Saturation physics with an ALICE-like detector at FHC

Some numbers and ideas – a discussion-starter

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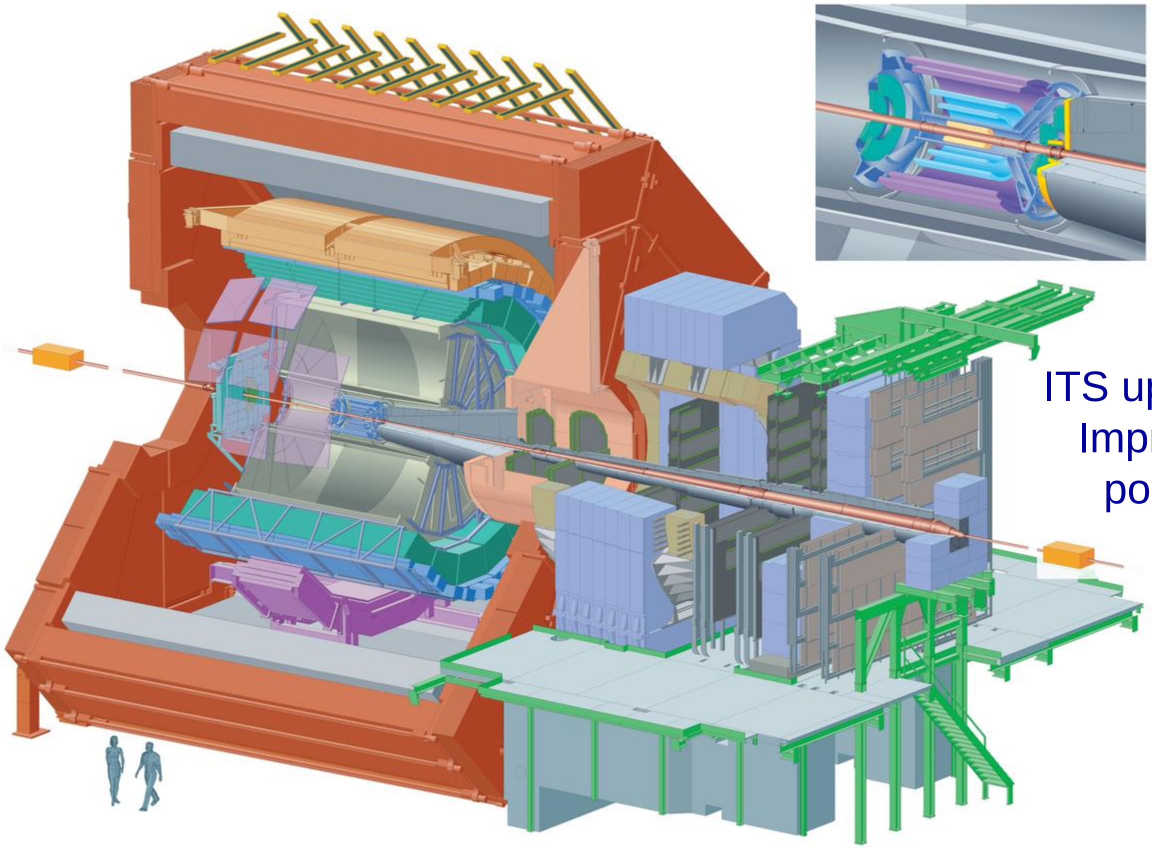
Observables for gluon density

This talk: focus on saturation of gluon density

Observables that are sensitive to the gluon density:

- Direct gamma
  - LO: $qg \rightarrow \gamma q$
- Drell-Yan
  - NLO: $qg \rightarrow l^+l^- q$ (tiny xsec)
- J/ψ
  - LO: $gg \rightarrow cc$
  - Kinematics uncertain; hadronisation likely plays a role
- Di-jet/di-hadron production
  - No parton selectivity; $gg \rightarrow gg/qq$ dominates at ‘low’ p_T

ALICE central barrel capabilities



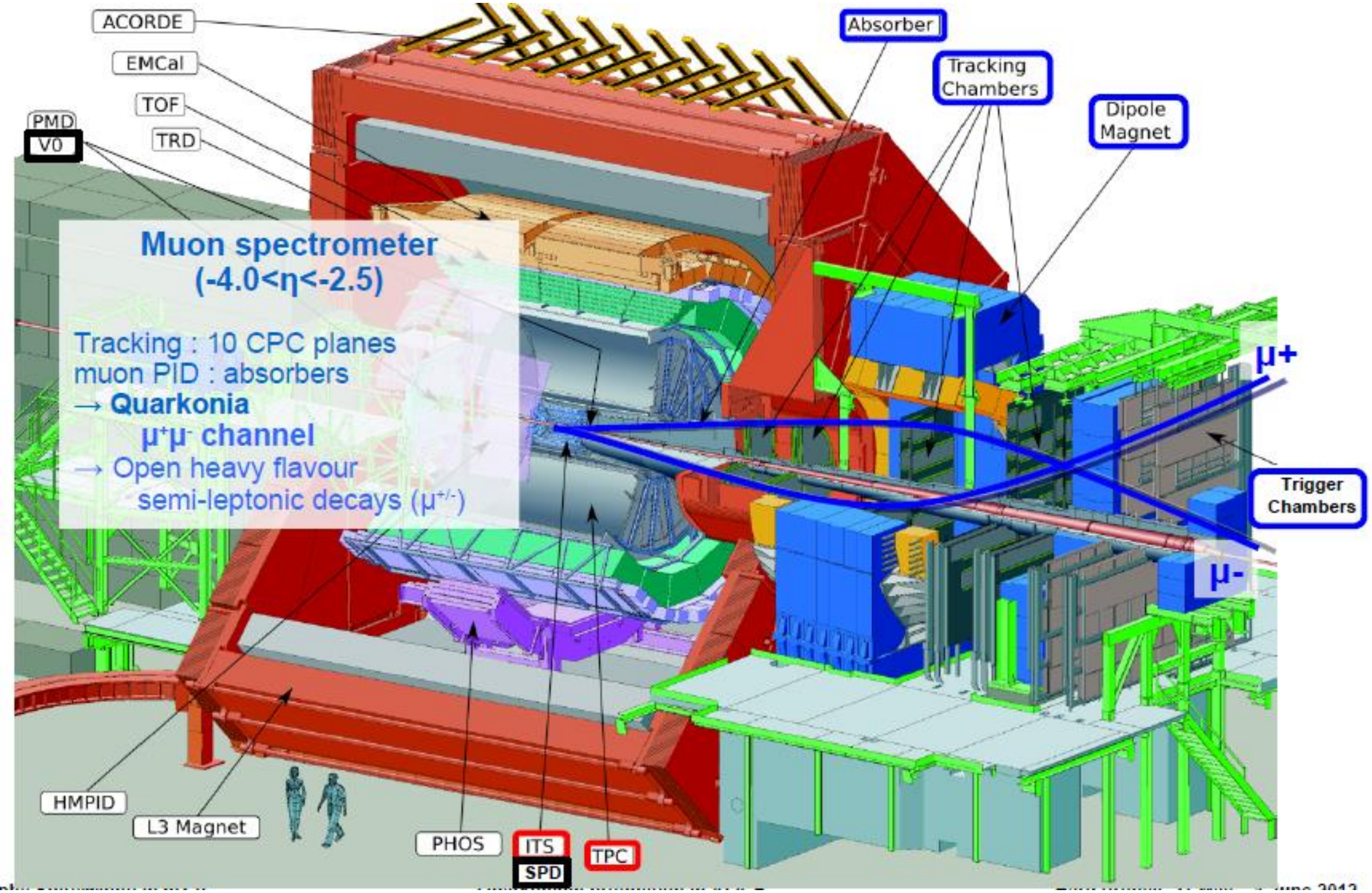
ITS upgrade under way:
Improved granularity,
pointing resolution

