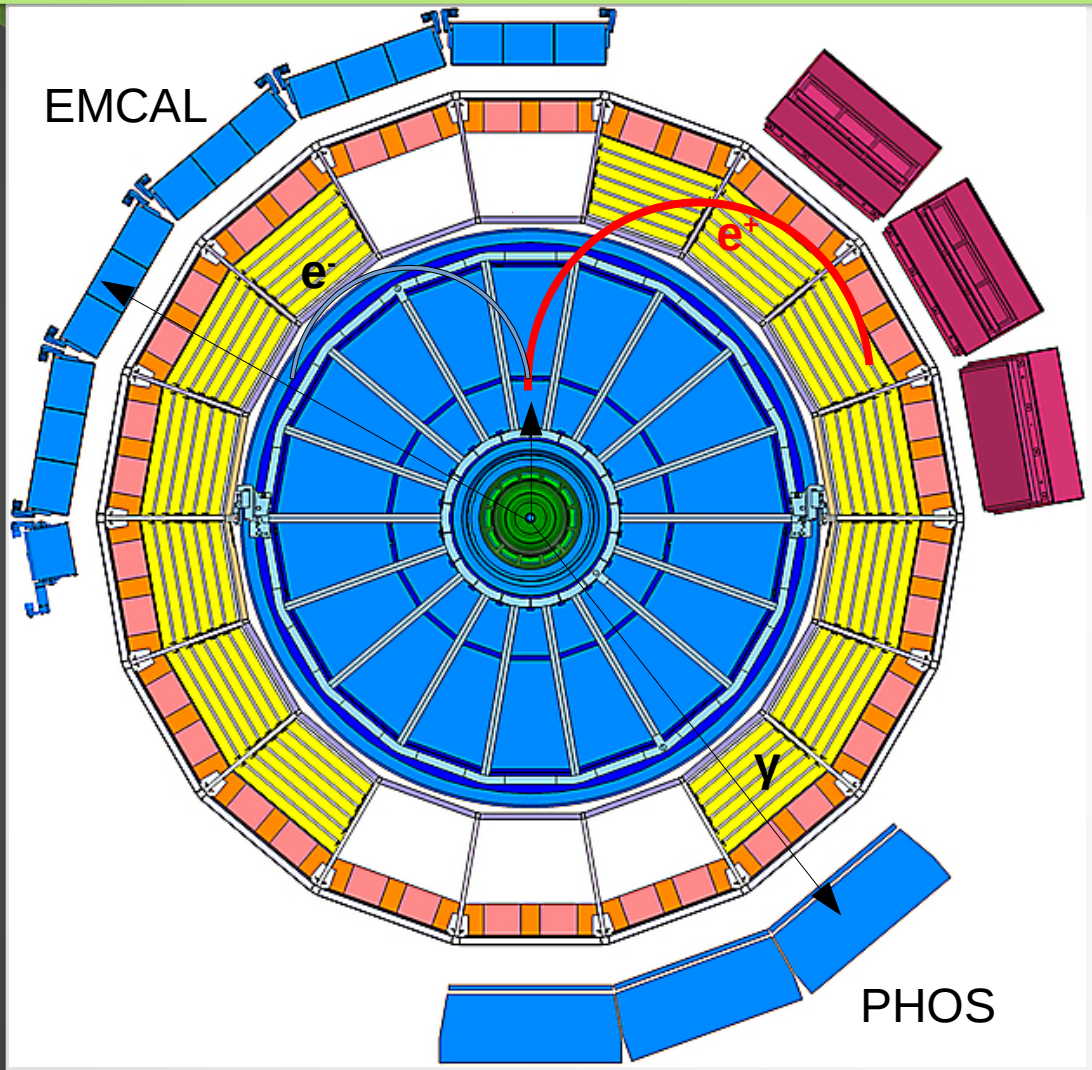
Direct photons and neutral mesons in pp, p-Pb and Pb-Pb collisions measured with the ALICE experiment

D.Peresunko
NRC "Kurchatov instityte"

for the ALICE collaboration

Photon detection in ALICE



Photon Conversion Method (PCM)

- Good resolution at low p_T
- Small conversion probability (~8.5%),
- Full azimuthal angle coverage, $|\eta|<0.9$
- Small contamination of the photon sample

PHOS

- Excellent resolution at high p_T
- High efficiency of the photon detection
- Limited acceptance (60^o) $|\eta|<0.135$

