A short introduction to the FoCal project

Marco van Leeuwen,
Nikhef, Utrecht University, and CERN

The FOCAL proposal

Under discussion within ALICE for LS3 (2024-)

Acceptance $3.2 < \eta < 5.3$

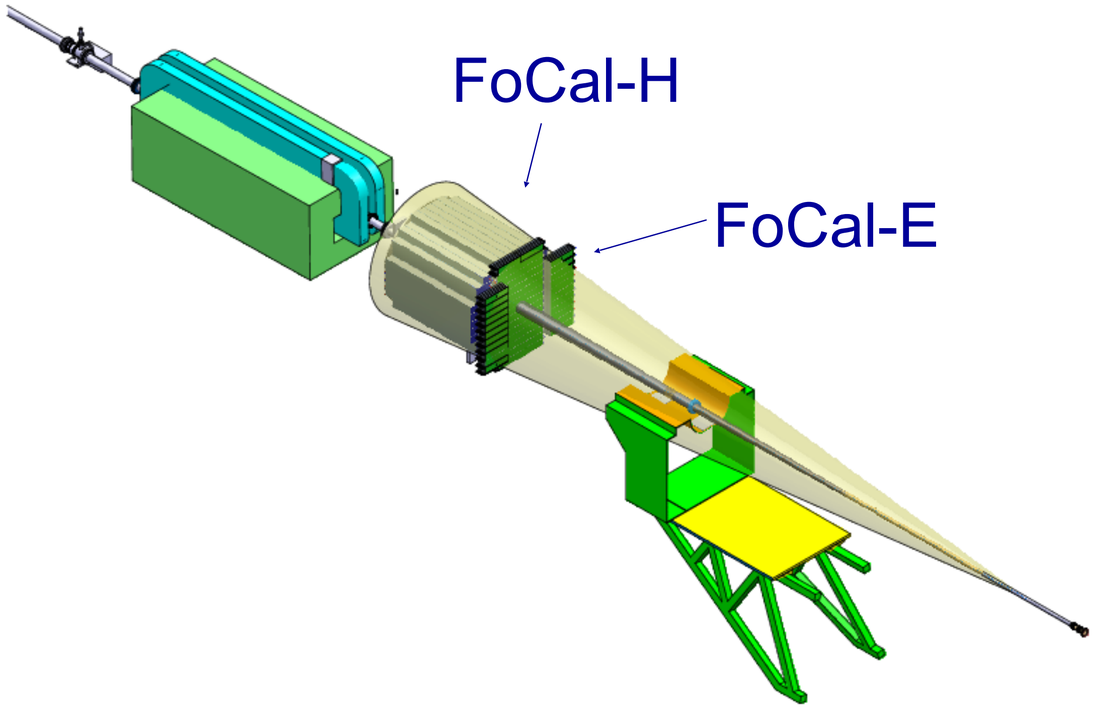
$3 < \eta < 5$ for isolated photons

FoCal-E: high-granularity Si-W calorimeter for photons and π^0

FoCal-H: hadronic calorimeter for photon isolation and jets

Observables:

- π^0
- Direct (isolated) photons
- Jets



Advantage in ALICE:
forward region not instrumented;
'unobstructed' view of interaction point

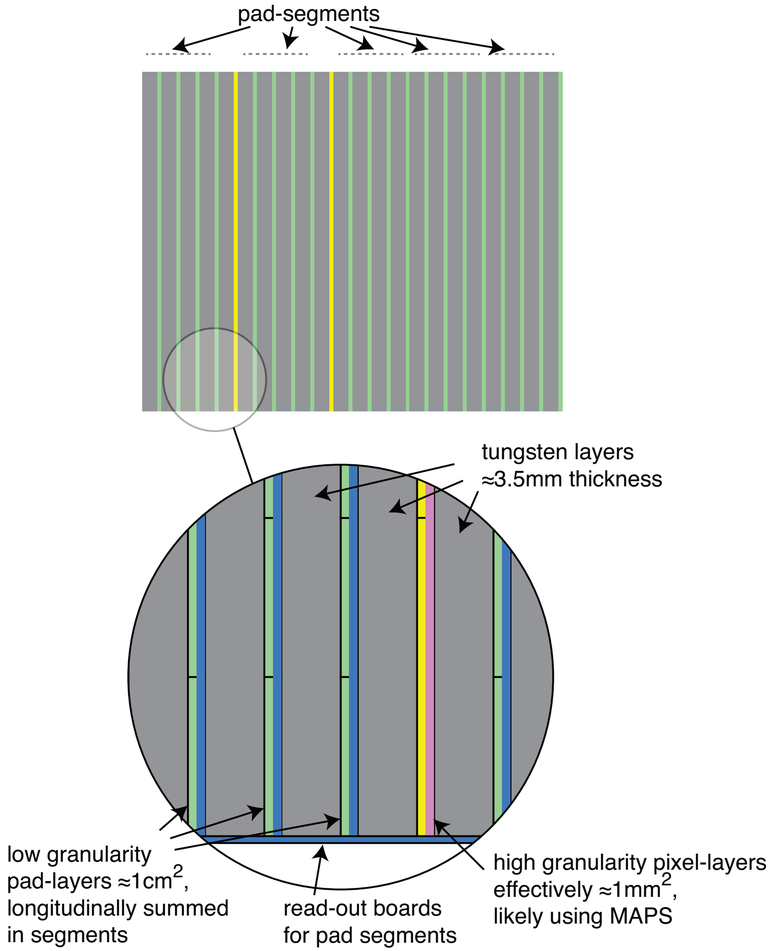
FoCal-E design concept: Si-W calorimeter

