

Forward Physics at the LHC with ALICE

T. Peitzmann (Utrecht University/Nikhef)
for the ALICE collaboration



ALICE

low-x meeting, Kyoto, June 17-21, 2014

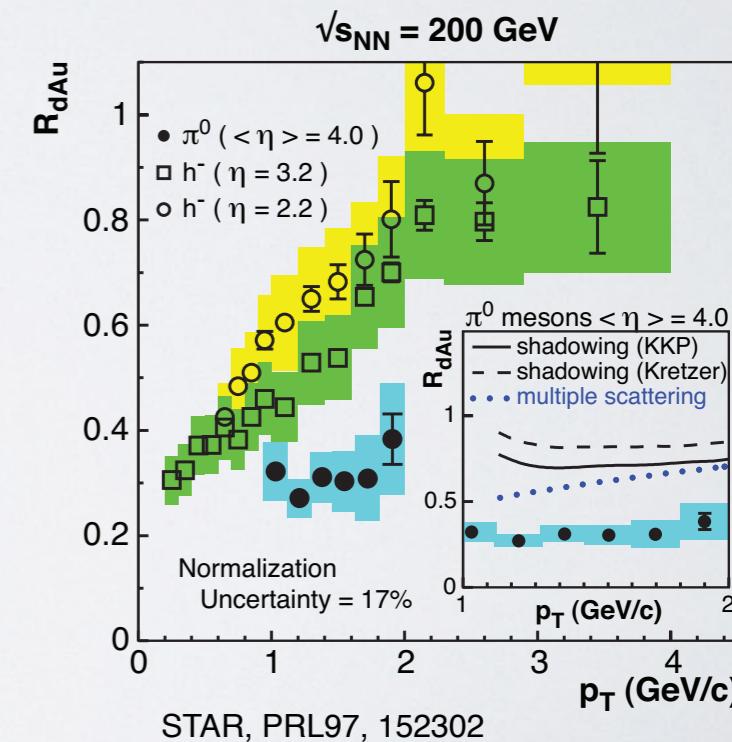
Outline

- Introduction
- Results from forward measurements in ALICE
 - p–Pb, pp
- Photons as probe of saturation
- FoCal upgrade proposal
 - Detector design
 - Performance simulations
- Conclusions

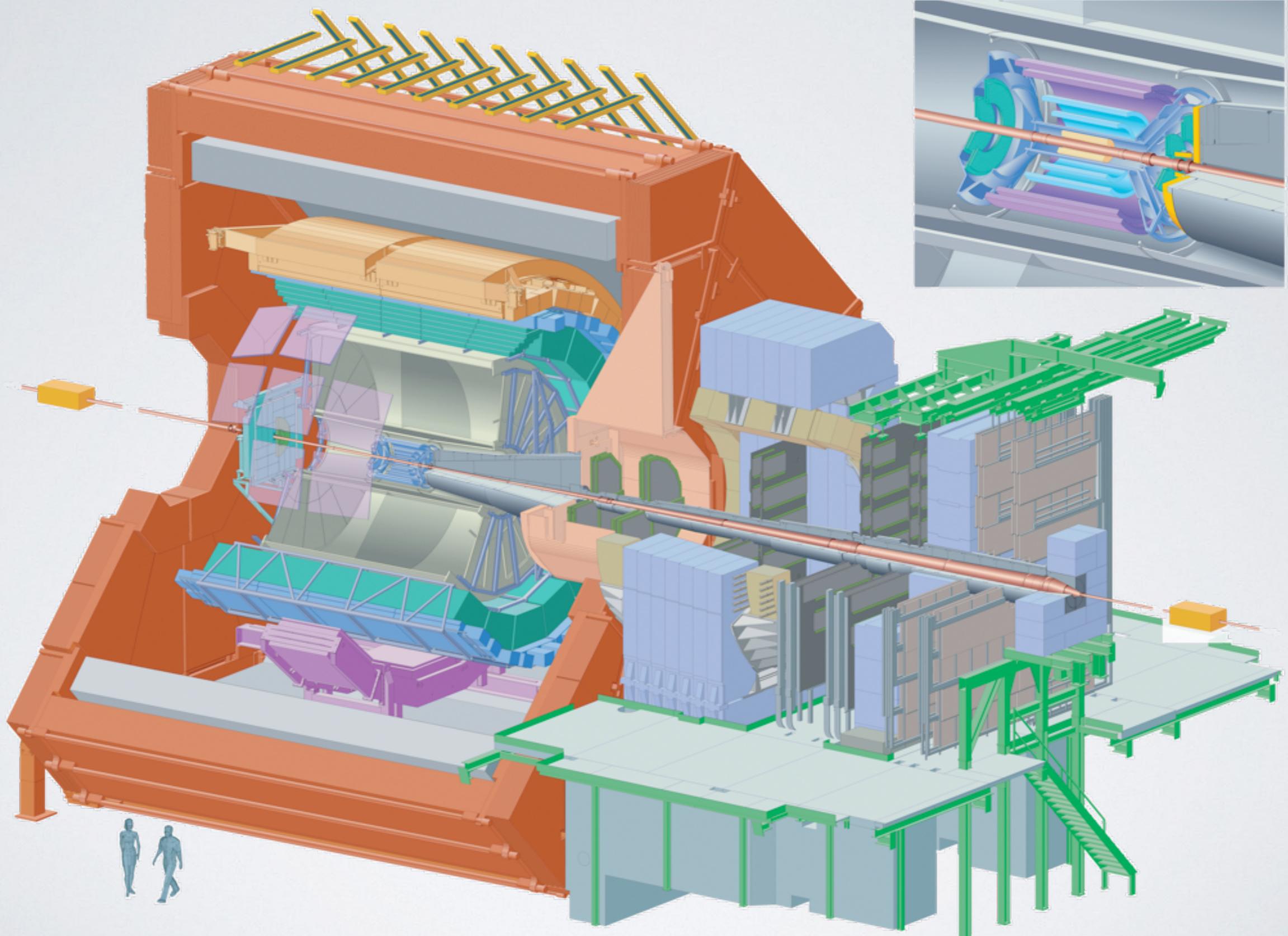
Evidence for Gluon Saturation?

- indirect hints of gluon saturation in a number of observables
 - e.g. geometric scaling, particle multiplicity in A–A collisions, “ridge” phenomena, ...
- more direct evidence for reduced gluon density:
 - suppression of particle yields in d–A/p–A vs pp at forward rapidity and intermediate p_T
 - hadron suppression observed at RHIC
 - difficult to interpret:
very low p_T , close to kinematic limit,
final state modifications?
 - still inconclusive, no proof of saturation yet
 - results at LHC?

$$x_2 \approx \frac{2p_T}{\sqrt{s}} \exp(-y)$$

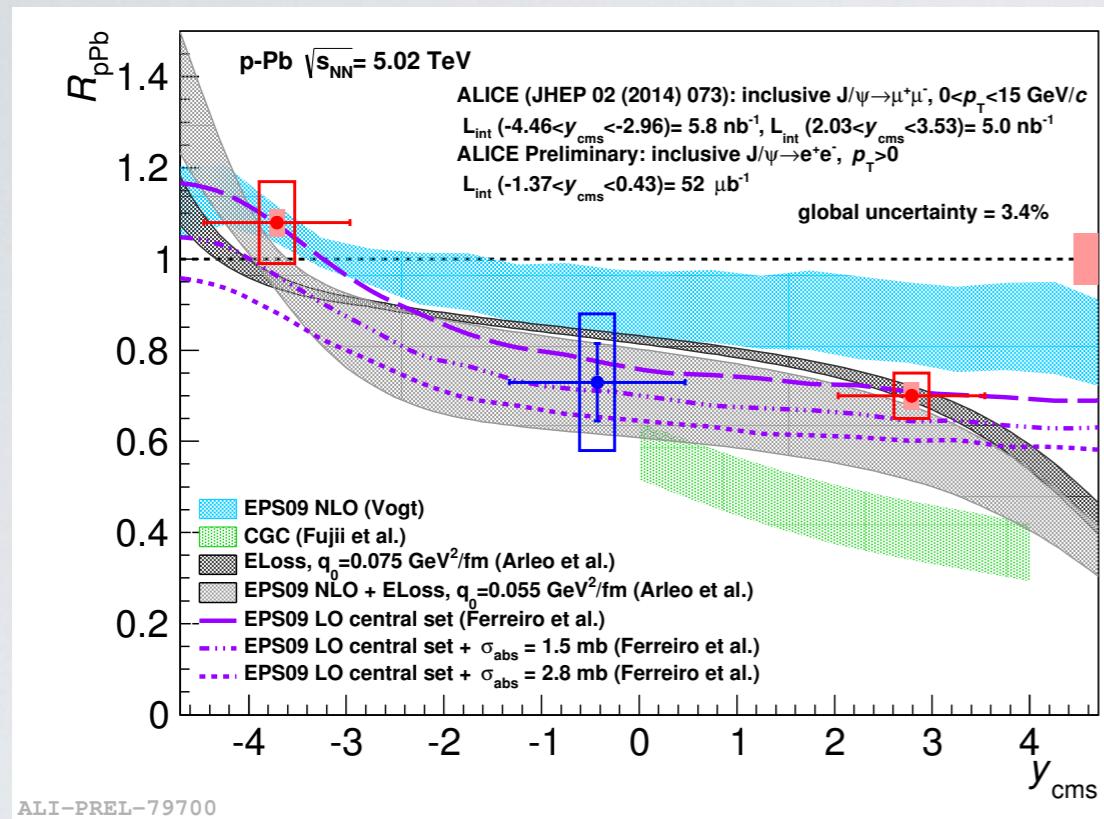


The ALICE Experiment

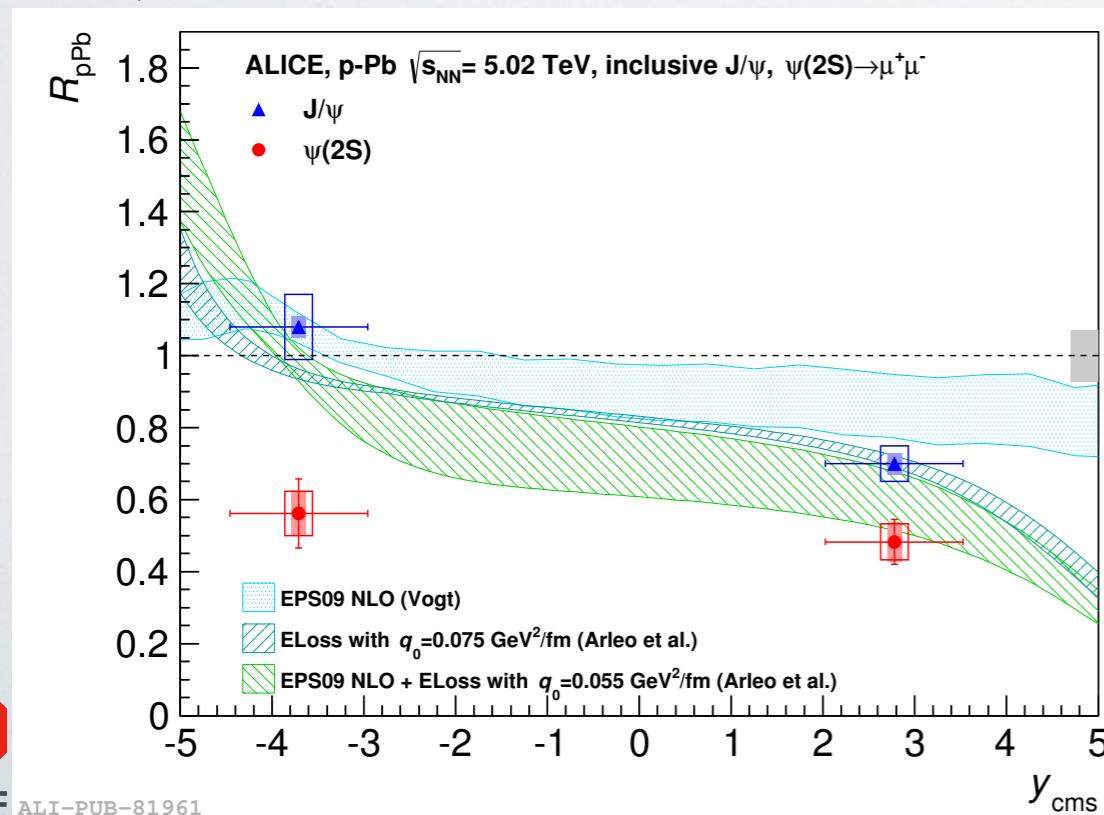


Results from p-Pb at LHC (1)