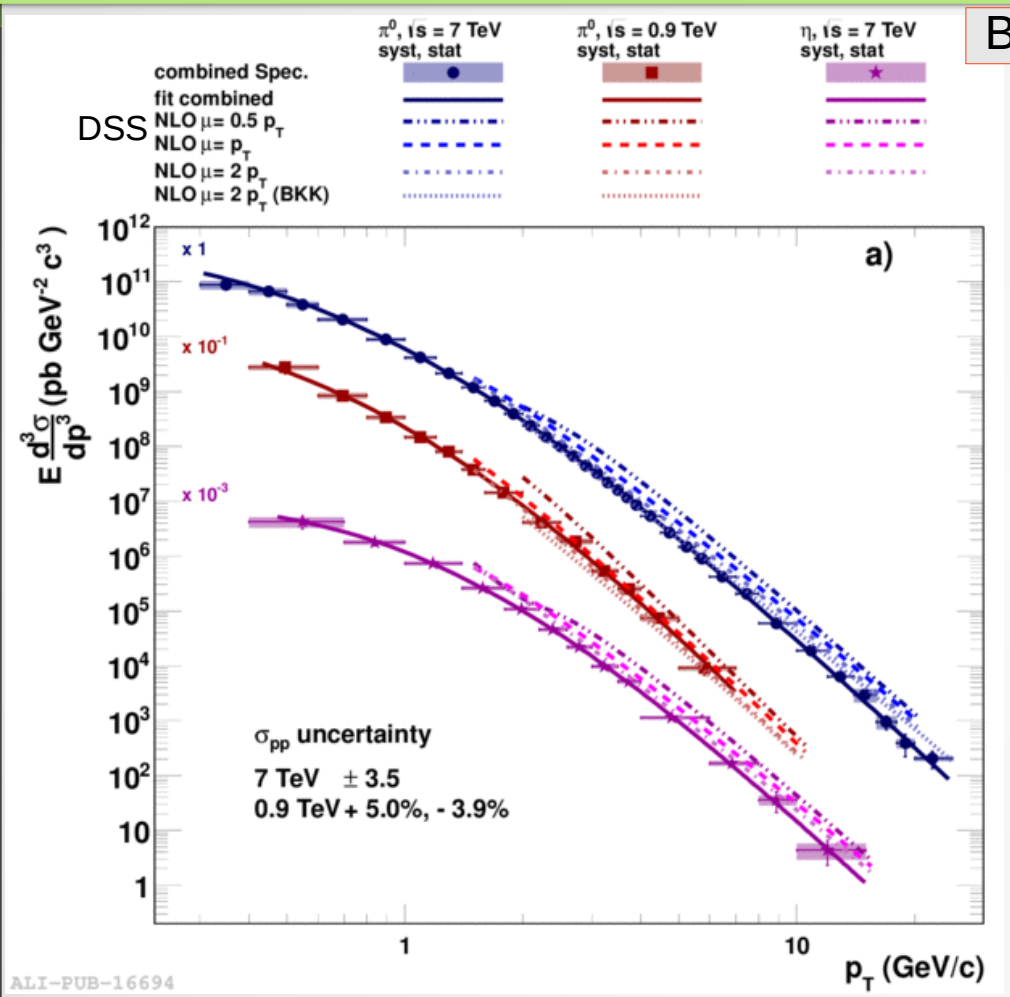
EMCAL

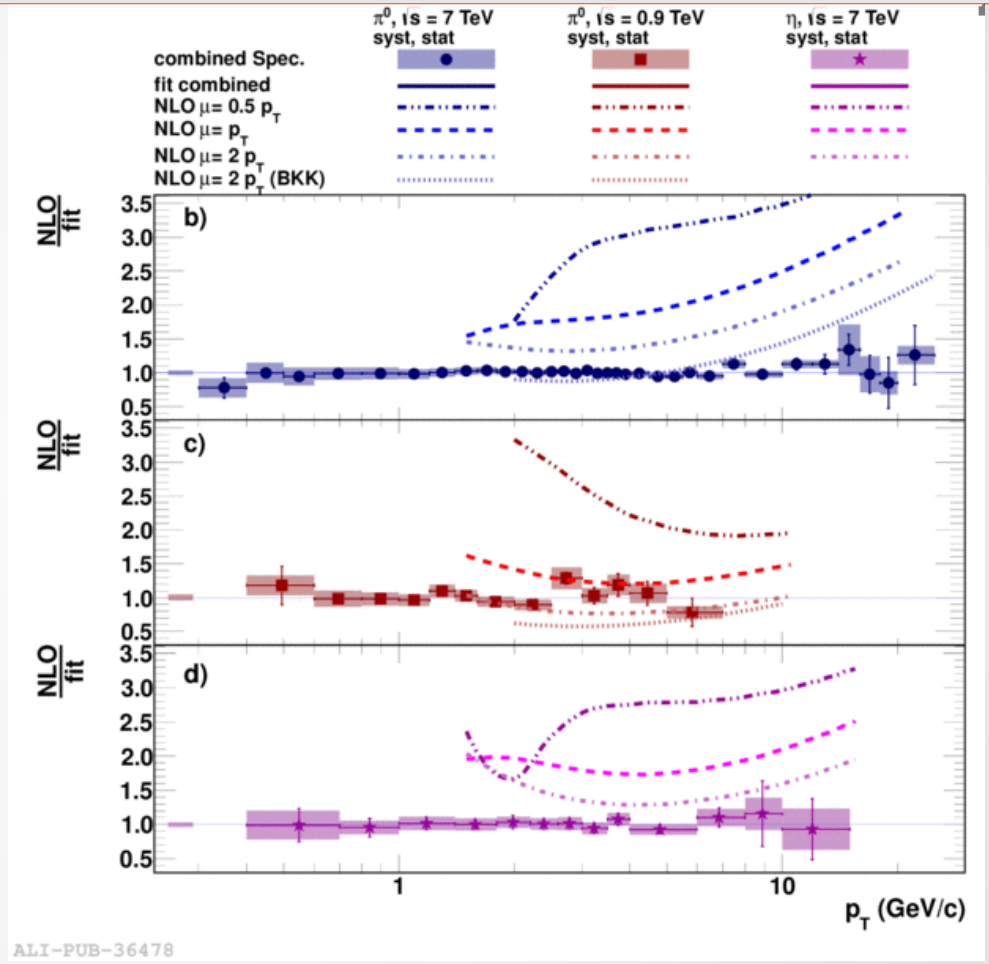
- Large acceptance (100^o) $|\eta|<0.9$
- Limited energy resolution