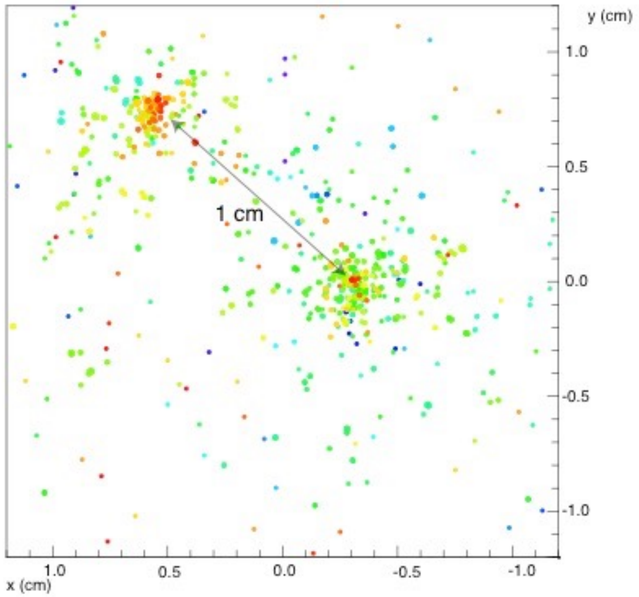
Combination of

- Silicon pad readout 1x1 cm
- 2 pixel layers after 5 and 10 X_0

PAD layers:
analog readout for energy resolution

Pixel layers:
high granularity for two-shower separation



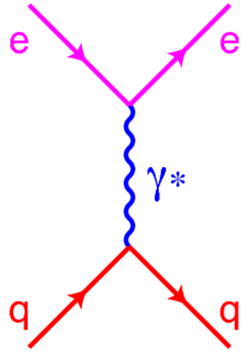


Two-shower
event
electron test beam

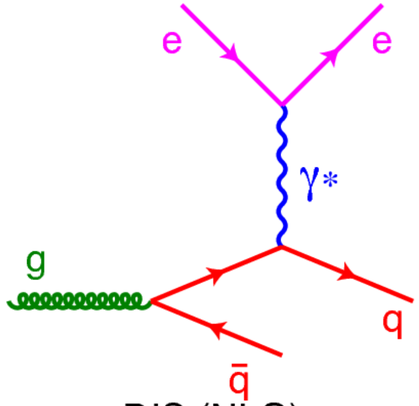
How to probe the gluon density

Deep-Inelastic Scattering (DIS)
Classical PDF method
Not sensitive to gluons at LO

Gluons from NLO/evolution
and/or F_L

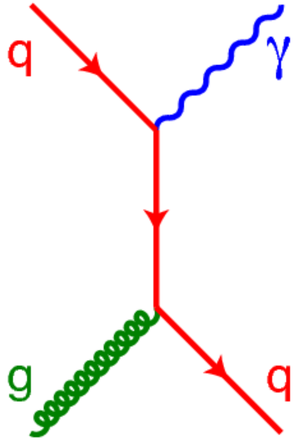


DIS (LO)



DIS (NLO)

Photon production
in hadronic collisions:
Sensitive to **gluons at LO**



direct-γ, Compton (LO)

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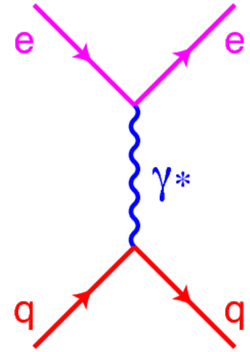

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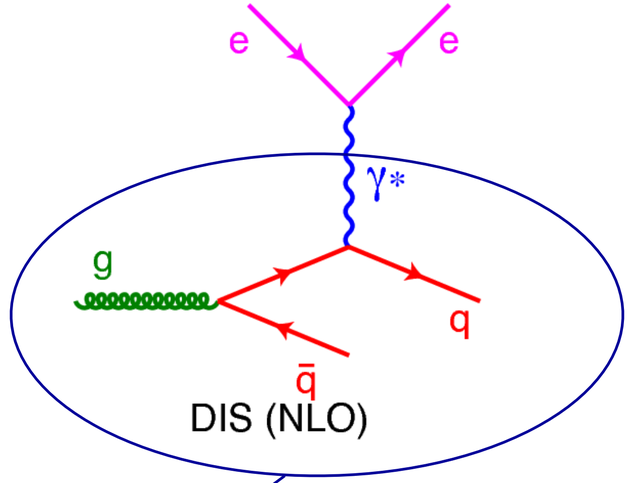

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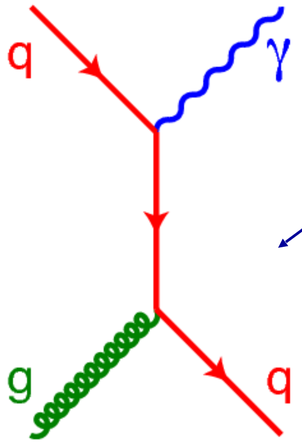


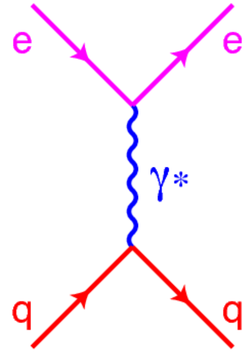
direct-γ, Compton (LO)

Directly related to DIS:
real instead of virtual photon

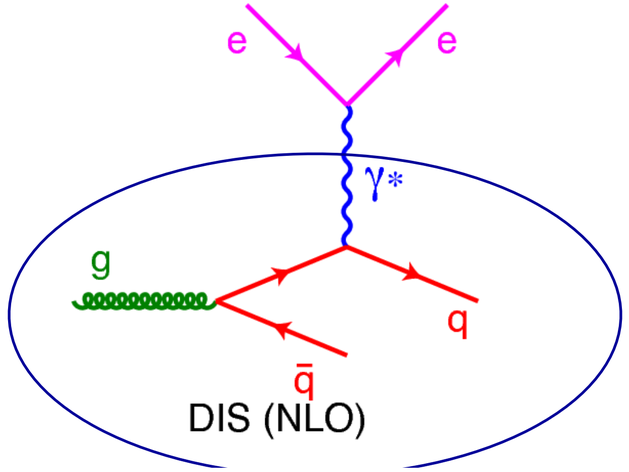
How to probe the gluon density

Deep-Inelastic Scattering (DIS)
Classical PDF method
Not sensitive to gluons at LO

Gluons from NLO/evolution
and/or F_L

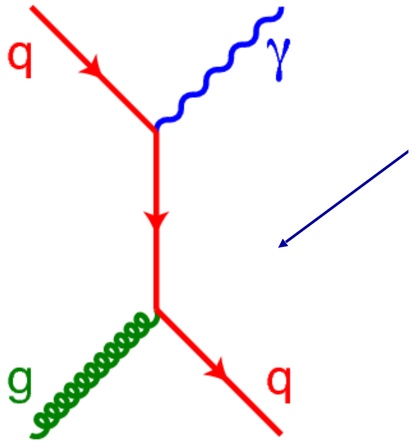


DIS (LO)

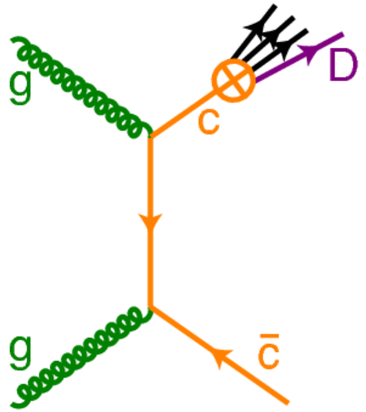


DIS (NLO)

Photon production
in hadronic collisions:
Sensitive to **gluons at LO**



direct-γ, Compton (LO)



