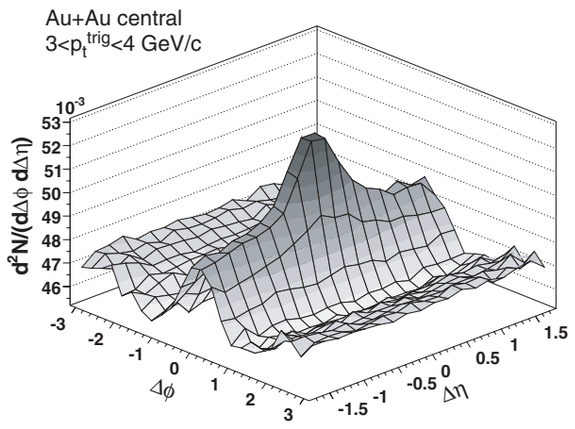
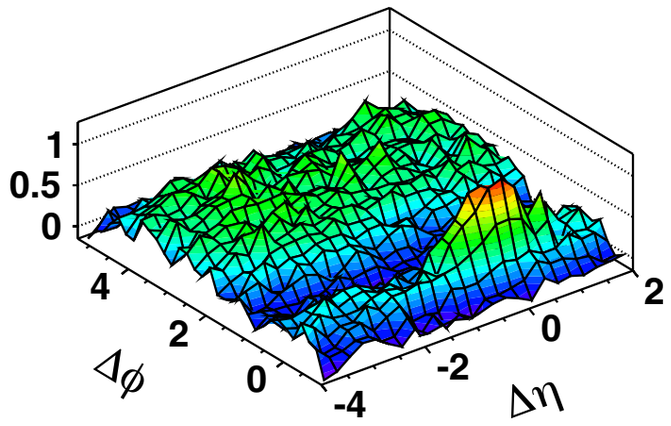
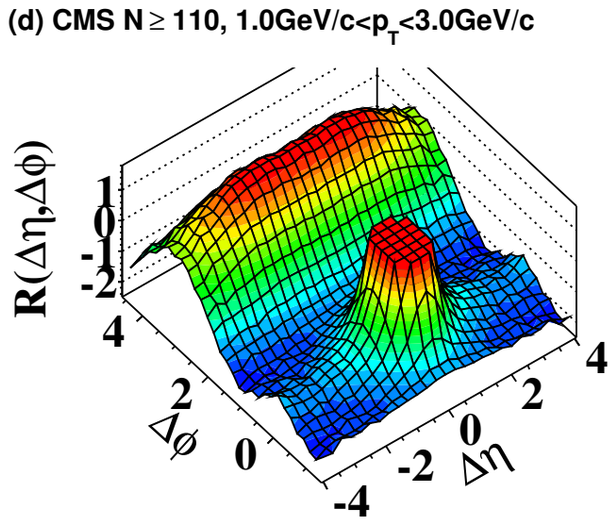
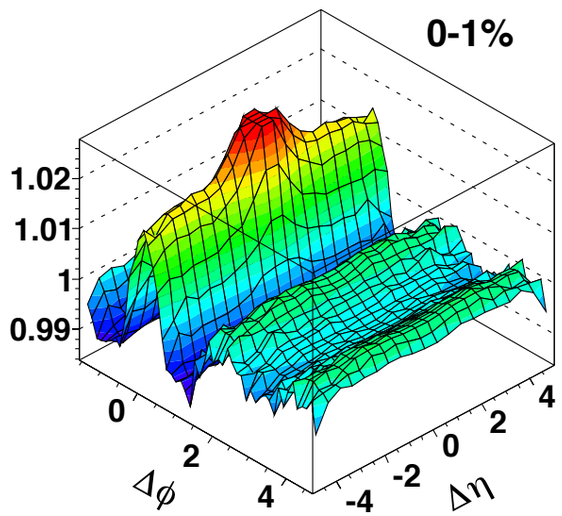
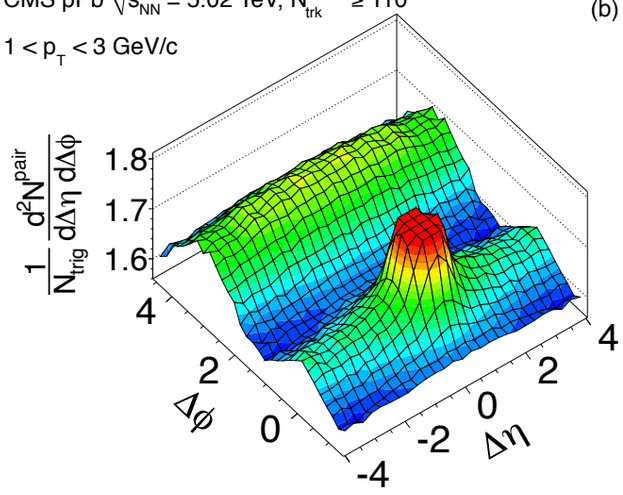




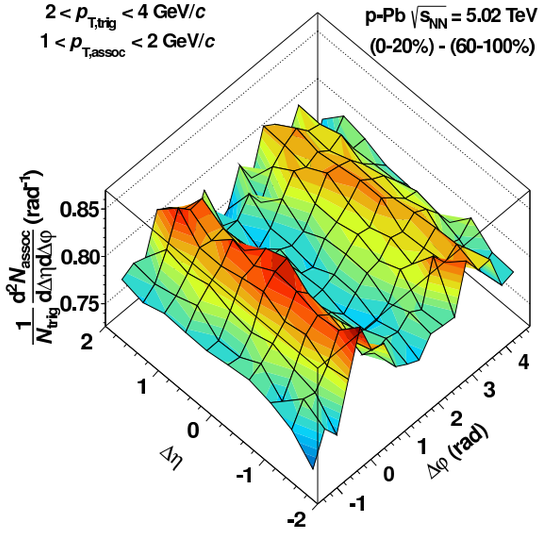
(b) Au+Au 0%-30% (PHOBOS)

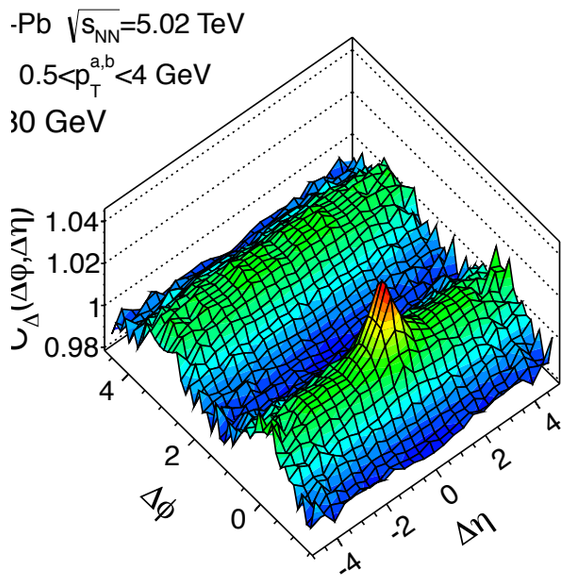






(b)





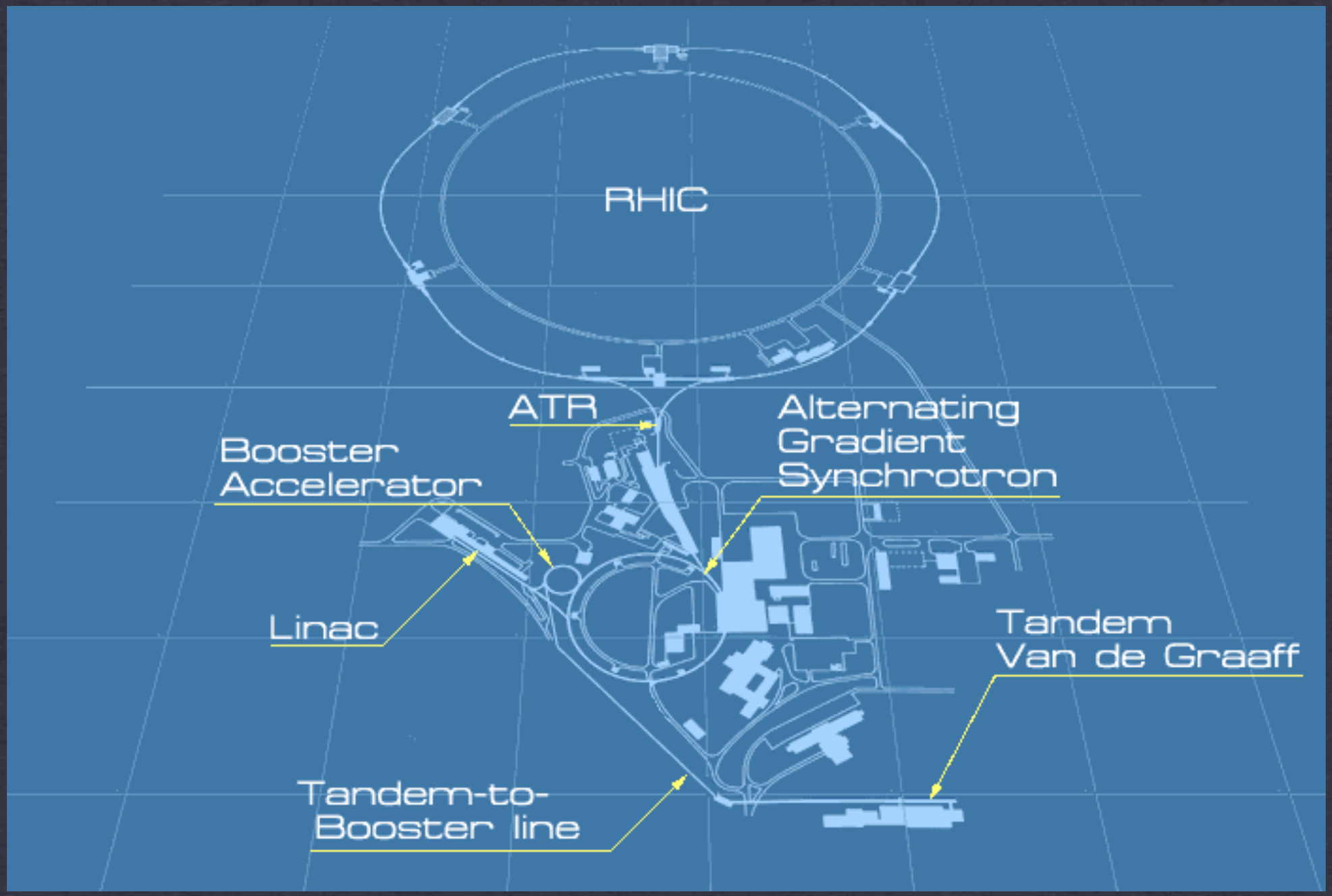
PROJECT

THE RIDGE AT RHIC & THE LHC

PETER STEINBERG, BNL

DATE APRIL 15, 2013

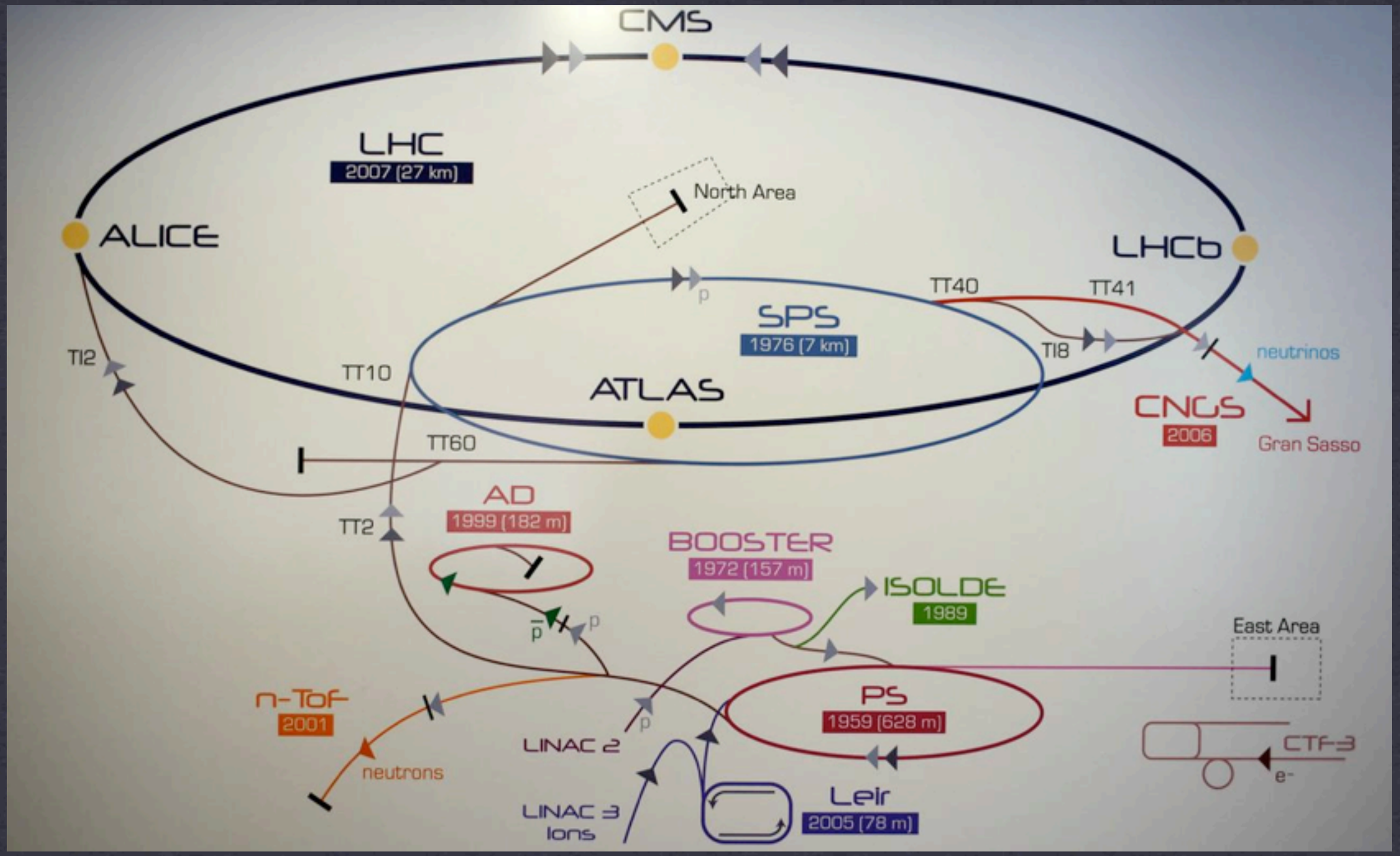
CLIENT JQR2013 @ BNL



PROJECT

RELATIVISTIC HEAVY ION COLLIDER
BROOKHAVEN NATIONAL LABORATORY, USA

DATE	CLIENT
JUNE 2000	HEAVY ION & SPIN COMMUNITIES

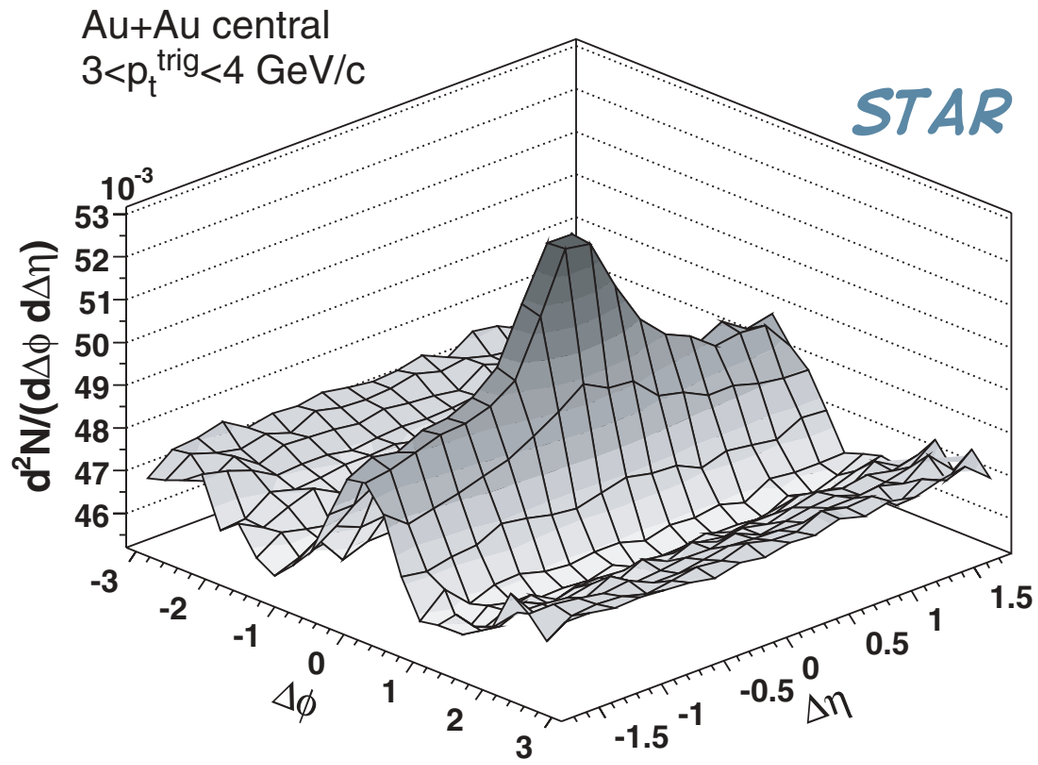


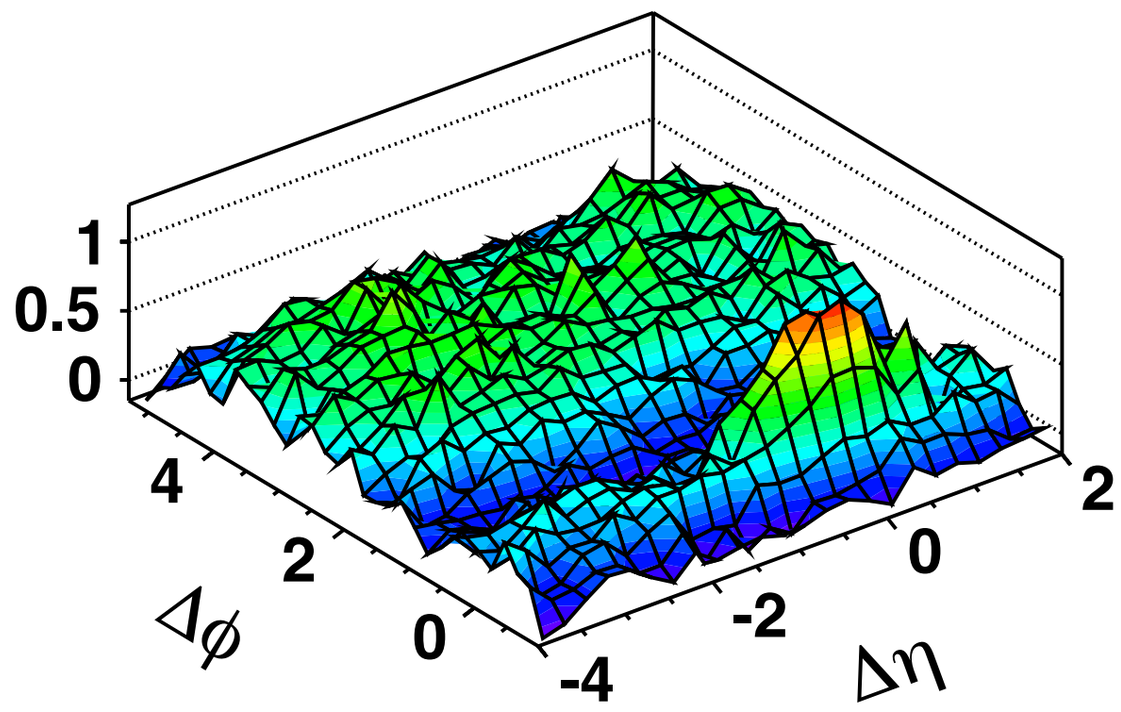
PROJECT

LARGE HADRON COLLIDER
CERN, SWITZERLAND

DATE NOVEMBER 2009

CLIENT HEP & HI COMMUNITIES





(b) Au+Au 0%-30% (PHOBOS)

. . .

PROJECT

THE RHIC RIDGE

PHENIX, PHOBOS, AND STAR

DATE 2004-2010

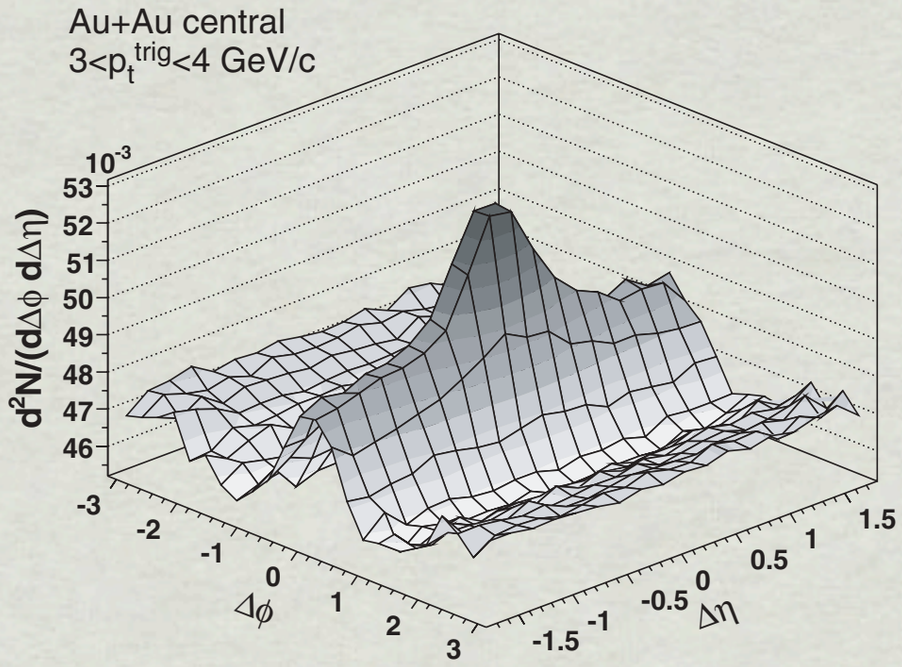
CLIENT HEAVY ION COMMUNITY

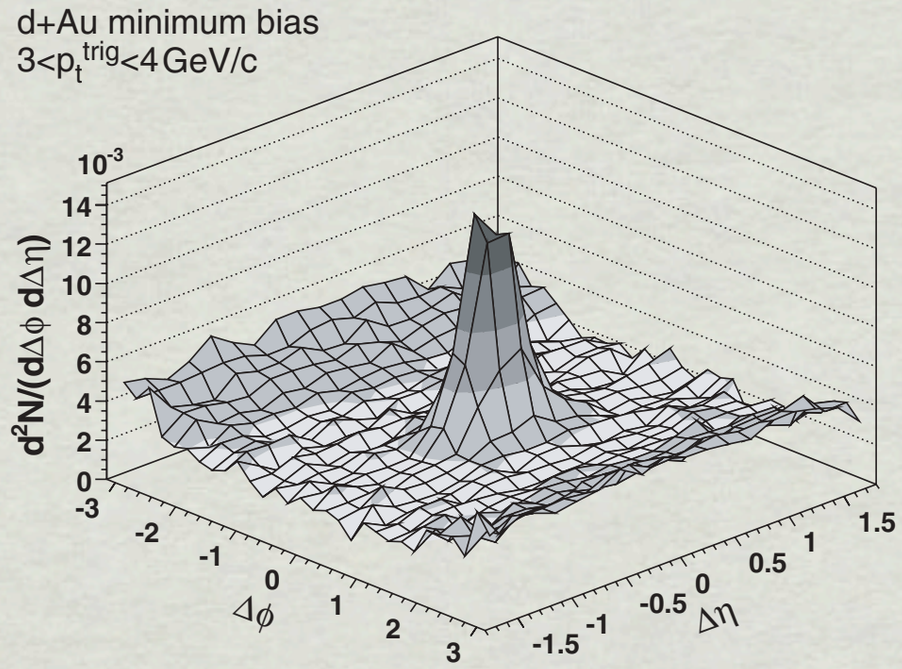
STAR AU+AU RIDGE

* RIDGE FIRST OBSERVED AT RHIC IN AU+AU
* BY-PRODUCT OF STUDY OF HIGH P_T CORRELATIONS
* CLEAR STRUCTURE EXTENDED IN ETA, BUT LOCALIZED IN PHI

CLEARLY SEEN IN AU+AU ...BUT NOT OBSERVED IN D+AU COLLISIONS!