Neutral pion production in pp

B.Abelev et al., Phys.Lett. B717 (2012) 162-172

DSS

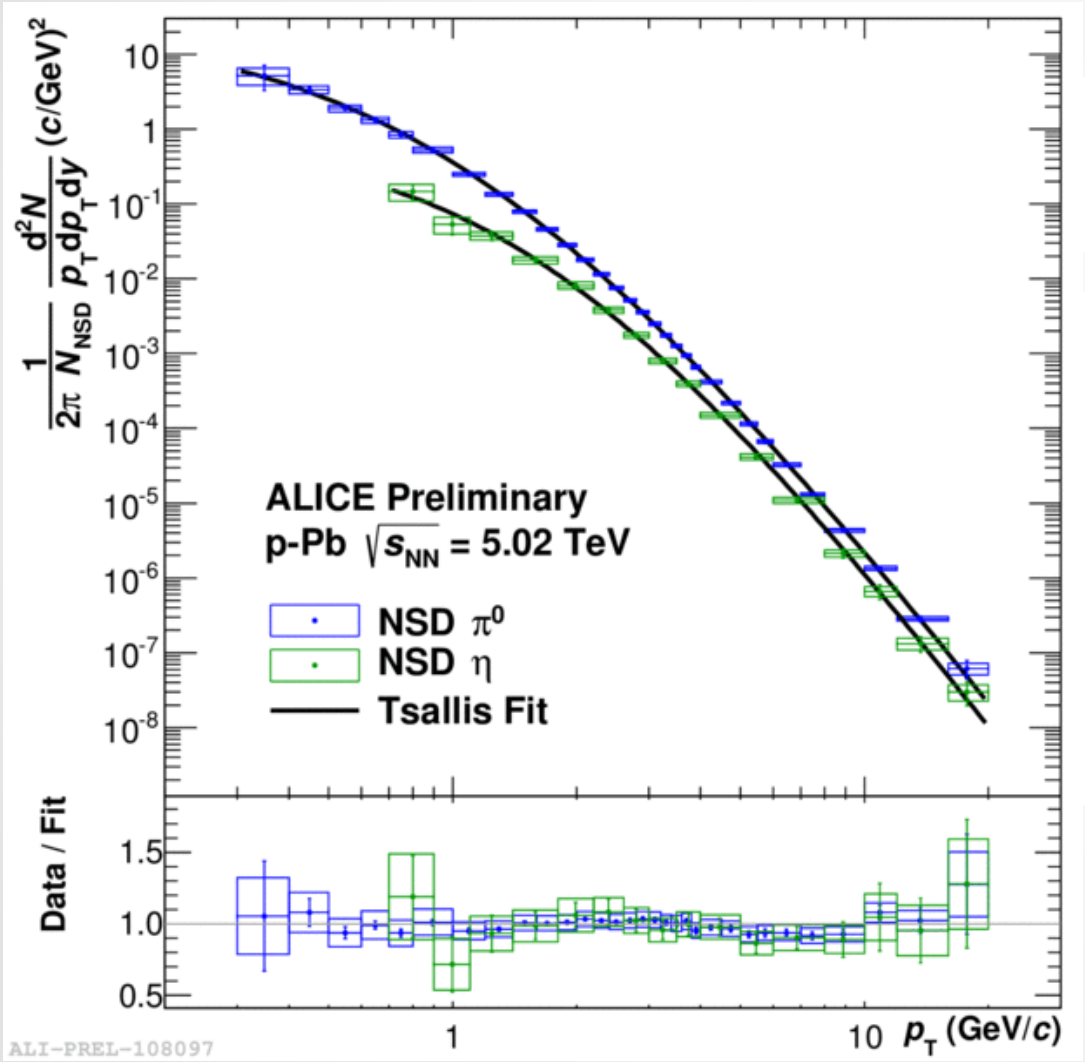




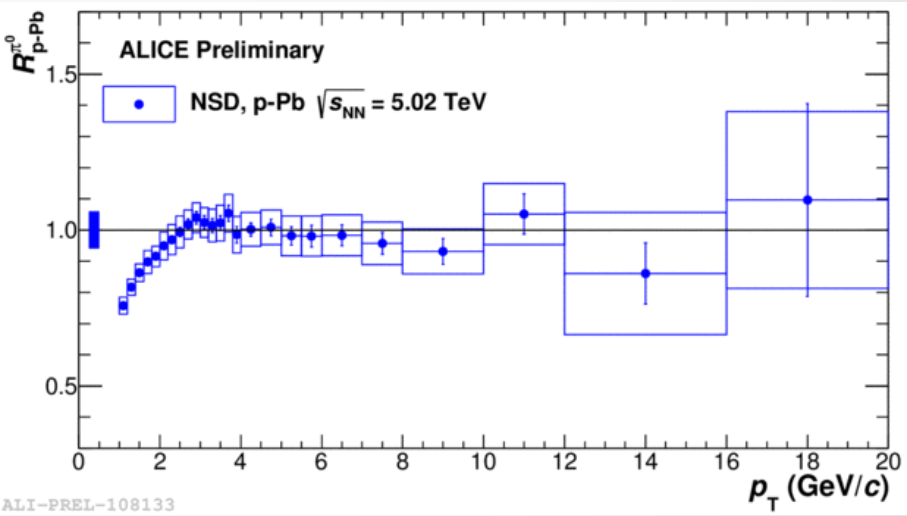
Updated DSS: “Global extraction of the parton-to-pion fragmentation functions at NLO accuracy in QCD”, R.J. Hernández-Pinto, M. Epele, D. de Florian, R. Sassot, M. Stratmann, arXiv:1609.02455:

Agreement with ALICE pp 7 TeV data :χ^2/NDF= 32.1/11

Neutral pion production in p-Pb

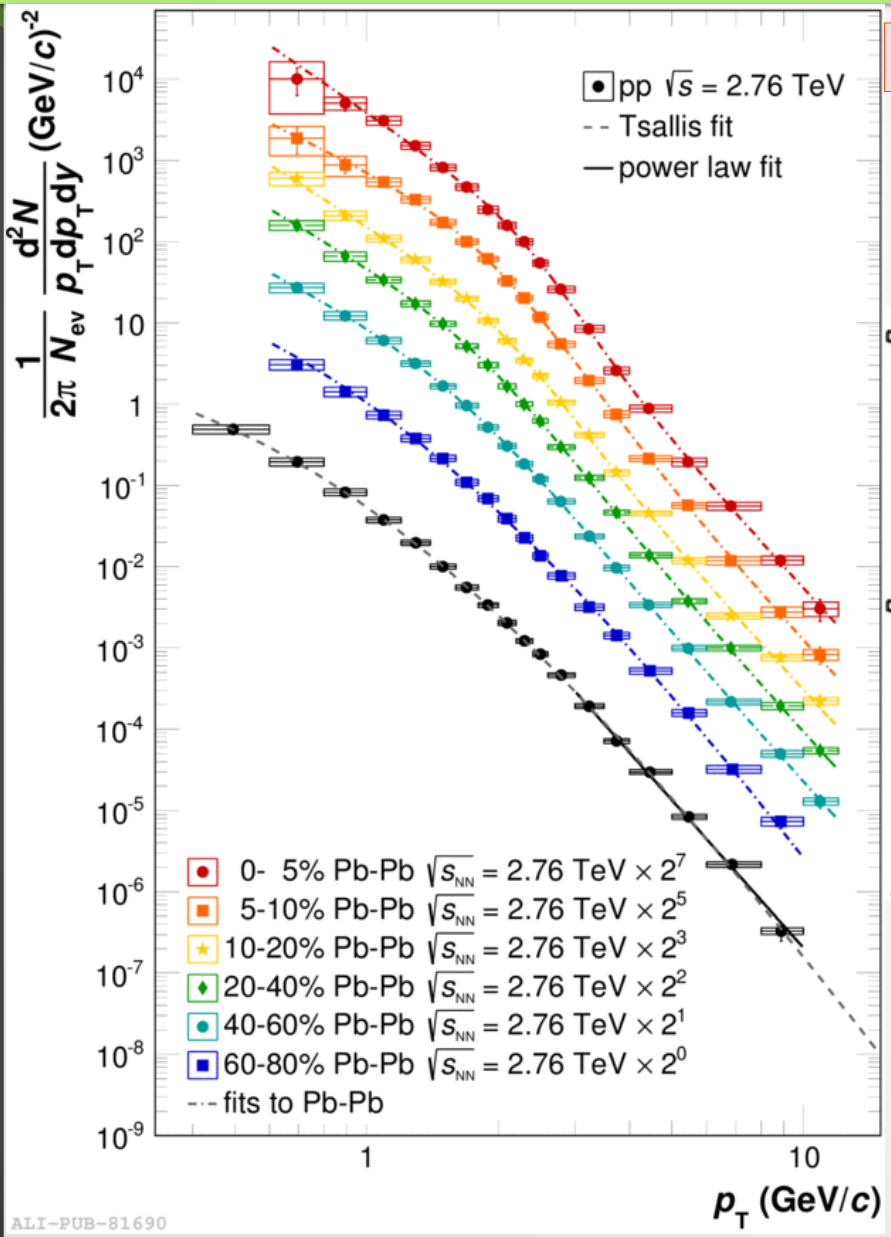


$$R_{AA}(p_T) = \frac{(1/N_{\mathrm{evt}}^{AA})\, d^2N_{\mathrm{ch}}^{AA}/d\eta\, dp_T}{\langle N_{\mathrm{coll}}\rangle (1/N_{\mathrm{evt}}^{pp})\, d^2N_{\mathrm{ch}}^{pp}/d\eta\, dp_T}$$



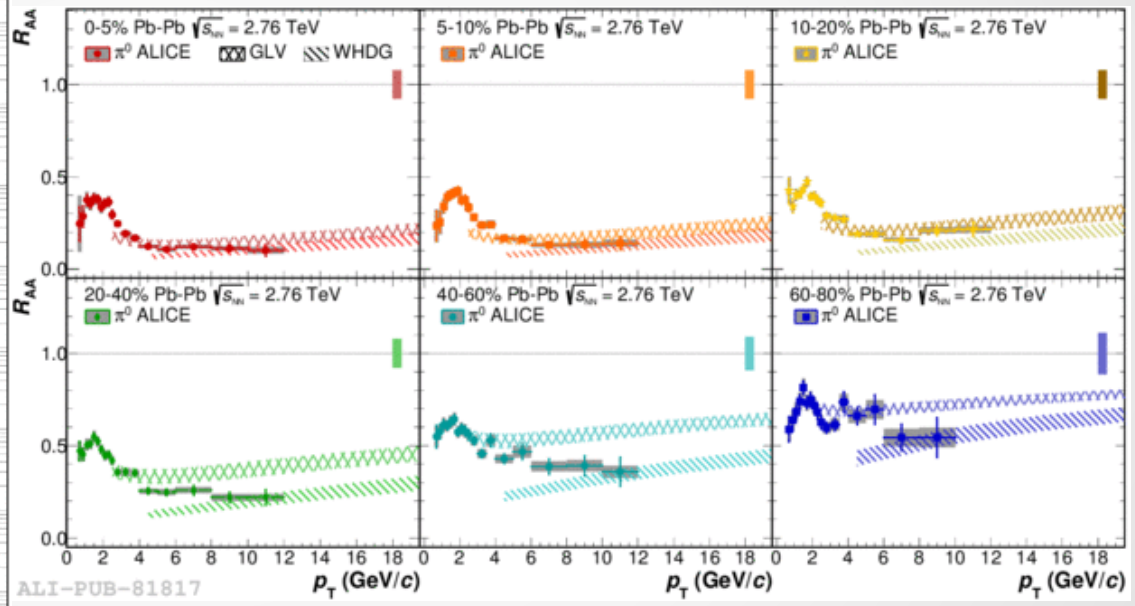
Preliminary data do not show cold nuclear effects in pion $R_{p\text{-}Pb}$