ALICE, JHEP02 (2014) 073

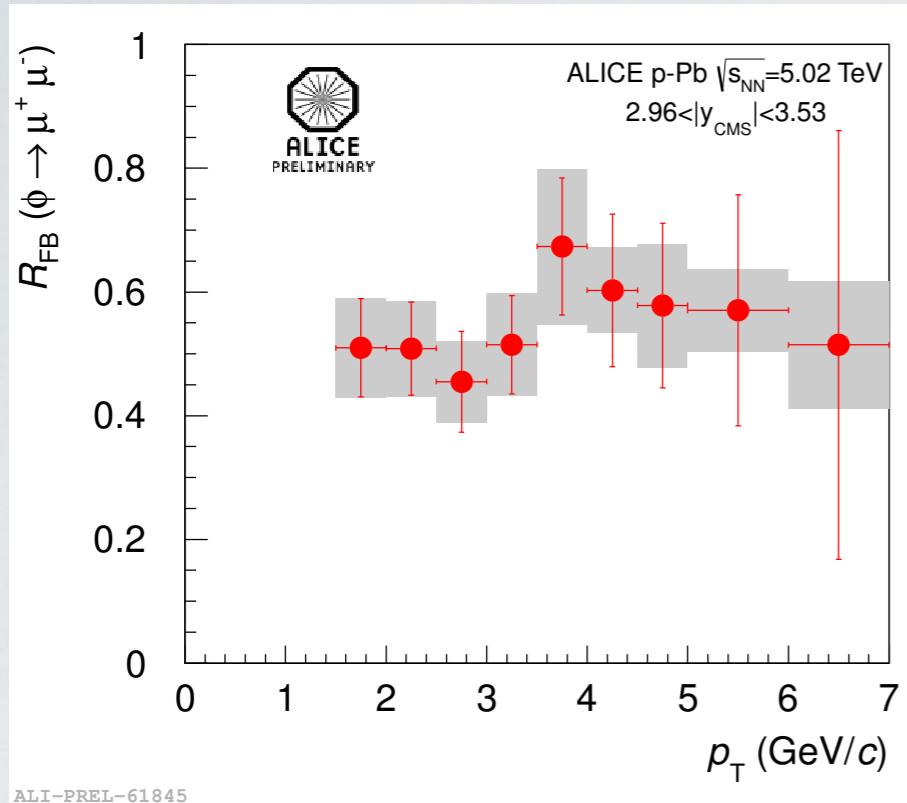


ALICE, arXiv:1405.3796



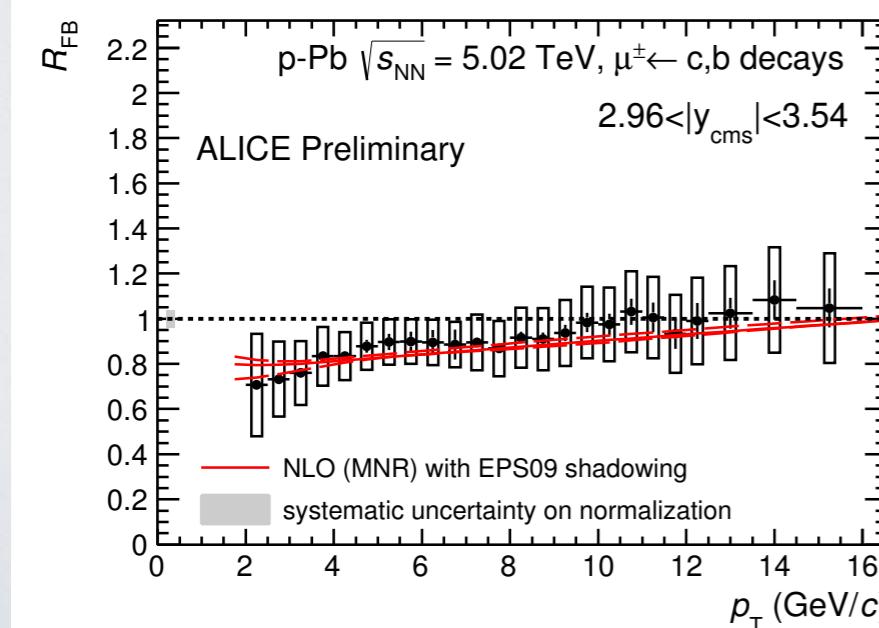
- nuclear modification factor $R_{p\text{Pb}}$ for charmonium measured in dimuons (large y) and dielectrons (midrapidity)
- J/ψ suppressed at forward rapidity
 - consistent with shadowing
 - not described by one CGC calculation (state of the art?)
- $\psi(2S)$ from dimuons more strongly suppressed independent of rapidity
 - final state modification?
 - consequences for interpretation of J/ψ measurement?

Results from p-Pb at LHC (2)



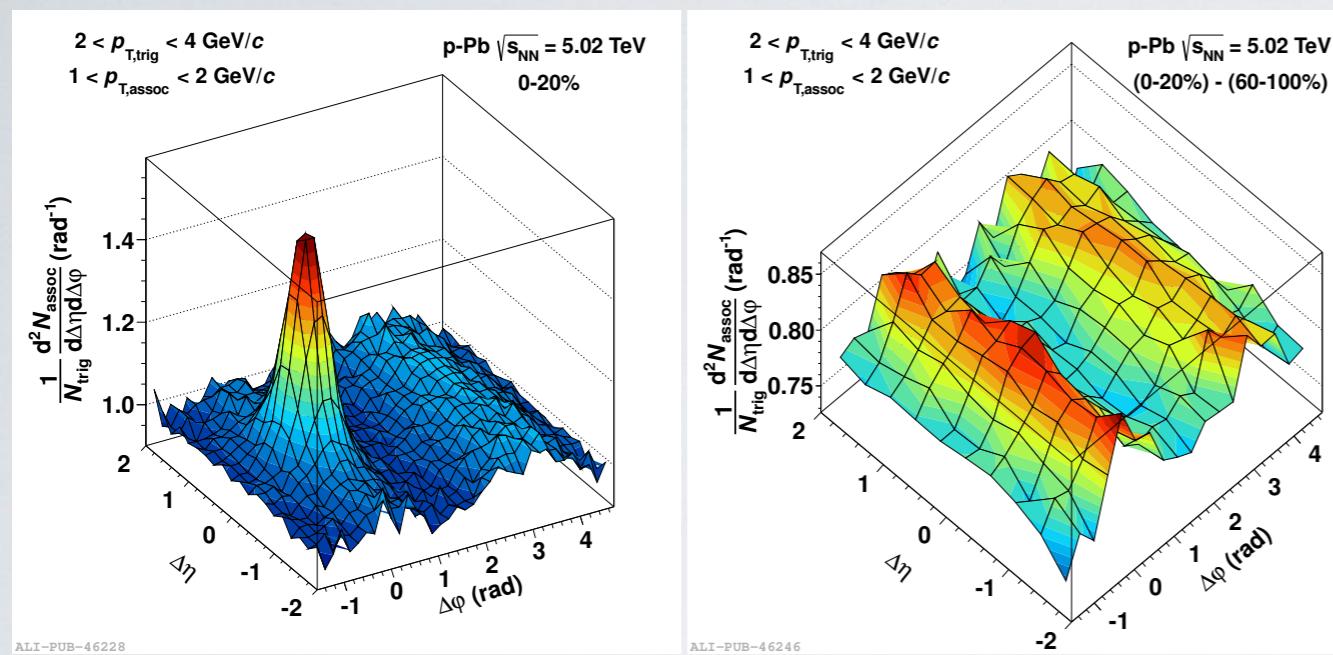
- forward/backward ratio R_{FB}
$$R_{FB} = \frac{dN/dp_T(p - \text{going})}{dN/dp_T(\text{Pb} - \text{going})}$$
for ϕ -mesons measured in dimuons and heavy-flavor decay muons

- ϕ strongly suppressed at forward rapidity
 - interpretation unclear
- heavy-flavor decay muons slightly suppressed at low p_T
 - consistent with shadowing
 - initial-state kinematics (x, Q^2) not well defined (HF-decay, c/b contribution)

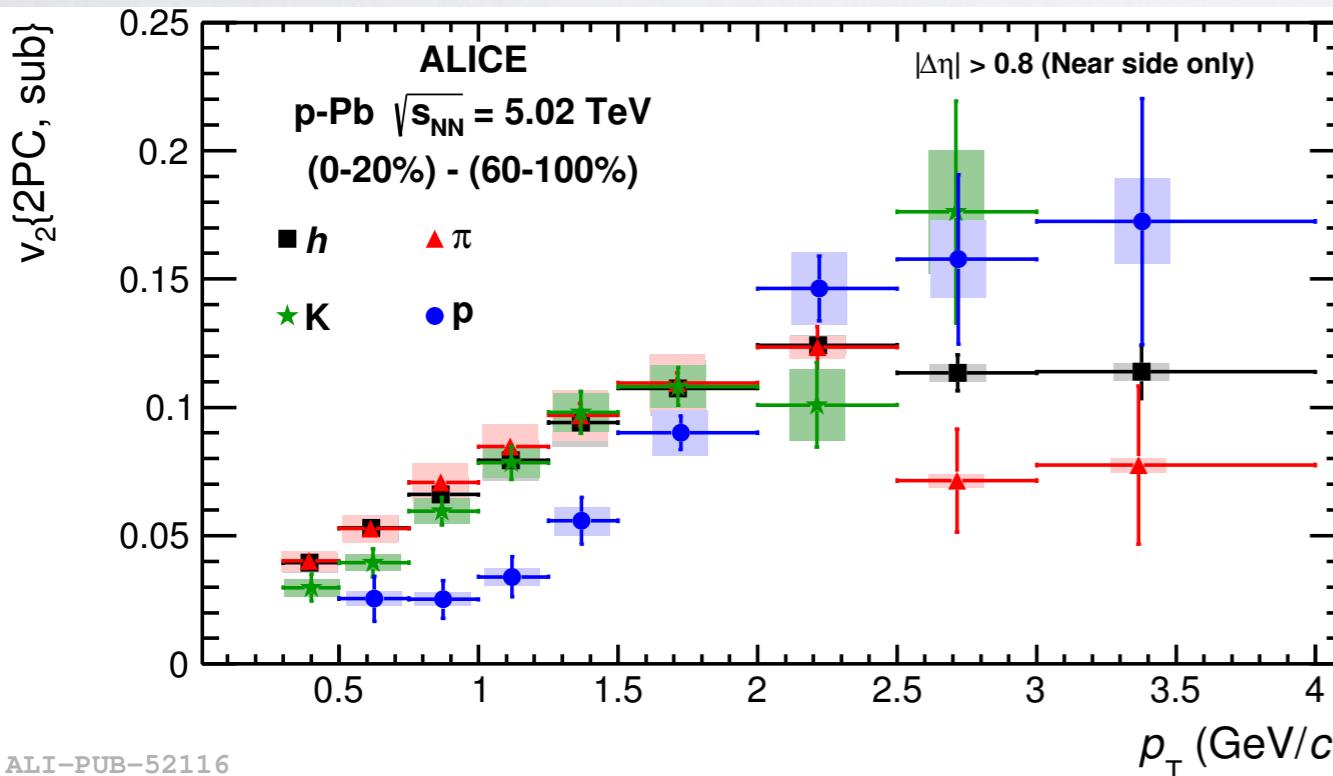


Results from p-Pb at LHC (3)

