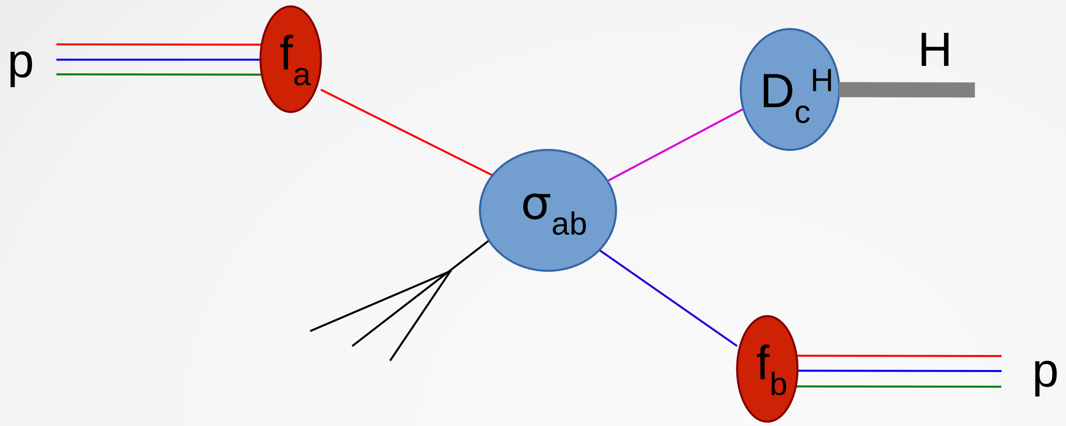
Measurement of neutral mesons and direct photons in pp, pPb and Pb-Pb collisions with ALICE at the LHC

D.Peresunko
NRC “Kurchatov institute”

for the ALICE collaboration

Hadron production in pp collisions



$$E\frac{d^3\sigma^H}{d\vec{p}} = \sum_{a,b,c} f_a(x_1,Q^2)\otimes f_b(x_2,Q^2)\otimes D_c^H(z_c,Q^2)\otimes d\hat{\sigma}_{ab\to cX}(Q^2,x_1,x_2)$$

$f_{a,b}$ – parton distribution functions in proton

σ_{ab} – parton cross-section

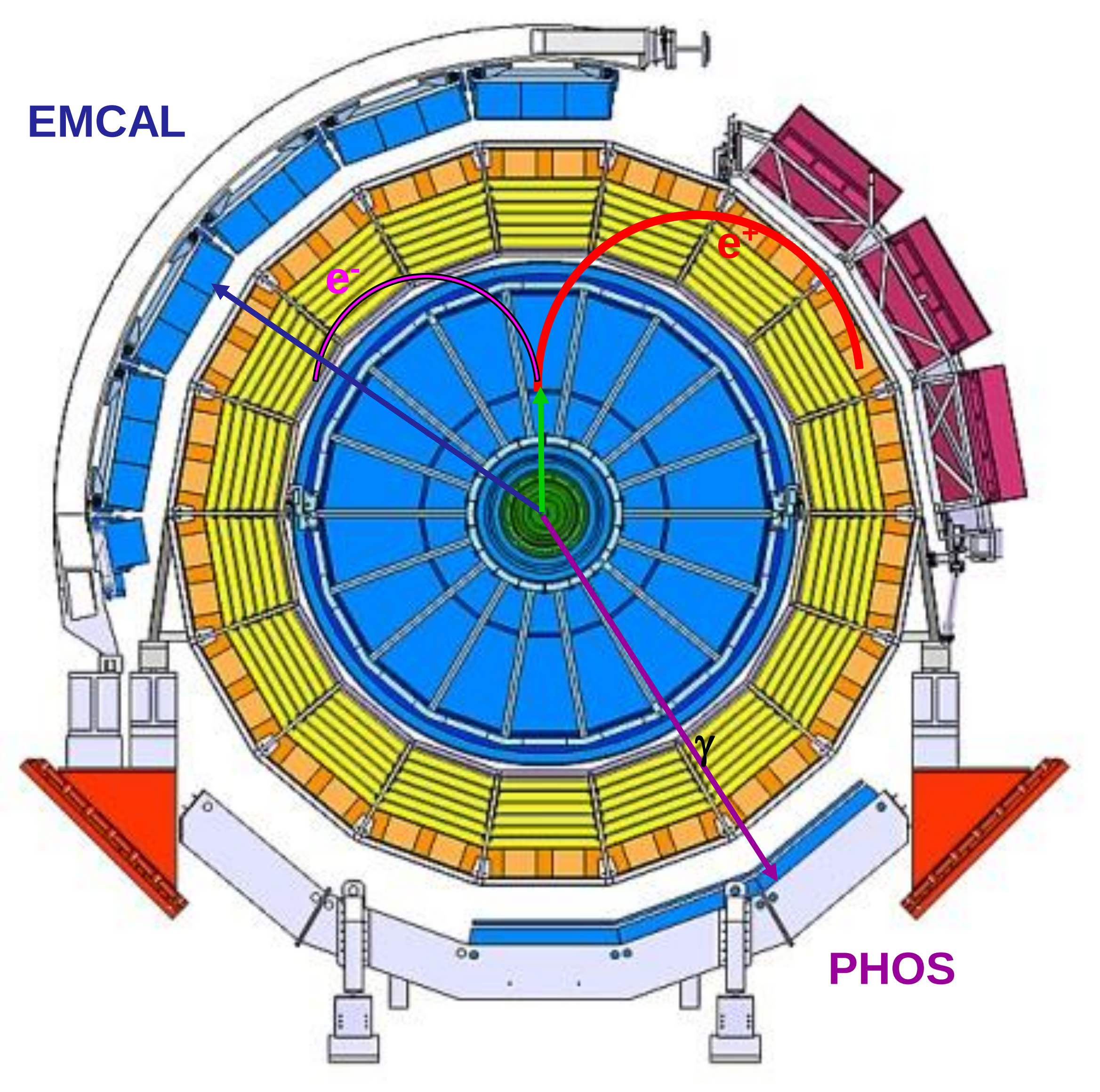
D_c^H – fragmentation function

Measurement of the hadron production cross-section provides possibility to constrain Parton Distribution Functions (f_a) and Fragmentation Functions (D_c^H)

Neutral mesons can be identified in wide p_T region

=> restrictions on PDF/FF in wide kinematic range.

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

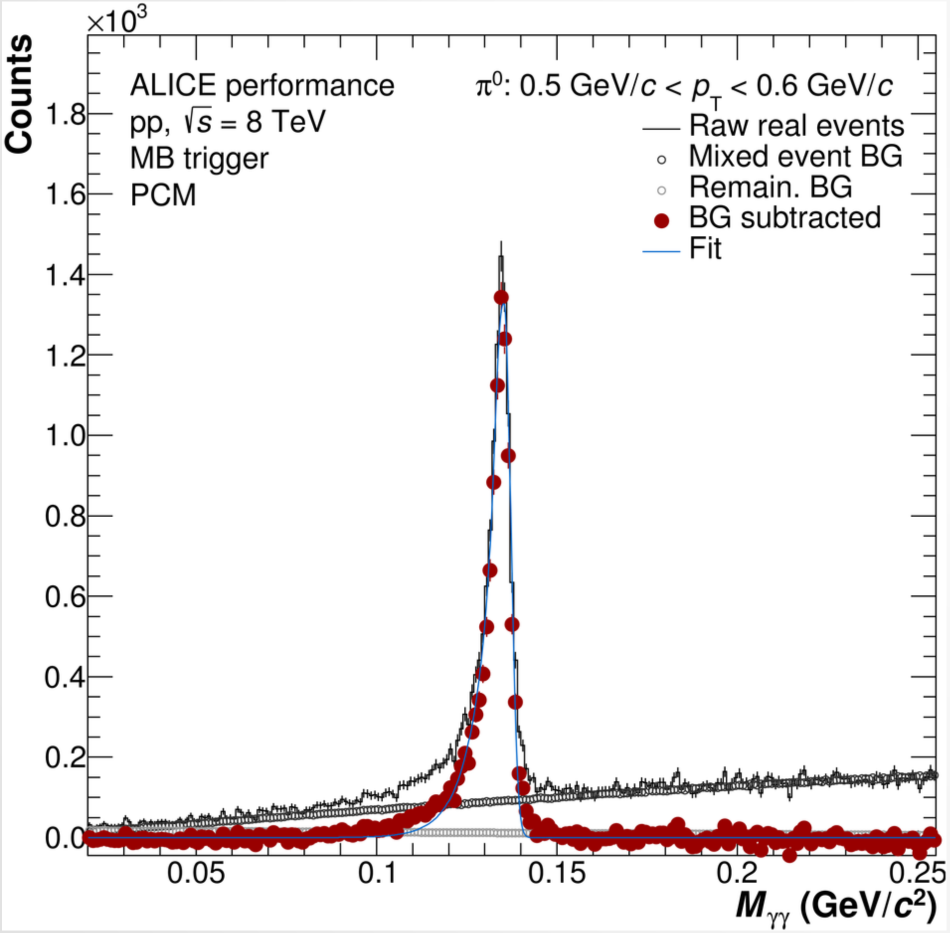
- Excellent resolution at high p_T
- High efficiency for the photon detection
- Limited acceptance (60º) $|\eta|<0.135$