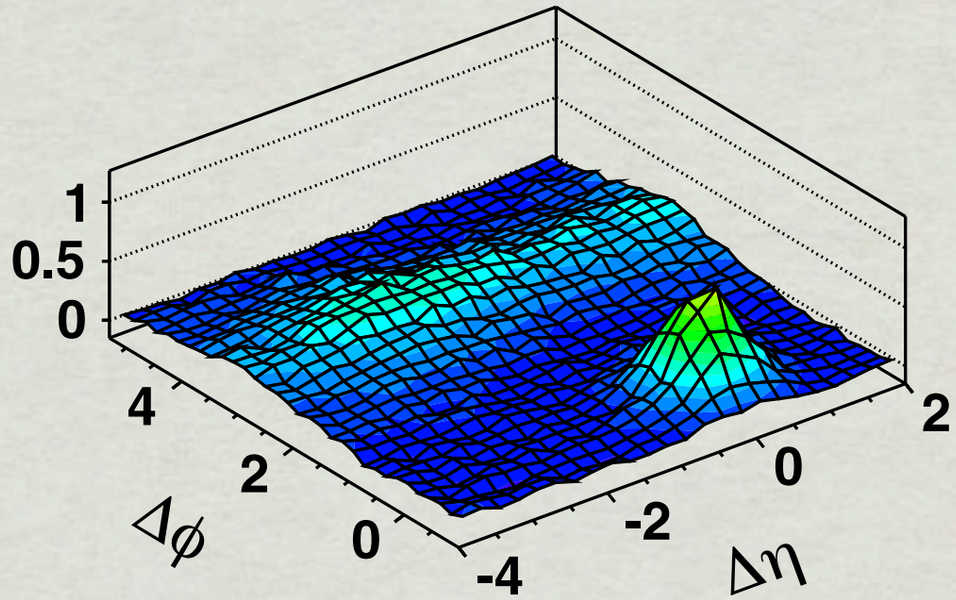
STAR, PRC 80 064912 (2009)



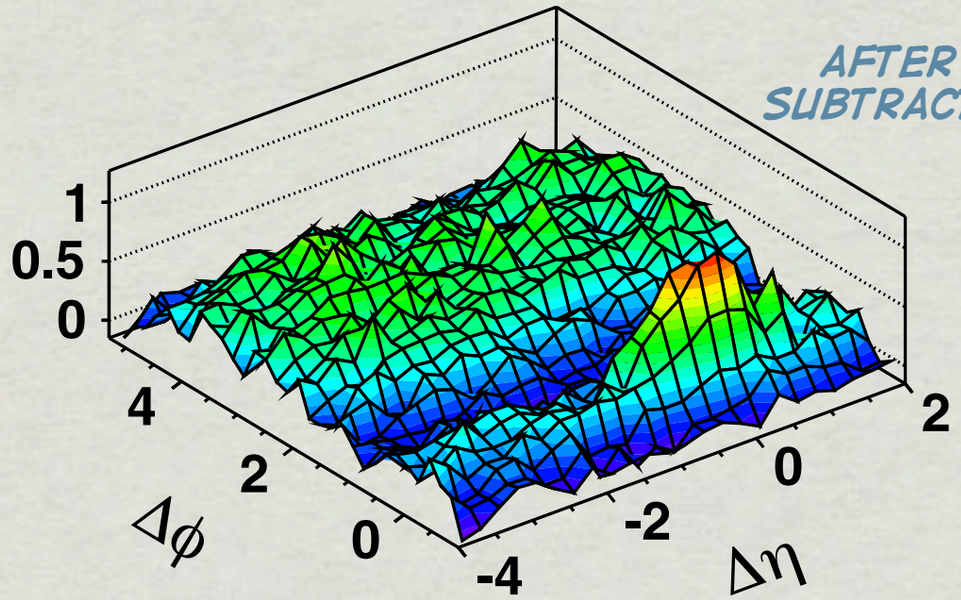


PHOBOS AU+AU RIDGE

PHOBOS, PRL 104 062301 (2010)



(a) p+p PYTHIA (version 6.325)



(b) Au+Au 0%-30% (PHOBOS)

WHILE PHOBOS COULD NOT PROVIDE P_T DEPENDENCE, THE LARGE ETA COVERAGE GAVE FIRST LOOK AT THE RIDGE AT VERY LARGE ΔETA SEPARATIONS...

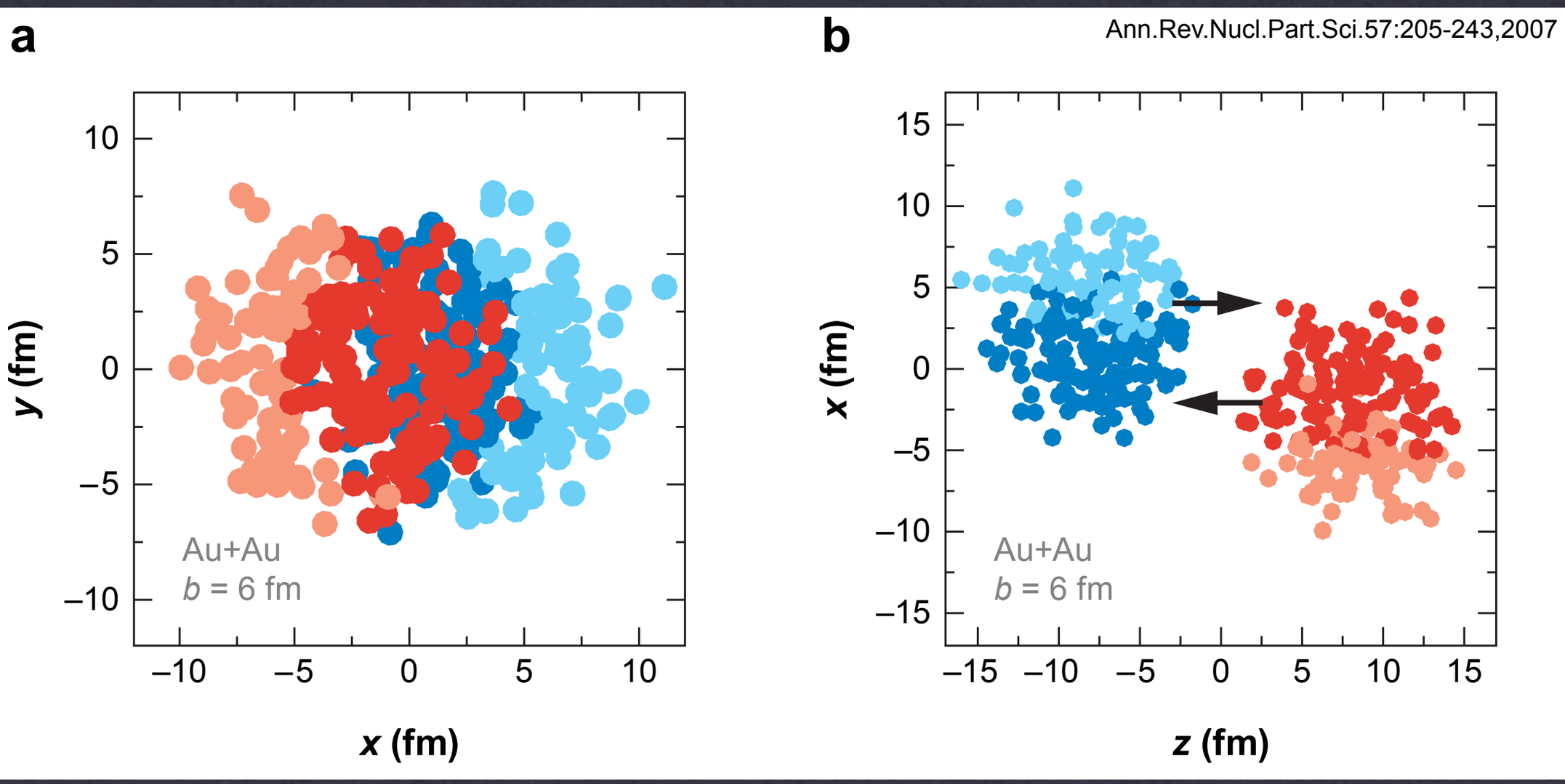
...AND THERE WAS NO END IN SIGHT!

MANY EXPLANATIONS…

…FROM A 2008 TALK BY ED WENGER (PHOBOS)

- **Coupling of induced radiation to longitudinal flow**
  Armesto et al., PRL 93, 242301
- **Recombination of shower + thermal partons**
  Hwa, arXiv:nucl-th/0609017v1
- **Anisotropic plasma**
  Romatschke, PRC 75, 014901
- **Turbulent color fields**
  Shuryak, arXiv:0706.3531v1
- **Bremsstrahlung + transverse flow + jet-quenching**
  Majumder, Muller, Bass, arXiv:hep-ph/0611135v2
- **Splashback from away-side shock**
  Pantuev, arXiv:0710.1882v1
- **Momentum kick imparted on medium partons**
  Wong, arXiv:0707.2385v2
- **Glasma Flux Tubes**
  Dumitru, Gelis, McLerran, Venugopalan, arXiv:0804.3858; Gavin, McLerran, Moscelli, arXiv:0806.4718

"RIDGE & CONE" KEPT US BUSY FOR 6 YEARS!



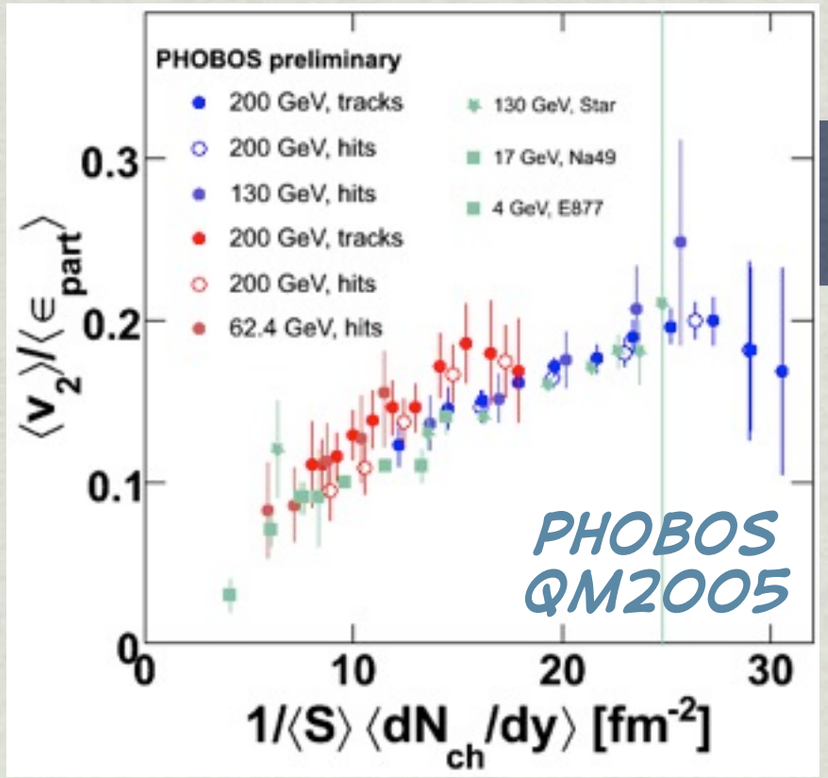
PROJECT

MONTE CARLO GLAUBER
PHOBOS (& ALVER & ROLAND)

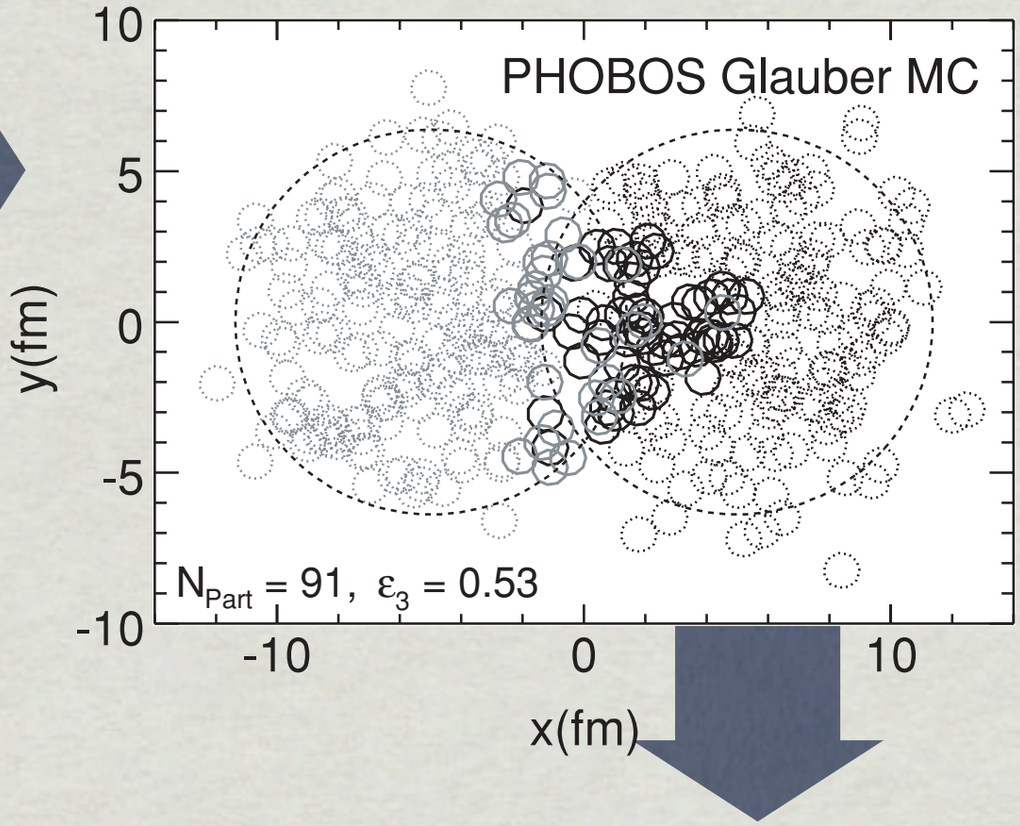
DATE JUNE 2005-MARCH 2010

CLIENT HI COMMUNITY

INITIAL STATE MATTERS

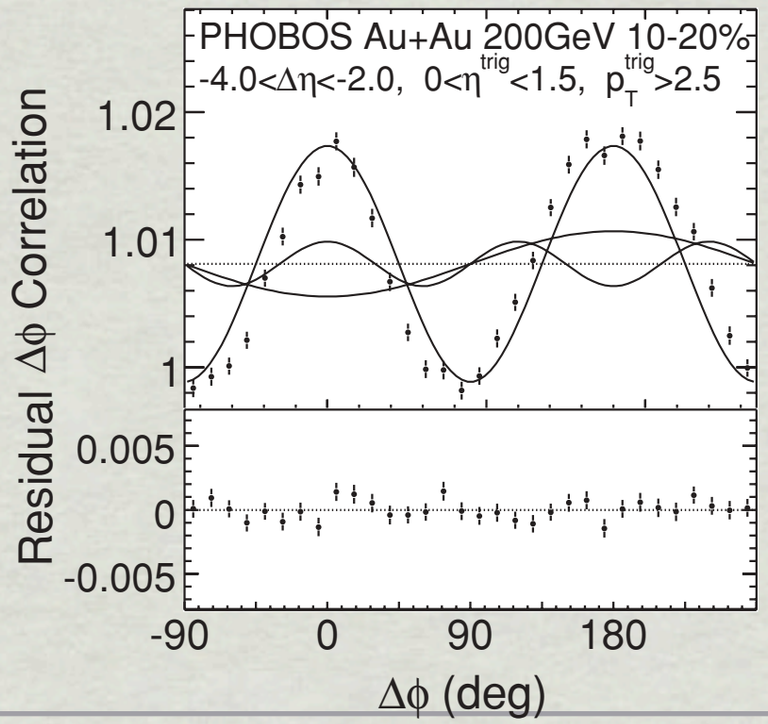


STAR, PRC 81 054905 (2010)



PARTICIPANT ECCENTRICITY BROUGHT AU+AU & CU+CU TOGETHER! **(PHOBOS 2005)**

ALVER & ROLAND WERE FIRST TO MAKE IT CLEAR THAT V_3 SHOULD EXIST AND, MORE IMPORTANTLY, **RIDGE AND CONE ARE "LEFT BEHIND" IF V_2 SUBTRACTED**



THE RIDGE, POST V_3

* ONCE SEEN, DIFFICULT TO FORGET

* FLUCTUATIONS IN THE INITIAL STATE PROVIDE SIMPLEST WAY TO HARMONIZE FLOW SYSTEMATICS

* THEY ARE ALSO THE SIMPLEST WAY TO UNDERSTAND THE RIDGE **AND** MACH CONE

...WAS THIS THE END OF THE RIDGE??

NOT SO FAST!...

Published for SISSA by Springer

Received: *September 22, 2010*
Accepted: *September 23, 2010*
Published: *September 27, 2010*

Observation of long-range, near-side angular correlations in proton-proton collisions at the LHC

The CMS collaboration

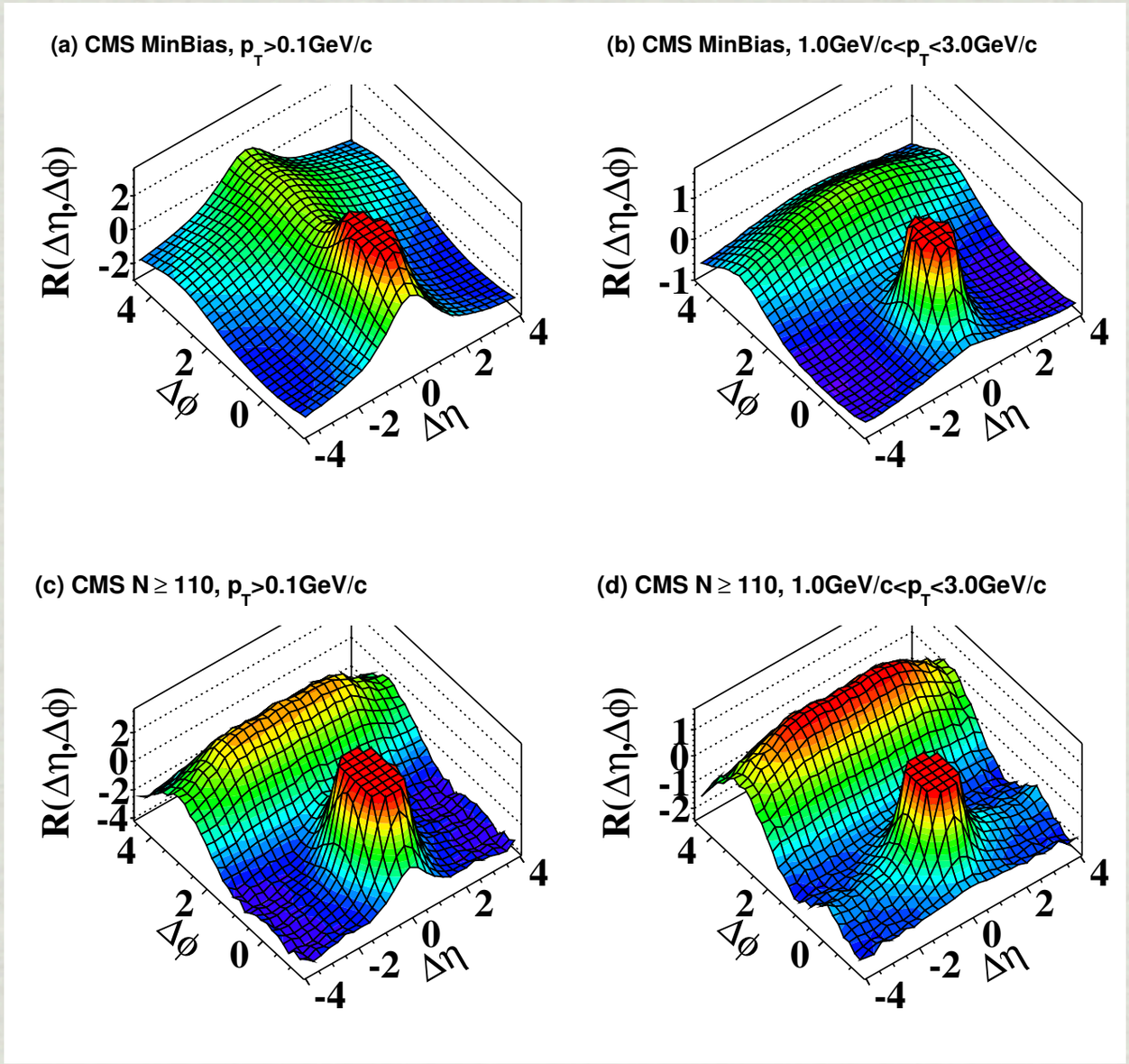
Abstract: Results on two-particle angular correlations for charged particles emitted in proton-proton collisions at center-of-mass energies of 0.9, 2.36, and 7 TeV are presented, using data collected with the CMS detector over a broad range of pseudorapidity (η) and azimuthal angle (ϕ). Short-range correlations in $\Delta\eta$, which are studied in minimum bias

JHEP09(2010)

PROJECT
THE PP RIDGE
CMS COLLABORATION

DATE SEPT. 2010-MARCH 2011 | CLIENT HEP (& HI?) COMMUNITY

SEPTEMBER SURPRISE



CMS, JHEP 1009 091 (2010)

$$R(\Delta\eta,\Delta\phi) = \left\langle (\langle N\rangle - 1)\left(\frac{S_N(\Delta\eta,\Delta\phi)}{B_N(\Delta\eta,\Delta\phi)} - 1\right)\right\rangle_{\text{bins}}$$

$$S_N(\Delta\eta,\Delta\phi) = \frac{1}{N(N-1)}\frac{d^2N^{\text{signal}}}{d\Delta\eta d\Delta\phi}$$

$$B_N(\Delta\eta,\Delta\phi) = \frac{1}{N^2}\frac{d^2N^{\text{mixed}}}{d\Delta\eta d\Delta\phi}$$

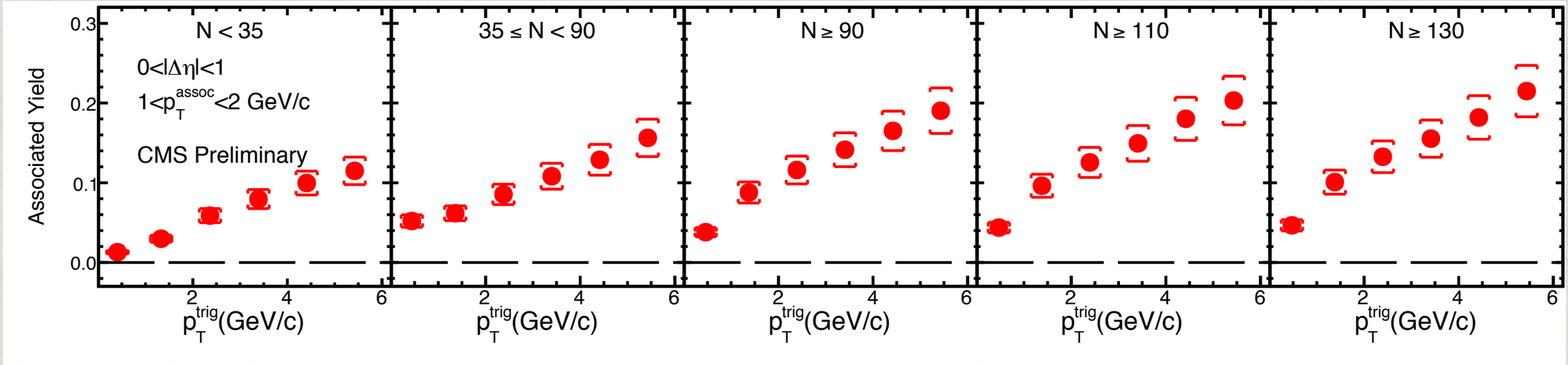
USING A **SPECIAL HIGH MULTIPLICITY TRIGGER**,
A DATA SAMPLE UNAVAILABLE TO THE OTHER EXPERIMENTS
REVEALED **A RIDGE IN PP!**

