Measurement of direct and isolated photons with ALICE

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on behalf of the ALICE collaboration

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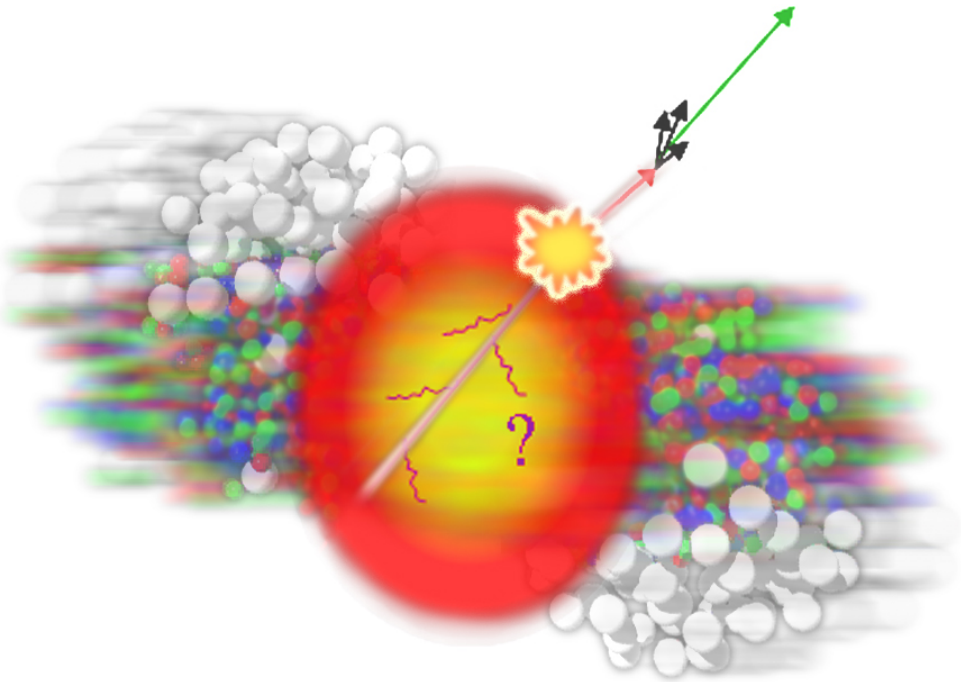
Motivation

Heavy-ion collisions

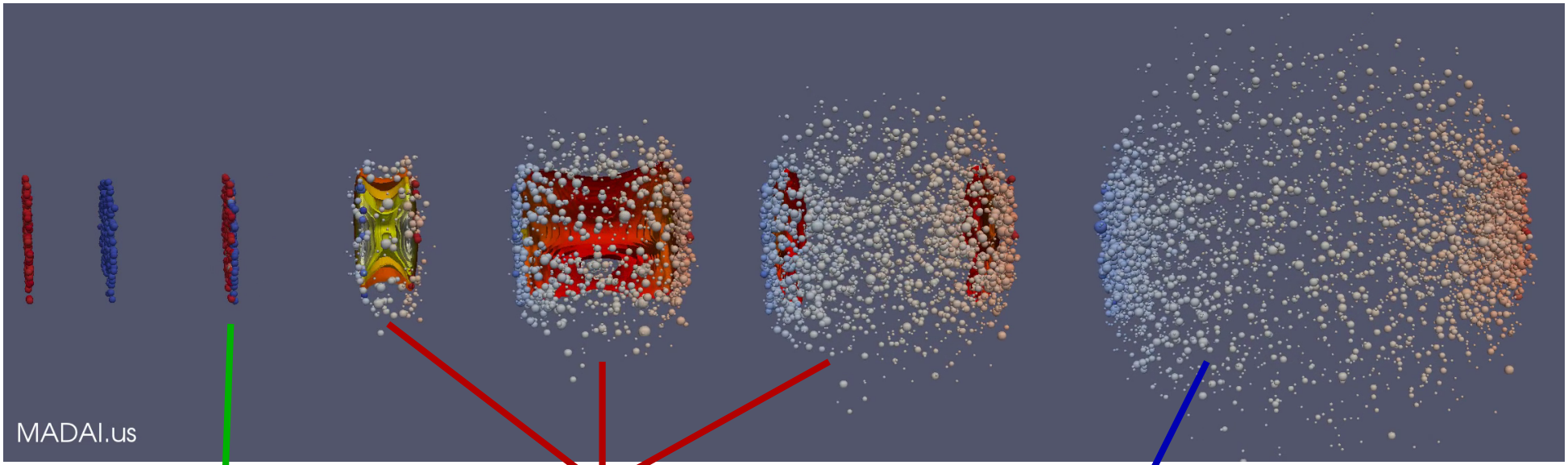
- high densities
- high temperatures
- new state of matter - Quark-Gluon-Plasma
  - medium properties
  - time evolution
- photons as weakly interacting probes



