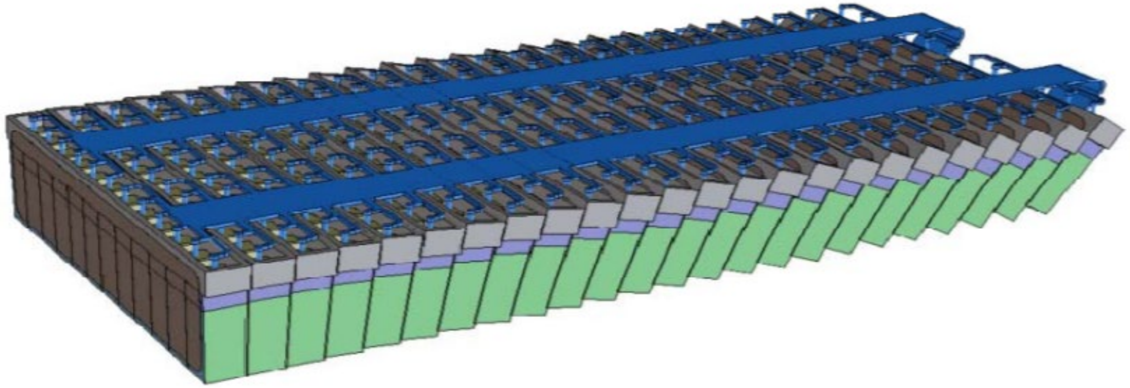
EMCAL,
Pb/Sc sampling calorimeter
Shashlik layout



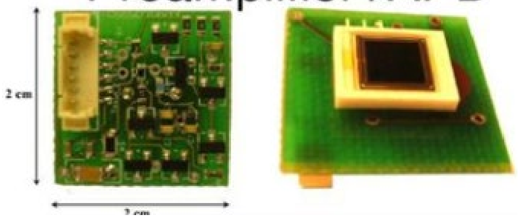
Module (2x2 towers)



Supermodule

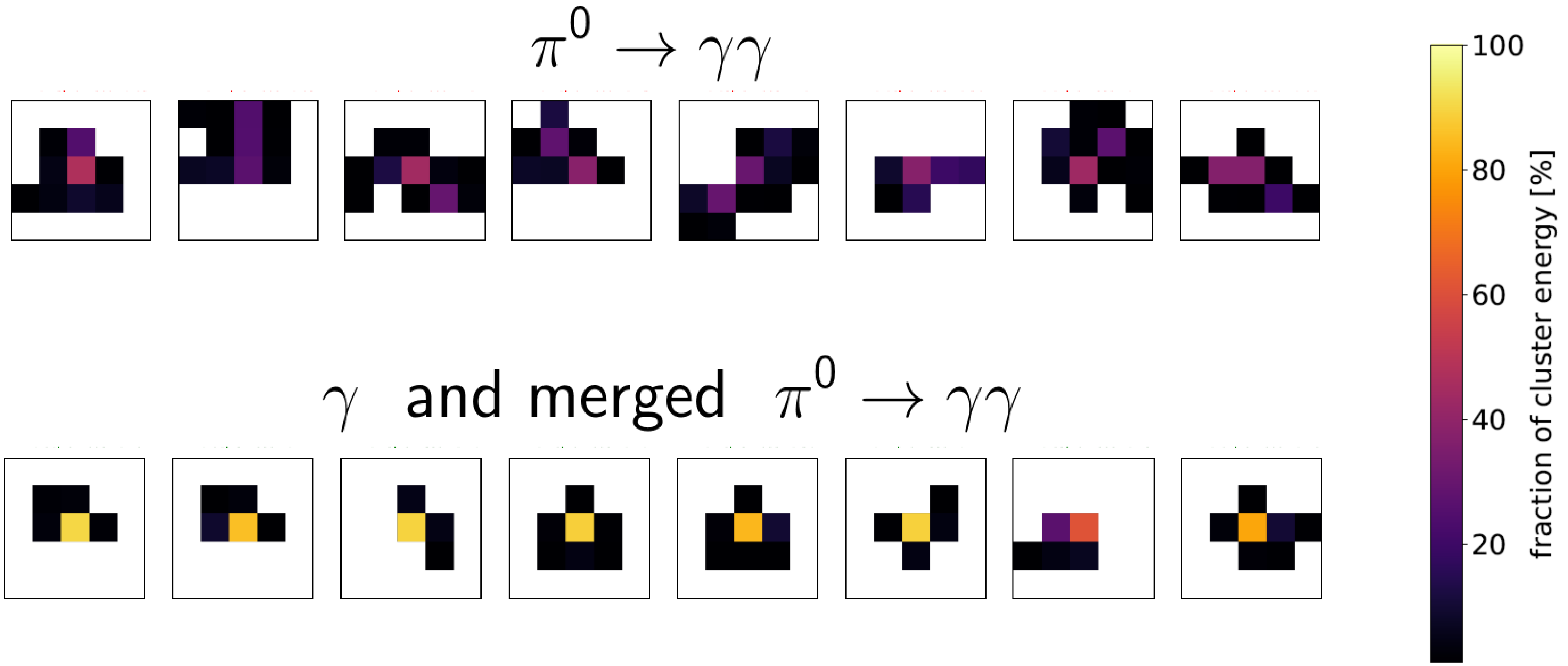


Preamplifier+APD



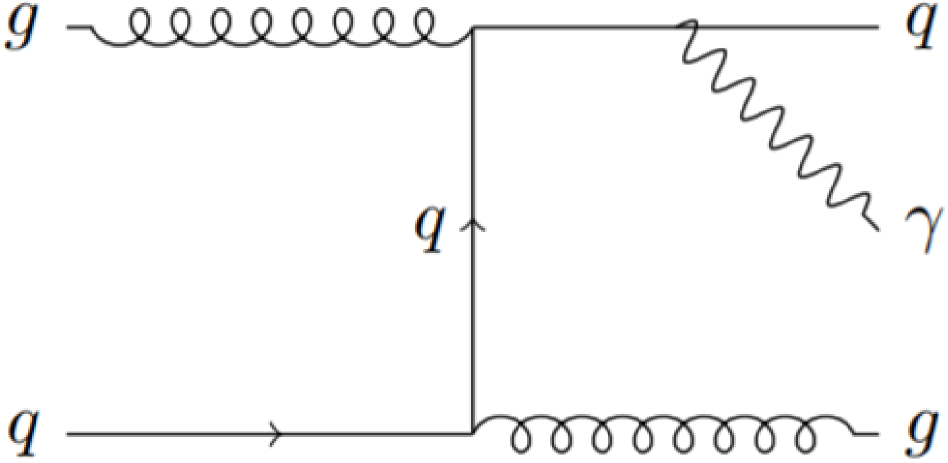
- 12 supermodules
  - 24 strips in η
  - 12 (or 6) modules in φ
- 12672 elementary sensors (towers)
  - 77 alternating layers of
    - 1.44 mm Pb (1% Sb)
    - 1.76 mm polystirene scintillator
  - $\Delta\eta \times \Delta\phi = 0.014 \times 0.014$

Photon identification with shower shapes

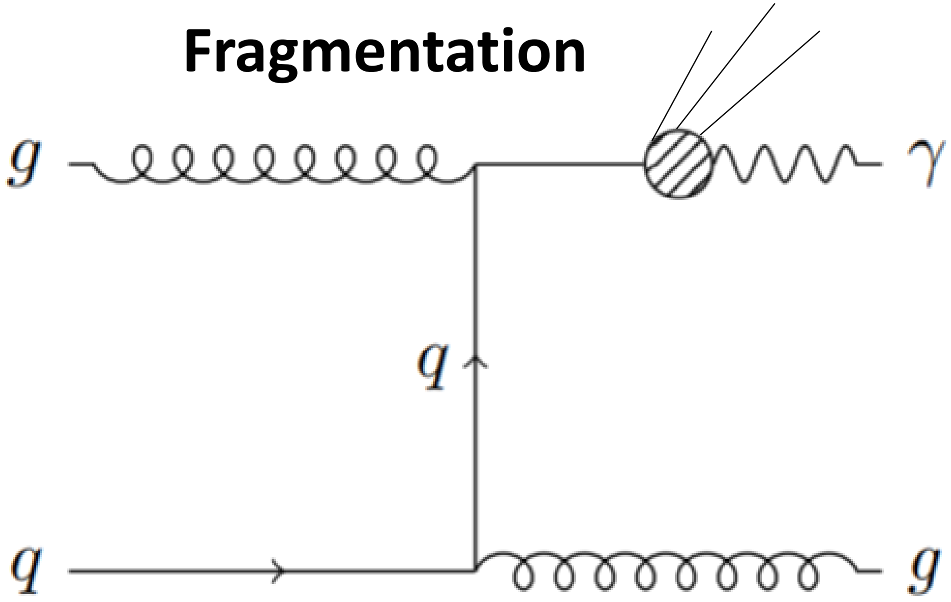


Higher-order processes yield **about 50%** of the photon cross-section

Bremsstrahlung

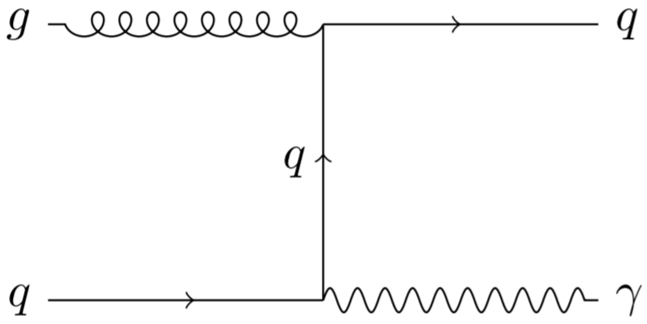


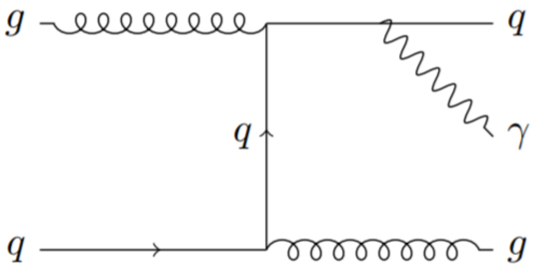
Fragmentation

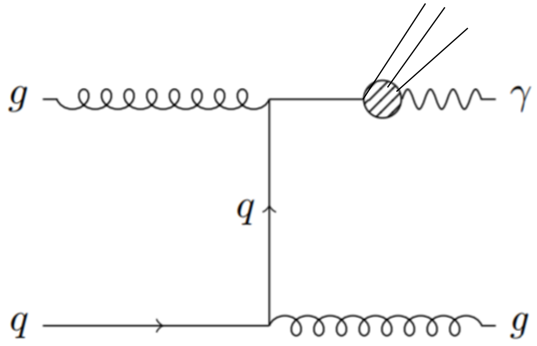


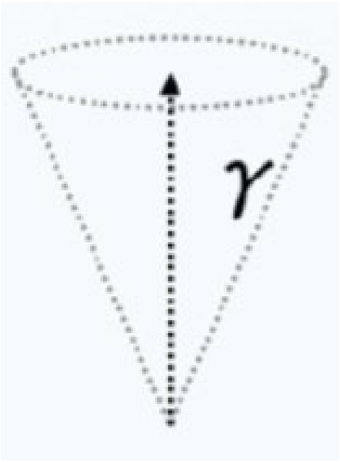
These are real photons, so shower-shape might

