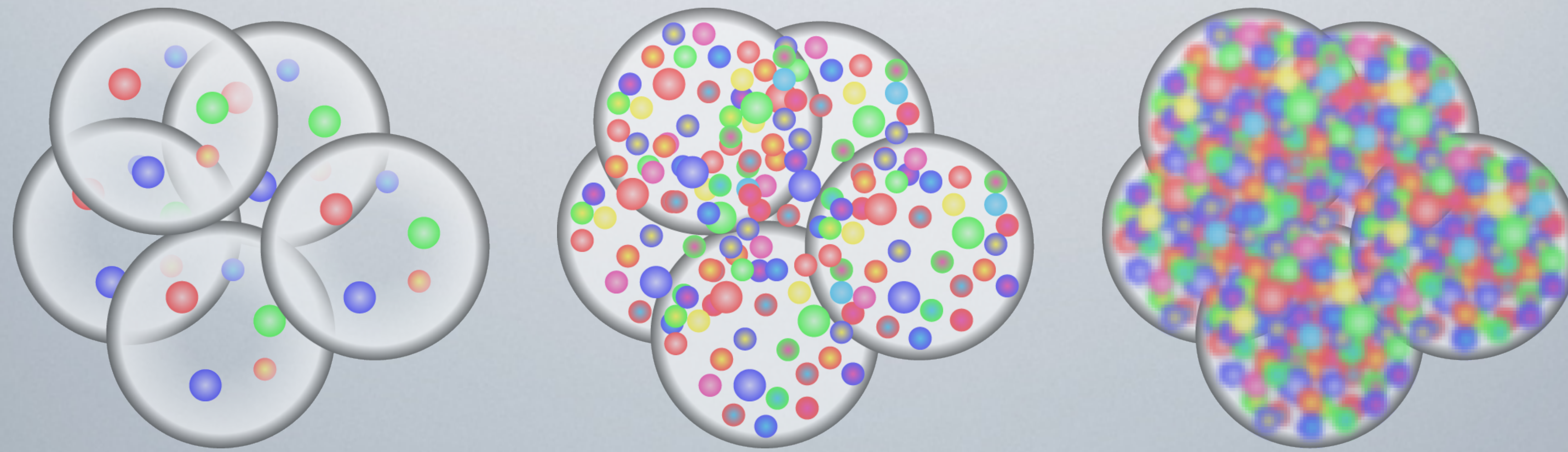

Measurement of forward direct photon production in p–A at LHC with ALICE
–
A probe for nuclear PDFs and saturation

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

DIS16, DESY, Hamburg, April 12, 2016

Outline

- Introduction
  - low-x physics, gluon saturation
  - results from RHIC and LHC
- Direct Photons
- FoCal - an ALICE Upgrade Proposal
  - baseline design: performance studies
  - progress on detector R&D
- Summary

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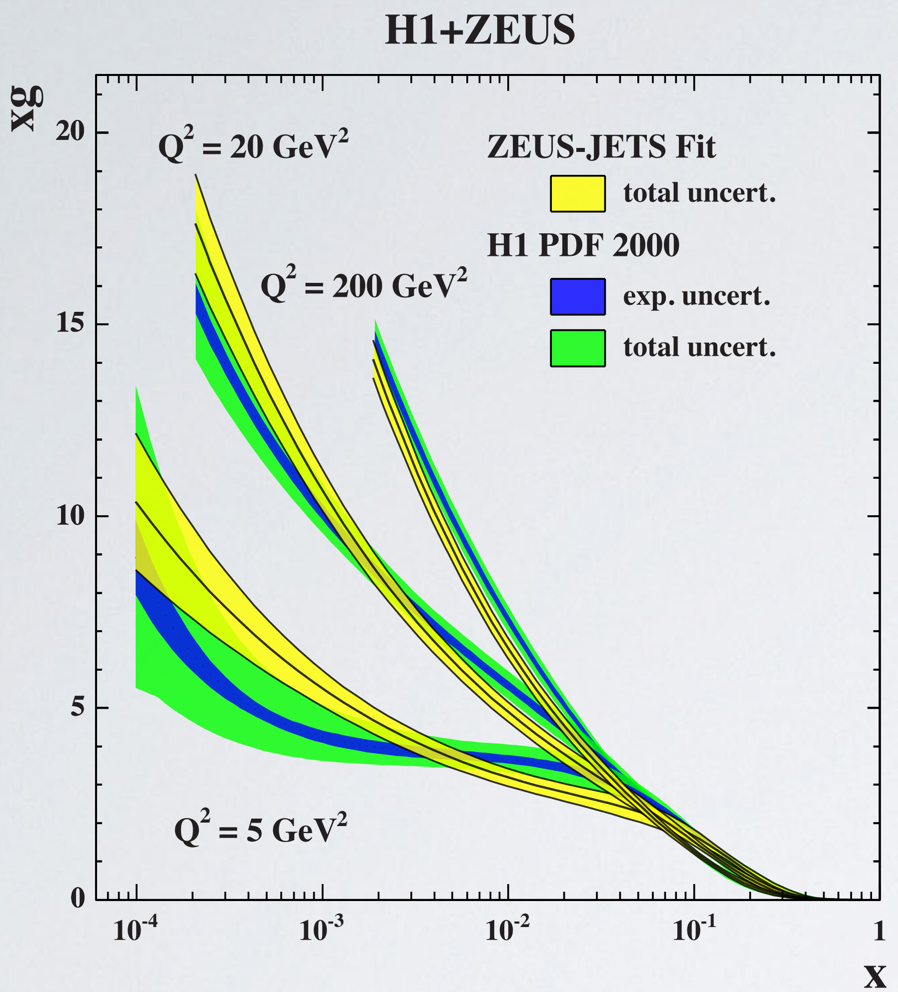
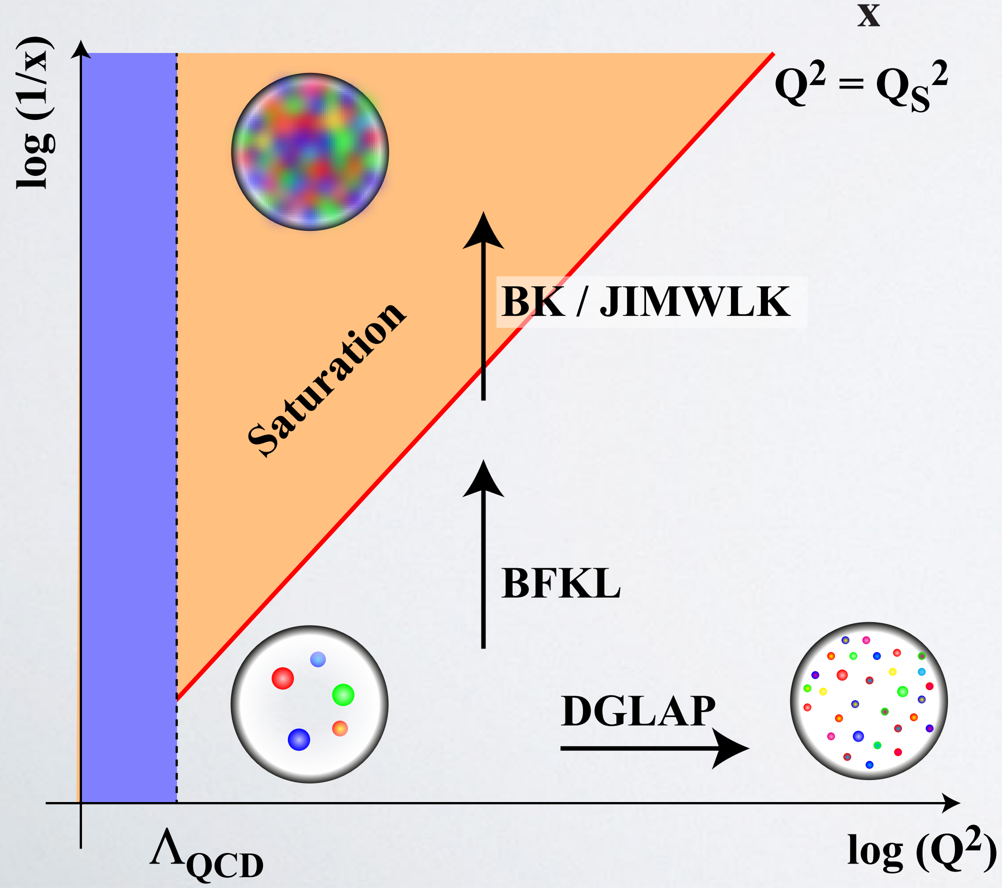
Gluon Saturation



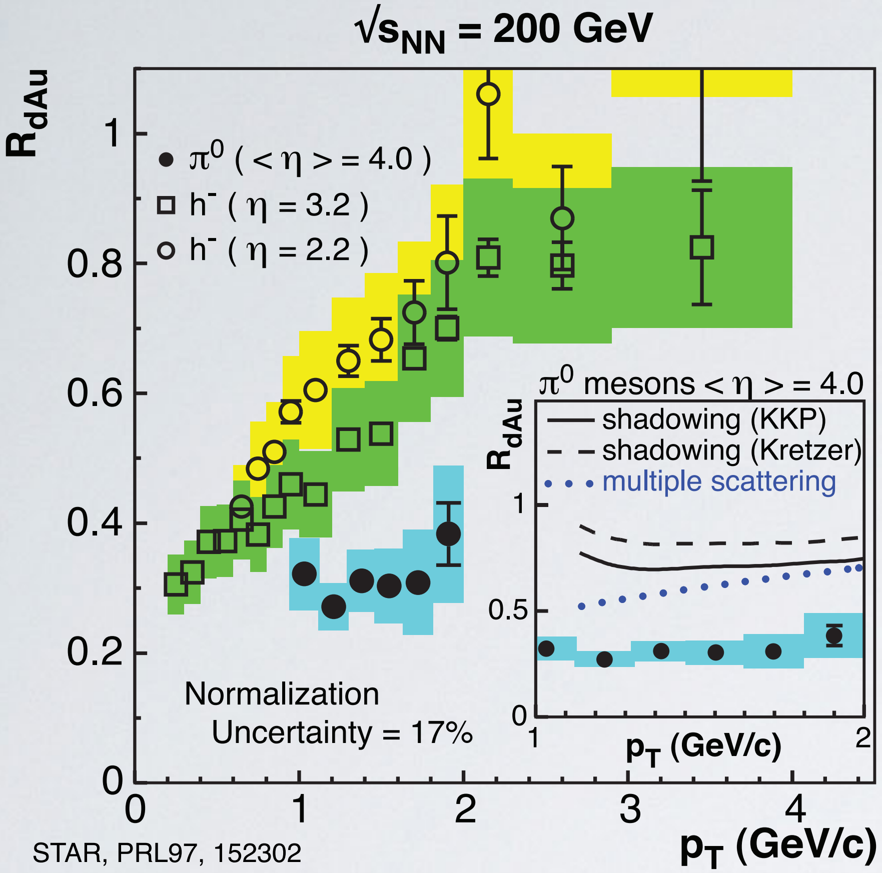


- from evolution equations (DGLAP, BFKL):
- gluon density increases with Q^2 and $1/x$
    - leads to very high gluon density
    - problems with unitarity
- for high density non-linear processes become important
- gluon saturation below saturation scale

$$Q_s^2(x) \approx \frac{\alpha_S}{\pi R^2} xG(x, Q^2) \propto A^{1/3} \cdot x^{-\lambda}$$