PHYSICS OF THE RIDGE

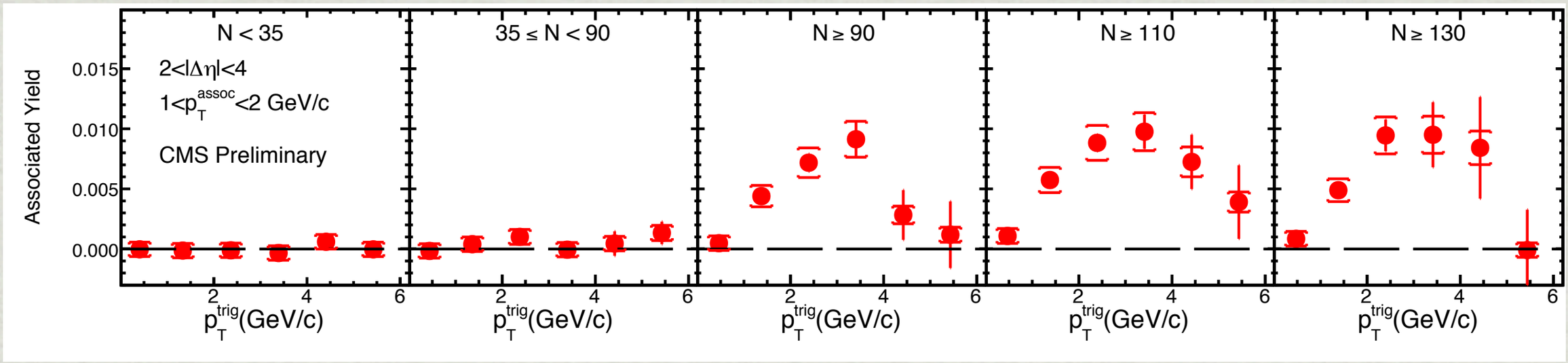
- I DEFER TO MY THEORIST COLLEAGUES, SPEAKING NEXT
- BUT THE **SAME DATA** LED TO A **WIDE VARIETY** OF EXPLANATIONS
  - PARTON SATURATION (VENUGOPALAN ET AL)
  - MULTIPARTON INTERACTIONS (STRIKMAN)
  - BREMSSTRAHLUNG IN STRONG FIELDS
  - "JET-MEDIUM" (HWA, WONG,...)
  - HYDRODYNAMICS (WERNER, AVSAR, ETC.)
- AS WITH THE RHIC RIDGE, MANY EXPLANATIONS BUT NO CLEAR WINNER
  - ABSENCE OF CRISP PREDICTIONS CONFRONTING NEW PP RIDGE DATA

PP RIDGE VS. P_T

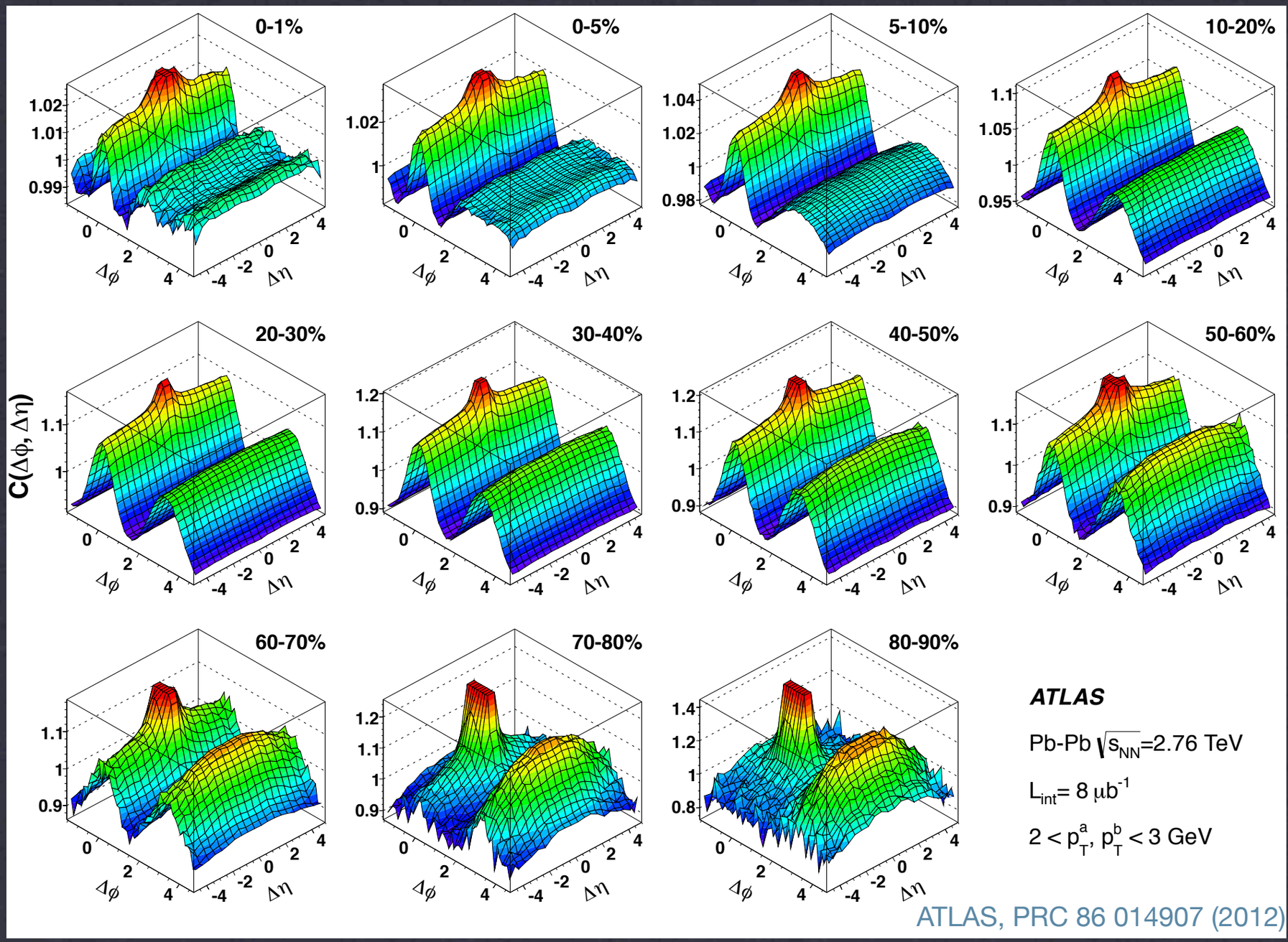
CMS, PAS-HIN-2011-006 (Mar 2011)



A SYSTEMATIC INCREASE IN JET REGION (ΔETA<1)



A CHARACTERISTIC PT DEPENDENCE IN "RIDGE" REGION: ONE WHICH LOOKED FAMILIAR FROM A+A



ATLAS, PRC 86 014907 (2012)

PROJECT

THE PB+PB RIDGE

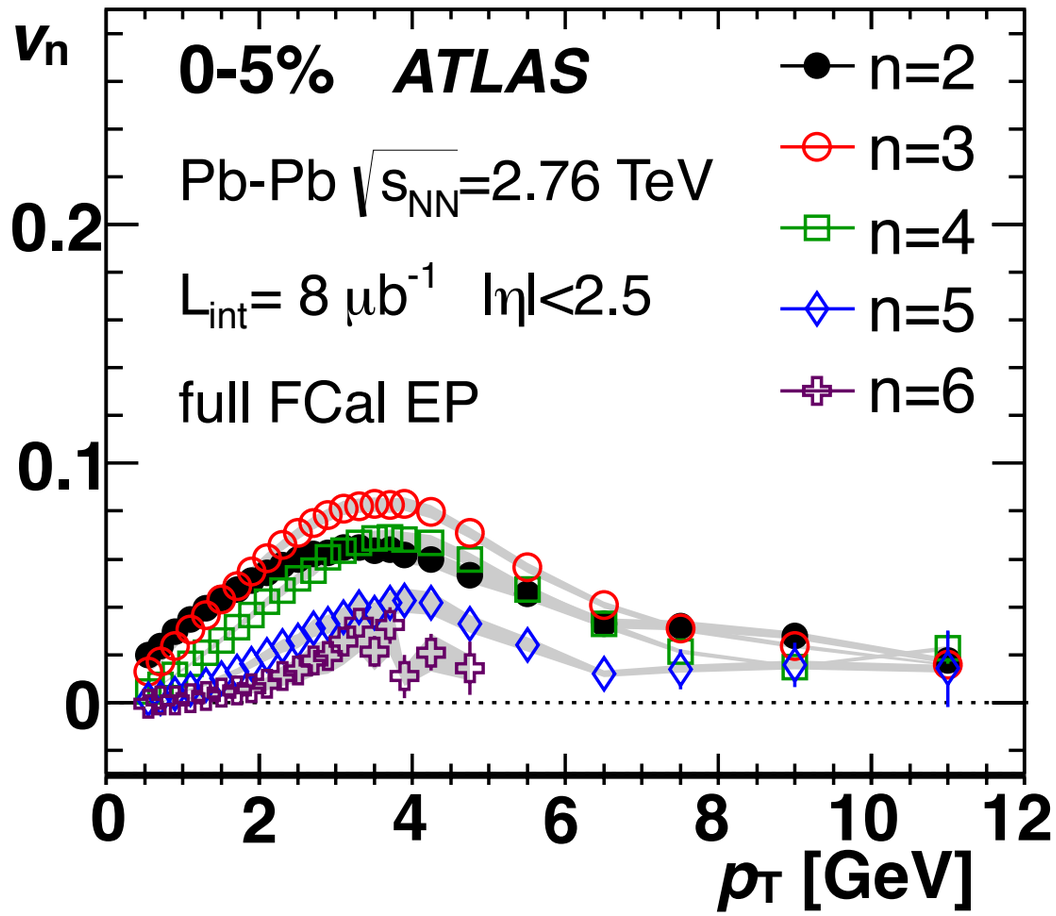
ALICE, ATLAS, CMS

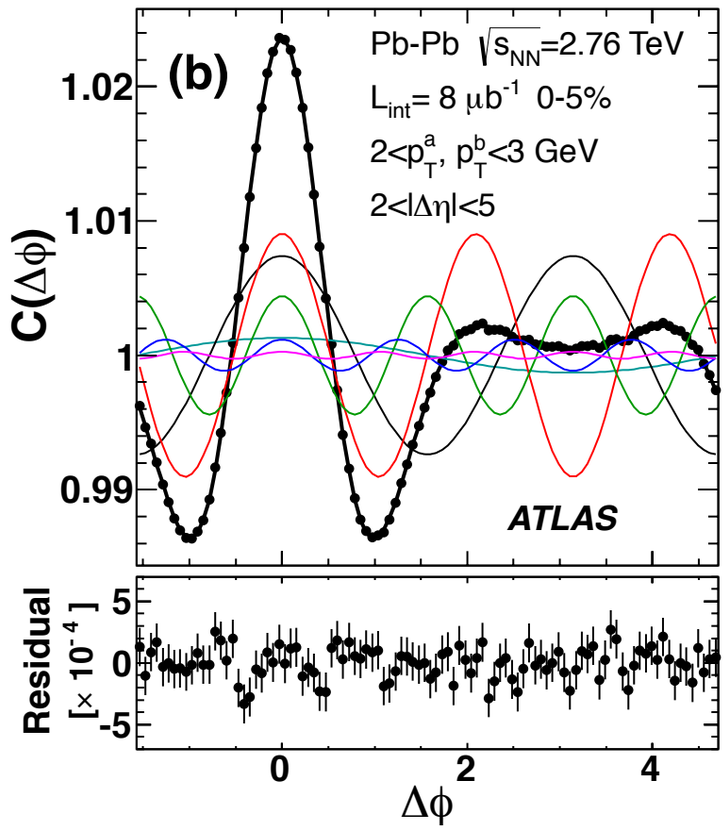
DATE SPRING 2011

CLIENT HEAVY ION COMMUNITY

FOURIER DECOMPOSITION

ATLAS, PRC 86 014907 (2012)



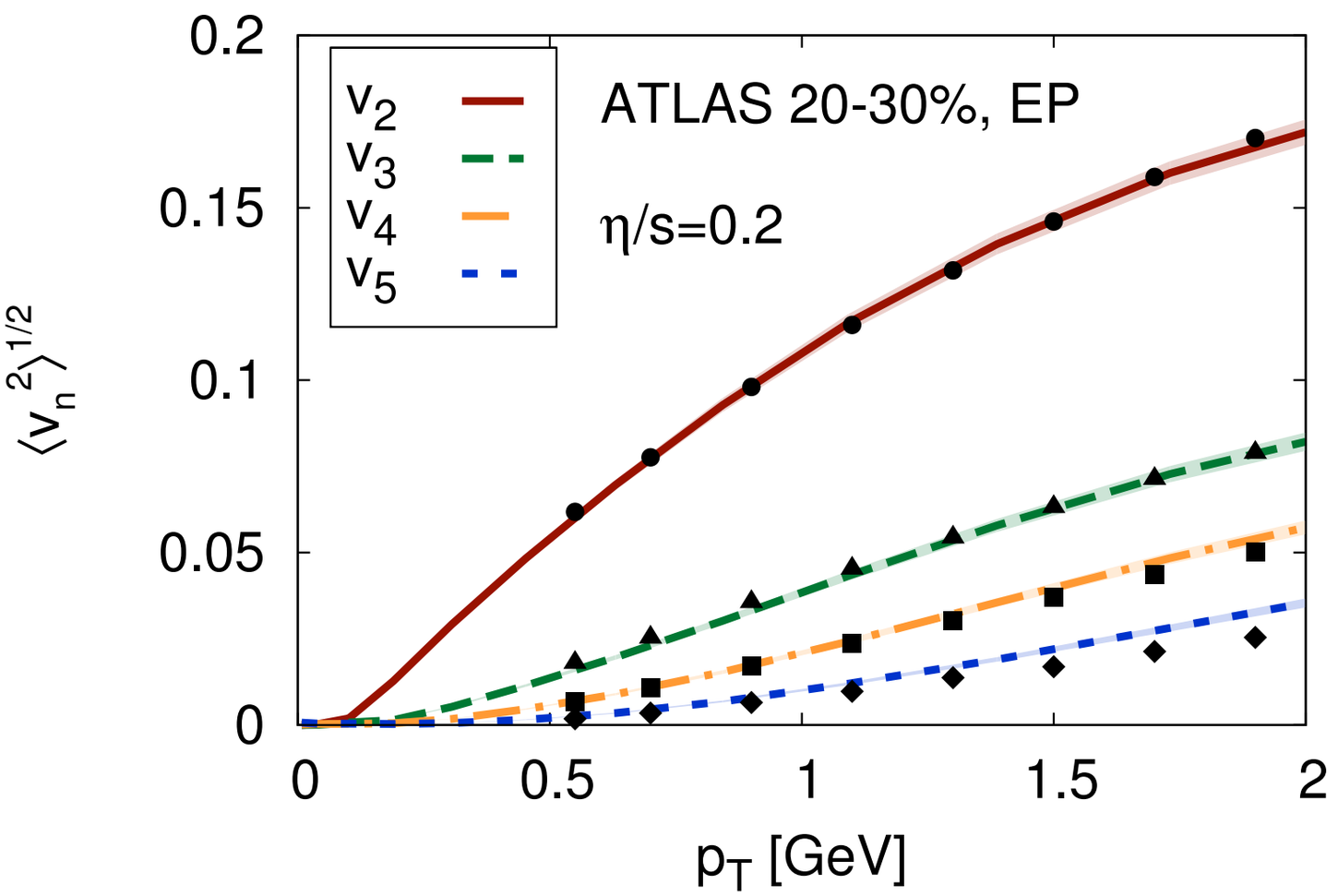


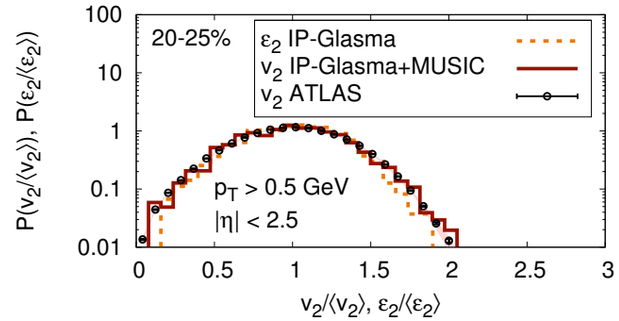
WHY STOP AT TRIANGULAR FLOW?

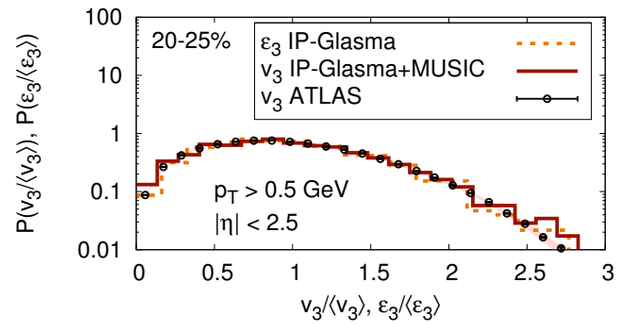
IN THIS VIEW, THE 2PC RIDGE IS SIMPLY ALL FOURIER COMPONENTS CONTRIBUTING AT ΔPHI=0!

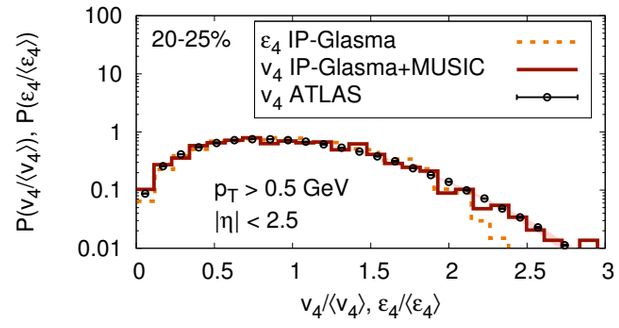
AND NOTE VERY SIMILAR SHAPE OF P_T DEPENDENCE TO PP RIDGE!

v_n FROM FLOW









BOTH MEAN VALUES AND FLUCTUATIONS NICELY DESCRIBED BY **EVENTWISE VISCOUS HYDRO WITH IP GLASMA IC.** (& OTHERS)

(SCHENKE ET AL, HEINZ ET AL, LUZUM ET AL,...)

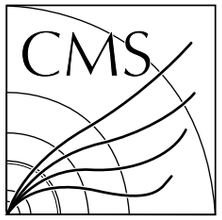
WITH THE HIGHER-ORDER HARMONICS...

HAD WE FINALLY BURIED THE RIDGE?...

...AT LEAST IN A+A, WHERE FLOW WAS ALREADY THE LEADING HYPOTHESIS

NOT SO FAST!...

EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH (CERN)



CERN-PH-EP/2012-320
2012/10/23

CMS-HIN-12-015

Observation of long-range, near-side angular correlations in pPb collisions at the LHC

The CMS Collaboration*

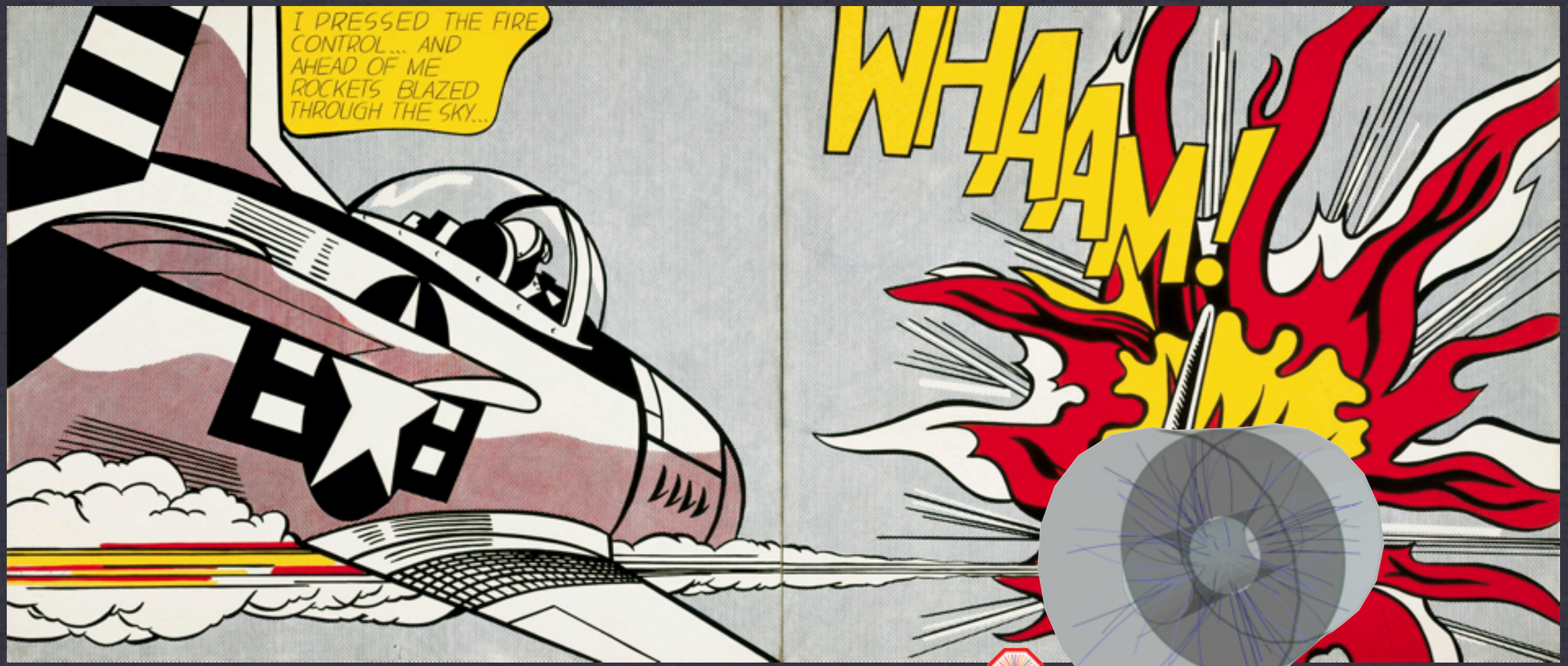
PROJECT

DISCOVERY OF A P+PB RIDGE
THE CMS COLLABORATION

DATE OCTOBER 23, 2013

CLIENT HEAVY ION COMMUNITY

EAT A MICROBARN OF LEAD, PROTONS!...