Isolation criteria reduces higher-order terms

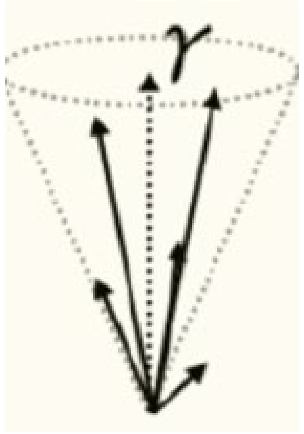






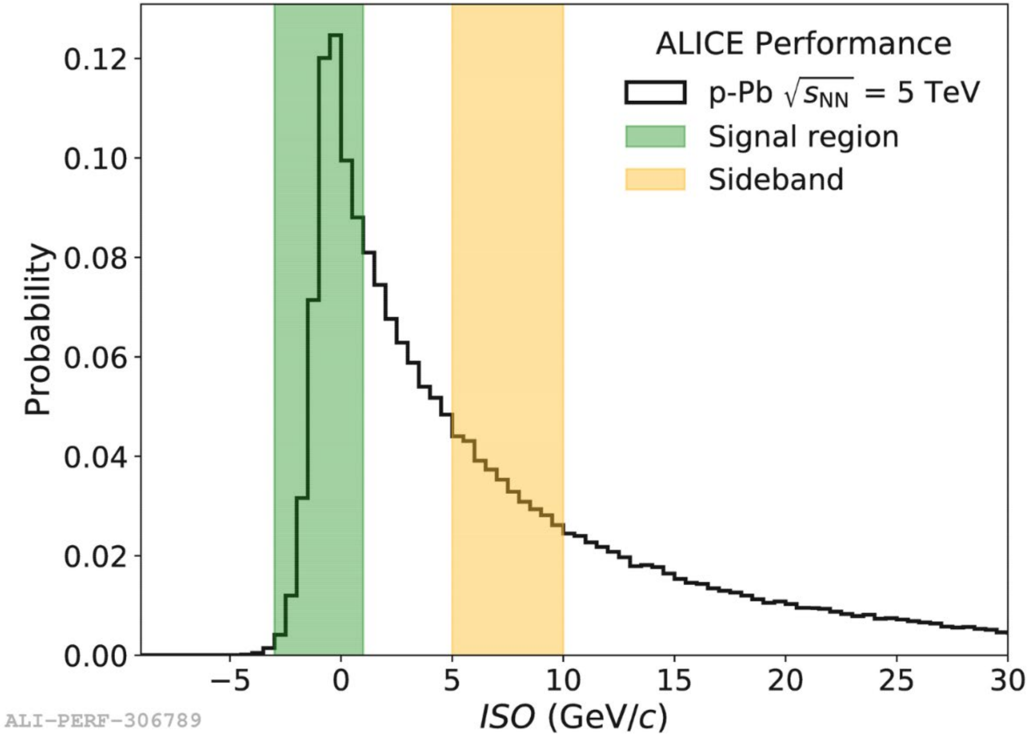


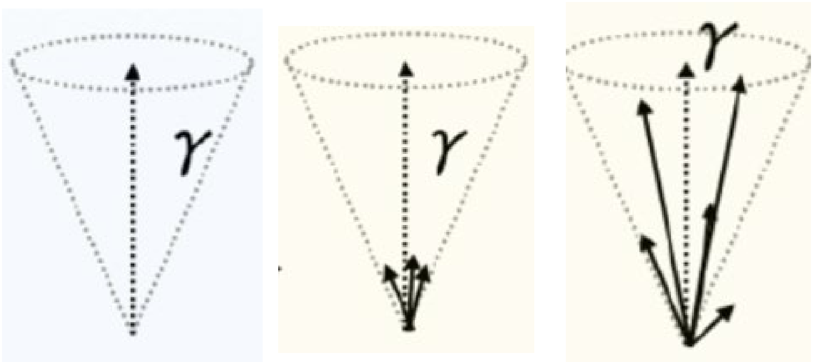
Isolated



Non Isolated

Photon Isolation distribution

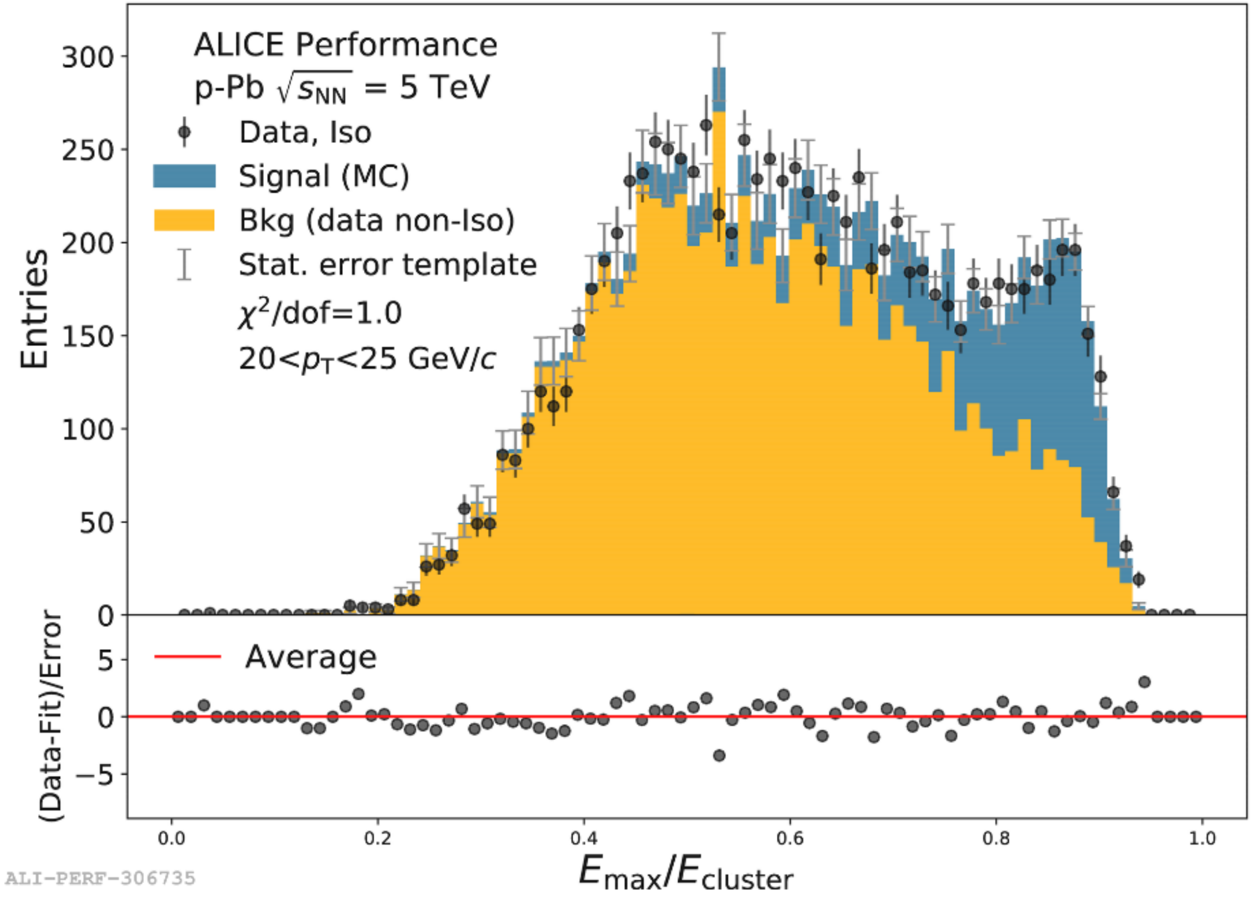




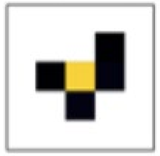
Isolation criteria reduces fragmentation photons background to about ~20%

It also reduces π^0 background (jet)

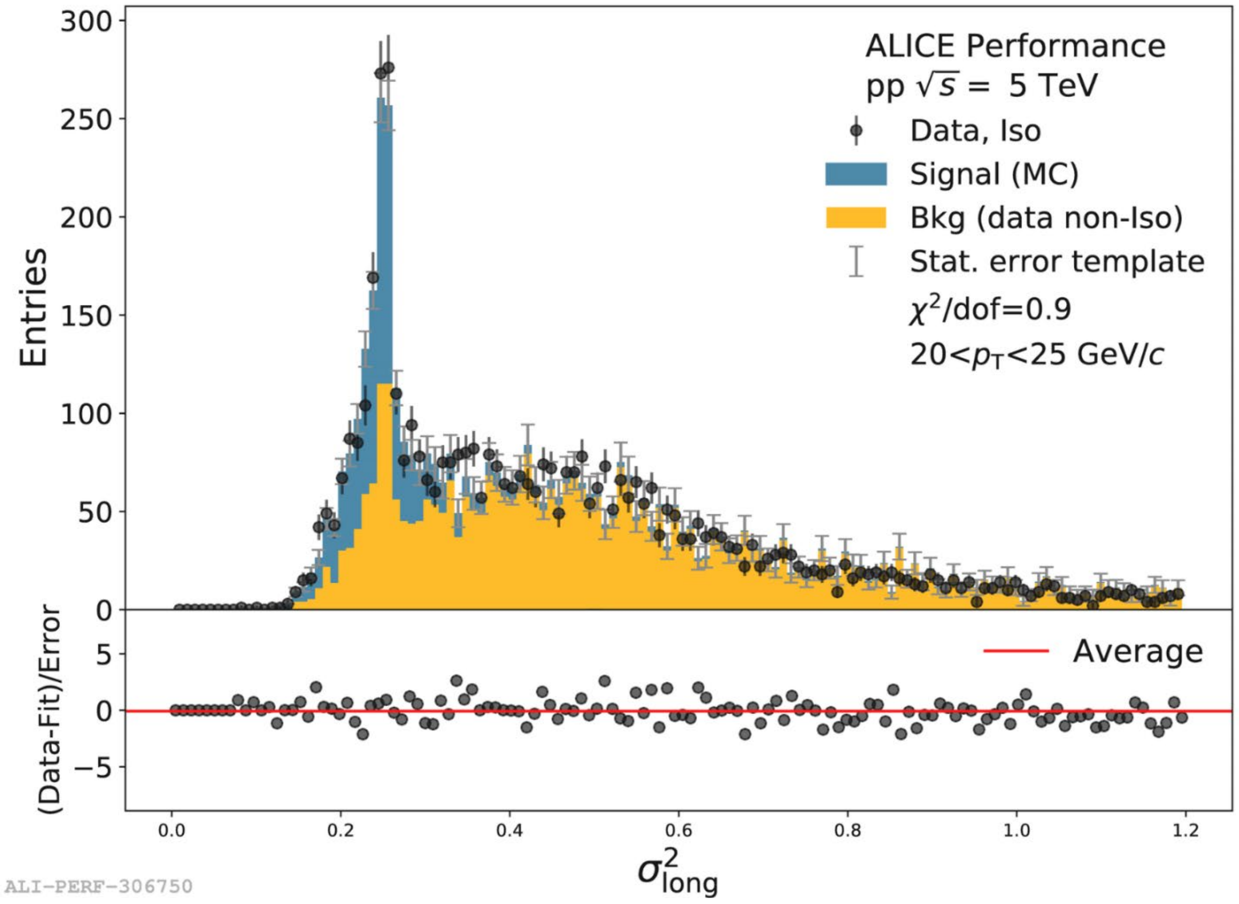
Template fit for purity measurement



- Data-driven background template
- Signal template from MC
- 1 free parameter

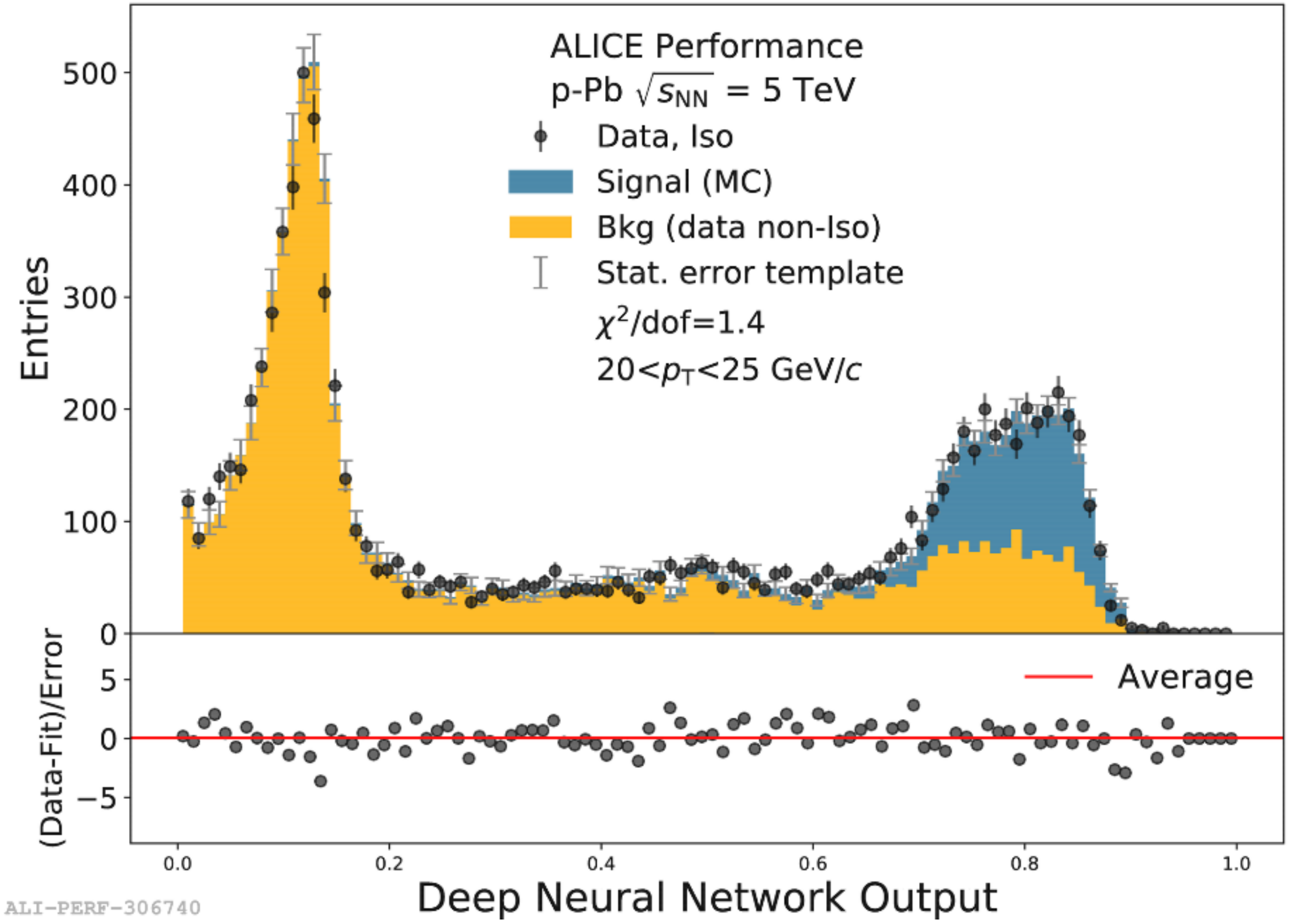
Width of the shower-shape

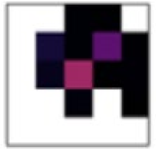


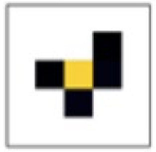
Energy-weighted
Spatial RMS of shower-shape