https://newscenter.lbl.gov

Motivation

Photon production time



prompt photons

thermal photons

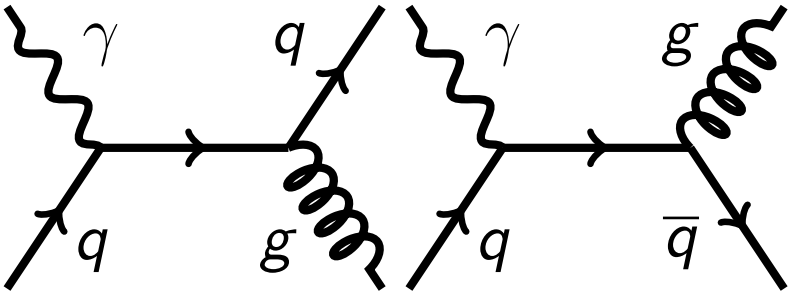
decay photons

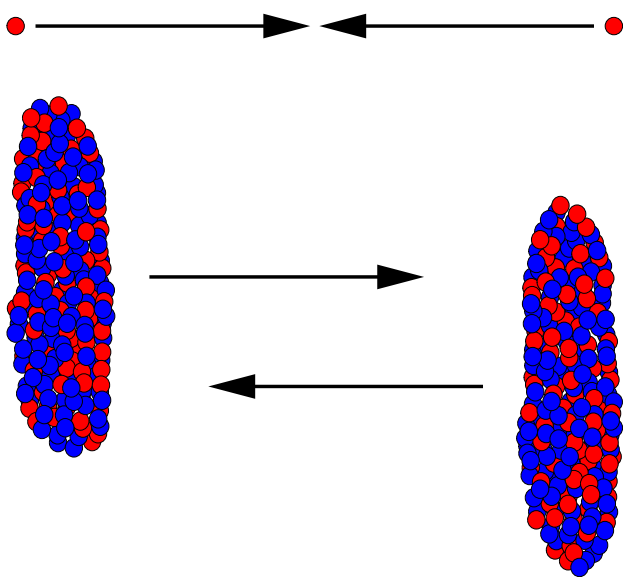
direct photons

Motivation

pp collisions

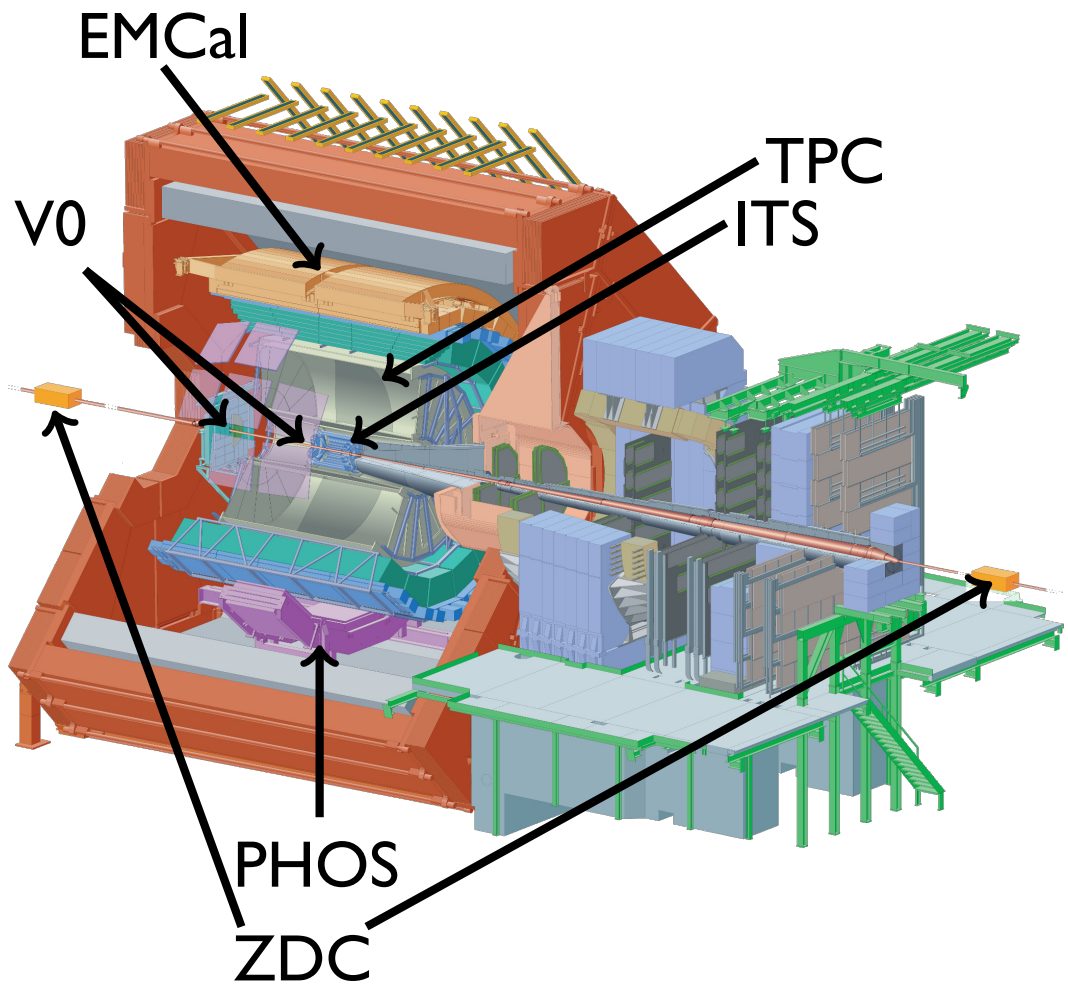
- baseline for heavy-ion measurements
- simpler collision system
- no medium effects
- photons in pp collisions
  - creation in hard scatterings
  - computable by pQCD





ALICE Experiment

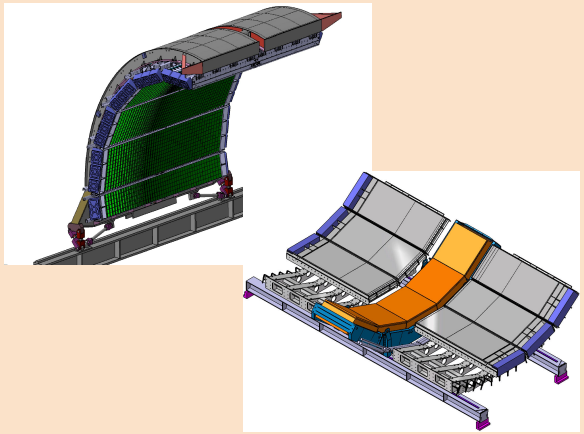
- V0, ZDC
  - trigger
  - centrality determination
  - event selection
- ITS, TPC
  - tracking
  - particle identification
- EMCal, PHOS
  - calorimeters
  - trigger



ALICE Experiment

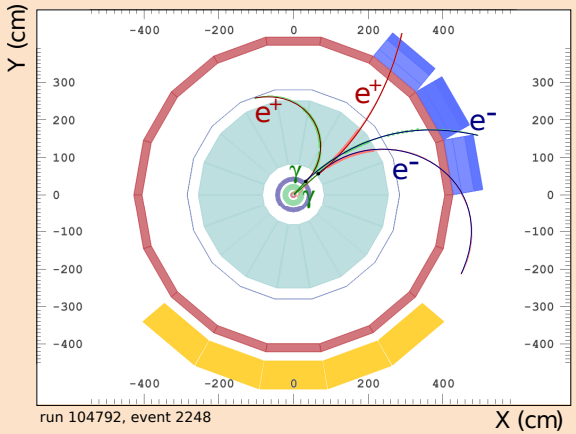
Calorimeters

- EMCal
  - Pb-scintillator design
  - $|\eta| < 0.7$
  - $\Delta\varphi = 100°$
- PHOS
  - $PbWO_4$ crystals
  - $|\eta| < 0.13$
  - $\Delta\varphi = 60°$

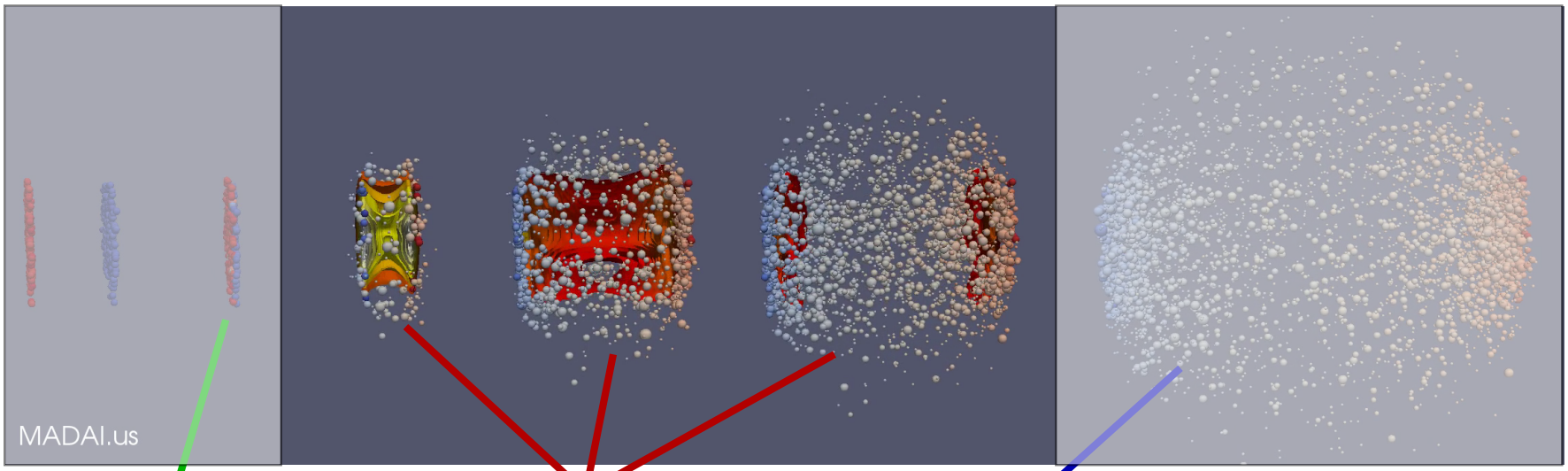


Photon conversion method (PCM)