ALICE, PLB 719 (2013) 29



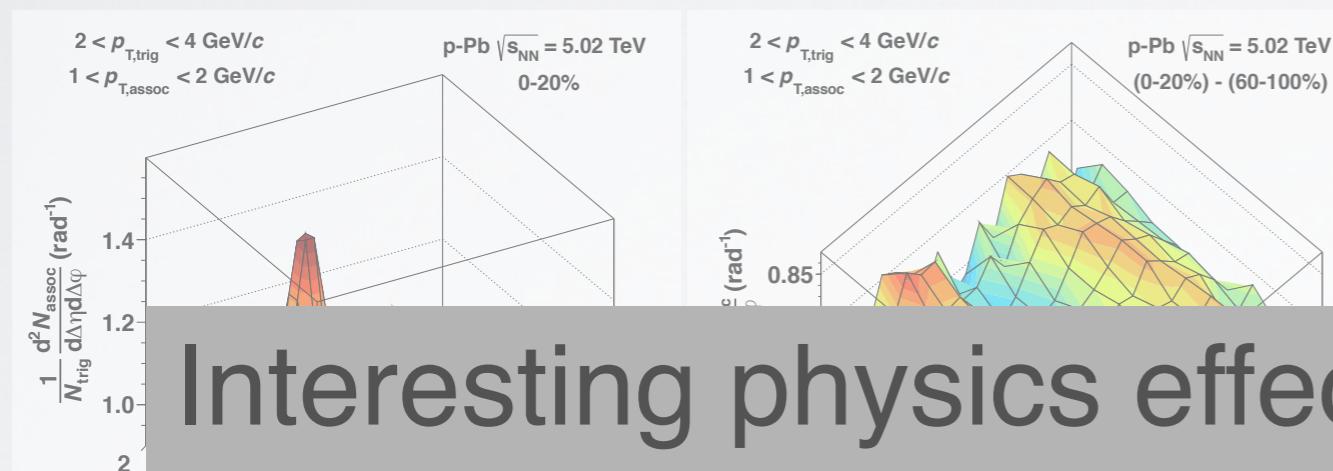
ALICE, PLB 726 (2013) 164



- 2-particle correlation functions reveal long-range correlation in $\Delta\eta$: the double-ridge
 - apparent after subtraction of jet-like correlation
 - origin under discussion
 - e.g. CGC, but also final state effects (flow)
 - can be described in terms of Fourier coefficients (dominantly v_2 and v_3)
 - v_2 of identified hadrons shows effects reminiscent of collective flow

Results from p-Pb at LHC (3)

ALICE, PLB 719 (2013) 29

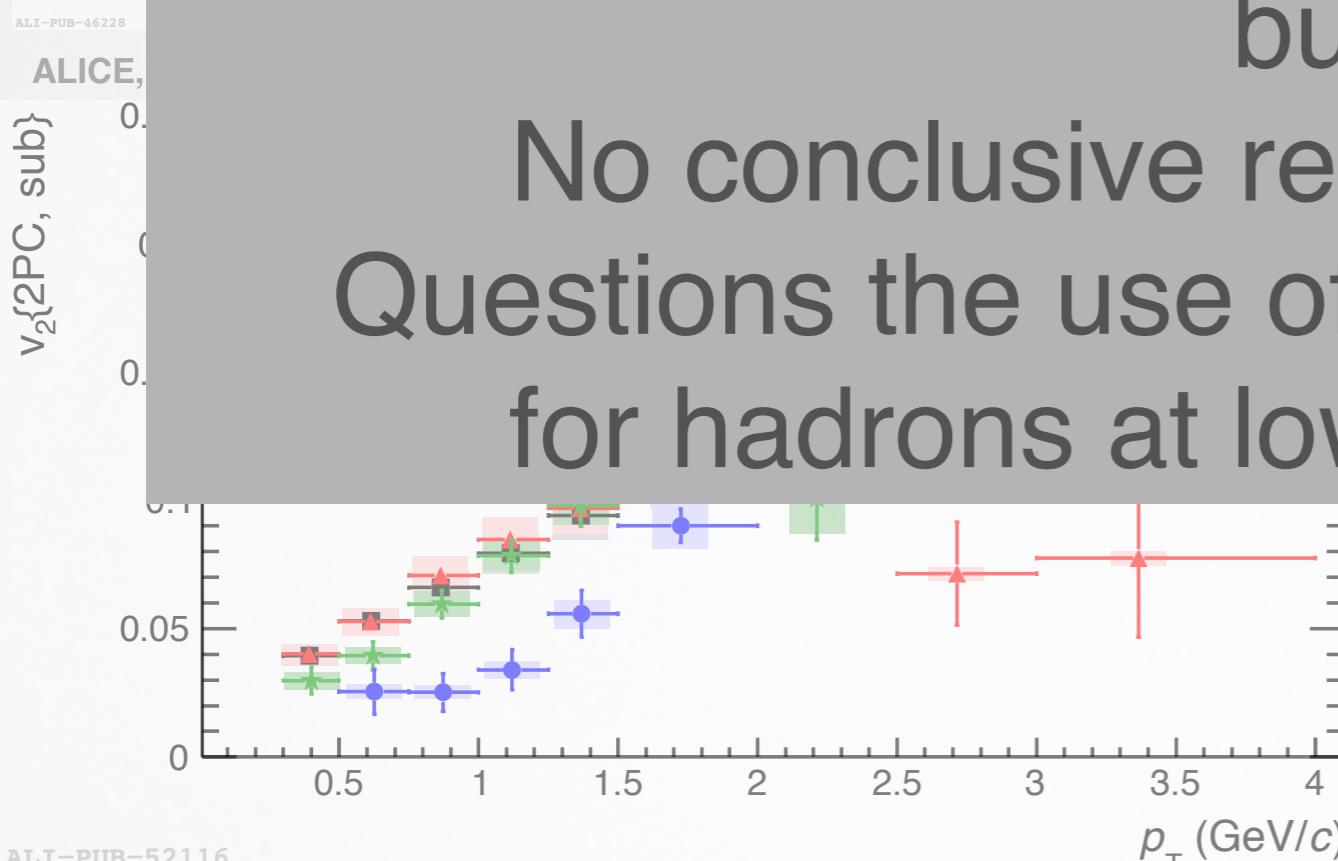


- 2-particle correlation functions reveal long-range correlation in $\Delta\eta$: the double-ridge

Interesting physics effects seen in p–Pb at LHC!

but.

No conclusive results on the CGC.
Questions the use of p–Pb as a reference
for hadrons at low-intermediate p

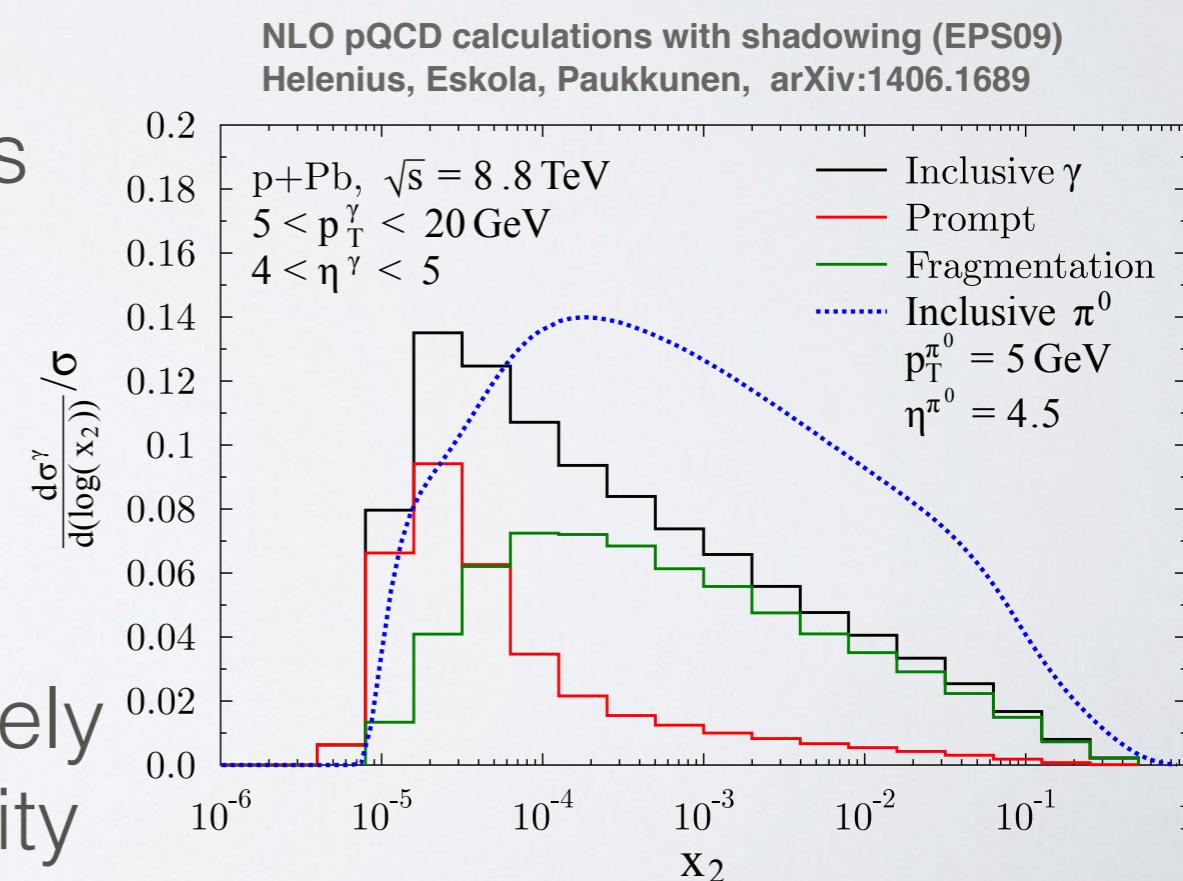


Fourier coefficients (dominantly v_2 and v_3)

- v_2 of identified hadrons shows effects reminiscent of collective flow

Saturation Studies with Hadrons

- interpretation of hadronic observables remains inconclusive
 - final state modifications in p–A collisions?
 - production process not fully understood for many hadrons
 - kinematic relation to Bjorken-x uncertain (e.g. fragmentation)
- cleaner observables: EM probes (direct photons, Drell-Yan)
 - no final state interaction
 - well-understood production process
 - well-defined kinematics
 - advantage of **direct photons**:
large cross section
 - forward p–A measurement of DY likely not possible with expected luminosity