Machine learning

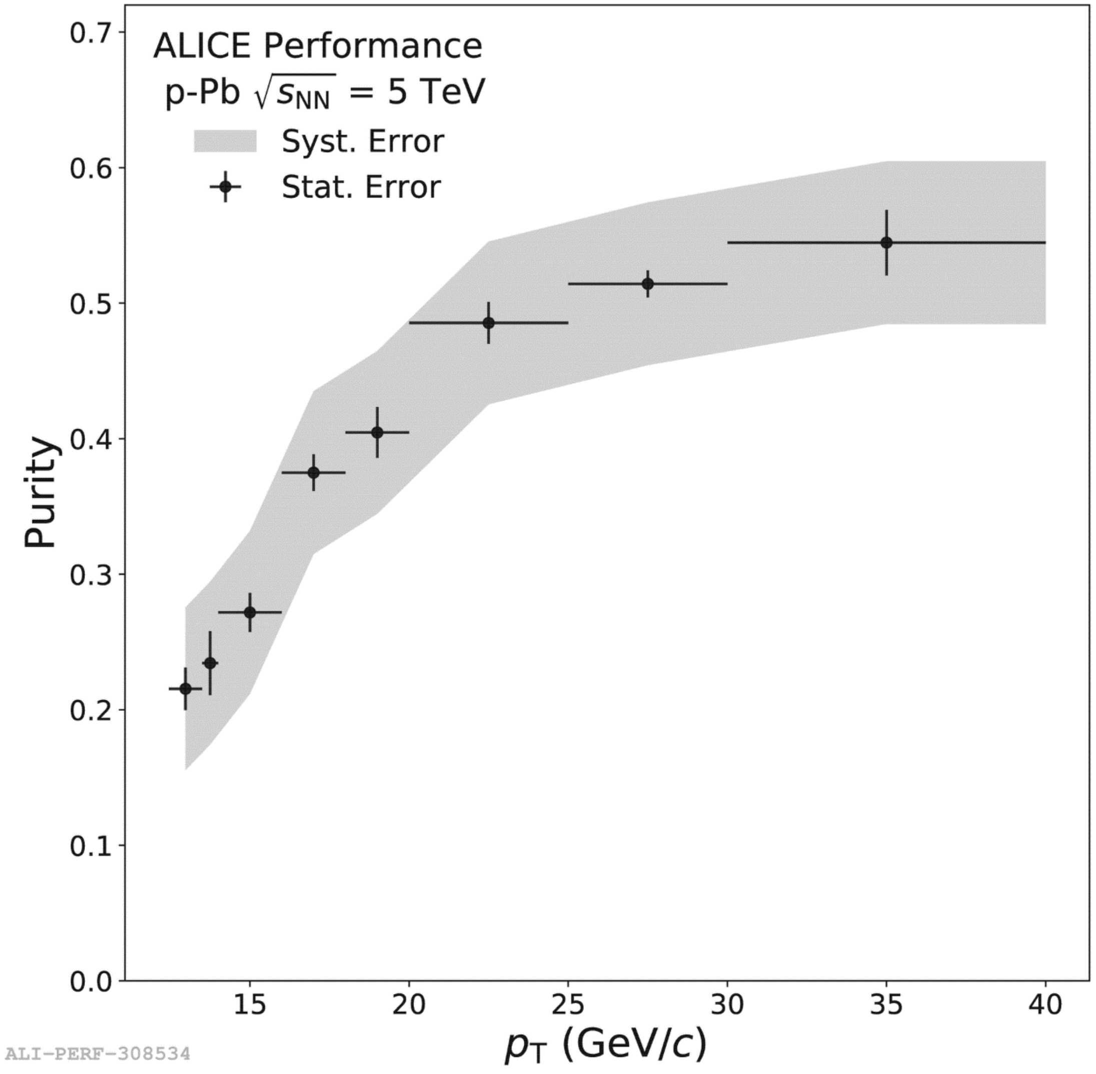
Work by Yue Shi Lai, (NSD)





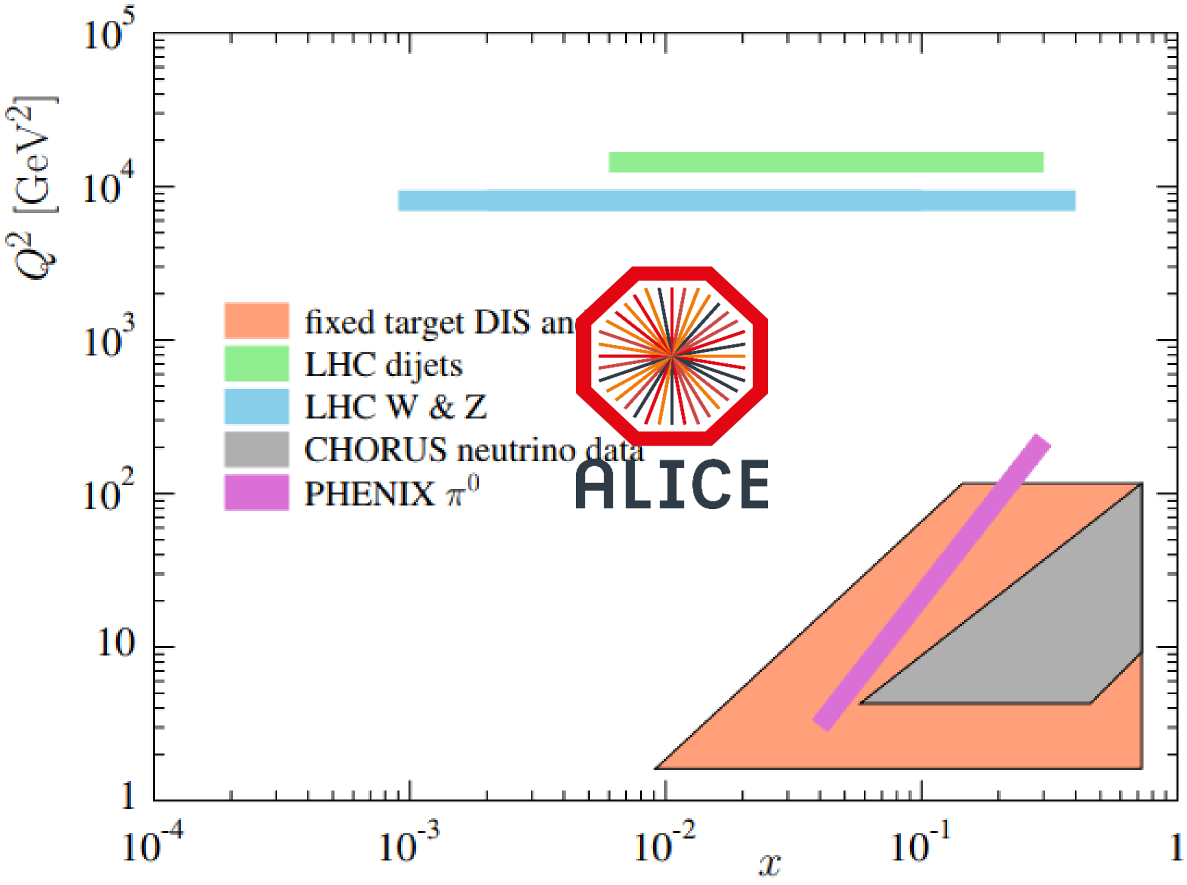


Photon Purity measurement



- Measurement reported down to pT ~ 12 GeV
- Most of the systematic uncertainties cancel in the pA/pp ratio.
- **Aim measurement with about 10% uncertainty**