- photons detected by neutral secondary vertex
- 8.5% conversion probability



Direct Photons



prompt photons

thermal photons

decay photons

direct photons

- thermal photons dominate at low E_T
- statistical subtraction of decay photons

Direct Photons

γ_{incl}: measured spectrum

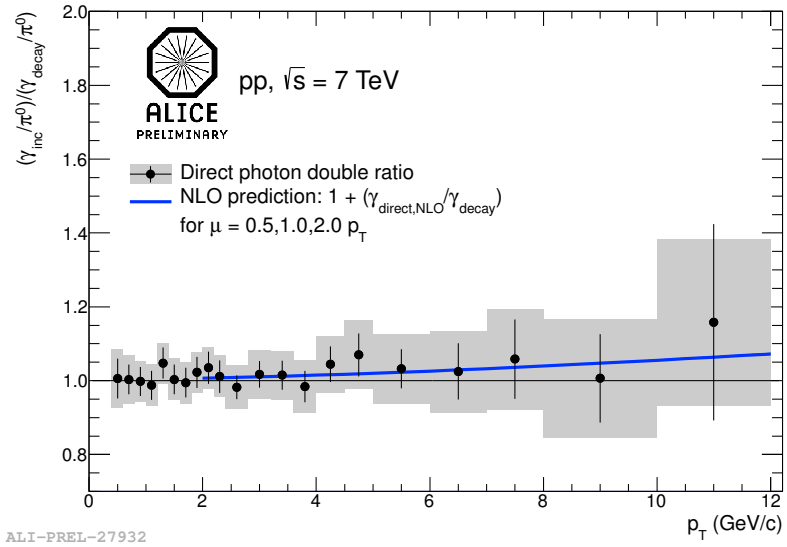
π^0_{param}: parametrisation of measured π^0

γ_{decay}: cocktail from MC simulation

$$\gamma_{\text{direct}} = \gamma_{\text{incl}} - \gamma_{\text{decay}} = \left(1 - \frac{1}{R_\gamma}\right) \cdot \gamma_{\text{incl}}$$

$$R_\gamma = \frac{\gamma_{\text{incl}}}{\gamma_{\text{decay}}} \equiv \frac{\gamma_{\text{incl}}}{\pi^0_{\text{param}}} \Big/ \frac{\gamma_{\text{decay}}}{\pi^0_{\text{param}}}$$

$$R_{\text{NLO}} = 1 + \frac{\gamma_{\text{direct,NLO}}}{\gamma_{\text{decay}}}$$

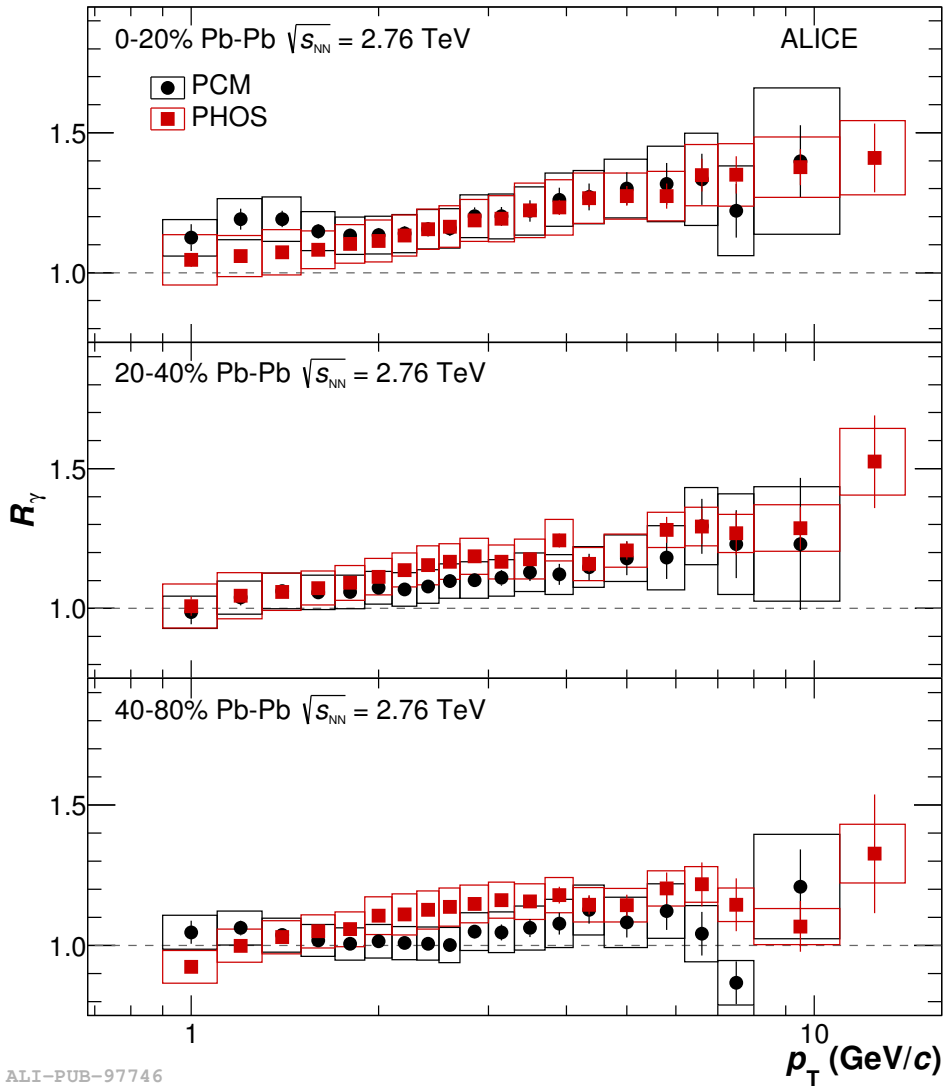


Nucl.Phys.A 904-905(2013)573c-576c proceeding of QM 2012

- no significant direct photon signal in pp at 7 TeV
- consistent with pQCD NLO calculation