ALICE Detector Upgrades

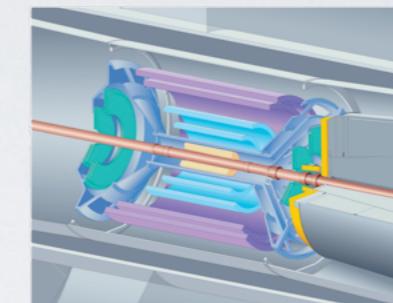
TPC: new GEM readout chambers,
pipelined readout

new ITS: high resolution,
low material budget

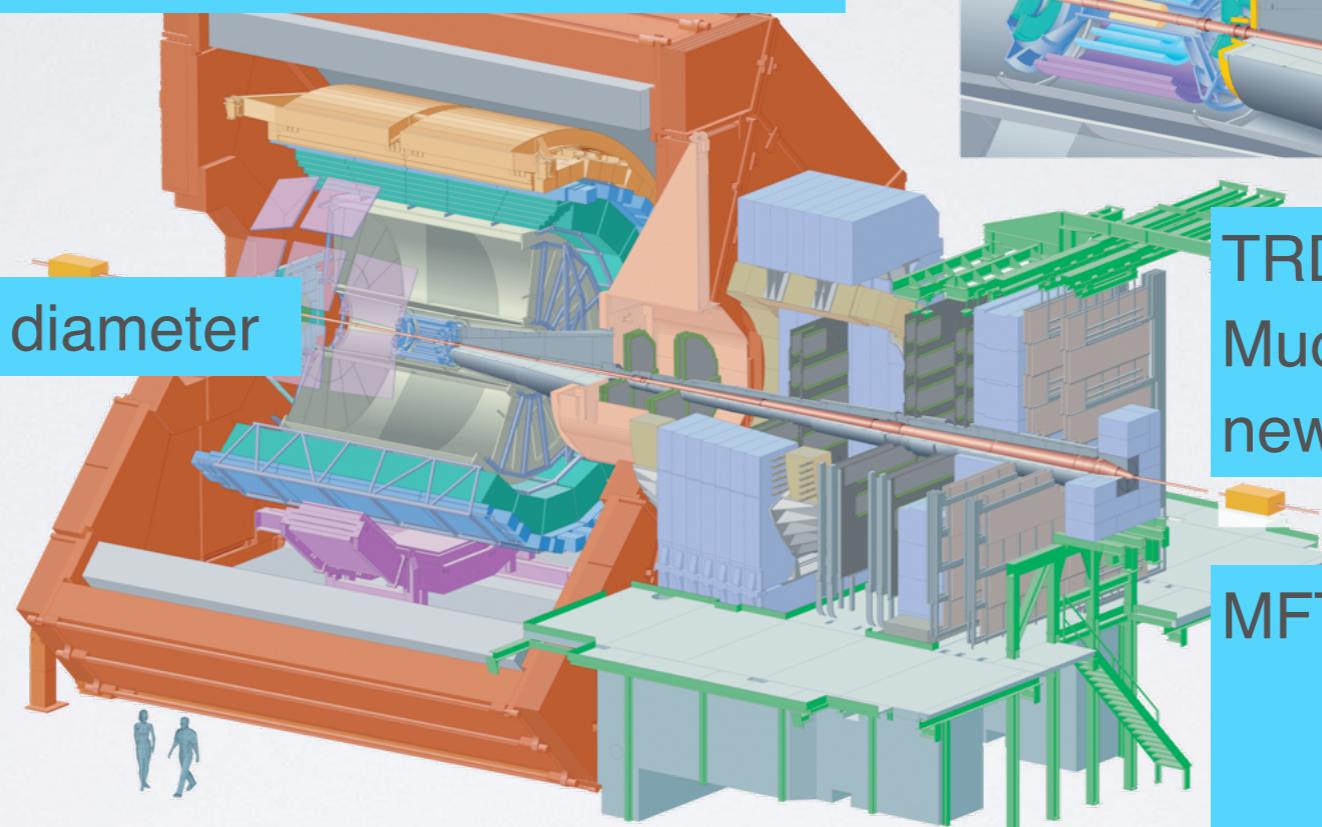
FoCal project

new beam pipe: smaller diameter

Upgrade of forward/
trigger detectors
(ZDC, VZERO, T0)



TRD, TOF, PHOS, EMCal,
Muon spectrometer:
new readout electronics



MFT: tracking in
front of absorber,
secondary vertex
resolution

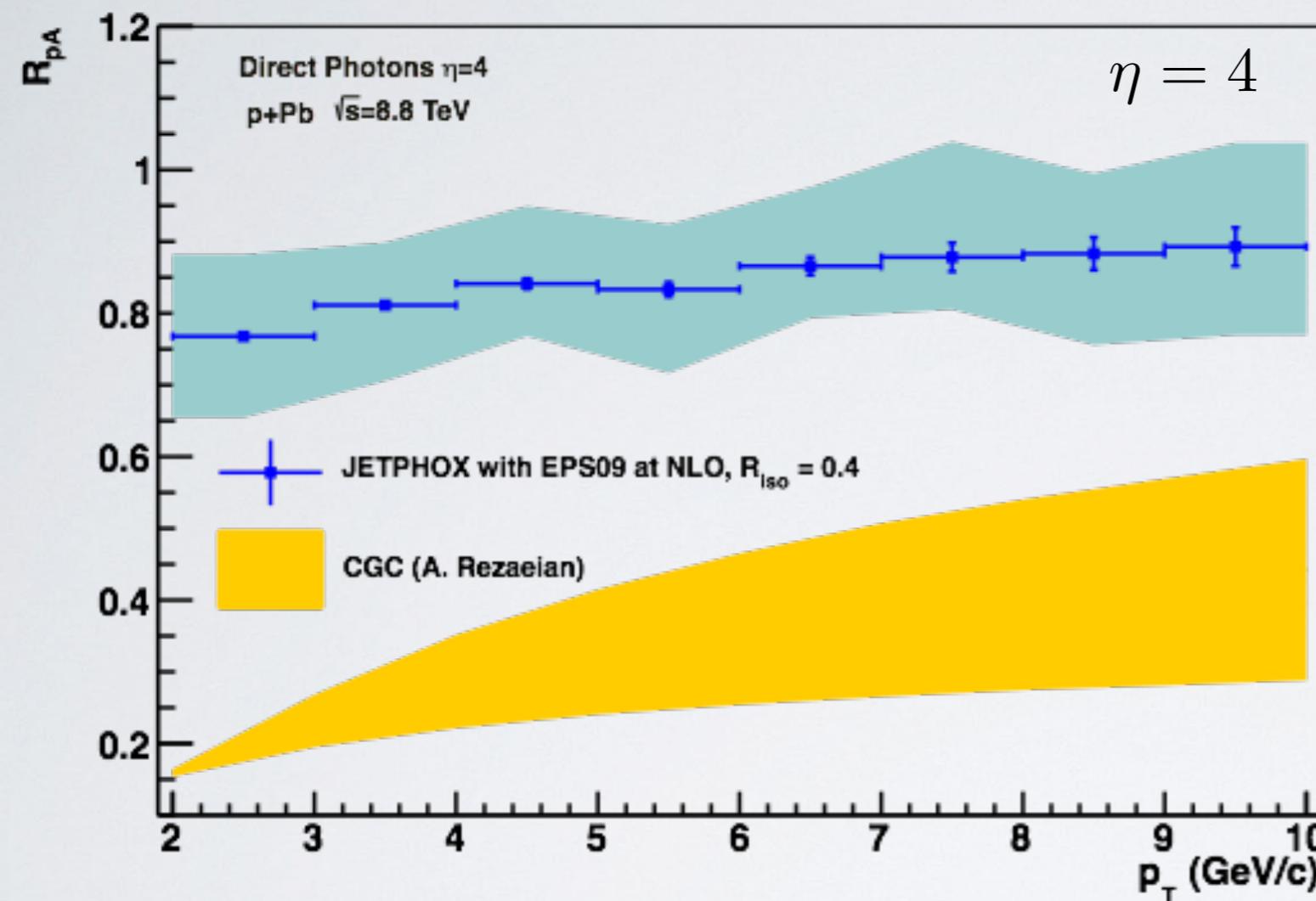
■ LoI endorsed by LHCC,
TDRs in preparation/submitted,
planned for installation in LS2 (2018/19)

■ under internal review

Forward Physics in ALICE

- additional physics potential in ALICE: forward/low-x physics
 - fundamental interest in low-x PDFs/gluon saturation
 - information on initial state yields important constraints for interpretation of QGP studies
 - e.g. knowledge of eccentricity for elliptic flow
 - forward detector enhances general physics scope
 - em calorimeter (FoCal): significant increase of coverage for photons, jets compared to existing calorimeters (PHOS, EMCAL)
- FoCal: new upgrade project under discussion
 - main objective: measurement of large rapidity direct photons
 - possible installation in LS3 (≈ 2024)

Benchmark Measurement: nPDF/DGLAP vs CGC

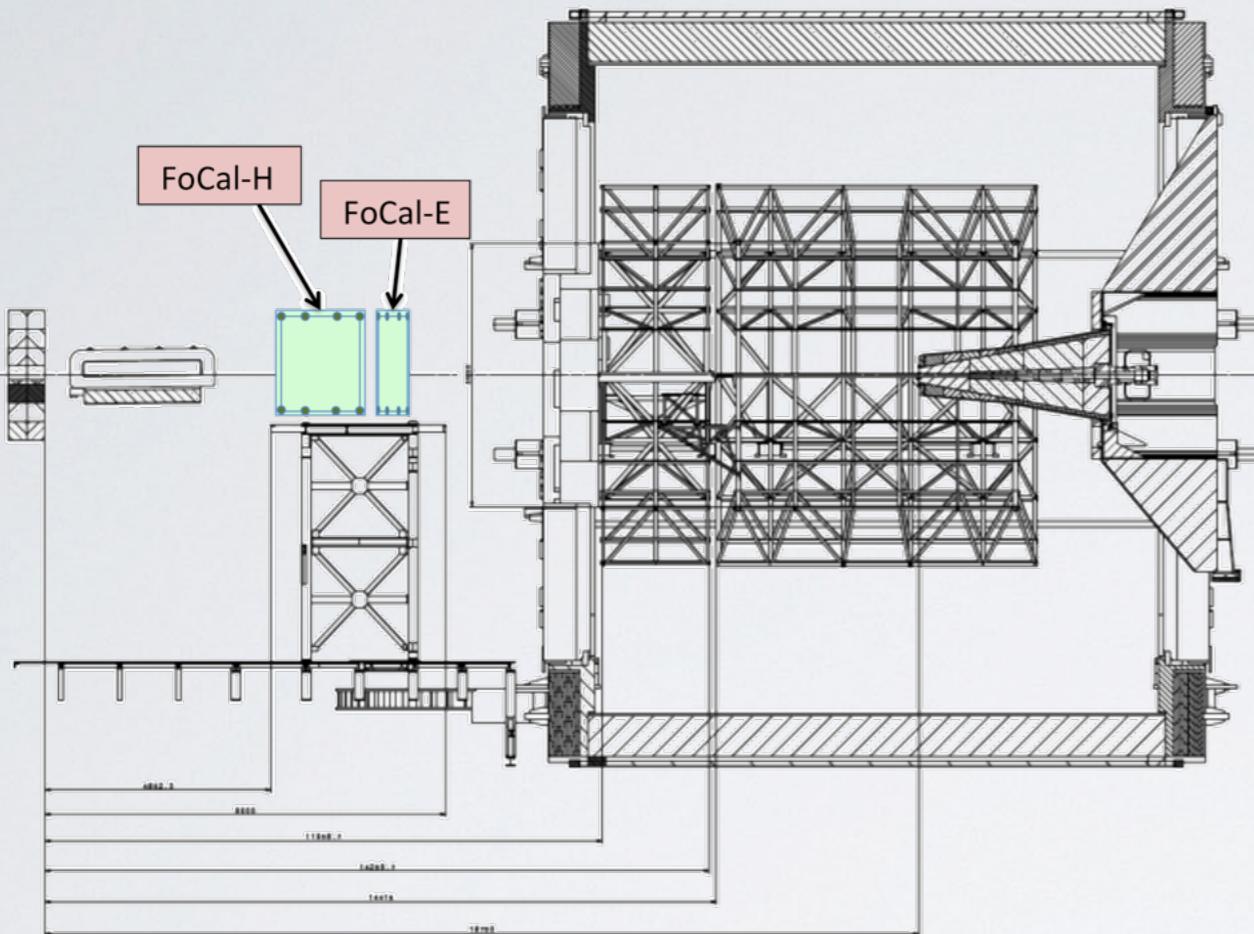


two scenarios for forward γ production in p-A at LHC:

- normal nuclear effects
linear evolution, shadowing
- saturation/CGC
running coupling BK evolution

- strong suppression in direct γ R_{pA}
- signals expected at forward η , low-intermediate p_T
- transition expected - where?