Tracking + PID over $|\eta|<0.9$, full azimuth

Designed for $dN/d\eta < 8000$

Tracking $p_T < 100$ GeV/*c* (current state; may improve; limited by B field, fake rates)

ALICE forward capabilities: muon arm

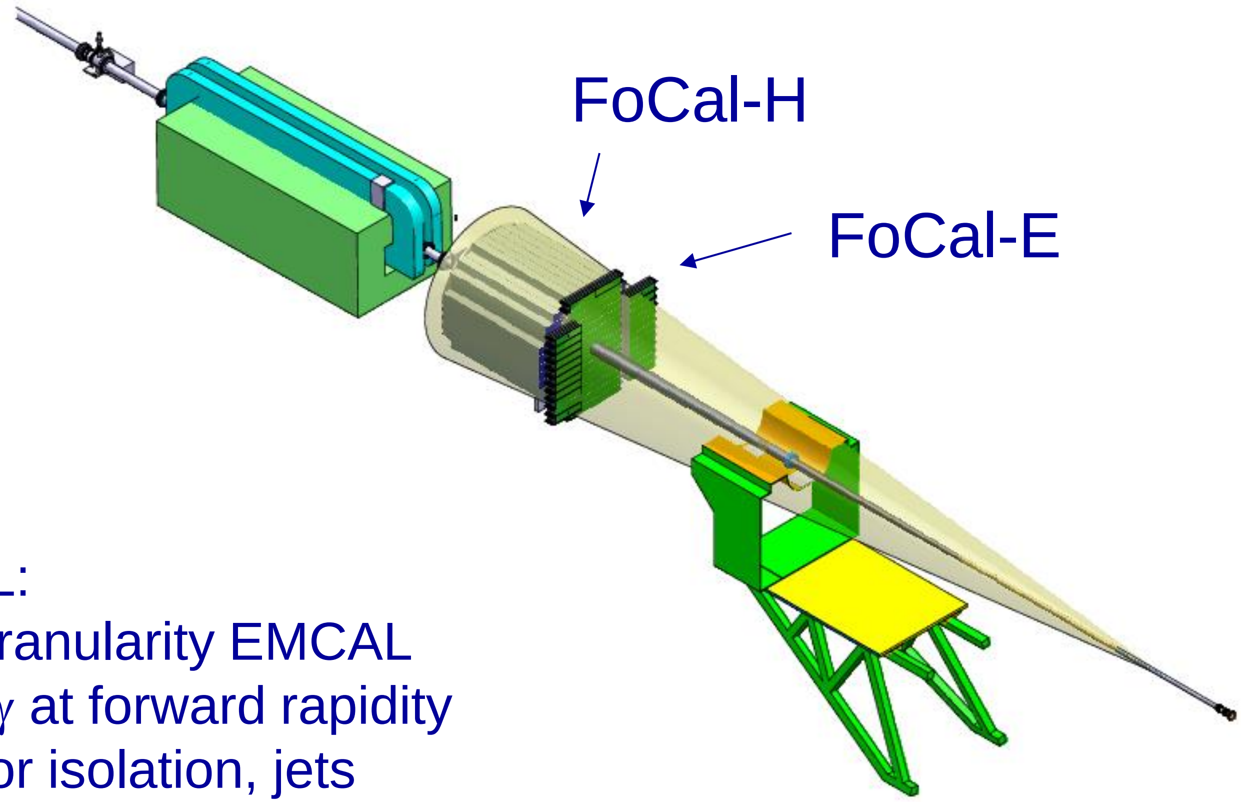


Muon arm: $2.5 < \eta < 4.0$
Focus on quarkonia (J/ψ, ψ', Υ)
Upgrade: MFT for HF secondary vertices + ψ'

A Forward Calorimeter: FOCAL

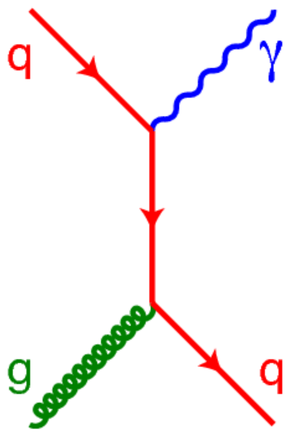
(under discussion in ALICE)

$3.2 < \eta < 5.3$

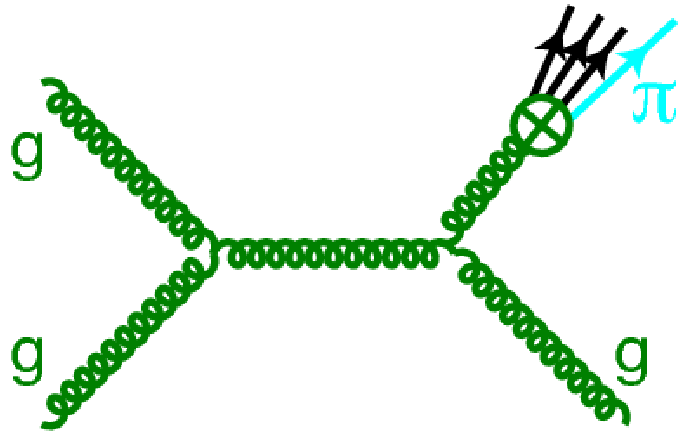


FOCAL:
High-granularity EMCAL
for π^0, γ at forward rapidity
HCal for isolation, jets

