

Highlights from the INT workshop

Daniel Tapia Takaki

LHC Working Group on Forward Physics and Diffraction

CERN, Geneva

22 March 2017

Plan of this talk

- Highlights from the INT workshop
- Discussions about the forward heavy-ion program at LHC

Heavy-ion physics within Forward LHC WG

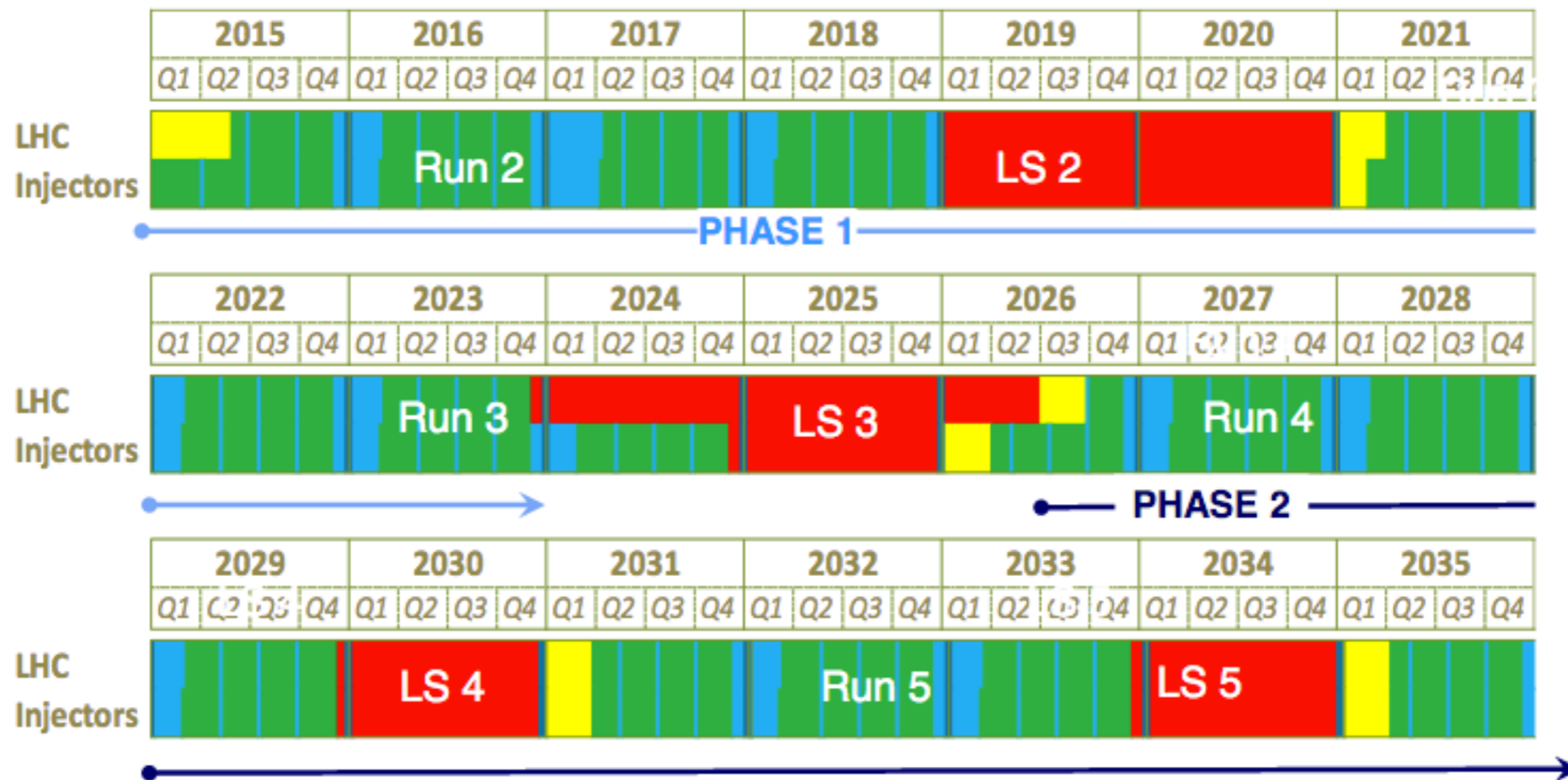
- CERN Yellow Report (K.Akiba et al. J. Phys. G43 (2016) 110201) discusses about forward physics using AA and pA collisions
- dedicated chapter on photon-induced collisions using heavy-ions (*UPCs: Ultra-peripheral collisions*)
- Since the CERN YR, we had one p-Pb run in Nov/Dec 2016

LHC schedule

CERN Yellow Report: *CERN-PH-LPCC-2015-001*

LHC roadmap: according to MTP 2016-2020 V1

LS2 starting in 2019 => 24 months + 3 months BC
 LS3 LHC: starting in 2024 => 30 months + 3 months BC
 Injectors: in 2025 => 13 months + 3 months BC



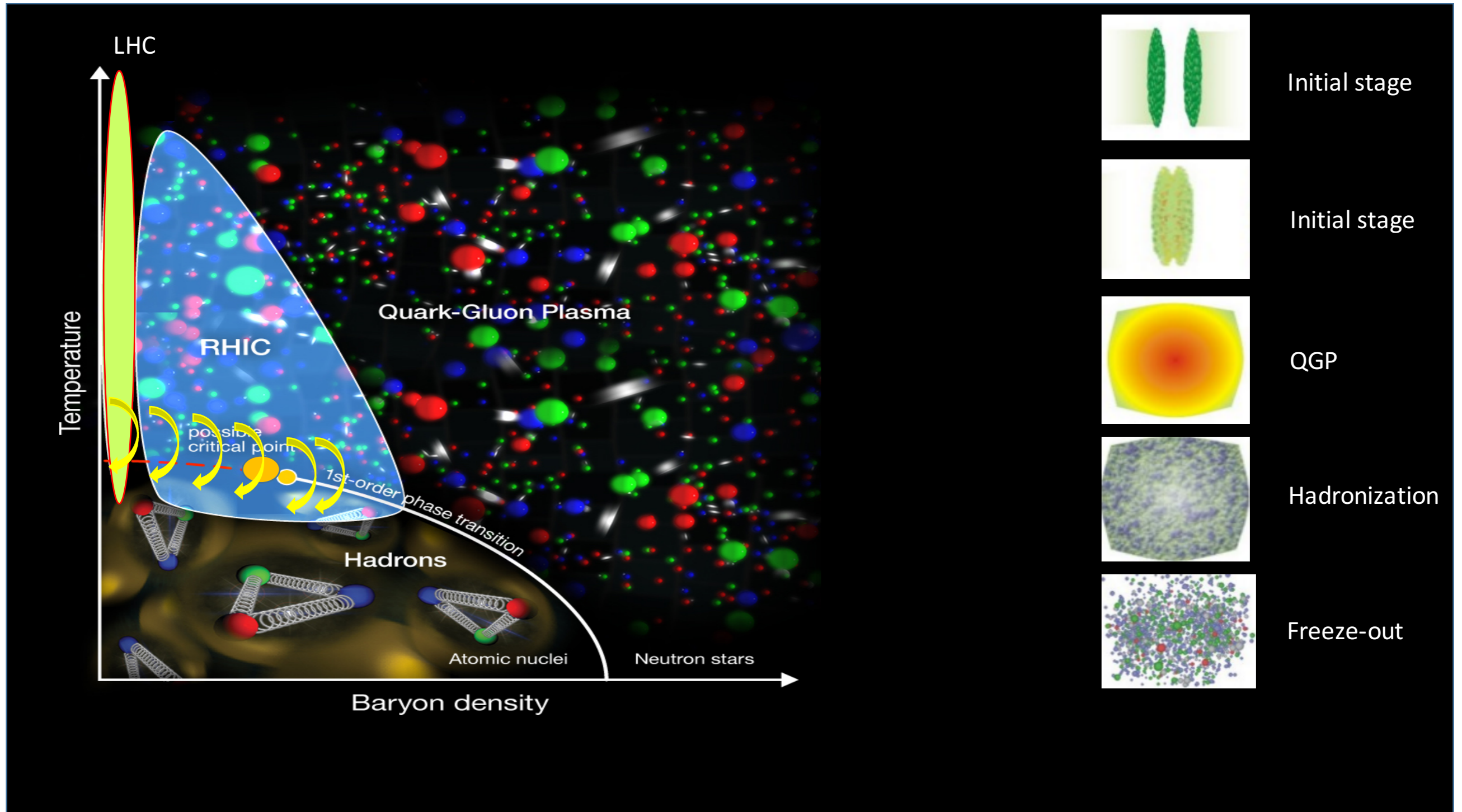
Heavy-ion physics within Forward LHC WG

- Growing interest from LHC collaborations on photon-induced collisions **using heavy ions**
- *Now all LHC experiments studying heavy ions*
- Dedicated/recent workshops at INT and Trento

UPCs: Several studies are possible

- Understanding of the initial state produced in high energy nucleus-nucleus collisions
- Understanding gluons and their self-interactions in nucleons/nuclei
- Glueballs, exotic quarkonia ...
- QED physics, radiative decays, strong fields
- Electro-weak final states
- Beyond the Standard Model