Direct Photons in Pb–Pb

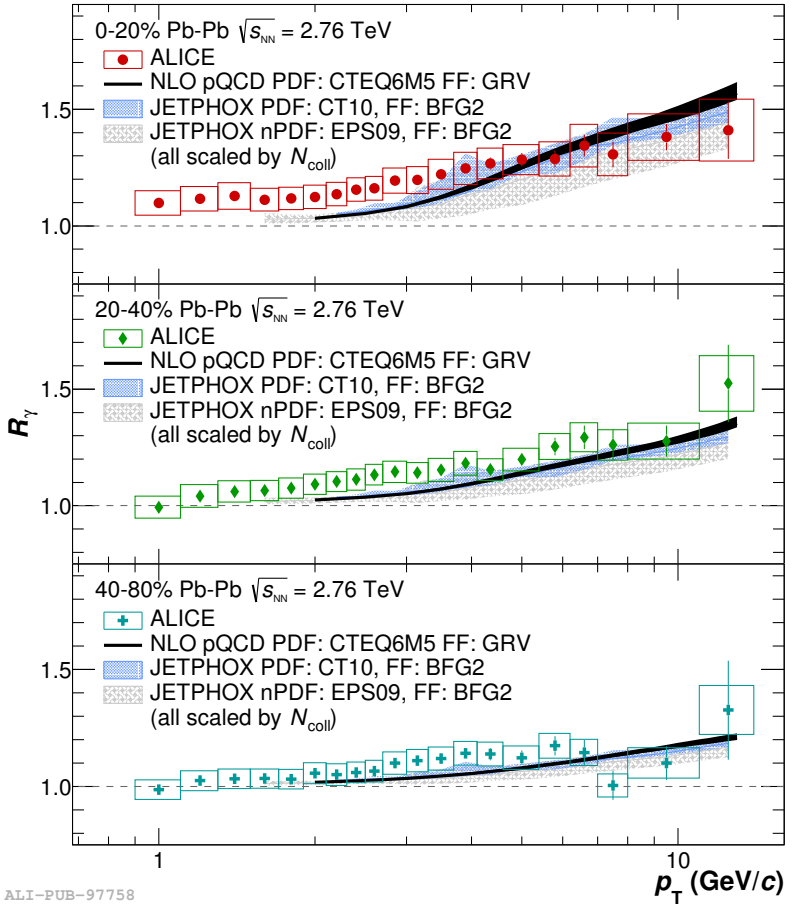
- combination of measurements from two independent detectors
- smaller uncertainties in double ratio



Phys.Lett.B754(2016)235-248

Direct Photons in Pb–Pb

- excess of photon yield for central and semi-central collisions
- increase at high p_T consistent with scaled NLO calculations



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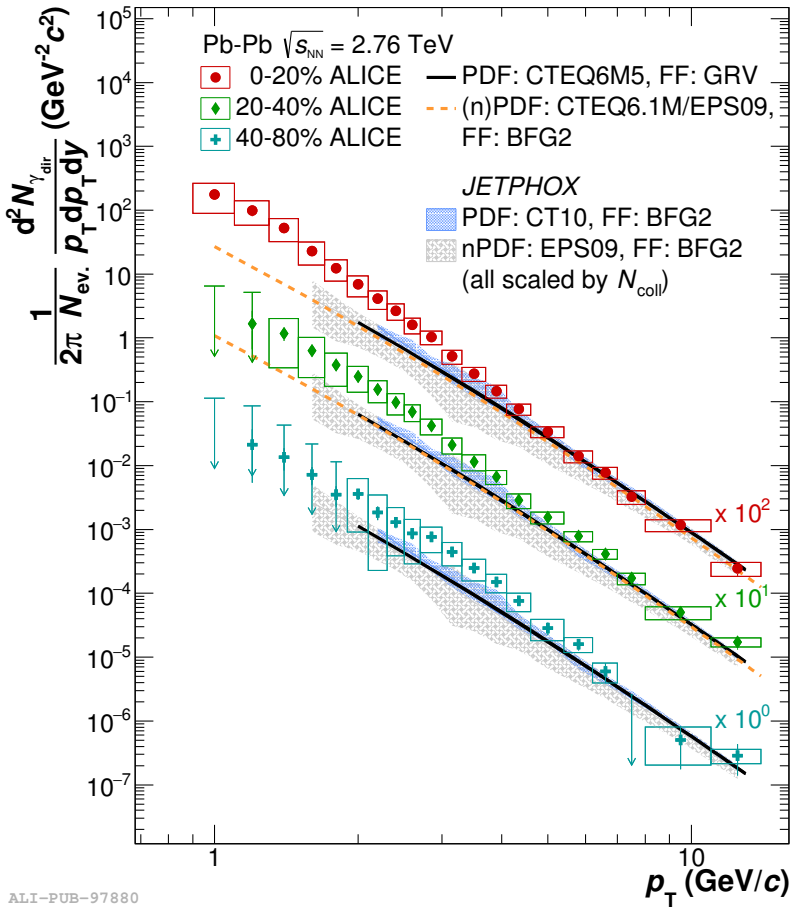
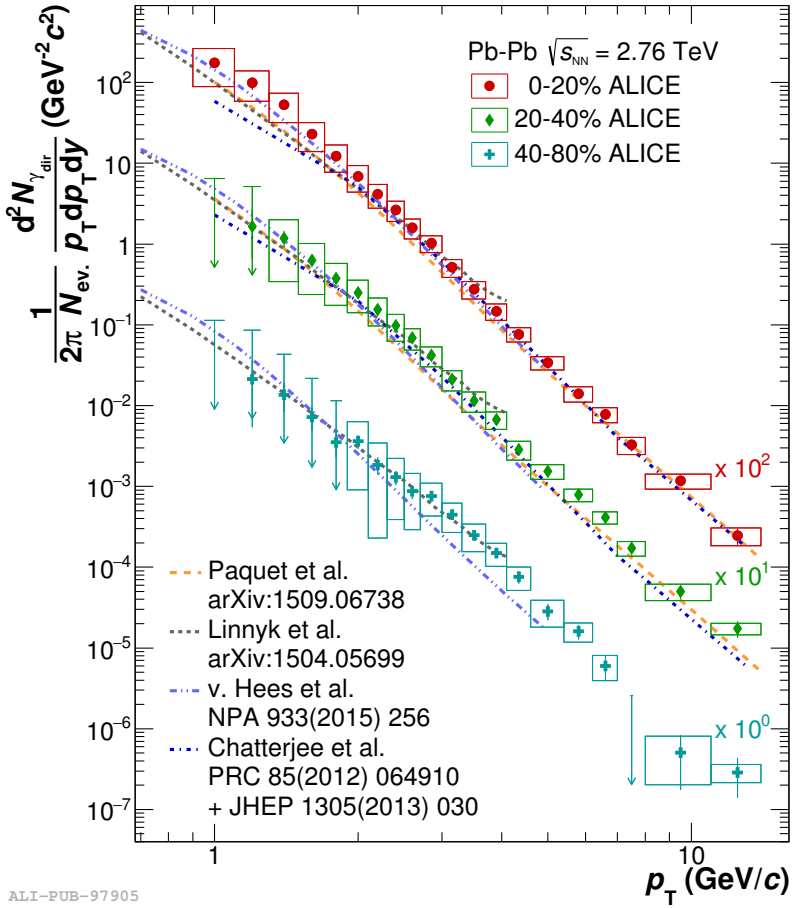