Neutral pions in Pb-Pb



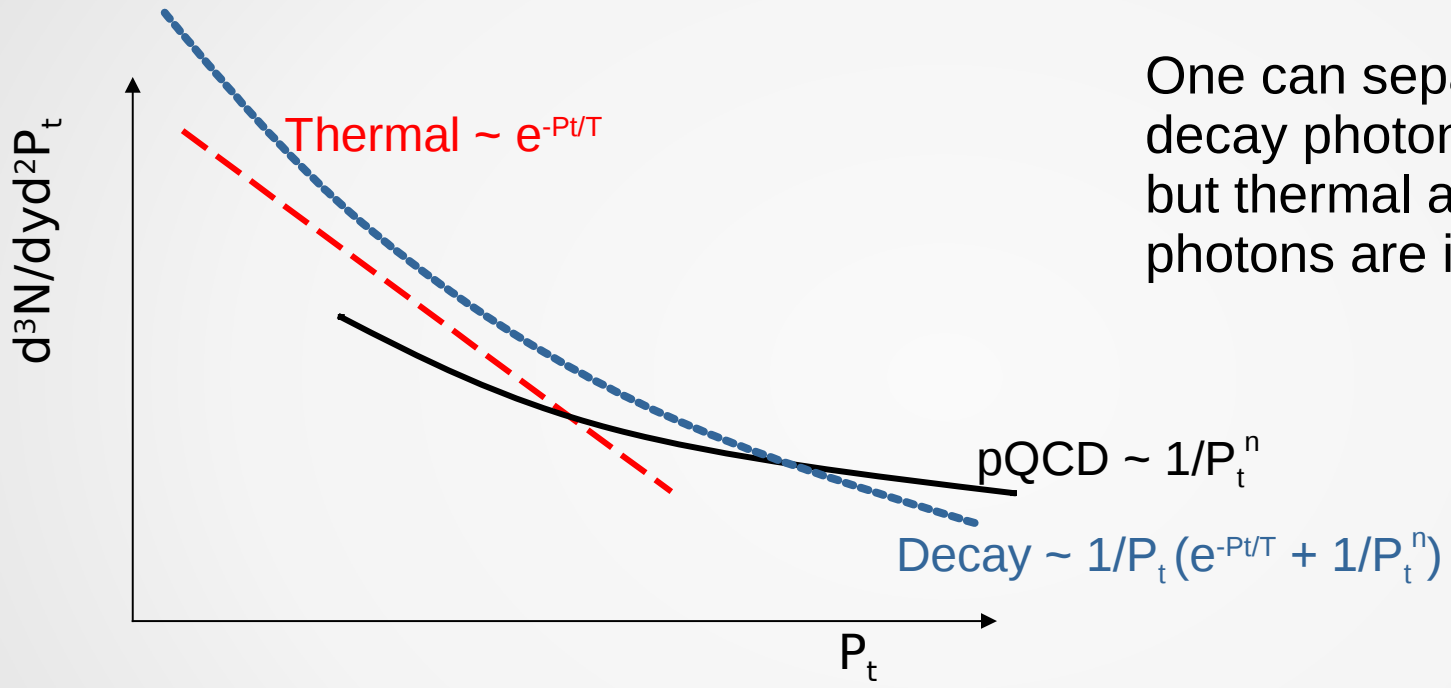
B.Abelev et al., Eur.Phys.J. C74 (2014), 3108

$$R_{AA}(p_T) = \frac{(1/N_{evt}^{AA})\, d^2N_{ch}^{AA}/d\eta\, dp_T}{\langle N_{coll}\rangle (1/N_{evt}^{pp})\, d^2N_{ch}^{pp}/d\eta\, dp_T}$$



Neutral pions show suppression at large p_T, which corresponds to the energy loss by hard parton.
Not all models are able to reproduce centrality and p_T dependence of the suppression.

Photon sources in AA collisions



One can separate direct and decay photons experimentally, but thermal and prompt direct photons are indistingushable

Prompt direct photons dominate at high p_T

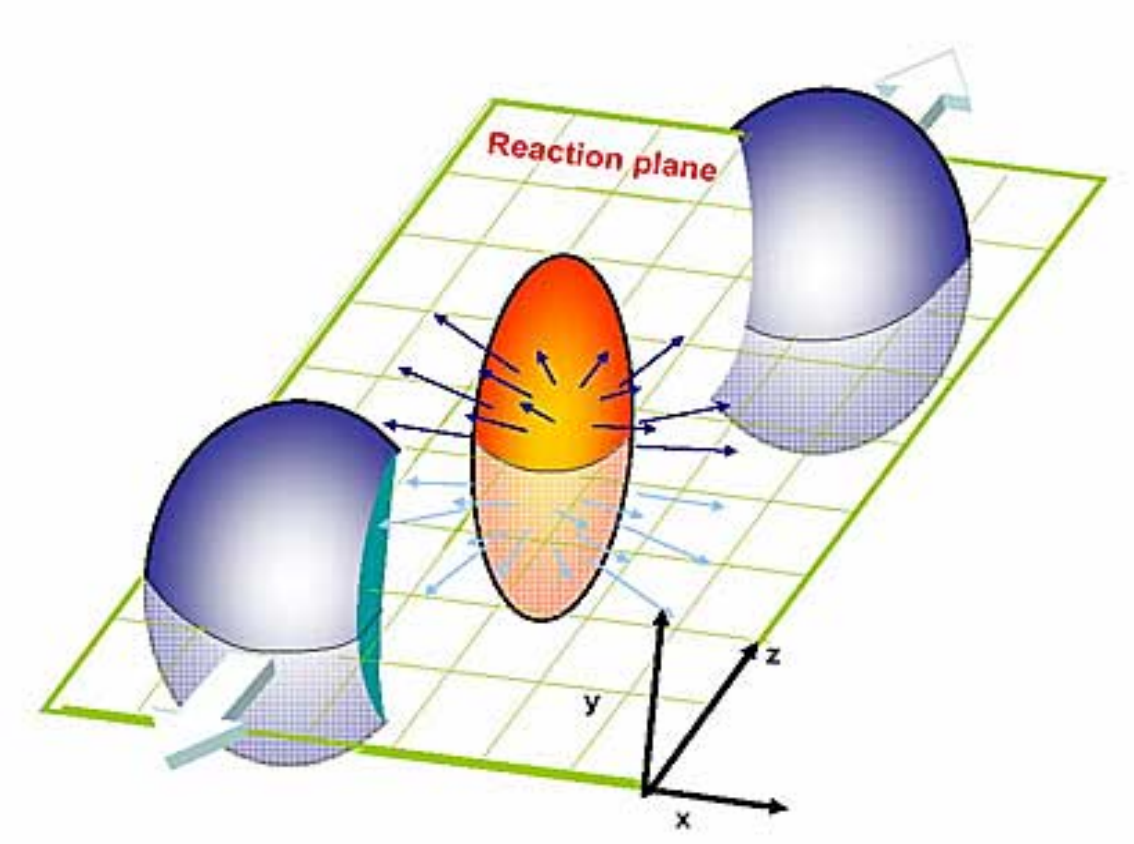
=> measure prompt direct photons in pp collisions, normalize to the number of binary collisions and subtract: produce thermal direct photon spectrum