Heavy hadron:
tag hard scattering,
but includes fragmentation

x-Q plane DIS+FoCal

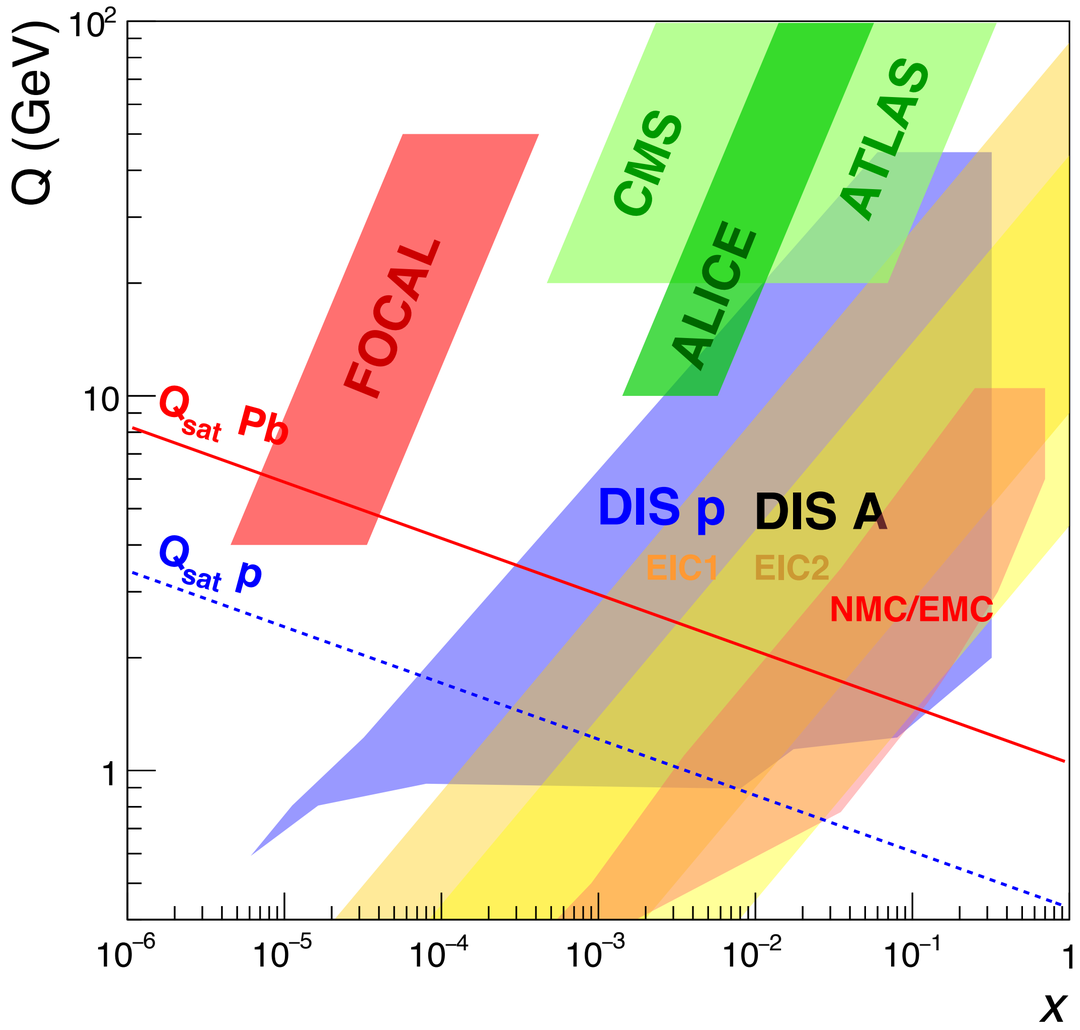
Constraints on gluon PDFs:

DIS (indirect):
$x > 10^{-4}$ for p
$x > 10^{-3}$ for A

γ in FoCal extend this range to 10^{-5}

Photons are free from final state effects
Important test for mechanisms
behind flow-like effects