FoCal in ALICE

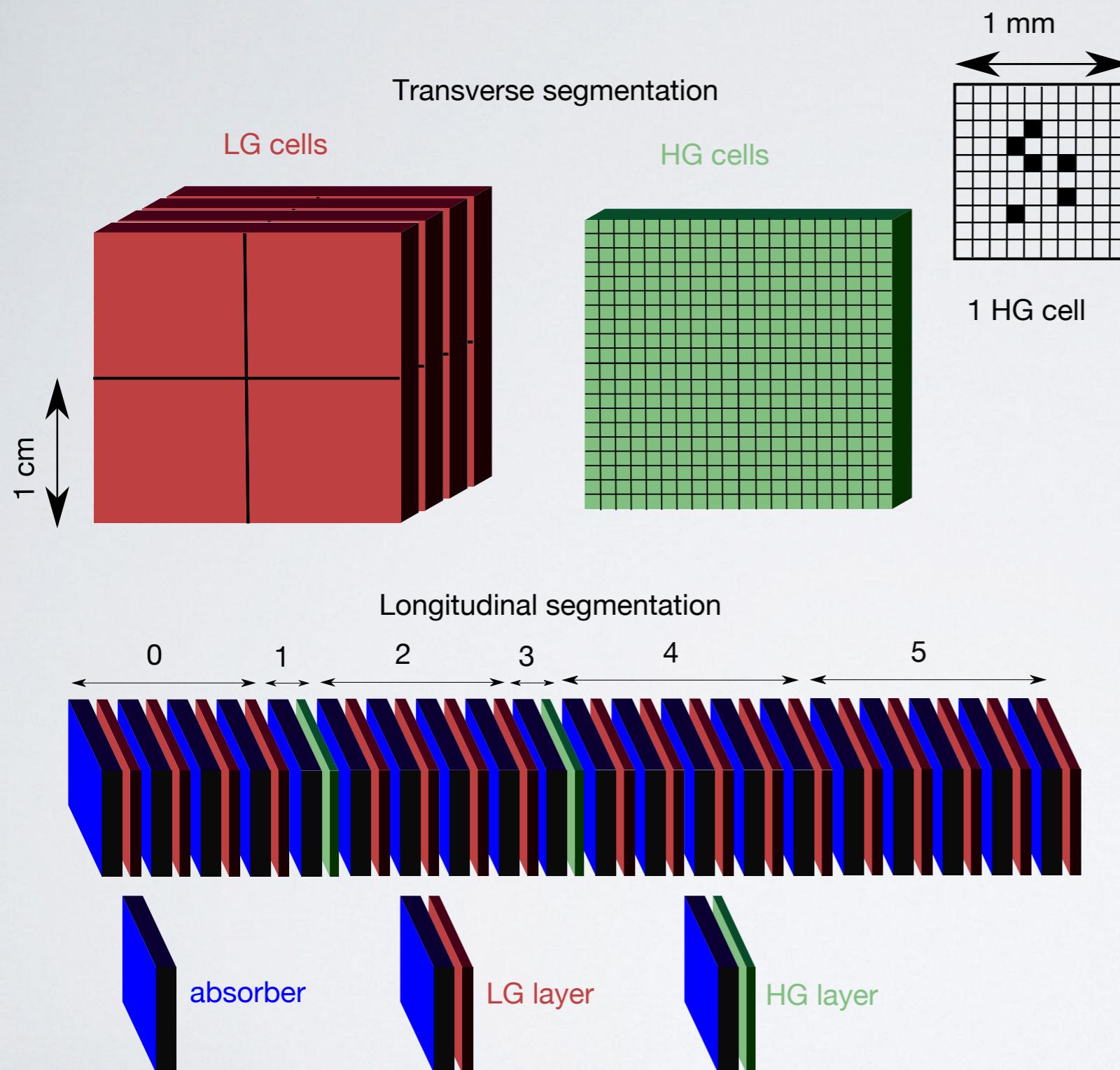


electromagnetic calorimeter for γ
and π^0 measurement
+ hadronic calorimeter for
isolation and jet measurement

baseline scenario:
at $z \approx 7\text{m}$ (outside magnet)
 $3.3 < \eta < 5.3$

- main challenge: separate γ/π^0 at high energy
- need small Molière radius, high-granularity read-out
 - Si-W calorimeter, granularity $\approx 1\text{mm}^2$

FoCal Strawman Design



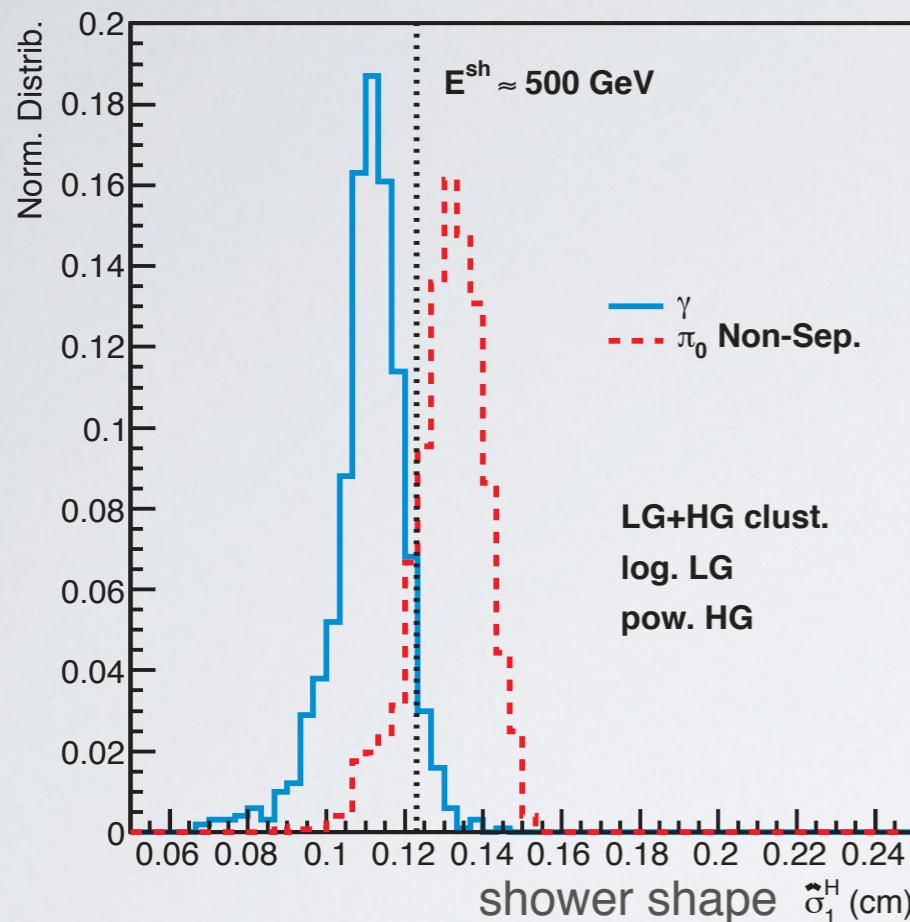
studied in performance simulations:

- 24 layers:
W ($3.5\text{mm} \approx 1 X_0$) +
Si-sensors (2 types)
 - low granularity ($\approx 1 \text{cm}^2$),
Si-pads
 - high granularity ($\approx 1 \text{mm}^2$),
obtained with pixels
(e.g. CMOS-MAPS)

FoCal Physics Program

- p-Pb: saturation/CGC effects
 - forward direct γ spectra, γ -hadron/jet correlations (unique!)
 - π^0 spectra, π^0 - π^0 correlations, possibly jets (had. calorimeter!)
- p+p: reference measurements
 - constraints on PDFs?
- Pb-Pb: QGP studies
 - extend acceptance for γ -hadron/jet, π^0 - π^0 correlations
 - $\pi^0 R_{AA}$ forward
 - longitudinal density profile, compare to forward J/ ψ
 - event plane determination, ...

π^0 Rejection Efficiency



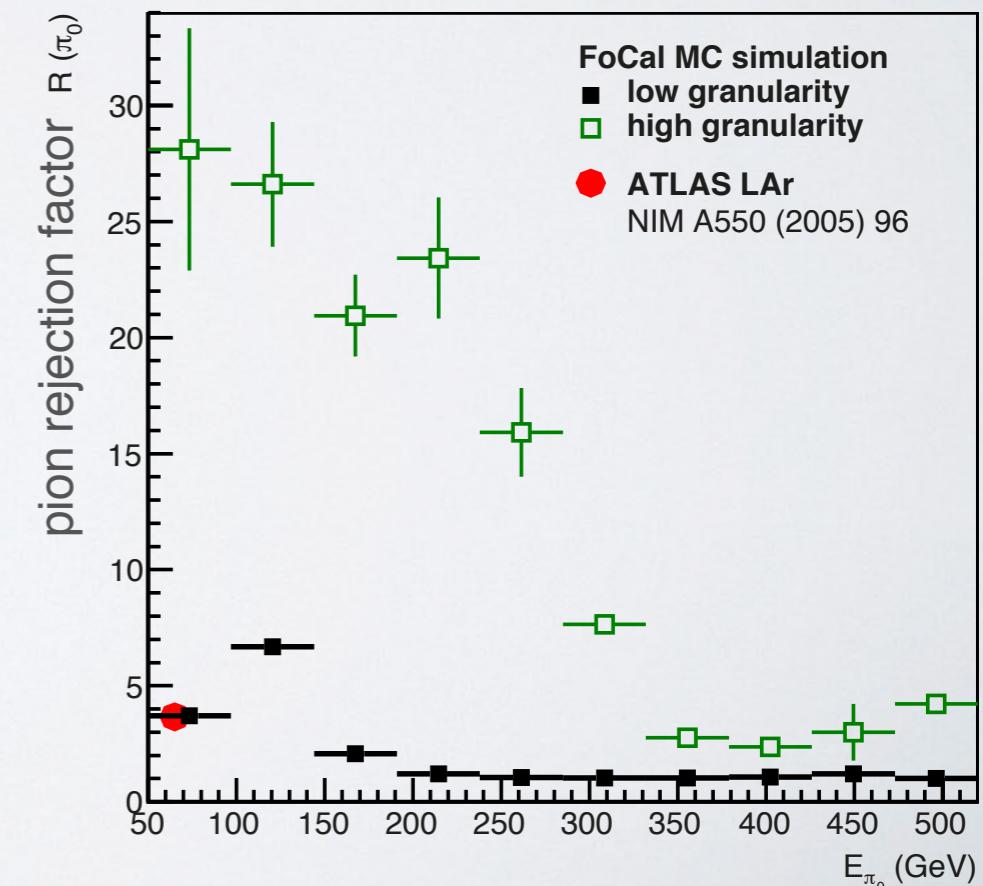
shower reconstruction algorithm under development
(e.g. new shower shape discrimination)