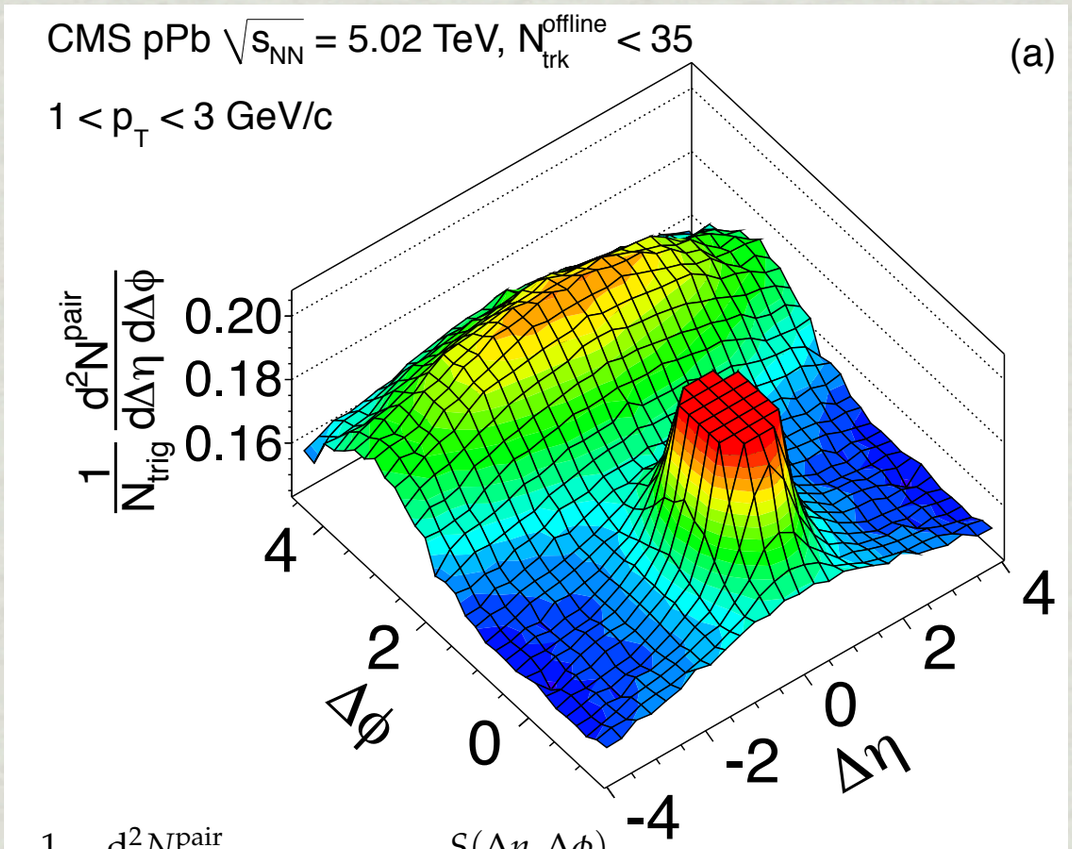
PROJECT

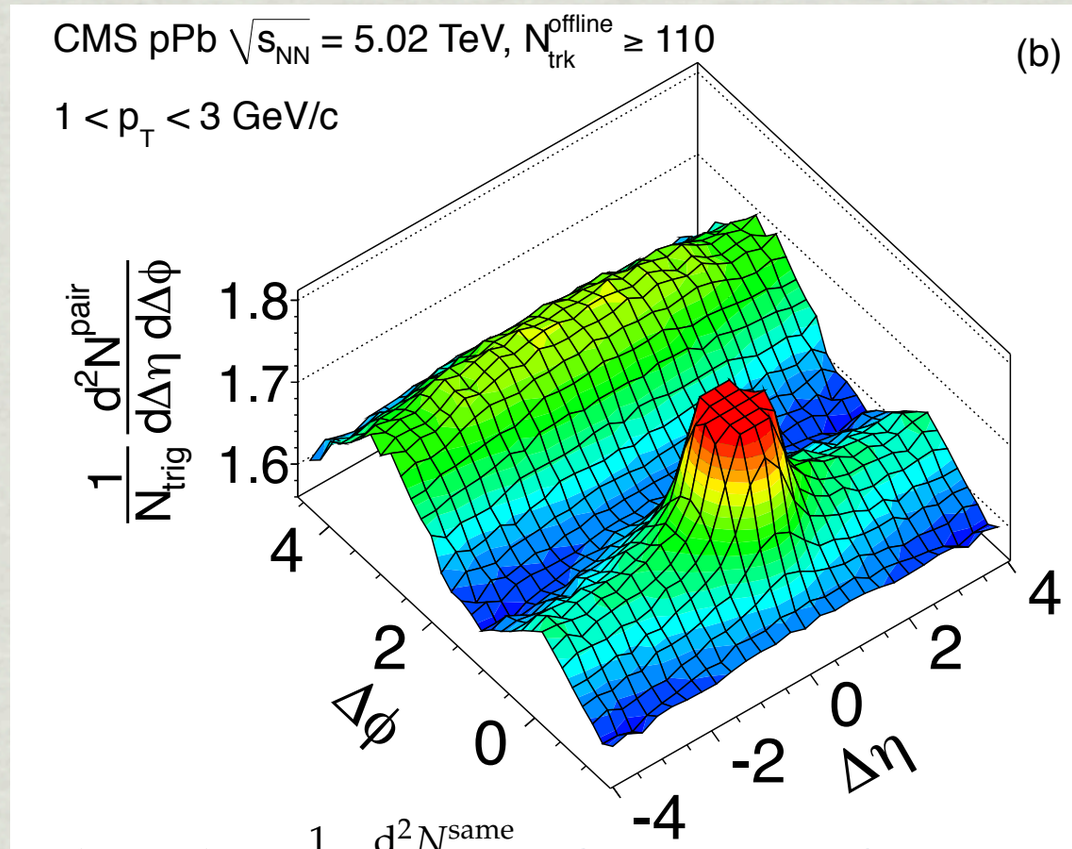
THE P+PB PILOT RUN
LARGE HADRON COLLIDER (J. JOWETT, ET AL)

DATE	CLIENT
SEPTEMBER 12, 2012	HI COMMUNITY & LHCB

RIDGE REDISCOVERED

CMS, PLB 718 795 (2013)





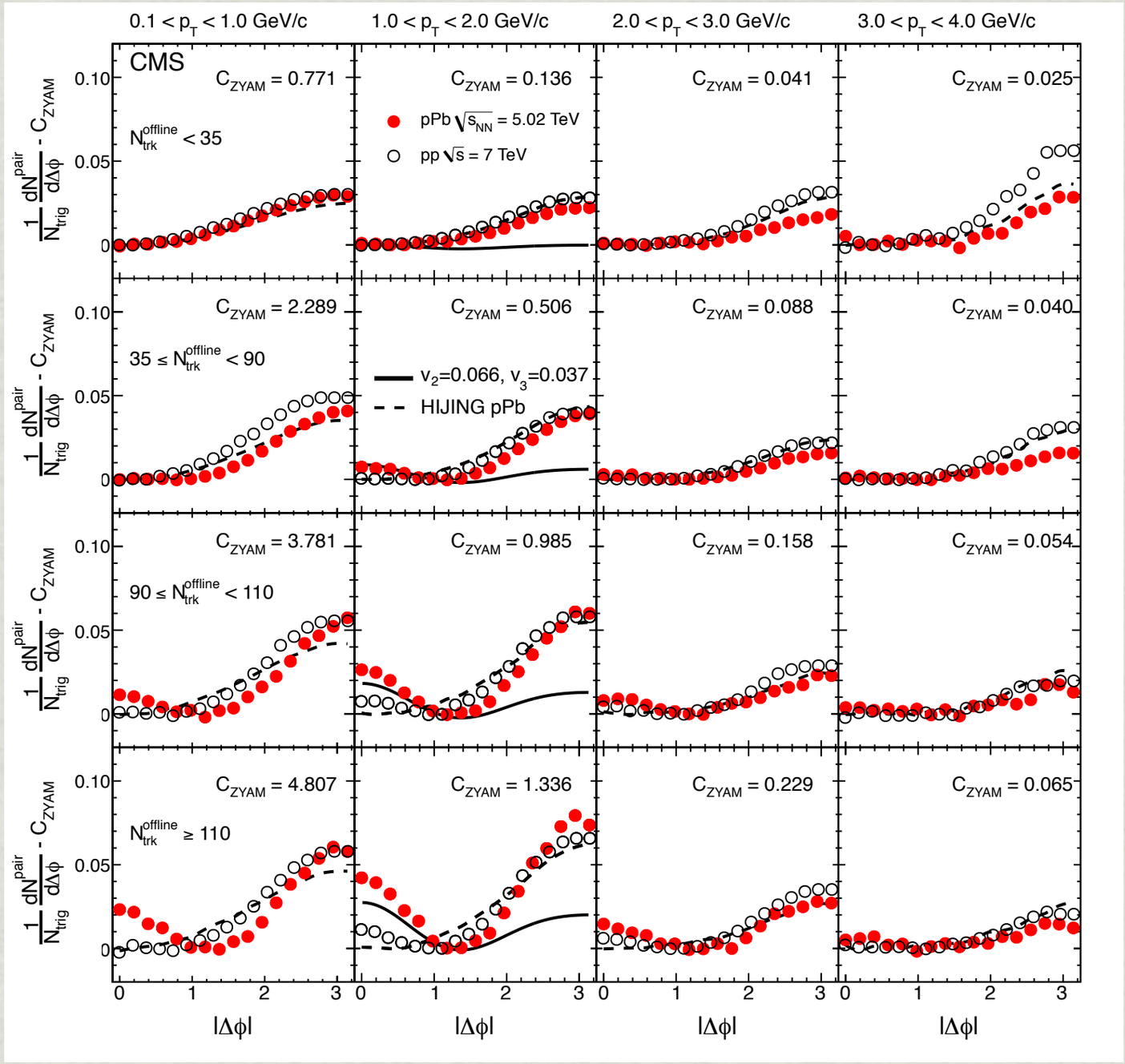
IN PP, RIDGE REQUIRED HIGHEST MULTIPLICITY COLLISIONS TO BE SEEN NEXT TO ENORMOUS NEAR-SIDE PEAK,

IN P+PB RIDGE WAS VISIBLE WITH RATHER MODEST MULTIPLICITIES (DUE TO MULTIPLE COLLISIONS)

CORRELATION FUNCTIONS

EQUAL MOMENTUM BINS

MULTIPLICITY BINS

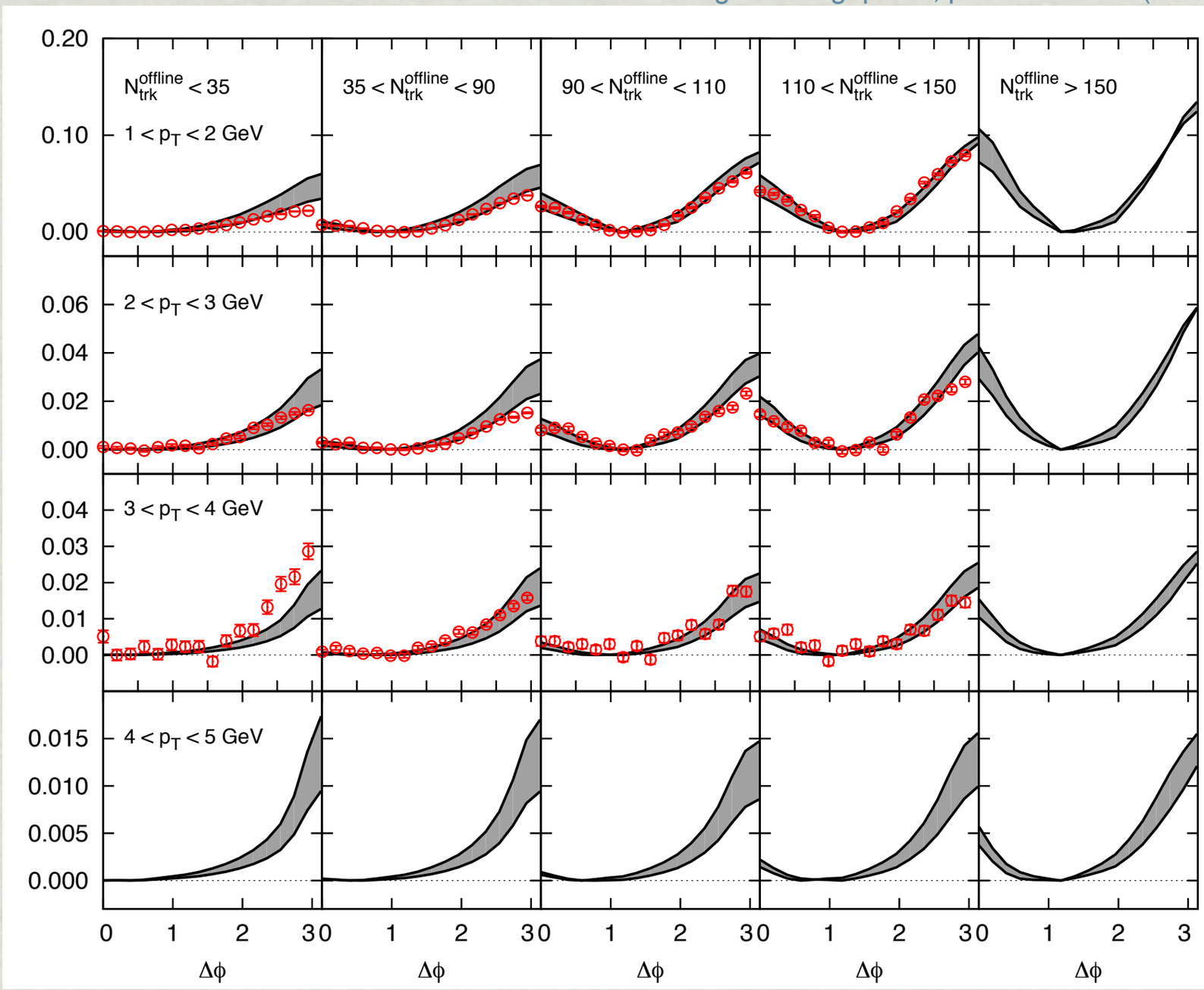


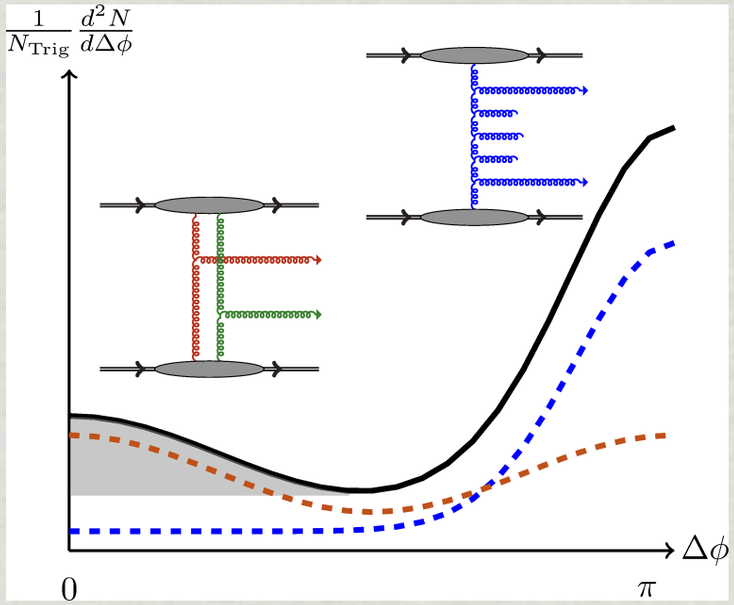
CMS, PLB 718 795 (2013)

COMPARISONS TO HIJING & HYDRO PREDICTIONS

CGC MODELING

Dusling & Venugopalan, prd 87 054014 (2013)





BASED ON PP EXPERIENCE, CGC GROUPS WERE **READY!**

THIS WORK AND COMPARISONS TO LATER DATA WILL BE COVERED IN RAJU'S TALK!...

ALSO WORK BY: KOVCHEGOV & WERPERTNY

MEANWHILE...

THE OTHER LHC EXPERIMENTS WERE BUSY AT WORK!...

...FINALIZING PAPERS SIMULTANEOUSLY (ALTHOUGH ALICE GOT THE JUMP ON ATLAS!)

EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

CERN-PH-EP-2012-359
03 Dec 2012

Long-range angular correlations on the near and away side in p–Pb collisions at $\sqrt{s_{NN}}$= 5.02 TeV

ALICE Collaboration*

Abstract

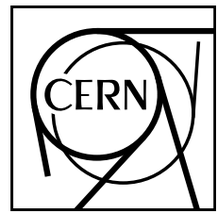
Angular correlations between charged trigger and associated particles are measured by the ALICE detector in p–Pb collisions at a nucleon–nucleon centre-of-mass energy of 5.02 TeV for transverse momentum ranges within $0.5 < p_{\mathrm{T,assoc}} < p_{\mathrm{T,trig}} < 4$ GeV/c. The correlations

PROJECT
THE P+PB RIDGE
ALICE COLLABORATION

DATE DECEMBER 10, 2012

CLIENT HEAVY ION COMMUNITY

EUROPEAN ORGANISATION FOR NUCLEAR RESEARCH (CERN)



CERN-PH-EP-2012-366

Submitted to: Phys. Rev. Lett.

Observation of Associated Near-side and Away-side Long-range Correlations in $\sqrt{s_{\rm NN}} = 5.02\,\text{TeV}$ Proton–lead Collisions with the ATLAS Detector

The ATLAS Collaboration

PROJECT
THE P+PB RIDGE
ATLAS COLLABORATION

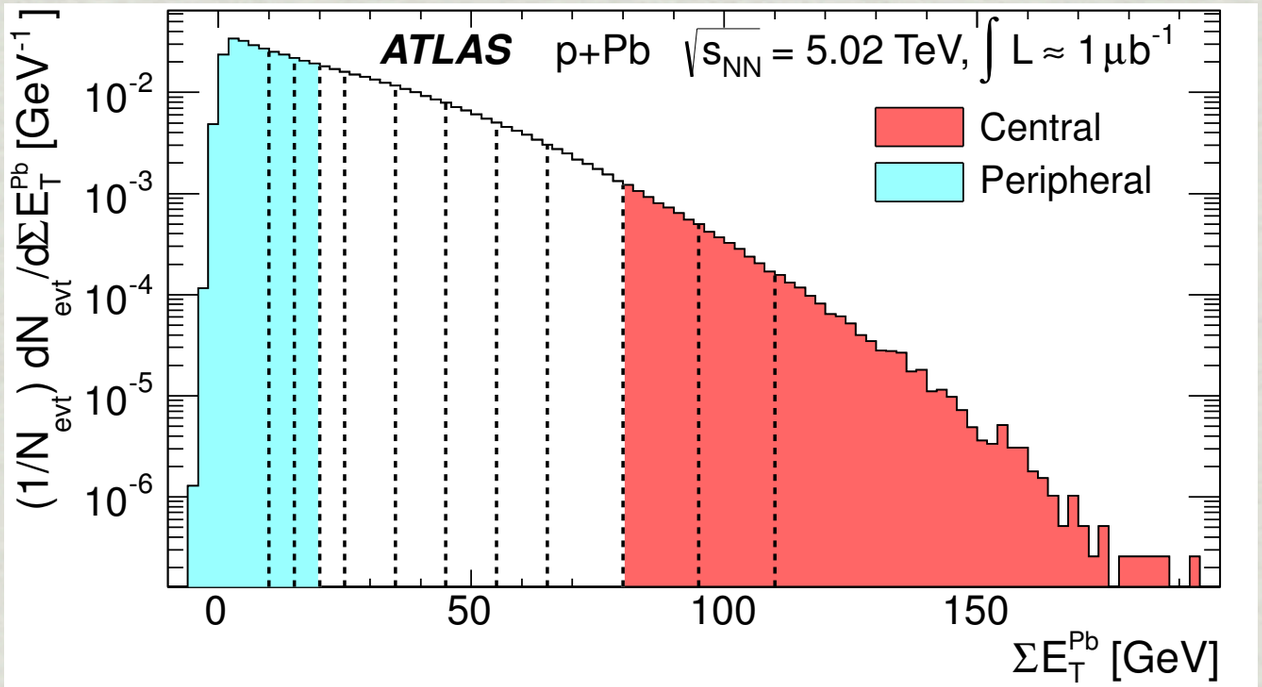
DATE DECEMBER 20, 2012 | CLIENT HEAVY ION COMMUNITY

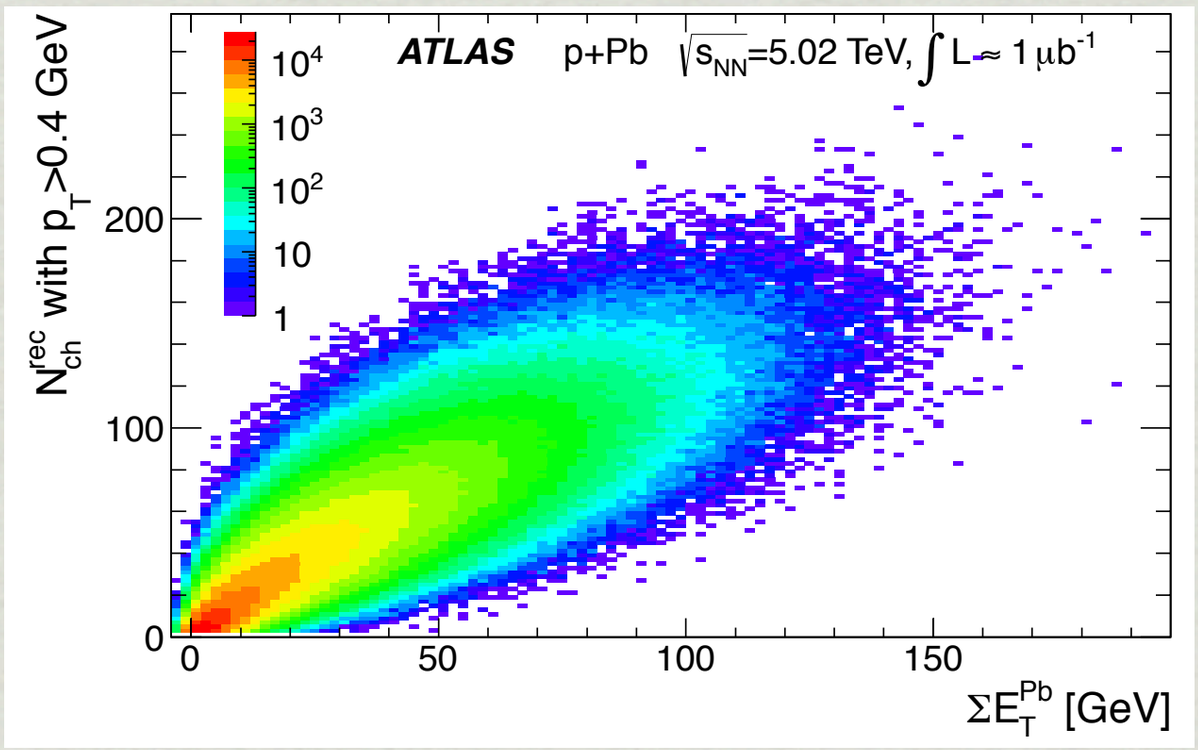
"EVENT ACTIVITY"

ATLAS, arXiv:1212.5198 (2013, accepted by PRL)

OVERALL ACTIVITY CHARACTERIZED BY ATLAS WITH E_T SUM IN $3.2<\eta<4.9$,

AND ALICE WITH VOM, MULTIPLICITY IN FORWARD DIRECTION

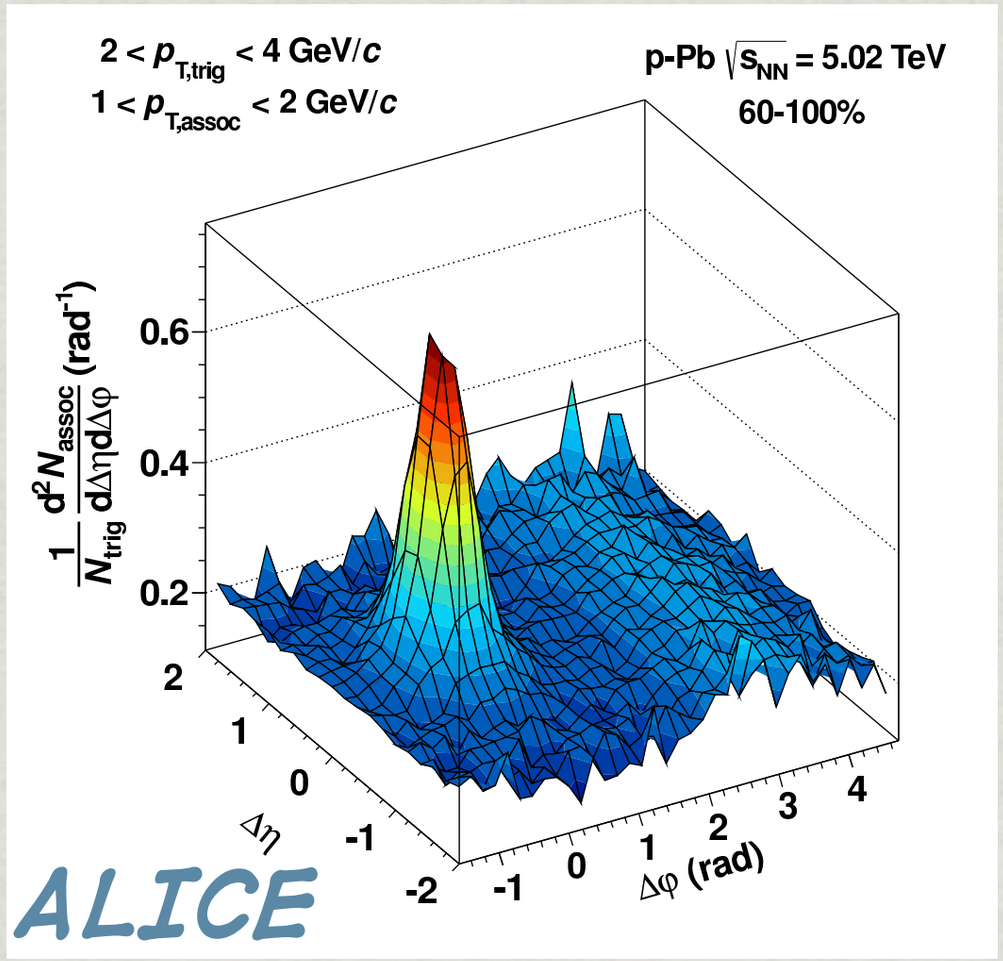


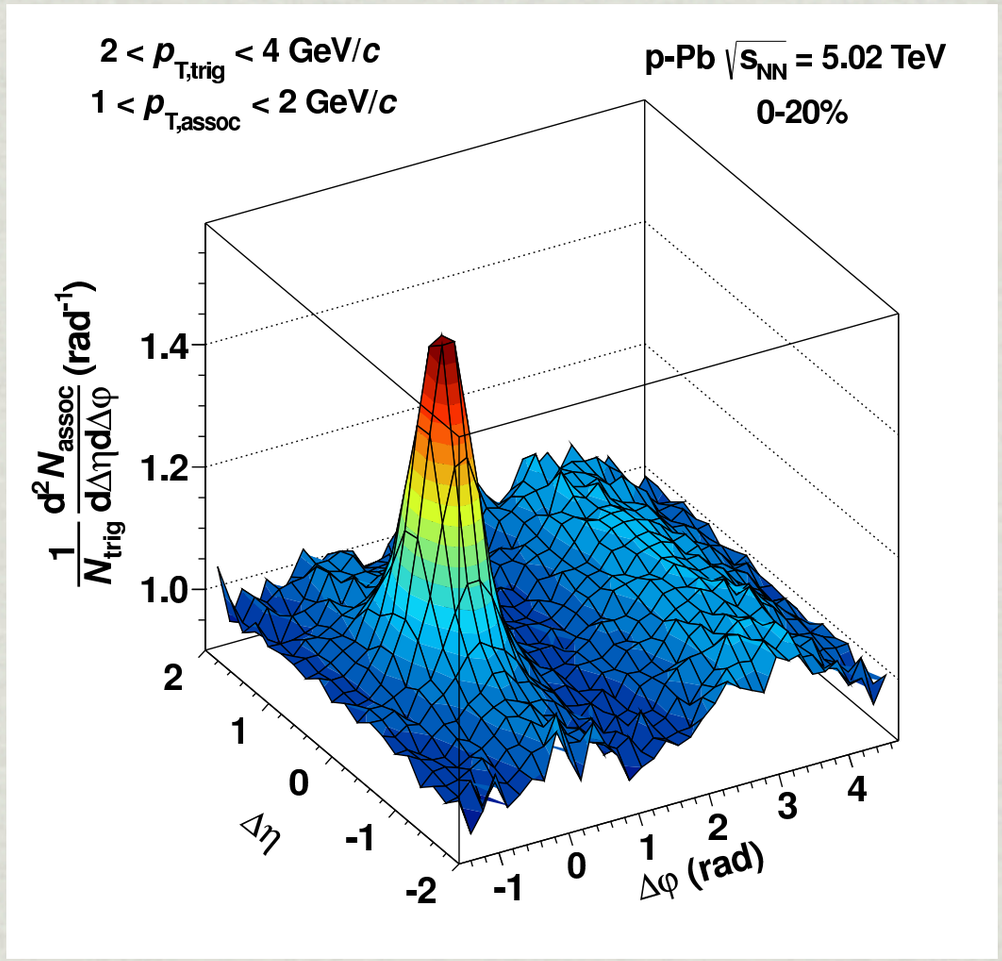


IMPORTANT TO AVOID CUTTING DIRECTLY INTO MULTIPLICITY DISTRIBUTION AT ETA~0

SECOND OBSERVATION!