x-Q acceptance for electromagnetic probes

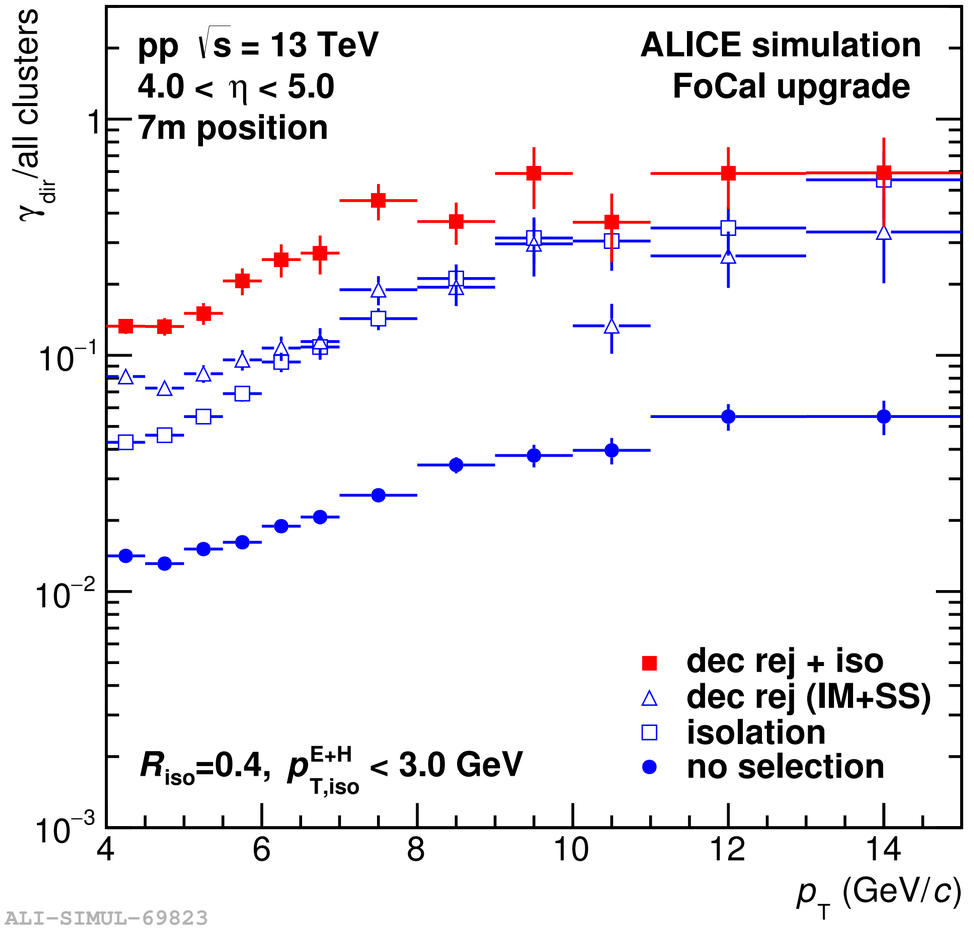


Direct γ analysis strategy

γ/π^0 ratio is small,
need to reject decay photons

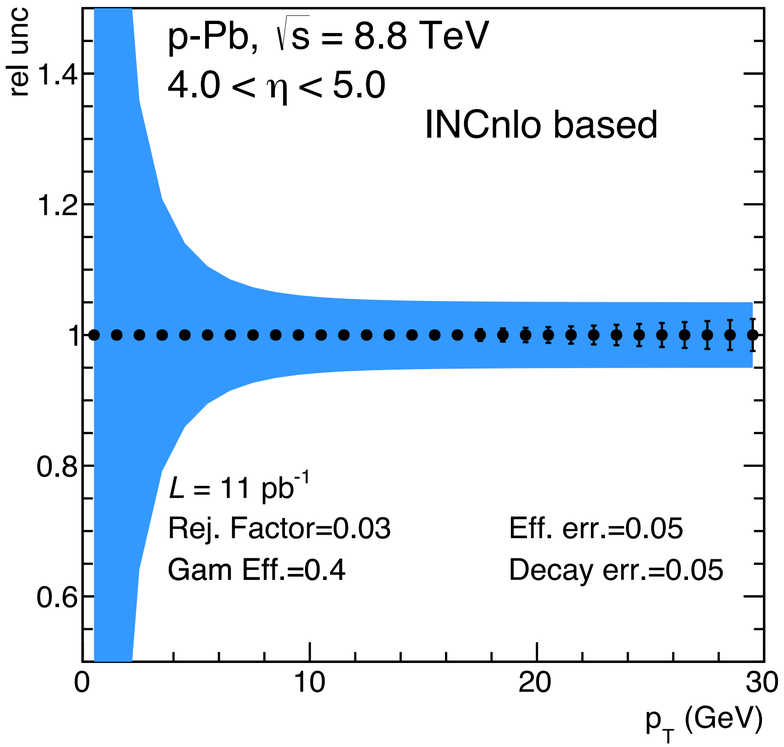
- **Direct rejection**: pair mass cut + shower shape cut enabled by high granularity
- **Isolation cut**: reject decay (+fragmentation) photons based on energy in cone

Combined rejection of background:
factor ~10



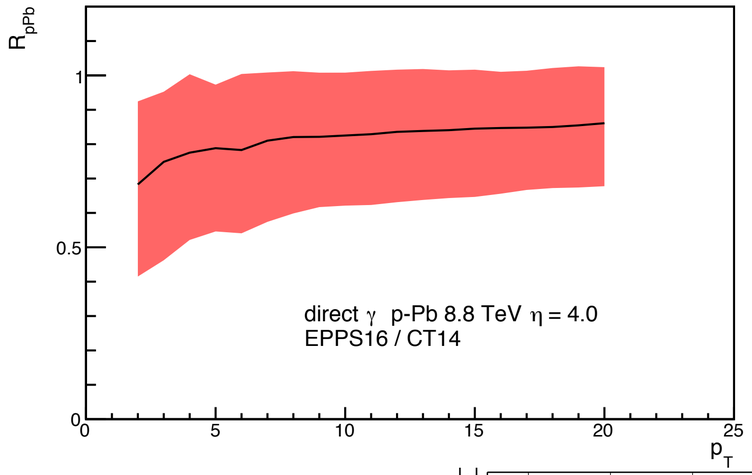
Direct γ projection

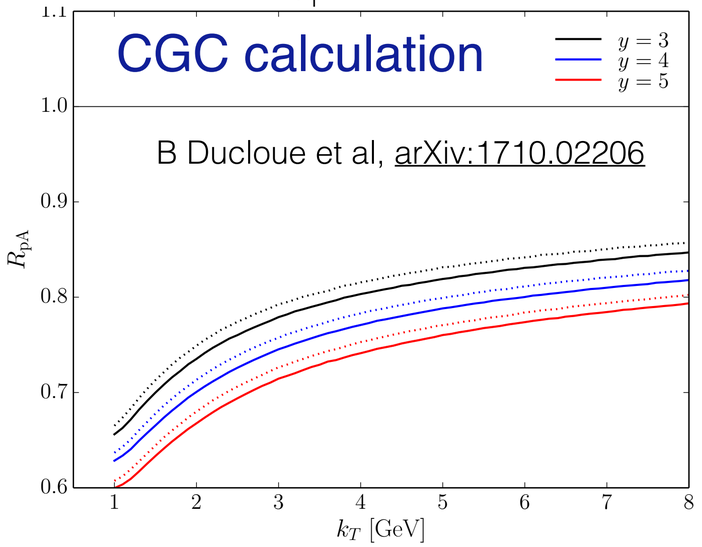
Projected uncertainty for direct γ R_{pPb}



FoCal can measure direct photons at forward rapidity with better than 10% uncertainty

nPDF calculation





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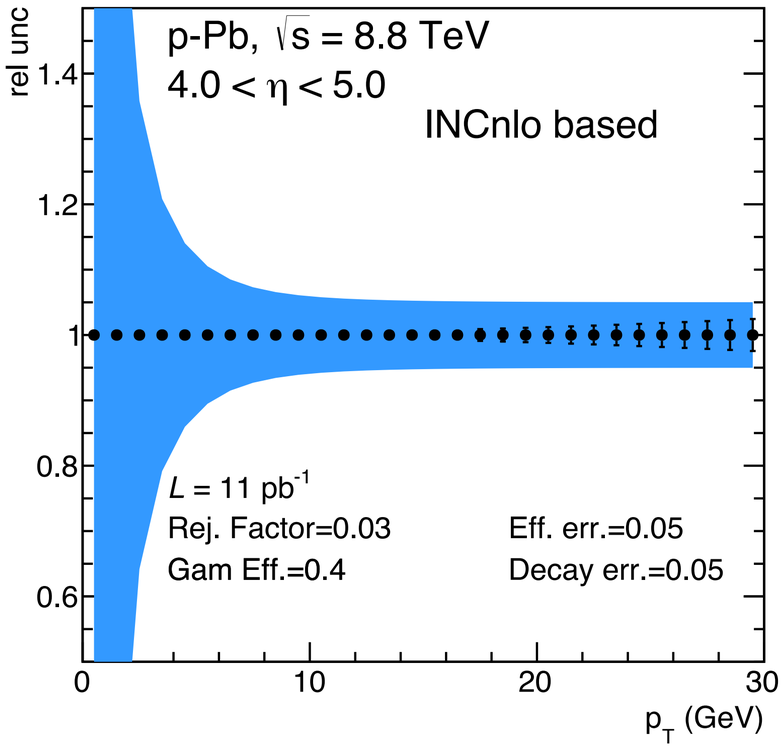