Understanding the initial state



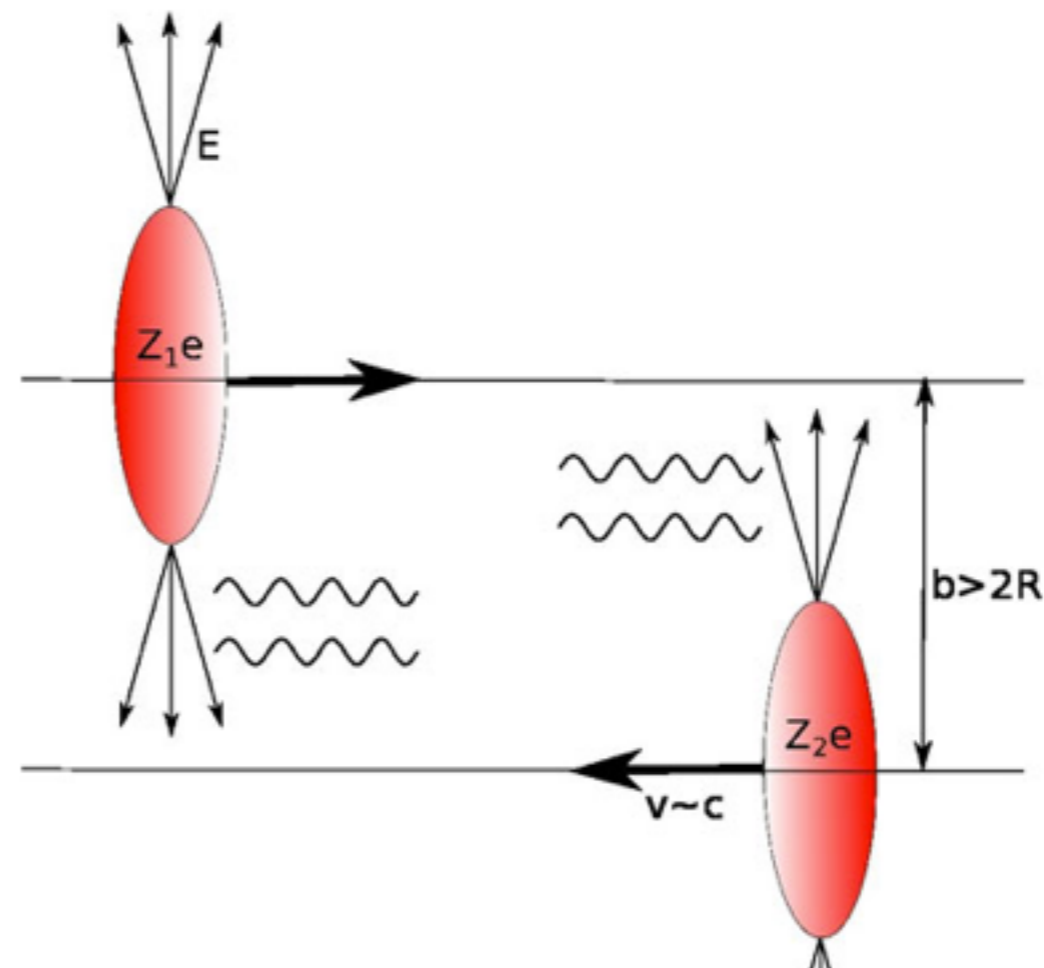
10 UPC studies with heavy ions at the LHC

- *Coherent J/ψ photoproduction in ultra-peripheral Pb-Pb collisions at $s_{NN}=2.76$ TeV* Phys.Lett. B718 (2013) 1273-1283
- *Charmonium and $e+e^-$ pair photoproduction at mid-rapidity in ultra-peripheral Pb-Pb collisions at $s_{NN}\sqrt{s}=2.76$ TeV* Eur.Phys.J. C73 (2013) 11, 2617
- *Exclusive J/ψ photoproduction off protons in ultra-peripheral p-Pb collisions at $s_{NN}\sqrt{s}=5.02$ TeV* Phys.Rev.Lett. 113 (2014) 23, 232504
- *Coherent ρ^0 photoproduction in ultra-peripheral Pb-Pb collisions at $s_{NN} = 2.76$ TeV* JHEP 1509 (2015) 095
- *Coherent $\psi(2S)$ photo-production in ultra-peripheral Pb Pb collisions at $s_{NN} = 2.76$ TeV* Phys.Lett. B751 (2015) 358-370
- *Measurement of an excess in the yield of J/ψ at very low p_T in Pb-Pb collisions at $s_{NN} = 2.76$ TeV* Phys. Rev. Lett. 116 (2016) 22, 222301
- *Coherent J/ψ photoproduction in ultra-peripheral Pb-Pb collisions at $s_{NN}=2.76$ TeV with the CMS detector* CMS-PAS-HIN-12-009. Submitted to PLB
- *Measurement of exclusive Upsilon in pPb collisions at $s_{NN} = 5.02$ TeV* CMS-PAS-FSQ-13-009
- *Measurement of high-mass dimuon pairs from ultraperipheral lead-lead collisions at $s_{NN} = 5.02$ TeV with the ATLAS detector at the LHC* ATLAS-CONF-2016-025
- *Light-by-light scattering in ultra-peripheral Pb+Pb collisions at $s_{NN} = 5.02$ TeV with the ATLAS detector at the LHC* ATLAS-CONF-2016-111

INT workshop

INT Workshop INT-17-65W Probing QCD in Photon-Nucleus Interactions at RHIC and LHC: the Path to EIC

February 13 - 17, 2017



<http://www.int.washington.edu/PROGRAMS/17-65w/>

Organizers:

Daniel Tapia Takaki
University of Kansas
Daniel.Tapia.Takaki@cern.ch

Carlos Bertulani
Texas A&M University-Commerce
carlos.bertulani@tamuc.edu

Spencer R. Klein
Lawrence Berkeley Laboratory
SRKlein@lbl.gov

Tuomas Lappi
University of Jyväskylä
tuomas.v.v.lappi@jyu.fi

Mark Strikman
Pennsylvania State University
strikman@phys.psu.edu

Program Coordinator:

Farha Habib
faraway@uw.edu
(206) 685-4286

Application form

For full consideration, please apply
by October 31, 2016.

Talks online

[Exit report](#)

[Visitor Information](#)

[Friends of the INT](#)

[Obtain an INT preprint number](#)

INT workshop

Organizers

Daniel Tapia Takaki
University of Kansas
Daniel.Tapia.Takaki@cern.ch

Carlos Bertulani
Texas A&M University-
Commerce
carlos.bertulani@tamuc.edu

Spencer R. Klein
Lawrence Berkeley
Laboratory
SRKlein@lbl.gov

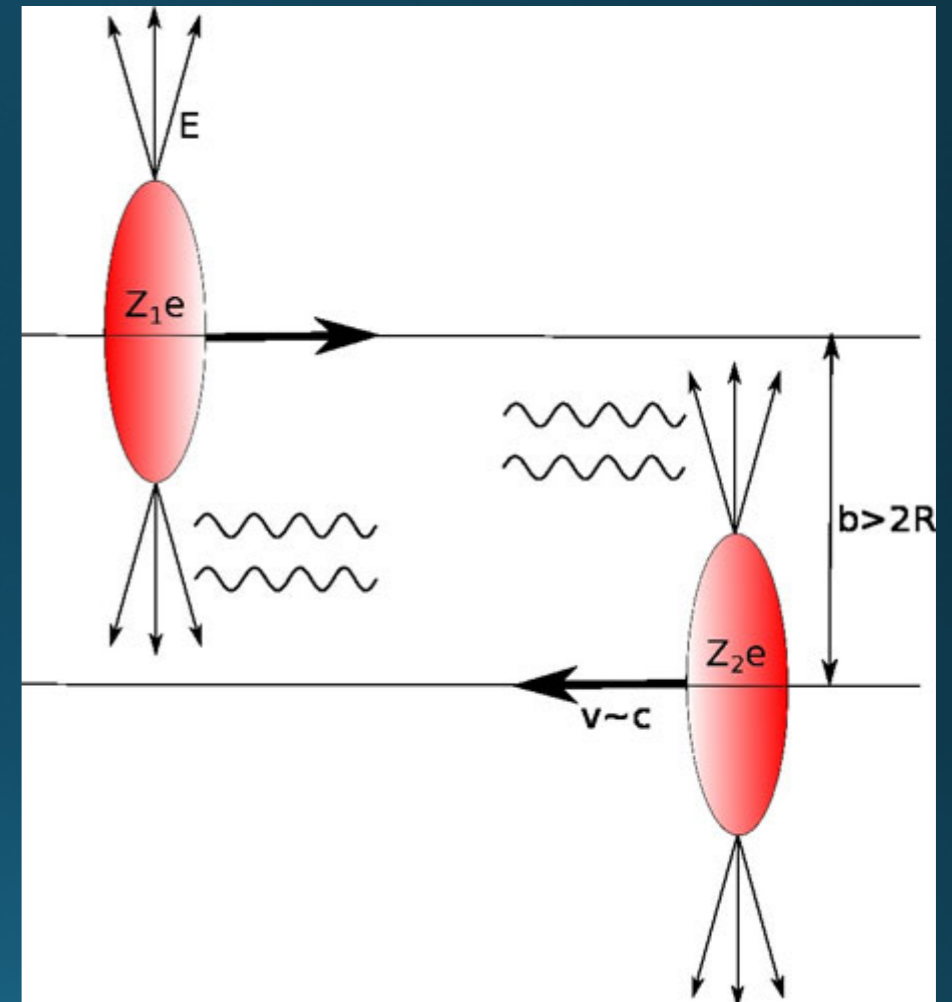
Tuomas Lappi
University of Jyvaskyla
tuomas.v.v.lappi@jyu.fi

Mark Strikman
Pennsylvania State University
strikman@phys.psu.edu

INT workshop

Overview

- High-energy photon-nucleon (nucleus) collisions offer us a unique opportunity to study the hadron and photon structure, QCD dynamics and small Bjorken- x gluon dynamics at photon intensities and energies that are unavailable elsewhere
- These interactions can already be studied in a wide energy range from $W \sim 10$ GeV (RHIC Au-Au) to $W \sim 500$ GeV (LHC Pb-Pb) using ultraperipheral collisions at hadronic colliders



INT workshop

Overview


- *UPC studies serve as a forerunner of the Electron Ion Collider (EIC) experiments.*
- The top of the energy range in UPCs at LHC is a factor of ten higher than that of the EIC, which offers a unique opportunity to explore this novel kinematic regime.
- At the same time, UPC collisions at RHIC and LHC have their own limitations, since it is not possible to study the Q^2 dependence systematically for most physics processes of interest.