ALICE, PLB 719 29 (2013)





EVEN WITH A SMALLER ΔETA ACCEPTANCE,
THE RIDGE WAS OBSERVED BY ALICE
AT THE FOOT OF THE JET MOUNTAIN...

$$\frac{1}{N_{\mathrm{trig}}}\frac{\mathrm{d}^2N_{\mathrm{assoc}}}{\mathrm{d}\Delta\eta\,\mathrm{d}\Delta\varphi}=\frac{S(\Delta\eta,\Delta\varphi)}{B(\Delta\eta,\Delta\varphi)}$$

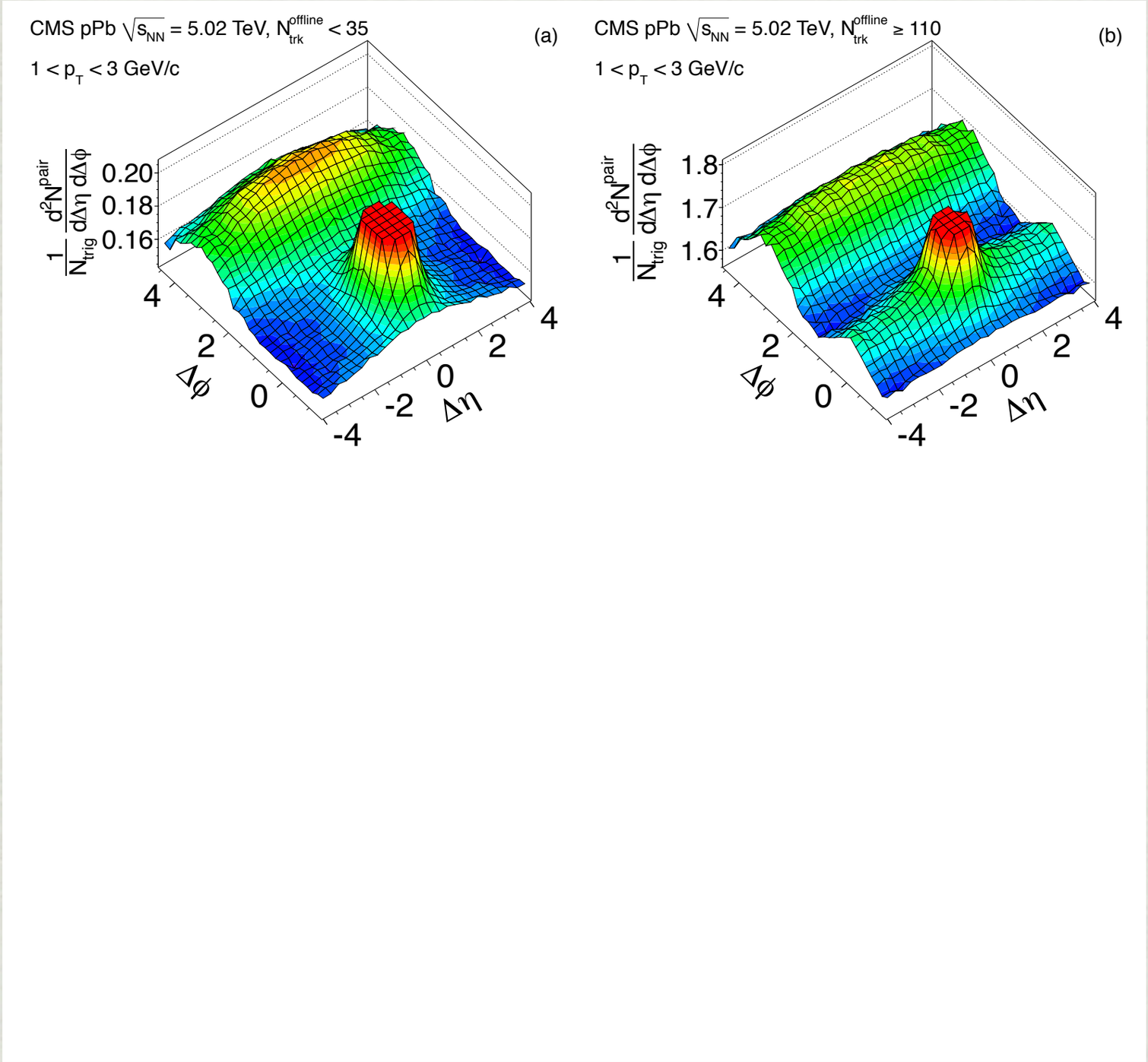
$$S(\Delta\eta,\Delta\varphi)=1/N_{\mathrm{trig}}\mathrm{d}^2N_{\mathrm{same}}/\mathrm{d}\Delta\eta\,\mathrm{d}\Delta\varphi$$

(SUMMED OVER MULTIPLICITY CLASS)

ATLAS VS. CMS

CMS

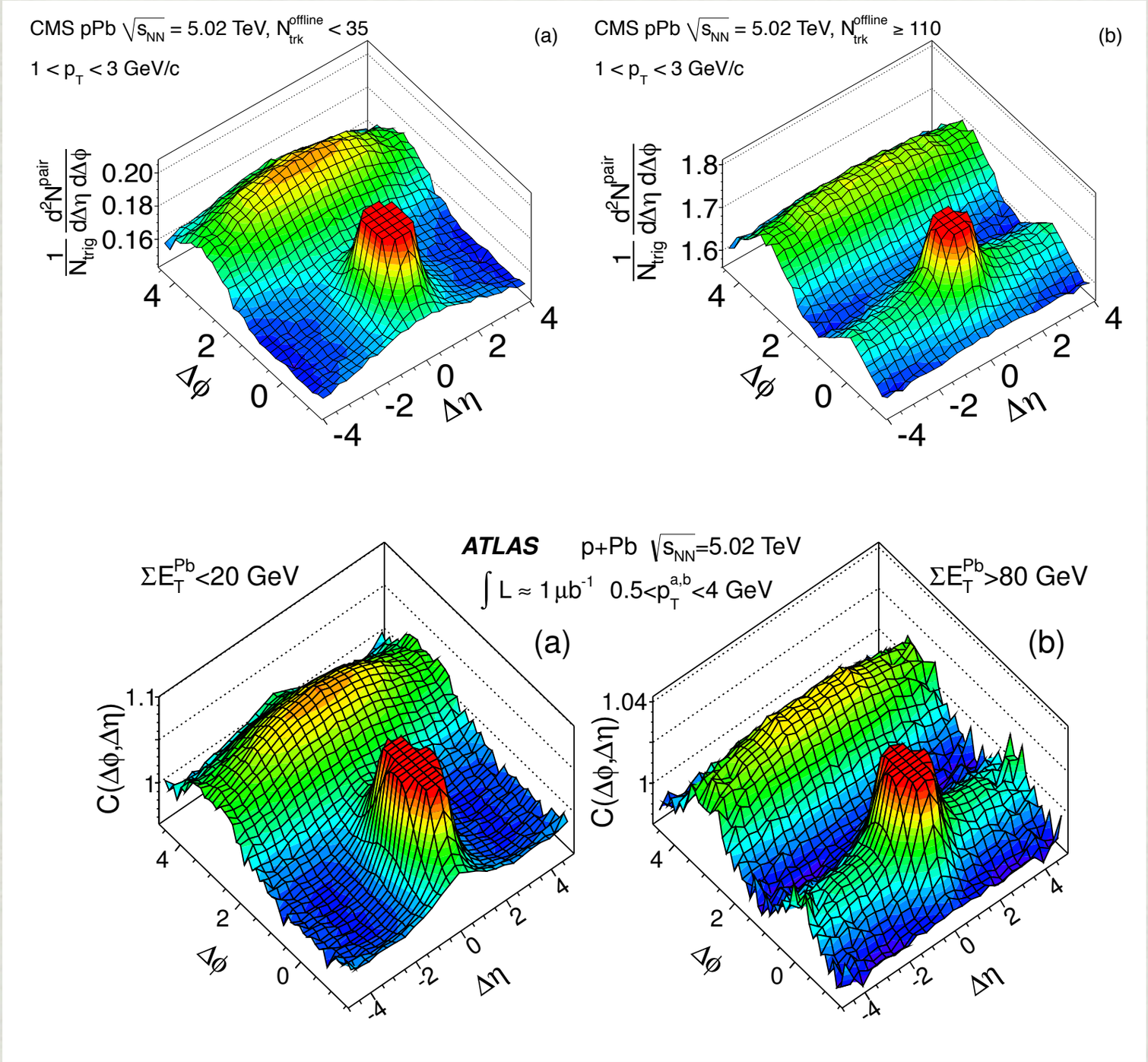
ATLAS



PERI. CENT.

ATLAS VS. CMS

CMS



ATLAS

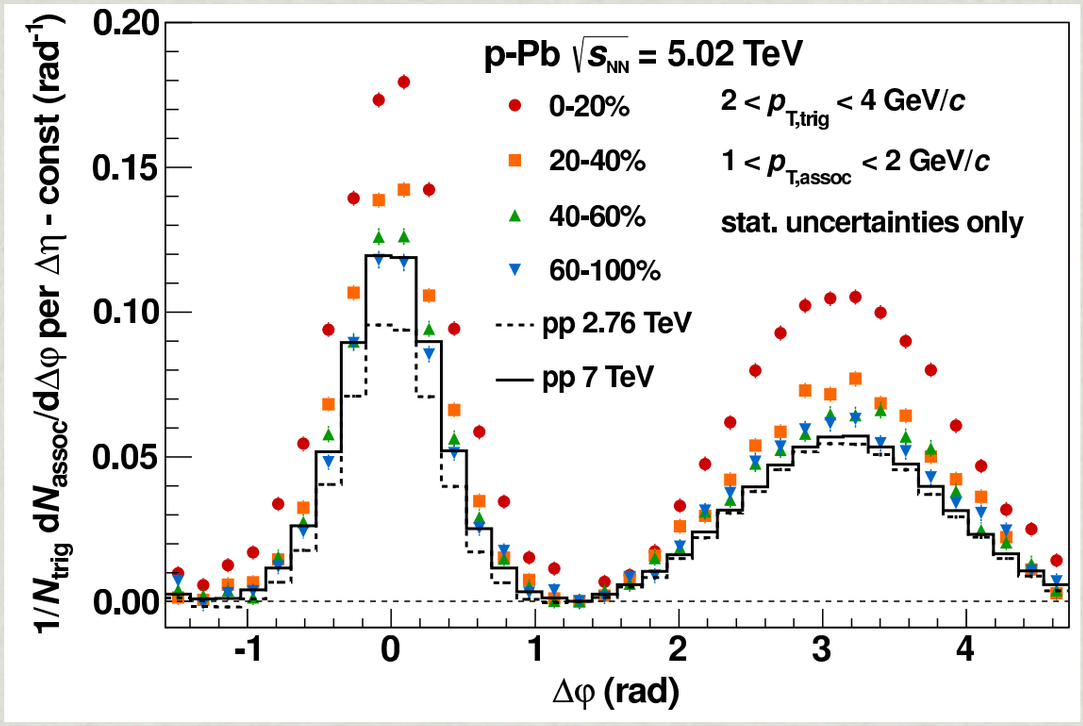
VERY SIMILAR OBSERVATION!

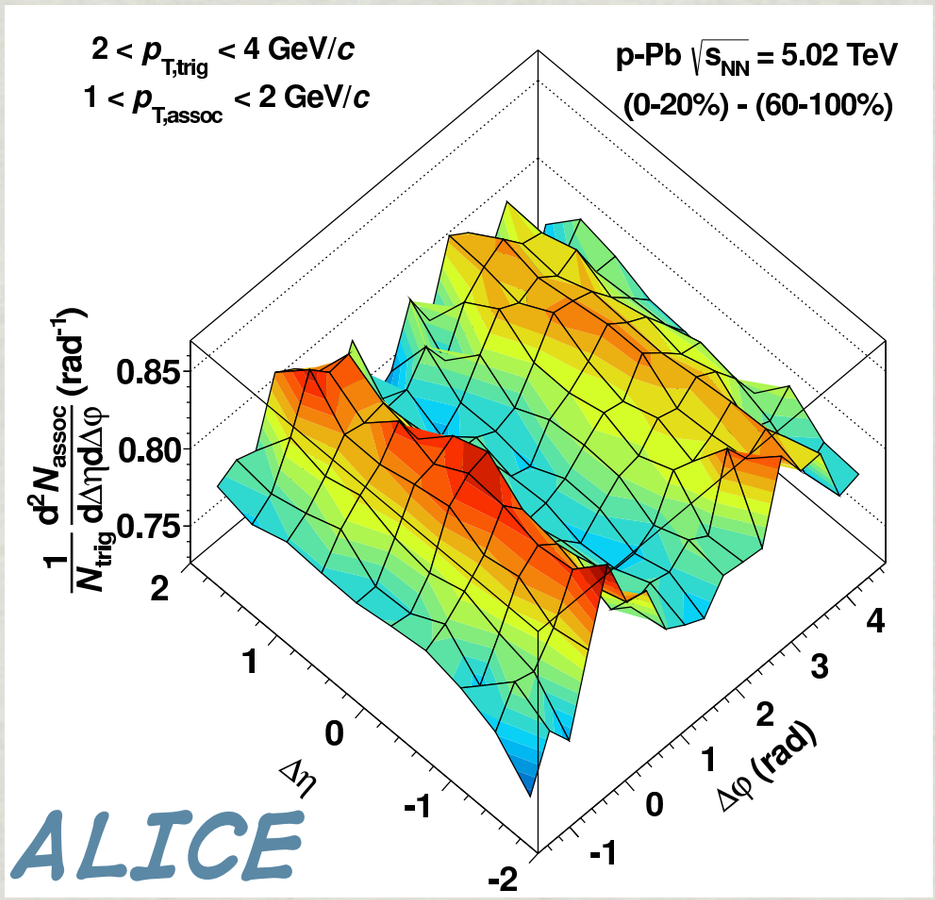
$$C(\Delta\phi, \Delta\eta) = \frac{S(\Delta\phi, \Delta\eta)}{B(\Delta\phi, \Delta\eta)}$$

(SUMMED OVER MULTIPLICITY CLASS)

PERI. CENT.

A TWIN?





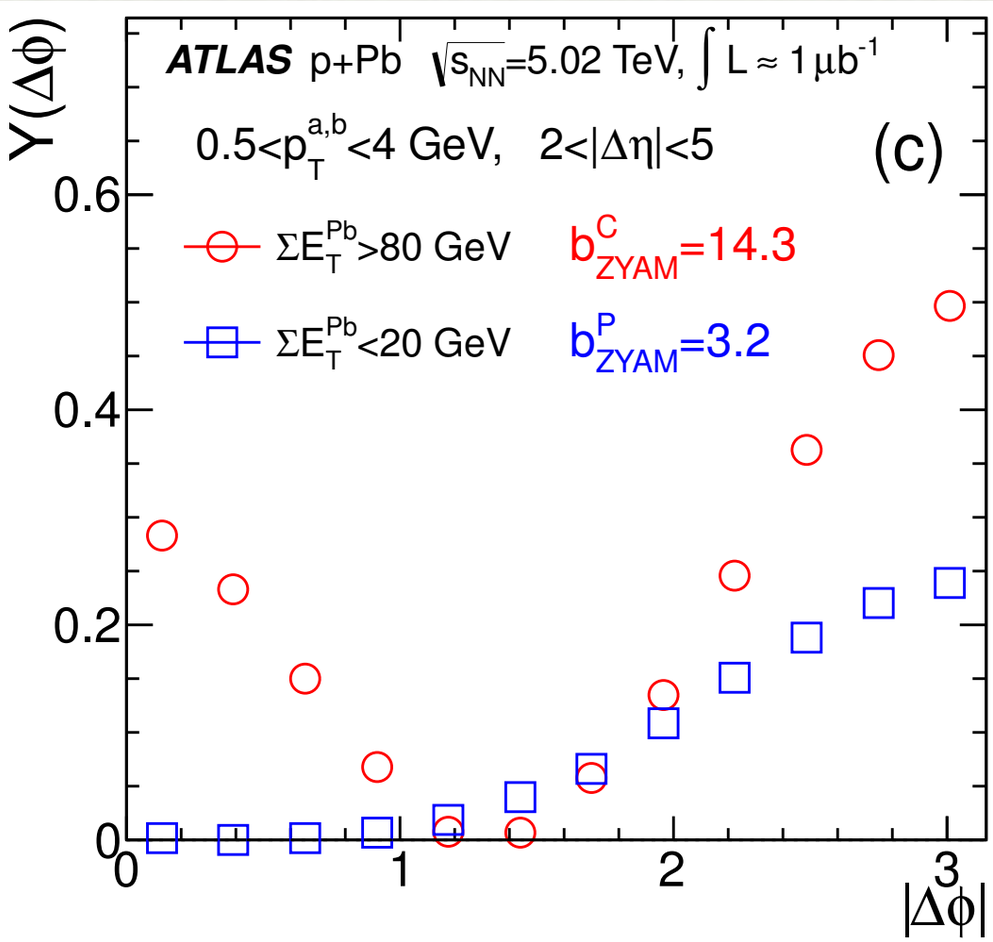
PERIPHERAL P+PB GAVE A SIMILAR YIELD AS SEEN IN PP AT SIMILAR ENERGIES...

USE PERIPHERAL AS A PROXY FOR PP

PERIPHERAL TURNED OUT TO SUBTRACT CLEANLY: LEAVING BEHIND TWO RIDGES!

ATLAS RECOIL REMOVAL

ATLAS, arXiv:1212.5198 (2013)



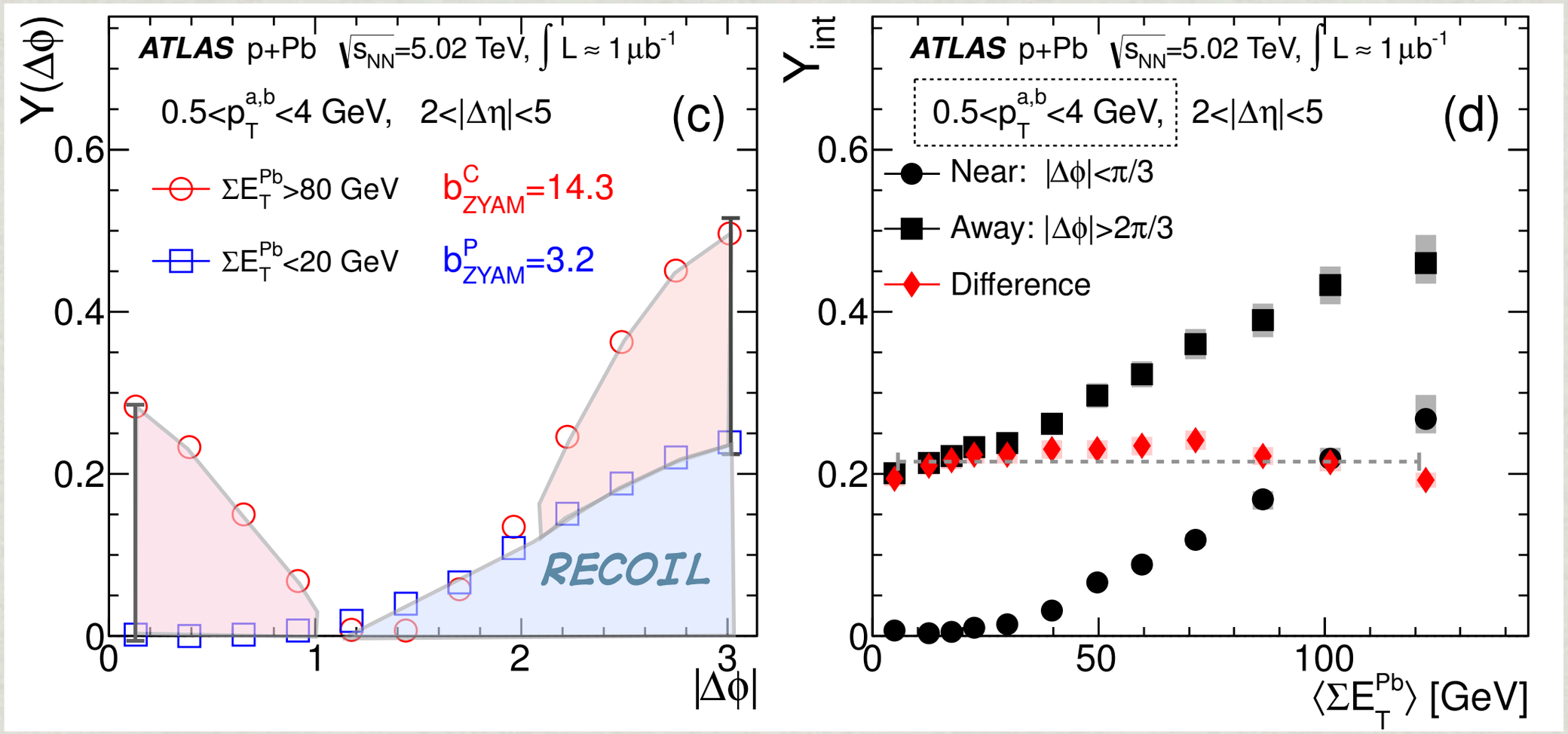
$$Y(\Delta\phi) = \left(\frac{\int B(\Delta\phi)d\Delta\phi}{\pi N_a}\right) C(\Delta\phi) - b_{\mathrm{ZYAM}}$$

(PER-TRIGGER YIELD, I.E. PAIRS/PARTICLE, AFTER ZYAM)

COMPARING Y(Δφ) IN CENTRAL TO PERIPHERAL:
OBSERVED THE DIFFERENCE IN YIELDS
TO BE ~**CONSTANT VS. CENTRALITY!**
STRAIGHTFORWARD INTERPRETATION AS "**RECOIL**"