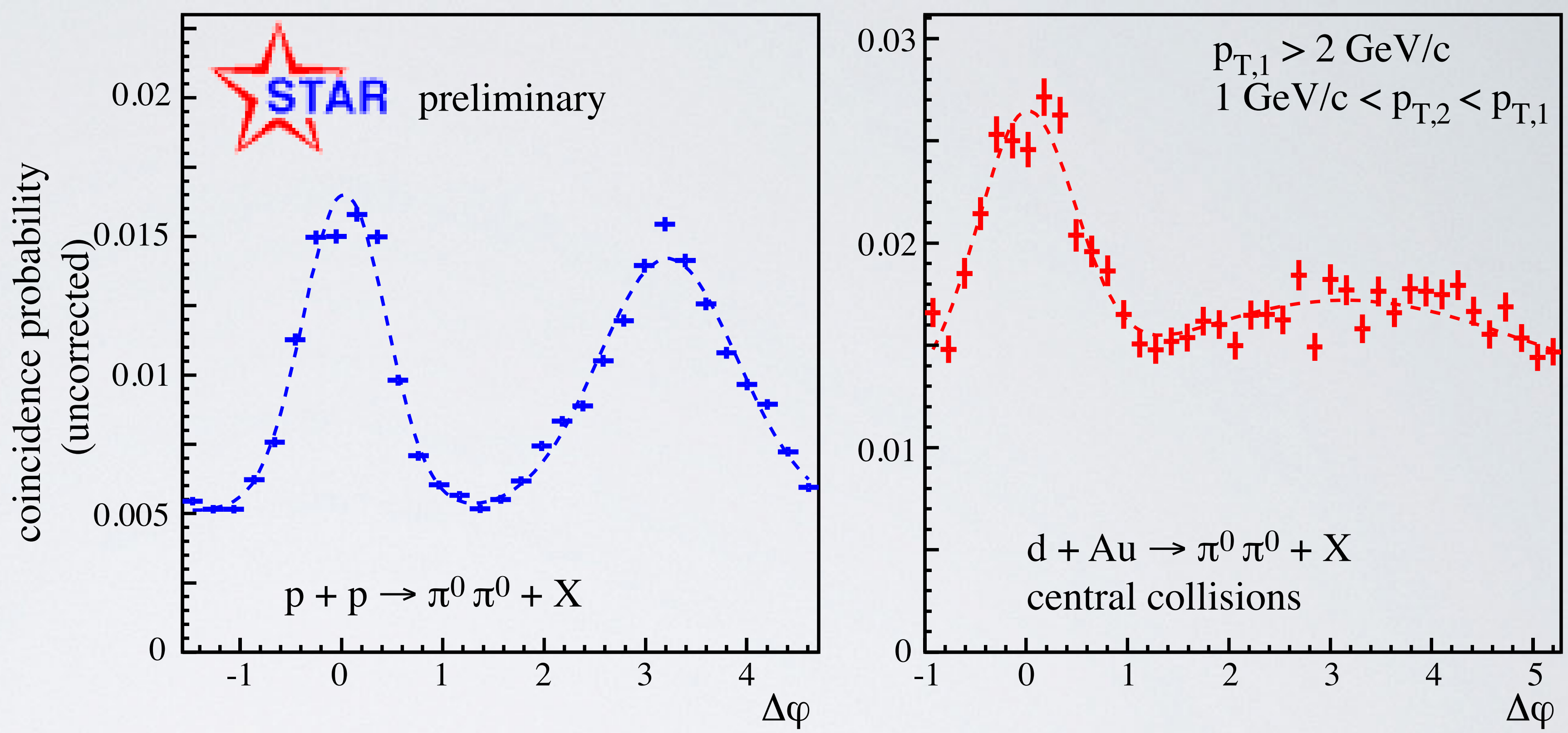
- enhanced in nuclei

Indications from RHIC



STAR, PRL97, 152302

STAR, Braidot, Ogawa et al.



R_{dA}: strong suppression of hadron yield at forward rapidity

di-hadron correlations: broadening/suppression of away-side peak in dAu

$$R_{dA} = \frac{dN/dp_T(dA)}{< N_{coll}(dA) > dN/dp_T(pp)}$$

- qualitatively consistent with CGC, but ...
  - very low p_T, close to kinematic limit, hadron observable (final state interactions)!
- extend p_T and y range (not possible at RHIC)

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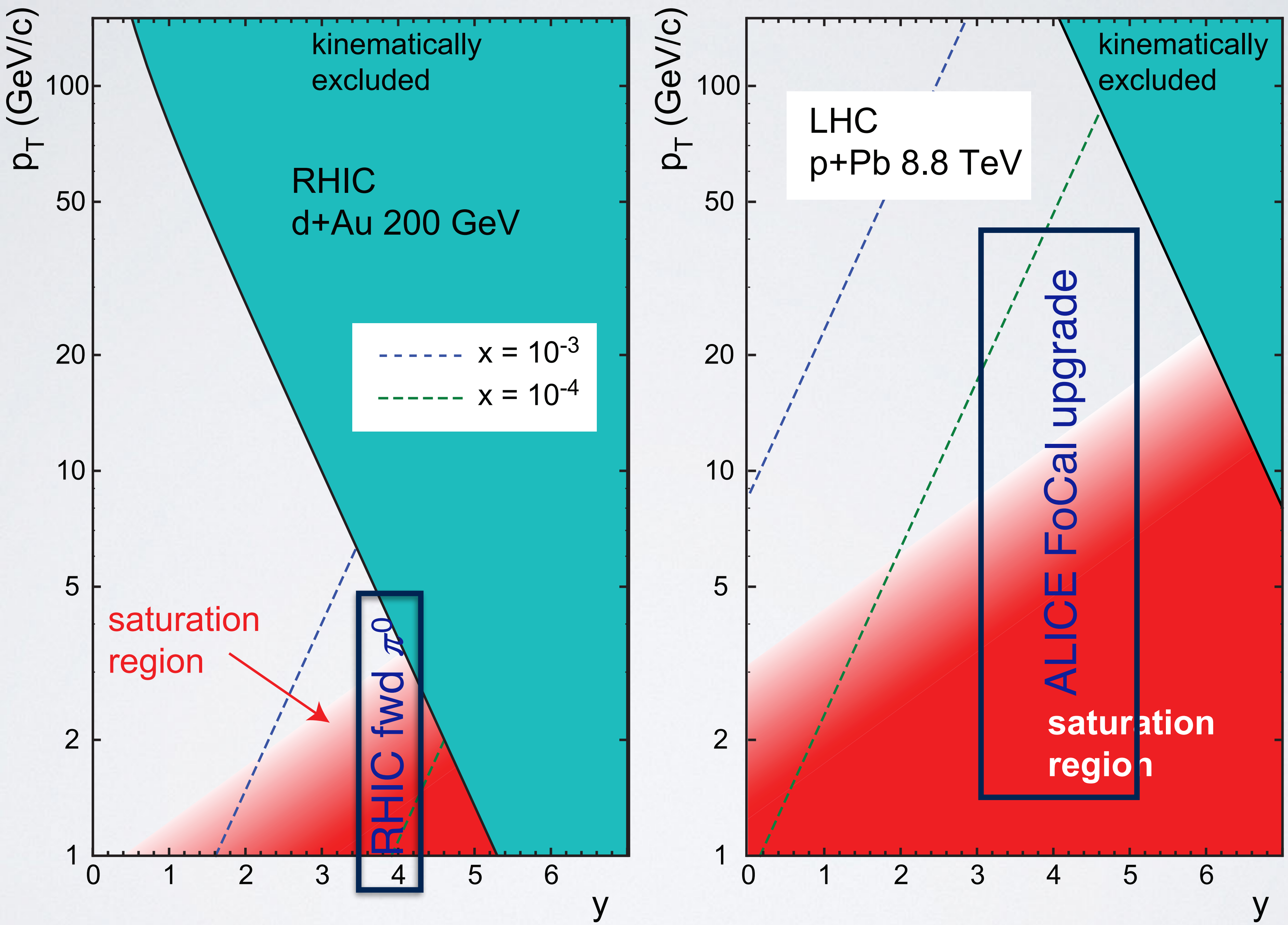
Forward measurements: RHIC vs LHC



RHIC: low p_T, kinematic limit at $p_T \approx 5$ GeV

LHC: $x = 10^{-4}$-10^{-5} accessible with $p_T \approx Q \approx 3$-5 GeV

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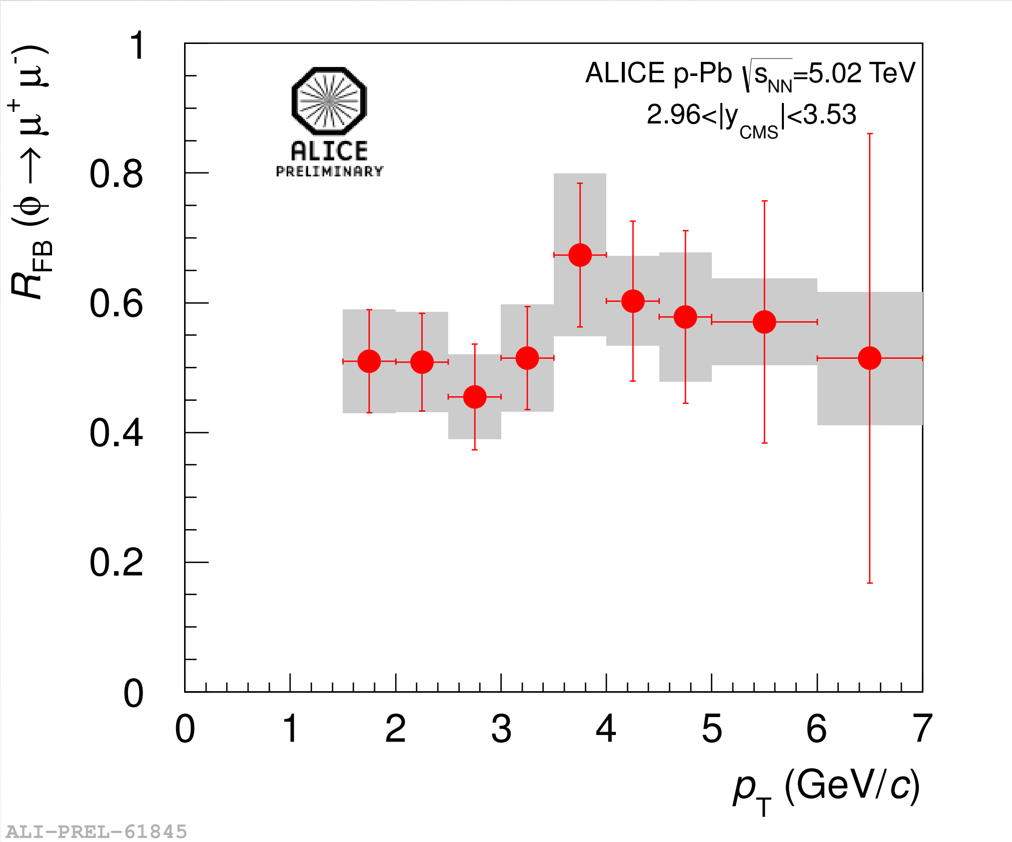
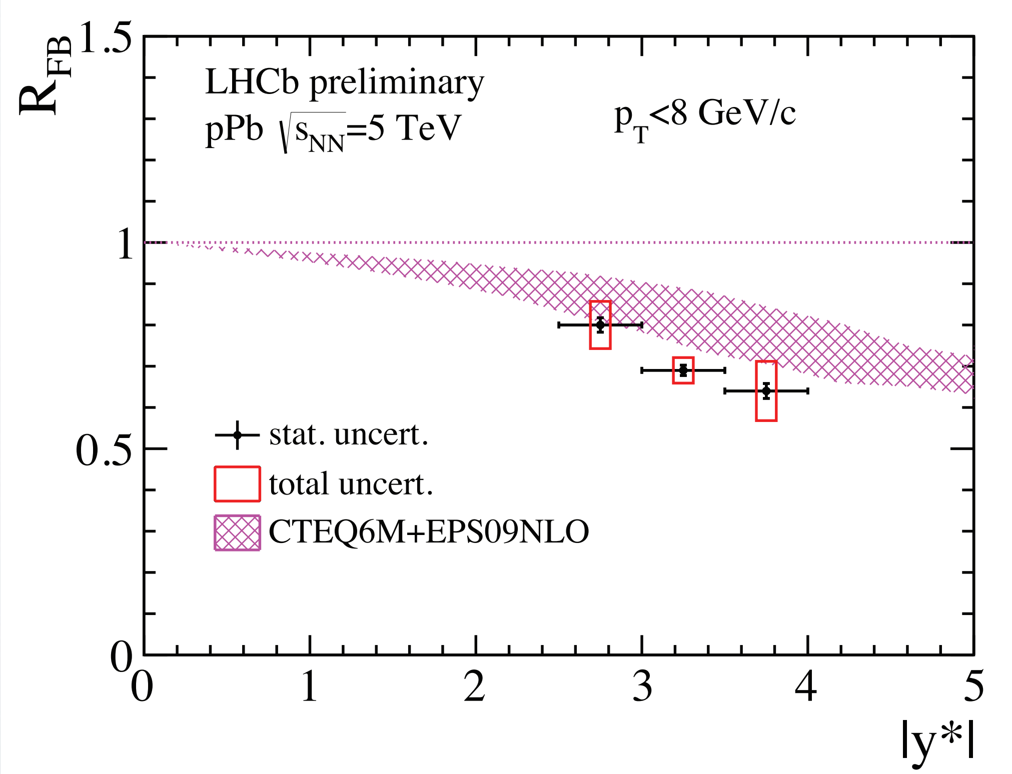
Results from p-Pb at LHC (1)