already very promising pion rejection performance achieved

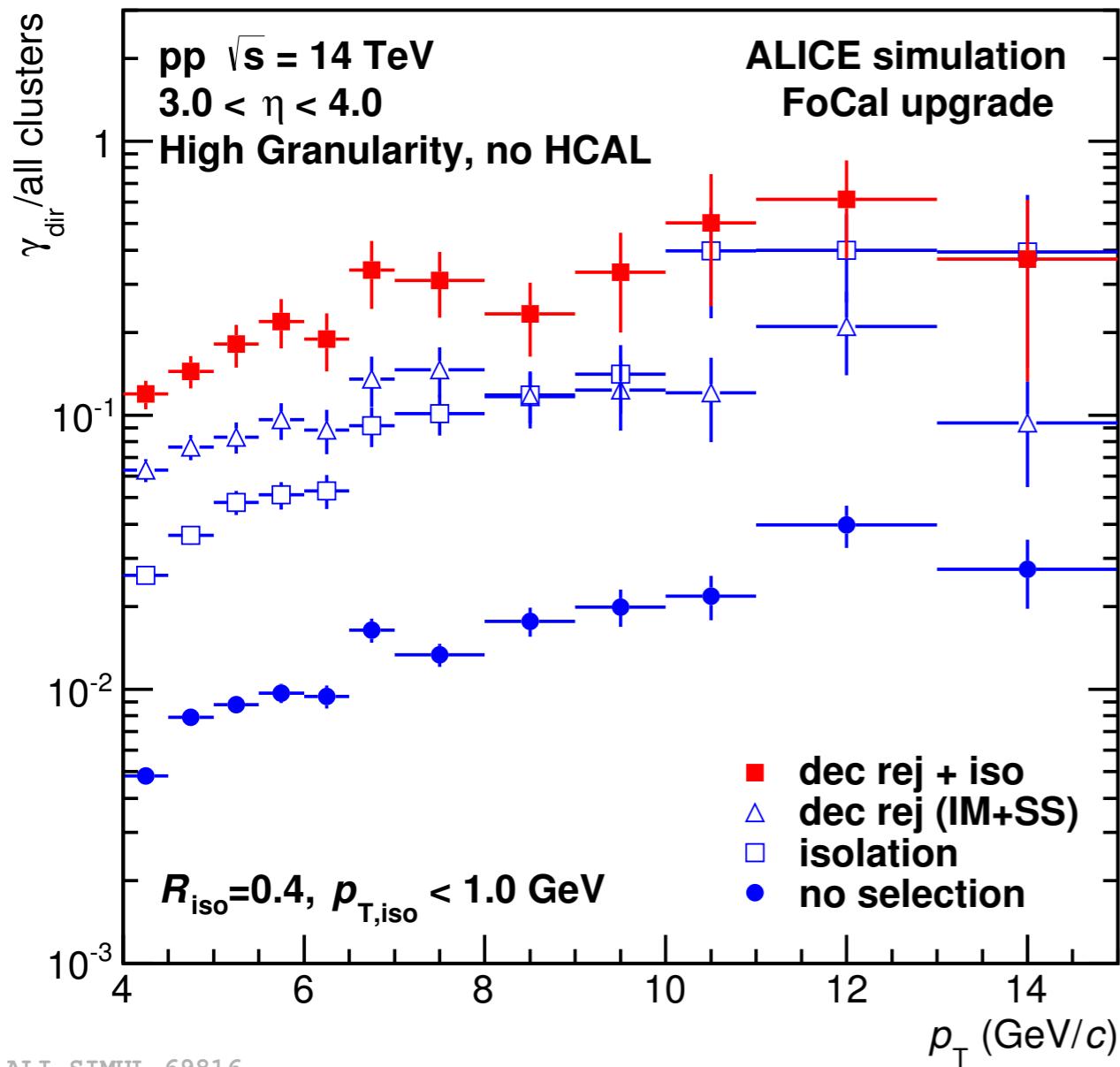
suppression of background for direct photon measurement:

isolation cuts (necessary, but not sufficient)

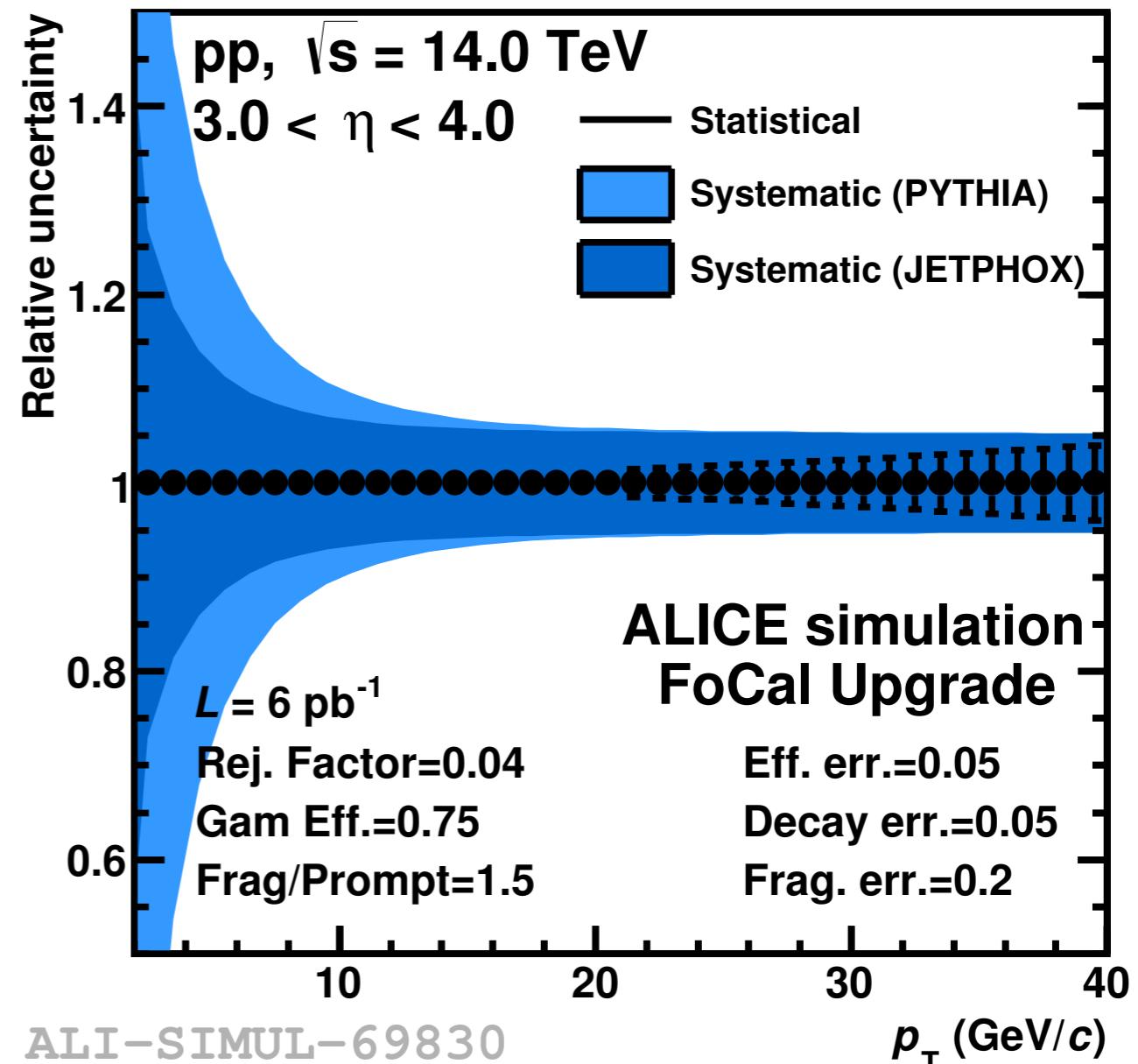
direct decay rejection (possible, but not with existing detectors)
needs extremely high granularity and small Molière radius