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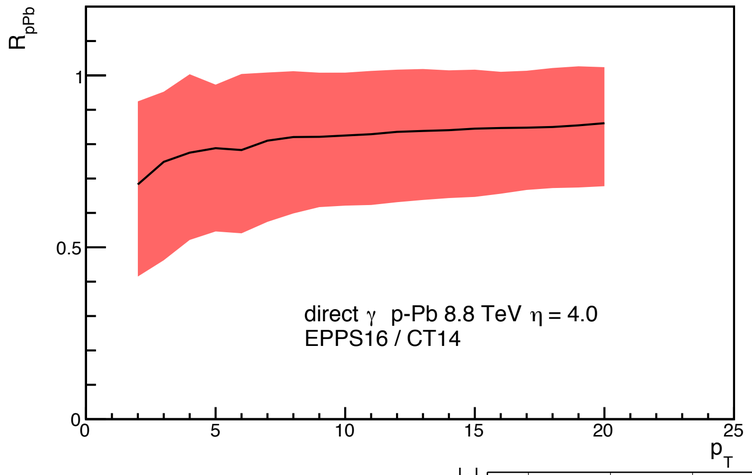
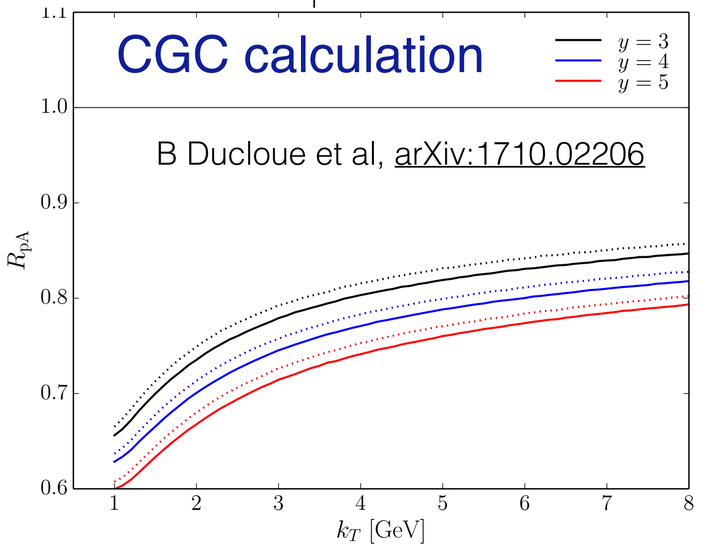
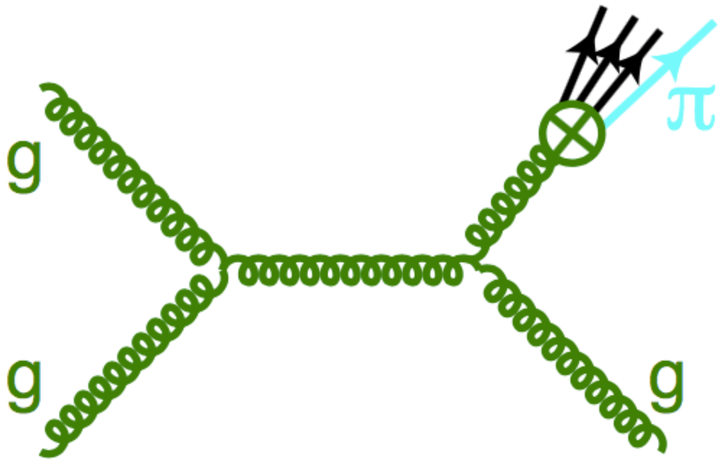




Goal of this workshop: quantify impact of this measurement on gluon nPDF, saturation models

Two-particle correlations

QCD 2 → 2 scattering

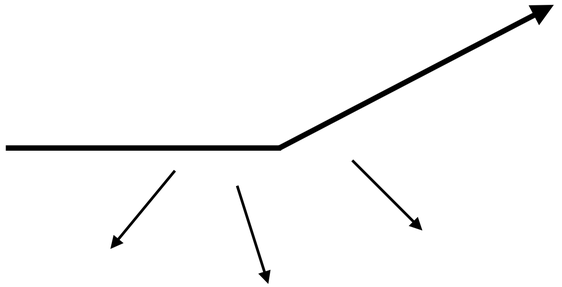


Produces a back-to-back jet

Measure rapidity of the away-side jet to constrain *x* further

γ-hadron correlations?

CGC: recoil taken by multiple gluons



Soft gluon recoil

Recoil jet broadened/disappears

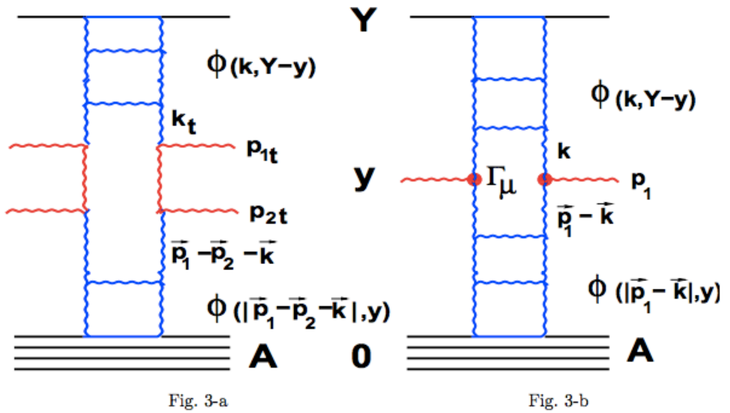


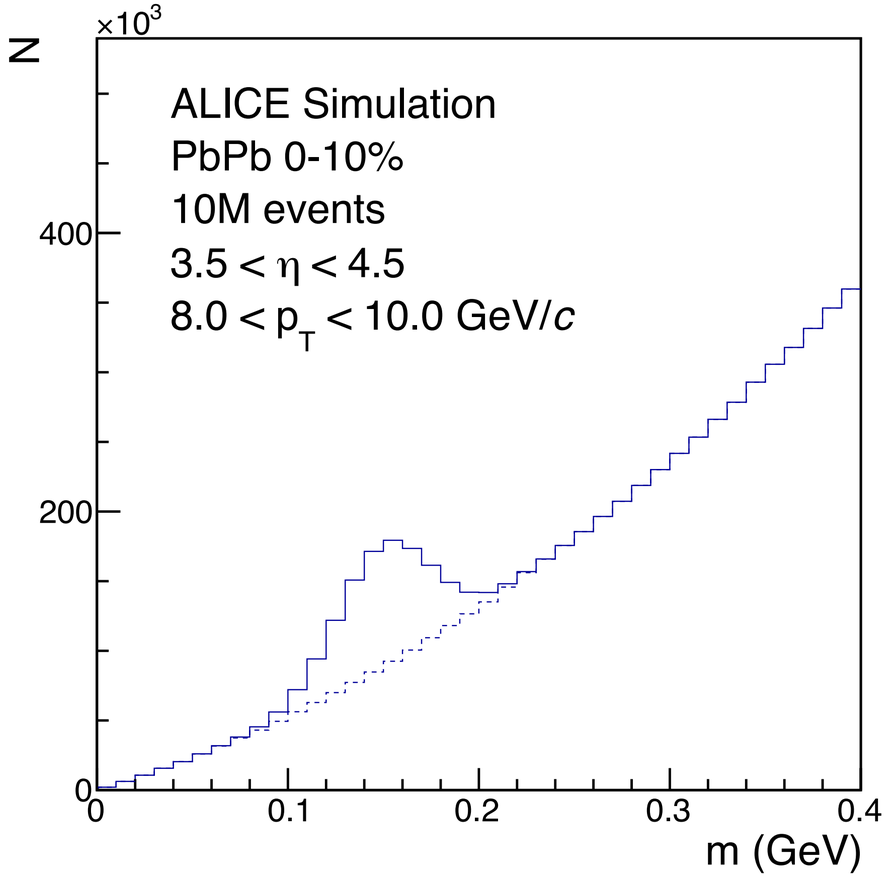
Fig. 3-a Fig. 3-b

Kharzeev et al, hep-ph/0403271

Other FoCal measurements

- π^0 in Pb-Pb collisions
  R_{AA} at forward rapidity
- Two-particle correlations:
  - π^0-π^0 in forward direction
  - mid-forward h-π^0
  - π^0-γ h-γ (TBC)

For PDF/CGC studies,
flow-like effects in photons?