Collective flow of direct photons

$$\frac{dN}{d\phi} = 1 + 2v_1\cos(\phi - \Psi_{RP}) + 2v_2\cos[2(\phi - \Psi_{RP})] + 2v_3\cos[3(\phi - \Psi_{RP})] + \ldots$$

Directed flow — **Elliptic flow** — **Reaction plane**

$$v_n = \langle \cos[n(\phi - \Psi_{RP})] \rangle$$



Collective flow of photons can be decomposed into contributions of decay and direct photons :

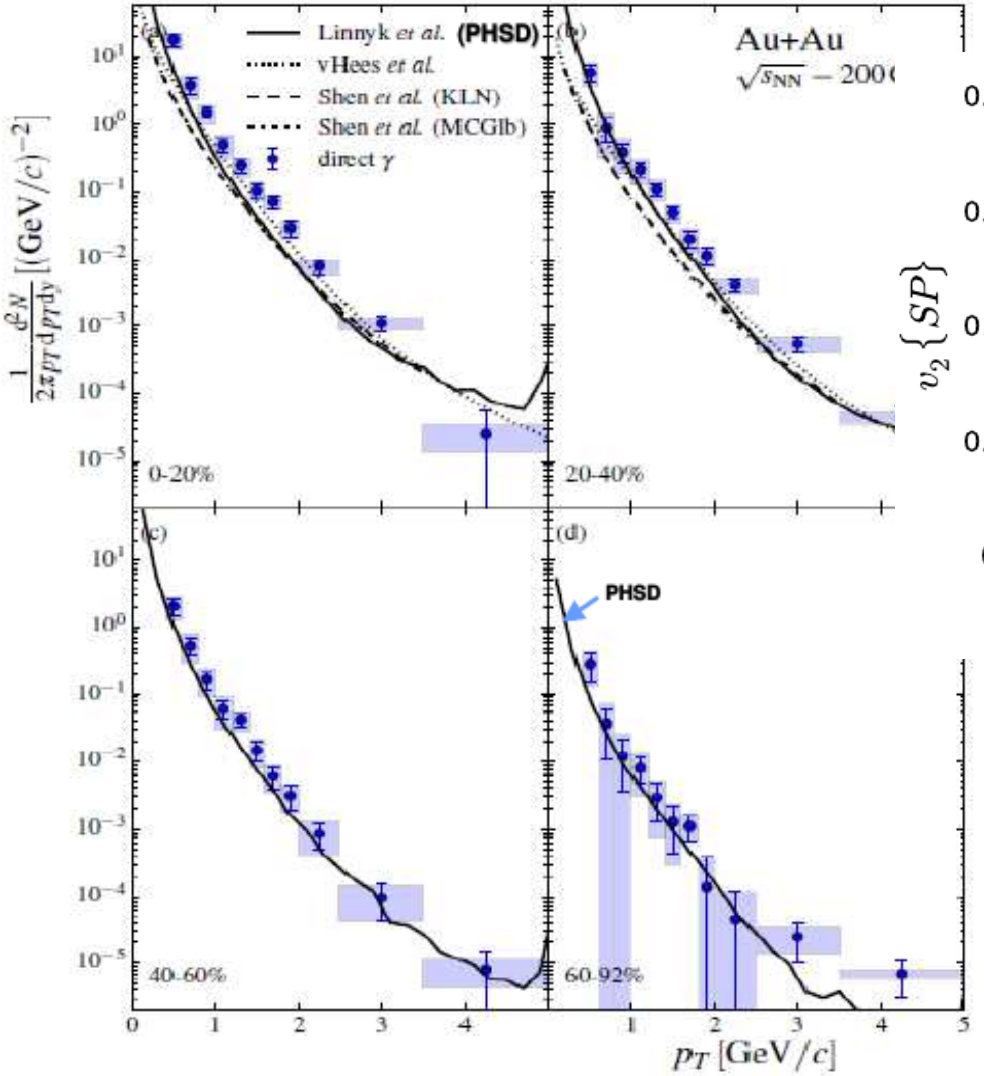
$$v_n^{\gamma,incl} = \frac{N_{\gamma,decay}}{N_{\gamma,all}} v_n^{decay} + \frac{N_{\gamma,dir}}{N_{\gamma,all}} v_n^{dir}$$

$$R = \frac{N_\gamma^{incl}}{N_\gamma^{decay}}$$

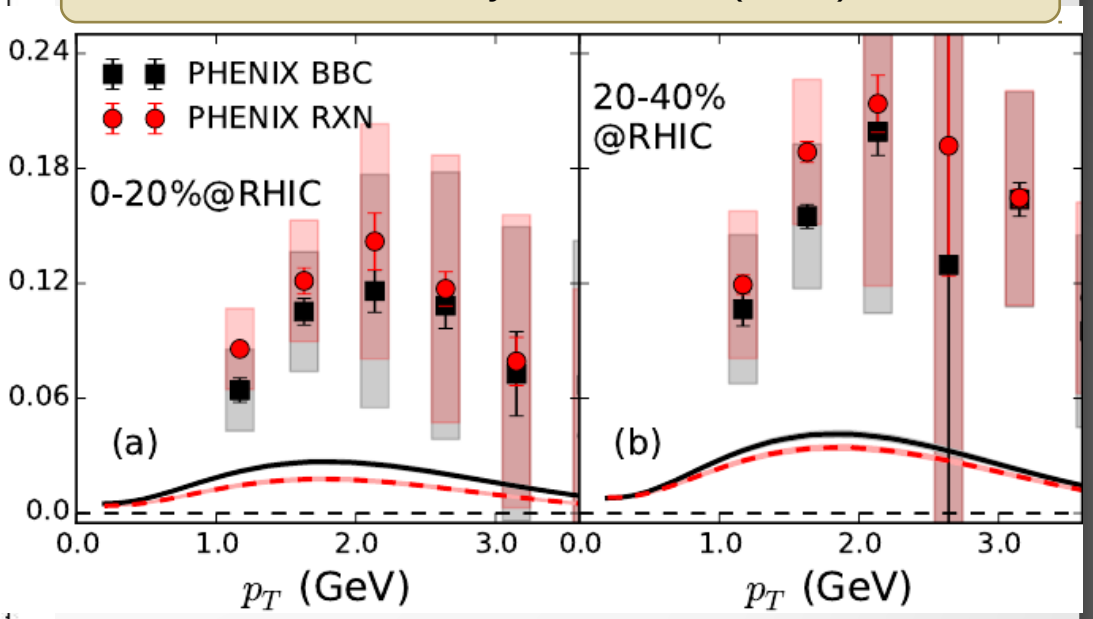
Intermediate result in direct photon spectrum extraction