Phys.Lett.B754(2016)235-248

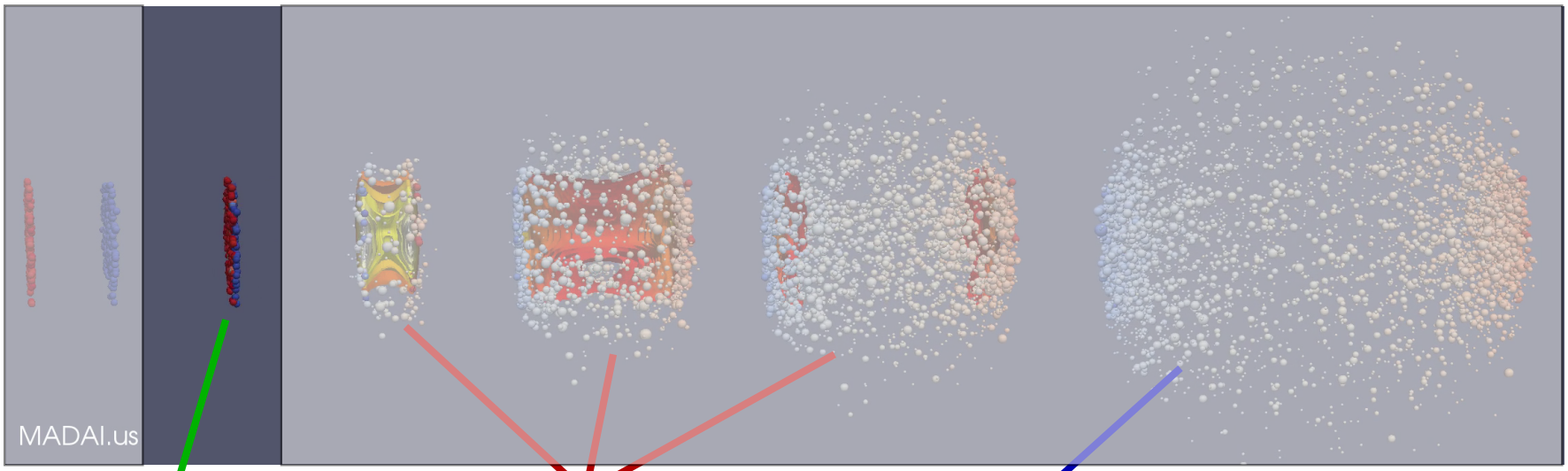
Direct Photons in Pb–Pb

- excess of photon yield for central and semi-central collisions
- spectrum at high p_T consistent with scaled NLO calculations
- increase at low p_T in agreement with thermal radiation
- all models assume QGP
- no discrimination between models possible



Phys.Lett.B754(2016)235-248

Prompt Photons



prompt photons

thermal photons

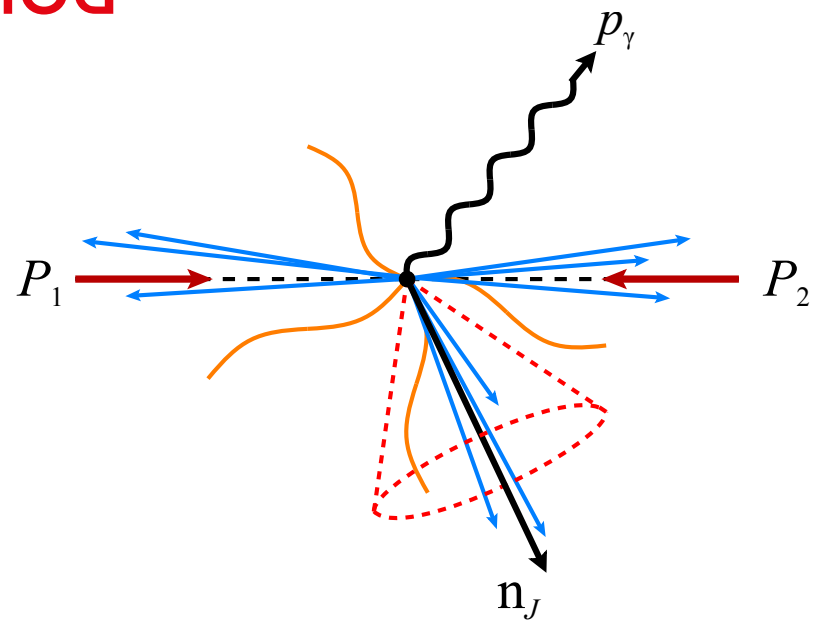
decay photons

- focus on prompt photons
- dominant at high E_T

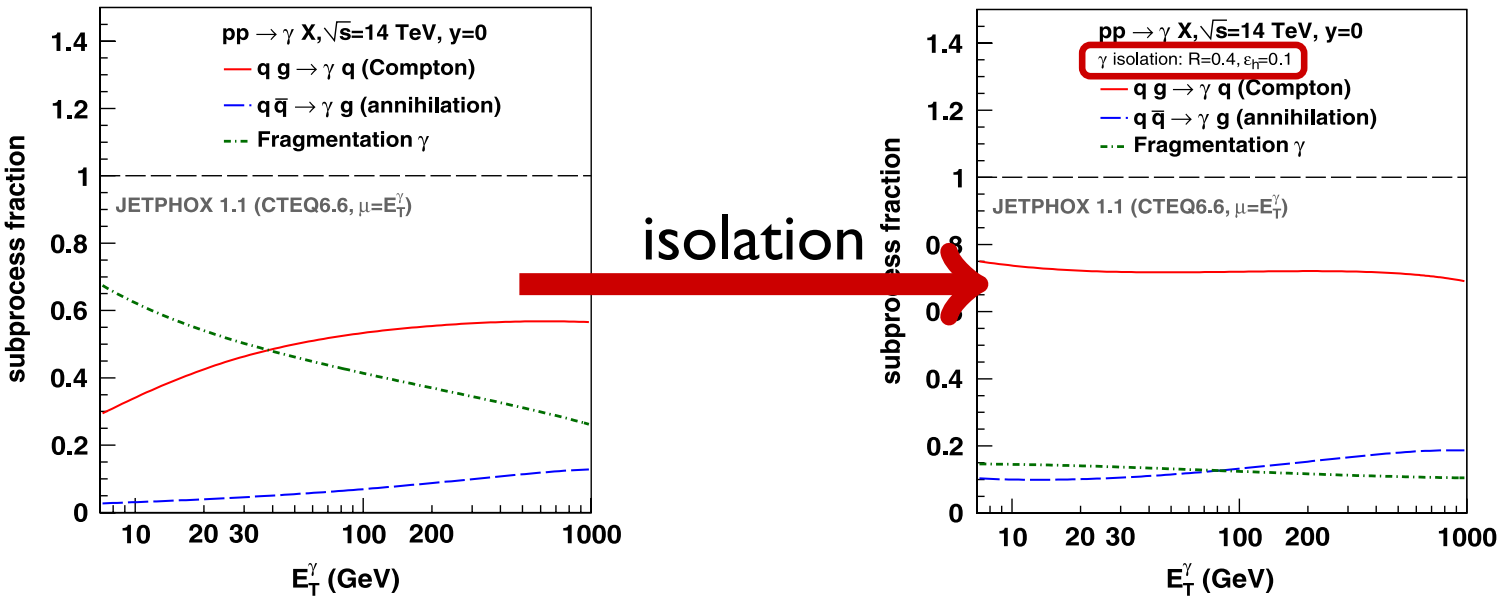
- study medium properties
- tag photons with corresponding jets