INT workshop

Overview

- Despite the recent experimental progress, work on the theoretical side is clearly not at a similar level to that of inclusive hard scattering.
- *The goal of this workshop is to identify and discuss the theoretical challenges of photon-induced physics, and how to use this knowledge for physics studies at the EIC.*

Topics (main focus)

- 
- **Current status of nuclear PDFs and developments using photon-nucleus data**
 - **Strategies for observing nonlinear and gluon saturation effects in photon - nucleus scattering**
 - Progress in understanding heavy quark hadronization in exclusive processes.
 - Models for coherent and incoherent soft photon - nucleon / nucleus interactions
 - Predictions of the leading twist models, dipole models and CGC models for exclusive gamma-p and gamma A scattering.
 - Exotic spectroscopy and searches for new physics

Overview

- **Studying QCD with high energy photon-photon, photon-proton and photon-nuclear interactions at RHIC and LHC**
 - **Searching for saturation effects in the proton**
 - **Nuclear effects at both low and high Bjorken- x**
- **So far, most analyses have been carried out for exclusive VM photoproduction but new studies possible and ongoing dijets, diphotons...**
- **Inclusive photo-nuclear and photon-proton reactions also possible and first studies ongoing**

INT workshop

PDFs

Ramona Vogt (LLNL)
Fred Olness (SMU)
Shunzo Kumano (KEK)

Diffraction, Jets, Saturation, and Dipoles

Beatriz Gay Ducati (UFRGS)
Anna Stasto (PSU)
Guangyao Chen (Iowa State)
Piotr Kotko (PSU)
Wolfgang Schaefer (Cracow)
Amir Rezaeian (Valparaiso)
Heikki Mantysaari (BNL)
Misak Sargsian (FIU)

Shadowing

Vadim Guzey (Petersburg)
Leonid Frankfurt (Tel Aviv)
Mark Strikman (PSU)
Boris Blok (Technion)

Polarization in UPCs and EIC

Maria Elena Tejeda-Yeomans
(Sonora)
John Ralston (Kansas)

Path to EIC

Elke Aschenauer (BNL)
Christian Weiss (JLab)
Michael Lomnitz (LBNL)

Experiments at RHIC and LHC

Jarda Adam (Creighton)
Aaron Angerami (Columbia)
Evgeny Kryshen (Petersburg)
Michael Murray (Kansas)

INT workshop

48 participants

Some selected slides....

INT workshop

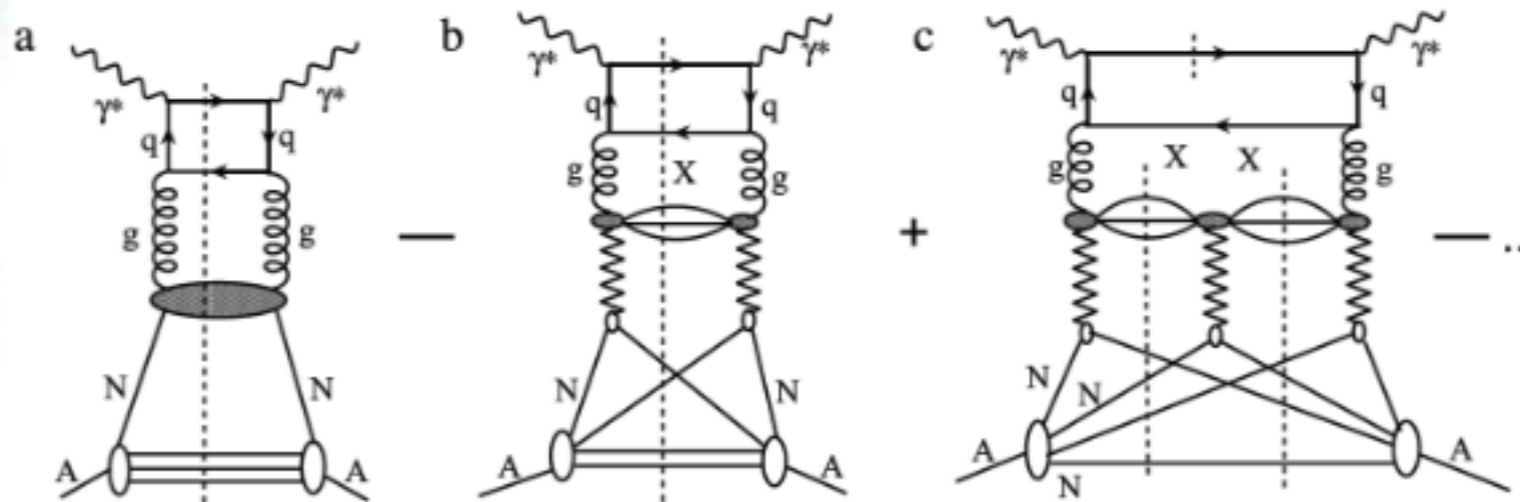
UPC in parallel with EIC

- UPCs and EIC complementary
 - Highest energy \leftrightarrow control of hard-process kinematics
- Concrete possibilities for “joint” studies
 - Mechanism of nuclear shadowing
 - Nuclear quarks/gluons at larger x
 - Transverse nucleon structure
 - Unitarity limit in hard interactions