2-body kinematics; some numbers



direct-γ, Compton (LO)



light hadron

For gluon density, need Q^2 and x_2:

$$x_2 = \frac{p_T}{\sqrt{s}}\left(e^{-\eta_3} + e^{-\eta_4}\right)$$

Final state parton $p_T \sim Q$ $\quad$ η of final state partons

Photon is a parton

Di-hadron, γ-hadron: additional constraint on x

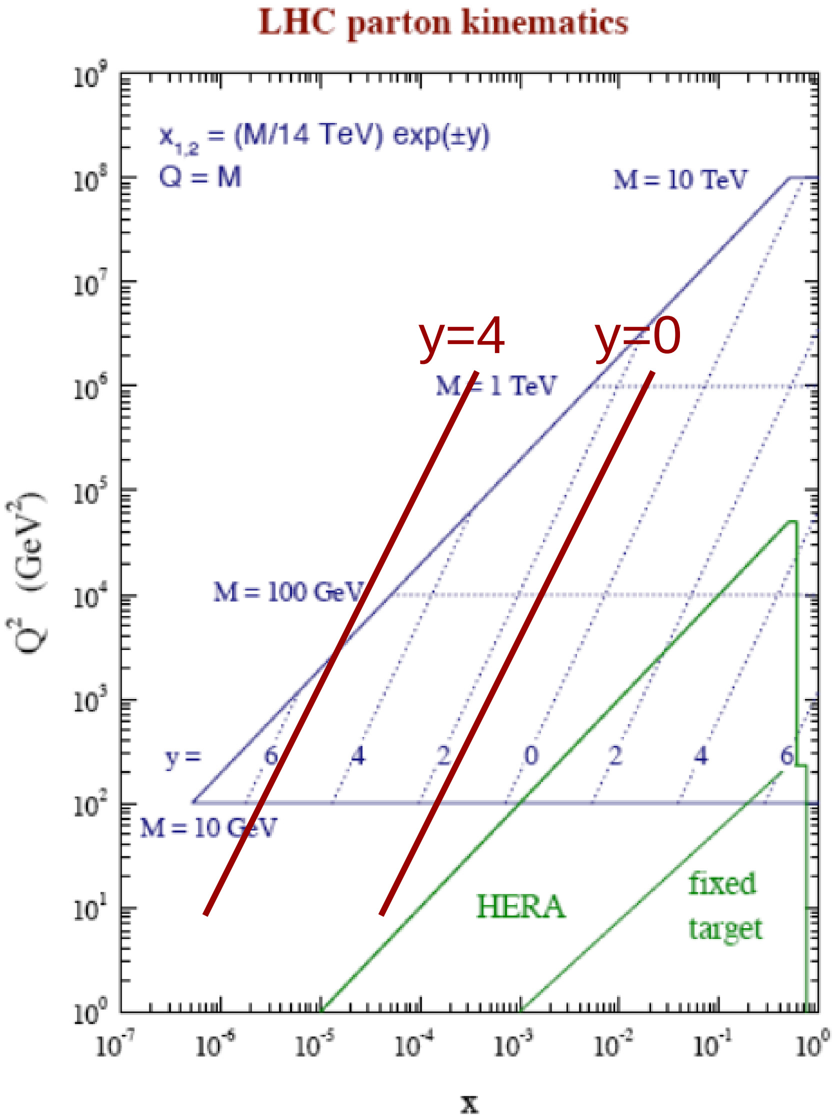
Some numbers

For example: p_T=5 GeV

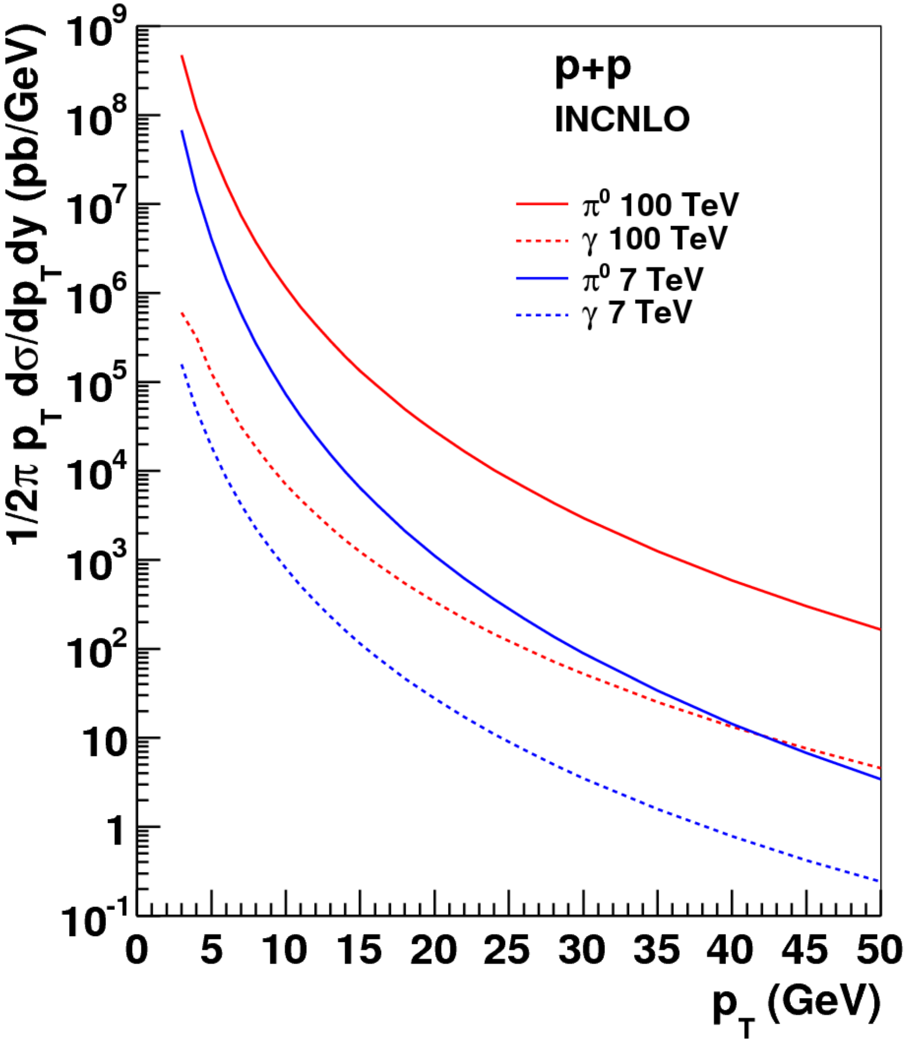
	y = 0	y = 4
$\sqrt{s}$ = 14 TeV	$x \approx 3.5\ 10^{-4}$	$x \approx 6.5\ 10^{-6}$
$\sqrt{s}$ = 100 TeV	$x \approx 5\ 10^{-5}$	$x \approx 9.1\ 10^{-7}$