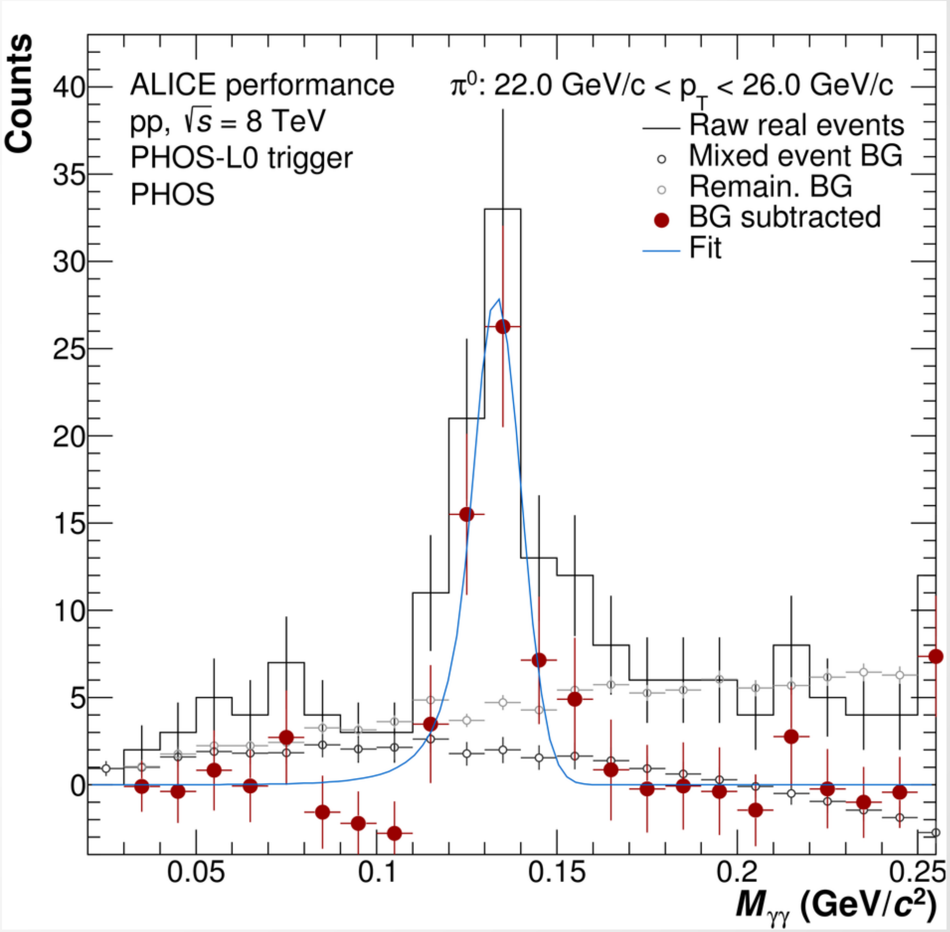
EMCAL

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

Invariant mass distributions: PCM and PHOS

S.Acharya et al., arXiv:1708.08745

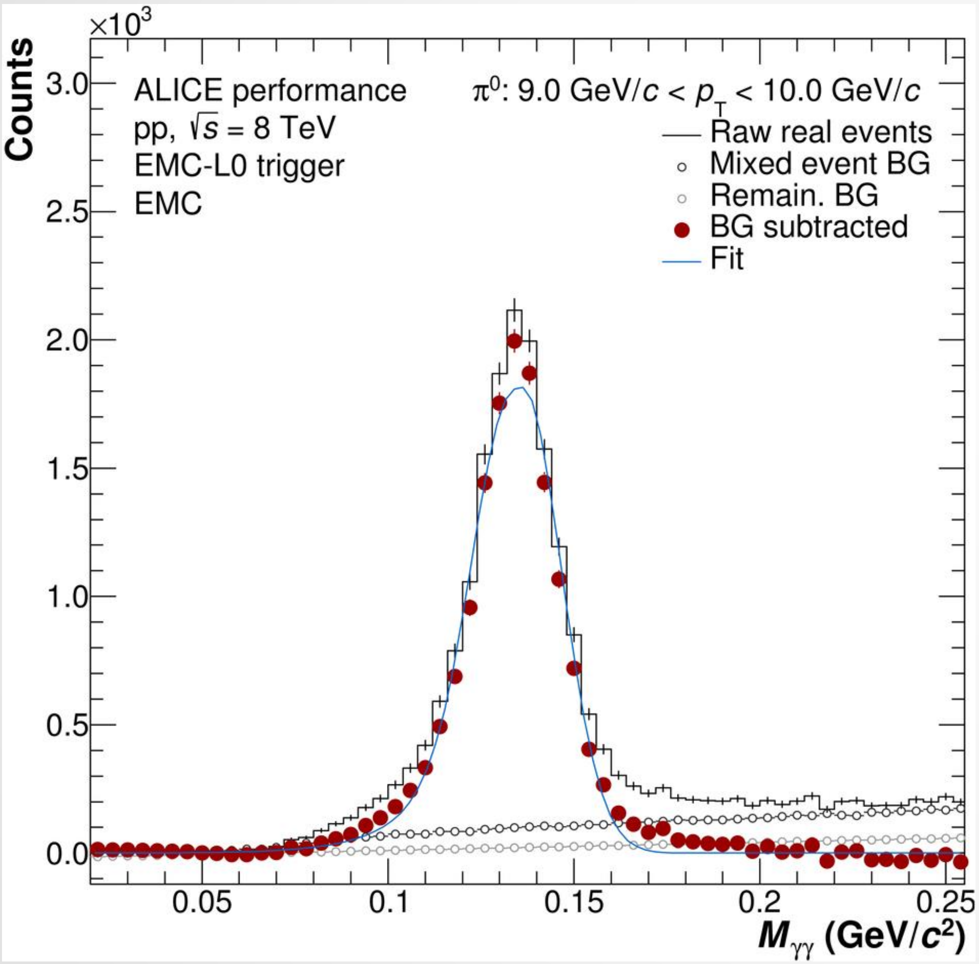


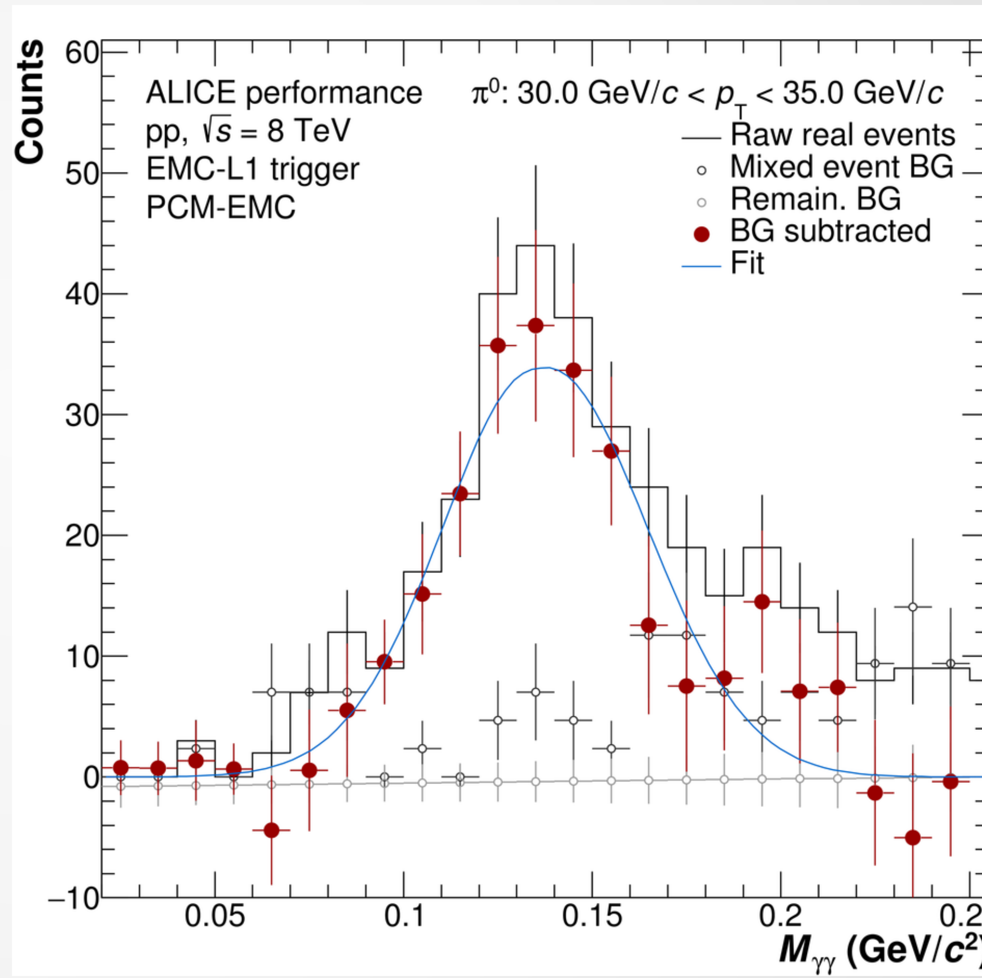


Photon Conversion Method (PCM) uses tracking detectors and provides excellent accuracy at low p_T, electromagnetic calorimeters PHOS has good resolution at high p_T.

Invariant mass distributions: EMCAL and combined

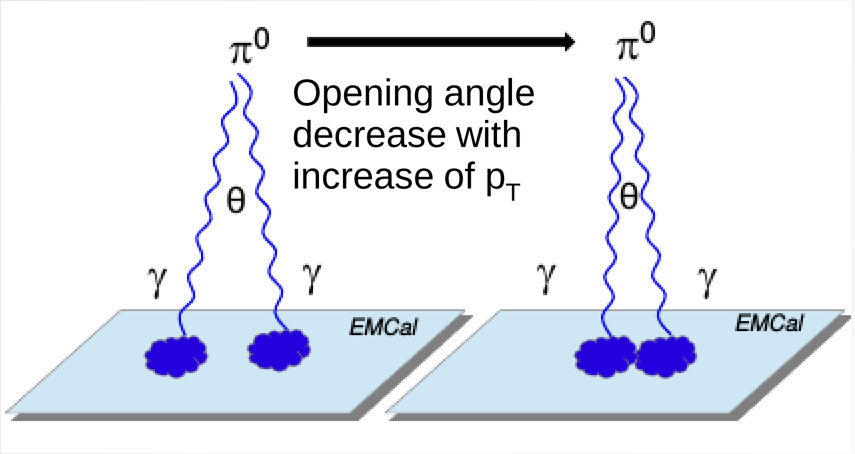
S.Acharya et al., arXiv:1708.08745





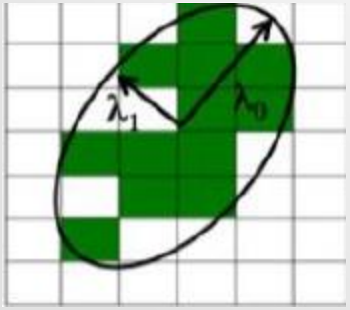
EM calorimeter EMCAL due to large acceptance has good statistical accuracy.
Combined PCM+EMCAL method allows to measure π^0 up to p_T~40 GeV/c.