Photons measured with ALICE access a poorly explored low Q^2, low-x region

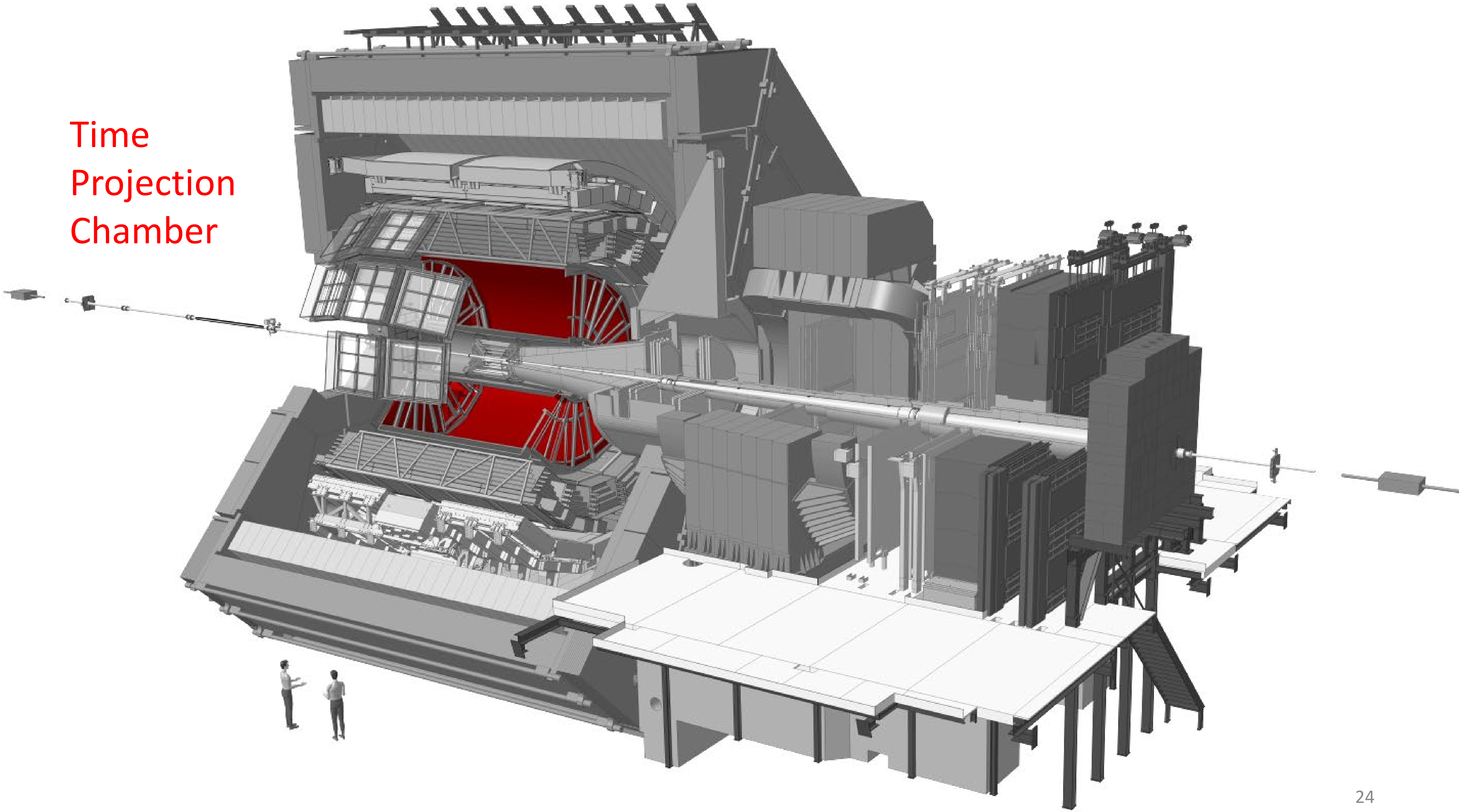


$$x \sim \frac{2p_T}{\sqrt{s}}$$

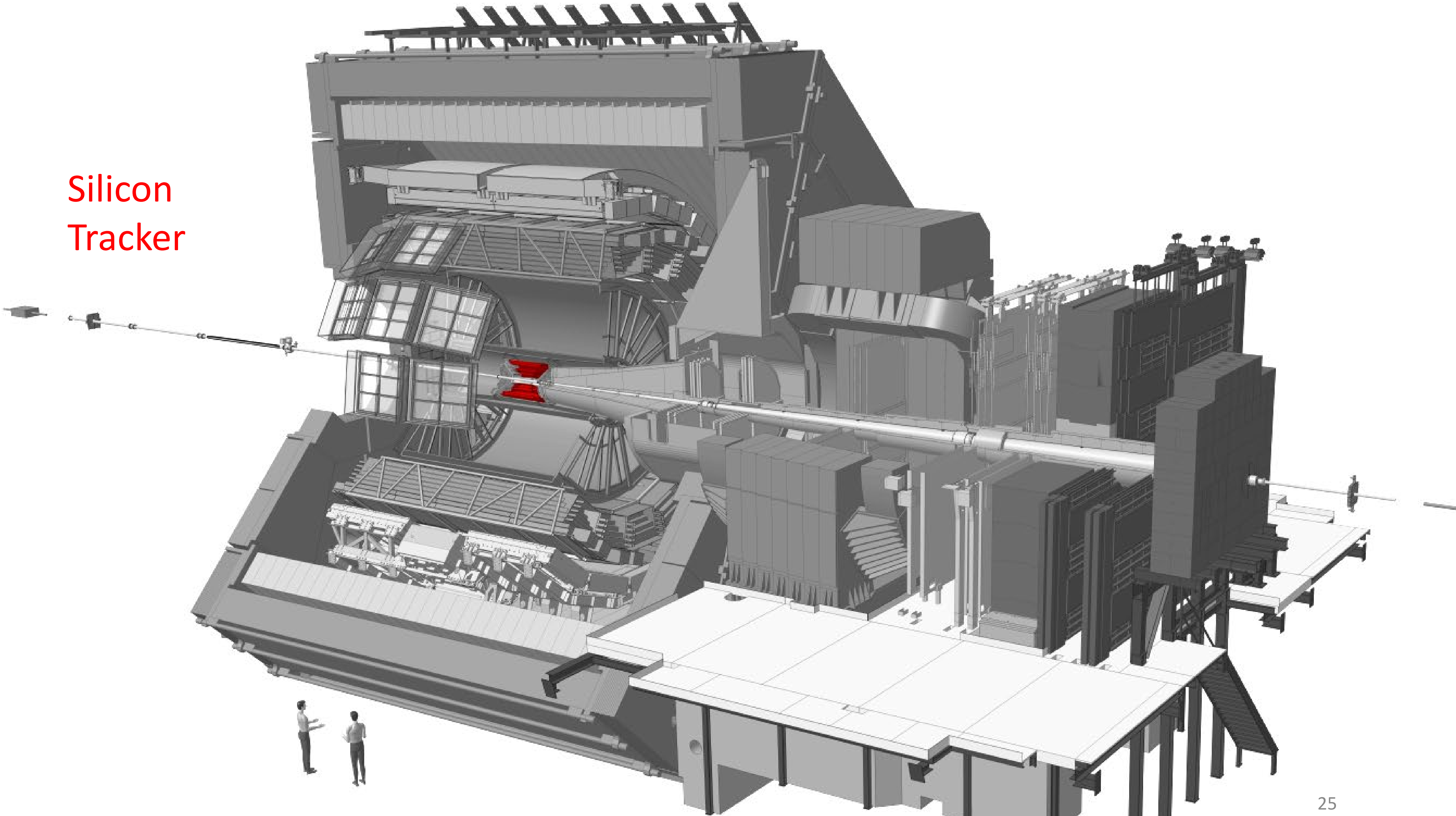
$$Q^2 \sim p_T^2$$

Isolated photon + jet correlations

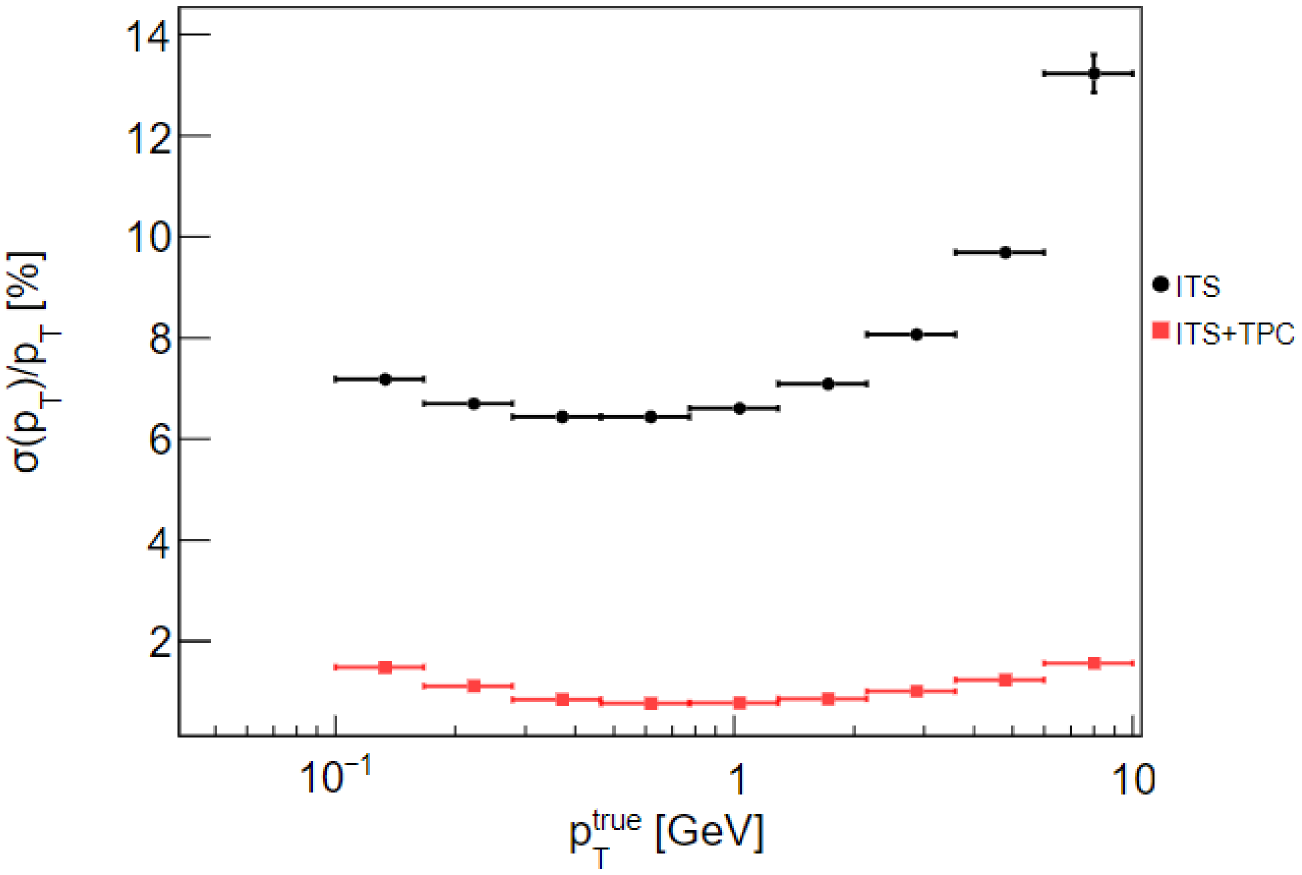
Time
Projection
Chamber



Silicon Tracker

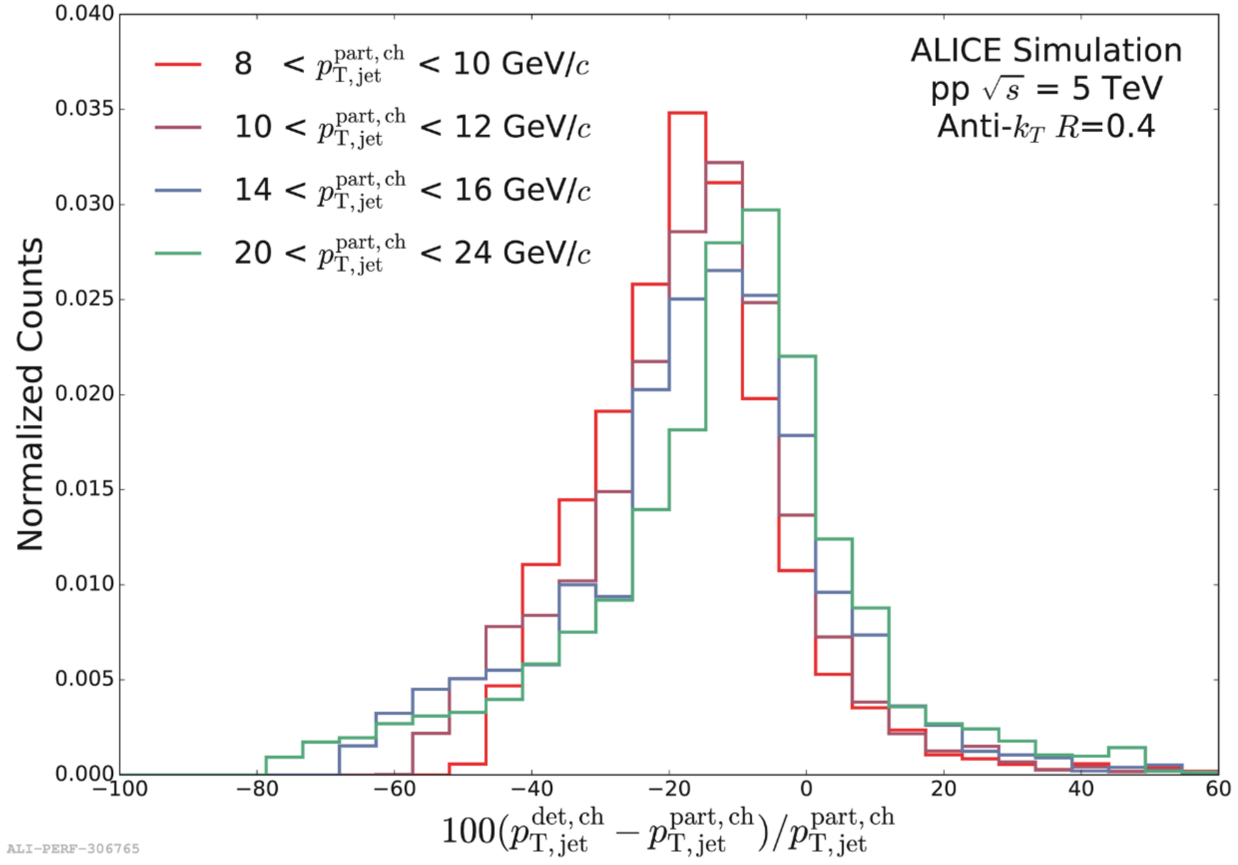


Track resolution with silicon-tracker



A good factor of 7 worse track resolution with silicon tracker only, Mainly due to larger TPC lever arm

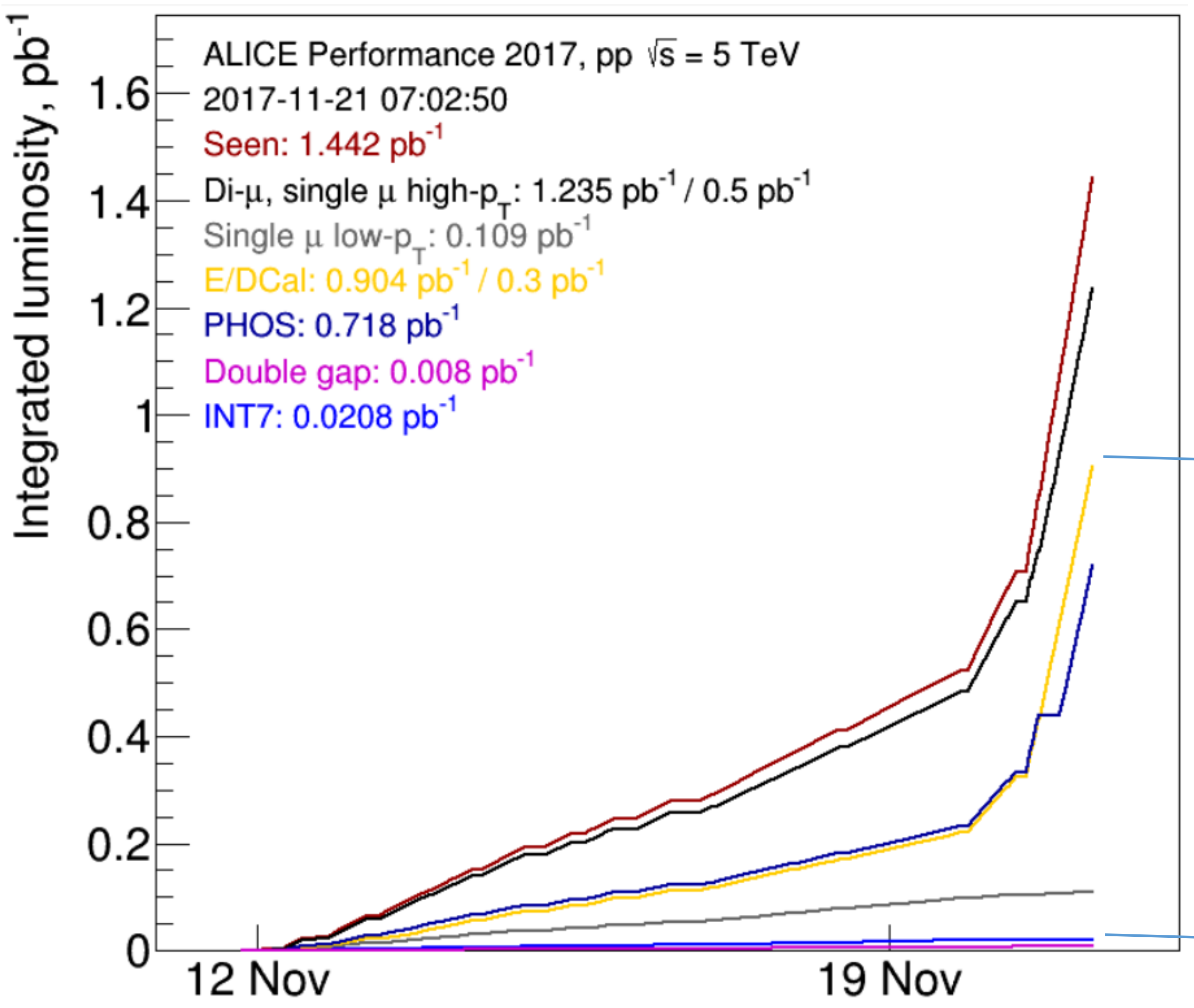
Jet performance (silicon tracker only)



- Jet energy resolution in 15-25% range
- Jet energy scale 13-16% range

This can be corrected with unfolding (deconvolution)

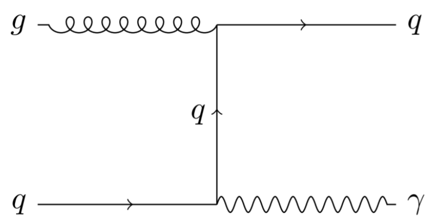
5 TeV pp run in (November 2017)

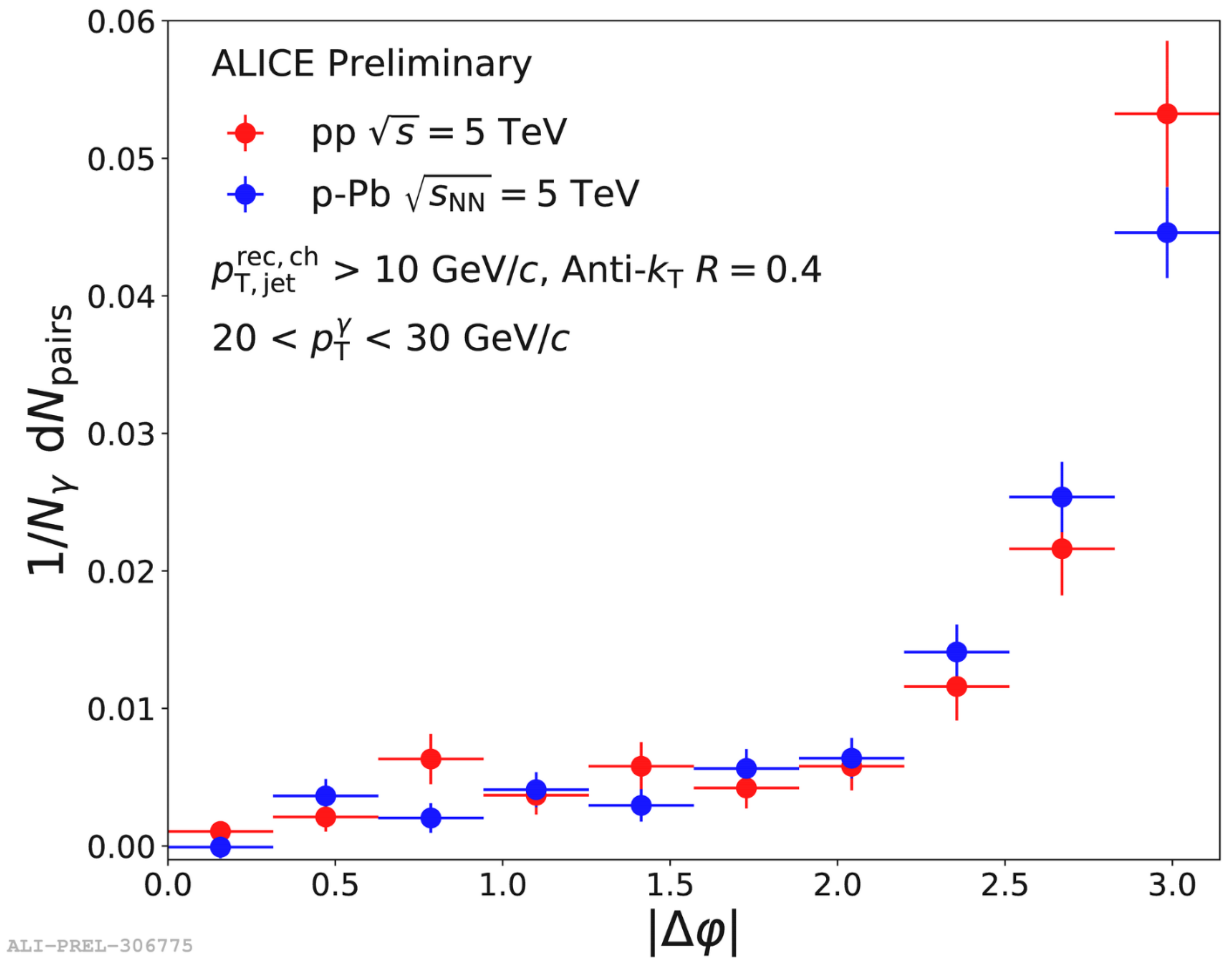


Our data-taking approach,
No TPC readout,
first-time used

Standard (1B events)