From **Christian Weiss'** talk

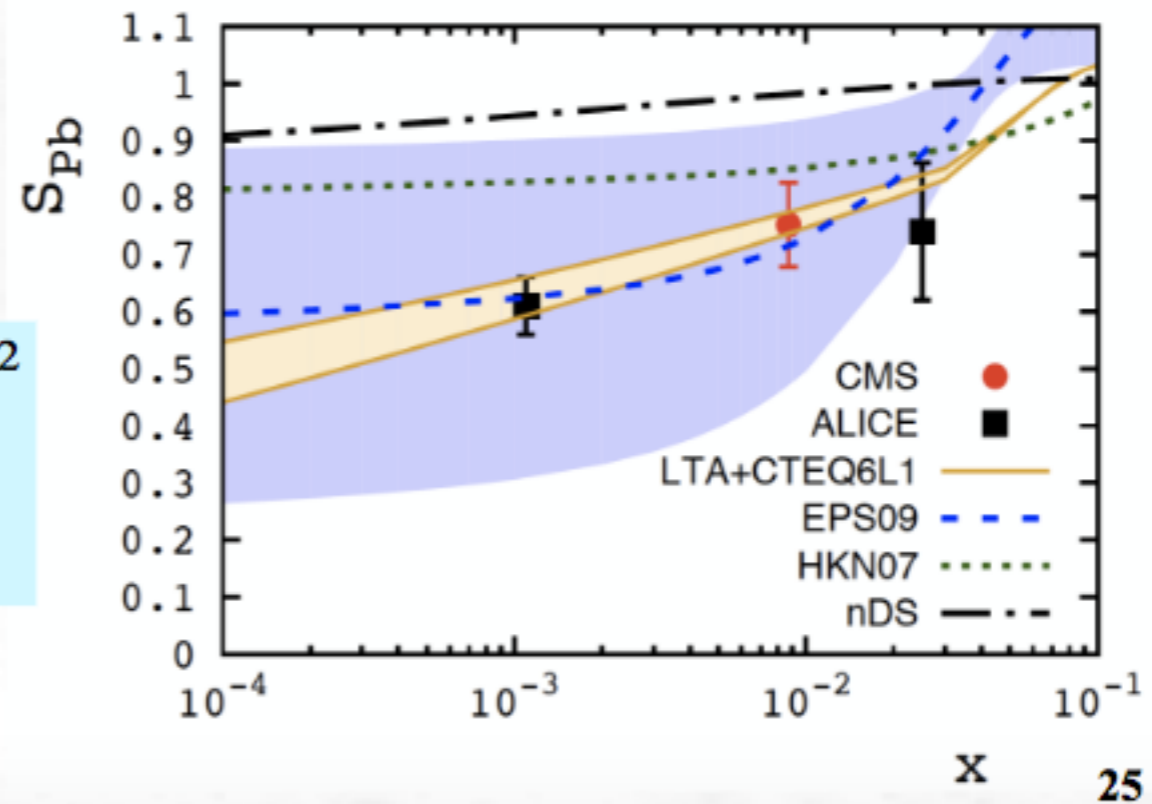
INT workshop

Leading Twist Shadowing Model



From **Vadim Guzey's** talk

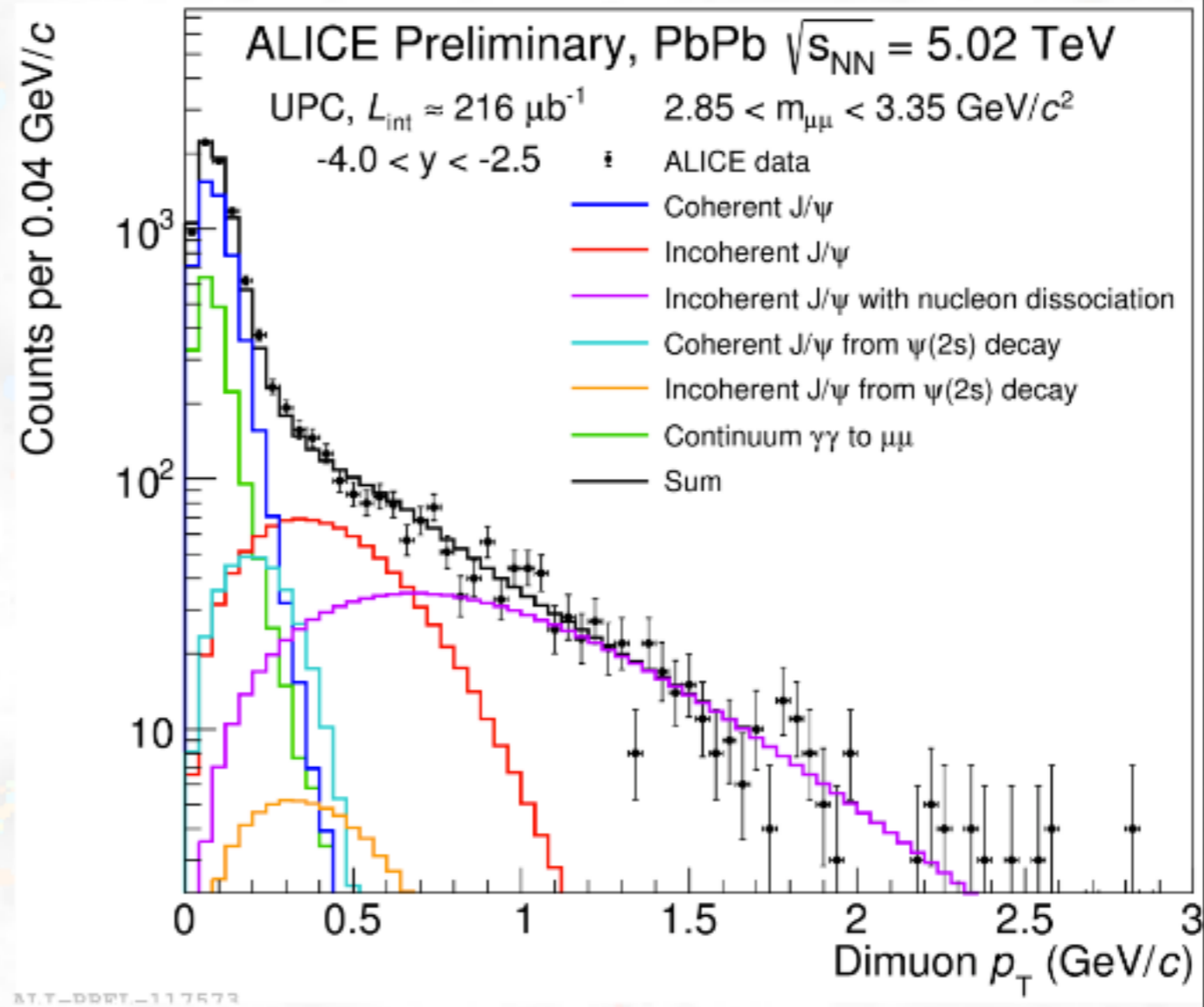
$$S(W_{\gamma P}) = \left[\frac{\sigma_{\gamma Pb \rightarrow J/\psi Pb}}{\sigma_{\gamma Pb \rightarrow J/\psi Pb}^{IA}} \right]^{1/2}$$



INT workshop

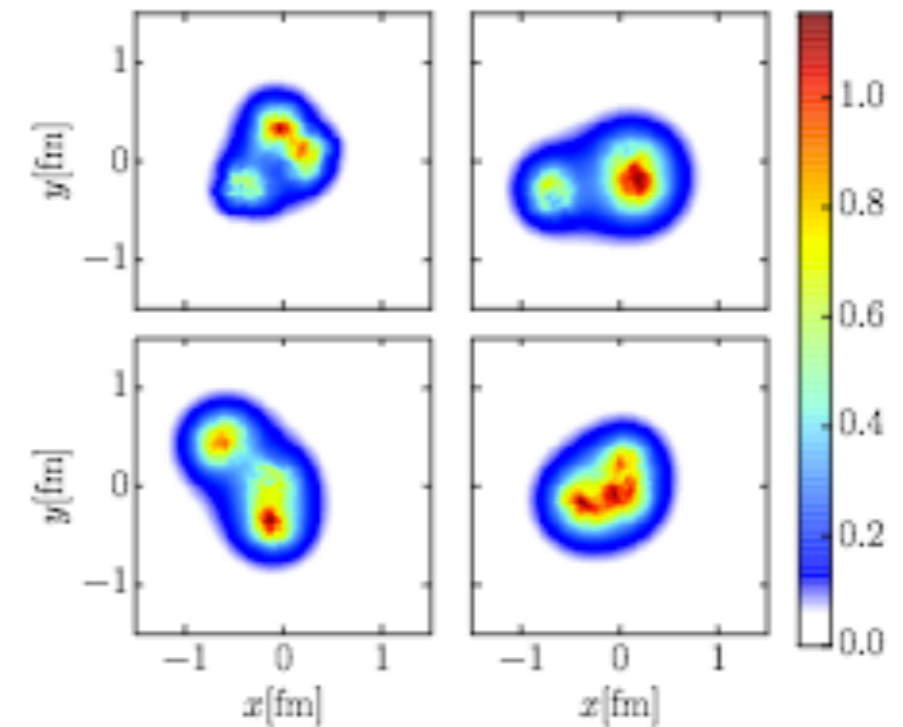
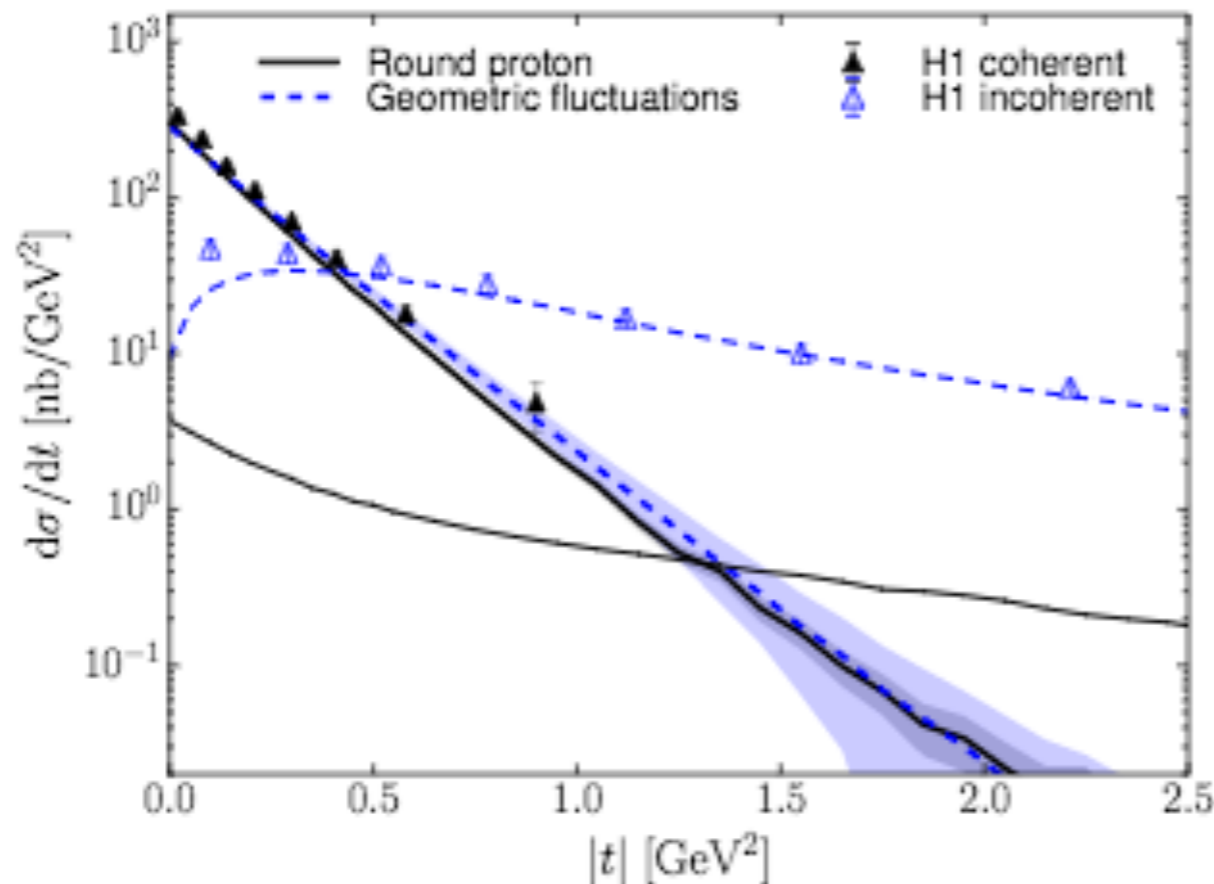
J/ψ p_T distribution

From E. Kryshen's talk



IP-Glasma and HERA data

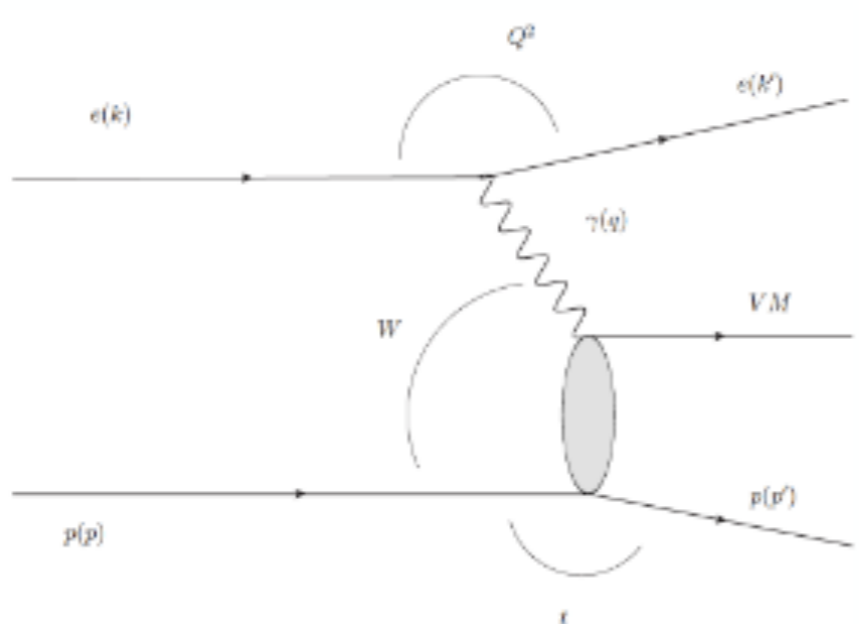
Include color charge fluctuation, parameters fitted to H1 data