EMCAL: merged clusters



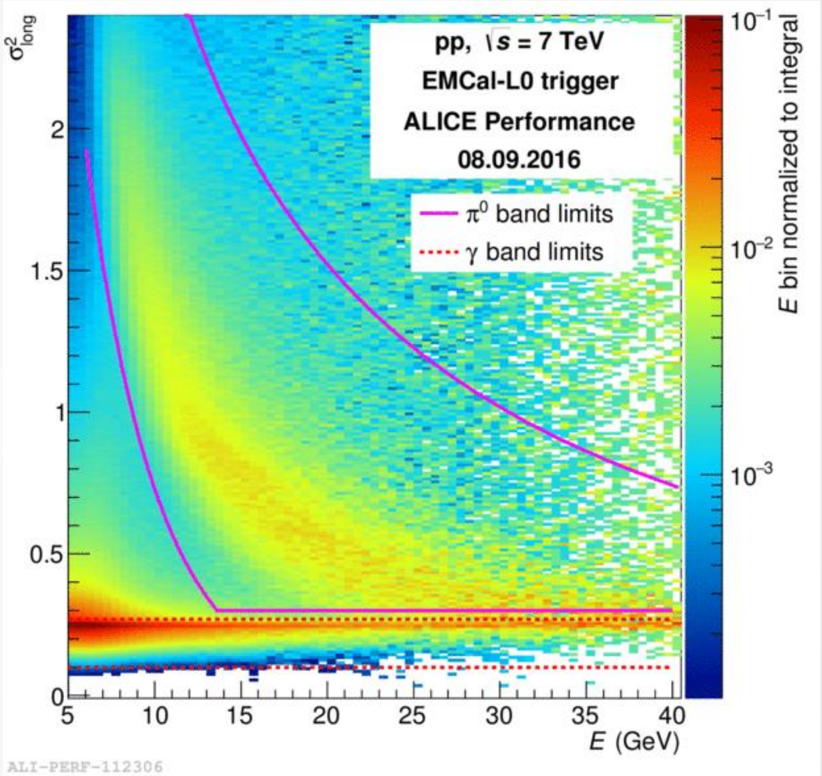
$$\sigma^2_{long} = \frac{1}{2}(\delta_{\varphi\varphi} + \delta_{\eta\eta}) + \sqrt{\frac{1}{4}(\delta_{\varphi\varphi} - \delta_{\eta\eta})^2 + {\delta_{\eta\varphi}}^2}$$

$$\sigma^2_{short} = \frac{1}{2}(\delta_{\varphi\varphi} + \delta_{\eta\eta}) - \sqrt{\frac{1}{4}(\delta_{\varphi\varphi} - \delta_{\eta\eta})^2 + {\delta_{\eta\varphi}}^2}$$



$$\delta_{\alpha\beta} = \sum_i \frac{w_i \alpha_i \beta_i}{w_{tot}} - \sum_i \frac{w_i \beta_i}{w_{tot}} \sum_i \frac{w_i \beta_i}{w_{tot}}$$

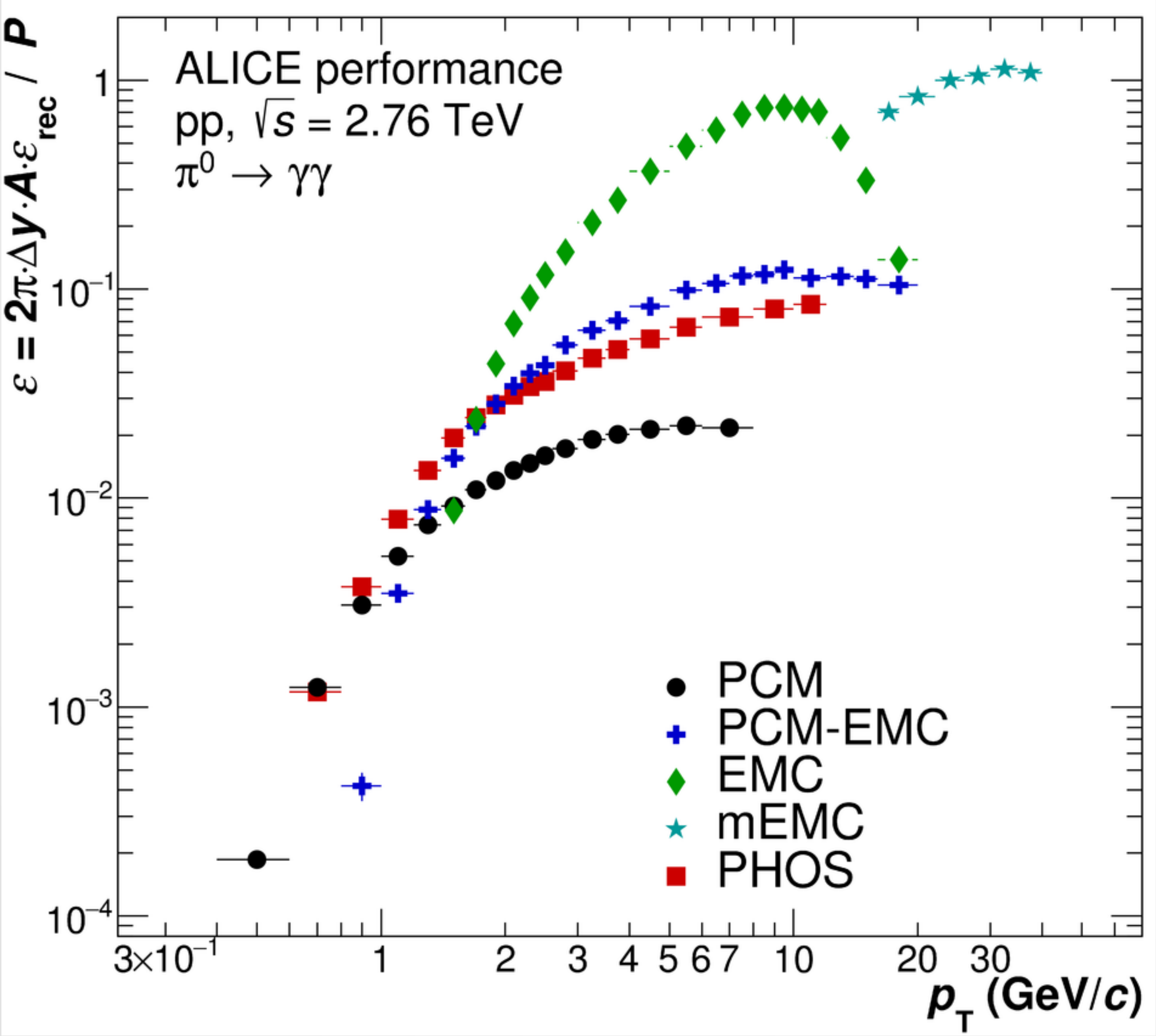
$$w_i = \max\left[\left(0, w_0 + \ln\left(\frac{E_i}{E_{cluster}}\right)\right)\right]$$



Smaller dispersion parameter σ_{short} is not sensitive to the kind of parent, but longer one σ_{long} shows clearly separated bands for single photons and π^0.

Efficiency of difference methods

S.Acharya et al., Eur. Phys. J. C 77 (2017) 339



EMCAL: εA is large but decrease at p_T>10 GeV/c because of cluster merging

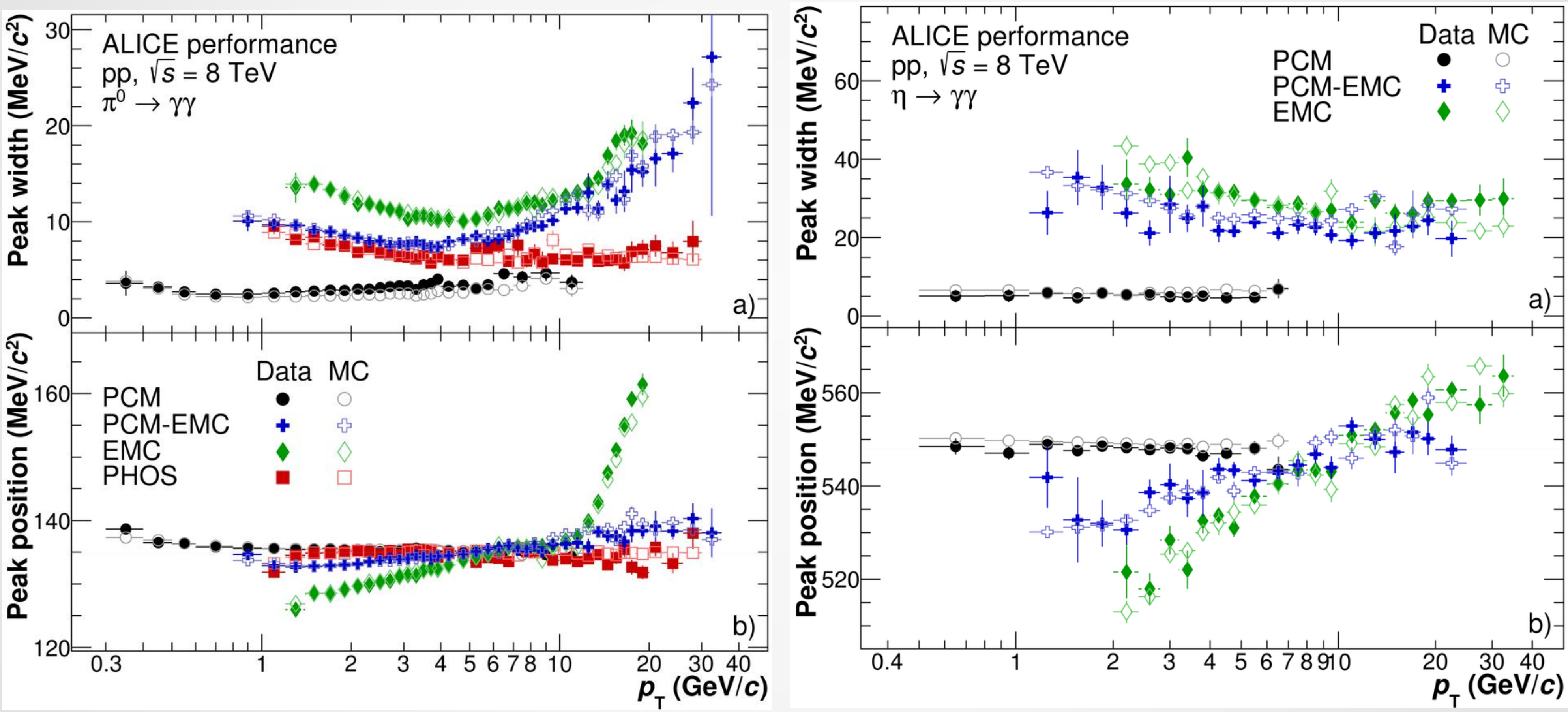
EMCAL merged: εA is large at 15<p_T<40 GeV/c

PHOS and **conversion+EMCAL** have similar εA

Conversion: εA somewhat smaller than one in PHOS because of small material budget in ALICE.