Main Physics Motivation for FoCal (A Hierarchy)

1. prove or refute gluon saturation
   - compare saturation models with linear QCD
   - depends on saturation model implementation and flexibility of PDF analytical shape
2. show invalidity of linear QCD at low *x*
   - can all potential measurement outcomes be absorbed in a modified PDF?
3. constrain the PDFs at low x
   - nuclei, also protons

observables of choice:

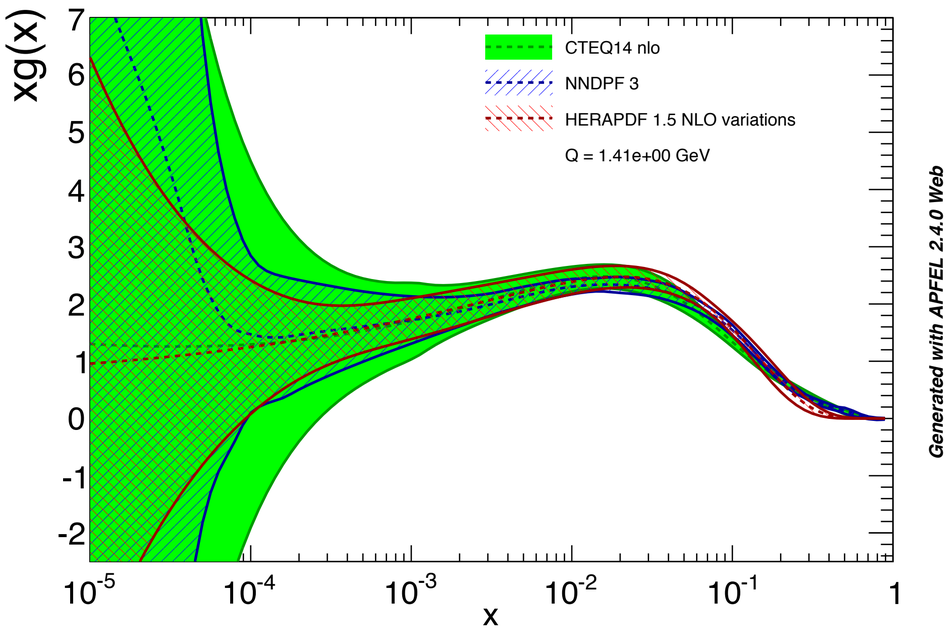
- nuclear modification factor R_{pA} of direct photons
  - saturation stronger in nuclei
  - possibly non-existent in protons (calculation of reference in models?)
- two-particle correlations: π^0 -π^0 y-π^0 and jet-jet being explored