LHCb-CONF-2016-003



- forward/backward ratio R_{FB}

$$R_{FB} = \frac{dN/dp_T(\mathrm{p-going})}{dN/dp_T(\mathrm{Pb-going})}$$

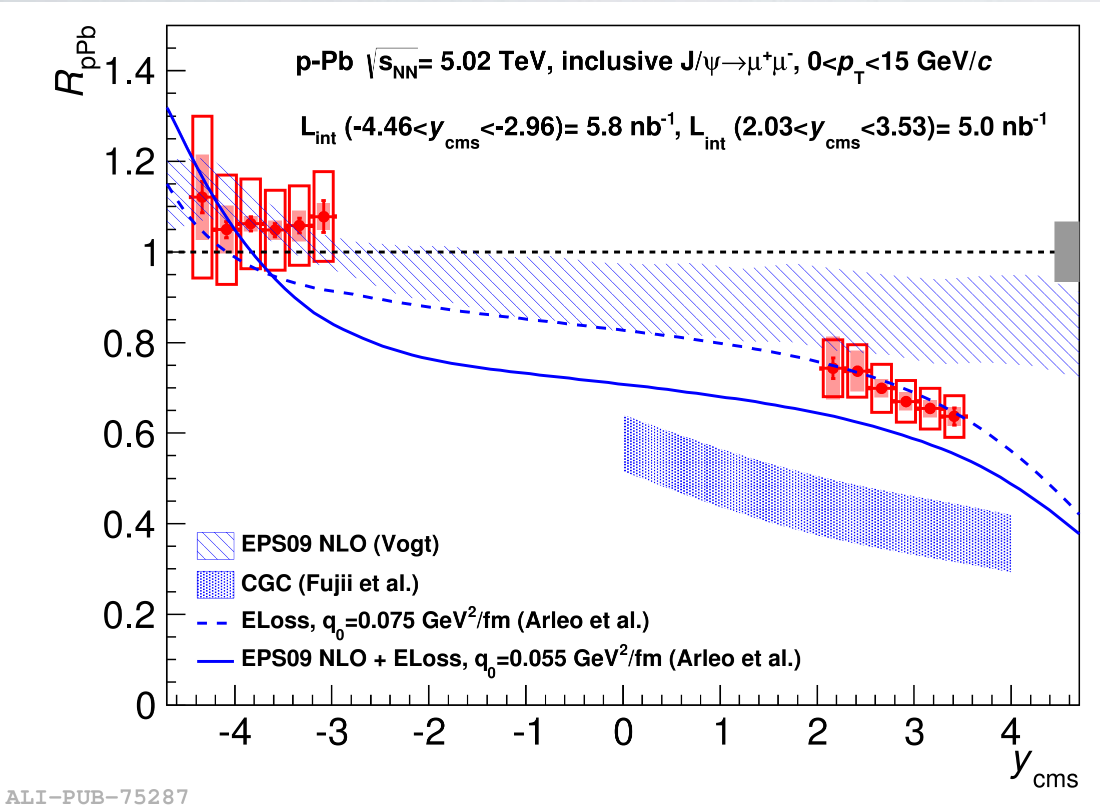
  for ϕ**-mesons** in ALICE (dimuons) and for open charm in LHCb

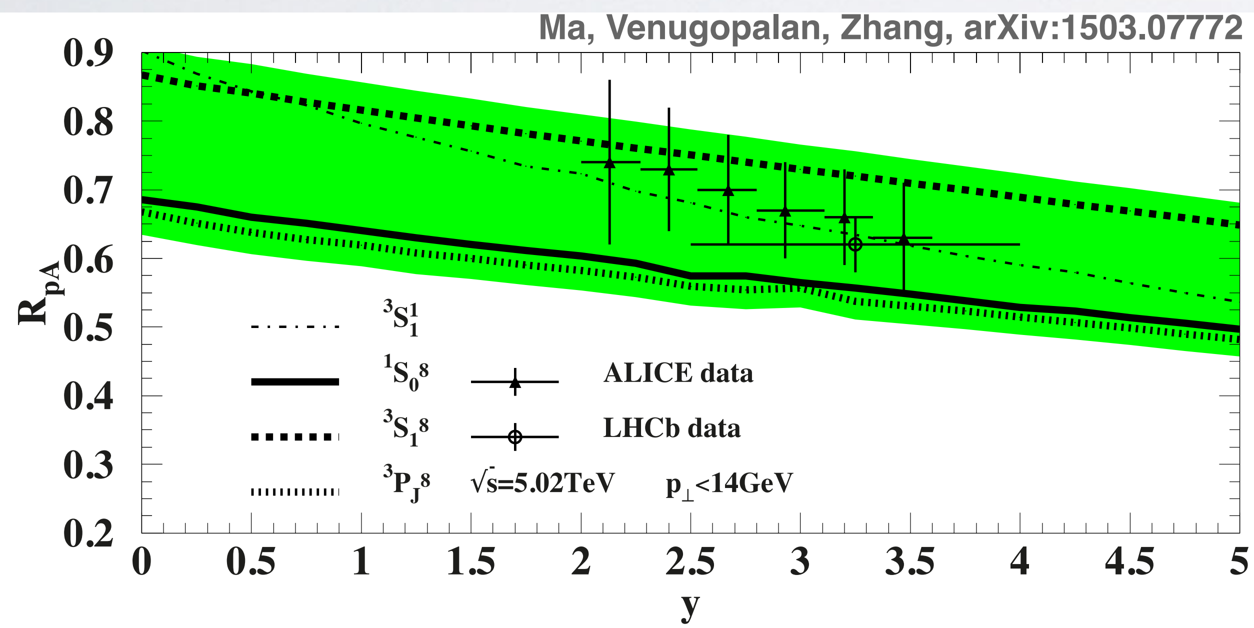
- ϕ strongly suppressed at forward rapidity
  - interpretation unclear

- prompt D^0 suppressed
  - comparison with shadowing (EPS09): consistent, but data slightly more suppressed

Results from p-Pb at LHC (2)

ALICE, JHEP02 (2014) 073





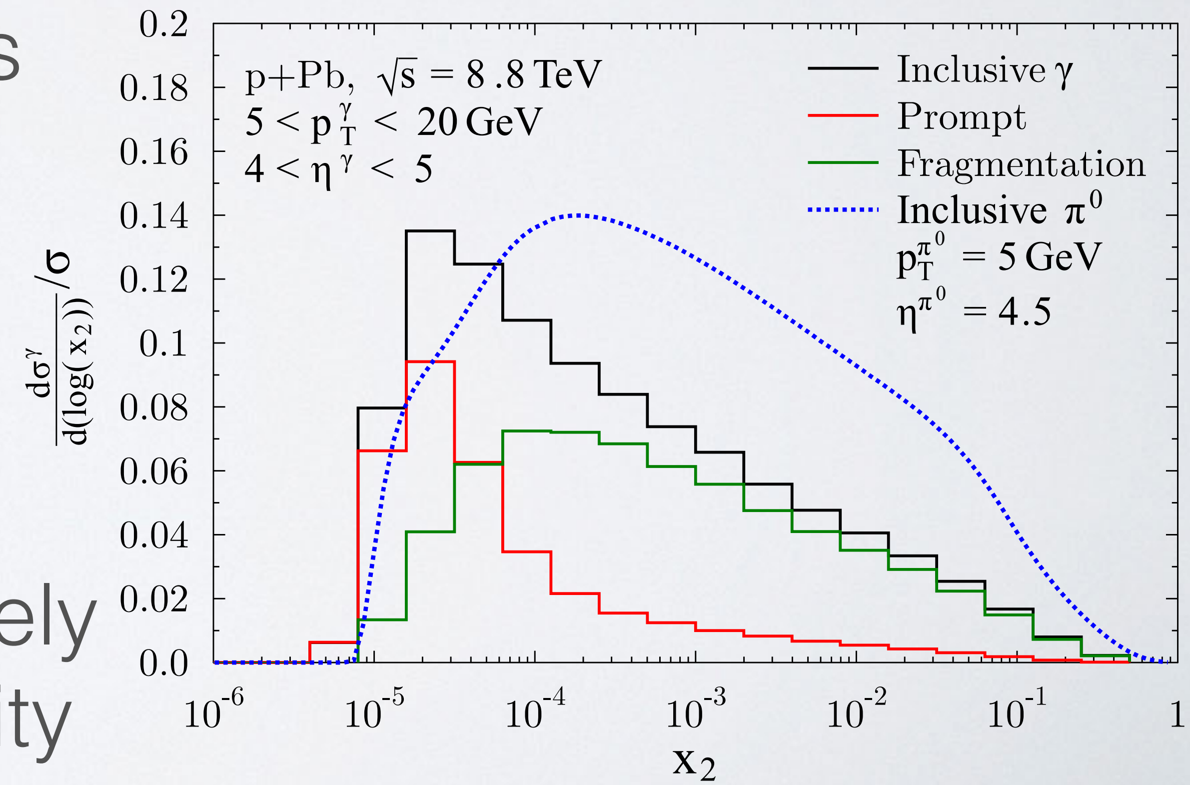
$$R_{pA} = \frac{dN/dp_T(pA)}{< N_{coll}(pA) > dN/dp_T(pp)}$$