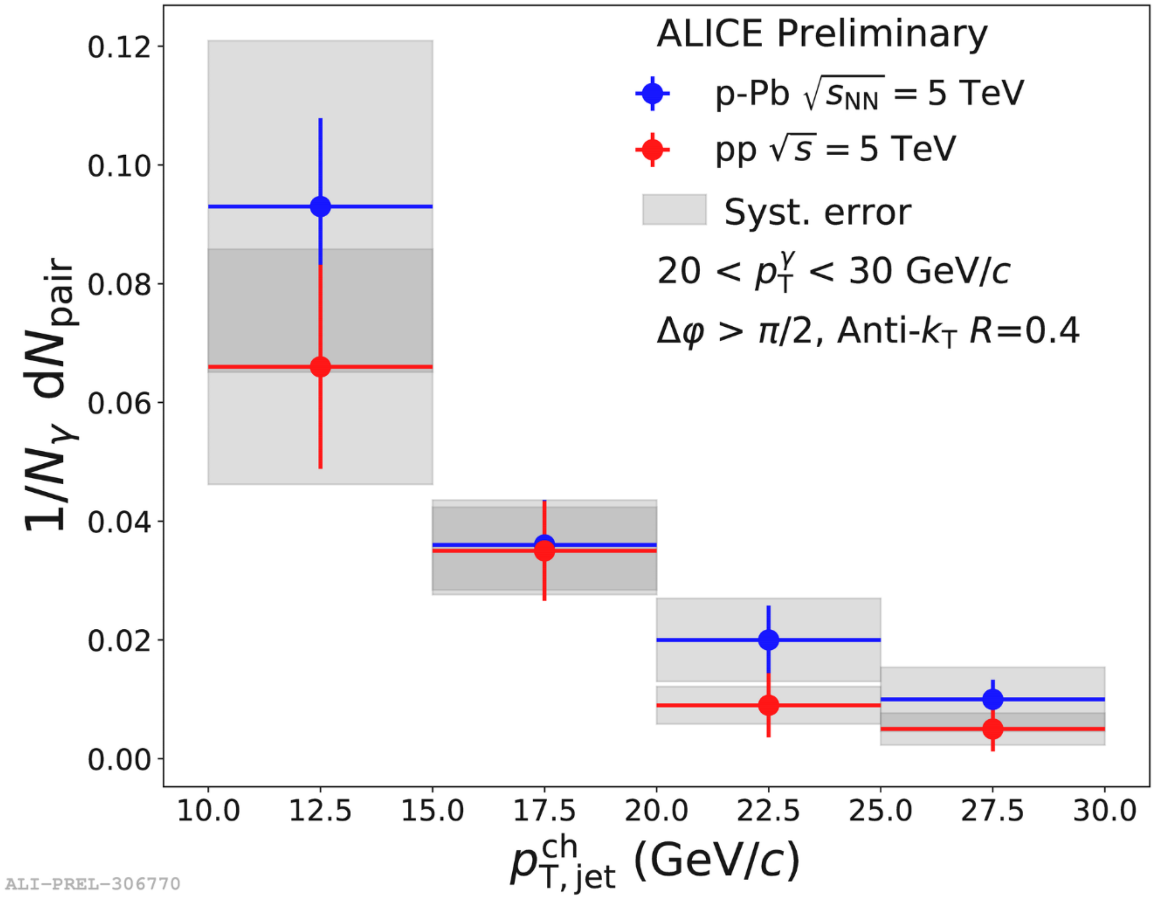
Photon + jet angular correlation





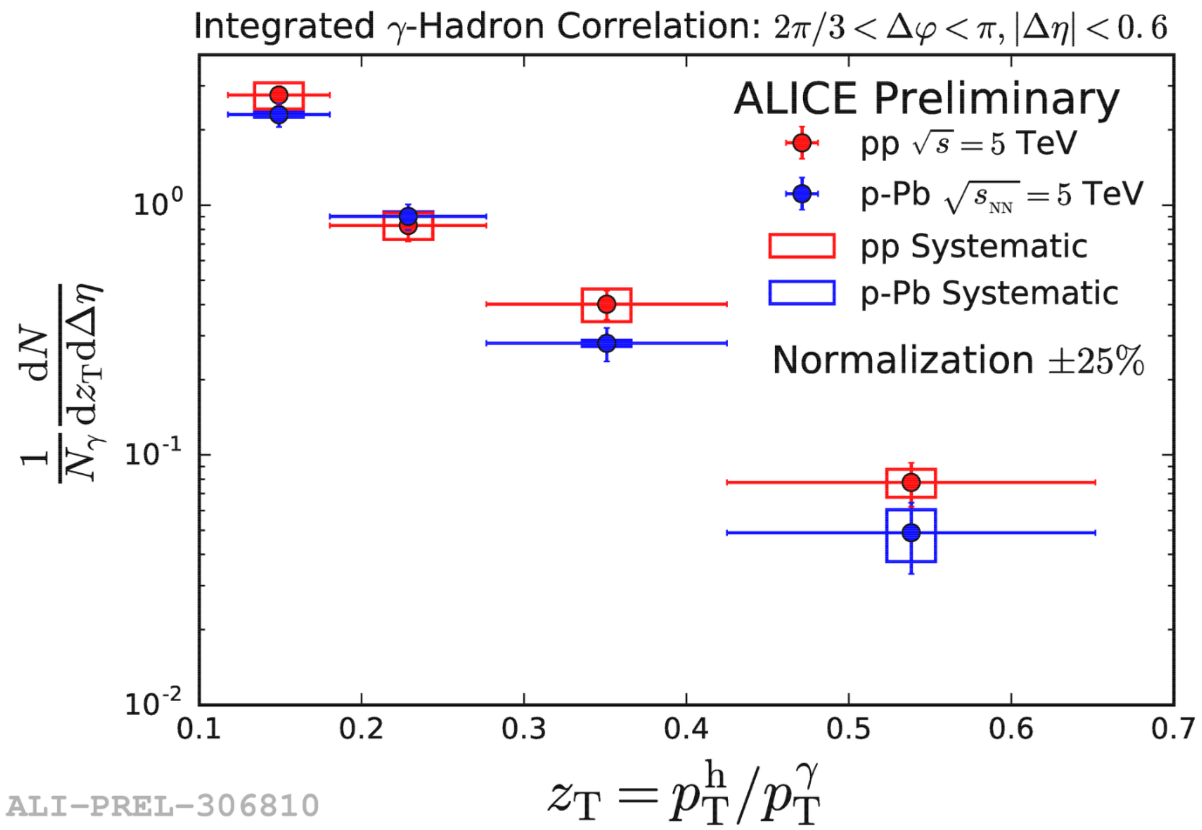
- Anti-*k*T *R*=0.4 jets. Track constituents
- Pairs with $\Delta\varphi > \pi/2$ kept

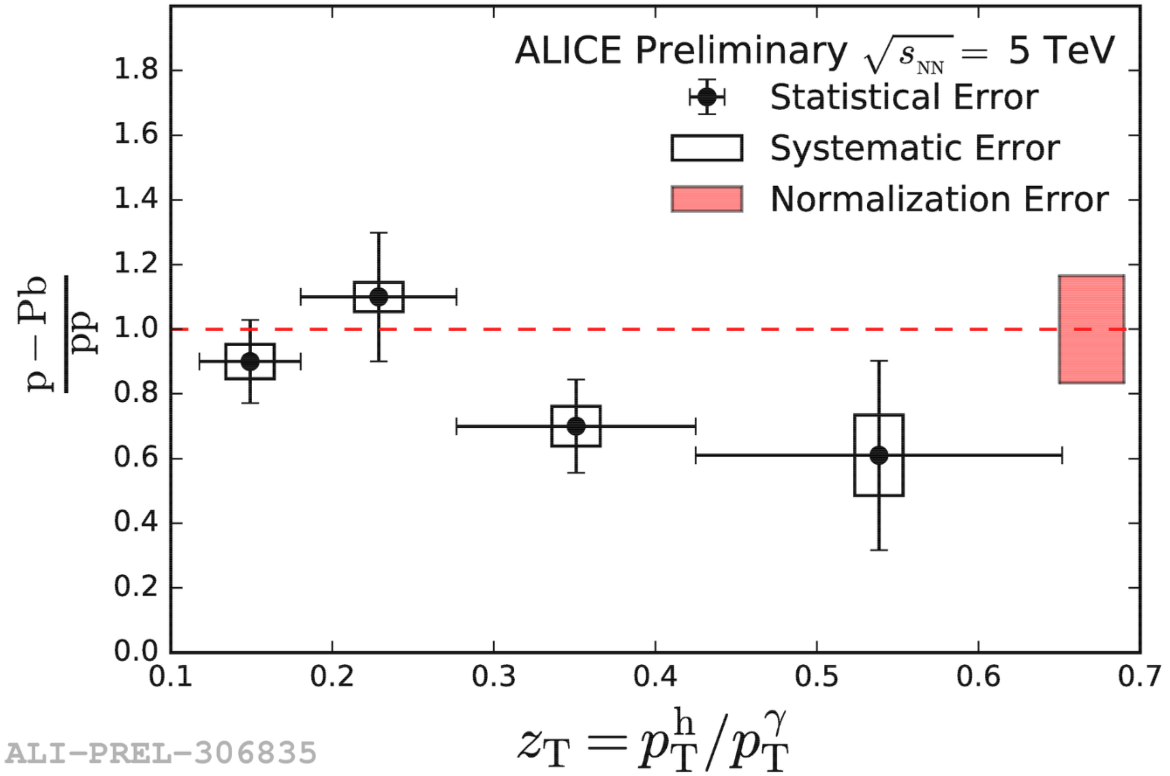
Spectrum of jets recoiling to isolated photons