Pb-Pb program: nuclear modification at forward rapidity and high p_T

Thank you for listening

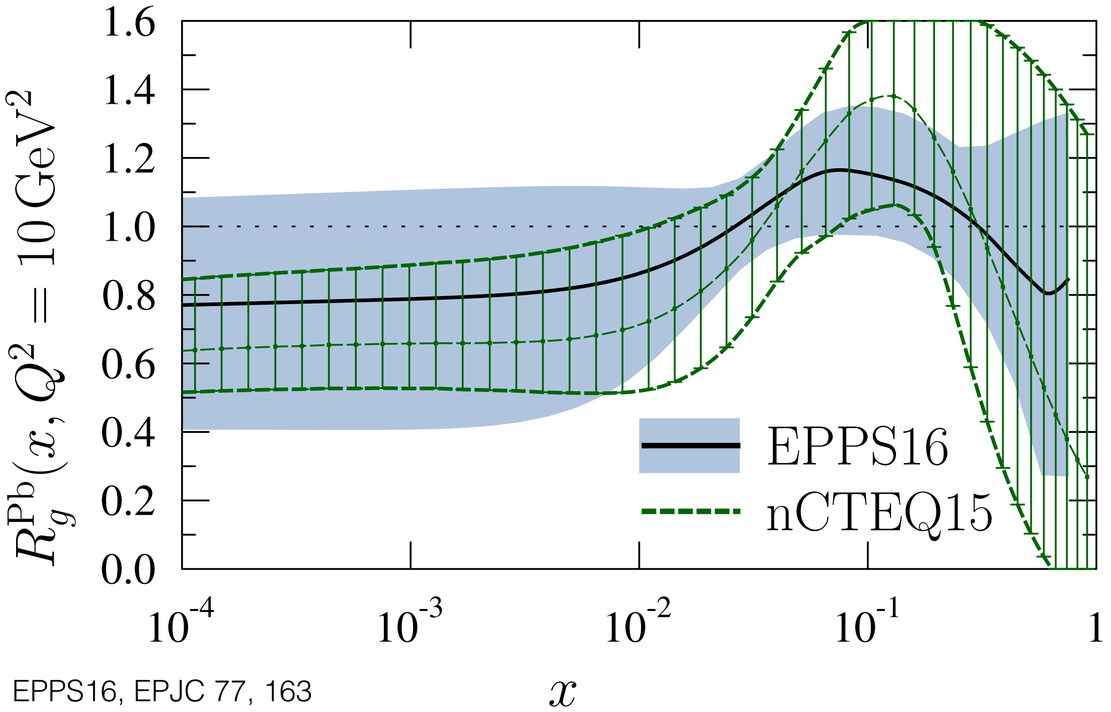
Gluon Densities at small x

Gluon density in proton



Even in the proton, (very) limited information about gluons at $x < 10^{-4}$

Gluon density in Pb nucleus

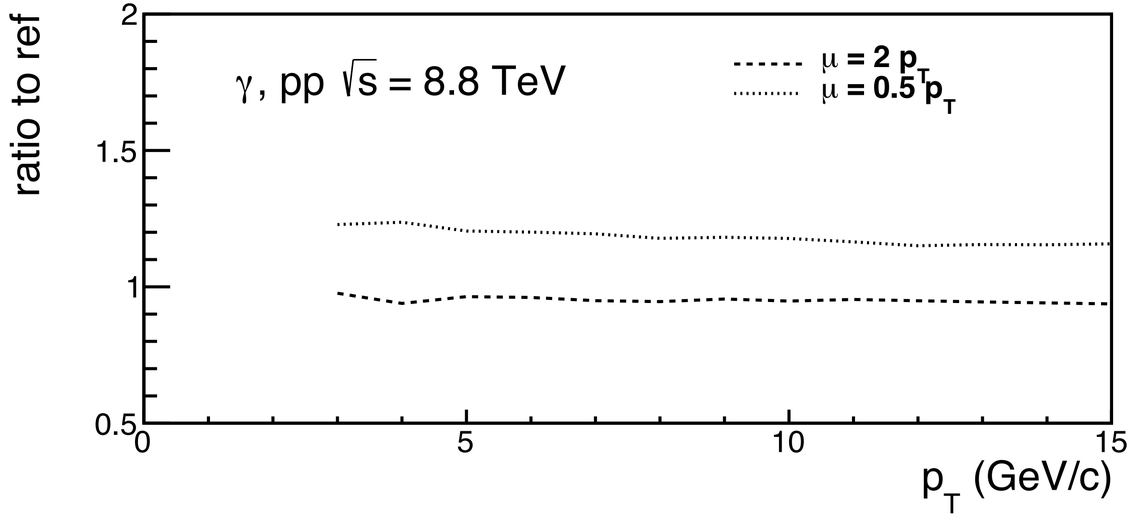


EPPS16, EPJC 77, 163

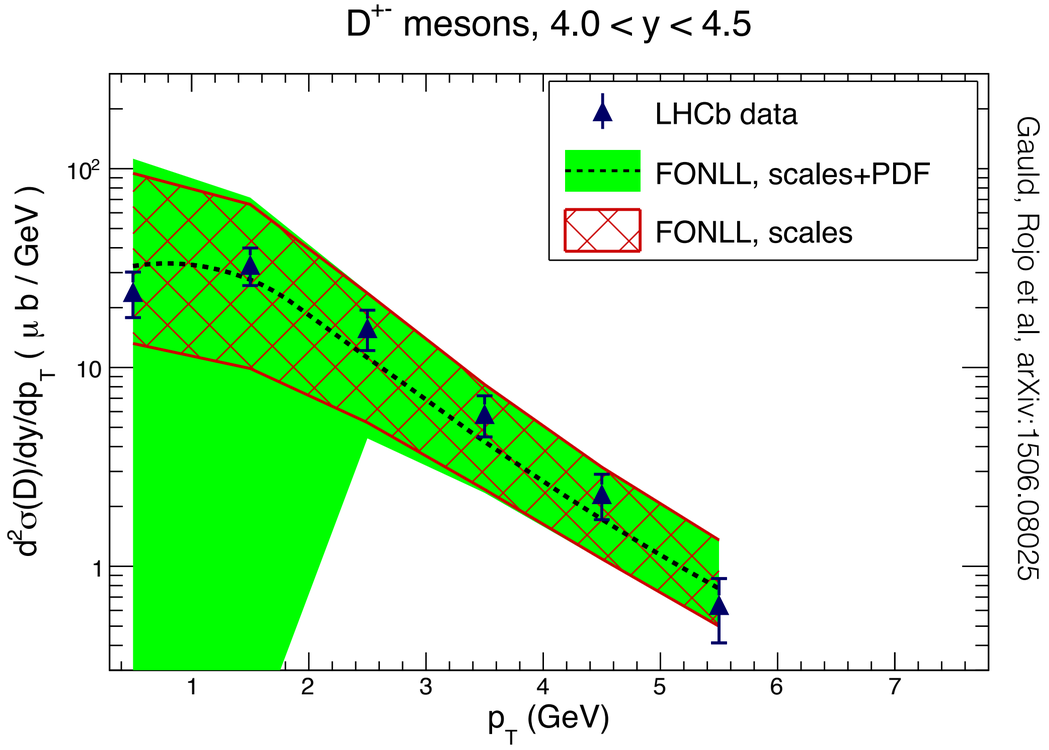
Ratio Pb/p has large uncertainties over broad x range

Theoretical uncertainties

Direct γ



Gamma: ± 5-20%

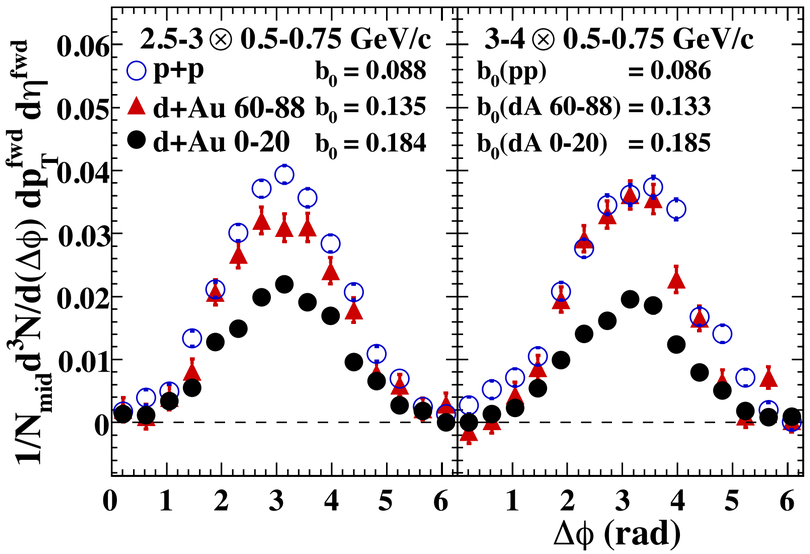


Scale uncertainty: factor 2

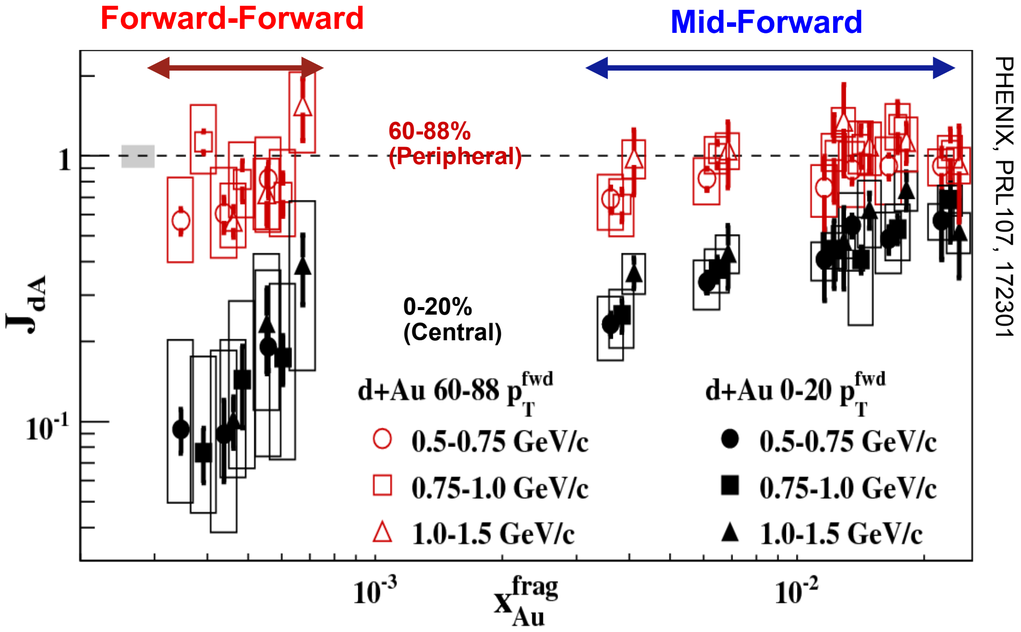
Current publications reduce this
by looking at rapidity-dependence
(taking ratios wrt to a specific point)