Lower x range by factor ~7 ~ e^{-2}

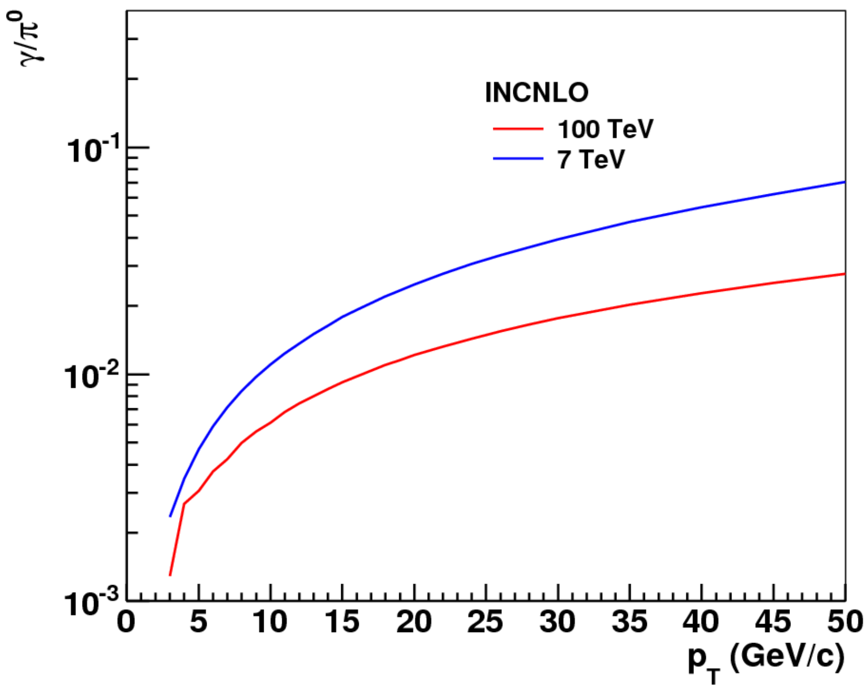
y = 0 at FHC is y = -2 at LHC (14 TeV)



π^0 production, γ/π ratio



~factor 10 increase of π^0 production
at 50 GeV
Less at lower p_T



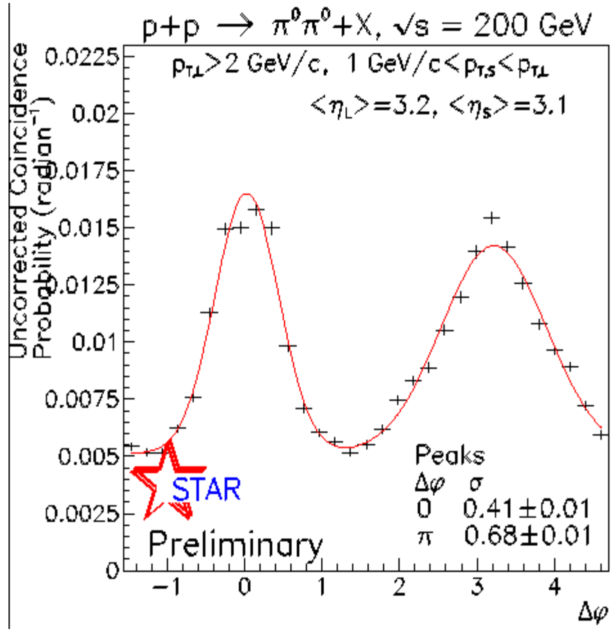
γ/π worse than at 7 TeV,
but not dramatic

Di-hadron correlations I

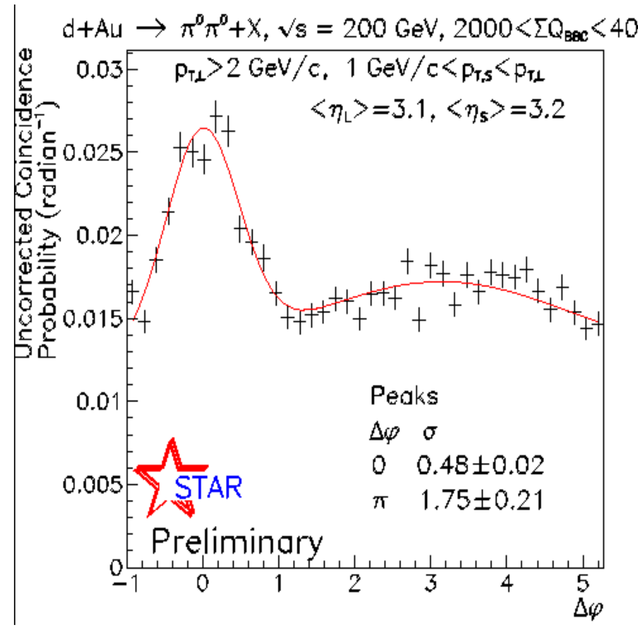
Motivation:
CGC: no 2-2 scattering:
multi-gluon recoil

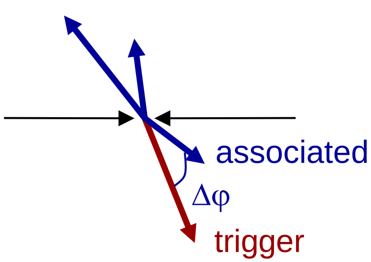
Also: di-hadron
constrains x
range

Minimum Bias



Central



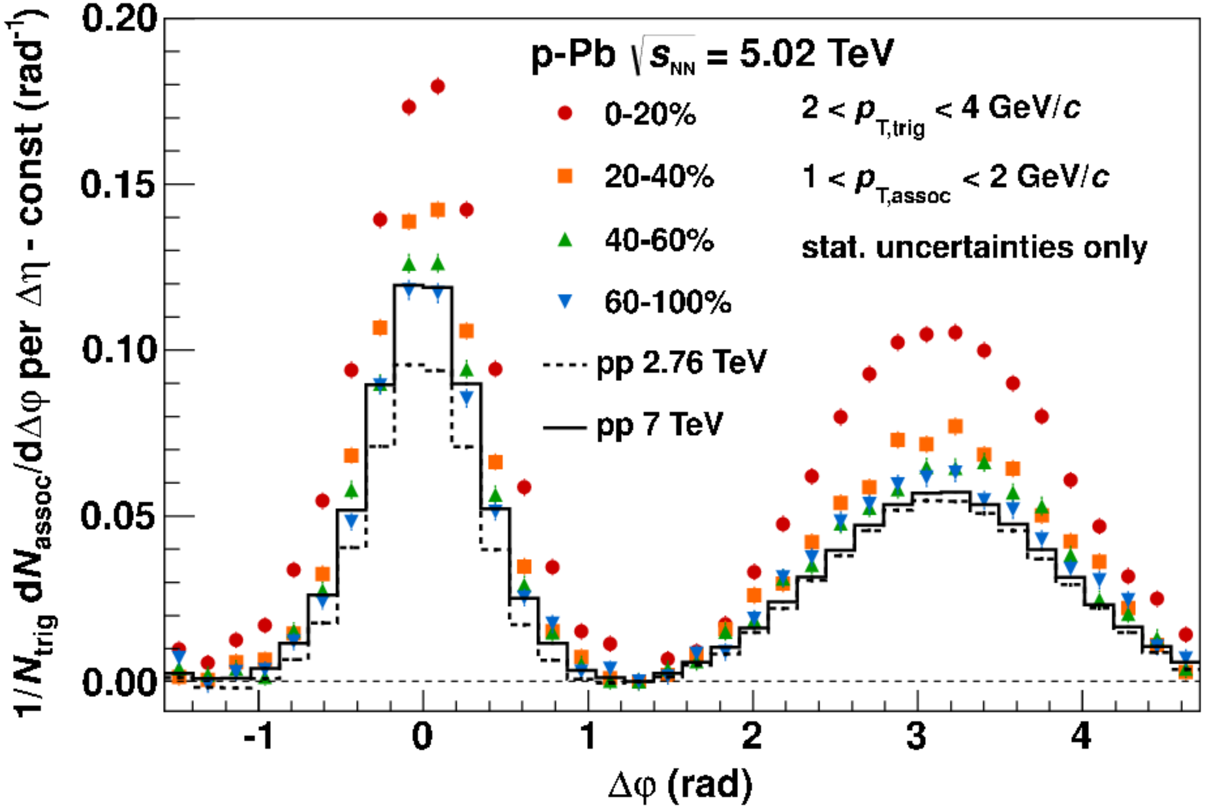


Observation at RHIC: recoil yield broadened, suppressed
Only in central events

η=3, p_T = 1-2 GeV

η=0 at LHC should be equivalent

Di-hadron correlations II



ALICE Phys Lett B719, 29

At LHC: enhancement of per-trigger yield
Opposite of expectations from RHIC!