Direct γ Performance in pp

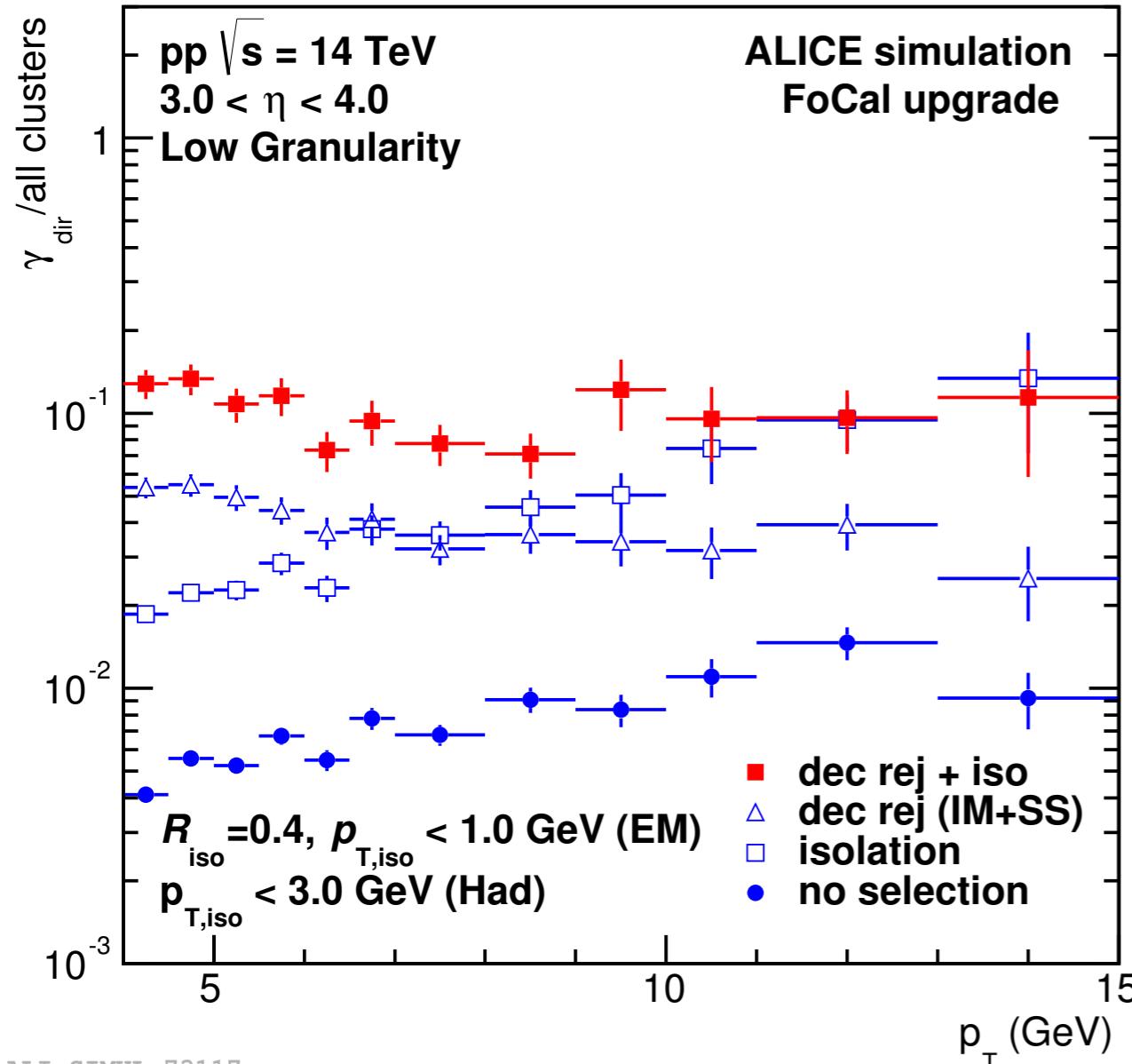


direct photon/all > 0.1
for $p_T > 4$ GeV/c

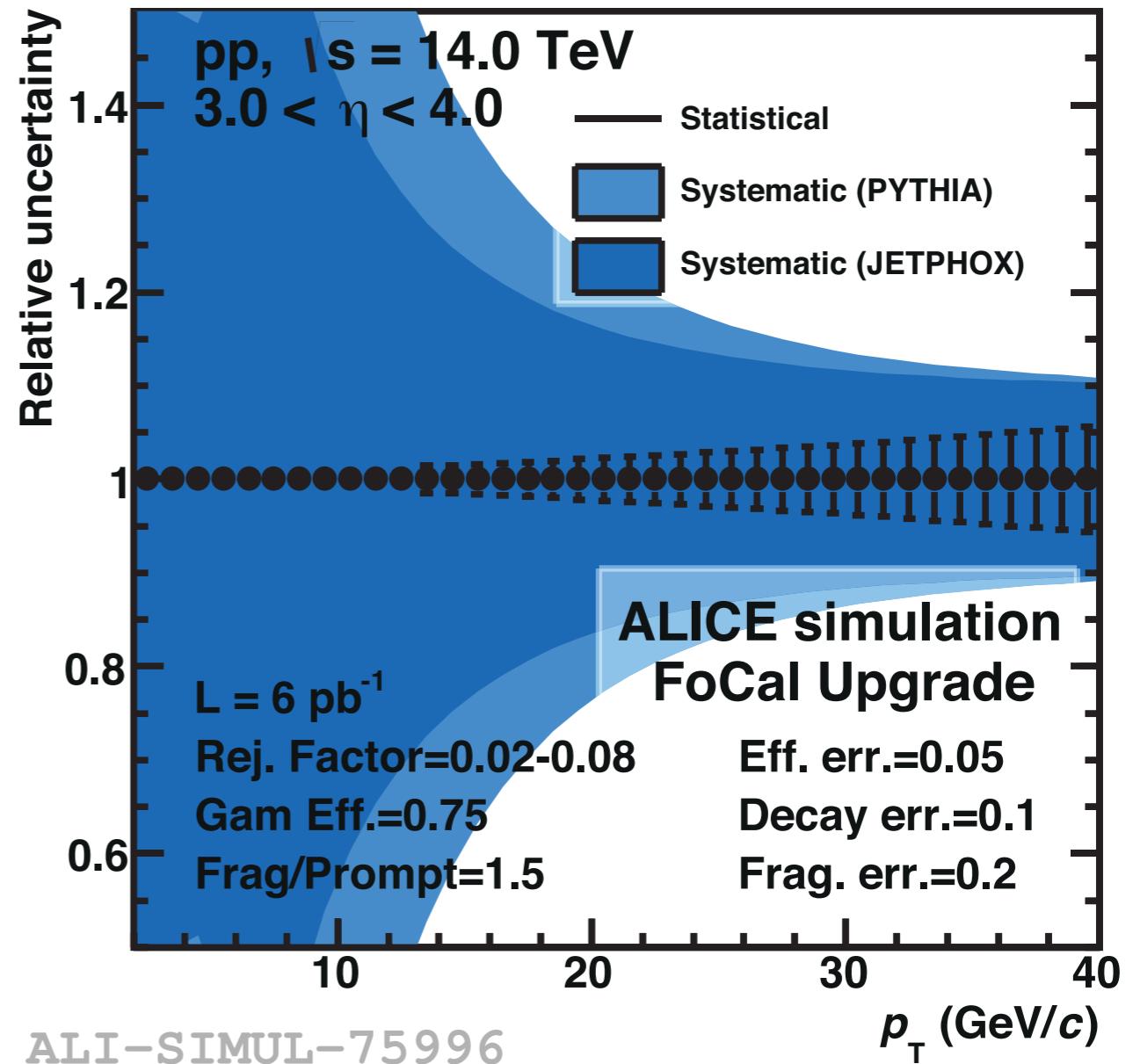


20-40% uncertainty
at $p_T = 4$ GeV/c
decreases with increasing p_T

Low Granularity Measurement



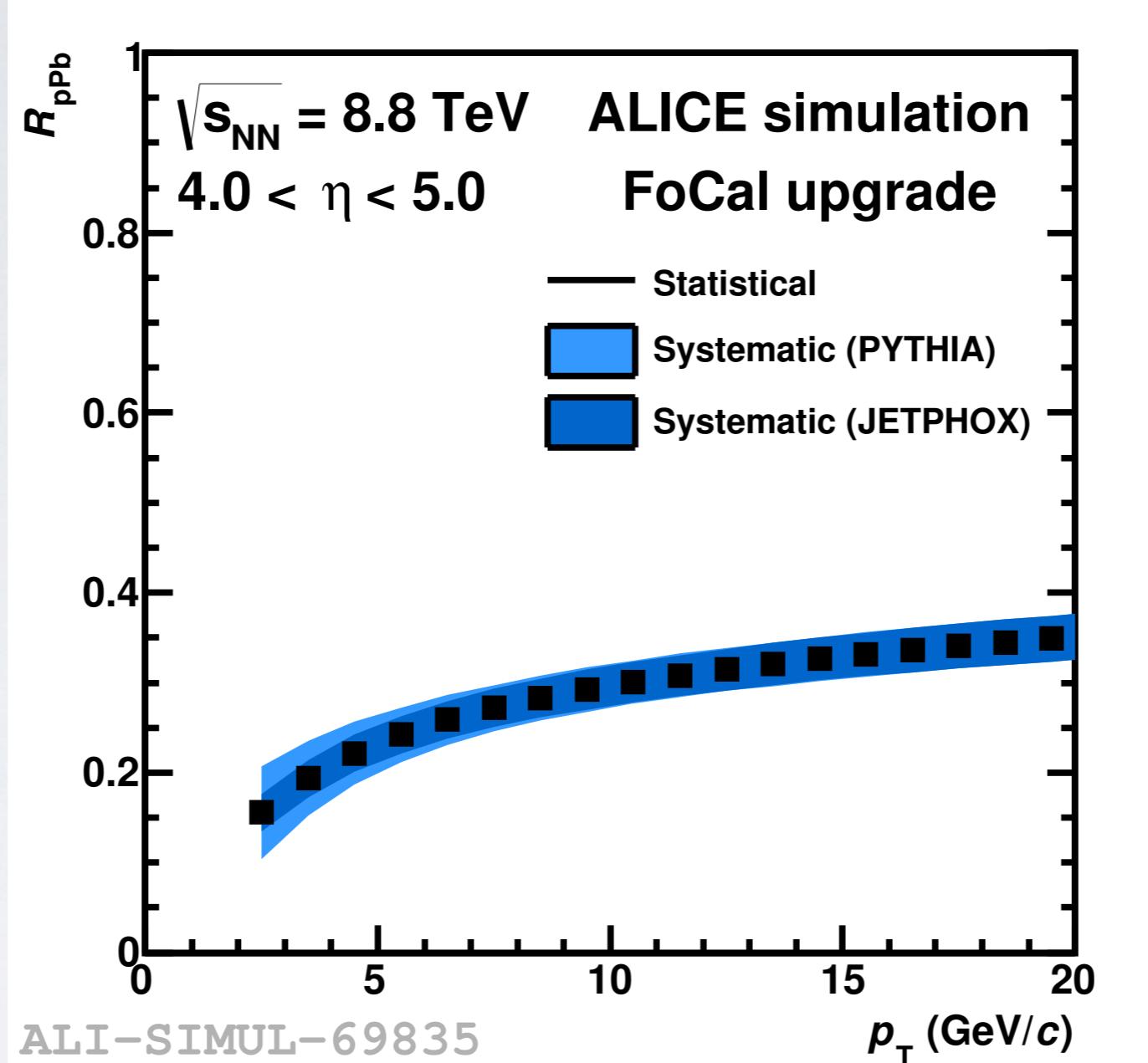
- low granularity (1cm^2) does not allow efficient decay rejection
- direct photon/all ≈ 0.1 for all p_T



significant measurement not possible at low p_T

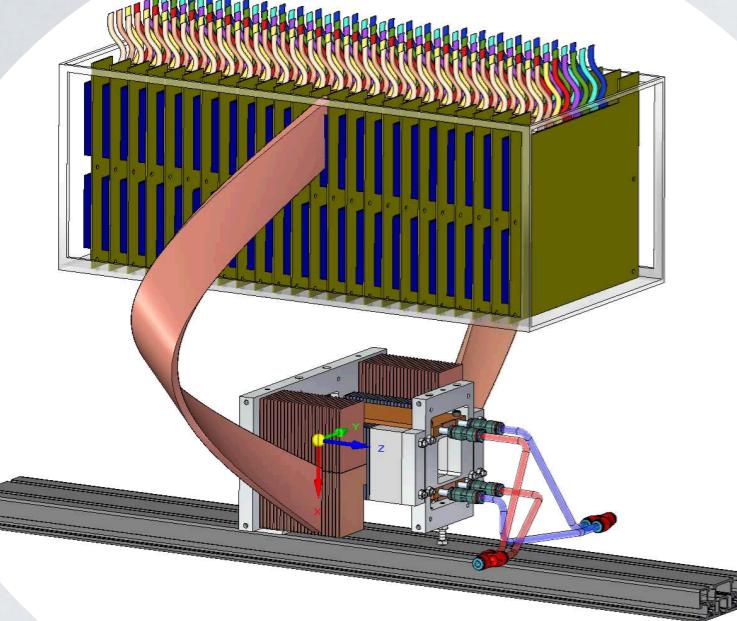
NB: conditions similar to LHCb

Performance on R_{pPb}



- expect significant constraint on direct photon R_{pPb}
- confirm or refute CGC effects, constrain nPDF