Peak position and width: tuning MC simulations

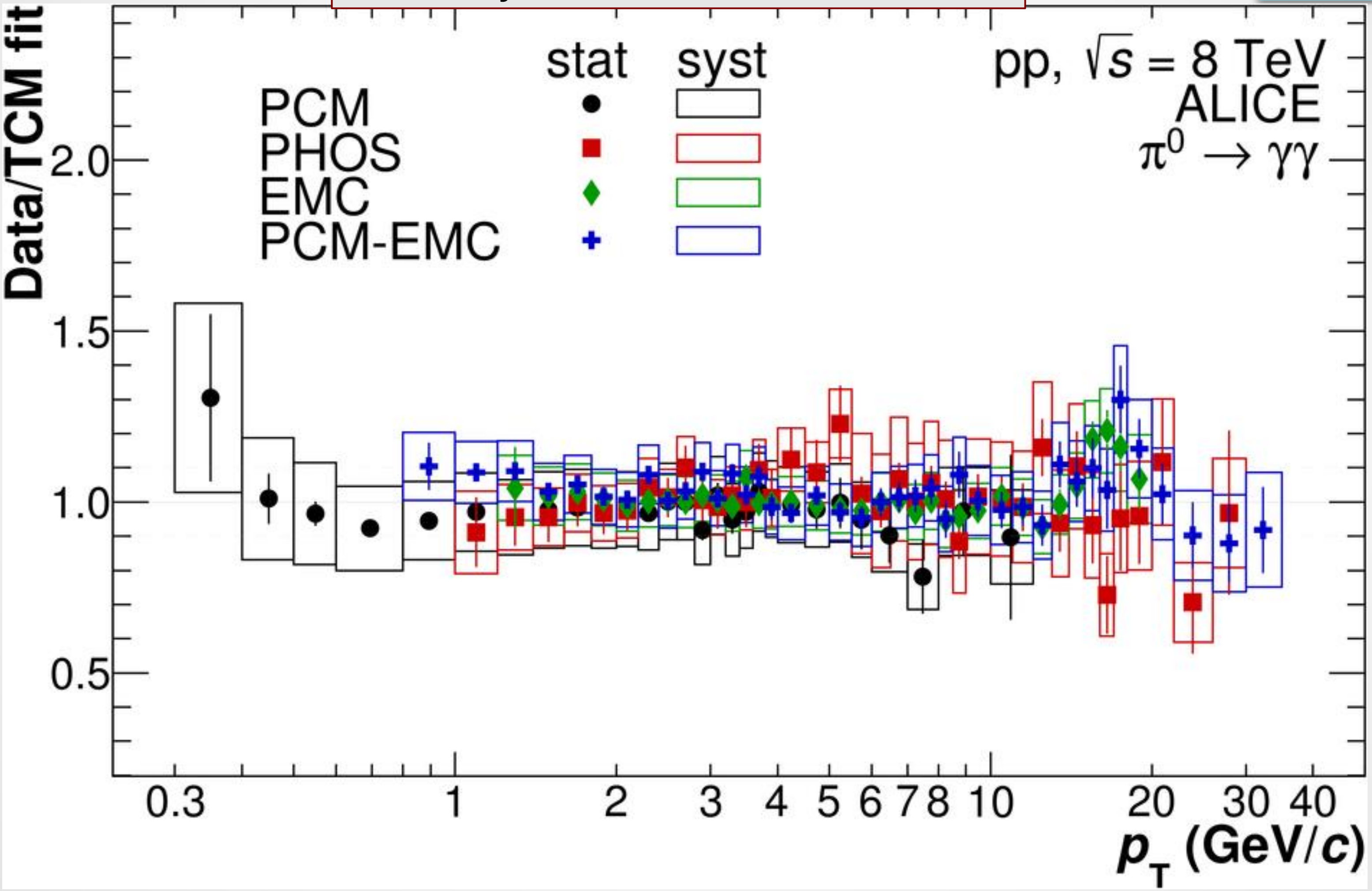
S.Acharya et al., arXiv:1708.08745



PCM method provides the best peak width, PHOS becomes comparable at p_T>10 GeV/c, EMCAL and EMCAL+PCM have larger width.

Consistency of different measurements

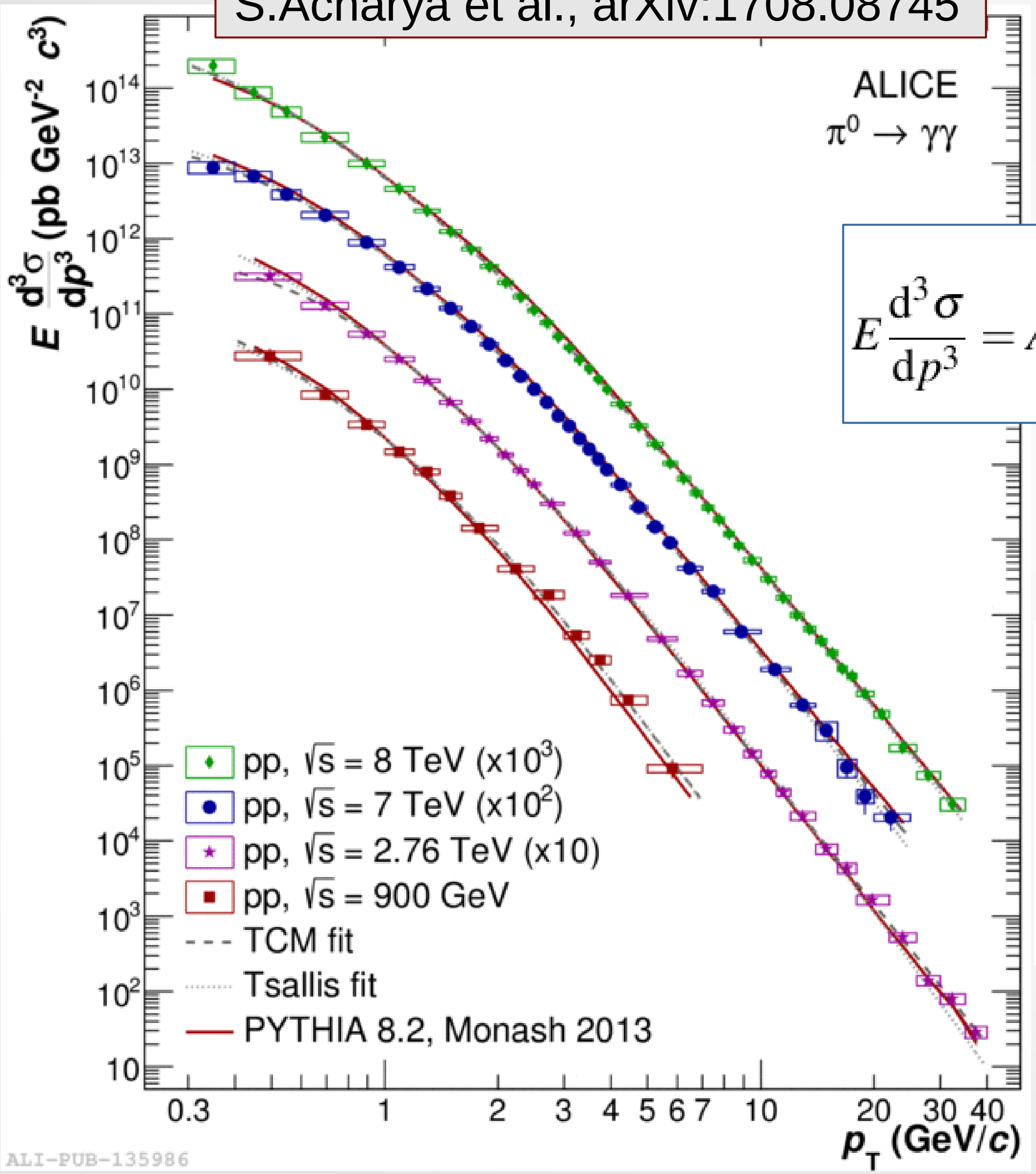
S.Acharya et al., arXiv:1708.08745



All measurements are consistent with each other within uncertainties both at √s=2.76 and √s=8 TeV.

Invariant π^0 spectra in pp collisions

S.Acharya et al., arXiv:1708.08745



Two-component fit (TCM)
(Bylinkin and Rostovtsev):