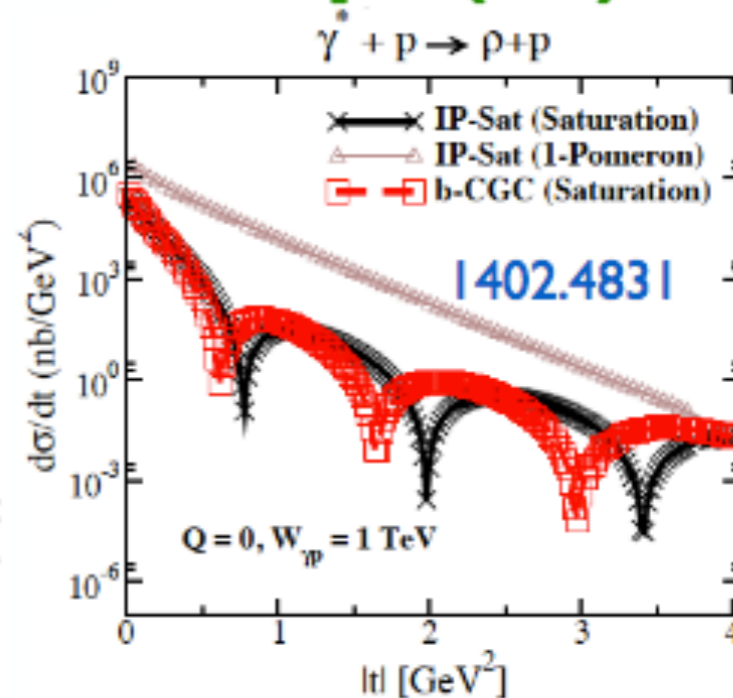
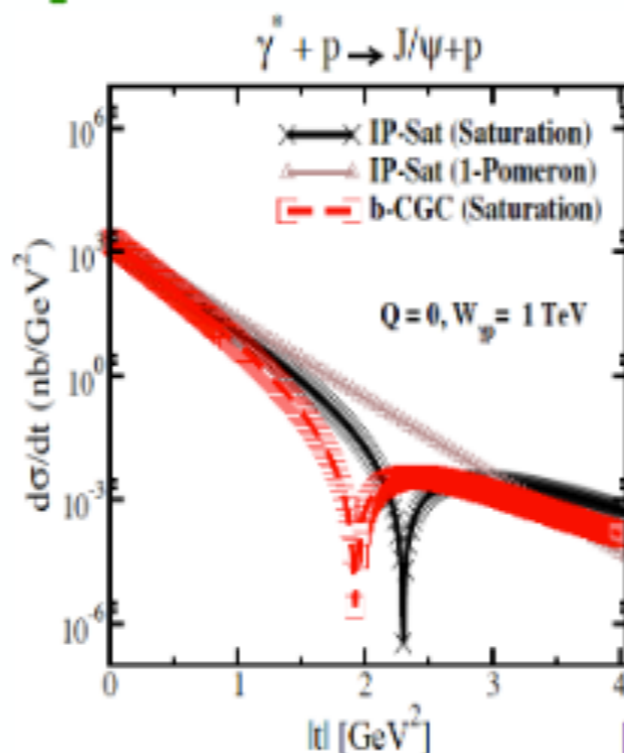
H.M., B. Schenke, PRD94 (2016), 034042

- Initial condition for pA hydro, good description of v_2 and v_3 data!

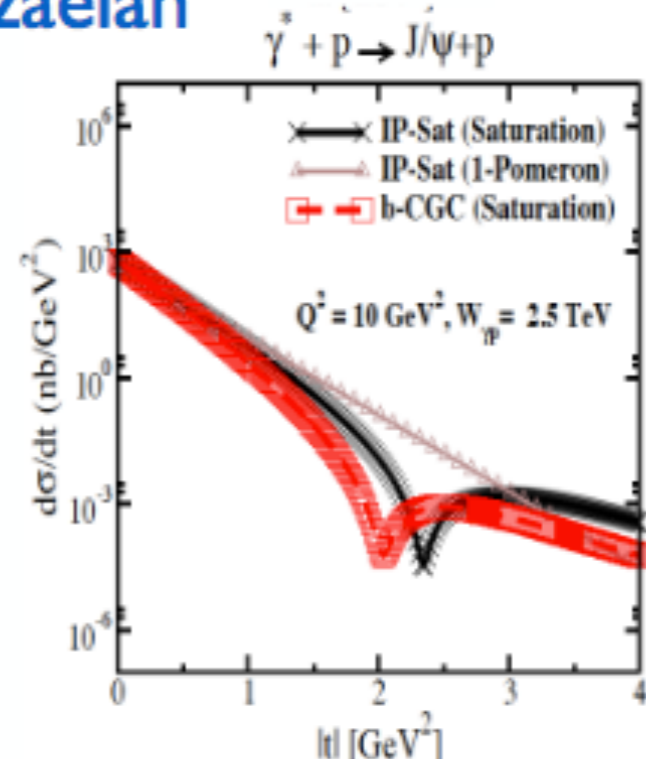
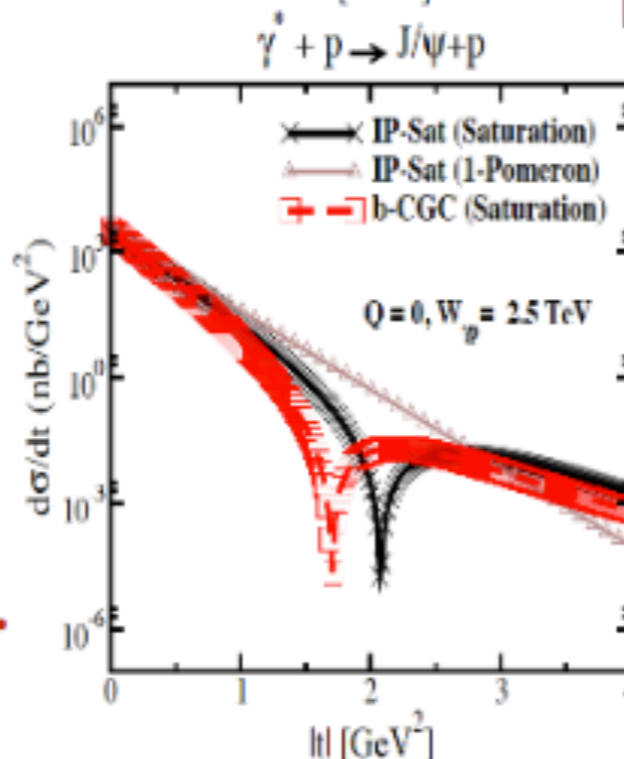
Elastic VM production in ep (III):



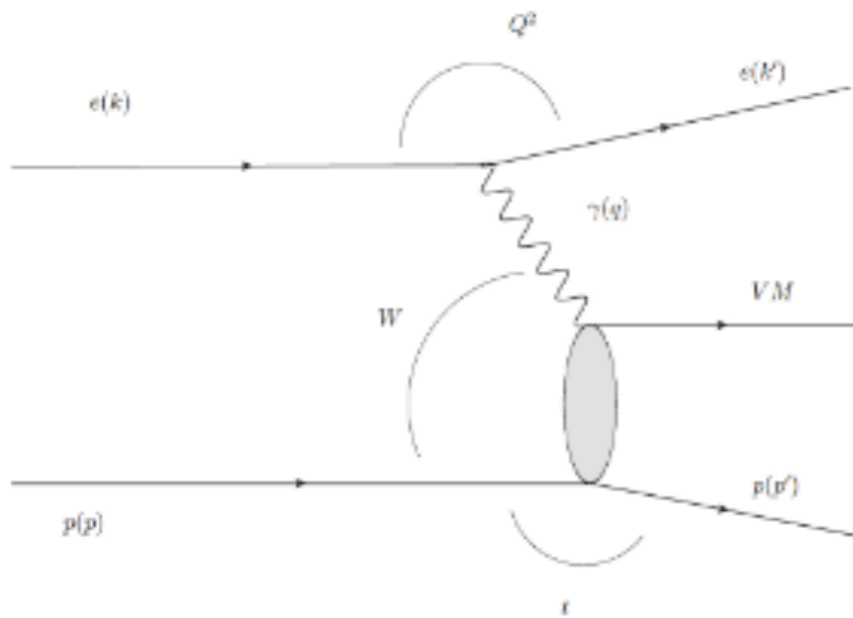
- Position of the dip and its evolution determined by the transverse structure of proton/nuclei; its shrinking is natural in non-linear evolution towards the black disk (unitarity) limit.



Rezaeian

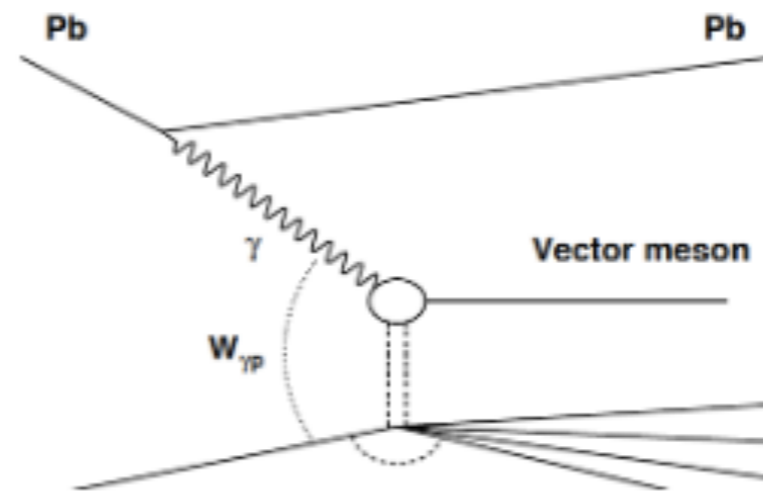


Elastic VM production in ep (III):