Isolated Photons: the Method

- select prompt photons via isolation criteria
- reject background from decays and jet fragments
- measure pp cross section as baseline



Phys. Rev. D 87 (2013), 014010



Phys. Rev. D 82 (2010), 01405

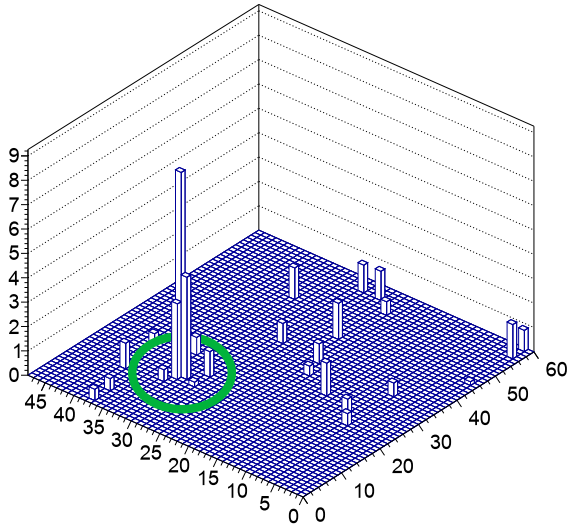
Isolated Photons: the Method

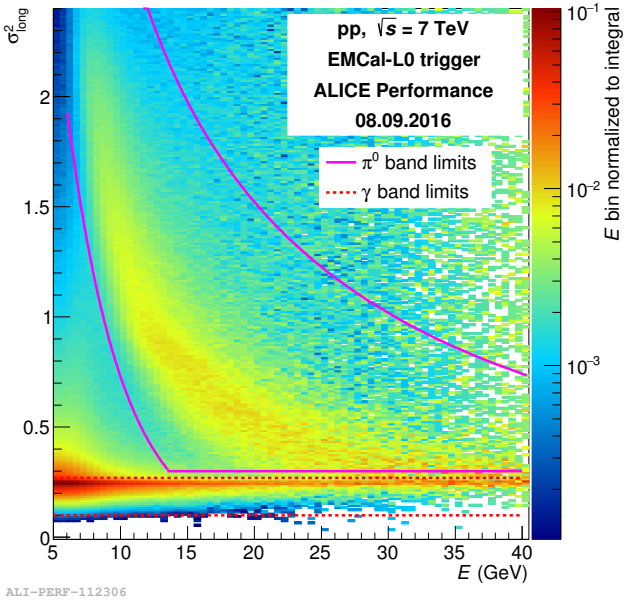
- two parameters

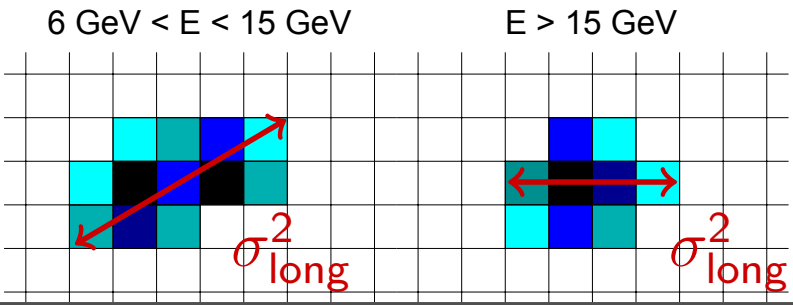
  $\sum E_{\mathrm{T}}^{\mathrm{incone}}$: energy in isolation cone (charge + neutral)

  σ^2_{long}: parametrisation of cluster width

- charged-particle veto
- acceptance limited to fully contain isolation cone in EMCal
- data-driven purity estimation with ABCD method







Isolated Photons: the Method

- estimate purity (P) in region A
- divide each axis in 2 regions

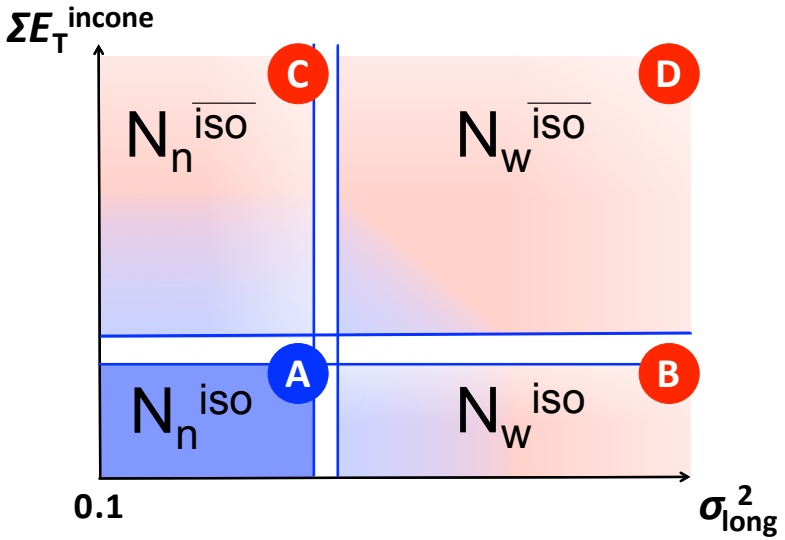
  ΣE_T^{incone}: isolated (iso) cluster
  non-isolated ($\overline{iso}$) cluster

  σ^2_{long}: narrow (n) cluster
  wide (w) cluster

- divide phase space in 4 regions

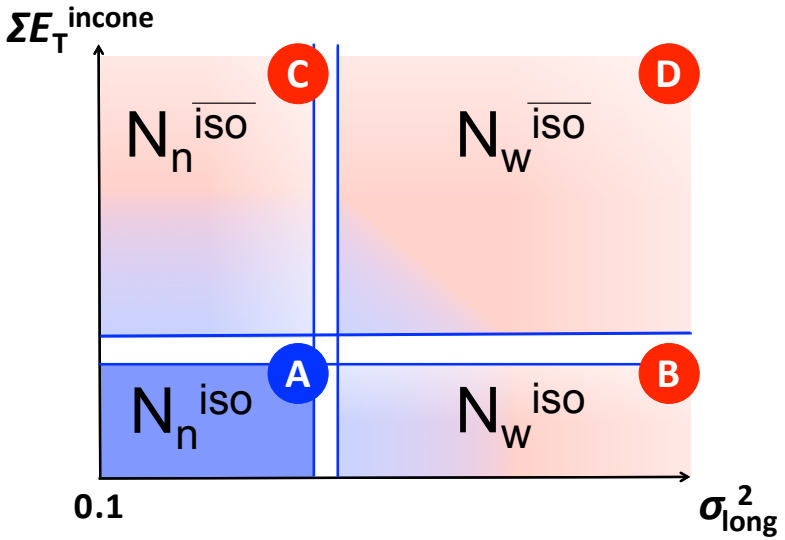
  A : mainly signal (S)