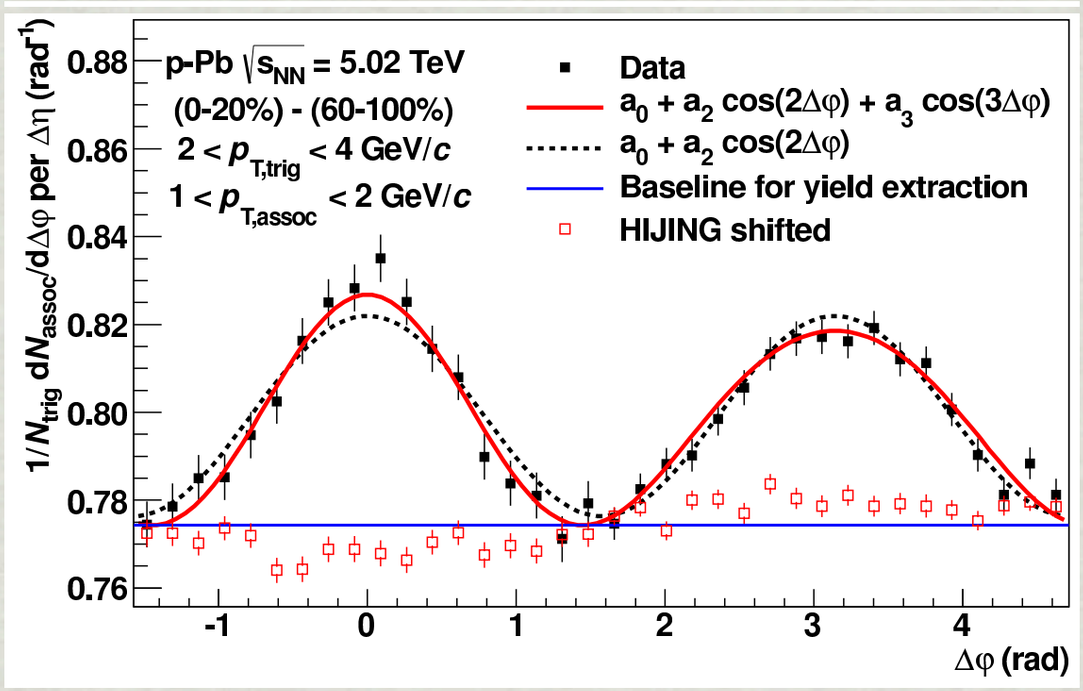
ATLAS RECOIL REMOVAL

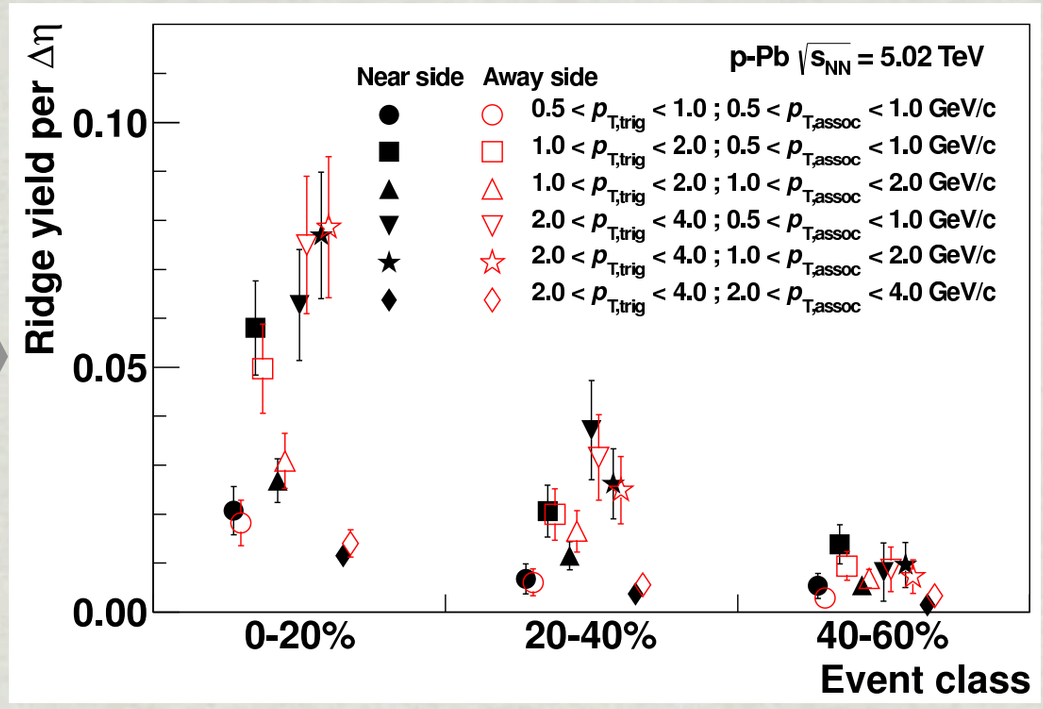
ATLAS, arXiv:1212.5198 (2013)



COMPARING Y(ΔΦ) IN CENTRAL TO PERIPHERAL:
OBSERVED THE DIFFERENCE IN YIELDS
TO BE ~**CONSTANT VS. CENTRALITY!**
STRAIGHTFORWARD INTERPRETATION AS "**RECOIL**"

AN IDENTICAL TWIN? (ALICE)





NEAR AND AWAY-SIDE RESPOND **IDENTICALLY** TO P_T SELECTIONS

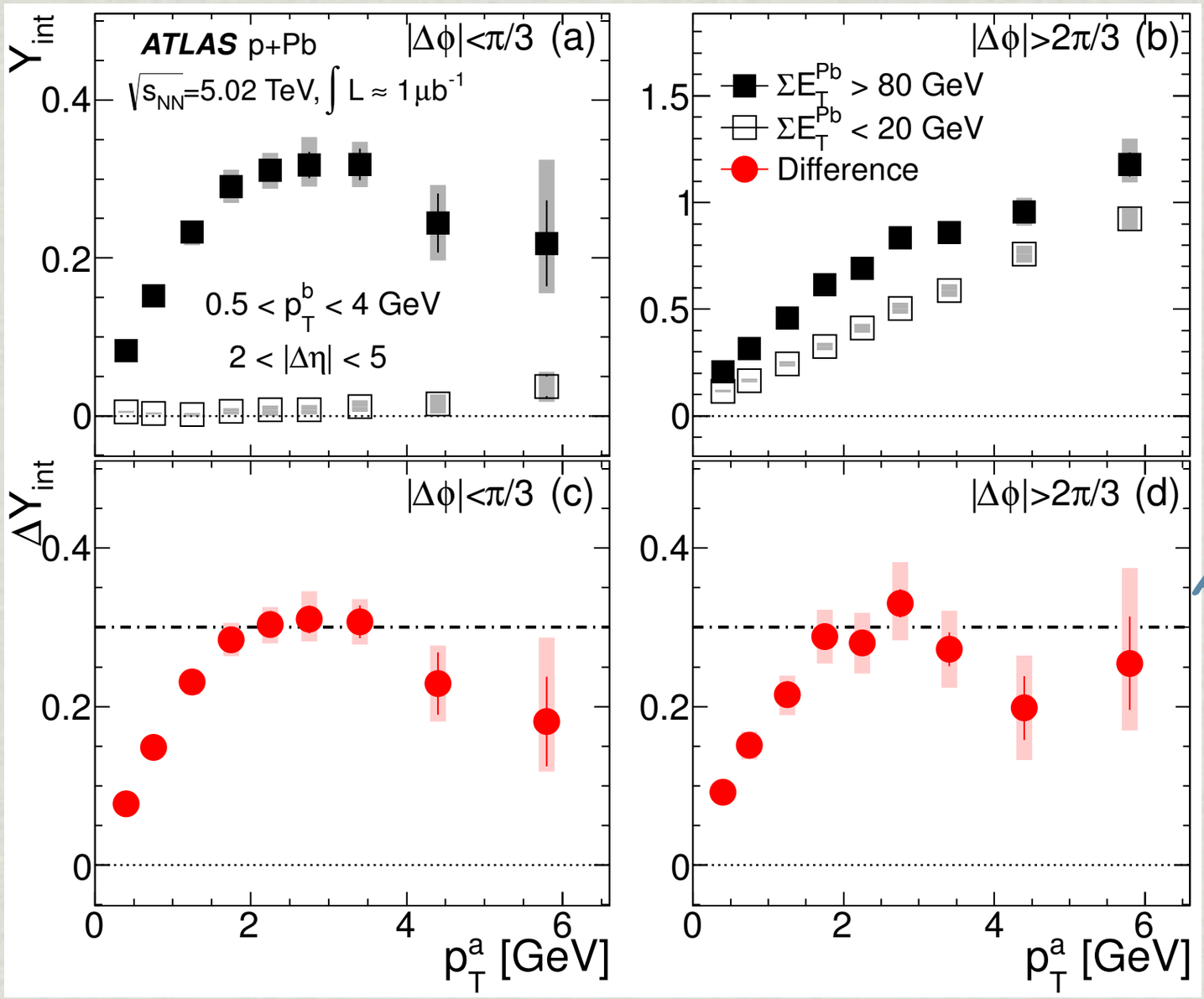
AN IDENTICAL TWIN? (ATLAS)

NEAR

AWAY

ATLAS, arXiv:1212.5198 (2013)

CENTRAL & PERIPH.



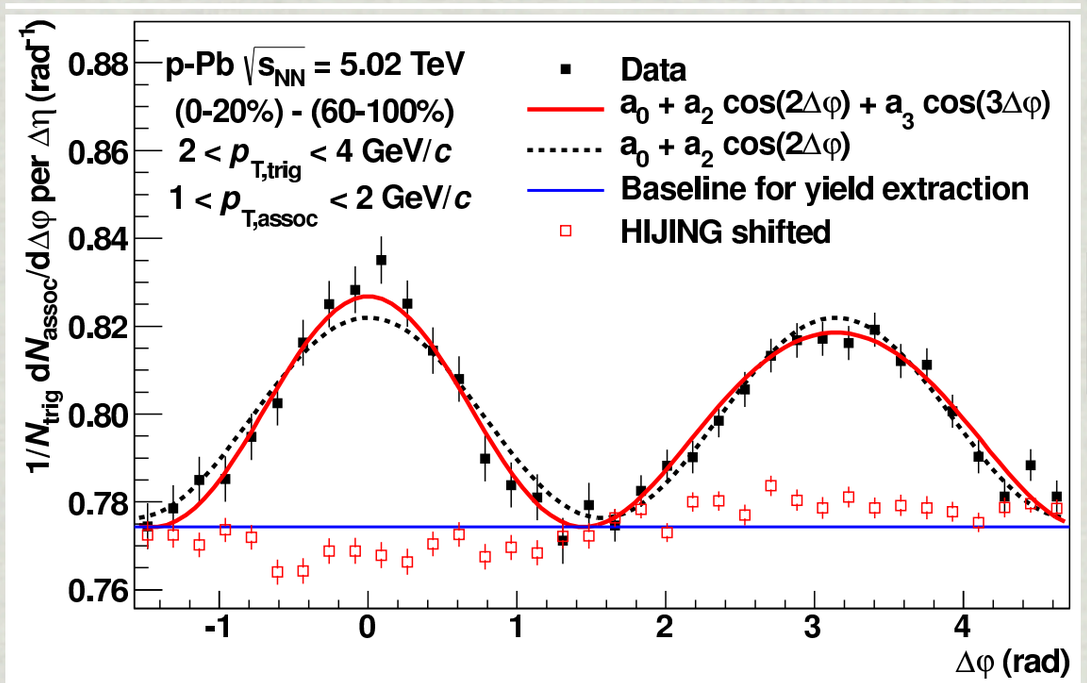
SUBTRACTED

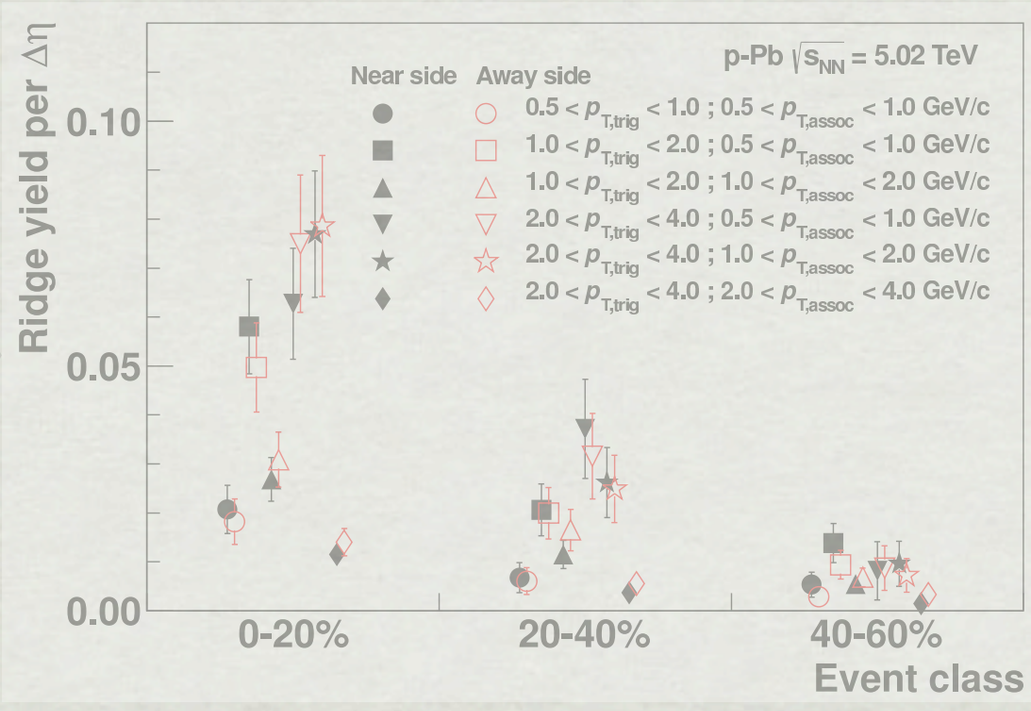
ATLAS RIDGE & ITS TWIN ARE IDENTICAL!

"THE RIDGE"

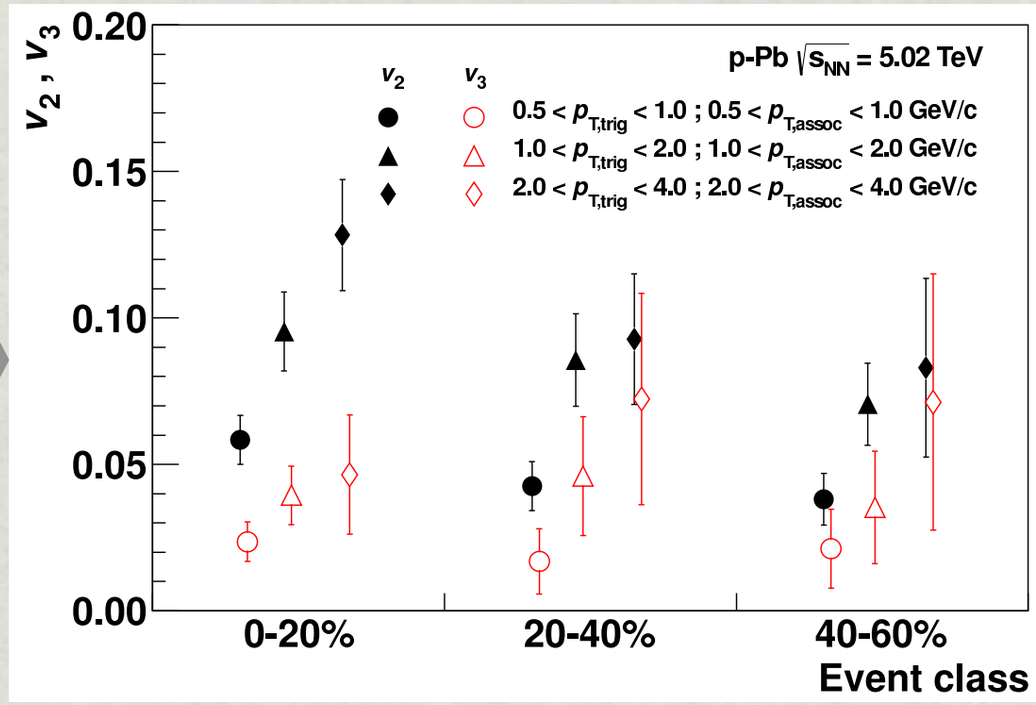
ITS TWIN

FLOW IN P+PB? (ALICE)





AFTER SUBTRACTION FOURIER COEFFS. DETERMINED BY FITS, IMPROVED BY A_3. V_2,V_3 EXTRACTED ASSUMING FACTORIZATION



SIGNIFICANT V_2 AND V_3 CONTRIBUTIONS!

HOLY SNEAKY SINUSOIDS!

FOR NEAR-INCLUSIVE ASSOCIATED PARTICLES (0.5-4 GEV), **SINUSOID DOMINATES** AFTER RECOIL SUBTRACTION FOR ALL P_T INTERVALS

SHOWN ARE:

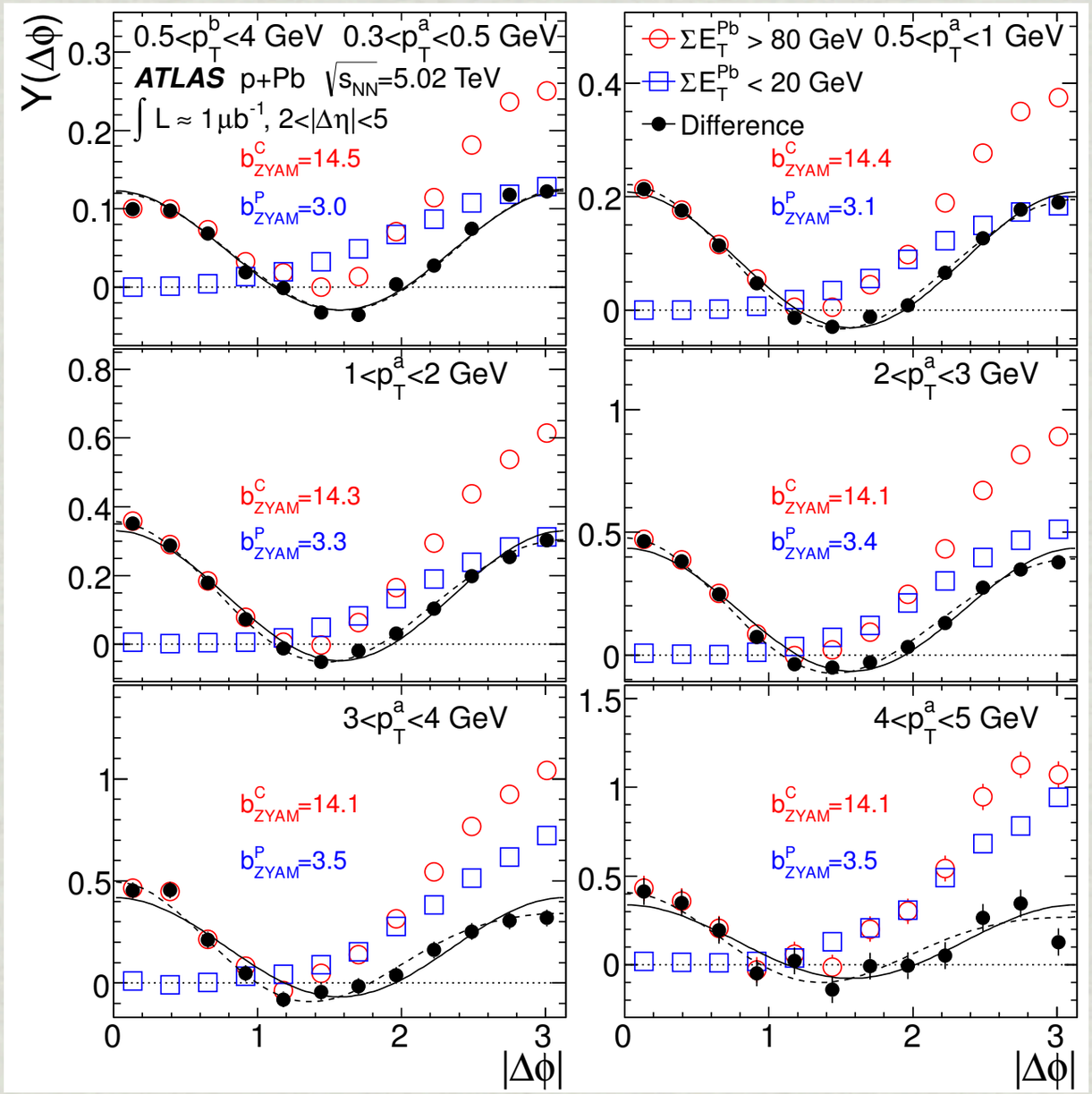
$a_0 + 2a_2 \cos 2\Delta\phi$ (SOLID)

$a_0 + 2a_2 \cos 2\Delta\phi + 2a_3 \cos 3\Delta\phi$ (DOTTED)

FOURIER COEFFS. CALCULATED USING DFT:

$$a_n = \langle \Delta Y(\Delta\phi) \cos n\Delta\phi \rangle$$

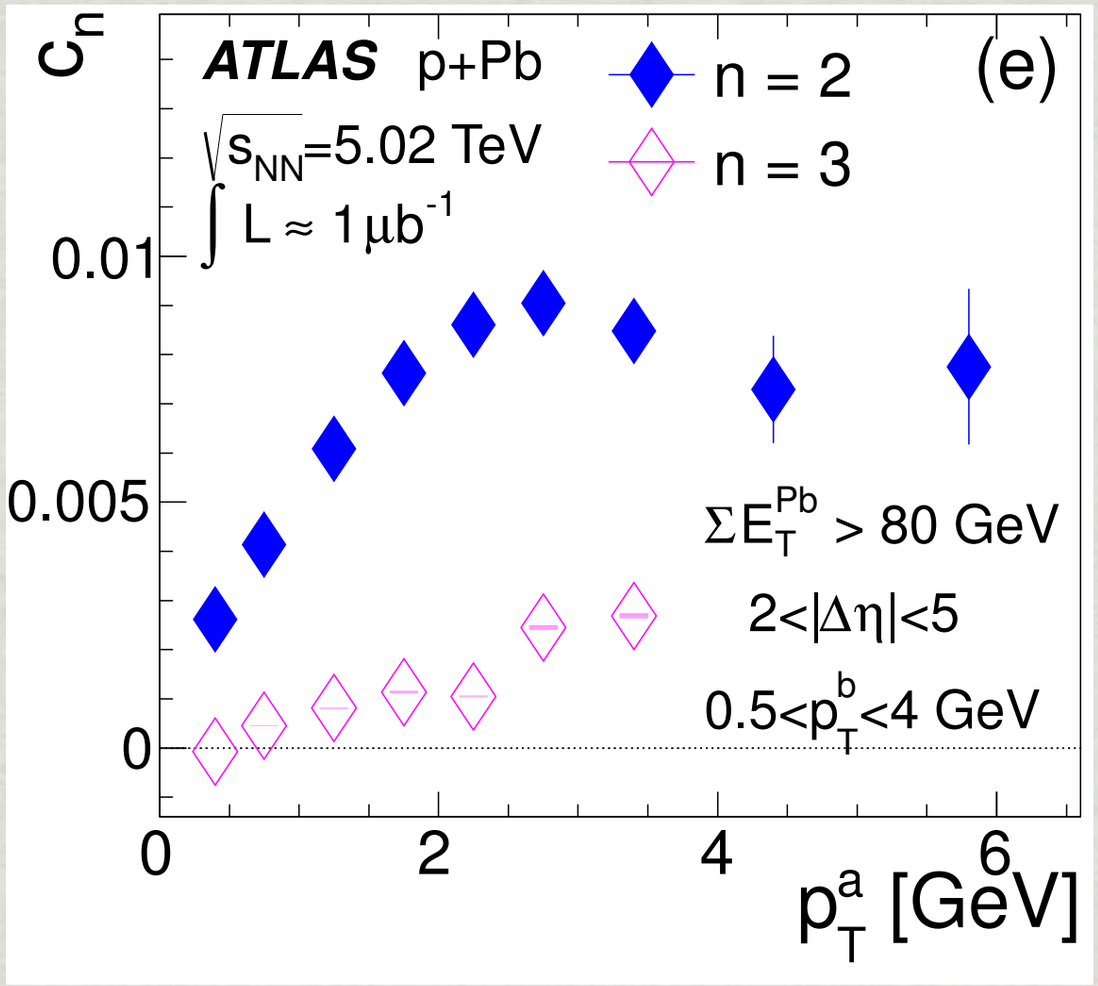
P_T(ASSOC) = 0.5-4 GEV

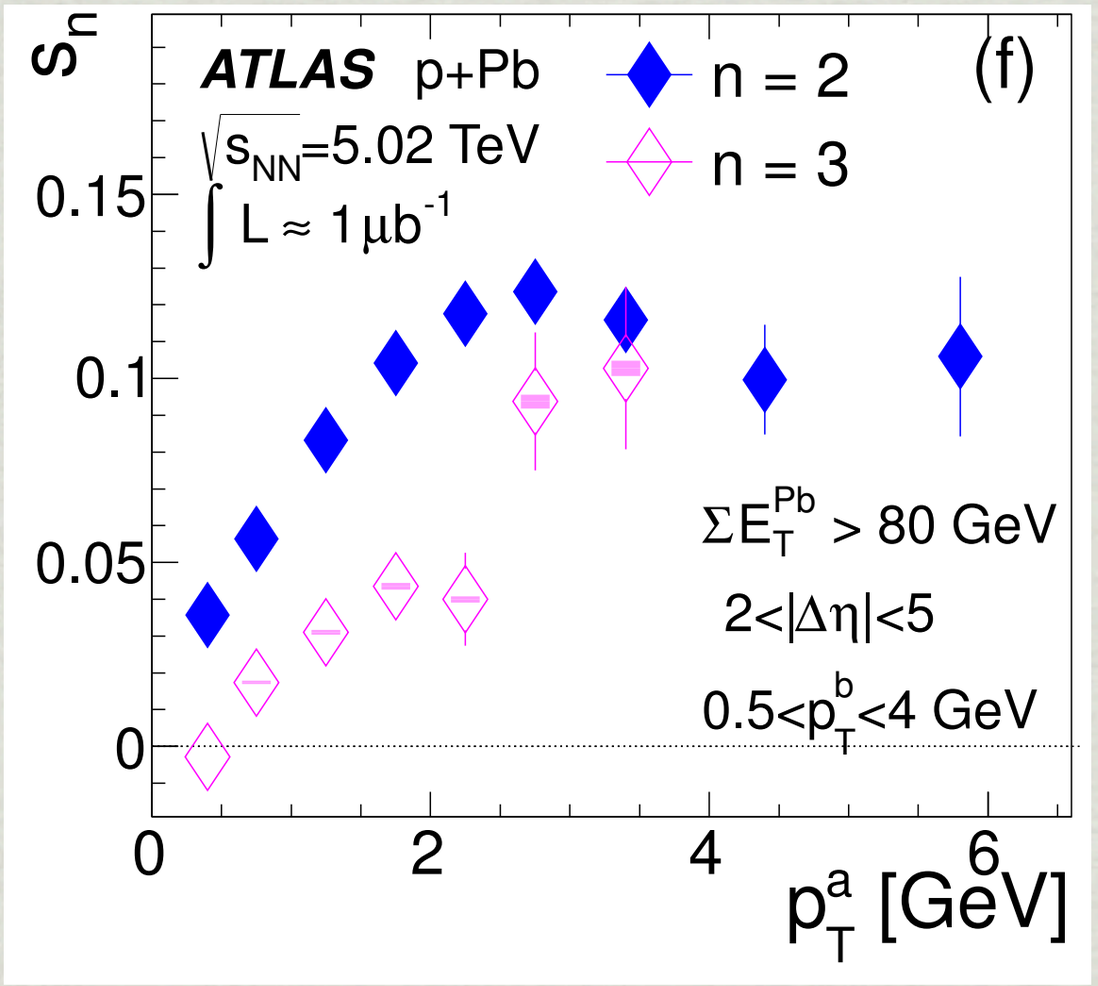


ATLAS, arXiv:1212.5198 (2013)