- nuclear modification factor R_{pPb} for **charmonium**
- J/ψ suppressed at forward rapidity
  - consistent with shadowing (EPS09)
  - not described by one CGC calculation (state of the art?)
- description by CGC
  - needs refined calculations
  - uncertainties due to population of different quantum states
- not conclusive

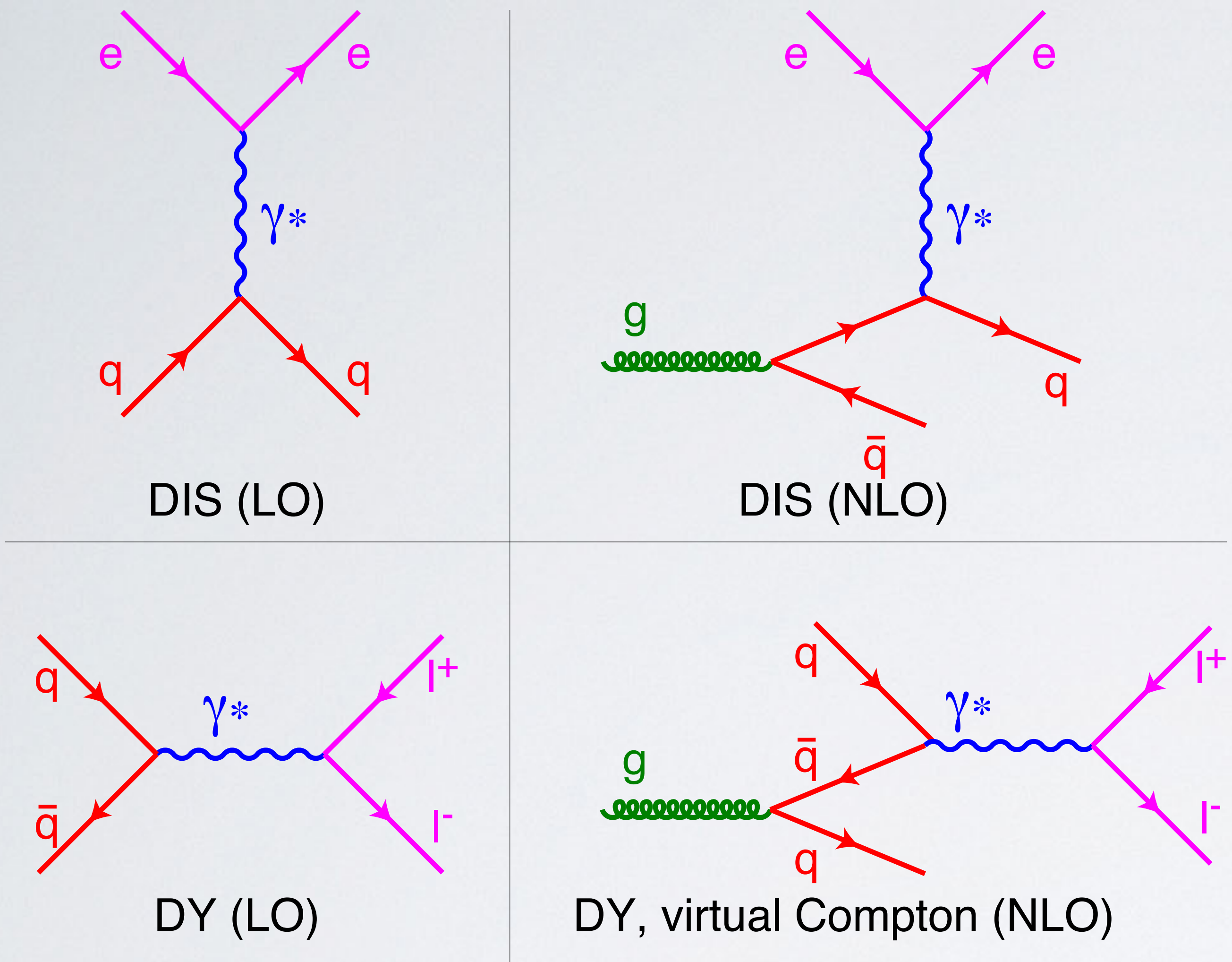
Signals of Saturation?

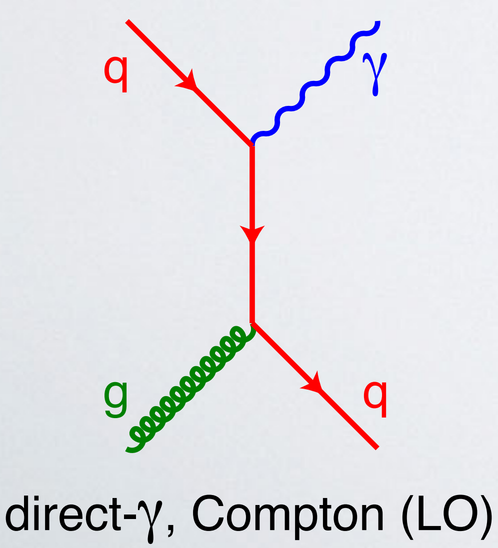
- interpretation of hadronic observables remains inconclusive
  - final state modifications in p–A collisions?
  - production process not fully understood for many hadrons
  - kinematic relation to Bjorken-x uncertain (e.g. fragmentation)
- cleaner observables: EM probes (direct photons, Drell-Yan)
  - 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

NLO pQCD calculations with shadowing (EPS09)
Helenius, Eskola, Paukkunen, arXiv:1406.1689



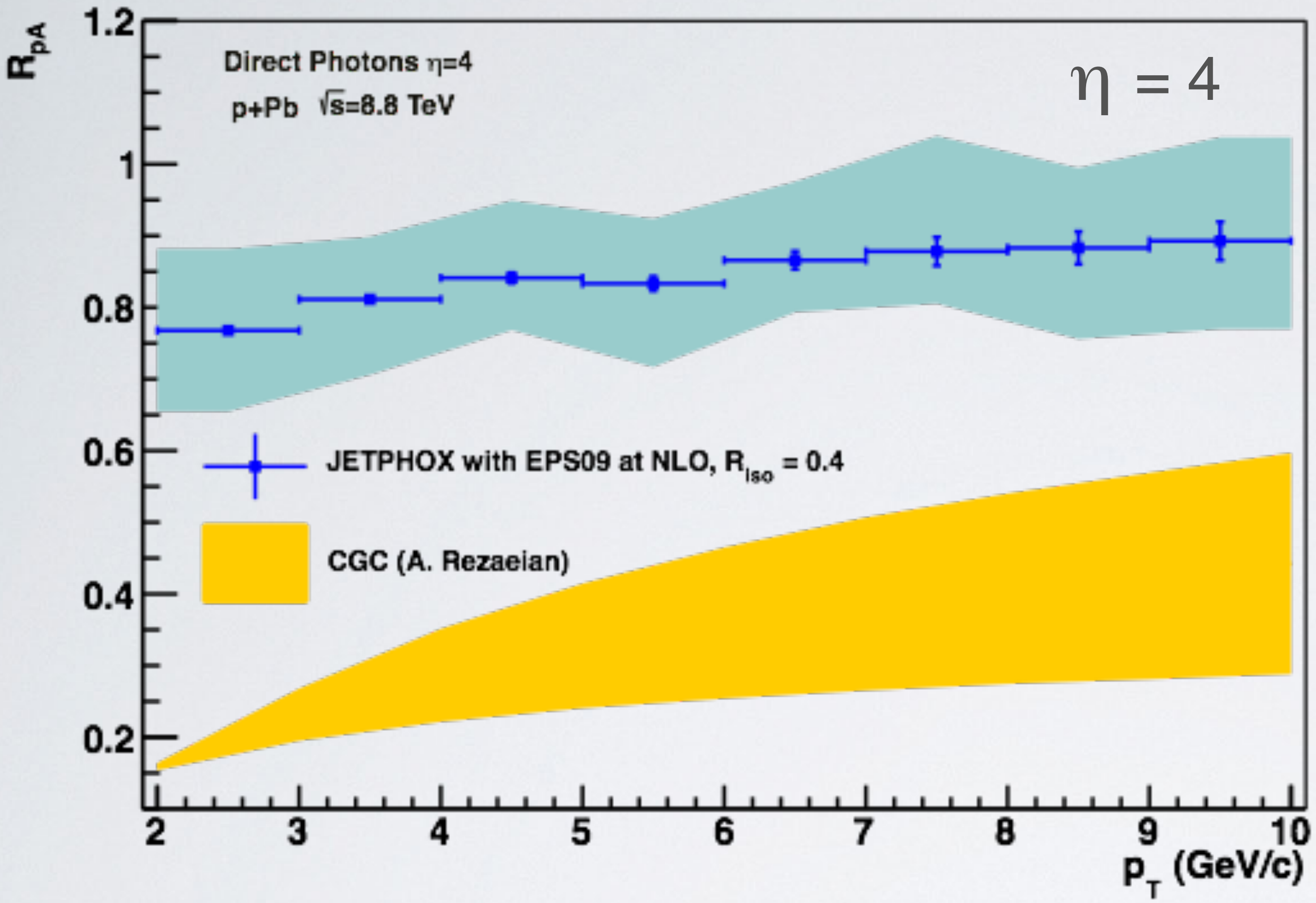
Electromagnetic Processes





- DIS and Drell-Yan are equivalent processes
  - crossing symmetry
  - sensitivity to gluons only at NLO
    - e.g. virtual qg-Compton
- main disadvantage of DY: very low cross section
  - not accessible in pA
- **real photons: sensitivity to gluons at LO, clear kinematic relation**
  - higher order corrections?

nPDF/DGLAP vs CGC



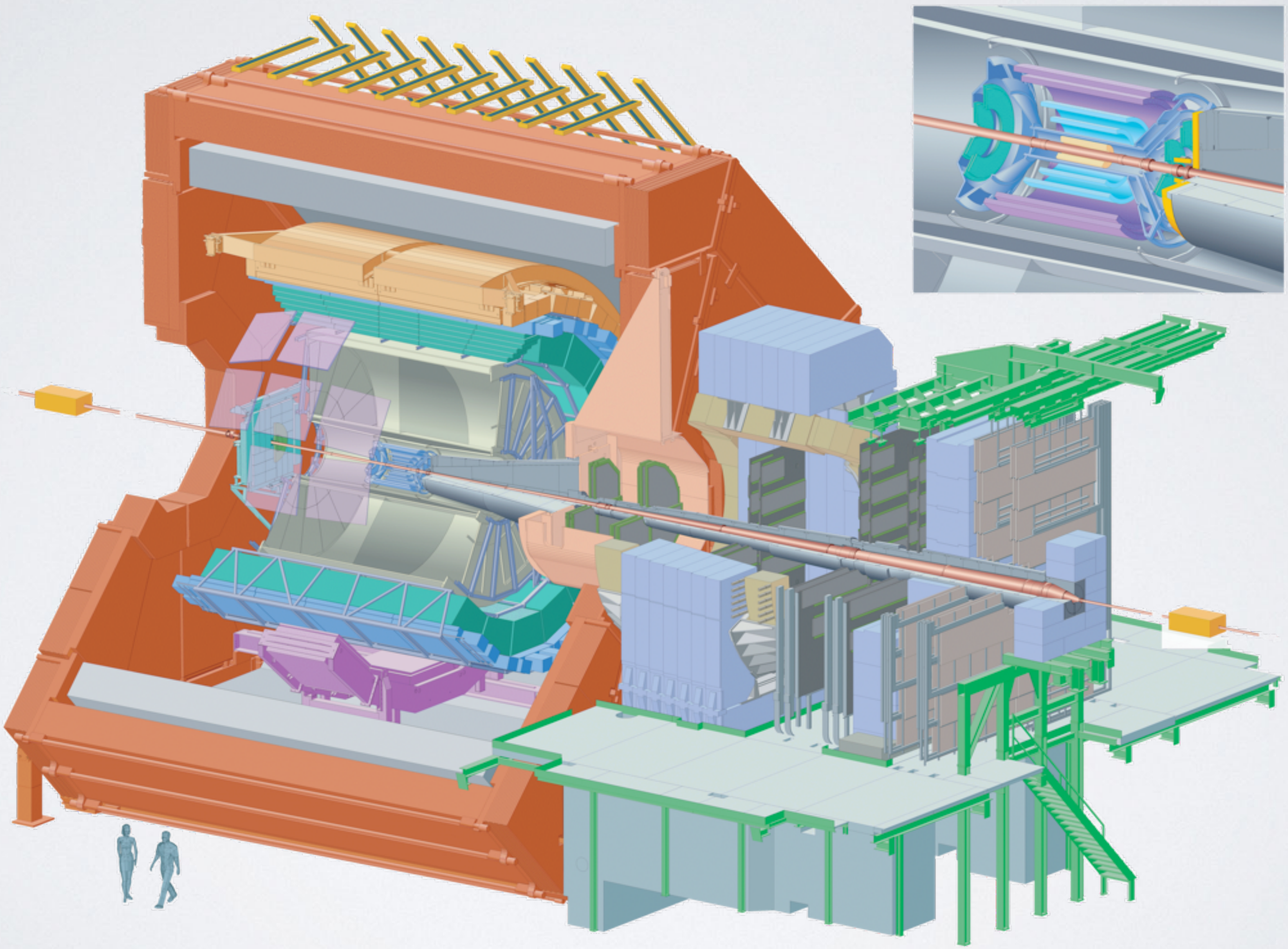
two scenarios for forward γ production in p+A at LHC:

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

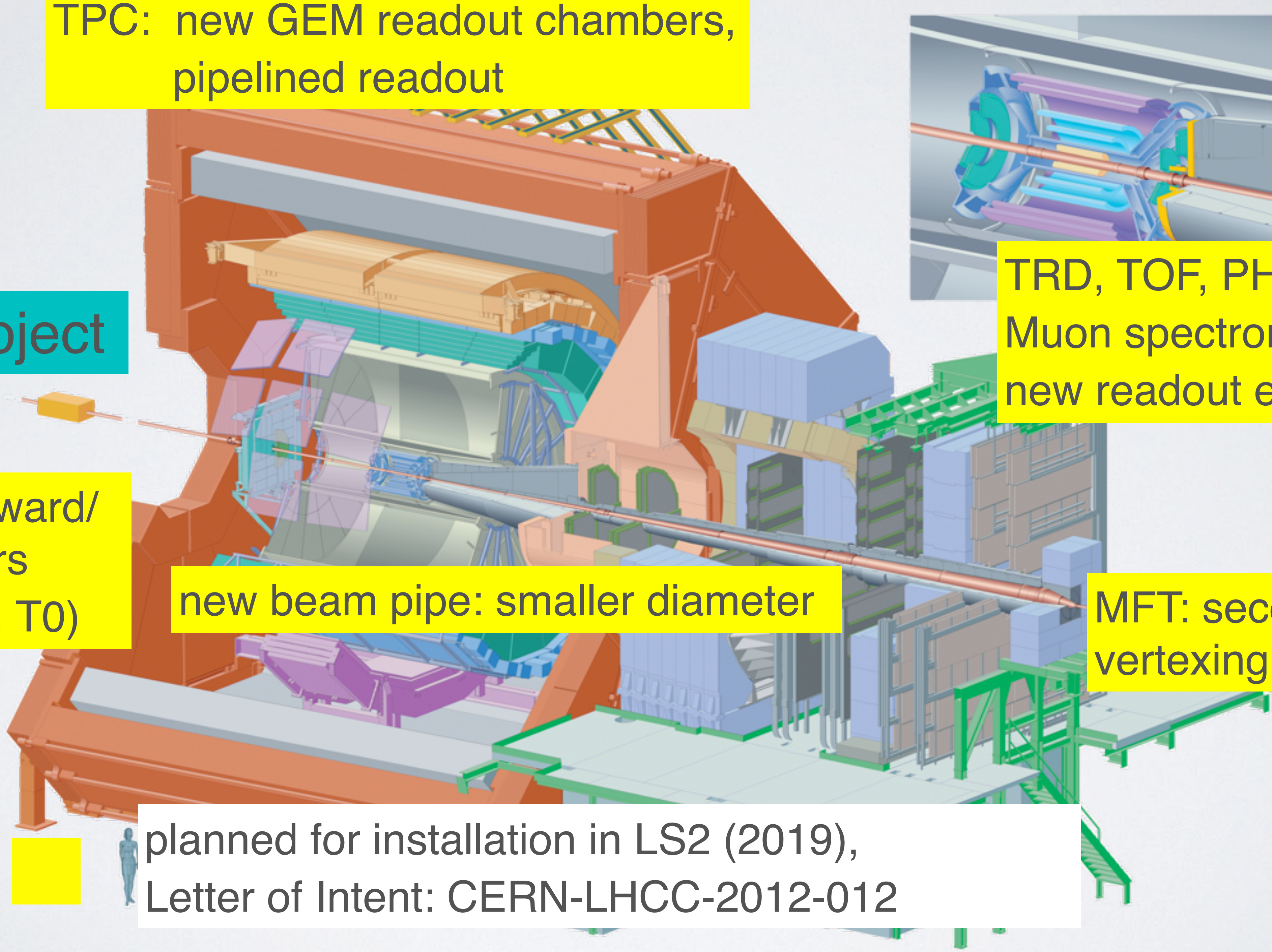
Rezaeian, PLB 718, 1058

- strong suppression in direct γ R_{pA}
  - clean signal for isolated photons
- signals expected at forward η, low-intermediate p_T

ALICE Detector



ALICE Detector & Upgrades



new ITS: high resolution,
low material budget

TPC: new GEM readout chambers,
pipelined readout

FoCal project

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

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

new beam pipe: smaller diameter

MFT: secondary
vertexing for muons

planned for installation in LS2 (2019),
Letter of Intent: CERN-LHCC-2012-012

under internal review

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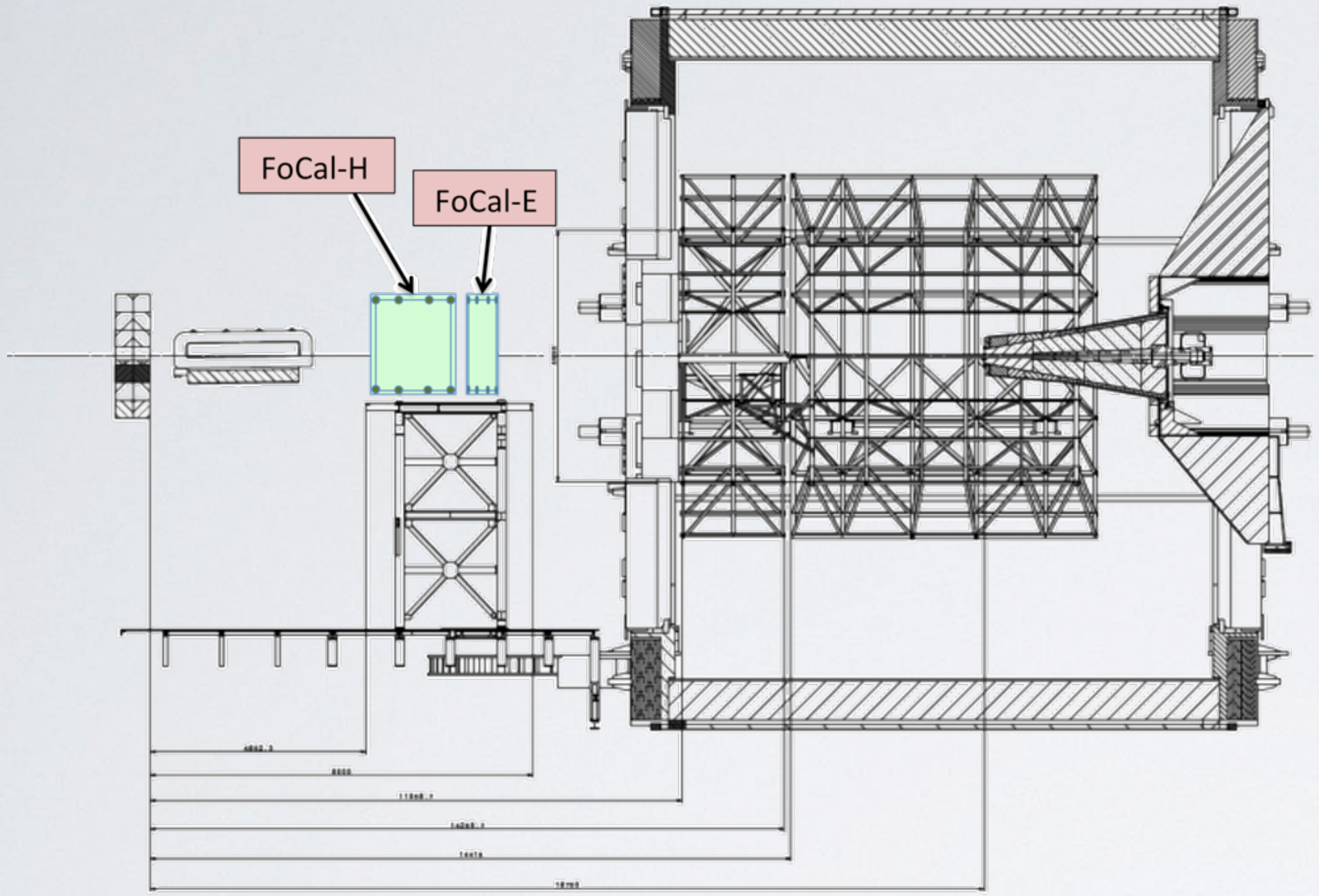
FoCal in ALICE