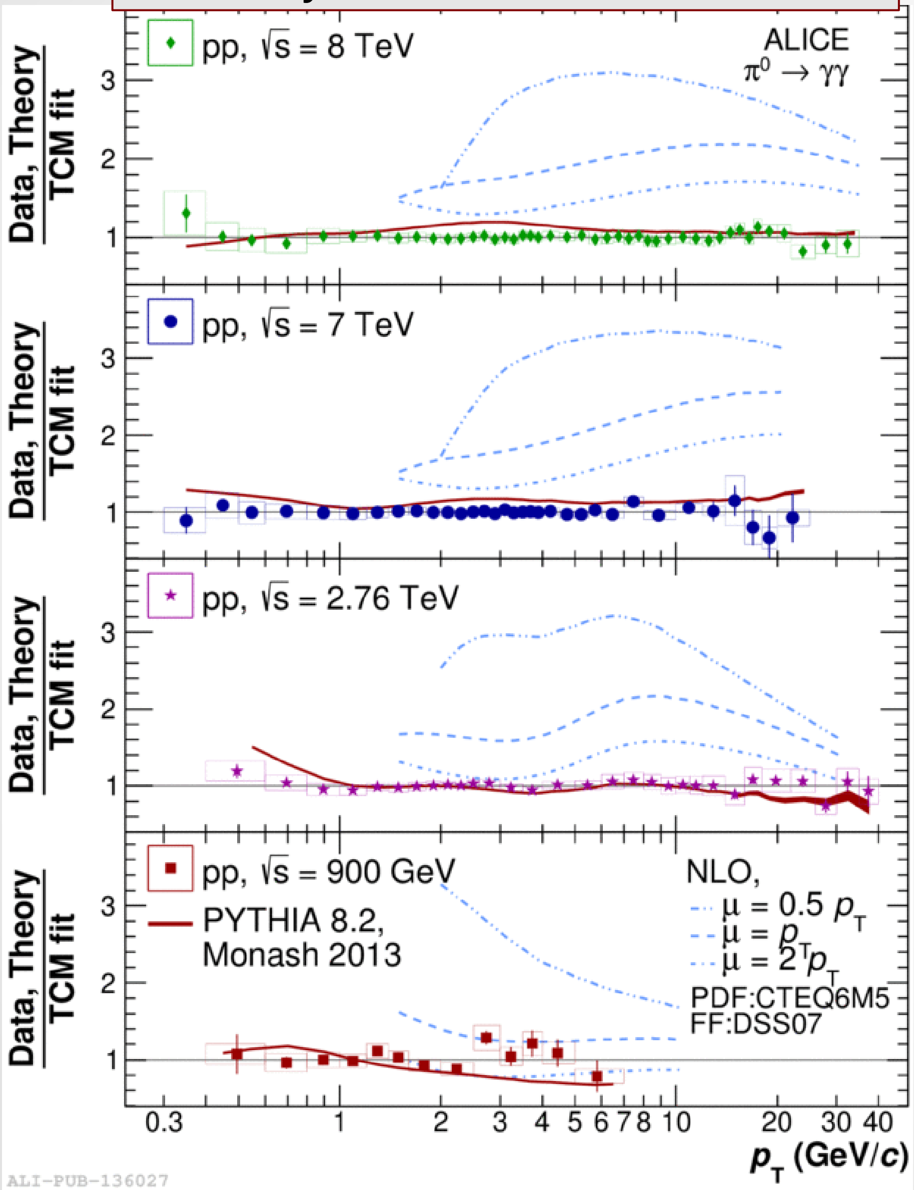
$$E\frac{d^3\sigma}{dp^3} = A_e \exp\frac{(M-\sqrt{p_T^2+M^2})}{T_e} + A\left(1+\frac{p_T^2}{n_{br}T^2}\right)^{-n_{br}}$$

Tsallis parameterization:

$$\frac{1}{2\pi p_T}\frac{d^2N}{dp_T dy} = \frac{A}{2\pi}\frac{(n-1)(n-2)}{nC[nC+m(n-2)]}\frac{1}{c^2} \cdot \left(1+\frac{\sqrt{p_T^2+m^2}-m}{nC}\right)^{-n}$$

Detailed comparison with theory

S.Acharya et al., arXiv:1708.08745

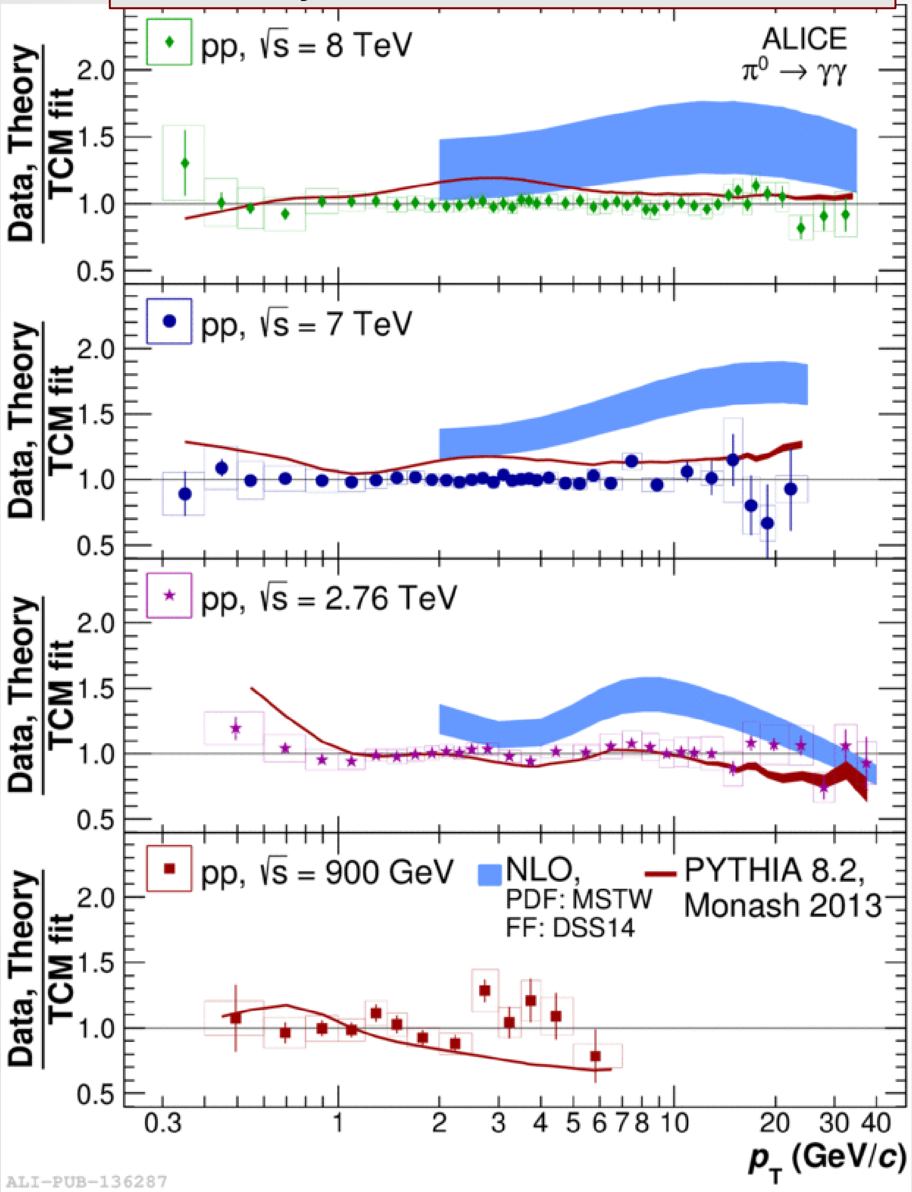


To make quantitative comparison, divide both data and theory by fit using Two-Component Model fit.

First NLO pQCD calculations with PDF CTEQ6M5 and FF DSS07 predict 50-100% higher π^0 yield.

Detailed comparison with theory (2)

S.Acharya et al., arXiv:1708.08745



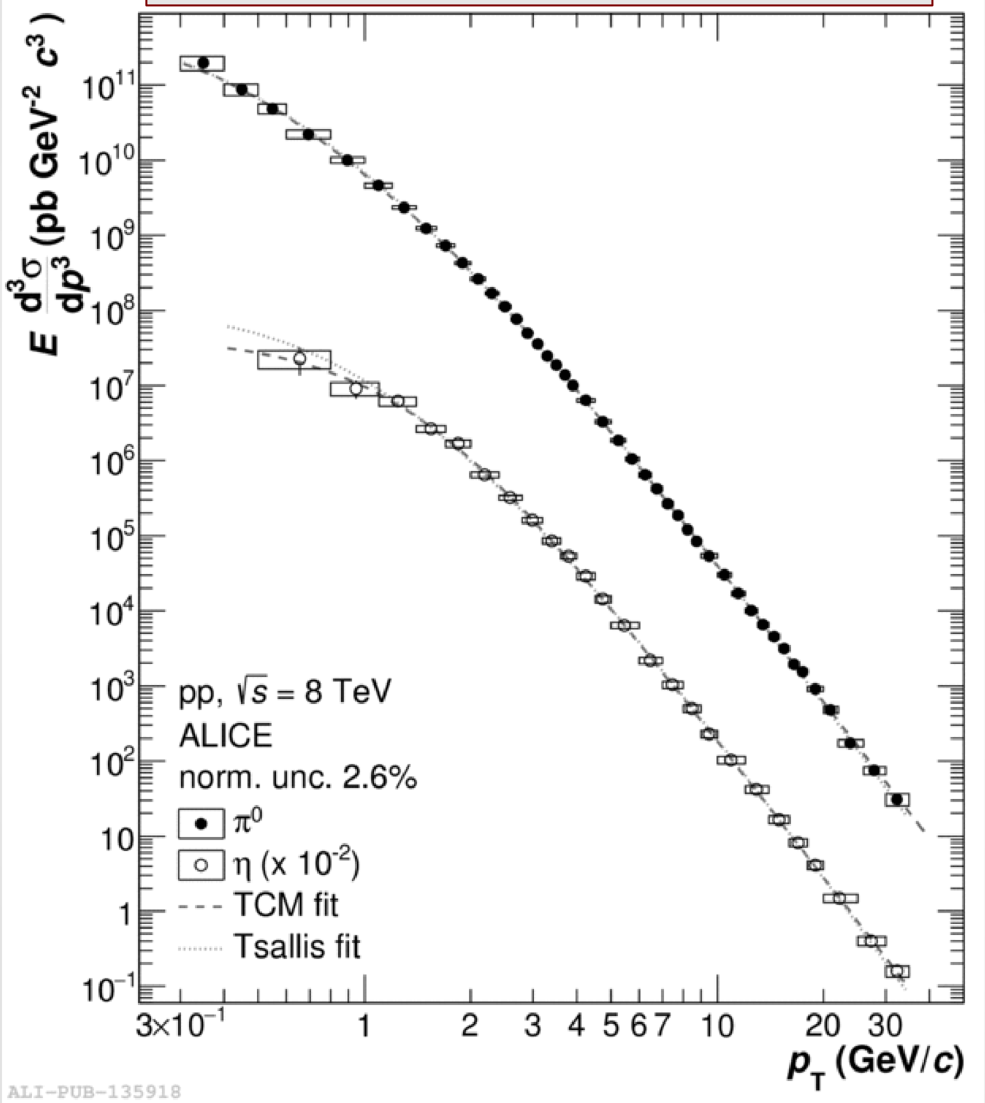
NLO pQCD calculations with improved Fragmentation Functions, incorporating first ALICE results on π^0 production in pp collisions at $\sqrt{s}$=7 TeV:

PDF: MSTW, FF: DSS14

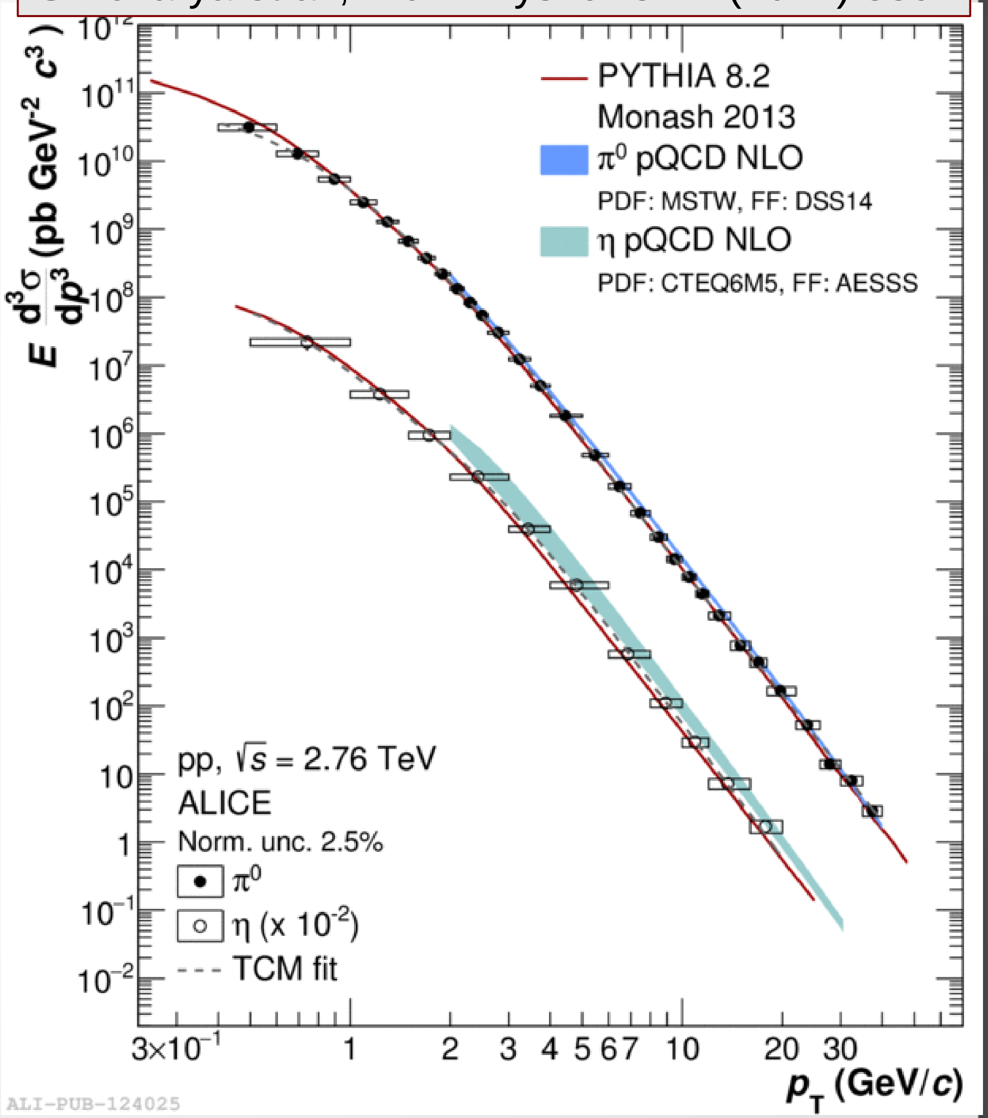
show better agreement though deviate up to ~30-50% at intermediate p_T

Invariant yield of η mesons

S.Acharya et al., arXiv:1708.08745

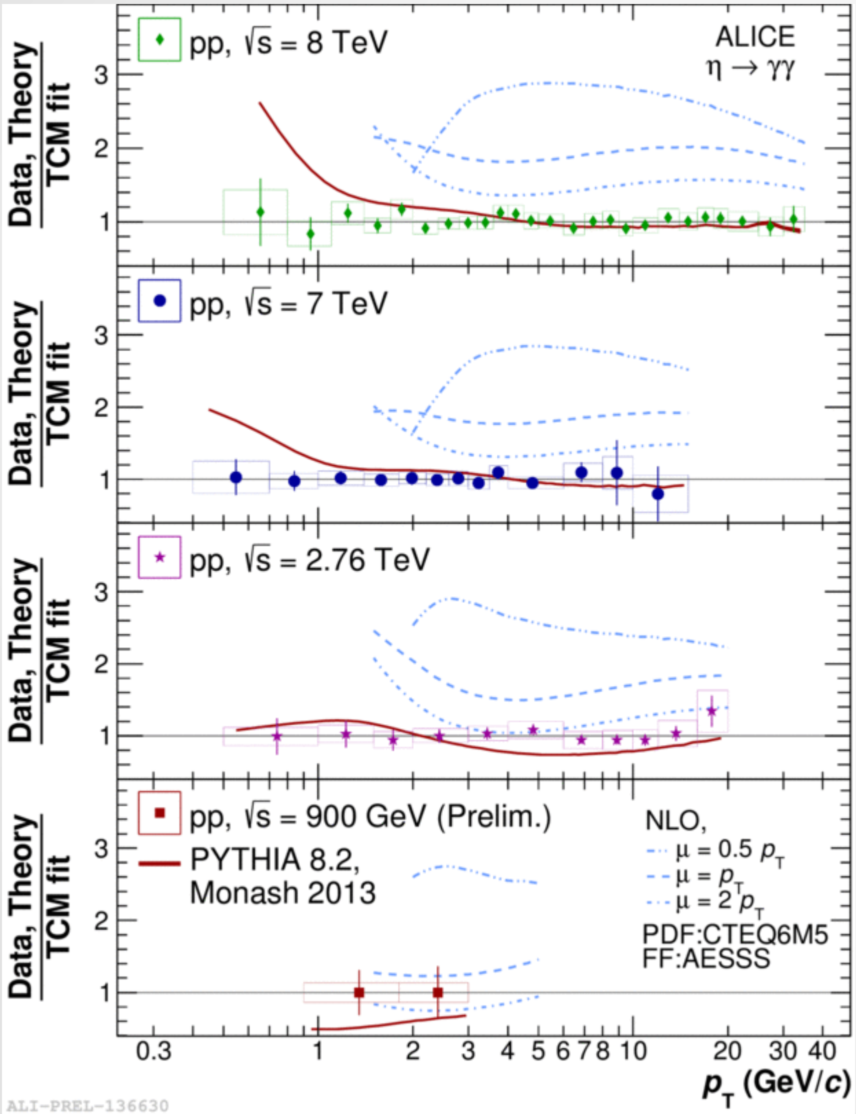


S.Acharya et al., Eur. Phys. J. C 77 (2017) 339

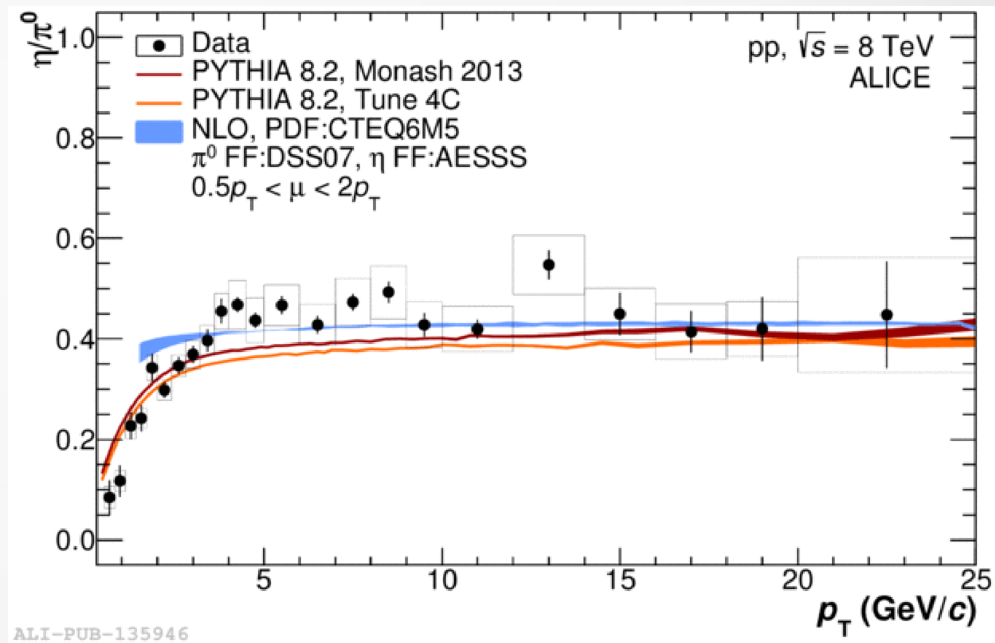


η/π^0 ratio

S.Acharya et al., arXiv:1708.08745



Some systematic uncertainties cancel in η/π^0 ratio both in data and in theoretical calculations.