- No significant difference between pp and p-Pb data

Integrated photon + hadron correlations

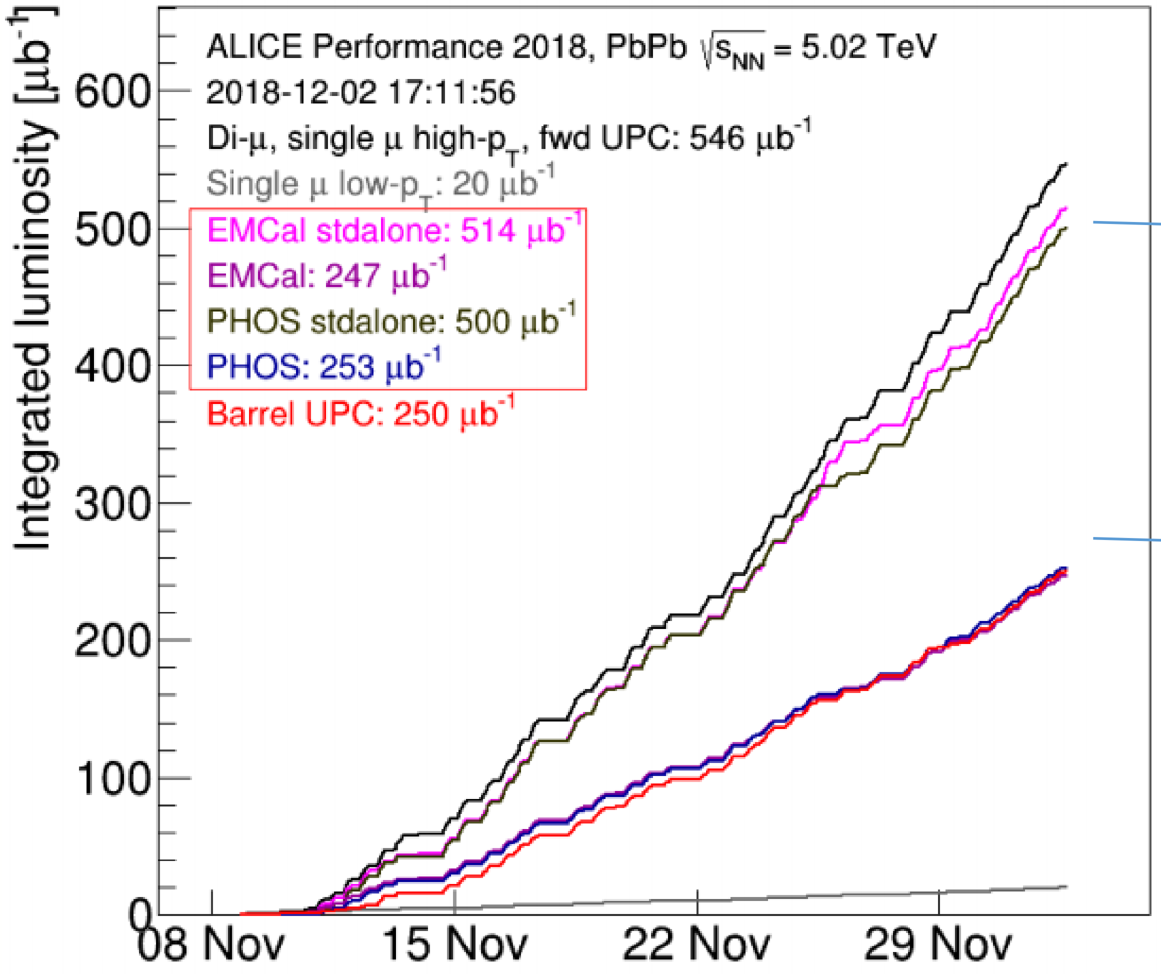




No significant difference between pp and p-Pb data

Future prospects

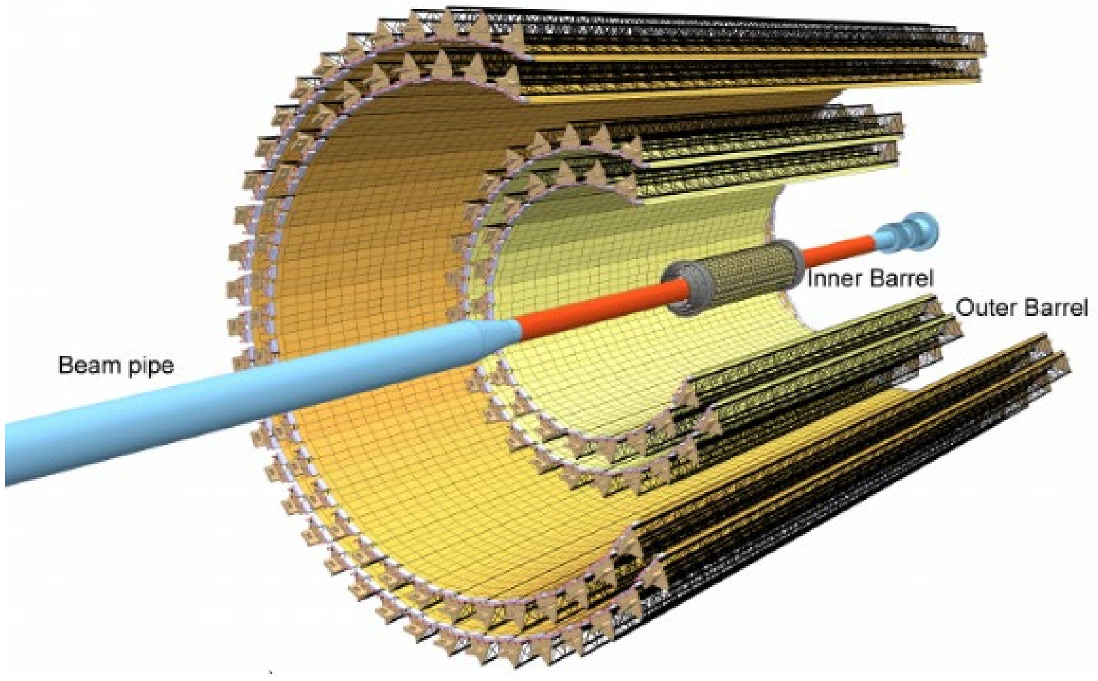
5 TeV **PbPb** run (November 2018)



Our data-taking approach,
No TPC readout,

Standard

Potential of upgraded silicon tracker



- Standalone tracking with upgraded silicon tracker (2021—2029).
- Better resolution and faster readout .
- The only way to enough pp/pA data statistics for photon/jet measurements.

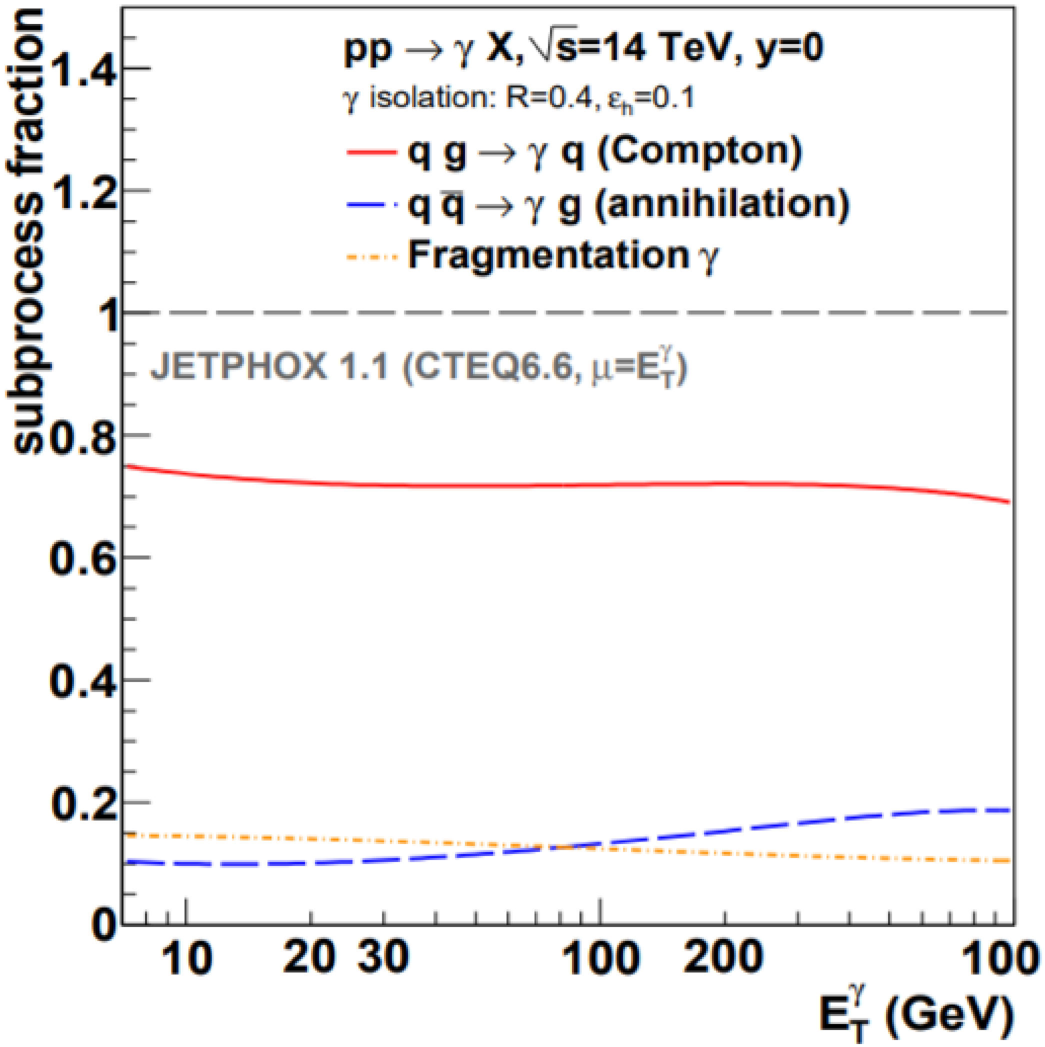
Summary

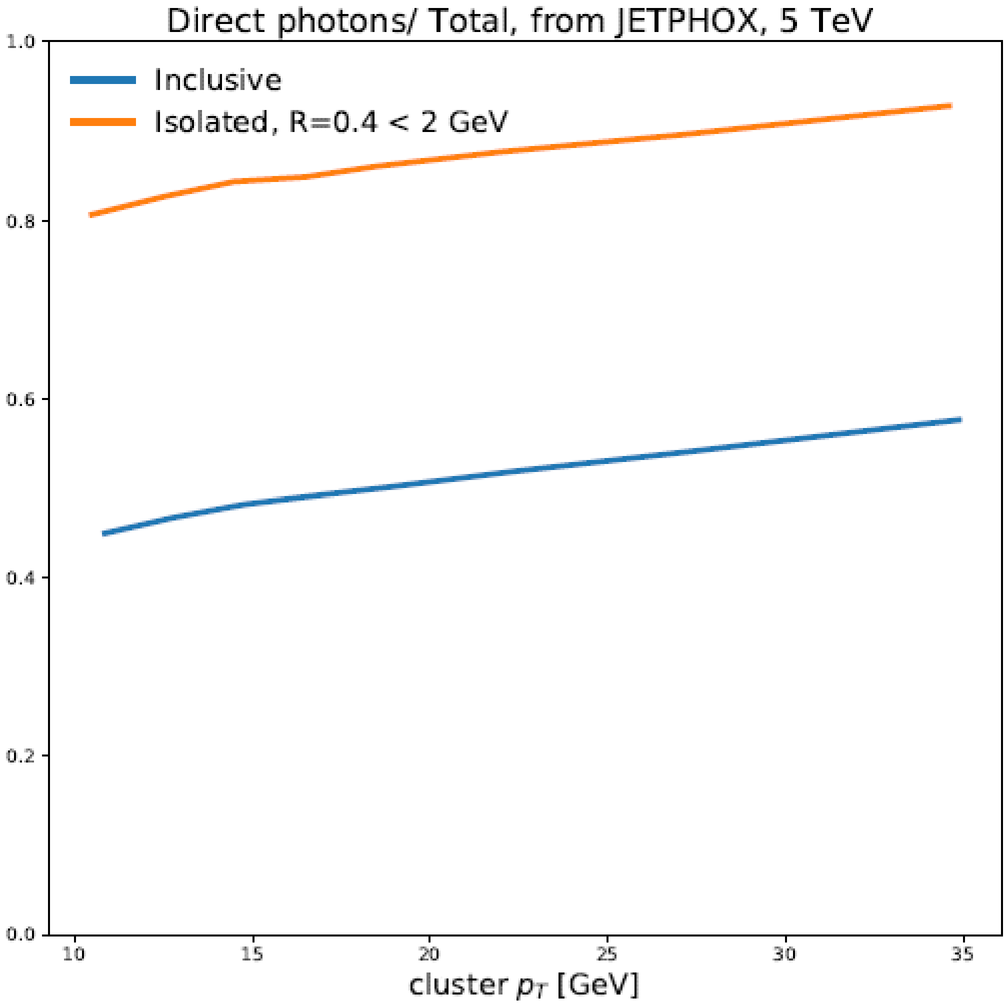
- I have presented work towards first isolated photon and jet analyzes with ALICE.
- These cover an unexplored kinematics at low momentum.
- No significant difference is observed between pp and p-Pb measurements
- This result establishes a benchmark for photon identification and jet reconstruction for future measurements with ALICE

Backup Slides

Fragmentation photons

Phys.Rev.D82:014015,2010

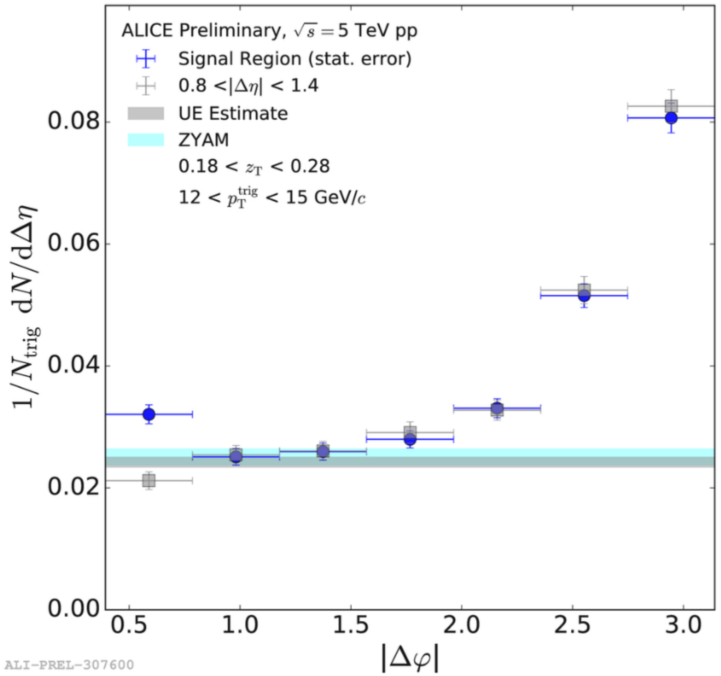


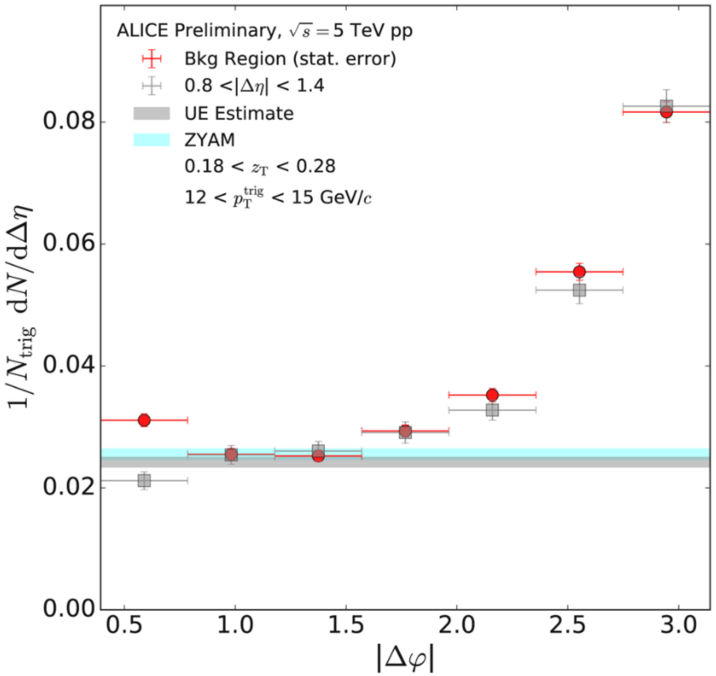


Correlation functions methodology

- Correlation between photons with 12—15 GeV/*c* and tracks, in different z_{T} bins. Corrected by acceptance (mixed events), efficiency and fake rate:

$$C(\Delta\varphi, \Delta\eta) = \frac{S(\Delta\varphi, \Delta\eta)}{M(\Delta\varphi, \Delta\eta)} \frac{1}{\epsilon}(1 - f)$$