electromagnetic calorimeter for γ and π^0 measurement

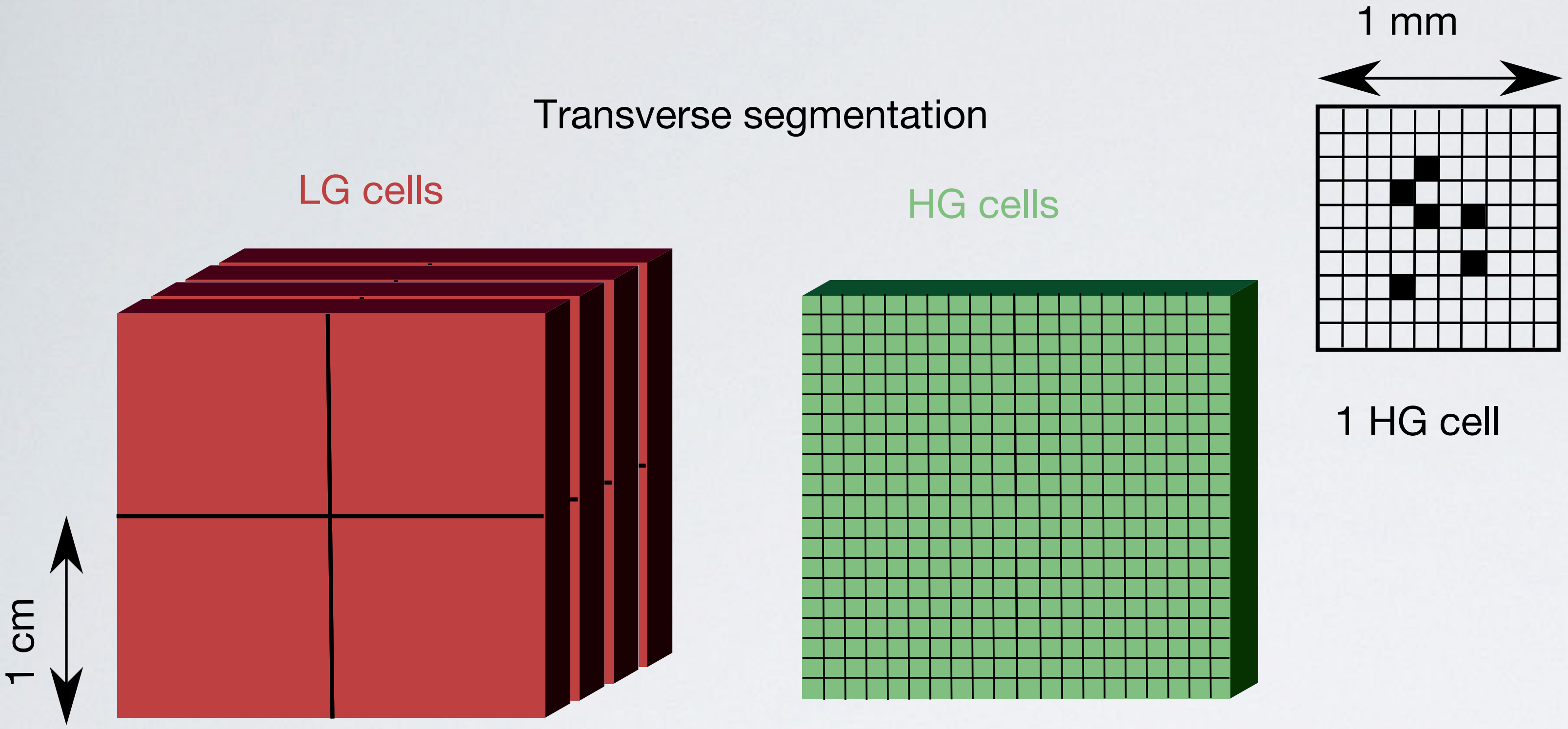
preferred scenario:

- at $z \approx$ 7m (outside magnet)
  3.3 < η < 5.3
  (space to add hadr. calorimeter)

under internal discussion
possible installation in LS3

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

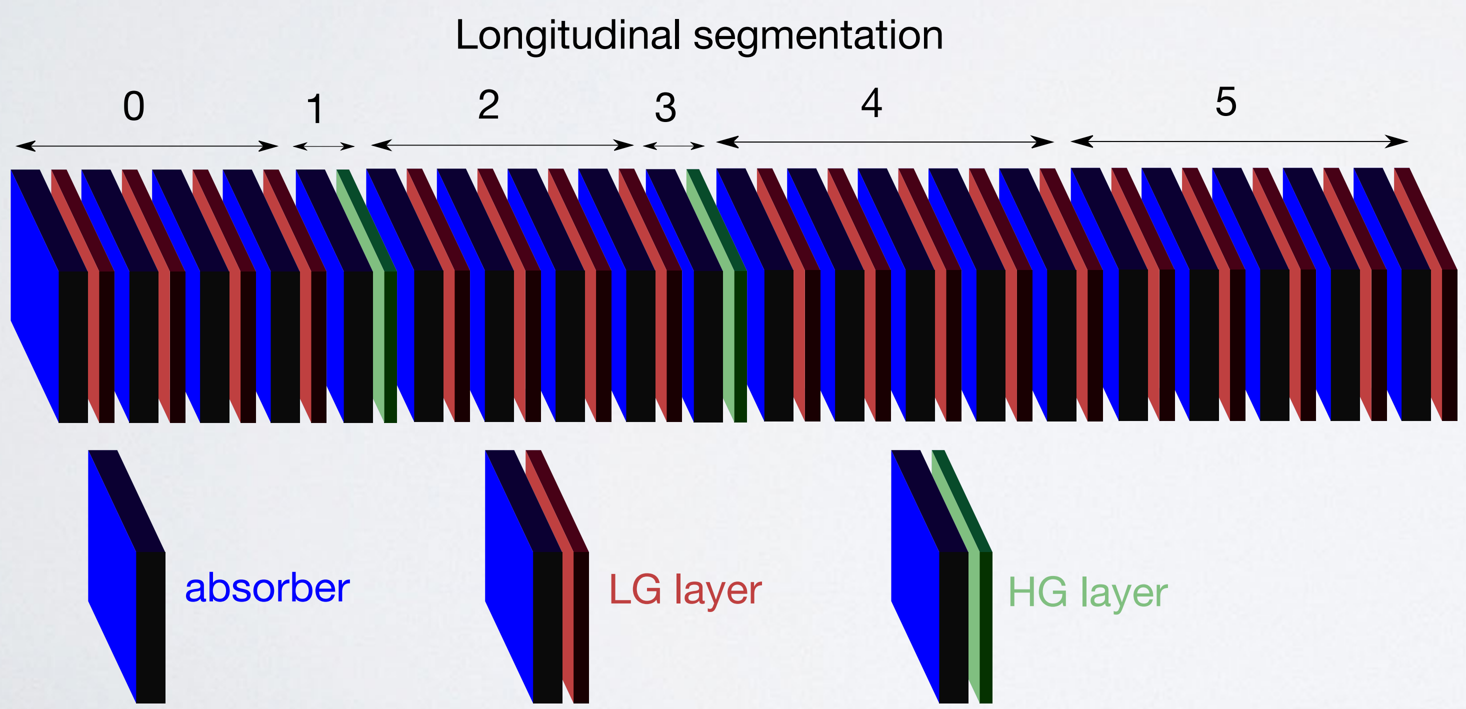
FoCal Strawman Design



studied in performance simulations:

24 layers: W (3.5mm ≈ 1 X_0) + Si-sensors (2 types)

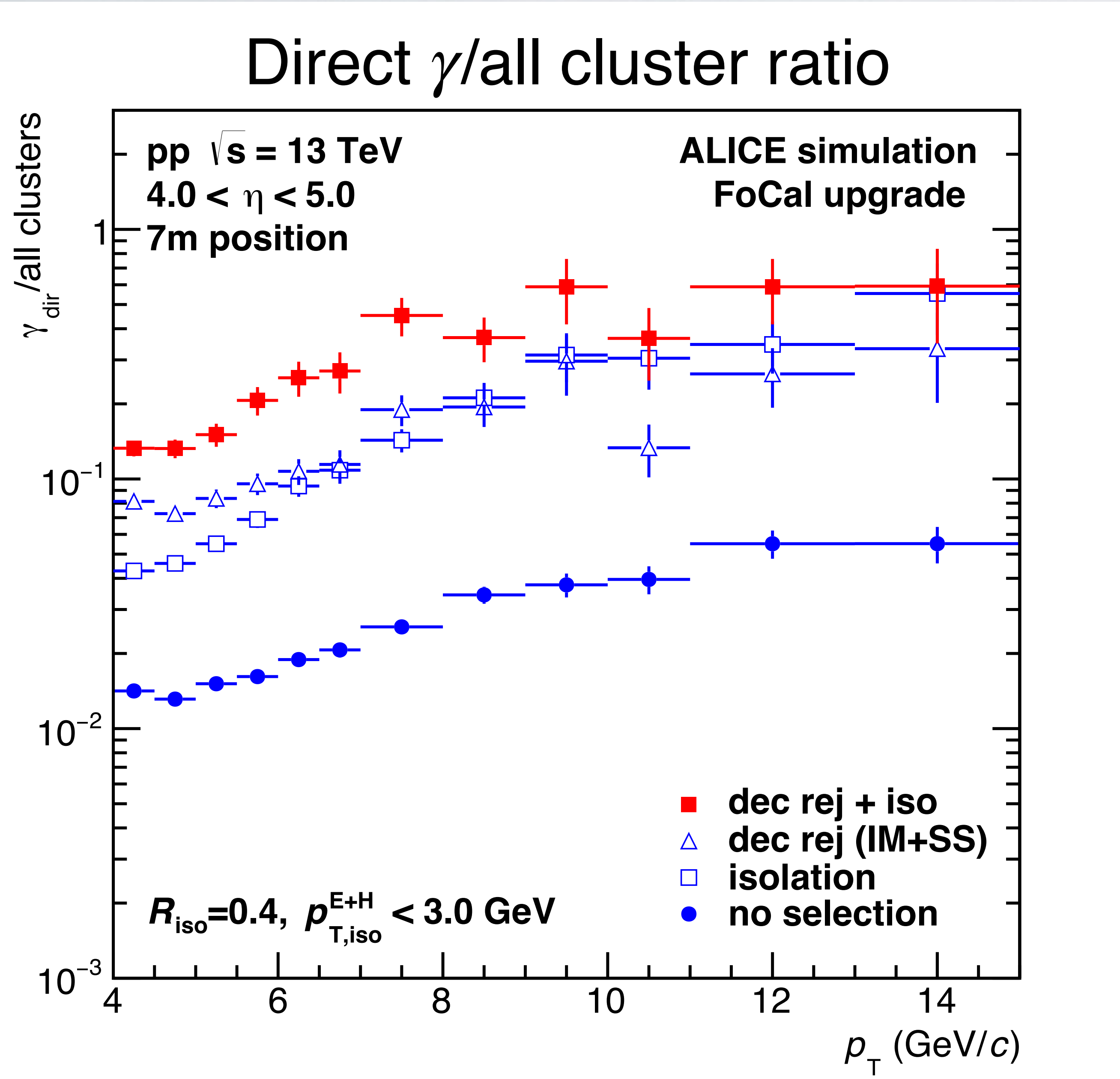
- low granularity (LG), Si-pads
- high granularity (HG), pixels (e.g. CMOS-MAPS)