  B,C,D : mainly background (B)



Isolated Photons: the Method

- two assumptions
  - (1) negligible signal contribution to regions B, C and D
  - (2) same isolation probability in narrow and wide clusters
- correction for signal in background regions and non-factorisation of the cut variables via MC



$$P = \frac{S_n^{iso}}{N_n^{iso}} = 1 - \frac{B_n^{iso}}{N_n^{iso}} \qquad (1)$$

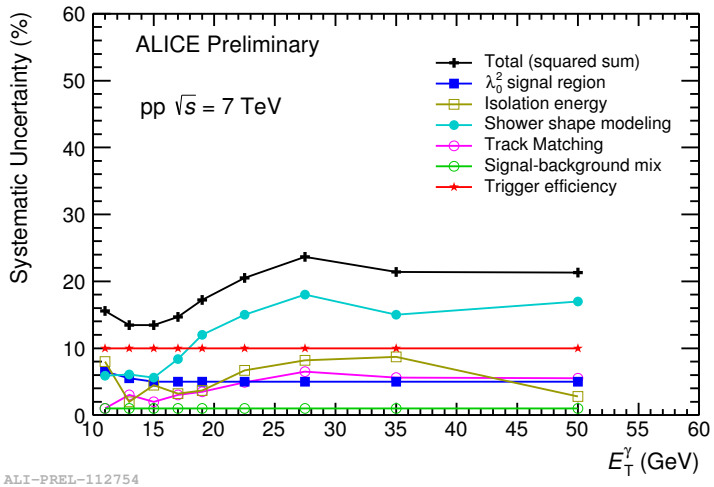
$$\frac{B_n^{iso}}{B_n^{\overline{iso}}} = \frac{B_w^{iso}}{B_w^{\overline{iso}}} \qquad (2)$$

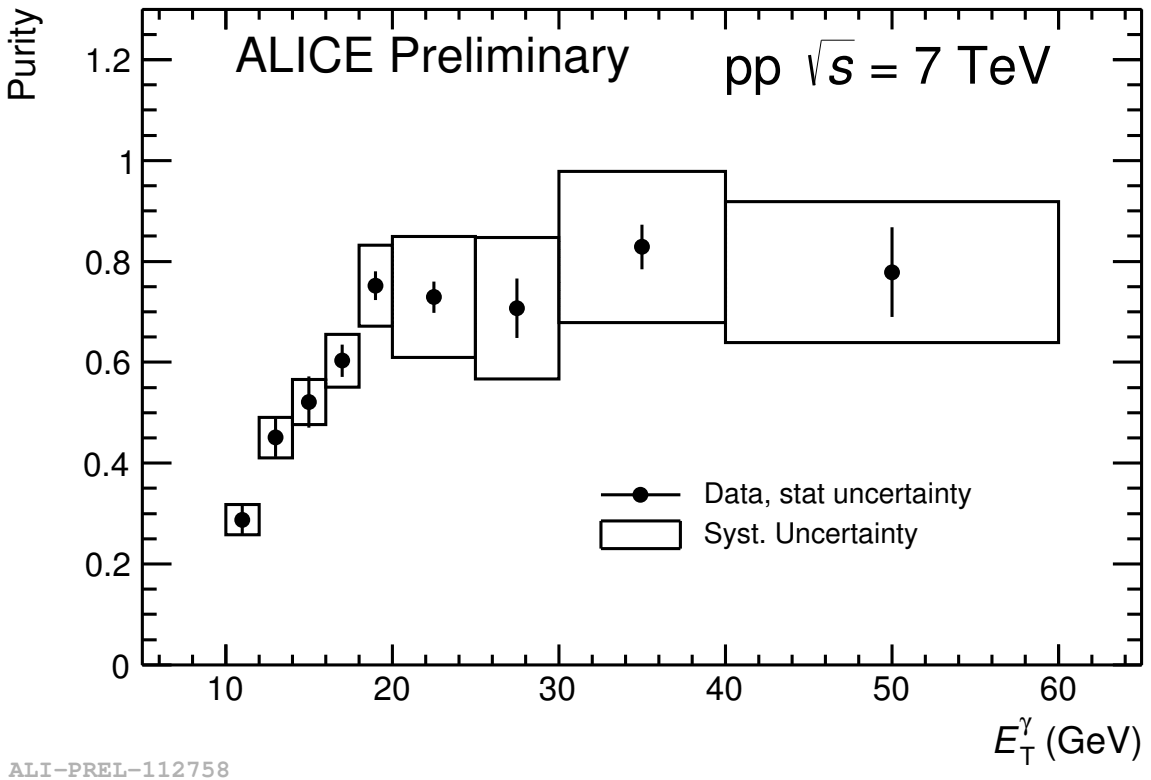
$$P = 1 - \left(\frac{N_n^{\overline{iso}} \cdot N_w^{iso}}{N_n^{iso} \cdot N_w^{\overline{iso}}} \right)$$

$$P' = 1 - \left(\frac{N_n^{\overline{iso}} \cdot N_w^{iso}}{N_n^{iso} \cdot N_w^{\overline{iso}}} \right) \times \left(\frac{B_n^{iso} \cdot N_w^{\overline{iso}}}{N_n^{\overline{iso}} \cdot N_w^{iso}} \right)_{MC}$$