Speculation: can this be seen in 100 TeV pp collisions (high mult?)

Experimental considerations for forward measurements

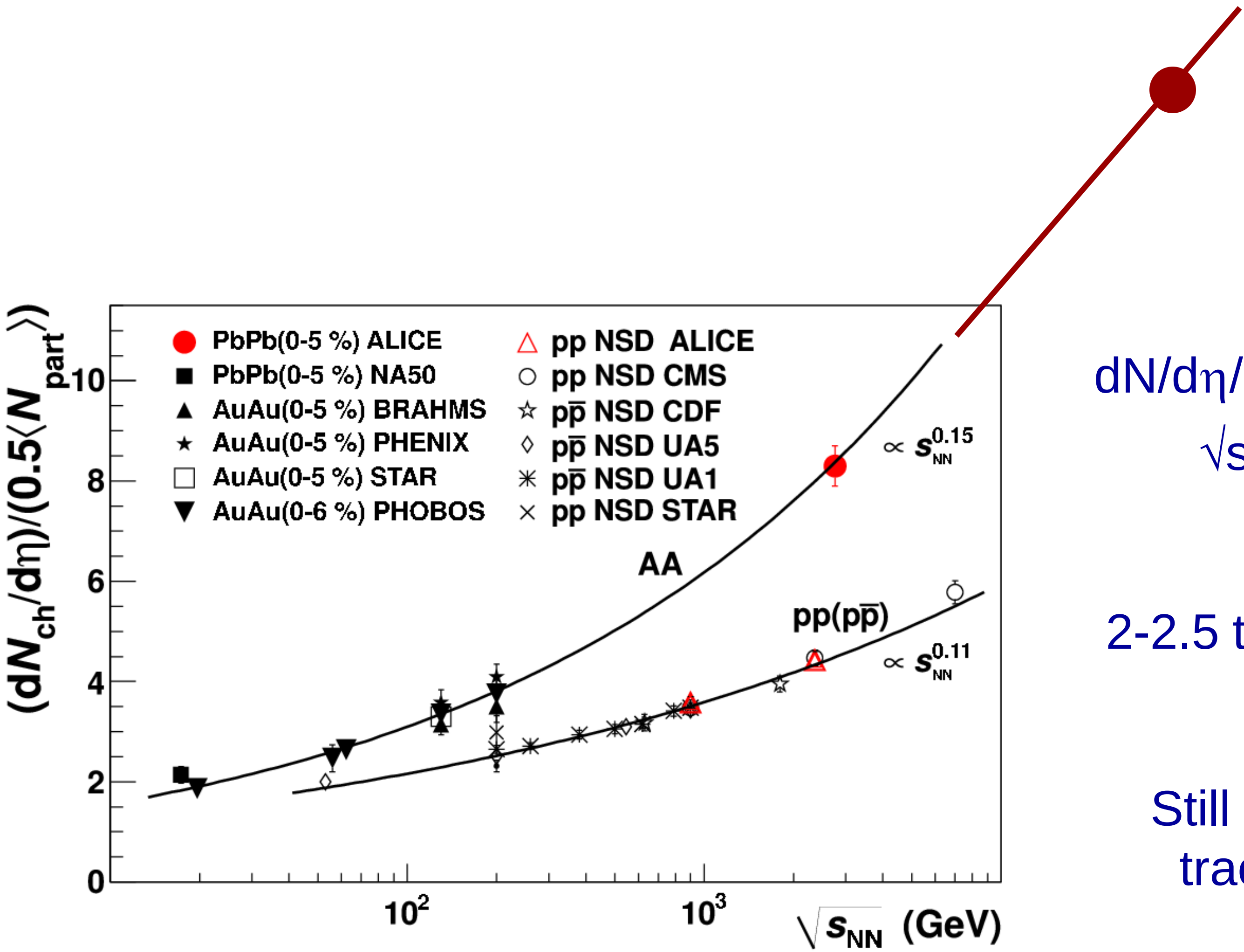
Larger energy:
larger y_{beam}; go to even larger y?

14 TeV: $y_{beam} = 9.61$
100 TeV: $y_{beam} = 11.6$

- Experimental challenges:
  - Large energy/p_T
    - Special mag fields for tracking
    - Less problematic for calorimeters (angle)
  - Large particle density
    - Mostly challenging for calorimeters
  - Small angle:
    - Need conical beam pipe for y >~ 5.5
    - y=5.3 is 1cm/m, factor 100: beam pipe 1mm path length 10cm !

η = 4-5 is a practical limit;
If we want to go higher; need good motivation+preparation

Multiplicity in PbPb



$dN/d\eta/0.5/N_{part}$ = 16-18
$\sqrt{s_{NN}}$ = 40 TeV

2-2.5 times 5.5 TeV

Still within ALICE tracking specs

Summary

- ALICE central barrel tracking:
  - $|\eta| < 0.9$ includes PID, $p_T < 100$ GeV
  - Can probably handle PbPb @ 40 TeV
- Forward 1: Muon arm
  - quarkonia+open heavy flavour
  - $2.5 < \eta < 4$
- Foward 2: FOCAL (under discussion)
  - $\gamma + \pi^0$ (jets, $J/\psi \rightarrow e^+e^-$)
  - $3.2 < \eta < 5.3$