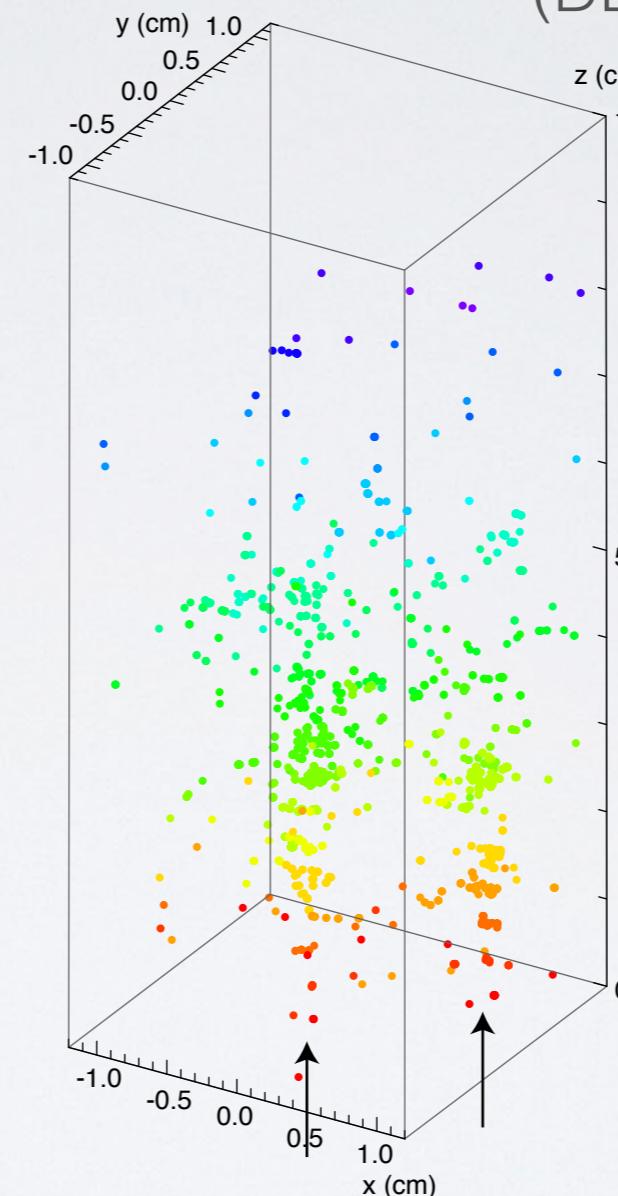
Prototypes and Test Beams



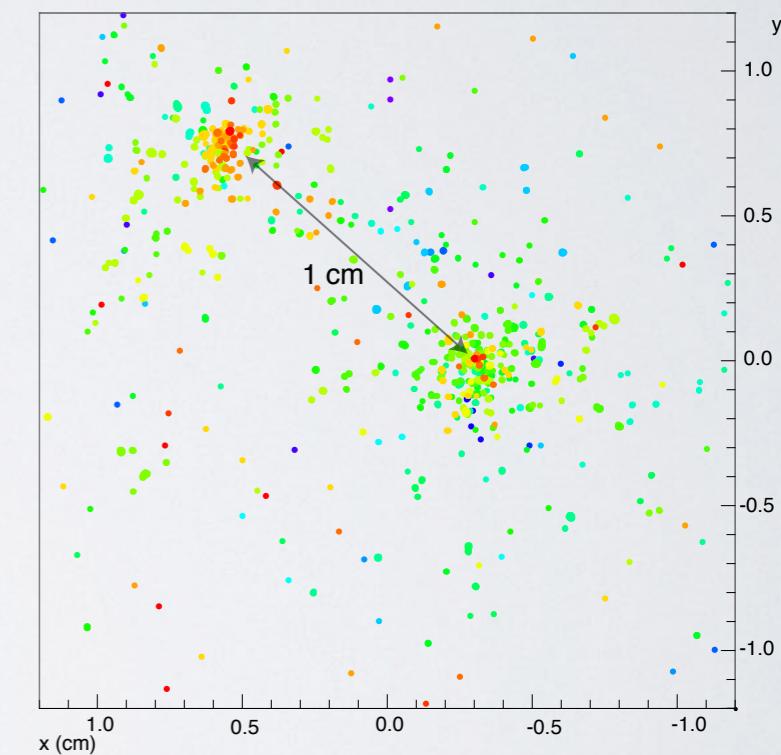
R&D ongoing
(Utrecht/Nikhef, Bergen, Tokyo,
ORNL, Kolkata, Prague, ...)

e.g. full MAPS prototype
• 39 M pixels in $4 \times 4 \times 10 \text{ cm}^3$!

first results from test beams
encouraging

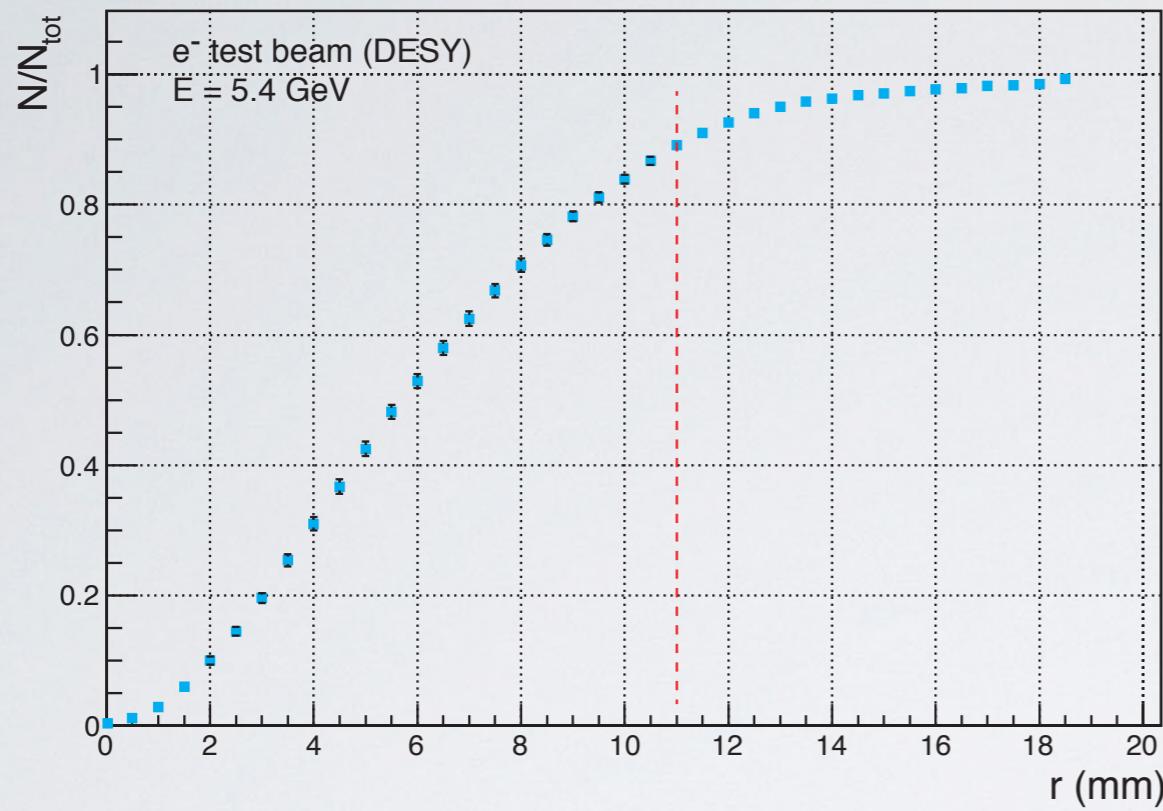


side view



front view

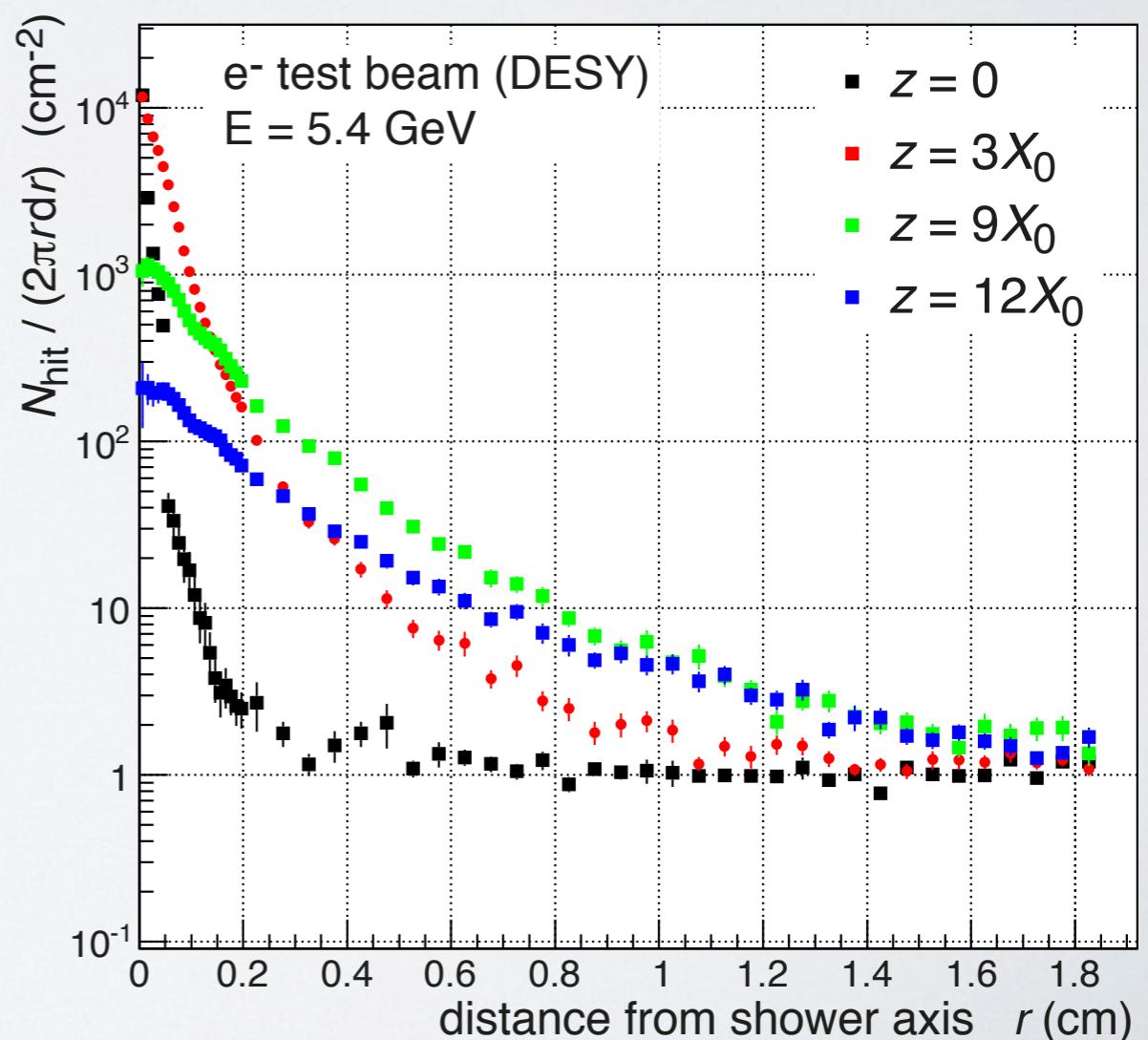
First Results: Shower Profile



very detailed measurements of lateral profile at different depths

awaits final alignment and calibration

cumulative lateral distribution of pixel hits:
confirms Molière radius of 11mm



Conclusions

- Very interesting results from p–Pb measurements in ALICE
 - Possible final state modifications
 - No conclusion on gluon saturation
- Forward direct photons suggested as a promising probe
- FoCal should allow unique direct photon measurements in pp and p-Pb at forward rapidity
 - High granularity calorimeter is crucial
 - Rich additional physics program (also in Pb-Pb)