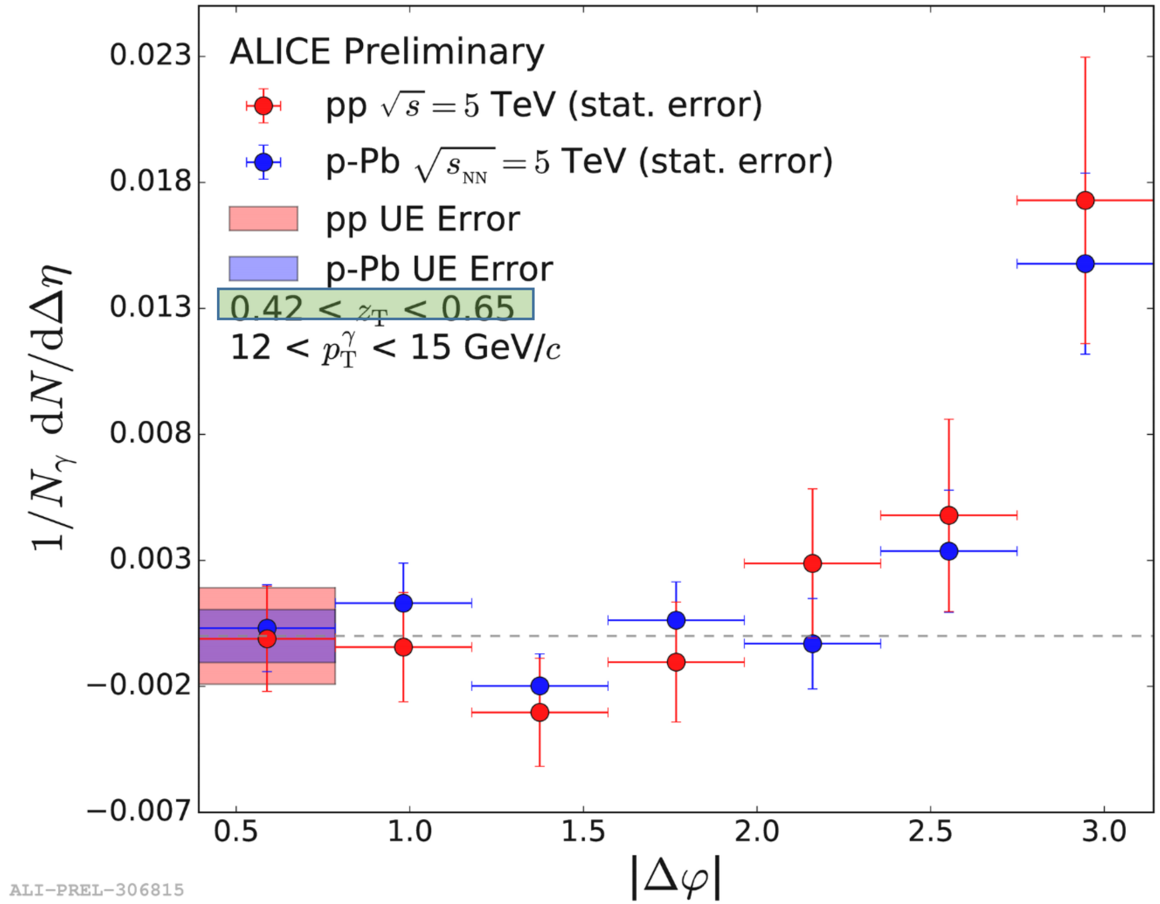
- Pedestal from underlying event, *U*, estimated with ZYAM and large $\Delta\eta$

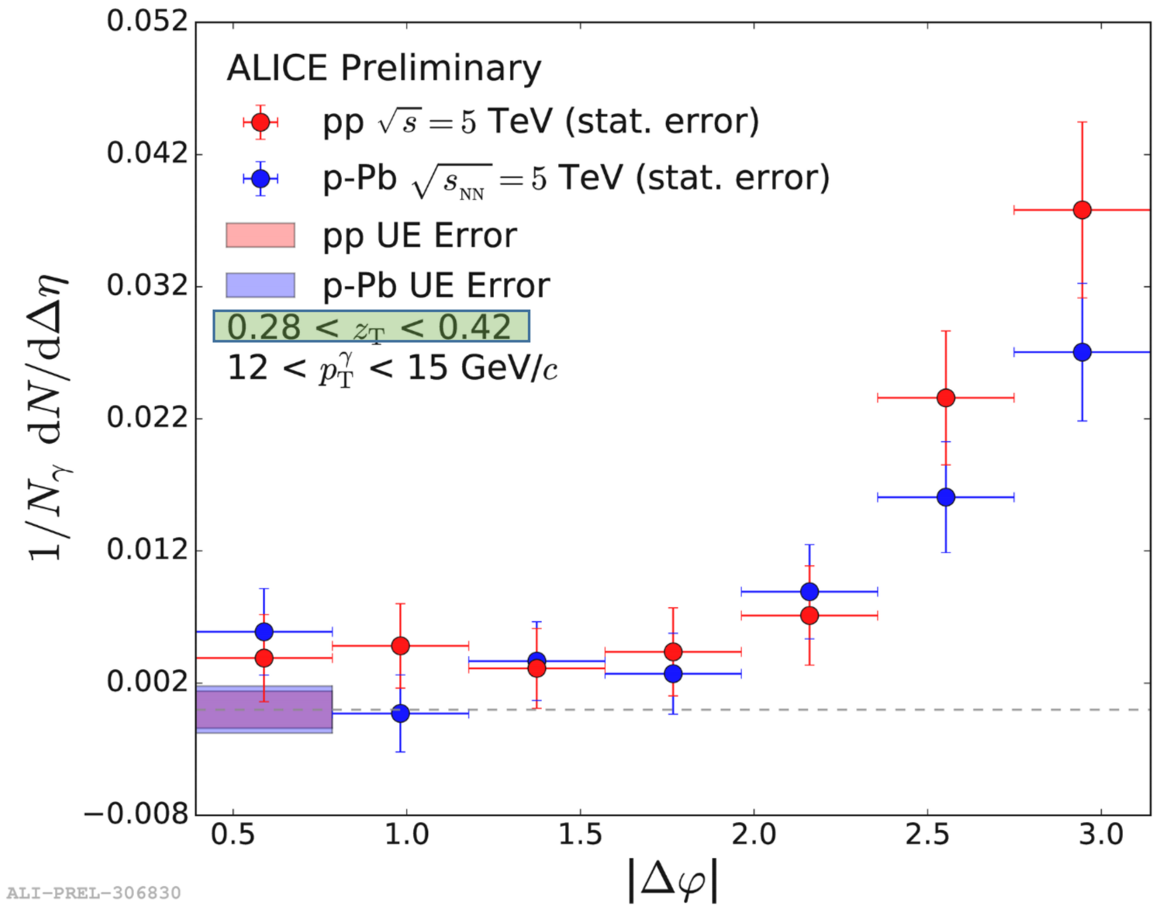
- These are ingredients for signal correlation, obtained with measured purity (*p*) 25%:

C_{SR}  C_{BR} 

$$C_S = \frac{(C_{SR} - U) - (1 - p)(C_{BR} - U)}{p}$$

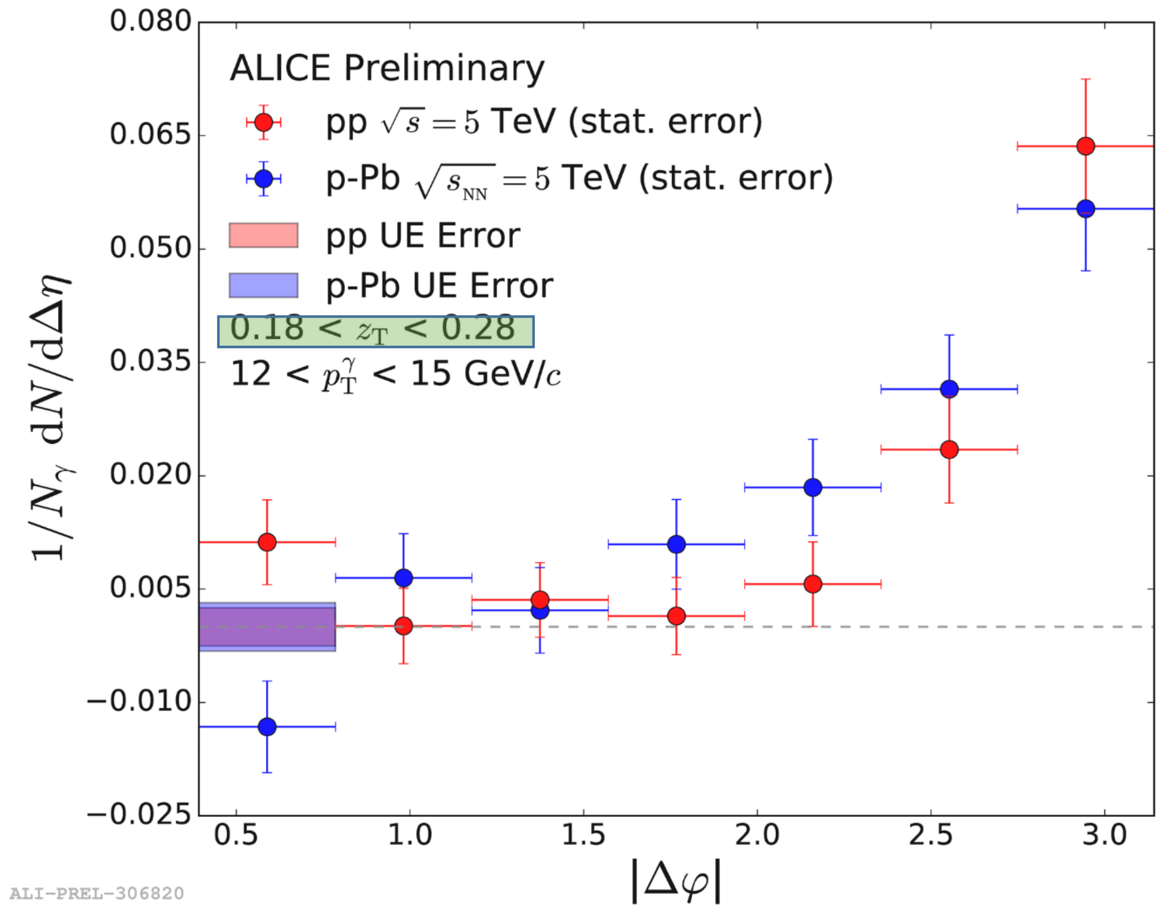
Isolated-photon + hadron correlations

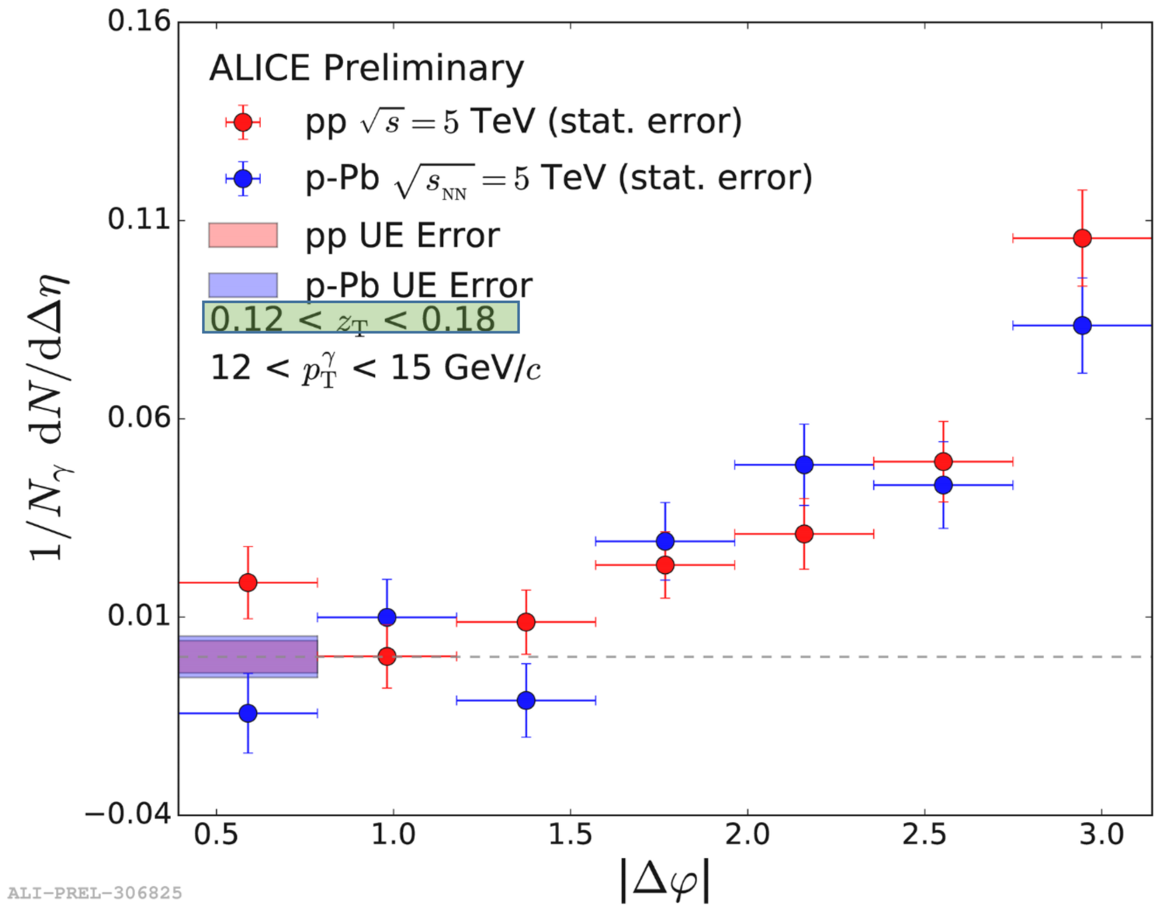




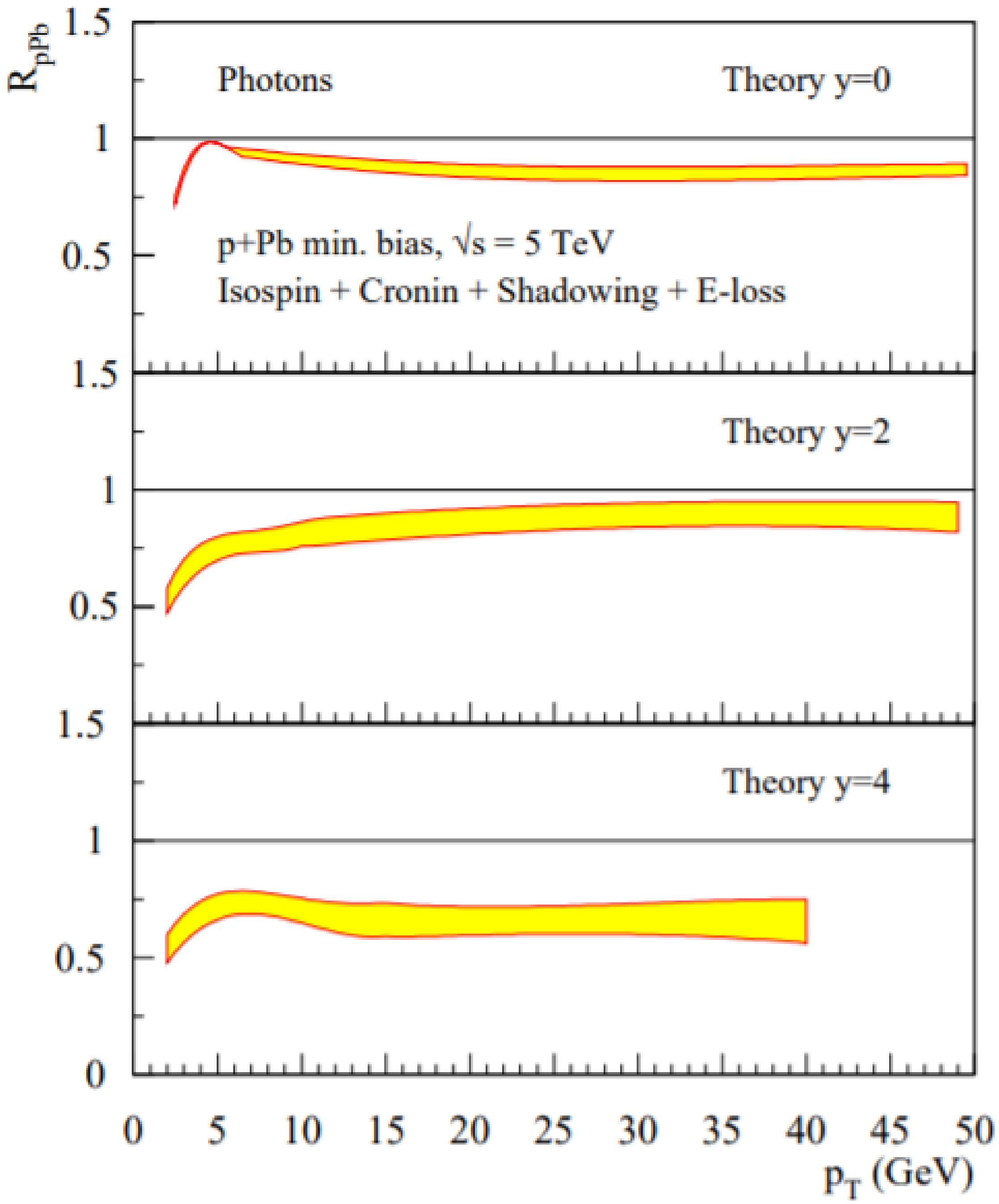
No significant difference between pp and p-Pb data

Isolated-photon + hadron correlations

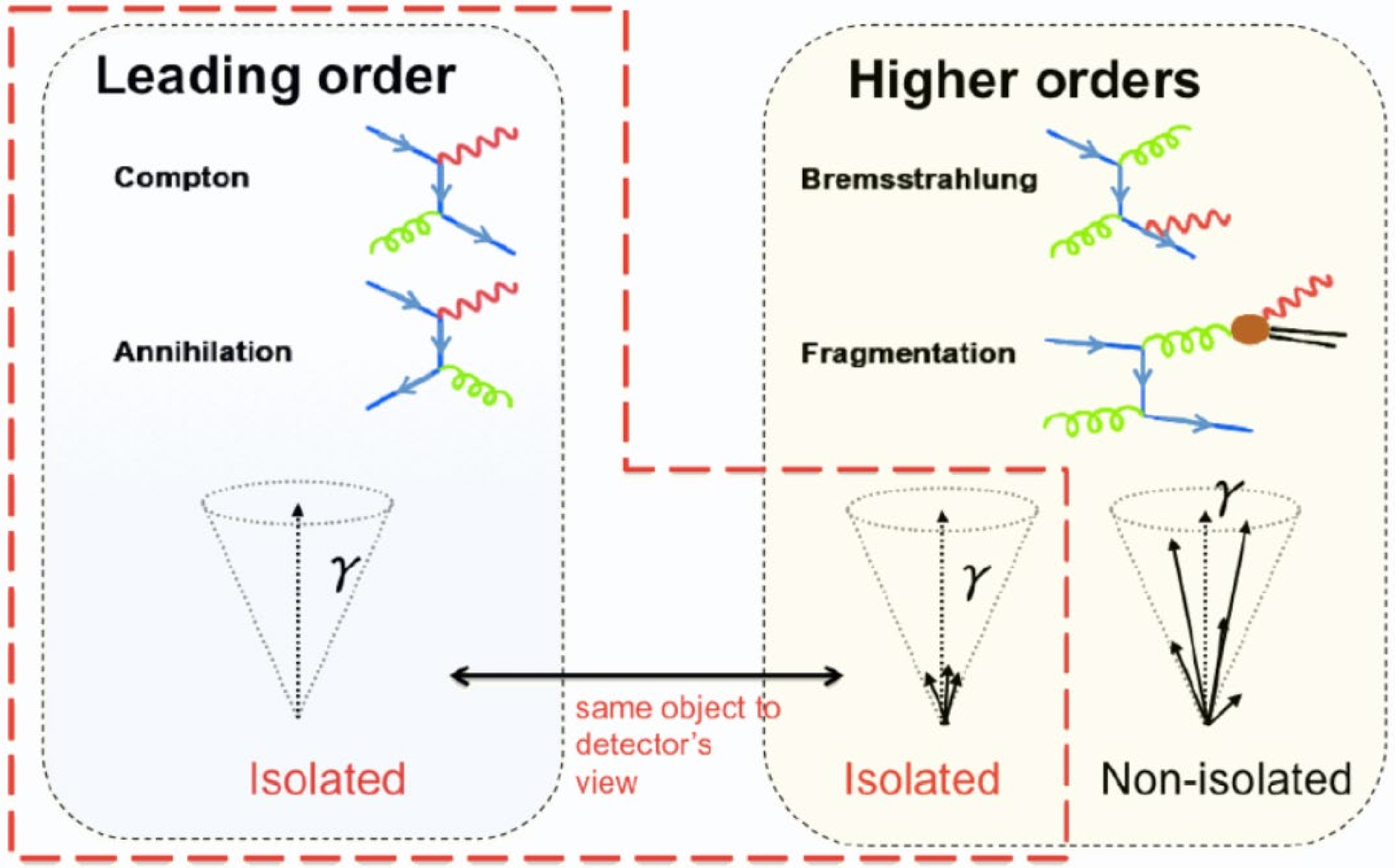




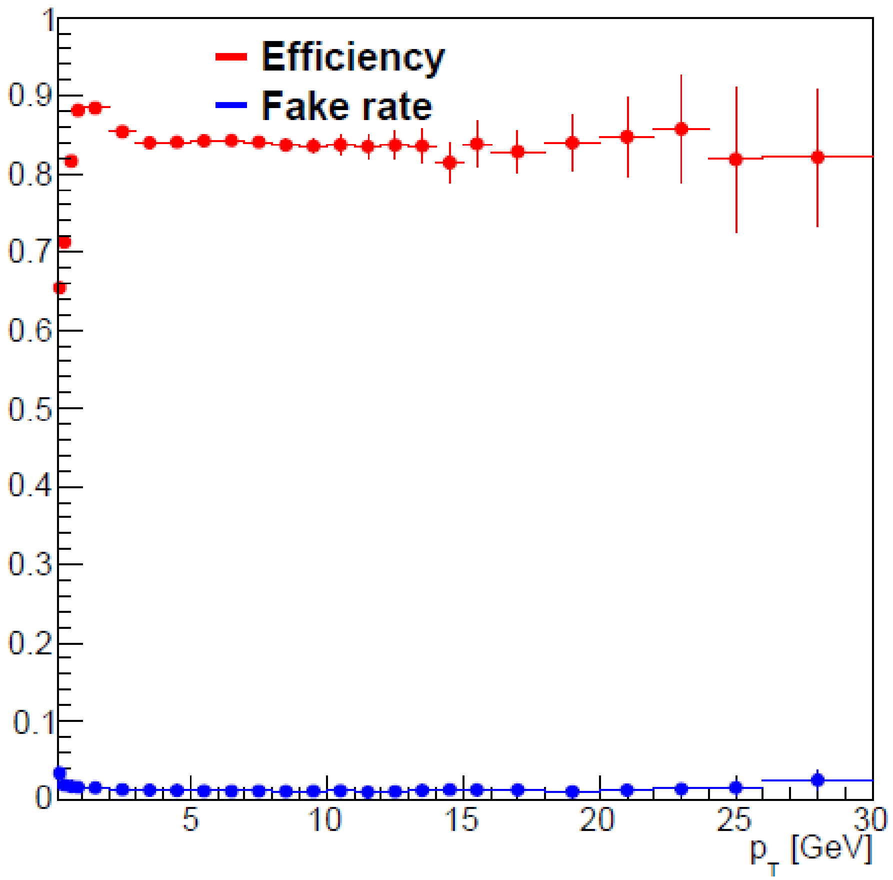
No significant difference between pp and p-Pb data



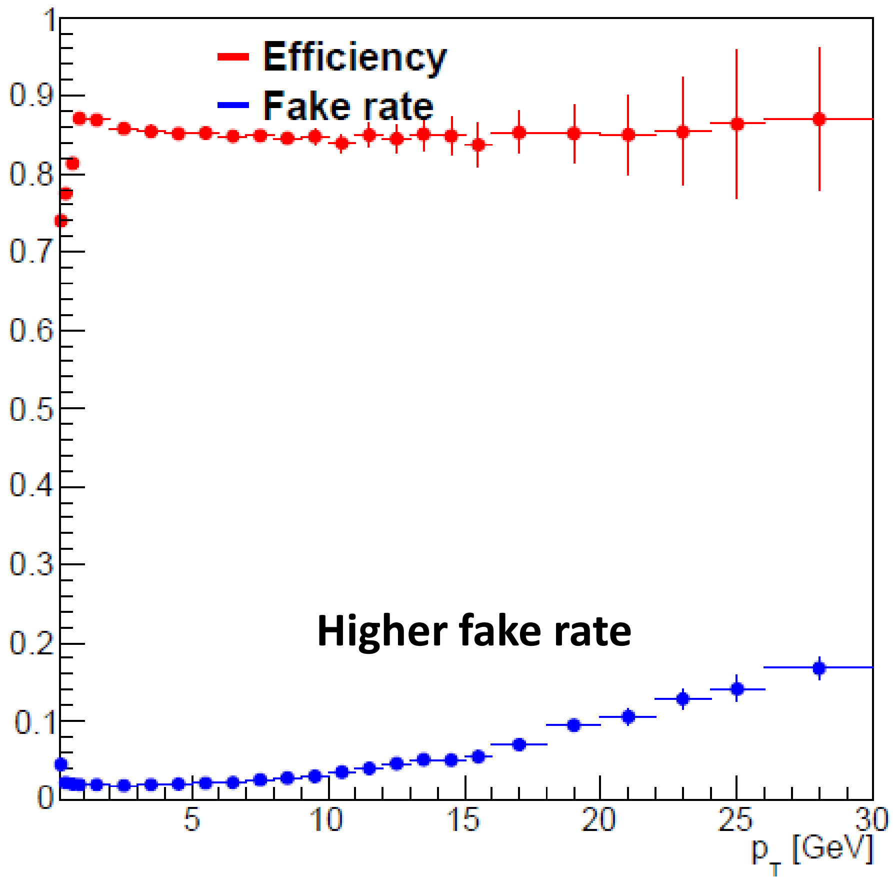
Phys.Lett. B718 (2012) 482-487


Leading order
Compton
Annihilation
γ
Isolated
same object to detector's view
Higher orders
Bremsstrahlung
Fragmentation
γ
Isolated
γ
Non-isolated

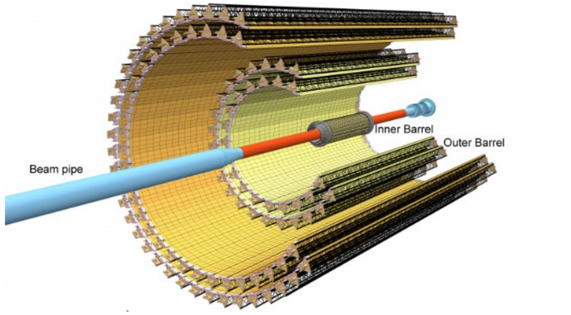
Silicon Tracker + TPC



Silicon Tracker only



Future prospects



- Standalone Silicon tracker during Run3/4.
  IMHO, only way to enough pp/pA data statistics for hard processes.

- ITS-only tracking during the High-Luminosity LHC era

ALICE in the 2030'?

ALICE

With the LS2 upgrade, ALICE will reach the maximal rate with a spectrometer based on a TPC

- Maximum interaction rate limited by space-charge (ions) accumulated in drift volume (distortions ≈10cm) and track density (inner region signal occupancy ≈ 40%)
- Running at higher rates seems excluded with a TPC

Running ALICE beyond LS4 ➪ Completely new detector without TPC?

The use of CMOS technologies opens new opportunities

➪ **Vertex detectors, large area tracking detectors and digital calorimeters**