$$v_n^{dir} = \frac{v_n^{incl} R - v_n^{decay}}{R - 1}$$

Direct photon spectrum and flow at RHIC



Chun Shen et al., Phys.Rev. C91 (2015) 2, 024908



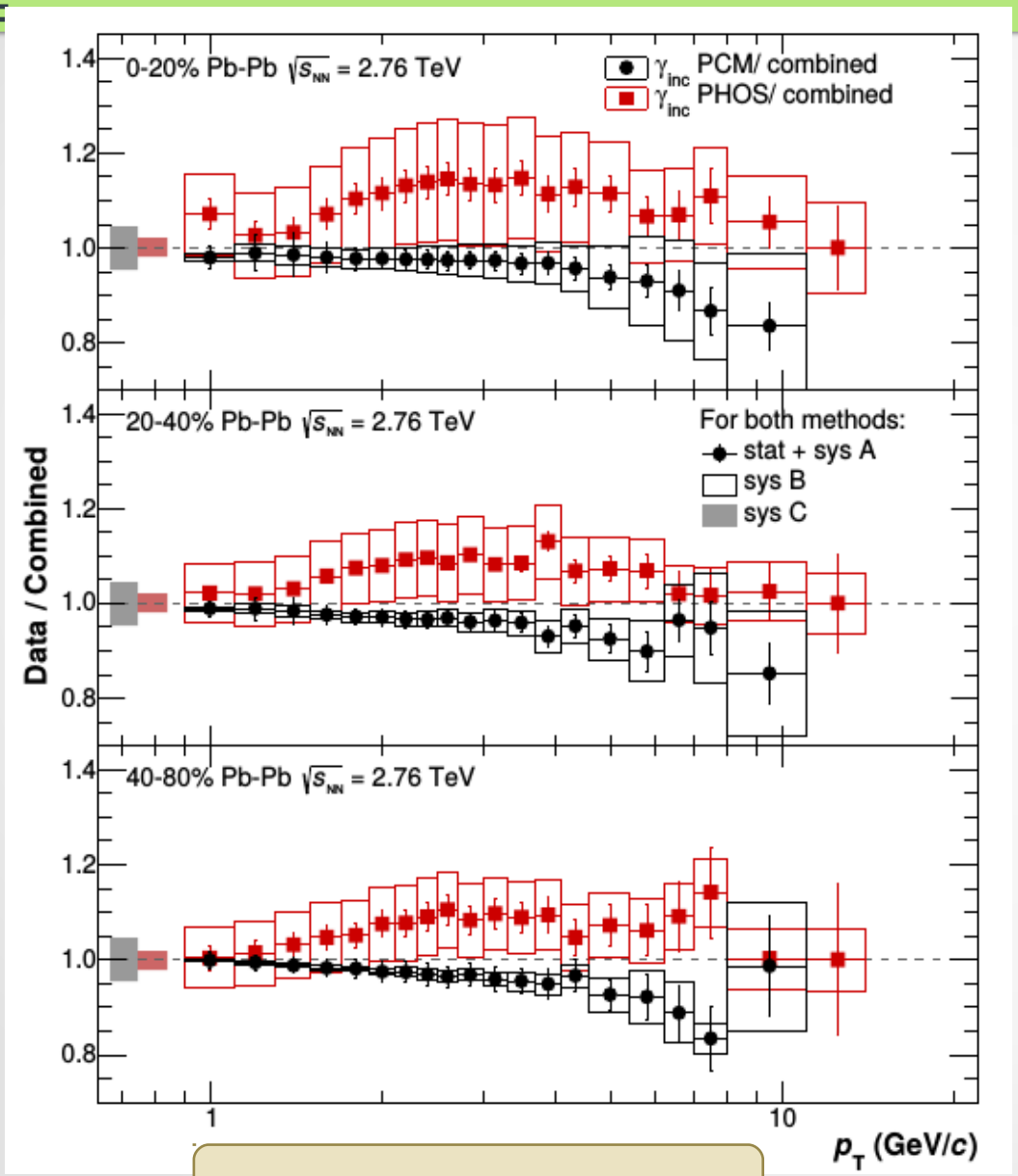
Amount of direct photon flow is comparable with flow of pions

Direct photon puzzle at RHIC:

- Theory understimates direct photon yield
- Strongly underestimates amount of direct photon flow.

Prog.Part.Nucl.Phys. 87 (2016) 50-115

Inclusive photon spectra in PHOS and PCM

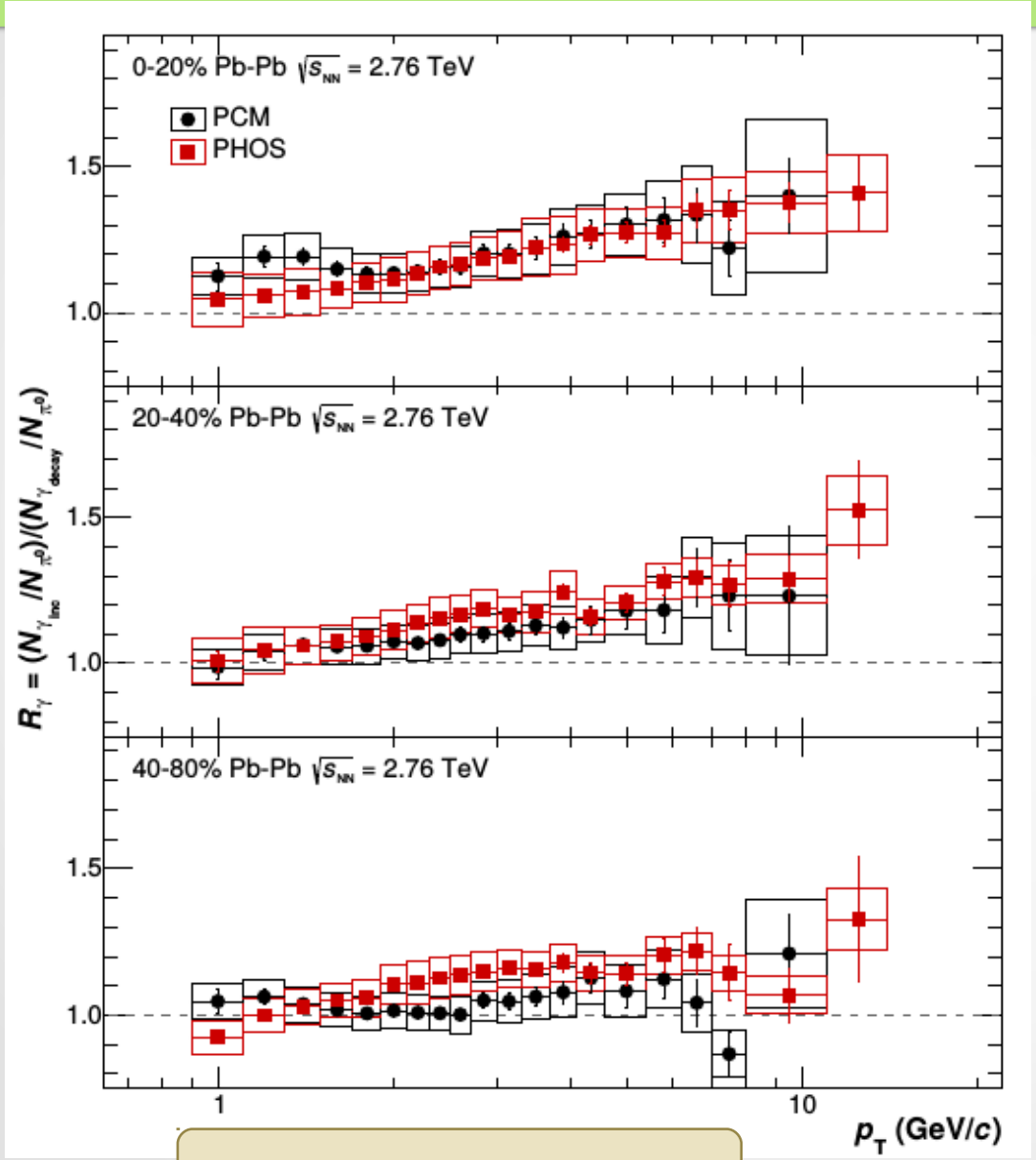


Phys.Lett. B754 (2016) 235-248

Systematic uncertainties are p_T correlated to large extend.

Detailed analysis shows that measurements are statistically consistent.