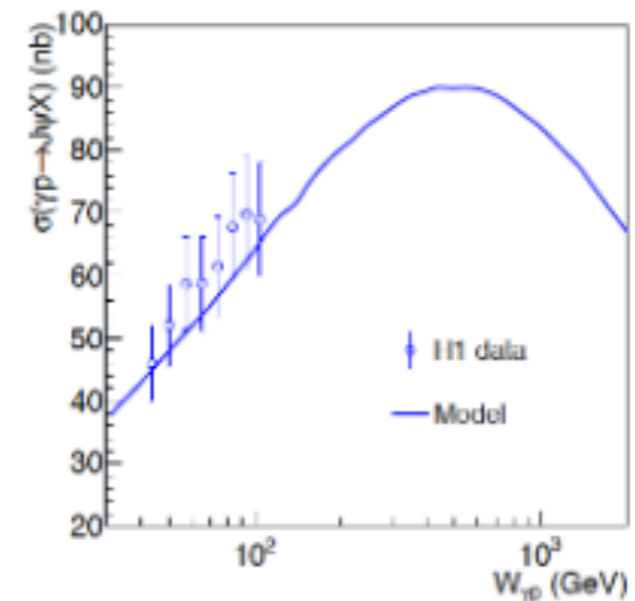
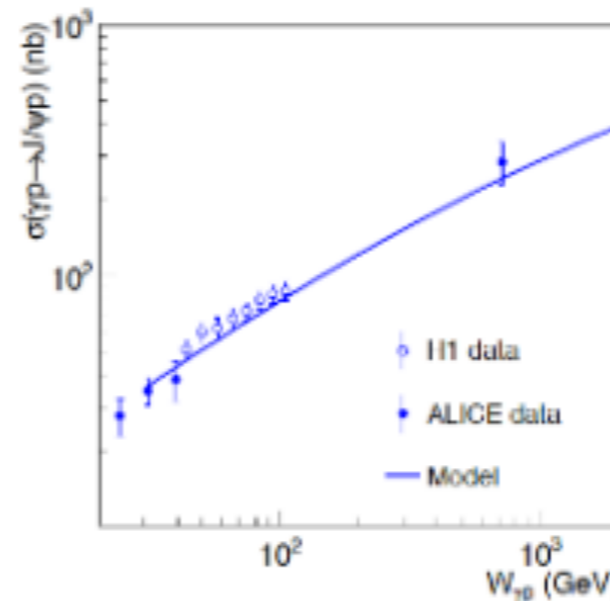


- Position of the dip and its evolution determined by the transverse structure of proton/nuclei; its shrinking is natural in non-linear evolution towards the black disk (unitarity) limit.

- For incoherent diffraction, sensitivity to the proton transverse structure: homogeneous versus lumpy.



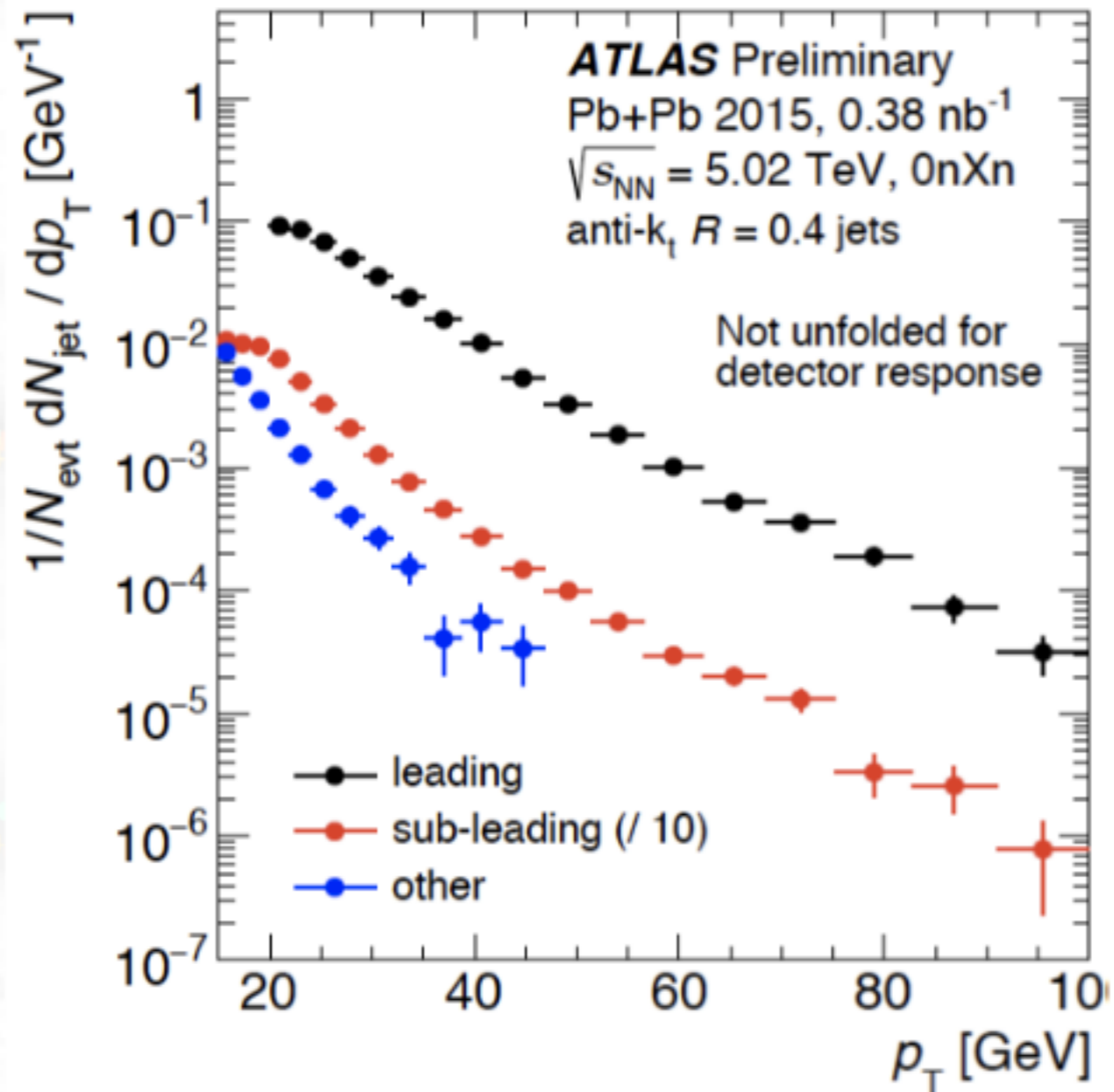
1608.07559



INT workshop

Jets

From
Aaron Angerami's
talk



INT workshop

Measurement Coverage

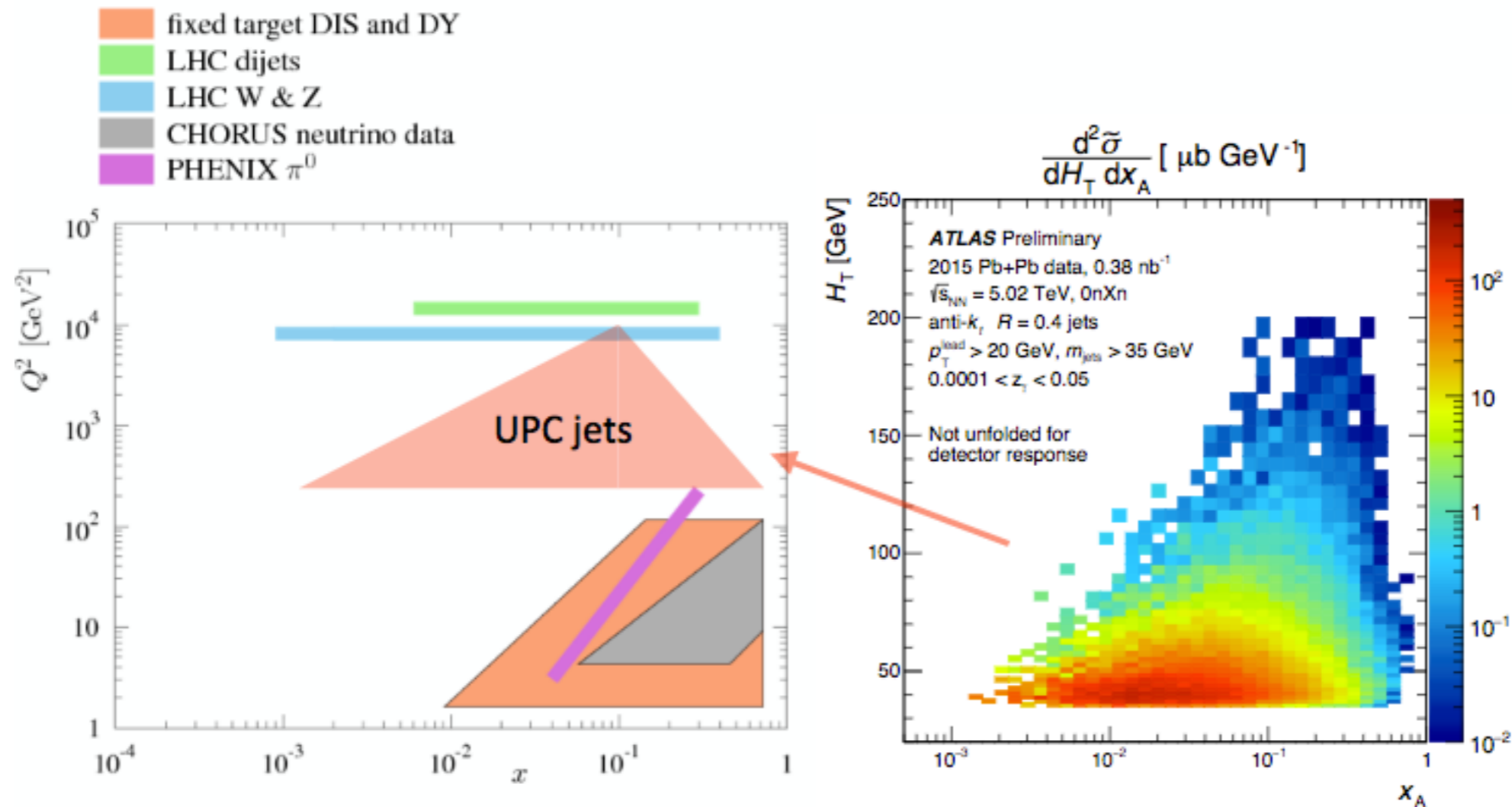


Figure adapted from EPPS16
 1612.05741 [hep-ph]