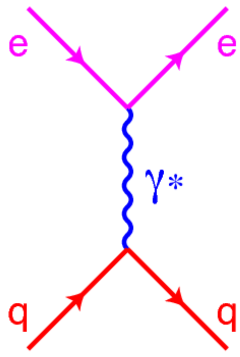
With FHC, reach $x \sim 10^{-6}$ at y=4

Extra slides

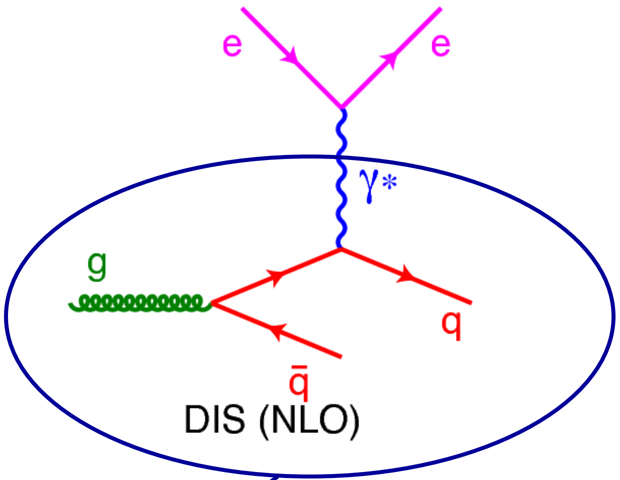
Reminder: how to probe gluon density

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

Gluons from NLO/evolution

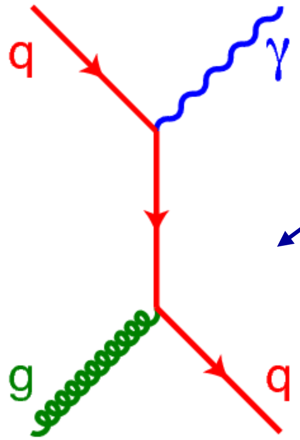


DIS (LO)



DIS (NLO)

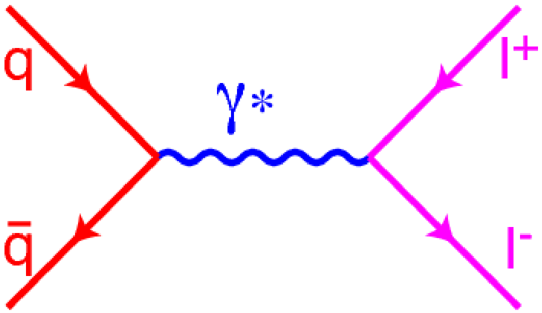
Photon production
in hadronic collisions:
Sensitive to **gluons at LO**



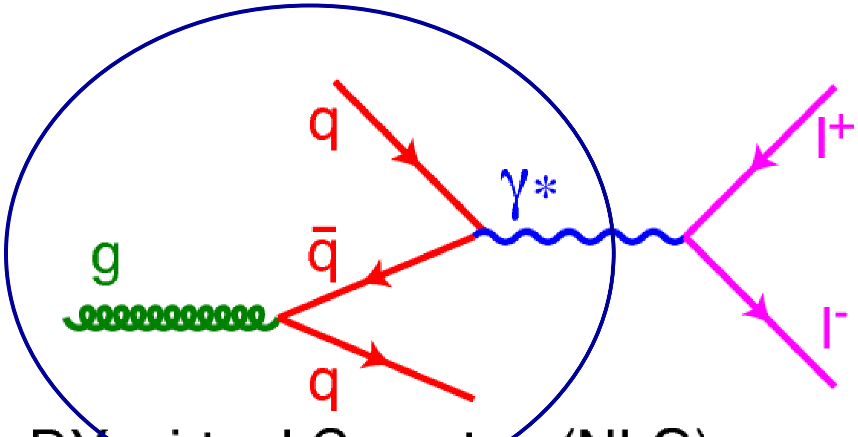
direct-γ, Compton (LO)

Directly related to DIS:
real instead of virtual photon

Virtual photon production: Drell-Yan

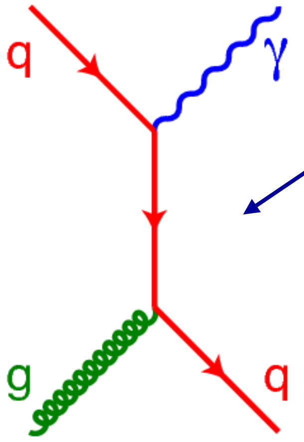


DY (LO)



DY, virtual Compton (NLO)

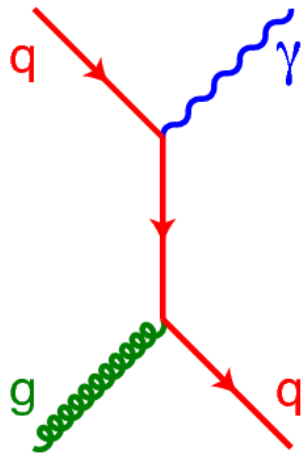
Drell-Yan only sensitive
to gluons at NLO



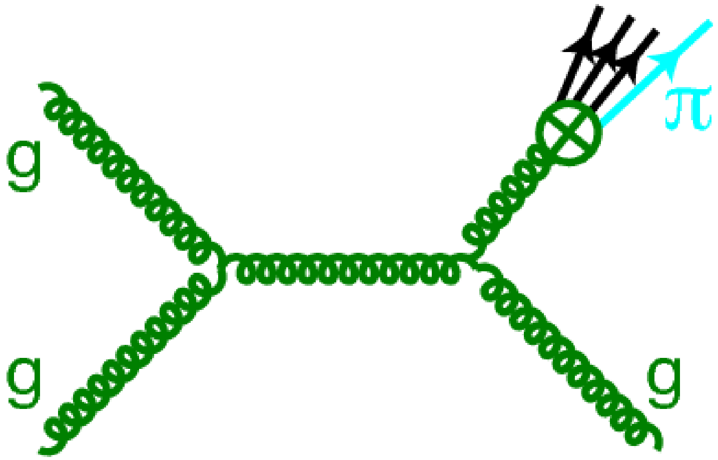
direct-γ, Compton (LO)

DY: small cross section

x ranges; 2→ 2 kinematics



direct-γ, Compton (LO)



light hadron

For gluon density, need Q^2 and x_2:

$$x_2 = \frac{p_T}{\sqrt{s}}\left(e^{-\eta_3} + e^{-\eta_4}\right)$$

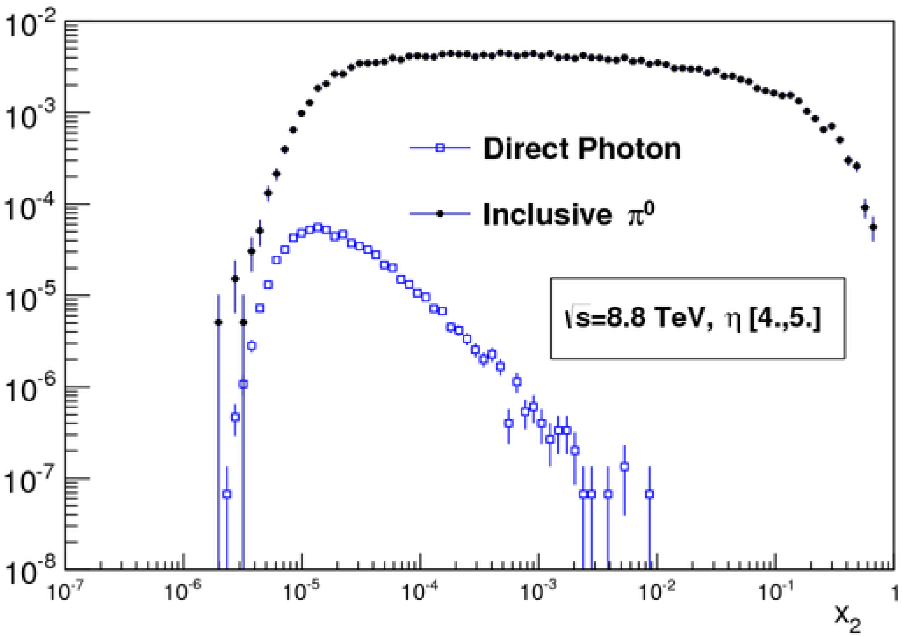
Final state parton $p_T \sim Q$

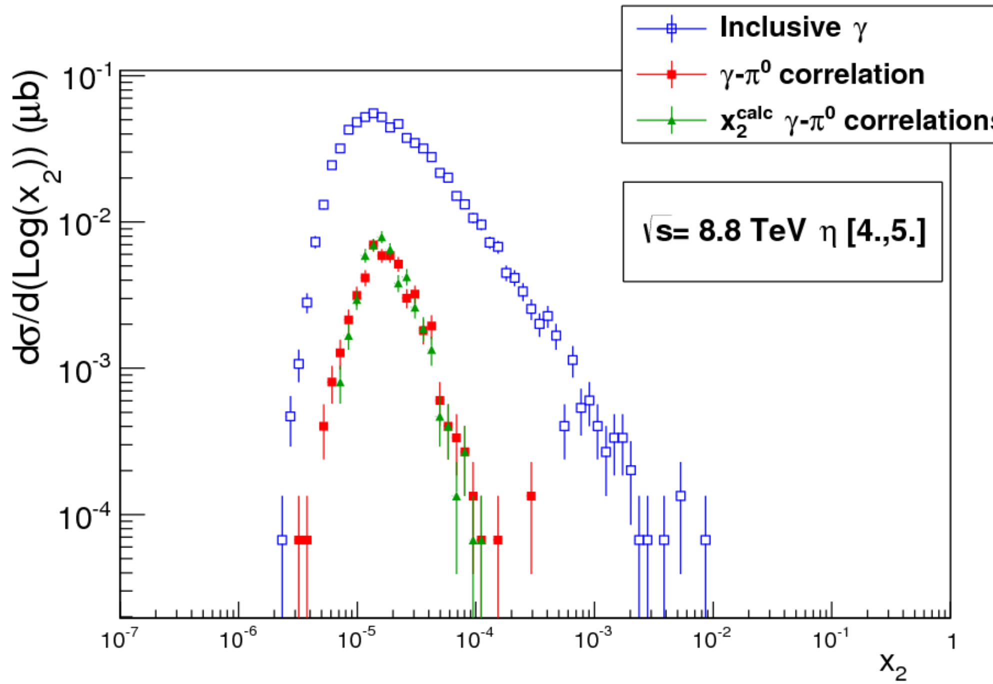
η of final state partons

Photon is a parton

x sensitivity pion vs gamma

PYTHIA simulations





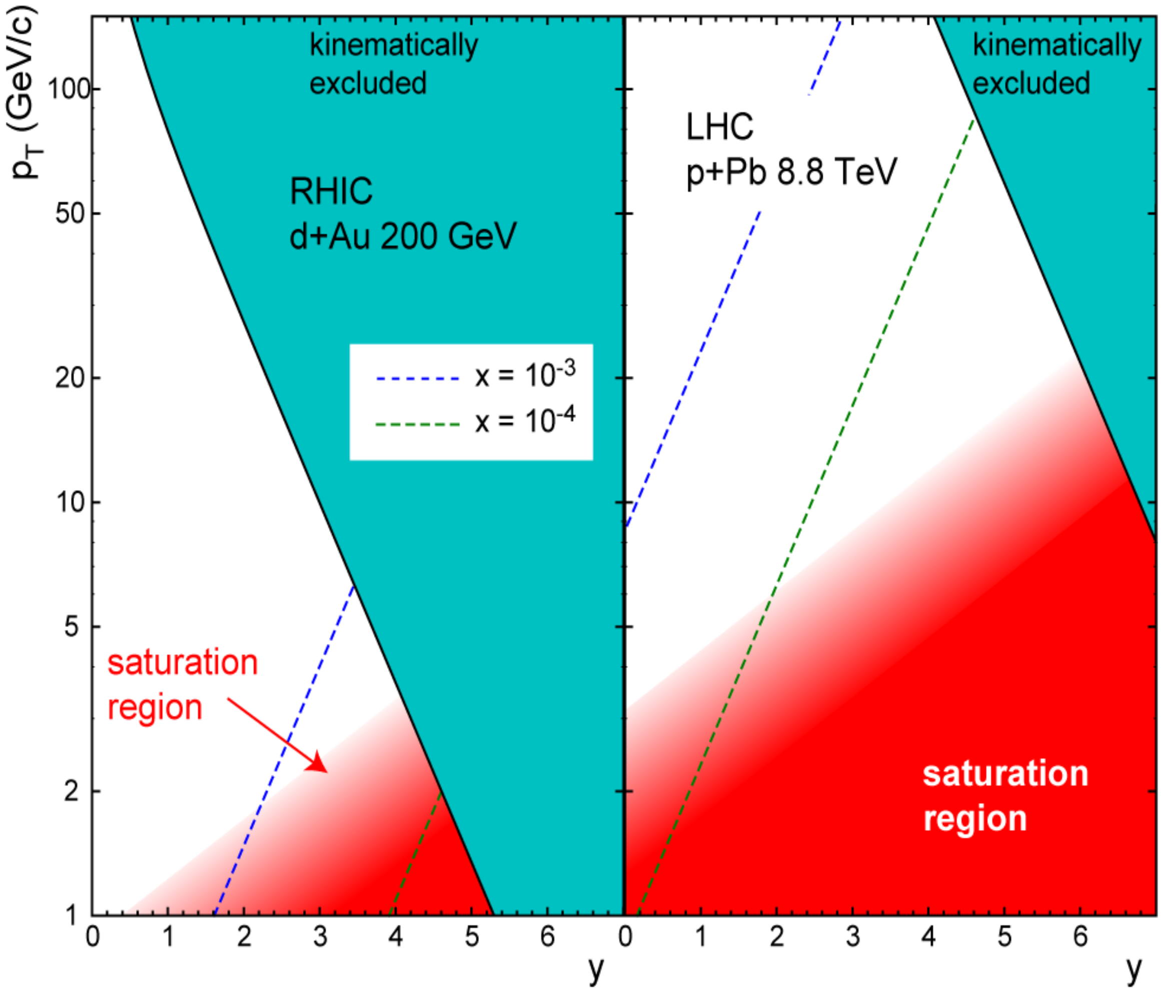
Forward γ much more selective than π^0

γ-π^0 correlations provide additional constraints

Pythia = LO + radiation

NLO effects under study – expect small effect for *isolated* photons