Direct photon double ratios in PHOS and PCM

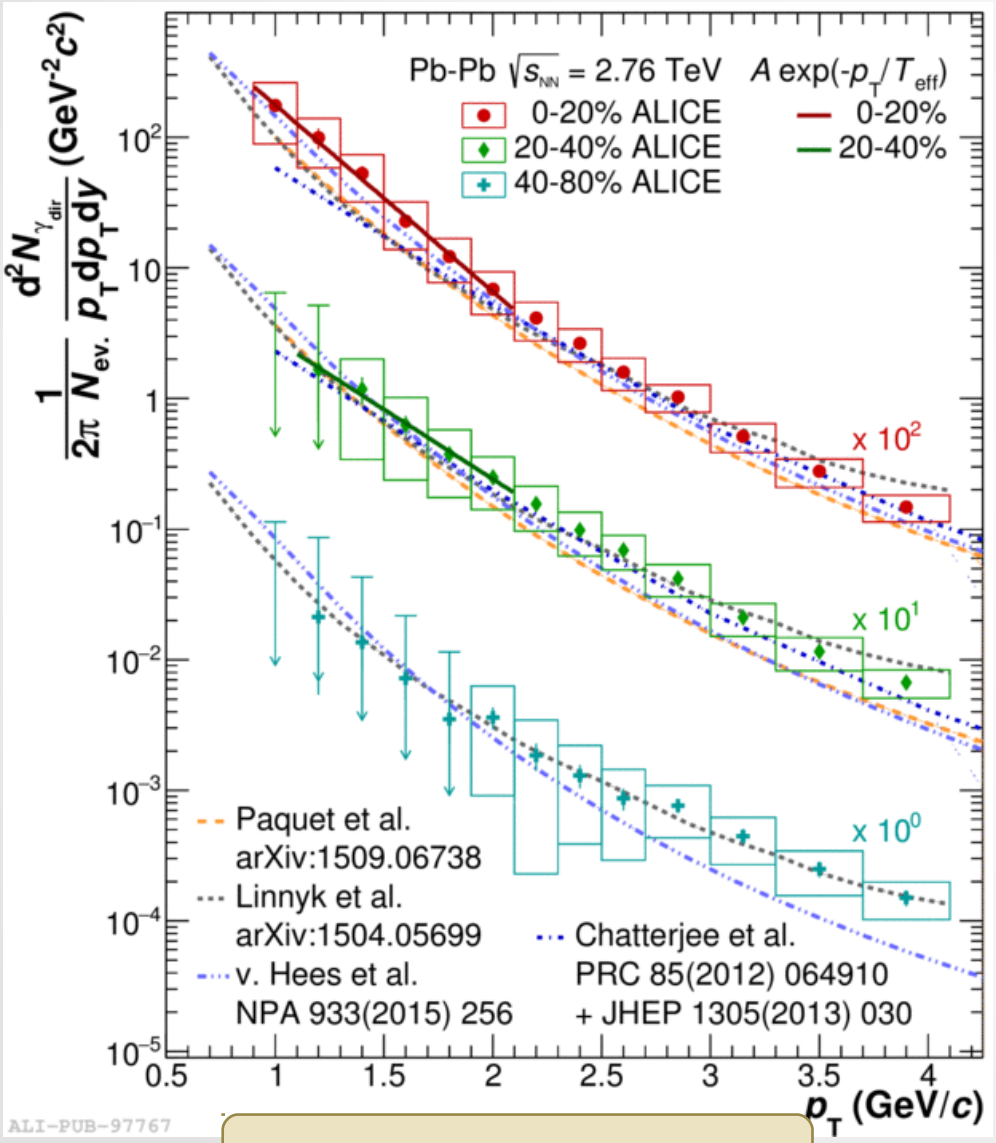


Phys.Lett. B754 (2016) 235-248

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

Double ratios in PHOS and PCM show better agreement with each other than inclusive photon spectra because some systematic uncertanties cancel.

Direct photon spectra in Pb-Pb collisions

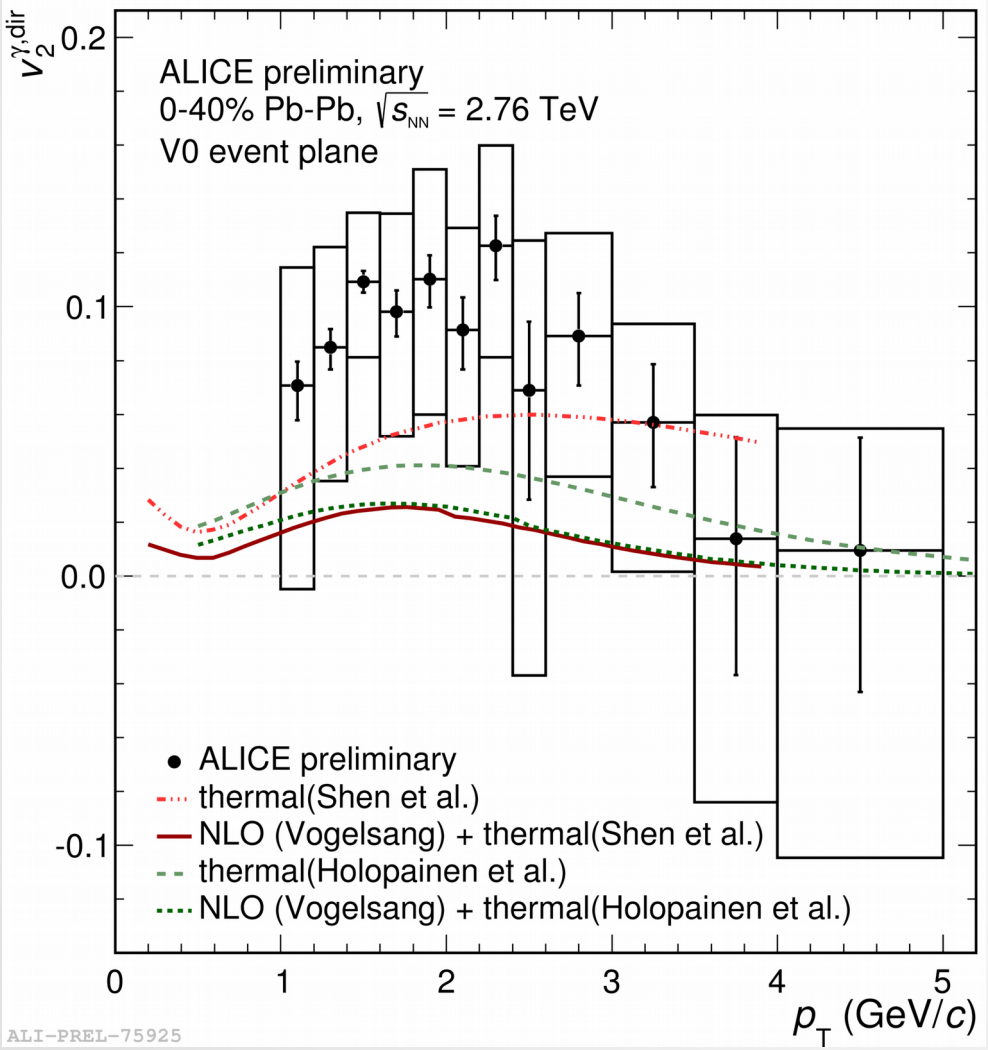


Phys.Lett. B754 (2016) 235-248

Measured direct photon spectra agree with NLO QCD predictions scaled with N_{coll}, and exceed them at p_T<4 GeV/c

Full theoretical predictions, including thermal direct photon predictions predict somewhat smaller yield, though touching systematic uncertanties.

Direct photon elliptic flow v_2



Similar to RHIC energy direct photon flow is underestimated by theoretical calculations especially at p_T<2 GeV/c approximately by factor 2-10.