• **ATLAS-CONF-2017-011**

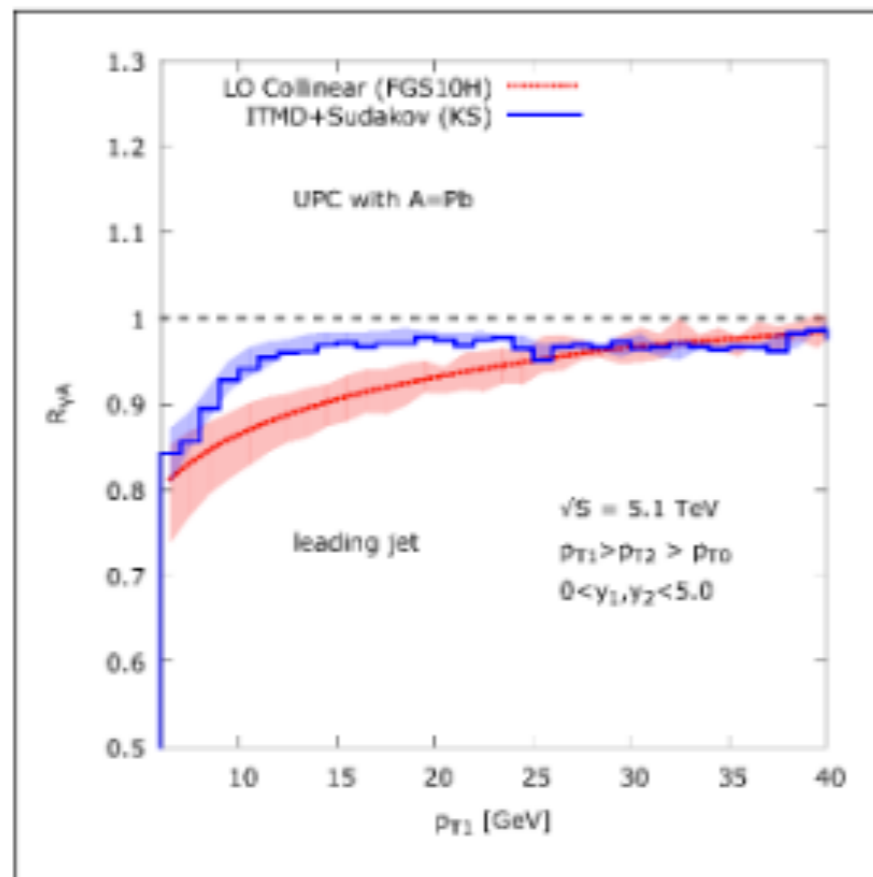
INT workshop

Results for dijets in UPC

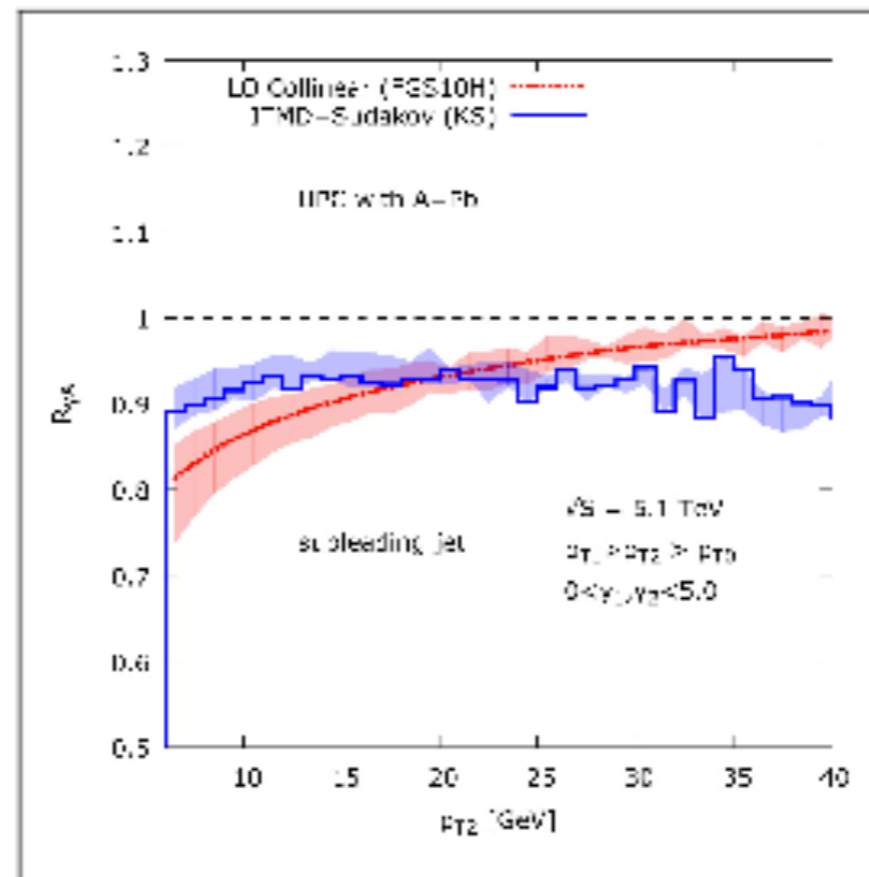
P. Kotko, A. Stasto, M. Strikman

Nuclear modification factor R_{pA}

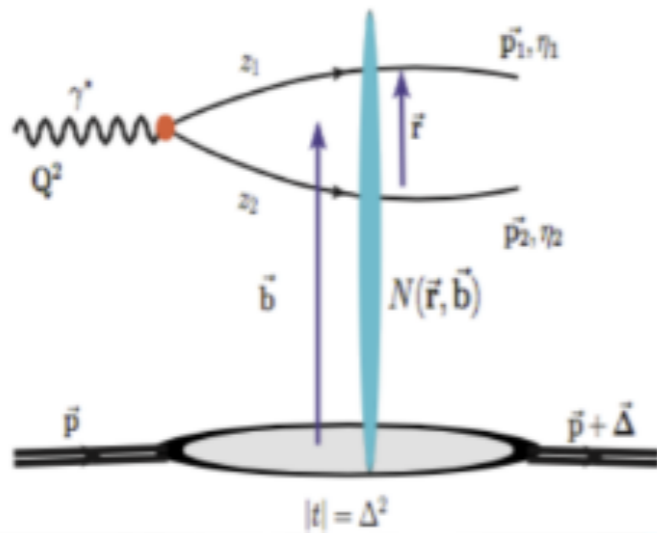
leading jet p_T



subleading jet p_T

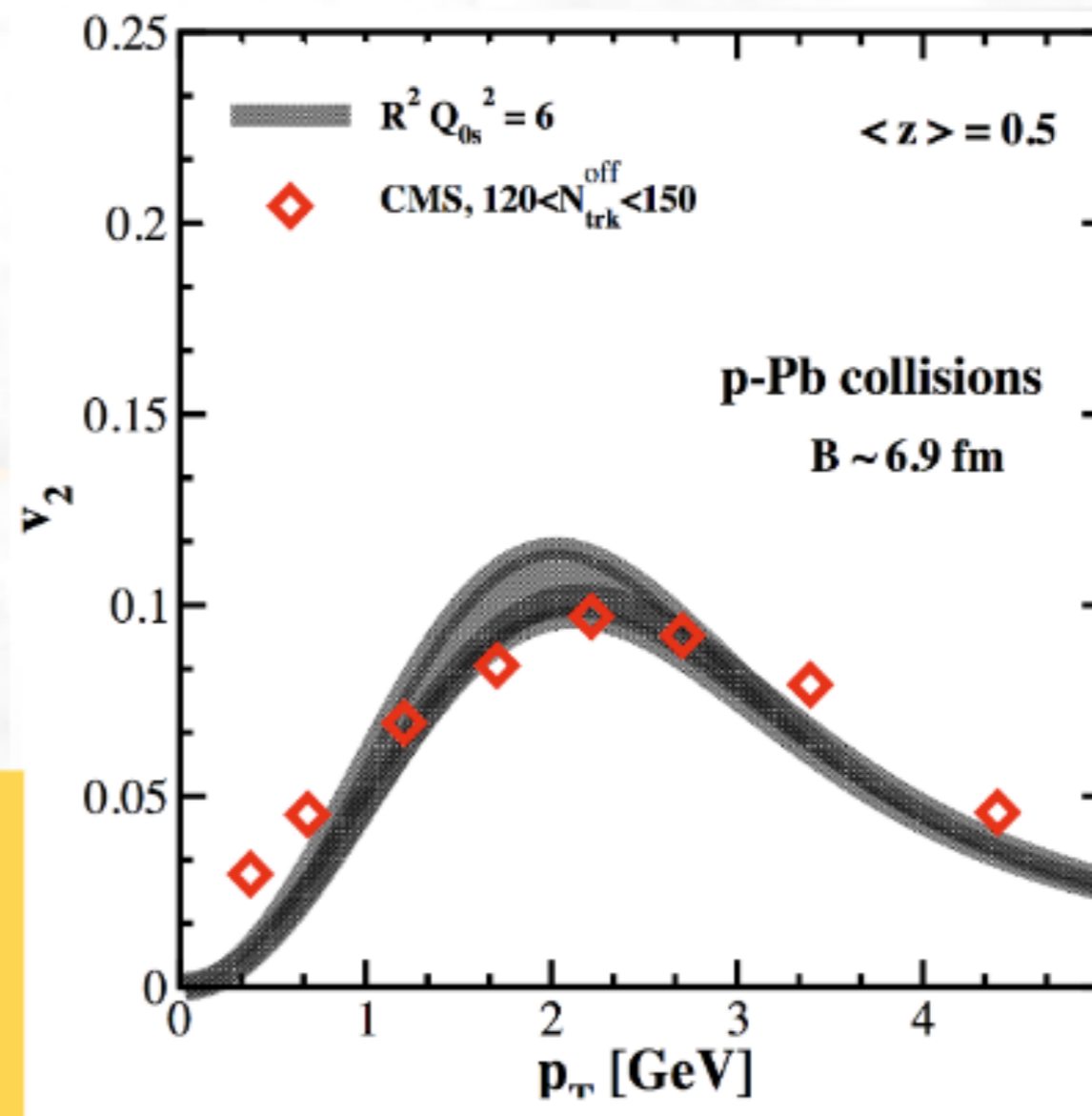


Motivation: Test gluon saturation model

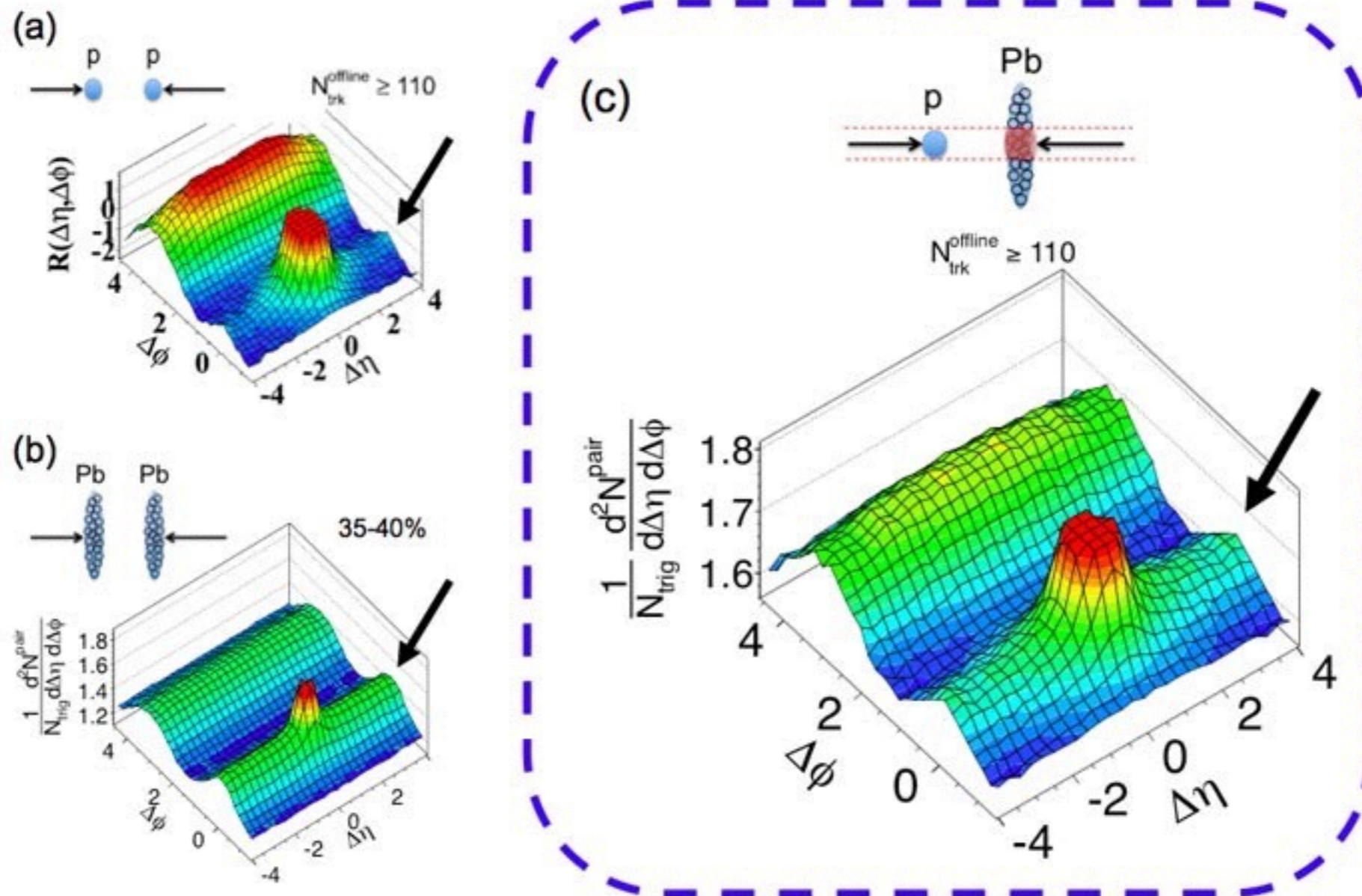


From Amir Rezaeian's talk

Since jet is color neutral, jet production dominated by q - q bar pairs of smaller transverse size with increasing saturation



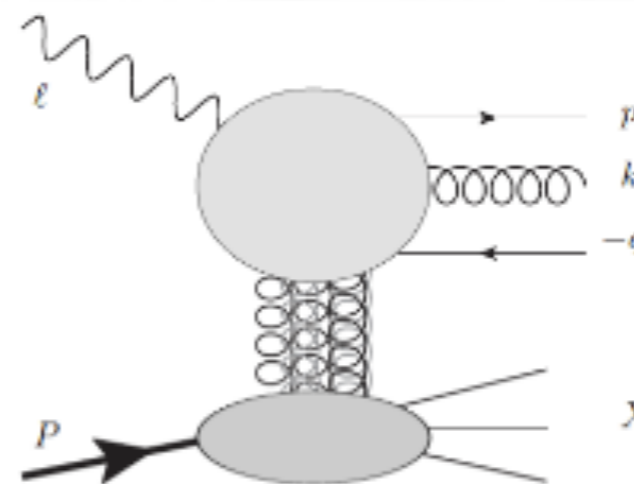
INT workshop



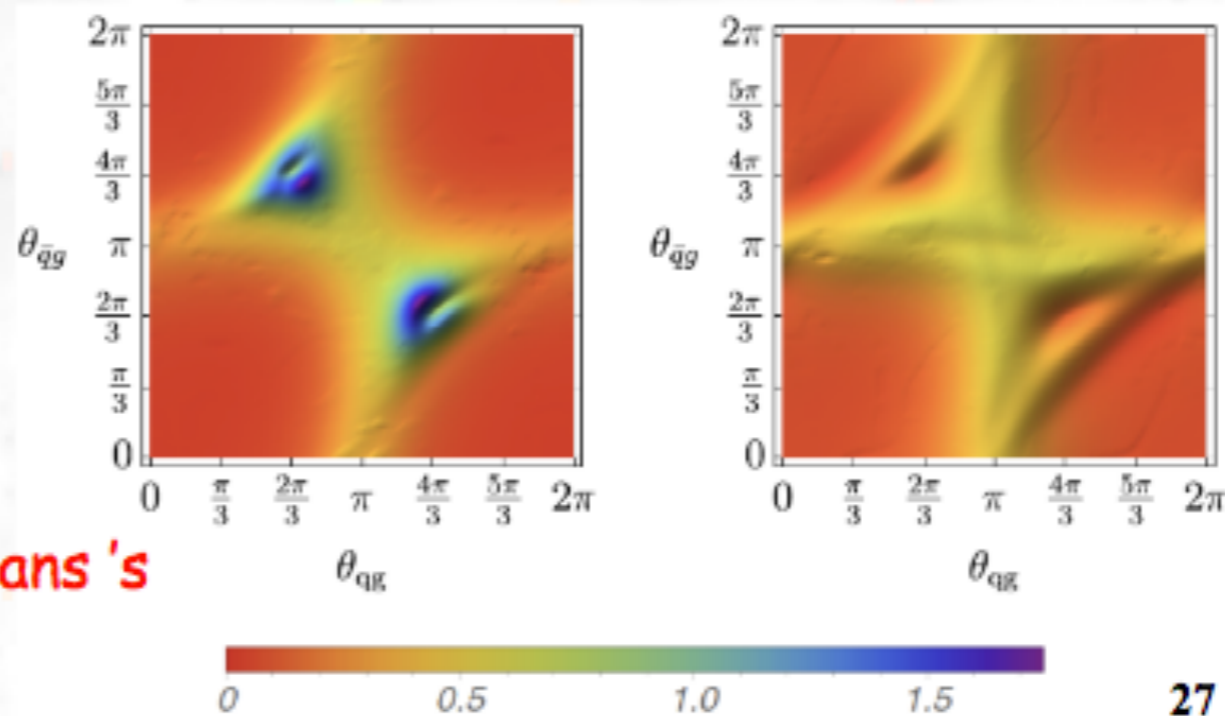
2-particle correlations in UPC collisions?

Polarization in UPCs and EIC

Motivation: use azimuthal angular correlations of 3 partons in inclusive DIS to explore the dynamics of saturated partonic matter



Azimuthal correlations between 3 partons in DIS



From
Maria Elena Tejeda-Yeomans's
talk

White paper

- Following the INT workshop, a White Paper on photon-nucleus/proton will be prepared in the US
- Coordinated by DTT

Heavy-ion physics within Forward LHC WG

- Forward/Diffractive LHC WG framework for discussing future runs and strategies
- Provide input to LHCC/LHCP and similar scientific board at CERN
- Important to continue acknowledging the specific needs of this physics program and find solutions that work for all LHC experiments: **special run within a special run**

Special run within a special run

- **Specific needs not always required in other physics programs using heavy ions**
- Luminosity determination (vdM scans)
- Forward detectors, require some additional overhead
- Use of RPs in p-Pb (special optics)

Based on recent experimental/theoretical results, important to provide inputs to the CERN/LHC scientific boards ...many people interested in more p-Pb runs

LHC roadmap: according to MTP 2016-2020 V1

LS2 starting in 2019 => 24 months + 3 months BC
 LS3 LHC: starting in 2024 => 30 months + 3 months BC
 Injectors: in 2025 => 13 months + 3 months BC