Di-hadron correlations at RHIC

π^0-π^0 mid - forward



$|\eta| < 0.35$ and $3.0 < \eta < 3.8$



Scan '*x*' with p_{T1} and forward, mid rapidity

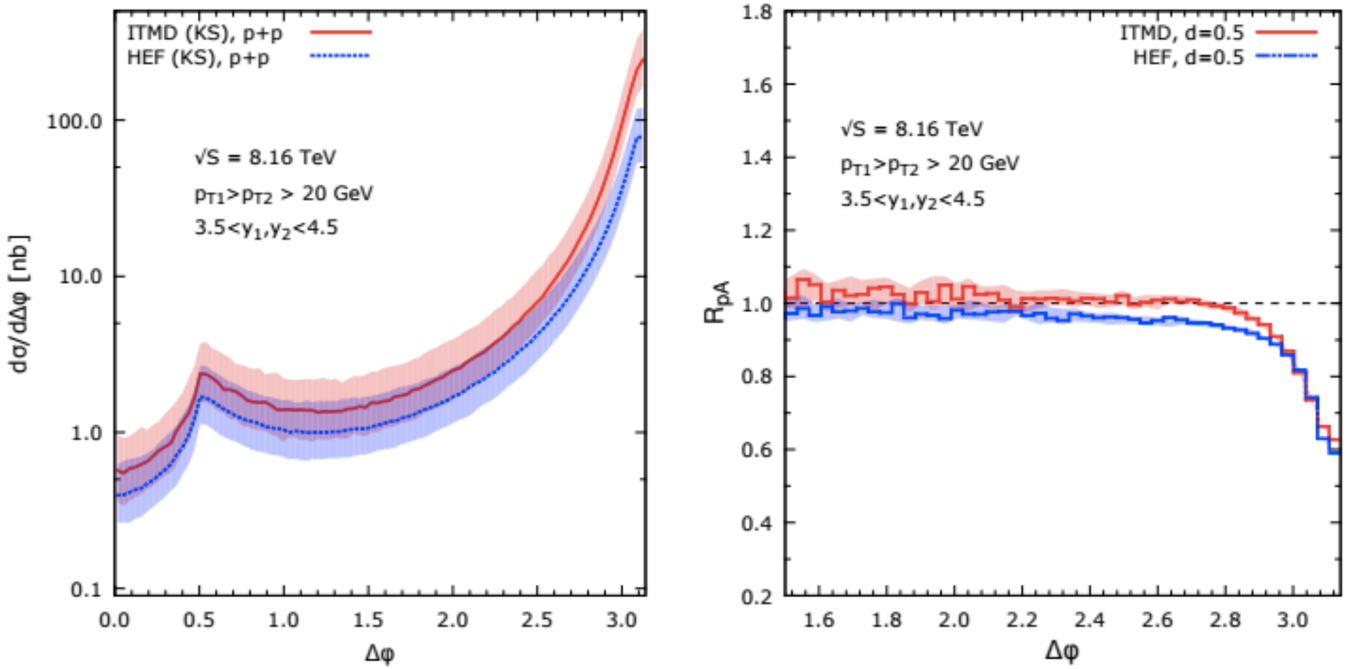
More systematic study shows similar effects, trends as a function of *x*

Large suppression at '*x*' < 10^{-3} in central events

Performance studies in Maya's talk

Di-jet distributions

van Hameren et al, arXiv:1607.0312



New calculations show similar effects in high-p_T dijets

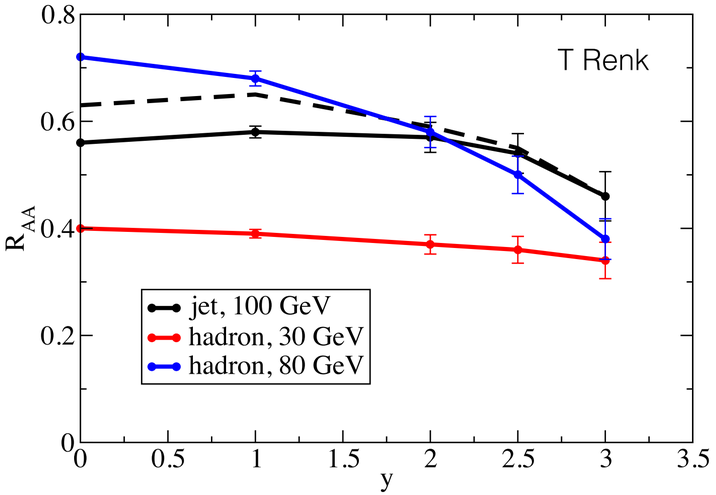
Using TMD factorisation framework

Technical problem in CGC framework: need four-point functions

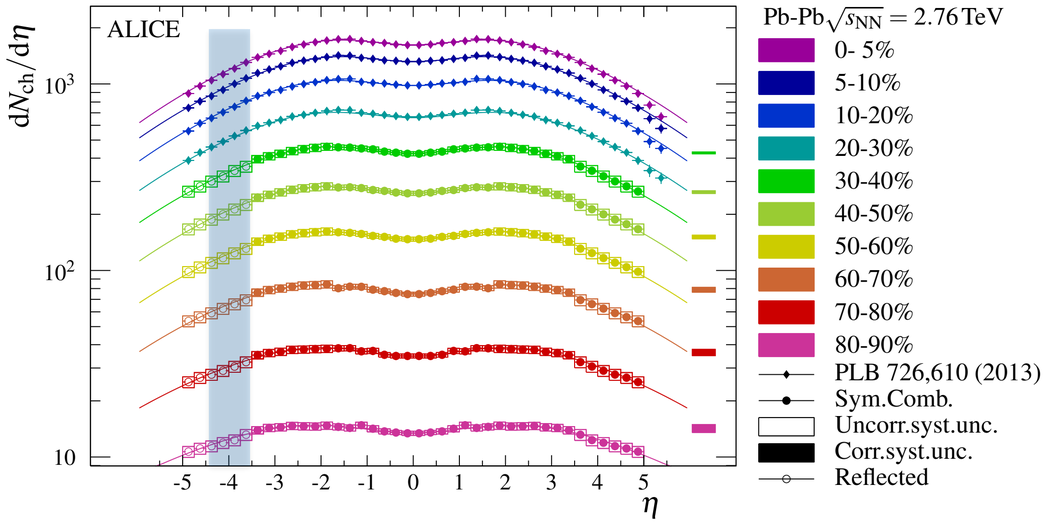
See also Toma's talk later

Forward R_{AA} to probe longitudinal medium evolution

Main observable: R_{AA} at forward rapidity



Expect trade-off between several effects
(density, time evolution,
q/g ratio, phase space limits)



Density at η~4 is about
0.8 times mid-rapidity

Forward R_{AA}: MUSIC

First look in MUSIC shows strong increase of R_{AA} at forward rapidity

C Park, S Jeon etc al