FLOW IN P+PB? (ATLAS)

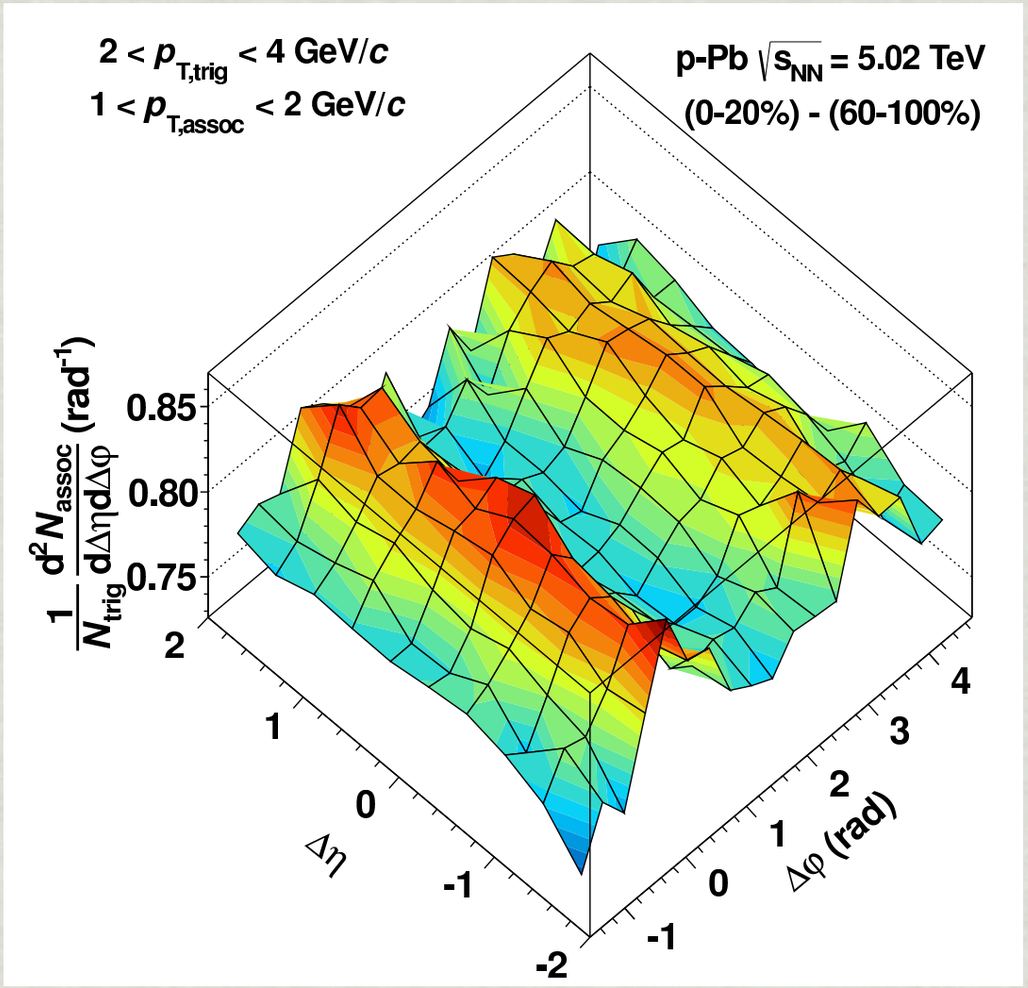
ATLAS, arXiv:1212.5198 (2013), accepted to PRL with new data!

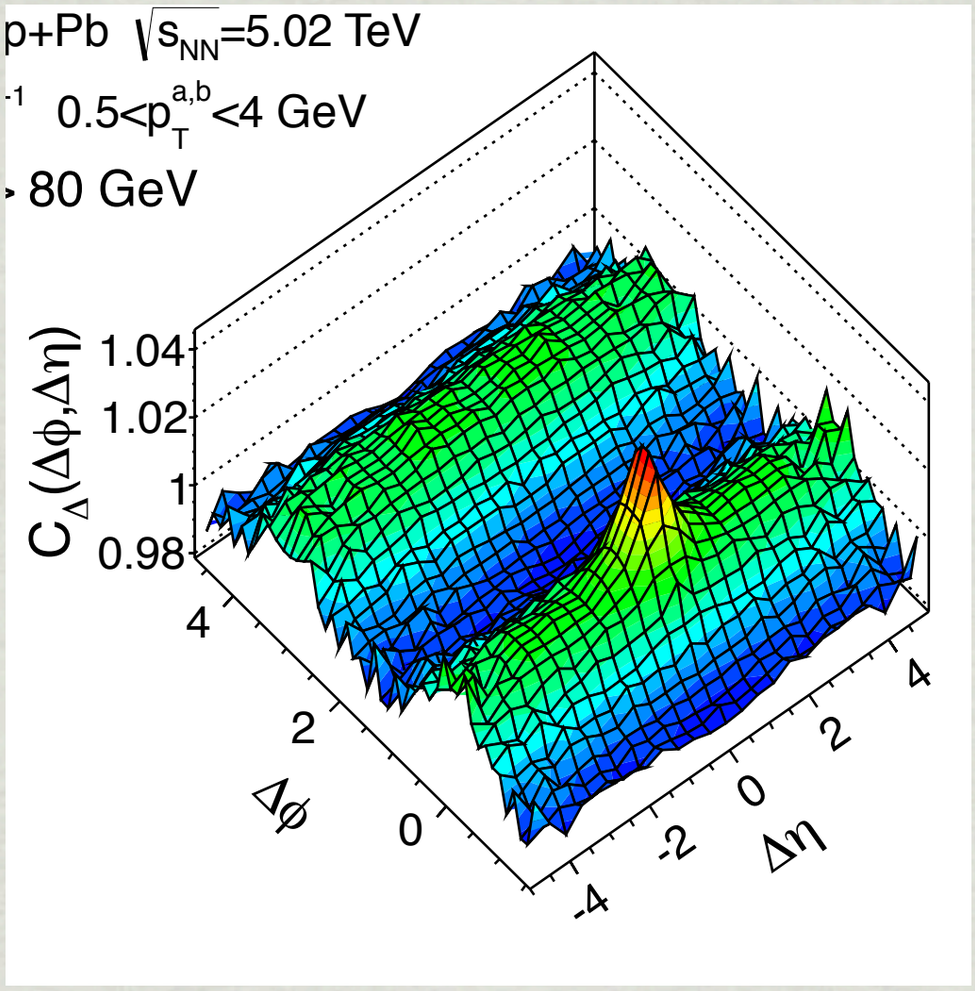




IF MODULATION OF 2PC **FACTORIZES** INTO CONVOLUTION OF **SINGLE-PARTICLE SINUSOIDS**, CAN EXPRESS MODULATION IN TERMS OF "S_N" (SAME PROCEDURE USED IN HI TO EXTRACT V_N): ...**ATLAS** EXTRACTS SIGNIFICANT S_2 **AND** S_3**!**

AT THE LHC, THE RIDGE IS NOT ALONE!





AND SOON AFTER, ACROSS THE ATLANTIC (& NEXT TO MY BNL OFFICE)...

AND SOON AFTER, ACROSS THE ATLANTIC (& NEXT TO MY BNL OFFICE)...

LO AND BEHOLD...

Quadrupole anisotropy in dihadron azimuthal correlations in central d+Au collisions at $\sqrt{s_{NN}}$=200 GeV

A. Adare,[13] C. Aidala,[41,42] N.N. Ajitanand,[58] Y. Akiba,[54,55] H. Al-Bataineh,[48] J. Alexander,[58] A. Angerami,[14] K. Aoki,[33,54] N. Apadula,[59] Y. Aramaki,[12,54] E.T. Atomssa,[34] R. Averbeck,[59] T.C. Awes,[50] B. Azmoun,[7] V. Babintsev,[23] M. Bai,[6] G. Baksay,[19] L. Baksay,[19] K.N. Barish,[8] B. Bassalleck,[47] A.T. Basye,[1] S. Bathe,[5,8,55] V. Baublis,[53] C. Baumann,[43] A. Bazilevsky,[7] S. Belikov,[7,*] R. Belmont,[63] R. Bennett,[59] J.H. Bhom,[67] D.S. Blau,[32] J.S. Bok,[67] K. Boyle,[59] M.L. Brooks,[37] H. Buesching,[7] V. Bumazhnov,[23] G. Bunce,[7,55] S. Butsyk,[37] S. Campbell,[59] A. Caringi,[44] C.-H. Chen,[59] C.Y. Chi,[14] M. Chiu,[7] I.J. Choi,[67] J.B. Choi,[10] R.K. Choudhury,[4] P. Christiansen,[39] T. Chujo,[62] P. Chung,[58] O. Chvala,[8] V. Cianciolo,[50] Z. Citron,[59] B.A. Cole,[14] Z. Conesa del Valle,[34] M. Connors,[59] M. Csanád,[17] T. Csörgő,[66] T. Dahms,[59] S. Dairaku,[33,54] I. Danchev,[63] K. Das,[20] A. Datta,[41] G. David,[7] M.K. Dayananda,[21] A. Denisov,[23] A. Deshpande,[55,59] E.J. Desmond,[7] K.V. Dharmawardane,[48] O. Dietzsch,[57] A. Dion,[27] M. Donadelli,[57] O. Drapier,[34] A. Drees,[59] K.A. Drees,[6] J.M. Durham,[59] A. Durum,[23] D. Dutta,[4] L. D'Orazio,[40] S. Edwards,[20] Y.V. Efremenko,[50] F. Ellinghaus,[13] T. Engelmore,[14] A. Enokizono,[50] H. En'yo,[54,55] S. Esumi,[62] B. Fadem,[44] D.E. Fields,[47] M. Finger,[9] M. Finger, Jr.,[9] F. Fleuret,[34] S.L. Fokin,[32] Z. Fraenkel,[65,*] J.E. Frantz,[49,59] A. Franz,[7] A.D. Frawley,[20] K. Fujiwara,[54] Y. Fukao,[54] T. Fusayasu,[46] I. Garishvili,[60] A. Glenn,[36] H. Gong,[59] M. Gonin,[34] Y. Goto,[54,55] R. Granier de Cassagnac,[34] N. Grau,[2,14] S.V. Greene,[63] G. Grim,[37] M. Grosse Perdekamp,[24] T. Gunji,[12] H.-Å. Gustafsson,[39,*] J.S. Haggerty,[7] K.I. Hahn,[18] H. Hamagaki,[12] J. Hamblen,[60] R. Han,[52] J. Hanks,[14] E. Haslum,[39] R. Hayano,[12] X. He,[21] M. Heffner,[36] T.K. Hemmick,[59] T. Hester,[8] J.C. Hill,[27] M. Hohlmann,[19] W. Holzmann,[14] K. Homma,[22] B. Hong,[31] T. Horaguchi,[22] D. Hornback,[60]

• • •

PROJECT

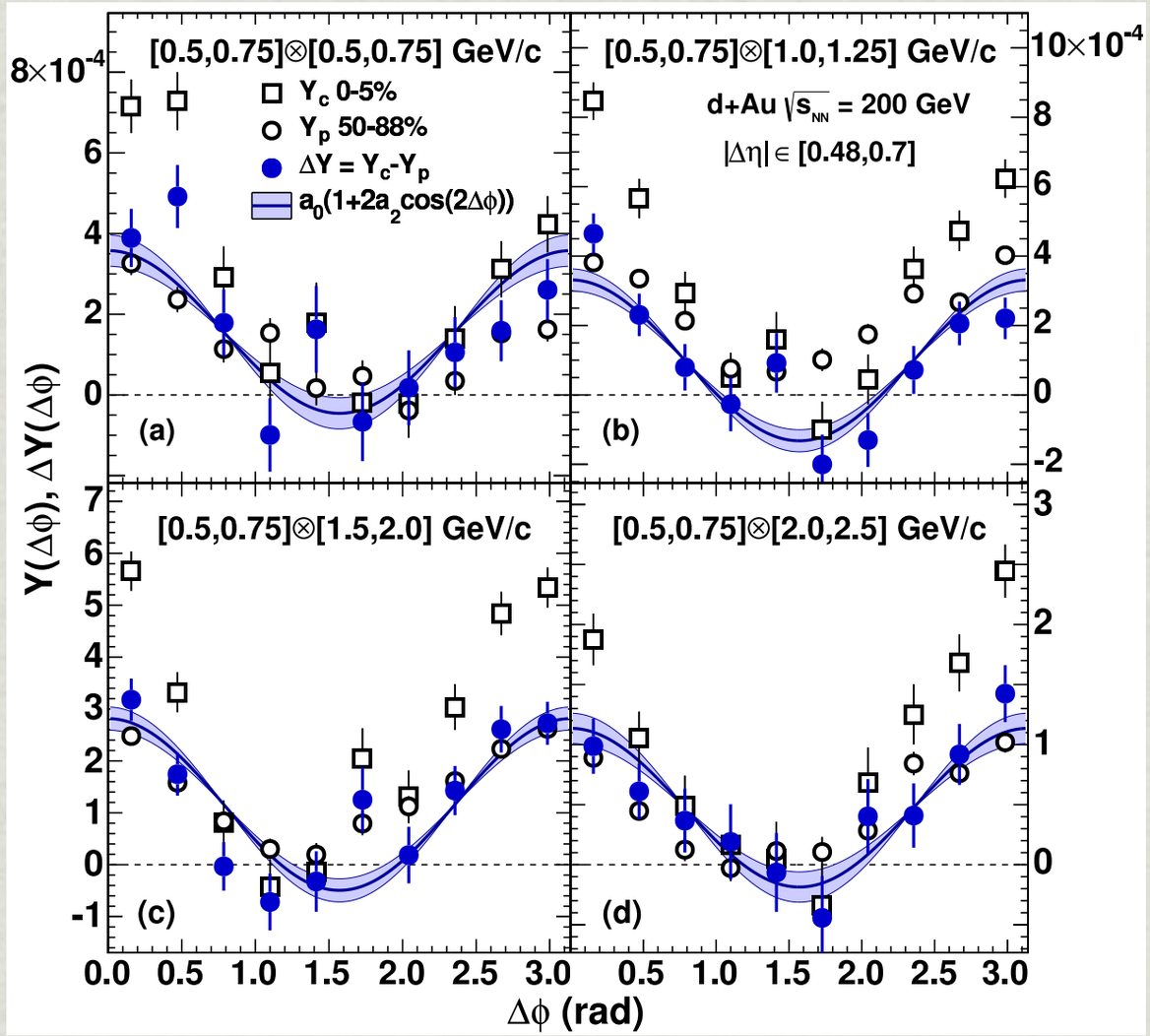
QUADRUPOLES IN D+AU

PHENIX COLLABORATION

DATE MARCH 7, 2013

CLIENT HEAVY ION COMMUNITY

PHENIX D+AU

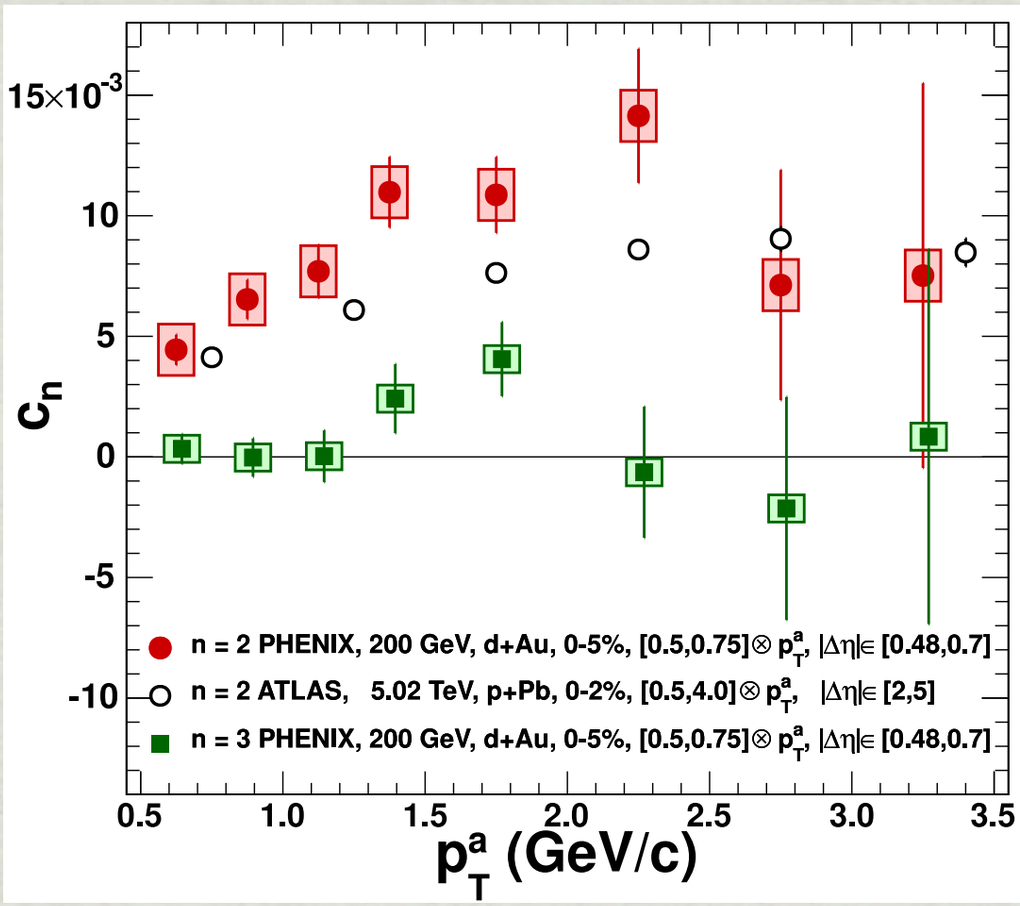


PHENIX, arXiv:1303.1794 (2013)

DESPITE SMALL ETA COVERAGE OF PHENIX, MADE GOOD USE OF THEIR **1.6 BILLION** EVENTS: CORRELATIONS WITH SOFT PARTICLES (0.5-0.75 GEV) ALSO EVINCE **QUADRUPOLE MODULATION**

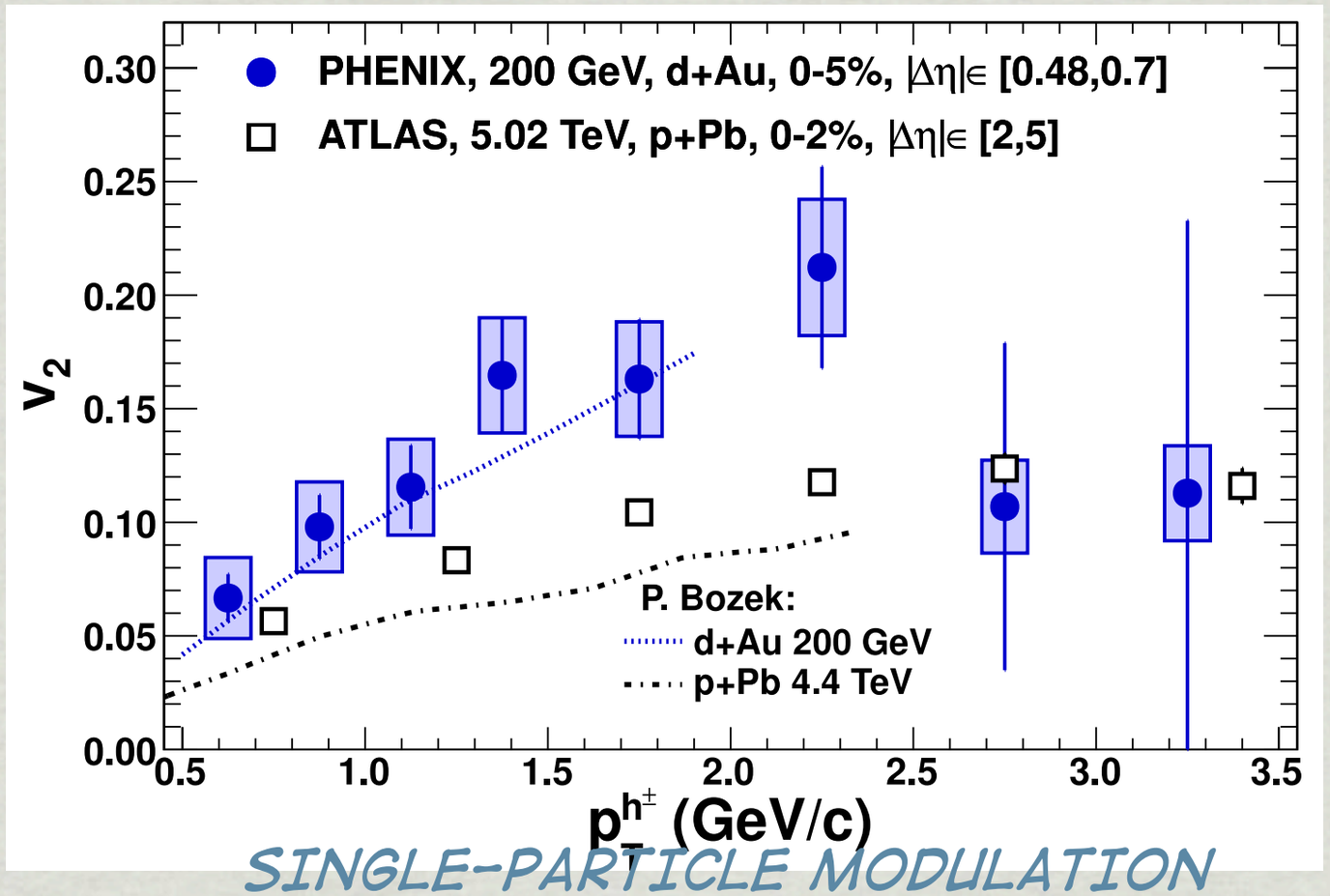
MODULATIONS @ RHIC

PHENIX, arXiv:1303.1794 (2013)



2PC MODULATIONS ARE OF **SIMILAR ORDER** TO THOSE SEEN @LHC

(QUANTITATIVE COMPARISON IS **NOT POSSIBLE** GIVEN DIFFERENT P_T AND ΔETA CUTS)

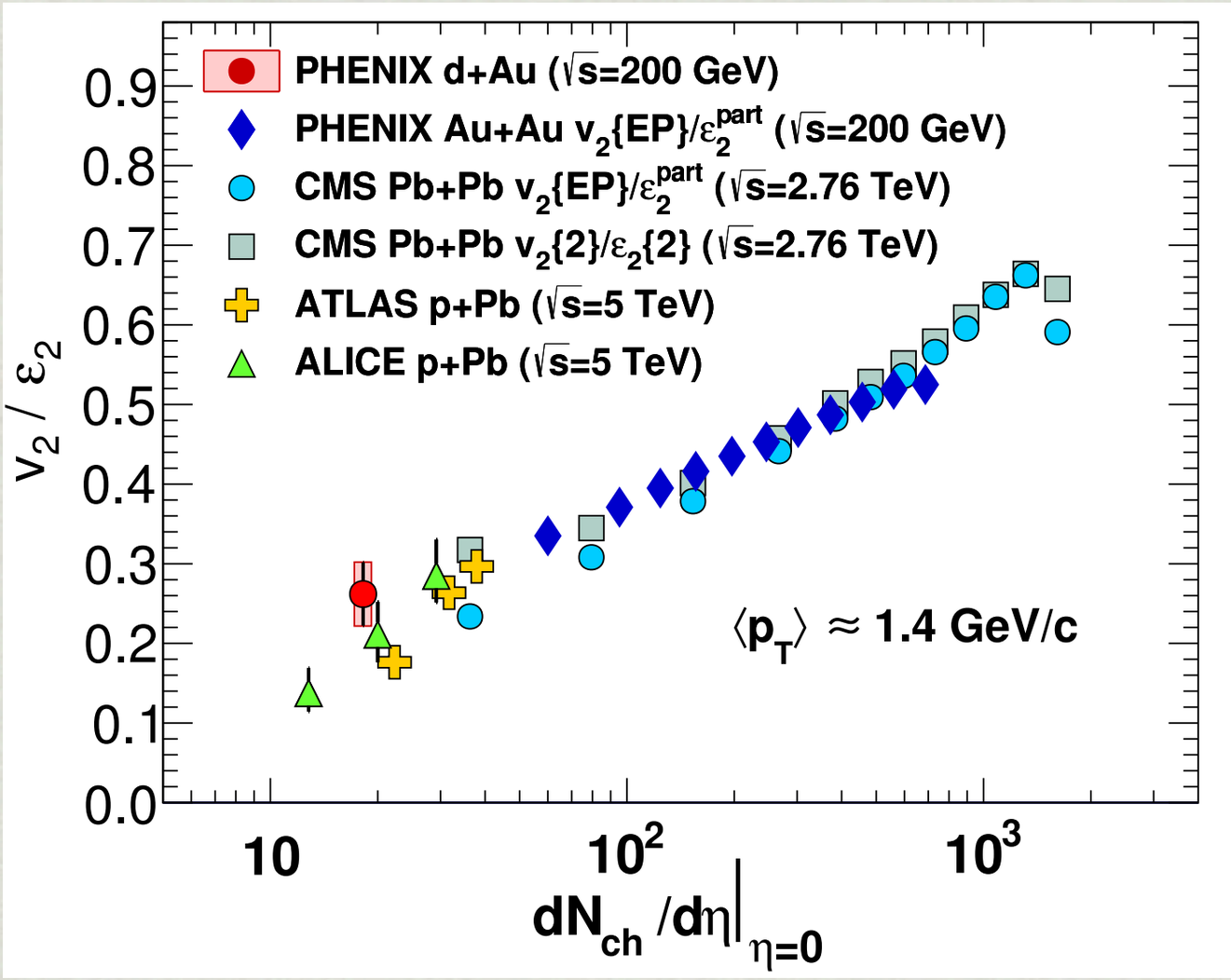


SINGLE-PARTICLE MODULATION CAN BE DIRECTLY COMPARED, AND **D+AU@RHIC** IS FOUND TO HAVE **LARGER V_2** THAN **P+PB@LHC!...**

REASONABLE AGREEMENT W/ HYDRO PREDICTIONS (N.B. LHC PREDICTIONS AT WRONG ENERGY!)