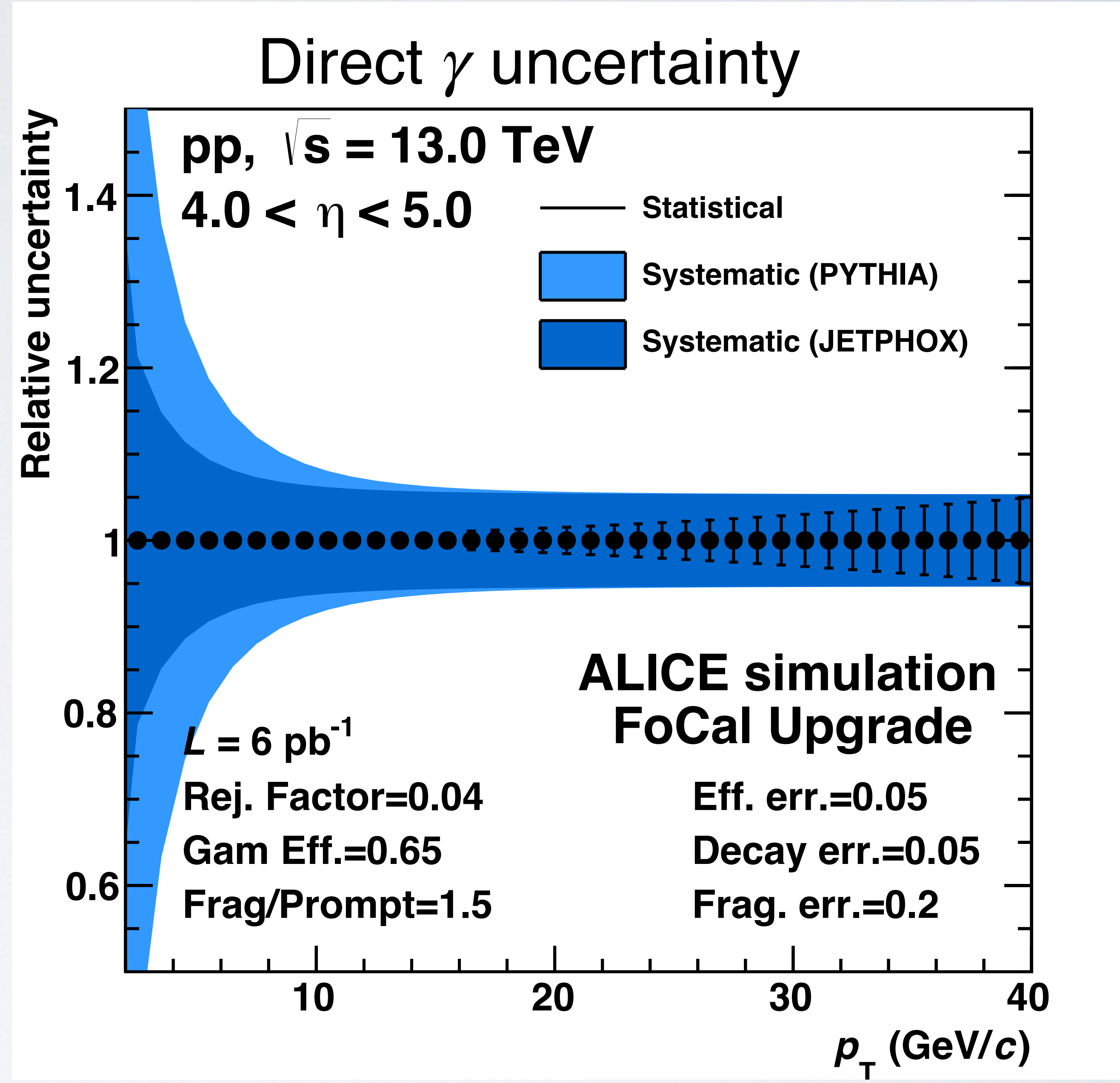


	LG	HG
pixel/pad size	≈ 1 cm^2	≈ 30x30 μm^2
total # pixels/pads	≈ 2.5 x 10^5	≈ 2.5 x 10^9
readout channels	≈ 5 x 10^4	≈ 2 x 10^6

assuming ≈ 1m^2 detector surface

Direct γ Performance in pp



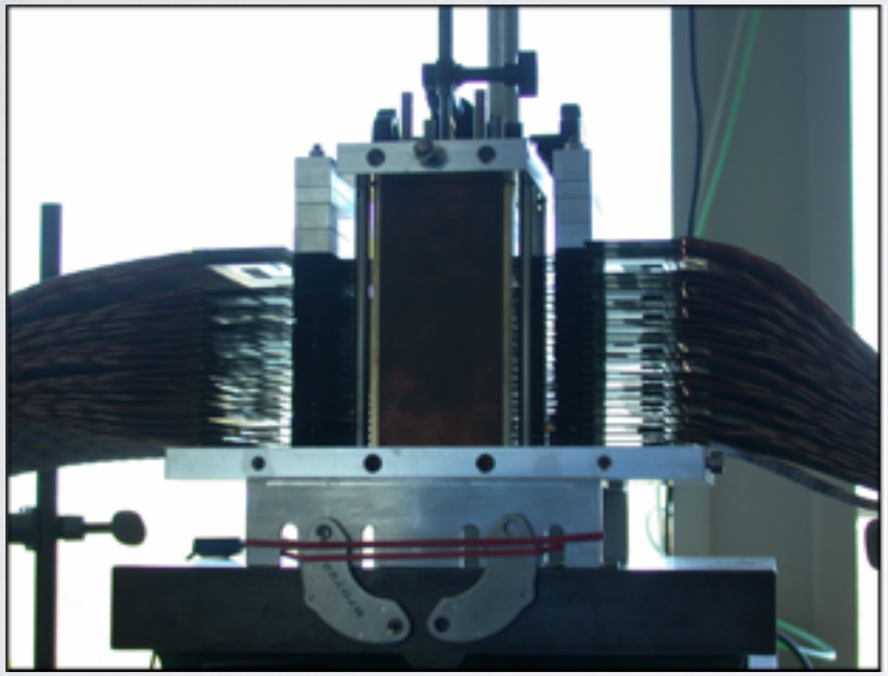


direct photon/all > 0.1
for p_T > 4 GeV/c

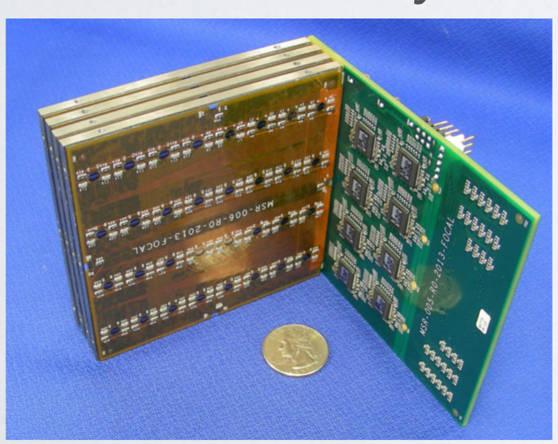
20-40% uncertainty
at p_T = 4 GeV/c
decreases with increasing p_T

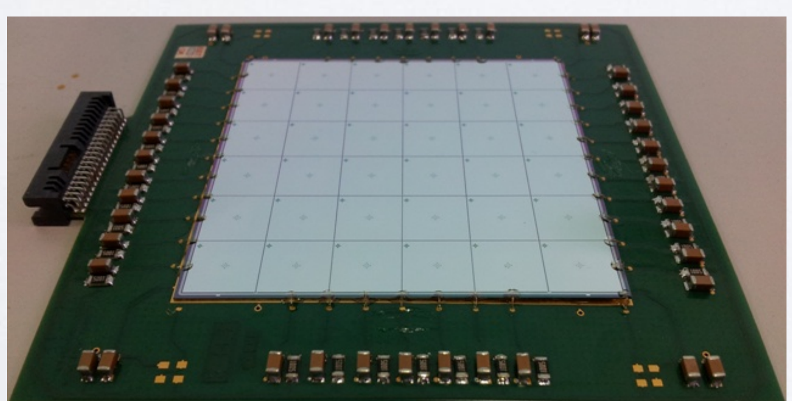
FoCal R&D: Si-W pixel and pad readout

20 layer pixel detector



Pad layer integration





- Several groups involved:
  - Full prototype with pixel detectors CMOS (MIMOSA) 39M pixels, 30μm pitch
    - use synergy with R&D for ALICE ITS upgrade
  - Full prototype with pad readout
- Performed systematic tests:
  - Test beam data from 2 to 250 GeV (DESY, PS, SPS)
  - Cosmic muons

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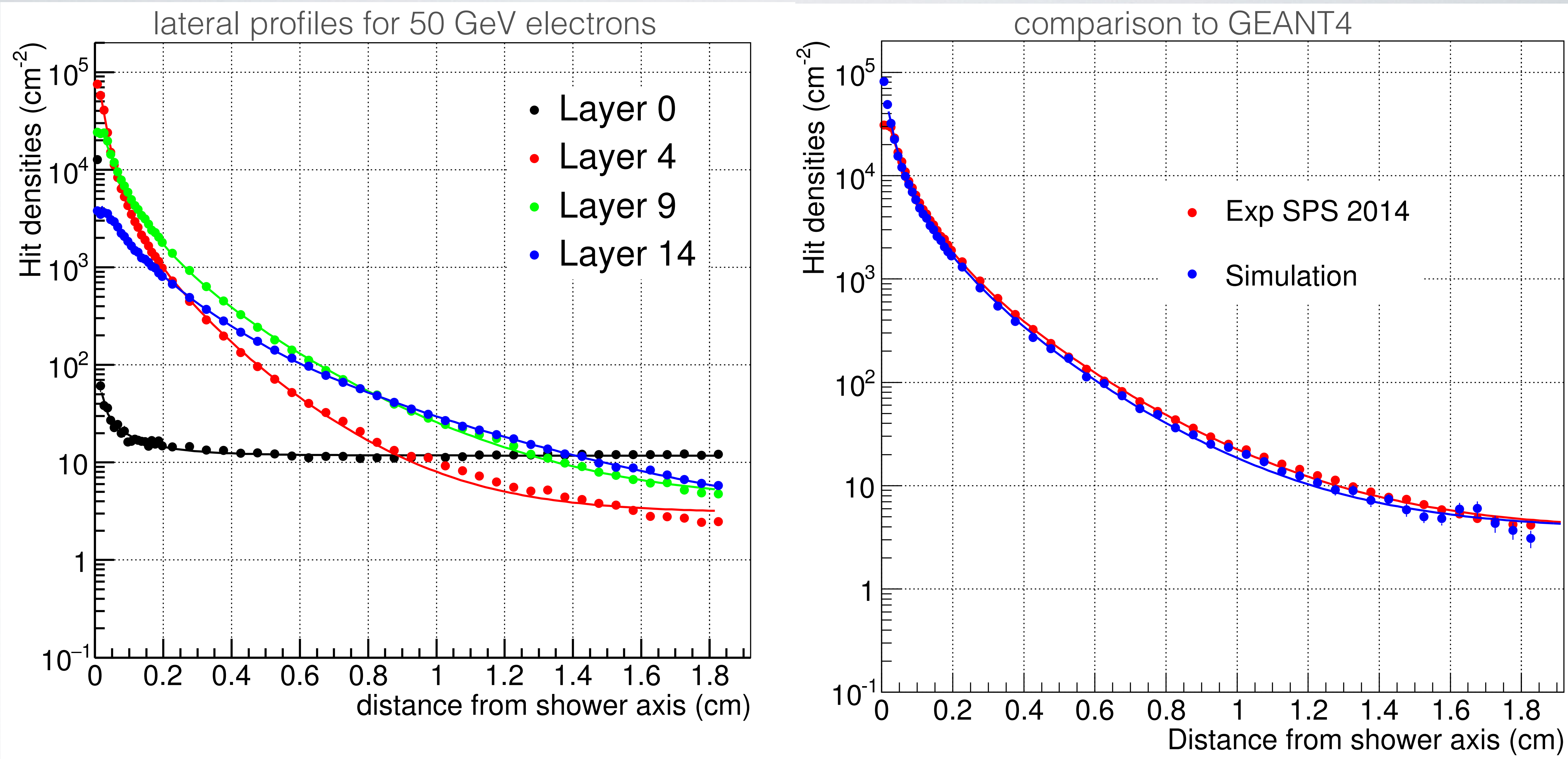
R&D Results: Lateral Profiles