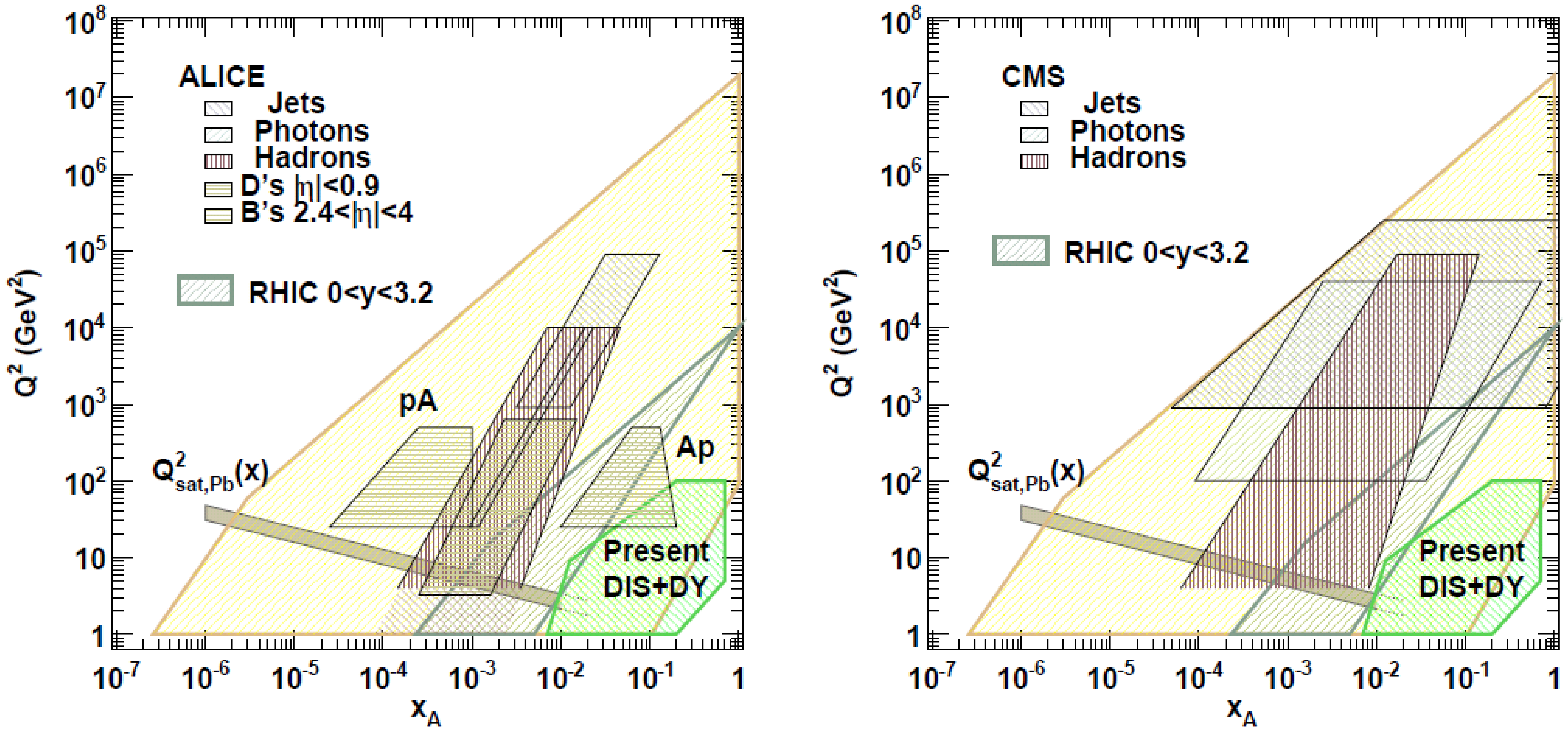
LHC vs RHIC



LHC: $x \sim 10^{-4} – 10^{-5}$ accessible, with $p_T \sim Q \sim 3\text{-}4$ GeV

x ranges for p+A

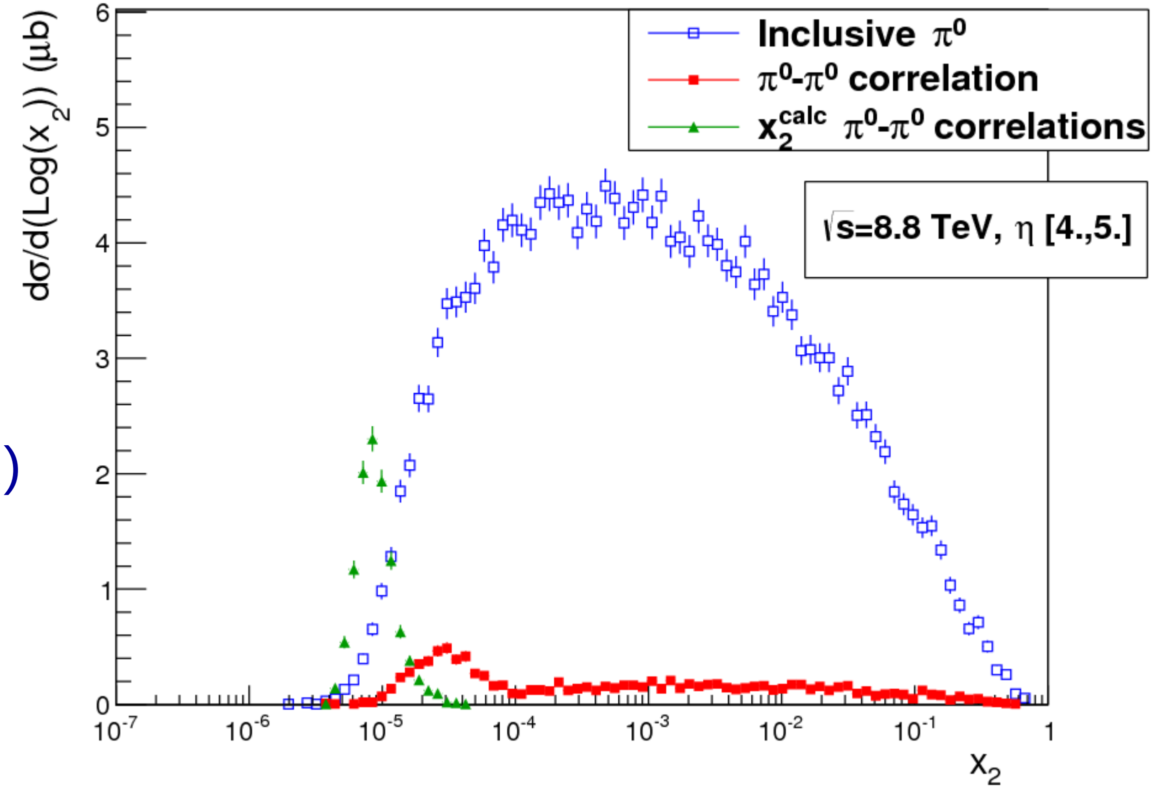
C. Salgado (ed) et al, arXiv:1105.3919



π^0-π^0 correlations: x sensitivity

$$x_2 = \frac{p_T}{\sqrt{s}}\left(e^{-\eta_3} + e^{-\eta_4}\right)$$

π^0-π^0 correlations
more selective
(select both π^0 to be forward)



However: still a long tail to large x
From fragmentation+underlying event