Difference between data and theory predictions ~1-2 standard deviations: not very significant.

One should carefully treat all uncertainties

Conclusions

- Neutral meson spectra in pp collisions provide possibility to test QCD predictions and restrict PDF and FF for identified hadrons in wide kinematic region.
- Neutral meson spectra in p-Pb an Pb-Pb collisions provide possibility to test energy loss by hard partons in hot quark-gluon matter.
- Direct photon spectrum and flow provide possibility to study initial state of the AA collision and evolution of the hot matter at the very beginning of the collision.
- ALICE has collected a large amount of high quality data in Run2, so one can expect many new results.

Acknowledgements

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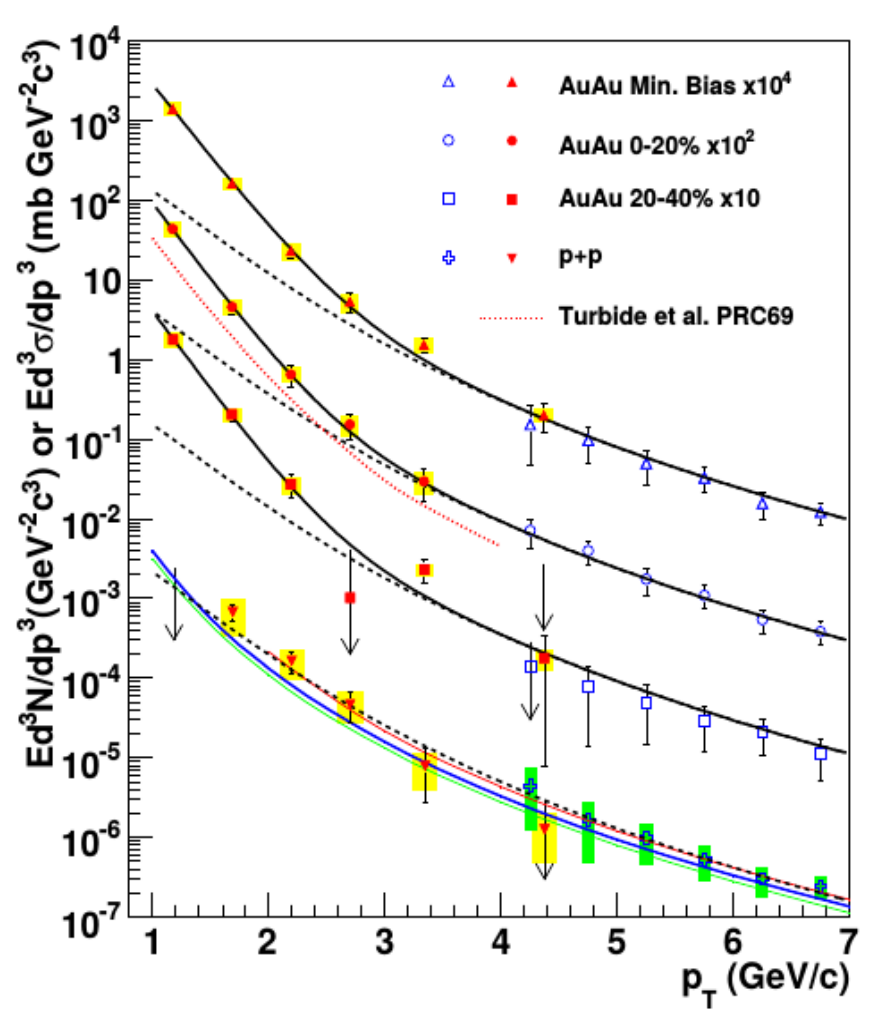
Direct photon spectrum at RHIC energy

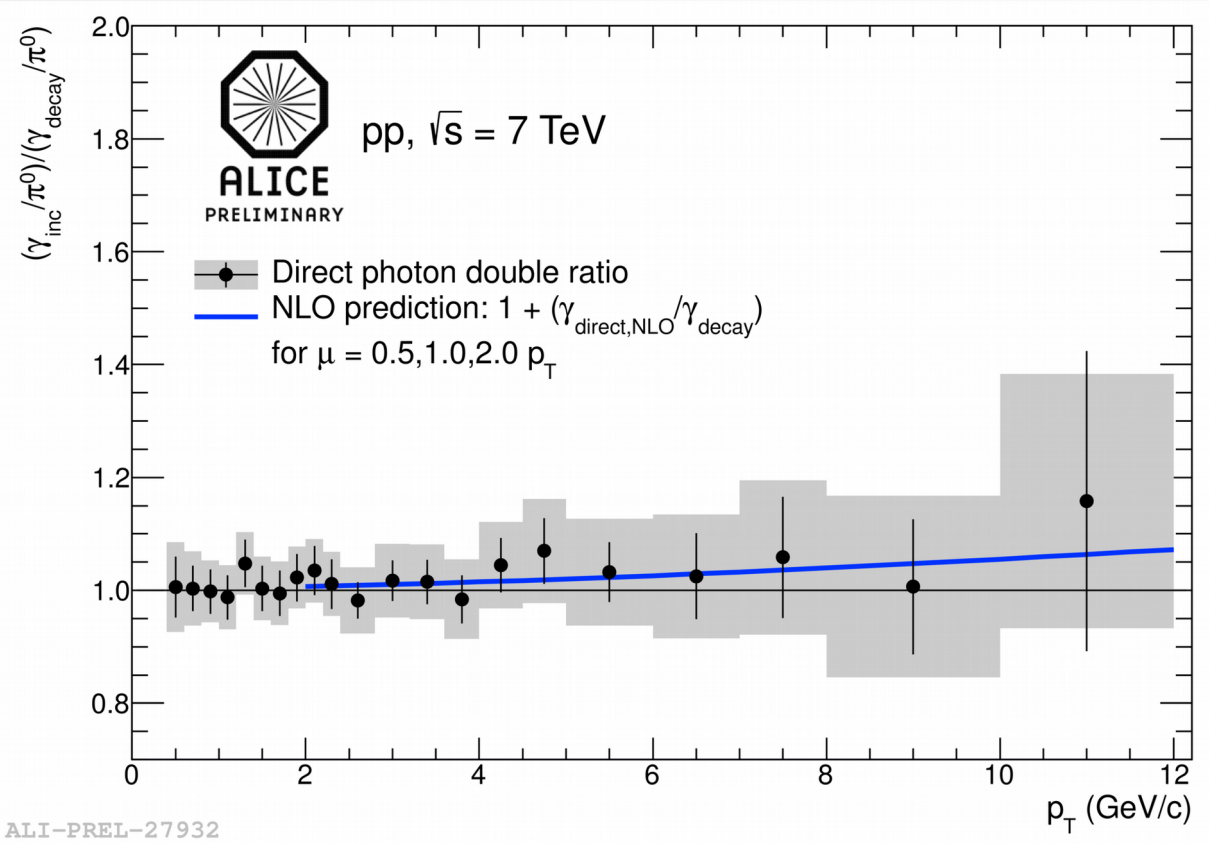


Phys.Rev. C81 (2010) 034911

Prompt direct photon spectrum at pp collisions is well reproduced by QCD calculations

There is agreement with N_{col} scaled pp spectrum at high p_T>4 GeV/c and clear eccess over the expected prompt photon yield at p_T<3 GeV/c

Double ratio in pp collisions at 7 TeV



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

$3.8 \cdot 10^8$ event were analyzed

Some unceratinties: :
- normalization,
- π^0 spectrum,
- Efficiency

partially cancel

Measurement agree with no direct photon signal and with NLO QCD predictions