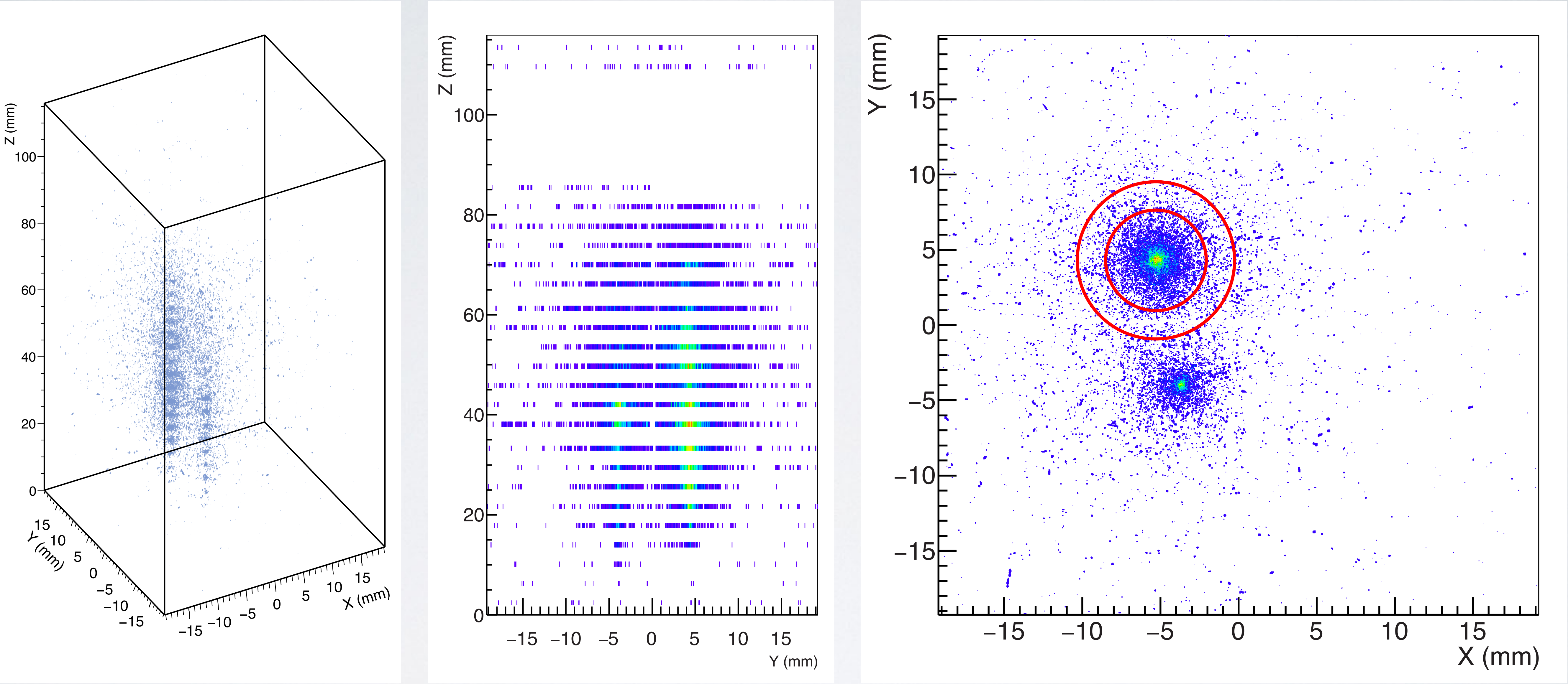


extremely good spatial resolution $R_M \approx$ 11mm (as estimated from cumulative distributions)

good agreement with simulations using GEANT4 + charge diffusion

Two Shower Separation

display of single event (with pile-up) from 244 GeV mixed beam

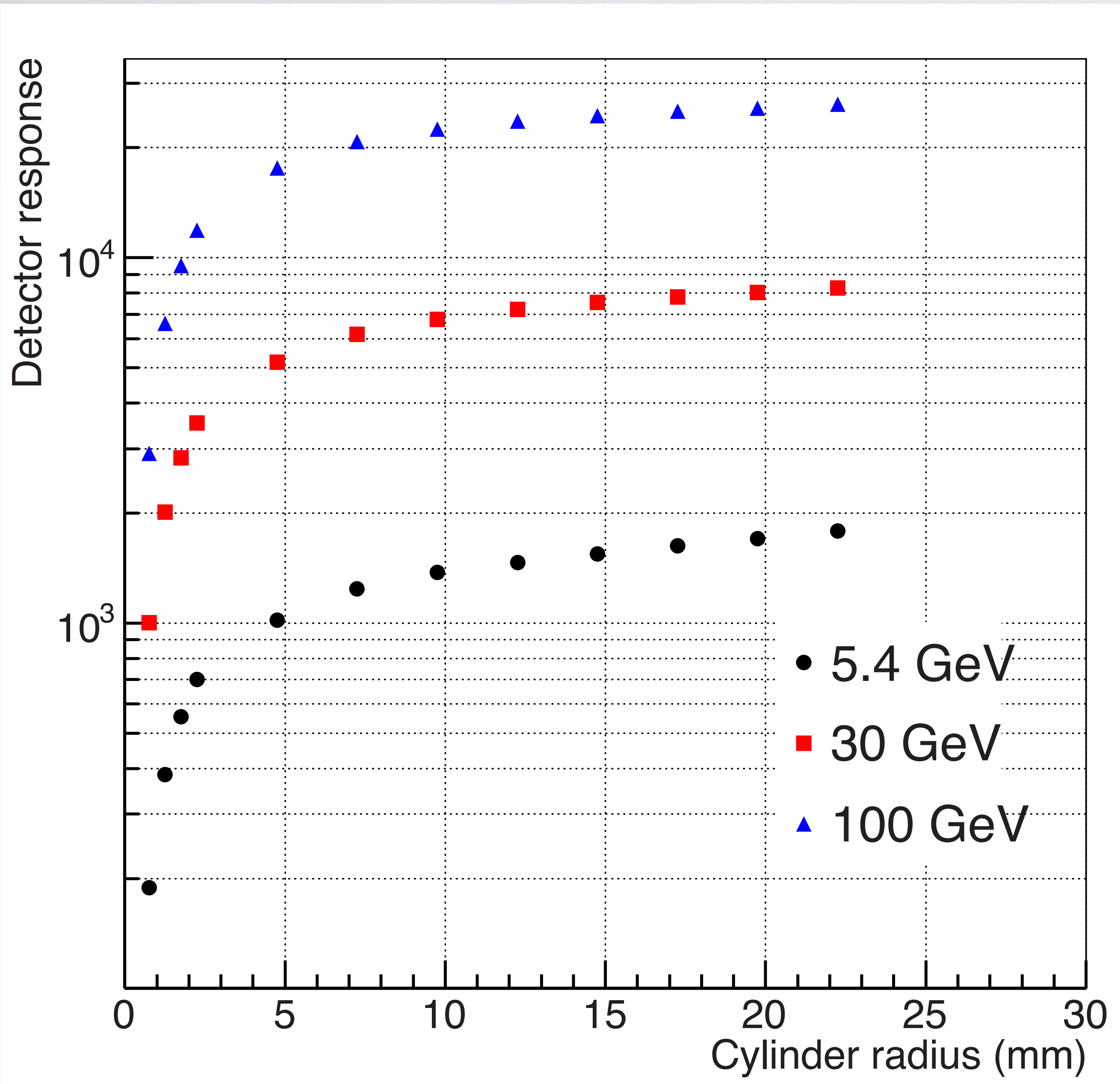


evaluate separation capability: core energy

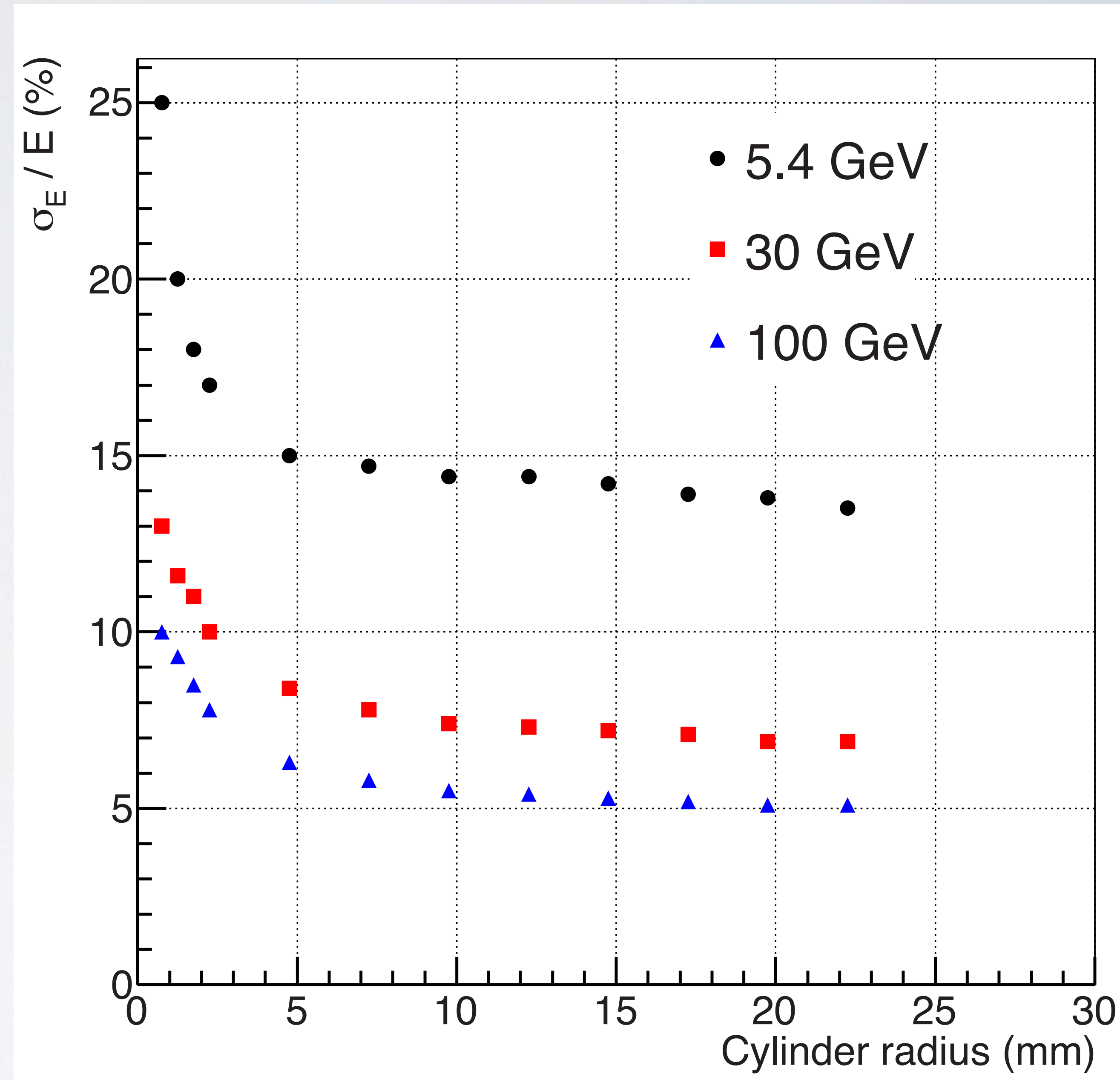
- calculate shower energy in cylinder of finite radius
- study as function of radius

R&D Results: Core Energy

detector response (number of hits)



energy resolution



reasonable energy resolution of pixel calorimeter, sufficient for conceptual design

response and resolution for core energy hardly affected down to r = 5mm:
adequate for very high particle density

Summary

- LHC forward measurements provide unique opportunity for low-x physics
  - hadronic probes inconclusive
  - advantage of EM probes: sensitivity to initial state, clean production process
- measurement needs detector upgrade at LHC
  - FoCal detector in ALICE
    - opportunity for forward direct photon measurement
    - particle density/kinematics require extremely high granularity: feasible with SiW pixel calorimeter

ALICE