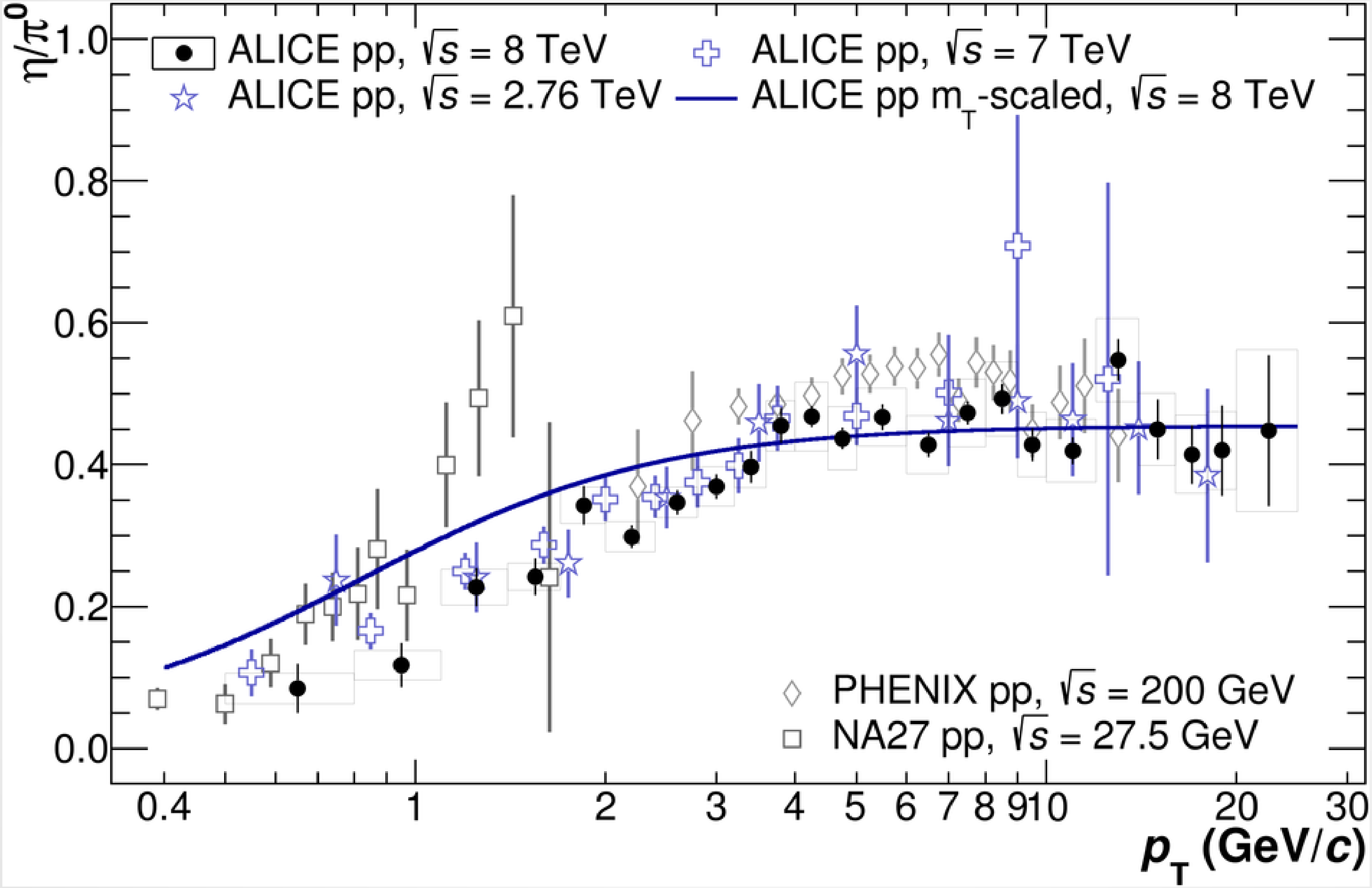


Pythia 8.2 with two tunes reproduces data within 1-2 sigma

NLO pQCD calculations reproduce the ratio well although do not reproduce spectra separately.

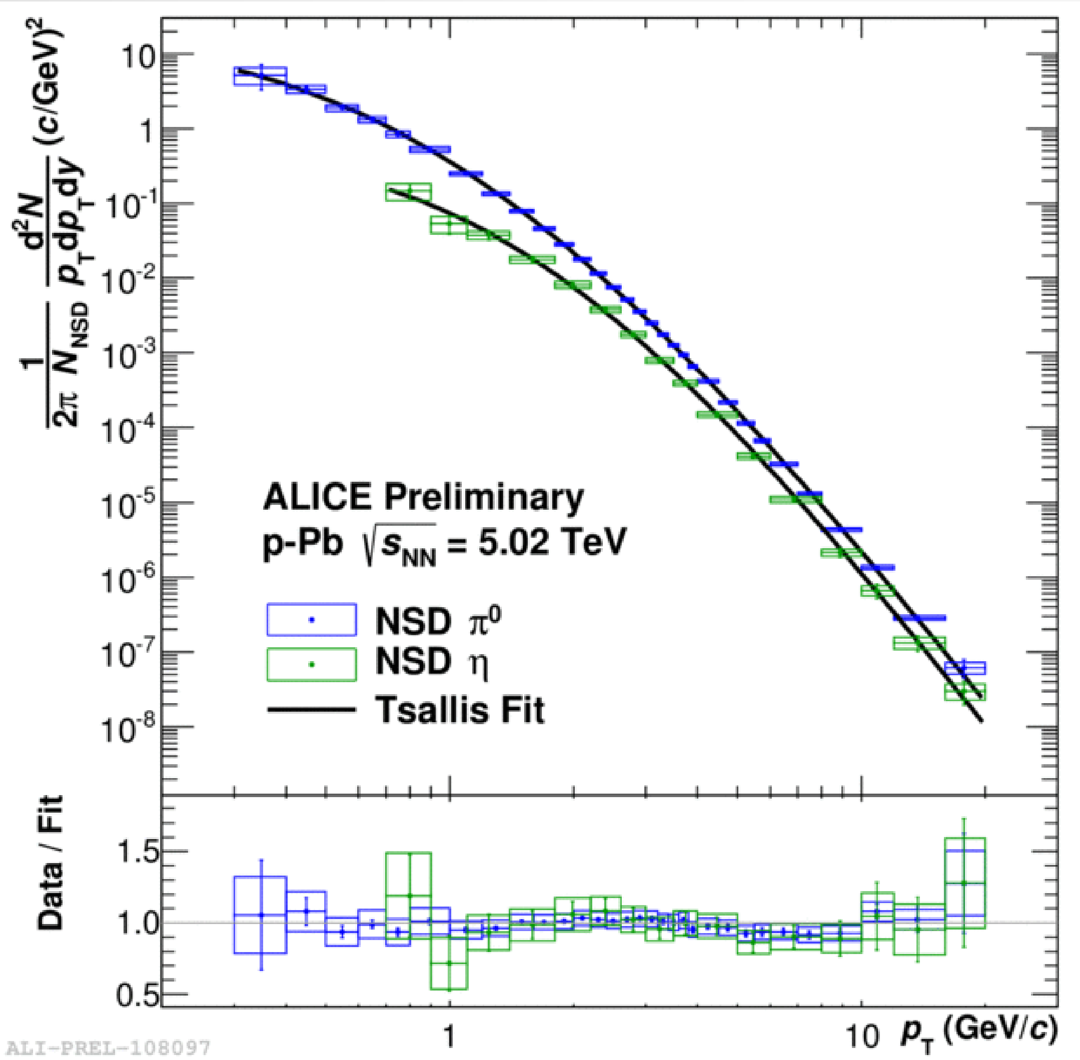
η/π^0 ratio at different energies

S.Acharya et al., arXiv:1708.08745

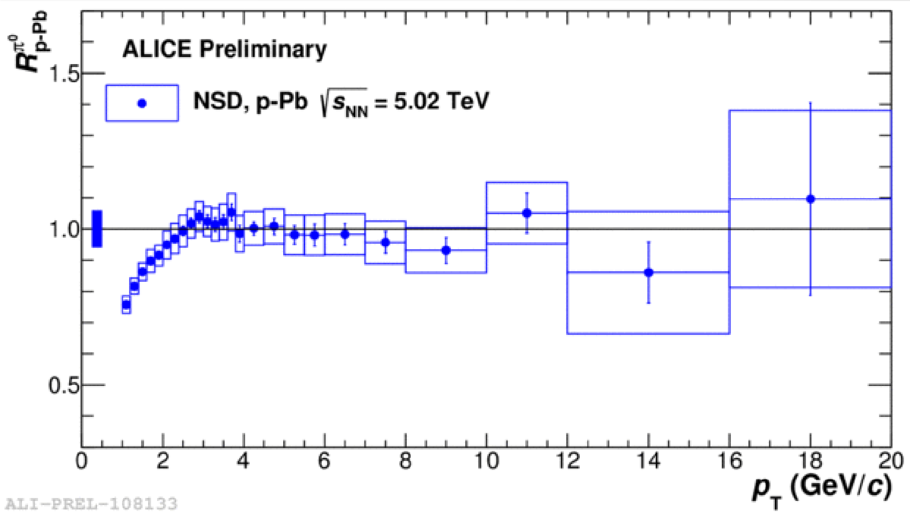


η/π^0 ratios measured by ALICE at different energies agree with each other and with ratios measured at lower energies.
=> There is some universality in meson production?

Neutral pion production in p-Pb

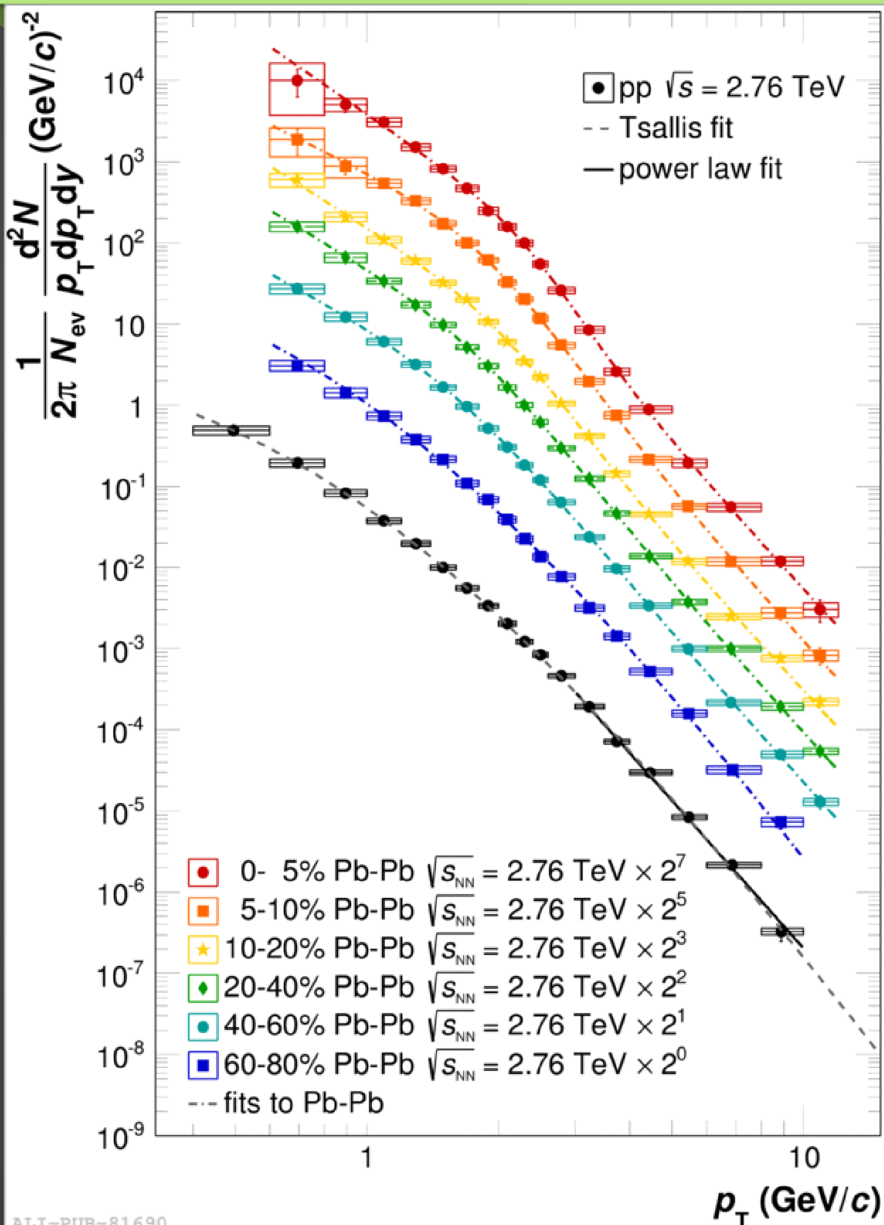


$$R_{AA}(p_T) = \frac{(1/N_{evt}^{AA})\, d^2N_{ch}^{AA}/d\eta\, dp_T}{\langle N_{coll}\rangle (1/N_{evt}^{pp})\, d^2N_{ch}^{pp}/d\eta\, dp_T}$$