Isolated Photons: Results in pp

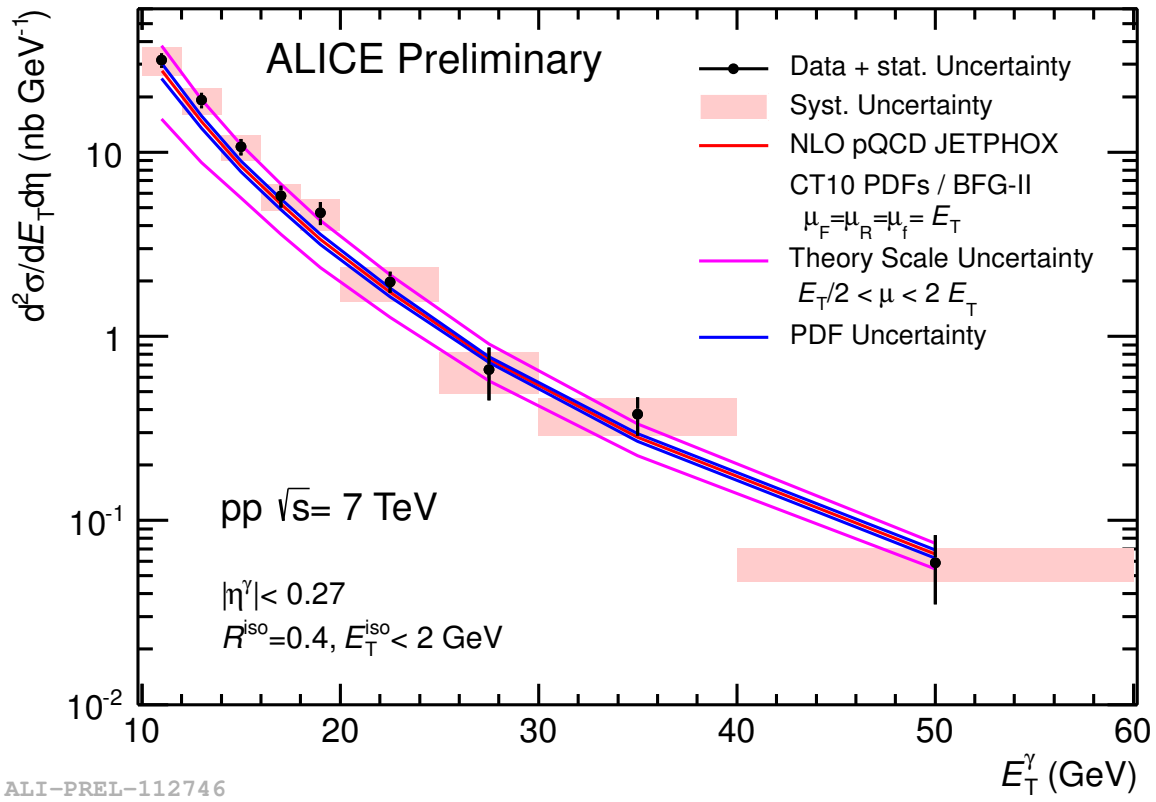
- purity increases with E_T
- above E_T=20 GeV purity stable around 80%
- modelling of cluster shape biggest systematic uncertainty





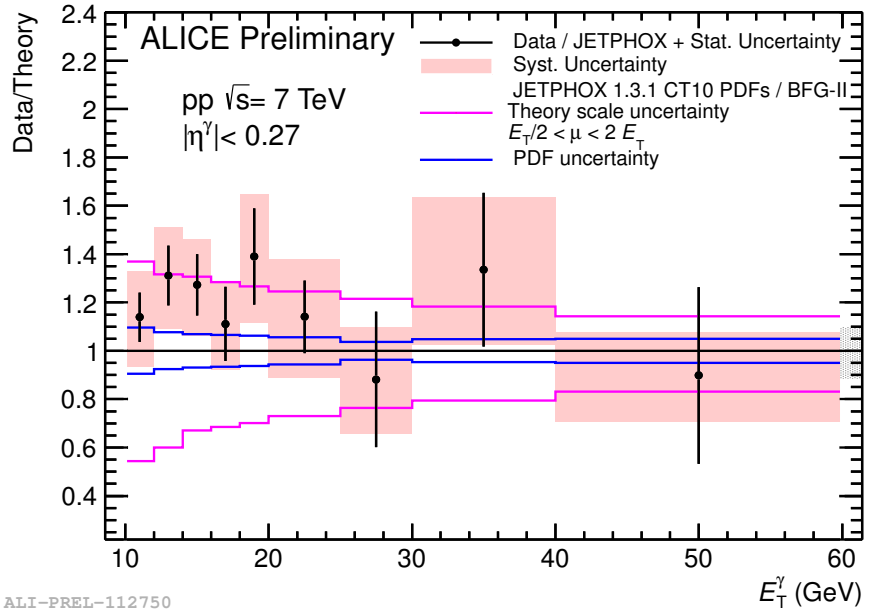
Isolated Photons: Results in pp

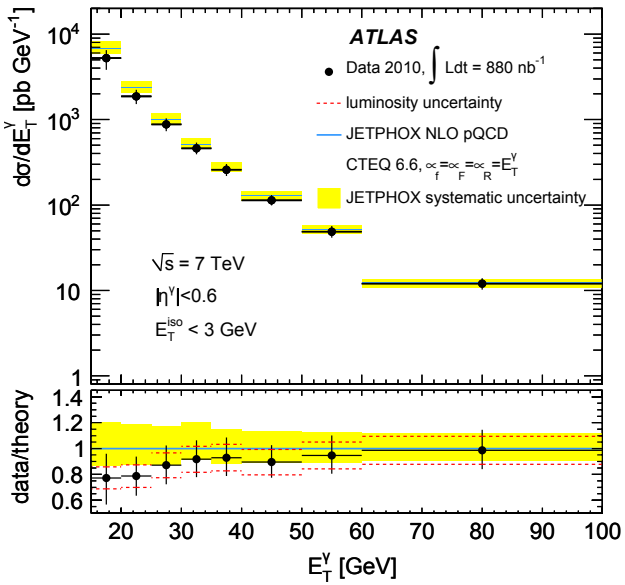
- isolated photon cross section measured for E_T= 10-60 GeV
- results in agreement with JETPHOX calculation



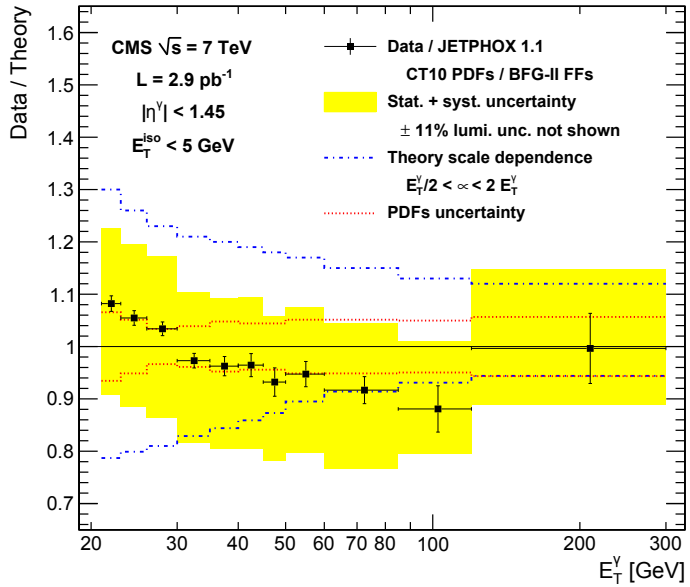
Isolated Photons

- 1:1 comparison not possible, due to different isolation criteria
- all experiments in agreement with theoretical predictions
- lower E_T reach than ATLAS and CMS





Phys.Rev. D83 (2011) 052005



Phys.Rev.Lett. 106 (2011) 082001

Summary and Outlook

- photons produced in all stages of a heavy-ion collision
- good probe to investigate QGP properties
- different analysis methods applicable in different ranges
  - different sensitivity to specific sources
- direct photons
  - agreement with pQCD calculations for pp and peripheral Pb–Pb collisions
  - excess in central and semi-central Pb–Pb collisions
  - analyse direct photons in p–Pb
- isolated photons
  - isolated photons in agreement with pQCD calculation
  - expand analysis to p–Pb and Pb–Pb collisions
- increased acceptance in run2 with DCal