HYDRO SCALING OF P/D+A?

PHENIX, arXiv:1303.1794 (2013)



SIMILAR, BUT **NOT IDENTICAL** TO OLDER VERSION (LEAVES OUT TRANSVERSE AREA).
DESPITE USE OF HIJING MULTIPLICITIES AND ECCENTRICITIES NOT PROVIDED BY THE EXPERIMENTS, DO **P/D+A DATA SCALE** TO THE O(50%) LEVEL?

BUT WAIT,
THERE'S MORE!

FOR NO ADDITIONAL RUNNING, WE CAN ADD TWO MORE PARTICLES!

EUROPEAN ORGANISATION FOR NUCLEAR RESEARCH (CERN)

CERN-PH-EP-2013-029

Submitted to: Physics Letters B

Measurement with the ATLAS detector of multi-particle azimuthal correlations in p+Pb collisions at $\sqrt{s_{\rm NN}} = 5.02$ TeV

The ATLAS Collaboration

PROJECT

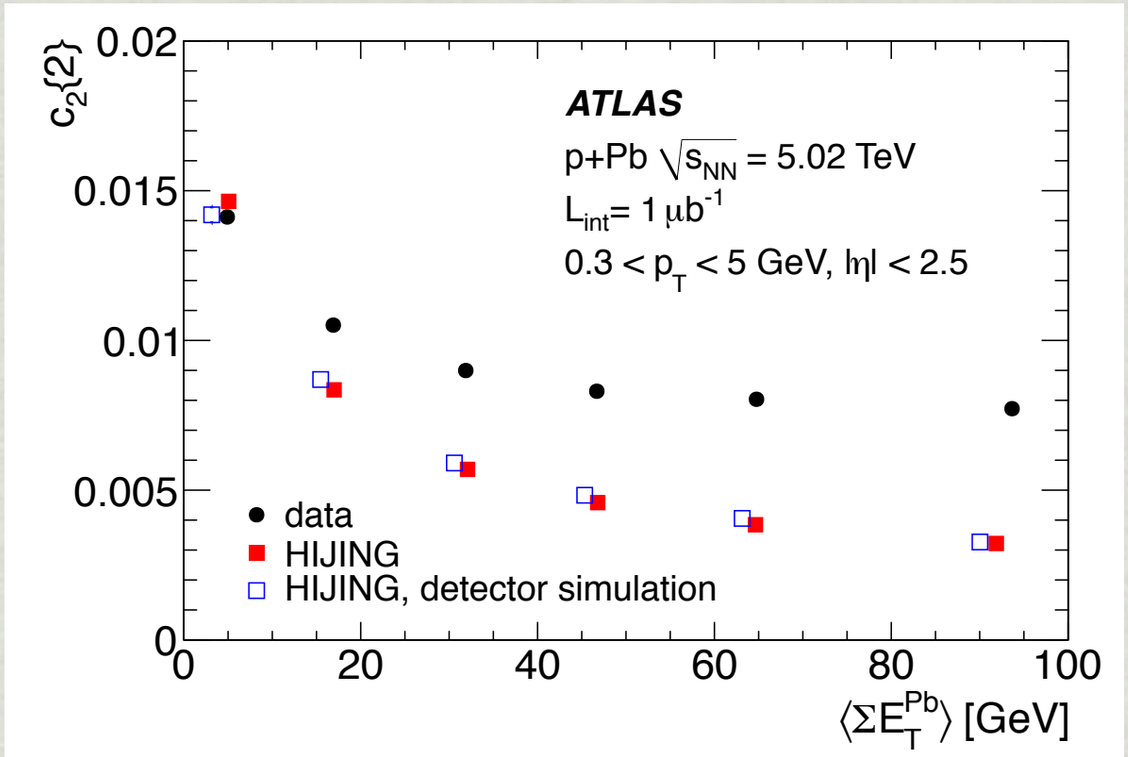
4-PARTICLE CORRELATIONS
ATLAS COLLABORATION

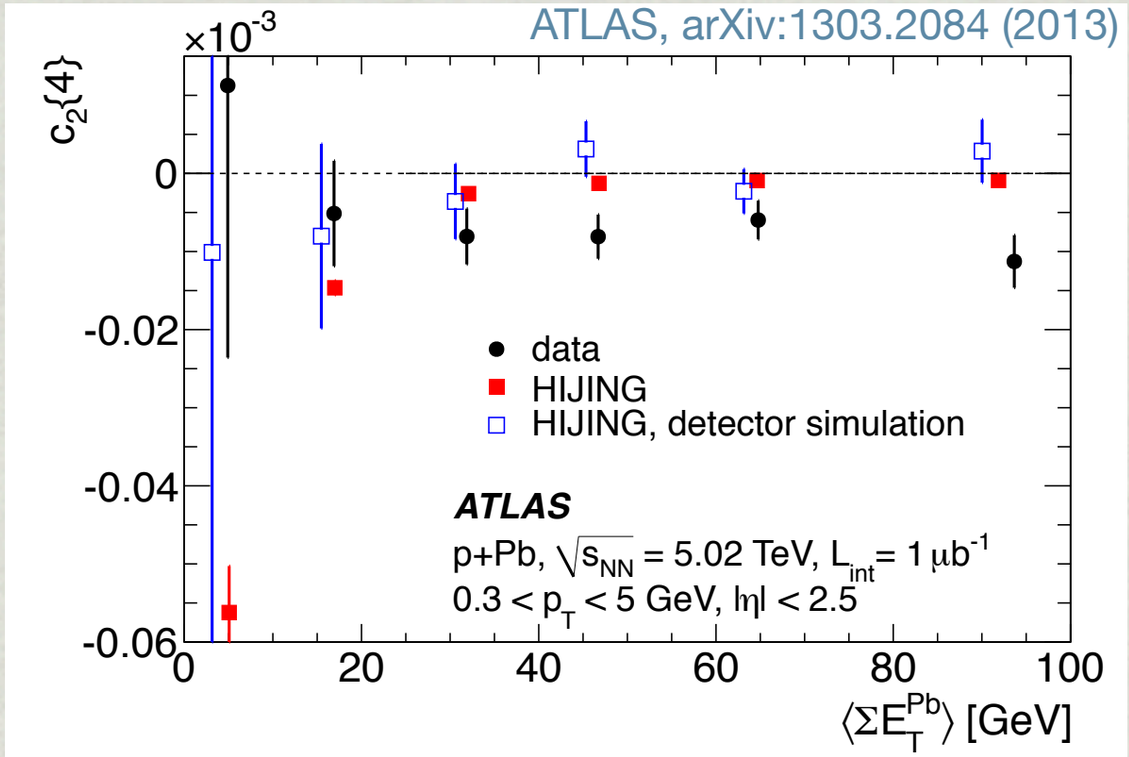
DATE MARCH 8, 2013

CLIENT HEAVY ION COMMUNITY

CUMULANTS IN P+PB

IF THE EFFECT IS DUE TO FINAL-STATE DYNAMICS, SHOULD OBSERVE TRUE **MULTIPARTICLE** CORRELATIONS: **CUMULANTS** ARE THE NATURAL WAY TO CHECK





$$corr_n\{2\} = \langle e^{in(\phi_1-\phi_2)} \rangle \qquad corr_n\{4\} = \langle e^{in(\phi_1+\phi_2-\phi_3-\phi_4)} \rangle$$

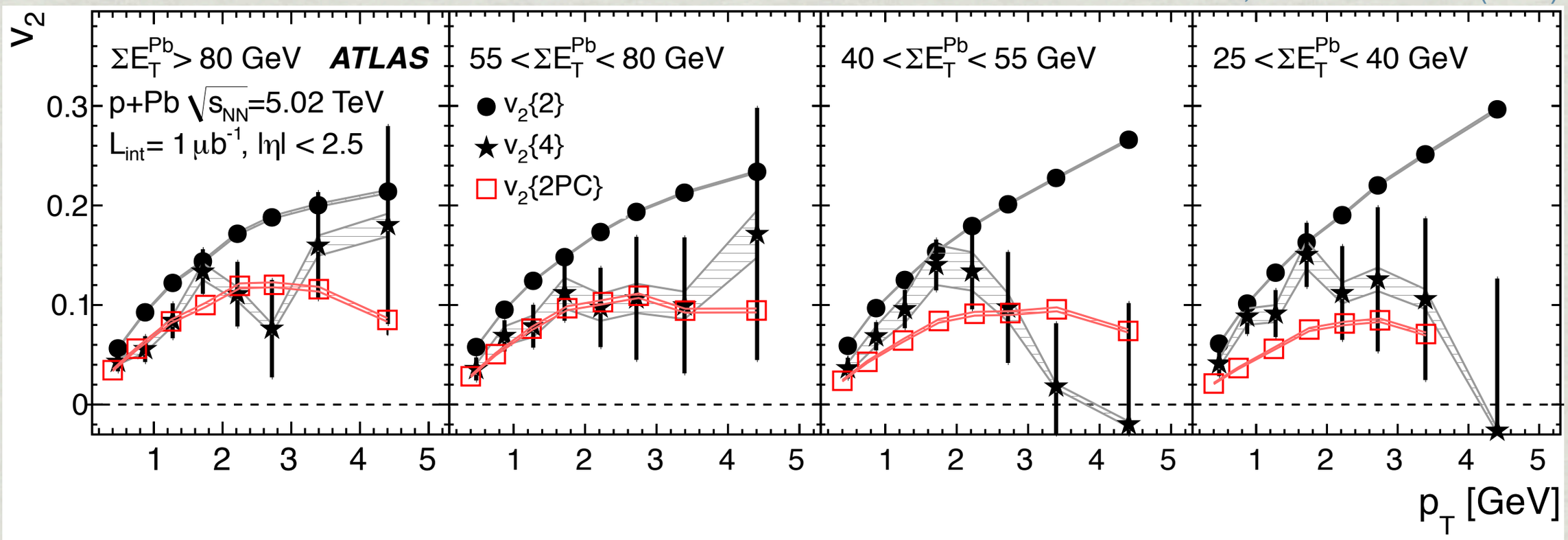
$$c_n\{2\} = \langle corr_n\{2\} \rangle \qquad c_n\{4\} = \langle corr_n\{4\} \rangle - 2 \cdot \langle corr_n\{2\} \rangle^2$$

$$v_2^{\mathrm{ref}}\{2\} = \sqrt{c_2\{2\}} \qquad v_2^{\mathrm{ref}}\{4\} = \sqrt[4]{-c_2\{4\}}$$

4 PARTICLE CUMULANT IS **NEGATIVE** (BUT SO IS PERIPHERAL **HIJING**, UNLESS WE USE |ETA|<1)

P_T DEPENDENCE

ATLAS, arXiv:1303.2084 (2013)

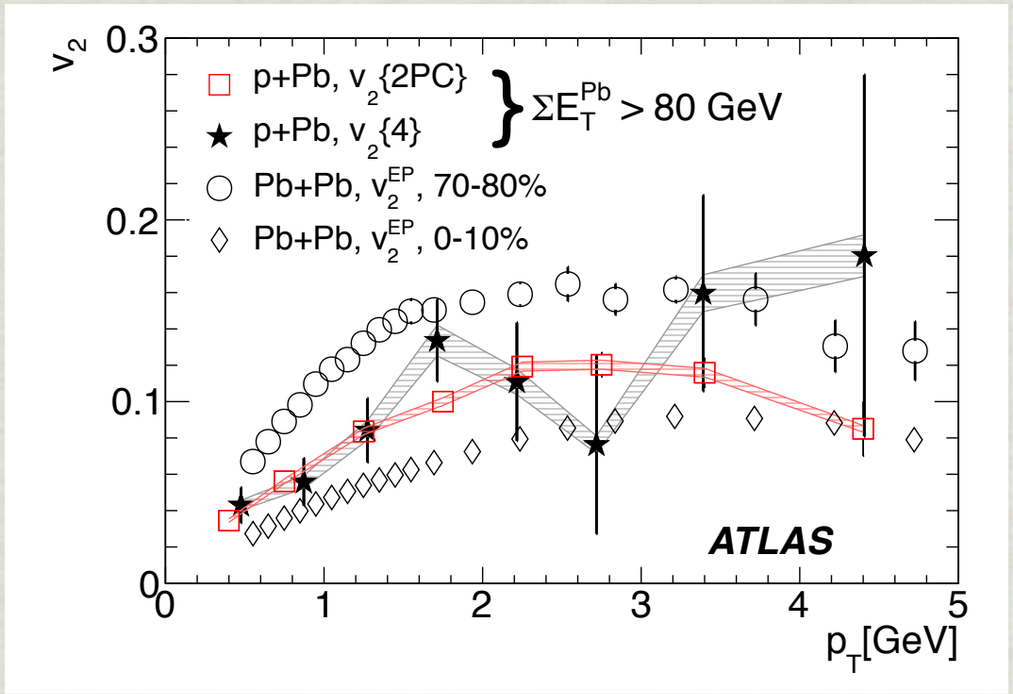


PT DEPENDENCE FROM CUMULANTS SHOWS:

1) CLEAR **DIJET CONTAMINATION** IN 2-PARTICLE

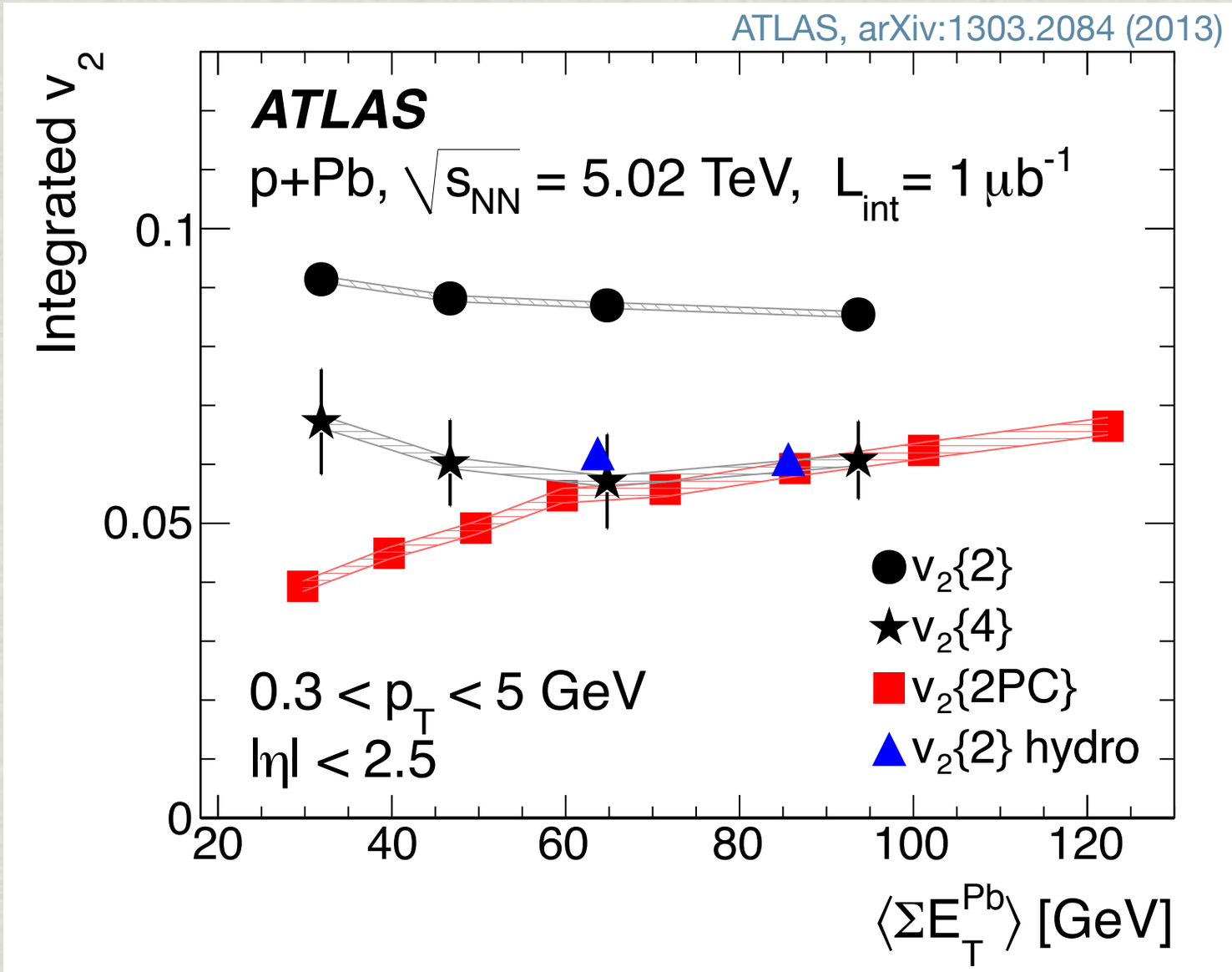
2) SIGNIFICANT 4-P, AND GOOD AGREEMENT OF 4-P WITH **2PC** IN CENTRAL EVENTS

3) SIMILAR PT SHAPE FOR 4-P AS FOUND IN **PB+PB** (EP METHOD)



INTEGRATED V_2

ATLAS, arXiv:1303.2084 (2013)



BOZEK ET AL, 5.02 TEV, PRIVATE COMM.

AGREEMENT WITH HYDRO IN MORE CENTRAL EVENTS:
SUPPORT FOR FINAL STATE INTERACTIONS?
SOME ISSUES: 1) HYDRO V2 DECREASES WITH CENTRALITY (DATA INCREASES) 2) SENSITIVITY OF CUMULANTS TO FLUCTUATIONS IN SMALL SYSTEMS

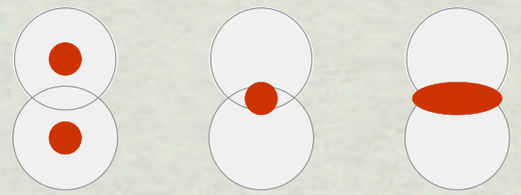
THE STORY SO FAR

- RIDGE DISCOVERED IN AU+AU @ RHIC
  - "EXPLAINED" BY TRIANGULAR FLOW, I.E. FLUCTUATIONS IN THE INITIAL STATE
  - STRONG SUPPORT FROM **LHC PB+PB**
- RIDGE REDISCOVERED IN PP
  - LET A MILLION EXPLANATIONS BLOOM, FROM CGC TO HYDRO
- NEAR-SIDE RIDGE DISCOVERED IN P+PB
  - IDENTICAL AWAY-SIDE RIDGE --> **ONE PHENOMENON!**
    - CGC INTERFERENCE GRAPHS?
    - HYDRODYNAMIC RESPONSE TO FLUCTUATIONS?
- D+AU DATA SHOW THE "DOUBLE RIDGE", I.E. QUADRUPOLE MODULATIONS
  - HYDRO PREDICTIONS, FLOW SCALING
- 4-PARTICLE CUMULANTS TILT TOWARDS HYDRO INTERPRETATION OF THE DATA...FOR NOW

STAY TUNED, FOR THE NEXT EPISODE!

IMPORTANT QUESTIONS!

- P+PB WAS SUPPOSED TO BE ABOUT INITIAL STATE (I.E. CGC) BUT WE HAVE A SURPRISING HINT OF FINAL STATE DYNAMICS (I.E. FLOW)
  - CGC & FLOW BOTH CLAIM TO HAVE **DESCRIPTIVE** AND **PREDICTIVE** POWER
- LIMITS OF HYDRODYNAMICS
  - CAN **THERMALIZATION** BE ACHIEVED FOR SUCH SMALL SPACE/TIME SCALES?
  - ARE **VISCOUS CORRECTIONS** TOO LARGE?
  - WHAT ABOUT **CUMULANTS**?
- SCOPE/PREDICTIVE POWER OF CGC APPROACH
  - IF MODEL IS COMPLETE, THEN **PREDICTIONS** ARE ESSENTIAL
  - WHAT ABOUT **MULTIPARTICLE EFFECTS**? V_3?
- WHAT ABOUT PP?
  - IN LIGHT OF P+PB, P+P RIDGE SUGGESTS THAT WE SHOULD BE THINKING MORE CAREFULLY ABOUT **PP INITIAL STATE**
  - HOW TO HANDLE **GEOMETRY/FLUCTUATIONS** IN PP?
- EXPLANATION FOR LONG RANGE CORRELATIONS
  - CGC (FLUX TUBES) VS. HYDRO (BUILT IN, BUT 3+1D??)



BZDAK, ET AL, STRIKMAN, ...

AVENUES FOR PROGRESS

* EVEN MORE MULTIPARTICLE OBSERVABLES $V_2(6)$, AND HIGHER ORDER MODULATION
* EVEN LONGER RANGE CORRELATIONS
  * PREDICTIONS FOR ETA DEPENDENCE FROM CGC OR HYDRO?
* PARTICLE SPECIES DEPENDENCE (CQ SCALING?)
* A COMPREHENSIVE DESCRIPTION, FROM SMALL TO LARGE SYSTEMS, ESPECIALLY WHERE THEY OVERLAP IN SIZE/DENSITY
* PREDICTIONS ARE CRUCIAL, SINCE VERY DIFFERENT APPROACHES ARE ABLE TO DESCRIBE THE SAME DATA!

A PARTING (PERSONAL) QUESTION:
WOULD WE HAVE IMAGINED DISCUSSING
4-PARTICLE CUMULANTS IN P+PB @ LHC?

I DIDN'T, BUT IT'S A VERY EXCITING MOMENT!

"THE BEST LAID SCHEMES OF MICE AND MEN GANG AFT AGLEY..."

("THE BEST LAID PLANS OF MICE AND MEN OFTEN GO ASTRAY")

IT SEEMS THE SAME IS TRUE FOR
MICE (PROTONS), MAMMOTHS (IONS),
AND **THE RIDGE!**

THANKS!!

(SPECIAL THANKS TO J. JIA FOR DISCUSSIONS)