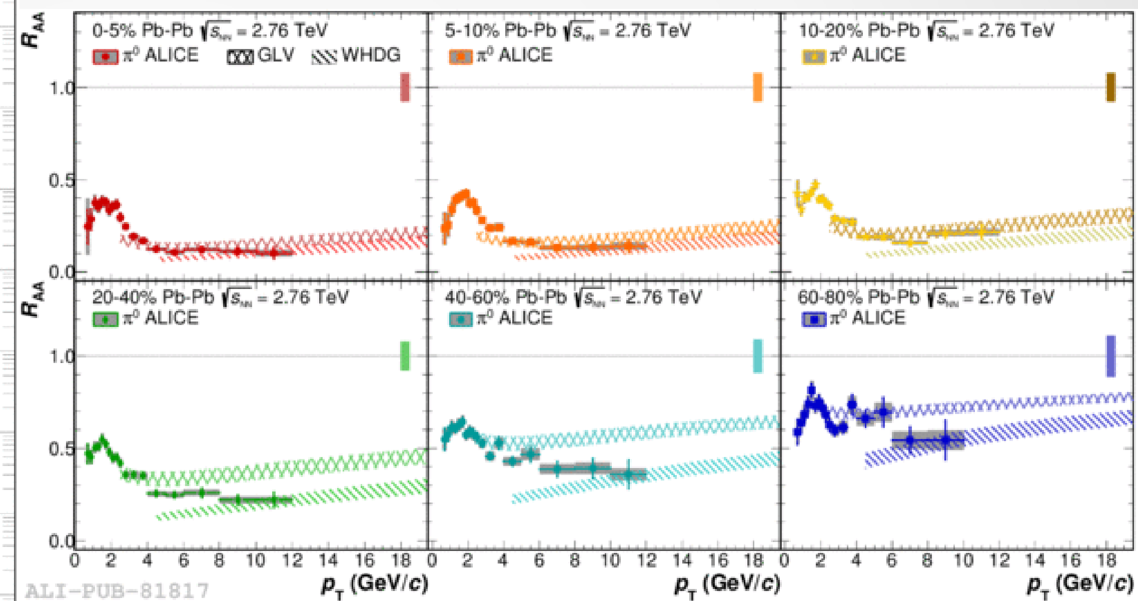
Preliminary data do not show cold nuclear effects in pion $R_{p\text{-}Pb}$

Neutral pions in Pb-Pb



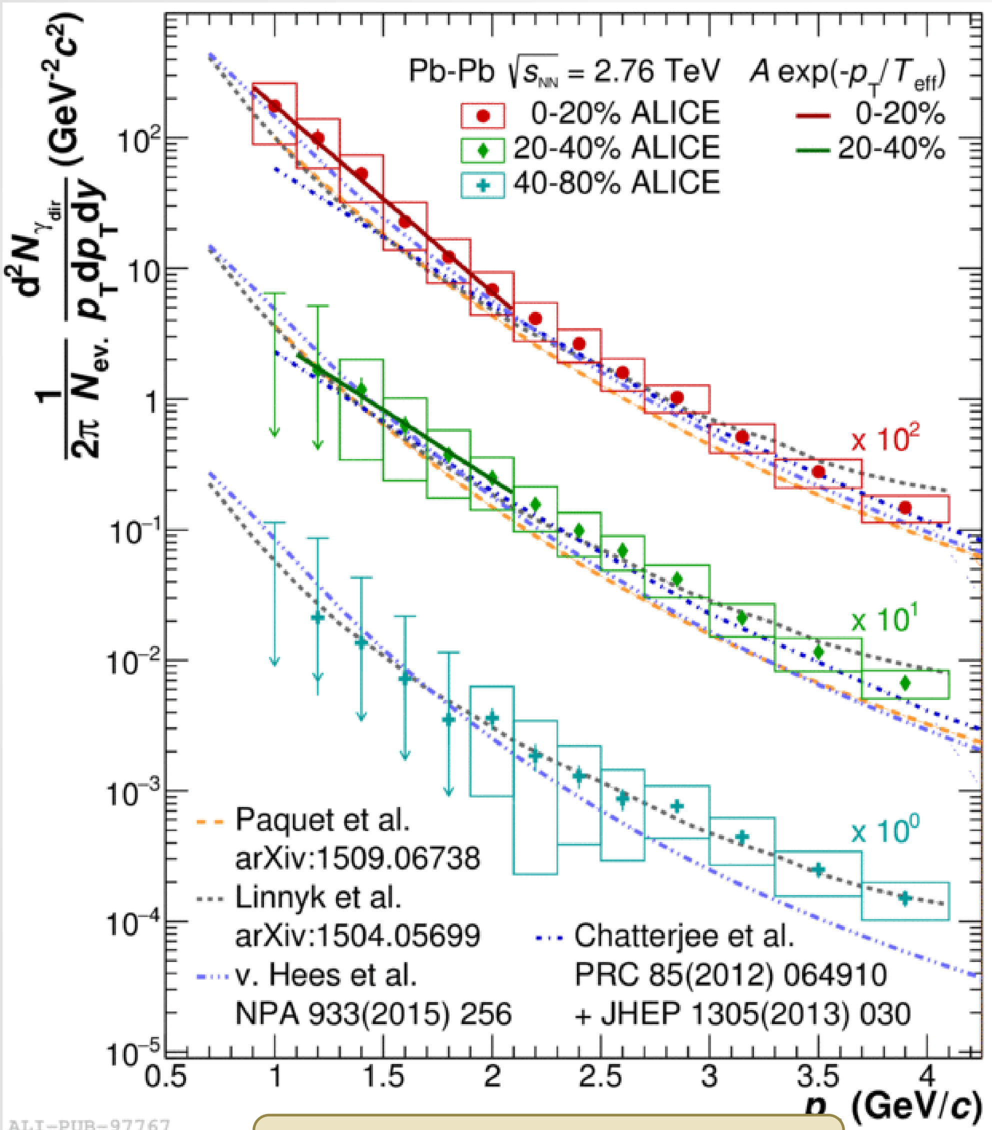
B.Abelev et al., Eur.Phys.J. C74 (2014), 3108

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

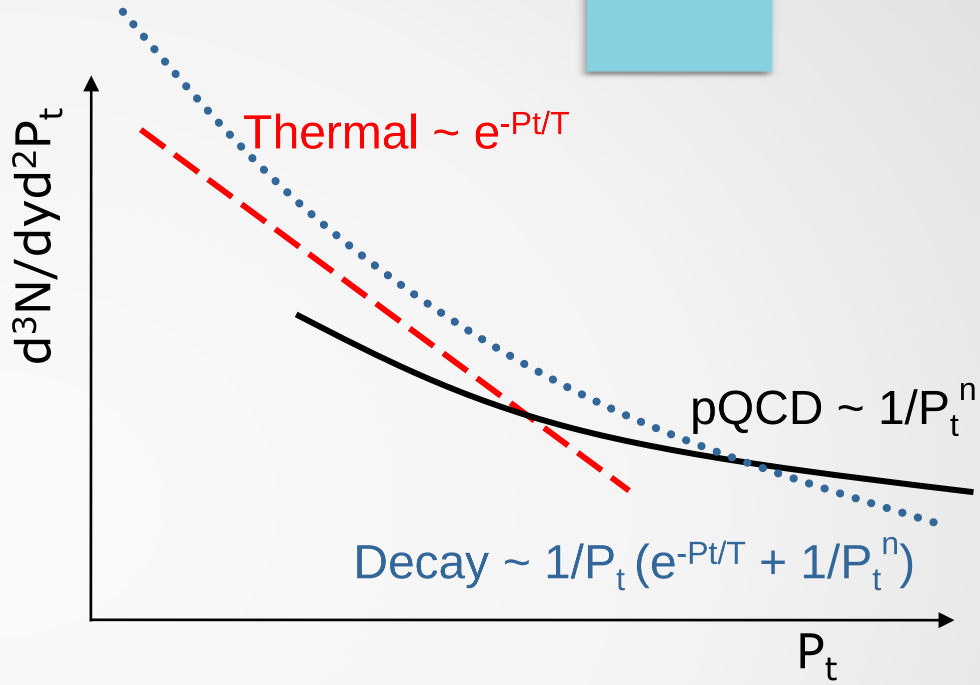


Neutral pions show suppression at large p_T, which corresponds to the energy loss by leading hard parton.
Not all models are able to reproduce centrality and p_T dependence of the suppression.

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.

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.
- ALICE has measured neutral meson spectra in pp collisions at $\sqrt{s}$=0.9, 2.76, 7 and 8 TeV with excellent accuracy and in wide range $0.3<p_T<40$ GeV/c.
- Strong suppression of the neutral pion yield at high p_T but no suppression in the direct photon yield was observed in Pb-Pb collisions at $\sqrt{s_{NN}}$=2.76 TeV.
- ALICE has collected a large amount of high quality data in Run2, so one can expect many new results.

Acknowledgements:

This work is supported by Russian Science Foundation grant 17-72-20234